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Relatório Final de Pesquisa

Influência da temperatura no comportamento de Pavimentos Flexíveis – uma análise direcionada às ilhas de calor.

Cliente: Concessionária da Rodovia Osório-Porto Alegre – CONCEPA

Documento N° 16-0010

Maio de 2016

Relatório de pesquisa preparado por Prime Engenharia e Consultoria LTDA.
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CNPJ 10.446.085/0001-90

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LISTA DE ABREVIATURAS

AASHTO: *American Association of State Highway and Transportation Officials*

CPTEC: Centro de Previsão do Tempo e Estudos Climáticos

EPA: *Environmental Protection Agency*

HCD: *Hourly Climatic Data*

ICM: *Integrated Climatic Model*

INMET: Instituto Nacional de Meteorologia

INPE: Instituto Nacional de Pesquisas Espaciais

METAR: *Metereological Aerodrome Report*

ONU: Organização das Nações Unidas

SYNOP: *Surface Synoptic Observation*

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1 INTRODUÇÃO

O crescimento populacional urbano é um processo em constante avanço, rápido e irreversível em países em desenvolvimento. Tipicamente, o primeiro impacto que se sente no processo de urbanização é a construção de uma malha de transporte com pavimentos asfálticos e de concreto que ocupam áreas antes nativas de cobertura vegetal.

Estas grandes áreas agora pavimentadas desenvolvem, então, capacidade de alta absorção e armazenamento de calor. Com esta conversão de áreas nativas férteis em superfícies agora impermeáveis em níveis alarmantes[1], o calor irradiado das áreas betuminosas termina por elevar a temperatura do ambiente, mudando os microclimas através da geração das chamadas ilhas de calor urbanas.

Por sua vez, a influência climática nos pavimentos altera seu comportamento e sua vida útil, tornando-se um fator importante a ser considerado no projeto de pavimentos. A maior presença de pavimentos e construções, com relação à cobertura dos terrenos naturais, e a produção de calor gerada por humanos são as maiores responsáveis pelo acréscimo de temperatura nas cidades, sendo as superfícies impermeáveis as maiores causas de aumento de temperatura durante o dia (Ryu & Baik, 2011).

Baseado nesse fenômeno, diferentes tipos de pavimentos são utilizados na tentativa de mitigar os efeitos, porém esses tipos de pavimentos ainda precisam de maior investigação para maior compreensão de suas características e habilidades. No Brasil, estudos sobre a influência dos pavimentos nas ilhas de calor ainda são escassos e ainda difíceis de serem encontrados.

Além disso, a falta de uma base de dados que permita a adequada modelagem do comportamento dos pavimentos faz-se importante para plantar um ponto de partida nos estudos sobre este tema. A exemplo, a utilização de softwares de dimensionamento, como o AASHTOWare Pavement ME Design – que já fora objetivo de estudo inicial pela Prime Engenharia no enfoque do dimensionamento de pavimentos – se vale de um extenso banco de informações para a modelagem do comportamento das camadas. Isto só é viável pelo fato dos Estados Unidos possuírem uma grande quantidade de dados históricos capaz abastecer estas análises.

No Brasil, os estudos feitos com o AASHTOWare Pavement ME Design ainda são todos realizados com base nos bancos de dados de temperatura norte-americanos. A defasagem entre os dias frios e quente associados à sazonalidade dos veículos, não podem ser adequadamente avaliados com estas considerações. Mais importante ainda é o fato das diferenças climáticas que, por mais cuidado que se tome na escolha de um ambiente similar, para efeitos de modelagem, não há nenhuma equivalência direta entre as cidades norte-americanas com as cidades brasileiras.

A presente pesquisa propôs, portanto, que seja montado um banco de dados climático para a cidade de Porto Alegre que seja completo o suficiente para permitir uma modelagem do

[1] Nos Estados Unidos da América (EUA), a exemplo, a adição de 60 milhões de carros em novas vias, estradas e áreas de estacionamento consumiu aproximadamente 1 milhão de hectares de áreas férteis – o suficiente para alimentar 45 milhões de pessoas se todas fossem com plantações de alimentos (Brown, L.R, 2006, Plan B 2.0, W.W. Norton Publishers, New York; "*Factors for global car production which has risen by circa 50% in the last 10 years*").

pavimento nas condições climáticas locais de forma a permitir uma avaliação do efeito da temperatura e das ilhas de calor no desempenho dos pavimentos. Estes dados foram subsídio para avaliações da potencialidade de geração de energia a partir das ilhas de calor disponível na rodovia – principalmente no caso da BR-290/RS Freeway, que apresenta plataformas pavimentadas de quase 20m por pista (na zona metropolitana), perfazendo grandes áreas com potencial energético.

1.1 OBJETIVOS

1.1.1 Objetivo geral

Esta pesquisa teve por objetivo principal compilar os dados climáticos para a cidade de Porto Alegre em formato de arquivos tipo ICMs (*Integrated Climatic Models*) de maneira a viabilizar uma análise da performance dos pavimentos devido às variações climáticas geradas pelo efeito de "Ilha de Calor Urbana" (ICU) para avanços no embasamento científico da modelagem do efeito termodinâmico do aquecimento de áreas metropolitanas.

1.1.2 Objetivos específicos

O presente projeto de pesquisa foi conciso e de curta duração. A grande magnitude da temática envolvida e sua interdisciplinaridade é objeto de diversas outras pesquisas na grande área de pavimentos autossustentáveis e que hoje engloba parcela expressiva de esforços. Nesta direção, pretendeu-se com esta pesquisa atender ao objetivo geral através das seguintes metas específicas:

1. Verificar os dados climáticos necessários à modelagem do comportamento mecânico dos pavimentos flexíveis e compilar os referidos dados para a cidade de Porto Alegre em uma série histórica de pelo menos quatro anos.
2. Gerar um arquivo tipo HCD (*Hourly climatic data*) que permita a geração no software AASHTOware® Pavement ME[2] a partir de um arquivo tipo ICM para Porto Alegre, e disponibilizá-lo de forma online para outros pesquisadores. A geração deste arquivo deverá, ainda, ter como resultado o detalhamento da forma de obtenção para outras cidades brasileiras.
3. Realizar análises no software AASHTOWare Pavement ME que avaliem o desempenho de pavimentos urbanos frente a variações climáticas devido às Ilhas de Calor, elucidando o impacto destas estruturas frente ao aquecimento concentrado de áreas.

[2] O software AASHTOware Pavement, é uma evolução do antigo ME-PDG que também foi chamado posteriormente de DARWin-ME e recentemente recebeu o nome de AASHTOWare® Pavement ME. http://www.aashtoware.org/Pavement/Pages/default.aspx

1.2 JUSTIFICATIVA

Fontes de energia alterativa, redução das emissões de gases poluentes, aquecimento global e otimização da matriz energética são todos temas de relevância nas pesquisas atuais. O calor gerado pelos pavimentos está diretamente associado a todos eles.

Este estudo teve a intenção de abrir um novo segmento de pesquisa diretamente relacionado ao impacto da temperatura no comportamento mecânico dos pavimentos como forma inicial de formar um banco de dados climáticos para a cidade de Porto Alegre e também fundamentar os conceitos básicos envolvidos na geração de ilhas de calor.

A Figura 1 demonstra o conceito envolvido na temática desta pesquisa. O desenvolvimento urbano leva a um necessário aumento das áreas pavimentadas, tanto pela construção de novas malhas viárias quando pela pavimentação de áreas de estacionamento e edificações em geral. Isto leva a duas consequências imediatas:

A) o aquecimento do ambiente urbano devido à grande capacidade térmica dos materiais asfálticos e também à geração de gases que confina este calor associado à redução das correntes de ar internas nas cidades.

B) ao aumento do consumo energético para abastecimento de áreas densamente populadas, principalmente para o conforto térmico que precisa ser regulado devido às altas temperaturas.

Em ambos os casos o calor gerado pelos pavimentos tem papel de suma importância. No primeiro, há maneiras de se contornar o aquecimento pelo uso de materiais mais termo eficientes; exemplo seriam os pavimentos asfálticos com pedras de elevado brilho que sejam capazes de refletir mais eficientemente os raios solares, ao invés de absorver sua energia.

No segundo, pode-se valer do calor absorvido para gerar energia; o calor aprisionado nos pavimentos é potencialmente uma "máquina térmica" capaz de converter o calor em trabalho mecânico. Com isto tem-se dois benefícios imediatos: a geração de energia para abastecimento, e o consequente resfriamento do pavimento nesta geração.

Pesquisadores norte-americanos estimam que com uma eficiência de 3,75% para a geração de energia a partir de canos instalados em pavimentos para montagem de uma máquina de calor, seria possível entregar 28 giga watts hora em apenas um dia nos Estados Unidos da América[3].

[3] Dados retirados da proposta de pesquisa submetida para o projeto "*Fully Sustainable Urban Heat Island Reduction by Energy Havesting from Roads*" submetido entre diversas entidades de pesquisa no mundo (Worcester Polytechnic Institute – WPI, University of New Hampshire, University of Nottingham/UK, Institute of Technology Madras, India e Universidade Federal do Rio Grande do Sul/UFRGS), no qual o consultor da Prime atuou como pesquisador convidado.

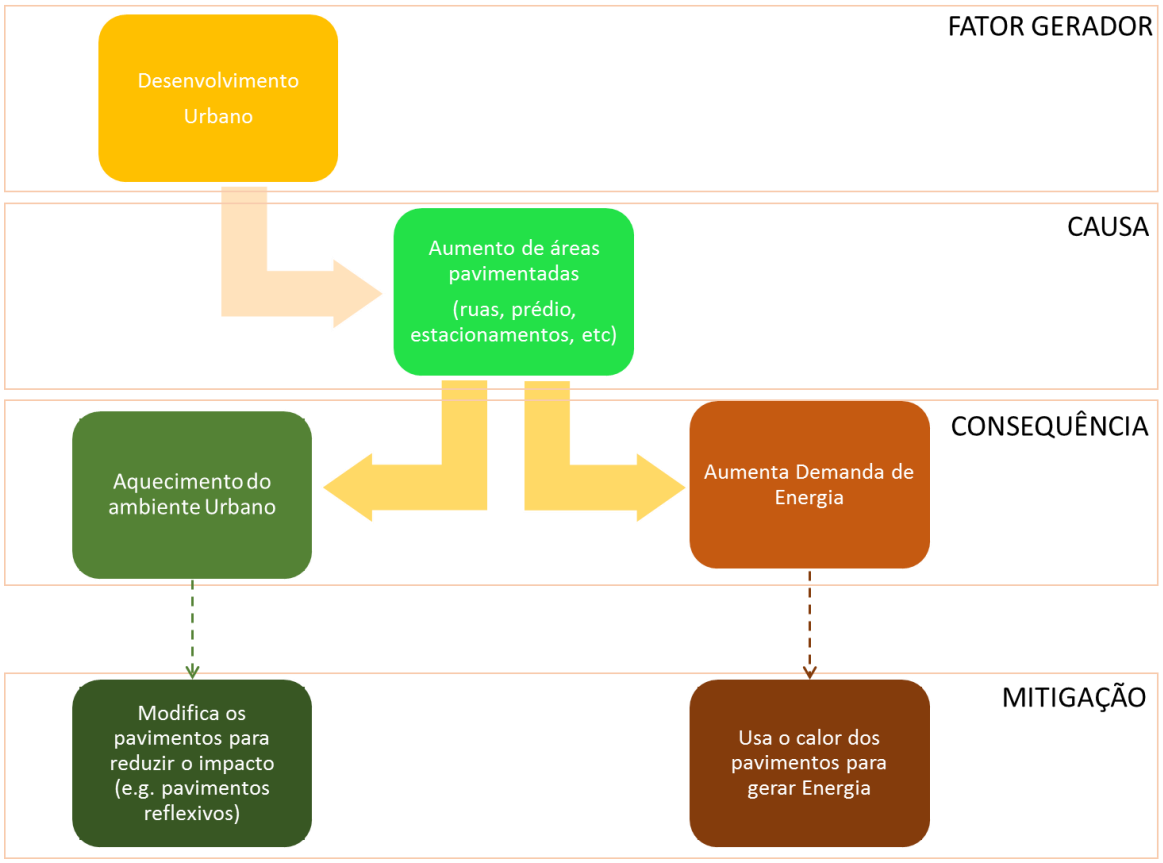


Figura 1 – Fluxograma do trabalho proposto

Os pavimentos reflexivos possuem diversos defensores e críticos sobre sua real eficácia. Pavimentos reflexivos tem uma proposta simples, o aumento do seu coeficiente de reflexão, conhecido como Albedo, que é a proporção de radiação refletida com a irradiada. Um aumento de em torno de 0,10 no albedo, pode resultar num decréscimo de temperatura da superfície dos pavimentos de 4ºC (Pomerantz et al. 2000).

Synnefa et al. (2011) fez uma série de levantamentos com materiais asfálticos com diferentes cores, resultando em albedos maiores que do asfalto preto convencional. Expondo placas dos materiais ao ambiente, foi medida a temperatura ao longo do dia. Depois de realizado os experimentos, as placas com maior albedo, marcaram temperaturas máximas e médias menores. Para avaliar então o impacto desses materiais, foi feita uma simulação com a substituição do asfalto preto, pela mistura mais clara. O resultado encontrado no estudo foi que, em condições com baixa velocidade do vento, uma diferença na temperatura do ar de até 5ºC poderia ser sentida.

Todo este estudo da geração de energia a partir de pavimentos, no entanto, passa por uma etapa anterior que é o conhecimento das características de clima, ambiente e de como os pavimentos aquecem. É nesta linha que a presente proposta de pesquisa se insere. Precisa-se de caraterização dos climas locais e de sua influência sobre a variação de temperatura nos pavimentos, bem como estudar o impacto que esta variação trará no desempenho destas caras estruturas para que se avance concomitante nas propostas de recuperação da energia de pavimentos

1.3 DESENVOLVIMENTO DO PROJETO

A seguir são elencadas as várias etapas do projeto programadas visando o atendimento dos objetivos propostos. Para que se possa atender ao desenvolvimento do projeto proposto, as seguintes etapas foram sugeridas em acordo com os métodos e técnicas descritos anteriormente:

1. Revisão sobre o impacto de temperatura em projeto de pavimentos – literatura nacional e internacional que aborde questões relacionadas à elevação ou queda de temperatura no desempenho de pavimentos flexíveis.
2. Descrição de como funciona a geração de calor nas cidades devido à pavimentação – típica elevação de temperatura nas cidades devido à pavimentação e seu efeito no microclima local.
3. Detalhamento das propriedades térmicas de pavimentos flexíveis com vistas à modelagem dos gradientes térmicos nos pavimentos – estudo da relação entre temperatura do ar e temperatura do pavimento em profundidade;
4. Investigação das estratégias para redução de temperatura de pavimentos – a exemplo do resfriamento de camadas quentes e a modificação do albedo de camadas superficiais (proporção de radiação refletida com a irradiada).
5. Delimitação das propriedades termodinâmicas dos materiais asfálticos e modelos de distribuição de calor em profundidade; correlacionar os parâmetros de temperatura ambiente (temperatura, irradiação, vento, etc.) com a temperatura dos pavimentos.
6. Procurar fontes confiáveis de informações climáticas locais com banco de dados de grande período – mínimo de quatro anos – para a cidade de Porto Alegre[4] que contenha os parâmetros necessários à montagem de um arquivo tipo HCD/ICM.
7. Organização e agrupamento dos dados climáticos obtidos e equacionar parâmetros eventualmente não disponíveis de forma a possibilitar a confecção de um HCD/ICM com auxílio do software AASHTOWare Pavement ME.
8. Validação do ICM/HCD gerado para Porto Alegre através de comparações da resposta de pavimentos previamente modelados com banco de dados climáticos de cidades norte americanas, como por exemplo Savannah.
9. Discussão da variação do comportamento frente às variáveis ambientais e delimitação dos parâmetros chave nas análises realizadas para balizamento da correlação parâmetro ambiental versus desempenho dos pavimentos flexíveis.
10. Avaliação do impacto da variação de temperatura no desempenho dos pavimentos típicos da região sul do país. Modelagem com o software AASHTOWare Pavement ME dos parâmetros de despenho para -4°, -2°, Referência (0°C de variação da temperatura média local), +2°, +4°C.
11. Considerações finais sobre a performance observada a partir dos modelos com avaliação integrada da discussão dos parâmetros climáticos de maior influência (item 9).
12. Relatório Final de Pesquisa e apresentação à equipe da Concessionária.

[4] Entende-se que a extensão da rodovia BR-290/RS no trecho sob Concessão poderá ser modelado com base no banco de dados da temperatura de Porto Alegre, sem necessidade de ajustes climáticos diretamente, salvo o de nível do lençol freático e elevação que poderá ser dinamicamente testado, caso seja determinada sensibilidade a estes parâmetros.

2 REVISÃO DE LITERATURA

2.1 ILHAS DE CALOR URBANAS

Descoberta no início dos anos 1800 e publicado por Luke Howard 1818 e 1830, a Ilha de Calor Urbana (ICU) é o fenômeno cujo a principal característica é as zonas urbanas possuírem uma temperatura superior as regiões rurais vizinhas, como demonstra a Figura 2. Segundo Ryu e Baik (2011) a maior presença de superfícies impermeáveis, como pavimentos e construções, em detrimento das superfícies permeáveis naturais e vegetação, como exemplo da cidade de New York na Figura 3, em conjunto com o calor antropomórfico, gerado com humanos, são os principais fatores da geração desse fenômeno.

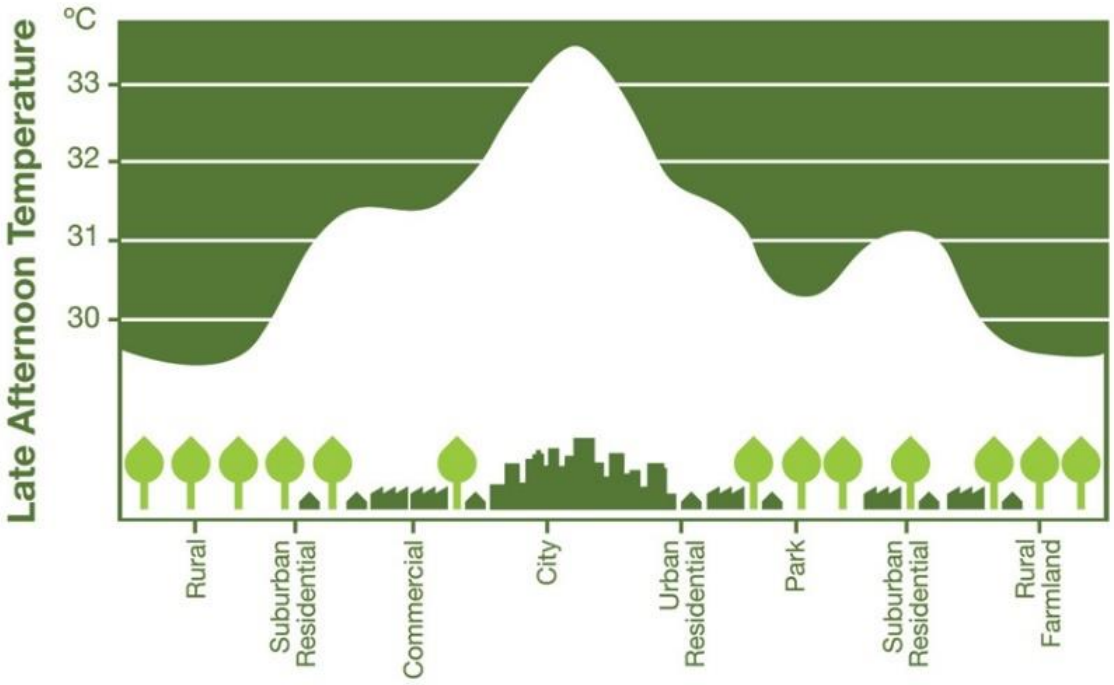


Figura 2 – Comparação da Temperatura Urbana com Rural. FONTE: http://healthyurbanhabitat.com.au/responding-to-the-urban-heat-island-optimising-the-implementation-of-green-infrastructure/

Esse aumento de temperatura, é responsável por efeitos indesejáveis, como maior desconforto térmico para os habitantes das grandes cidades, maior consumo de ar condicionado, desequilíbrios ambientais, incluindo nas bacias hidrográficas locais, com o aumento de temperatura da água de escoamento. Existem ainda estudos que relacionam o fenômeno com uma diminuição da vida útil dos pavimentos, resultado de maiores desgastes térmicos. (EPA, 2014)

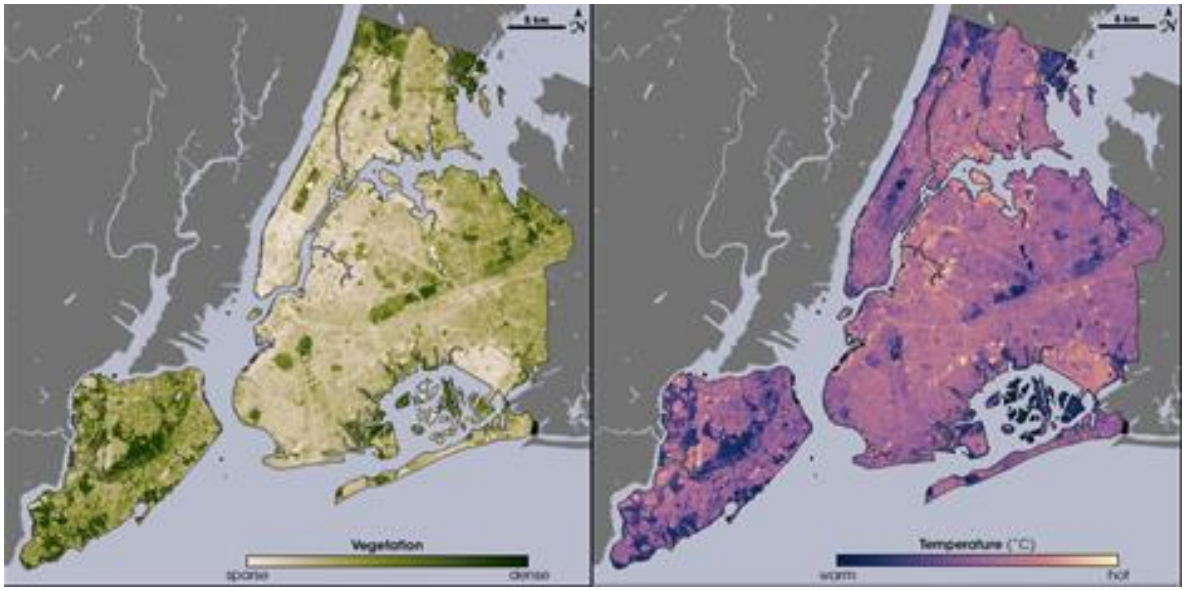


Figura 3 - Fotos de satélite de New York City - relação entre Vegetação (esquerda) e Temperatura (direita). FONTE: Site NASA Visible Earth, créditos para Robert Simmon.

Desde os primeiros relatos desse fenômeno, a população mundial cresceu e houve uma mudança do perfil, iniciando um processo forte de urbanização. O aumento populacional nas cidades gera uma demanda de malhas rodoviárias e geração de energia cada vez maior. As atuais projeções de população indicam que o êxodo rural ainda é forte, aliado ao aumento natural da população. A ONU (2014) relatou que 54% da população do mundo era urbana, com uma tendência que até 2050 um acréscimo estimado de 2,5 bilhões de pessoas em ambientes urbanos, totalizando 66% da população mundial.

Essa tendência mundial também é observada no Brasil e Rio Grande do Sul. De acordo com os dados dos censos do IBGE, a população rural do país teve seu pico em 1970 com 41 milhões de habitantes e diminuiu para 29 milhões no censo de 2010. Em compensação, a população urbana passou de 32 milhões em 1960 no primeiro censo para 160 milhões em 2010. O mesmo acontecimento pode ser relatado no Rio Grande do Sul, onde a população em sua maioria rural em 1960 com 3 milhões de habitantes na zona rural e 2,4 milhões na urbana, passou a um estado fortemente urbano com 9,1 milhões vivendo em cidades e apenas 1,5 milhões em zonas rurais.

Outra observação importante é o crescimento da capital Porto Alegre, que passou de 266 mil habitantes em 1940 para 1,3 milhões em 2000 e manteve uma taxa positiva de crescimento apresentando 1,4 milhões de habitantes em 2014. Essa tendência de maiores centros urbanos que se apresenta tanto em escala global e local, acaba fortalecendo o fenômeno de Ilha de Calor Urbana.

Com o surgimento desse problema, métodos de mitigações são apresentados na tentativa de diminuição dos efeitos negativos. As principais estratégias envolvem o resfriamento das superfícies impermeáveis, ou com a plantação de mais árvores de sombra próximas aos pavimentos, mudanças de características dos pavimentos para a geração de pavimentos frios e a criação de métodos que aproveitam a energia do pavimento, tirando o calor da estrutura e utilizado para algum outro fim, como esquentar água ou gerar eletricidade.

Os pavimentos frios mencionados envolvem a alteração da sua refletância ou permeabilidade, aumentando a radiação refletida e a evaporação, respectivamente. Desses dois tipos de pavimentos, os reflexivos recebem grande atenção dos pesquisadores e muitas divergências. Enquanto alguns defendem que a radiação refletida seria responsável por uma queda na temperatura do microclima local, outros defendem que essa radiação refletida pode ser prejudicial, sem saber os reais efeitos.

Os pavimentos reflexivos se baseiam no aumento do albedo, relação da radiação refletida com a irradiada, aumentando a quantidade de radiação solar refletida de volta ao espaço, absorvendo menos energia e consequentemente a temperatura desses pavimentos tendem a ser mais baixas que os convencionais e diminuirá o aumento da temperatura do ar no microclima local, mitigando os efeitos da Ilha de Calor Urbana. Um aumento de 0,10 no albedo poderia resultar em uma diminuição de até 4°C na temperatura dos pavimentos (Pomerantz et al., 2000).

Nacionalmente, Trichês (2014) testa diferentes tipos de misturas asfálticas coloridas, utilizando pigmentos para tornar a sua cor mais clara, conseguindo aumentar o albedo do asfalto convencional em 73%, entretanto sem atingir o albedo do concreto Portland convencional. O autor concluiu que tais misturas asfálticas podem ser aplicadas nas camadas de rolamento para baratear custos e por possuírem uma temperatura interna menor, poderiam possuir uma vida útil maior.

Em um estudo (Synnefa et al., 2011) diversos materiais asfálticos de diferentes colorações, resultando em albedos maiores que o do asfalto convencional foram medidos em exposição ao sol com diversas medições durante o dia. Após realizado os levantamentos em campo, as misturas mais claras apresentaram temperaturas máximas e médias menores. Com essas informações, um modelo foi testado com a substituição do asfalto preto convencional por uma mistura mais clara e os resultados da simulação apontaram para uma diferença de até 5°C na temperatura do ar, em condições com baixa velocidade do vento.

Apesar que os efeitos causados pela Ilha de Calor são normalmente negativos, alguns efeitos podem parecer positivos, como o maior tempo de crescimento de plantas e a redução de energia para aquecimento das casas durante o inverno, entretanto a maior parte dos efeitos será negativo, e mesmo o ganho de energia no inverno normalmente não supera o maior gasto de energia durante o verão para o condicionamento das edificações (Li, 2012).

Em um estudo em larga escala recente, Santamouris et al. (2012) realizaram o monitoramento de um parque em Atenas, Grécia, que recebeu a instalação de 4500 m^2 de pavimentos reflexivos. As cinco etapas para esse experimento foram o monitoramento da condição antes da aplicação, modelo computacional inicial, monitoramento pós aplicação, modelo computacional para a condição final e comparação entre os dois modelos para avaliação dos resultados.

Segundo os autores, não existia registro de um experimento real em maior escala, até então. Nesse estudo então foi concluído que a aplicação possibilitou uma queda da temperatura da superfície dos pavimentos em até 12°C e a diminuição da temperatura máxima em um dia de verão poderia cair em 1,9K, e cálculos indicam um conforto térmico maior para humanos. As diminuições ocorrem em menor escala em algumas condições, como fortes ventos, baixa incidência solar e temperatura. Durante o inverno, quedas de temperatura não são esperadas devido ao pavimento reflexivo.

Uma queda de temperatura pode parecer negativo no inverno, tornando-o mais rigoroso, mas conforme explicam Akbari e Konopacki (2005) em estudo comparativo entre cidades, regiões

frias durante a época de inverno possuem uma incidência solar menor, por isso superfícies reflexivas não possuem muito impacto nessa época. Essa avaliação pode ser analisada nos resultados, onde Chicago possuiu uma penalidade de aquecimento de apenas 1% enquanto Houston atingiu 25%. Entretanto a economia de Chicago por ter um período quente menor também é menor, apenas 9% contra 30% de Houston.

A EPA, *Environmental Protection Agency*, (2014) cita diversos efeitos positivos que uma eventual mitigação da Ilha de Calor geraria, como a diminuição da temperatura da água de escoamento, ocasionado por uma superfície menos quente, diminuindo possíveis impactos ambientais com o choque que poderia ser causado quando essa água é despejada novamente no meio ambiente, como rios. O conforto humano também é levado em consideração, já que a agencia diz que uma potencial queda de temperatura nas superfícies com concentração de pessoas, ajuda no conforto térmico. Outros benefícios de utilizar pavimentos reflexivos, seriam a menor necessidade de iluminação noturna e melhor visibilidade, gerando mais segurança para motoristas durante a noite.

Na contramão dos estudos que apontam um efeito positivo da utilização de pavimentos reflexivos na mitigação da Ilha de Calor Urbano, existem autores que citam os efeitos negativos dessa aplicação, que em alguns casos poderiam superar os positivos. Para Li (2012) autores consideram normalmente que os pavimentos reflexivos têm apenas efeitos indiretos sobre os climas, como a diminuição da temperatura do ar, porém existe o efeito direto da interação direta entre pavimentos e construções, através da radiação refletida.

Li (2012) para testar esse efeito, analisou a temperatura de duas paredes com características iguais, uma próxima a um pavimento de concreto Portland e outra de asfalto convencional. Próximo ao meio dia o resultado indicava que o concreto possuía uma temperatura de superfície menor que a de asfalto, entretanto a parede posicionada próxima ao concreto possuía uma temperatura maior e menos uniforme que a parede próxima ao asfalto. Com esses resultados, Li (2012) indica que devido a radiação refletida a melhor aplicação para os pavimentos reflexivos é em grandes áreas abertas, e árvores de sombra

Yaghoobian e Kleissl (2012) em uma simulação de uma construção de 1820 m^2 com uma porcentagem de 47% de janelas para paredes, em Phoenix, Arizona, uma cidade com altas temperaturas nos Estados Unidos, o aumento do albedo das superfícies próximas a edificação de 0,1 para 0,5 iria gerar um aumento da carga de ar condicionado para resfriamento, anulando o efeito positivo da menor temperatura do ar com a radiação refletida.

Lynn et al (2009) simularam o impacto que Nova Iorque teria com a implantação de um pavimento reflexivo, utilizando um software de análise de temperaturas de fluídos modificado. O resultado foi que o aumento de albedo causa uma diminuição da temperatura do ar, porém alteraria o balanço energético das pessoas com a radiação refletida, de forma que mesmo com a menor temperatura do ar e superfície, um ser humano não sentiria nenhuma melhora, ou até mesmo poderia sofrer uma piora no conforto térmico.

Yang et al. (2014), afirmam que o albedo não deve ser a única característica a ser considerada, principalmente porque a maior diferença entre a temperatura urbana e rural é durante a noite, uma mudança nas características que alteram a temperatura noturna das superfícies, como capacidade térmica e porosidade, deve ser o objetivo. Citando outros problemas dos pavimentos reflexivos os autores citam o problema de saúde que o maior fluxo de radiação pode ter, além da poluição visual que a luz refletida nesses pavimentos geraria.

2.2 PERFIL DE TEMPERATURA E PROPRIEDADES TÉRMICAS DOS PAVIMENTOS

A temperatura dos pavimentos depende das características térmicas que cada material possui. Essas características são utilizadas em diversos estudos para a criação de modelos de balanço térmico e diversos autores utilizam as mesmas características, com pequenas variações em seus estudos.

Dehdezi (2012) lista quatro propriedades térmicas para sua tese de aproveitamento da energia dos pavimentos. A condutividade térmica, calor específico, difusividade térmica e efusividade térmica são utilizados para seus estudos.

Li (2012) fala sobre as características que devem ser alteradas para a criação de pavimentos com efeitos de mitigação da ilha de calor. É considerada a condutividade térmica e calor específico, para o autor, diminuindo a condutividade a temperatura do pavimento subiria em um ritmo menor e aumentando o calor específico a quantidade de energia necessária para o aumento da temperatura também é maior. Como novas características, é citado a refletância ou albedo. Para o Li, o aumento desse albedo significa menos radiação absorvida, diminuindo a temperatura durante o dia da superfície.

Di Maria et al. (2014) descreve brevemente mais algumas características térmicas dos pavimentos. Além do albedo já citado, descreve o Índice de Refletância Solar e Emissividade (SRI na sigla em inglês).

Shi et al. (2015) utiliza um modelo para o balanço térmico considerando os três modos de transmissão de calor, condução, radiação e convenção. Na condução é utilizado a condutividade térmica e a capacidade térmica volumétrica. A capacidade térmica é relacionada ao calor específico, esse sendo a capacidade térmica por unidade de massa da substância. A convecção utiliza o coeficiente de transferência de calor por convecção. A radiação utiliza o coeficiente de radiação, que é obtido pela emissividade do material.

As propriedades térmicas pertencentes aos pavimentos flexíveis citados pelos autores e utilizados pelo modelo da AASHTO são os listados abaixo.

- Calor específico: O calor específico, é medido por joule por quilograma e kelvin (j/(kg * K)) que indica quanto de energia o material necessita para aumentar a temperatura de uma unidade de massa em uma unidade de temperatura. O calor específico e a capacidade térmica são relacionados, sendo o primeiro a capacidade térmica por unidade de massa da substância.
- Condutividade térmica: Unidade medida em watt por metro kelvin no Sistema Universal de Unidades (SI), determina a capacidade do material de conduzir calor, quanto maior for a condutividade térmica do material, mais facilidade tem o material para transmitir o calor na forma de condução.
- Difusividade térmica: A difusividade térmica relaciona as duas primeiras características e indica a velocidade com que o material muda exposto a alteração da temperatura. Uma baixa difusividade térmica significa que o material passa pouco calor adiante.
- Efusividade térmica: Indica a habilidade de troca de calor com o meio, uma alta efusividade indica um material com boa capacidade de armazenamento de calor e transferência de calor eficiente.

- Refletância ou Albedo: O albedo representa a quantidade de radiação refletida com base na radiação incidente, sendo expresso em porcentagem.
- SRI – *Solar Reflectance Index:* Usado para determinar o efeito da refletância e da emissividade, varia em porcentagem, sendo 100 para uma superfície branca e 0 para uma superfície preta. O índice analisa em comparação com as superfícies pretas e brancas, e quanto maior o SRI, mais frio o material se torna, sendo indicado para a utilização nas técnicas de mitigação da Ilha de Calor.
- Emissividade: A emissividade representa o fluxo de calor emitido ou liberado pela superfície, expresso através de um coeficiente entre o fluxo radiante do objeto comparado a um objeto preto em mesmas condições.
- Coeficiente de Convecção: O coeficiente de transferência de calor através da convecção é obtido em diversos modelos por diferentes fórmulas empíricas, envolvendo a velocidade do vento, temperatura do ar e temperatura do pavimento. Utilizado para a obtenção da taxa de calor transmitida através da convecção.
- Coeficiente de Stephan Boltzmann: O modelo utilizado no guia da NCHRP, utiliza em suas fórmulas o coeficiente de proporcionalidade da lei de Stefan Boltzmann, que indica que a energia irradiada por um corpo negro, em uma unidade de área, é proporcional à quarta potência de sua temperatura.

2.3 PARAMÊTROS CLIMÁTICOS PARA PROJETOS DE PAVIMENTOS FLEXÍVEIS

O método do DNER (1981) desenvolvido pelo engenheiro Murillo Lopes de Souza continua sendo utilizado para o dimensionamento dos pavimentos no Brasil. Desenvolvido utilizando a metodologia da AASHTO e do Corpo de Engenheiros do Exército Americano (USACE), o método é antigo e não sofreu nenhuma mudança significativa, ficando obsoleto. A própria AASHTO possui métodos mais avançados atualmente, inclusive com softwares de apoio.

O Guia Mecânico-Empírico da AASHTO trouxe um novo jeito de modelar pavimentos, abandonando apenas a abordagem empírica para uma abordagem mista com a mecânica, que sozinha não era capaz de prever com exatidão como pavimentos iriam se comportar. Os programas contam com diversas caracterizações complexas dos volumes de tráficos durante os períodos do ano, características mais avançadas dos materiais e a consideração do clima, fatores com impacto nos pavimentos que não são considerados na metodologia brasileira.

O fator do clima permite a construção de um pavimento mais adequado para cada região e é necessário na adequação do programa para utilização no Brasil. No seu guia para projetos a *National Cooperative Highway Research Program*, NCHRP, indica que os cinco parâmetros climáticos necessários para a utilização do método são os seguintes: Temperatura, Umidade Relativa, Velocidade do Vento, Precipitação e Incidência de Luz Solar. Esses dados são fornecidos pelas estações automáticas nos EUA e necessitam de um período de dados de pelo menos 24 meses.

A temperatura é responsável pela alteração do modulo de elasticidade dos pavimentos flexíveis de valores próximos a 700 MPa no verão para valores superiores a 20000 MPa no inverno. Altos gradientes de temperatura e umidade são responsáveis pela perda de vida útil nos pavimentos rígidos, gerando deformações, afetando o contato da placa de concreto e a sub-base, que acabam fraturando. A umidade ainda altera as propriedades de alguns materiais, os módulos

das camadas e pode alterar as estruturas dos materiais. O programa então precisa dessas características para avaliar o ambiente e calcular o impacto em pavimentos implantados nessa região.

A temperatura do ar determina os ciclos de congelamento e descongelamento na região, quando existentes, e em conjunto com a incidência da luz solar elas entraram nas equações de balanço de calor. A velocidade do vento é utilizada para o programa, para calcular os coeficientes de transferência de calor através de convecção nos pavimentos, que dependem da velocidade do vento. Utilizando essas três variáveis, em conjunto com os coeficientes térmicos dos pavimentos, o programa irá resolver as equações, determinando a temperatura dos pavimentos e o fluxo de calor entre as camadas.

A precipitação é utilizada na definição da infiltração, necessária para analisar impactos em pavimentos reabilitados e no processo de envelhecimento. O seu papel, conforme a NCHRP (2014) no balanço térmico não é completamente claro, por isso é optado por deixar esse fator de fora das equações. A umidade relativa é utilizada para a determinação das umidades das camadas de pavimentos rígidos e no impacto das trincas iniciais e espaçamento entre elas.

Todos esses fatores são necessários no HCD do local a ser analisado, fornecidos de hora em hora. Através do arquivo HCD e com o fornecimento informações complementares a respeito do local, como profundidade do lençol freático, latitude e longitude, o programa irá fornecer um resultado apropriado para a região a ser aplicado o pavimento.

O balanceamento térmico ainda utiliza a radiação de ondas curtas e longas do local, obtidas através da posição geográfica, fornecida ao programa em forma de latitude e longitude, e quanto dessa radiação não chega ao solo ou é refletida em função da cobertura de nuvem ou da composição do material.

A radiação é dividida em radiação de ondas curtas e ondas longas. A radiação de ondas curtas é proveniente do sol e terá parte refletida pela superfície do material e nuvens ou absorvida pela atmosfera. O restante dessa radiação é absorvido pelo material, aquecendo sua superfície

A radiação de ondas longas é a radiação terrestre, emitida pela superfície. Uma parte dessa radiação é efetivamente devolvida ao espaço, enquanto outra parte é absorvida novamente pela superfície. A radiação efetiva, sendo a diferença entre o total emitido e o absorvido de ondas longas, irá dizer quanta energia a superfície liberou.

2.4 IMPACTO DA TEMPERATURA EM PROJETO DE PAVIMENTOS

A importância desses modelos e características é devido ao impacto que os pavimentos recebem de temperaturas. Grandes variações ou extremos de temperaturas possuem diferentes efeitos nos pavimentos, desde a construção até o final da vida útil, impactando as propriedades dos materiais, vida útil e comportamento.

A etapa de construção dos pavimentos necessita cuidados com relação a temperatura de compactação das camadas da estrutura, para garantir um resultado apropriado. O Departamento de Transportes de Minnesota informa, em seu site, que pavimentos flexíveis devem ser compactados a uma temperatura mínima, evitando que enrijeçam e dificultem a

compactação adequada, evitando problemas em obras, principalmente em locais com baixa temperatura.

O próprio departamento de Minnesota disponibiliza um programa para calcular o tempo máximo parar compactar as camadas antes que elas baixem da temperatura mínima necessária. O programa PaveCool recebe uma série de informações então sobre a obra, como localização geográfica, época de execução, o tipo de solo, a mistura asfáltica que será utilizada, temperatura da entrega na obra do material transportado, velocidade do vento e o tamanho das camadas de compactação. Essas informações permitem o software calcular o tempo disponível para a compactação de cada camada do pavimento. Atualmente, existem aplicativos semelhantes disponíveis para smartphones, como o Multicool.

Huang (2004) cita os efeitos da temperatura que atingem os pavimentos, afetando a camada de concreto asfáltico, as placas de concreto Portland ou ambos os tipos de pavimentos. Os problemas gerados pelos ciclos de congelamento e descongelamento que ocorrem em regiões com invernos rígidos, também são considerados, onde o gelo formado durante o inverno, liquidifica durante a primavera, saturando os materiais da sub-base, enfraquecendo-a.

Nos pavimentos flexíveis, Huang (2004) considera a alteração do módulo de elasticidade com a variação da temperatura. Menores temperaturas tornam o pavimento mais rígido, o que pode diminuir a vida útil de fadiga da mistura asfáltica. Regiões com altas variações de temperatura durante o dia geram esforços nos pavimentos, gerando fadiga e desgastando os mesmos.

Nos pavimentos rígidos, Huang (2004) também destaca as grandes variações de temperatura, que afetam o contato entre as placas de concreto e a sub-base. A temperatura durante o dia irá aquecer mais as camadas superiores que as inferiores, o que faz com que a placa se curve com o centro para cima, afastando-o da sub-base. A temperatura noturna faz o efeito oposto, refrigerando as camadas superiores, enquanto as inferiores ainda possuem calor adquirido durante o dia, curvando a placa de modo oposto, afastando as bordas da sub-base. A diferença de temperatura máxima e mínima também afeta abertura de juntas, rachaduras e prejudica a transferência das cargas de maneira eficiente.

Pomerantz et al. (2000) realizaram experimento em pavimentos flexíveis com diferentes temperaturas para testar a resistência a deformações no trilho de roda. Com uma diferença de 11°C, diminuindo de 53°C para 42°C, os resultados indicaram que o pavimento na temperatura menor poderia resistir mais de 10 vezes, atingindo 270 mil repetições, enquanto o outro pavimento falhou com 20 mil repetições (Figura 4).

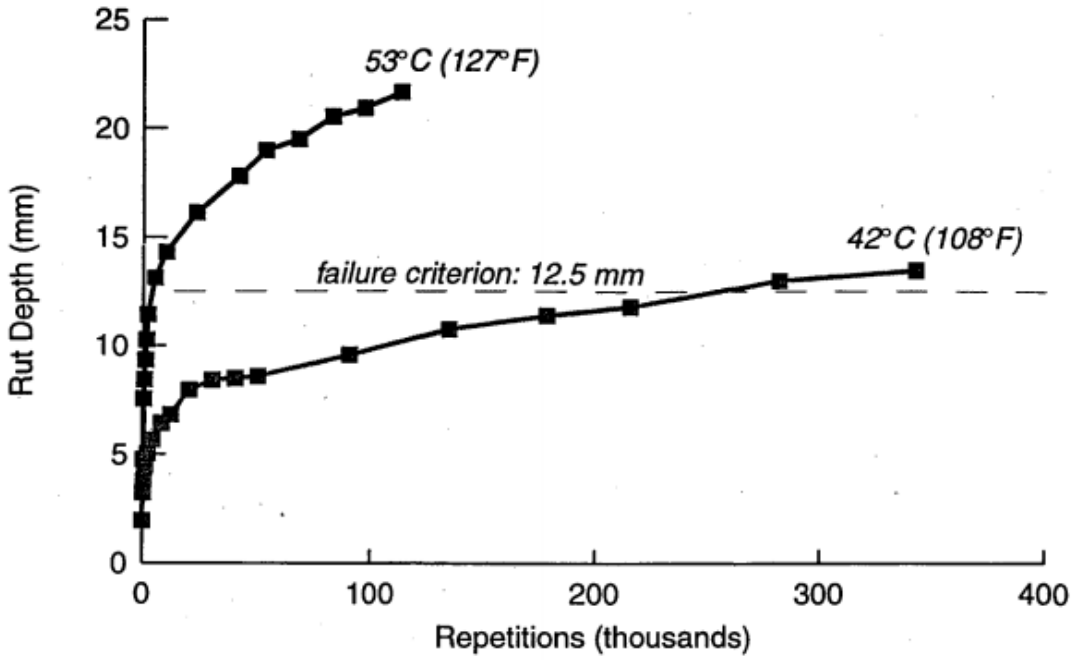


Figura 4 – Relação de repetições e deformações em diferentes temperaturas. FONTE: Pomerantz et al. (2000)

O estudo também constatou que a temperatura causa um efeito de envelhecimento acelerado nos pavimentos (Figura 5), uma fragilização maior ocorre com uma temperatura maior, devido ao aumento de viscosidade e enrijecimento dos pavimentos flexíveis ao longo do tempo, colaborando para rachaduras. O efeito não é linear com o aumento da temperatura. Uma camada reflexiva poderia diminuir essa temperatura e ainda reduzir o dano causado por luzes ultravioletas (Pomerantz et al., 2000).

O programa *AASHTOWare Pavement ME Design*, conforme explicado no guia de projeto da NCHRP (2004), em seus critérios de desempenho utiliza três principais critérios, com subdivisões. Rachaduras térmicas, trincas por fadigas e deformação permanente no trilho de roda. Os fatores climáticos influem também em cada um desses métodos.

A deformação permanente é influenciada pela temperatura, afetando a rigidez do asfalto e consequentemente o módulo das misturas de concreto asfáltico, necessitando que seja levado em conta em função do tempo e profundidade do pavimento. O trilho de rodas ainda tem a consideração da umidade do solo. Uma mudança de valor da umidade, diminui o modulo de resiliência de um solo granular, aumentando a deformação elástica, quando mantidas as demais condições, e causando um maior trilho de rodas.

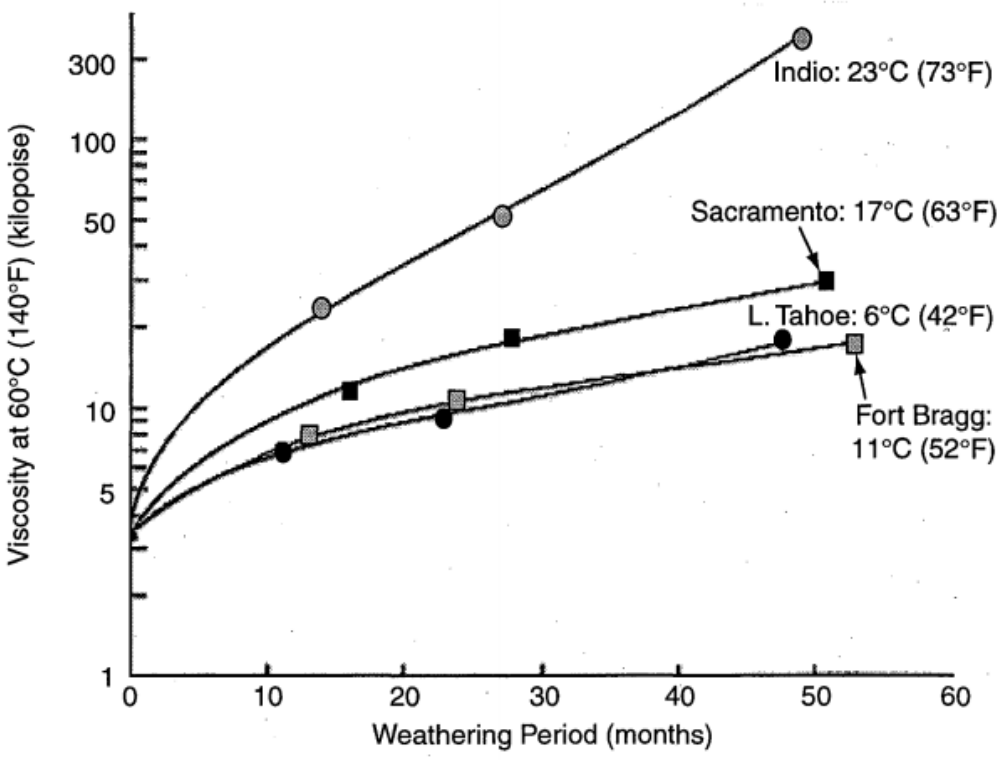


Figura 5 – Gráfico de tempo e viscosidade em pavimento expostos a diferentes temperaturas.
FONTE: Pomerantz et al. (2000)

As rachaduras térmicas necessitam do perfil de temperatura ao longo da profundidade do pavimento, explicado no Item 2.7, para a definição da temperatura durante a vida útil do pavimento utilizado, permitindo a análise dos esforços térmicos.

Já as trincas por fadiga são divididas na análise final em trincas longitudinais ou trincas do tipo couro de jacaré. Do mesmo modo que as deformações permanentes, a variação da temperatura sobre a rigidez do asfalto e a alteração da umidade nas camadas granulares, alterando o módulo de resiliência impactam na formação desse modo de trinca. Um aumento de rigidez diminui os impactos de fadiga, tornando a temperatura em um fator importante para a determinação da fadiga.

2.5 ALBEDO E FORMAS DE MEDIÇÃO

O albedo, como citado anteriormente, é o sinônimo de refletância, significando a razão entre a radiação refletida e radiação incidente, podendo ser expresso em um número ou porcentagem, os albedos das superfícies mais comuns são conforme a Tabela 1. O albedo global de superfície tem um importante papel no equilíbrio de temperatura do planeta, conforme Pistone et al. (2013) em seu estudo alerta, o albedo global tem diminuído, colaborando para o efeito estufa. É estimado que a diminuição do albedo no Ártico tem um impacto aproximadamente de 25% ao do CO2, um impacto muito superior ao que estudos anteriores demonstravam.

Tabela 1 – Tabela de Albedos (Fonte: Li et al, 2014)

Material	Albedo	
	Faixa	Médio
Concreto Asfáltico (CA)	0,05 - 0,15	0,10
CA com Capa Reflexiva	0,2 - 0,3	0,20
Concreto Portland	0,15 - 0,35	0,25
CA Permeável	0,08 - 0,12	0,10
Concreto Portland Permeável	0,18 - 0,28	0,25
Solo	0,21 - 0,23	0,22
Grama	0,18 - 0,20	0,19

O importante papel do albedo na criação de métodos para mitigar a Ilha de Calor Urbana torna importante o processo de medição dessa característica. O método oficial para a medição envolve o uso de dois piranômetros, um para medir o fluxo de radiação que incide sobre a superfície e um para medir o fluxo de radiação refletido, formando o aparelho chamado albedometro. Normalmente esses materiais possuem preços elevados, impossibilitando medições para fins educacionais ou simples experimentos.

Gilchrist (2011) na procura por métodos com baixo custo para medir o albedo, sugere a utilização de luxímetros para a medição do albedo. O método sugere a medição de lux refletido da superfície com o posicionamento do aparelho um metro de distância e depois colocado na superfície virado para cima, medir a luminosidade recebida. Após as medições, a divisão da taxa refletida pela recebida é realizada para obter o albedo. Segundo o autor esses valores estão de acordo com o albedo real da superfície.

Porém na procura por um método sem nenhuma necessidade de um aparelho dedicado, Gilchrist (2011) testa a utilização de fotografias digitais para a obtenção aproximada do albedo do material considerado. O experimento sugere a colocação de uma folha branca A4 de albedo conhecido sobre a superfície a qual se deseja calcular o albedo. Desse modo, utilizando um software de edição de imagens, o albedo do material pode ser calculado utilizando uma relação com o papel e depois um resultado final obtido com a multiplicação do albedo relativo com o albedo do papel. Os resultados apontam que esse método teve uma margem de erro de apenas 3% quando comparado ao primeiro método apresentado pelo autor de usar um luxímetro.

2.6 ESTRATÉGIA PARA REDUÇÃO DE TEMPERATURA EM PAVIMENTOS

Algumas pesquisas já realizadas, principalmente no estado da Califórnia, no Estados Unidos, preocupam-se com estratégias para a redução de temperaturas em pavimentos. Uma as maneiras mais diretas de promover tal redução é fazendo com o que o pavimento tenha albedos maiores. Naturalmente é de se esperar que pavimentos "claros", como o concreto desenvolvam tal habilidade – isto será demostrado a seguir no item 3.5, p. 39, deste relatório. No entanto, a seleção do tipo de pavimento não é restrita ao seu albedo, mas a outros elementos prioritariamente de escolha em função de características mecânicas e construtivas.

No que tange os pavimentos flexíveis, a pesquisa realizada por Ongel & Harvey (2004) demonstra que pavimentos flexíveis construídos com agregados minerais com maior quantidade de elementos que reflitam os raios solares, elevam o albedo do material. Com isto, passam a ser pavimentos mais "claros", de albedo maior. Outro método utilizado é a utilização de uma capa reflexiva sobre o pavimento, conforme citado pela EPA (2014).

Outro método estudado para a redução da temperatura nos pavimentos é a alteração da permeabilidade, gerando pavimentos permeáveis, aumentando desse modo a evapotranspiração do local. Para Santamouris (2013) essa opção é viável para ser implantada em locais com climas quentes e úmidos, onde a chuva serviria para a refrigeração do pavimento. Climas secos com pavimentos permeáveis geram temperaturas de superfície ainda maiores, devido aos poros do pavimento, por isso o autor cita que em alguns casos, os pavimentos poderiam ser molhados com águas residuais.

Yang et al. (2014) também apoia a utilização de pavimentos com maior porosidade, por terem um efeito maior que os reflexivos durante os períodos noturnos, quando o efeito da ilha de calor é mais proeminente, além de não possuir alguns efeitos negativos que o pavimento reflexivo tem, conforme citados no item 2.1 na página 13.

Outras pesquisas como aquela realizada por Dehdezi (2012) demonstra a potencialidade de se inserir nos pavimentos elementos tipo "radiadores" que venham a se valer do aquecimento da massa asfáltica para o aquecimento de fluídos em transiente nestes elementos de forma a gerar fluxos que podem até mesmo gerar energia pelo princípio de máquinas de calor.

Dutos com fluídos pelo pavimento além de gerar energia, utilizam o calor do pavimento para o aquecimento desses fluídos, resfriando a temperatura da superfície do pavimento. Estudo realizado por Chiarelli et al (2014) utiliza dutos com ar, concluindo que é possível gerar uma redução de 6°C na temperatura da superfície do pavimento. Esse método de utilizar ar, ao invés de água, principal fluído estudado, tem a vantagem de não ter riscos de infiltração de um fluído liquido dentro da estrutura do pavimento, que podem comprometer a vida útil, porém como método para utilização para gerar energia, não é eficiente. O autor conclui que além de ser um eficiente método para mitigação, pode ser utilizado para o descongelamento de estradas durante o inverno, guardando a energia dos dias quentes.

Alguns estudos demonstram a importância da redução de temperatura em pavimentos, como o de Yaning et al (2015), no qual os pesquisadores relatam que com mínima manutenção, impactos significantes são esperados no planejamento de manutenções rodoviárias. No caso particular estudados por aqueles autores, as intervenções necessárias foram antecipadas em média entre 8% e 16% do tempo previsto, correspondendo a um aumento de custos de 1 a 2% superiores do valor presente líquido.

2.7 MODELOS DE DISTRIBUIÇÃO DE TEMPERATURA EM PAVIMENTOS

A AASHTO através de seu manual para dimensionamento de pavimentos pelo modo empírico mecânico (NCHRP, 2014) revela que a temperatura do ar não pode ser utilizada num modo direto para estimar a temperatura do pavimento, então apresenta um balanço térmico que é utilizado pelo seu *software*. A condição inicial de contorno na superfície do pavimento é encontrada através do seguinte balanço térmico:

$$Qi - Qr + Qa - Qe \pm Qc \pm Qh \pm Qg = 0$$

Onde,

Qi = Radiação de ondas curtas incidentes.

Qr = Radiação de ondas curtas refletidas.

Qa = Radiação de ondas longas incidentes.

Qe = Radiação de ondas longas emitidas.

Qc = Transferência de calor por convecção.

Qh = Efeitos da transpiração, condensação, evaporação e sublimação.

Qg = Energia absorvida pela superfície.

As duas variáveis das ondas curtas podem ser representadas em conjunto, como Qs que significa a rede de ondas curtas, diminuindo as ondas refletidas das ondas incidentes (Qi – Qr). O mesmo pode ser realizado para as ondas longas, com a variável Ql, sendo a diferença entre as radiações recebida e emitidas. Qs é calculada da seguinte maneira.

$$Qs = as\ R * \left[A + B\frac{Sc}{100}\right]$$

Onde,

as = Absorção da superfície do pavimento para ondas curtas.

*R** = Radiação extraterrestre incidente em uma superfície horizontal na atmosfera exterior. Depende da latitude e da declinação solar, sendo essa uma função da época do ano.

A,B = constantes para dispersão difusa e adsorção da atmosfera.

Sc = Porcentagem de incidência solar que considera a cobertura de nuvens.

A rede de ondas longas (Ql) é tratada separadamente, através da seguinte fórmula:

$$Ql = (Qz - Qx)\left(1 - \frac{NW}{100}\right)$$

Onde,

N = Fator para nuvens, dependente da altitude.

W = Cobertura de nuvens média para dia e noite (100-Sc).

Qz = Radiação de ondas curtas incidente sem considerar a cobertura de nuvem.

$$Qz = \sigma sb\ Tair\ \left(G - \frac{J}{10^{\rho P}}\right)$$

σsb = Constante de Stefan Boltzmann

G = 0,77.

J = 0,28.

ρ = 0,074.

P = Pressão de vapor do ar.

Qx = Radiação de ondas curtas emitida sem considerar a cobertura de nuvem.

$$Qx = \sigma sb\, \varepsilon Ts^4$$

ε = Emissividade do pavimento, dependente de cor, textura e temperatura.

Ts = Temperatura da superfície pela escala de Rankine.

O outro fator detalhado pelo manual da AASHTO é a transferência de calor por convecção que acontece com o ar logo acima do pavimento. Essa transferência é assim expressa:

$$Qc = H(Tair - Ts)$$

Sendo H o coeficiente de transferência de calor por convecção. Para determinar esse coeficiente é utilizado a temperatura do pavimento, temperatura do ar, média da temperatura do ar e da do pavimento e média da velocidade diária do vento. A fórmula empírica usada para isso é:

$$H = 122{,}93[0{,}00144Tm^{0{,}3}U^{0{,}7} + 0{,}00097(Ts - Tair)^{0{,}3}]$$

Após essas primeiras variáveis descobertas, através do balanço térmico original proposto pelo manual é possível saber quanto calor irá restar na superfície do pavimento. Conhecido esse calor, para as demais camadas do pavimento a transferência de calor será feita através da condutividade térmica. Conforme Shi et al (2014), uma equação de condução de calor, unidimensional pode ser usada no interior do pavimento:

$$\frac{\partial T}{\partial t} - \frac{k}{c}\left(\frac{\partial^2 T}{\partial z^2}\right)$$

A condição de contorno entre camadas os autores apresentam a equação como:

$$k_1 \frac{\partial T_1}{\partial z} = k_2 \frac{\partial T_2}{\partial z}$$

Onde T é temperatura, t é o tempo, k é a condutividade térmica da camada estudada, c é a capacidade térmica volumétrica do material e z é a profundidade do pavimento. A utilização desses modelos de contorno e fórmulas de transferência de calor são responsáveis para a determinação das temperaturas nas diversas camadas de pavimento pelo *software* da AASHTO, possibilitando a sequência de cálculo.

2.8 SISTEMAS DE APROVEITAMENTO DE ENERGIA EM PAVIMENTOS

As grandes áreas pavimentadas e a dificuldade para abastecer as regiões afastadas das estradas, além da preocupação com energia limpa e modelos de construções autossustentáveis geram a busca por novas soluções, como a utilização do próprio potencial energético das rodovias para a geração de energia, através da temperatura ou deformação gerada pelos carros, na tentativa de criar estradas que possam fornecer energia para a rede ou simplesmente não necessitar uma rede externa.

Nessa ideia Lee et al (2014) propõem quatro tipos de soluções na intenção de aproveitar a energia solar nas rodovias. A primeira opção envolve a utilização das placas fotovoltaicas em pontos da rodovia como as divisas centrais de pistas. Os autores, porém, destacam que placas fotovoltaicas não possuem a eficiência esperada atualmente, mas acreditam que em um futuro próximo placas solares serão instaladas onde o terreno não tenha grande importância. A

segunda opção envolve a criação de um sistema de dutos com água no interior do pavimento. Como os pavimentos podem atingir temperaturas superiores a 60°C, esse calor pode ser utilizado para aquecer água no interior dos pavimentos, permitindo o seu uso para a utilização residencial, como aquecimento das construções ou água quente nas tubulações.

O uso desse sistema seria principalmente indicado para grandes estacionamentos ou arredores de construções. Esse modelo além de utilizar energia, ainda reduz a temperatura dos pavimentos, e conforme dito anteriormente, uma diminuição de temperatura tem efeitos positivos para a vida útil. O estudo ainda relata a possibilidade de criação de sistemas termoelétricos que aplicam o Efeito Seebeck, utilizado para gerar calor em automóveis, possibilitando com a recepção de calor, armazenar energia que pode ser convertida depois. A última proposta dos autores é a futura criação de uma Rodovia Solar, utilizando um material para a pavimentação que replicaria as placas solares, desse modo, toda a rodovia seria uma grande placa voltaica.

Outro método para o aproveitamento de energia, utilizando o princípio de redes de dutos internamente no pavimento, envolve a utilização de ar, no lugar de água, proposto por Chiarelli et al (2015). Os autores indicam que isso elimina o risco de infiltração com líquidos nas camadas inferiores do pavimento. O método possibilita a redução da temperatura dos pavimentos em até 6°C e permite a produção de energia para lâmpadas ao longo das rodovias e em regiões frias, pode ser utilizada para o descongelamento do gelo na pista.

Xiong et al (2014) aponta que os esforços causados pelos veículos sobre os pavimentos podem ser convertidos para energia elétrica, através de coletores instalados embaixo da camada do pavimento. A piezeletricidade é o processo reverso de aplicar um campo elétrico em um material piezoeléctrico para causar deformações. O estudo aponta que esse tipo de energia poderia abastecer as balanças de pesagem ao longo das rodovias.

Os impactos de energia causados por esse tipo de aproveitamento foram estudados além por Guo e Lu (2015), revelando que um sistema de energia piezelétrico ao longo de toda a malha rodoviária da Florida nos Estados Unidos, geraria 5,5 GWh por dia, um benefício estimado de 6,6 milhões de dólares. Segundo eles a tecnologia atual poderia gerar um ganho de 2,3 kWh por quilômetro de rodovia.

3 METODOLOGIA DA PESQUSA

O início da metodologia da pesquisa envolve a coleta de informações necessárias para o desenvolvimento de atividades. O conhecimento das características dos pavimentos é uma necessidade para a criação futura de um modelo matemático que possa calcular a temperatura ou o potencial de energia gerada pelos métodos de aproveitamento de energia. Como as medidas convencionais de albedo costumam ser onerosas, torna-se interessante o teste de métodos alternativos, a exemplo do método de medir o albedo através de fotografias digitais.

Dados climáticos também são utilizados para que seja possível a criação de um HCD (*Hourly Climatic Data*, ou Dados climáticos horários) para que a utilização dos softwares de dimensionamento de pavimentos seja possível. Esses dados normalmente são obtidos através de estações climáticas automáticas.

3.1 MODELOS DE DISTRIBUIÇÃO DE TEMPERATURA EM PAVIMENTOS

O modelo de distribuição de temperatura utilizado nas simulações dos pavimentos foi o modelo da AASHTO do guia de 2002, em função de ser utilizado o software *AASHTOWare Pavement ME Design* para as análises do pavimento, conforme explicado no item 2.7. A condição da superfície é obtida através do seguinte balanço térmico:

$$Qi - Qr + Qa - Qe \pm Qc \pm Qh \pm Qg = 0$$

Resolvido esse balanço térmico é obtido a quantidade de calor que o pavimento absorve do ambiente e pode-se obter a temperatura das camadas inferiores da estrutura. O programa utiliza então uma fórmula de transferência de temperatura unidimensional.

$$\frac{\partial T}{\partial t} - \frac{k}{c}\left(\frac{\partial^2 T}{\partial z^2}\right)$$

Além da transferência de temperatura dentro da camada é necessária que seja feito levada em conta as condições de contorno entre duas camadas diferentes, utilizando uma fórmula adequada para isso.

$$k_1 \frac{\partial T_1}{\partial z} = k_2 \frac{\partial T_2}{\partial z}$$

Utilizando modelo semelhante a esse apresentado, o programa é capaz de estimar as temperaturas das camadas do pavimento quando recebe as informações climáticas através dos HCDs criados.

3.2 DADOS CLIMÁTICOS – SÉRIES HISTÓRICAS E CRIAÇÃO DO HCD

A criação de um HCD que servirá de base para uso no ICM (*Integrated Climatic Model*) começa pela coleta dos dados climáticos necessários. Esses dados são Precipitação, Temperatura do ar,

umidade relativa do ar, incidência de luz solar e velocidade do vento. Esses dados devem estar em base horária, obtidas através de estações climáticas com pelo menos 60 meses de dados. É importante ressaltar que as estações utilizadas possuem entradas para cobertura de nuvens e não incidência solar, porém como visto no item 2.7 e conforme Truax et al. (2011) presume em seu trabalho sobre a criação de HCDs para a região de Mississipi, a incidência solar pode ser considerada o inverso da cobertura de nuvens (Incidência Solar = 100% - Cobertura de Nuvens).

O levantamento desses dados foi realizado com procuras nos websites do Instituto Nacional de Meteorologia (INMET) e do Centro de Previsão do Tempo e Estudos Climáticos do Instituto Nacional de Pesquisas Espaciais (CPTEC/INPE). O site do INMET fornece os dados das estações meteorológicas convencionais desde a sua fundação, porém os dados climáticos das estações automáticas disponíveis são apenas dos 90 anteriores. O acesso aos demais dados é realizado através de solicitações diretas ao Instituto. As estações convencionais possuem três entradas por dia, com umidade relativa do ar, temperatura, precipitação e velocidade do vento. As estações automáticas fornecem os mesmos dados que as estações automáticas, entretanto com uma base horária.

O site do INPE disponibiliza os dados de estações METAR (*Metereological Aerodrome Report*, Relatório Meteorológico de Aeroporto) e SYNOP (*Surface Synoptic Observation*, Observação Sinótica de Superfície). Essas estações disponibilizam os dados em base horária no caso da METAR e de 3 em 3 horas no caso da SYNOP. As estações METAR possuem os dados de temperatura do ar, velocidade do vento e a cobertura de nuvens. No caso do SYNOP os dados são os de velocidade do vento, cobertura de nuvens, temperatura do ar e umidade relativa do ar.

Analisando os dados obtidos percebeu-se que existem diversas falhas, que encontraram algum erro de leitura. Com base nisso os dados foram mesclados e tratados em conjunto, para a criação do HCD. Essas falhas fizeram com que os dados recebidos e os HCDs tiveram datas diferentes de início e fim, para adequar um período sem erros. Os dados das estações também se encontram em UTM, o horário universal, portanto é necessário que seja descontada 3 horas para o horário de Brasília, isso faz com que o dia final não possa ser inteiramente utilizado. As datas recebidas e utilizadas estão indicadas na Tabela 2.

Tabela 2 – Tabelas das datas de início e fim, recebidas e utilizadas nos HCDs.

Cidade	INMET Aut.		Utilizado HCDs	
	Início	Final	Início	Final
Brasília	07/05/2000	31/12/2015	08/05/2000	30/12/2015
Fortaleza	18/02/2003	31/12/2015	18/02/2003	30/12/2015
Porto Alegre	22/09/2000	30/09/2015	01/01/2005	29/09/2015
Rio de Janeiro	24/05/2000	31/12/2015	01/01/2003	30/12/2015
São Paulo	25/07/2006	31/12/2015	25/07/2005	30/12/2015

Os dados da estação convencional da INMET e das automáticas do SYNOP e METAR vieram com seus dados escritos de maneira semelhante as necessárias, com os dados posicionadas em colunas únicas e cada linha significando uma hora conforme indicado nas Figura 6.

A estação automática do INMET, entretanto, vem com um formato diferente de escrita, com os dados formando uma tabela (Figura 7), com cada linha significando um dia e cada coluna uma hora, necessitando que seja reescrito. Para reescrever essa planilha, o jeito mais simples encontrado foi a utilização de um código de VBA (Figura 8), permitindo que as planilhas sejam convertidas de maneiras automáticas após a primeira.

As planilhas das estações automáticas foram escolhidas para serem as bases principais de dados para a criação do HCD para os parâmetros de temperatura, velocidade do vento e umidade relativa do ar. Para a precipitação é utilizada a estação convencional que possui menos erros que a estação automática. Por último a cobertura de nuvens é fornecida pelas estações METAR que possuem base de dados horária. Como as bases de dados que foram utilizadas possuem erros, tornou-se necessário a criação de um método para a correção desses erros, conforme pode se observar na Figura 9.

Data/Hora	Veloc. do Vento (m/s)	Cobertura de nuvens (%)	Precip. acumulada (mm)	Temp. do Ar (C)"	Umidade Relativa do Ar (%)
01/01/2006 00:00	1.5	50.0	0.0	27.0	70.0
01/01/2006 03:00	1.0	50.0	0.0	26.0	79.0
01/01/2006 06:00	2.6	62.0	0.0	25.0	83.0
01/01/2006 09:00	0.0	75.0	0.0	27.0	79.0
01/01/2006 12:00	1.0	88.0	0.0	30.0	66.0
01/01/2006 15:00	4.1	75.0	0.0	34.0	47.0
01/01/2006 18:00	8.2	75.0	0.0	30.0	62.0
01/01/2006 21:00	5.0	100.0	0.0	23.0	0.0
02/01/2006 00:00	1.5	100.0	0.0	23.0	94.0
02/01/2006 03:00	2.1	100.0	0.0	24.0	89.0
02/01/2006 06:00	0.0	100.0	0.0	24.0	89.0
02/01/2006 09:00	2.1	100.0	0.0	24.0	94.0
02/01/2006 12:00	2.1	100.0	16.0	26.0	79.0
02/01/2006 15:00	1.5	100.0	0.0	27.0	79.0
02/01/2006 18:00	1.0	100.0	0.0	28.0	74.0
02/01/2006 21:00	1.5	100.0	0.0	25.0	94.0
03/01/2006 00:00	1.5	100.0	0.0	25.0	89.0

Figura 6 – Formato das tabelas SYNOP, com cada linha sendo uma entrada de uma hora diferente

	TEMPERATURA DO AR (°C)	TEMPERATURA DO AR (°C)	TEMPERATURA DO AR (°C)	TEMPERATURA DO AR (°C)	TEMPERATURA DO AR (°C)	TEMPERATURA DO AR (°C)
HORA UTC	0000	0100	0200	0300	0400	0500
01-jan-2015	24,3	25,0	25,2	25,3	25,0	25,6
02-jan-2015	24,6	24,4	25,8	25,2	26,8	26,5
03-jan-2015	27,7	27,2	26,6	26,4	26,1	24,6
04-jan-2015	26,5	26,5	26,4	25,9	25,7	25,8
05-jan-2015	23,4	23,8	23,7	23,5	23,4	23,1
06-jan-2015	22,8	22,7	22,5	22,3	22,3	22,5
07-jan-2015	25,5	25,6	23,9	23,6	23,5	22,9
08-jan-2015	28,7	29,2	28,8	27,5	24,5	24,2
09-jan-2015	26,6	25,3	24,3	24,2	23,1	23,1
10-jan-2015	28,0	25,4	27,2	29,4	29,0	28,2
11-jan-2015	25,1	24,6	24,3	24,1	23,9	24,0
12-jan-2015	26,6	26,3	25,0	24,8	24,6	24,4
13-jan-2015	28,1	27,6	28,6	27,6	28,6	26,9
14-jan-2015	27,6	27,2	26,2	25,5	24,9	25,6
15-jan-2015	27,7	26,1	25,4	25,4	25,7	25,6
16-jan-2015	27,8	27,2	26,6	24,7	24,7	24,3
17-jan-2015	26,5	25,4	24,8	24,7	23,8	25,5
18-jan-2015	27,3	25,1	24,5	23,7	23,2	24,0
19-jan-2015	27,0	26,5	24,6	24,2	24,1	24,4
20-jan-2015	28,0	26,8	25,3	25,1	24,1	25,6
21-jan-2015	27,4	26,7	24,8	24,3	24,5	24,5
22-jan-2015	25,9	25,3	24,4	24,6	24,3	23,9
23-jan-2015	21,5	22,1	21,7	22,0	21,9	21,9

Figura 7 – Formato dos dados recebidos do INMET, com necessidade de adaptação

Ordenar

```
Private Sub Ordenar_Click()
LastRow = ActiveSheet.Cells(Rows.Count, 1).End(xlUp).Row

For x = 1 To LastRow
For y = 1 To 24
Cells(((x - 1) * 24) + y, 30) = Cells(x, y)
Next y
Next x

End Sub
```

Figura 8 – Comando VBA para alinhamento da tabela do INMET

					METAR				SYNOP				INMET				automatico		
aaaa	mm	dd	hh	Concatenar	vento	nuvens	oitavos	temp.	Vento	Nuvens	Temp	Umidade	Temp	Umidade	Vento	Chuva	TEMP	UMIDADE	VENTO
2000	9	22	0	2000092200	1	100	7	17	1	100	16.8	94	16.4	95	0	null	NULL	NULL	NULL
2000	9	22	1	2000092201	4	100	7	17	Null	Null	Null	Null	Null	Null	Null	null	NULL	NULL	NULL
2000	9	22	2	2000092202	1	100	4	17	Null	Null	Null	Null	Null	Null	Null	null	NULL	NULL	NULL
2000	9	22	3	2000092203	Null	Null	Null	Null	Null	Null	Null	Null	Null	Null	Null	null	NULL	NULL	NULL
2000	9	22	4	2000092204	0	100	7	16	Null	Null	Null	Null	Null	Null	Null	null	15.5	94	1.2
2000	9	22	5	2000092205	1	100	7	16	Null	Null	Null	Null	Null	Null	Null	null	15.3	95	2.2
2000	9	22	6	2000092206	1.5	100	7	16	1.5	100	16	96	Null	Null	Null	null	15.1	94	1.9
2000	9	22	7	2000092207	1	100	7	16	Null	Null	Null	Null	Null	Null	Null	null	14.8	95	1.5
2000	9	22	8	2000092208	2.1	100	7	16	Null	Null	Null	Null	Null	Null	Null	null	14.5	94	1.7
2000	9	22	9	2000092209	1.5	100	2	16	1.5	100	15.8	96	Null	Null	Null	null	14.4	85	1.7
2000	9	22	10	2000092210	0	75	2	15	Null	Null	Null	Null	Null	Null	Null	null	14.4	86	1.8
2000	9	22	11	2000092211	Null	Null	Null	Null	Null	Null	Null	Null	Null	Null	Null	null	15.3	84	2.2
2000	9	22	12	2000092212	Null	Null	Null	Null	3.1	50	18	75	16.9	76	2.8	57.6	16.6	76	2.2
2000	9	22	13	2000092213	3.1	40	4	19	Null	Null	Null	Null	Null	Null	Null	null	17.9	62	2.3
2000	9	22	14	2000092214	3.1	40	4	20	Null	Null	Null	Null	Null	Null	Null	null	18.6	49	1.6
2000	9	22	15	2000092215	3.6	40	4	21	Null	Null	Null	Null	Null	Null	Null	null	19.5	45	1.7
2000	9	22	16	2000092216	2.1	40	4	21	Null	Null	Null	Null	Null	Null	Null	null	19.8	45	1.2
2000	9	22	17	2000092217	5	50	4	22	Null	Null	Null	Null	Null	Null	Null	null	20.9	44	1.7
2000	9	22	18	2000092218	4	50	4	22	Null	Null	Null	Null	21.2	45	1.6	null	20.9	40	1.1
2000	9	22	19	2000092219	4	25	2	22	Null	Null	Null	Null	Null	Null	Null	null	20.9	42	1.7
2000	9	22	20	2000092220	2	25	2	22	Null	Null	Null	Null	Null	Null	Null	null	19.8	52	1.7
2000	9	22	21	2000092221	4	0	0	18	Null	Null	Null	Null	Null	Null	Null	null	17.8	63	2.2
2000	9	22	22	2000092222	5.2	0	0	18	Null	Null	Null	Null	Null	Null	Null	null	15.7	68	2.4
2000	9	22	23	2000092223	2.6	0	0	15	Null	Null	Null	Null	Null	Null	Null	null	14.7	70	2.6

Figura 9 – Tabela com os valores de todas as estações e erros.

Para corrigir os problemas dos três parâmetros que utilizam a base de dados das estações automáticas seguem a seguinte metodologia.

- Interpolar valores próximos

  O primeiro passo para a correção dos valores é a interpolação direta dos dados quando os valores logo acima e abaixo estão corretos.

- Inserir os valores das estações convencionais do INMET.

  Com a persistência dos erros, mesmo após a primeira interpolação, para preencher as demais falhas então, a próxima alternativa é a substituição dos valores nulos pelos valores do mesmo instante encontrado na base das estações convencionais do INMET.

- Inserir os valores do banco de dados do SYNOP e METAR

  Depois de realizada a primeira substituição, colocaram-se os dados encontrados no site da INPE, o banco do SYNOP e METAR. Como o SYNOP e METAR possuem mais erros que os da estação convencional do INMET, mesmo com a base com menor intervalo, foi decidido que seria utilizado para complementar o banco de dados final, após a utilização dos dados da estação convencional do INMET.

- Interpolação linear dos valores restantes

  Caso algum erro persista, ou se algum dos bancos de dados que poderia ser utilizado para a substituição de valores, a opção restante para corrigir esses erros é a interpolação linear dos erros até a tabela estar completa e sem erros, conforme Figura 10.

	metar	synop	INMET	automatico				
DATA	temp.	Temp	Temp	TEMP	Primeira Interp.	Substituição	Interpolação Final	Final
2000092200	17	16.8	16.4	NULL	xx	16.4	16.4	16.4
2000092201	17	Null	Null	NULL	xx	17	17	17
2000092202	17	Null	Null	NULL	xx	17	17	17
2000092203	Null	Null	Null	NULL	xx	xx	16.25	16.25
2000092204	16	Null	Null	15.5	15.5	15.5	15.5	15.5
2000092205	16	Null	Null	15.3	15.3	15.3	15.3	15.3
2000092206	16	16	Null	15.1	15.1	15.1	15.1	15.1
2000092207	16	Null	Null	14.8	14.8	14.8	14.8	14.8
2000092208	16	Null	Null	14.5	14.5	14.5	14.5	14.5
2000092209	16	15.8	Null	14.4	14.4	14.4	14.4	14.4
2000092210	15	Null	Null	14.4	14.4	14.4	14.4	14.4
2000092211	Null	Null	Null	15.3	15.3	15.3	15.3	15.3
2000092212	Null	18	16.9	16.6	16.6	16.6	16.6	16.6
2000092213	19	Null	Null	17.9	17.9	17.9	17.9	17.9
2000092214	20	Null	Null	18.6	18.6	18.6	18.6	18.6
2000092215	21	Null	Null	19.5	19.5	19.5	19.5	19.5
2000092216	21	Null	Null	19.8	19.8	19.8	19.8	19.8
2000092217	22	Null	Null	20.9	20.9	20.9	20.9	20.9
2000092218	22	Null	21.2	20.9	20.9	20.9	20.9	20.9

Figura 10 – Tabela com o método de interpolação aplicado.

Após essa metodologia aplicada, a velocidade do vento deve ser convertida de metros por segundo, o padrão das estações, para quilômetros por hora, a unidade utilizada pelo programa de dimensionamento, no modo de unidades do SI. Para a utilização da versão do software original deve se converter para as unidades do padrão imperial.

Para a chuva as estações encontraram poucas falhas, e em períodos grandes de falhas, os dados foram substituídos pelo das estações automáticas. A cobertura de nuvens foi determinada através das estações METAR, inserindo valores das estações SYNOP nos valores nulos. Os valores restantes foram interpolados para completar as tabelas. A cobertura de nuvens então foi

transformada para incidência solar, como citado anteriormente, diminuindo o valor de cobertura de nuvens, de 100% com o resultado obtido sendo a incidência solar. Após converter as unidades, os resultados obtidos foram colocados na ordem: data, temperatura, vento, incidência solar, precipitação e umidade relativa. A data é escrita no formato AMDH.

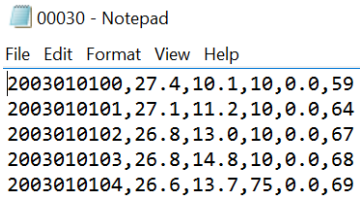


Figura 11 – Formato HCDs.

Finalizado os HCDs, é necessário a colocação deles no programa. Os HCDs devem receber uma numeração para que sejam reconhecidos pelo programa e inseridos dentro da pasta de HCDs nos arquivos de programas da *AASHTOWare*. Arquivos novos gerados não possuem uma numeração pré-estabelecida, então é necessário que a numeração adotada esteja vaga e seja inserida dentro do arquivo *station.dat* nas pastas *Default* e dos HCDs, com a linha contendo em ordem, numeração, cidade, estado, nome da estação, latitude, longitude, elevação, data de início, indicação com letra "C" para um HCD completo e data de final, conforme o exemplo na Figura 12.

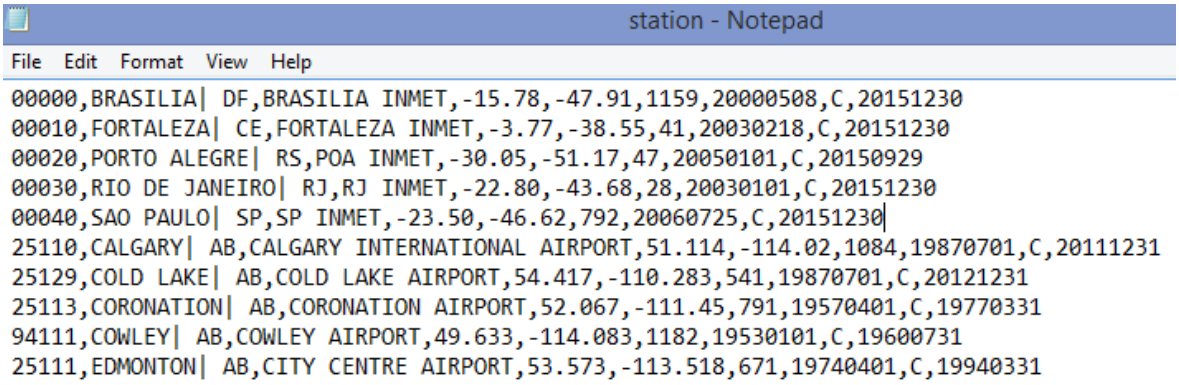


Figura 12 – Exemplo do arquivo station.dat com HCDs criados inseridos.

As alterações dos HCDs para os testes das interferências climáticas foram realizadas conforme proposto inicialmente, com a alteração da temperatura com uma diferença de +4, +2, -2 e -4°C. Além do método proposto inicialmente, foram modificados os parâmetros de velocidade do vento, precipitação, cobertura de nuvens e temperatura em 5%, conforme método proposto por Qiao et al (2013). Com essa alteração é possível a análise da sensibilidade dos desgastes sofrido pelos pavimentos.

No método de Qiao et al (2013) são acrescidos mais 5% ao valor do parâmetro horário para velocidade do vento, precipitação e cobertura de nuvens. A temperatura é somada 5% da média anual a cada hora, porém para as cidades de São Paulo e Porto Alegre que possuem uma maior variação anual, foi usada uma função senoide para a variação máxima ser de 5% para mais no verão e 5% a menos no inverno. A função irá manter a média anual semelhante, porém intensificando os extremos, uma tendência apontada pelos autores como consequência do

aquecimento global. A modificação da temperatura através dessa função é vista conforme a Figura 13.

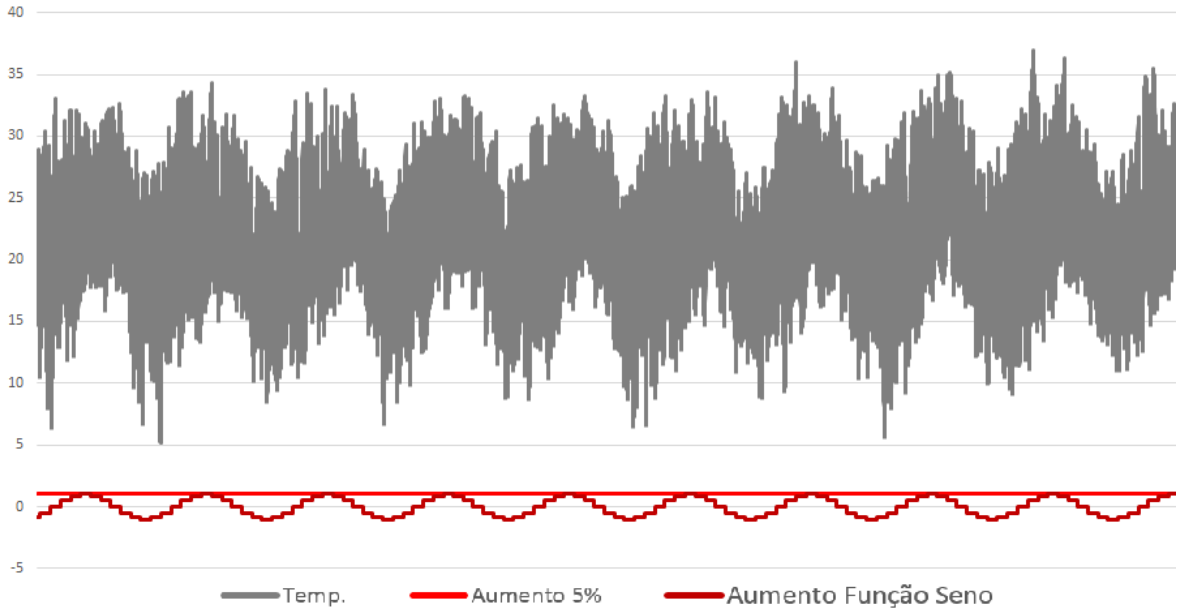


Figura 13 – Gráfico com a temperatura de São Paulo no período do HCD e indicação dos acréscimos a serem realizados.

3.3 MEDIÇÃO DE ALBEDO POR FOTOGRAFIA DIGITAL

A medição do albedo utilizando fotografia digital oferece a facilidade que câmeras fotográficas são de fácil acesso, devido a quantidade de pessoas que possuem câmeras digitais e pela grande quantidade de celulares com câmeras de boa qualidade embutidas. O método de Gilchrist (2011) insiste em tirar uma fotografia de uma folha branca A4 centralizada no material que deseja se calcular o albedo. Nesse experimento foram testadas uma superfície de concreto e algumas de asfalto (Figura 14).

Com essa fotografia então utiliza-se um programa de imagens, nesse caso o ImageJ, que é um programa gratuito para analisar então o histograma da imagem. O valor médio da superfície e do papel são então adotados para a utilização de cálculo (Figura 15).

Anotado os dados, é possível então calcular uma estimativa baseada nesses dados. Primeiro é calculado o Albedo relativo do material ao do papel branco. A média do histograma do material testado é dividido pelo do papel para se obter os valores de albedo relativo. O albedo relativo é multiplicado pelo do papel para se obter o albedo do material.



Figura 14 – Exemplos de Imagem dos pavimentos.

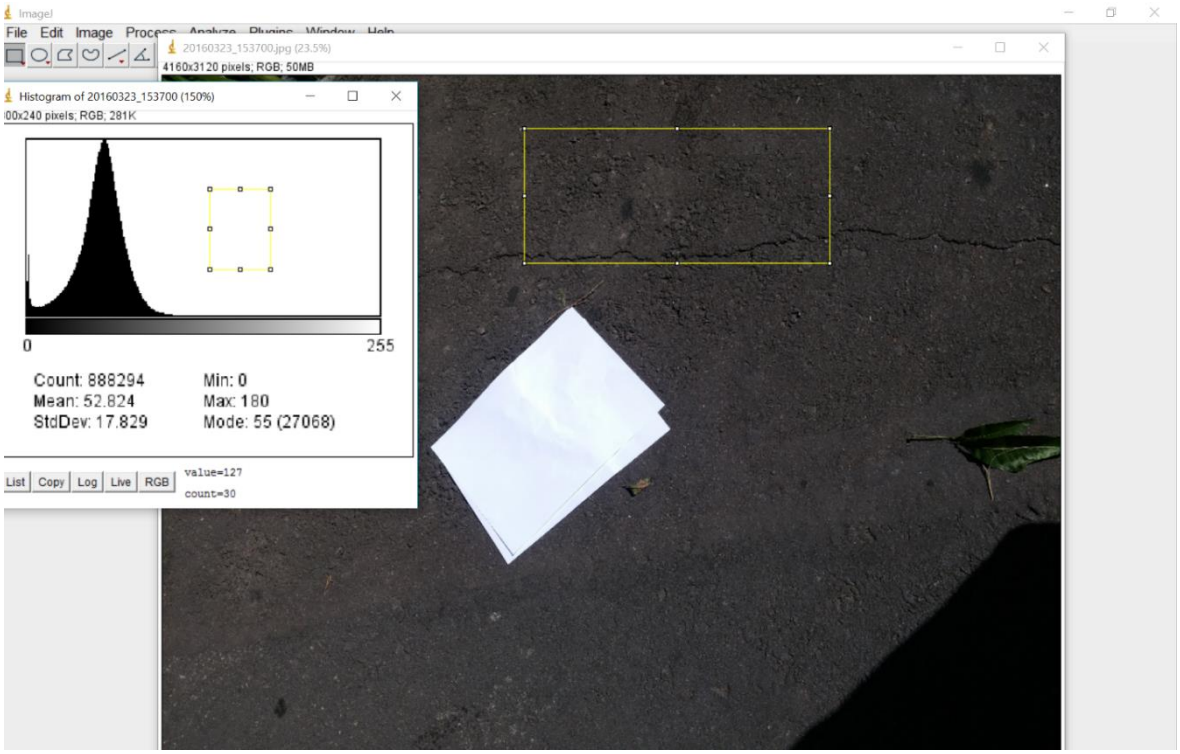


Figura 15 – Exemplo do Software ImageJ e histograma

3.4 RESULTADOS DOS DADOS CLIMÁTICOS

Os dados climáticos obtidos das cidades estudadas foram representados em formato de gráfico e são demonstrados abaixo entre a Figura 16 e a Figura 20. As respectivas cidades que foram objeto deste estudo (Brasília, Fortaleza, Porto Alegre, Rio de Janeiro e São Paulo) estão indicadas nas legendas. Os dados são representativos das médias históricas para o período disponibilizado pelo Banco de Dados Histórico do INMET, com início em 31/01/1980.

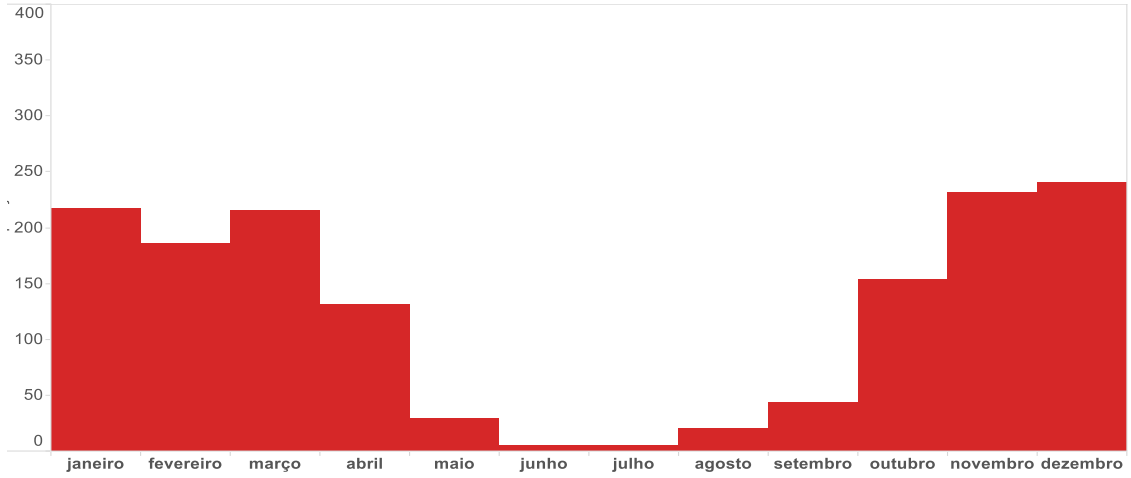


Figura 16 – Gráfico de Precipitação de Brasília – média histórica

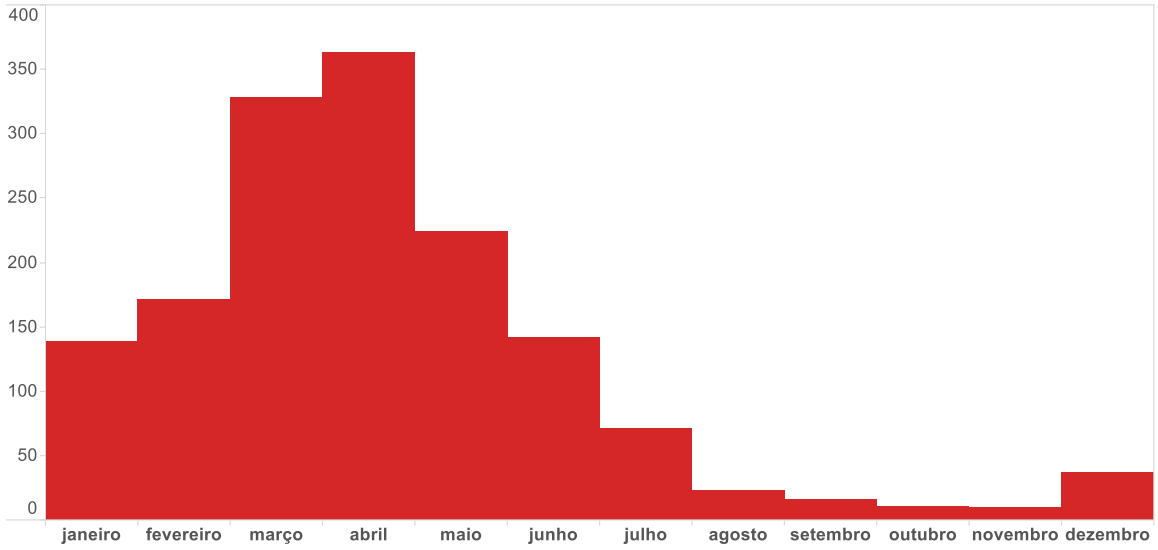


Figura 17 – Gráfico de Precipitação de Fortaleza – média histórica

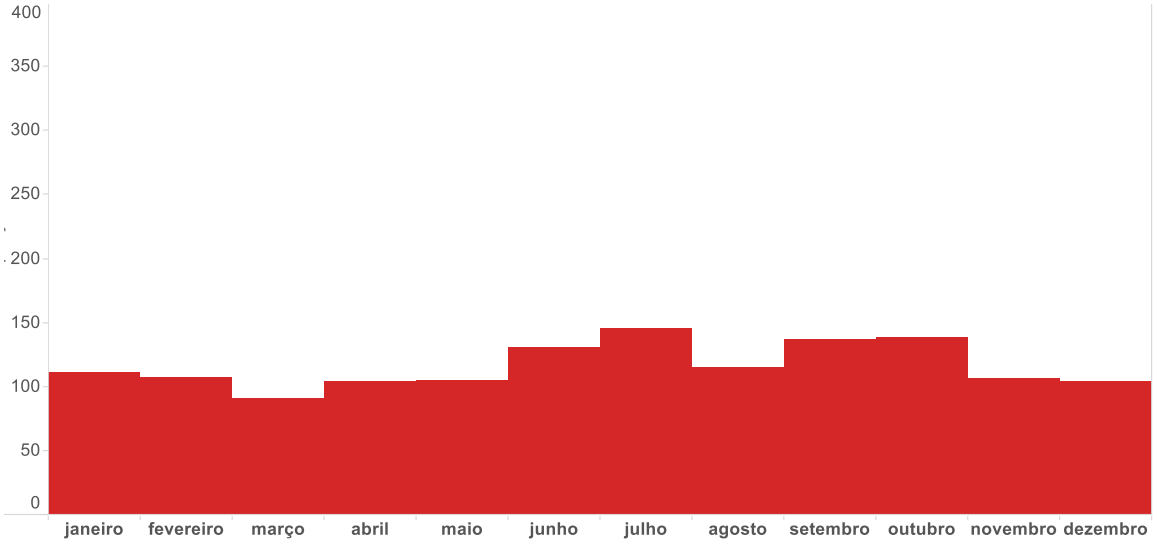


Figura 18 – Gráfico de Precipitação de Porto Alegre – média histórica

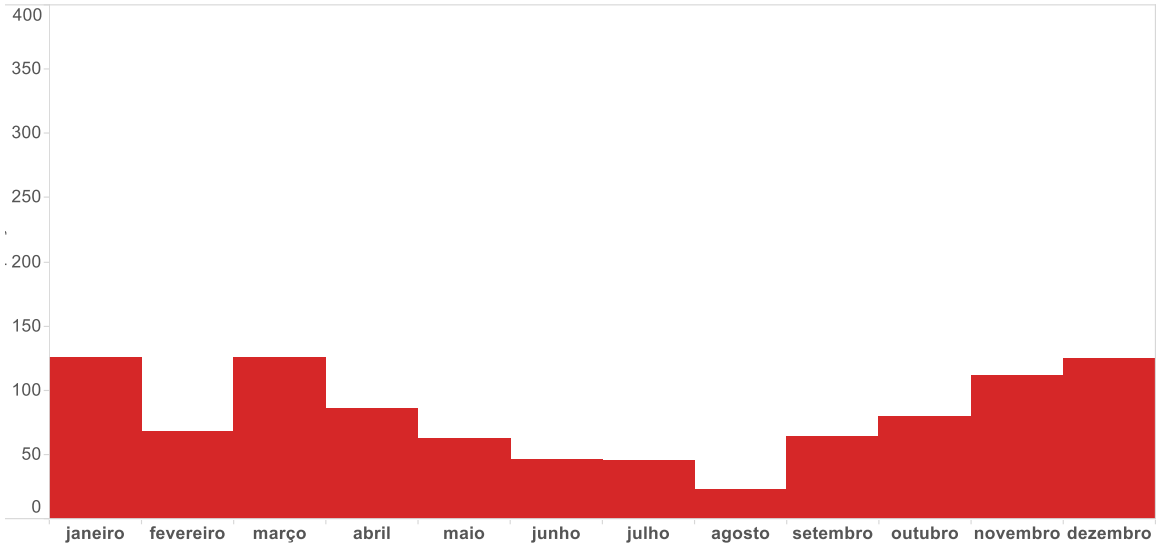


Figura 19 – Gráfico de Precipitação de Rio de Janeiro – média histórica

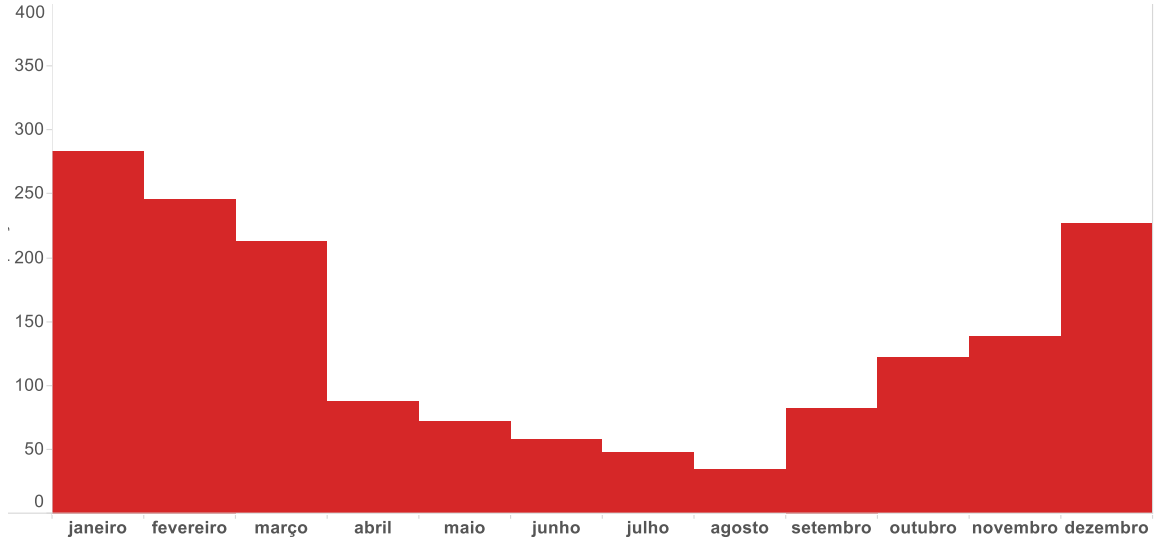


Figura 20 – Gráfico de Precipitação de São Paulo – média histórica

A precipitação das cinco cidades escolhidas varia bastante, com períodos diferentes de secas, e Porto Alegre com uma chuva muito espalhada, não seguindo um padrão muito definido. O padrão de temperatura é definido conforme as tendências apresentadas entre a Figura 21 e a Figura 25 abaixo.

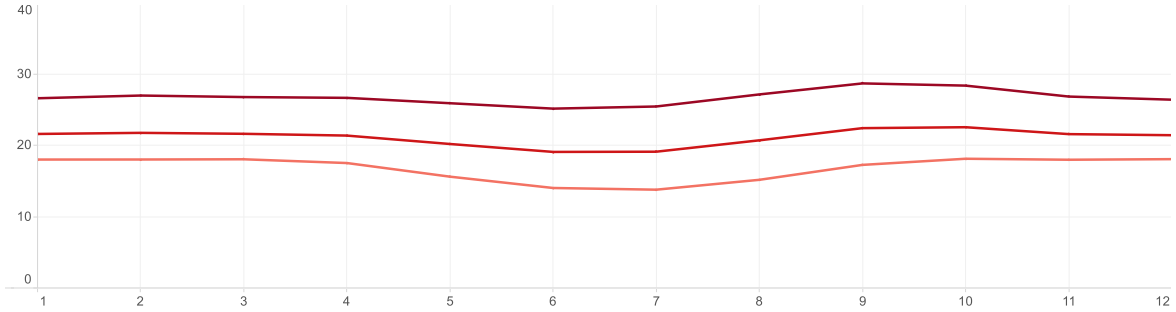


Figura 21 – Gráfico de temperaturas máx., média e mín. de Brasília – média histórica

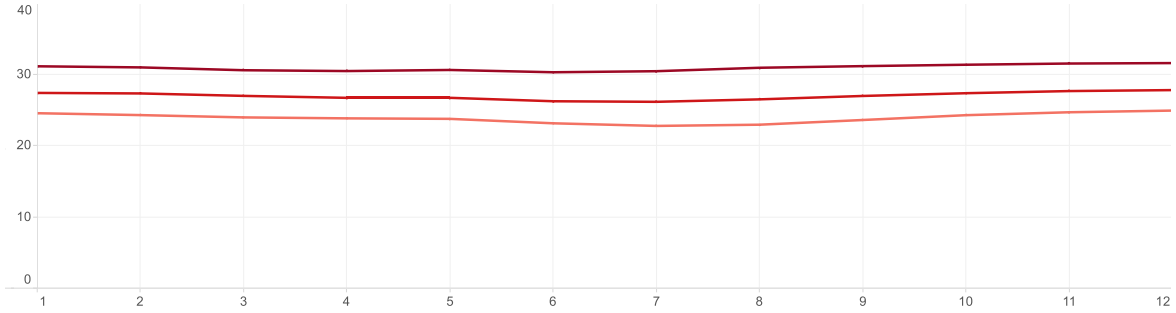


Figura 22 – Gráfico de temperaturas máx., média e mín. de Fortaleza – média histórica

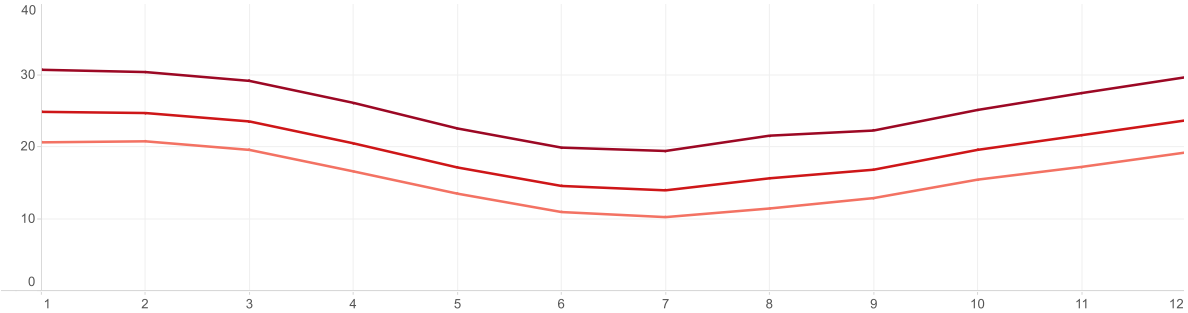


Figura 23 – Gráfico de temperaturas máx., média e mín. de Porto Alegre – média histórica

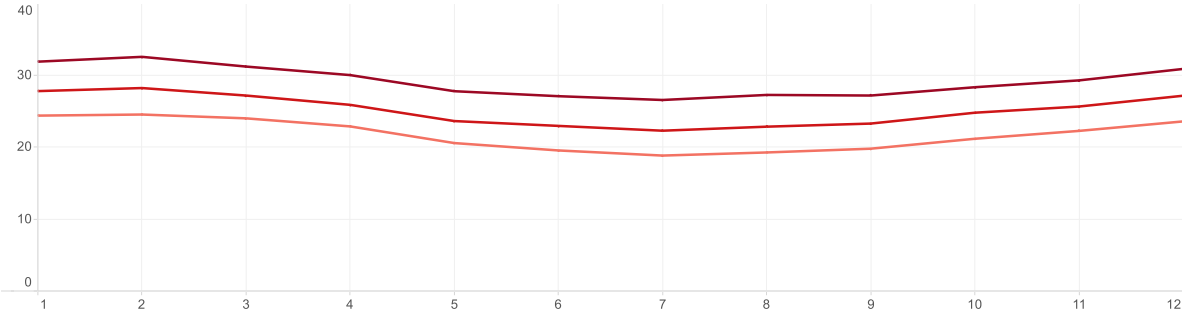


Figura 24 – Gráfico de temperaturas máx., média e mín. do Rio de Janeiro – média histórica

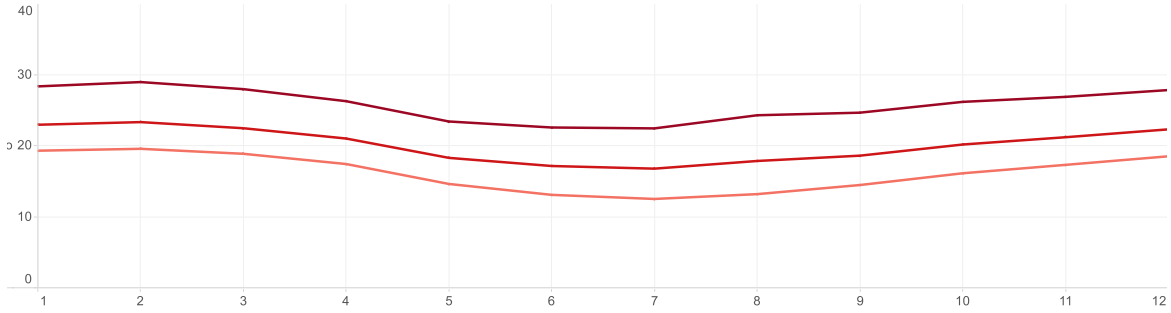


Figura 25 – Gráfico de temperaturas máx., média e mín. de São Paulo – média histórica

As temperaturas das cidades possuem grandes diferenças entre as cidades, com Porto Alegre atingindo temperaturas muito baixas, com uma clara estação fria, e Fortaleza com uma linha quase continua de temperaturas médias, máximas e mínimas. As outras três cidades se encaixam entre esses dois padrões, possuindo invernos menos rigorosos que Porto Alegre, porém uma tendência de temperaturas mais frias em determinados meses do ano.

Os climas das cidades diferem bastante nas cidades brasileiras estudadas, em suas várias características, demonstrando que o Brasil possui cidades com grandes variedades de climas, o que tornaria os pavimentos calculados em cada uma dessas cidades diferentes.

3.5 RESULTADOS PRÉVIOS DAS FOTOGRAFIAS DIGITAIS PARA MEDIÇÃO DE ALBEDO

Os resultados das medições de albedo foram obtidos conforme a Tabela 3; lá se demonstra os valores obtidos para cada material. Entre a Figura 26 e a Figura 29 apresentam-se os registros fotográficos com as medições realizadas.

Tabela 3 – Tabelas de Albedo através de fotografia

Material	Média Histograma	Histograma Papel	Albedo Relativo	Albedo Final (AlbRel * Albedo do Papel (0,65)
Asfalto A	62.85	225.06	0.279	0.182
Asfalto B	55.92	244.81	0.228	0.148
Asfalto C	59.74	240.20	0.248	0.162
Concreto	116.10	199.91	0.581	0.378

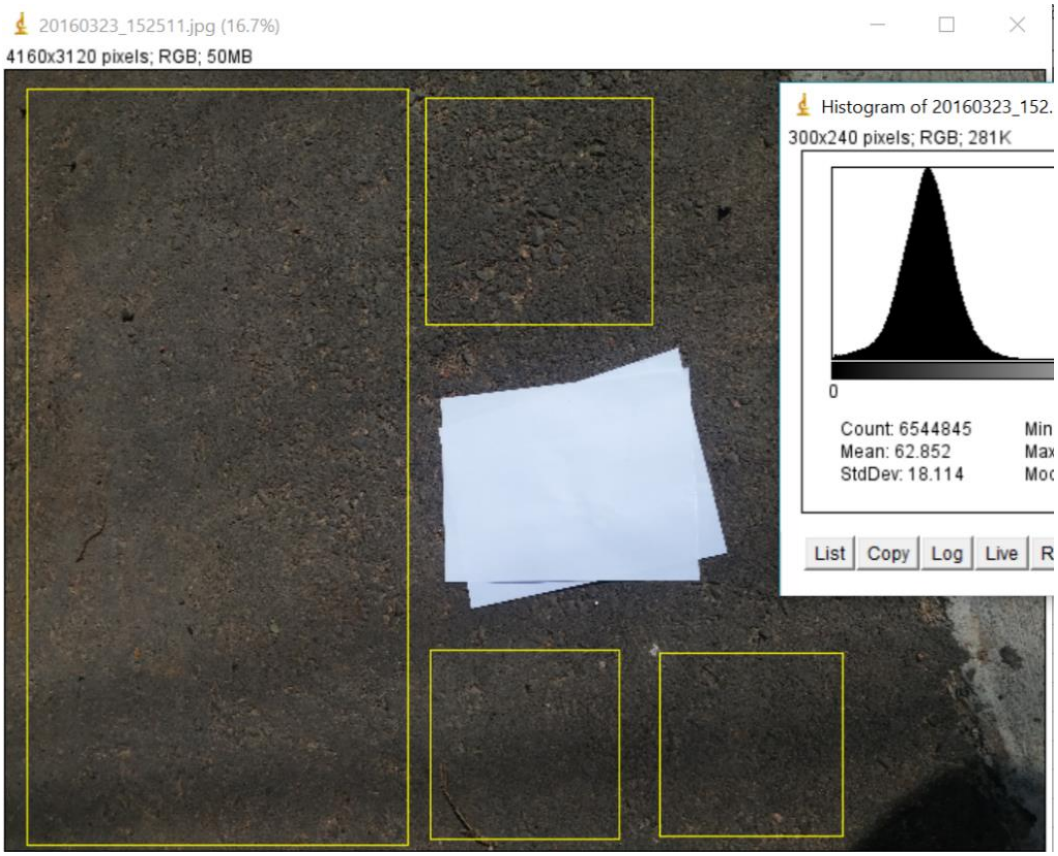


Figura 26 – Exemplo Asfalto A e Histograma

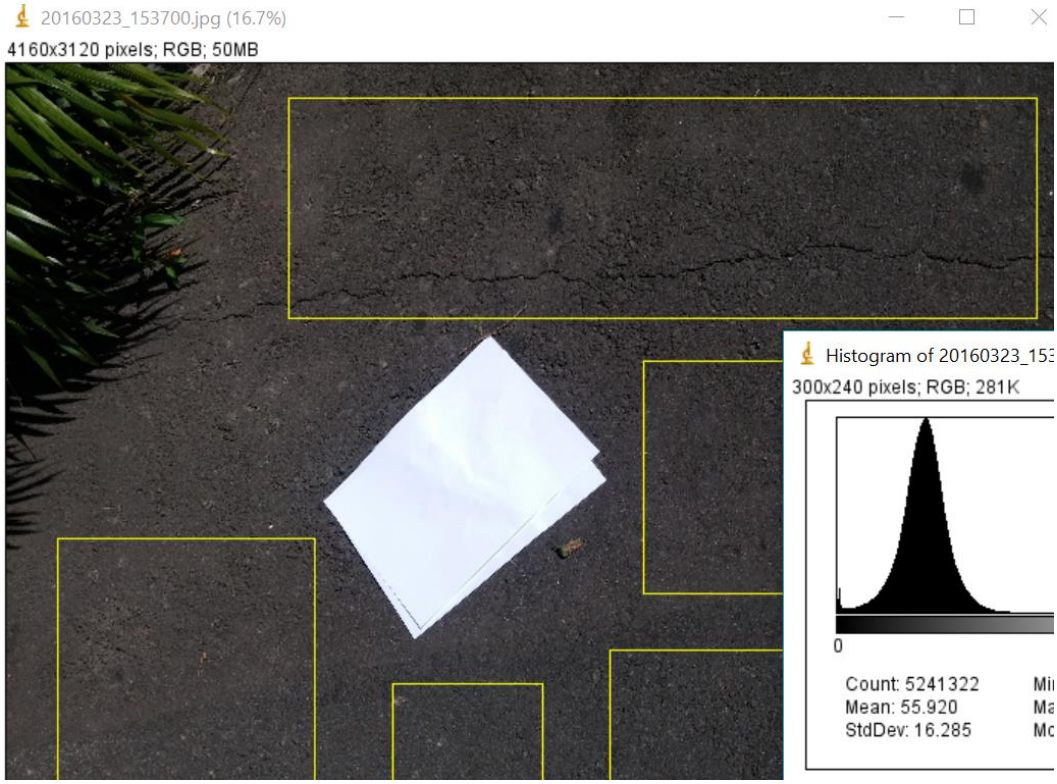


Figura 27 – Exemplo Asfalto B e Histograma



Figura 28 – Exemplo Asfalto C e Histograma

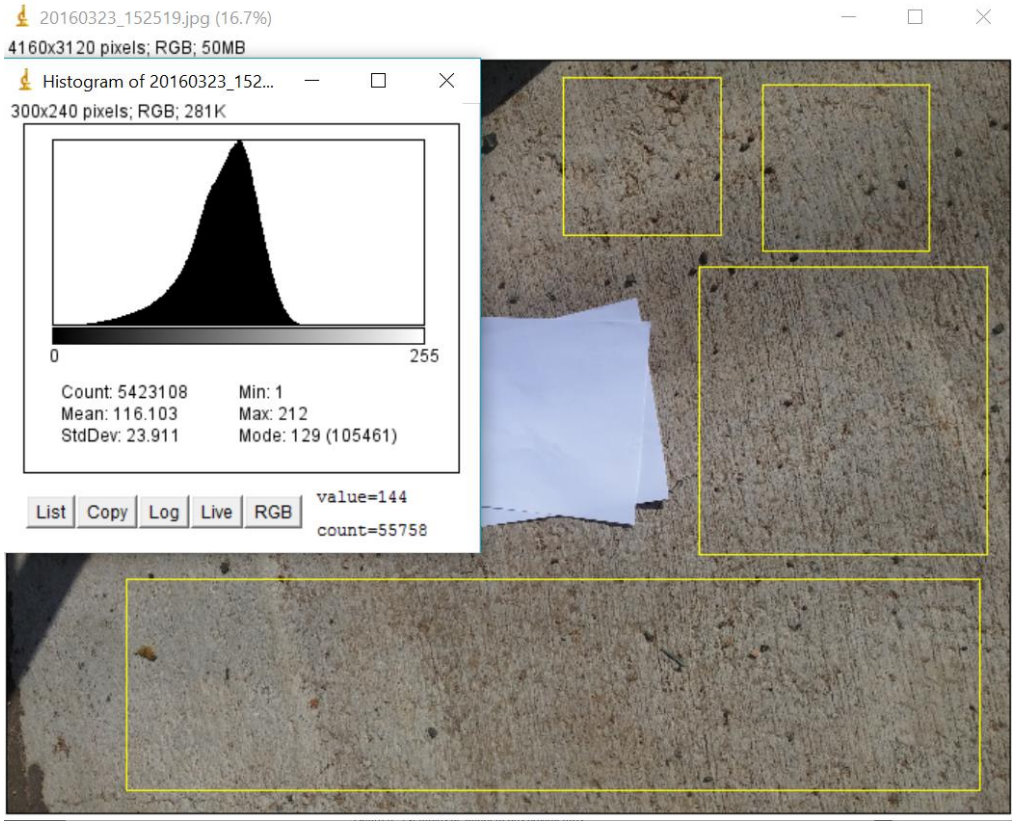


Figura 29 – Exemplo Concreto e Histograma

Os resultados ficaram próximos a valores normalmente citados para asfaltos gastos e para concreto armado. As diferenças de valores podem ser devido a sujeira presente nos pavimentos ao longo do tempo, alterando a superfície, tornando pavimentos de asfalto escuro em mais claro, e pavimentos de concreto claro em uma coloração mais escura.

Os erros variam de 6% de albedo para o pavimento de concreto asfáltico que é considerado 12% por Gilchrist (2011) e 2,3% nos pavimentos claro, com o padrão sendo 0,40, mostrando que os valores possuem uma conexão com a realidade, desse modo, o método pode ser utilizado para se ter uma boa aproximação.

3.6 HCD GERADO PARA PORTO ALEGRE & VALIDAÇÃO

O arquivo HCD de Porto Alegre gerado com a aplicação da metodologia apresentada nos dados climáticos obtidos foi submetido a teste no *software* da AASHTO a fim de validação do método e avaliação de resultados coerentes, para a validação do arquivo gerado. O arquivo ICM, portanto, foi gerado com a utilização do programa, a partir do HCD gerado originalmente e um modelo teste de pavimento rodado. Conforme a Figura 30 ilustra foi possível perceber que o programa leu as informações do HCD.

Os resultados dos esforços a qual o pavimento é submetido foram os conforme a Tabela 4, com comparação com duas cidades americanas, Savannah e Miami, para análise de coerência.

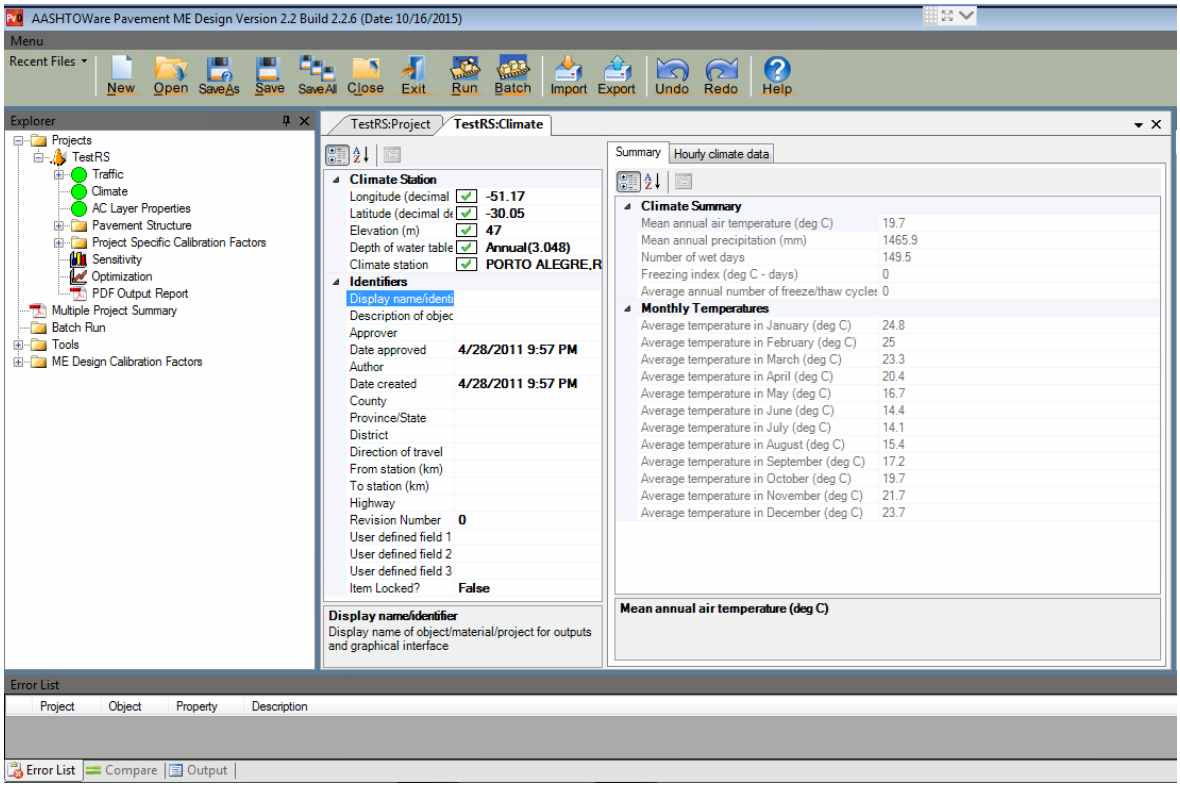


Figura 30 – Aba do clima no programa, demonstrando que o HCD foi reconhecido.

Tabela 4 – Comparativo dos resultados do HCD de Porto Alegre

Critério de Desempenho	Porto Alegre	Miami	Savannah
IRI Final (m/km)	2.85	2.84	2.84
Deformação Permanente (mm)	21.82	20.98	21.34
Trincamento por Fadiga (Porcentagem)	23.50	24.04	22.93
Trincamento por retração térmica (m/km)	5.15	5.15	5.15
Trincas Longitudinais (m/km)	669.95	687.68	658.08
Deformação Permanente (Apenas CA) (mm)	9.61	9.11	9.36

Nota-se que os resultados obtidos para Porto Alegre são próximos aos das duas cidades americanas, mostrando coerência e permitindo que o HCD possa ser considerado válido para a continuidade de estudos. Complementando a comparação, o módulo de elasticidade do pavimento foi comparado, conforme Figura 31.

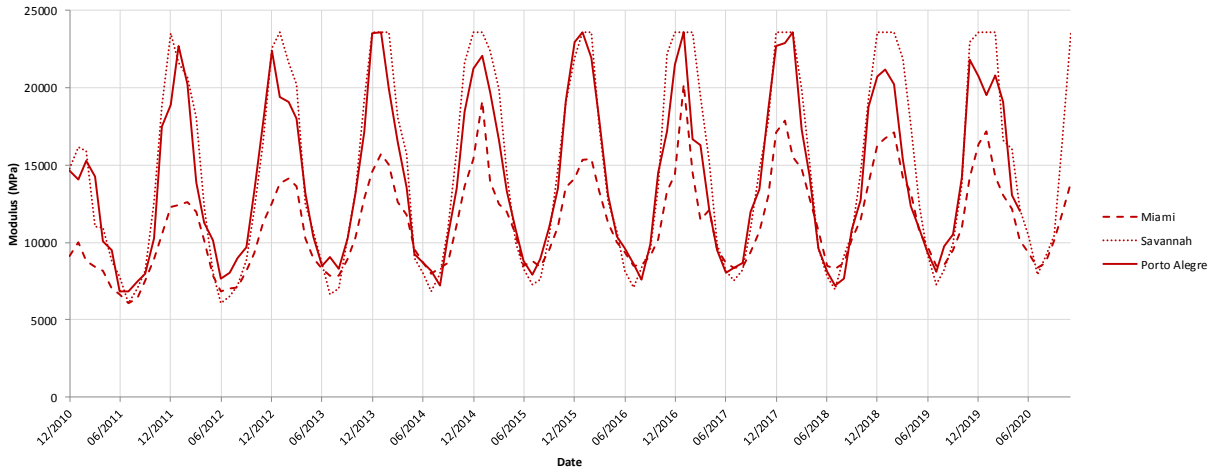


Figura 31 – Gráficos de Módulos das cidades.

O gráfico demonstra o módulo de Porto Alegre próximo a das cidades americanas. Os picos maiores de Savannah se explicam pelo inverno mais rigoroso que a cidade possui, enquanto os valores baixos de Miami ocorrem devido as altas temperaturas anuais da cidade. É importante ressaltar que para fins de visualização do gráfico, os resultados de Porto Alegre foram deslocados 6 meses para coincidir com o inverno e verão do hemisfério Norte.

3.7 HCD GERADO PARA AS DEMAIS CIDADES

Arquivos HCDs foram gerados para as cidades de Brasília, Fortaleza, Rio de Janeiro e São Paulo além de Porto Alegre. Os resultados de desgastes previstos nos pavimentos seguem a Tabela 5.

Tabela 5 – Comparativo de Resultados entre as cidades testadas.

Critério de Desempenho	Brasília	Fortaleza	Porto Alegre	Rio de Janeiro	São Paulo
IRI Final (m/km)	2.79	2.90	2.85	2.90	2.83
Deformação Permanente (mm)	19.01	23.07	21.82	23.35	20.56
Trincamento por Fadiga (%)	23.72	24.91	23.50	24.34	24.03
Trinc. por retração térmica (m/km)	5.15	5.15	5.15	5.15	5.15
Trincas Longitudinais (m/km)	650.81	744.27	669.95	721.27	663.19
Deformação Permanente (CA) (mm)	7.48	10.72	9.61	10.92	8.56

Os resultados demonstram coerência entre as cidades, mostrando que os HCDs gerados possuem uma relação com a realidade. Esses resultados validando os arquivos permitiram a realização dos testes sobre a variação da temperatura e parâmetros climáticos. Os valores de módulos de cada cidade estão representados na Figura 32.

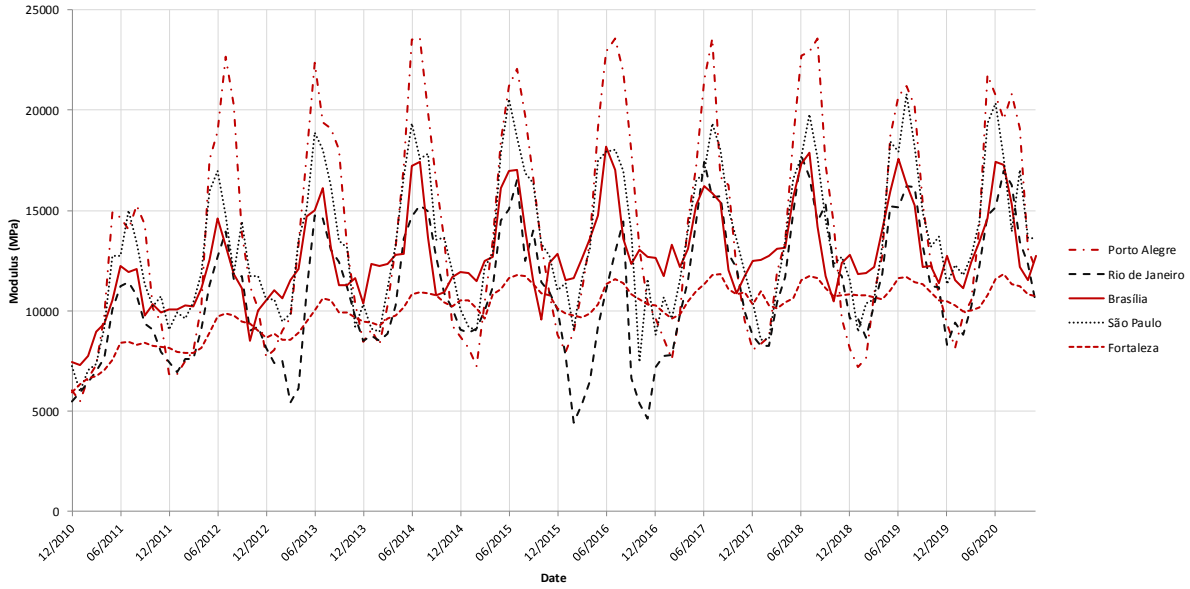


Figura 32 – Gráfico de módulos das diferentes cidades testadas.

Os módulos apresentados seguem um comportamento esperado, com Fortaleza que apresentando um comportamento mais linear, enquanto Porto Alegre atinge os maiores picos, devido aos invernos mais rigorosos da região sul do País. Os gráficos se demonstraram coerentes com o esperado através dos dados históricos das regiões.

3.8 RESULTADO DAS VARIAÇÕES CLIMÁTICAS ENCONTRADAS

Os HCDs modificados com a primeira opção, com variações de temperatura de +4, +2, -4 e -2 foram testados com o software para todas as cidades e os resultados encontrados foram conforme a Tabela 6.

Tabela 6 – Efeitos da Variação de Temperatura

Cidade	Var.	IRI Final (m/km)	Deformação Permanente (mm)	Trincas por Fadiga (Porcentagem)	Trincas Longitudinais (m/km)	Deformação Permanente (CA) (mm)
Brasília	-4	2.71	16.27	22.85	598.98	5.32
	-2	2.75	17.5	23.28	622.16	6.29
	0	2.79	19.01	23.72	650.81	7.48
	+2	2.83	20.67	24.16	684.18	8.8
	+4	2.88	22.54	24.58	723.43	10.27
Fortaleza	-4	2.79	19.16	23.88	660.35	7.64
	-2	2.84	21	24.42	699.47	9.09
	0	2.9	23.07	24.91	744.27	10.72
	+2	2.96	25.33	25.31	800.02	12.49
	+4	3.03	27.76	25.65	885.52	14.4
Porto Alegre	-4	2.77	18.84	22.84	620.92	7.24
	-2	2.81	20.25	23.14	643.07	8.36
	0	2.85	21.82	23.5	669.95	9.61
	+2	2.9	23.58	23.89	703.97	11.02
	+4	2.96	25.5	24.23	755.6	12.55
Rio de Janeiro	-4	2.8	19.92	23.55	650.81	8.23
	-2	2.85	21.6	23.98	684.18	9.55
	0	2.9	23.35	24.34	721.27	10.92
	+2	2.95	25.43	24.72	777.98	12.55
	+4	3.01	27.58	25.05	845.32	14.24
São Paulo	-4	2.75	17.69	23.21	613.3	6.28
	-2	2.79	19.07	23.65	636.55	7.36
	0	2.83	20.56	24.03	663.19	8.56
	+2	2.88	22.18	24.37	694.57	9.86
	+4	2.92	23.99	24.68	732.58	11.32

Observa-se que o aumento da temperatura causa um impacto negativo em todos os requisitos testados, conforme era esperado pela bibliografia estudada. A segunda análise com as variações em vários parâmetros dos HCDs em 5% foi realizada, possibilitando desse modo um melhor entendimento que cada elemento causa em cada um dos desgastes calculados pelo programa. Os resultados foram colocados em formato de variação percentual, criando uma análise de sensibilidade, e são demonstrados na Figura 33 e Figura 34.

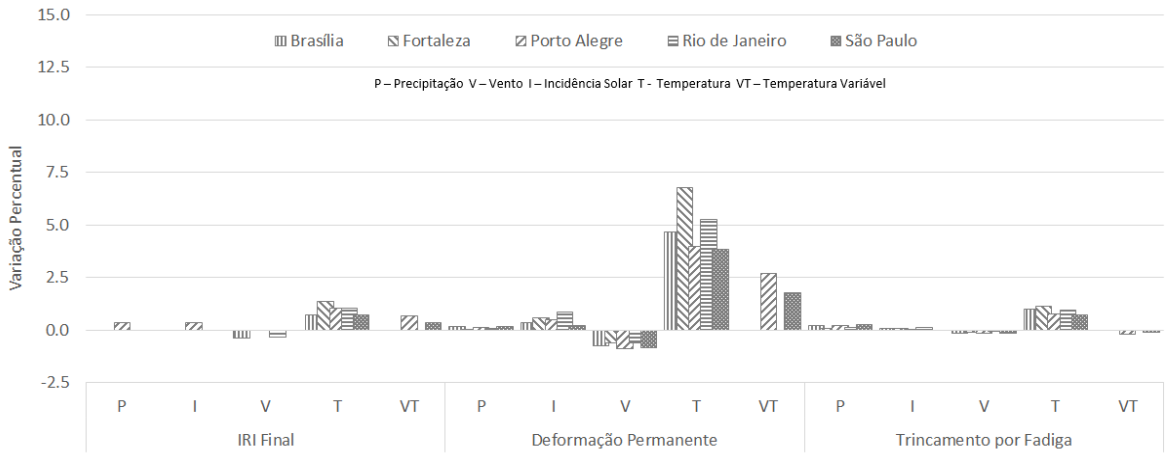


Figura 33 – Gráfico 1 da sensibilidade dos parâmetros através da modificação das características climáticas. (*a ausência de barras legíveis, significa "zero" = sem alteração no parâmetro*)

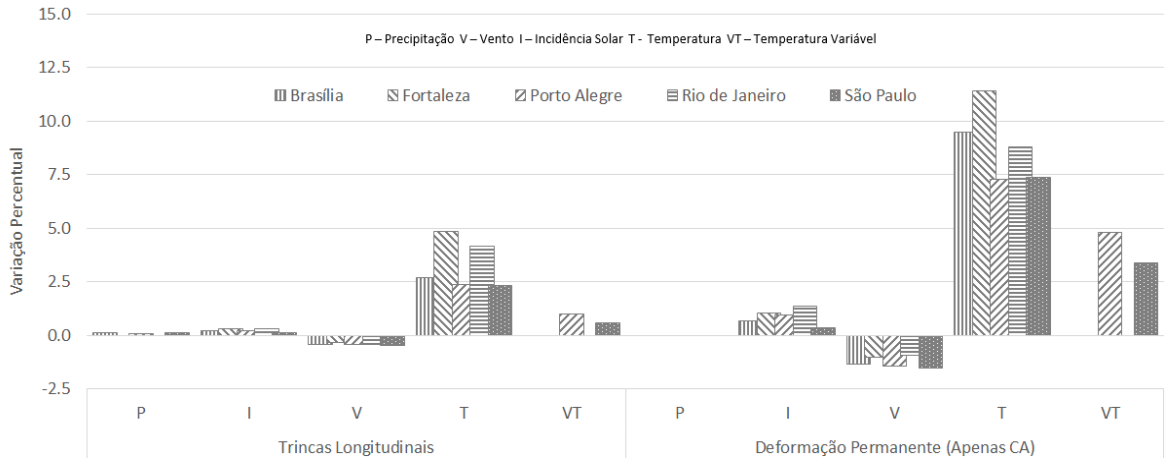


Figura 34 – Gráfico 2 da sensibilidade dos parâmetros através da modificação das características climáticas. (*a ausência de barras legíveis, significa "zero" = sem alteração no parâmetro*)

Os resultados demonstrados nos gráficos mostram que a temperatura é o principal parâmetro nos desgastes dos pavimentos. A alteração de 5% elevou as trincas longitudinais na ordem de 5% e causou um aumento nos trilhos de rodas no concreto asfáltico de aproximadamente 12% no pior dos casos. Precipitação e incidência solar são padrões com menor interferência nos desgastes causados nos pavimentos. A velocidade do vento é o único parâmetro que reduz os desgastes ocorridos nos pavimentos. Isso ocorre, pois, o vento age no balanço térmico reduzindo a temperatura de superfície, acelerando a convecção e a liberação de calor da superfície do pavimento.

A variação da temperatura através de uma função senoide, mantendo a mesma média anual, porém aumentando os máximos e mínimos, teve um impacto menos acintoso que o aumento de 5% da média em todos as entradas de temperatura, porém foi responsável aumentar os

desgastes em praticamente todos os parâmetros citados, exceto no trincamento por fadiga, onde sua ação é quase nula.

Esse resultado demonstra que mesmo a média de temperatura permanecendo igual, temperaturas mais rigorosas no verão e inverno tendem a gerar impactos negativos para os pavimentos.

As deformações permanentes apresentaram a maior sensibilidade com o aumento de temperatura. Deformações e trilhos de rodas tendem a ter esse tipo de comportamento devido a diminuição do módulo de elasticidade que ocorre com o aumento da temperatura tornando o pavimento deformável. Os módulos para Porto Alegre com as versões alteradas são conforme o gráfico da Figura 35.

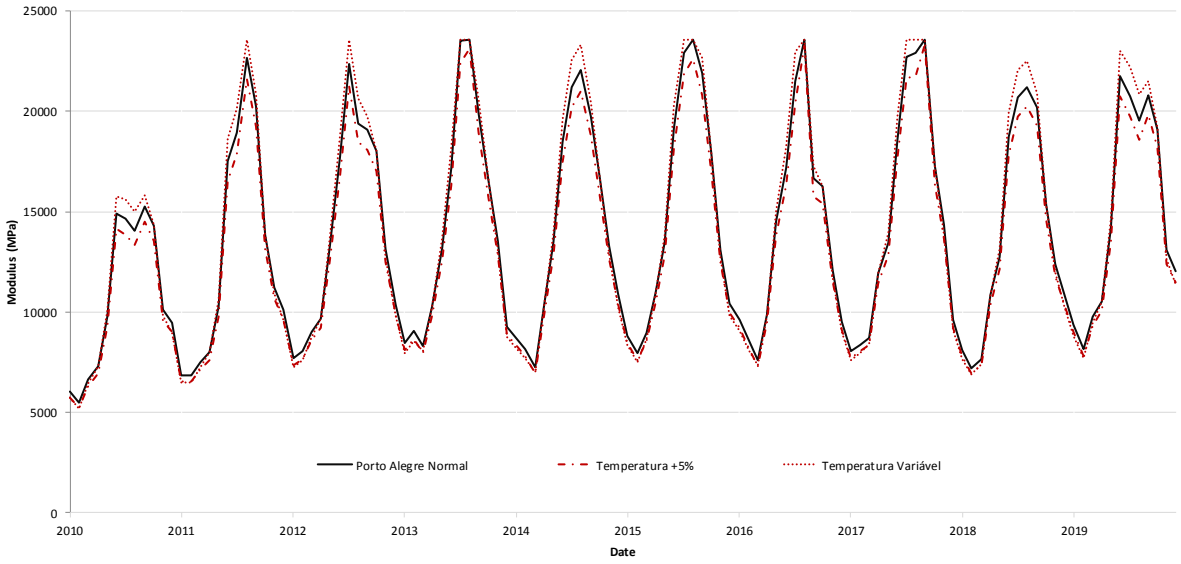


Figura 35 – Gráfico de Módulo para Porto Alegre

O gráfico demonstra que a temperatura variável aumenta os picos tanto negativos quanto positivos do gráfico, enquanto a soma simples de 5% da média desloca o gráfico de gráfico levemente para um valor menor, devido ao módulo ser inverso da temperatura. Essas diferenças sutis nos módulos ajudam a entender parte do fenômeno que aumenta as deformações permanentes.

4 RESULTADOS FINAIS

Os resultados obtidos na pesquisa sugerem que a diferença de temperatura nas cidades brasileiras causará uma diferença no dimensionamento dos pavimentos, justificando essa pesquisa e a utilização de métodos novos de dimensionamento que contemplem parâmetros climáticos. Apesar de haver dados disponíveis para este equacionamento, e a literatura internacional já apontar maneiras de incorporar tal variação do dimensionamento dos pavimentos flexíveis, as ferramentas disponíveis para tal dimensionamento no Brasil ainda são bastante incipientes. Com vistas ao desenvolvimento de uma nova metodologia de dimensionamento de pavimentos flexíveis no país que terá uma base mecanicista para análise do comportamento destas estruturas, o presente estudo avança na intenção de fornecer um banco de dados para algumas das principais cidades no Brasil.

O método para medir albedo, baseado em fotografias utilizado nesta pesquisa, e que pode, portanto, ser utilizado para facilmente se obter um valor aproximado no futuro, encontrou resultados aproximados, porém com alguns erros com materiais semelhantes previamente estudados. Analisando que os resultados obtidos possuem uma certa aproximação com os esperados. As diferenças podem ser explicadas pelos materiais não serem exatamente iguais, com composições nos pavimentos diferentes, pela presença de poeira e outros resíduos nas superfícies testadas e pelo fato de câmeras digitais comuns não receberem luz infravermelha.

No que tange ao principal objetivo da pesquisa – o de compilar os dados climáticos para a cidade de Porto Alegre para fins de uso do modelo integrado climático (icm) utilizado no software da AASHTOWare Pavement ME, o arquivo tipo *hourly climatic data* (hcd) foi feito com sucesso. Devido a disponibilidade dos dados por parte do INMET, foi possível estender as análises propostos para mais outras quatro capitais nacionais: Fortaleza, Rio de Janeiro, São Paulo e Brasília. Desta forma foram compilados os cinco arquivos com séries históricas de dados climáticos que variaram entre 12 e 15 anos – tempo suficiente que excede as recomendações mínimas para um período de 5 anos.

As análises realizadas demonstraram haver uma coerência com dados de estações similares norte americanas. Uma análise comparando o comportamento de uma estrutura padrão de um pavimento flexível foi realizada considerando três diferentes climas: Porto Alegre, Miami/FL e Savannah/GA. As cidades de Miami e Savannah foram escolhidas por apresentam médias de temperatura e chuva semelhantes ao clima de Porto Alegre, como forma de observar a coerência e exatidão dos resultados de Porto Alegre. As coerências do padrão de comportamento asseguraram que o hcd montado pode ser considerado válido – há, no entanto, diferenças nos valores de módulo – principalmente com relação Poa-Miami; Poa-Savannah foram consideravelmente mais coesos.

Os resultados das análises da variação dos gradientes de temperatura, demonstraram um elevado comprometimento do comportamento da estrutura com variações térmicas de +/-4°. Estratégias hoje pensadas para redução dos efeitos de ilha de calor em áreas metropolitanas, ou mesmo devido às variações climáticas causadas pelas grandes áreas impermeabilizadas, serão significativos na avaliação de desempenho dos pavimentos.

A alteração de 5% no gradiente de temperaturas elevou as trincas longitudinais na ordem de 5% e causou um aumento nos trilhos de rodas no concreto asfáltico de aproximadamente 12% no

pior dos casos. A precipitação e incidência solar são padrões com menor interferência nos desgastes causados nos pavimentos e a velocidade do vento é o único parâmetro que reduz os desgastes ocorridos nos pavimentos. Estes elementos auxiliam na identificação de parâmetros a serem monitorados e também na compreensão do mecanismo de funcionamento combinado pavimento – clima.

Na análise feita através de uma função senoide, mantendo-se a mesma média anual, porém aumentando os máximos e mínimos – condições cada vez mais frequentes devido aos eventos climáticos extremos, houve um impacto pequeno impacto em todos as entradas de temperatura, porém que resultou num aumento dos desgastes em praticamente todos os parâmetros testados, exceto no trincamento por fadiga, onde sua ação foi quase nula.

Esse resultado demonstra que mesmo a média de temperatura permanecendo igual, temperaturas mais rigorosas no verão e inverno tendem a gerar impactos negativos para os pavimentos.

Na pesquisa, foram realizadas todas as tarefas previstas no cronograma original da pesquisa. Todos os objetivos foram atingidos e foi possível alcançar resultados além do que se esperava com a compilação de dados climáticos para cinco capitais brasileiras ao invés de uma, como originalmente proposto. Abaixo está citado uma tabela de correspondência entre o que foi proposto e seu respectivo atendimento neste relatório.

ATIVIDADES DESENVOLVIDAS	Etapas do Projeto (Item 5.1 Proposta de Pesquisa) (= 1.3, pág 12)	Relatório
Parte 1		
Revisão sobre o impacto da temperatura em projeto de pavimentos	1	Capítulo 2 Itens 2.1, 2.4
Geração de Ilhas de Calor - geração de calor nas cidades devido à pavimentação	2	Capítulo 2 Itens 2.1, 2.4
Propriedades térmicas de pavimentos flexíveis	3, 9	Capítulo 2 Itens 2.2, 2.3, 2.5
Estratégia para a redução de temperatura em pavimentos	4	Capítulo 2 Itens 2.6, 2.8
Parte 2		
Modelos de distribuição de temperatura em pavimentos	5	Capítulo 2 & 3 Item 2.7, Item 3.1
Dados Climáticos de Porto Alegre - série histórica de pelo menos 4 anos	6	Capítulo 3 Itens 3.2, 3.4
Agrupamento de dados e cálculo de parâmetros adicionais para confecção de um HCD	7	Capítulo 3 Itens 3.2 a 3.6
Validação do HCD gerado para Porto Alegre	8	Capítulo 3 Item 3.6
Parte 3		
Avaliação do impacto da variação de temperatura	10	Capítulo 3 Item 3.8
Considerações sobre a performance dos pavimentos com uso de modelos do Paveware	11	Capítulo 3 & 4 Item 3.8, Item 4
Reunião com equipe de trabalho, concessionária & ANTT	12	Capítulo 4, Anexo B

Importante notar que no dia 29/02/2016 foi realizada uma reunião com representantes da Concessionária e ANTT com vistas a apresentação do andamento das pesquisas de RDT, foto do encontro na Figura 36. A apresentação contou com representantes da GEROR Brasília e também da URRS. A apresentação realizada está apresentada no ANEXO B. Está agendando para nova apresentação dos resultados à Concessionária os resultados aqui obtidos, ainda que diversos encontros ocorridos durante o desenvolvimento da pesquisa tenham mantido as partes em contato para análise conjunta dos resultados aqui abordados.



Figura 36 – Foto do encontro ANTT – Triunfo|Concepa para apresentação do andamento das pesquisas em desenvolvimento (29/02/2016).

Por fim, ainda como expressivo resultado do trabalho realizado, workshop "*Pavaments for energy harvesting and dependable low-volume roads workshop*" um evento organizado pelo Prof. Lélio Brito e que trouxe a Porto Alegre um total de 27 pesquisadores – 13 britânicos e 14 brasileiros, unindo diversas universidades, entre elas [UK] University of Nottingham, Imperial College London, University of Birmingham, Aston University, Queens Belfast e Heriot Watt Edinburgh; [USA] Rutgers University; [BR] UFRGS, UFSC, USP, UFRJ, UFCG, UFSCAR, UNESC, UERGS e UPF. O evento buscou discutir justamente sobre a temática do efeito do calor de pavimentos nas ilhas de calores e estratégias de redução deste efeito combinado com a produção de energia a partir do calor dos pavimentos.

Esta pesquisa serviu, desta forma, como elemento de discussão sobre elementos ainda pouco estudados no Brasil, mas que estão em linha com tendências de pesquisas no âmbito internacional. Os resultados obtidos serão publicados e serão fonte de informação para novos estudos na área.

INSTRUÇÕES PARA USO DOS ARQUIVOS HCDs GERADOS NA PESQUISA

Baixe os arquivos disponibilizados em: www.primengenharia.com/downloads/hcd.zip ou acesse o código QR ao lado:

Coloque os arquivos ".hcd" no diretório relativo à instalação dos arquivos climáticos do AASHTOWare Pavement ME. O local padrão destes arquivos, na instalação feita no Sistema Internacional (SI), arquivos é:

32-bit Windows: C:\Program Files\AASHTOWare\ME Design\HCD_SI\

64-bit Windows: C:\Program Files (x86)\AASHTOWare\ME Design\HCD_SI\

Após colocar os arquivos é importante editar o arquivo "station.dat" para indicar a presença dos novos arquivos HCD e desta forma viabilizar ao software que disponibilize as novas estações para uso. Os arquivos estão contidos no zip descarregado estão com as estações numeradas da seguinte forma: "00000 para BRASILIA"; "00010 para FORTALEZA"; "00020 para PORTO ALEGRE"; "00030 para RIO DE JANEIRO"; "00040 para SAO PAULO". Sugere-se que se mantenham os nomes dos arquivos na forma original e neste caso, deverá ser adicionado as seguintes linhas no início imediato do arquivo "station.dat". O arquivo ficará então como mostra-se na Figura 37.

```
00000,BRASILIA| DF,BRASILIA INMET,-15.78,-47.91,1159,20000508,C,20151230
00010,FORTALEZA| CE,FORTALEZA INMET,-3.77,-38.55,41,20030218,C,20151230
00020,PORTO ALEGRE| RS,POA INMET,-30.05,-51.17,47,20050101,C,20150929
00030,RIO DE JANEIRO| RJ,RJ INMET,-22.80,-43.68,28,20030101,C,20151230
00040,SAO PAULO| SP,SP INMET,-23.50,-46.62,792,20060725,C,20151230
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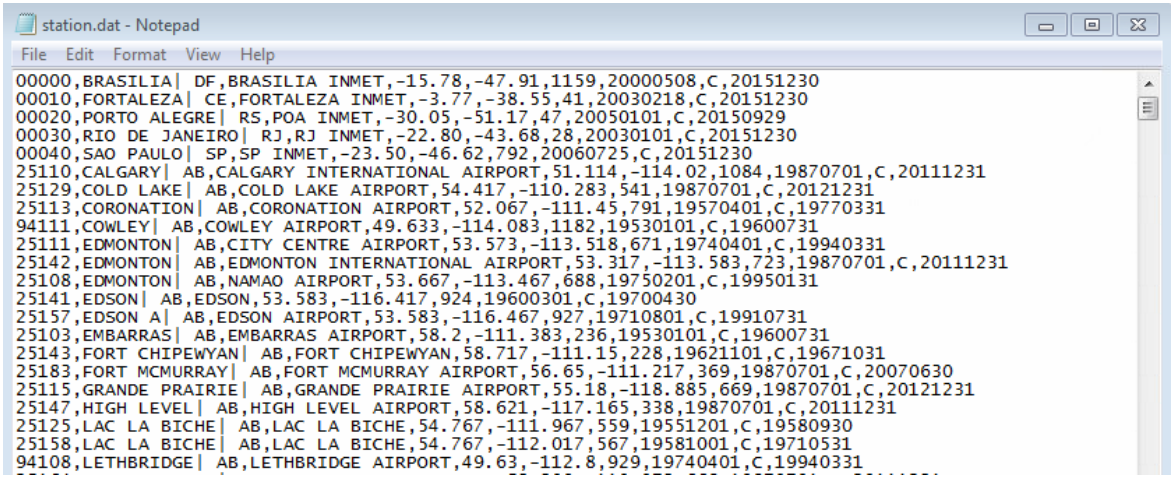


Figura 37 – Formato final do arquivo "stantion.dat" com as novas estações inseridas

Os arquivos disponibilizados podem ser amplamente divulgados desde que mencionem a fonte obtida:

Brito, L. A.T; Heller, L. (2016). Relatório Final de Pesquisa "Influência da temperatura no comportamento de Pavimentos Flexíveis – uma análise direcionada às ilhas de calor" v1.1. 1049p.

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SANTAMOURIS, M. **Using cool pavements as a mitigation strategy to fight urban heat island — A review of the actual developments. Renewable and Sustainable Energy Reviews.** [S.l.]. 2013.

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ANEXO A – ANÁLISES PAVEWARE REALIZADAS

TestDF

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestDF.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -15.78, -47.91

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

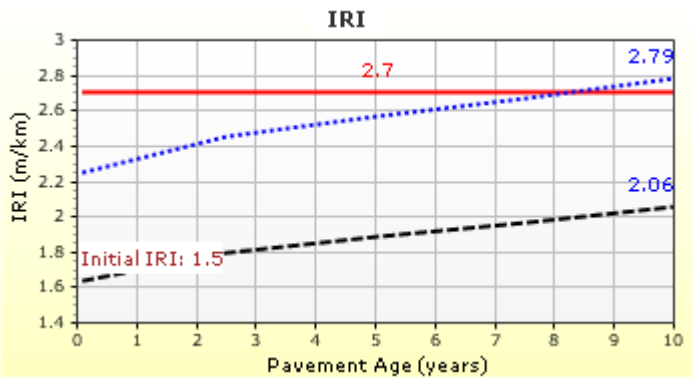
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

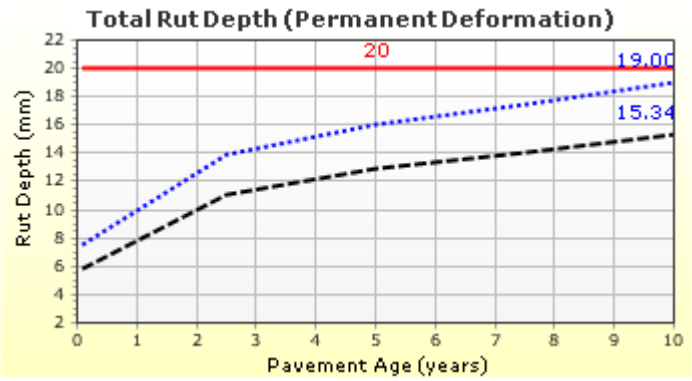
Design Outputs

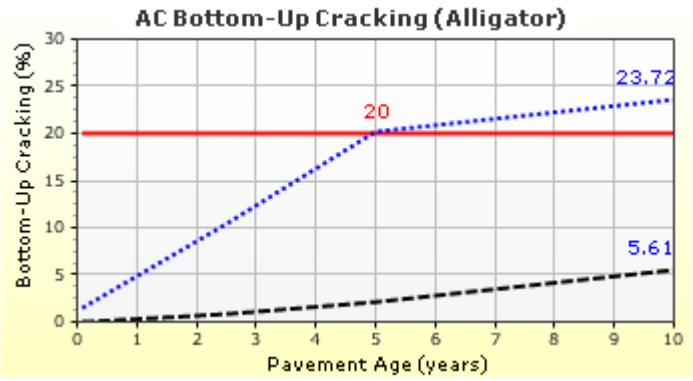
Distress Prediction Summary

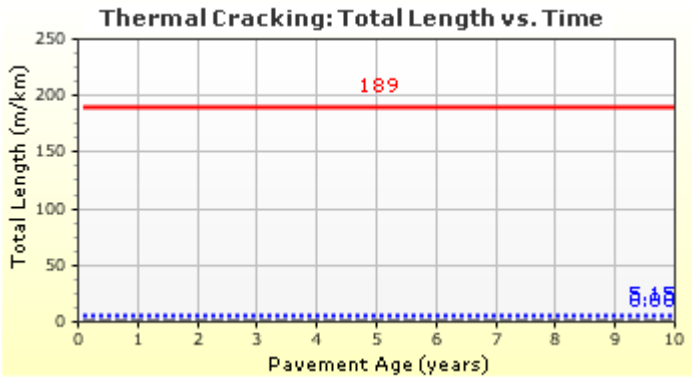
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.79	90.00	87.01	Fail
Permanent deformation - total pavement (mm)	20.00	19.01	90.00	94.78	Pass
AC bottom-up fatigue cracking (percent)	20.00	23.72	90.00	84.58	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	650.81	90.00	72.70	Fail
Permanent deformation - AC only (mm)	5.00	7.48	50.00	14.19	Fail

Distress Charts







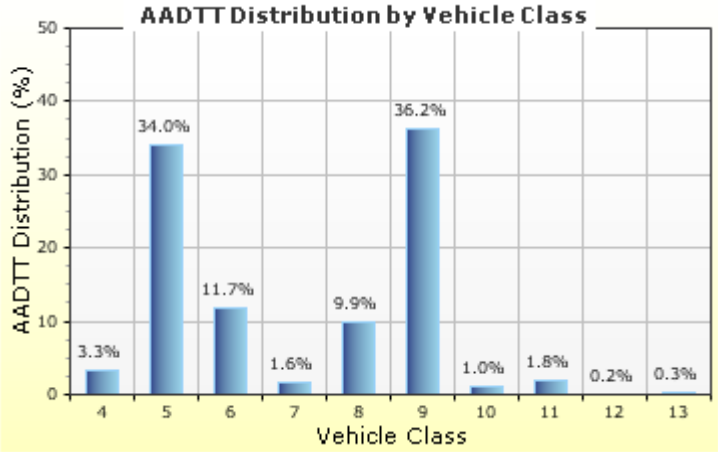


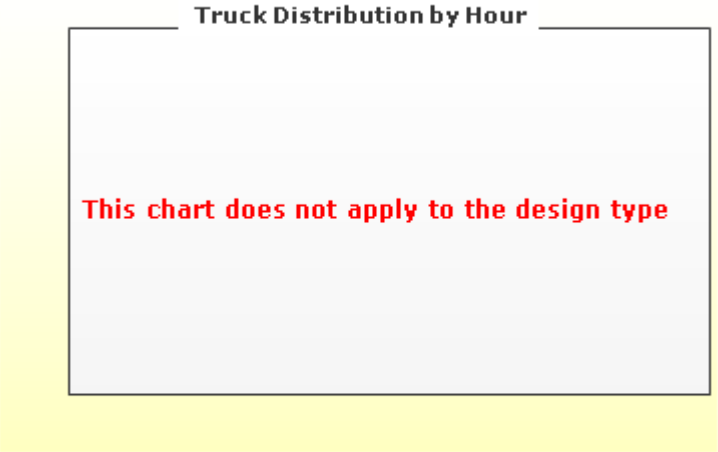
Threshold Value @ Specified Reliability @ 50% Reliability

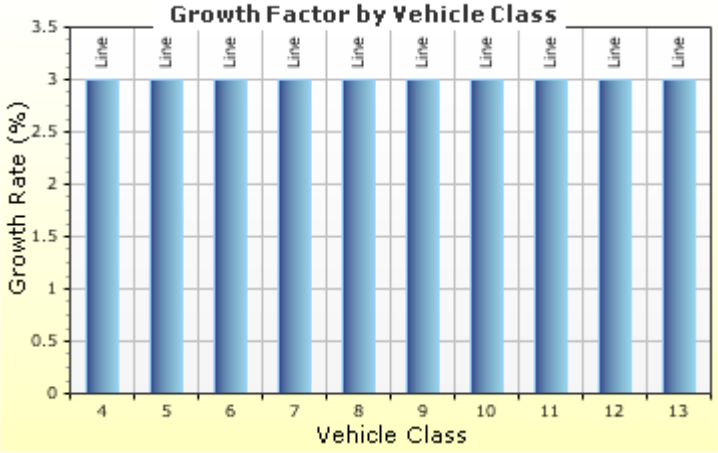
Traffic Inputs

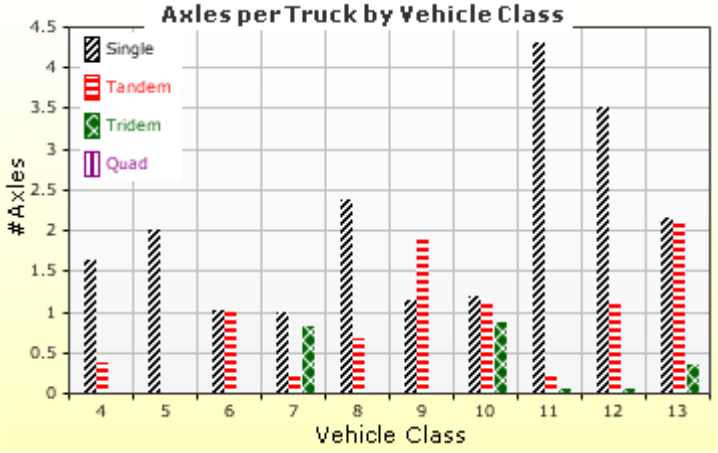
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

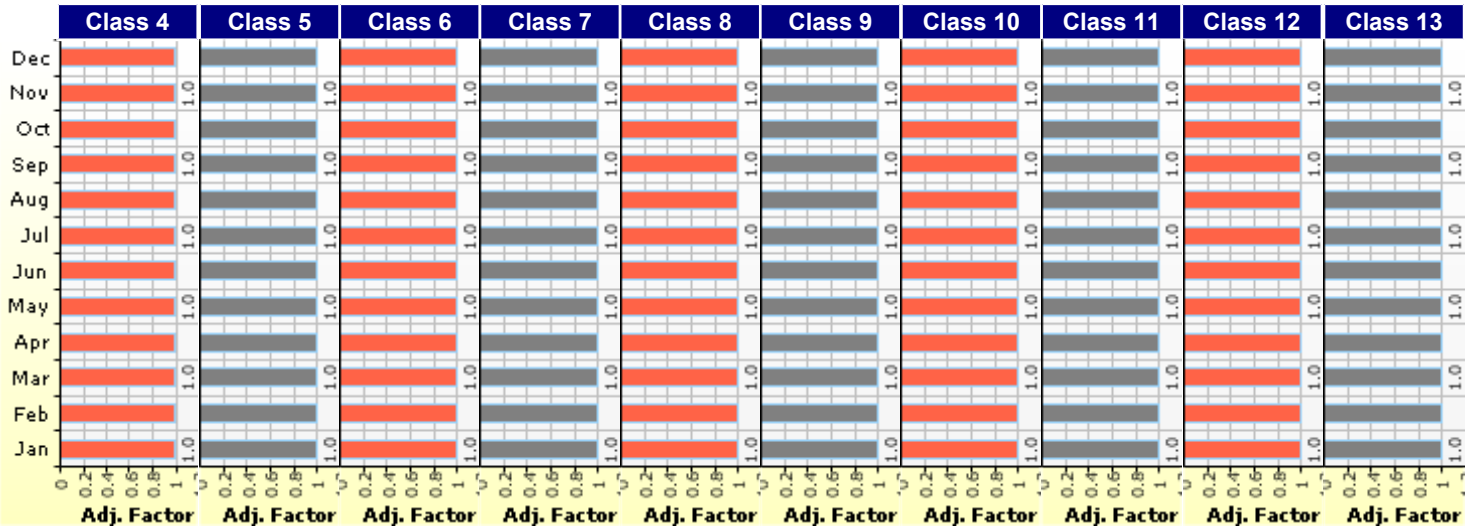








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

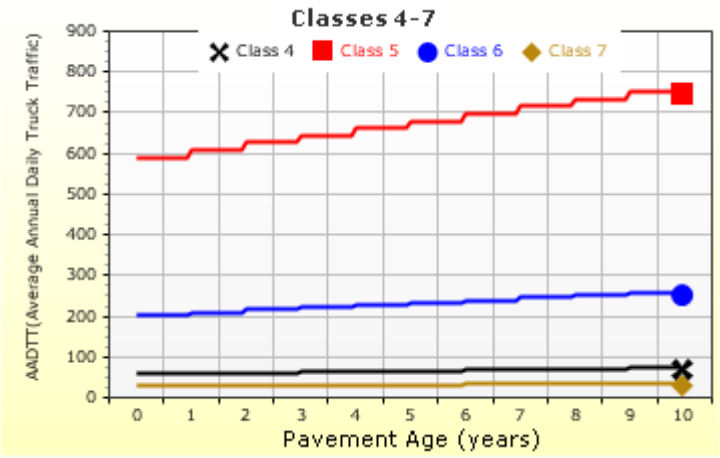
Wheelbase does not apply

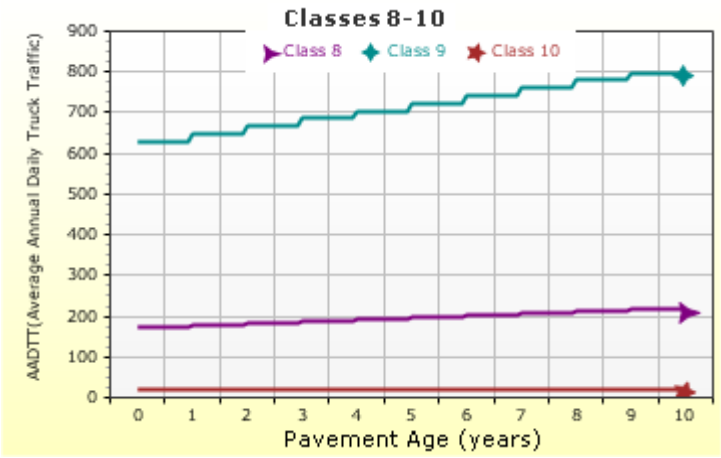
Number of Axles per Truck

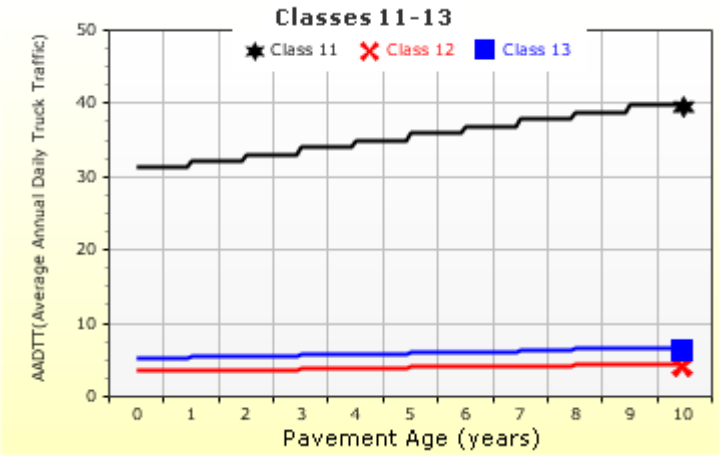
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

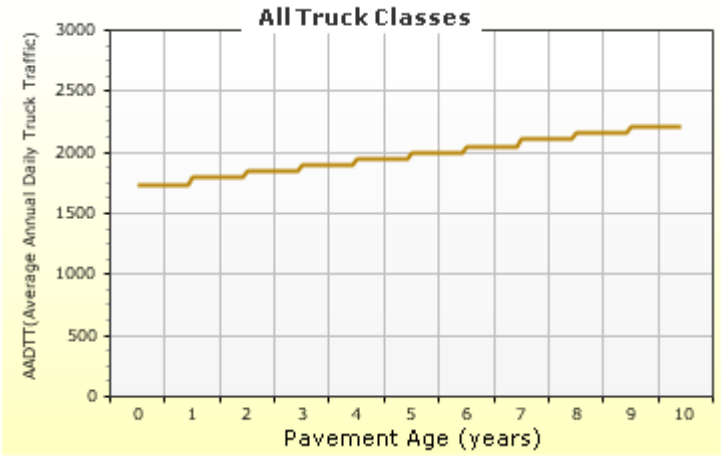
AADTT (Average Annual Daily Truck Traffic) Growth

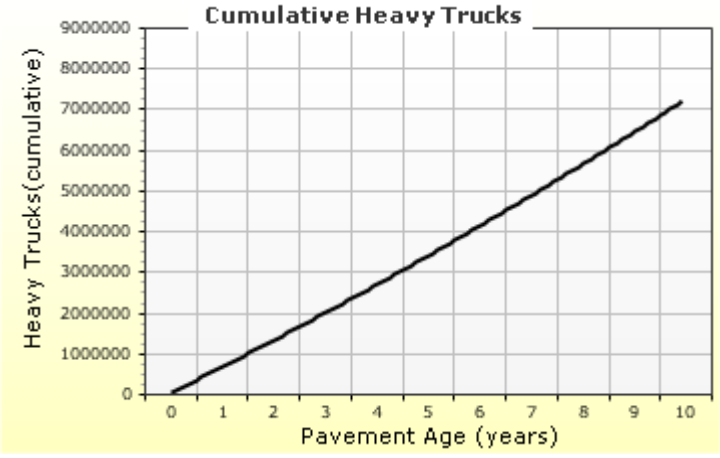
*** Traffic cap is not enforced**







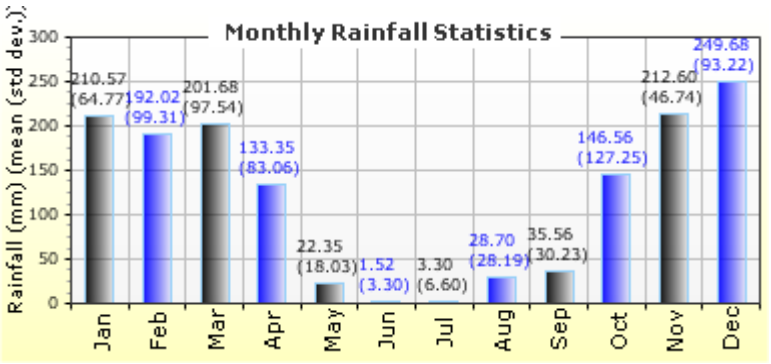




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
BRASILIA, DF	-15.78000 -47.91000 1159

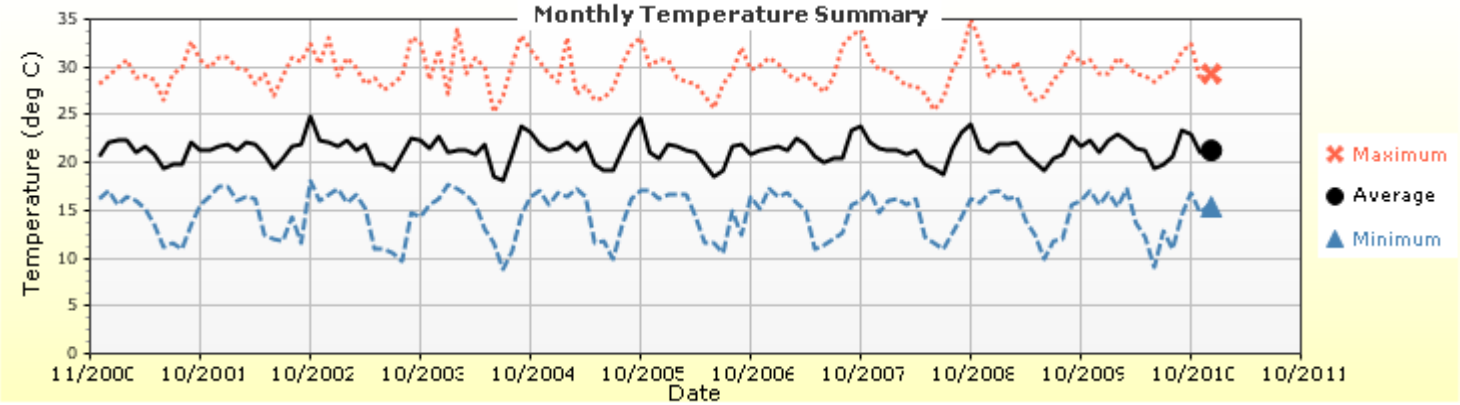


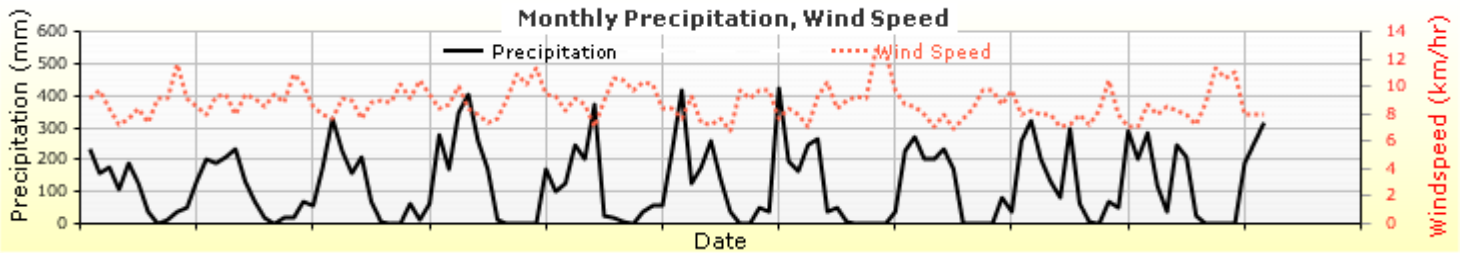
Annual Statistics:

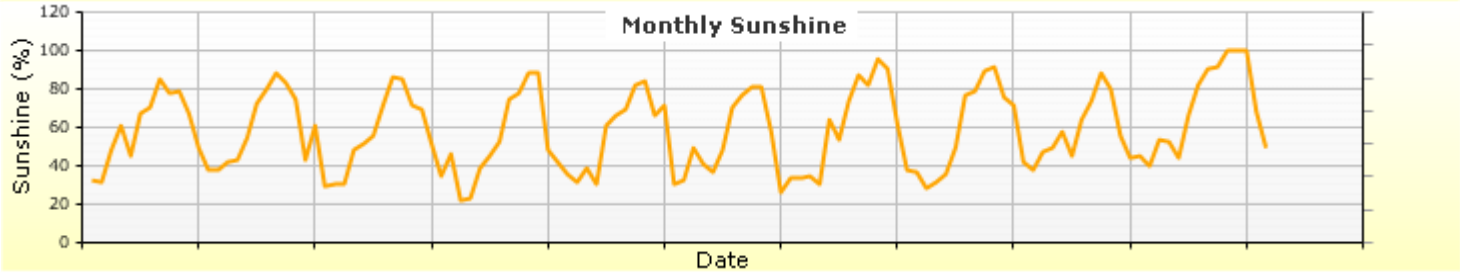
Mean annual air temperature (ºC)	21.35
Mean annual precipitation (mm)	1461.01
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

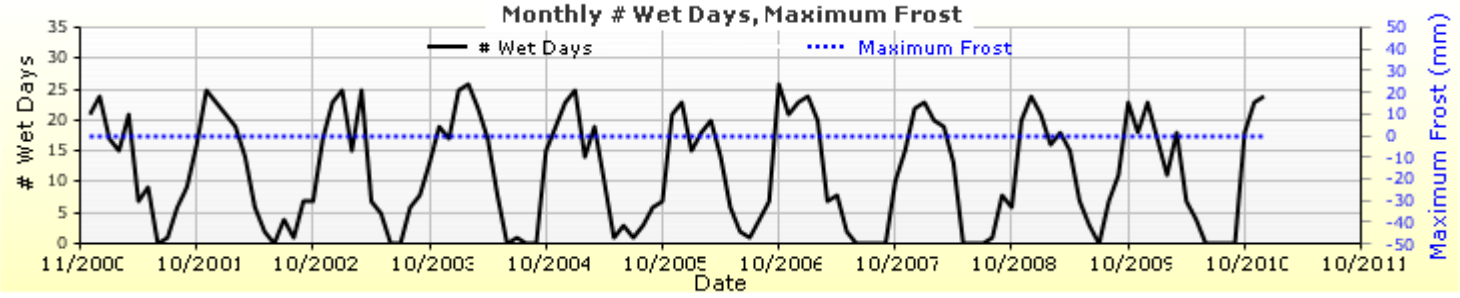
Water table depth (m): 3.05

Monthly Climate Summary:

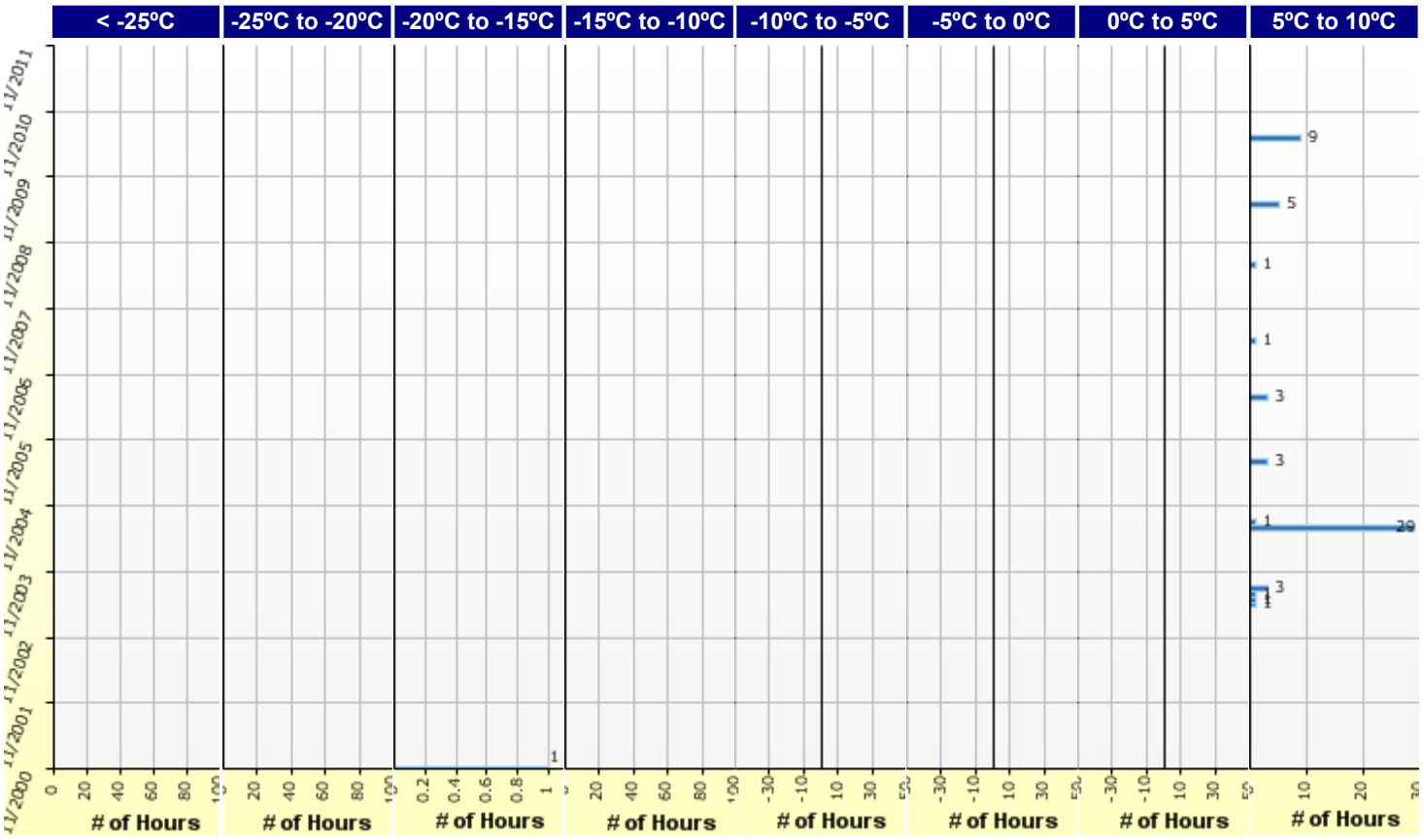


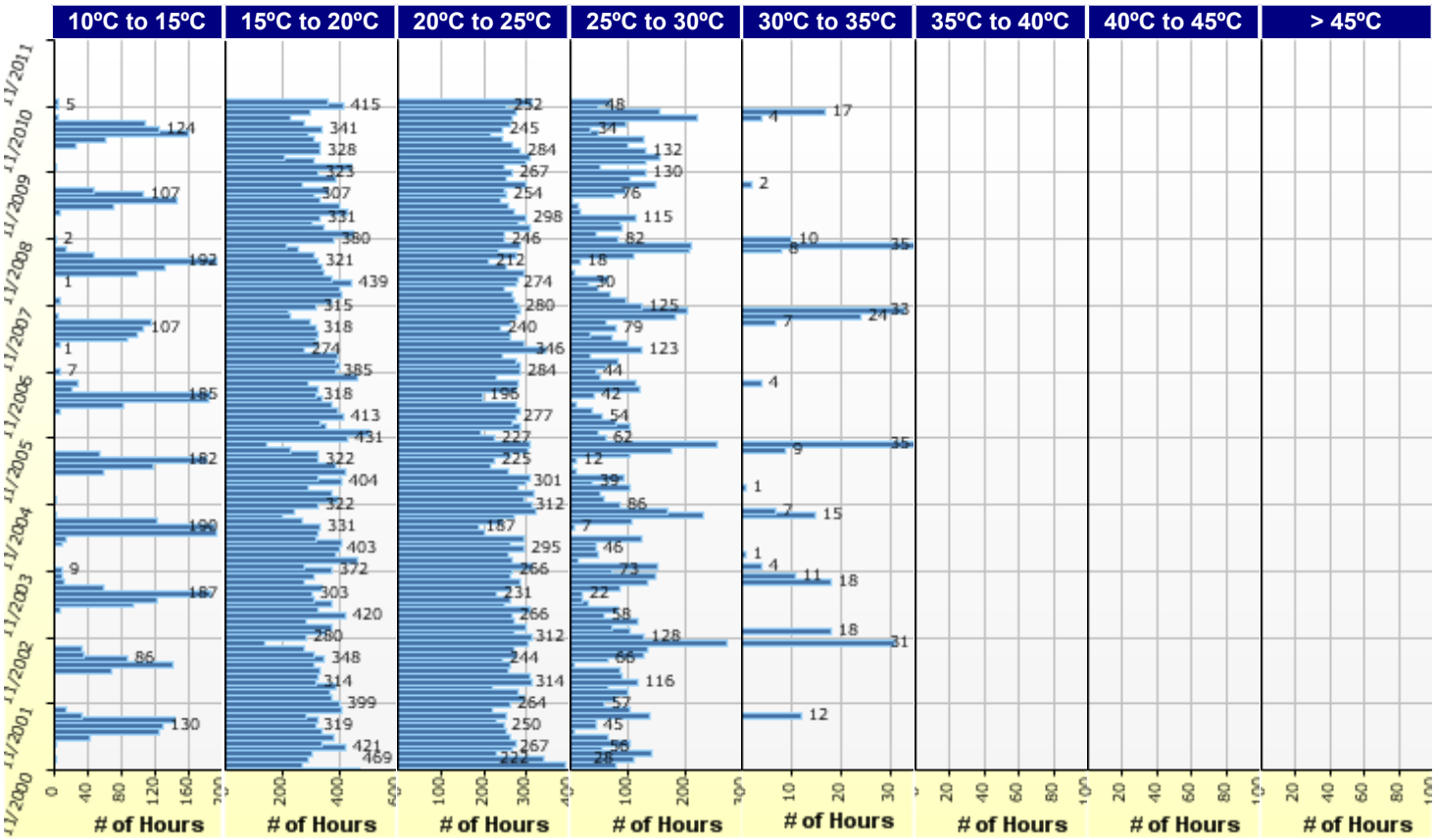






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

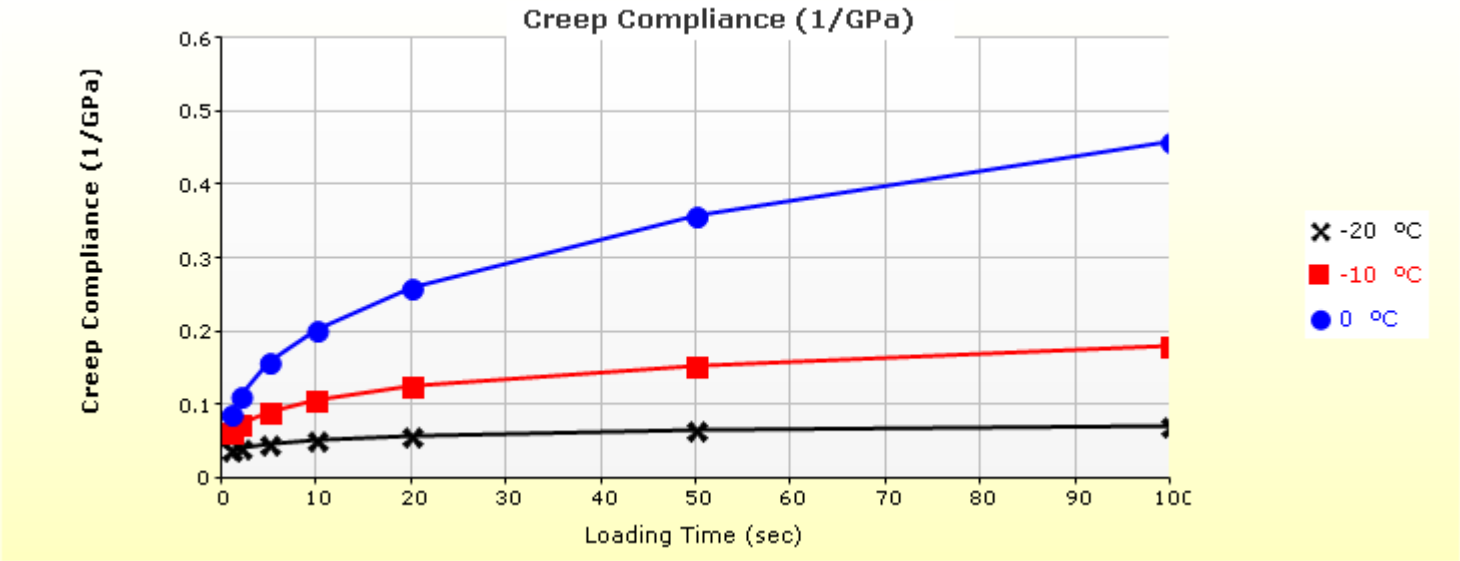
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

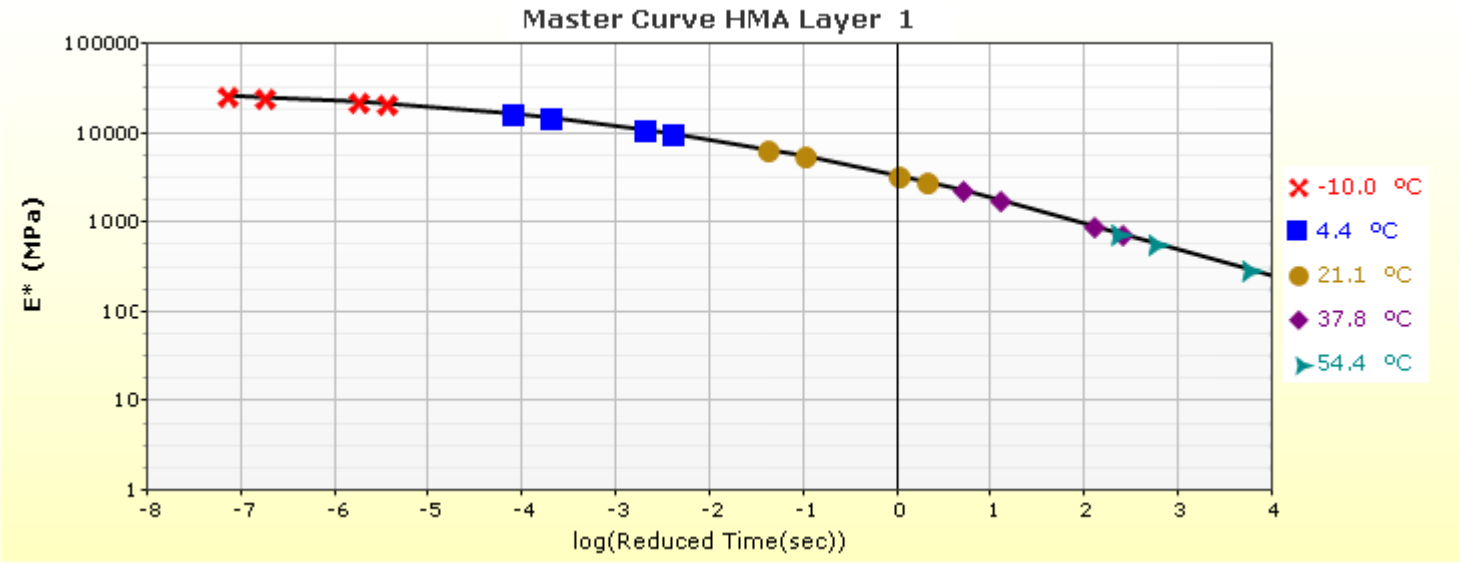
Indirect tensile strength at -10 ºC (MPa)	2.69

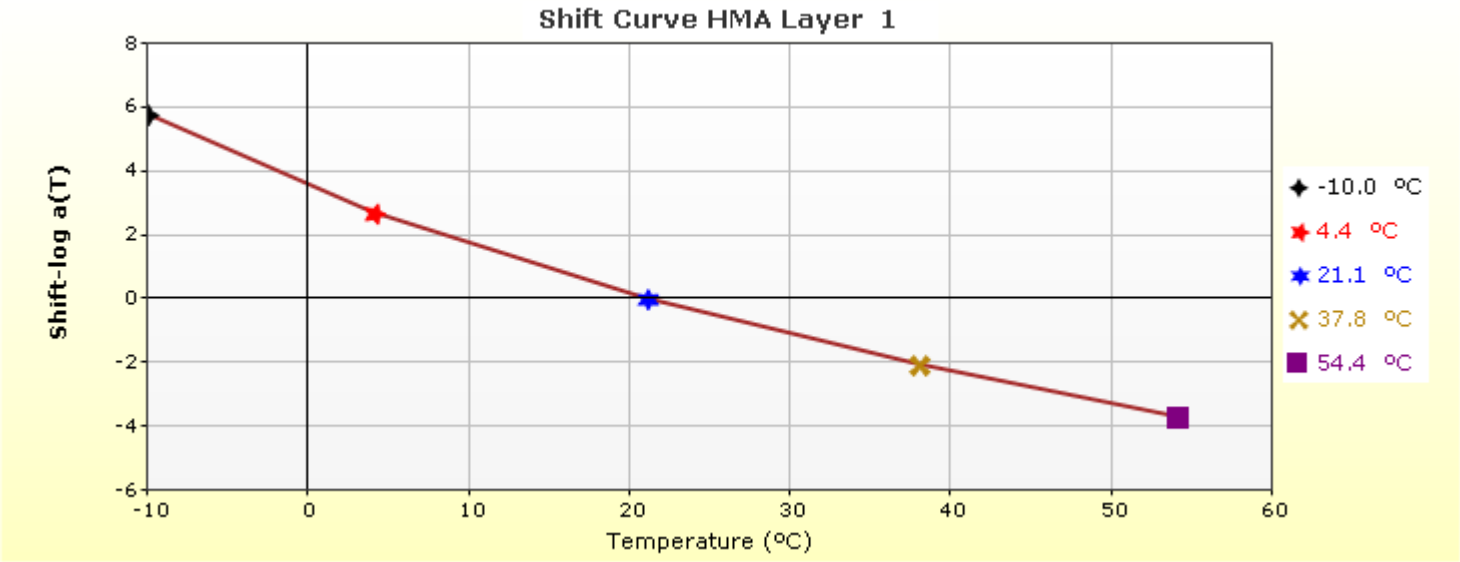
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

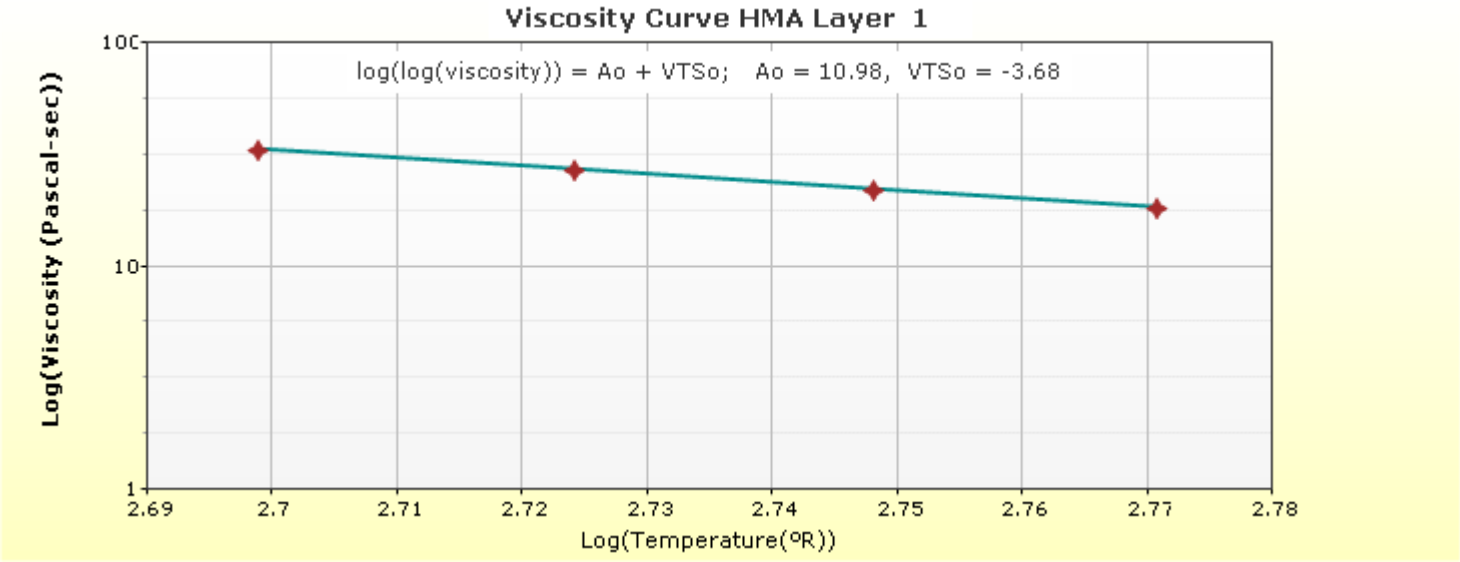
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



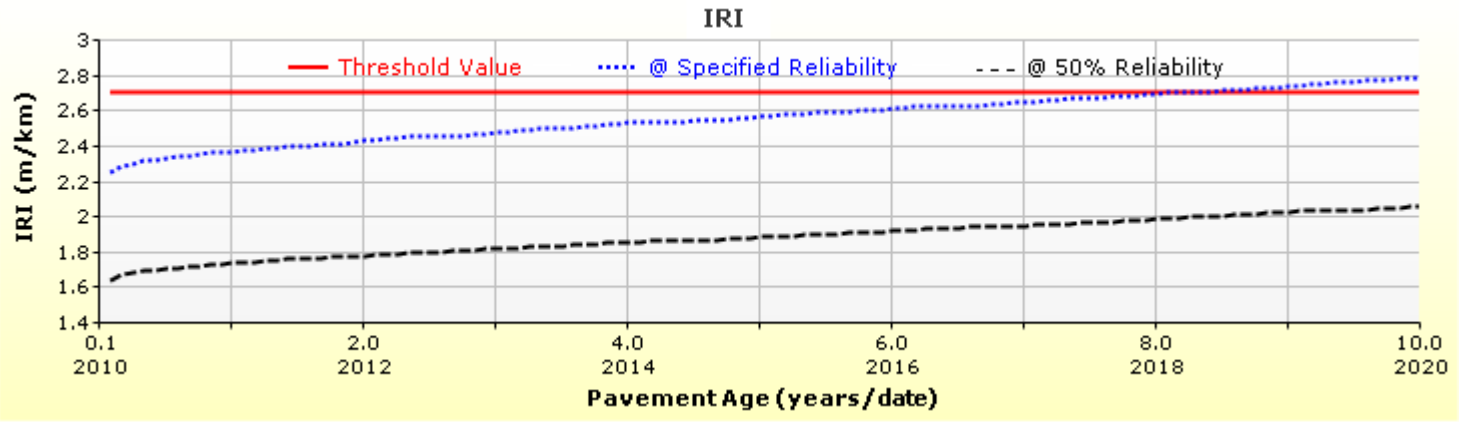
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

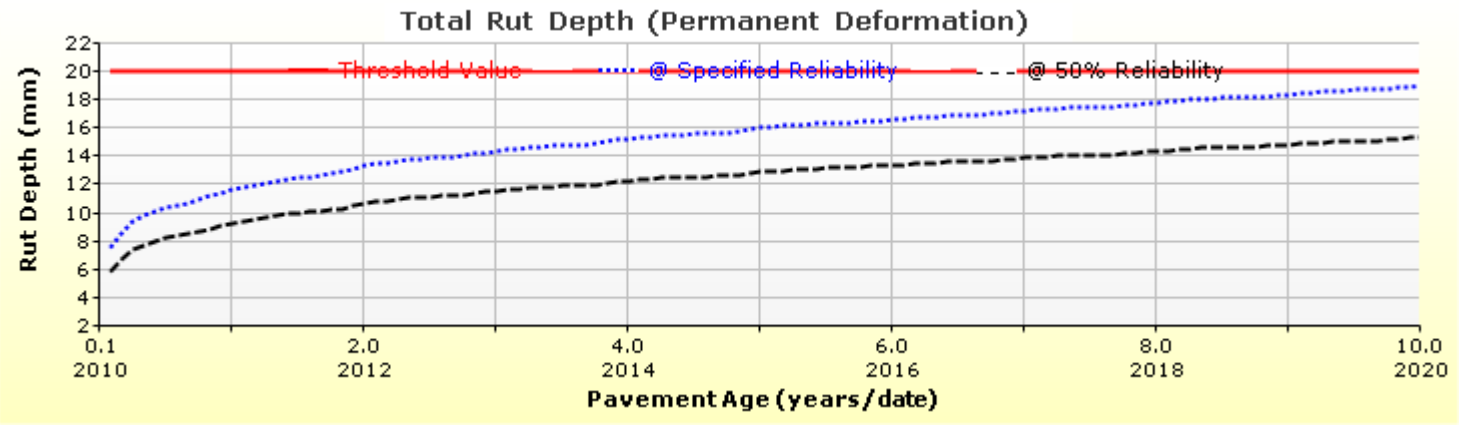


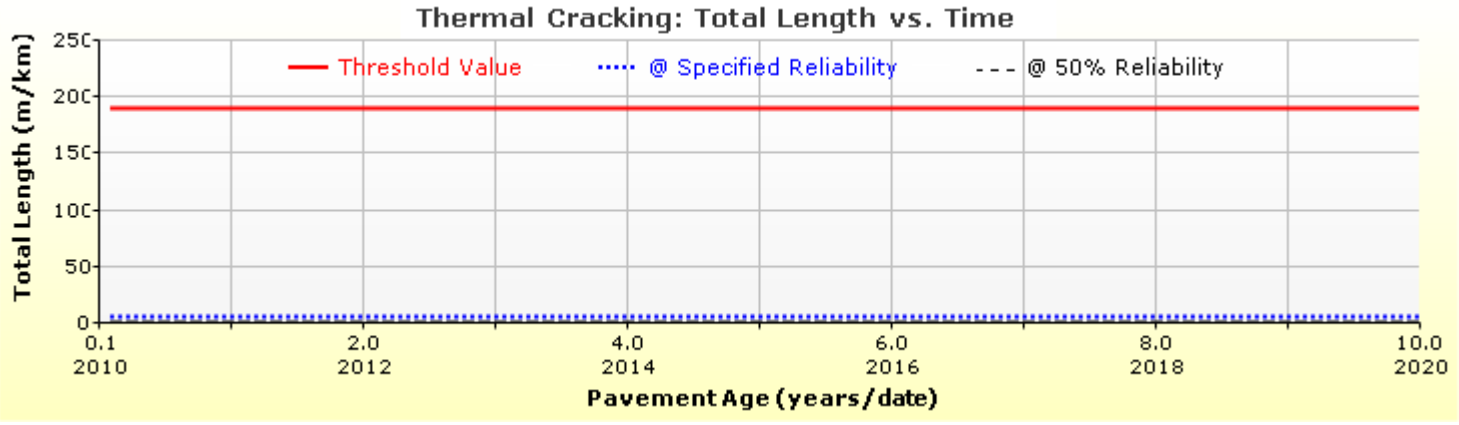


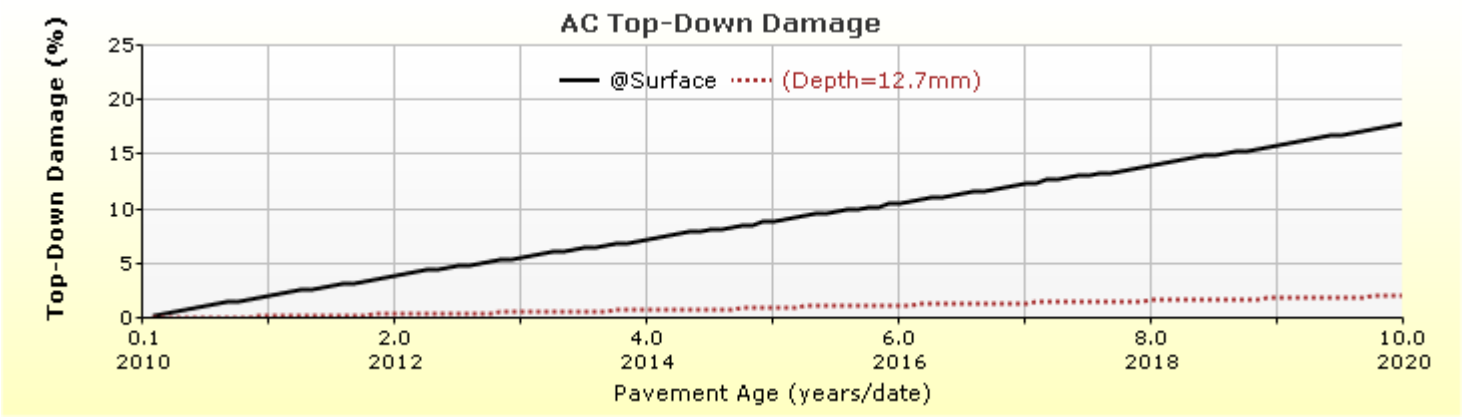


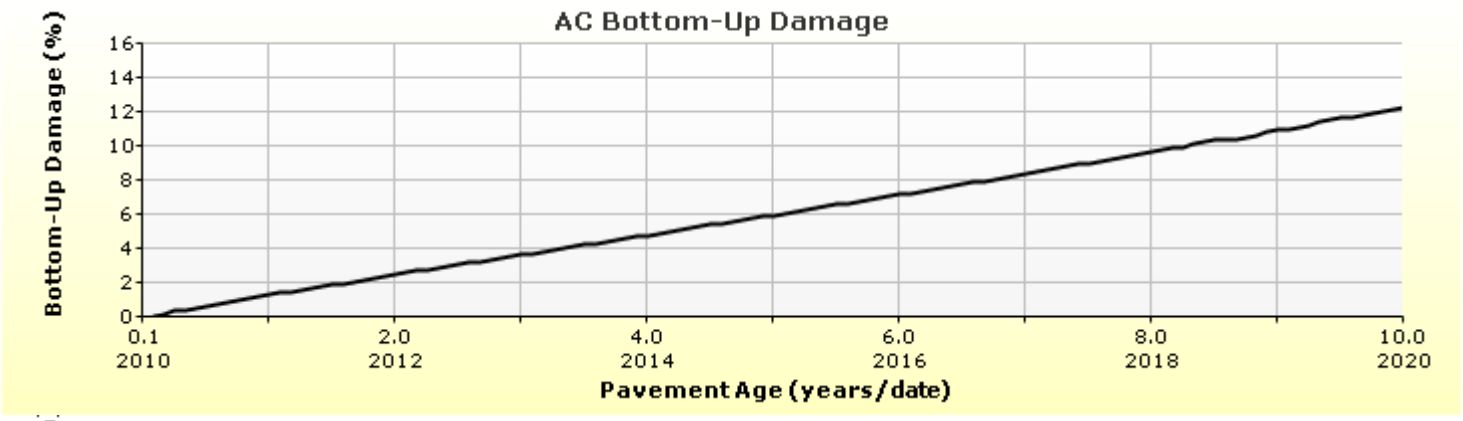
Analysis Output Charts

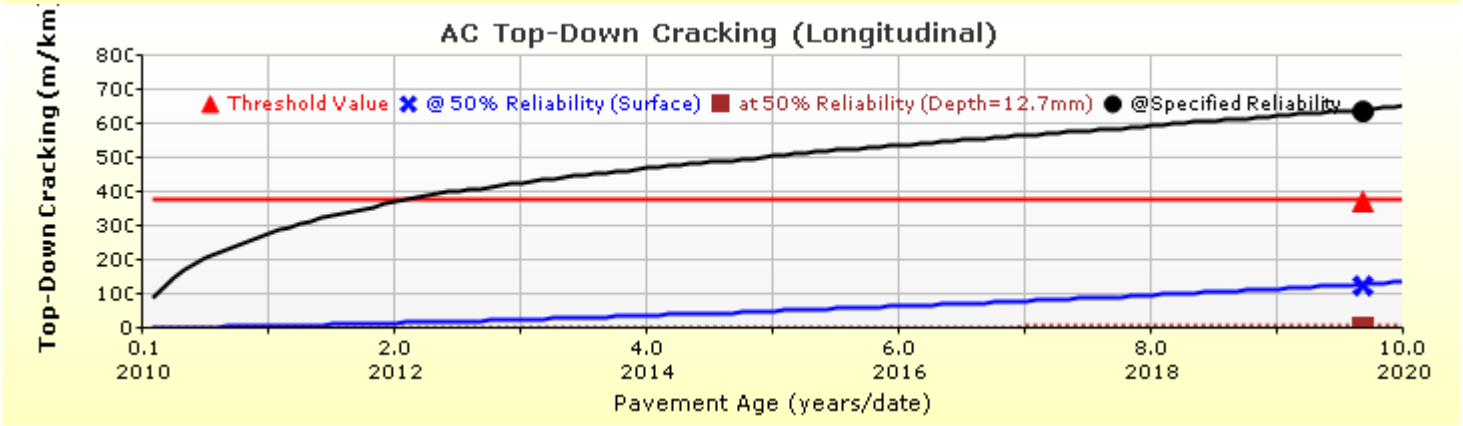


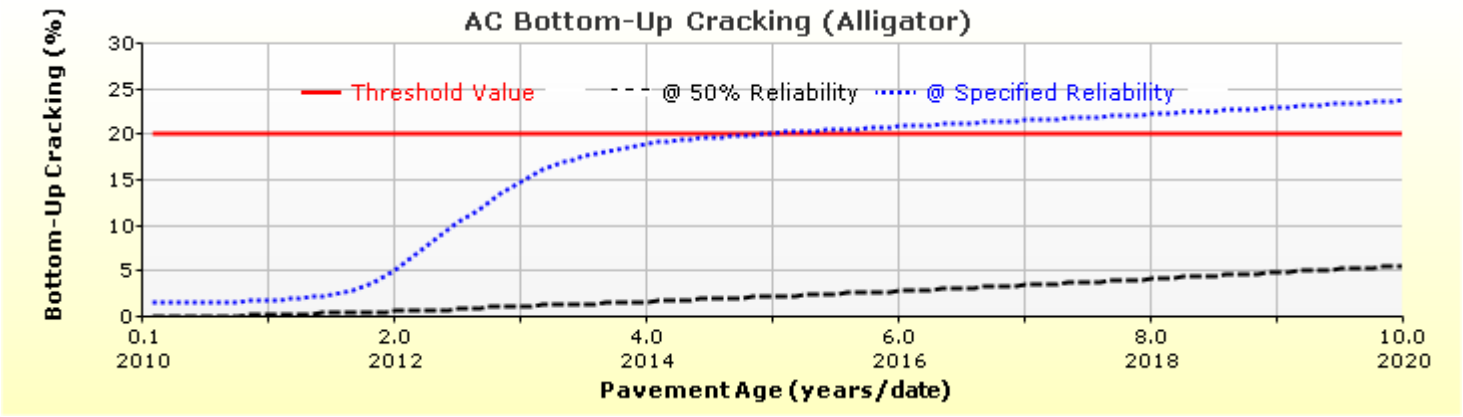


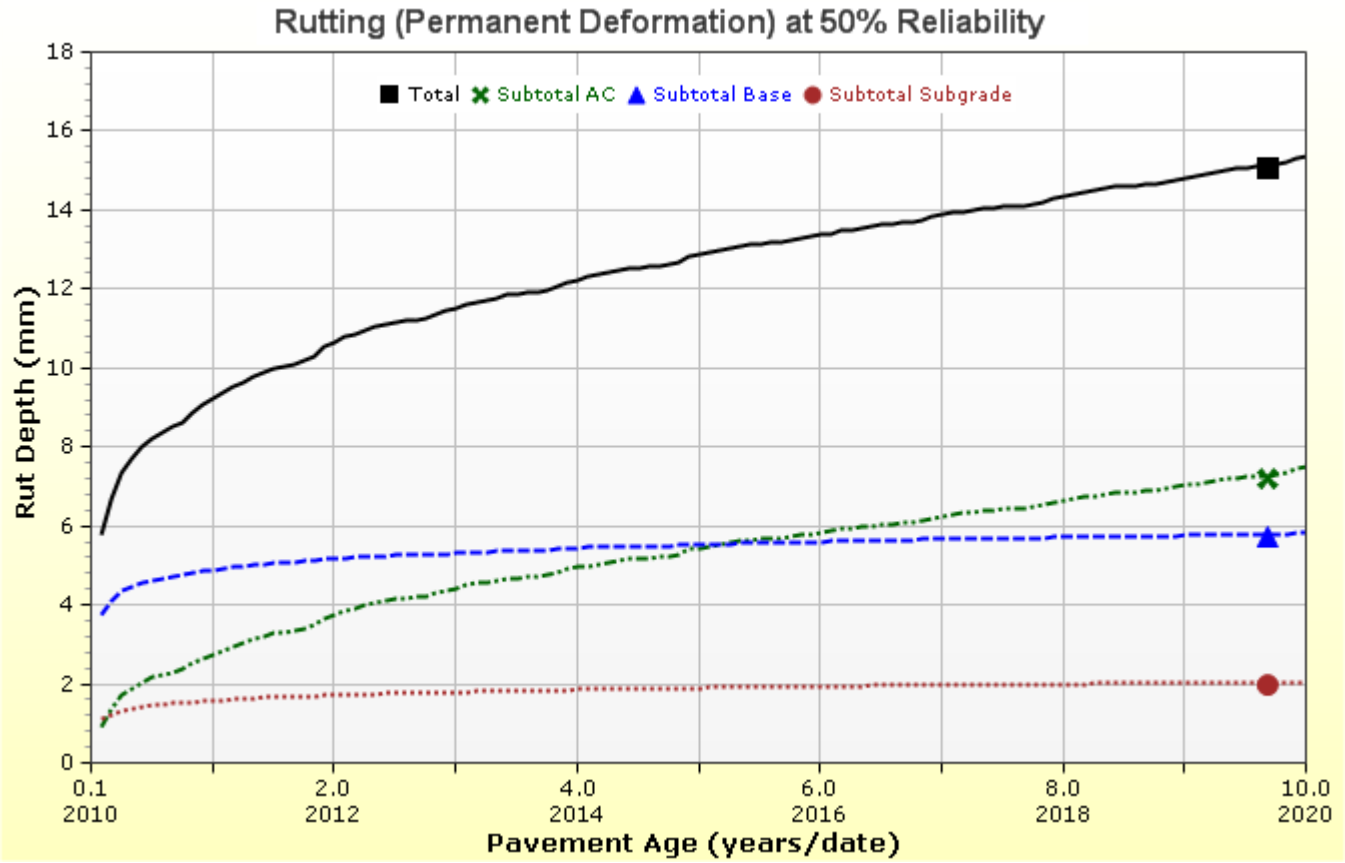


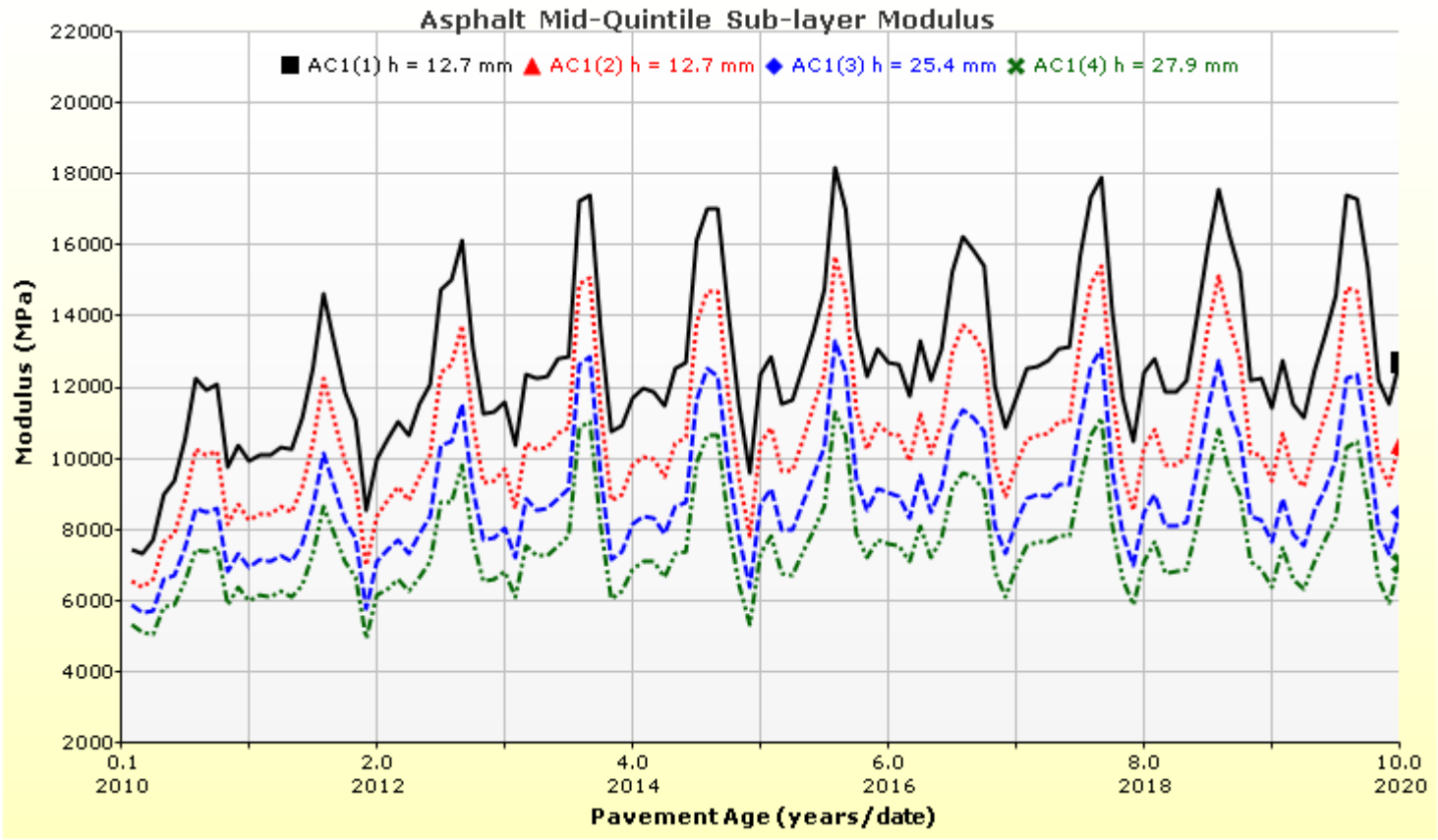

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

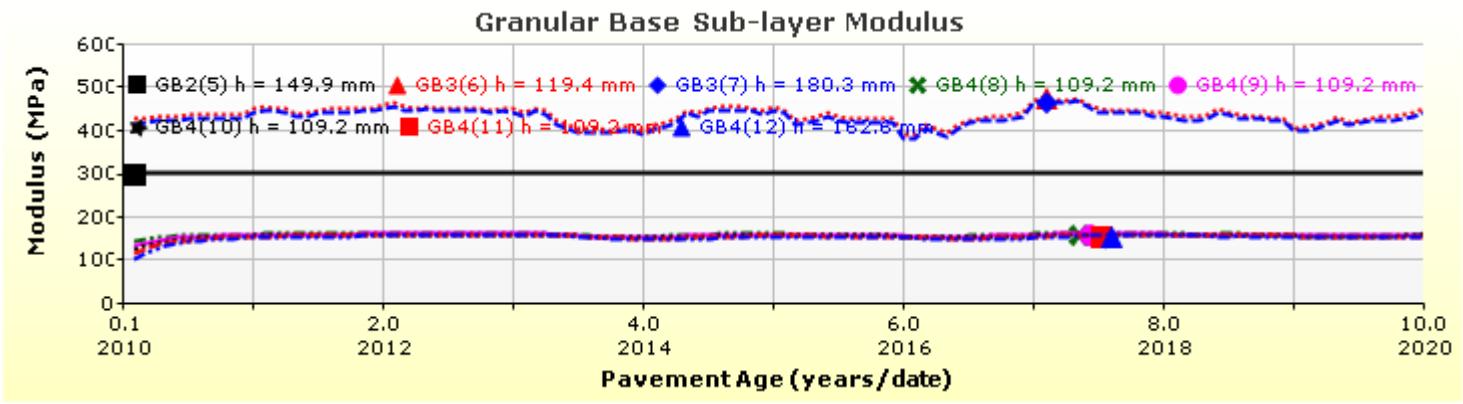

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

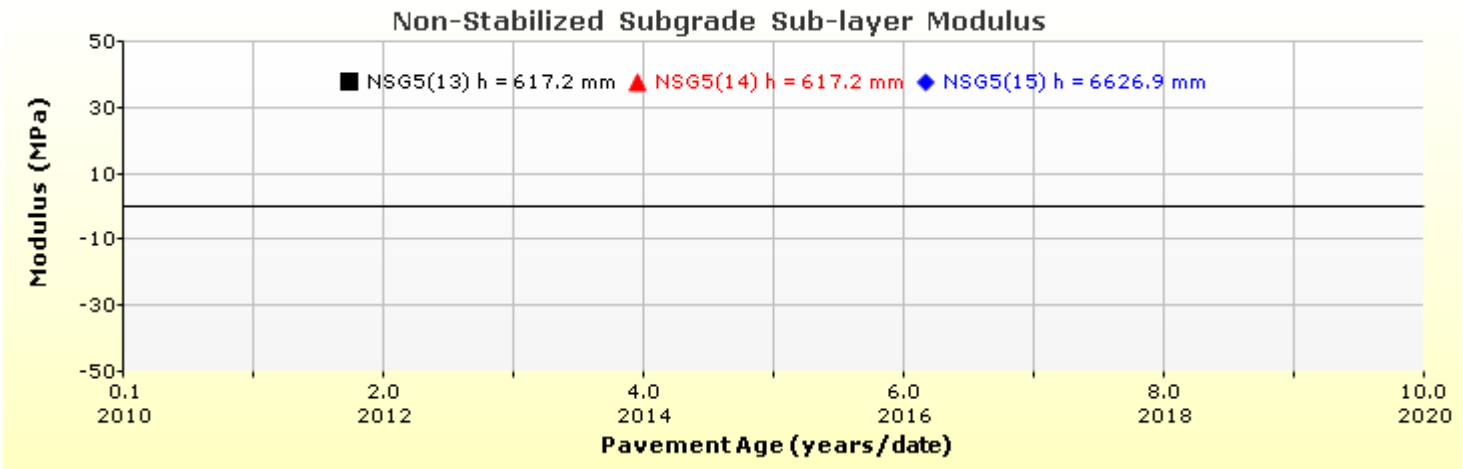

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.8 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestDF+2

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestDF+2.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -15.78, -47.91

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

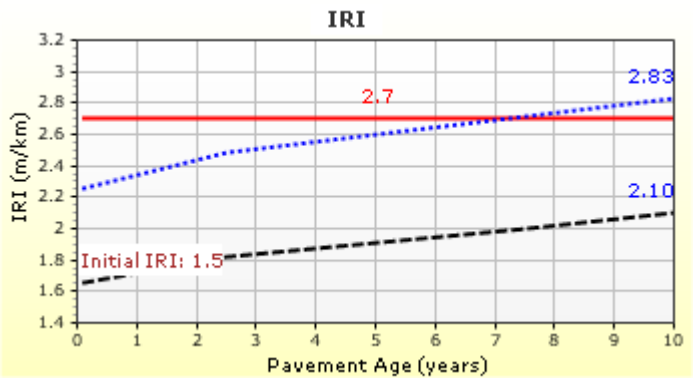
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

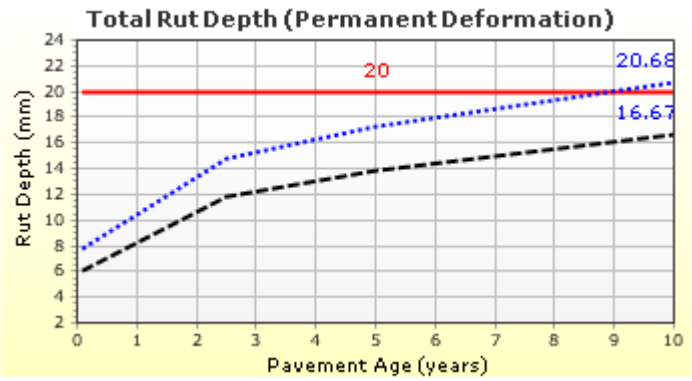
Design Outputs

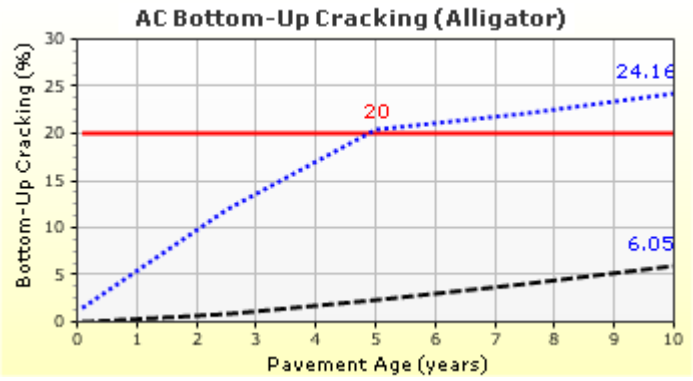
Distress Prediction Summary

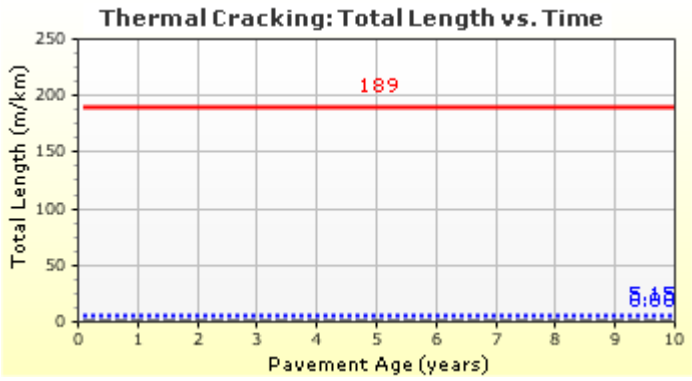
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.83	90.00	85.28	Fail
Permanent deformation - total pavement (mm)	20.00	20.67	90.00	85.60	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.16	90.00	83.83	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	684.18	90.00	70.30	Fail
Permanent deformation - AC only (mm)	5.00	8.80	50.00	7.45	Fail

Distress Charts







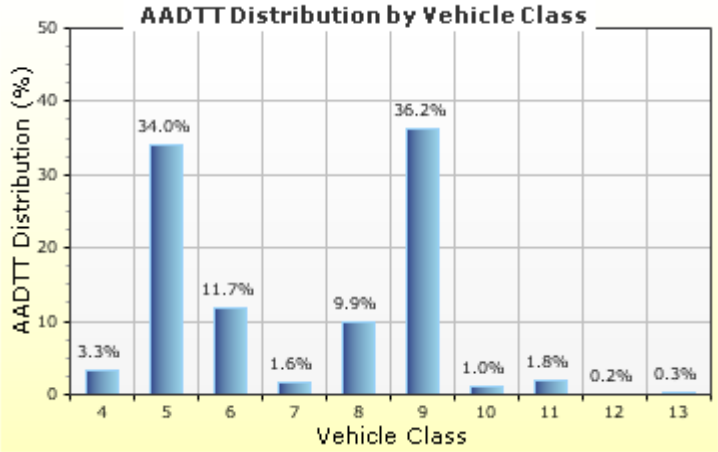


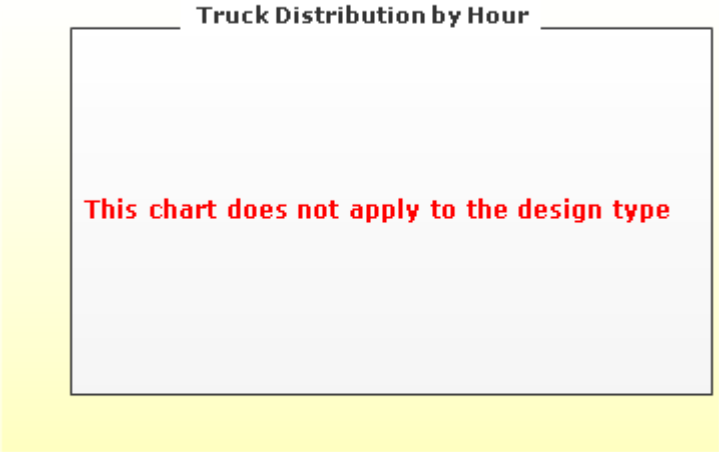


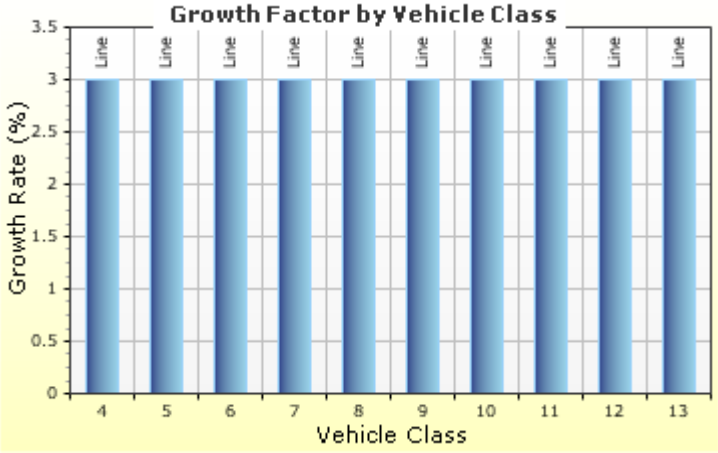
Traffic Inputs

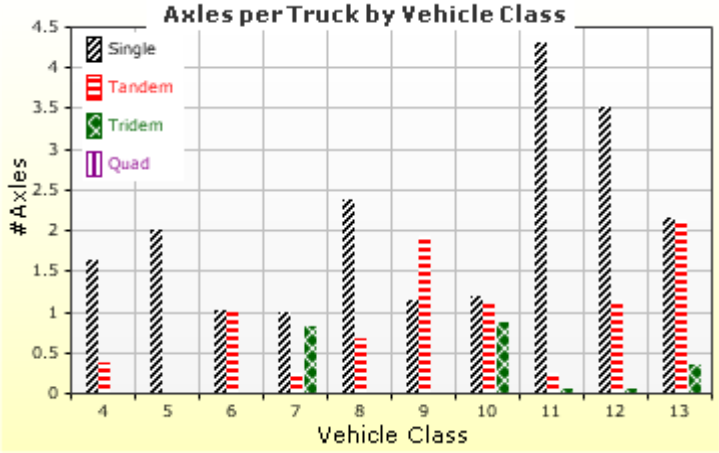
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

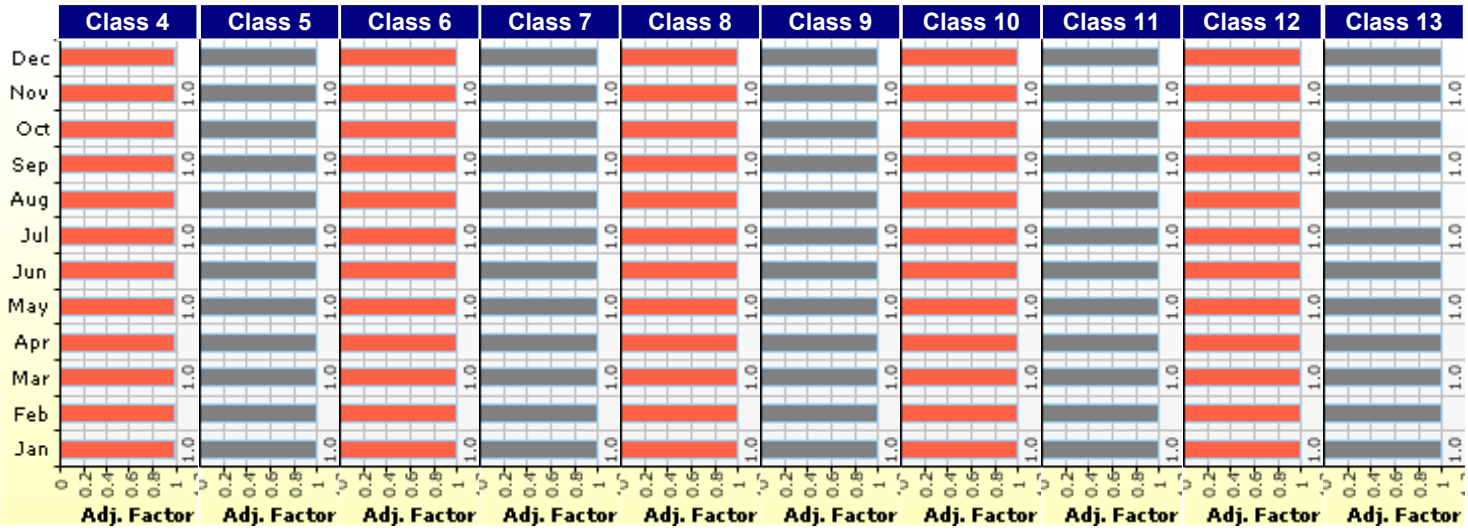








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

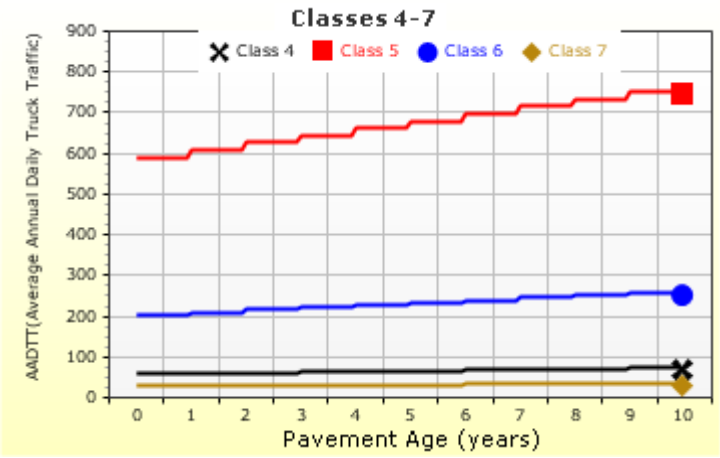
Wheelbase does not apply

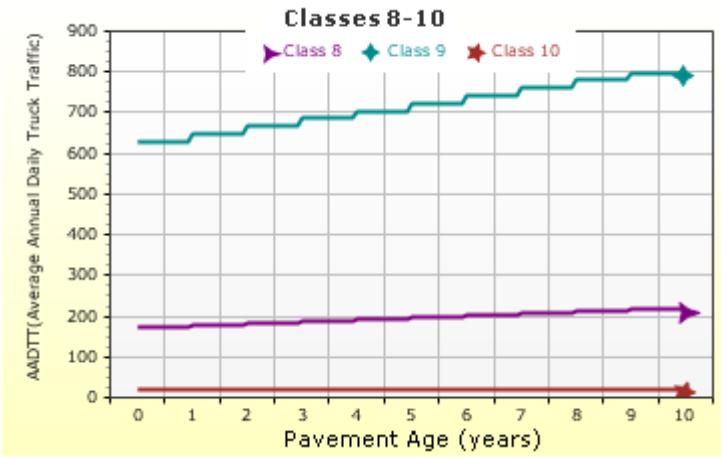
Number of Axles per Truck

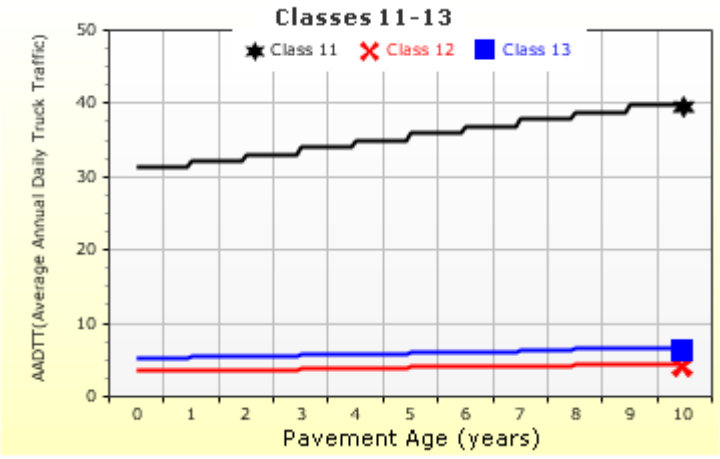
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

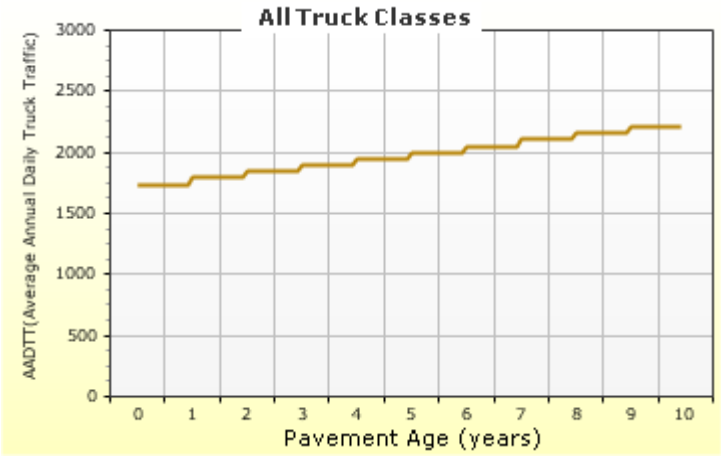
AADTT (Average Annual Daily Truck Traffic) Growth

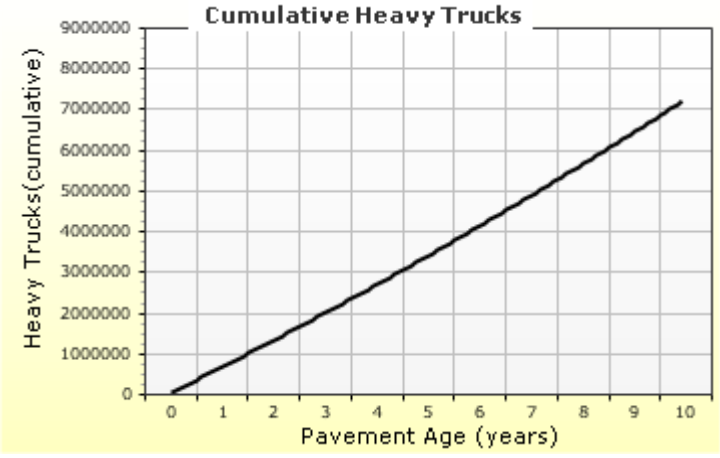
*** Traffic cap is not enforced**







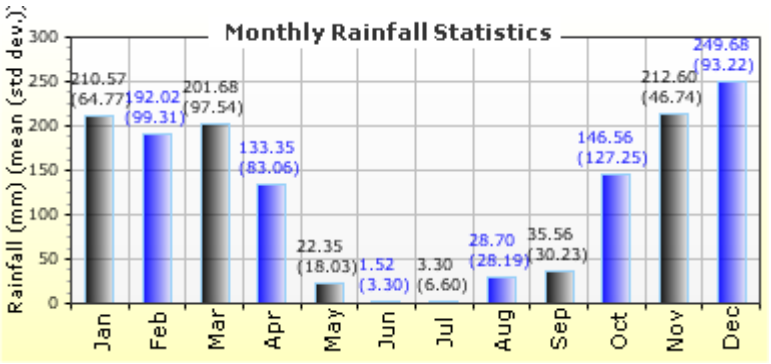




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
BRASILIA, DF	-15.78000 -47.91000 1159

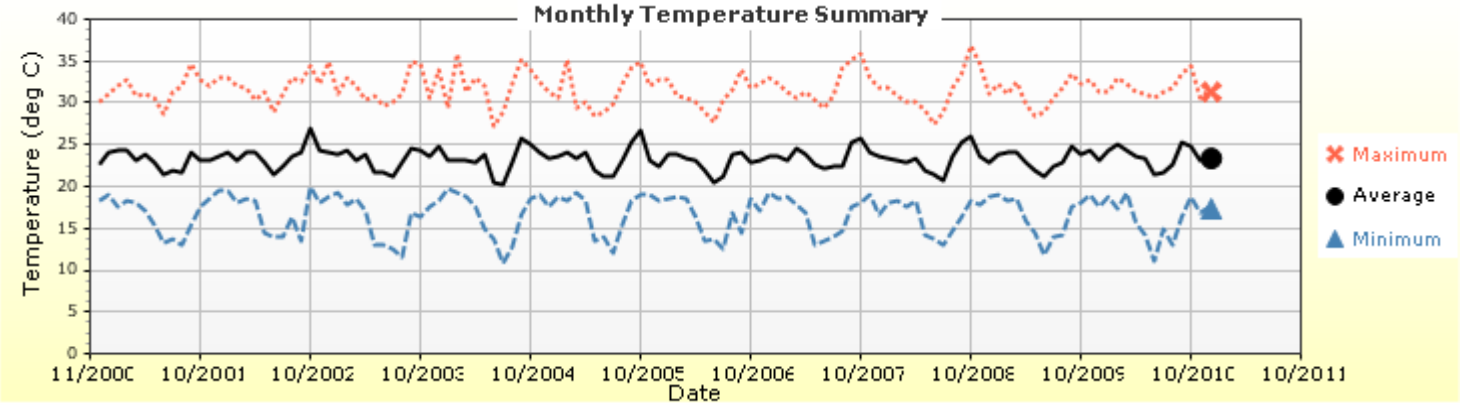


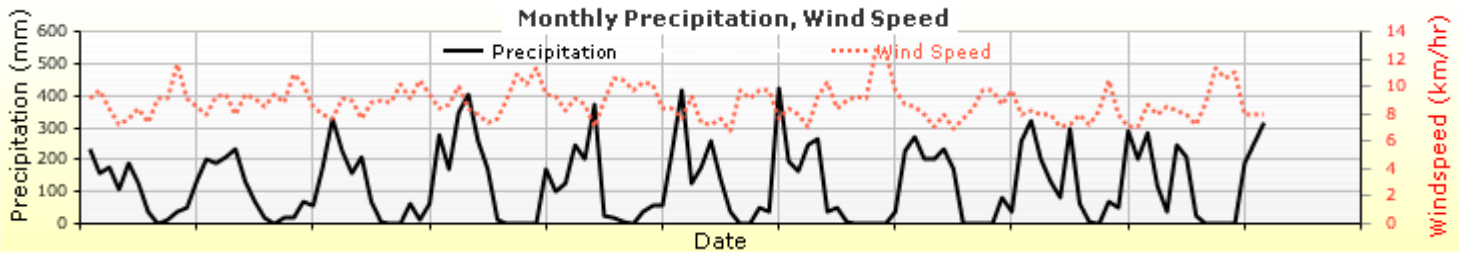
Annual Statistics:

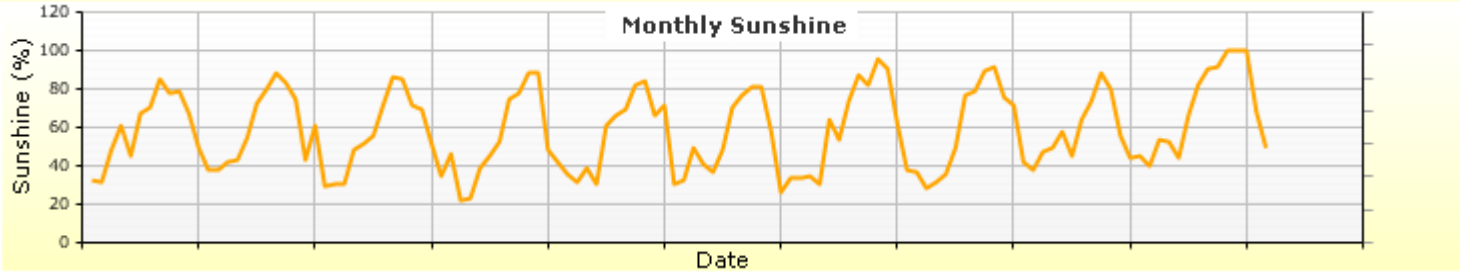
Mean annual air temperature (ºC)	23.35
Mean annual precipitation (mm)	1461.01
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

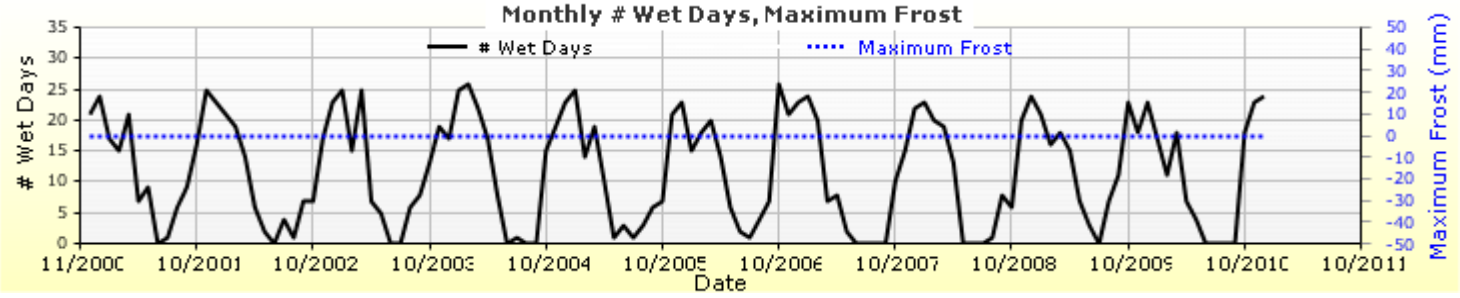
Water table depth (m): 3.05

Monthly Climate Summary:

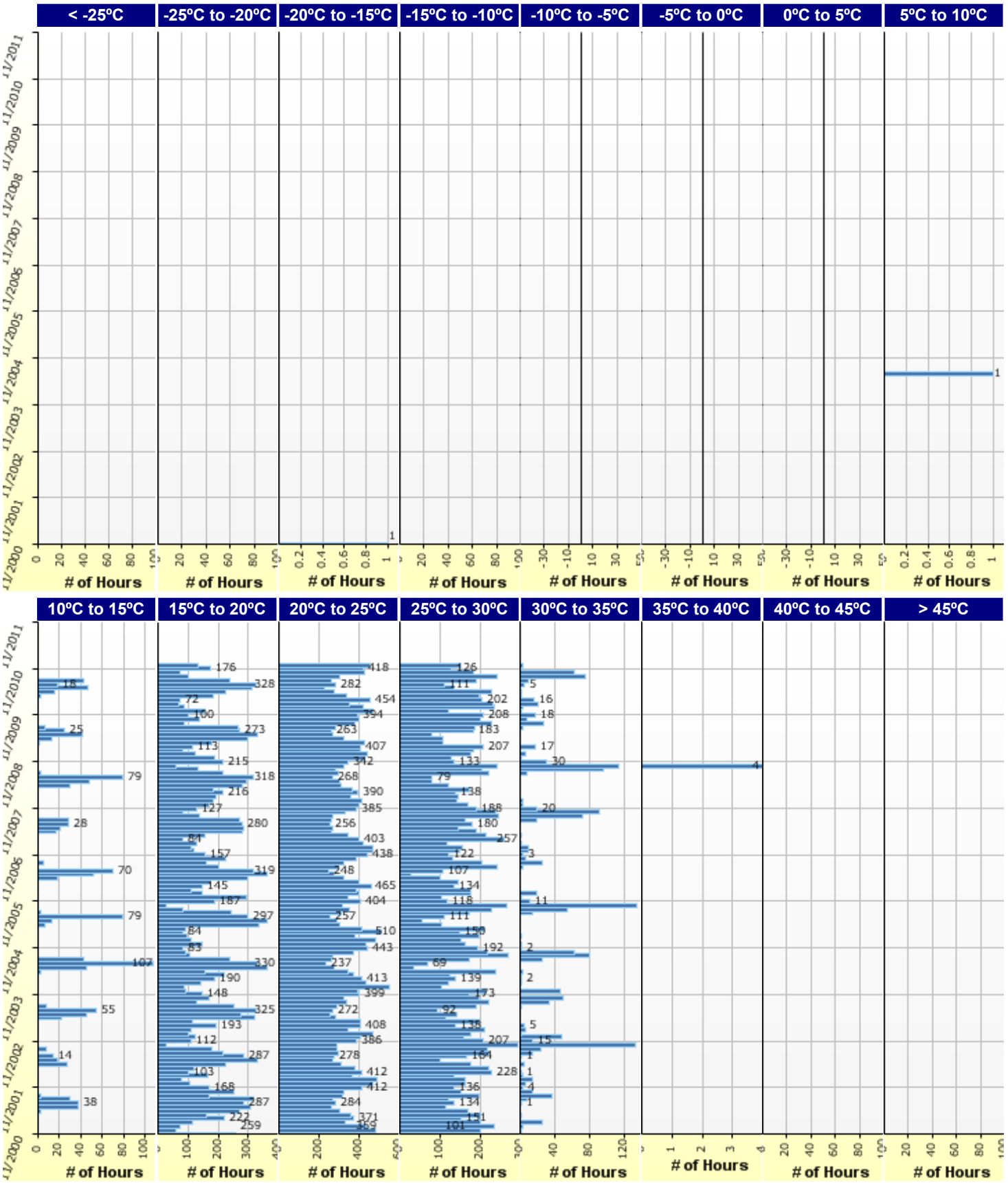








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

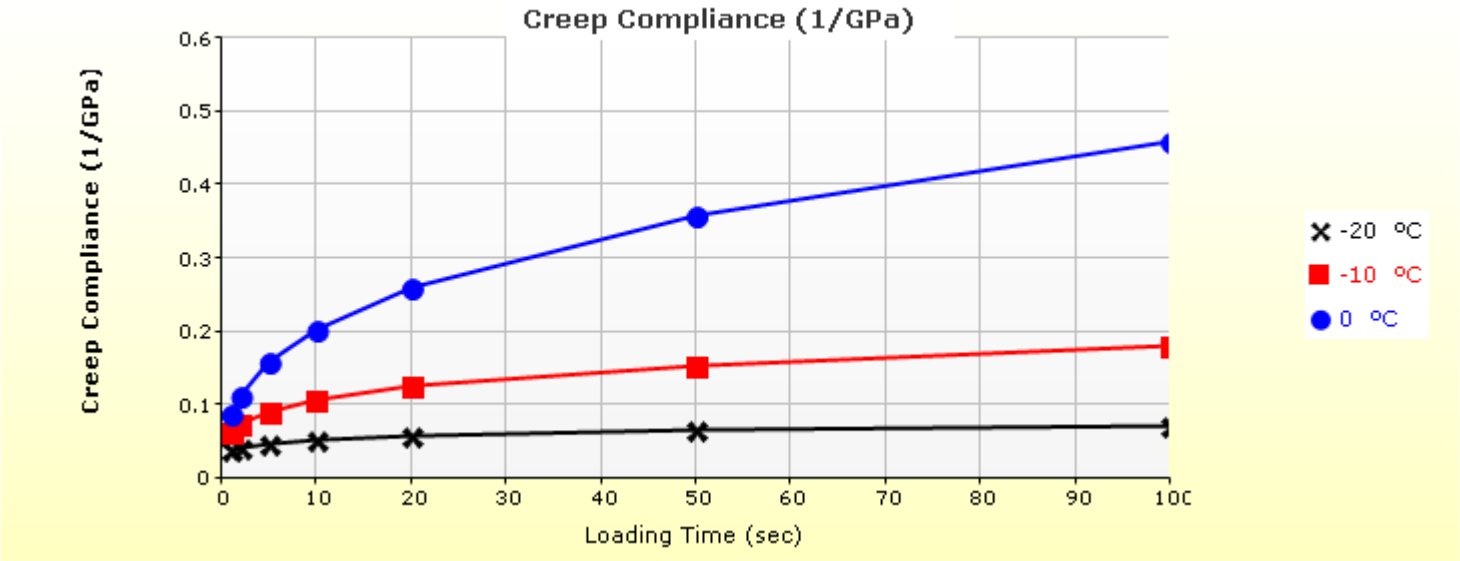
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

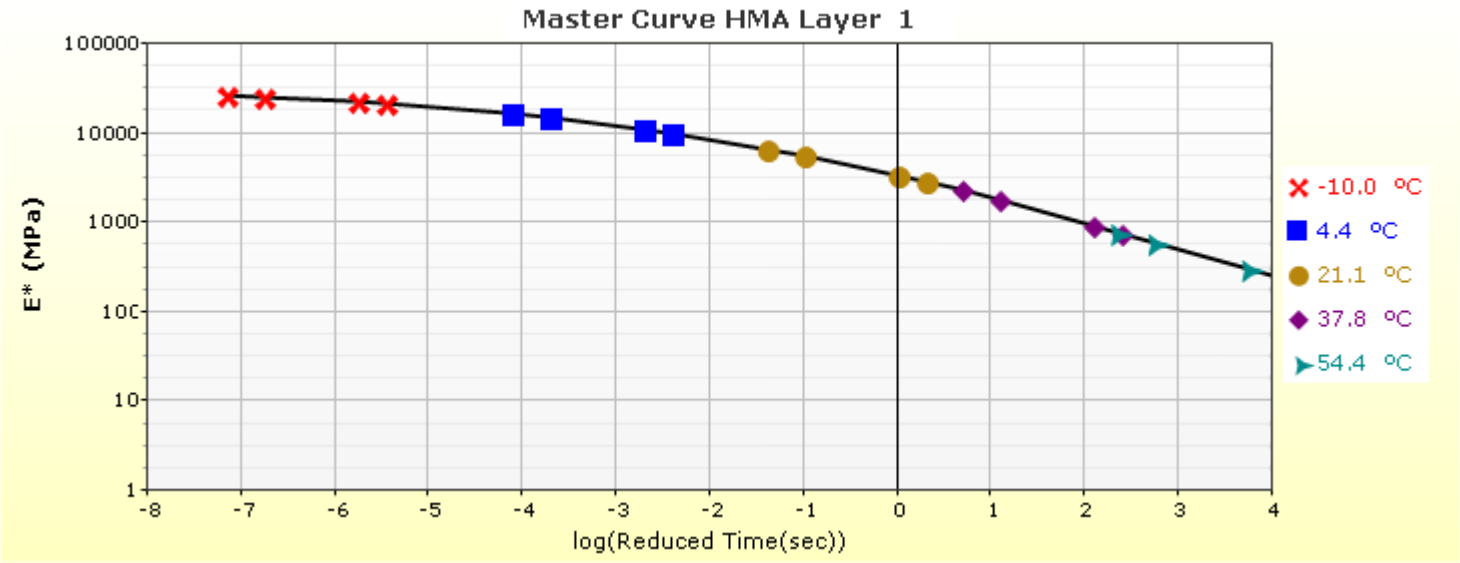
Indirect tensile strength at -10 ºC (MPa)	2.69

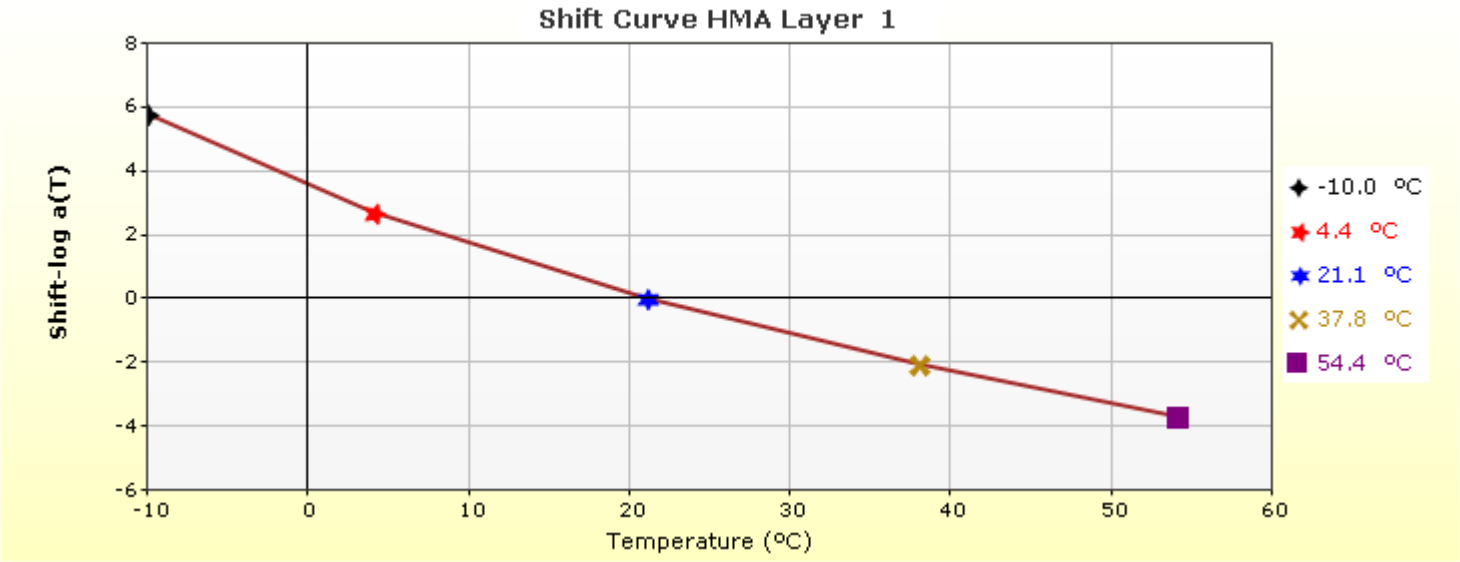
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

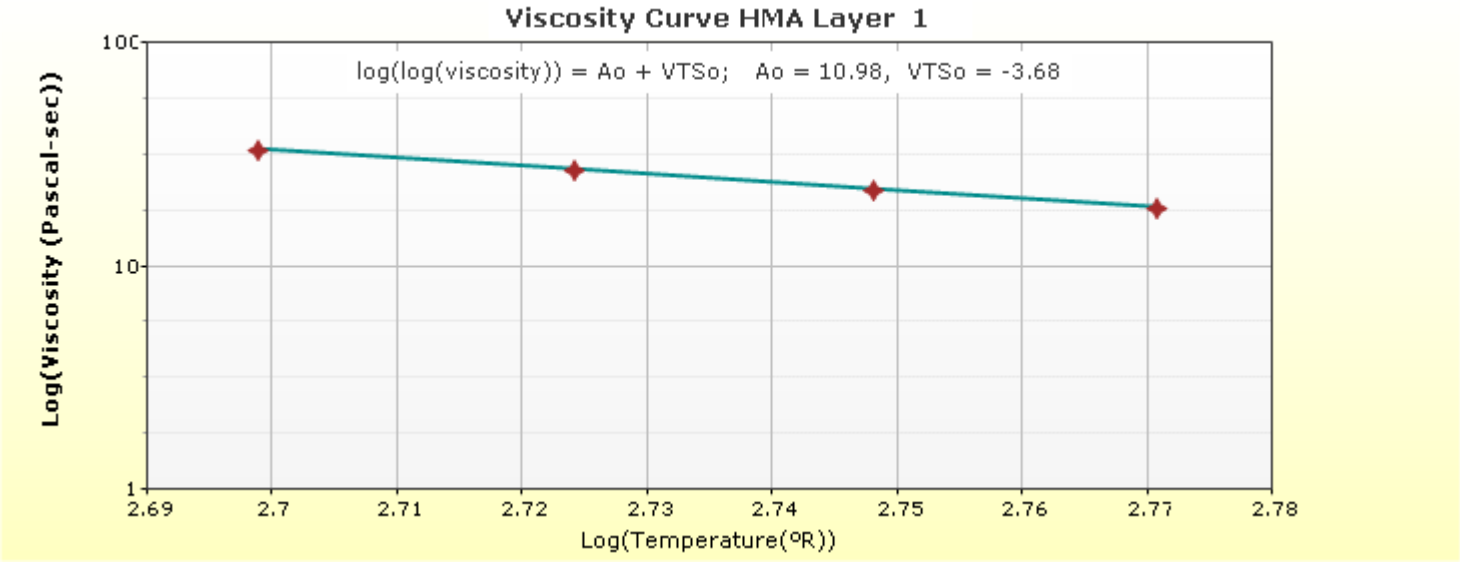
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



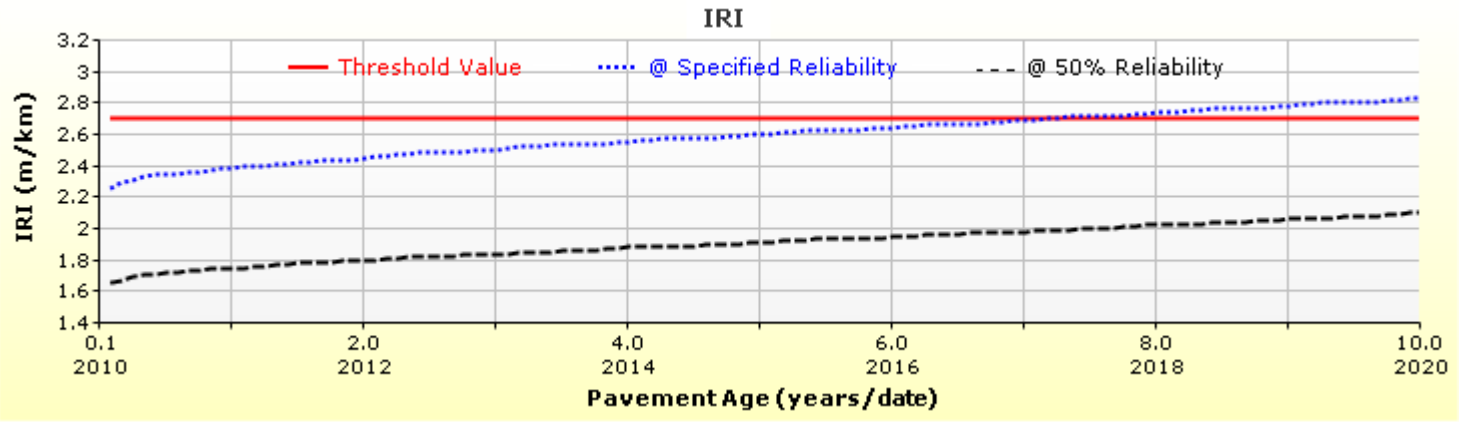
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

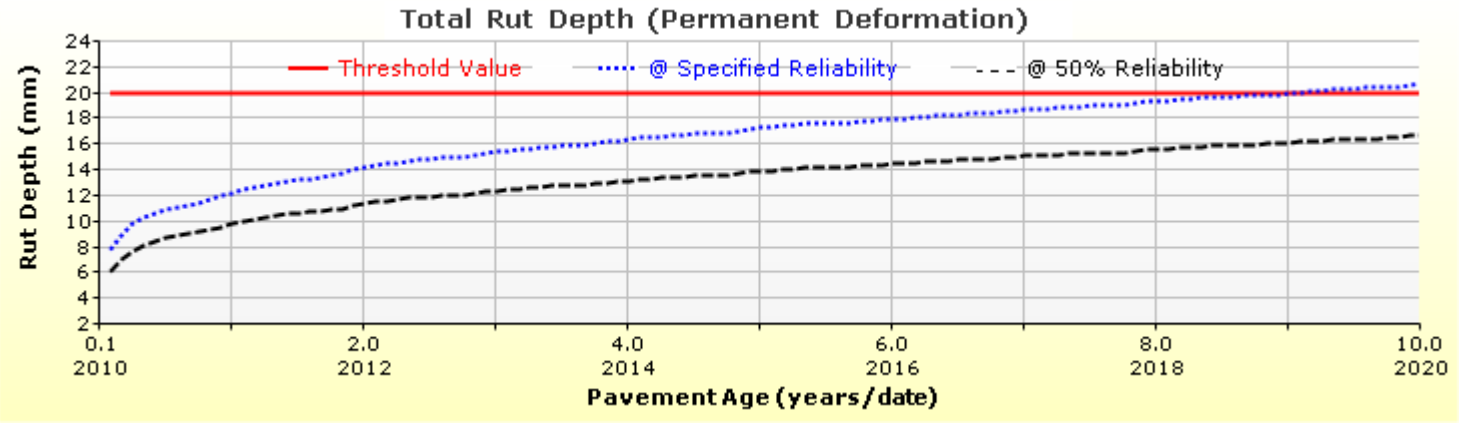


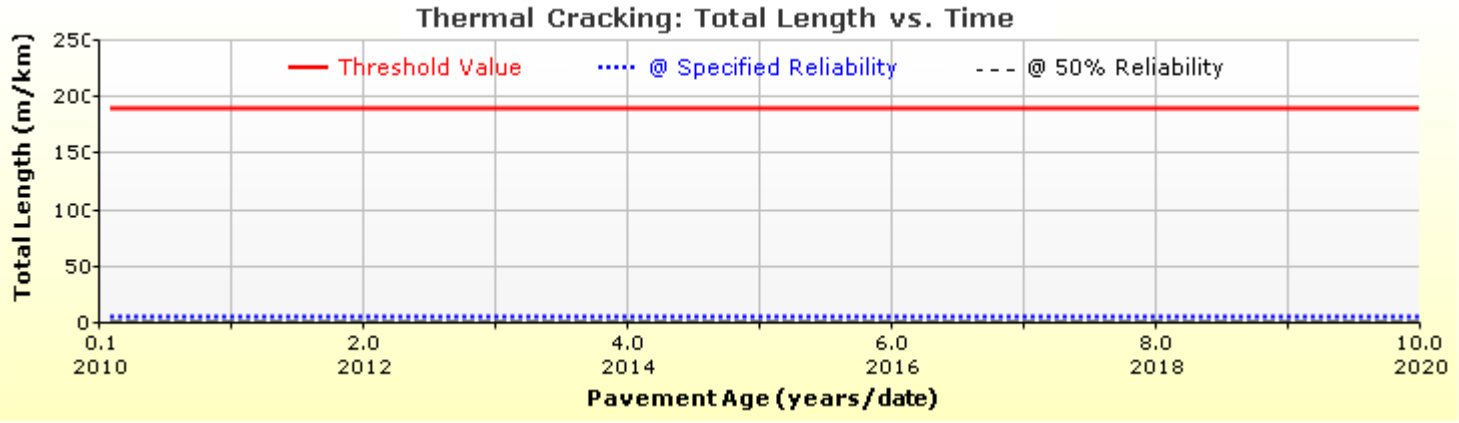


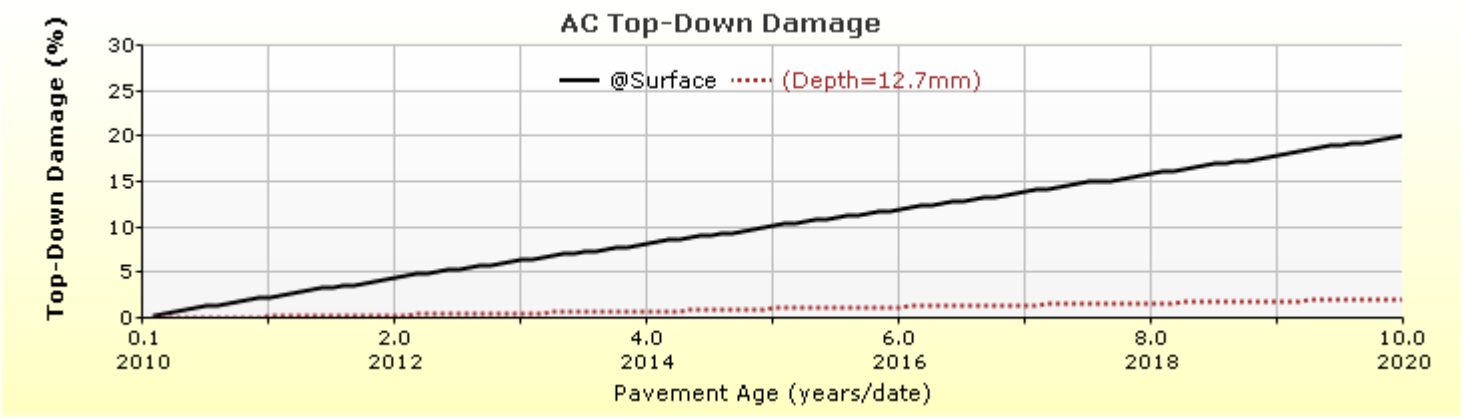


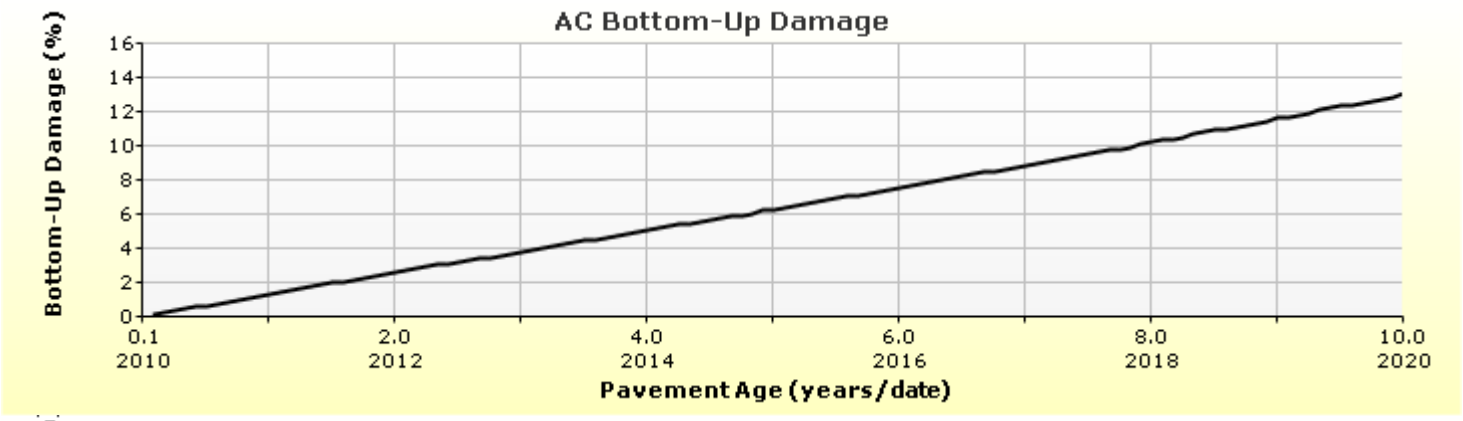
Analysis Output Charts

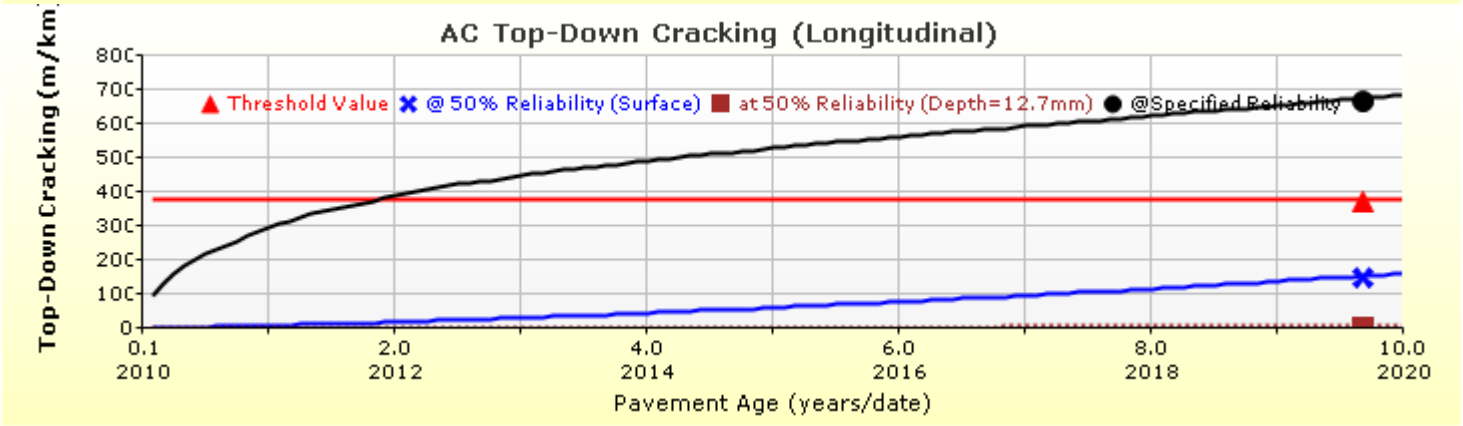


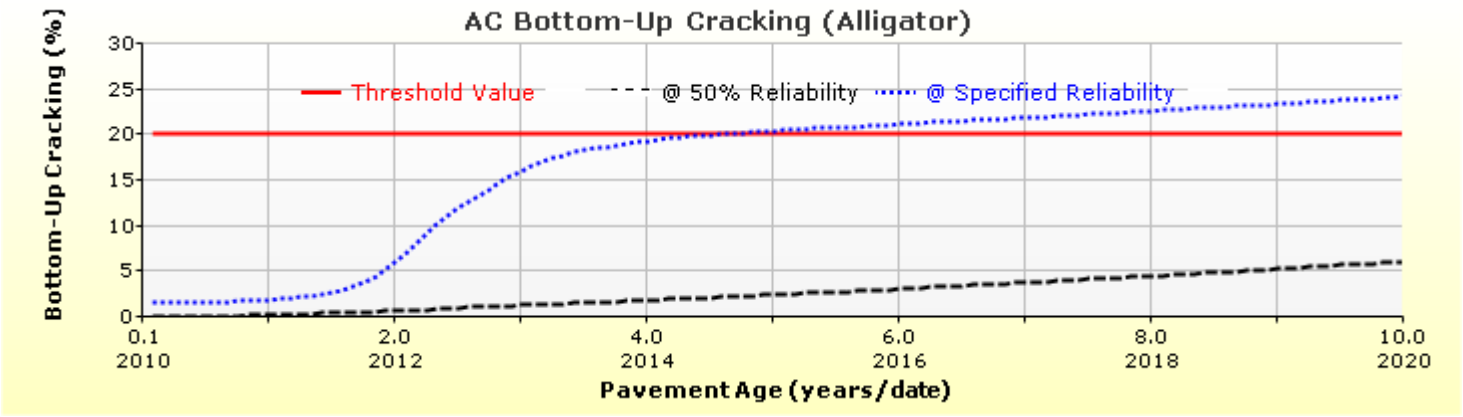


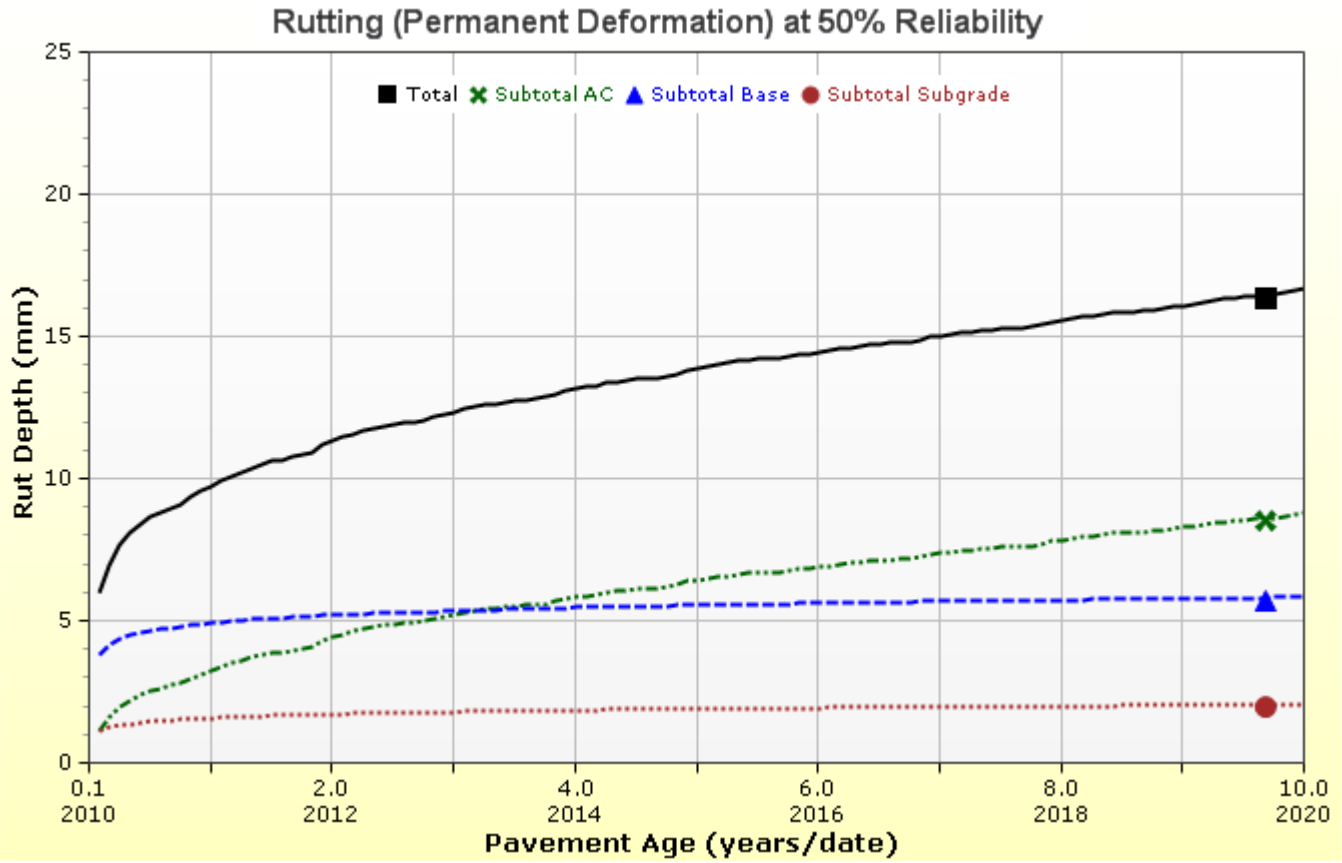


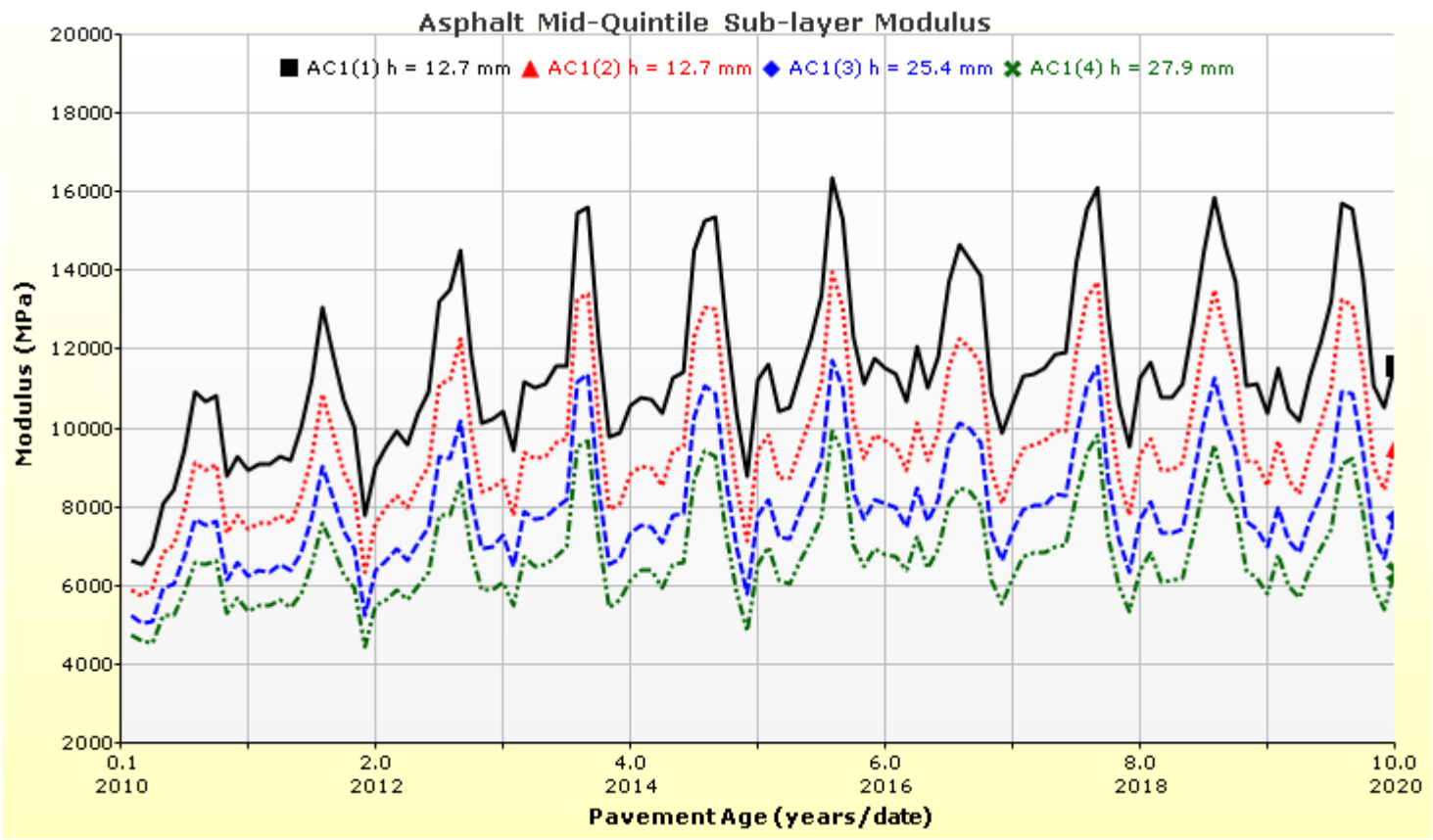

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

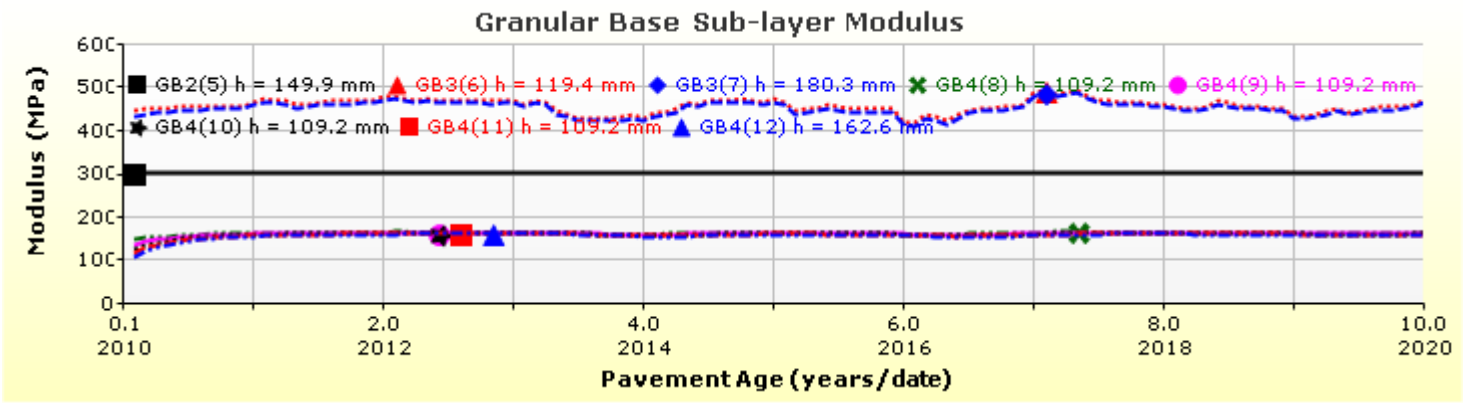

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

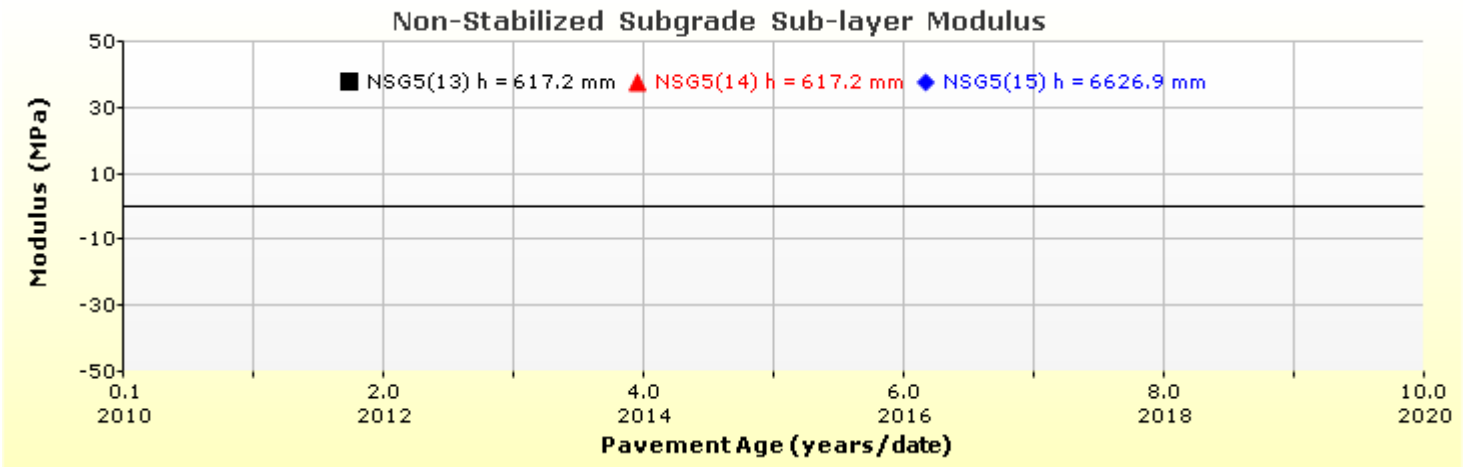

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2\beta_{r2}} N^{k_3 B_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

$$H_{ac} = total\ AC\ thickness(in)$$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestDF+4

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestDF+4.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -15.78, -47.91

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

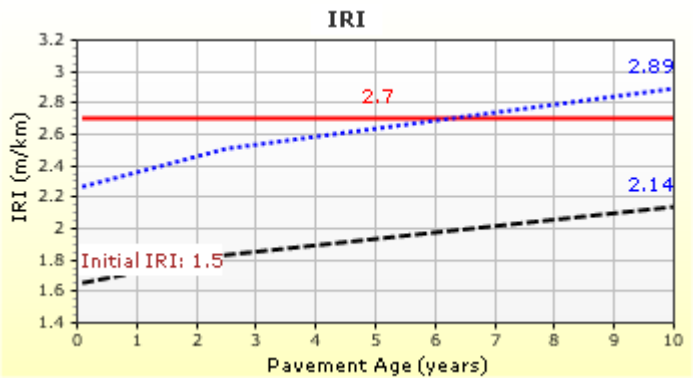
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

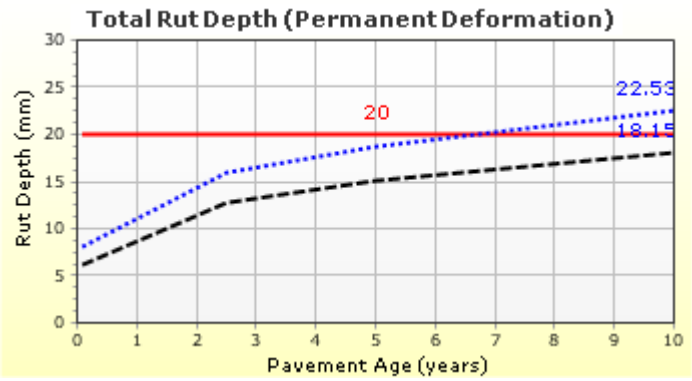
Design Outputs

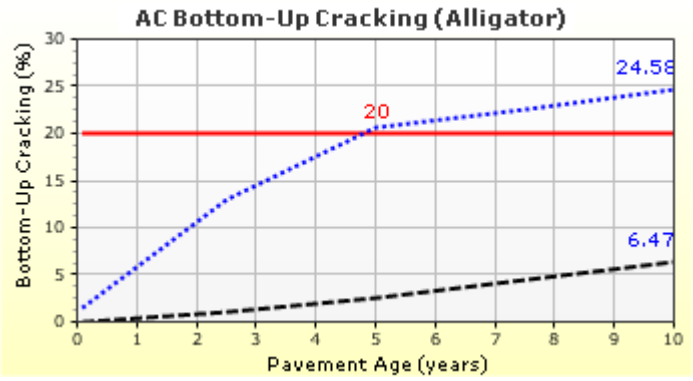
Distress Prediction Summary

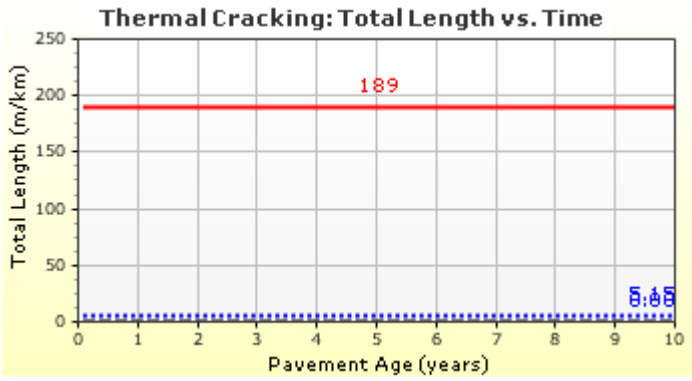
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.88	90.00	83.25	Fail
Permanent deformation - total pavement (mm)	20.00	22.54	90.00	70.44	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.58	90.00	83.09	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	723.43	90.00	67.35	Fail
Permanent deformation - AC only (mm)	5.00	10.27	50.00	3.82	Fail

Distress Charts







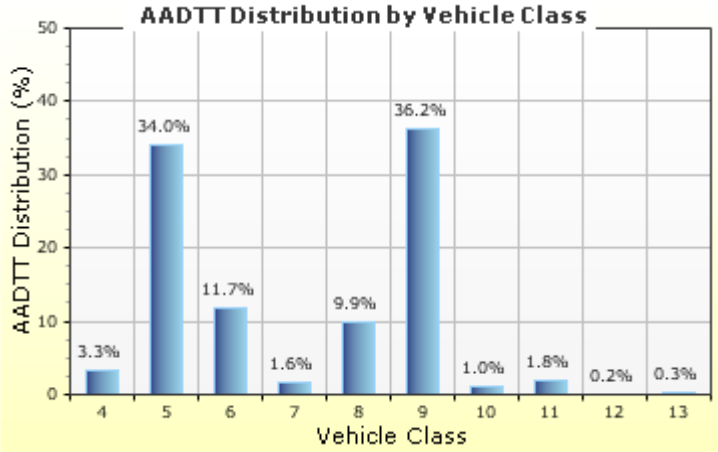


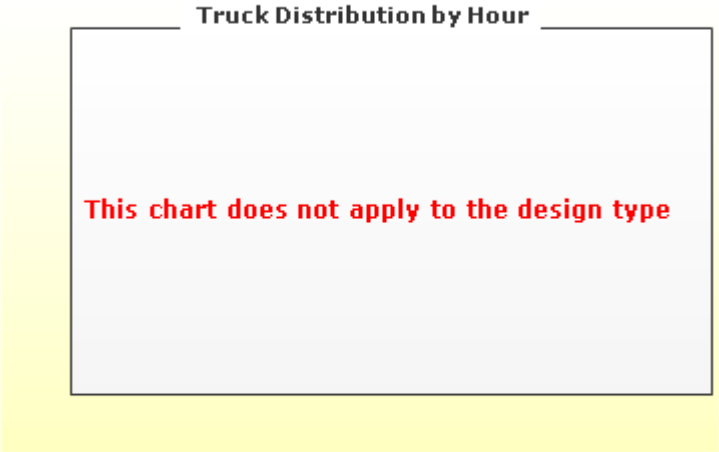


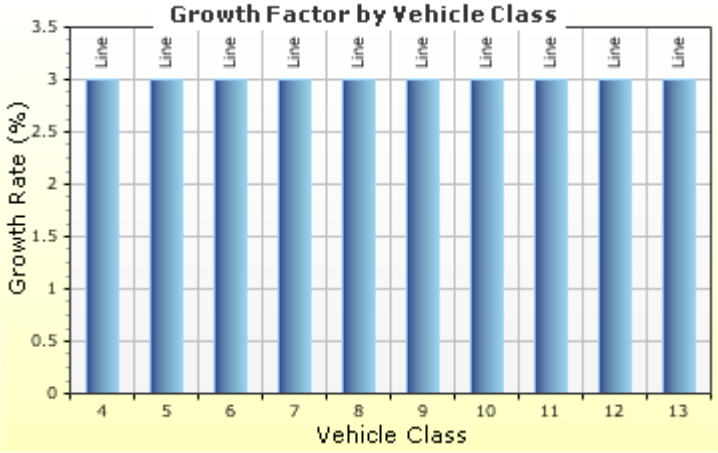
Traffic Inputs

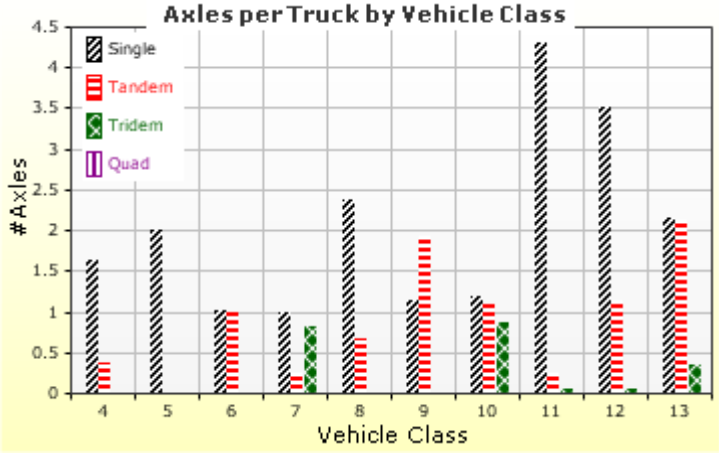
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

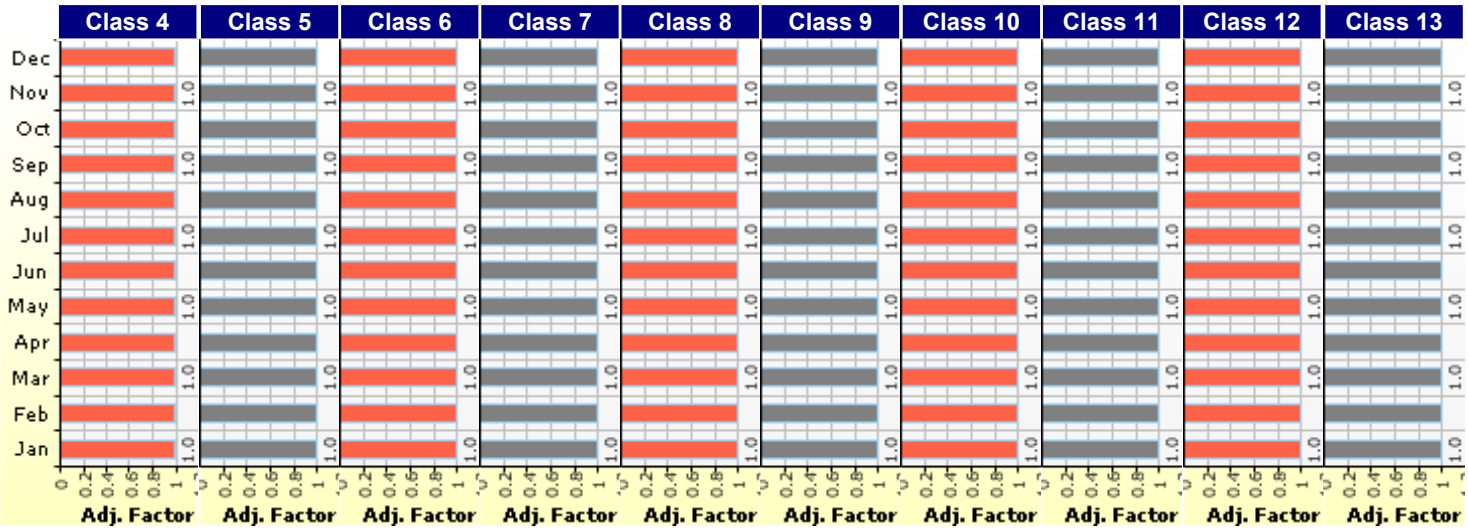








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

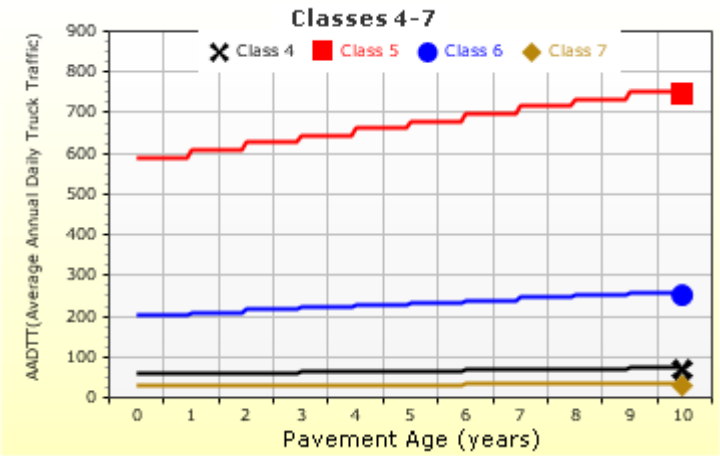
Wheelbase does not apply

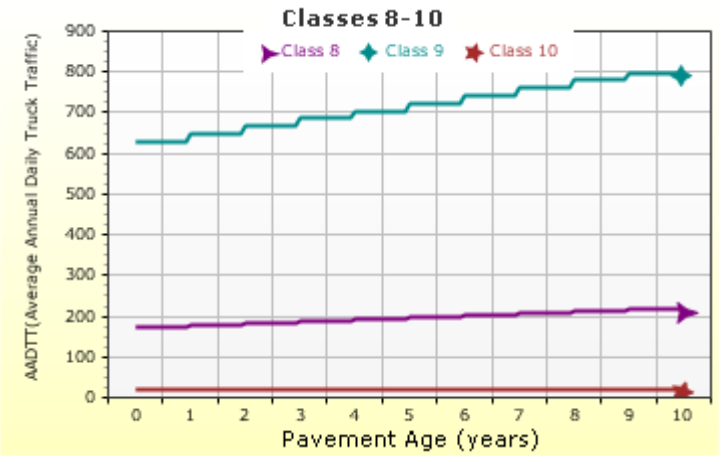
Number of Axles per Truck

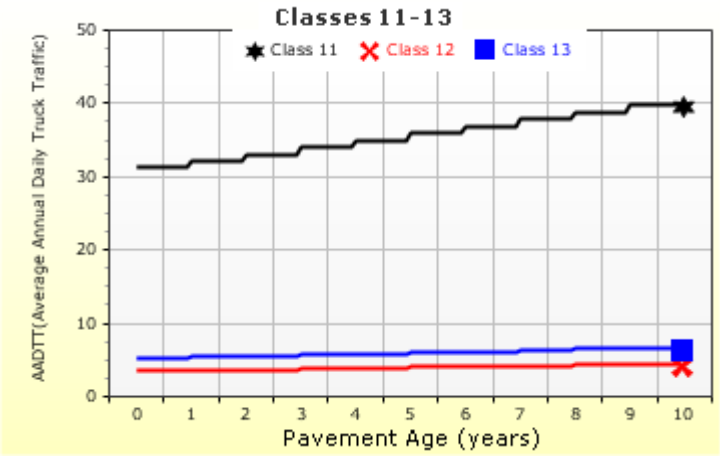
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

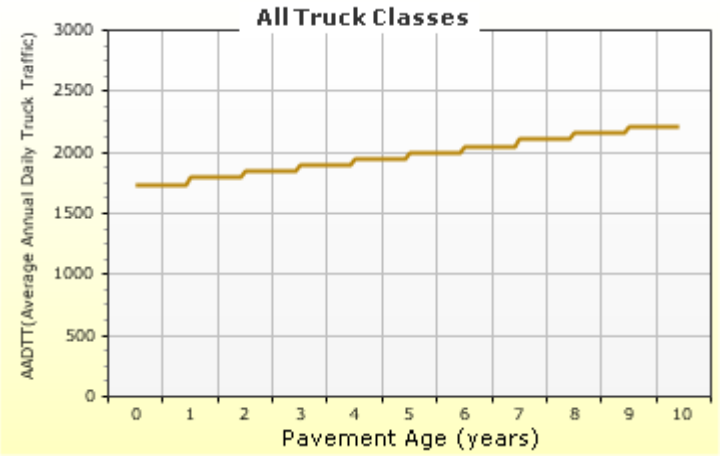
AADTT (Average Annual Daily Truck Traffic) Growth

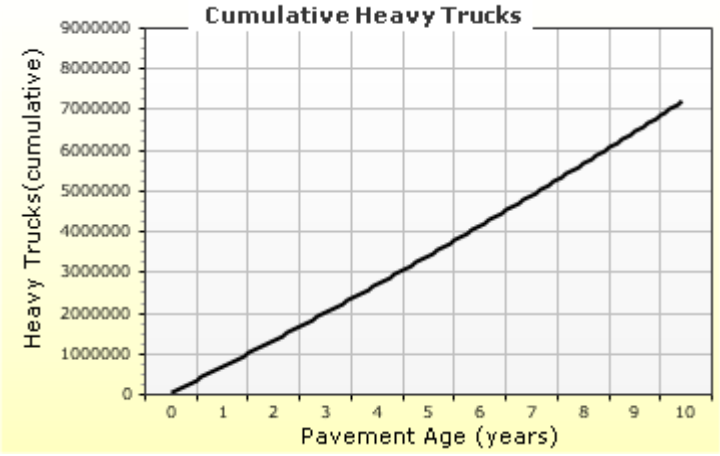
*** Traffic cap is not enforced**







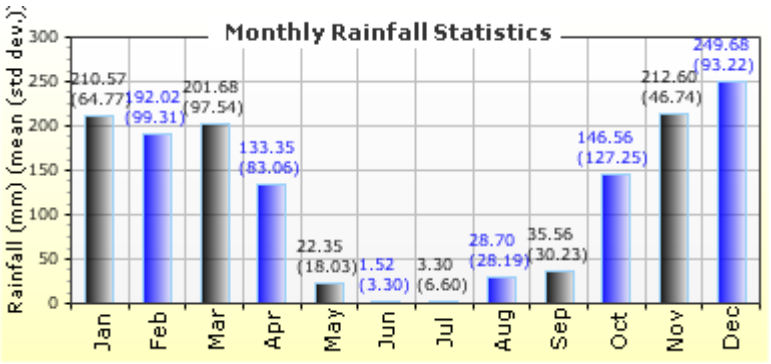




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
BRASILIA, DF	-15.78000 -47.91000 1159

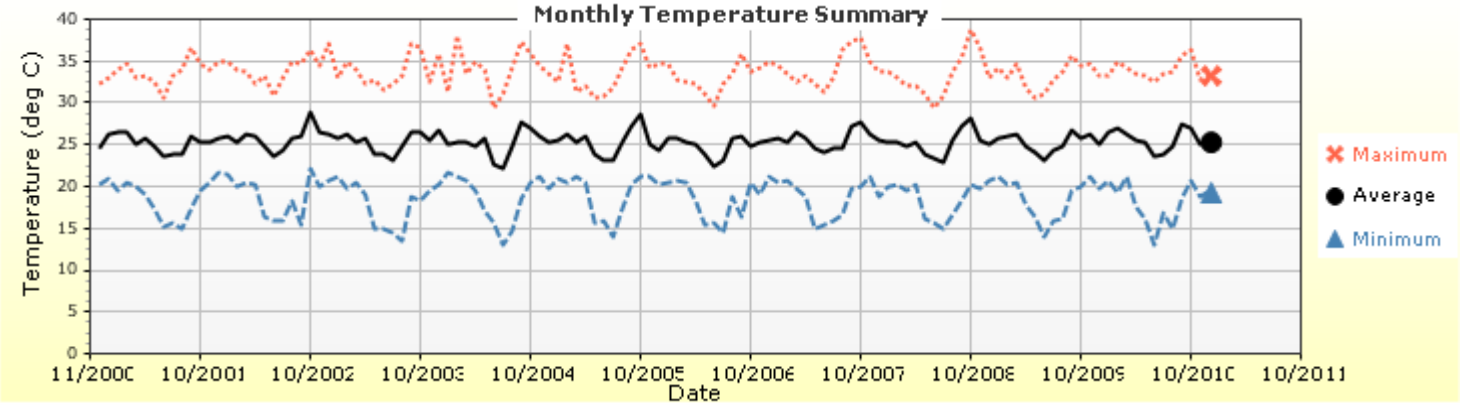


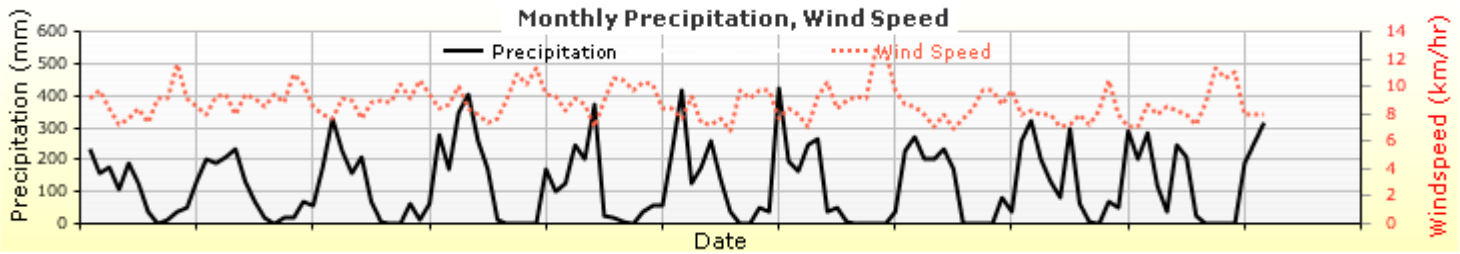
Annual Statistics:

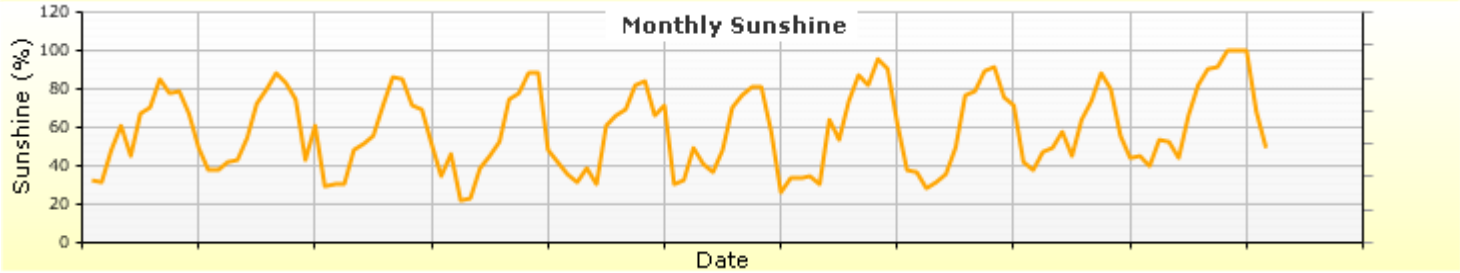
Mean annual air temperature (ºC)	25.35
Mean annual precipitation (mm)	1461.01
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

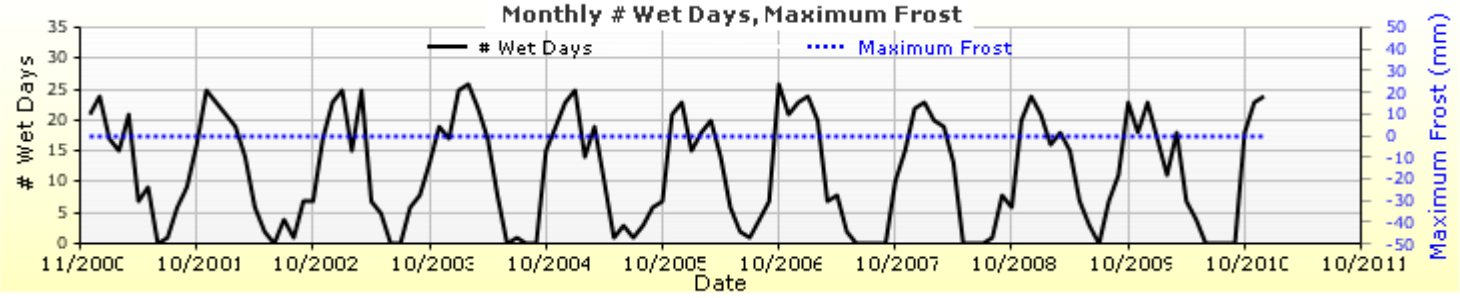
Water table depth (m): 3.05

Monthly Climate Summary:

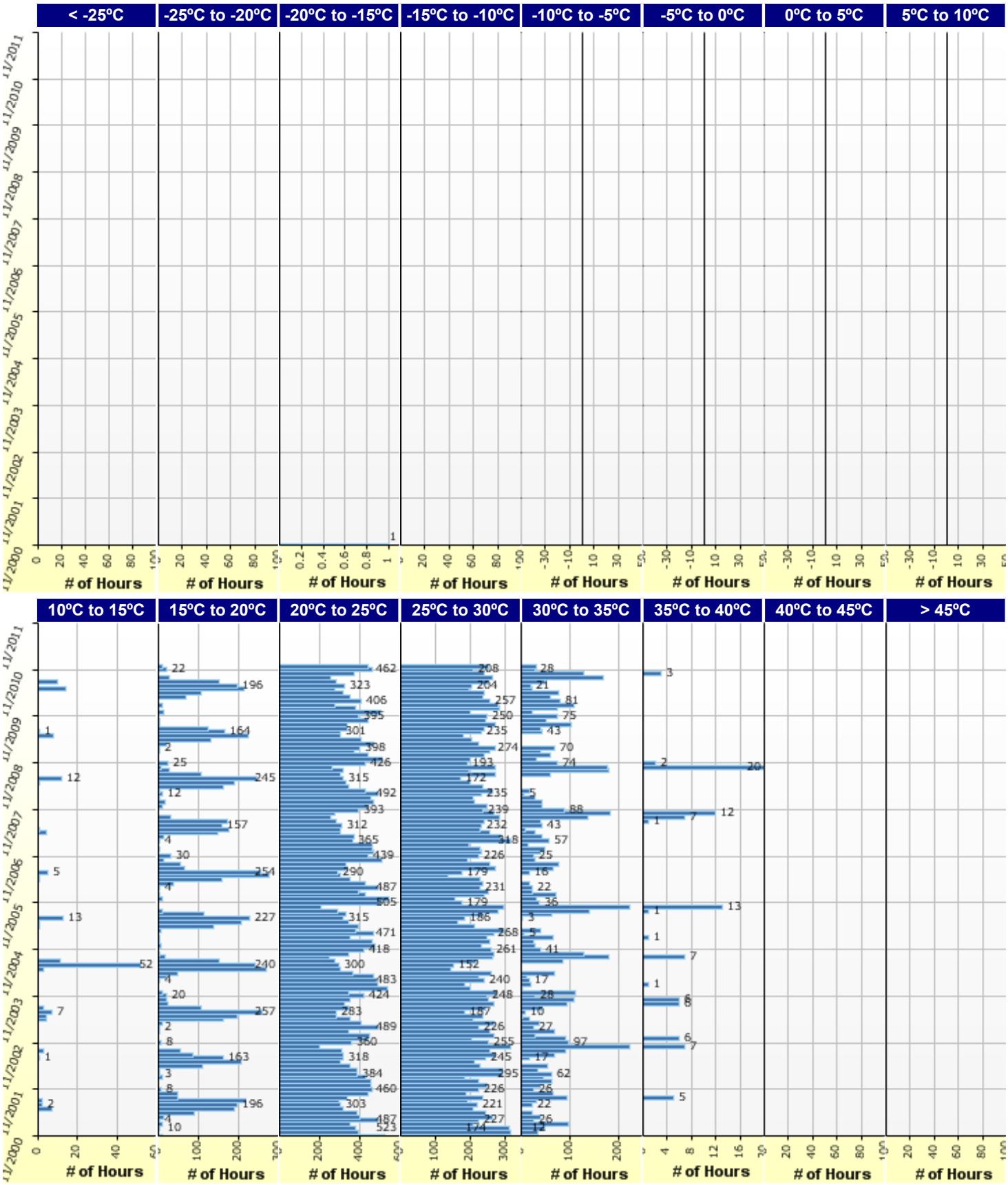








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

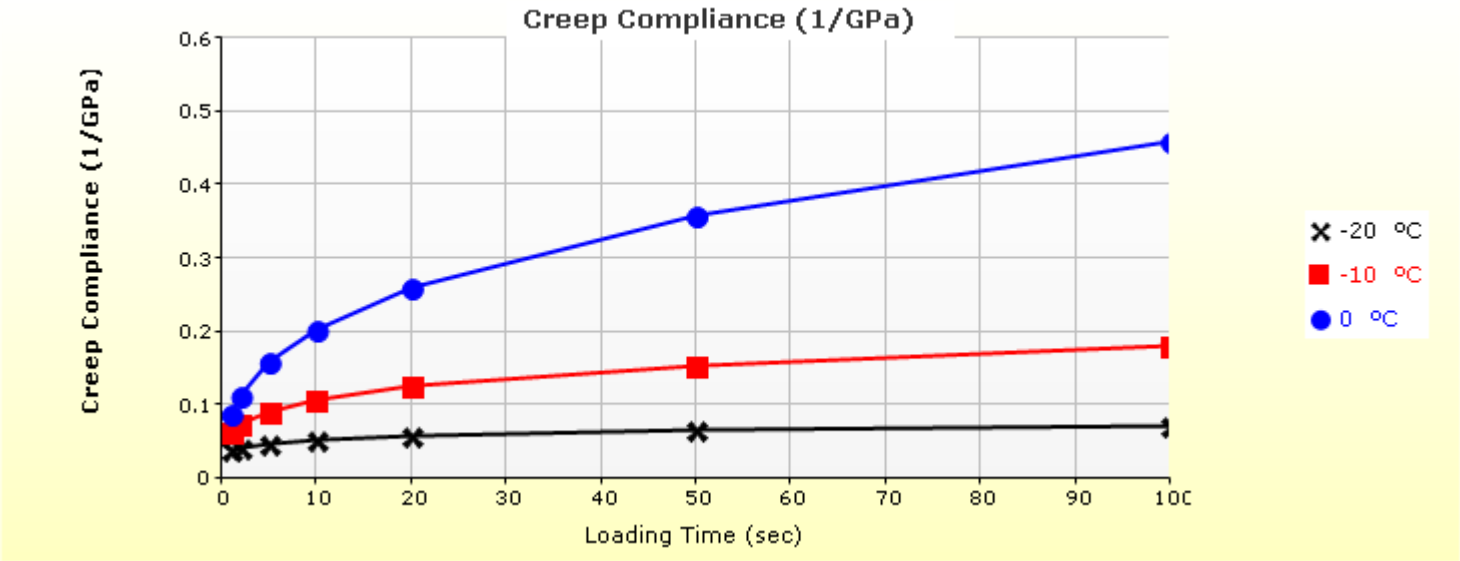
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

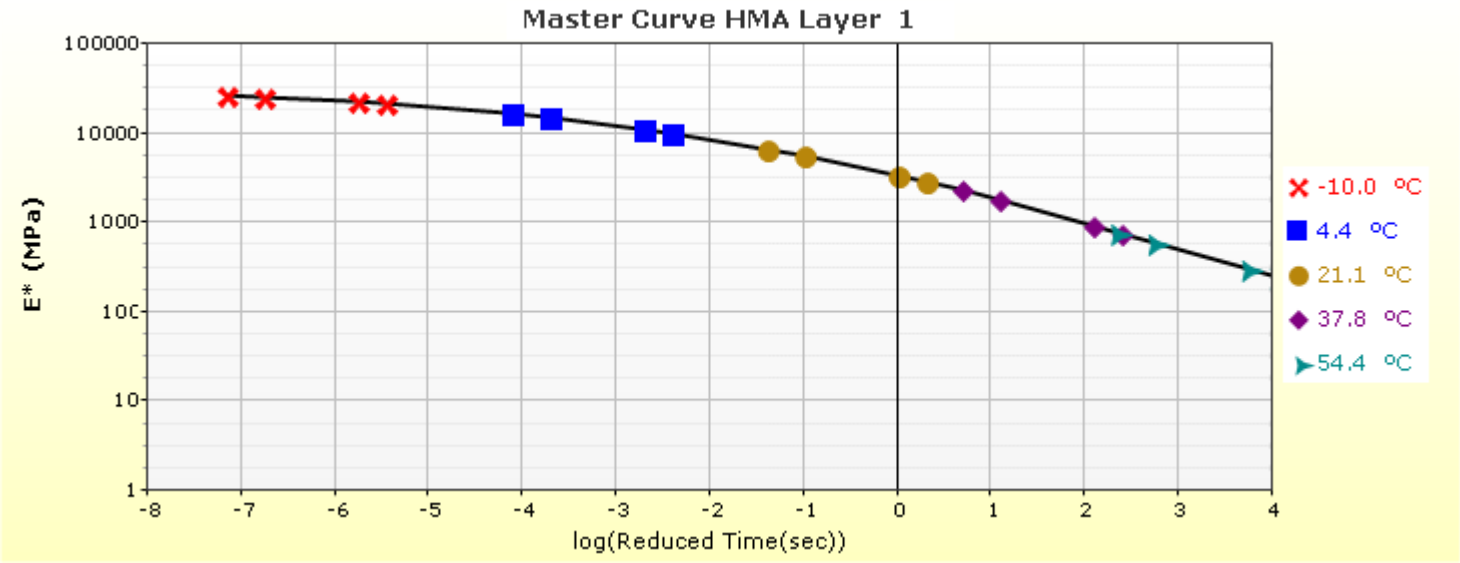
Indirect tensile strength at -10 ºC (MPa)	2.69

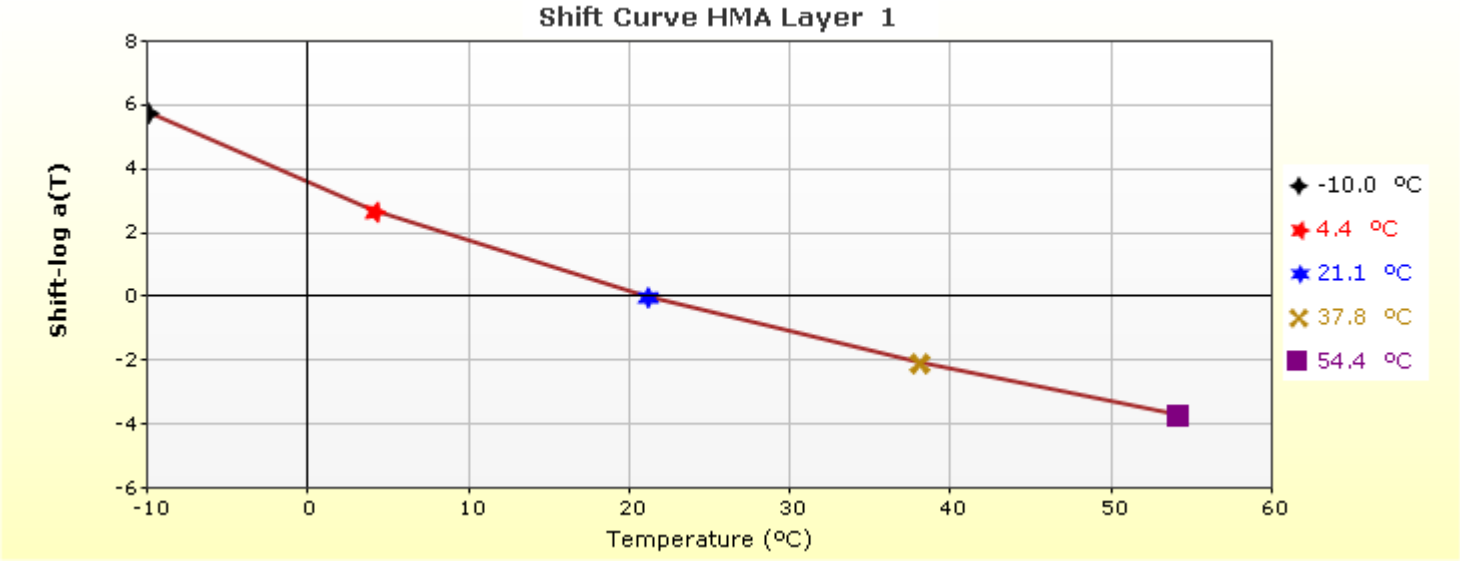
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

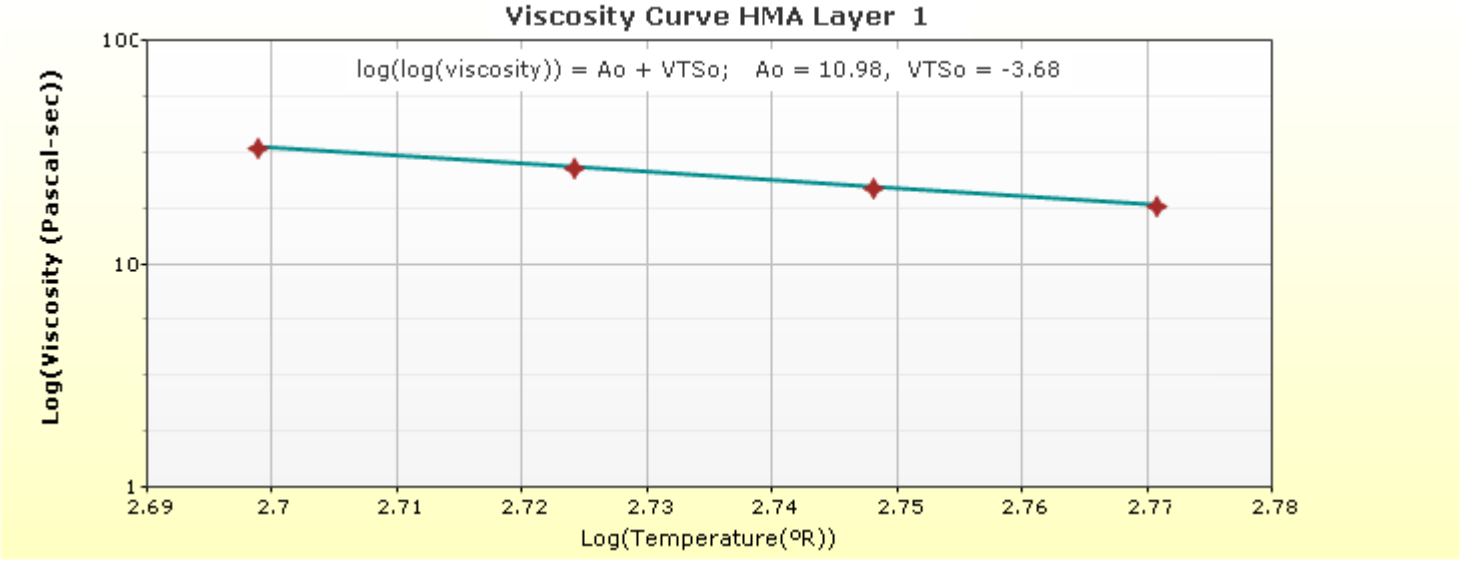
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



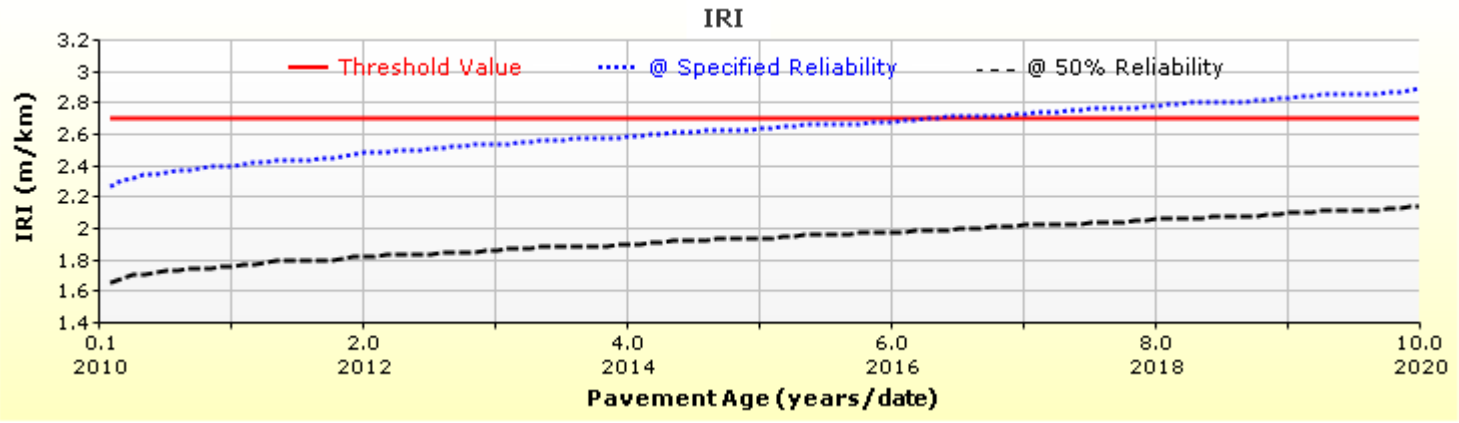
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

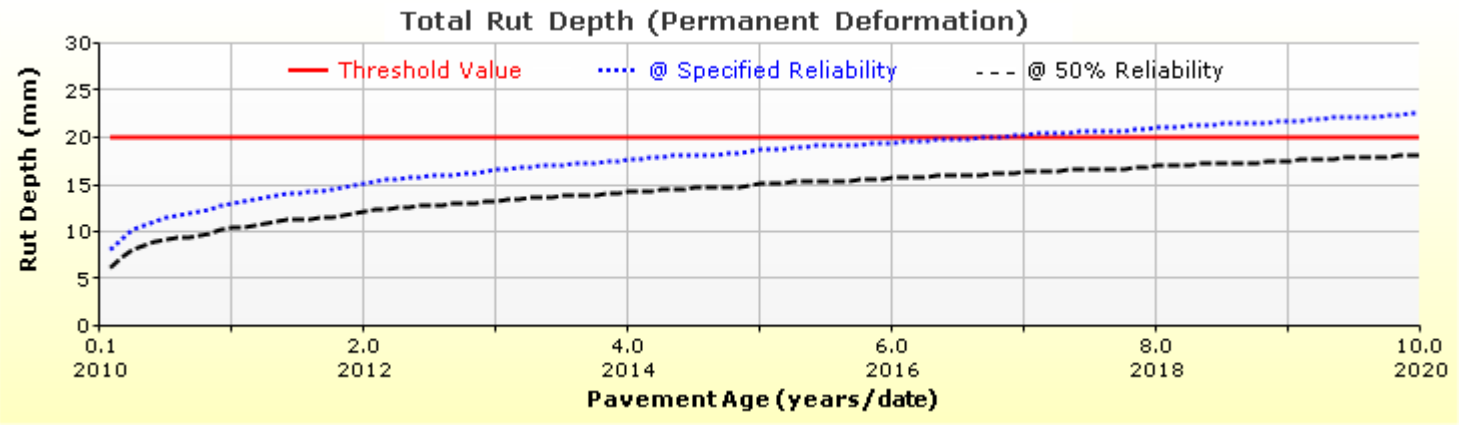


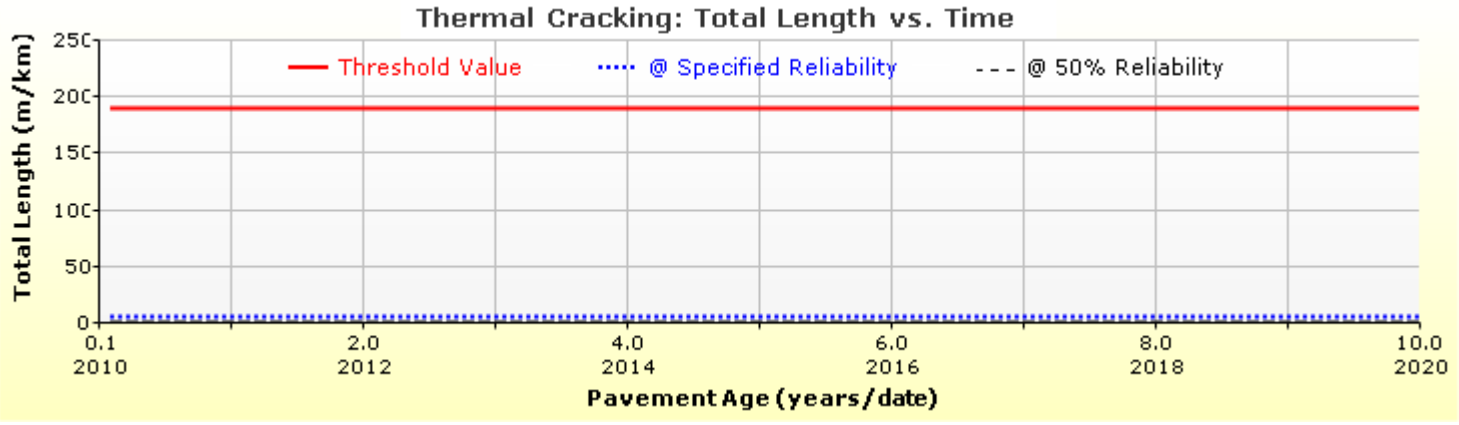


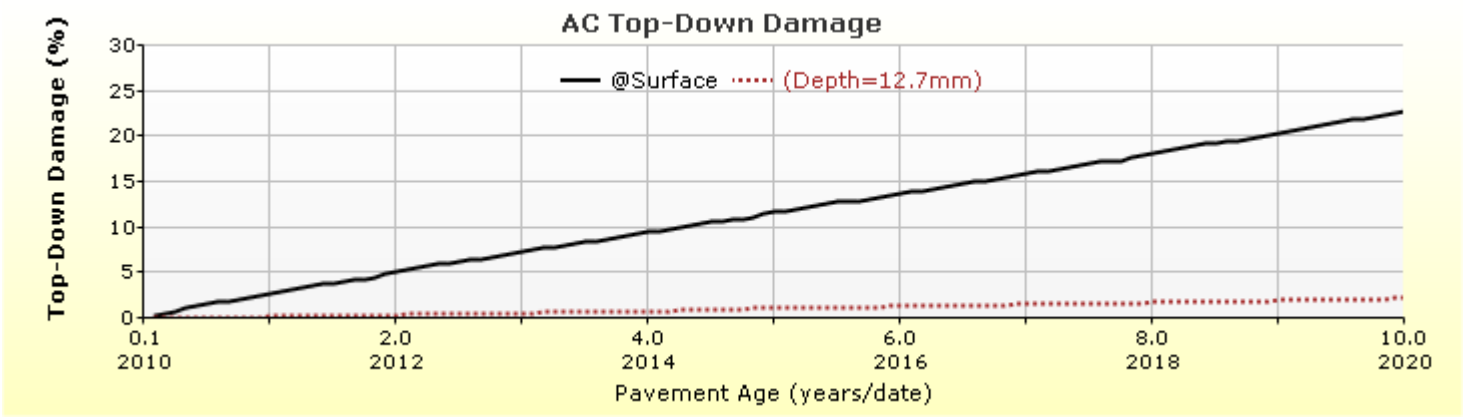


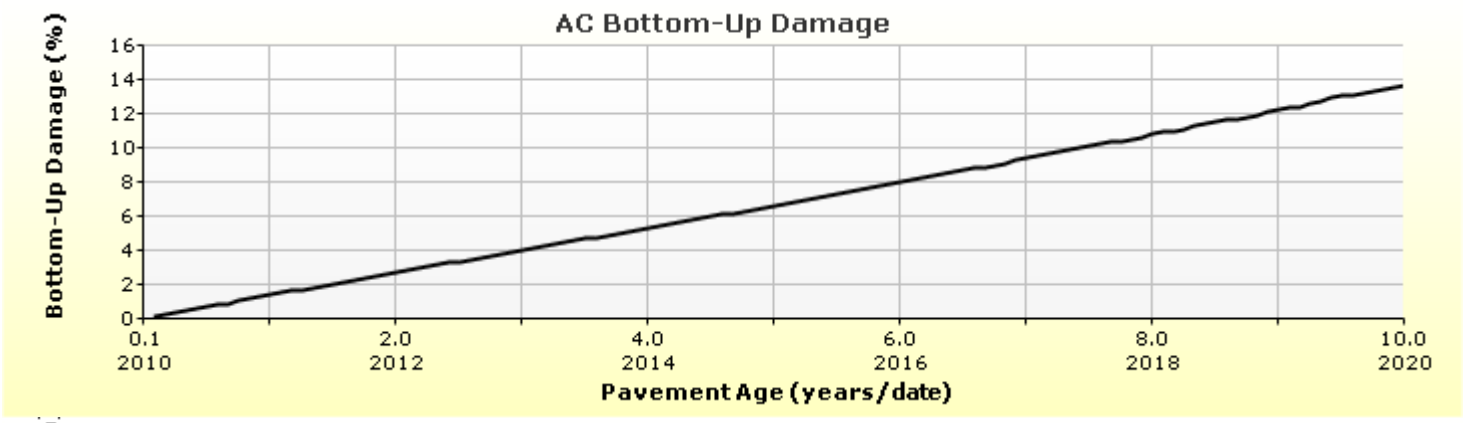
Analysis Output Charts

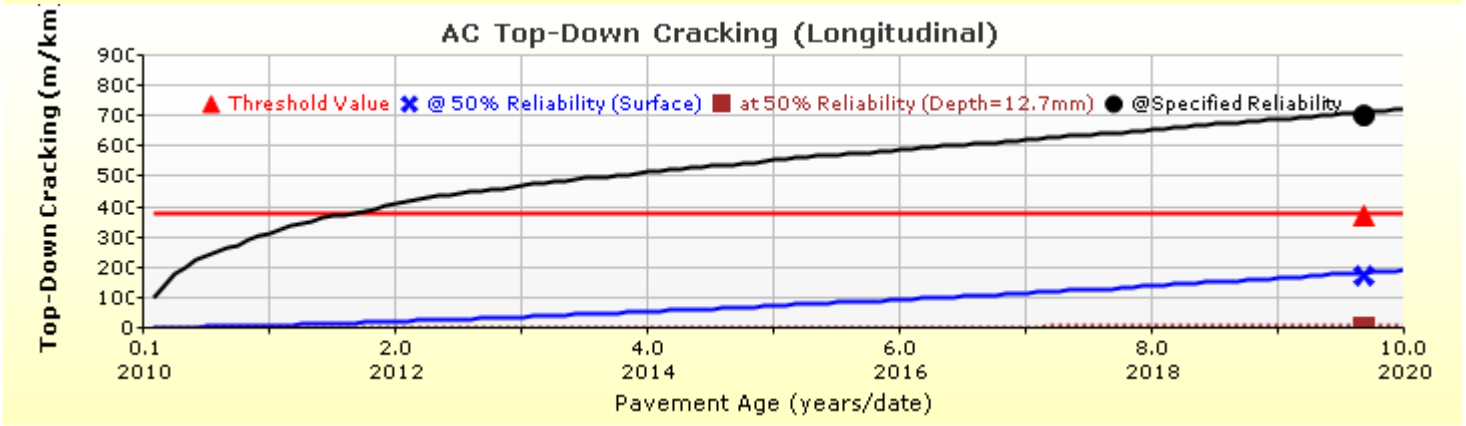


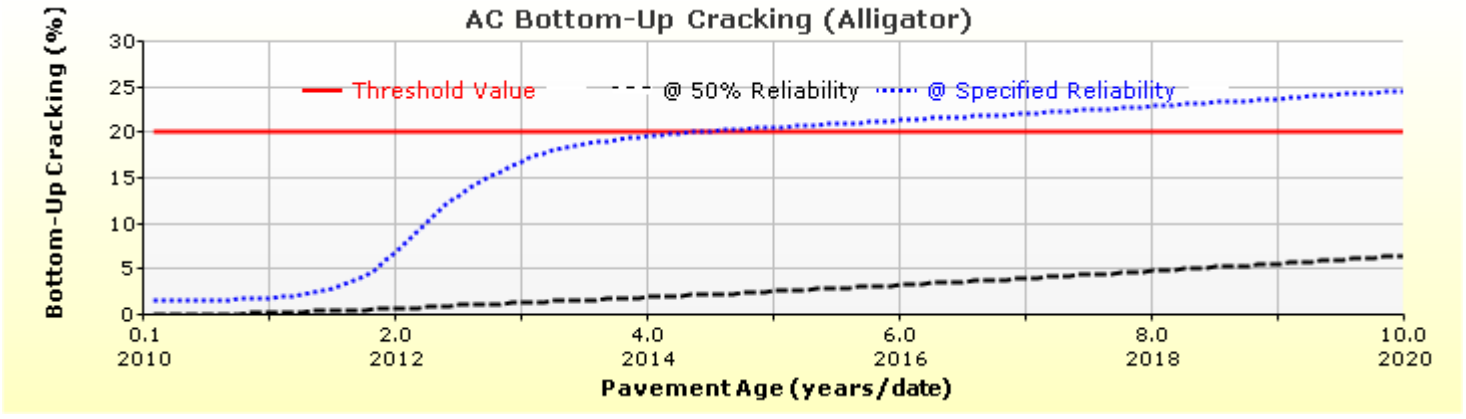


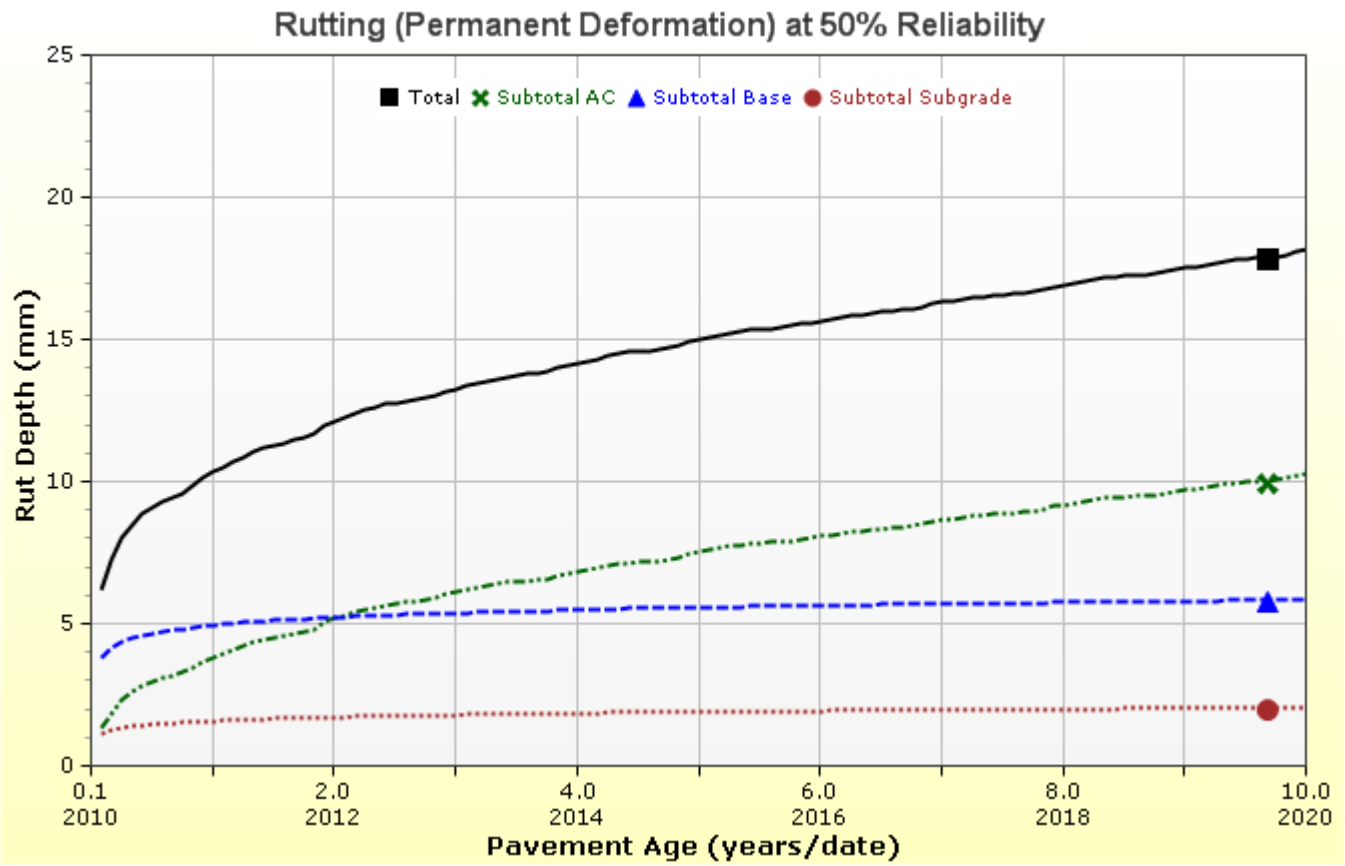


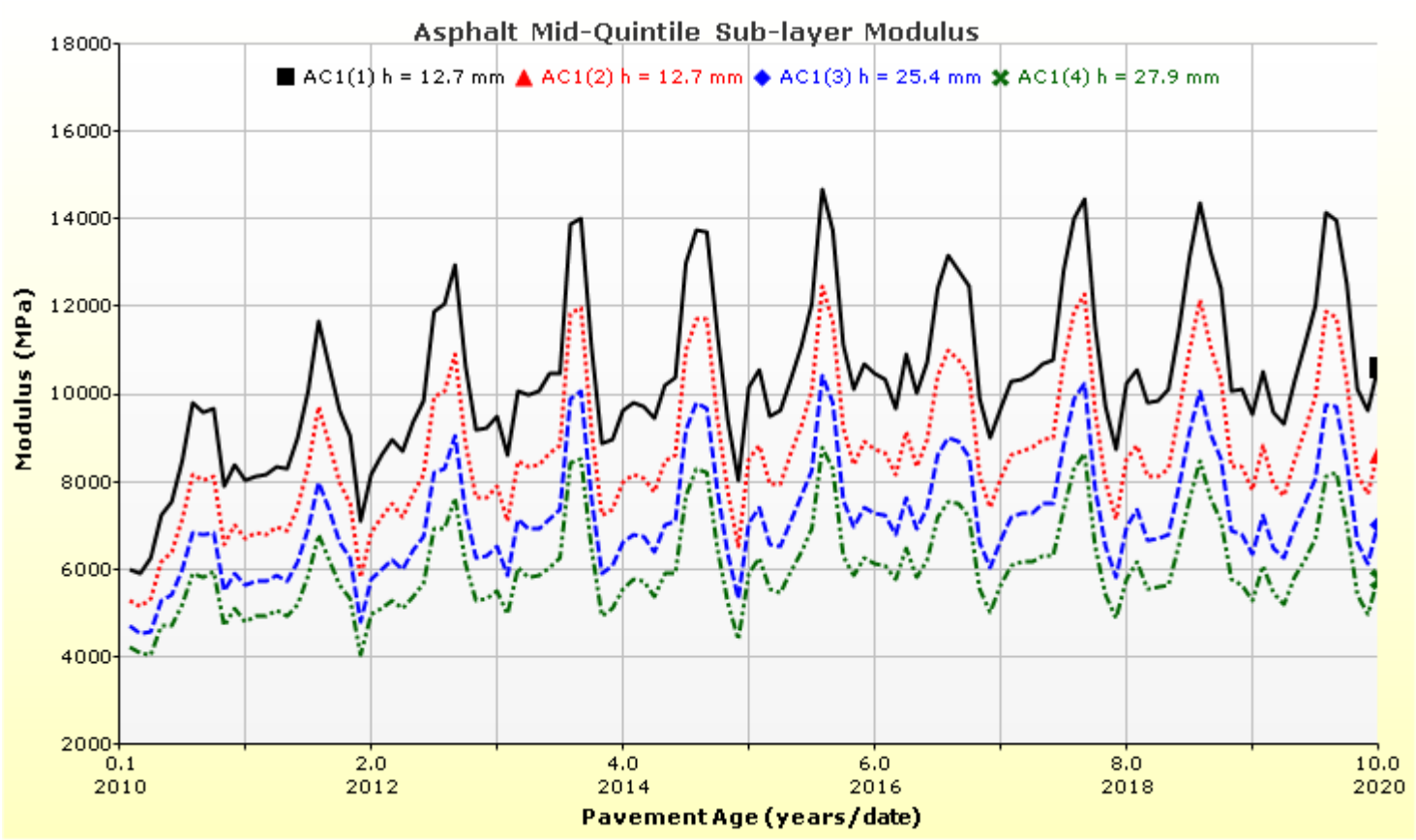

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

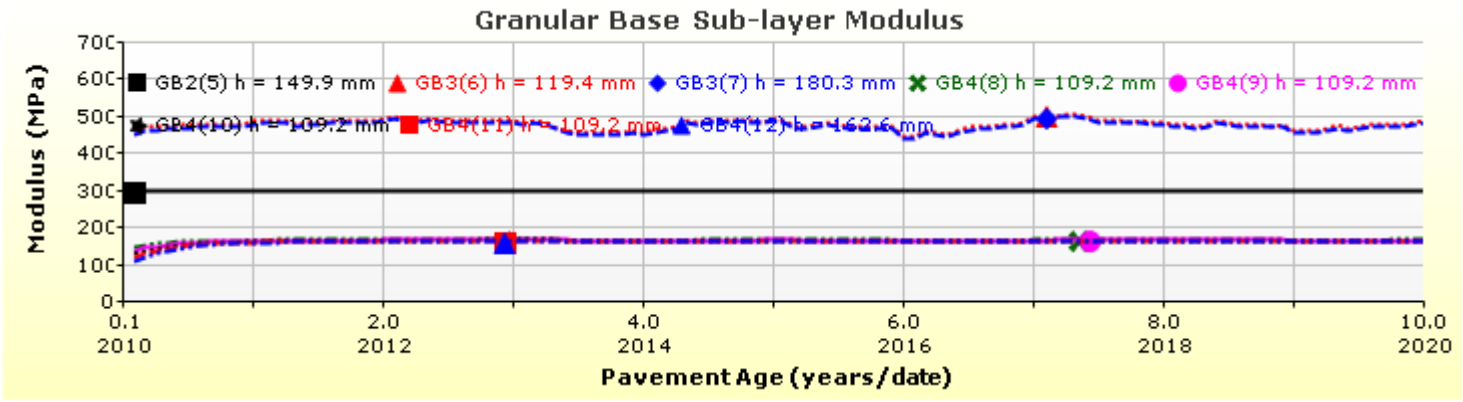

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

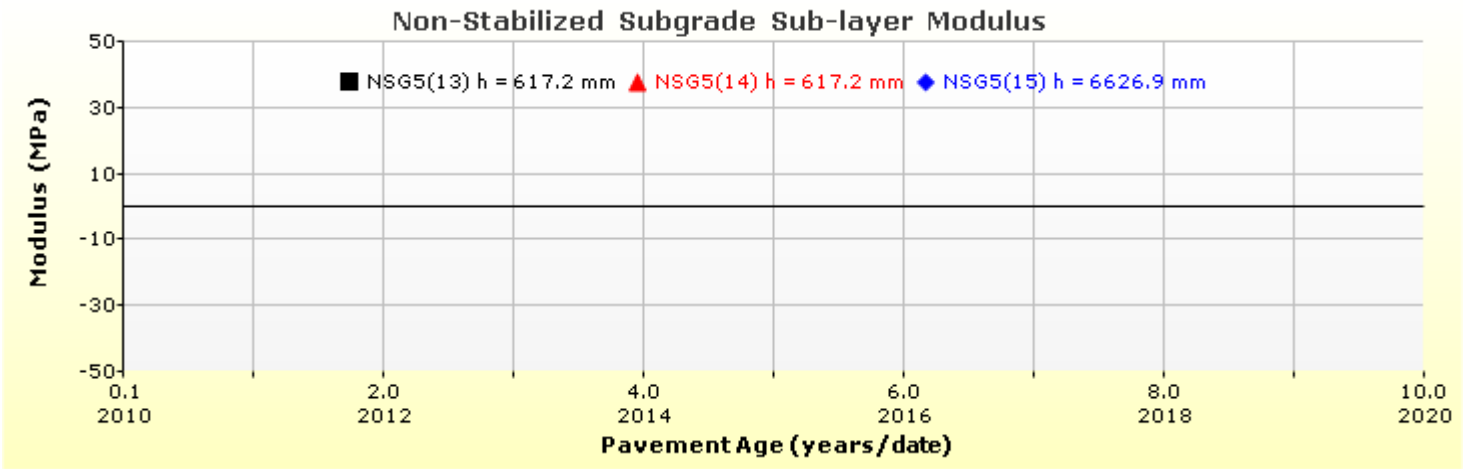

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
900
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestDF-2

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestDF-2.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -15.78, -47.91

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

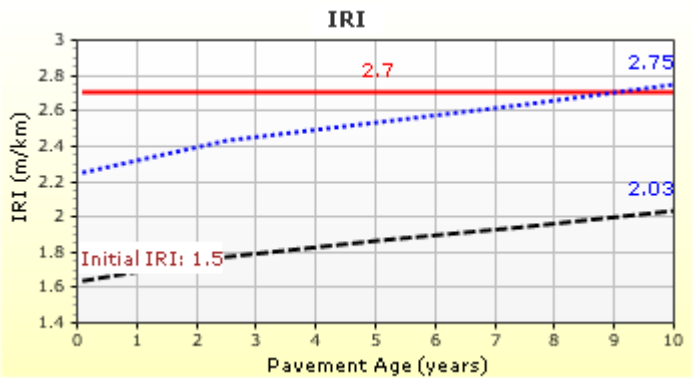
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

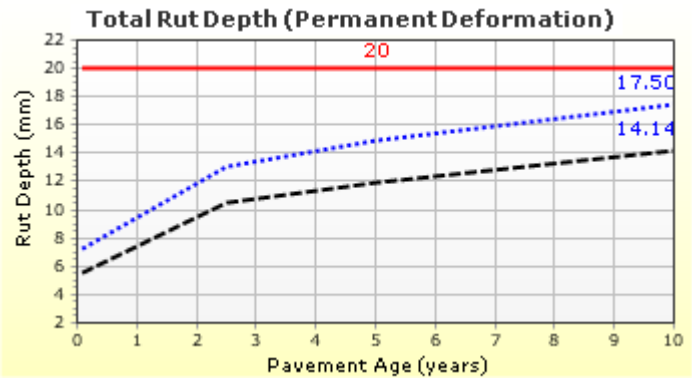
Design Outputs

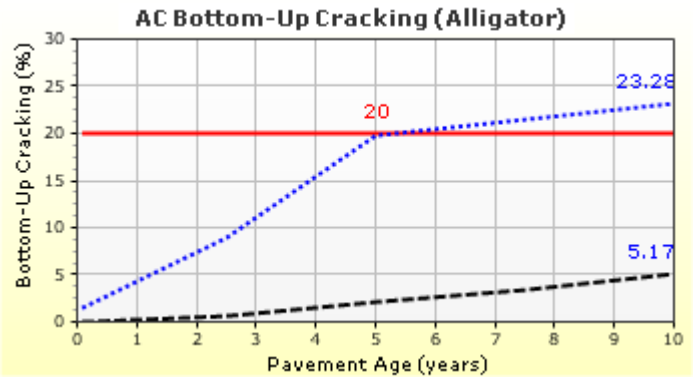
Distress Prediction Summary

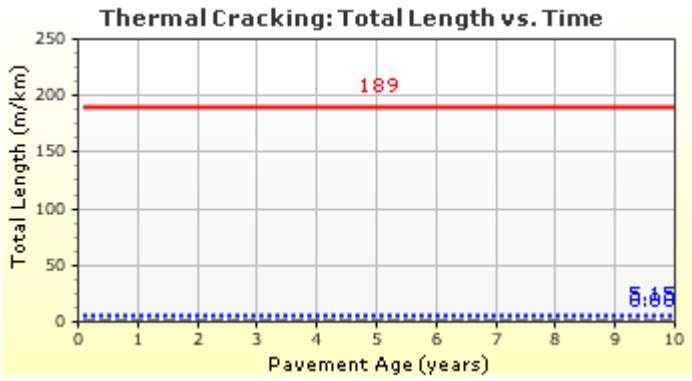
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.75	90.00	88.50	Fail
Permanent deformation - total pavement (mm)	20.00	17.50	90.00	98.71	Pass
AC bottom-up fatigue cracking (percent)	20.00	23.28	90.00	85.31	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	622.16	90.00	74.69	Fail
Permanent deformation - AC only (mm)	5.00	6.29	50.00	26.20	Fail

Distress Charts







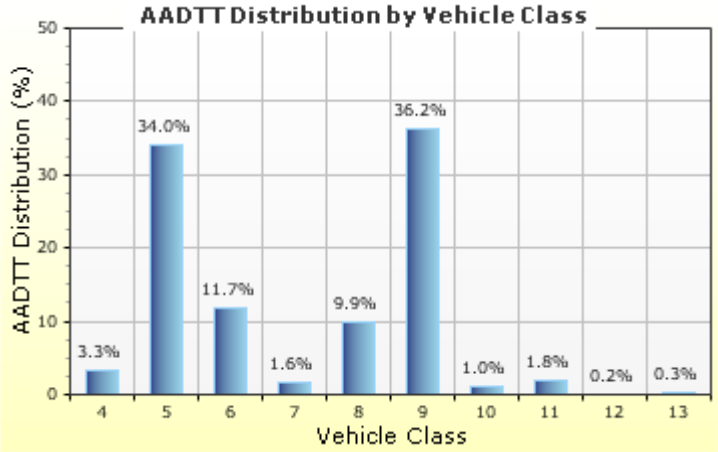


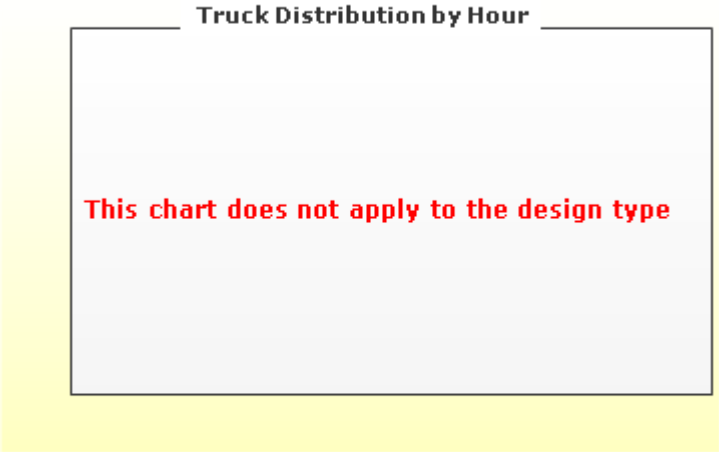
Threshold Value @ Specified Reliability @ 50% Reliability

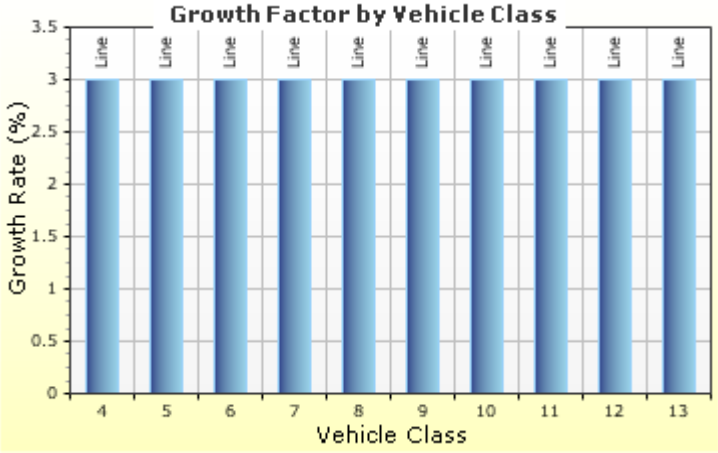
Traffic Inputs

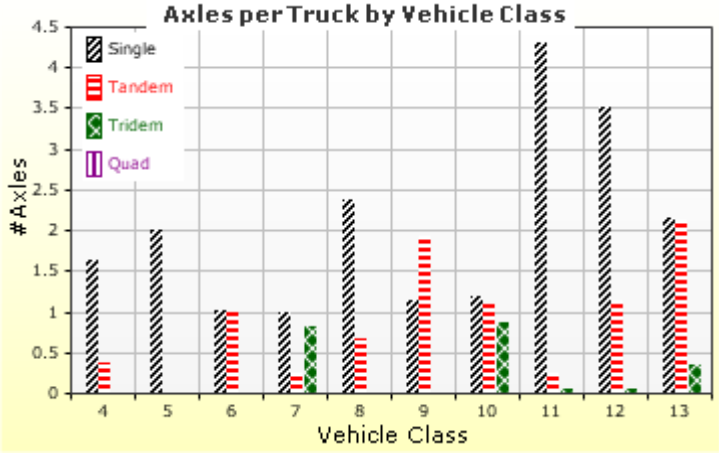
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

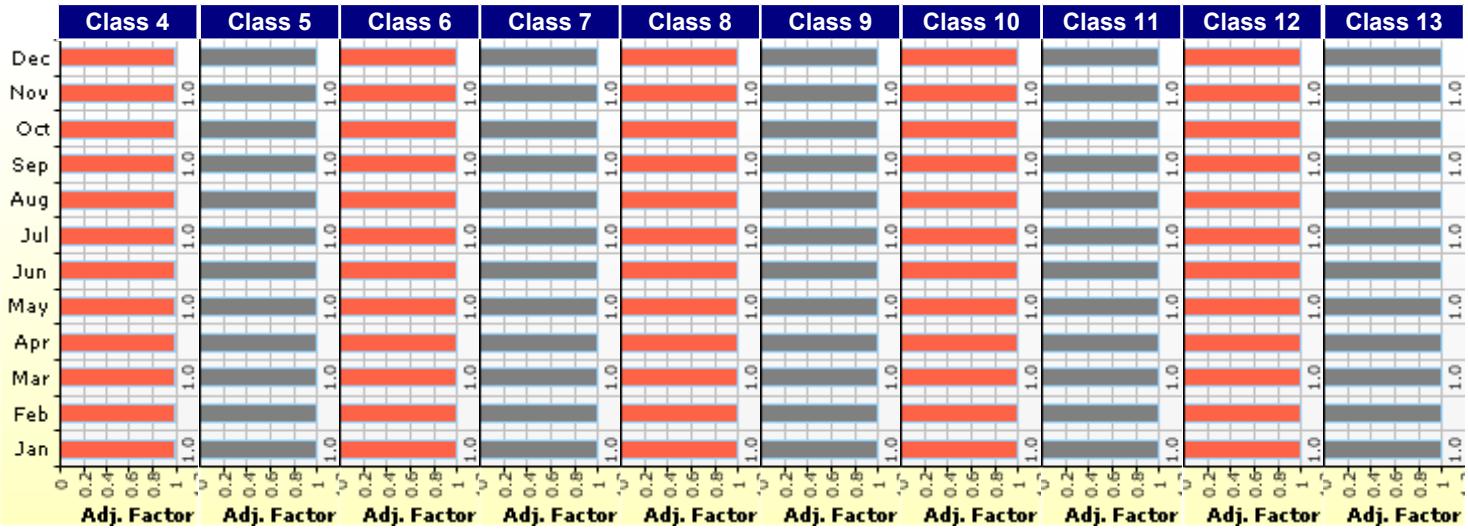








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

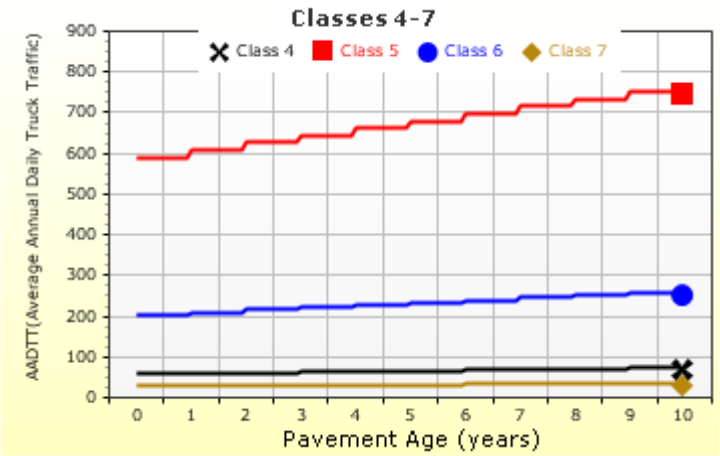
Wheelbase does not apply

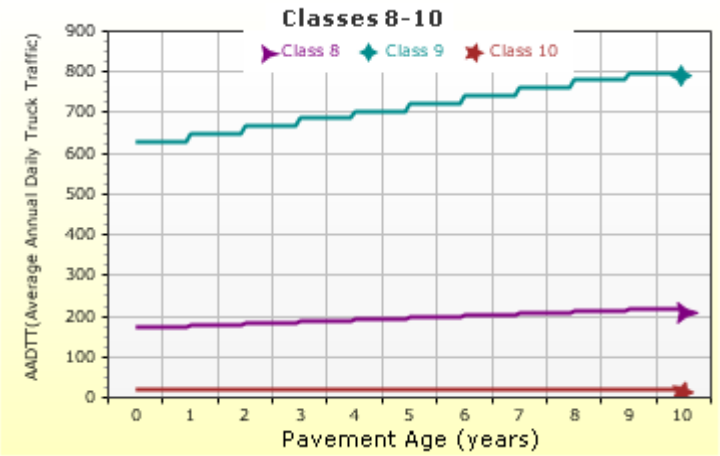
Number of Axles per Truck

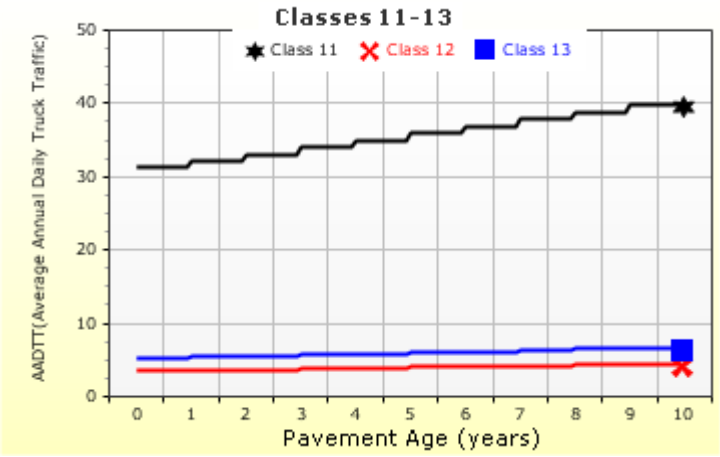
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

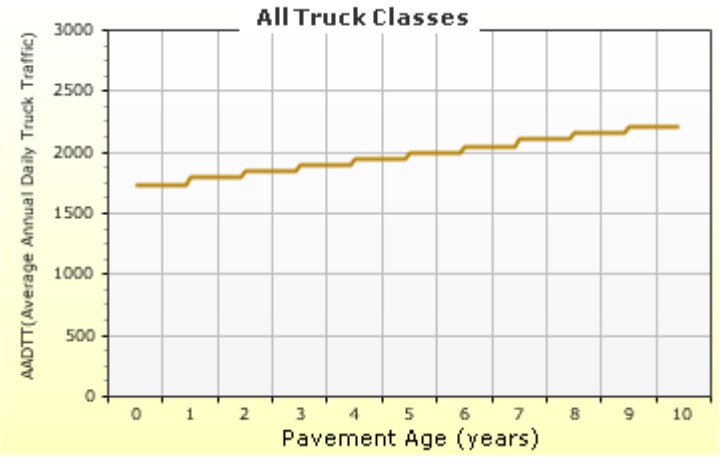
AADTT (Average Annual Daily Truck Traffic) Growth

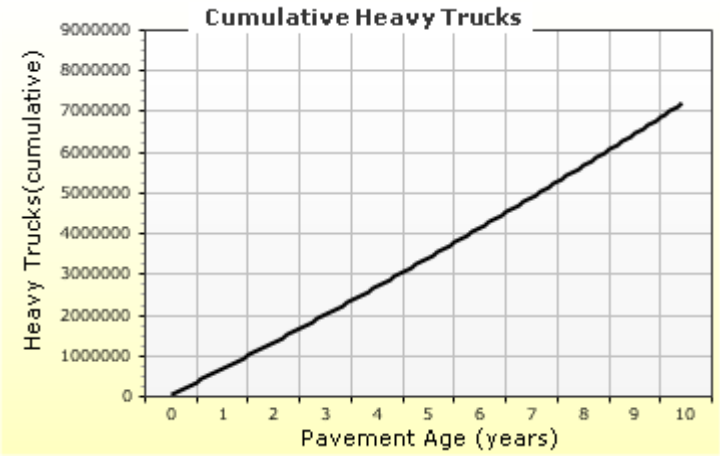
*** Traffic cap is not enforced**







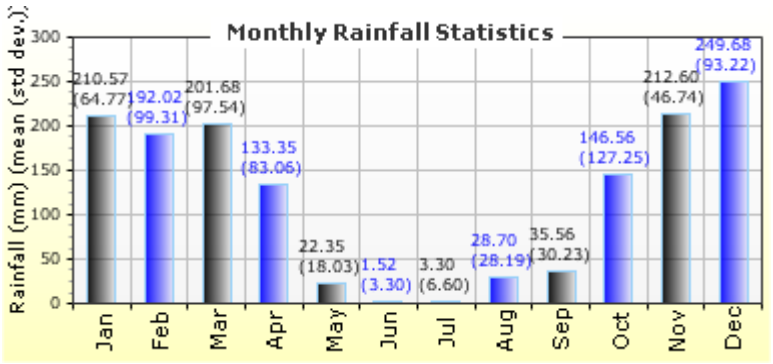




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
BRASILIA, DF	-15.78000 -47.91000 1159

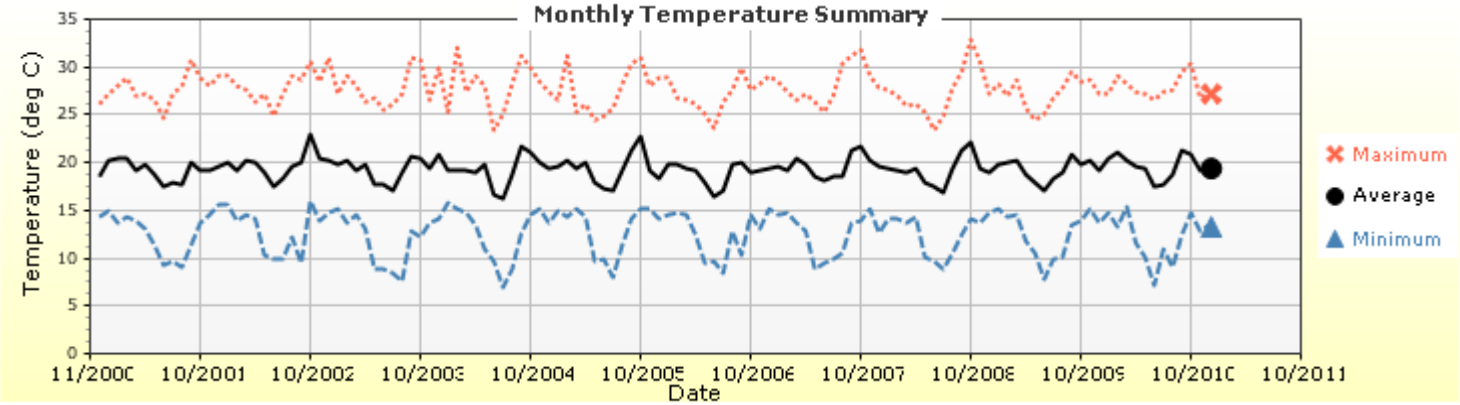


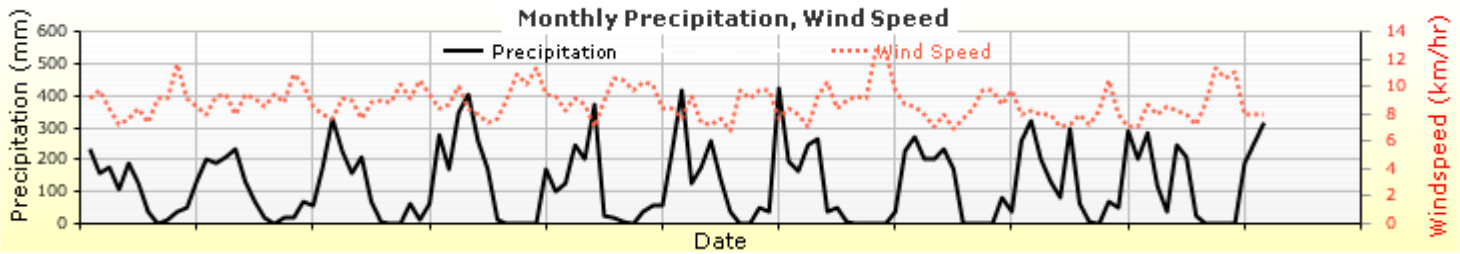
Annual Statistics:

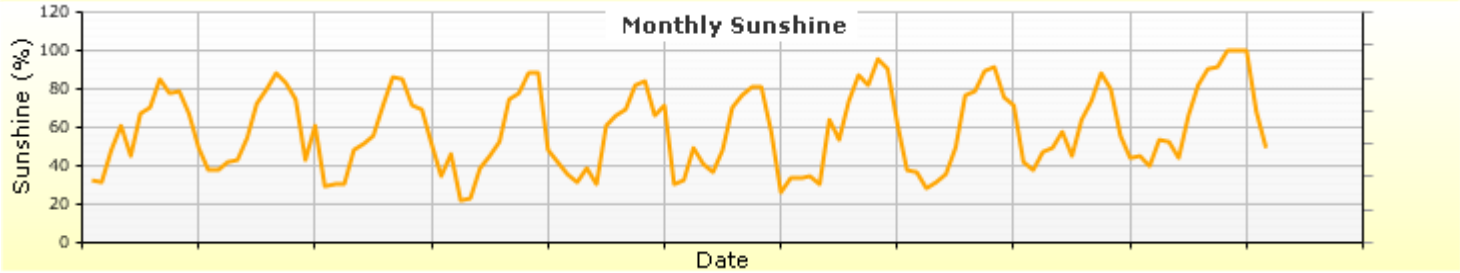
Mean annual air temperature (ºC)	19.35
Mean annual precipitation (mm)	1461.01
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

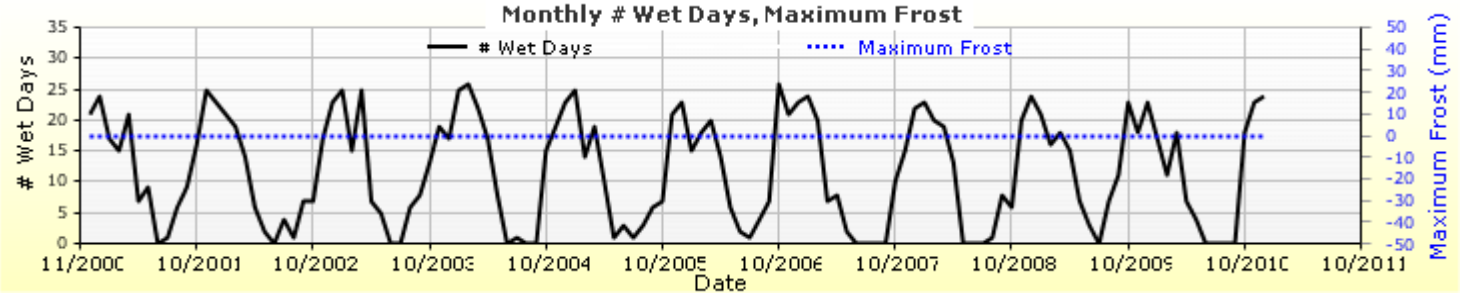
Water table depth (m): 3.05

Monthly Climate Summary:

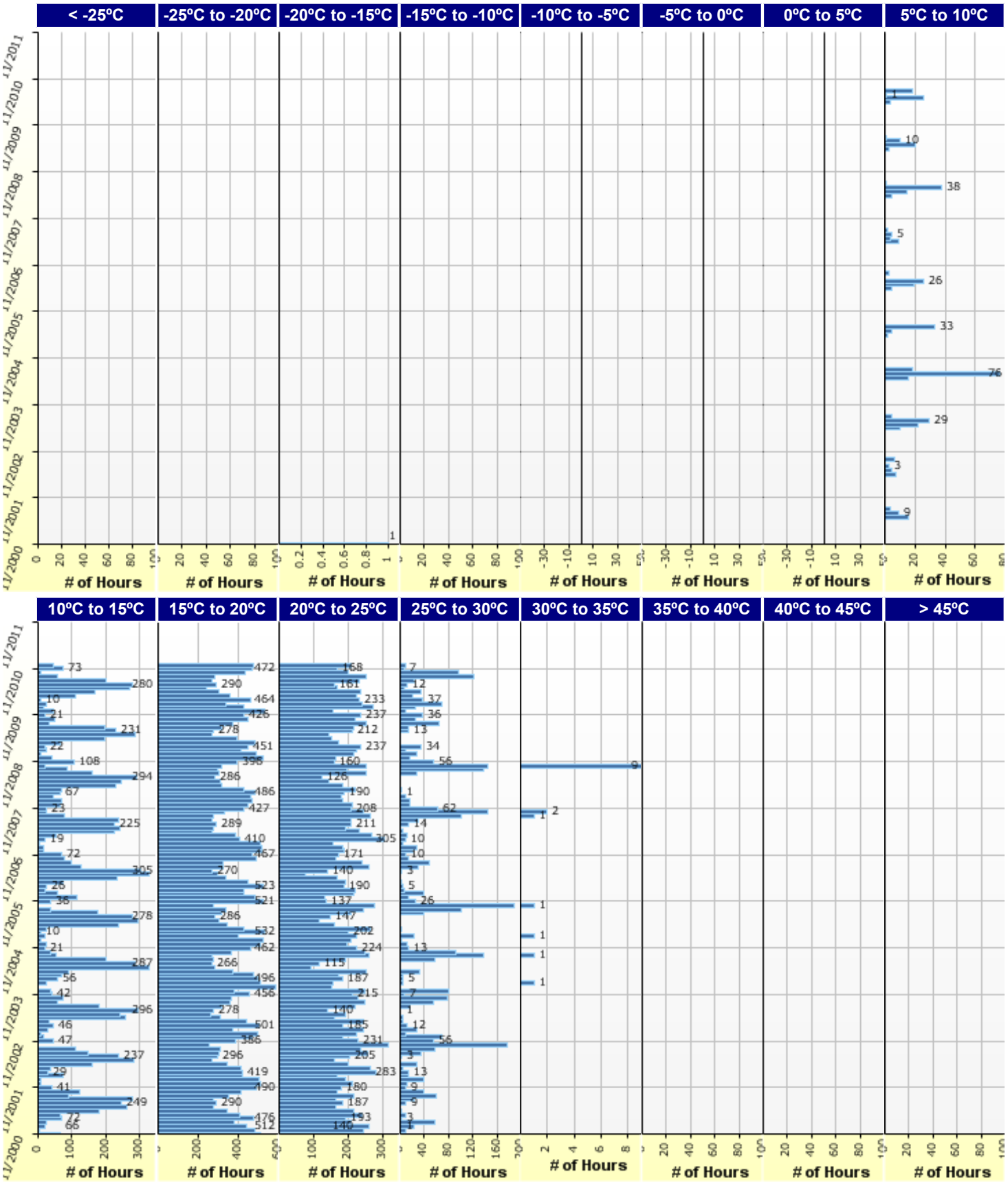








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

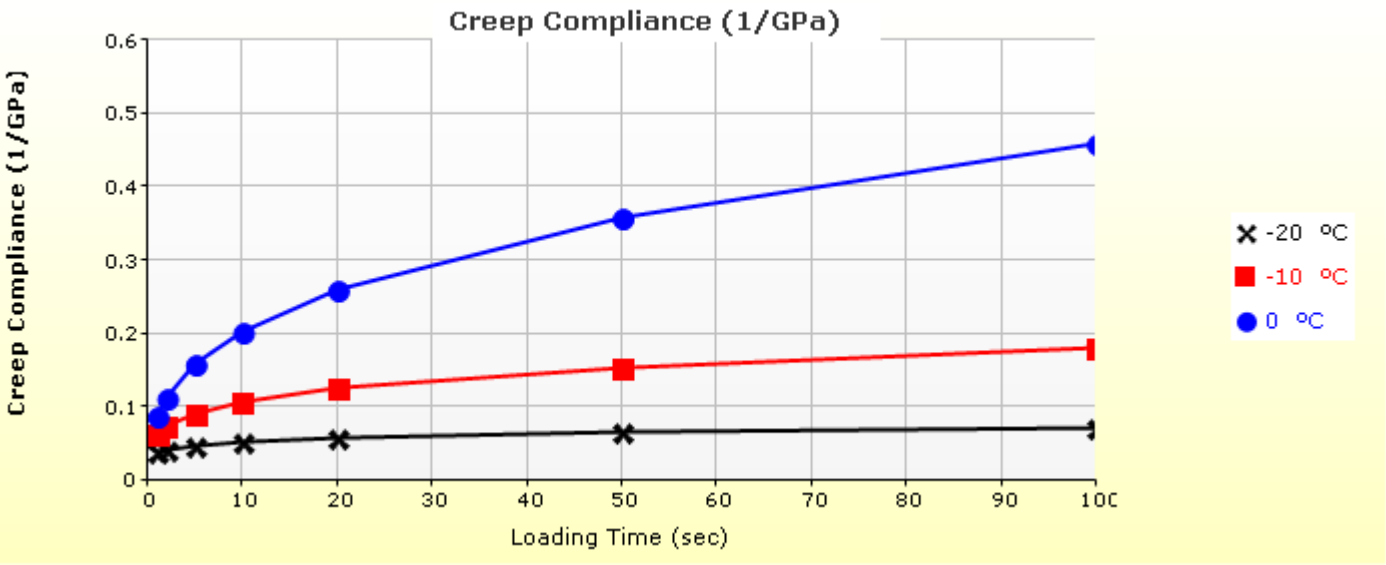
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

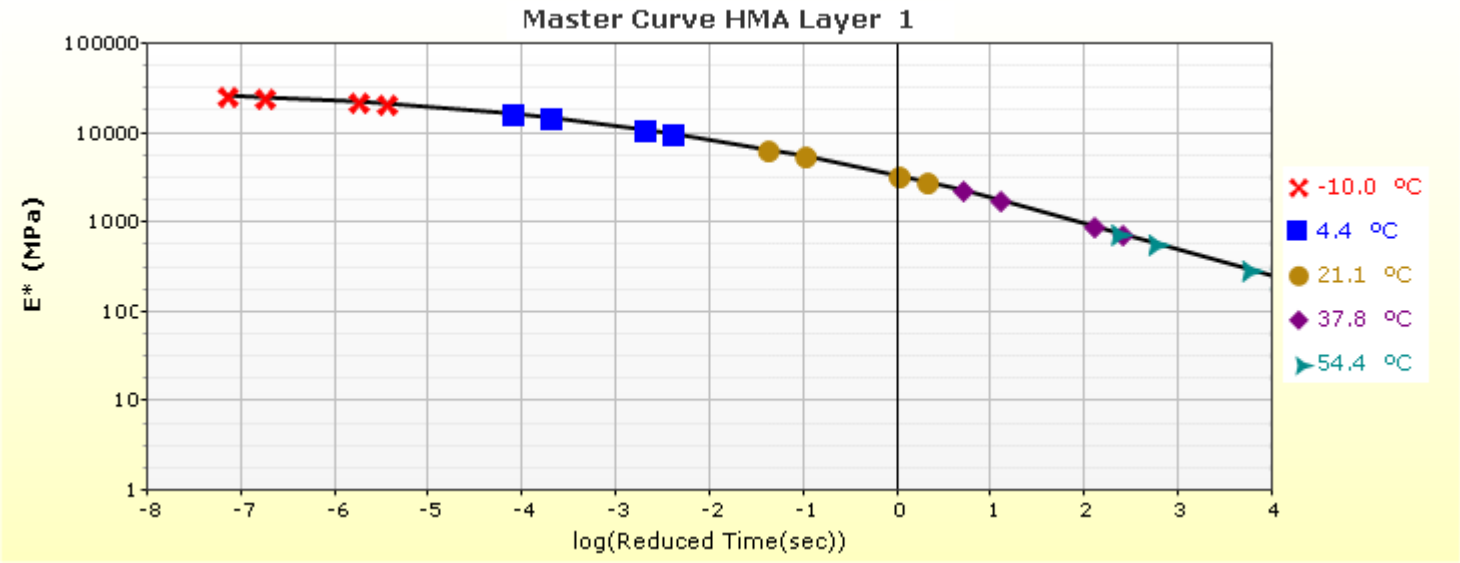
Indirect tensile strength at -10 ºC (MPa)	2.69

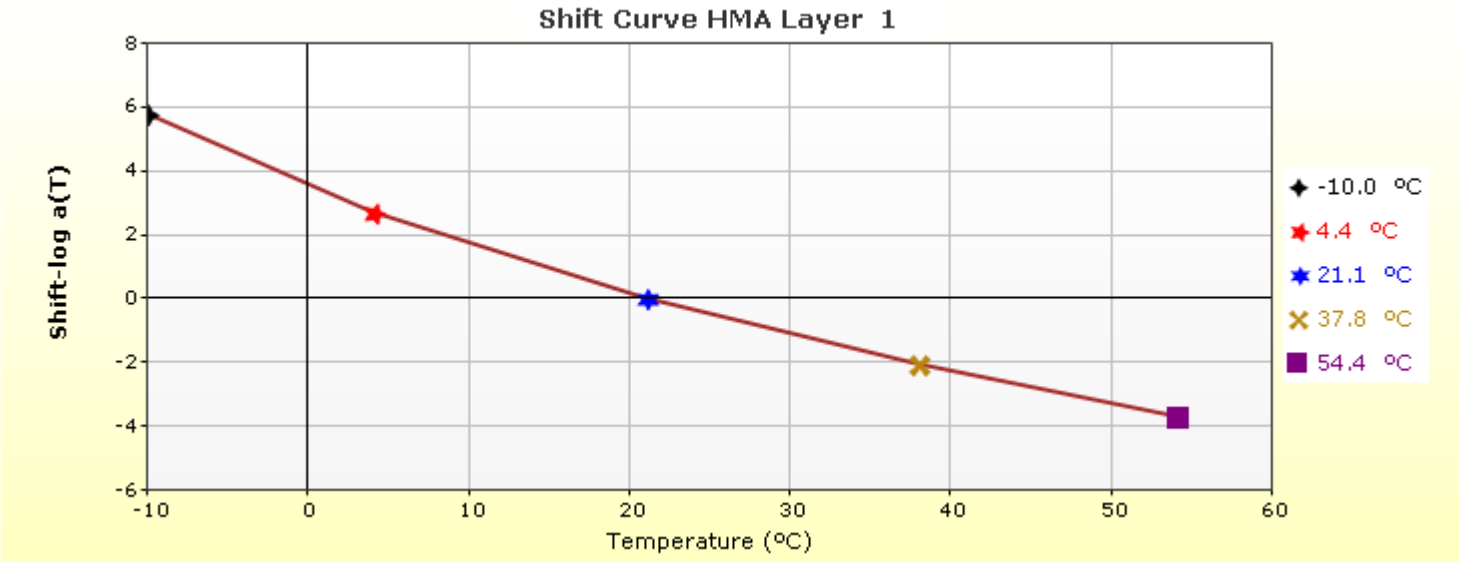
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

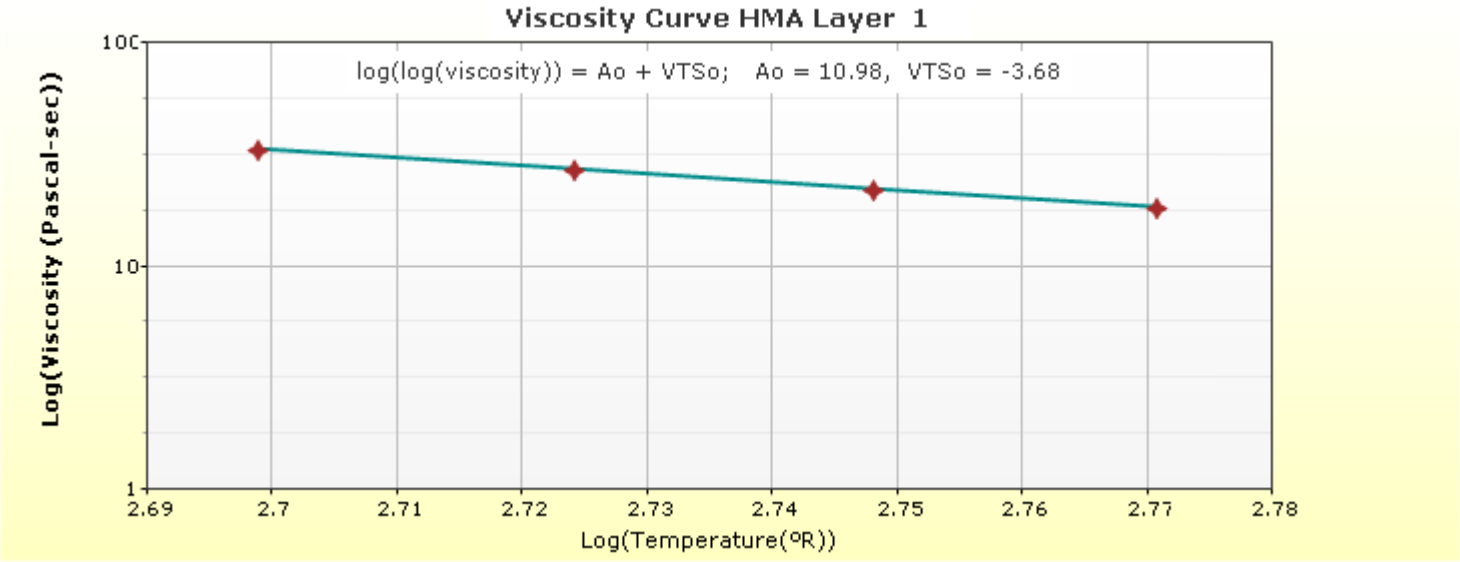
	Creep Compliance (1/GPa)		
Loading time (sec)	**-20 ºC**	**-10 ºC**	**0 ºC**
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



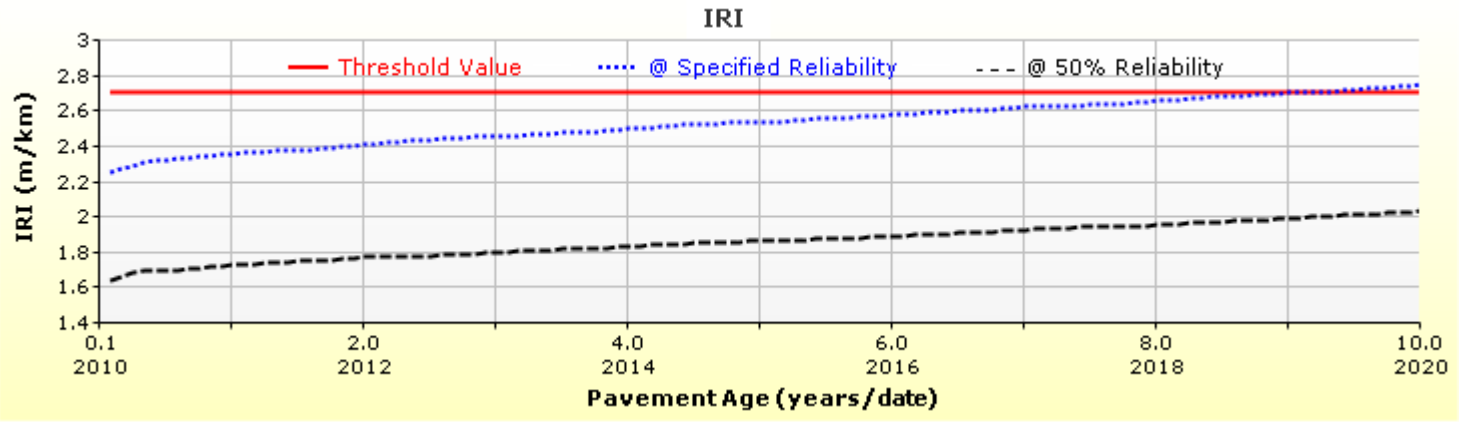
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

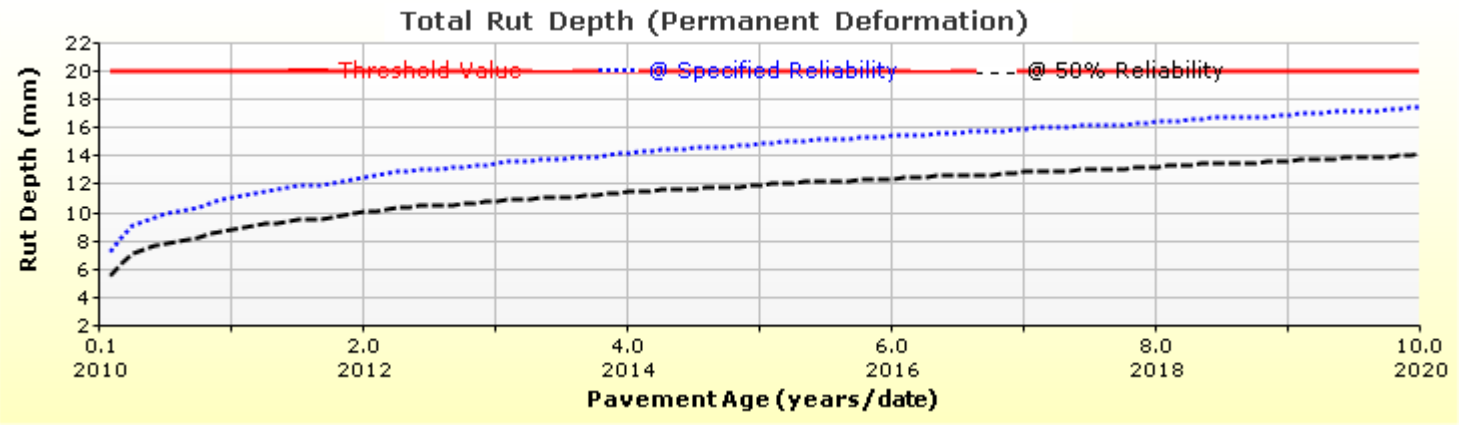


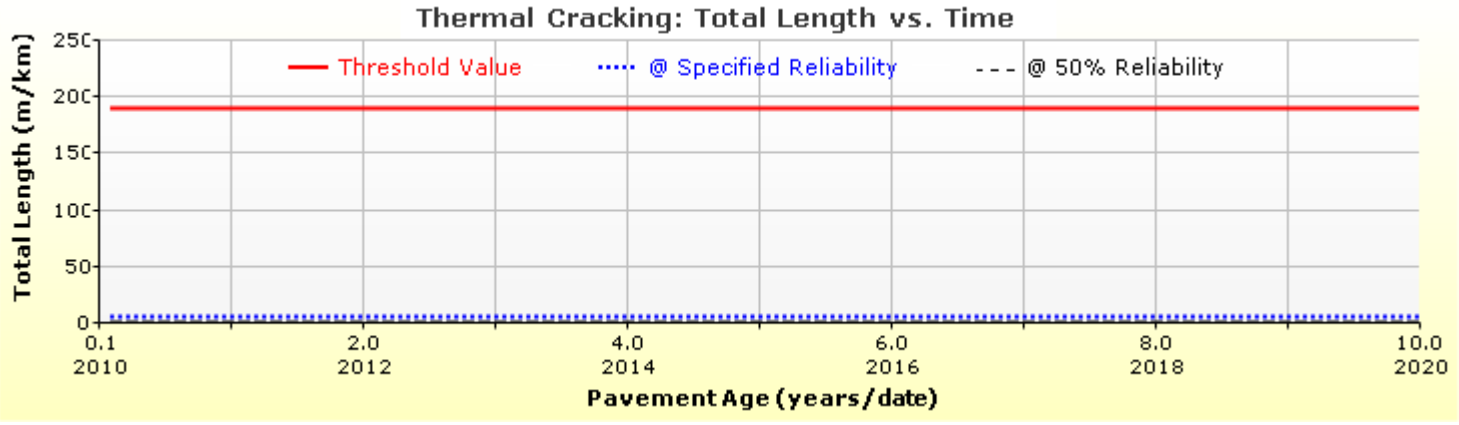


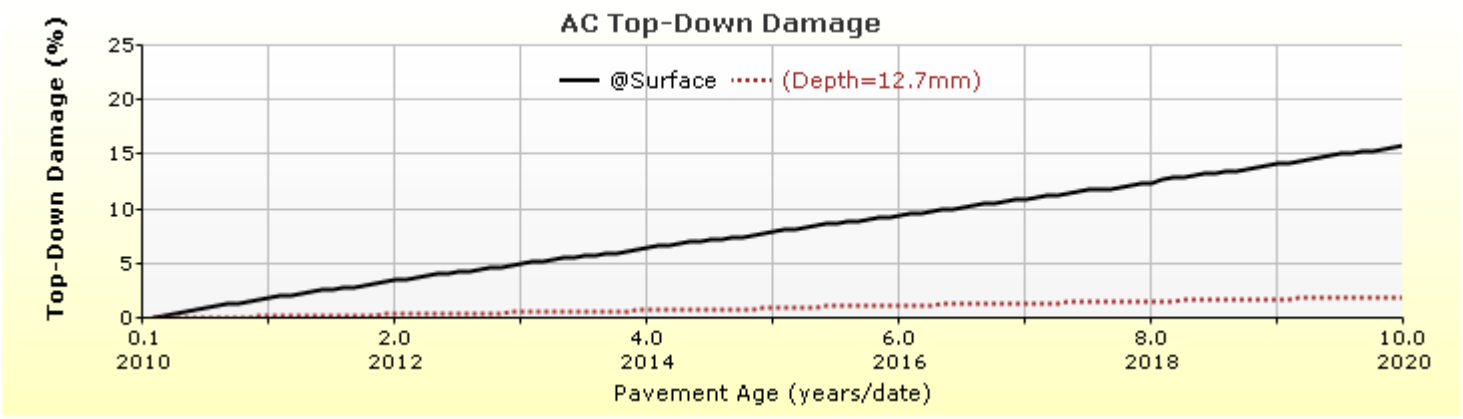


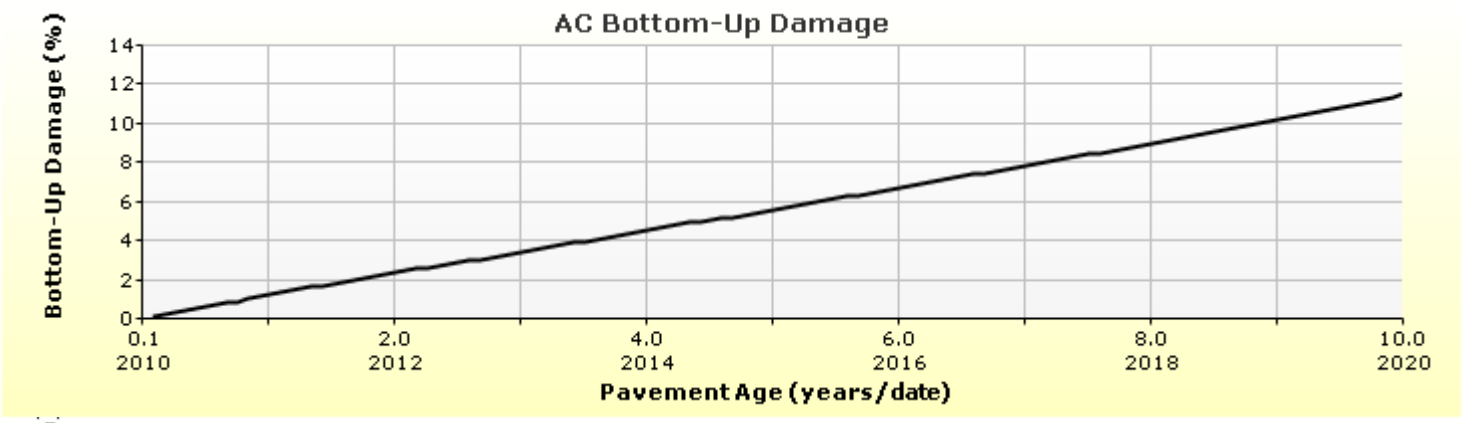
Analysis Output Charts

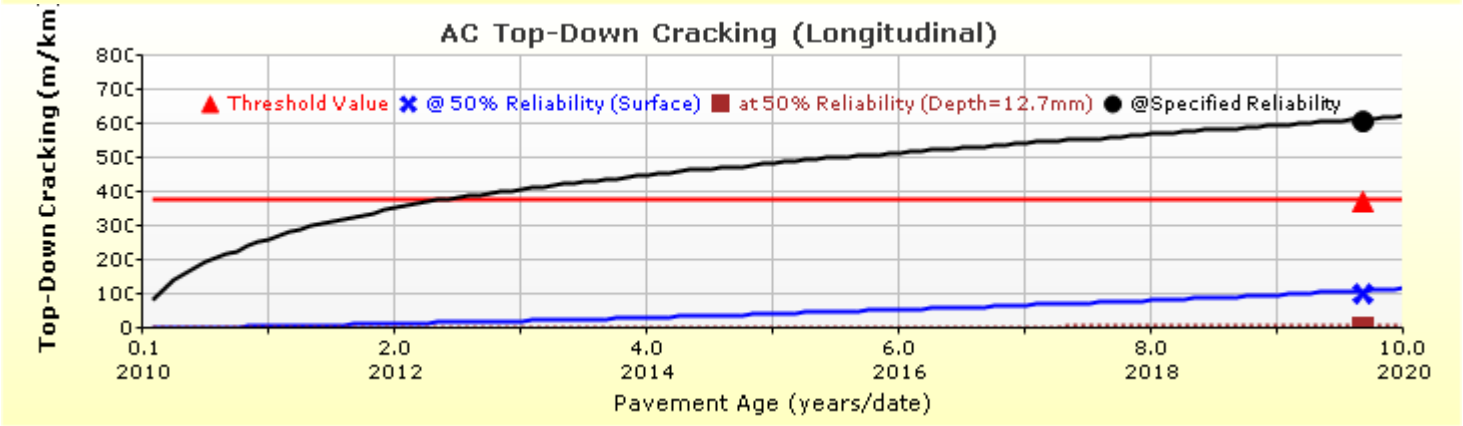


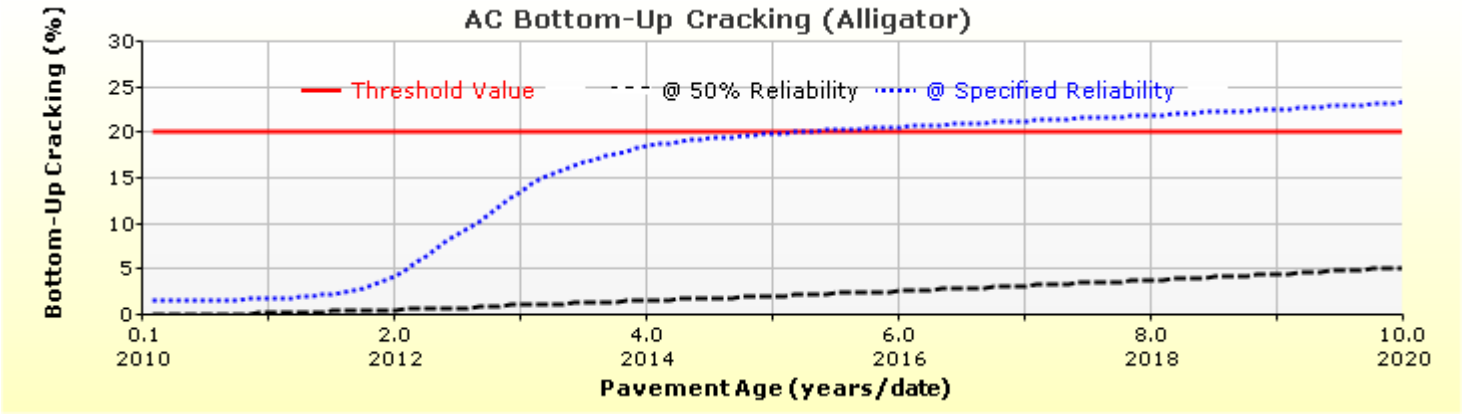


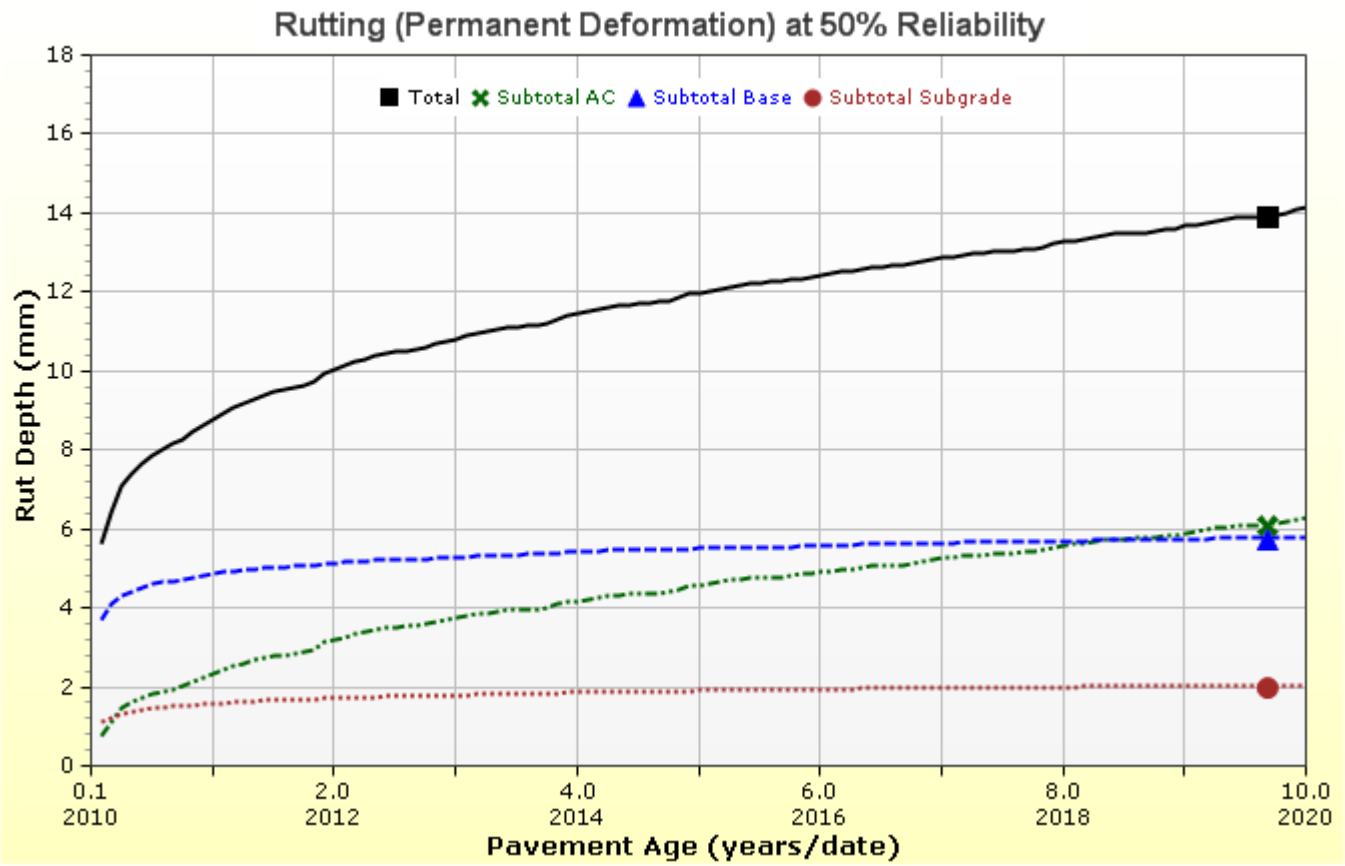


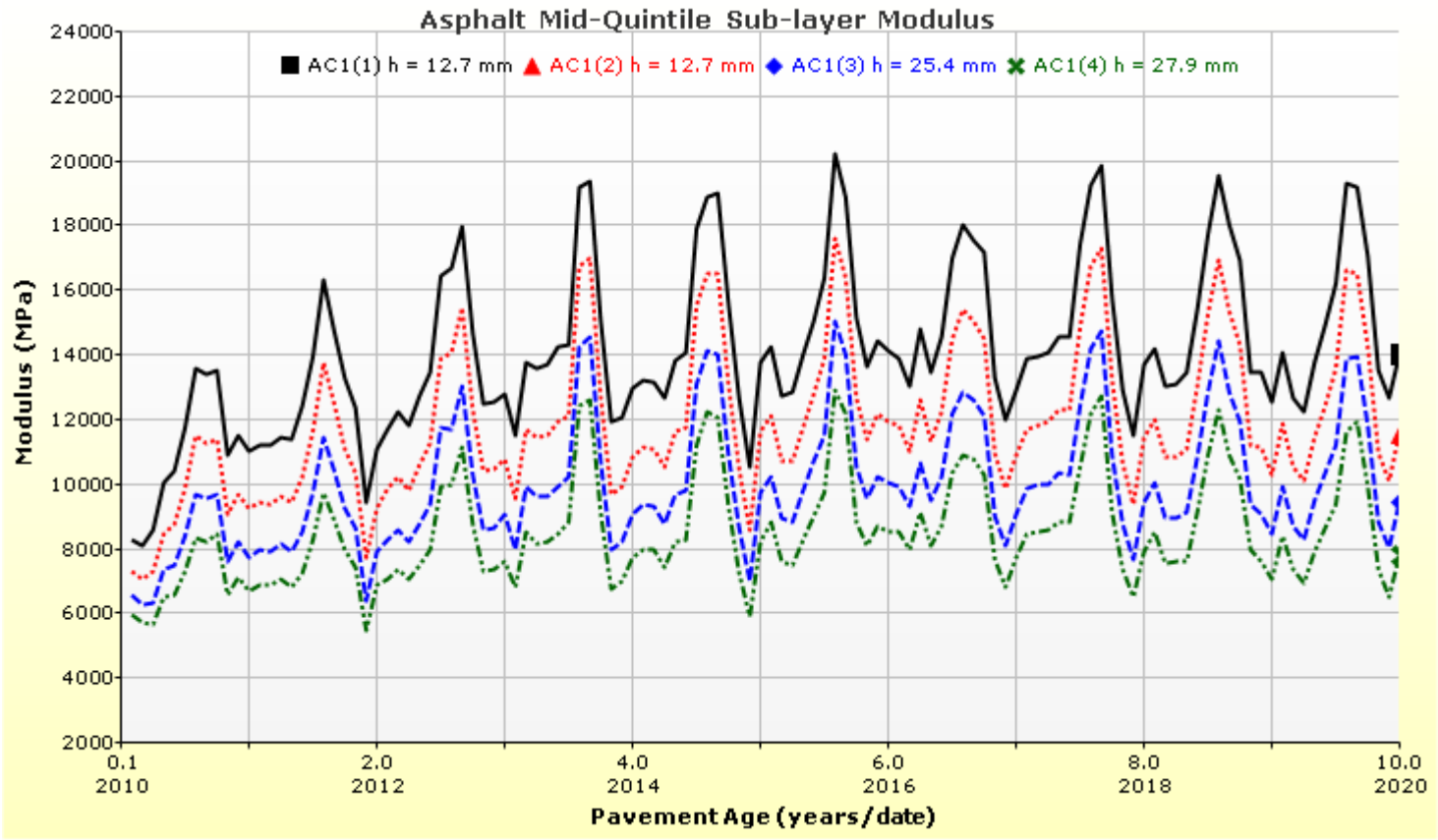

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

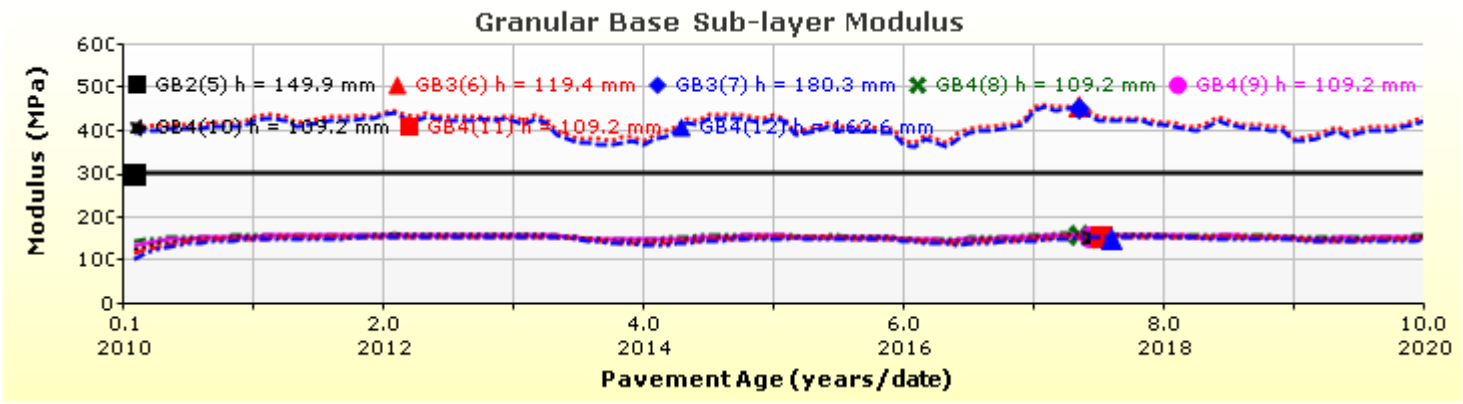

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

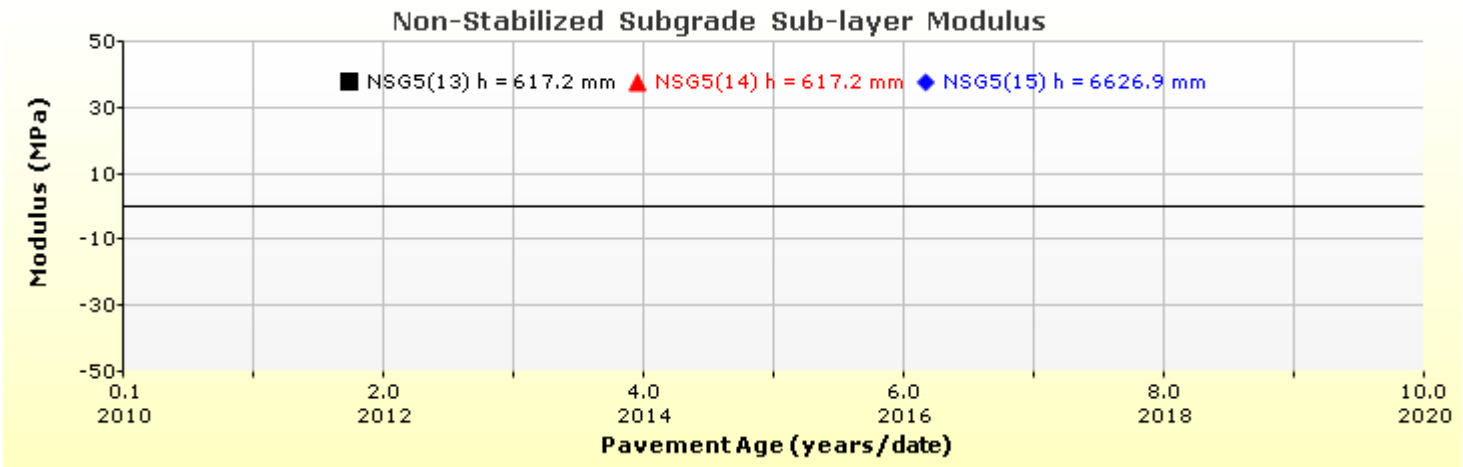

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 462.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$

$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$

$T = layer\ temperature(^{\circ}F)$

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestDF-4

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestDF-4.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -15.78, -47.91

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

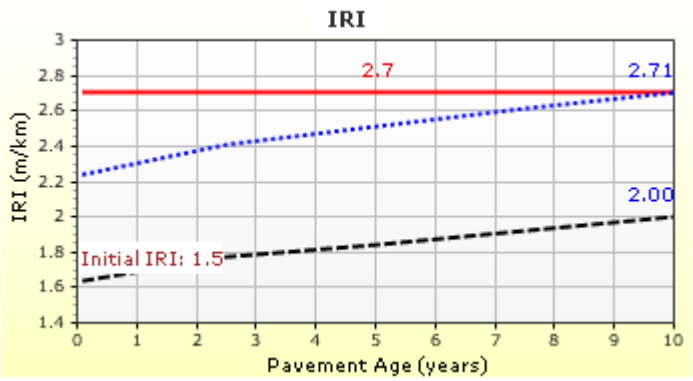
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

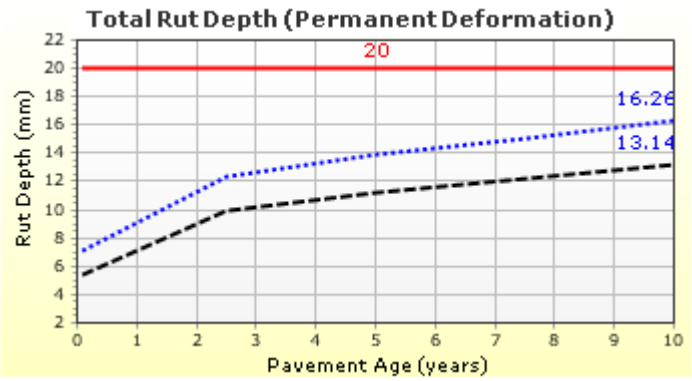
Design Outputs

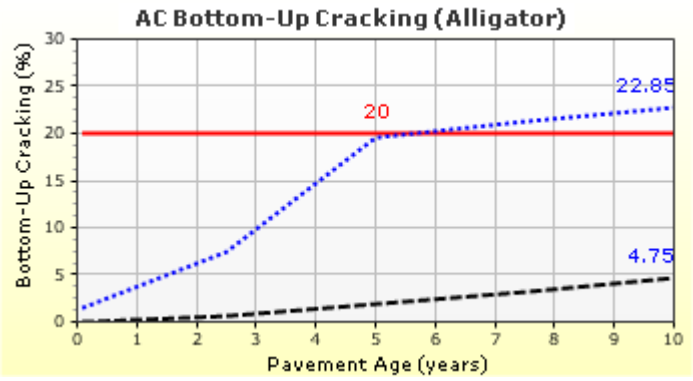
Distress Prediction Summary

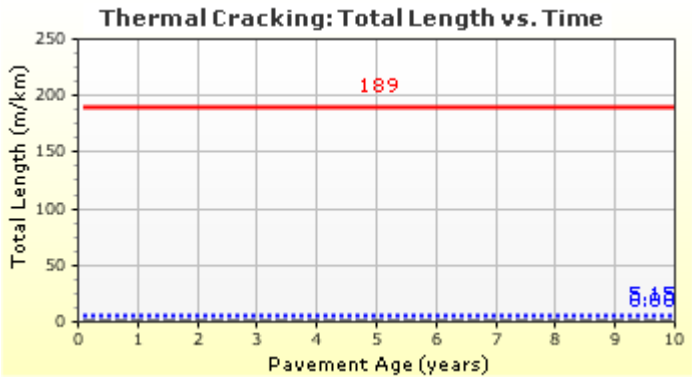
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.71	90.00	89.66	Fail
Permanent deformation - total pavement (mm)	20.00	16.27	90.00	99.75	Pass
AC bottom-up fatigue cracking (percent)	20.00	22.85	90.00	85.98	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	598.98	90.00	76.26	Fail
Permanent deformation - AC only (mm)	5.00	5.32	50.00	42.97	Fail

Distress Charts







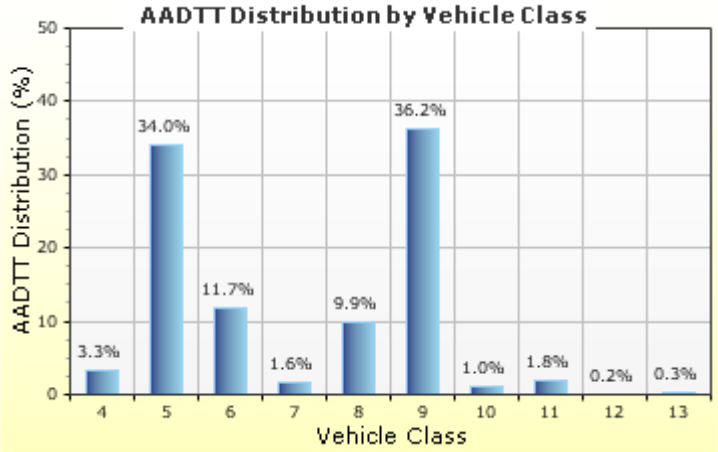


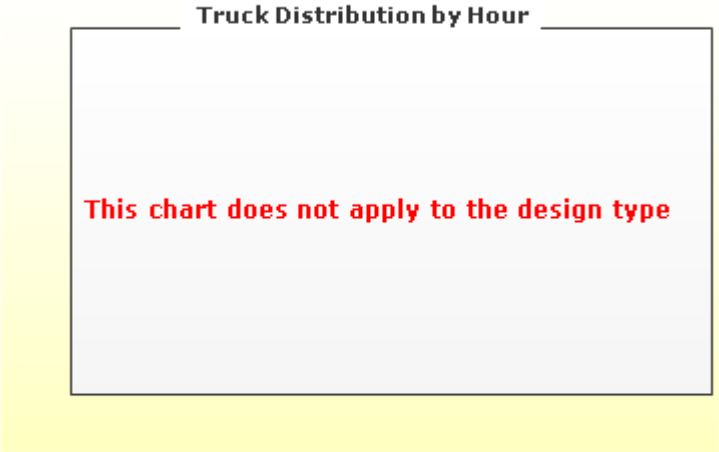
Threshold Value ····· @ Specified Reliability - - - @ 50% Reliability

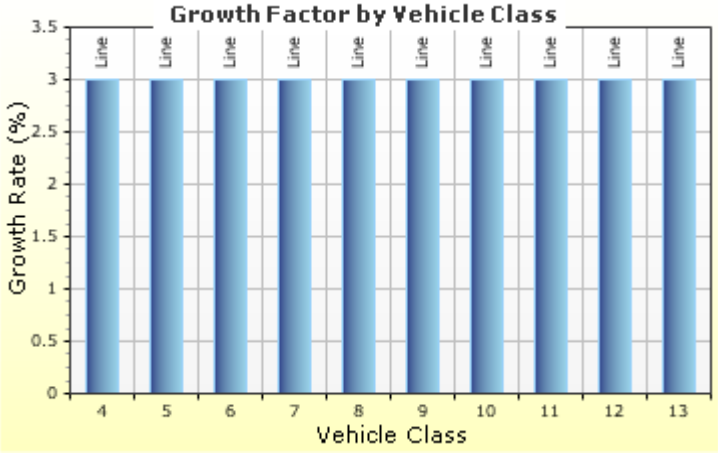
Traffic Inputs

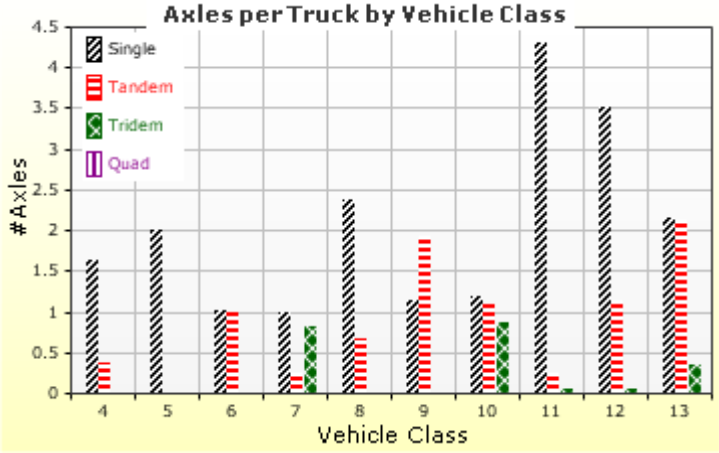
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

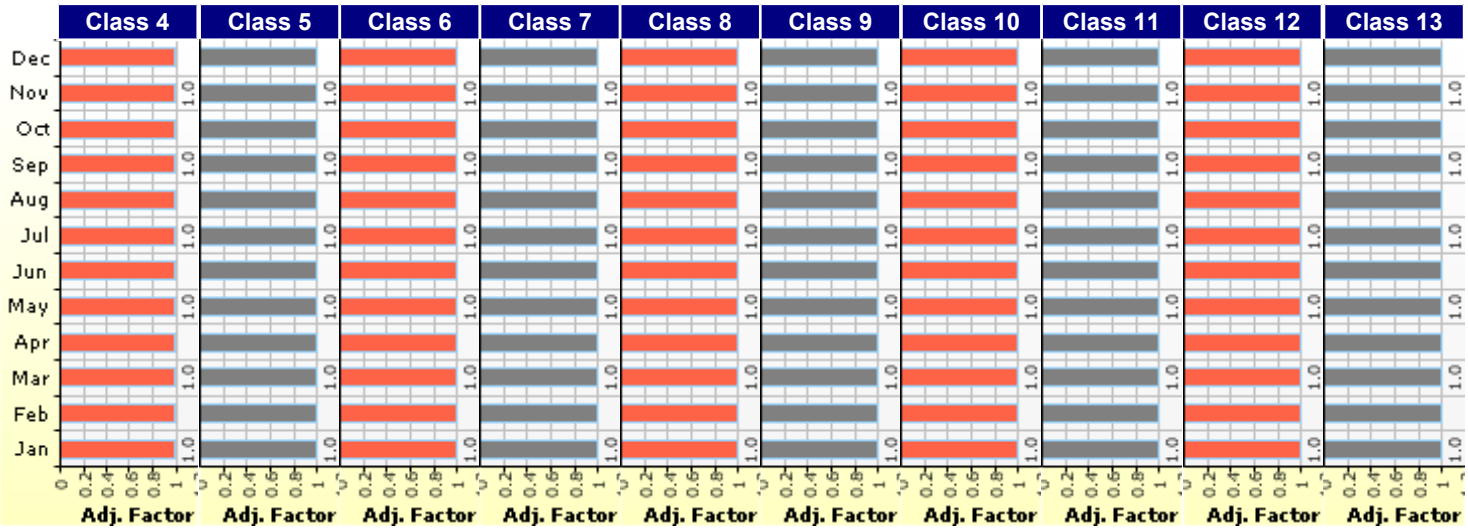








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

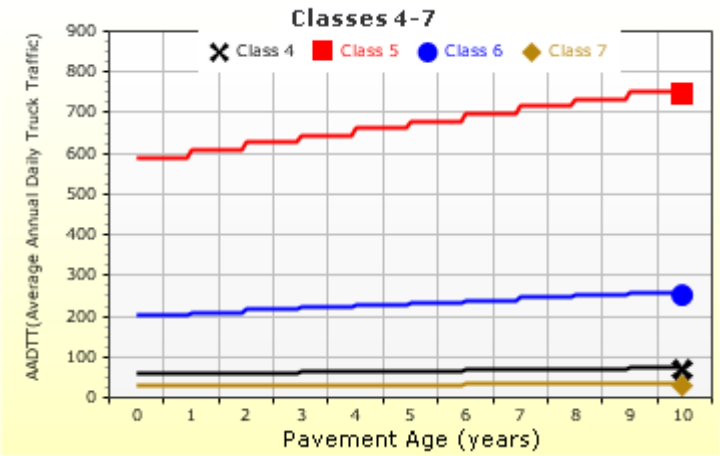
Wheelbase does not apply

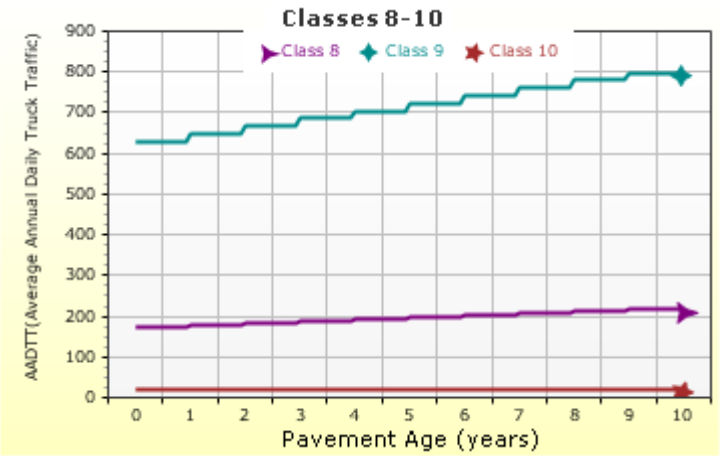
Number of Axles per Truck

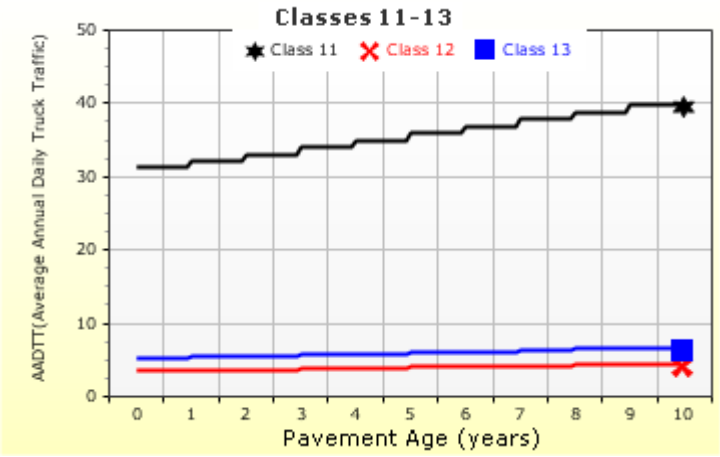
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

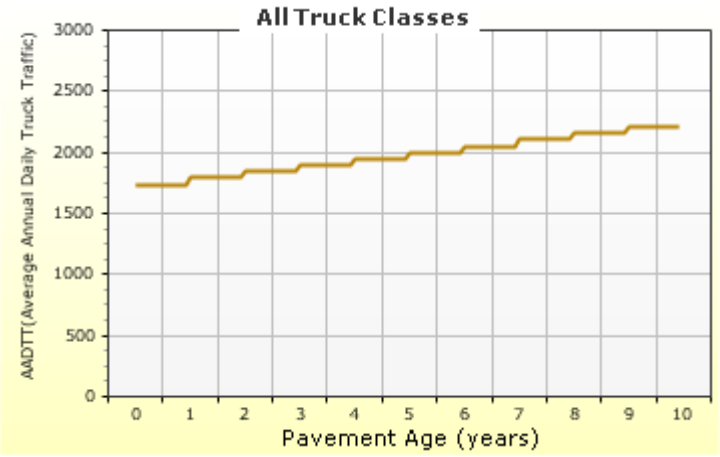
AADTT (Average Annual Daily Truck Traffic) Growth

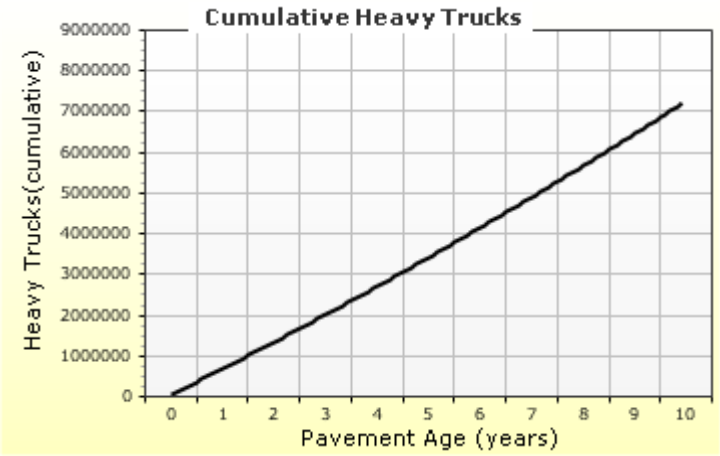
*** Traffic cap is not enforced**







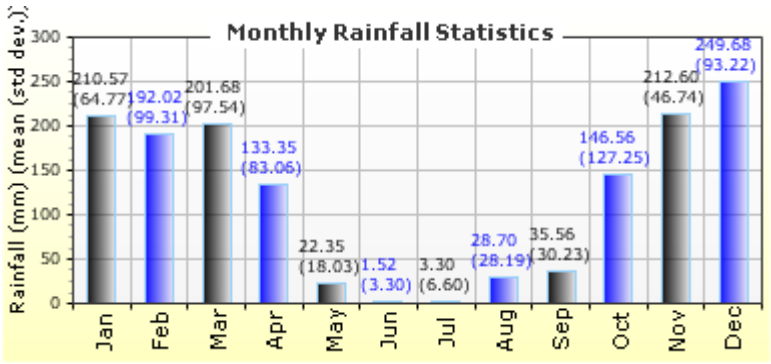




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
BRASILIA, DF	-15.78000 -47.91000 1159

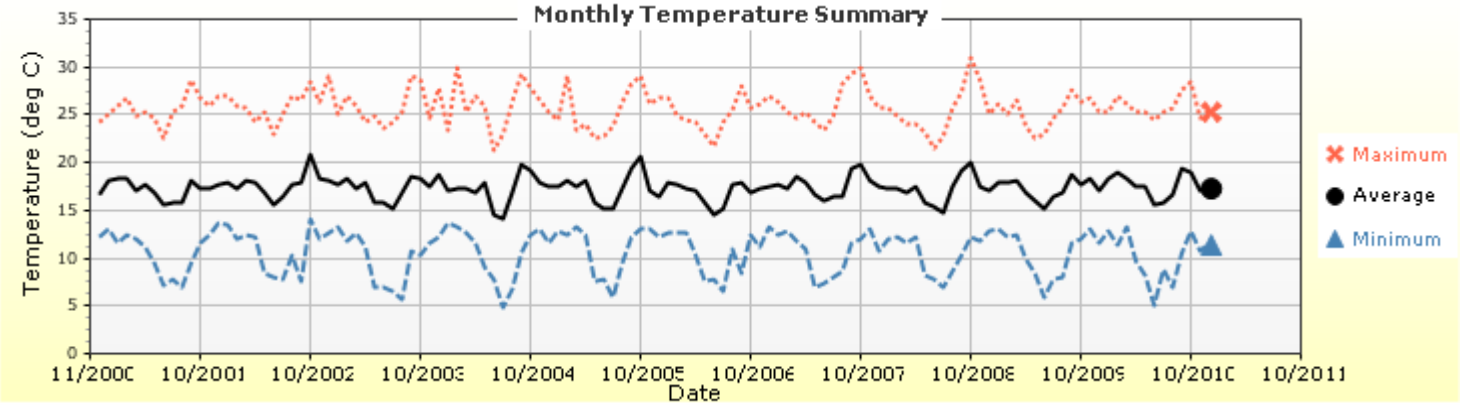


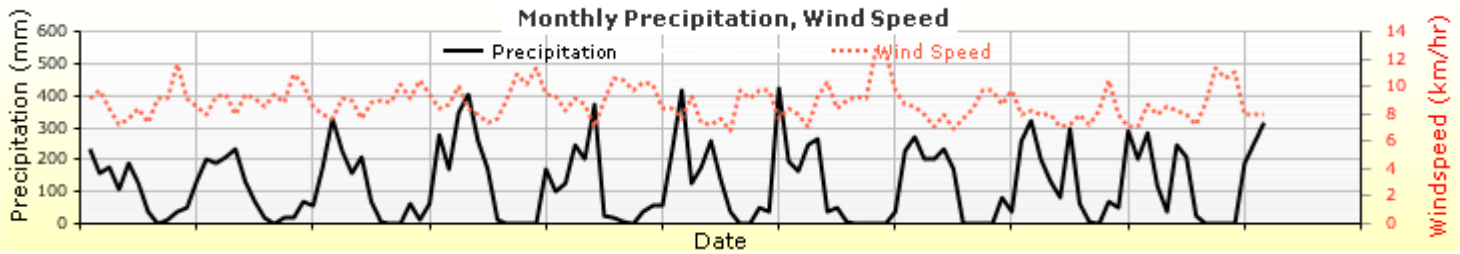
Annual Statistics:

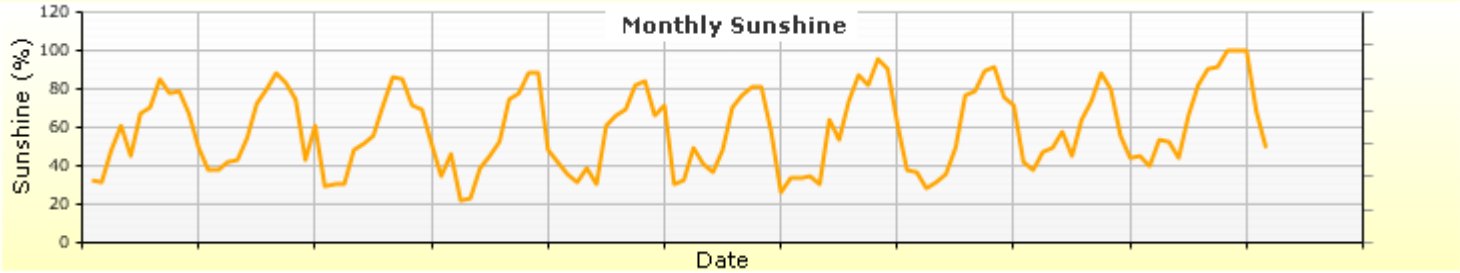
Mean annual air temperature (ºC)	17.35
Mean annual precipitation (mm)	1461.01
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

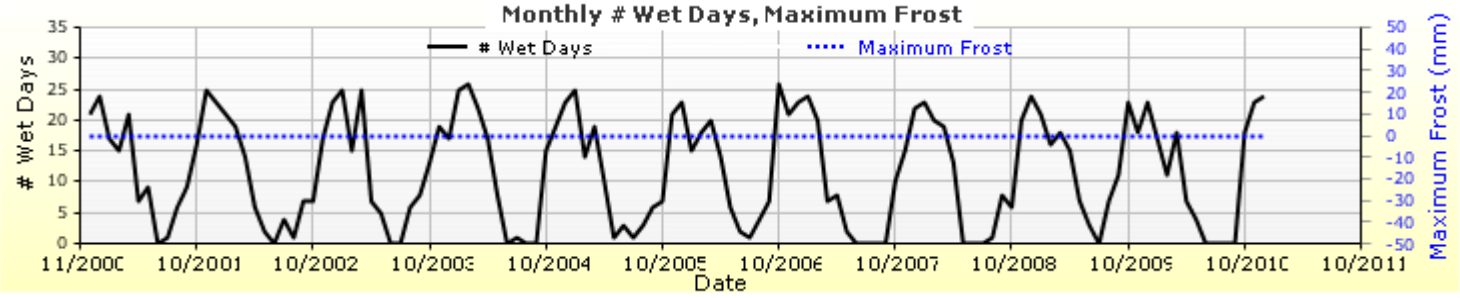
Water table depth (m): 3.05

Monthly Climate Summary:

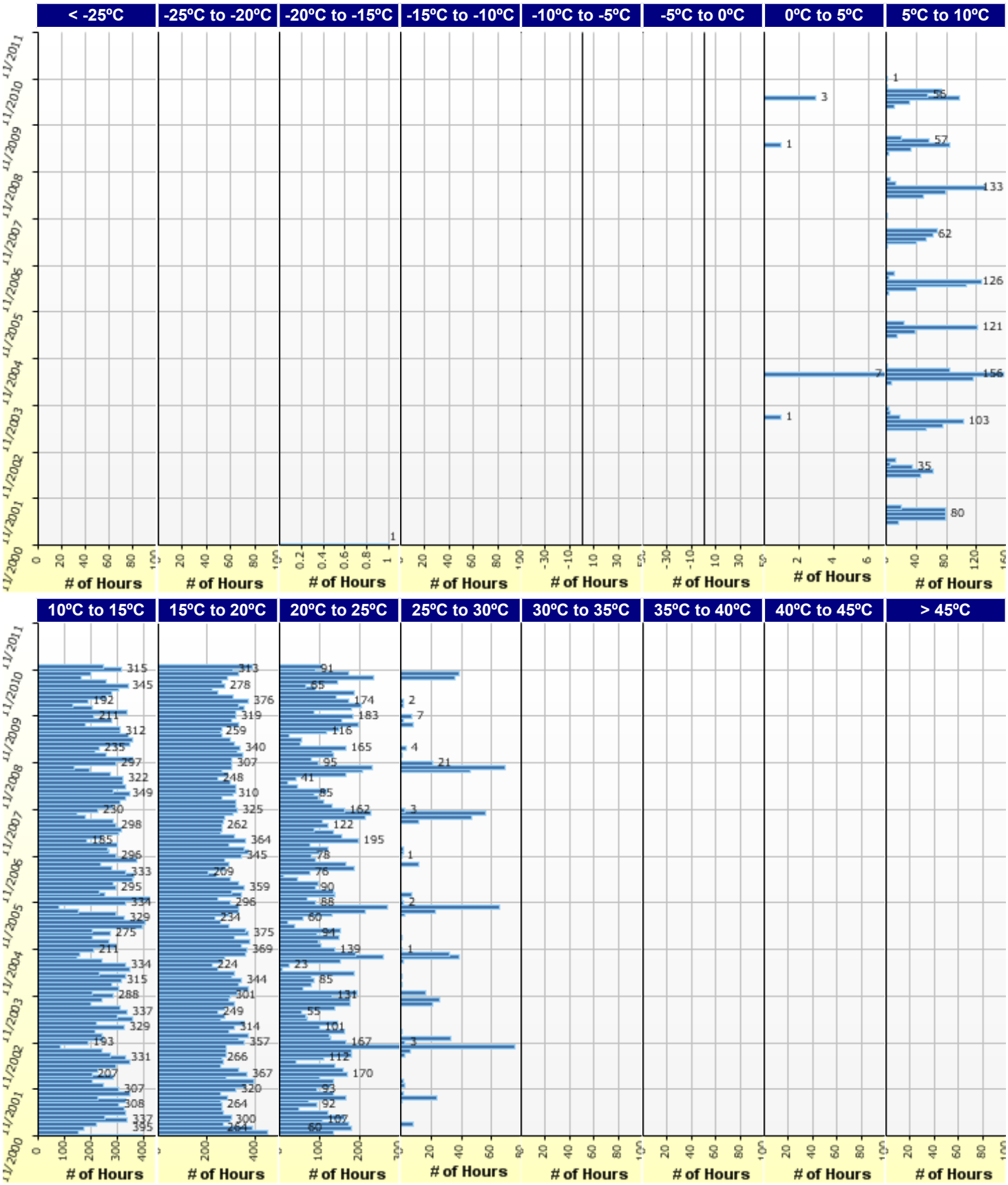








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

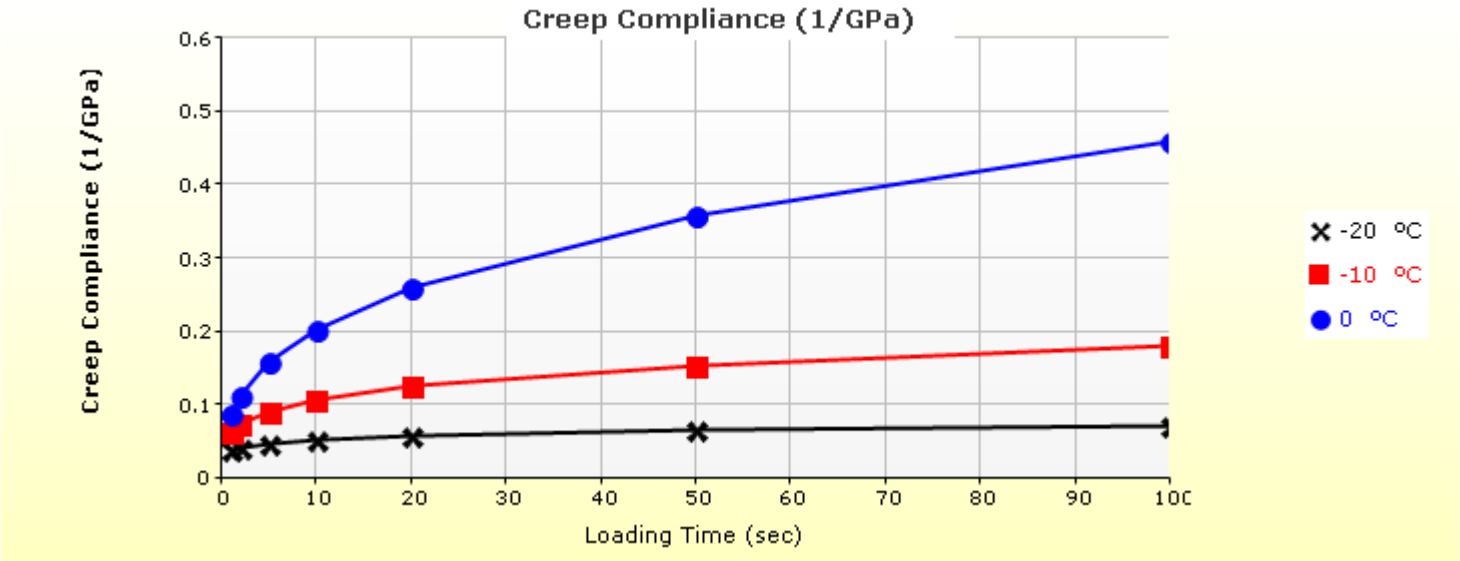
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

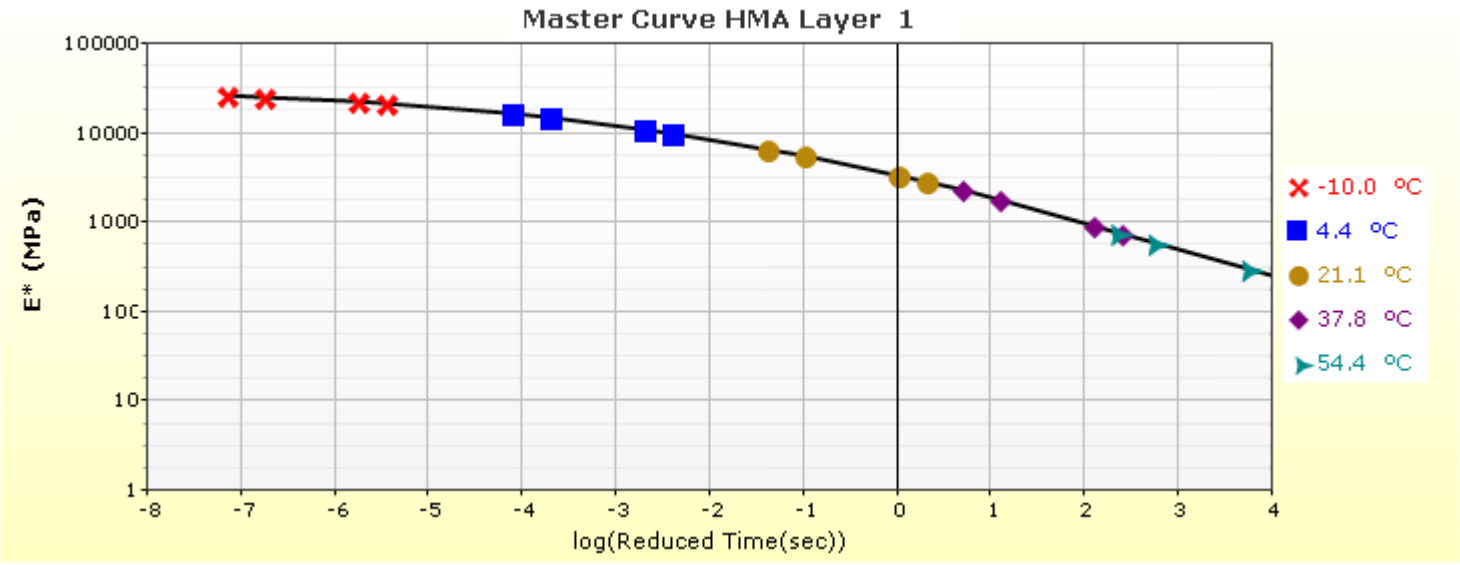
Indirect tensile strength at -10 ºC (MPa)	2.69

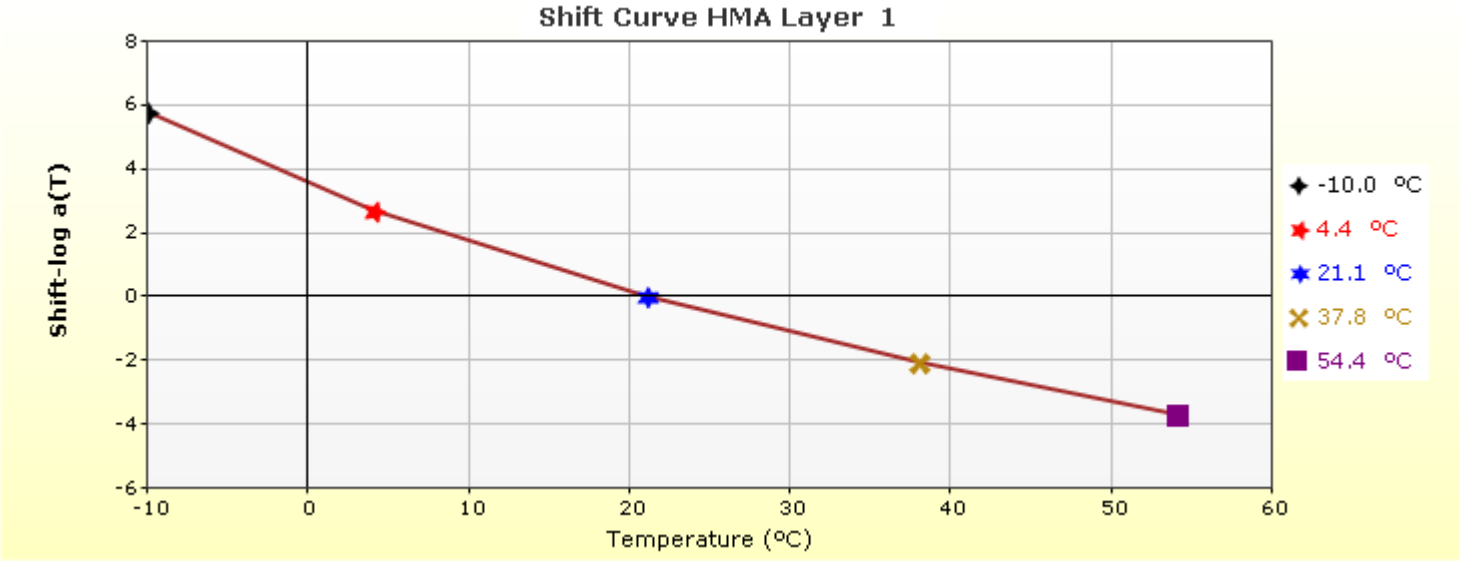
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

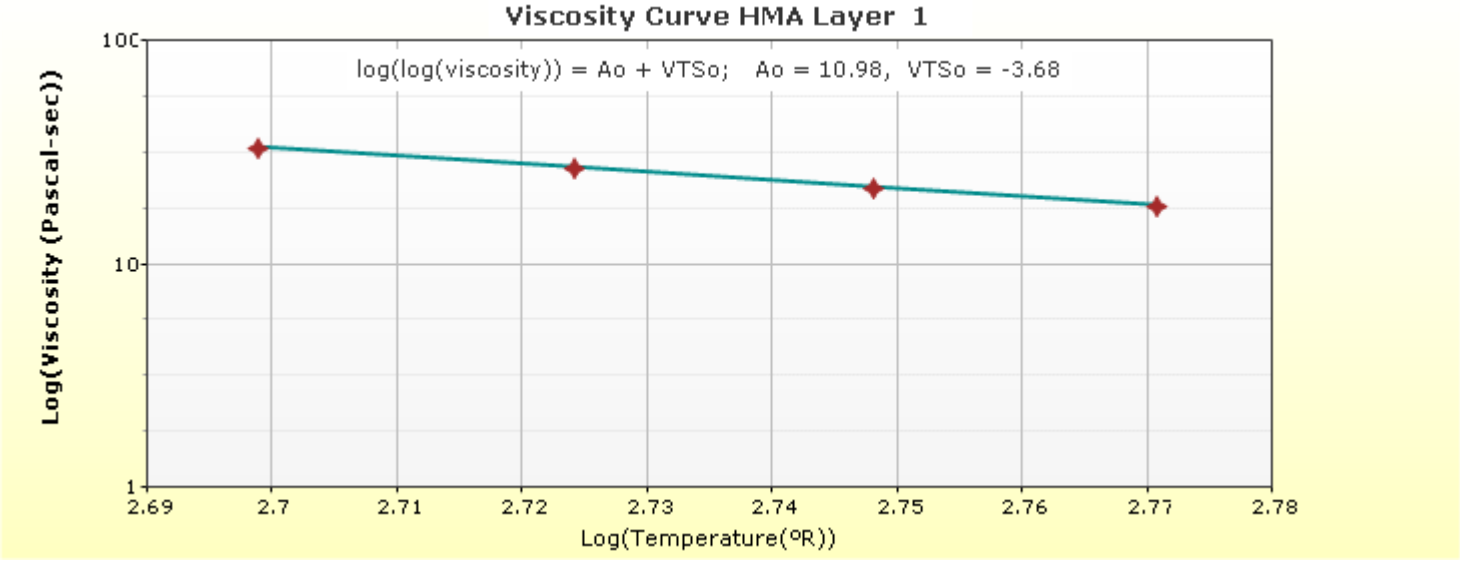
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



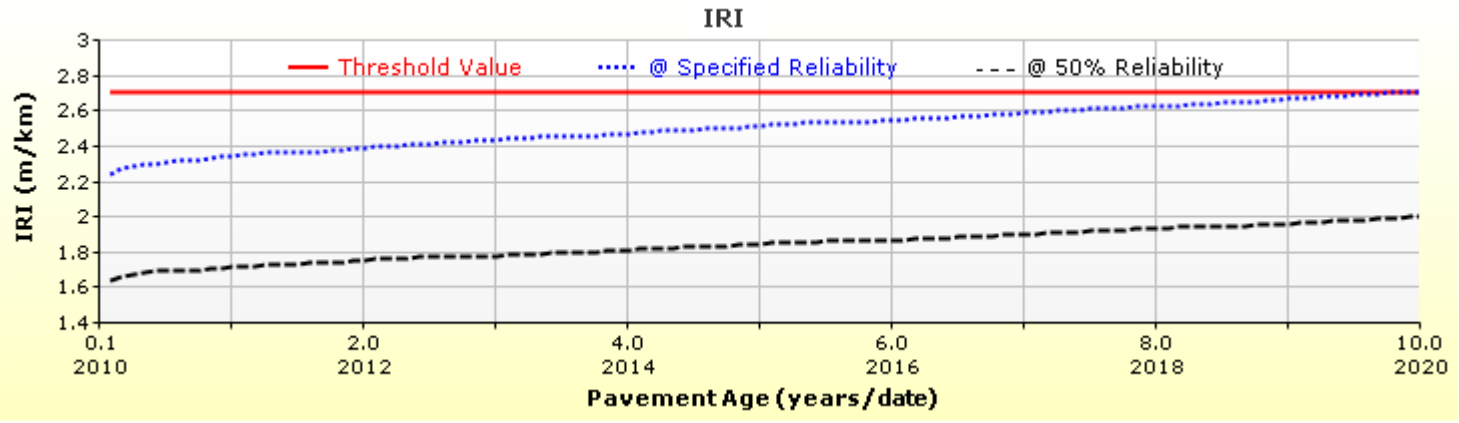
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

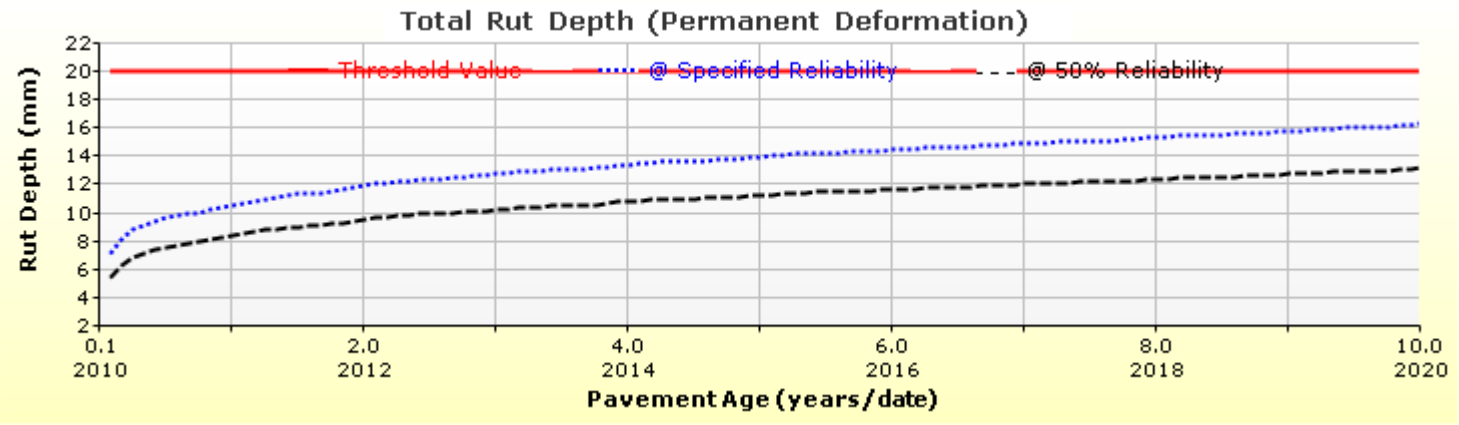


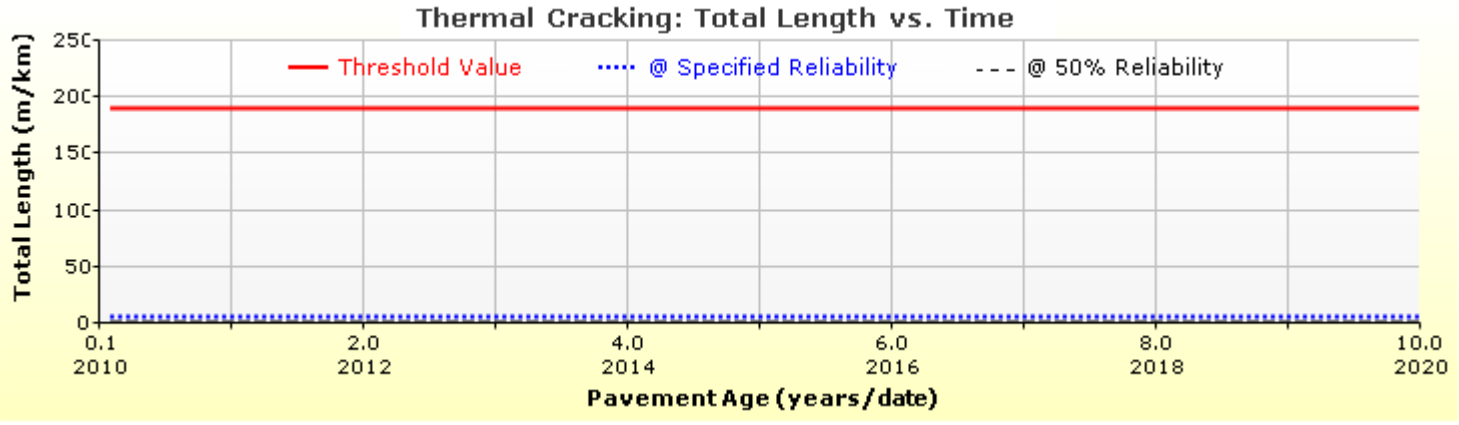


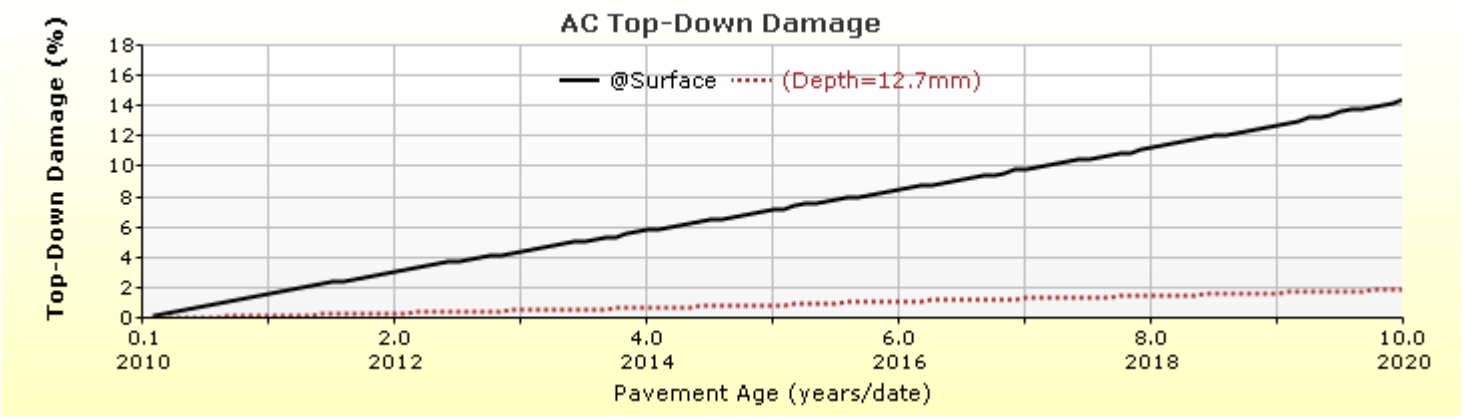


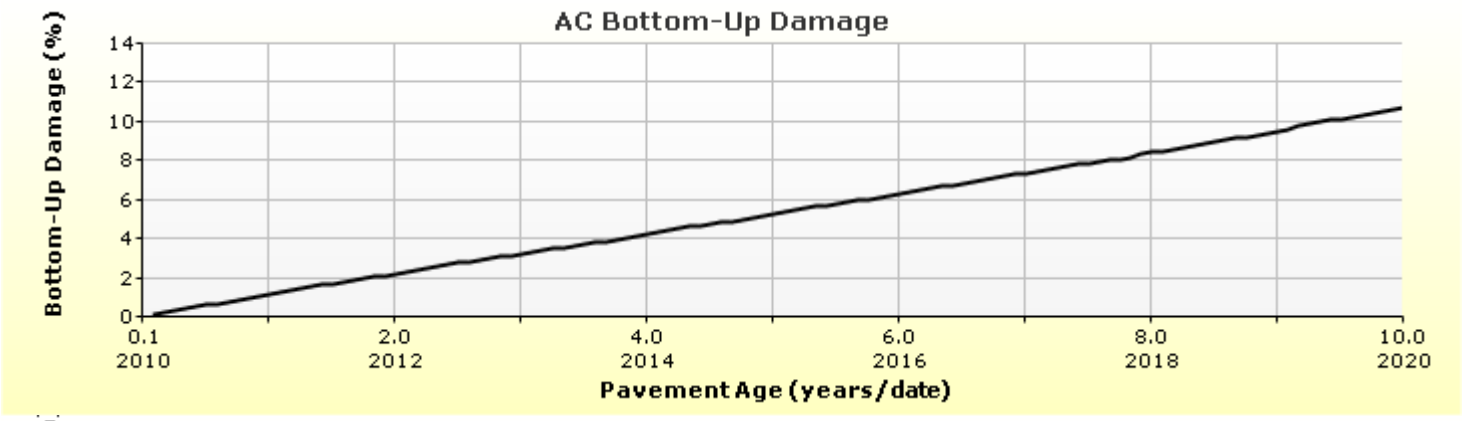
Analysis Output Charts

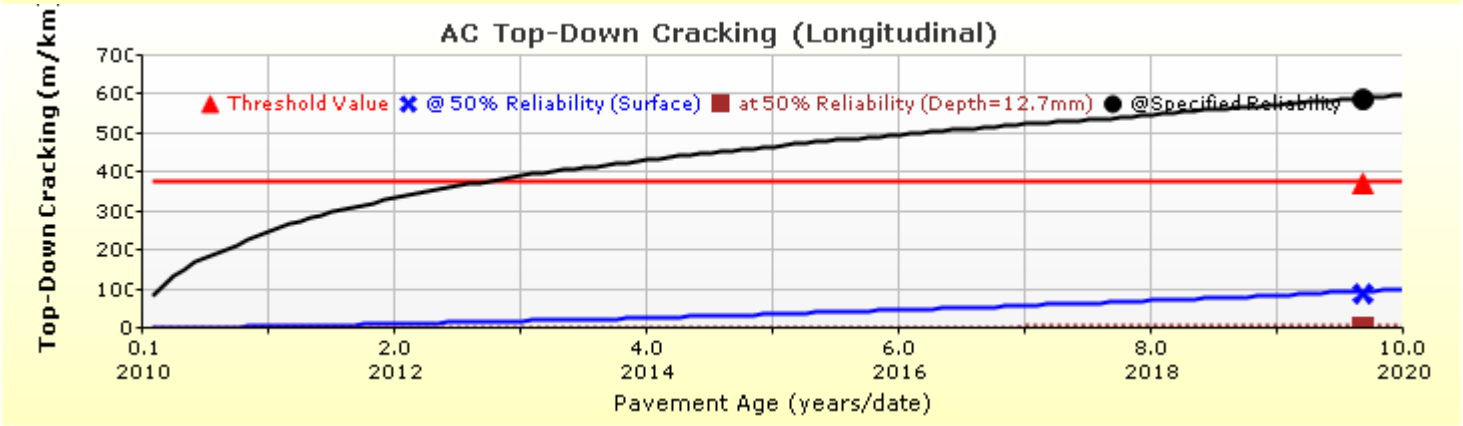


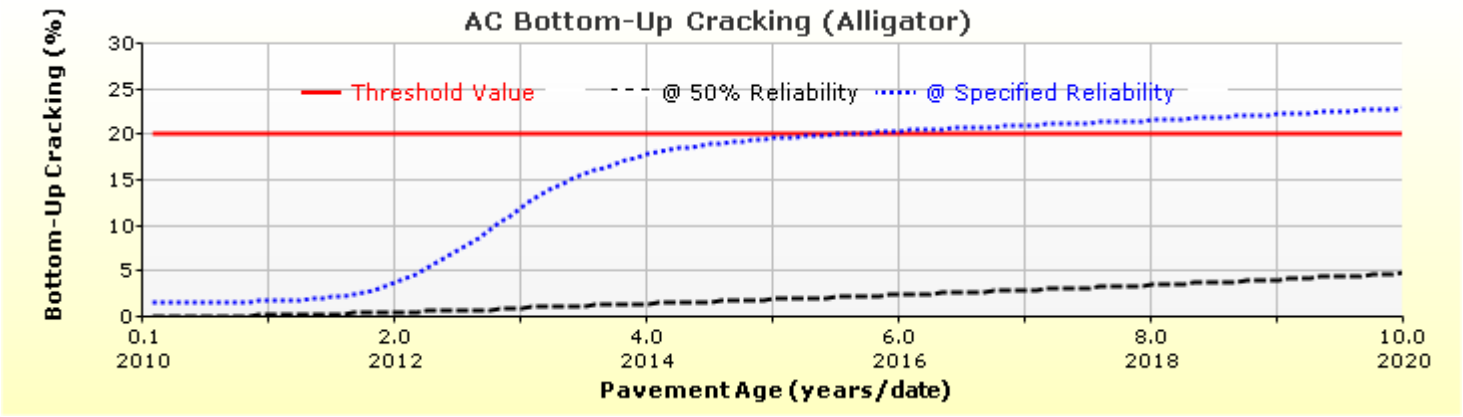


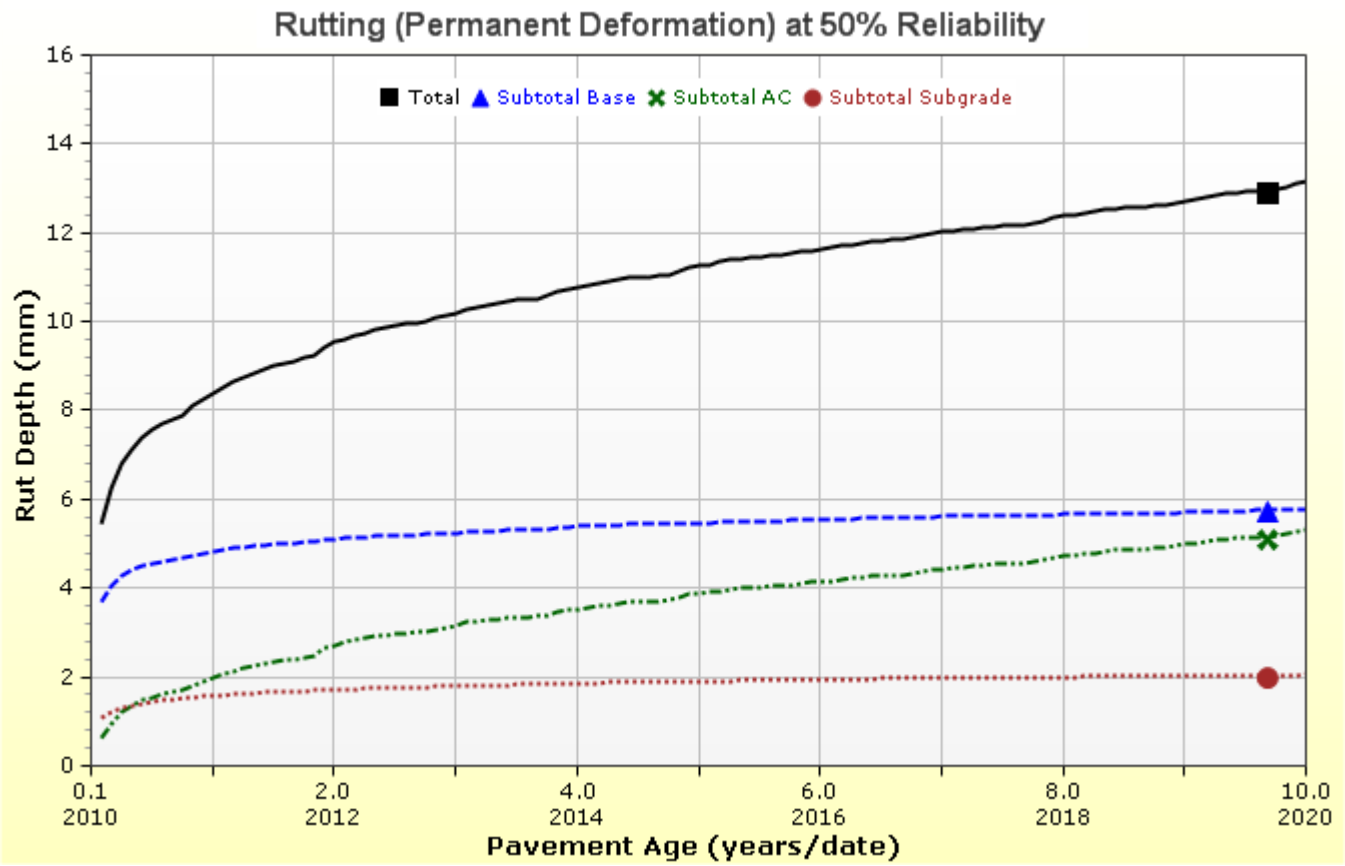


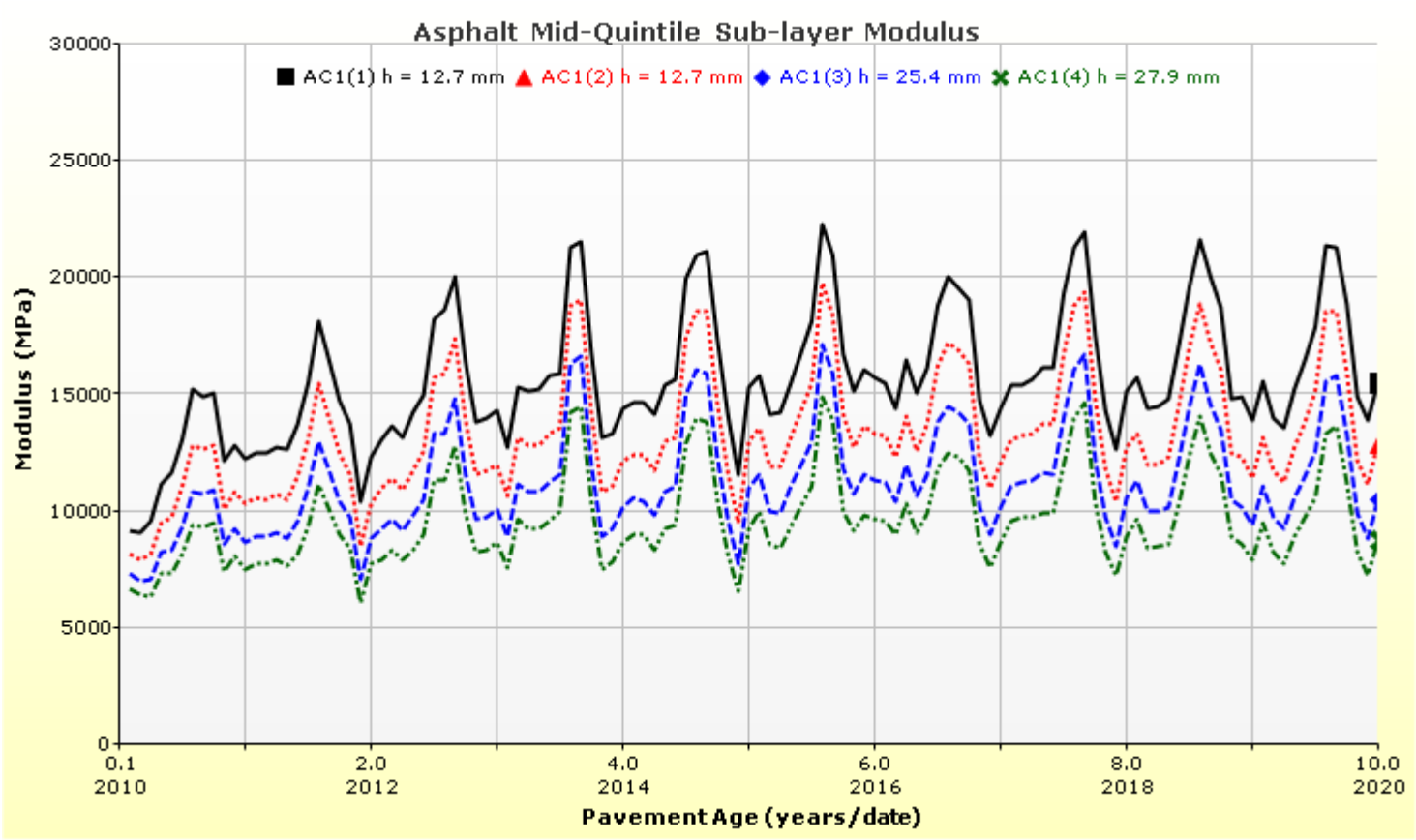

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

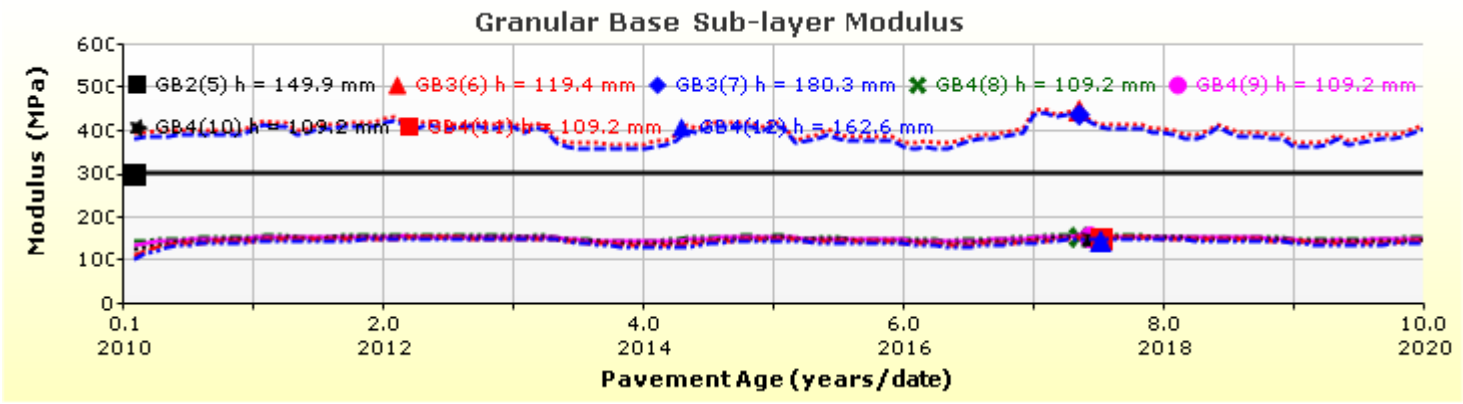

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

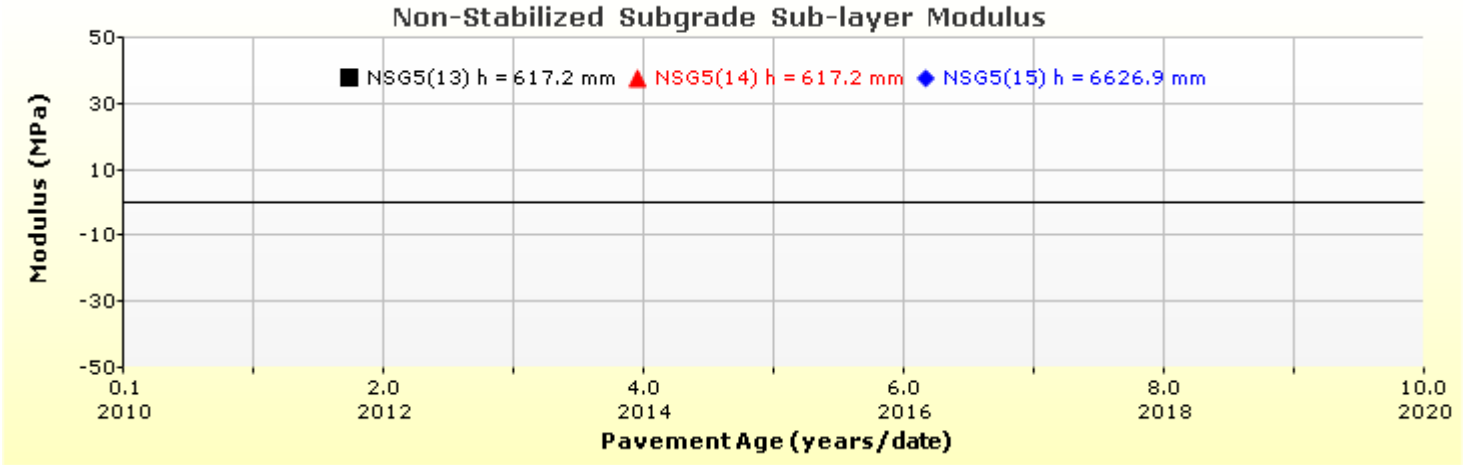

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal Base
Subtotal AC
Subtotal Subgrade
Rut Depth (mm)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60000
50000
40000
30000
20000
10000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestDF_cobertura

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestDF_cobertura.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -15.78, -47.91

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

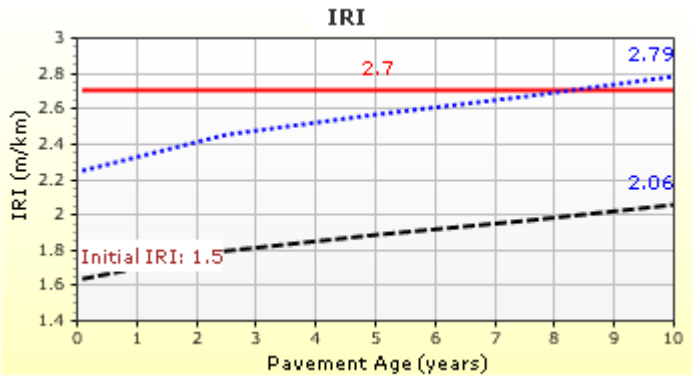
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

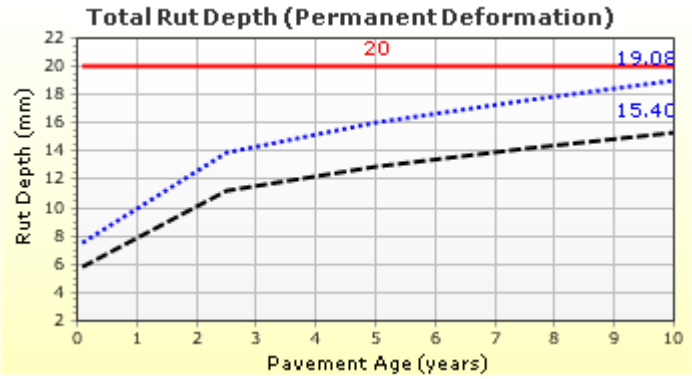
Design Outputs

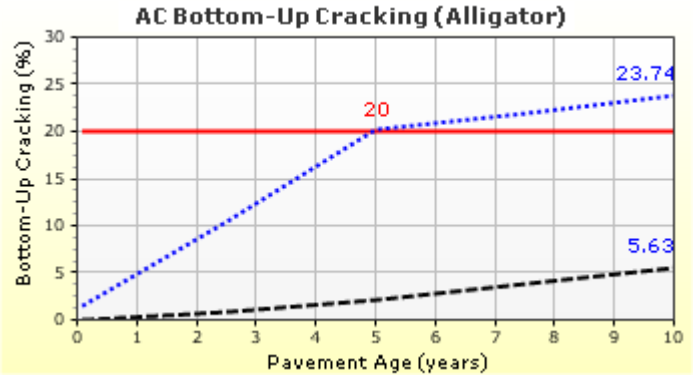
Distress Prediction Summary

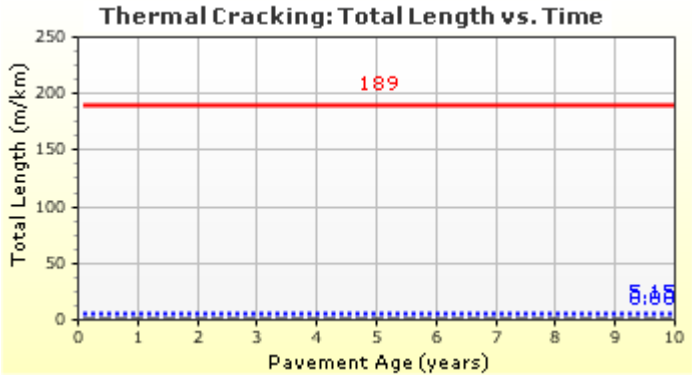
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.79	90.00	86.94	Fail
Permanent deformation - total pavement (mm)	20.00	19.08	90.00	94.50	Pass
AC bottom-up fatigue cracking (percent)	20.00	23.74	90.00	84.54	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	652.15	90.00	72.60	Fail
Permanent deformation - AC only (mm)	5.00	7.53	50.00	13.83	Fail

Distress Charts







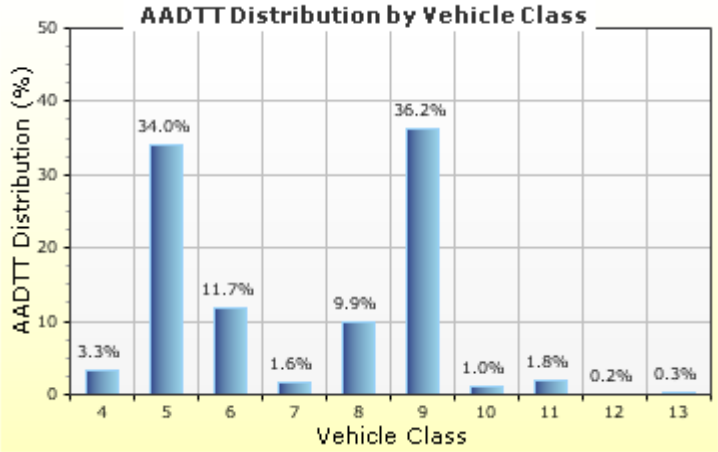


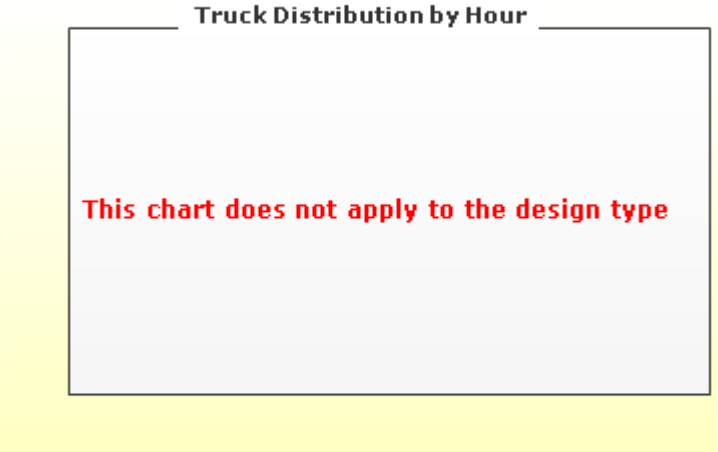


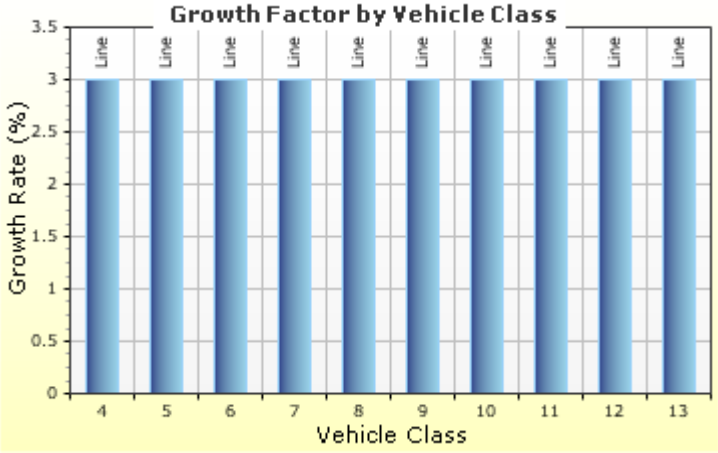
Traffic Inputs

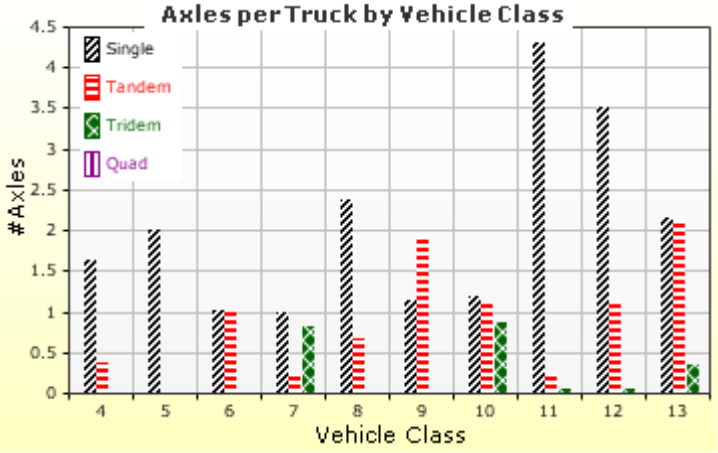
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

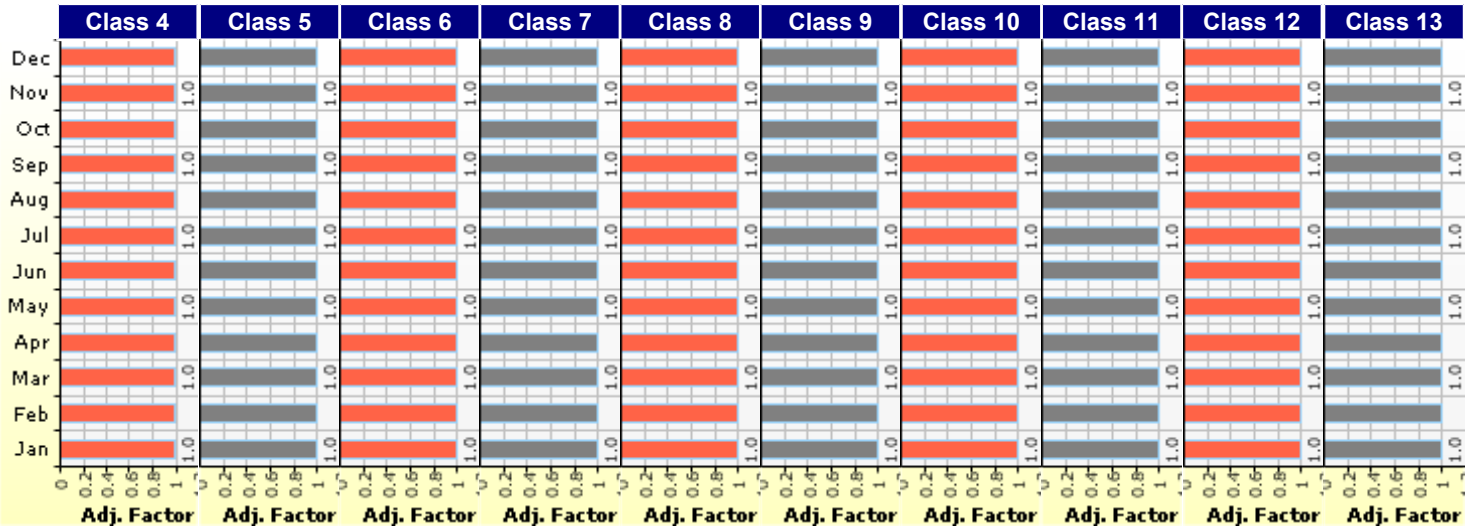








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

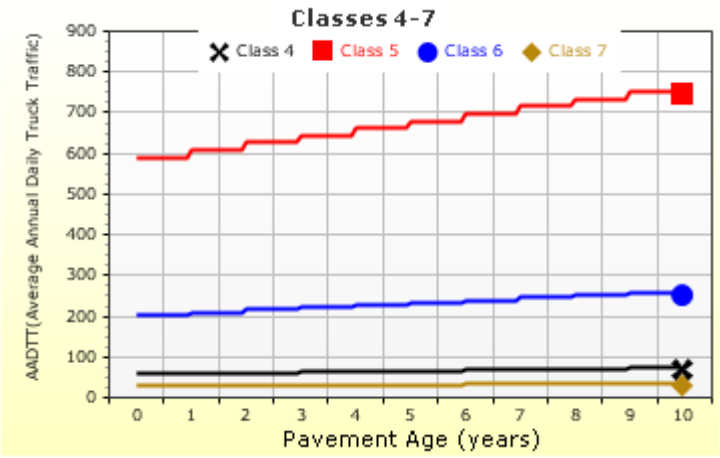
Wheelbase does not apply

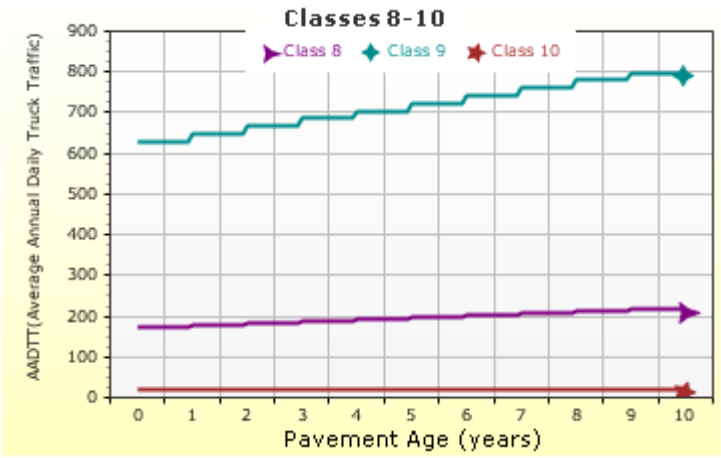
Number of Axles per Truck

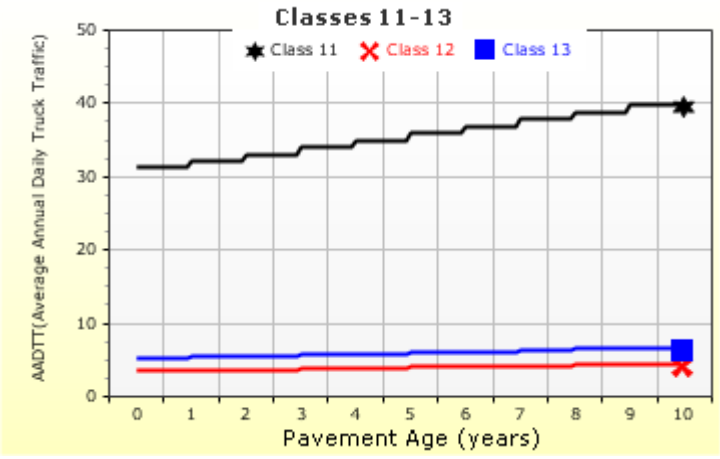
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

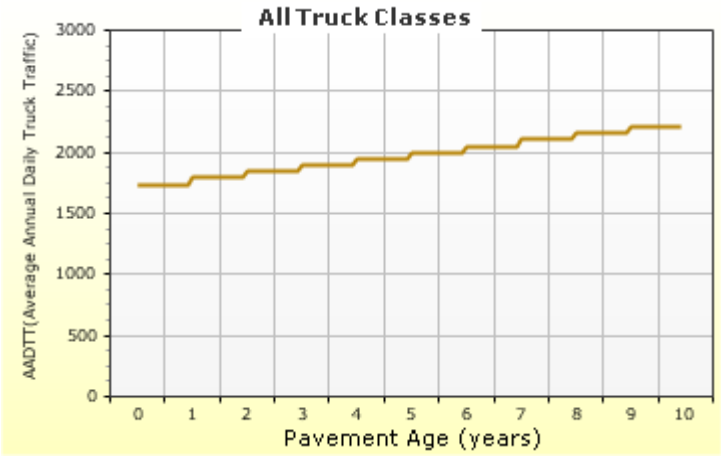
AADTT (Average Annual Daily Truck Traffic) Growth

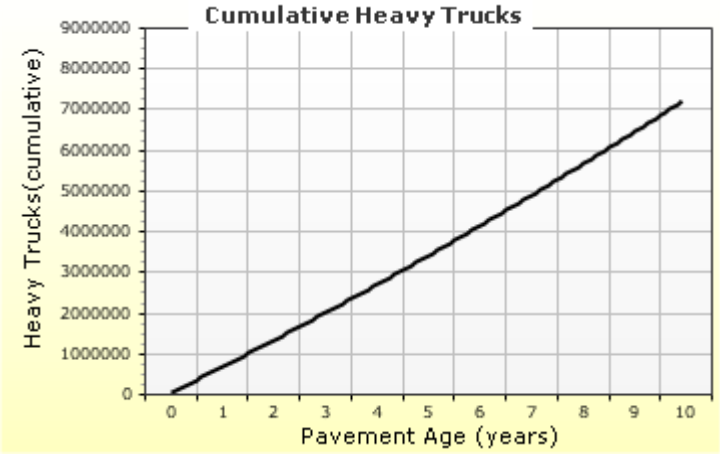
*** Traffic cap is not enforced**







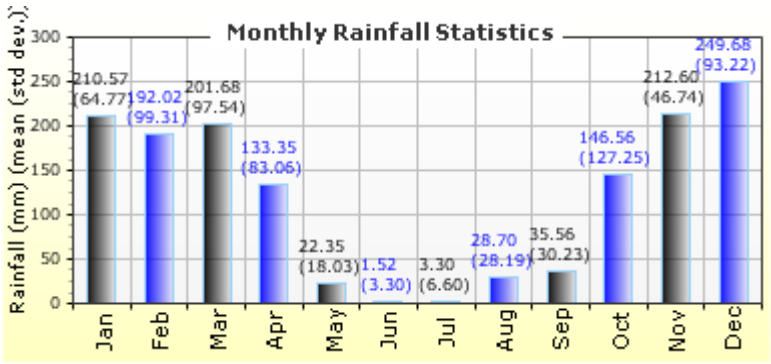




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
BRASILIA, DF	-15.78000 -47.91000 1159

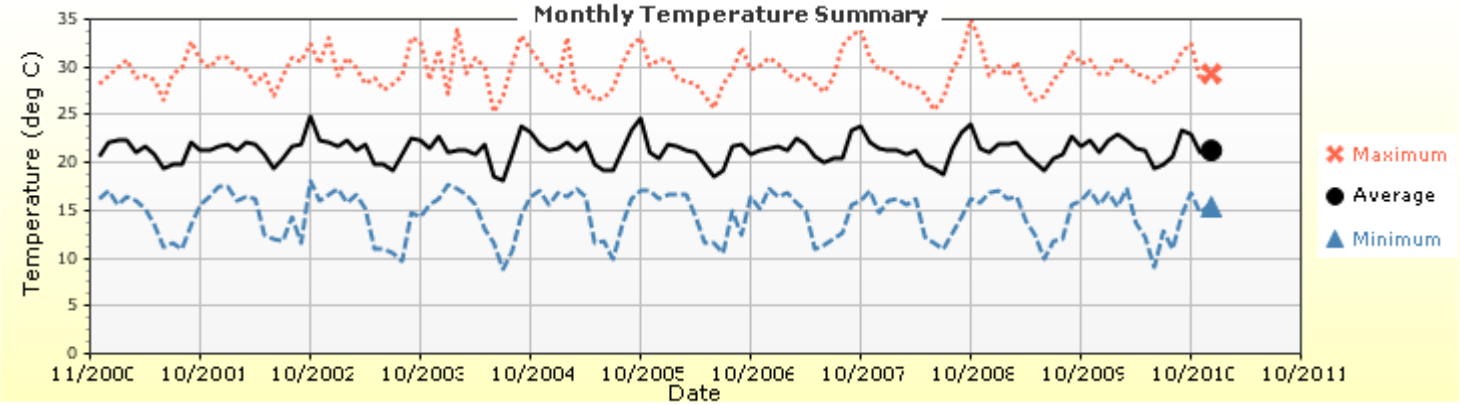


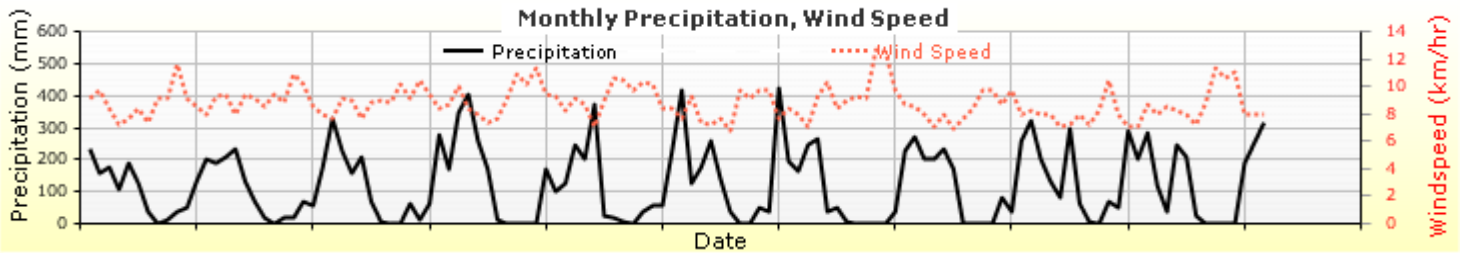
Annual Statistics:

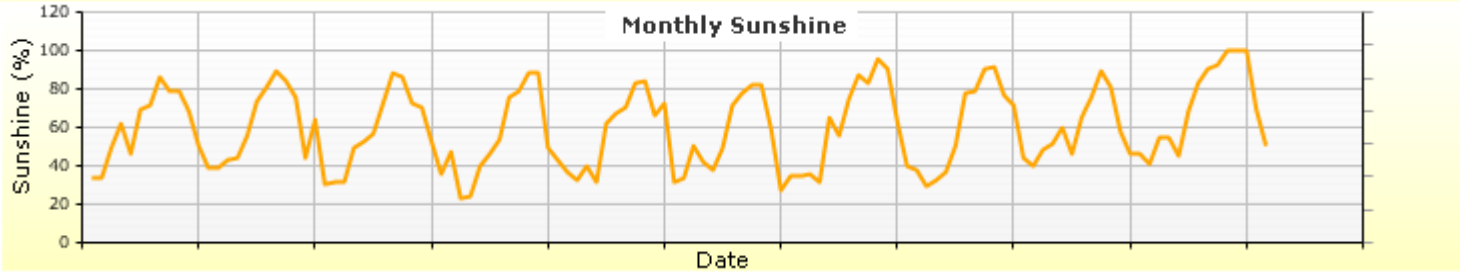
Mean annual air temperature (ºC)	21.35
Mean annual precipitation (mm)	1461.01
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

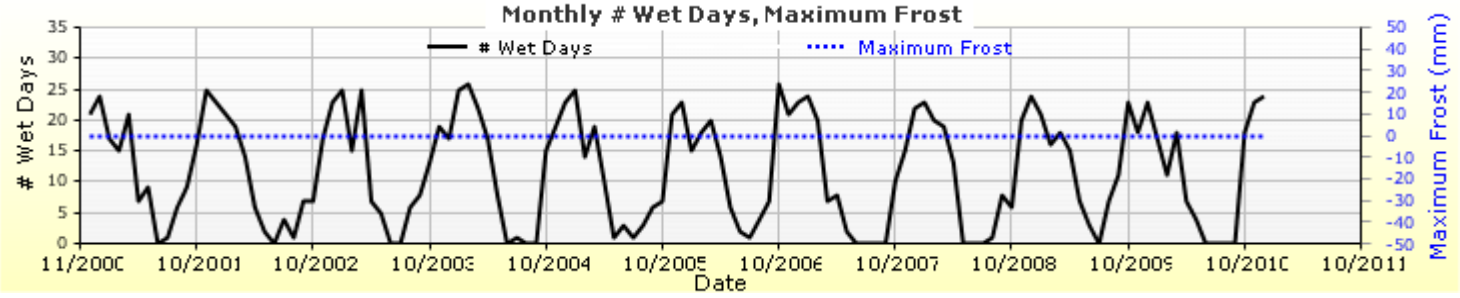
Water table depth (m): 3.05

Monthly Climate Summary:

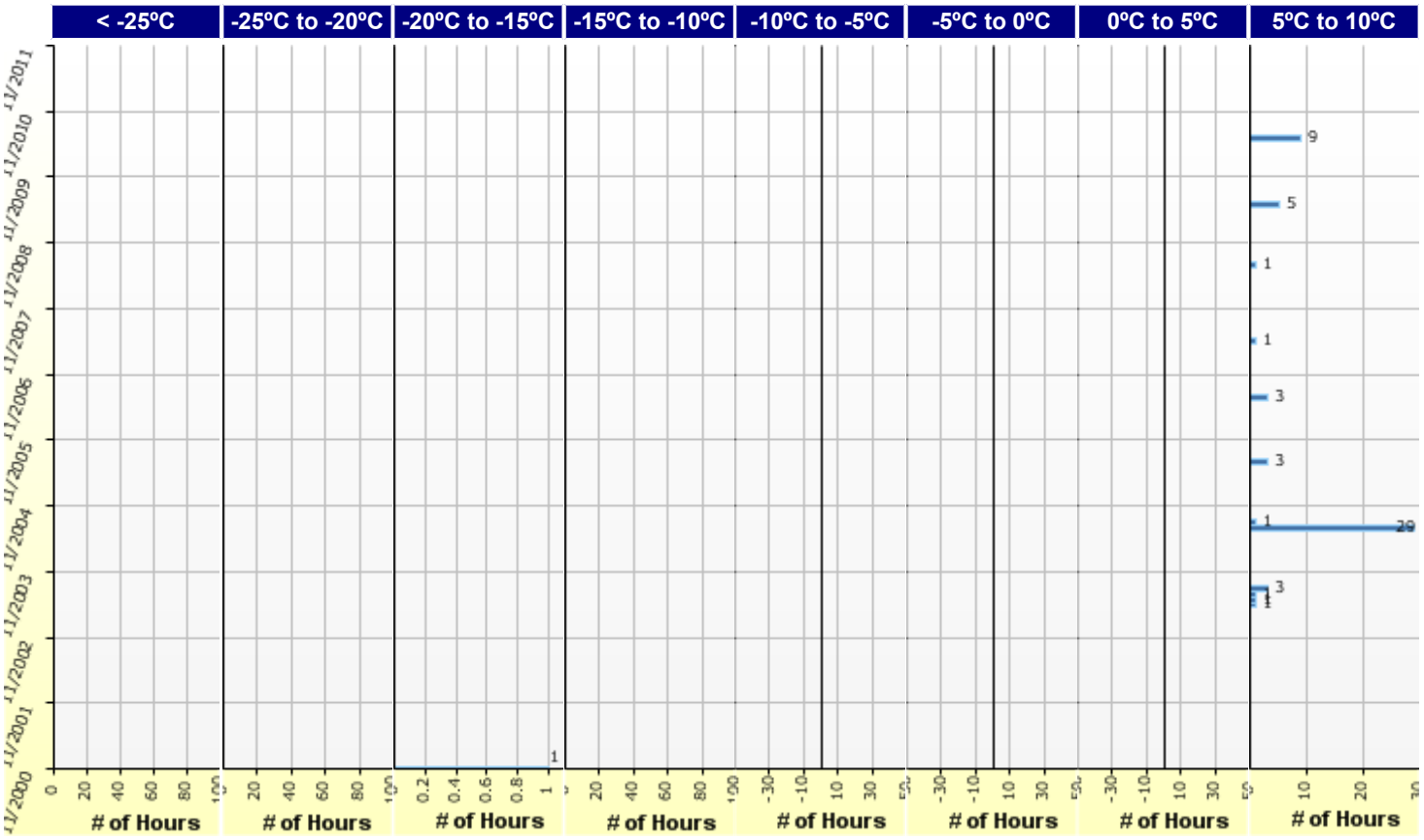


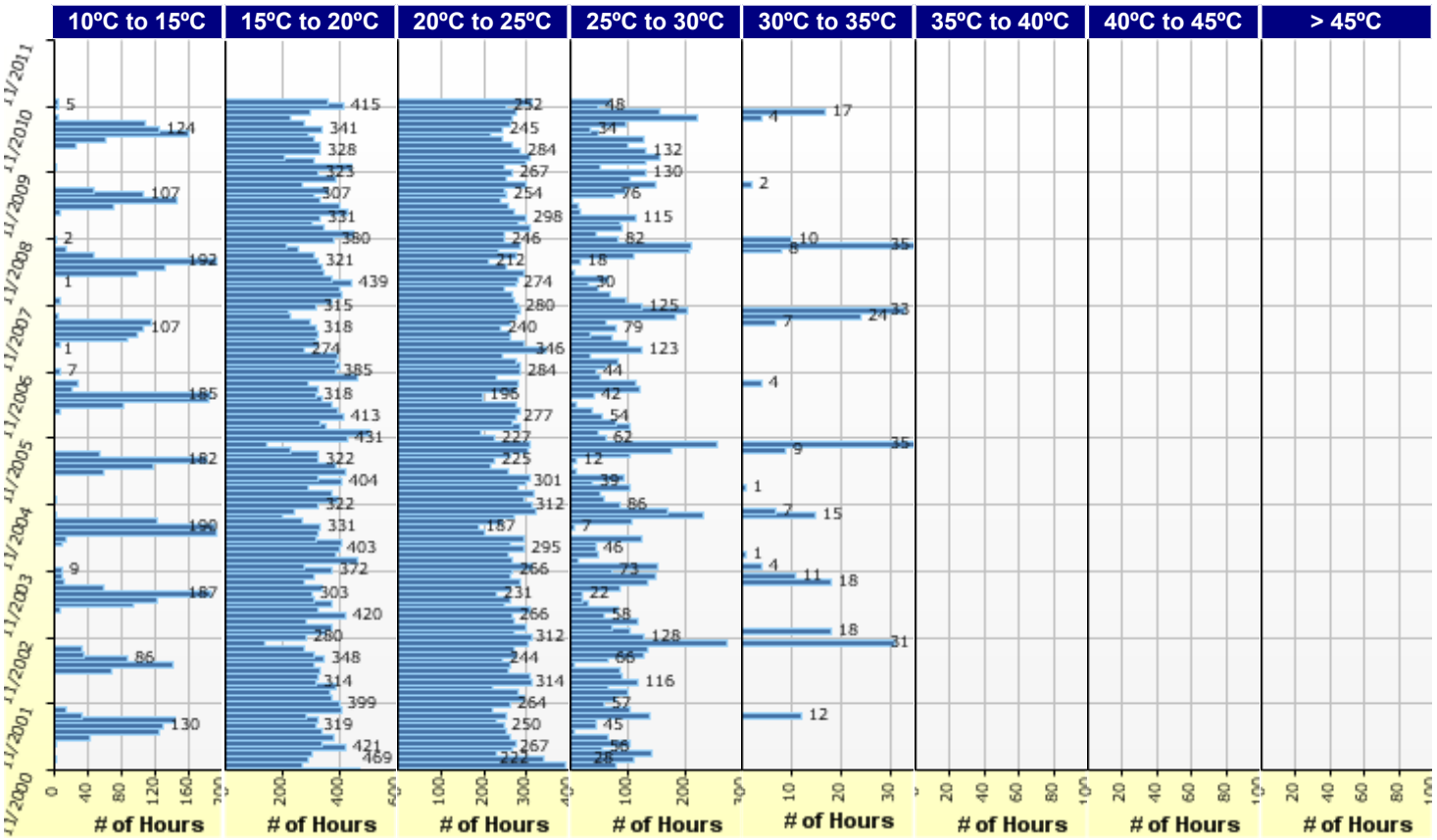






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

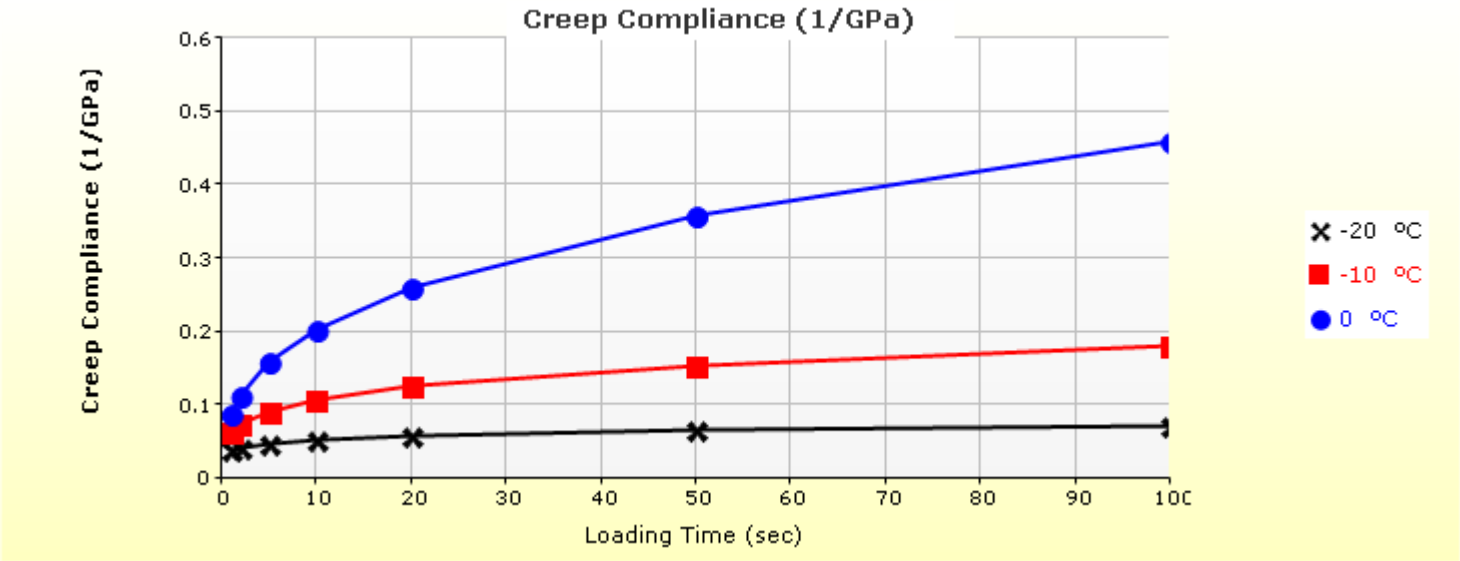
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

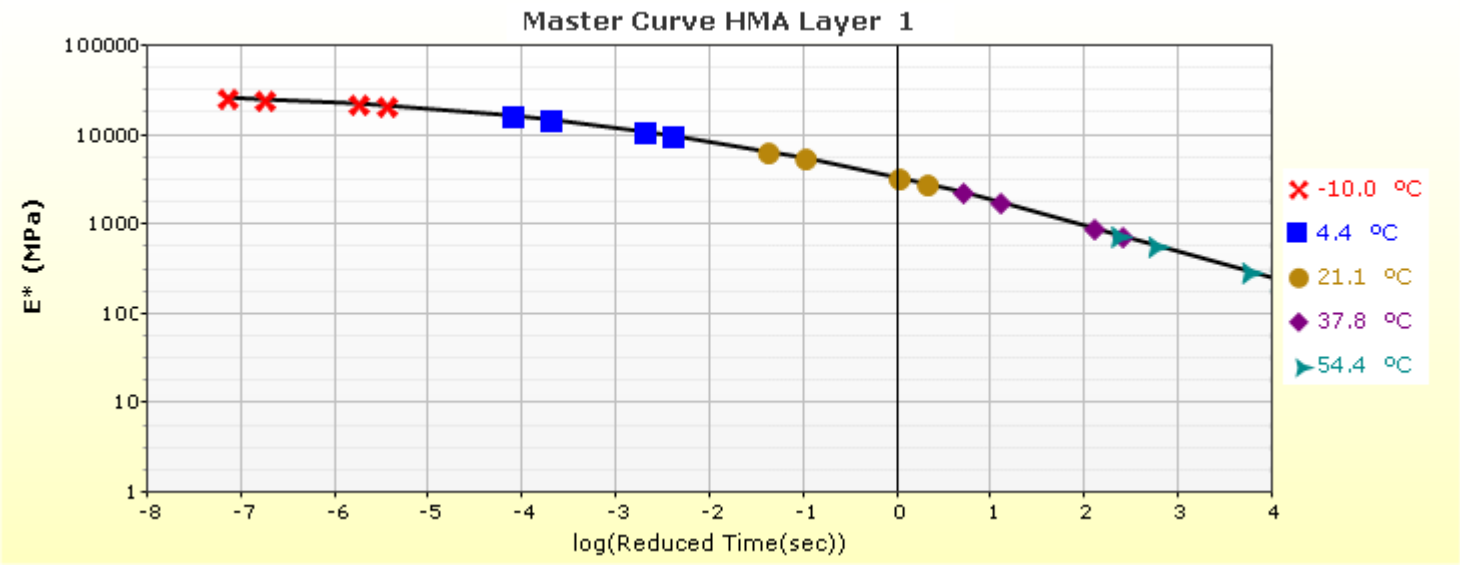
Indirect tensile strength at -10 ºC (MPa)	2.69

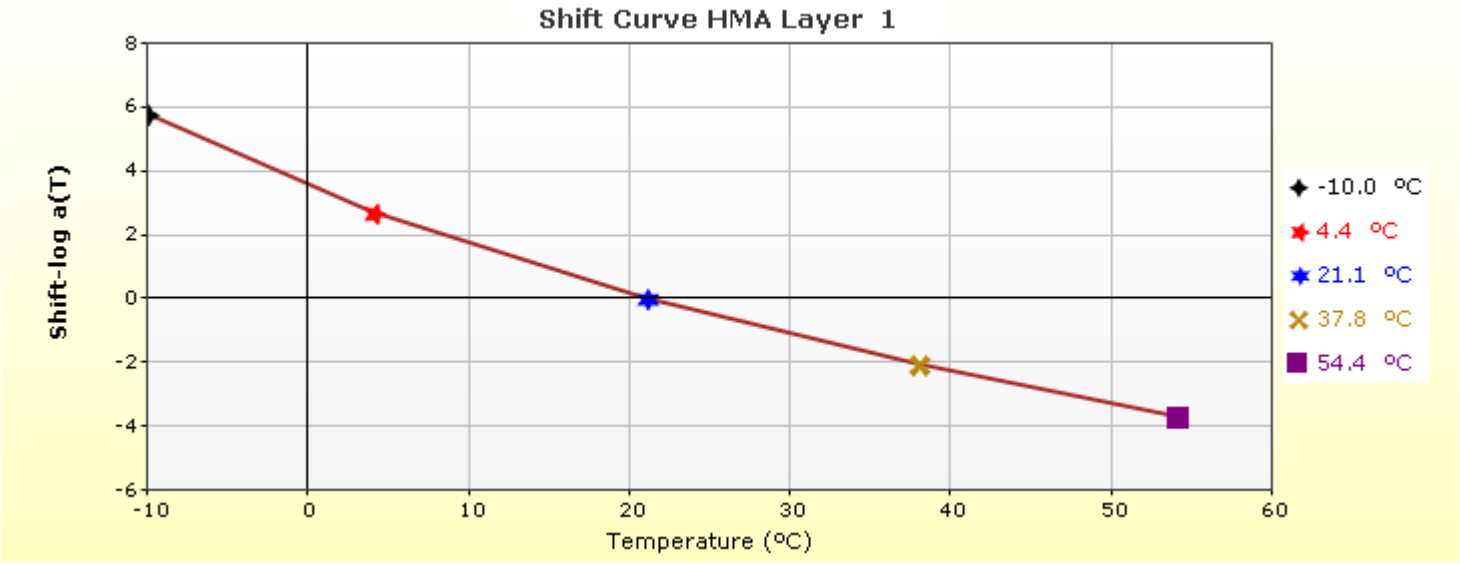
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

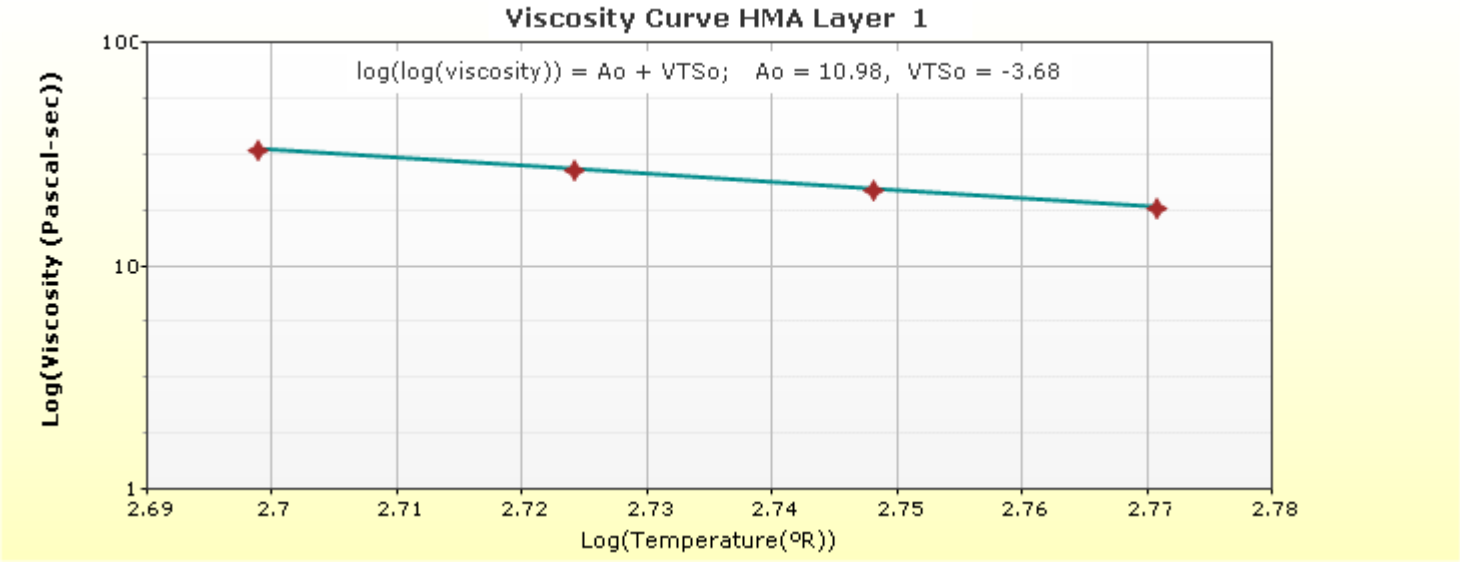
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



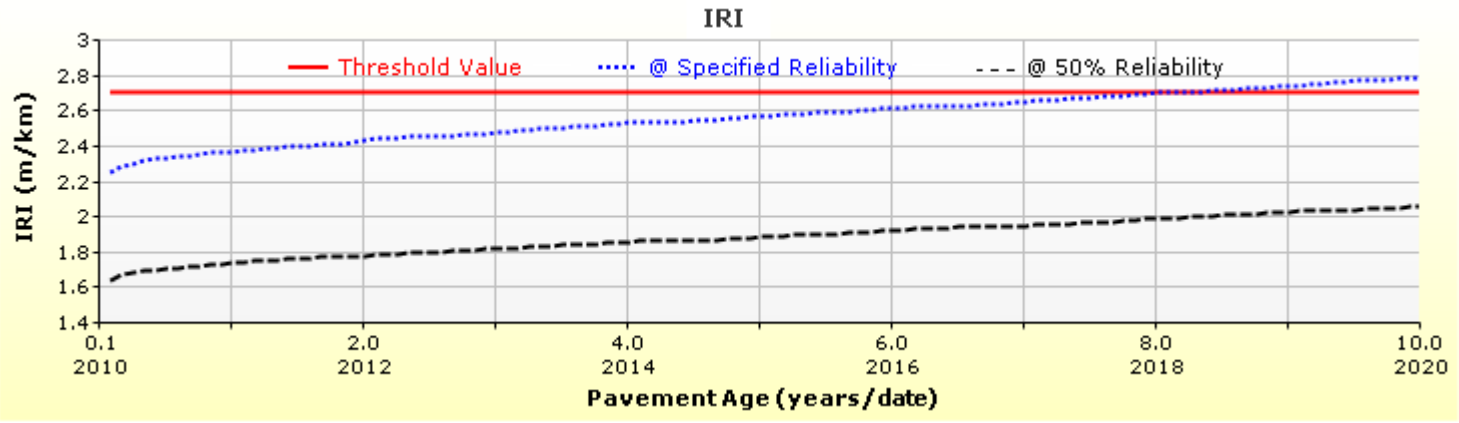
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

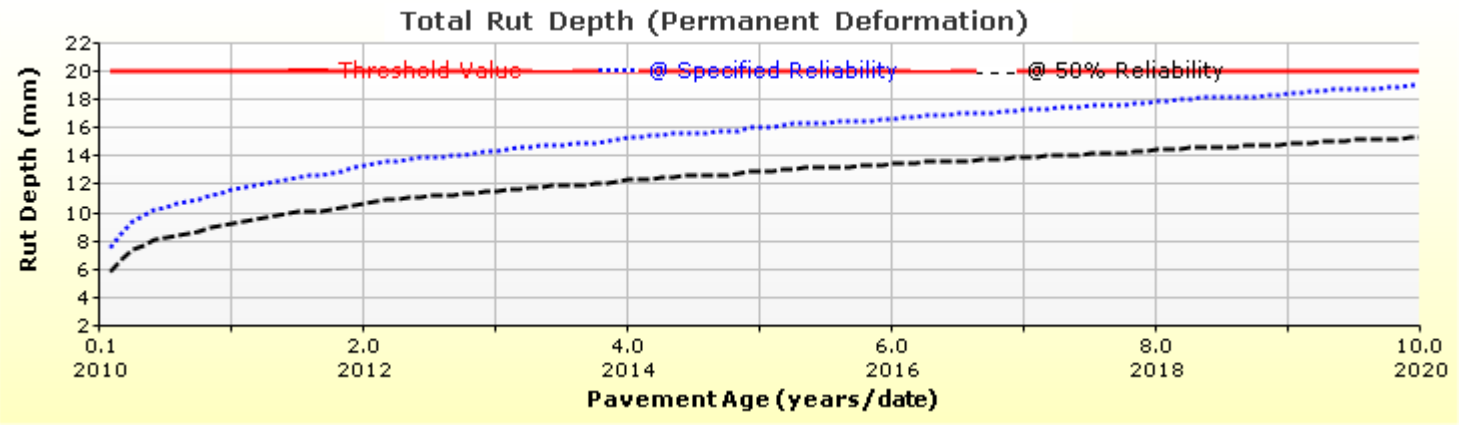


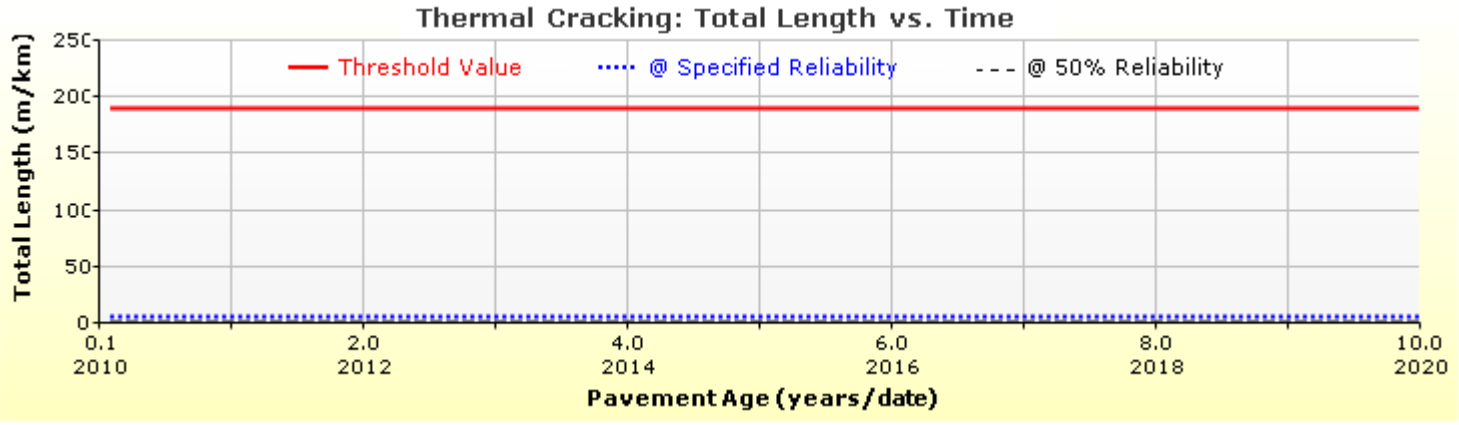


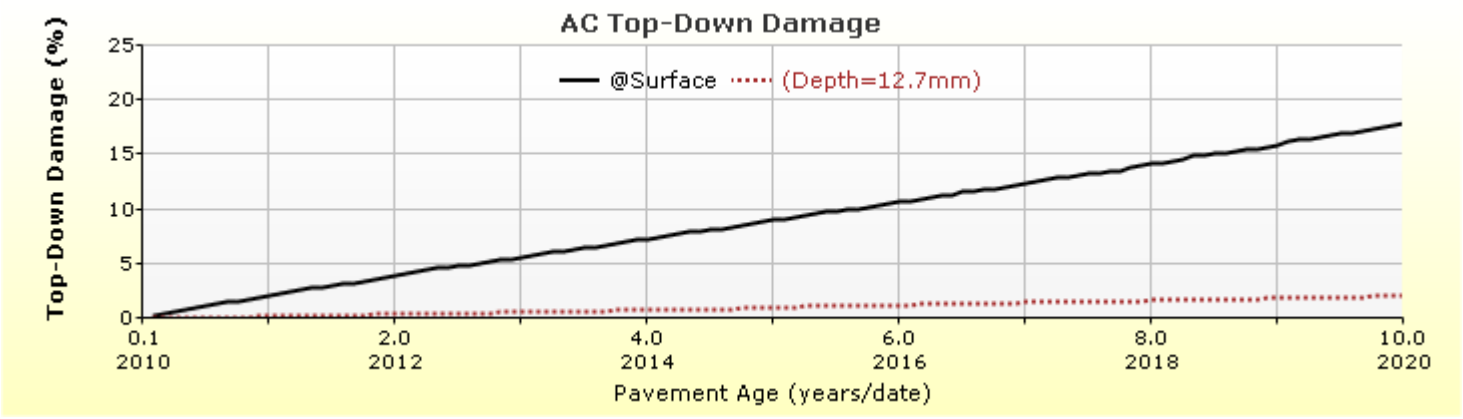


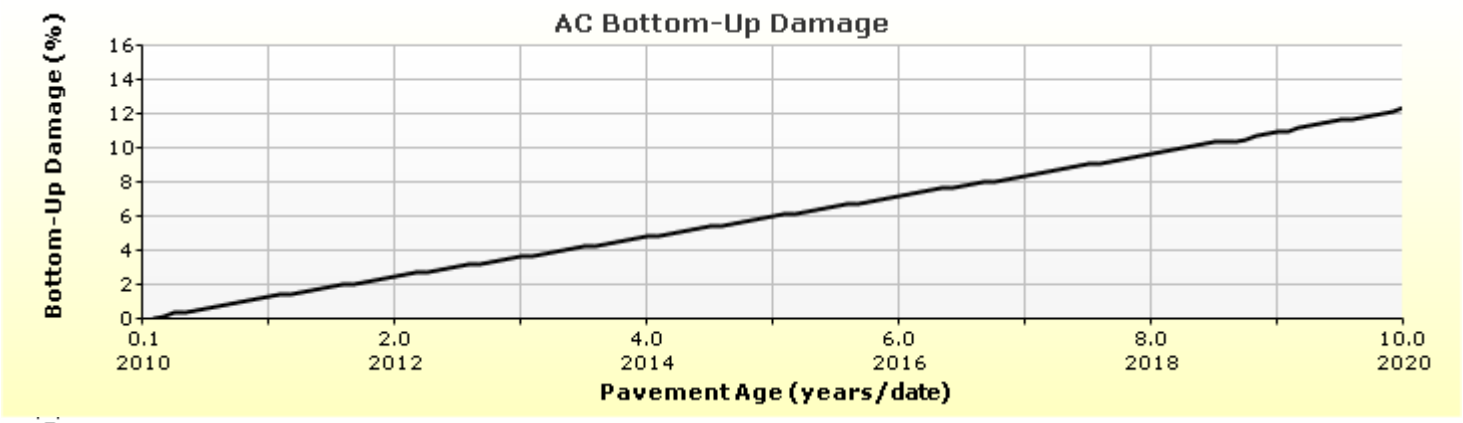
Analysis Output Charts

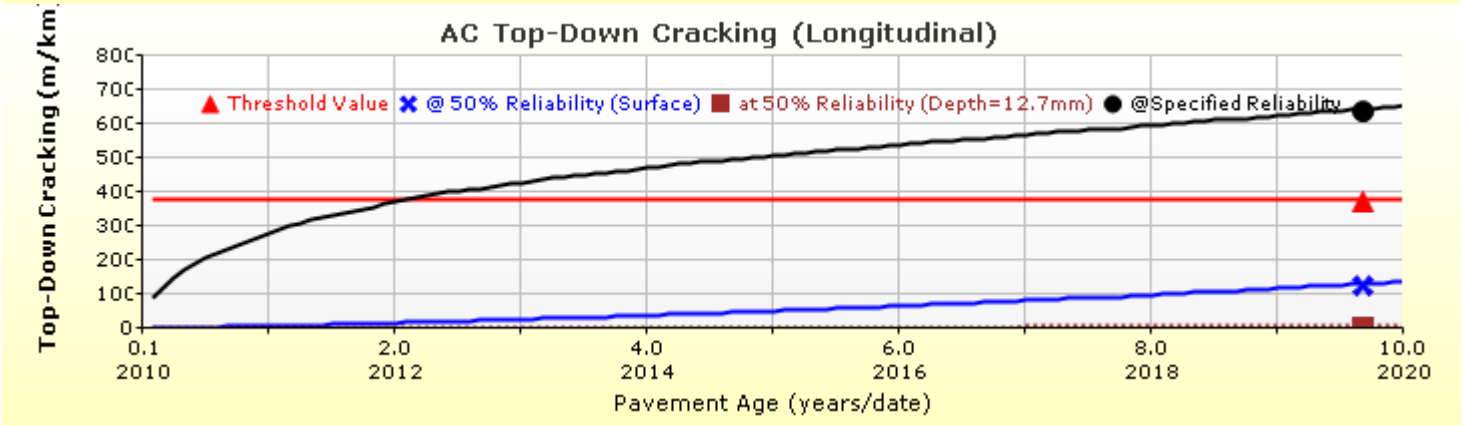


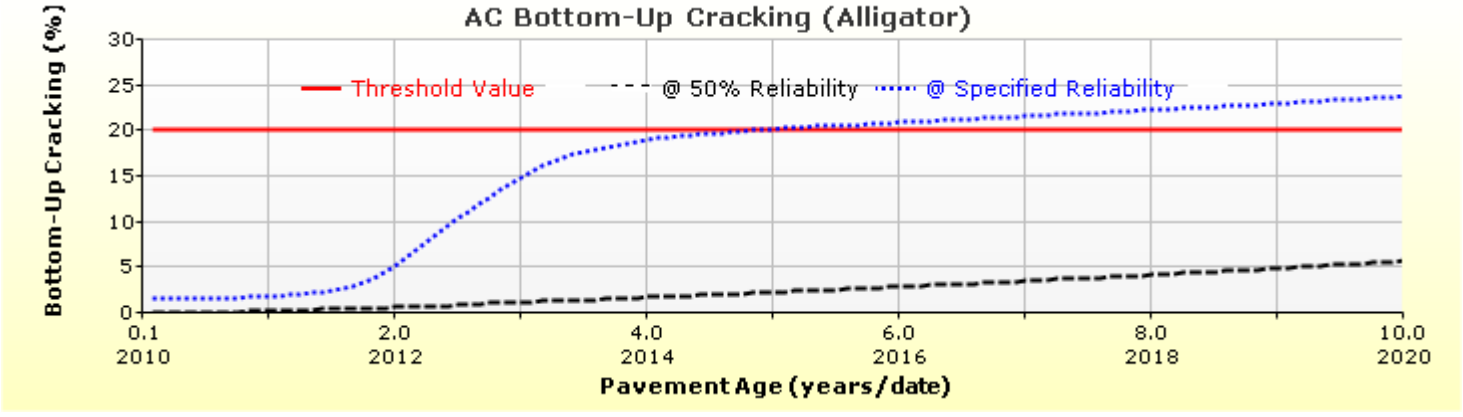


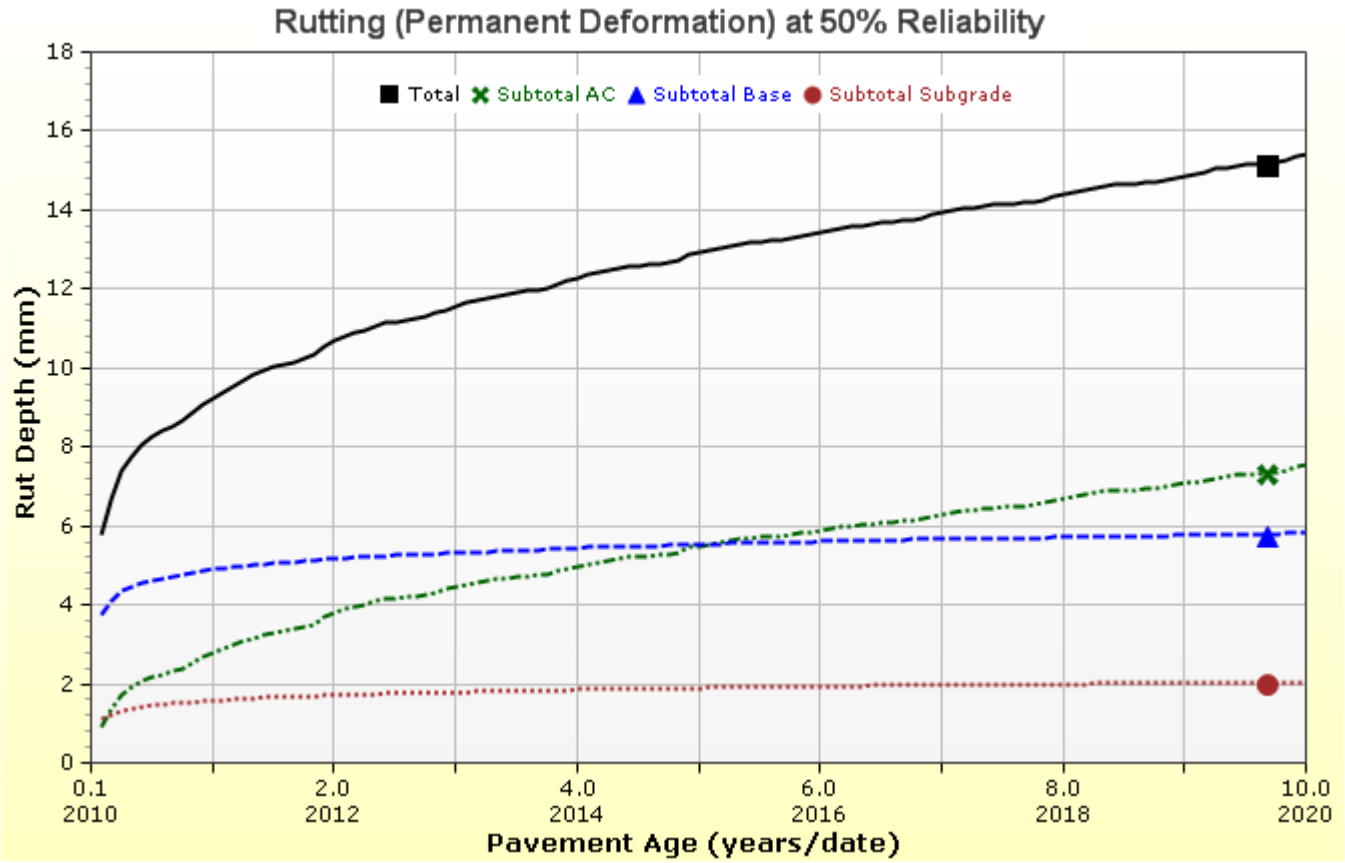


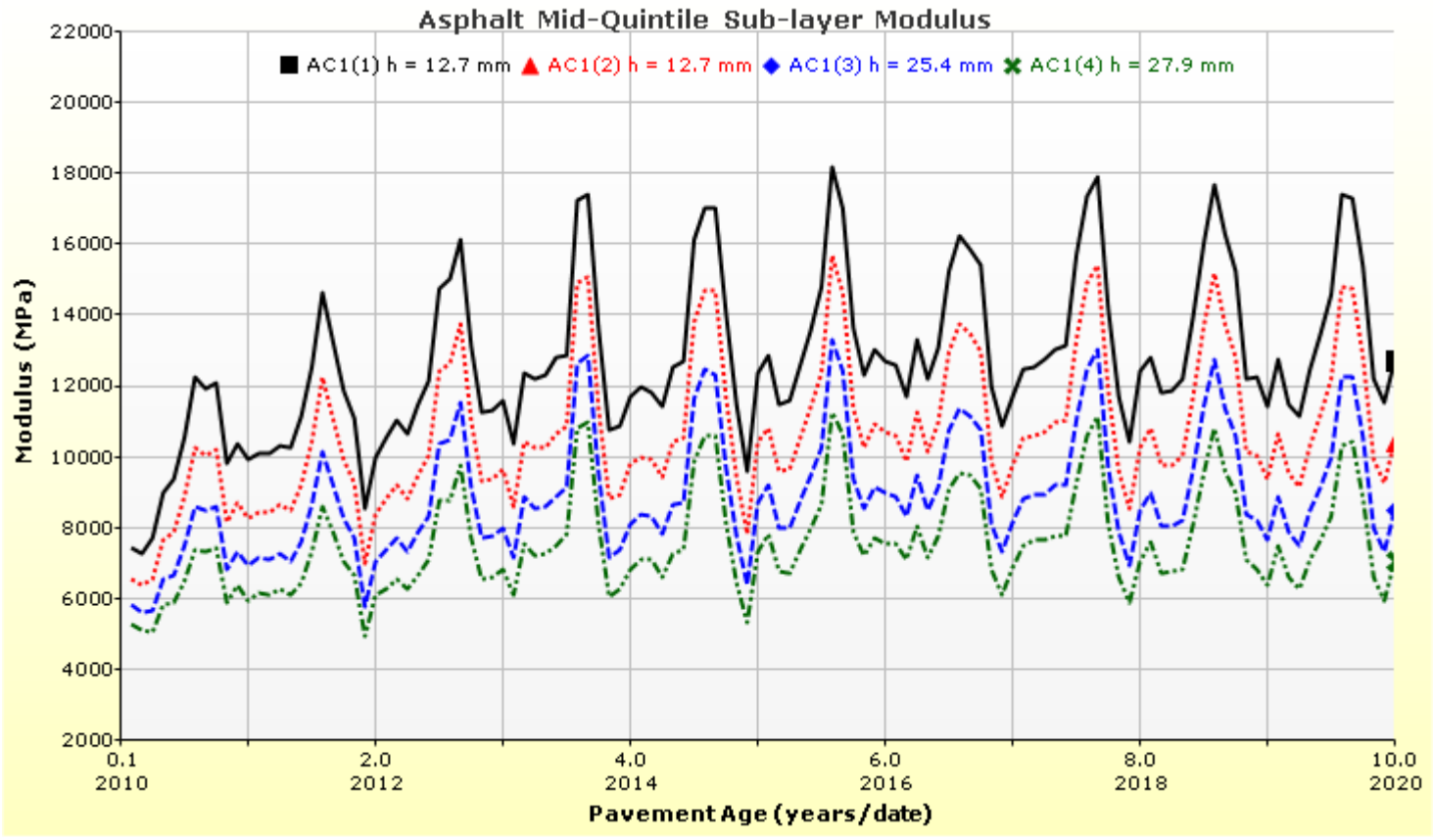

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

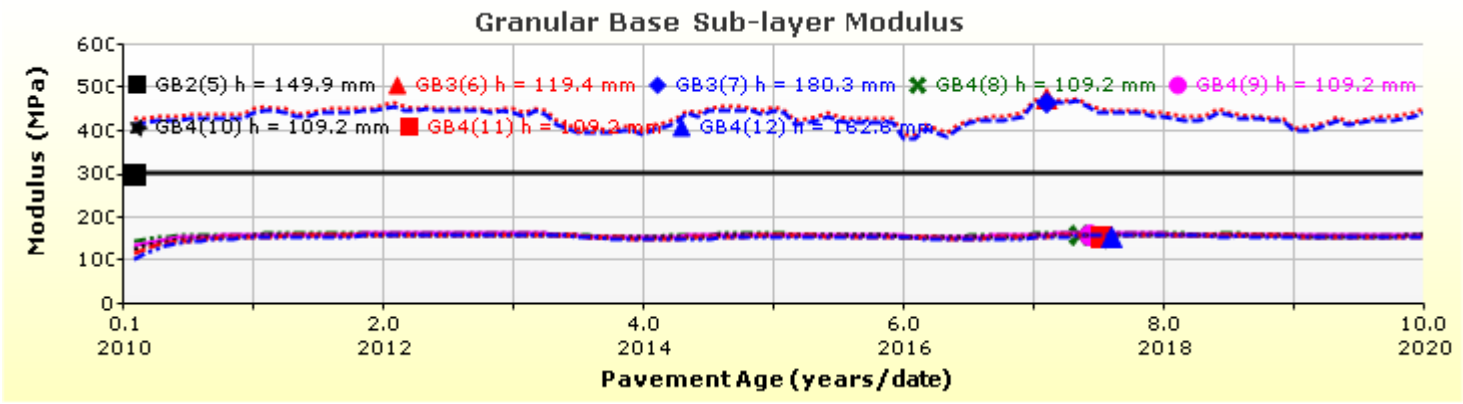

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

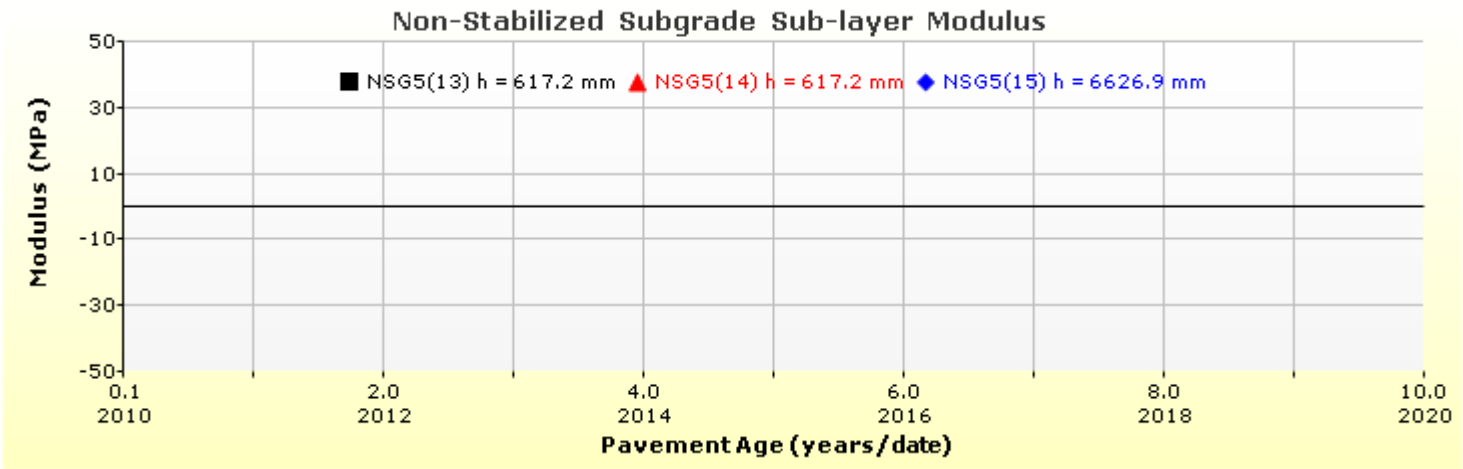

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 1
Bf2: 1
Bf3: 1

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestDF_precip

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestDF_precip.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -15.78, -47.91

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

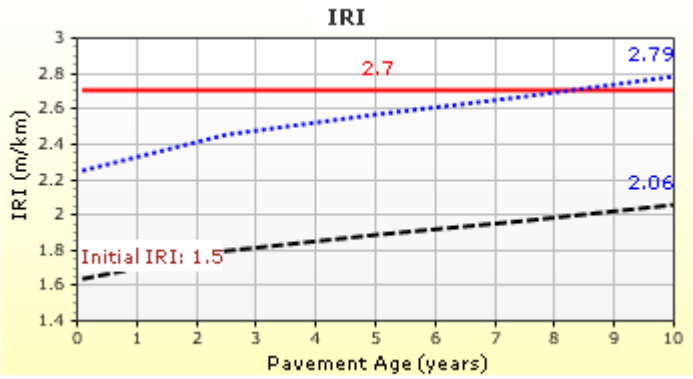
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

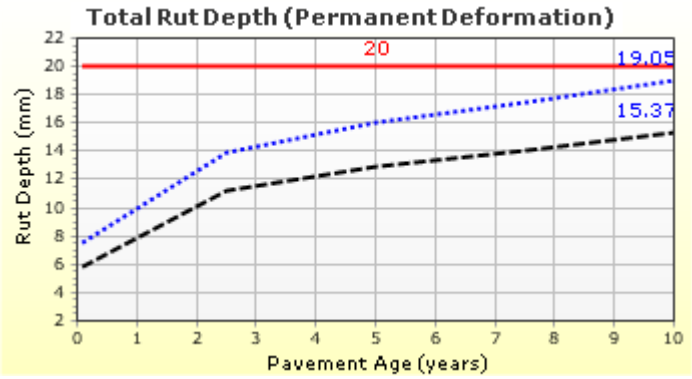
Design Outputs

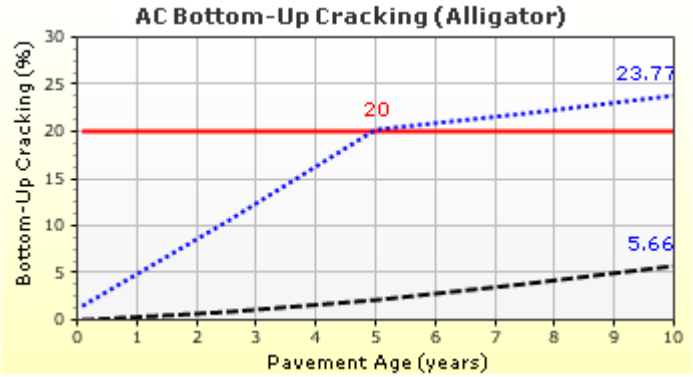
Distress Prediction Summary

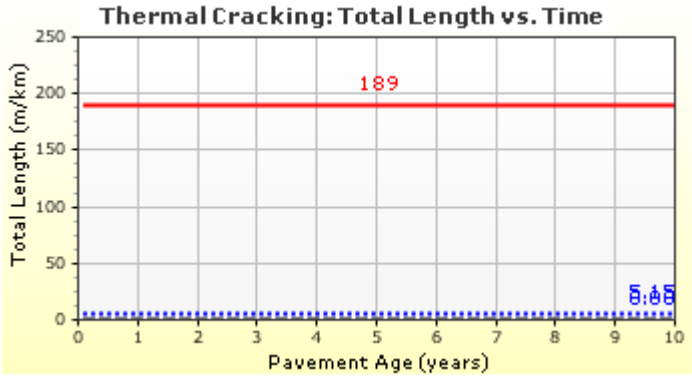
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.79	90.00	86.94	Fail
Permanent deformation - total pavement (mm)	20.00	19.04	90.00	94.67	Pass
AC bottom-up fatigue cracking (percent)	20.00	23.77	90.00	84.49	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	651.56	90.00	72.64	Fail
Permanent deformation - AC only (mm)	5.00	7.48	50.00	14.21	Fail

Distress Charts







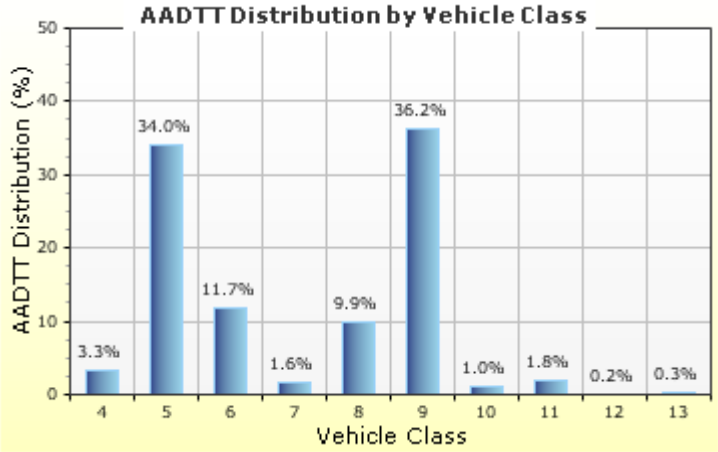


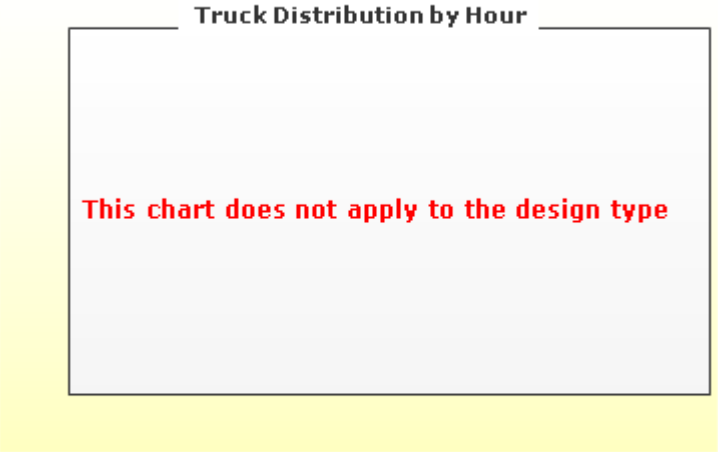


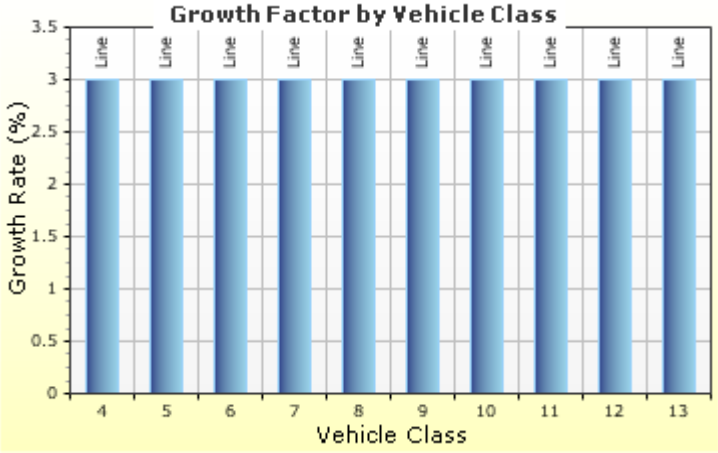
Traffic Inputs

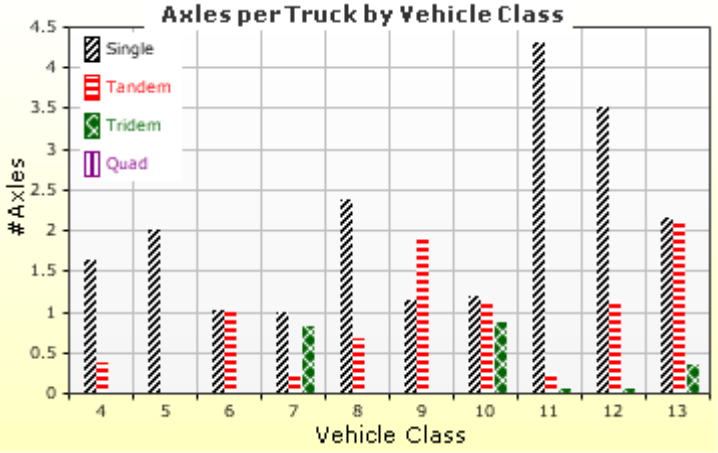
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

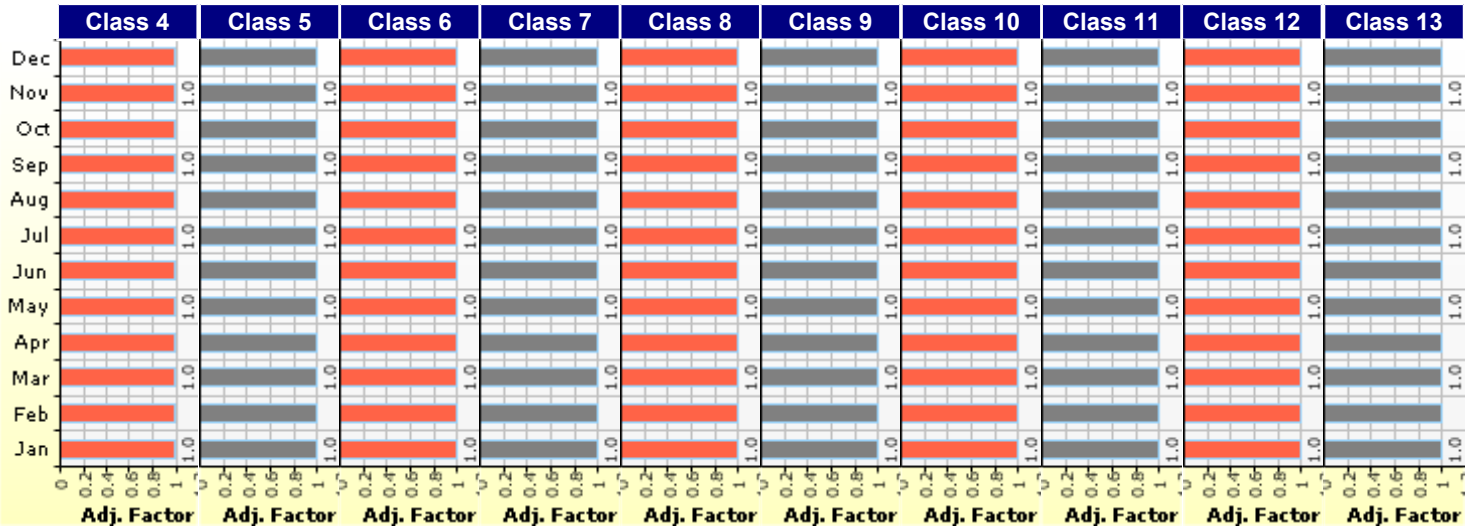








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

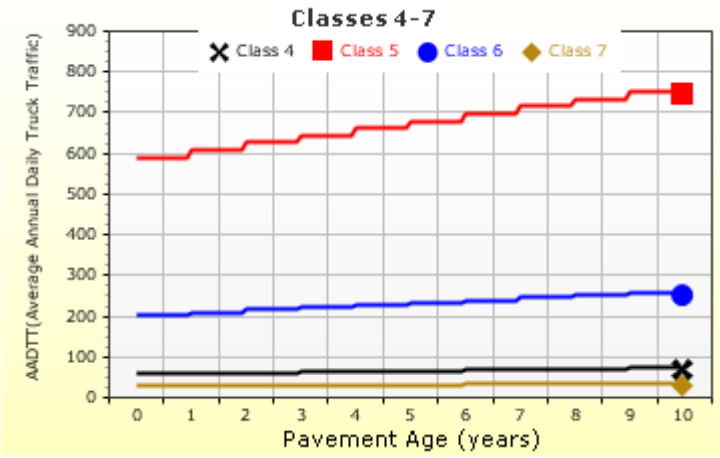
Wheelbase does not apply

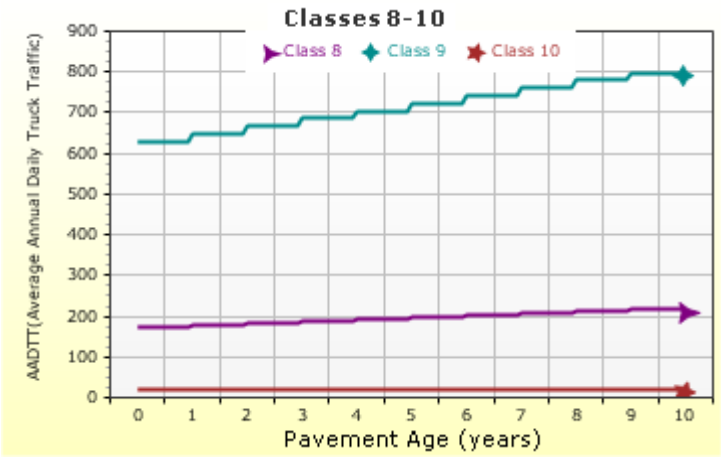
Number of Axles per Truck

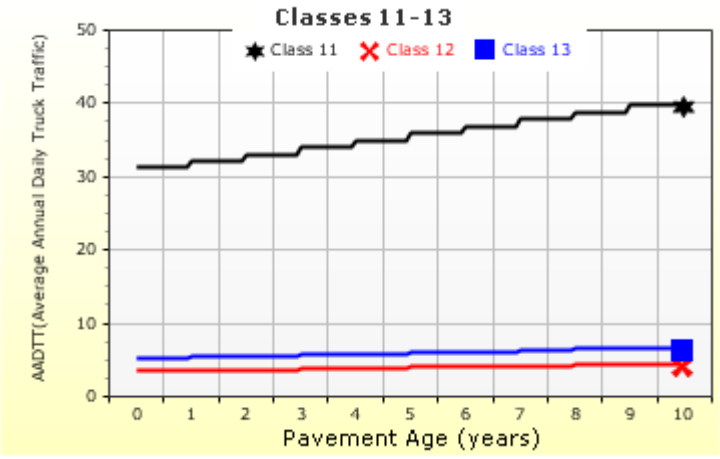
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

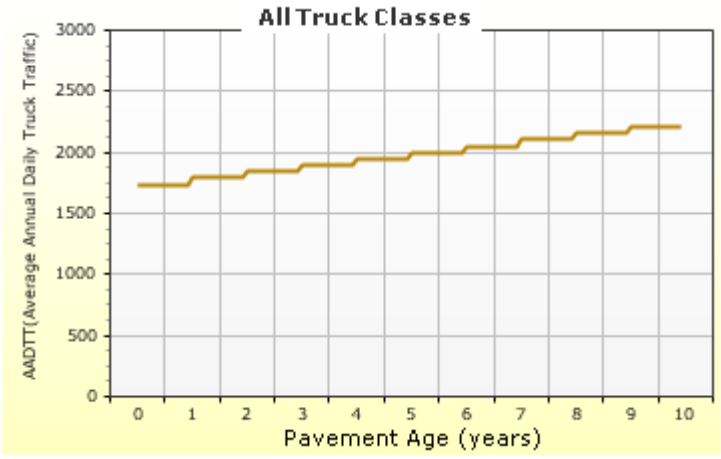
AADTT (Average Annual Daily Truck Traffic) Growth

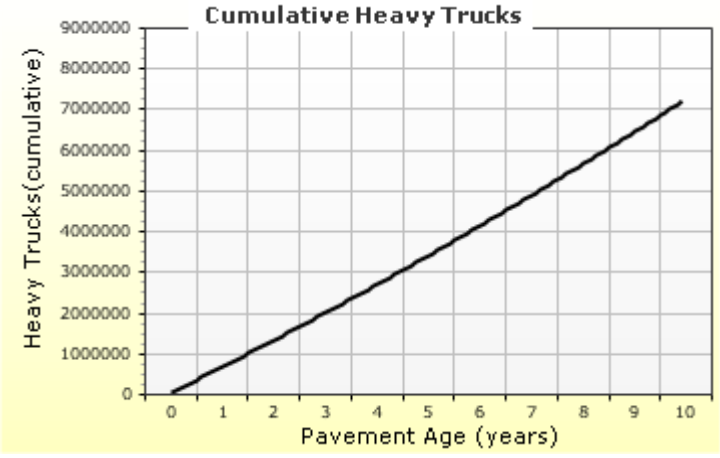
*** Traffic cap is not enforced**







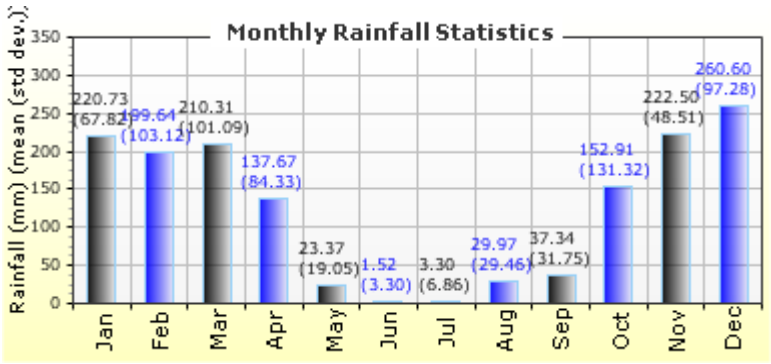




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
BRASILIA, DF	-15.78000 -47.91000 1159

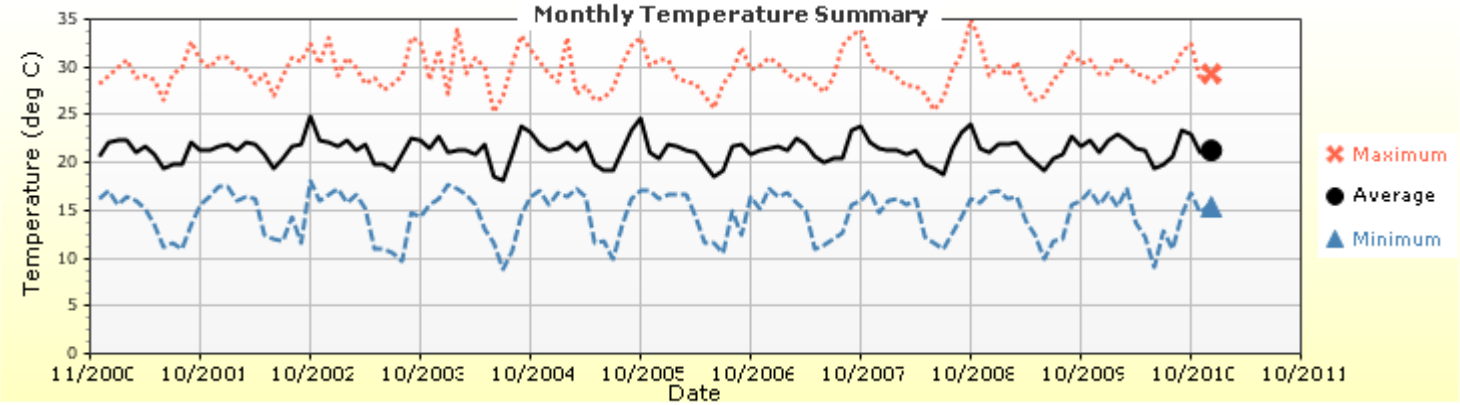


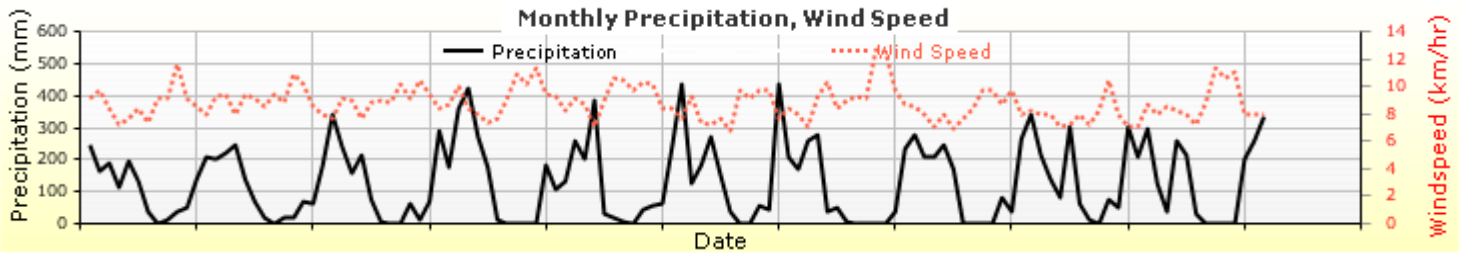
Annual Statistics:

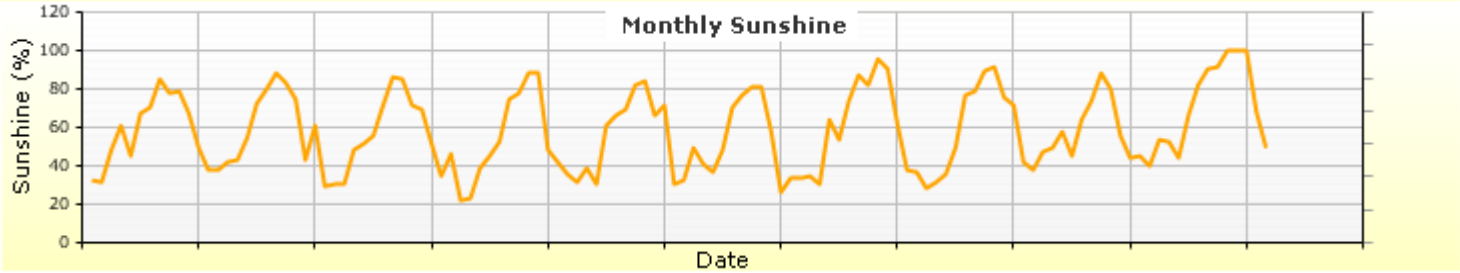
Mean annual air temperature (ºC)	21.35
Mean annual precipitation (mm)	1524.51
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

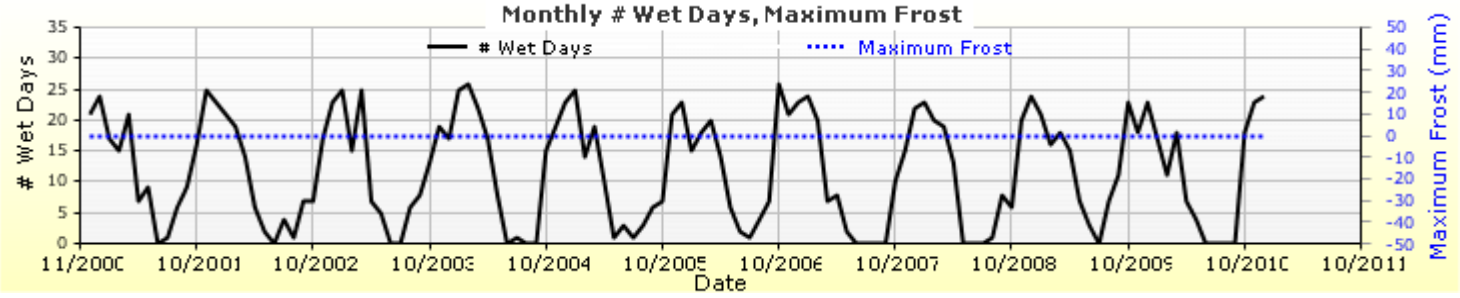
Water table depth (m): 3.05

Monthly Climate Summary:

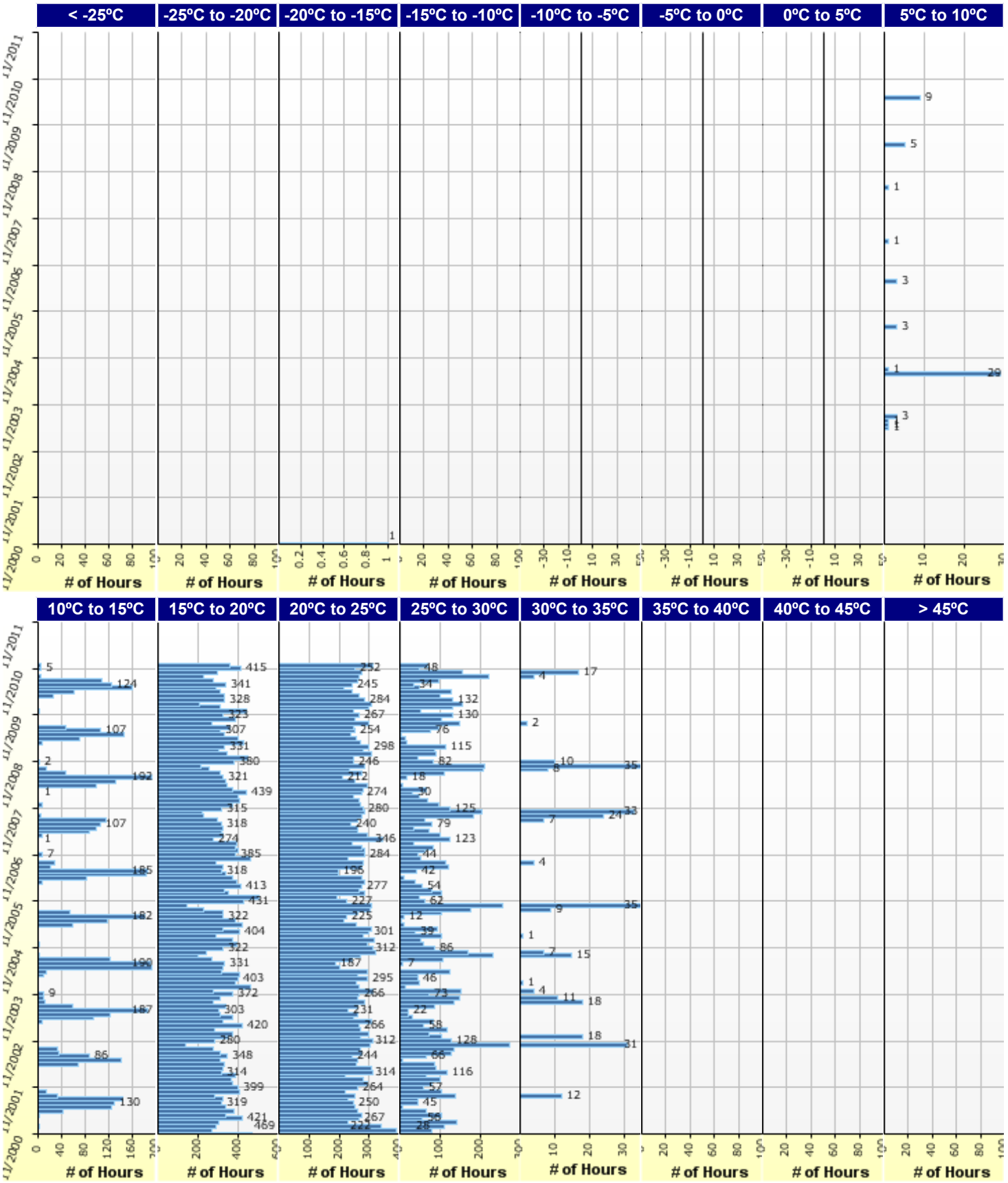








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

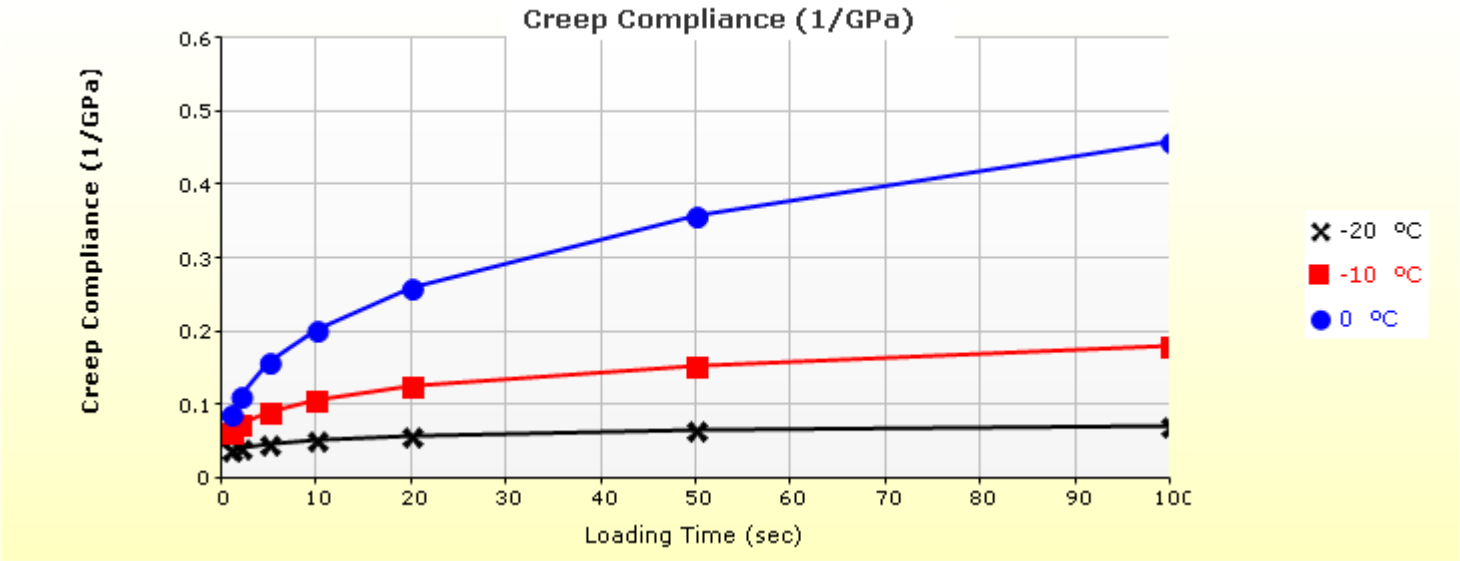
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

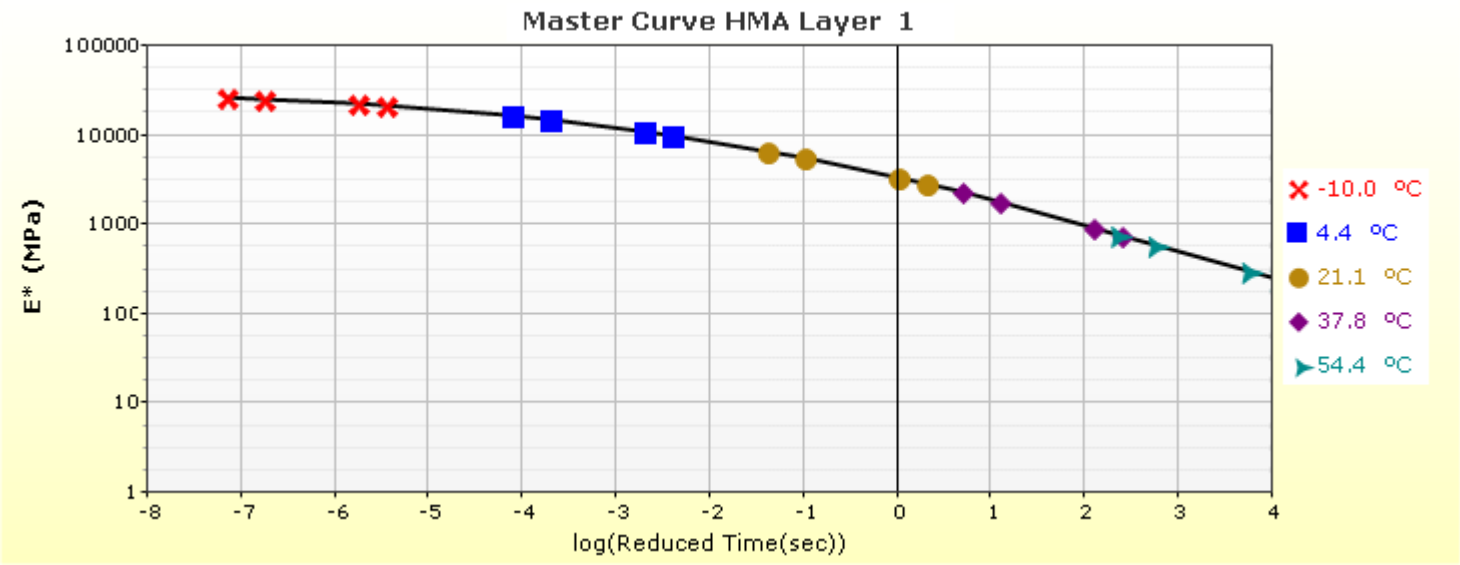
Indirect tensile strength at -10 ºC (MPa)	2.69

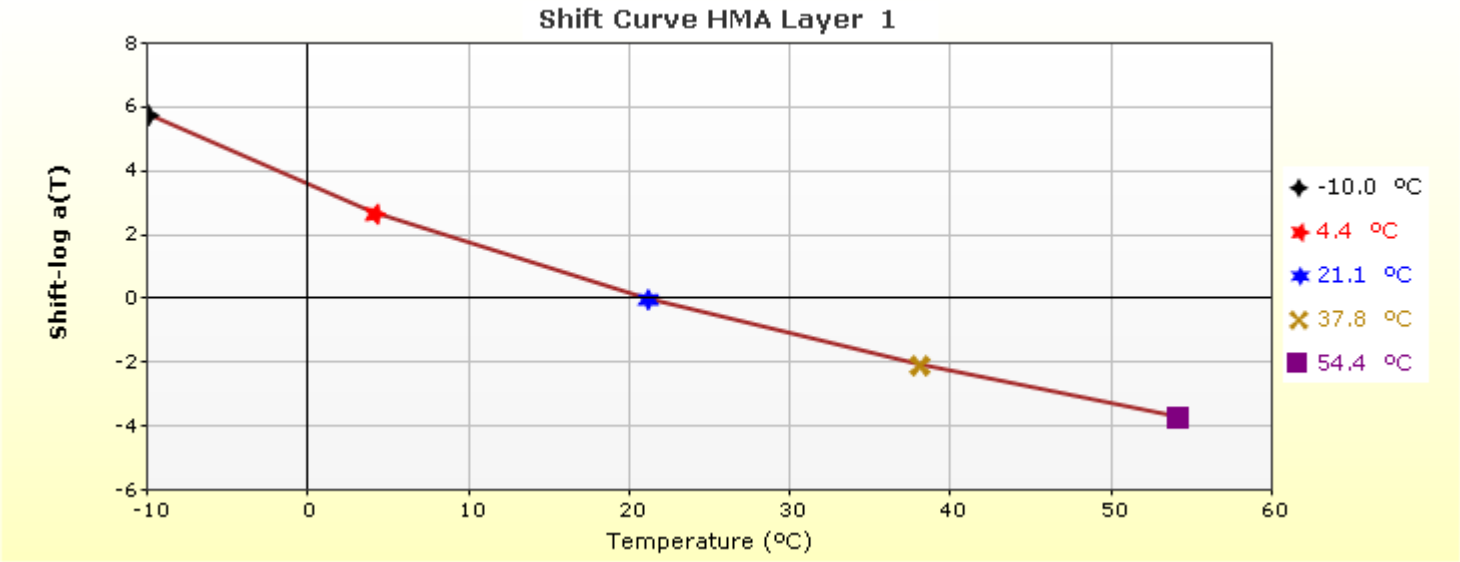
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

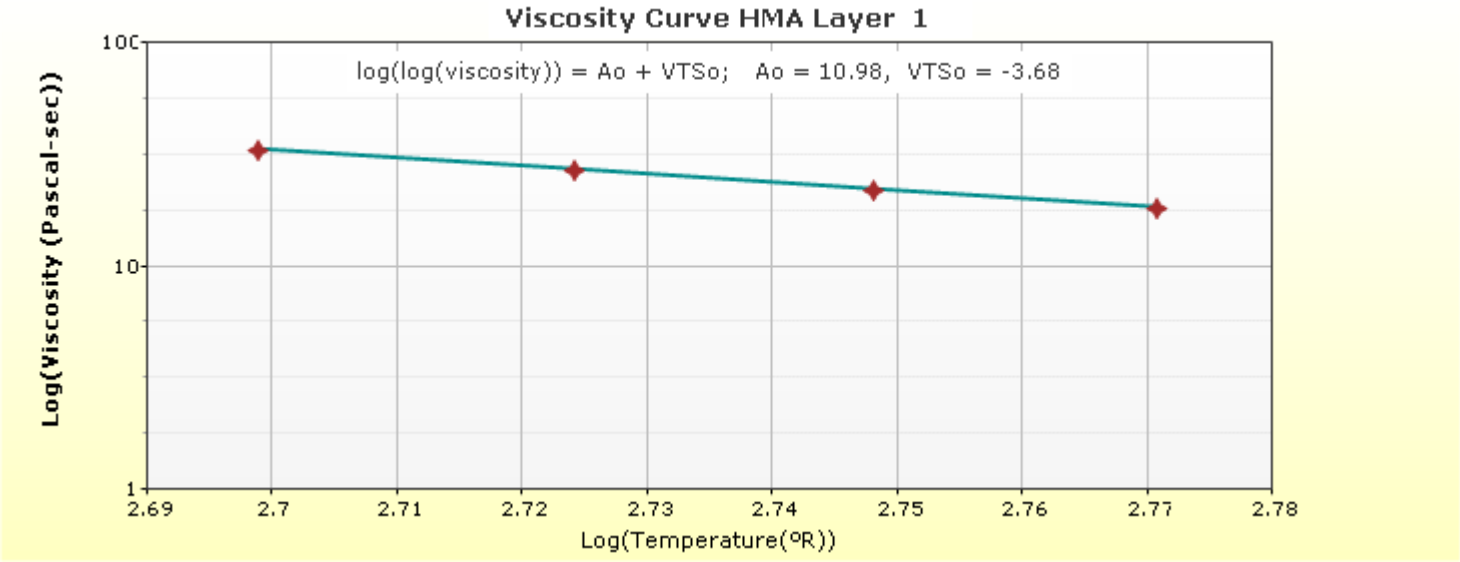
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



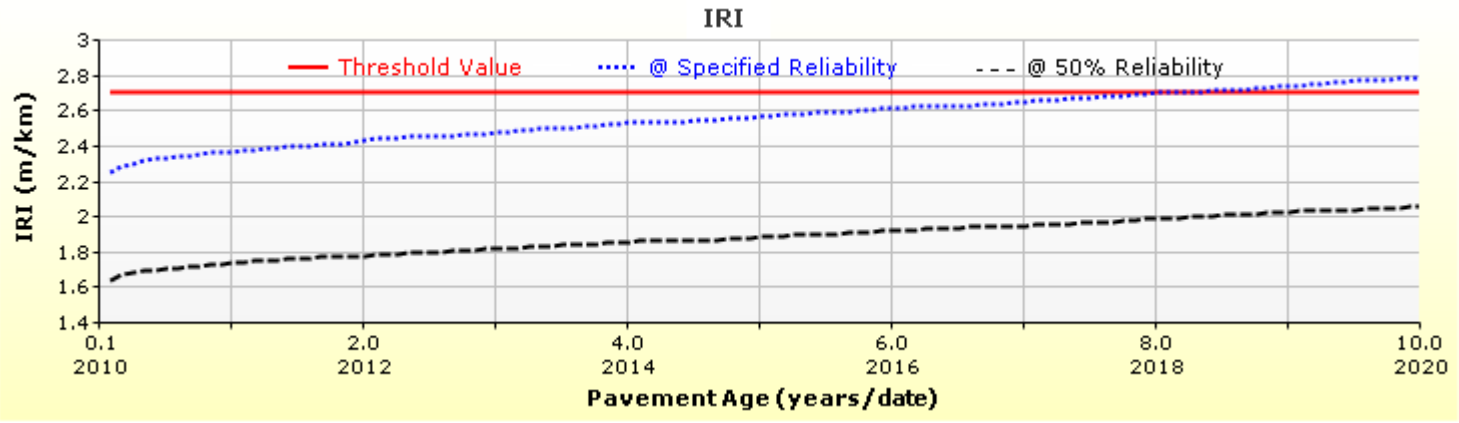
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

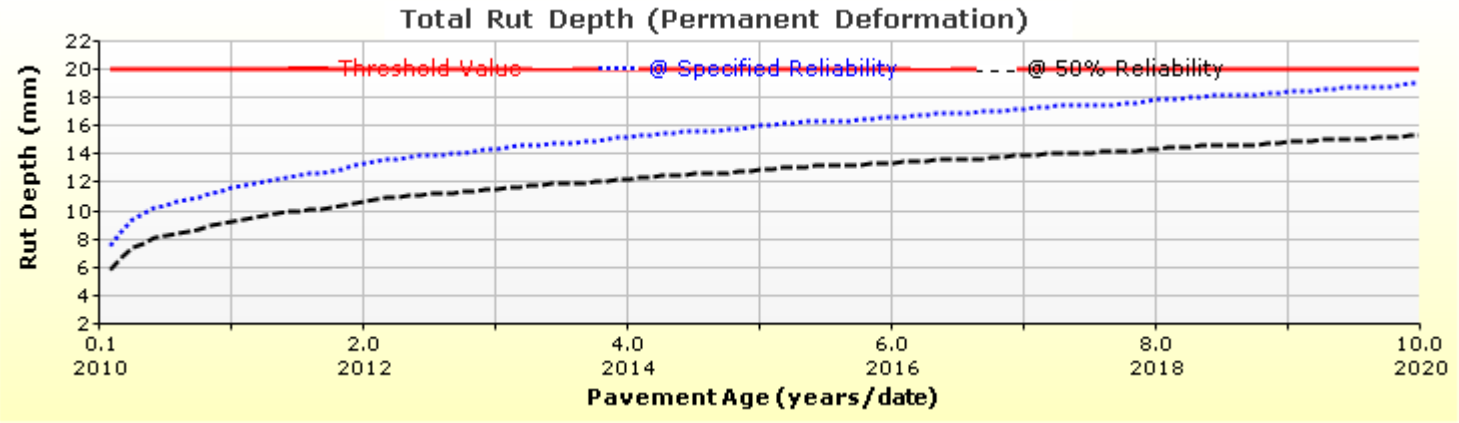


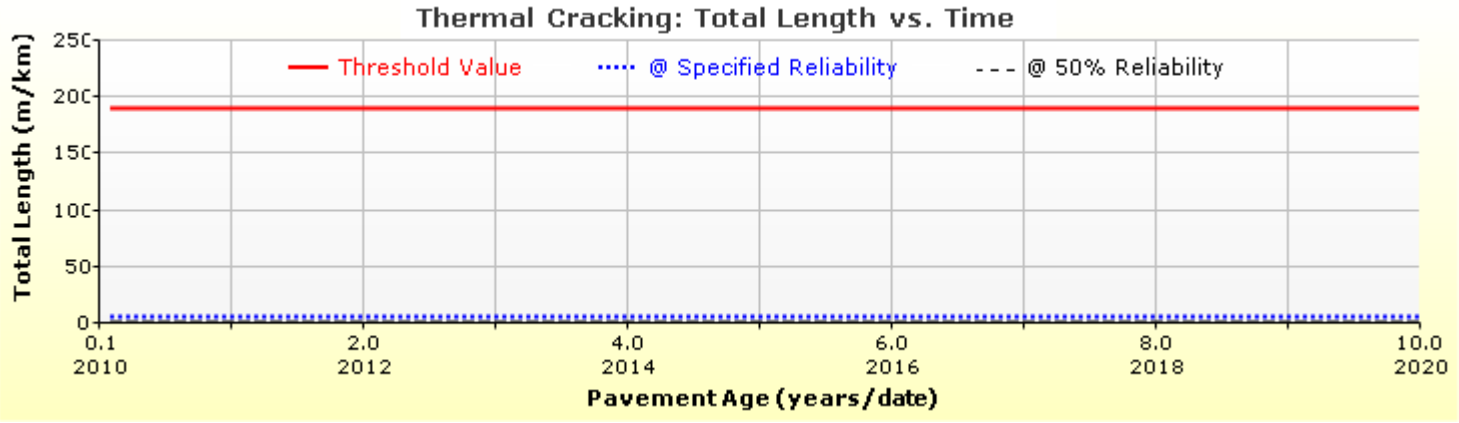


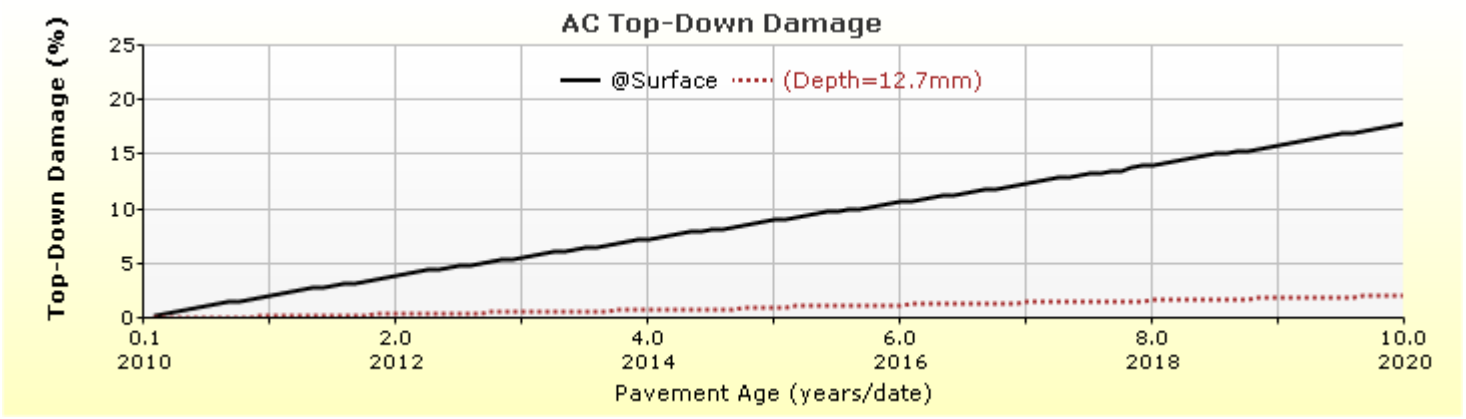


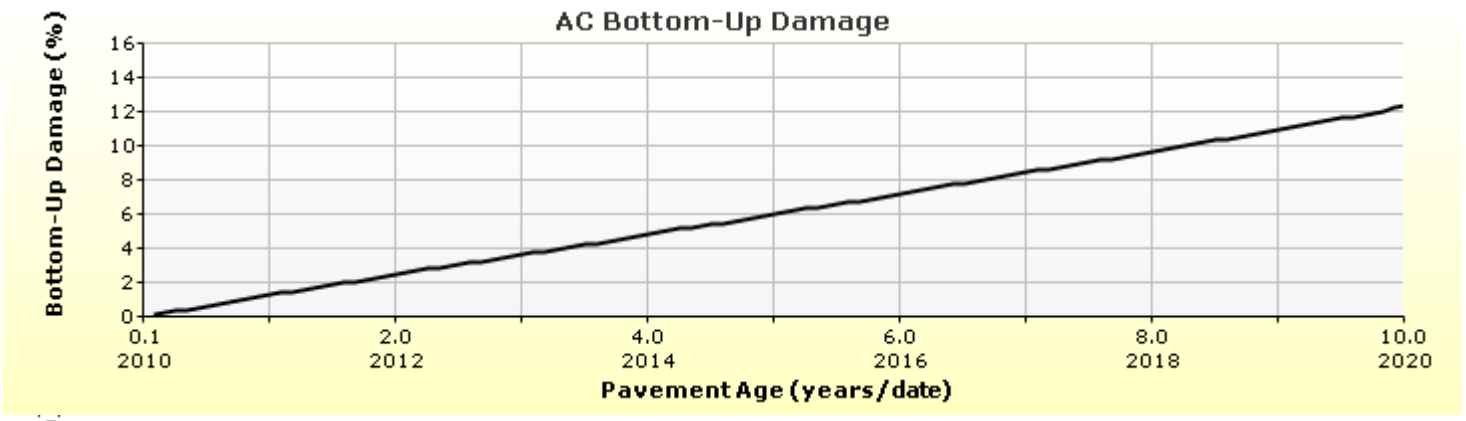
Analysis Output Charts

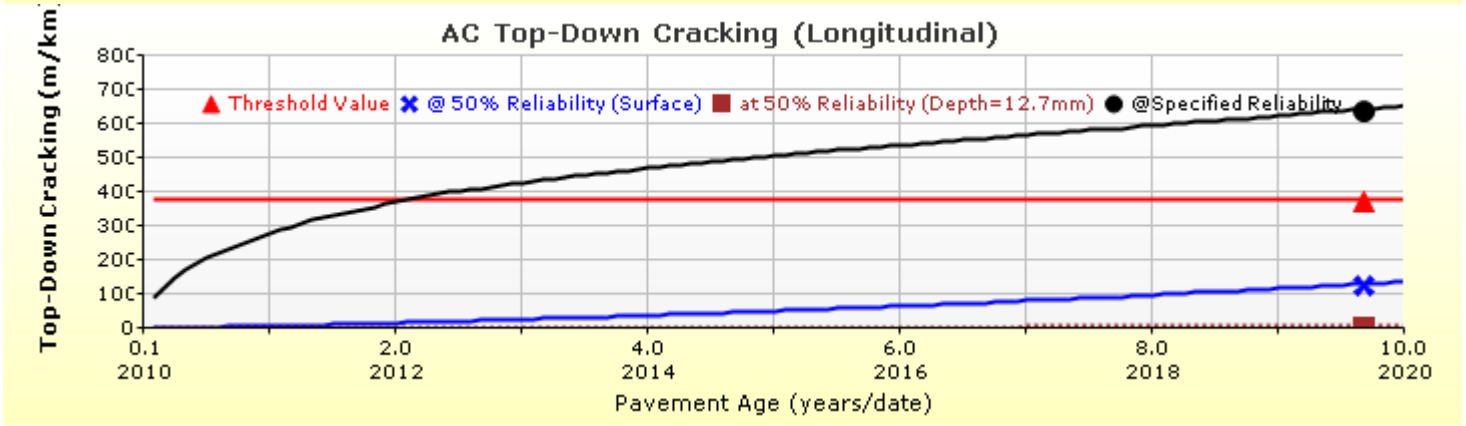


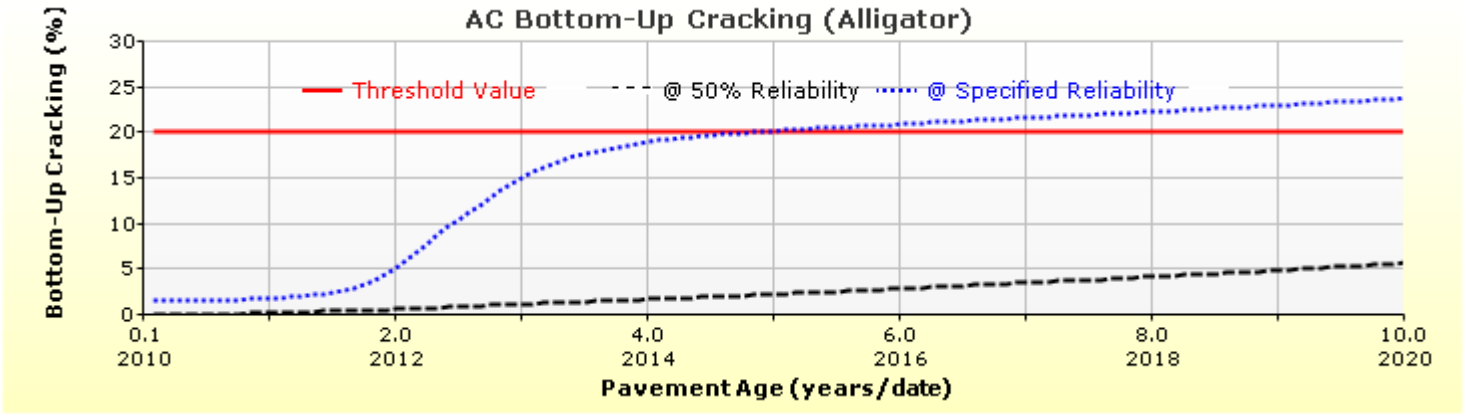


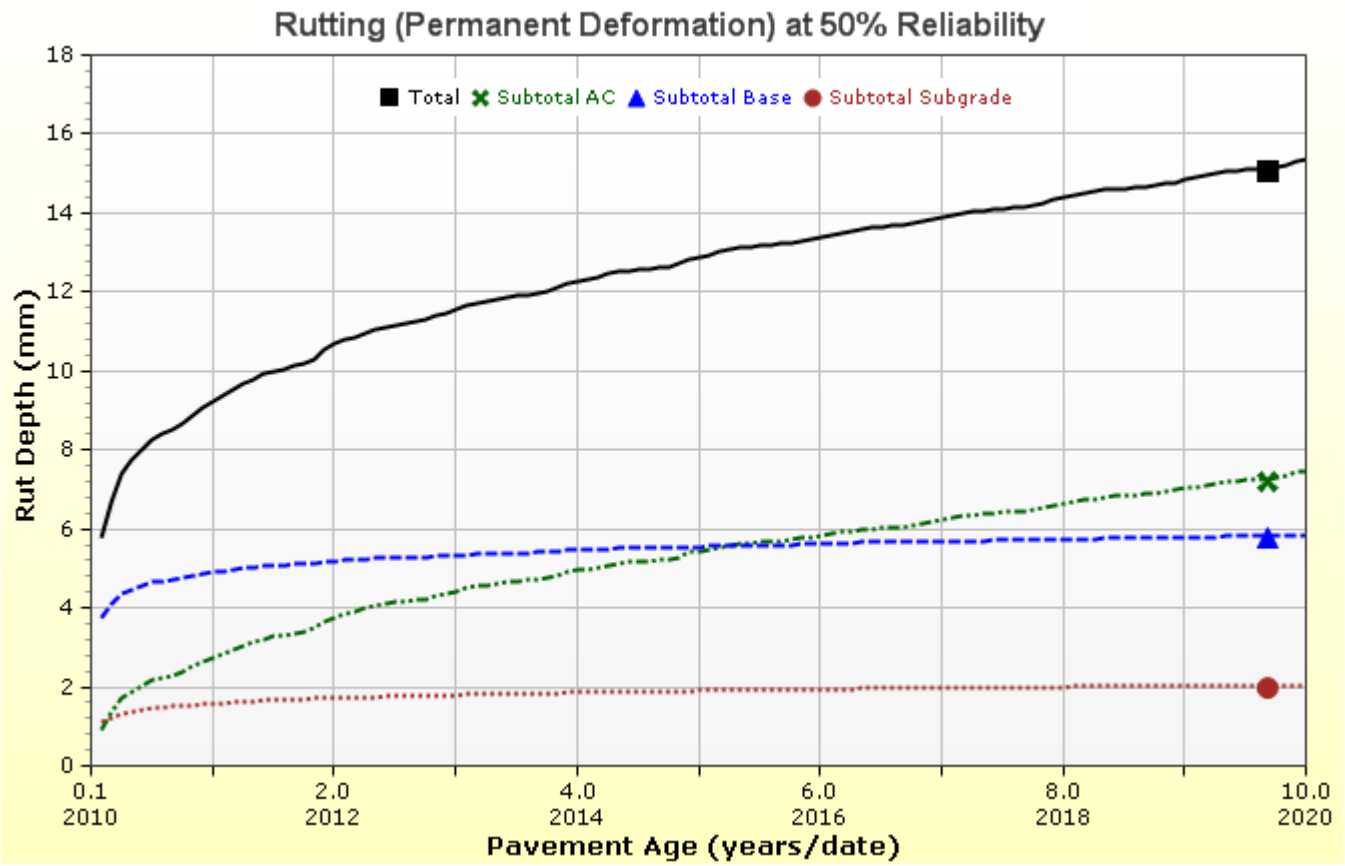


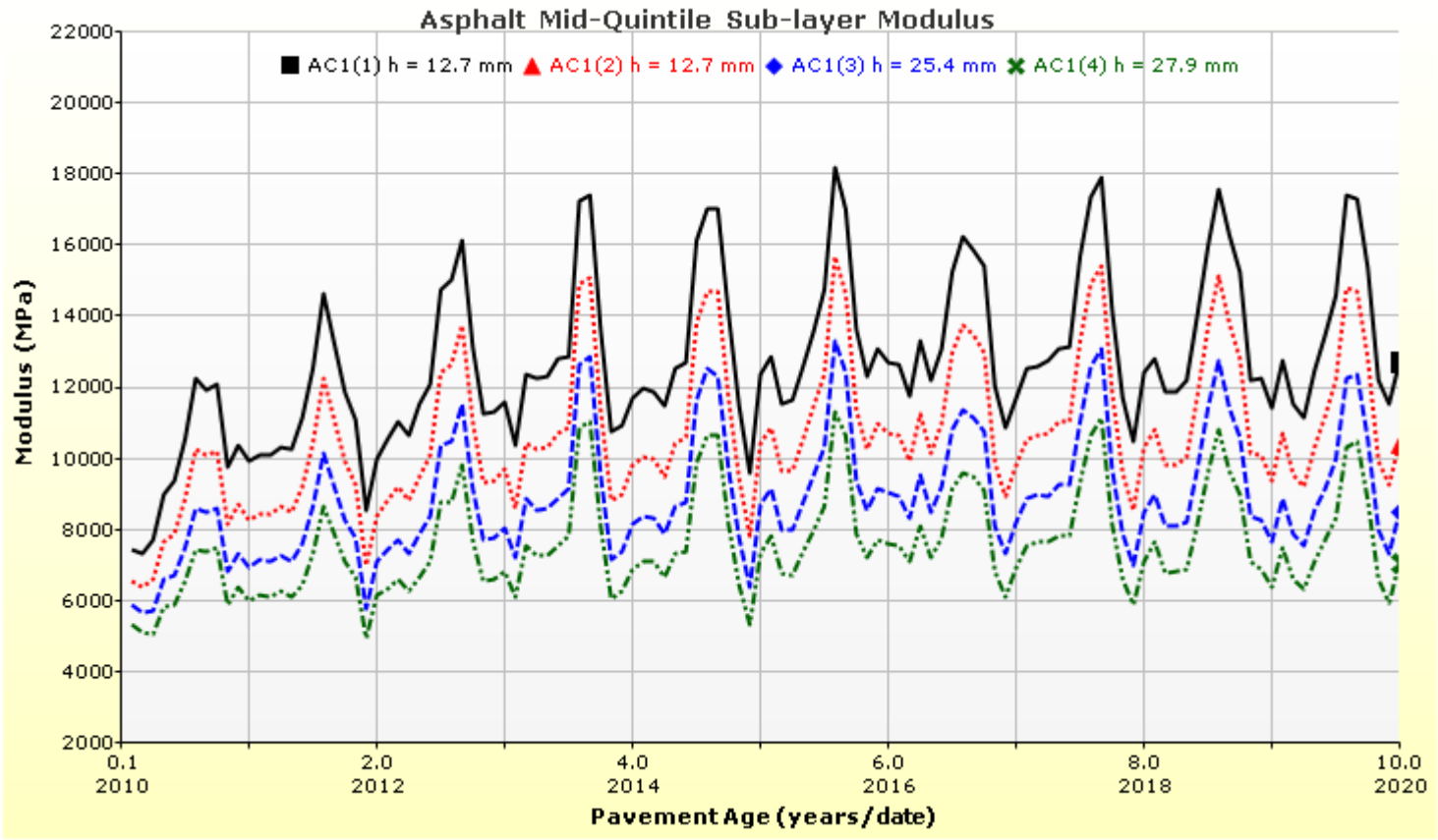

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

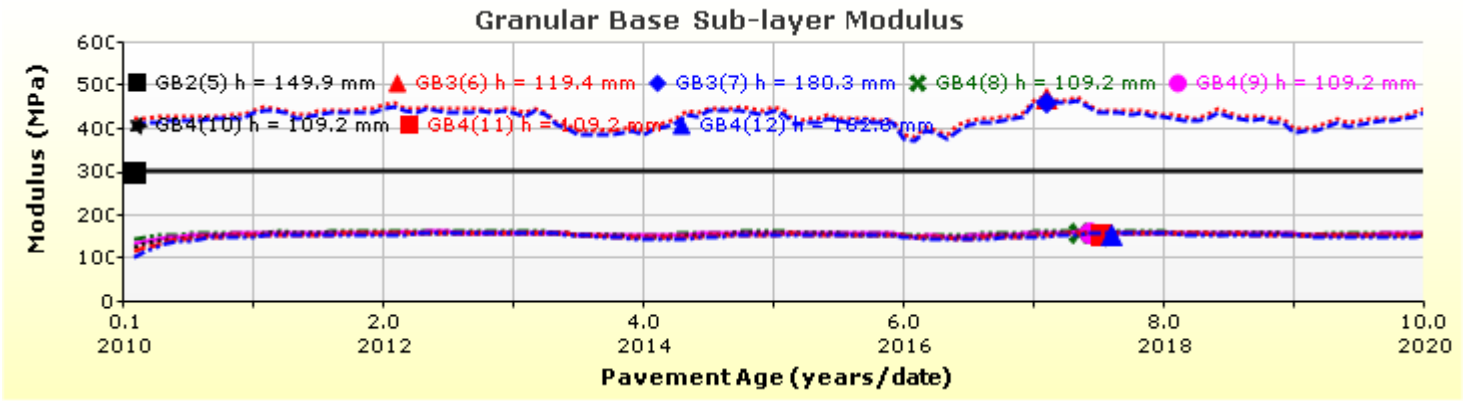

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

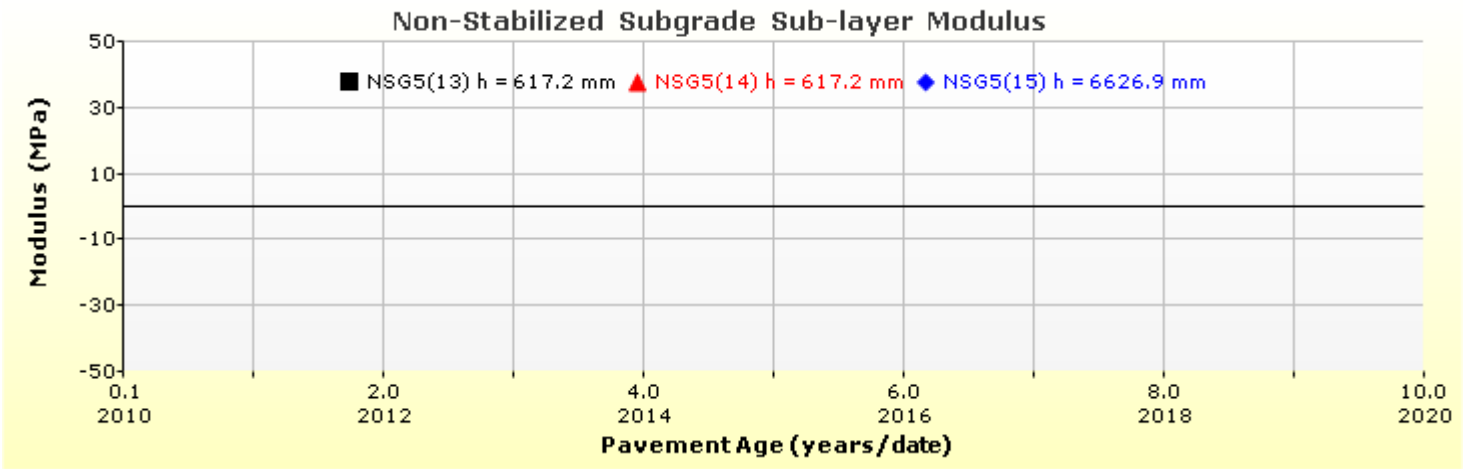

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 182.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestDF_Temp

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestDF_Temp.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -15.78, -47.91

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

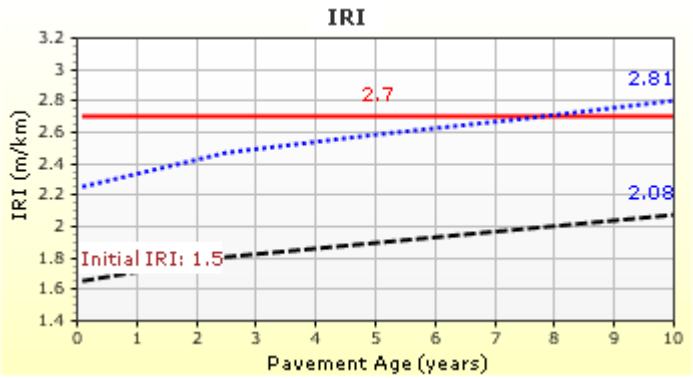
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

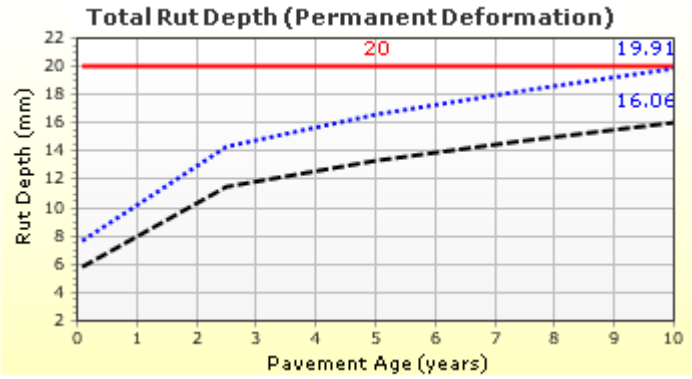
Design Outputs

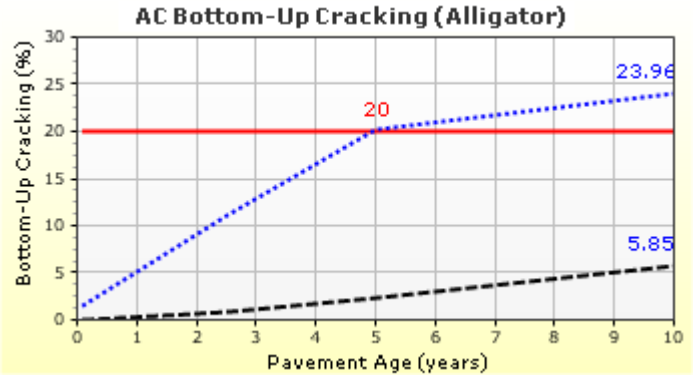
Distress Prediction Summary

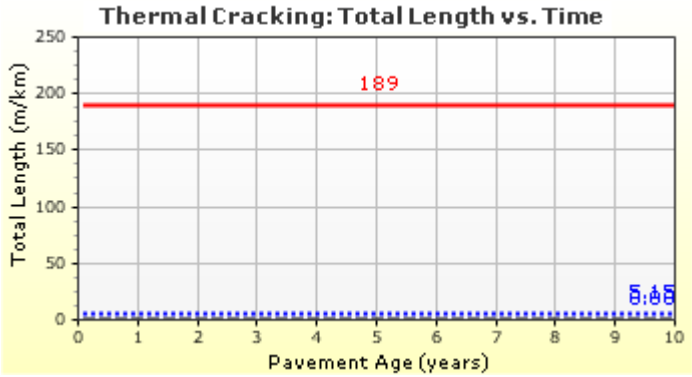
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.81	90.00	86.10	Fail
Permanent deformation - total pavement (mm)	20.00	19.90	90.00	90.50	Pass
AC bottom-up fatigue cracking (percent)	20.00	23.96	90.00	84.17	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	668.26	90.00	71.45	Fail
Permanent deformation - AC only (mm)	5.00	8.19	50.00	9.99	Fail

Distress Charts







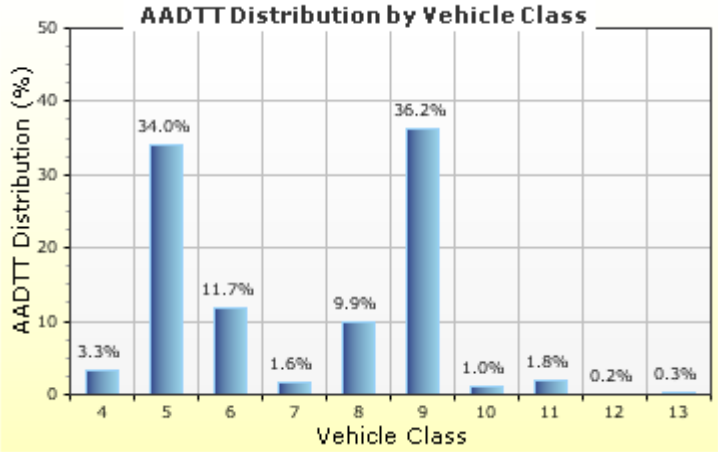


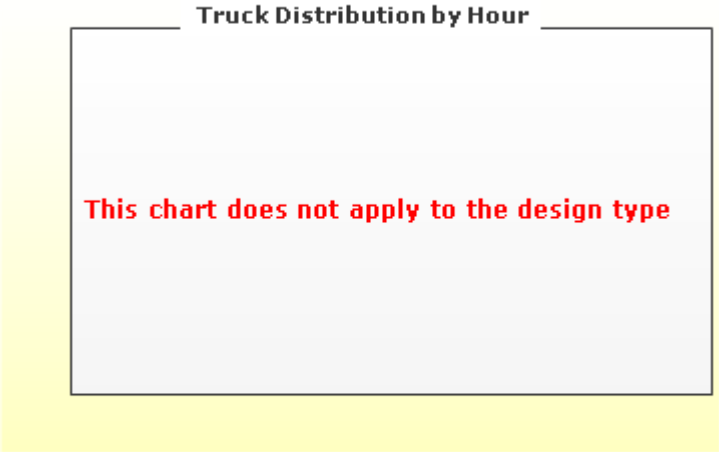


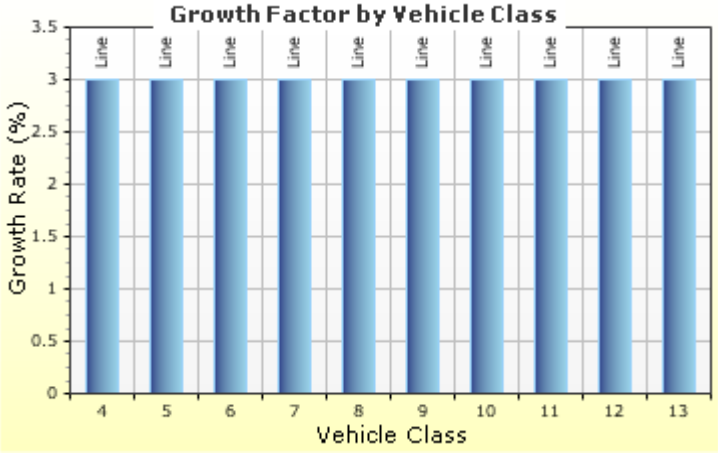
Traffic Inputs

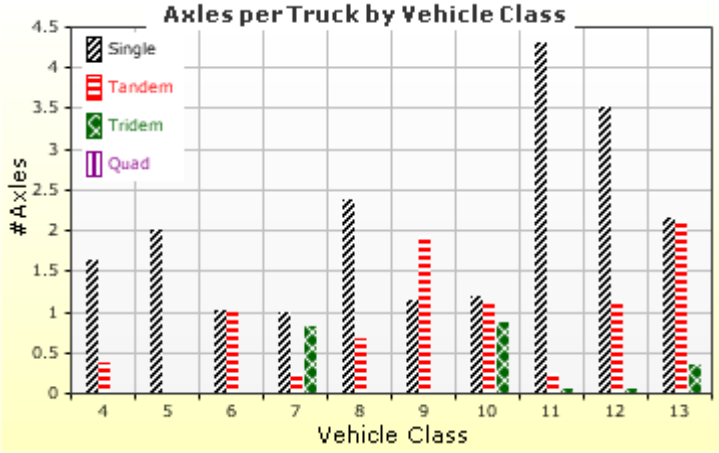
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

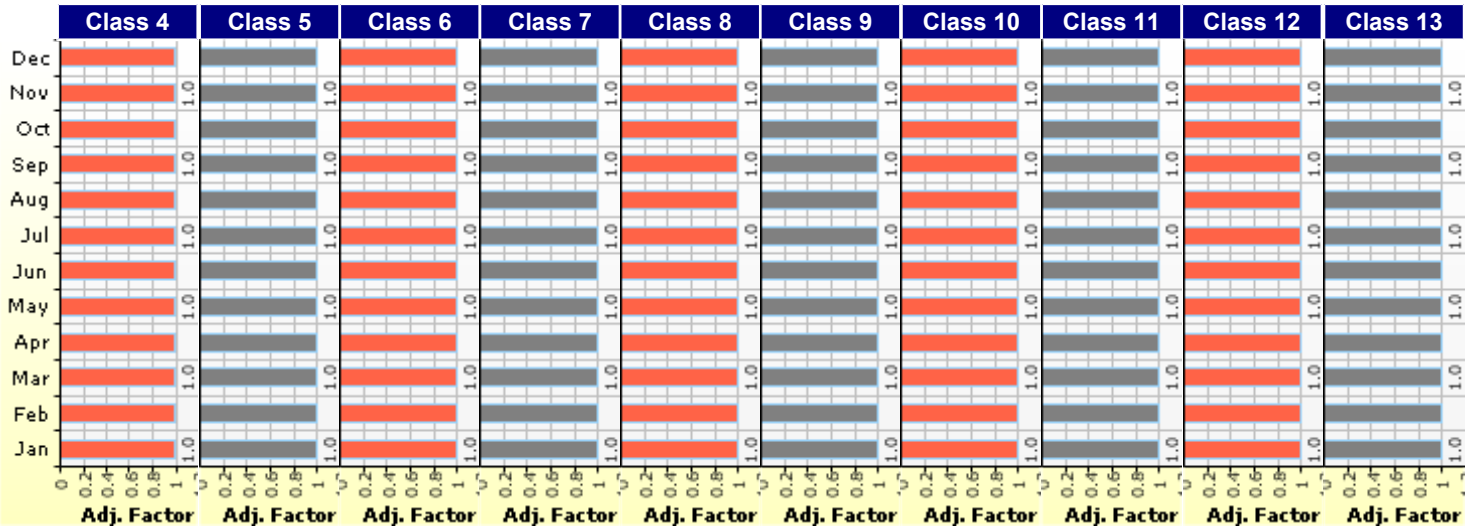








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

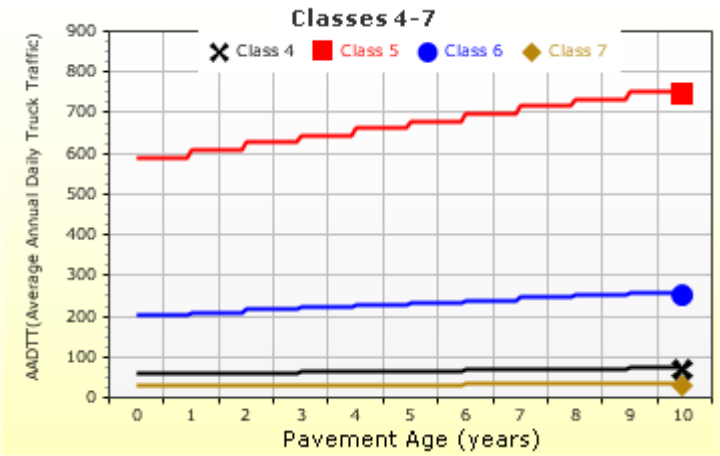
Wheelbase does not apply

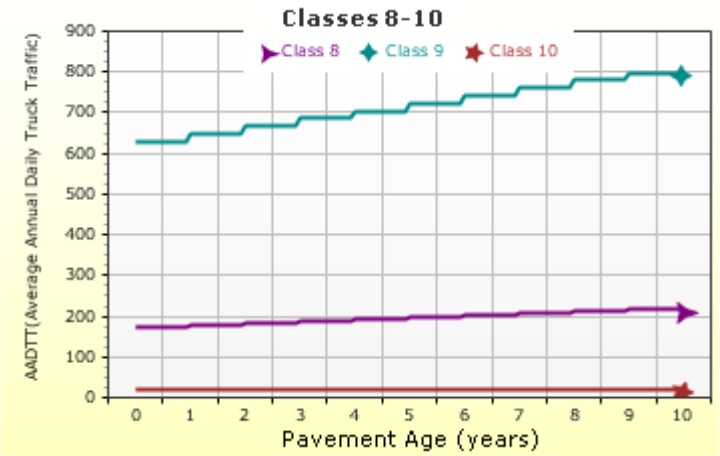
Number of Axles per Truck

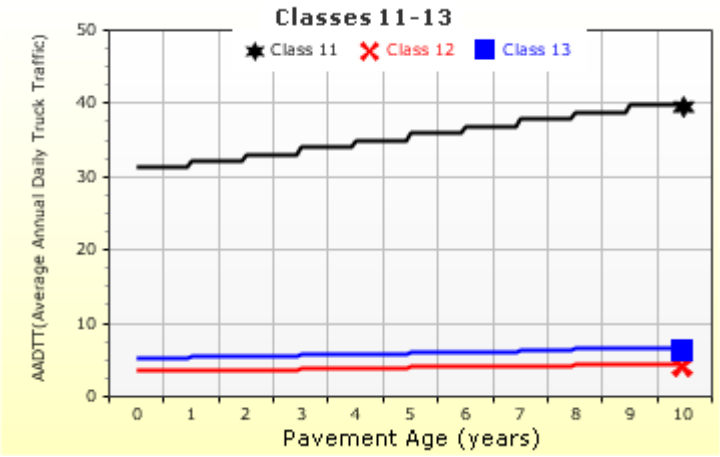
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

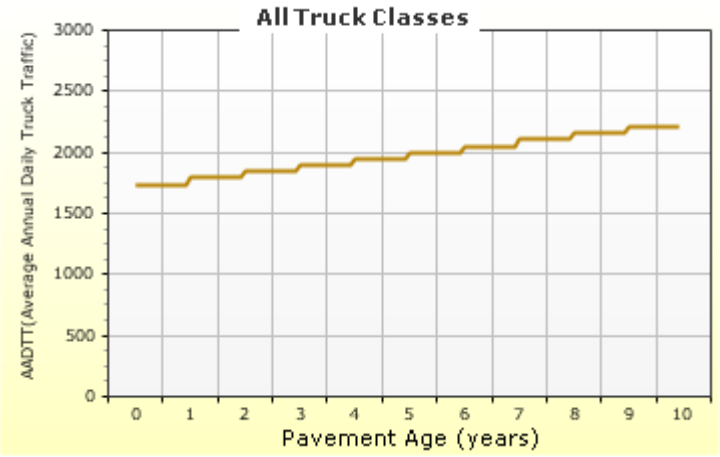
AADTT (Average Annual Daily Truck Traffic) Growth

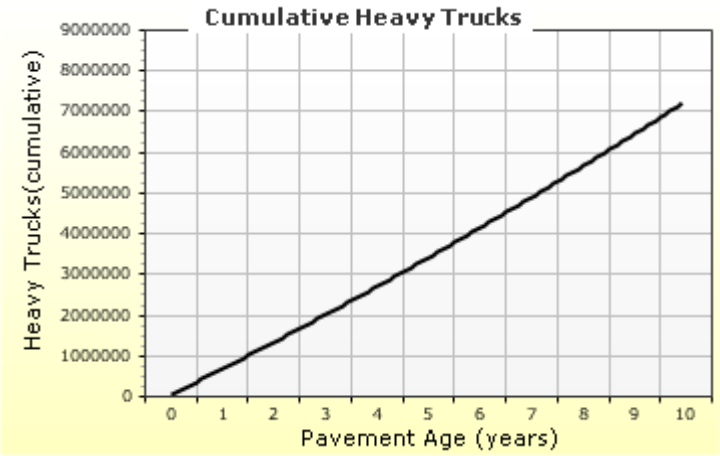
*** Traffic cap is not enforced**







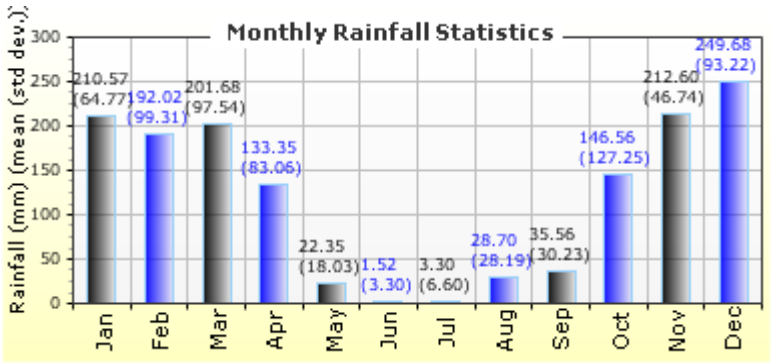




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
BRASILIA, DF	-15.78000 -47.91000 1159

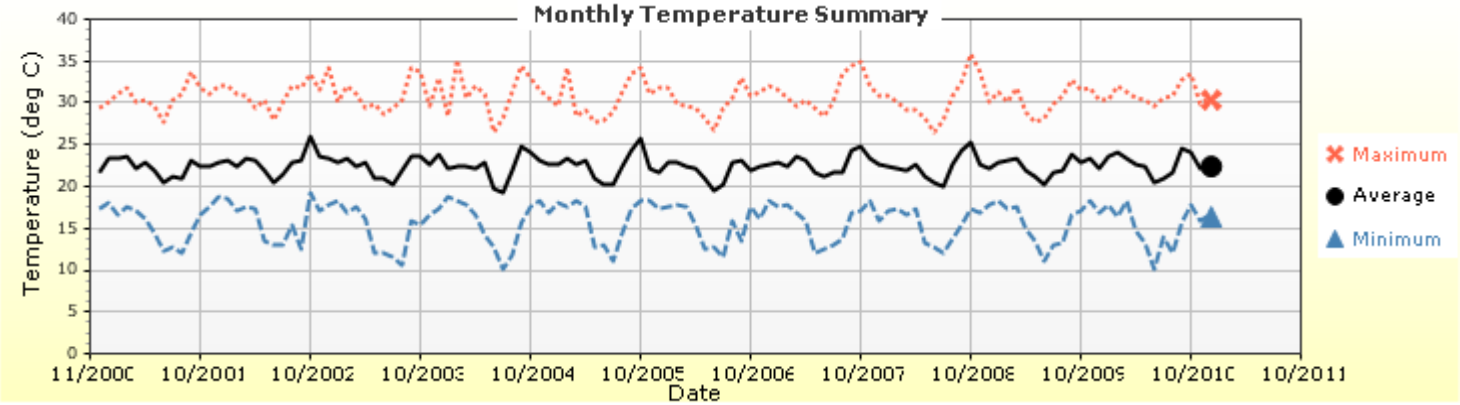


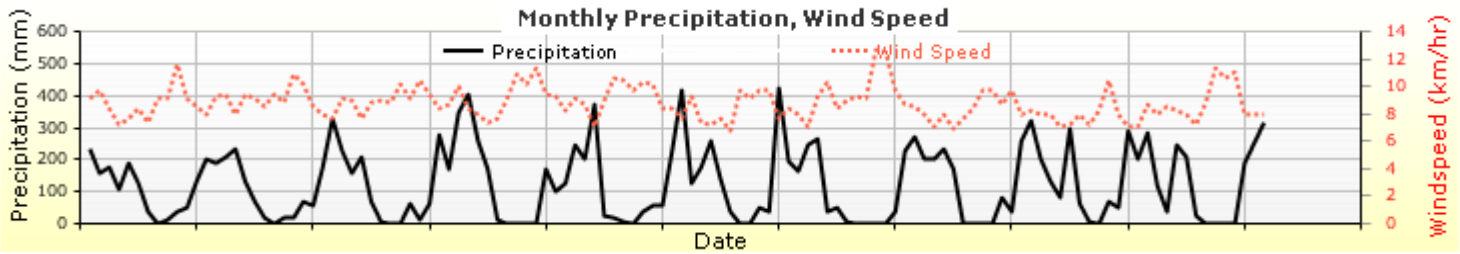
Annual Statistics:

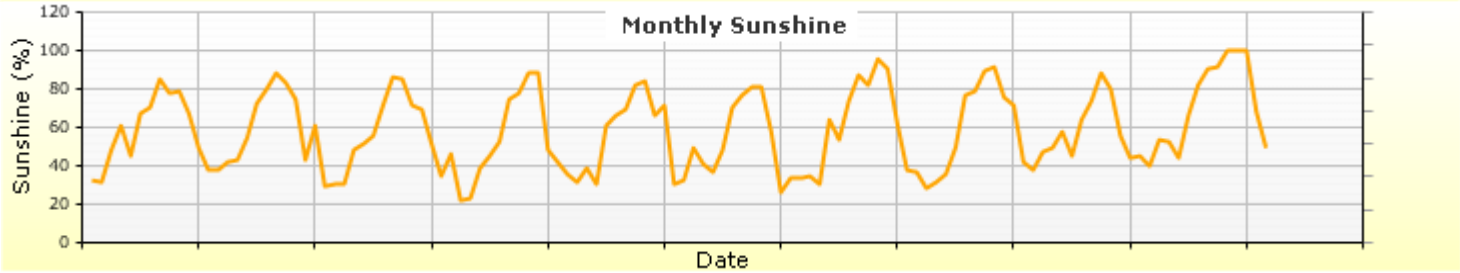
Mean annual air temperature (ºC)	22.45
Mean annual precipitation (mm)	1461.01
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

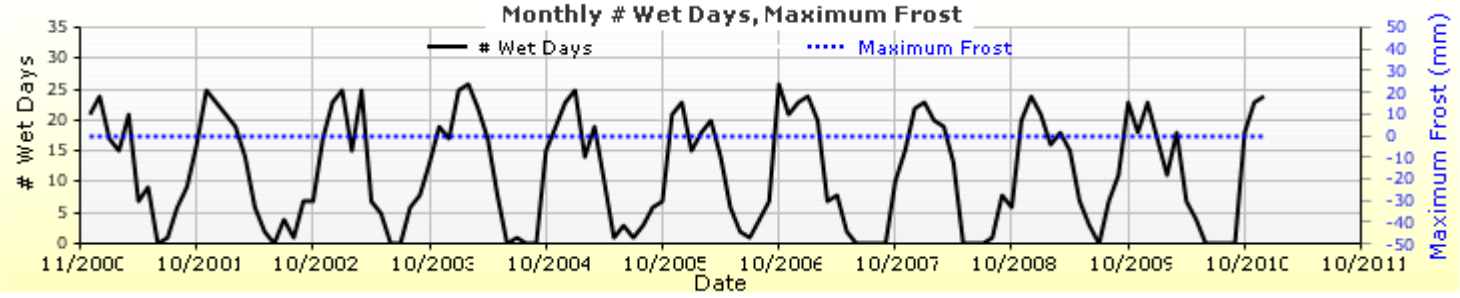
Water table depth (m): 3.05

Monthly Climate Summary:

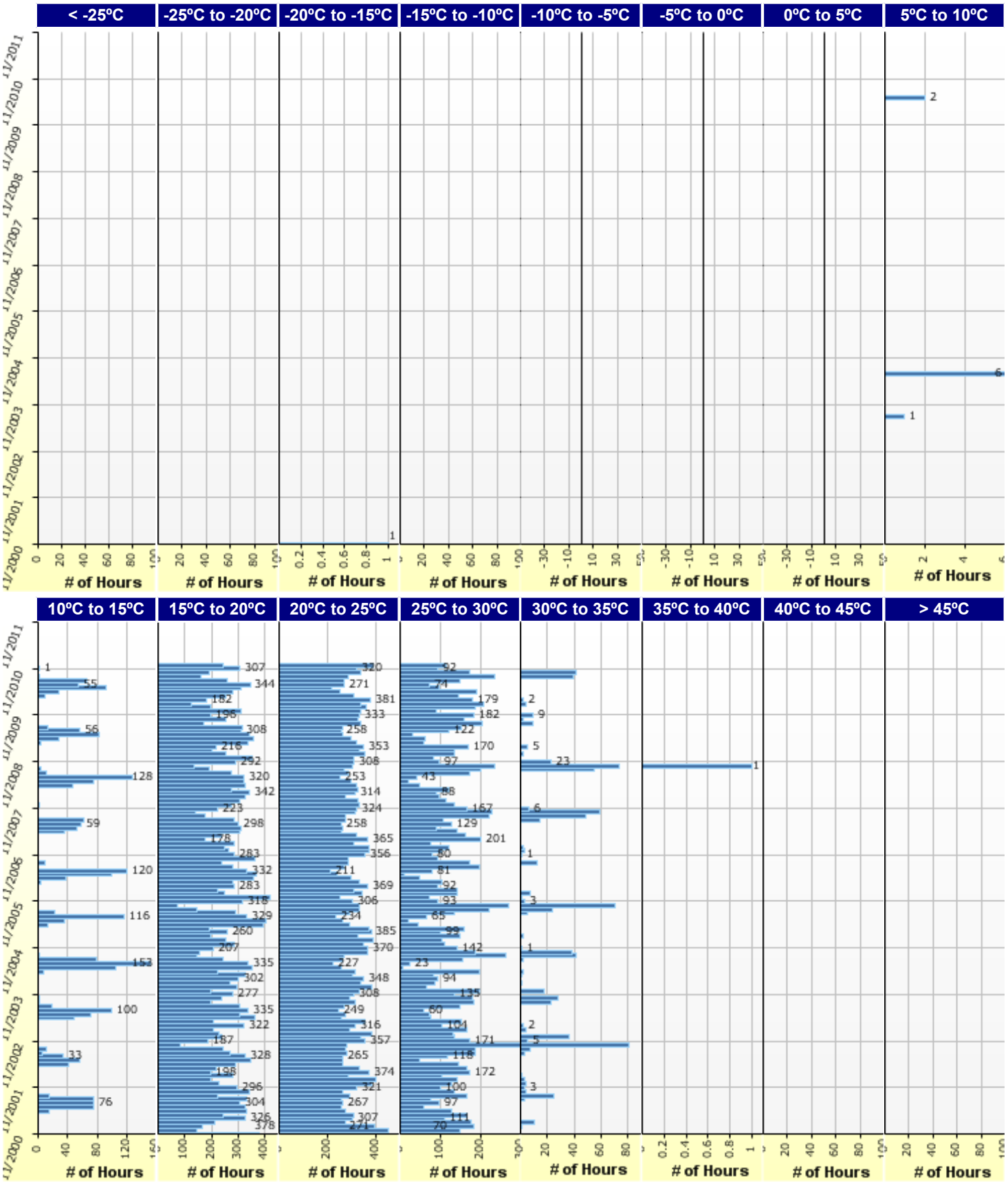








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

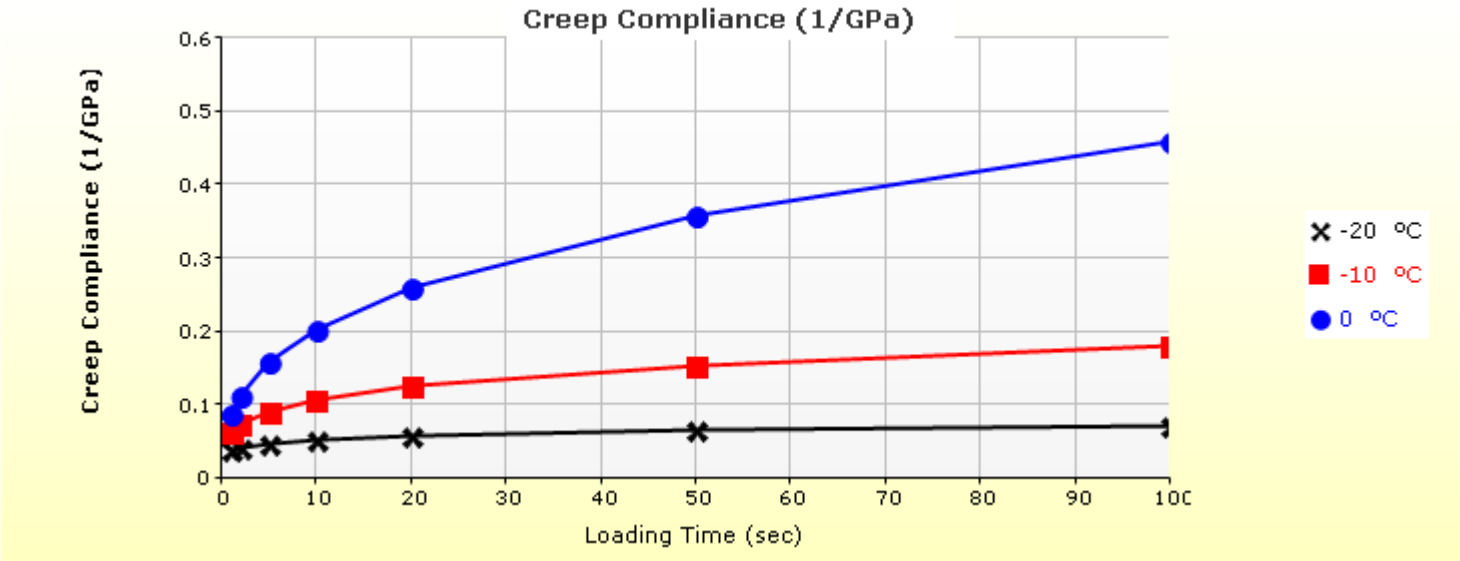
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

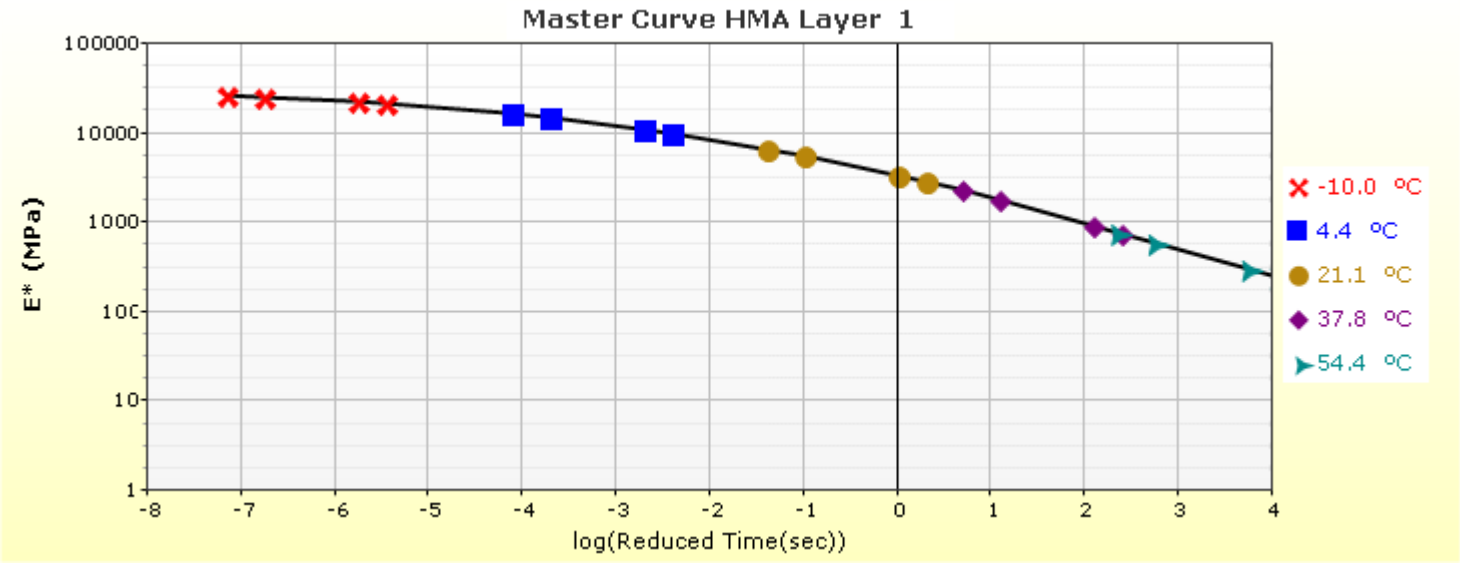
Indirect tensile strength at -10 ºC (MPa)	2.69

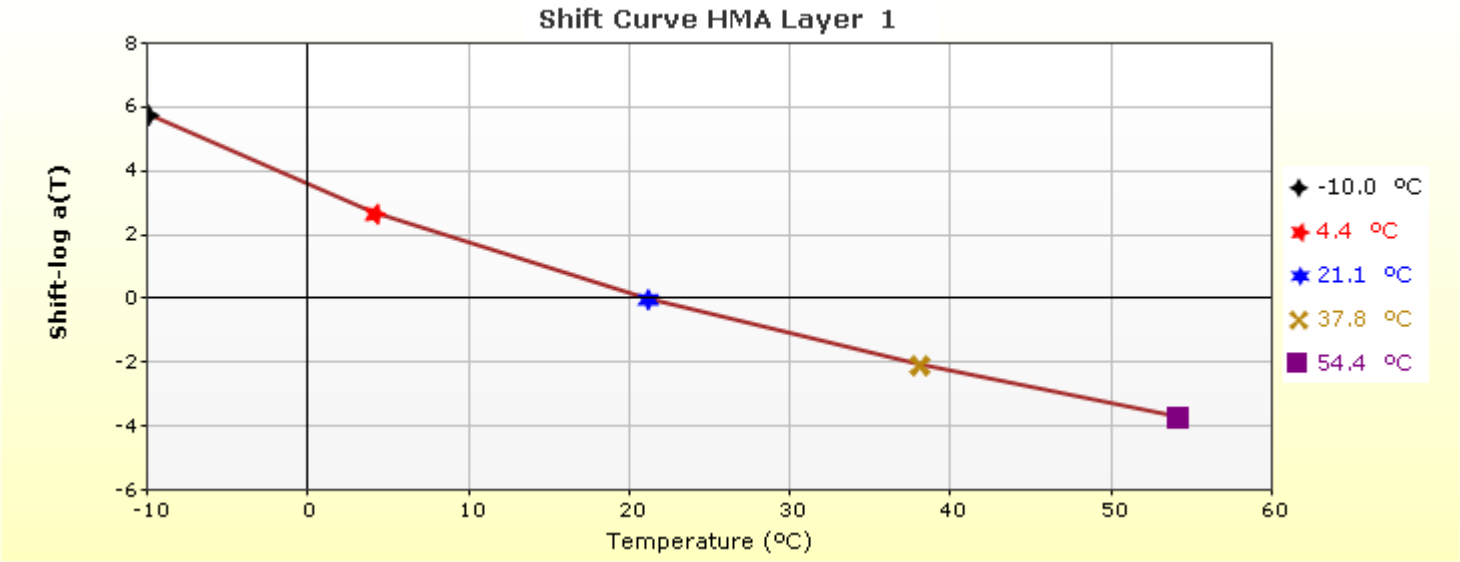
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

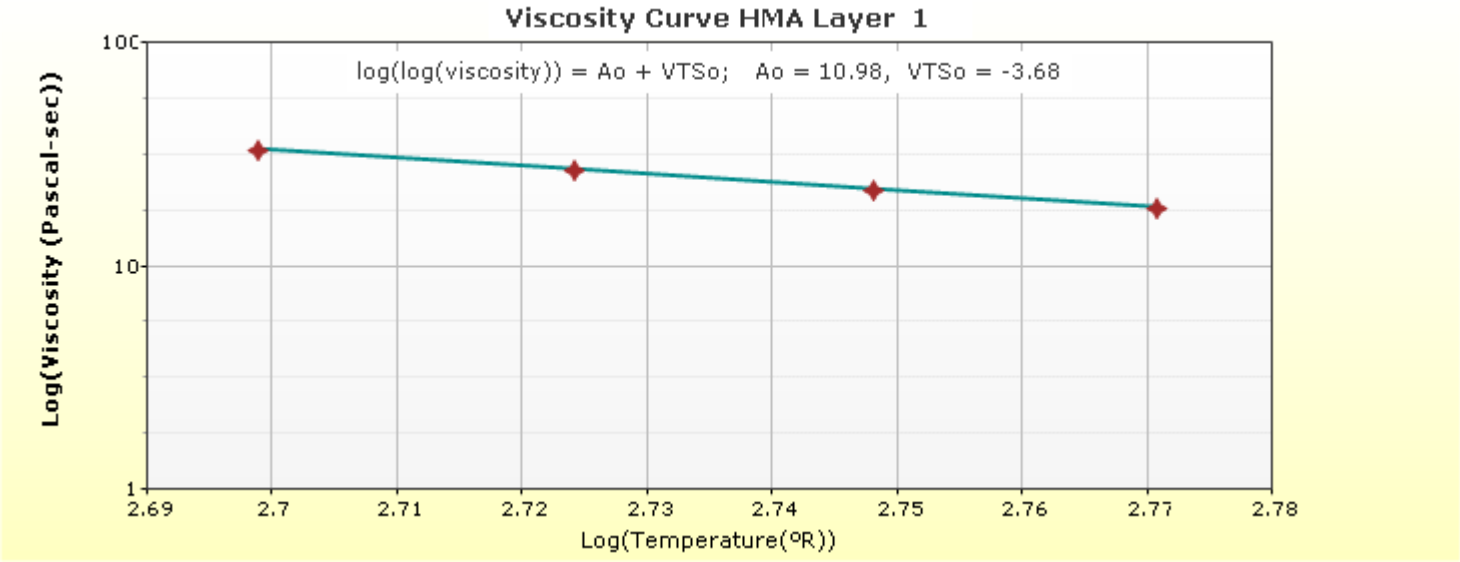
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



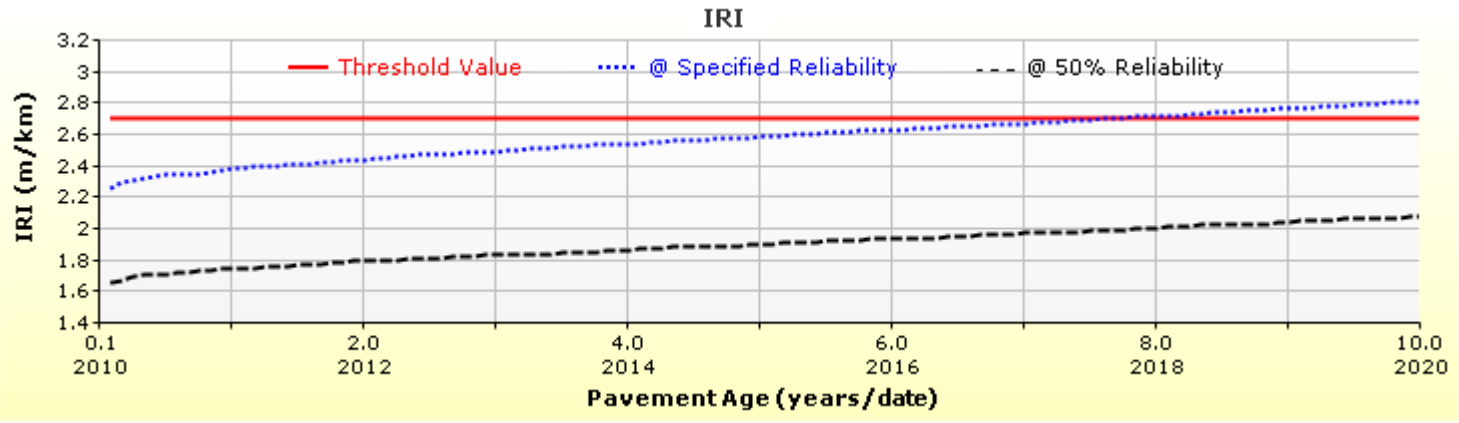
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

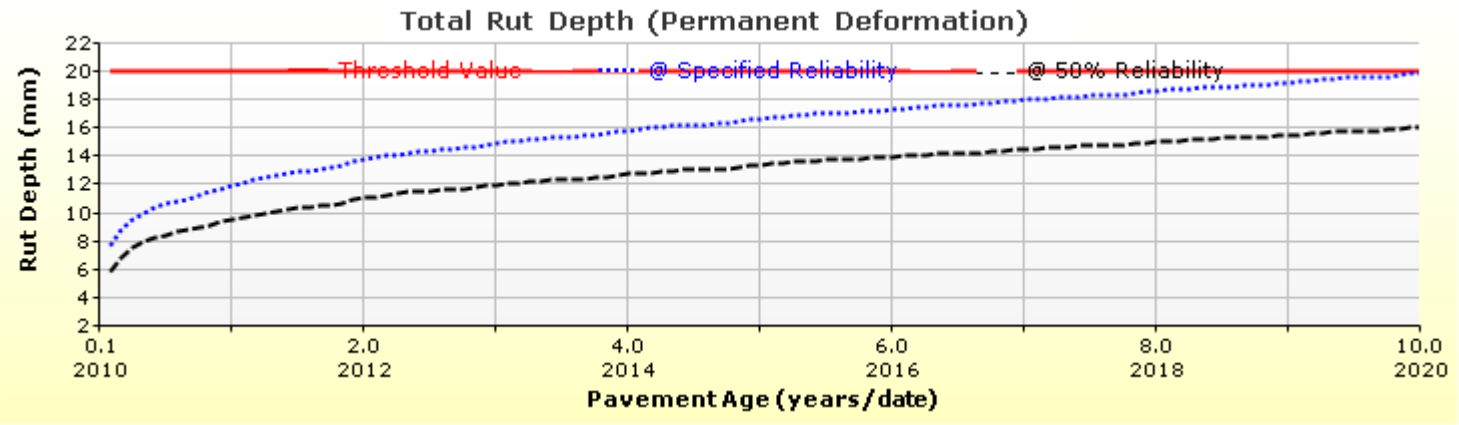


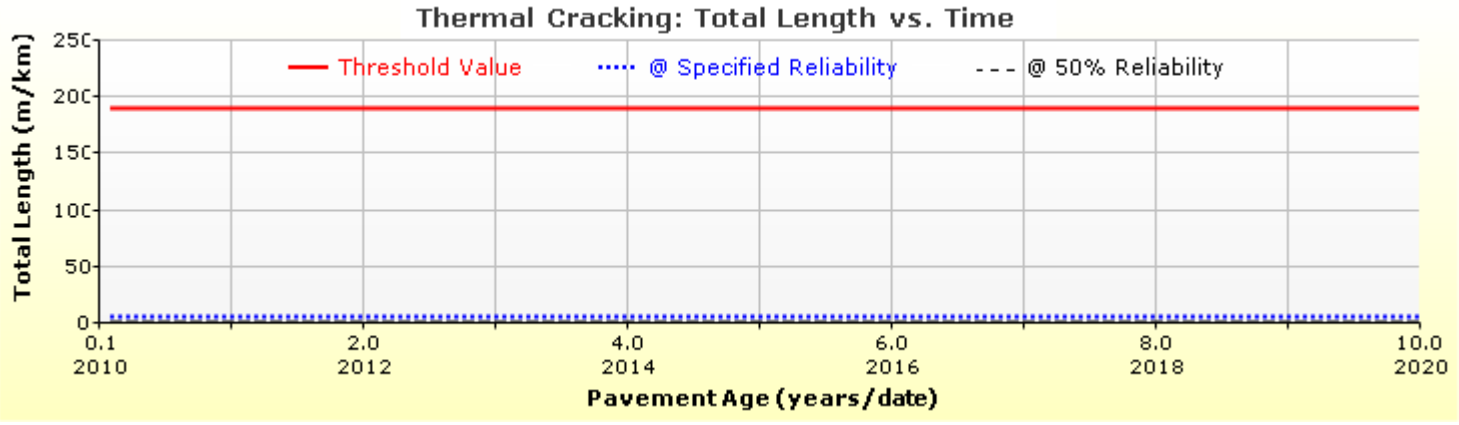


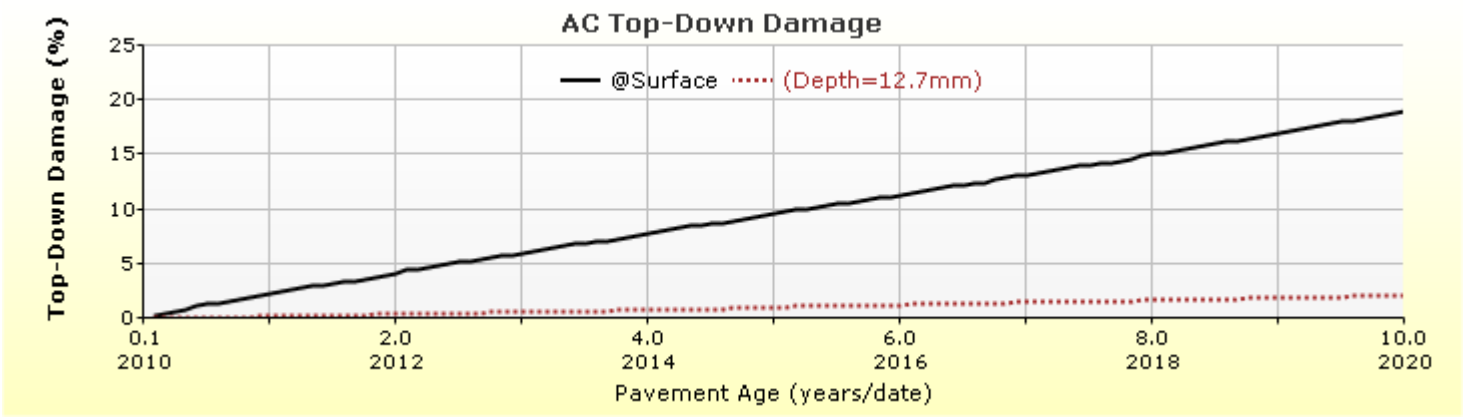


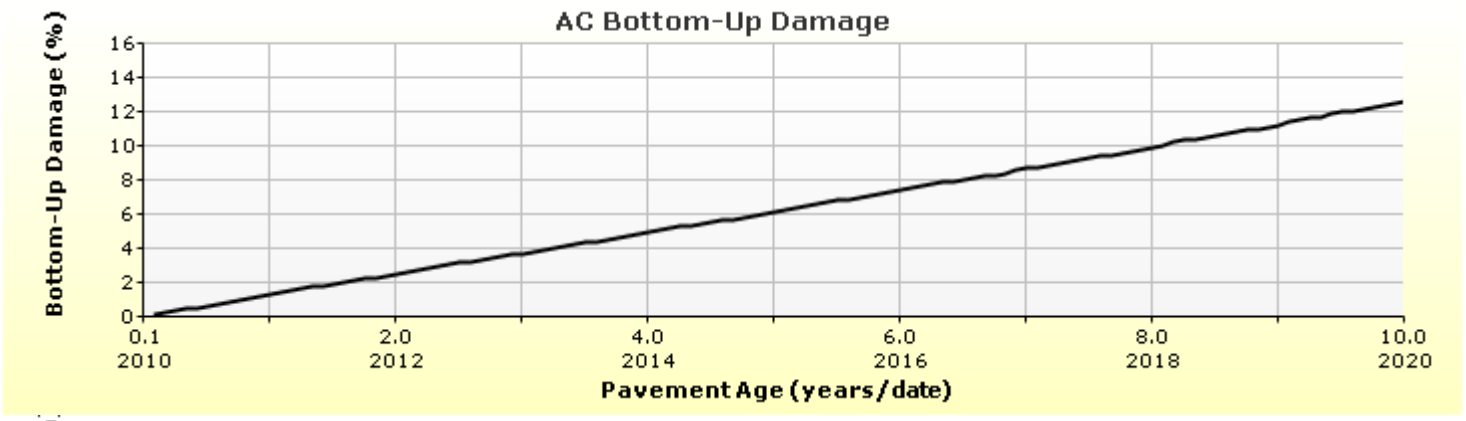
Analysis Output Charts

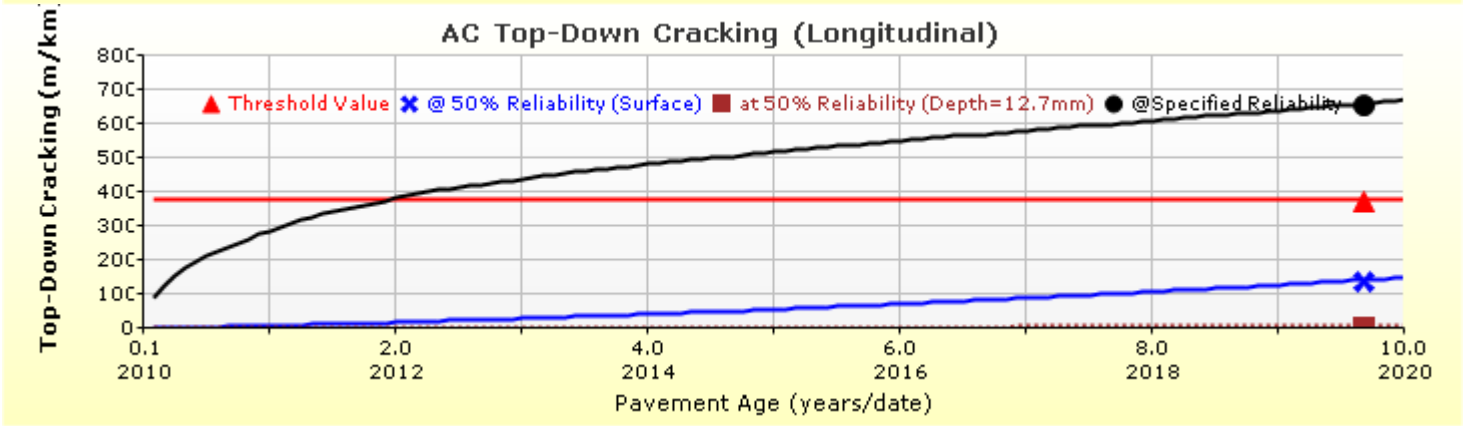


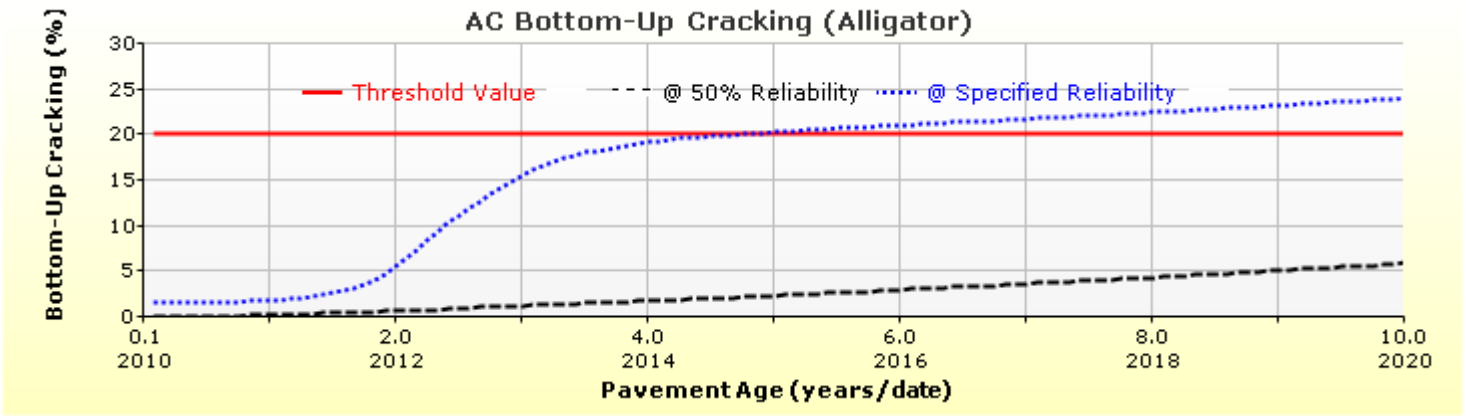


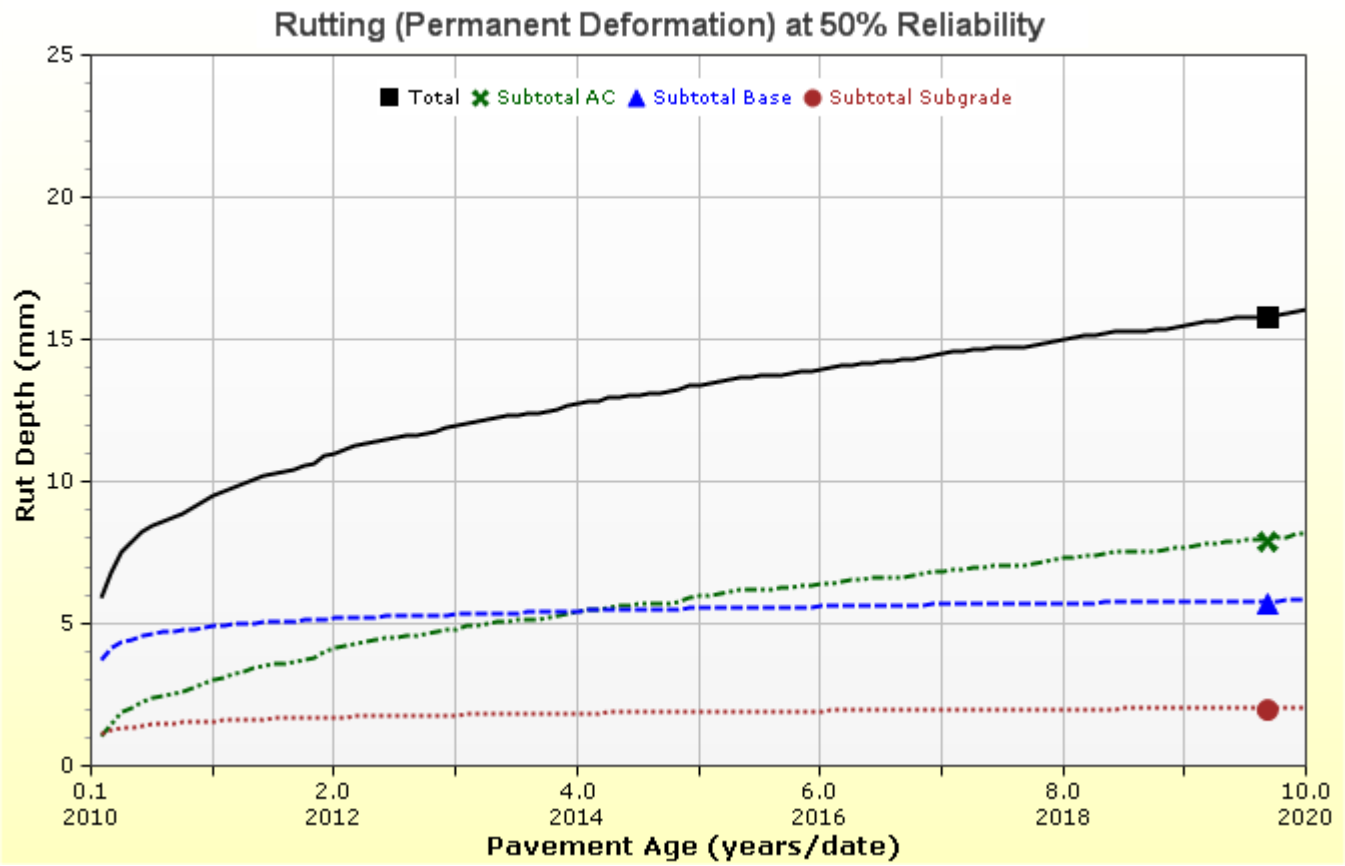


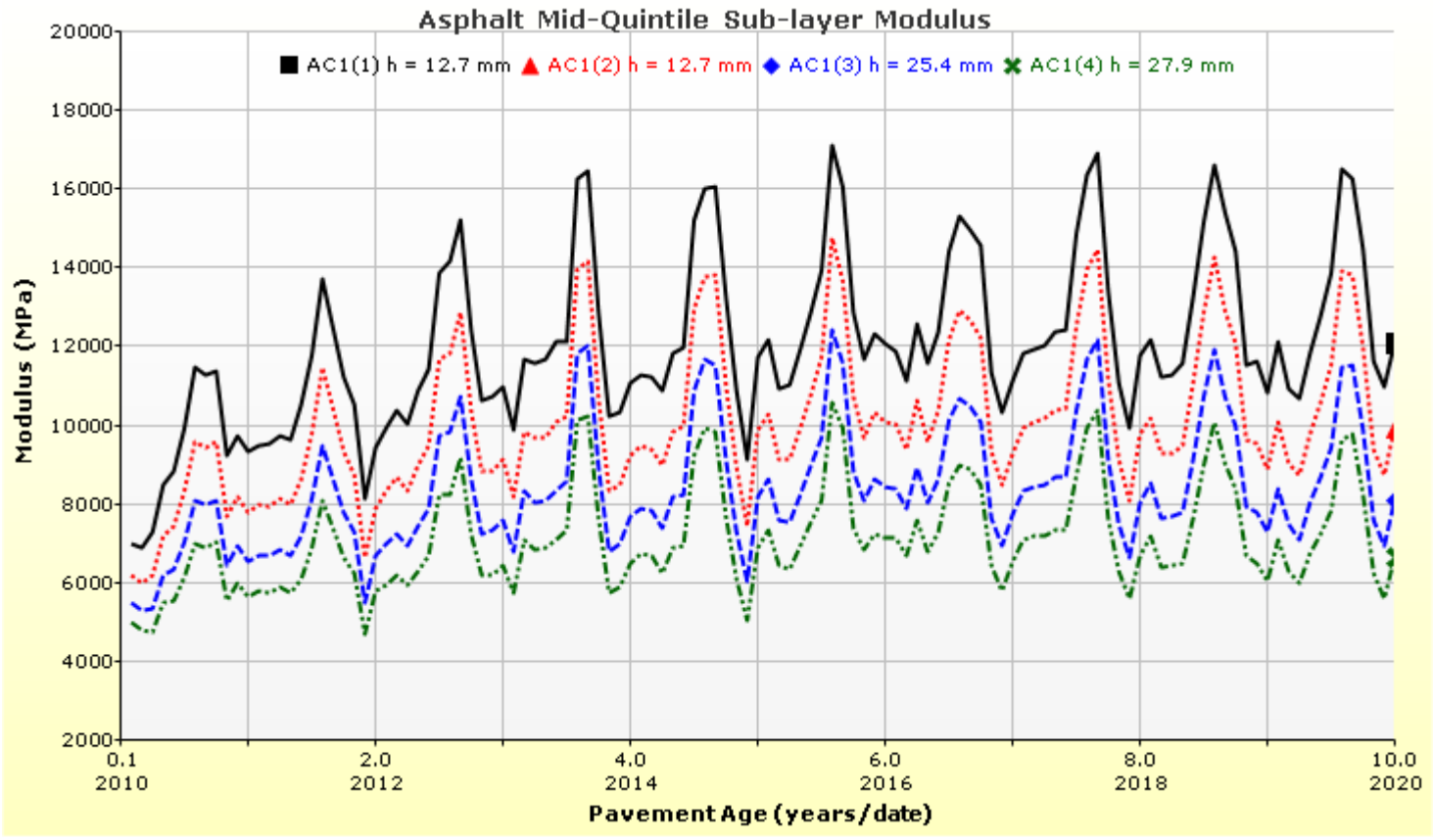

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

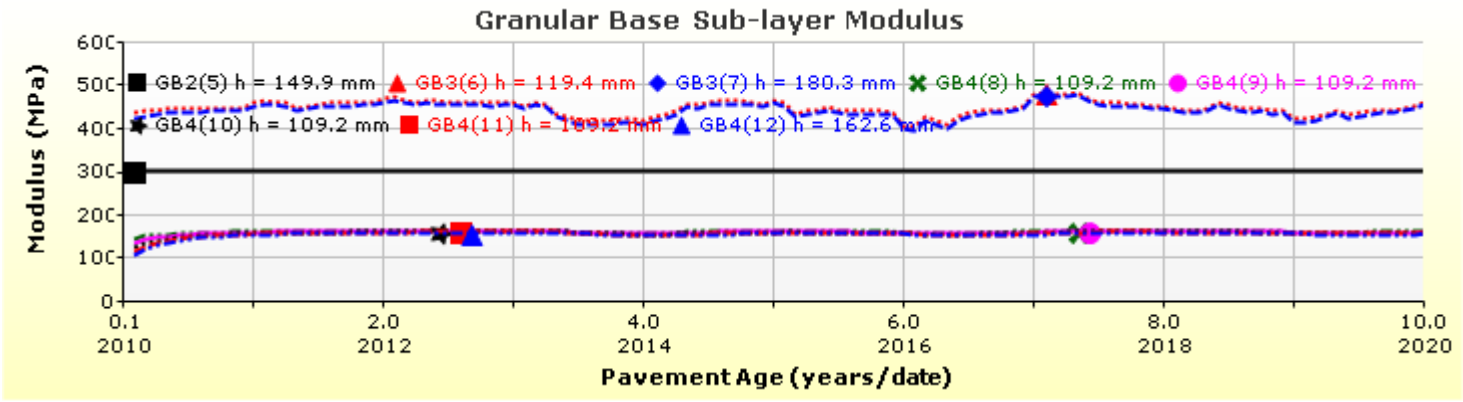

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

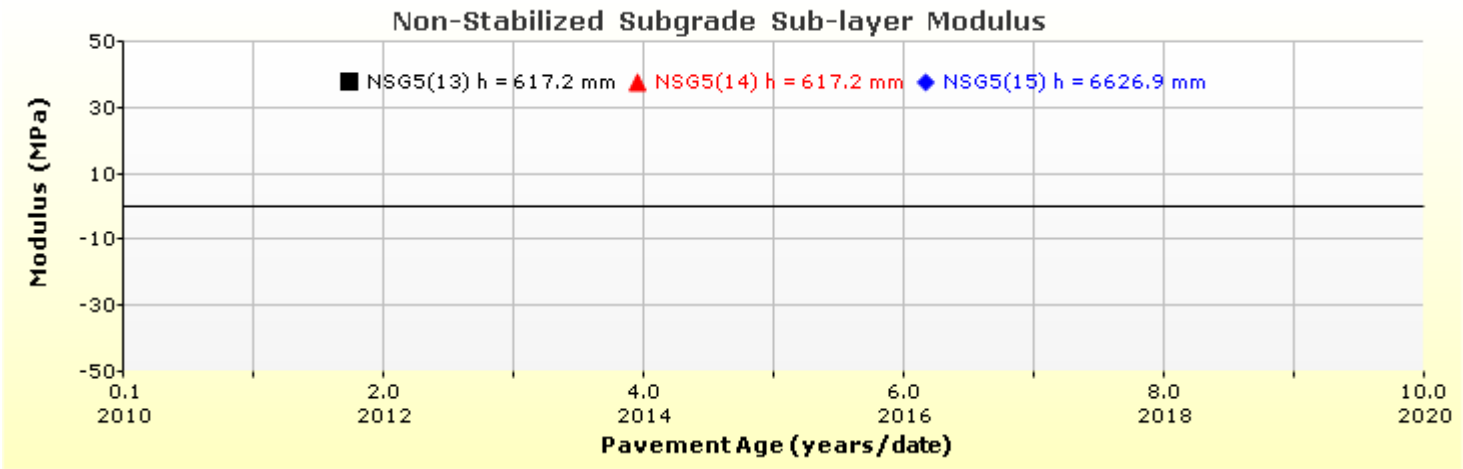

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestDF_vento

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestDF_vento.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -15.78, -47.91

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

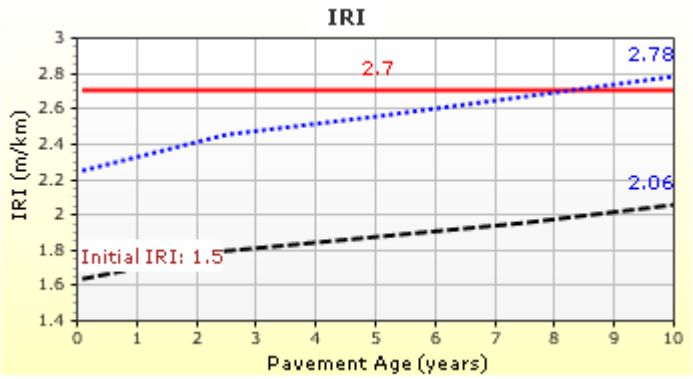
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

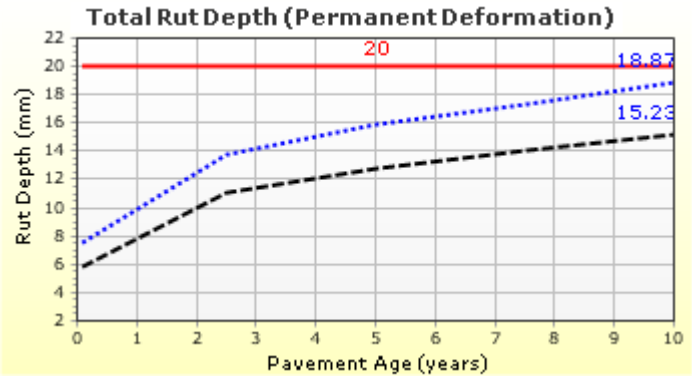
Design Outputs

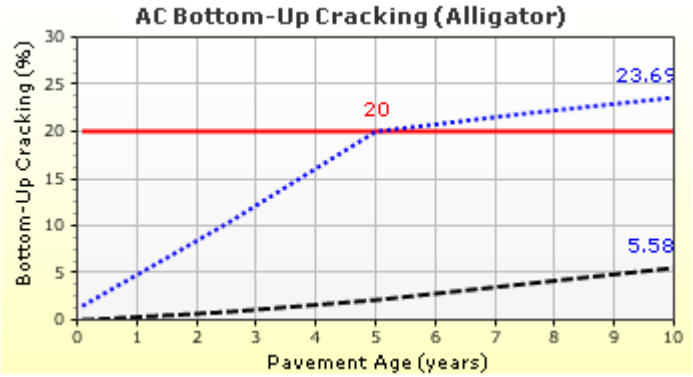
Distress Prediction Summary

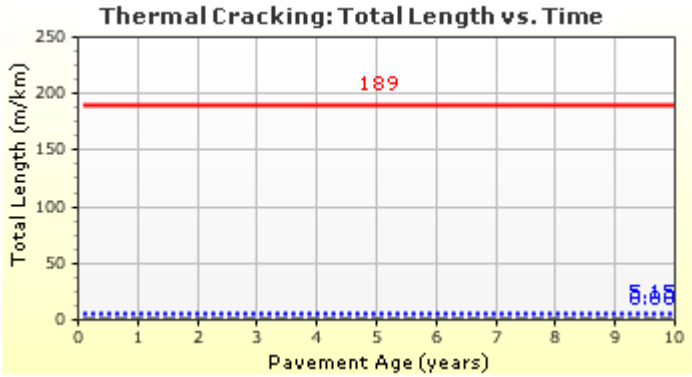
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.78	90.00	87.15	Fail
Permanent deformation - total pavement (mm)	20.00	18.87	90.00	95.31	Pass
AC bottom-up fatigue cracking (percent)	20.00	23.69	90.00	84.63	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	648.10	90.00	72.89	Fail
Permanent deformation - AC only (mm)	5.00	7.38	50.00	14.96	Fail

Distress Charts







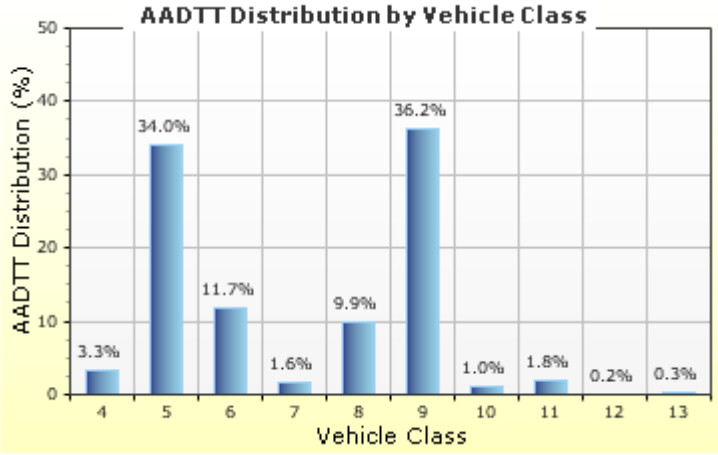


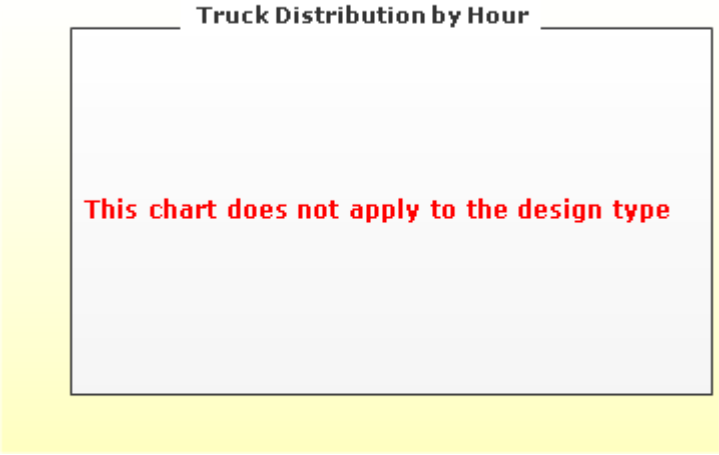


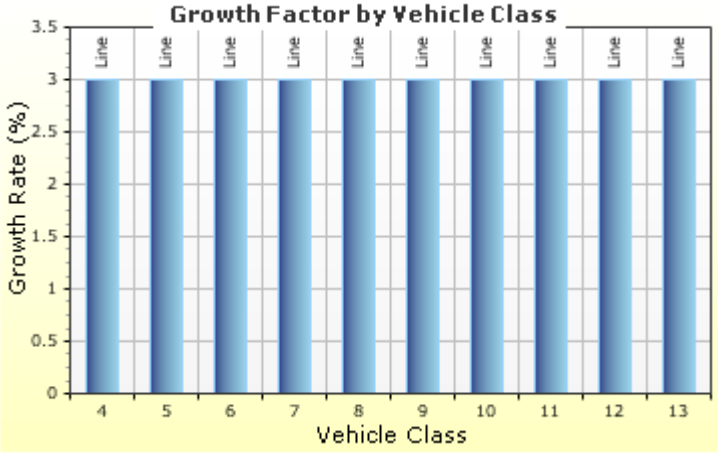
Traffic Inputs

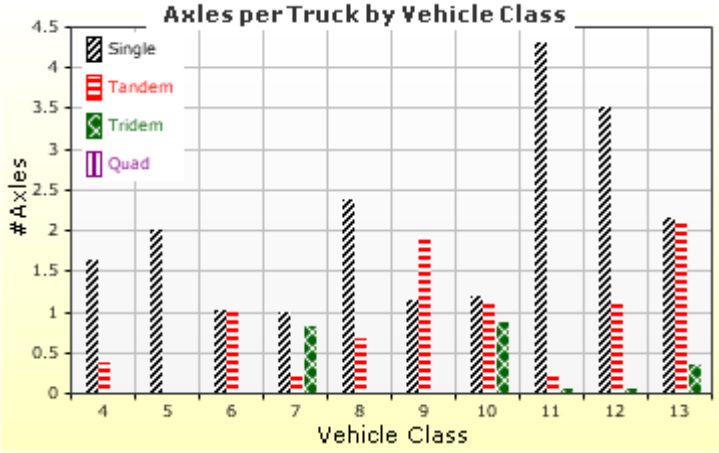
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

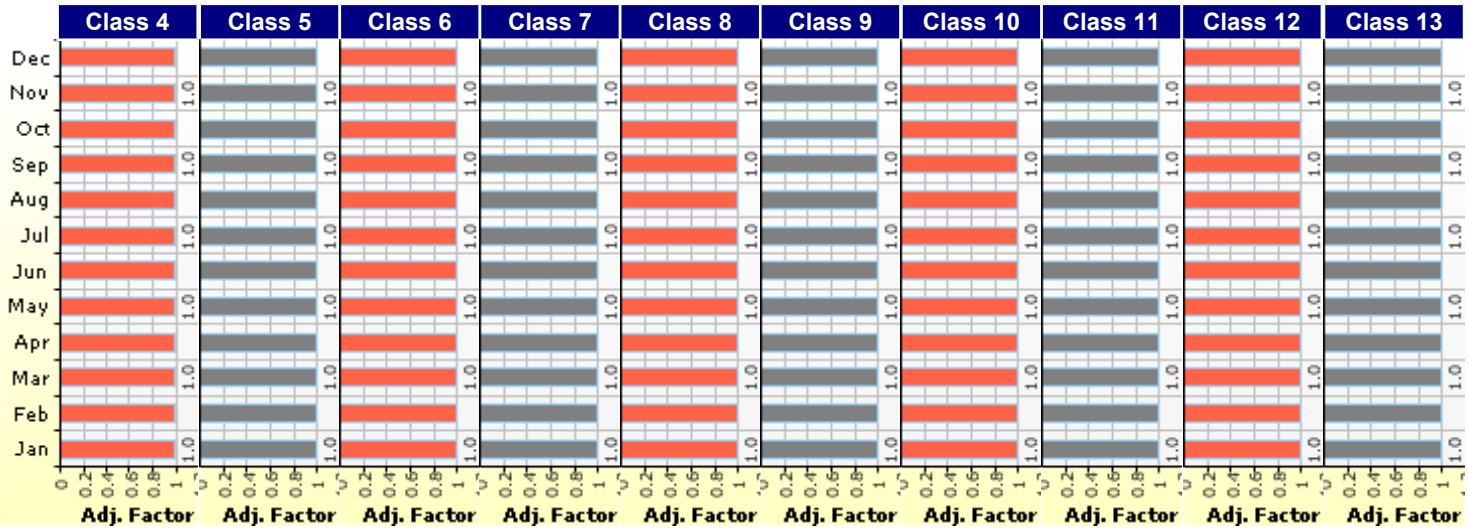








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

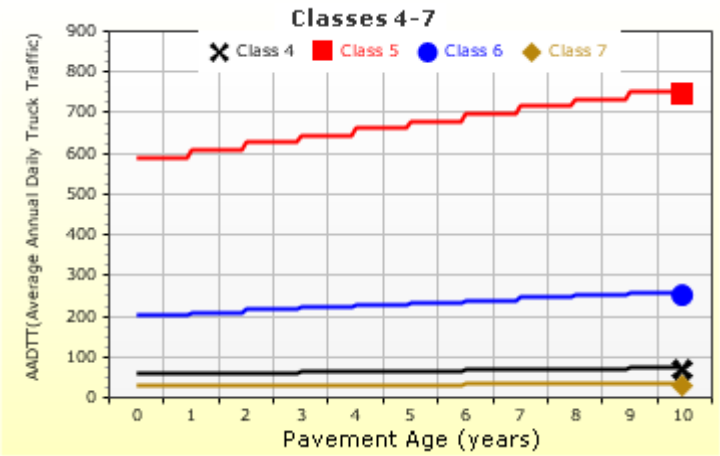
Wheelbase does not apply

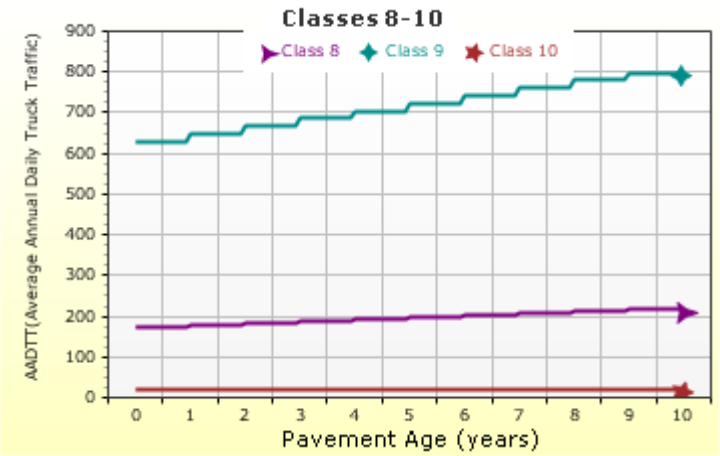
Number of Axles per Truck

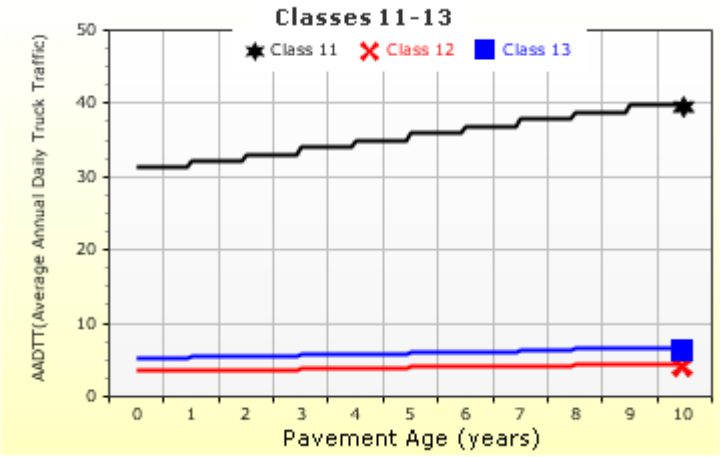
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

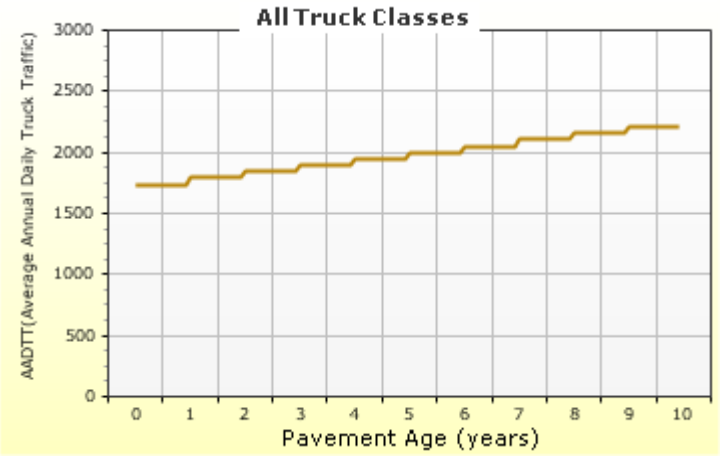
AADTT (Average Annual Daily Truck Traffic) Growth

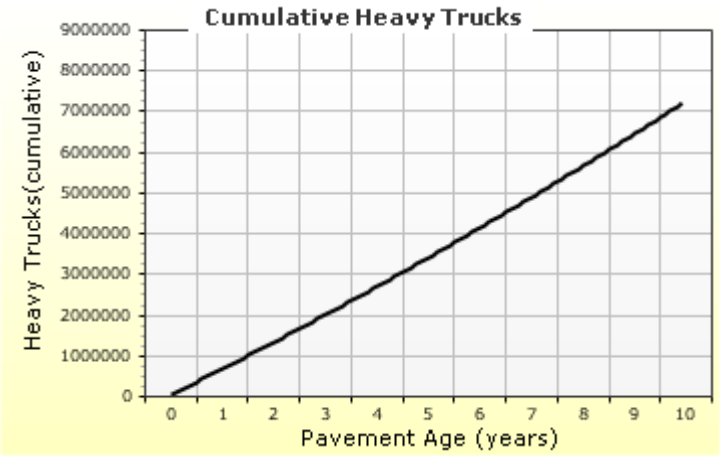
*** Traffic cap is not enforced**







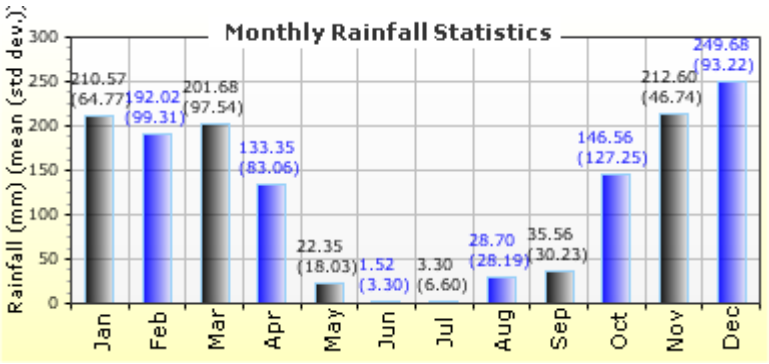




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
BRASILIA, DF	-15.78000 -47.91000 1159

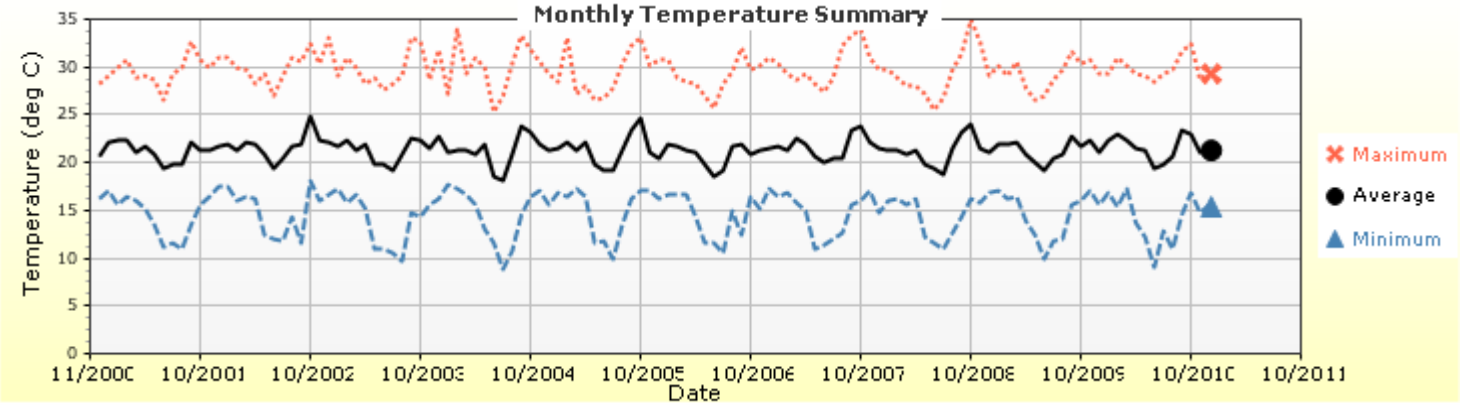


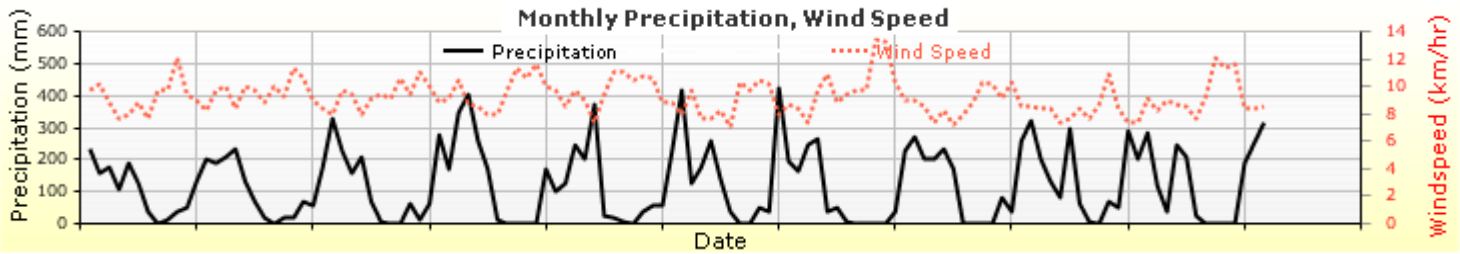
Annual Statistics:

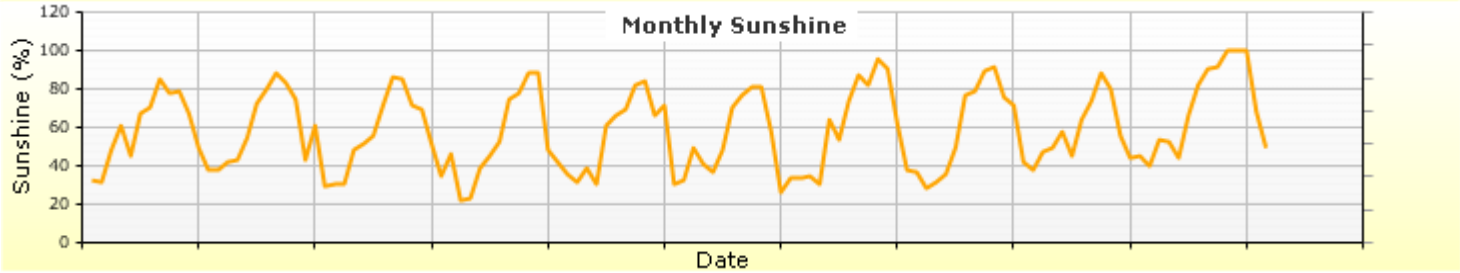
Mean annual air temperature (ºC)	21.35
Mean annual precipitation (mm)	1461.01
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

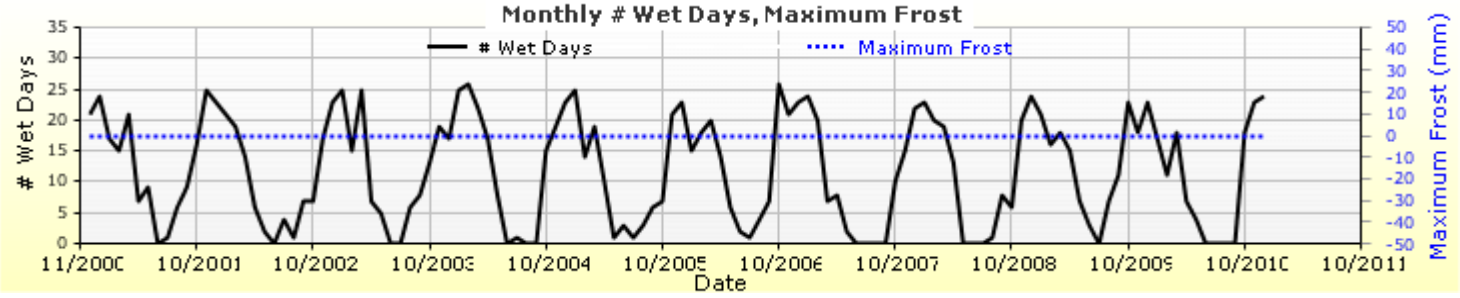
Water table depth (m)	3.05

Monthly Climate Summary:

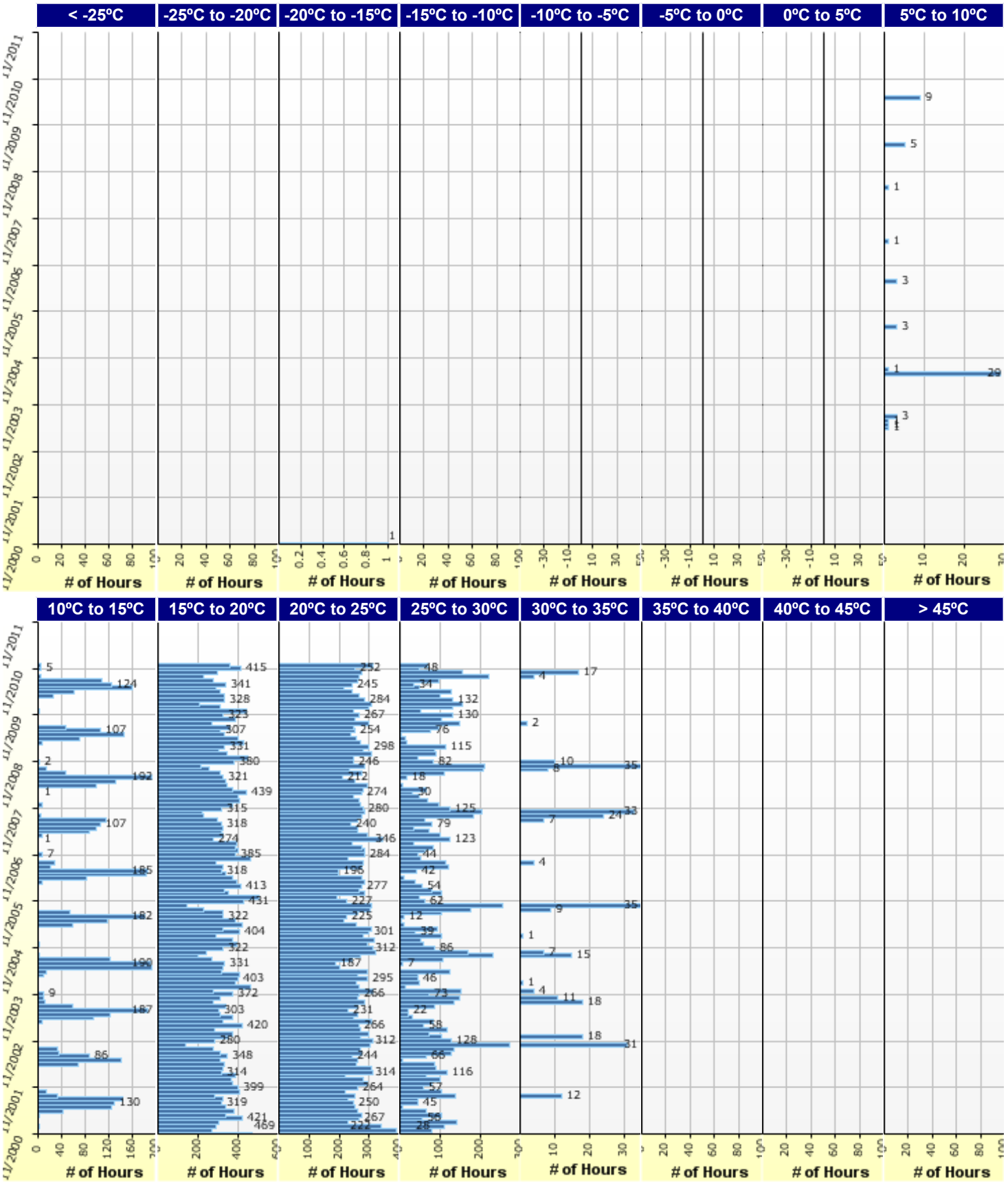








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

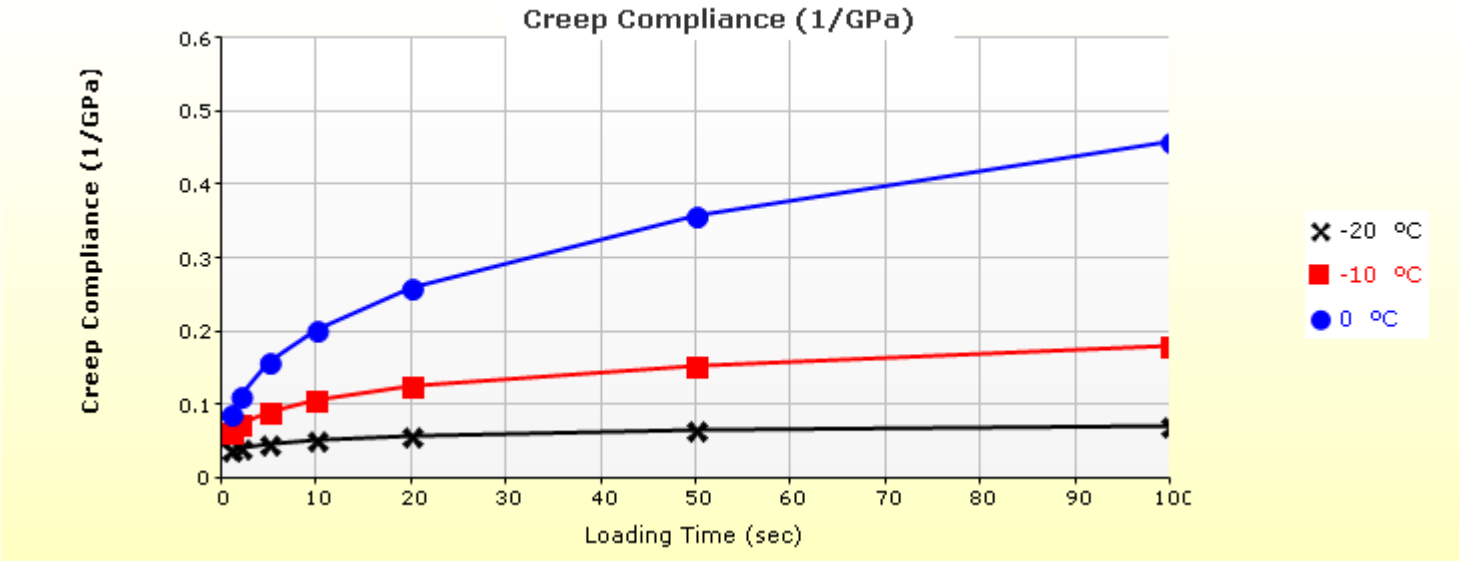
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

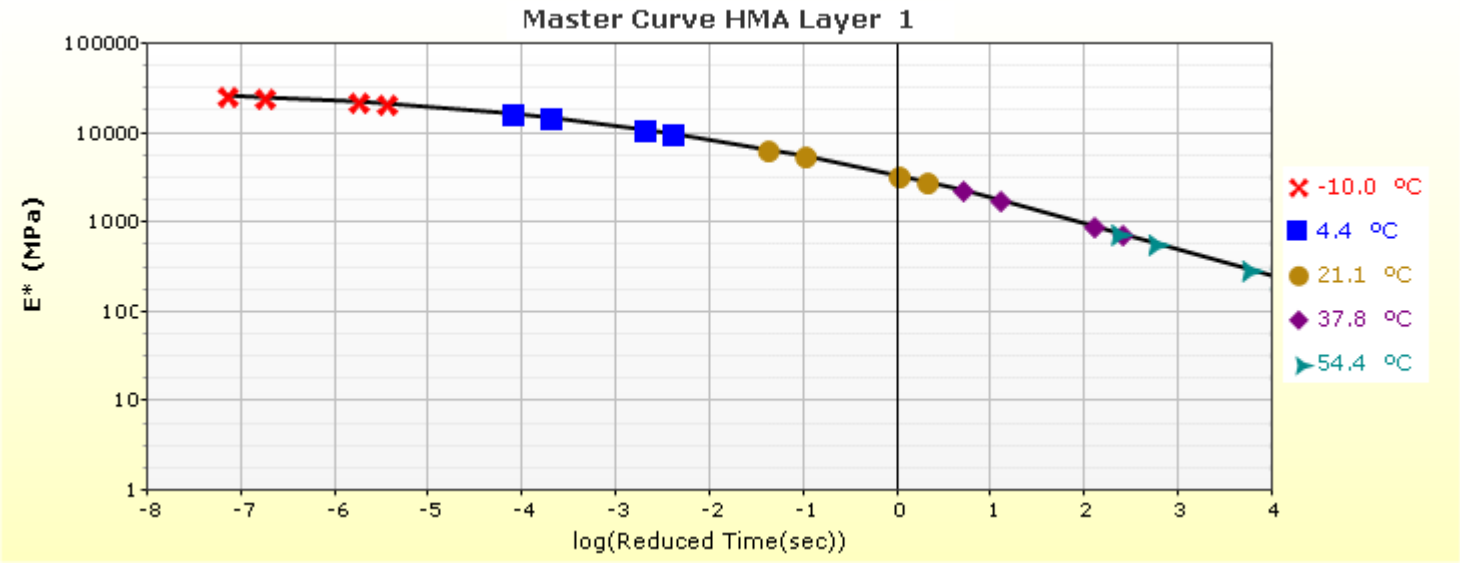
Indirect tensile strength at -10 ºC (MPa)	2.69

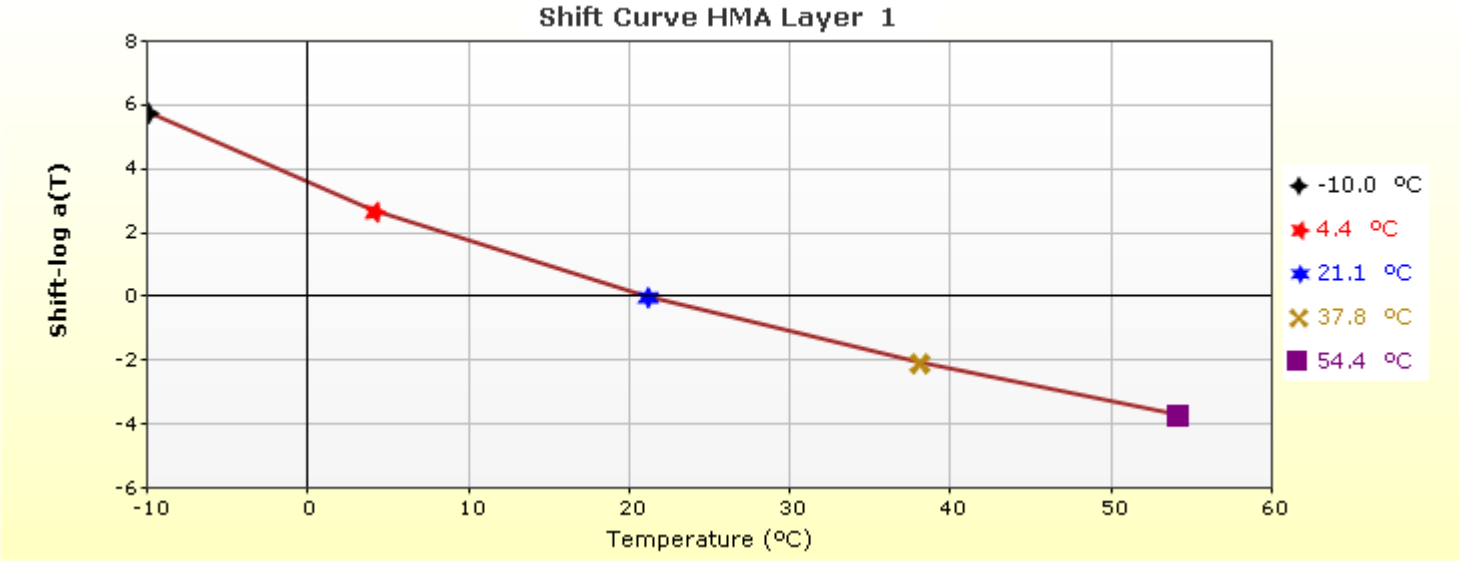
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

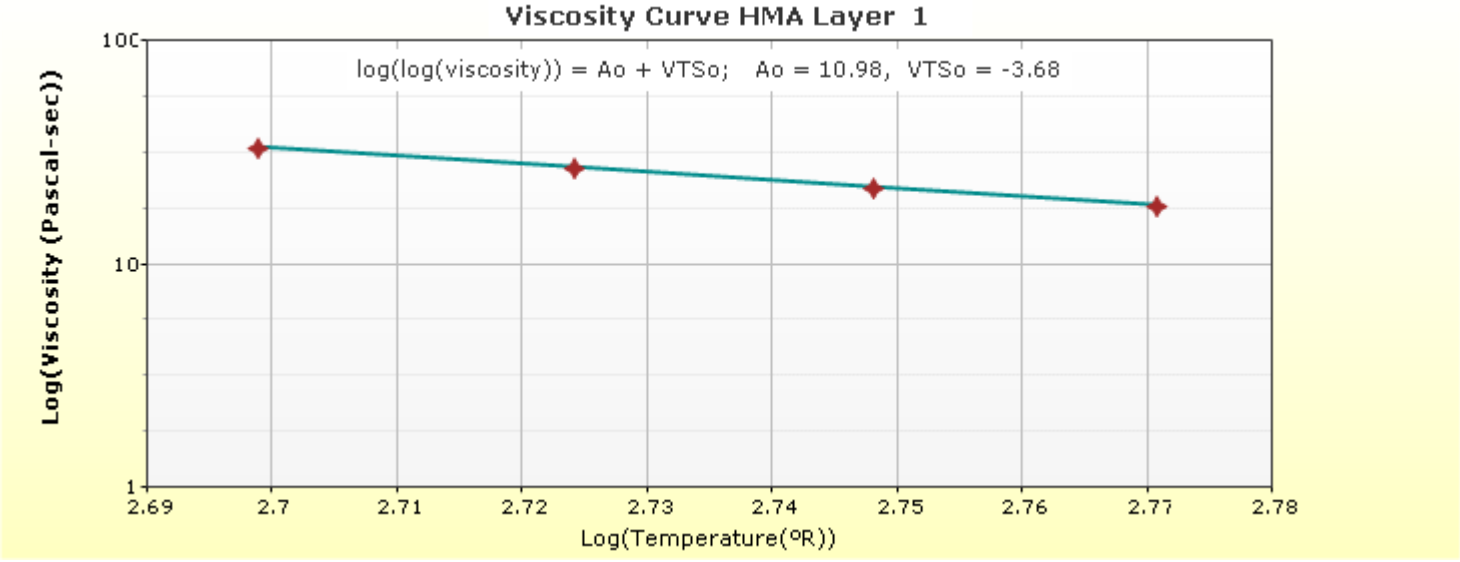
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



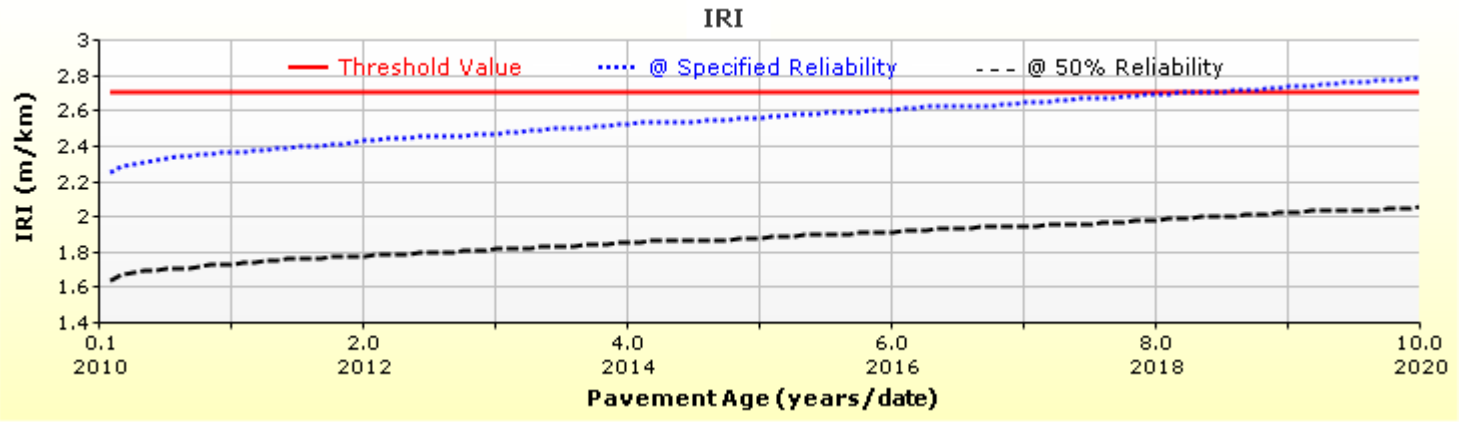
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

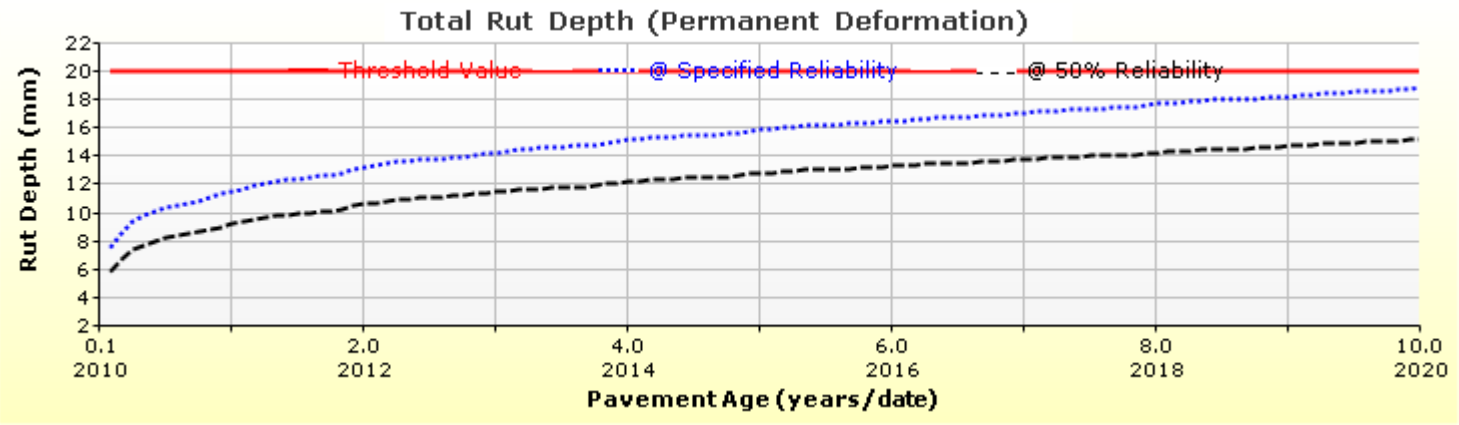


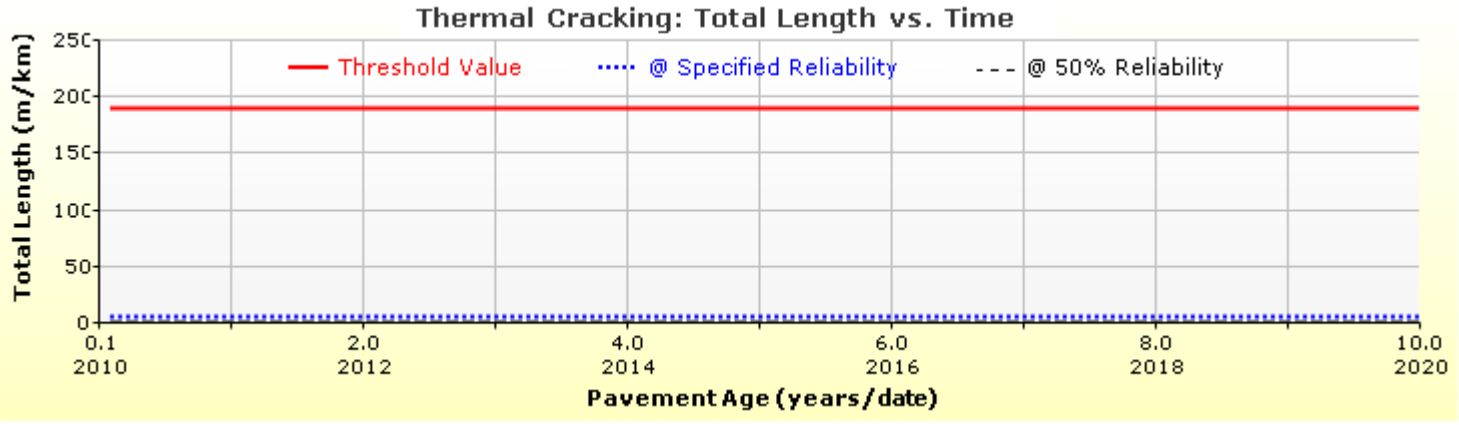


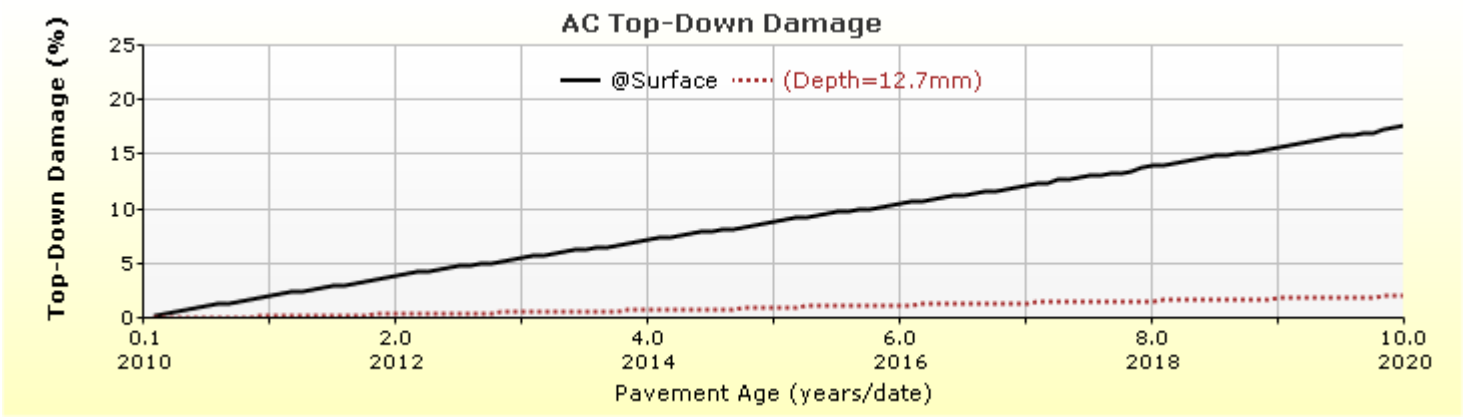


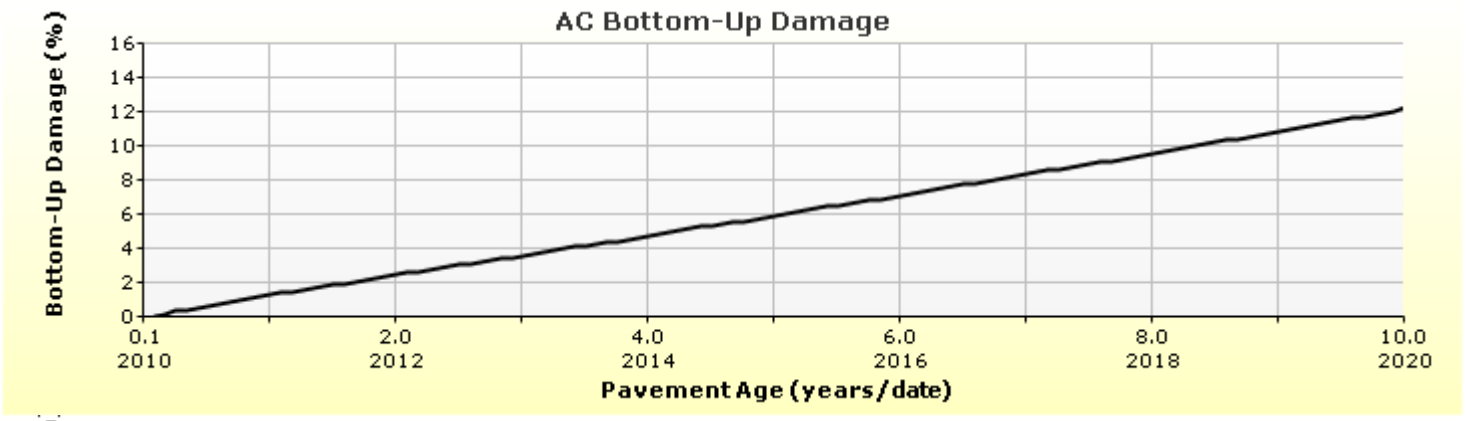
Analysis Output Charts

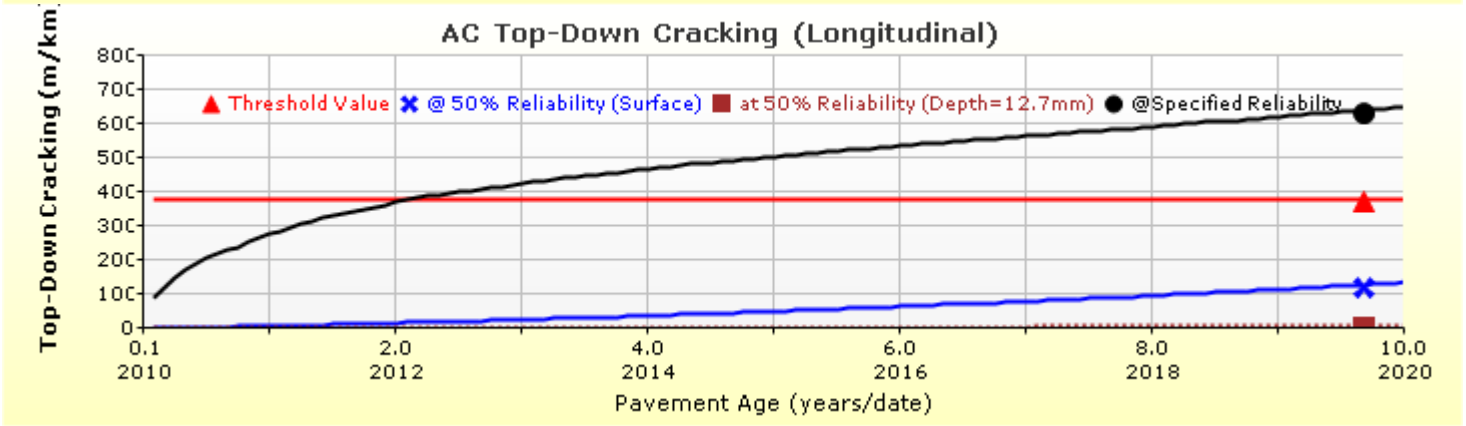


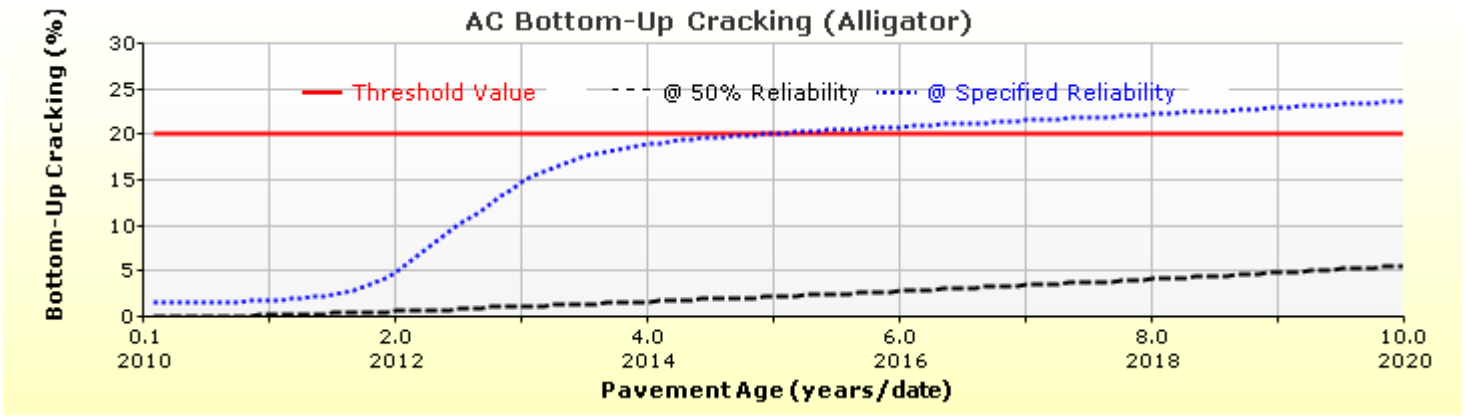


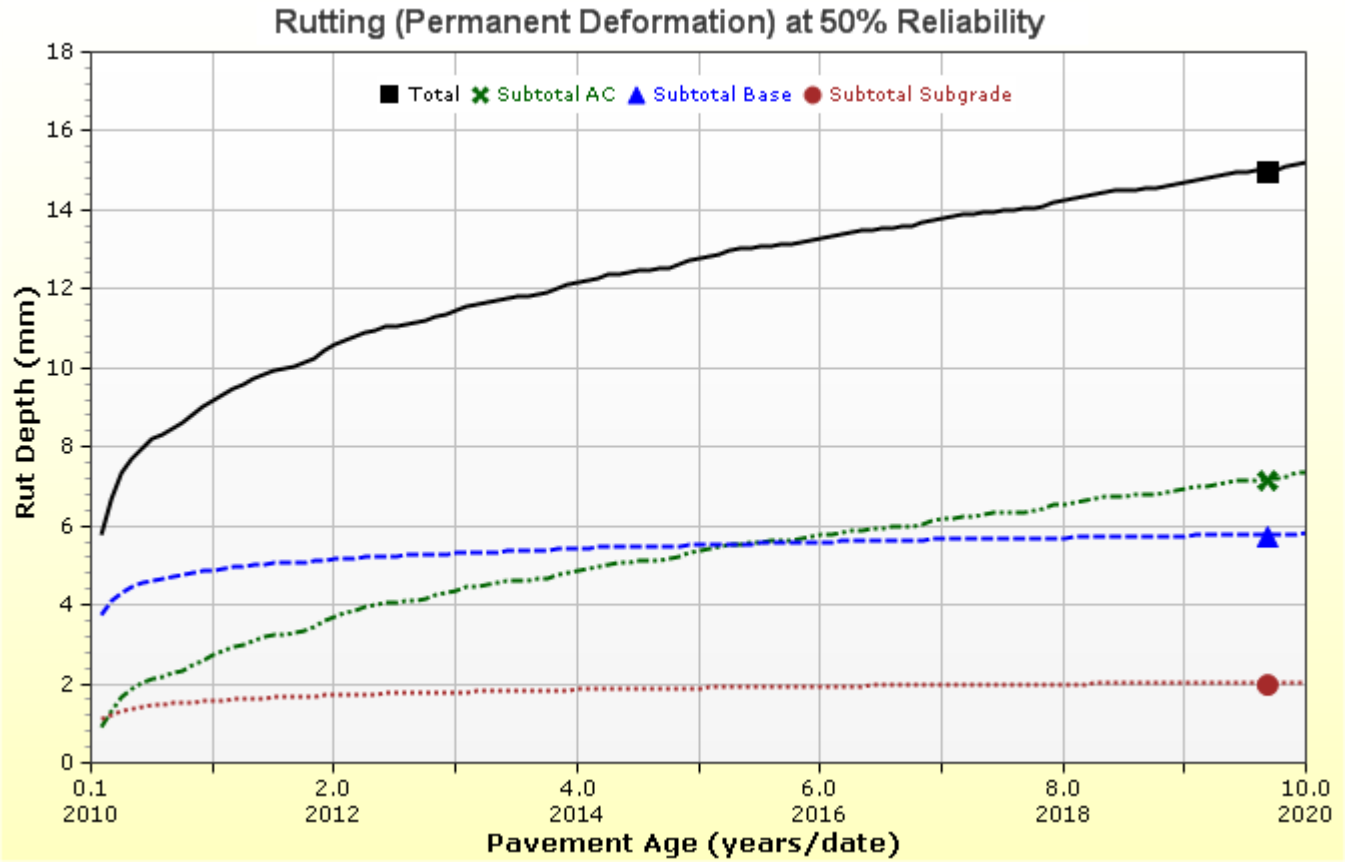


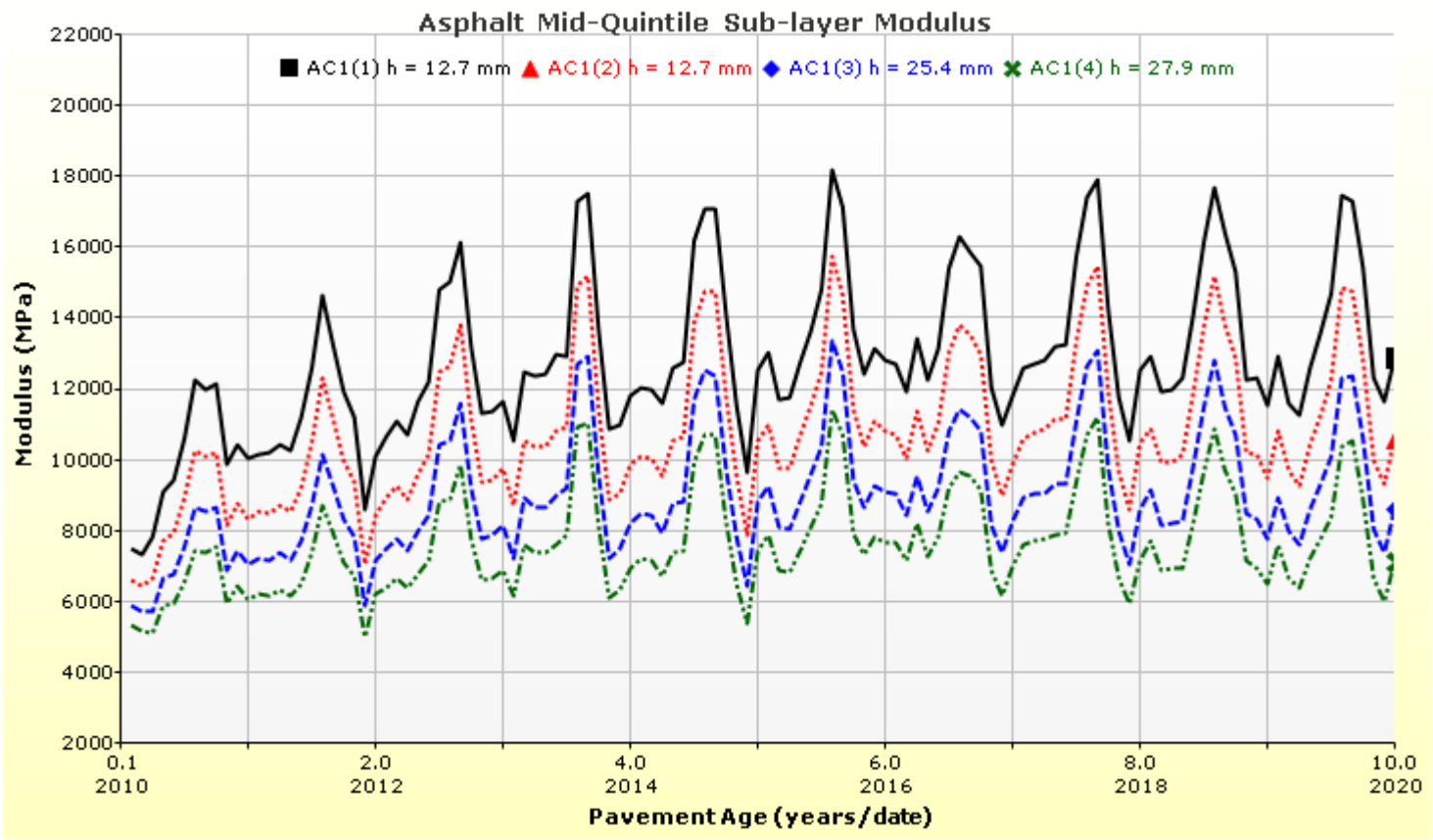

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

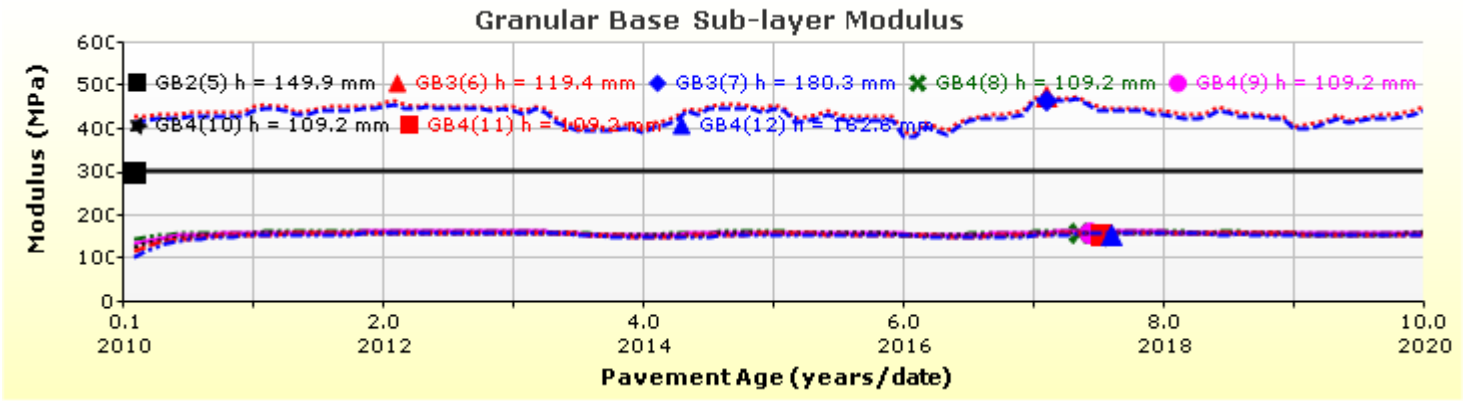

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

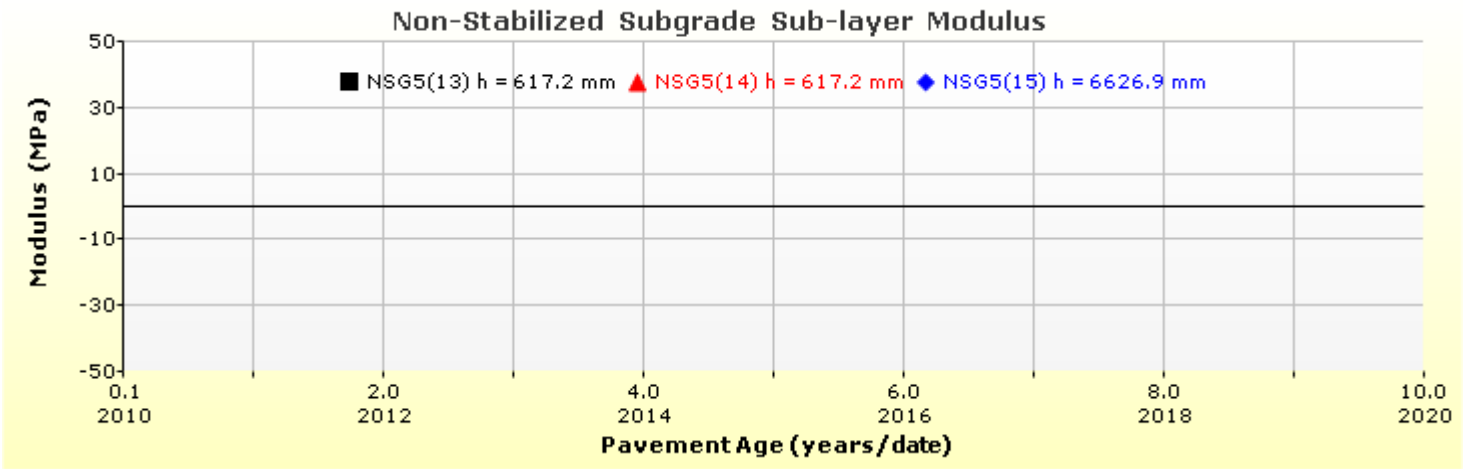

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.8 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestFZ

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestFZ.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -3.77, -38.55

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

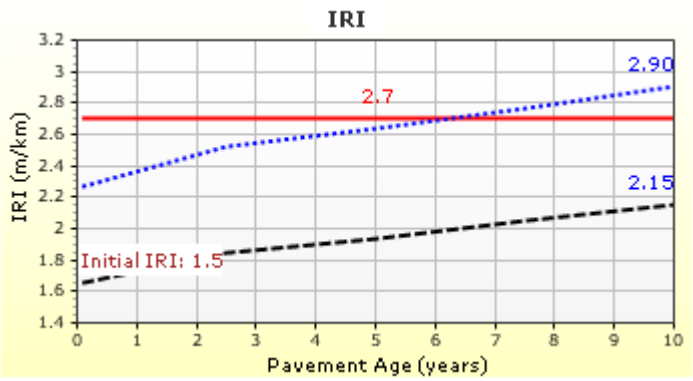
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

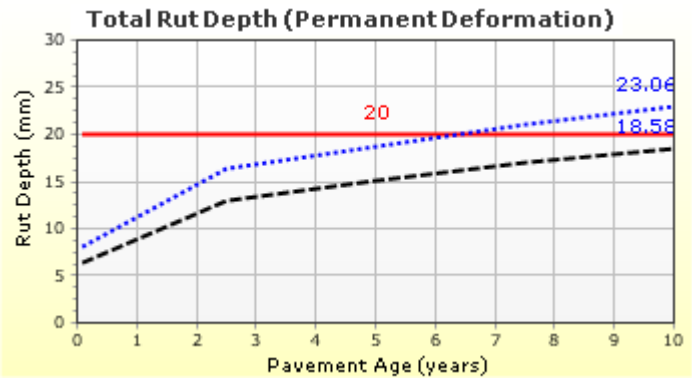
Design Outputs

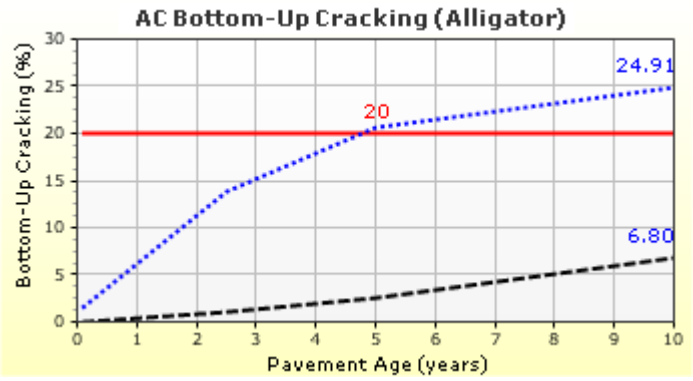
Distress Prediction Summary

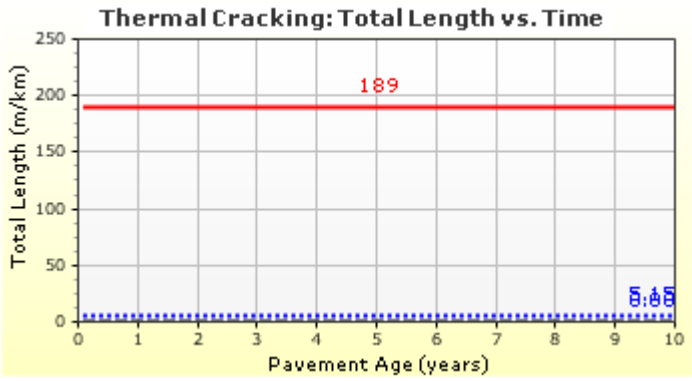
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.90	90.00	82.60	Fail
Permanent deformation - total pavement (mm)	20.00	23.07	90.00	65.66	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.91	90.00	82.49	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	744.27	90.00	65.75	Fail
Permanent deformation - AC only (mm)	5.00	10.72	50.00	3.16	Fail

Distress Charts







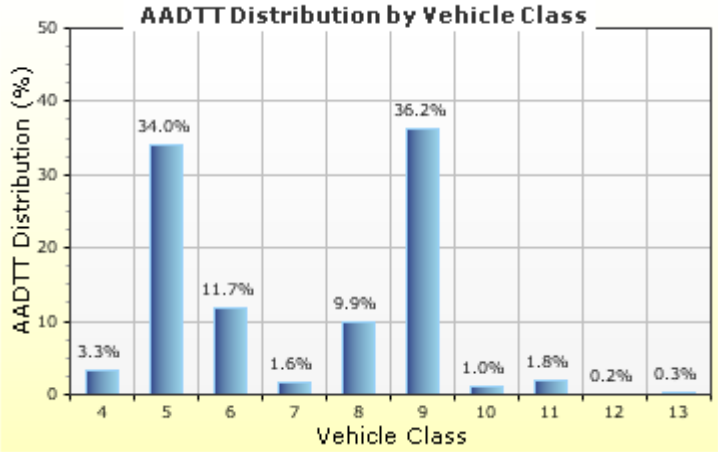


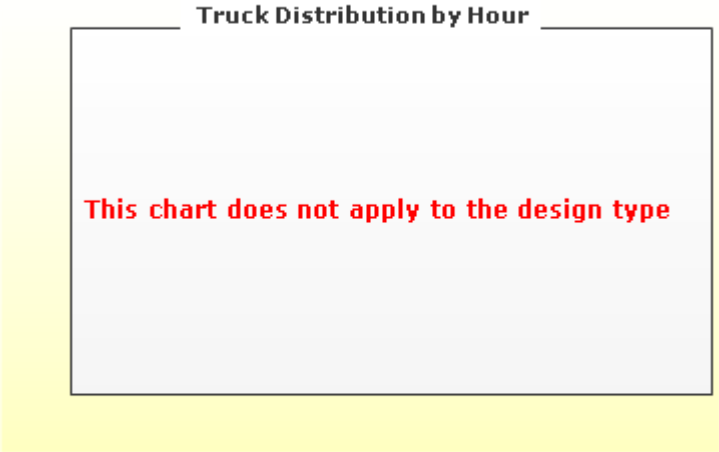


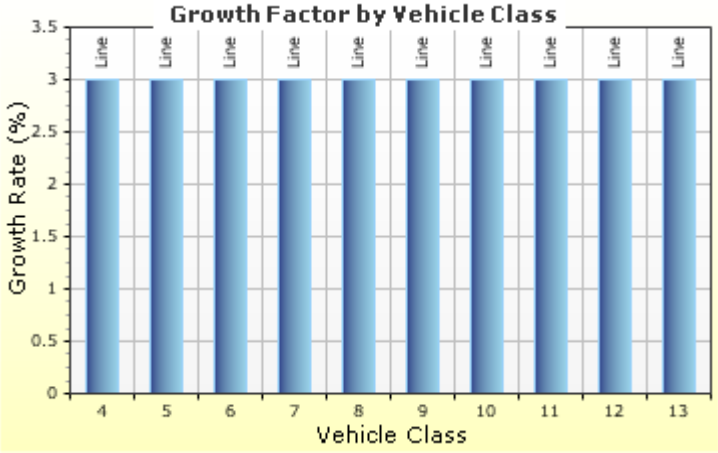
Traffic Inputs

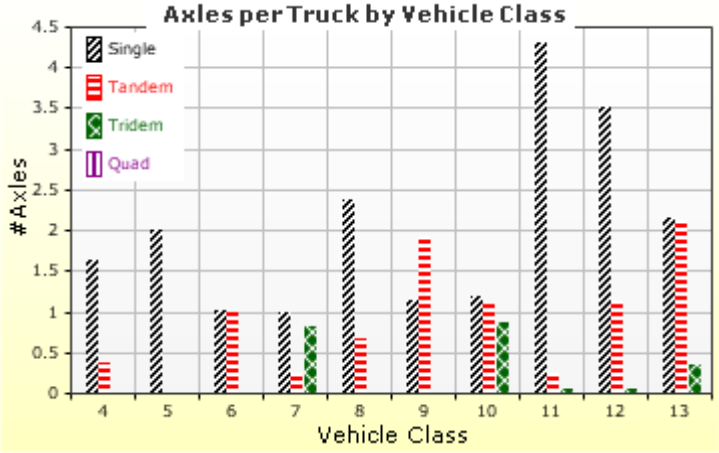
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

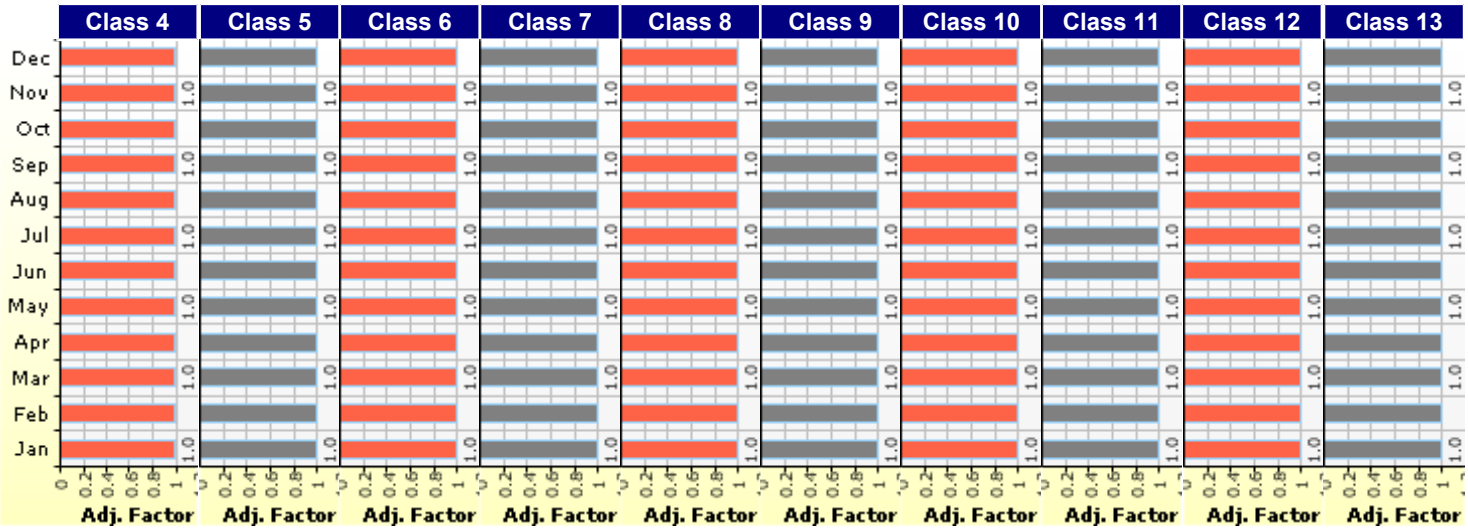








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

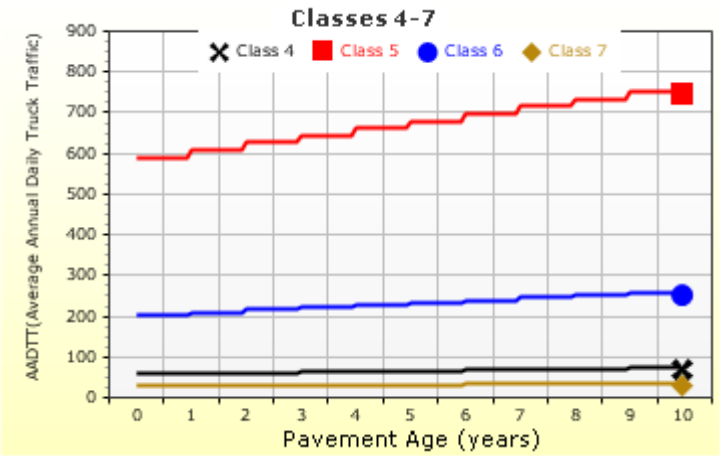
Wheelbase does not apply

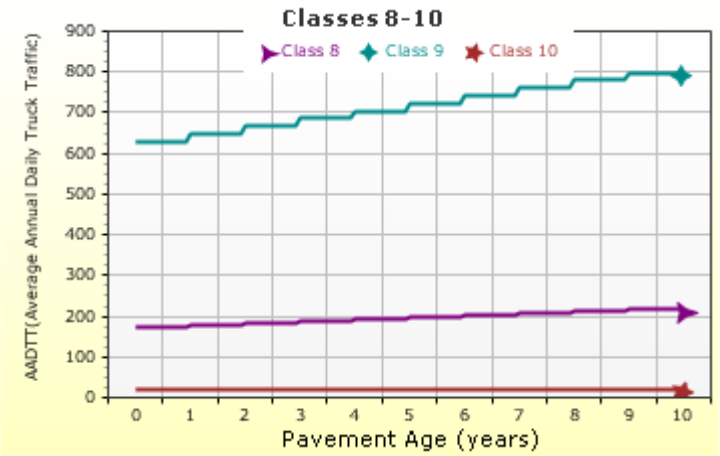
Number of Axles per Truck

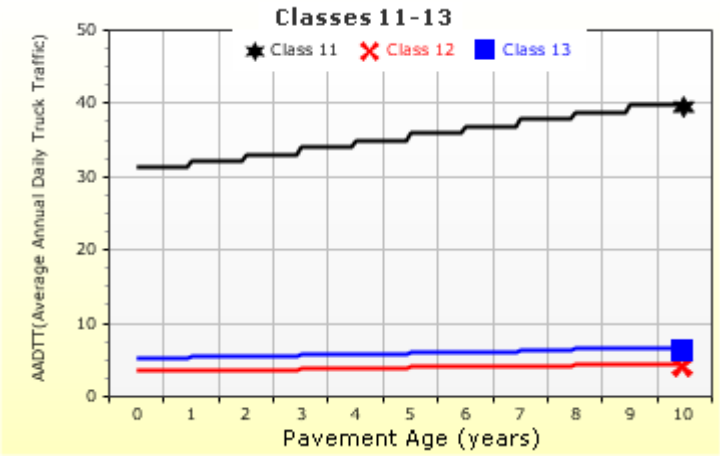
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

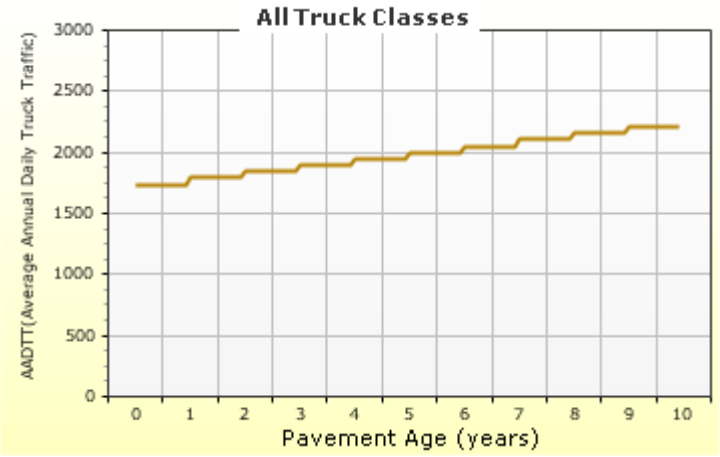
AADTT (Average Annual Daily Truck Traffic) Growth

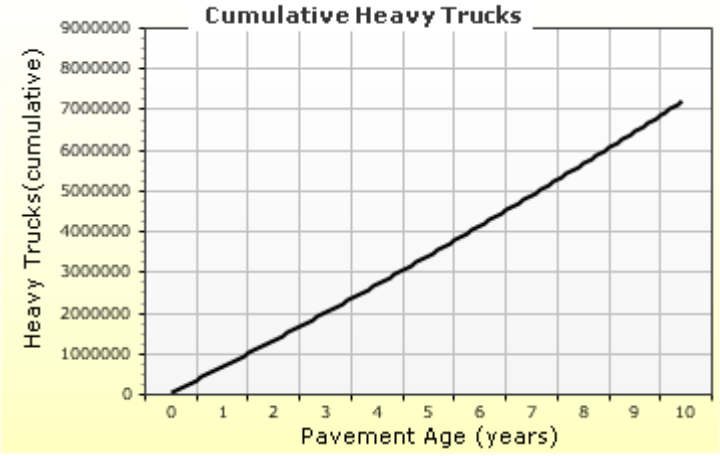
*** Traffic cap is not enforced**







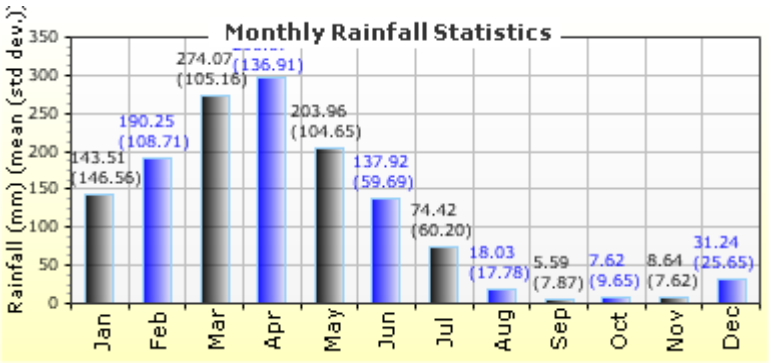




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
FORTALEZA, CE	-3.77000 -38.55000 41

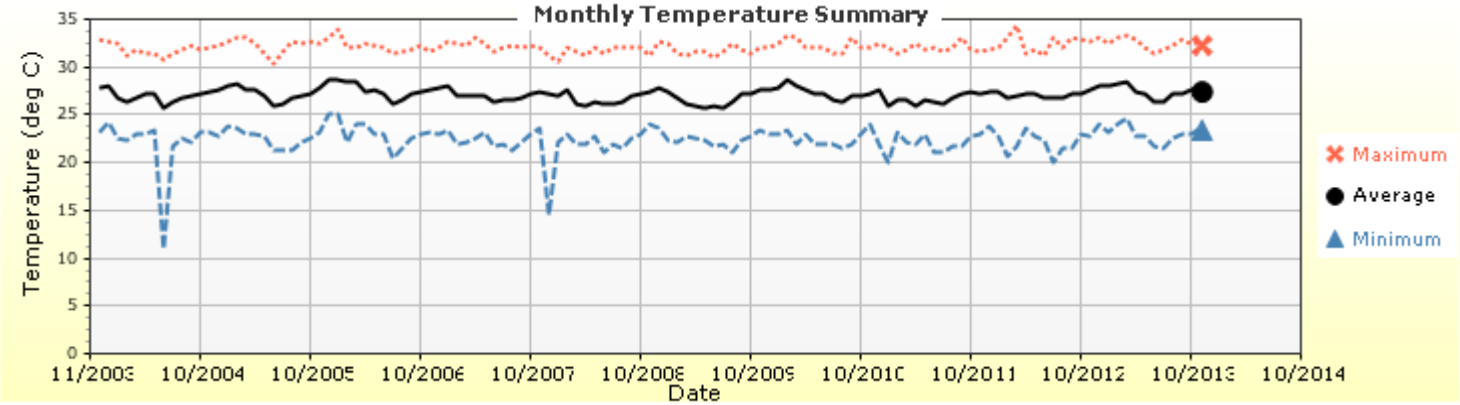


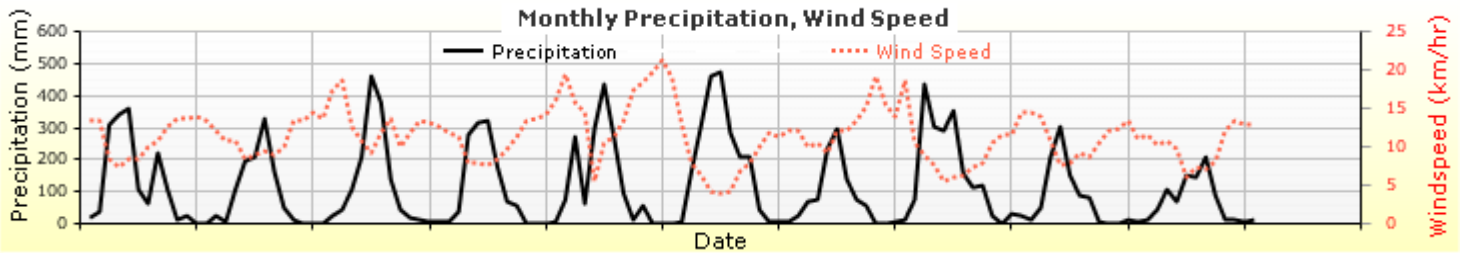
Annual Statistics:

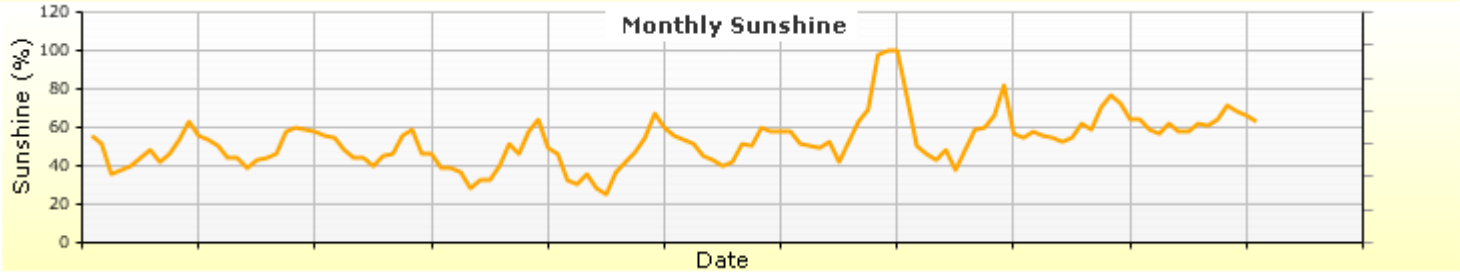
Mean annual air temperature (ºC)	27.09
Mean annual precipitation (mm)	1370.58
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

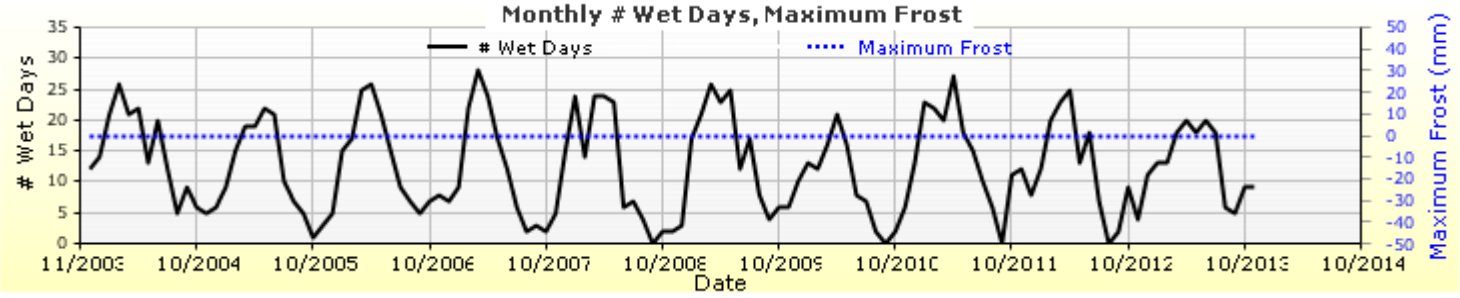
Water table depth (m): 3.05

Monthly Climate Summary:

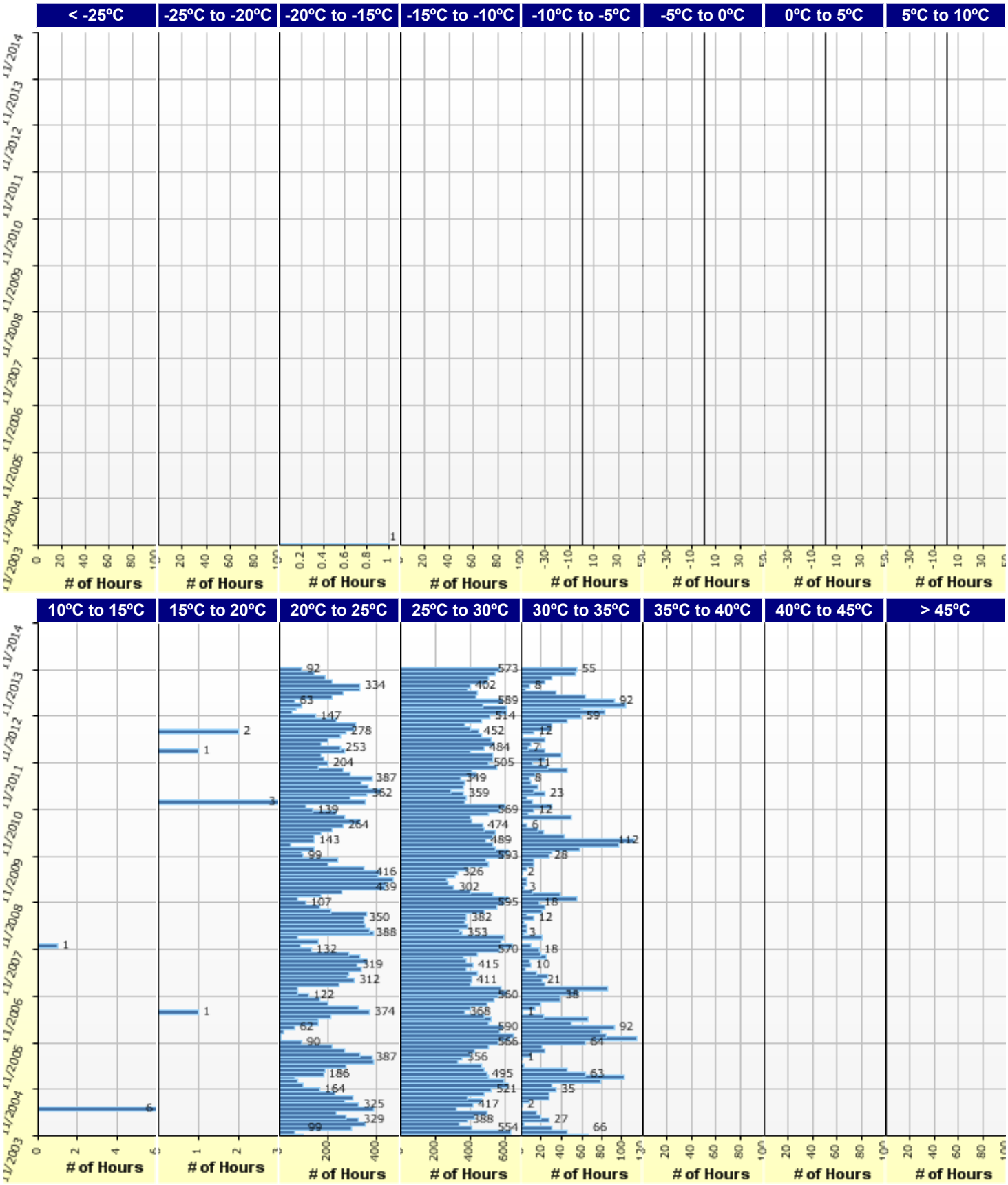








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

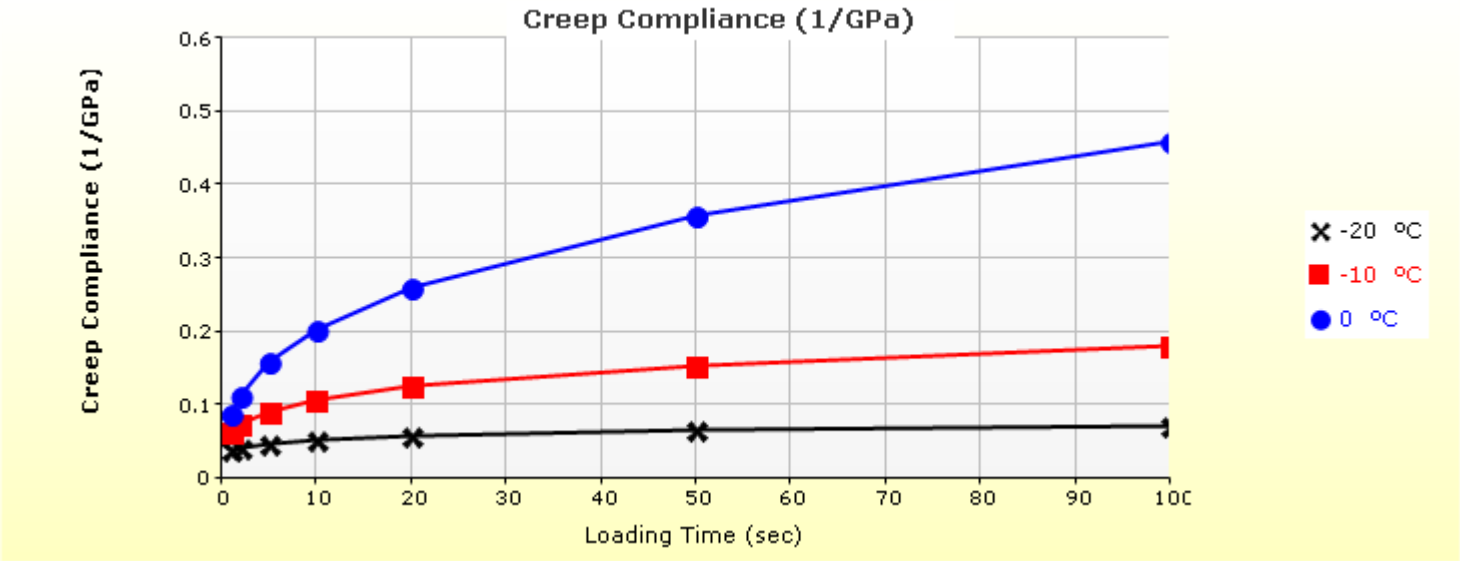
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

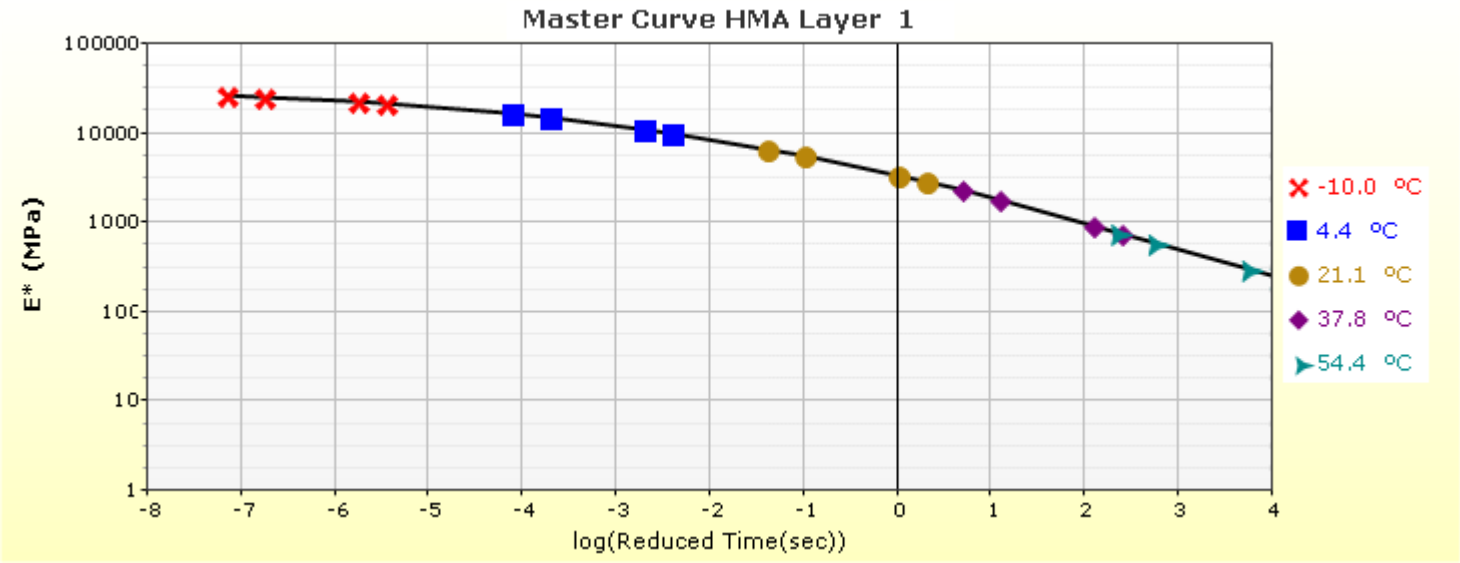
Indirect tensile strength at -10 ºC (MPa)	2.69

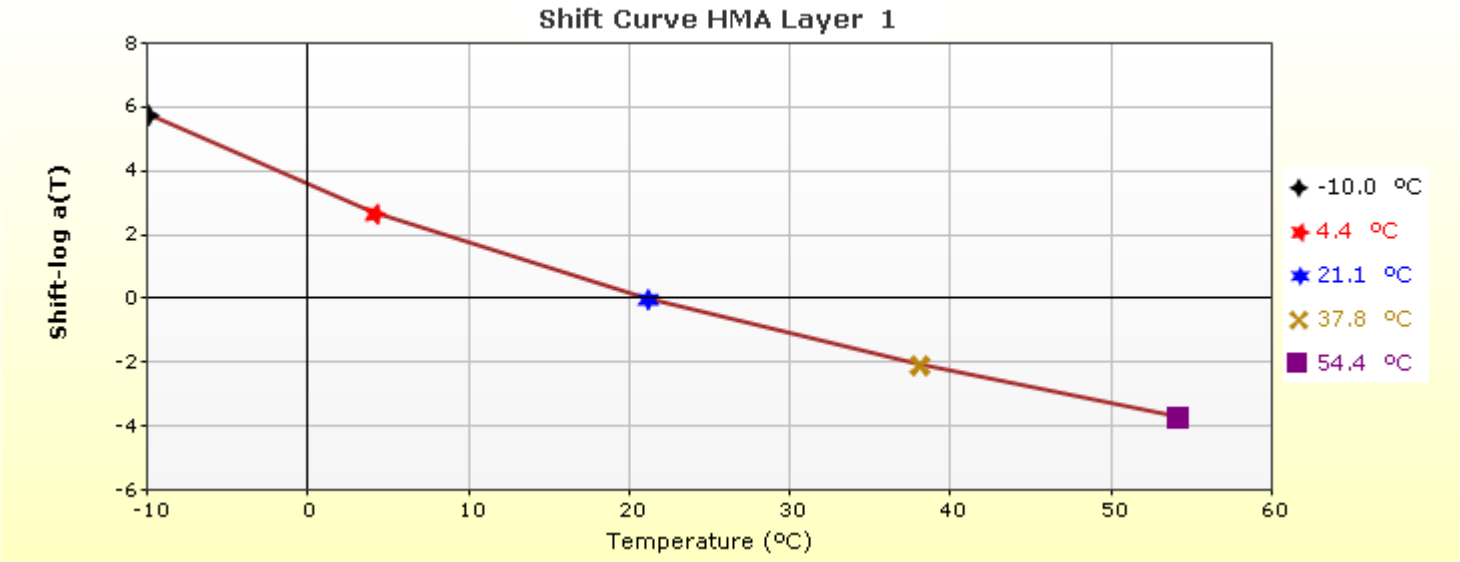
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

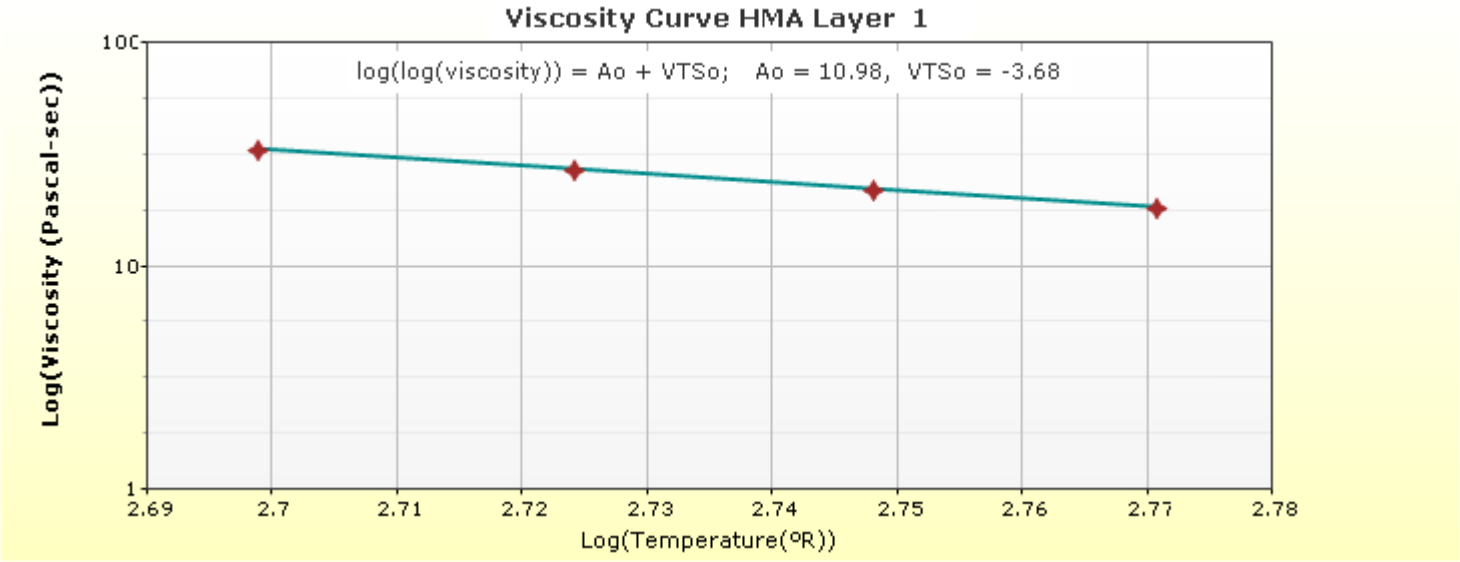
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



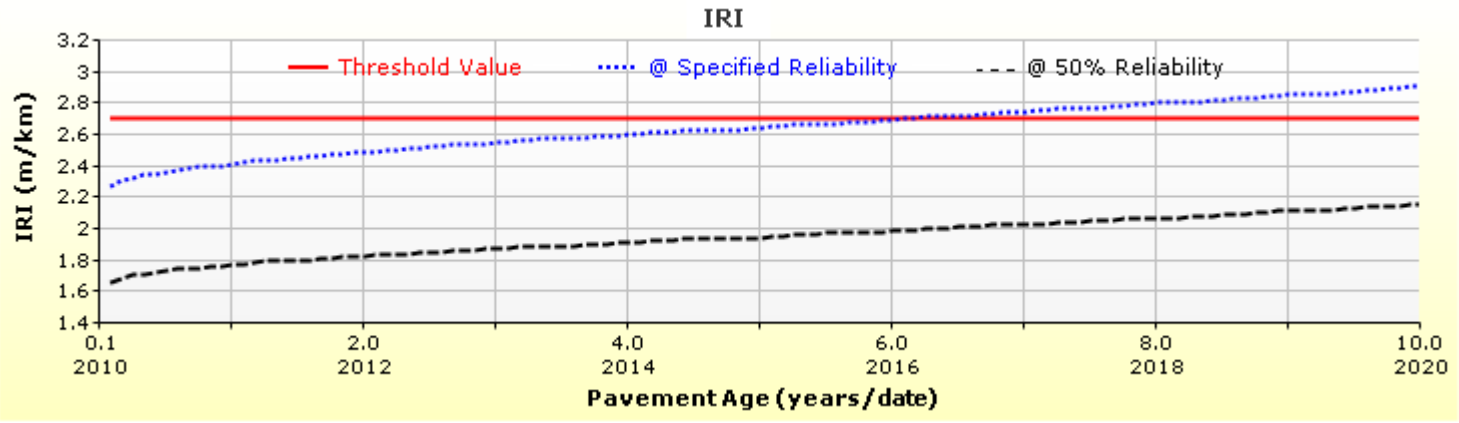
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

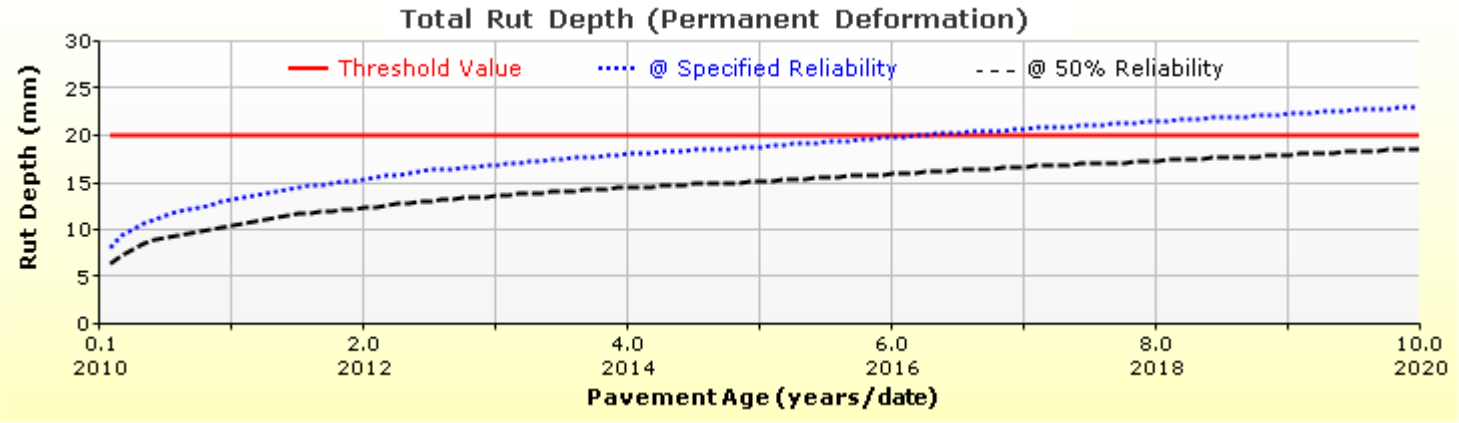


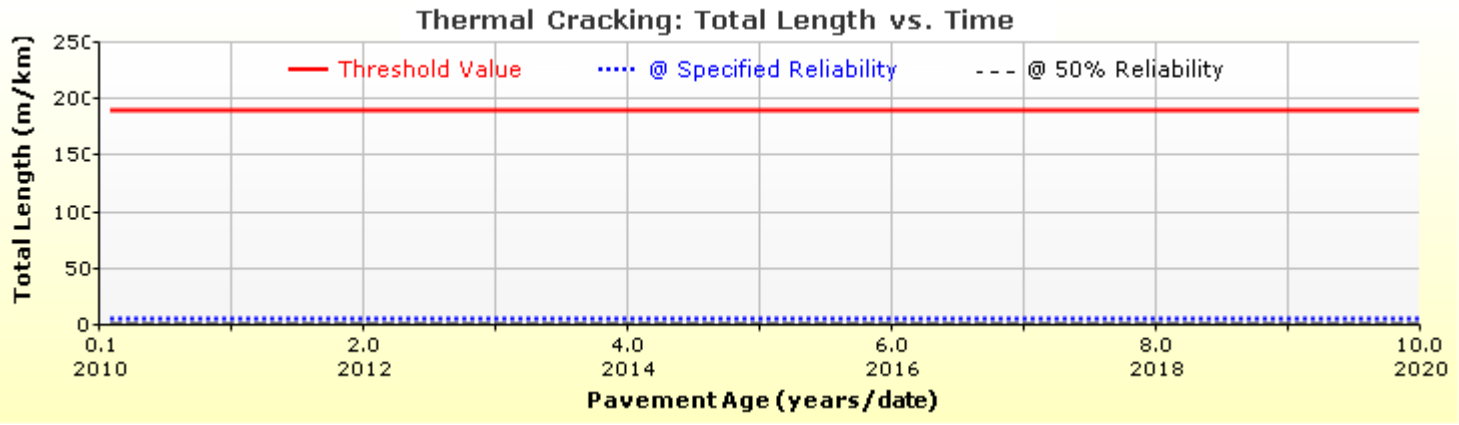


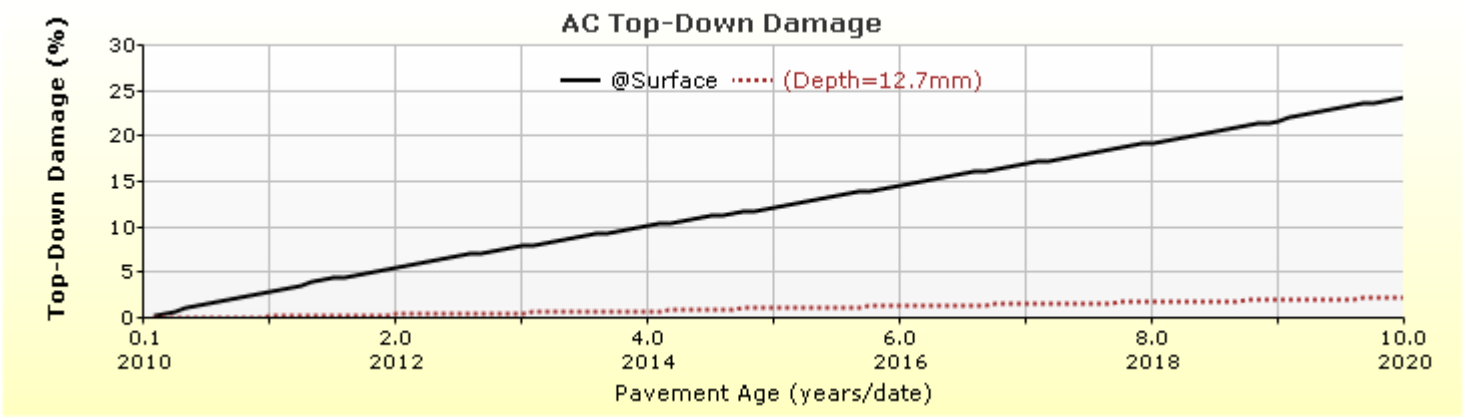


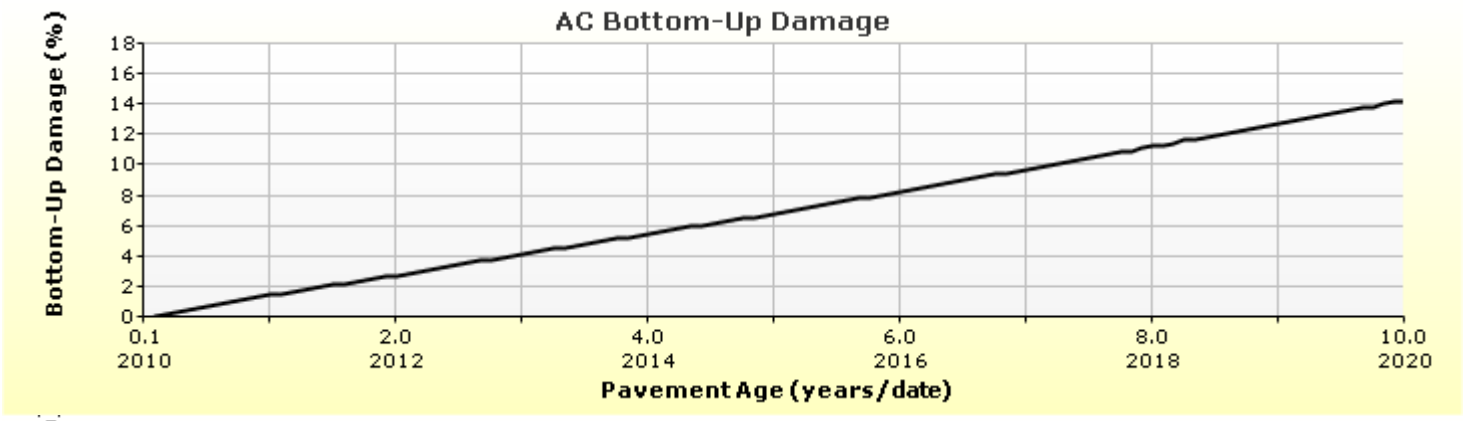
Analysis Output Charts

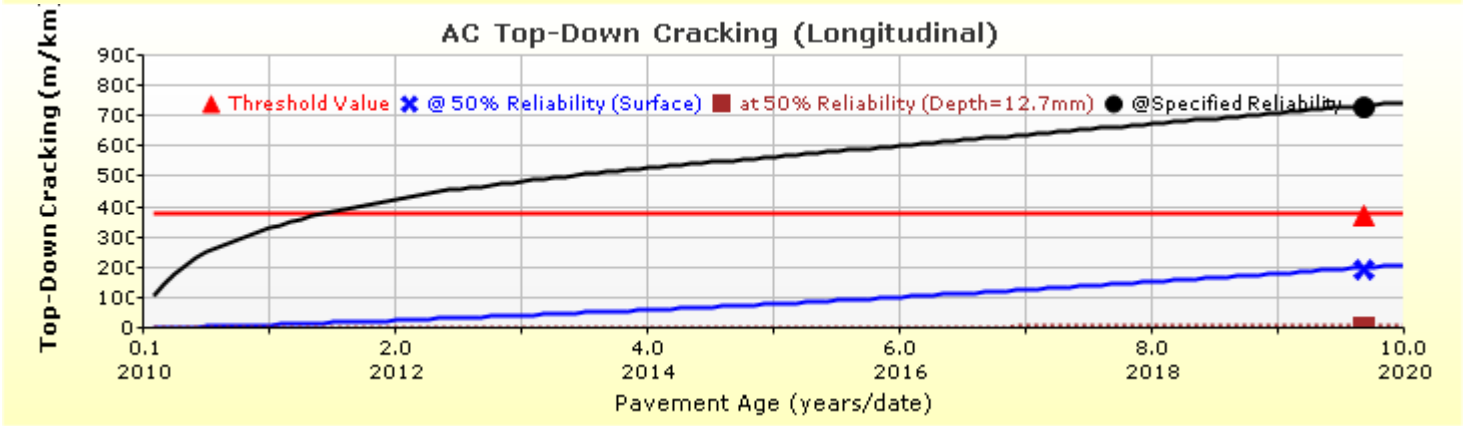


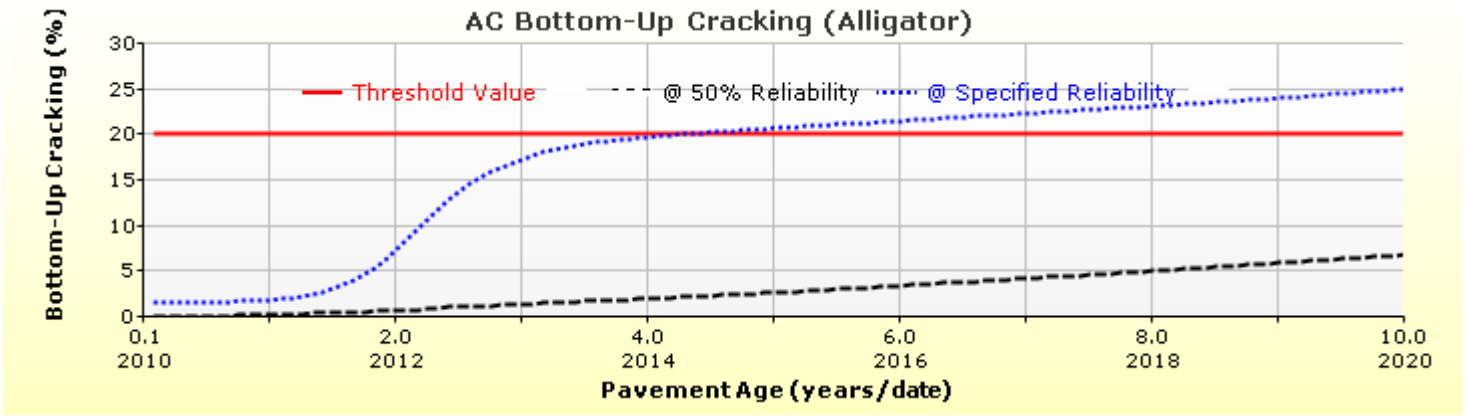


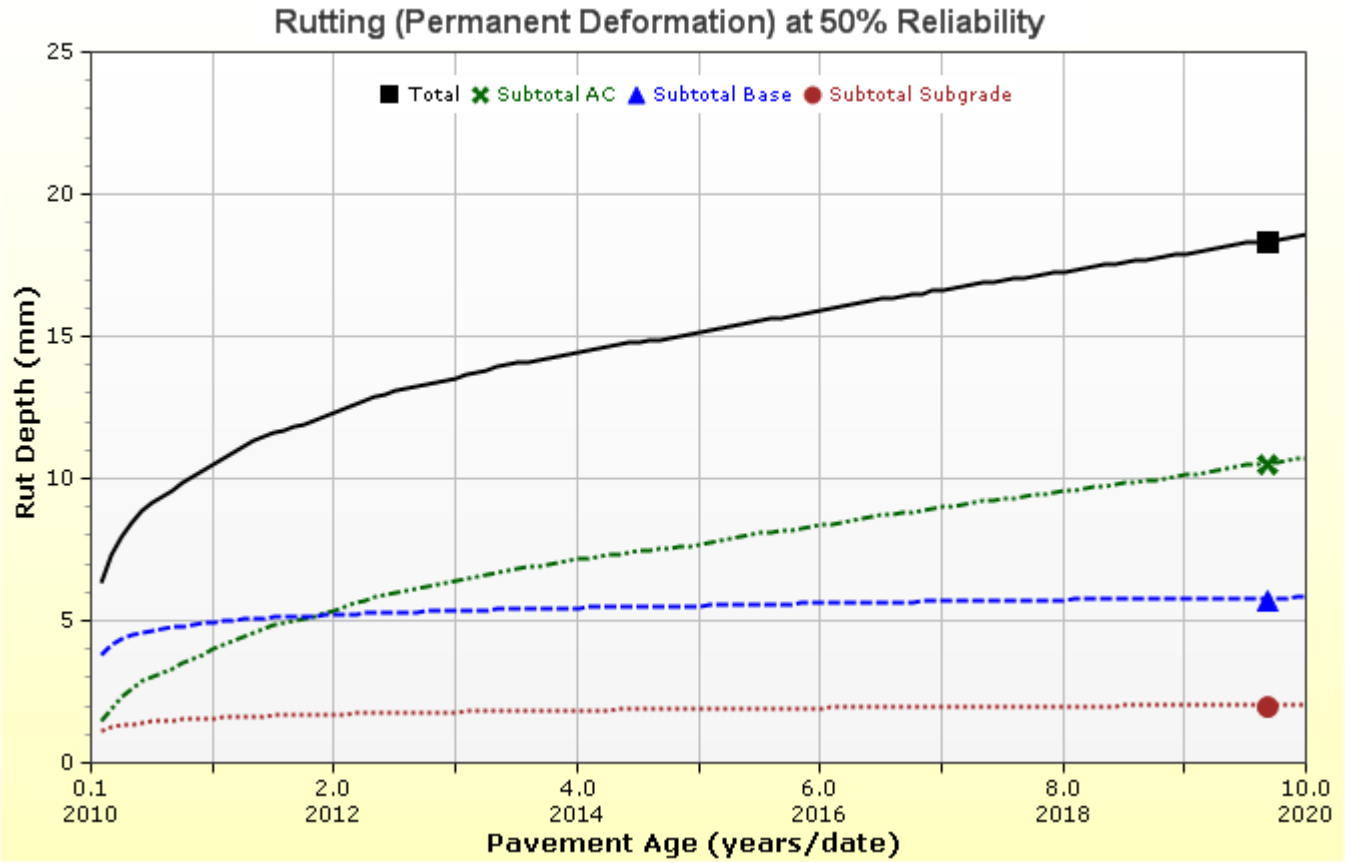


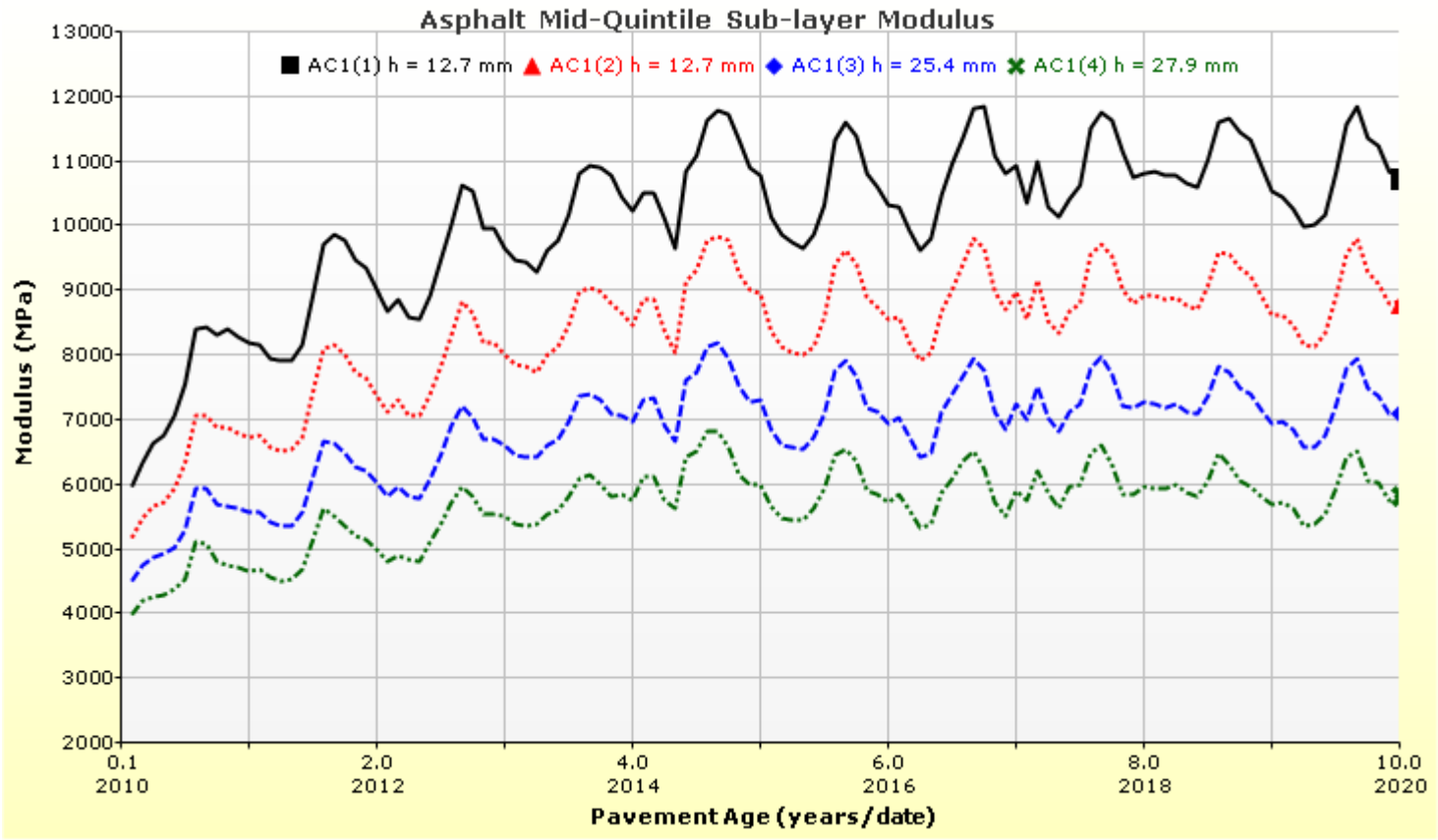

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

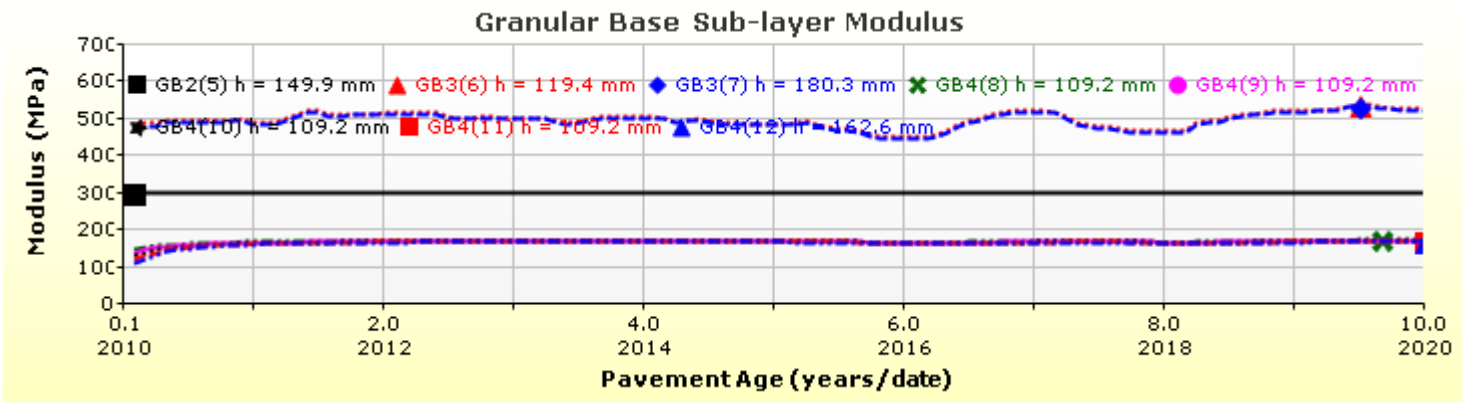

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

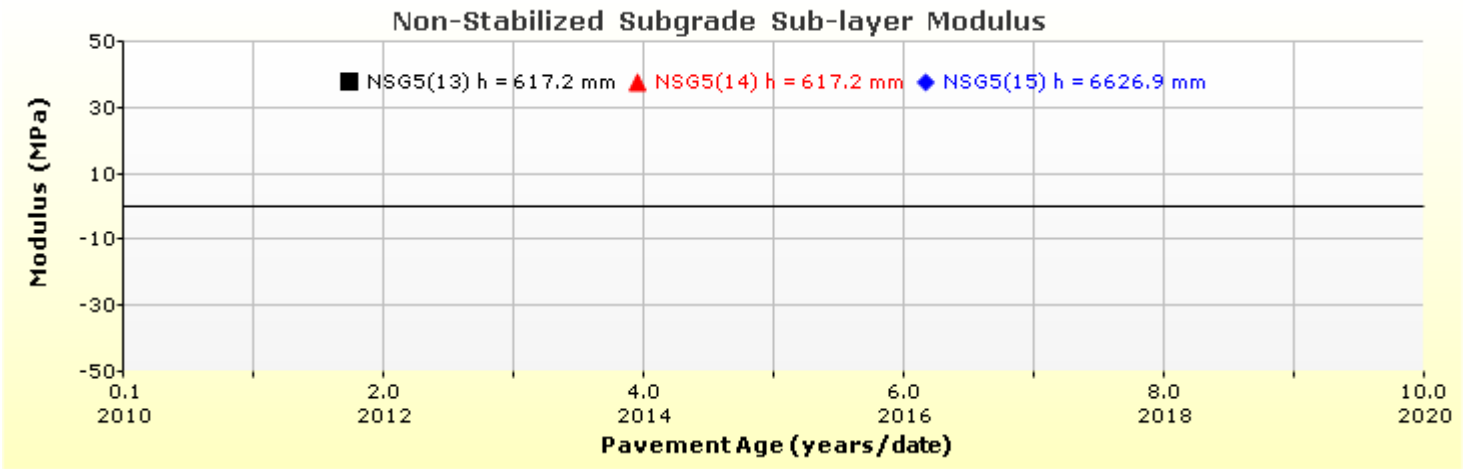

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
900
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 1
Bf2: 1
Bf3: 1

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

$$H_{ac} = total\ AC\ thickness(in)$$

$\varepsilon_p = plastic\ strain\left({}^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left({}^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestFZ+2

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestFZ+2.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -3.77, -38.55

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

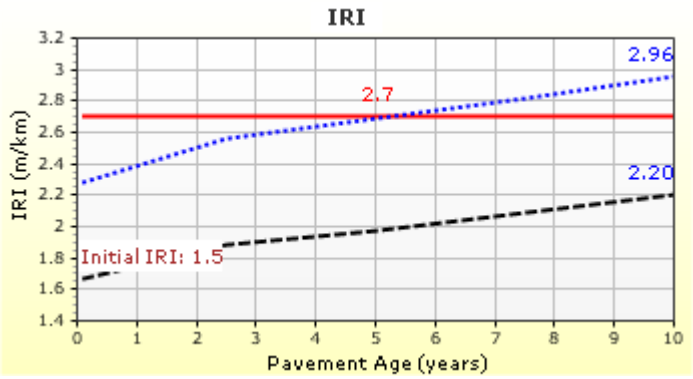
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

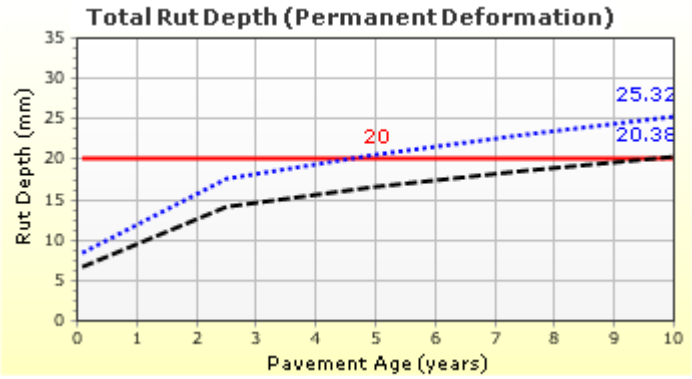
Design Outputs

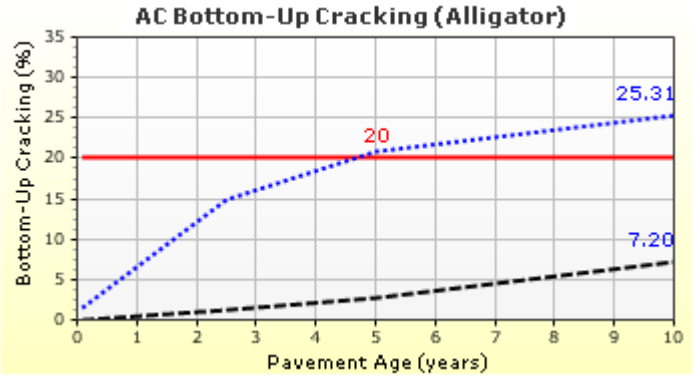
Distress Prediction Summary

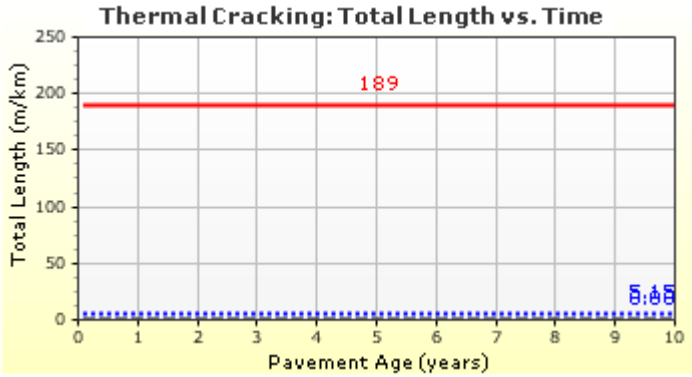
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.96	90.00	79.95	Fail
Permanent deformation - total pavement (mm)	20.00	25.33	90.00	45.99	Fail
AC bottom-up fatigue cracking (percent)	20.00	25.31	90.00	81.75	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	800.02	90.00	61.33	Fail
Permanent deformation - AC only (mm)	5.00	12.49	50.00	1.56	Fail

Distress Charts







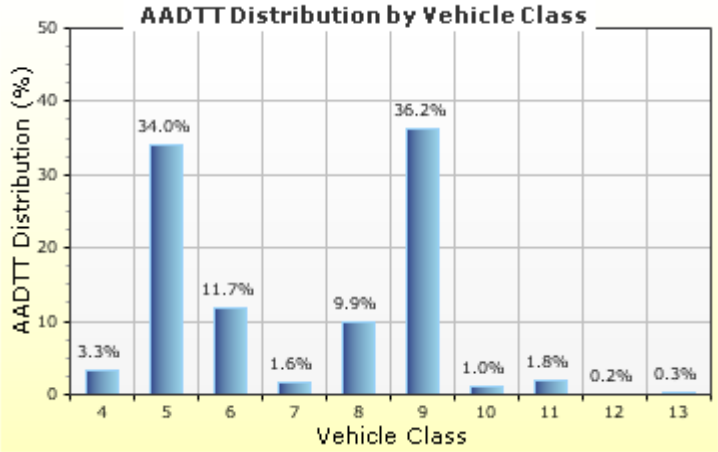


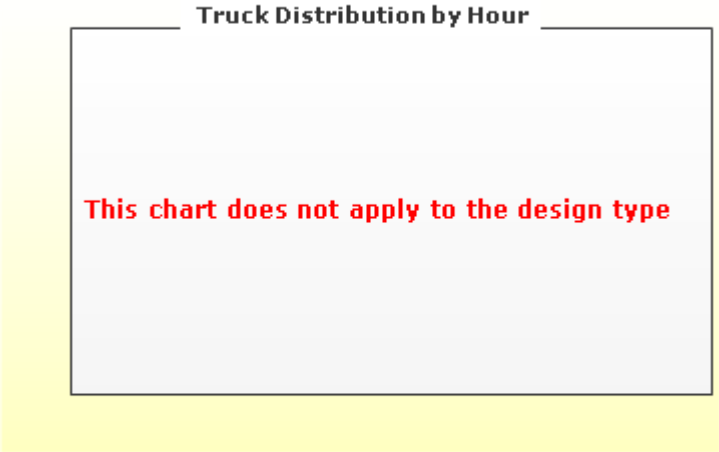


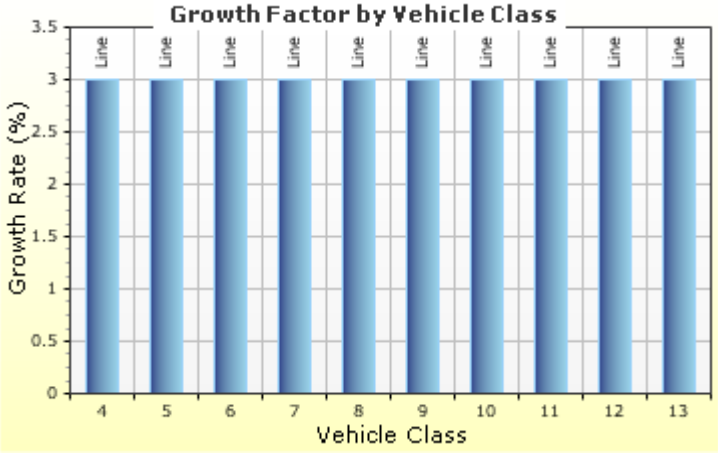
Traffic Inputs

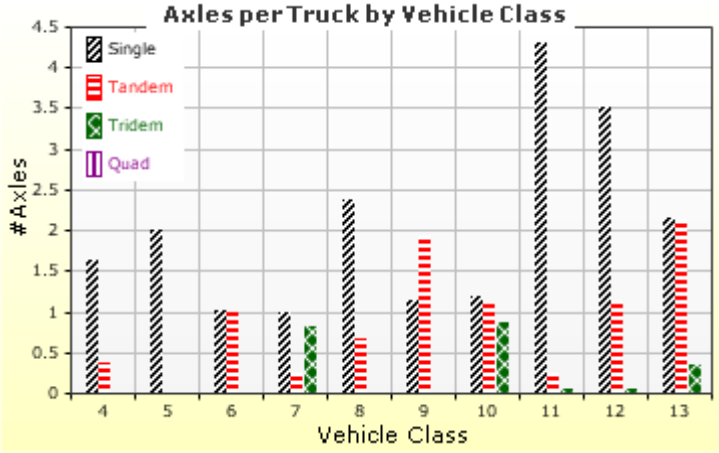
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

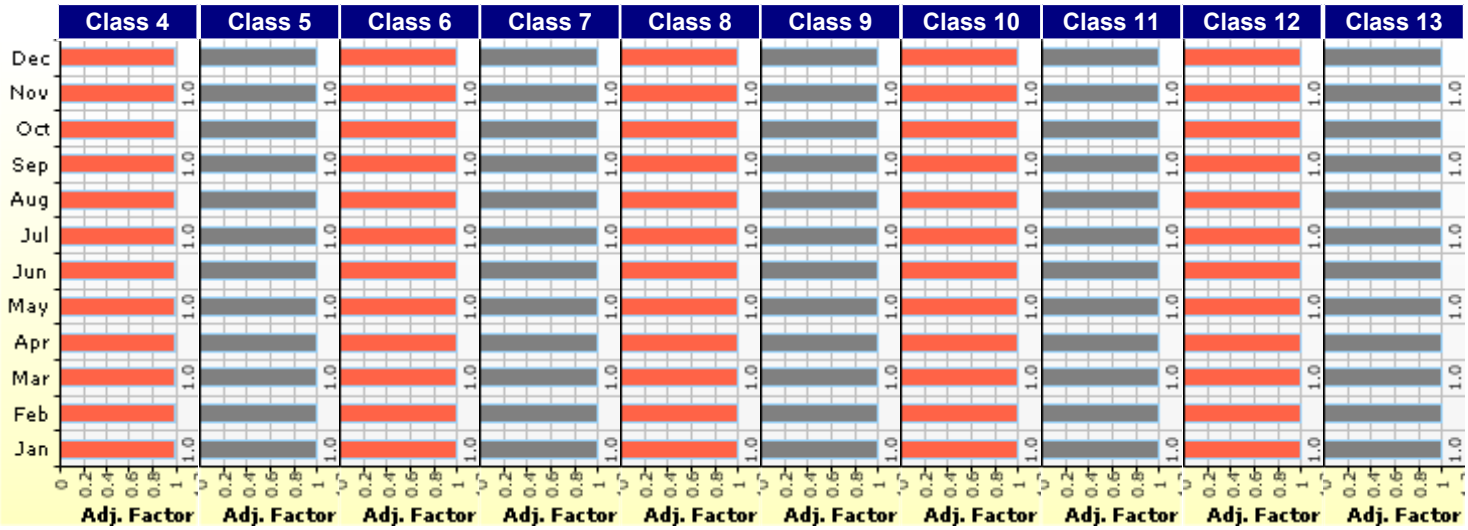








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

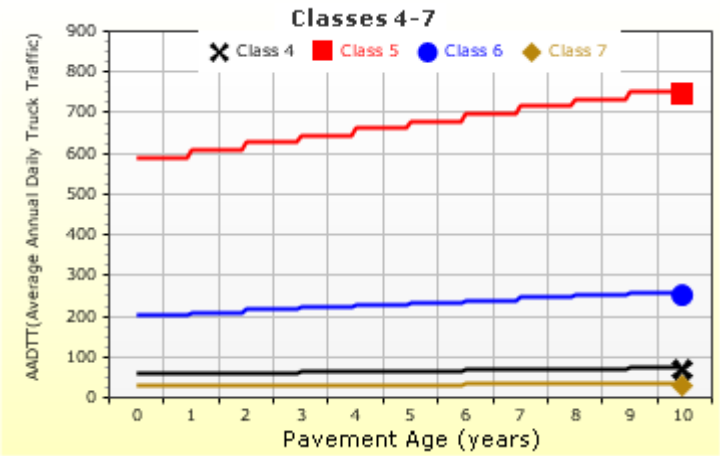
Wheelbase does not apply

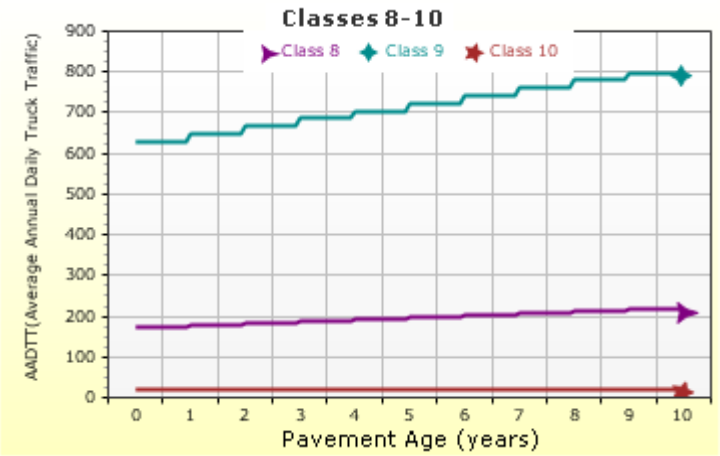
Number of Axles per Truck

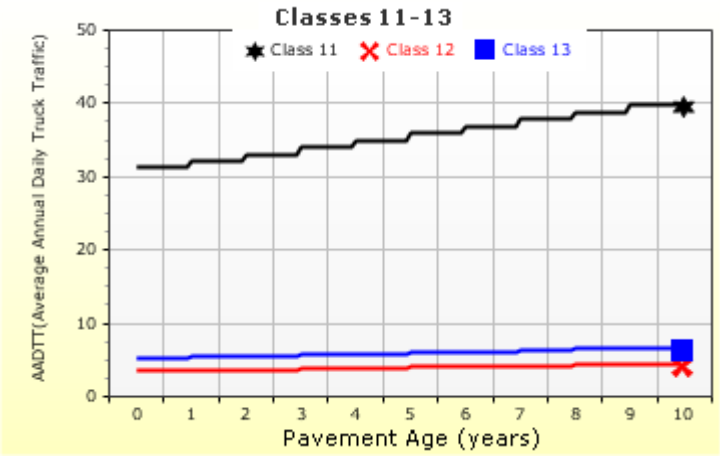
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

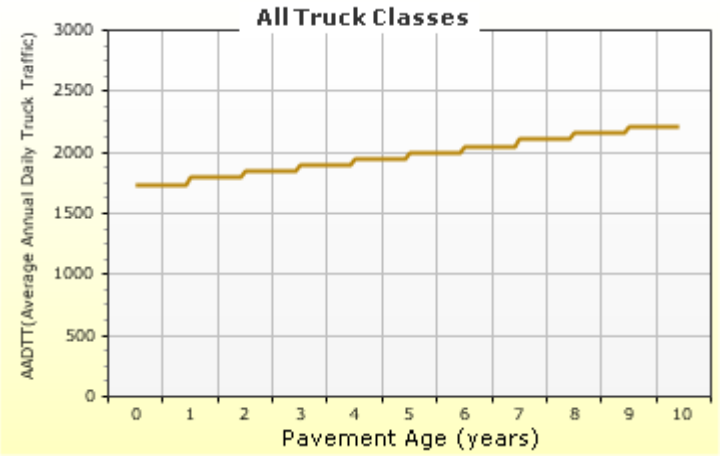
AADTT (Average Annual Daily Truck Traffic) Growth

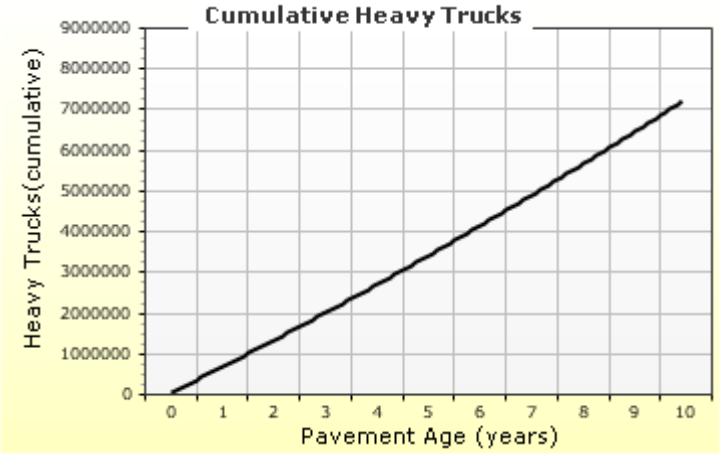
*** Traffic cap is not enforced**







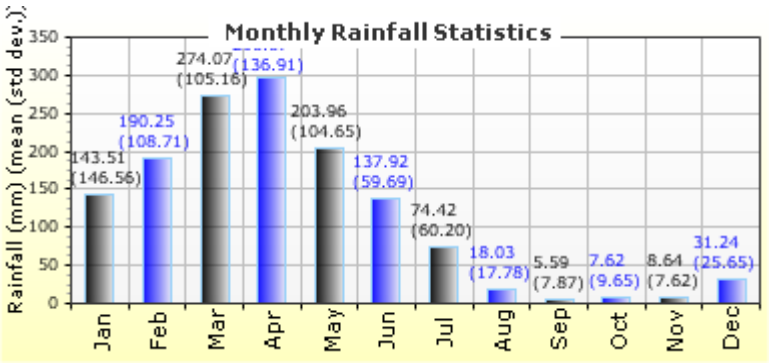




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
FORTALEZA, CE	-3.77000 -38.55000 41

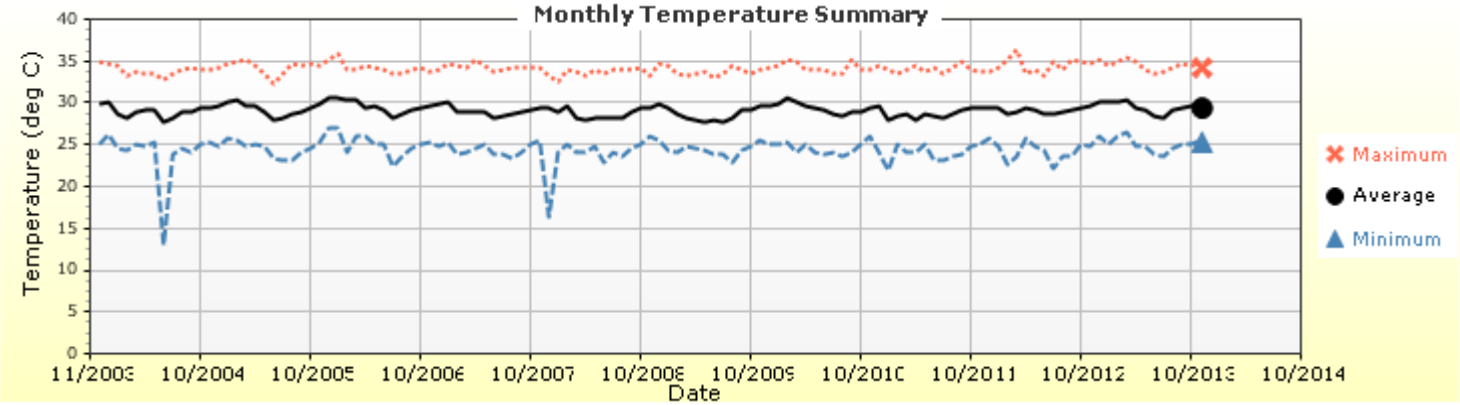


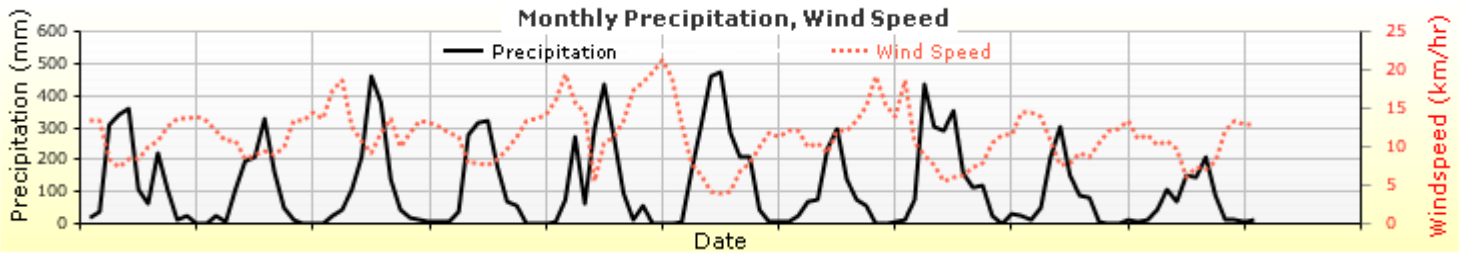
Annual Statistics:

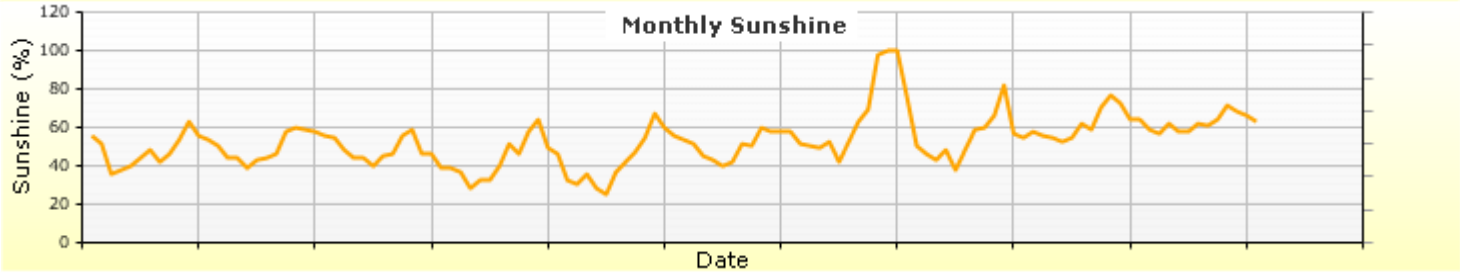
Mean annual air temperature (ºC)	29.10
Mean annual precipitation (mm)	1370.58
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

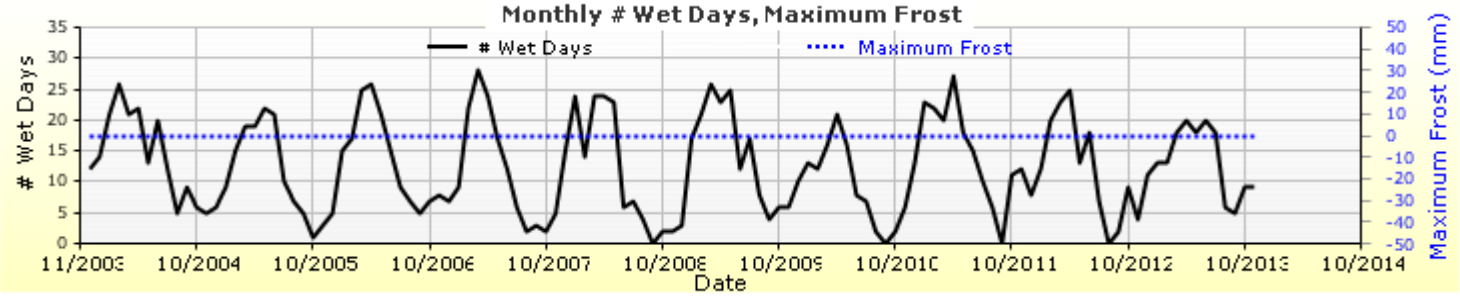
Water table depth (m)	3.05

Monthly Climate Summary:

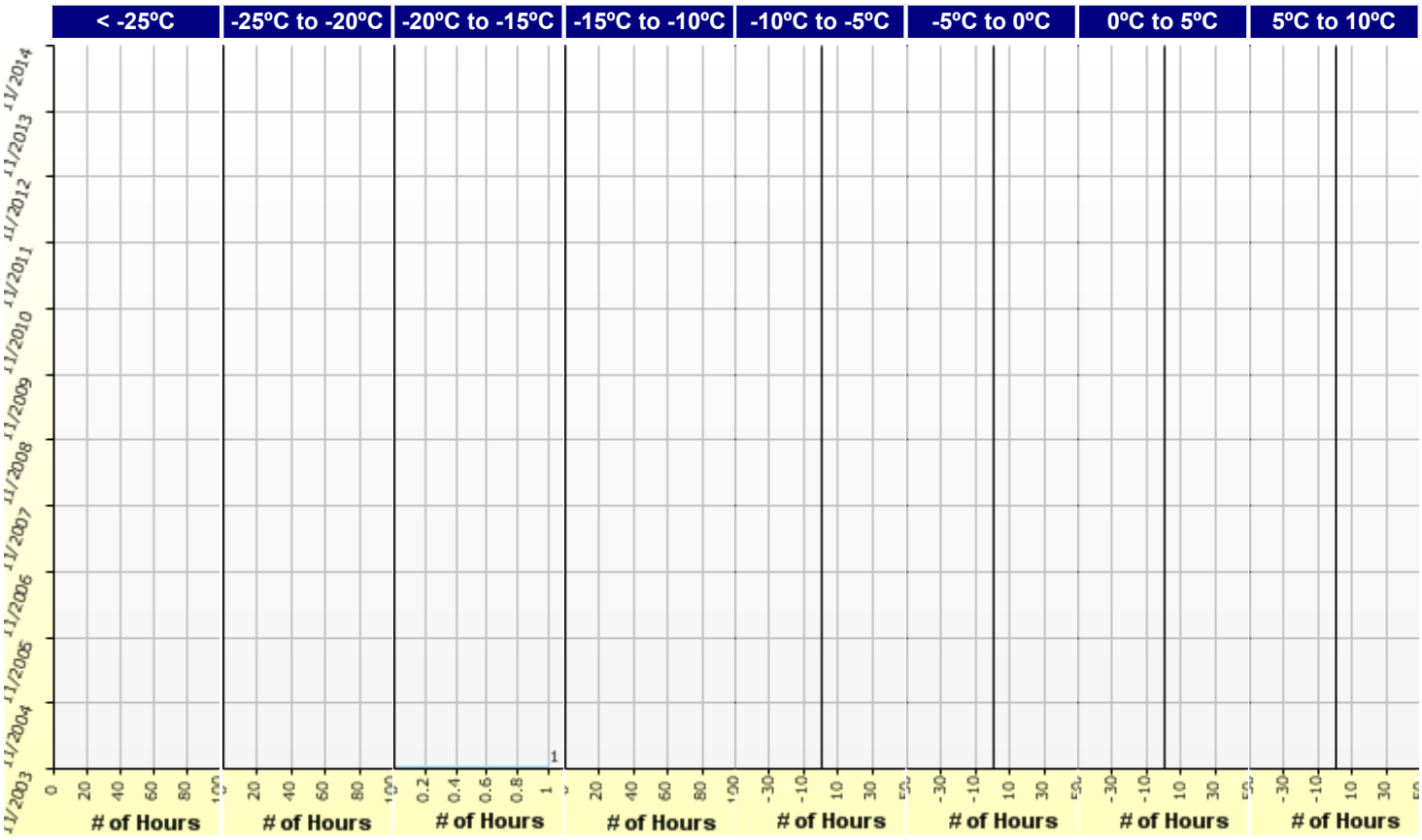


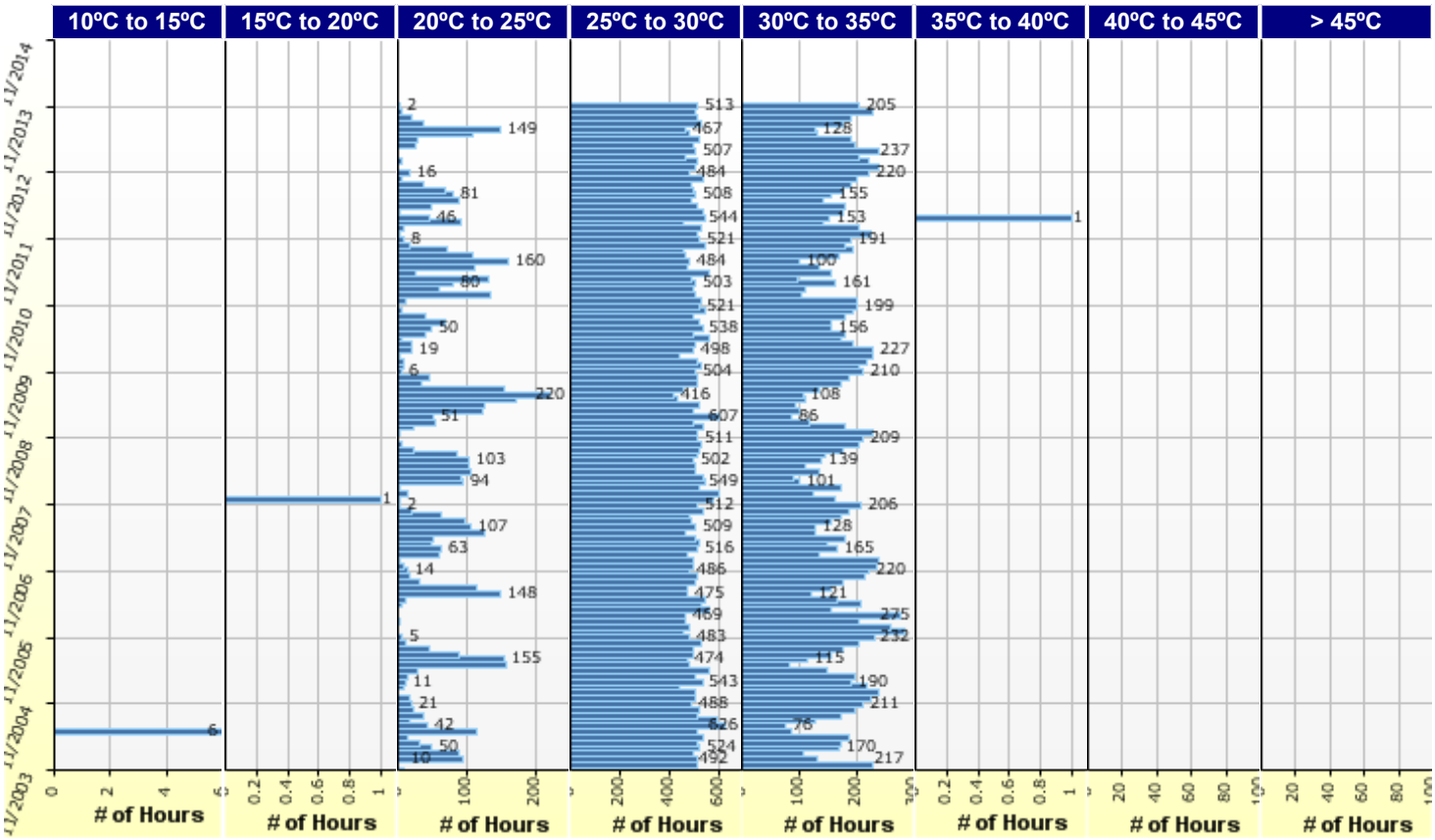






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

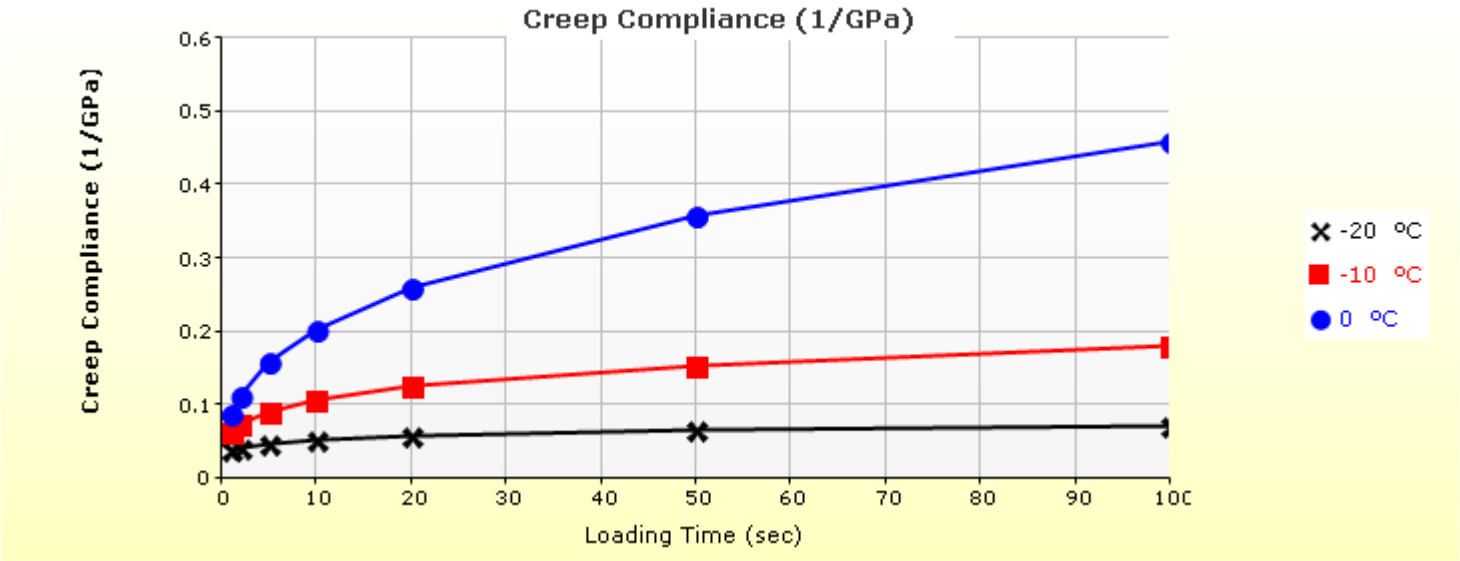
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

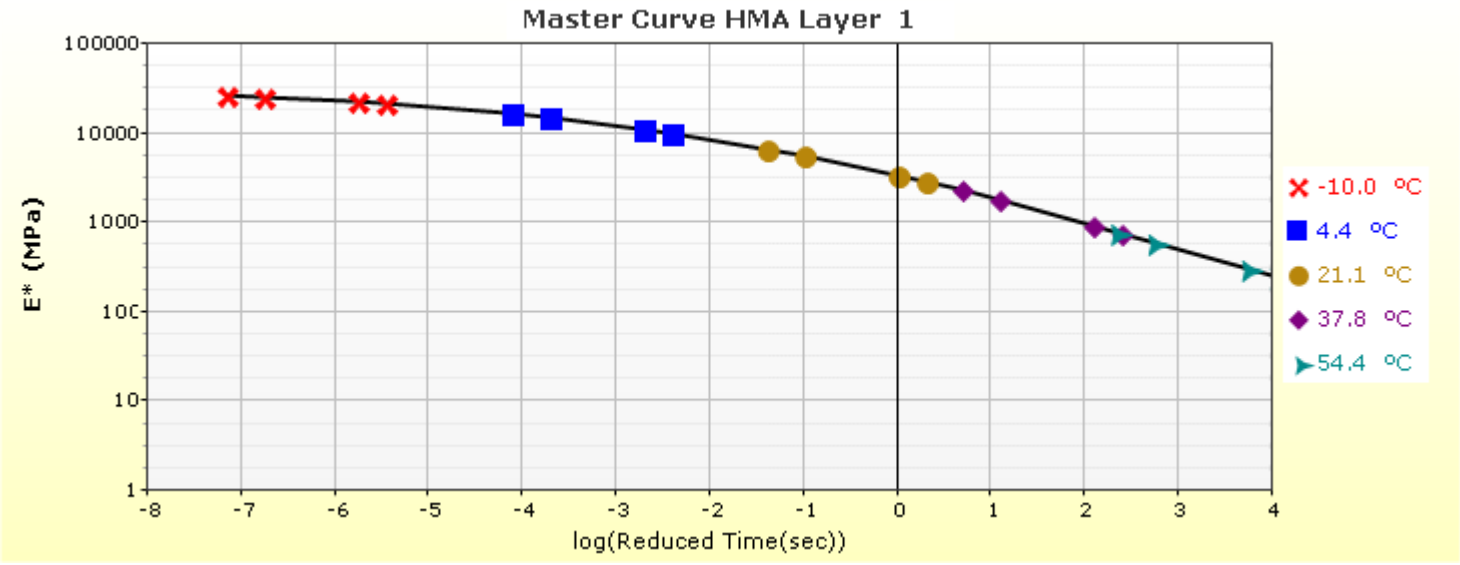
Indirect tensile strength at -10 ºC (MPa)	2.69

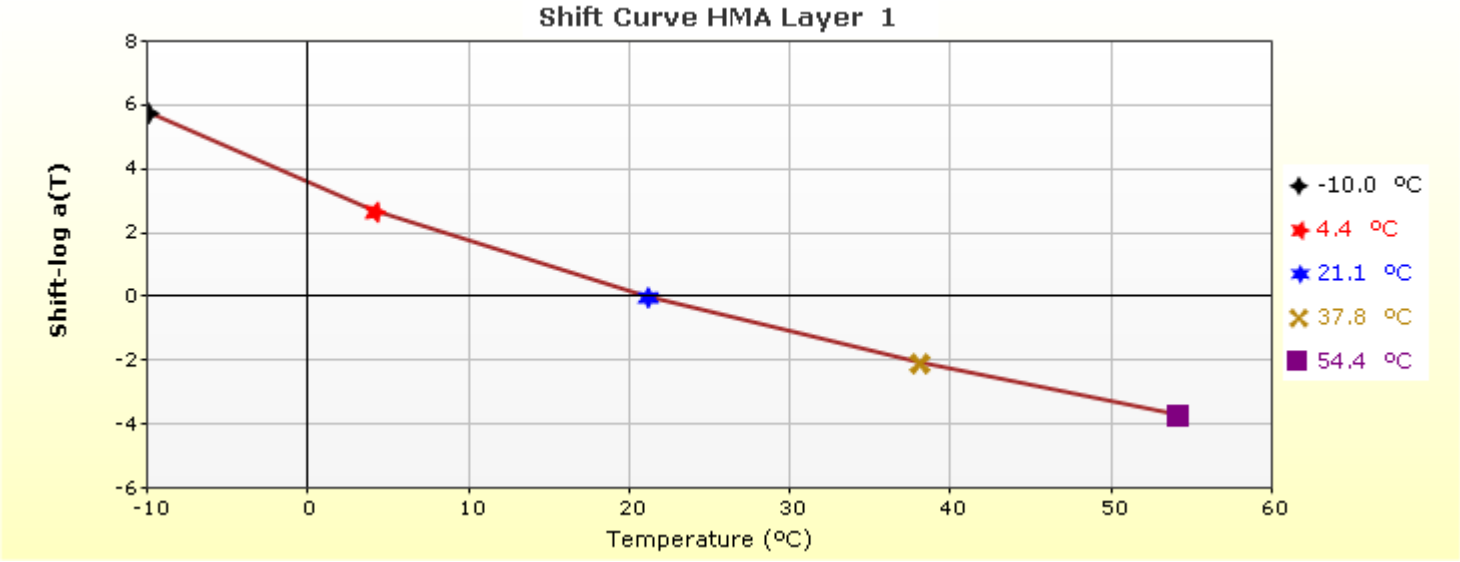
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

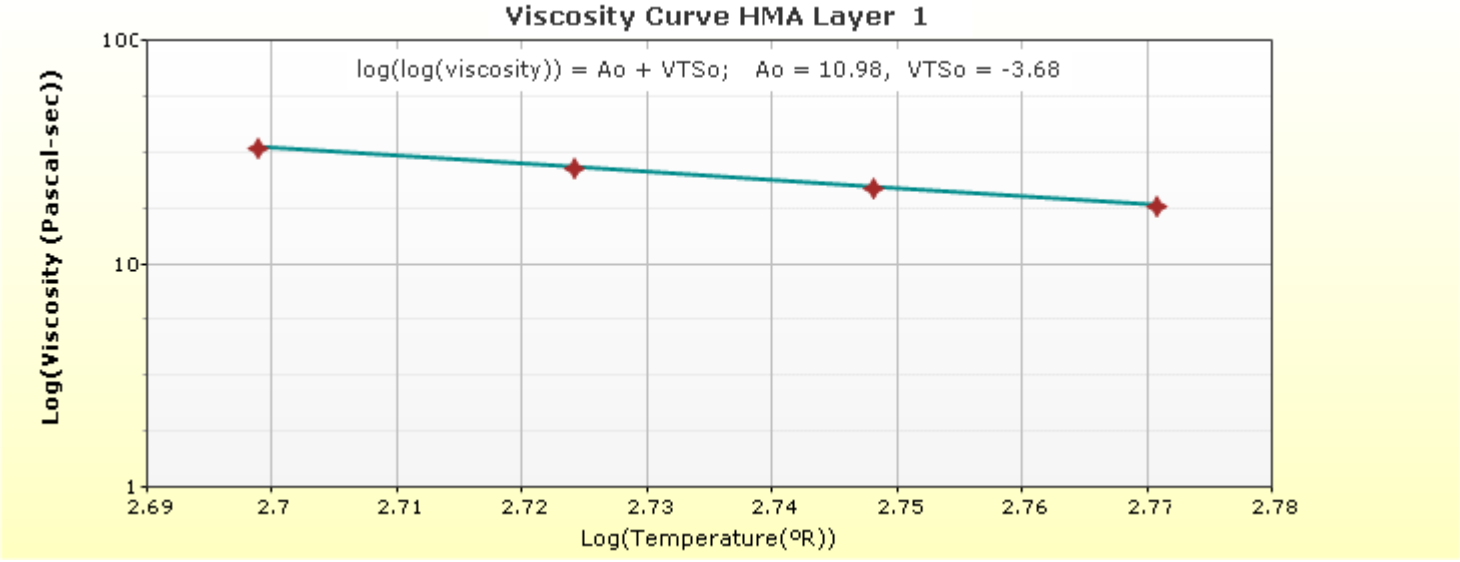
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



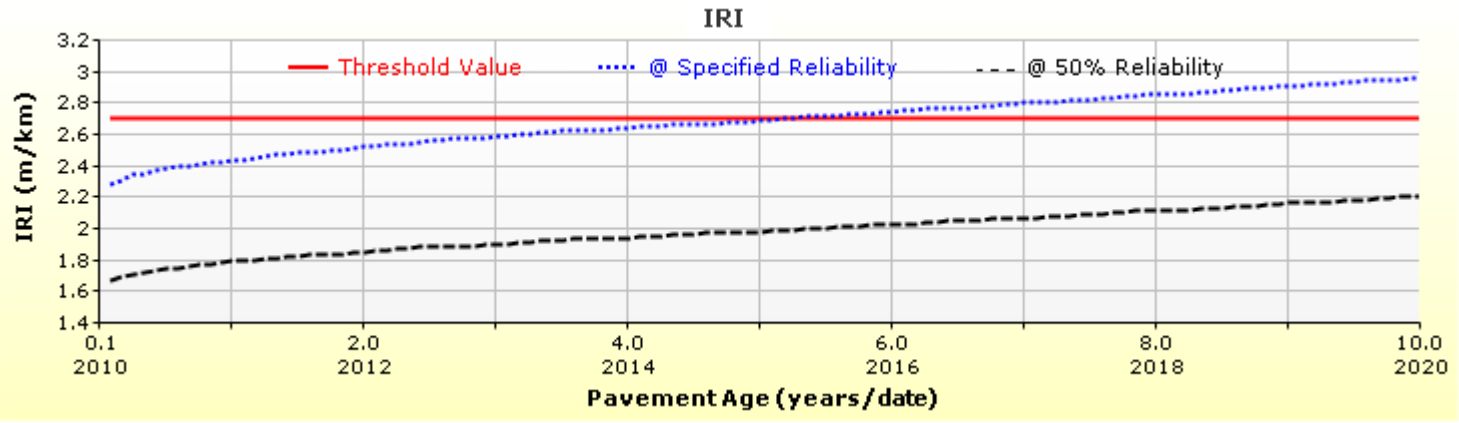
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

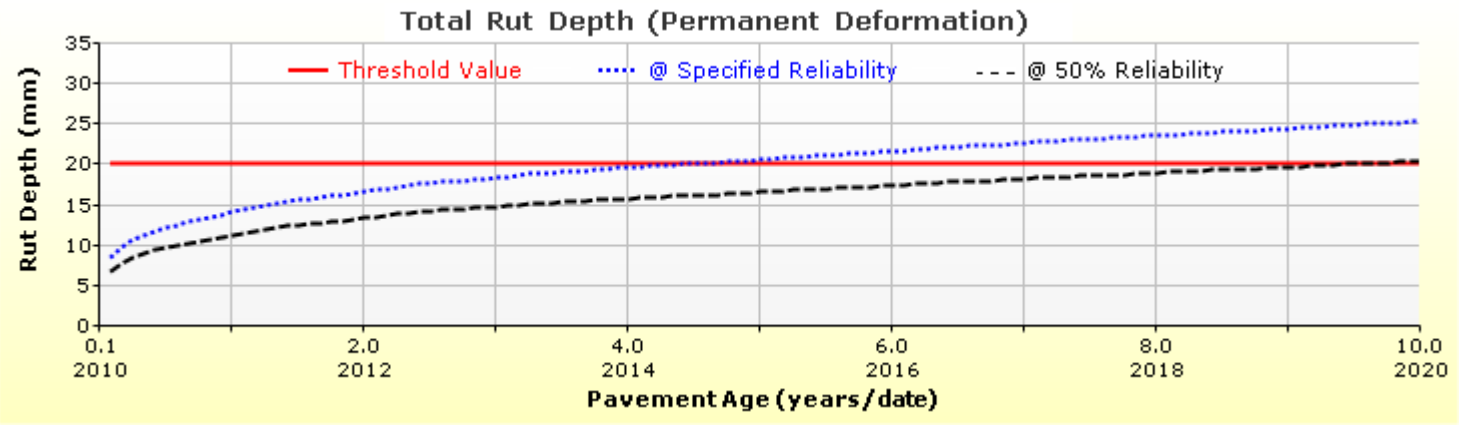


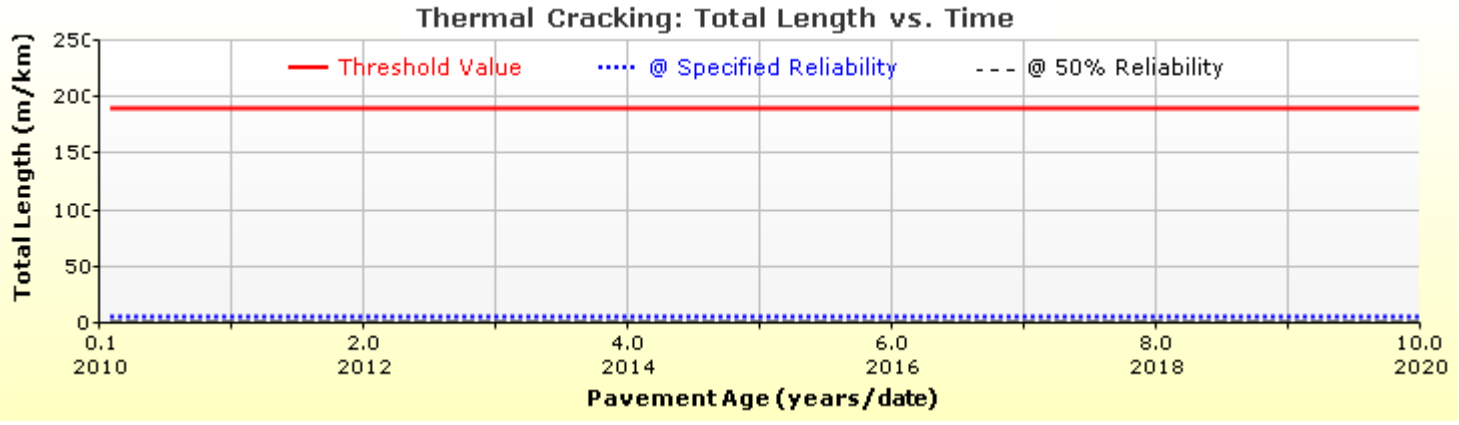


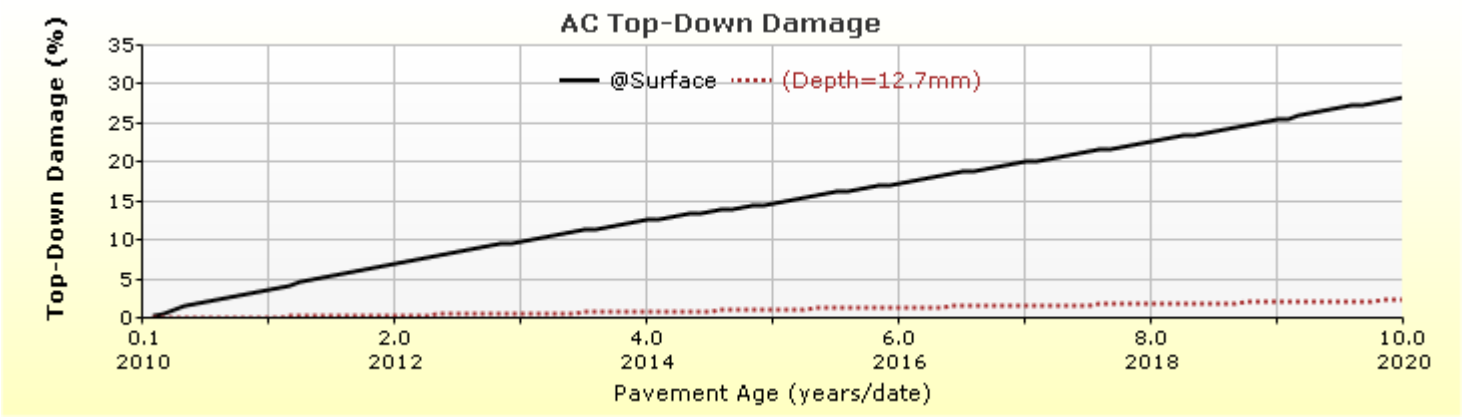


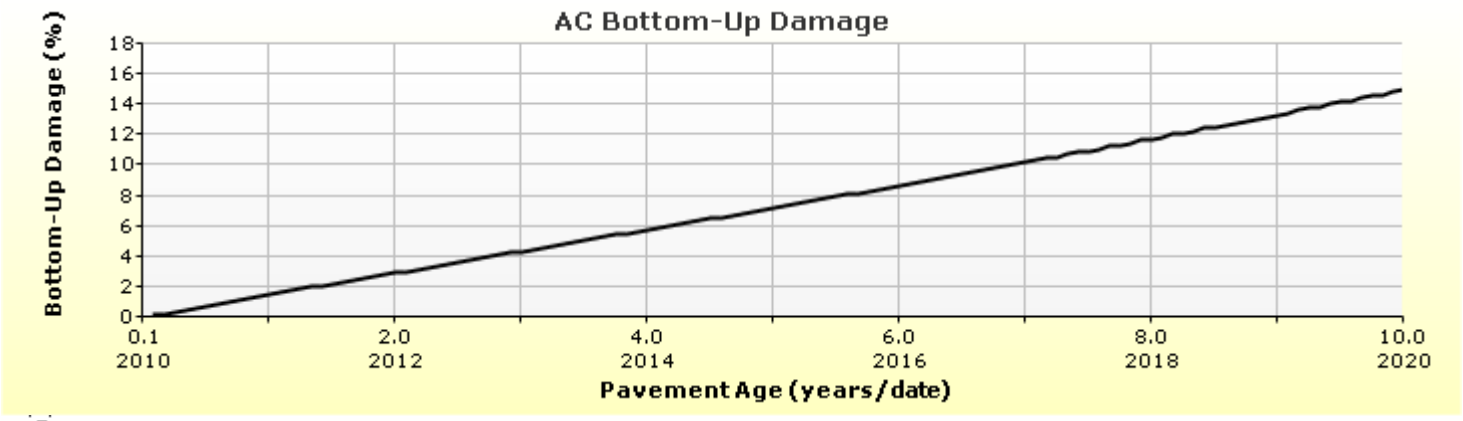
Analysis Output Charts

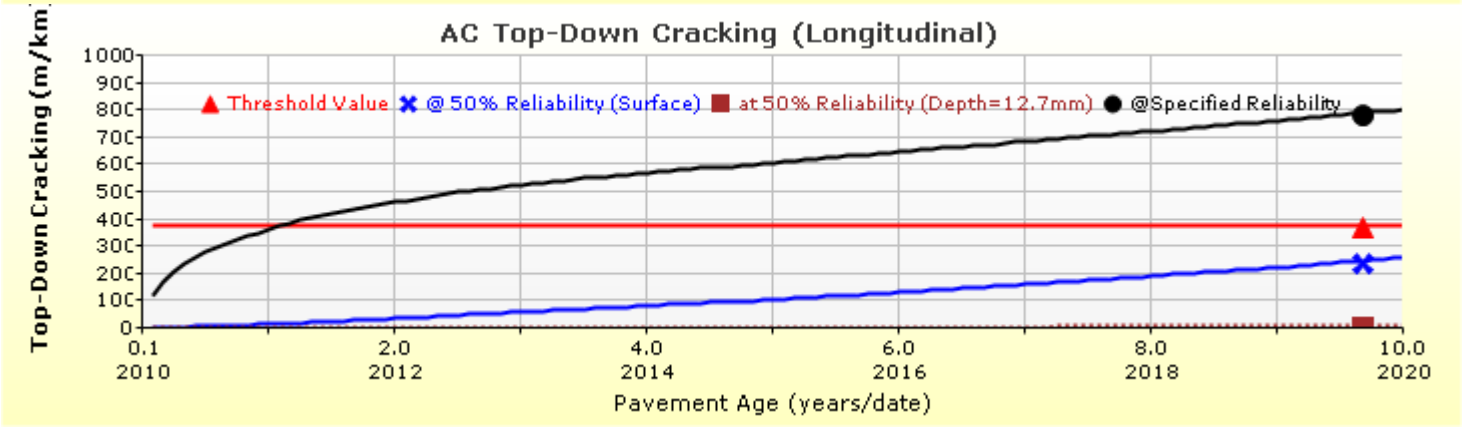


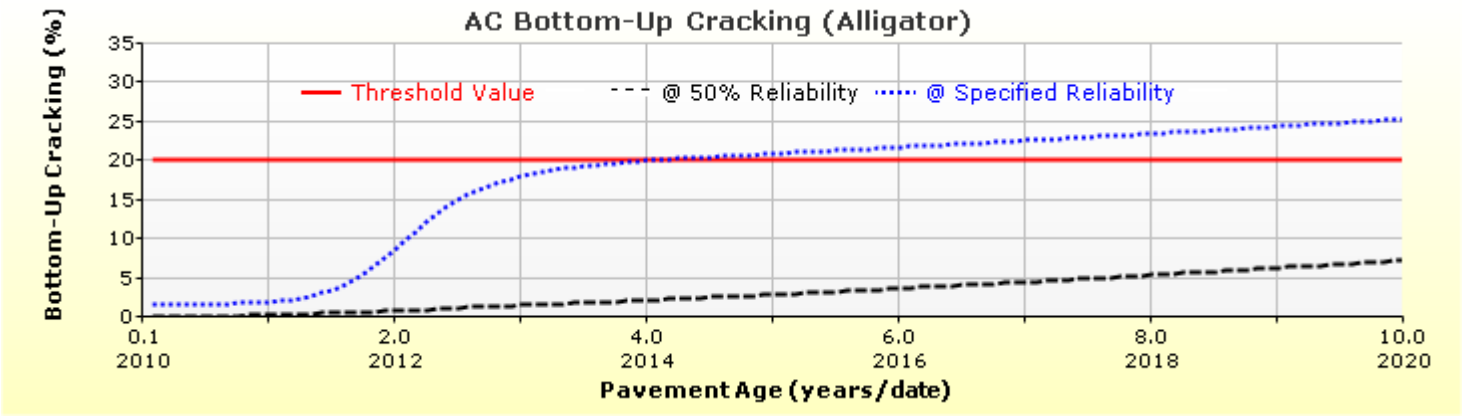


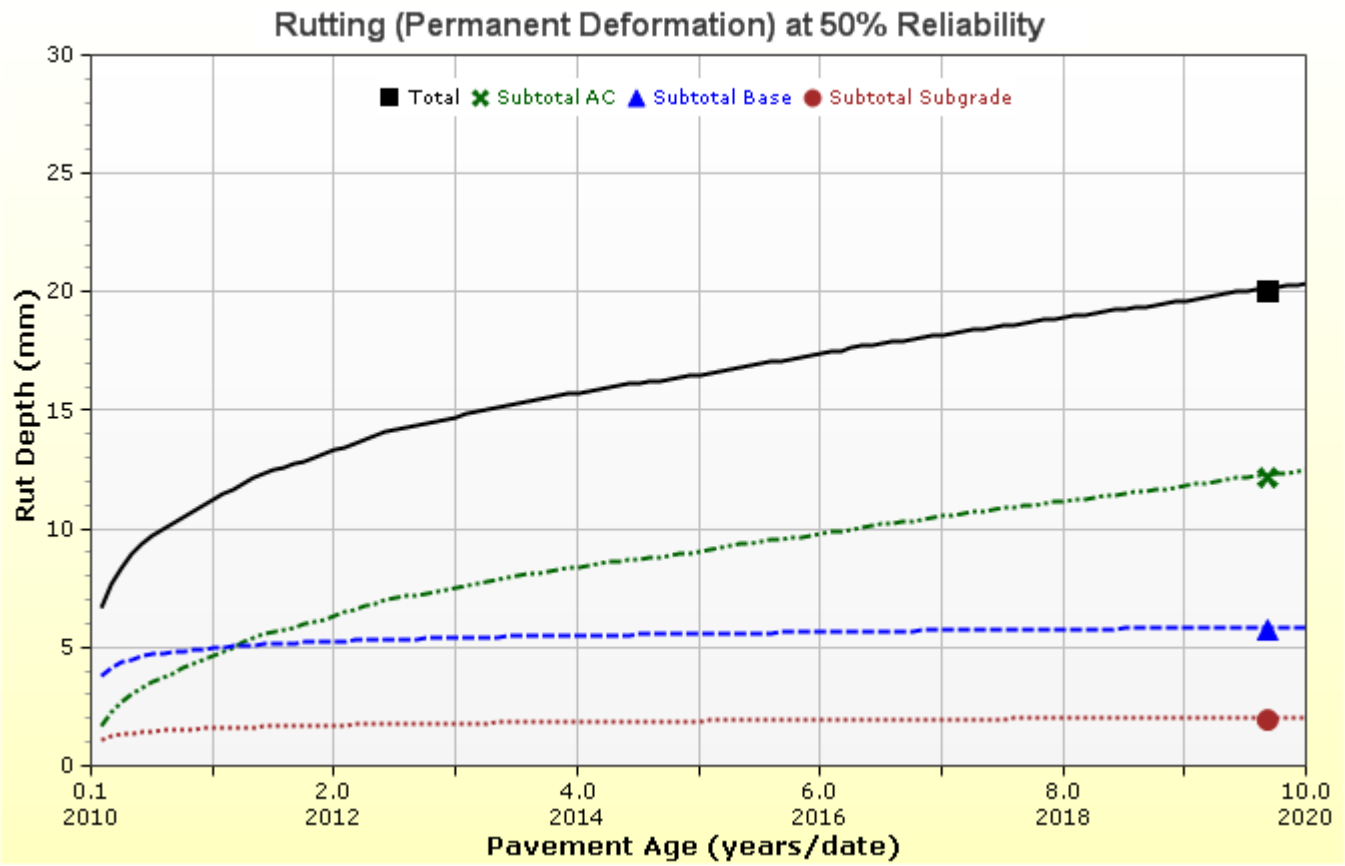


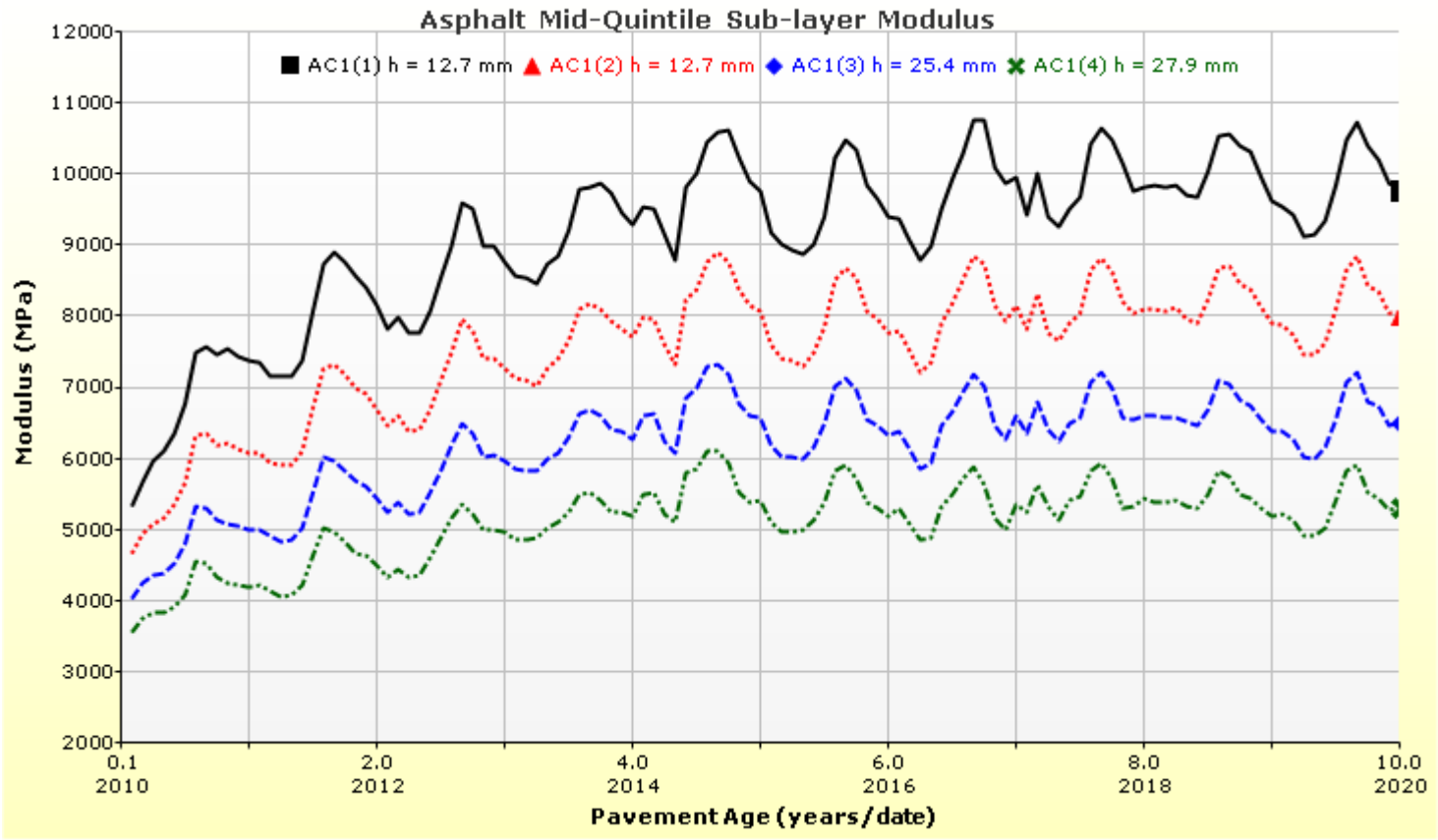

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
35
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

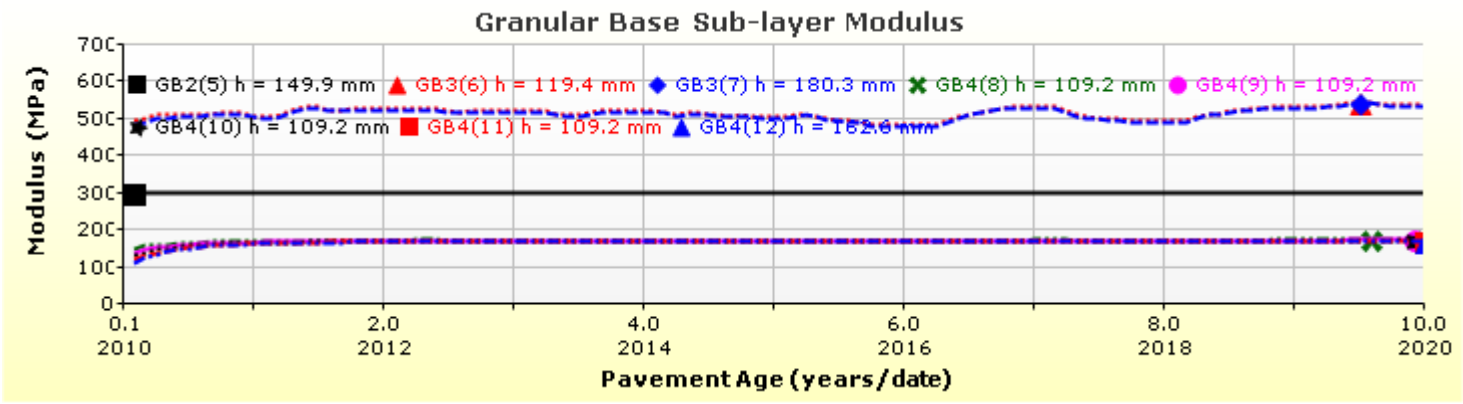

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
18
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

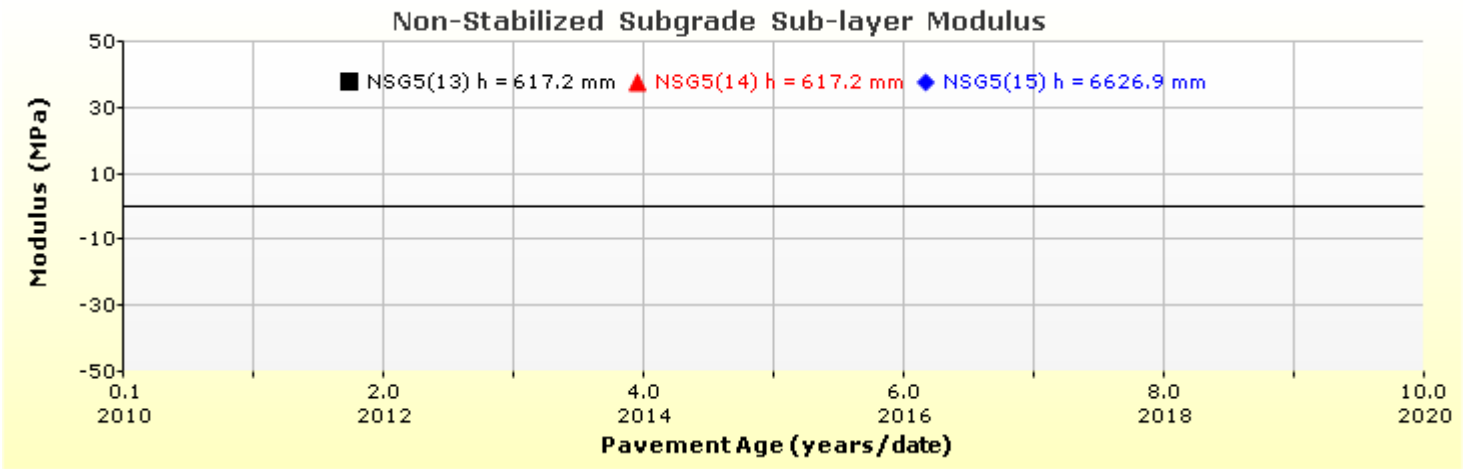

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
900
1000
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
35
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
30
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$

$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$

$T = layer\ temperature(^{\circ}F)$

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestFZ+4

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestFZ+4.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -3.77, -38.55

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

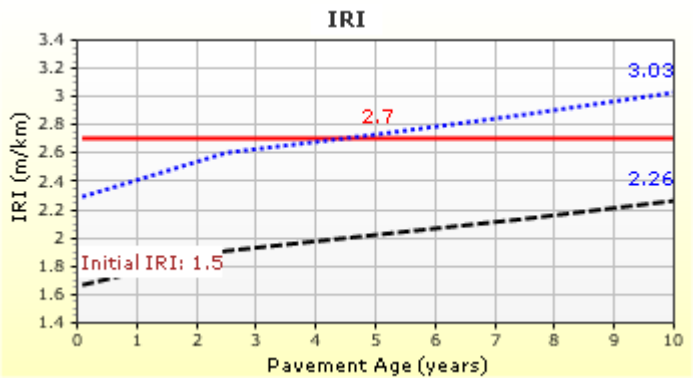
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

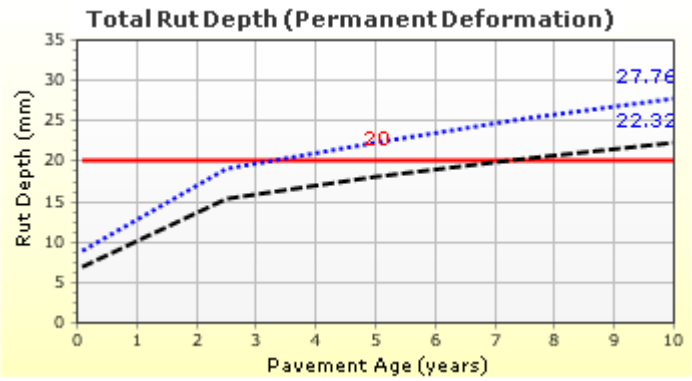
Design Outputs

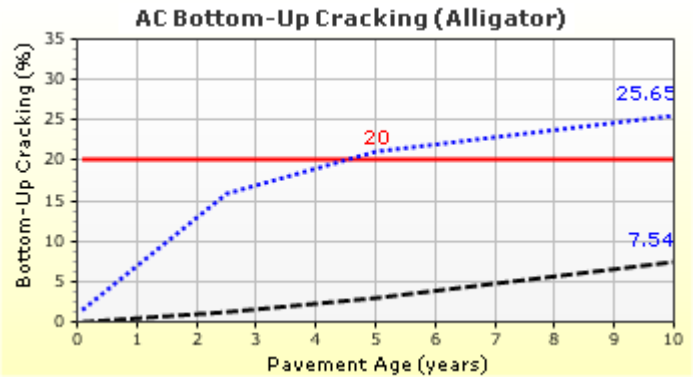
Distress Prediction Summary

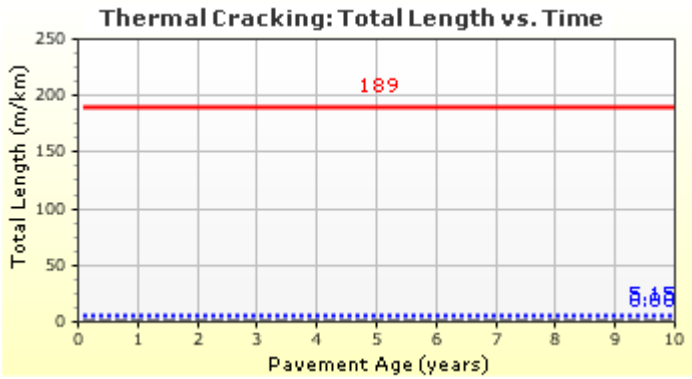
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	3.03	90.00	76.89	Fail
Permanent deformation - total pavement (mm)	20.00	27.76	90.00	29.12	Fail
AC bottom-up fatigue cracking (percent)	20.00	25.65	90.00	81.11	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	885.52	90.00	54.29	Fail
Permanent deformation - AC only (mm)	5.00	14.40	50.00	0.79	Fail

Distress Charts







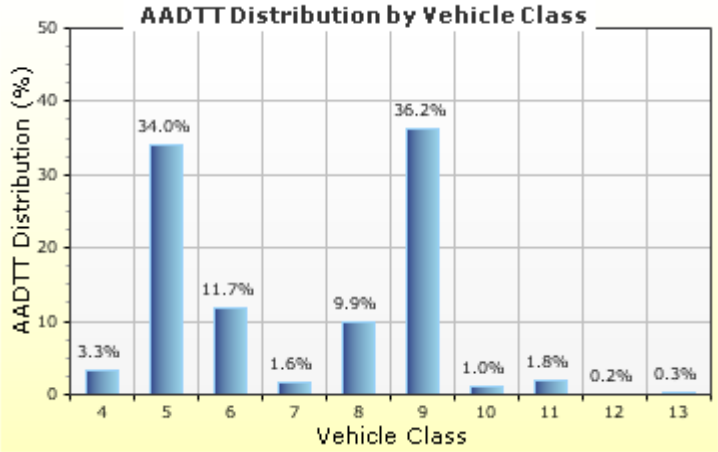


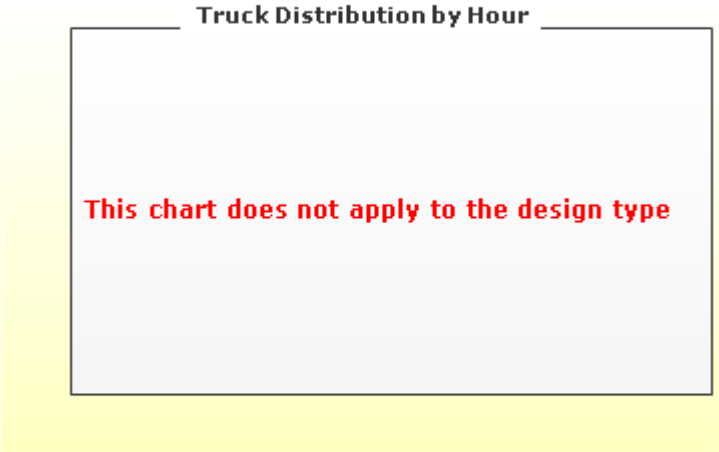


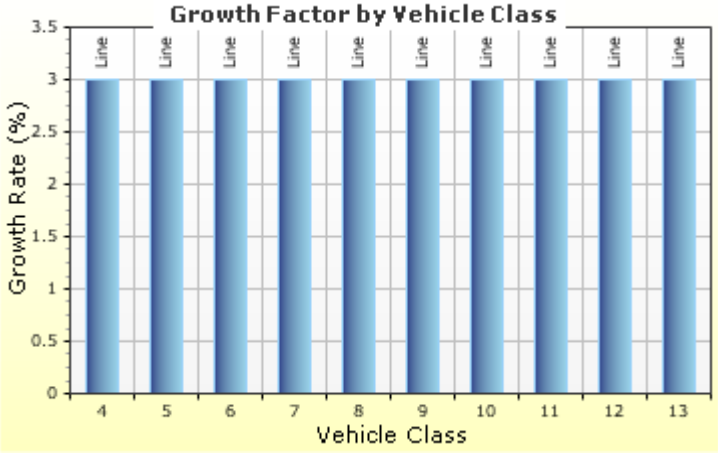
Traffic Inputs

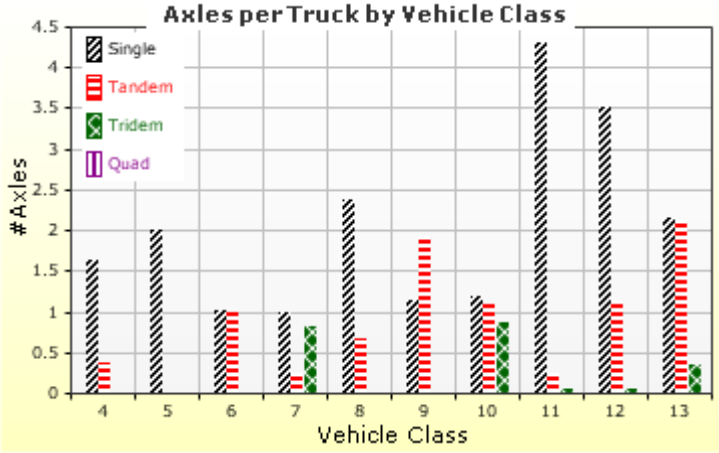
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

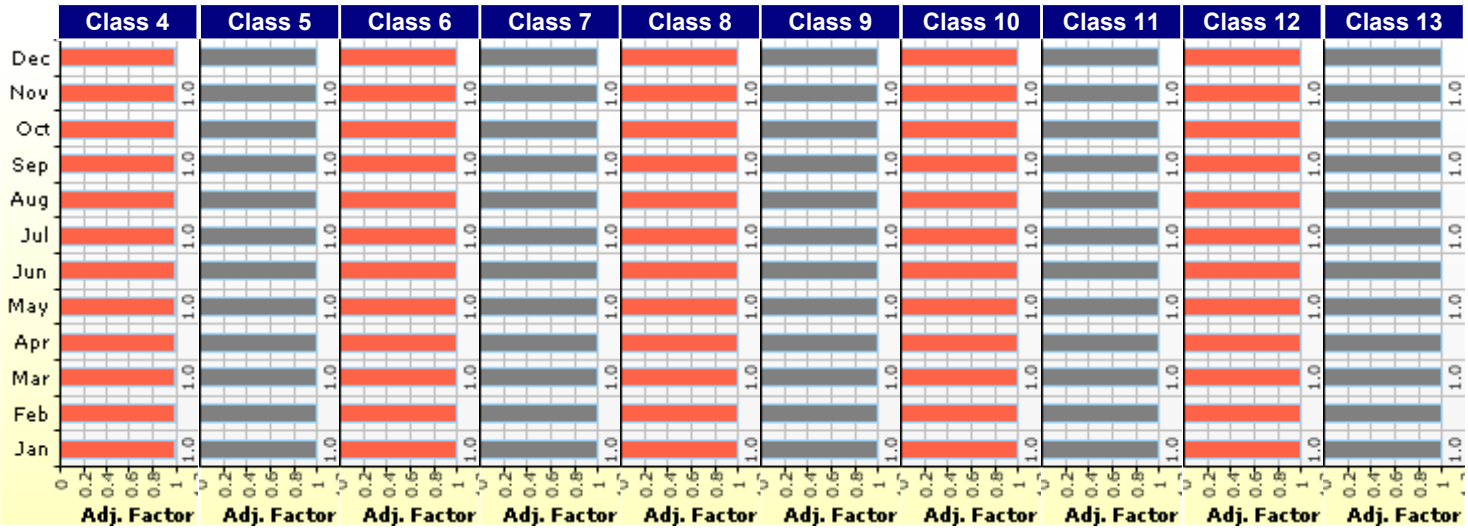








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

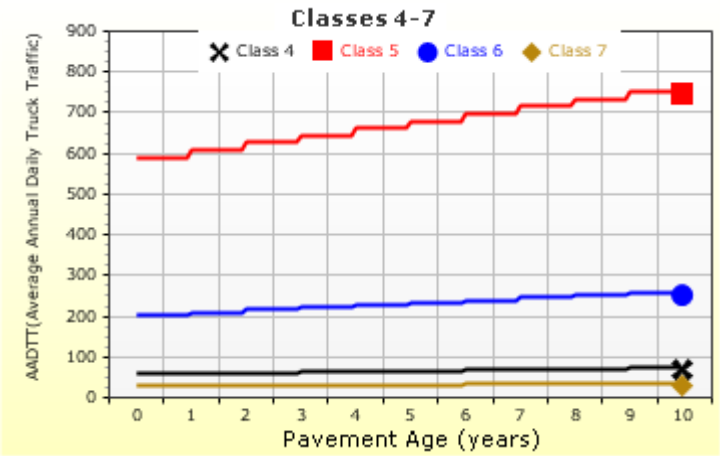
Wheelbase does not apply

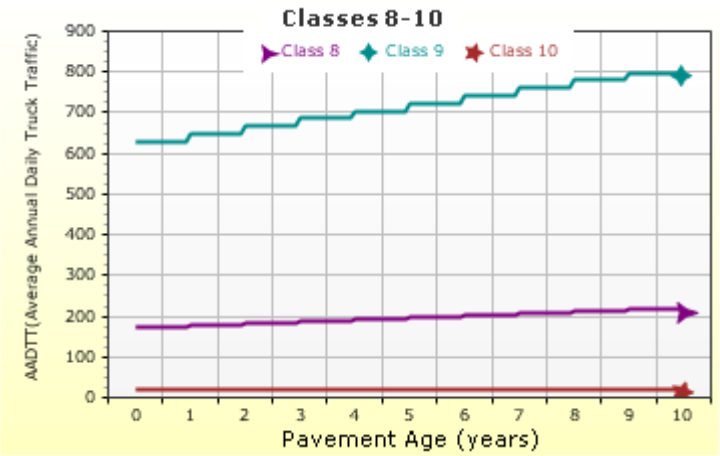
Number of Axles per Truck

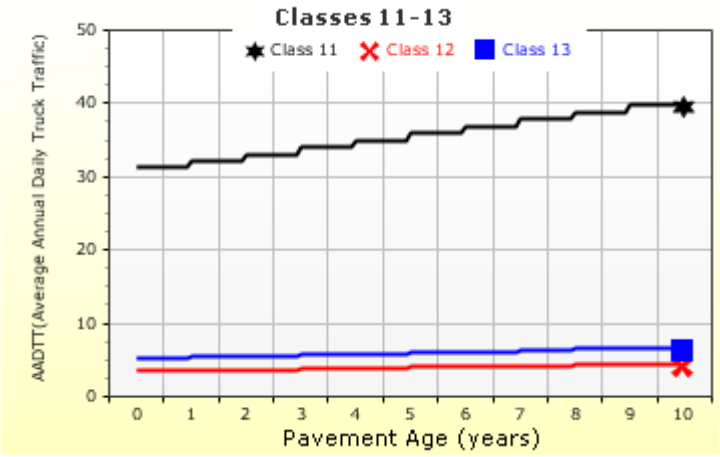
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

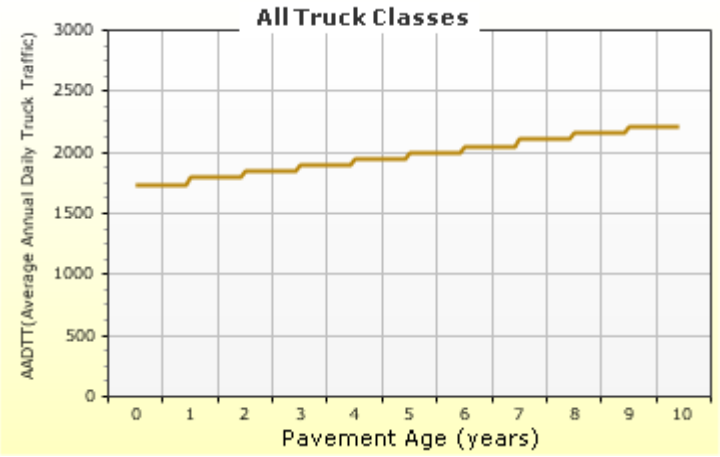
AADTT (Average Annual Daily Truck Traffic) Growth

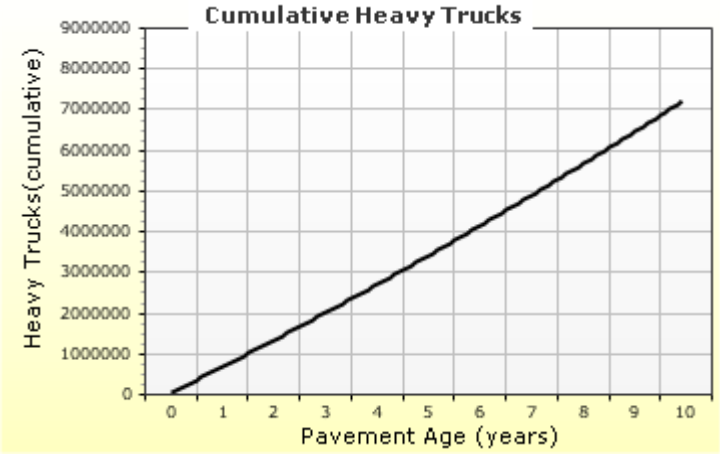
*** Traffic cap is not enforced**







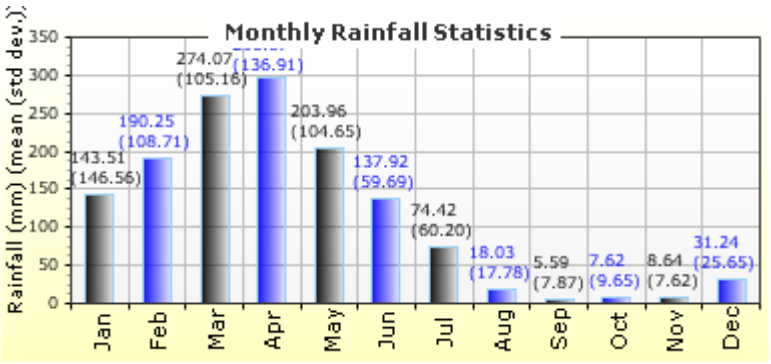




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
FORTALEZA, CE	-3.77000 -38.55000 41

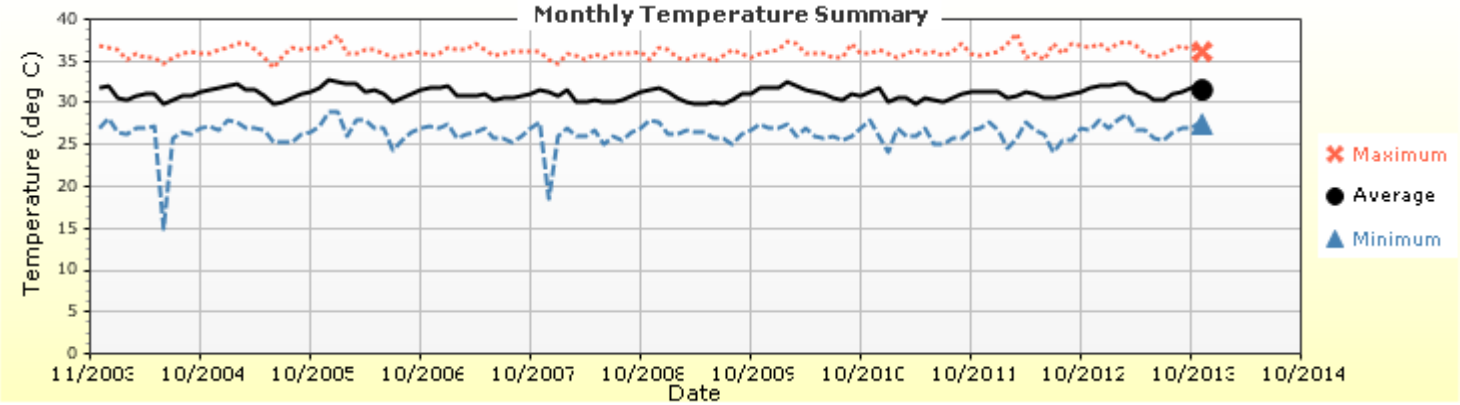


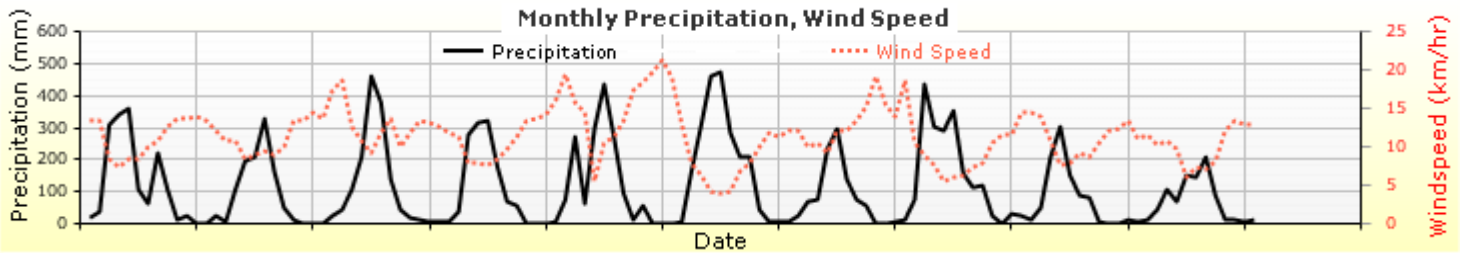
Annual Statistics:

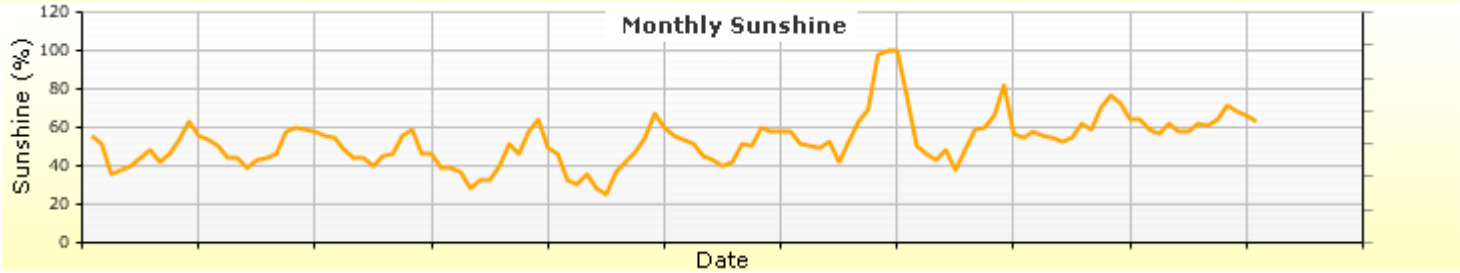
Mean annual air temperature (ºC)	31.10
Mean annual precipitation (mm)	1370.58
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

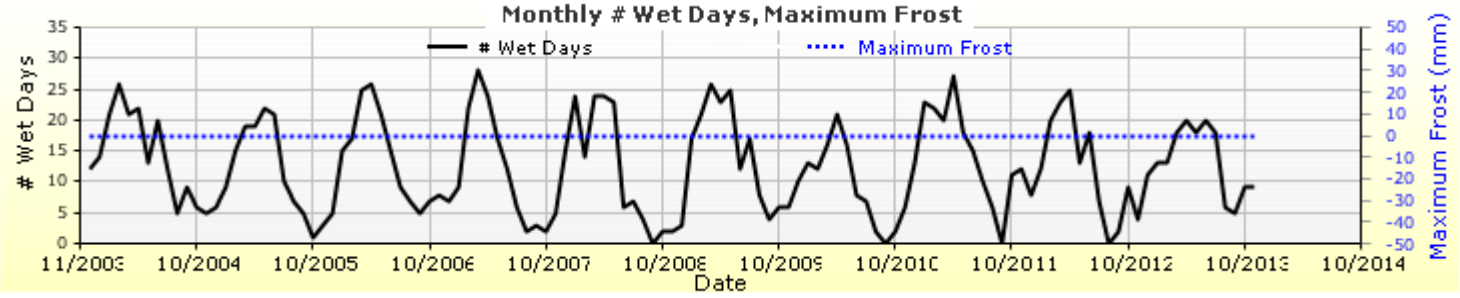
Water table depth (m): 3.05

Monthly Climate Summary:

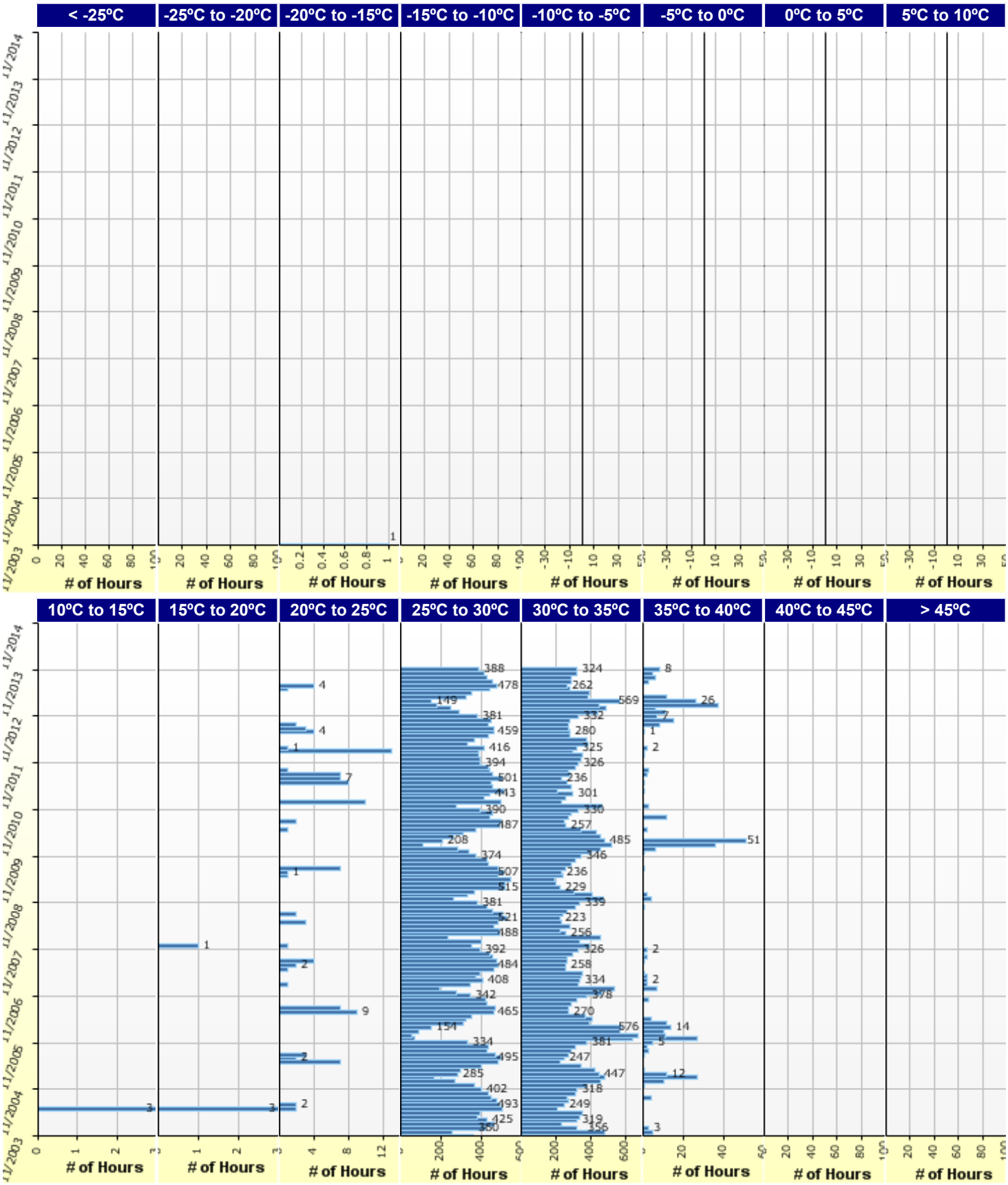








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

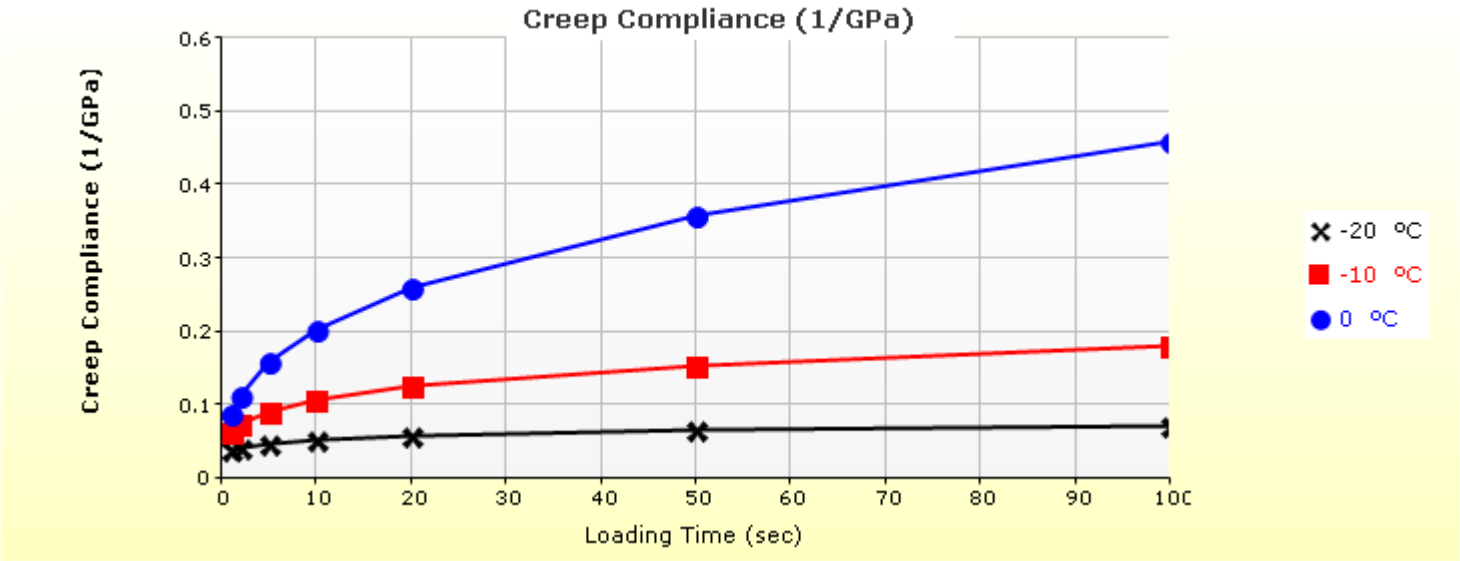
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

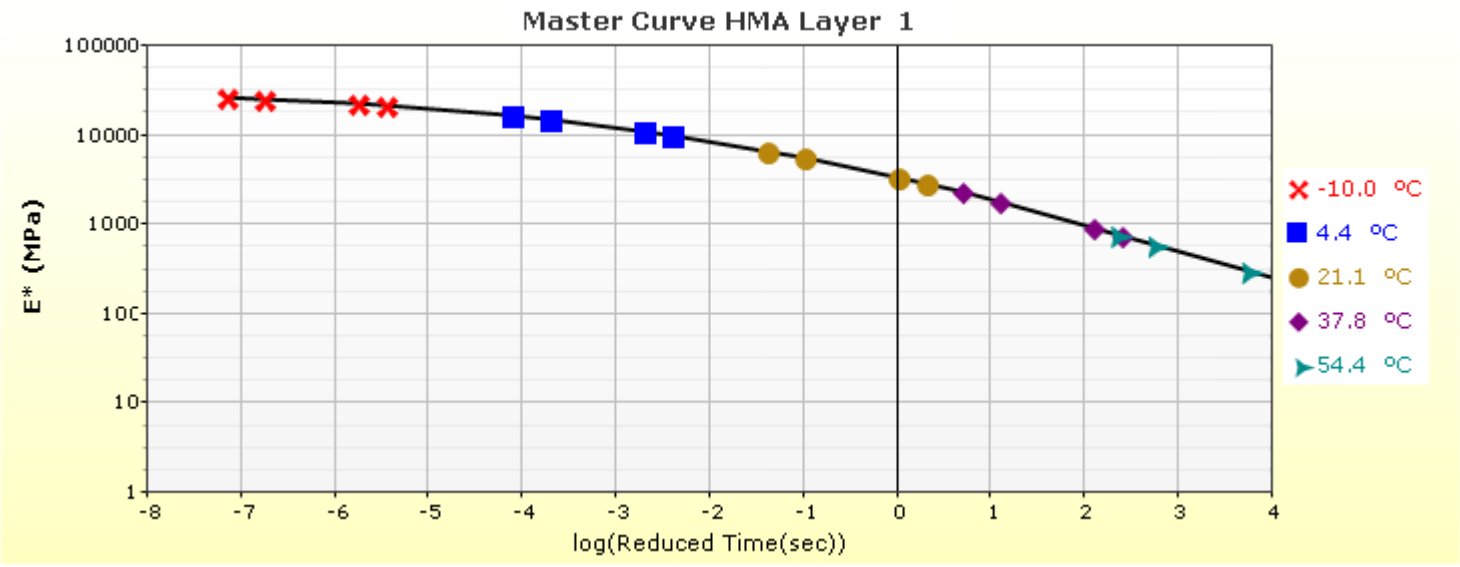
Indirect tensile strength at -10 ºC (MPa)	2.69

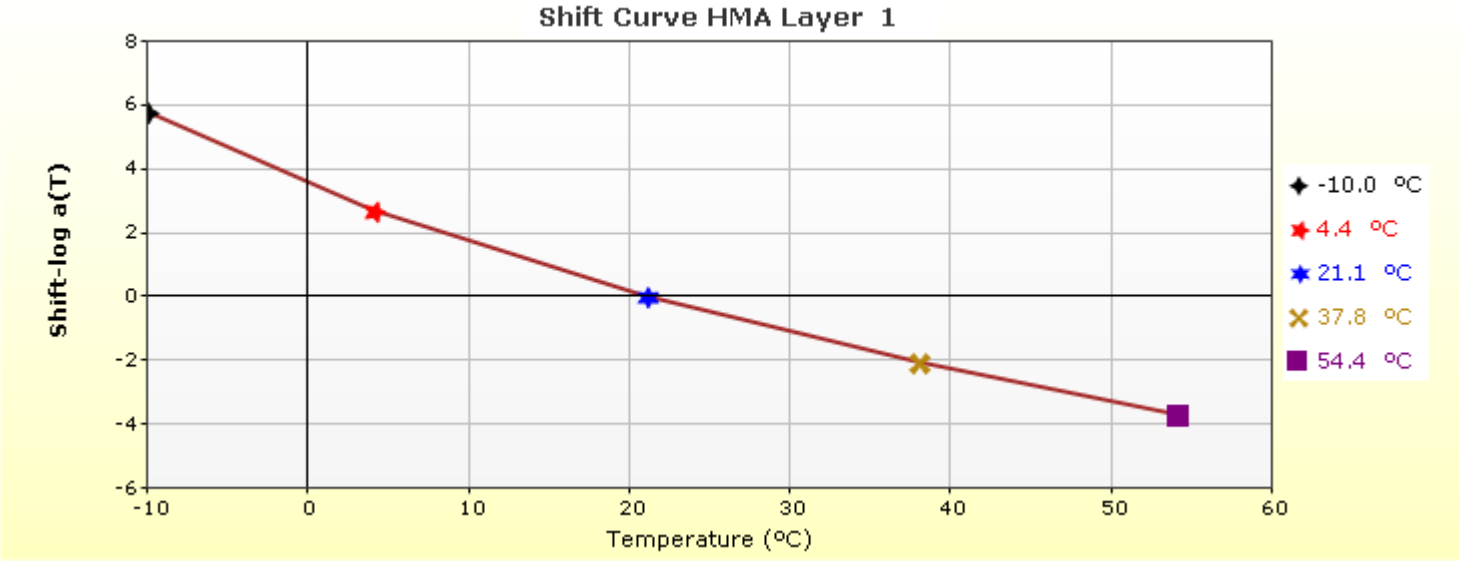
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

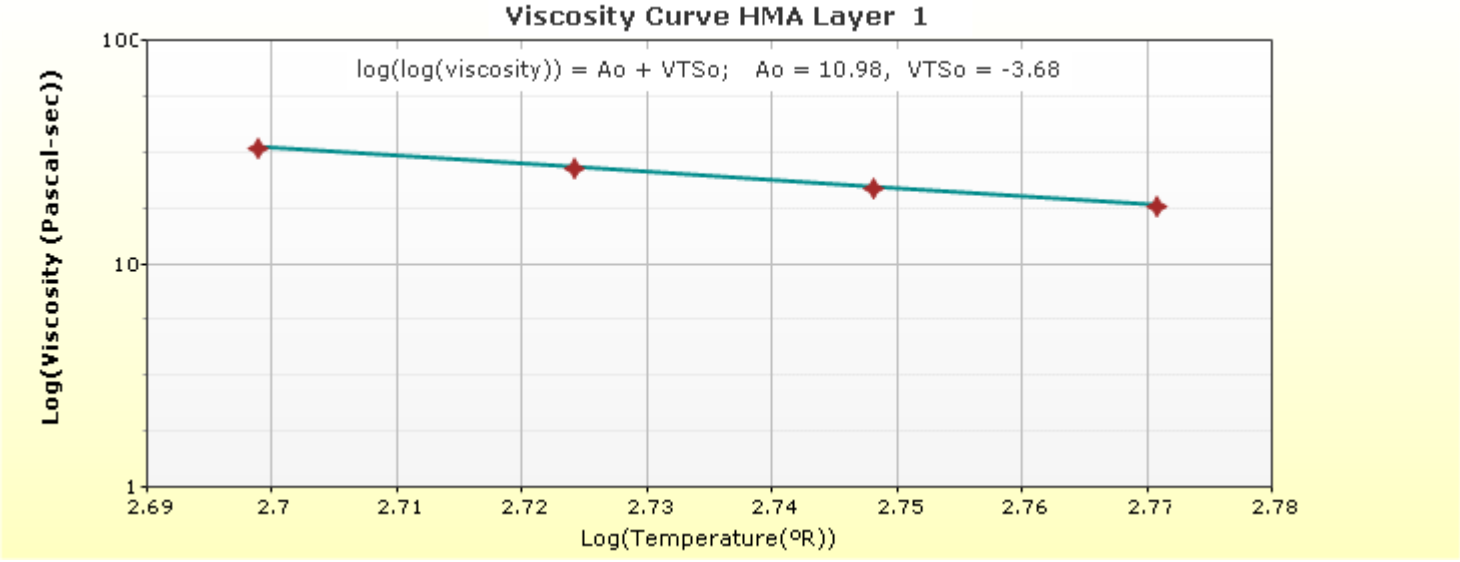
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



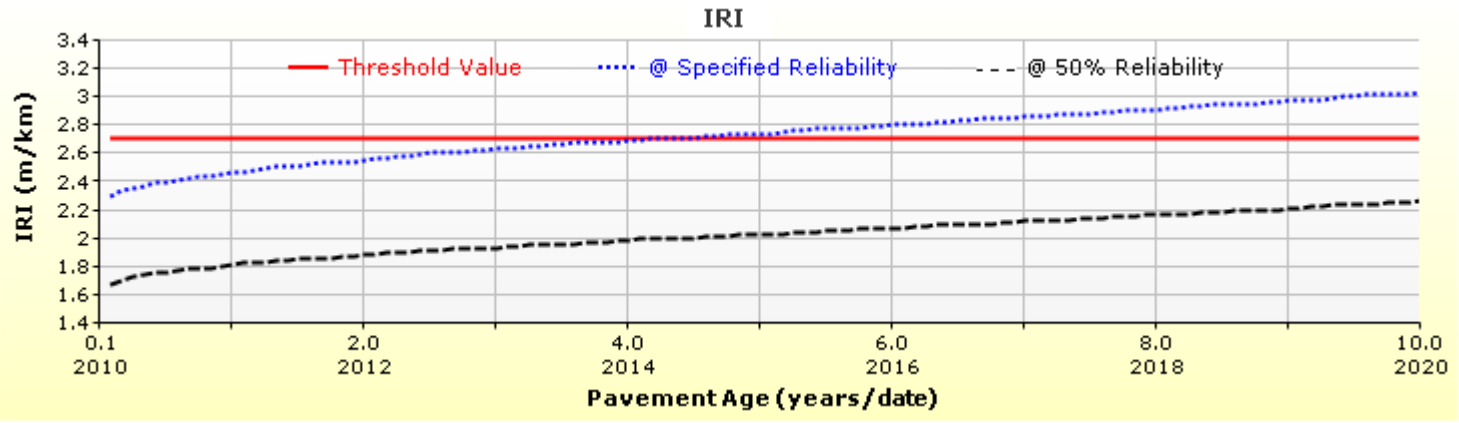
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

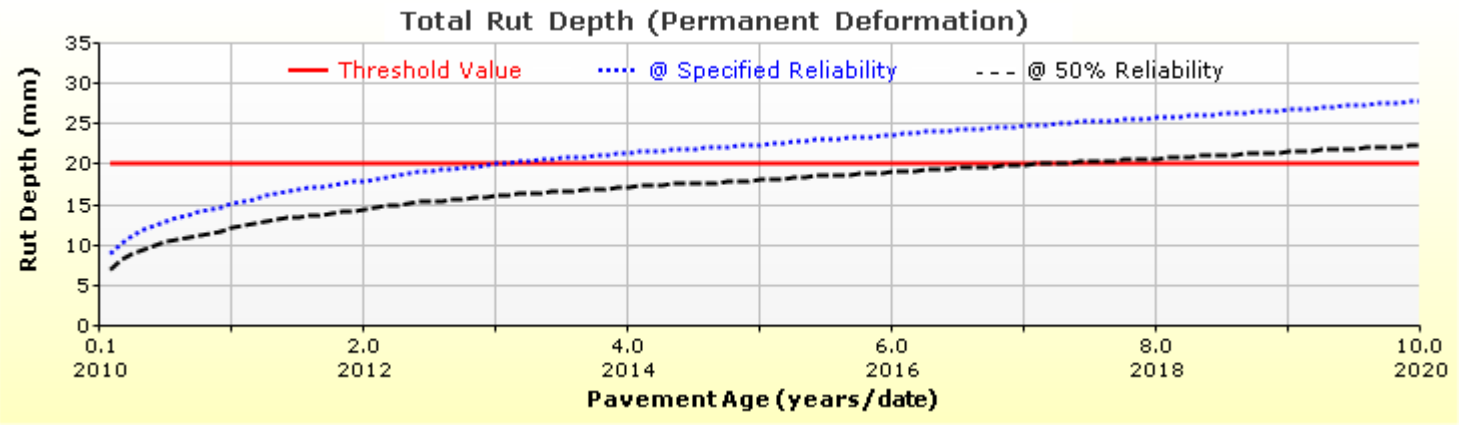


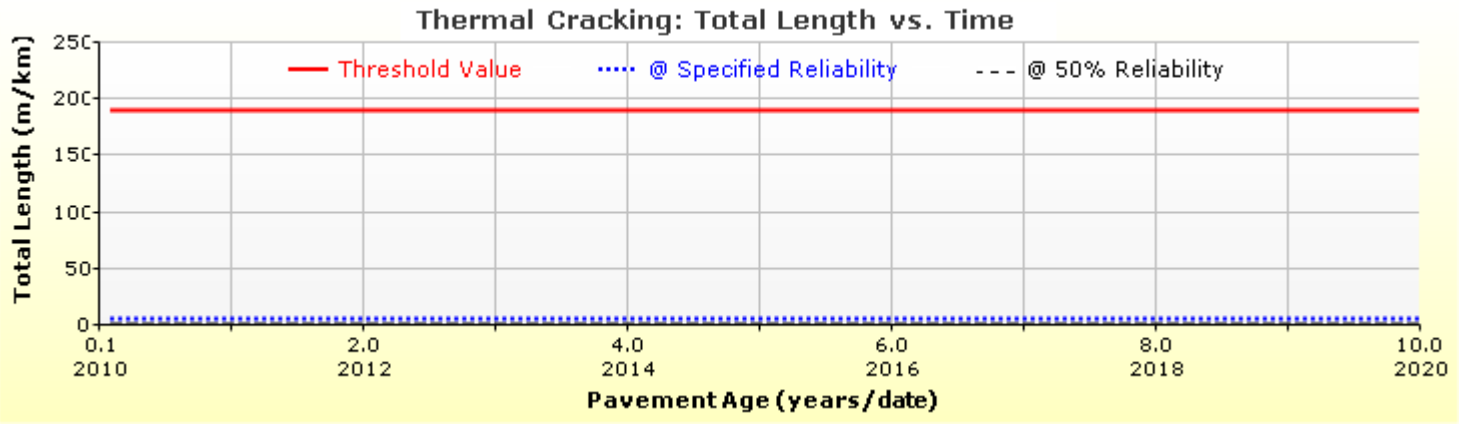


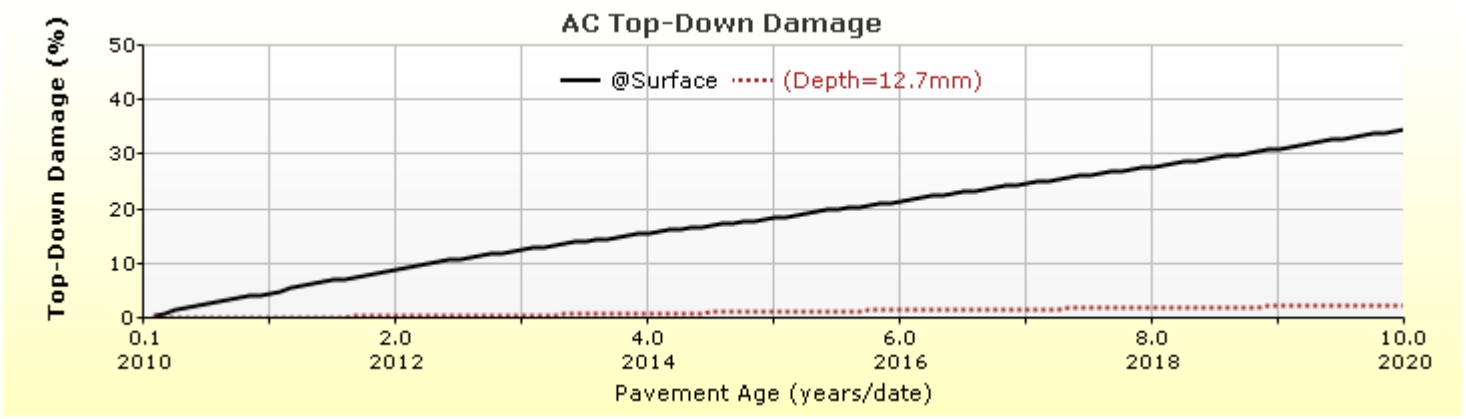


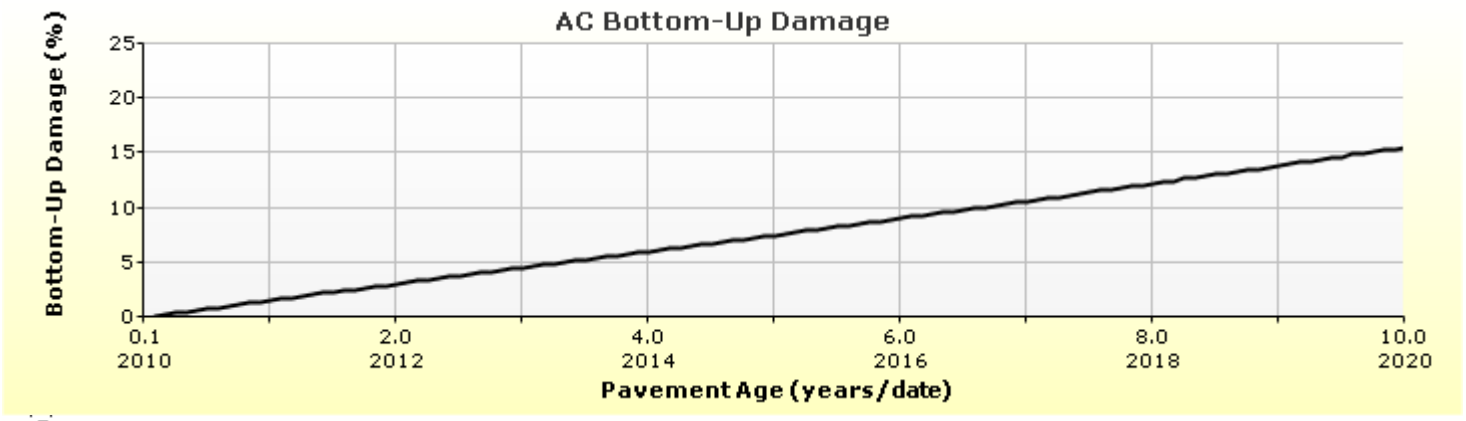
Analysis Output Charts

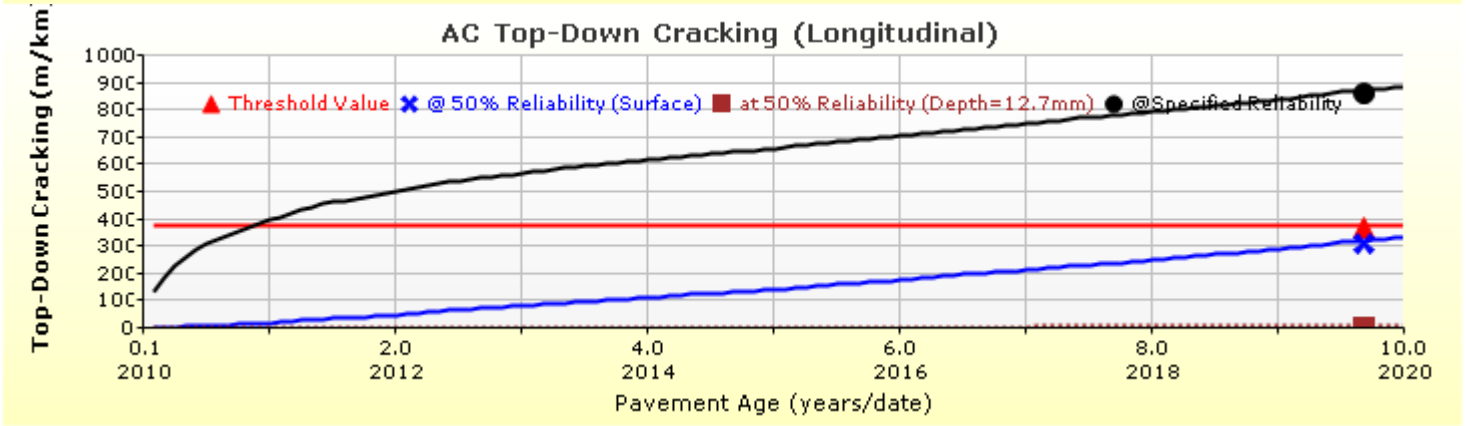


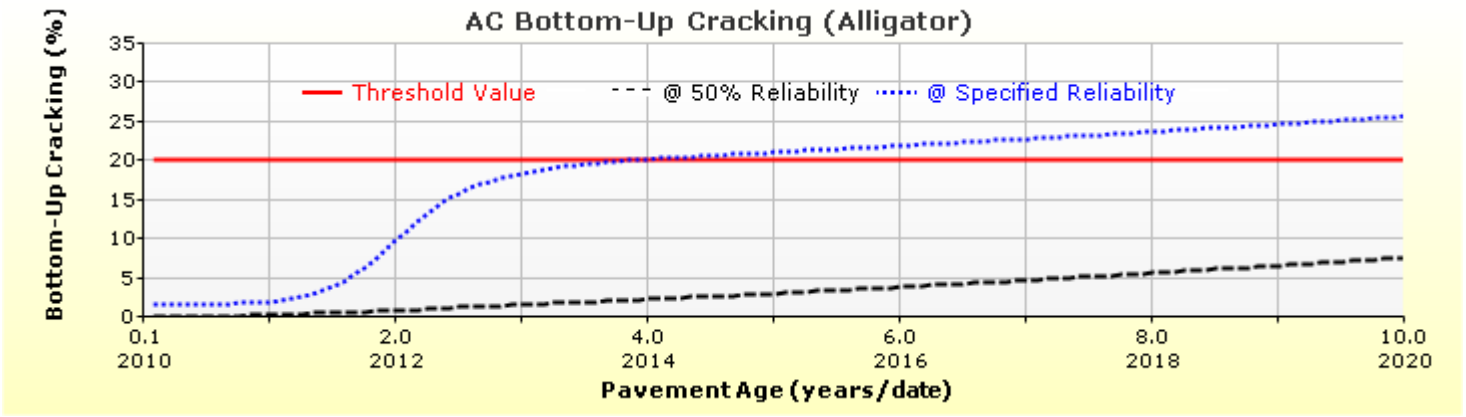


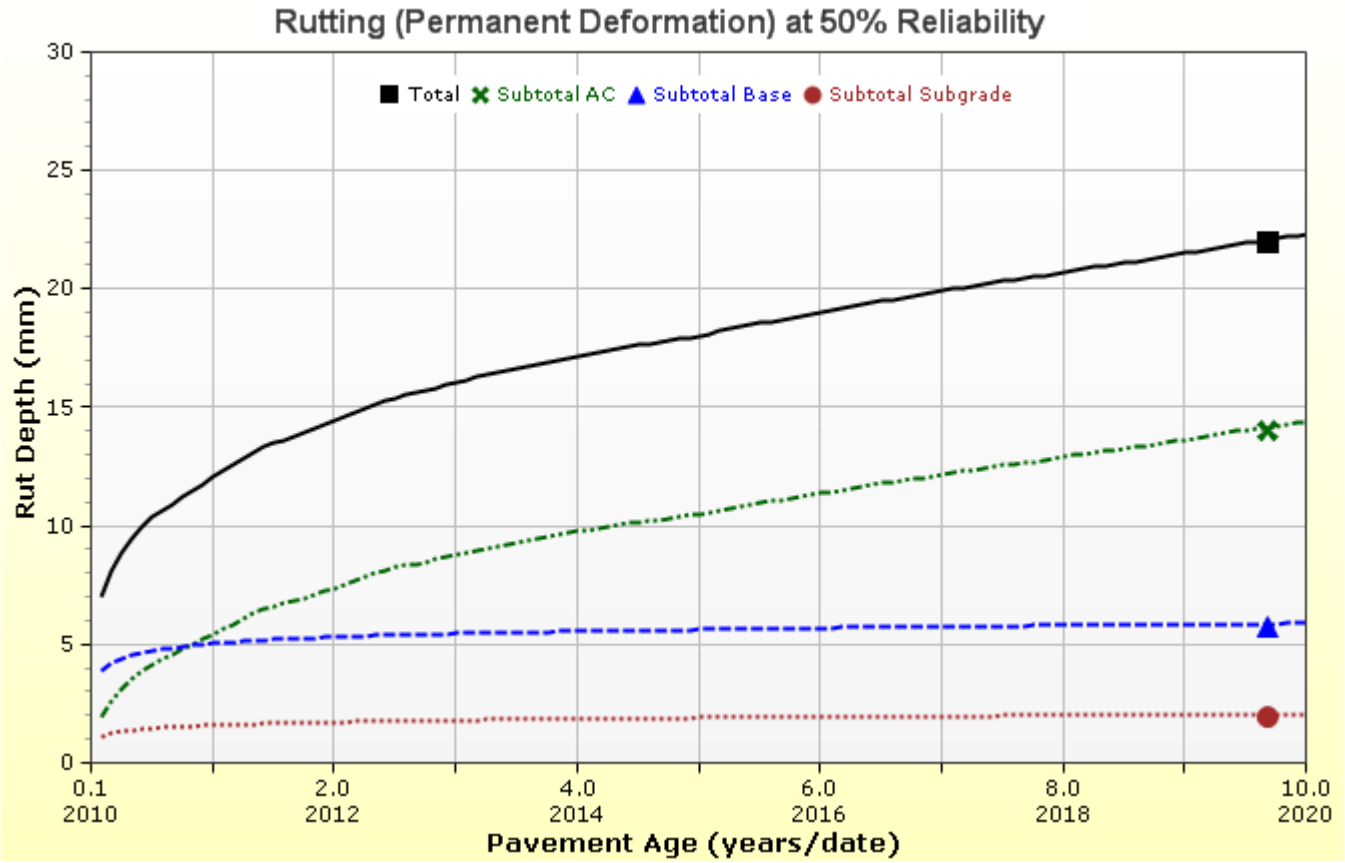


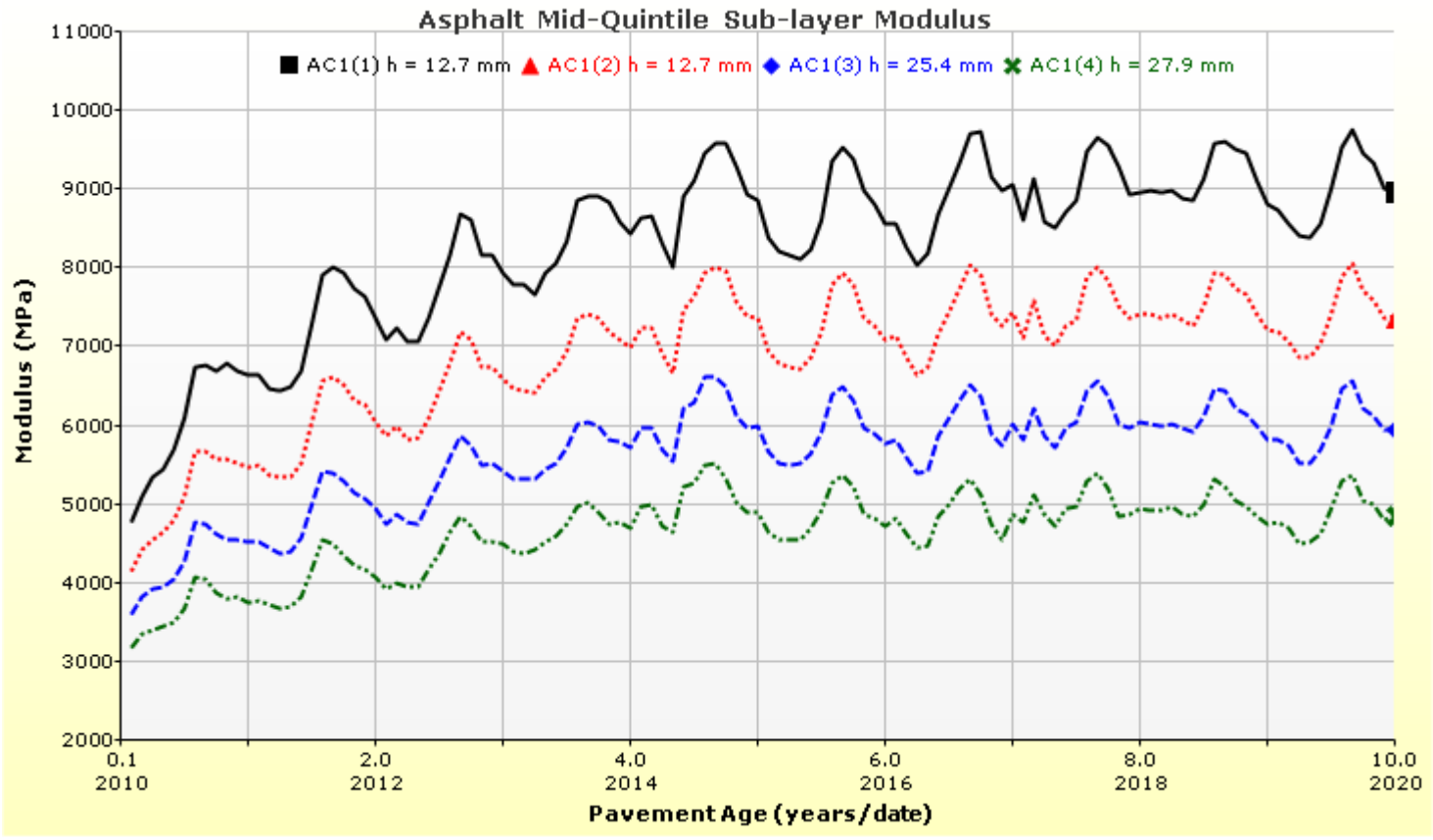

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
10
20
30
40
50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

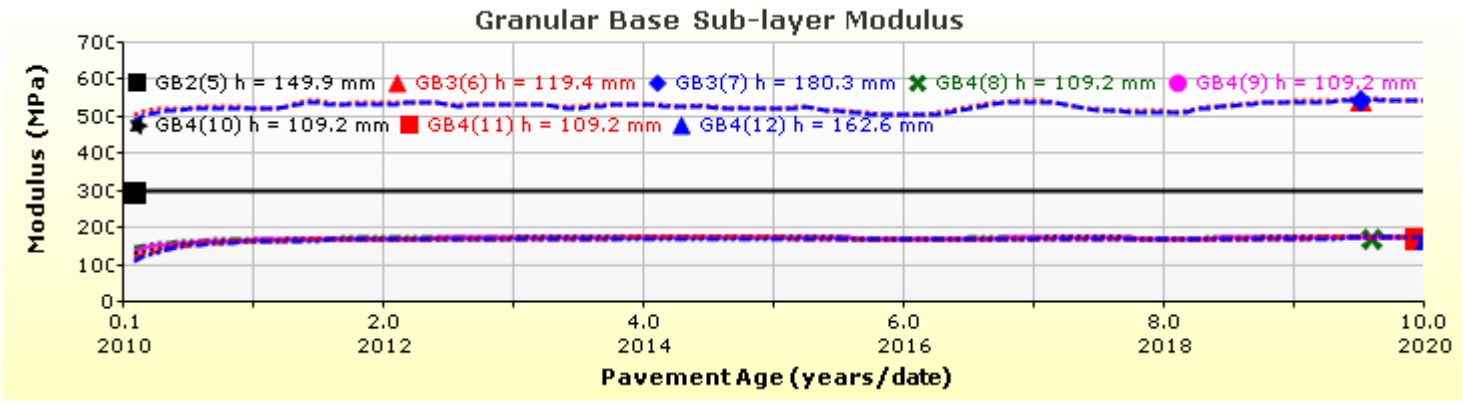

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

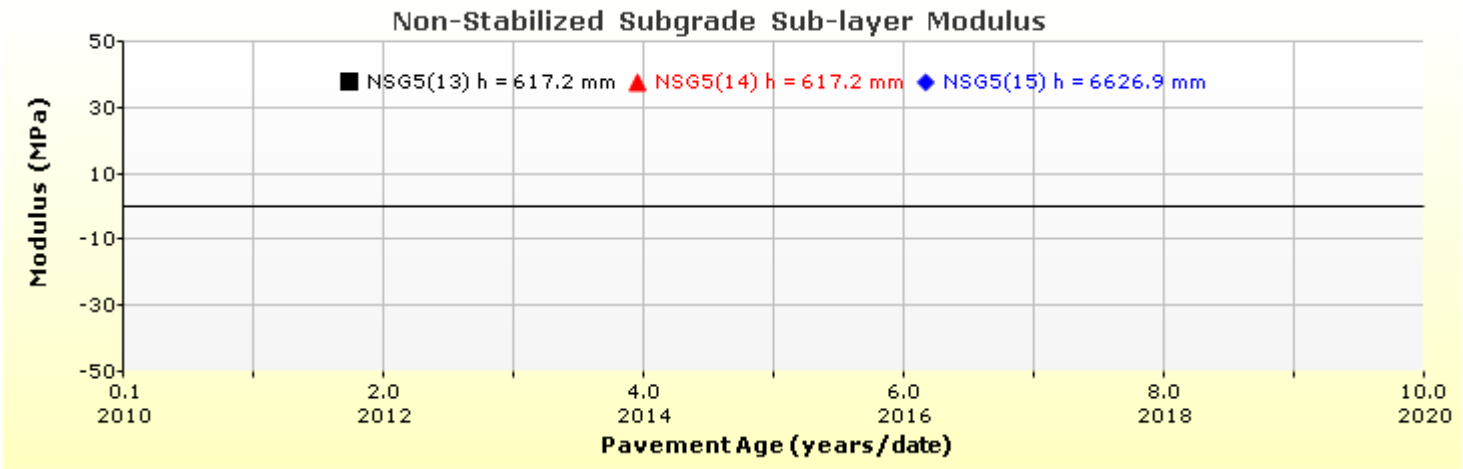

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
900
1000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
35
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
30
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left({}^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left({}^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestFZ-2

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestFZ-2.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -3.77, -38.55

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

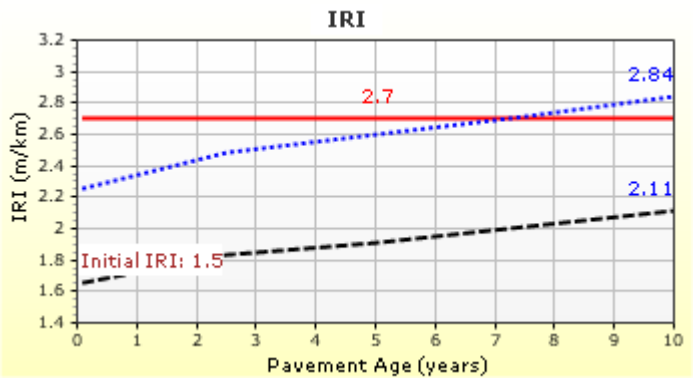
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

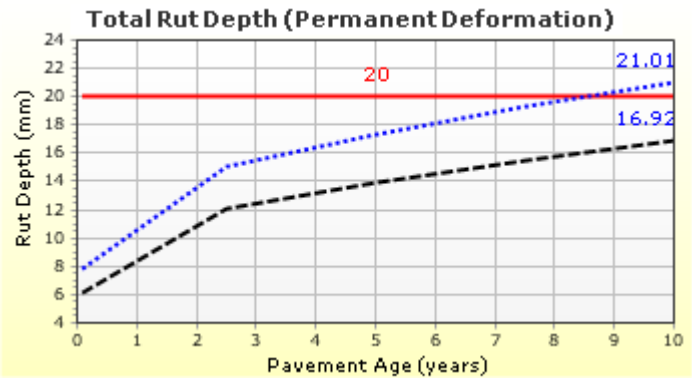
Design Outputs

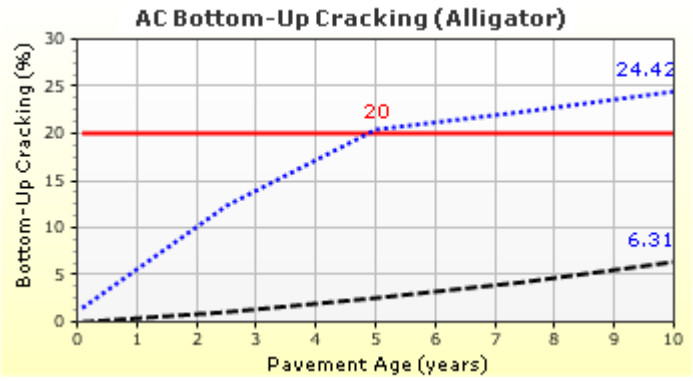
Distress Prediction Summary

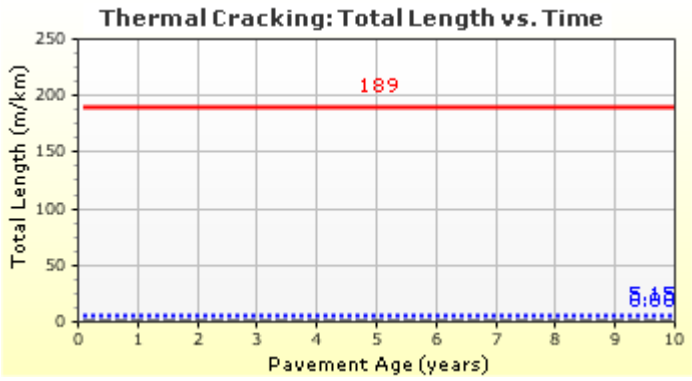
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.84	90.00	84.92	Fail
Permanent deformation - total pavement (mm)	20.00	21.00	90.00	83.27	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.42	90.00	83.37	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	699.47	90.00	69.16	Fail
Permanent deformation - AC only (mm)	5.00	9.09	50.00	6.49	Fail

Distress Charts







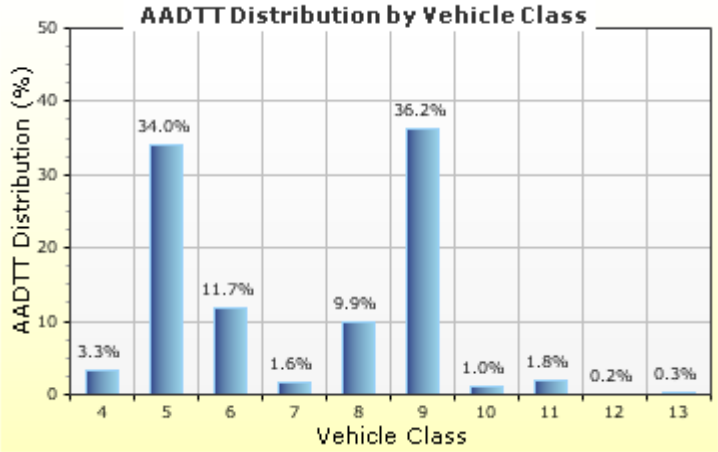


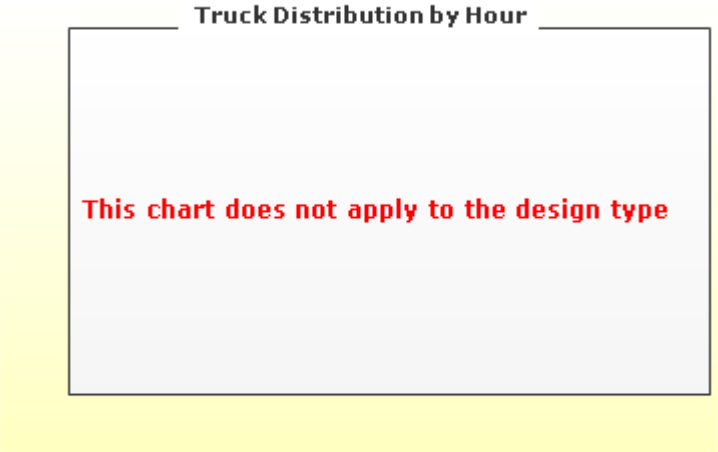


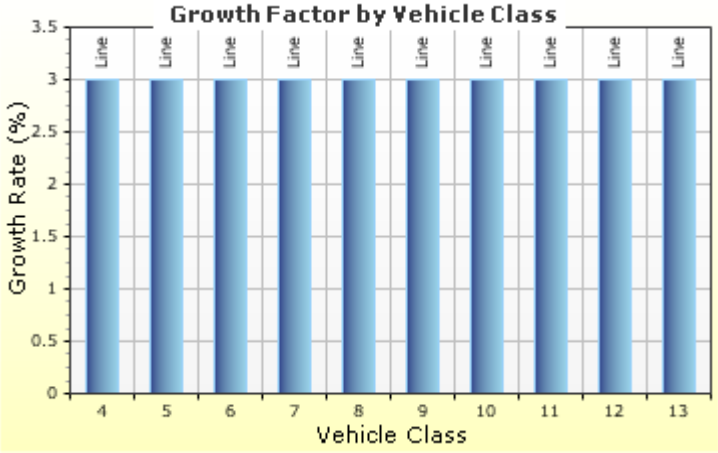
Traffic Inputs

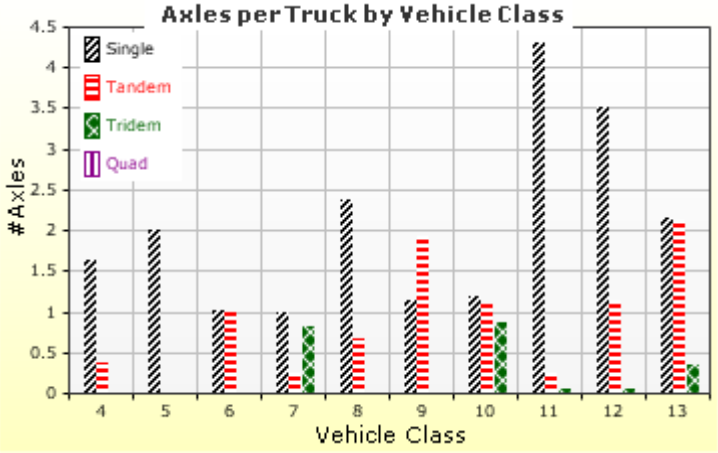
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

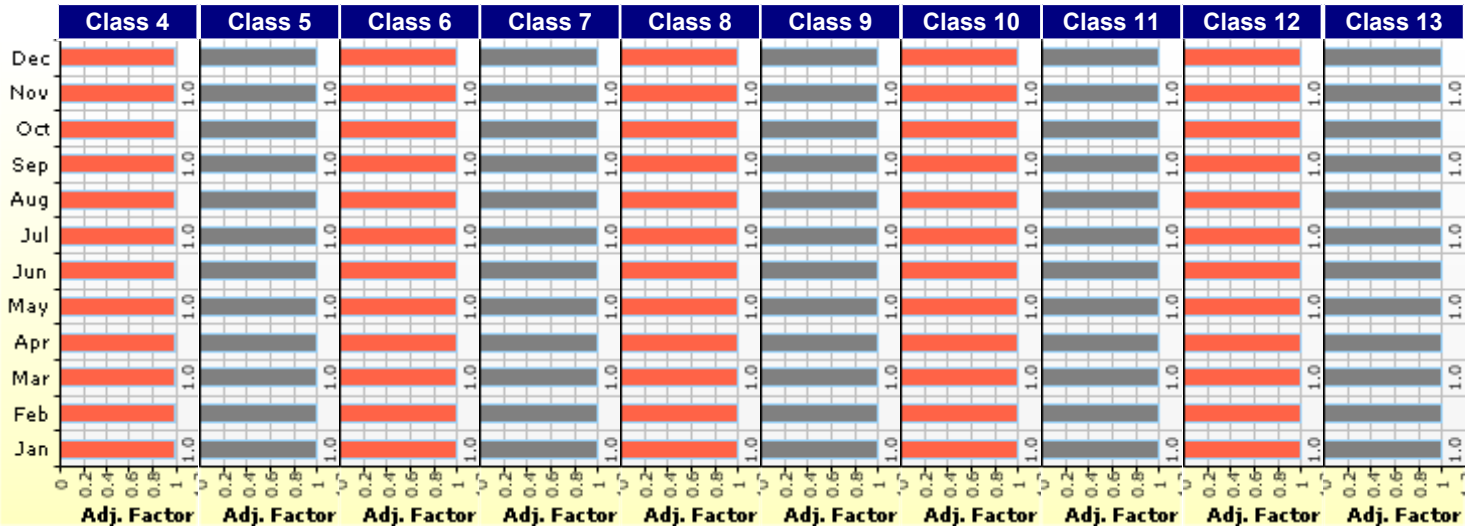








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

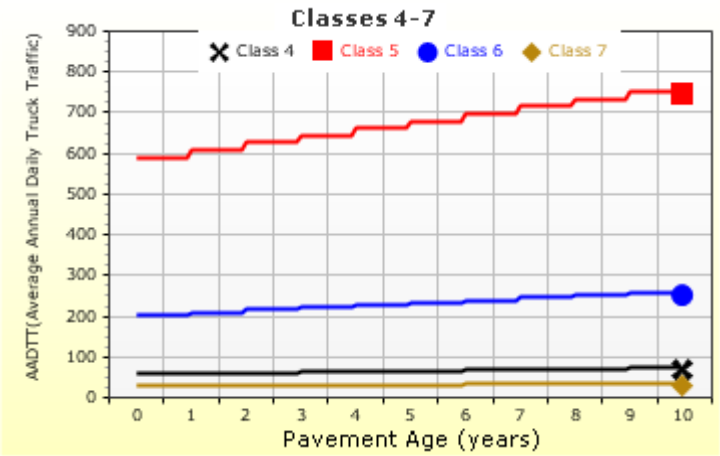
Wheelbase does not apply

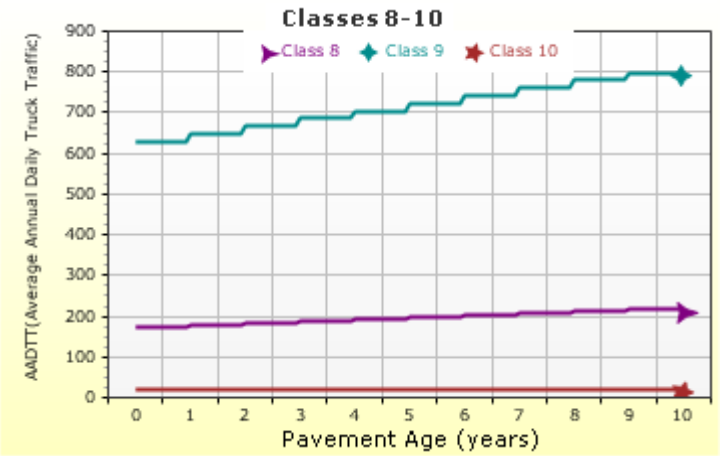
Number of Axles per Truck

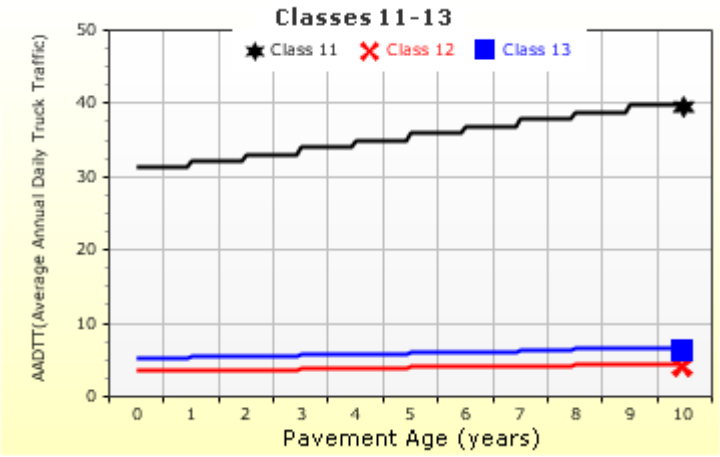
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

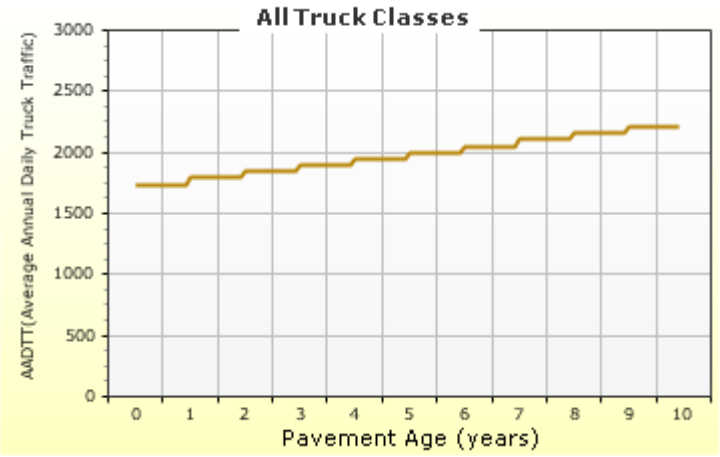
AADTT (Average Annual Daily Truck Traffic) Growth

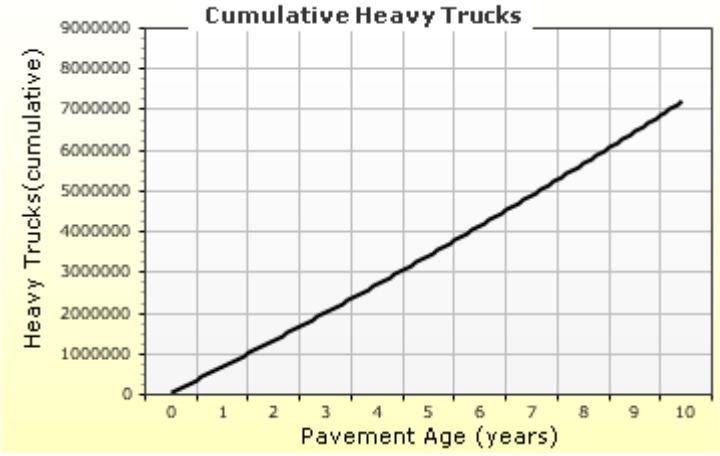
*** Traffic cap is not enforced**







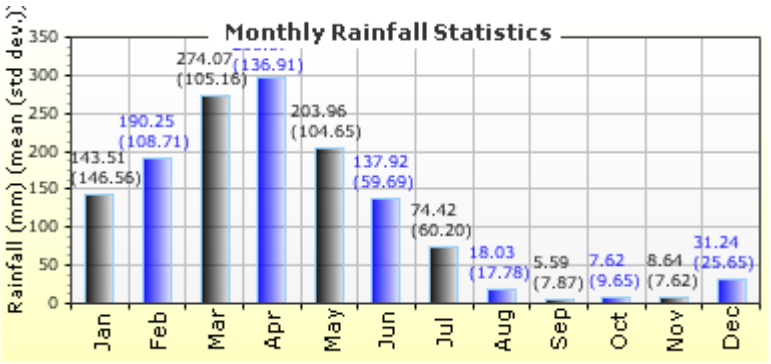




Climate Inputs

Climate Data Sources:

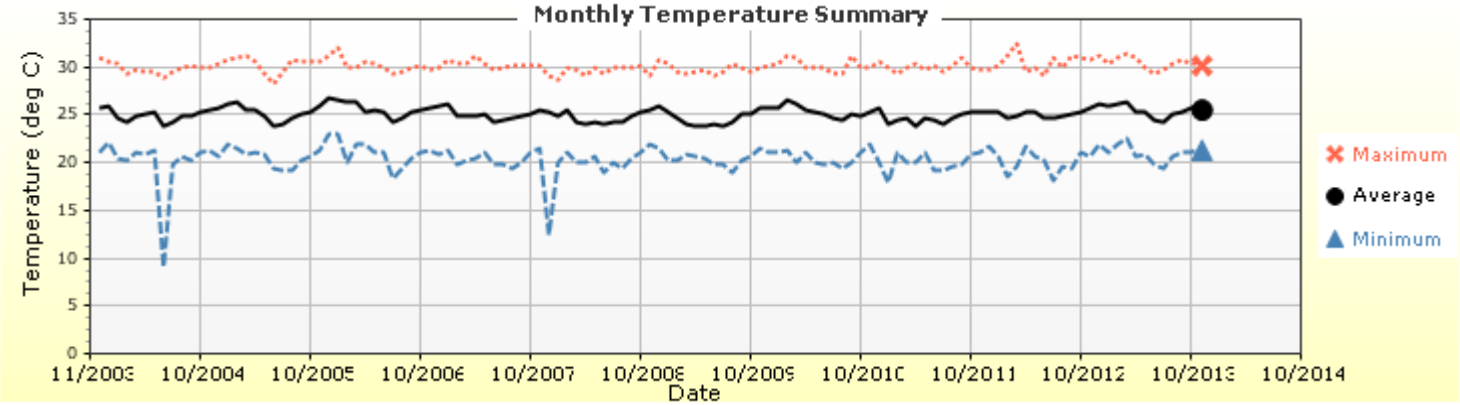
Climate Station Cities:	Location (lat lon elevation(m))
FORTALEZA, CE	-3.77000 -38.55000 41

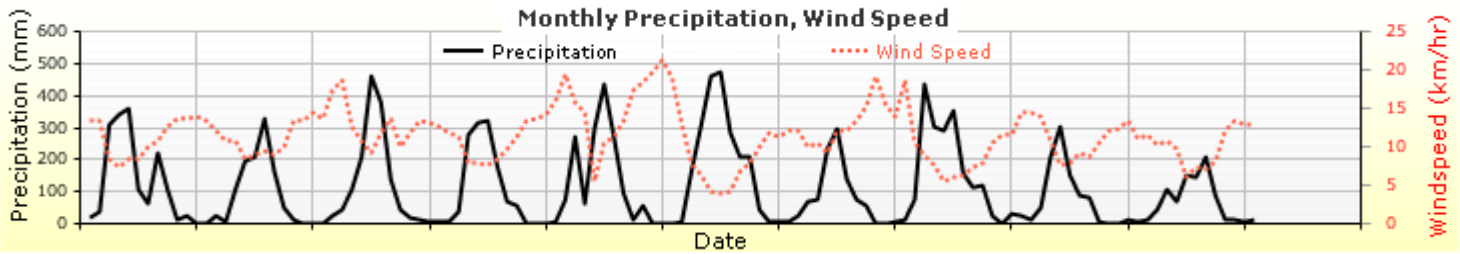


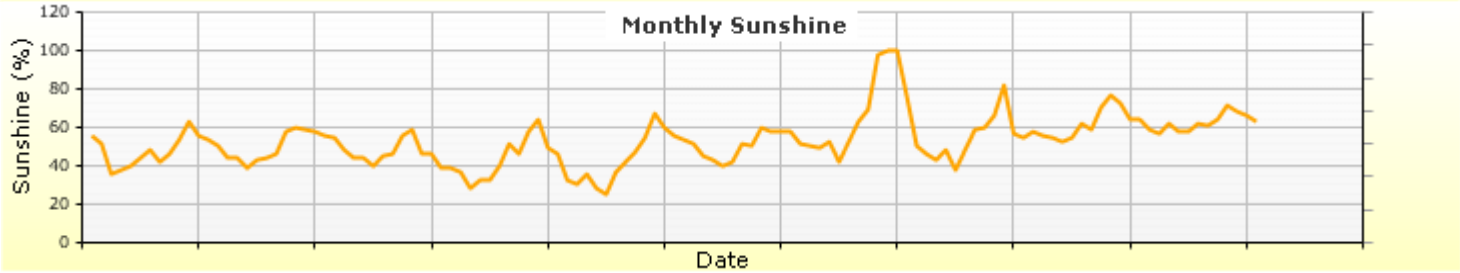
Annual Statistics:

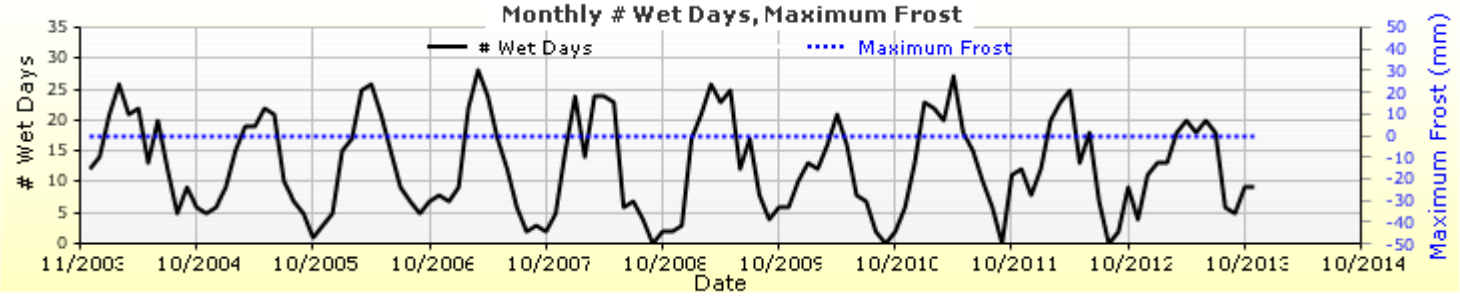
Mean annual air temperature (ºC)	25.10
Mean annual precipitation (mm)	1370.58
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00
Water table depth (m)	3.05

Monthly Climate Summary:

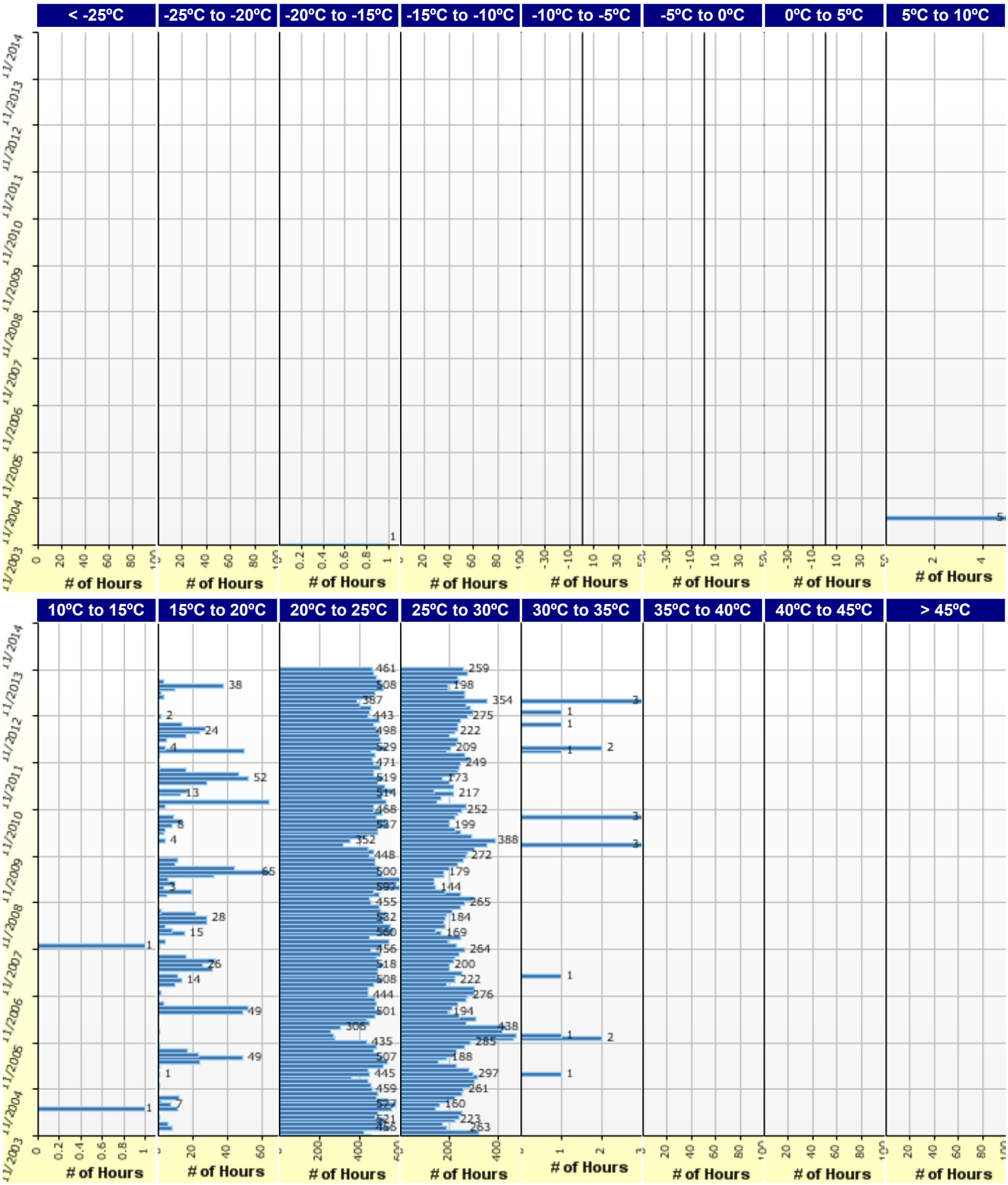








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

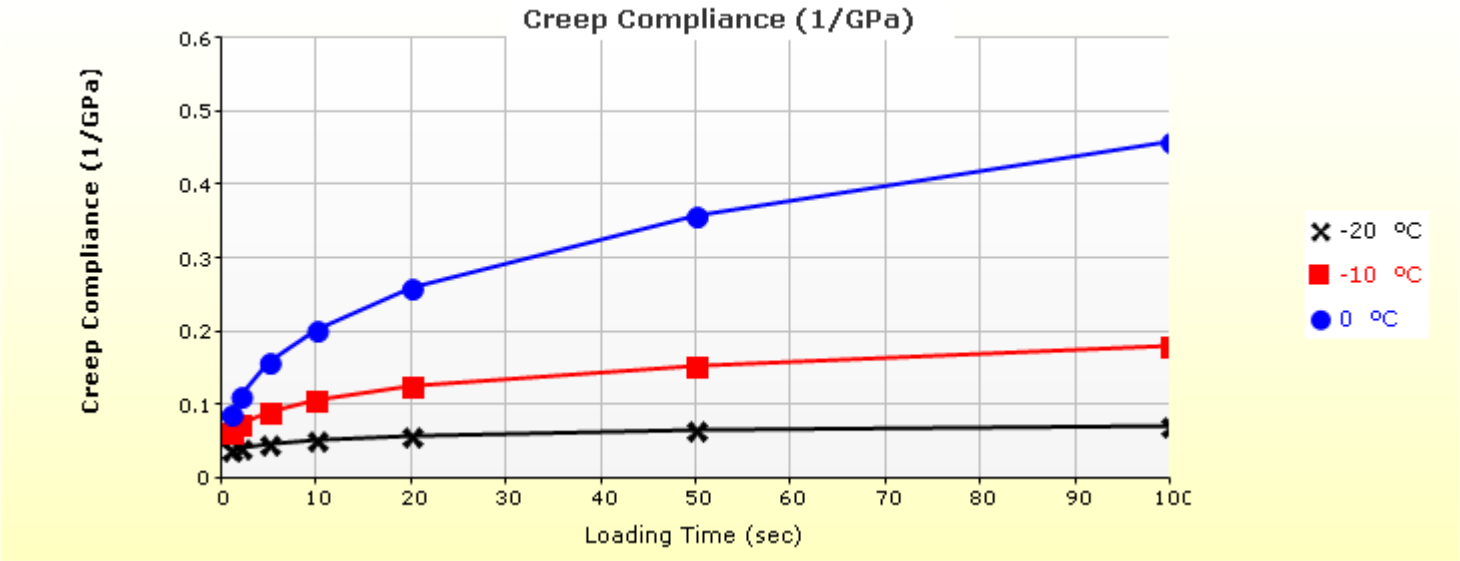
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

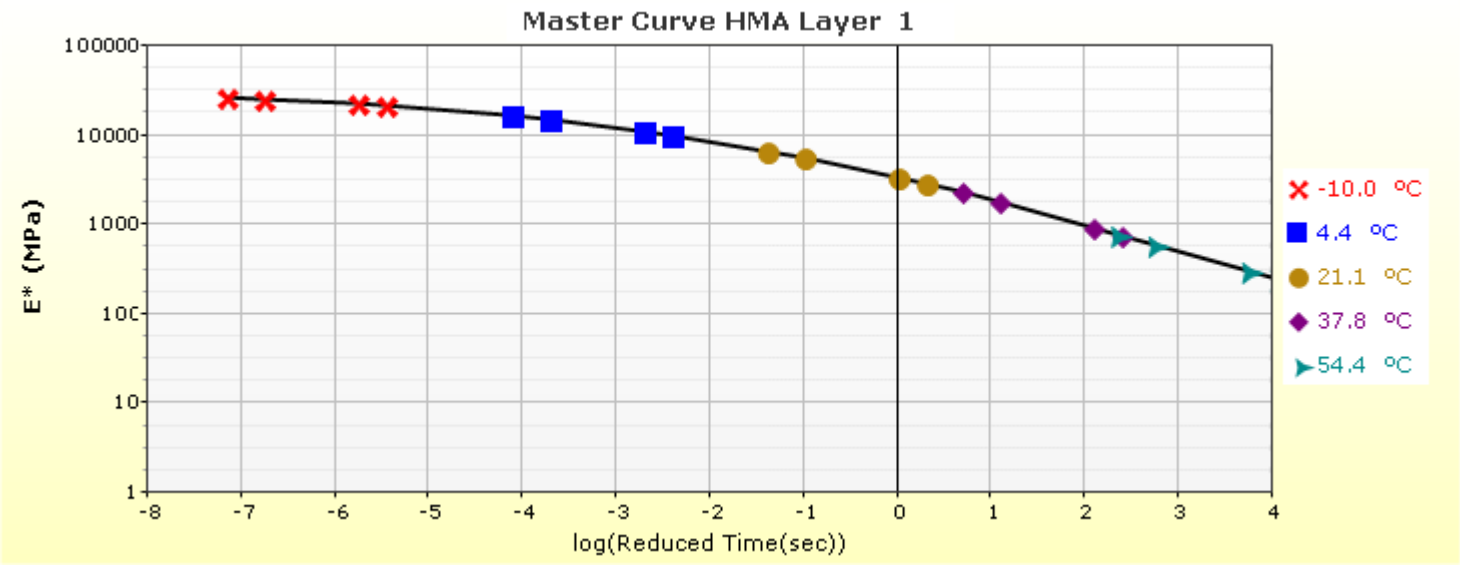
Indirect tensile strength at -10 ºC (MPa)	2.69

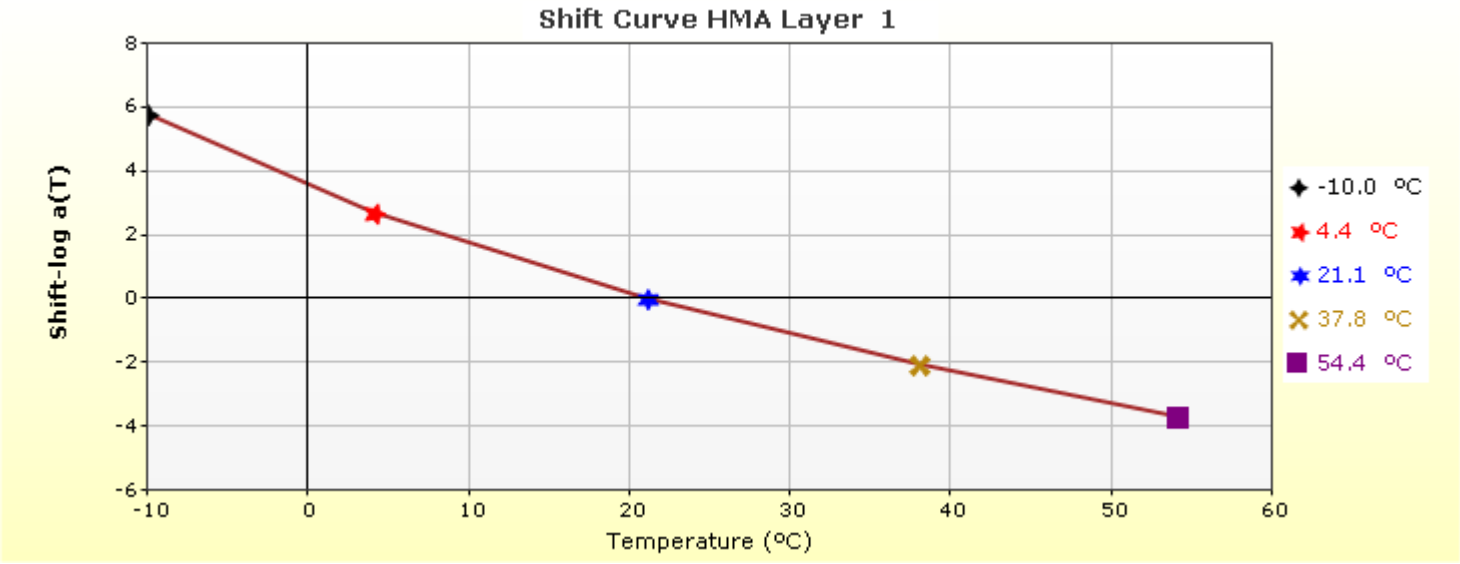
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

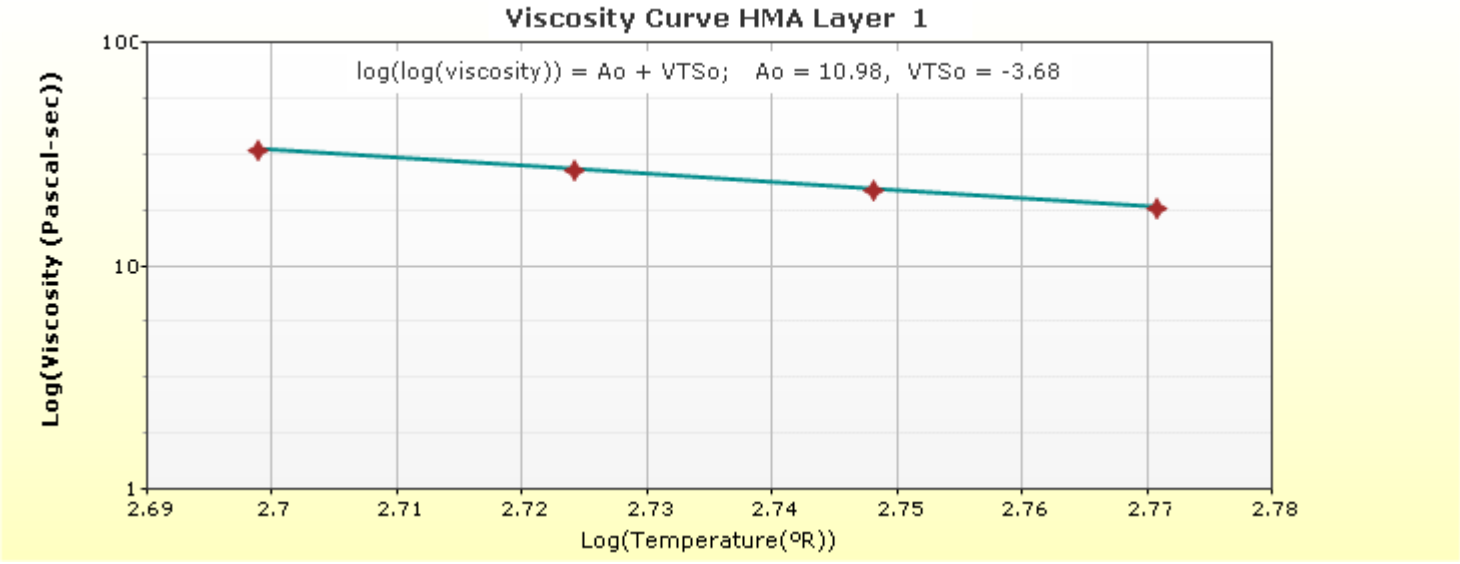
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



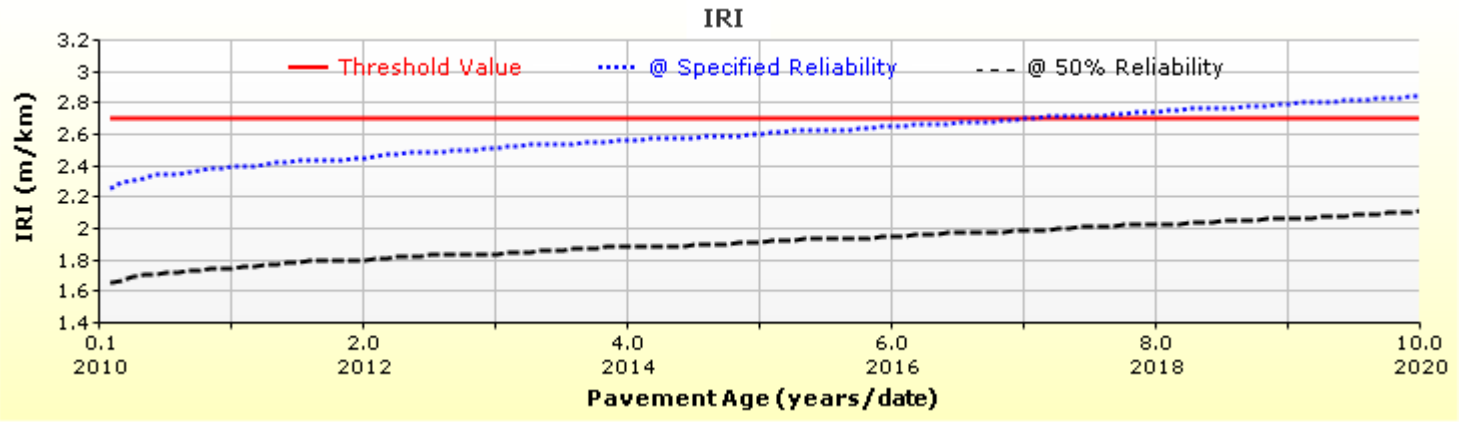
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

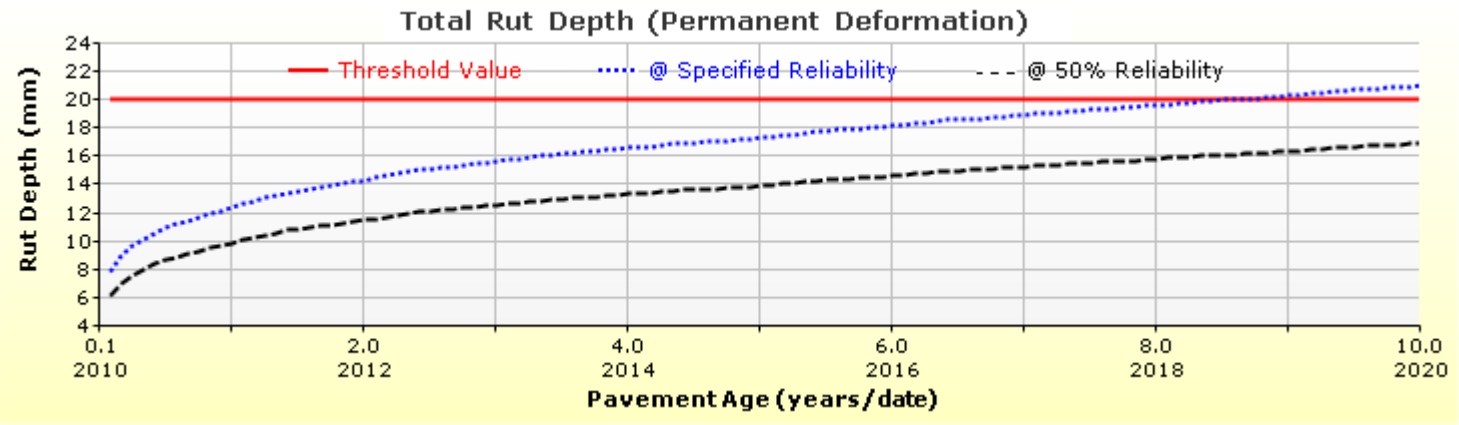


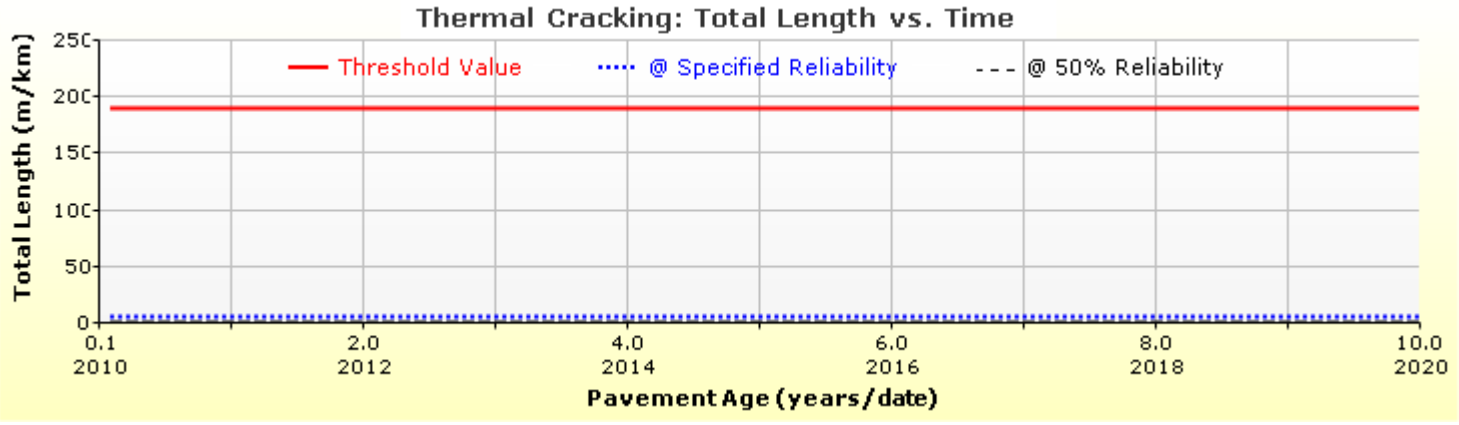


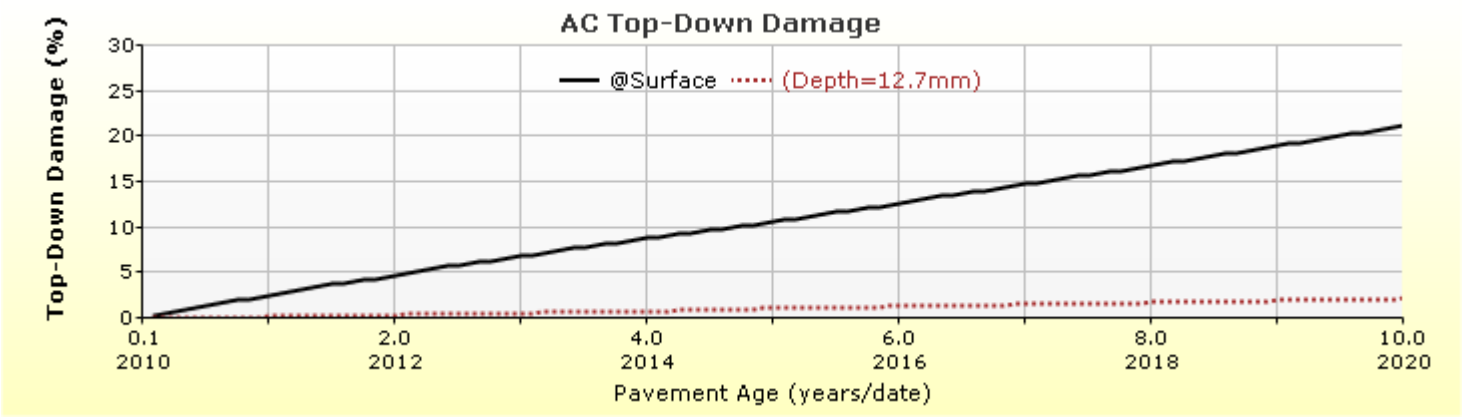


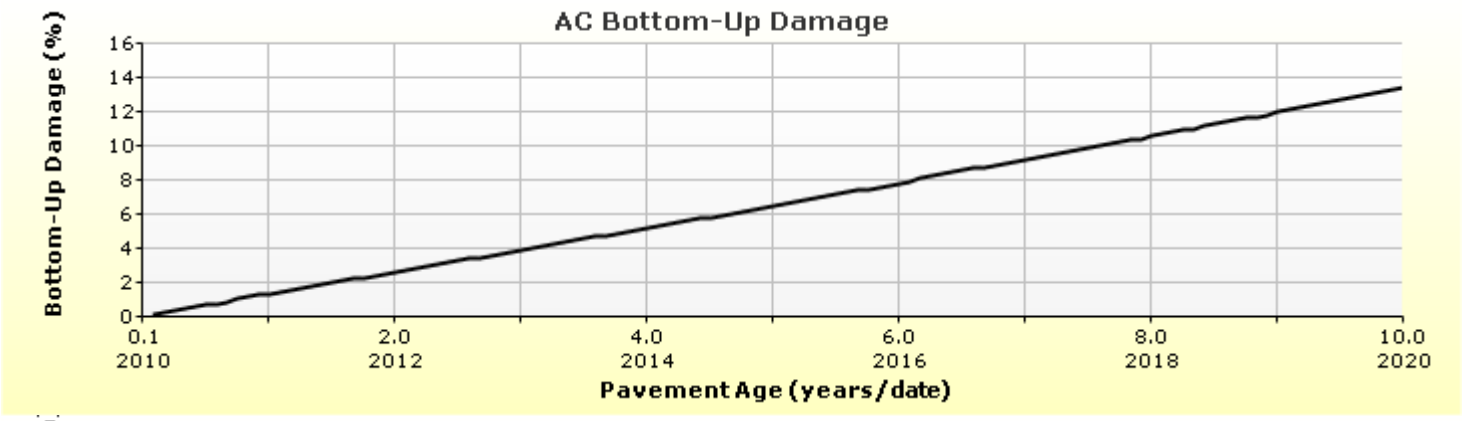
Analysis Output Charts

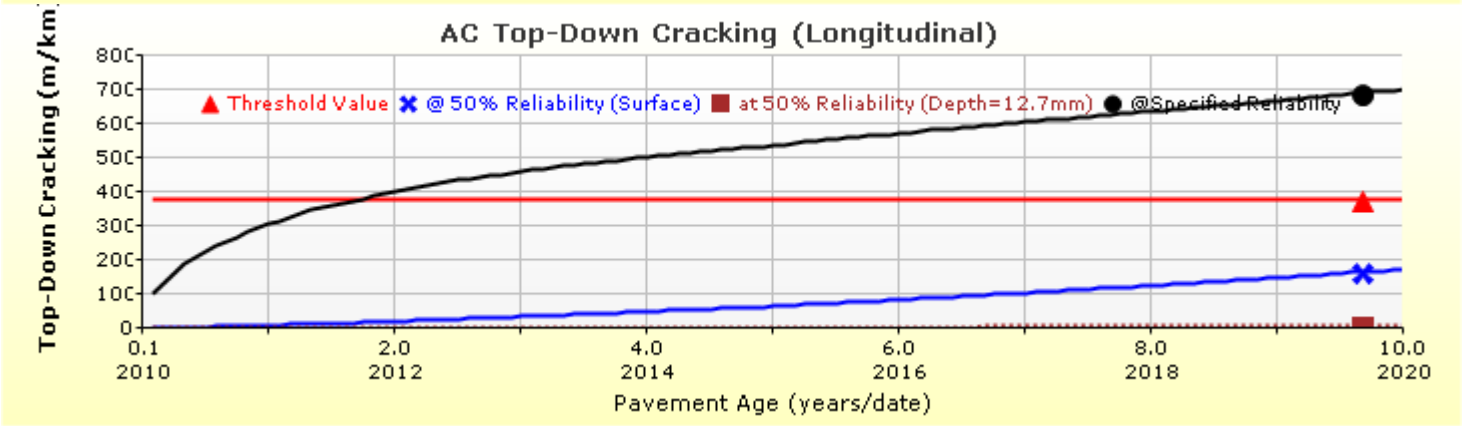


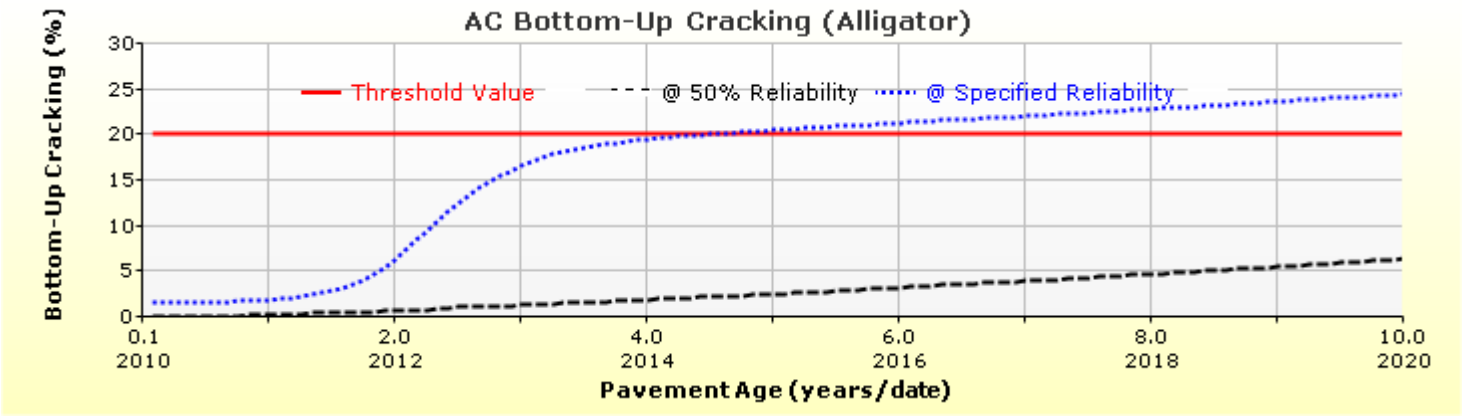


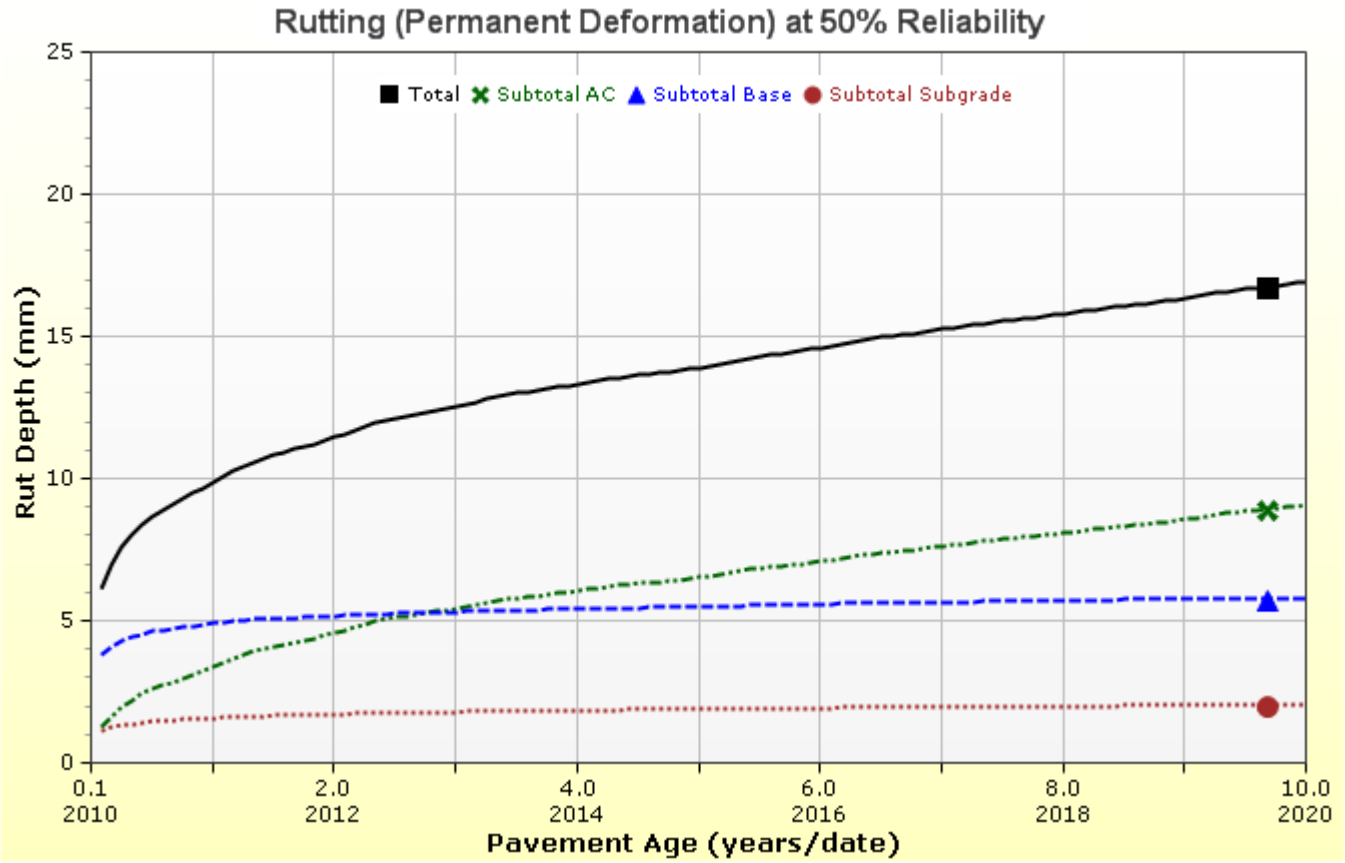


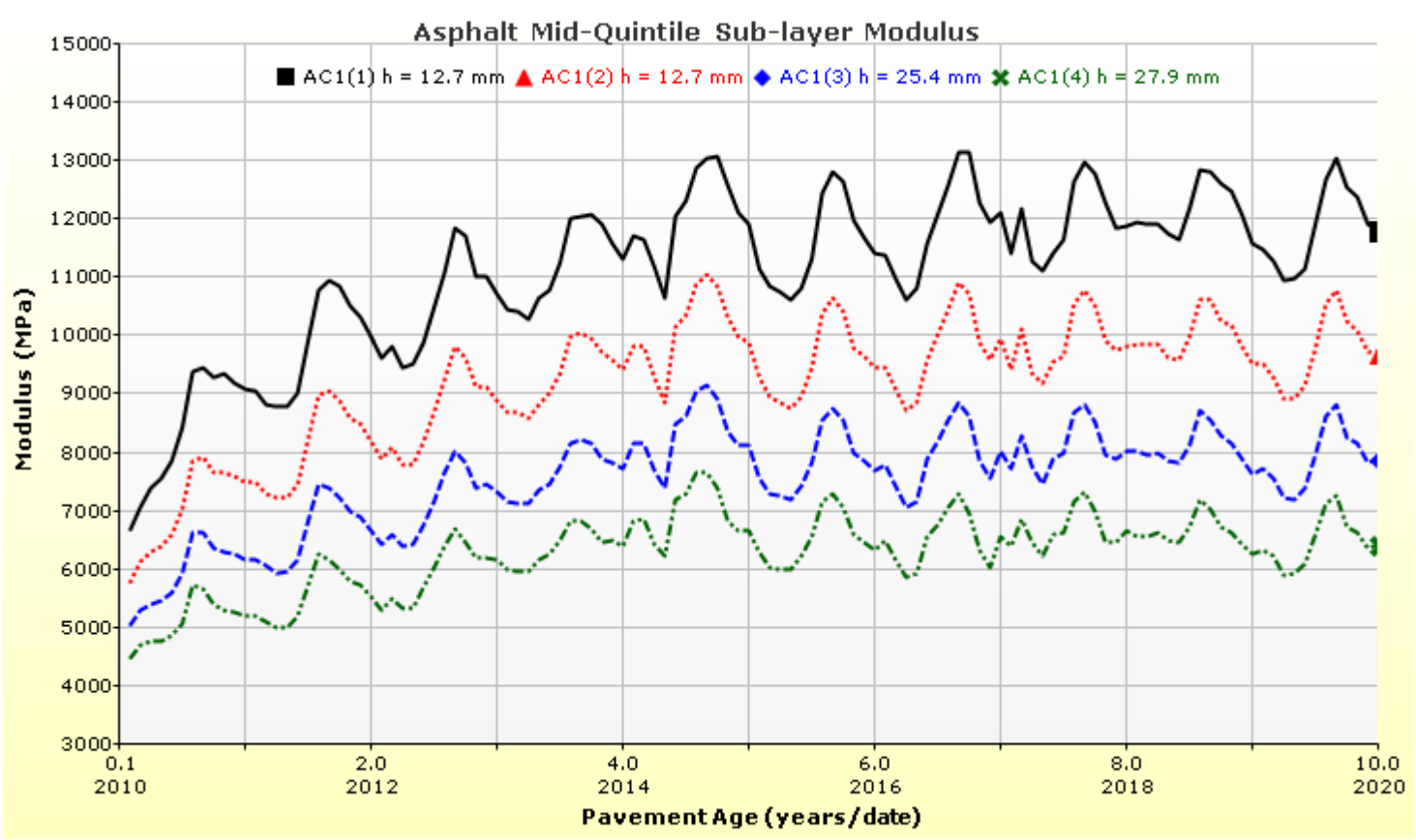

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

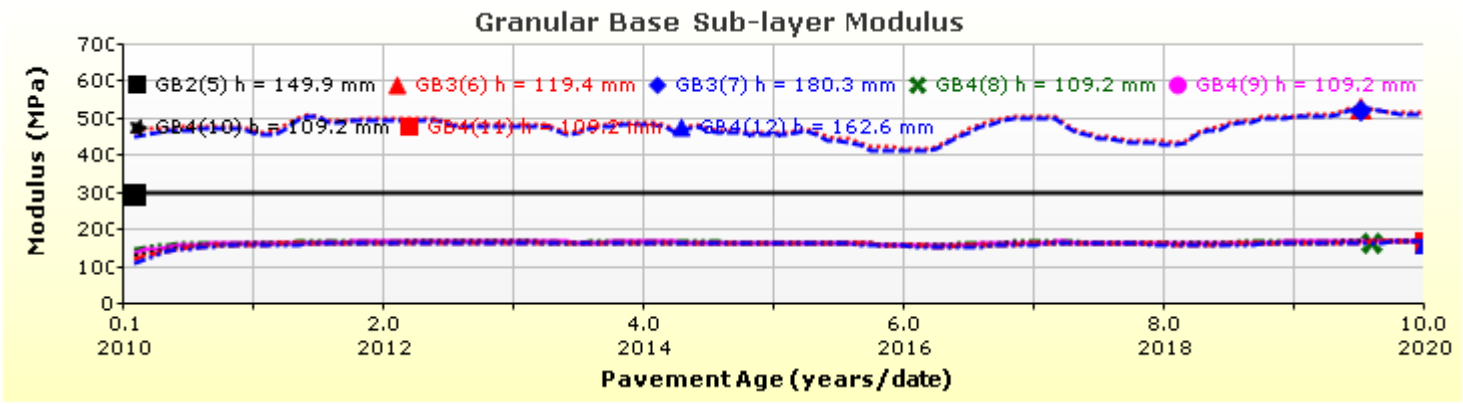

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

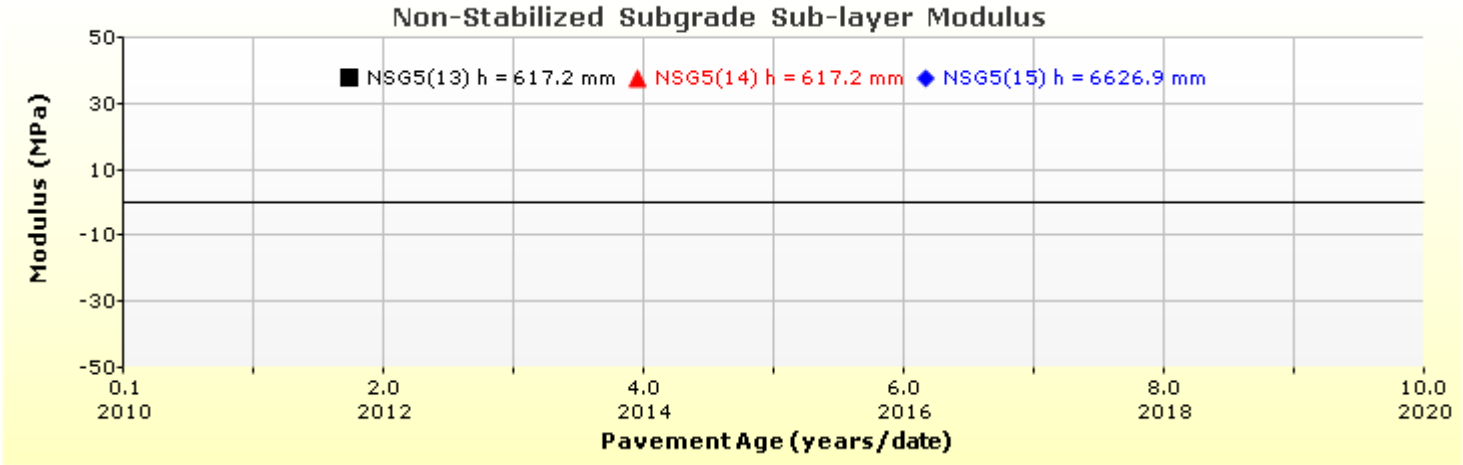

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestFZ-4

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestFZ-4.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -3.77, -38.55

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

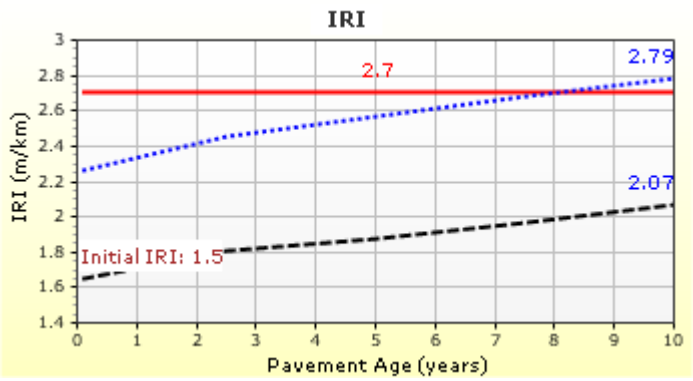
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

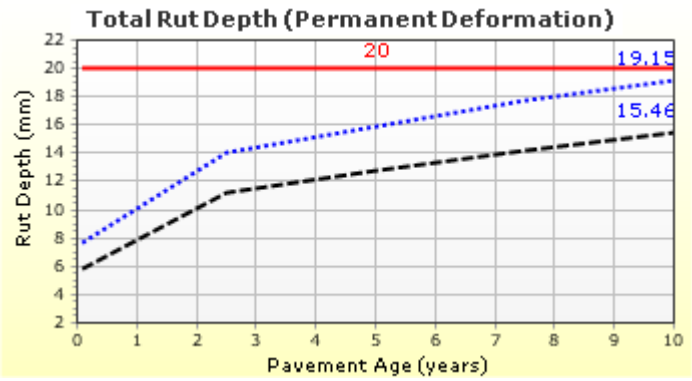
Design Outputs

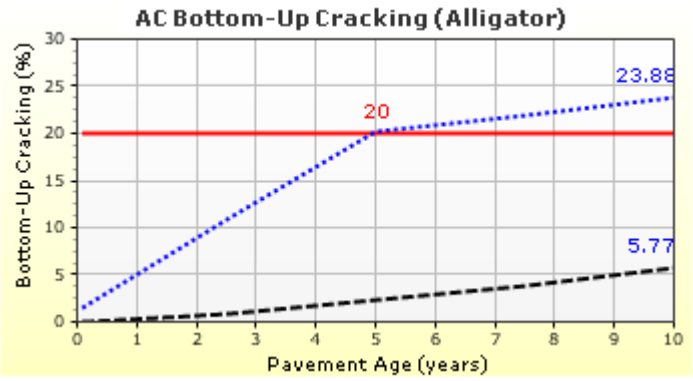
Distress Prediction Summary

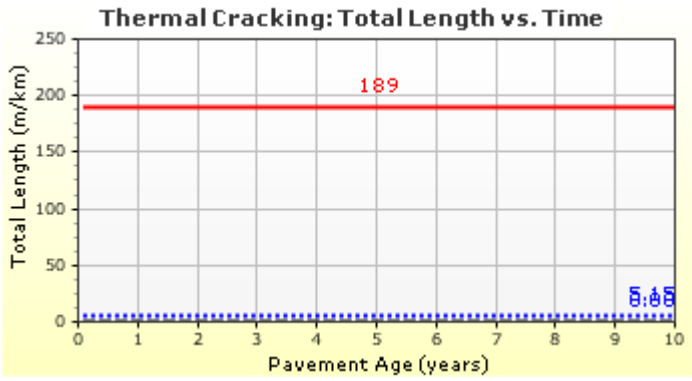
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.79	90.00	86.86	Fail
Permanent deformation - total pavement (mm)	20.00	19.16	90.00	94.16	Pass
AC bottom-up fatigue cracking (percent)	20.00	23.88	90.00	84.31	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	660.35	90.00	72.01	Fail
Permanent deformation - AC only (mm)	5.00	7.64	50.00	13.09	Fail

Distress Charts







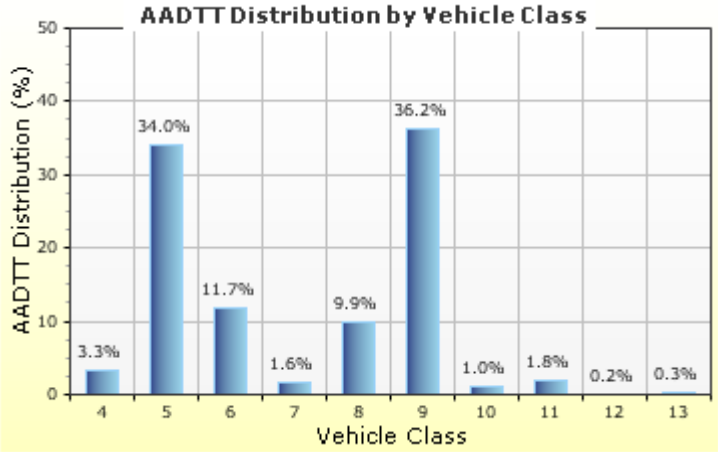


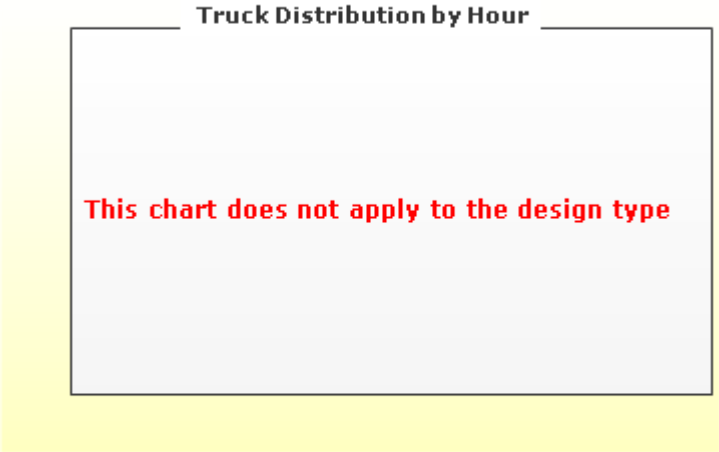


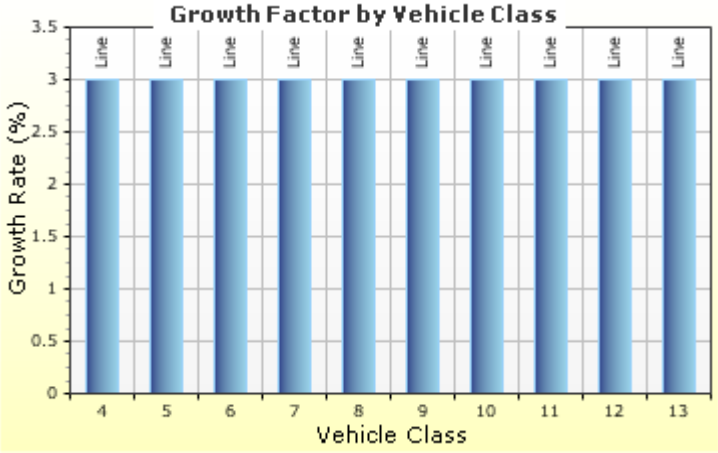
Traffic Inputs

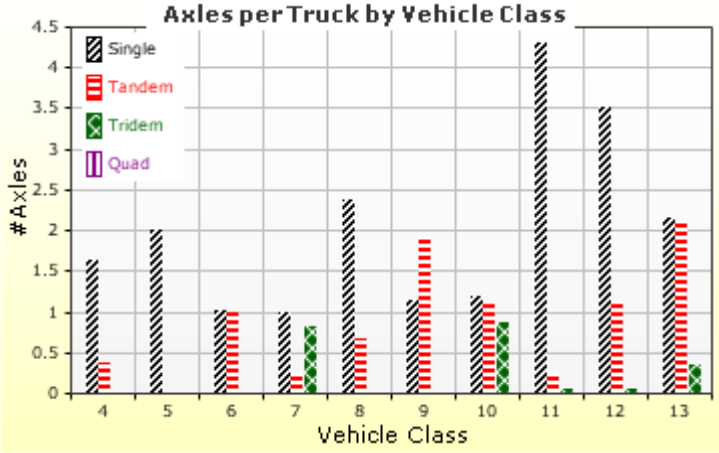
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

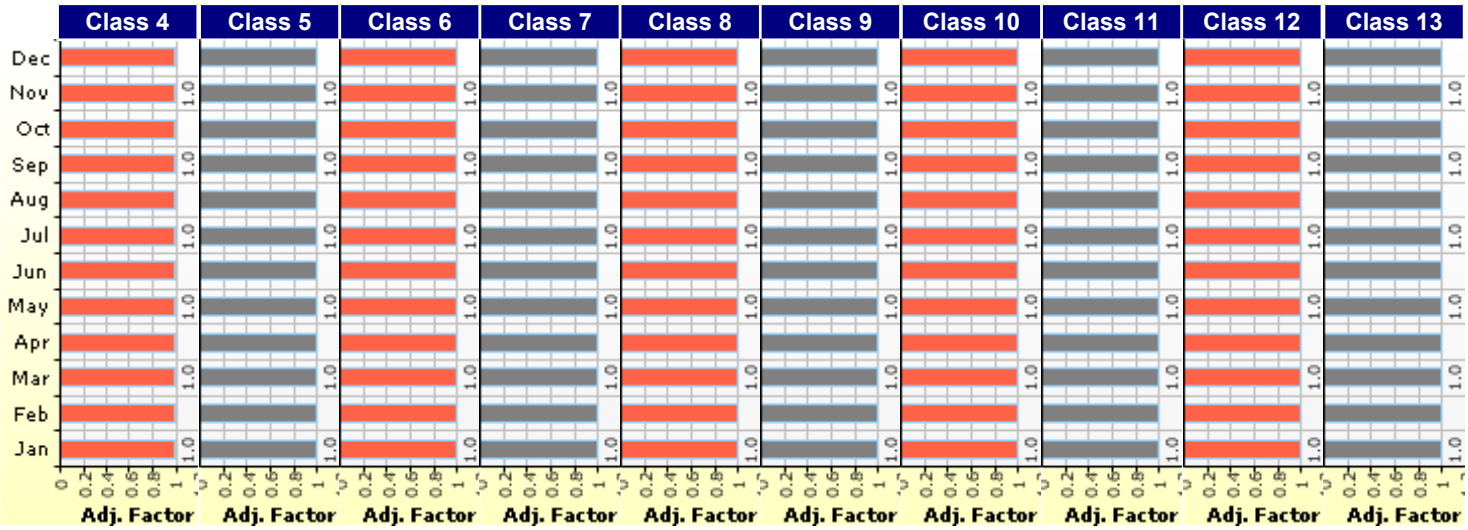








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

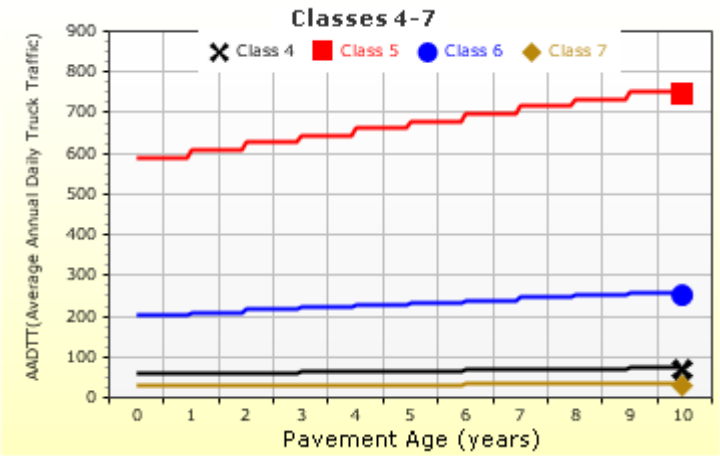
Wheelbase does not apply

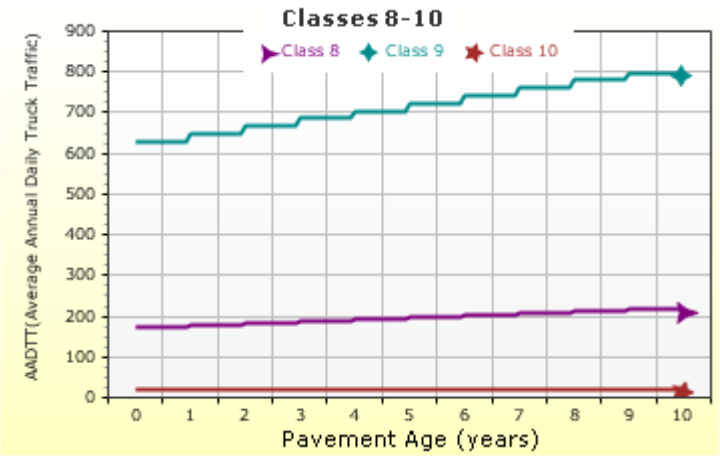
Number of Axles per Truck

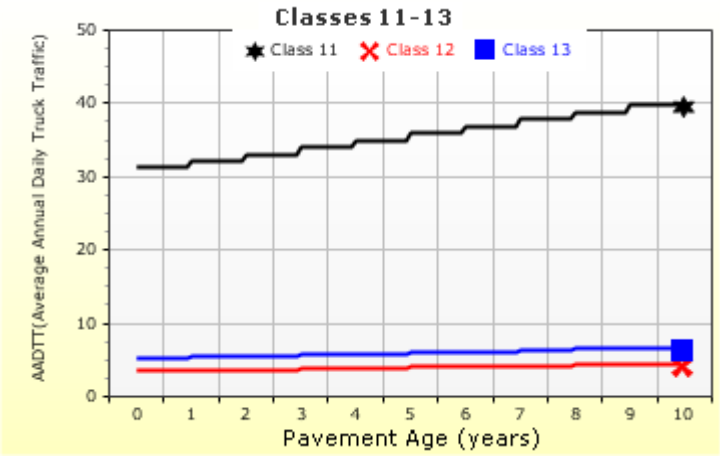
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

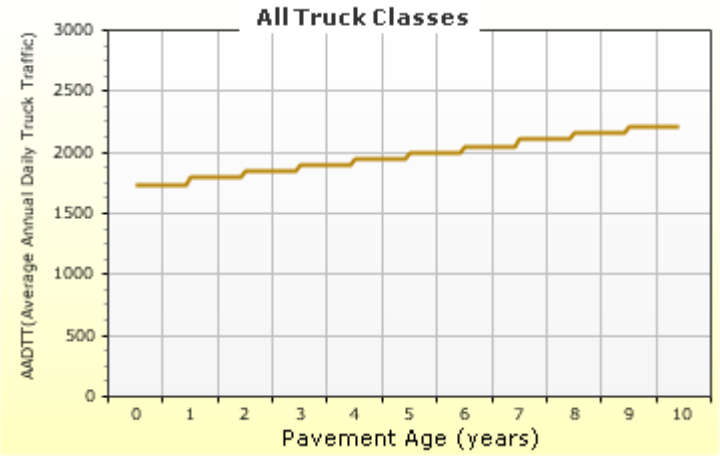
AADTT (Average Annual Daily Truck Traffic) Growth

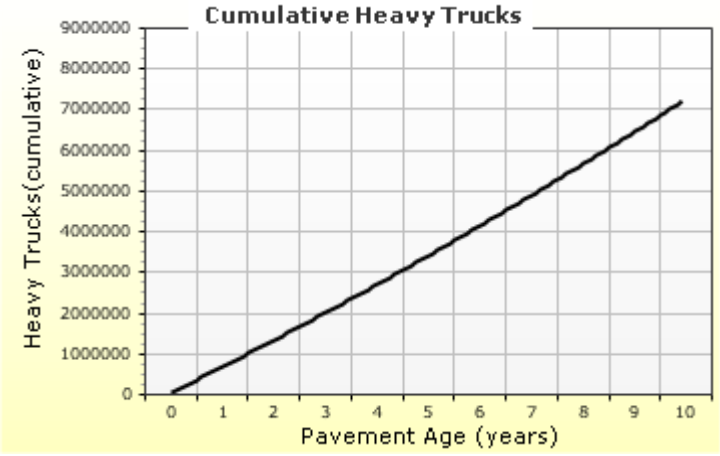
*** Traffic cap is not enforced**







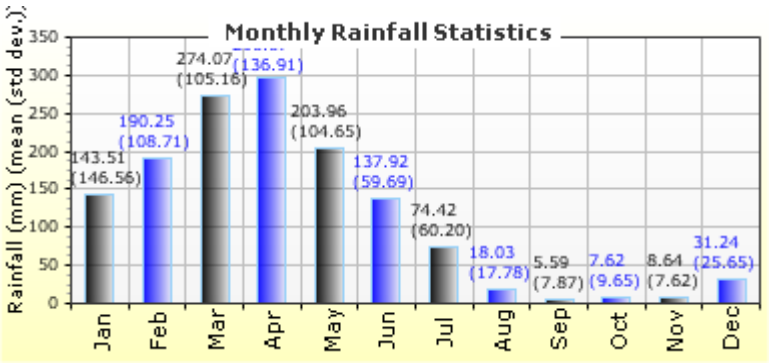




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
FORTALEZA, CE	-3.77000 -38.55000 41

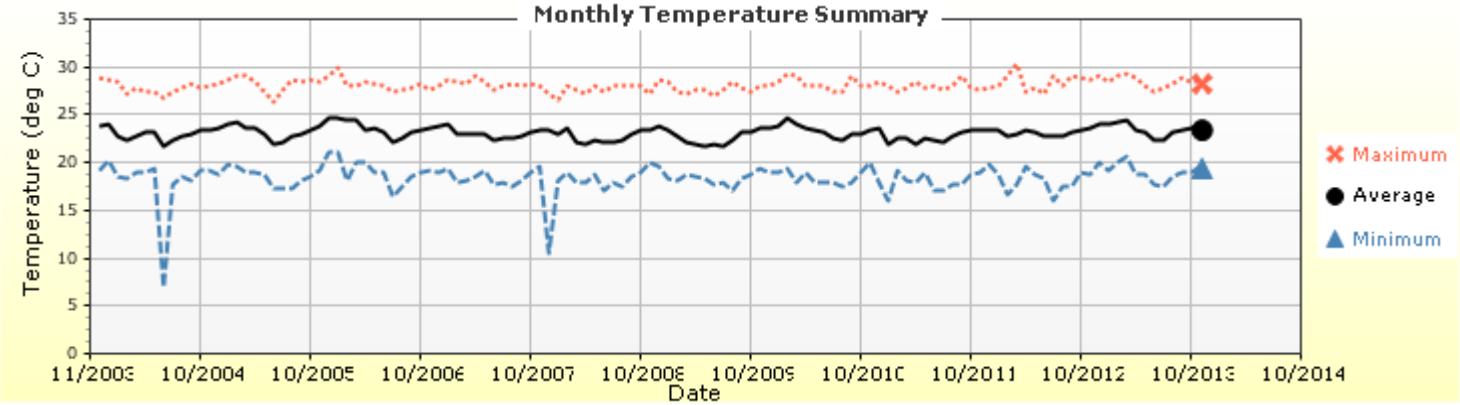


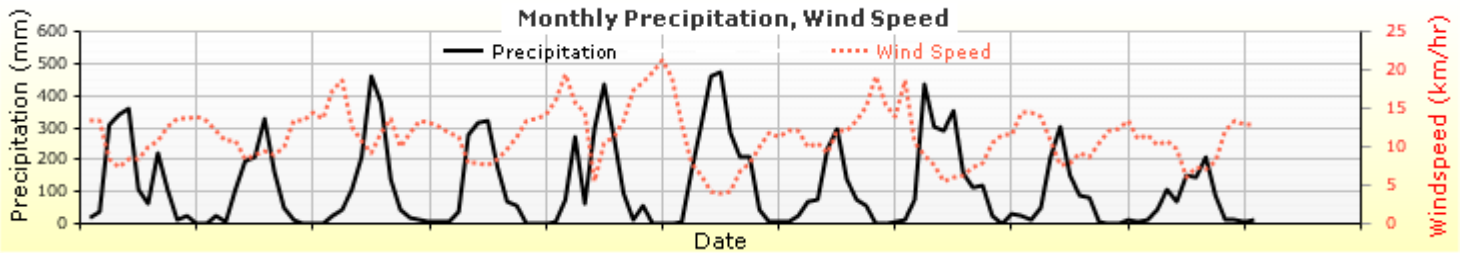
Annual Statistics:

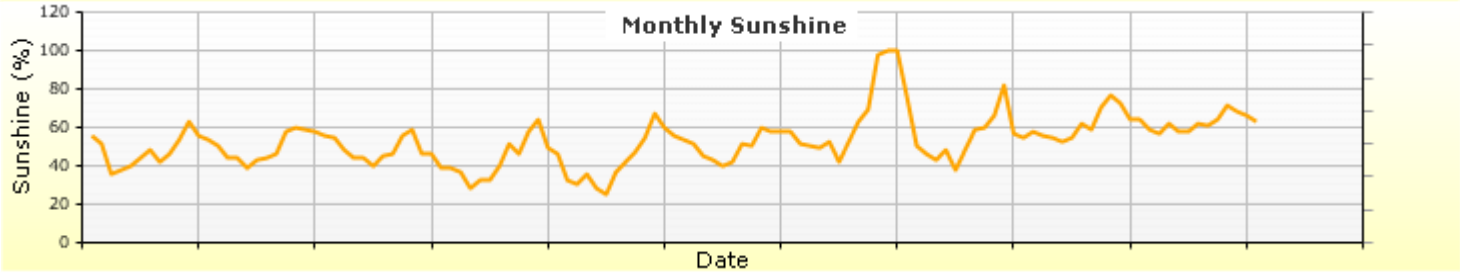
Mean annual air temperature (ºC)	23.09
Mean annual precipitation (mm)	1370.58
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

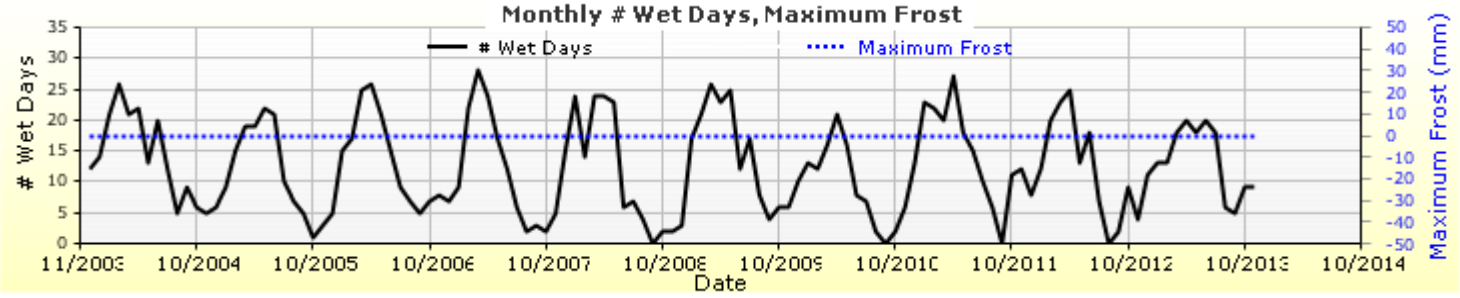
Water table depth (m)	3.05

Monthly Climate Summary:

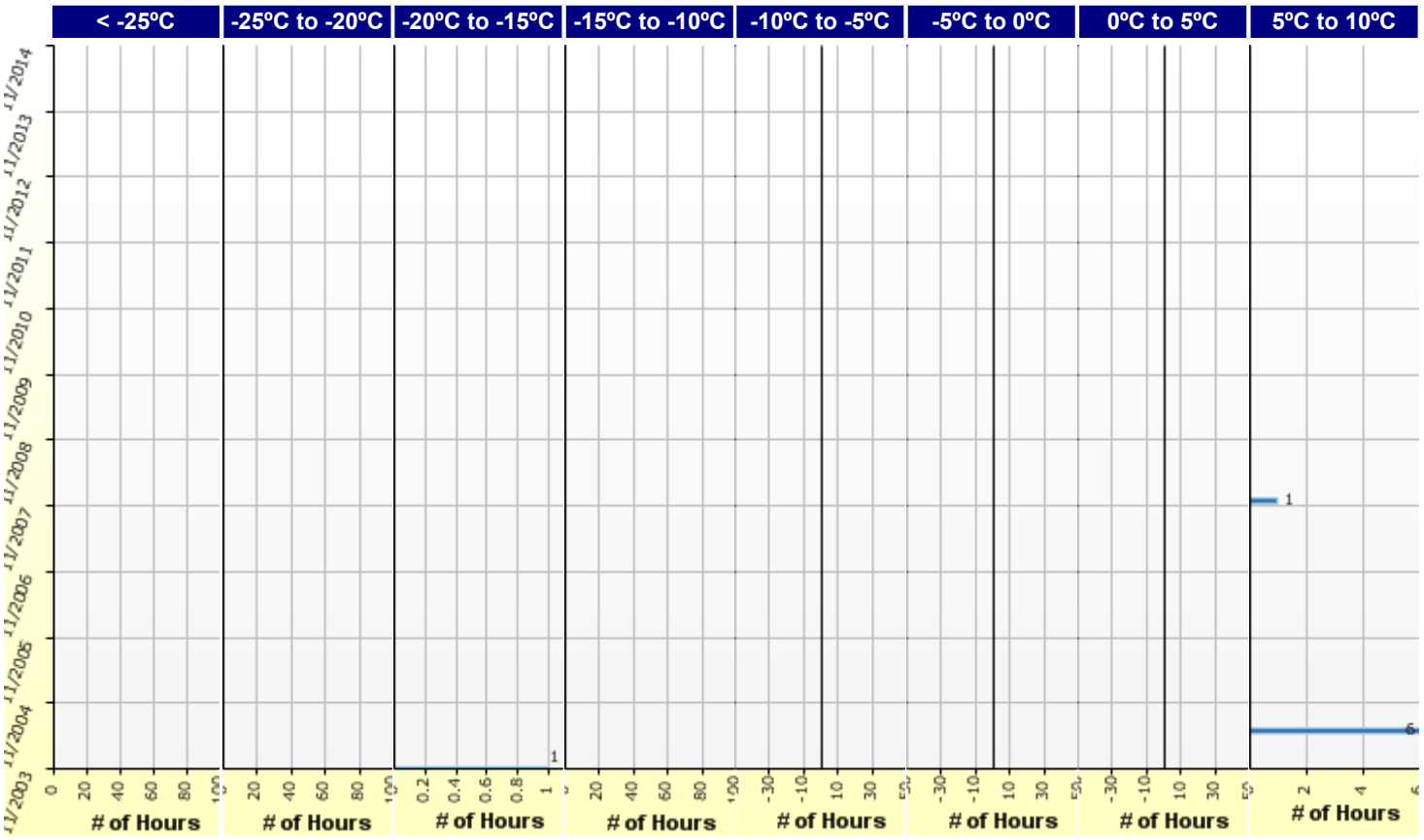


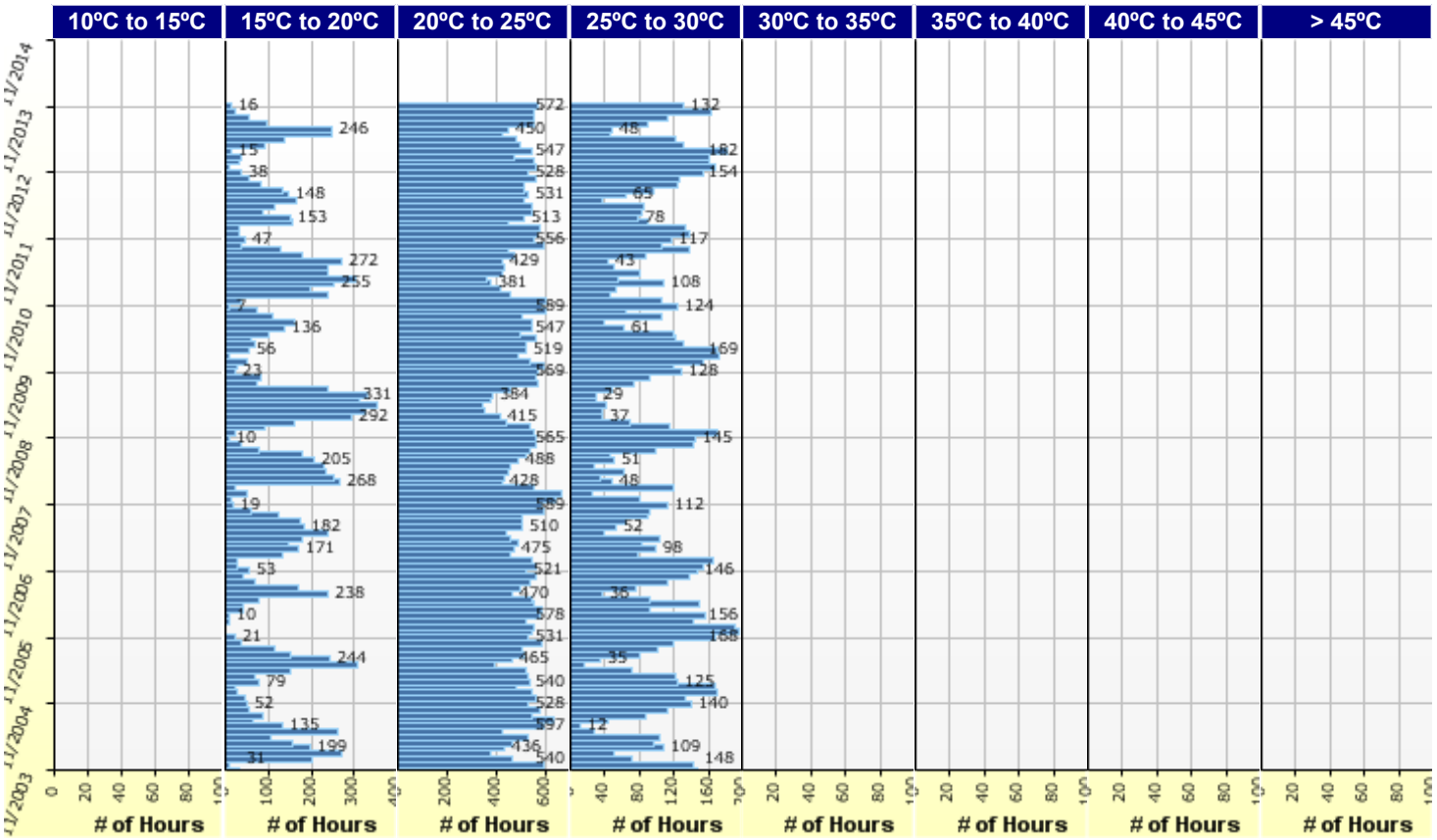






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

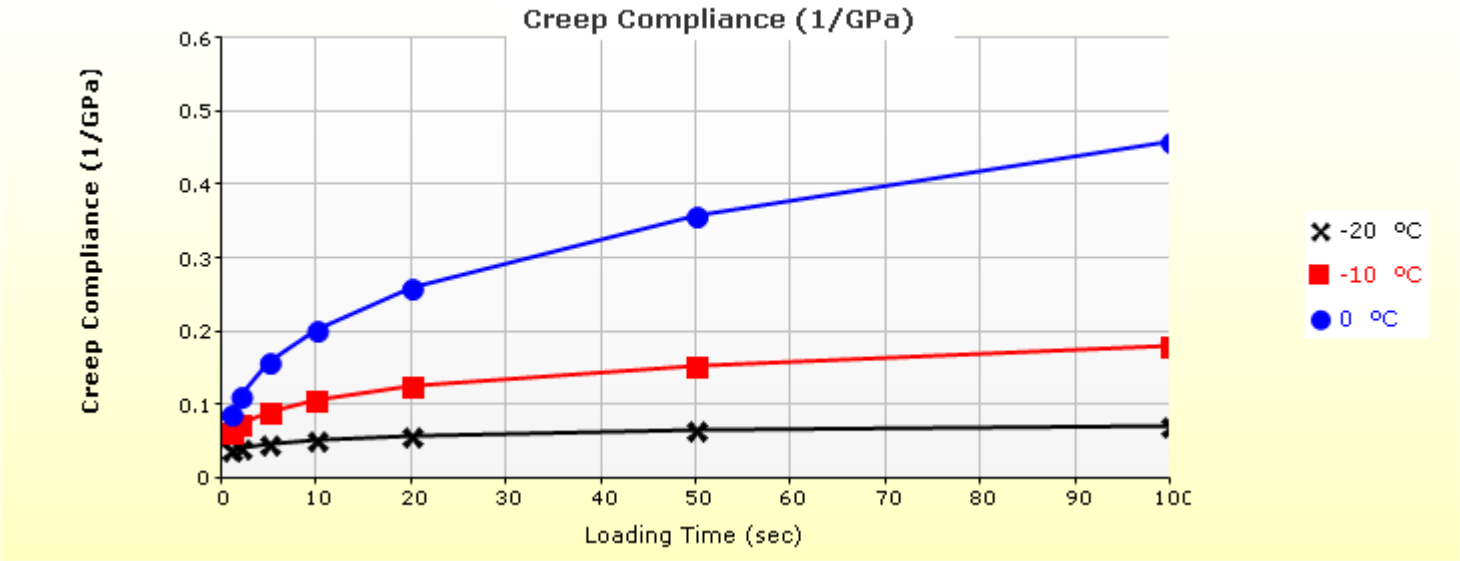
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

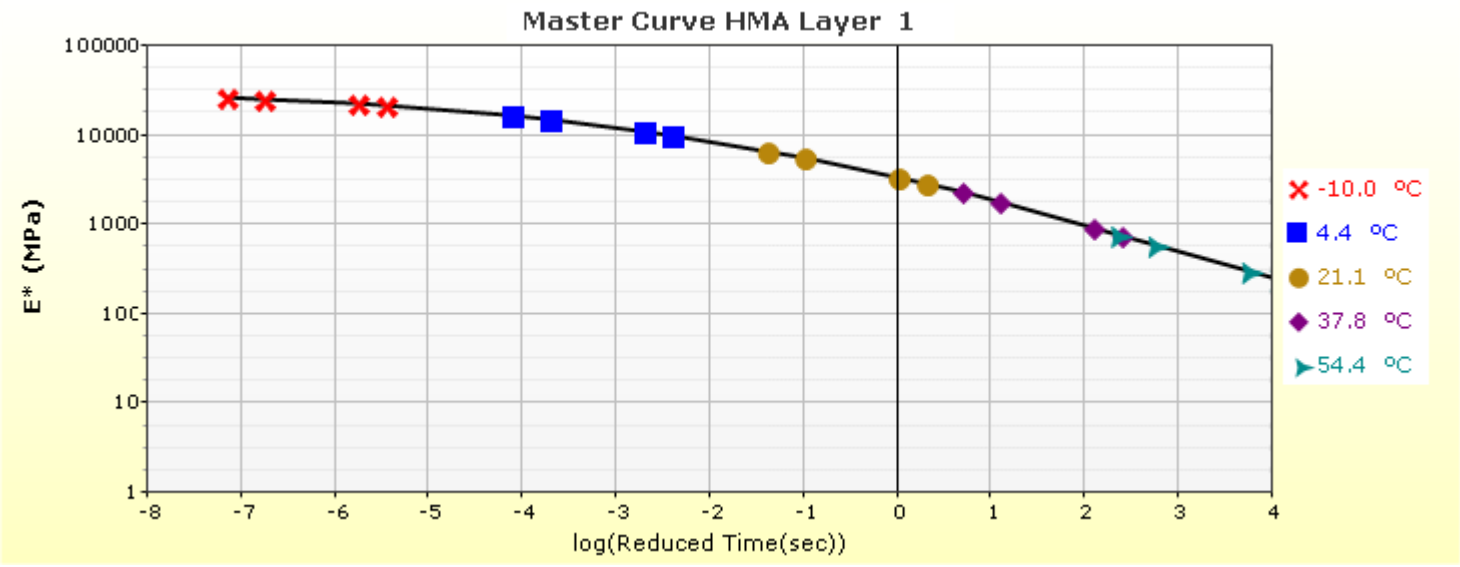
Indirect tensile strength at -10 ºC (MPa)	2.69

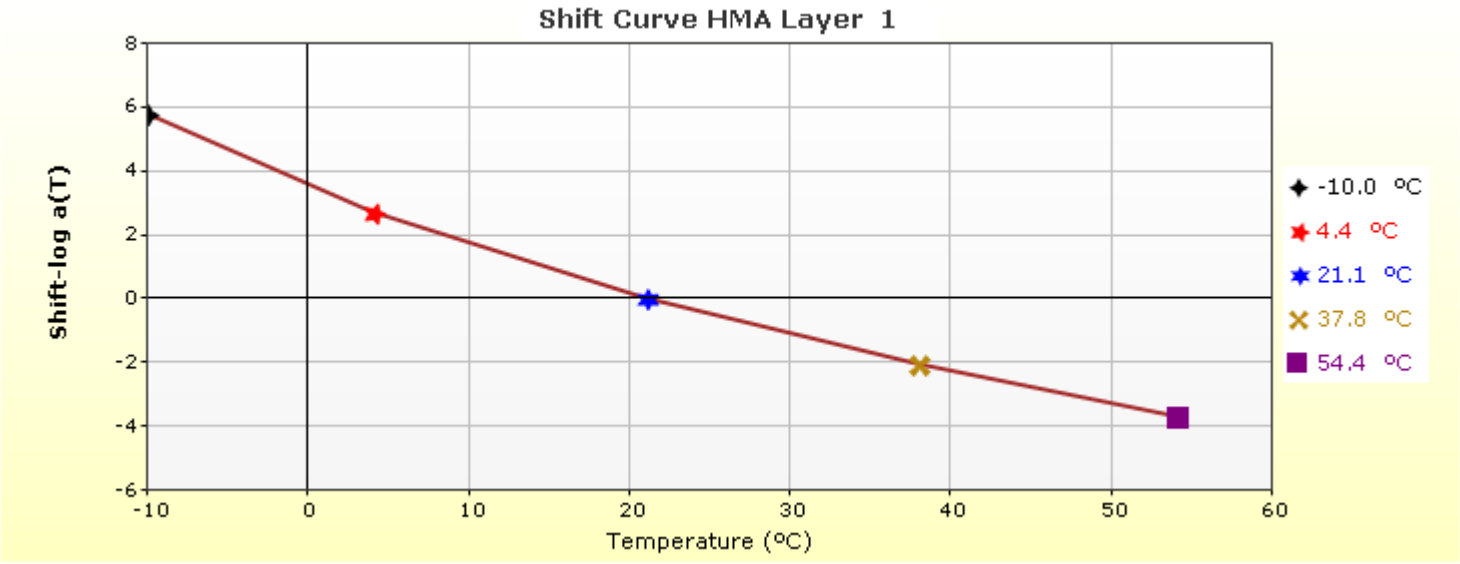
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

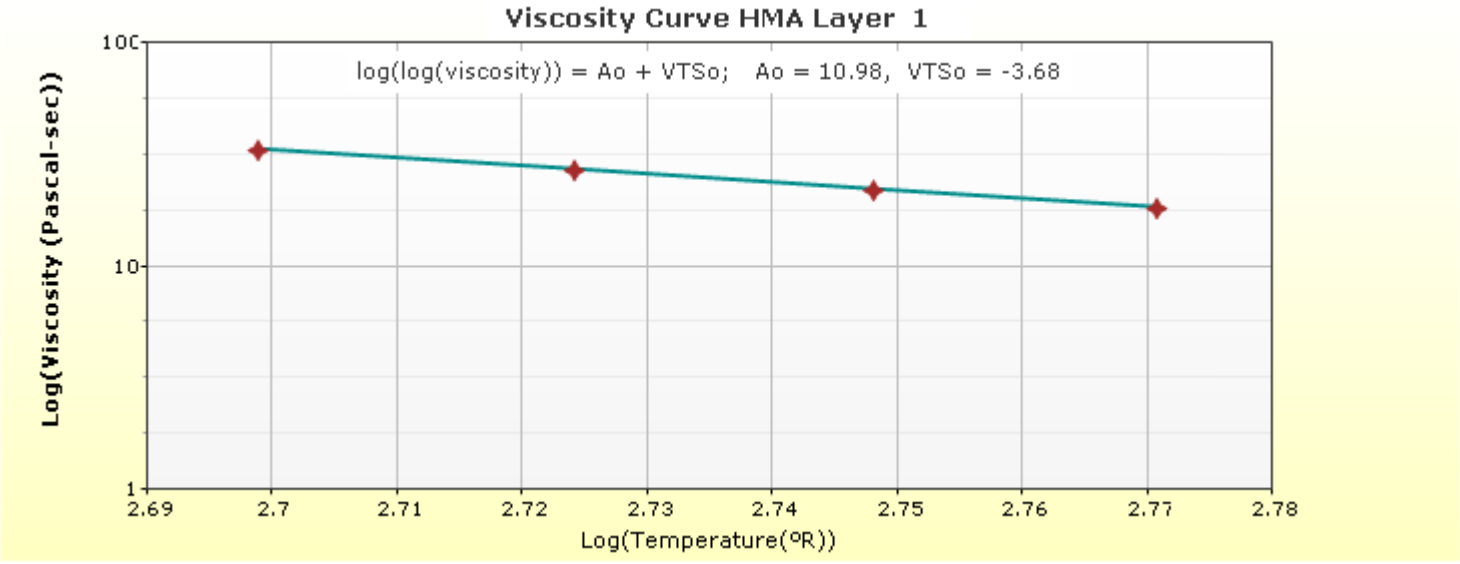
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



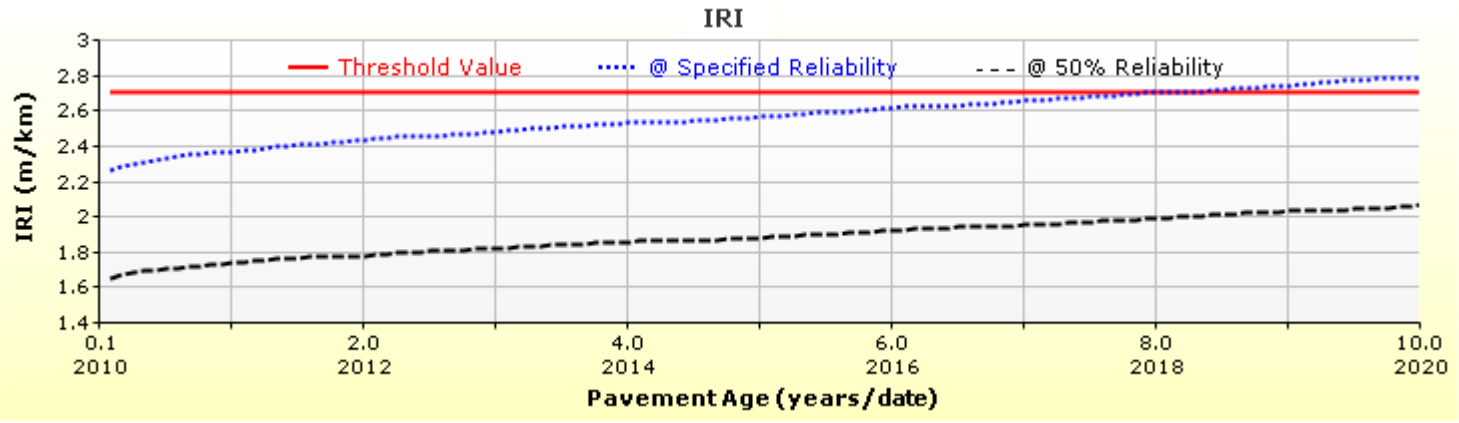
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

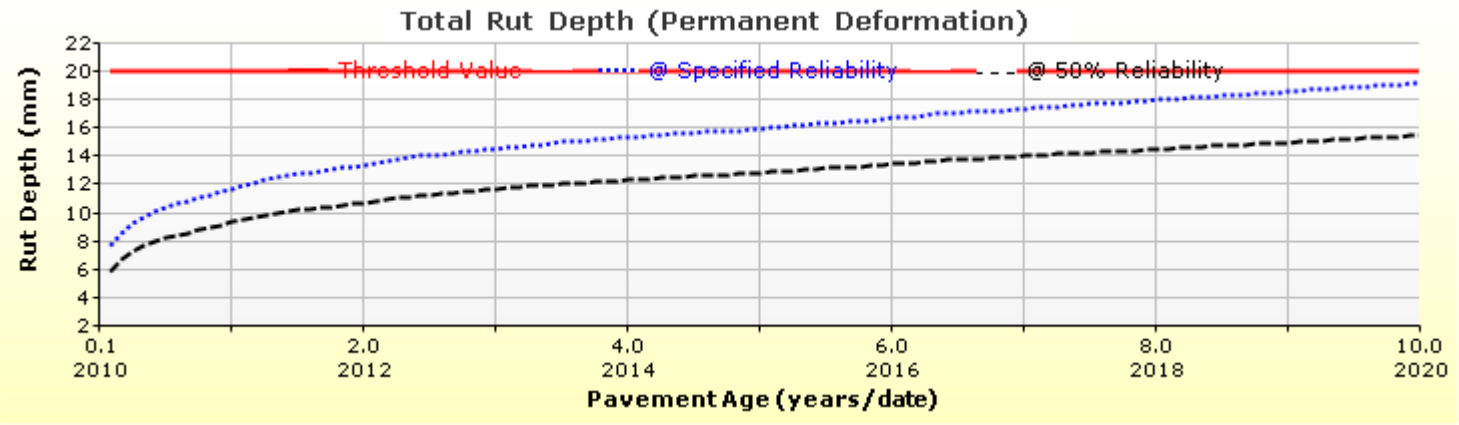


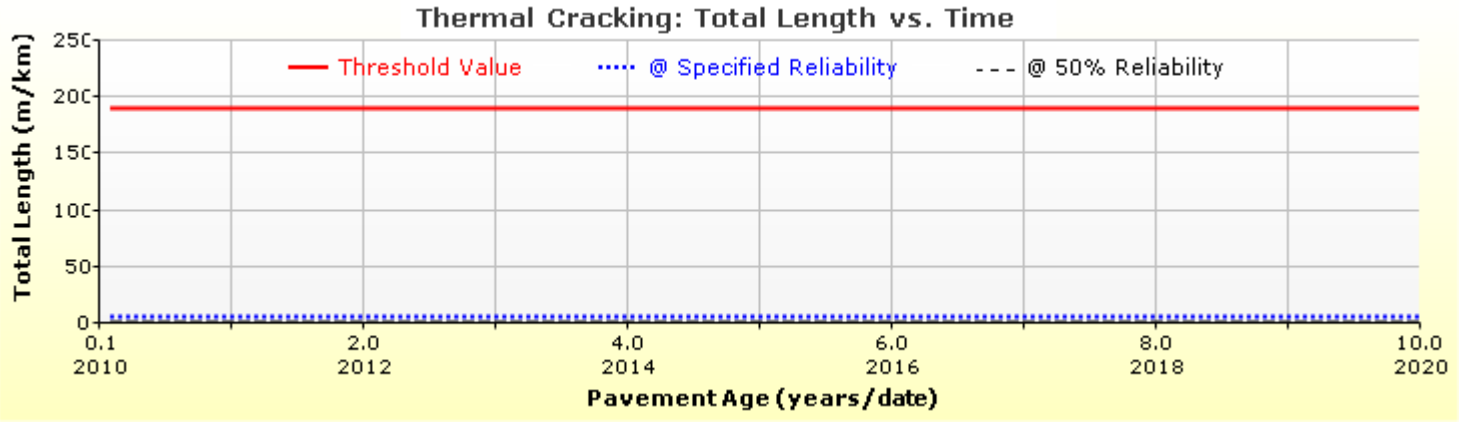


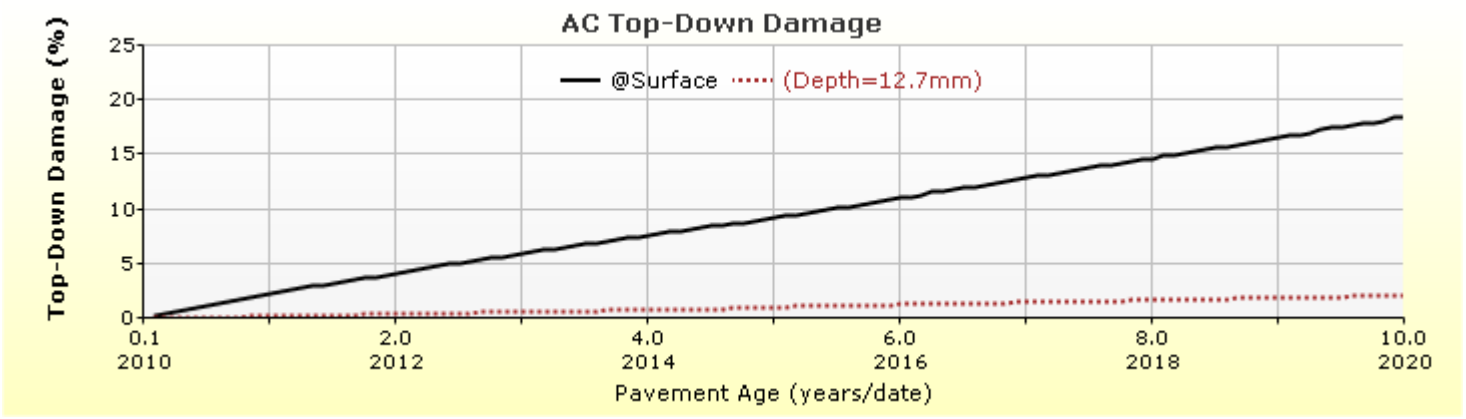


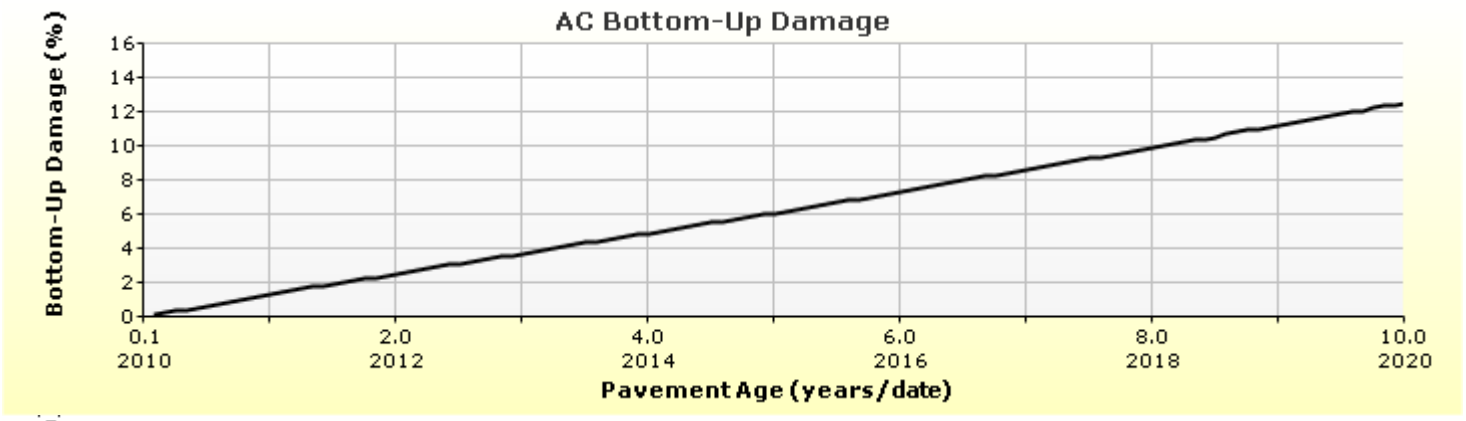
Analysis Output Charts

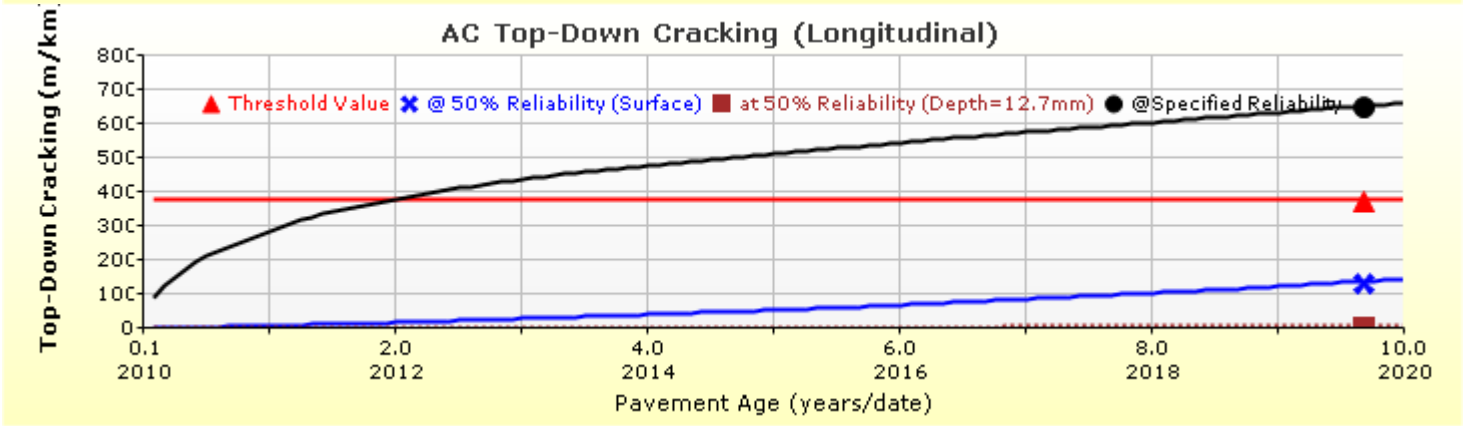


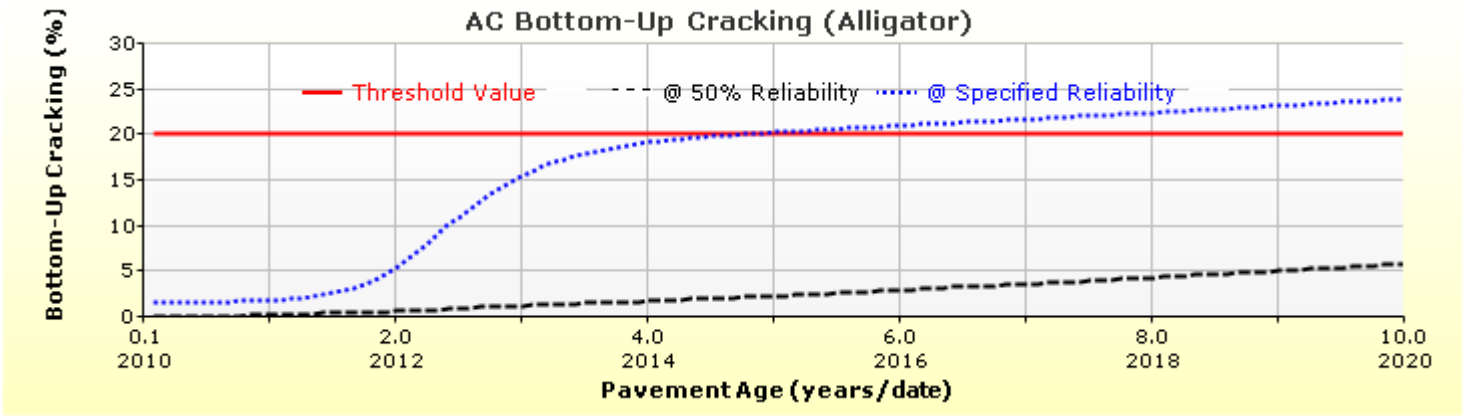


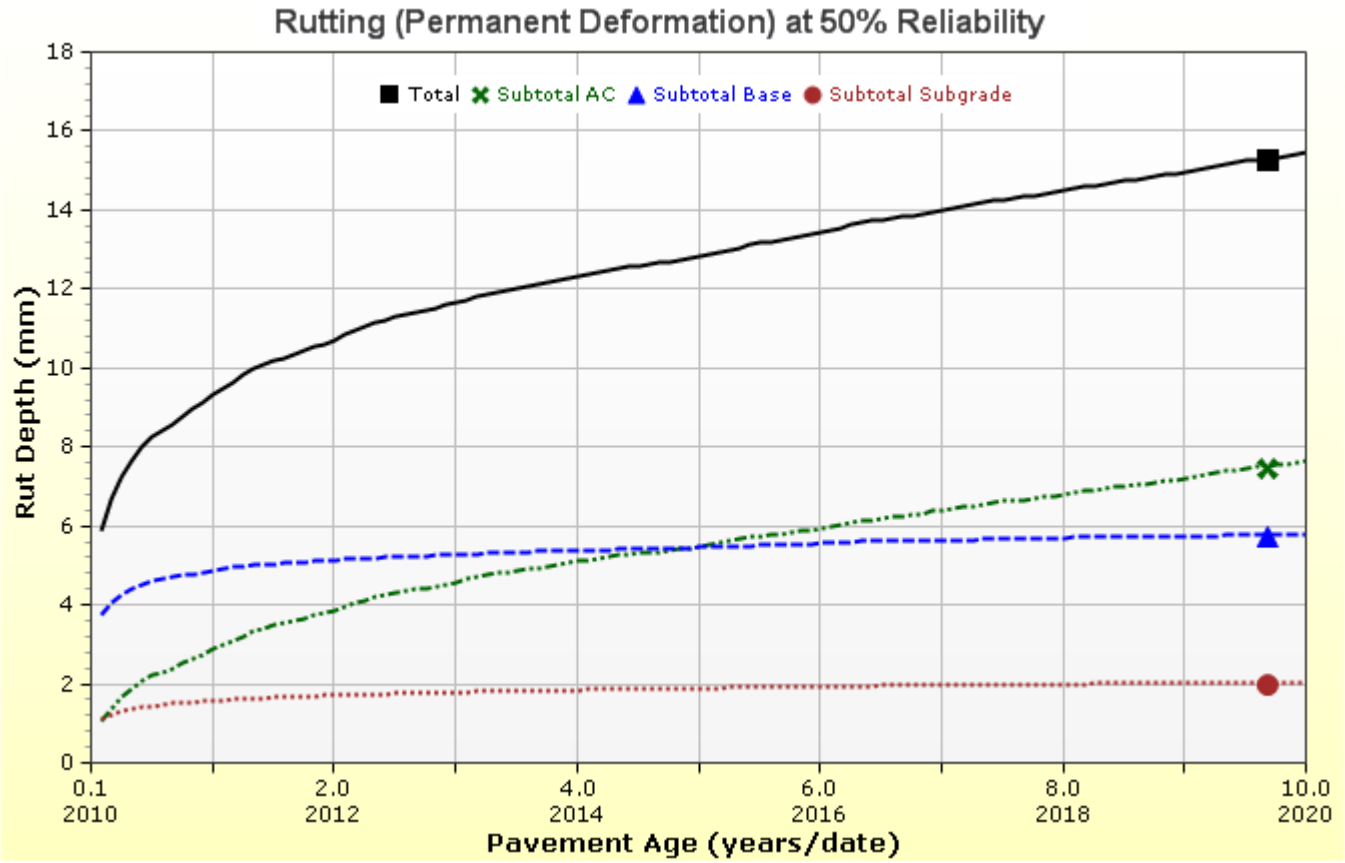


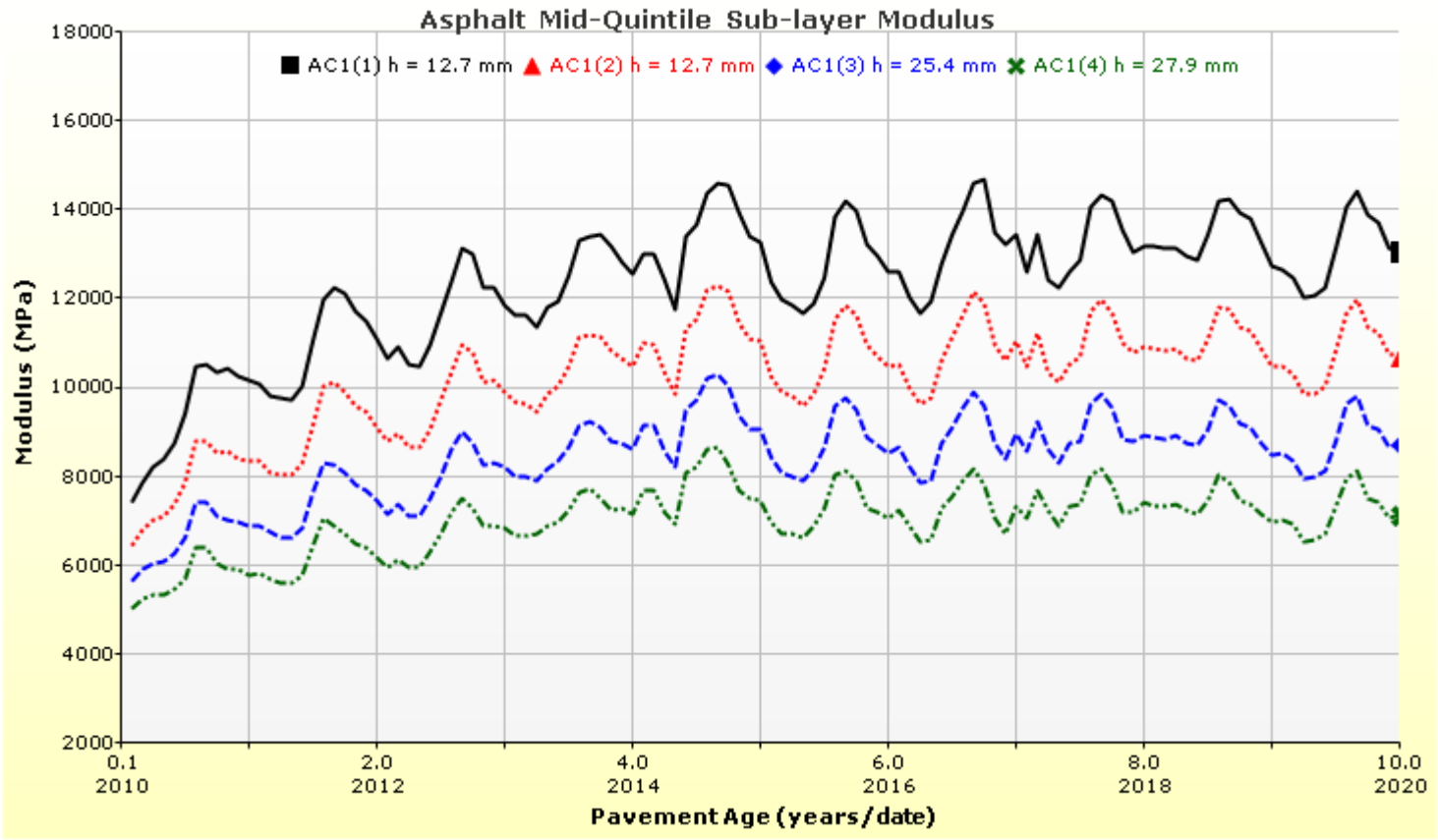

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

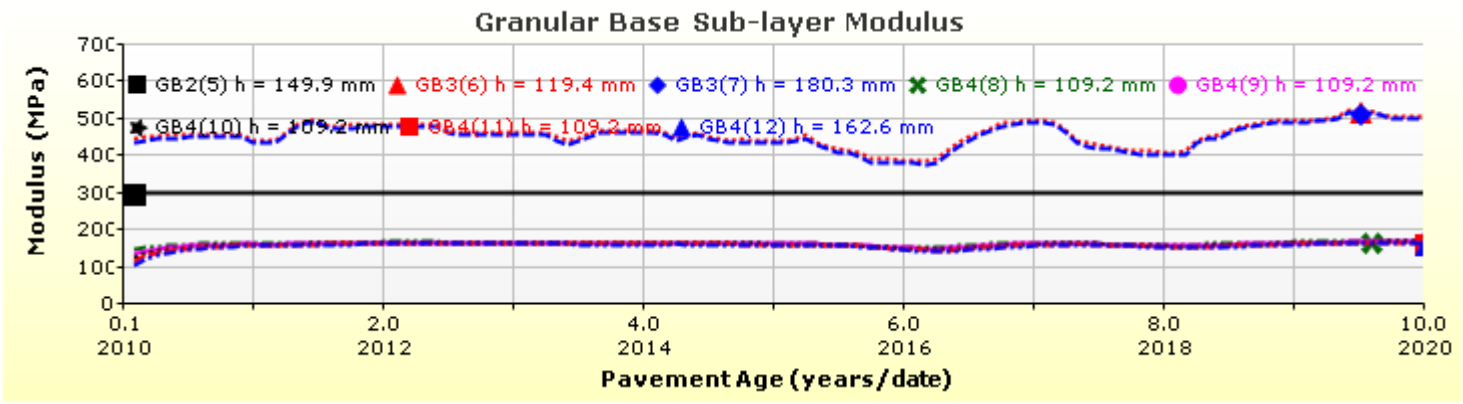

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

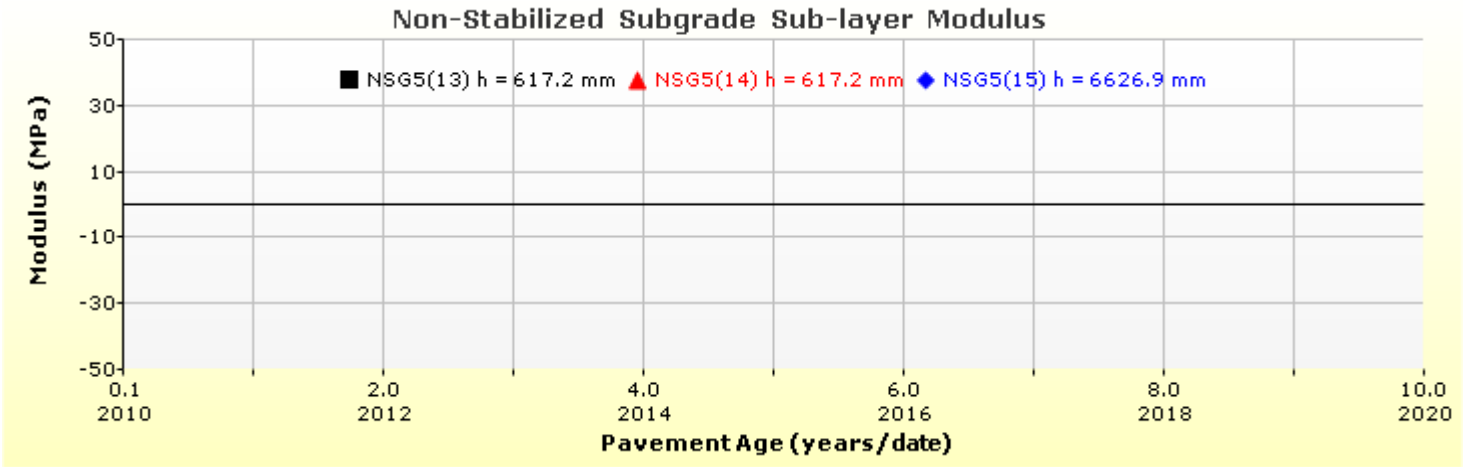

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

$$H_{ac} = total\ AC\ thickness(in)$$

$\varepsilon_p = plastic\ strain\left({}^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left({}^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestCE_coberturea

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestCE_coberturea.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -3.77, -38.55

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

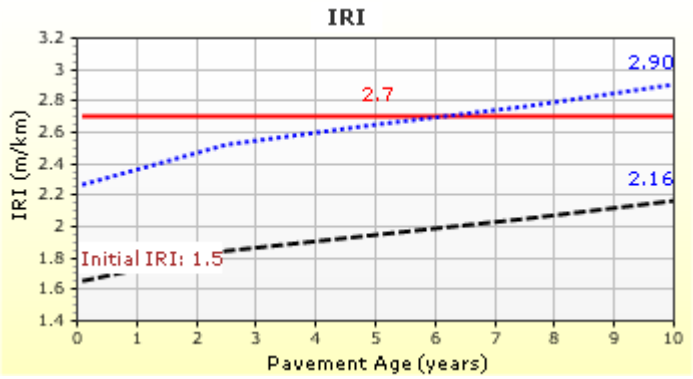
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

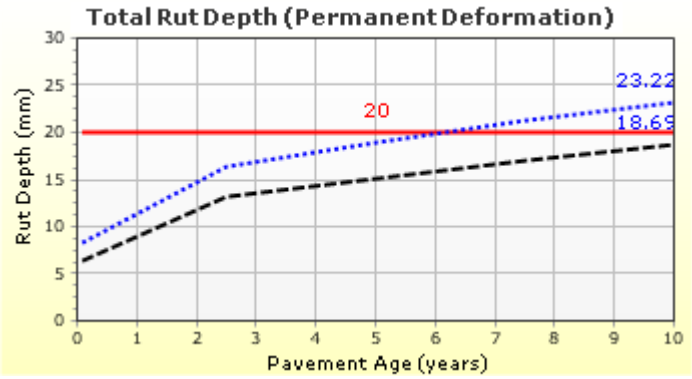
Design Outputs

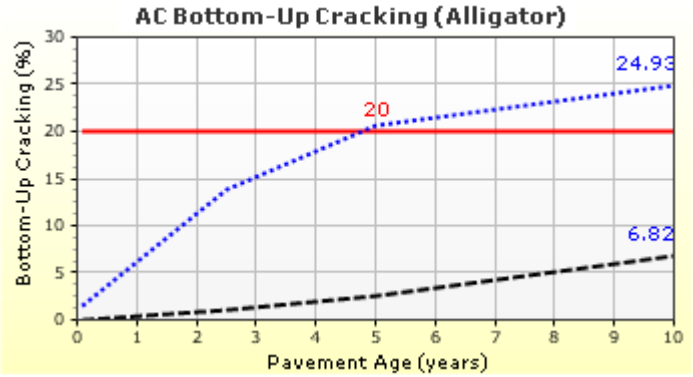
Distress Prediction Summary

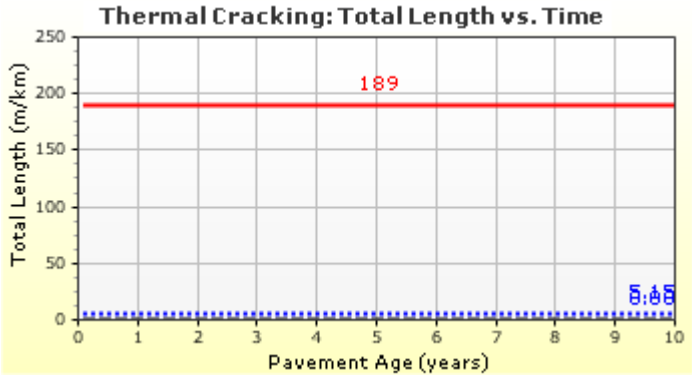
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.90	90.00	82.45	Fail
Permanent deformation - total pavement (mm)	20.00	23.21	90.00	64.40	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.93	90.00	82.45	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	746.64	90.00	65.57	Fail
Permanent deformation - AC only (mm)	5.00	10.83	50.00	3.02	Fail

Distress Charts







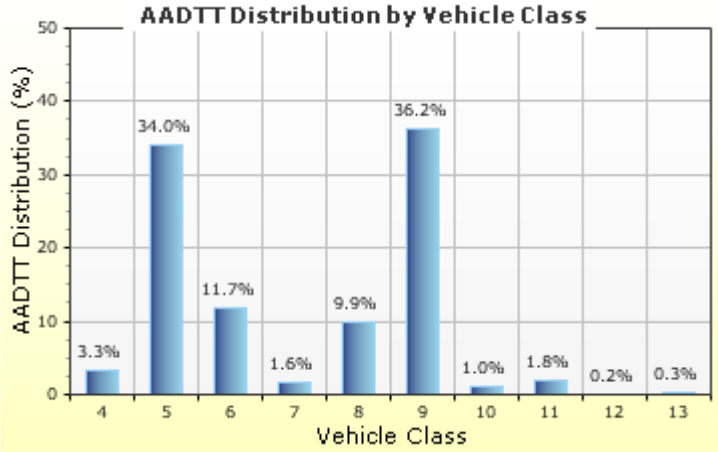


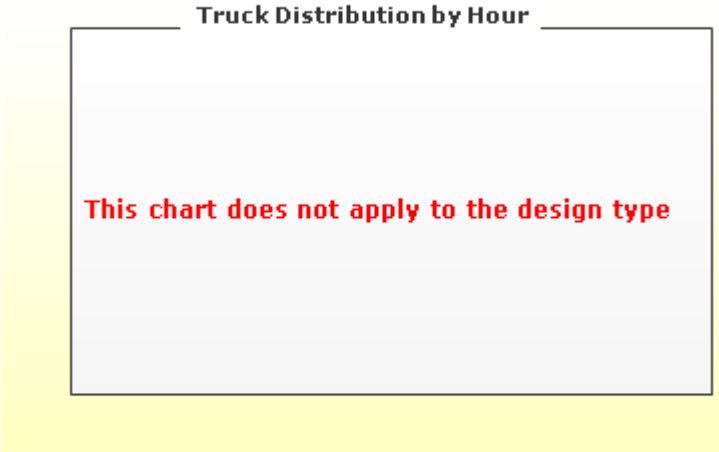


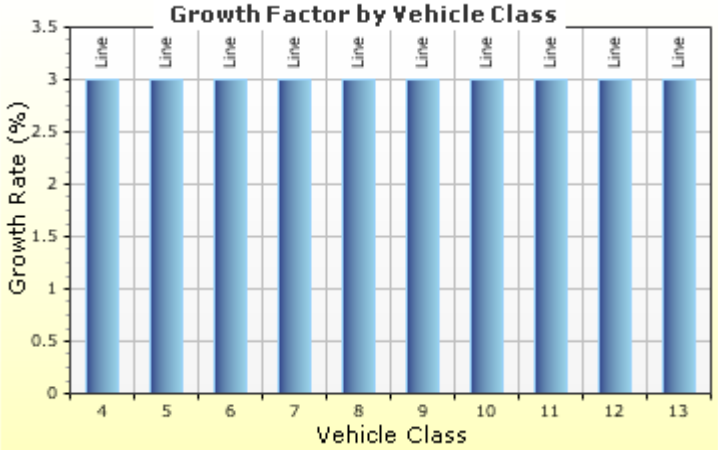
Traffic Inputs

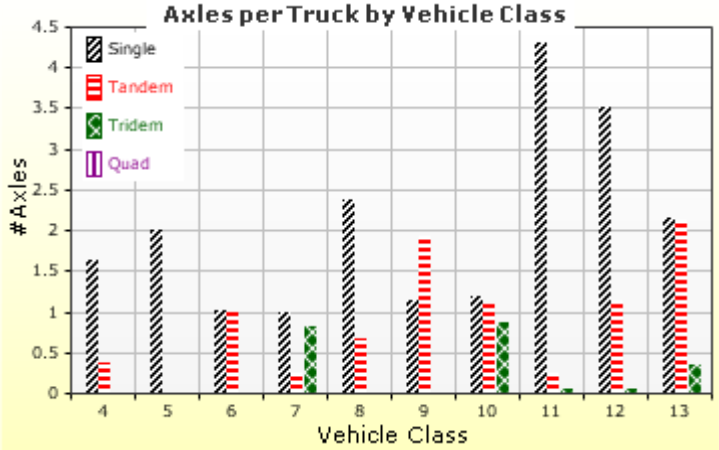
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

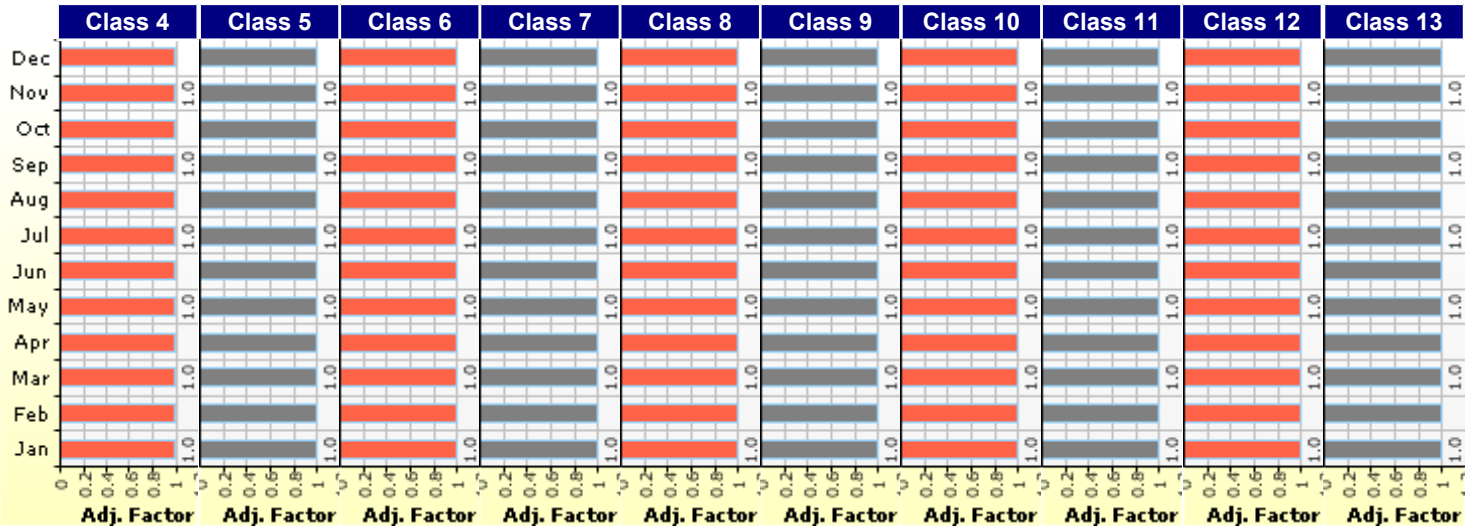








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

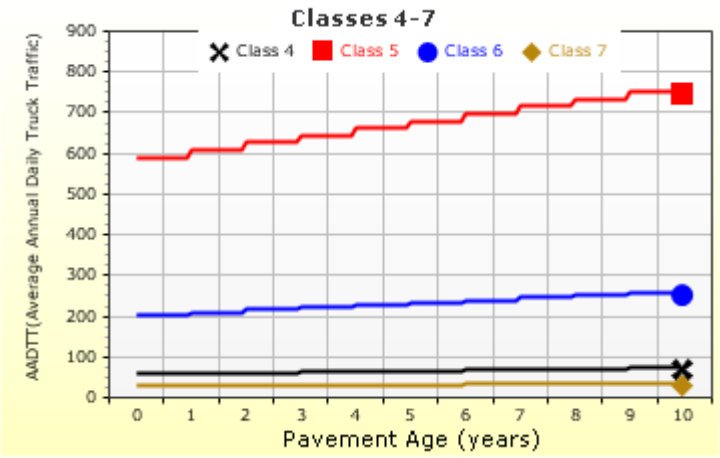
Wheelbase does not apply

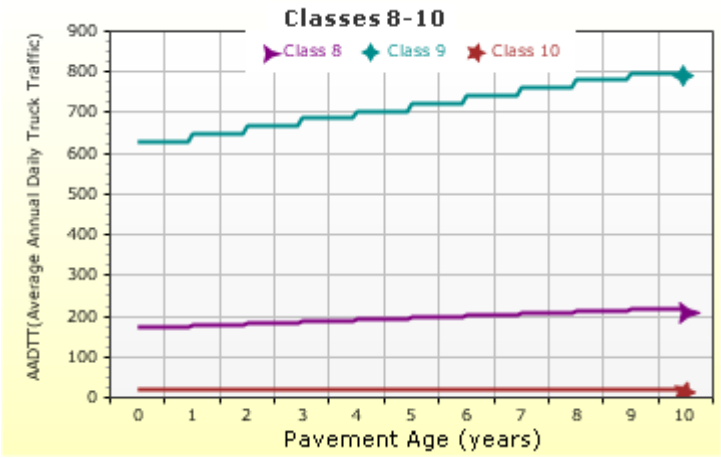
Number of Axles per Truck

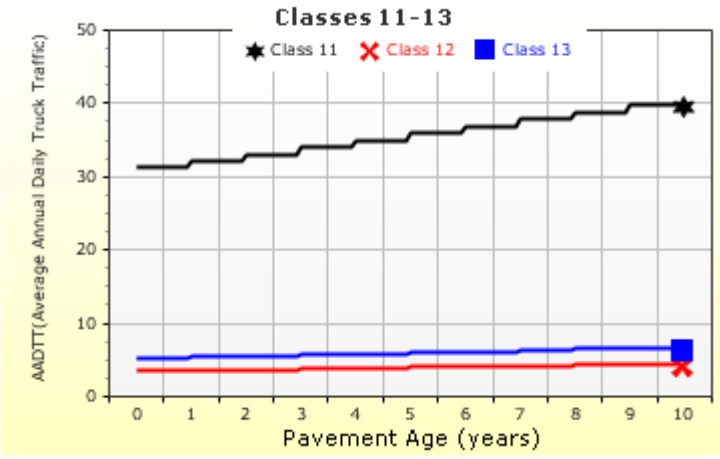
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

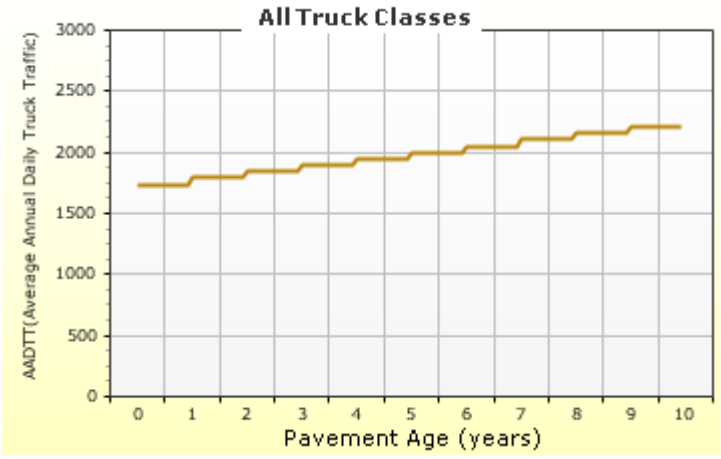
AADTT (Average Annual Daily Truck Traffic) Growth

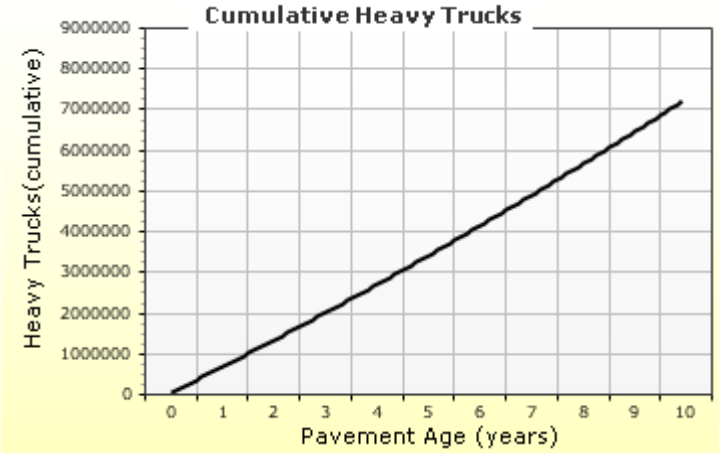
*** Traffic cap is not enforced**







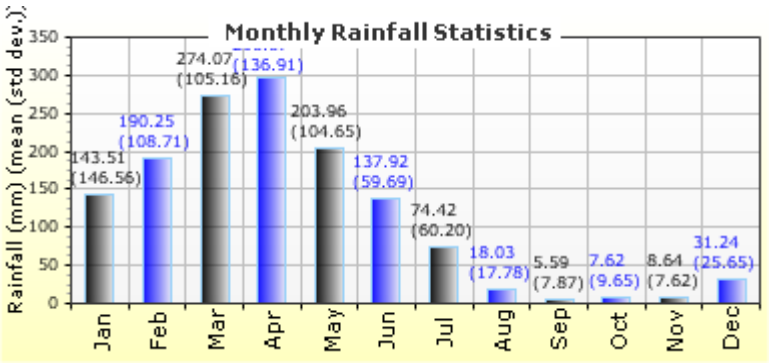




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
FORTALEZA, CE	-3.77000 -38.55000 41

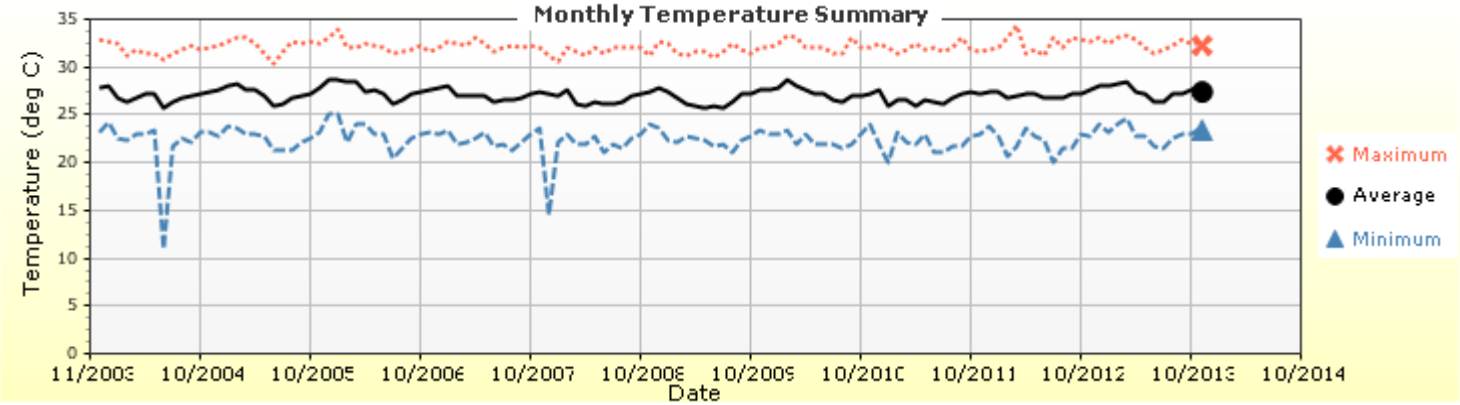


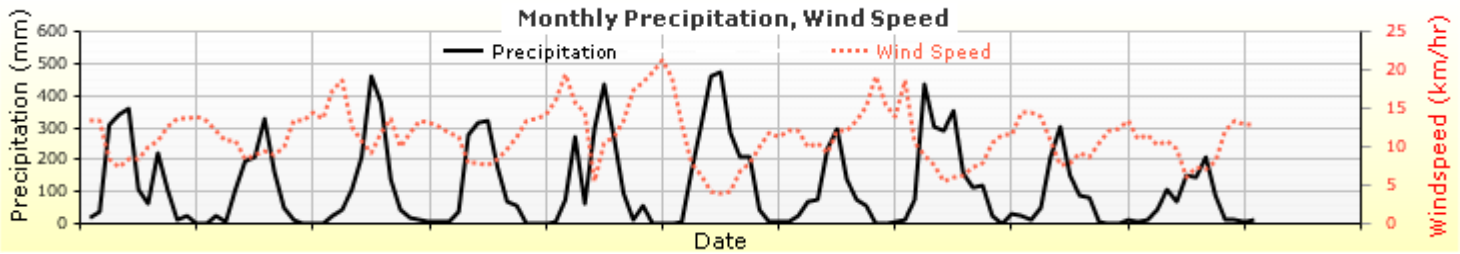
Annual Statistics:

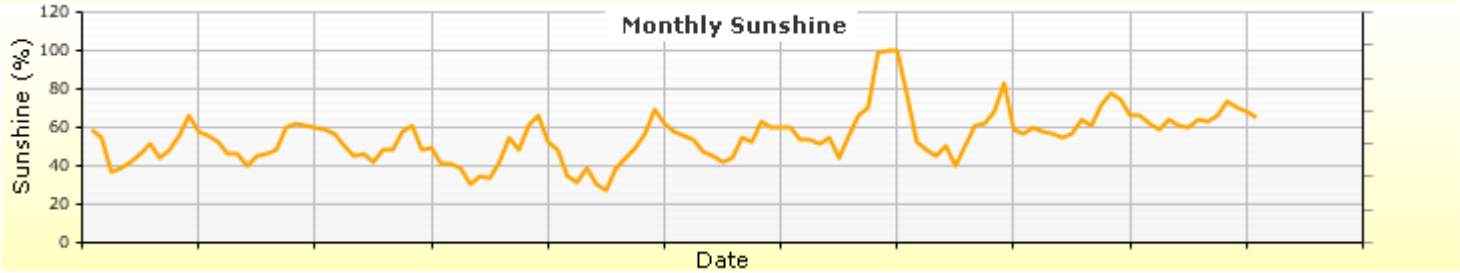
Mean annual air temperature (ºC)	27.09
Mean annual precipitation (mm)	1370.58
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

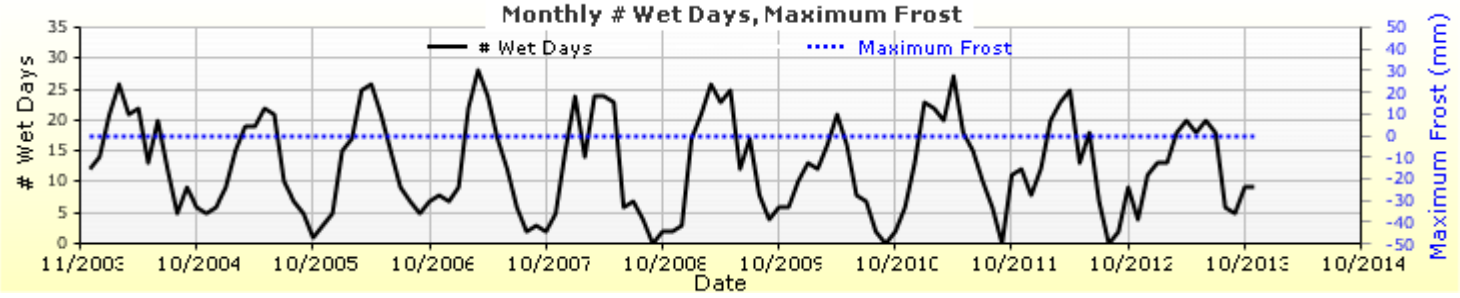
Water table depth (m): 3.05

Monthly Climate Summary:

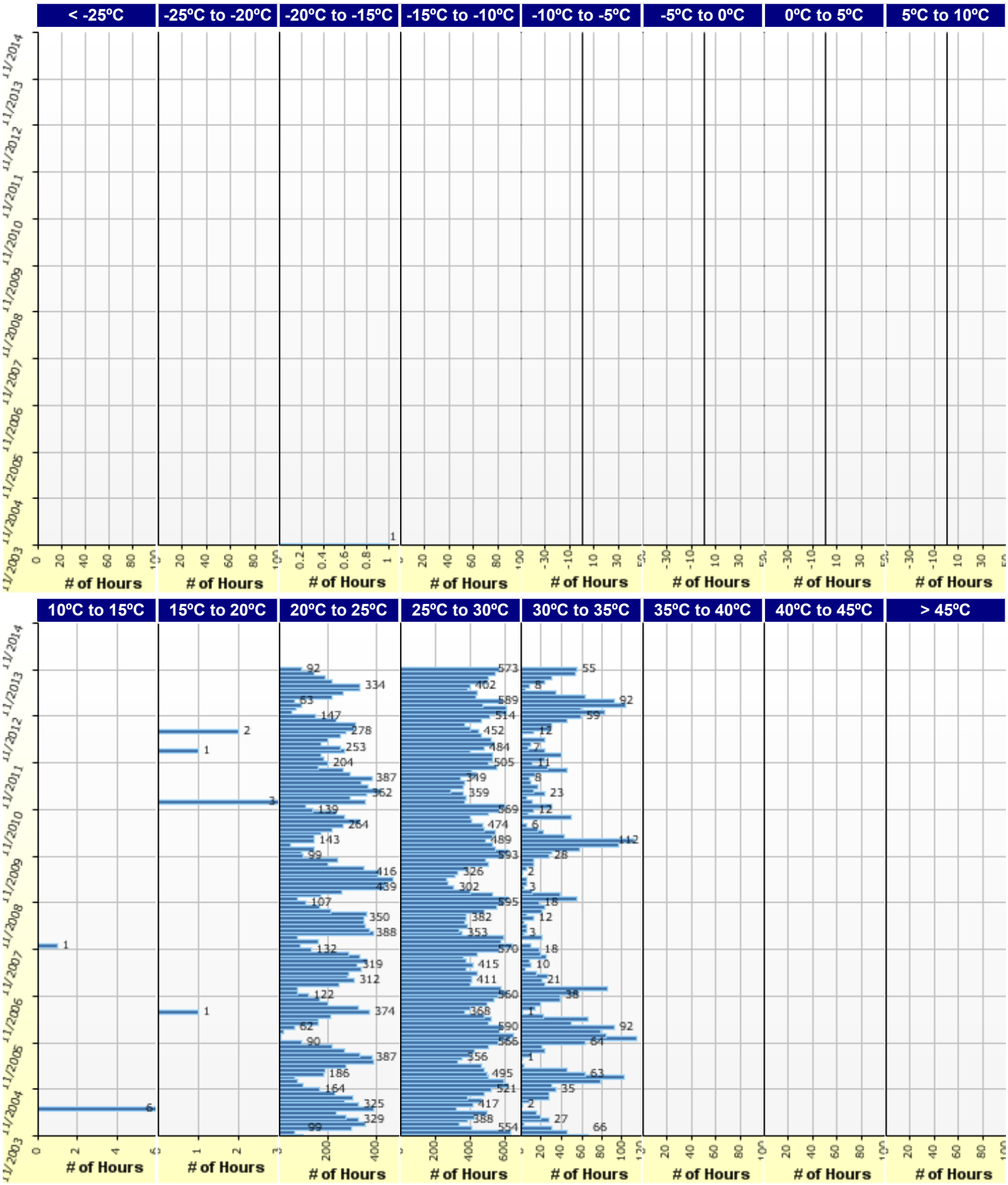








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

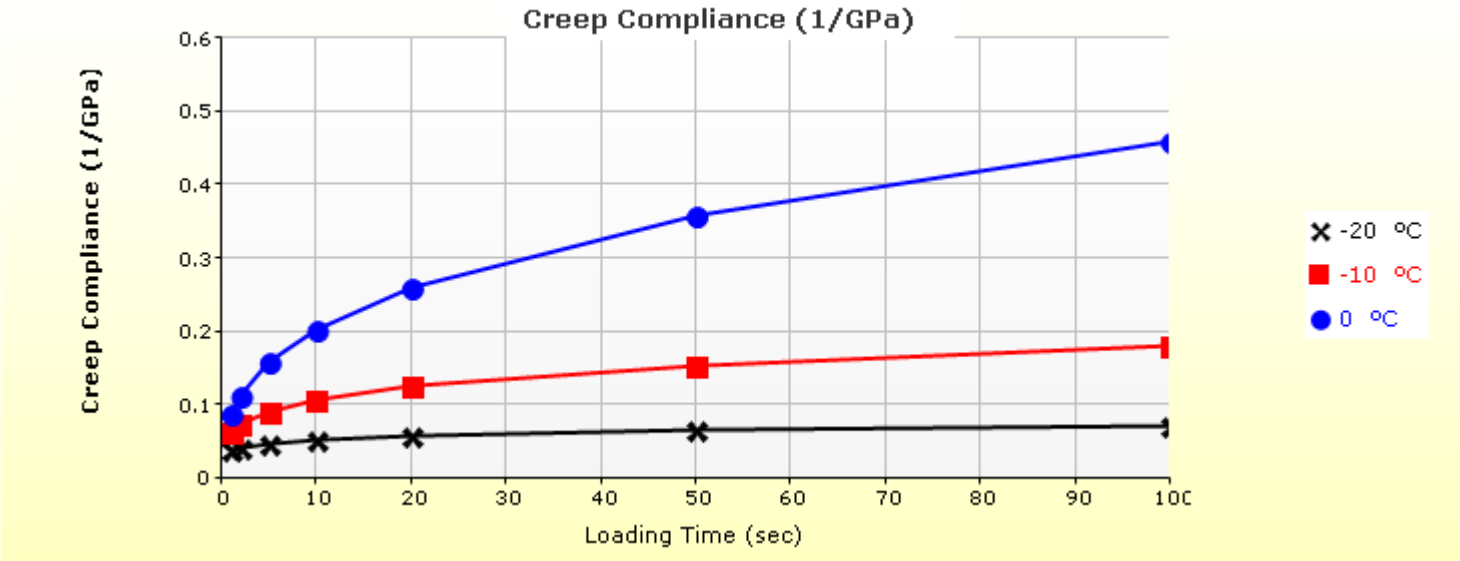
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

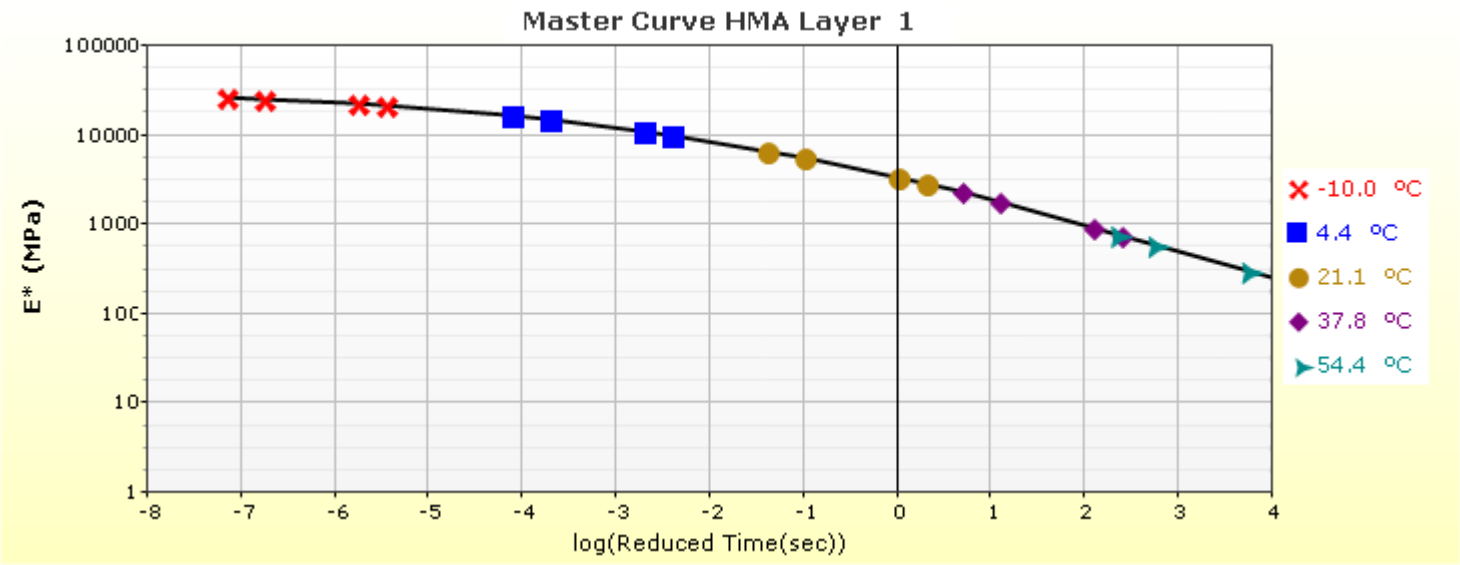
Indirect tensile strength at -10 ºC (MPa)	2.69

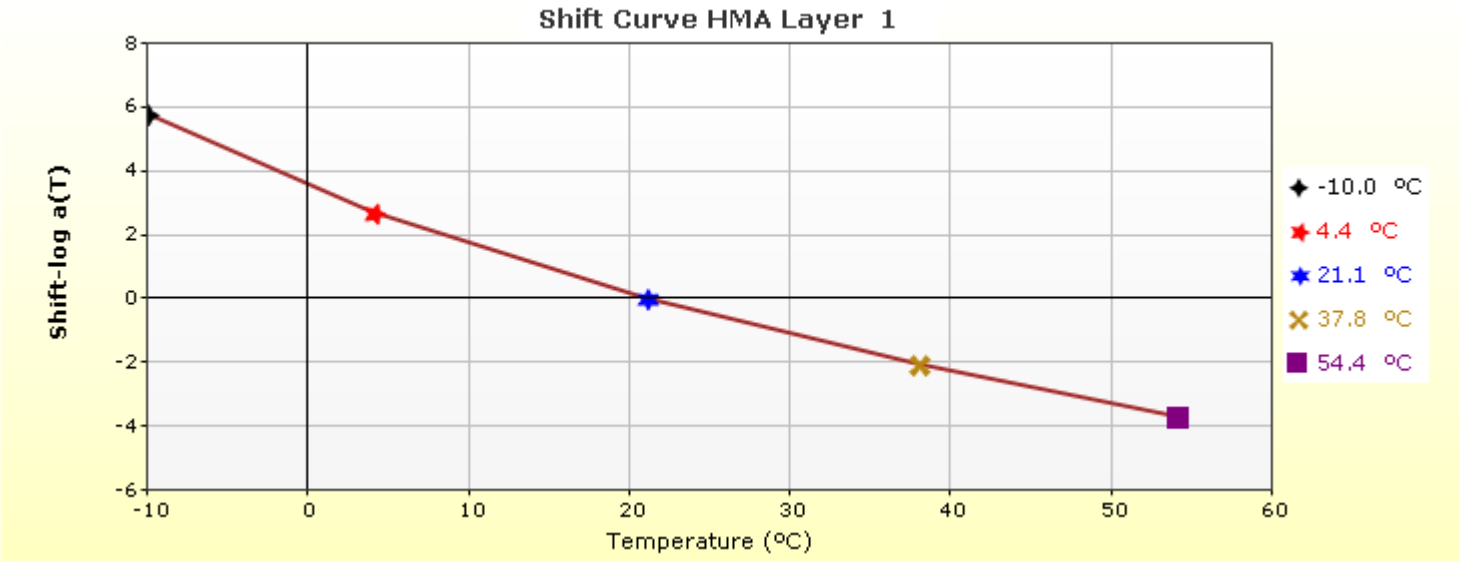
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

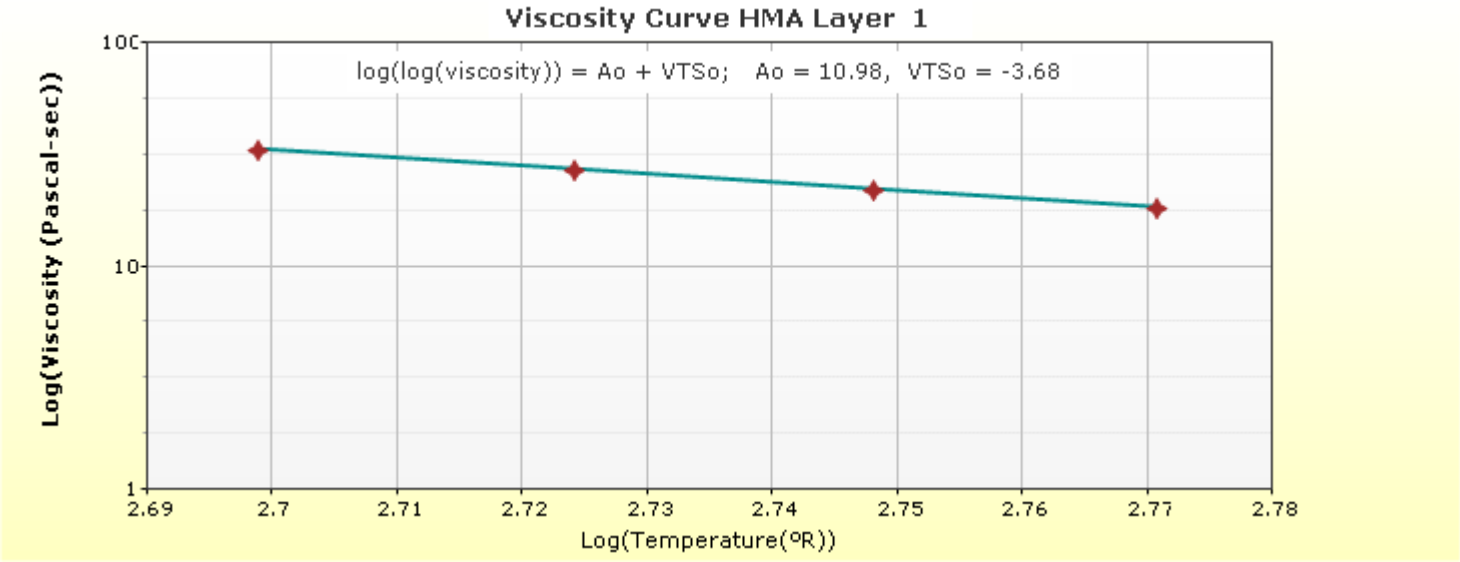
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



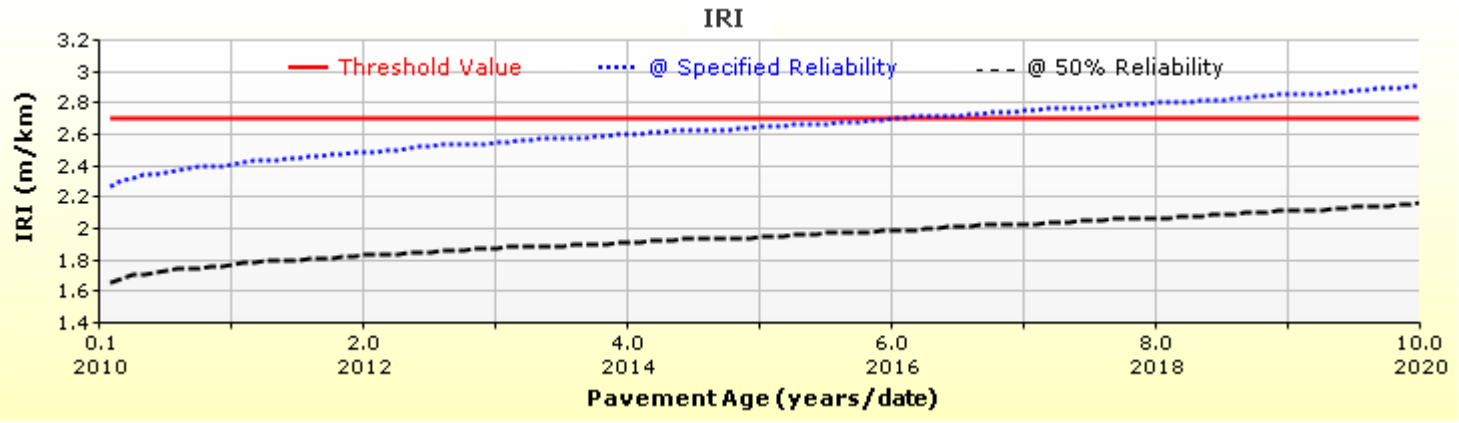
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

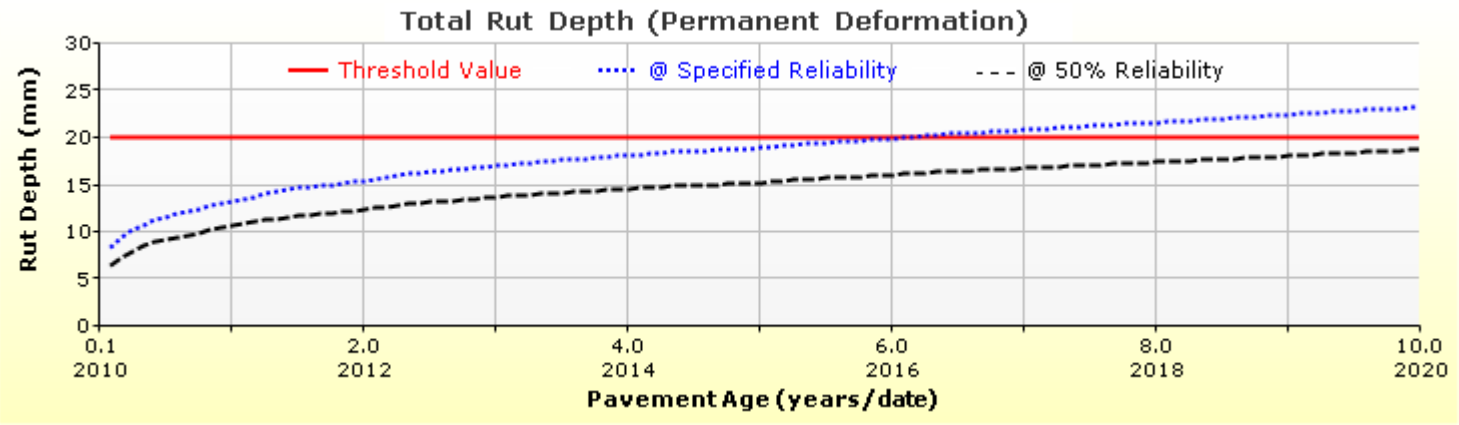


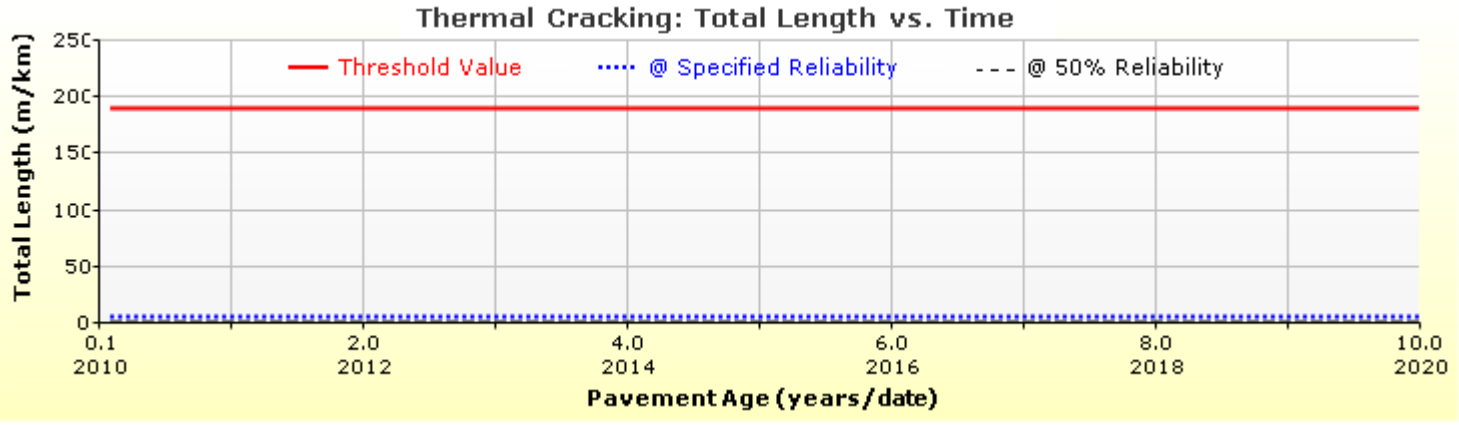


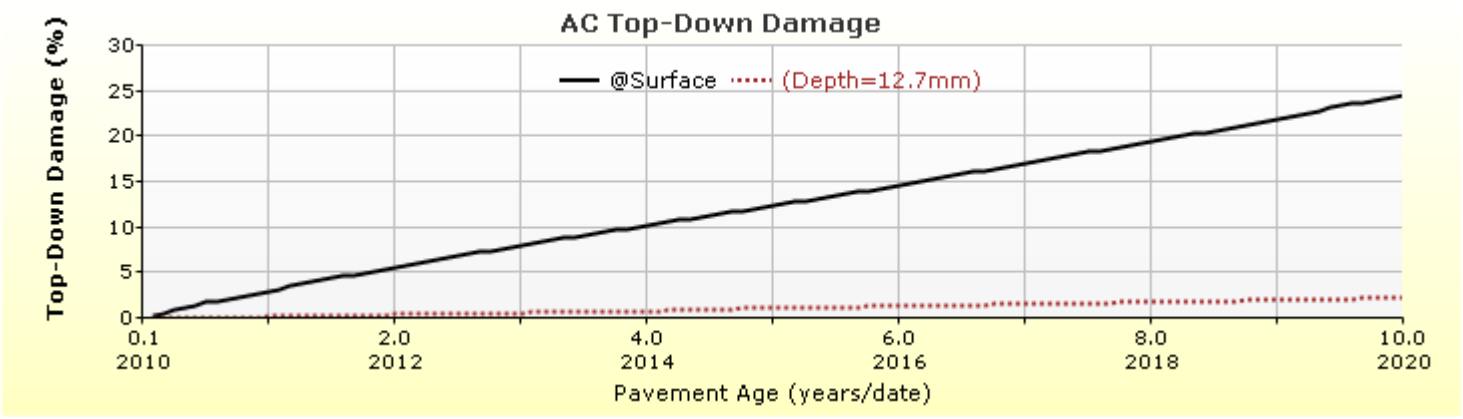


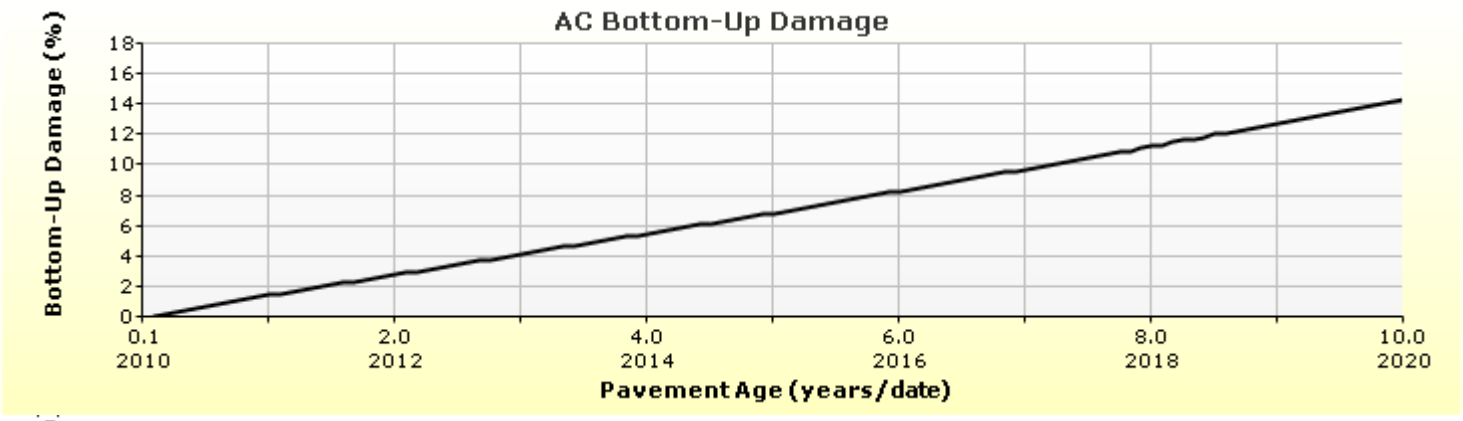
Analysis Output Charts

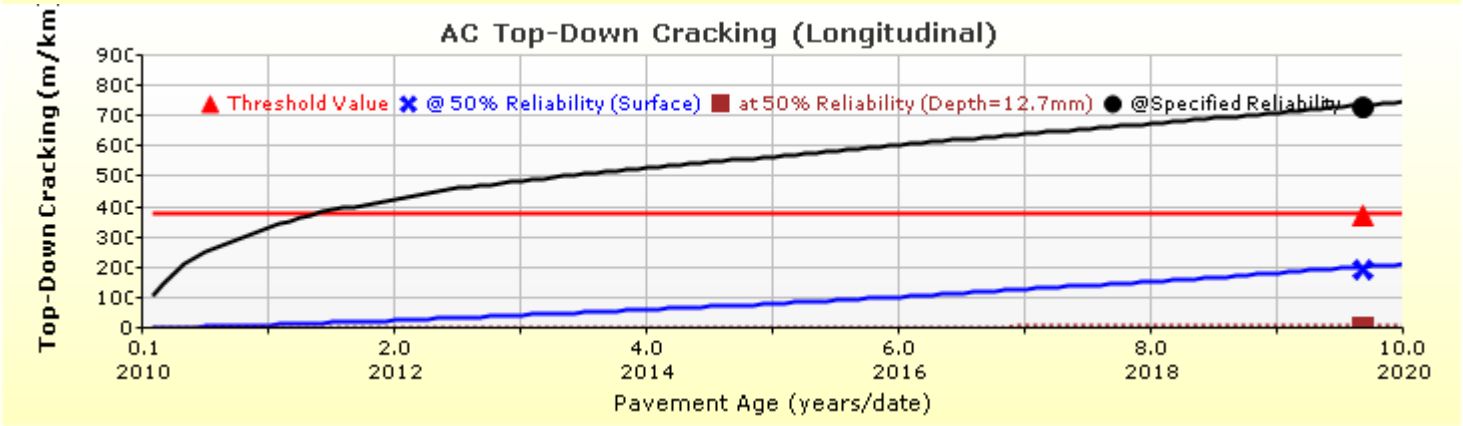


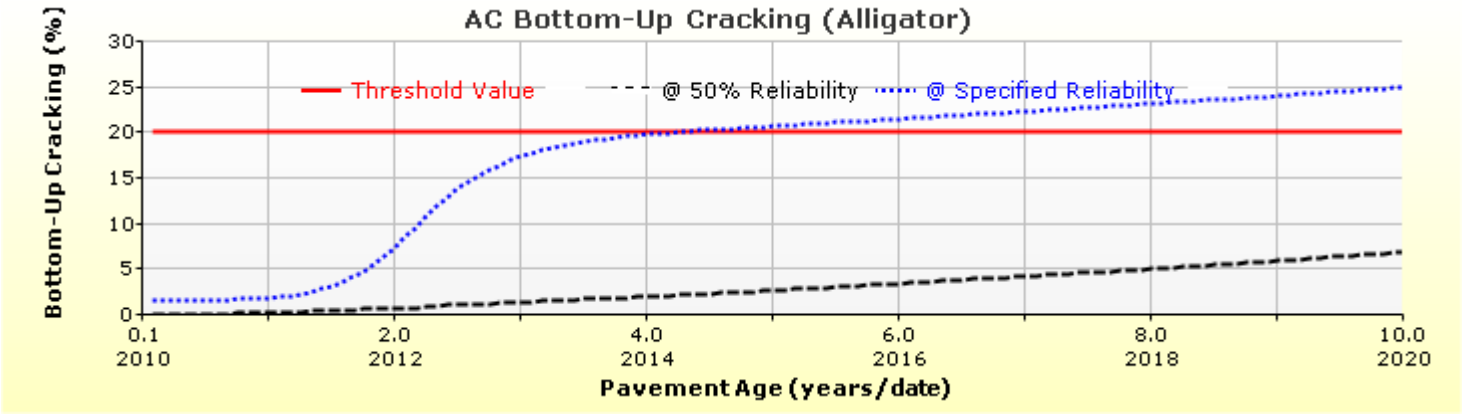


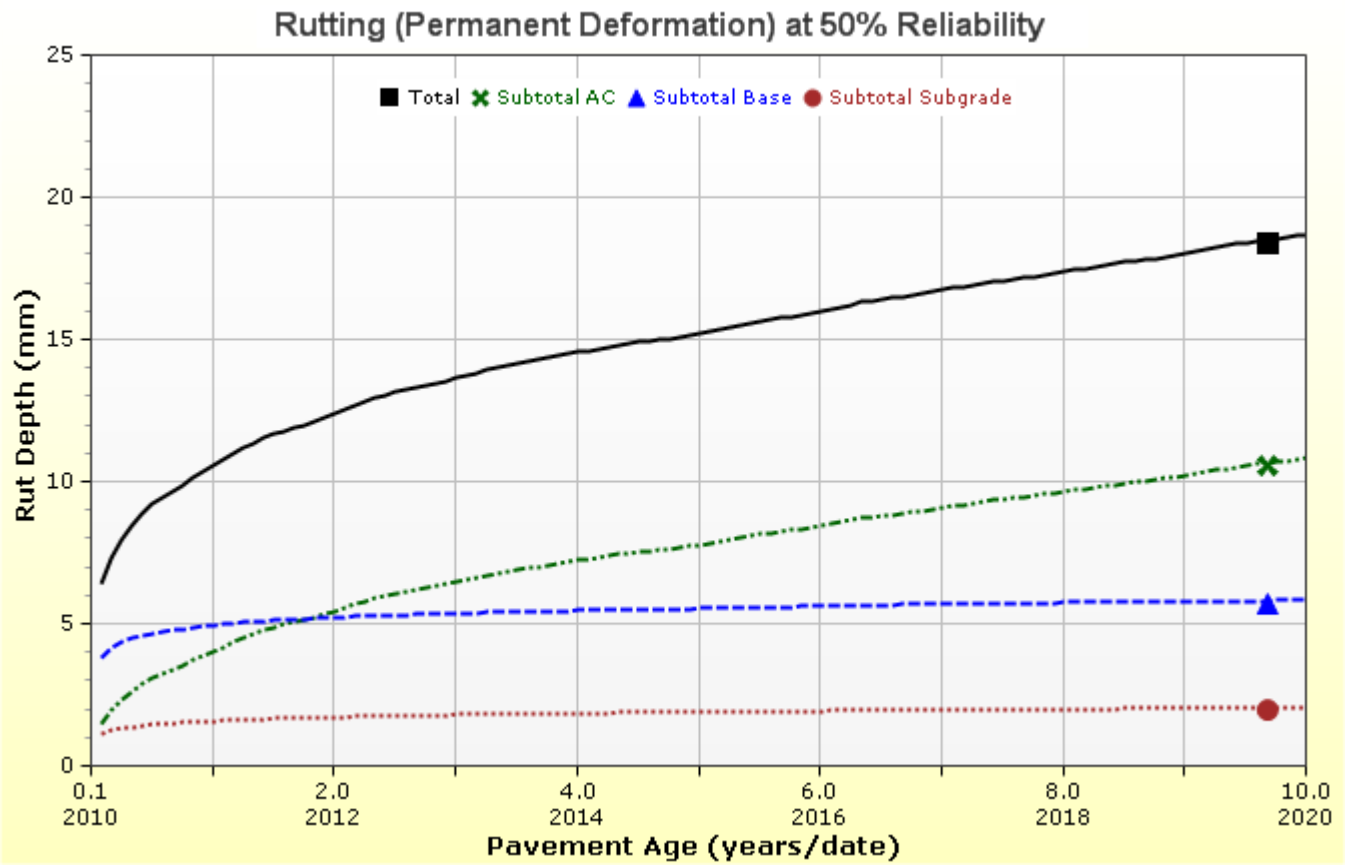


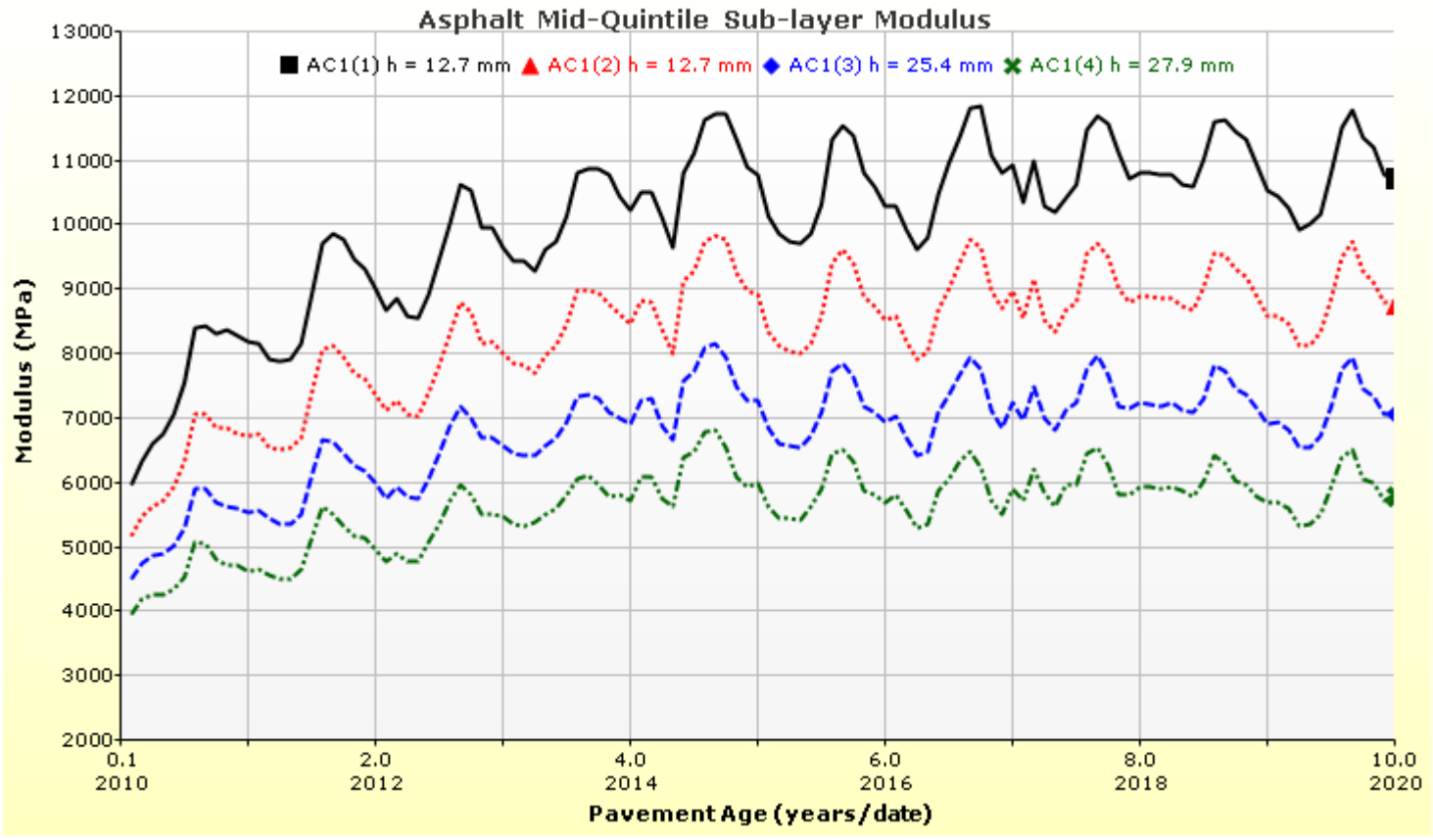

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

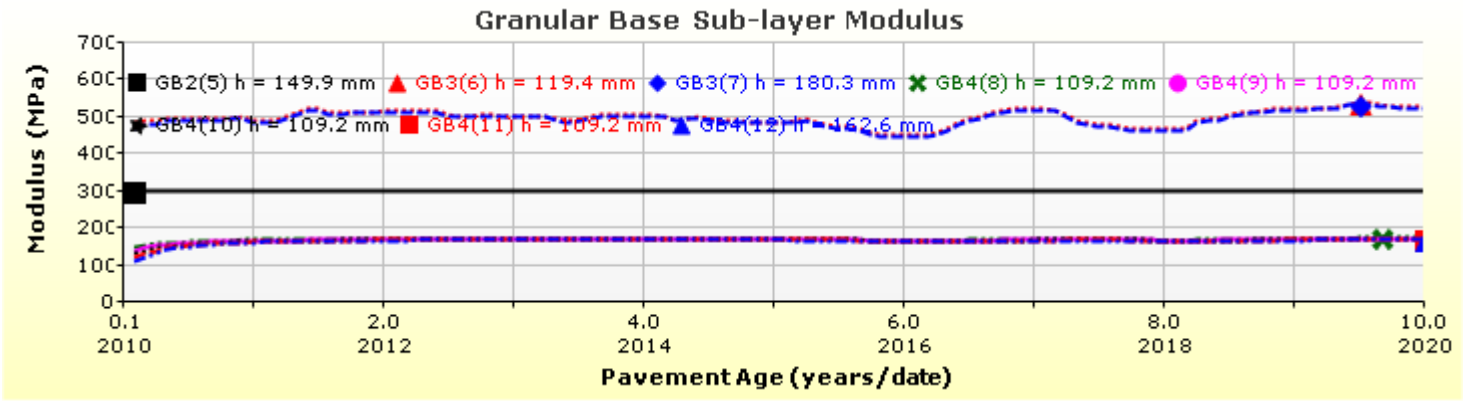

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

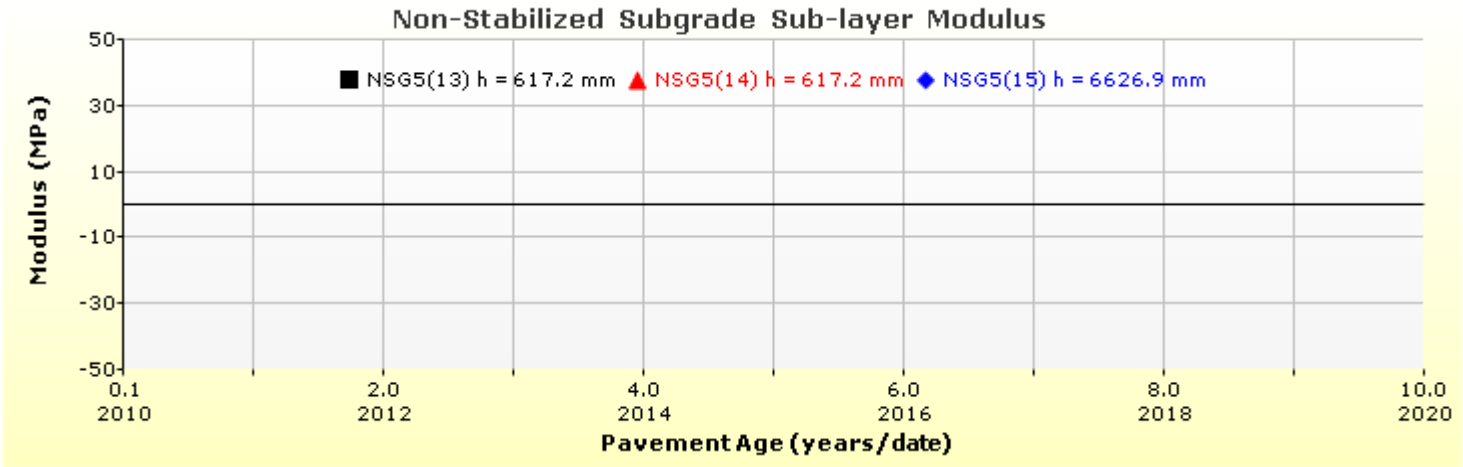

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
90
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2\beta_{r2}} N^{k_3\beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

$$H_{ac} = total\ AC\ thickness(in)$$

$\varepsilon_p = plastic\ strain\left({}^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left({}^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestCE_precip

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestCE_precip.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -3.77, -38.55

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

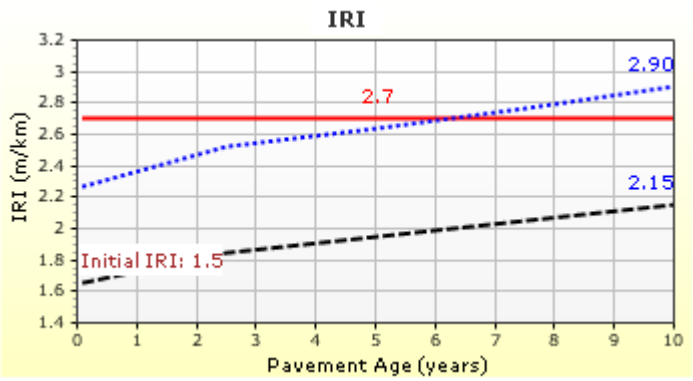
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

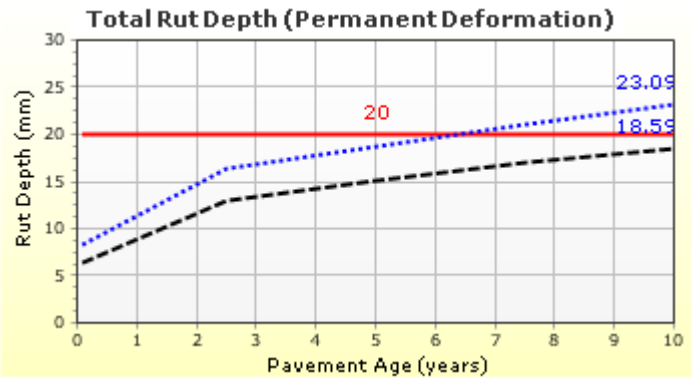
Design Outputs

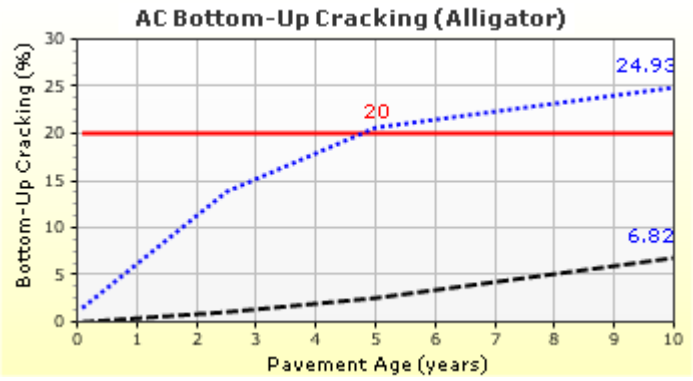
Distress Prediction Summary

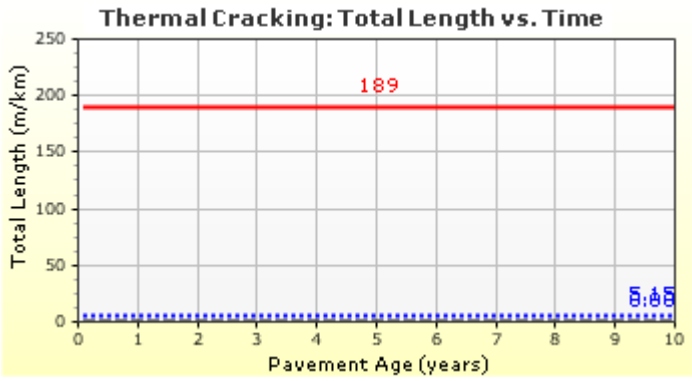
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.90	90.00	82.55	Fail
Permanent deformation - total pavement (mm)	20.00	23.08	90.00	65.55	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.93	90.00	82.45	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	744.27	90.00	65.75	Fail
Permanent deformation - AC only (mm)	5.00	10.72	50.00	3.16	Fail

Distress Charts







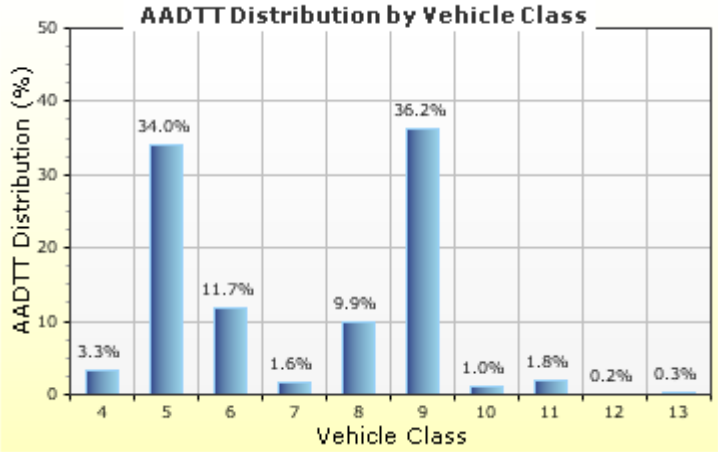


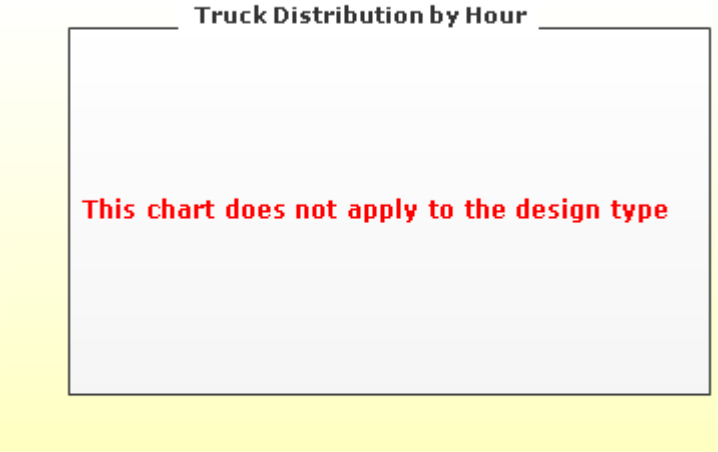


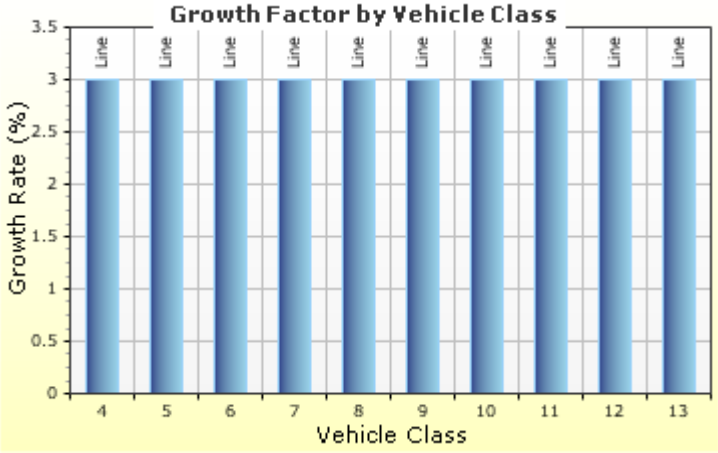
Traffic Inputs

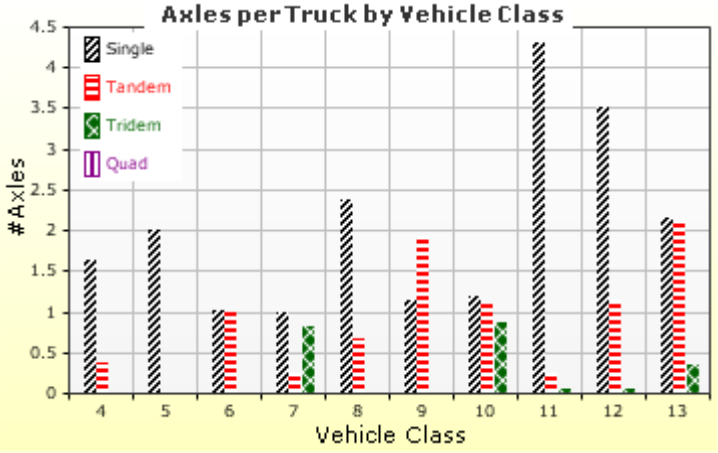
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

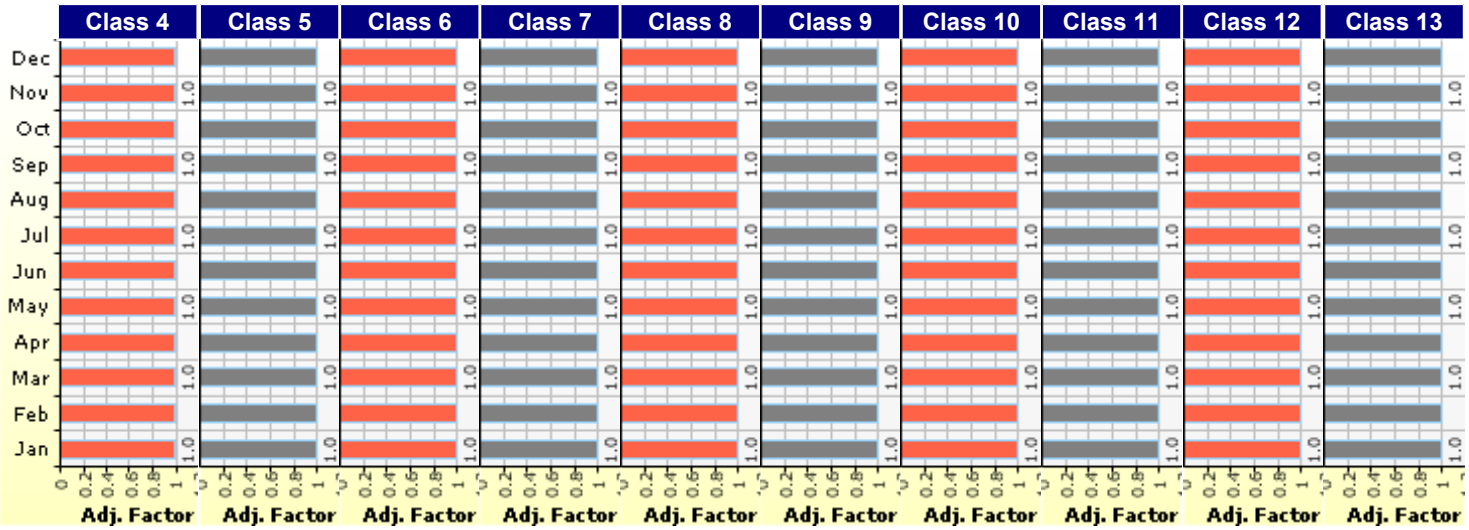








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

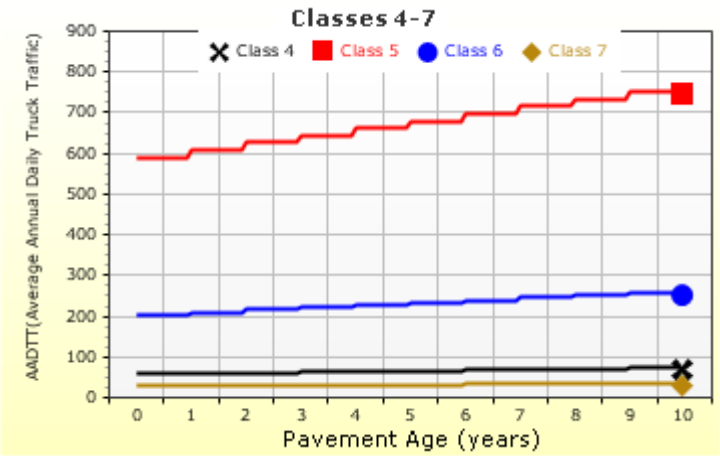
Wheelbase does not apply

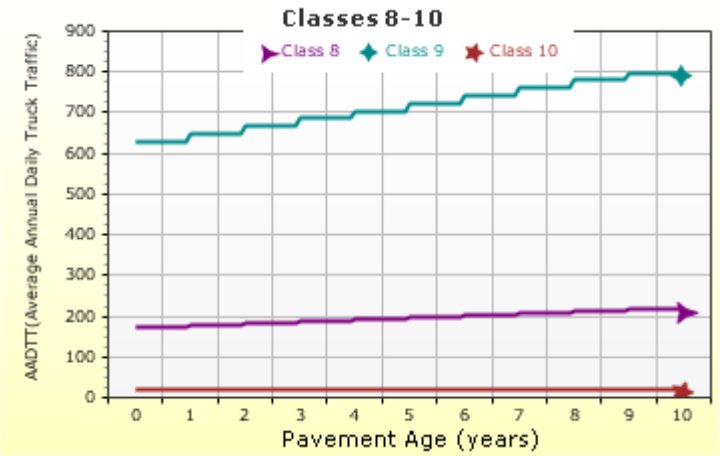
Number of Axles per Truck

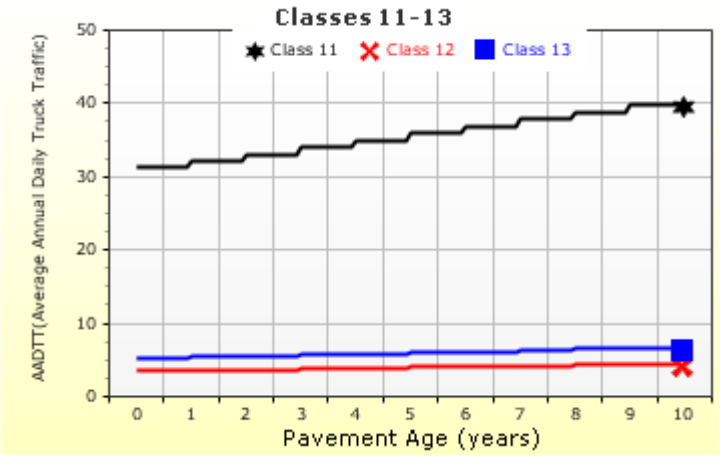
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

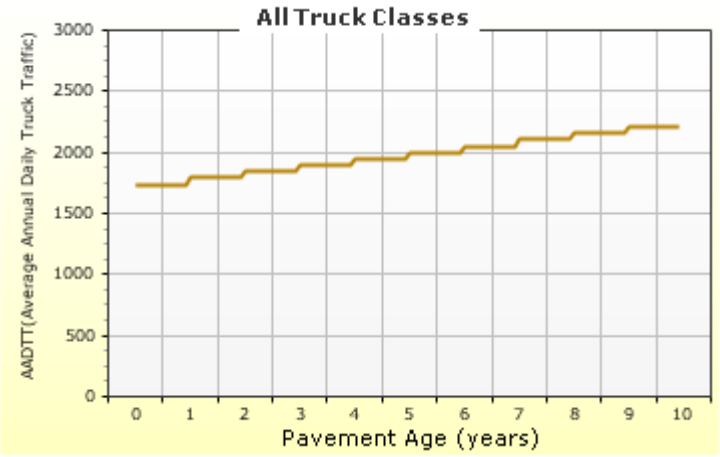
AADTT (Average Annual Daily Truck Traffic) Growth

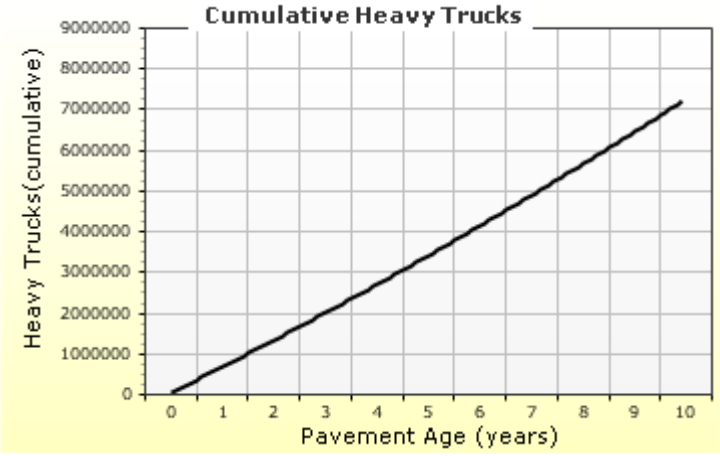
*** Traffic cap is not enforced**







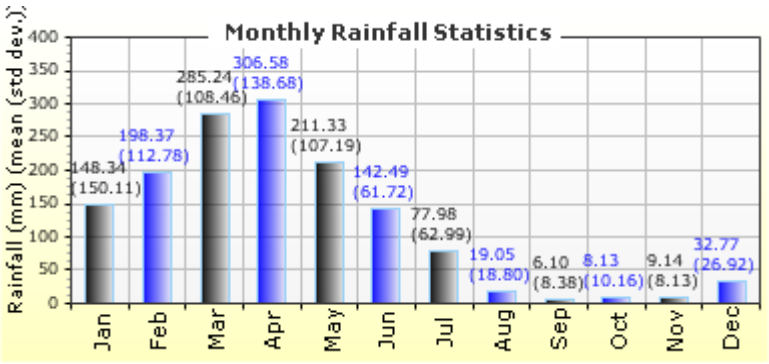




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
FORTALEZA, CE	-3.77000 -38.55000 41

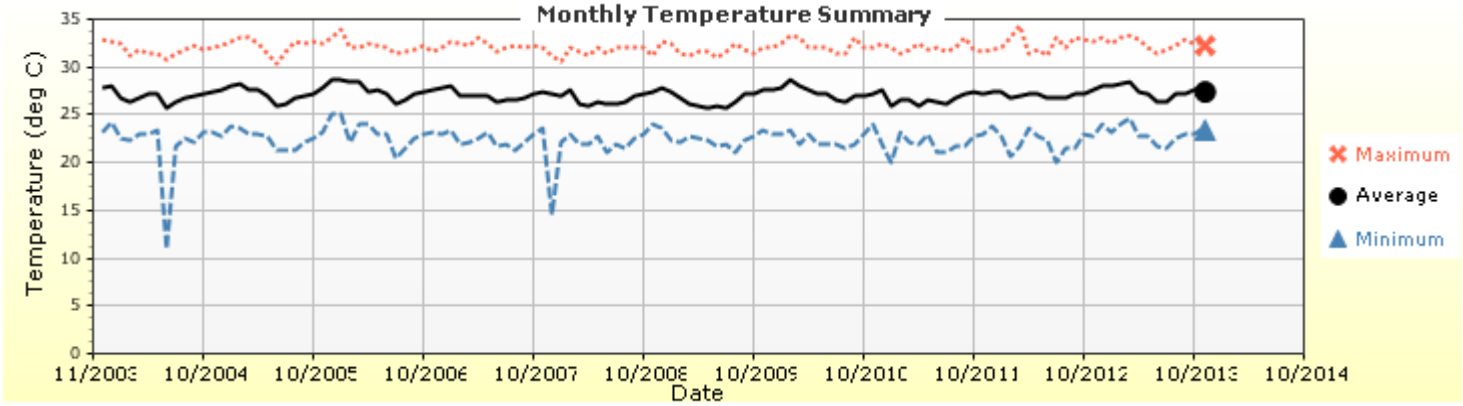


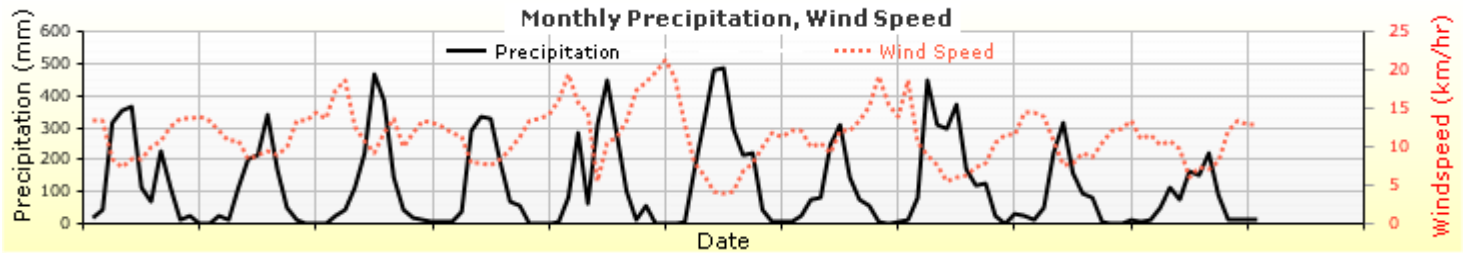
Annual Statistics:

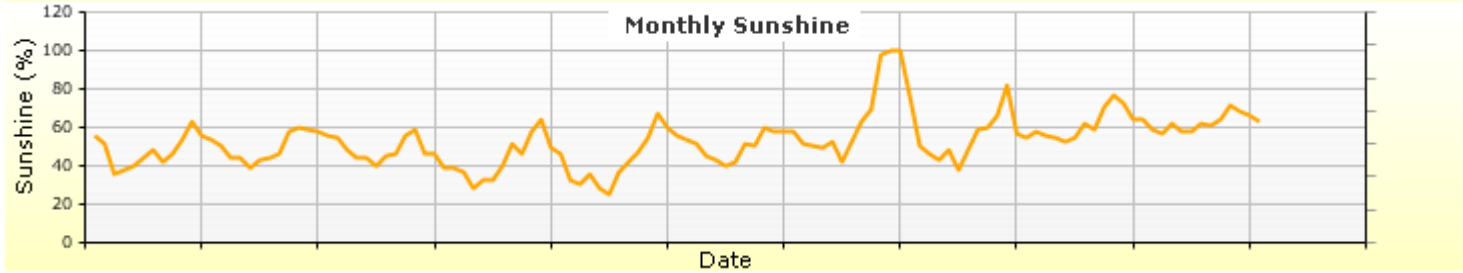
Mean annual air temperature (ºC)	27.09
Mean annual precipitation (mm)	1423.16
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

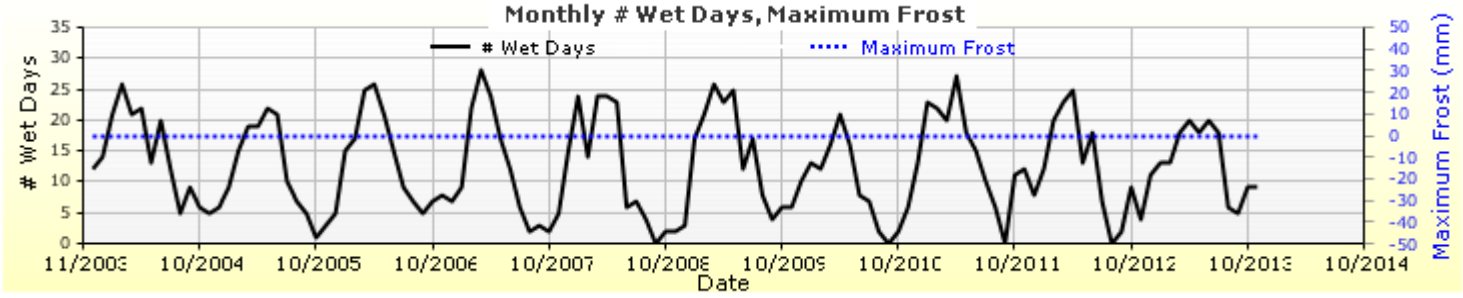
Water table depth (m)	3.05

Monthly Climate Summary:

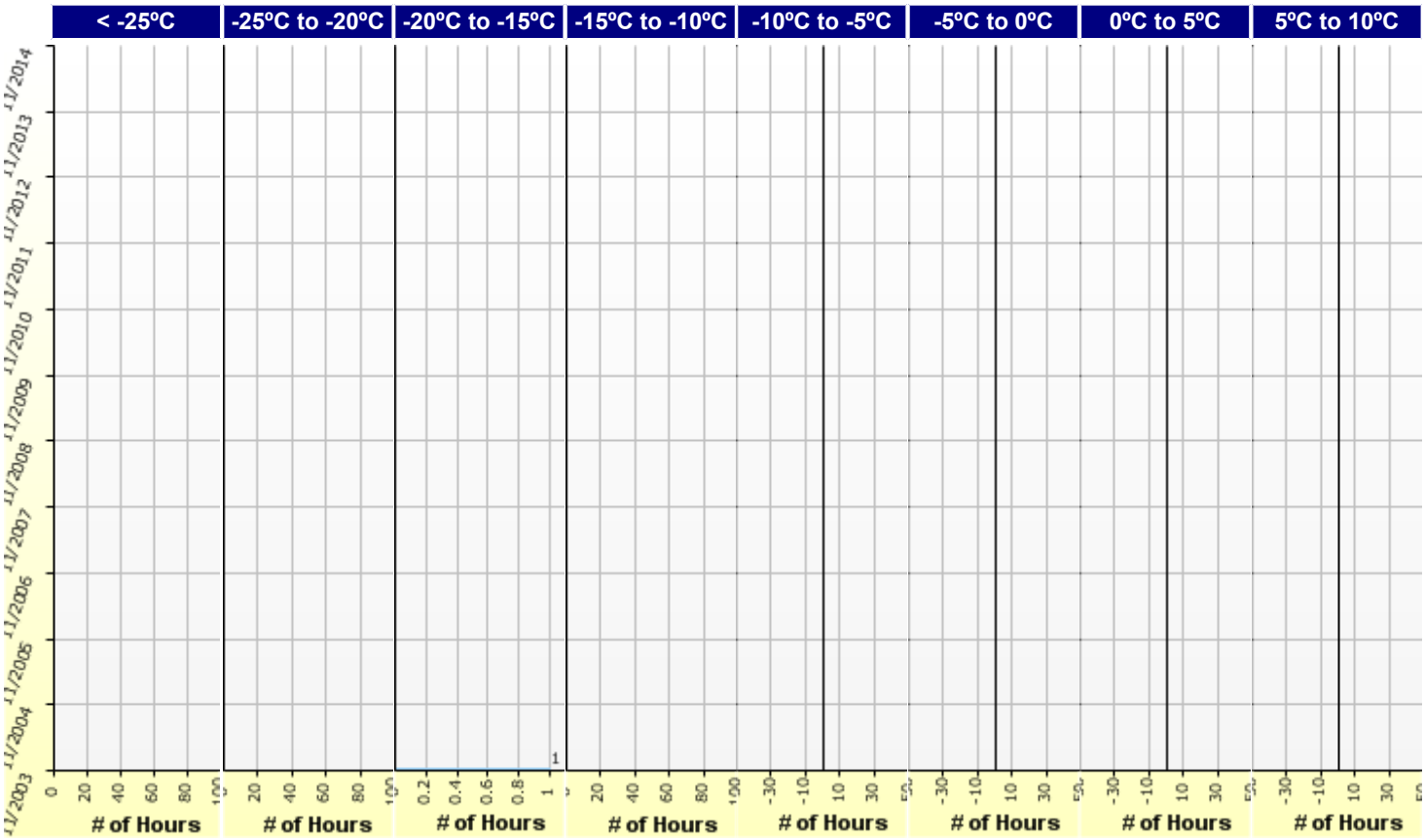


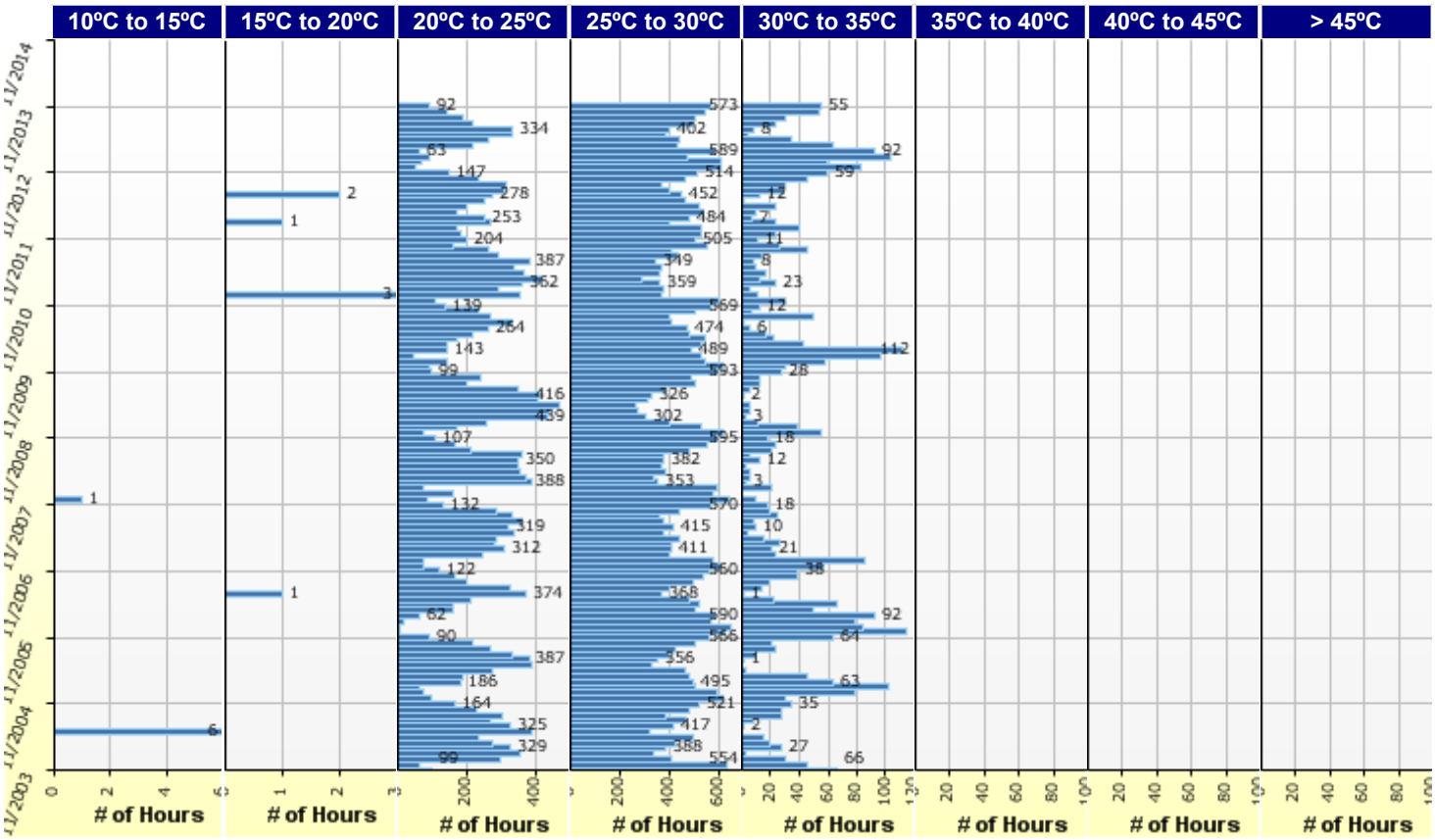






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

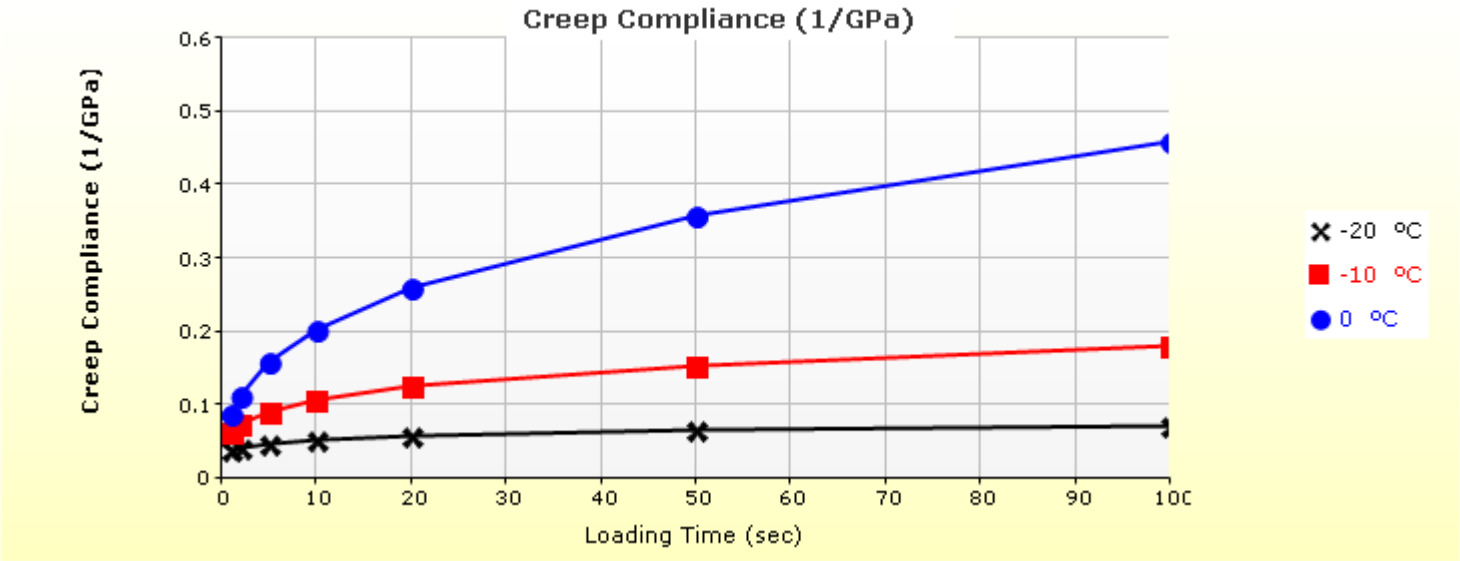
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

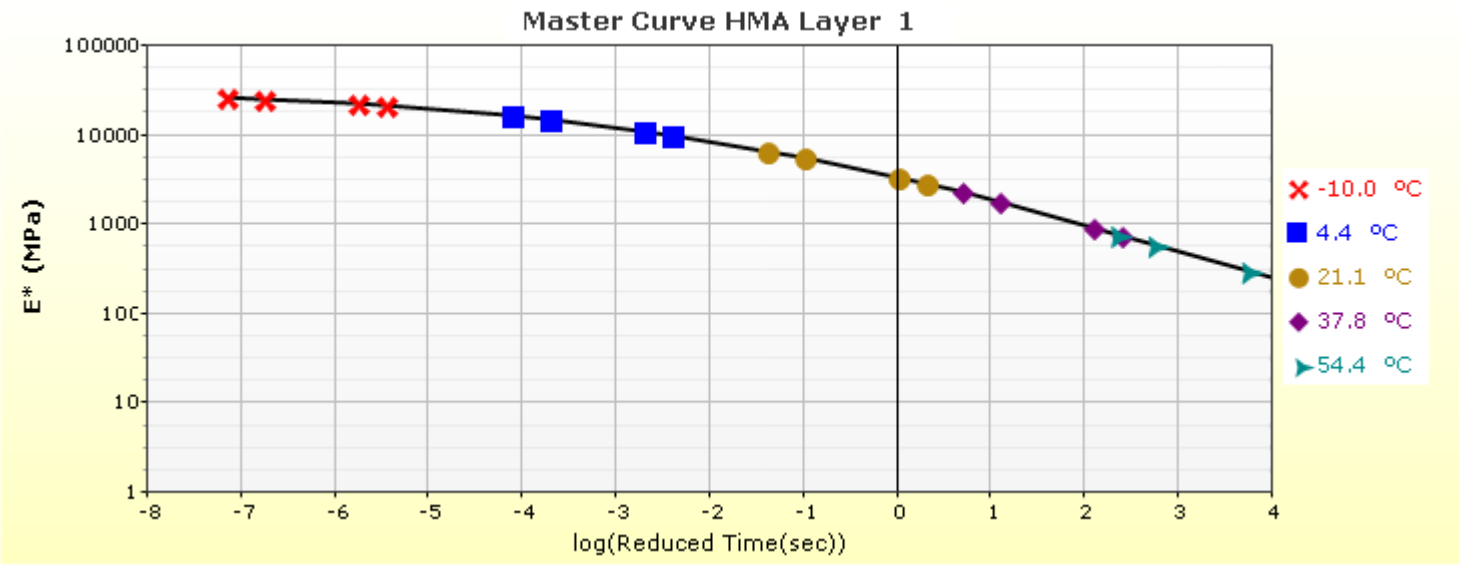
Indirect tensile strength at -10 ºC (MPa)	2.69

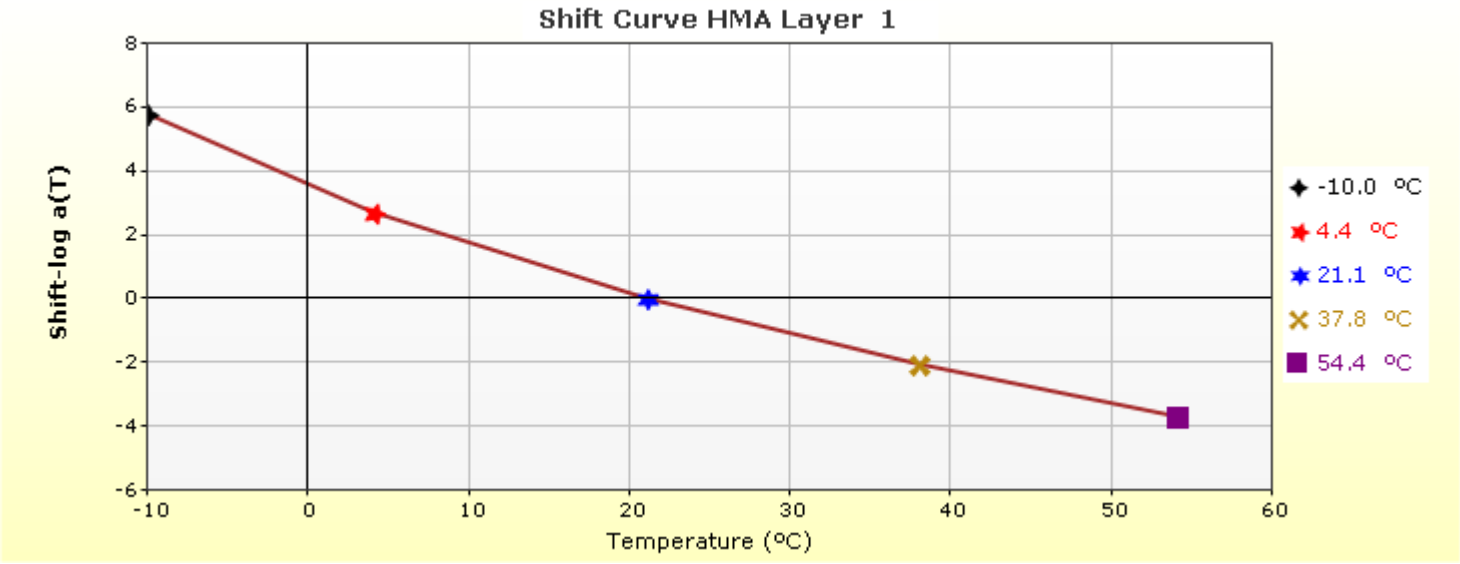
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

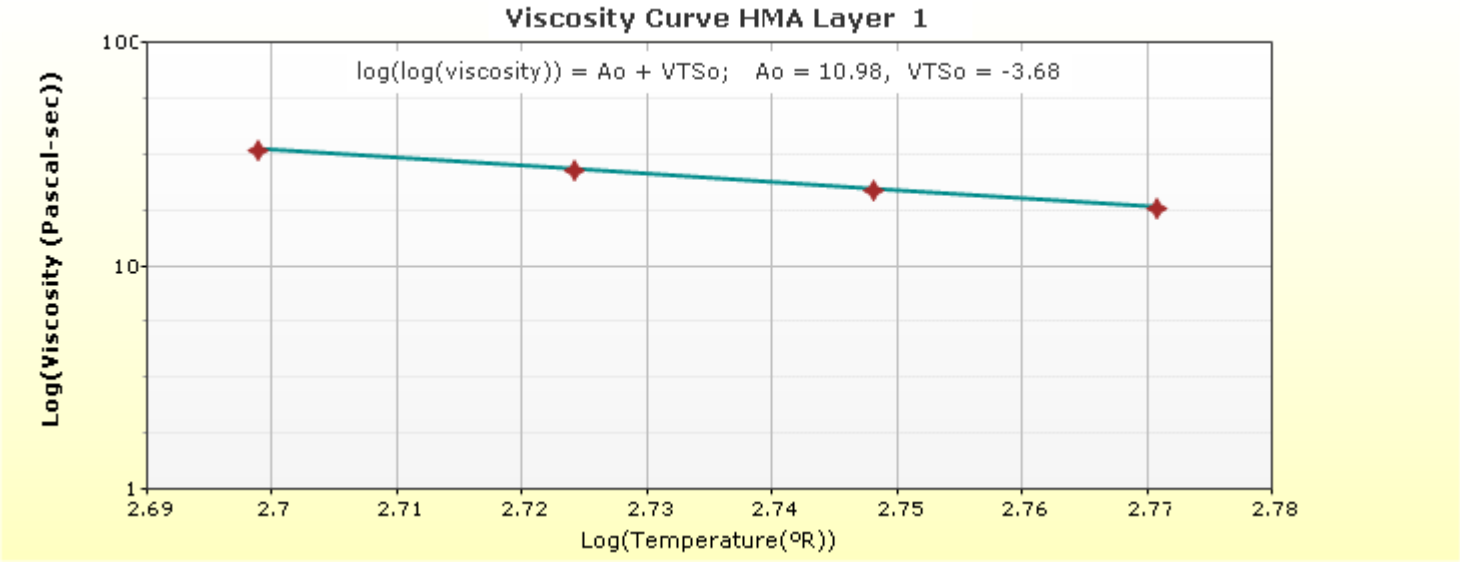
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



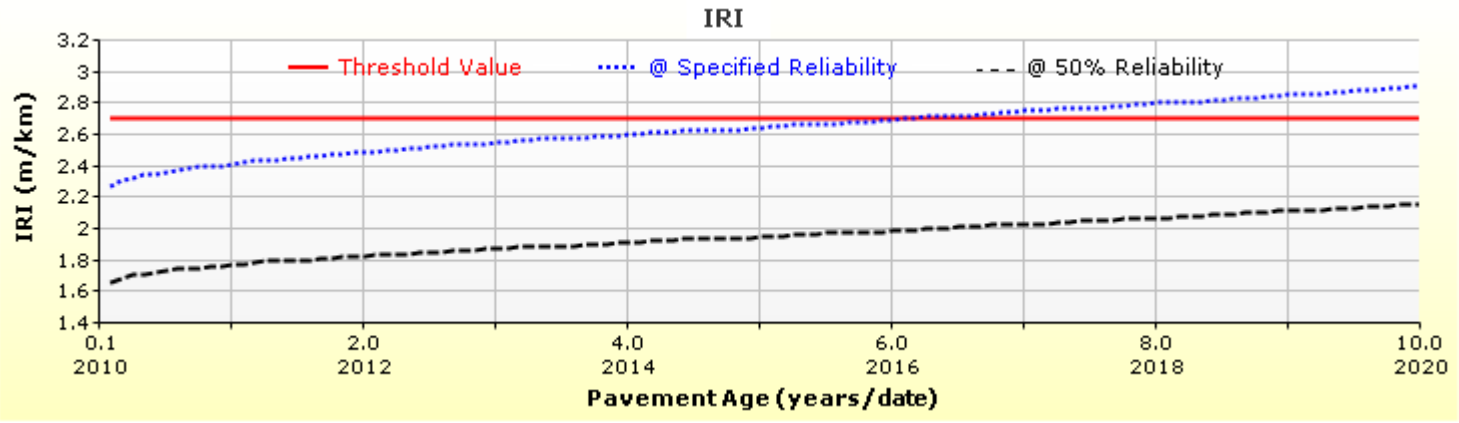
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

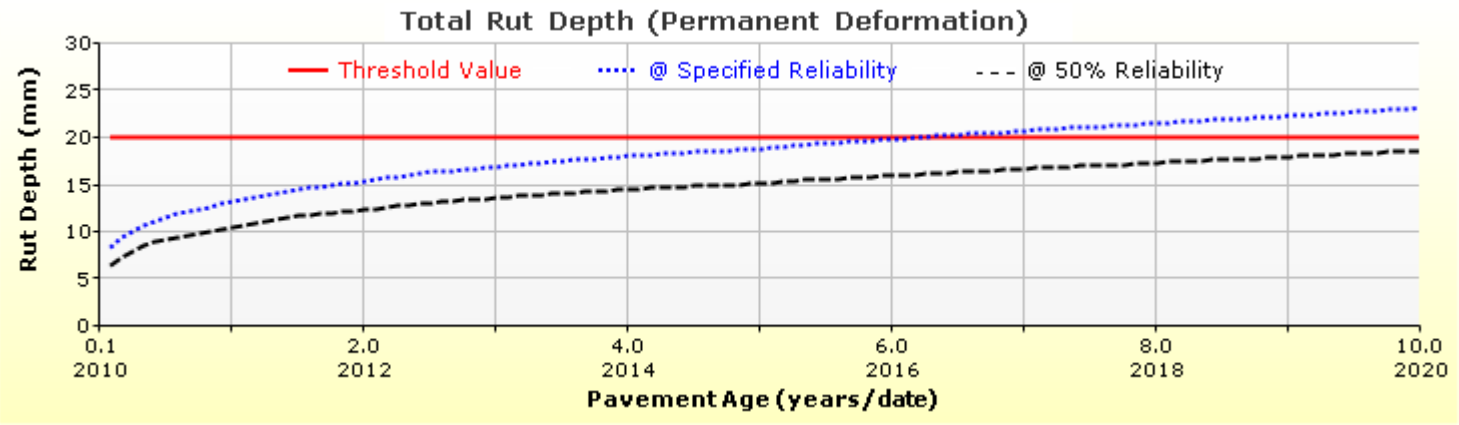


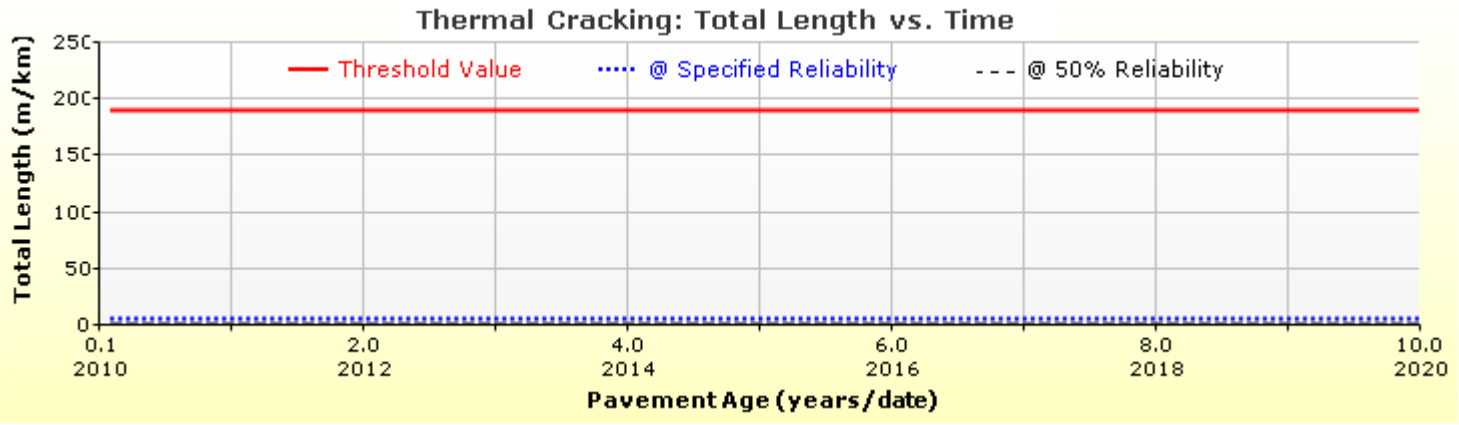


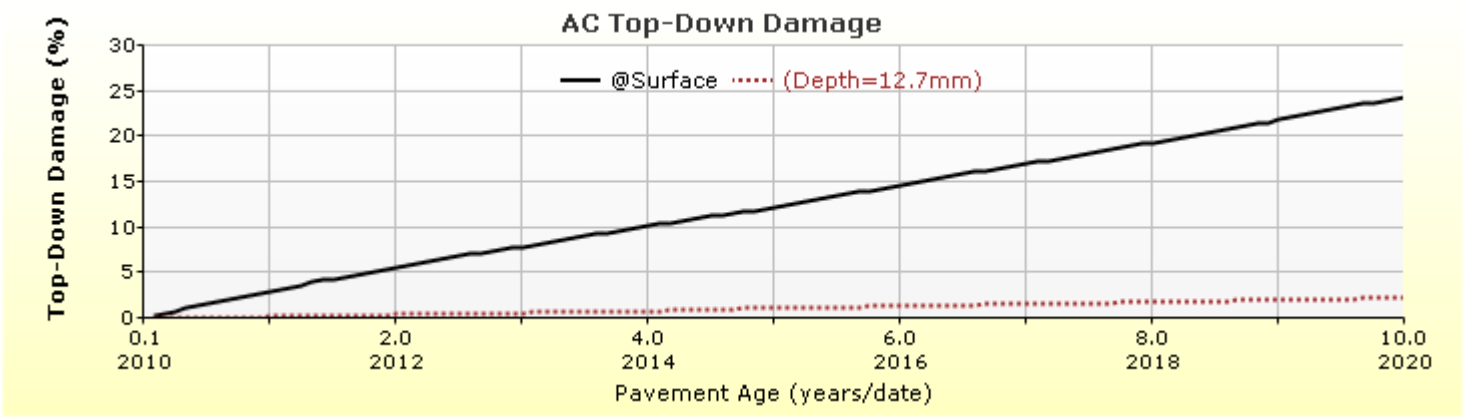


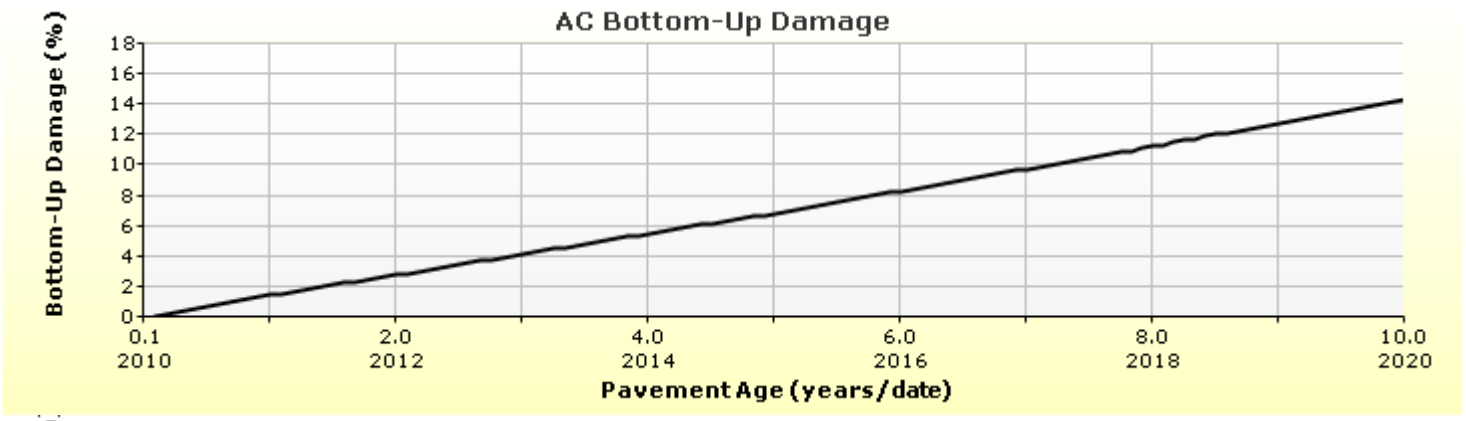
Analysis Output Charts

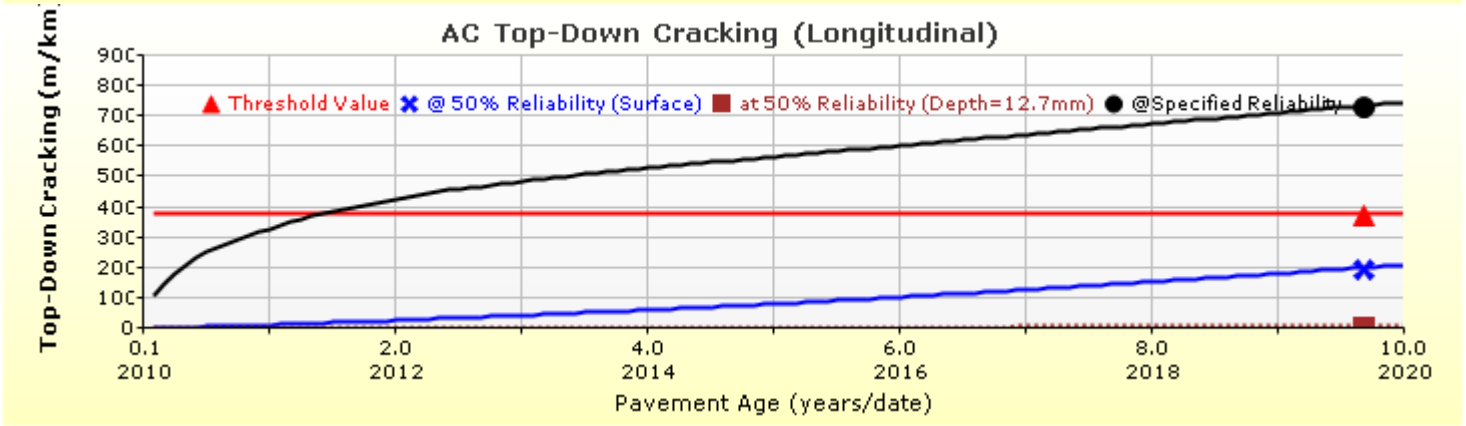


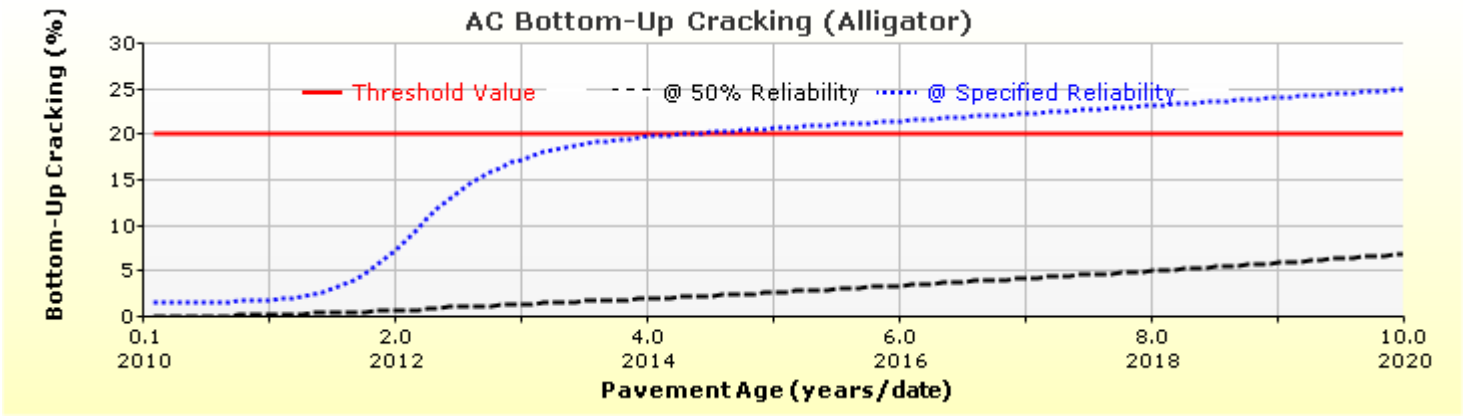


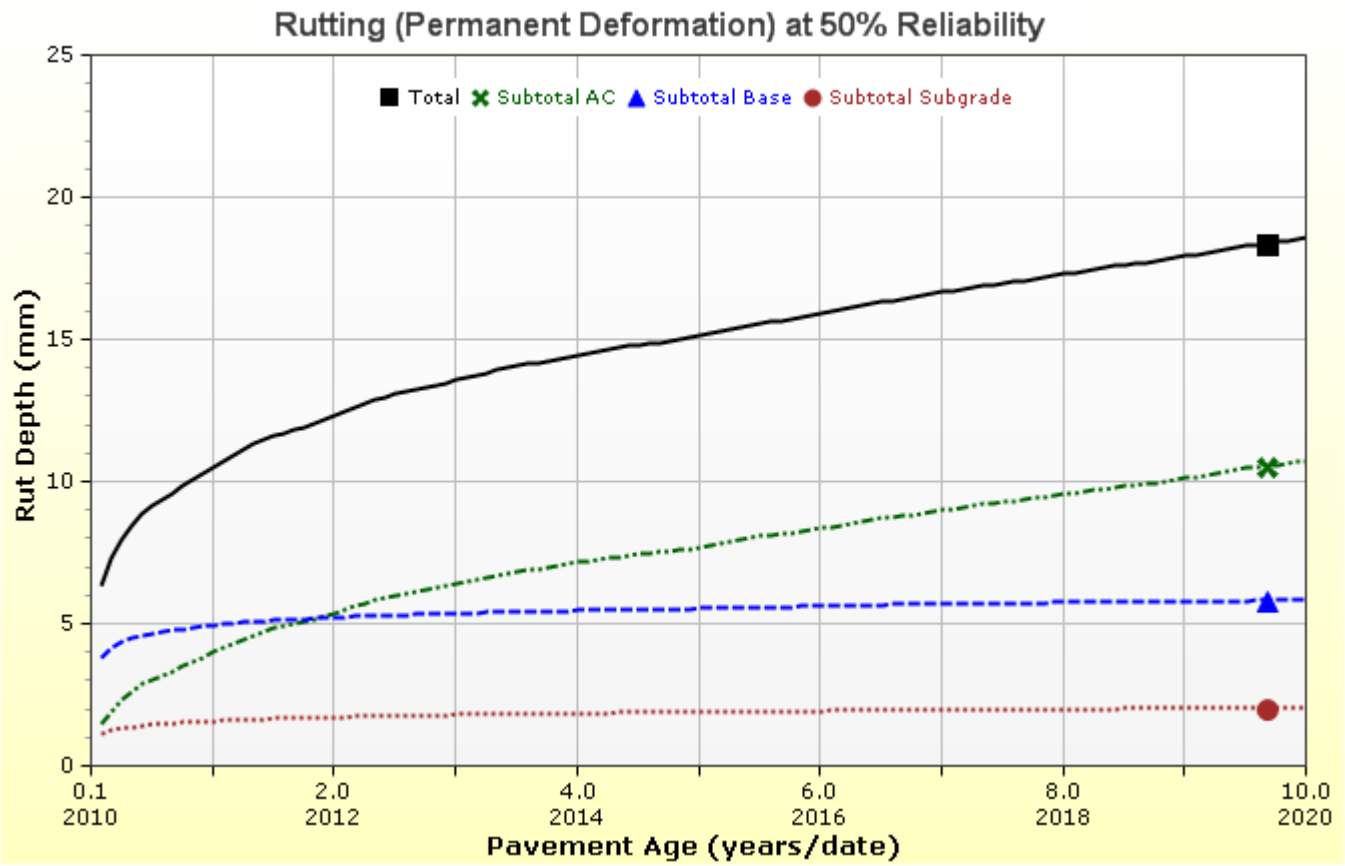


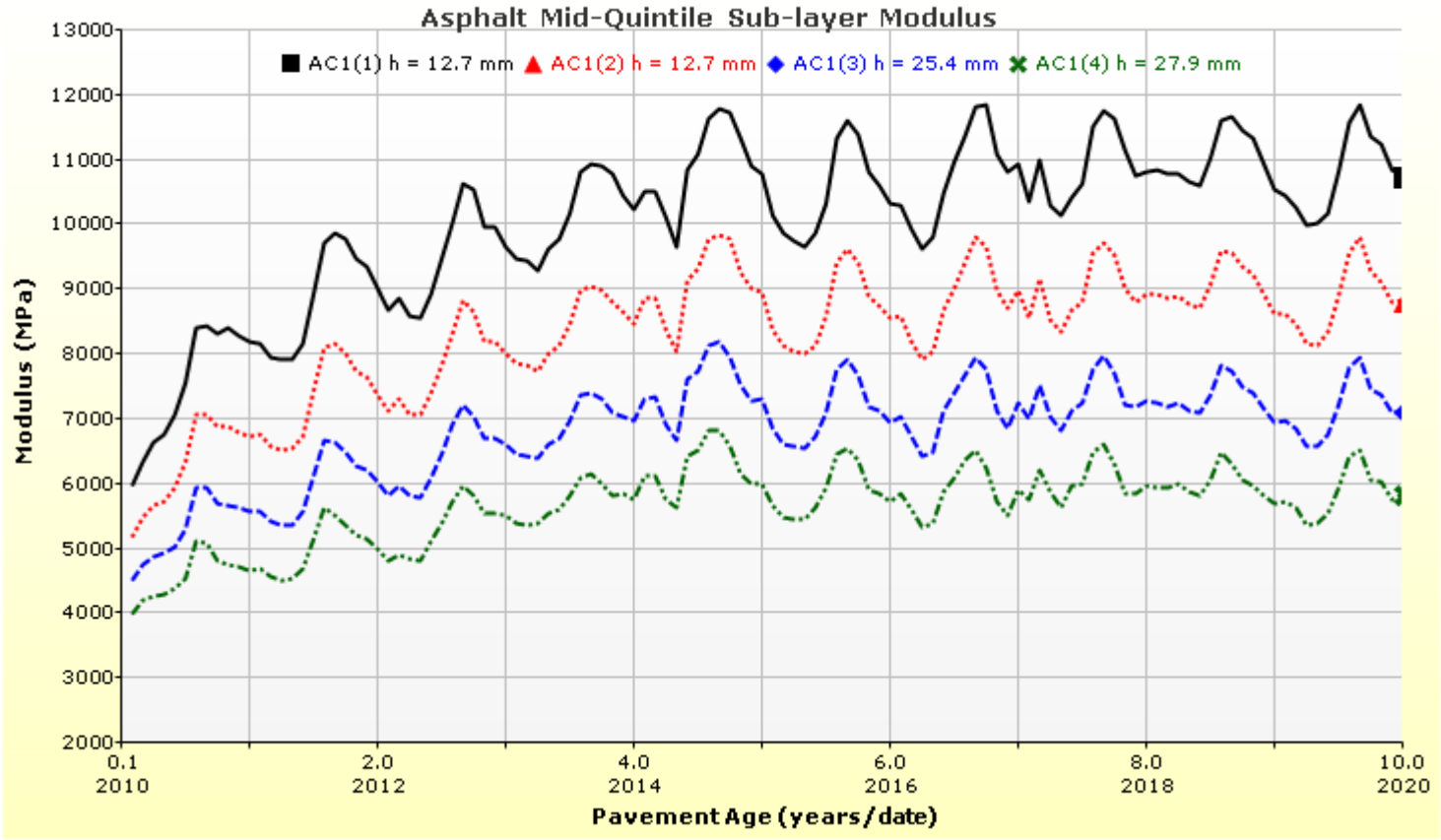

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

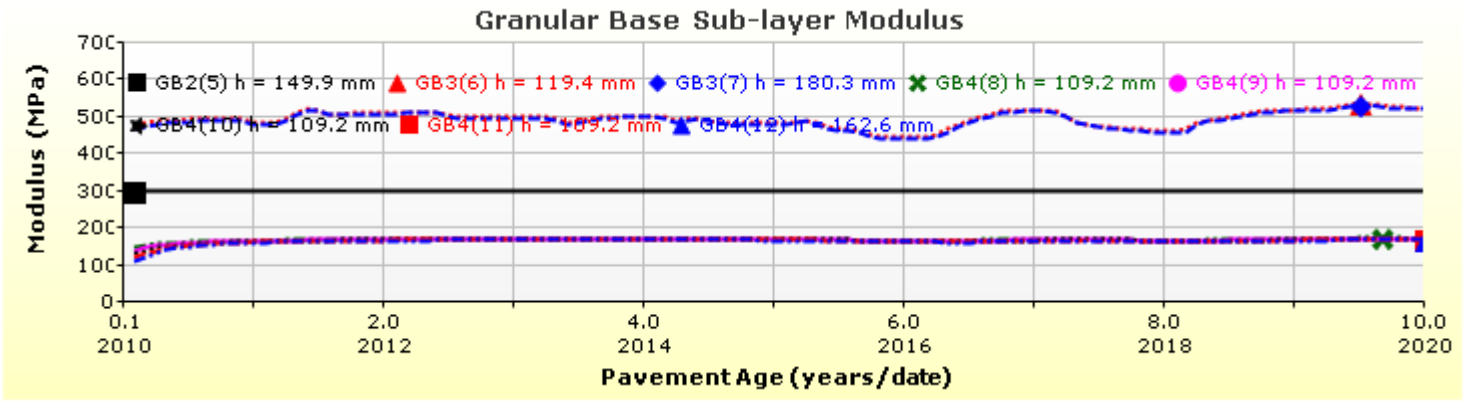

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

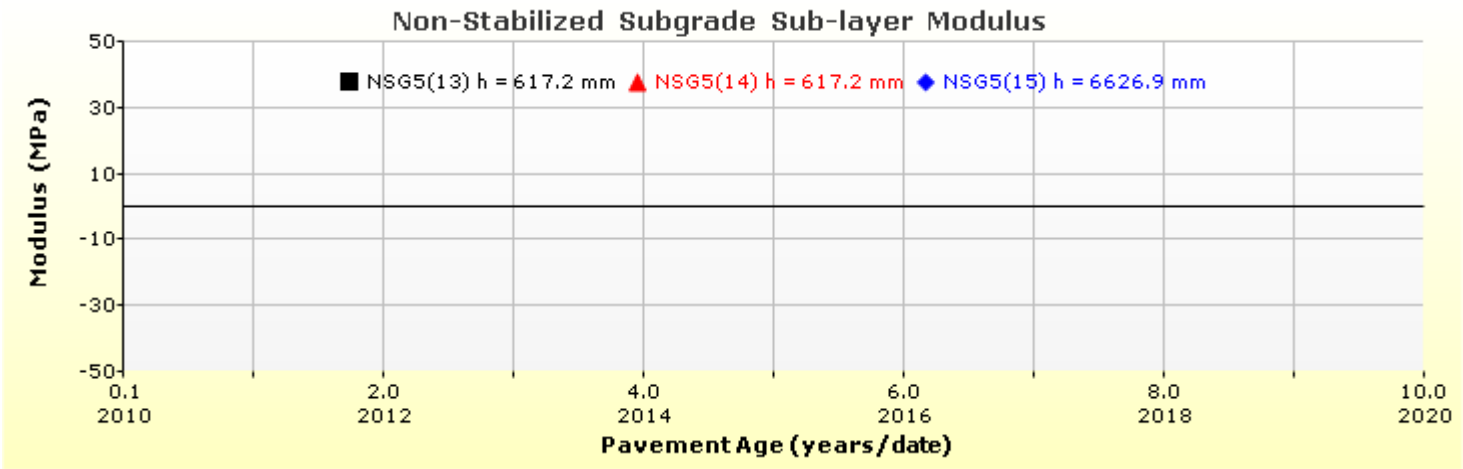

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
90
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestCE_Temp

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestCE_Temp.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -3.77, -38.55

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

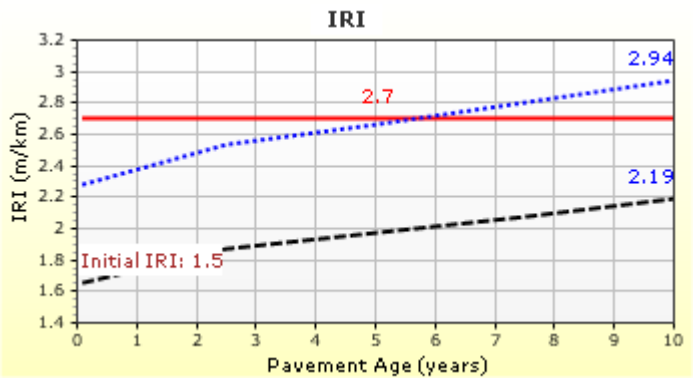
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

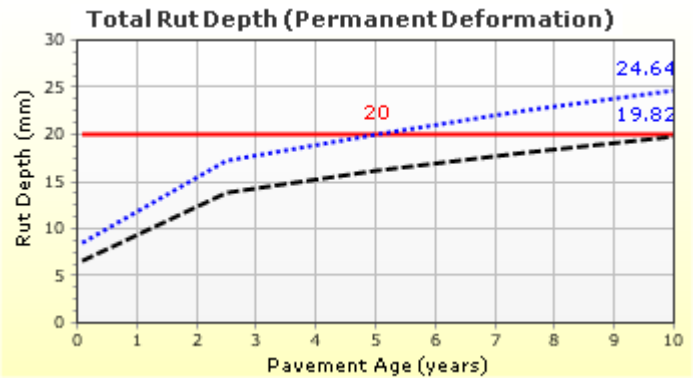
Design Outputs

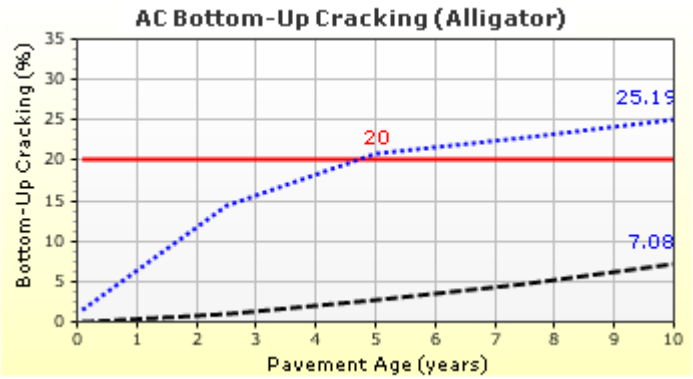
Distress Prediction Summary

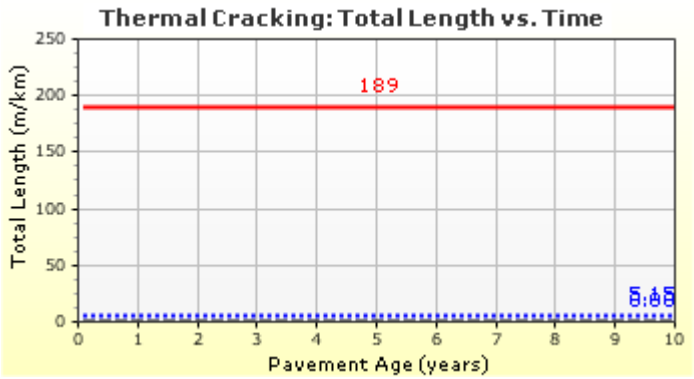
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.94	90.00	80.80	Fail
Permanent deformation - total pavement (mm)	20.00	24.63	90.00	51.83	Fail
AC bottom-up fatigue cracking (percent)	20.00	25.19	90.00	81.97	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	780.28	90.00	62.92	Fail
Permanent deformation - AC only (mm)	5.00	11.94	50.00	1.92	Fail

Distress Charts







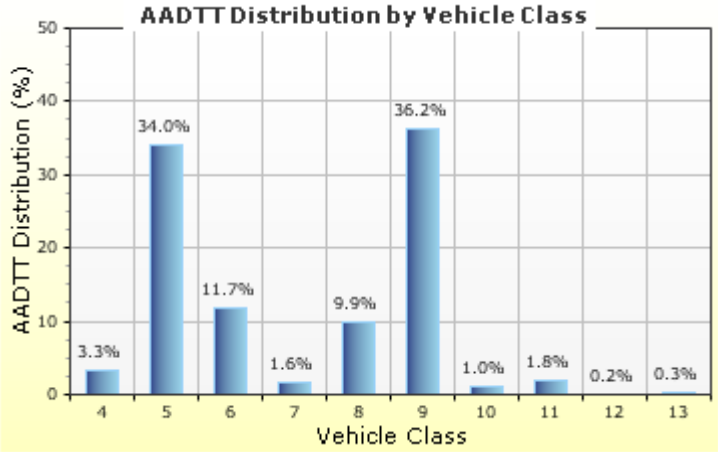


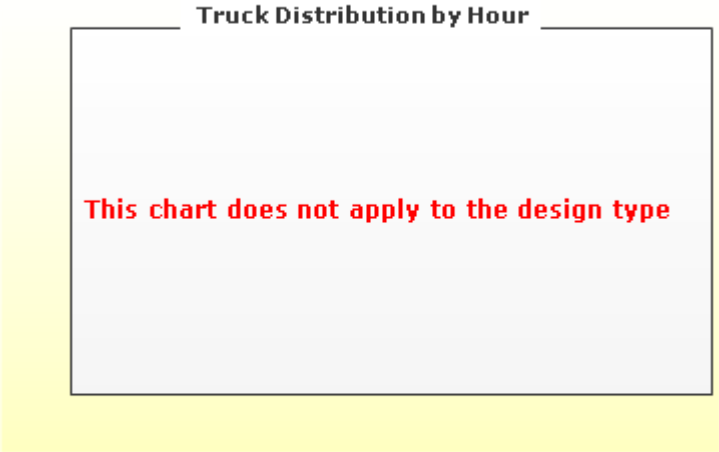


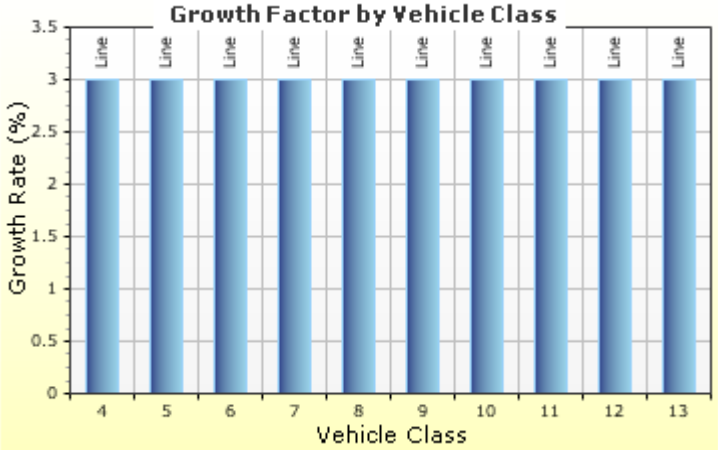
Traffic Inputs

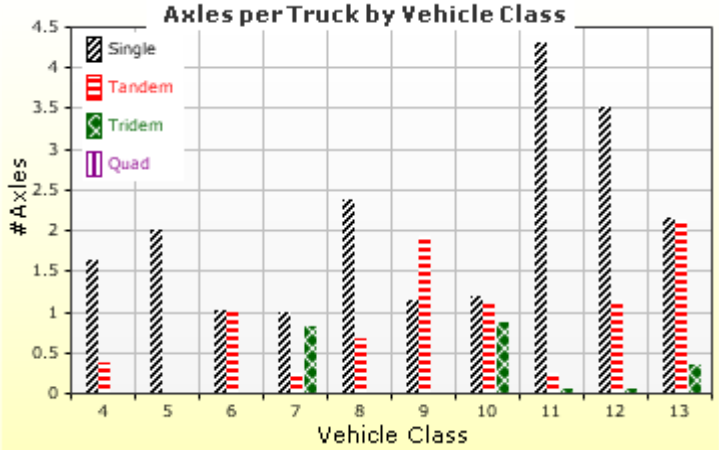
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

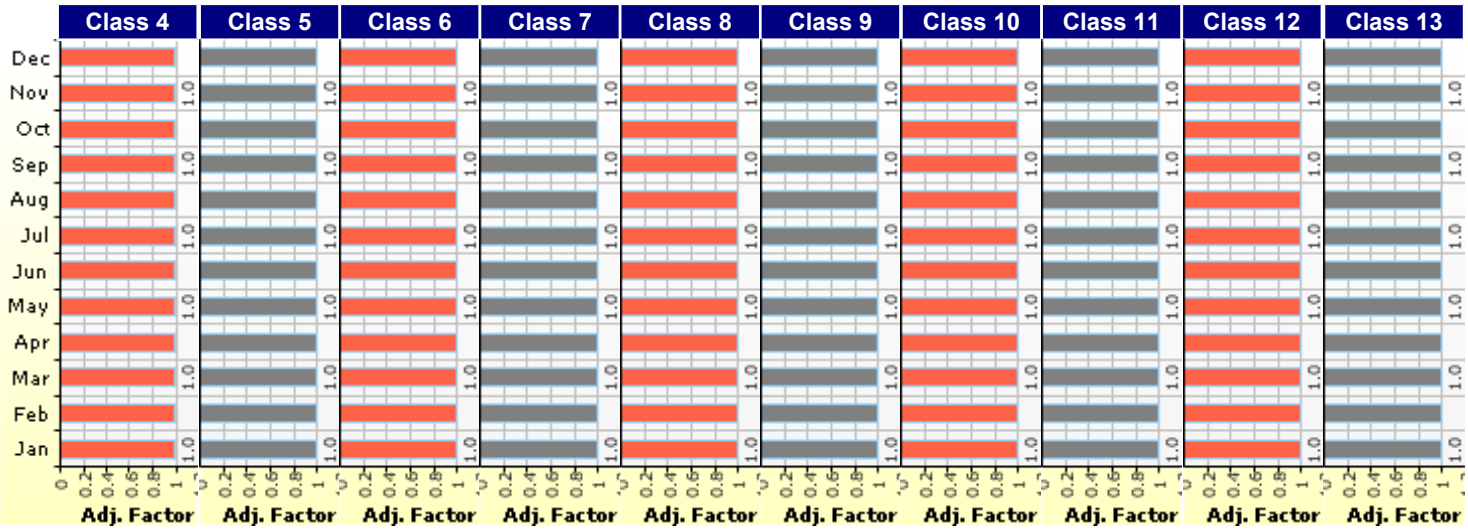








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

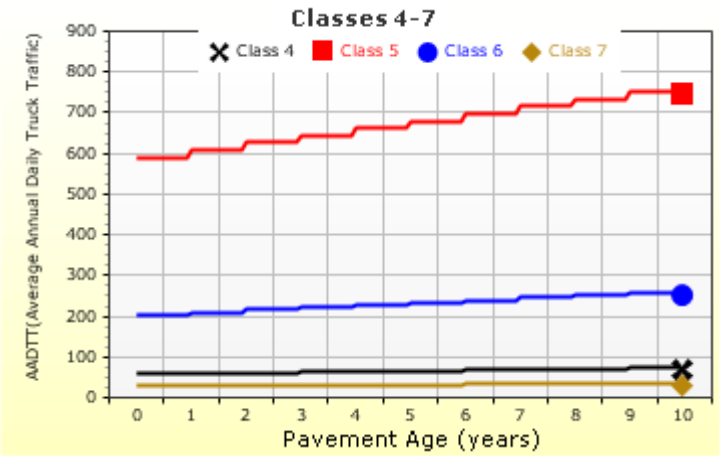
Wheelbase does not apply

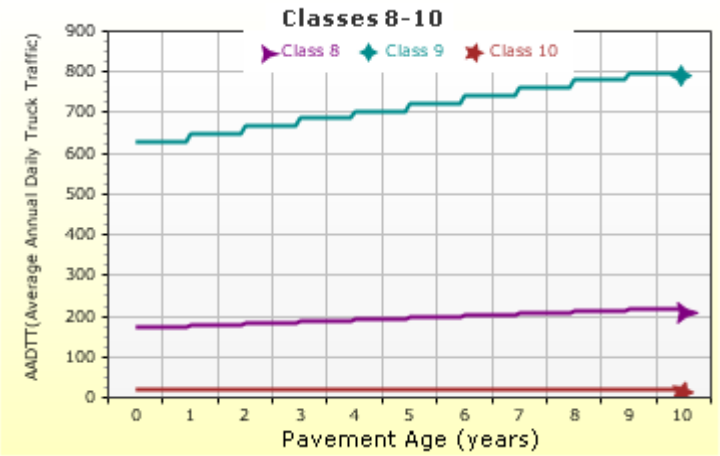
Number of Axles per Truck

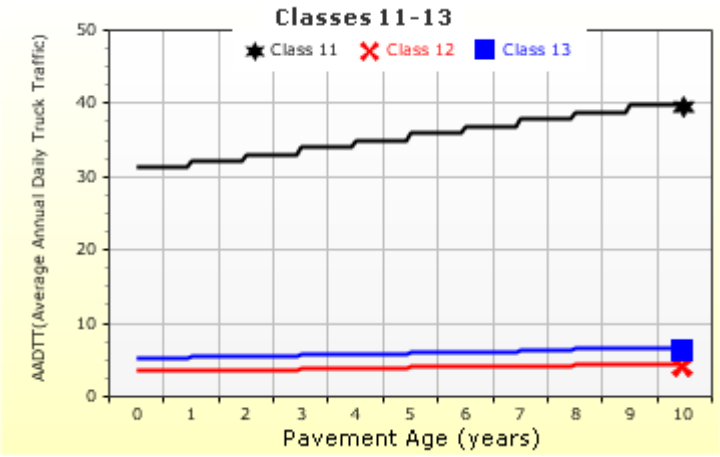
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

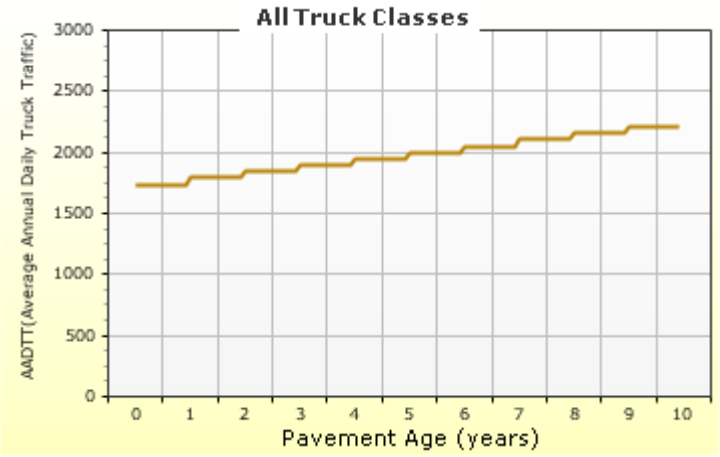
AADTT (Average Annual Daily Truck Traffic) Growth

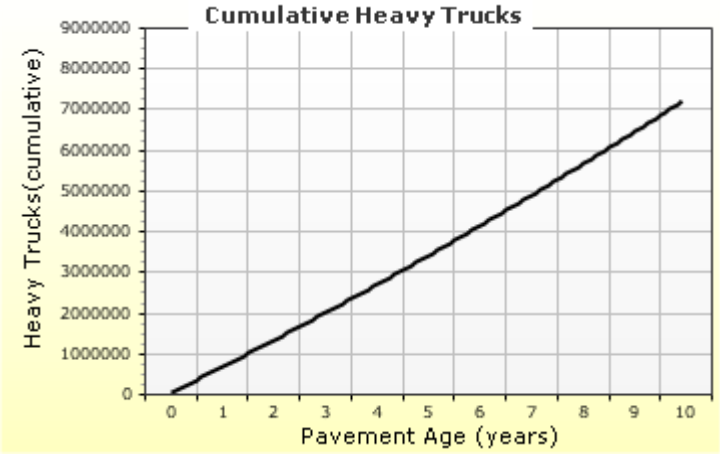
*** Traffic cap is not enforced**







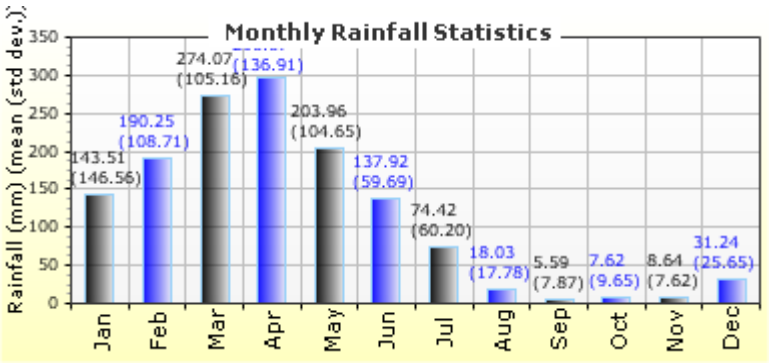




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
FORTALEZA, CE	-3.77000 -38.55000 41

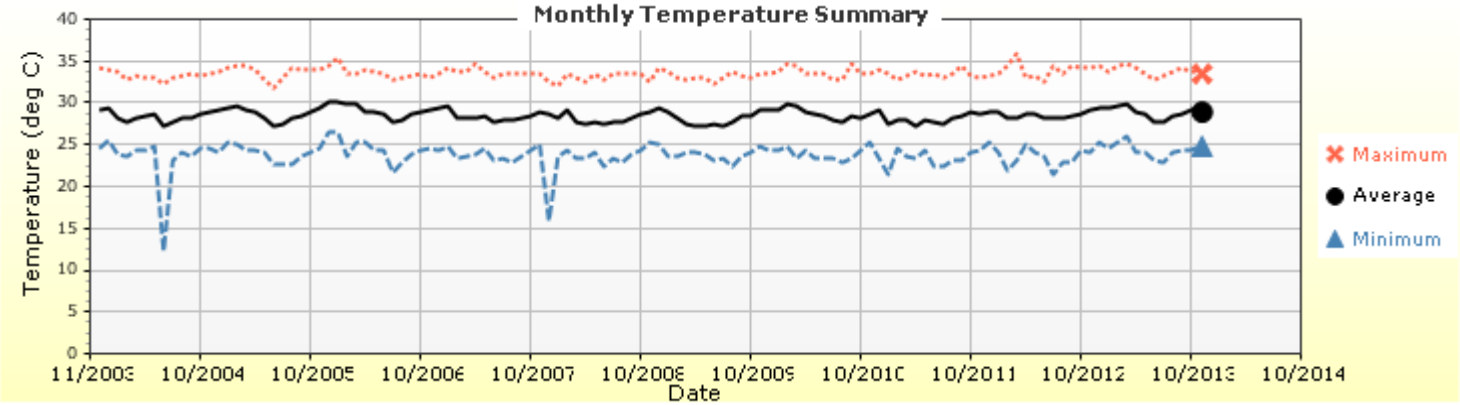


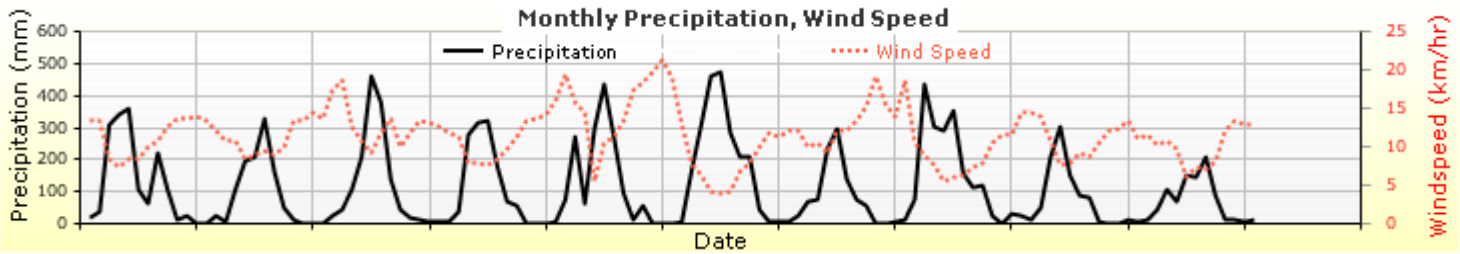
Annual Statistics:

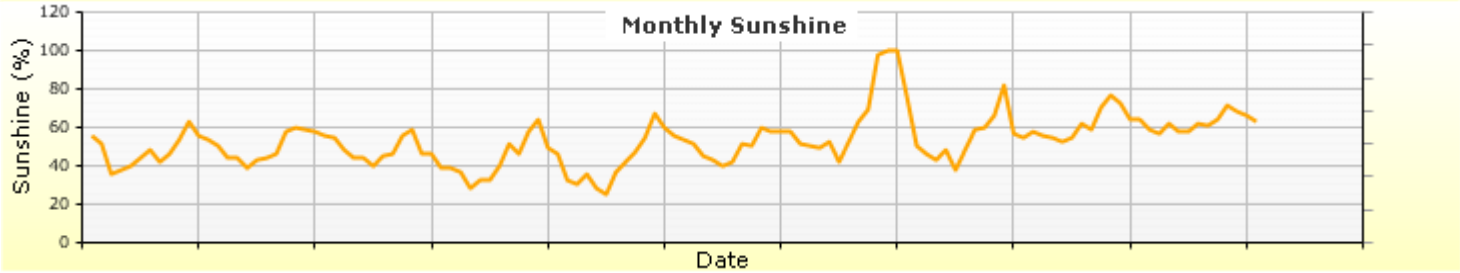
Mean annual air temperature (ºC)	28.49
Mean annual precipitation (mm)	1370.58
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

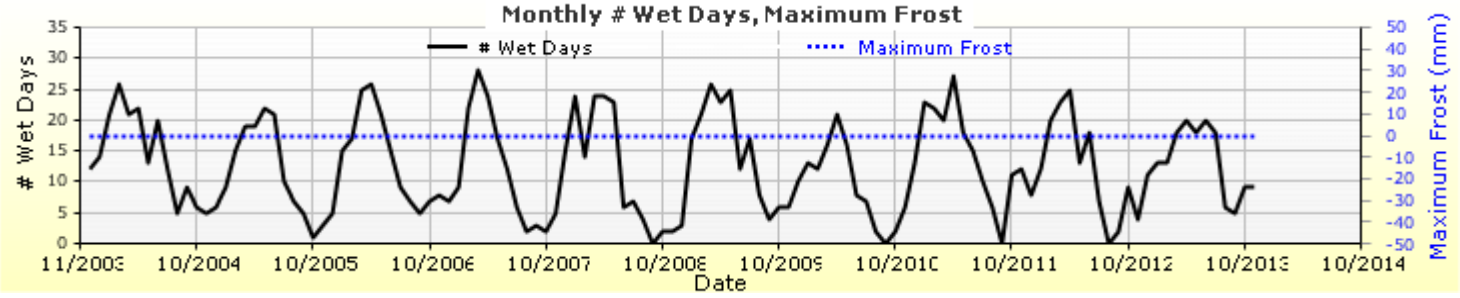
Water table depth (m): 3.05

Monthly Climate Summary:

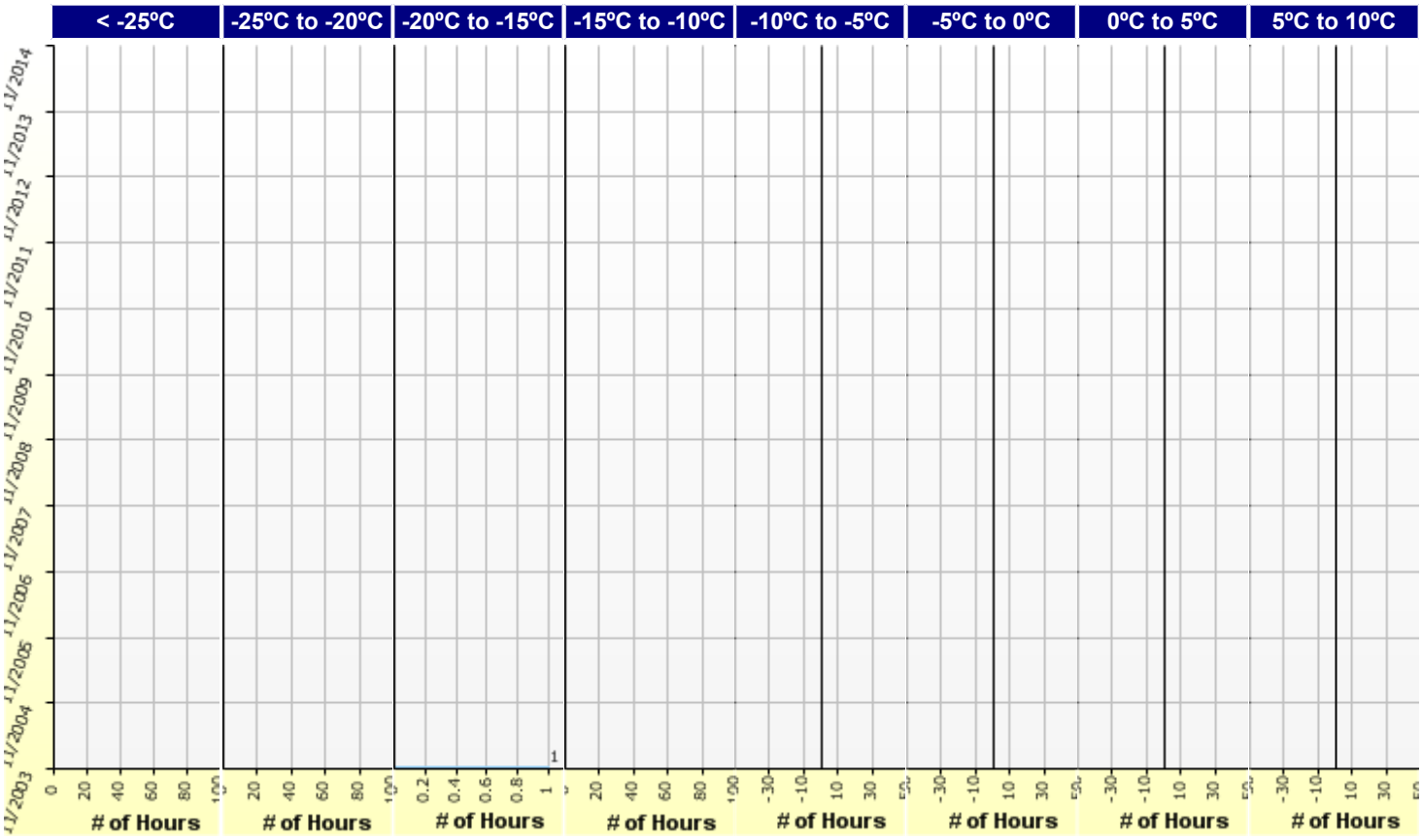


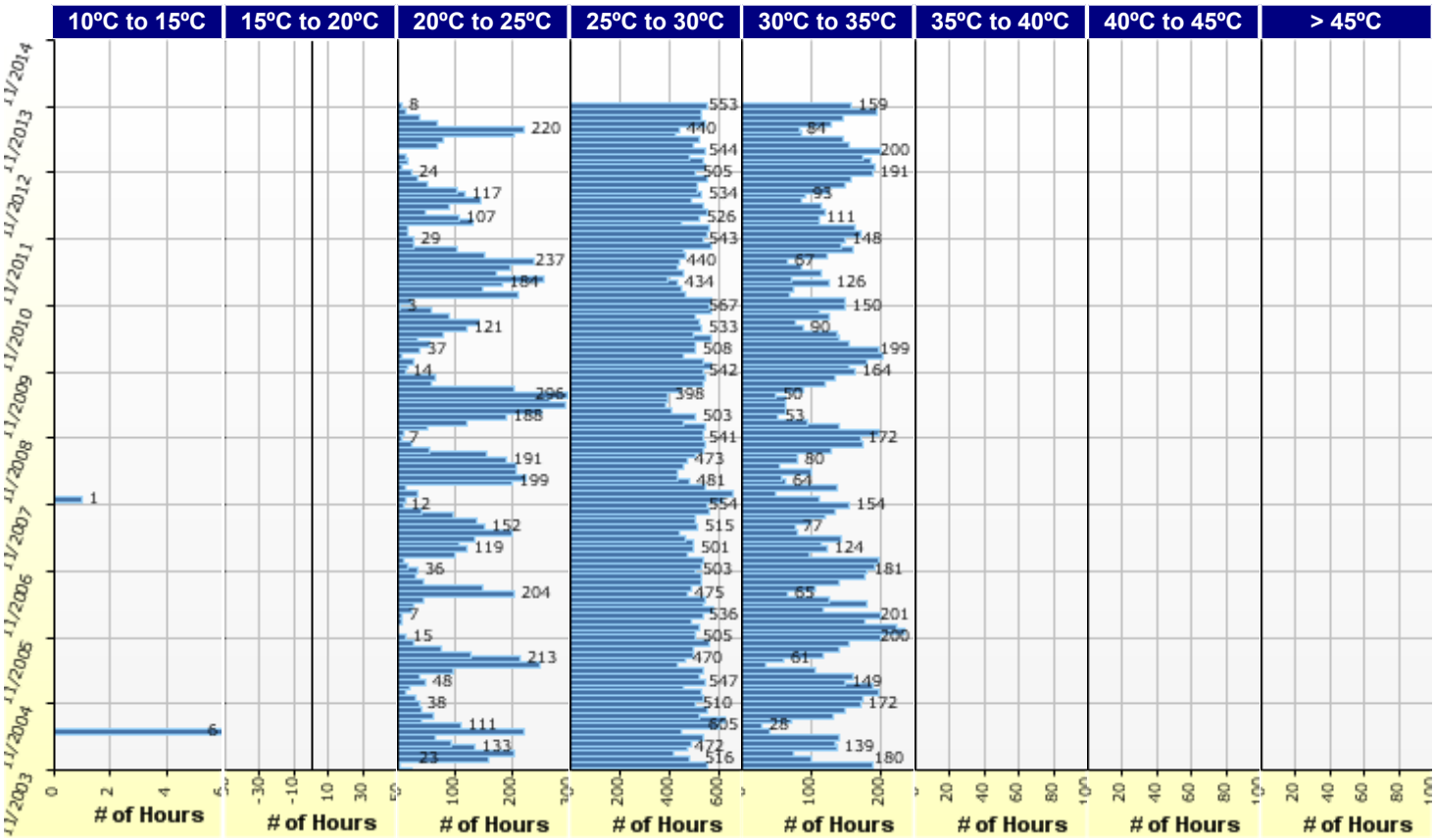






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

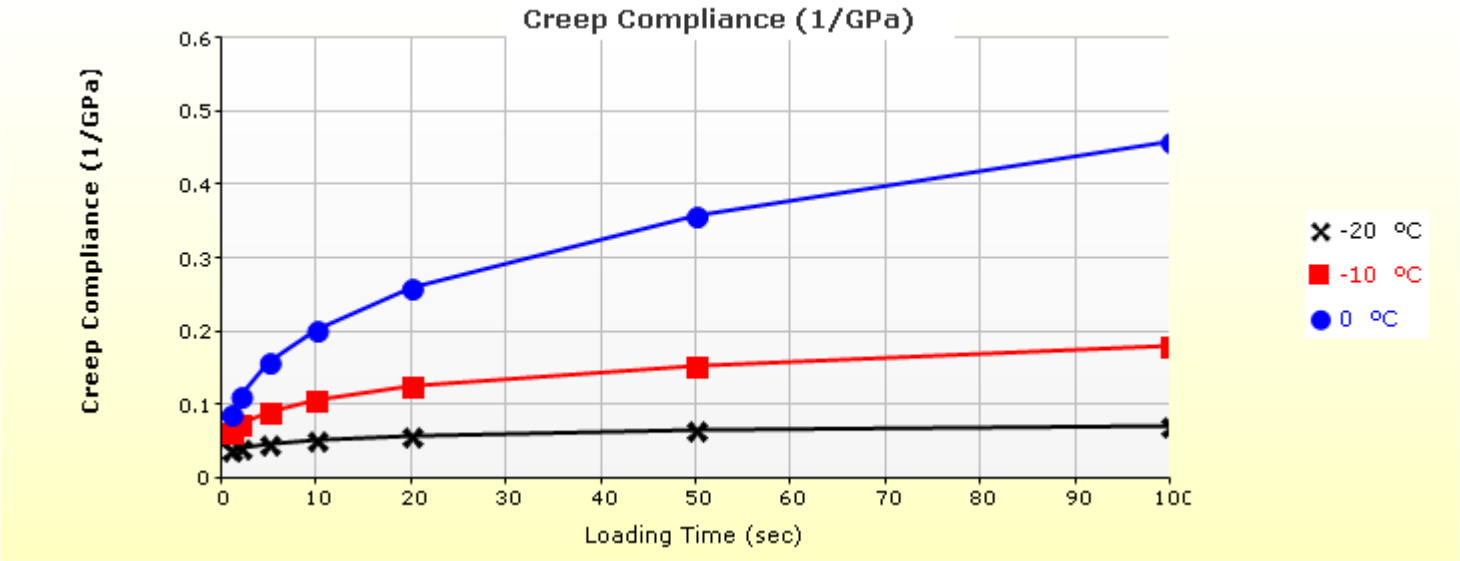
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

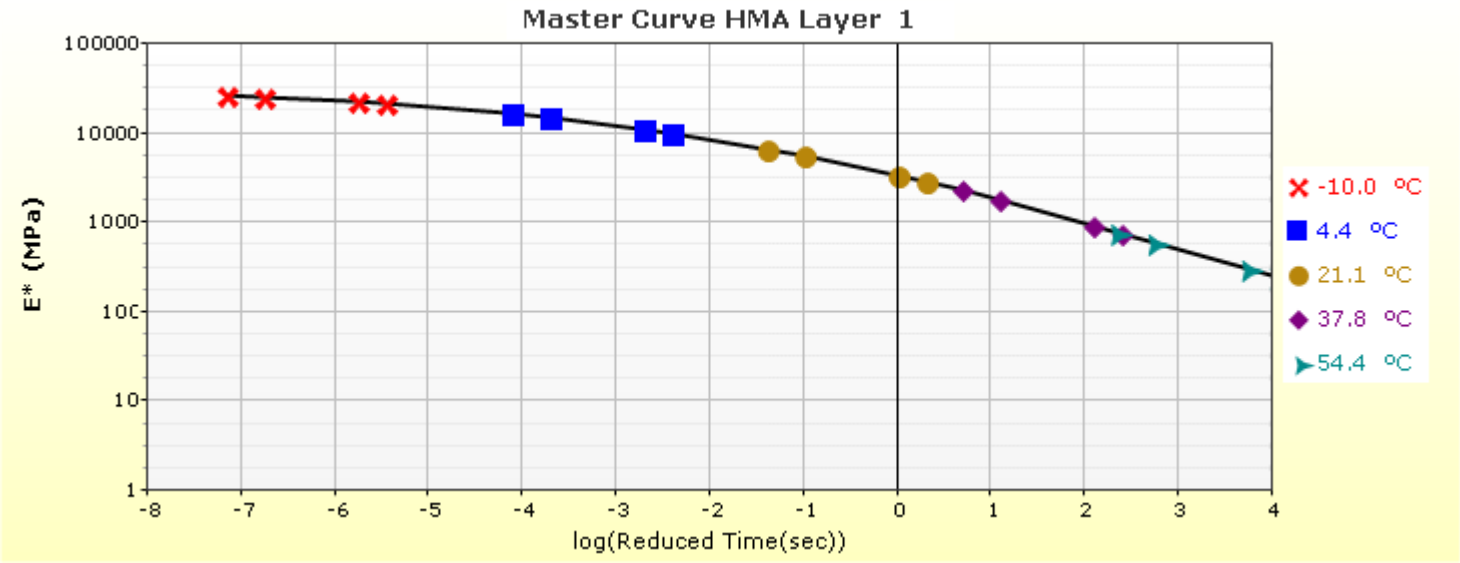
Indirect tensile strength at -10 ºC (MPa)	2.69

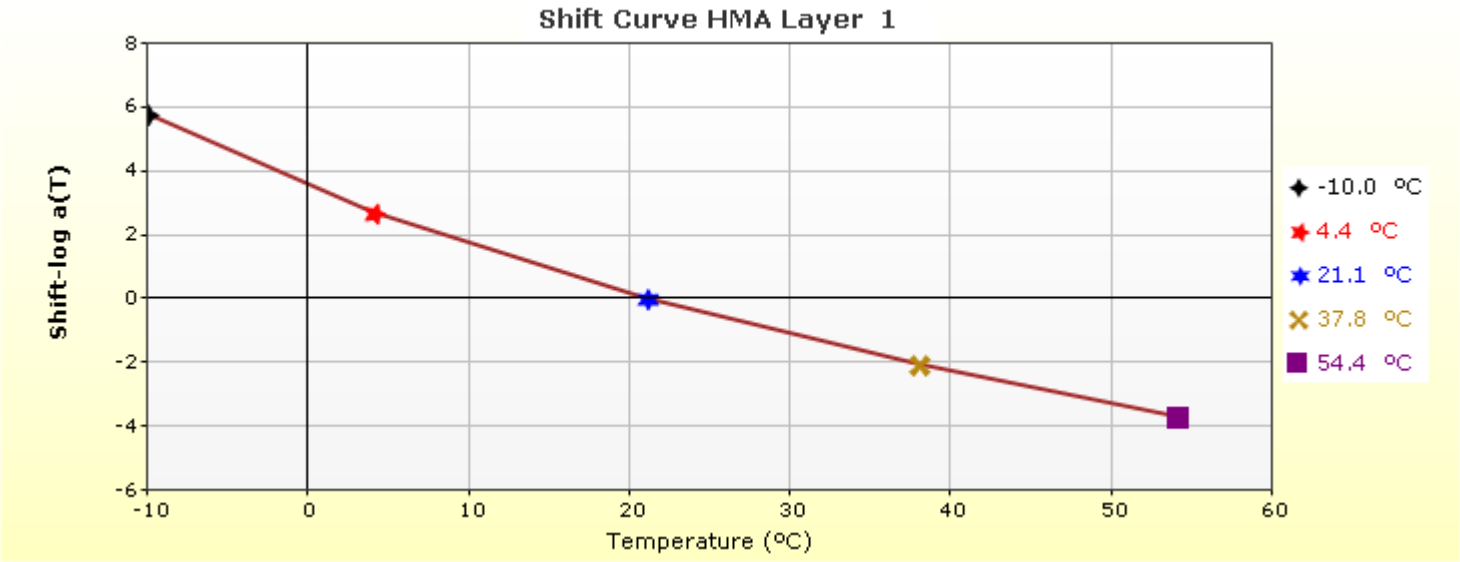
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

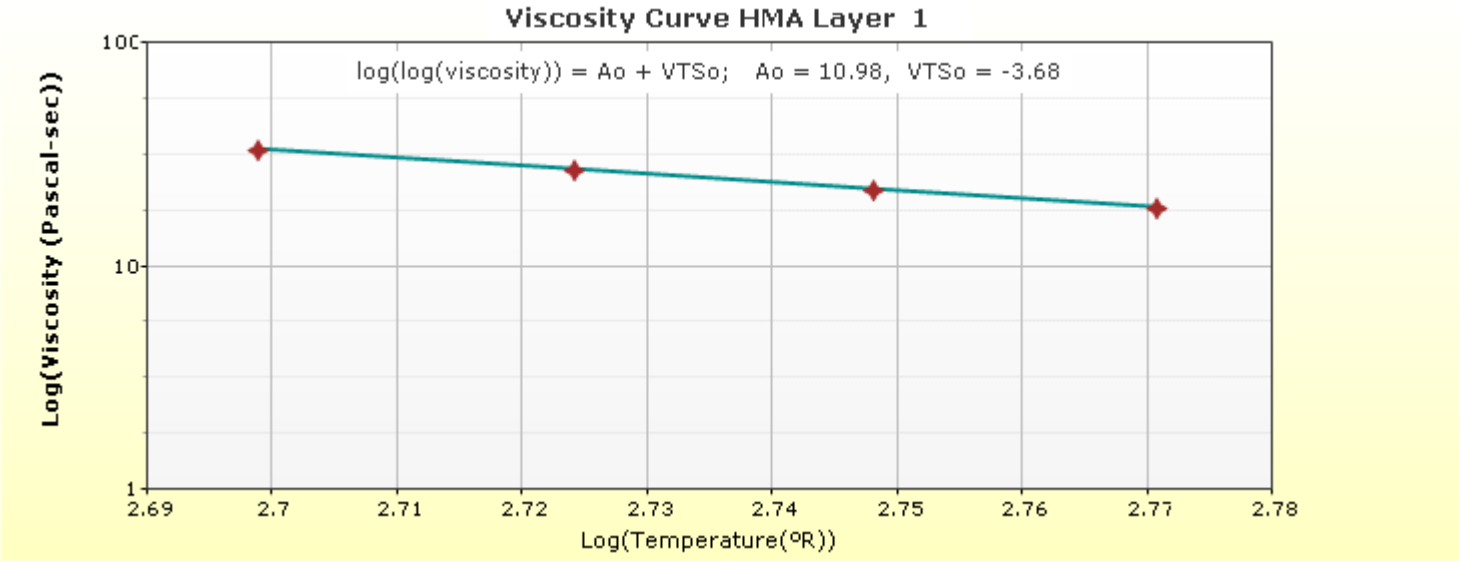
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



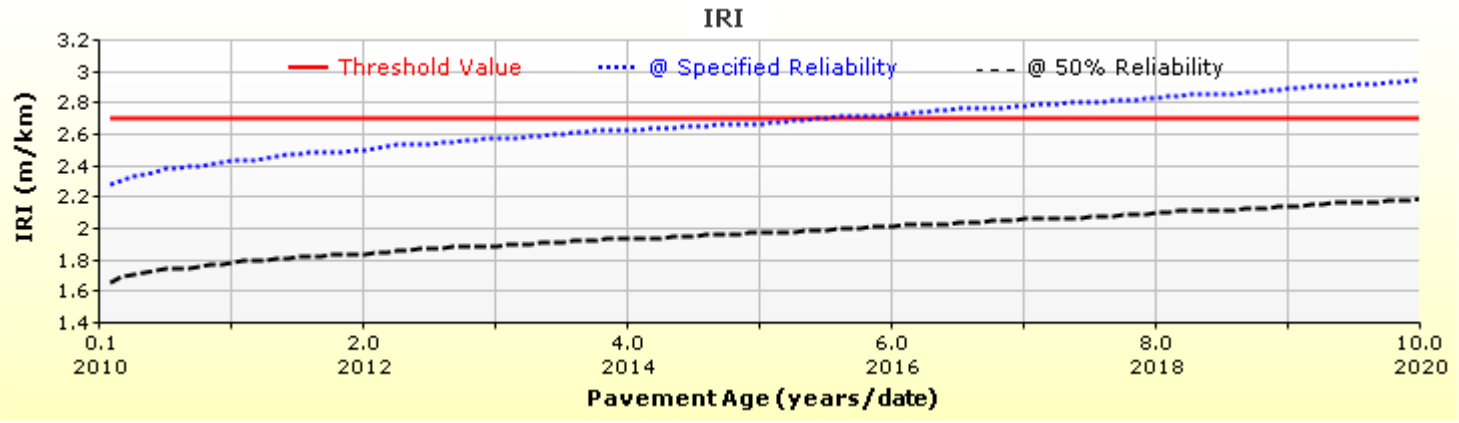
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

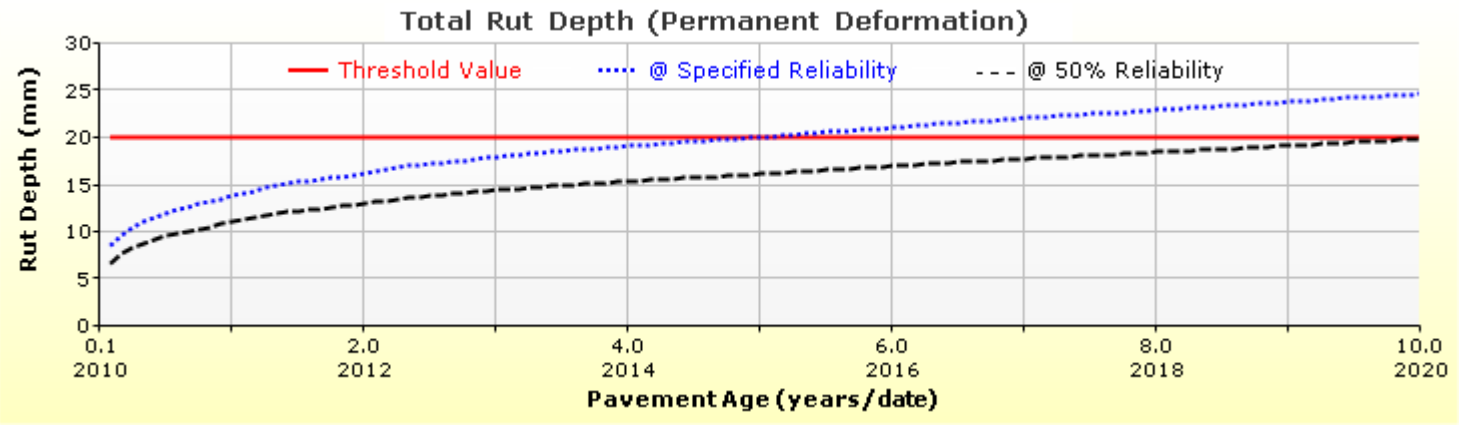


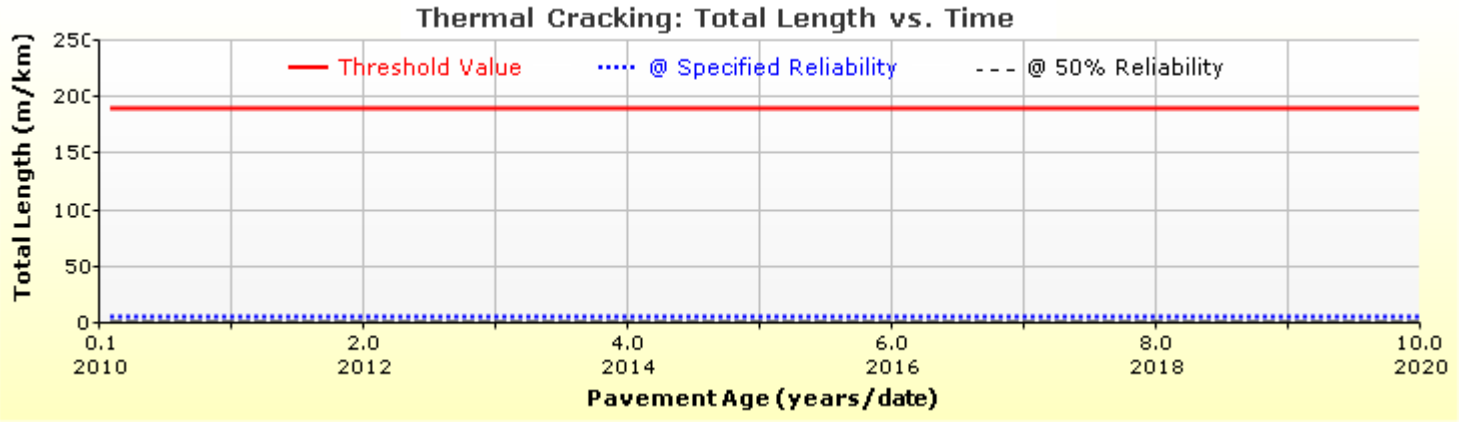


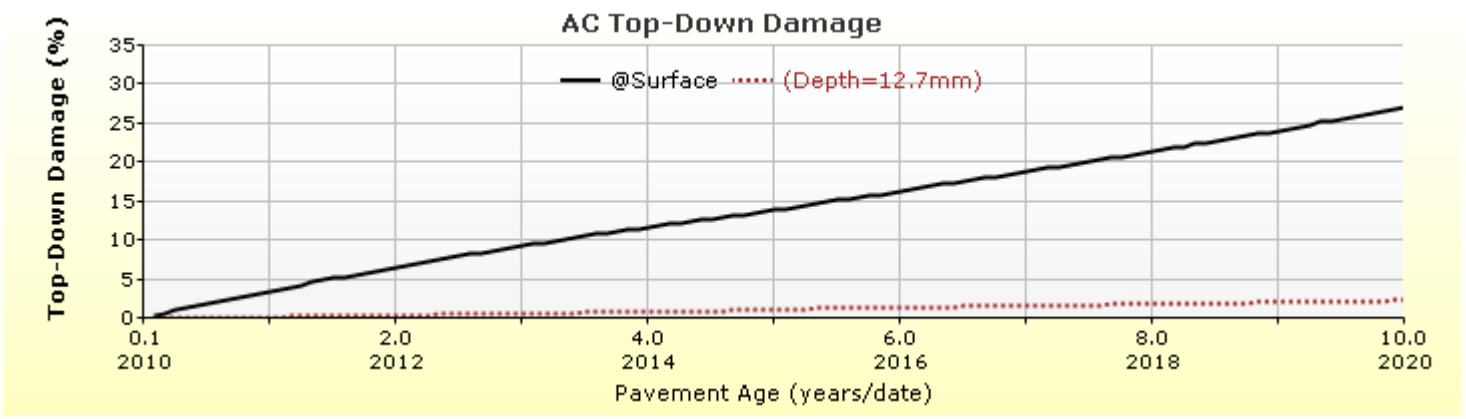


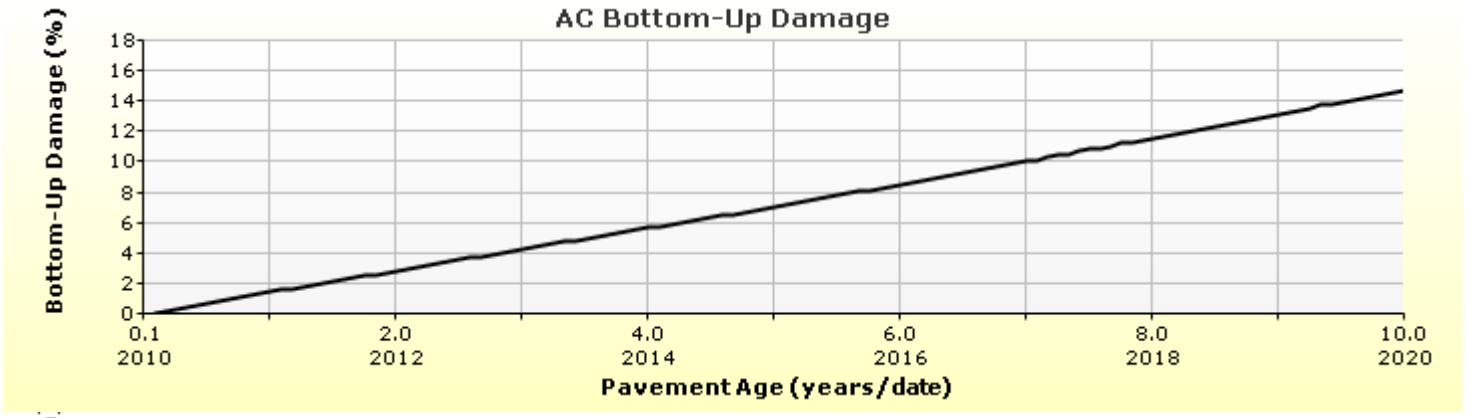
Analysis Output Charts

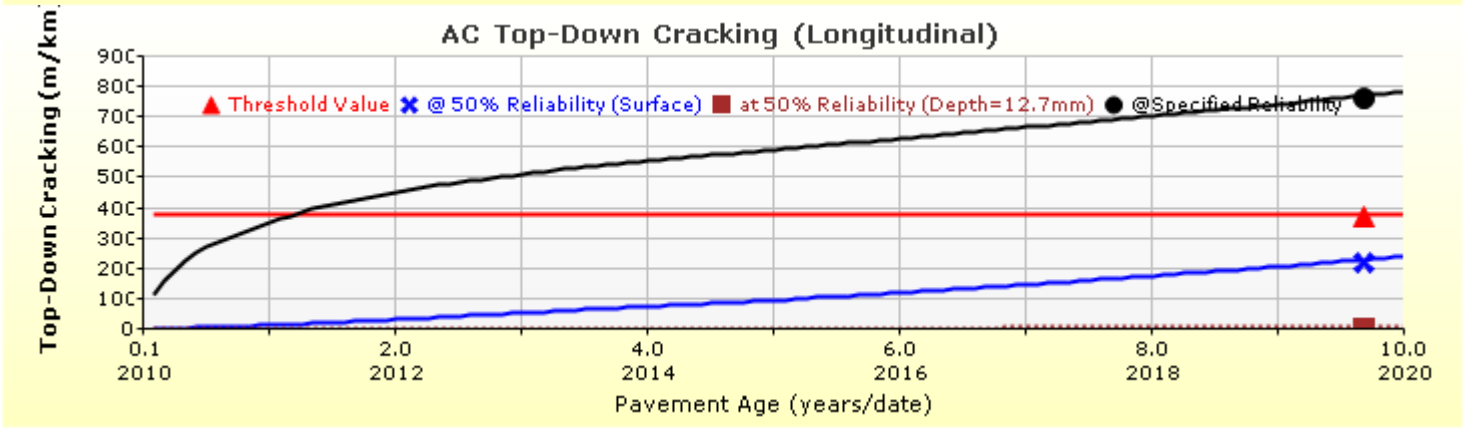


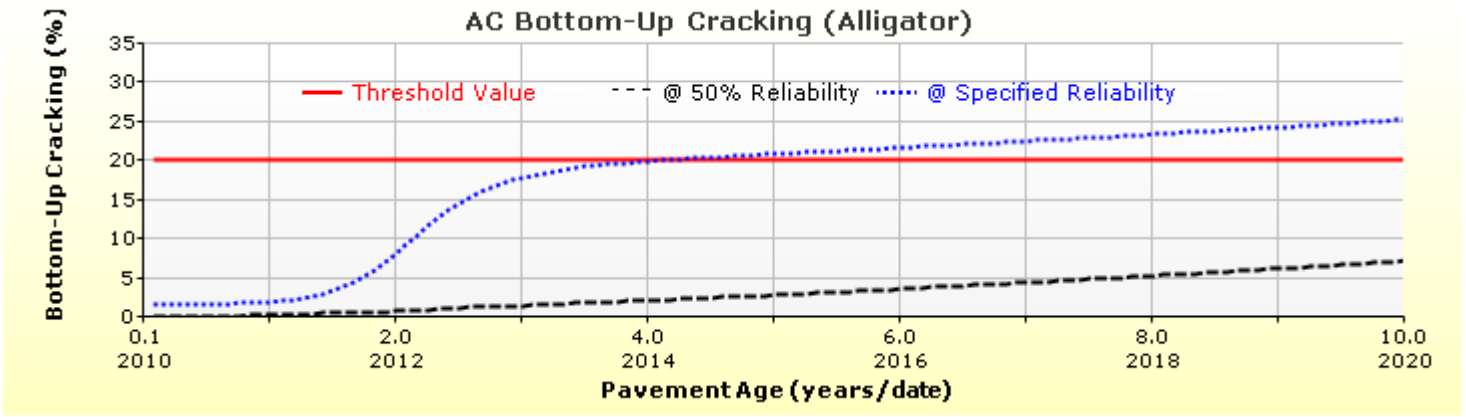


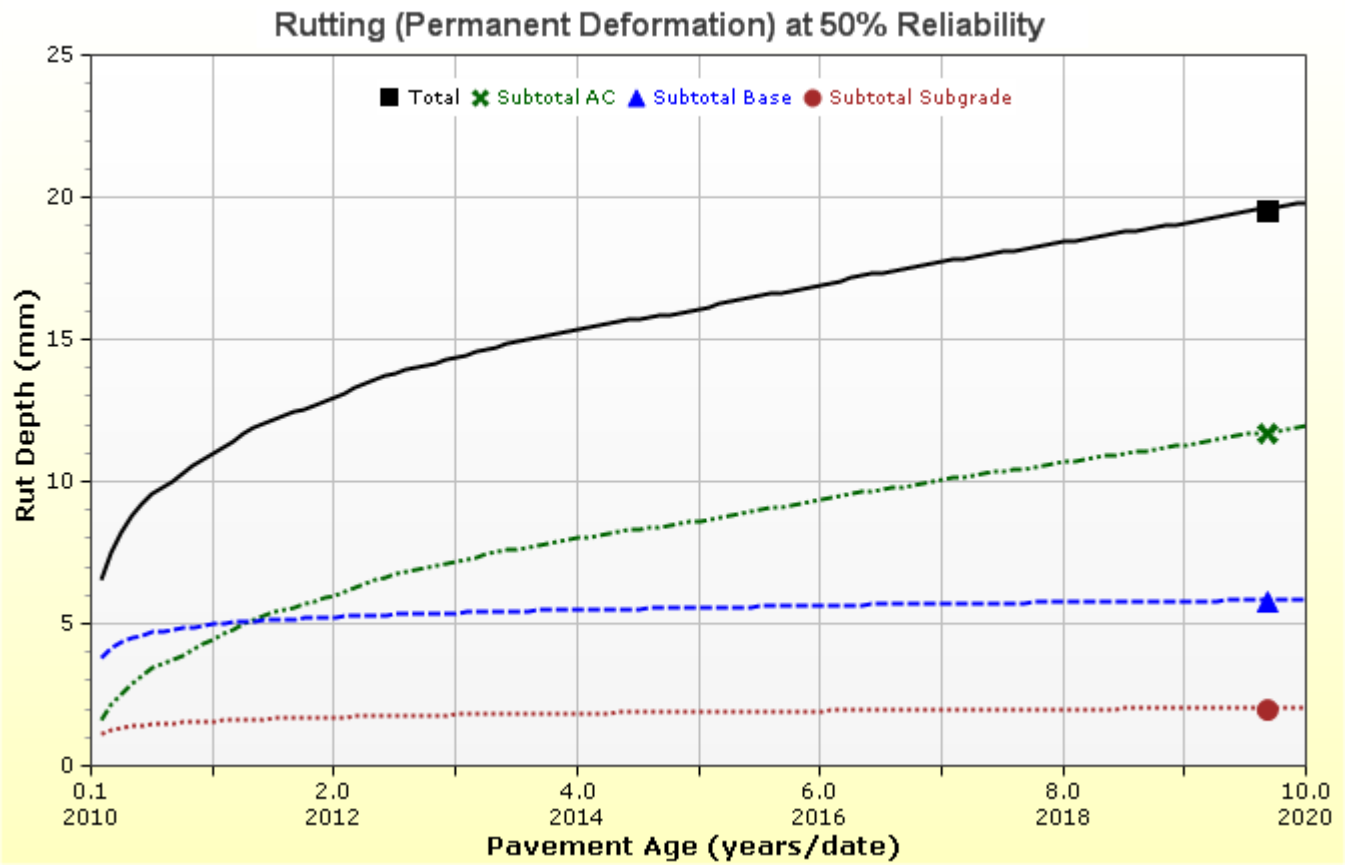


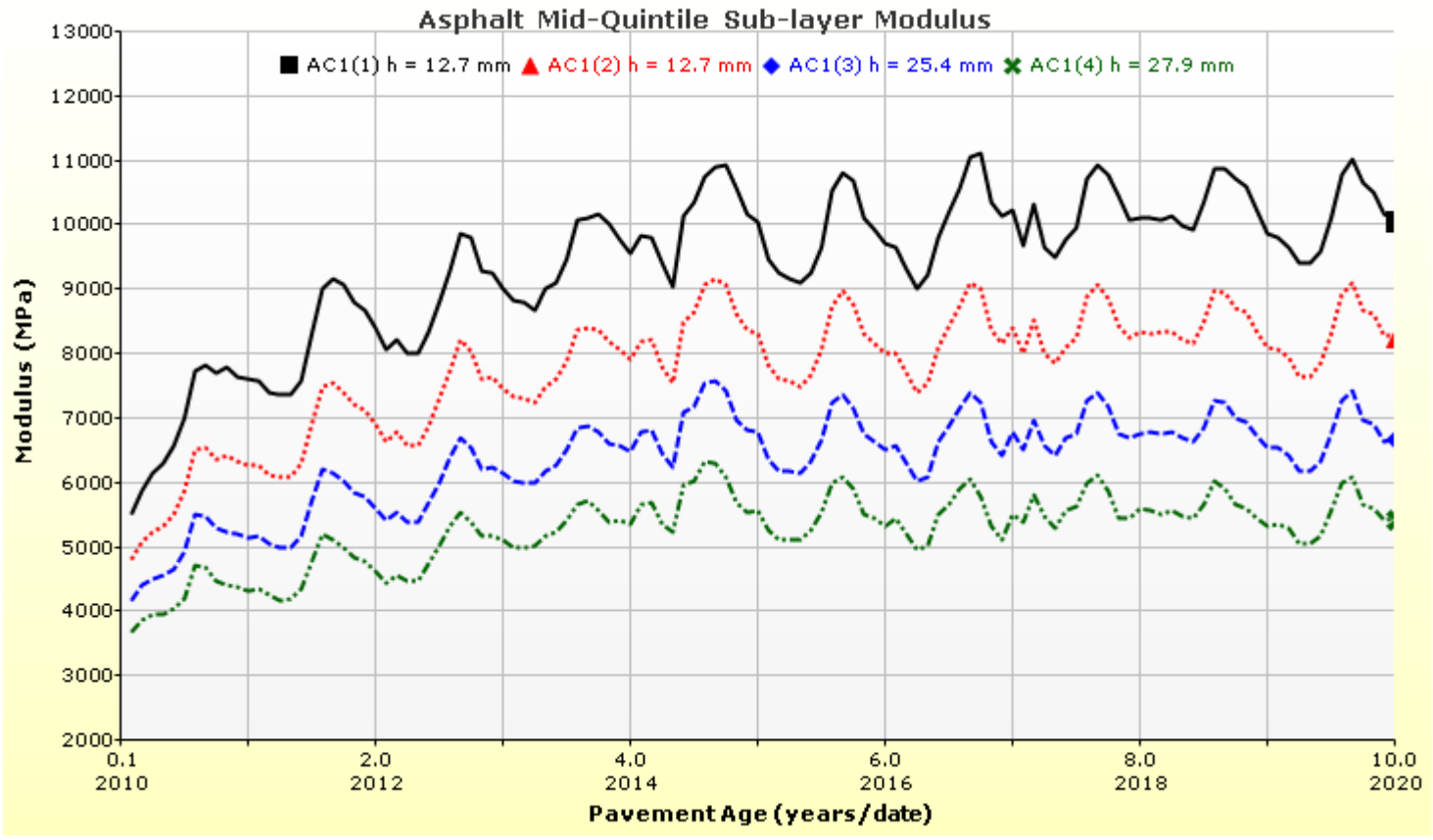

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
35
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

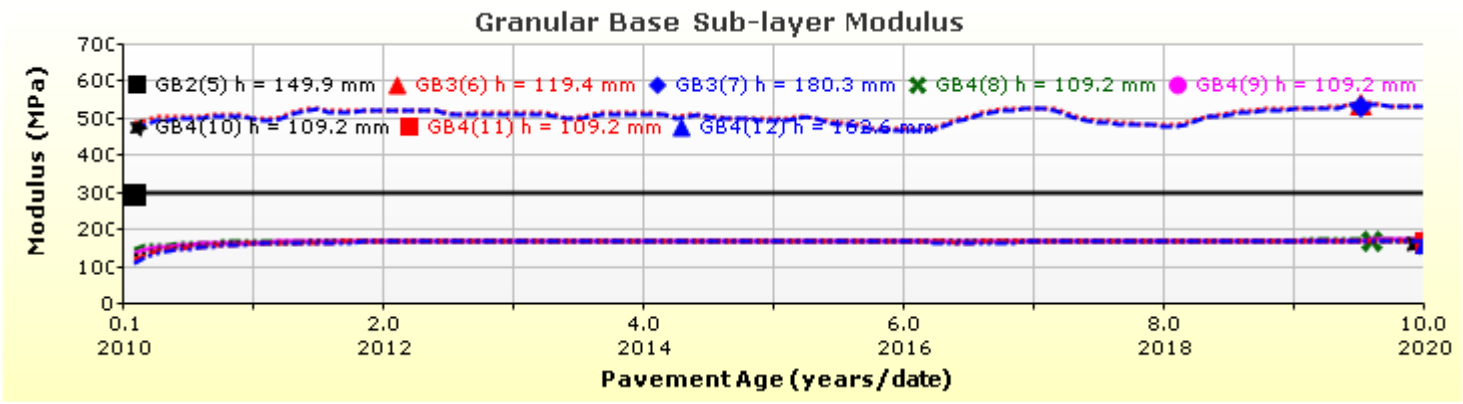

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
18
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

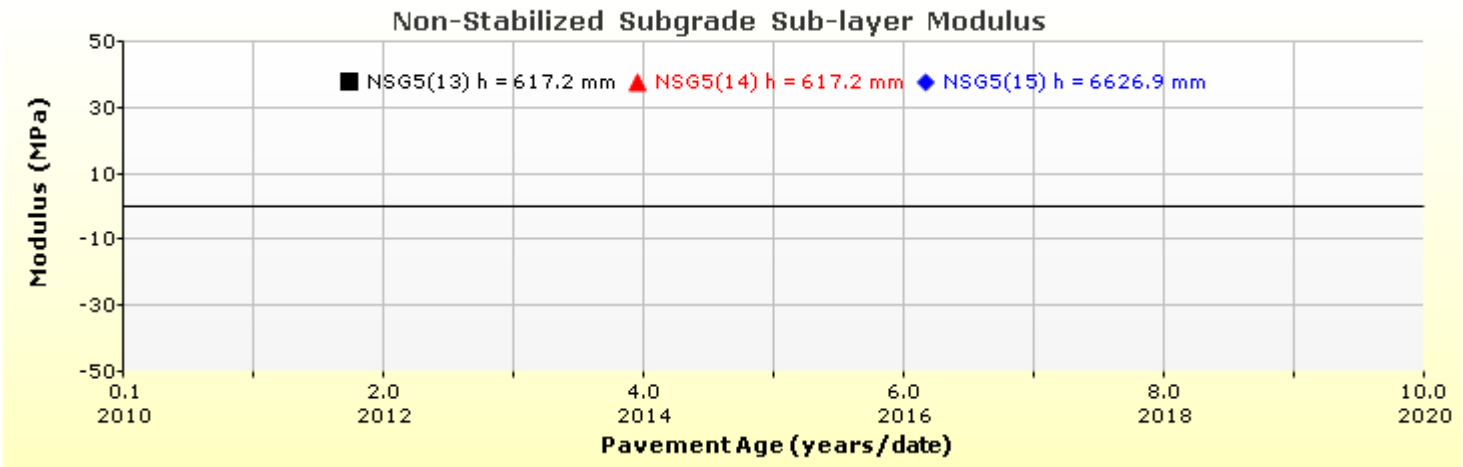

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
90
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
35
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 168.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 1
Bf2: 1
Bf3: 1

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestCE_vento

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestCE_vento.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -3.77, -38.55

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

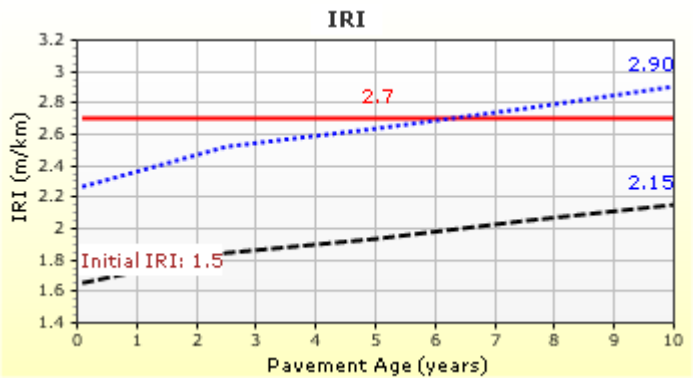
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

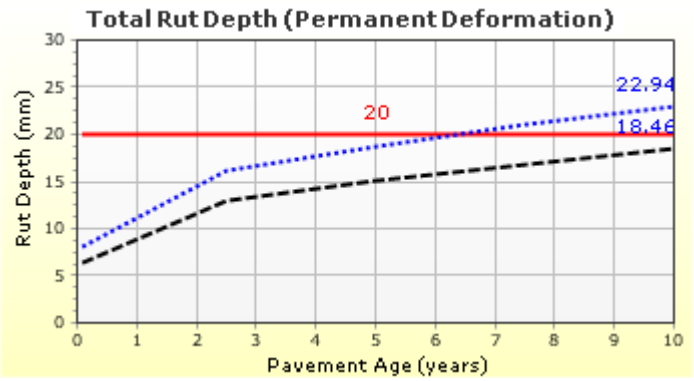
Design Outputs

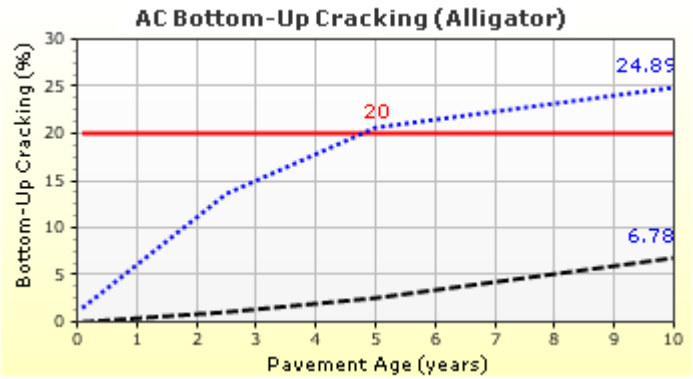
Distress Prediction Summary

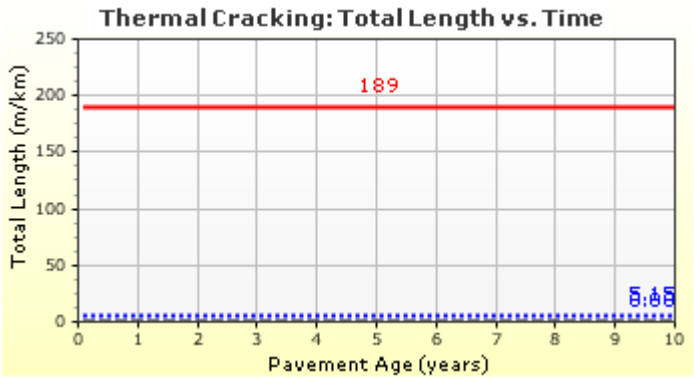
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.90	90.00	82.76	Fail
Permanent deformation - total pavement (mm)	20.00	22.93	90.00	66.92	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.89	90.00	82.53	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	741.89	90.00	65.93	Fail
Permanent deformation - AC only (mm)	5.00	10.61	50.00	3.30	Fail

Distress Charts







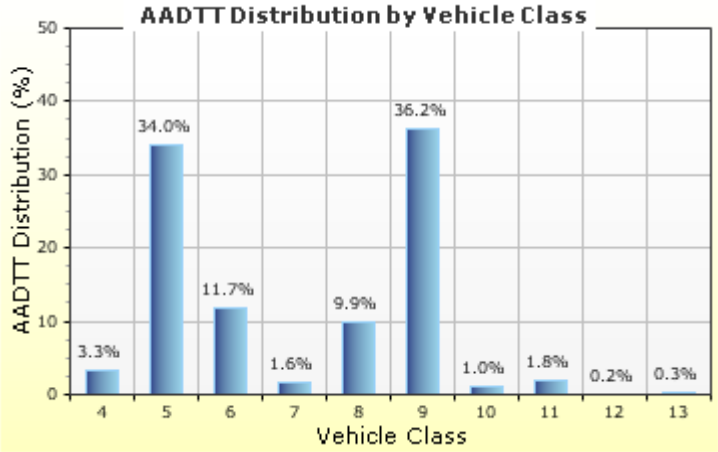


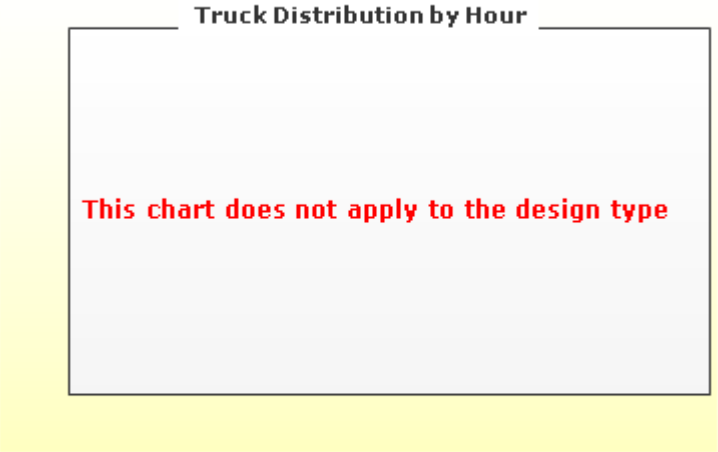


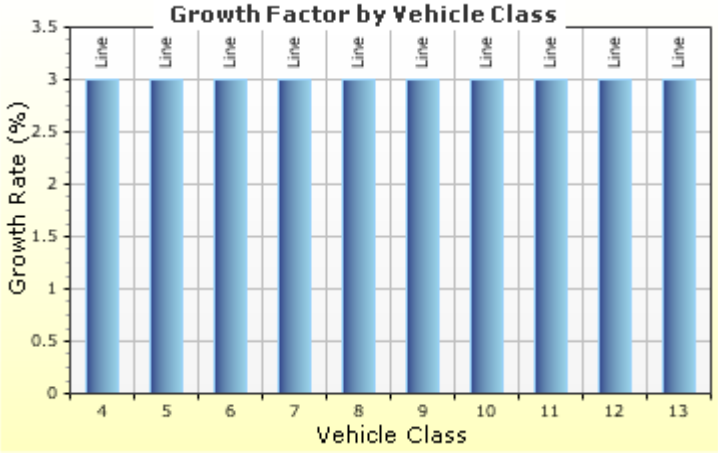
Traffic Inputs

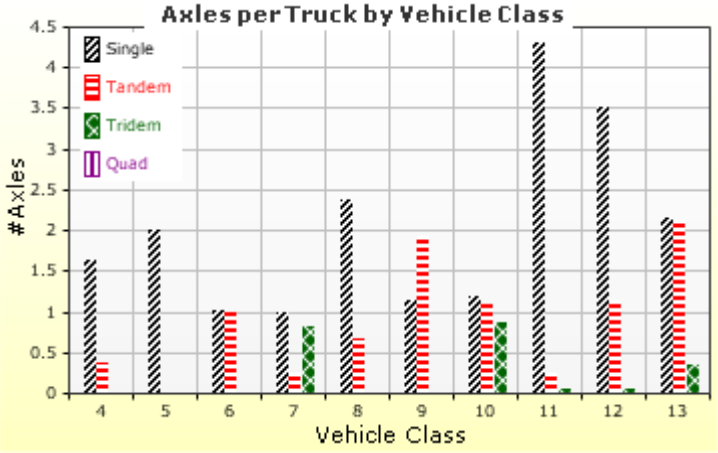
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

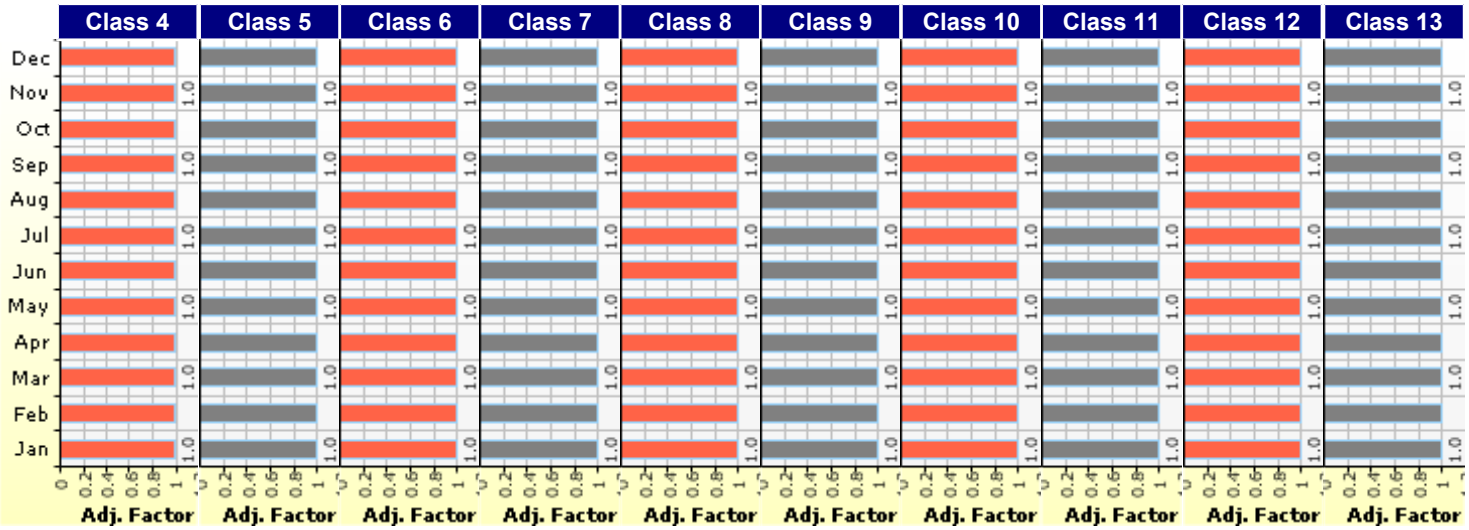








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

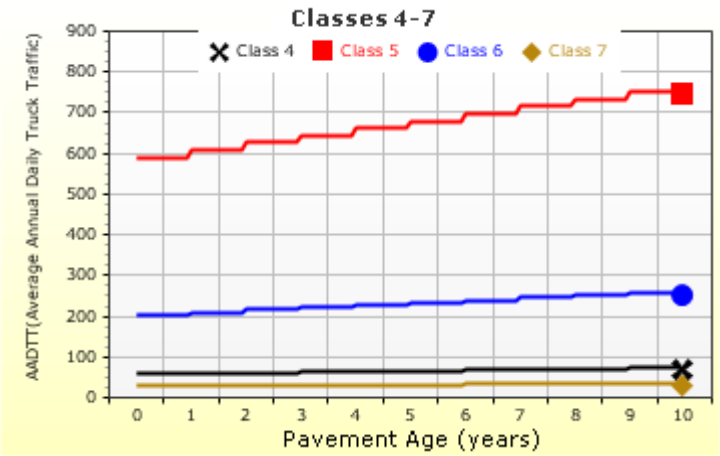
Wheelbase does not apply

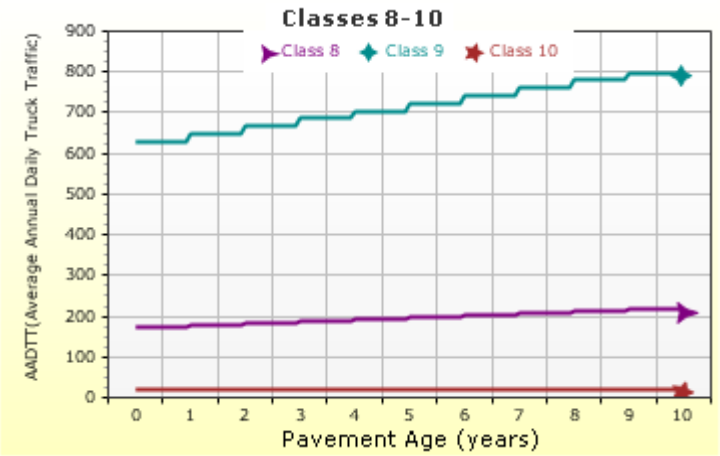
Number of Axles per Truck

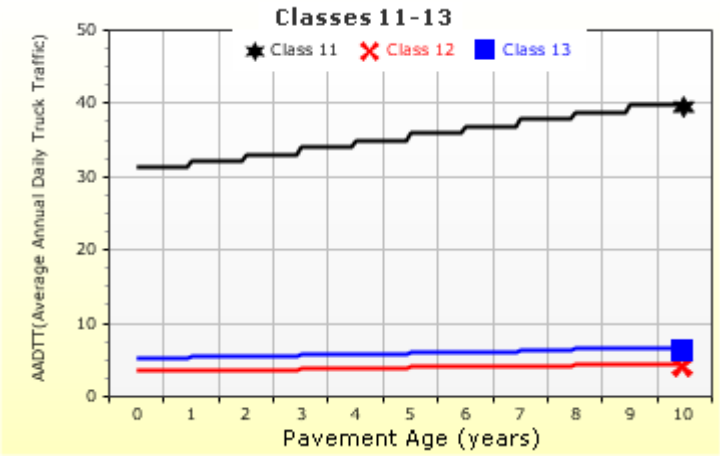
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

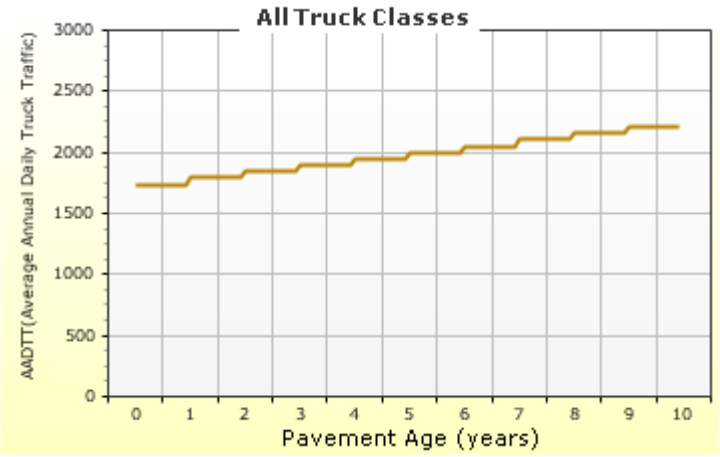
AADTT (Average Annual Daily Truck Traffic) Growth

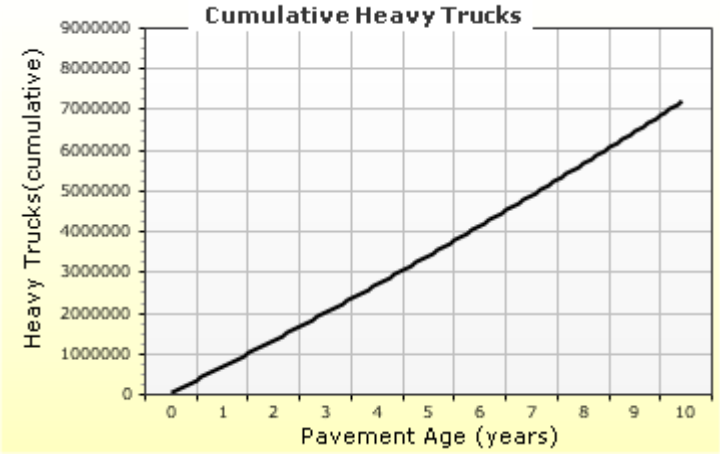
*** Traffic cap is not enforced**







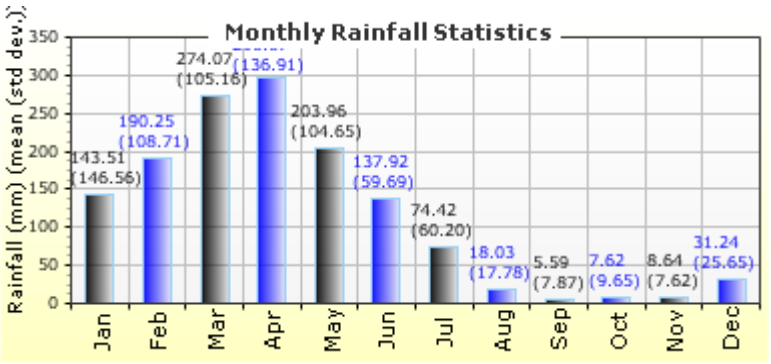




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
FORTALEZA, CE	-3.77000 -38.55000 41

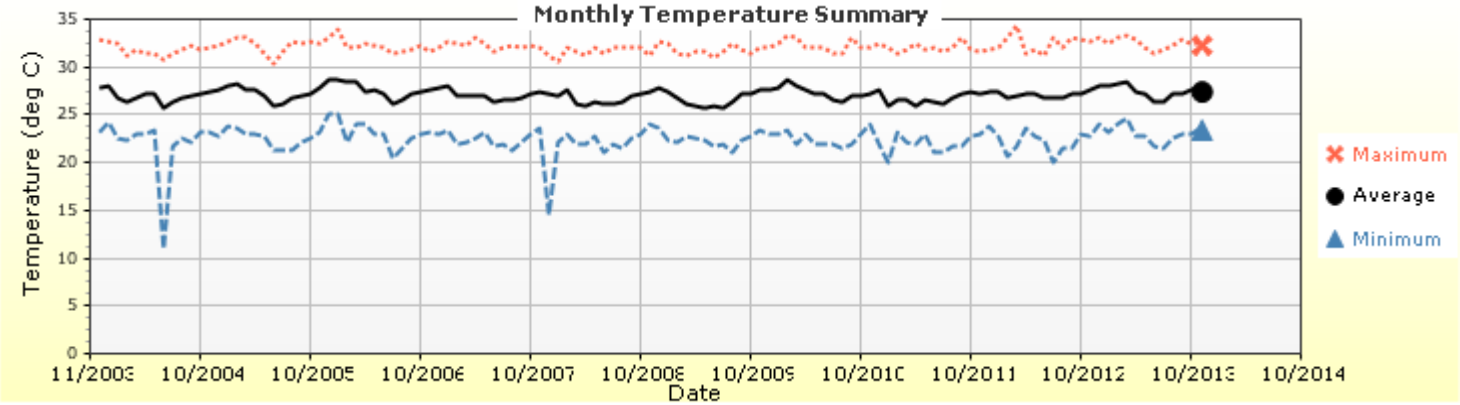


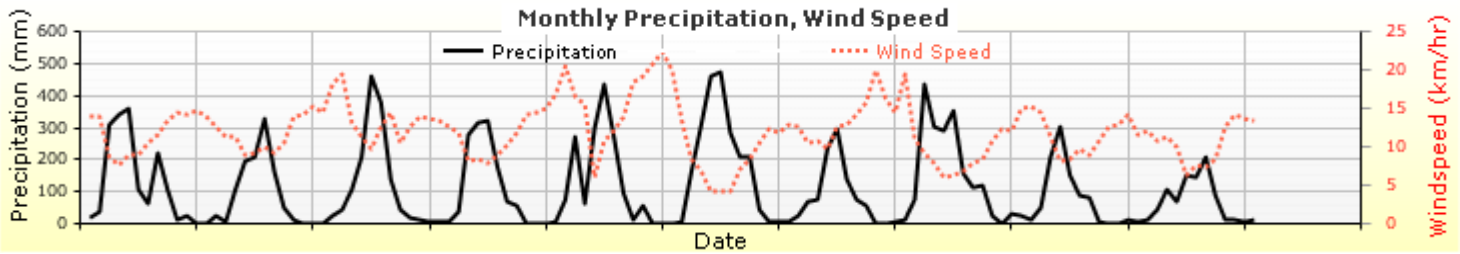
Annual Statistics:

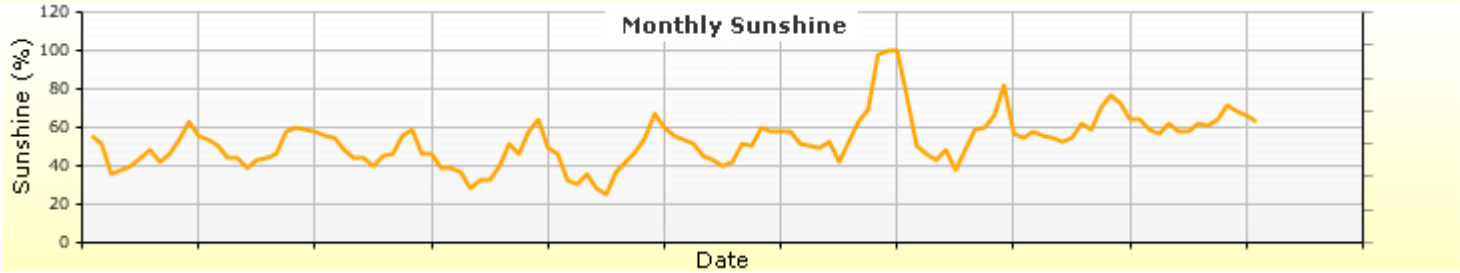
Mean annual air temperature (ºC)	27.09
Mean annual precipitation (mm)	1370.58
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

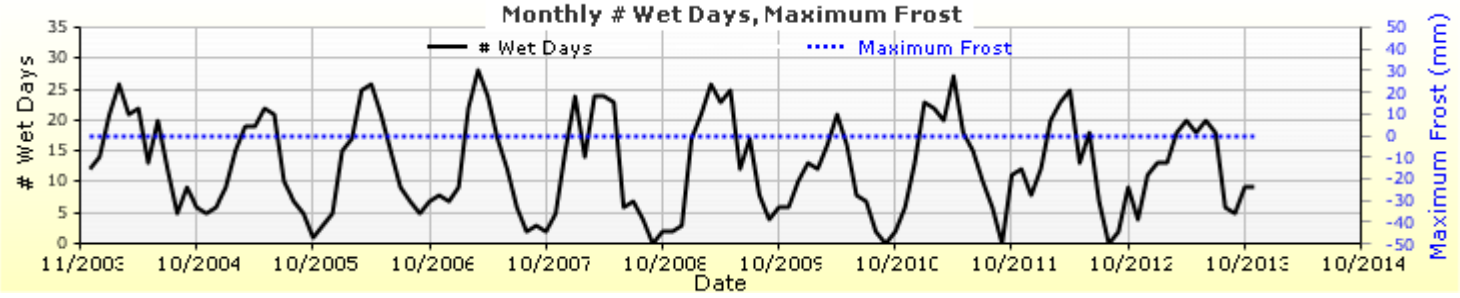
Water table depth (m): 3.05

Monthly Climate Summary:

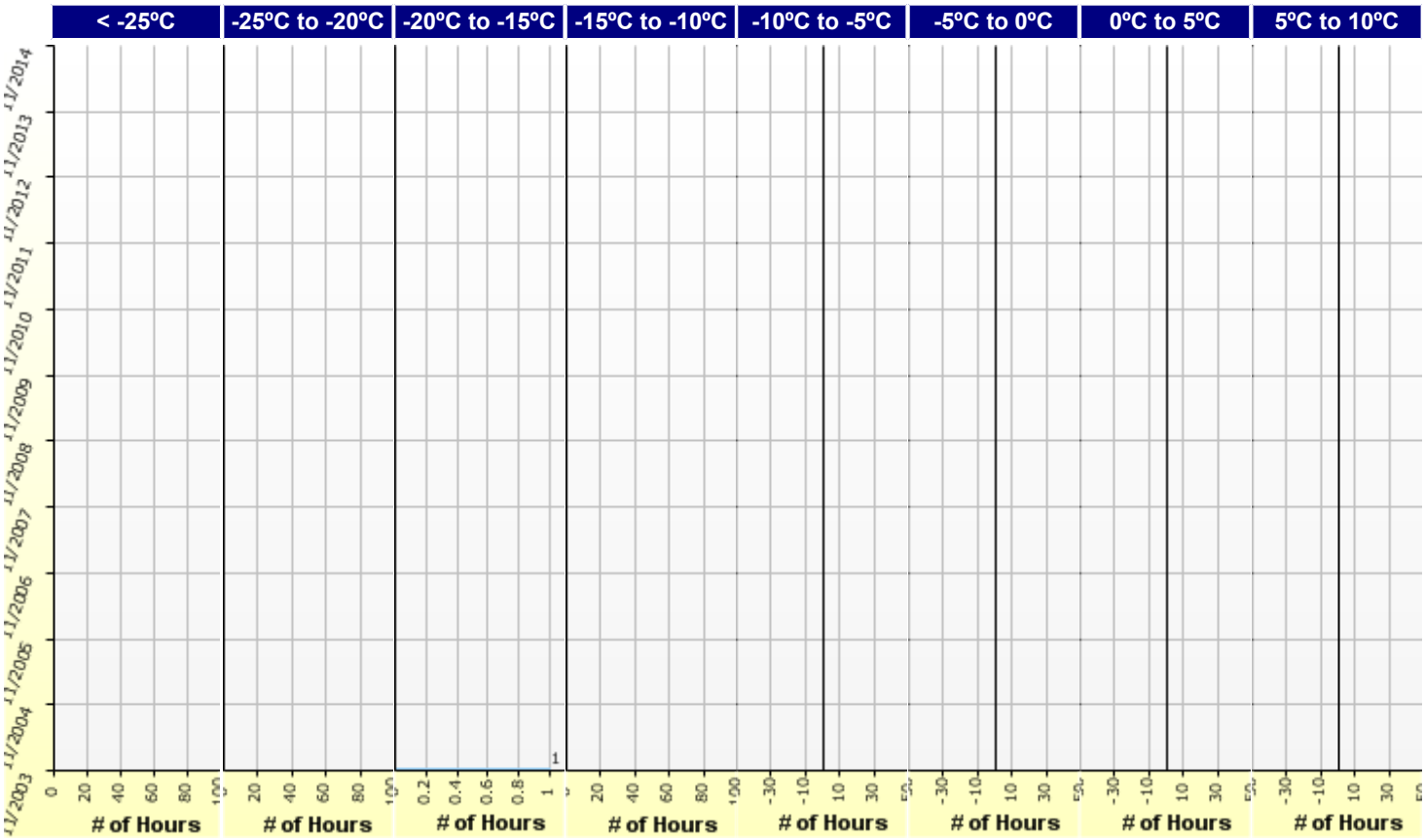


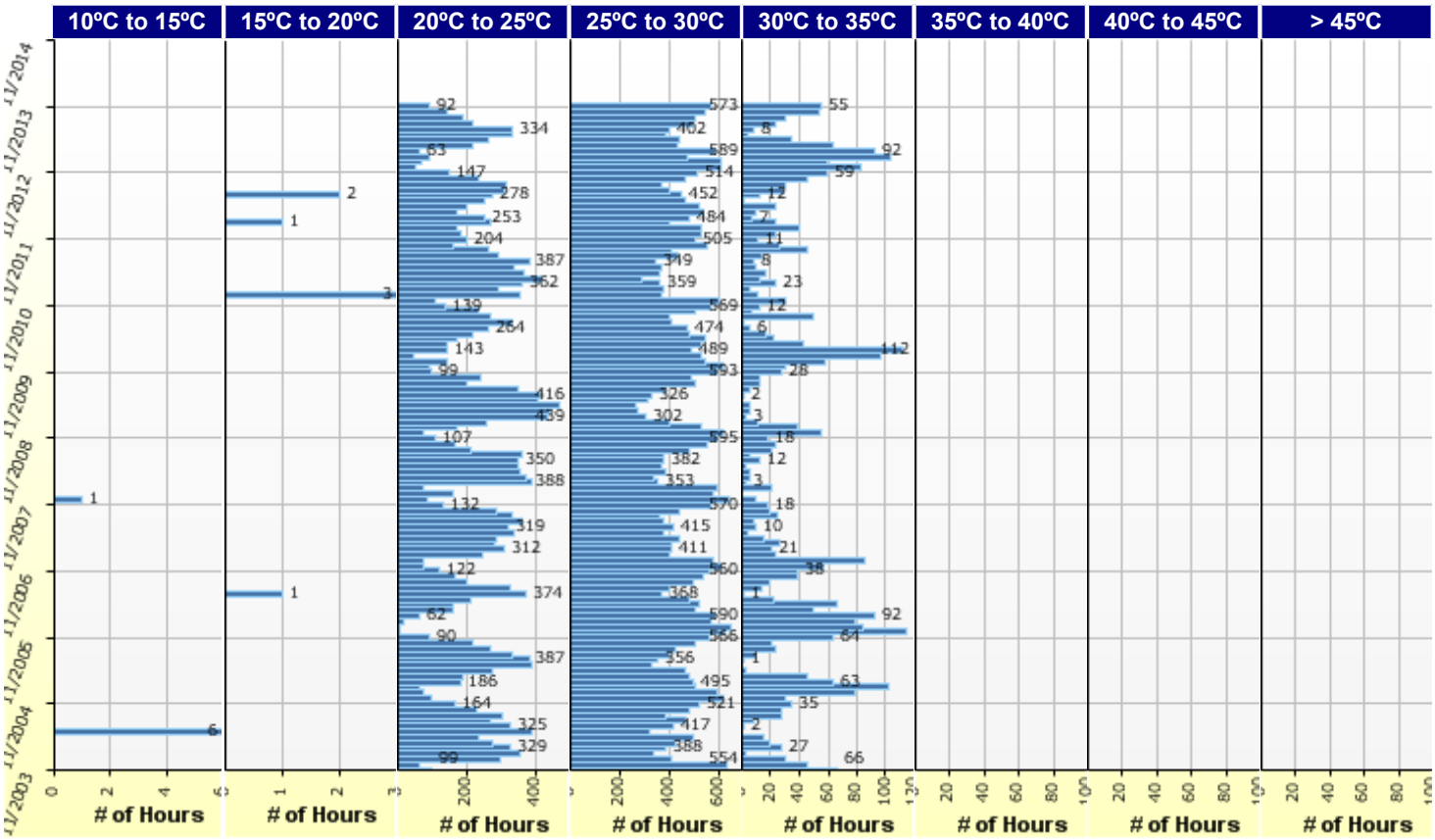






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

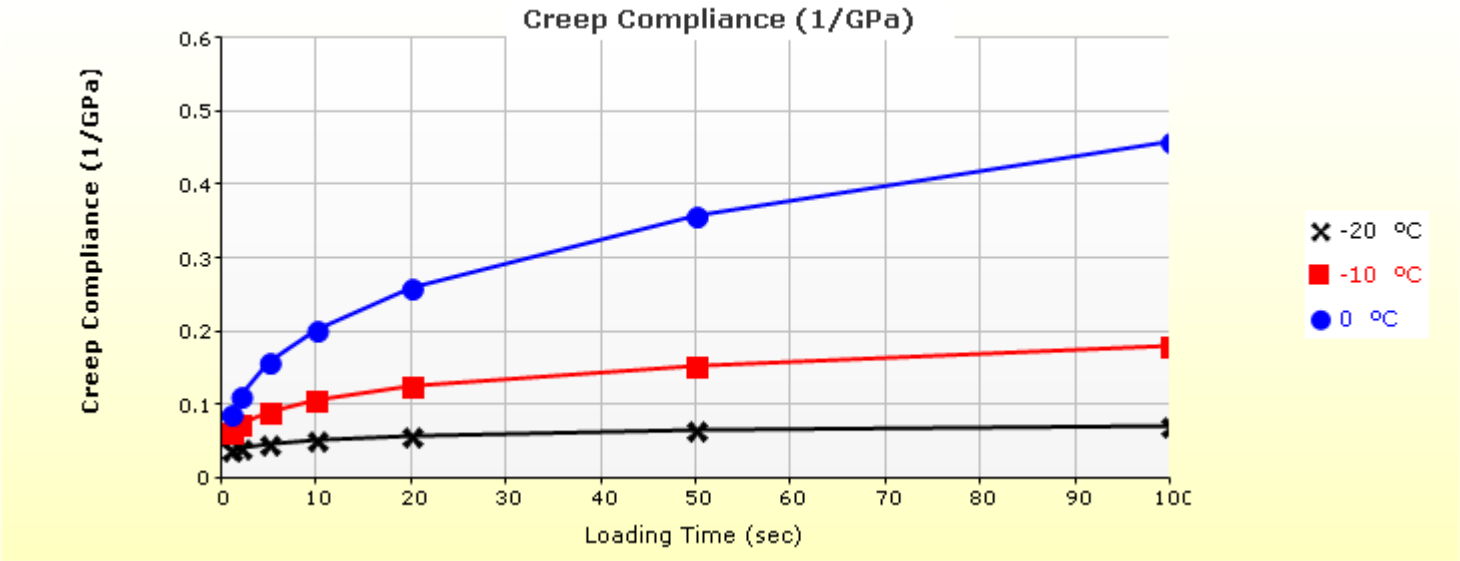
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

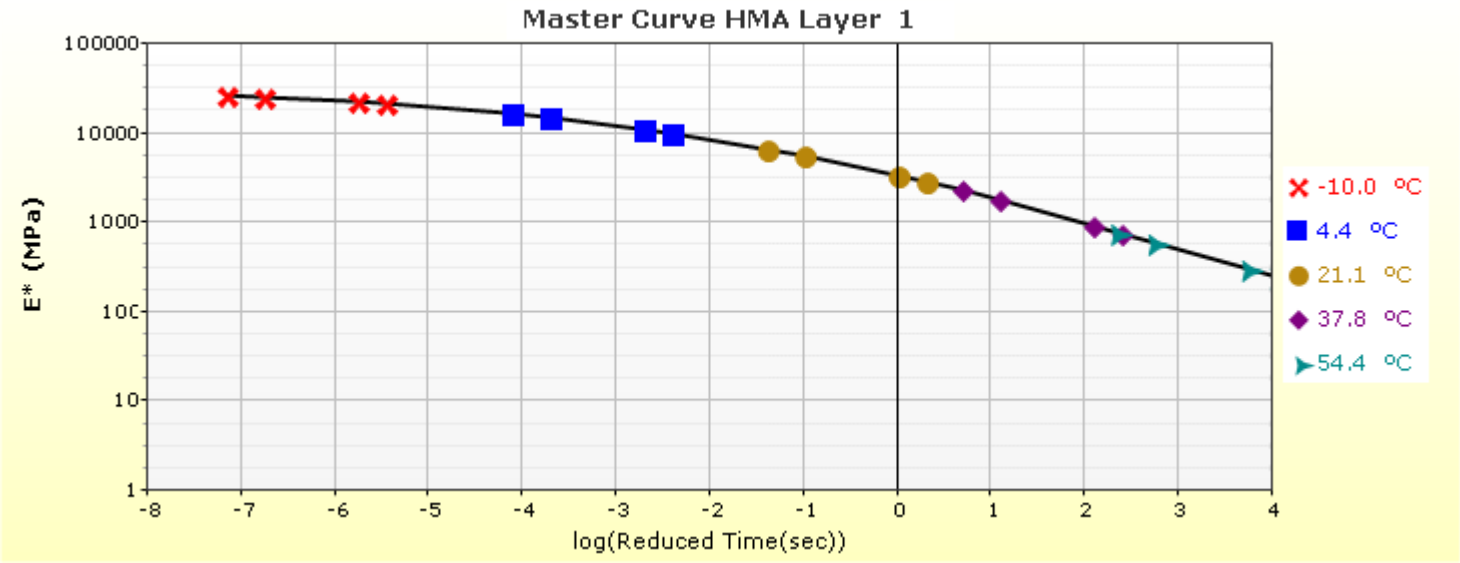
Indirect tensile strength at -10 ºC (MPa)	2.69

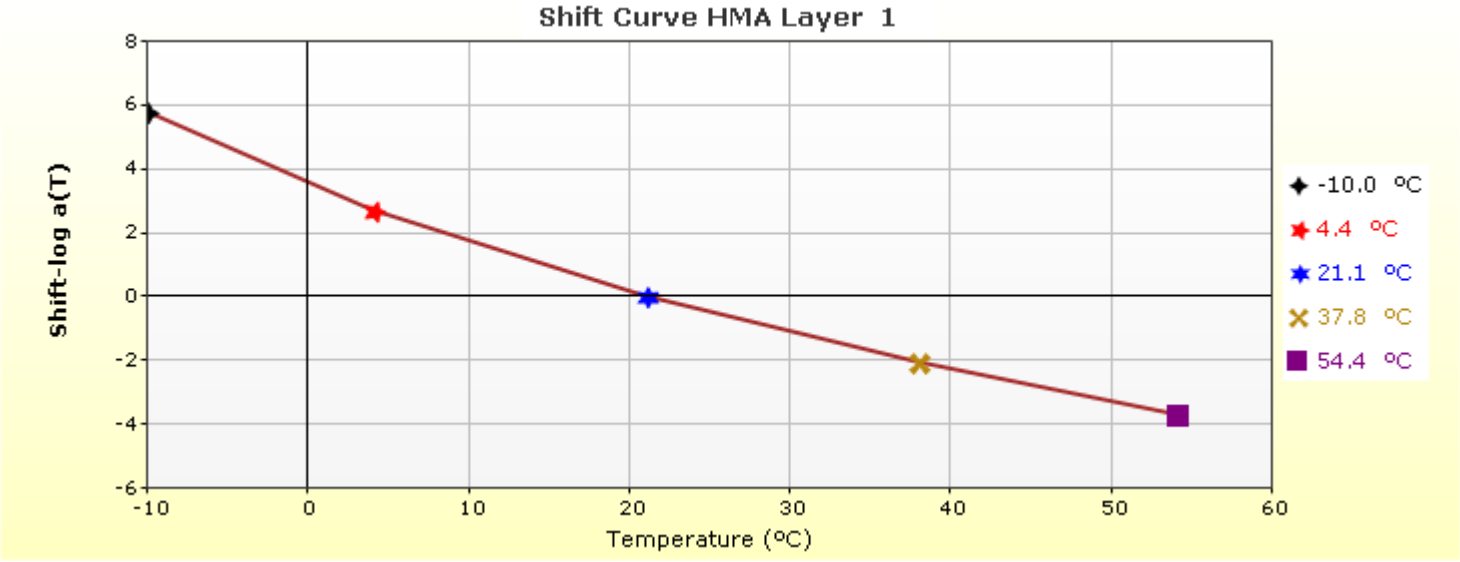
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

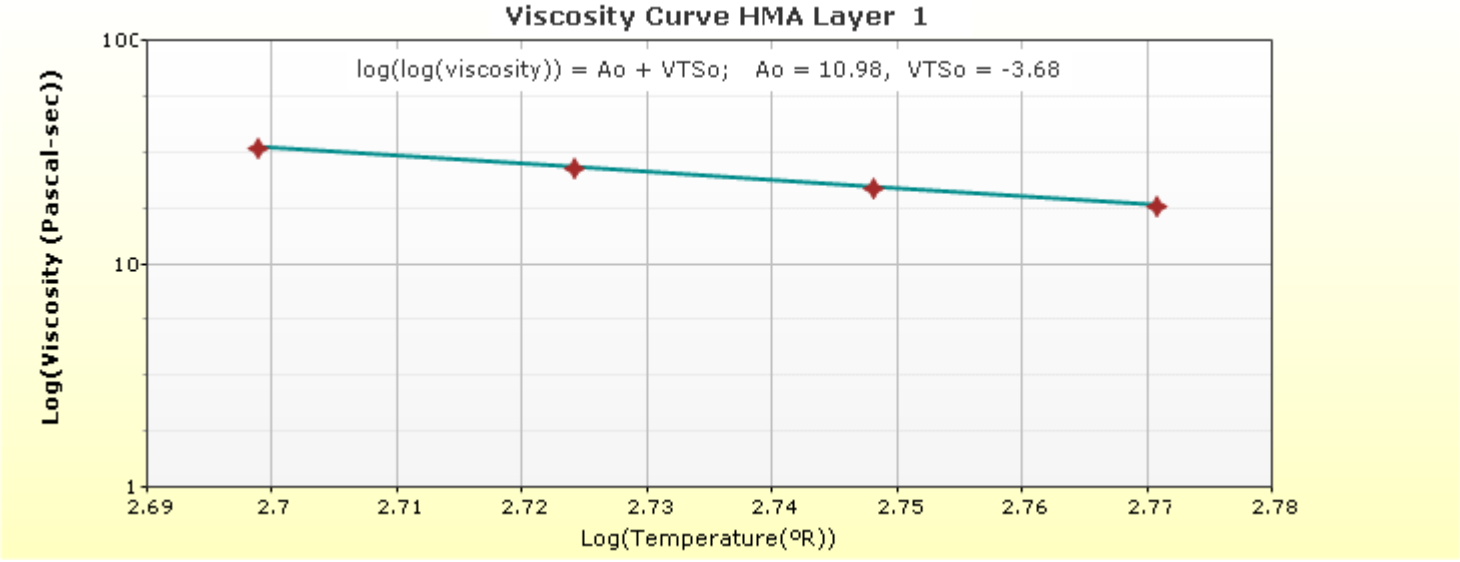
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



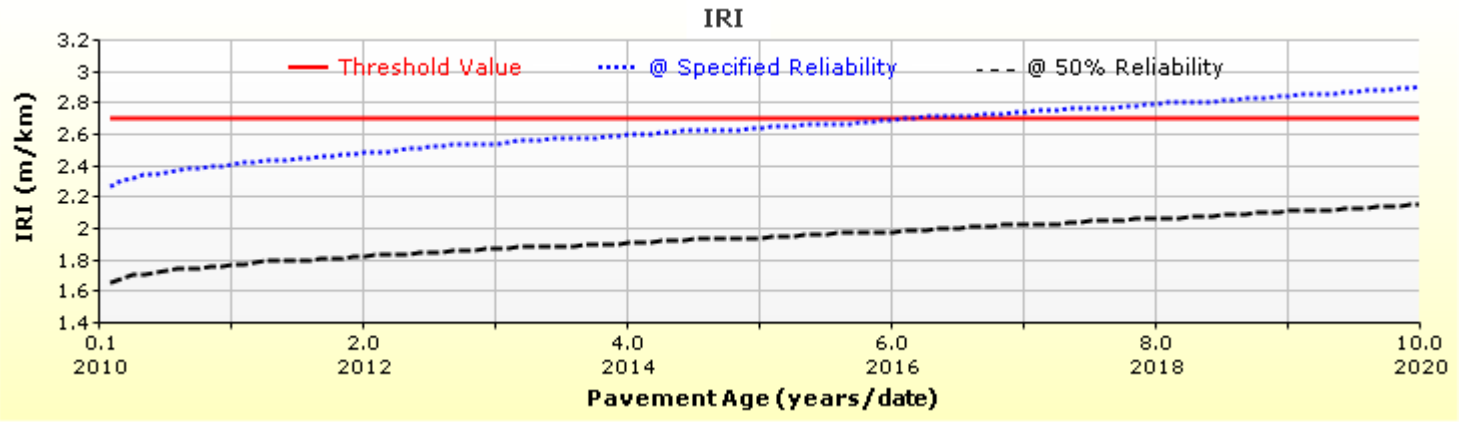
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

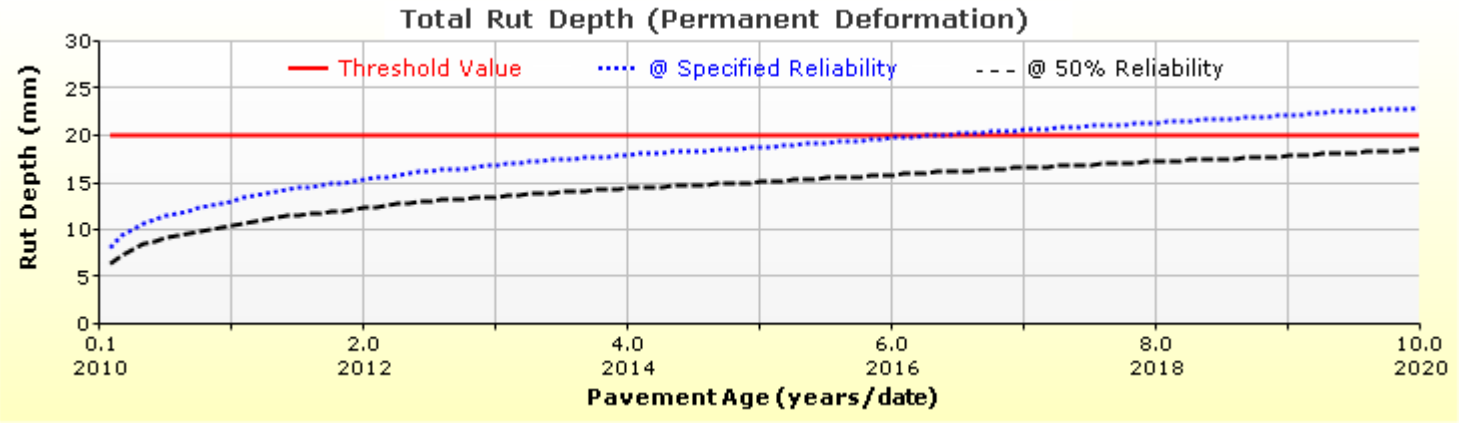


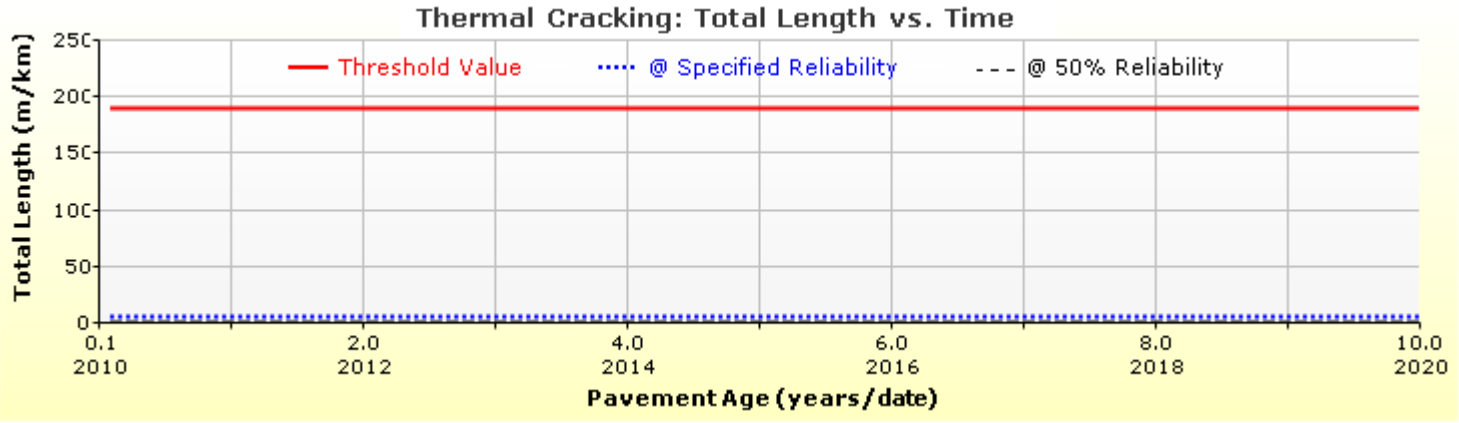


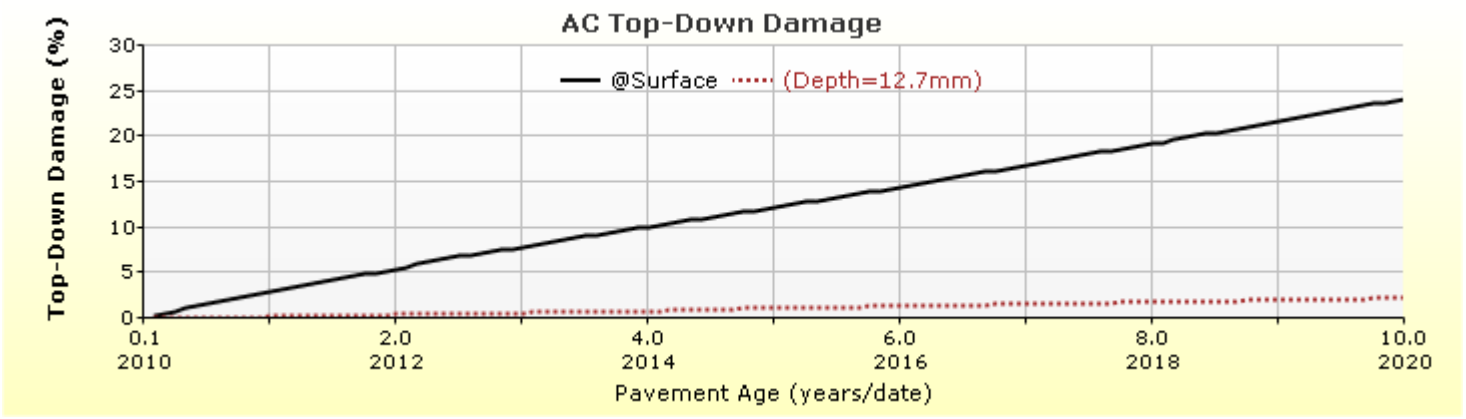


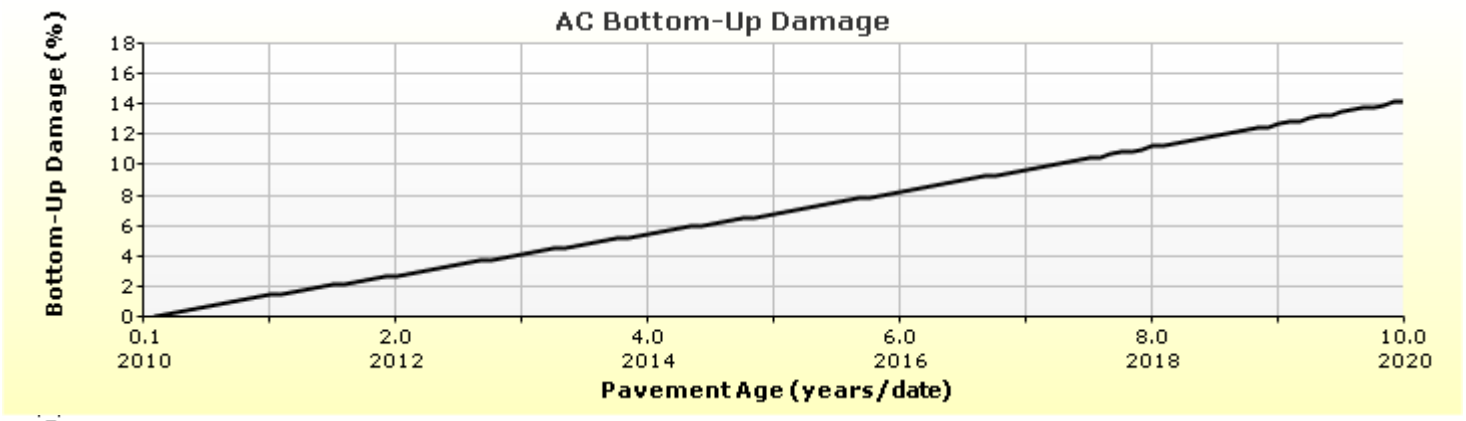
Analysis Output Charts

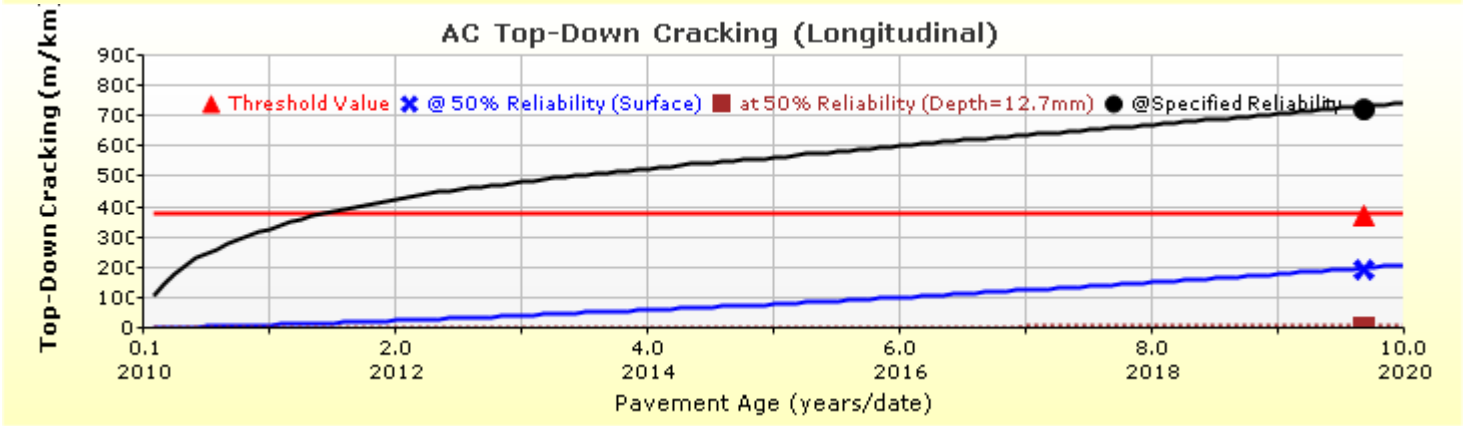


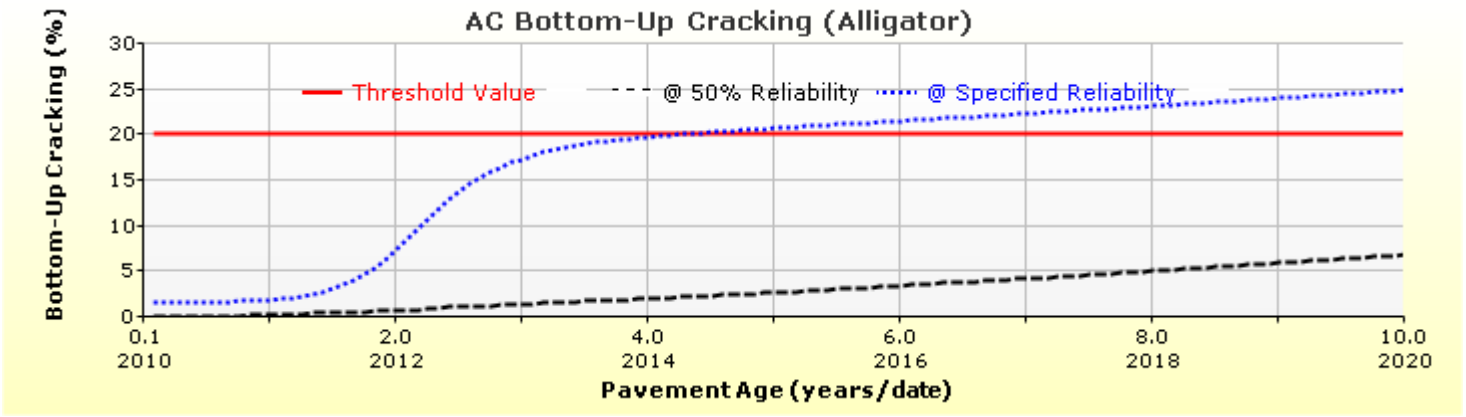


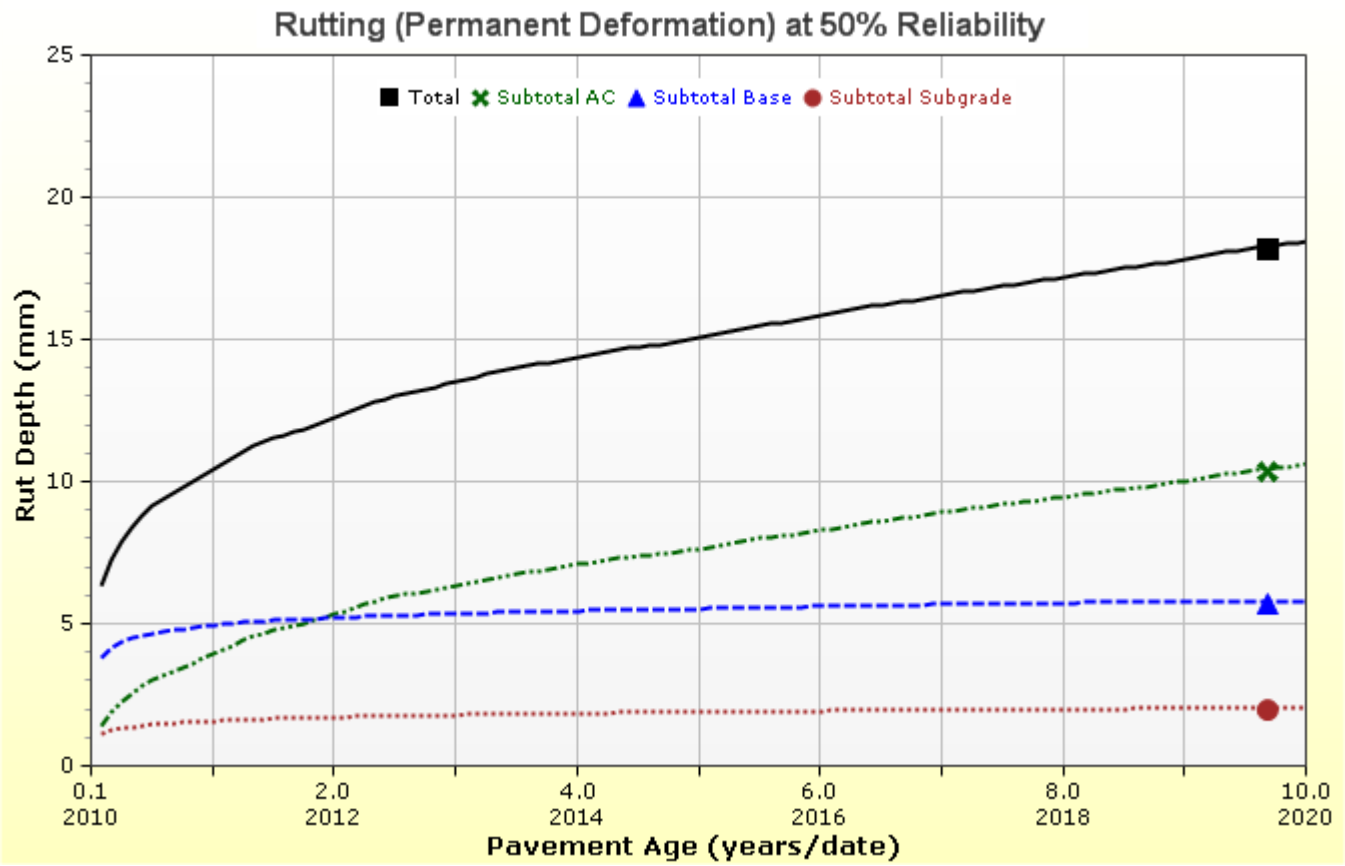


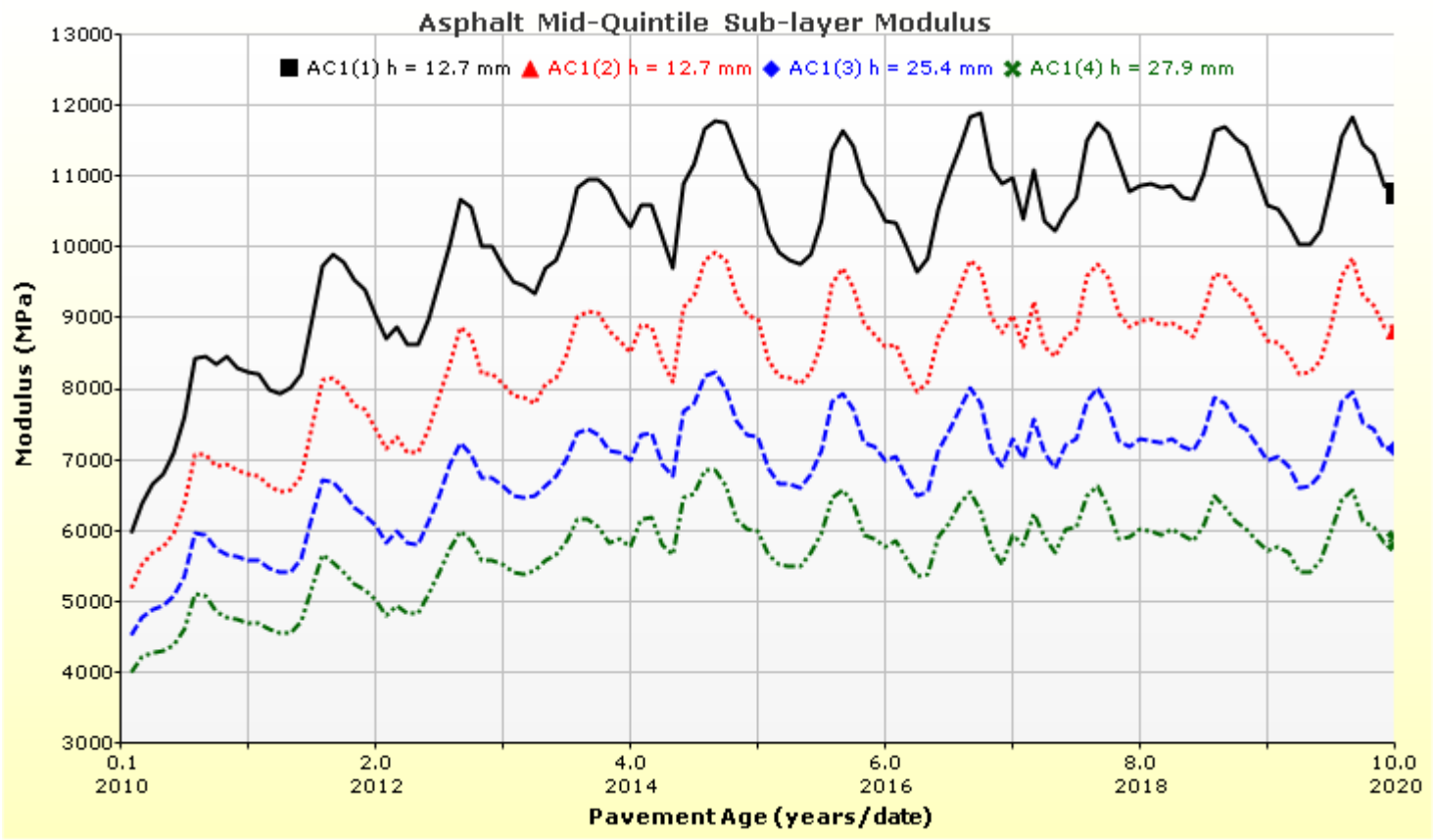

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

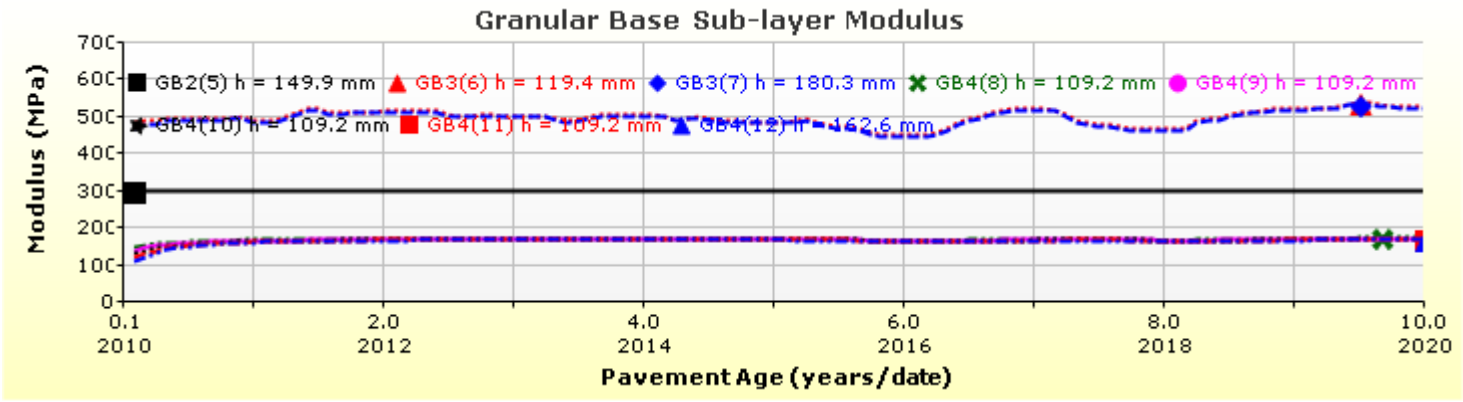

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

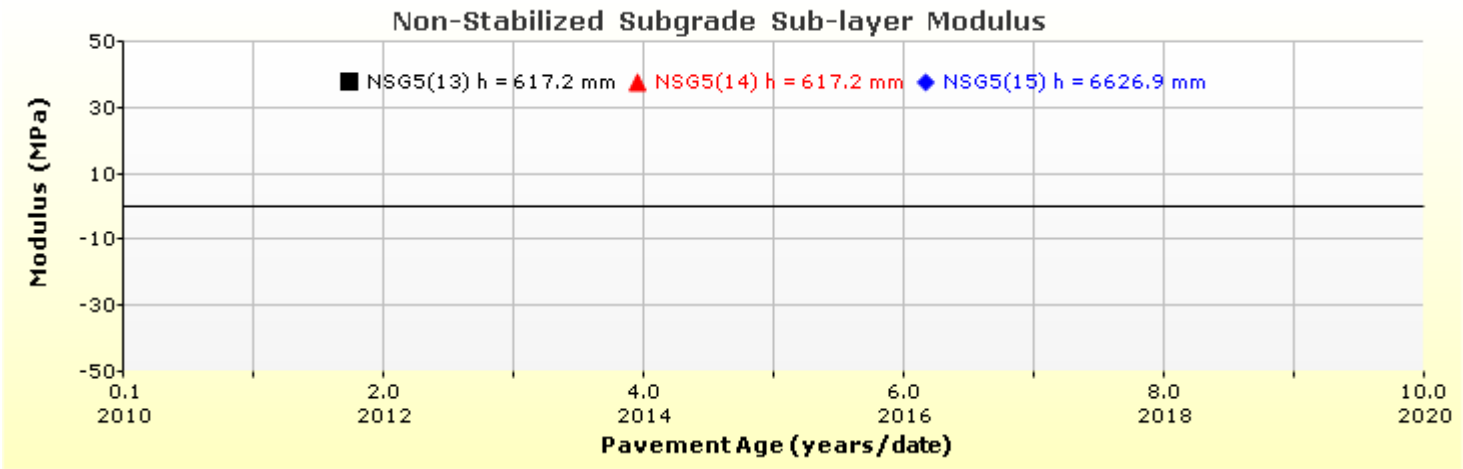

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
90
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2\beta_{r2}} N^{k_3\beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{\alpha}^2 + 2.4868 * H_{\alpha} - 17.342$$

$$C_2 = 0.0172 * H_{\alpha}^2 - 1.7331 * H_{\alpha} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRS

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRS.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -30.05, -51.17

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

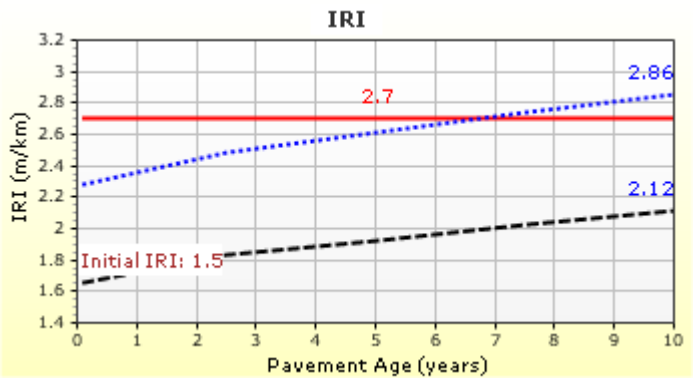
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

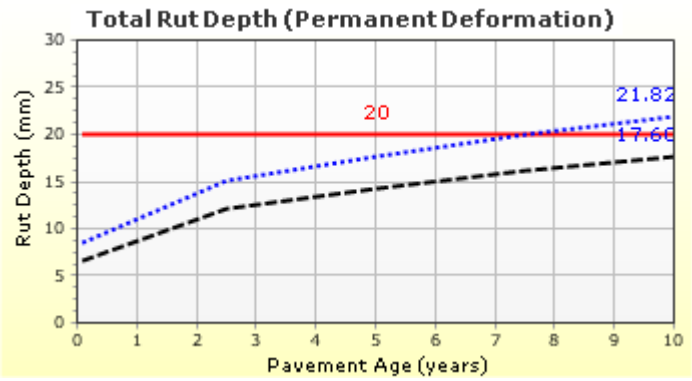
Design Outputs

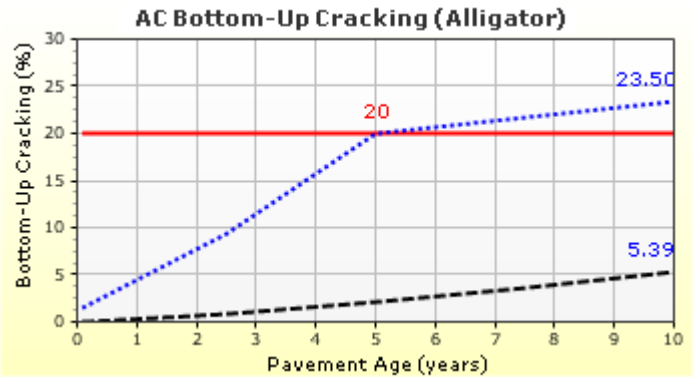
Distress Prediction Summary

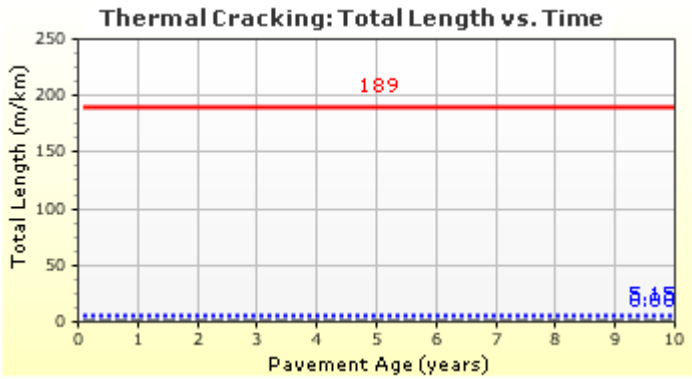
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.85	90.00	84.45	Fail
Permanent deformation - total pavement (mm)	20.00	21.82	90.00	76.63	Fail
AC bottom-up fatigue cracking (percent)	20.00	23.50	90.00	84.95	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	669.95	90.00	71.33	Fail
Permanent deformation - AC only (mm)	5.00	9.61	50.00	5.11	Fail

Distress Charts







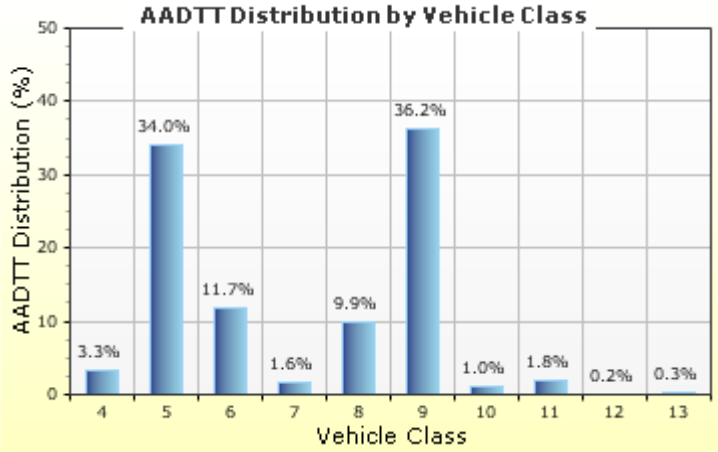


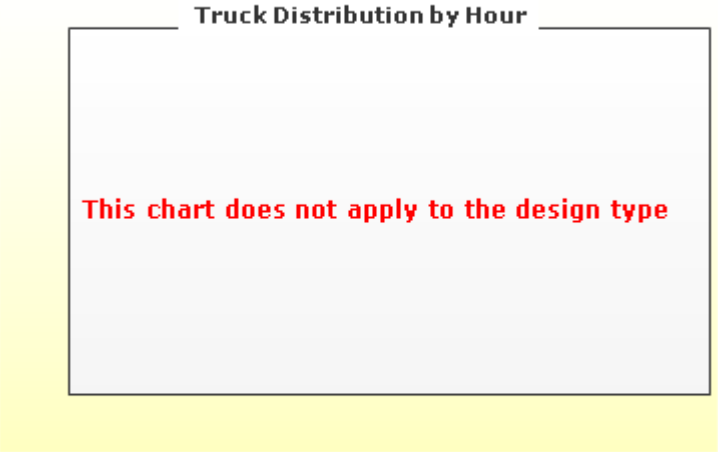
Threshold Value @ Specified Reliability @ 50% Reliability

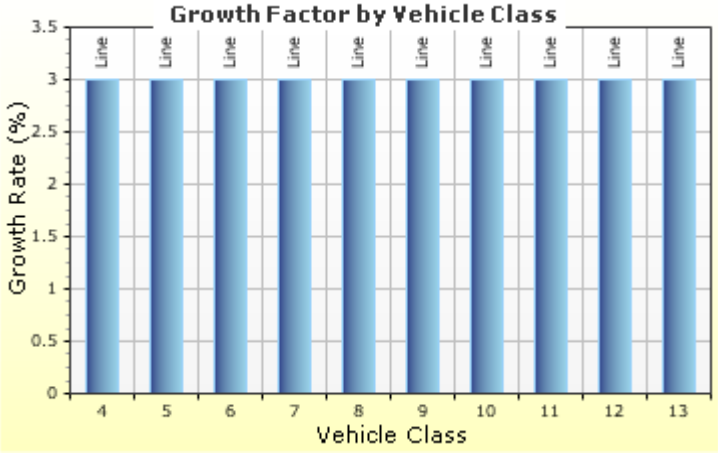
Traffic Inputs

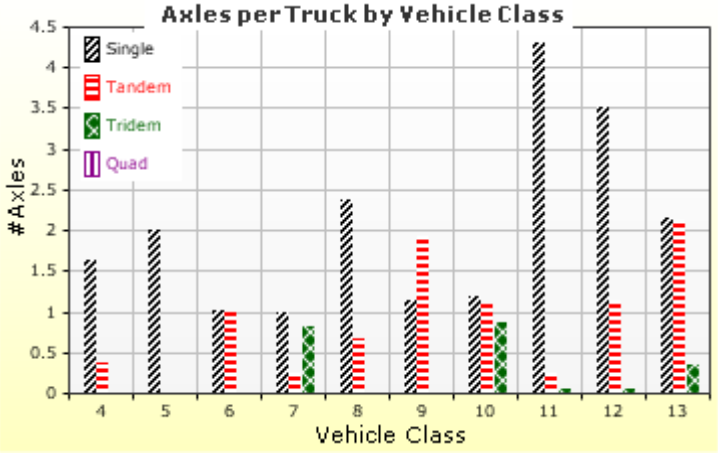
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

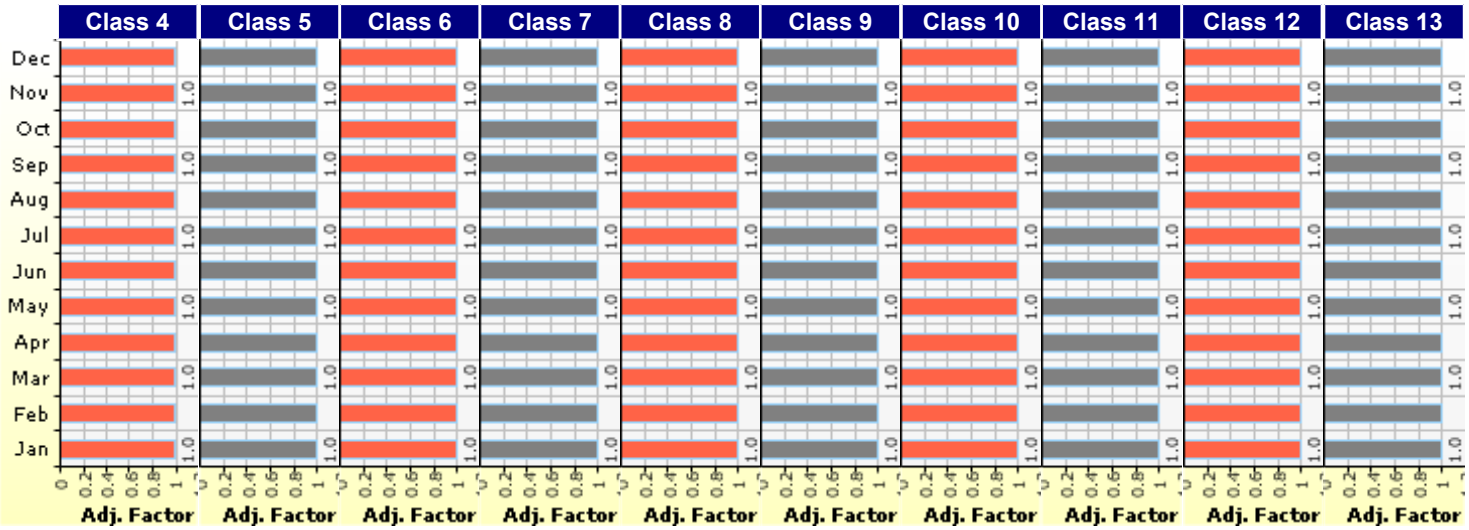








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

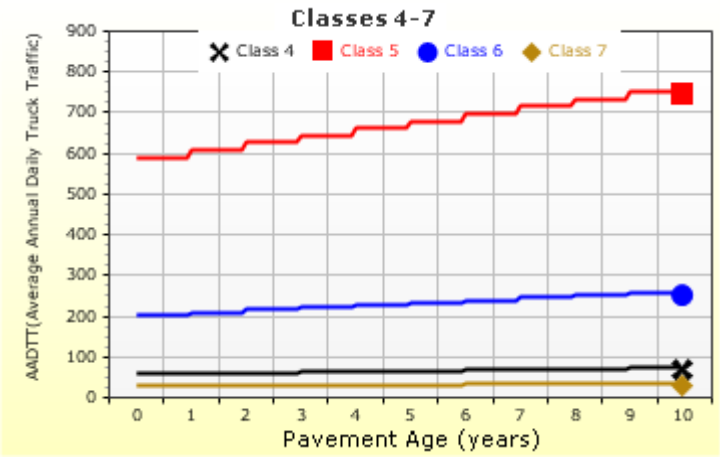
Wheelbase does not apply

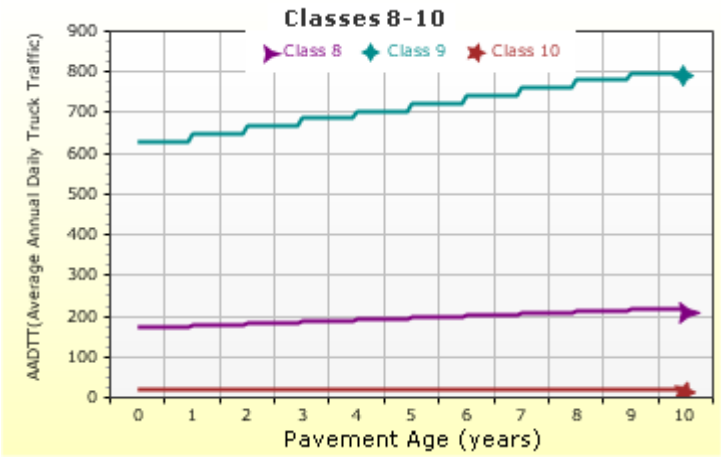
Number of Axles per Truck

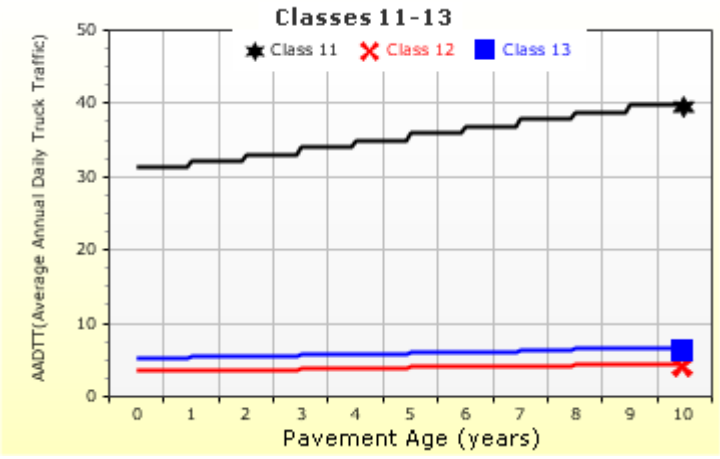
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

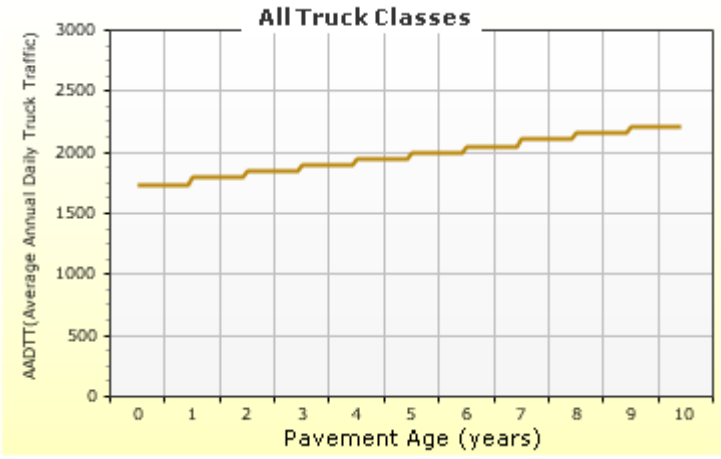
AADTT (Average Annual Daily Truck Traffic) Growth

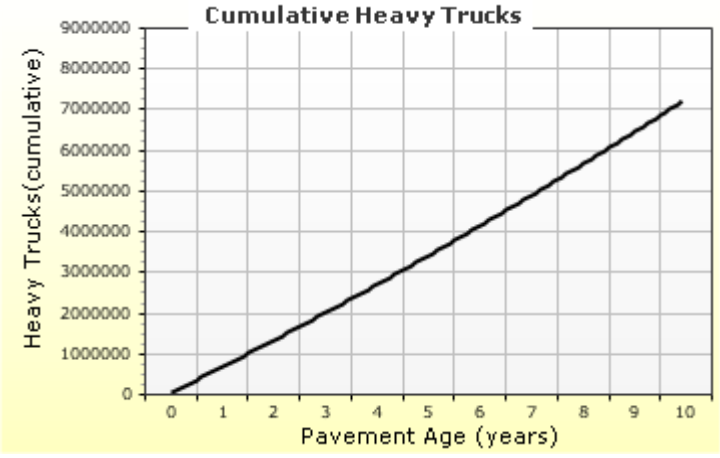
*** Traffic cap is not enforced**







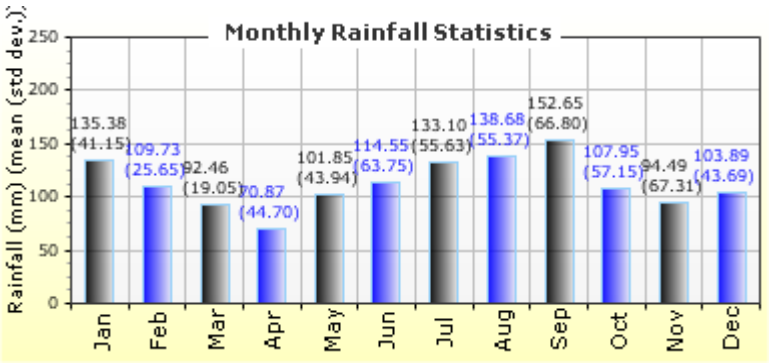




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
PORTO ALEGRE, RS	-30.05000 -51.17000 47

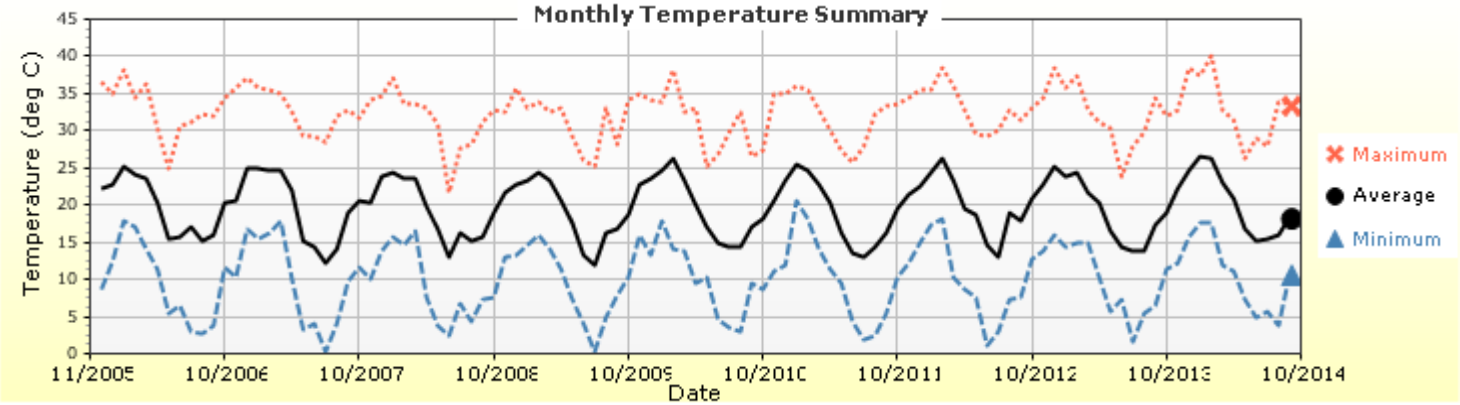


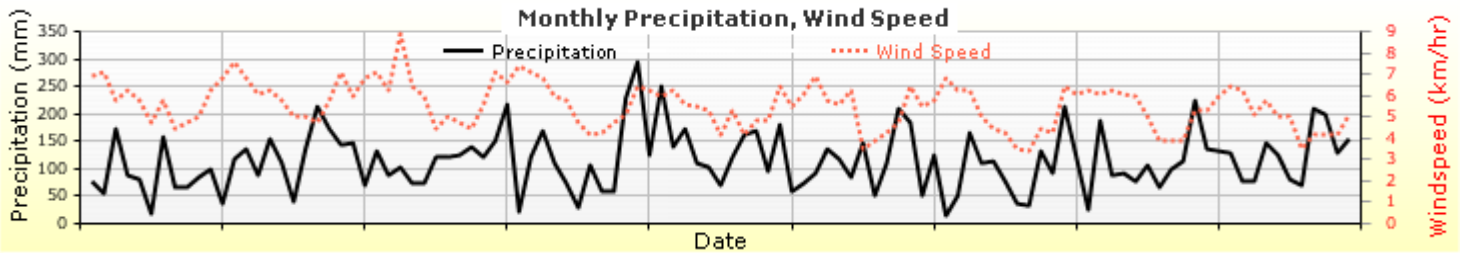
Annual Statistics:

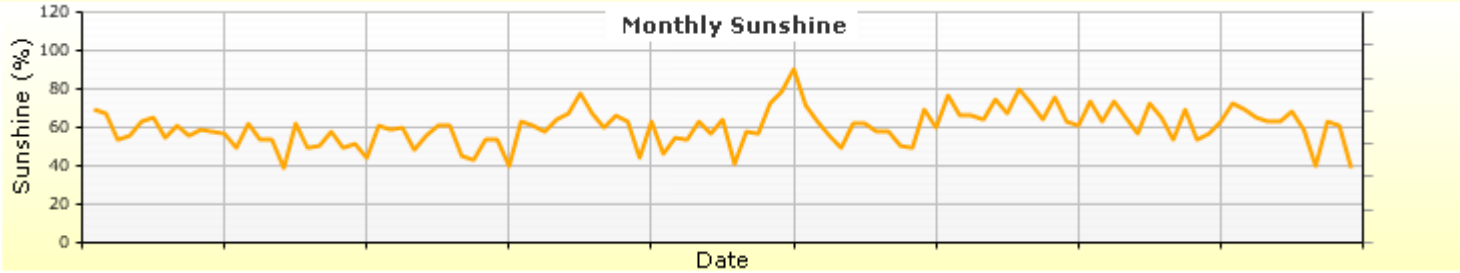
Mean annual air temperature (ºC)	19.73
Mean annual precipitation (mm)	1352.30
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

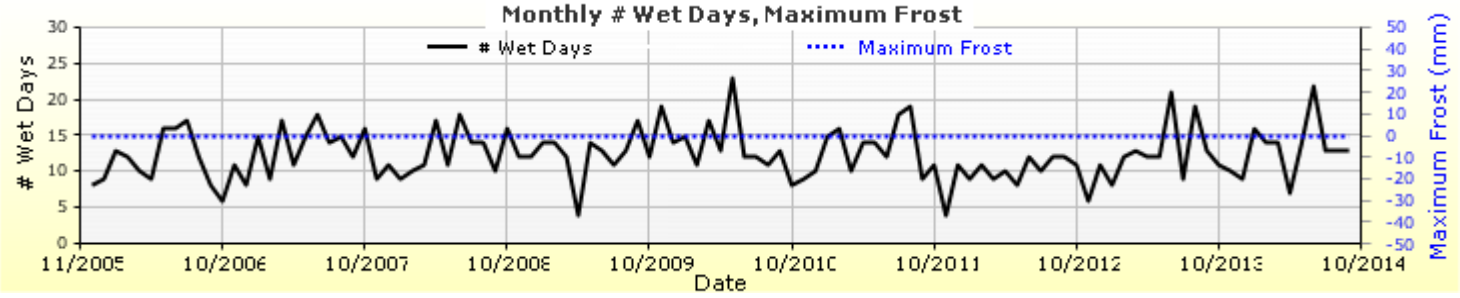
Water table depth (m)	3.05

Monthly Climate Summary:

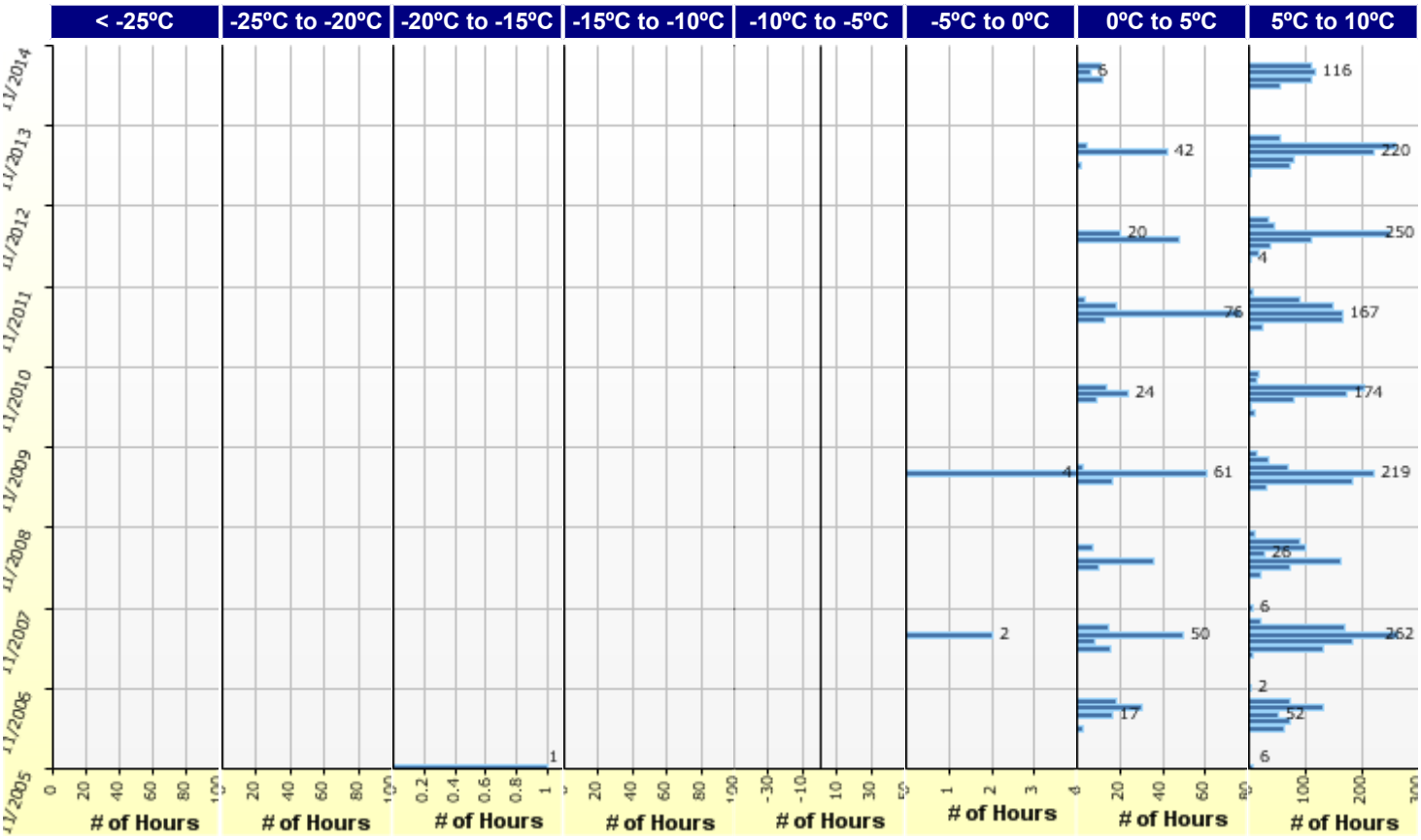


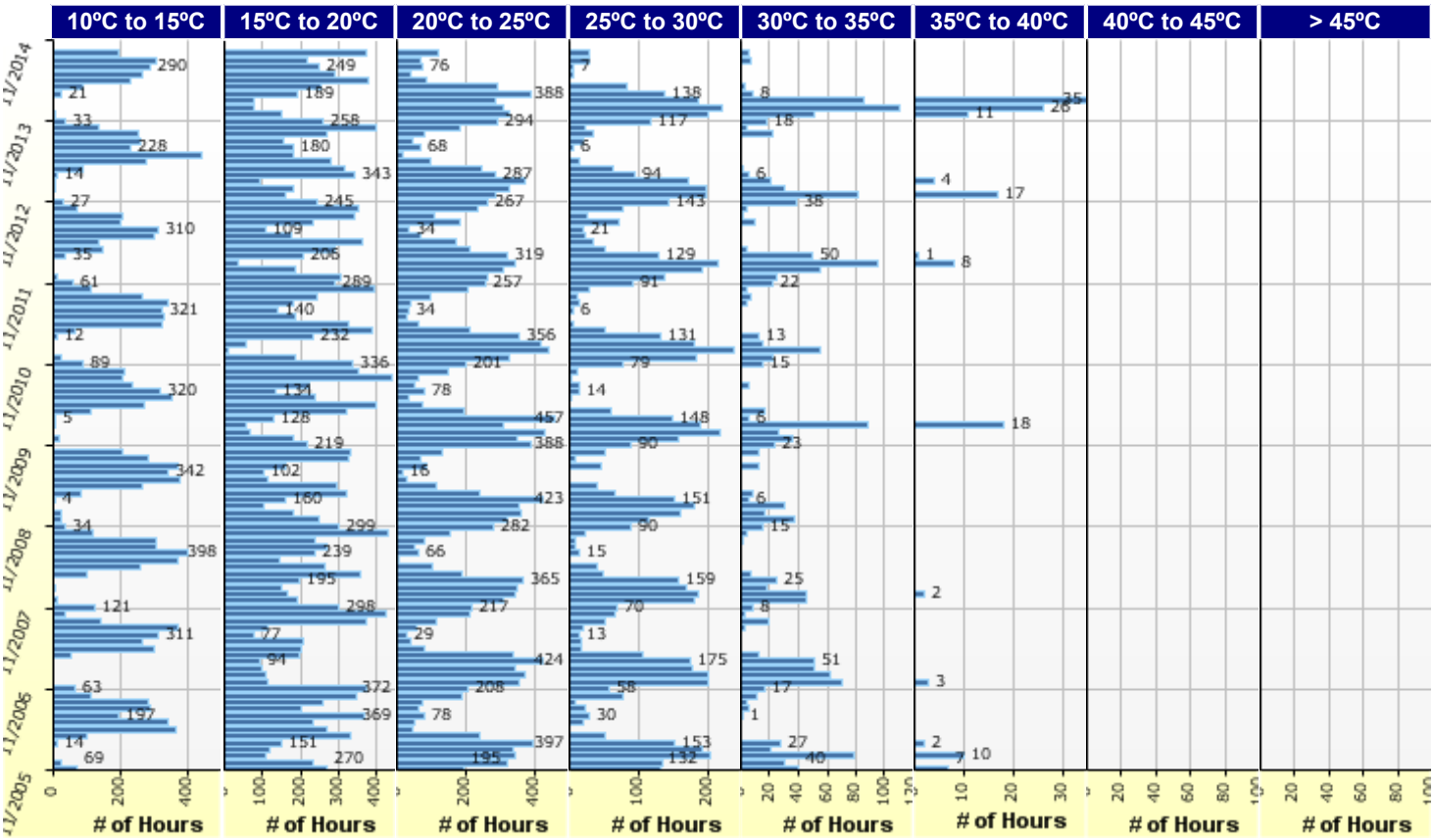






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

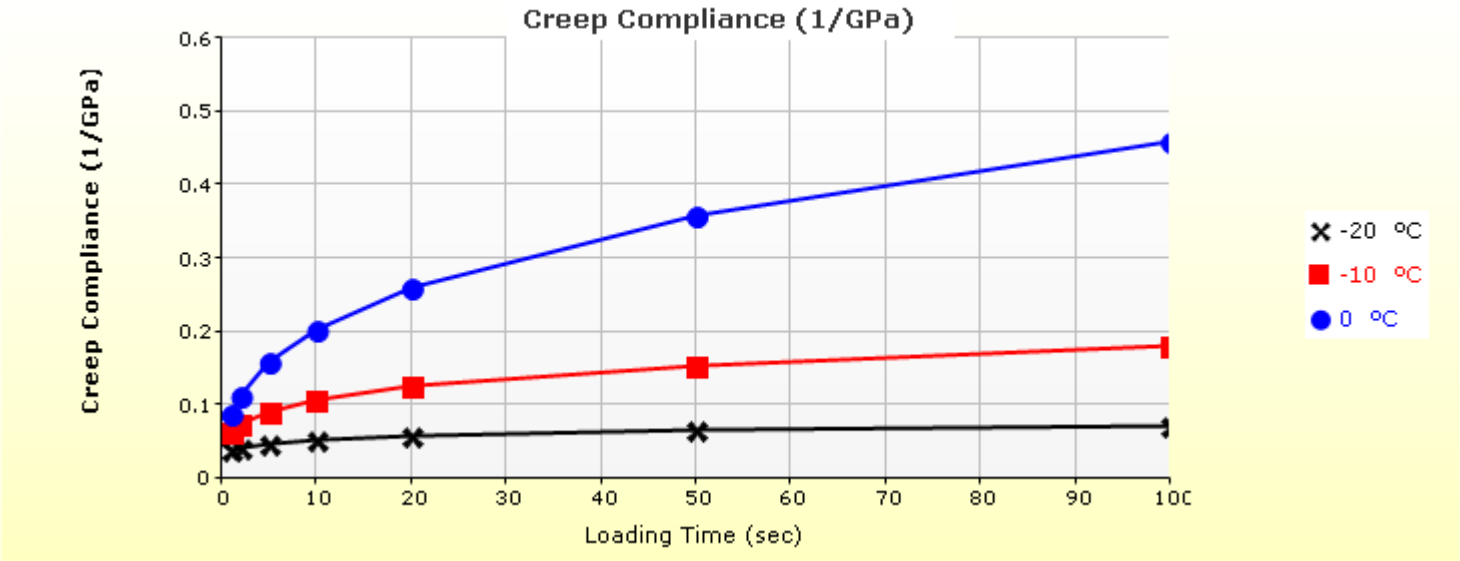
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

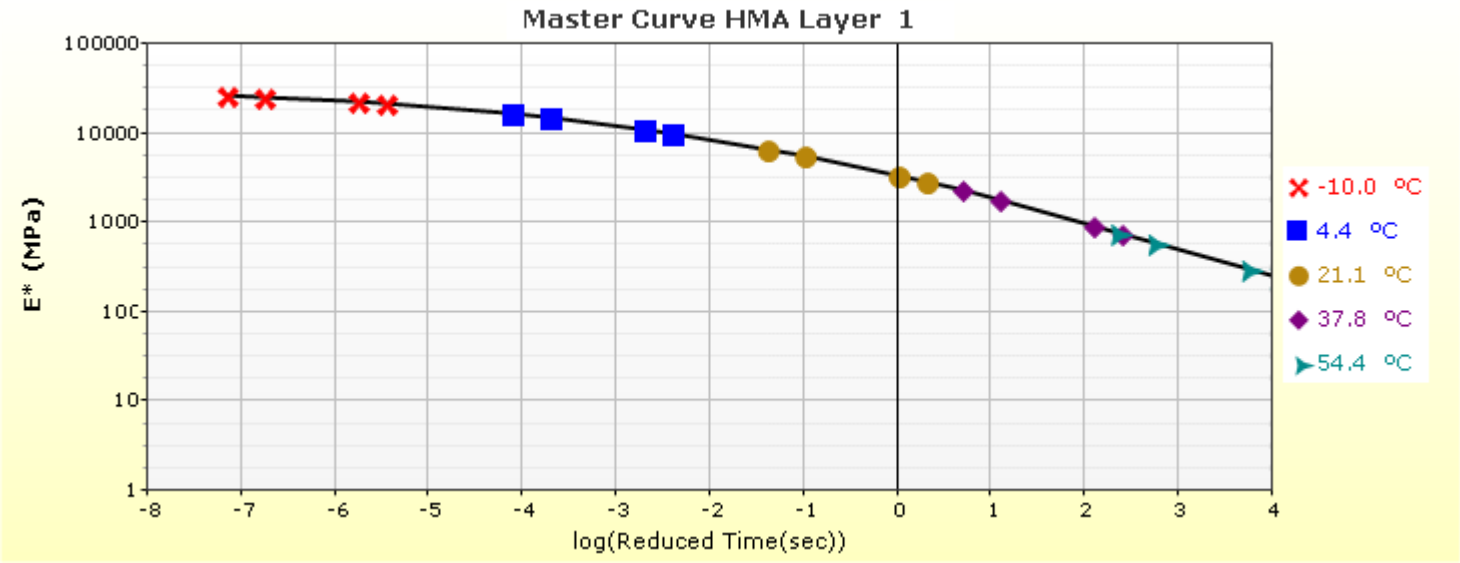
Indirect tensile strength at -10 ºC (MPa)	2.69

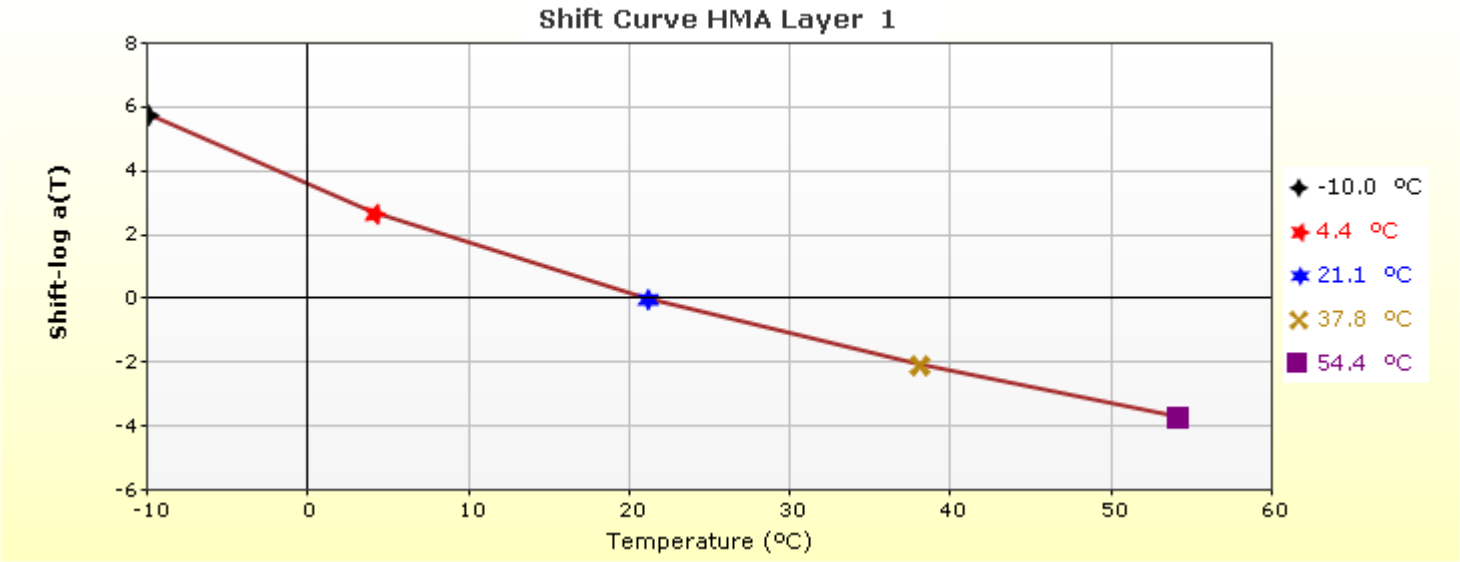
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

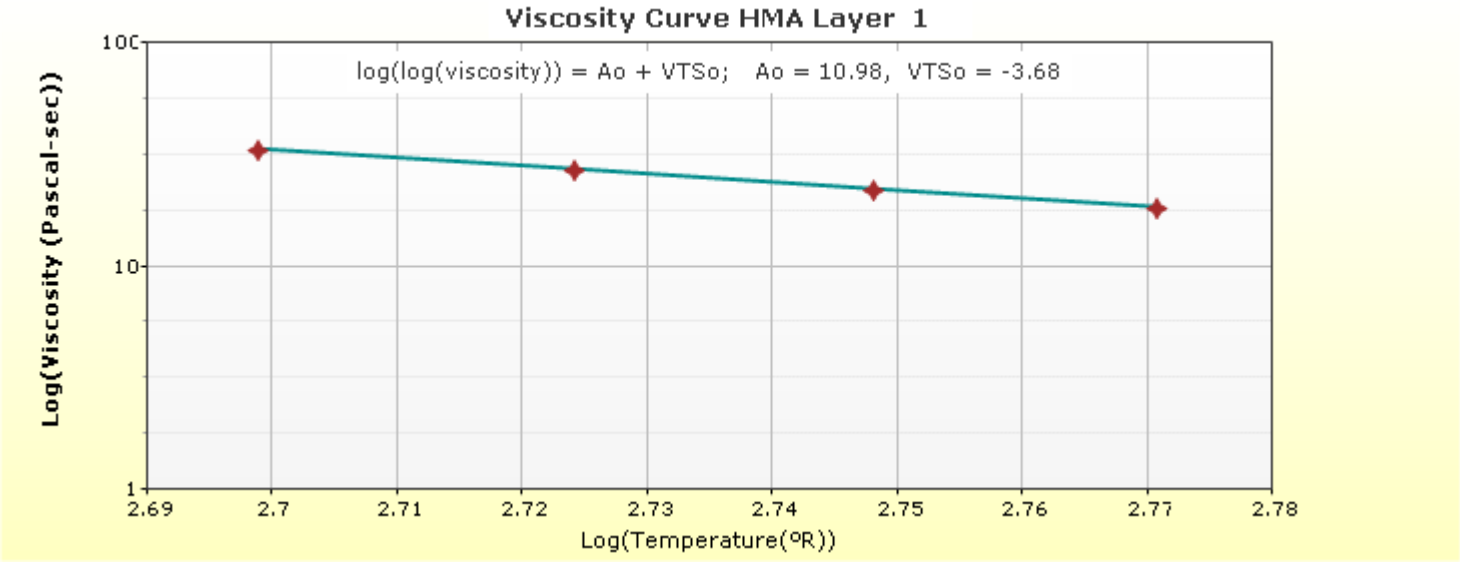
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



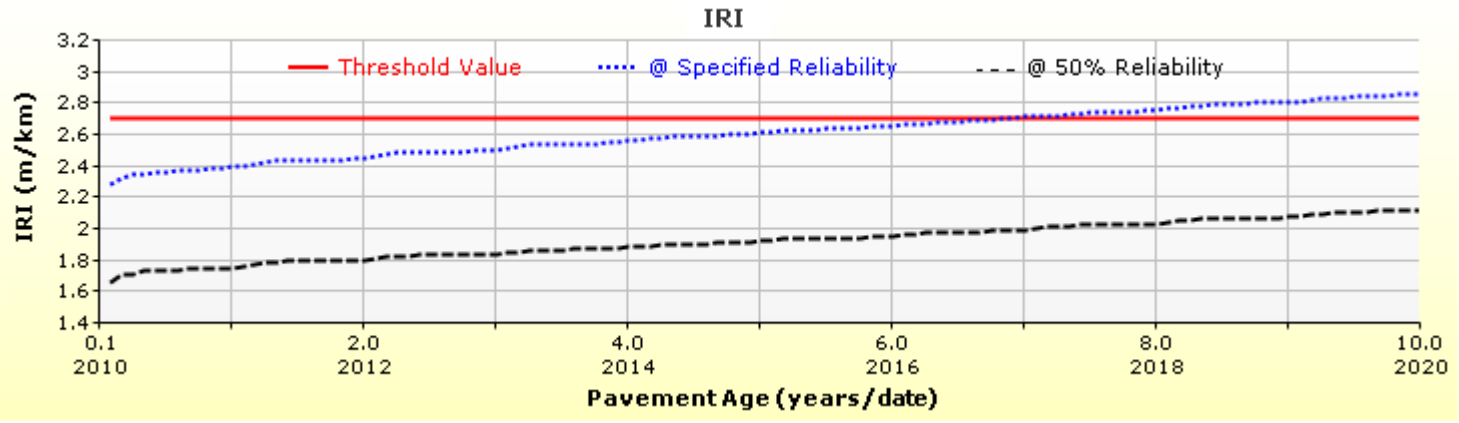
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

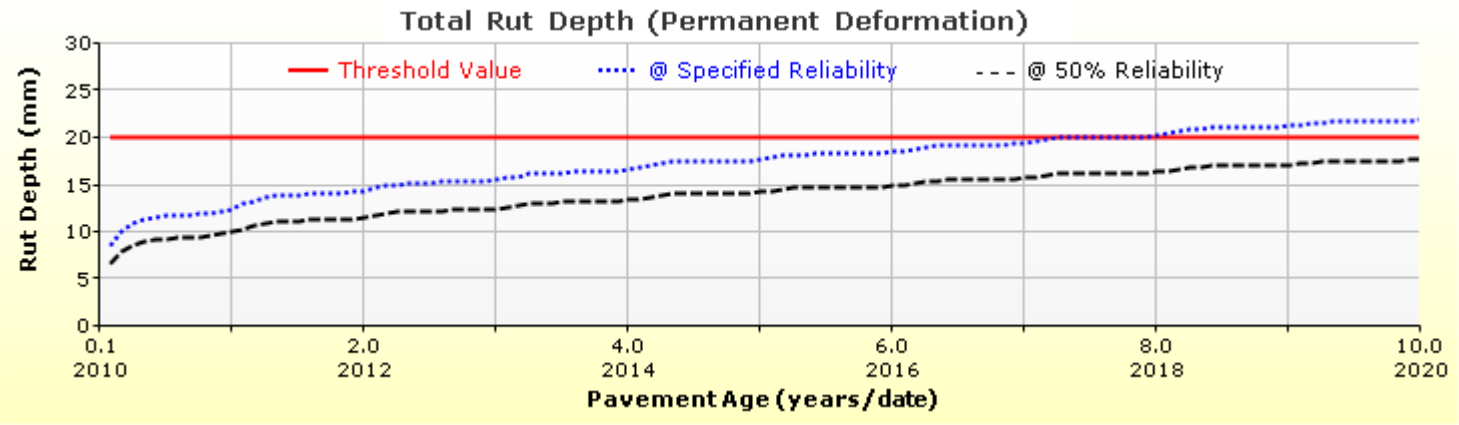


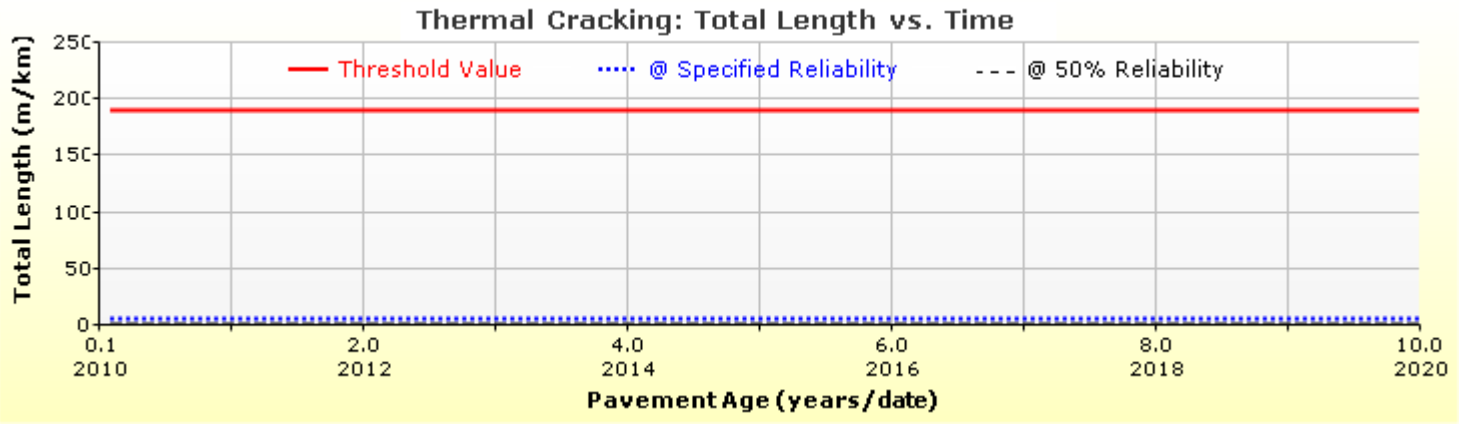


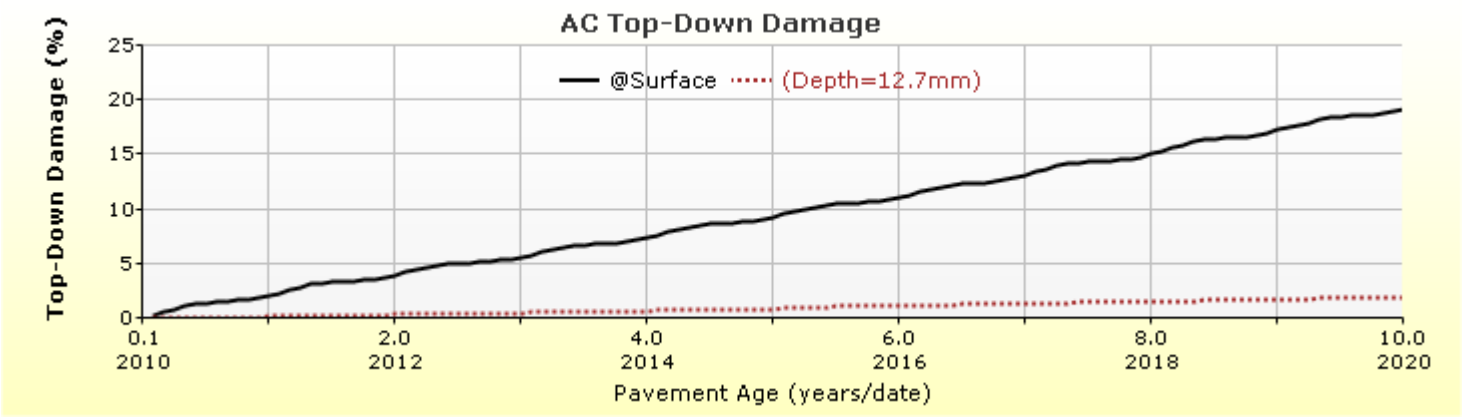


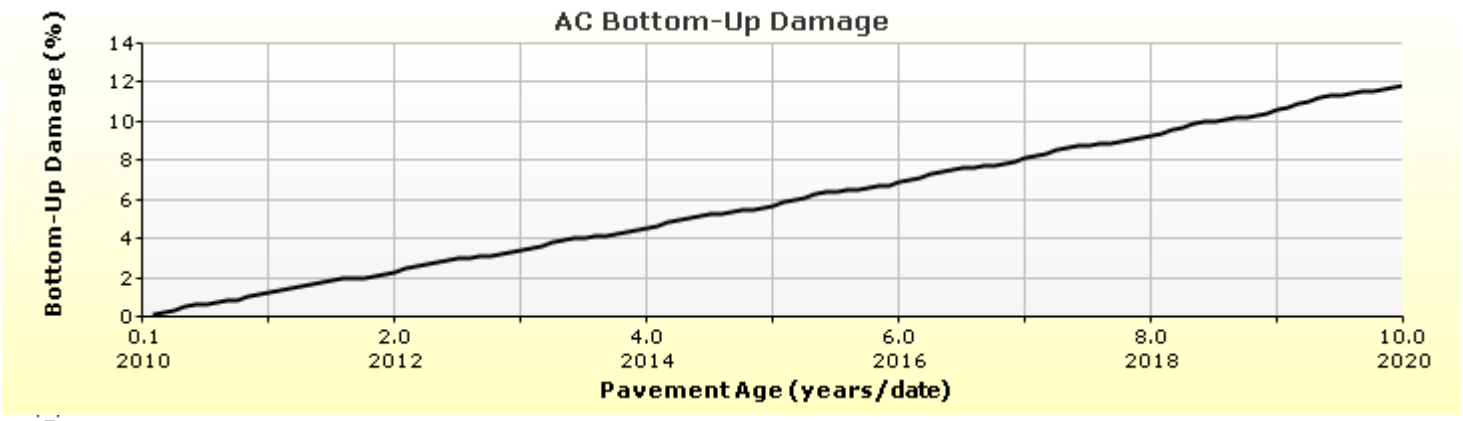
Analysis Output Charts

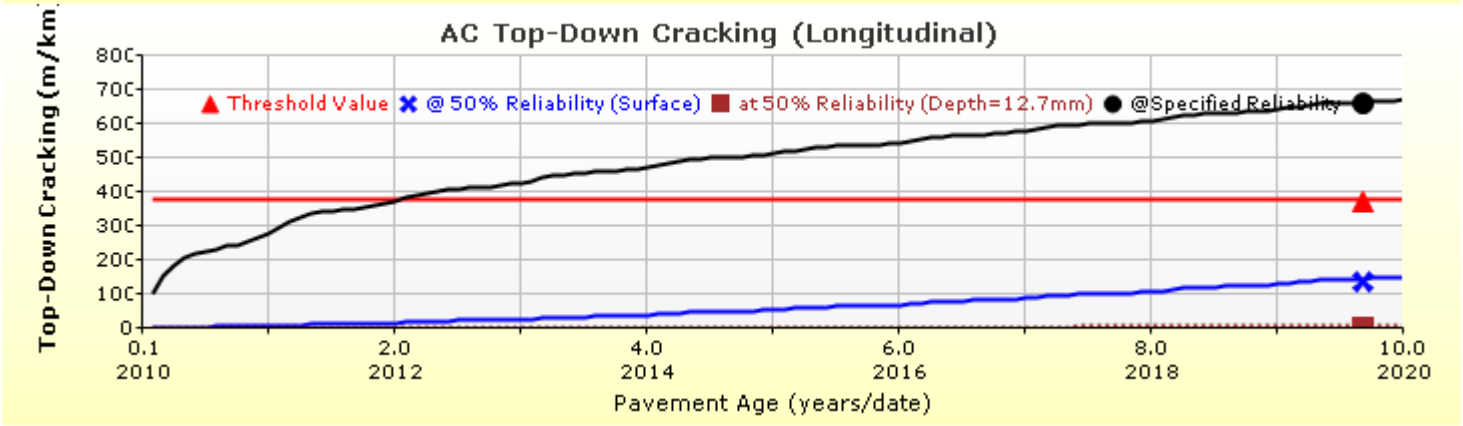


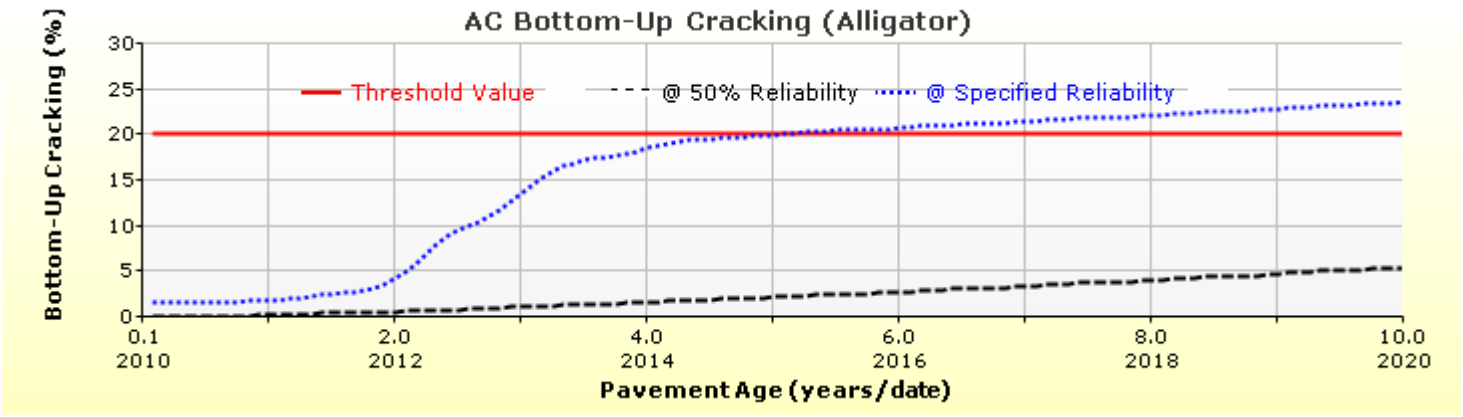


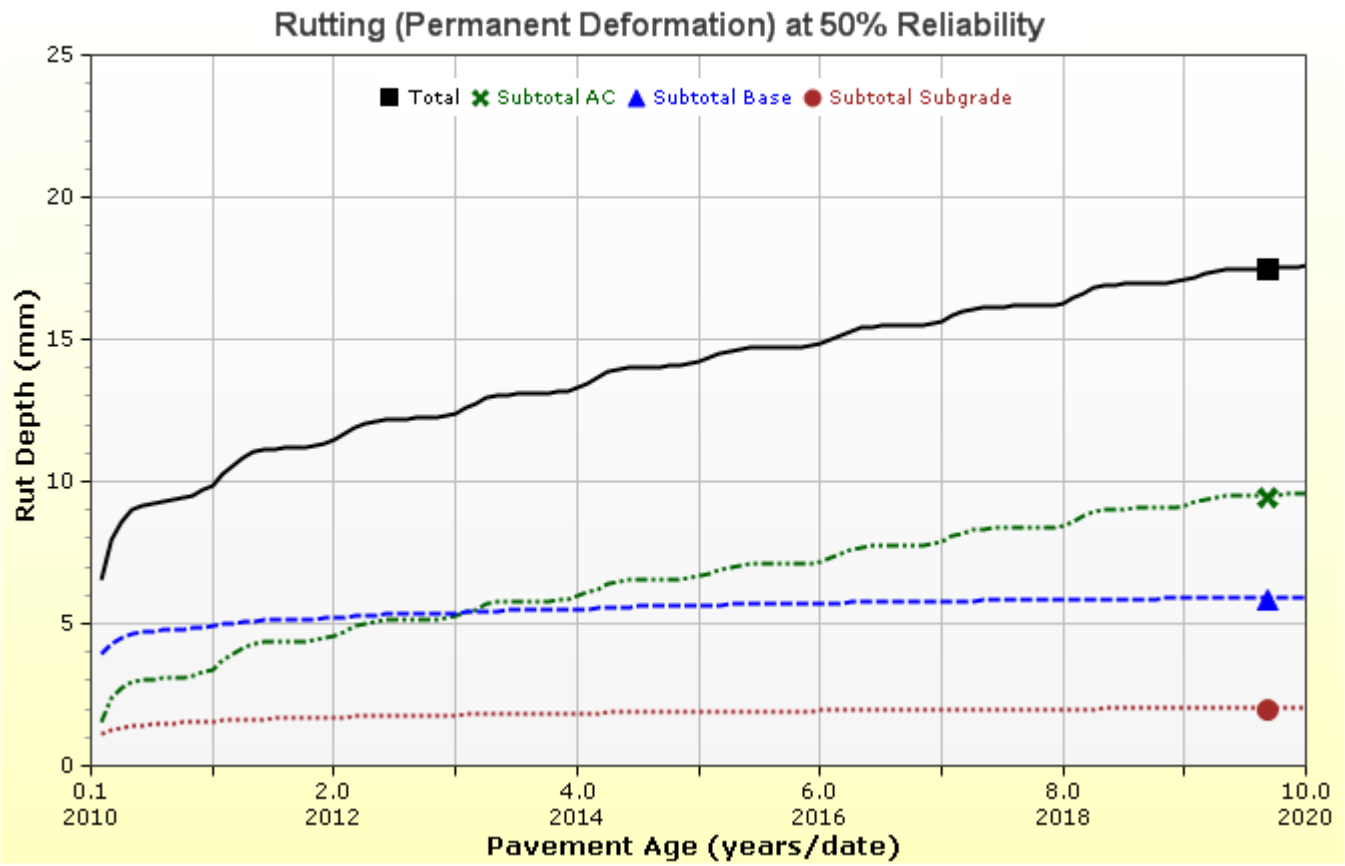


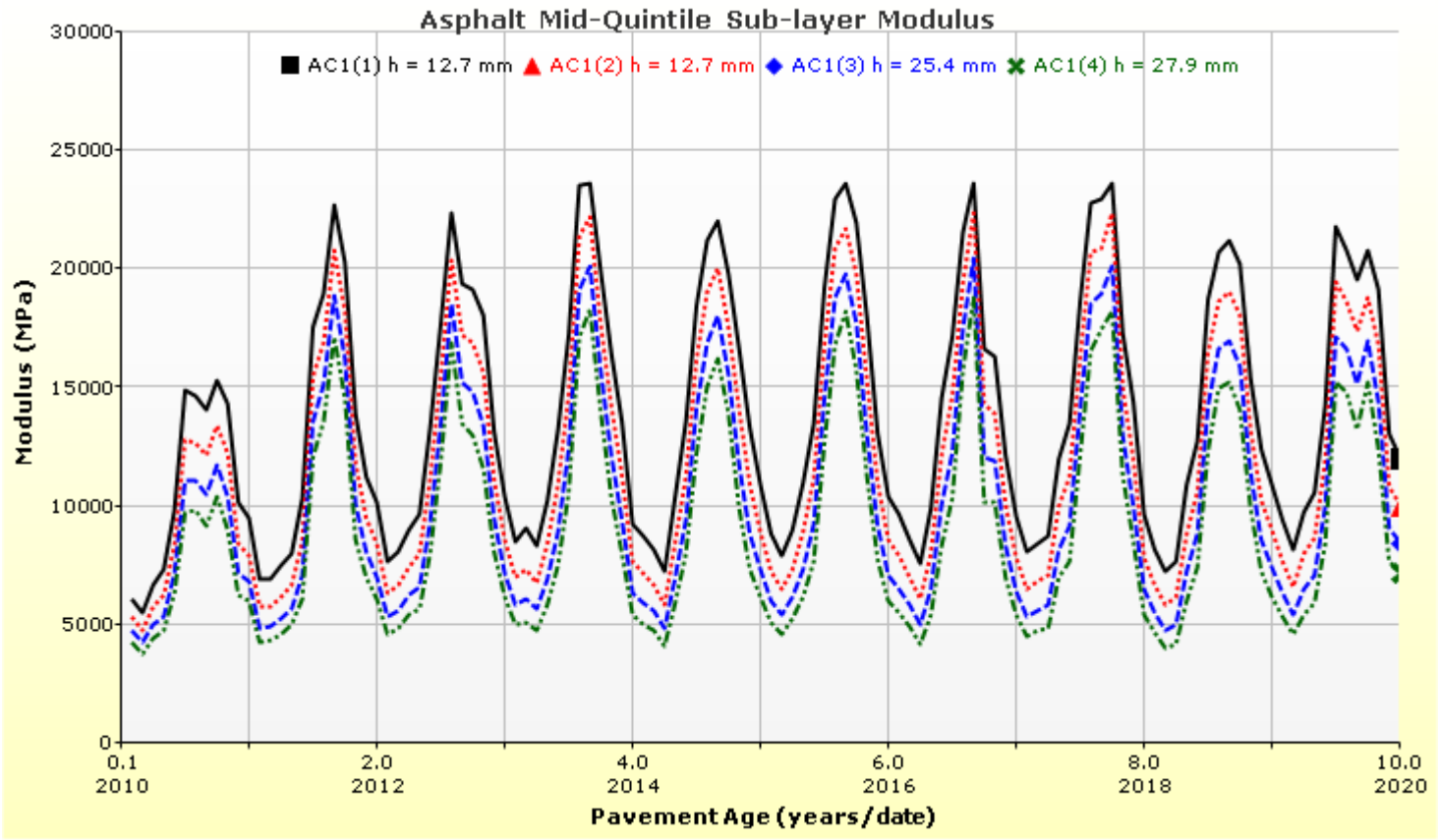

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

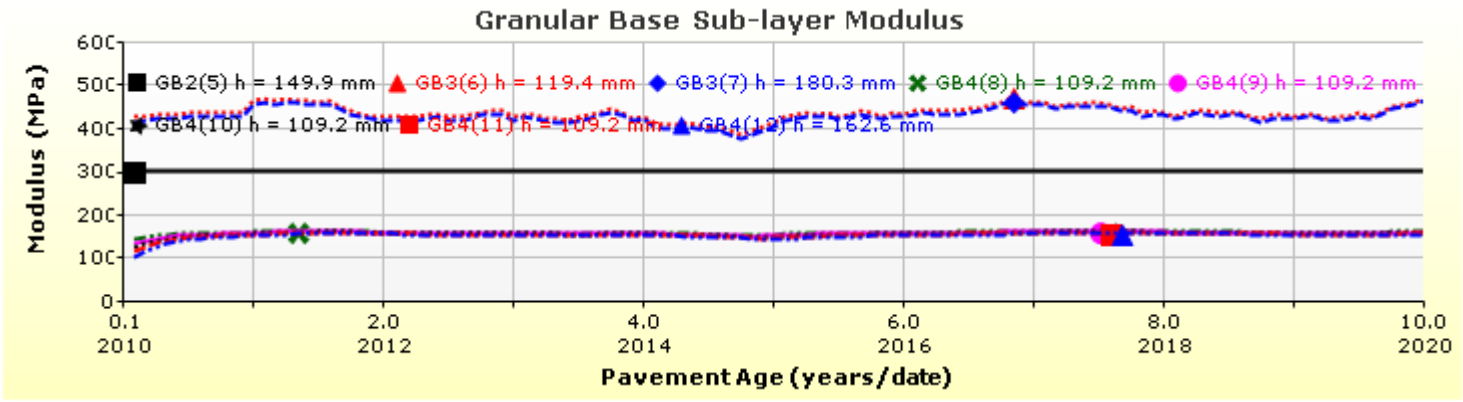

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

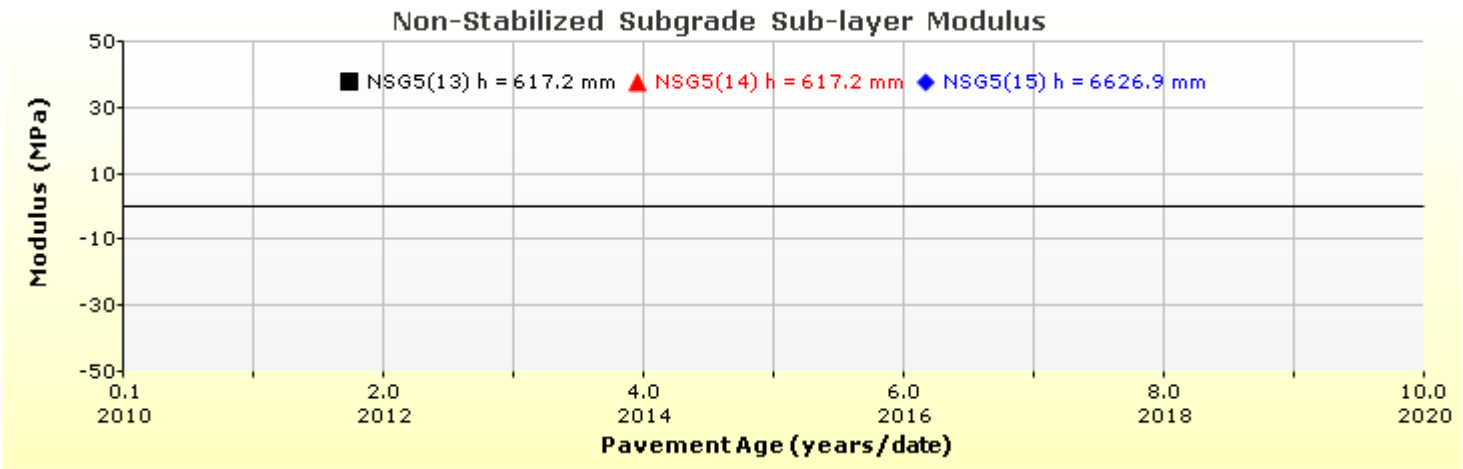

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60C
50C
40C
30C
20C
10C
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 1
Bf2: 1
Bf3: 1

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2\beta_{r2}} N^{k_3\beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

$$H_{ac} = total\ AC\ thickness(in)$$

$\varepsilon_p = plastic\ strain\left({}^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left({}^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRS+2

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRS+2.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -30.05, -51.17

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

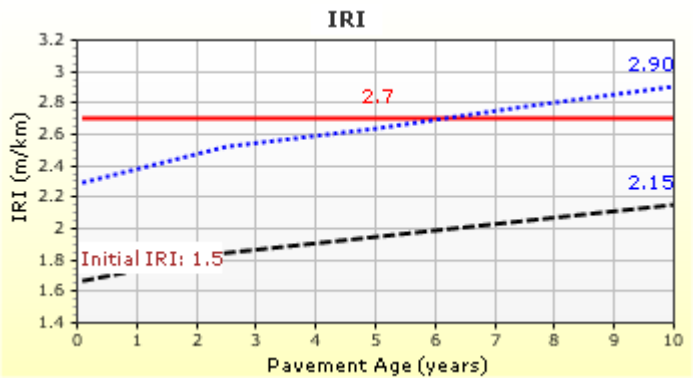
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

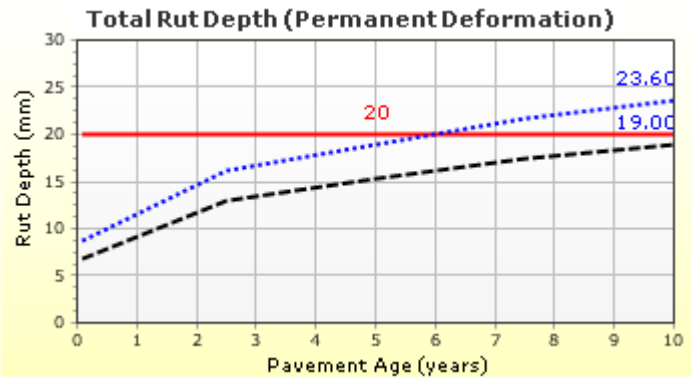
Design Outputs

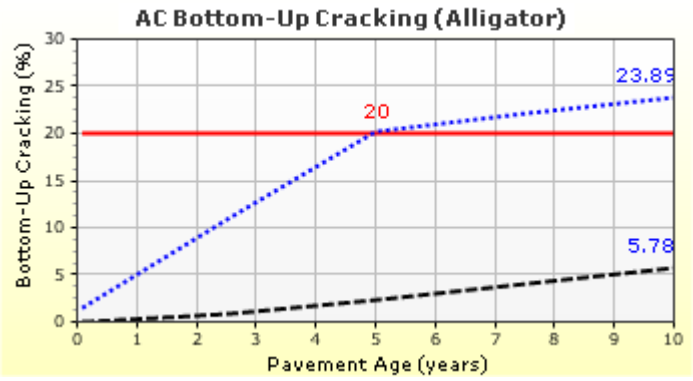
Distress Prediction Summary

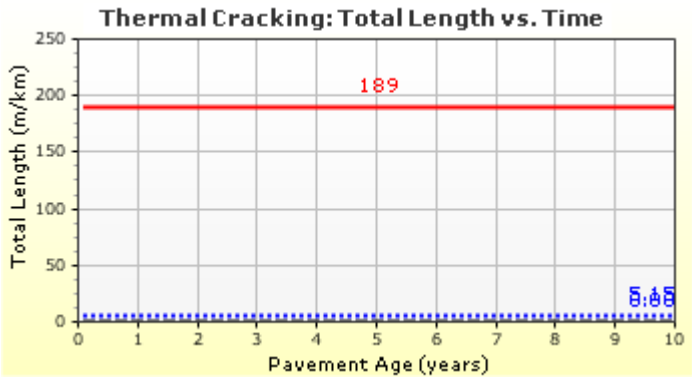
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.90	90.00	82.49	Fail
Permanent deformation - total pavement (mm)	20.00	23.58	90.00	60.88	Fail
AC bottom-up fatigue cracking (percent)	20.00	23.89	90.00	84.29	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	703.97	90.00	68.82	Fail
Permanent deformation - AC only (mm)	5.00	11.02	50.00	2.79	Fail

Distress Charts







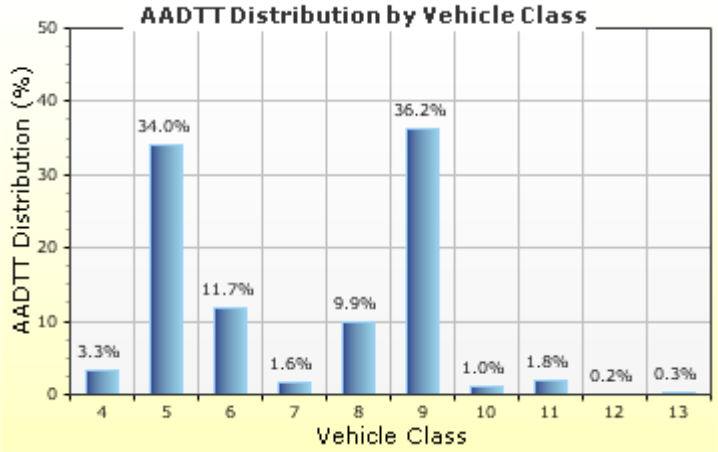


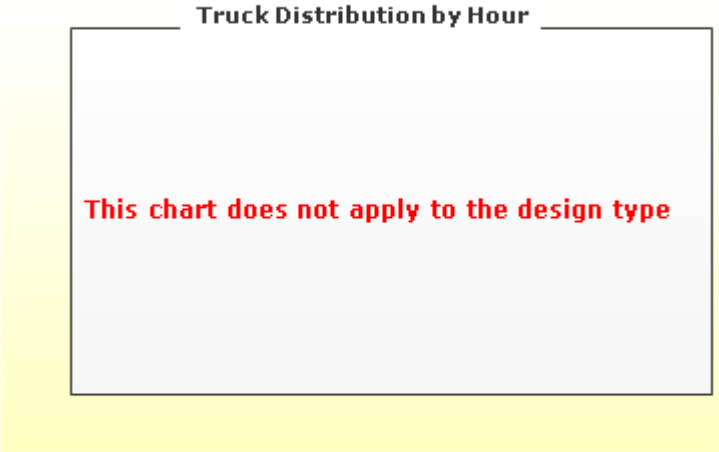


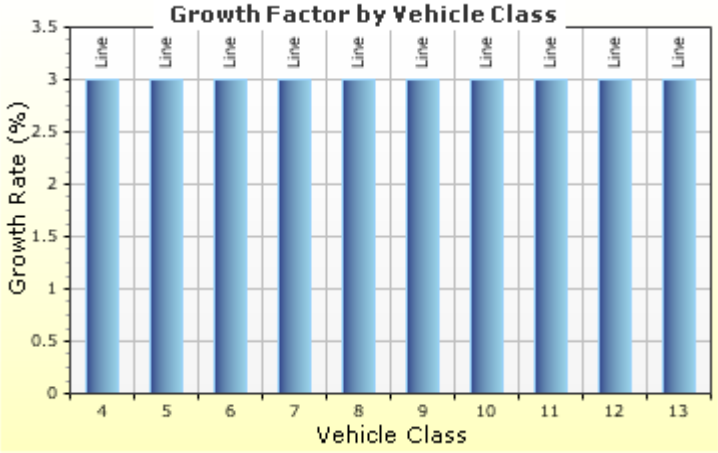
Traffic Inputs

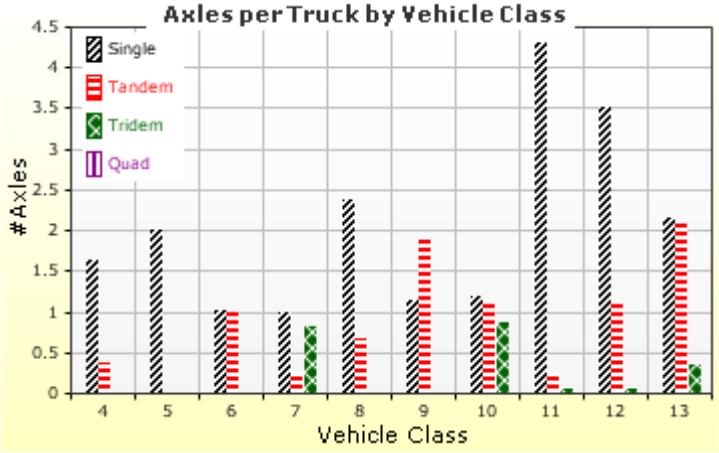
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

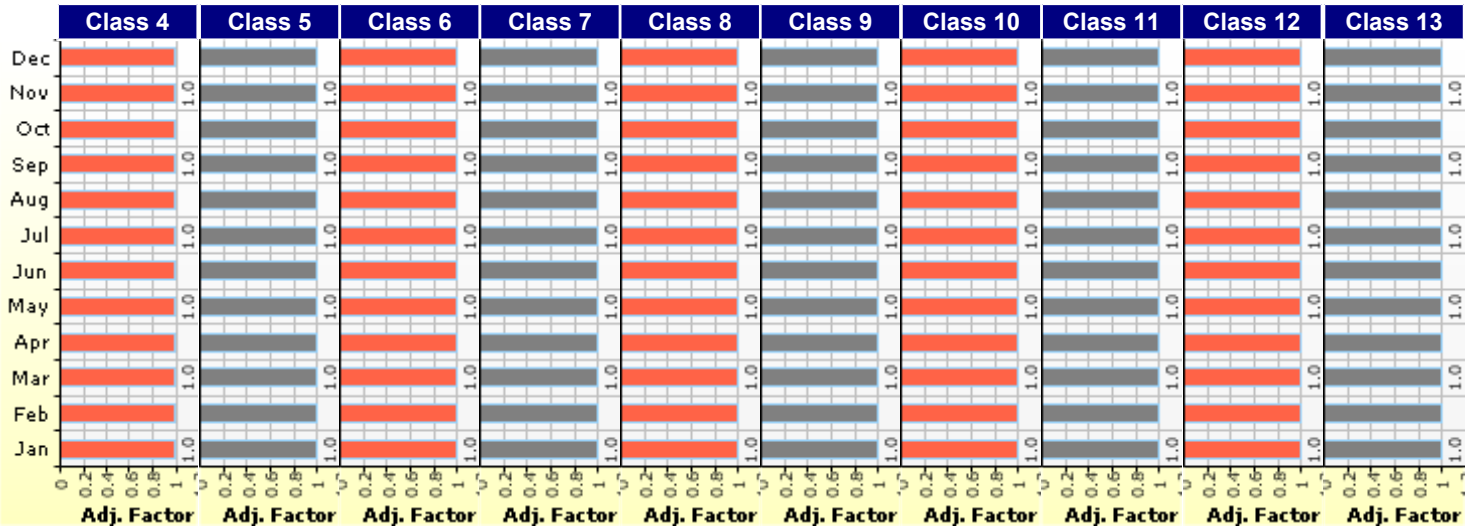








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

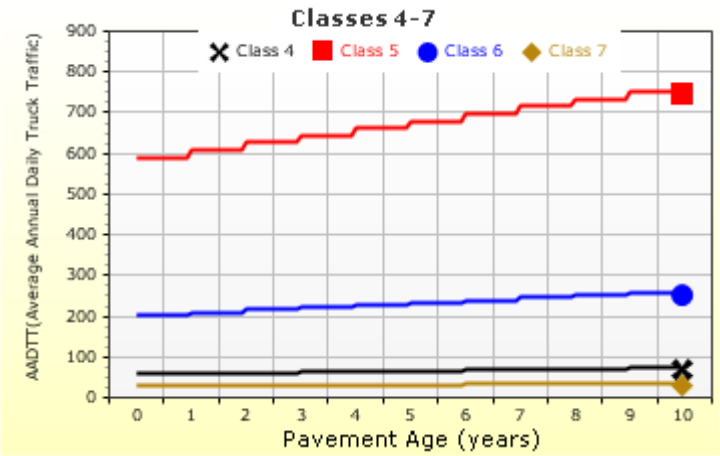
Wheelbase does not apply

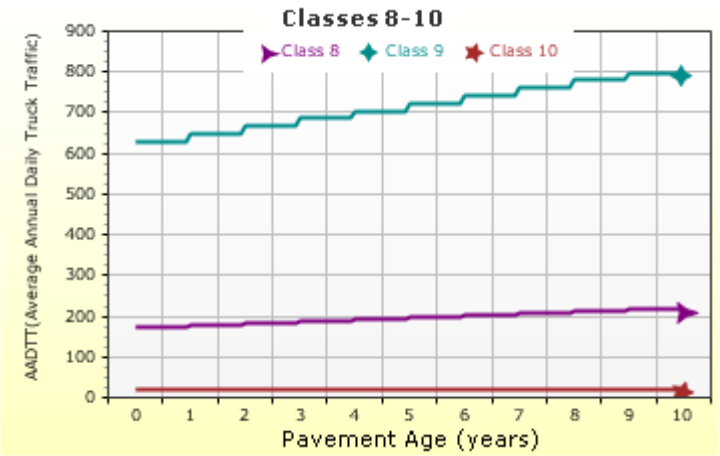
Number of Axles per Truck

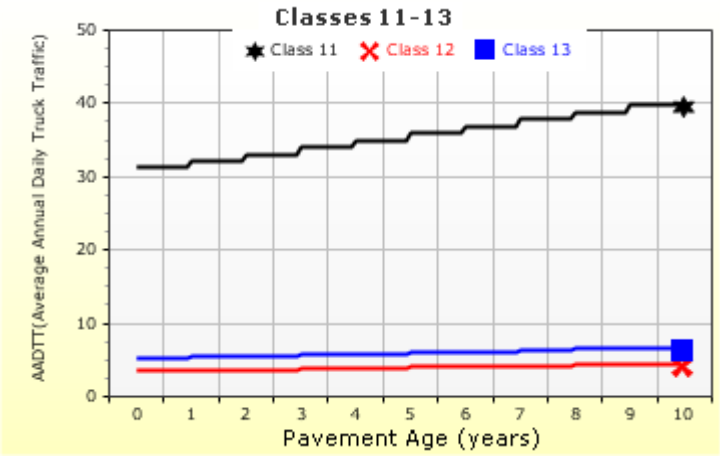
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

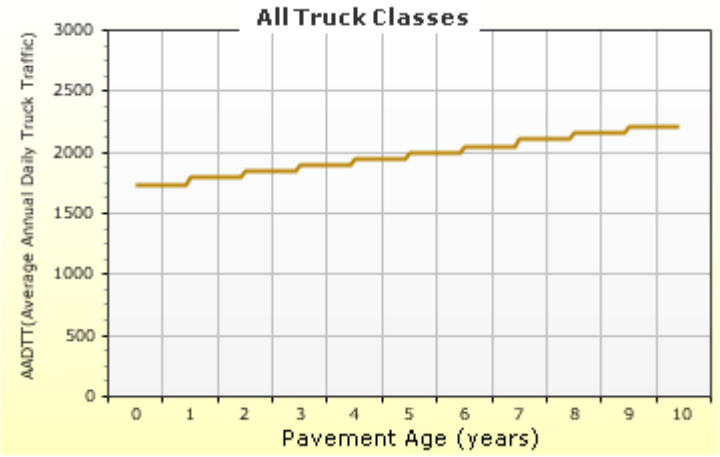
AADTT (Average Annual Daily Truck Traffic) Growth

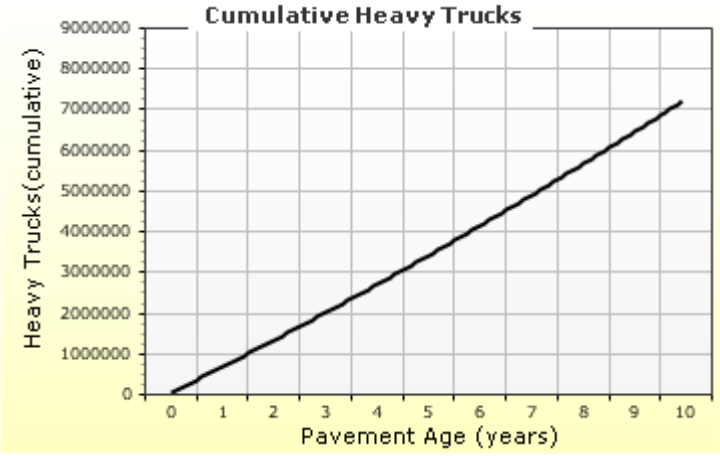
*** Traffic cap is not enforced**







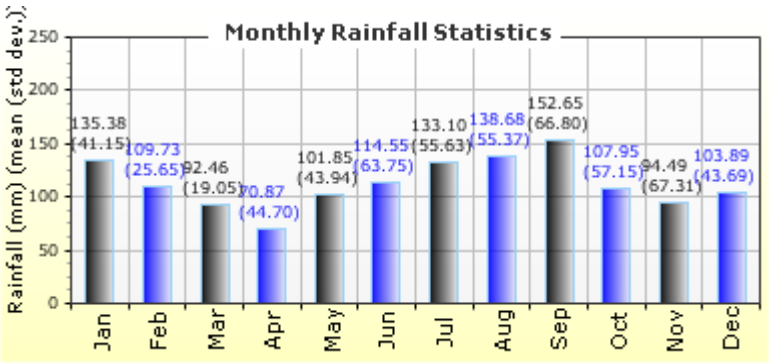




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
PORTO ALEGRE, RS	-30.05000 -51.17000 47

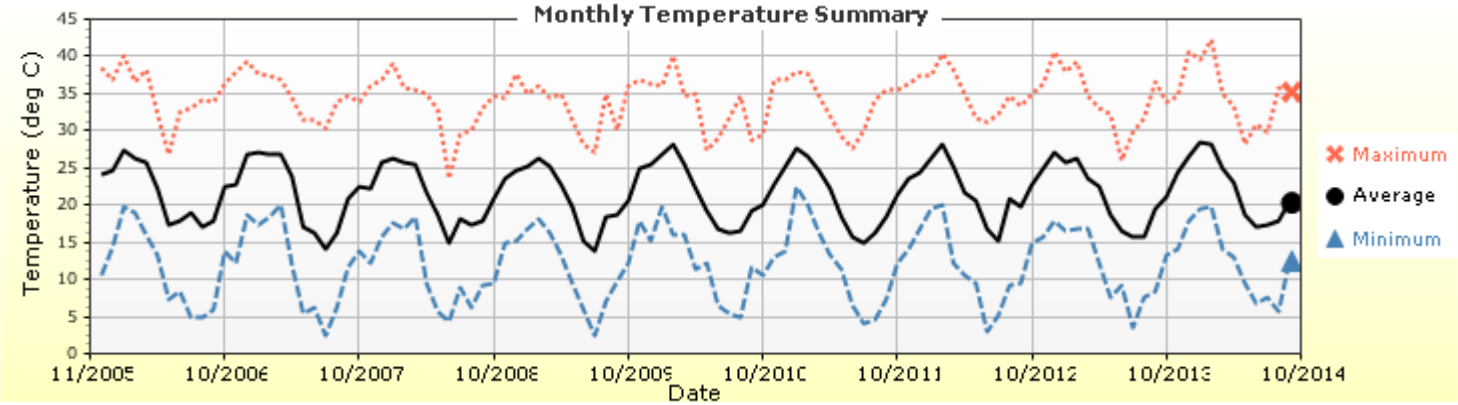


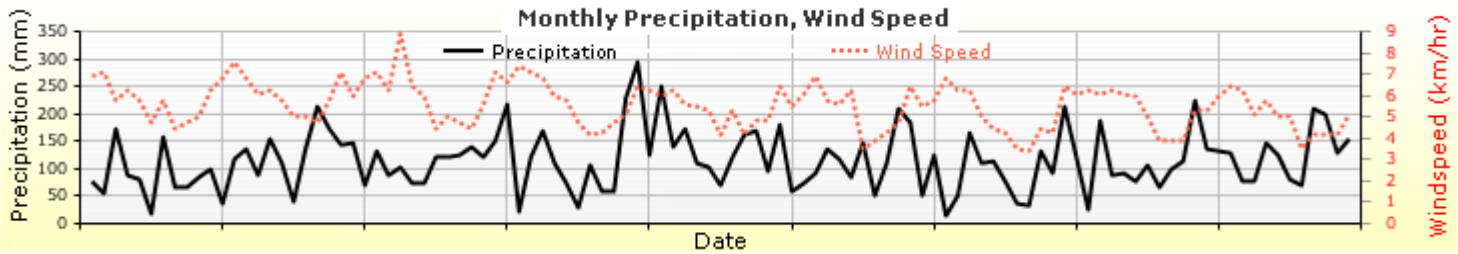
Annual Statistics:

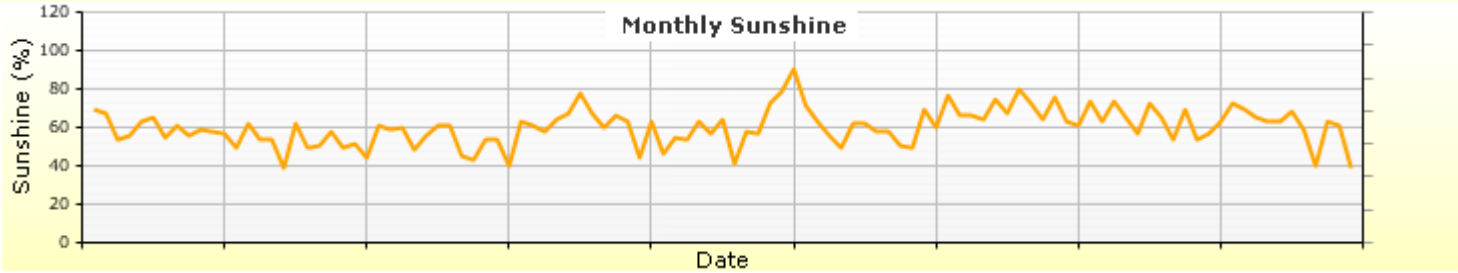
Mean annual air temperature (ºC)	21.73
Mean annual precipitation (mm)	1352.30
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

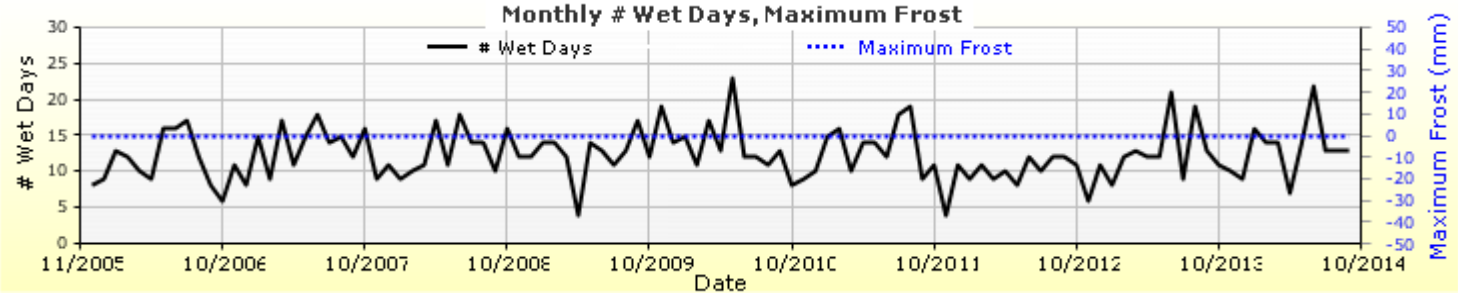
Water table depth (m): 3.05

Monthly Climate Summary:

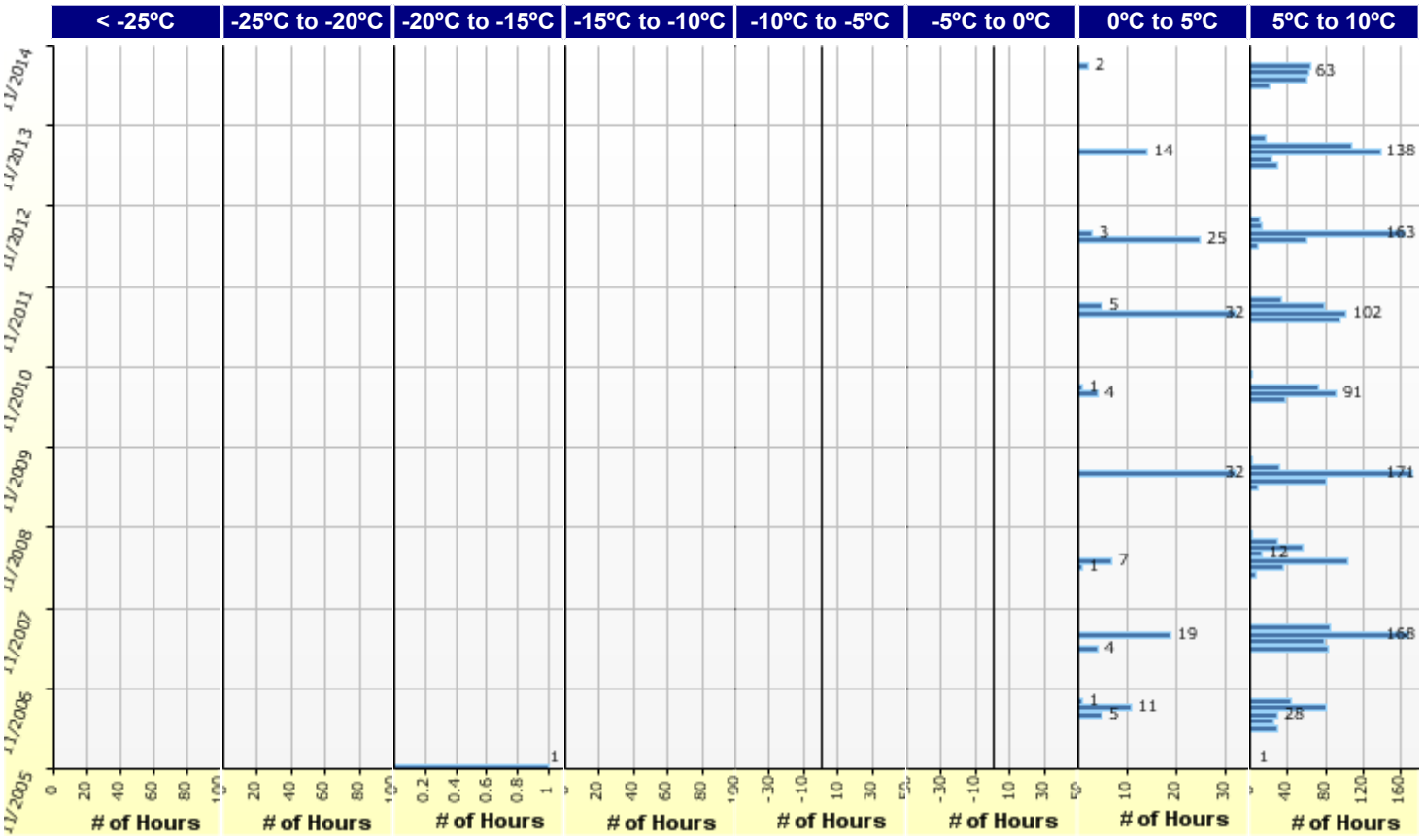


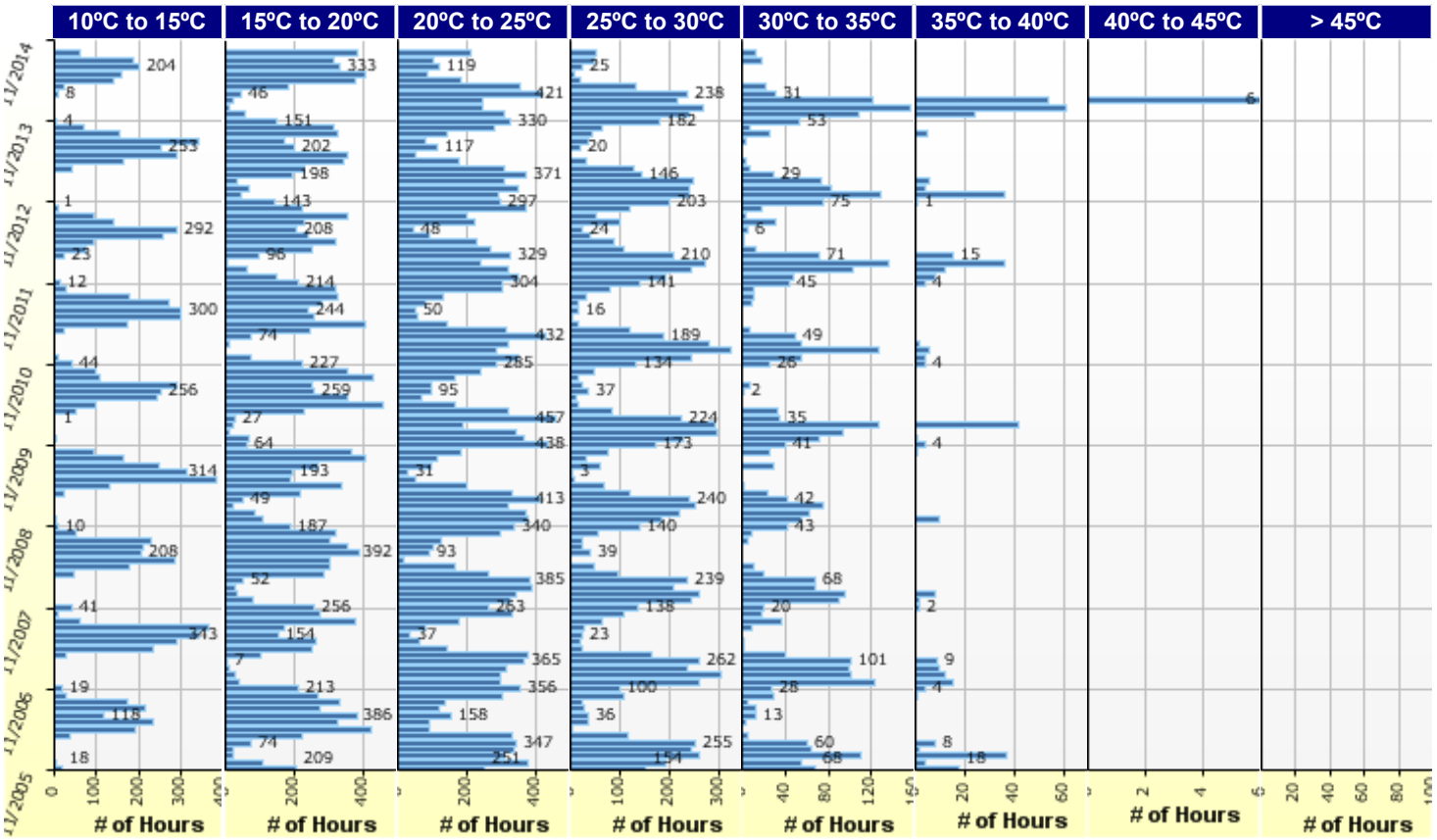






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

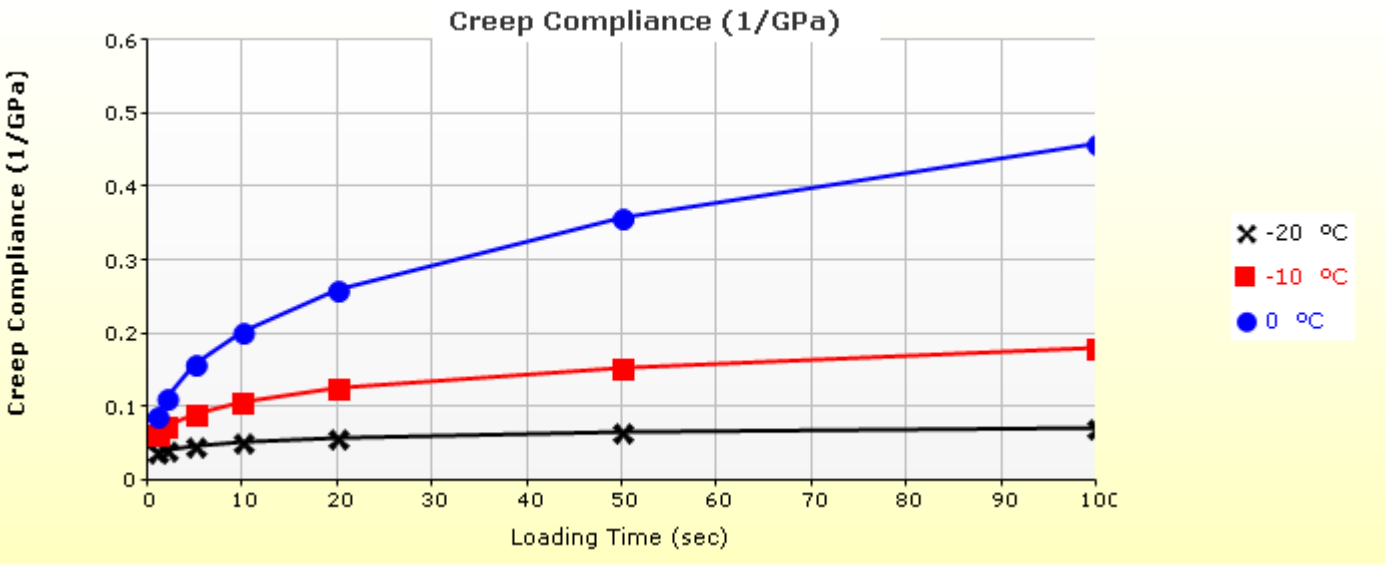
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

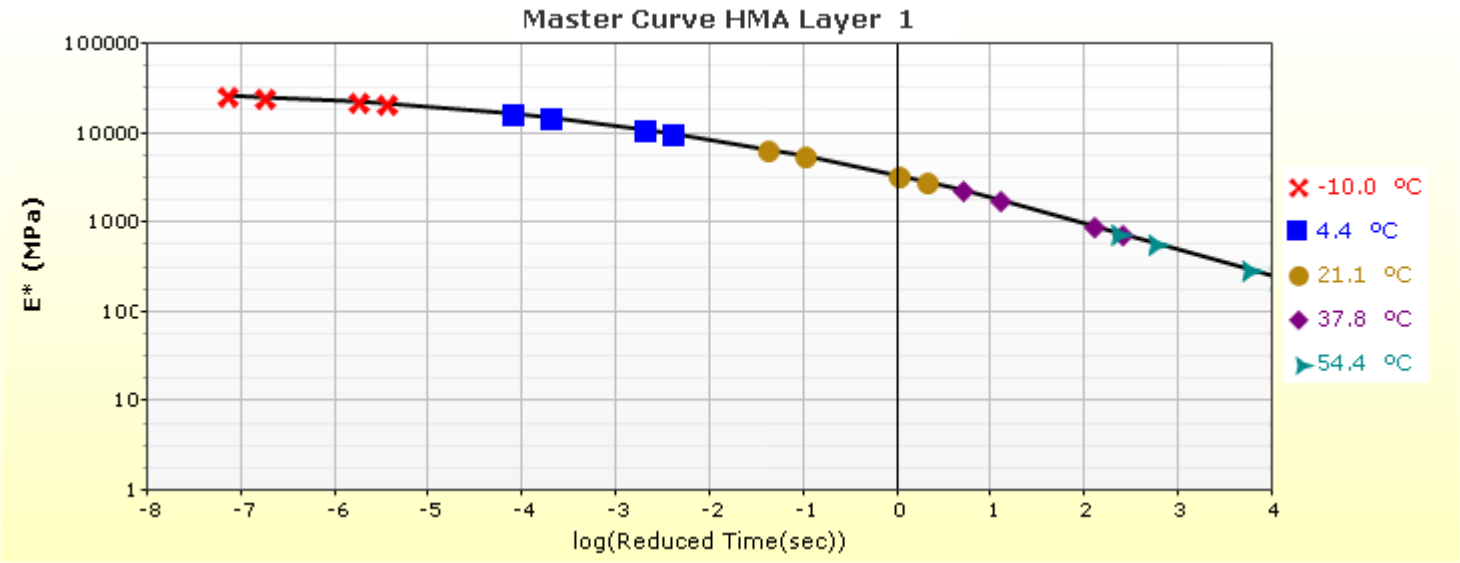
Indirect tensile strength at -10 ºC (MPa)	2.69

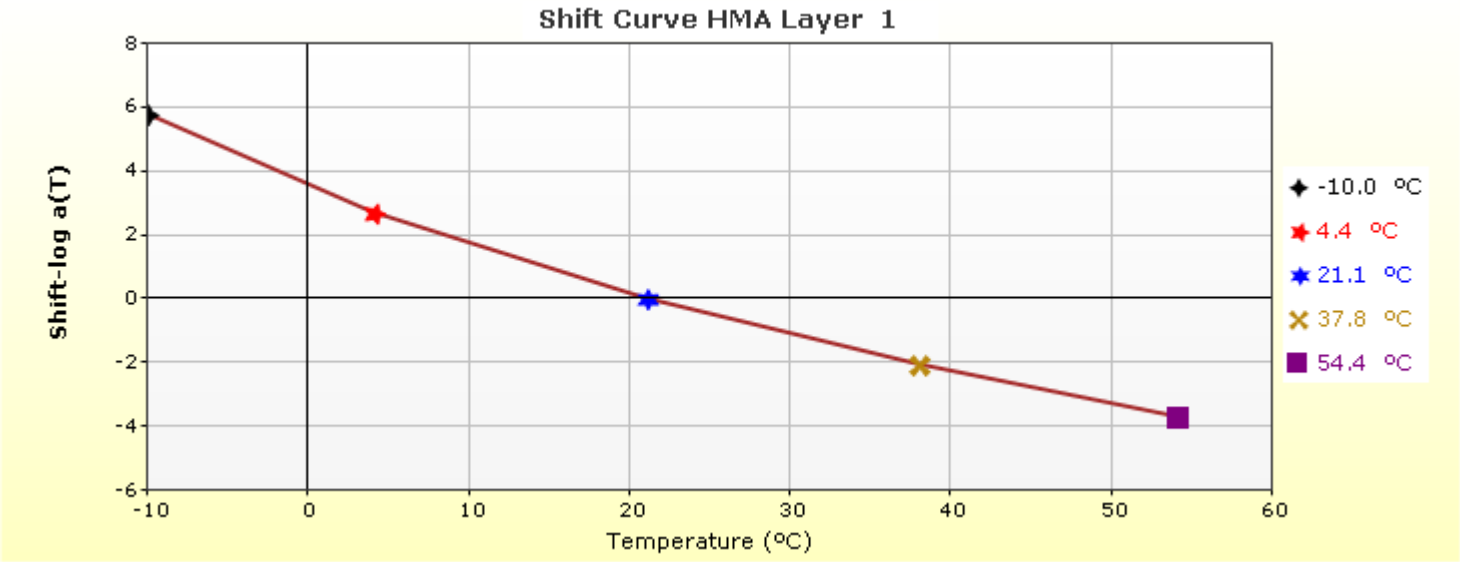
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

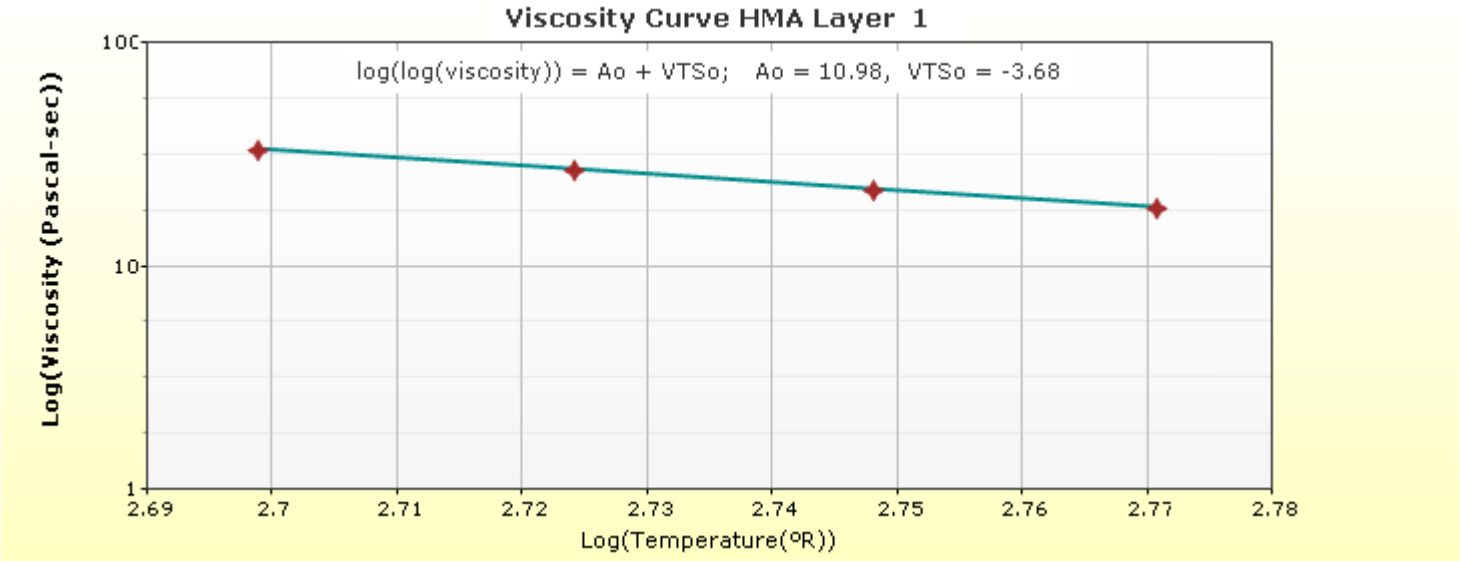
	Creep Compliance (1/GPa)		
Loading time (sec)	**-20 ºC**	**-10 ºC**	**0 ºC**
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



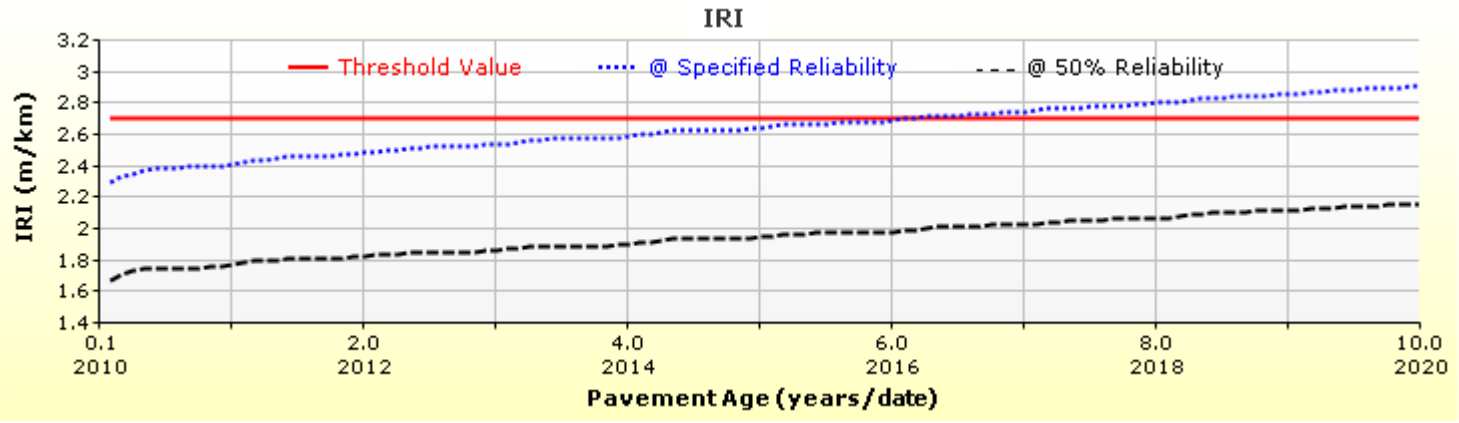
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

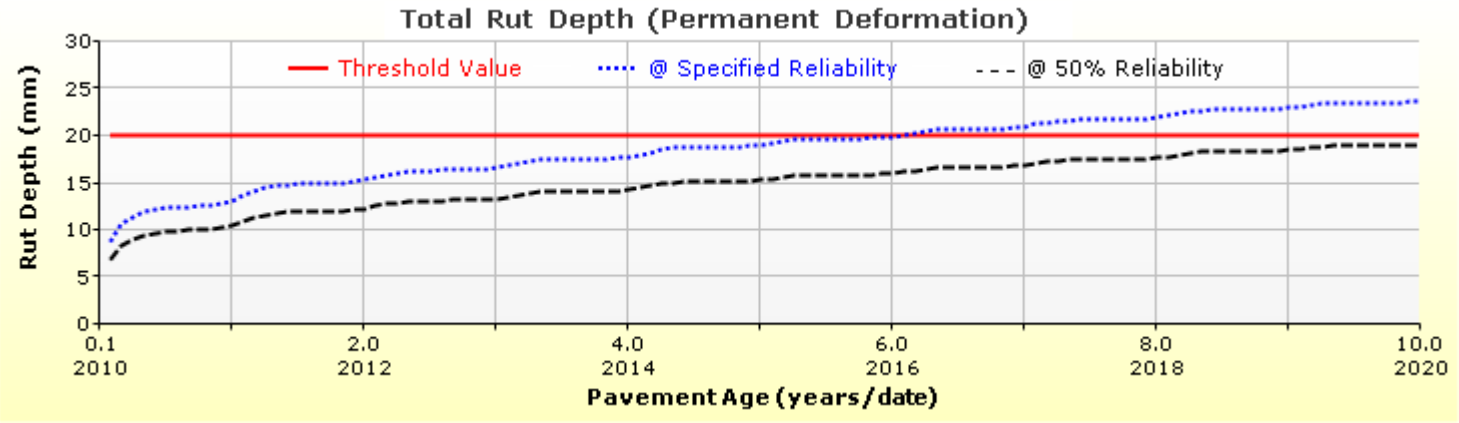


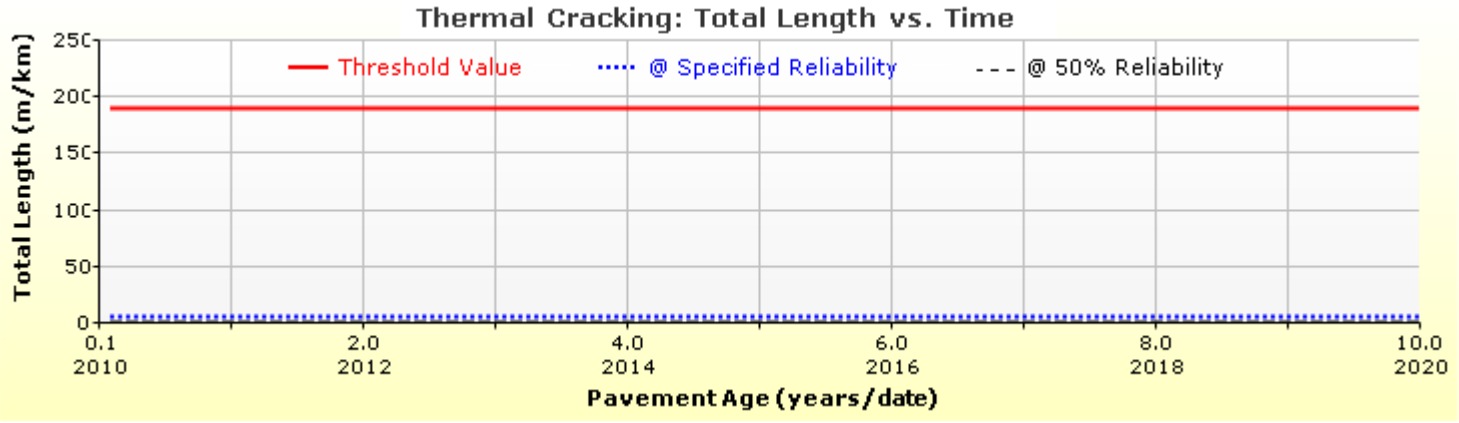


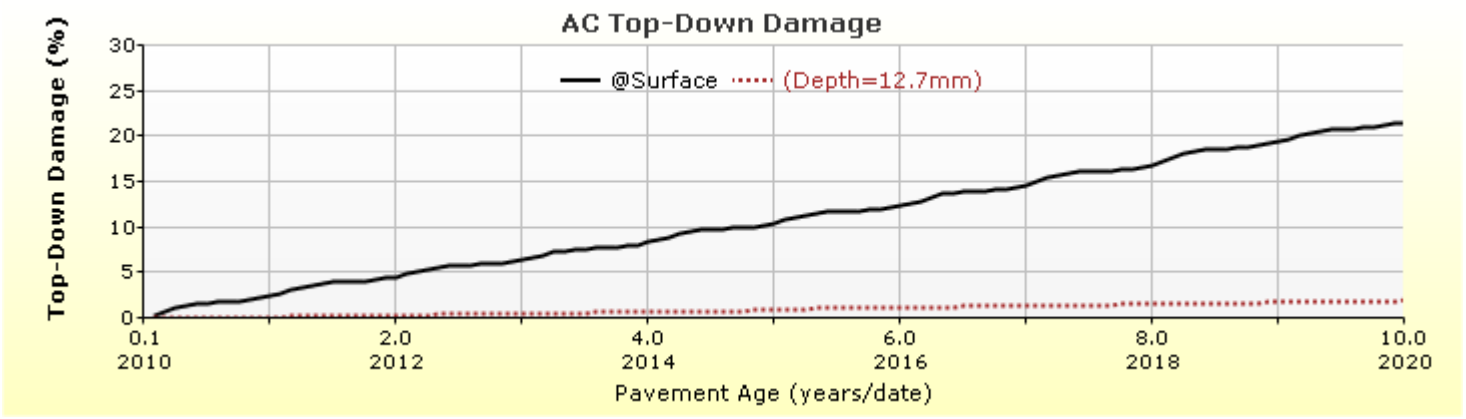


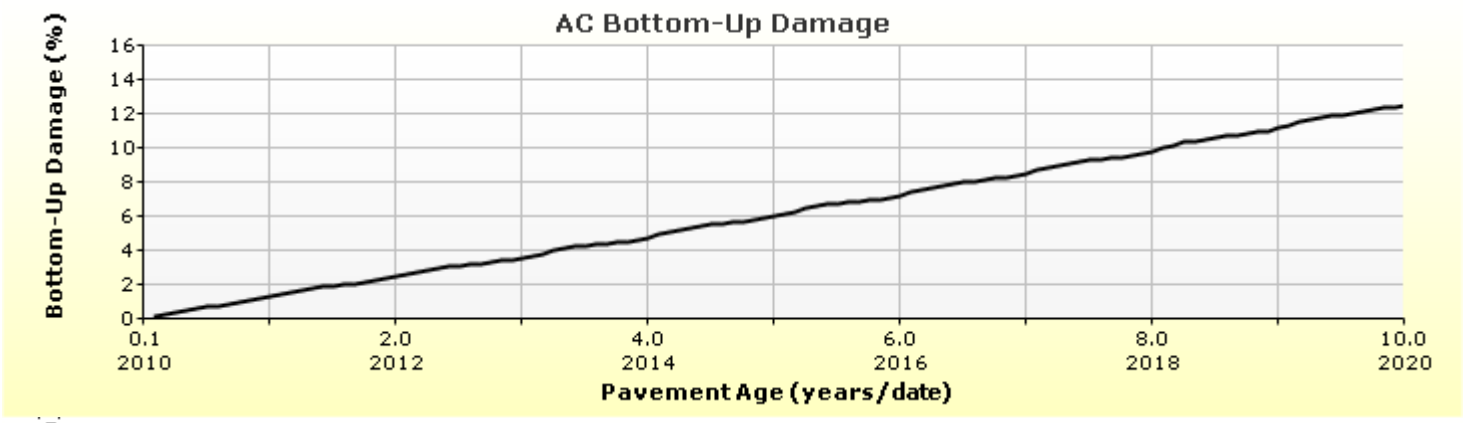
Analysis Output Charts

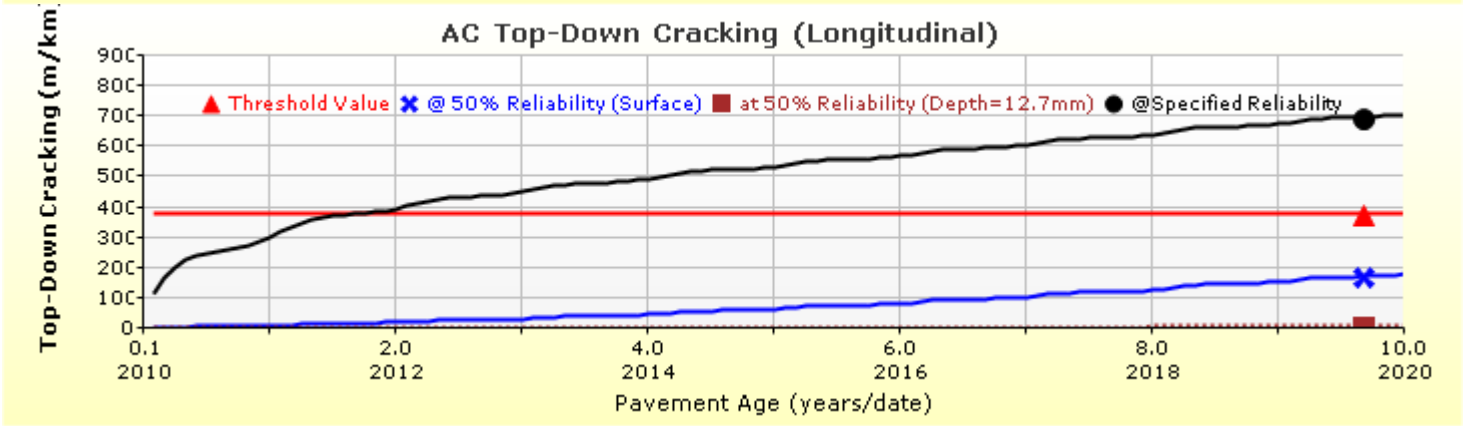


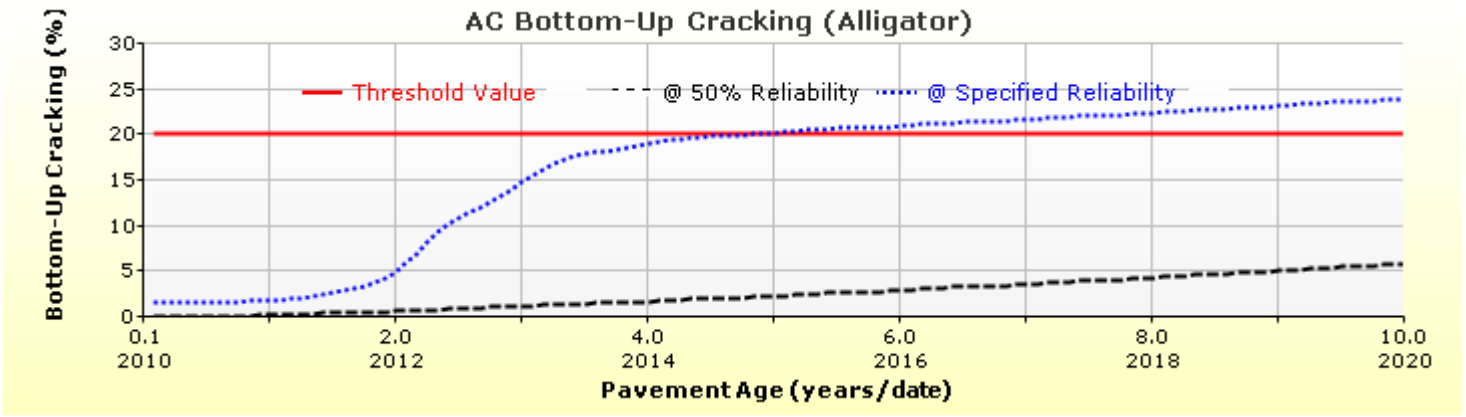


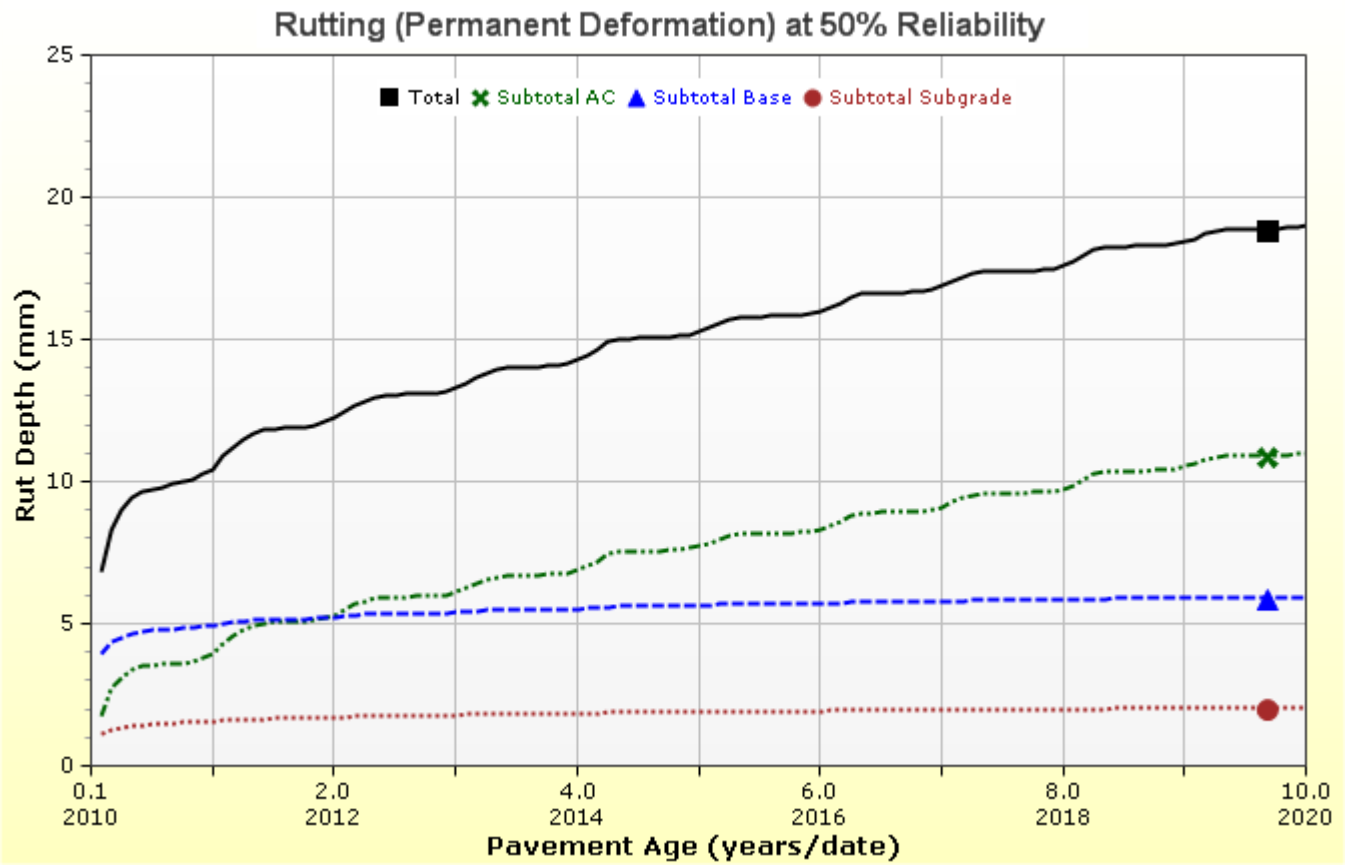


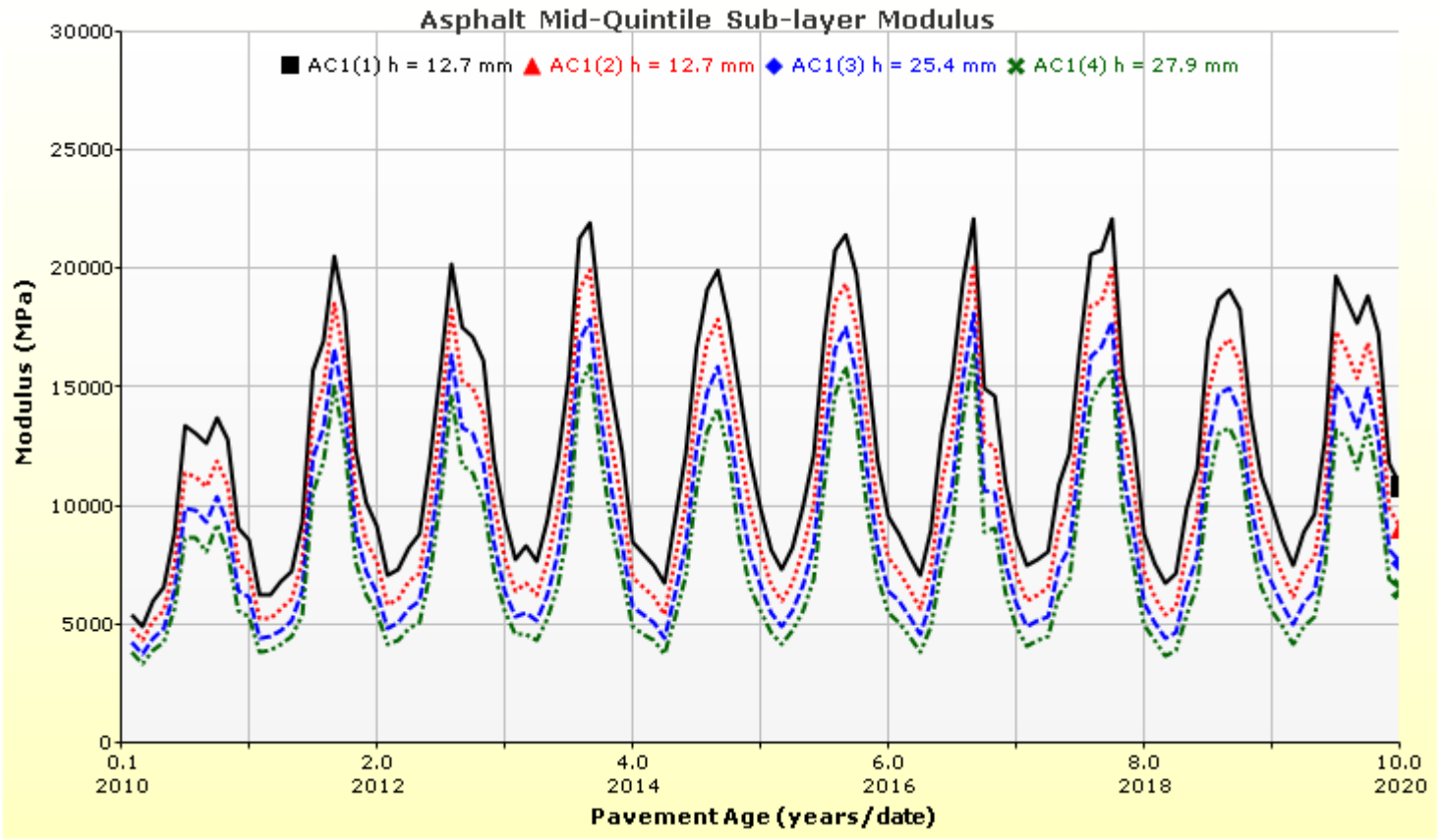

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

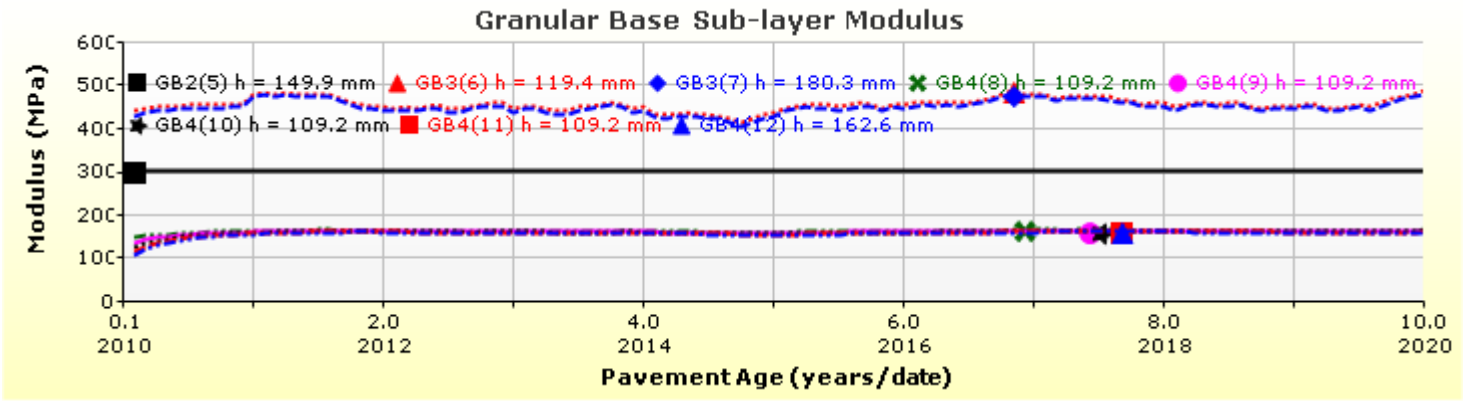

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

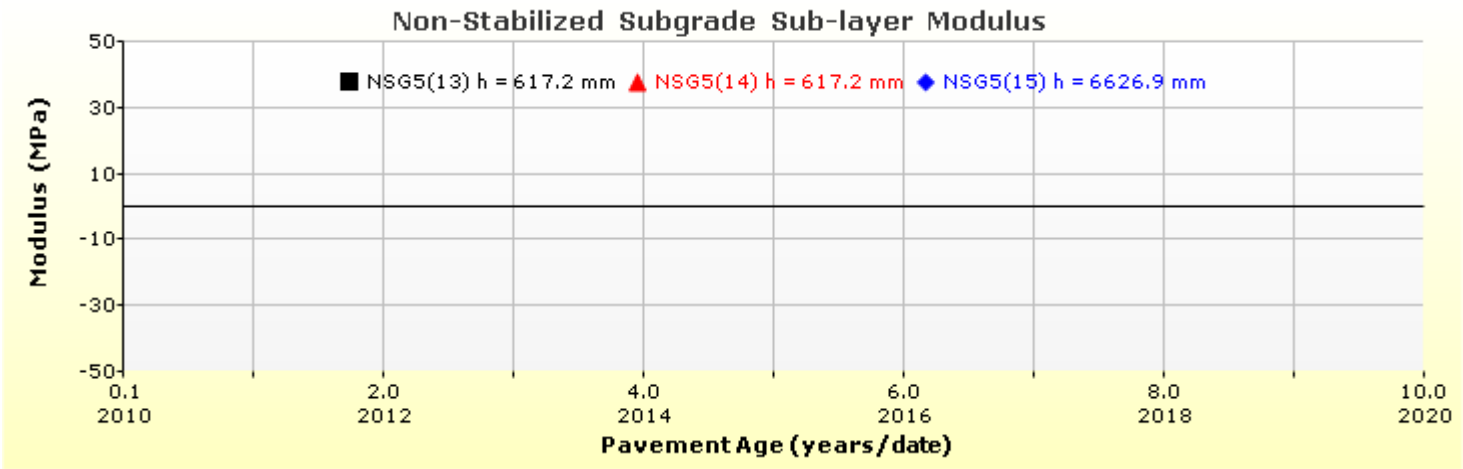

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
90
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRS+4

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRS+4.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -30.05, -51.17

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

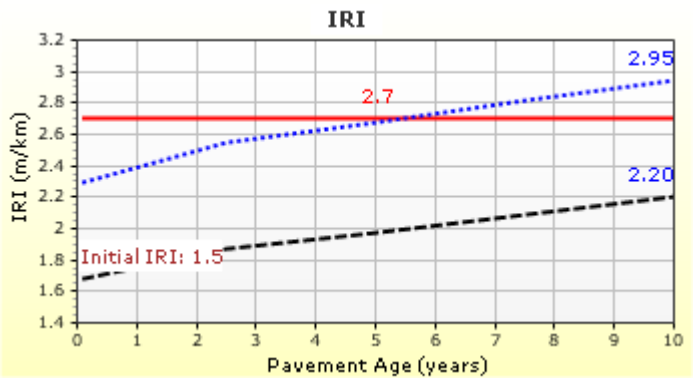
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

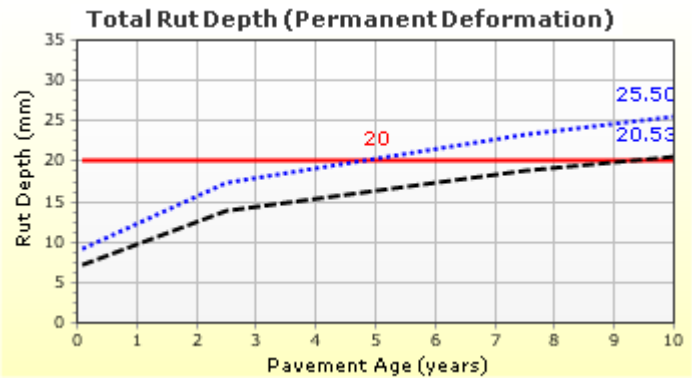
Design Outputs

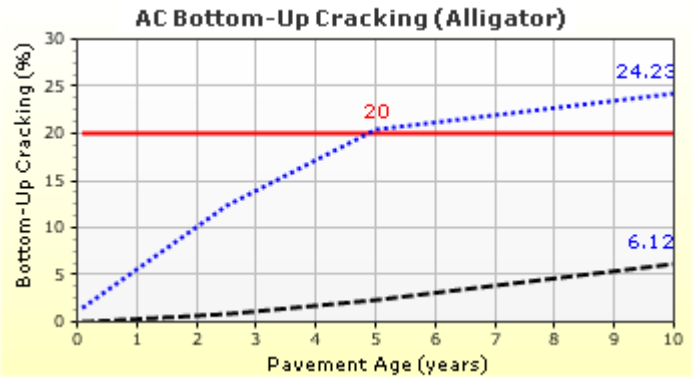
Distress Prediction Summary

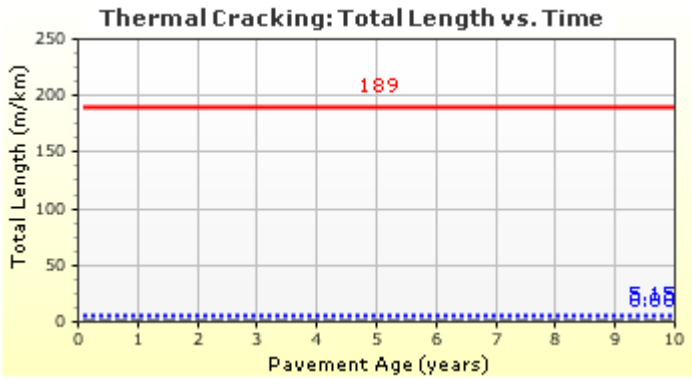
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.96	90.00	80.23	Fail
Permanent deformation - total pavement (mm)	20.00	25.50	90.00	44.46	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.23	90.00	83.70	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	755.60	90.00	64.87	Fail
Permanent deformation - AC only (mm)	5.00	12.55	50.00	1.53	Fail

Distress Charts







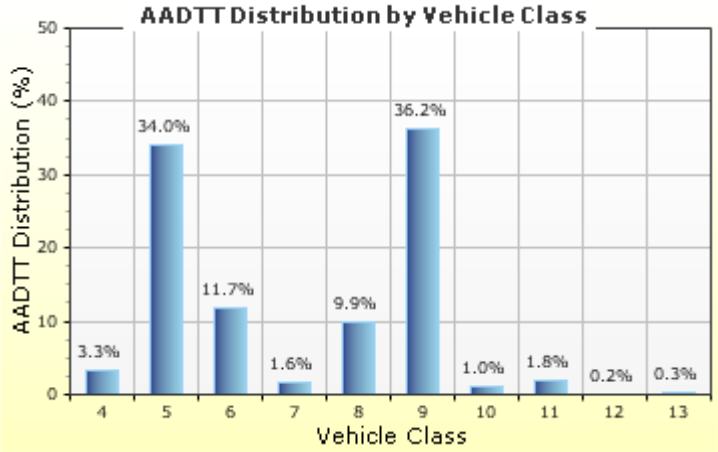


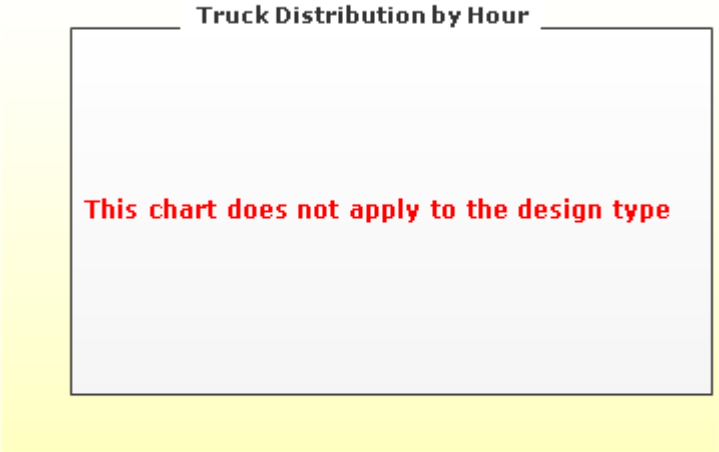


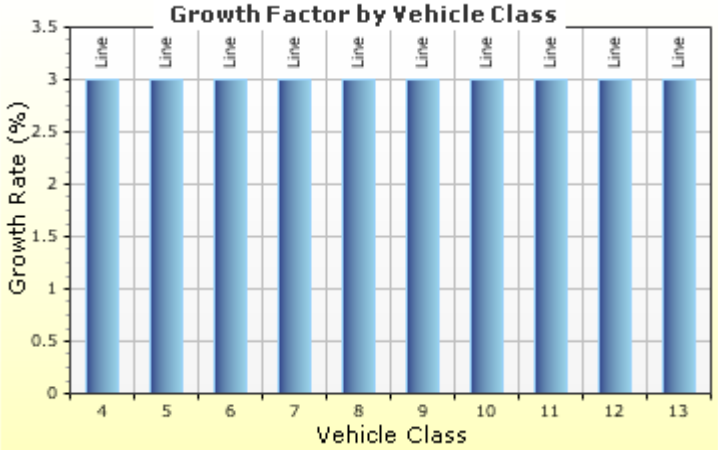
Traffic Inputs

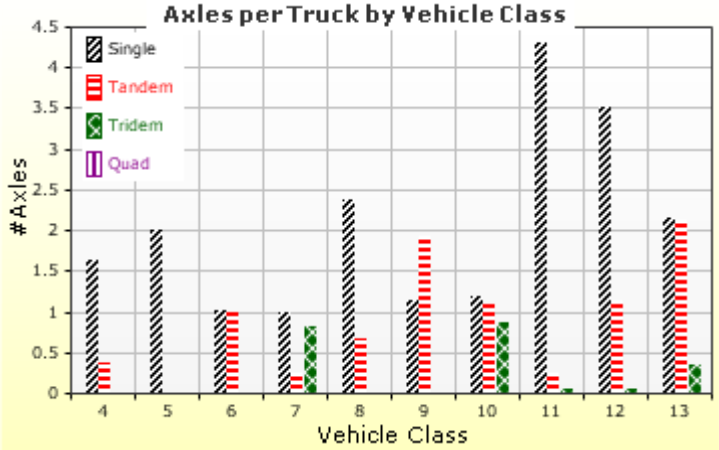
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

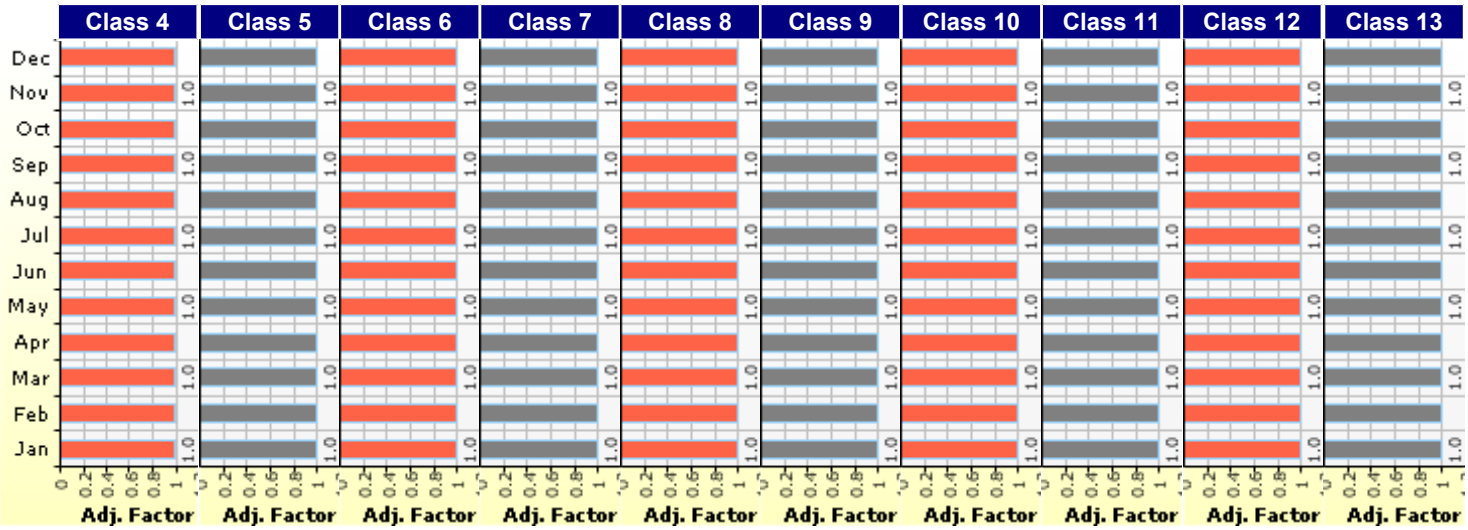








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

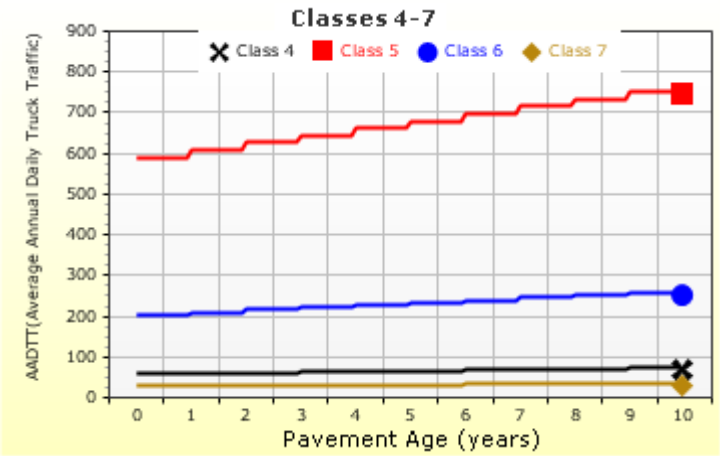
Wheelbase does not apply

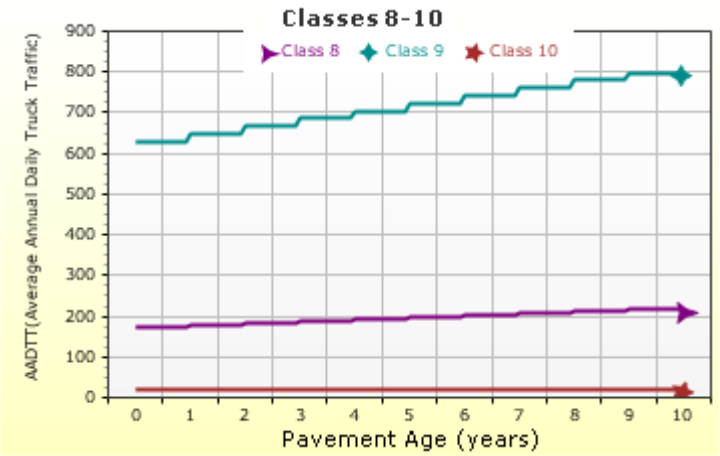
Number of Axles per Truck

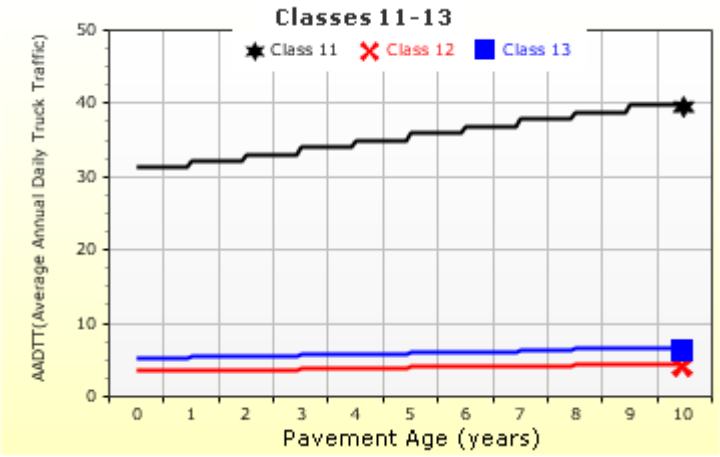
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

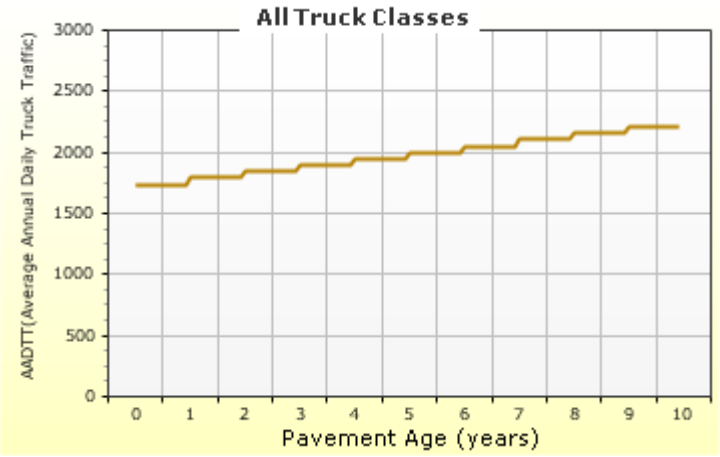
AADTT (Average Annual Daily Truck Traffic) Growth

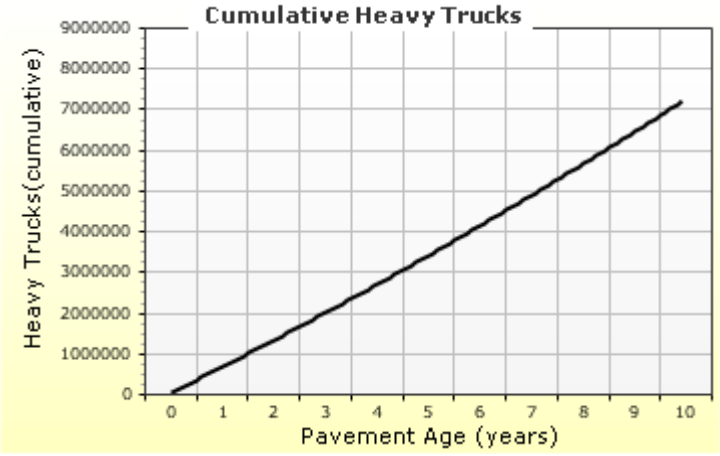
*** Traffic cap is not enforced**







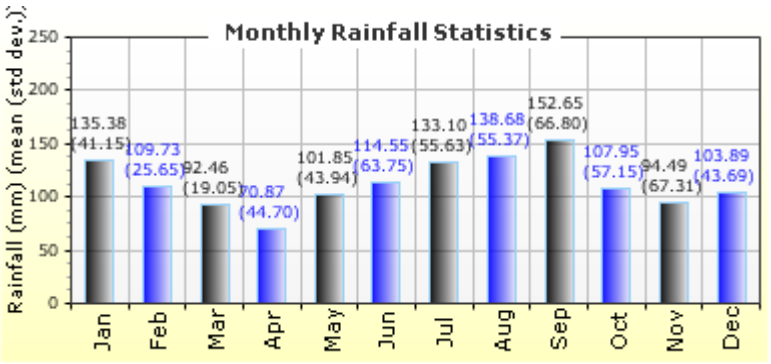




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
PORTO ALEGRE, RS	-30.05000 -51.17000 47

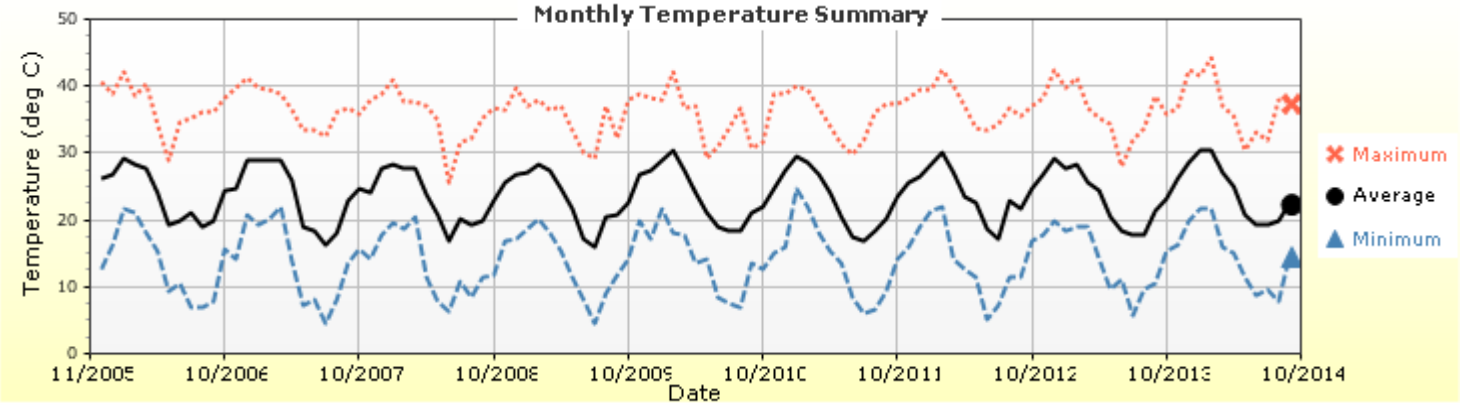


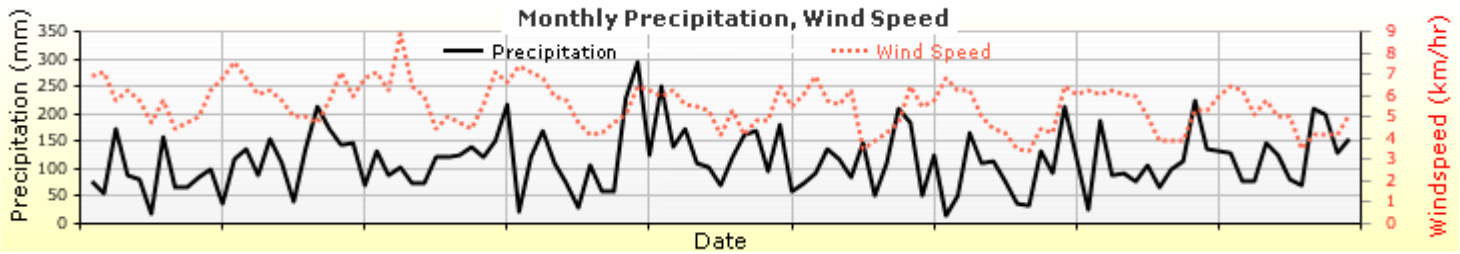
Annual Statistics:

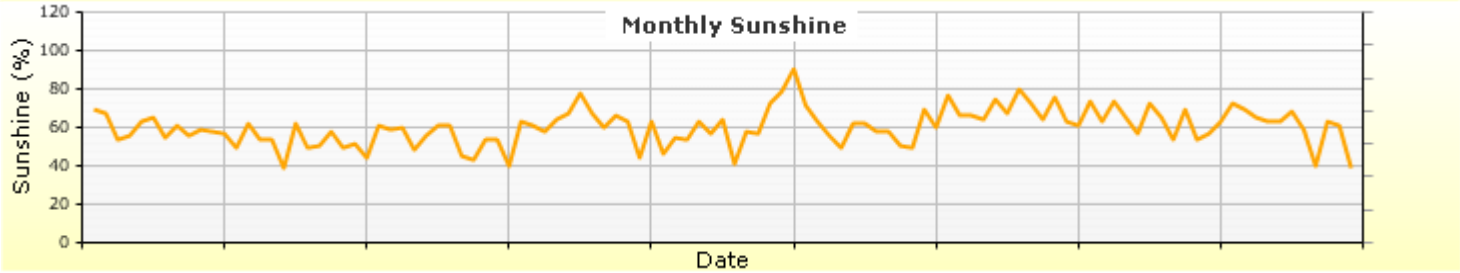
Mean annual air temperature (ºC)	23.73
Mean annual precipitation (mm)	1352.30
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

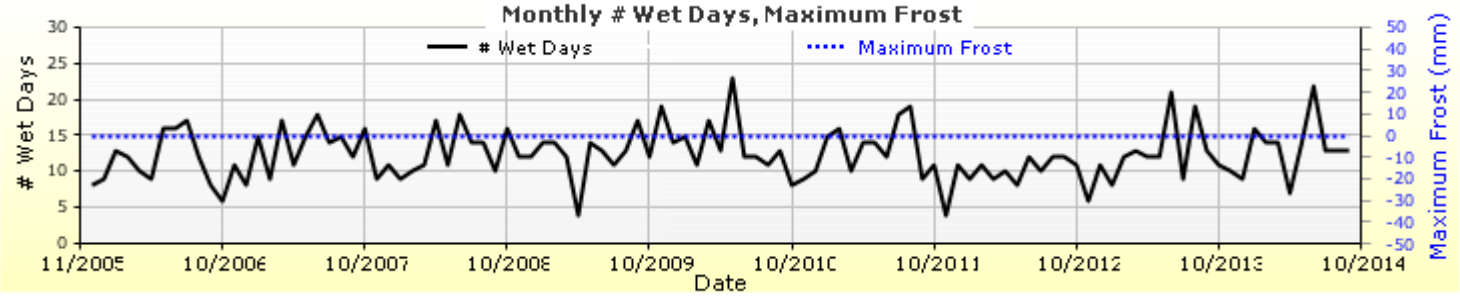
Water table depth (m)	3.05

Monthly Climate Summary:

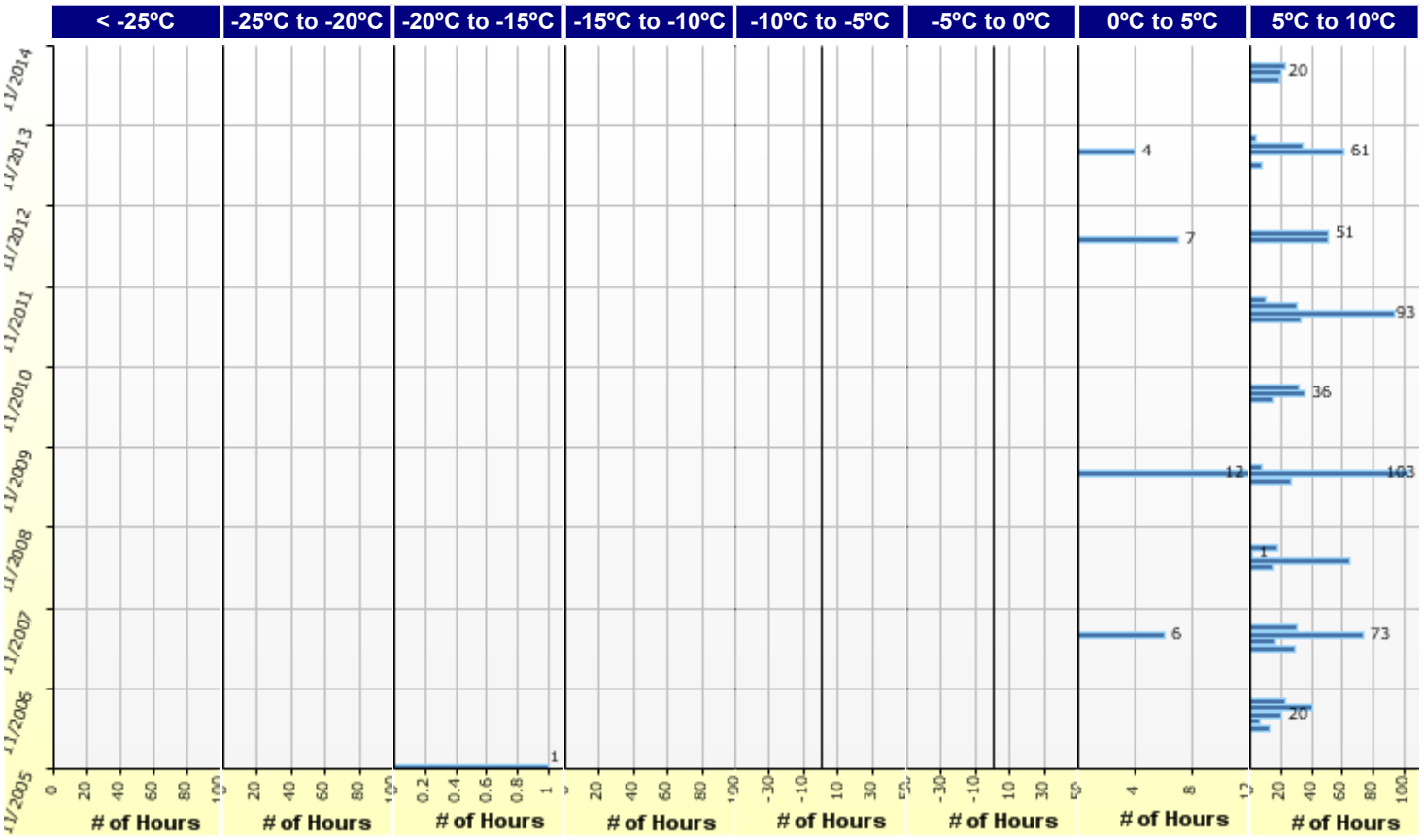


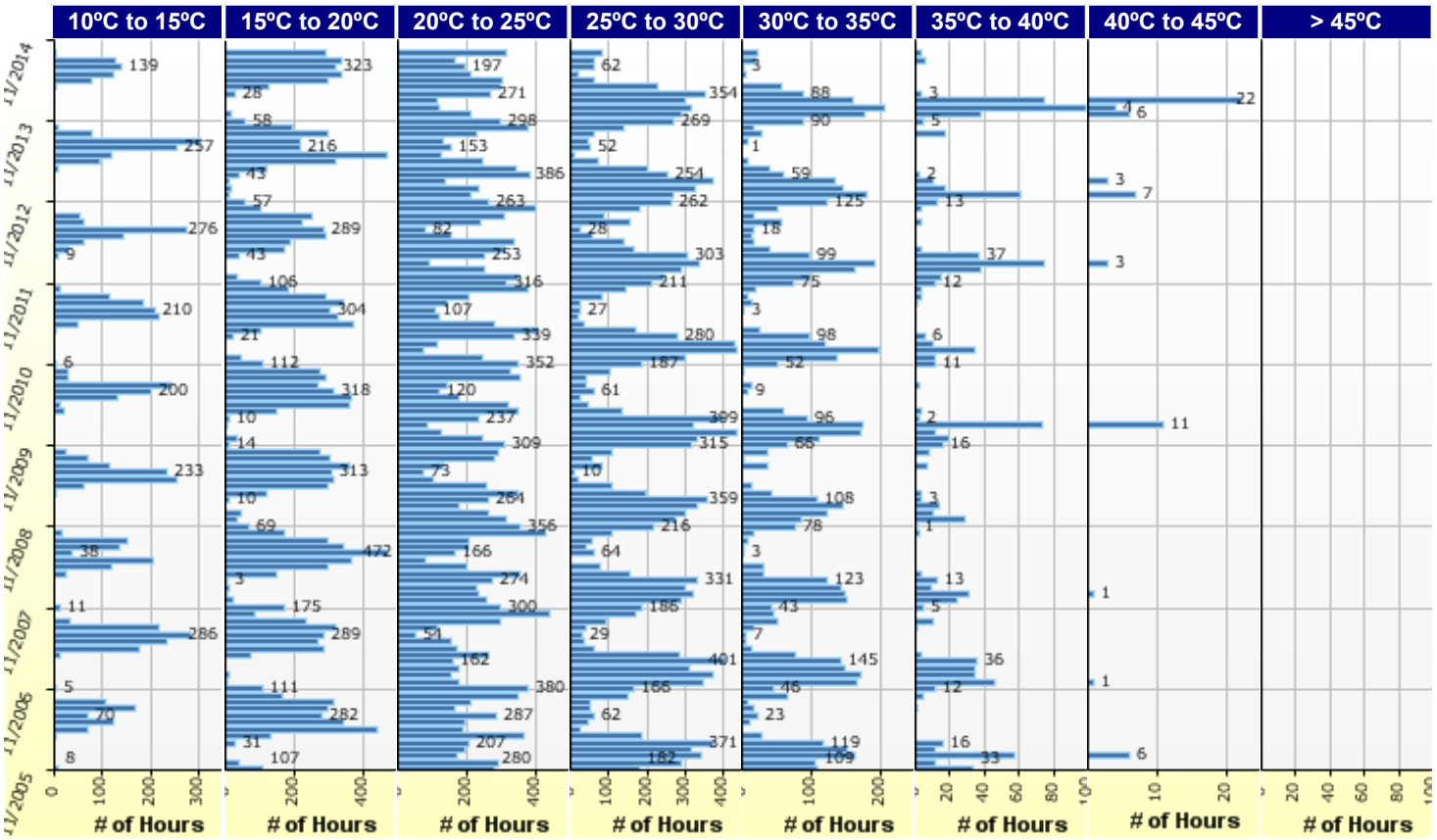






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

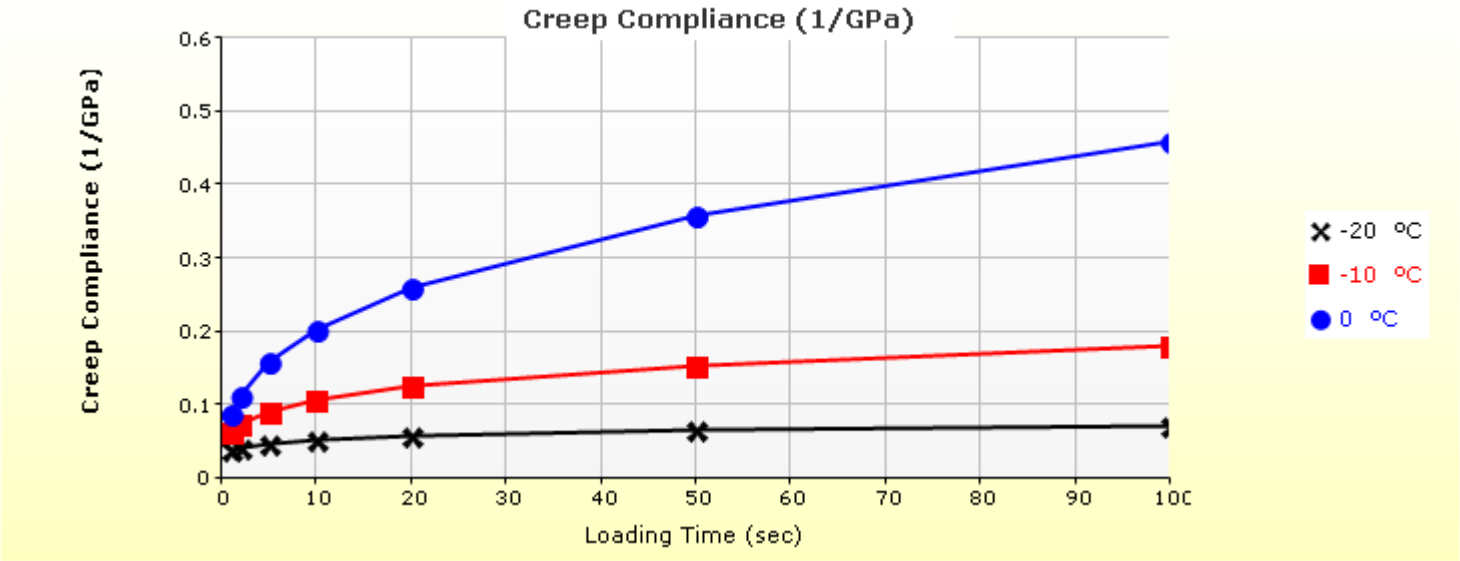
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

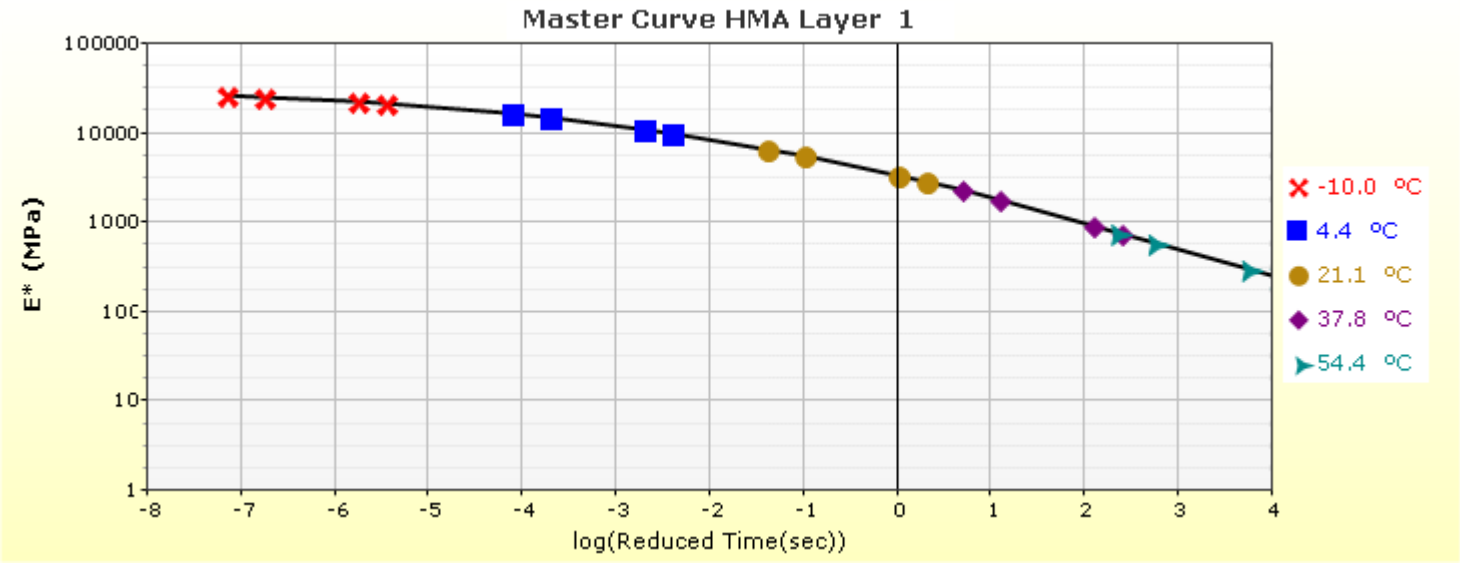
Indirect tensile strength at -10 ºC (MPa)	2.69

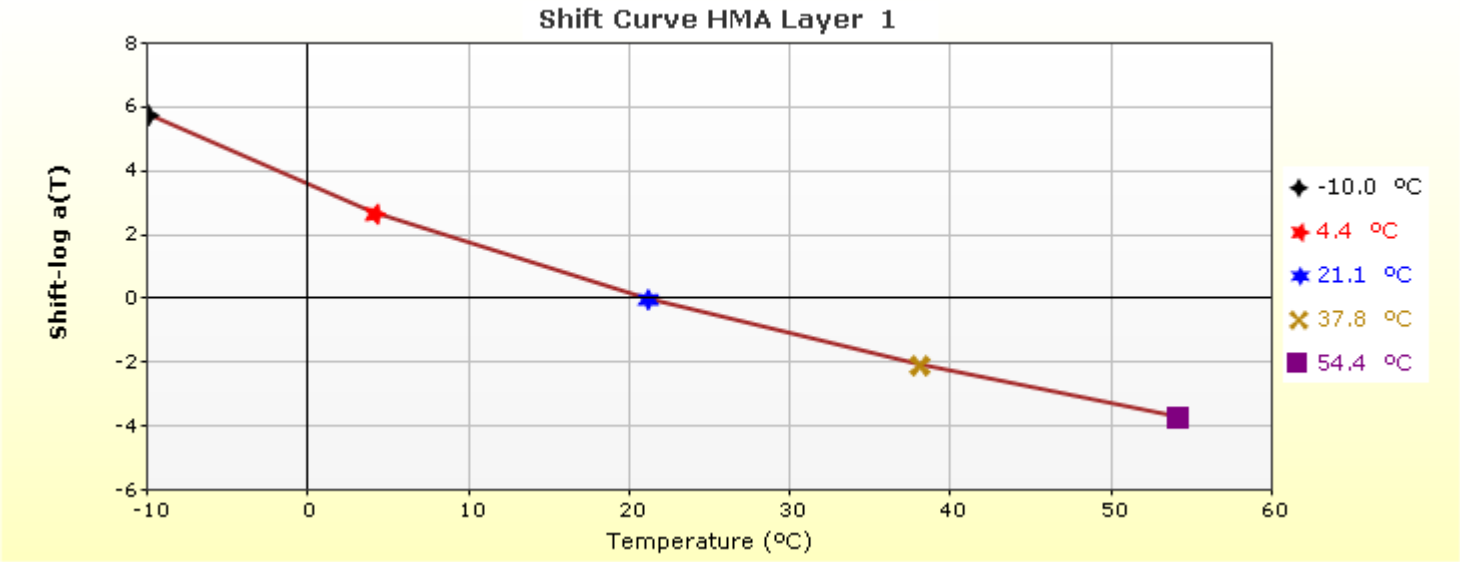
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

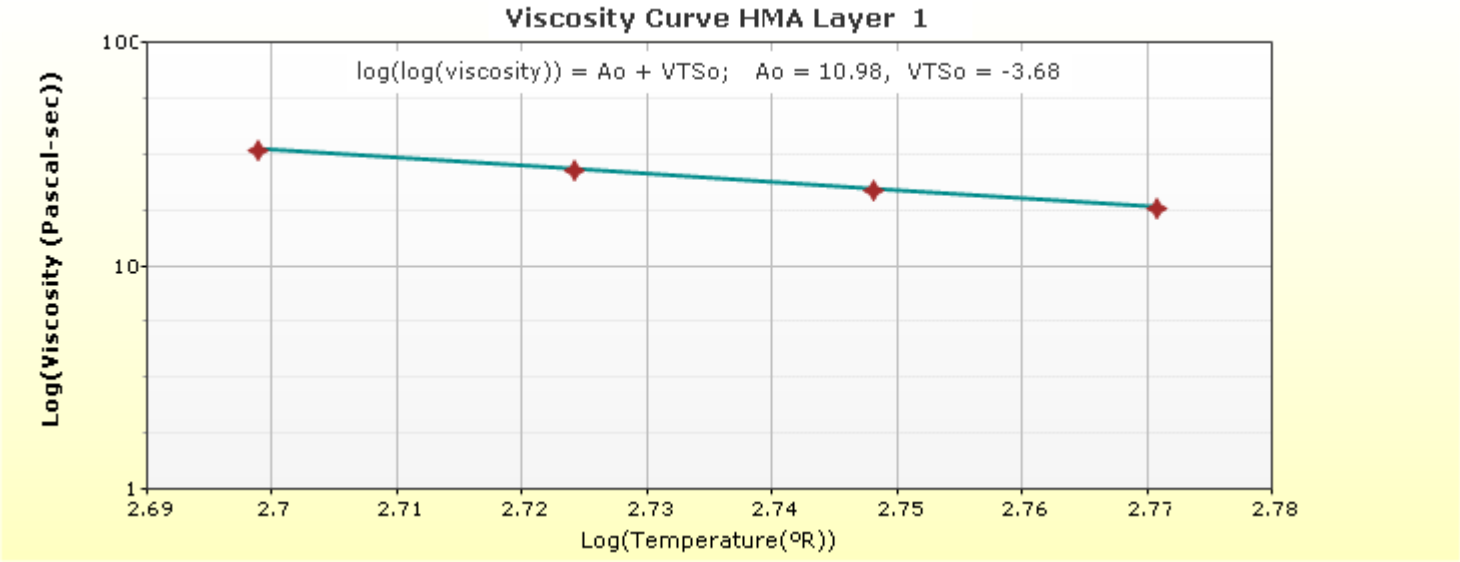
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



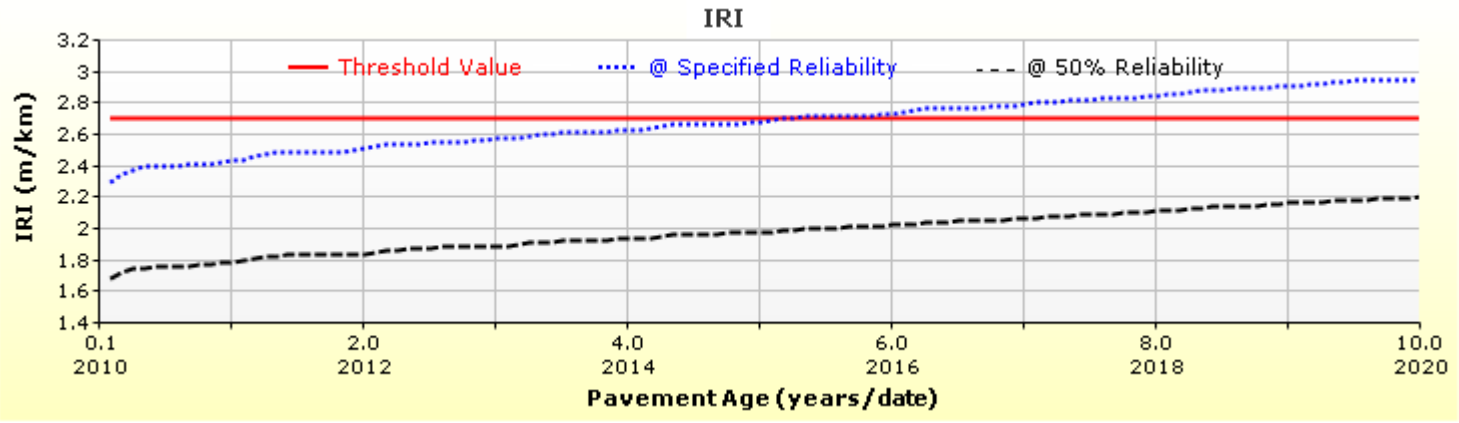
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

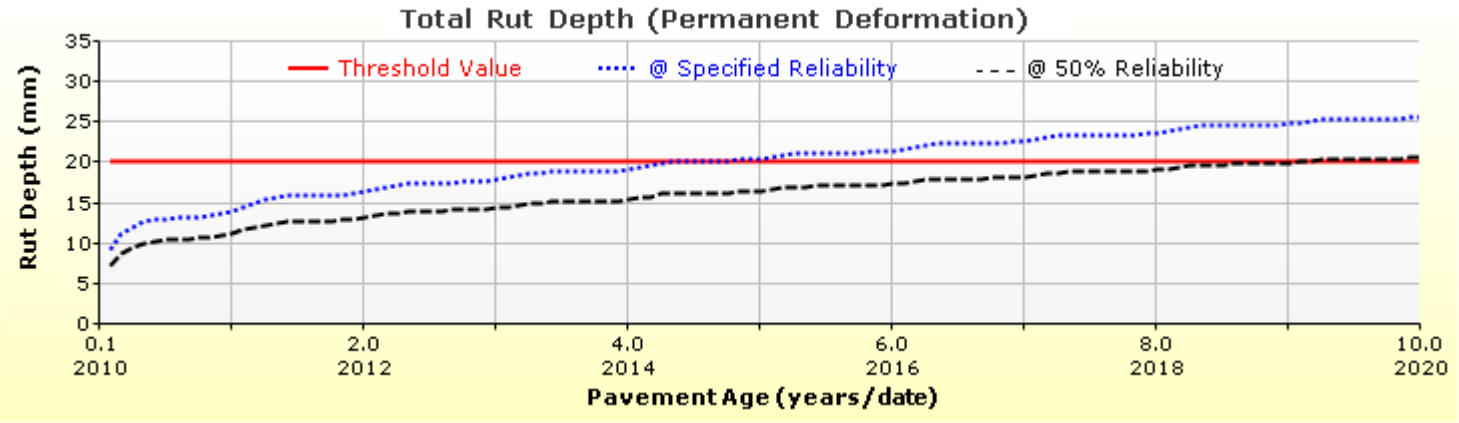


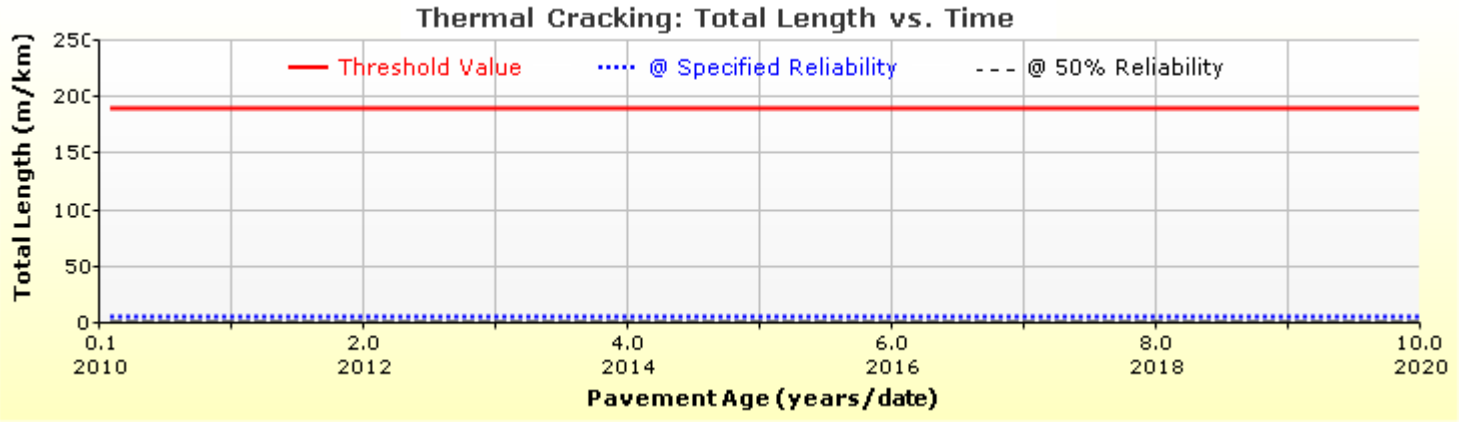


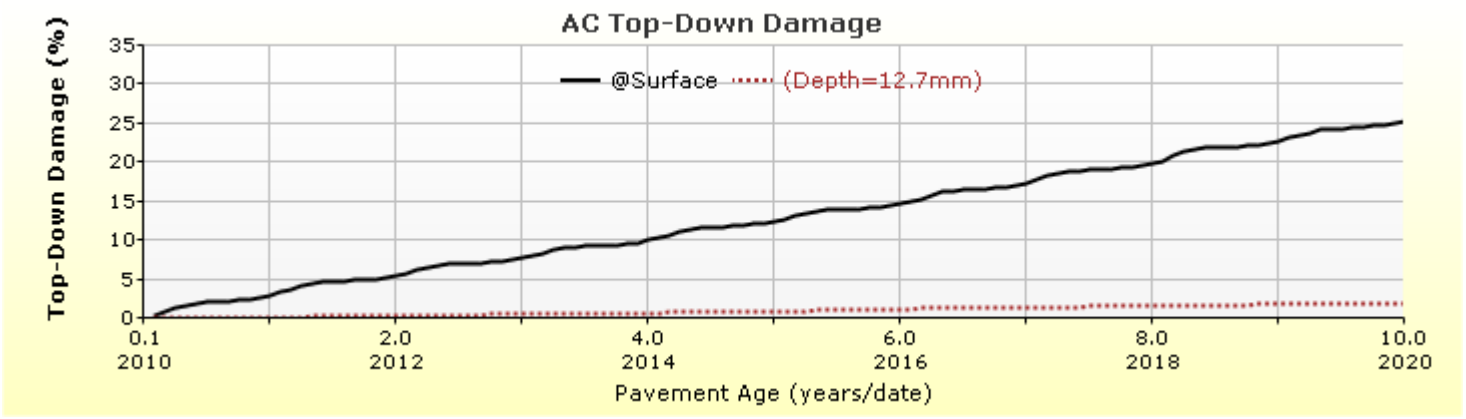


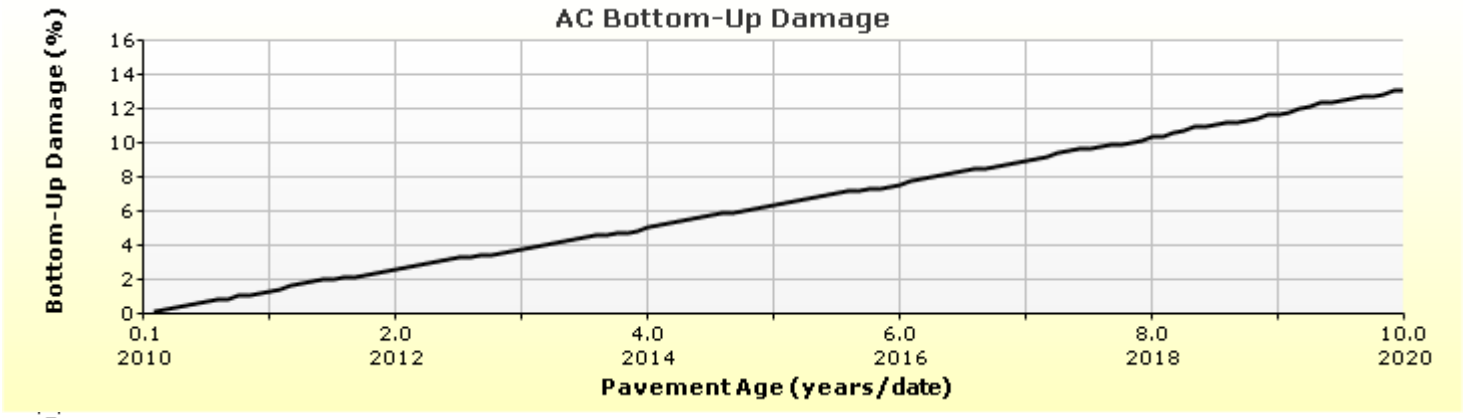
Analysis Output Charts

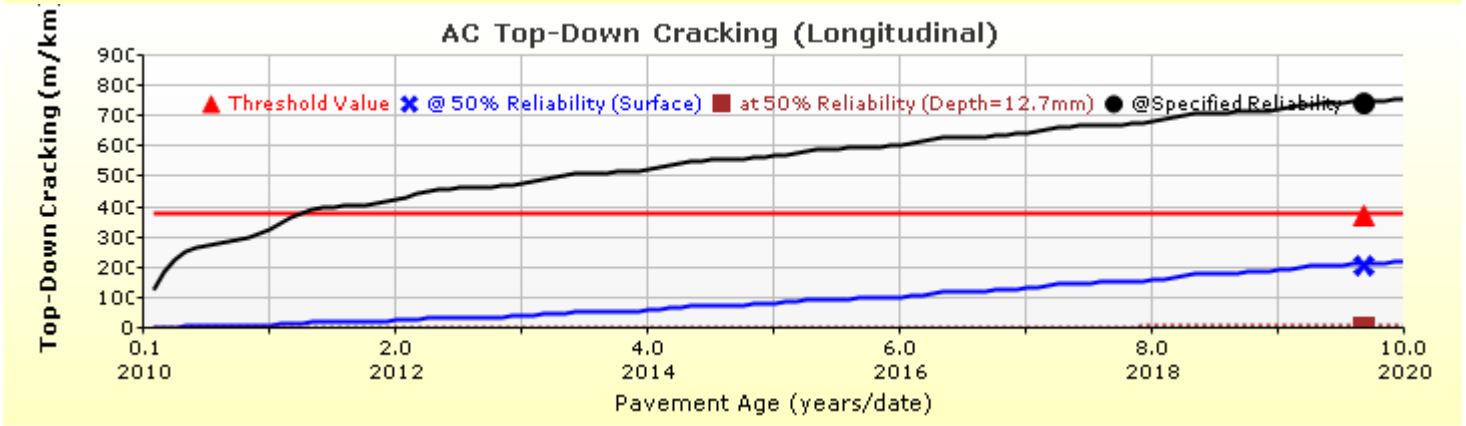


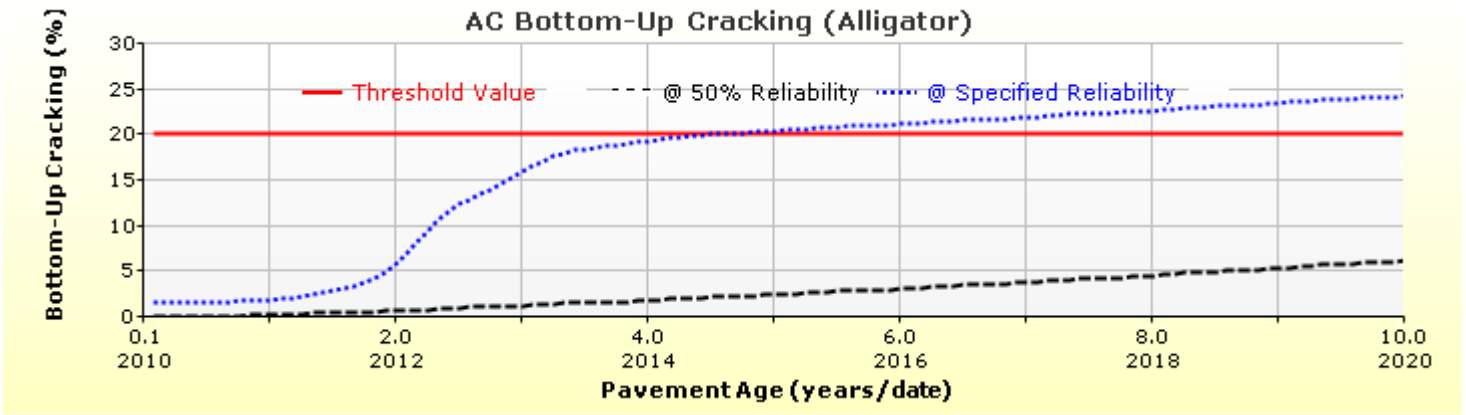


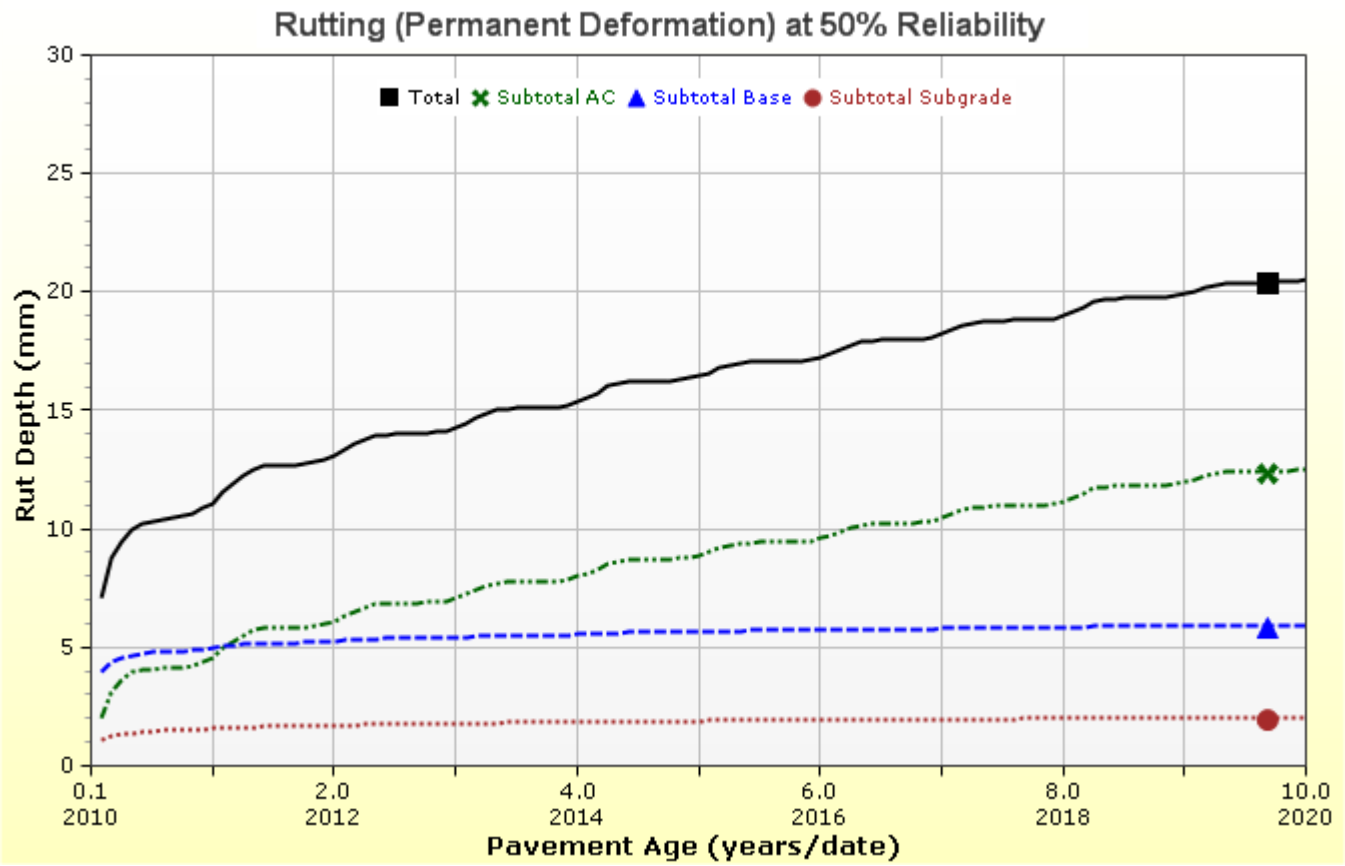


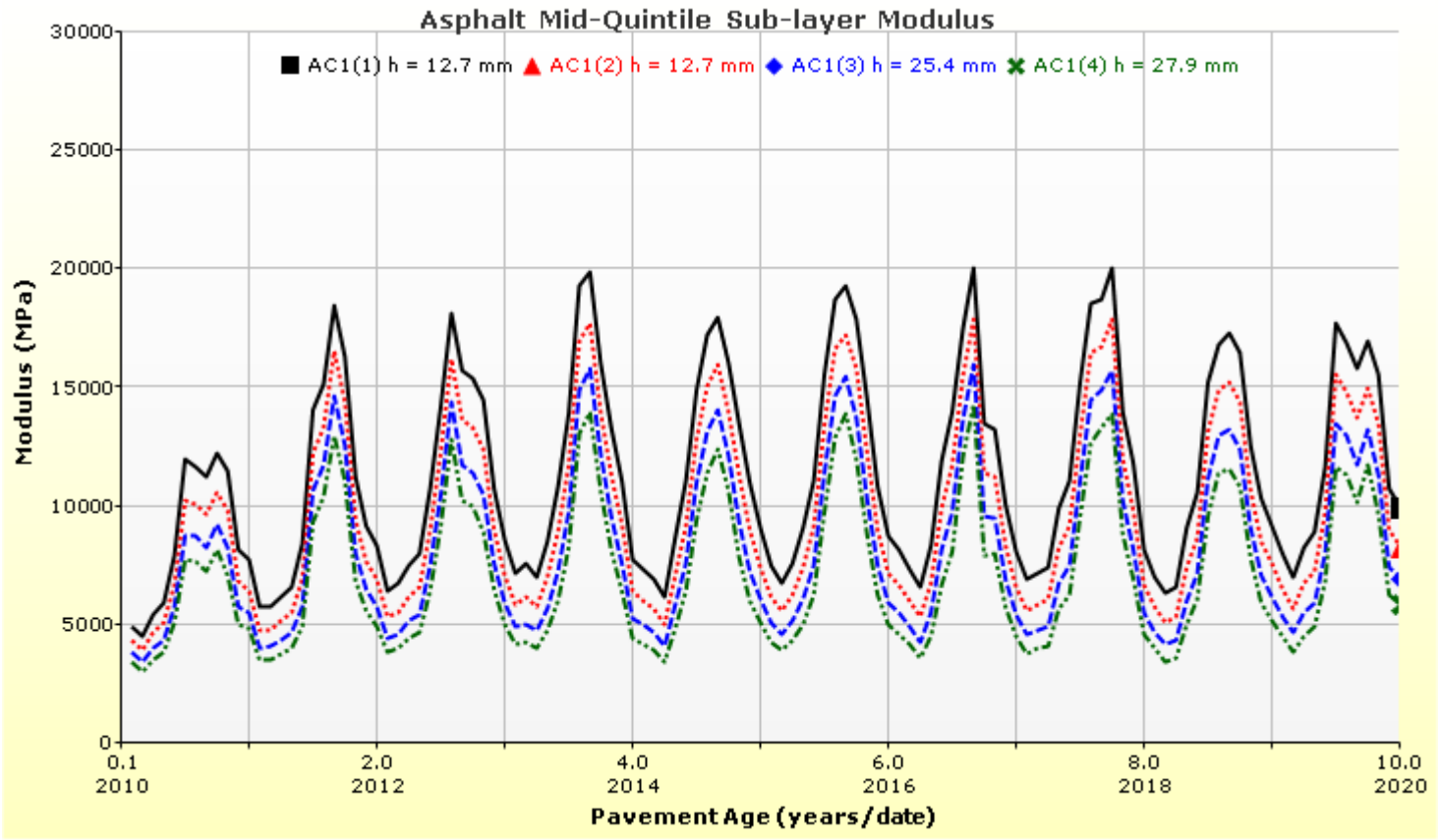

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
35
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

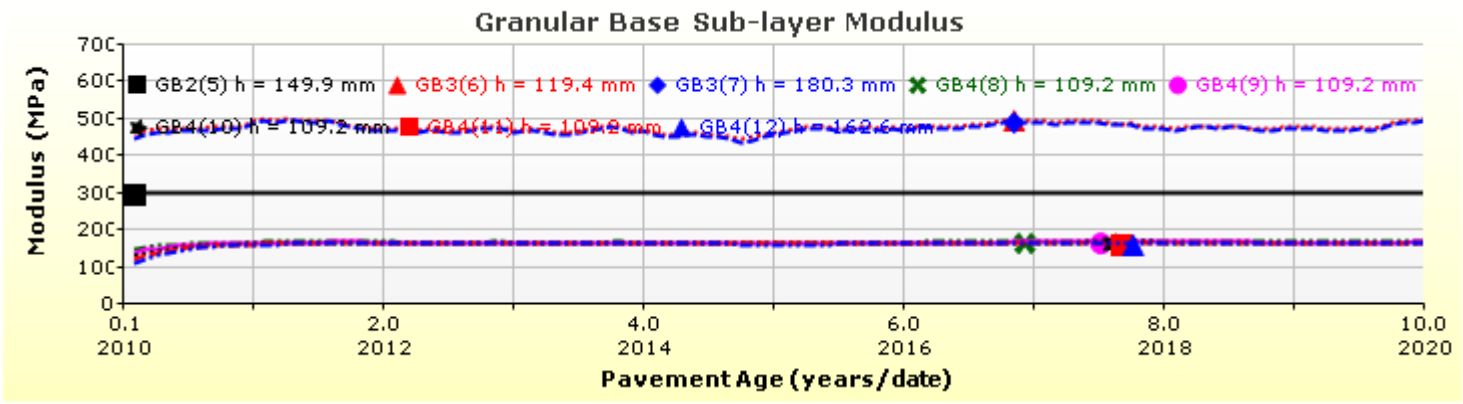

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

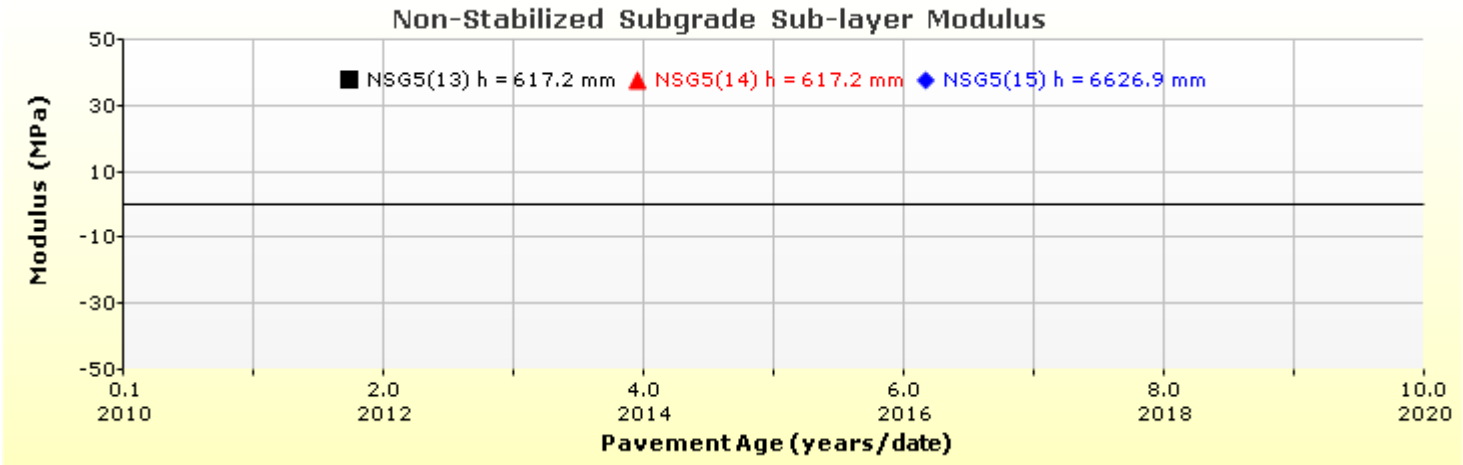

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
90
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
30
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 168.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 1
Bf2: 1
Bf3: 1

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRS-2

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRS-2.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -30.05, -51.17

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

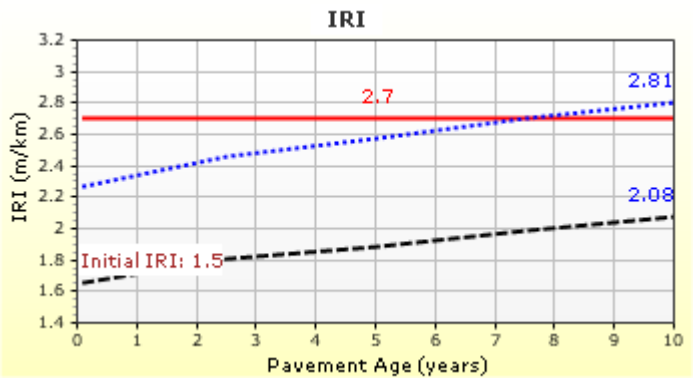
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

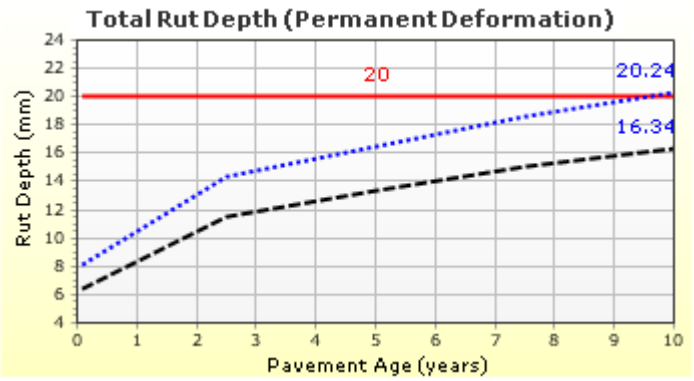
Design Outputs

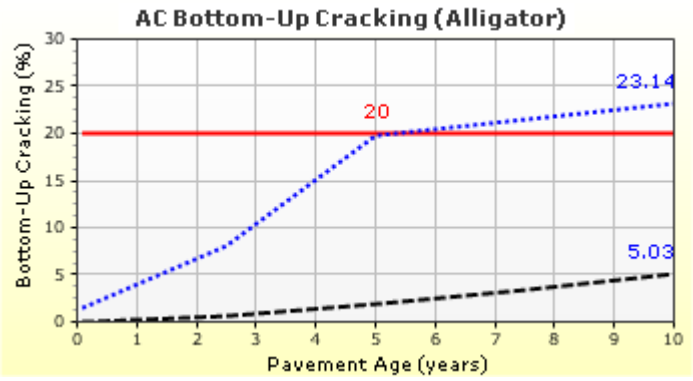
Distress Prediction Summary

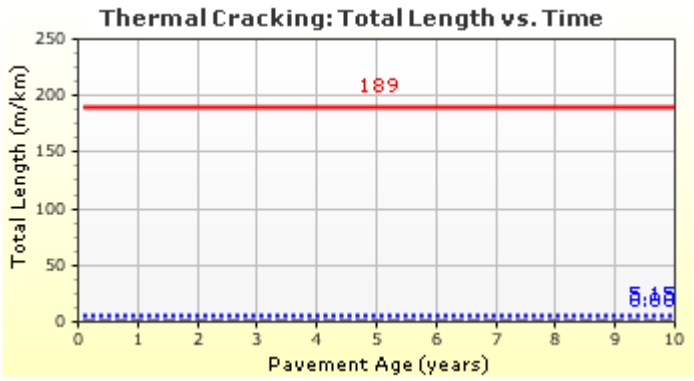
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.81	90.00	86.11	Fail
Permanent deformation - total pavement (mm)	20.00	20.25	90.00	88.44	Fail
AC bottom-up fatigue cracking (percent)	20.00	23.14	90.00	85.53	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	643.07	90.00	73.25	Fail
Permanent deformation - AC only (mm)	5.00	8.36	50.00	9.18	Fail

Distress Charts







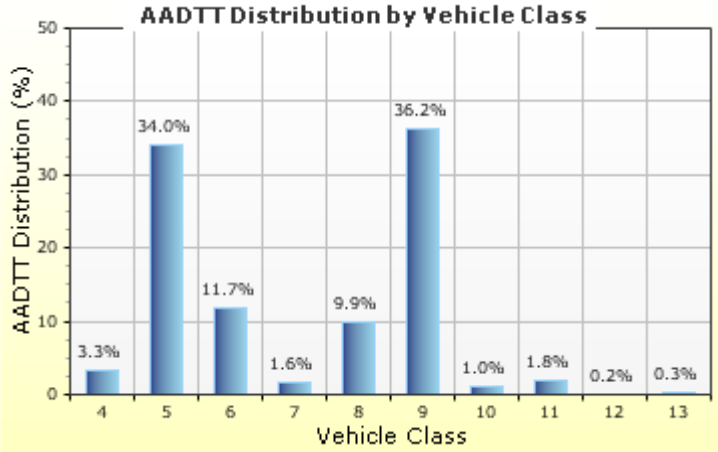


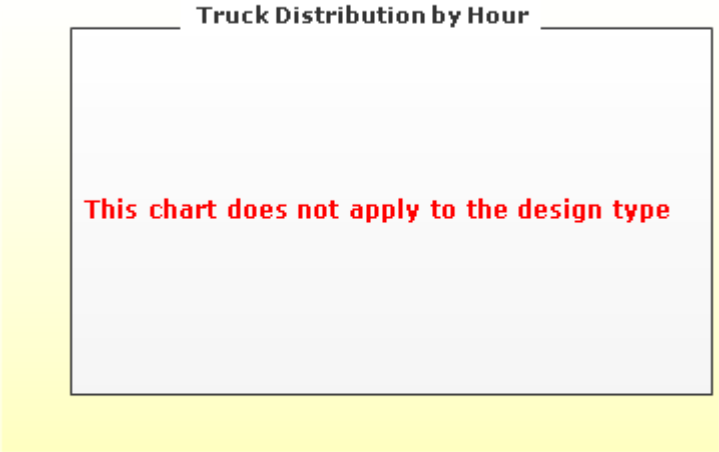
Threshold Value ····· @ Specified Reliability - - - @ 50% Reliability

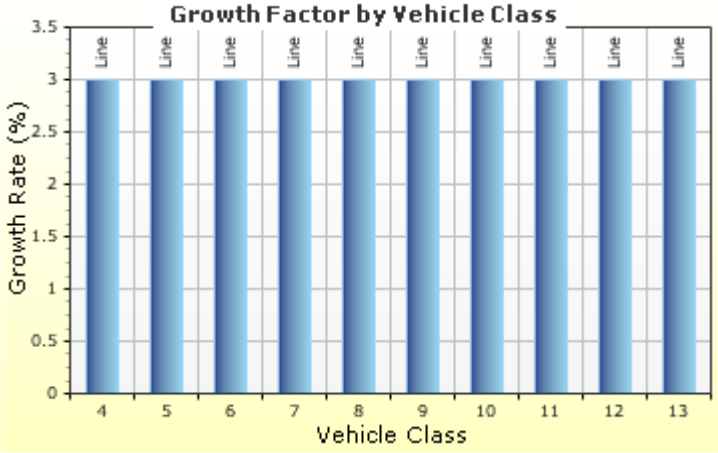
Traffic Inputs

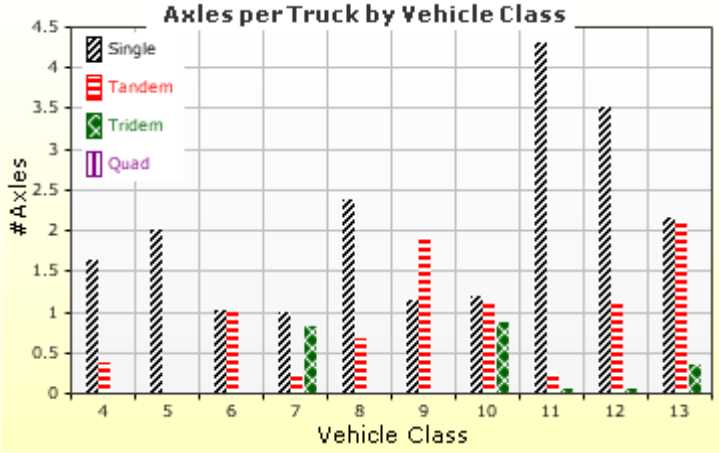
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

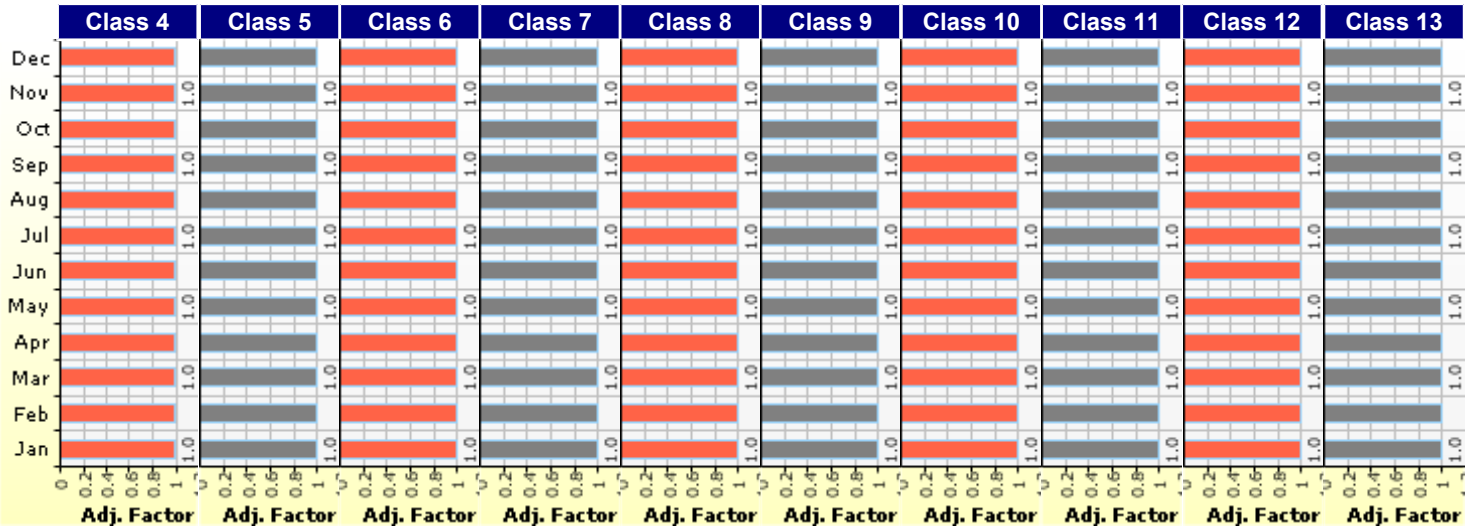








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

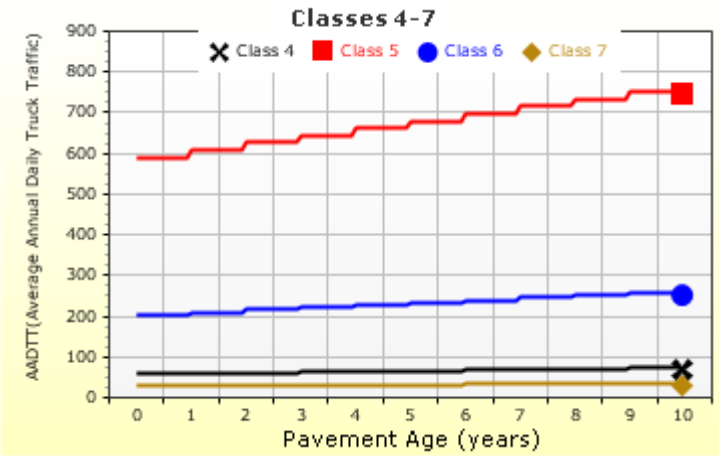
Wheelbase does not apply

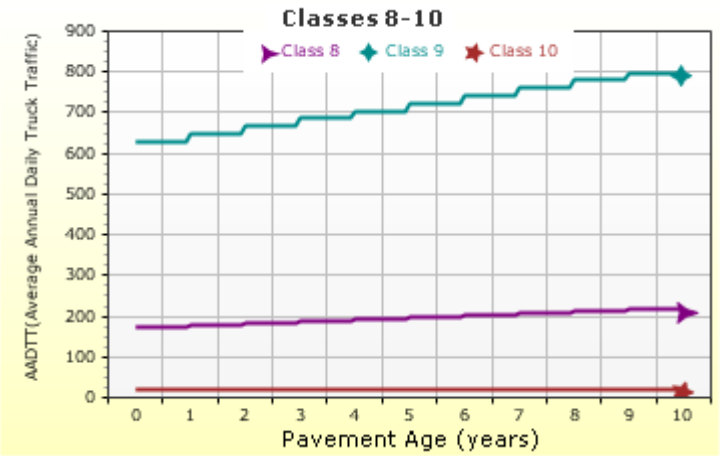
Number of Axles per Truck

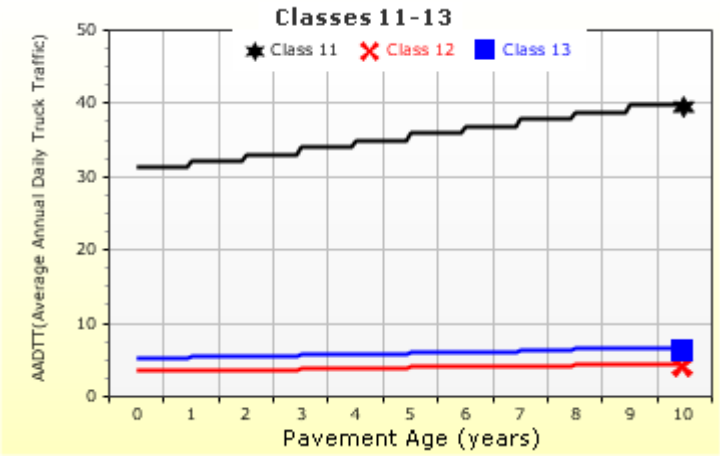
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

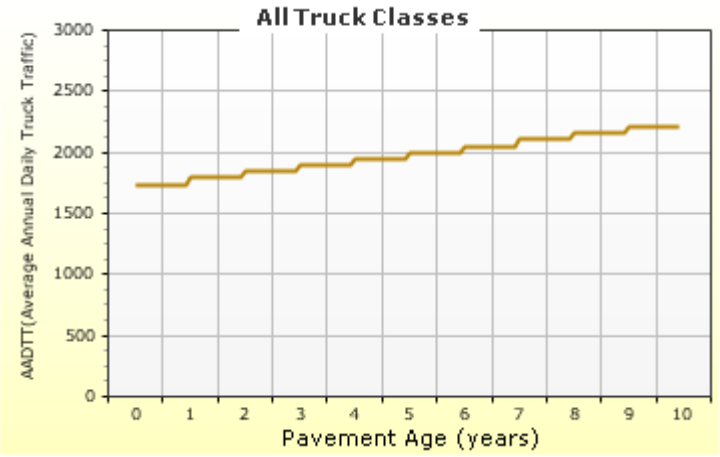
AADTT (Average Annual Daily Truck Traffic) Growth

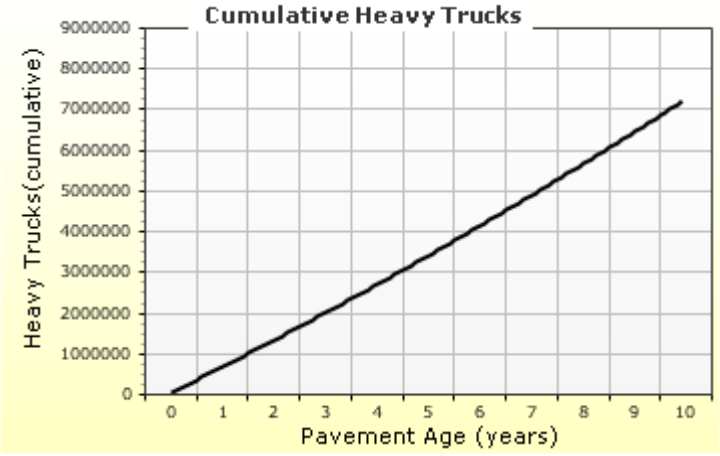
*** Traffic cap is not enforced**







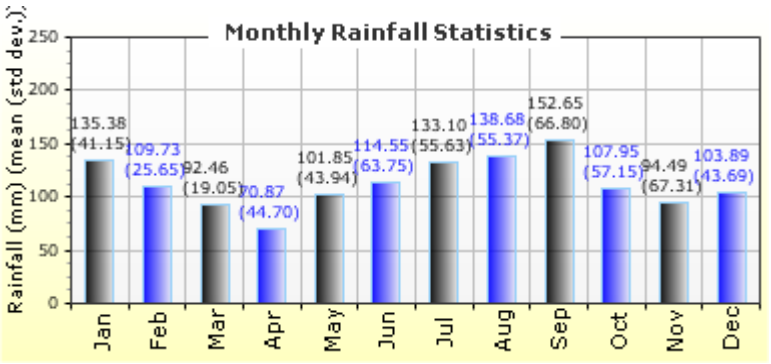




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
PORTO ALEGRE, RS	-30.05000 -51.17000 47

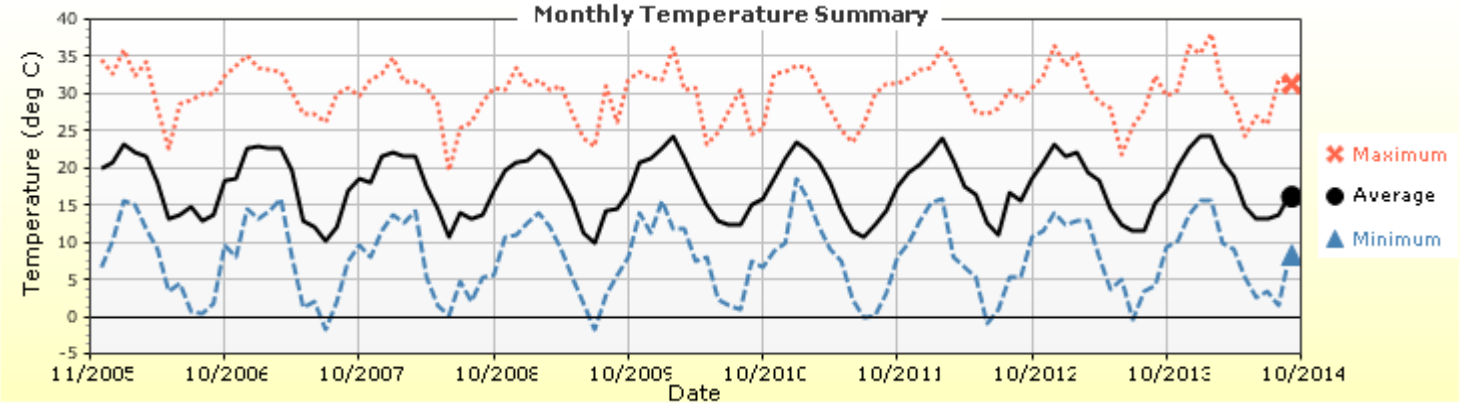


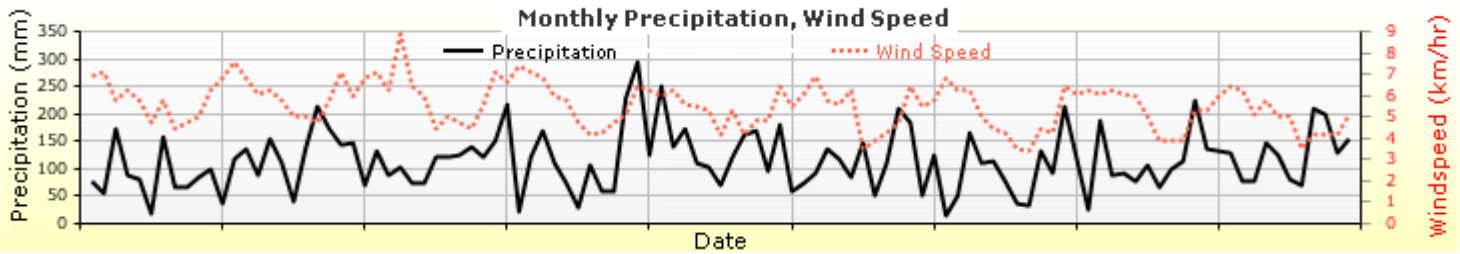
Annual Statistics:

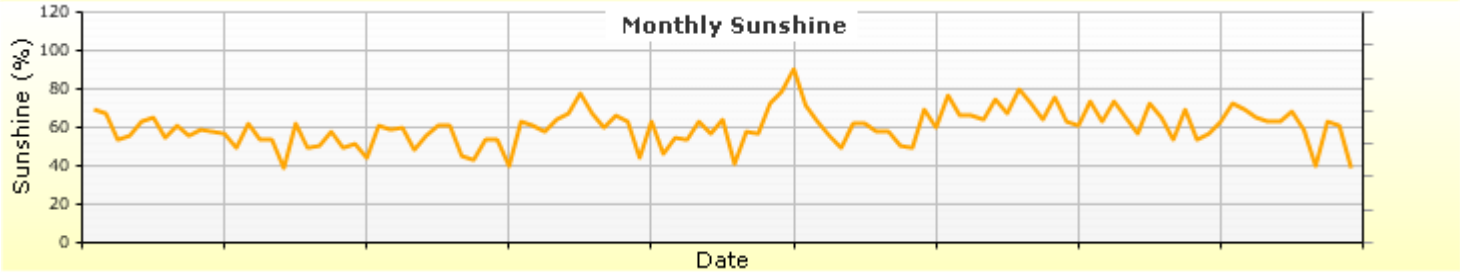
Mean annual air temperature (ºC)	17.73
Mean annual precipitation (mm)	1352.30
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.67

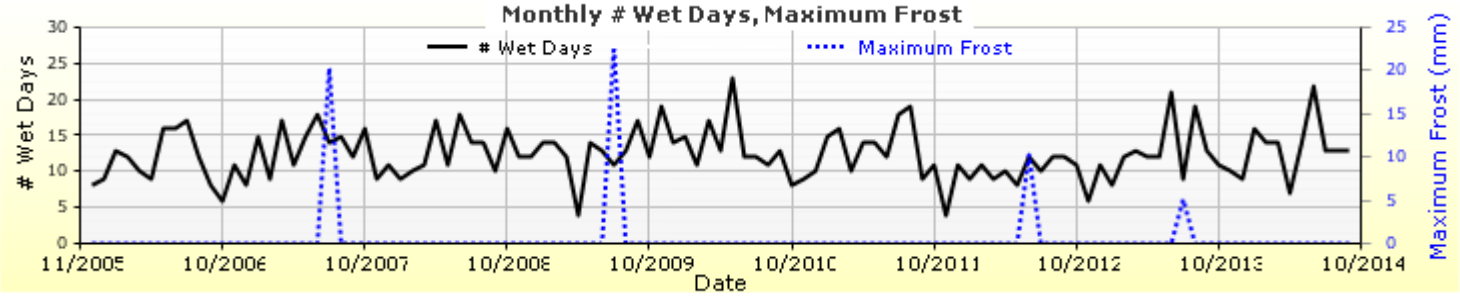
Water table depth (m)	3.05

Monthly Climate Summary:

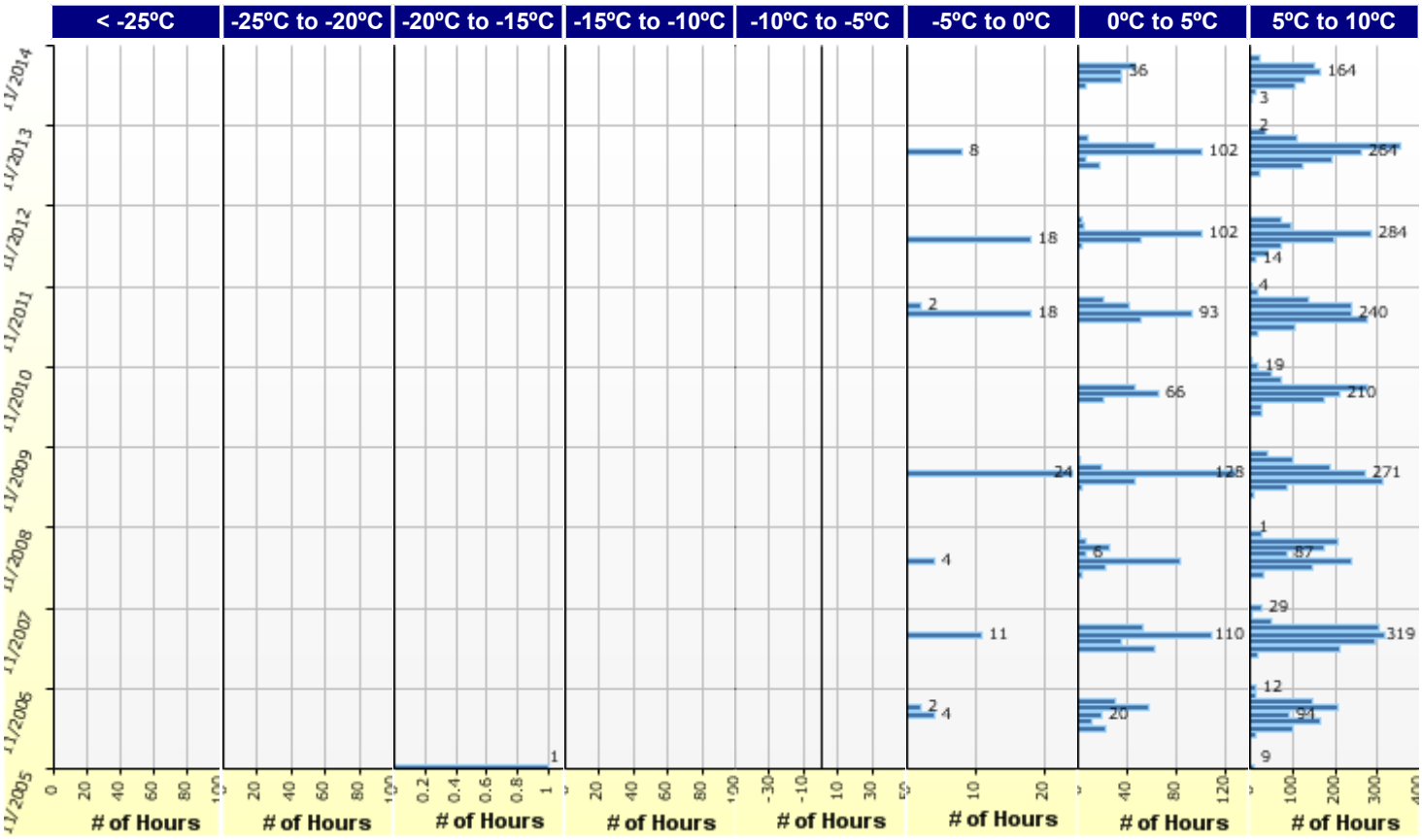


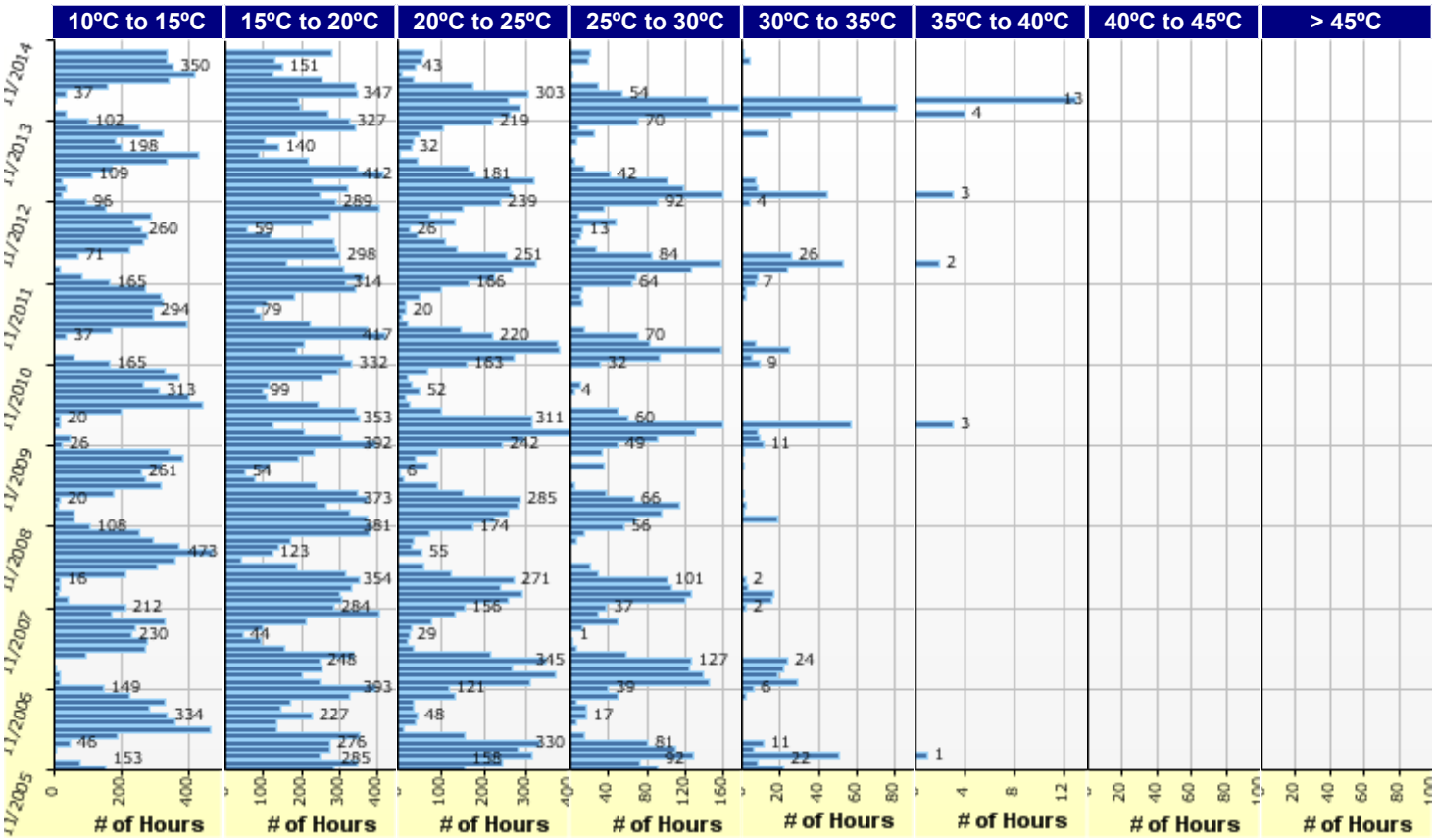






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

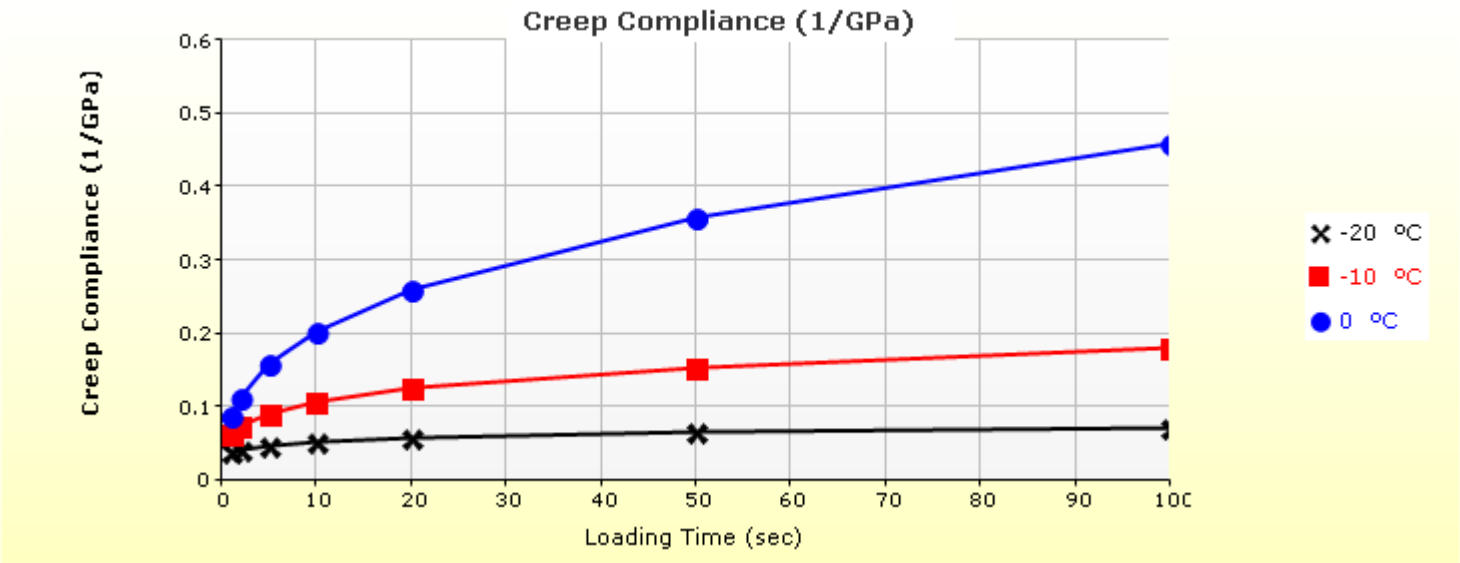
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

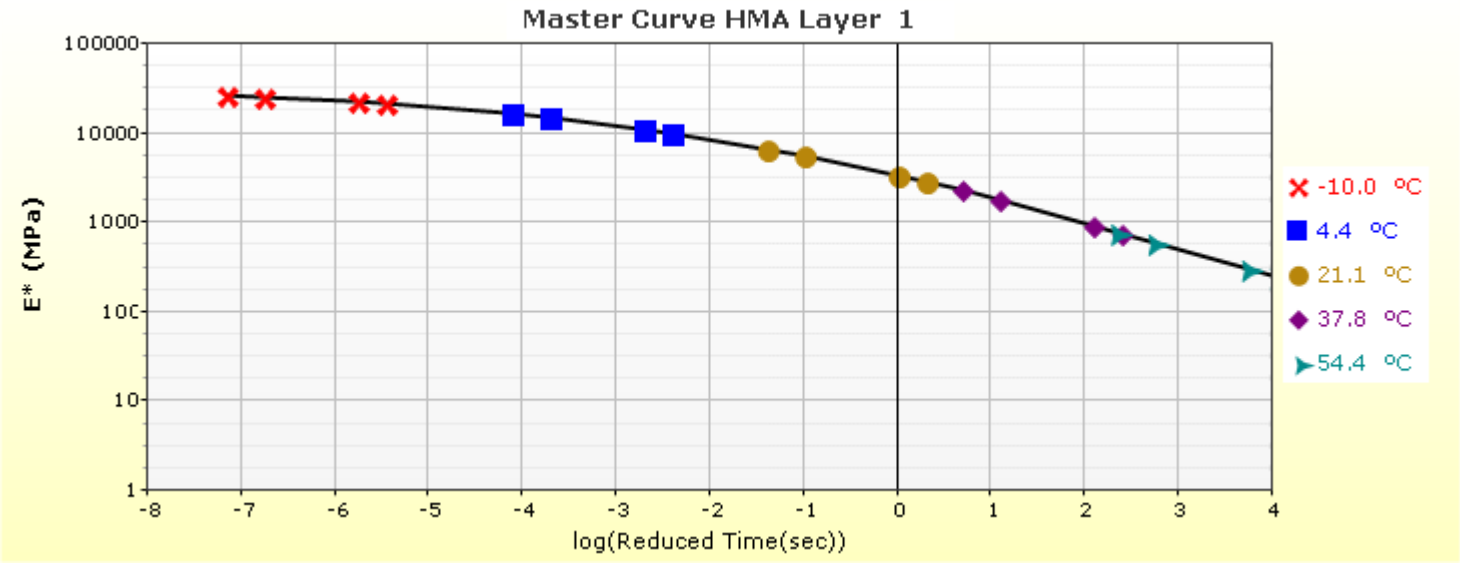
Indirect tensile strength at -10 ºC (MPa)	2.69

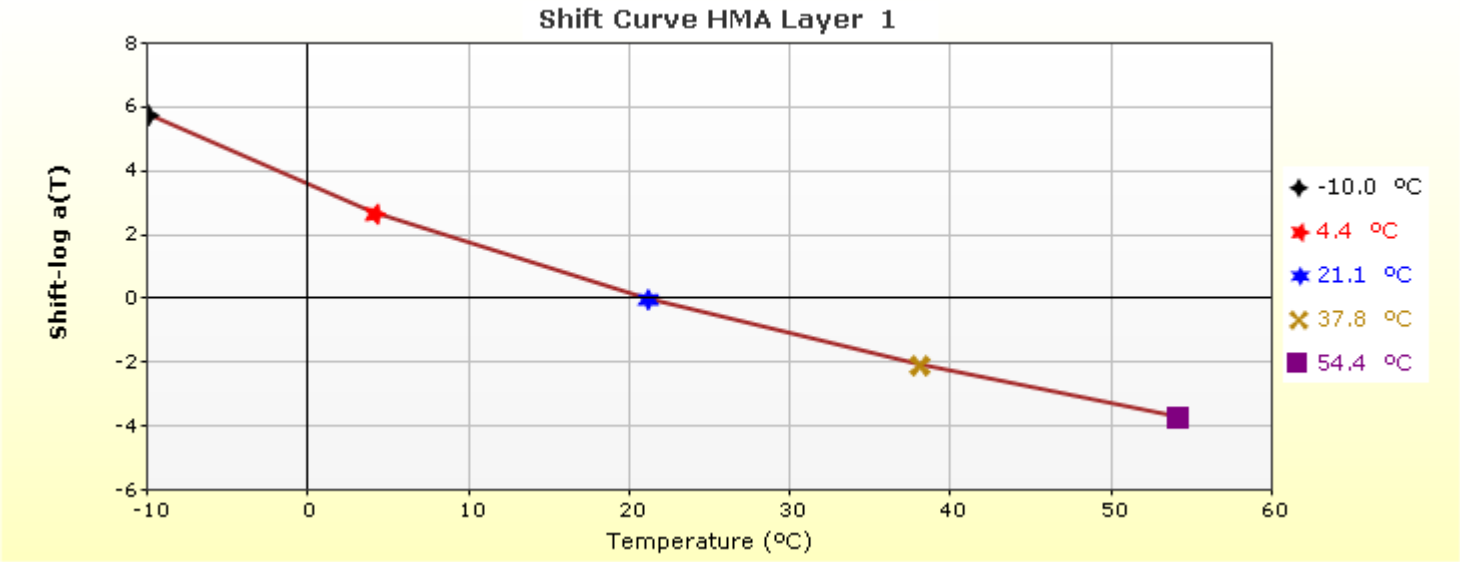
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

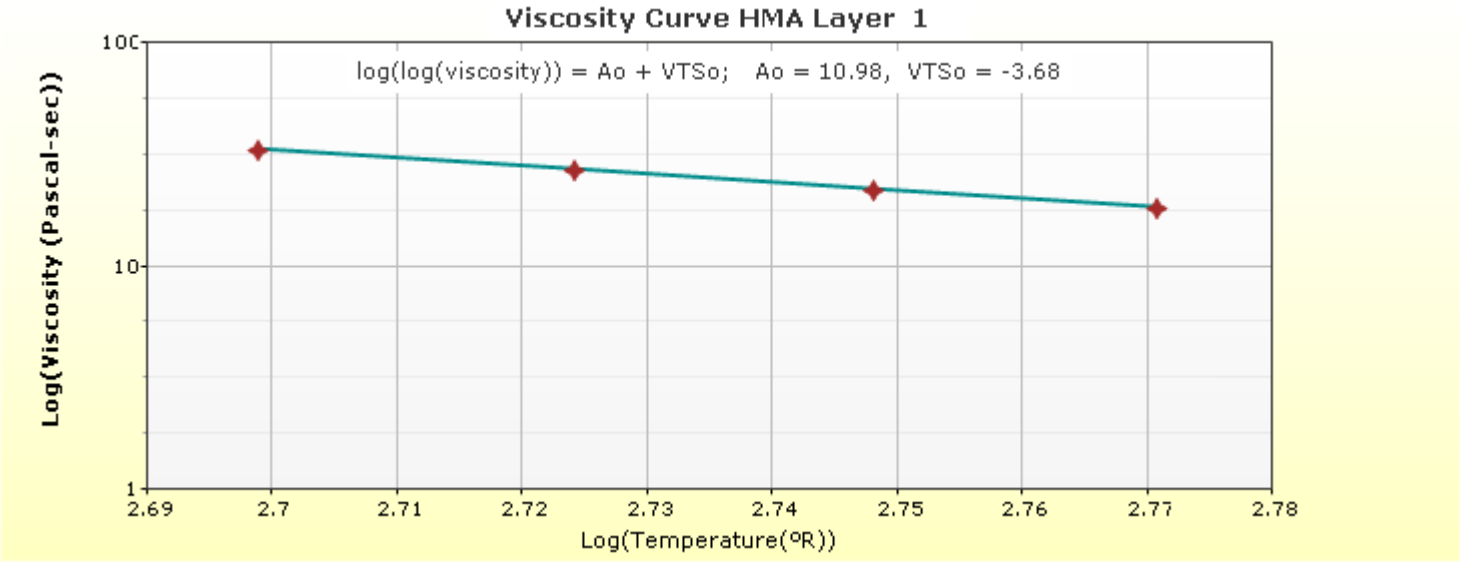
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



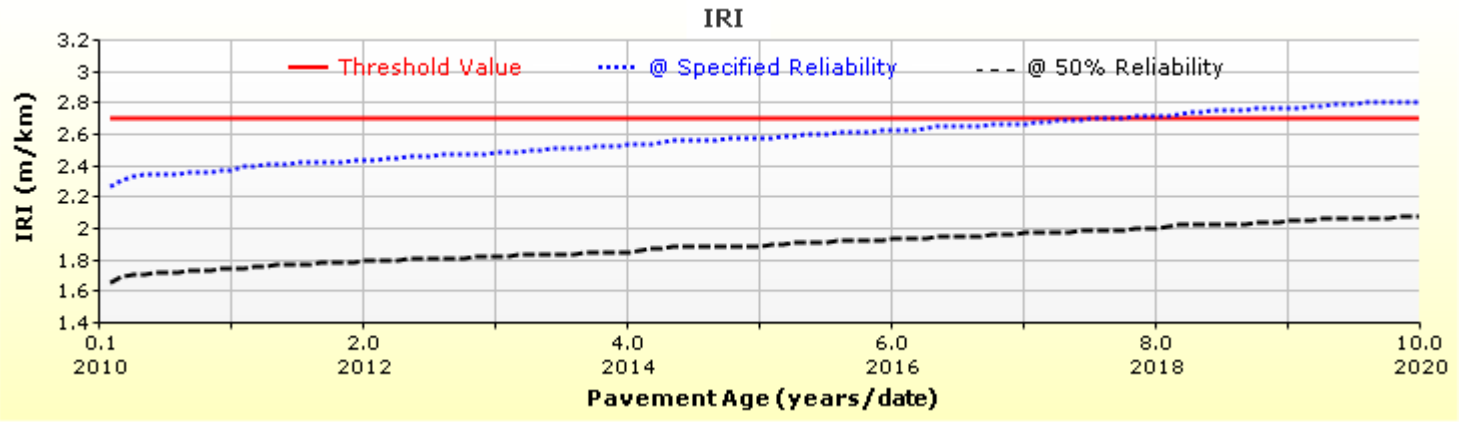
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

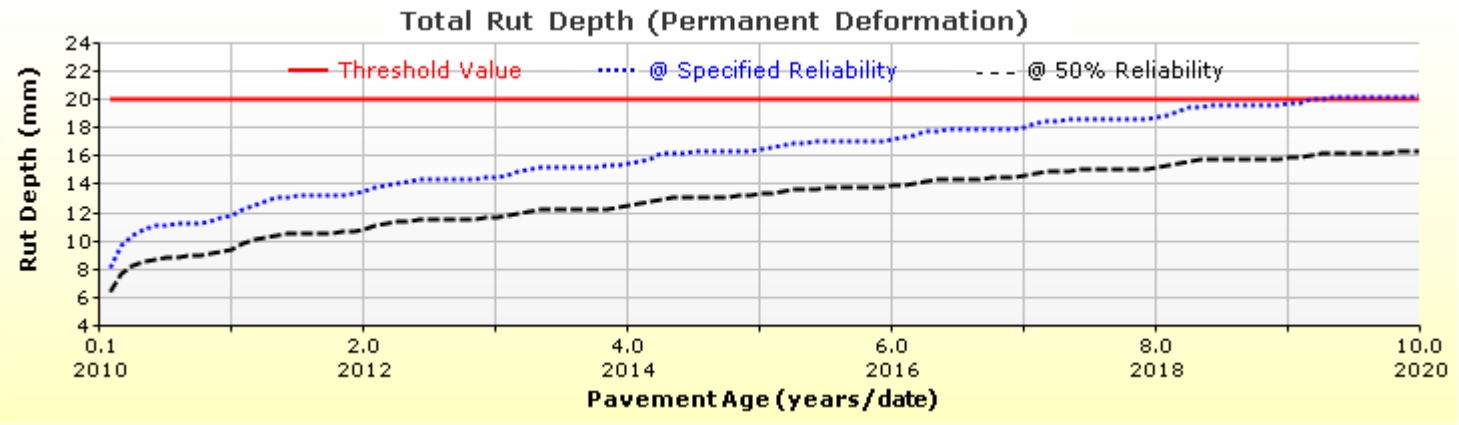


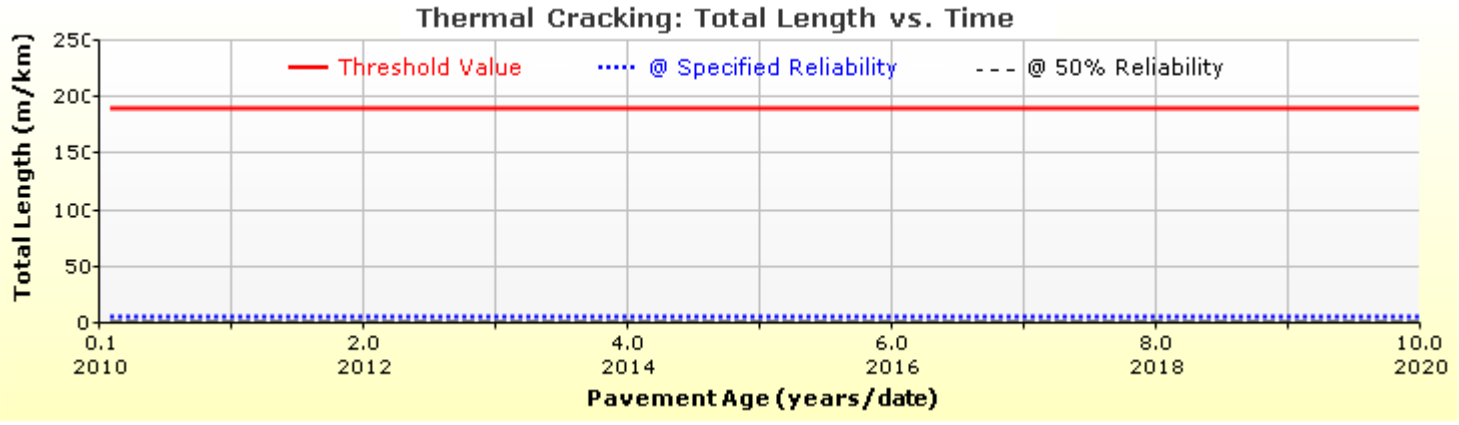


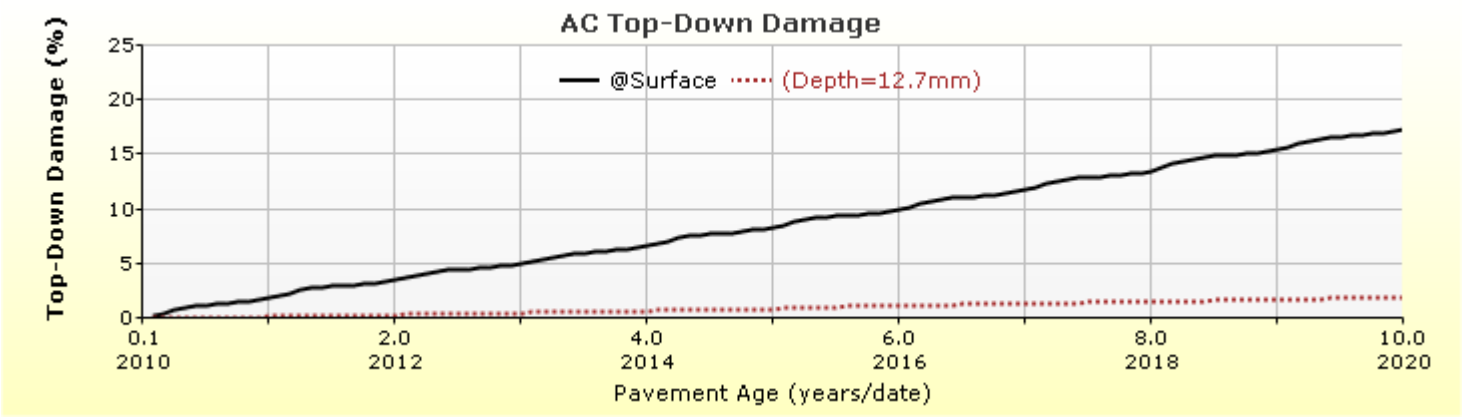


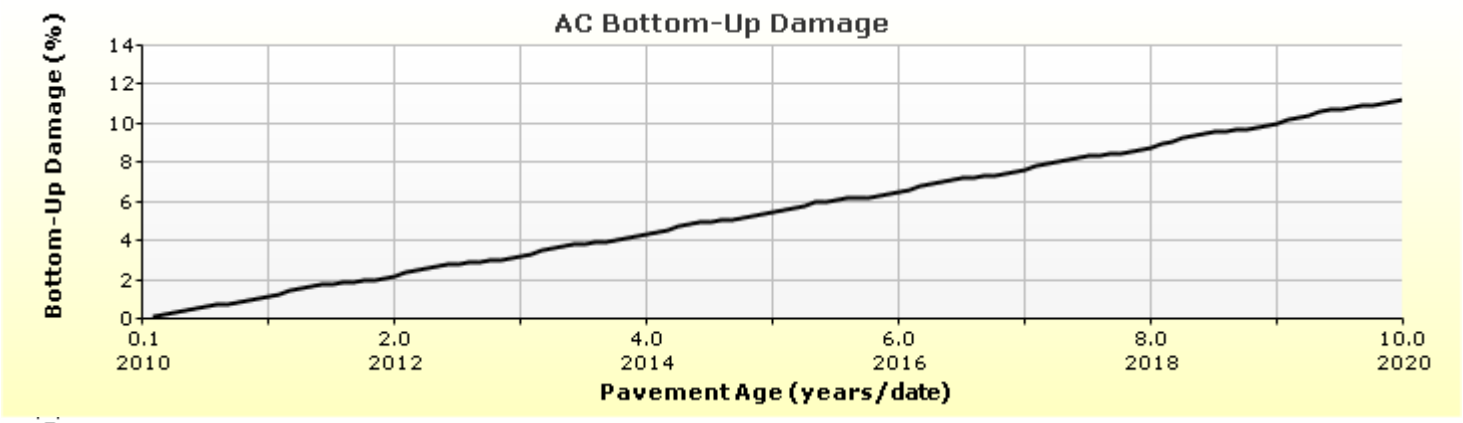
Analysis Output Charts

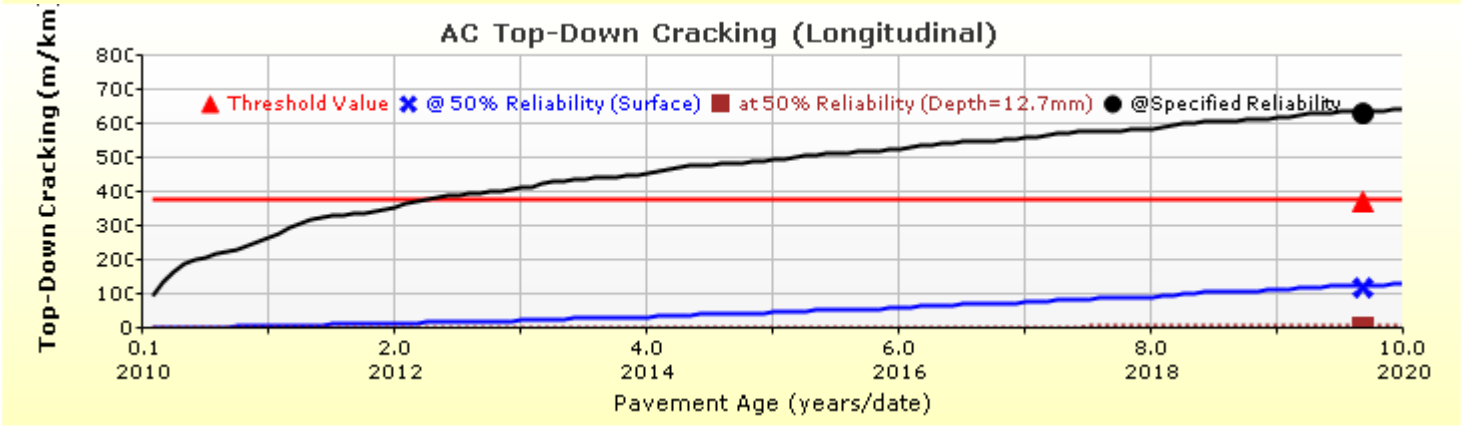


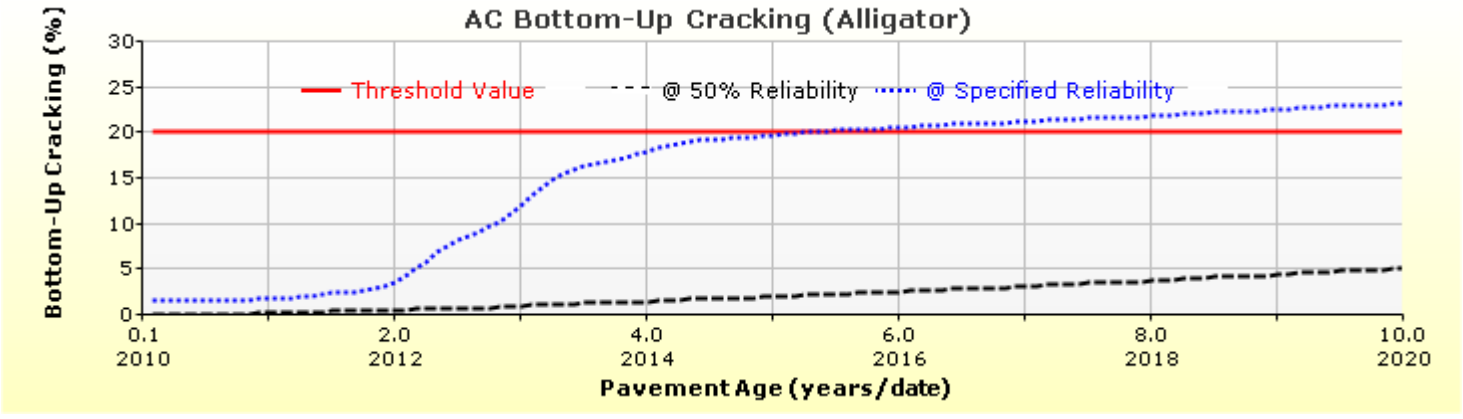


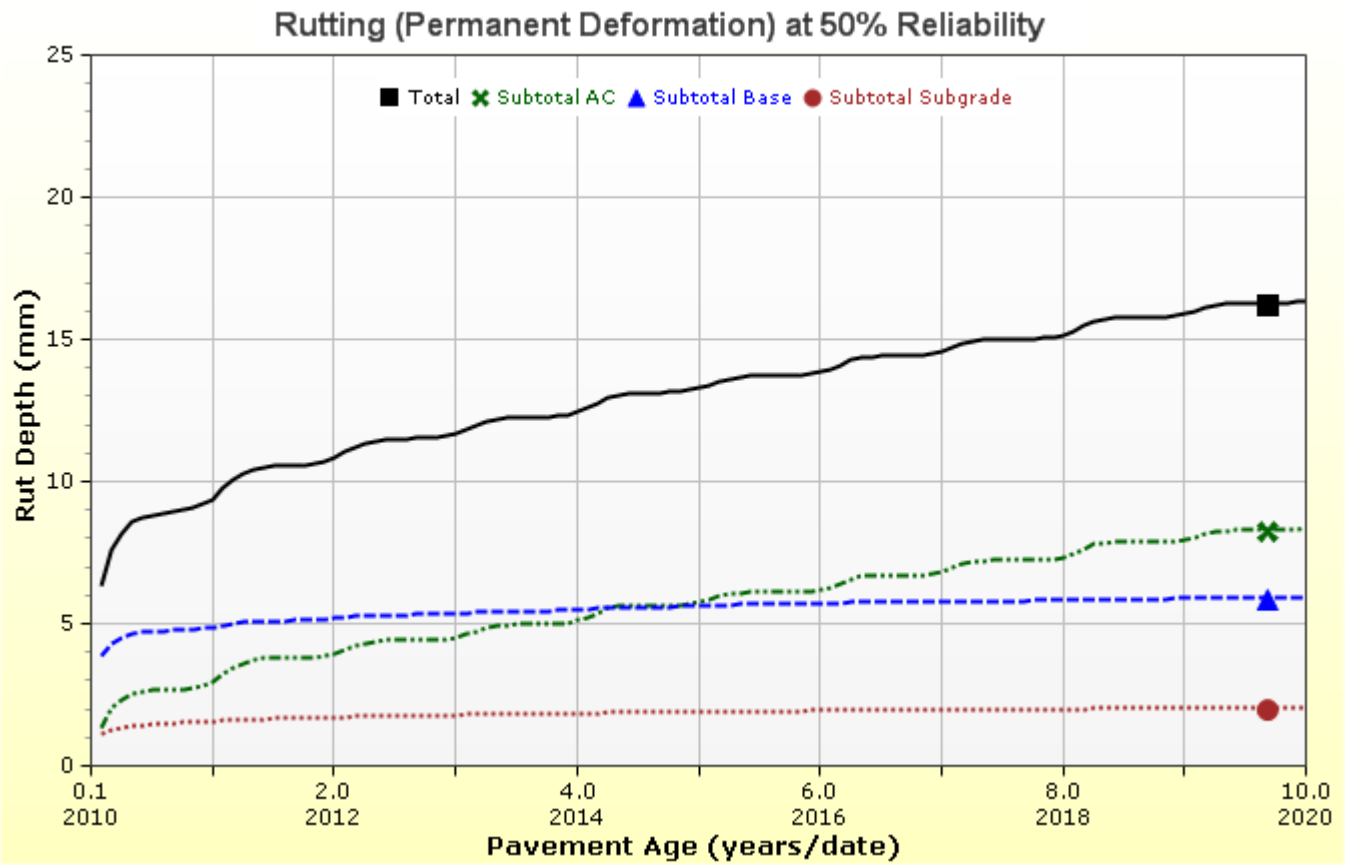


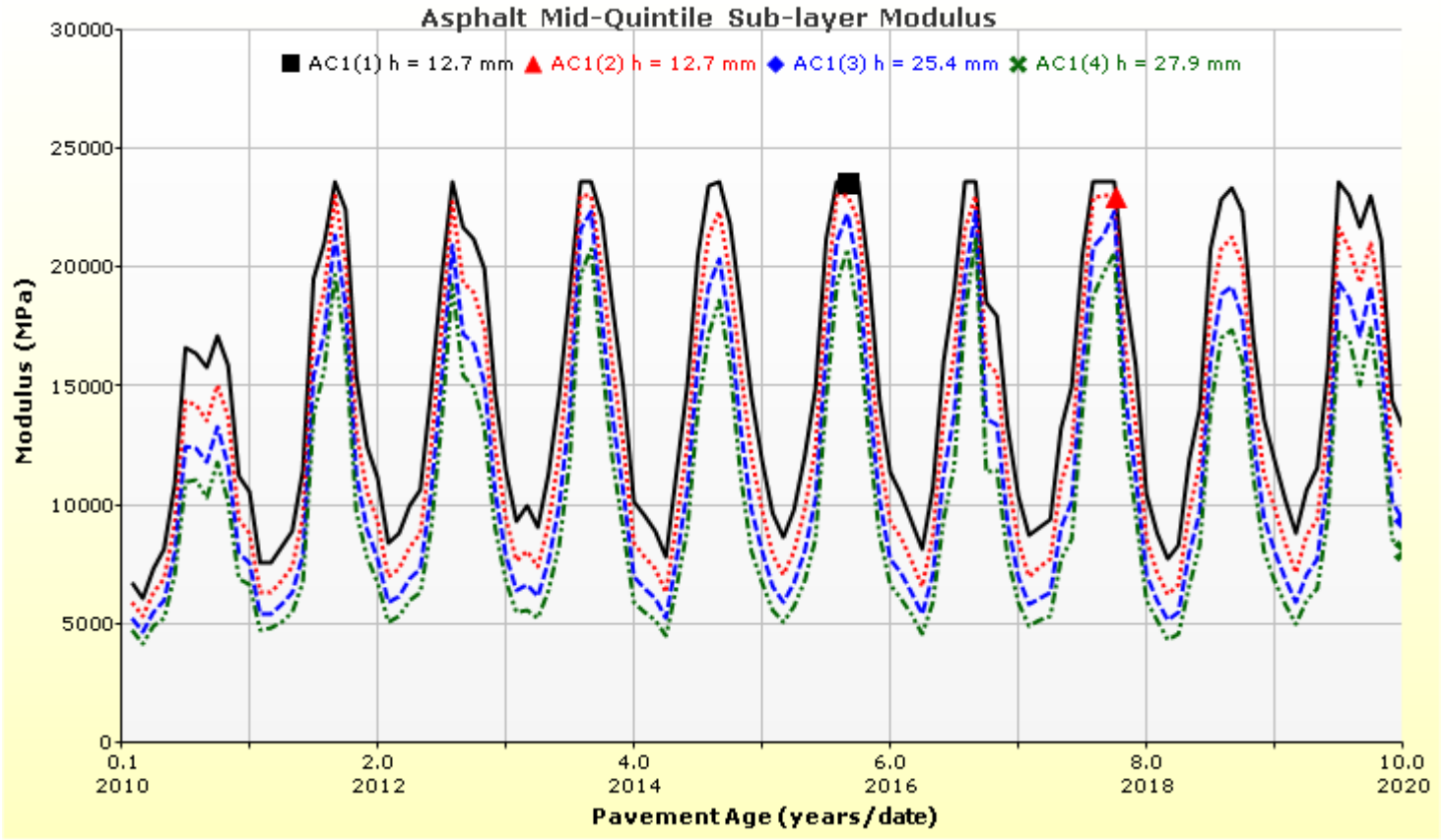

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

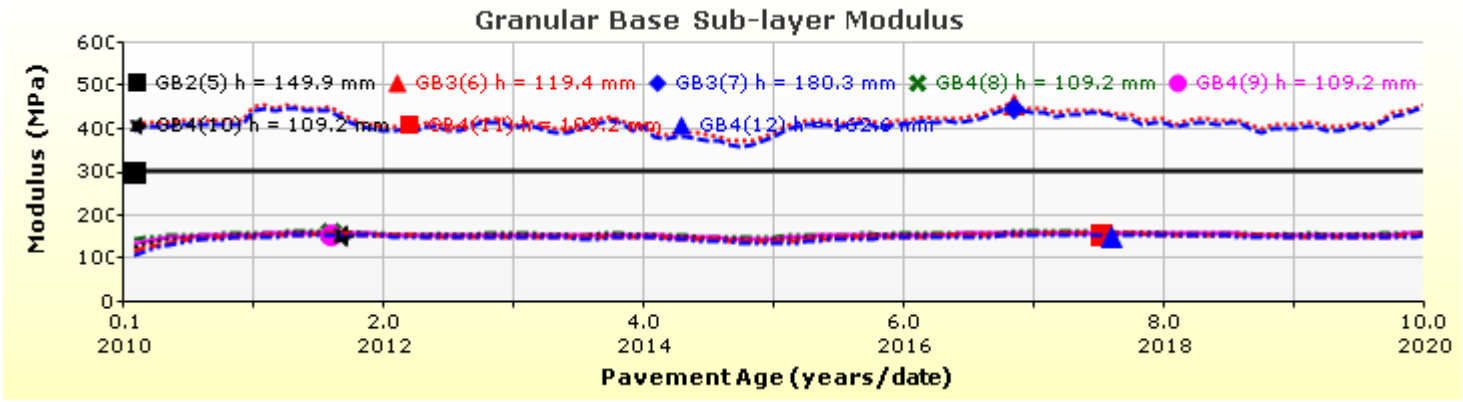

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

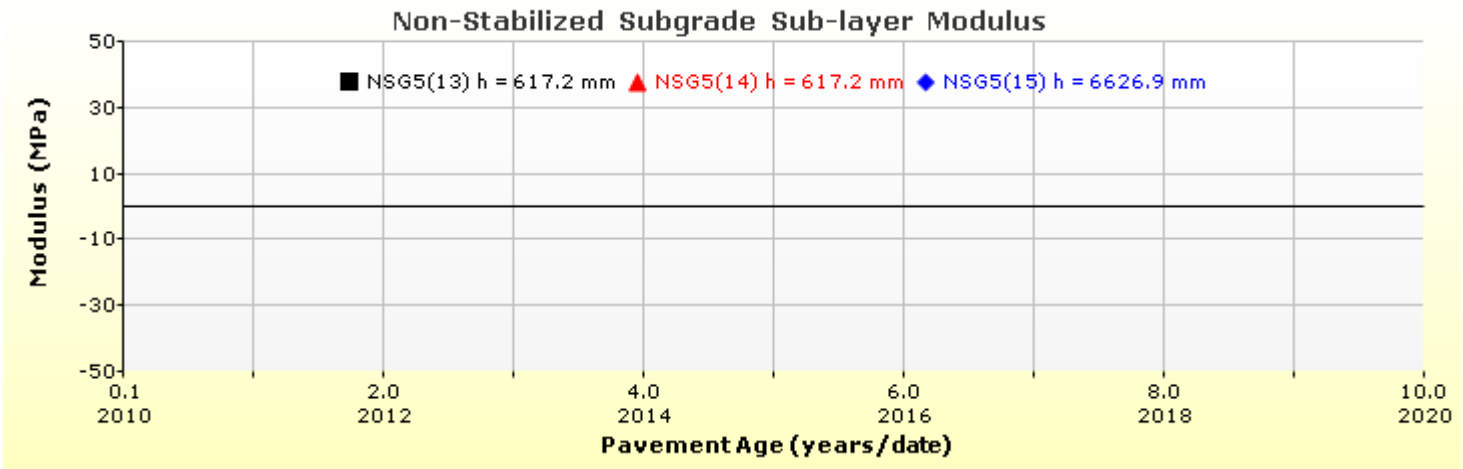

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRS-4

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRS-4.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -30.05, -51.17

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

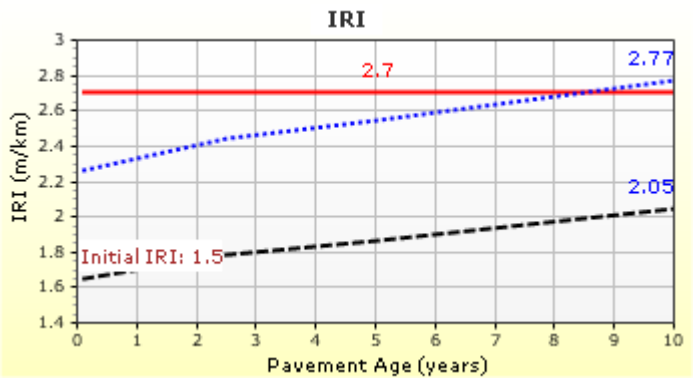
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

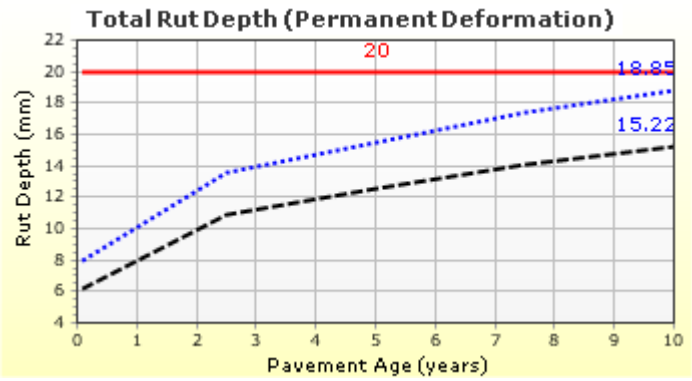
Design Outputs

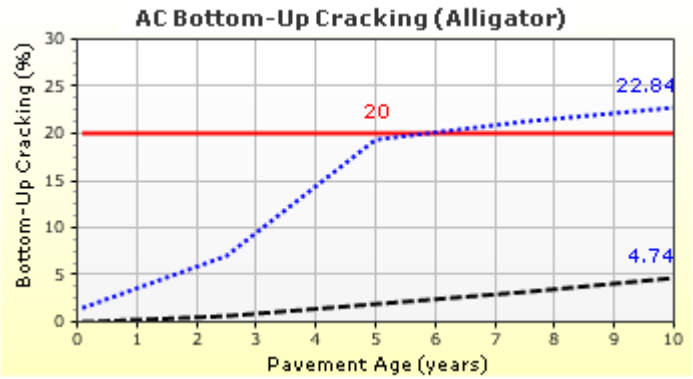
Distress Prediction Summary

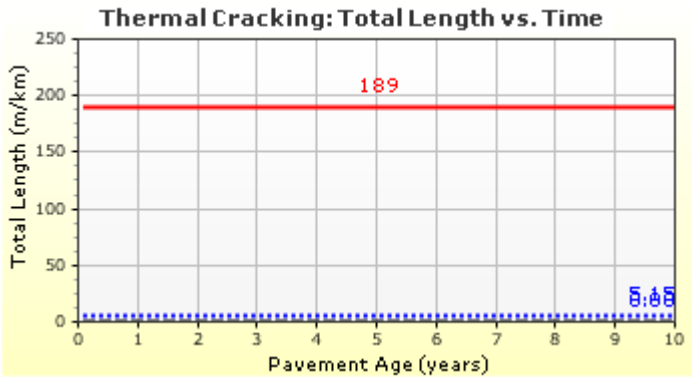
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.77	90.00	87.50	Fail
Permanent deformation - total pavement (mm)	20.00	18.84	90.00	95.43	Pass
AC bottom-up fatigue cracking (percent)	20.00	22.84	90.00	86.00	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	620.92	90.00	74.77	Fail
Permanent deformation - AC only (mm)	5.00	7.24	50.00	16.02	Fail

Distress Charts







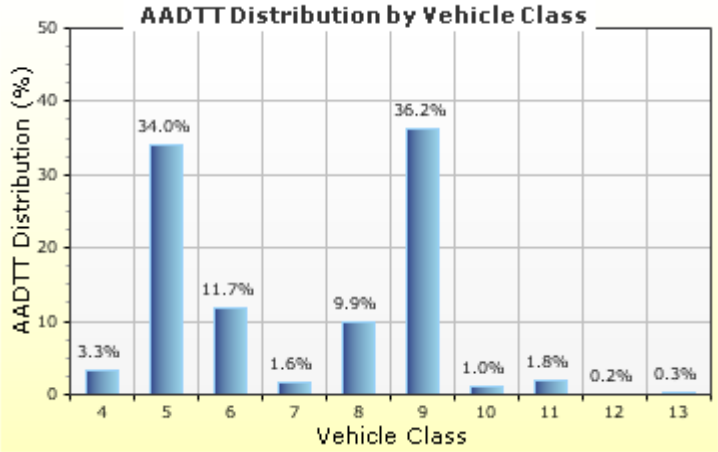


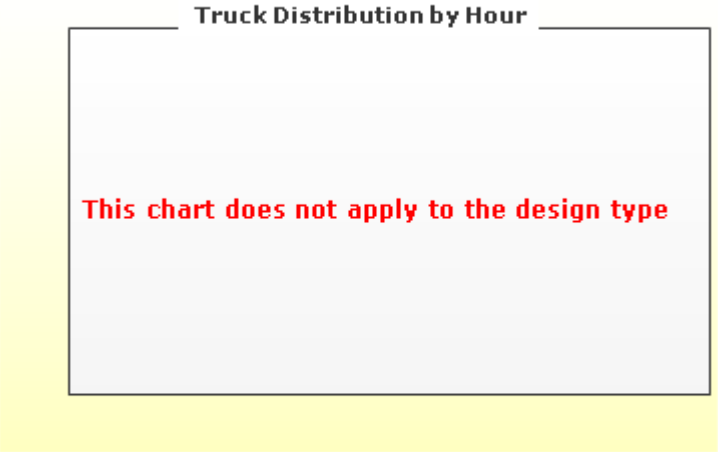
Threshold Value ····· @ Specified Reliability - - - @ 50% Reliability

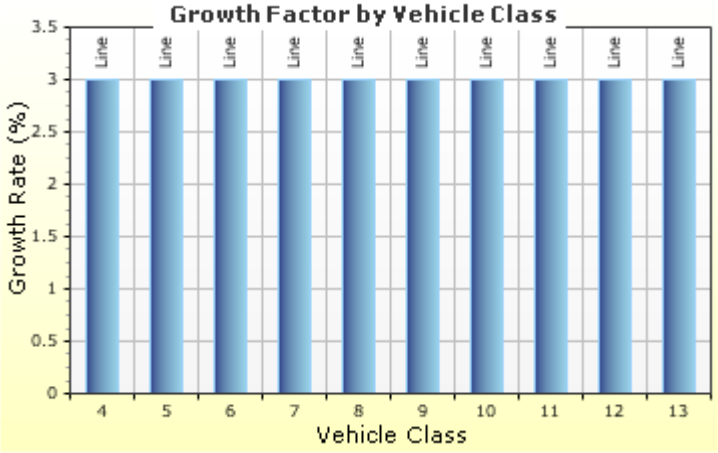
Traffic Inputs

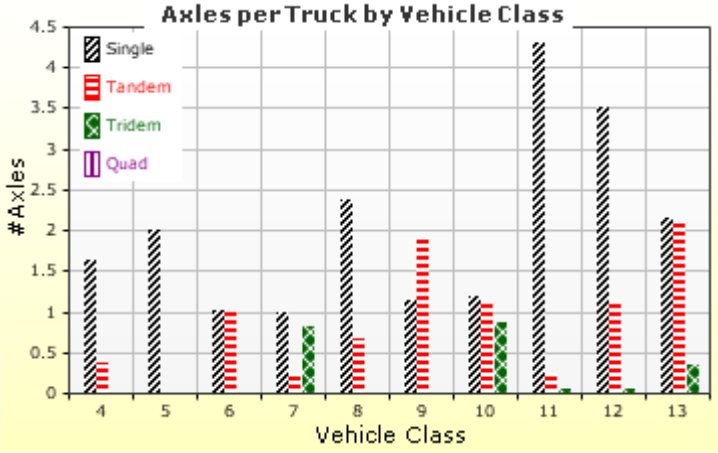
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

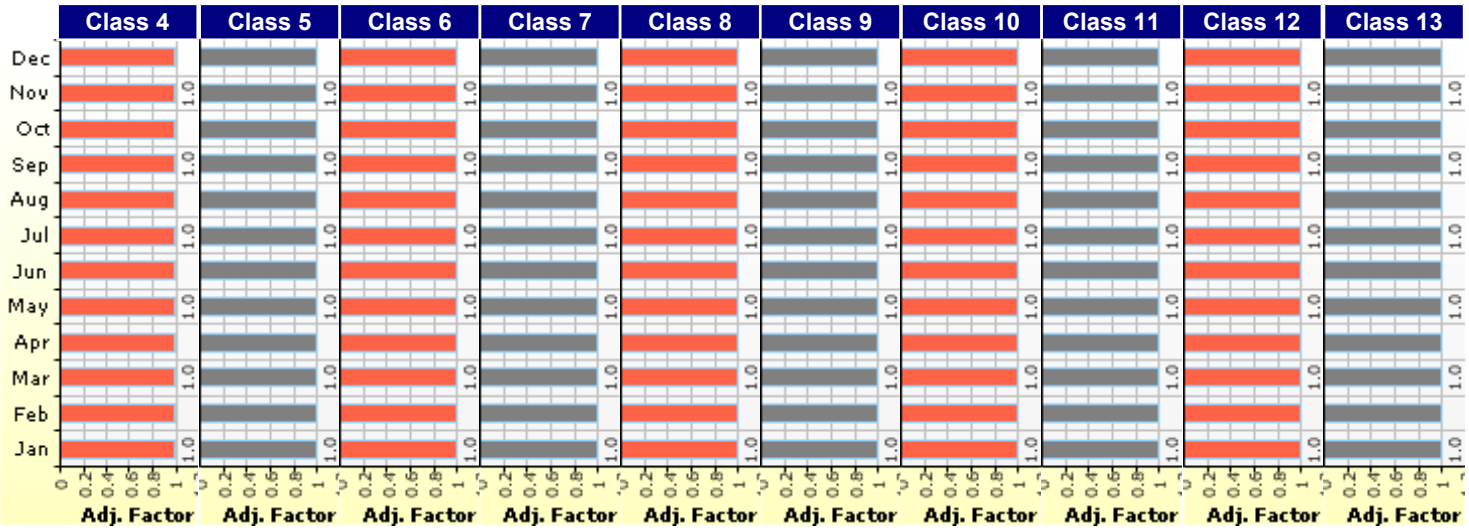








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

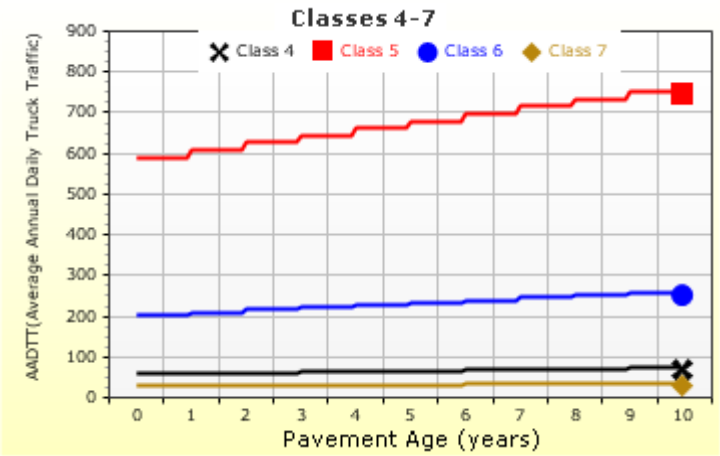
Wheelbase does not apply

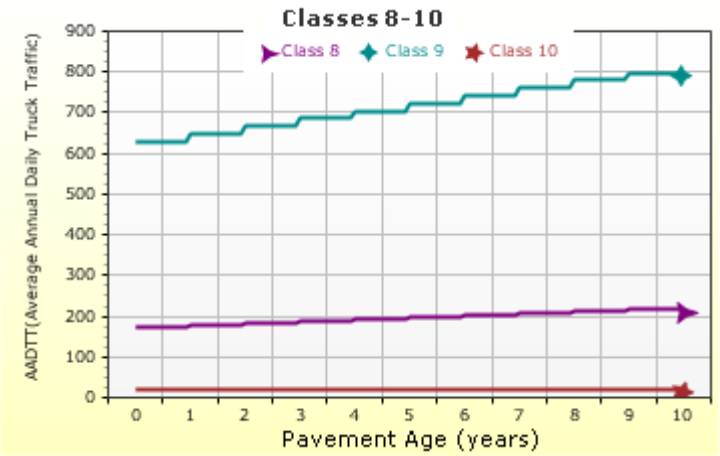
Number of Axles per Truck

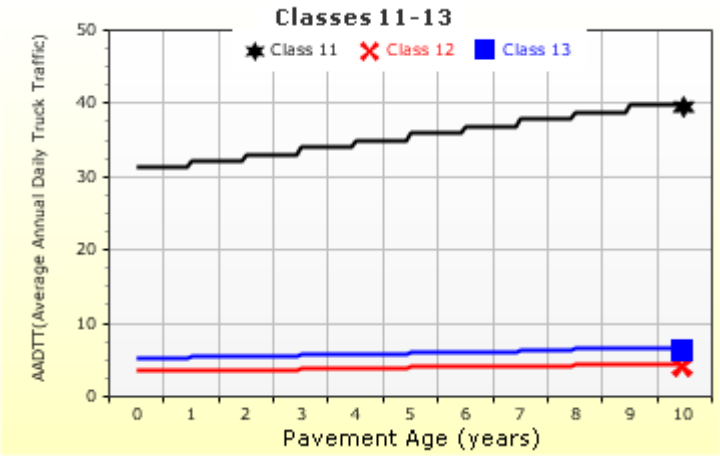
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

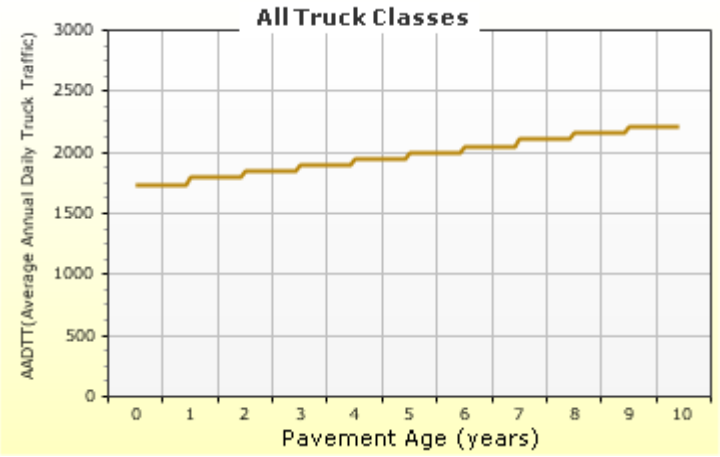
AADTT (Average Annual Daily Truck Traffic) Growth

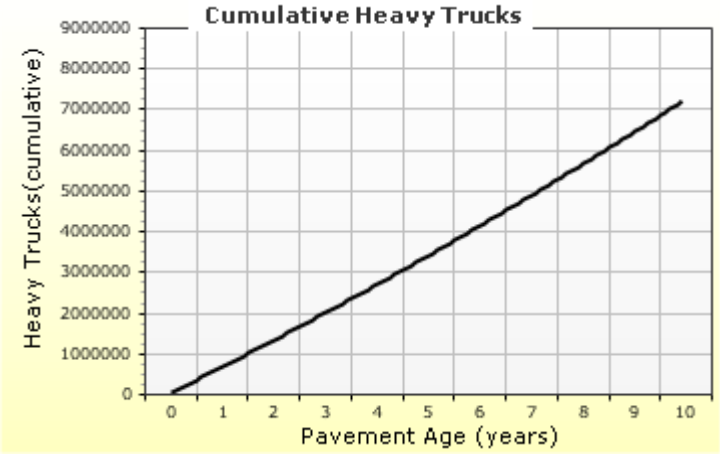
*** Traffic cap is not enforced**







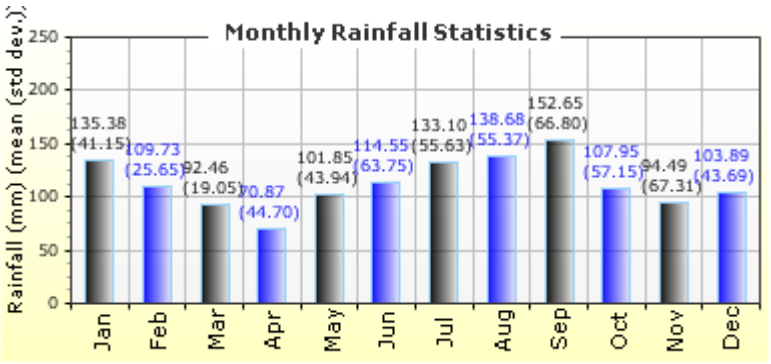




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
PORTO ALEGRE, RS	-30.05000 -51.17000 47

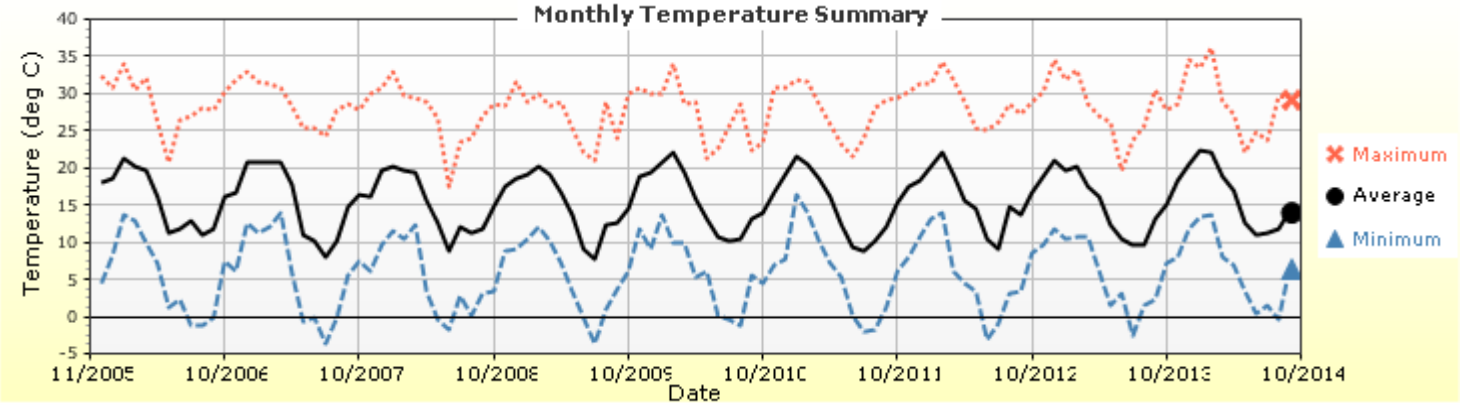


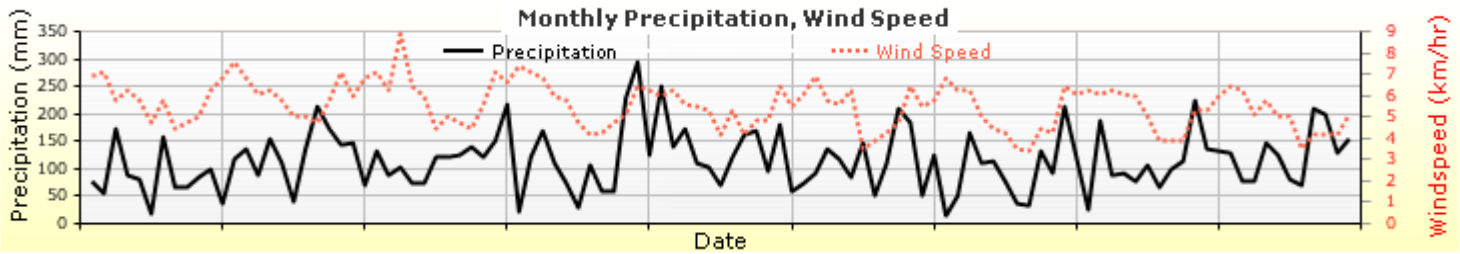
Annual Statistics:

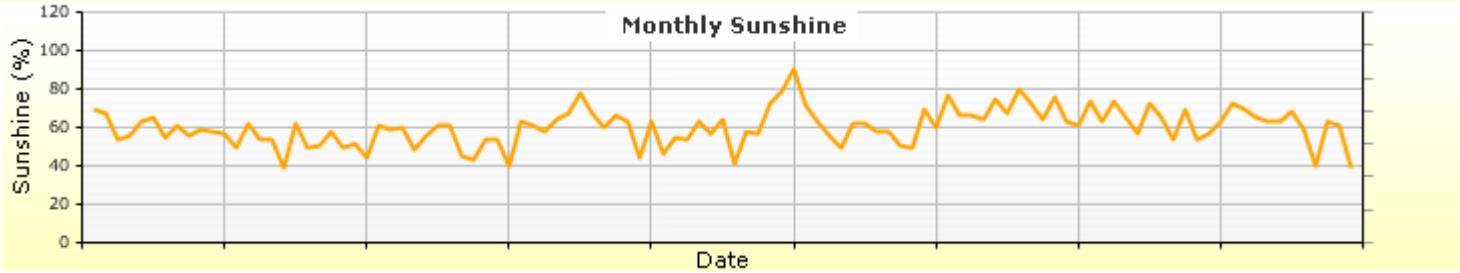
Mean annual air temperature (ºC)	15.73
Mean annual precipitation (mm)	1352.30
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	3.89

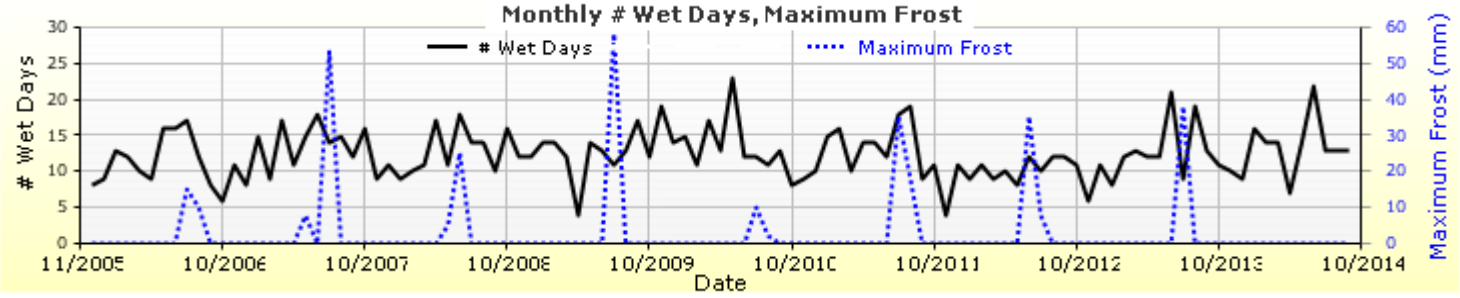
Water table depth (m)	3.05

Monthly Climate Summary:

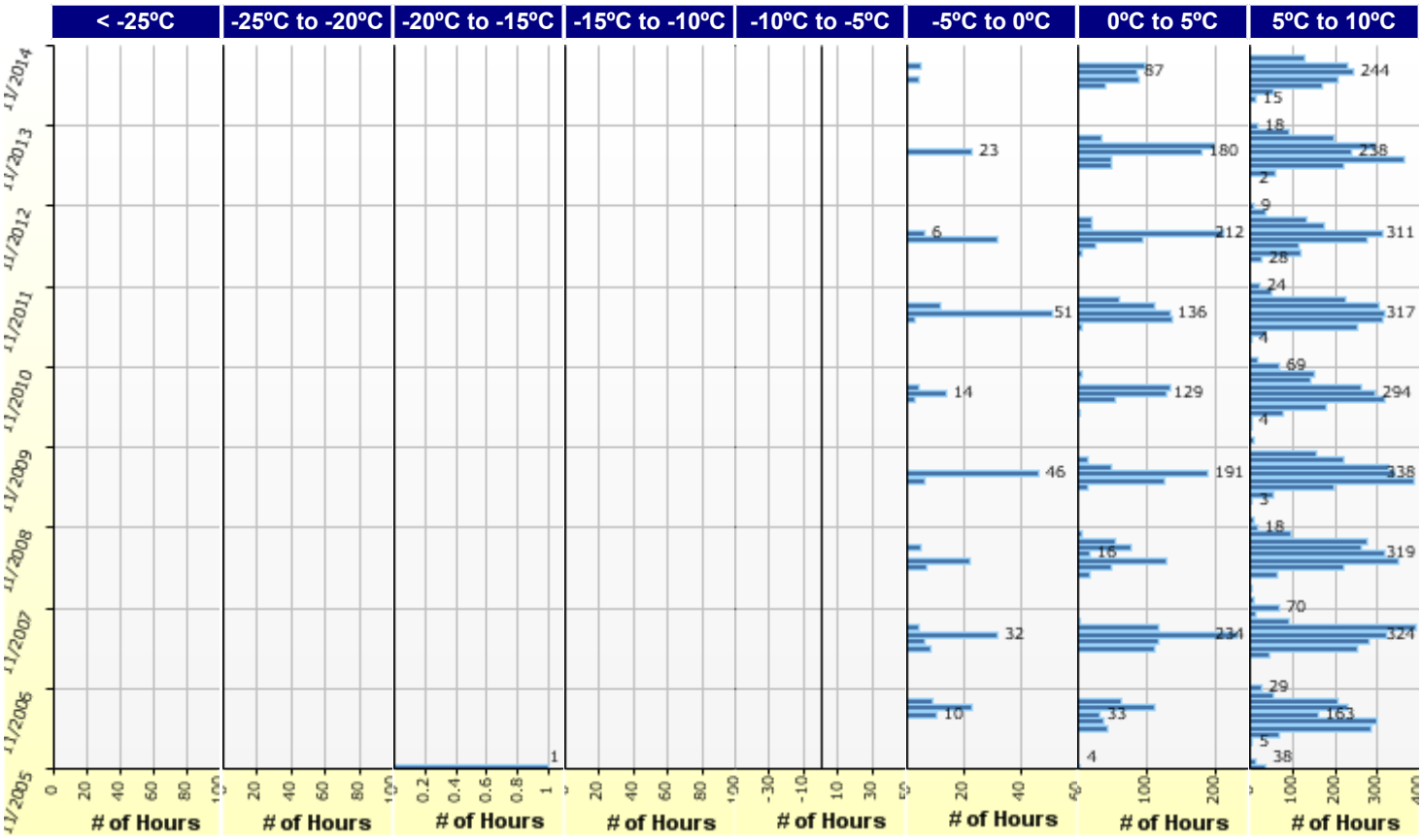


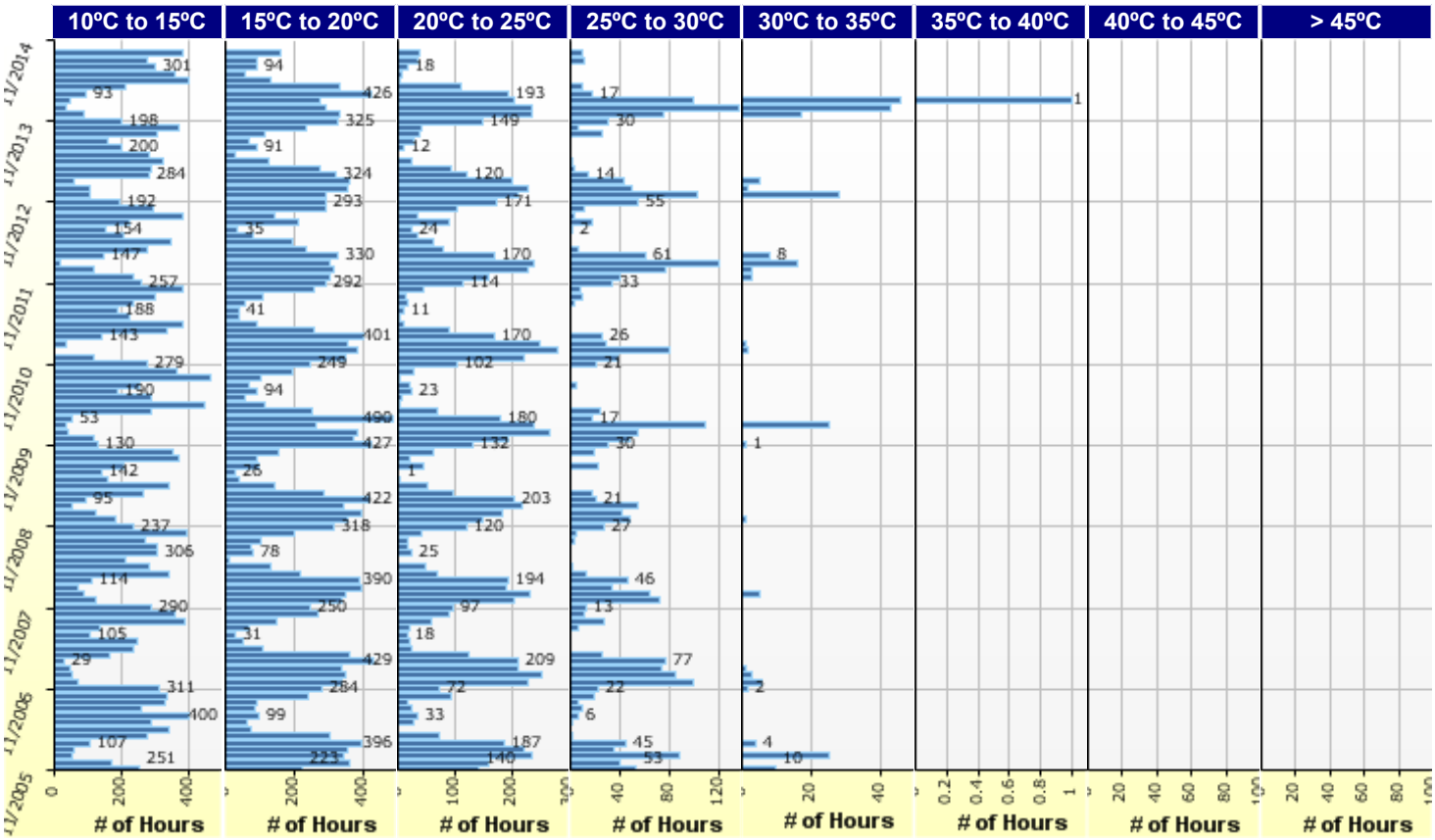






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

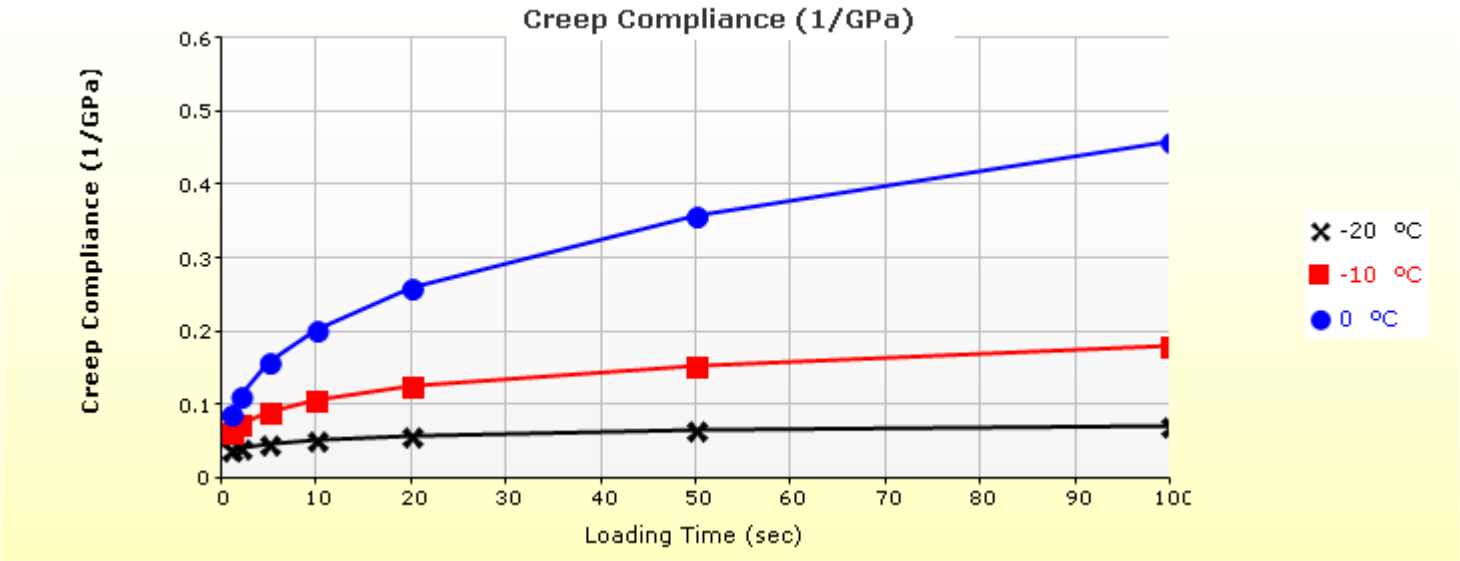
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

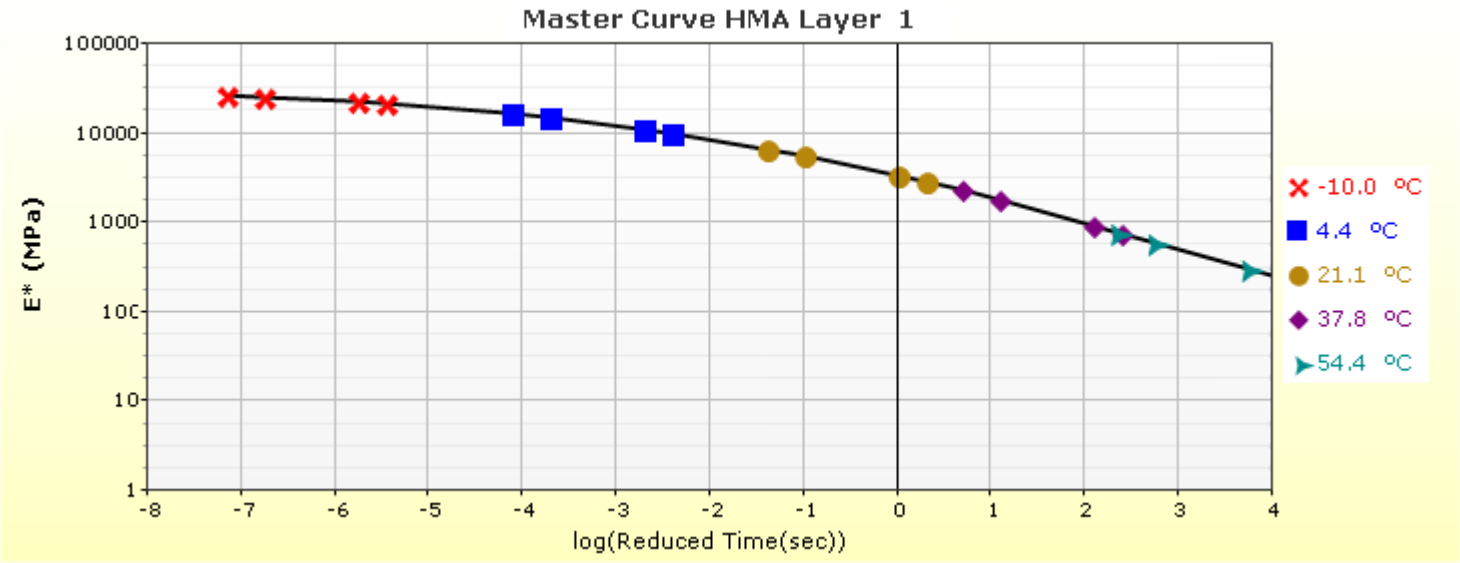
Indirect tensile strength at -10 ºC (MPa)	2.69

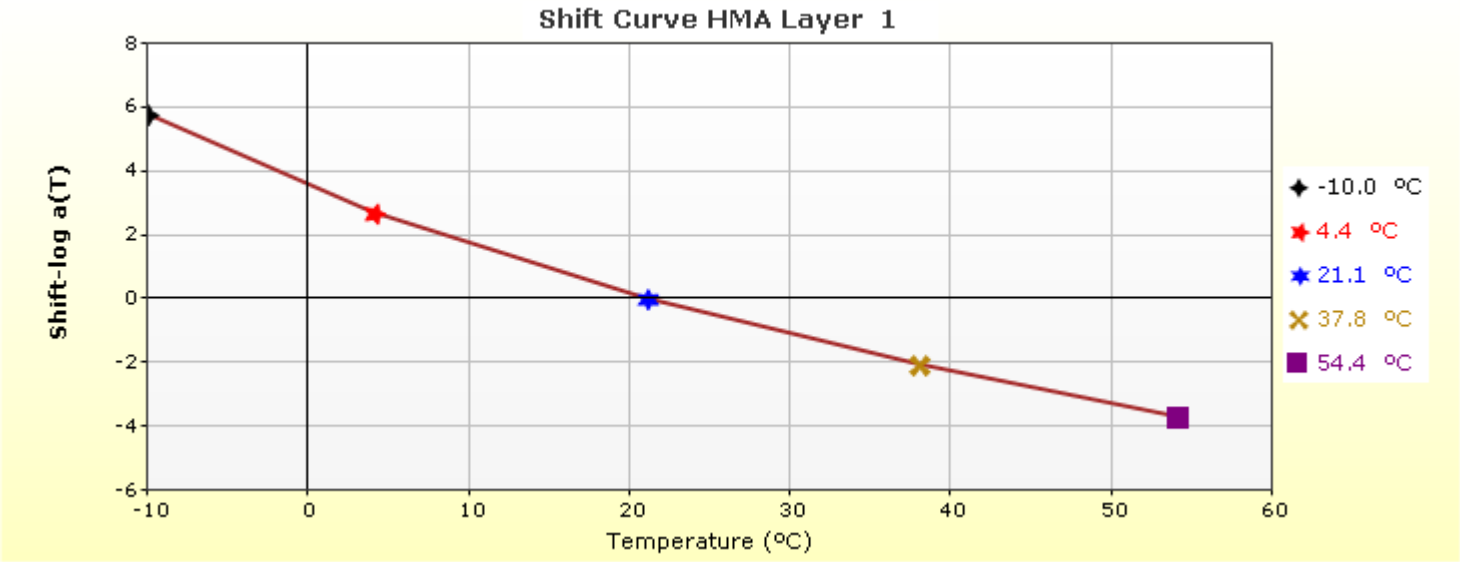
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

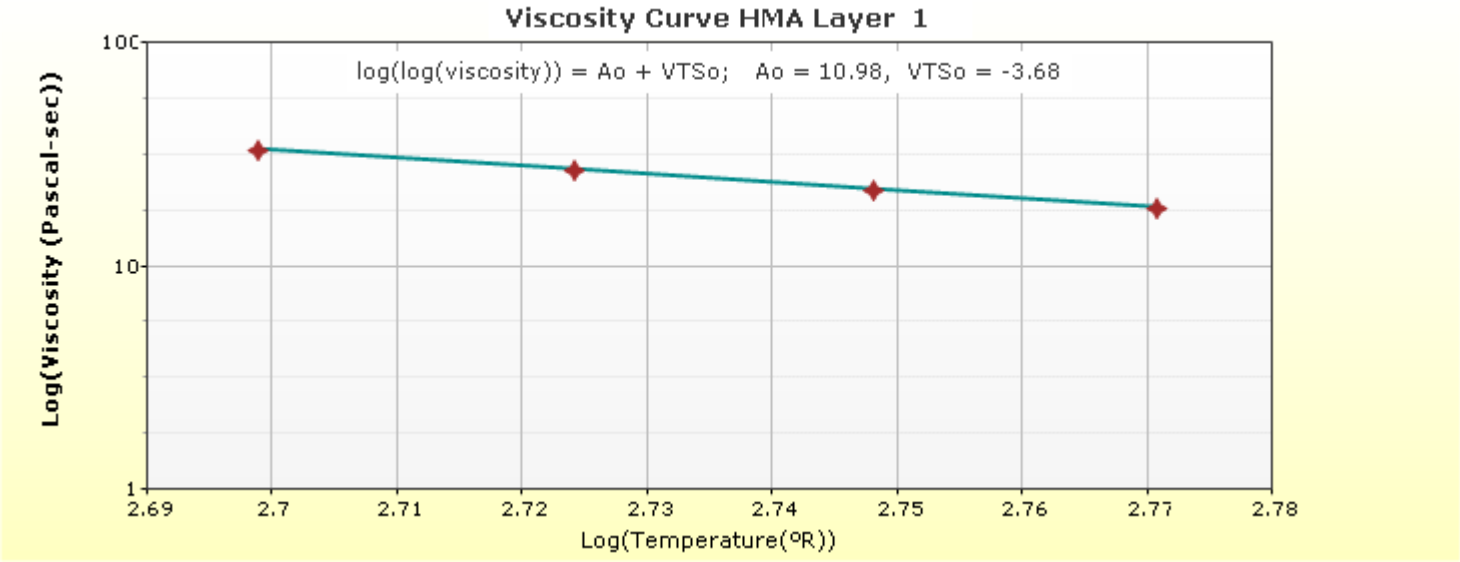
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



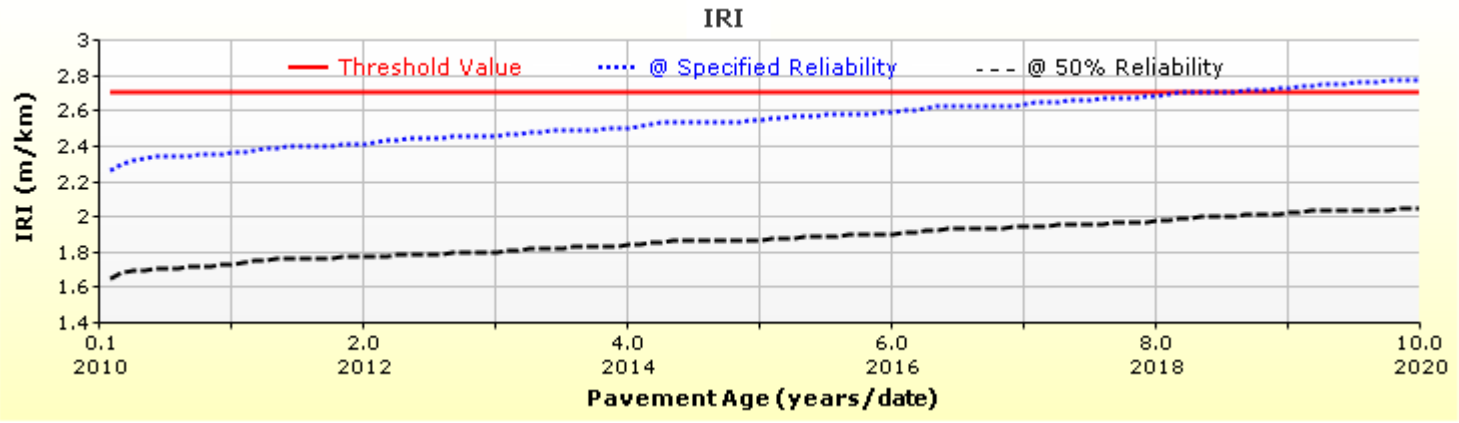
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

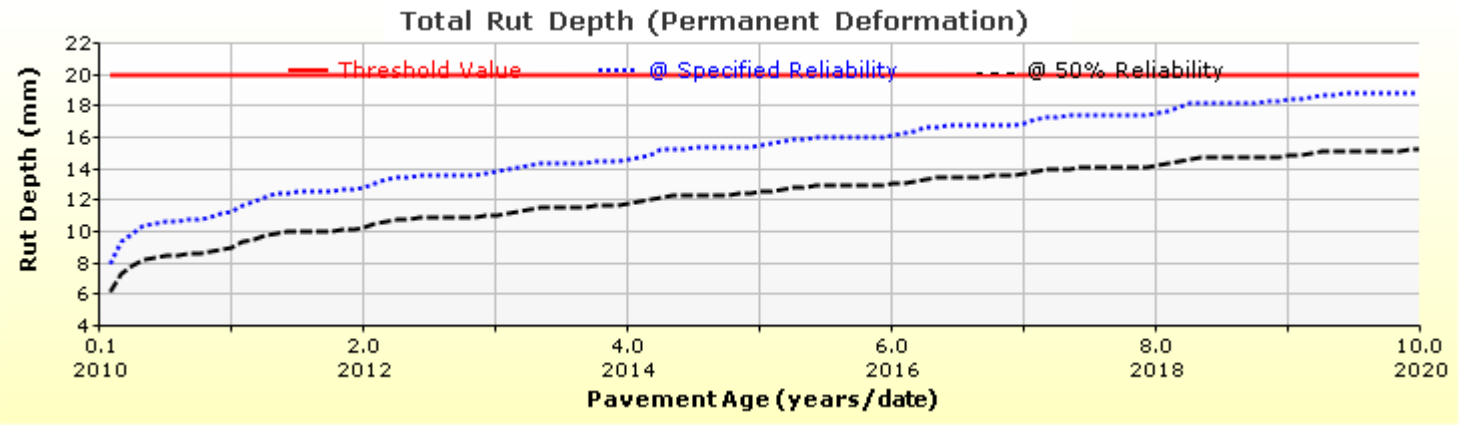


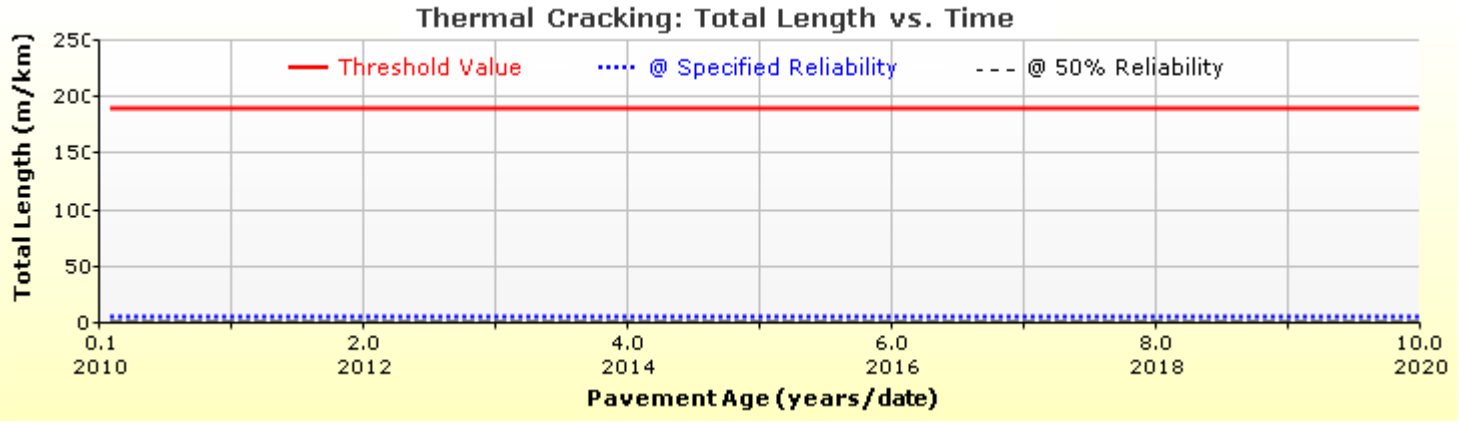


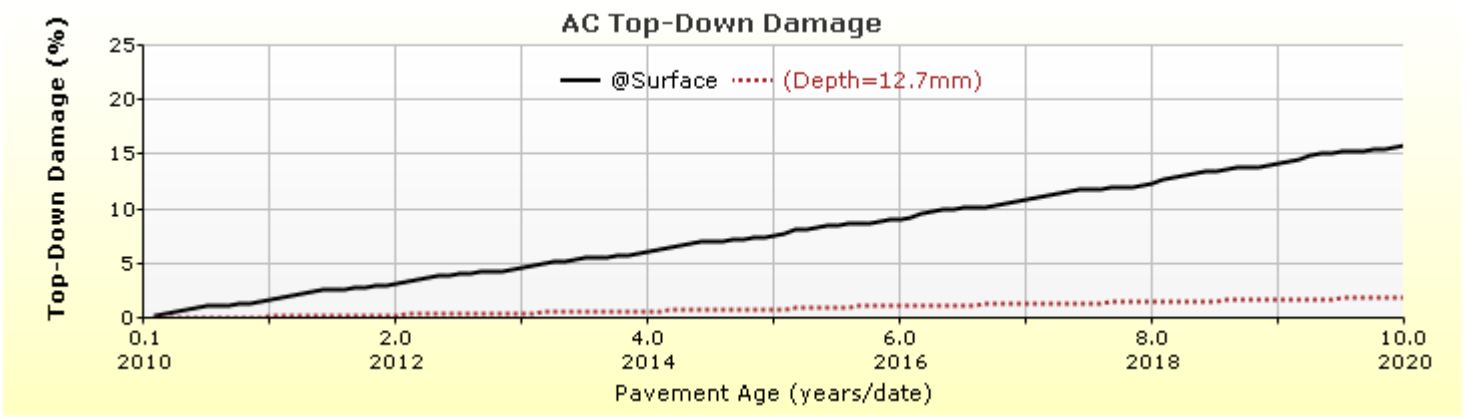


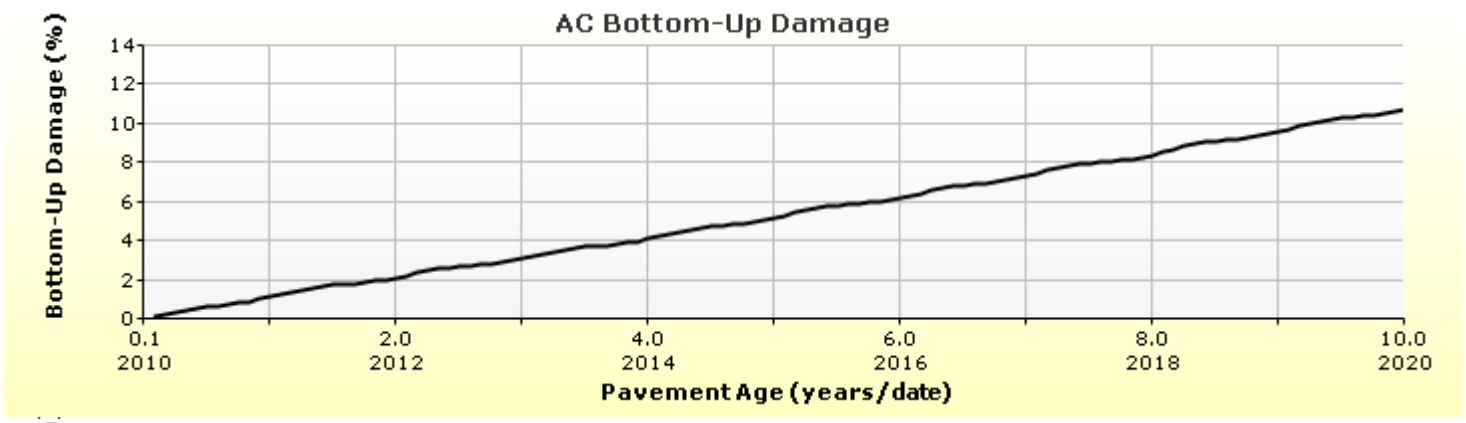
Analysis Output Charts

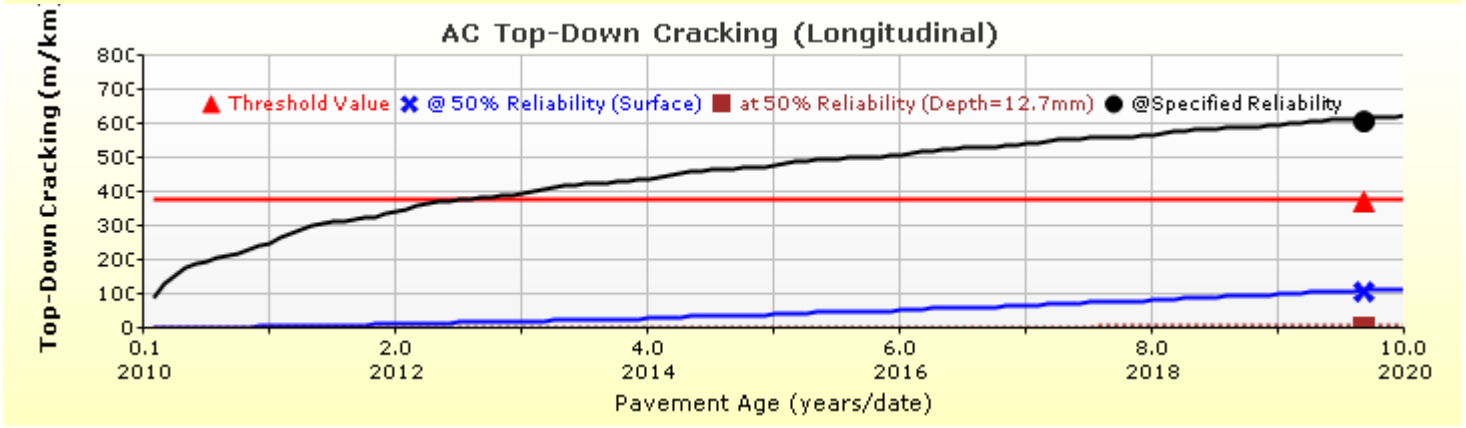


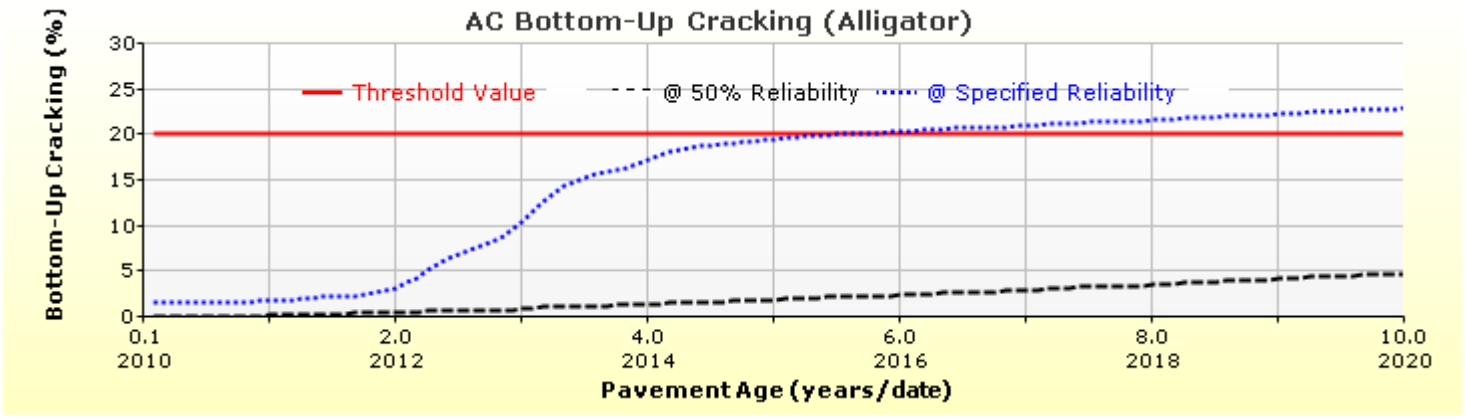


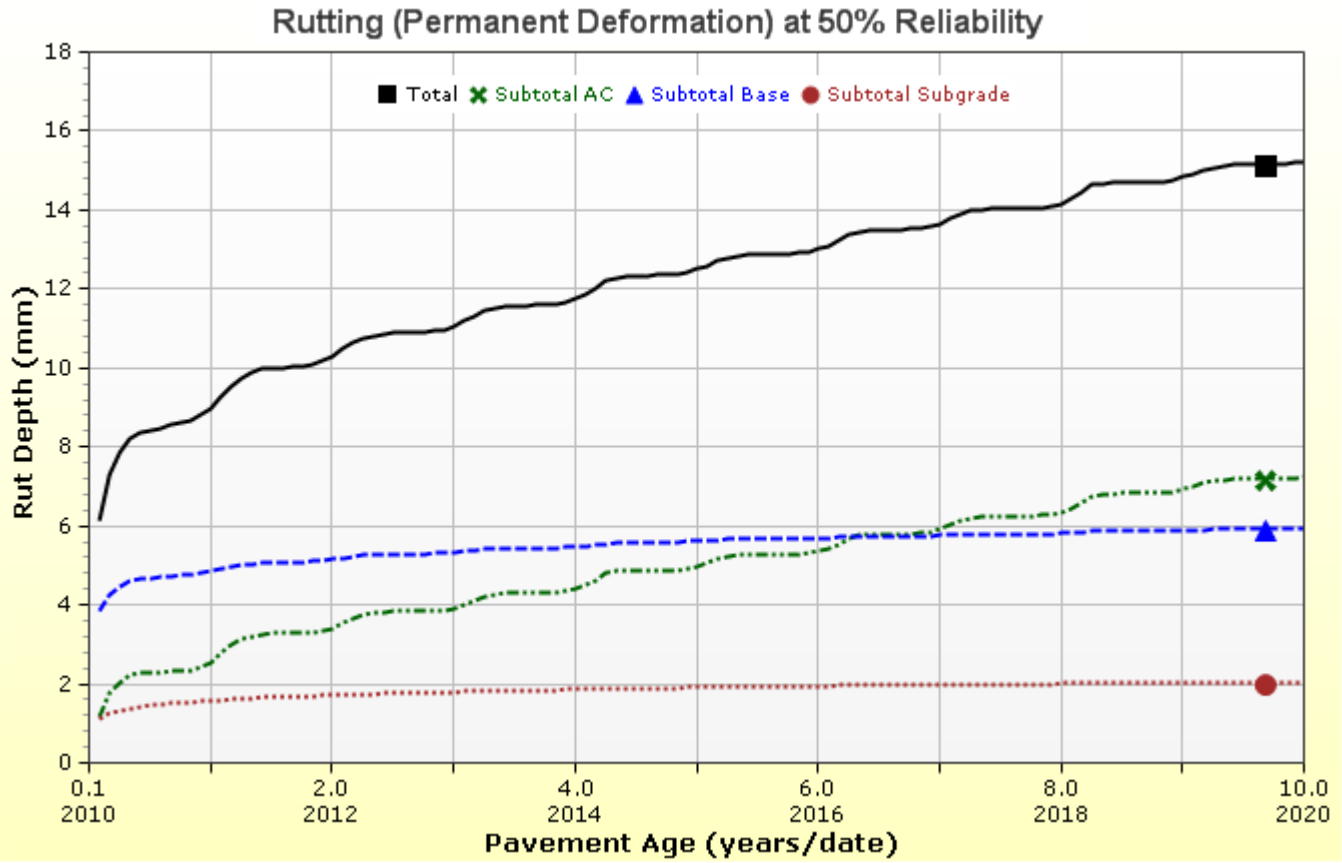


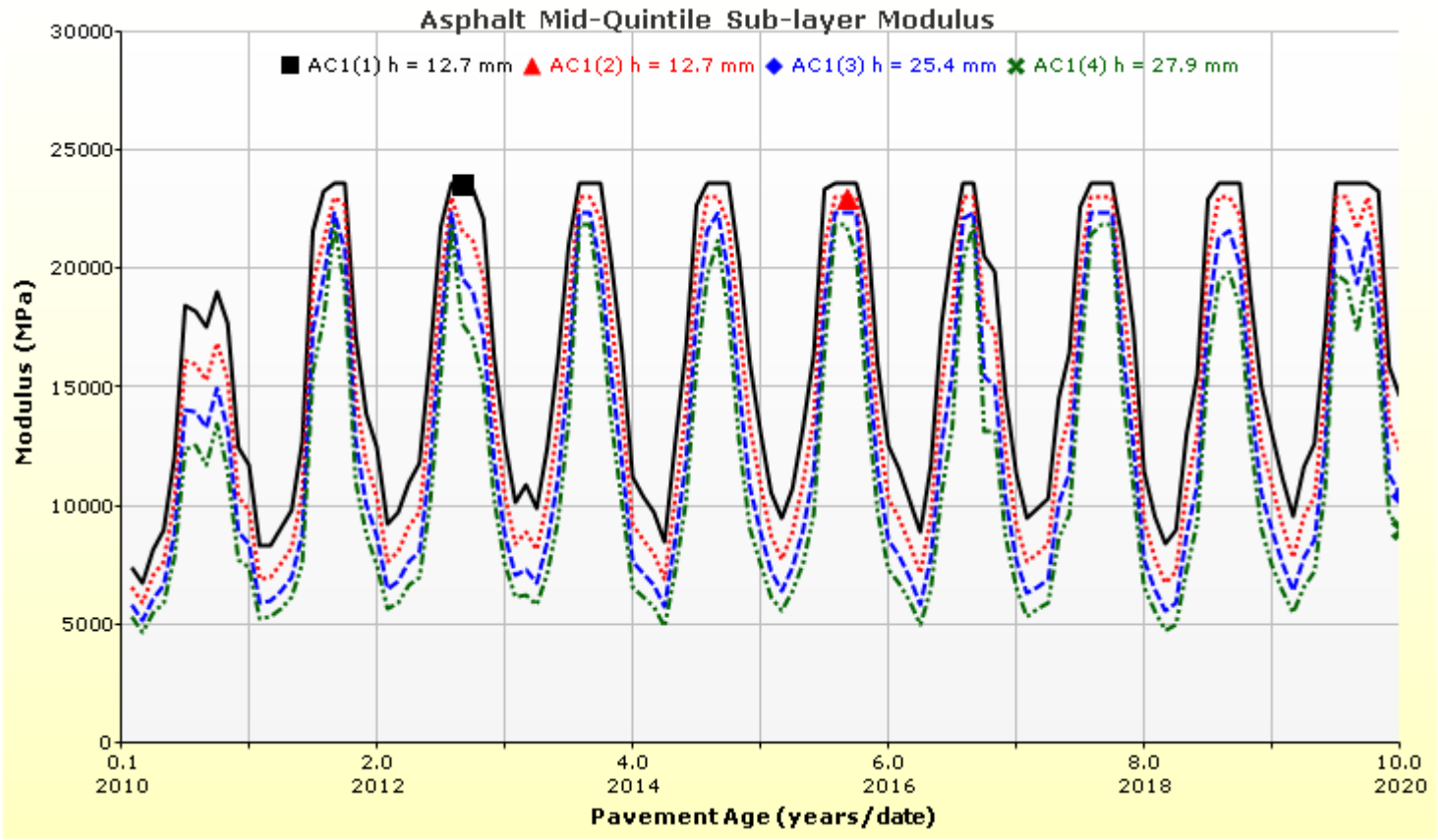

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

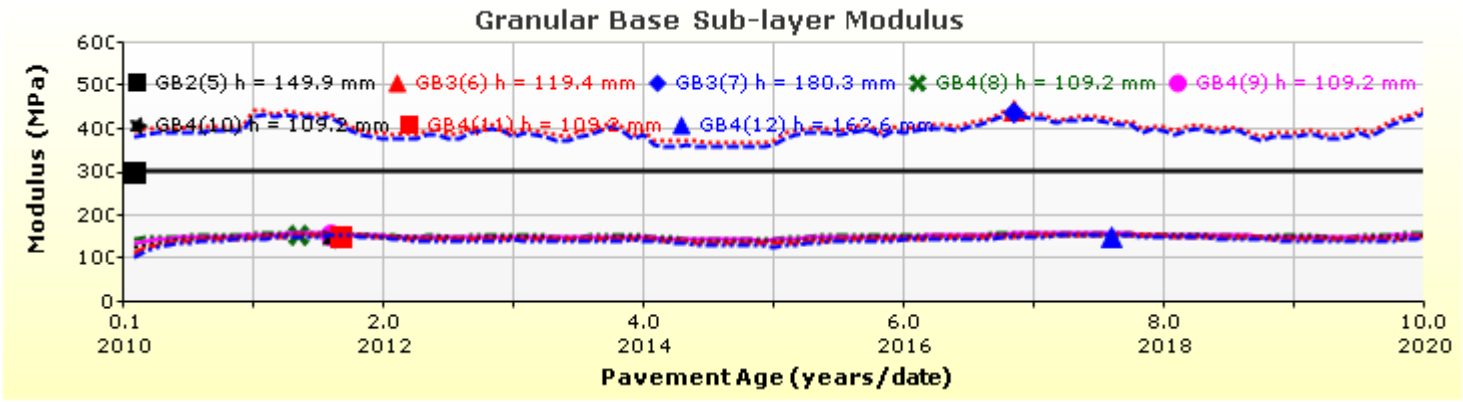

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

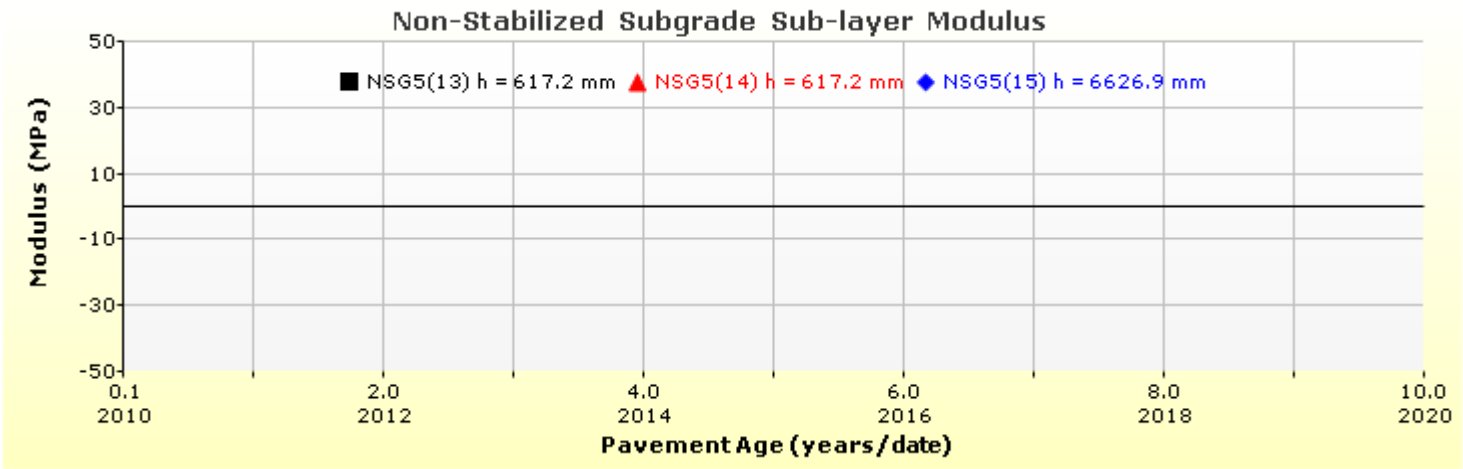

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60000
50000
40000
30000
20000
10000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRS_cobertura

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRS_cobertura.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -30.05, -51.17

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

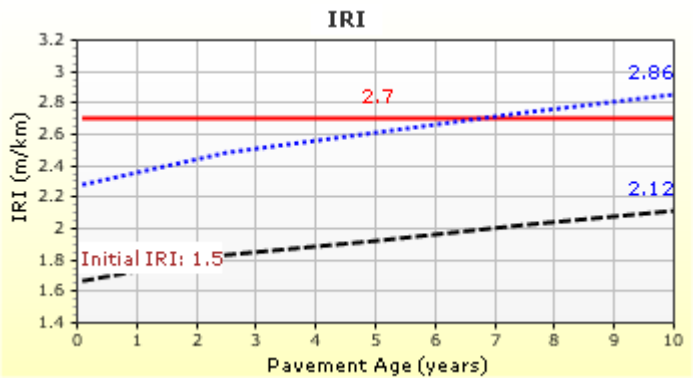
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

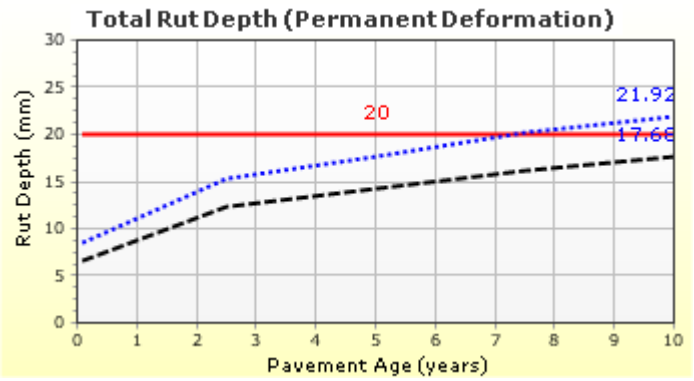
Design Outputs

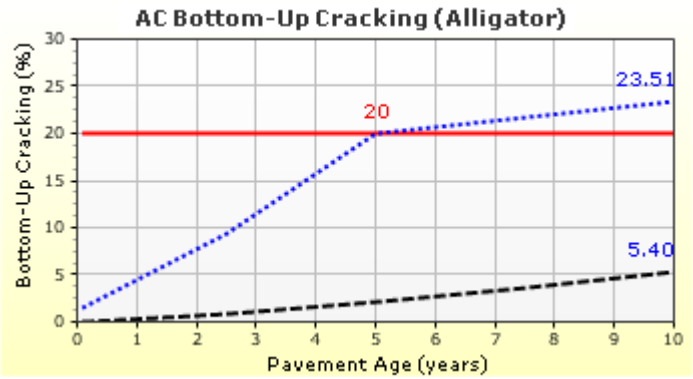
Distress Prediction Summary

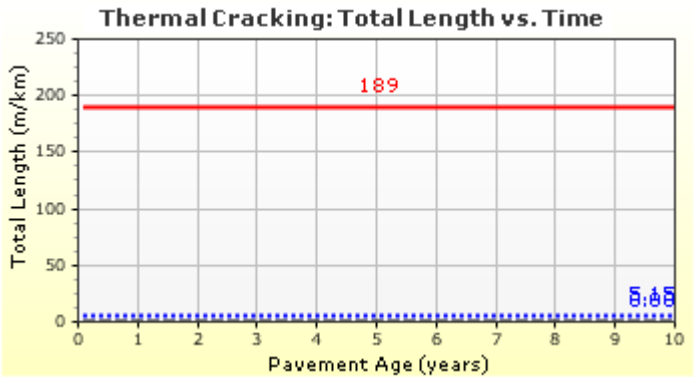
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.86	90.00	84.34	Fail
Permanent deformation - total pavement (mm)	20.00	21.93	90.00	75.69	Fail
AC bottom-up fatigue cracking (percent)	20.00	23.51	90.00	84.93	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	671.25	90.00	71.24	Fail
Permanent deformation - AC only (mm)	5.00	9.70	50.00	4.92	Fail

Distress Charts







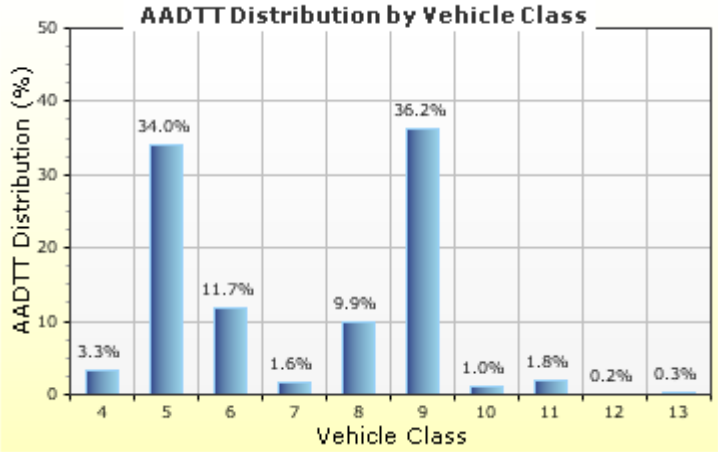


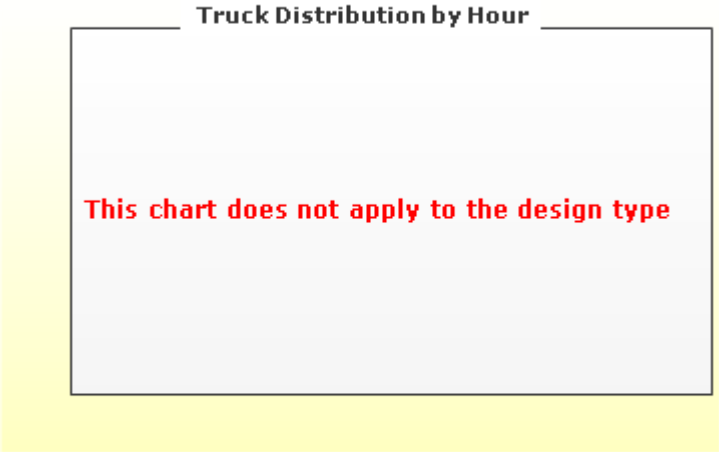


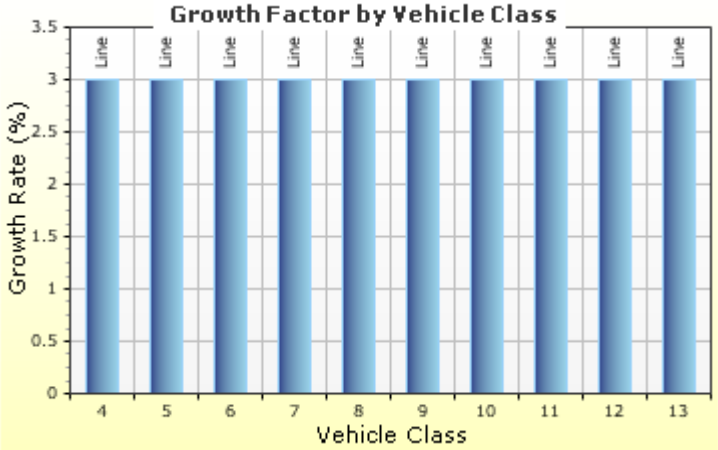
Traffic Inputs

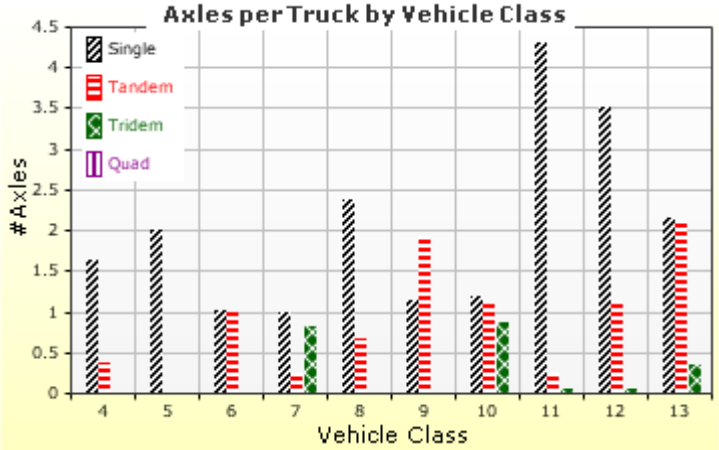
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

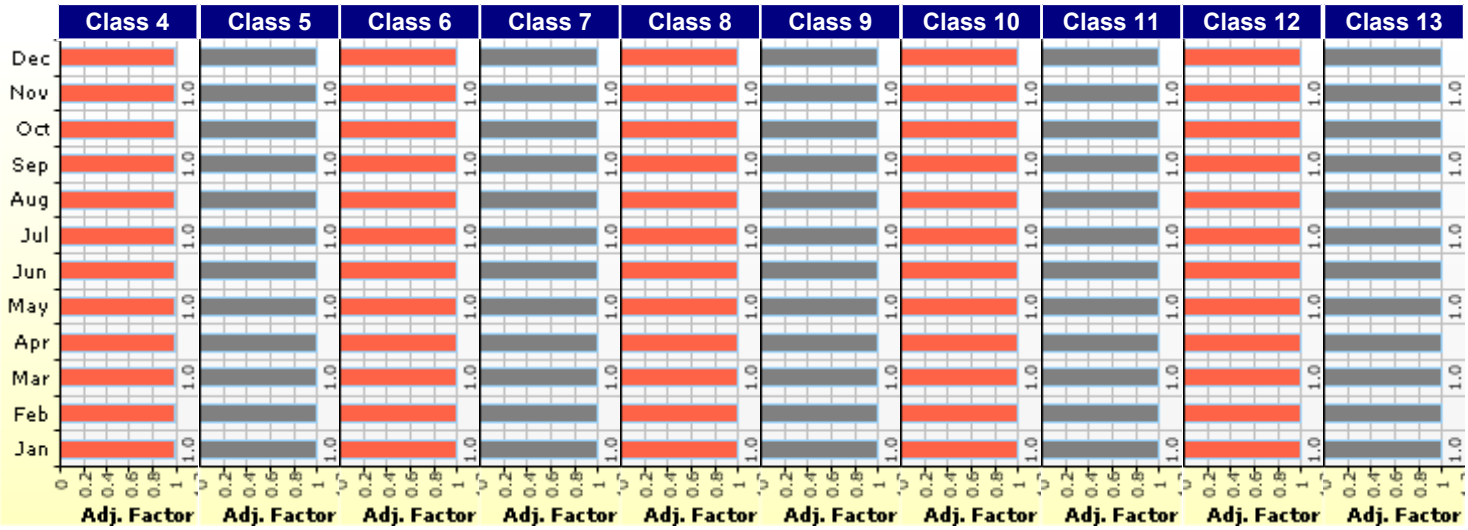








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

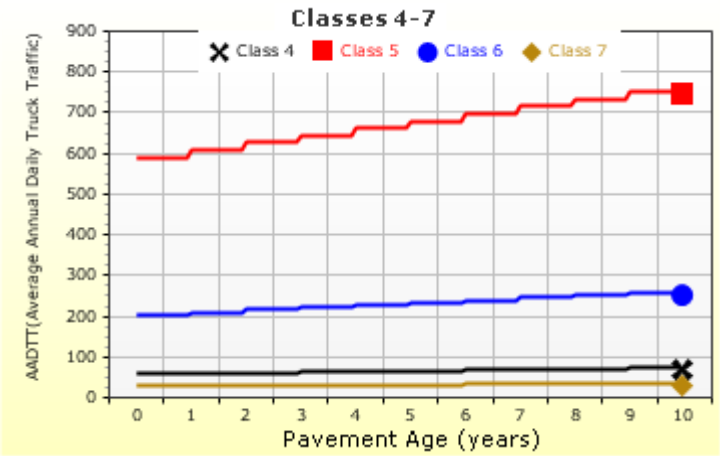
Wheelbase does not apply

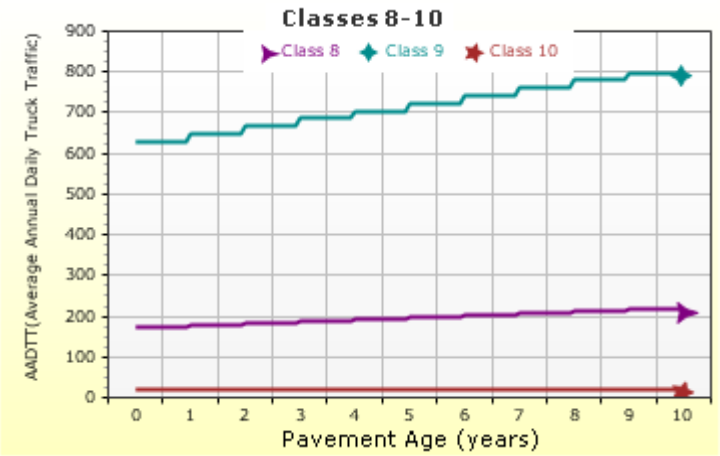
Number of Axles per Truck

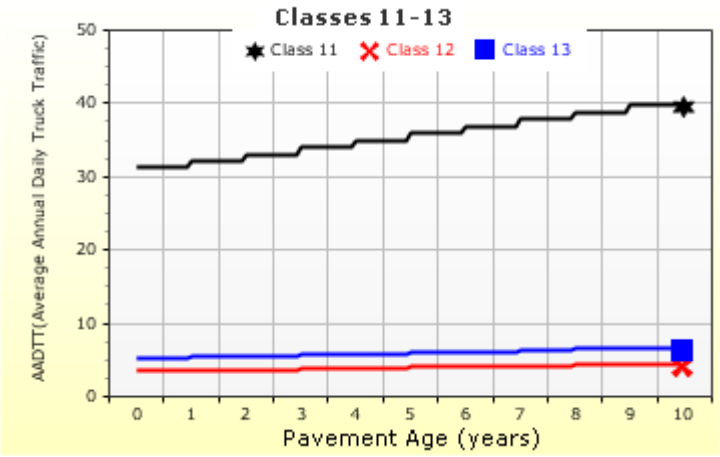
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

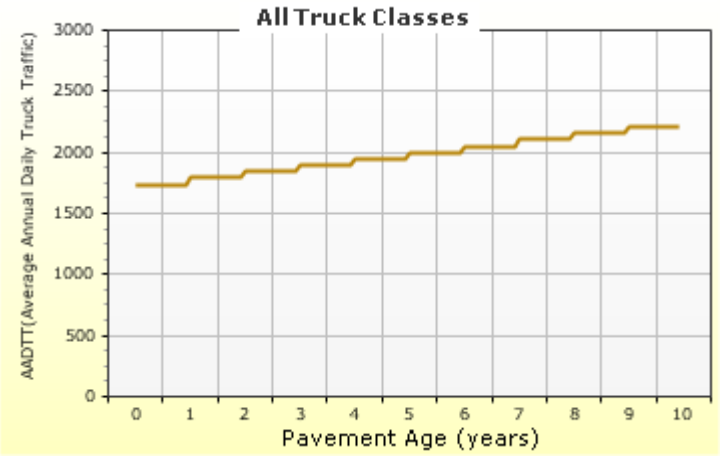
AADTT (Average Annual Daily Truck Traffic) Growth

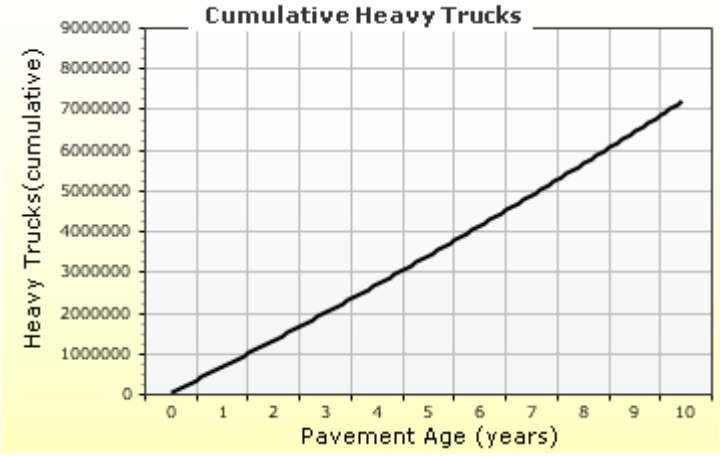
*** Traffic cap is not enforced**







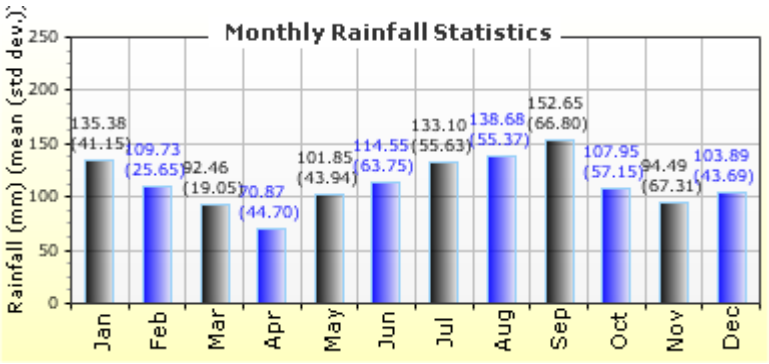




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
PORTO ALEGRE, RS	-30.05000 -51.17000 47

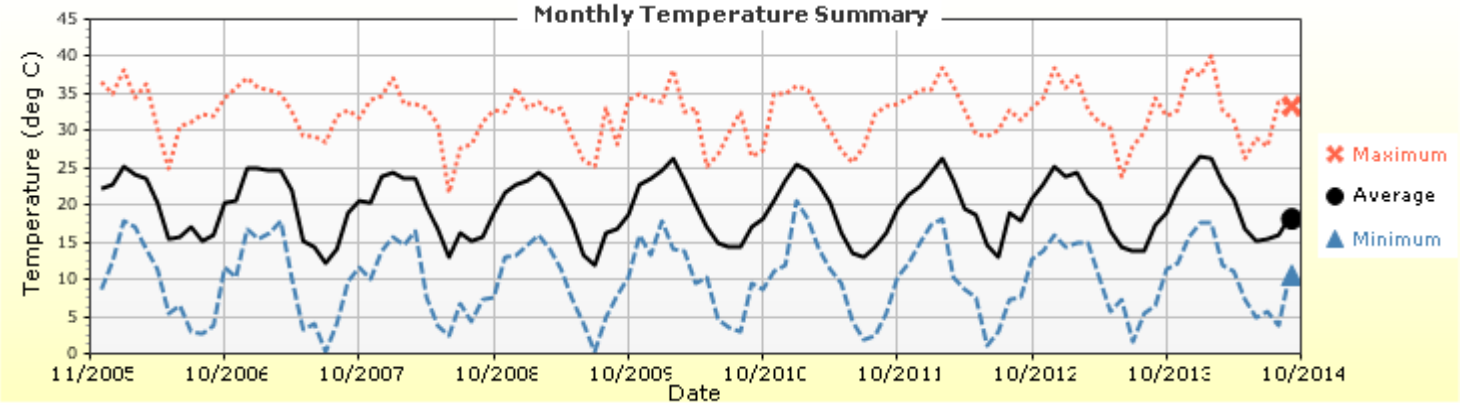


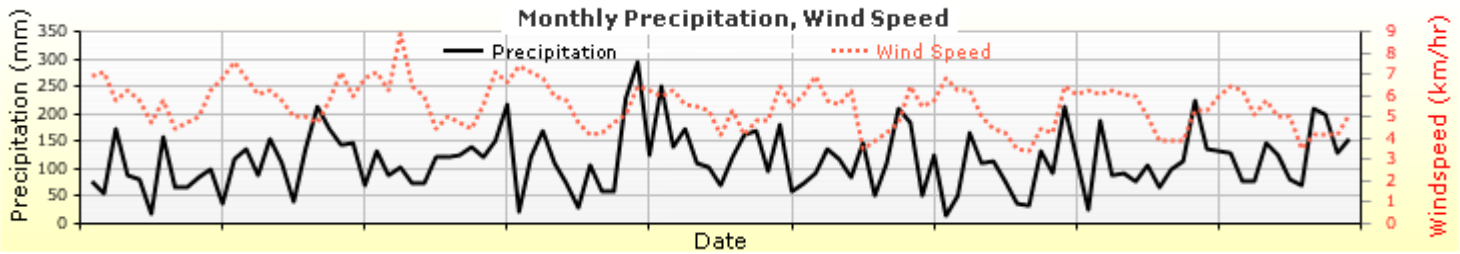
Annual Statistics:

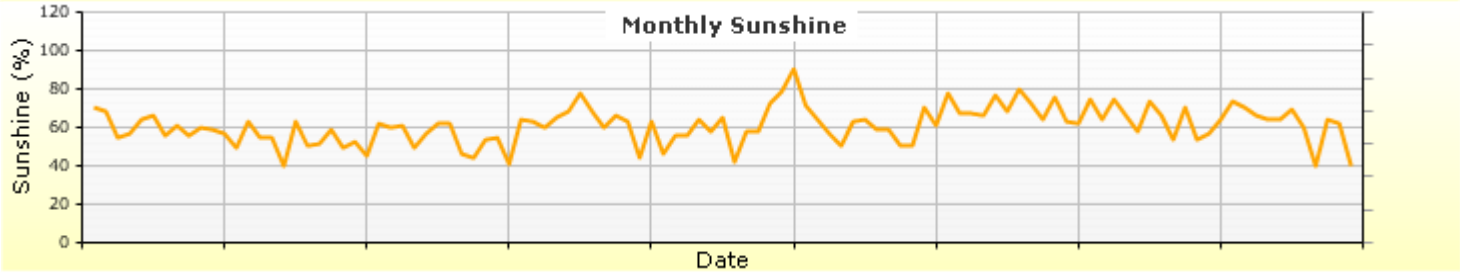
Mean annual air temperature (ºC)	19.73
Mean annual precipitation (mm)	1352.30
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

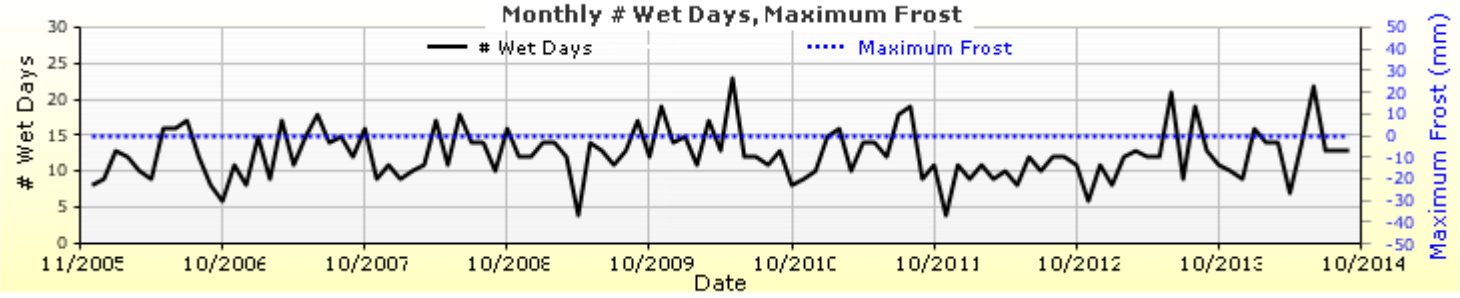
Water table depth (m) 3.05

Monthly Climate Summary:

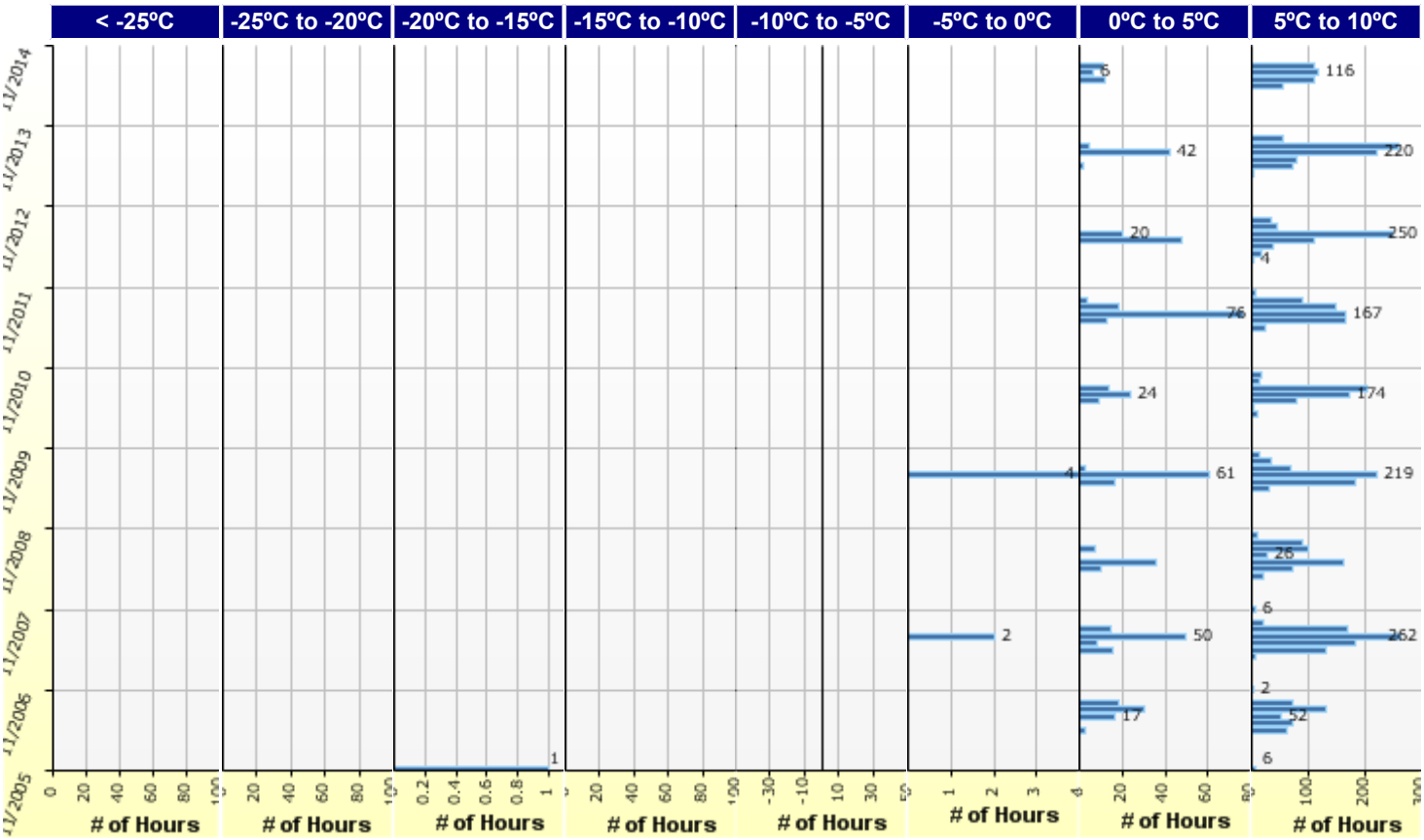


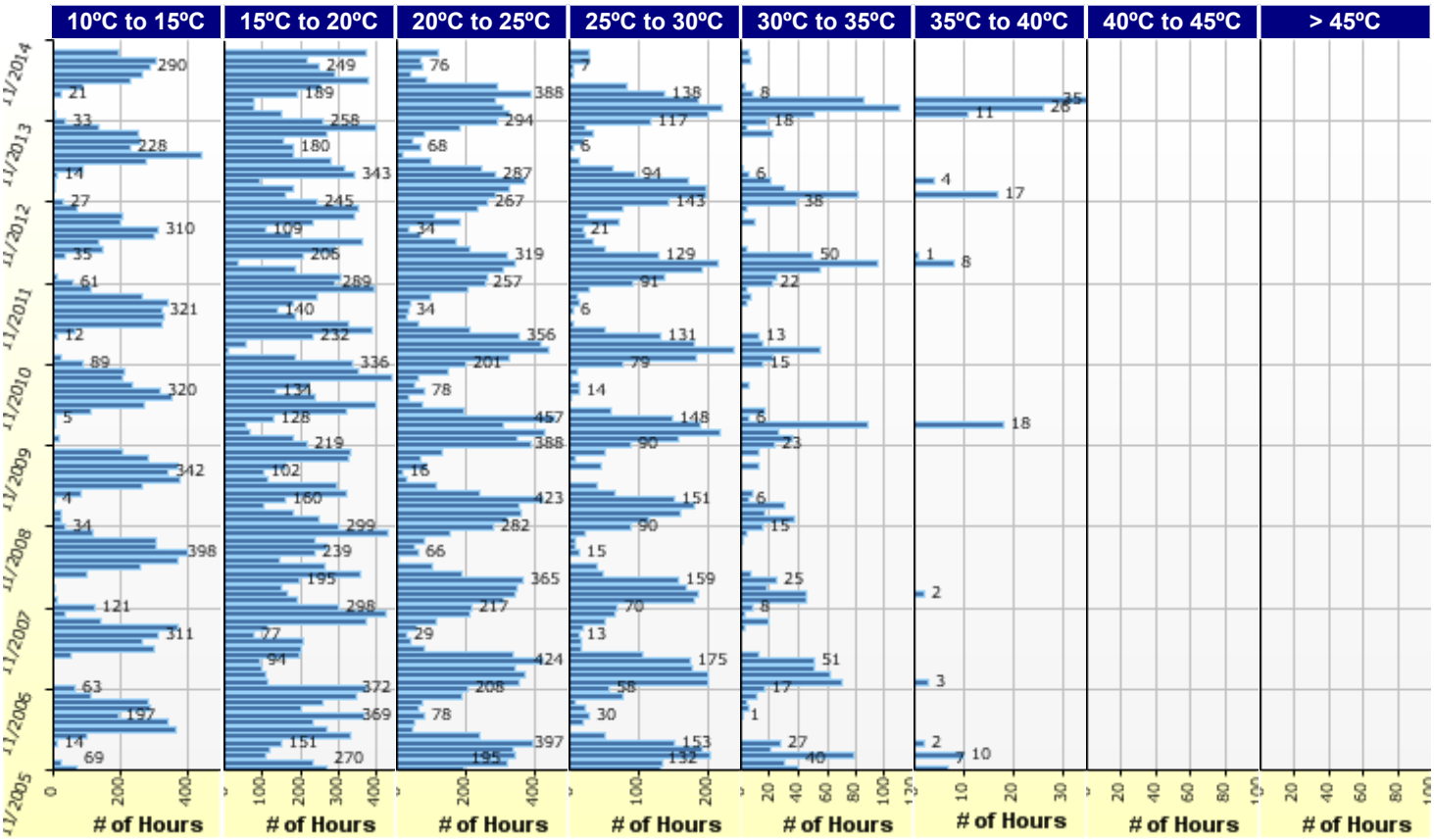






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

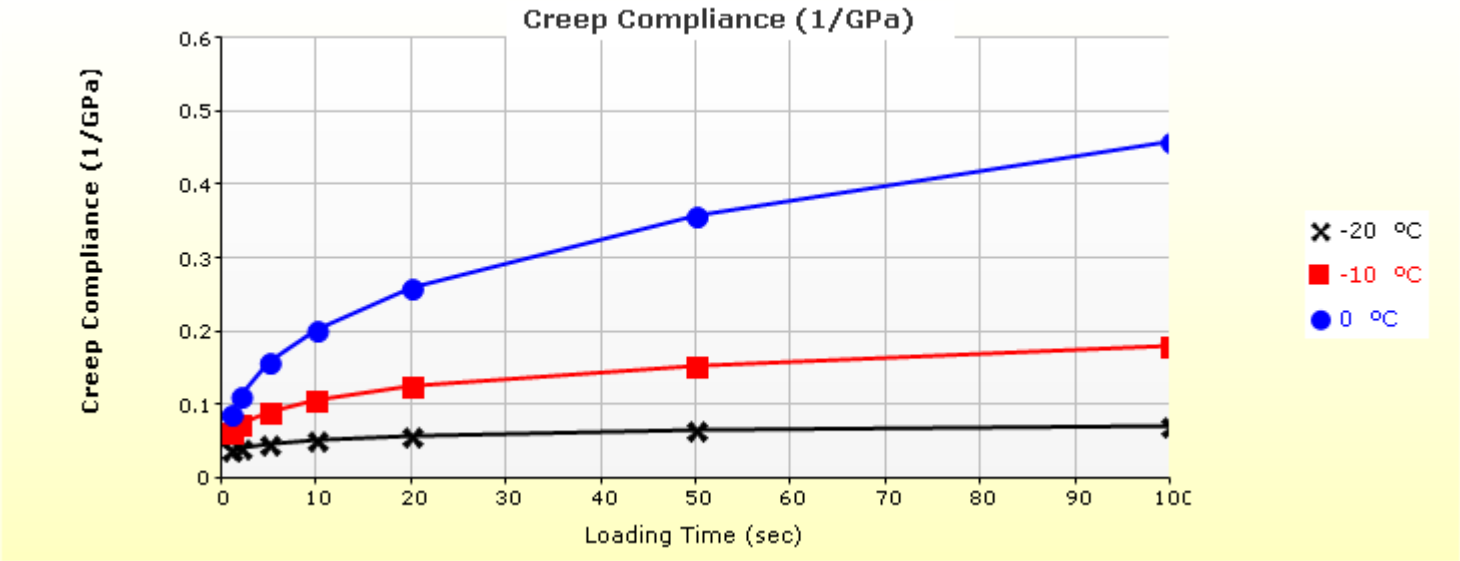
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

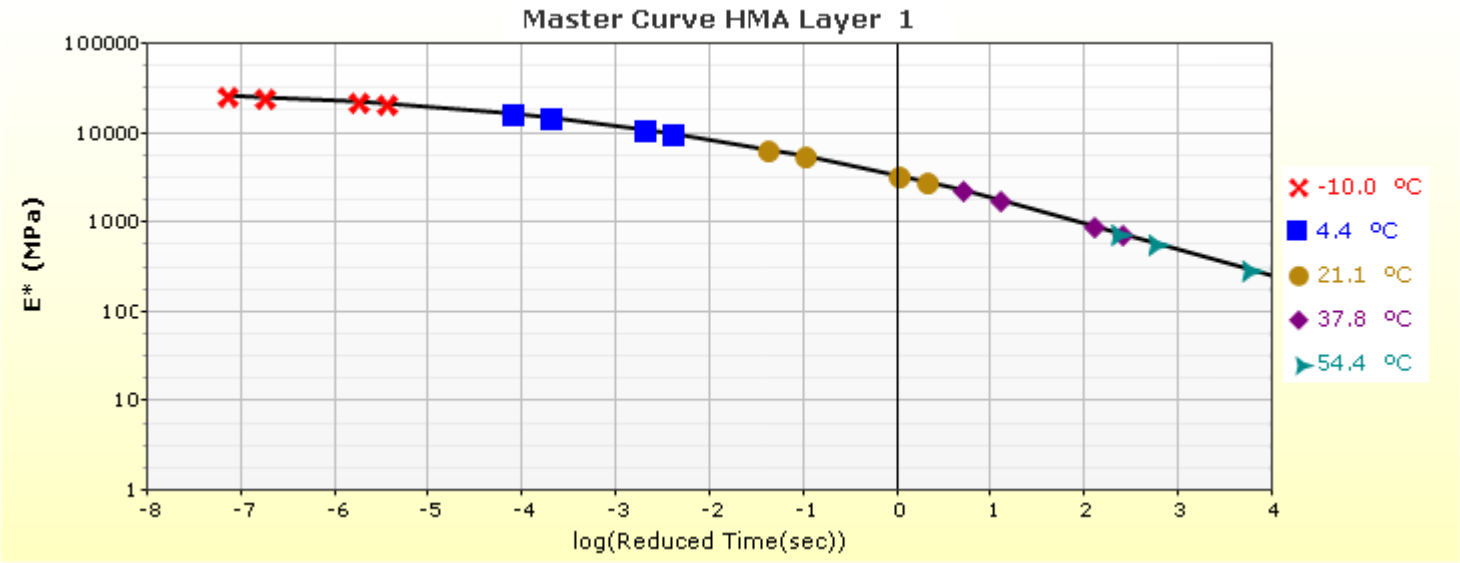
Indirect tensile strength at -10 ºC (MPa)	2.69

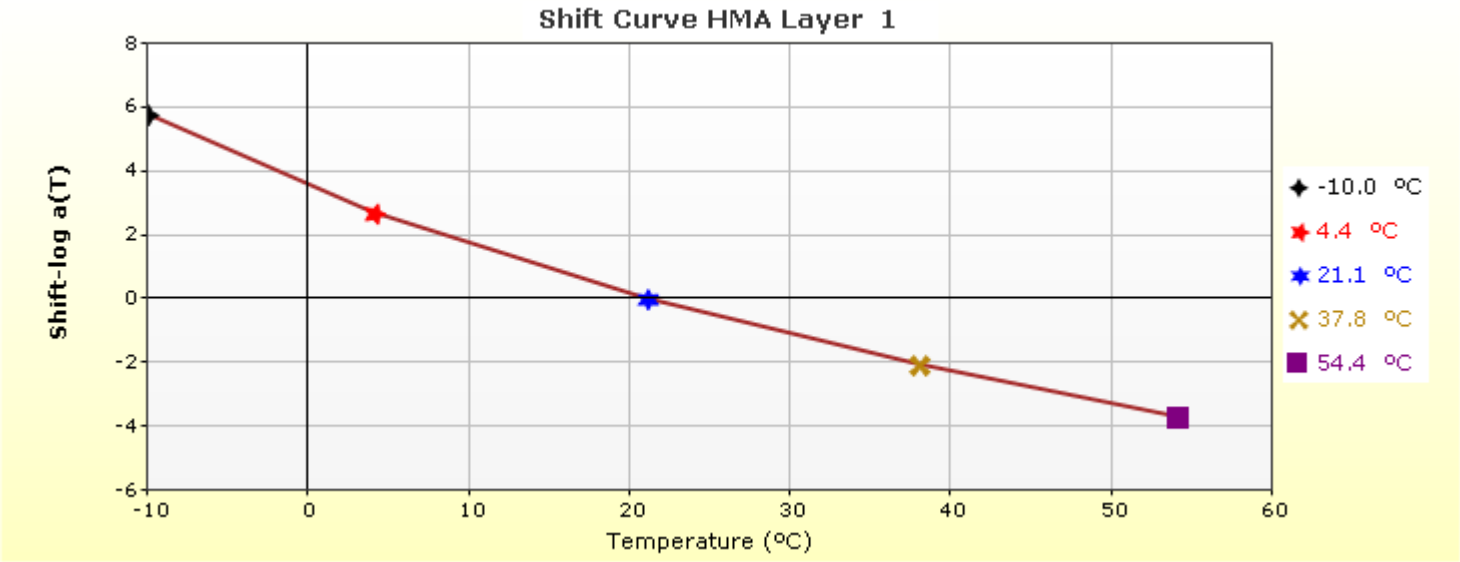
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

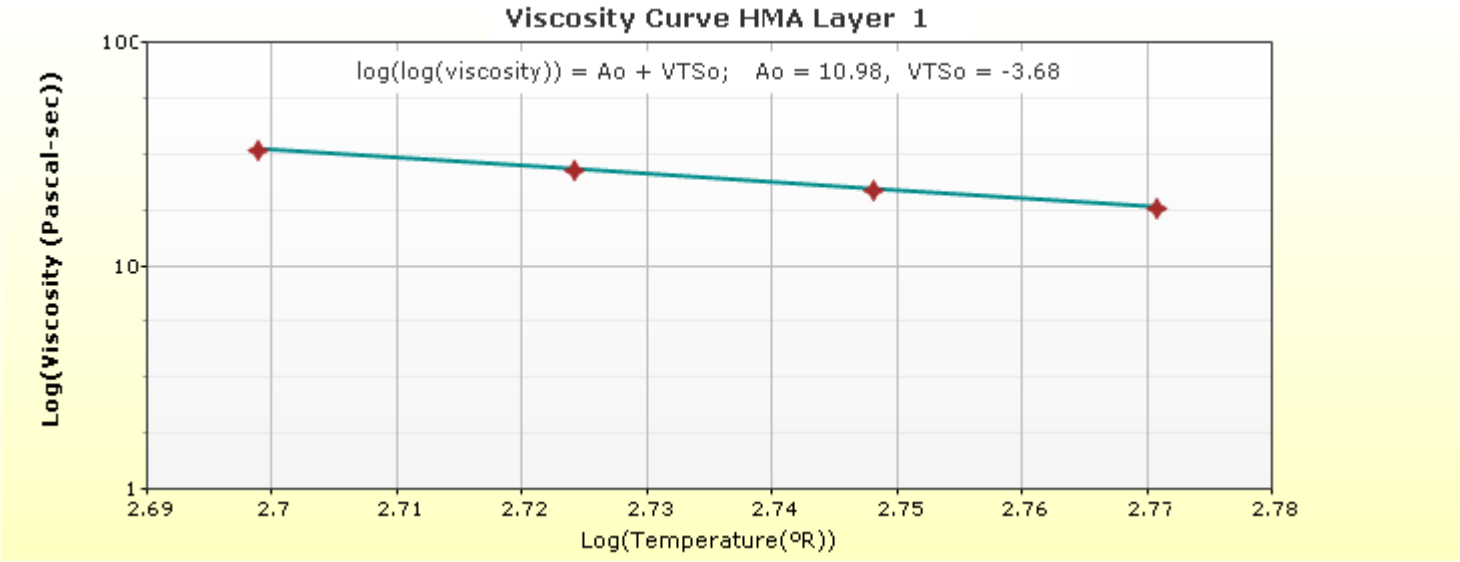
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



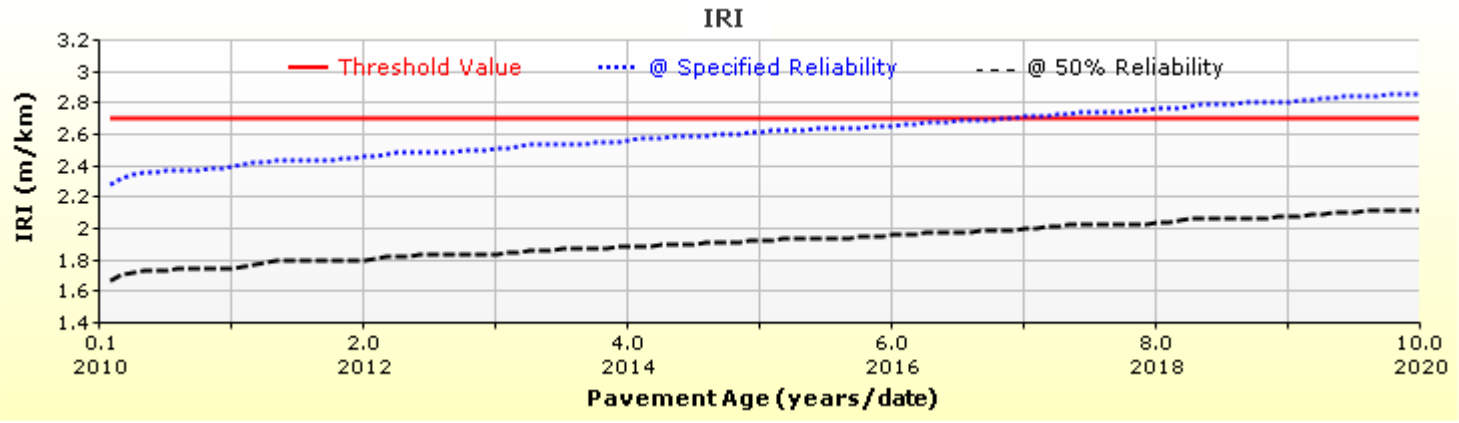
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

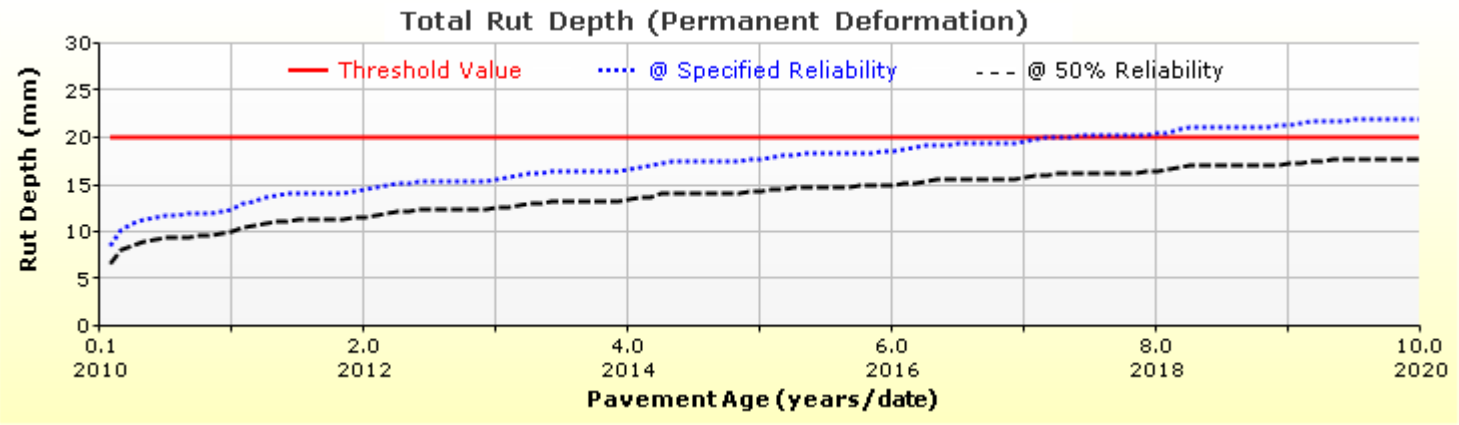


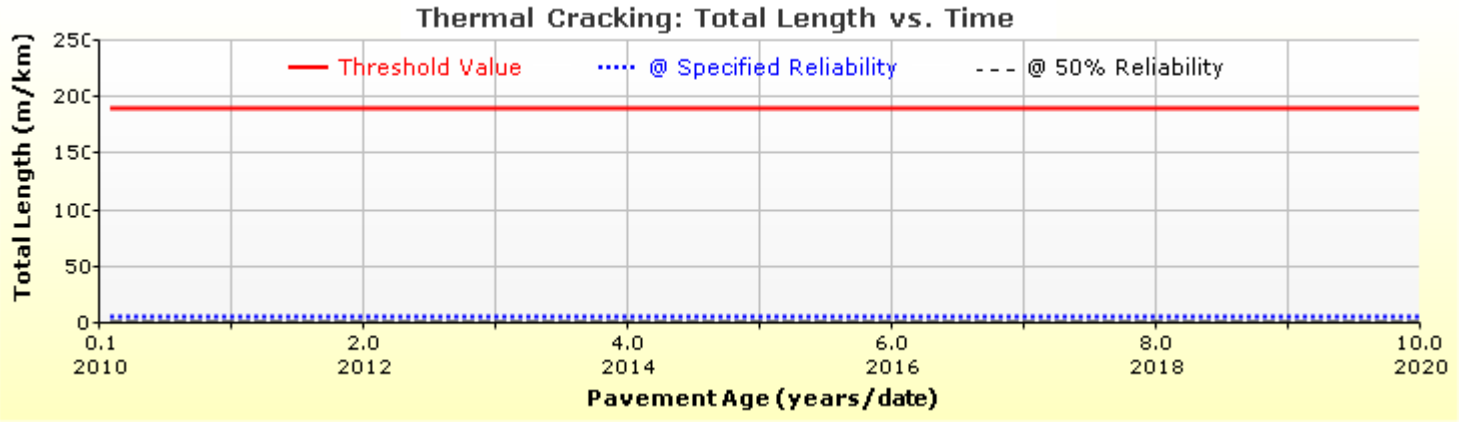


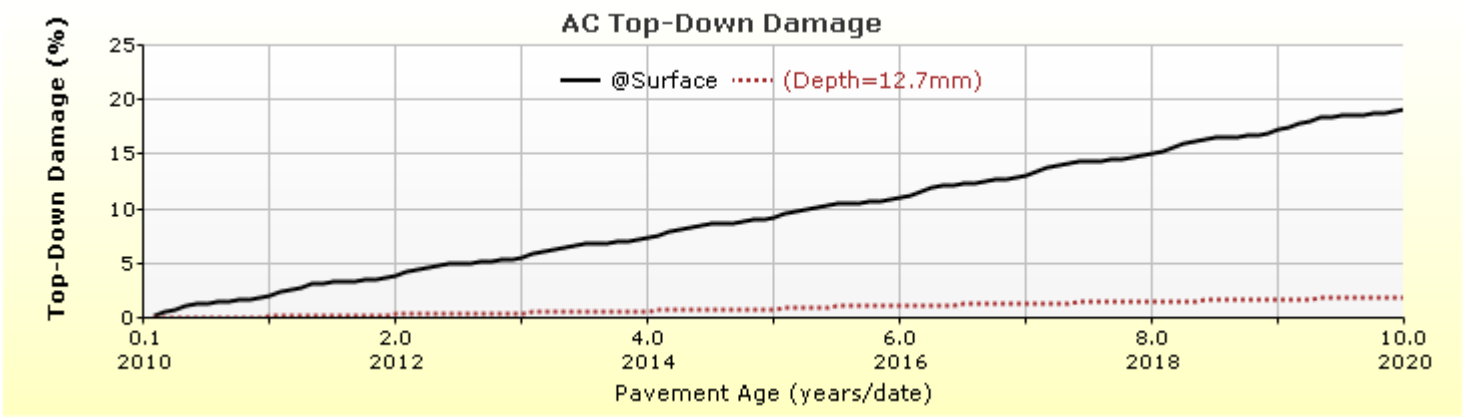


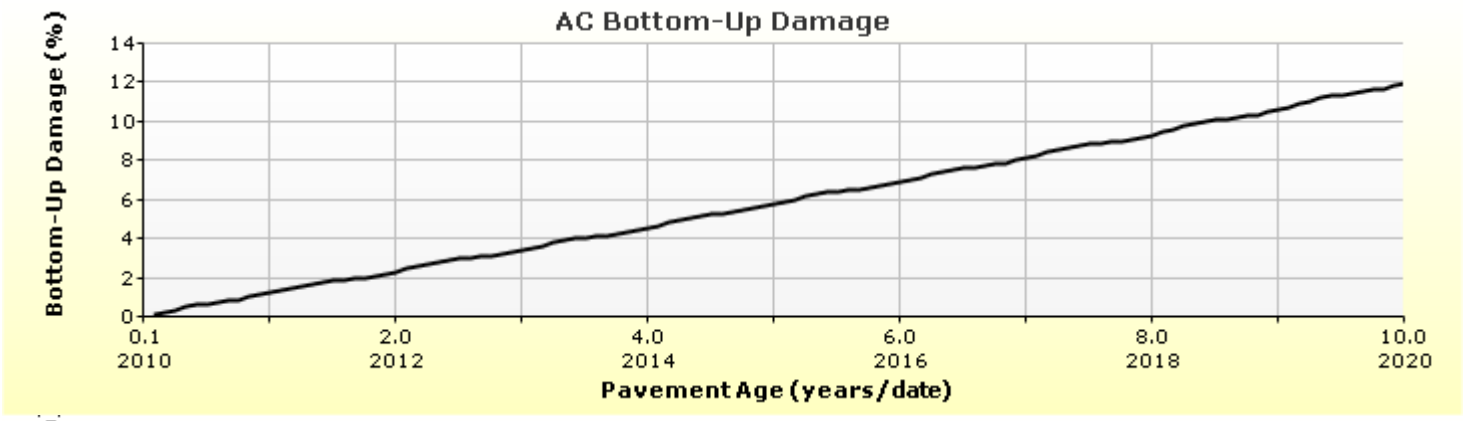
Analysis Output Charts

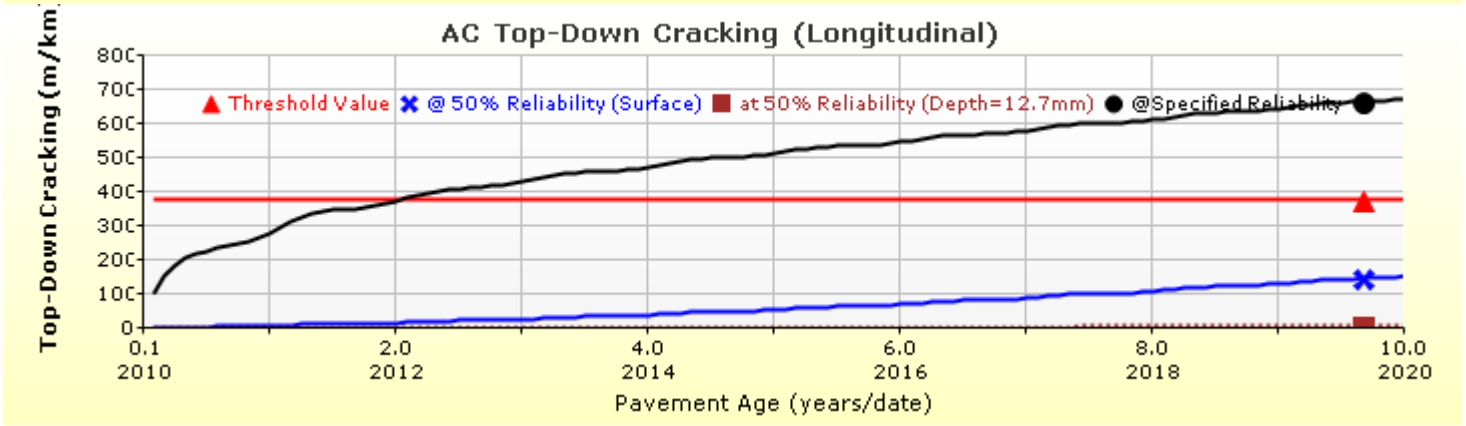


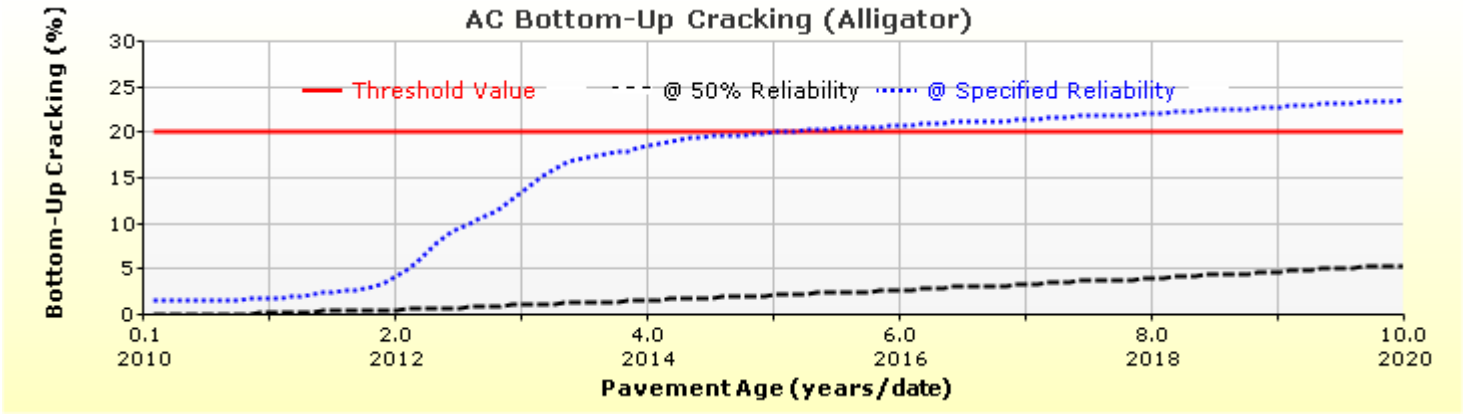


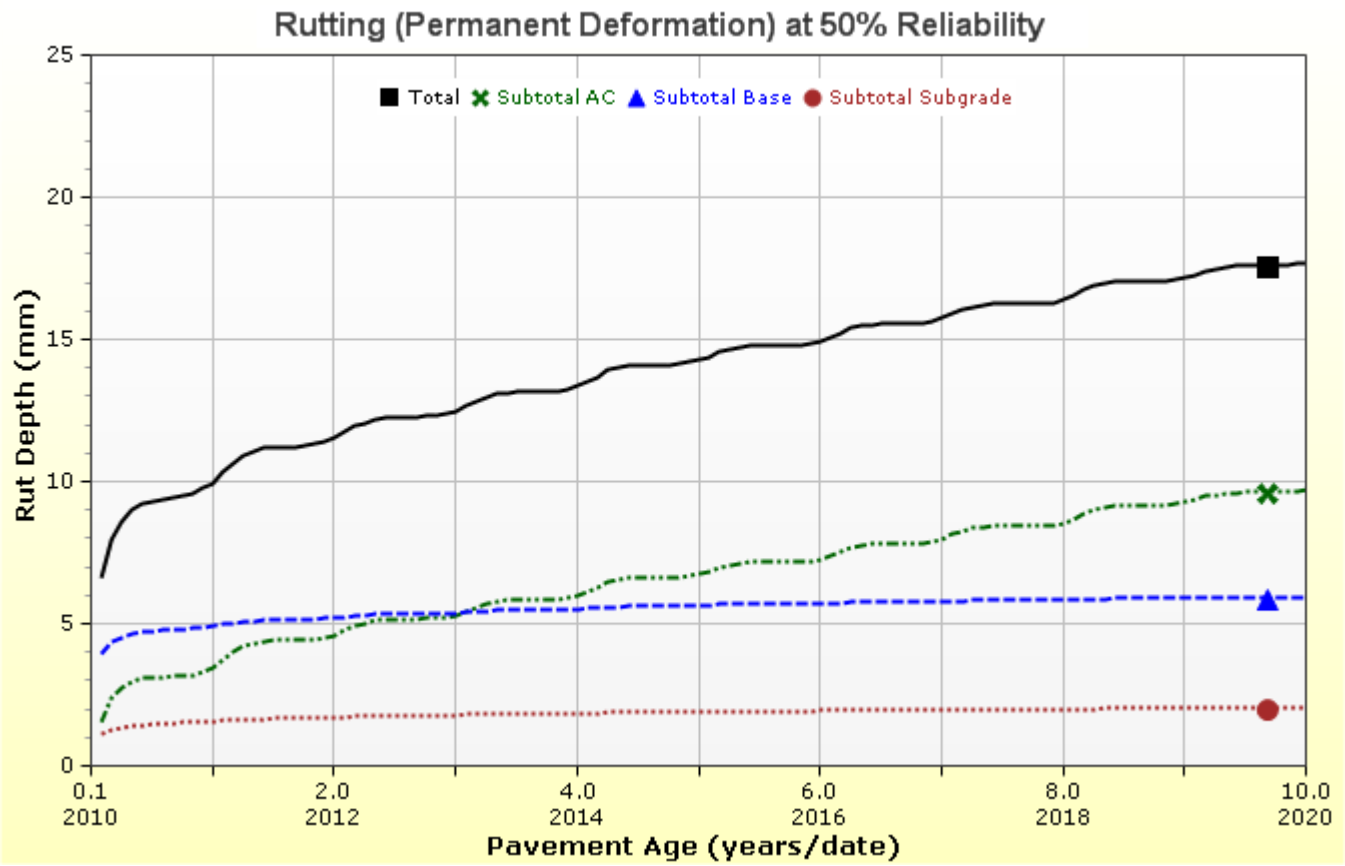


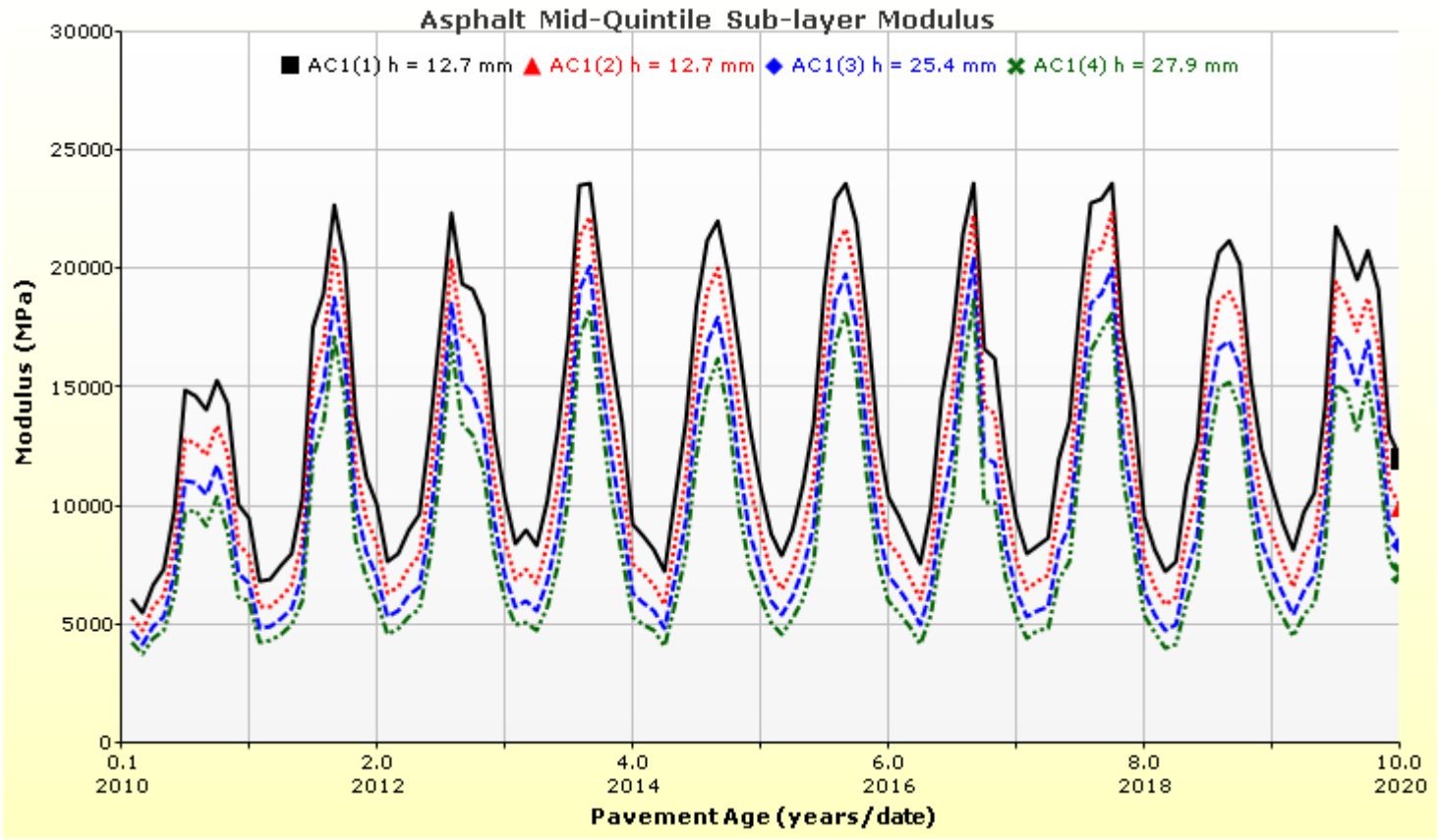

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

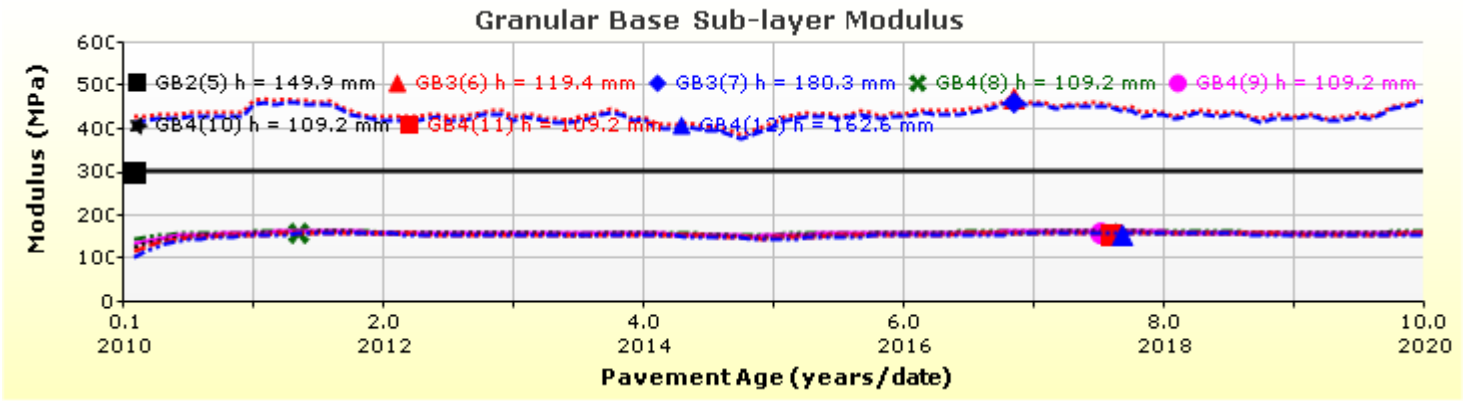

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

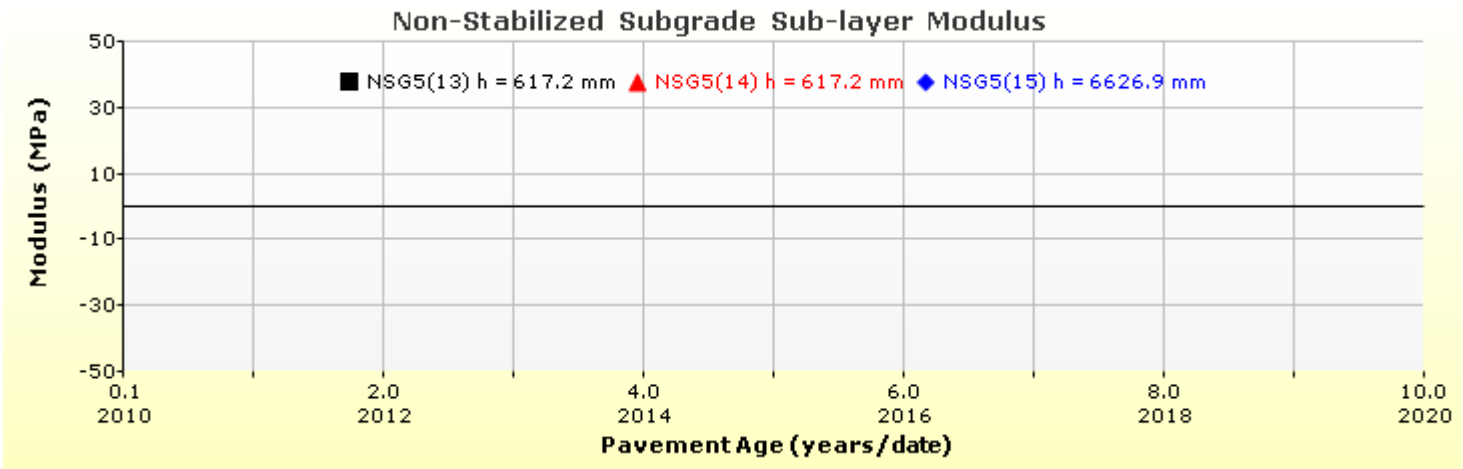

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60C
50C
40C
30C
20C
10C
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRS_precip

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRS_precip.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -30.05, -51.17

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

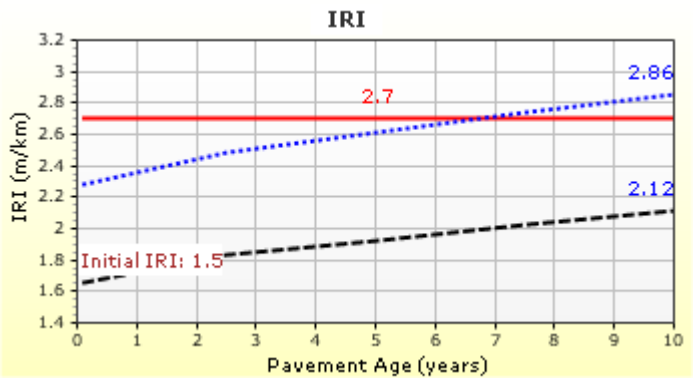
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

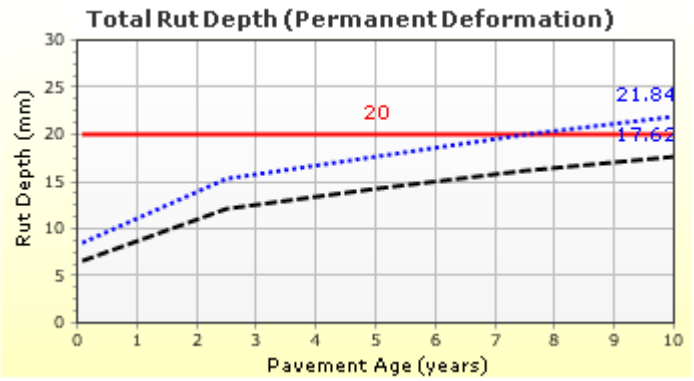
Design Outputs

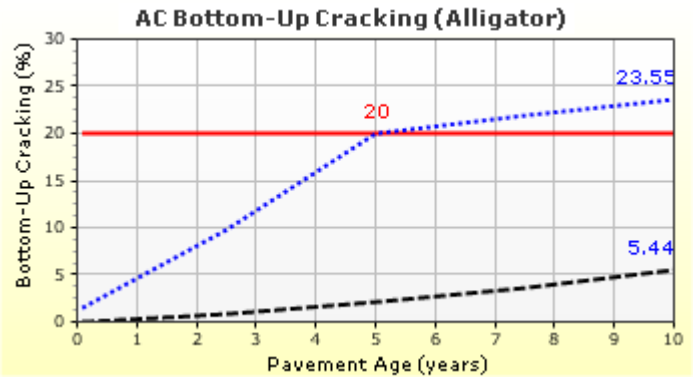
Distress Prediction Summary

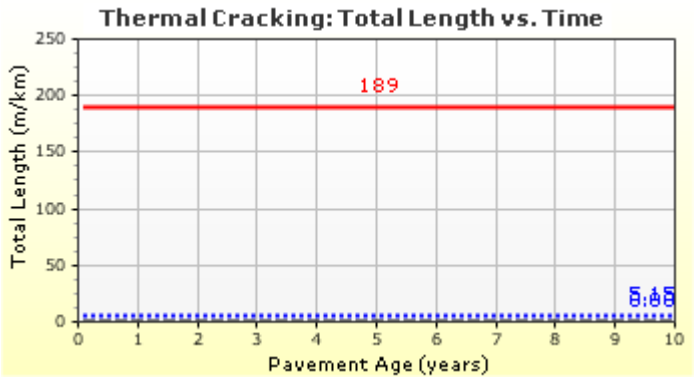
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.86	90.00	84.38	Fail
Permanent deformation - total pavement (mm)	20.00	21.85	90.00	76.39	Fail
AC bottom-up fatigue cracking (percent)	20.00	23.55	90.00	84.86	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	670.33	90.00	71.30	Fail
Permanent deformation - AC only (mm)	5.00	9.61	50.00	5.11	Fail

Distress Charts







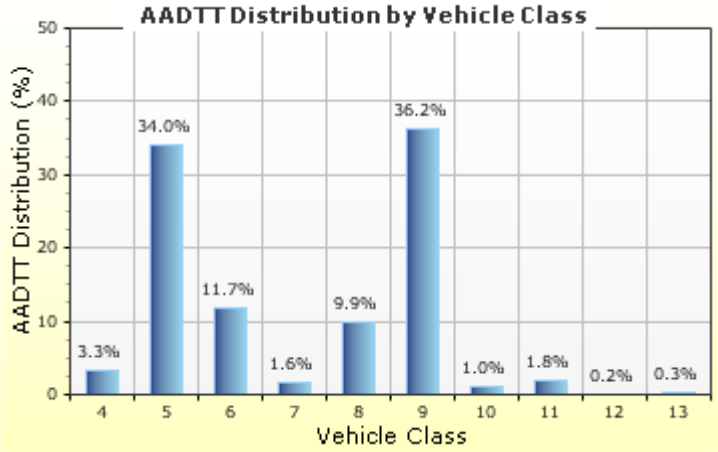


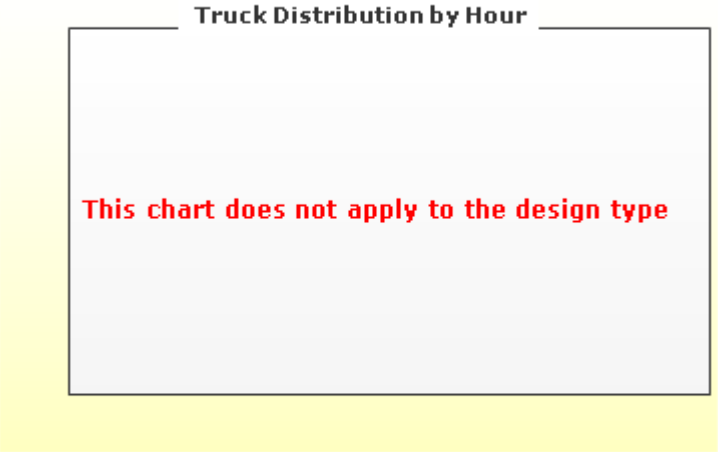


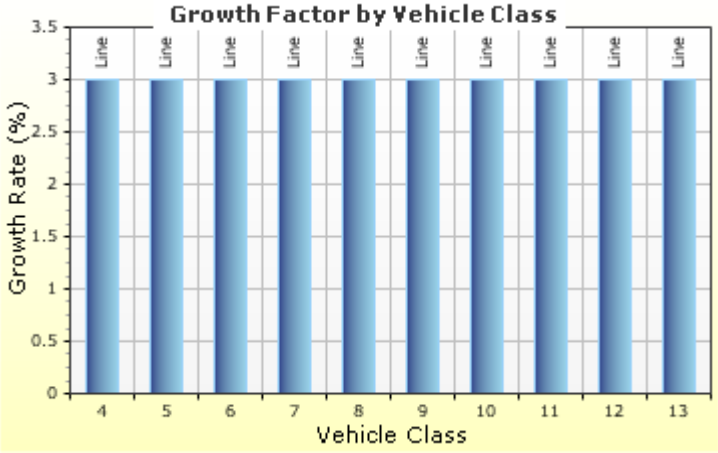
Traffic Inputs

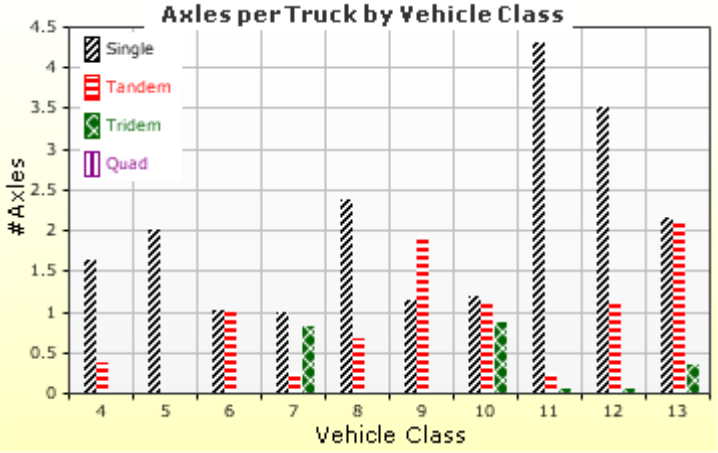
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

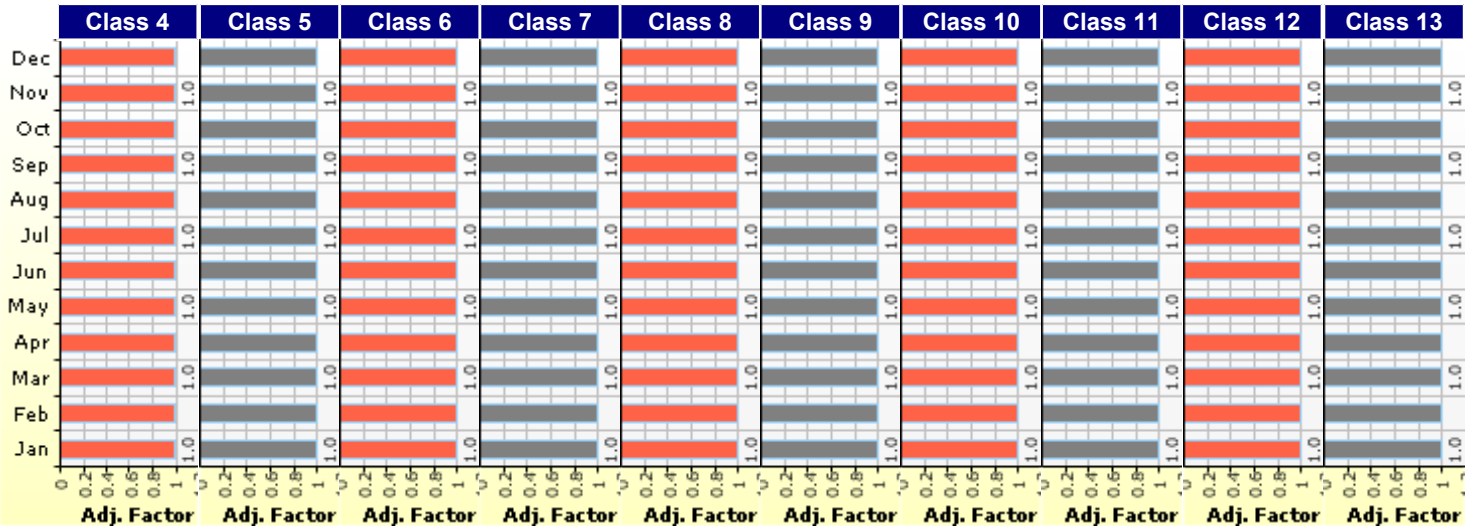








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

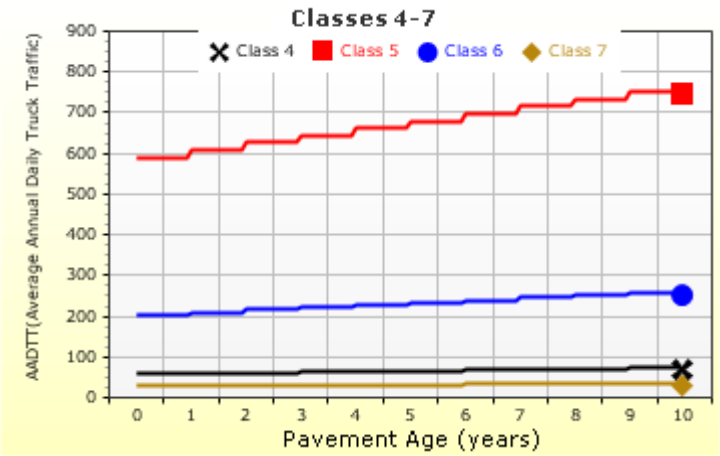
Wheelbase does not apply

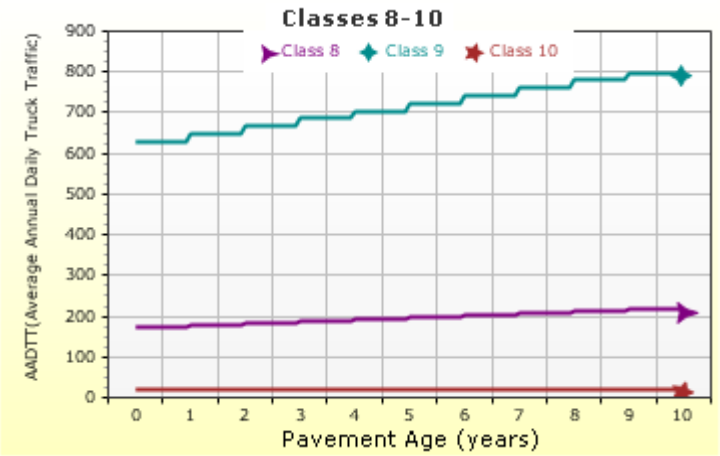
Number of Axles per Truck

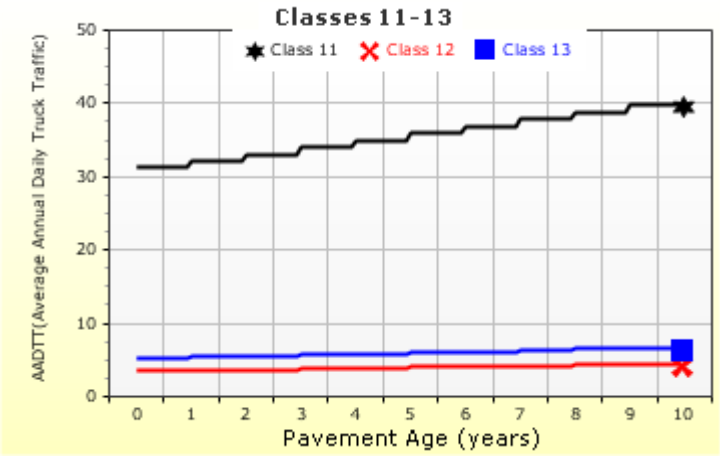
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

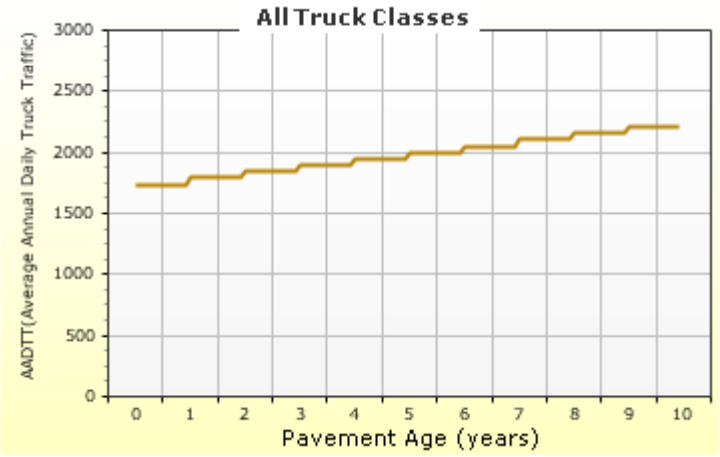
AADTT (Average Annual Daily Truck Traffic) Growth

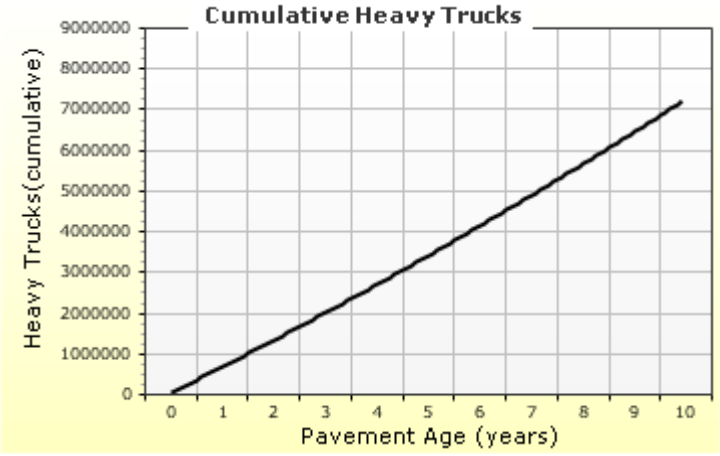
*** Traffic cap is not enforced**







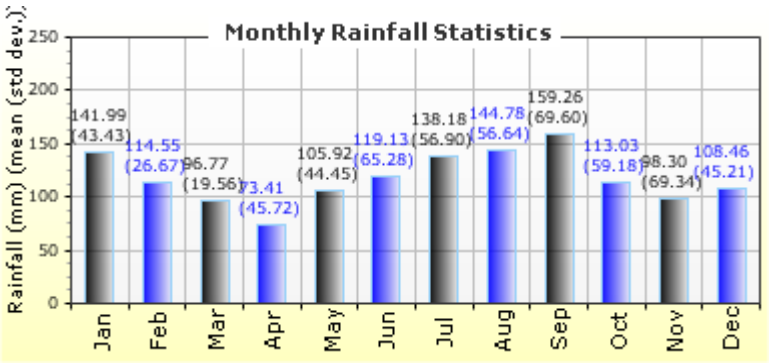




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
PORTO ALEGRE, RS	-30.05000 -51.17000 47

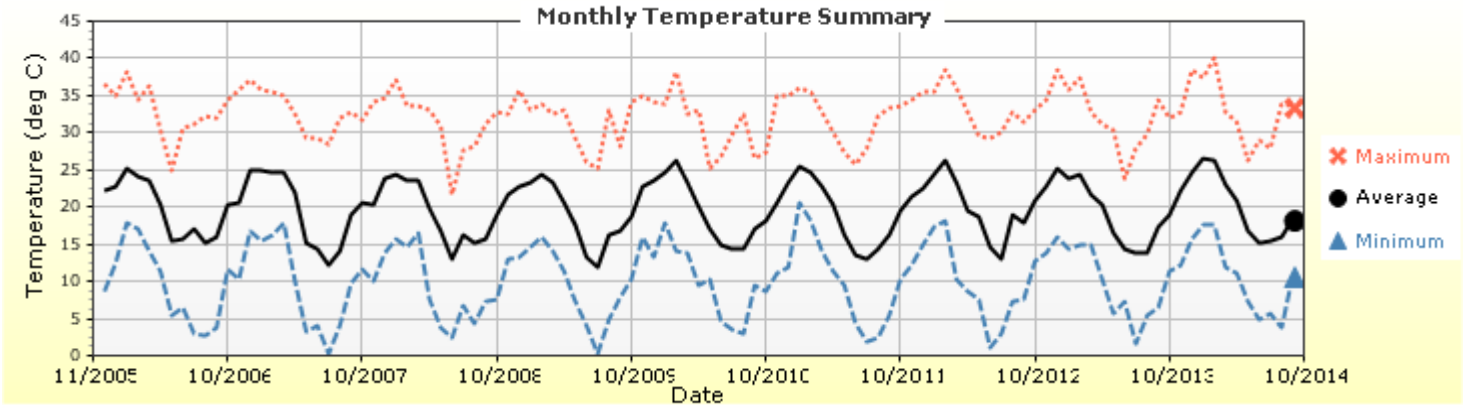


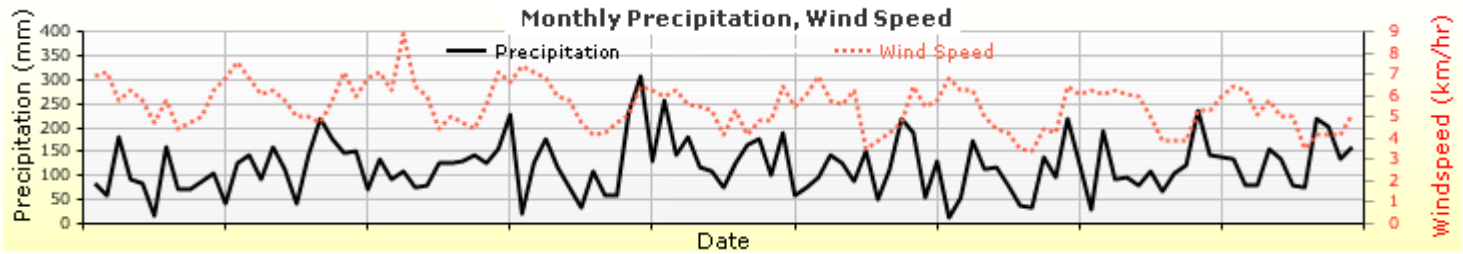
Annual Statistics:

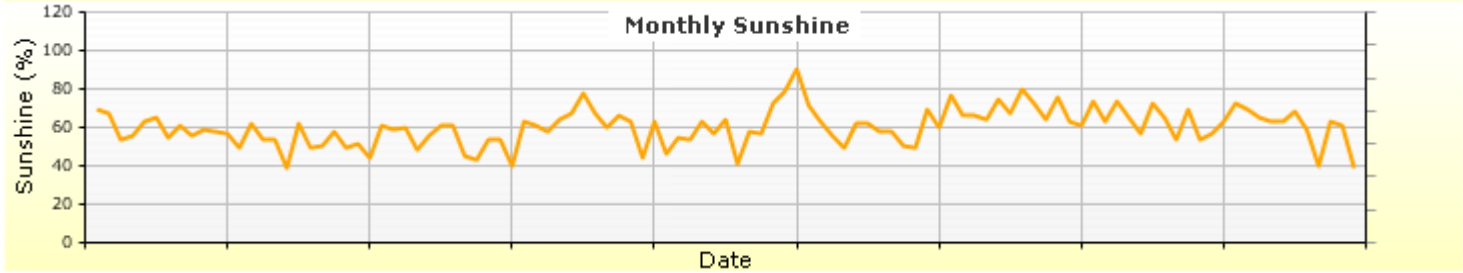
Mean annual air temperature (ºC)	19.73
Mean annual precipitation (mm)	1409.95
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

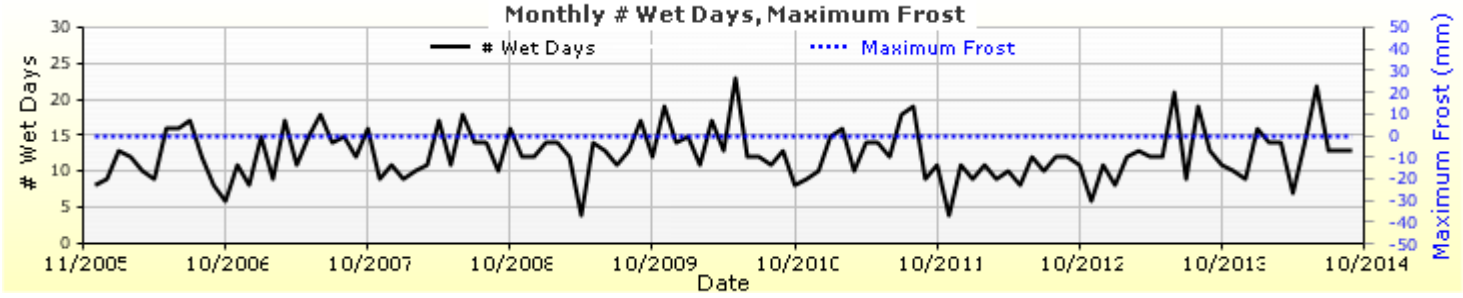
Water table depth (m): 3.05

Monthly Climate Summary:

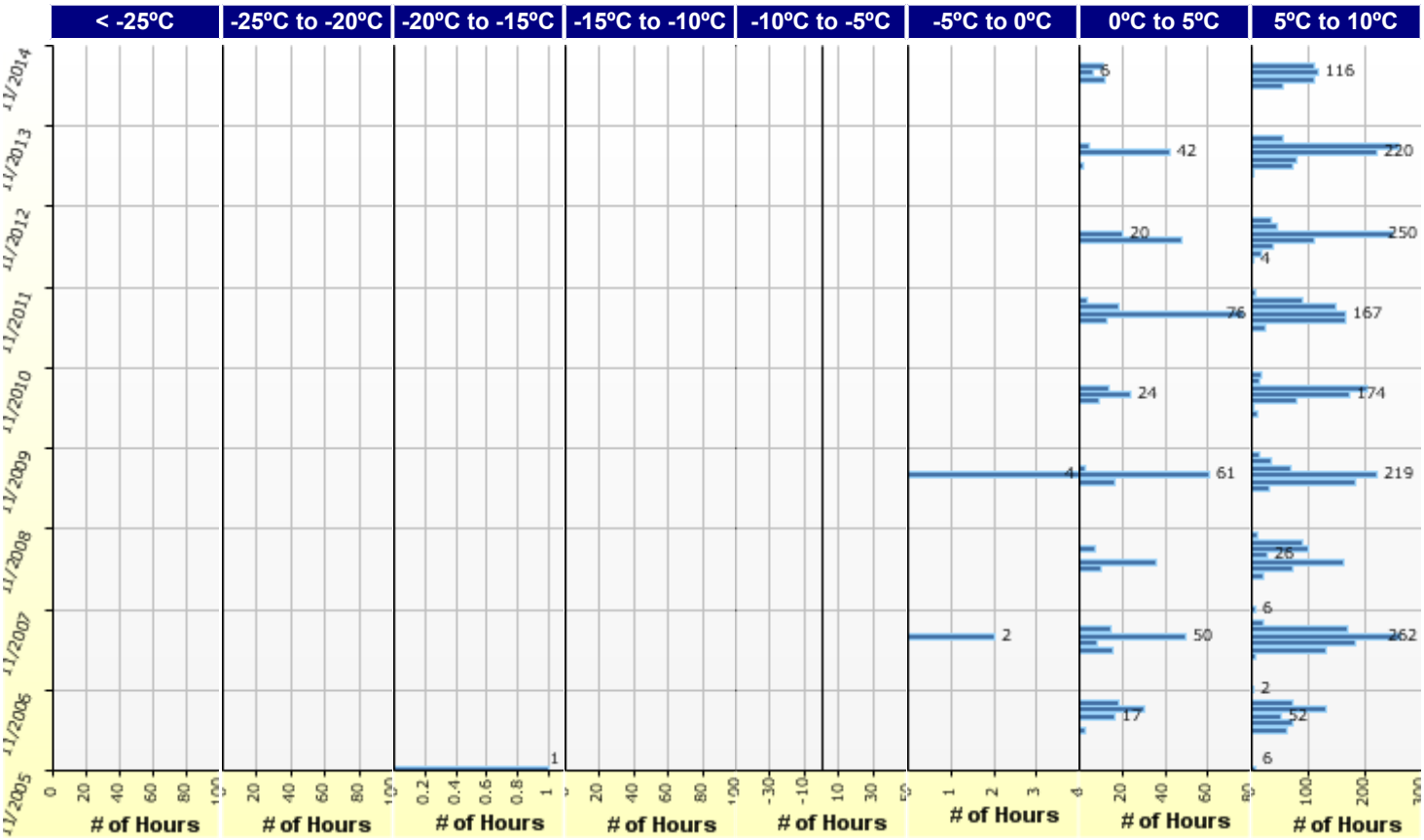


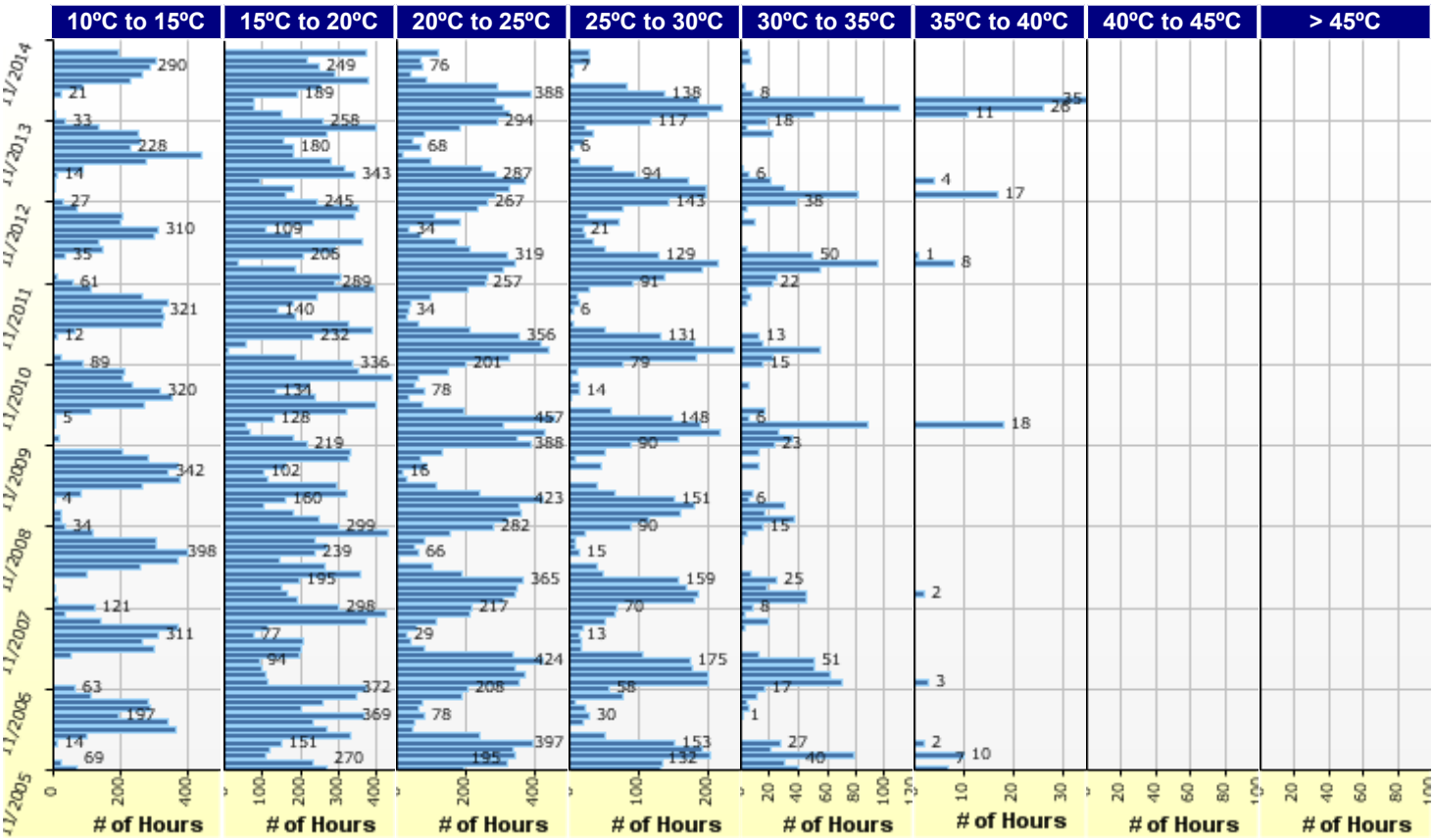






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

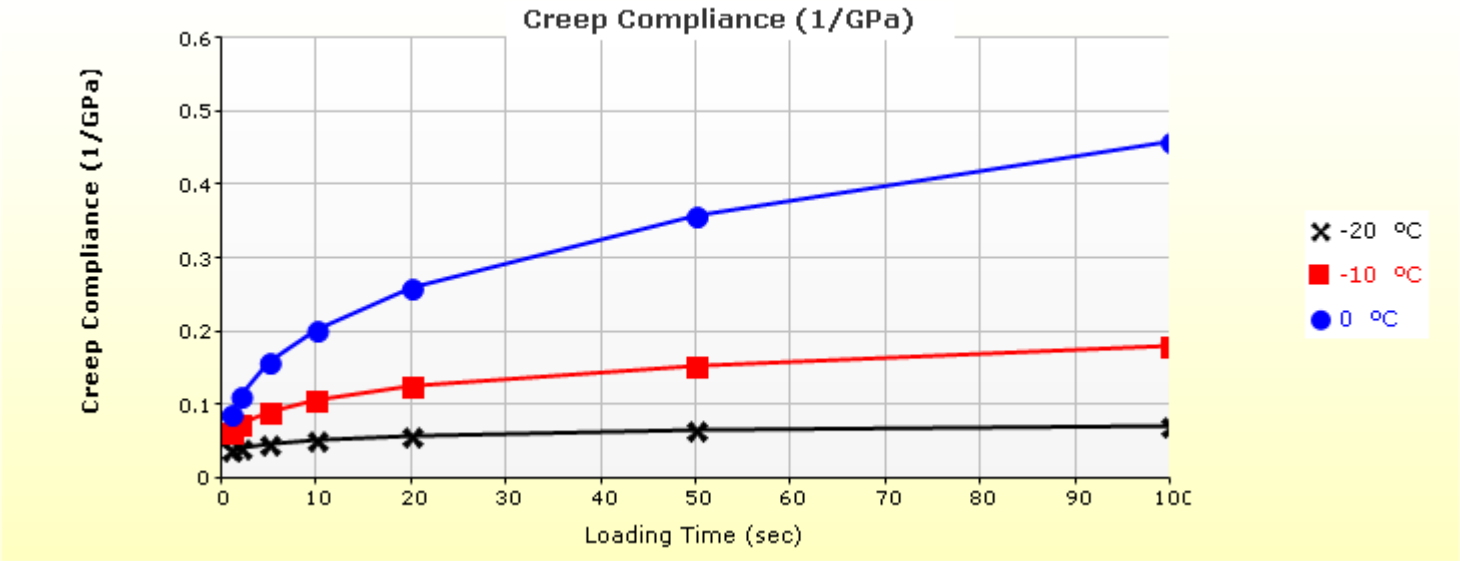
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

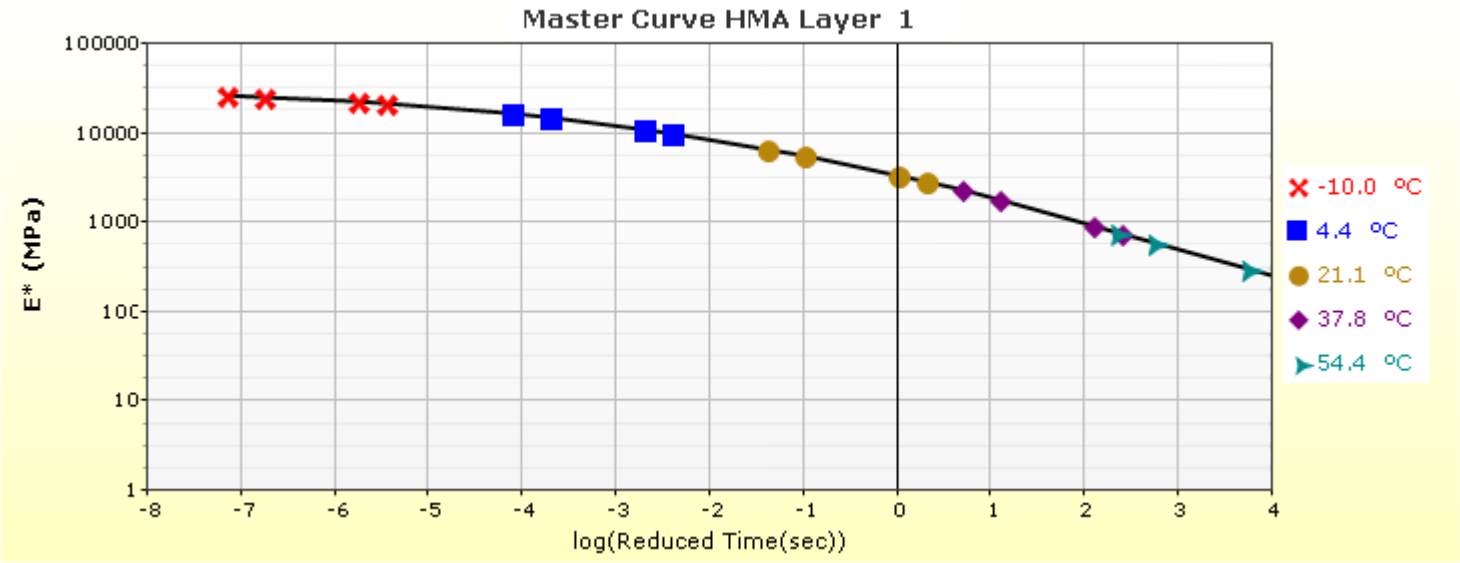
Indirect tensile strength at -10 ºC (MPa)	2.69

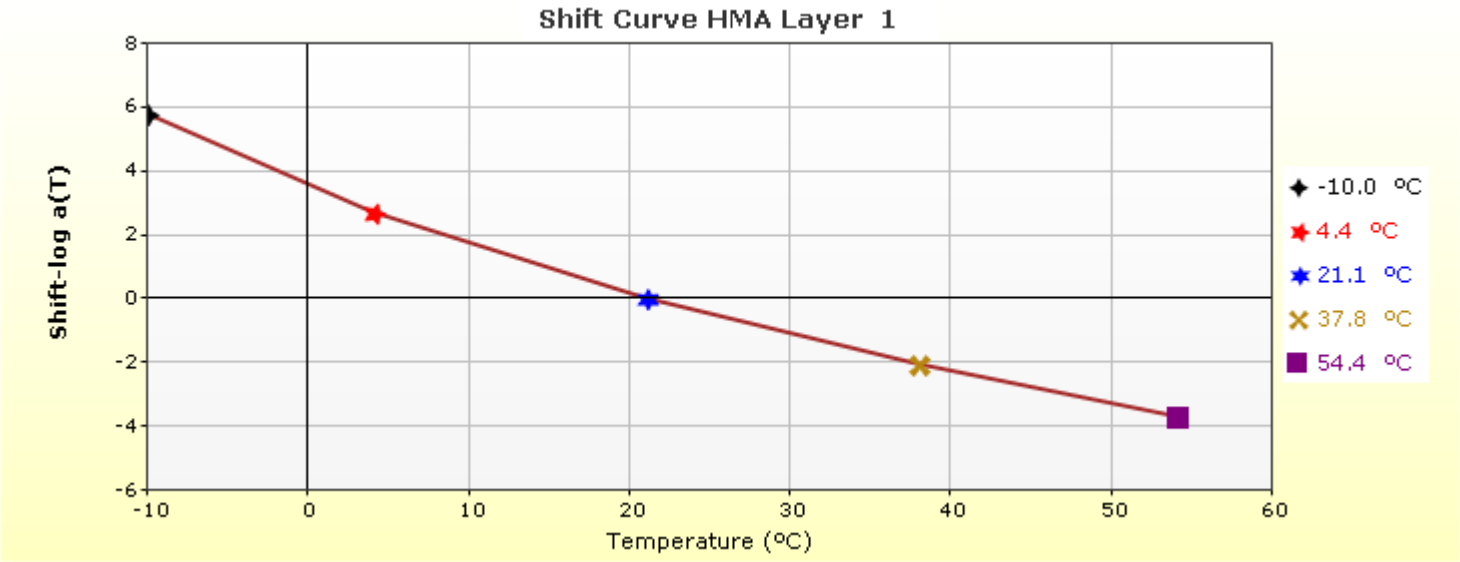
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

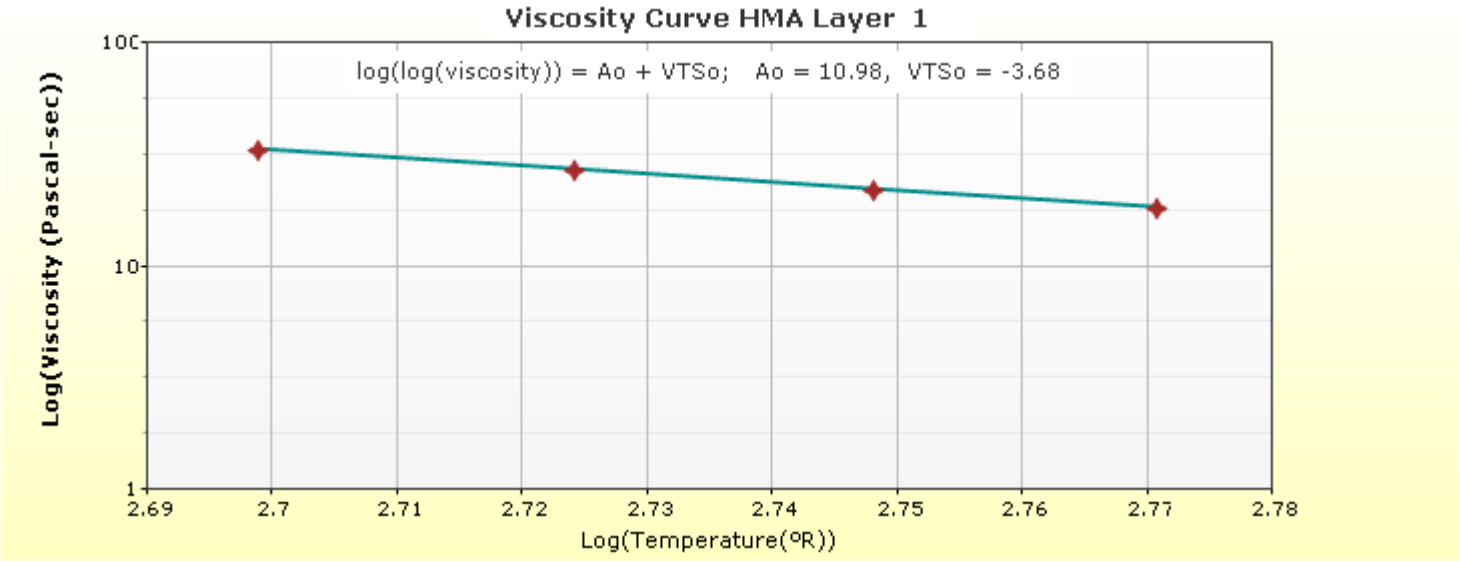
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



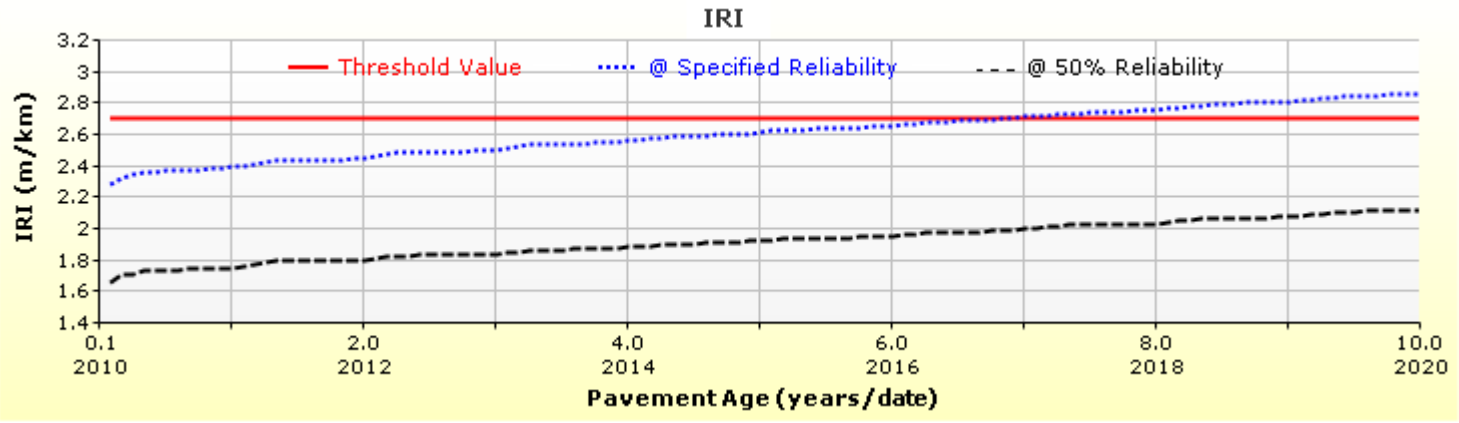
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

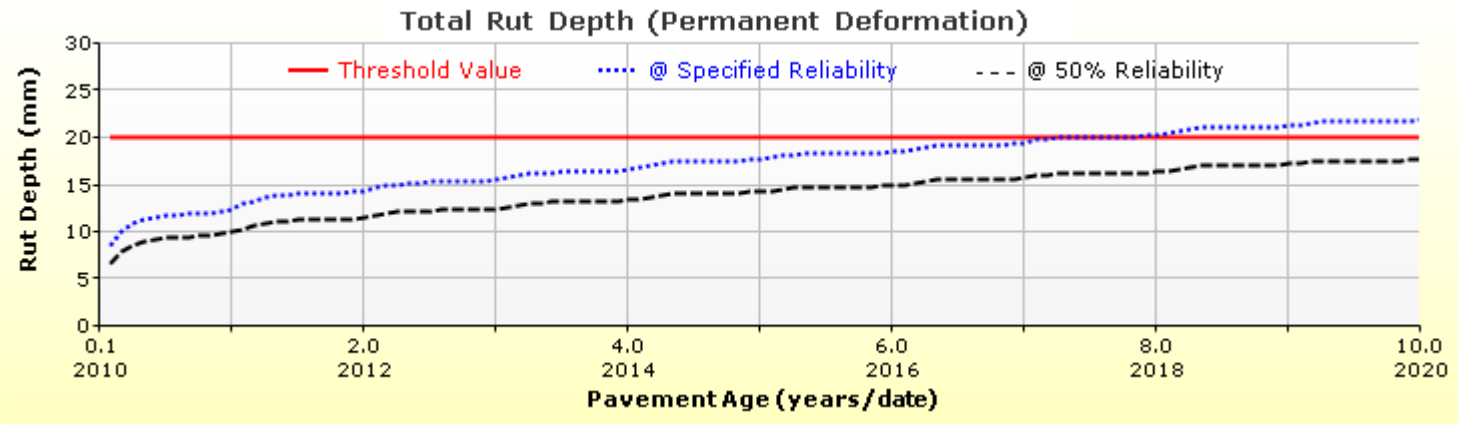


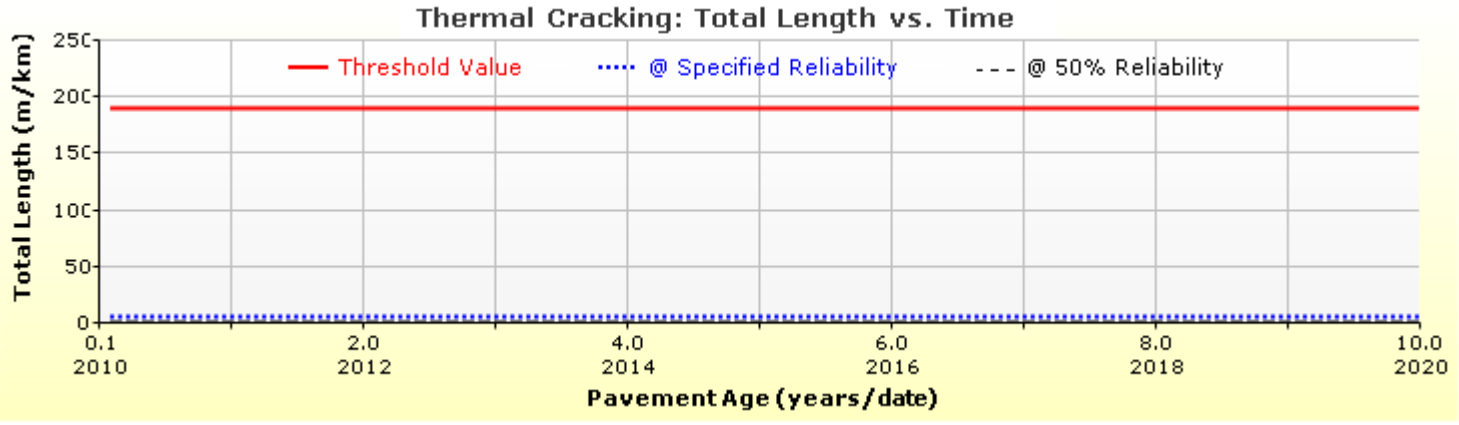


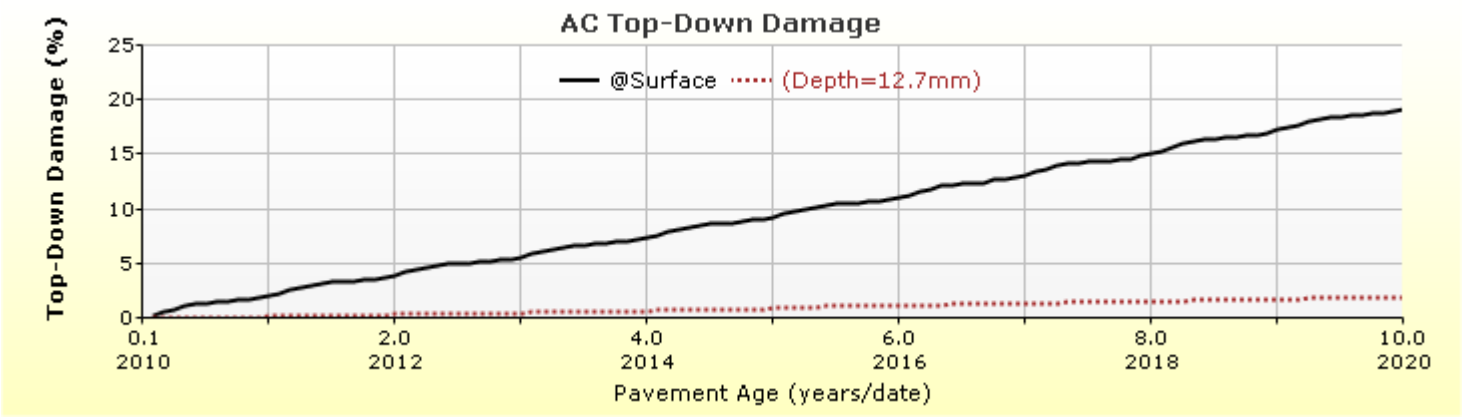


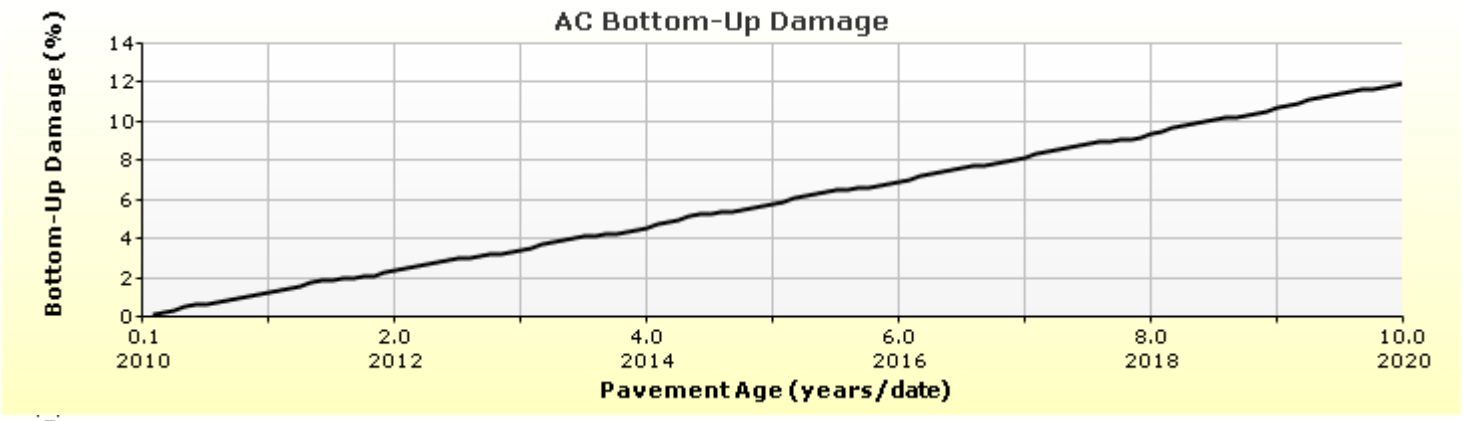
Analysis Output Charts

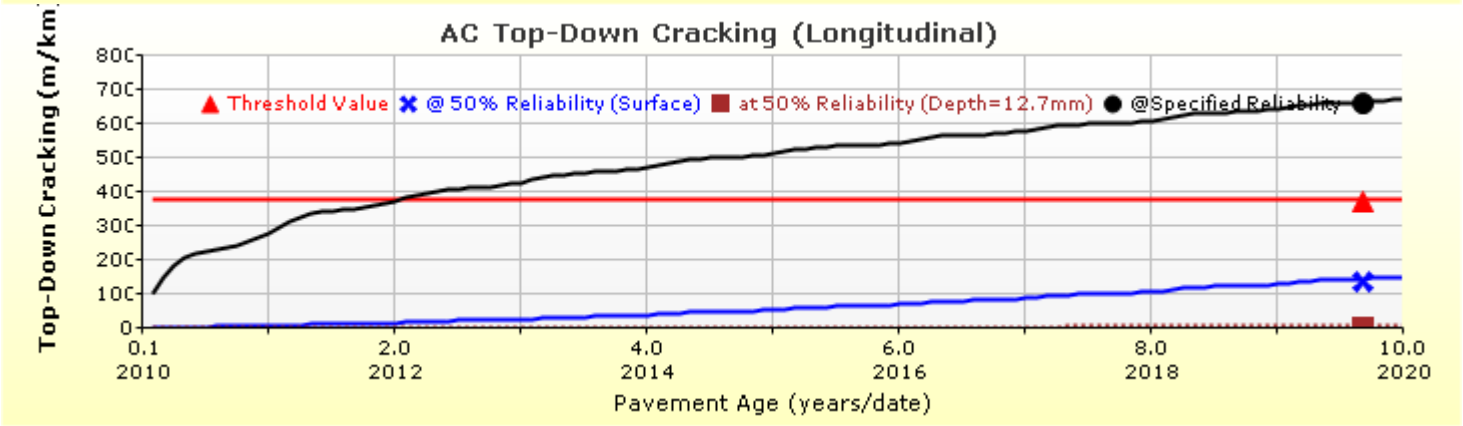


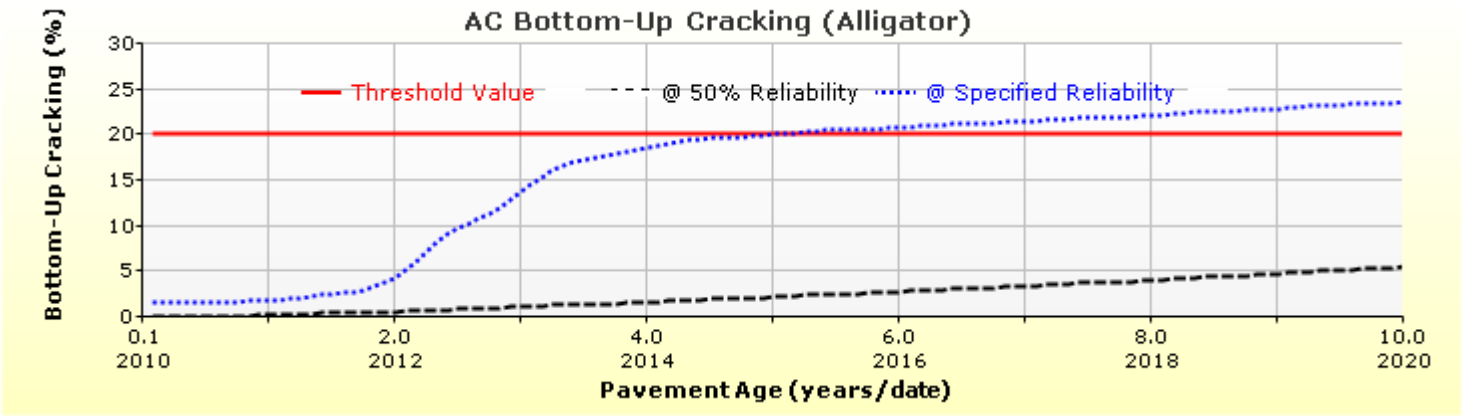


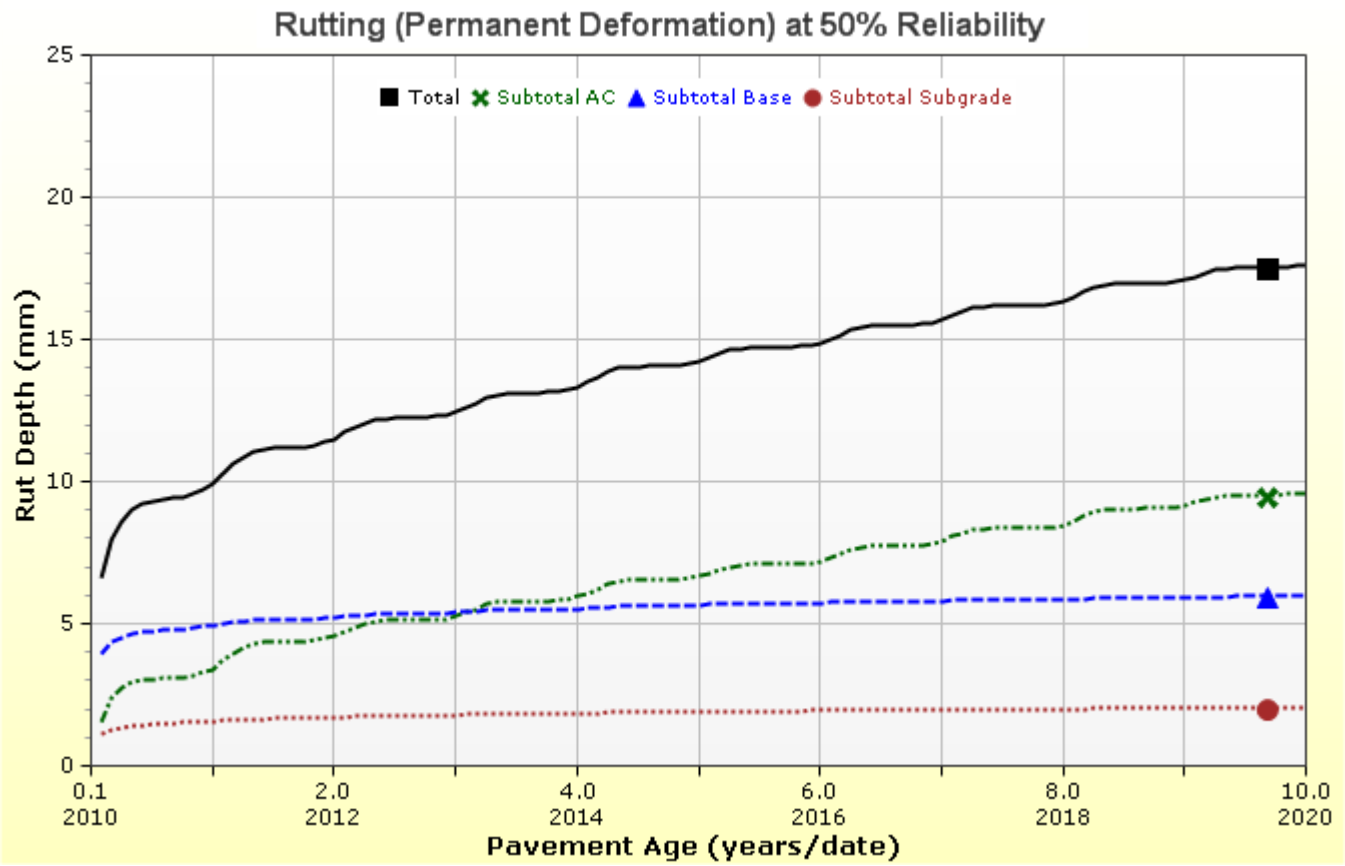


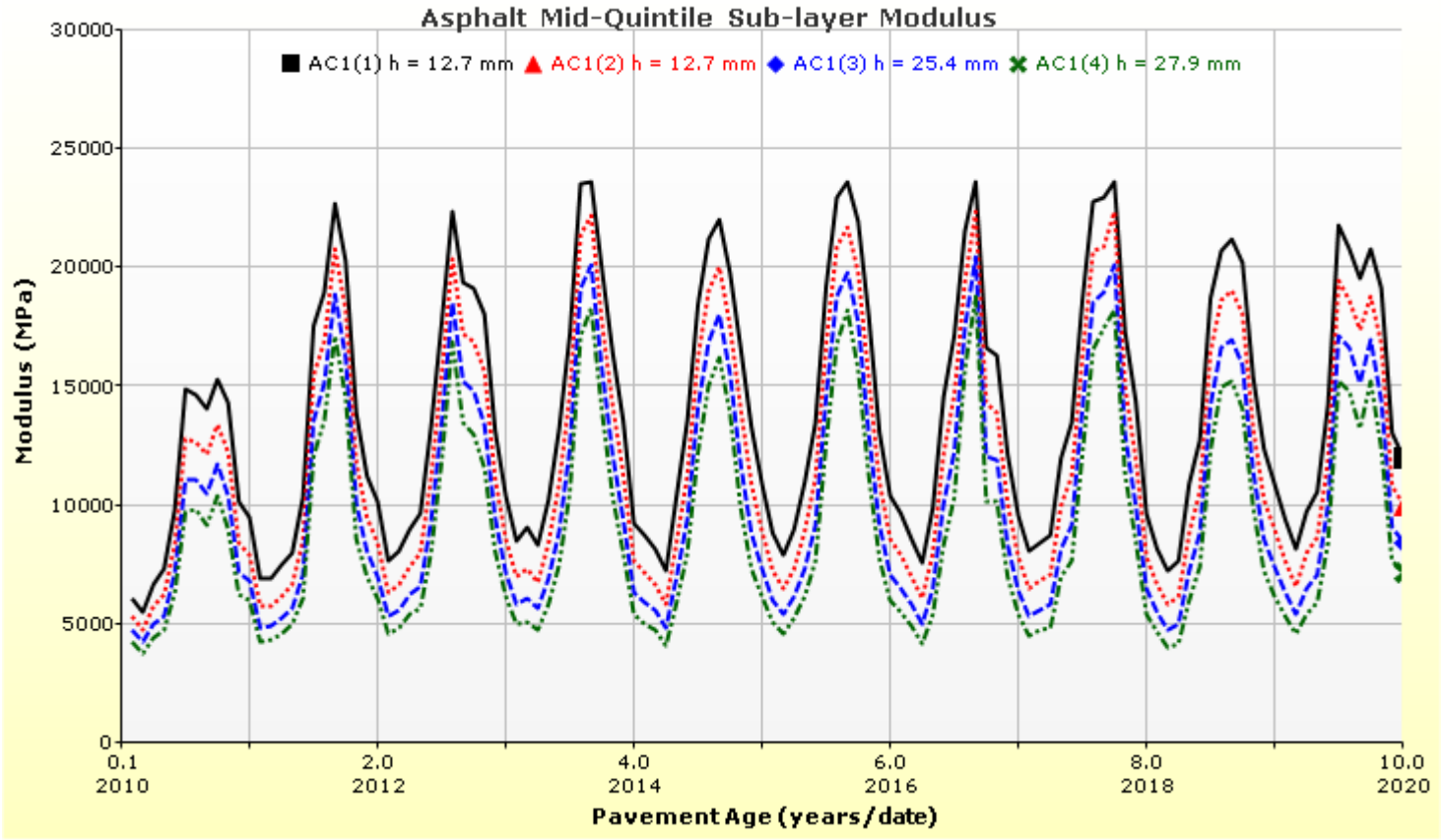

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

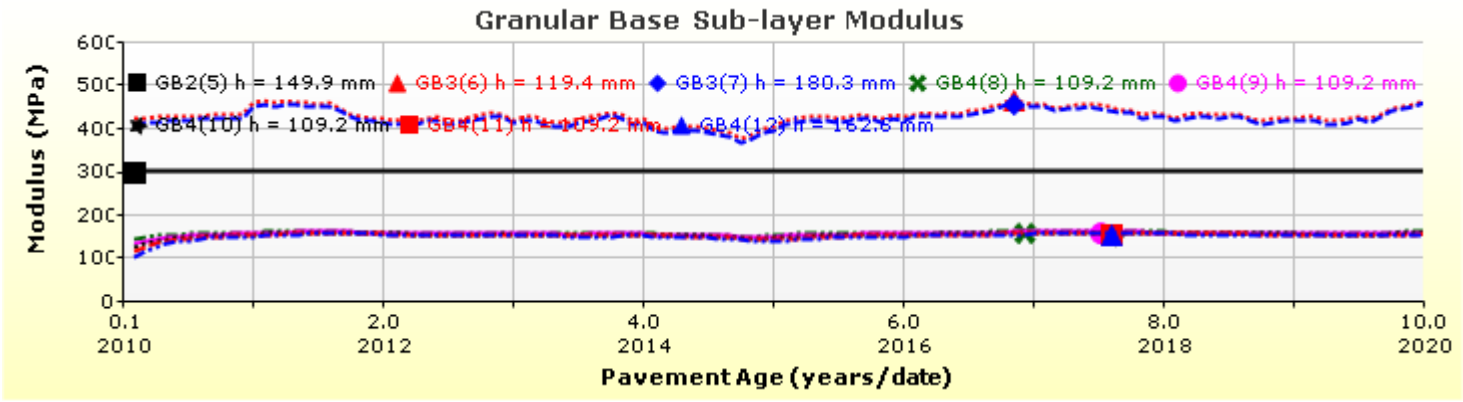

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

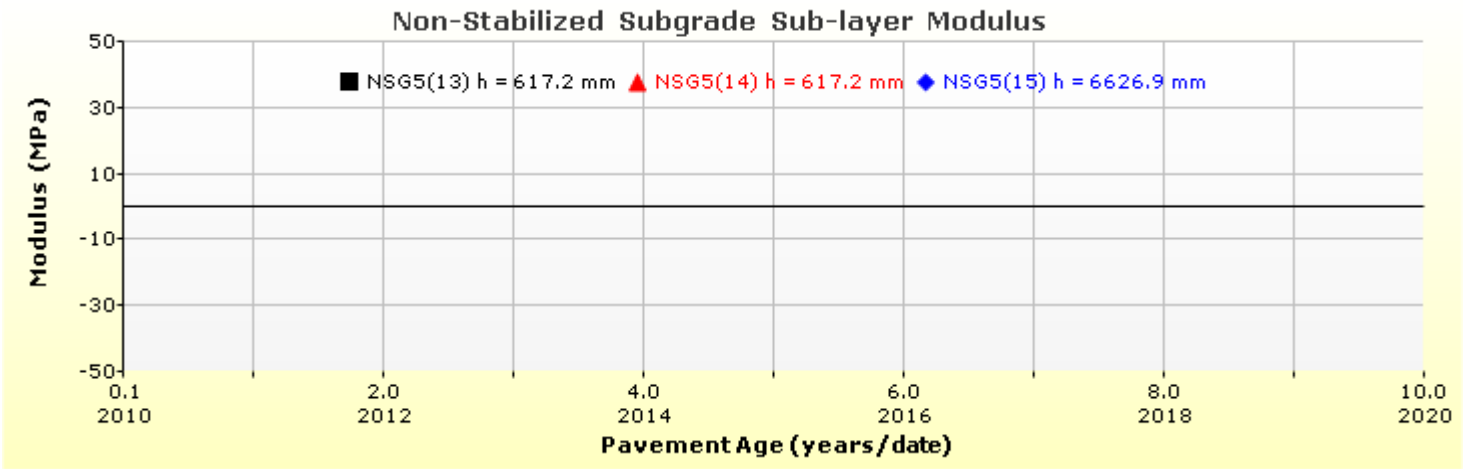

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60C
50C
40C
30C
20C
10C
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRS_Temp

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRS_Temp.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -30.05, -51.17

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

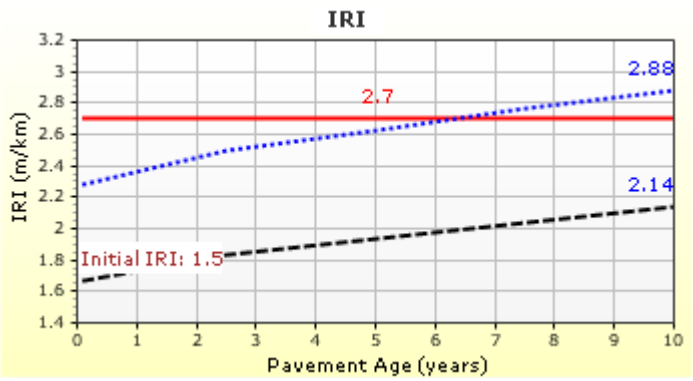
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

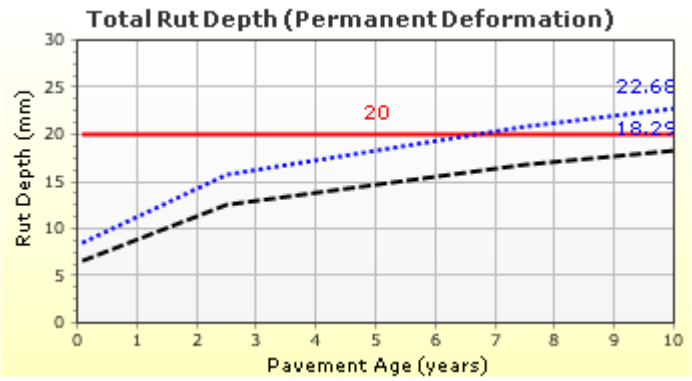
Design Outputs

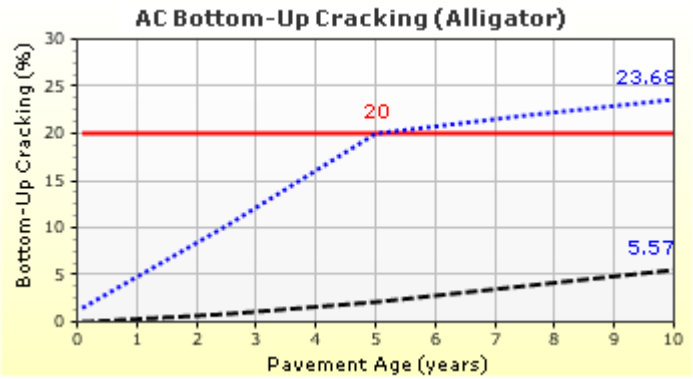
Distress Prediction Summary

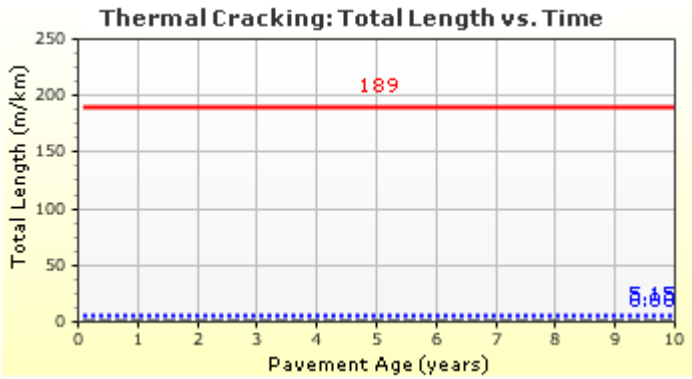
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.88	90.00	83.50	Fail
Permanent deformation - total pavement (mm)	20.00	22.69	90.00	68.96	Fail
AC bottom-up fatigue cracking (percent)	20.00	23.68	90.00	84.64	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	685.84	90.00	70.17	Fail
Permanent deformation - AC only (mm)	5.00	10.31	50.00	3.76	Fail

Distress Charts







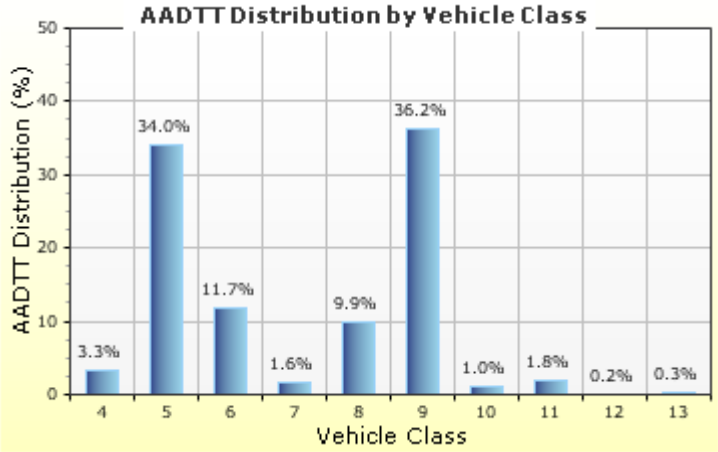


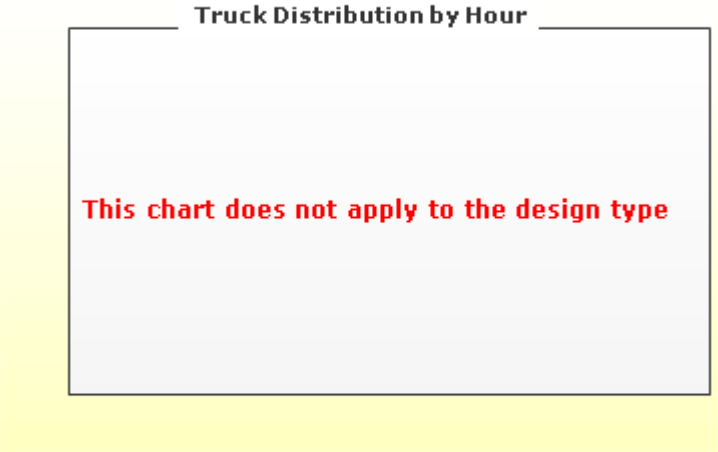


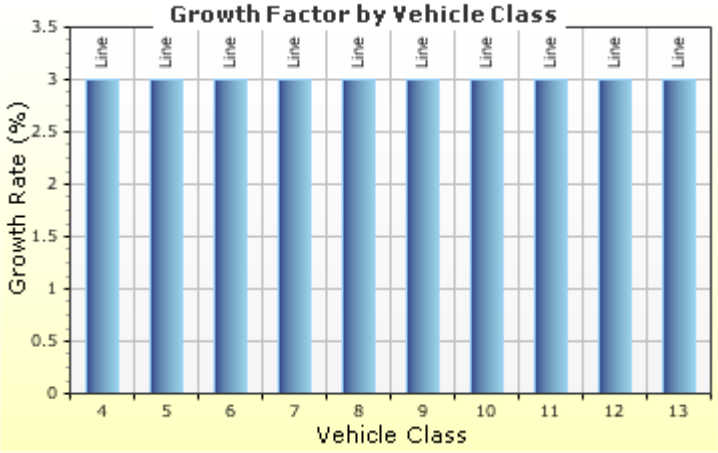
Traffic Inputs

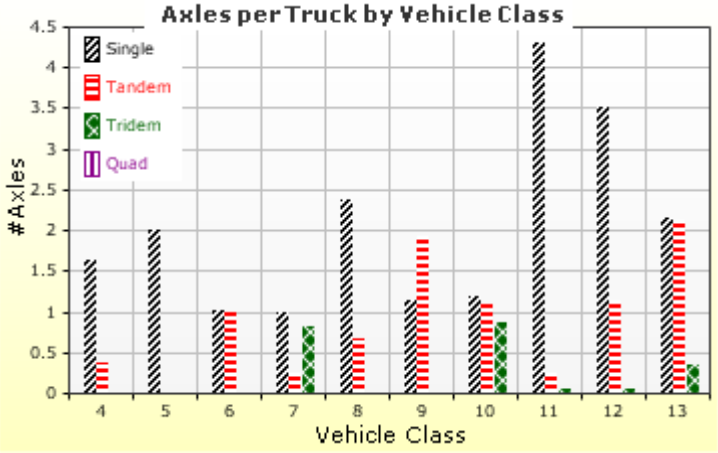
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

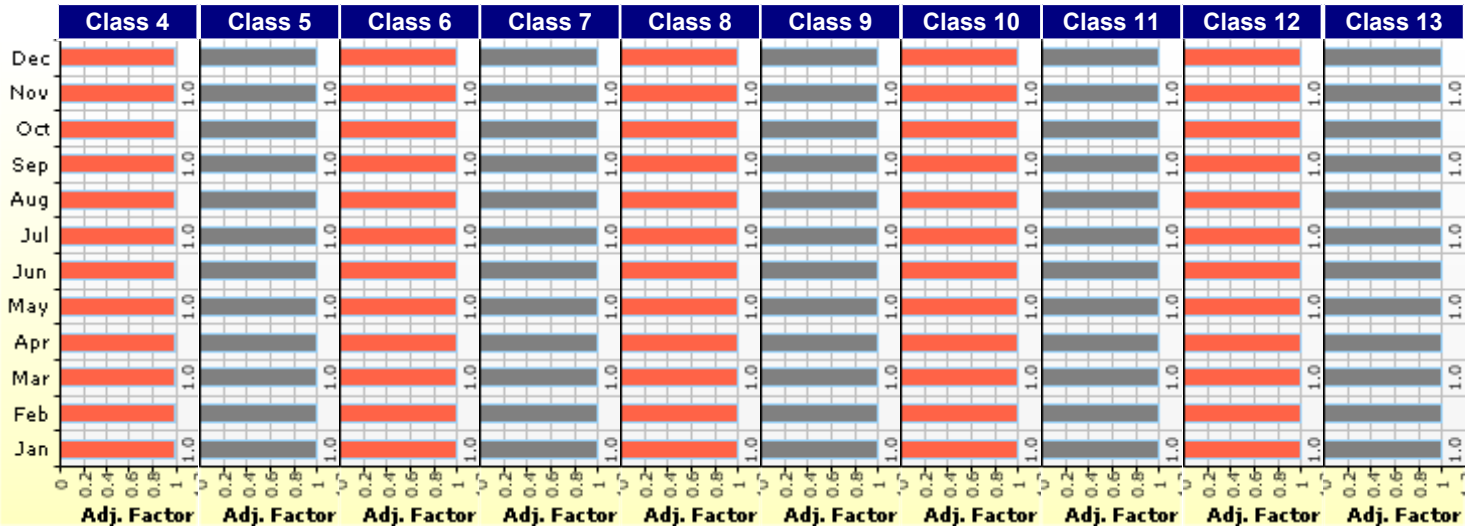








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

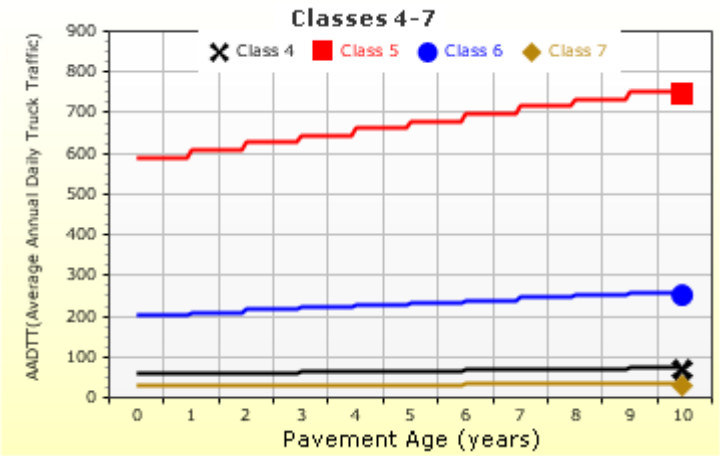
Wheelbase does not apply

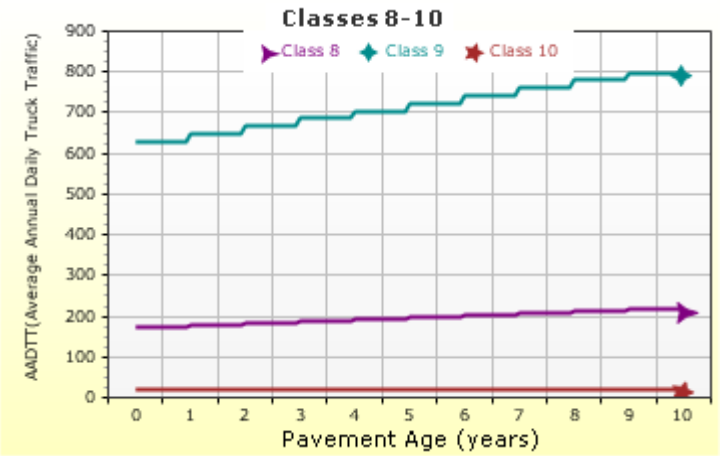
Number of Axles per Truck

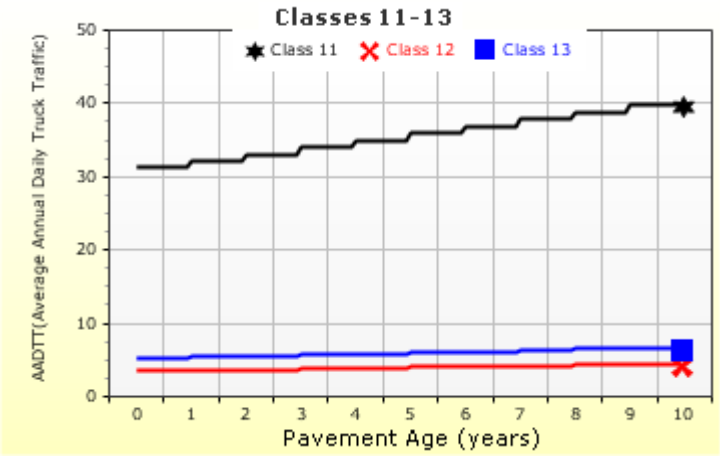
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

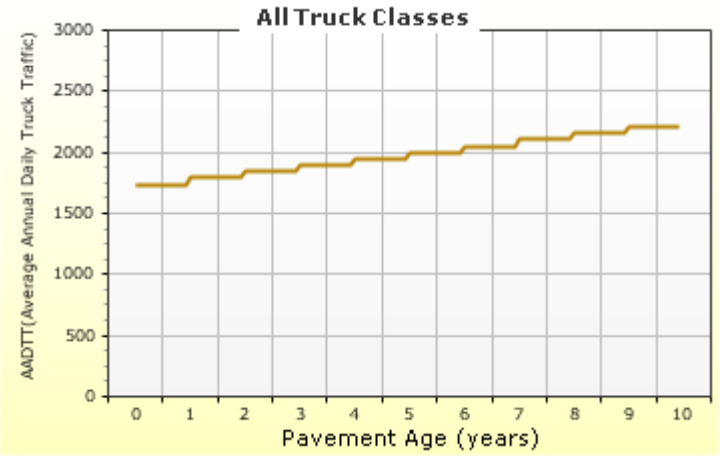
AADTT (Average Annual Daily Truck Traffic) Growth

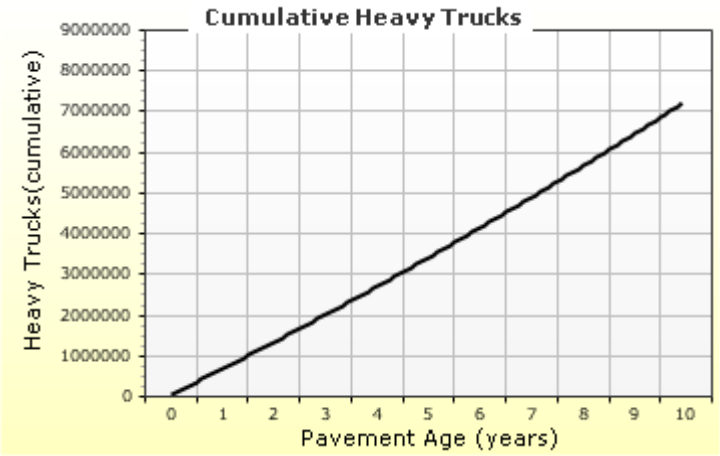
*** Traffic cap is not enforced**







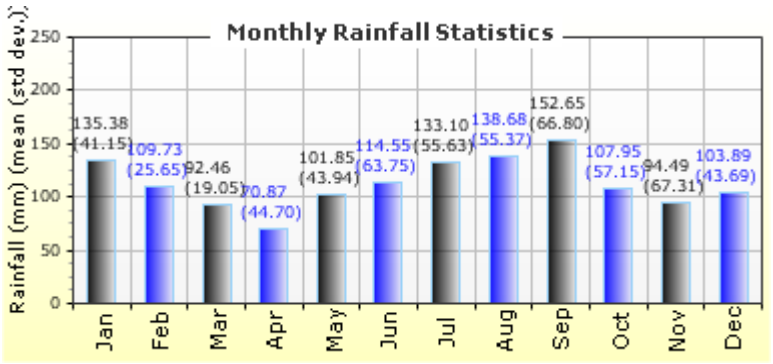




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
PORTO ALEGRE, RS	-30.05000 -51.17000 47

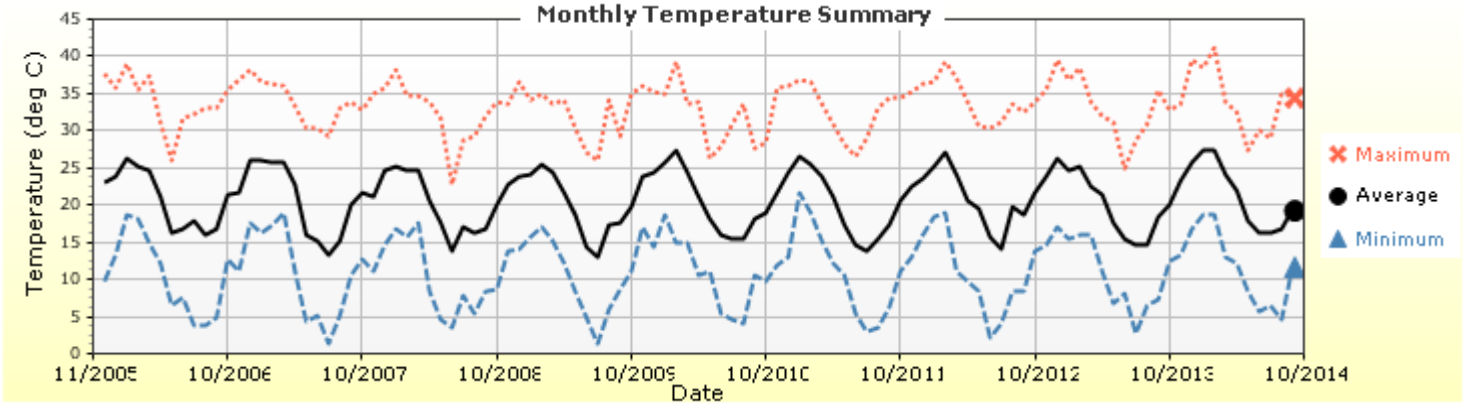


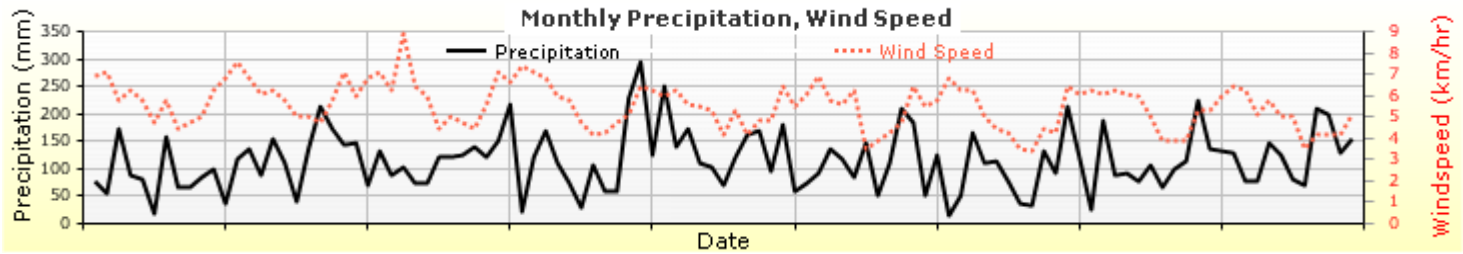
Annual Statistics:

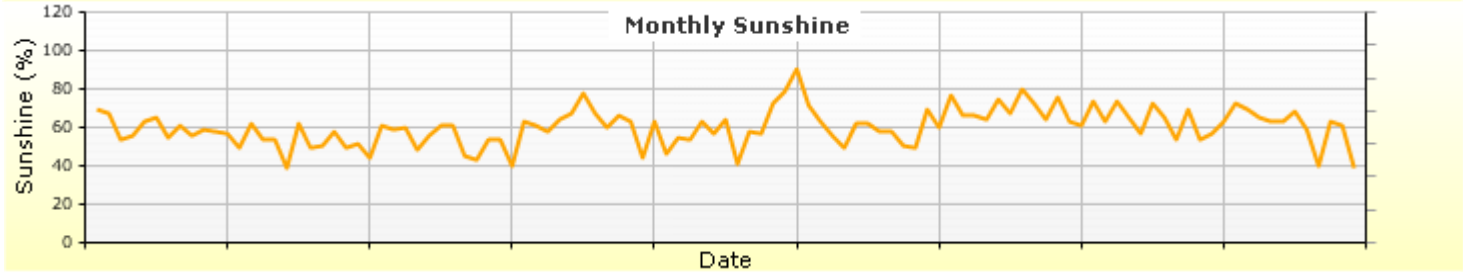
Mean annual air temperature (ºC)	20.73
Mean annual precipitation (mm)	1352.30
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

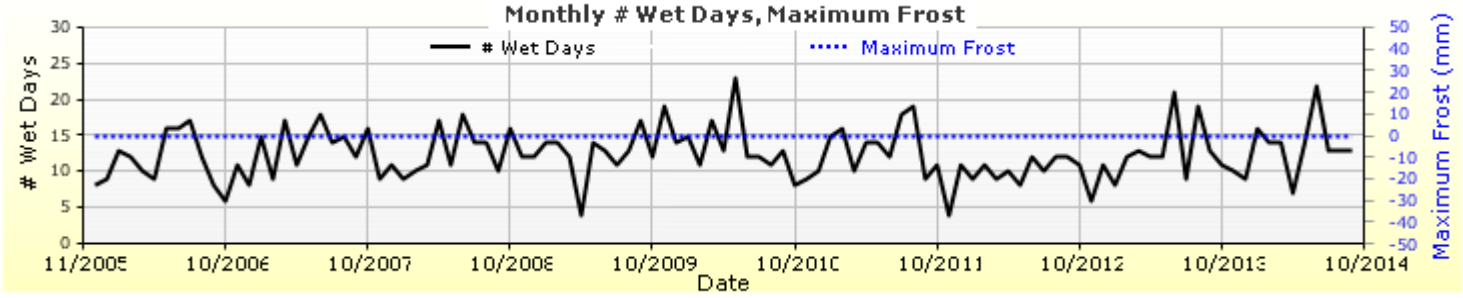
Water table depth (m)	3.05

Monthly Climate Summary:

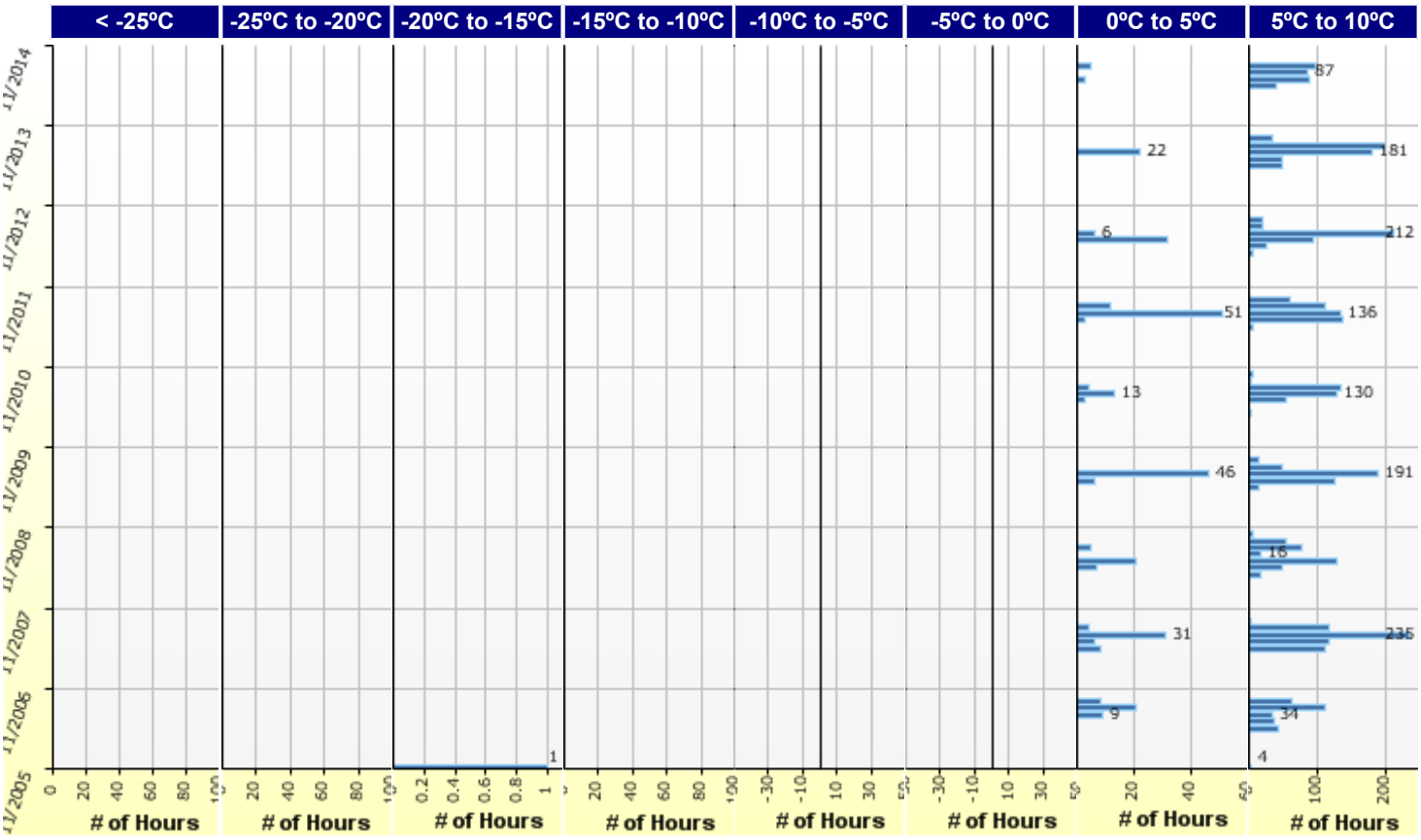


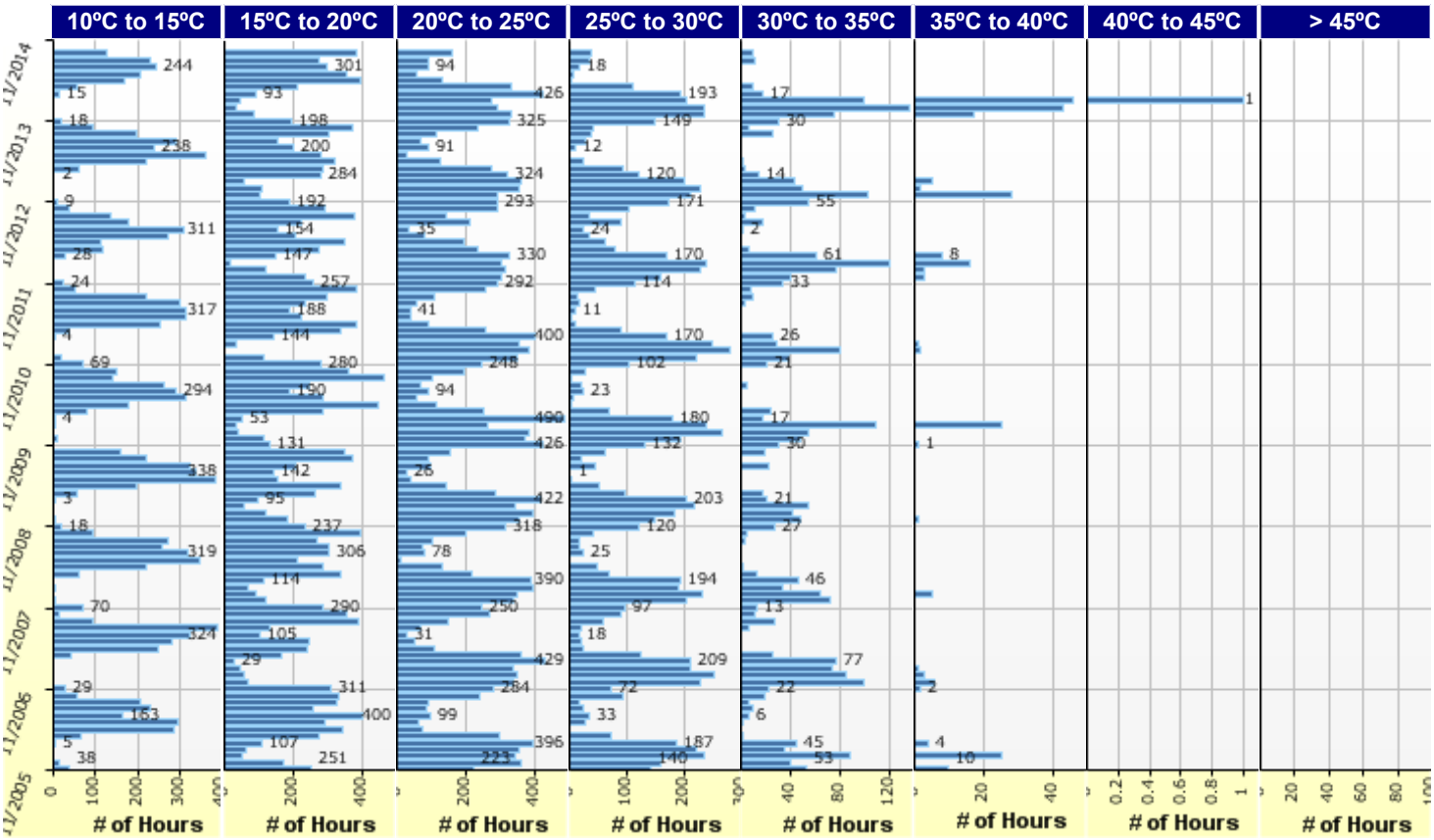






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

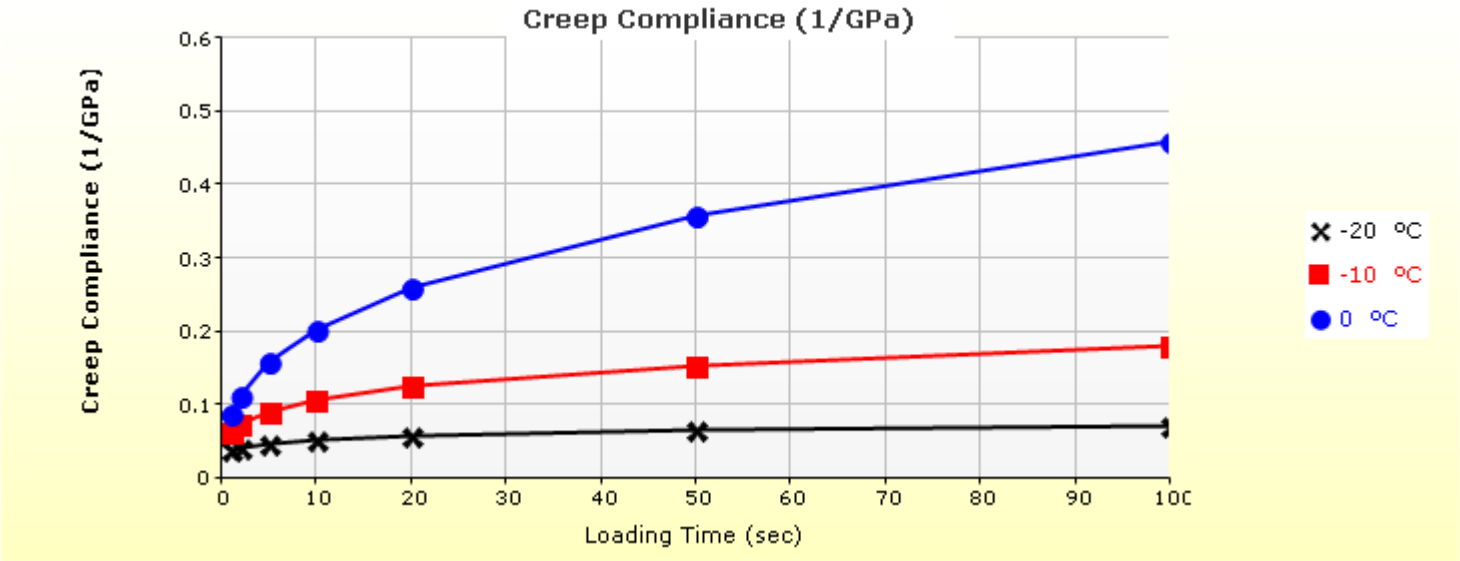
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

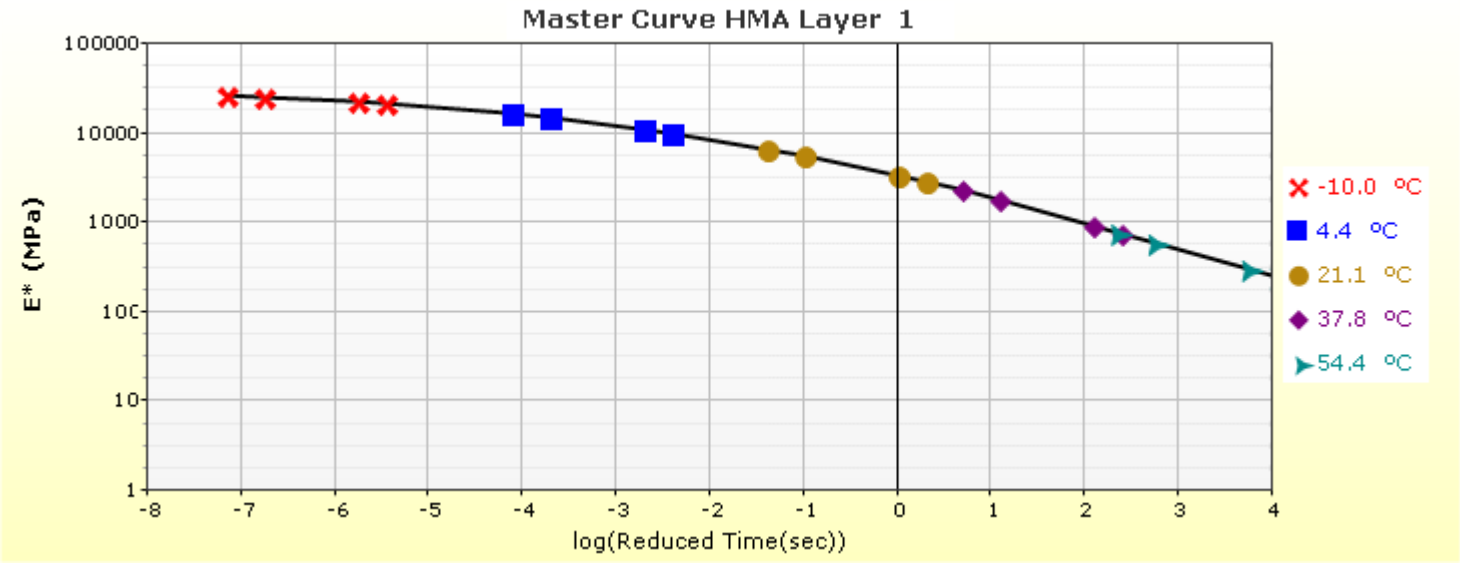
Indirect tensile strength at -10 ºC (MPa)	2.69

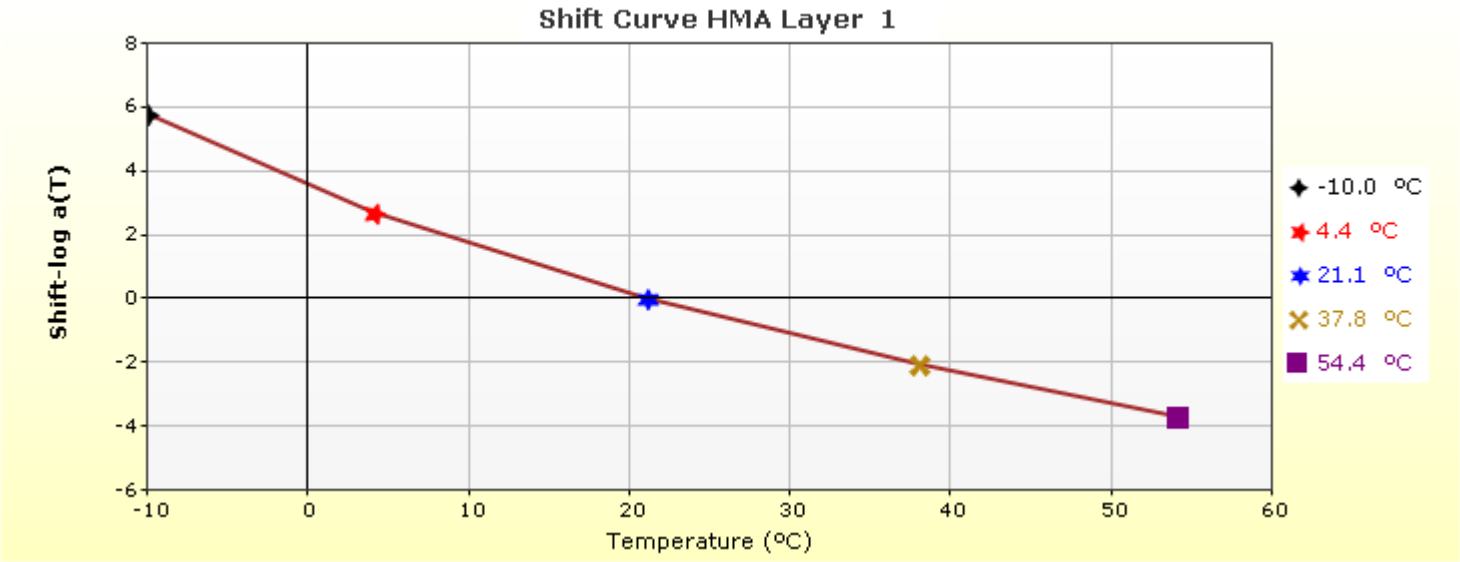
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

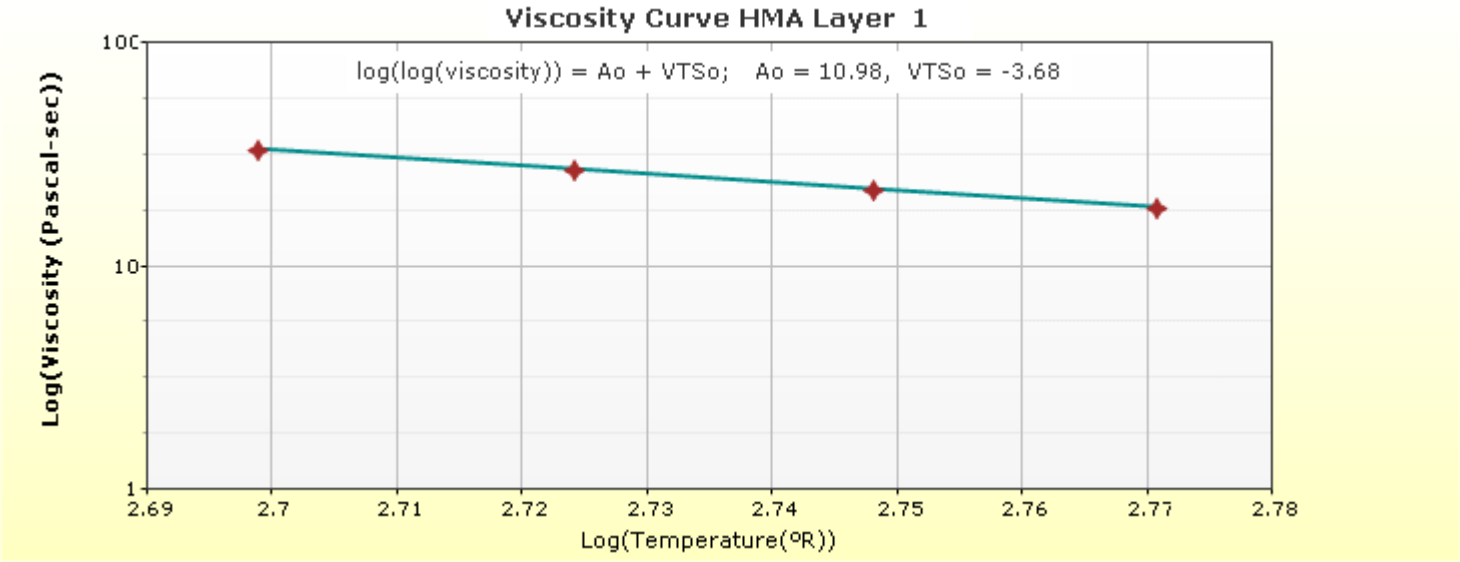
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



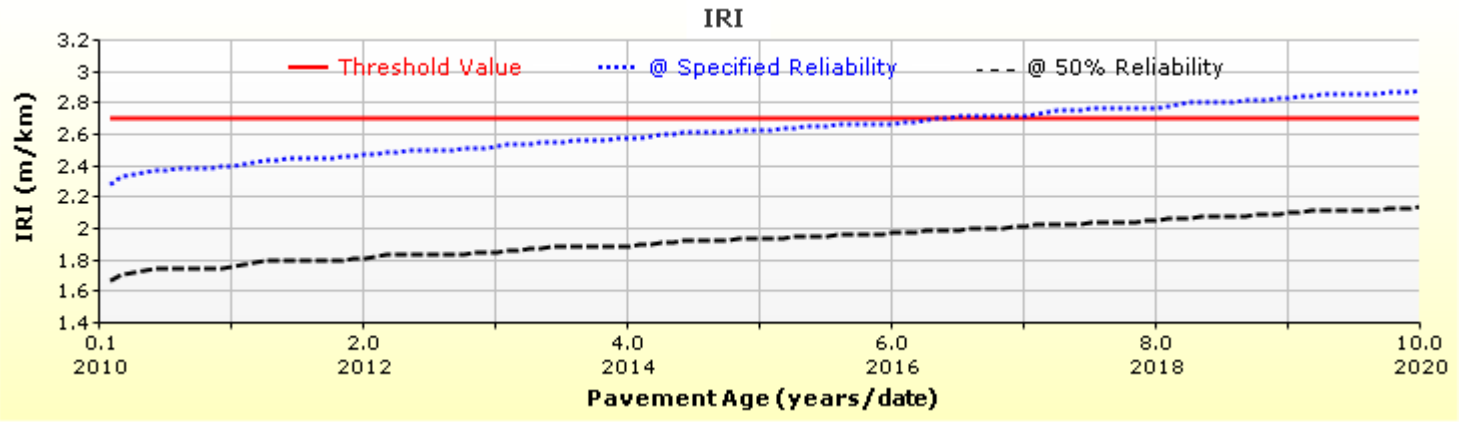
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

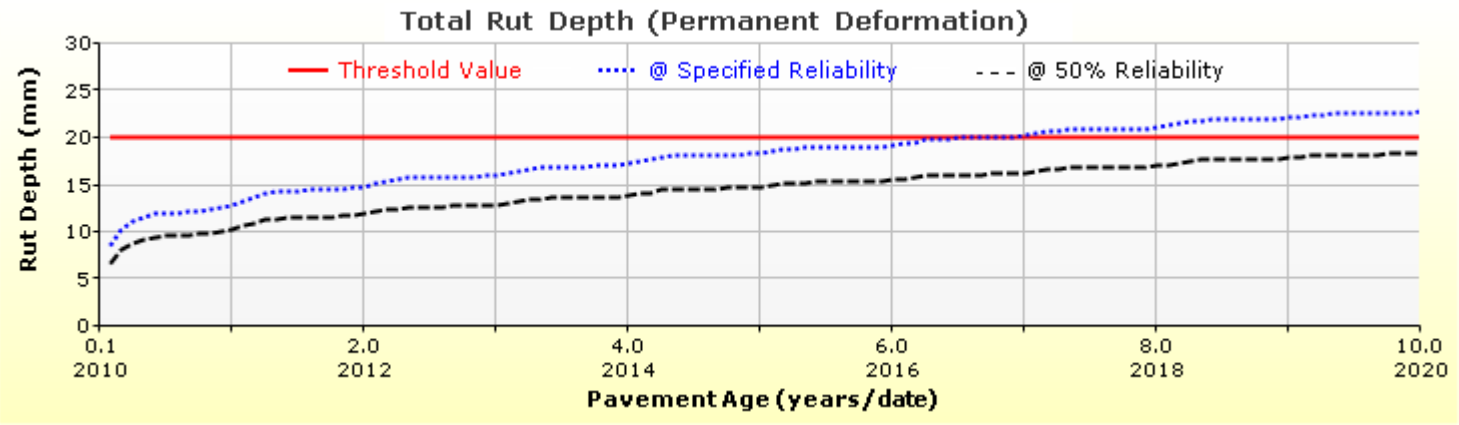


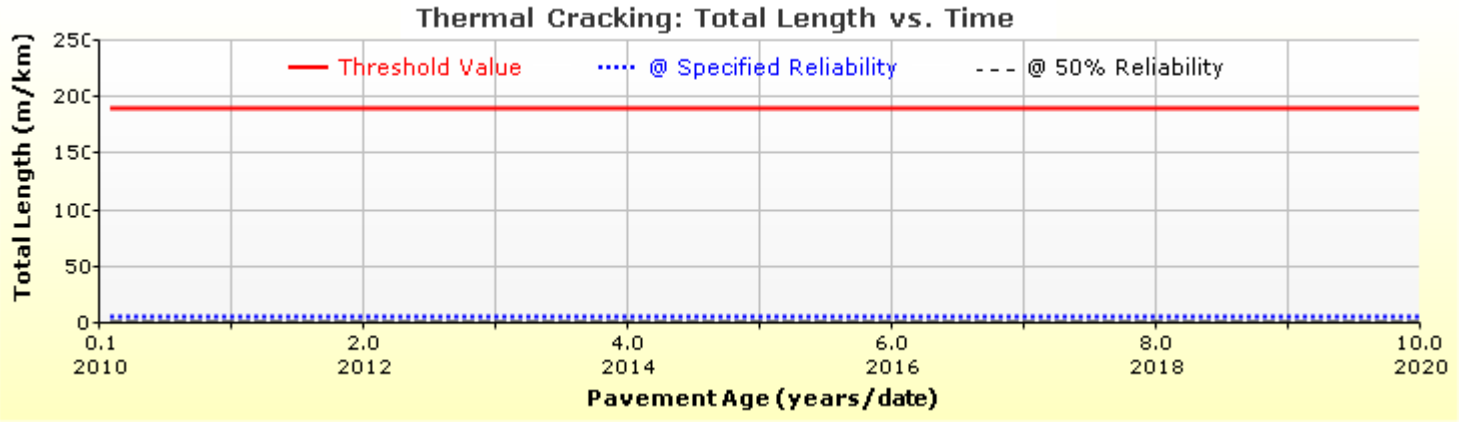


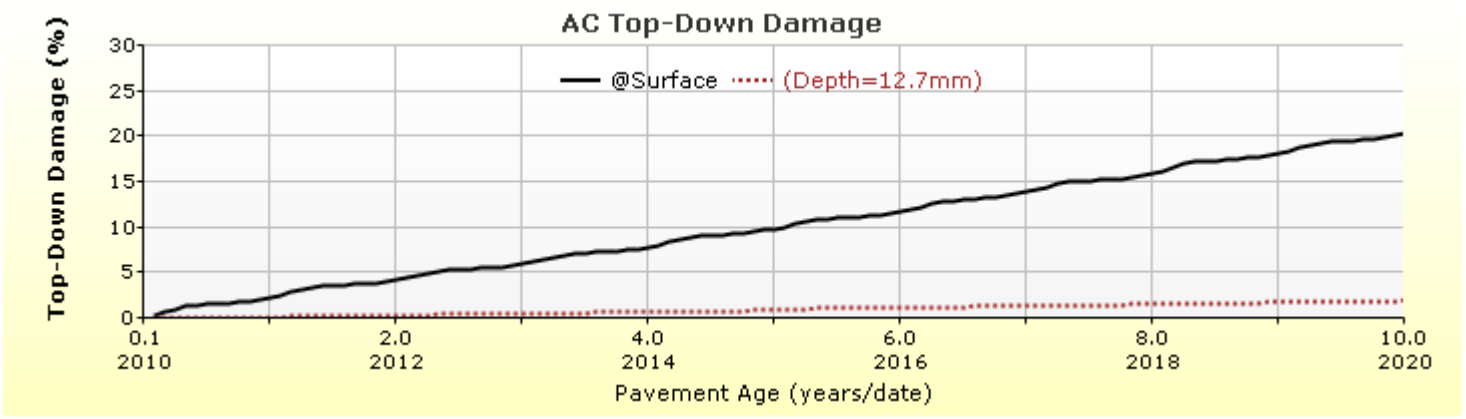


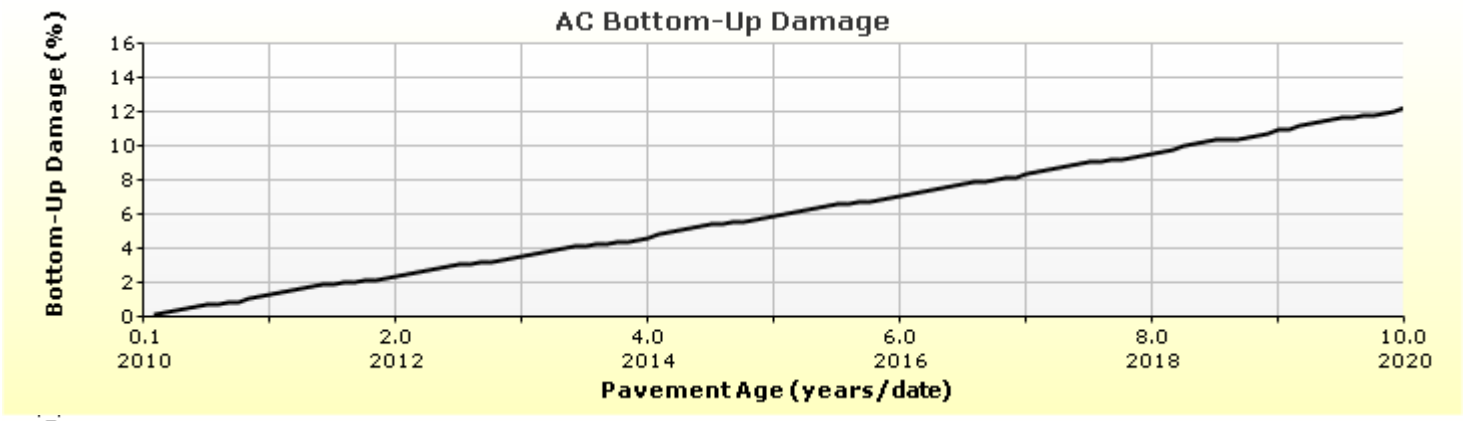
Analysis Output Charts

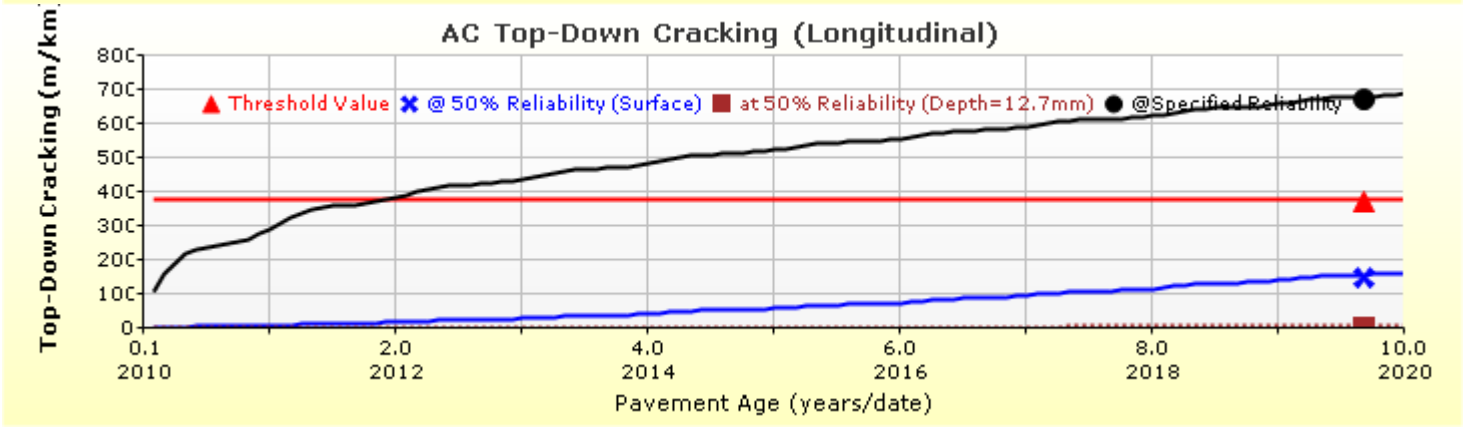


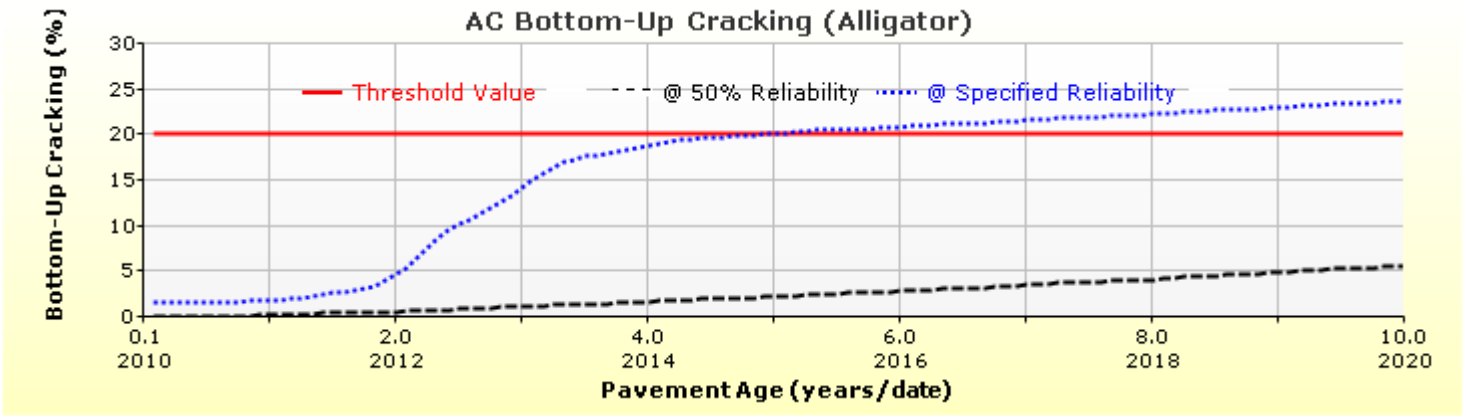


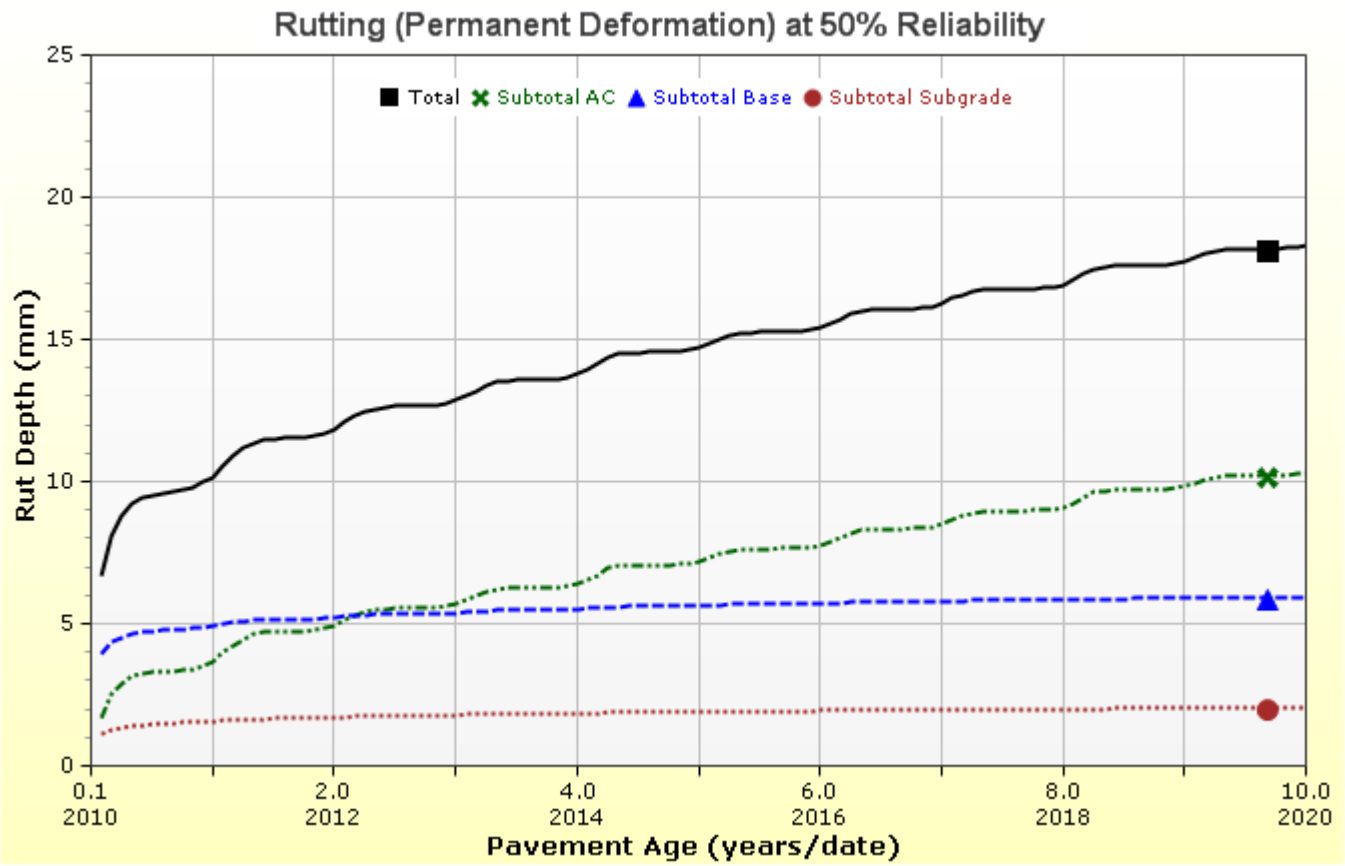


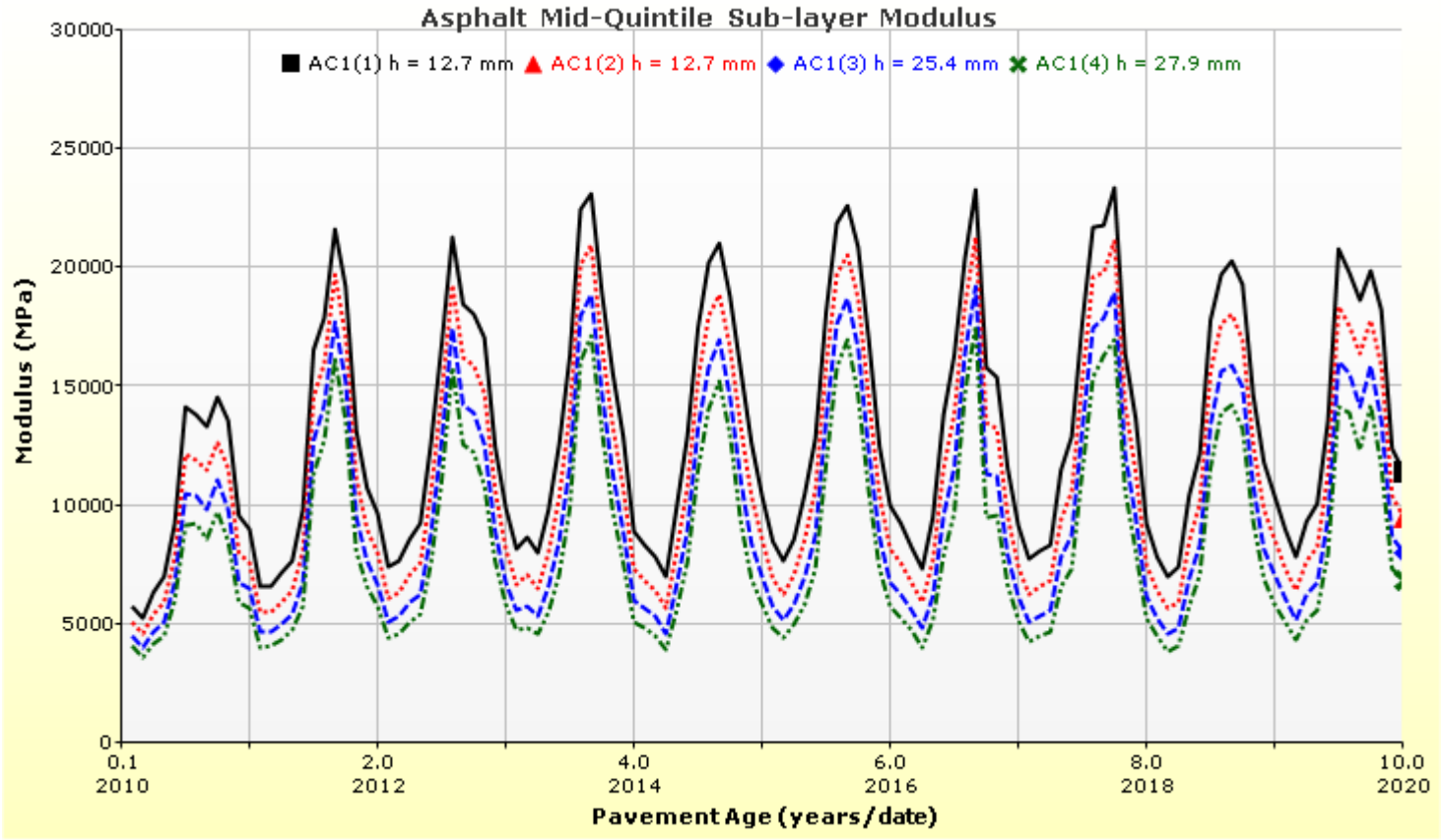

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

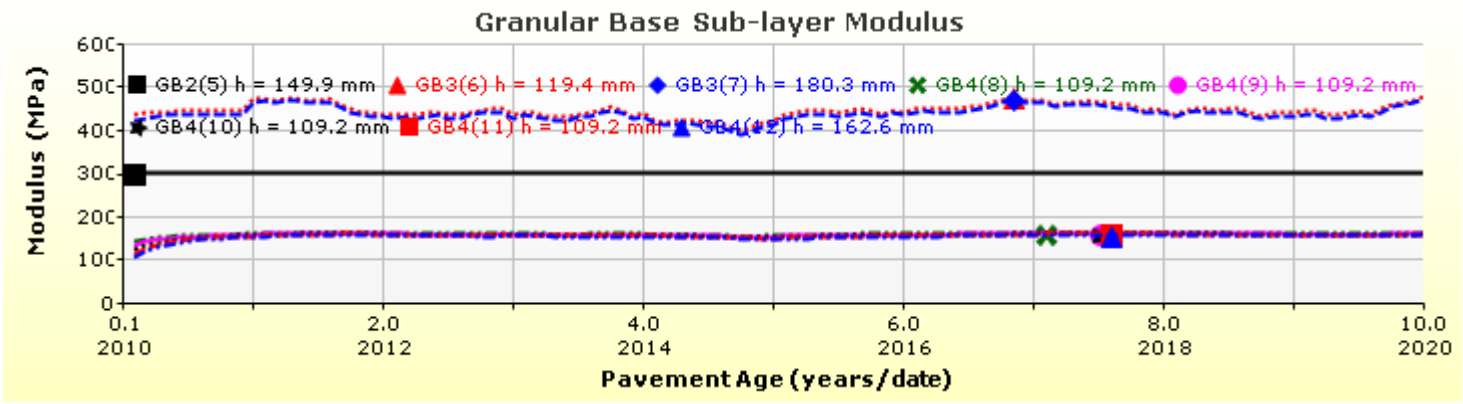

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

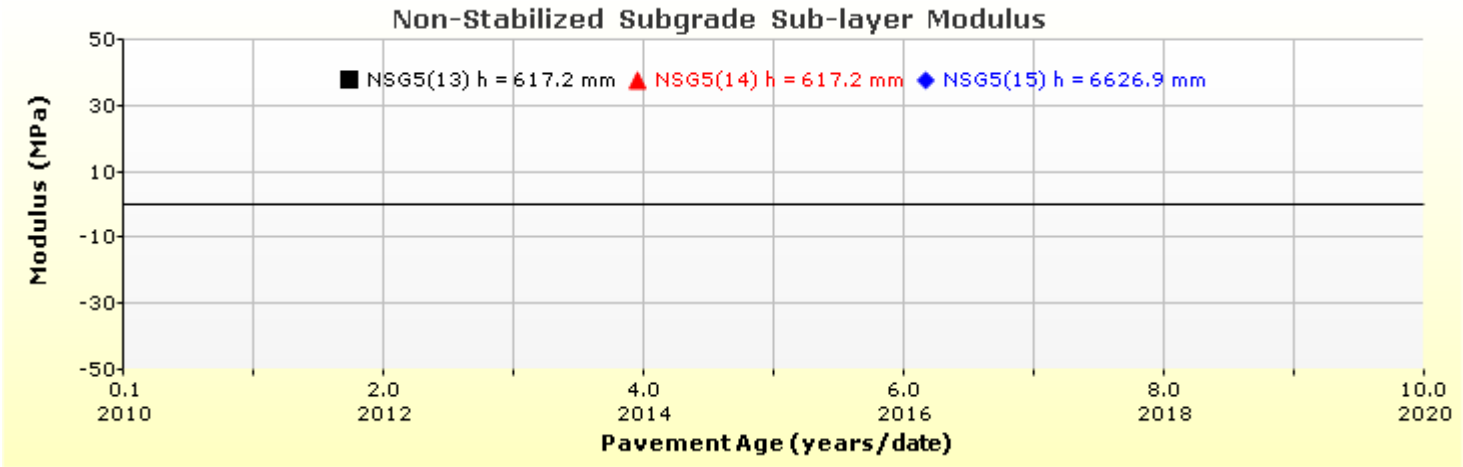

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10C
20C
30C
40C
50C
60C
70C
80C
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60C
50C
40C
30C
20C
10C
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRS_Temp5

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRS_Temp5.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -30.05, -51.17

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

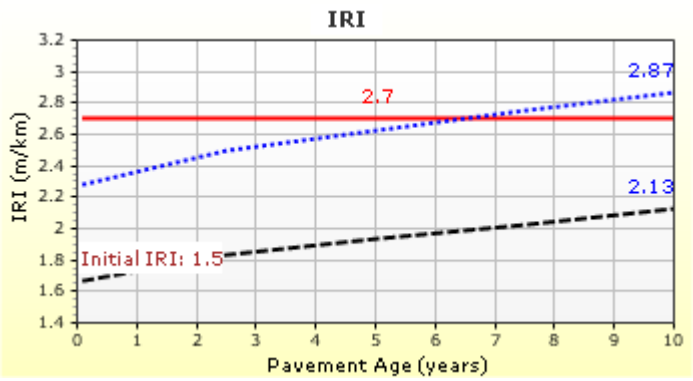
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

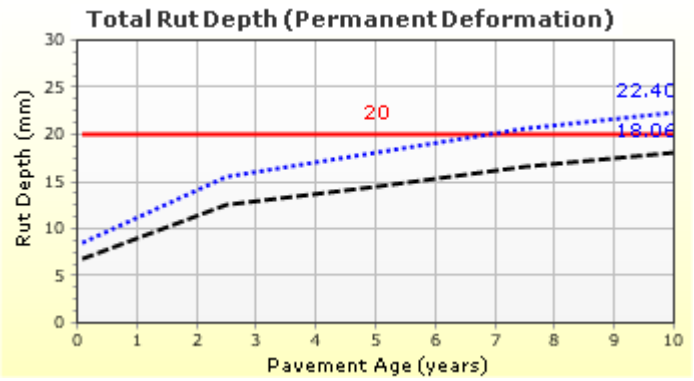
Design Outputs

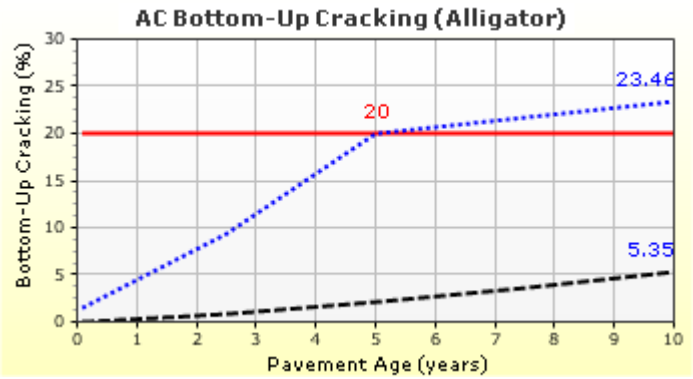
Distress Prediction Summary

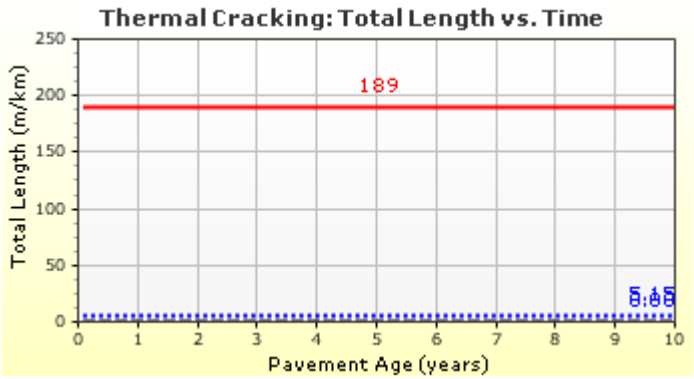
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.87	90.00	83.87	Fail
Permanent deformation - total pavement (mm)	20.00	22.41	90.00	71.51	Fail
AC bottom-up fatigue cracking (percent)	20.00	23.46	90.00	85.01	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	676.47	90.00	70.85	Fail
Permanent deformation - AC only (mm)	5.00	10.07	50.00	4.17	Fail

Distress Charts







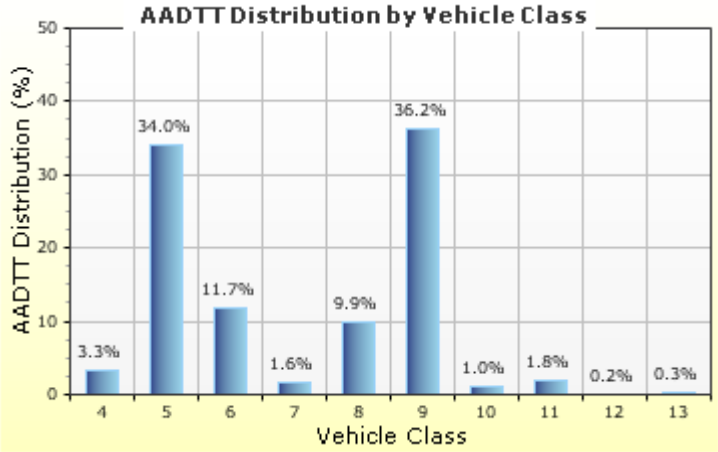


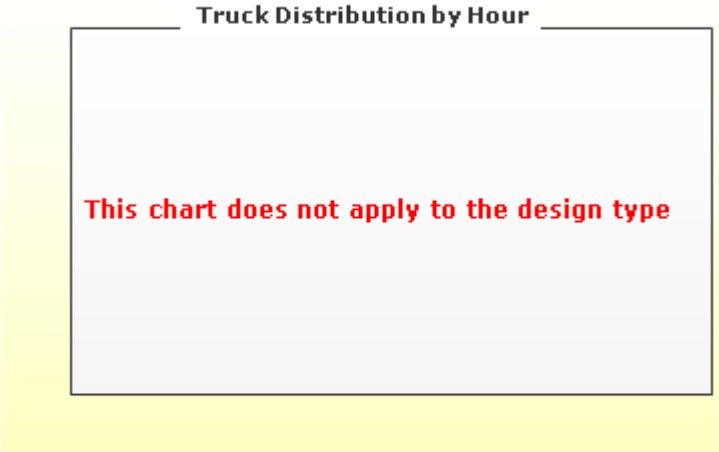


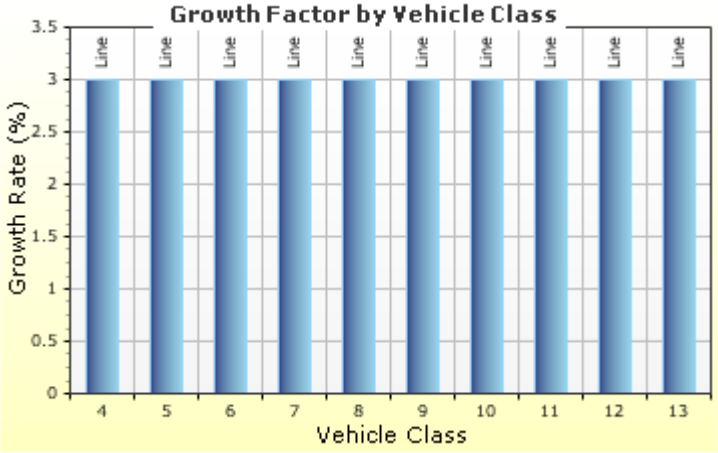
Traffic Inputs

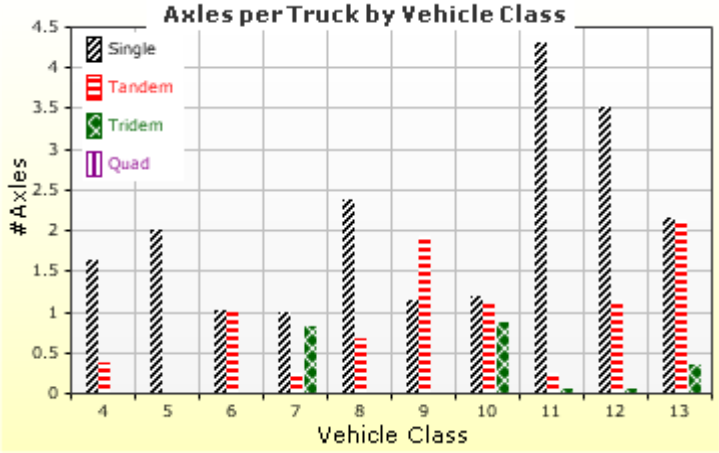
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

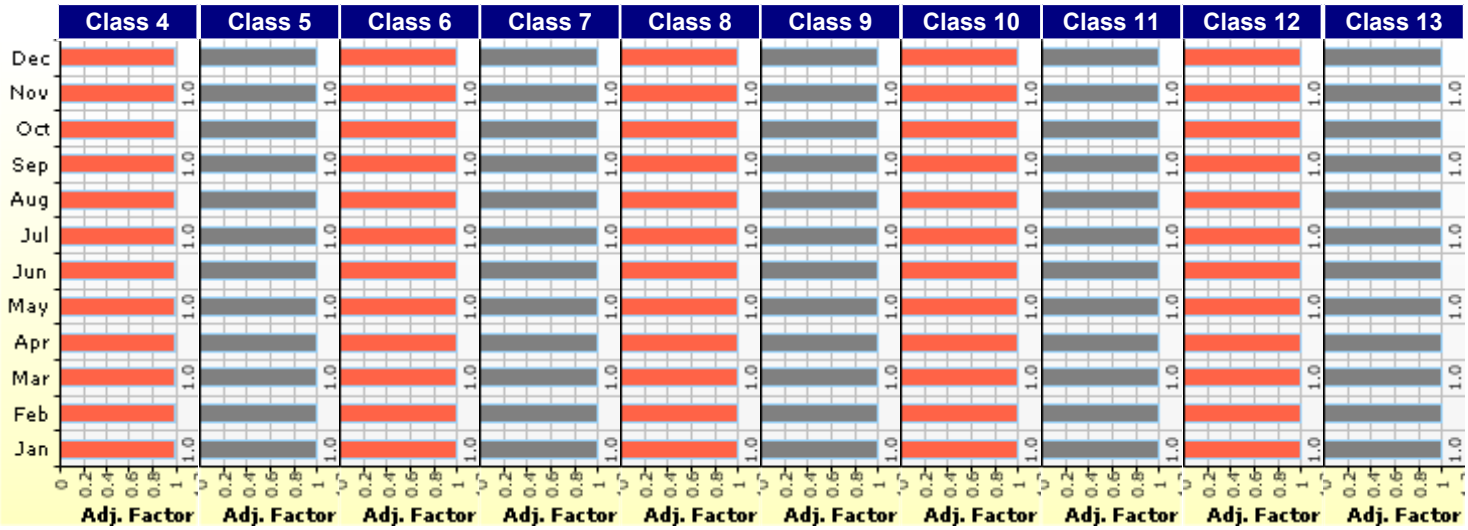








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

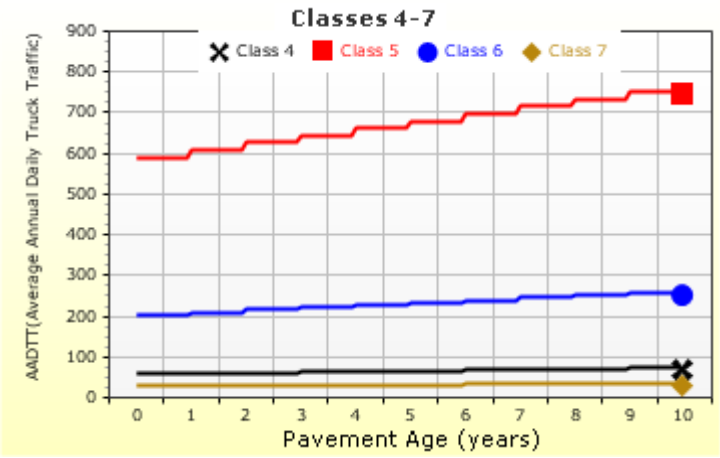
Wheelbase does not apply

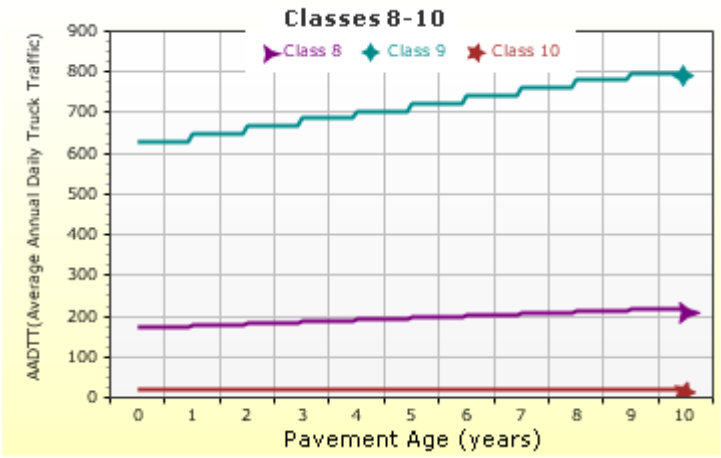
Number of Axles per Truck

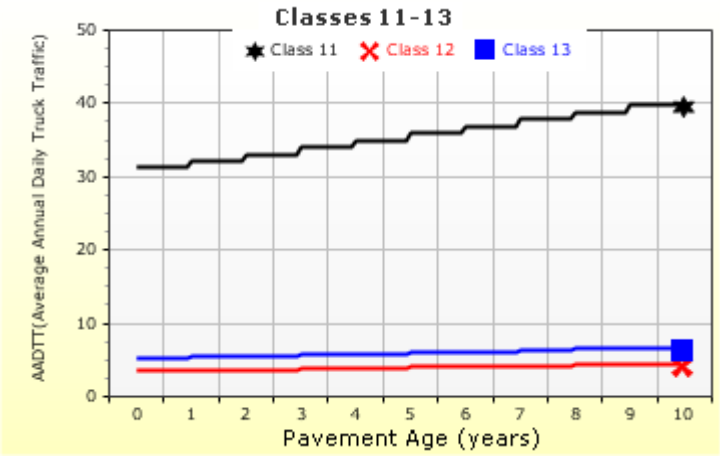
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

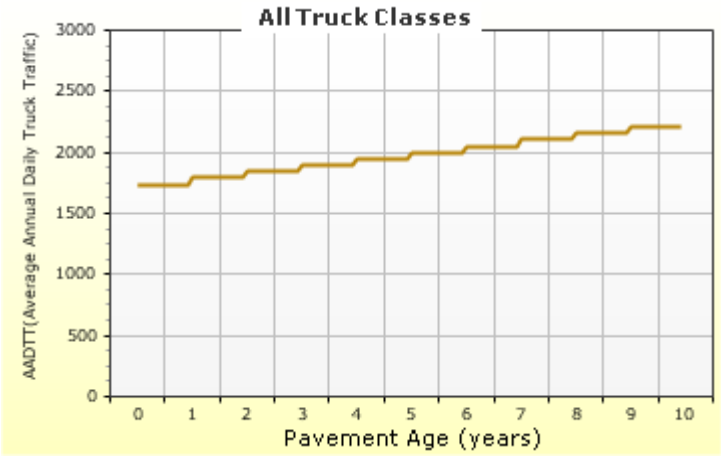
AADTT (Average Annual Daily Truck Traffic) Growth

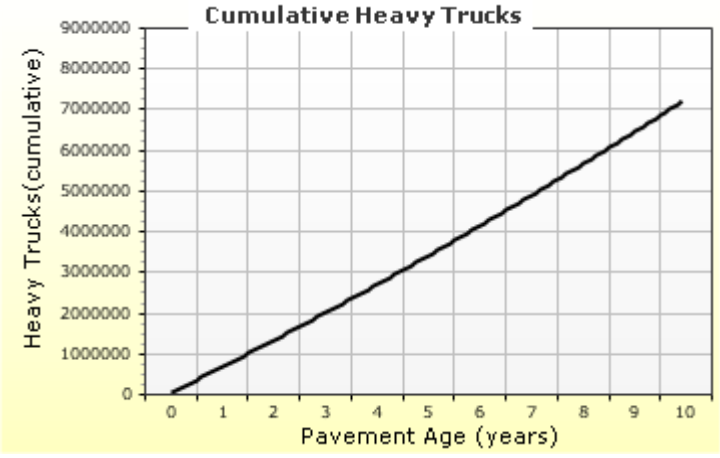
*** Traffic cap is not enforced**







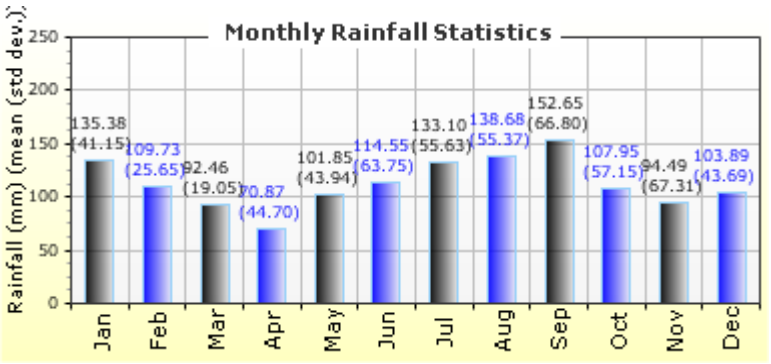




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
PORTO ALEGRE, RS	-30.05000 -51.17000 47

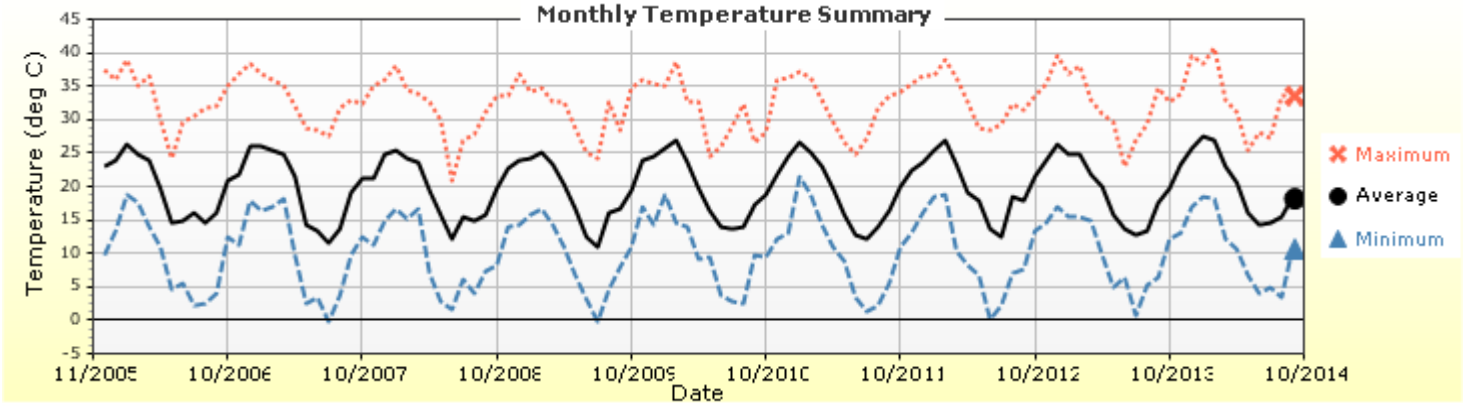


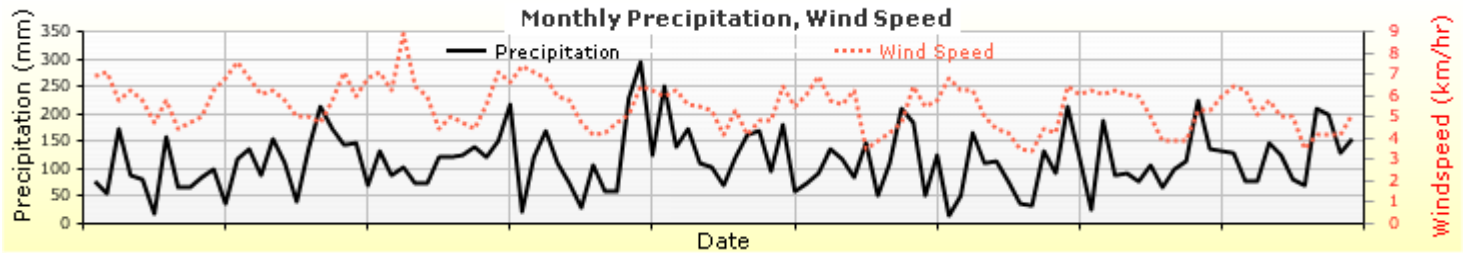
Annual Statistics:

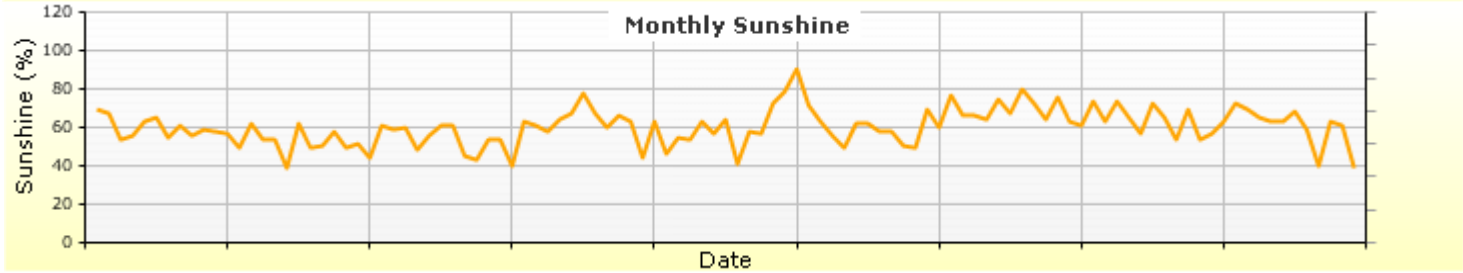
Mean annual air temperature (ºC)	19.74
Mean annual precipitation (mm)	1352.30
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.22

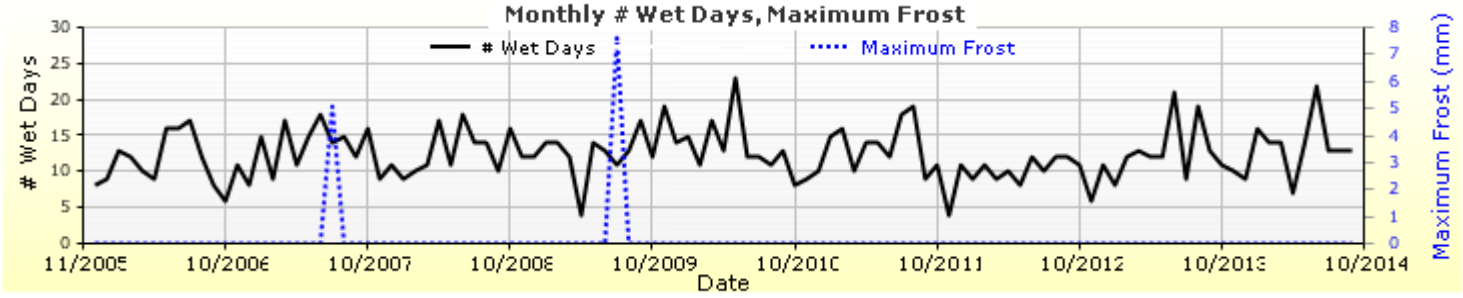
Water table depth (m)	3.05

Monthly Climate Summary:

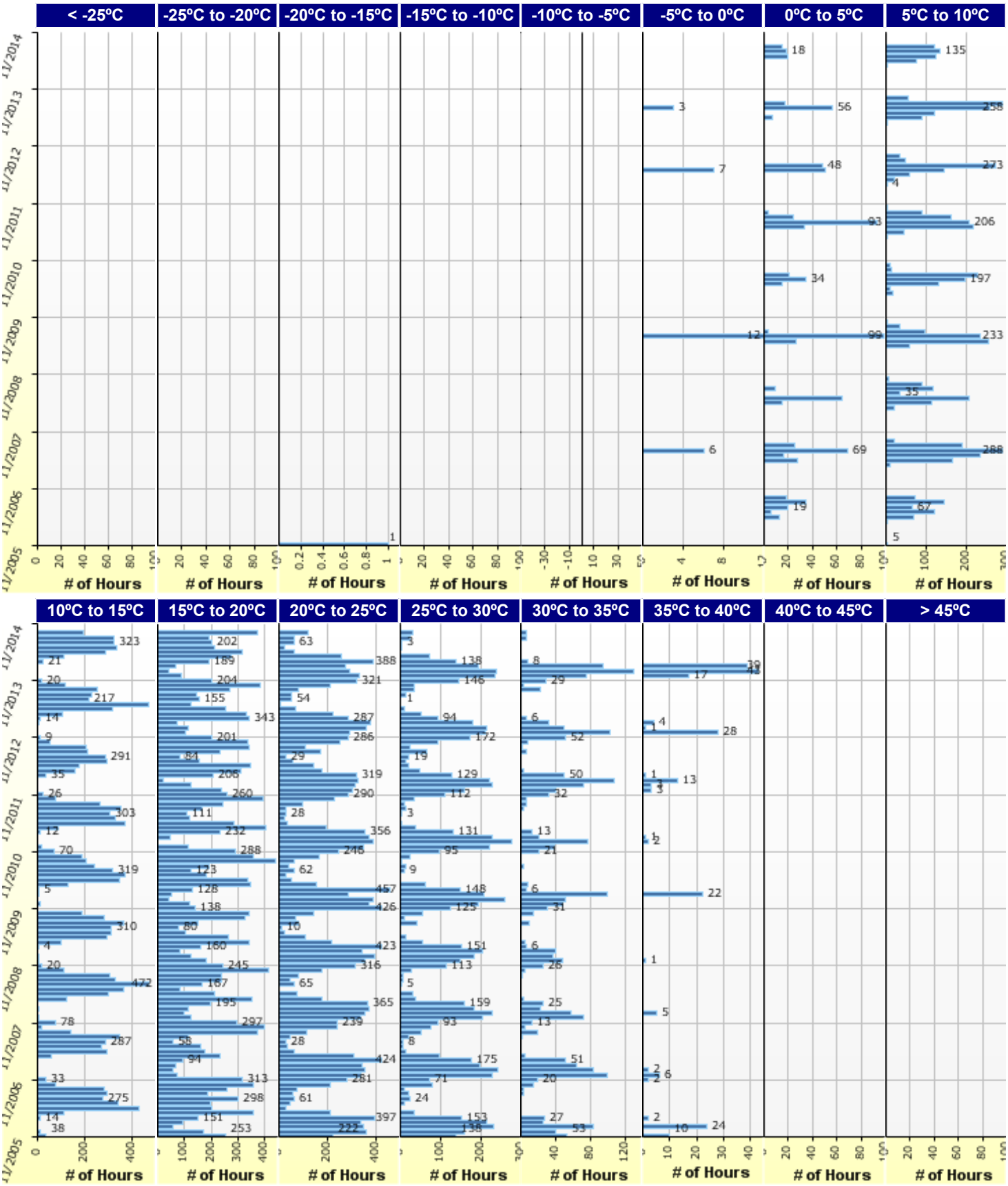








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

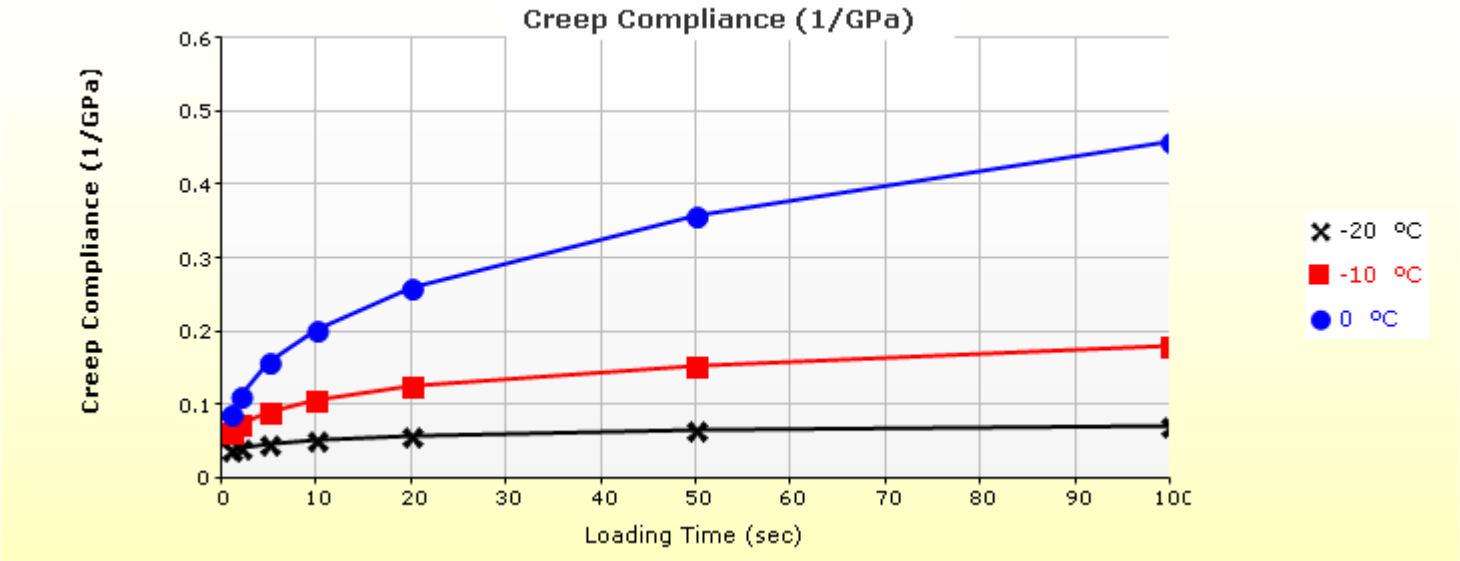
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

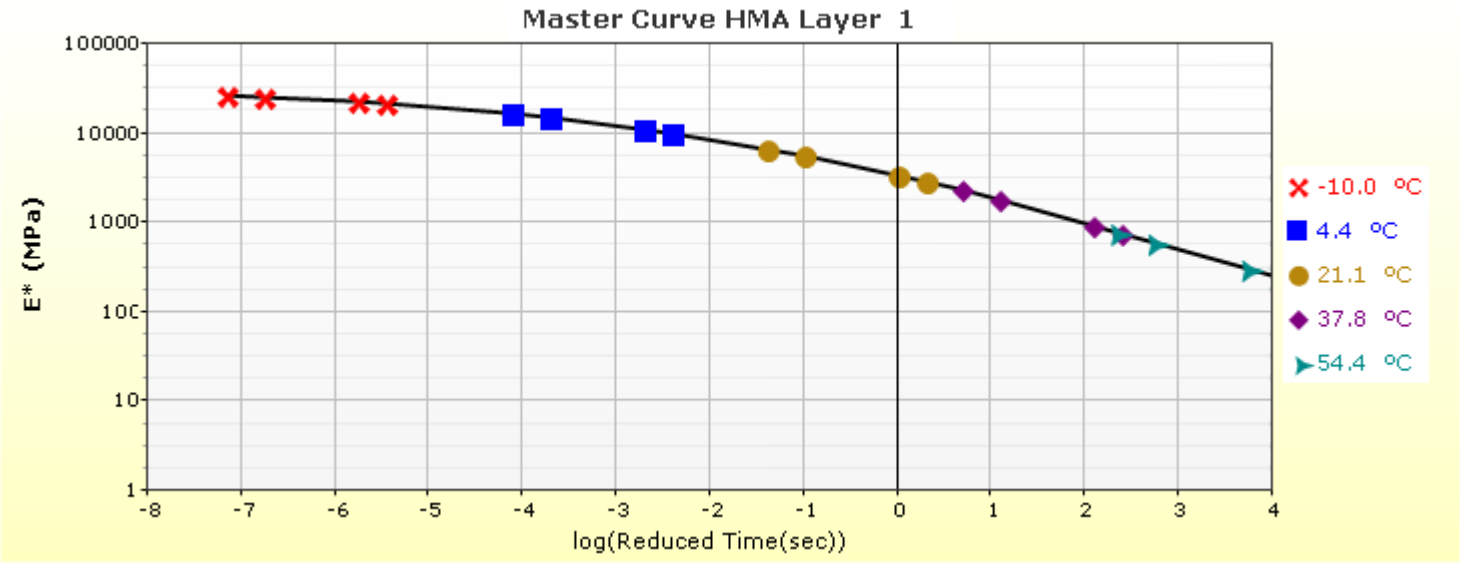
Indirect tensile strength at -10 ºC (MPa)	2.69

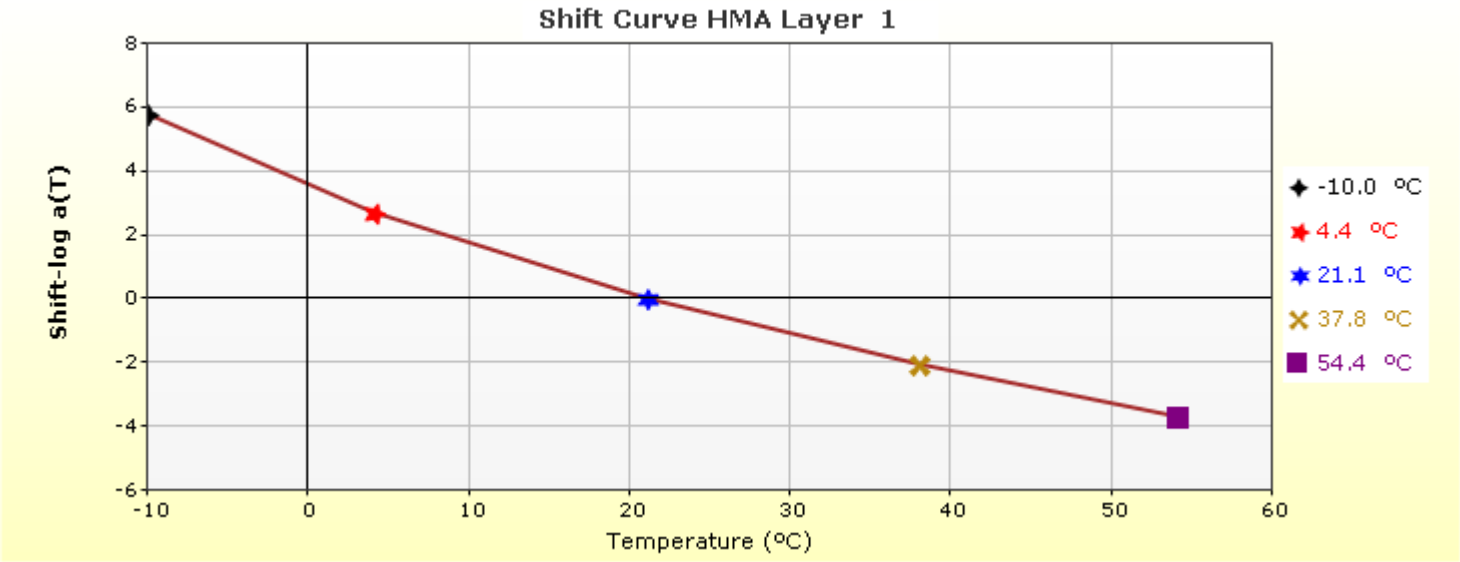
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

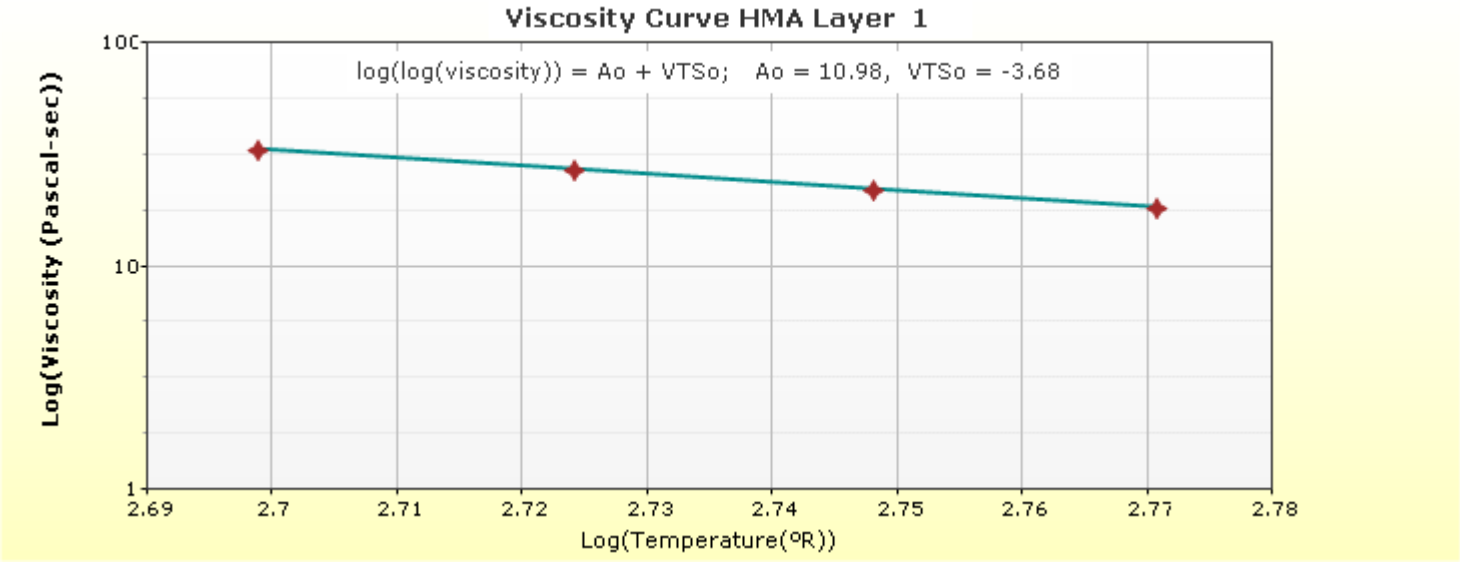
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



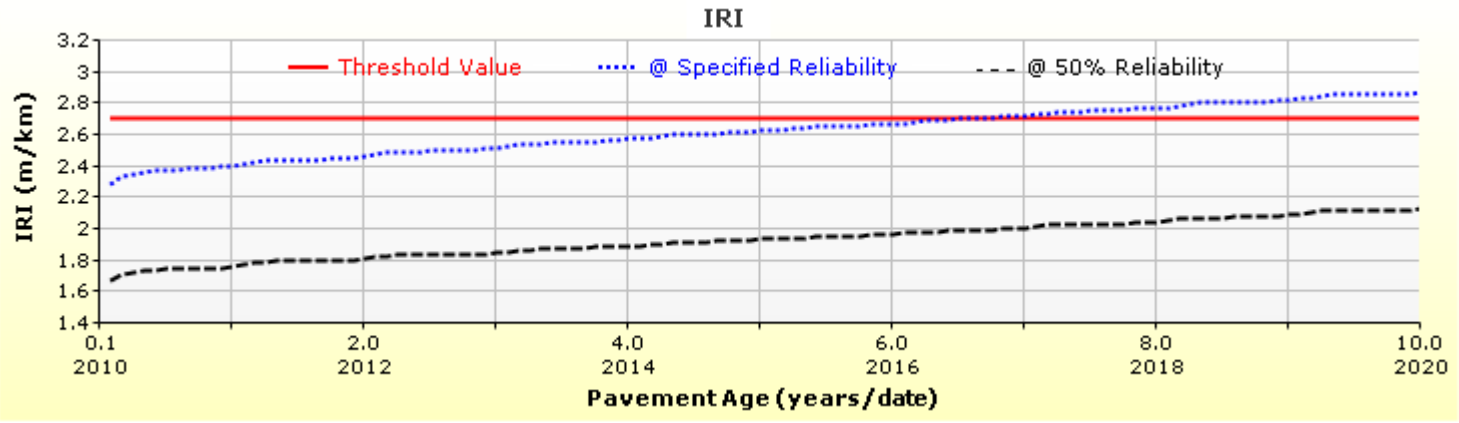
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

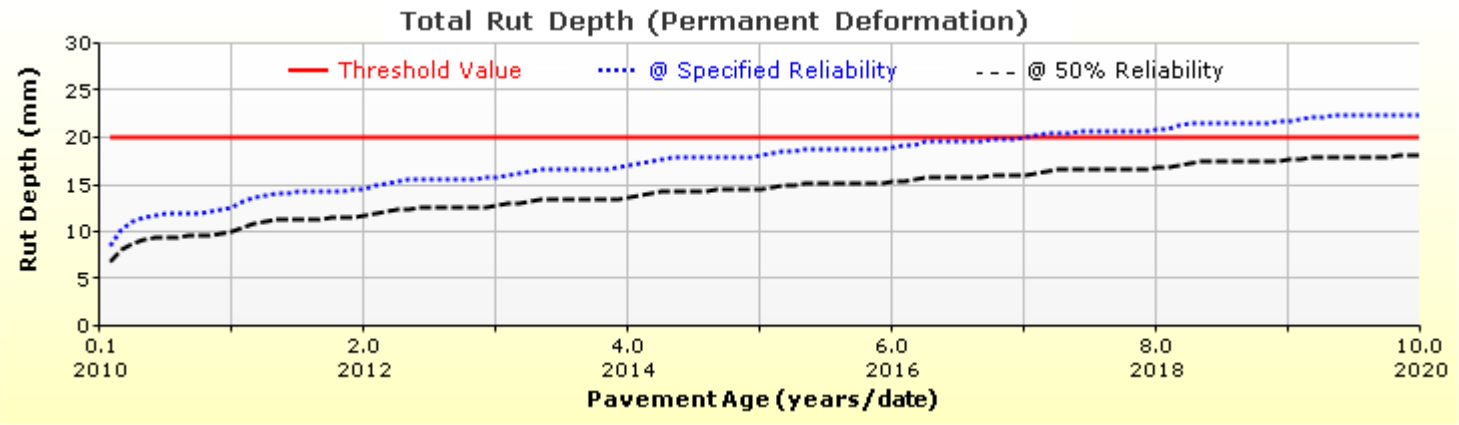


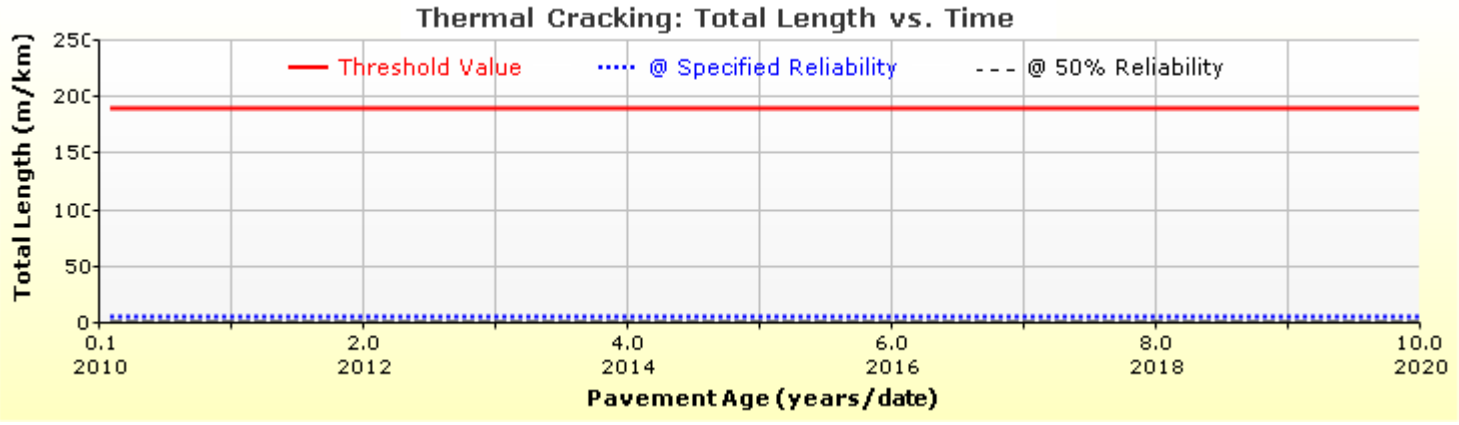


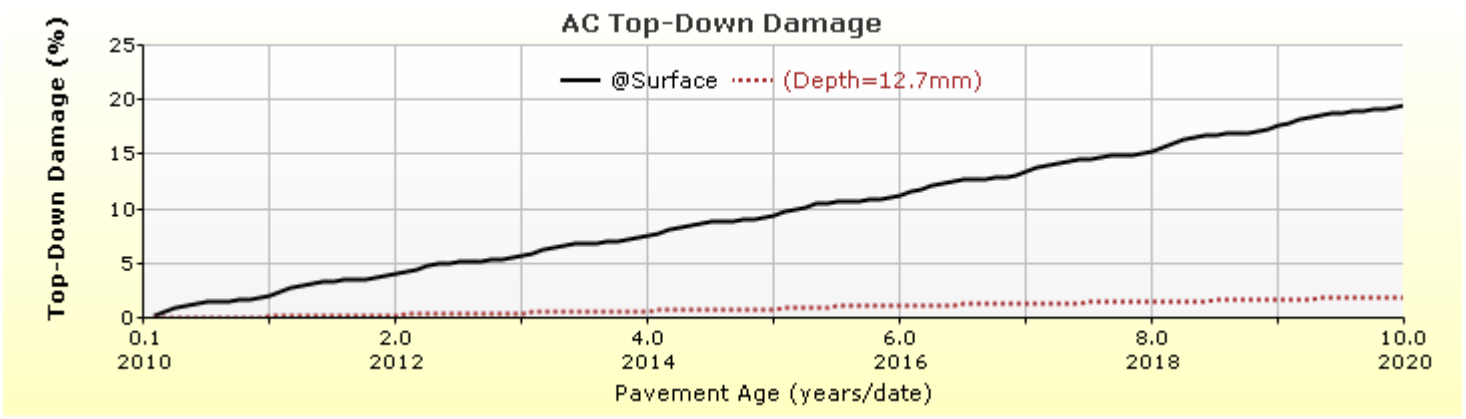


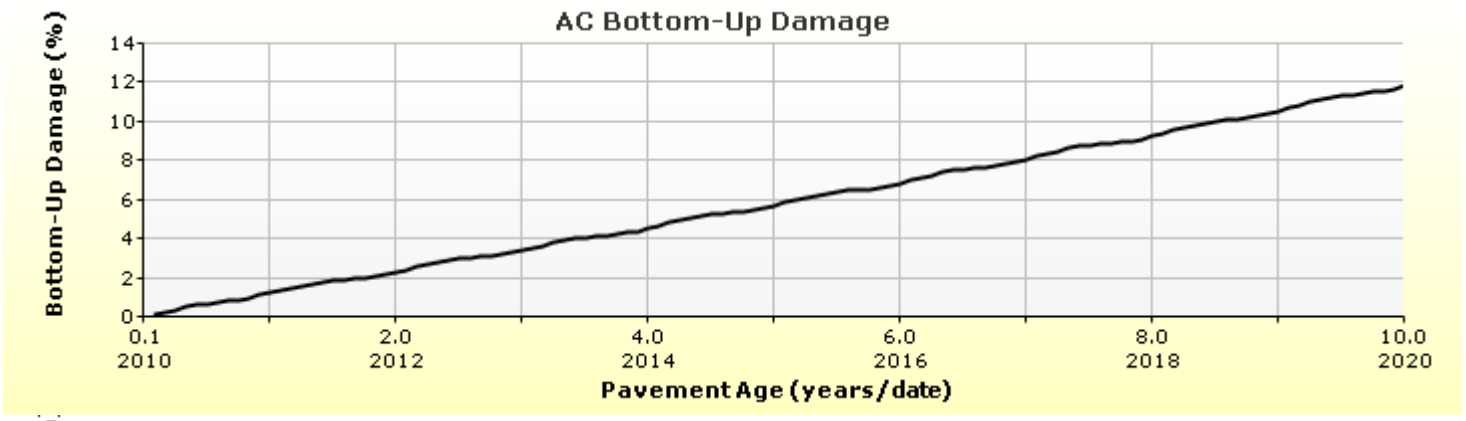
Analysis Output Charts

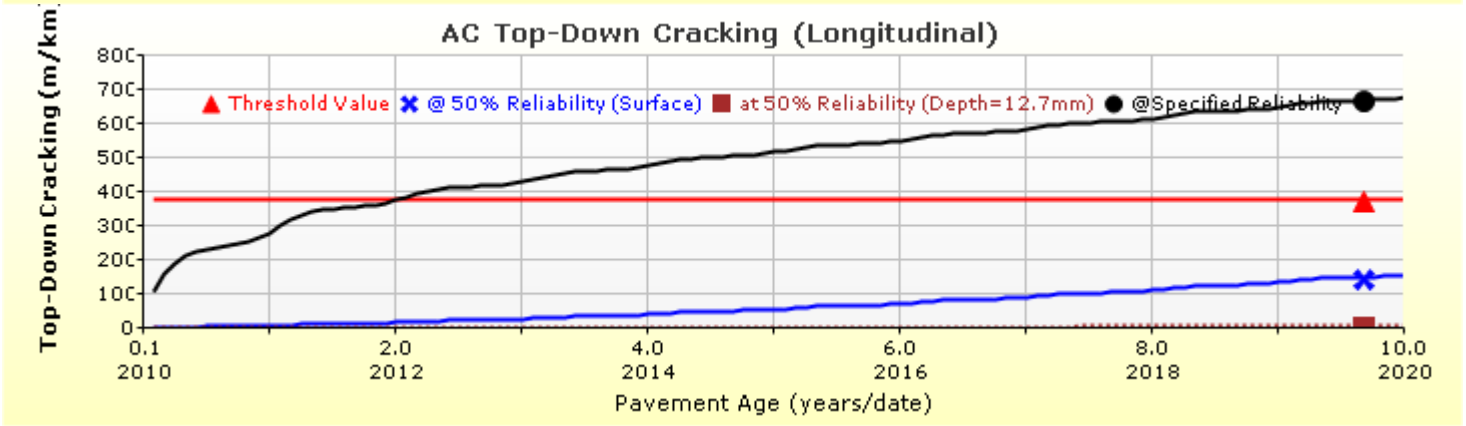


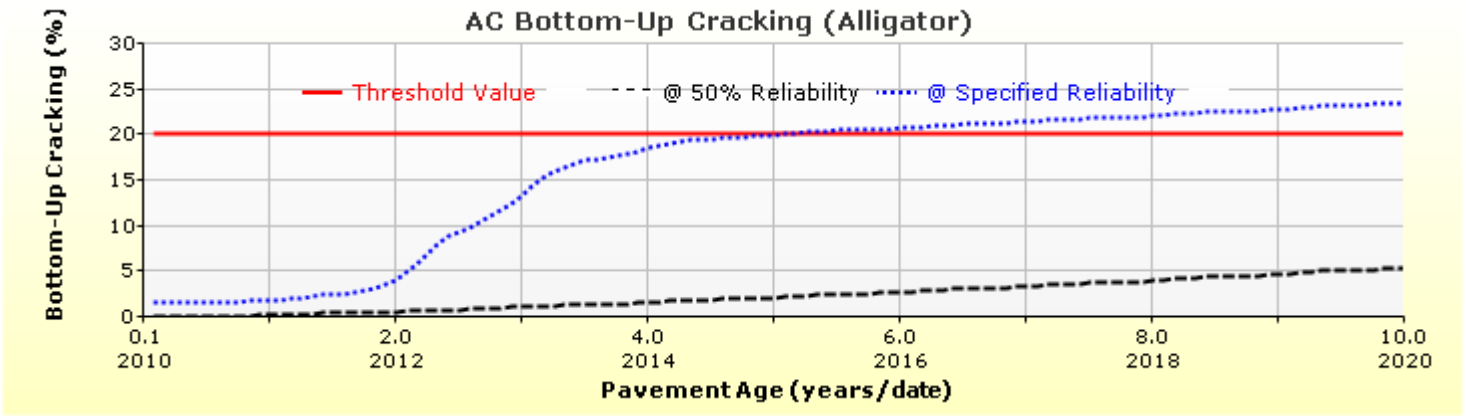


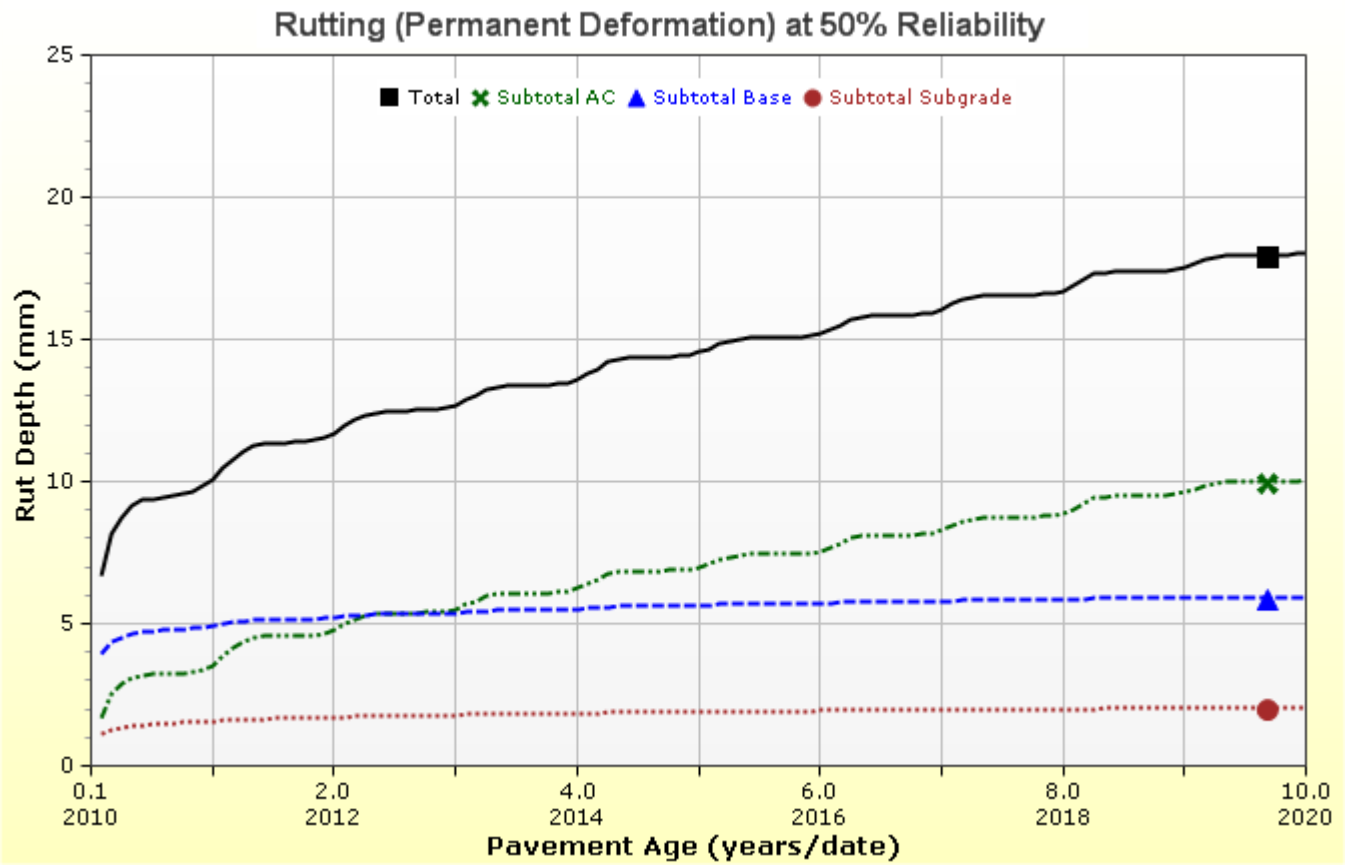


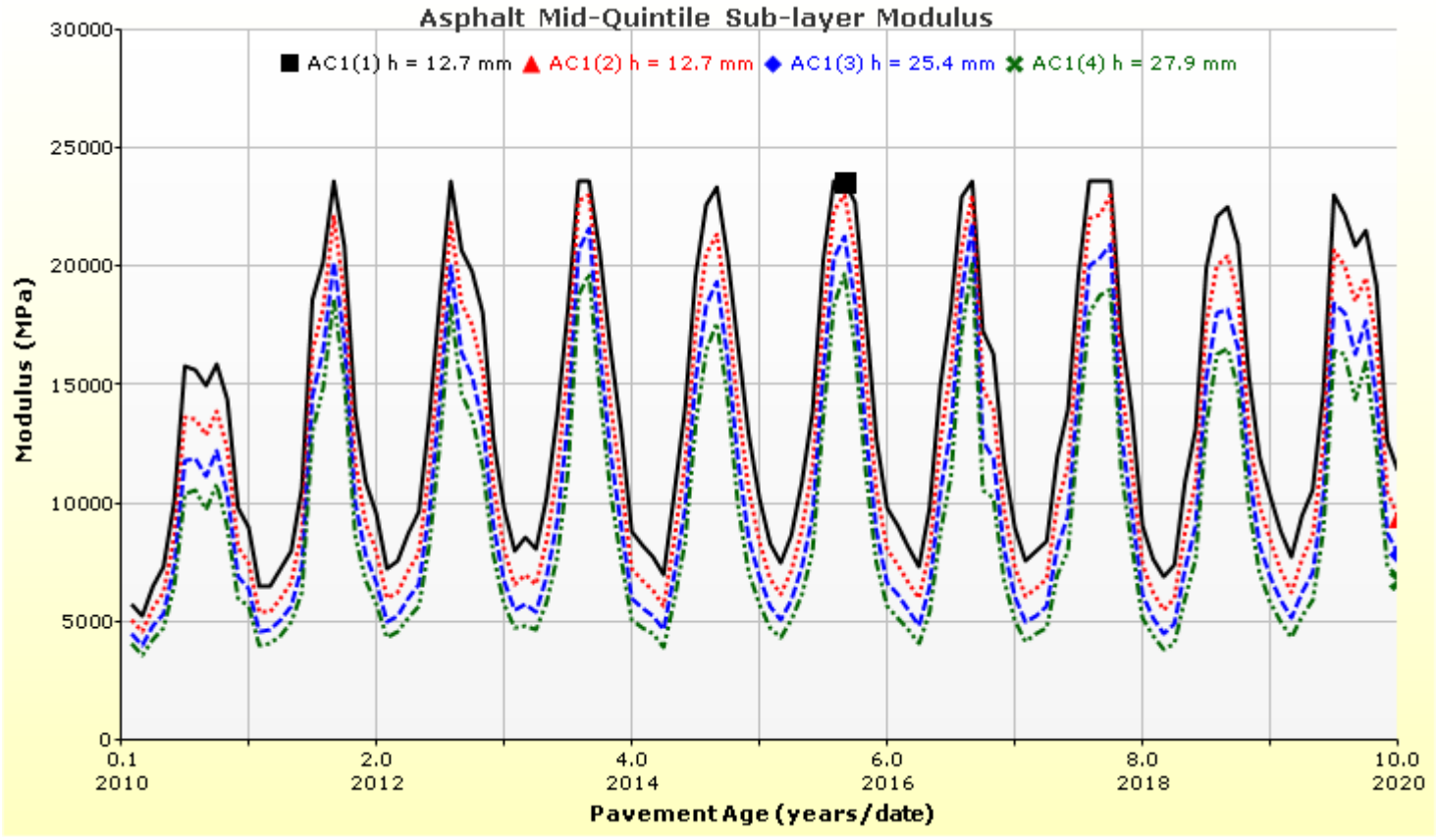

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

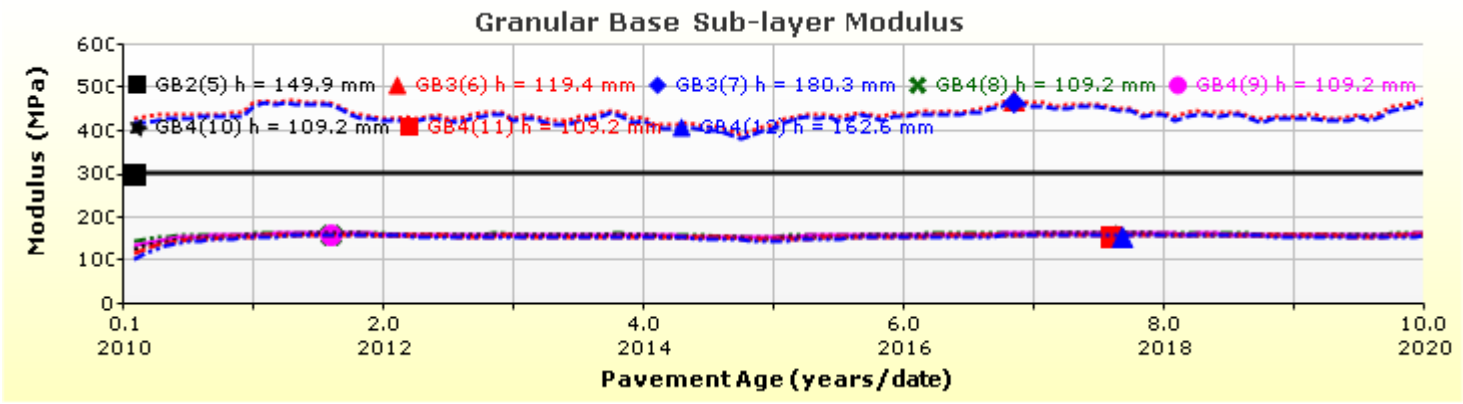

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

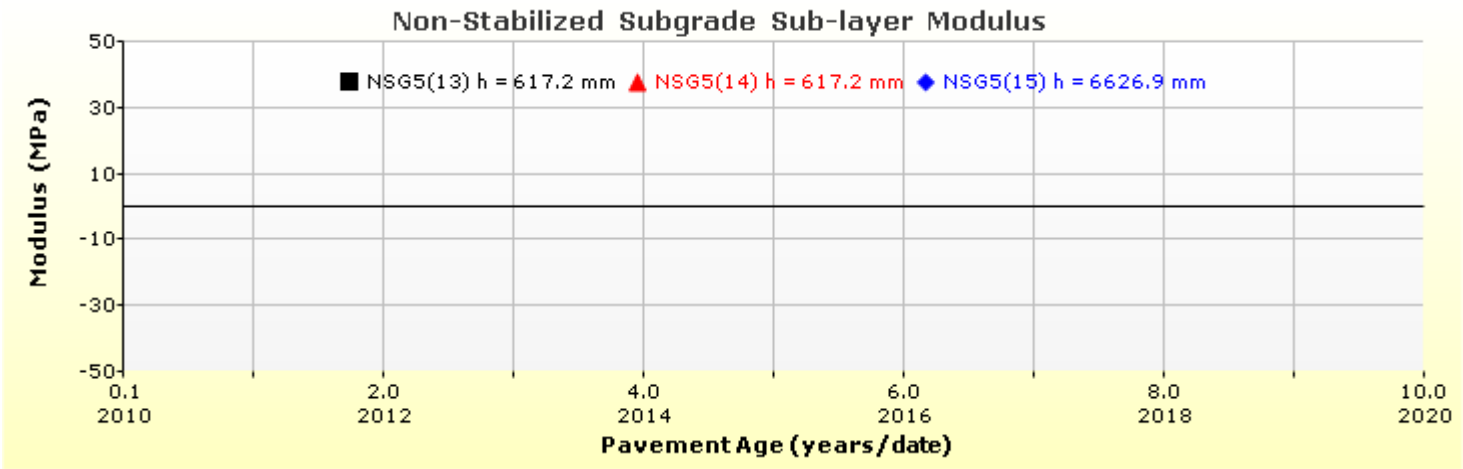

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 1
Bf2: 1
Bf3: 1

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2\beta_{r2}} N^{k_3\beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

$$H_{ac} = total\ AC\ thickness(in)$$

$\varepsilon_p = plastic\ strain\left({}^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left({}^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRS_vento

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRS_vento.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -30.05, -51.17

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

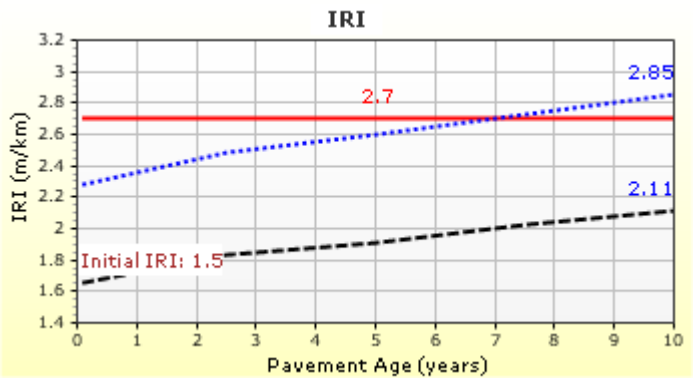
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

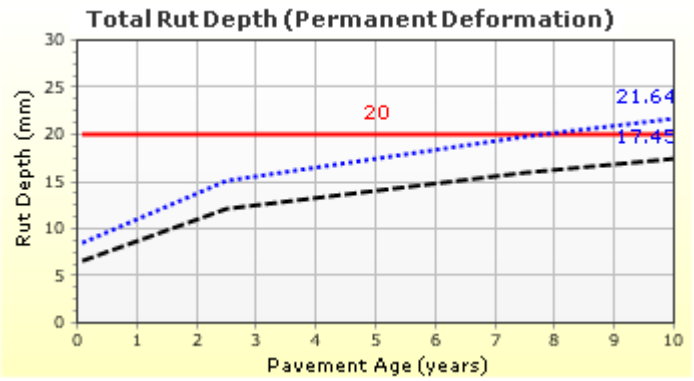
Design Outputs

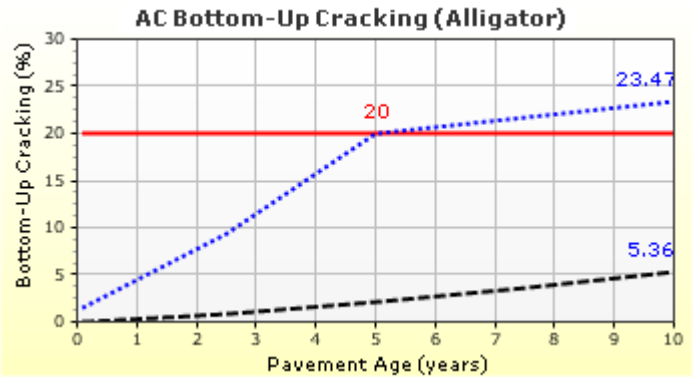
Distress Prediction Summary

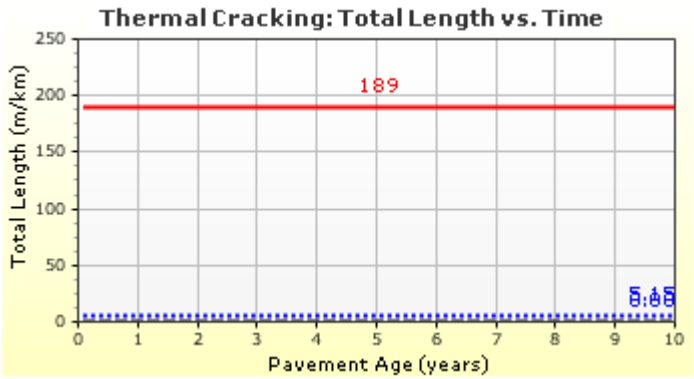
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.85	90.00	84.65	Fail
Permanent deformation - total pavement (mm)	20.00	21.63	90.00	78.20	Fail
AC bottom-up fatigue cracking (percent)	20.00	23.47	90.00	84.99	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	667.14	90.00	71.53	Fail
Permanent deformation - AC only (mm)	5.00	9.47	50.00	5.45	Fail

Distress Charts







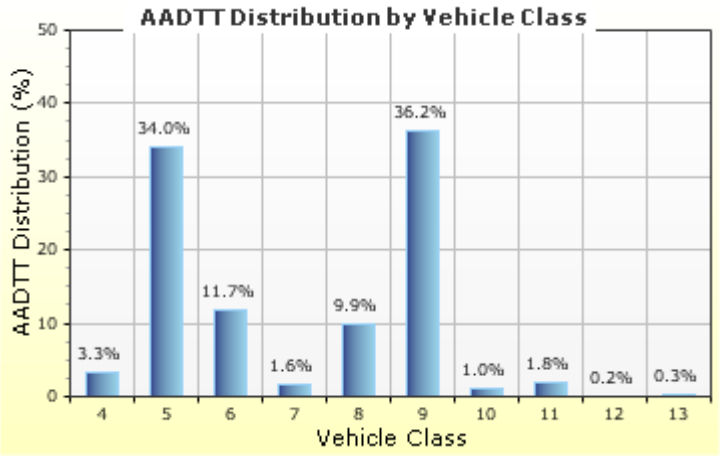


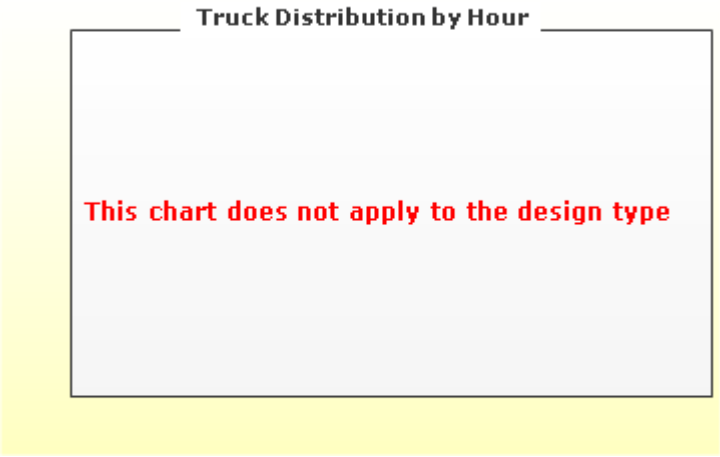


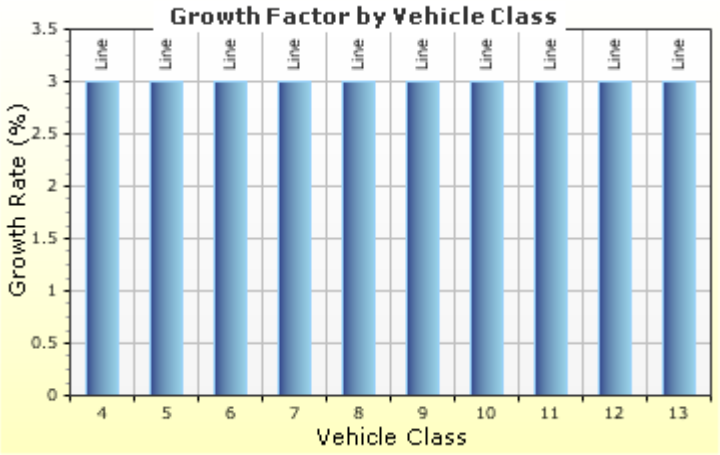
Traffic Inputs

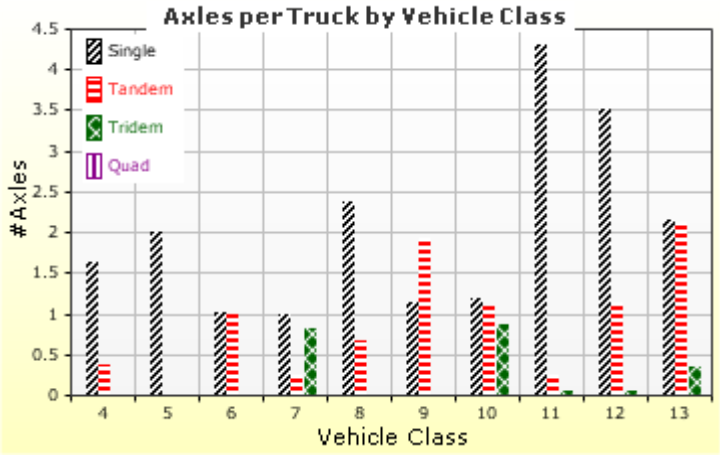
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

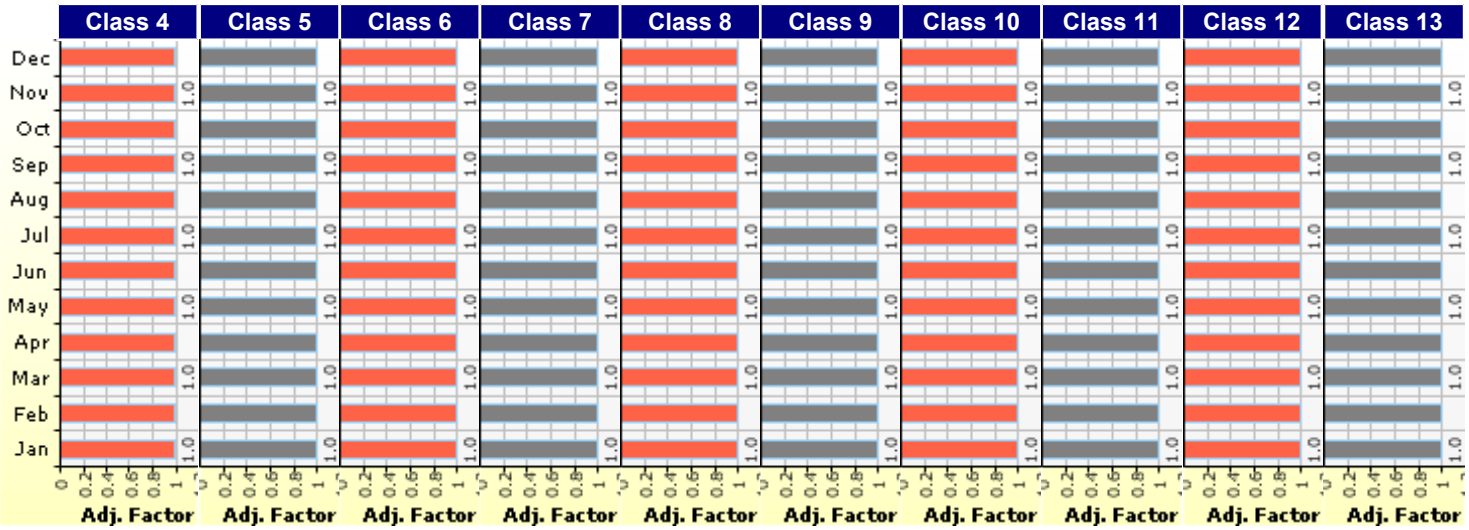








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

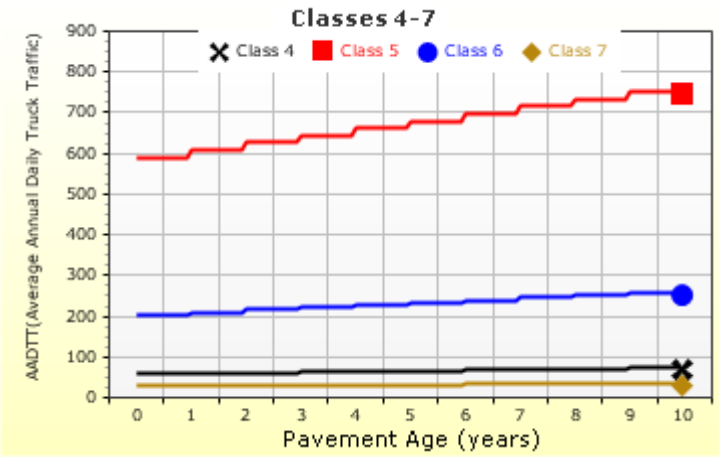
Wheelbase does not apply

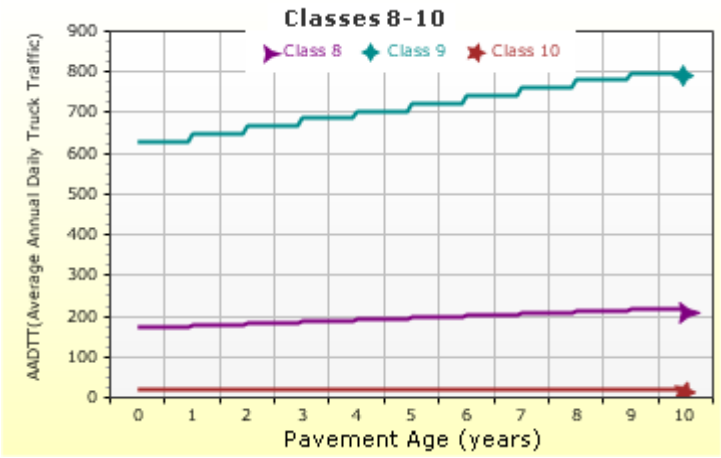
Number of Axles per Truck

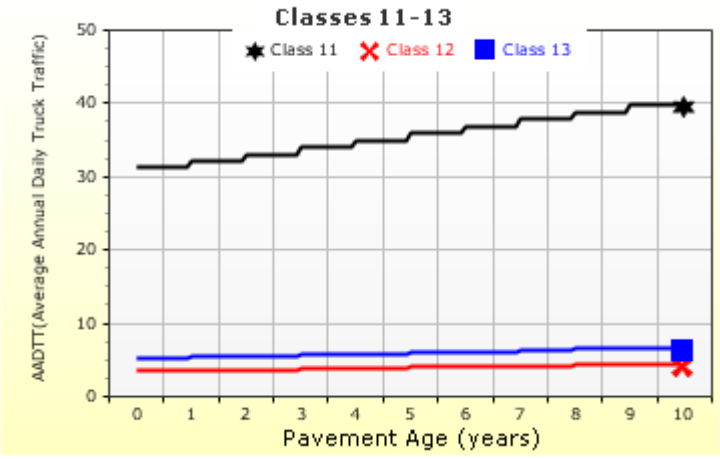
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

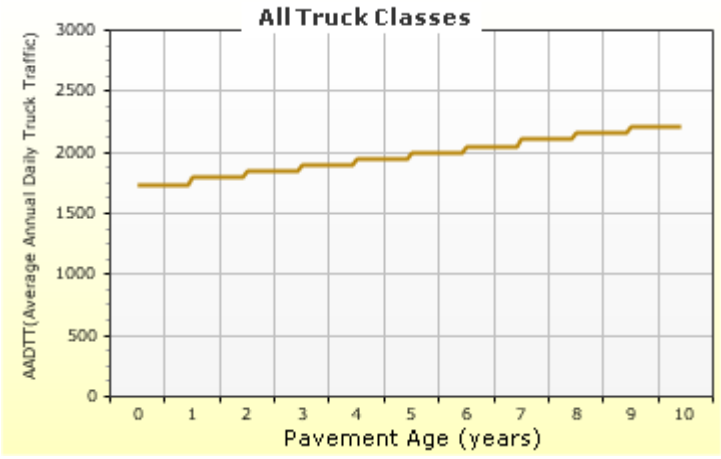
AADTT (Average Annual Daily Truck Traffic) Growth

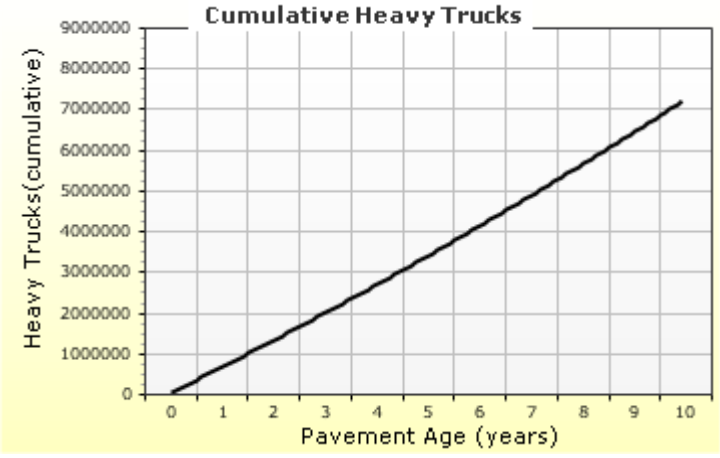
*** Traffic cap is not enforced**







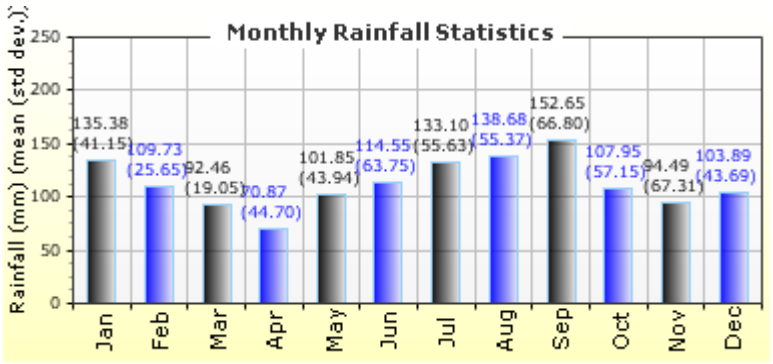




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
PORTO ALEGRE, RS	-30.05000 -51.17000 47

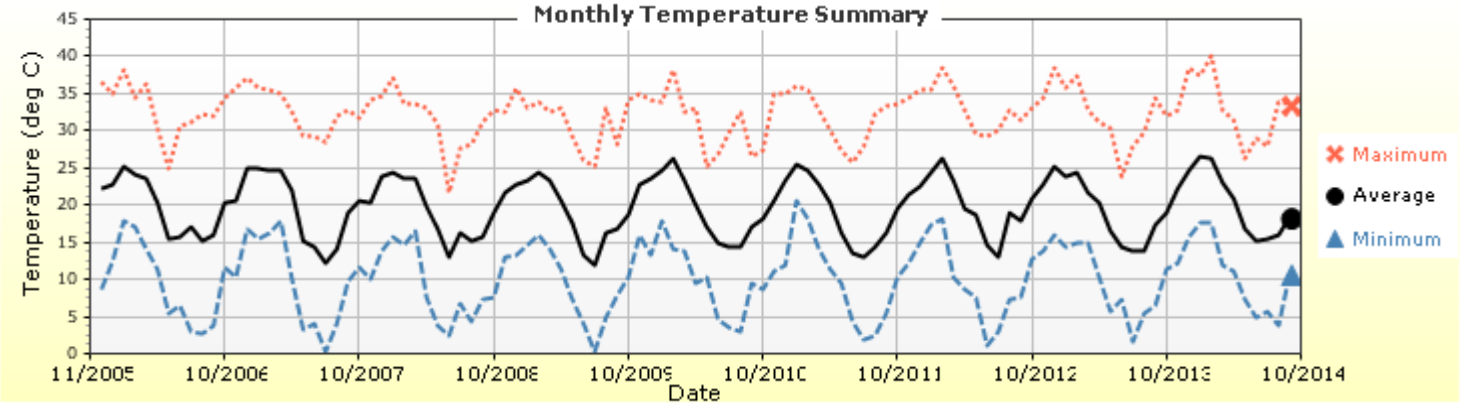


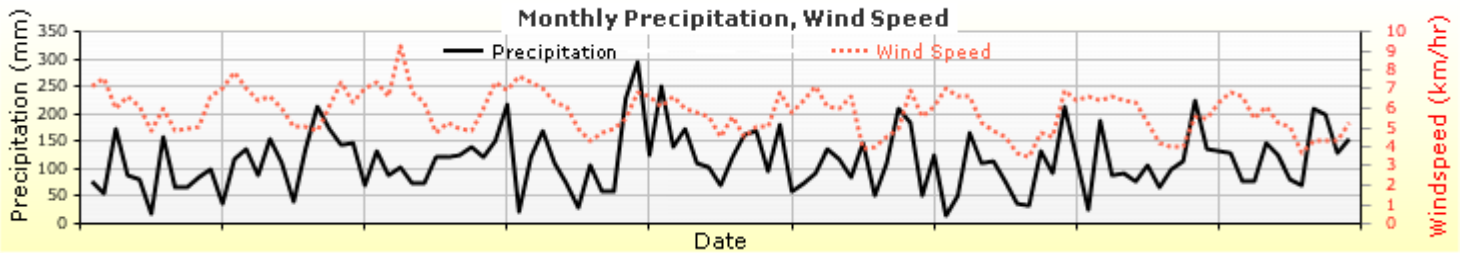
Annual Statistics:

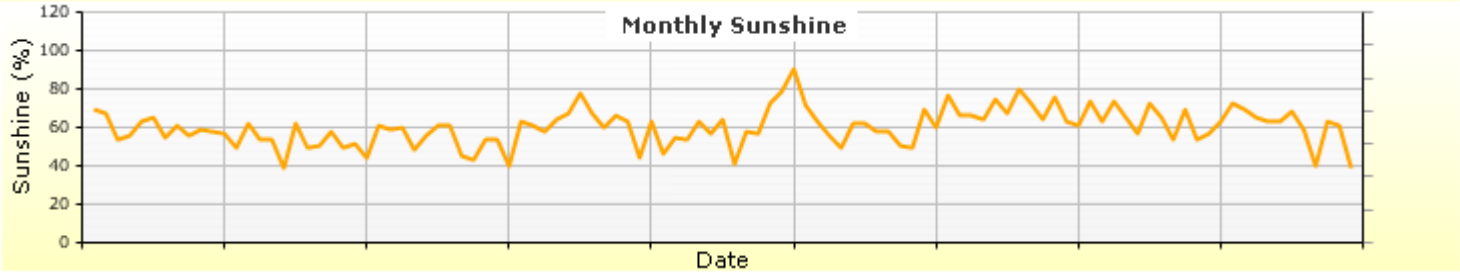
Mean annual air temperature (ºC)	19.73
Mean annual precipitation (mm)	1352.30
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

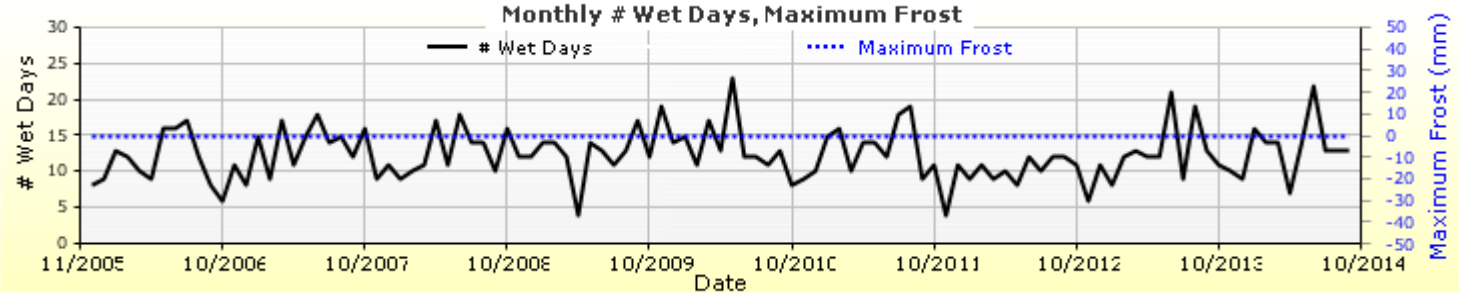
Water table depth (m) 3.05

Monthly Climate Summary:

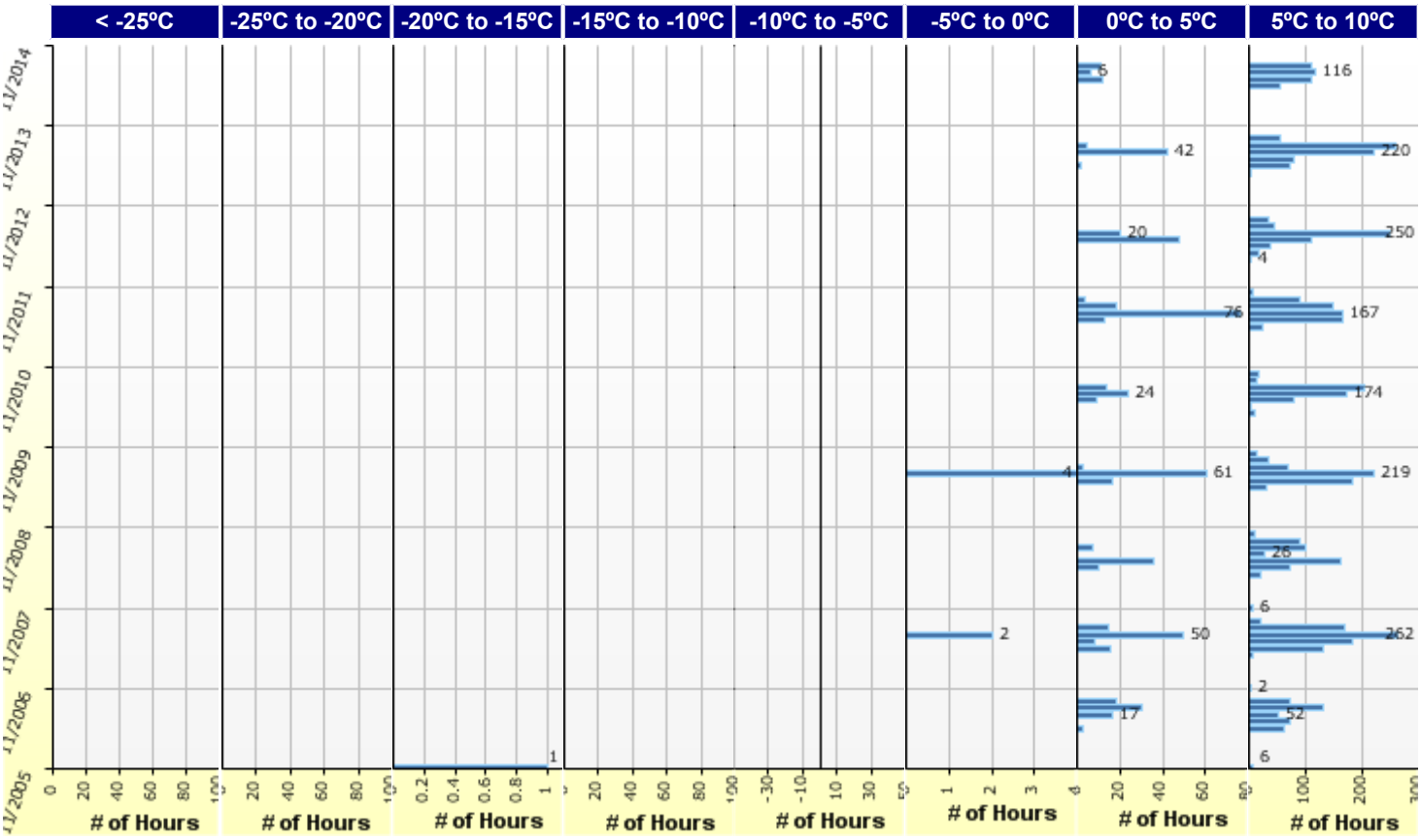


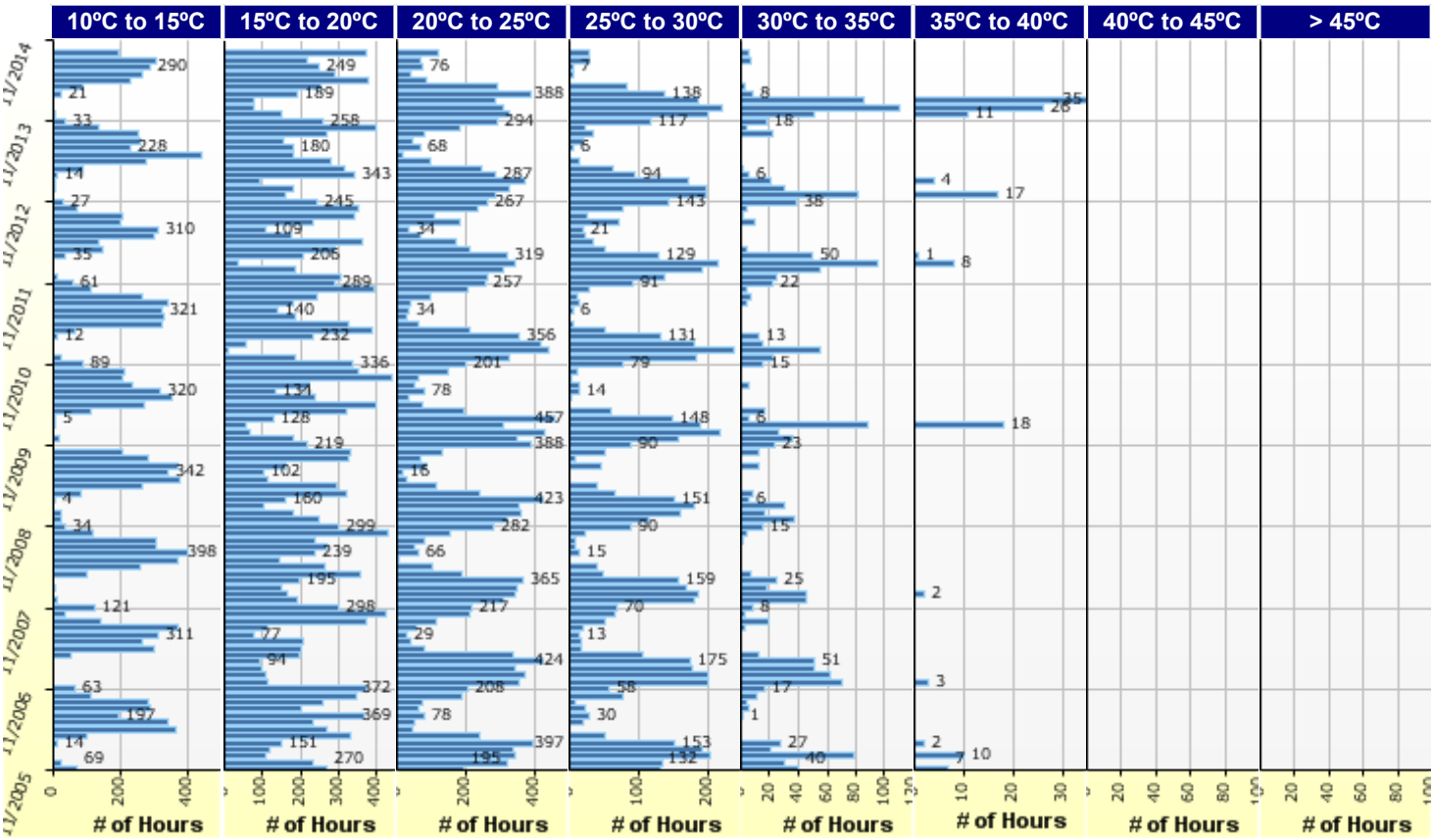






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

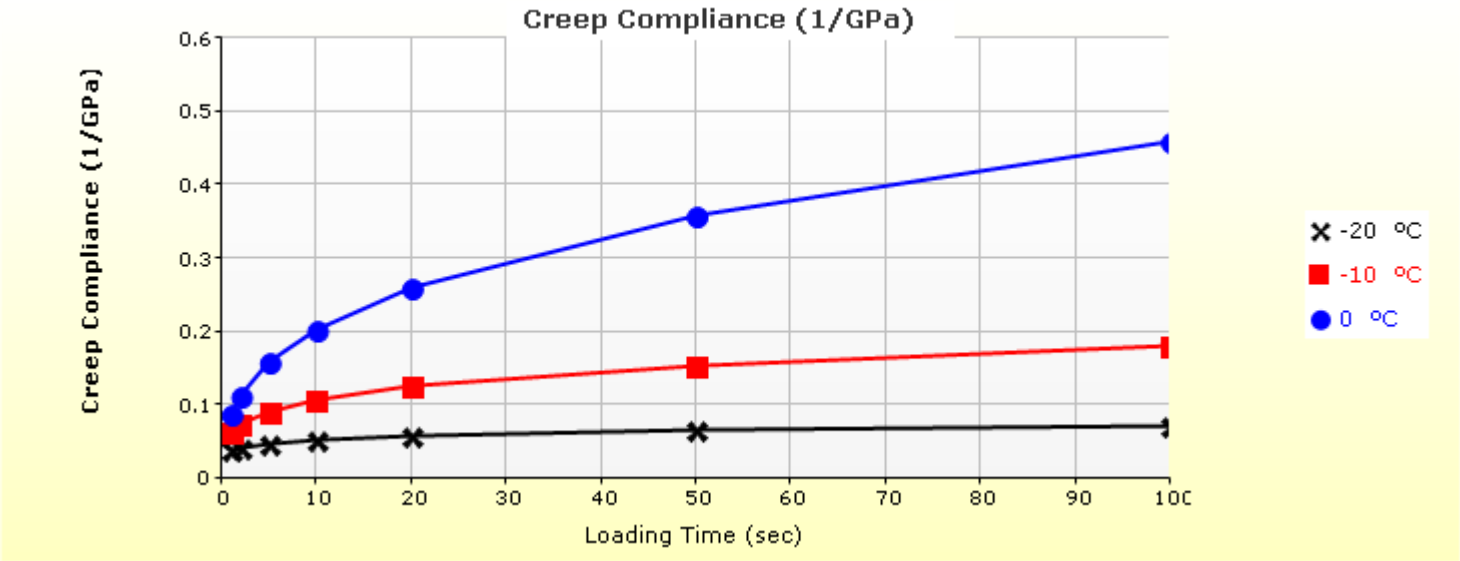
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

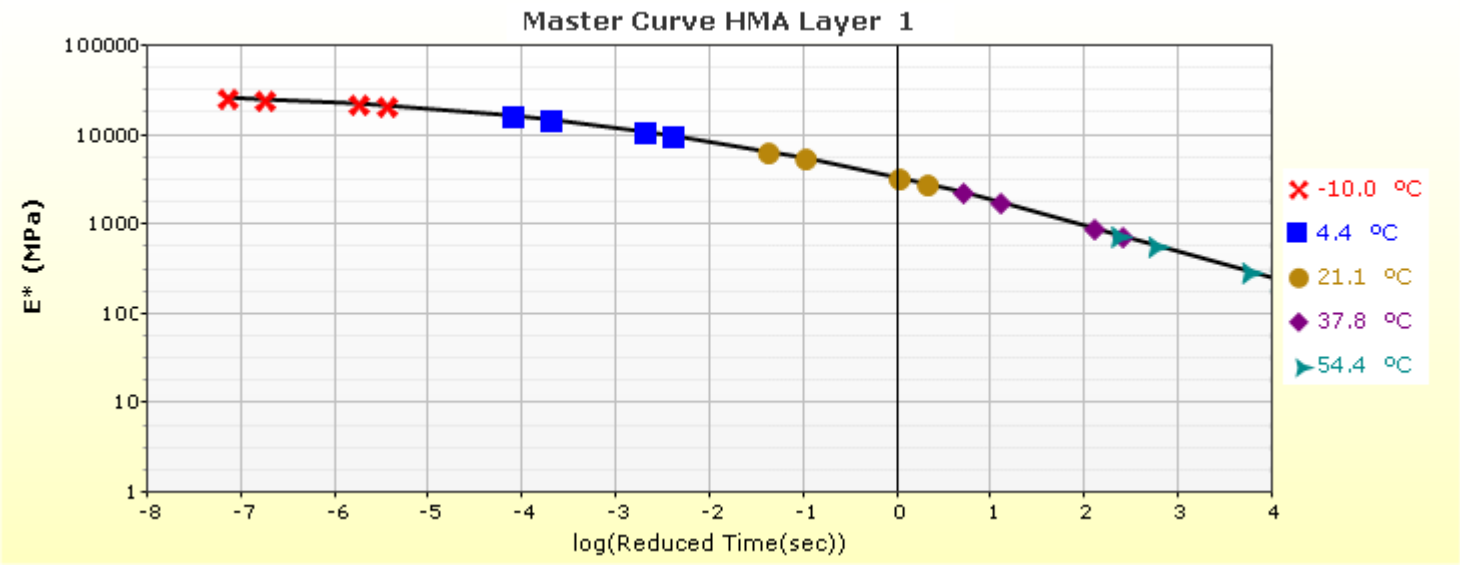
Indirect tensile strength at -10 ºC (MPa)	2.69

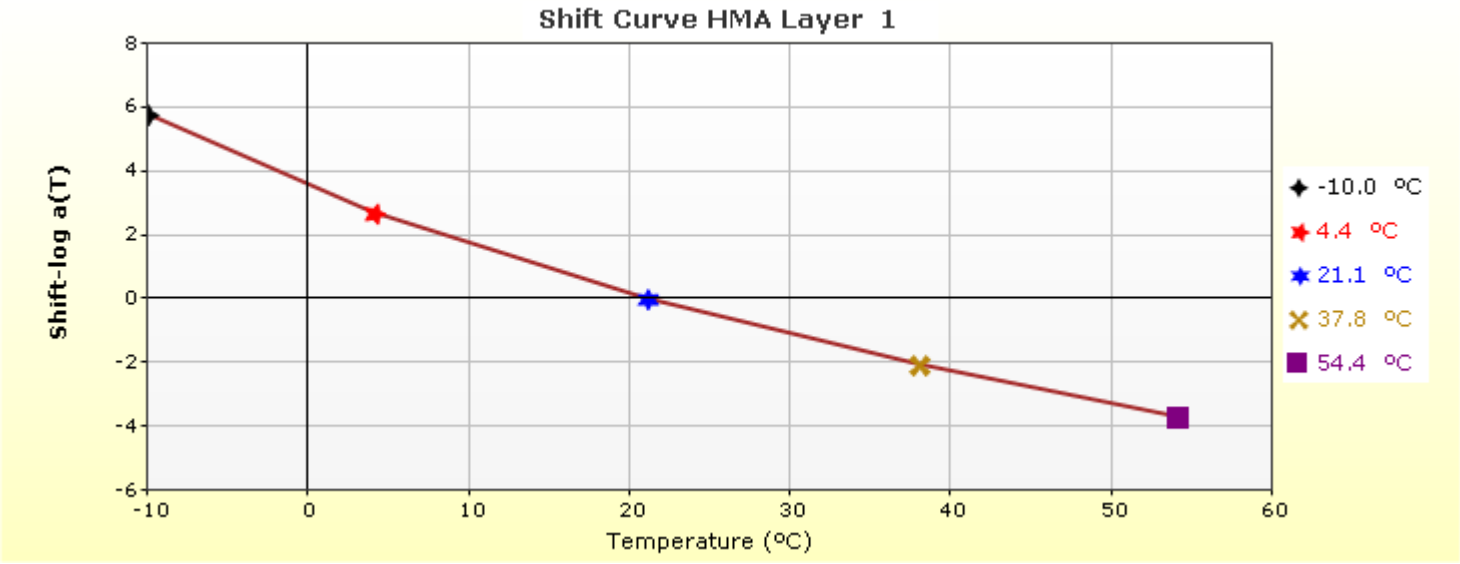
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

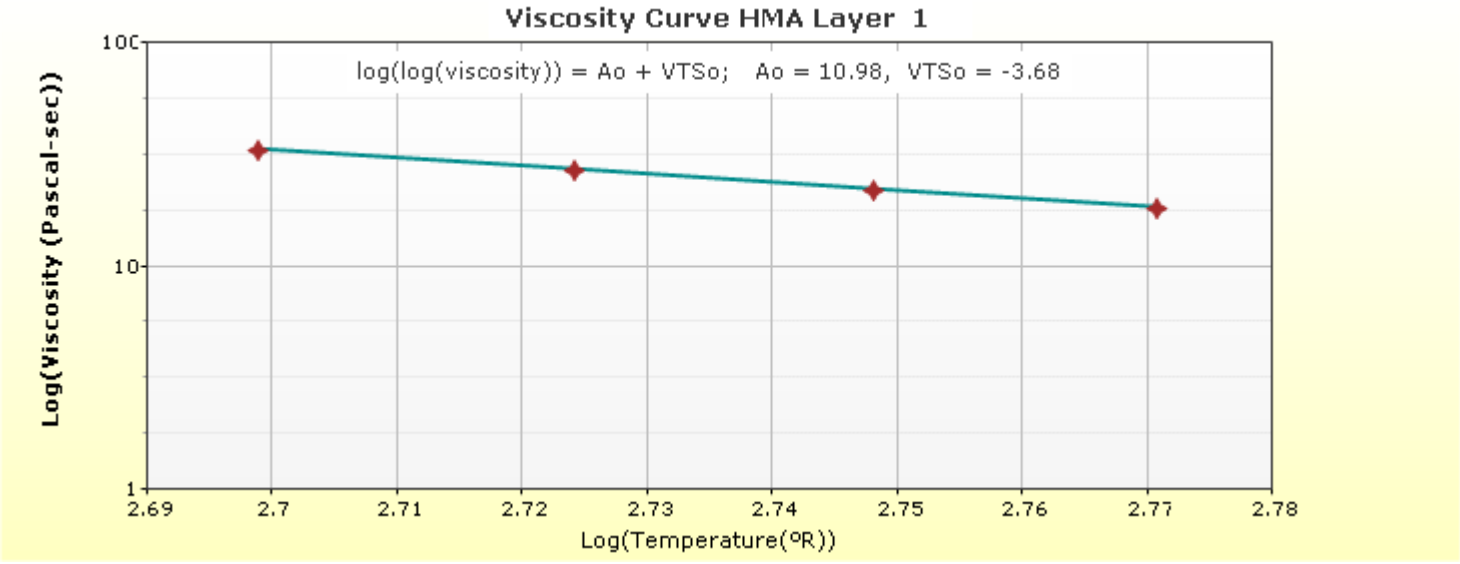
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



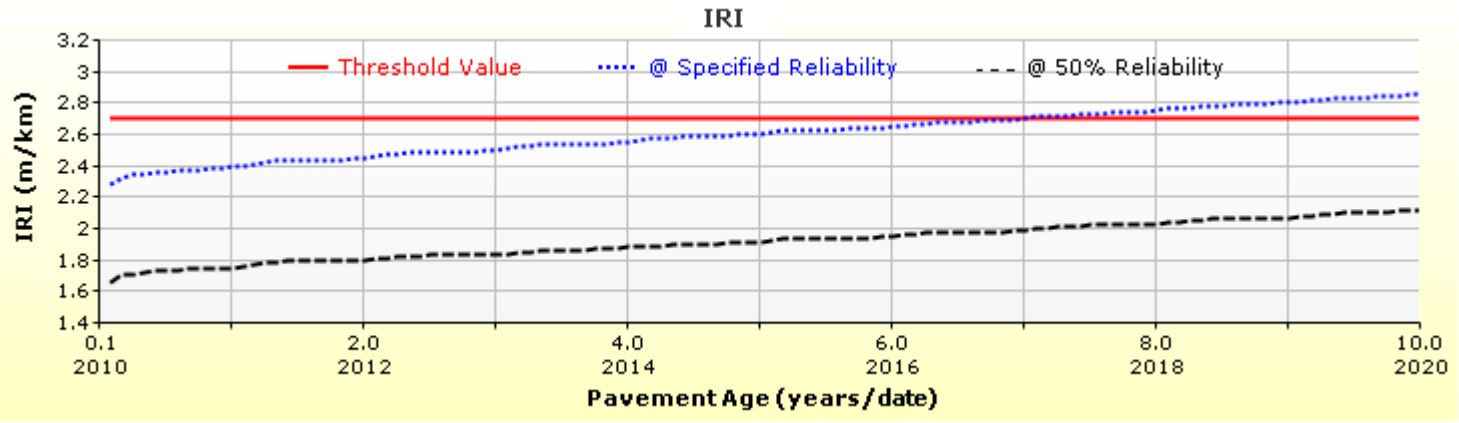
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

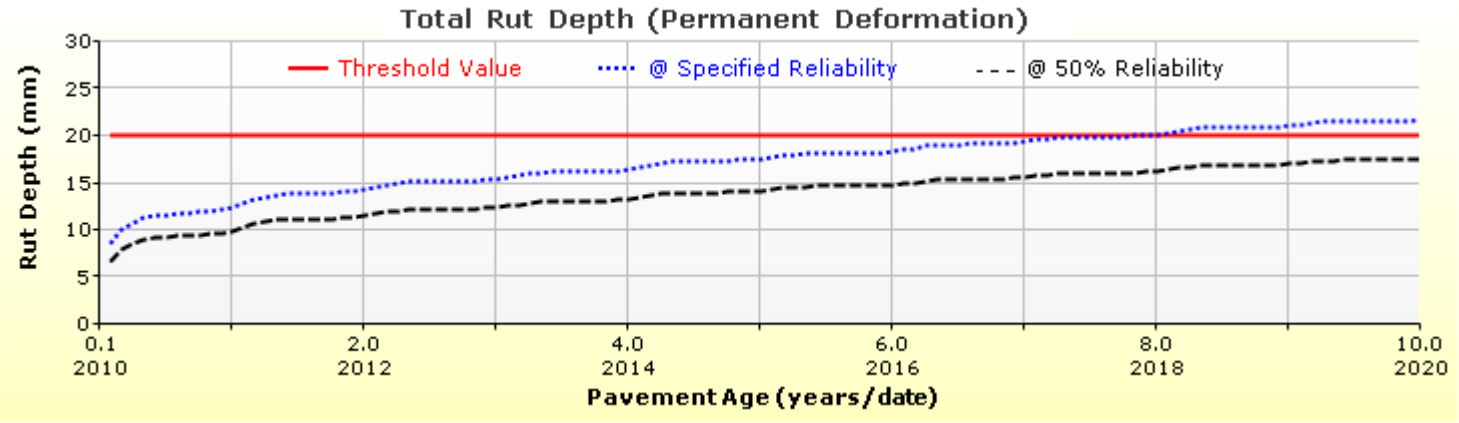


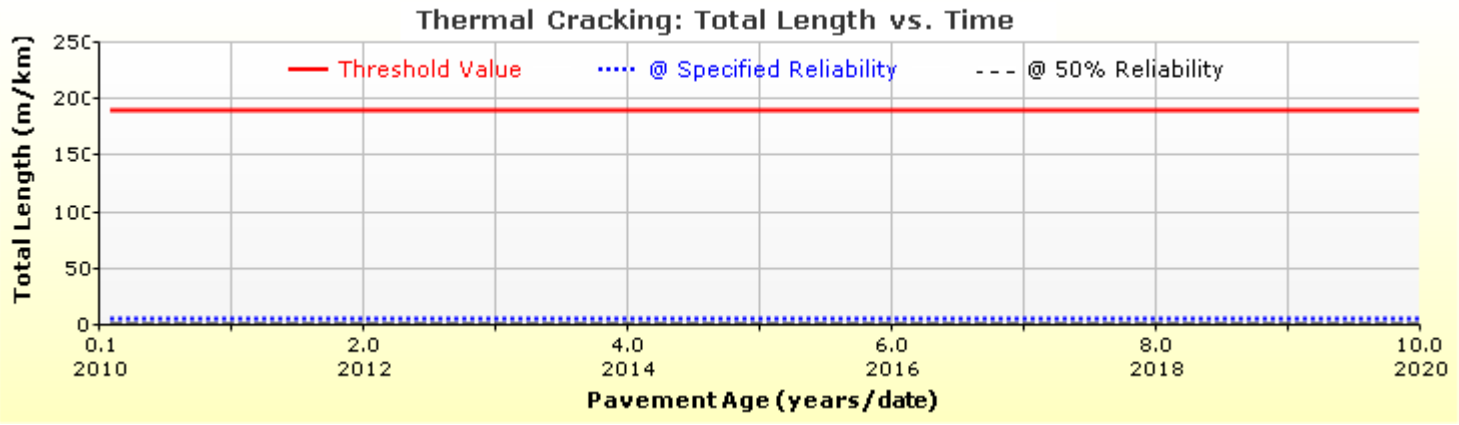


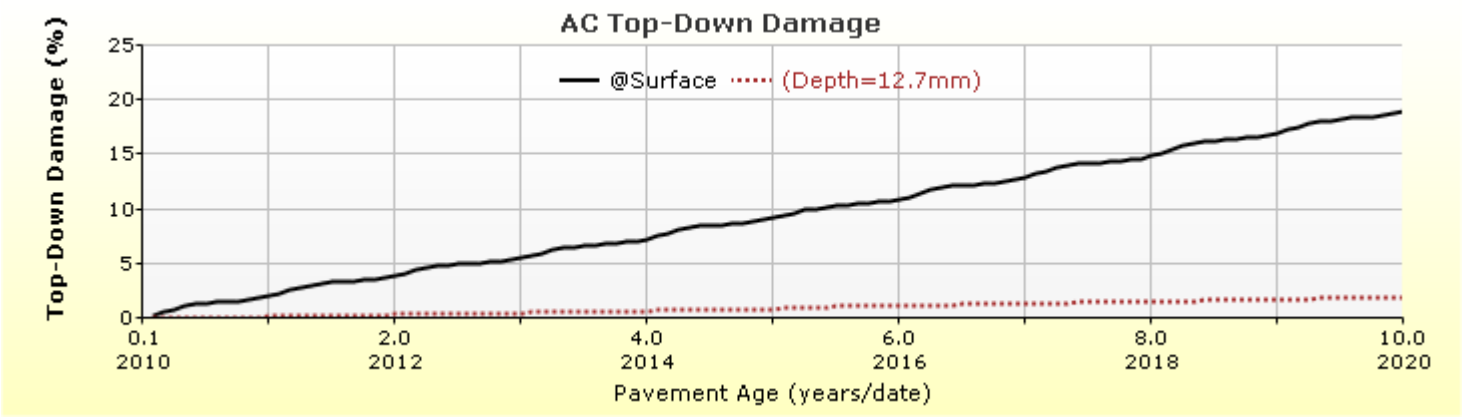


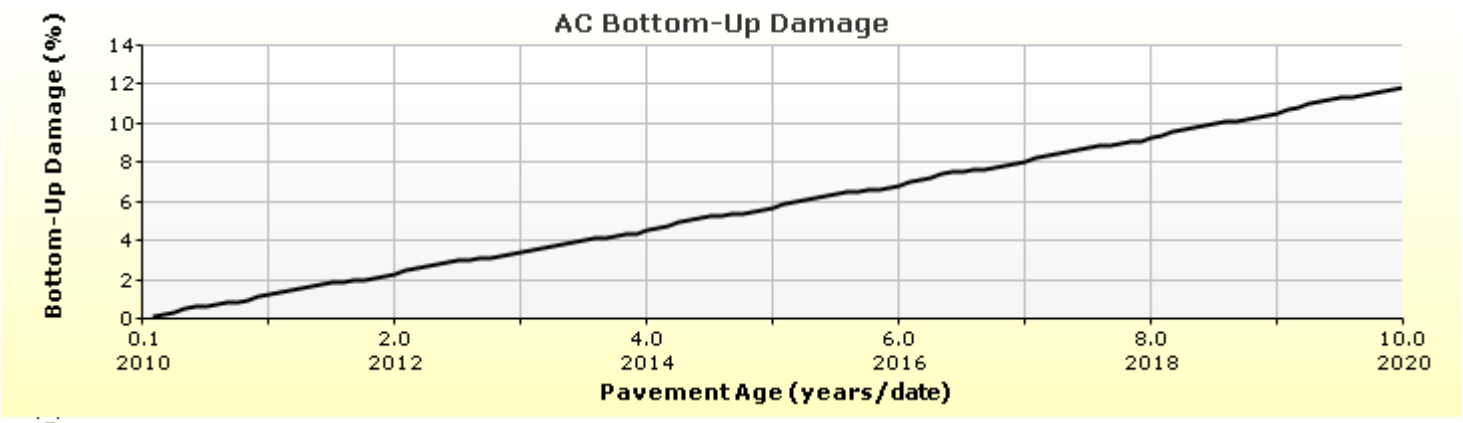
Analysis Output Charts

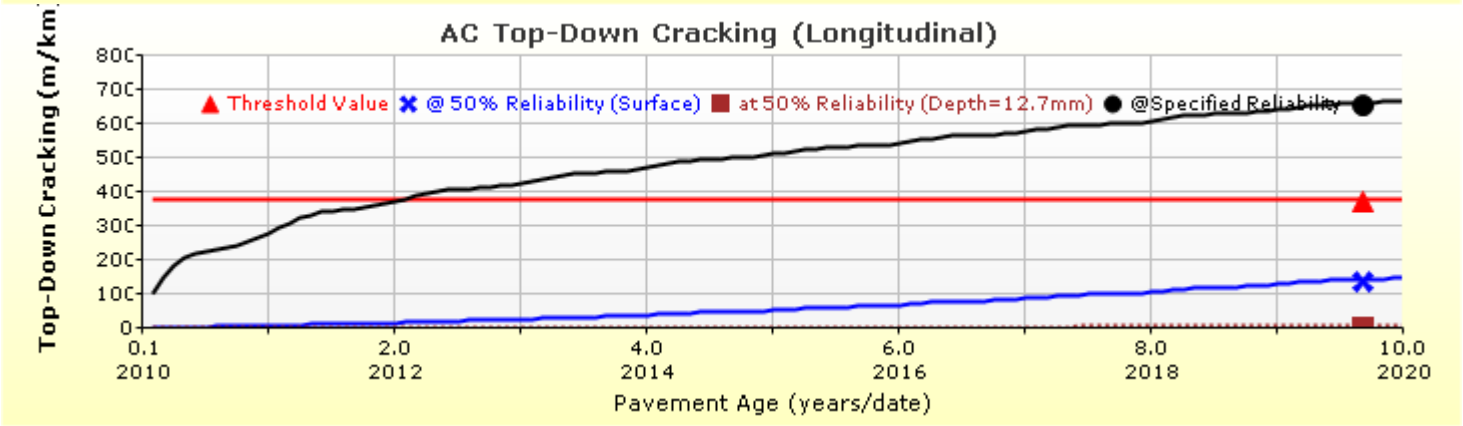


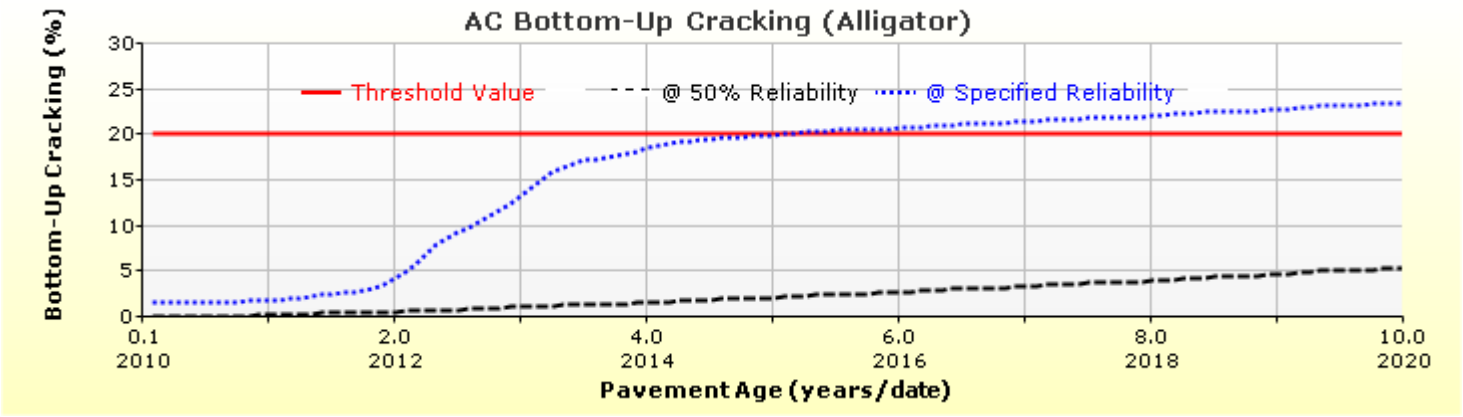


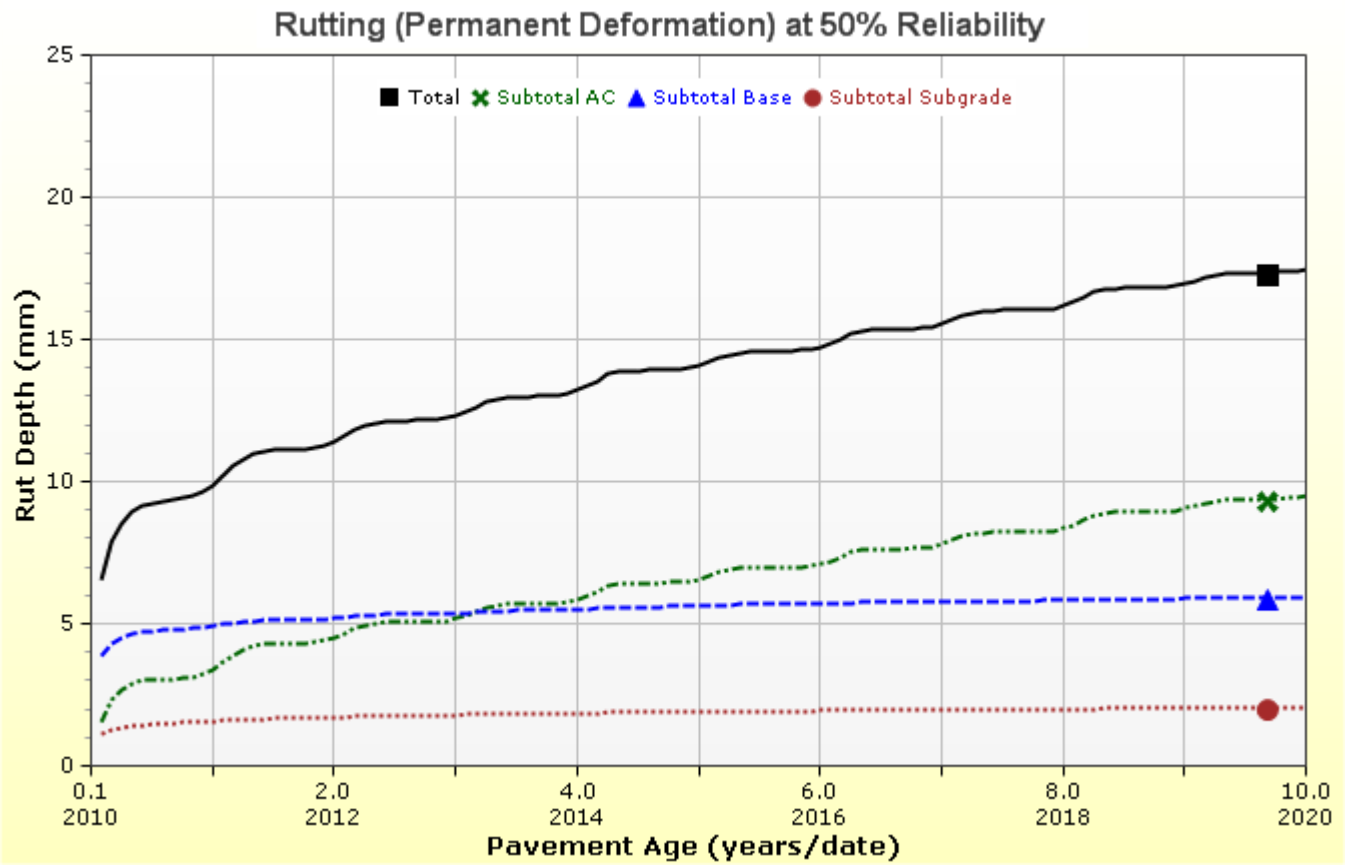


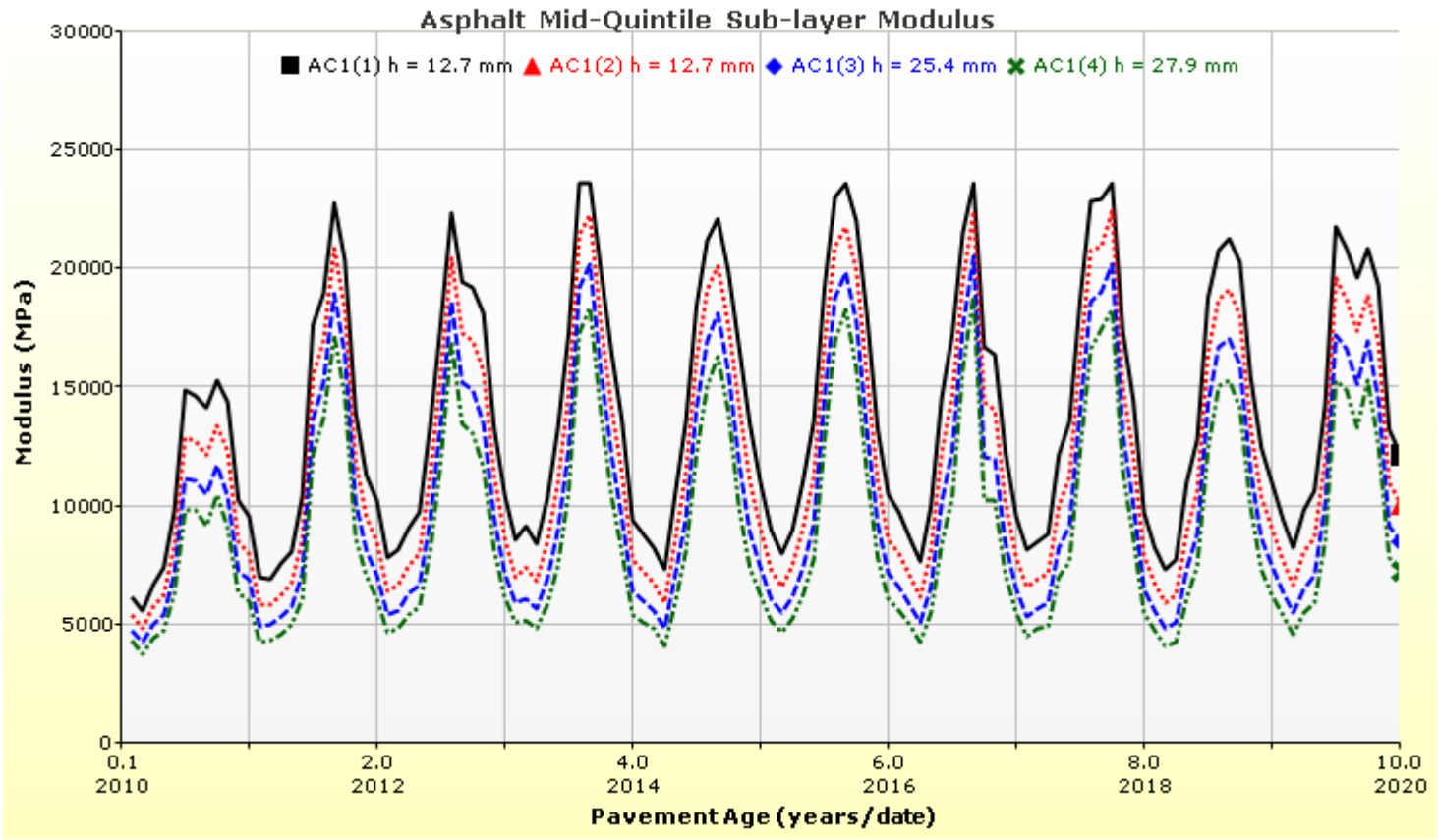

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

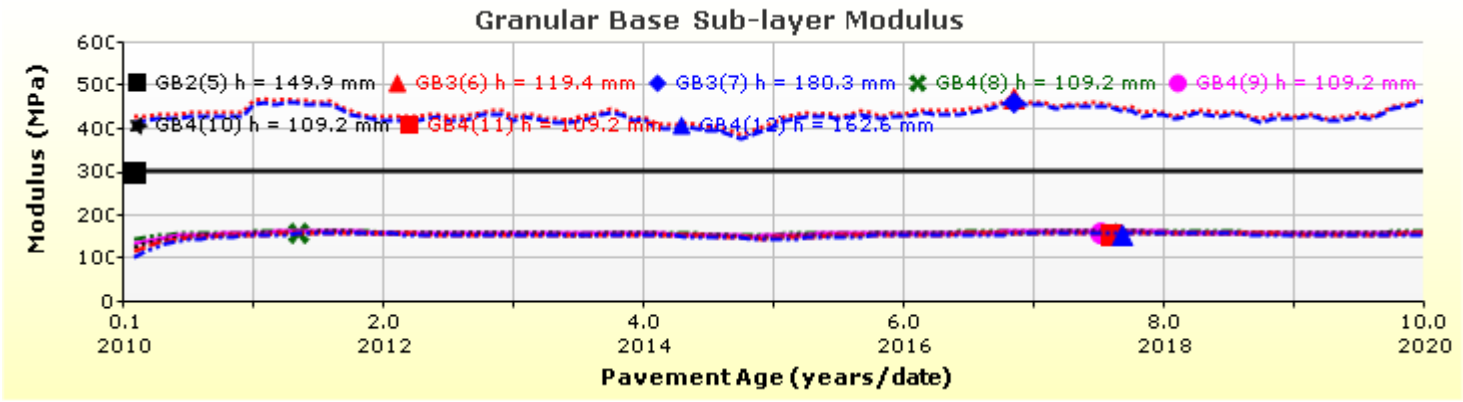

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

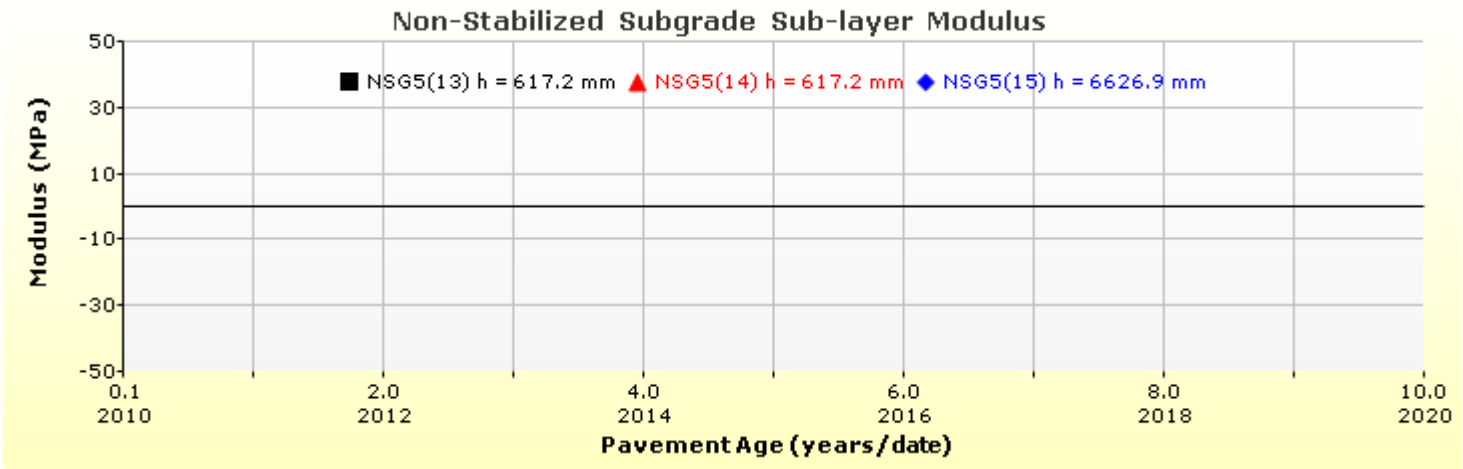

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2\beta_{r2}} N^{k_3\beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{\alpha}^2 + 2.4868 * H_{\alpha} - 17.342$$

$$C_2 = 0.0172 * H_{\alpha}^2 - 1.7331 * H_{\alpha} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRJ

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRJ.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -22.8, -43.68

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

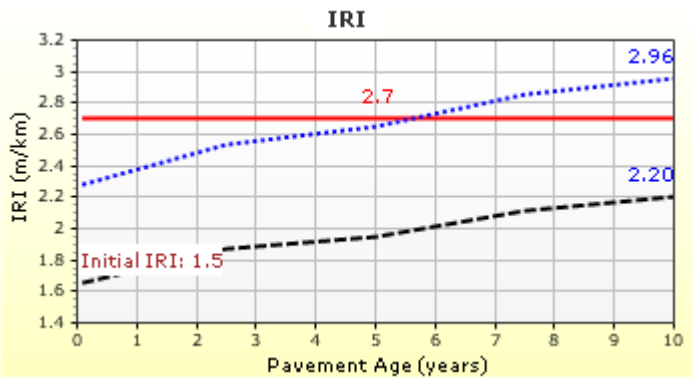
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

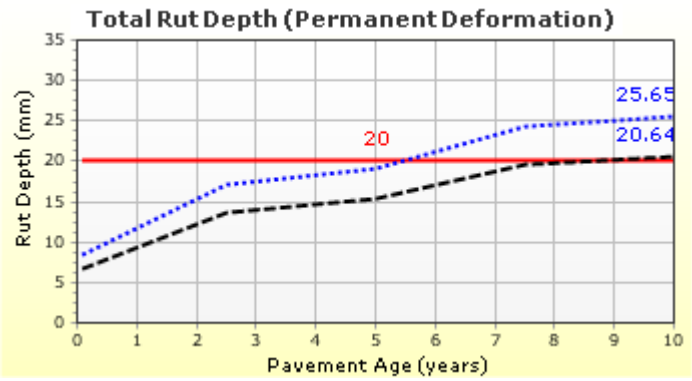
Design Outputs

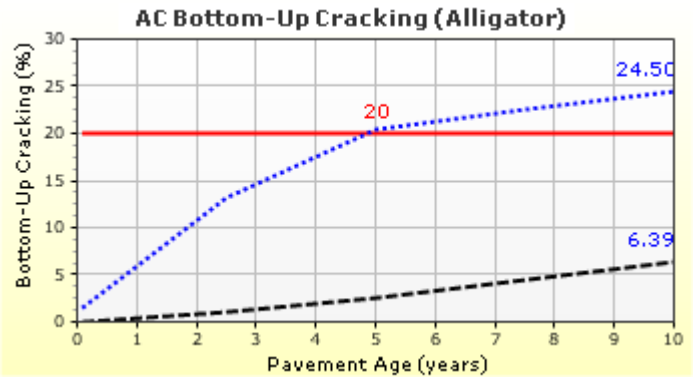
Distress Prediction Summary

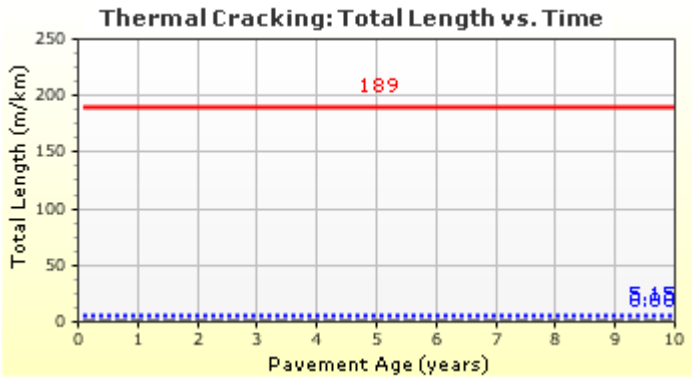
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.96	90.00	80.13	Fail
Permanent deformation - total pavement (mm)	20.00	25.64	90.00	43.41	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.50	90.00	83.23	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	760.06	90.00	64.51	Fail
Permanent deformation - AC only (mm)	5.00	12.68	50.00	1.45	Fail

Distress Charts







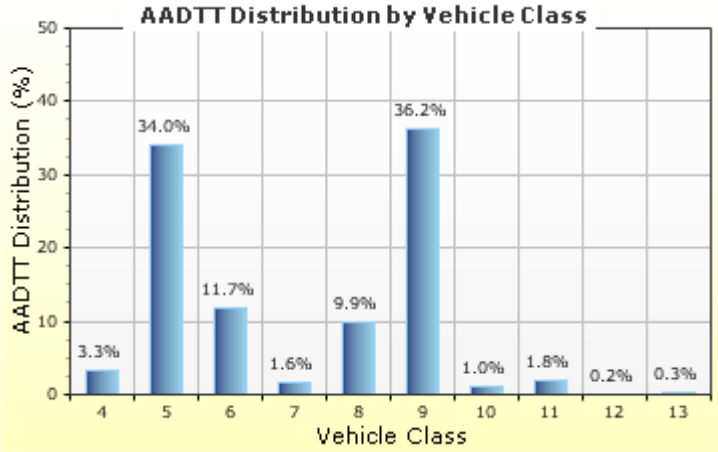


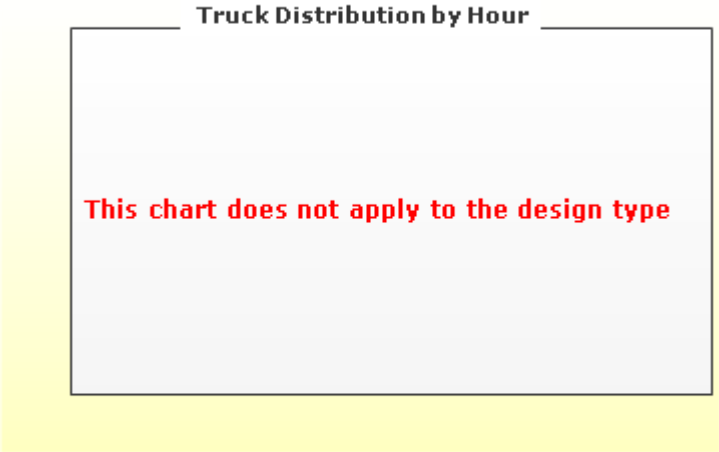


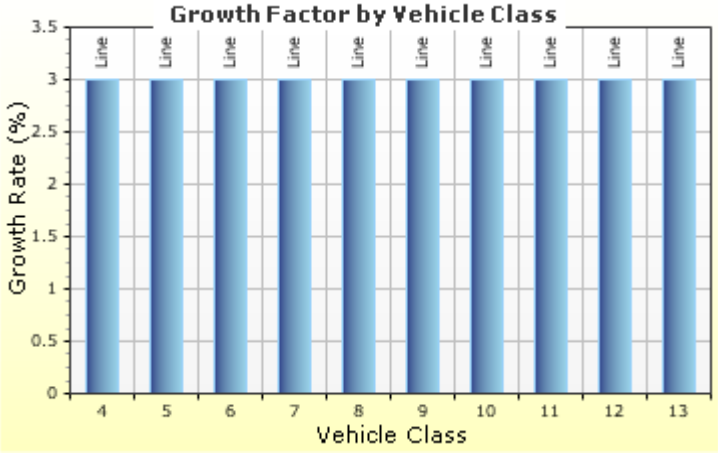
Traffic Inputs

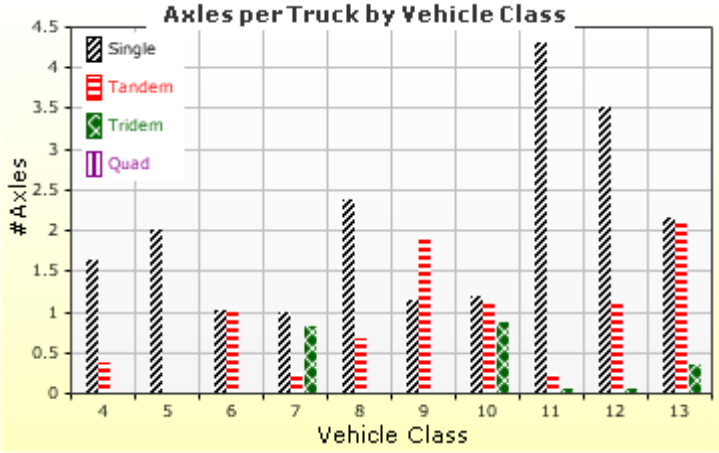
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

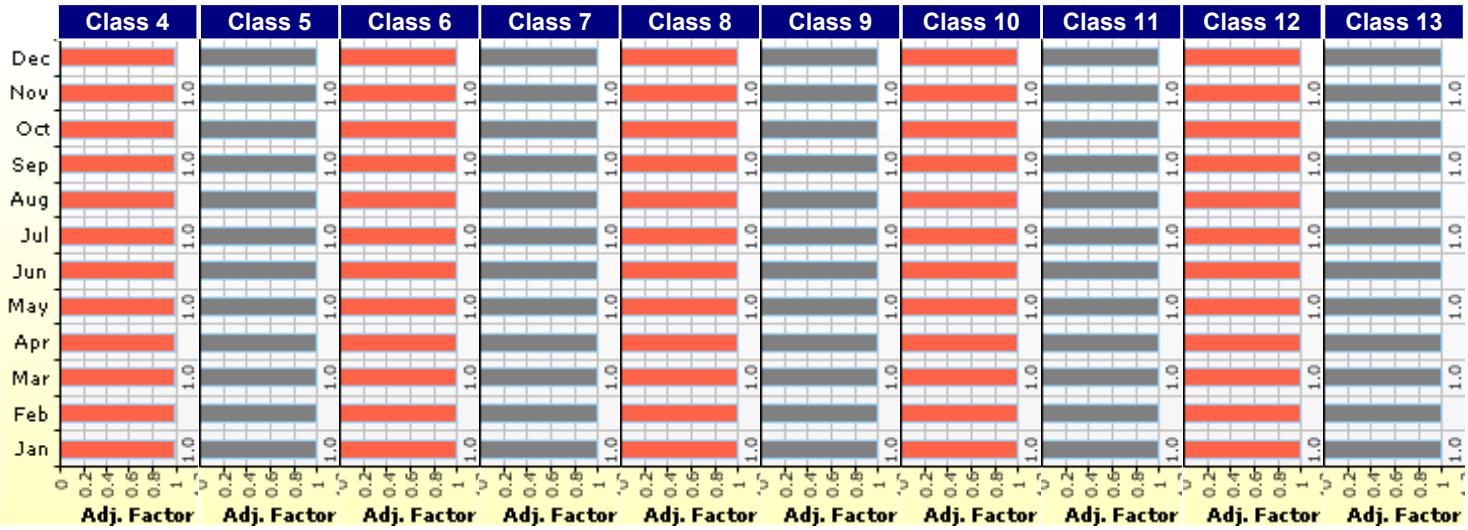








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

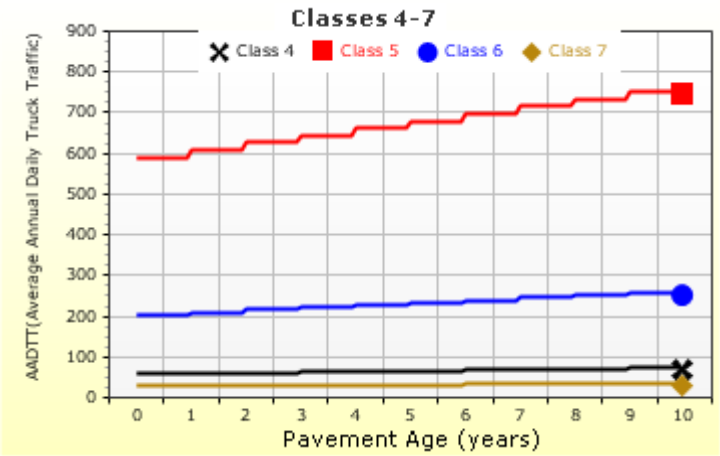
Wheelbase does not apply

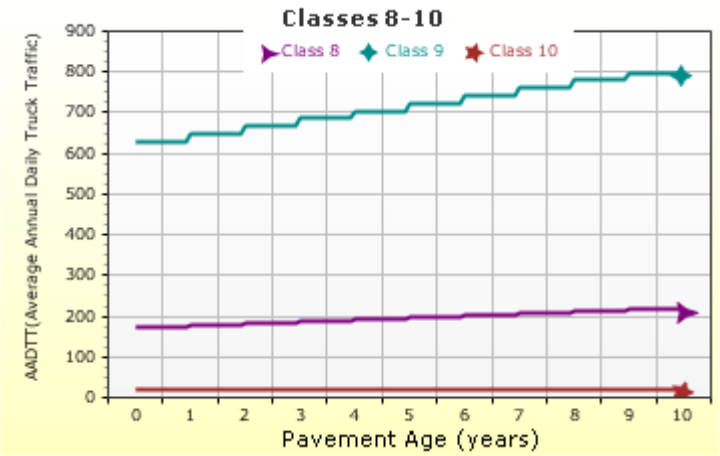
Number of Axles per Truck

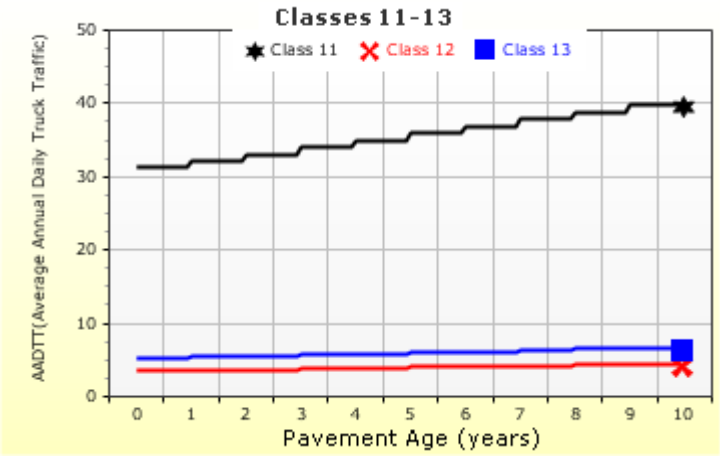
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

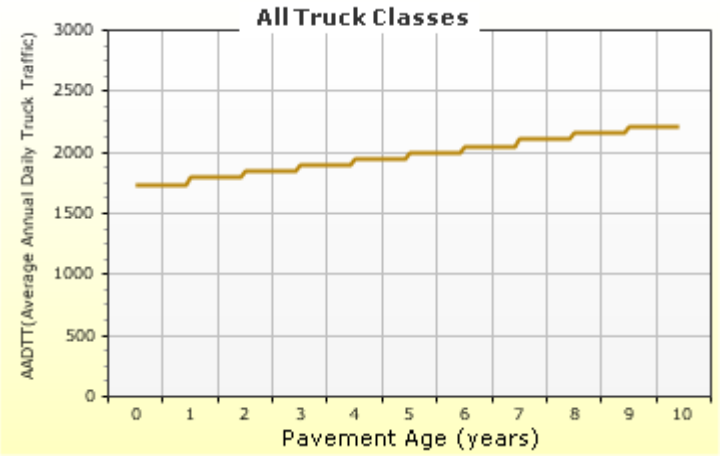
AADTT (Average Annual Daily Truck Traffic) Growth

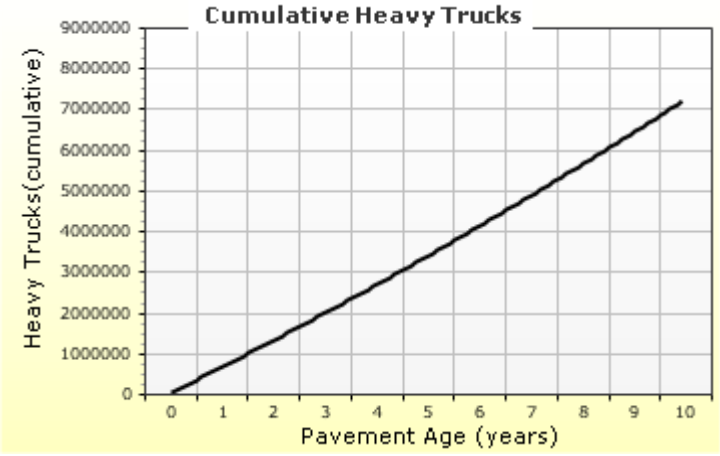
*** Traffic cap is not enforced**







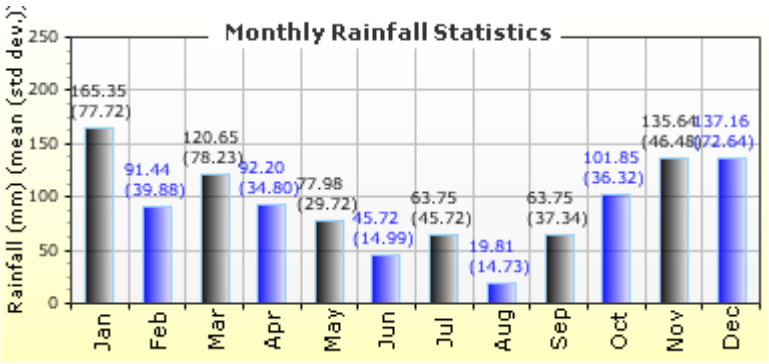




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
RIO DE JANEIRO, RJ	-22.80000 -43.68000 28

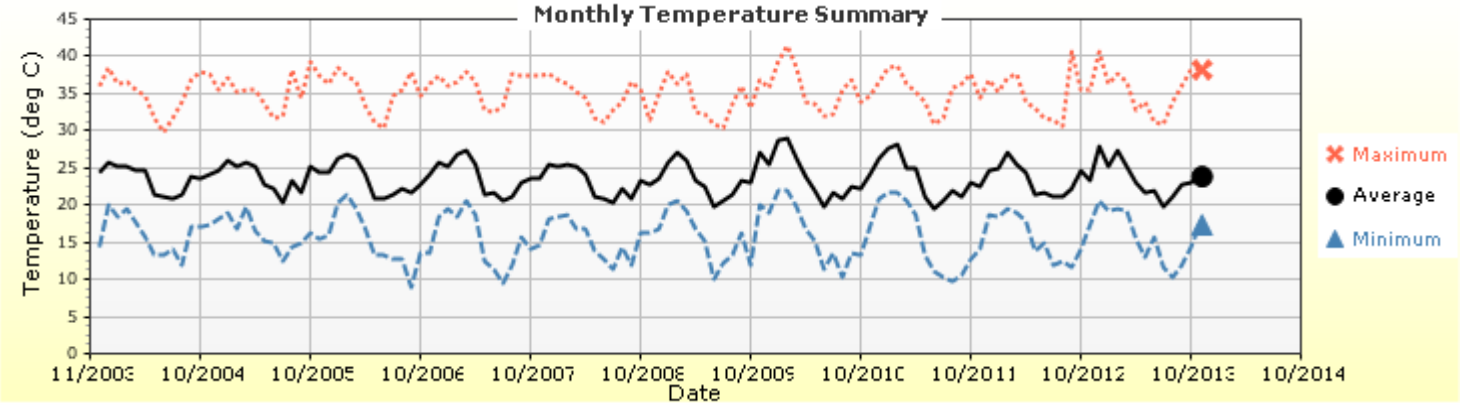


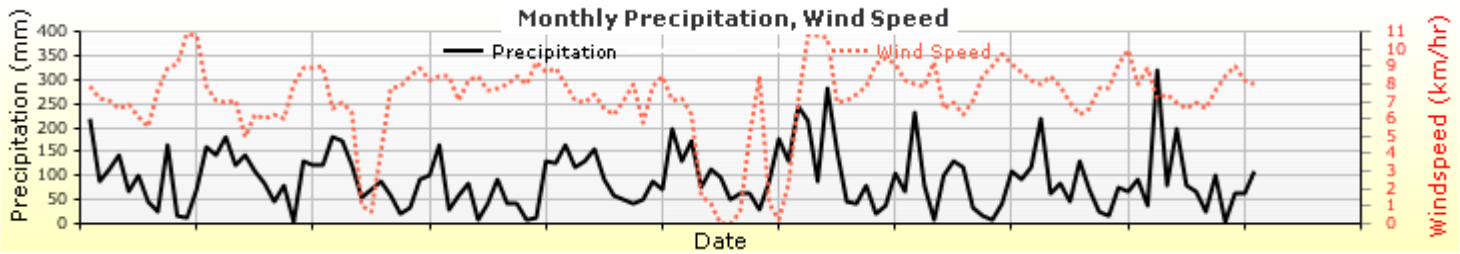
Annual Statistics:

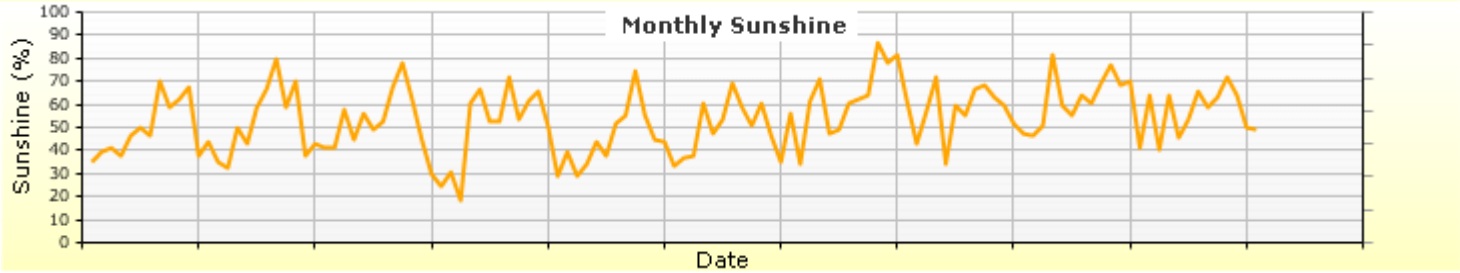
Mean annual air temperature (ºC)	23.59
Mean annual precipitation (mm)	1122.68
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

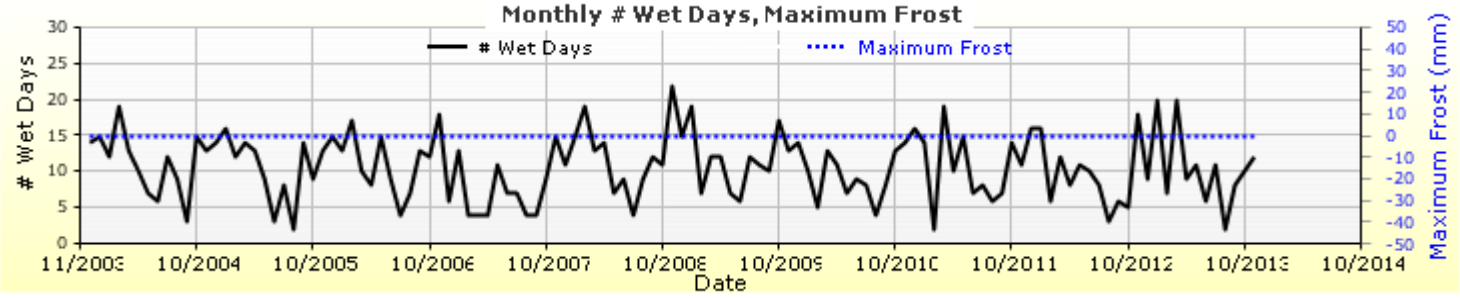
Water table depth (m): 3.05

Monthly Climate Summary:

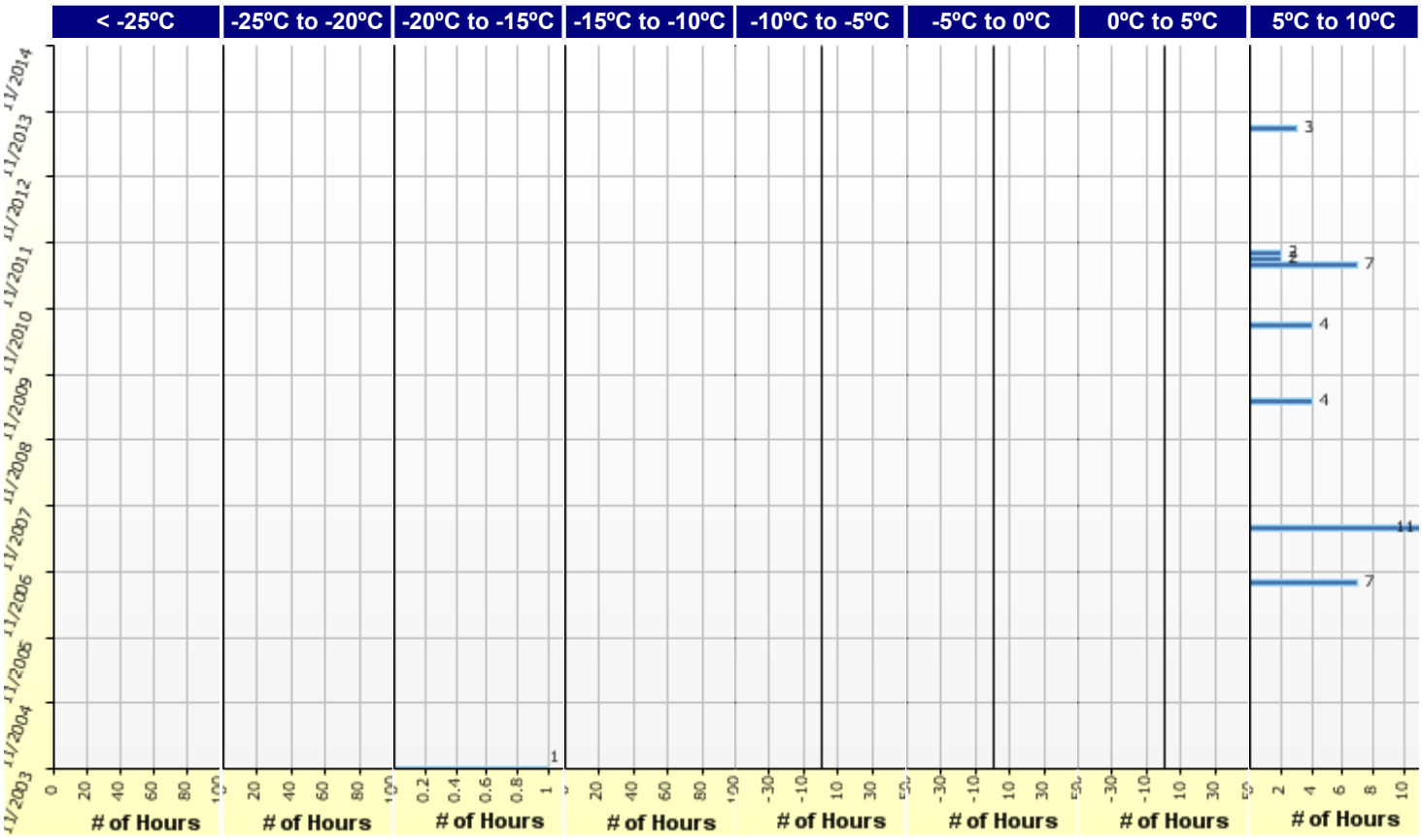


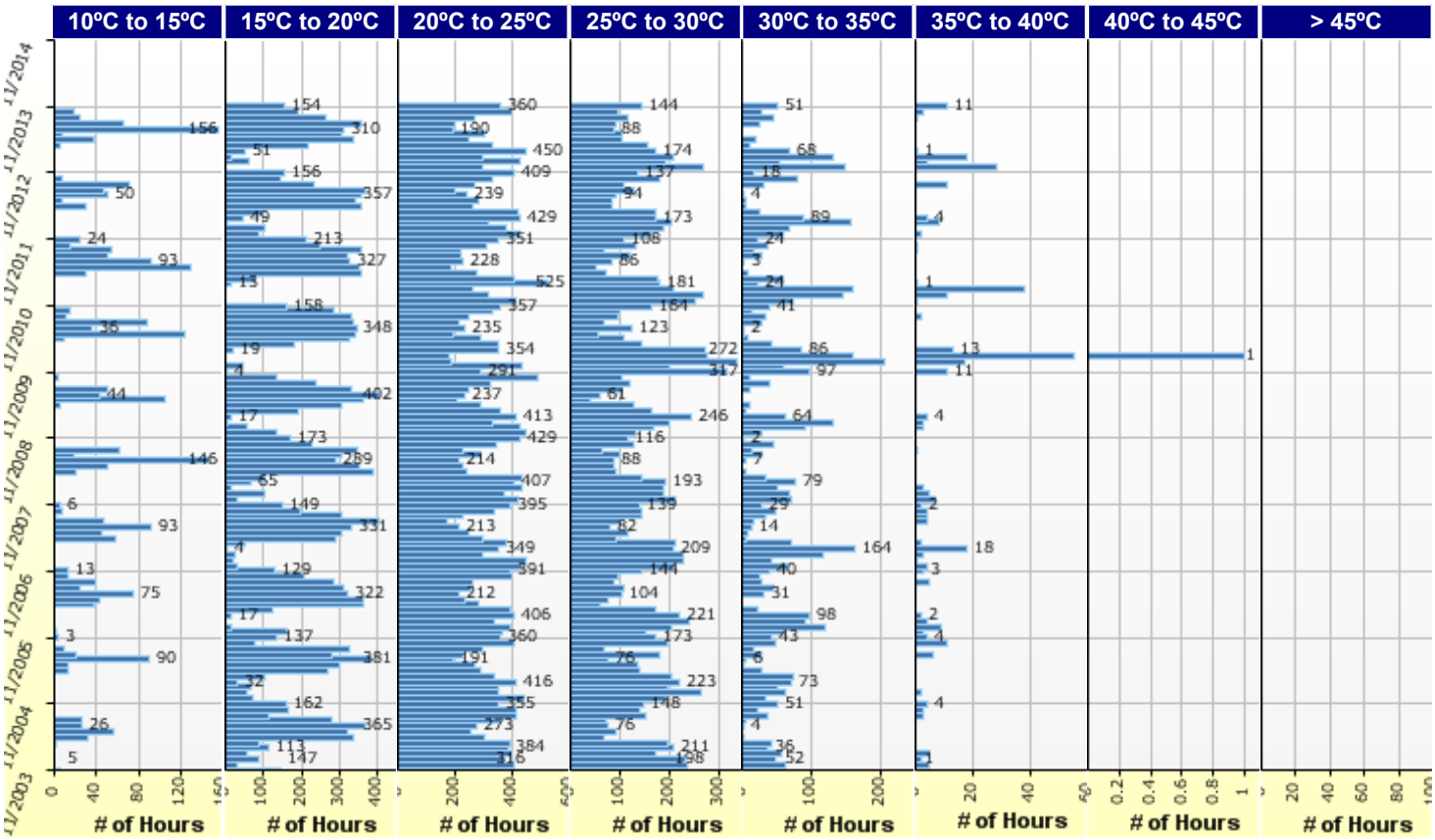






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

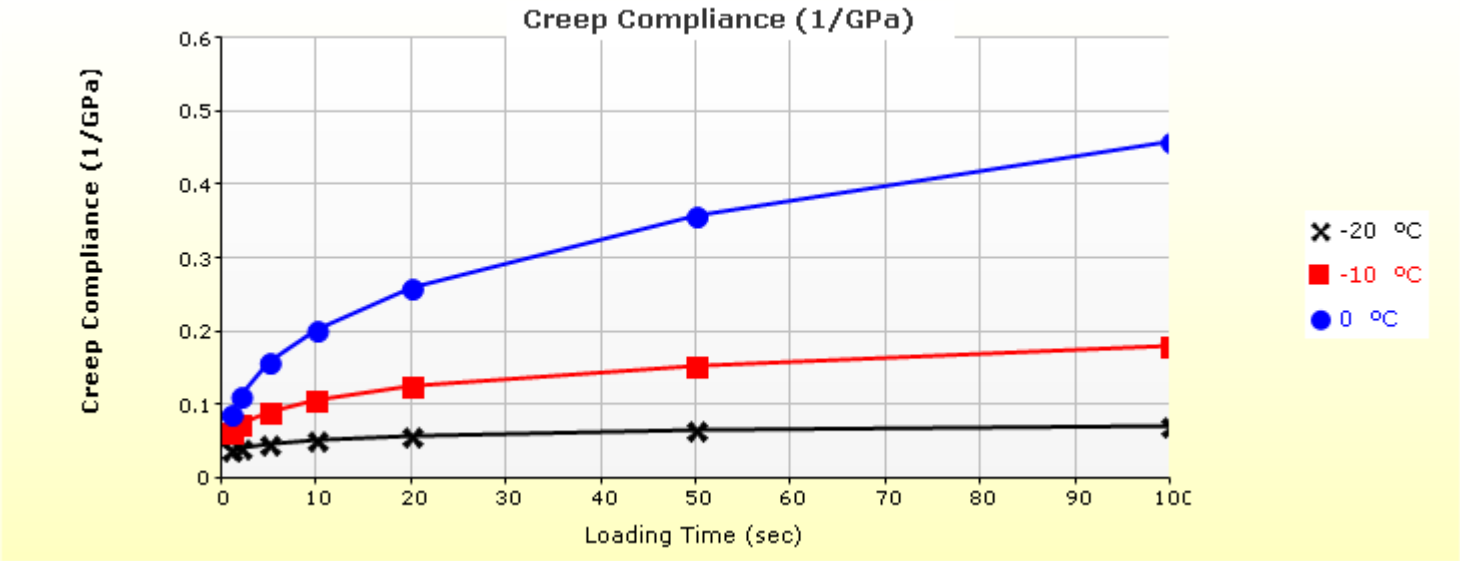
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

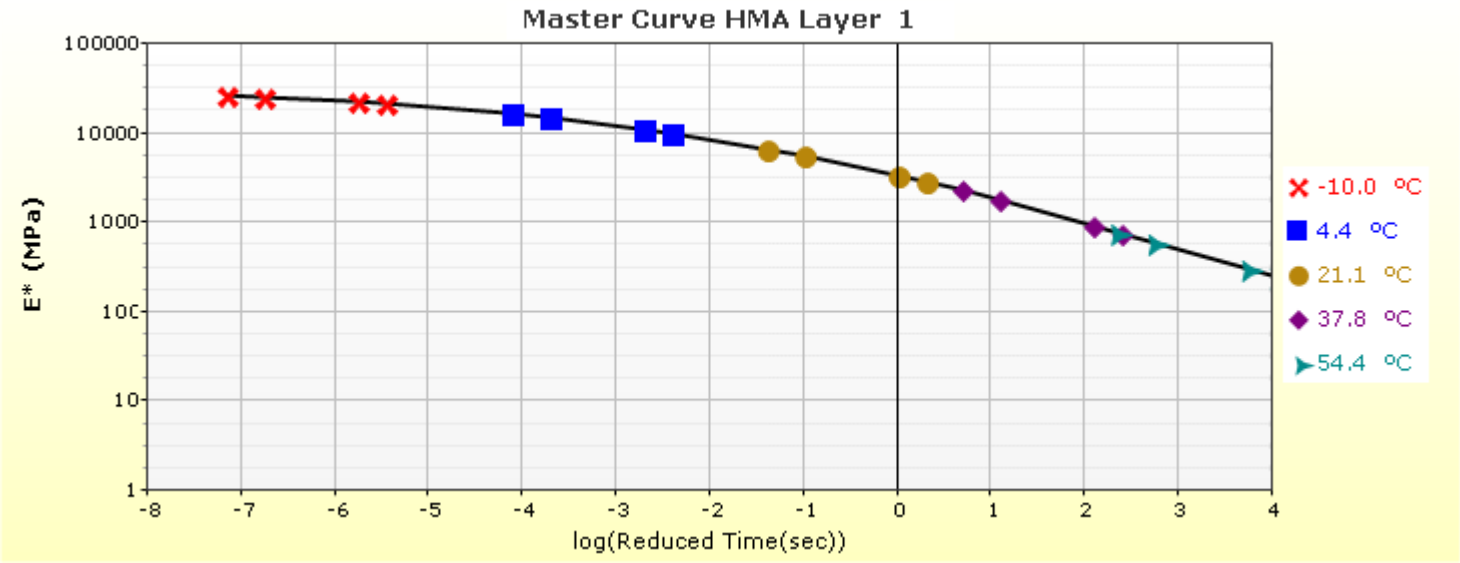
Indirect tensile strength at -10 ºC (MPa)	2.69

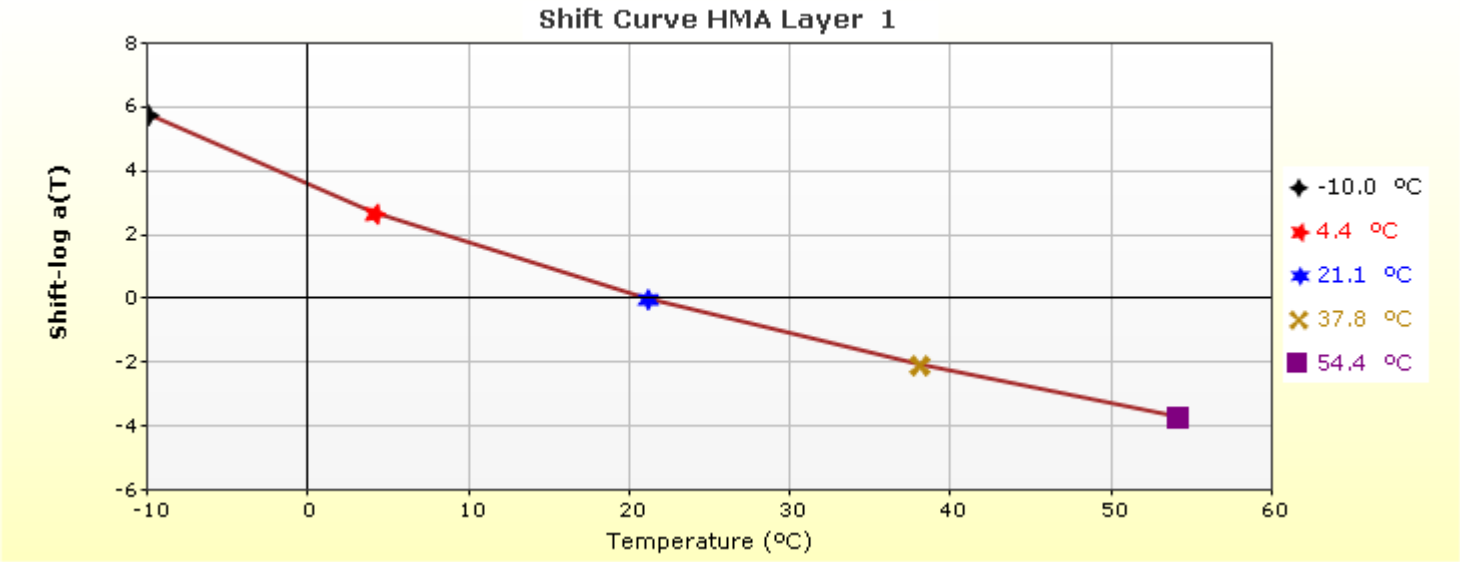
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

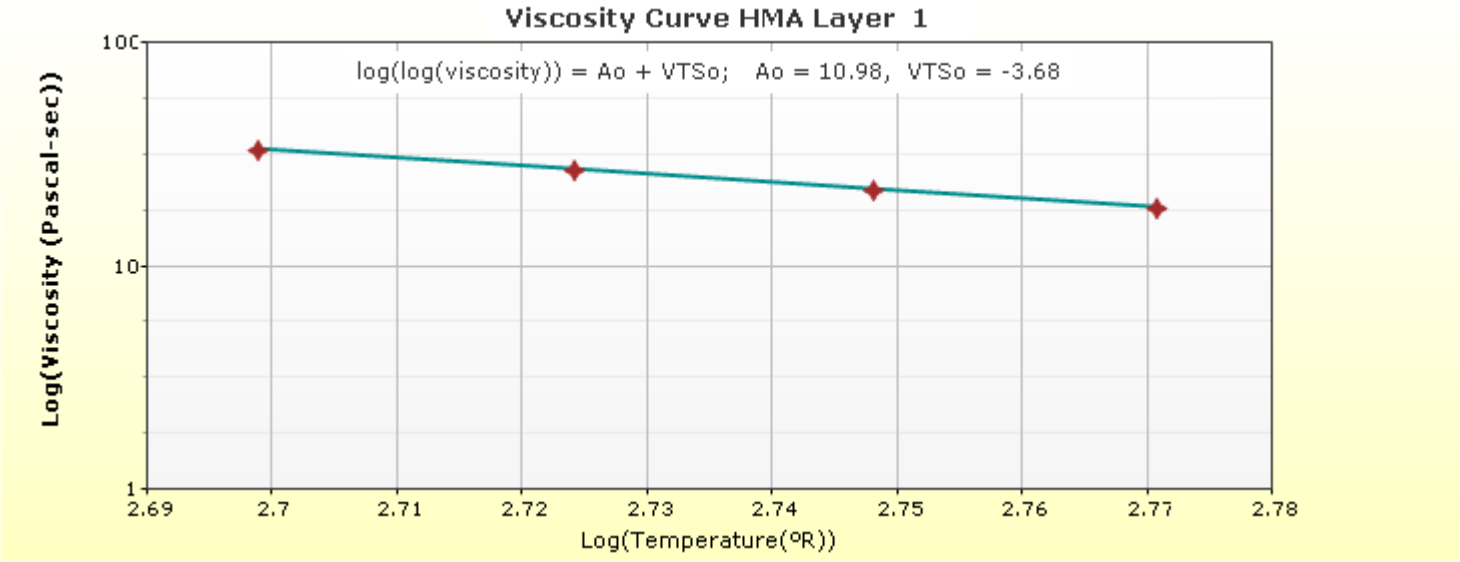
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



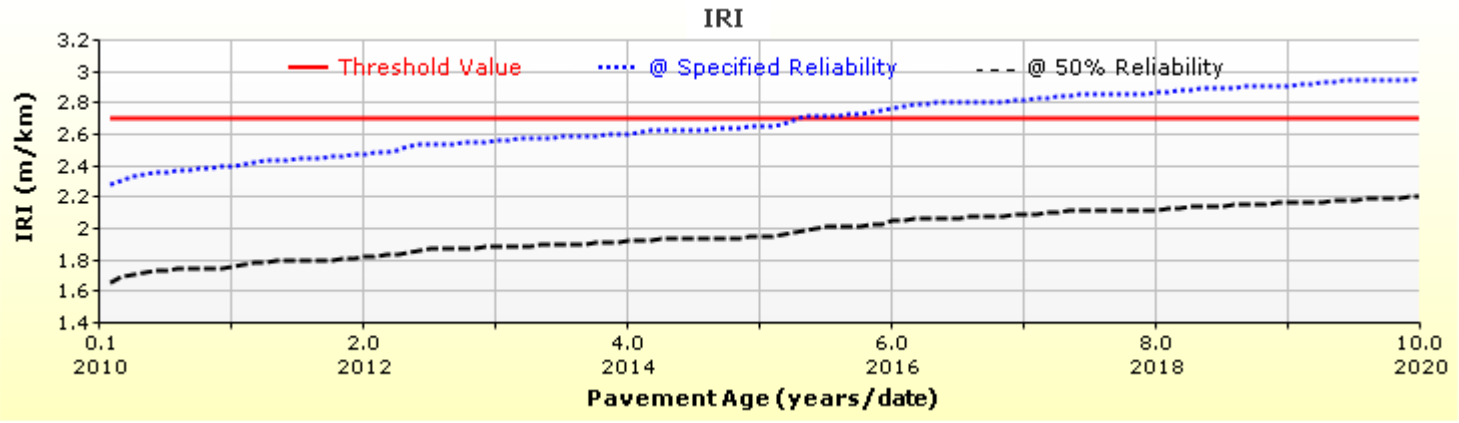
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

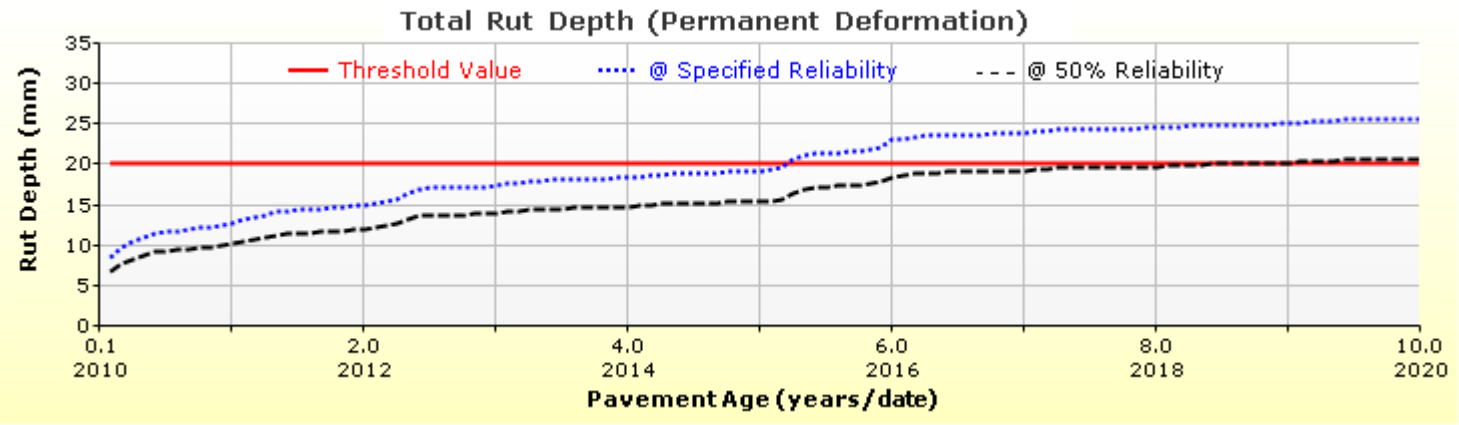


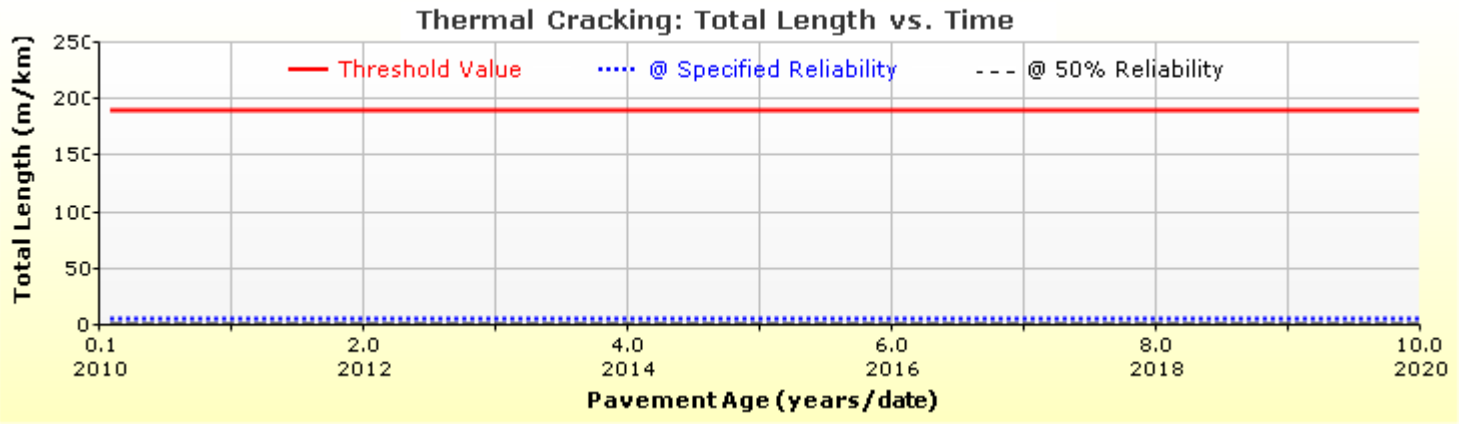


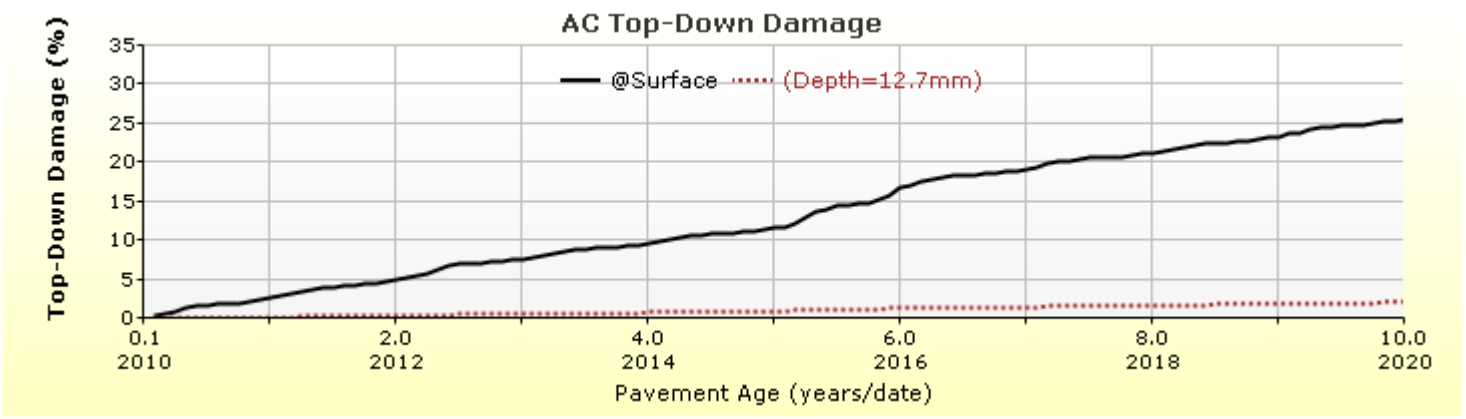


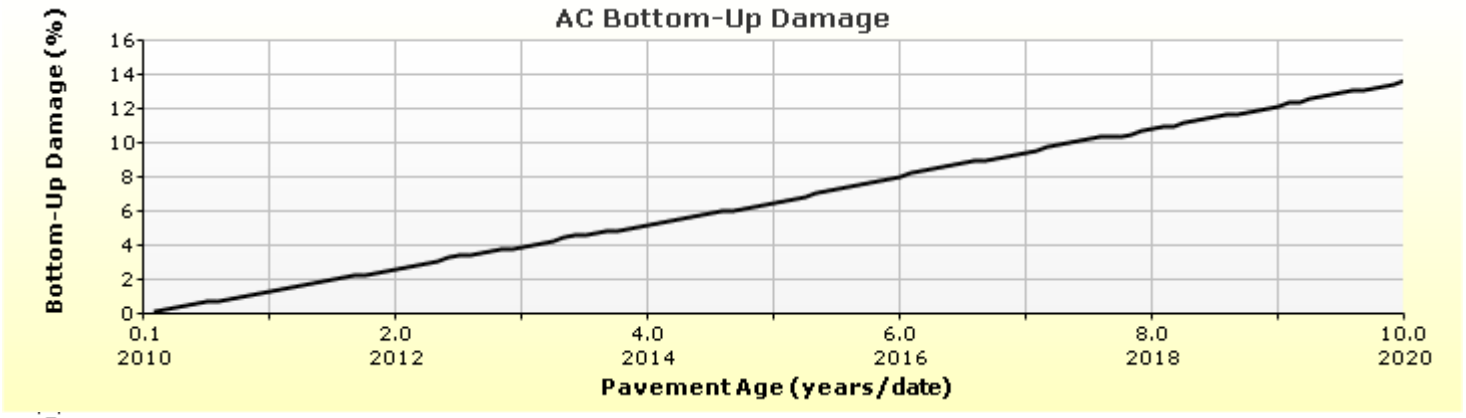
Analysis Output Charts

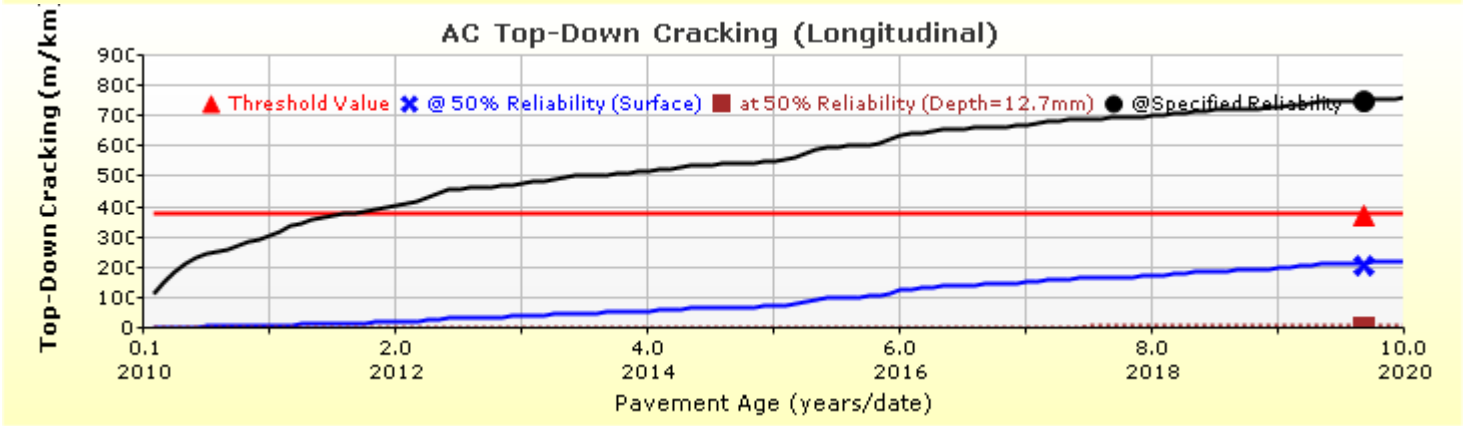


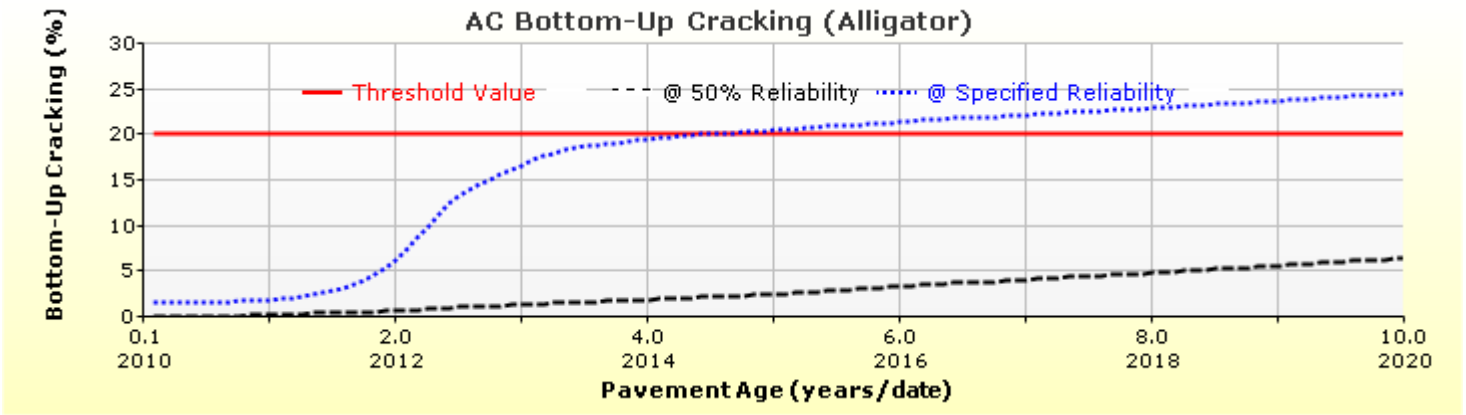


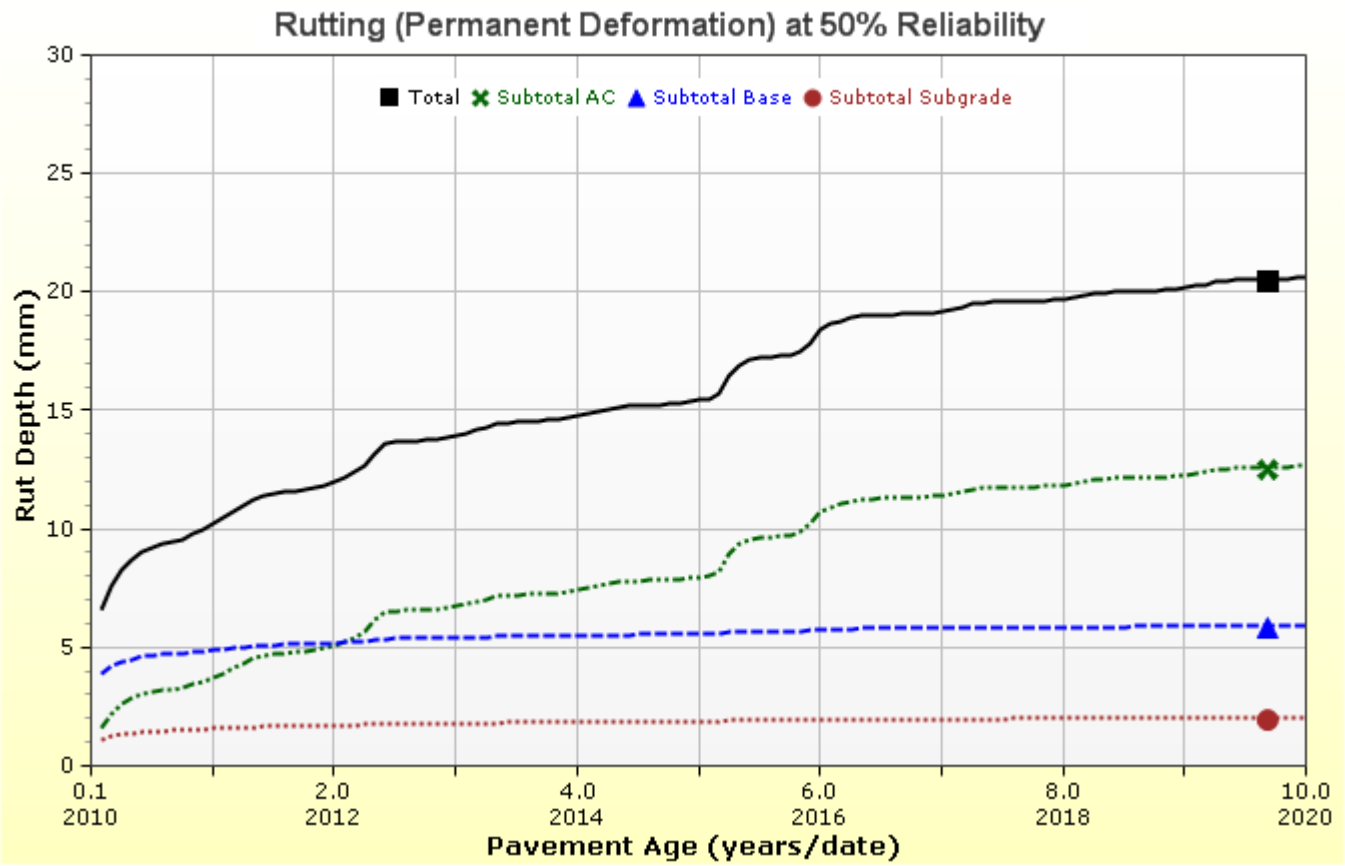


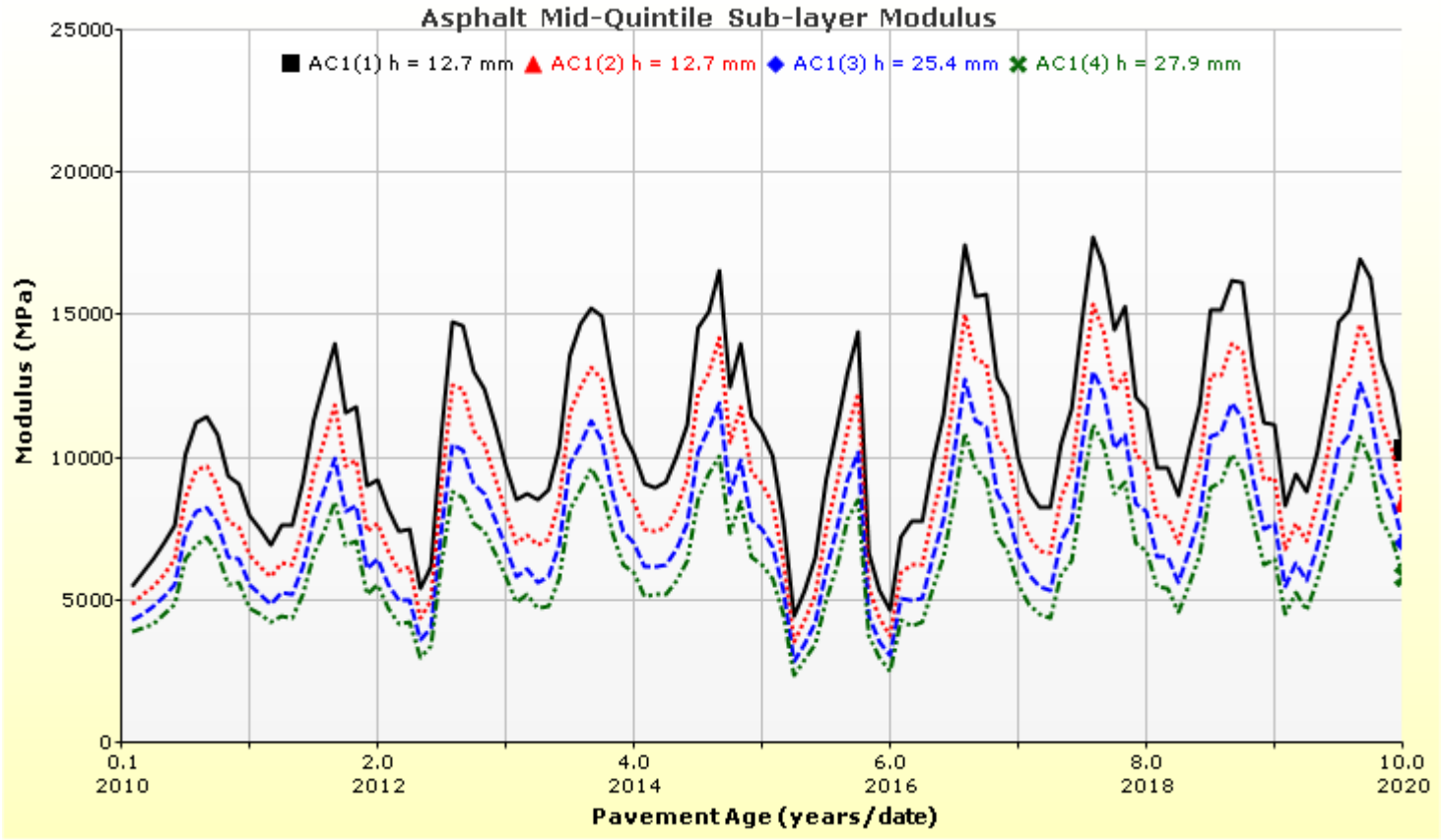

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
35
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

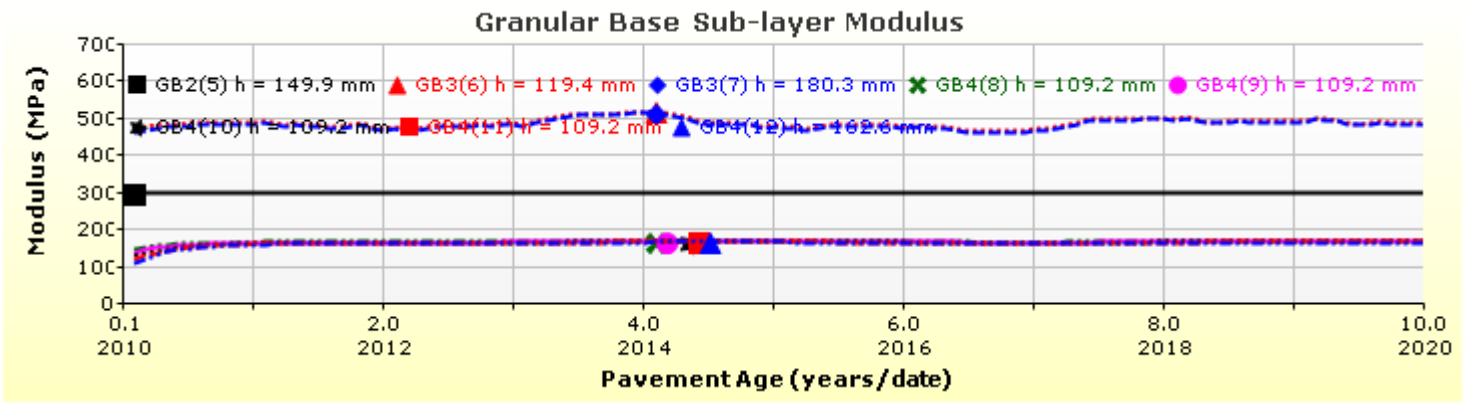

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

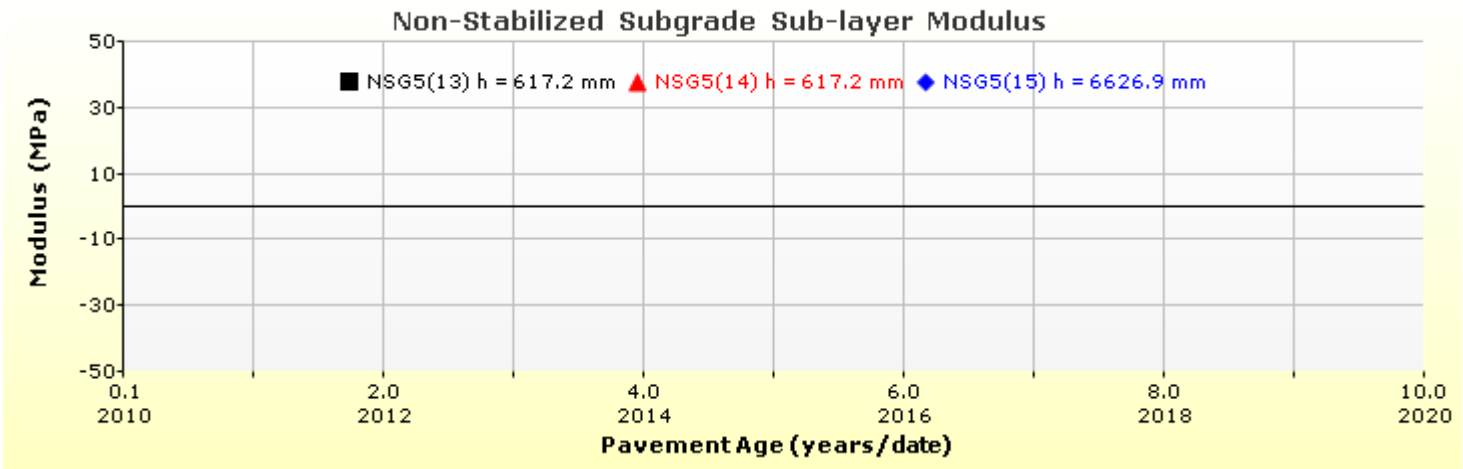

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
90
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
30
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 109.2 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2\beta_{r2}} N^{k_3\beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left({}^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left({}^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRJ+2

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRJ+2.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -22.8, -43.68

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

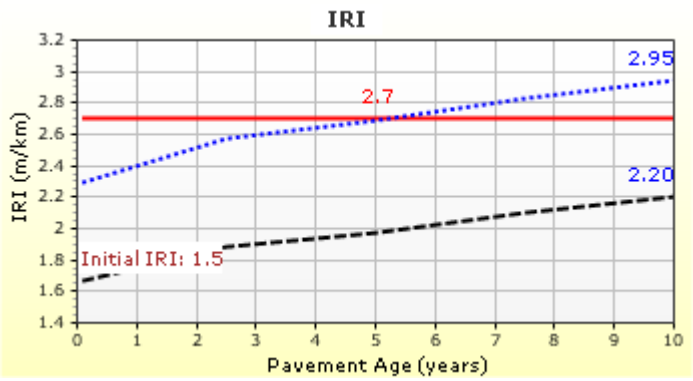
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

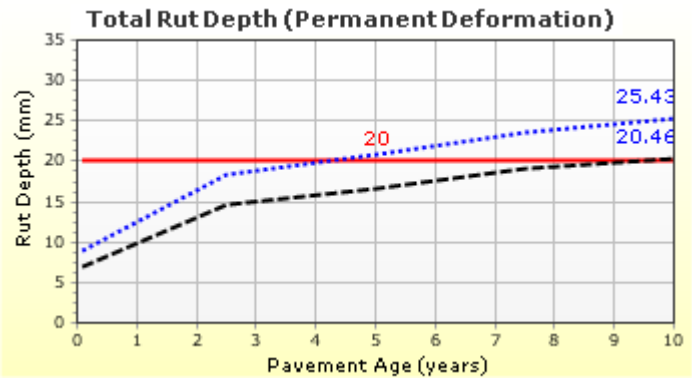
Design Outputs

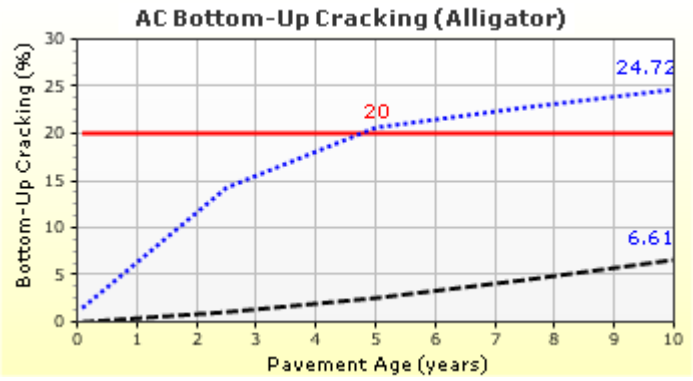
Distress Prediction Summary

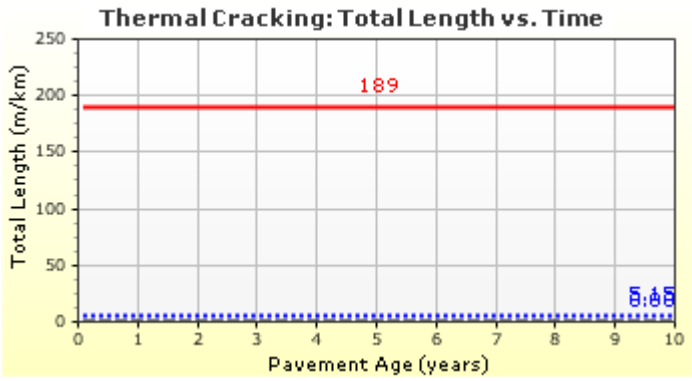
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.95	90.00	80.26	Fail
Permanent deformation - total pavement (mm)	20.00	25.43	90.00	45.20	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.72	90.00	82.83	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	777.98	90.00	63.10	Fail
Permanent deformation - AC only (mm)	5.00	12.55	50.00	1.52	Fail

Distress Charts







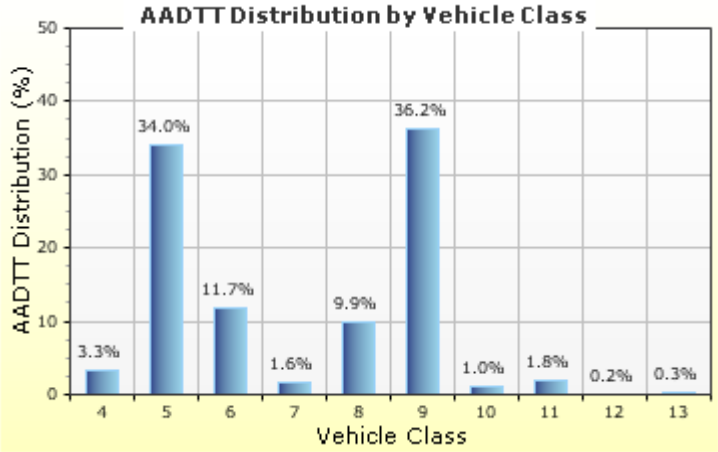


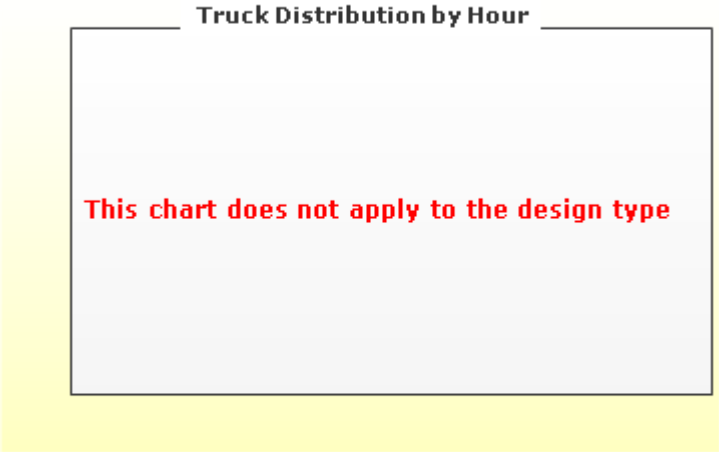


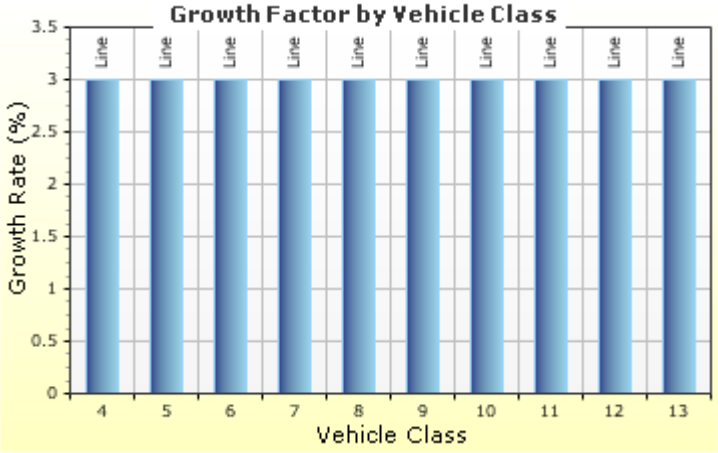
Traffic Inputs

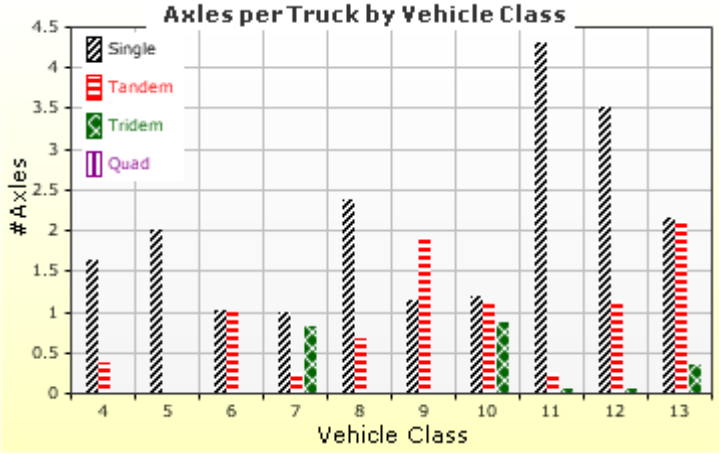
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

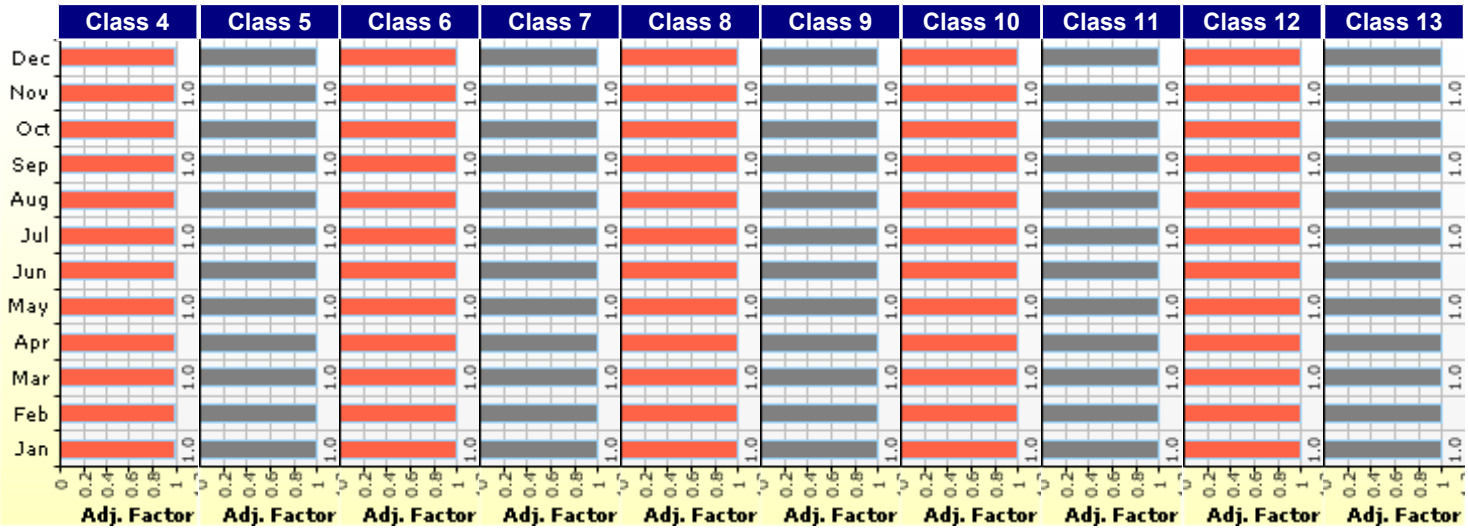








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

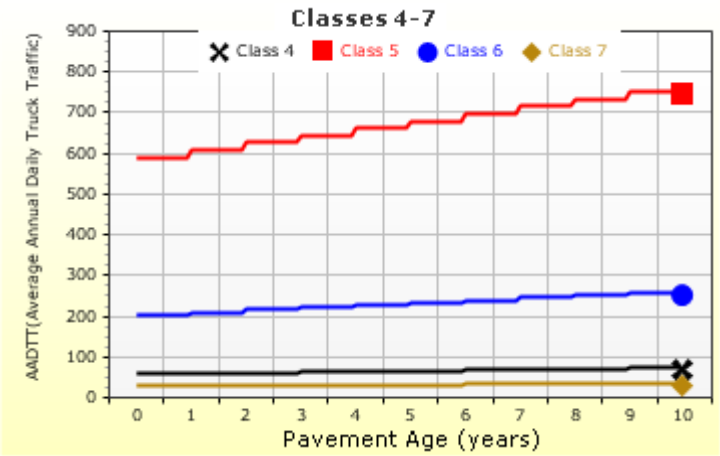
Wheelbase does not apply

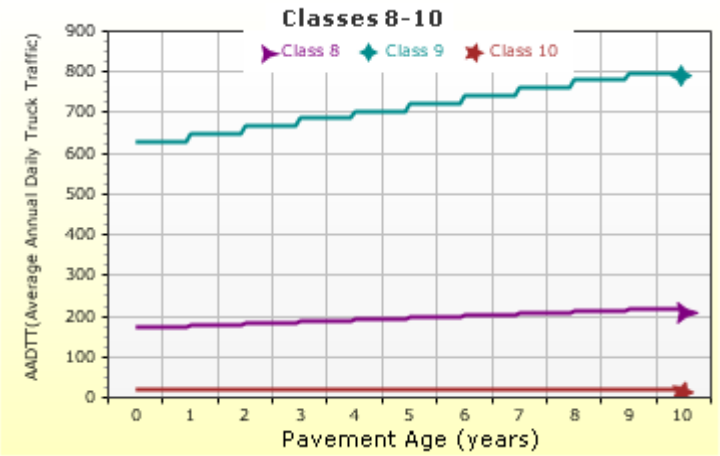
Number of Axles per Truck

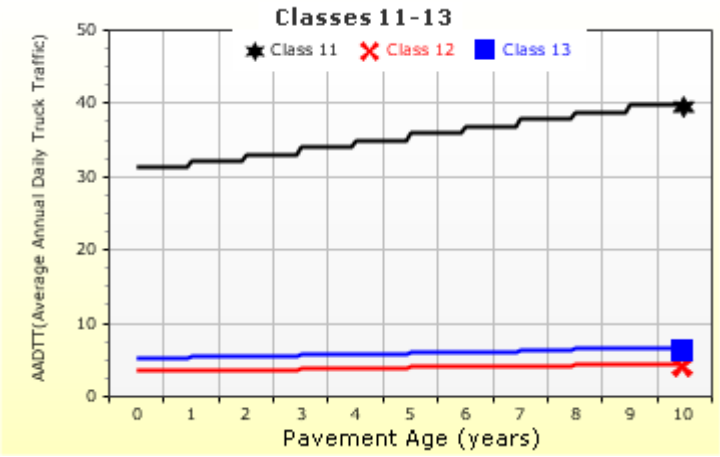
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

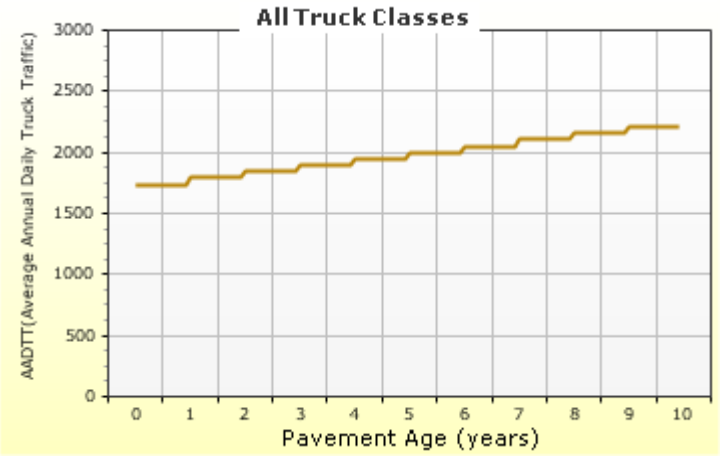
AADTT (Average Annual Daily Truck Traffic) Growth

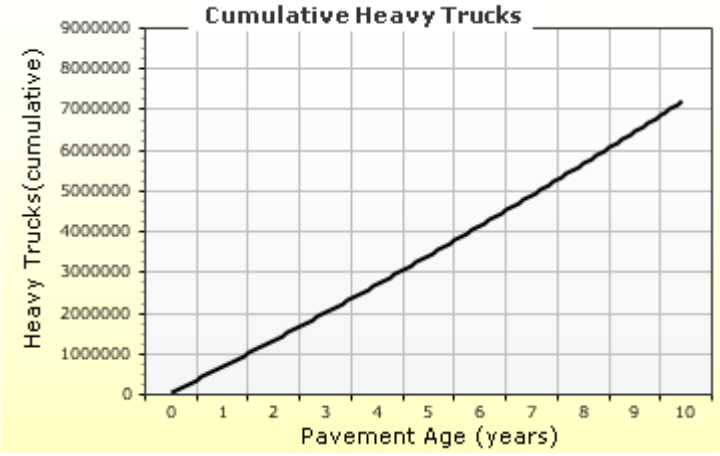
*** Traffic cap is not enforced**







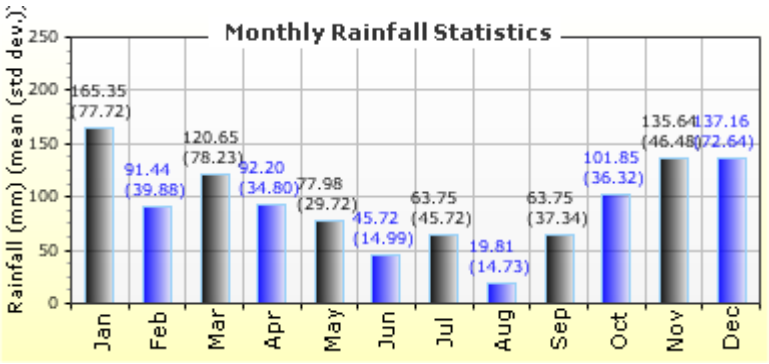




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
RIO DE JANEIRO, RJ	-22.80000 -43.68000 28

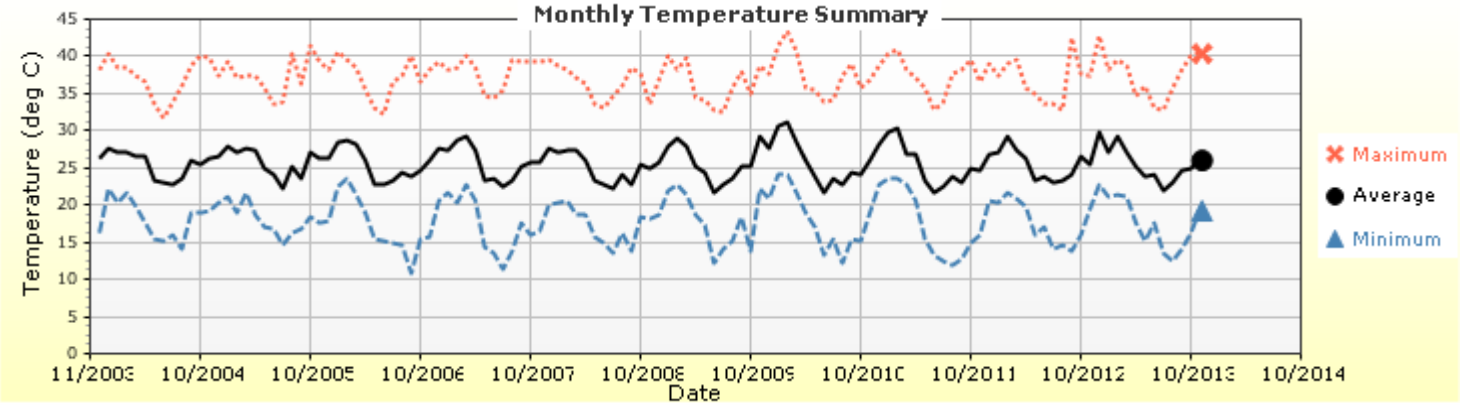


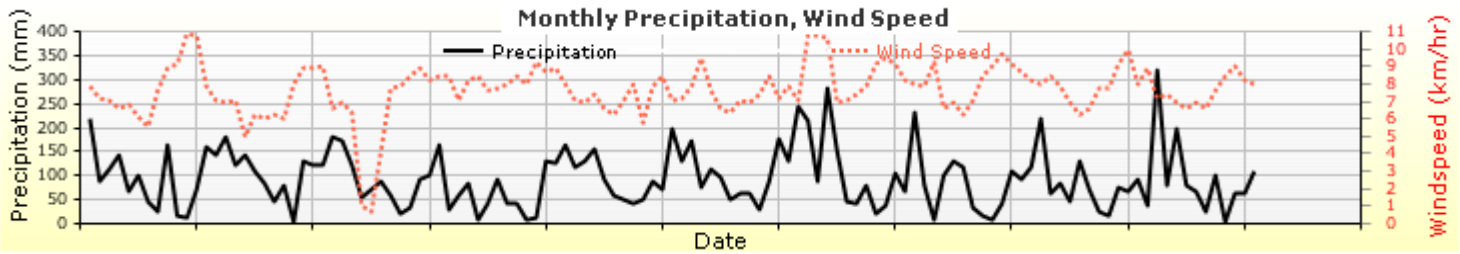
Annual Statistics:

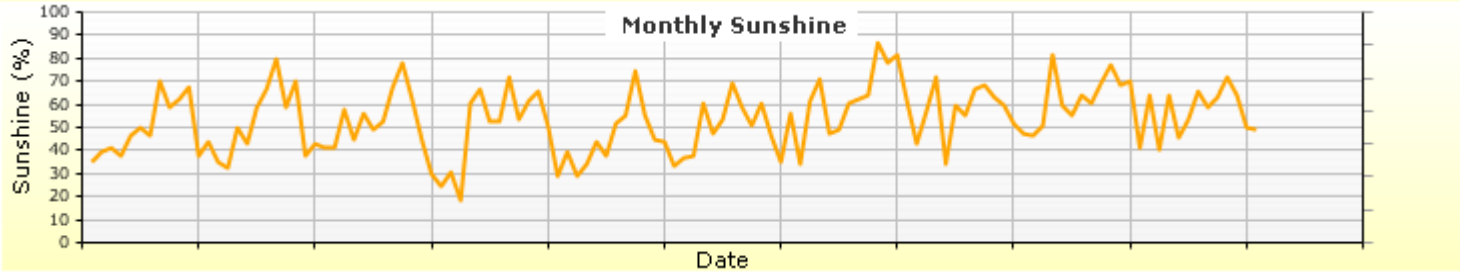
Mean annual air temperature (ºC)	25.59
Mean annual precipitation (mm)	1122.68
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

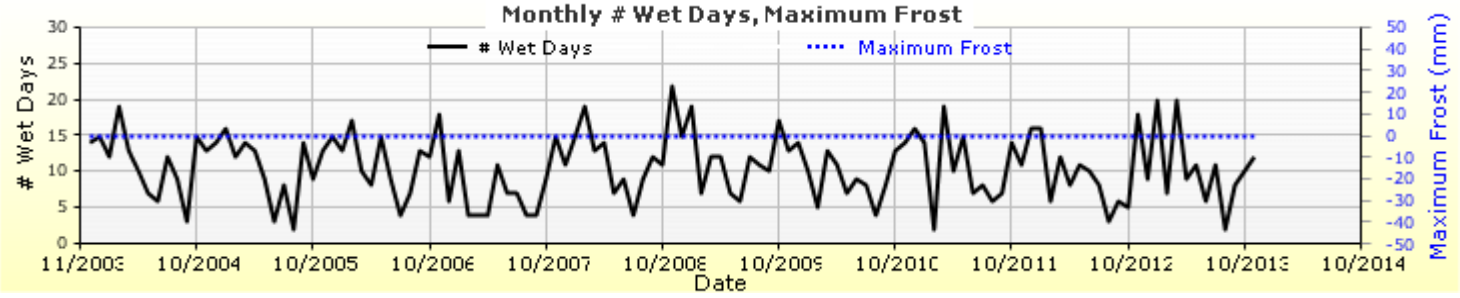
Water table depth (m): 3.05

Monthly Climate Summary:

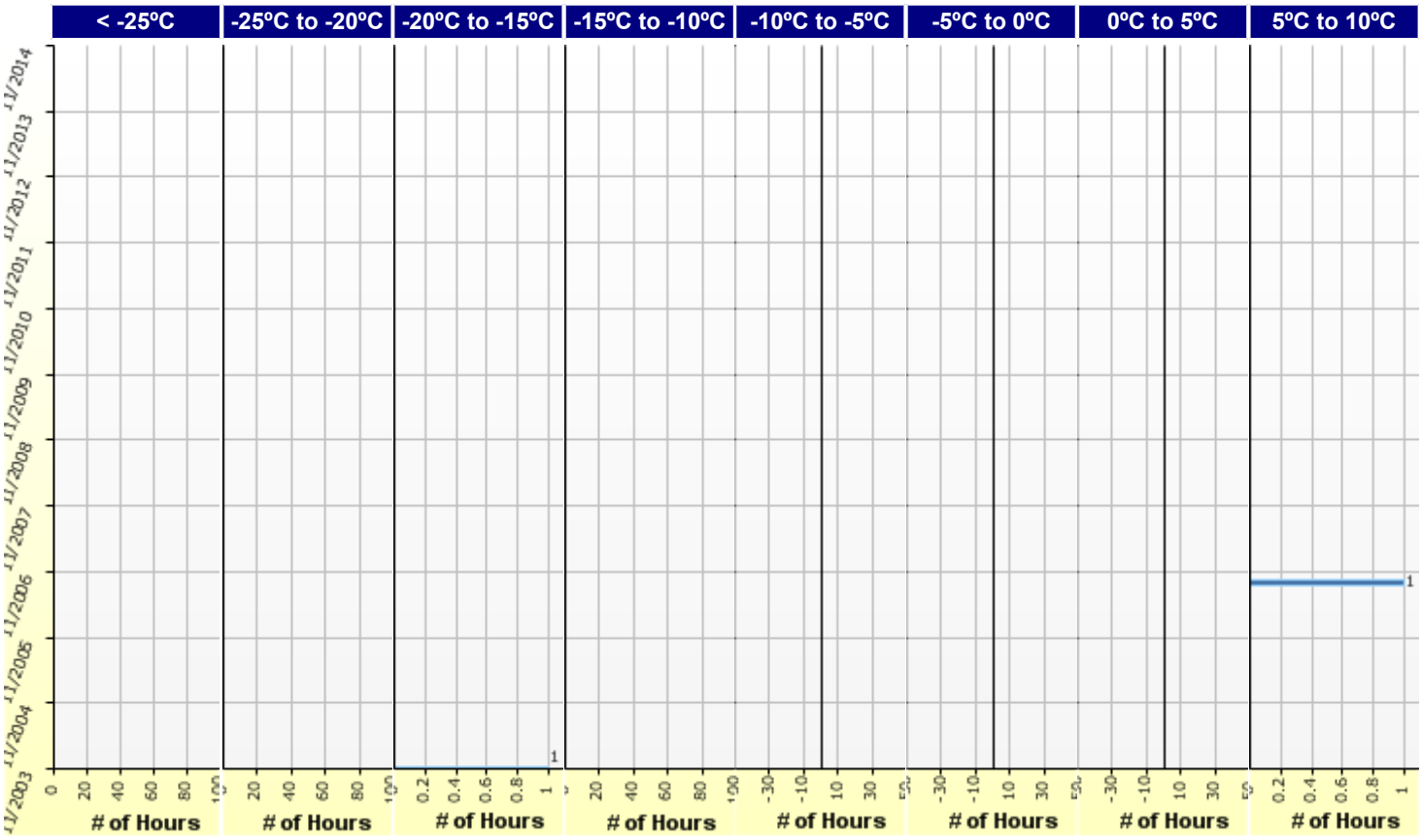


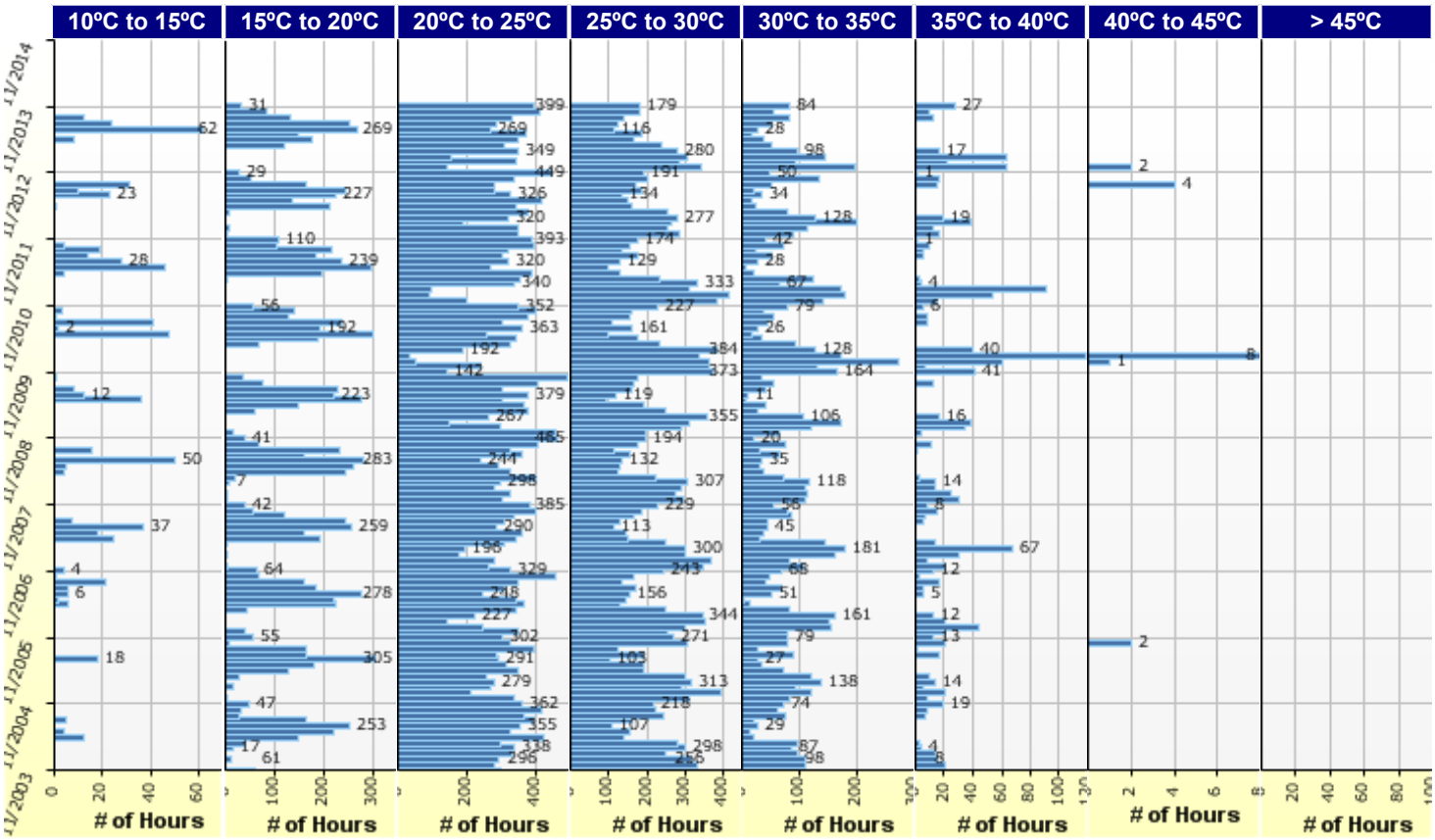






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

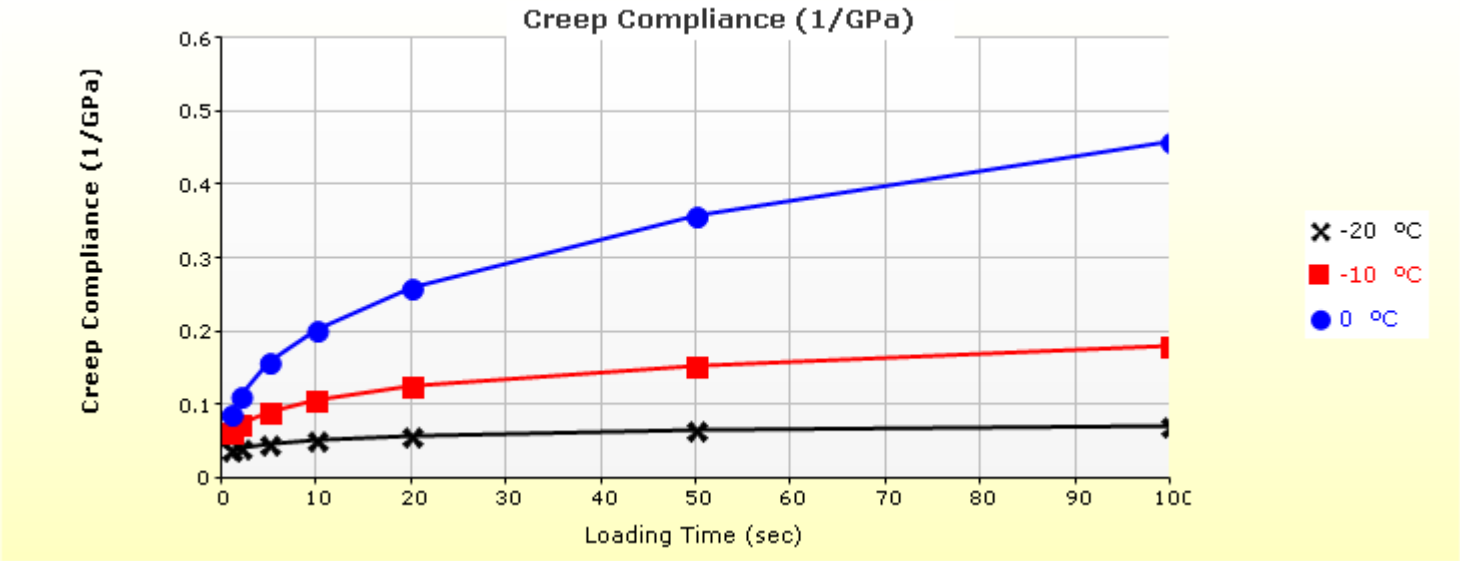
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

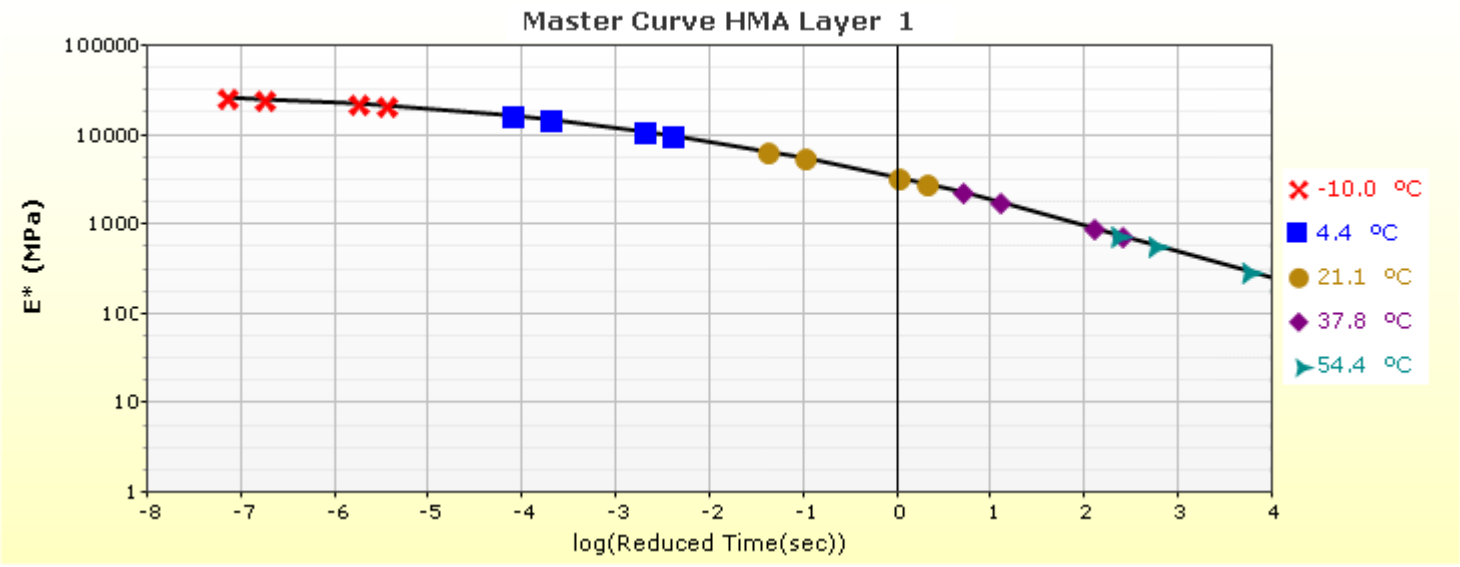
Indirect tensile strength at -10 ºC (MPa)	2.69

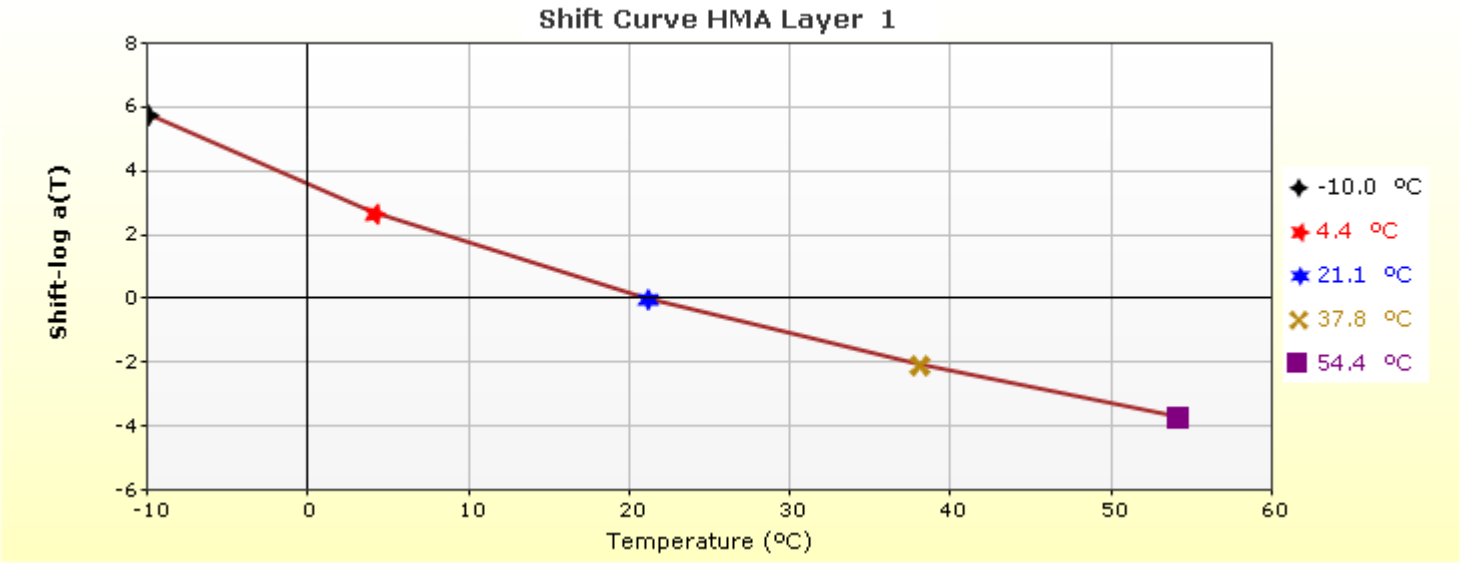
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

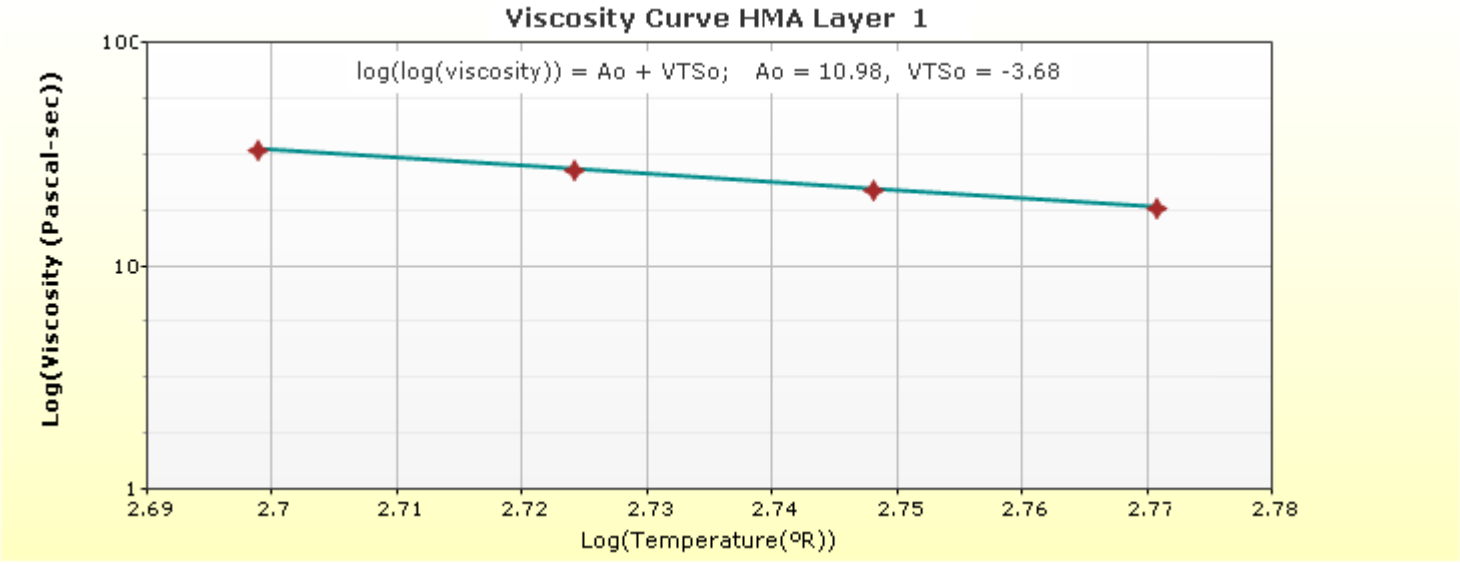
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



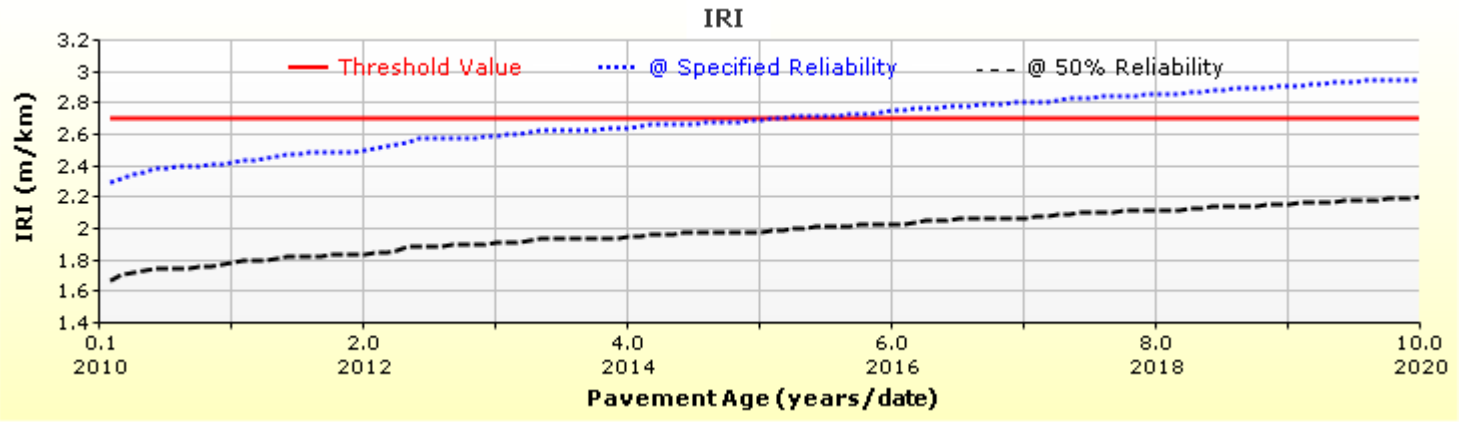
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

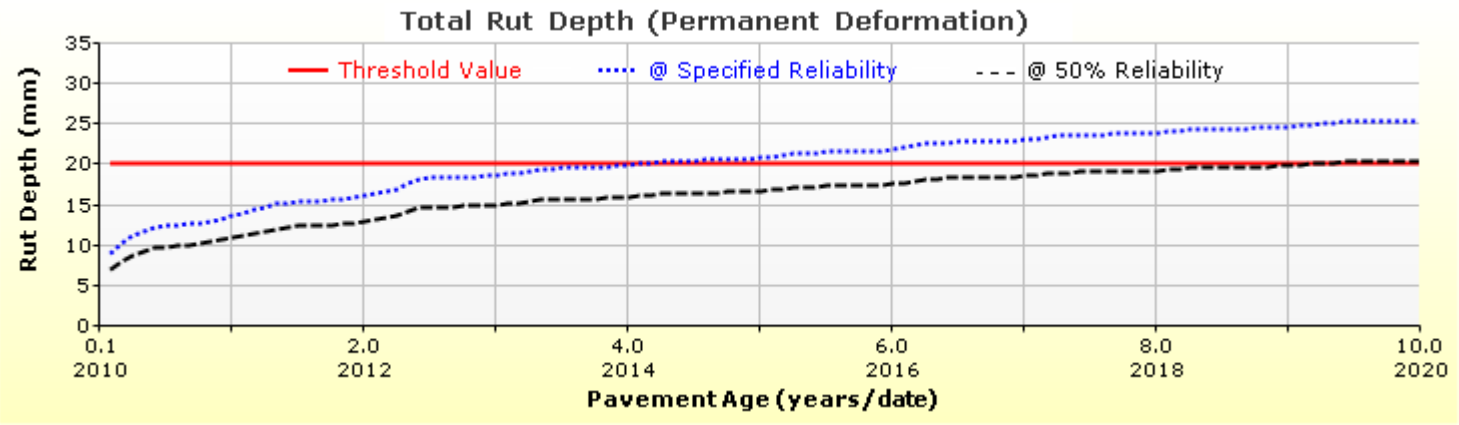


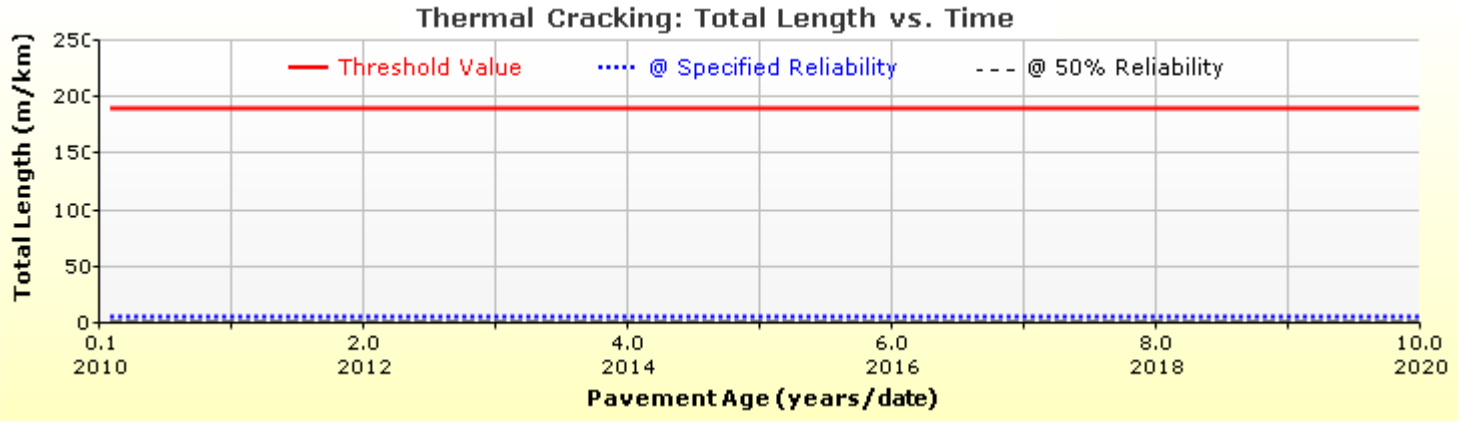


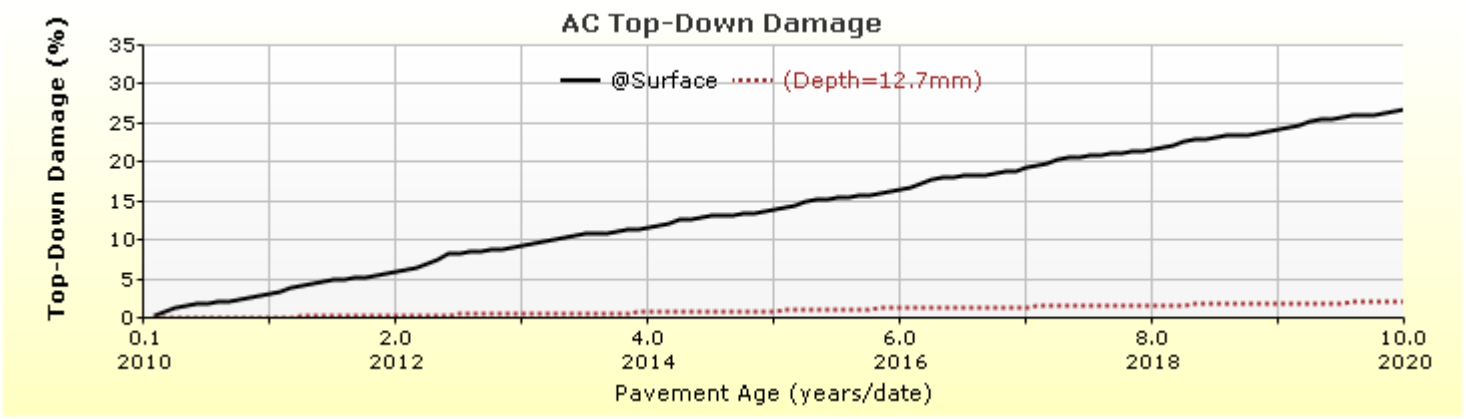


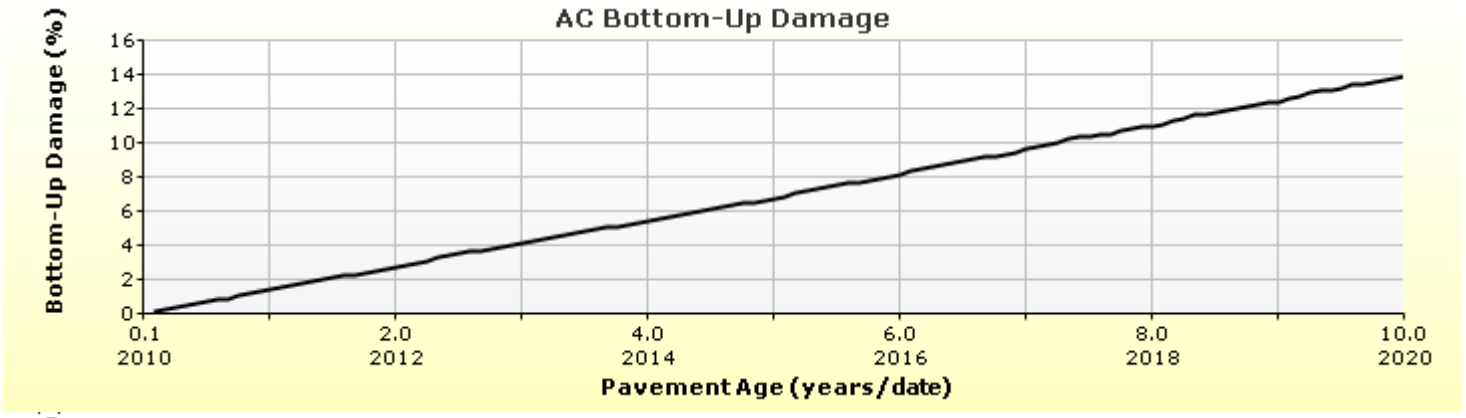
Analysis Output Charts

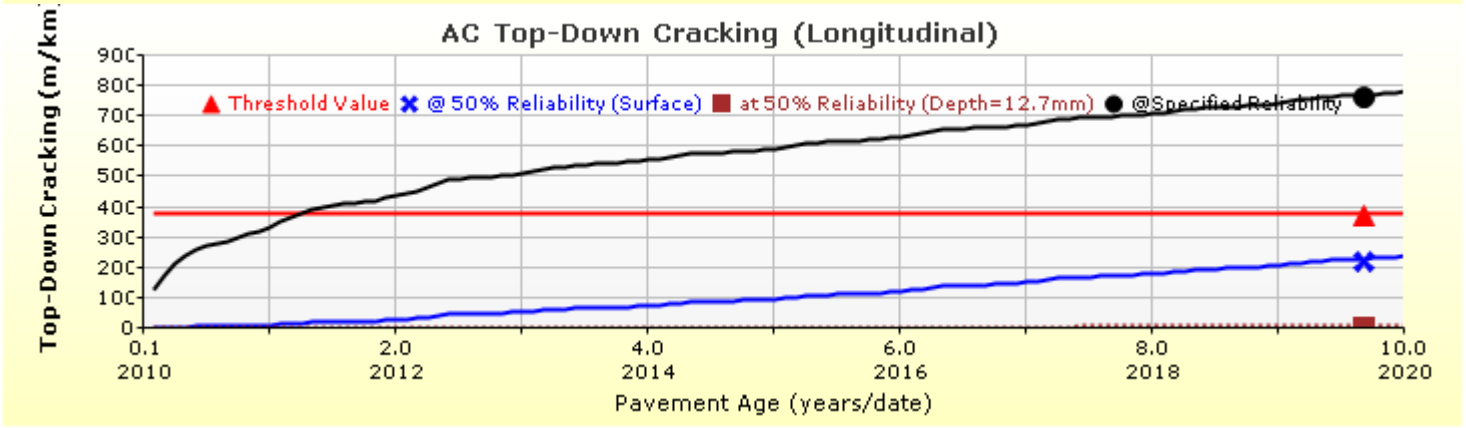


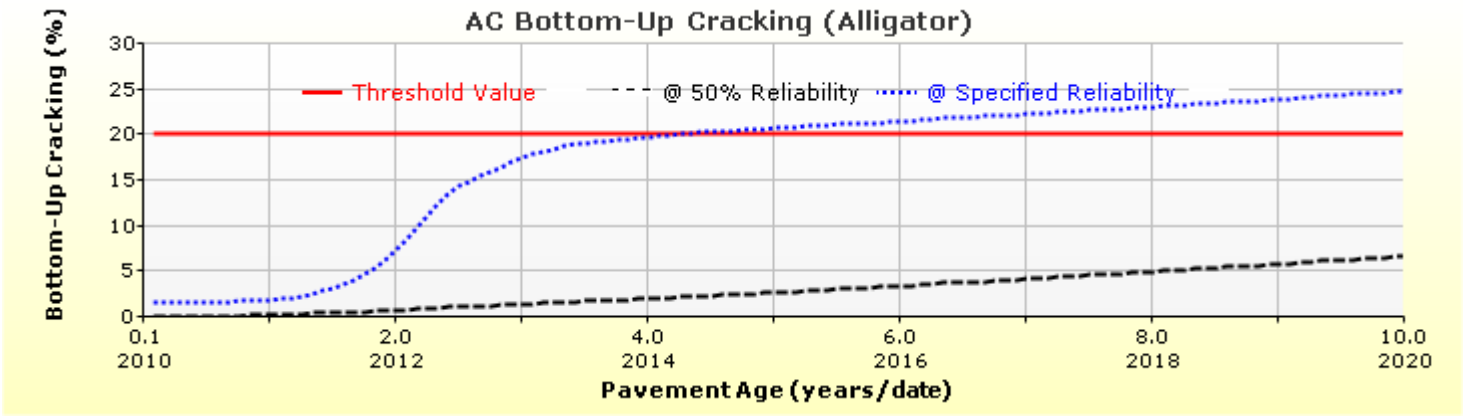


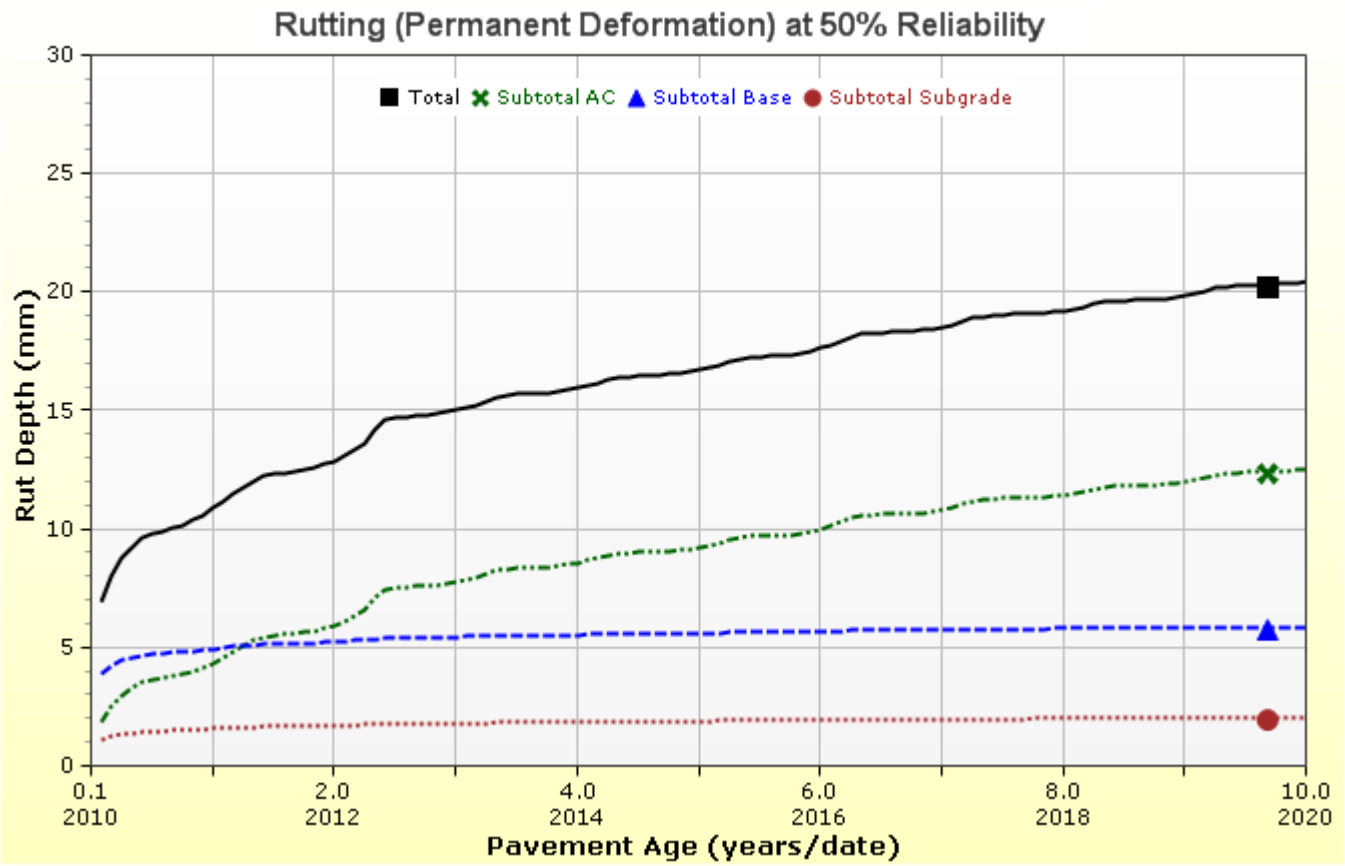


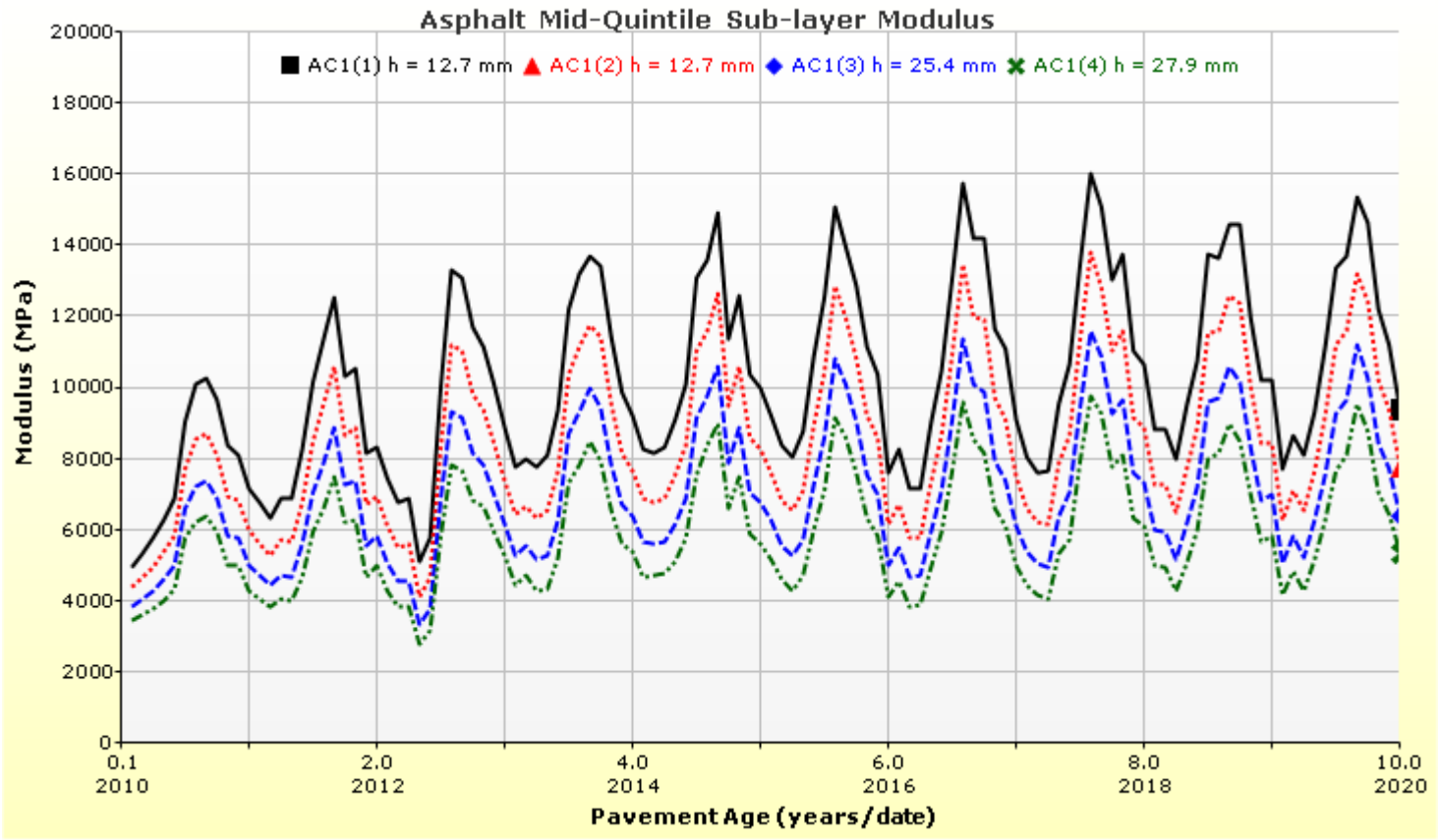

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
35
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

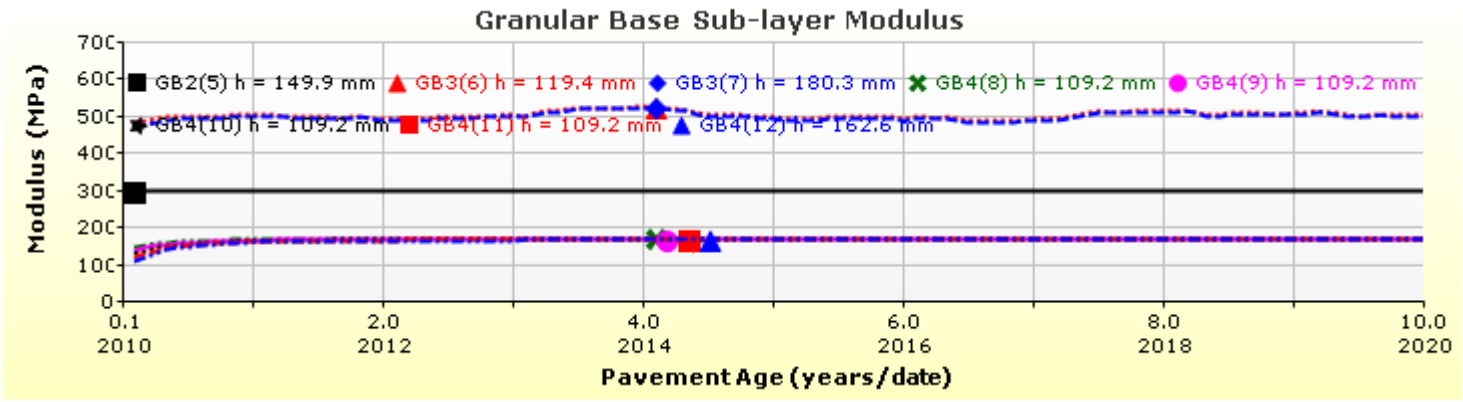

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)

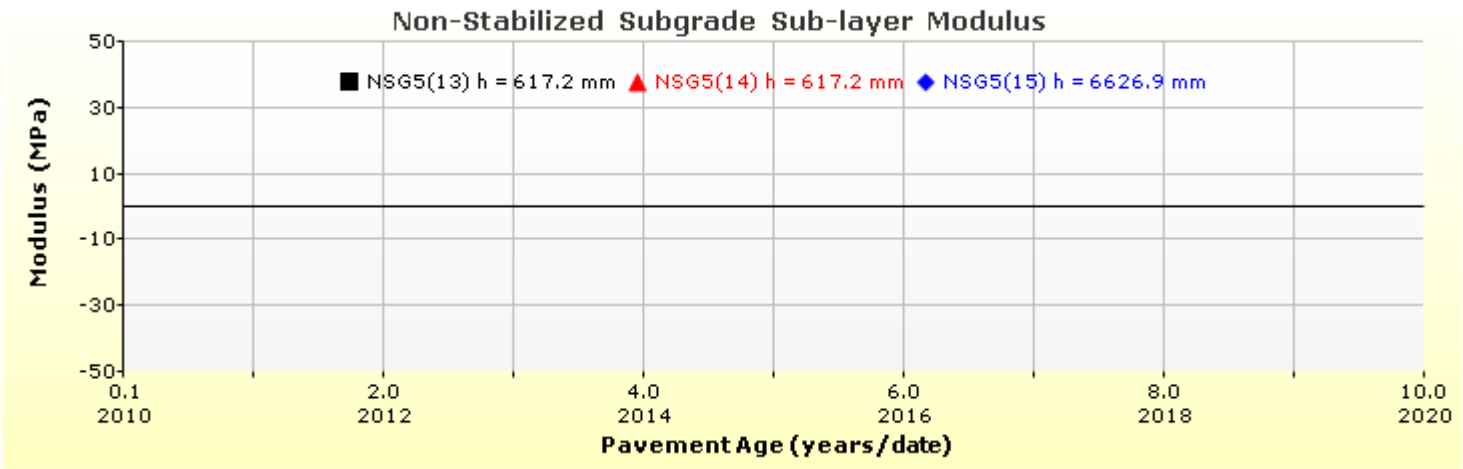

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
900
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2.0
4.0
6.0
8.0
10.0
2010
2012
2014
2016
2018
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
30
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$

$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$

$T = layer\ temperature(^{\circ}F)$

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRJ+4

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRJ+4.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -22.8, -43.68

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

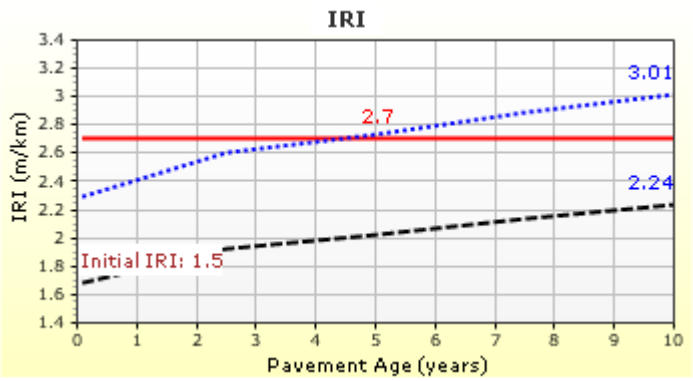
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

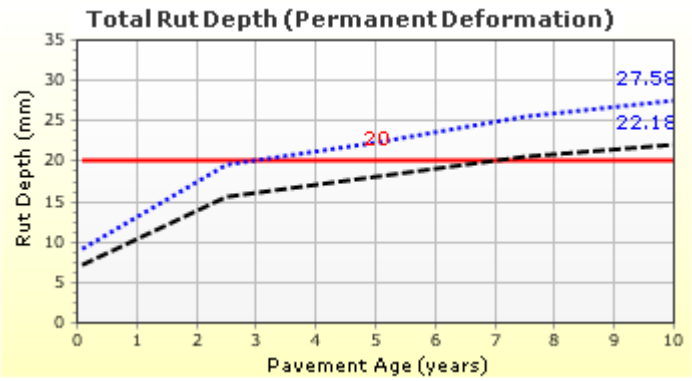
Design Outputs

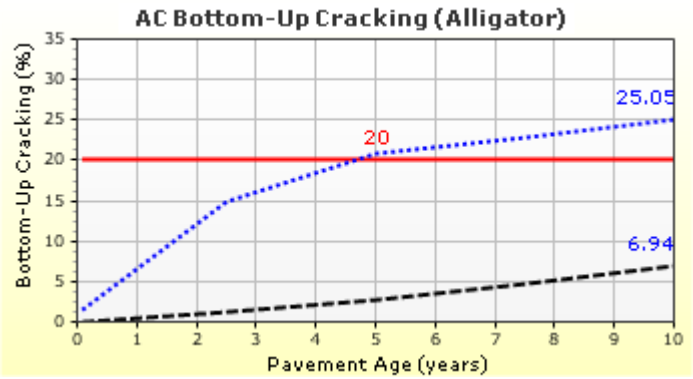
Distress Prediction Summary

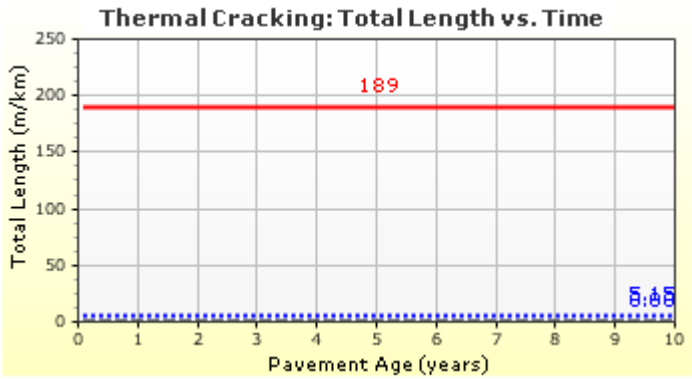
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	3.01	90.00	77.59	Fail
Permanent deformation - total pavement (mm)	20.00	27.58	90.00	30.17	Fail
AC bottom-up fatigue cracking (percent)	20.00	25.05	90.00	82.23	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	845.32	90.00	57.63	Fail
Permanent deformation - AC only (mm)	5.00	14.24	50.00	0.83	Fail

Distress Charts







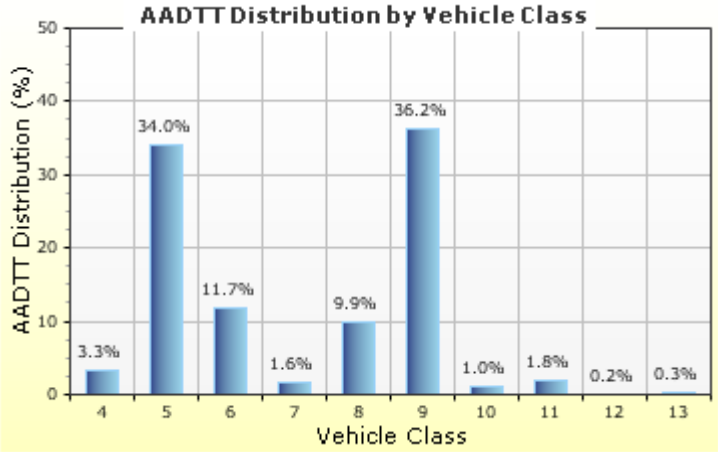


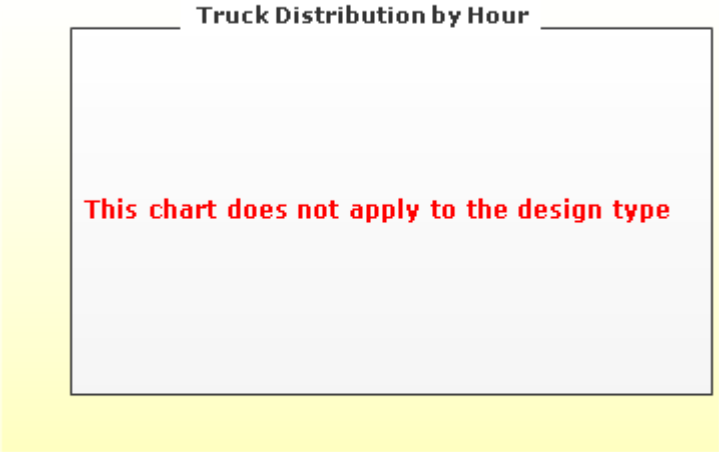


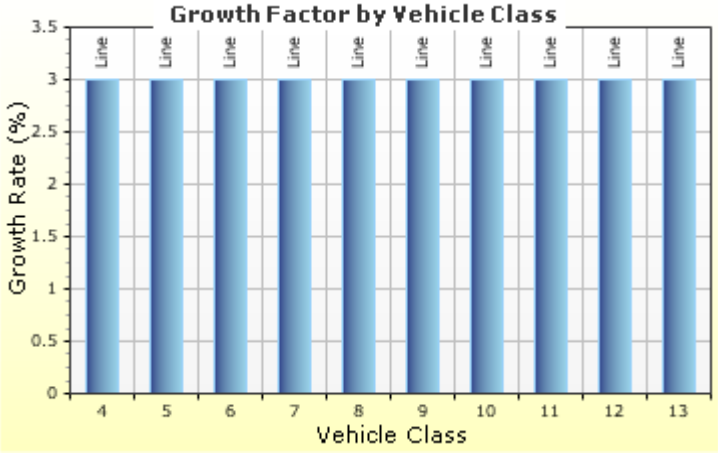
Traffic Inputs

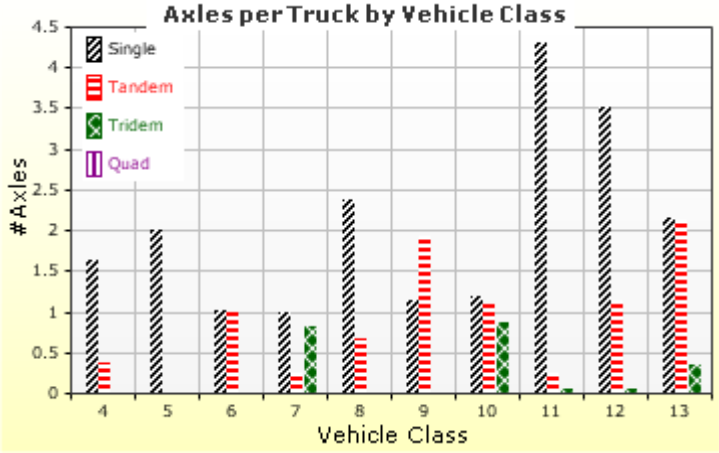
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

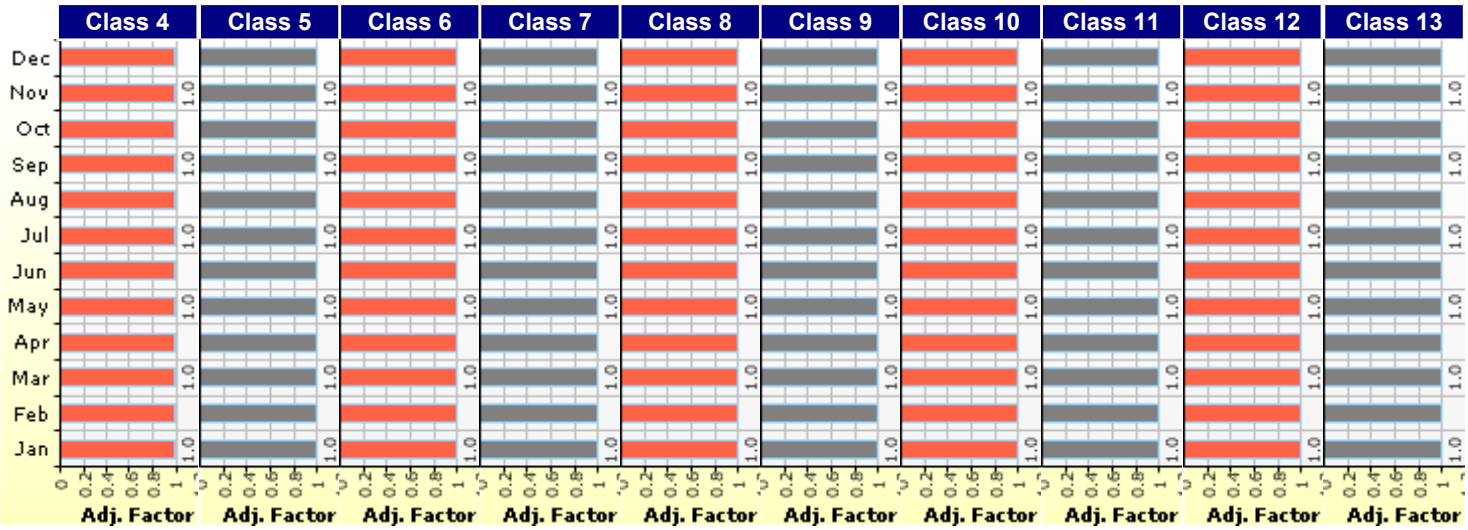








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

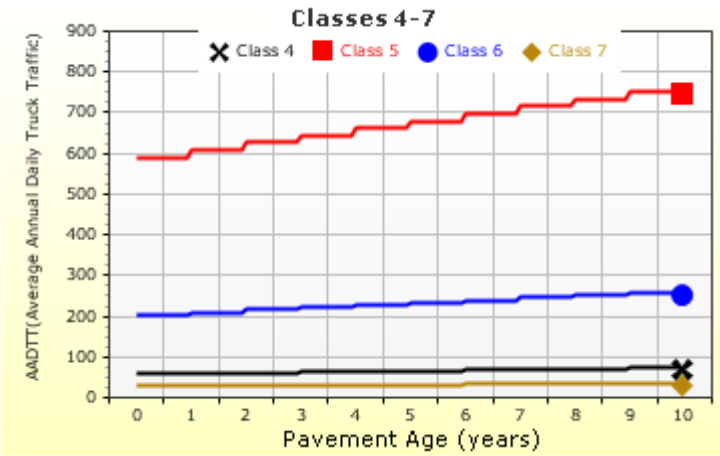
Wheelbase does not apply

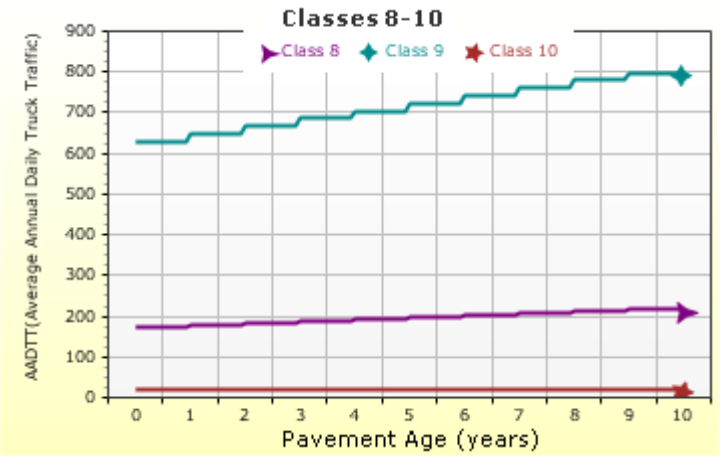
Number of Axles per Truck

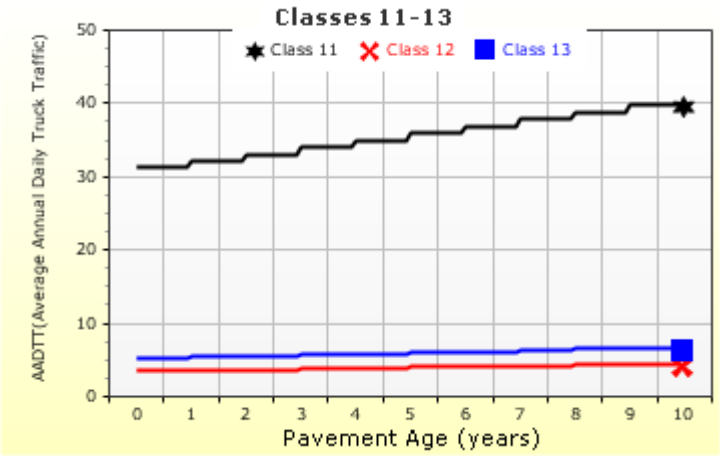
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

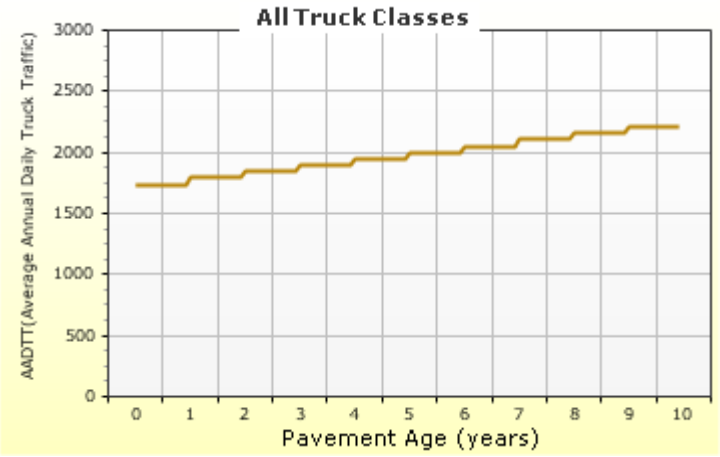
AADTT (Average Annual Daily Truck Traffic) Growth

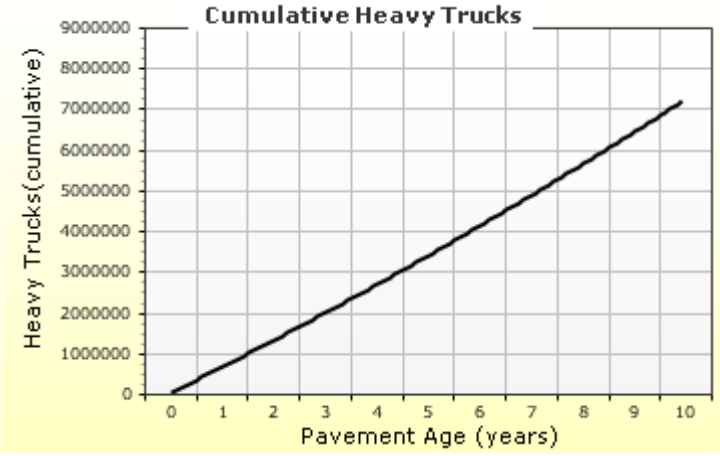
*** Traffic cap is not enforced**







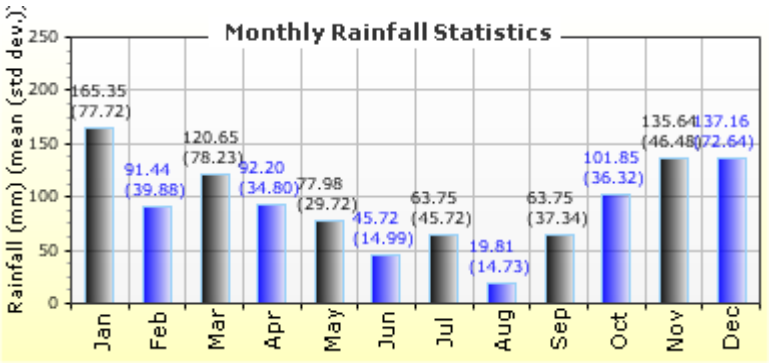




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
RIO DE JANEIRO, RJ	-22.80000 -43.68000 28

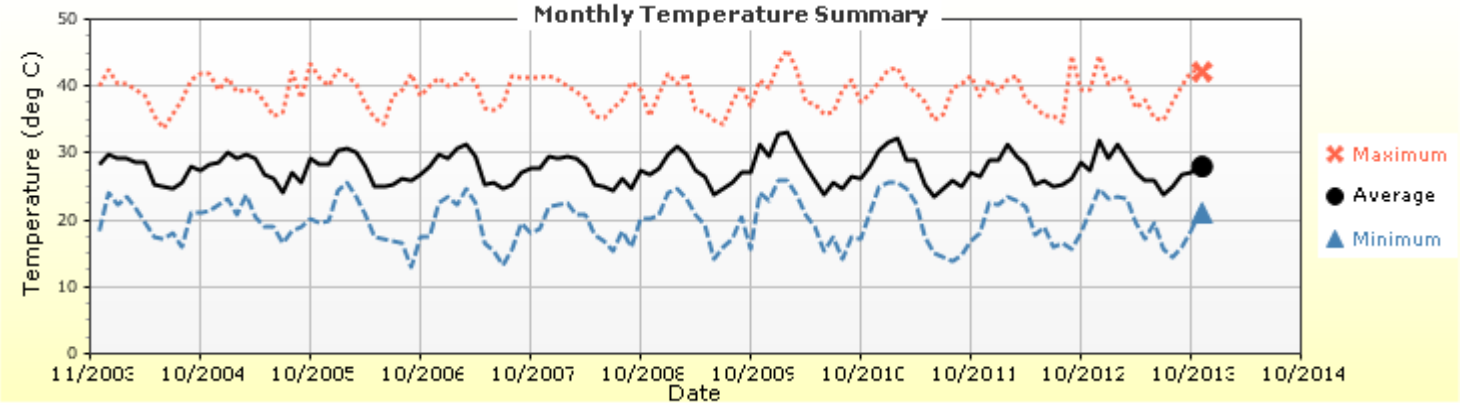


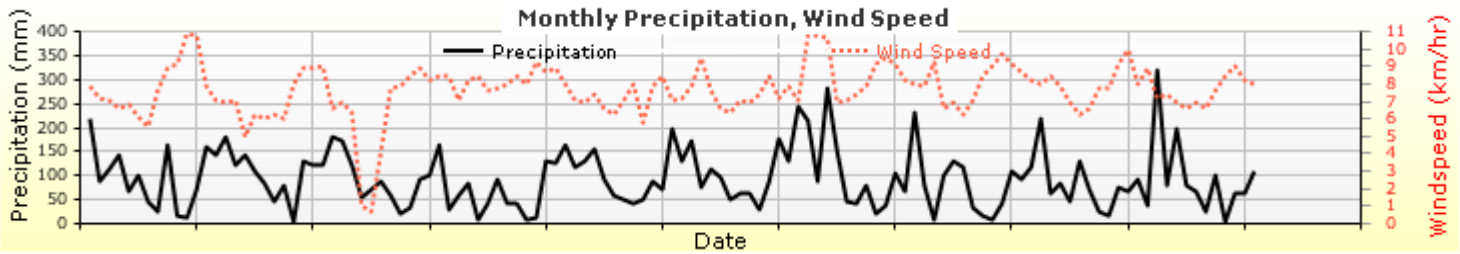
Annual Statistics:

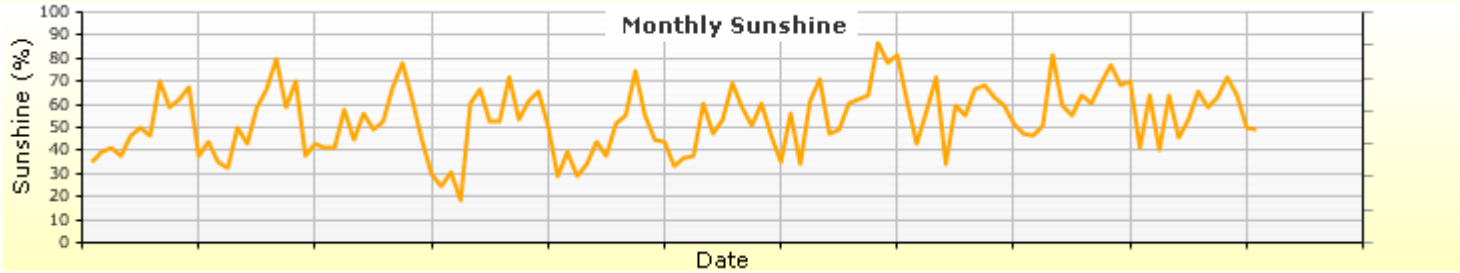
Mean annual air temperature (ºC)	27.59
Mean annual precipitation (mm)	1122.68
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

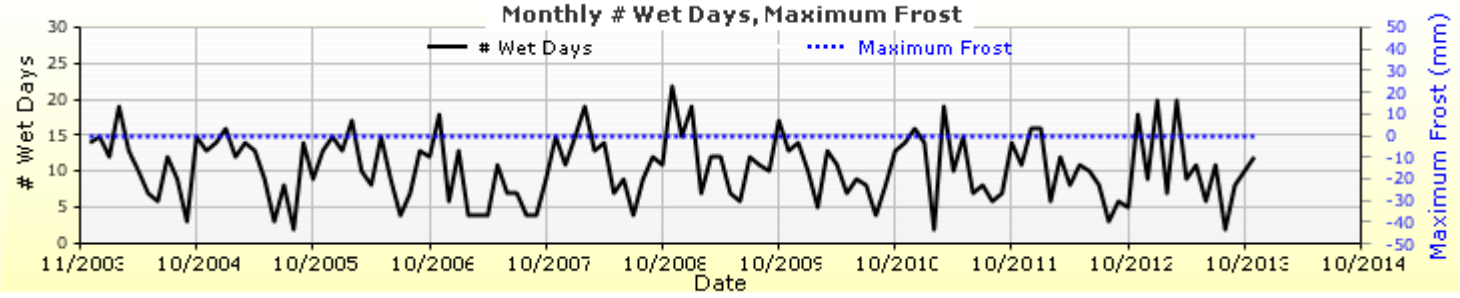
Water table depth (m): 3.05

Monthly Climate Summary:

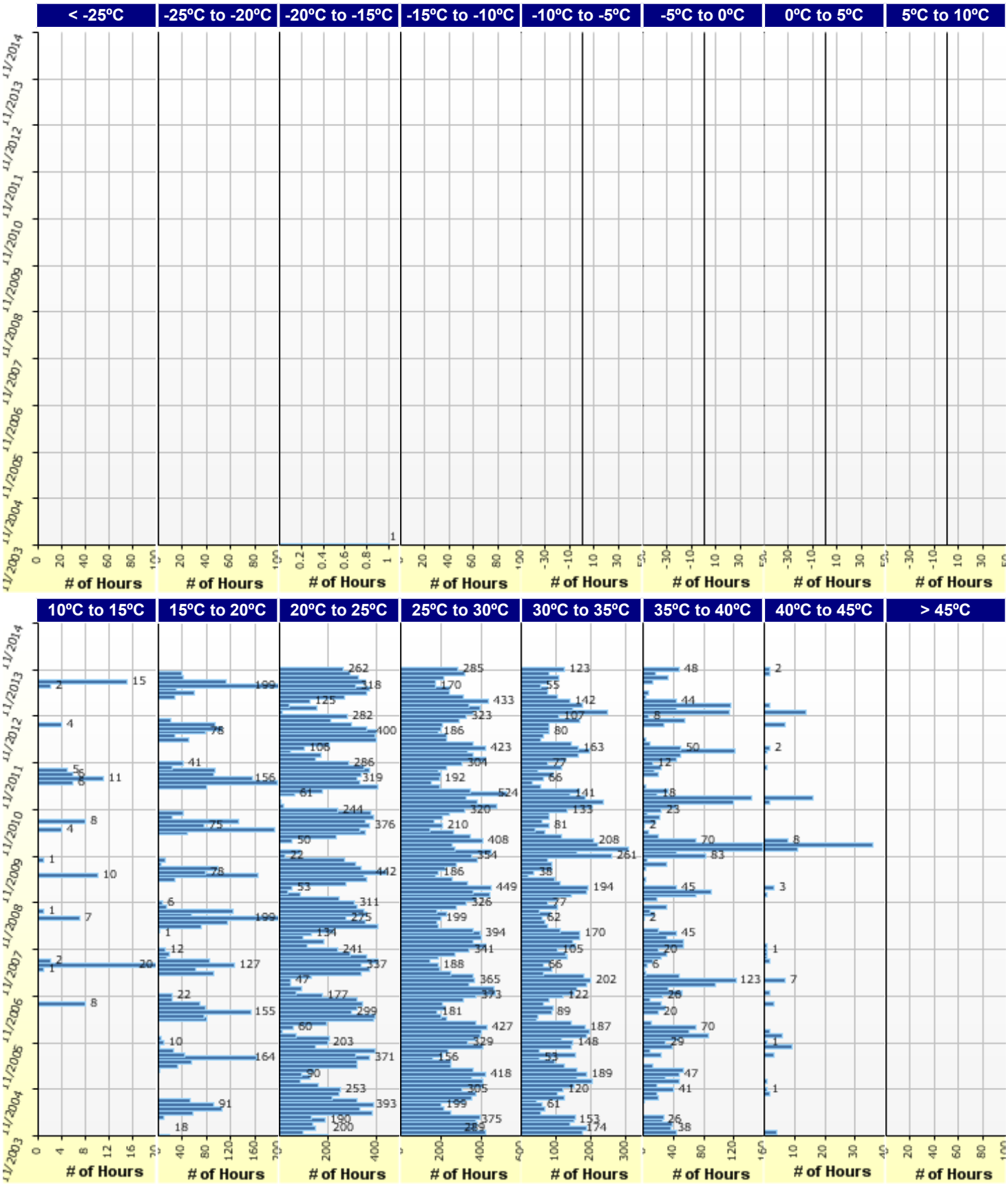








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

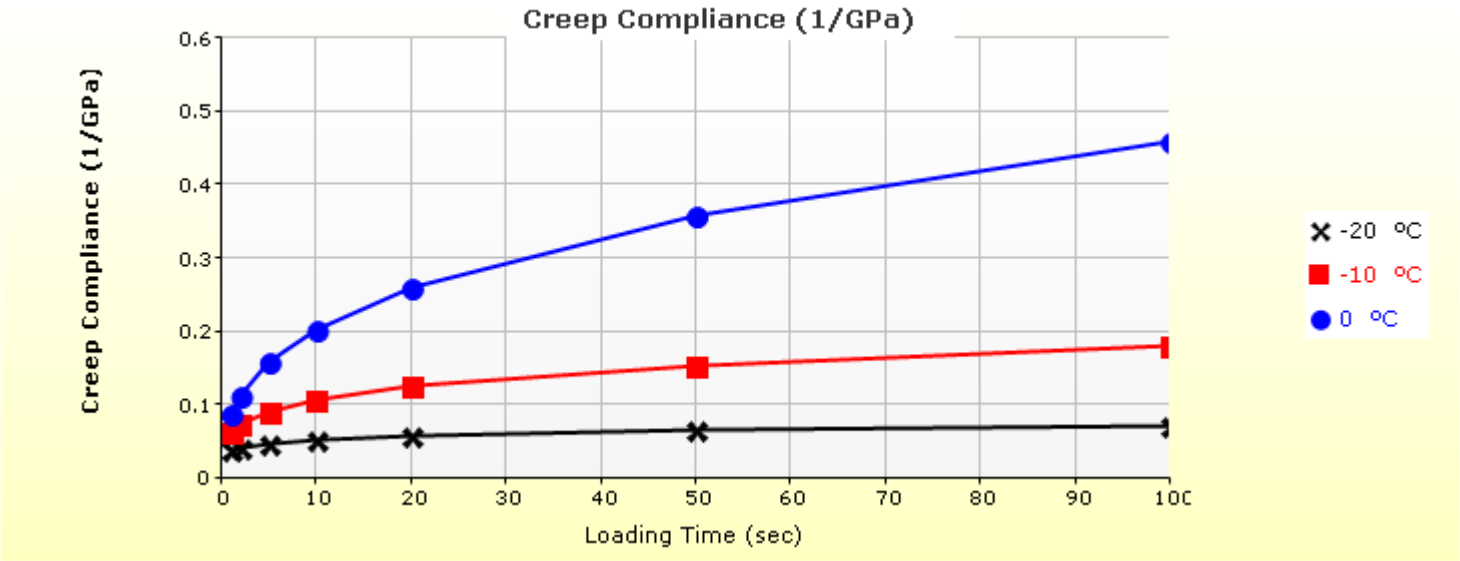
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

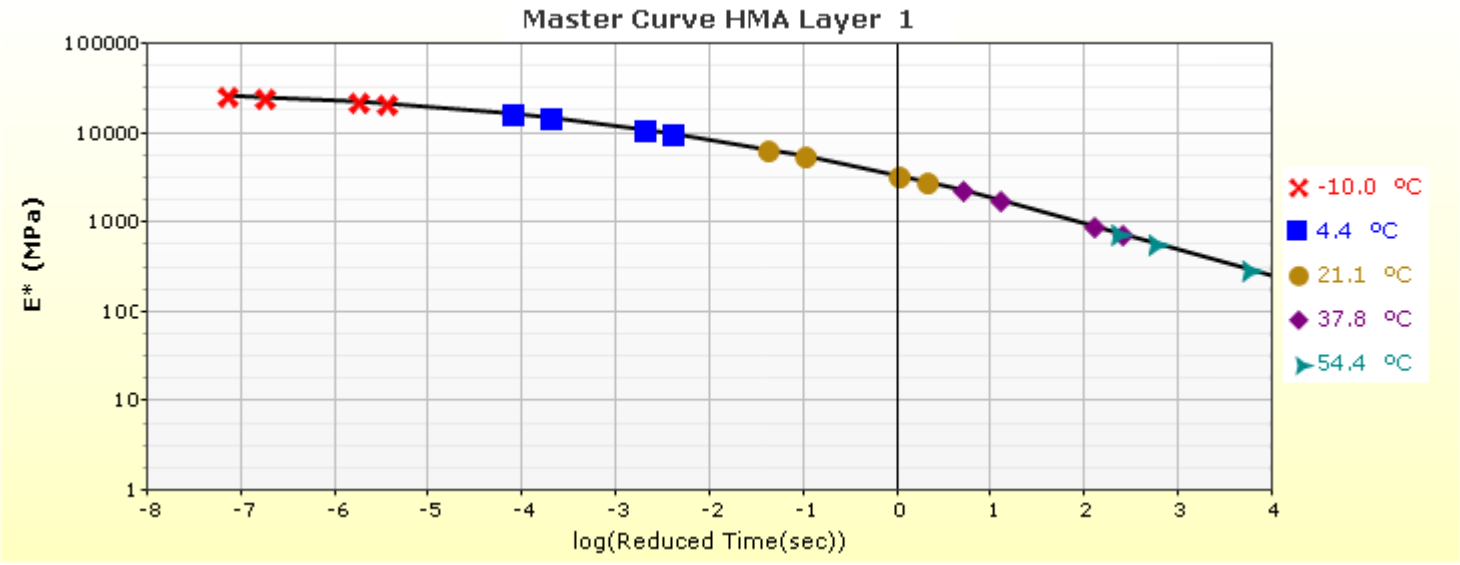
Indirect tensile strength at -10 ºC (MPa)	2.69

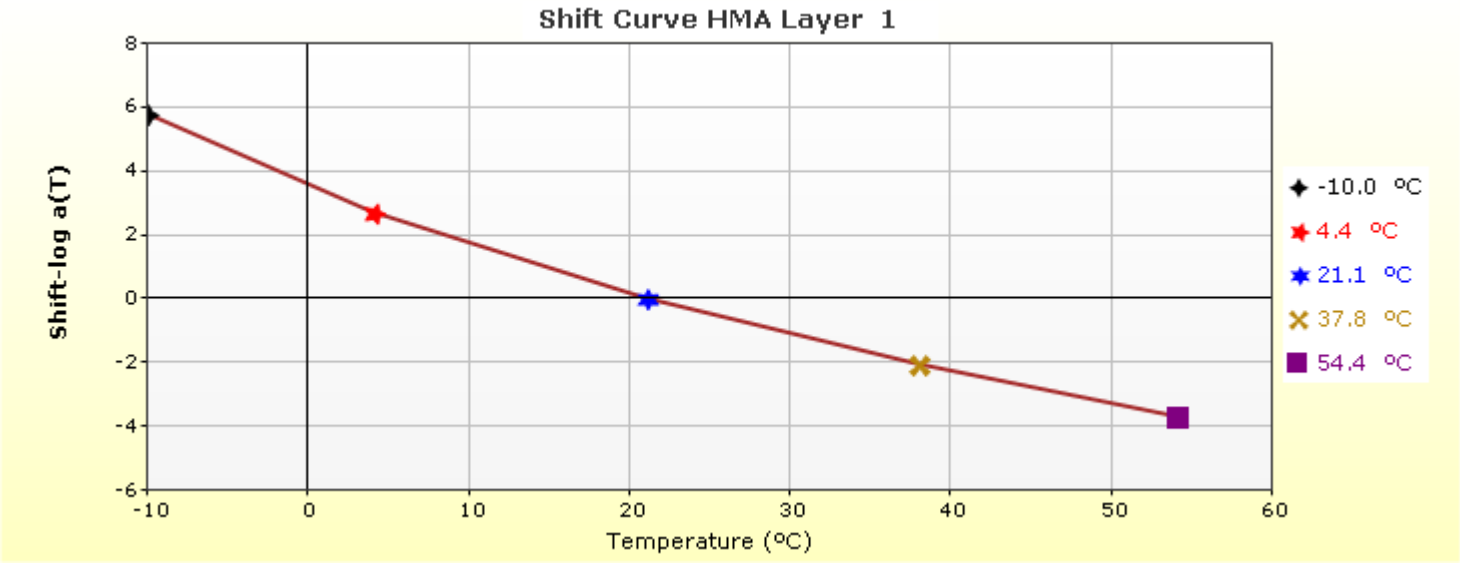
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

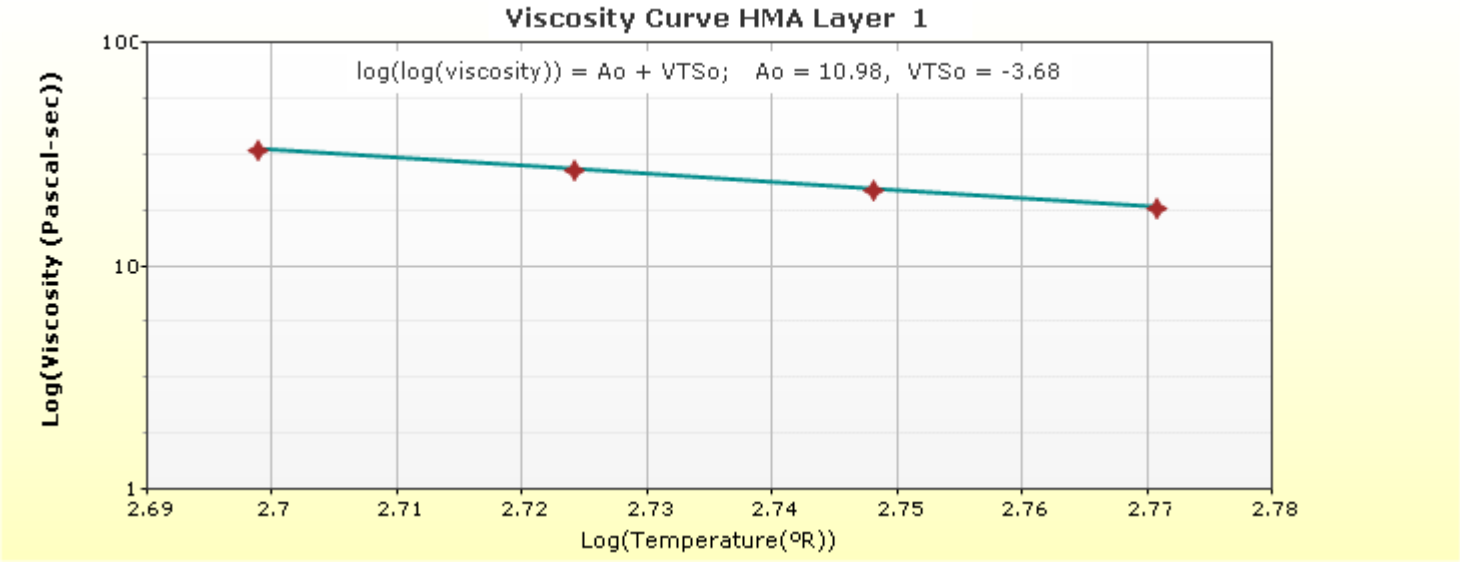
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



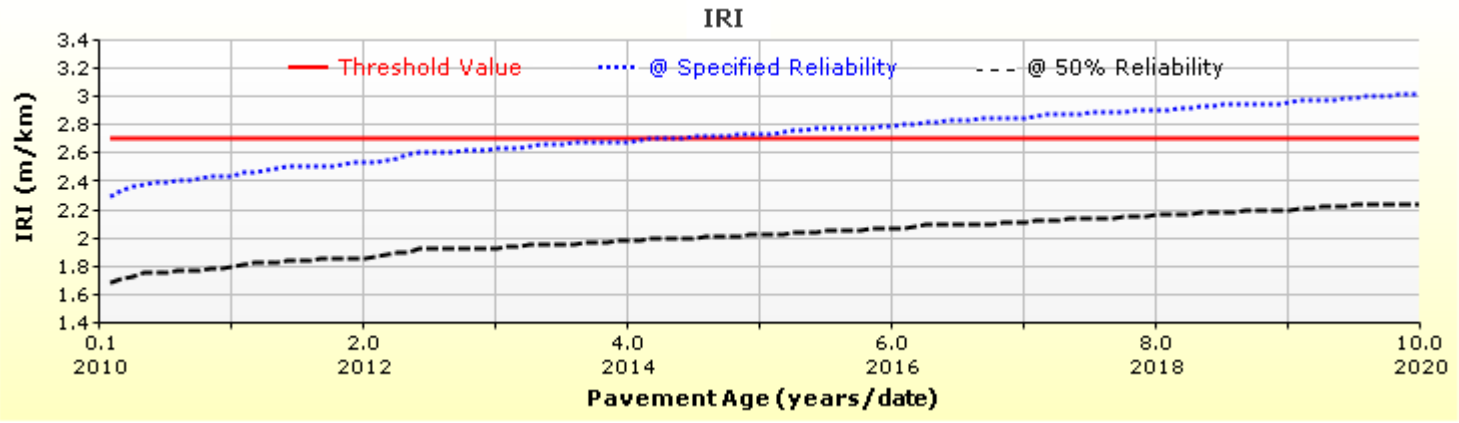
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

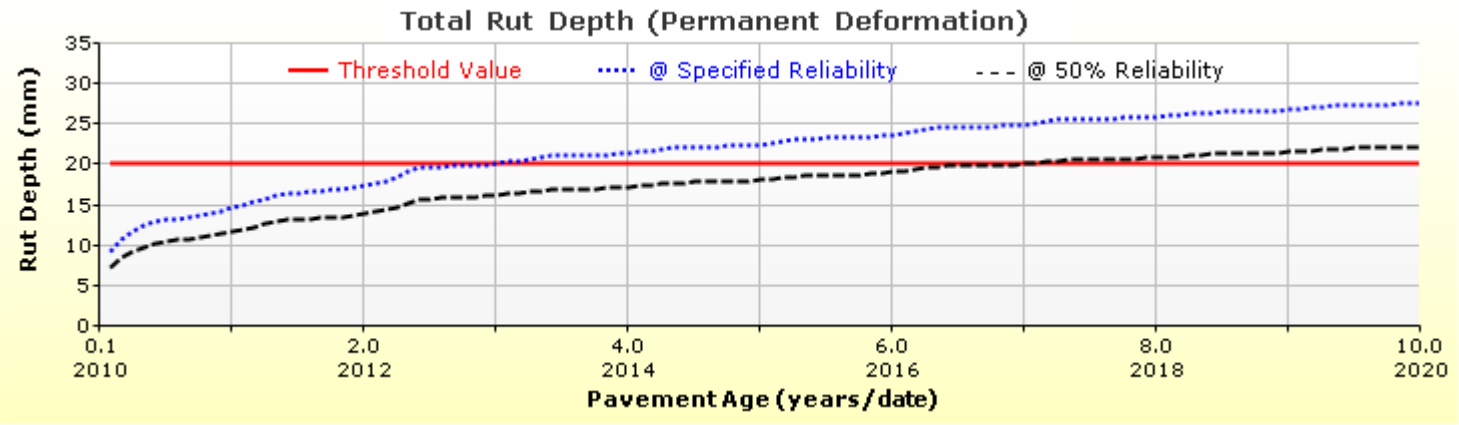


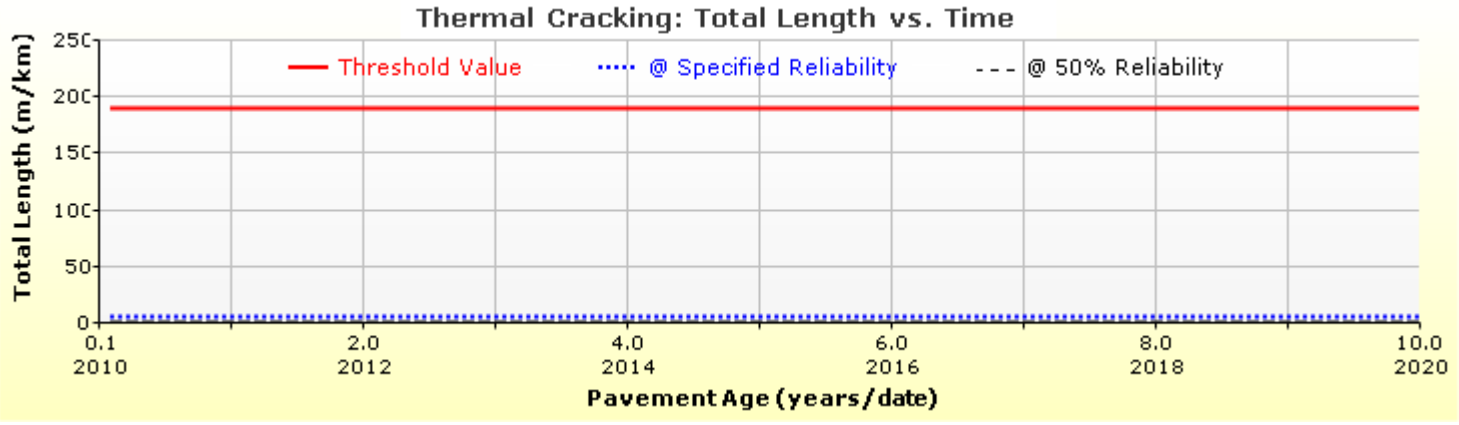


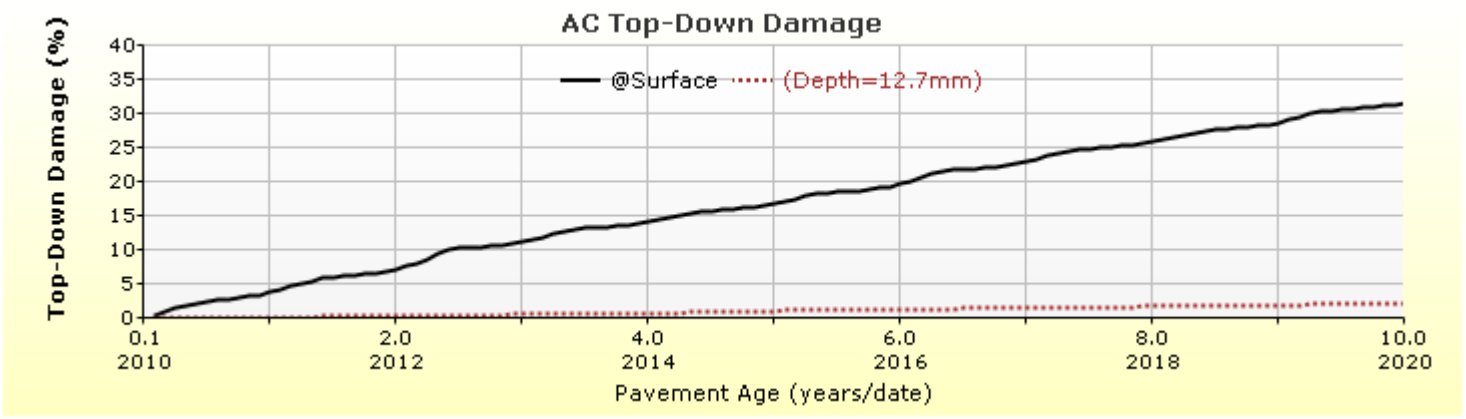


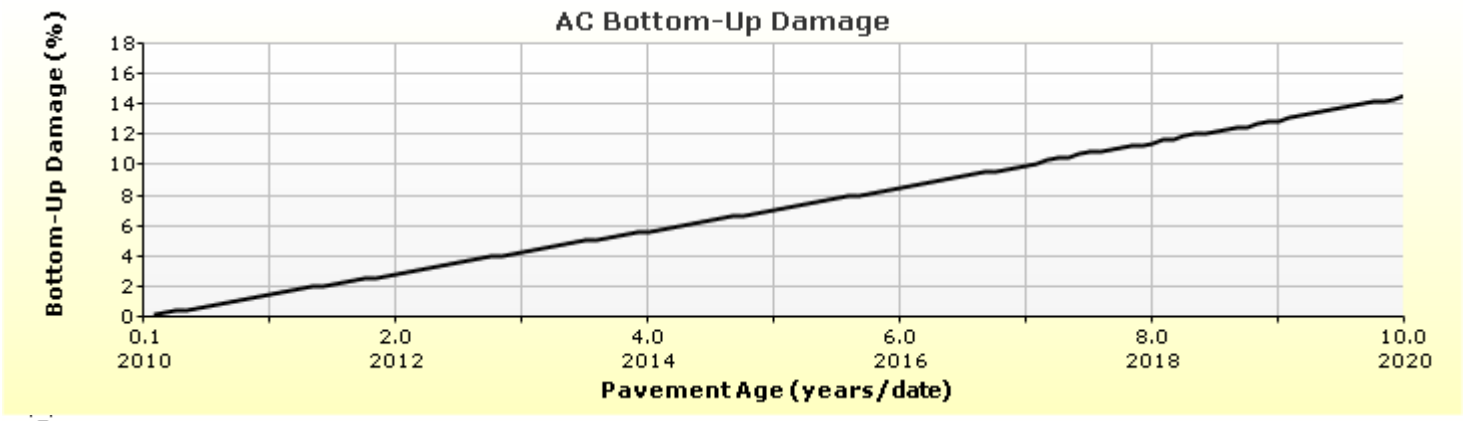
Analysis Output Charts

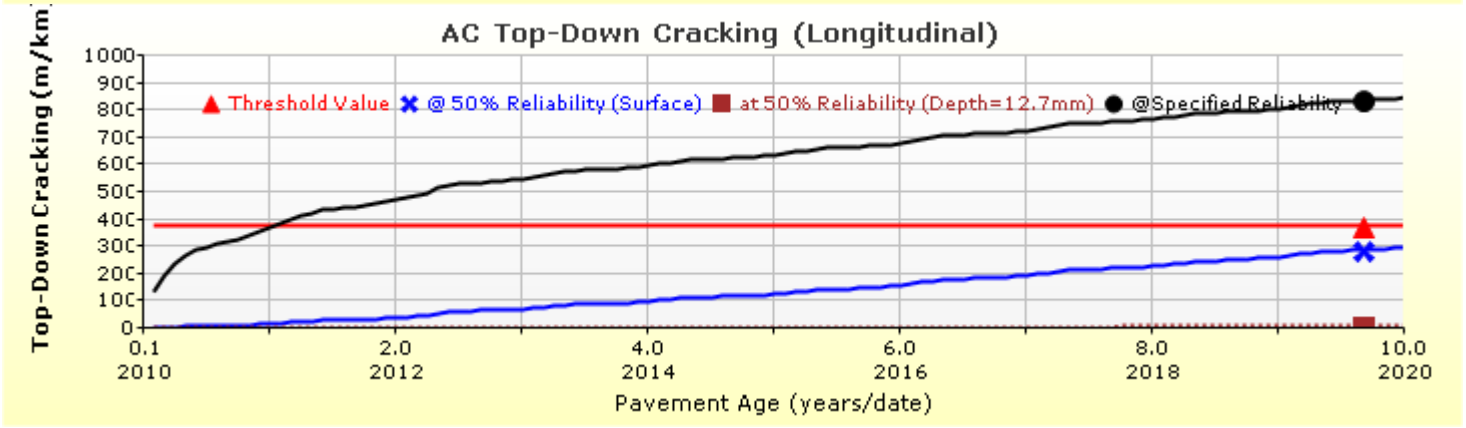


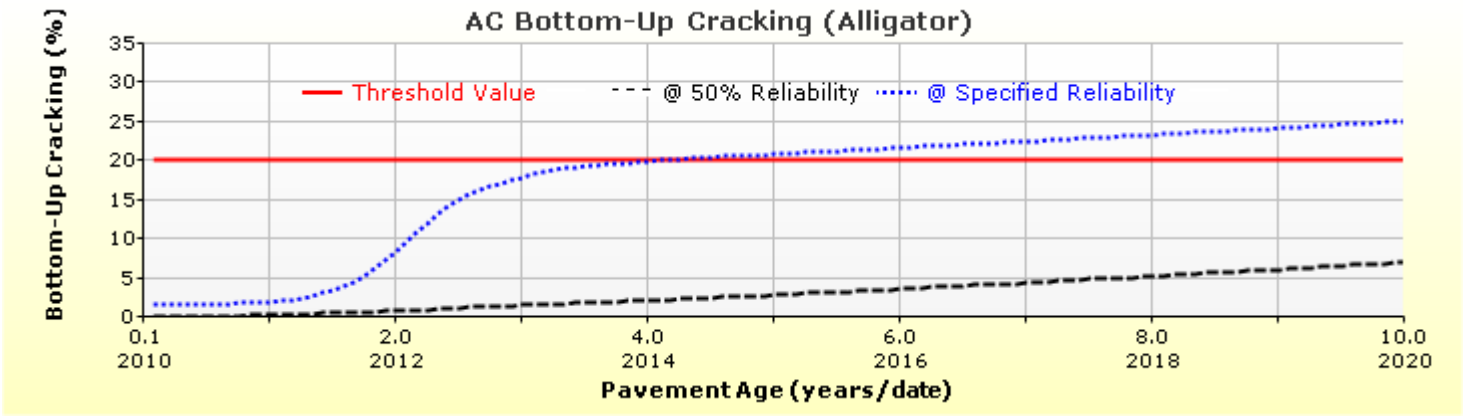


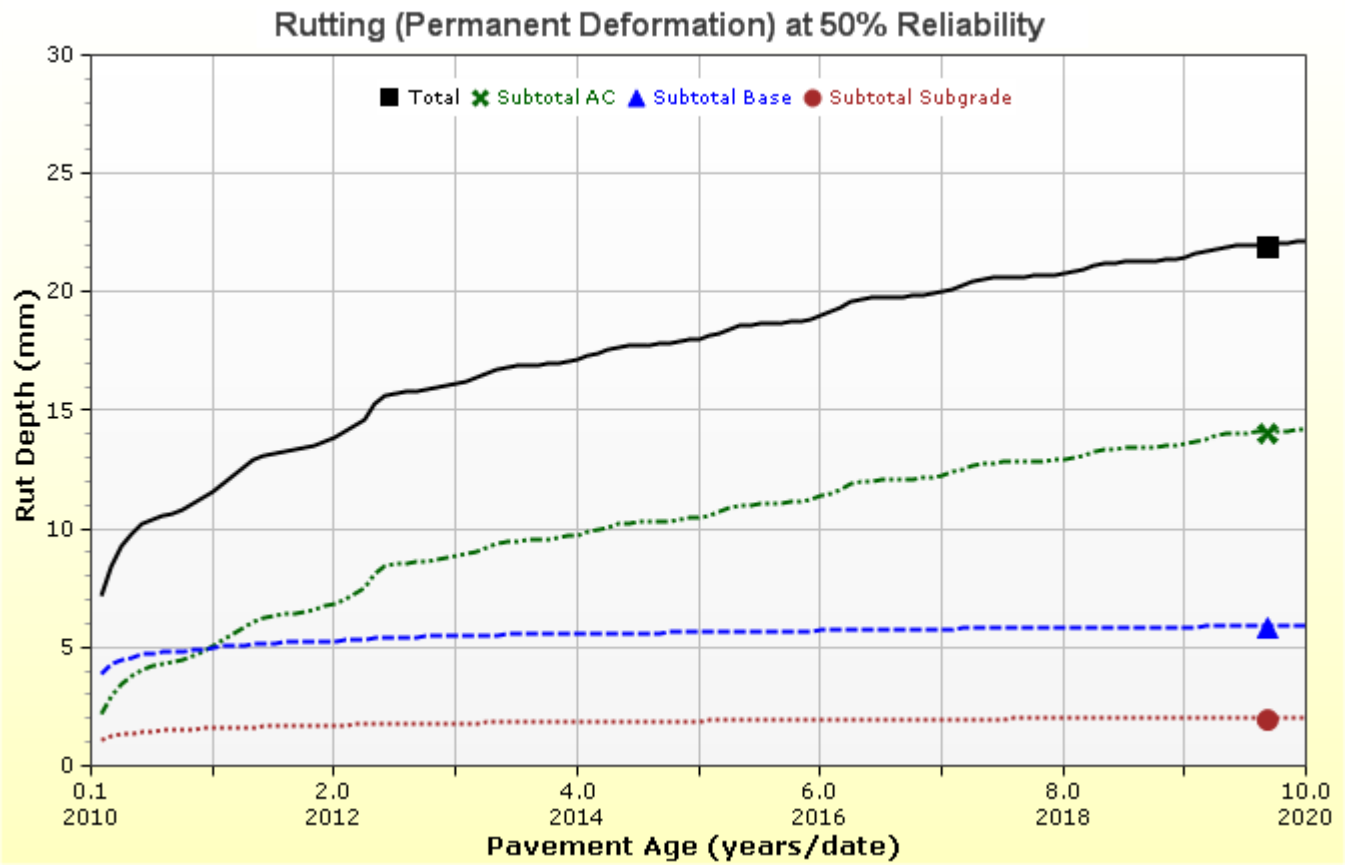


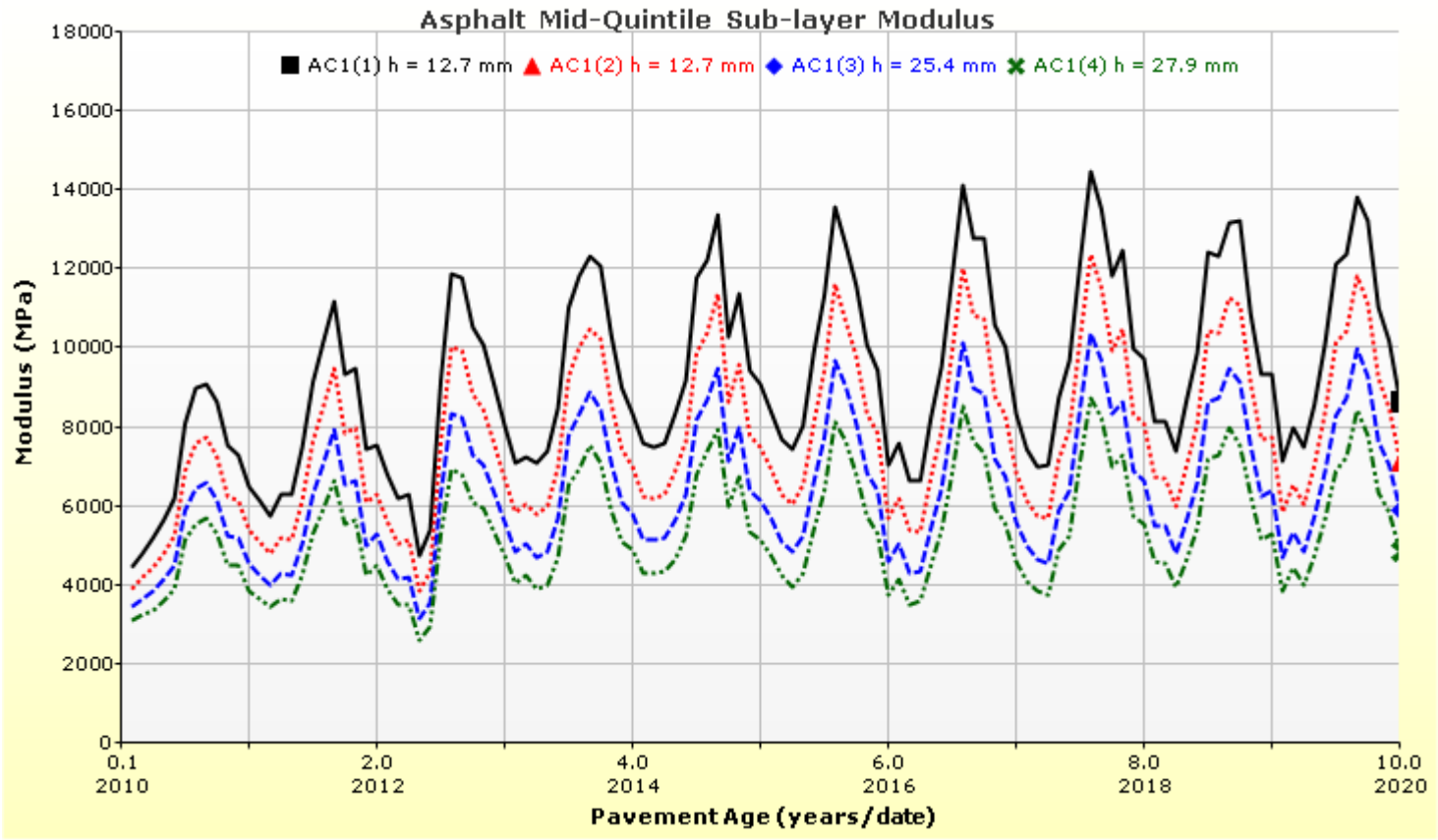

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
35
40
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

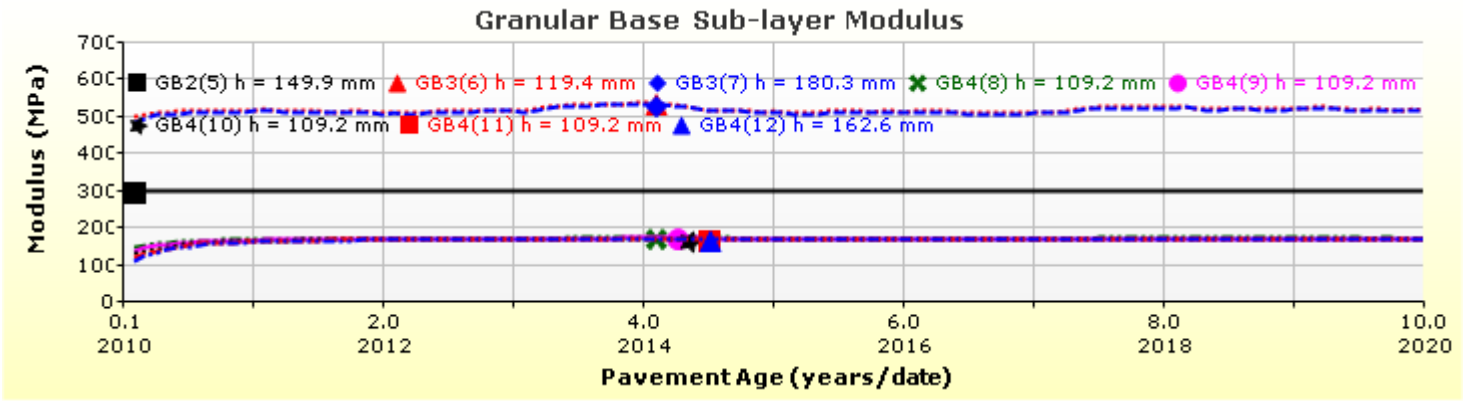

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

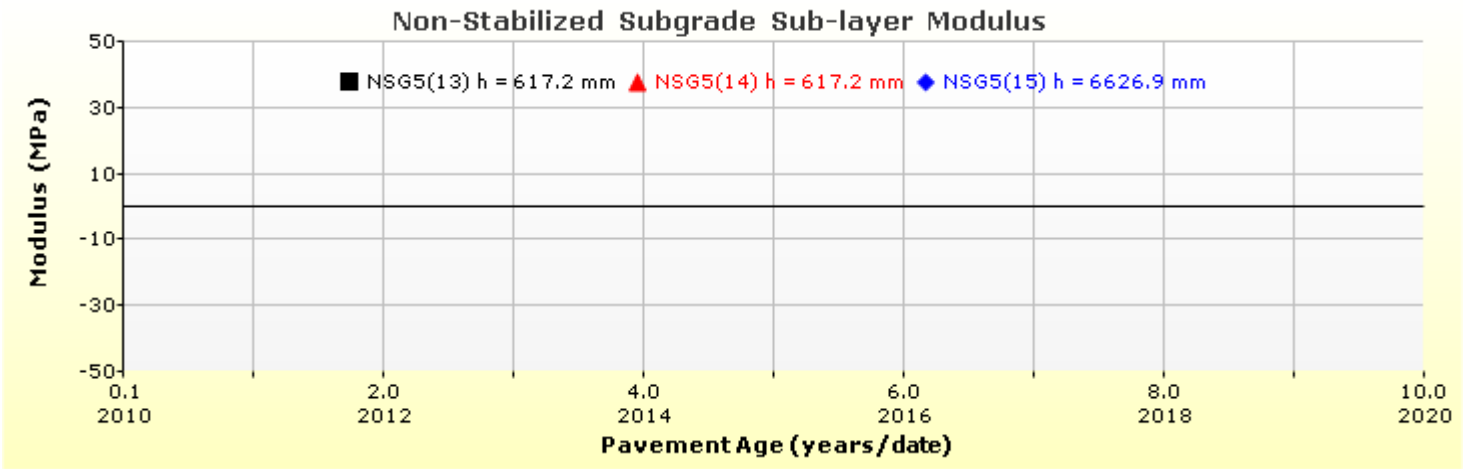

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
900
1000
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
35
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
30
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRJ-2

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRJ-2.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -22.8, -43.68

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

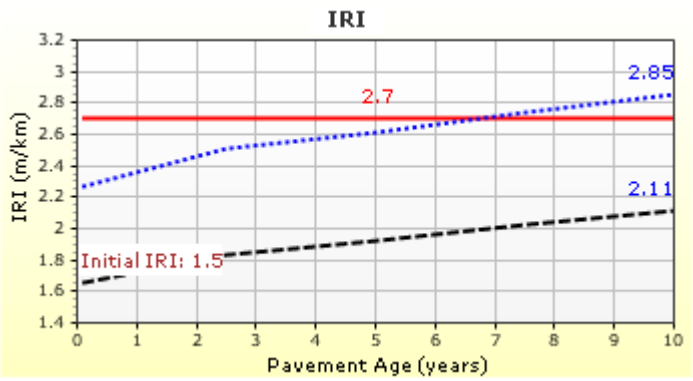
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

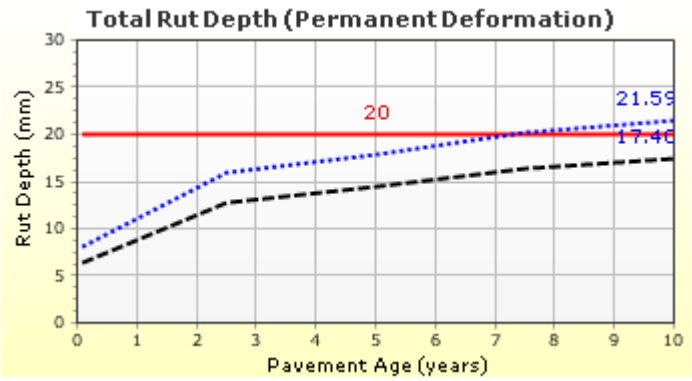
Design Outputs

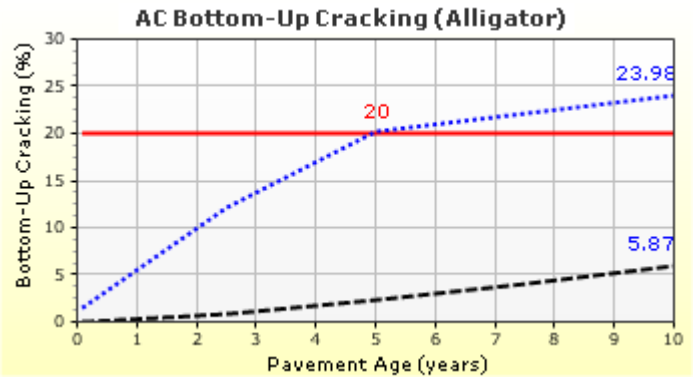
Distress Prediction Summary

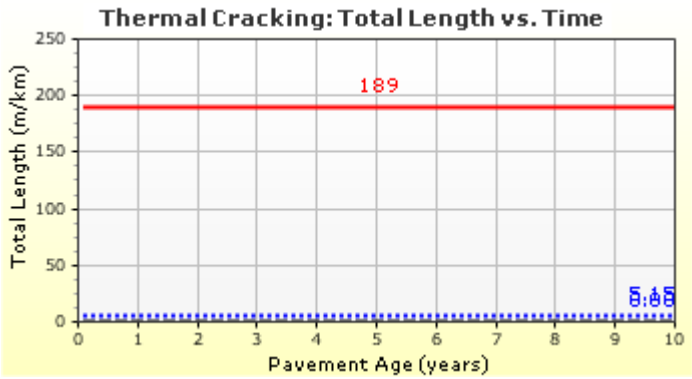
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.85	90.00	84.64	Fail
Permanent deformation - total pavement (mm)	20.00	21.60	90.00	78.54	Fail
AC bottom-up fatigue cracking (percent)	20.00	23.98	90.00	84.14	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	684.18	90.00	70.30	Fail
Permanent deformation - AC only (mm)	5.00	9.55	50.00	5.26	Fail

Distress Charts







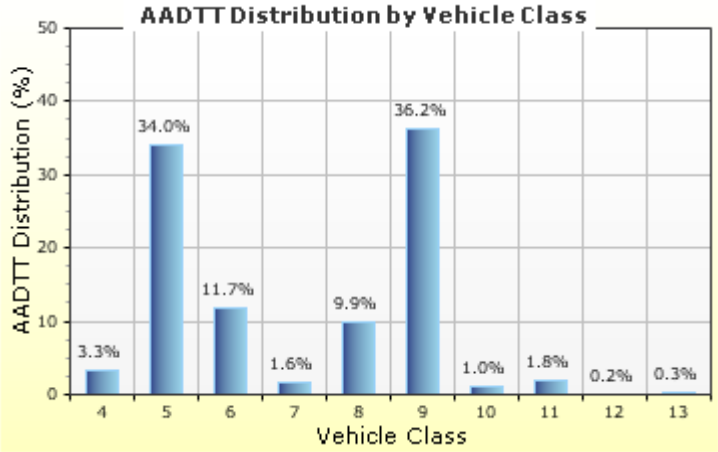


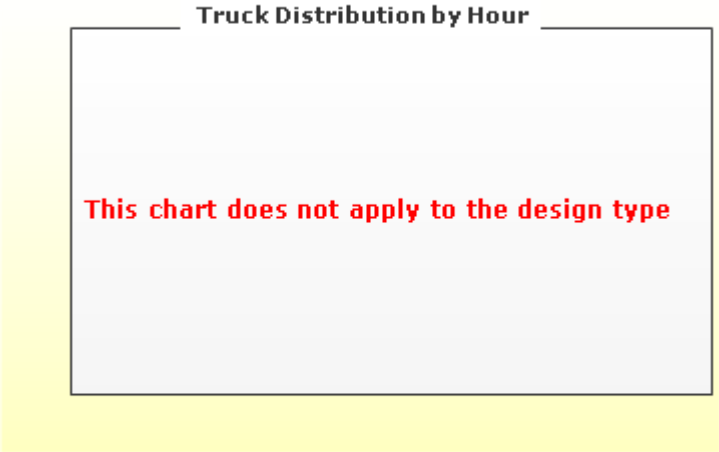


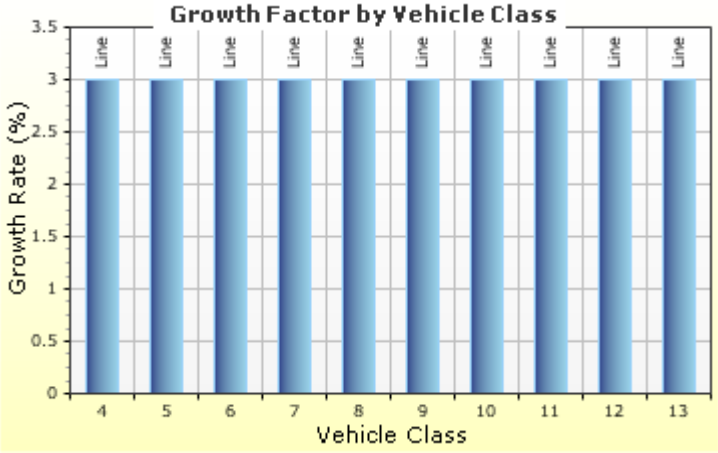
Traffic Inputs

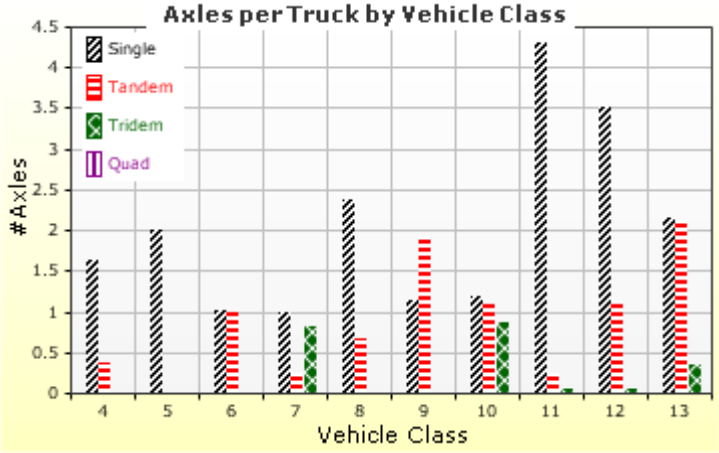
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

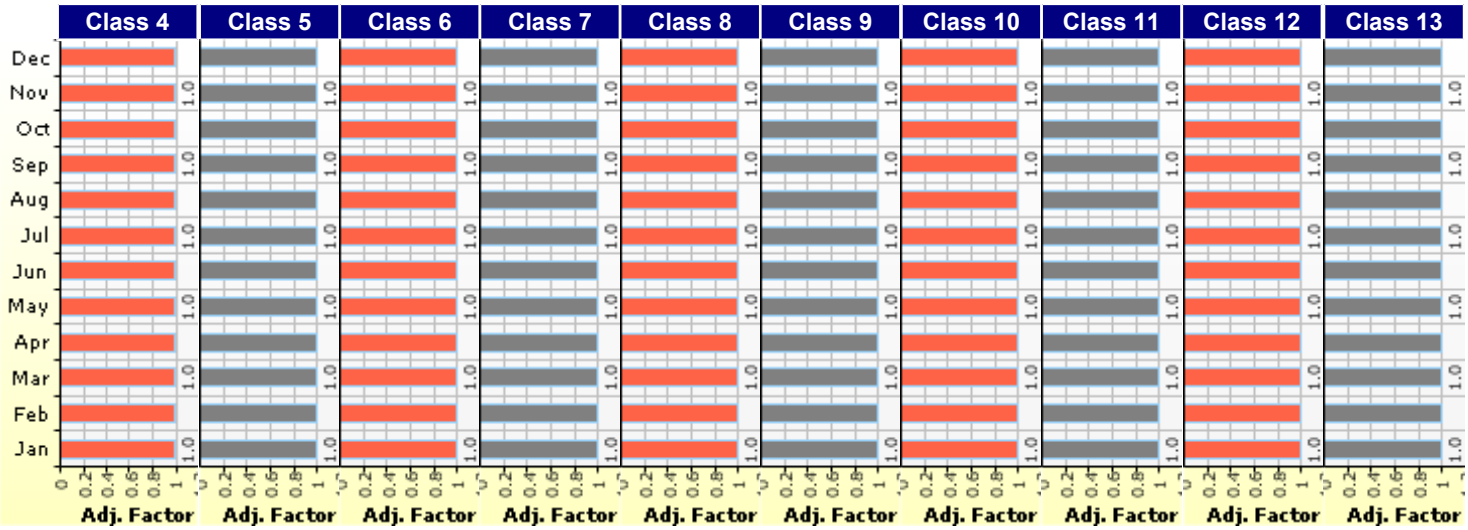








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

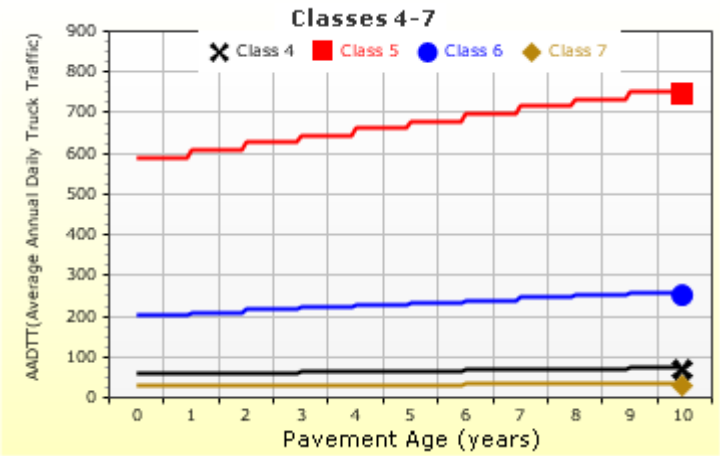
Wheelbase does not apply

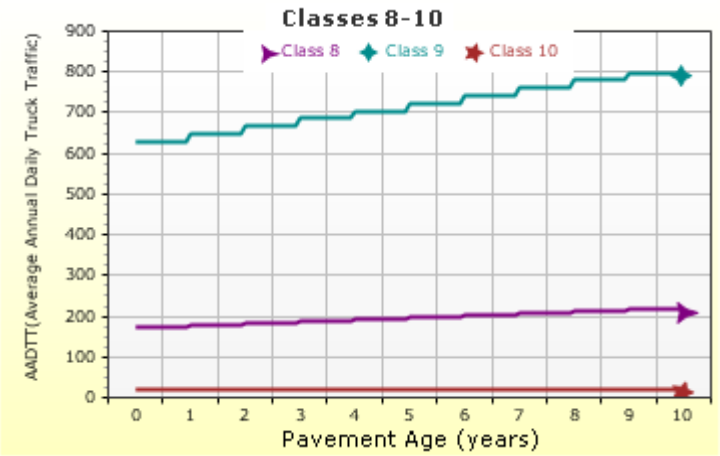
Number of Axles per Truck

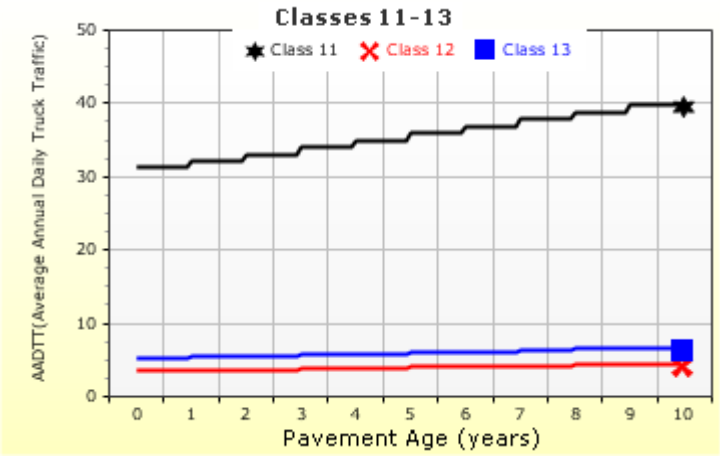
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

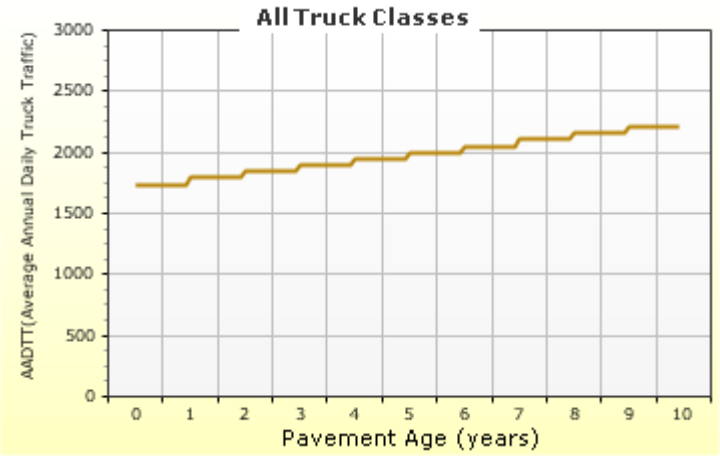
AADTT (Average Annual Daily Truck Traffic) Growth

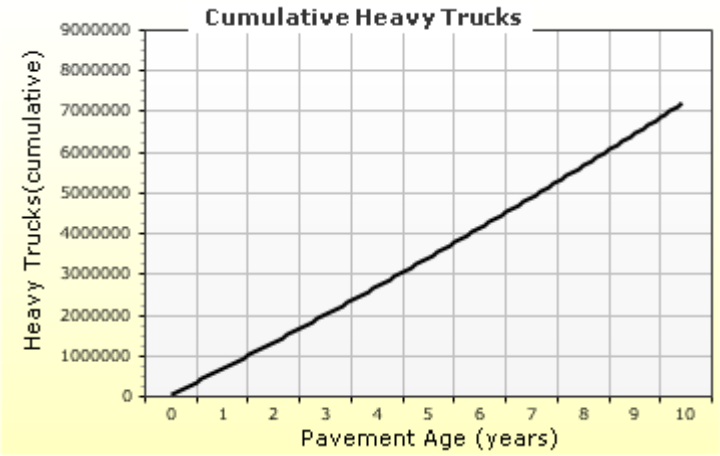
*** Traffic cap is not enforced**







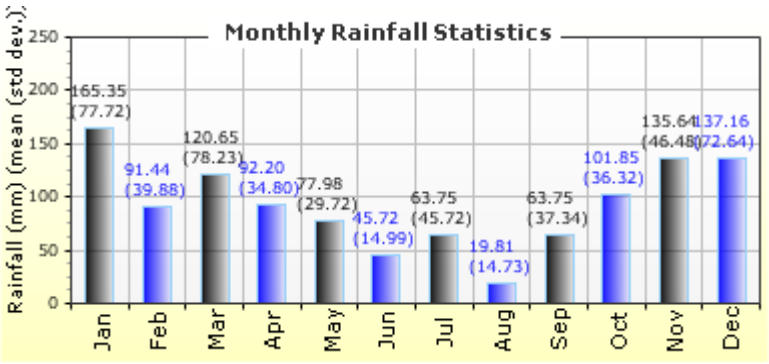




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
RIO DE JANEIRO, RJ	-22.80000 -43.68000 28

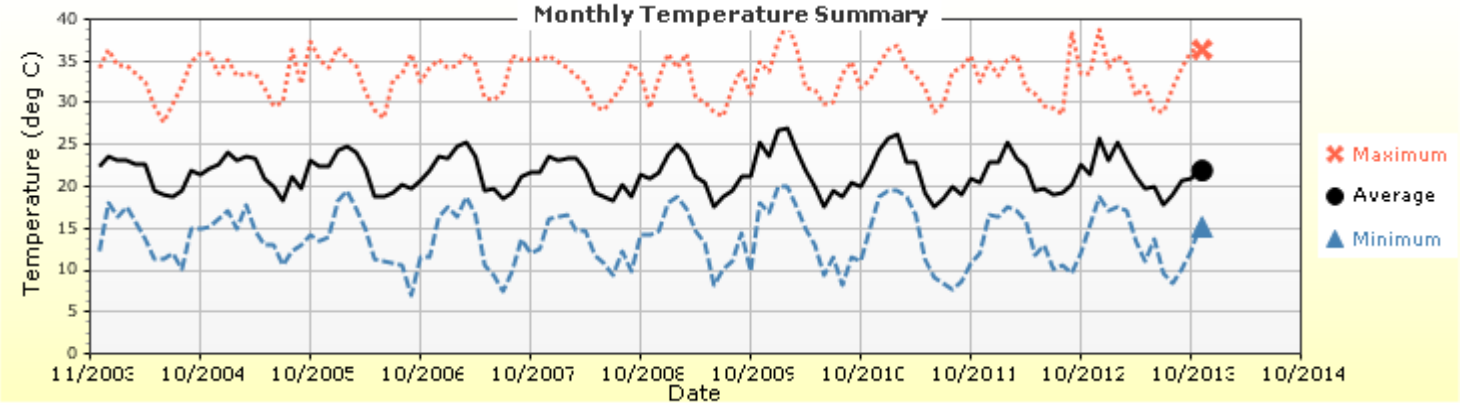


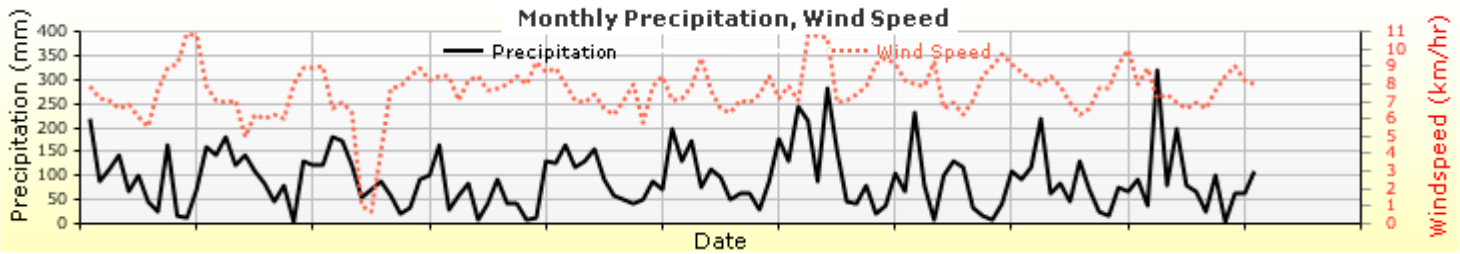
Annual Statistics:

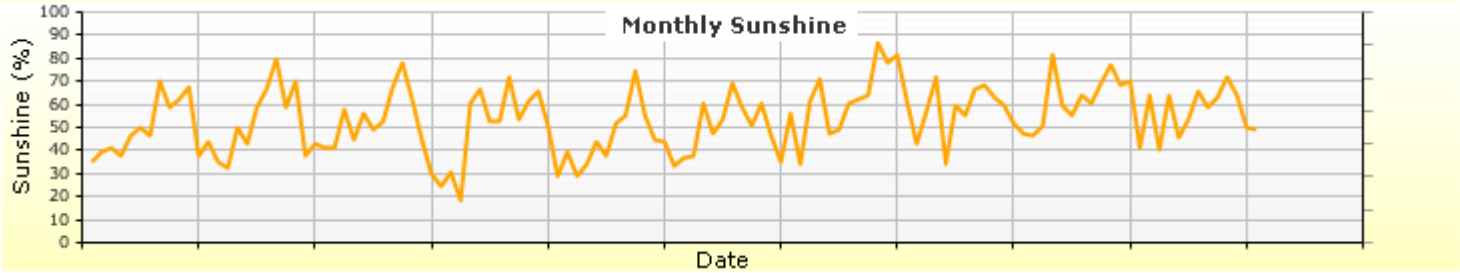
Mean annual air temperature (ºC)	21.59
Mean annual precipitation (mm)	1122.68
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

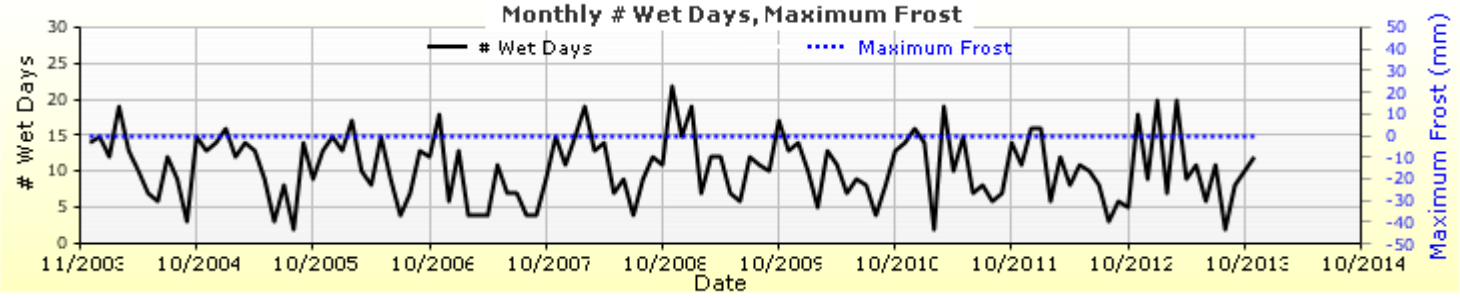
Water table depth (m): 3.05

Monthly Climate Summary:

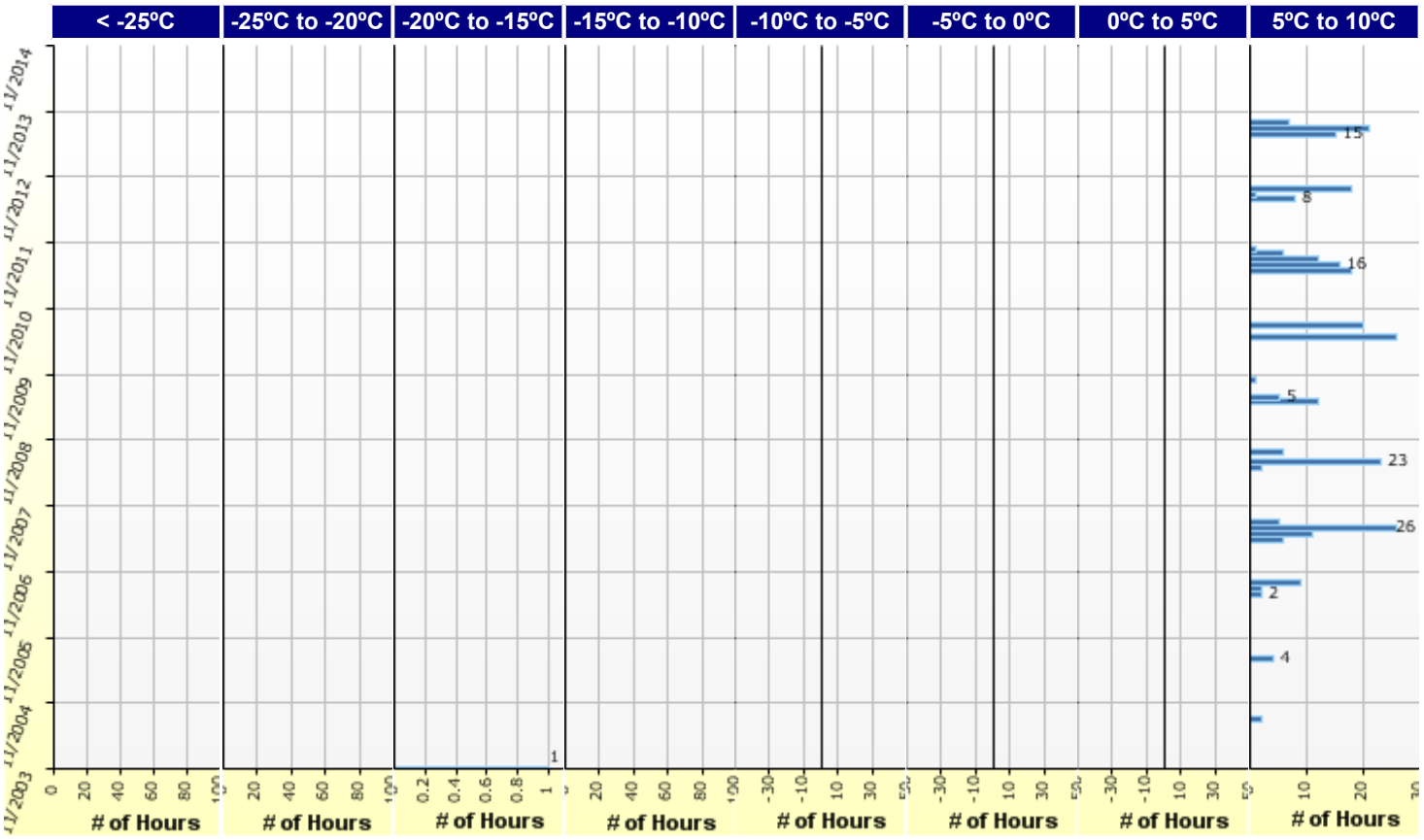


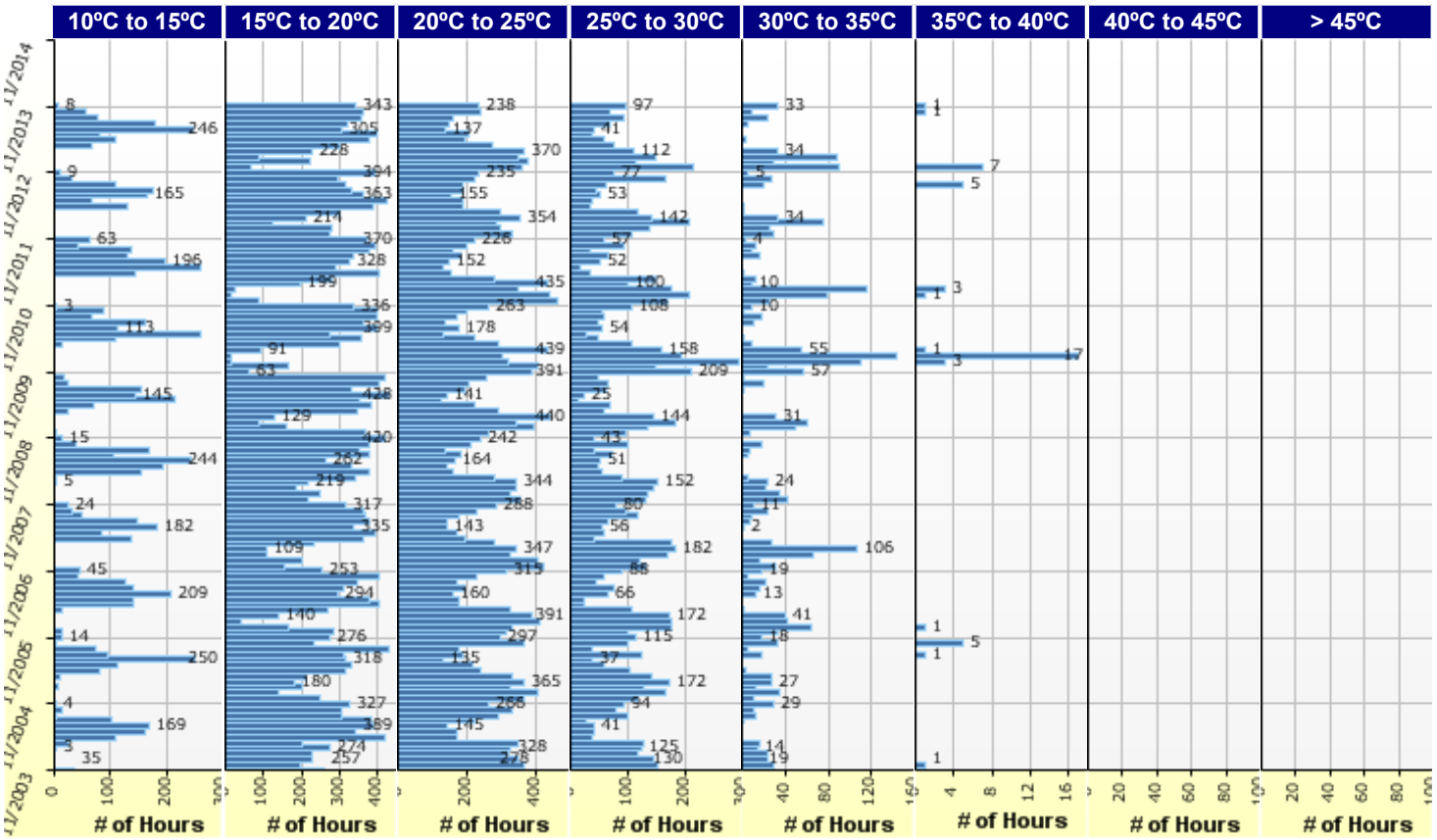






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

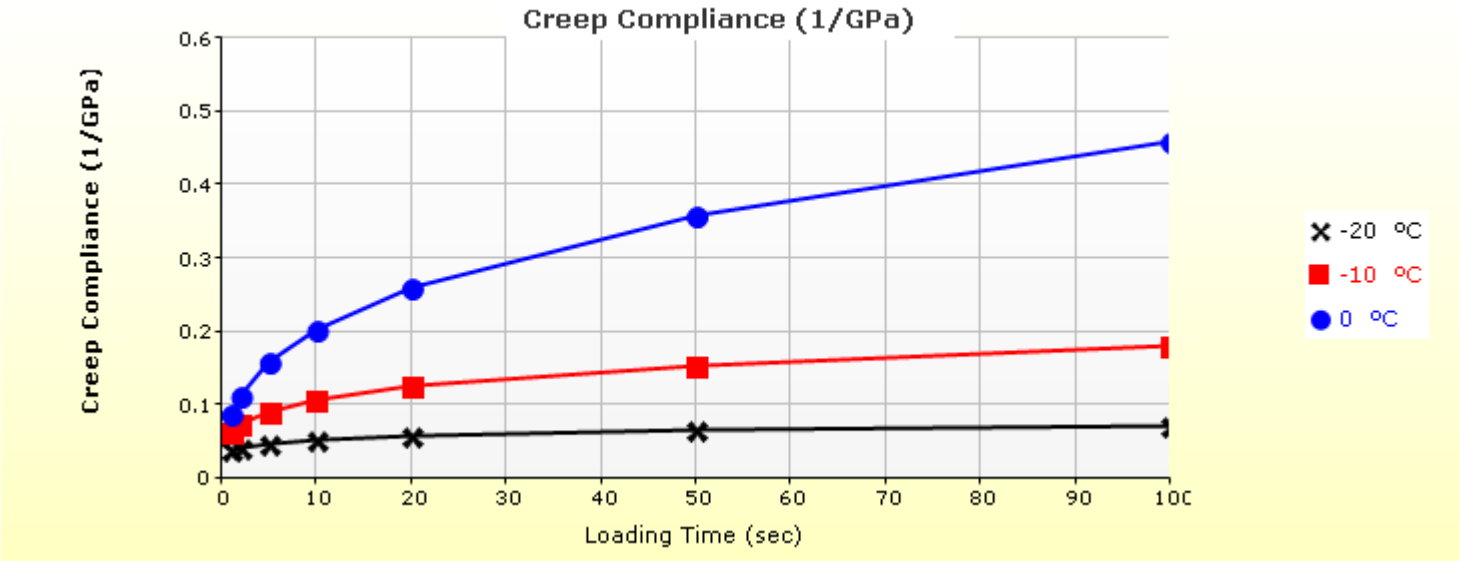
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

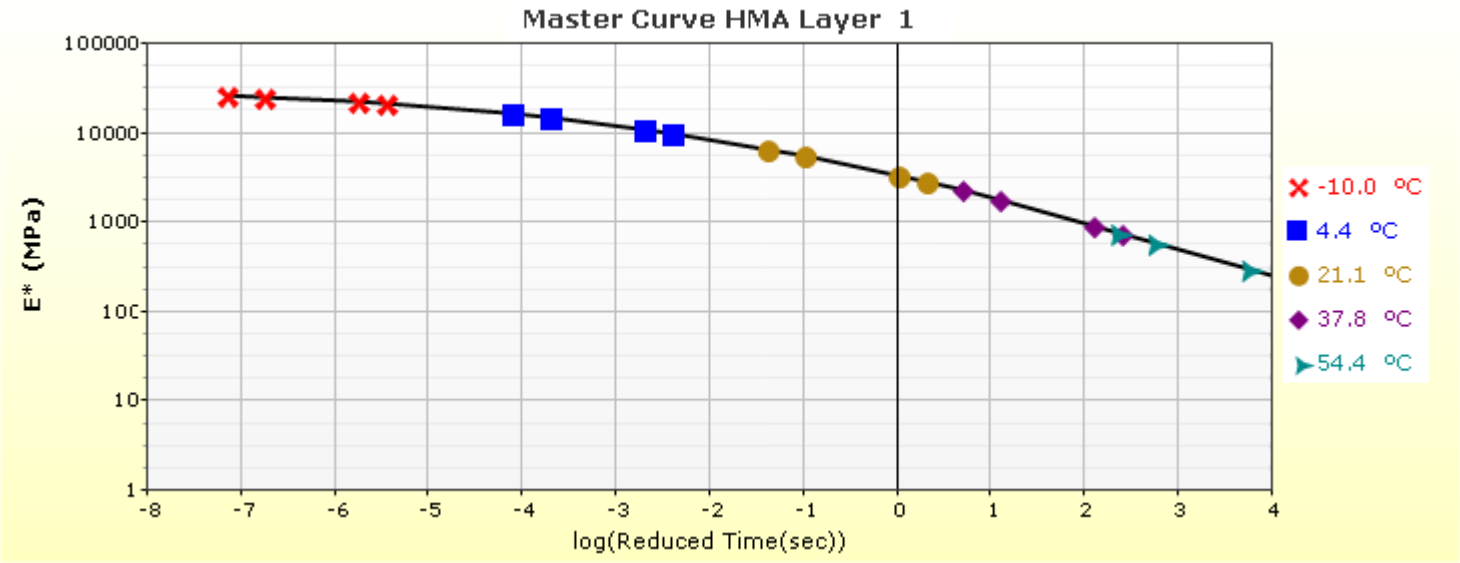
Indirect tensile strength at -10 ºC (MPa)	2.69

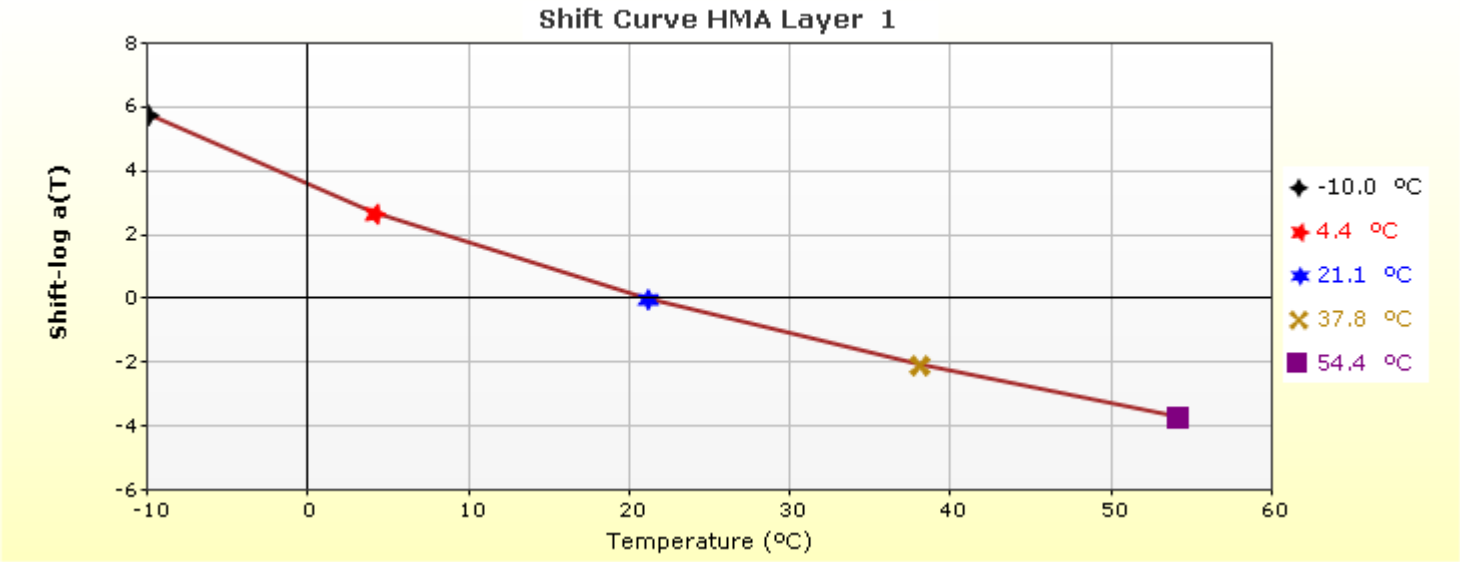
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

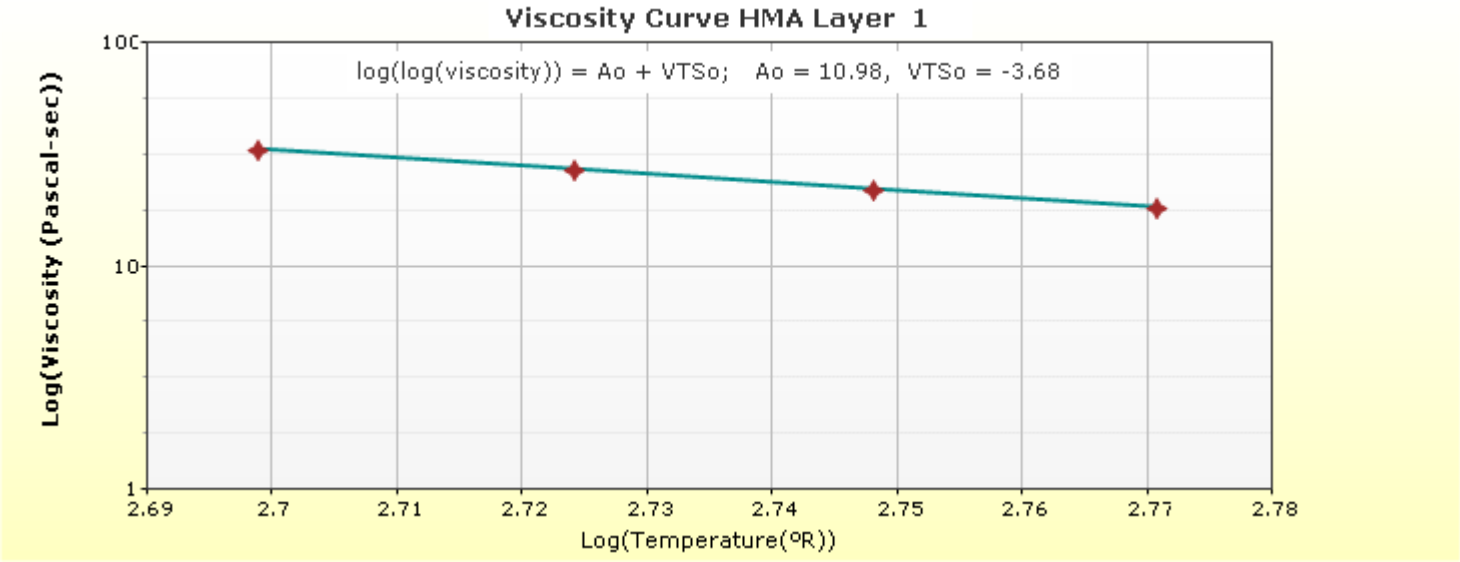
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



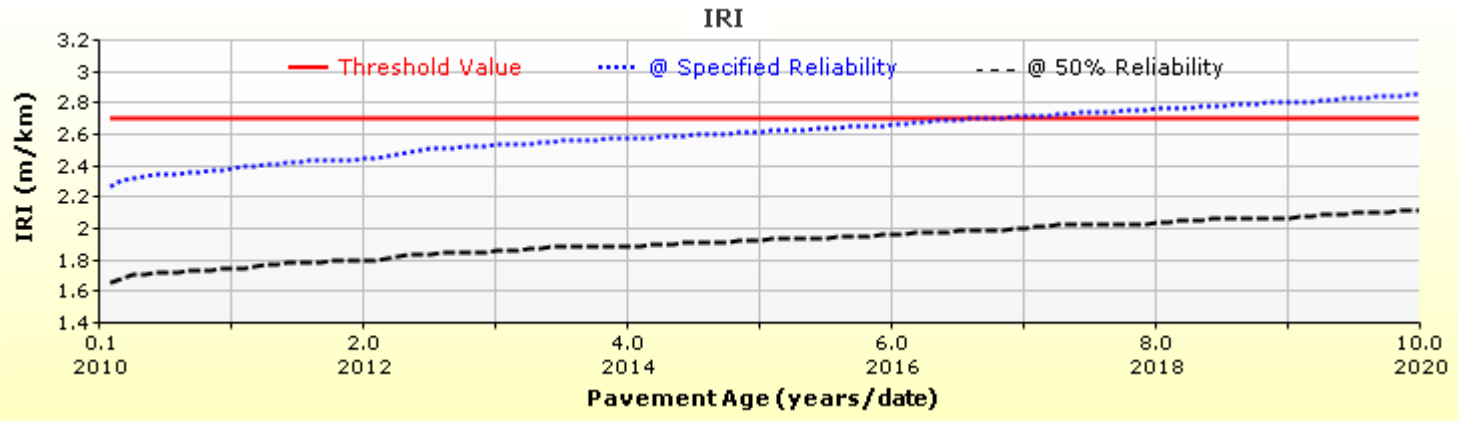
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

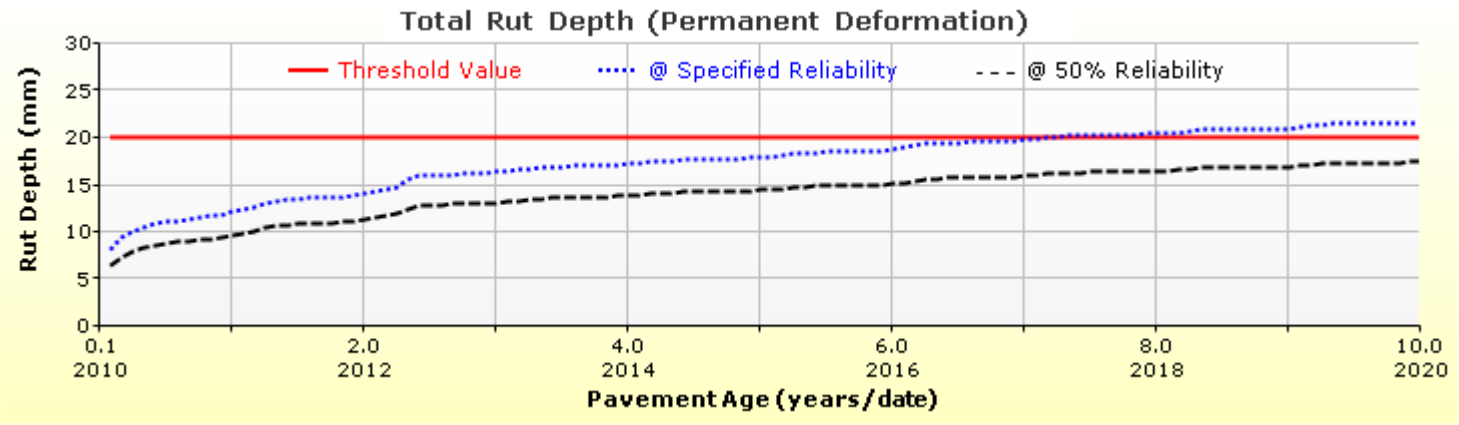


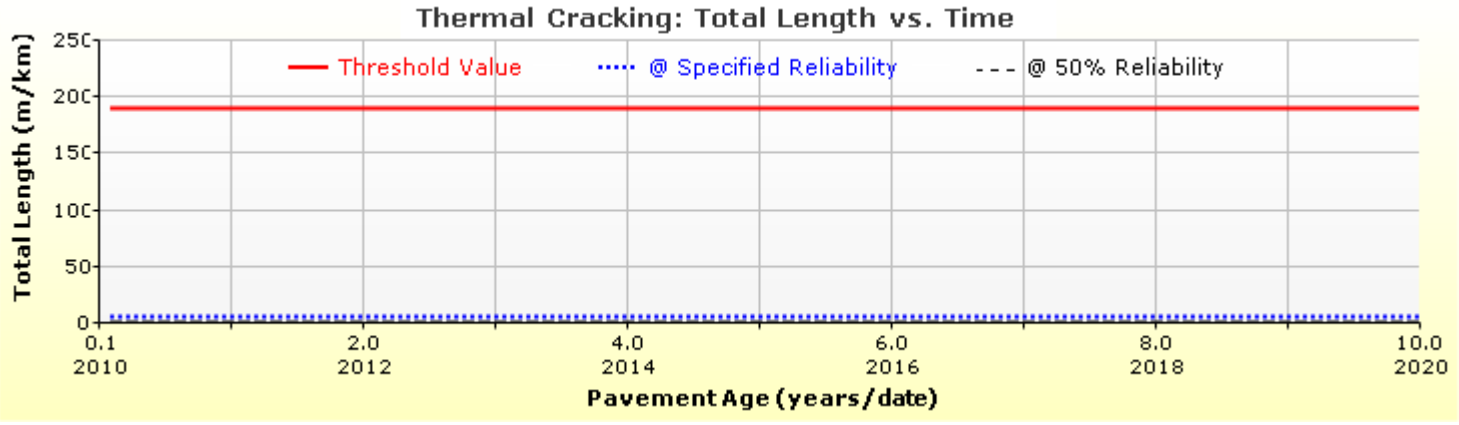


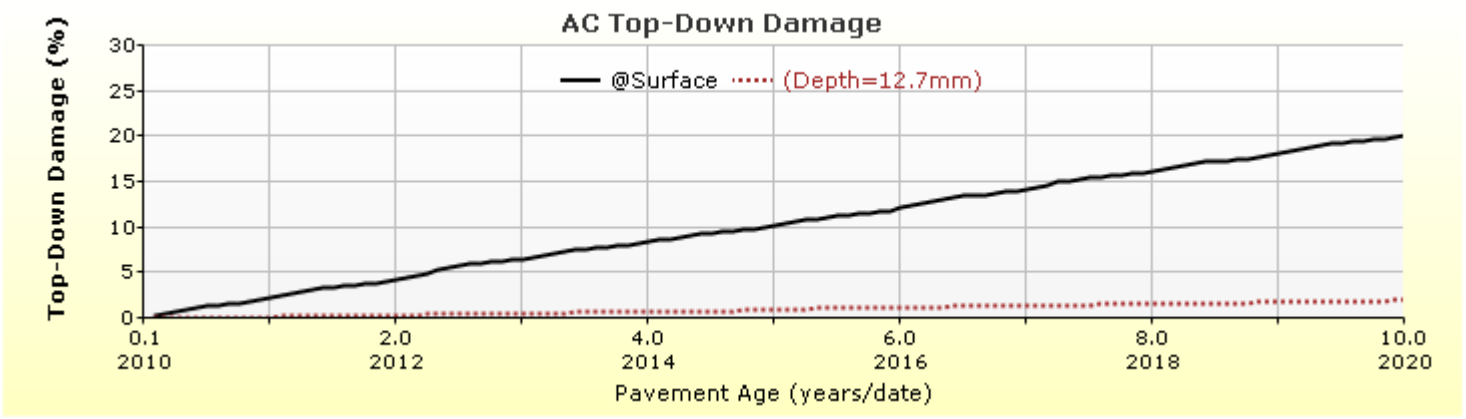


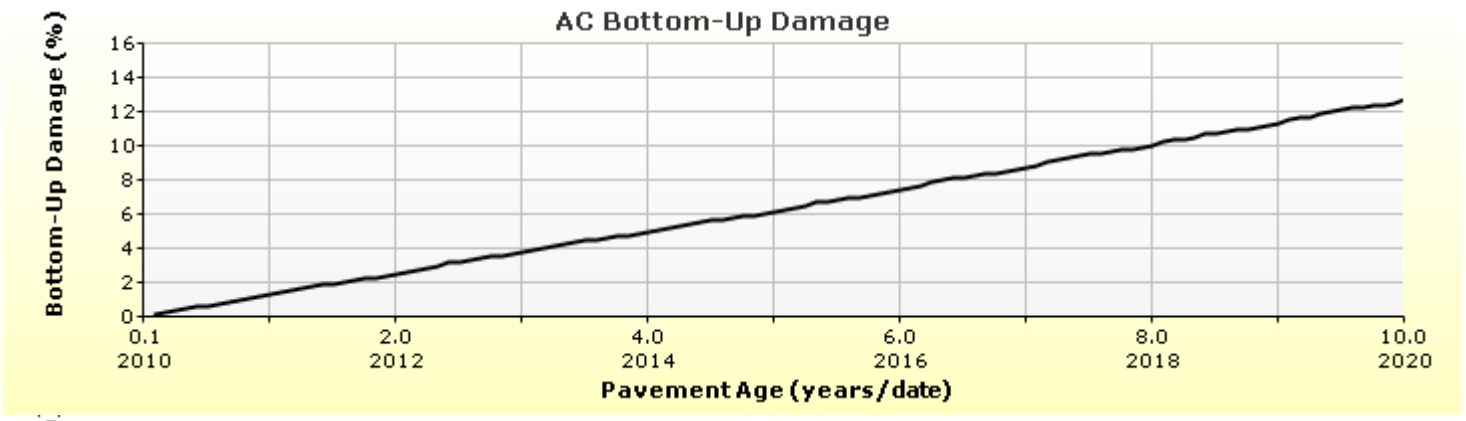
Analysis Output Charts

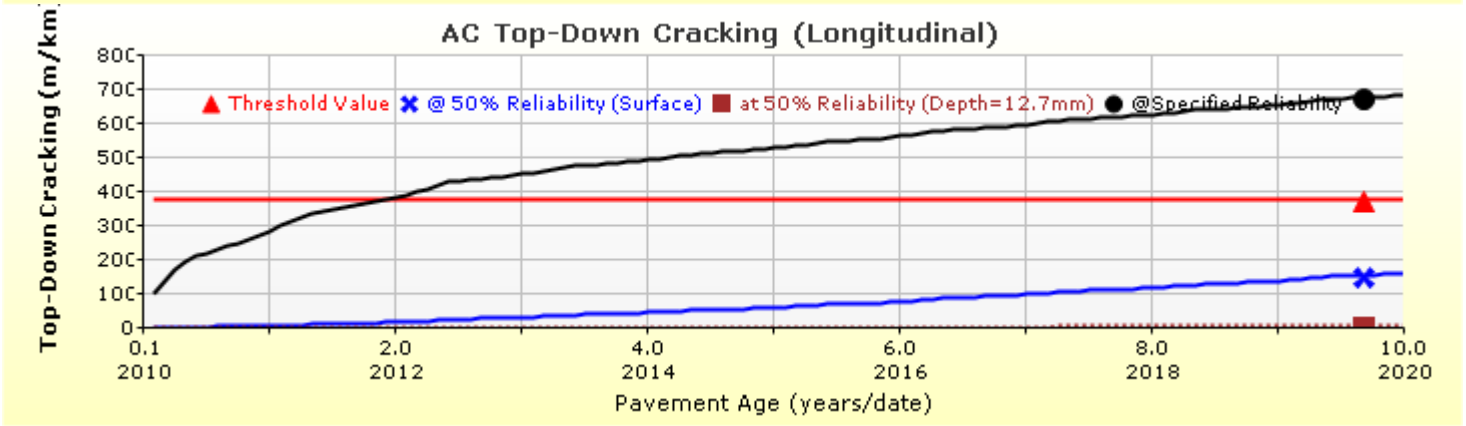


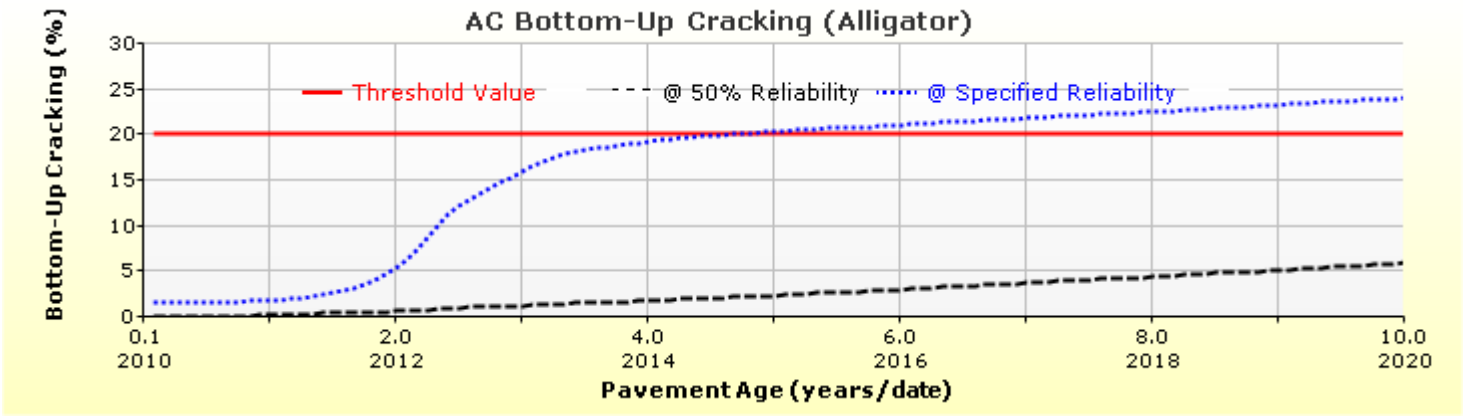


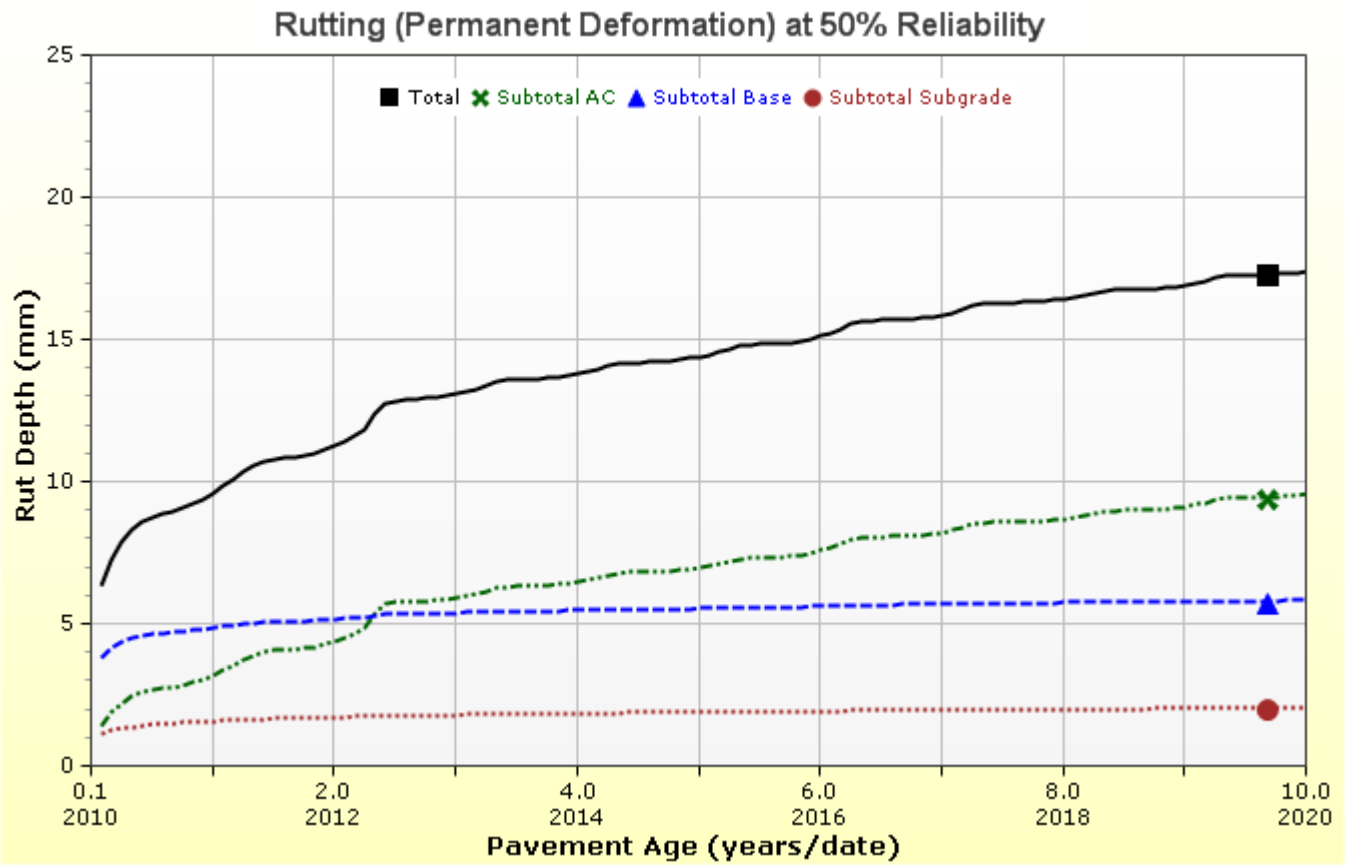


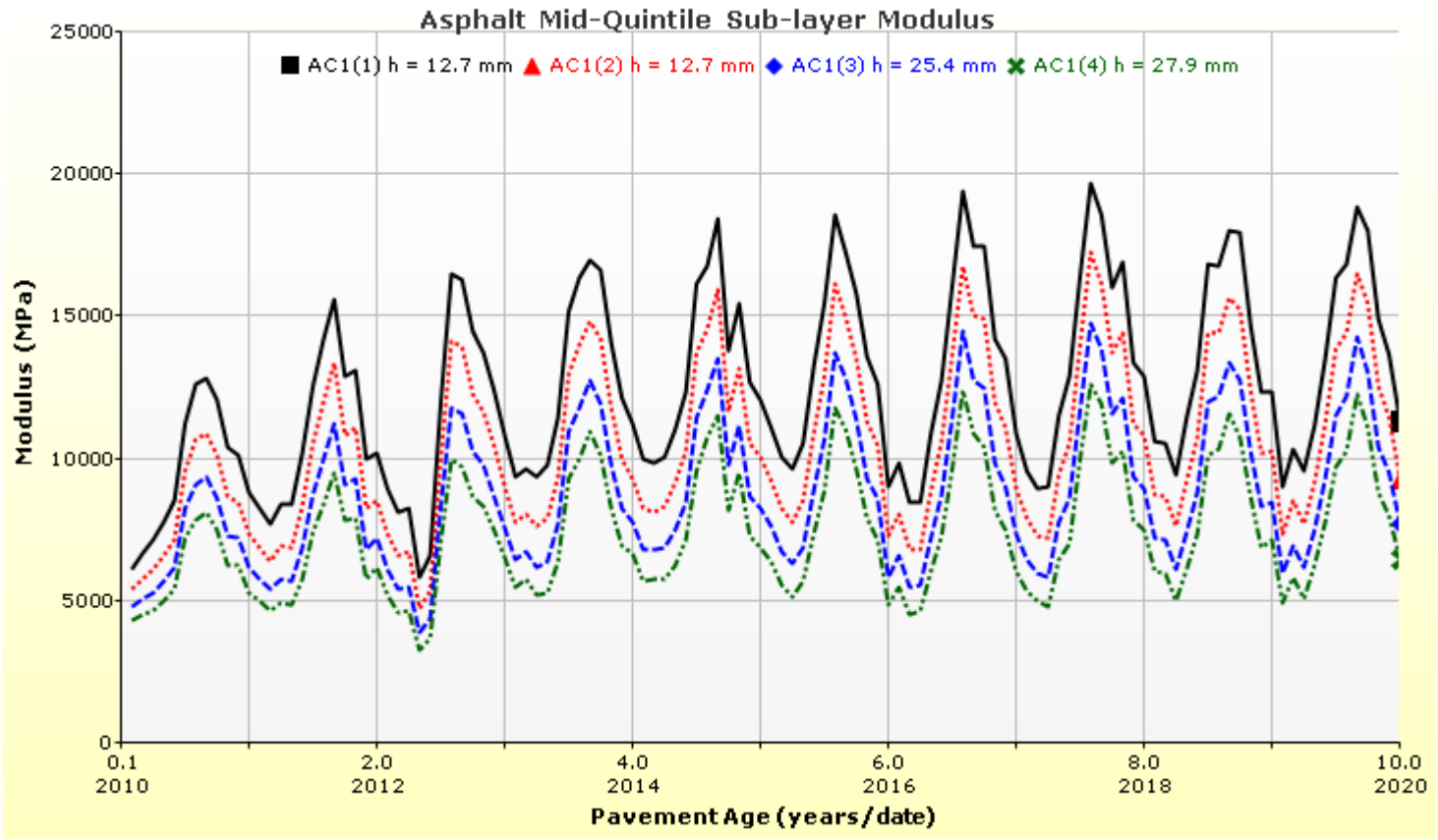

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

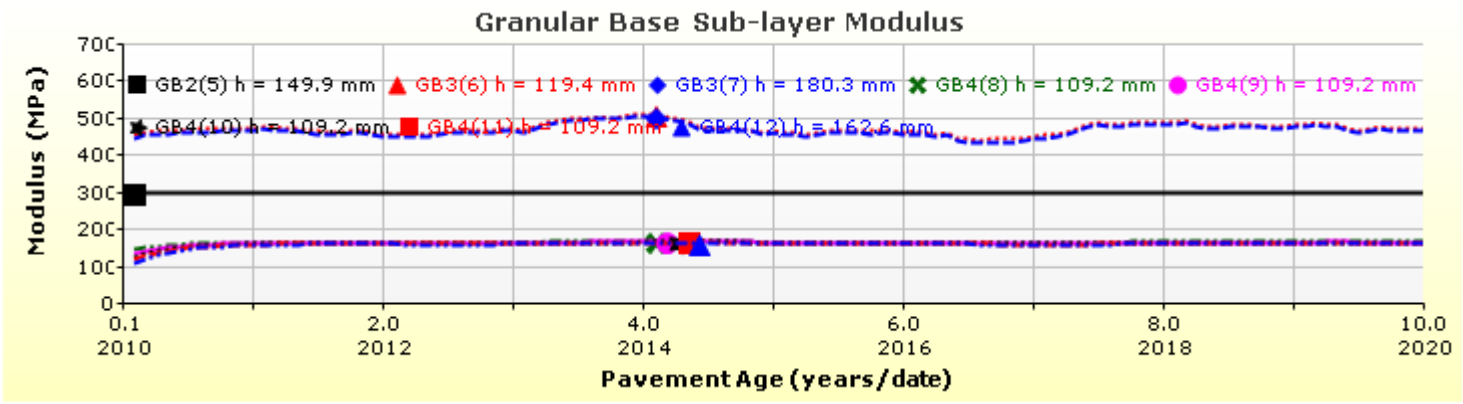

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

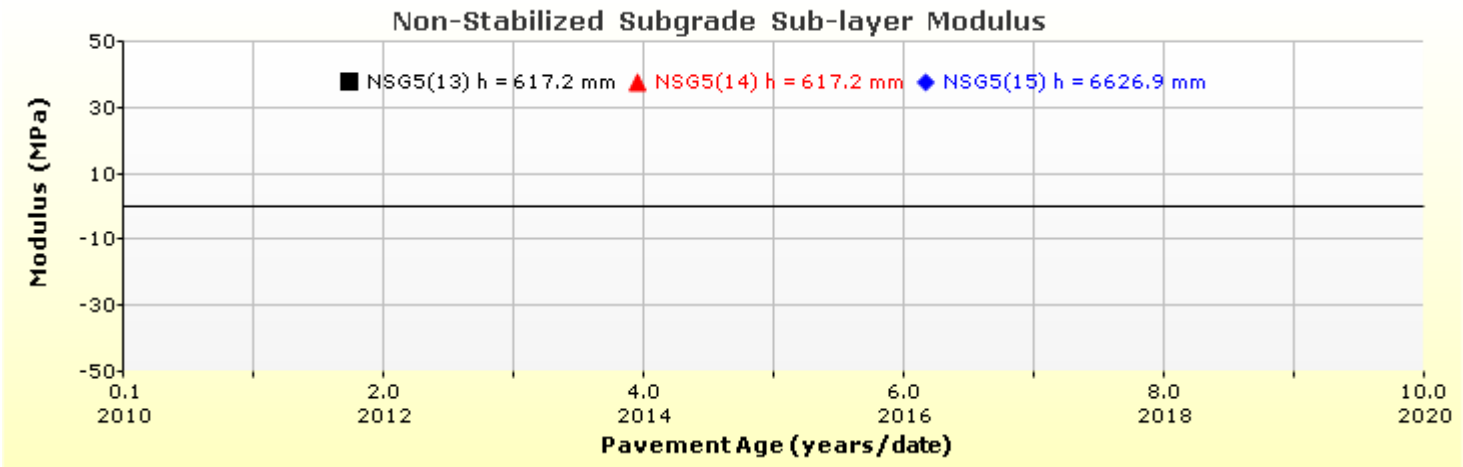

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRJ-4

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRJ-4.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -22.8, -43.68

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

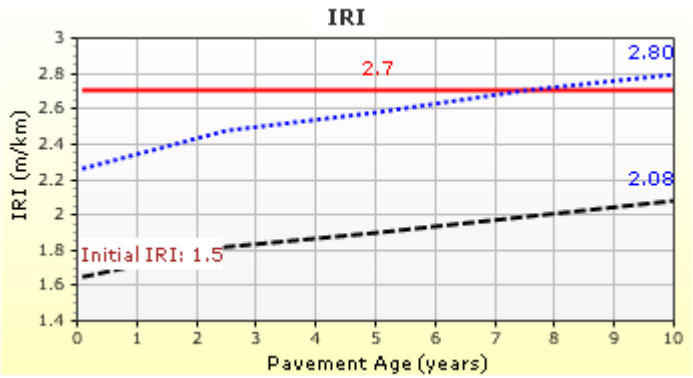
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

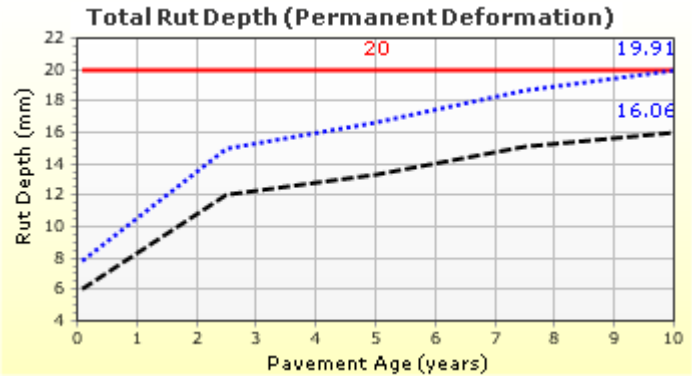
Design Outputs

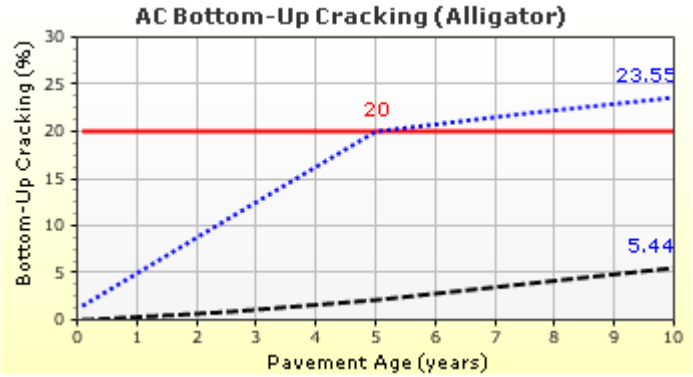
Distress Prediction Summary

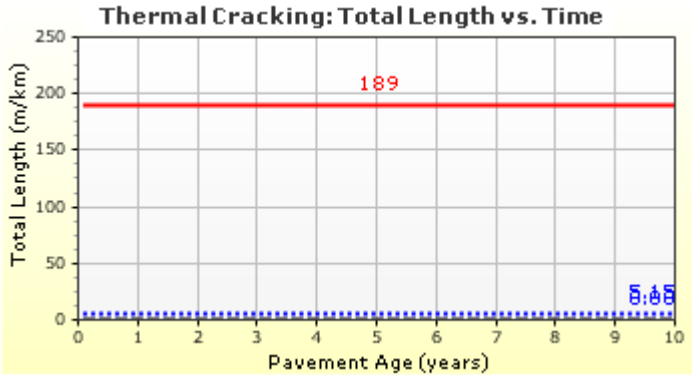
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.80	90.00	86.42	Fail
Permanent deformation - total pavement (mm)	20.00	19.92	90.00	90.42	Pass
AC bottom-up fatigue cracking (percent)	20.00	23.55	90.00	84.86	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	650.81	90.00	72.70	Fail
Permanent deformation - AC only (mm)	5.00	8.23	50.00	9.76	Fail

Distress Charts







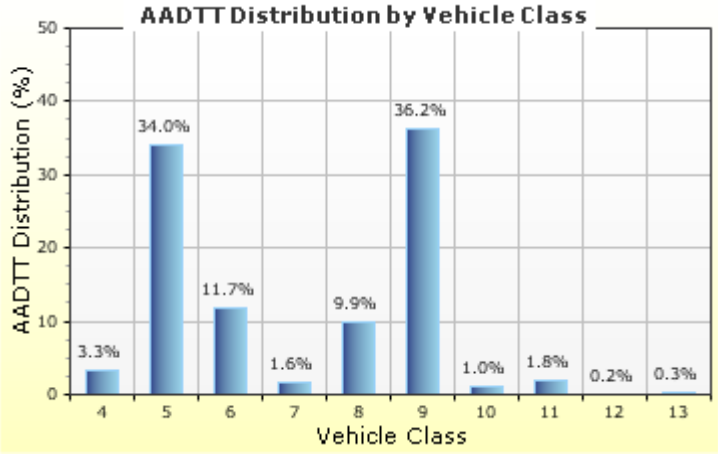


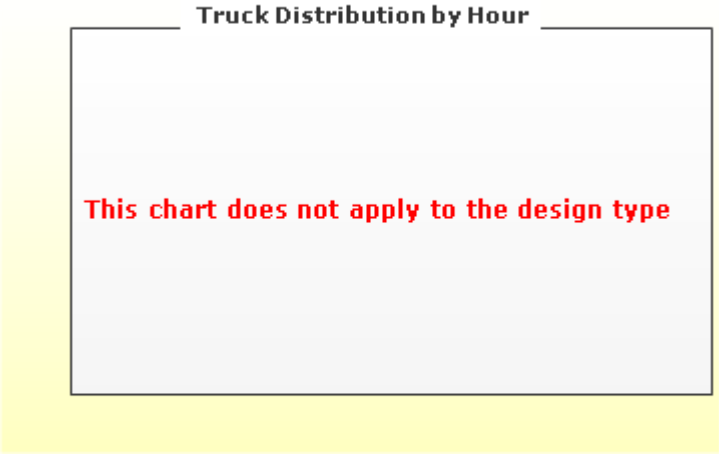


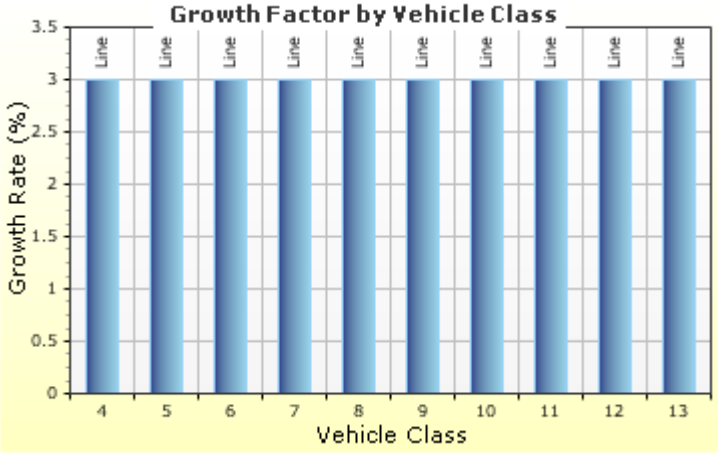
Traffic Inputs

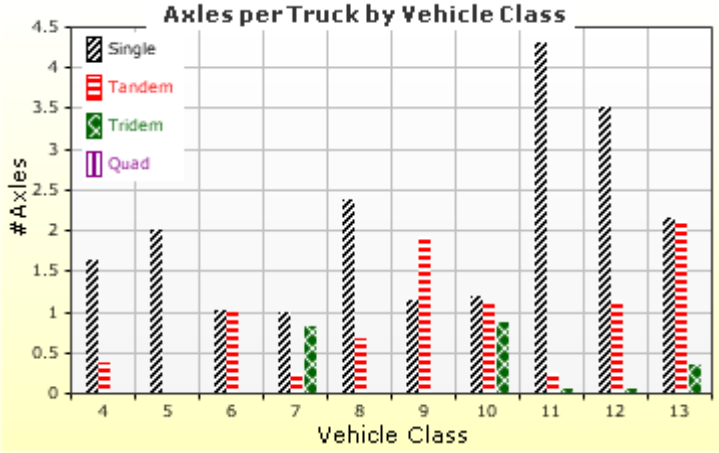
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

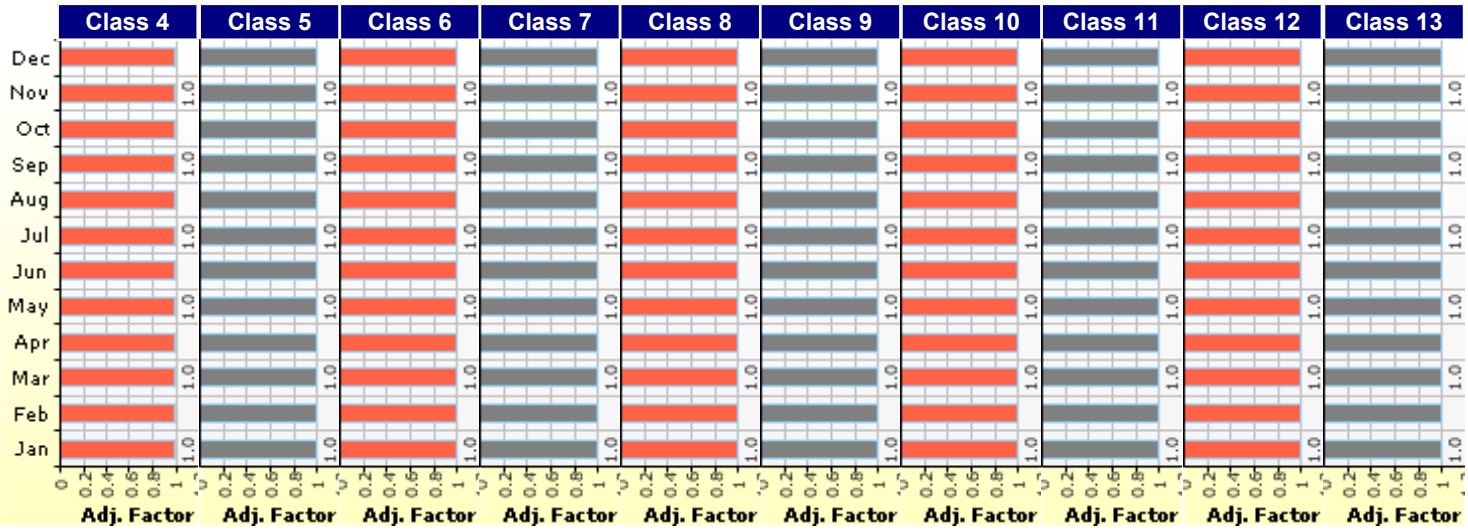








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

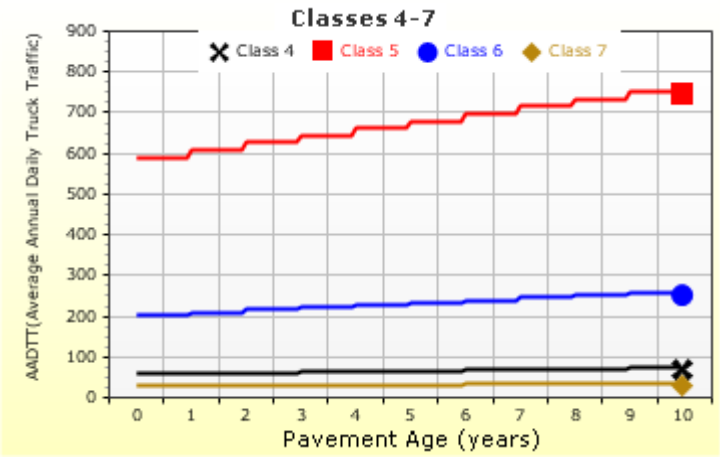
Wheelbase does not apply

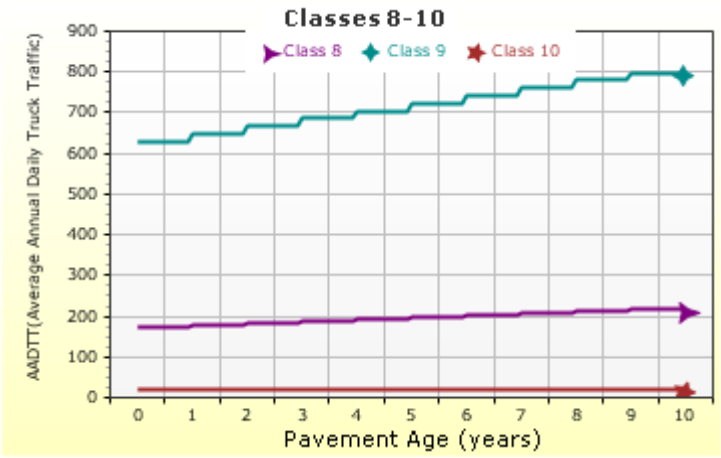
Number of Axles per Truck

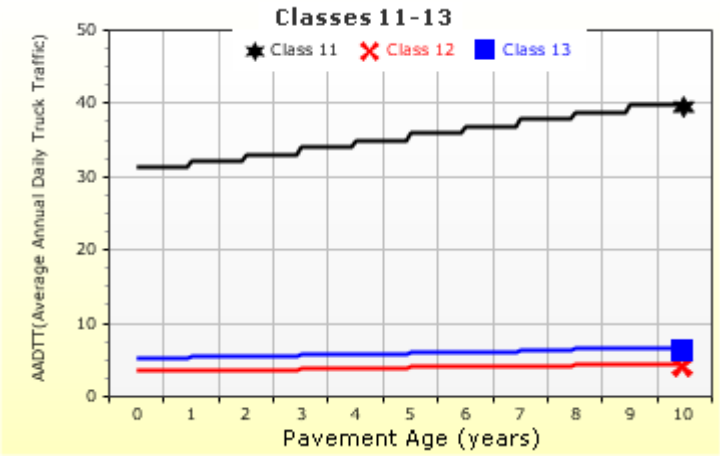
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

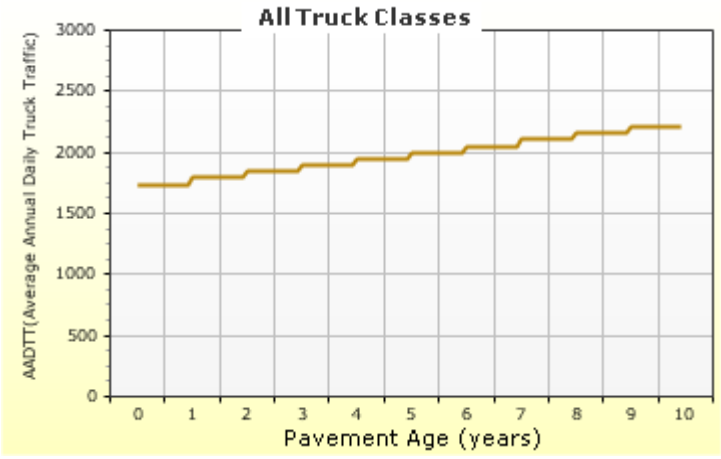
AADTT (Average Annual Daily Truck Traffic) Growth

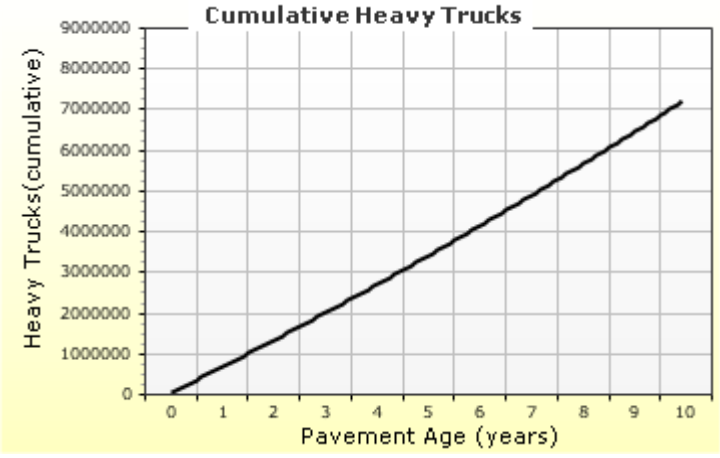
*** Traffic cap is not enforced**







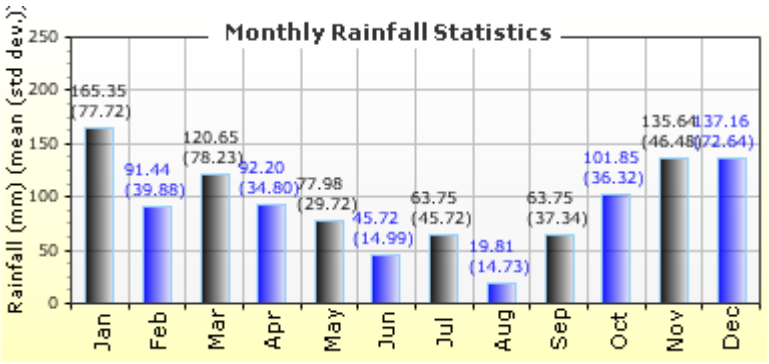




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
RIO DE JANEIRO, RJ	-22.80000 -43.68000 28

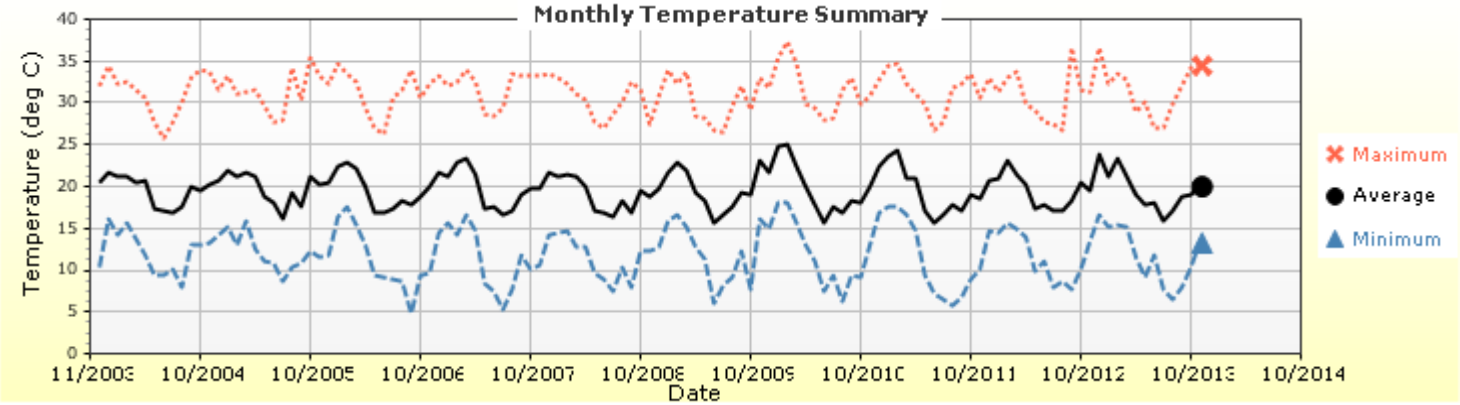


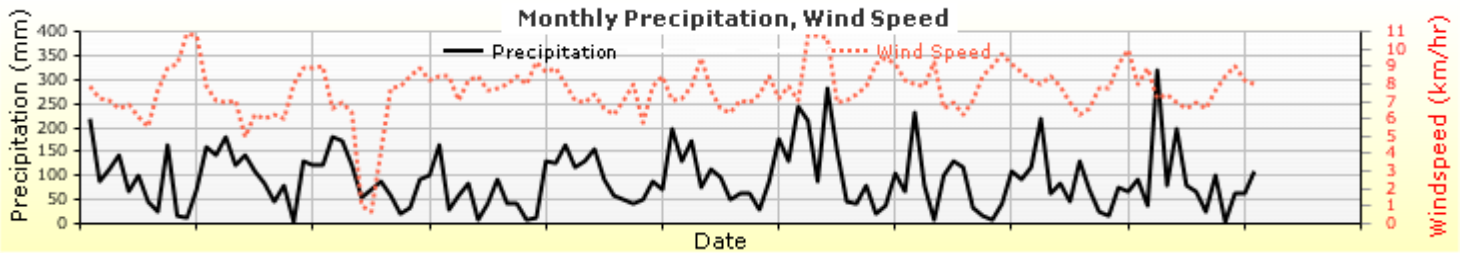
Annual Statistics:

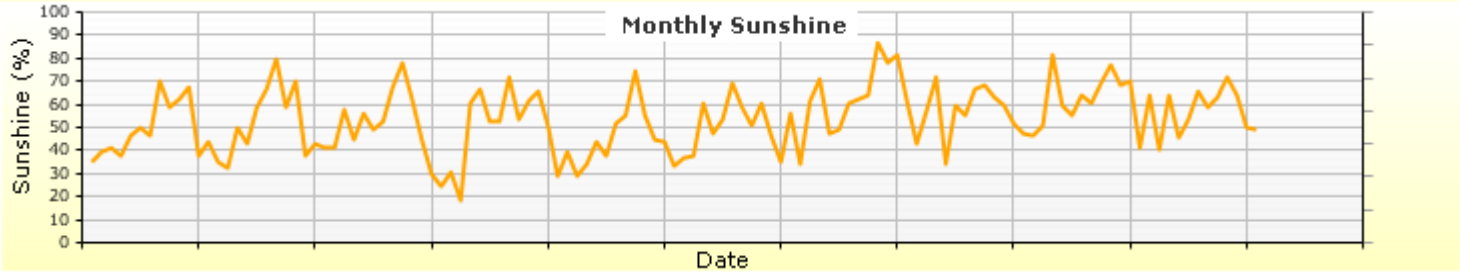
Mean annual air temperature (ºC)	19.59
Mean annual precipitation (mm)	1122.68
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

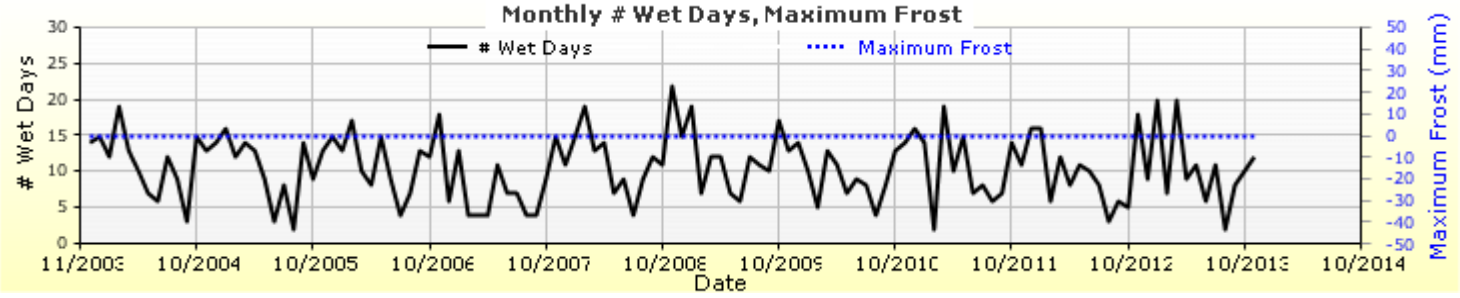
Water table depth (m)	3.05

Monthly Climate Summary:

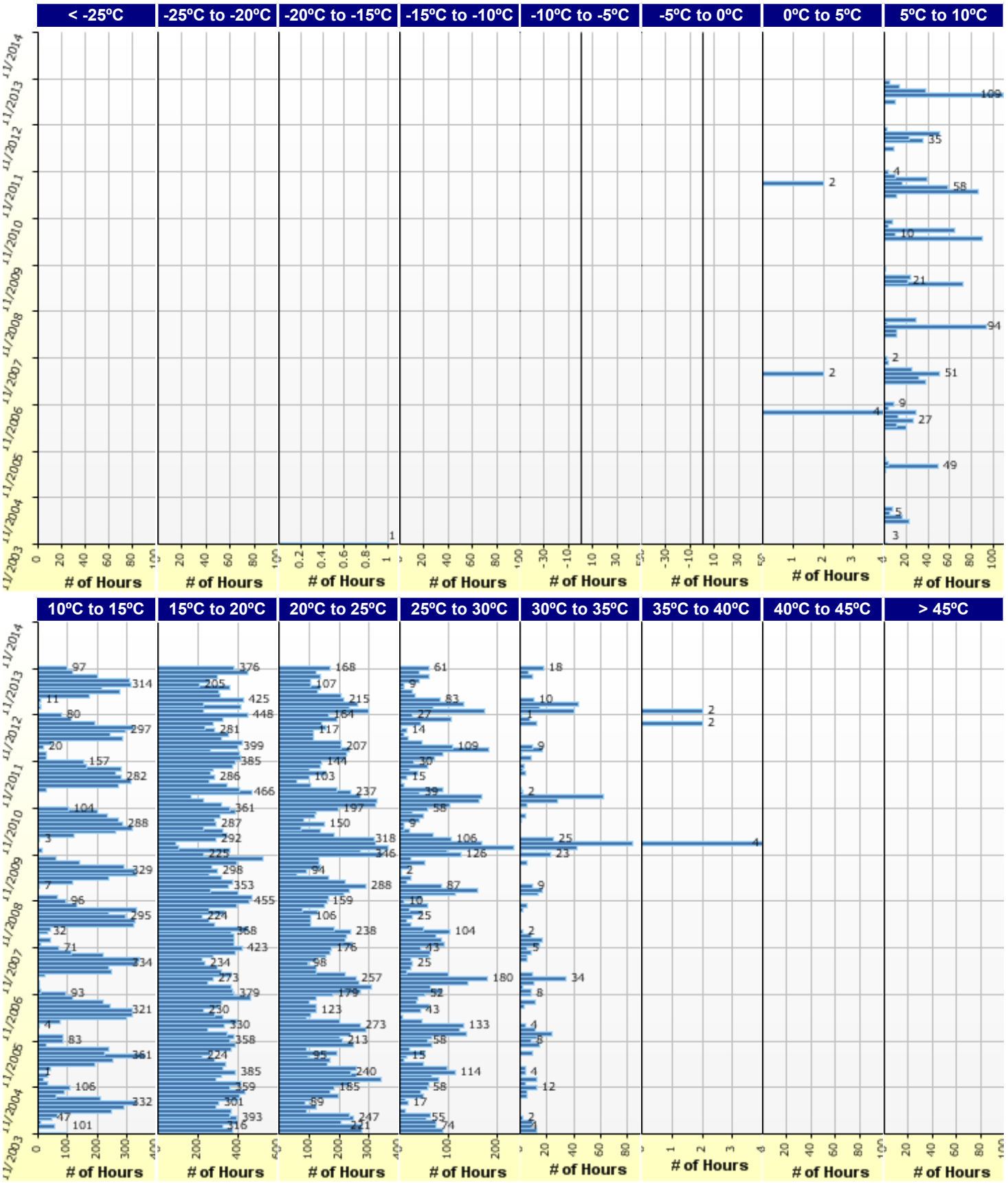








Hourly Air Temperature Distribution by Month:



Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

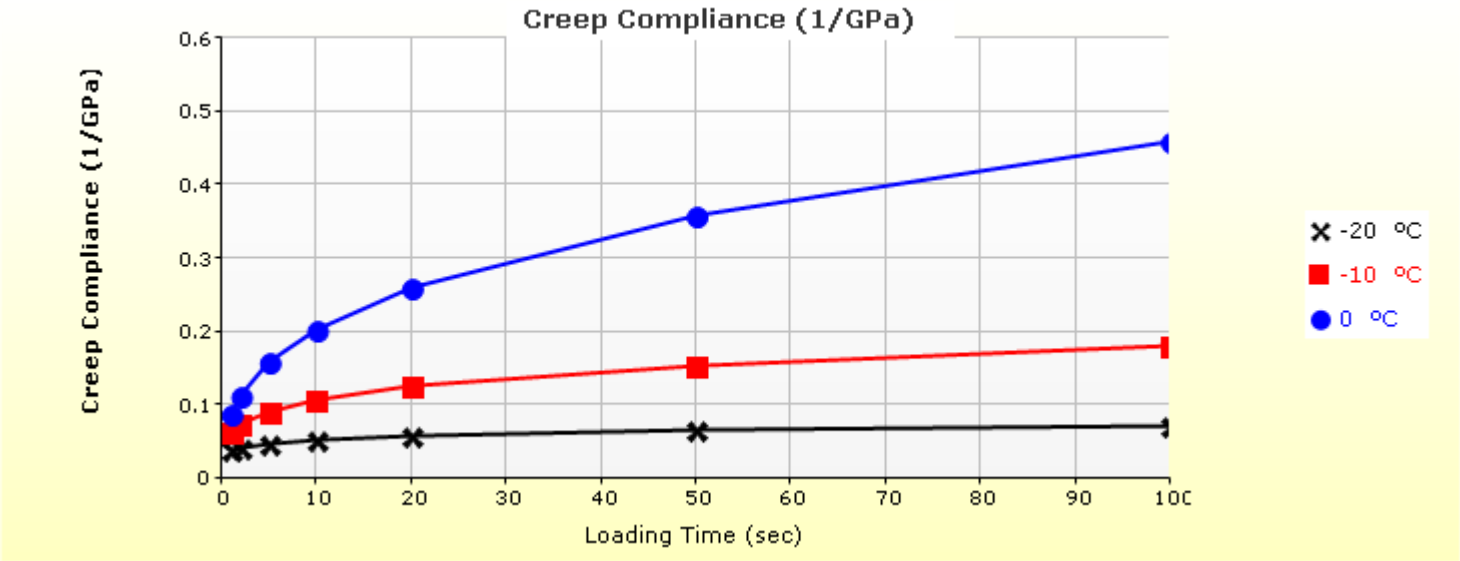
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

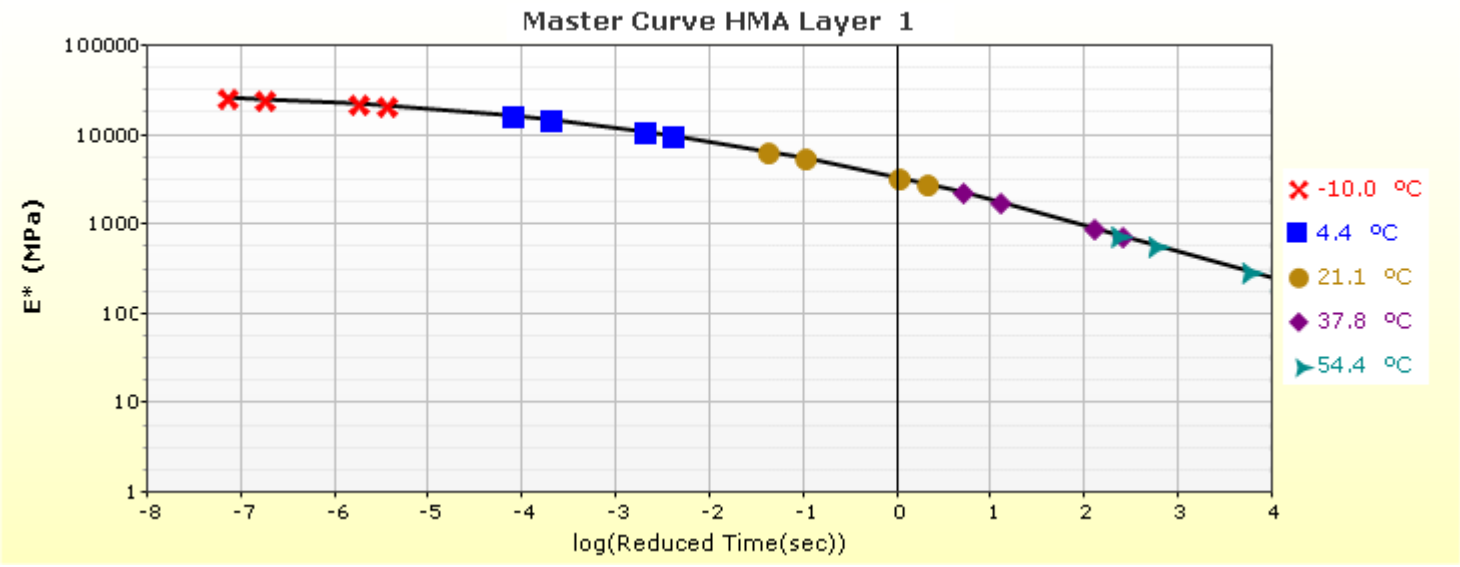
Indirect tensile strength at -10 ºC (MPa)	2.69

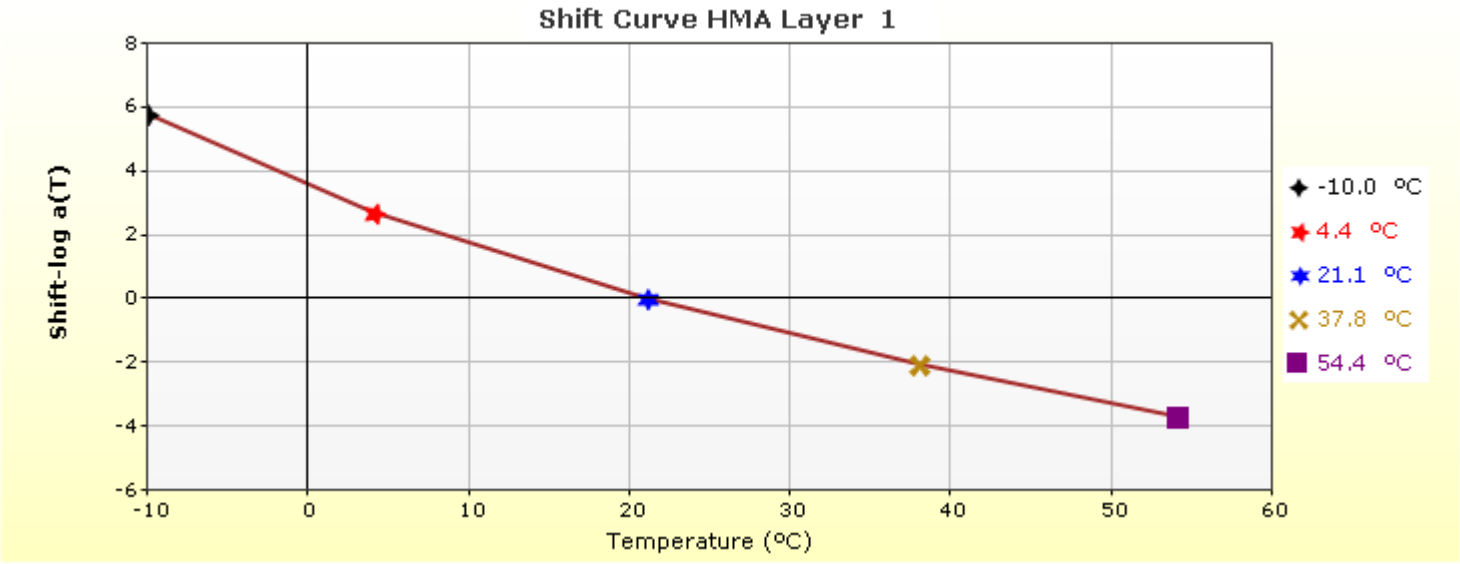
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

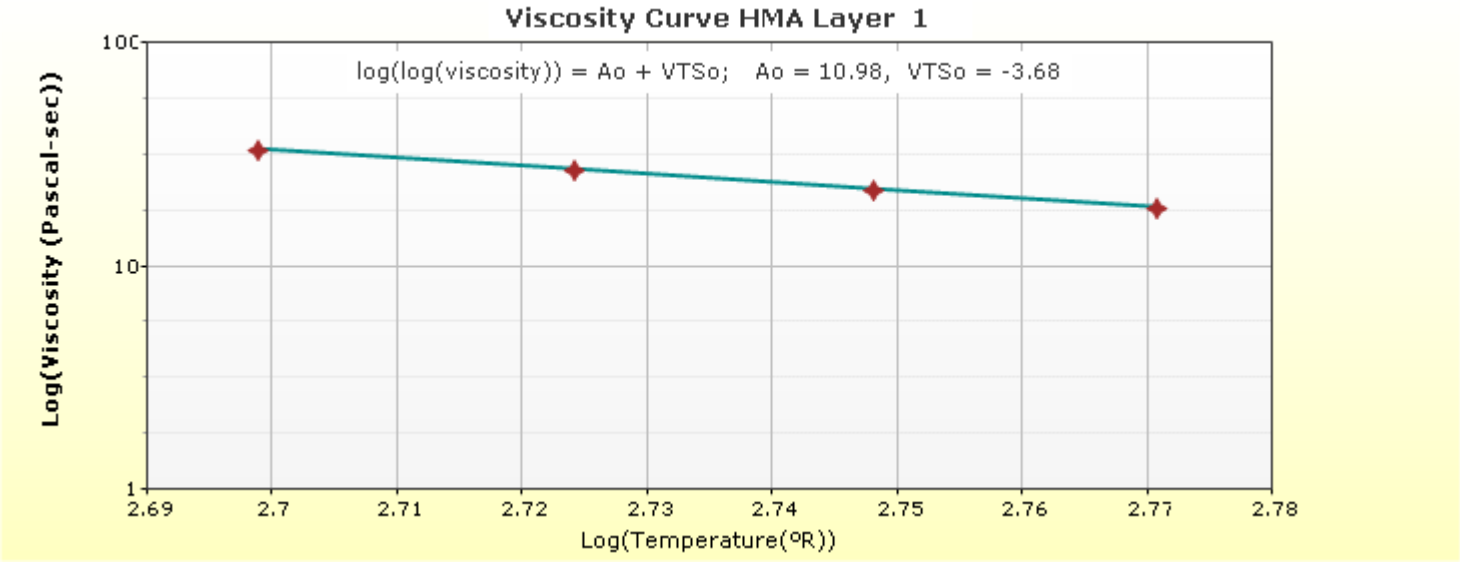
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



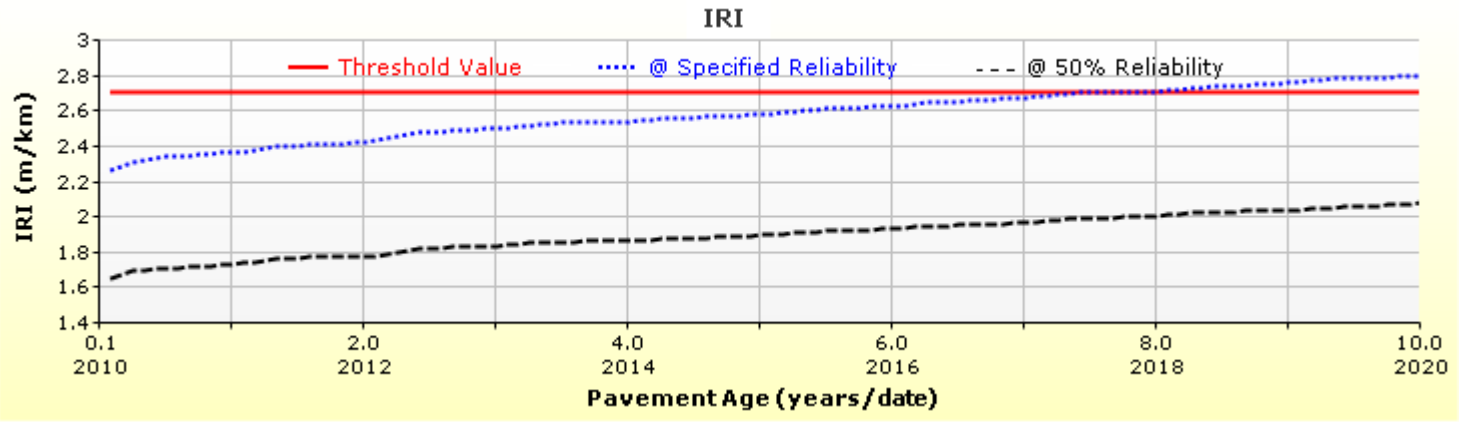
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

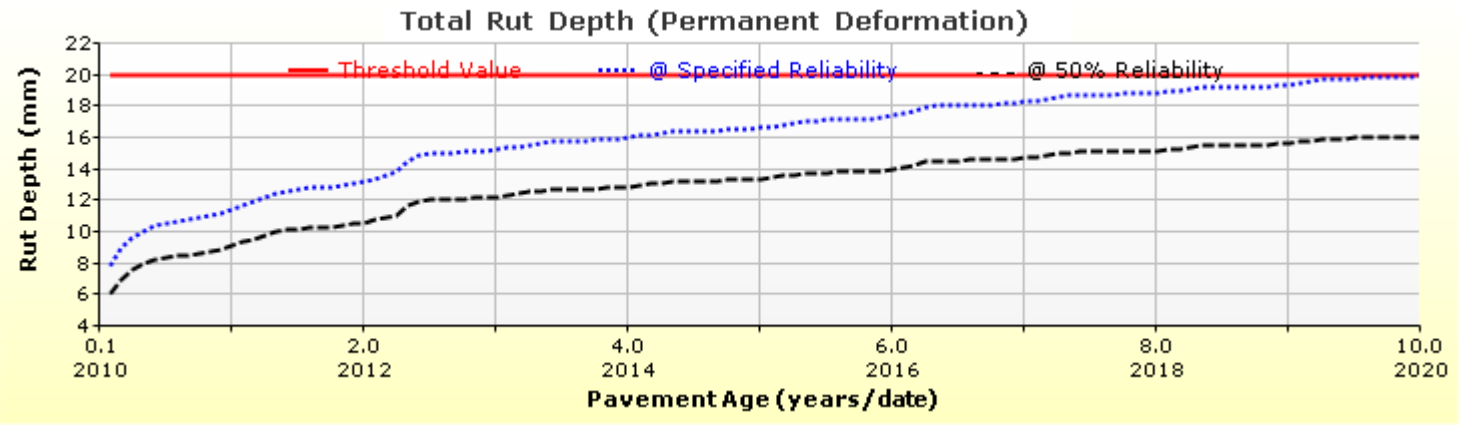


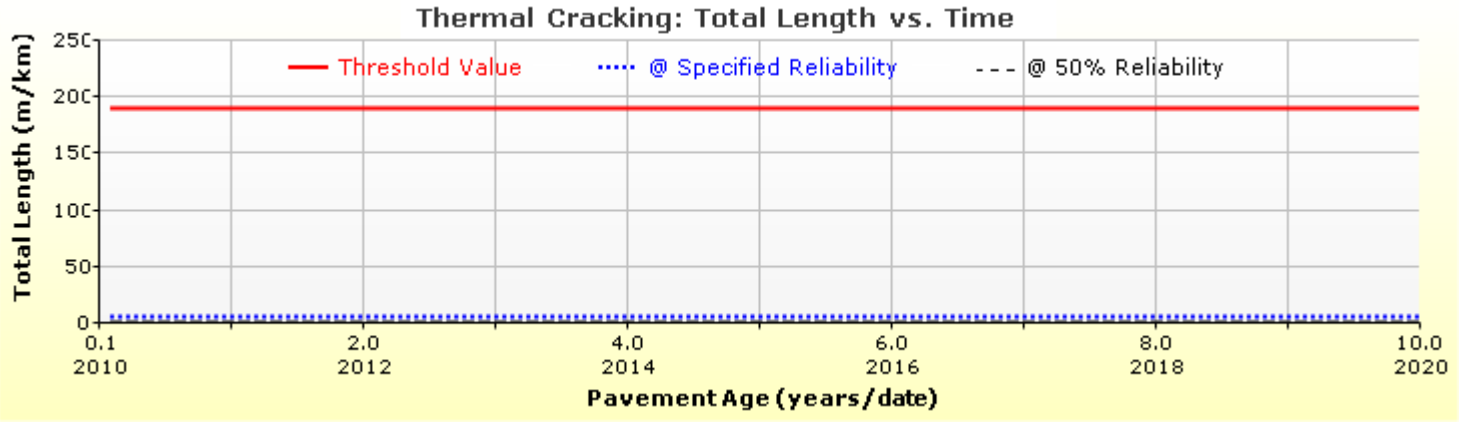


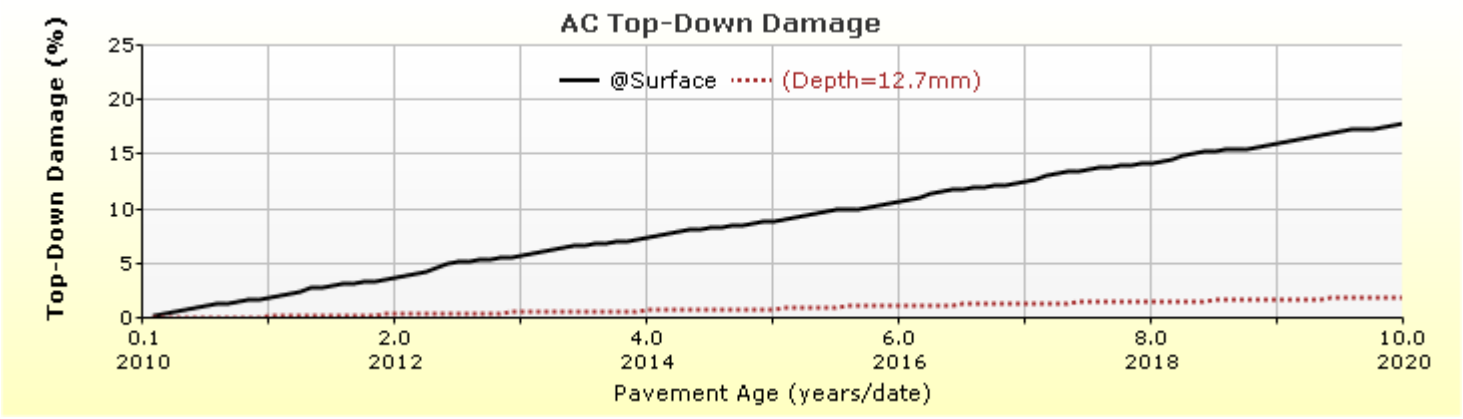


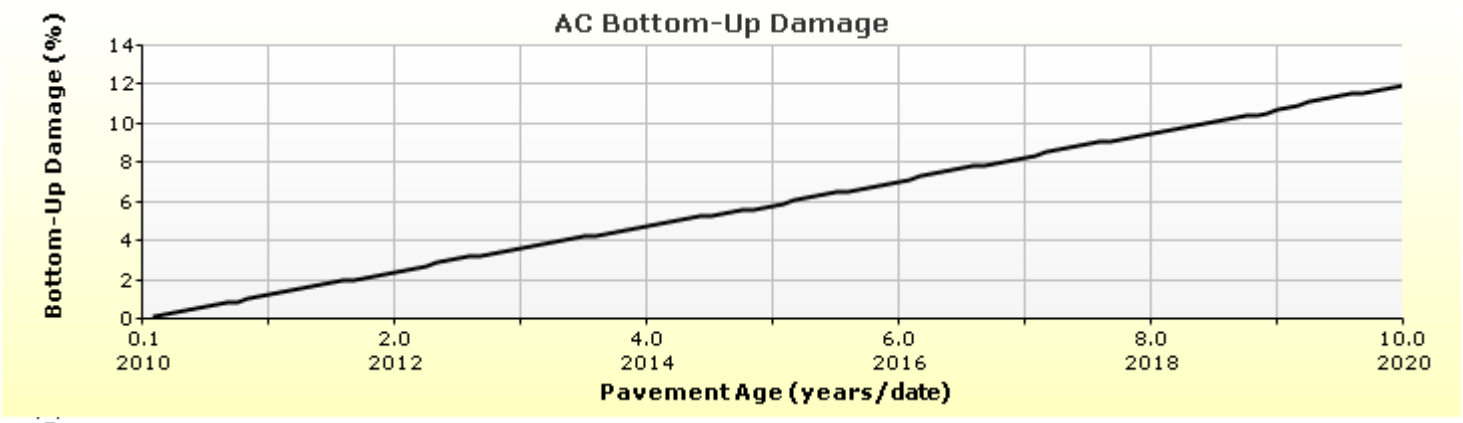
Analysis Output Charts

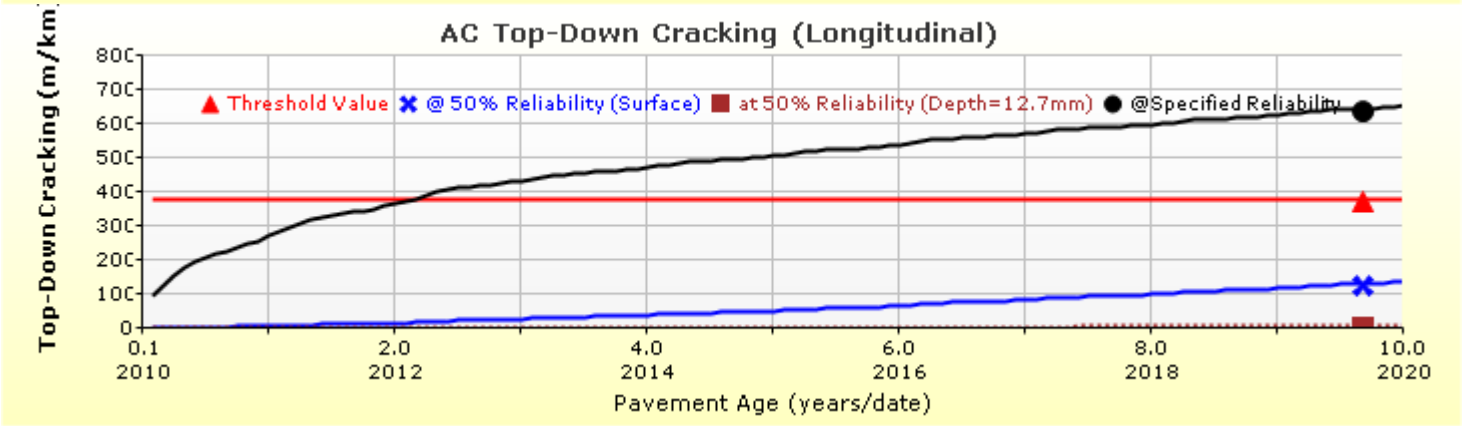


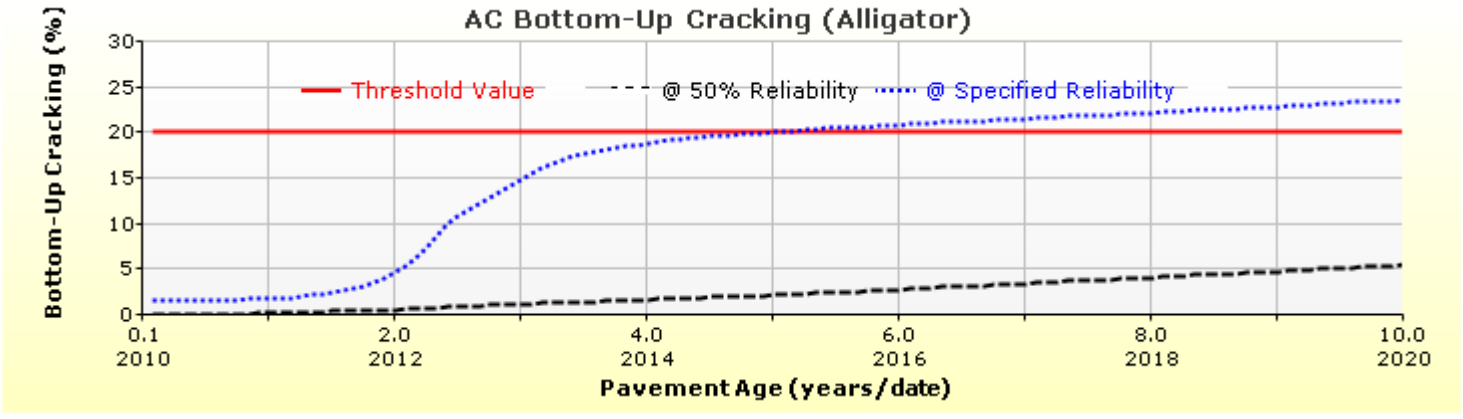


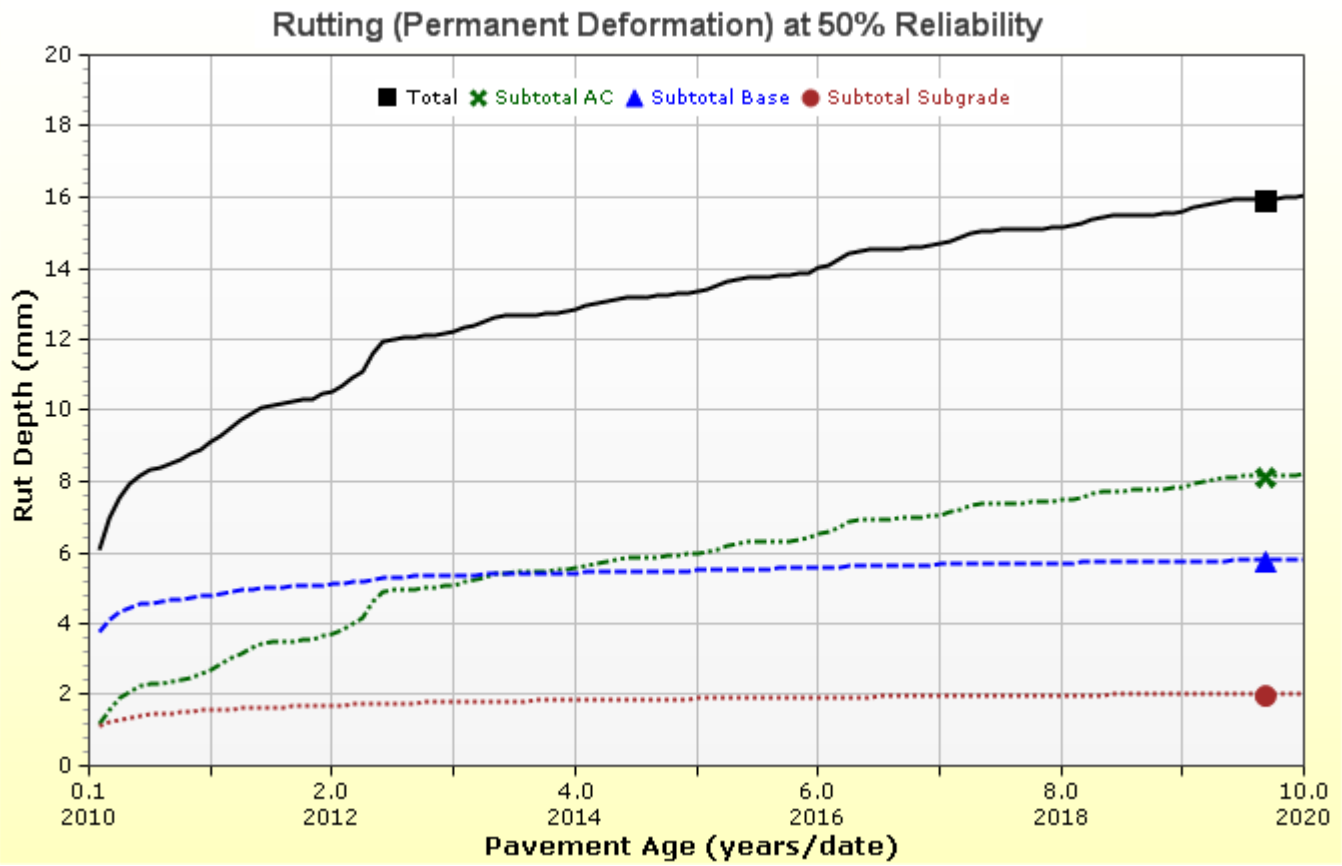


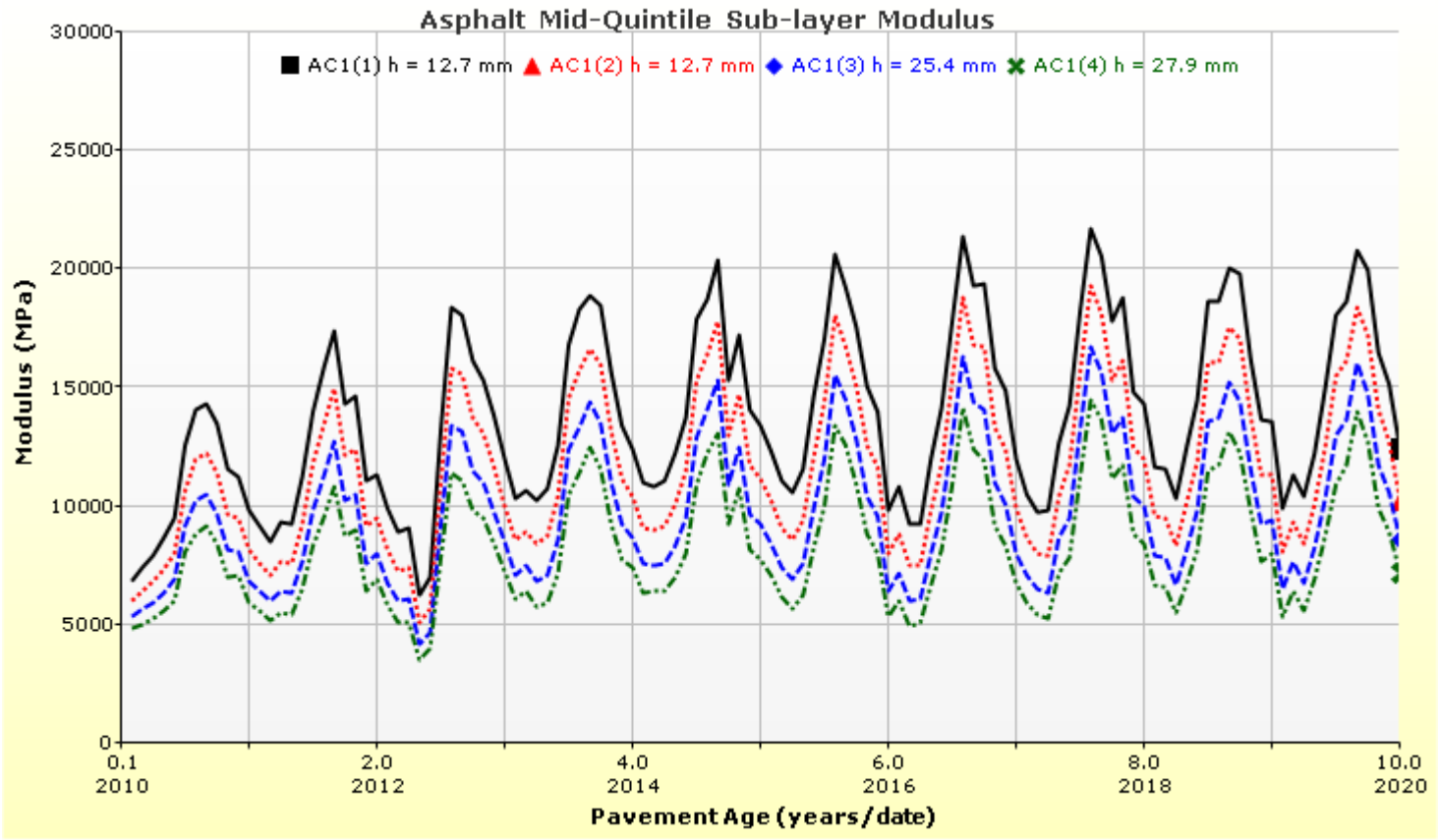

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

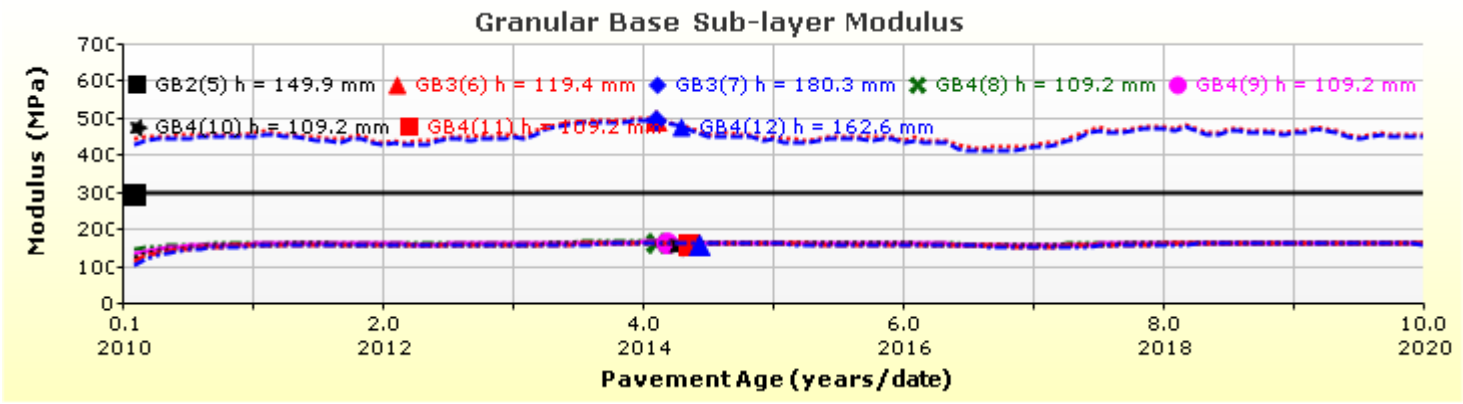

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

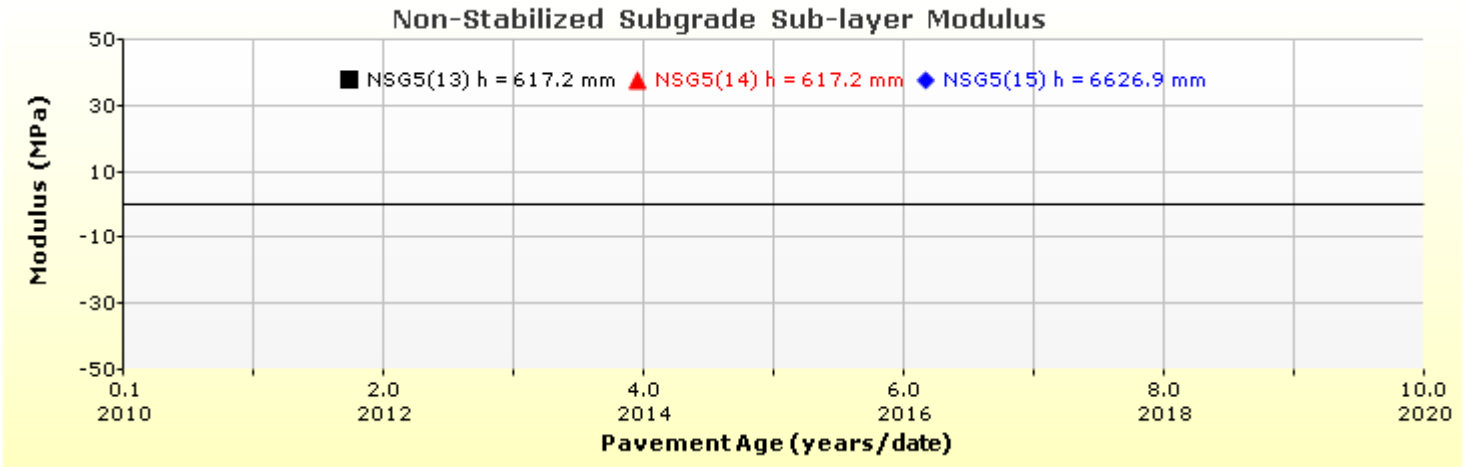

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
0
2
4
6
8
10
12
14
16
18
20
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRJ_Cobertura

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRJ_Cobertura.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -22.8, -43.68

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

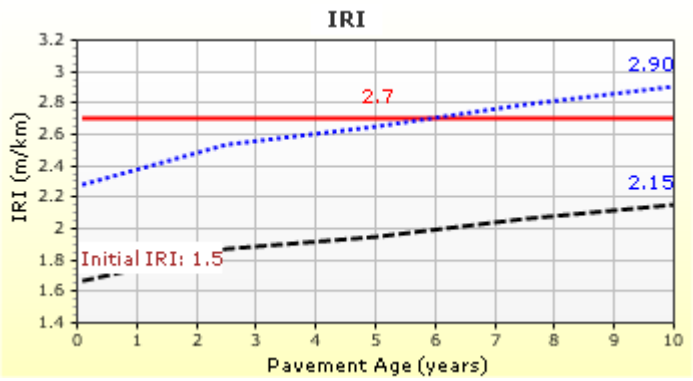
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

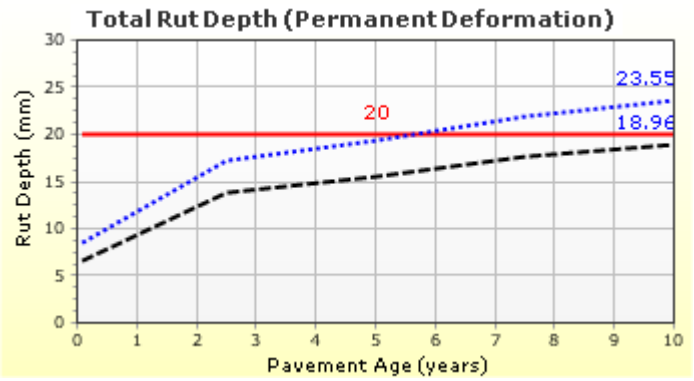
Design Outputs

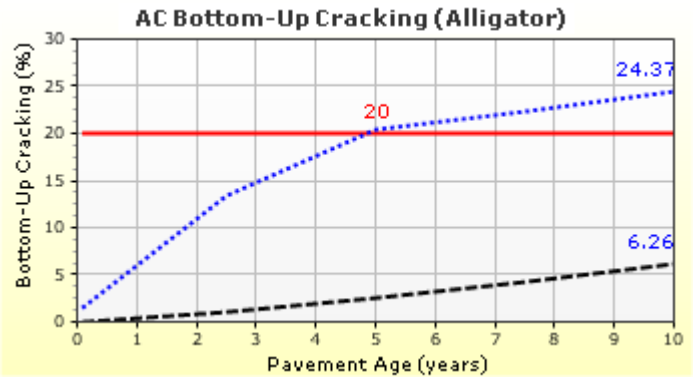
Distress Prediction Summary

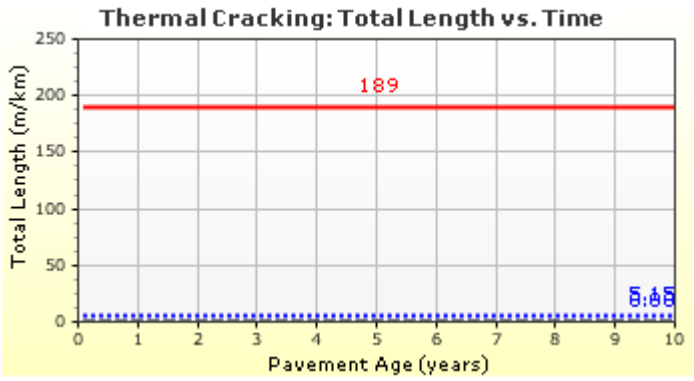
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.90	90.00	82.48	Fail
Permanent deformation - total pavement (mm)	20.00	23.55	90.00	61.30	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.37	90.00	83.46	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	723.43	90.00	67.35	Fail
Permanent deformation - AC only (mm)	5.00	11.07	50.00	2.72	Fail

Distress Charts







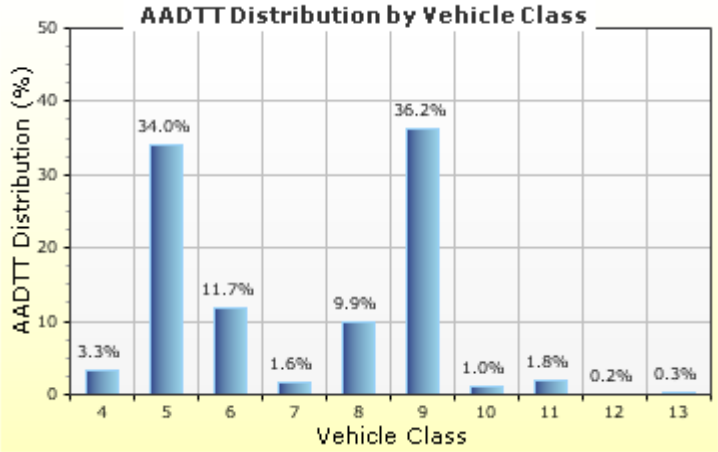


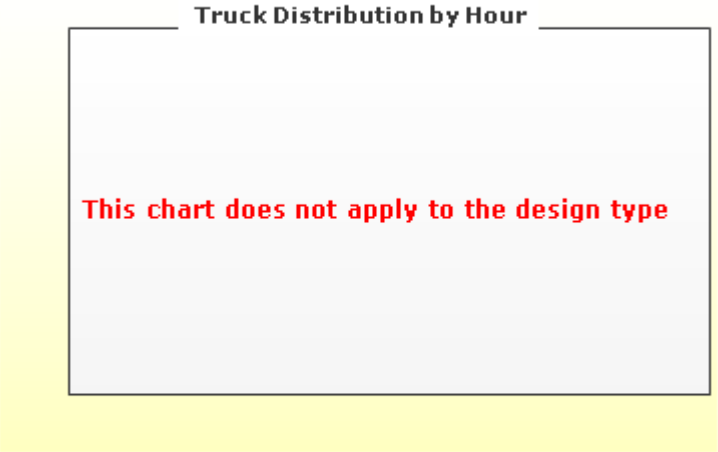


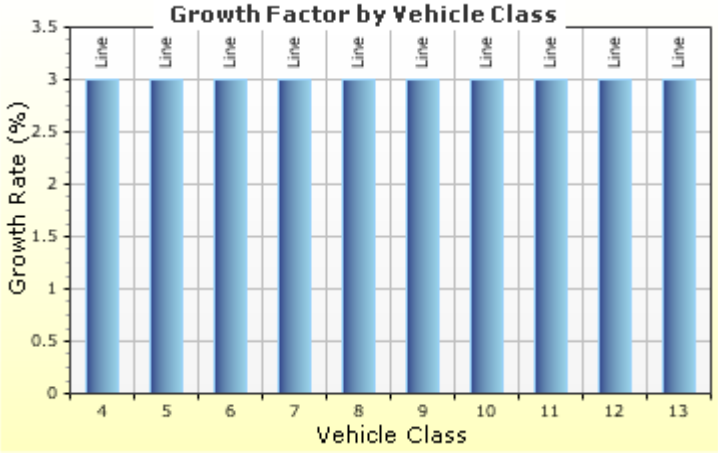
Traffic Inputs

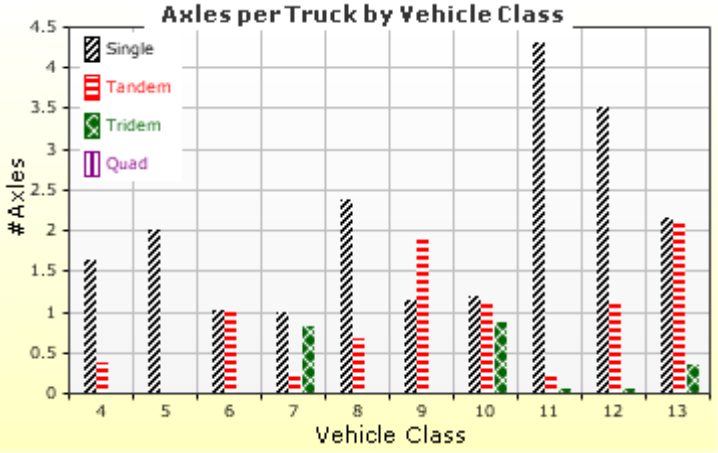
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

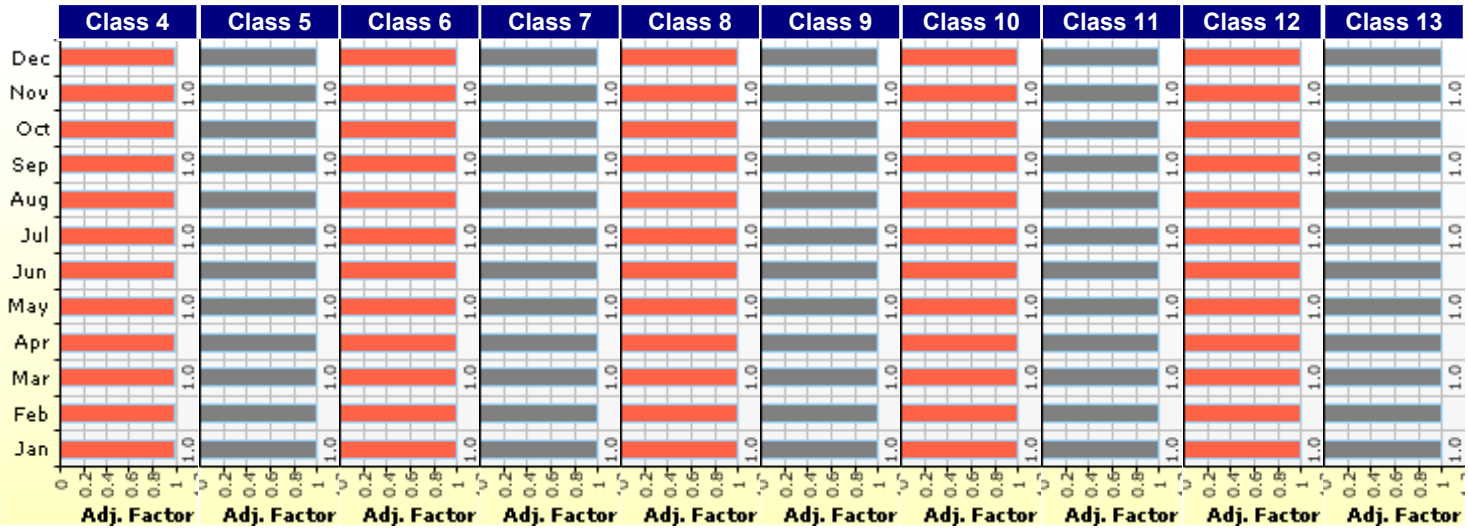








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

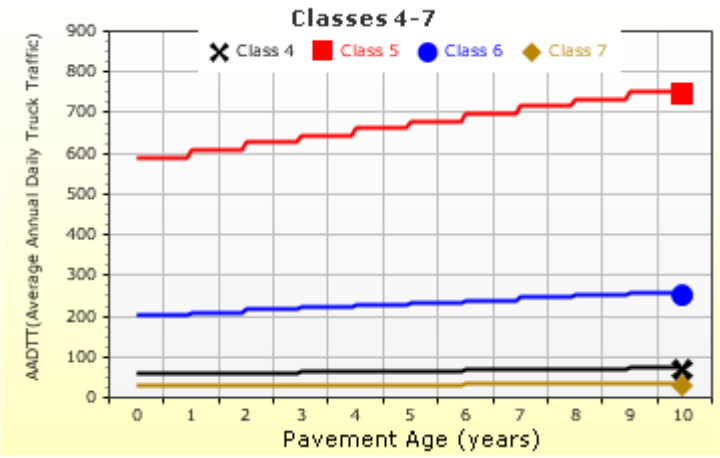
Wheelbase does not apply

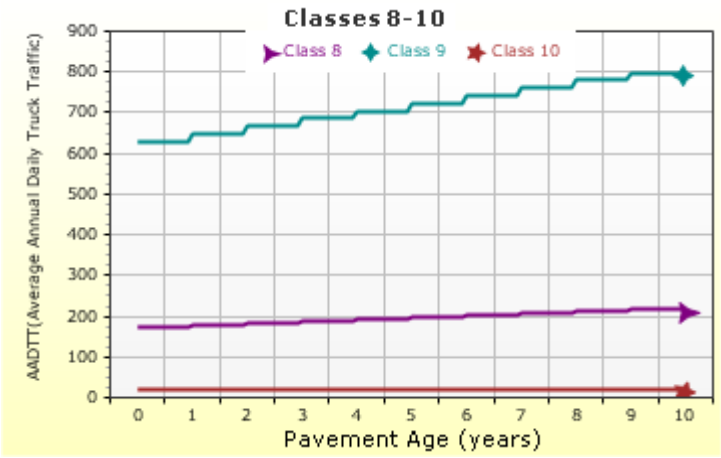
Number of Axles per Truck

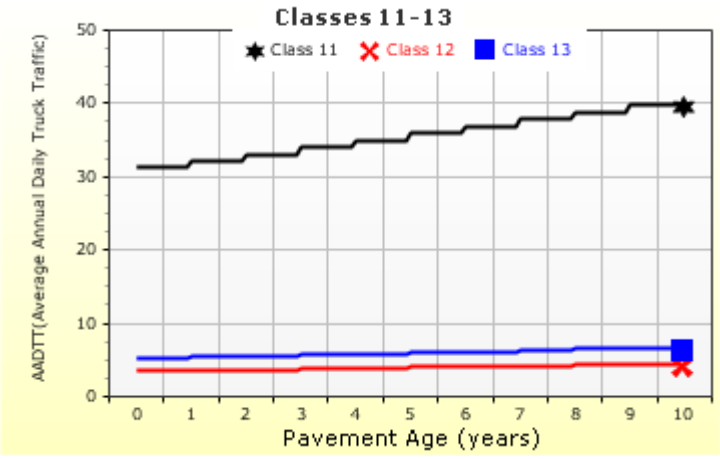
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

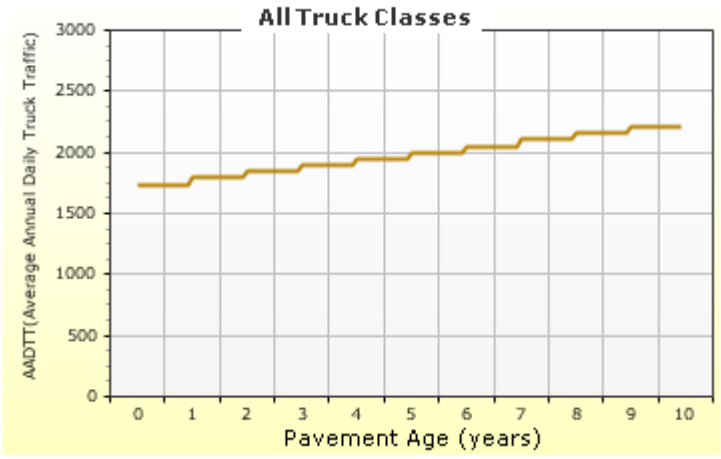
AADTT (Average Annual Daily Truck Traffic) Growth

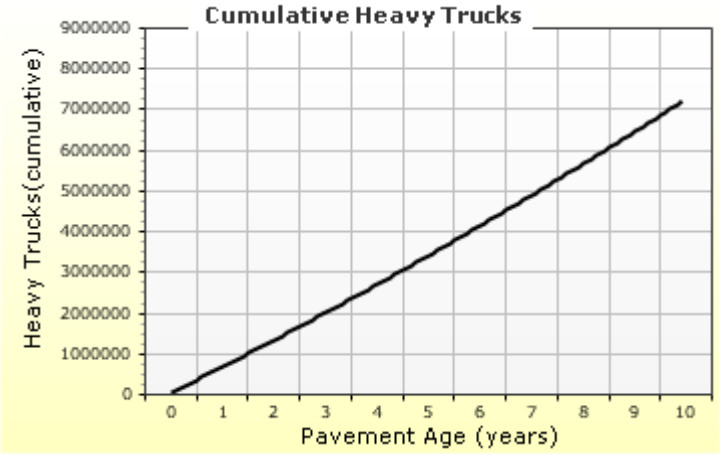
*** Traffic cap is not enforced**







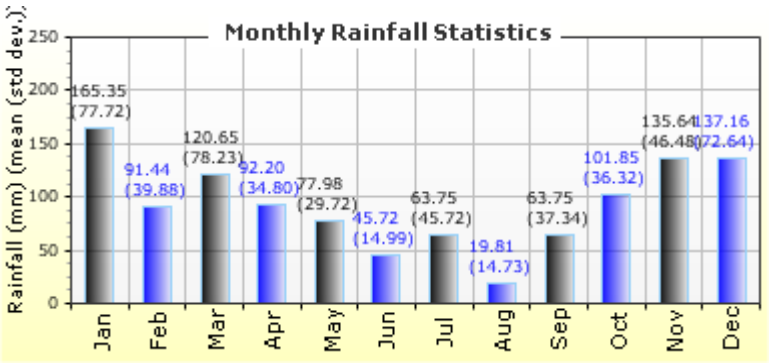




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
RIO DE JANEIRO, RJ	-22.80000 -43.68000 28

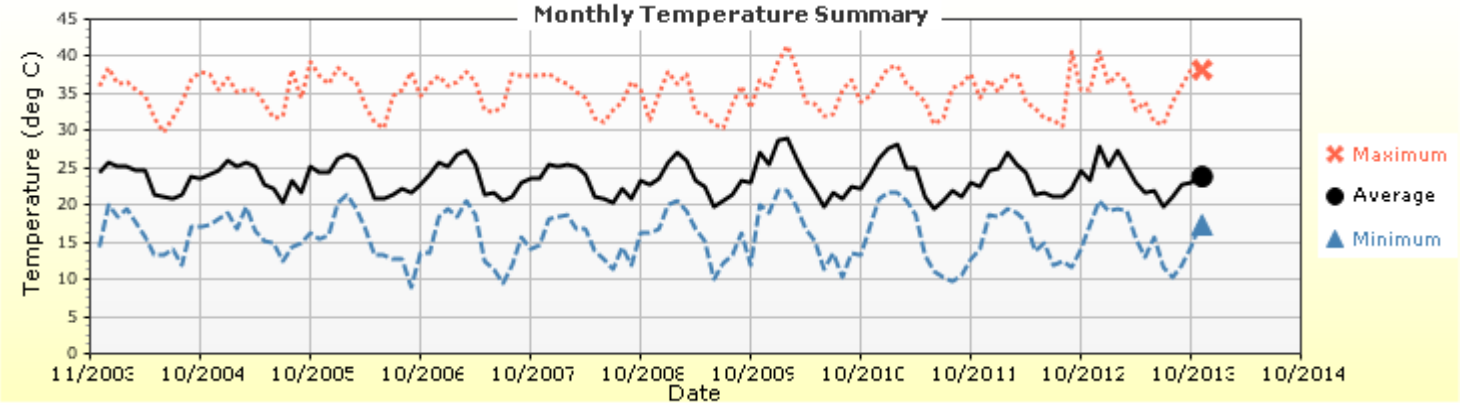


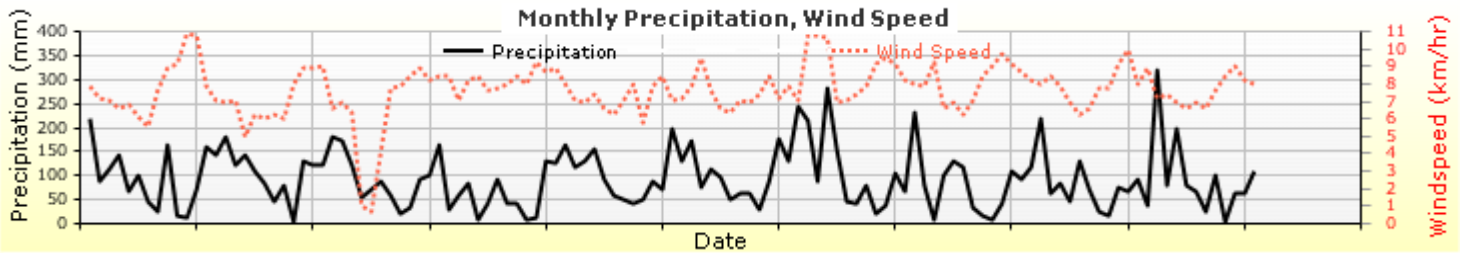
Annual Statistics:

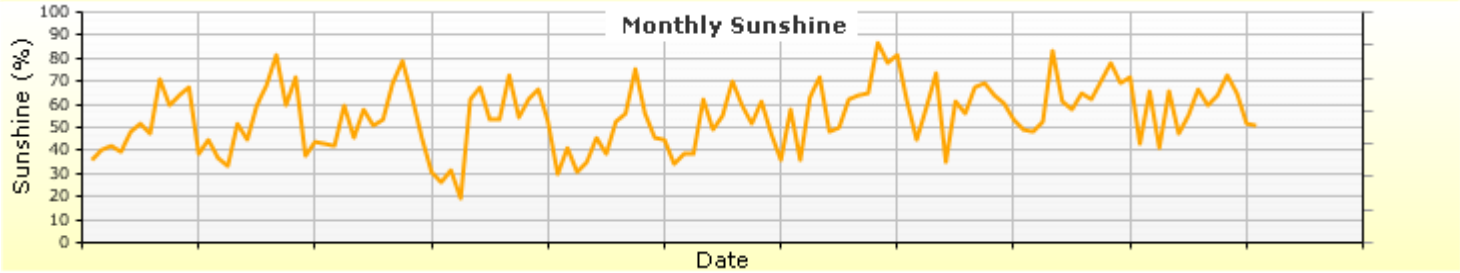
Mean annual air temperature (ºC)	23.59
Mean annual precipitation (mm)	1122.68
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

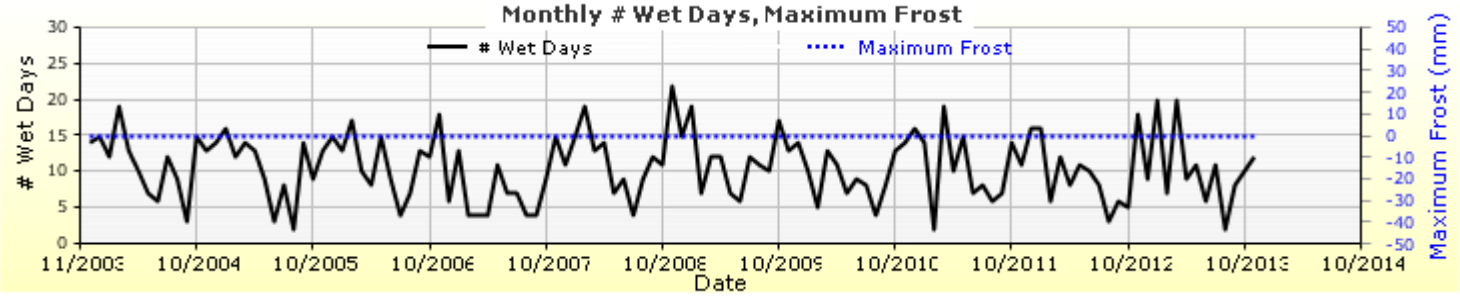
Water table depth (m): 3.05

Monthly Climate Summary:

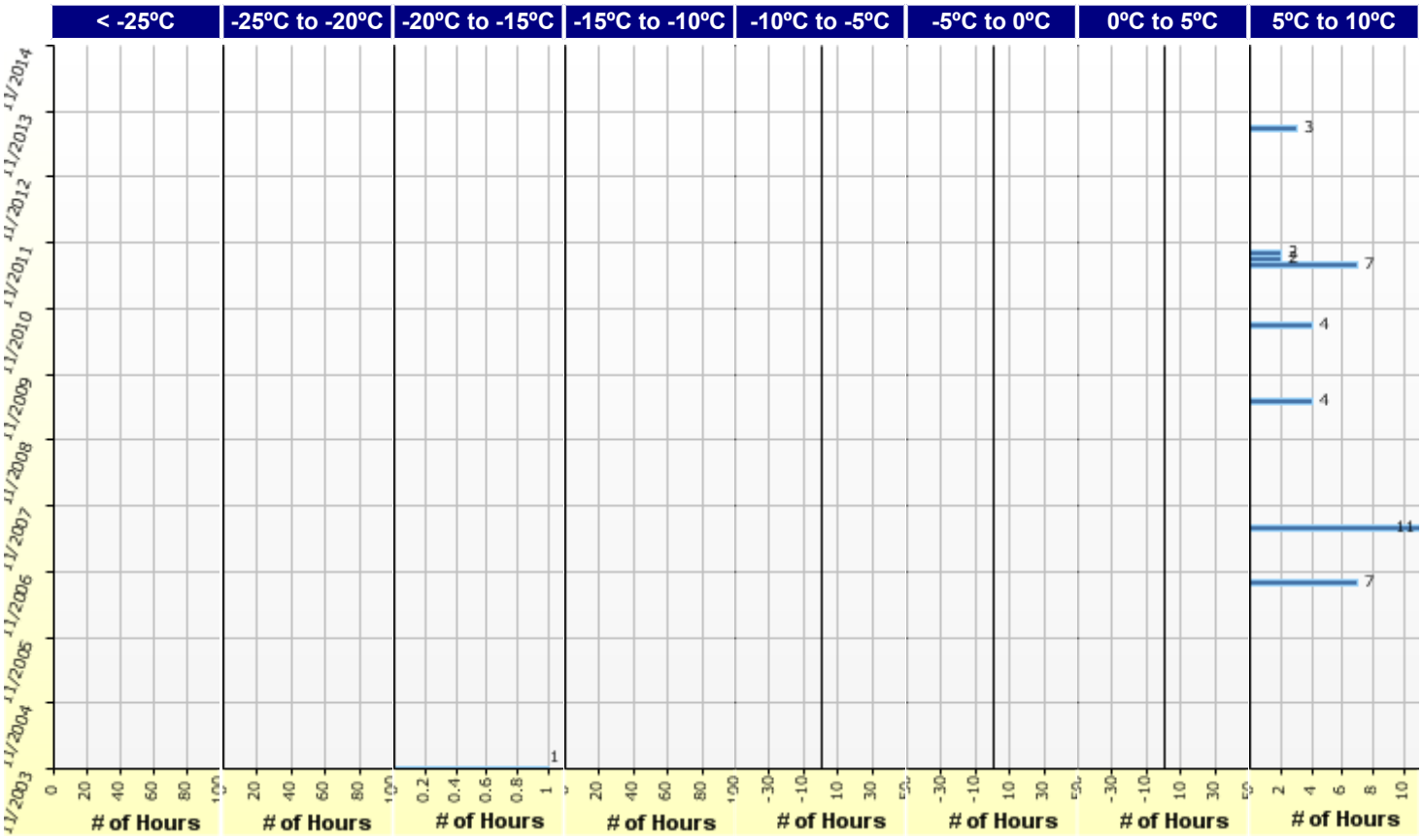


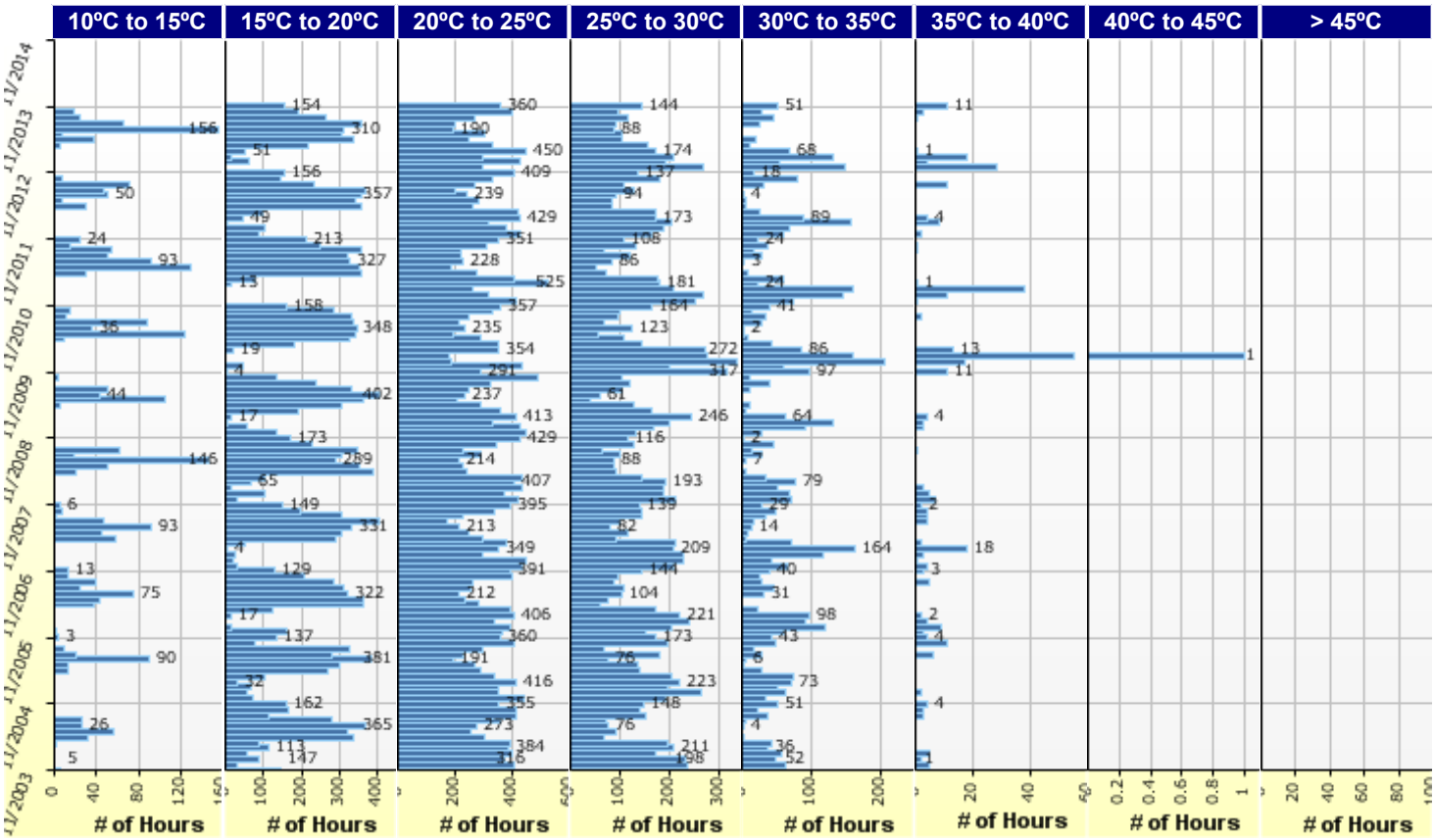






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

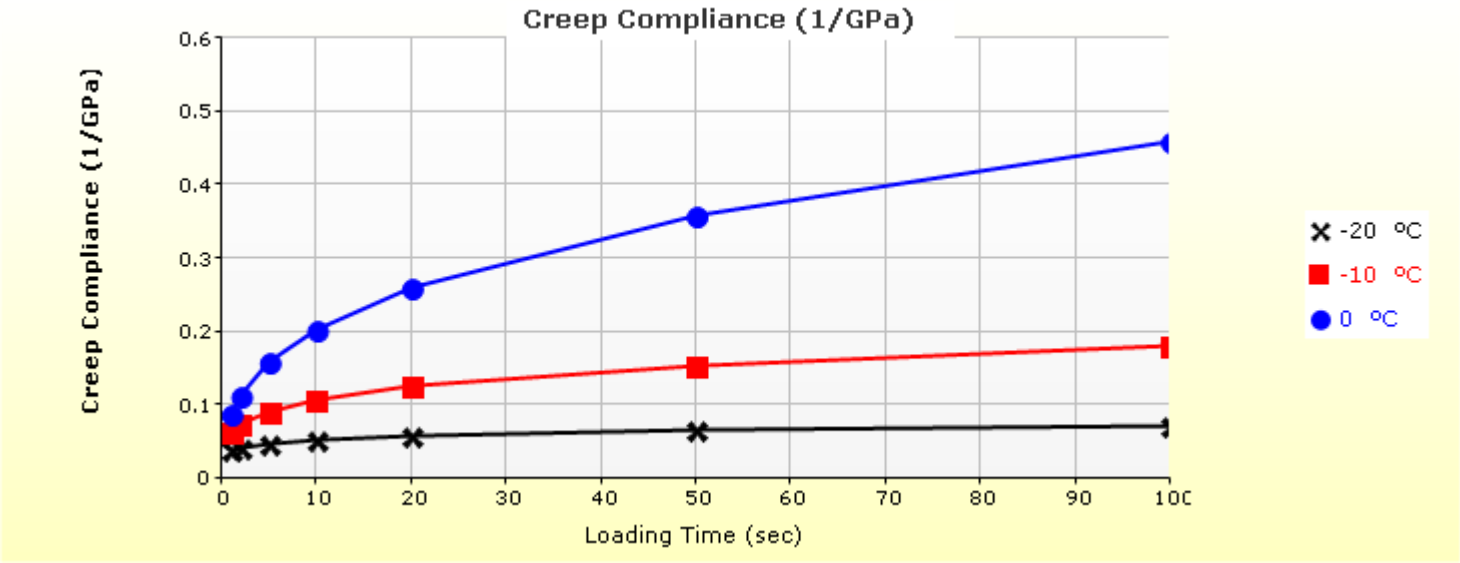
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

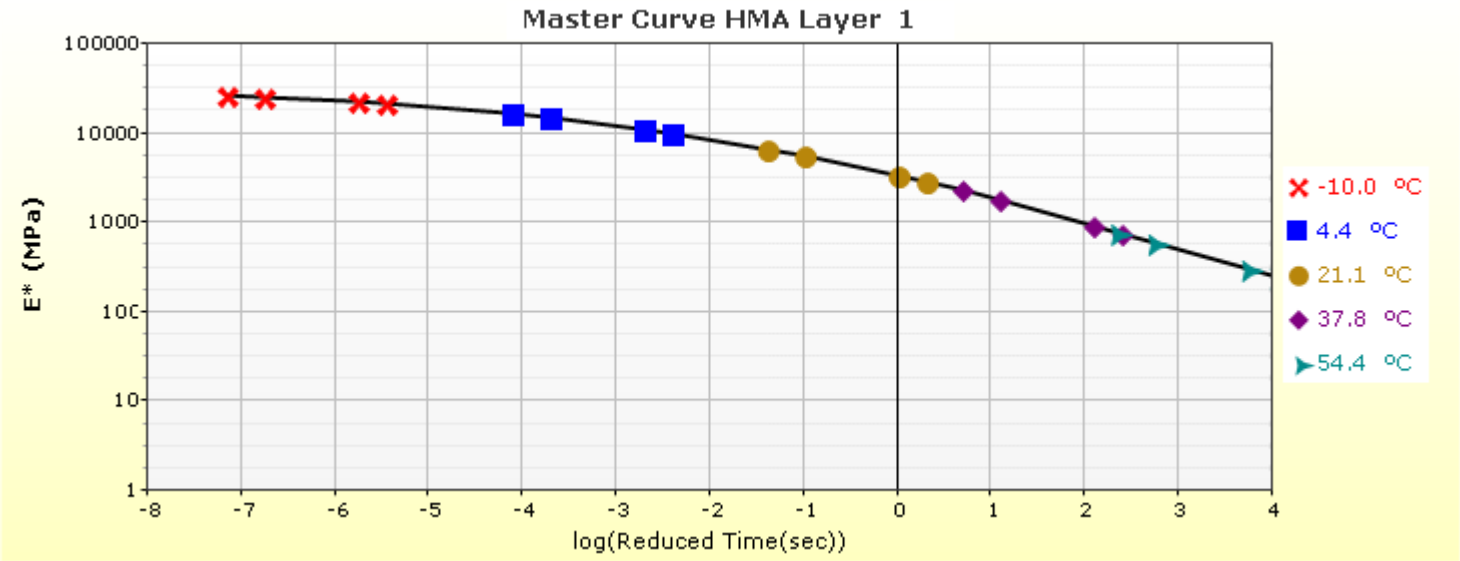
Indirect tensile strength at -10 ºC (MPa)	2.69

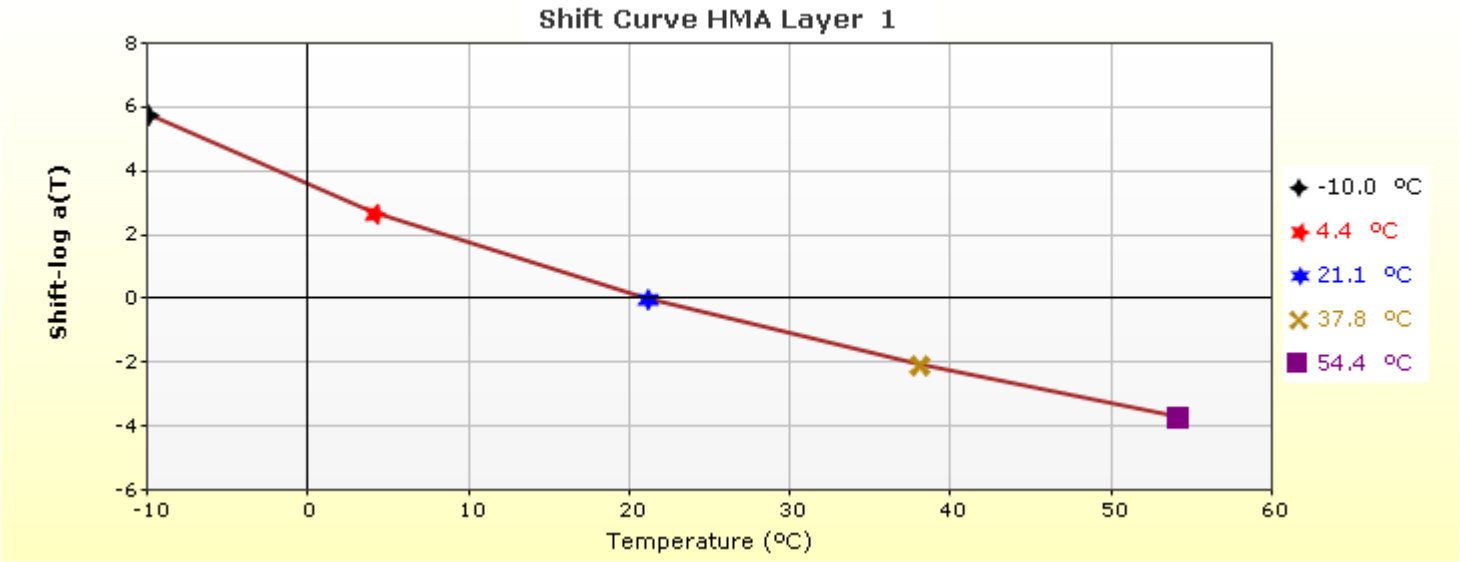
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

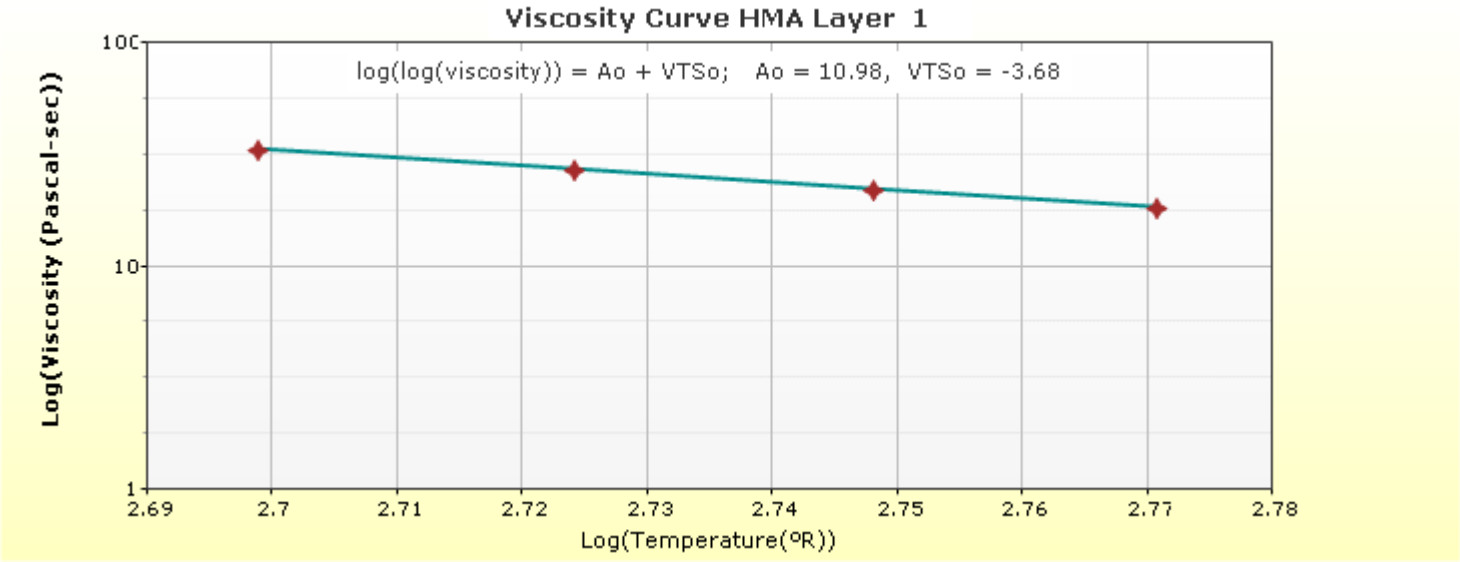
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



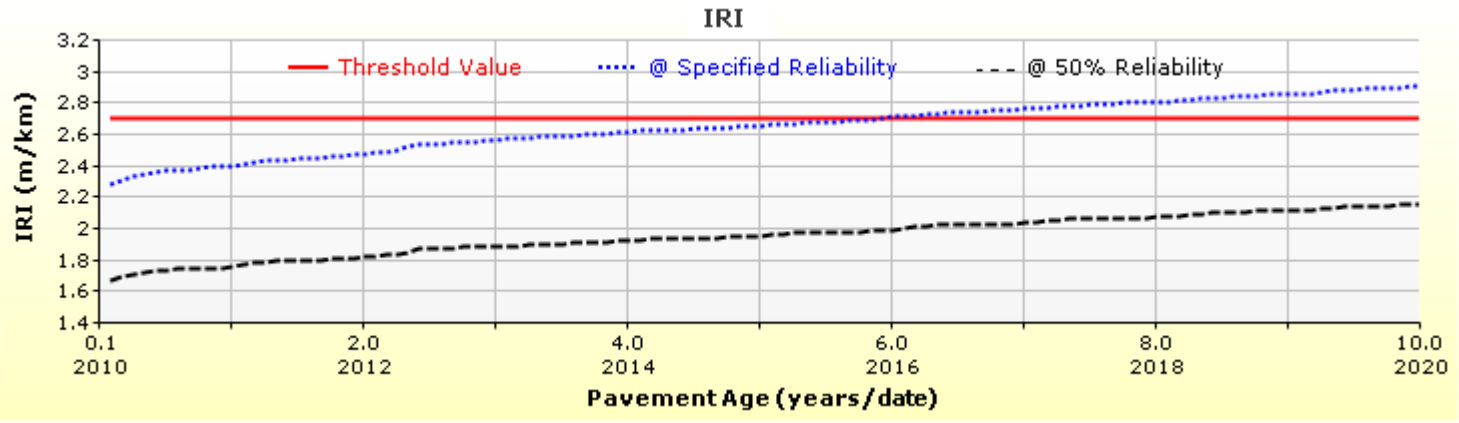
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

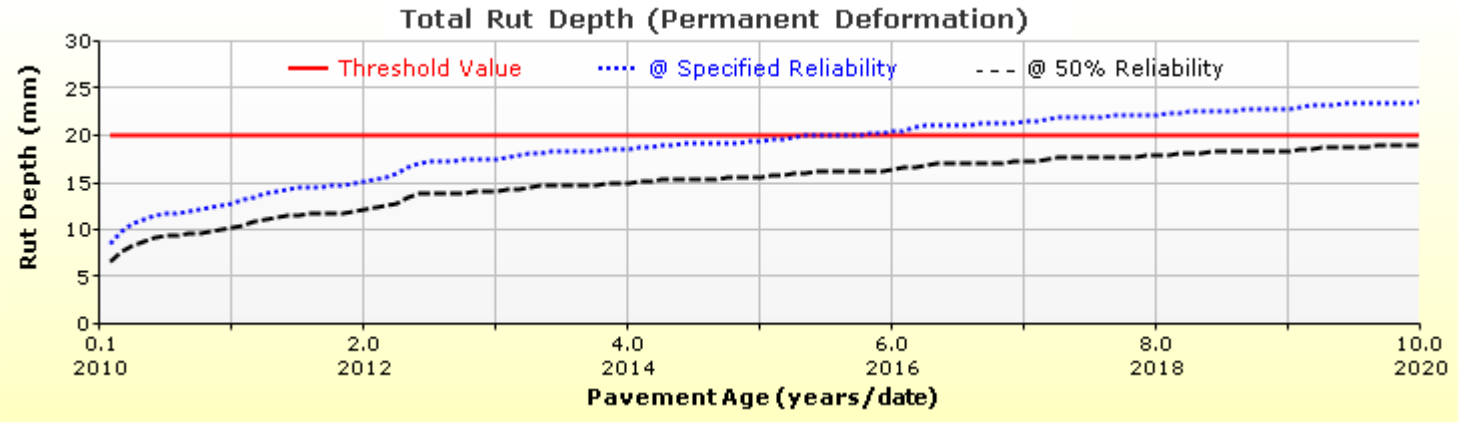


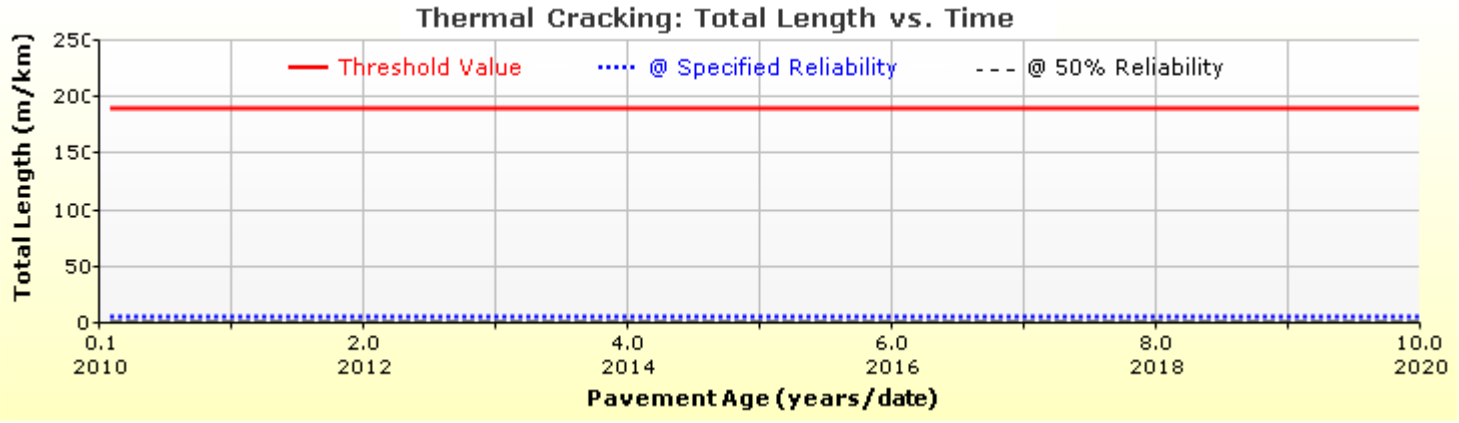


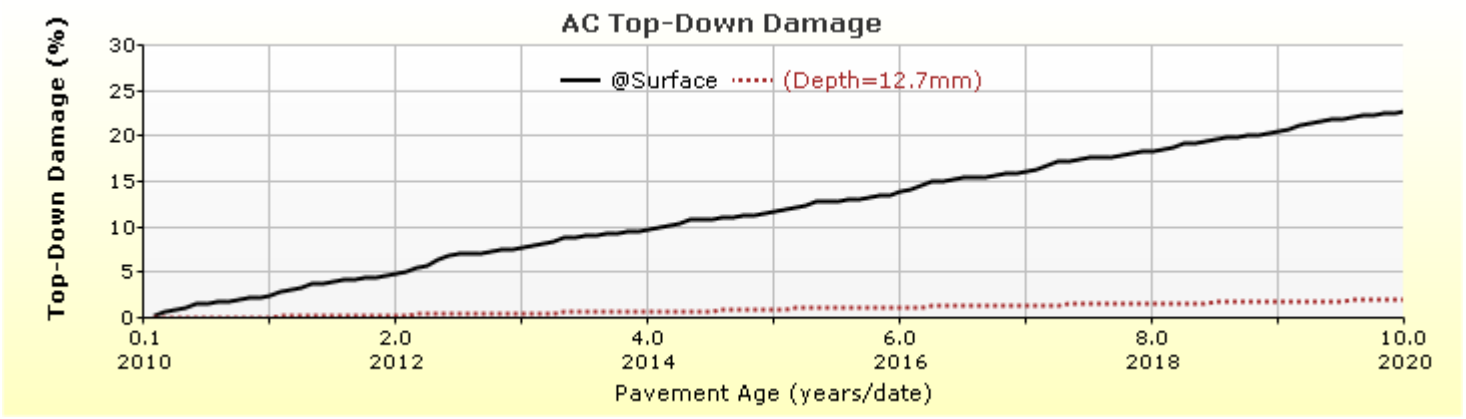


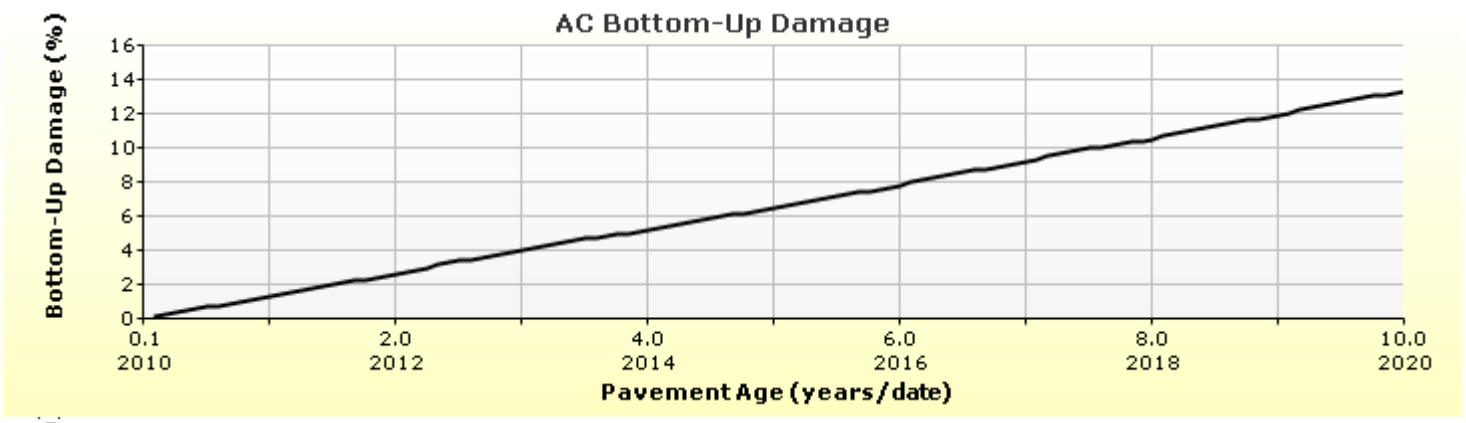
Analysis Output Charts

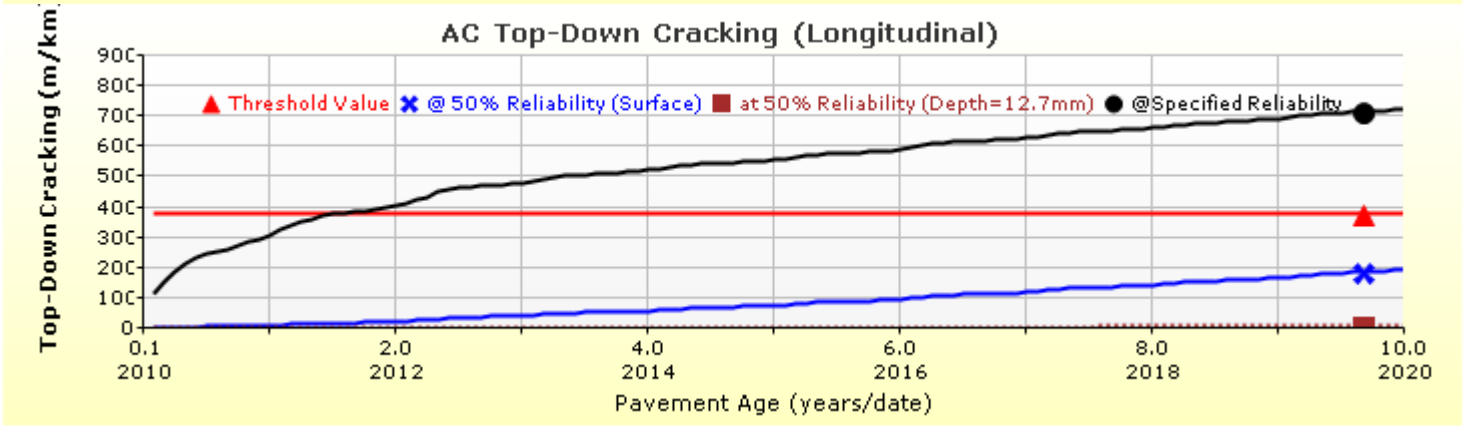


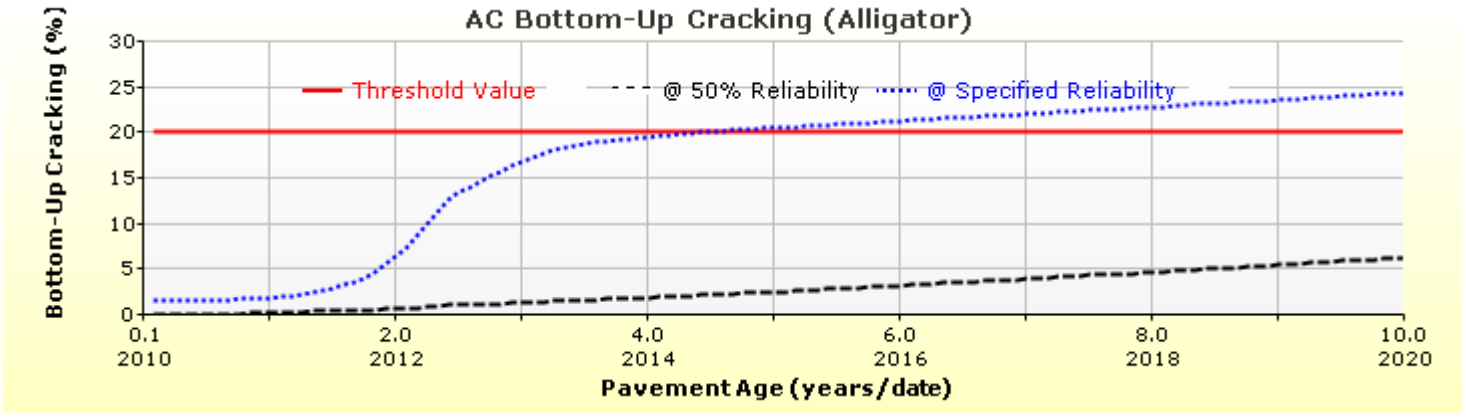


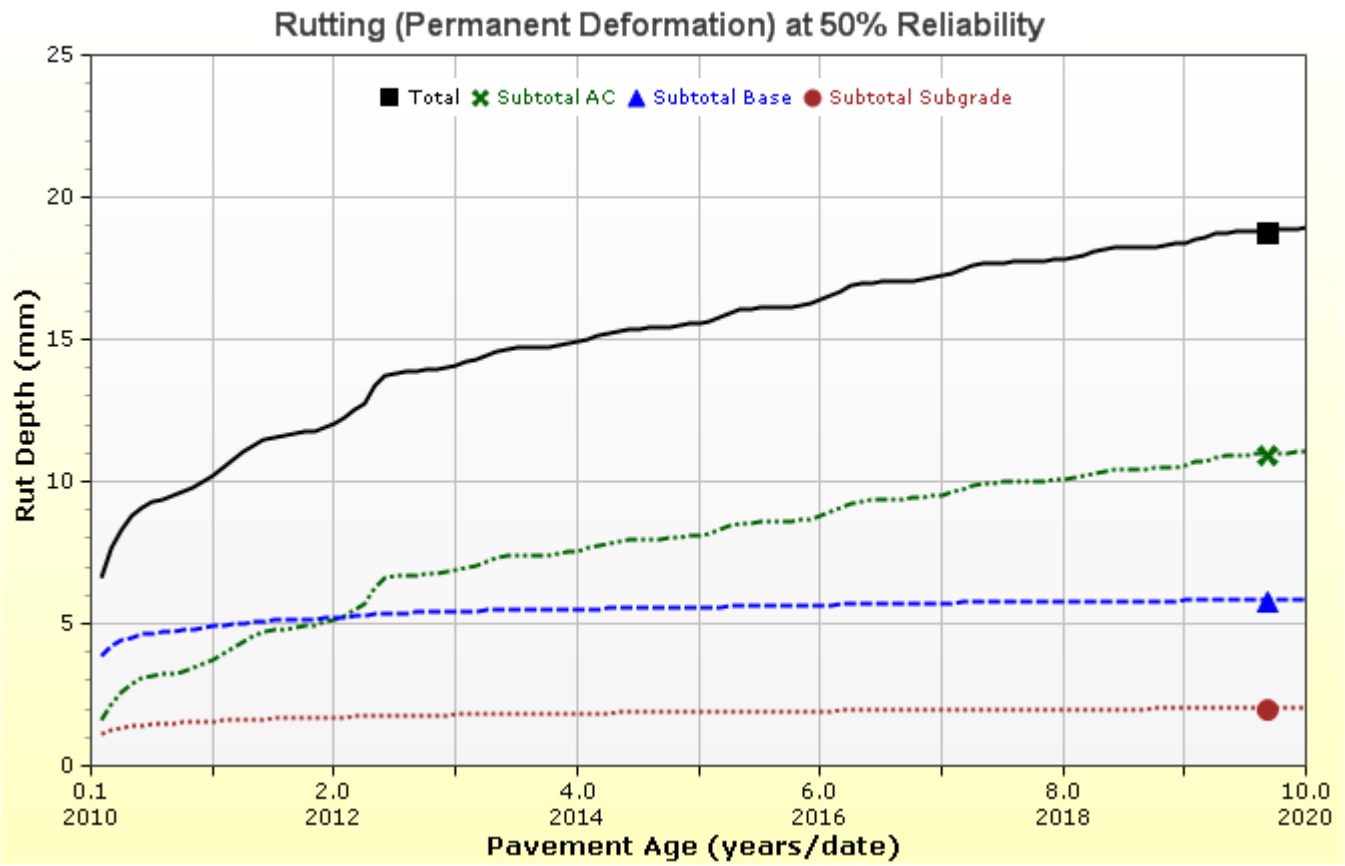


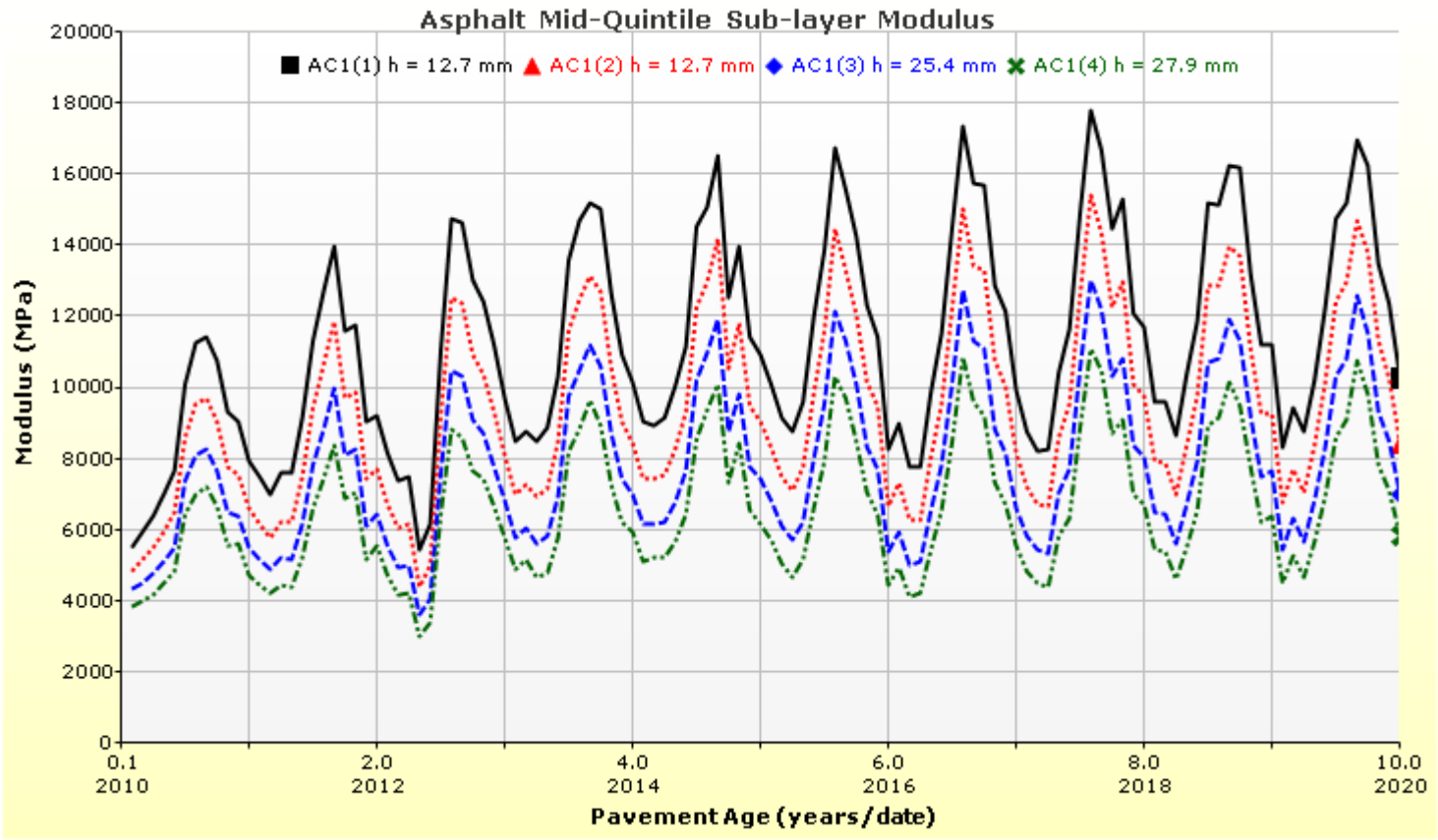

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

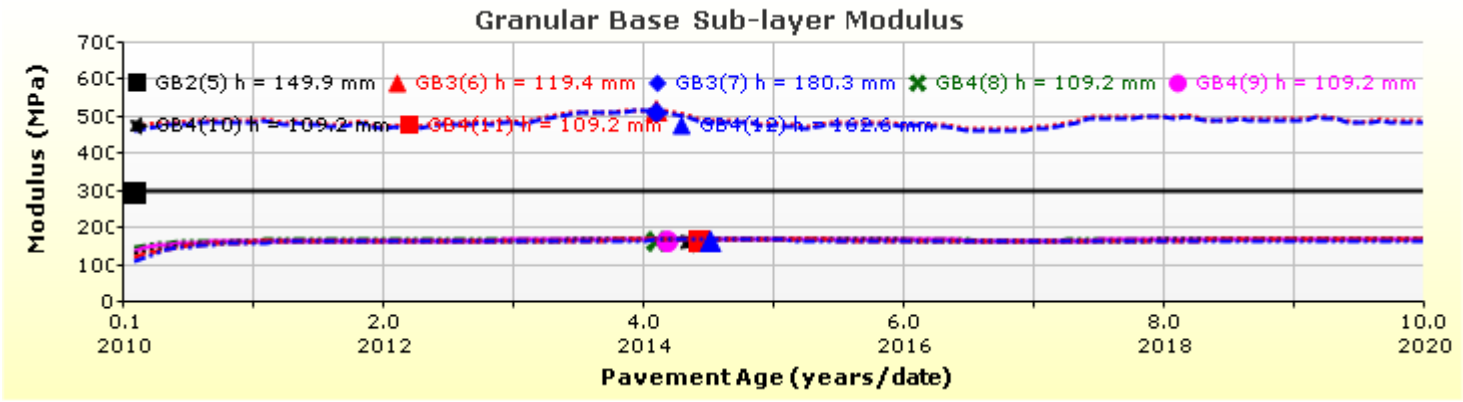

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

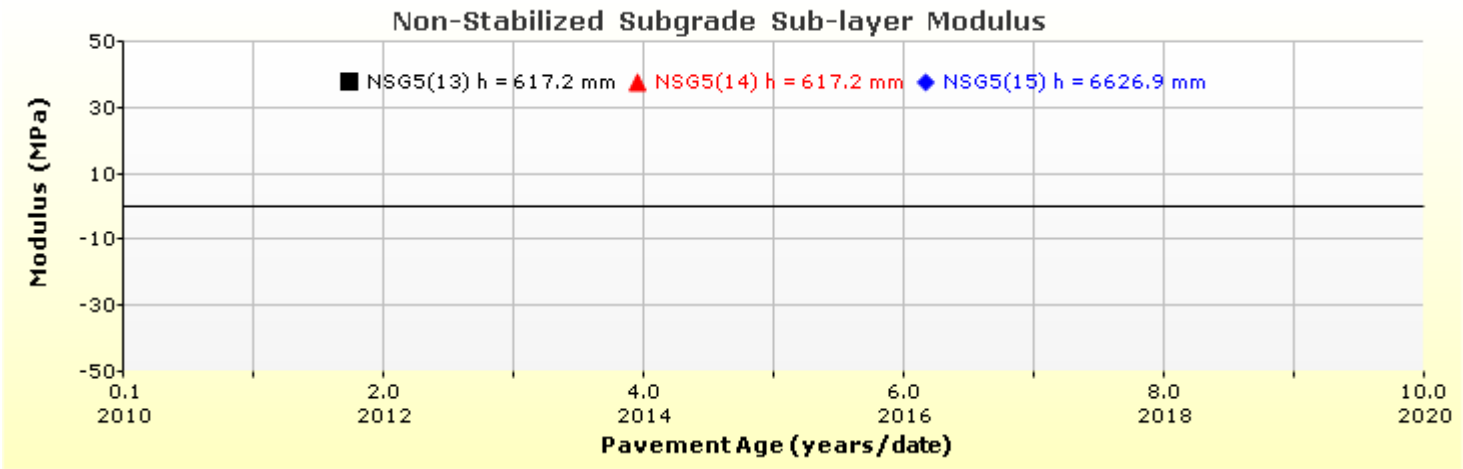

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
90
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 1
Bf2: 1
Bf3: 1

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRJ_Precip

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRJ_Precip.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -22.8, -43.68

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

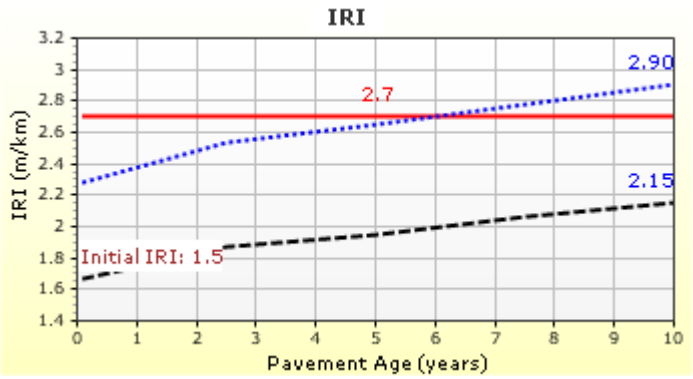
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

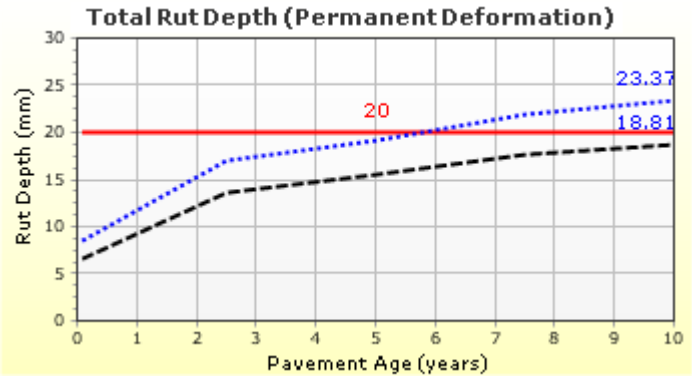
Design Outputs

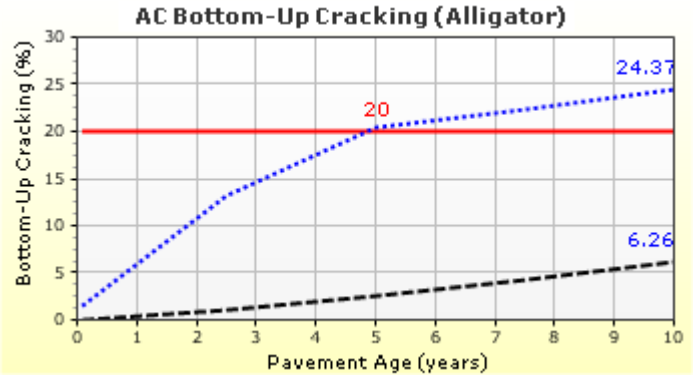
Distress Prediction Summary

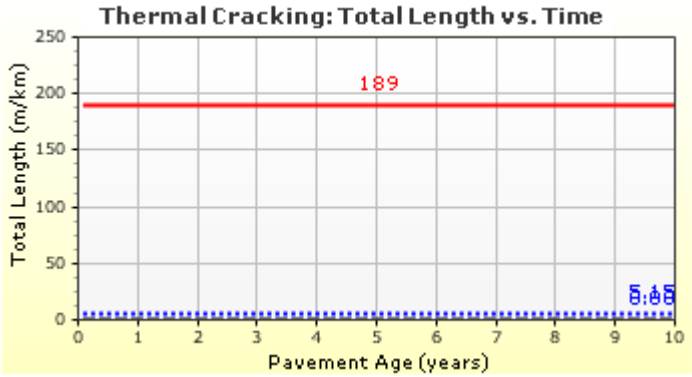
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.90	90.00	82.64	Fail
Permanent deformation - total pavement (mm)	20.00	23.37	90.00	62.97	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.37	90.00	83.46	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	721.27	90.00	67.52	Fail
Permanent deformation - AC only (mm)	5.00	10.92	50.00	2.90	Fail

Distress Charts







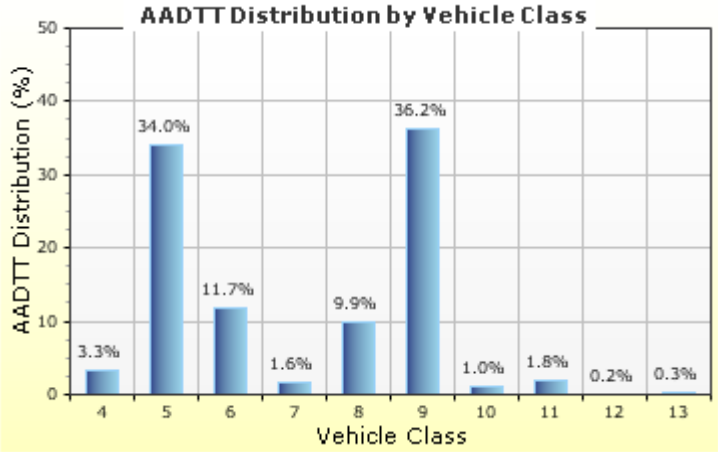


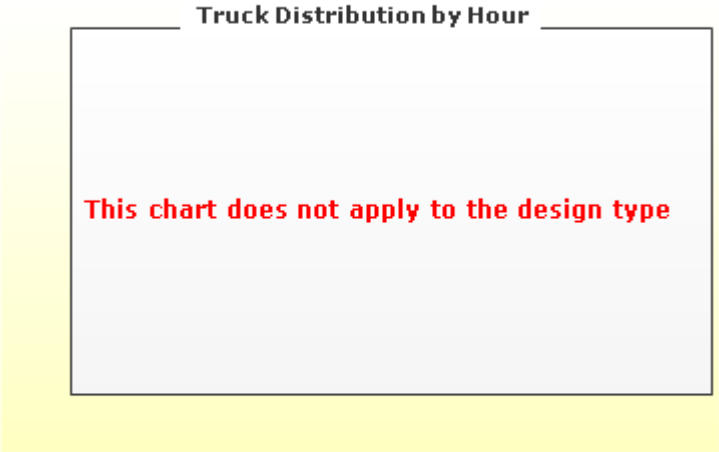


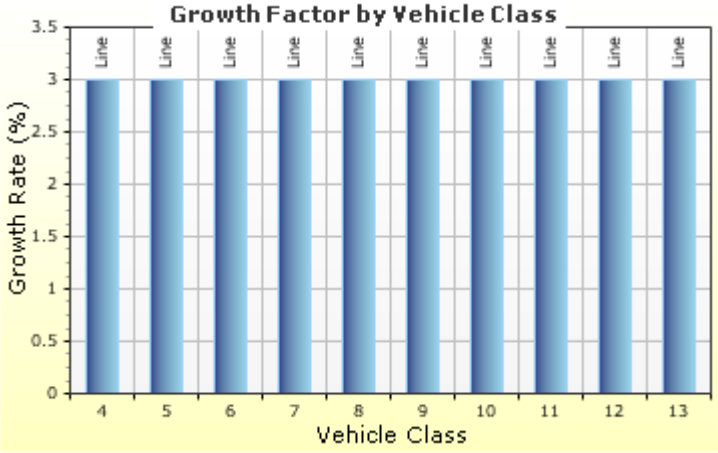
Traffic Inputs

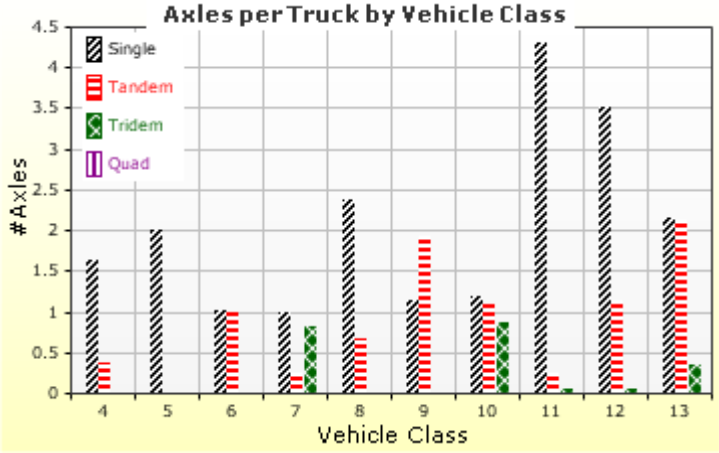
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

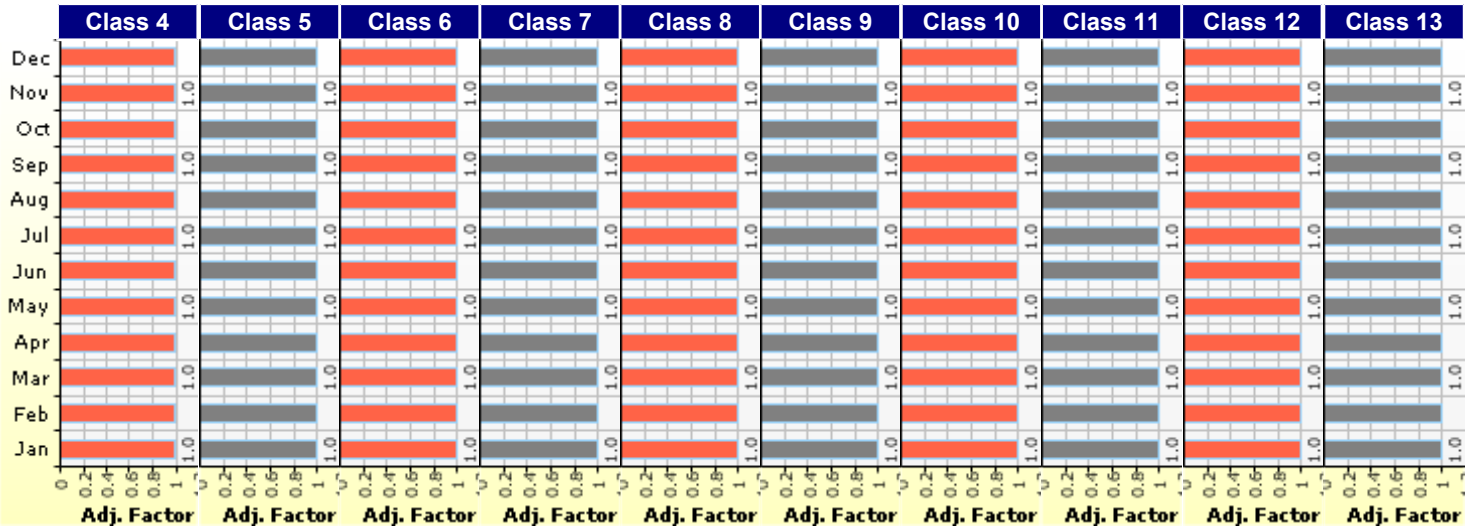








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

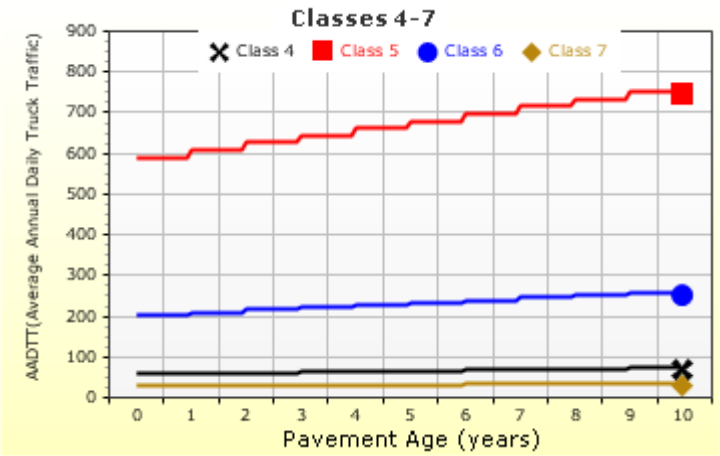
Wheelbase does not apply

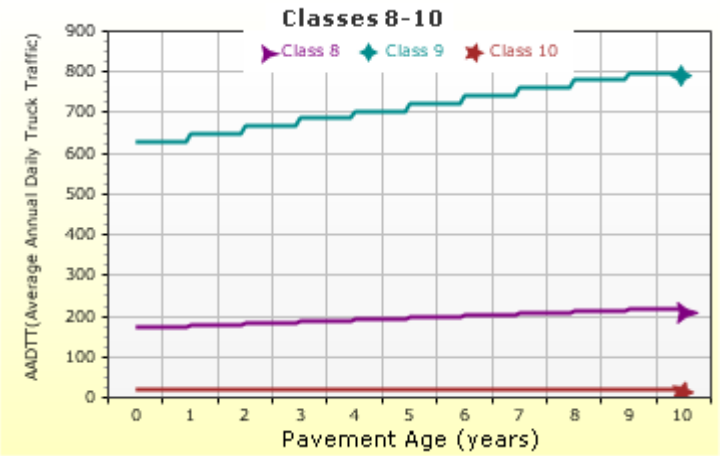
Number of Axles per Truck

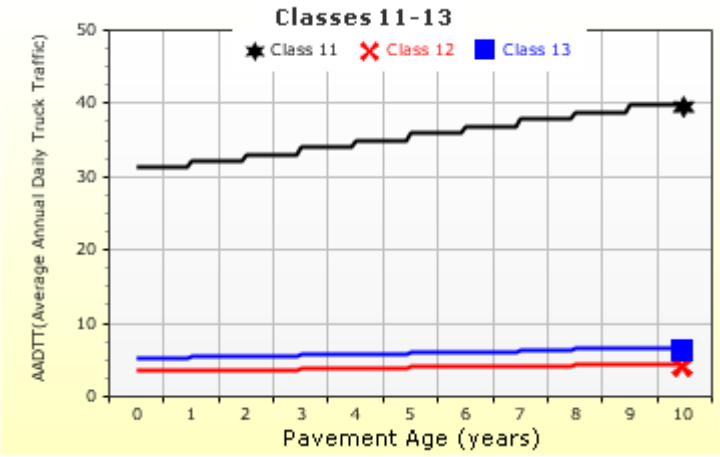
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

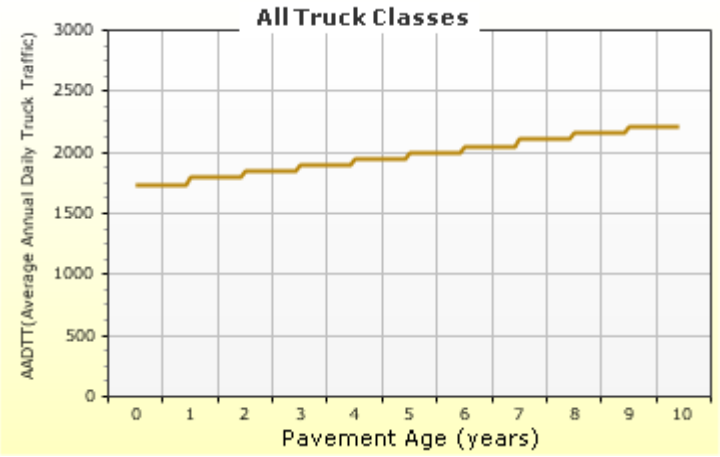
AADTT (Average Annual Daily Truck Traffic) Growth

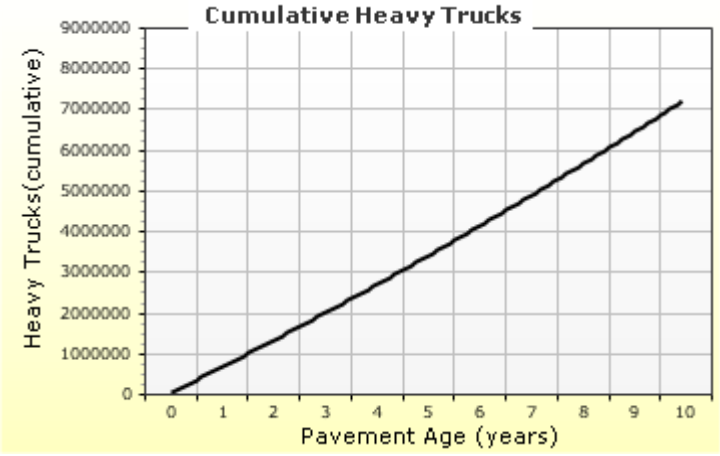
*** Traffic cap is not enforced**







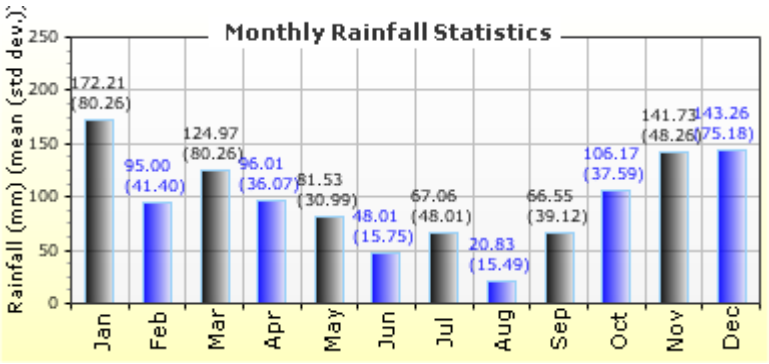




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
RIO DE JANEIRO, RJ	-22.80000 -43.68000 28

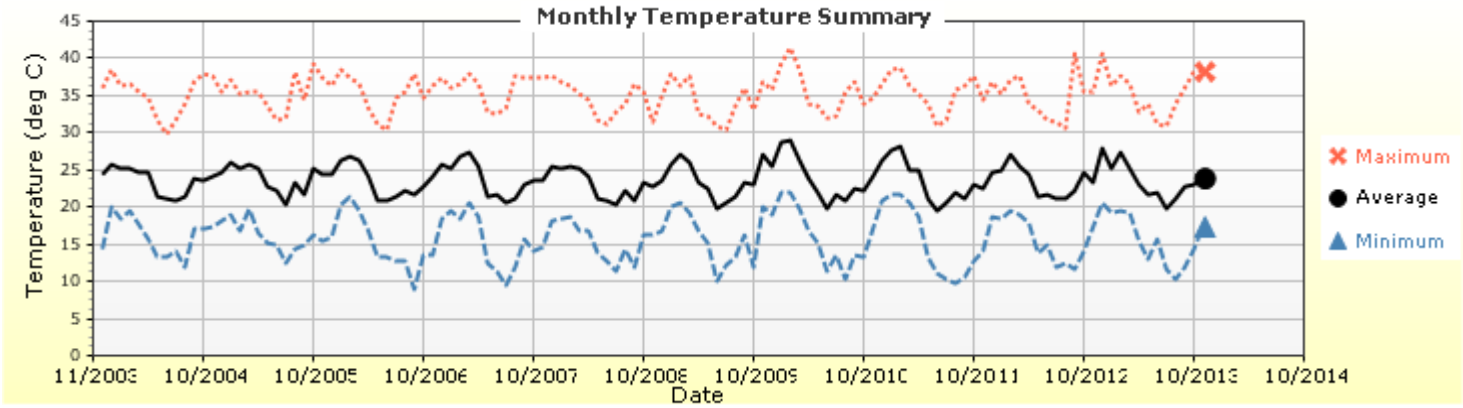


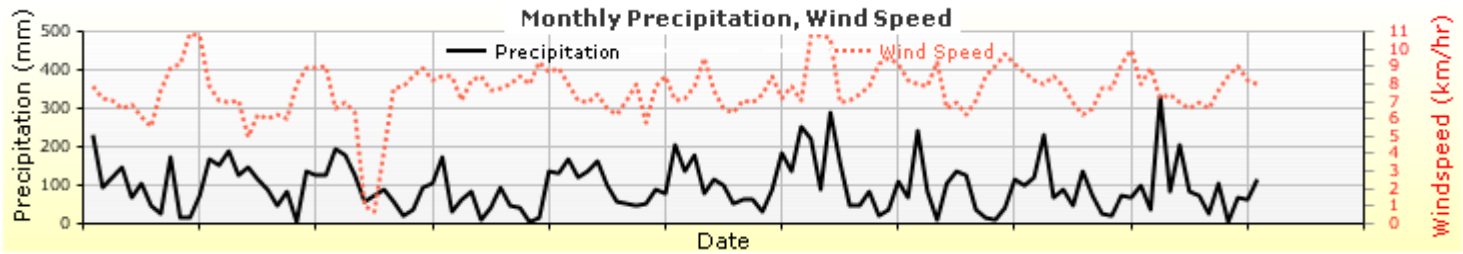
Annual Statistics:

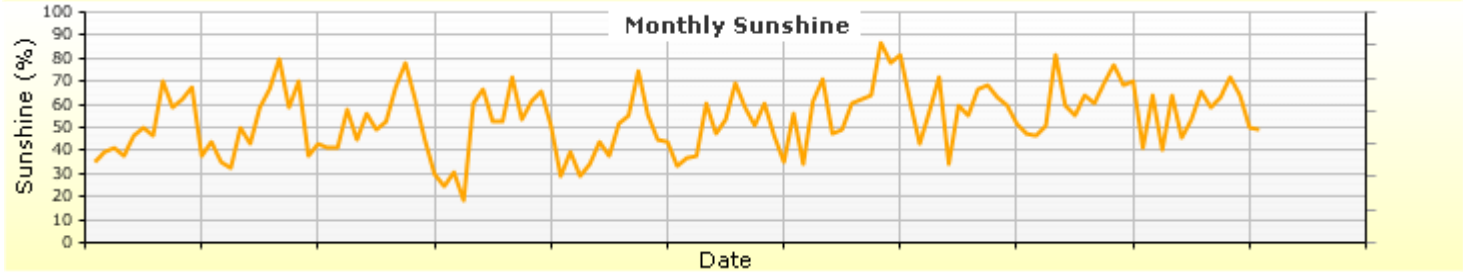
Mean annual air temperature (ºC)	23.59
Mean annual precipitation (mm)	1170.94
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

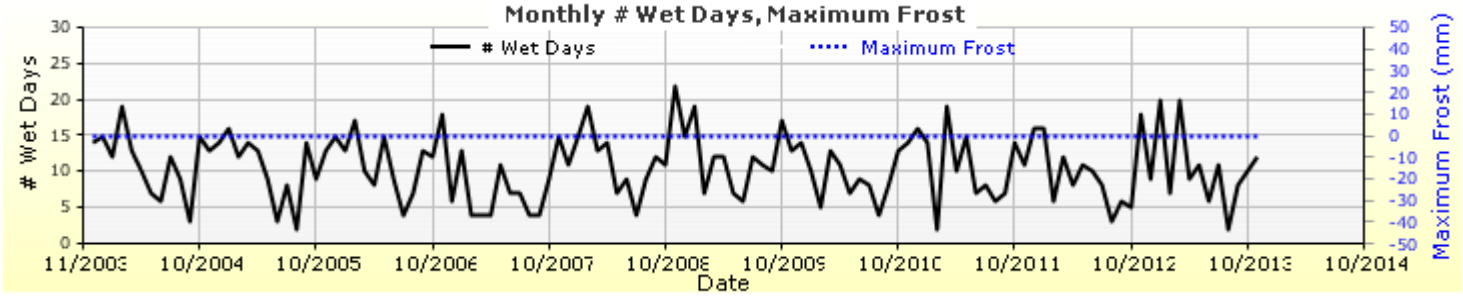
Water table depth (m): 3.05

Monthly Climate Summary:

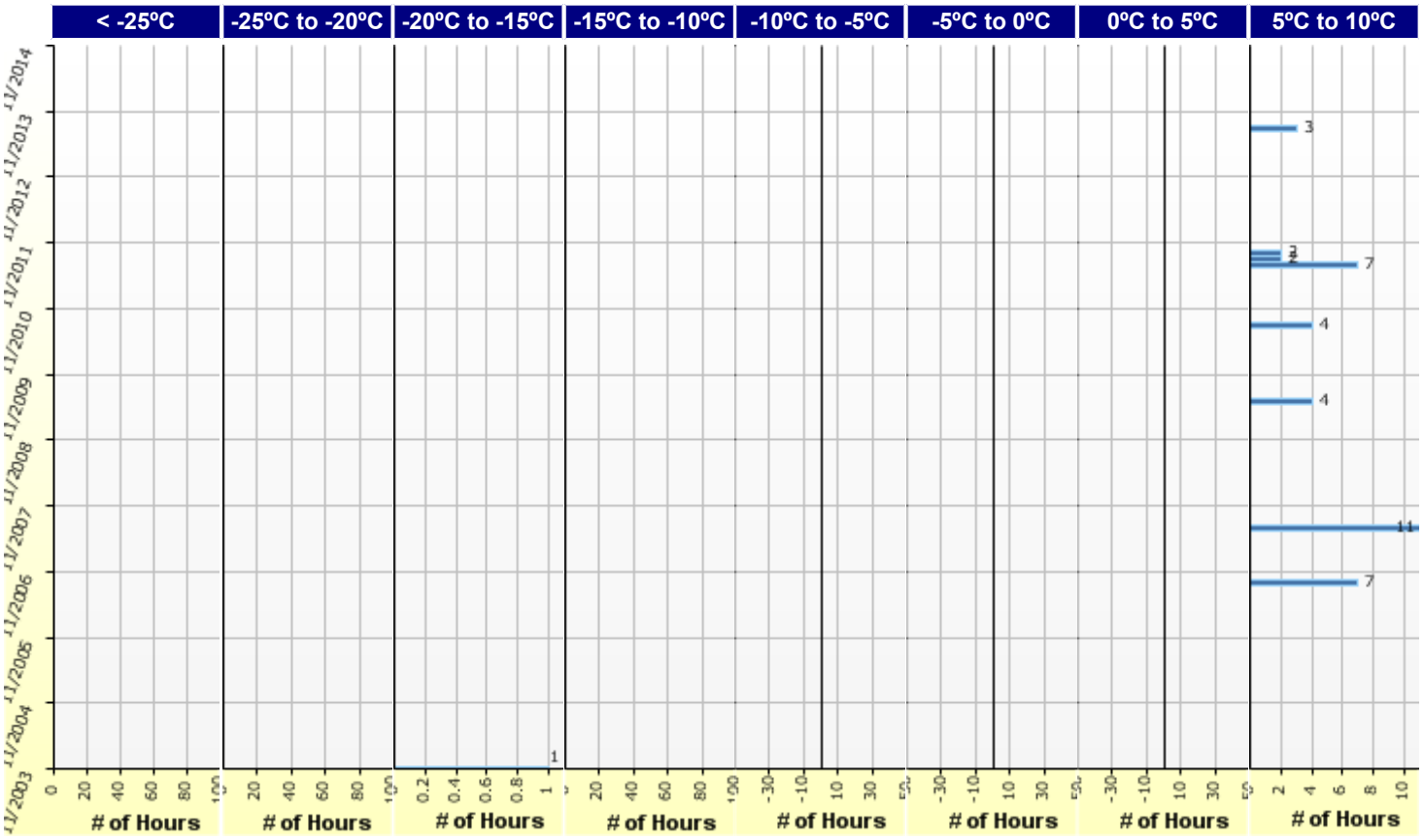


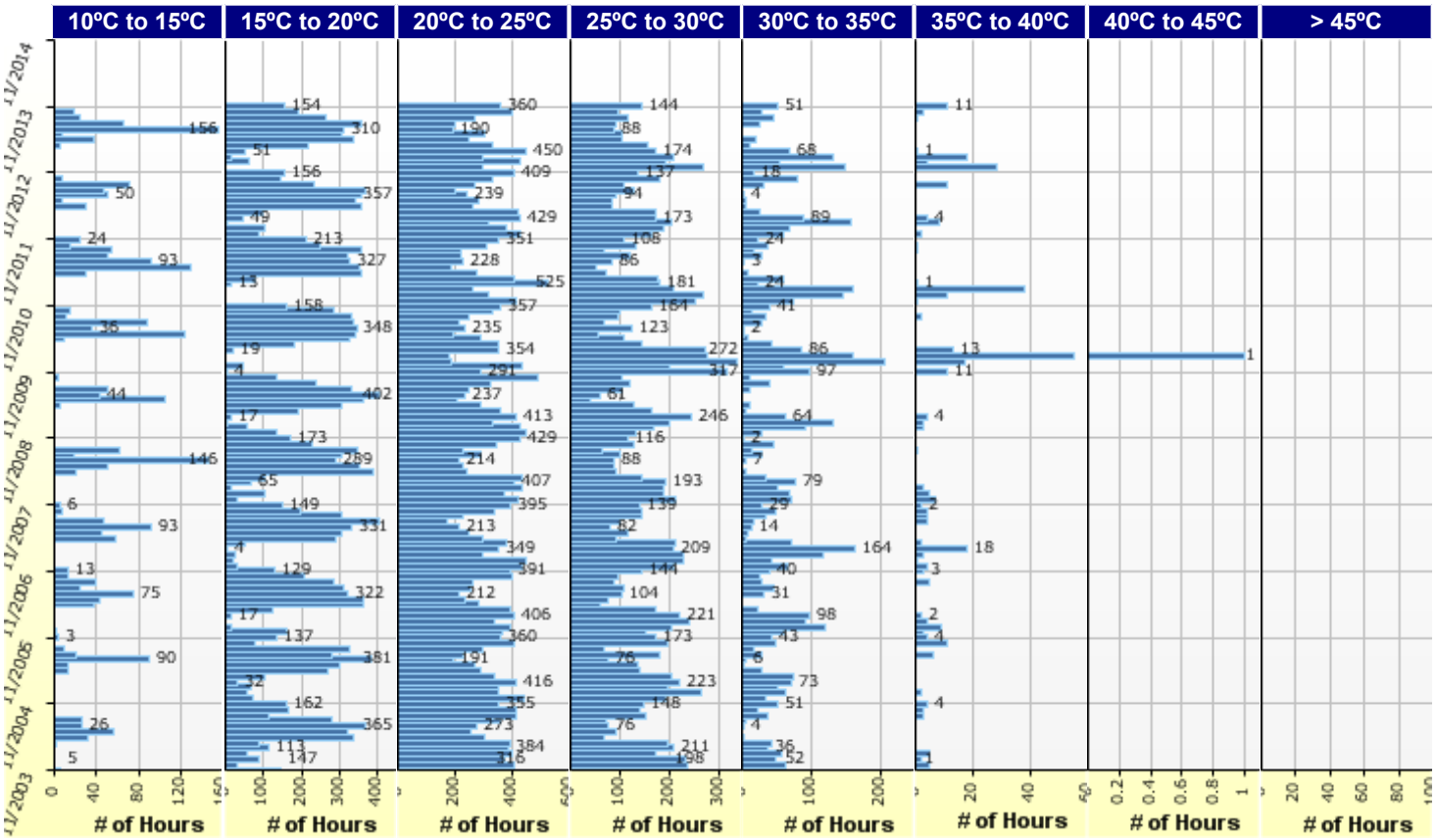






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

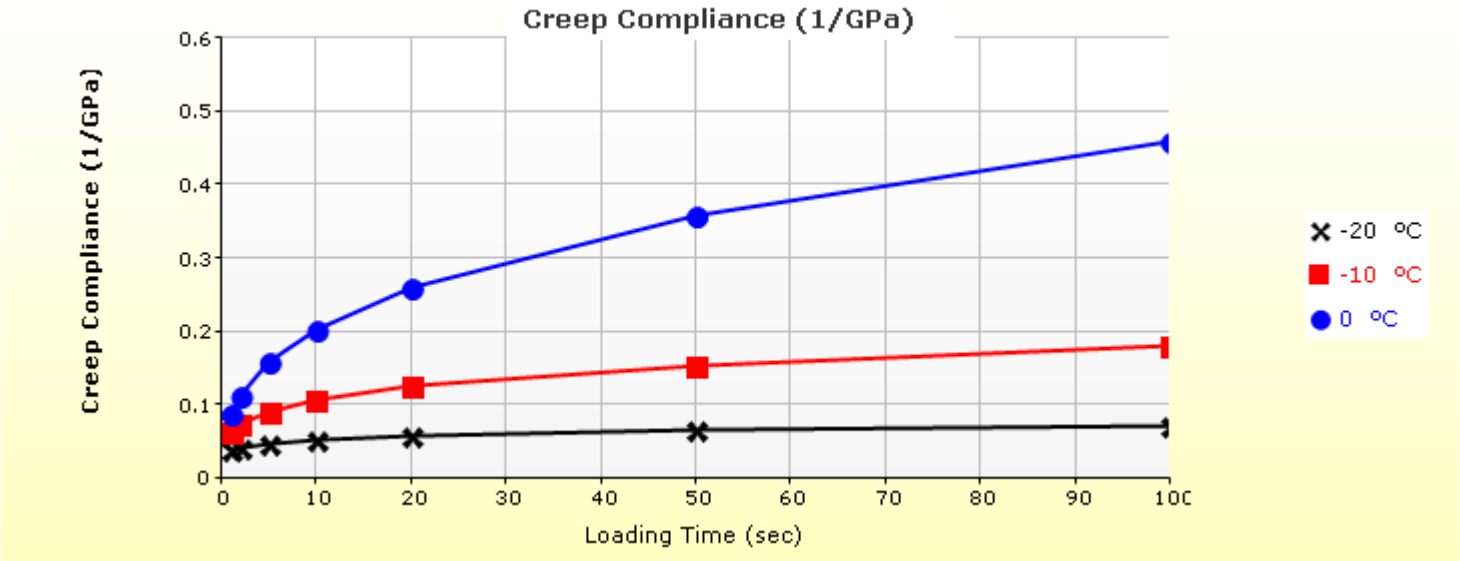
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

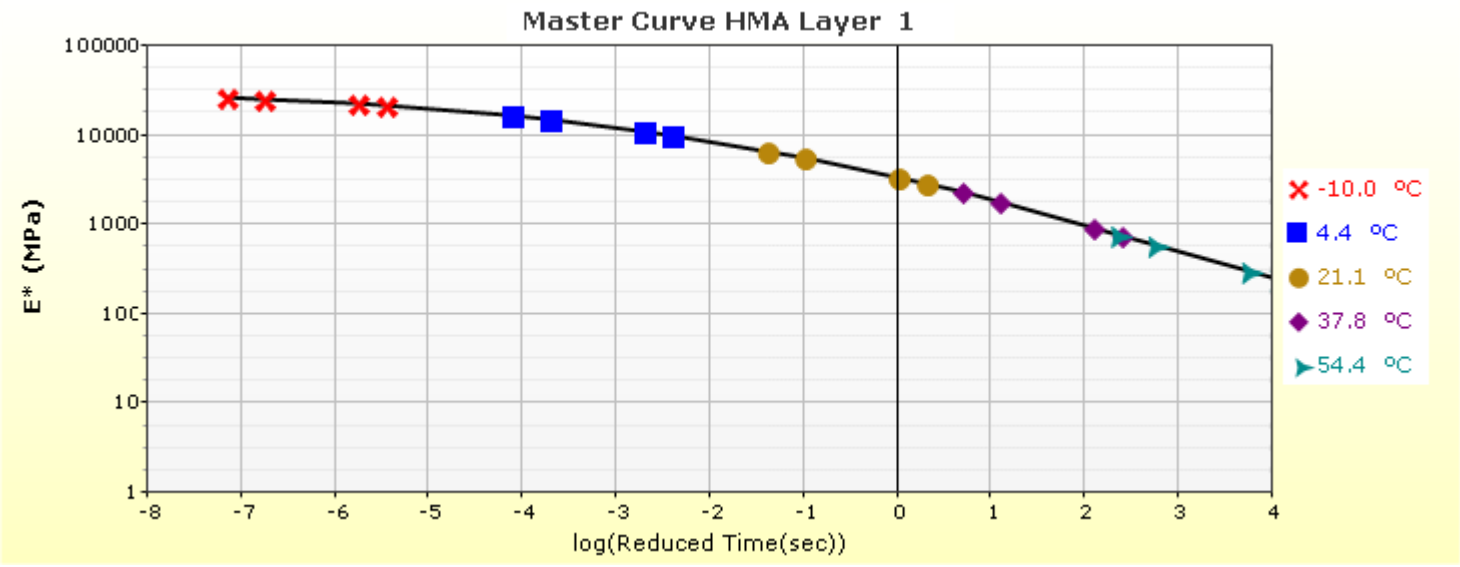
Indirect tensile strength at -10 ºC (MPa)	2.69

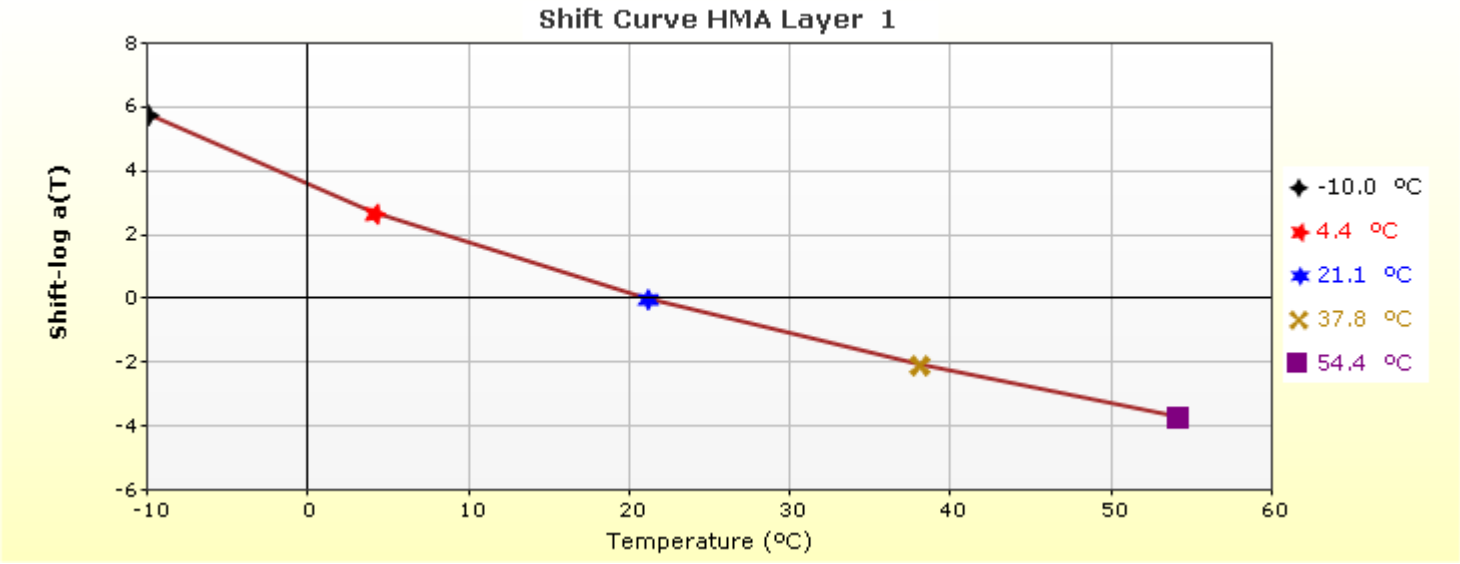
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

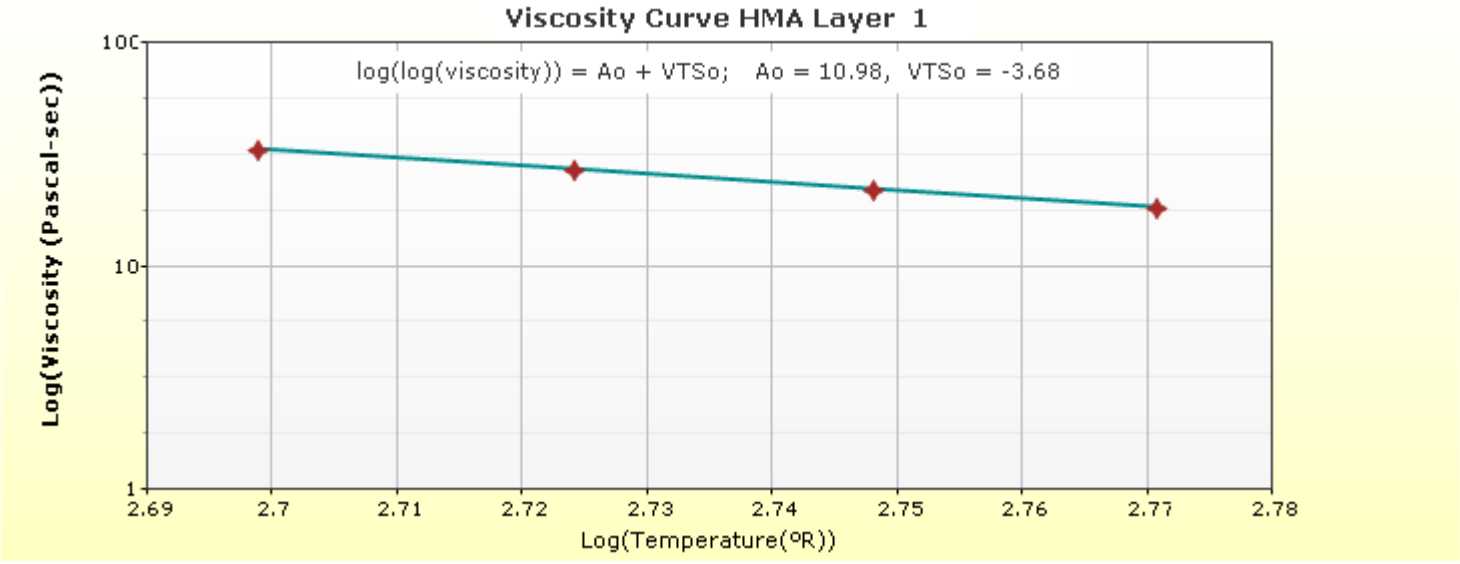
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



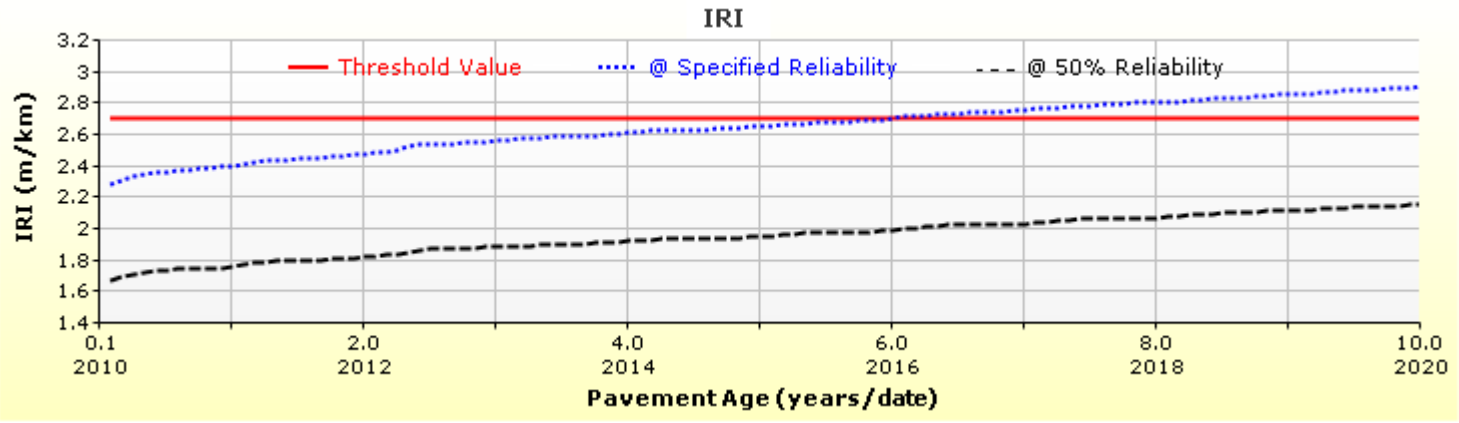
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

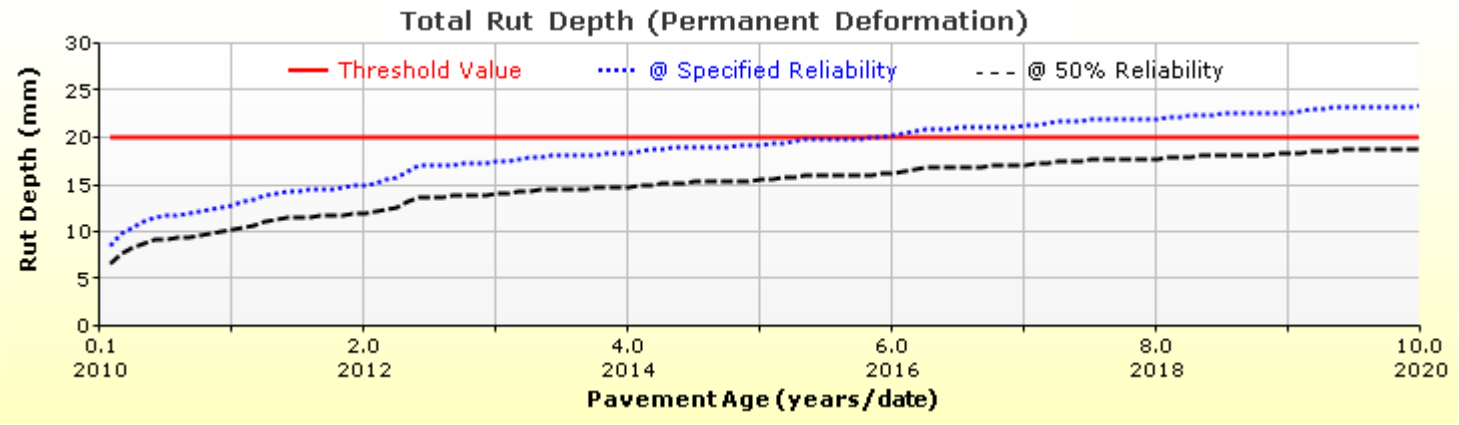


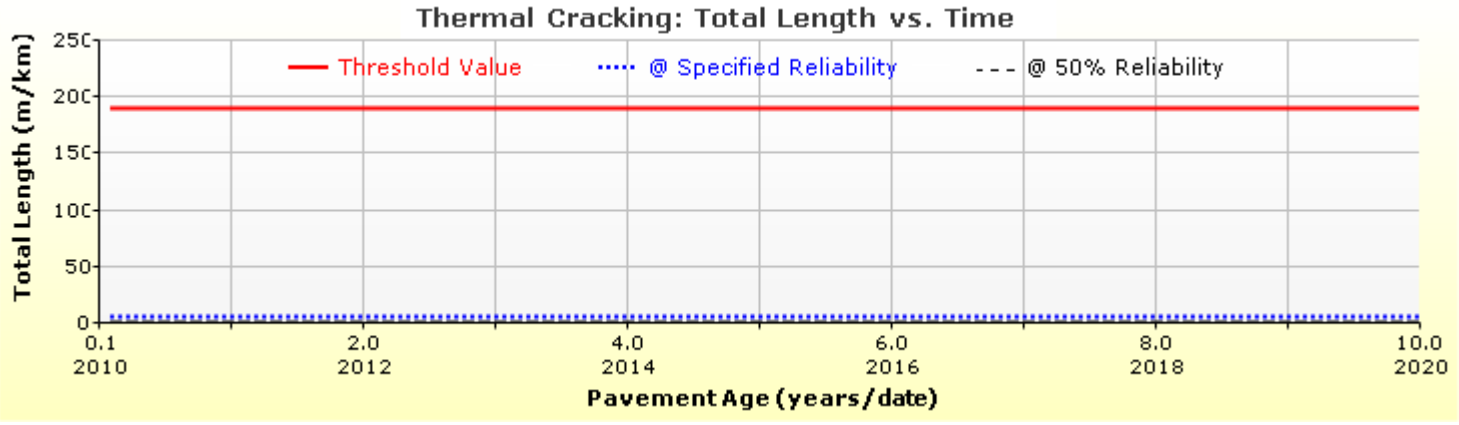


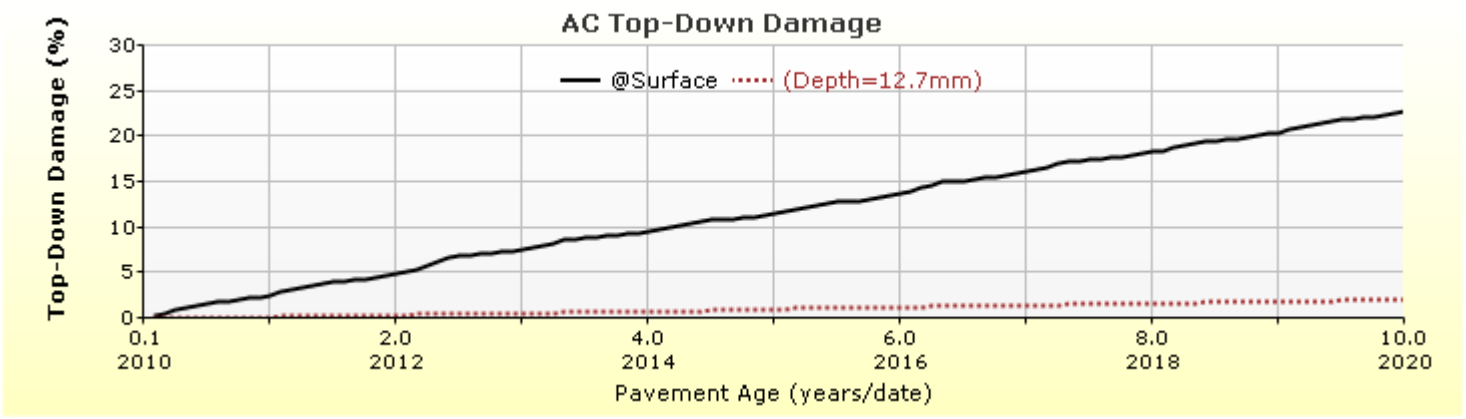


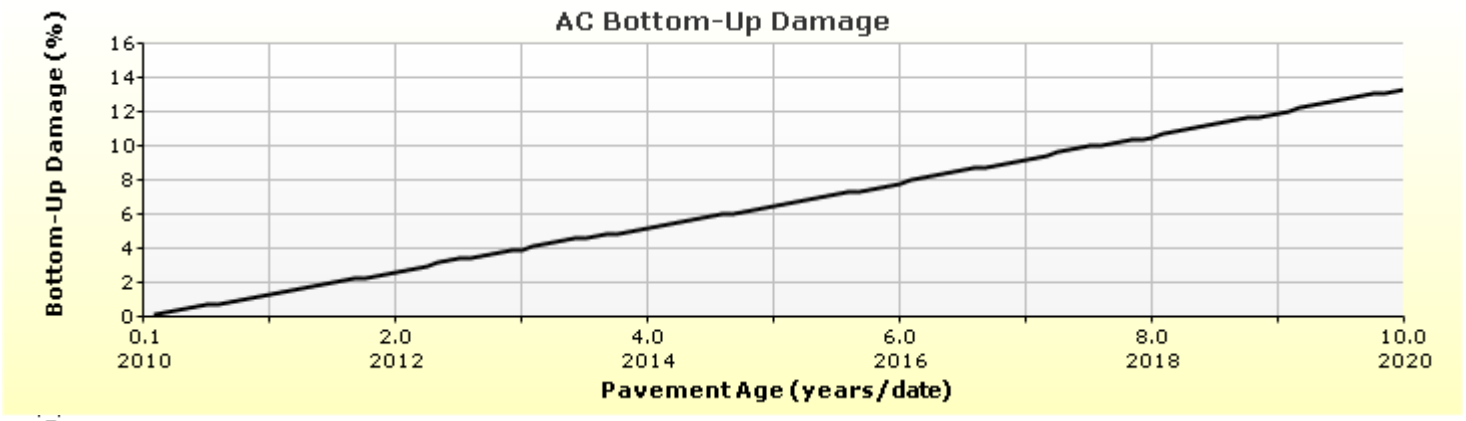
Analysis Output Charts

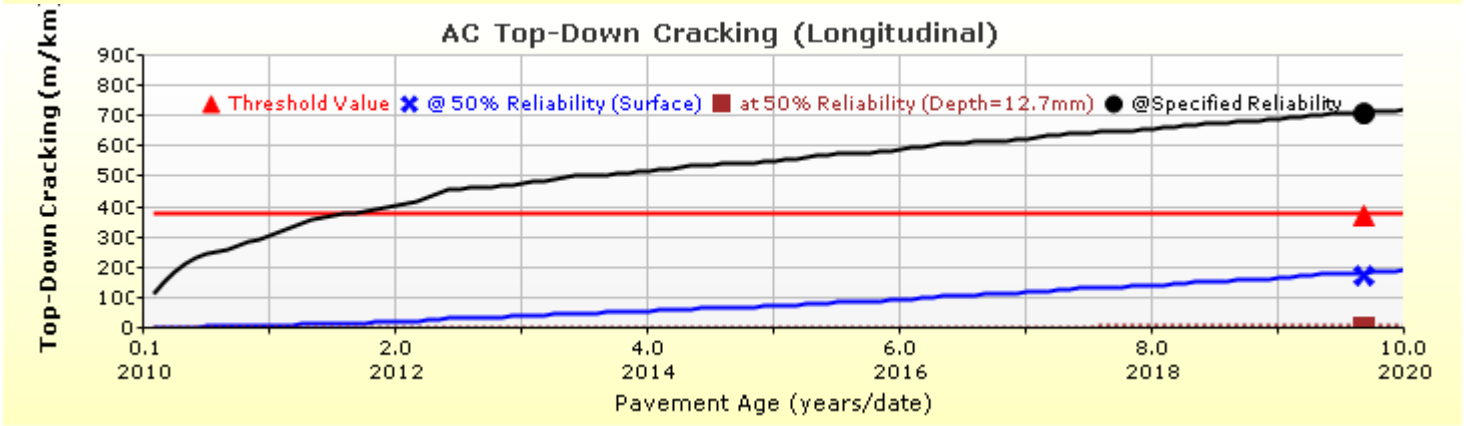


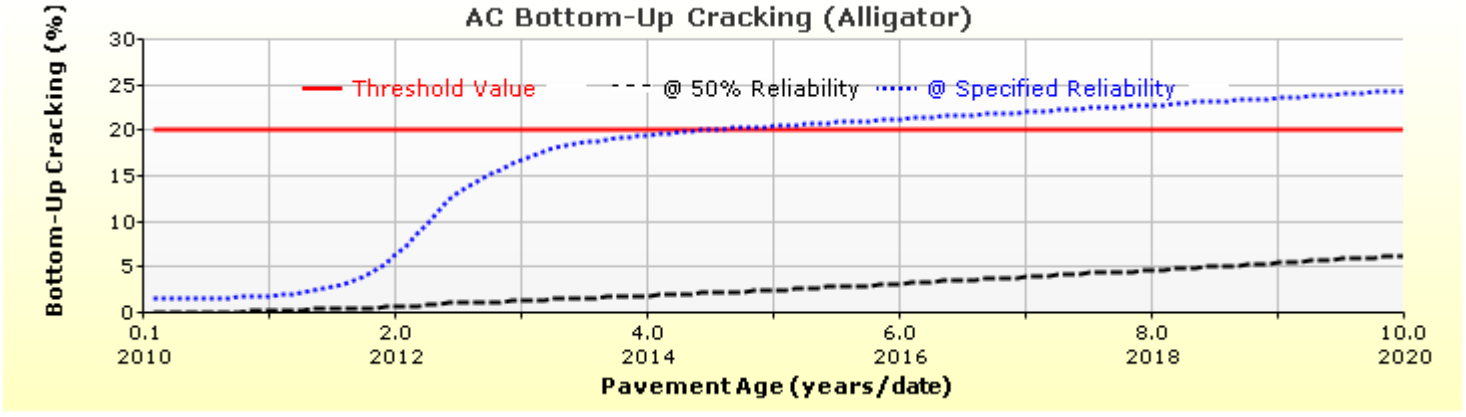


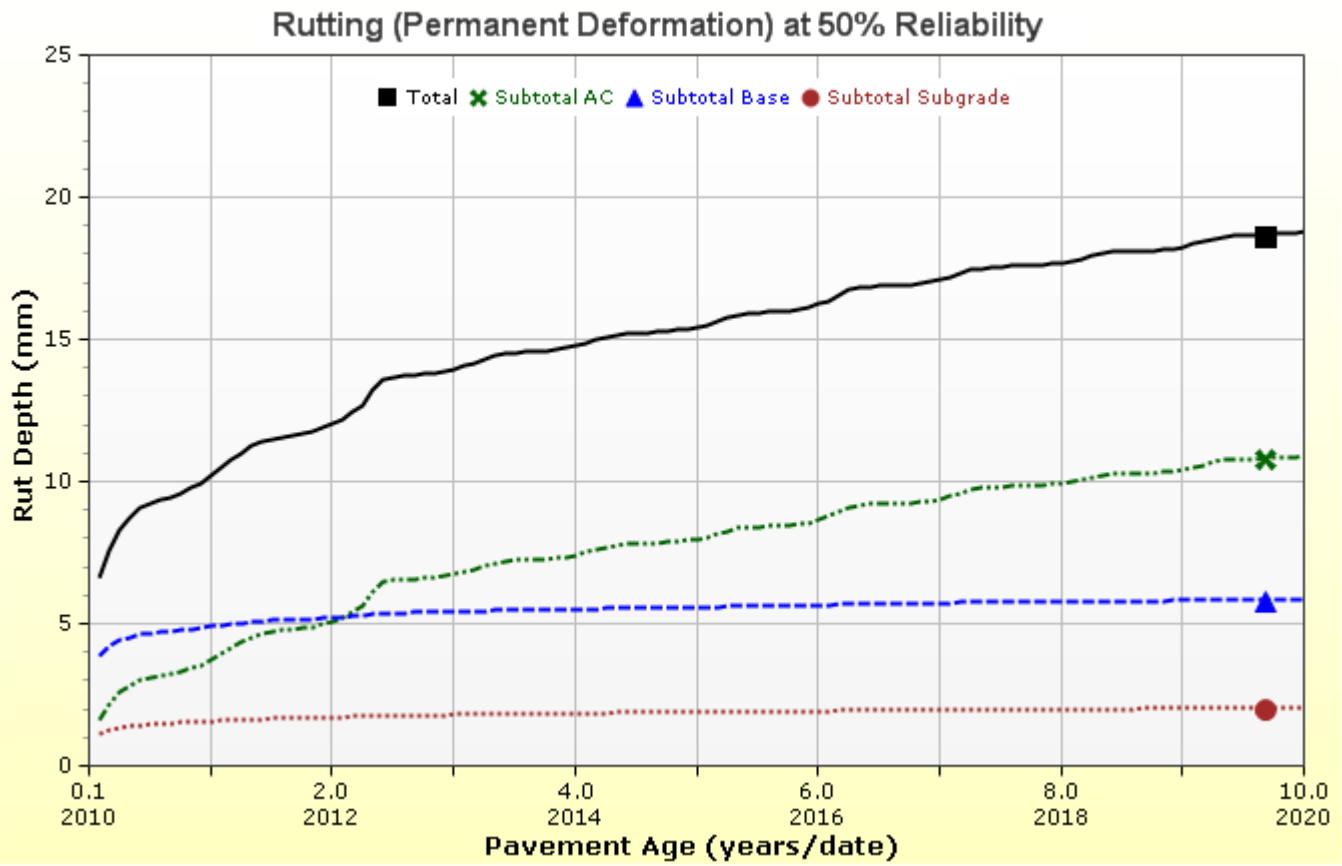


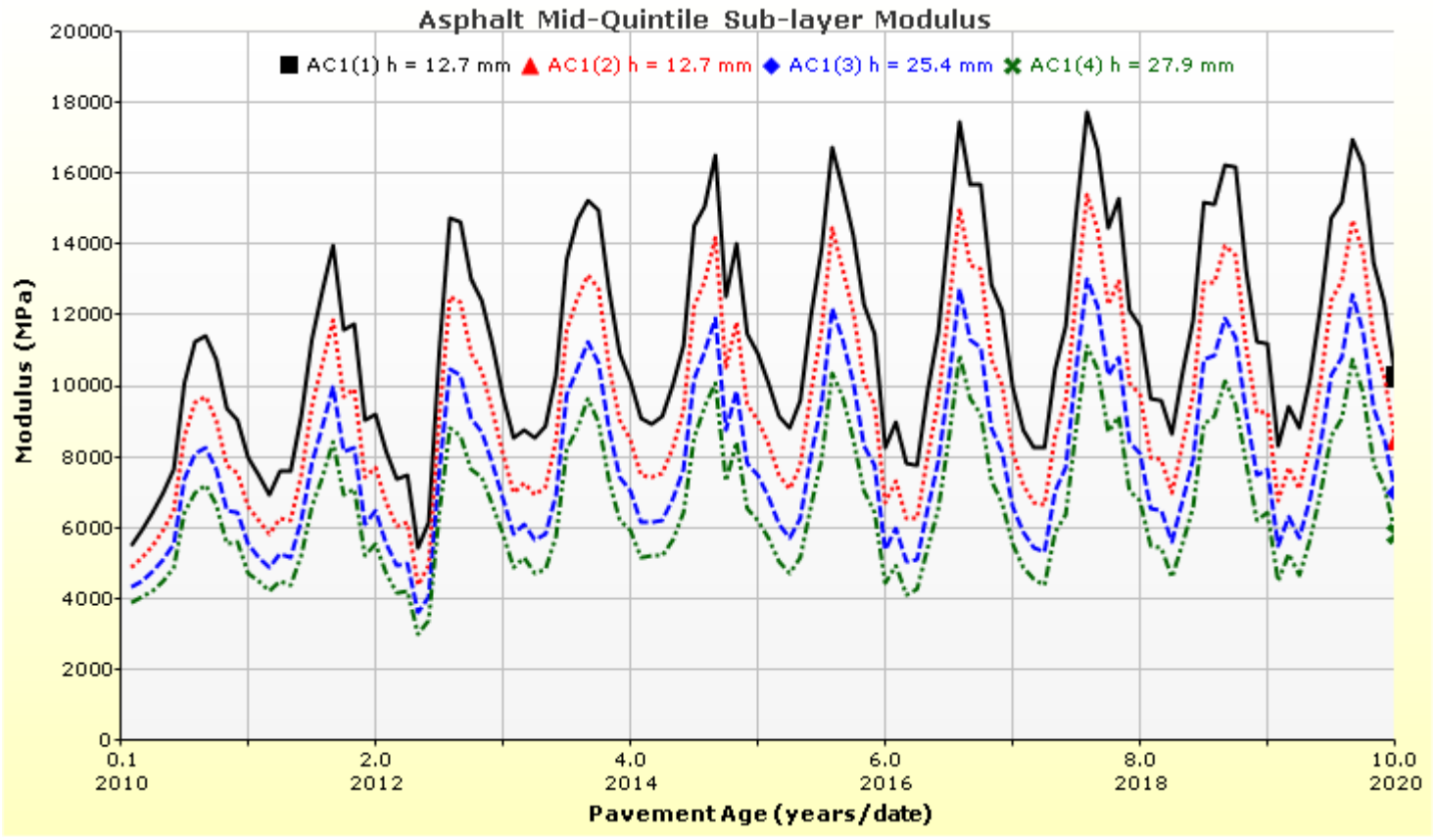

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

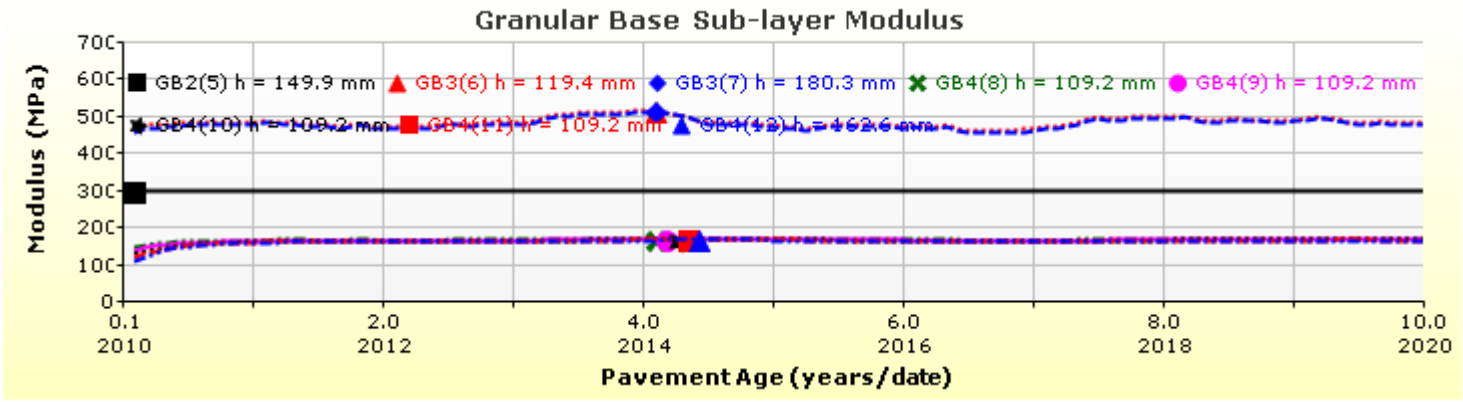

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

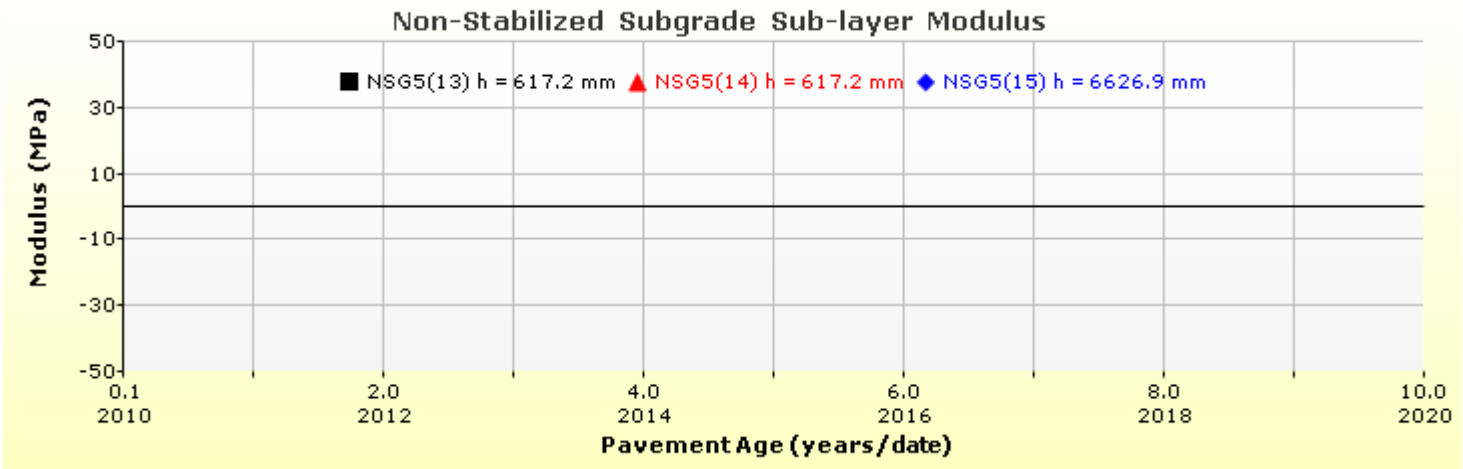

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
90
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 462.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRJ_Temp

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRJ_Temp.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -22.8, -43.68

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

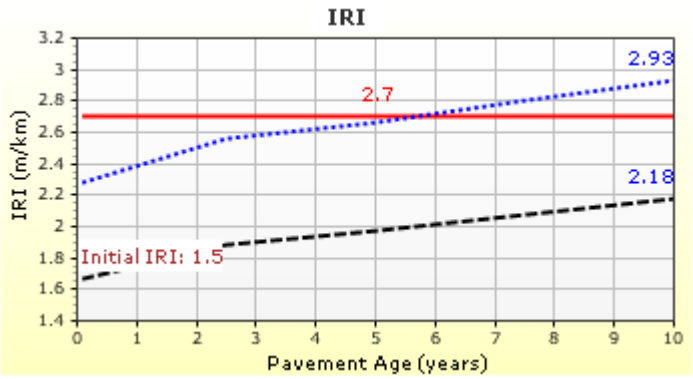
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

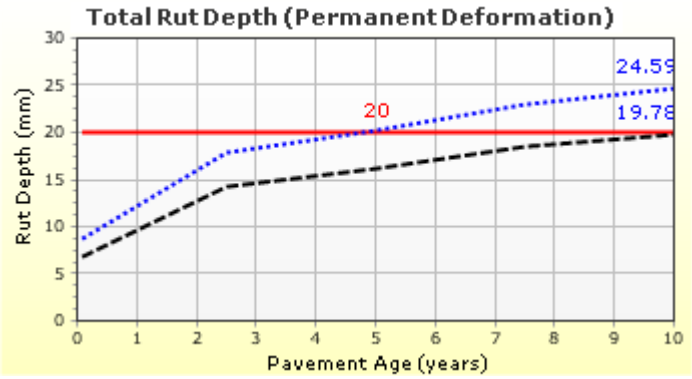
Design Outputs

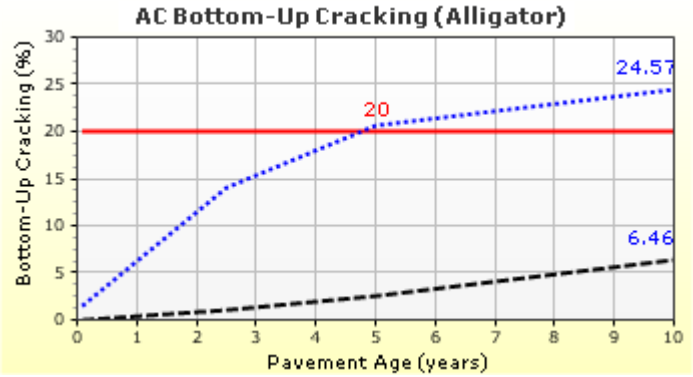
Distress Prediction Summary

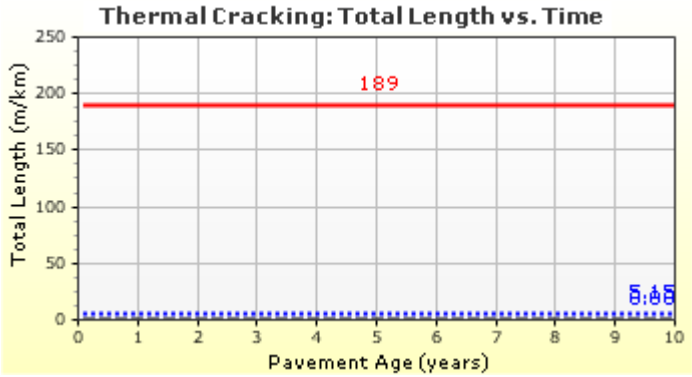
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.93	90.00	81.28	Fail
Permanent deformation - total pavement (mm)	20.00	24.58	90.00	52.25	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.57	90.00	83.10	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	751.13	90.00	65.22	Fail
Permanent deformation - AC only (mm)	5.00	11.88	50.00	1.97	Fail

Distress Charts







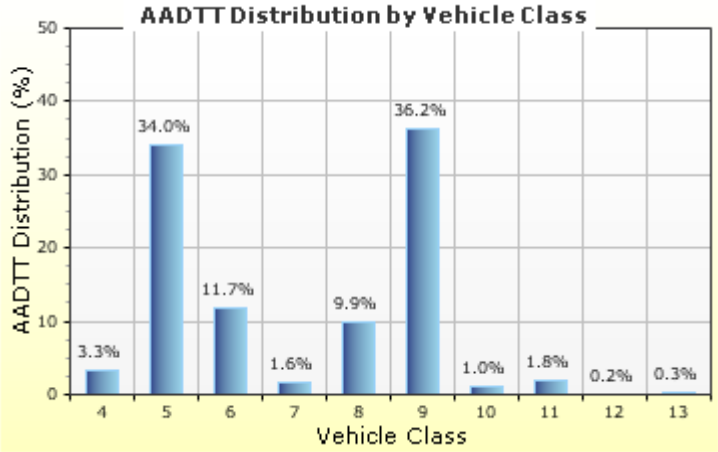


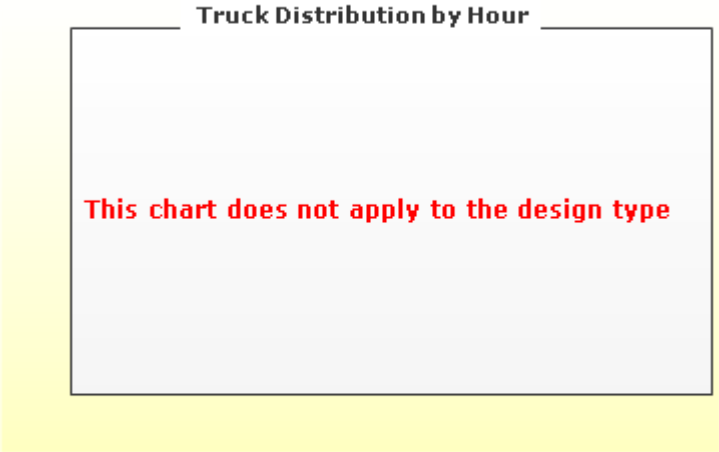


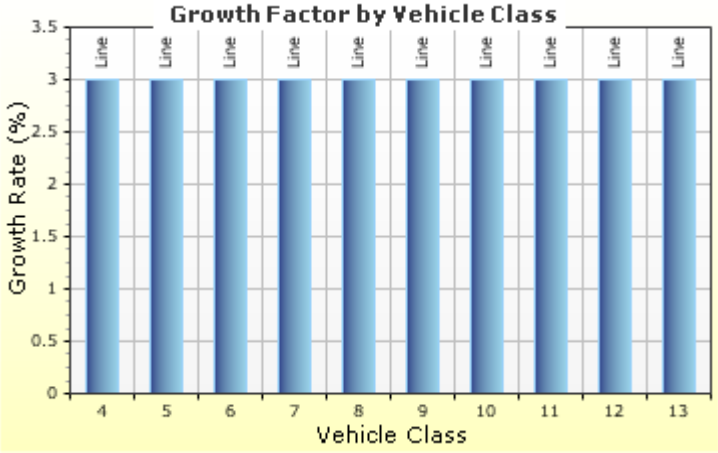
Traffic Inputs

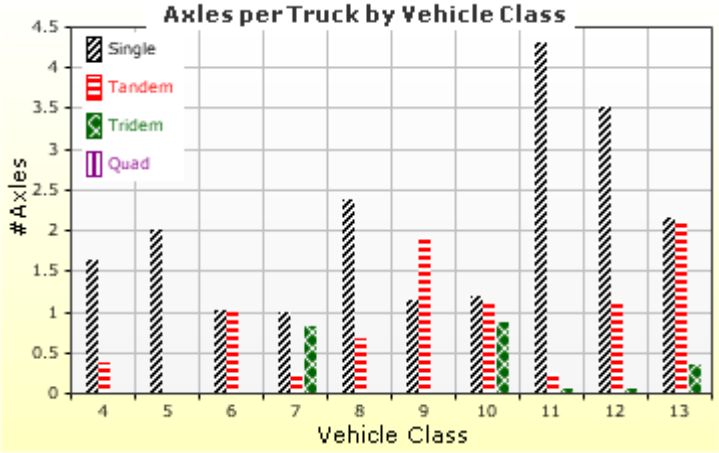
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

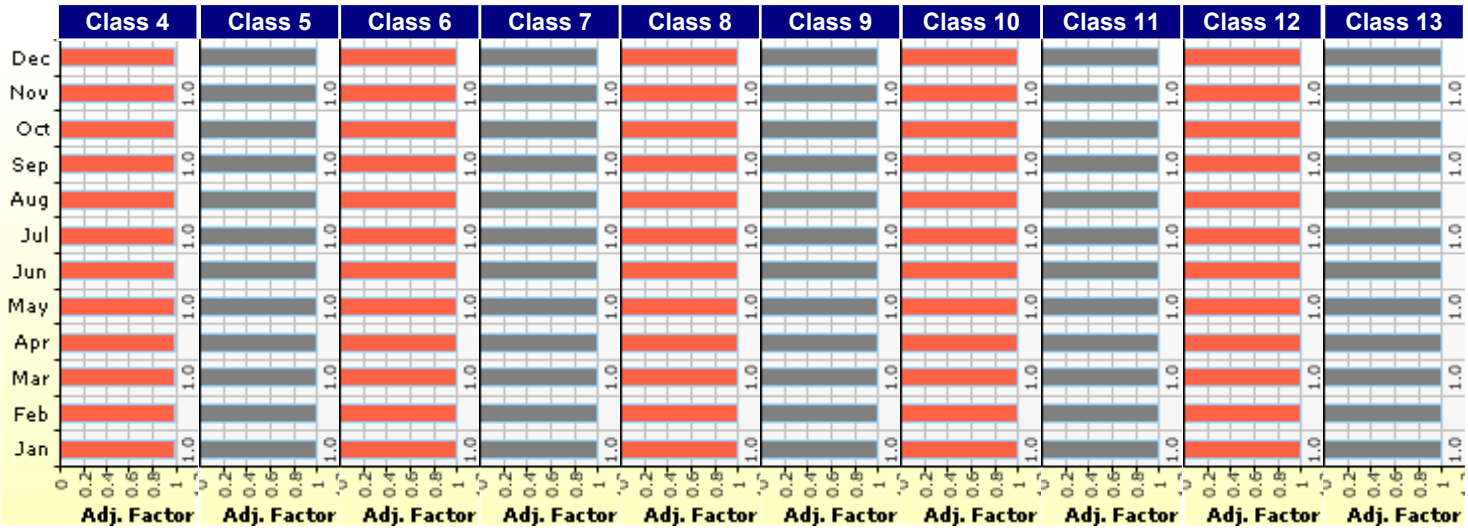








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

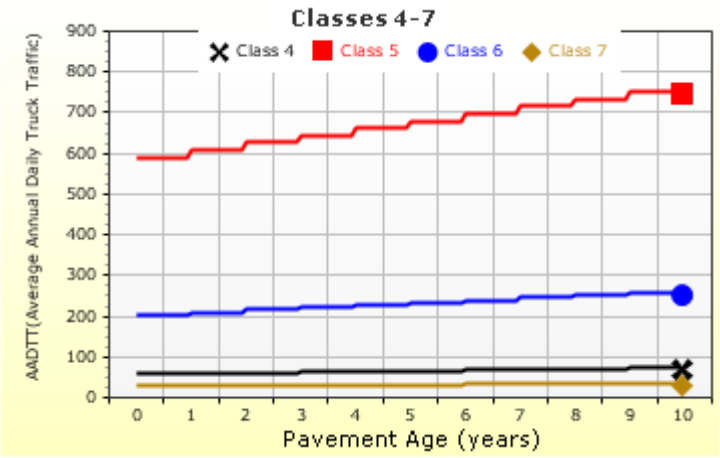
Wheelbase does not apply

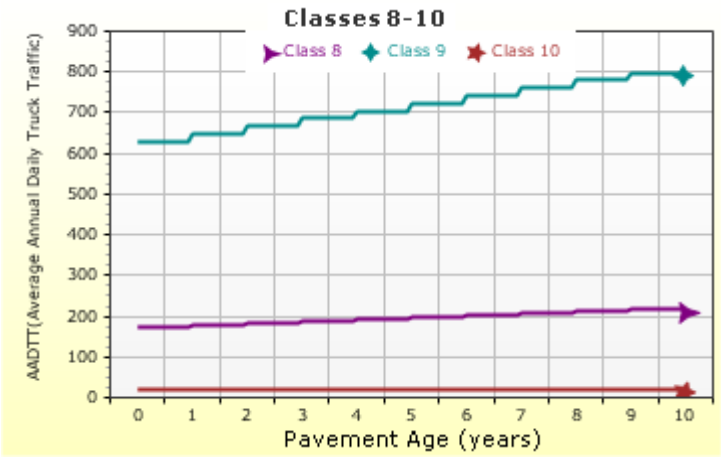
Number of Axles per Truck

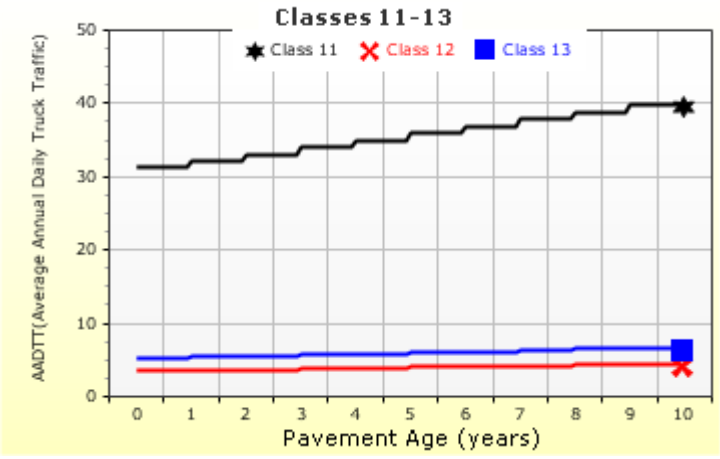
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

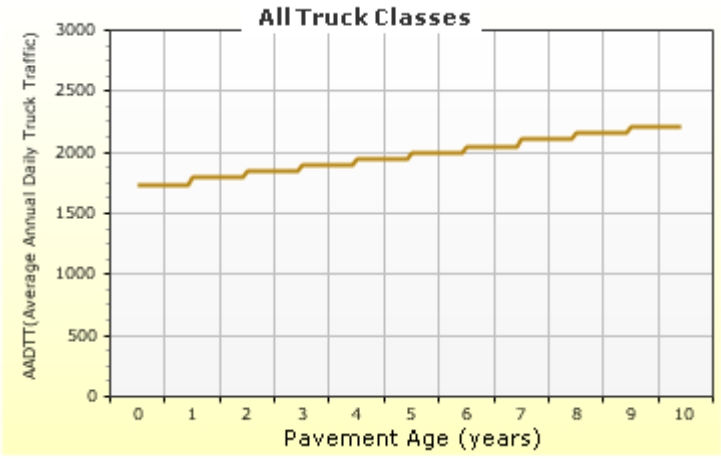
AADTT (Average Annual Daily Truck Traffic) Growth

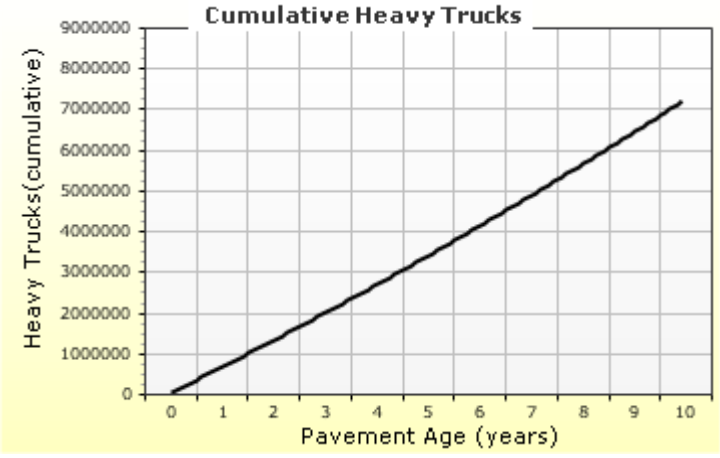
*** Traffic cap is not enforced**







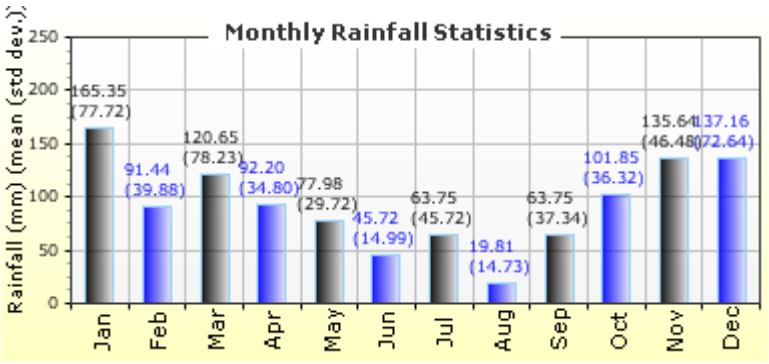




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
RIO DE JANEIRO, RJ	-22.80000 -43.68000 28

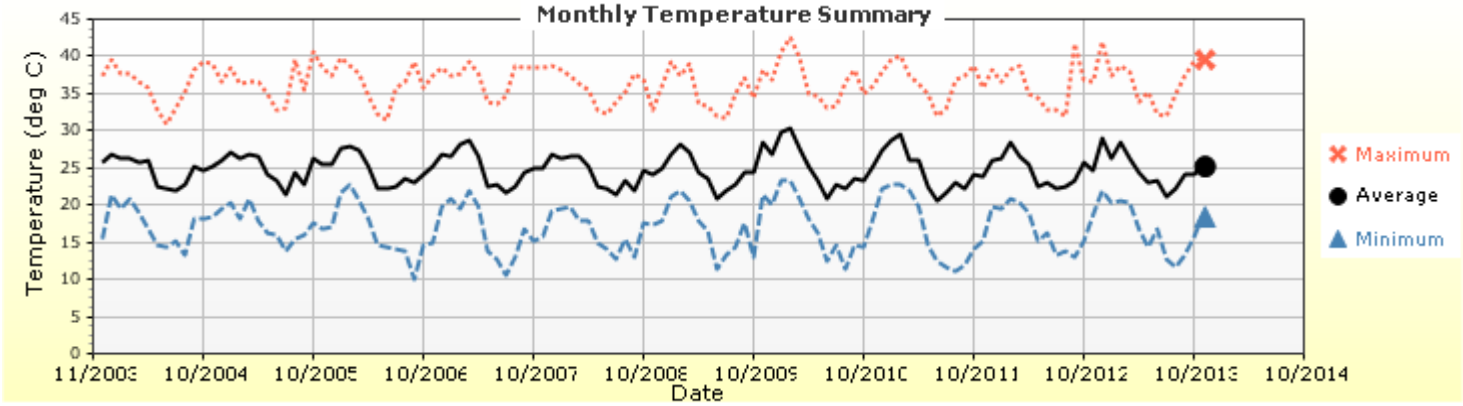


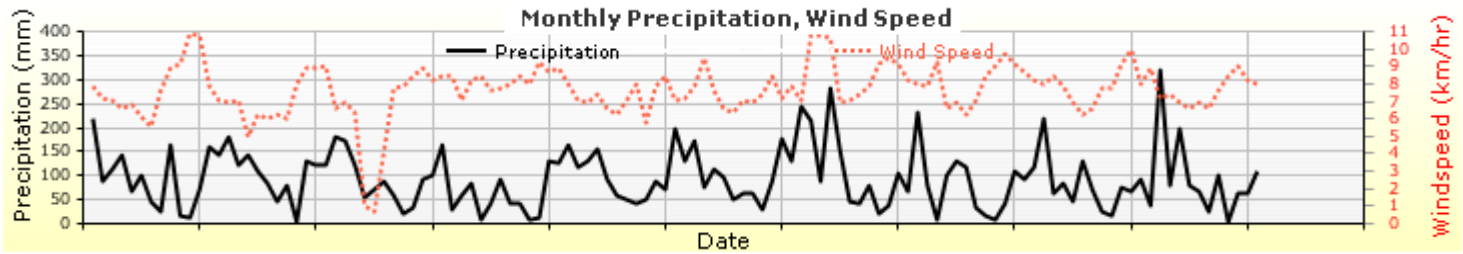
Annual Statistics:

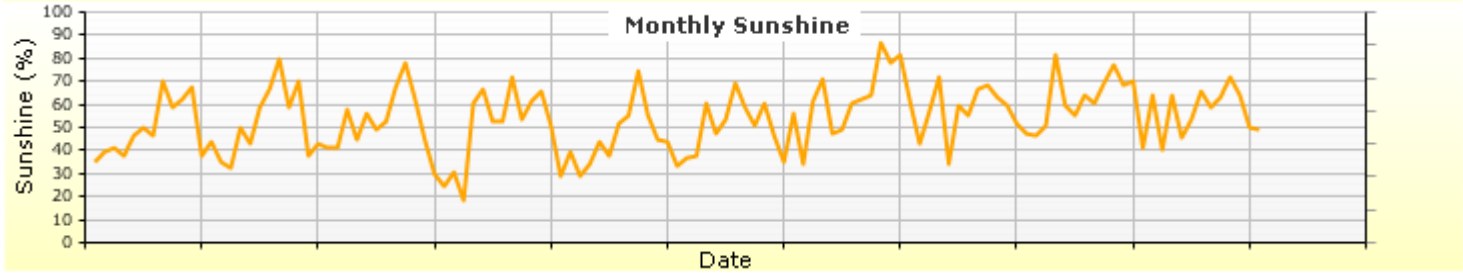
Mean annual air temperature (ºC)	24.79
Mean annual precipitation (mm)	1122.68
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

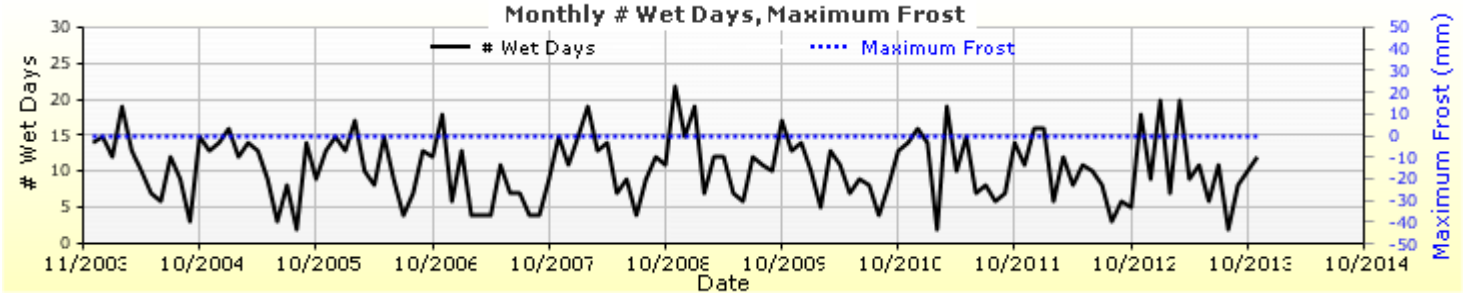
Water table depth (m)	3.05

Monthly Climate Summary:

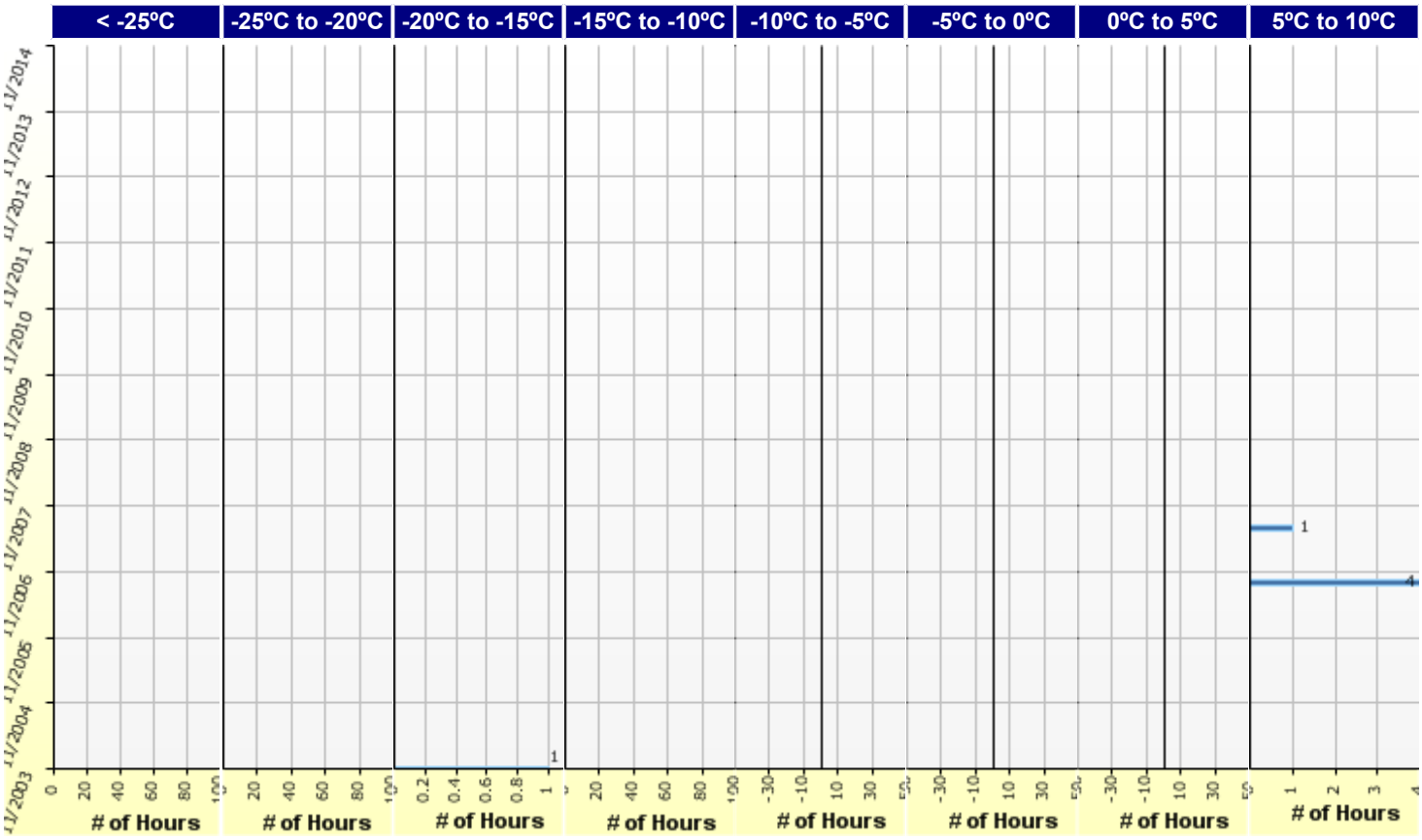


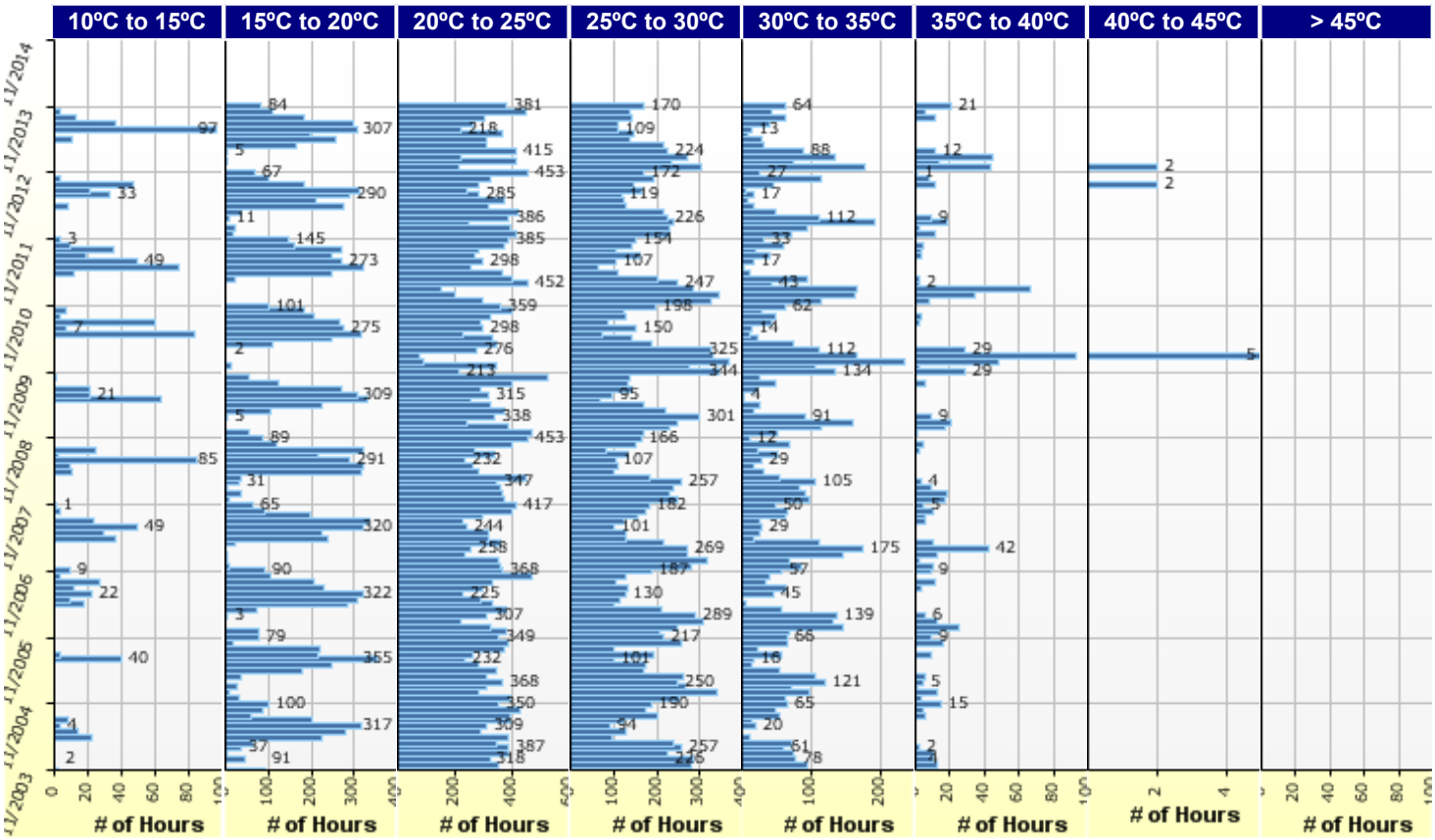






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

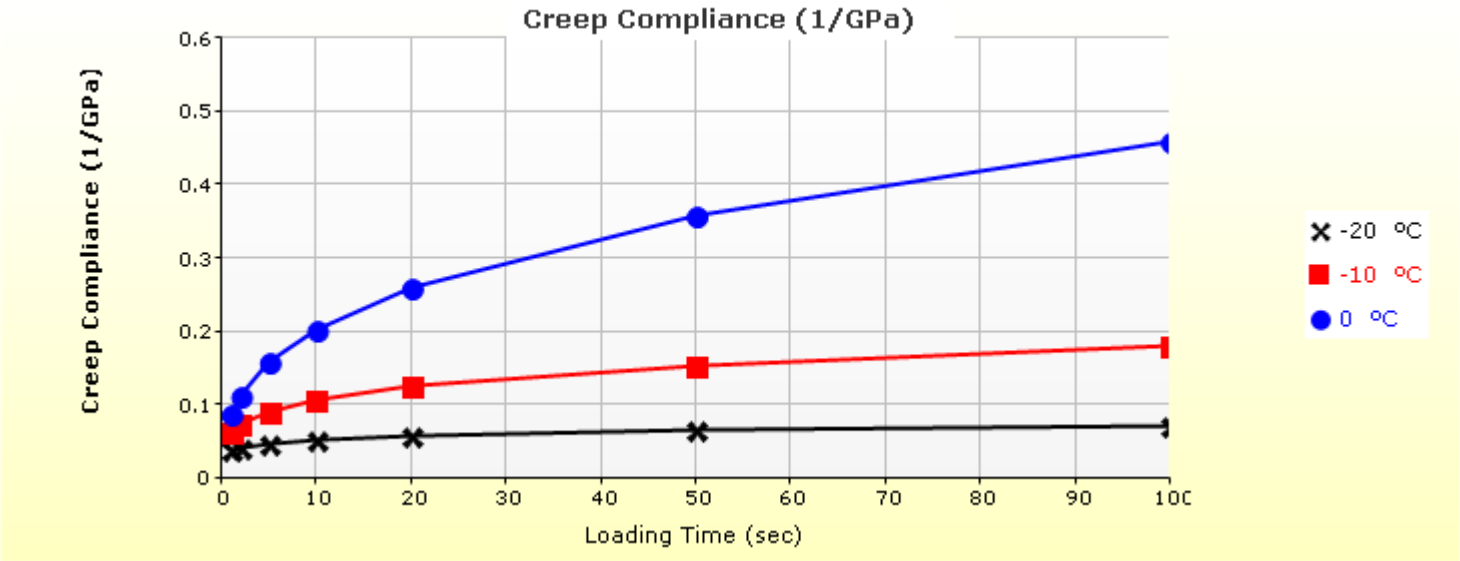
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

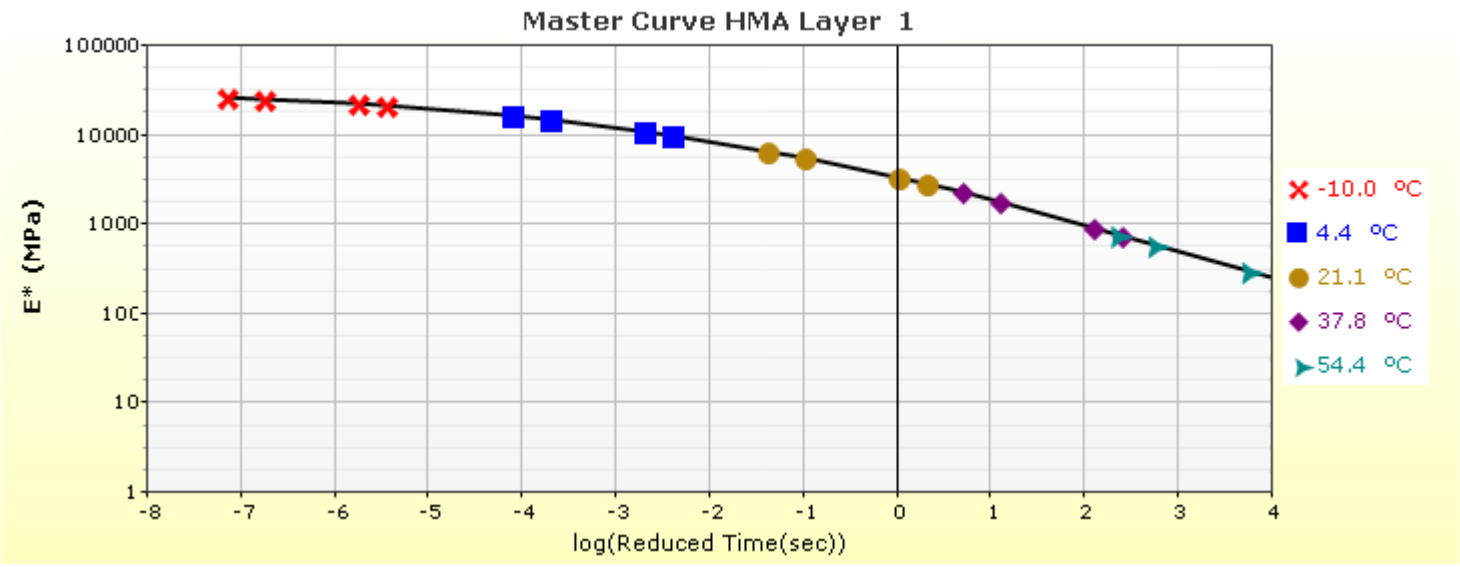
Indirect tensile strength at -10 ºC (MPa)	2.69

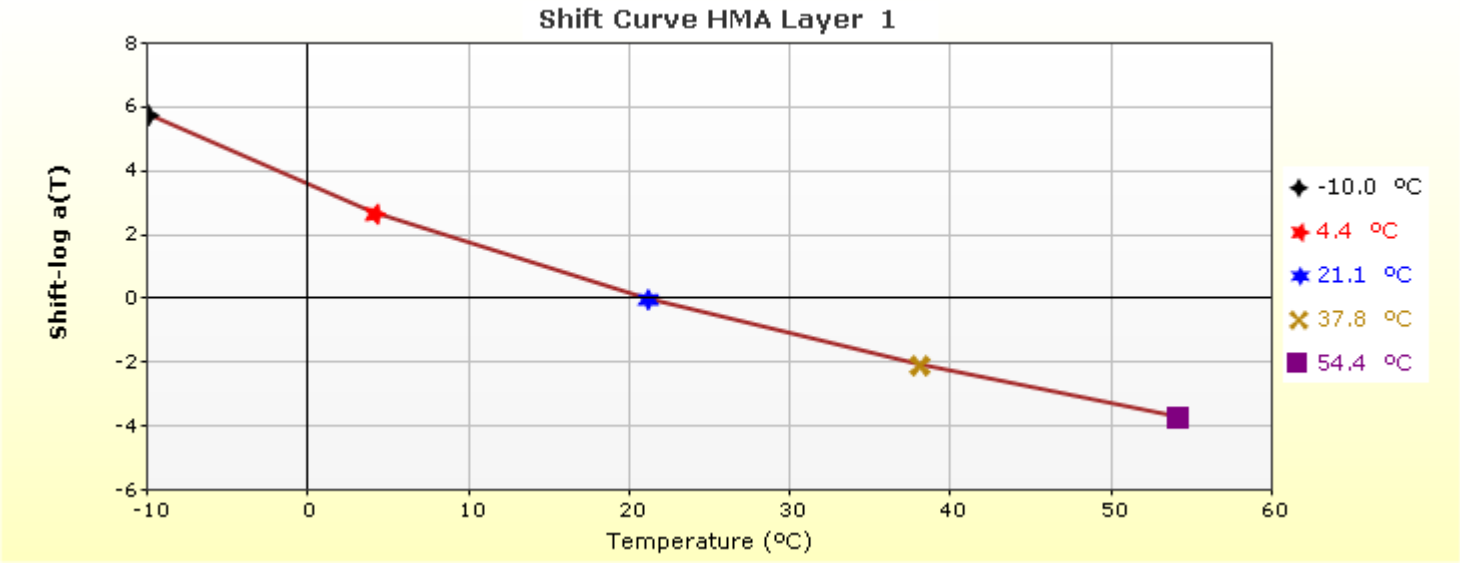
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

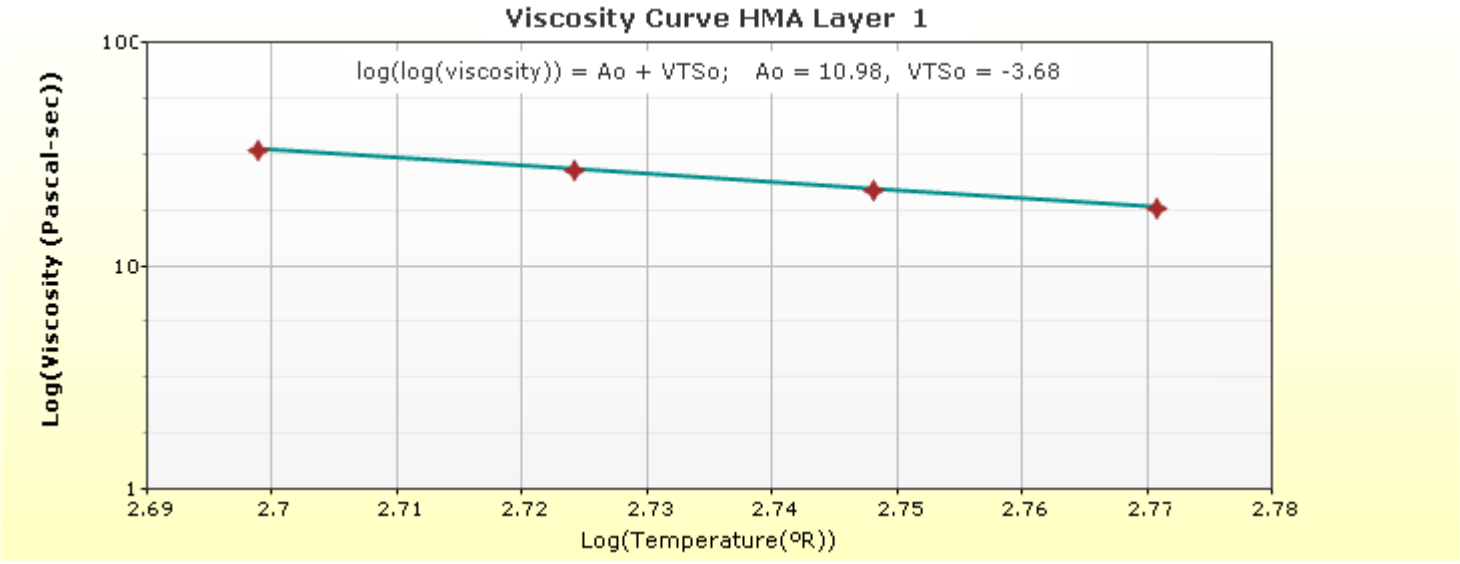
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



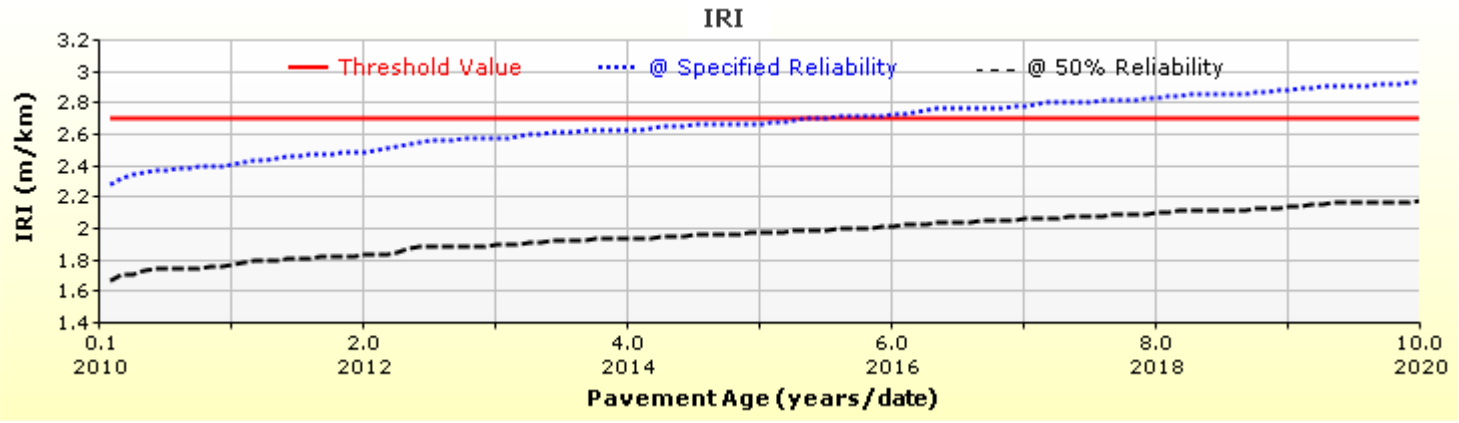
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

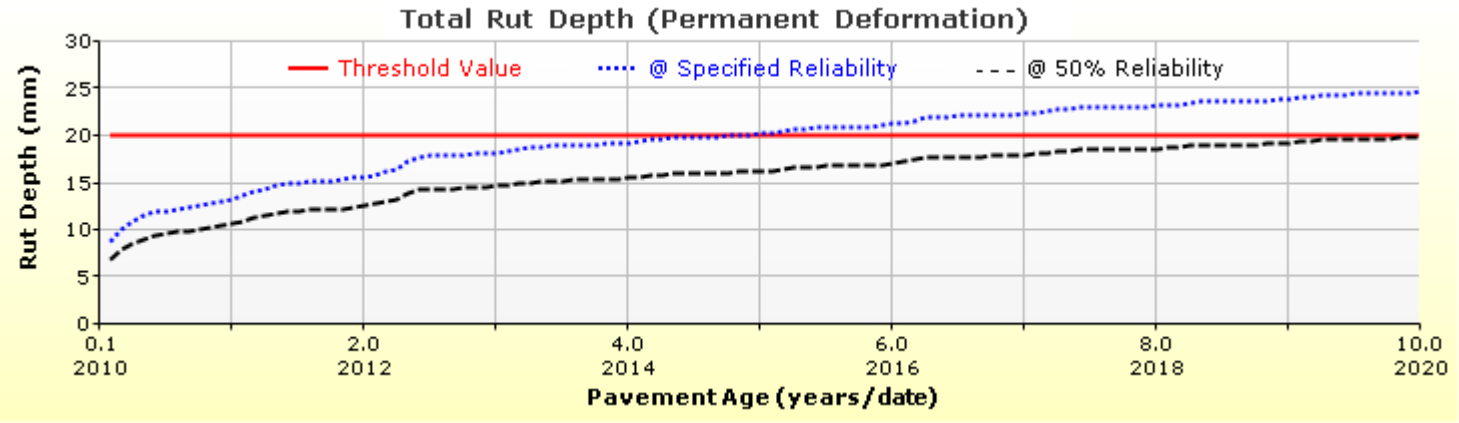


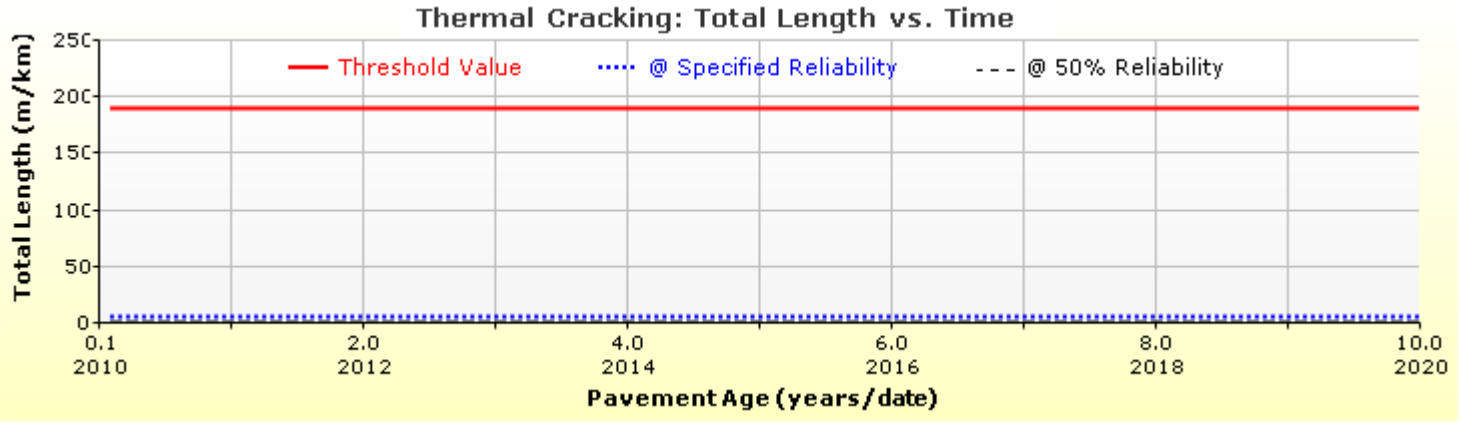


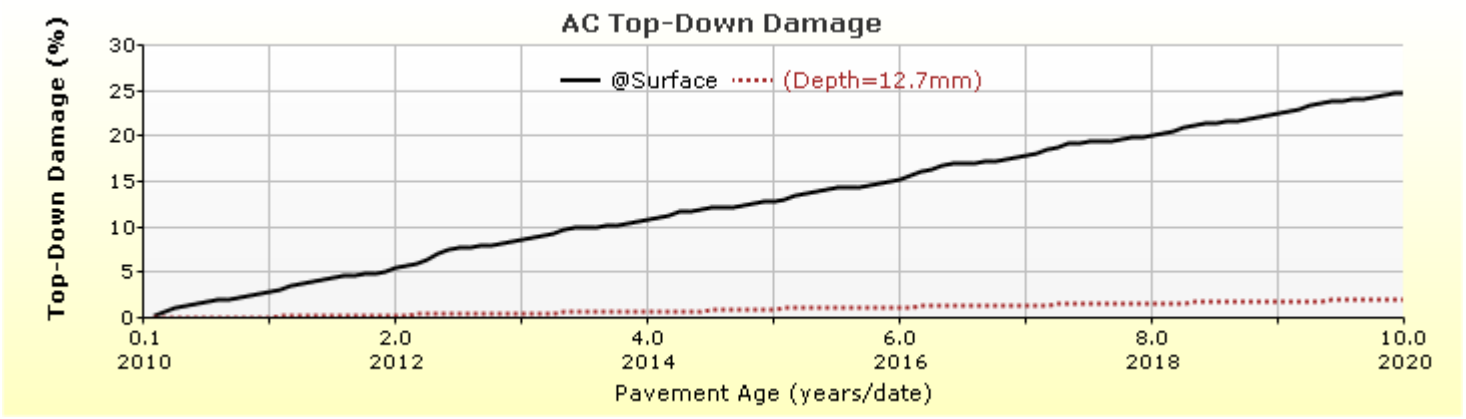


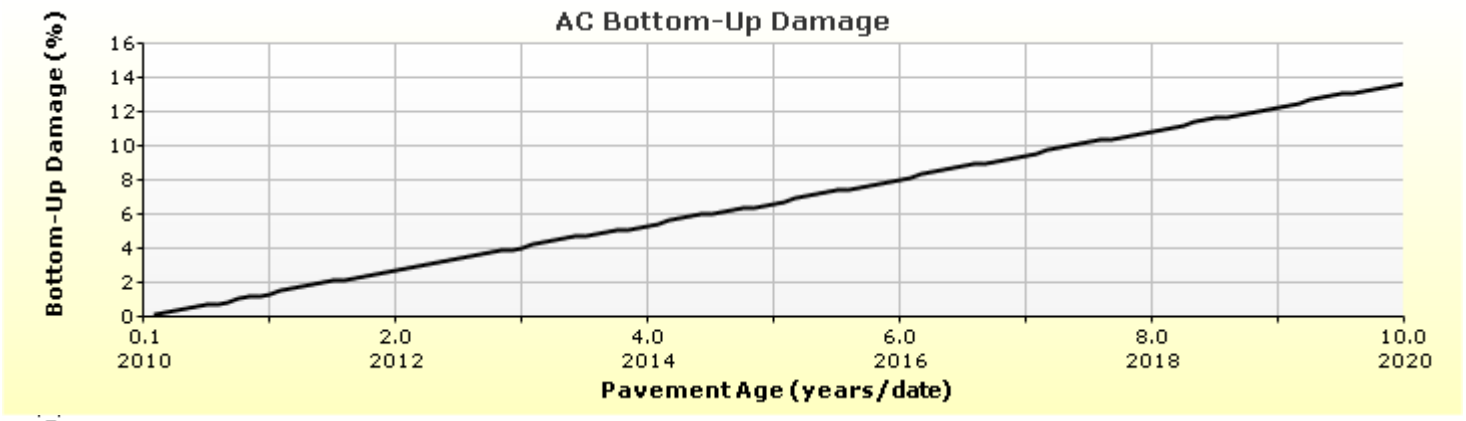
Analysis Output Charts

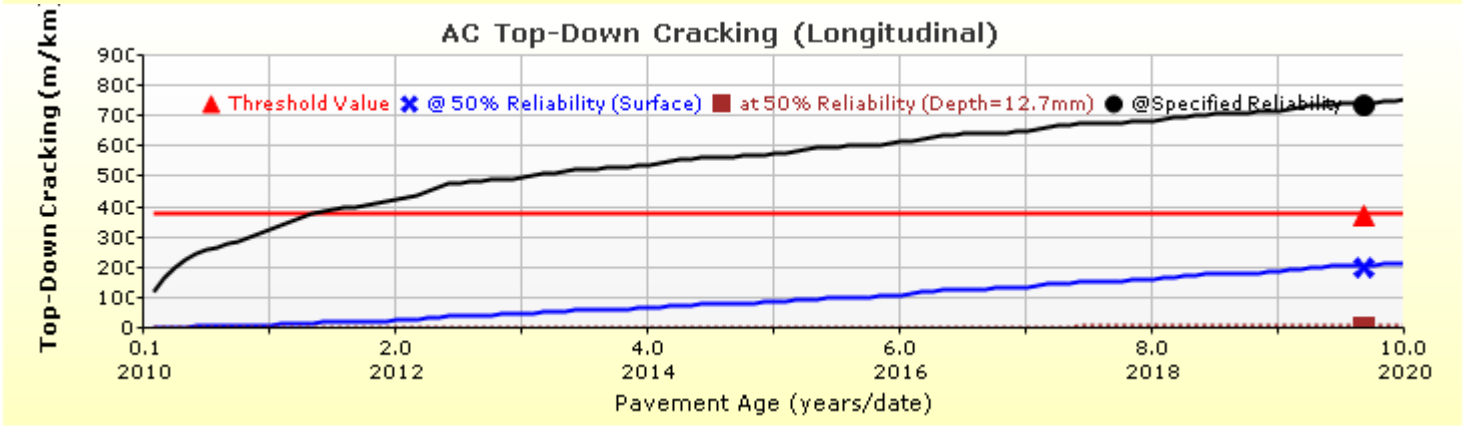


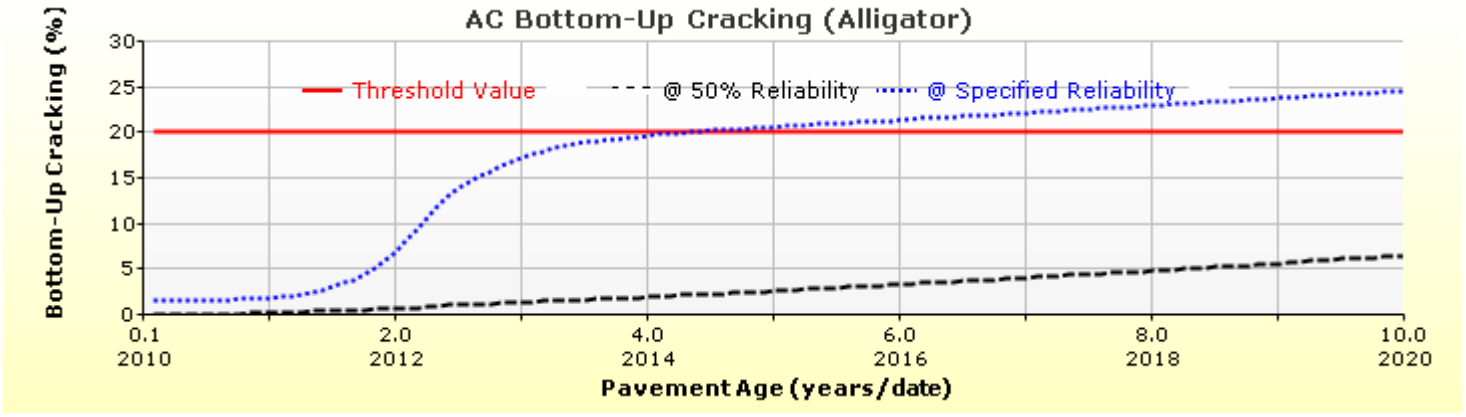


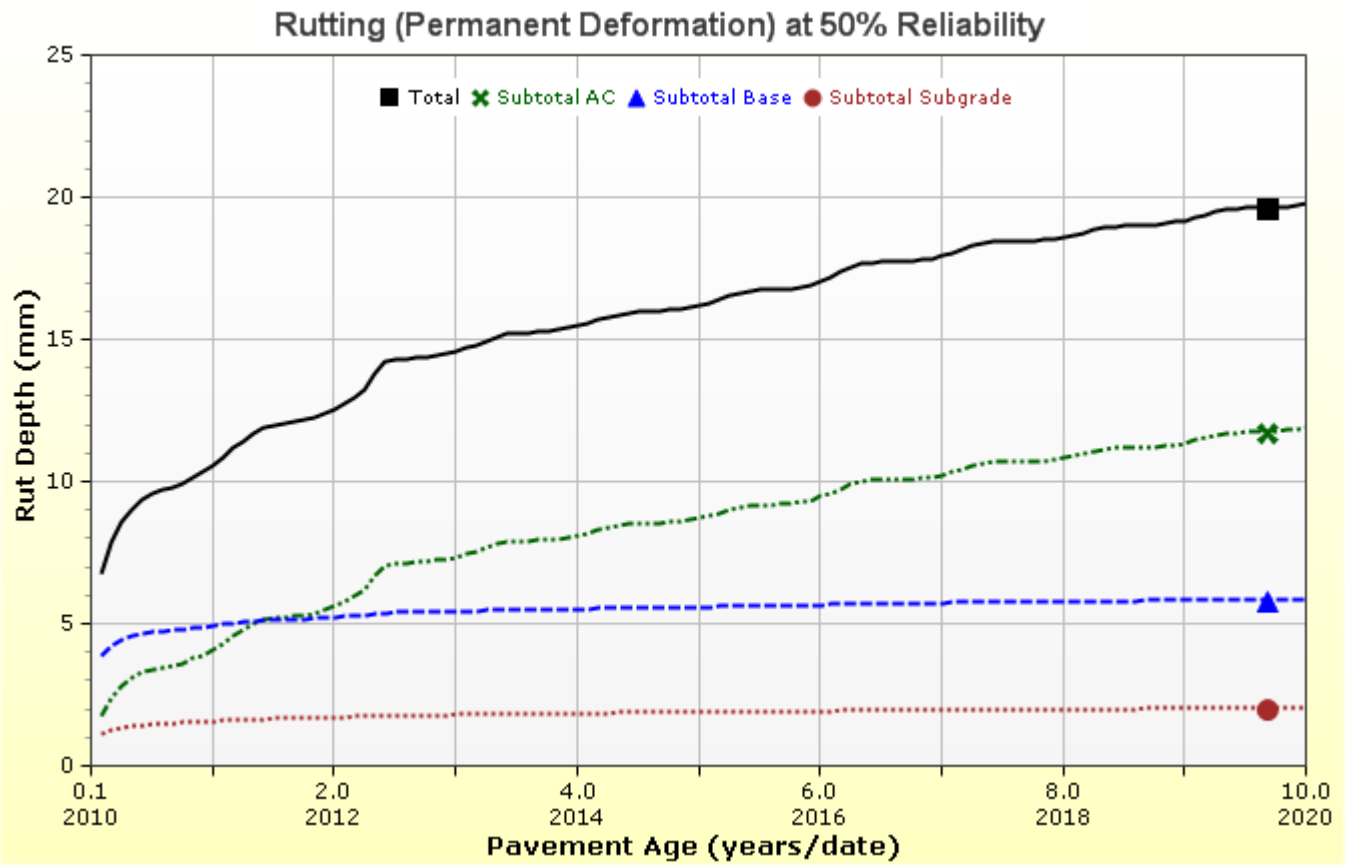


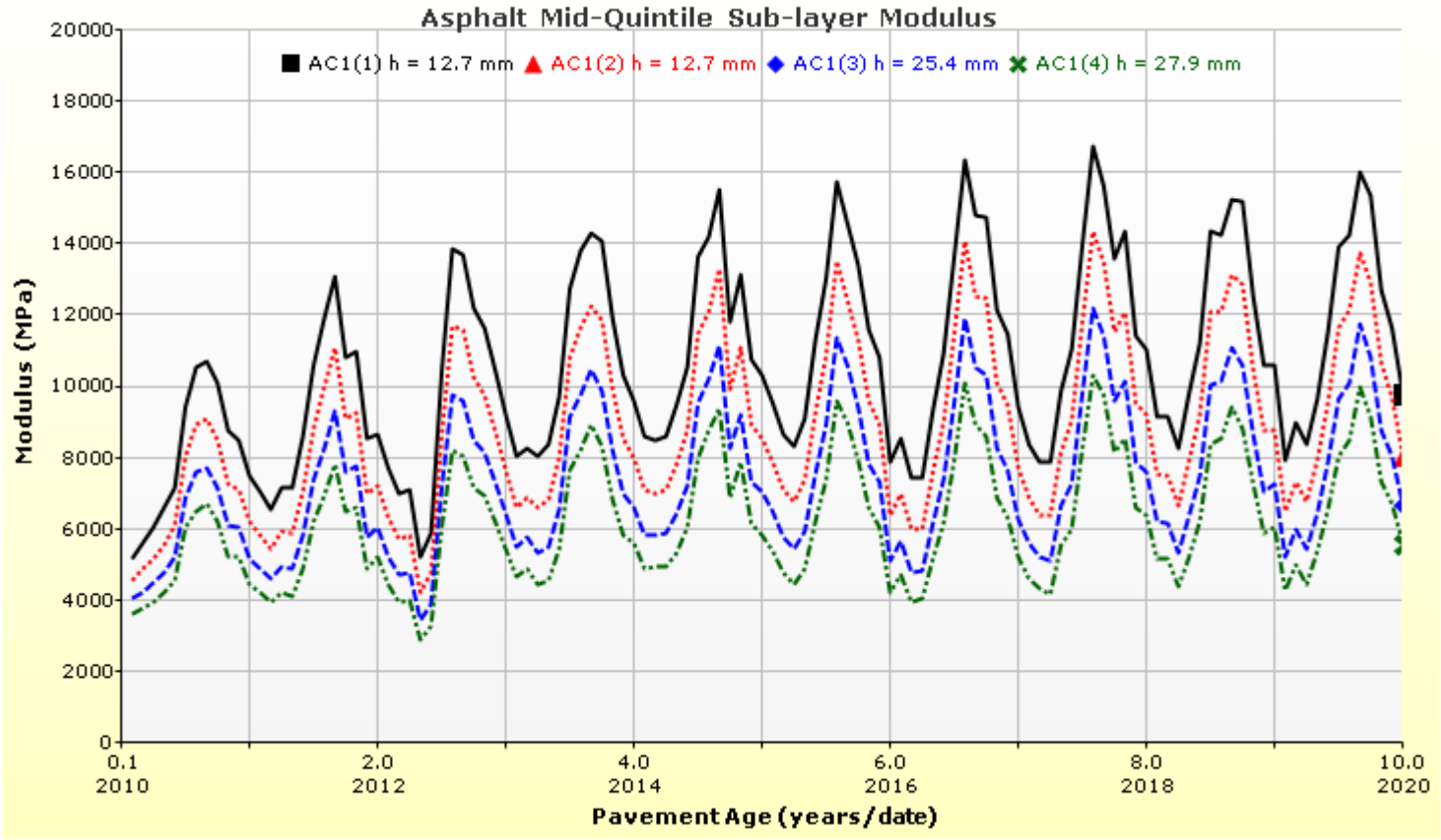

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

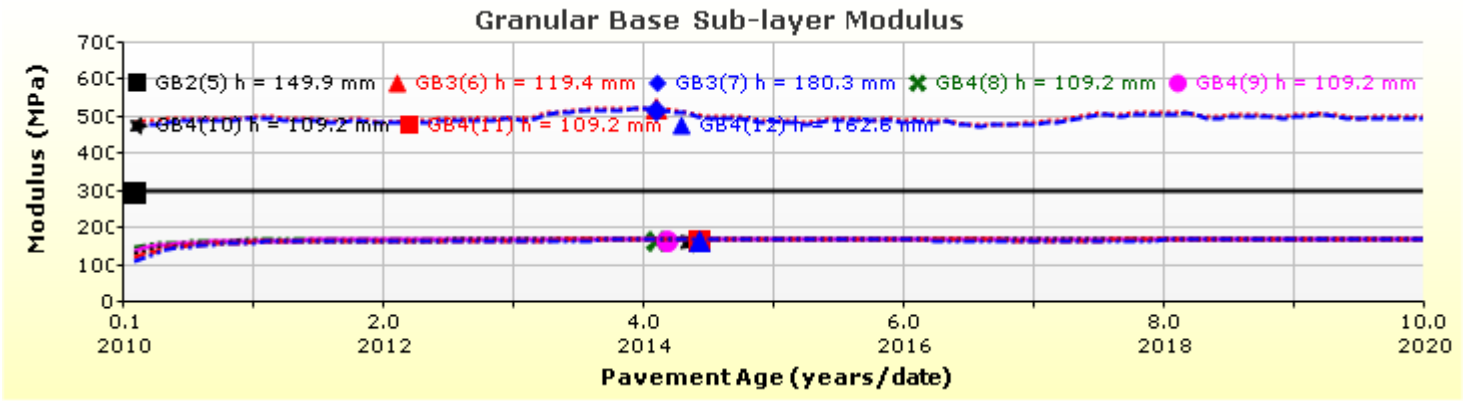

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

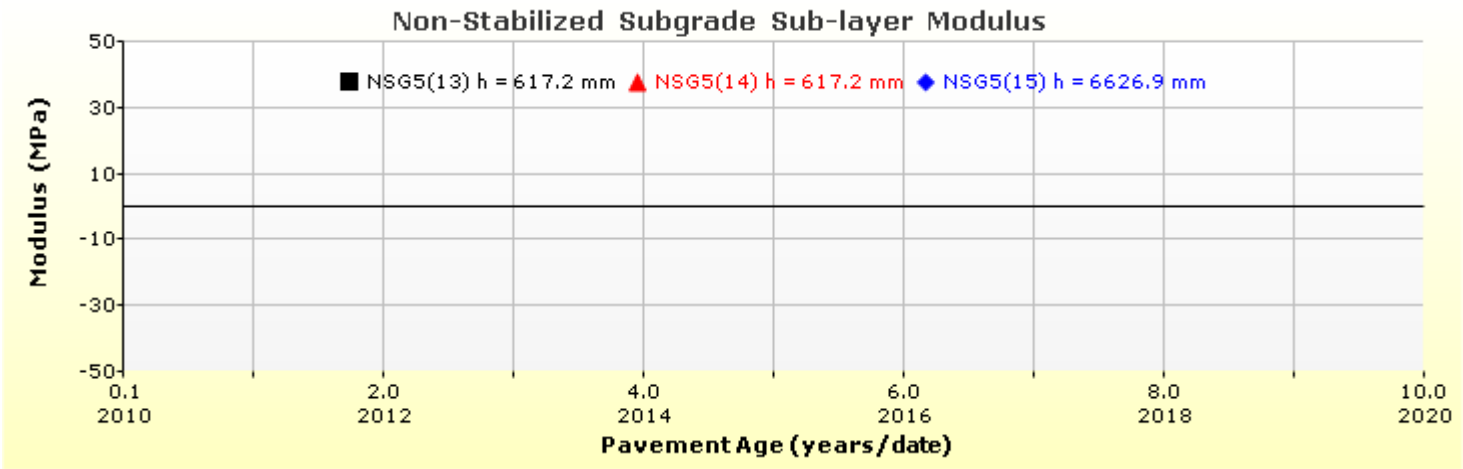

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
90
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.8 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 1
Bf2: 1
Bf3: 1

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestRJ_Vento

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestRJ_Vento.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -22.8, -43.68

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

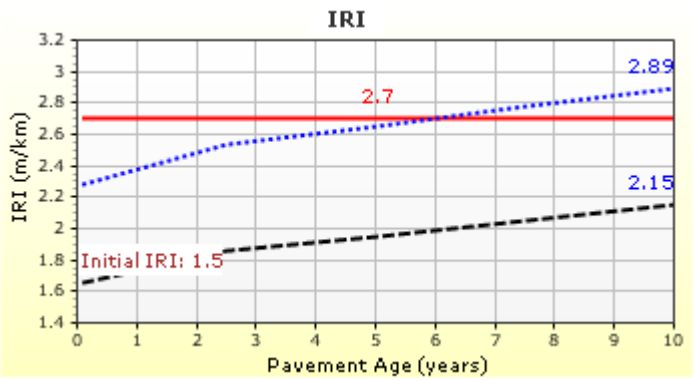
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

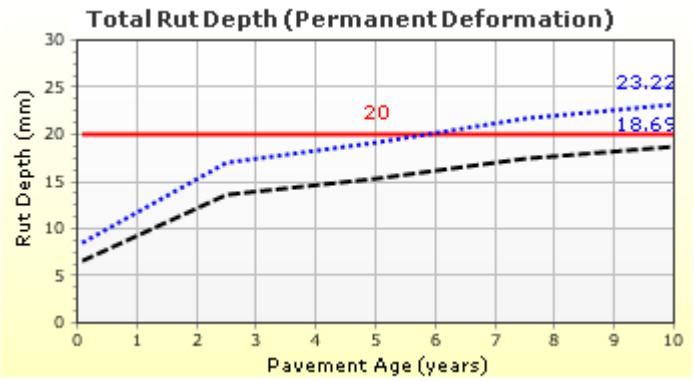
Design Outputs

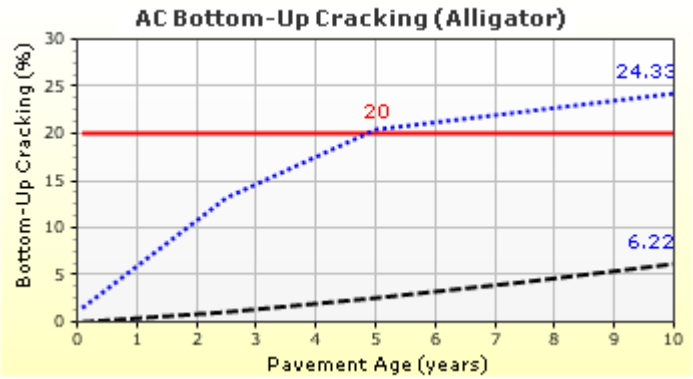
Distress Prediction Summary

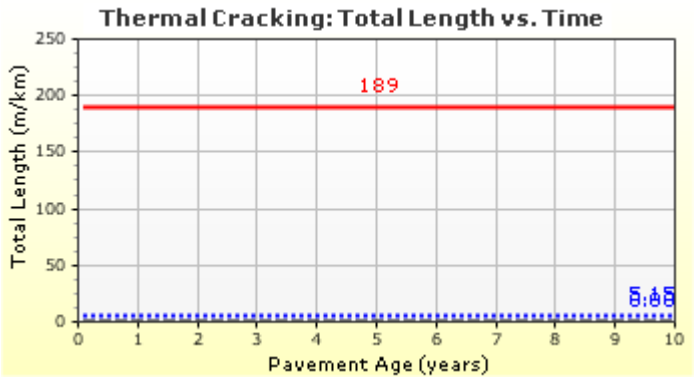
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.89	90.00	82.85	Fail
Permanent deformation - total pavement (mm)	20.00	23.21	90.00	64.38	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.33	90.00	83.53	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	718.19	90.00	67.75	Fail
Permanent deformation - AC only (mm)	5.00	10.82	50.00	3.03	Fail

Distress Charts







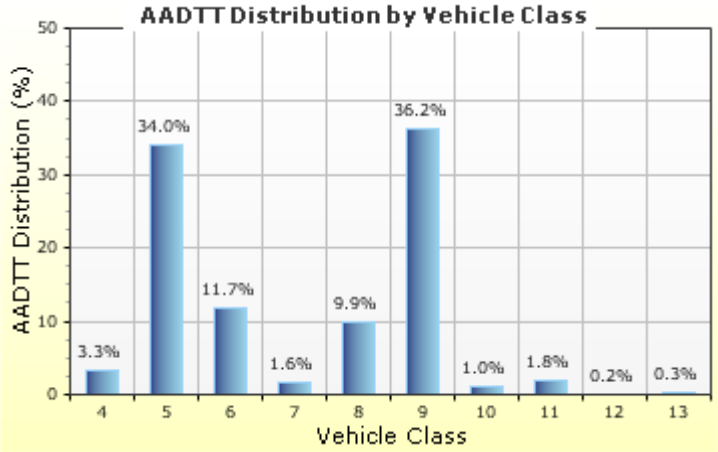


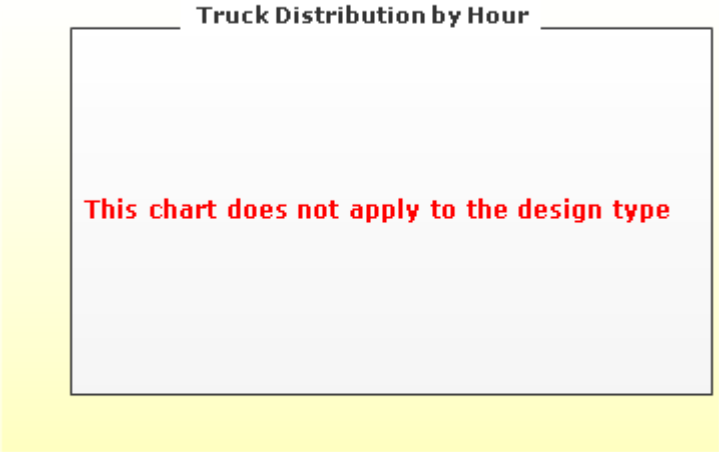


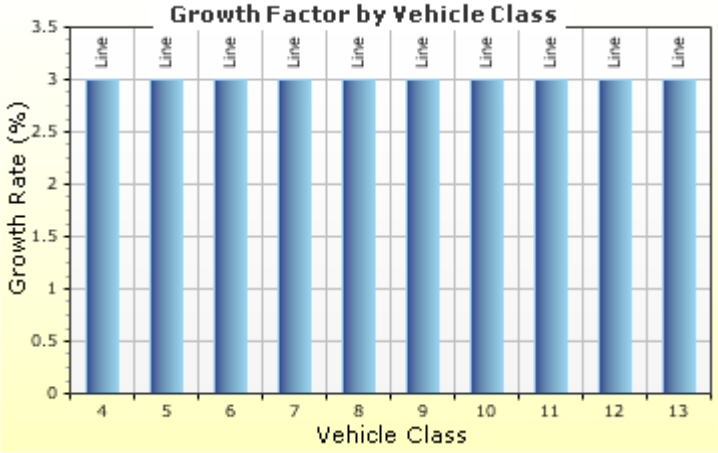
Traffic Inputs

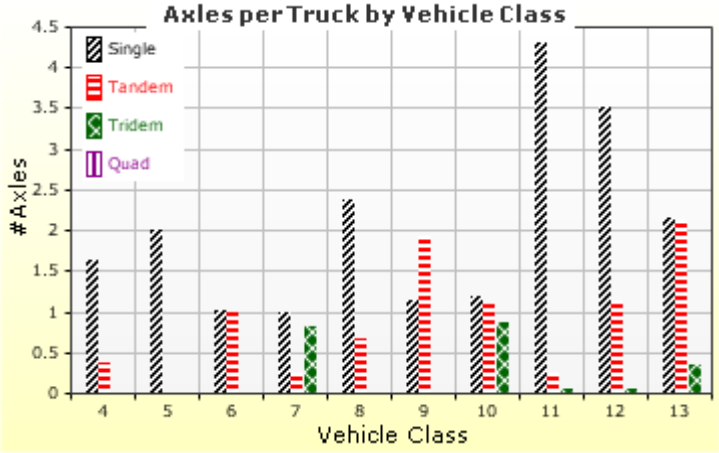
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

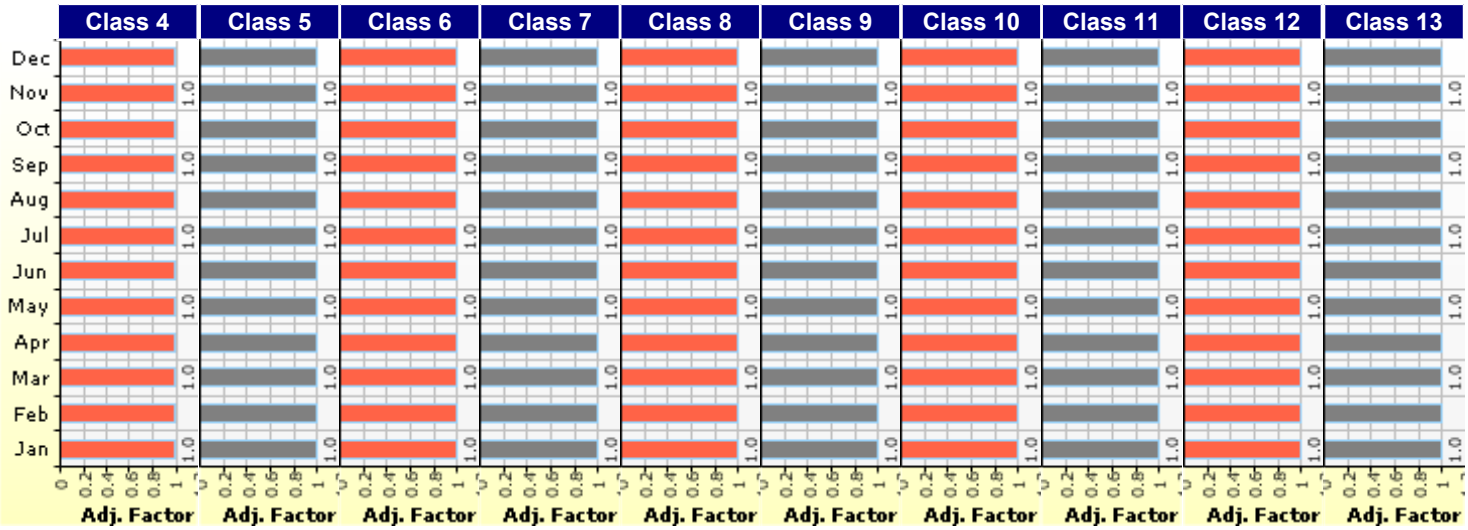








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

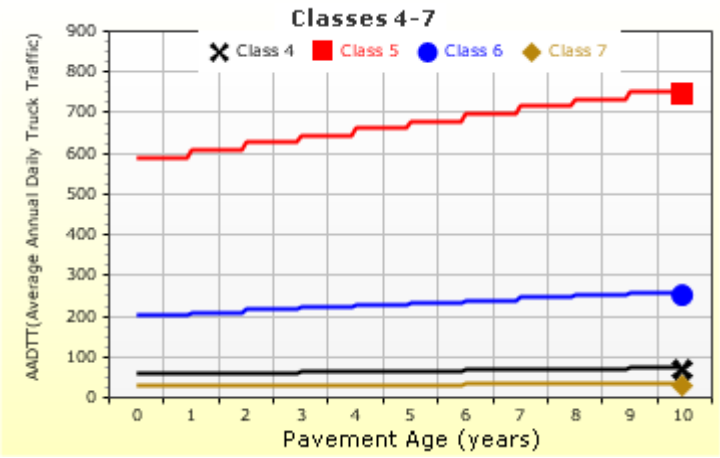
Wheelbase does not apply

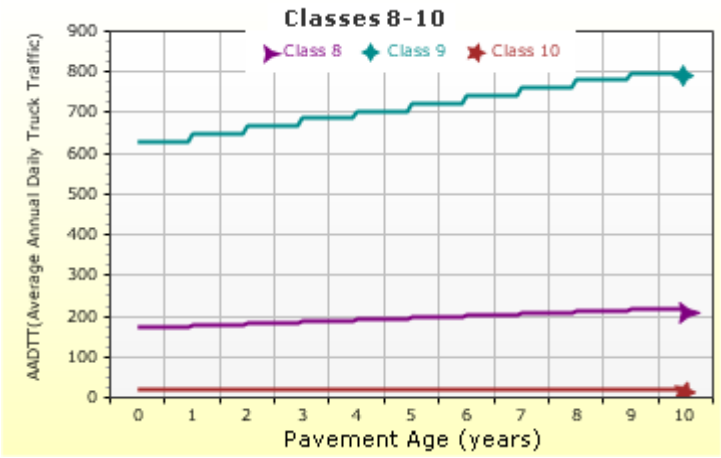
Number of Axles per Truck

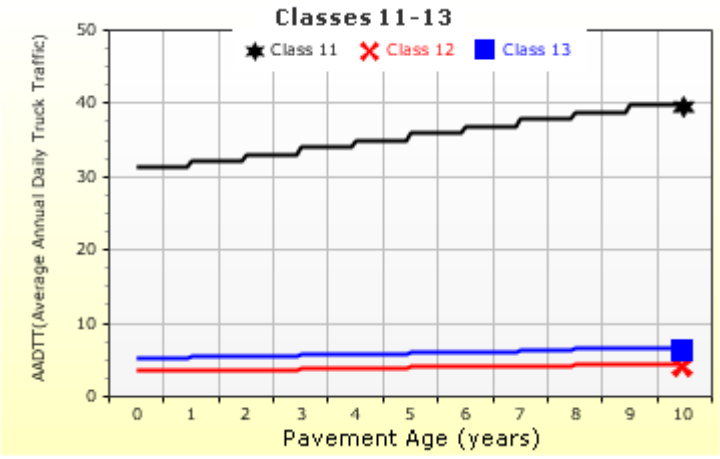
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

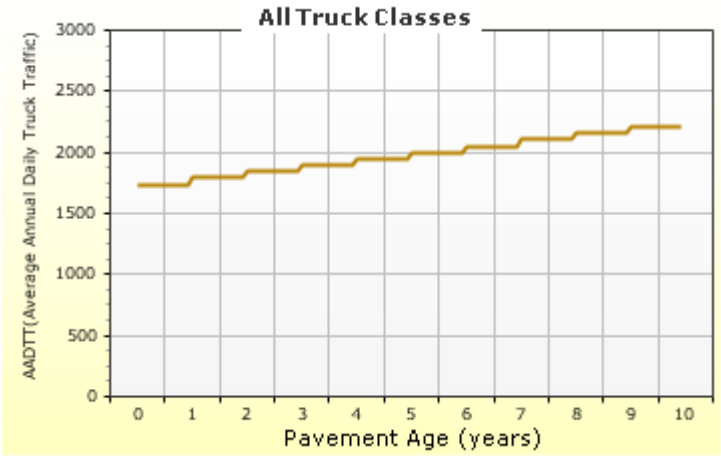
AADTT (Average Annual Daily Truck Traffic) Growth

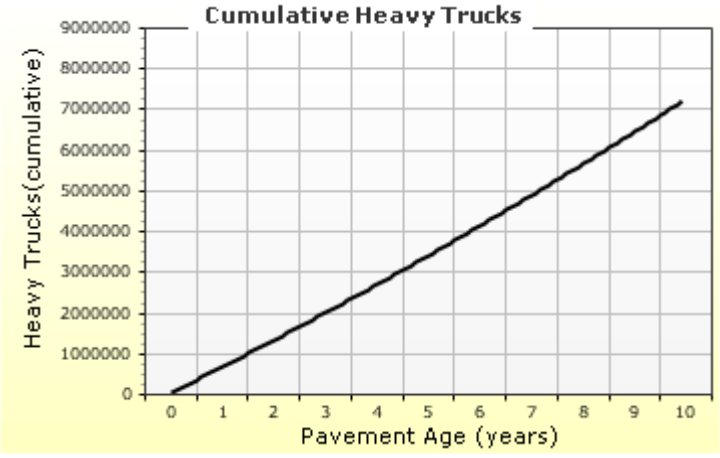
*** Traffic cap is not enforced**







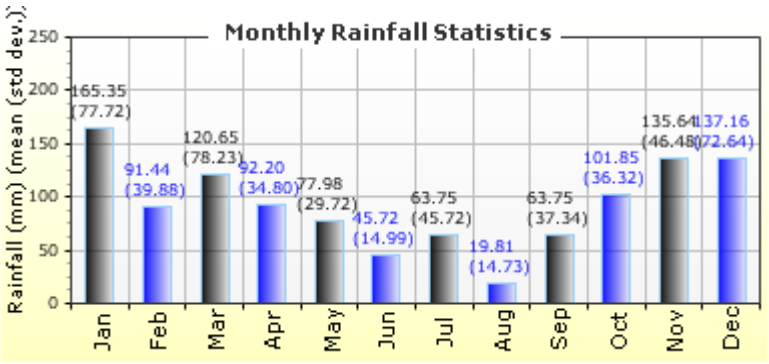




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
RIO DE JANEIRO, RJ	-22.80000 -43.68000 28

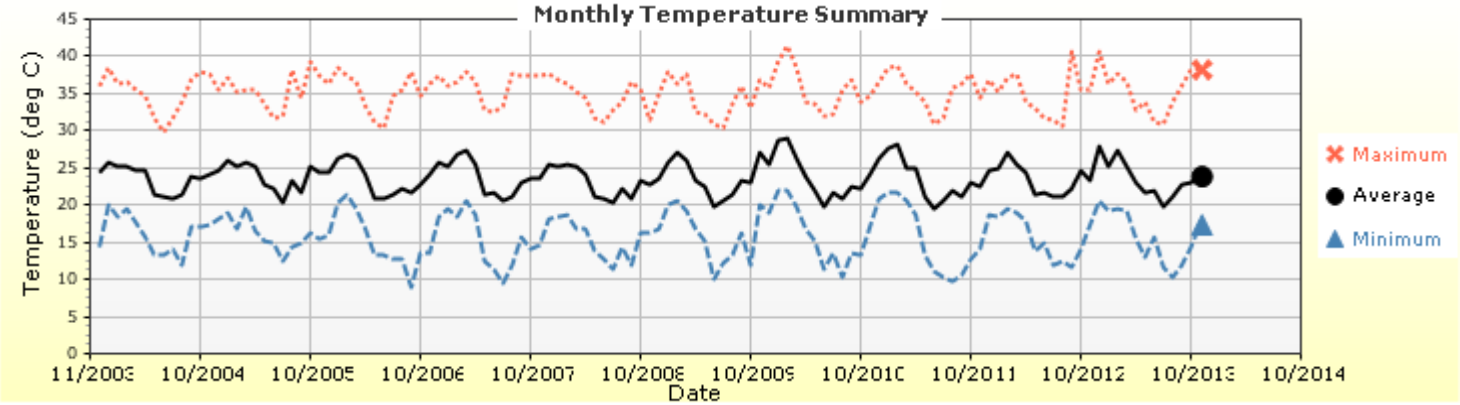


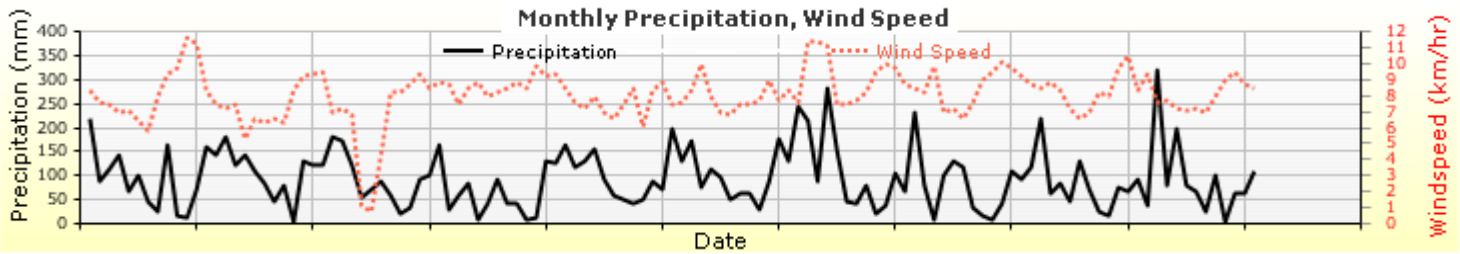
Annual Statistics:

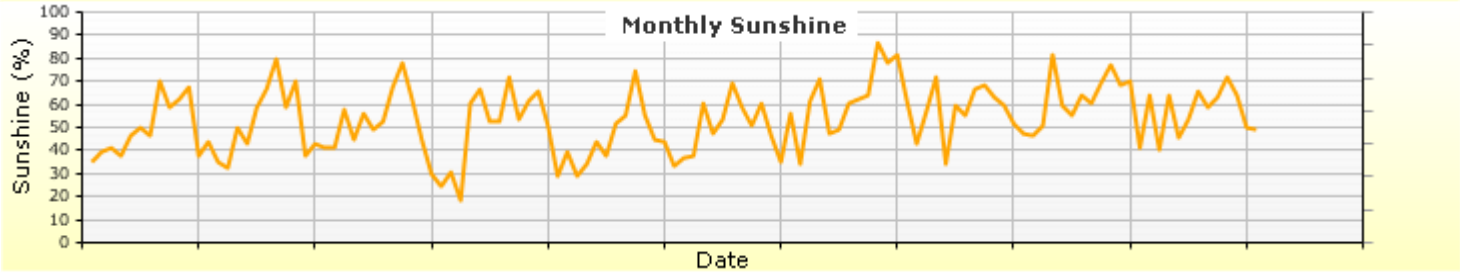
Mean annual air temperature (ºC)	23.59
Mean annual precipitation (mm)	1122.68
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

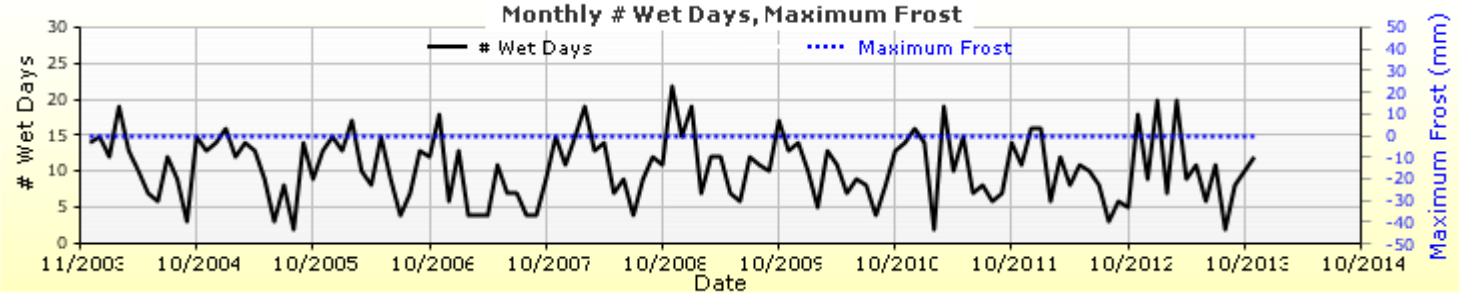
Water table depth (m): 3.05

Monthly Climate Summary:

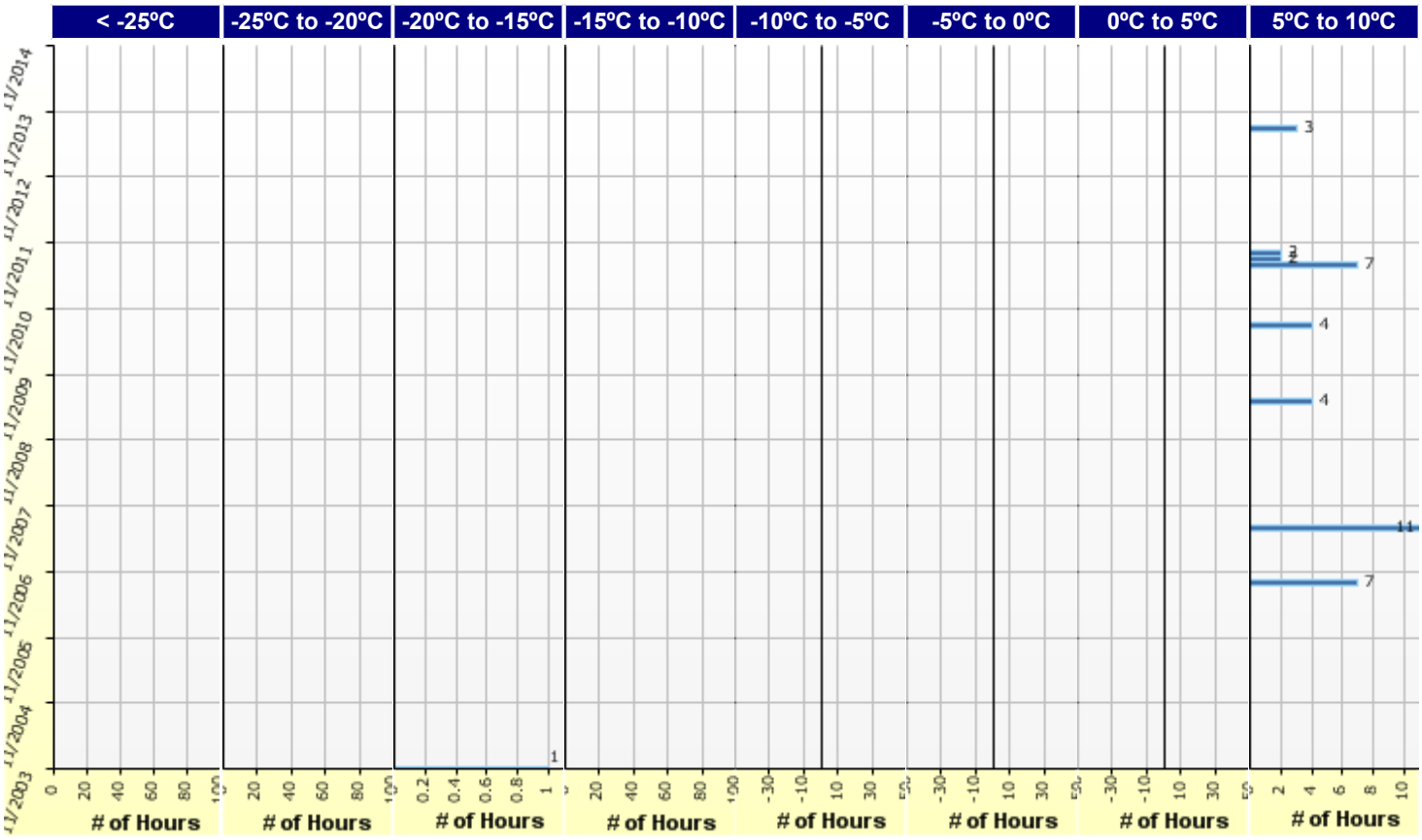


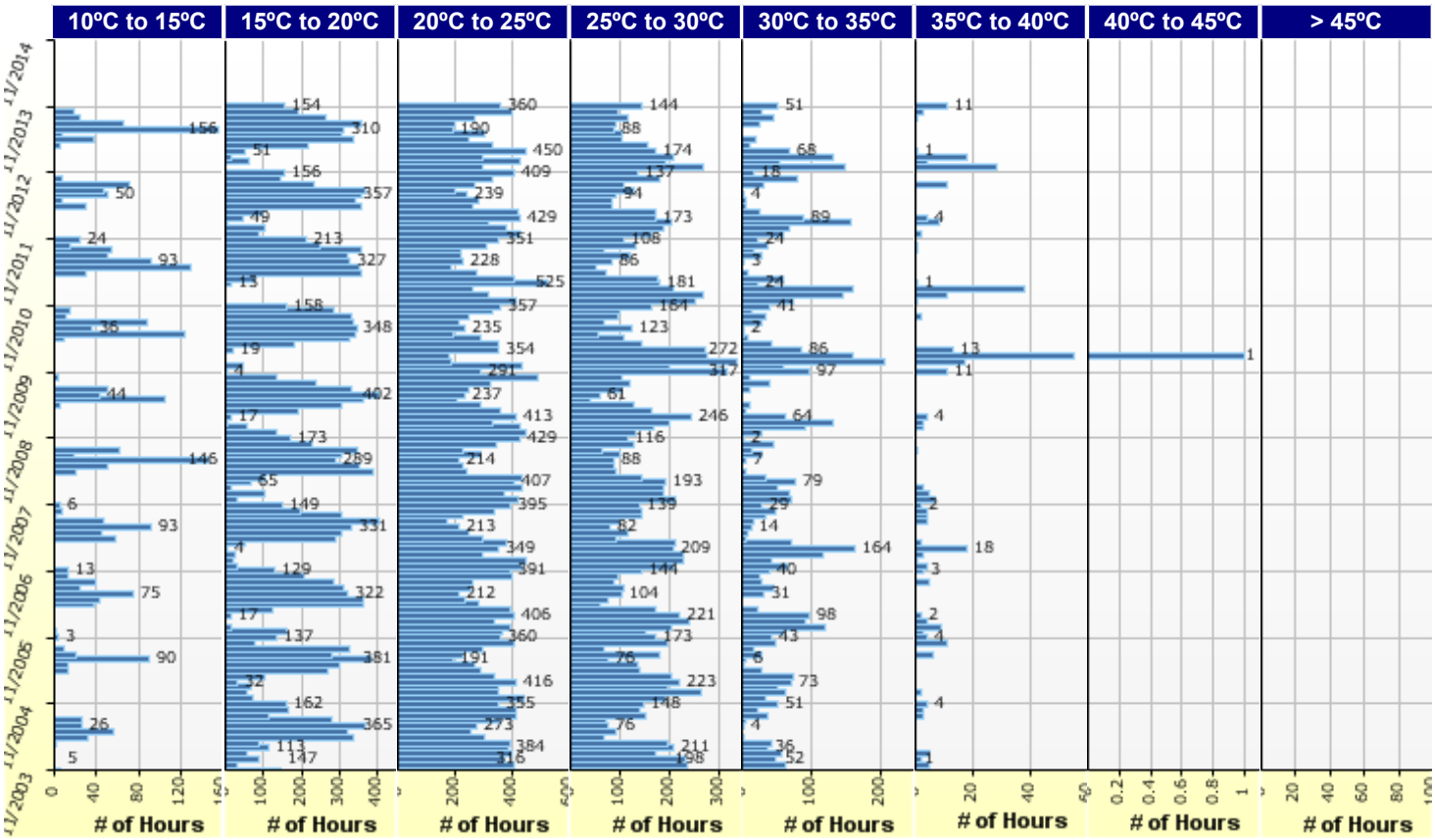






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

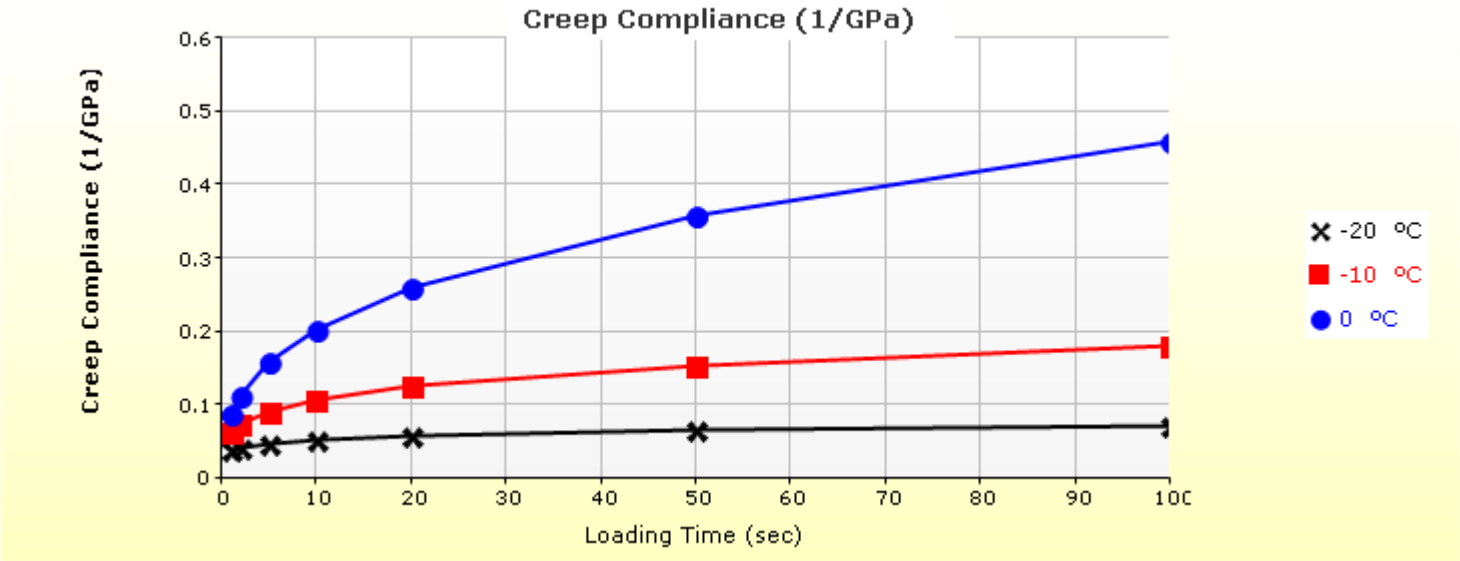
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

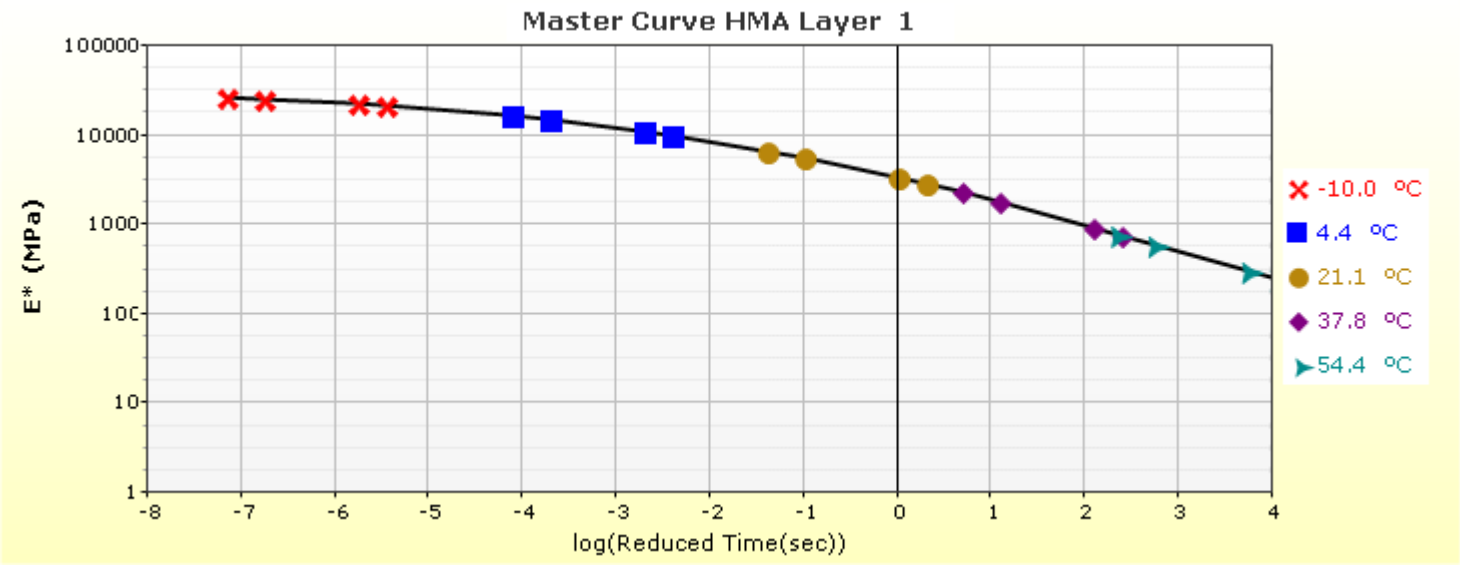
Indirect tensile strength at -10 ºC (MPa)	2.69

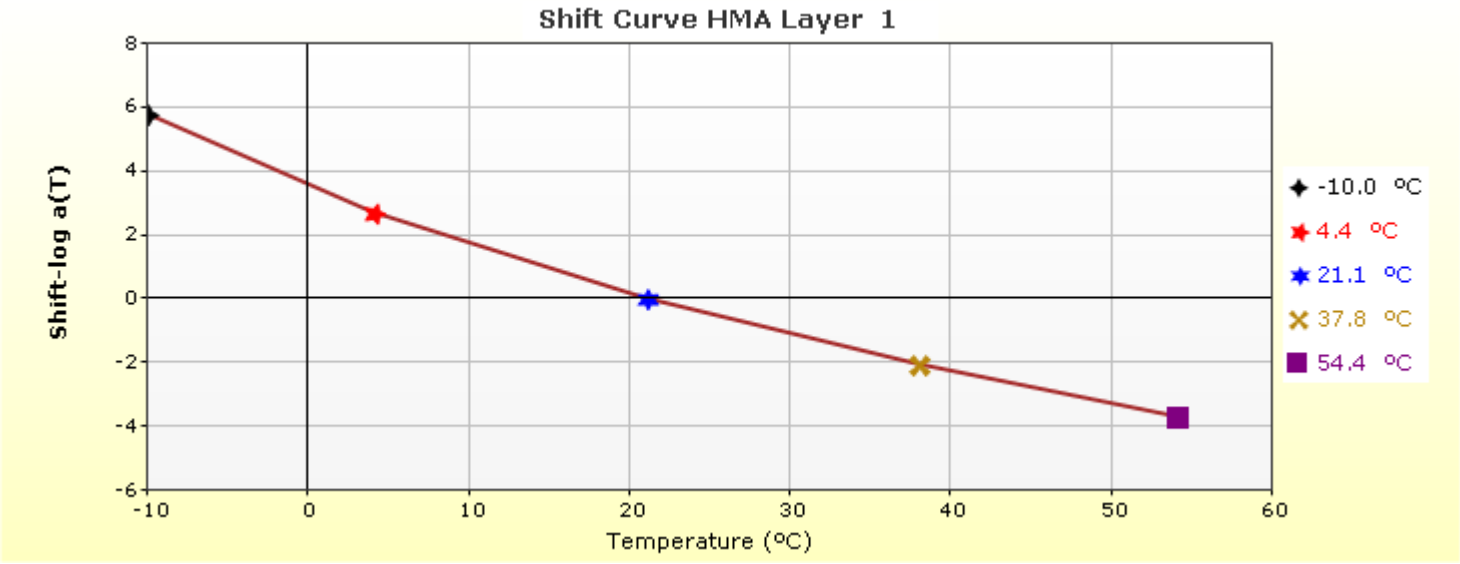
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

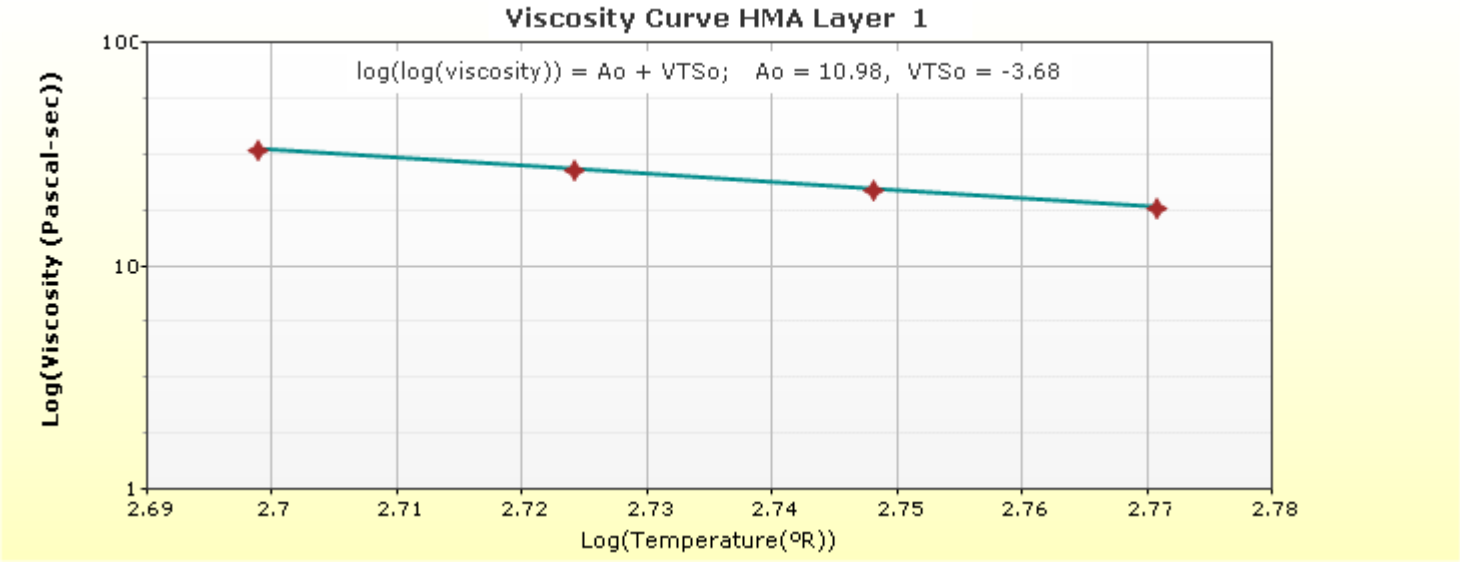
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



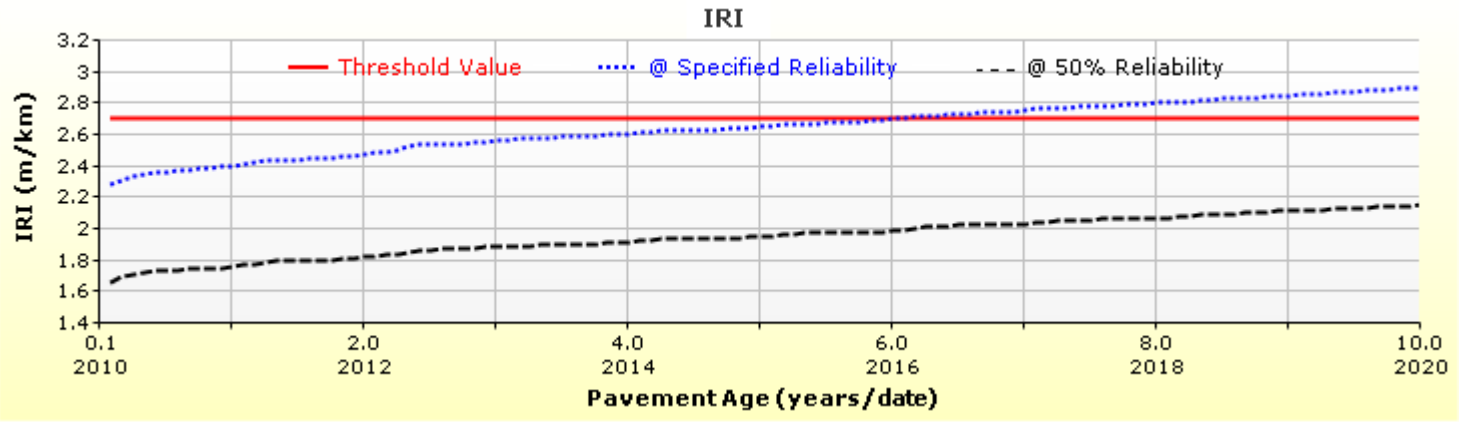
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

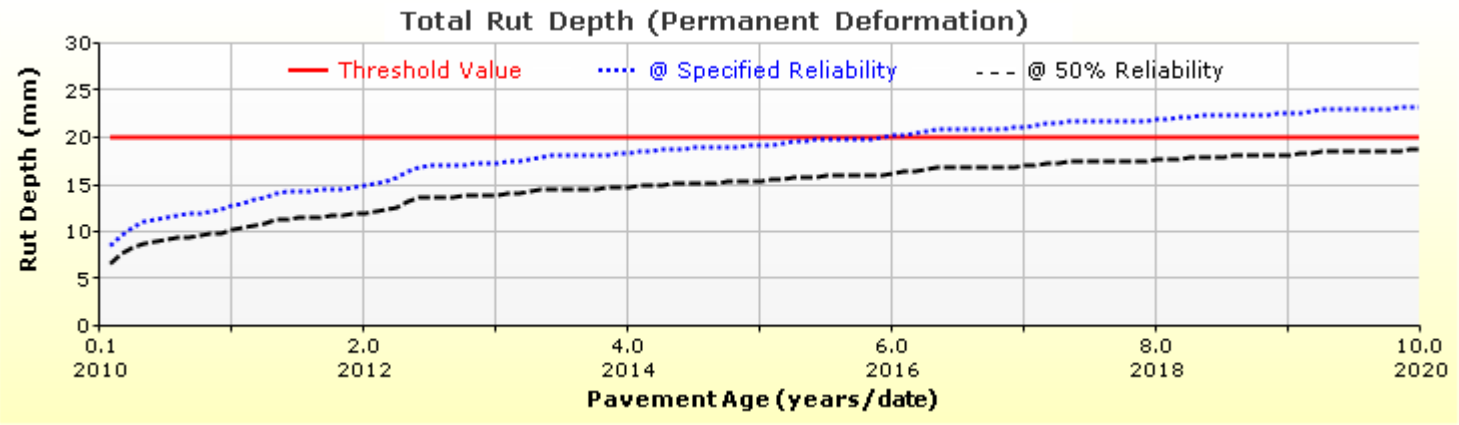


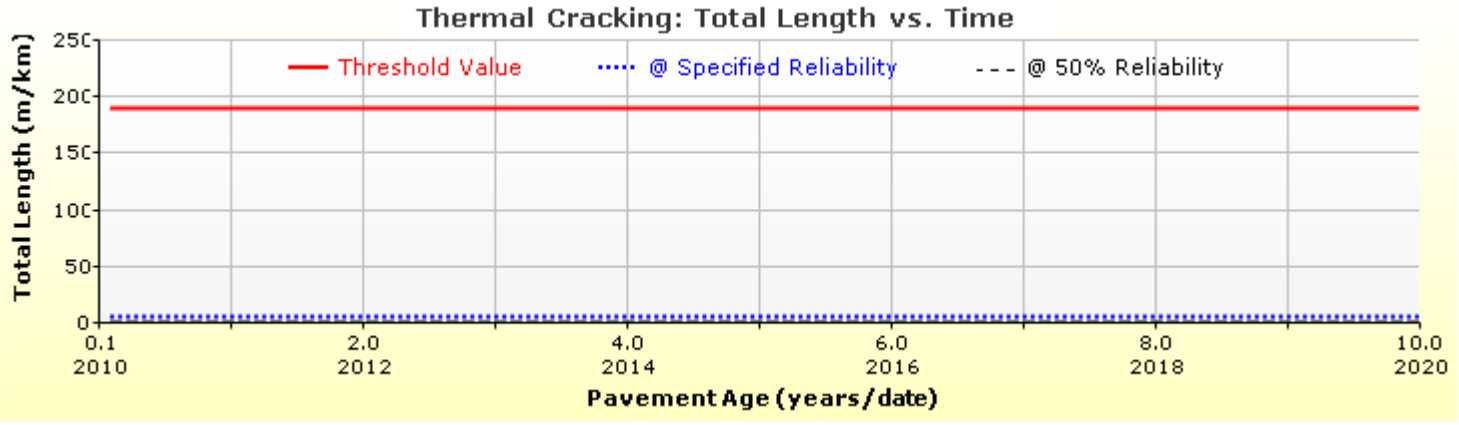


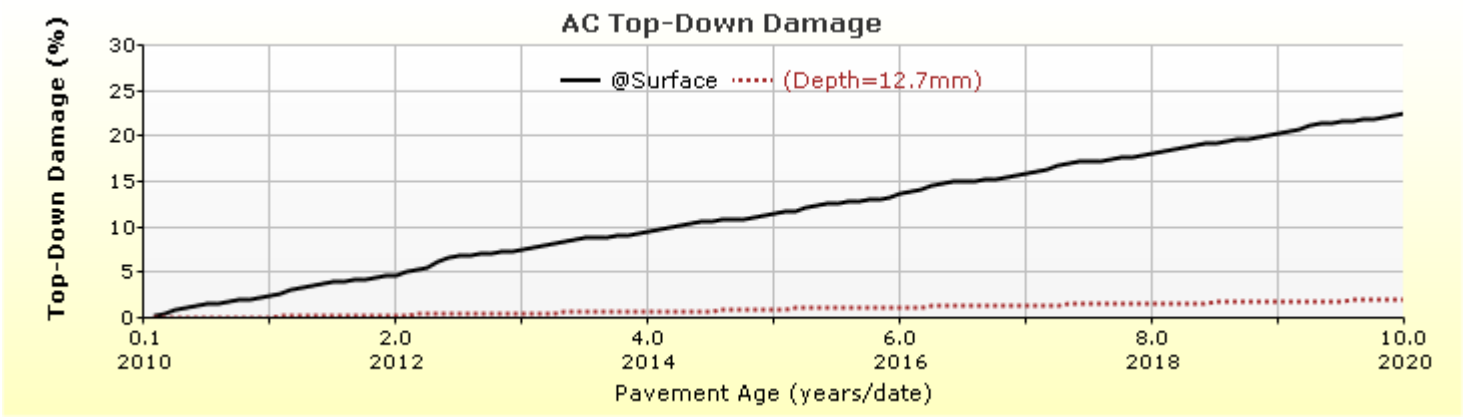


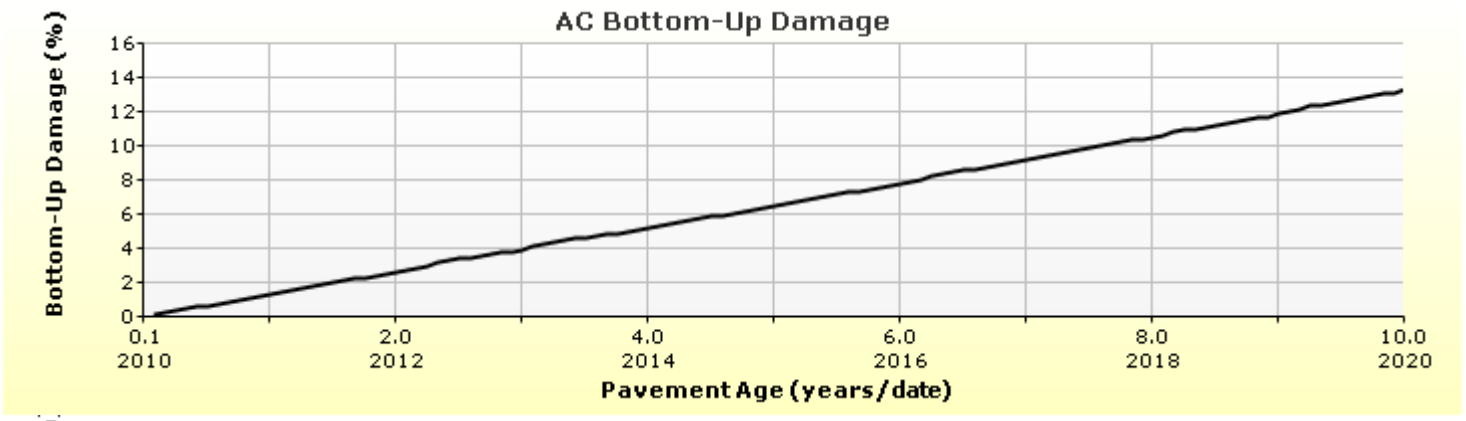
Analysis Output Charts

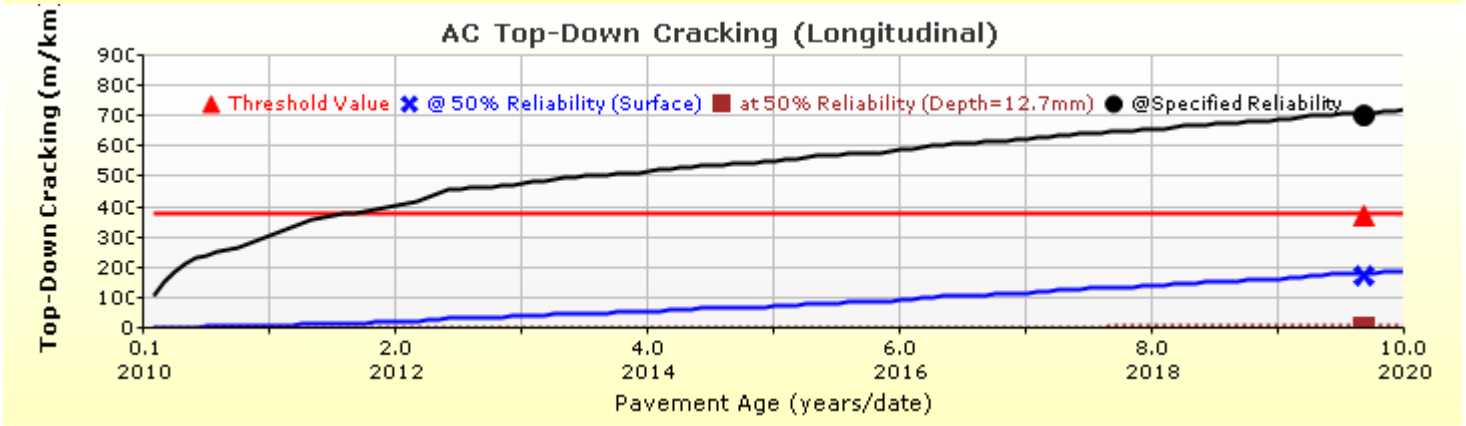


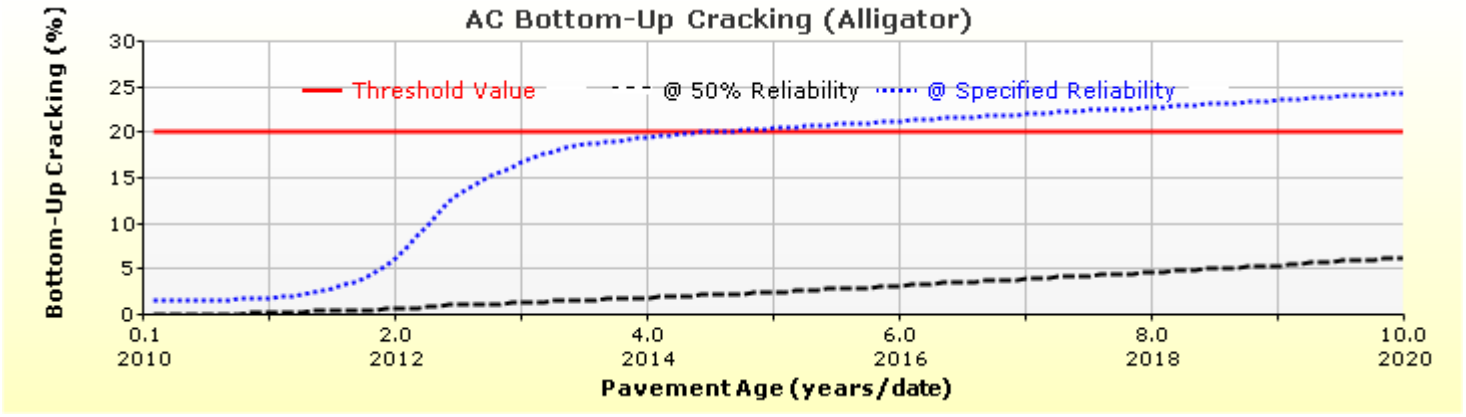


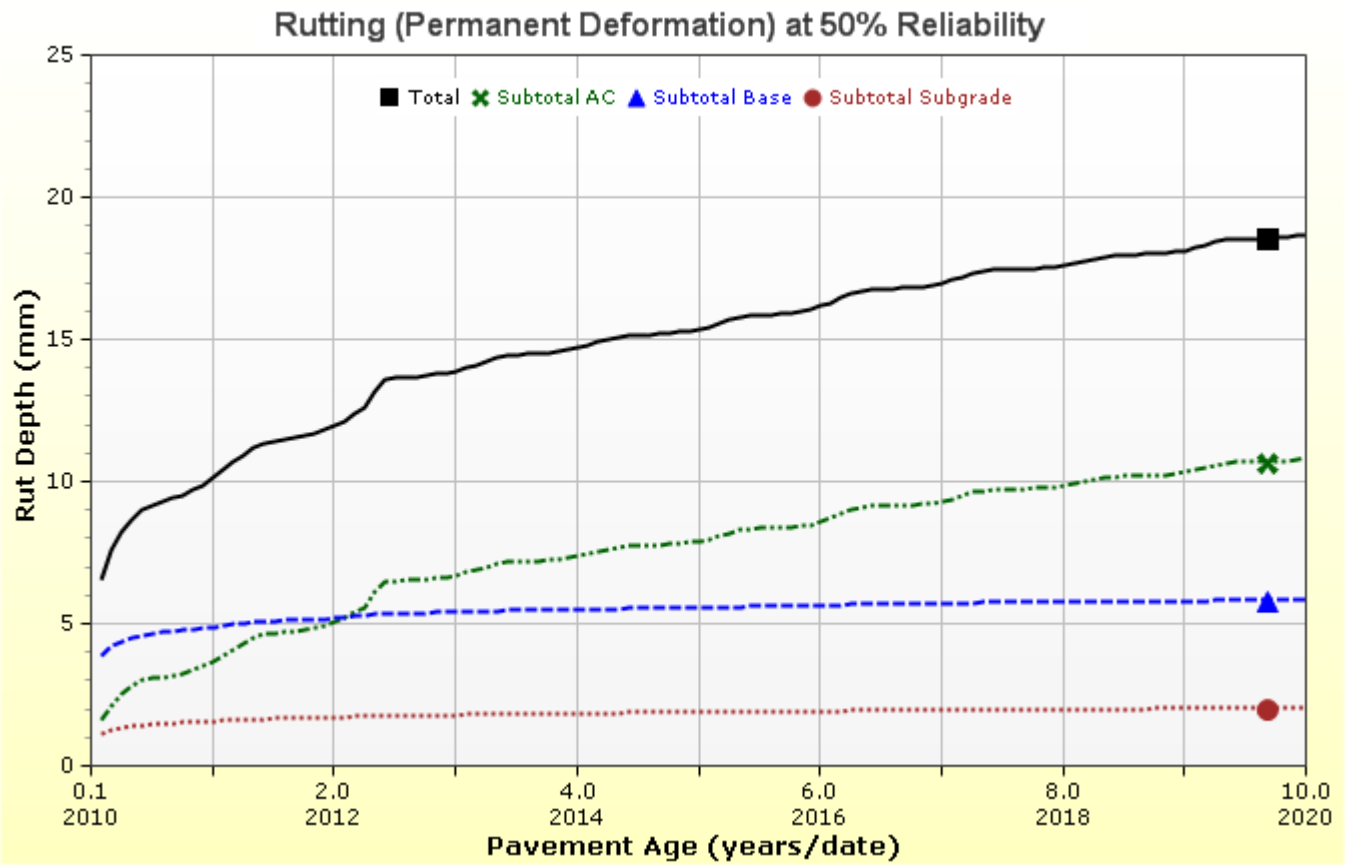


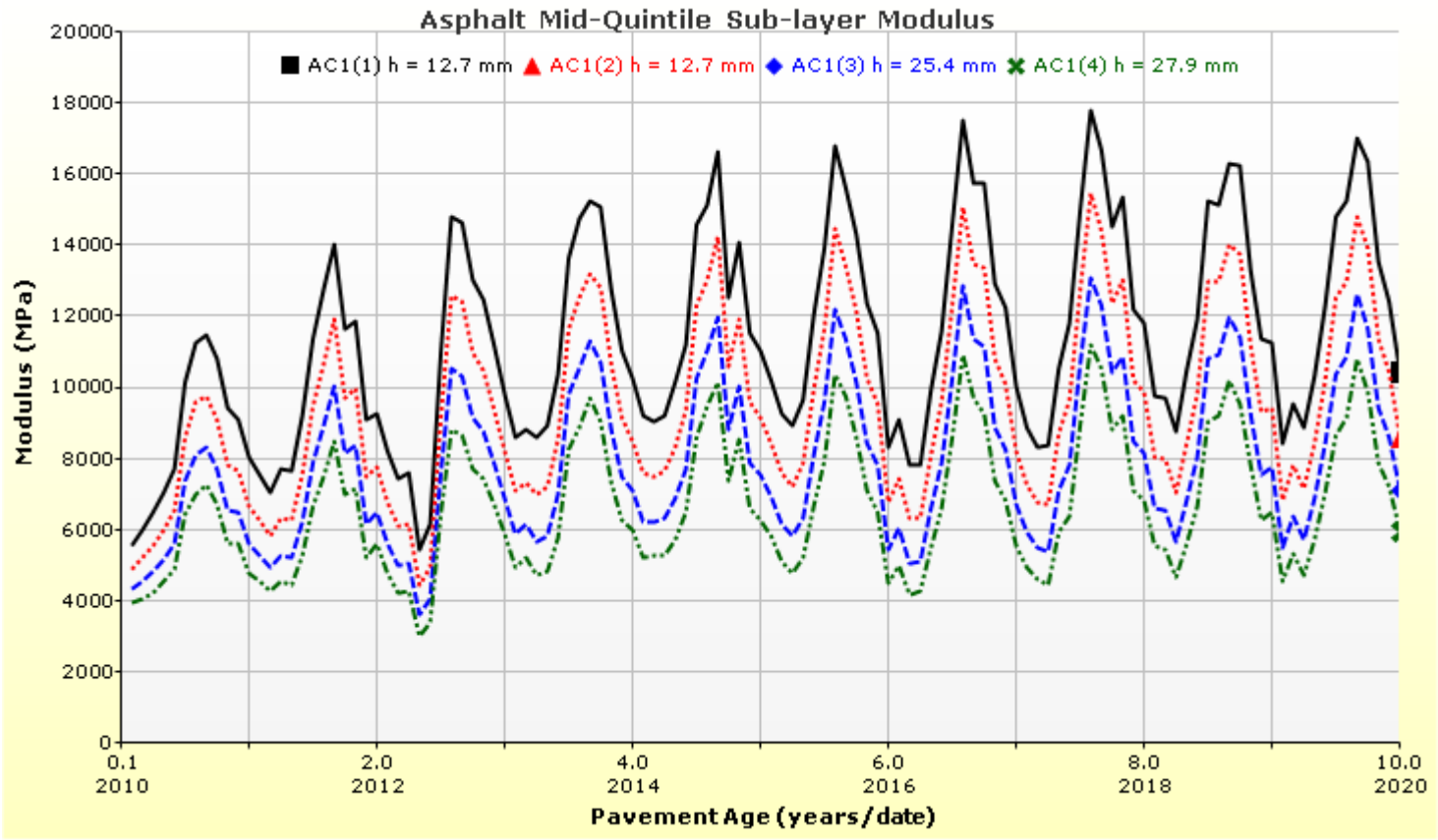

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

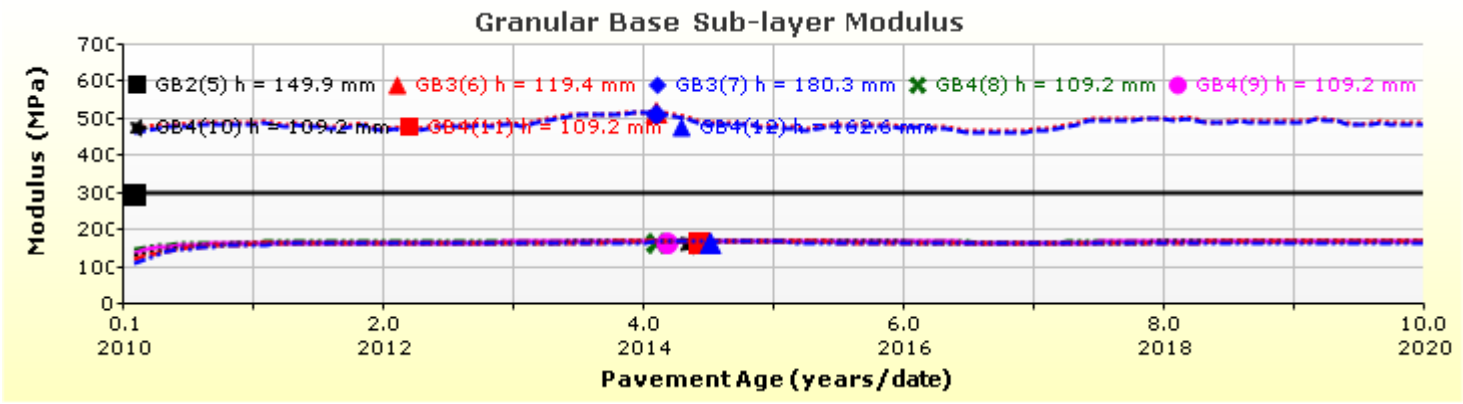

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

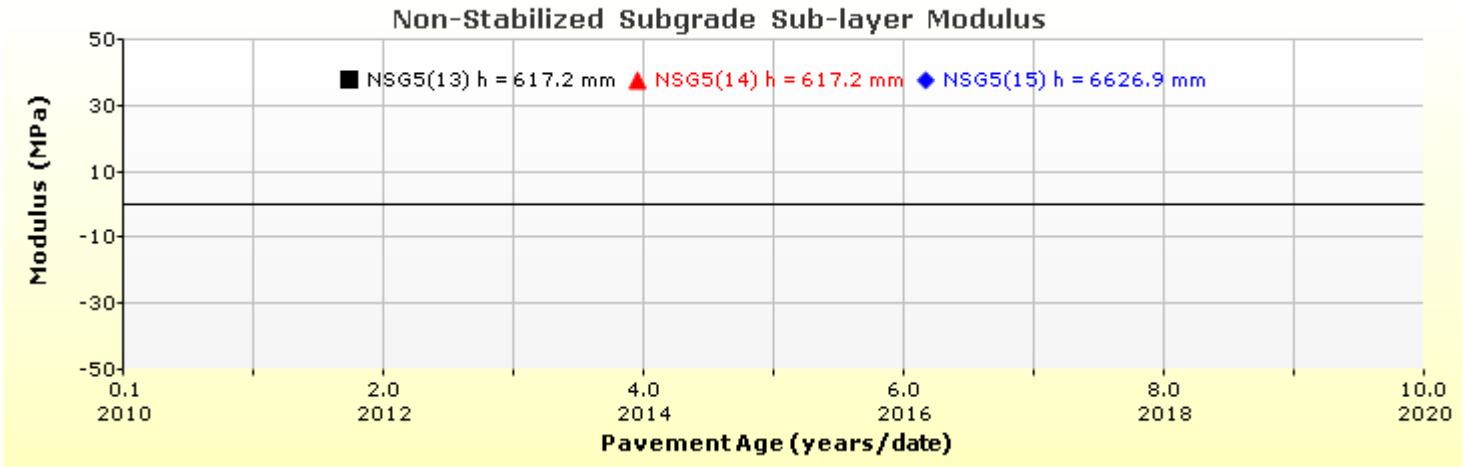

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
10
20
30
40
50
60
70
80
90
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 168.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2\beta_{r2}} N^{k_3\beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestSP

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestSP.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -23.5, -46.62

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

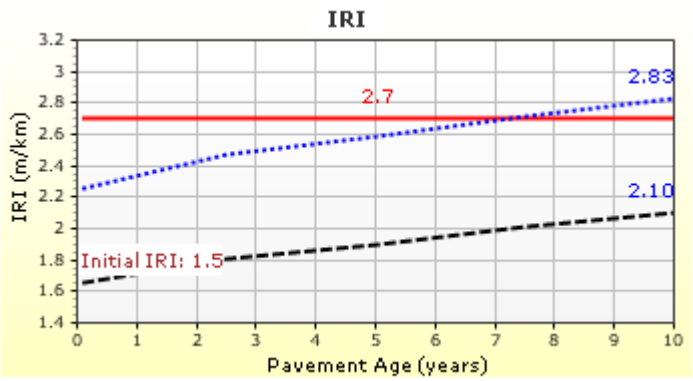
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

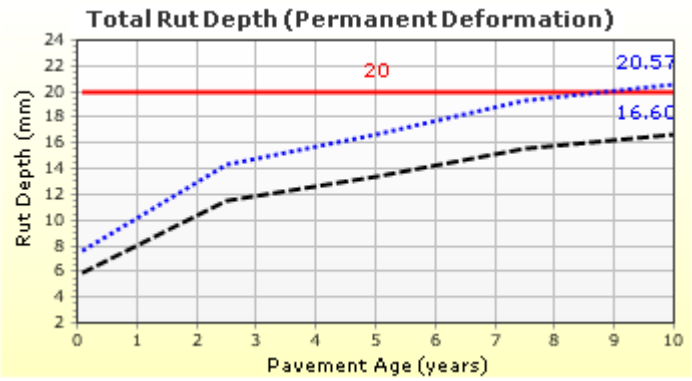
Design Outputs

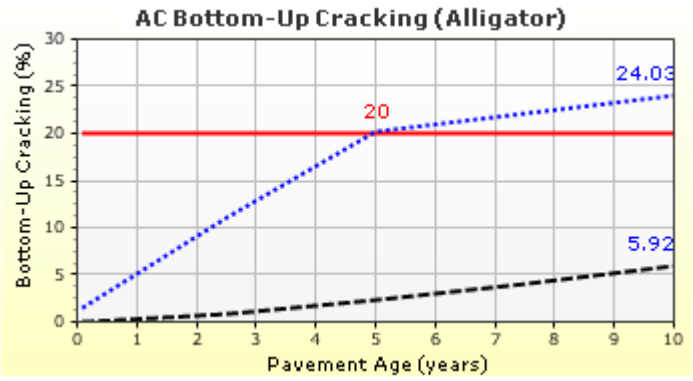
Distress Prediction Summary

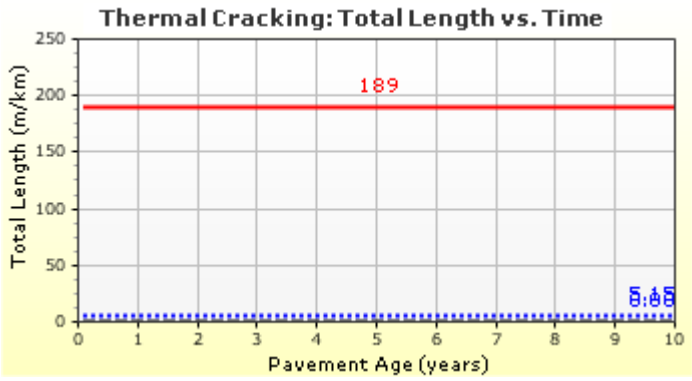
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.83	90.00	85.37	Fail
Permanent deformation - total pavement (mm)	20.00	20.56	90.00	86.34	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.03	90.00	84.05	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	663.19	90.00	71.81	Fail
Permanent deformation - AC only (mm)	5.00	8.56	50.00	8.34	Fail

Distress Charts







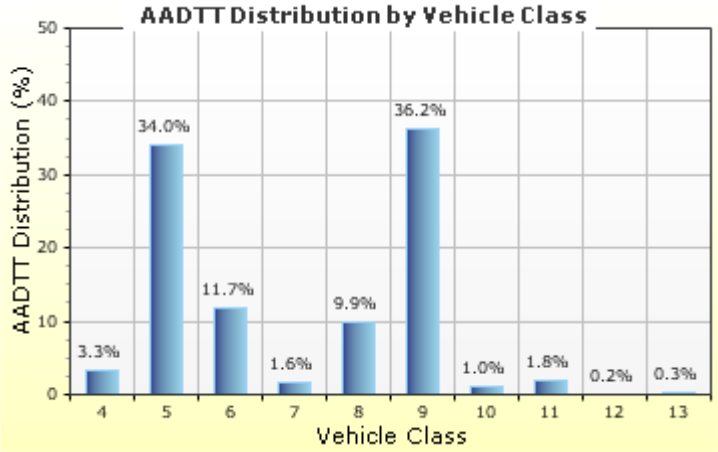


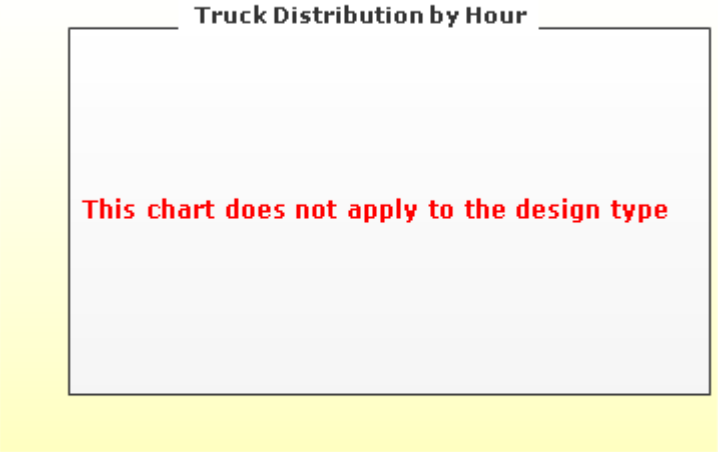


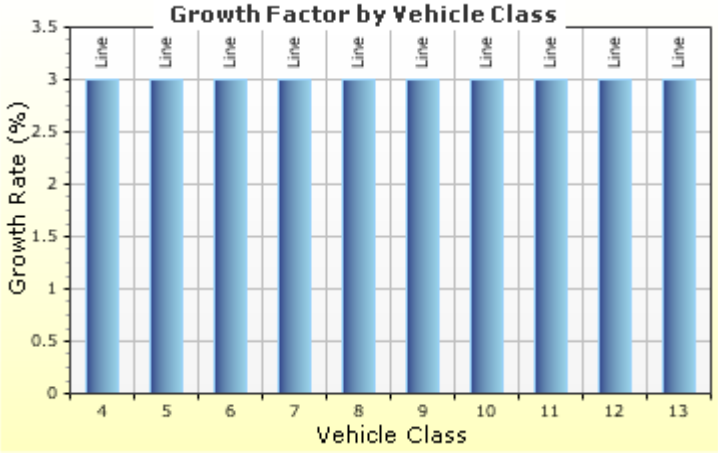
Traffic Inputs

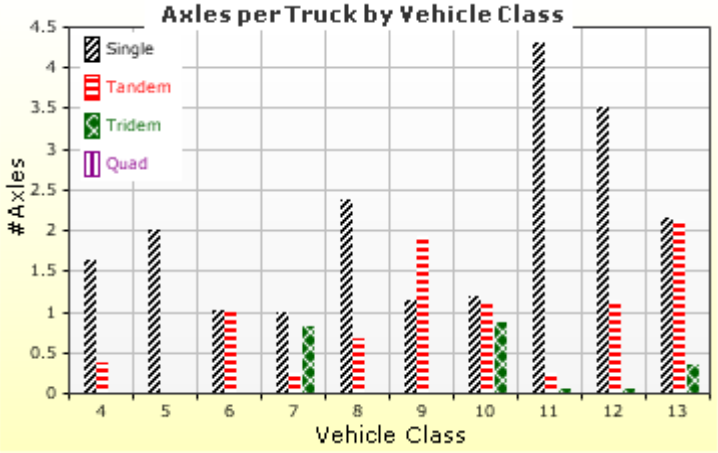
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

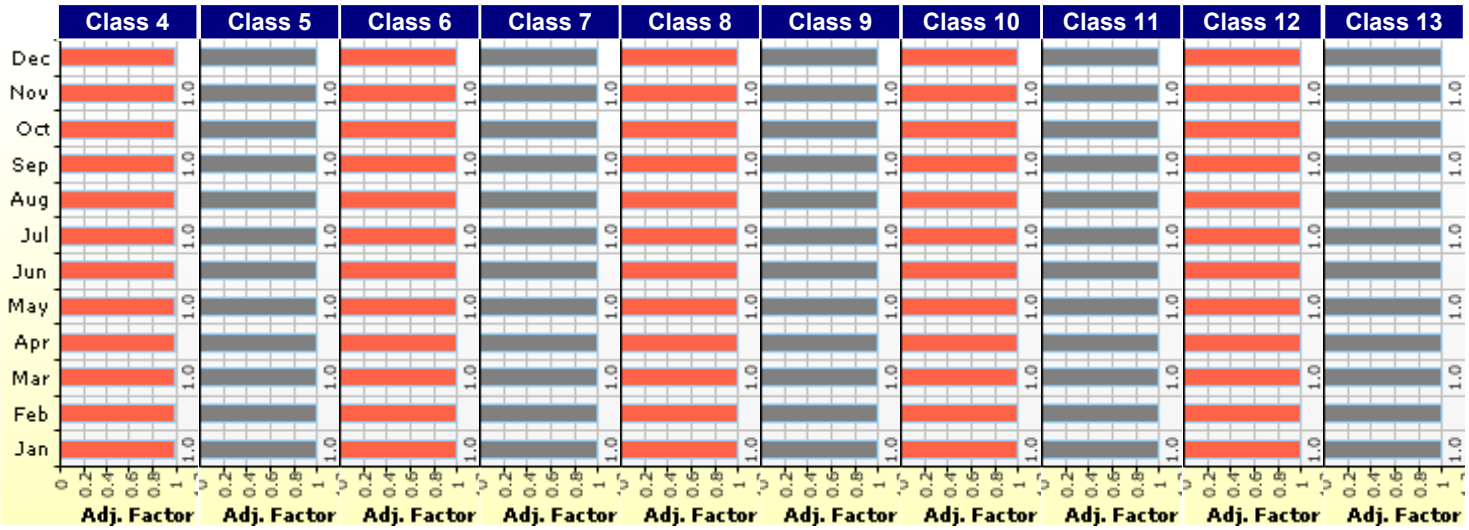








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

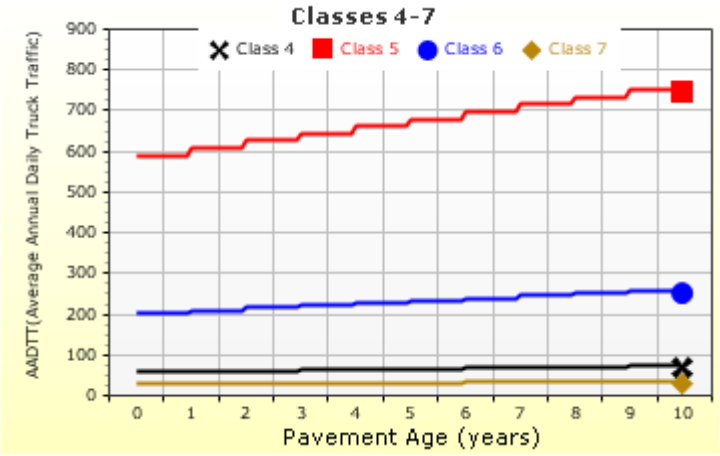
Wheelbase does not apply

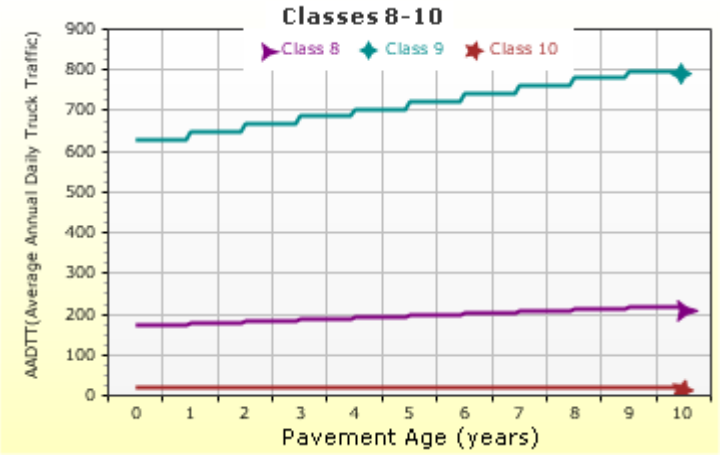
Number of Axles per Truck

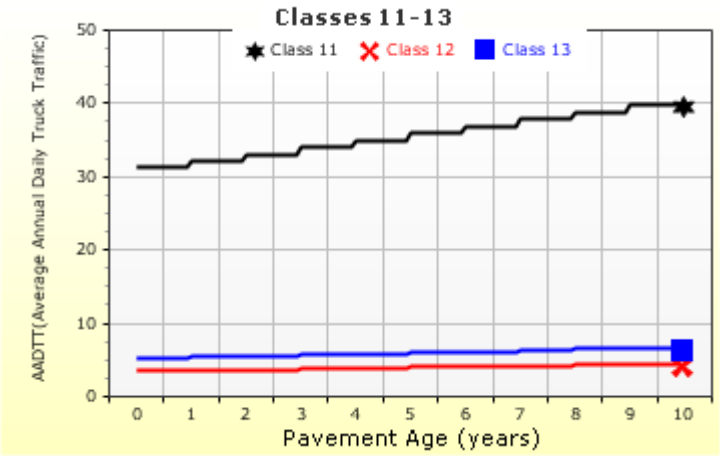
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

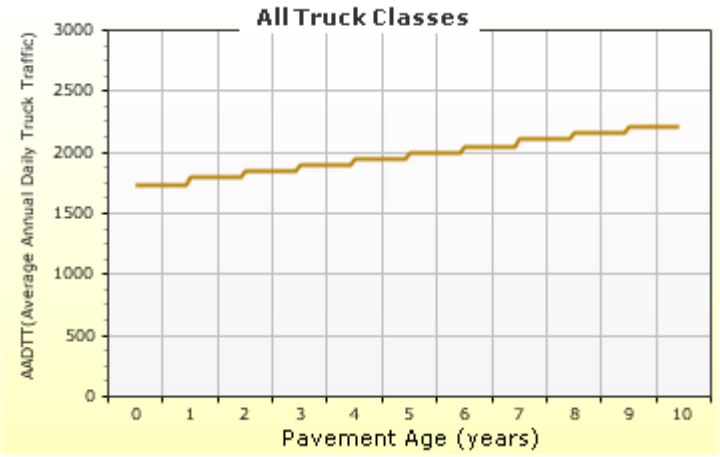
AADTT (Average Annual Daily Truck Traffic) Growth

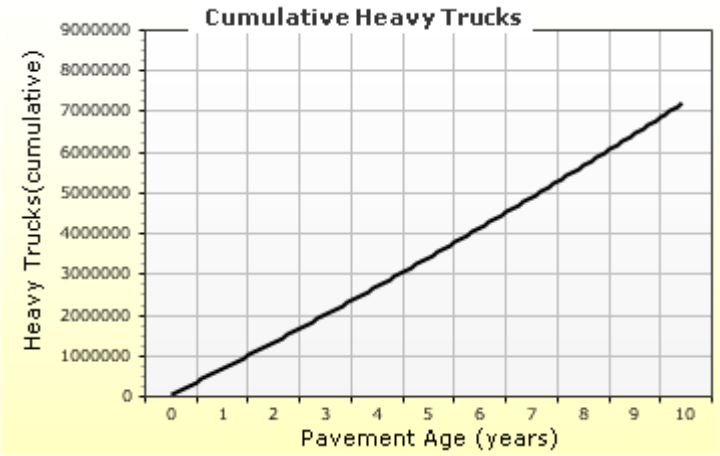
*** Traffic cap is not enforced**







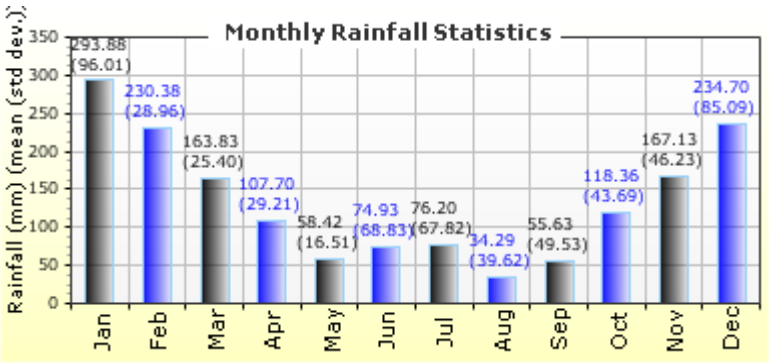




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
SAO PAULO, SP	-23.50000 -46.62000 792

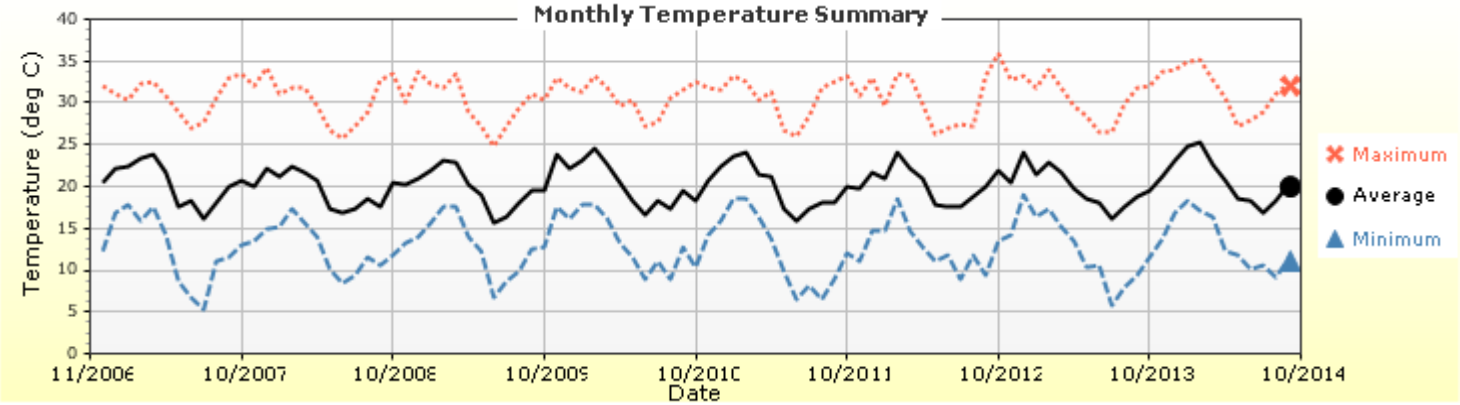


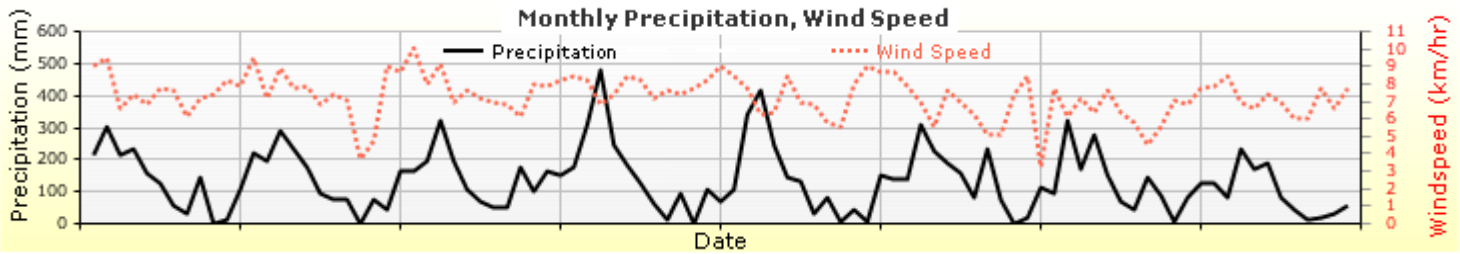
Annual Statistics:

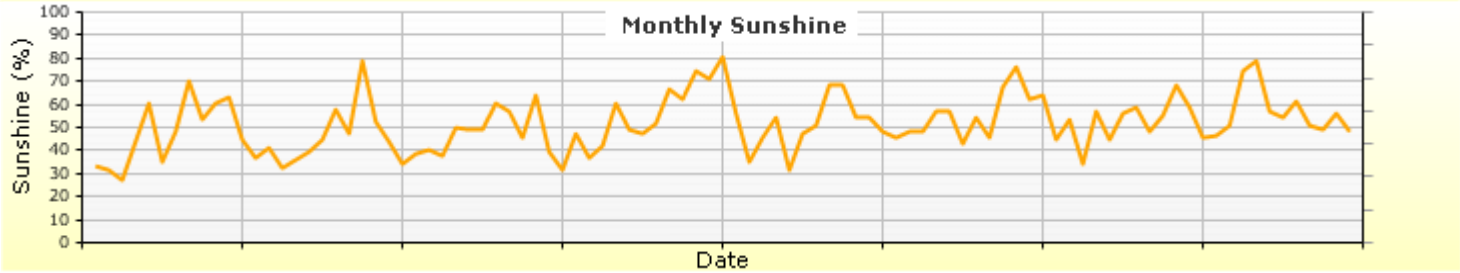
Mean annual air temperature (ºC)	20.15
Mean annual precipitation (mm)	1628.14
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

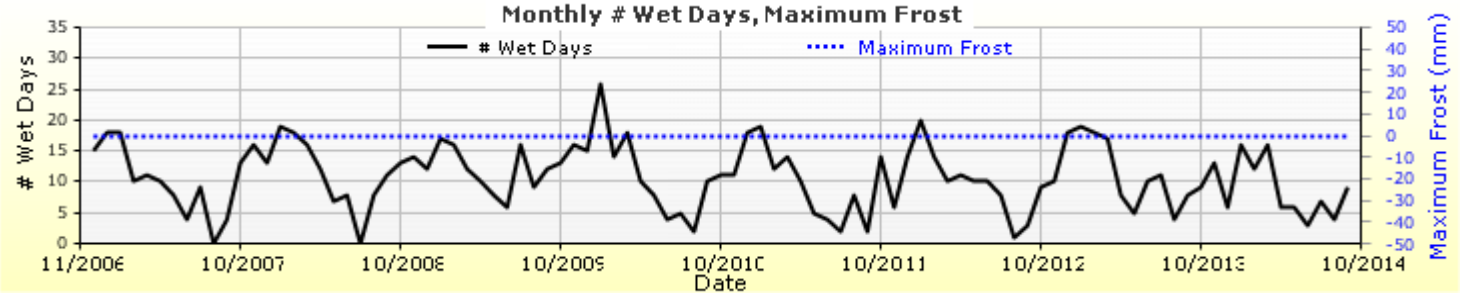
Water table depth (m): 3.05

Monthly Climate Summary:

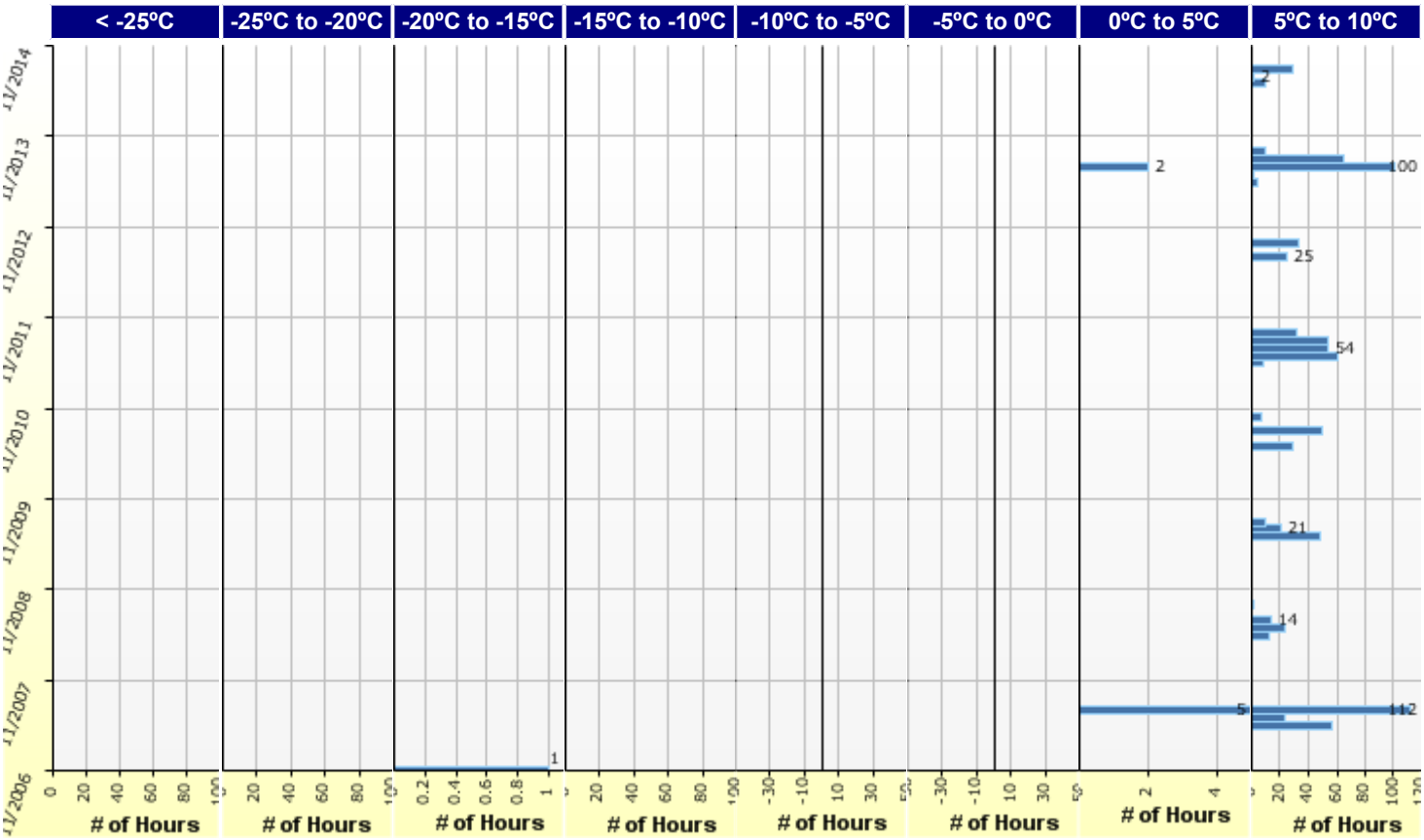


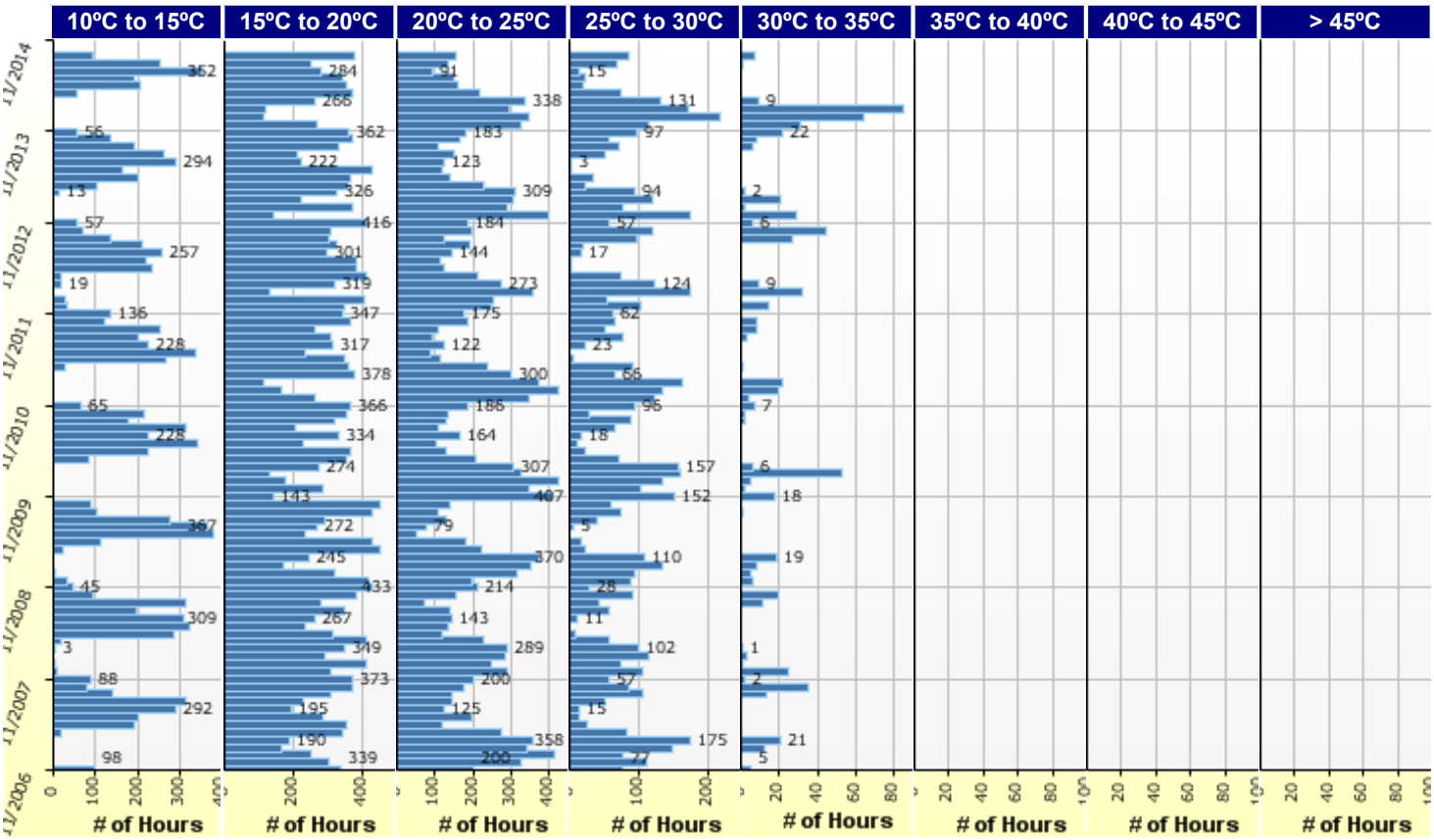






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

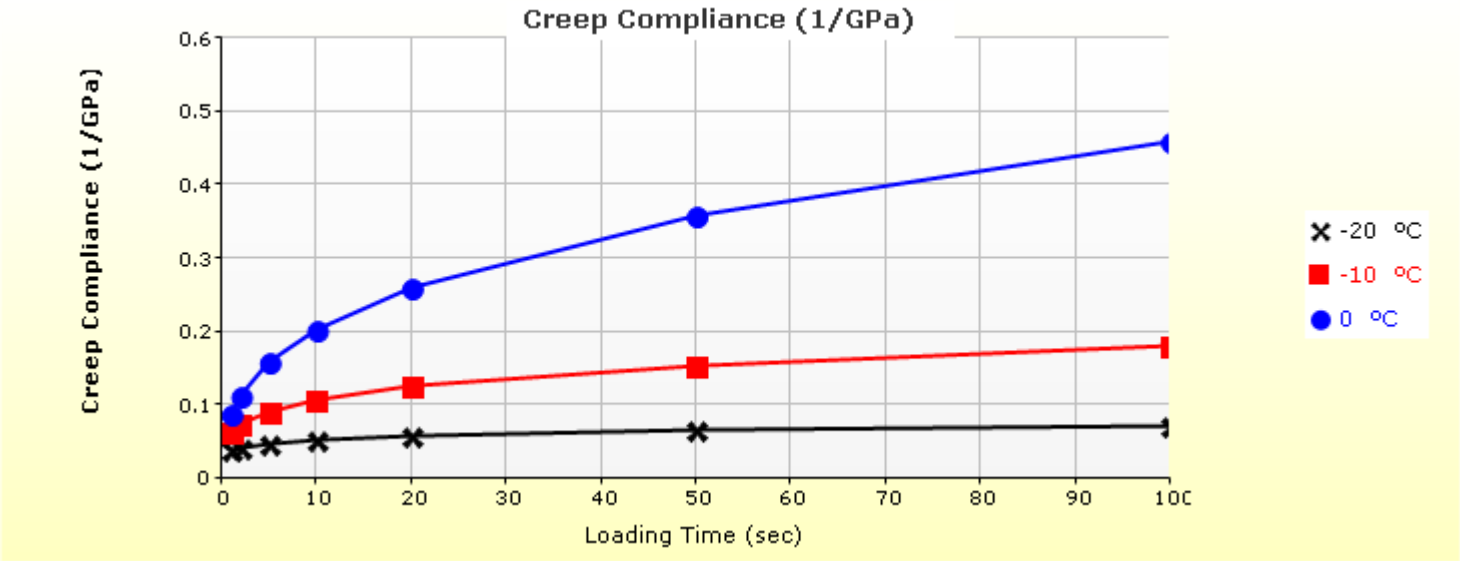
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

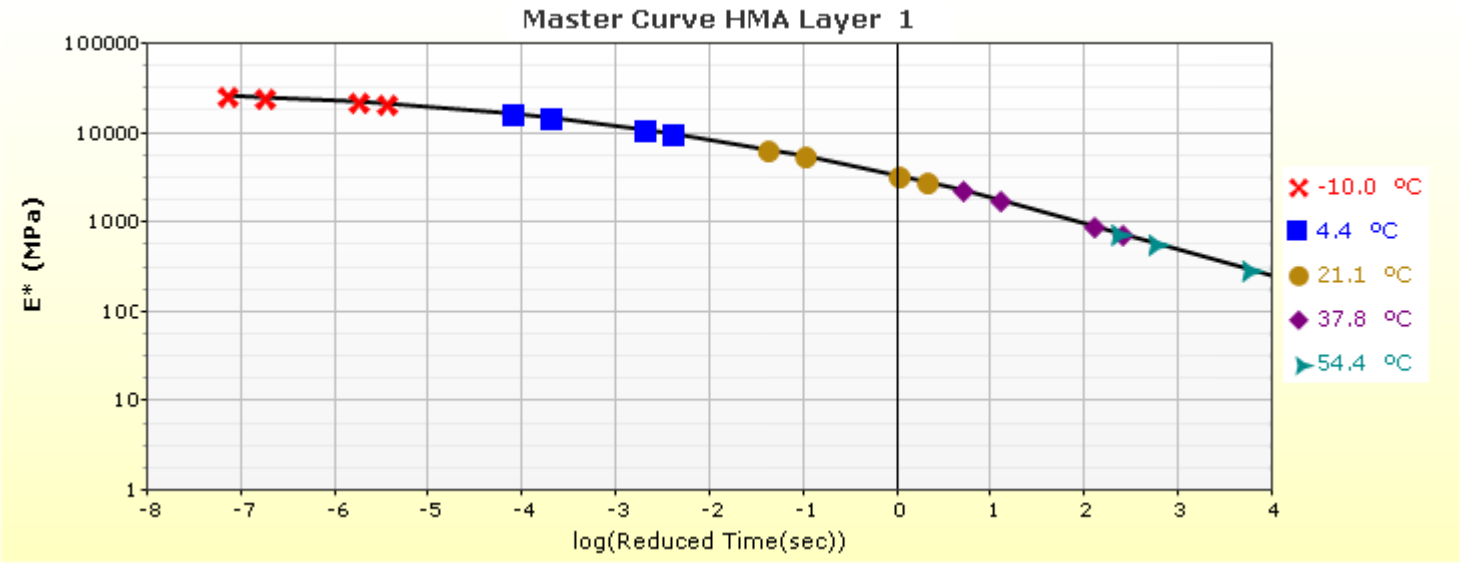
Indirect tensile strength at -10 ºC (MPa)	2.69

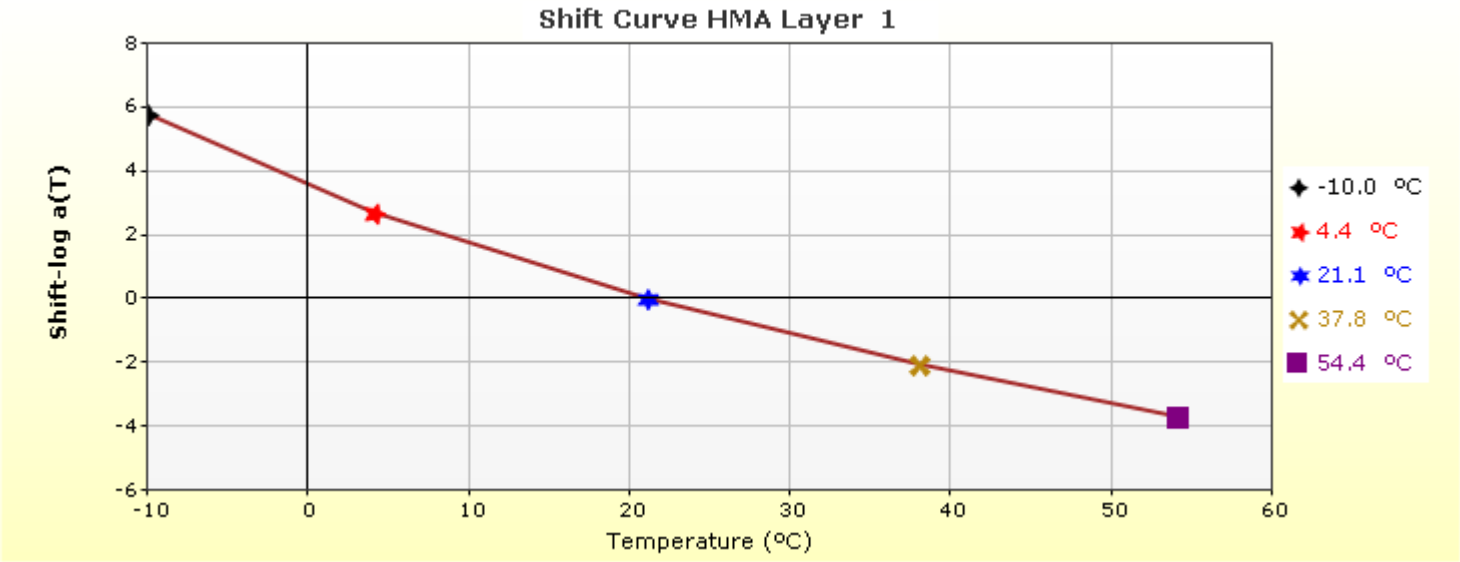
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

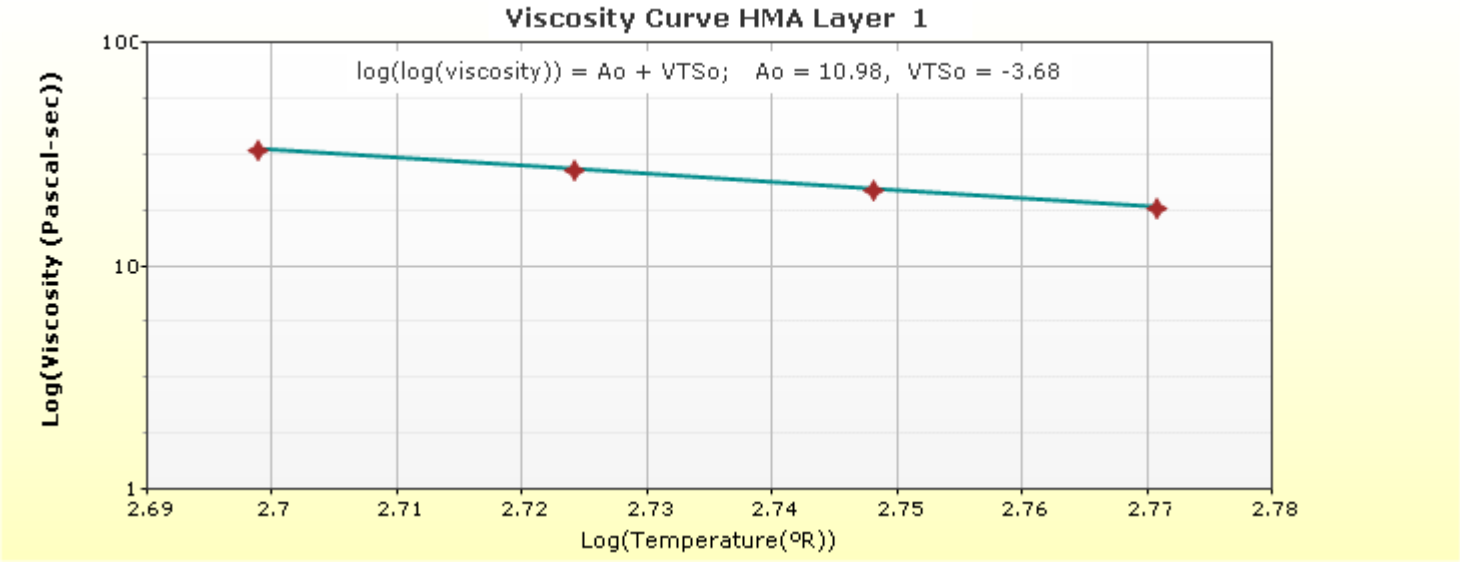
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



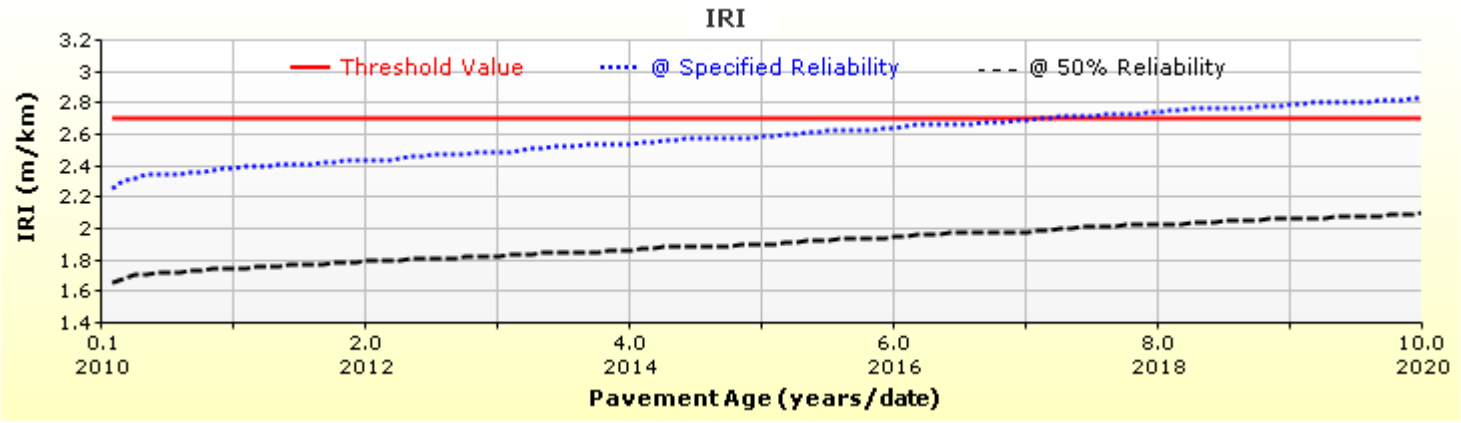
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

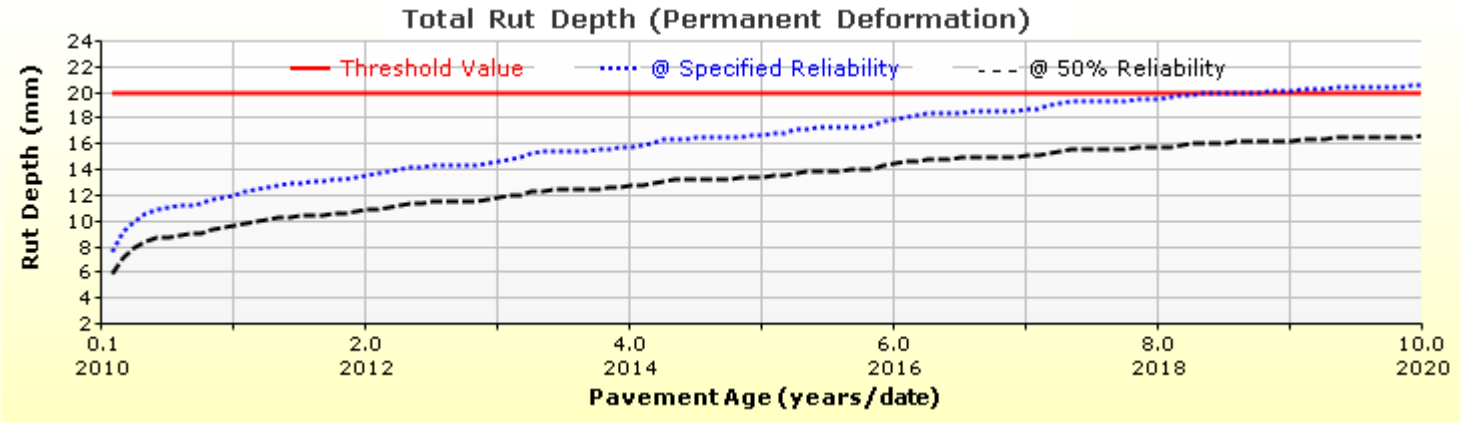


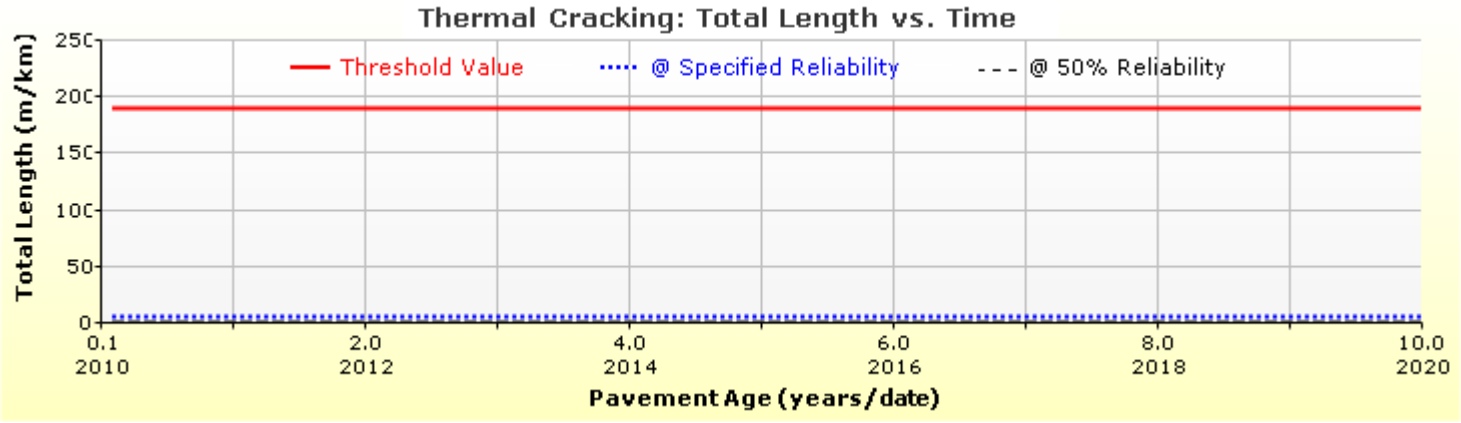


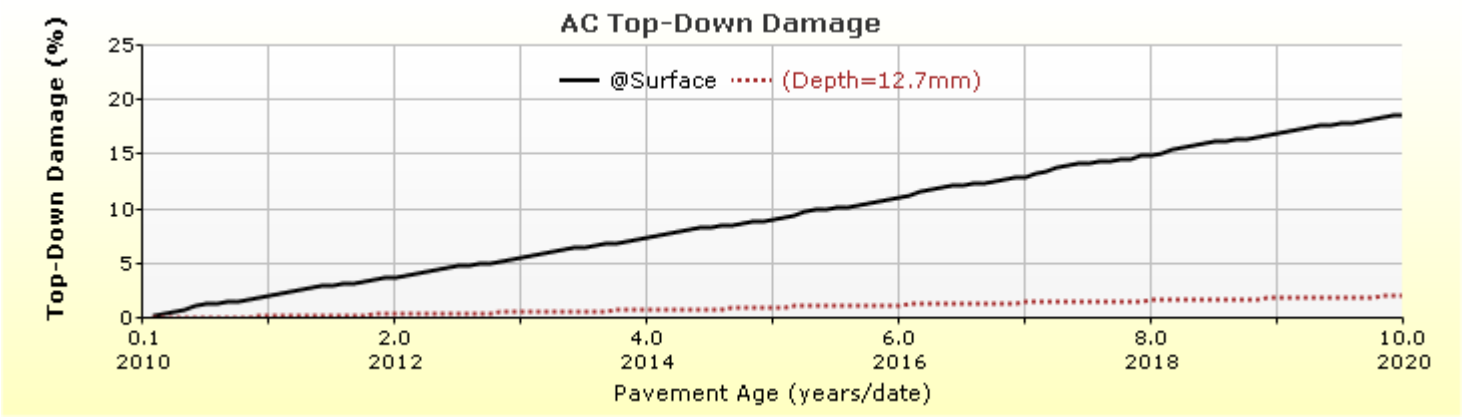


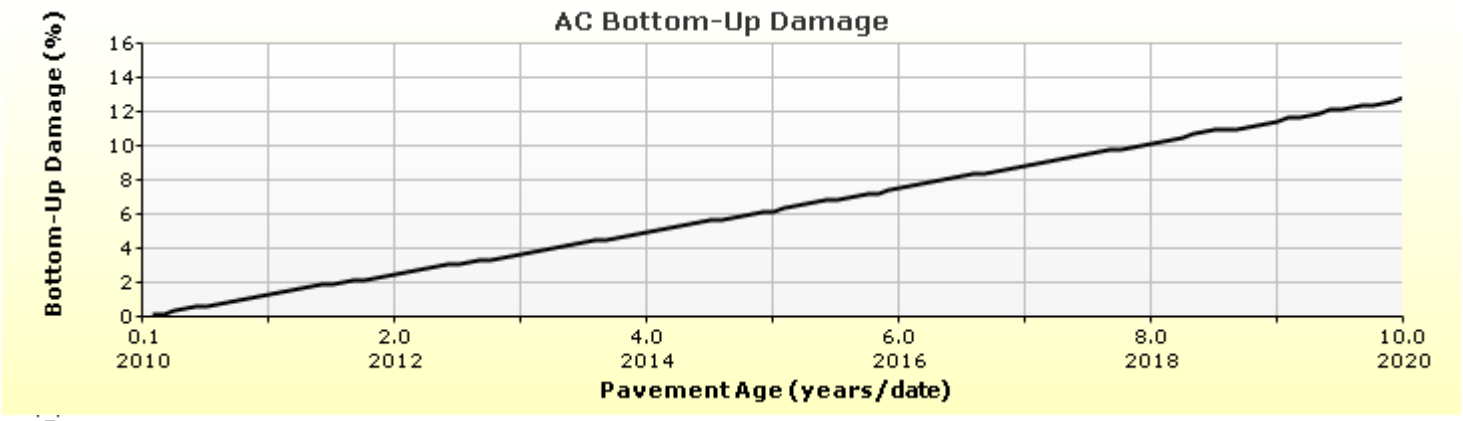
Analysis Output Charts

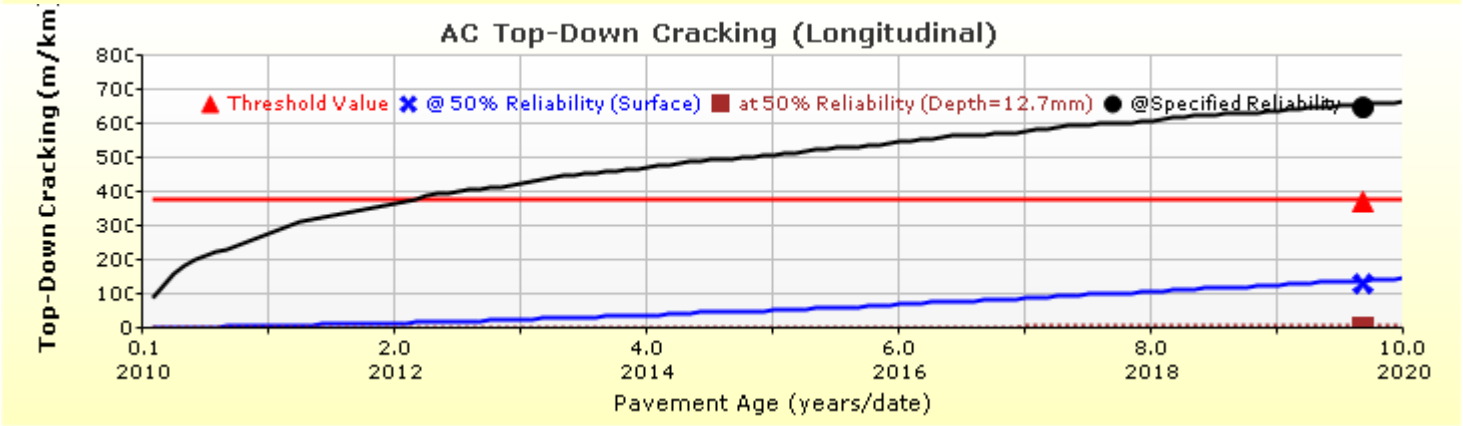


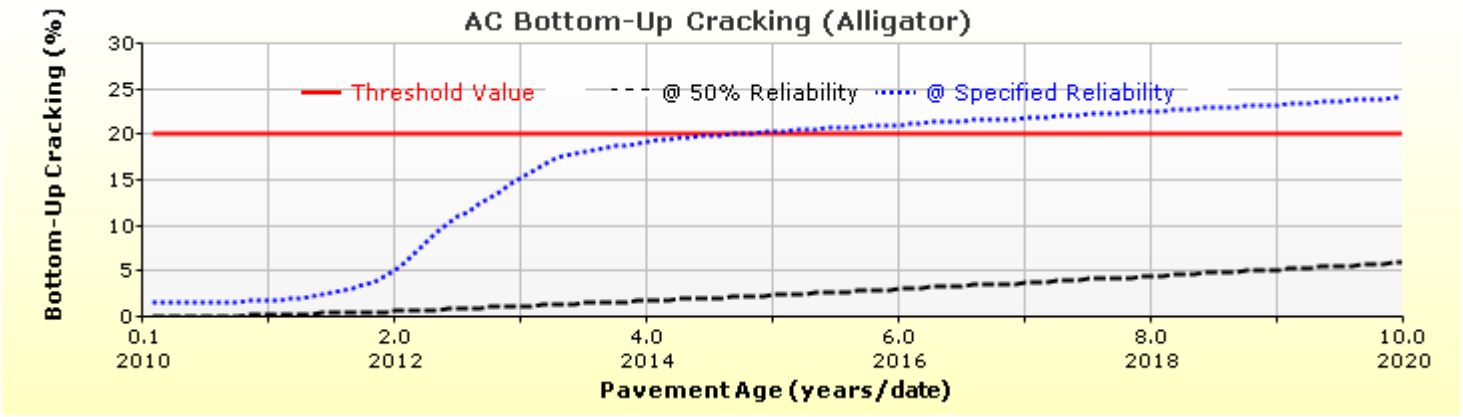


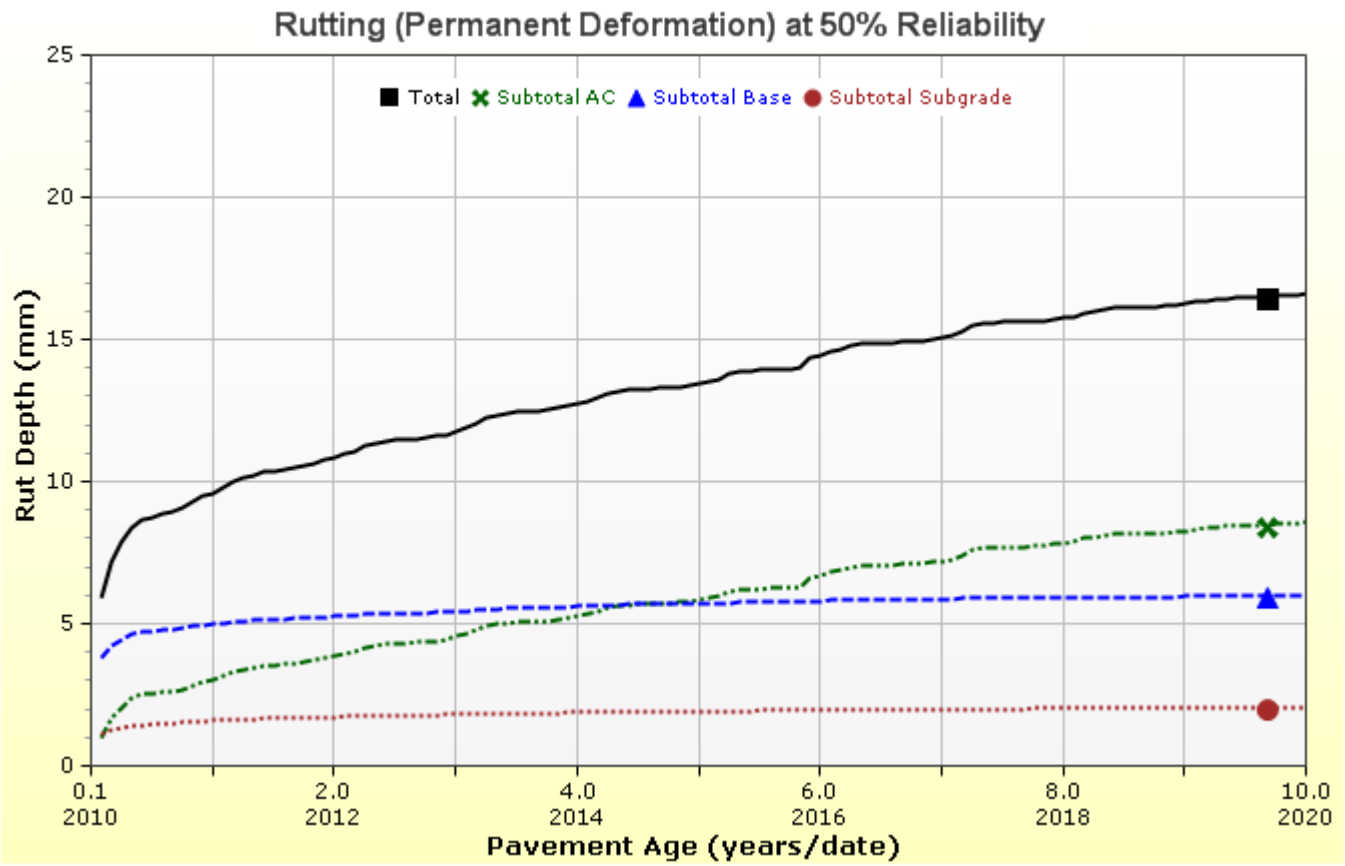


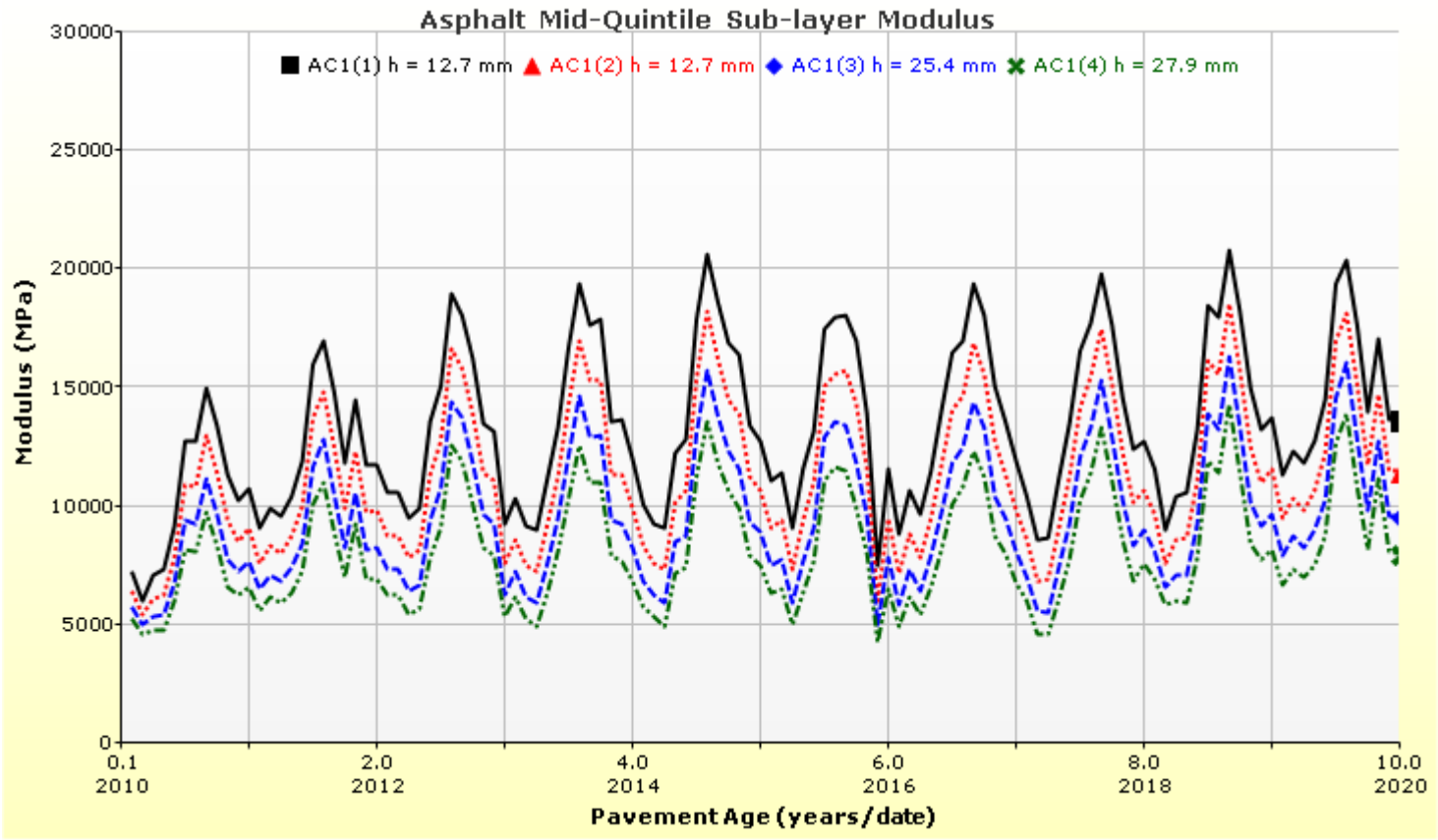

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

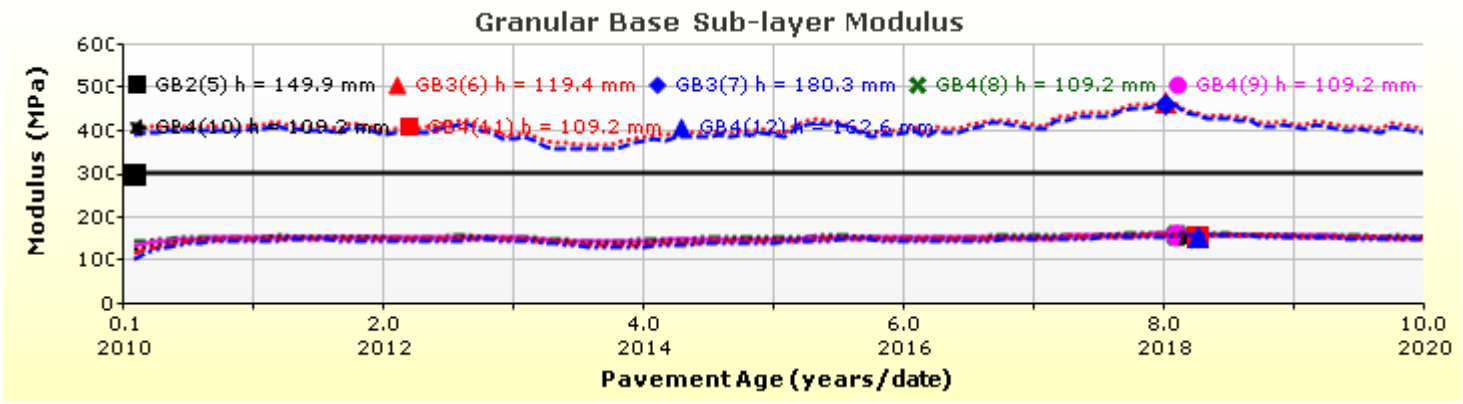

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

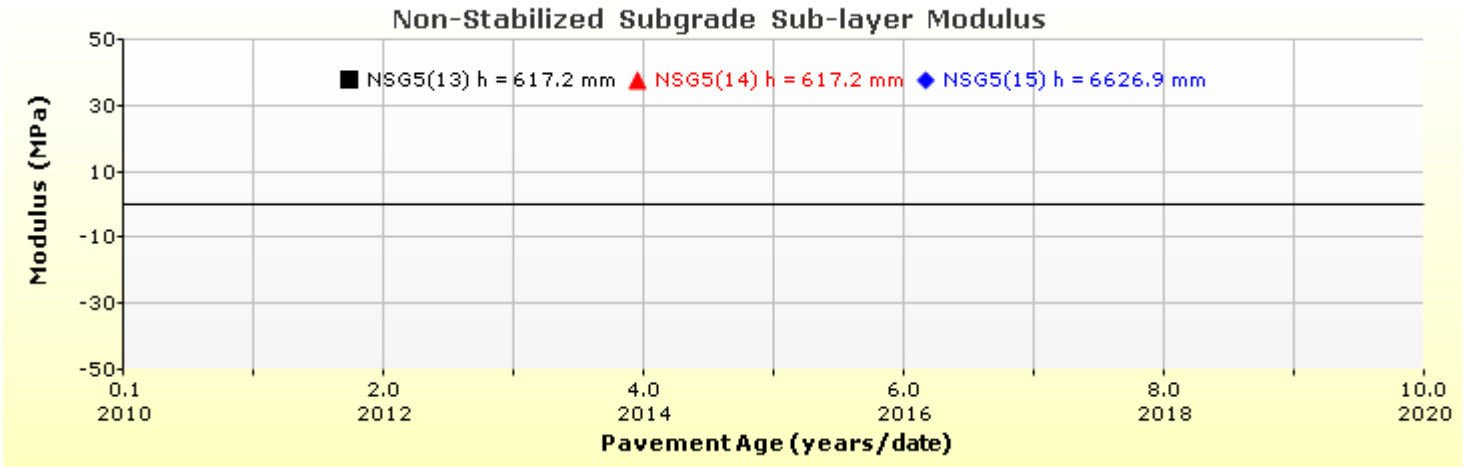

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

$$H_{ac} = total\ AC\ thickness(in)$$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestSP+2

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestSP+2.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -23.5, -46.62

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

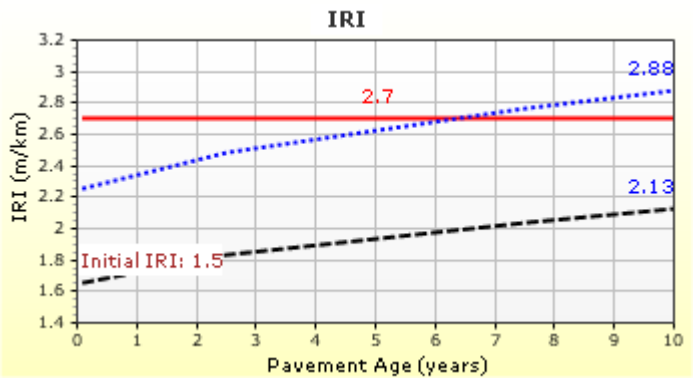
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

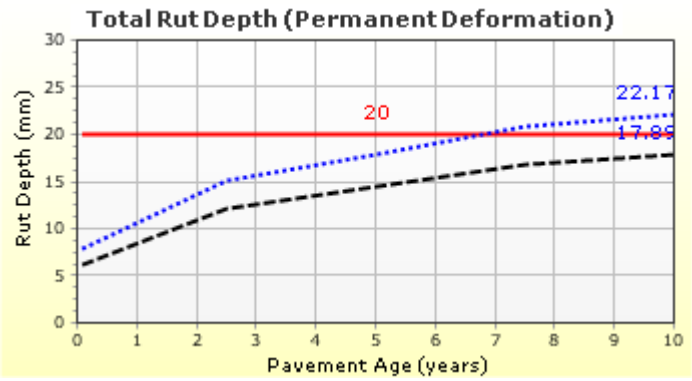
Design Outputs

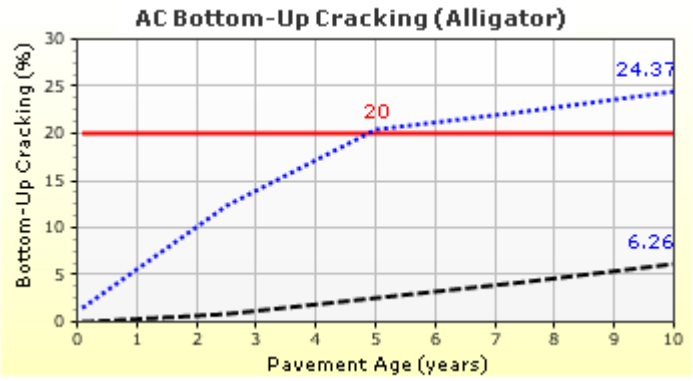
Distress Prediction Summary

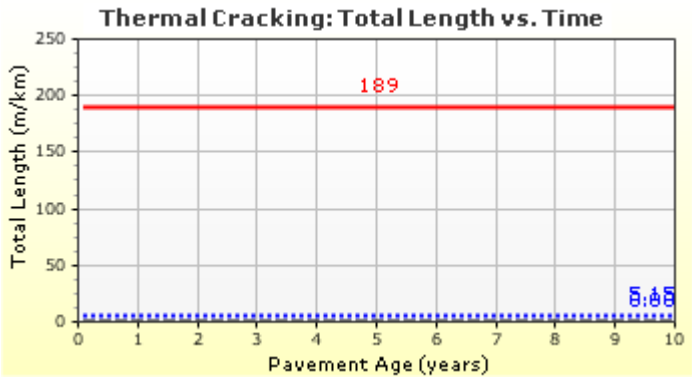
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.88	90.00	83.63	Fail
Permanent deformation - total pavement (mm)	20.00	22.18	90.00	73.48	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.37	90.00	83.46	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	694.57	90.00	69.53	Fail
Permanent deformation - AC only (mm)	5.00	9.86	50.00	4.57	Fail

Distress Charts







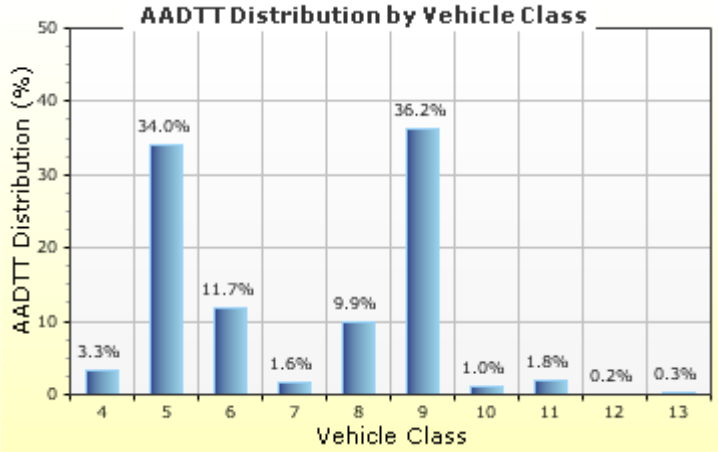


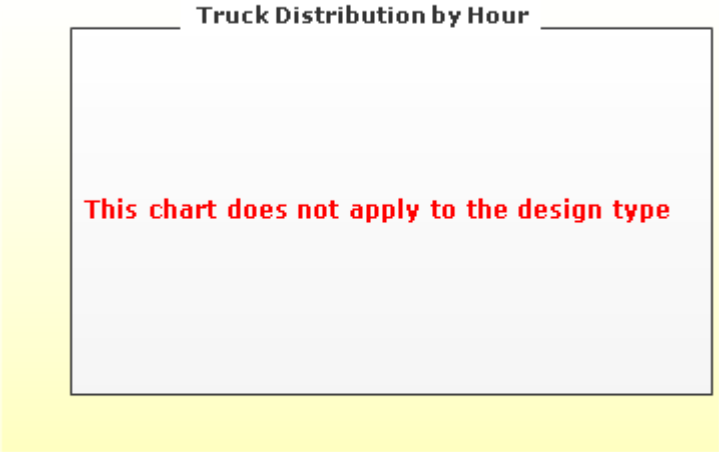


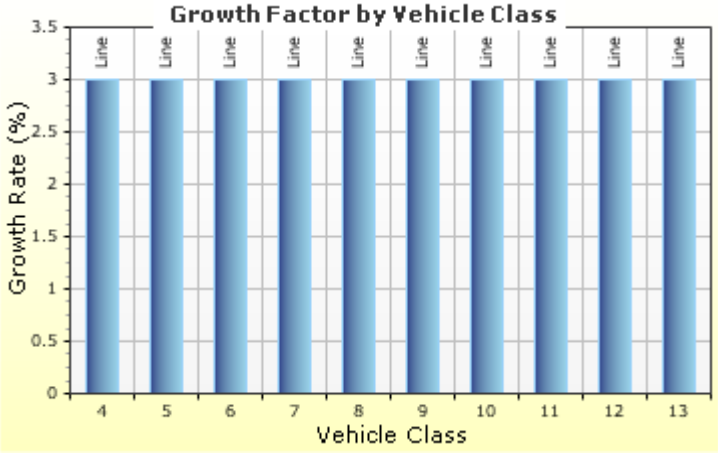
Traffic Inputs

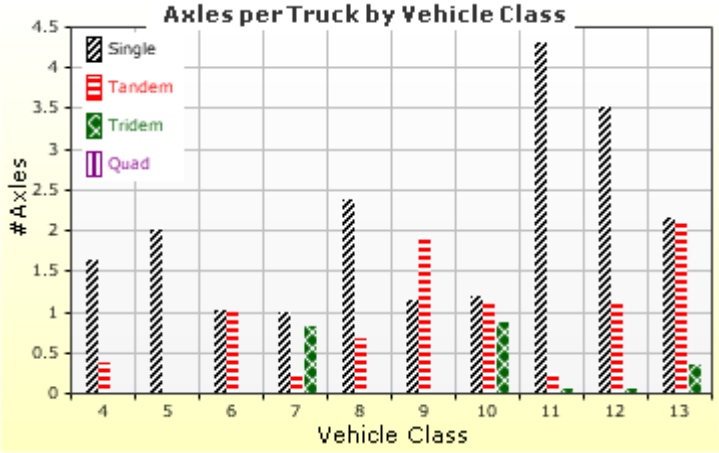
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

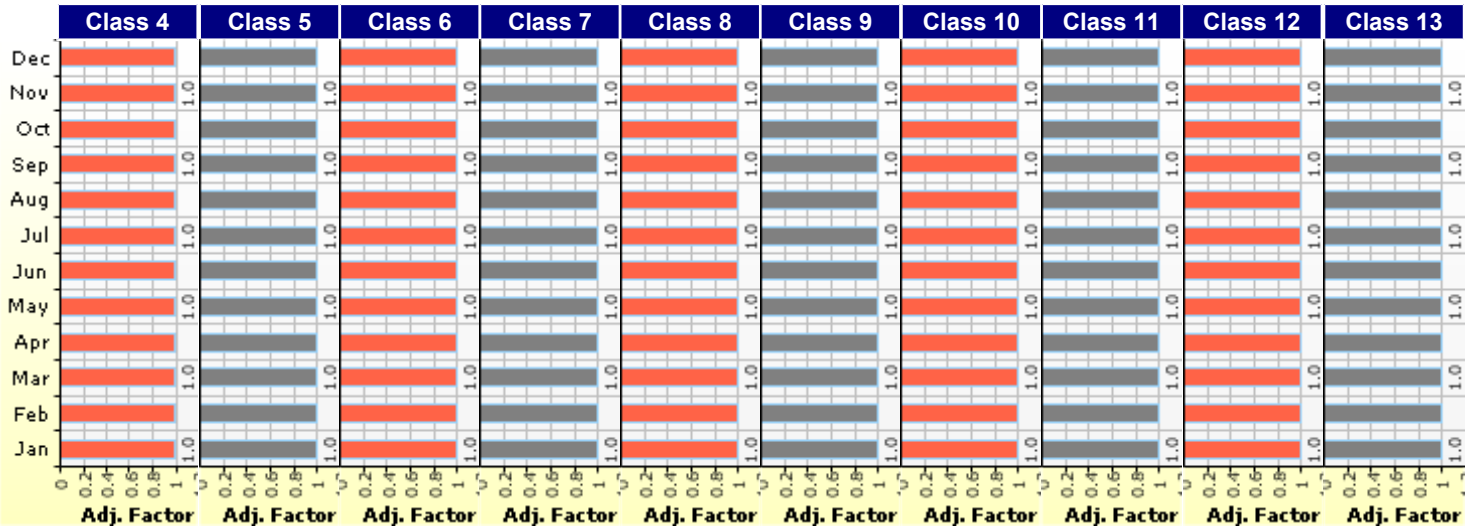








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

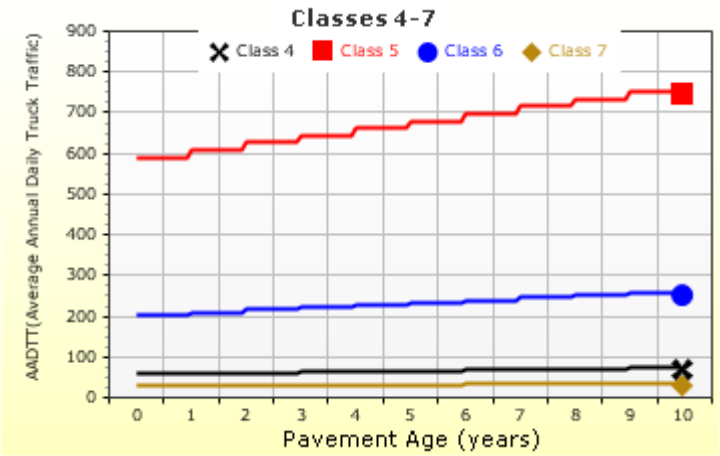
Wheelbase does not apply

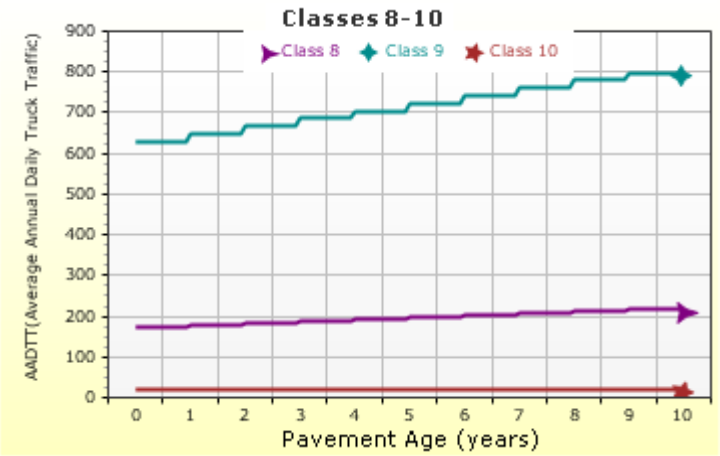
Number of Axles per Truck

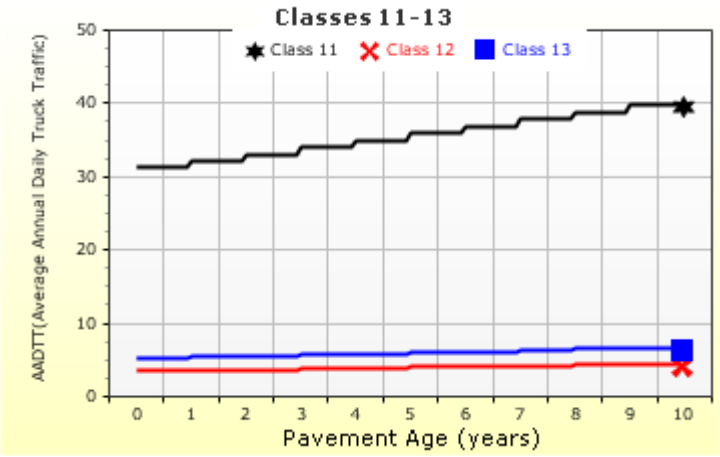
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

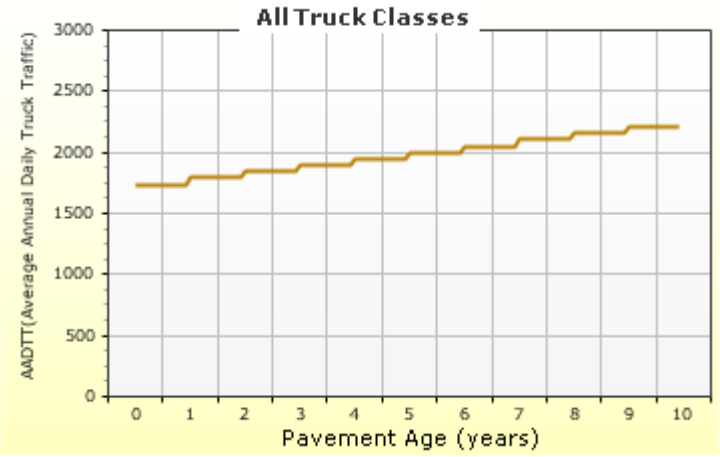
AADTT (Average Annual Daily Truck Traffic) Growth

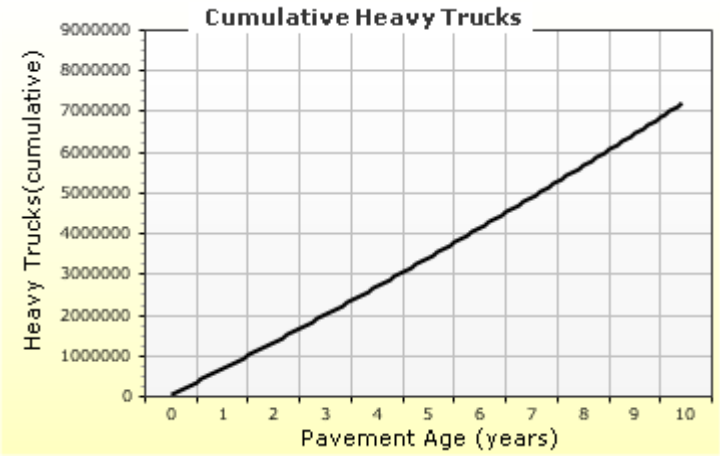
*** Traffic cap is not enforced**







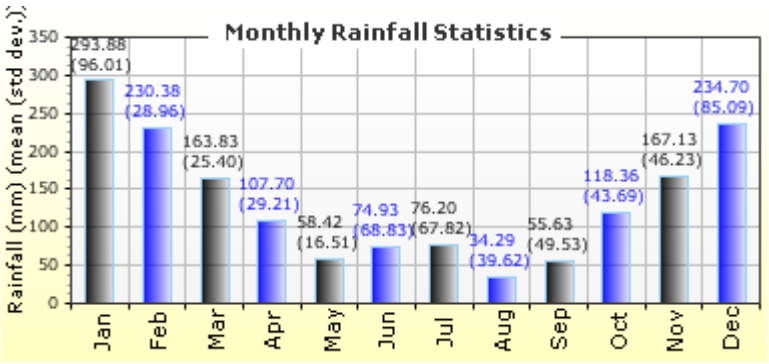




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
SAO PAULO, SP	-23.50000 -46.62000 792

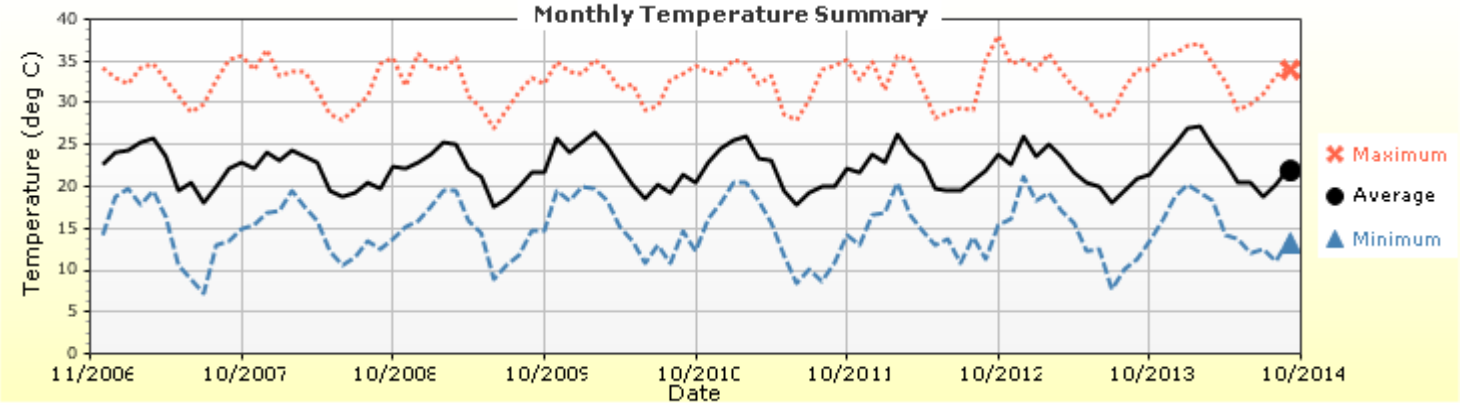


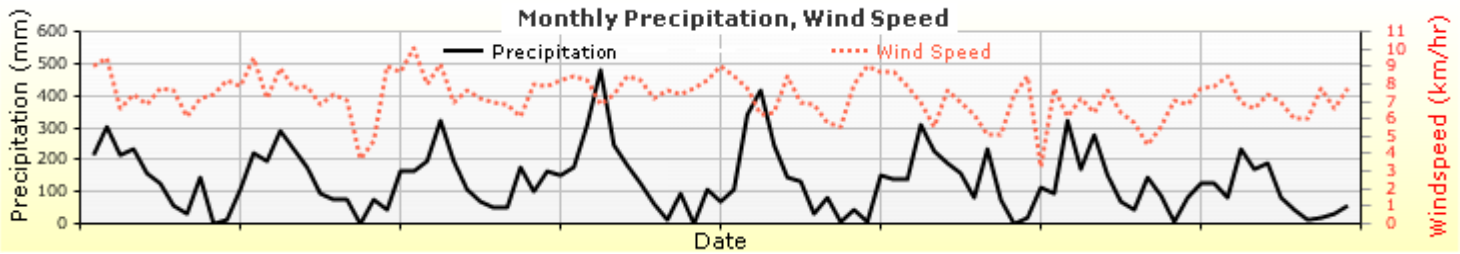
Annual Statistics:

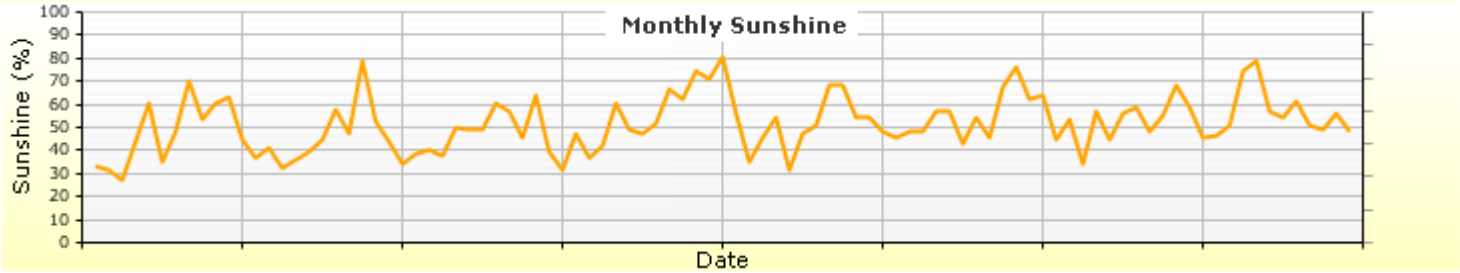
Mean annual air temperature (ºC)	22.15
Mean annual precipitation (mm)	1628.14
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

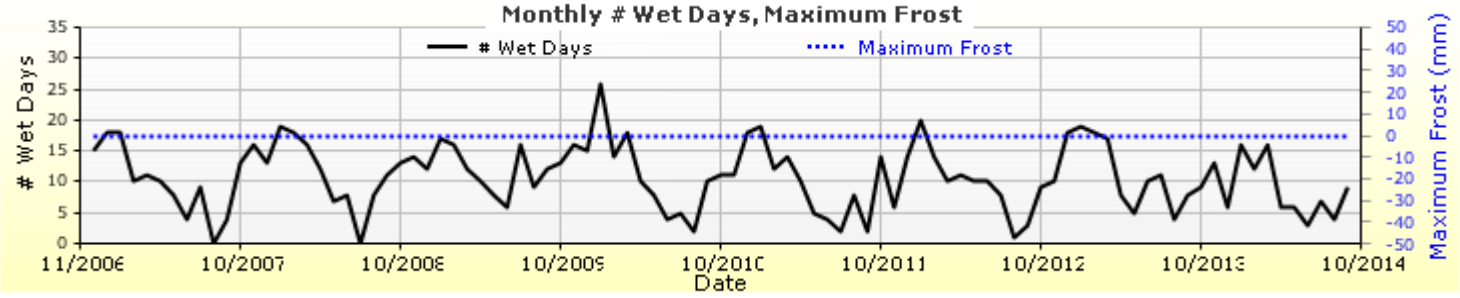
Water table depth (m) 3.05

Monthly Climate Summary:

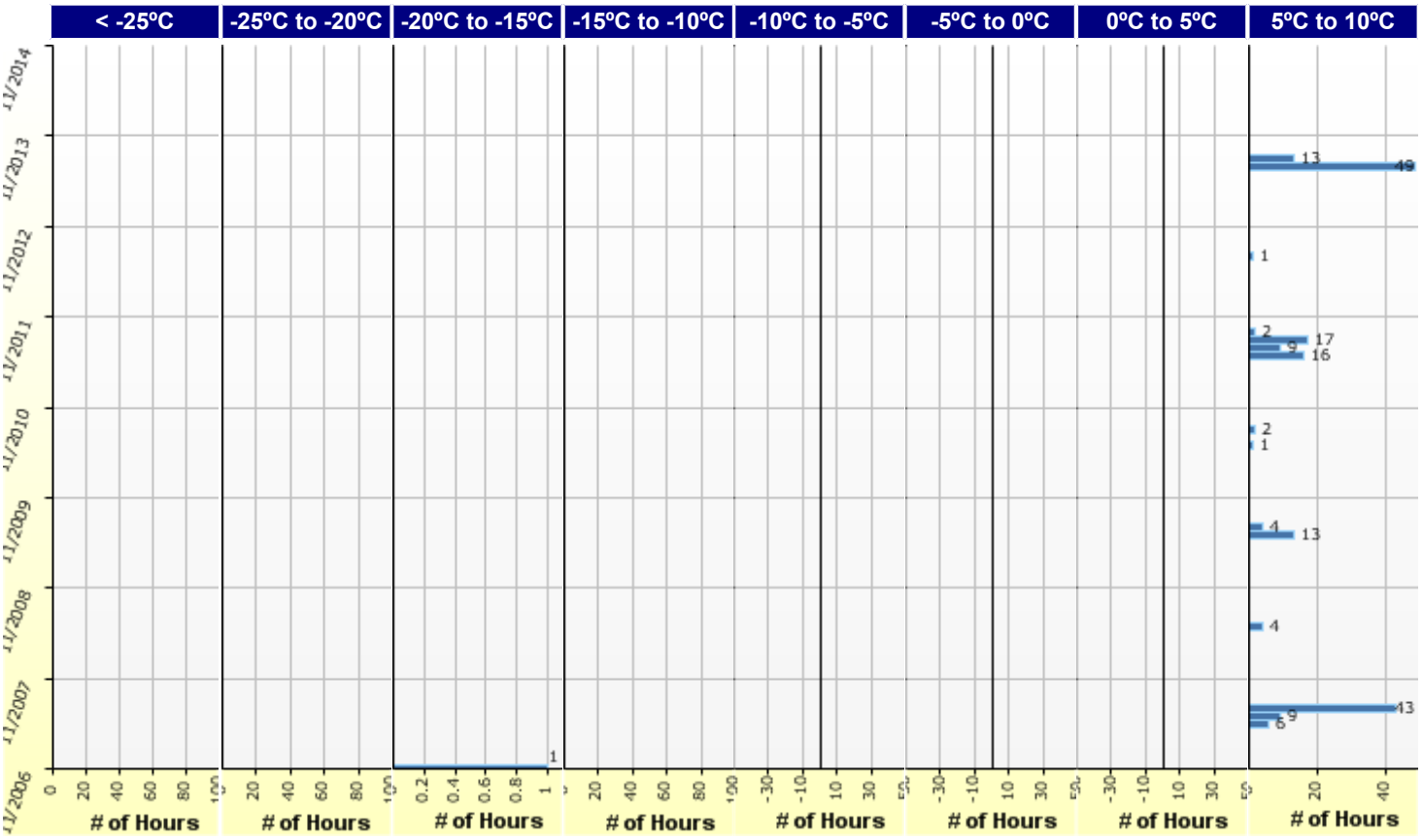


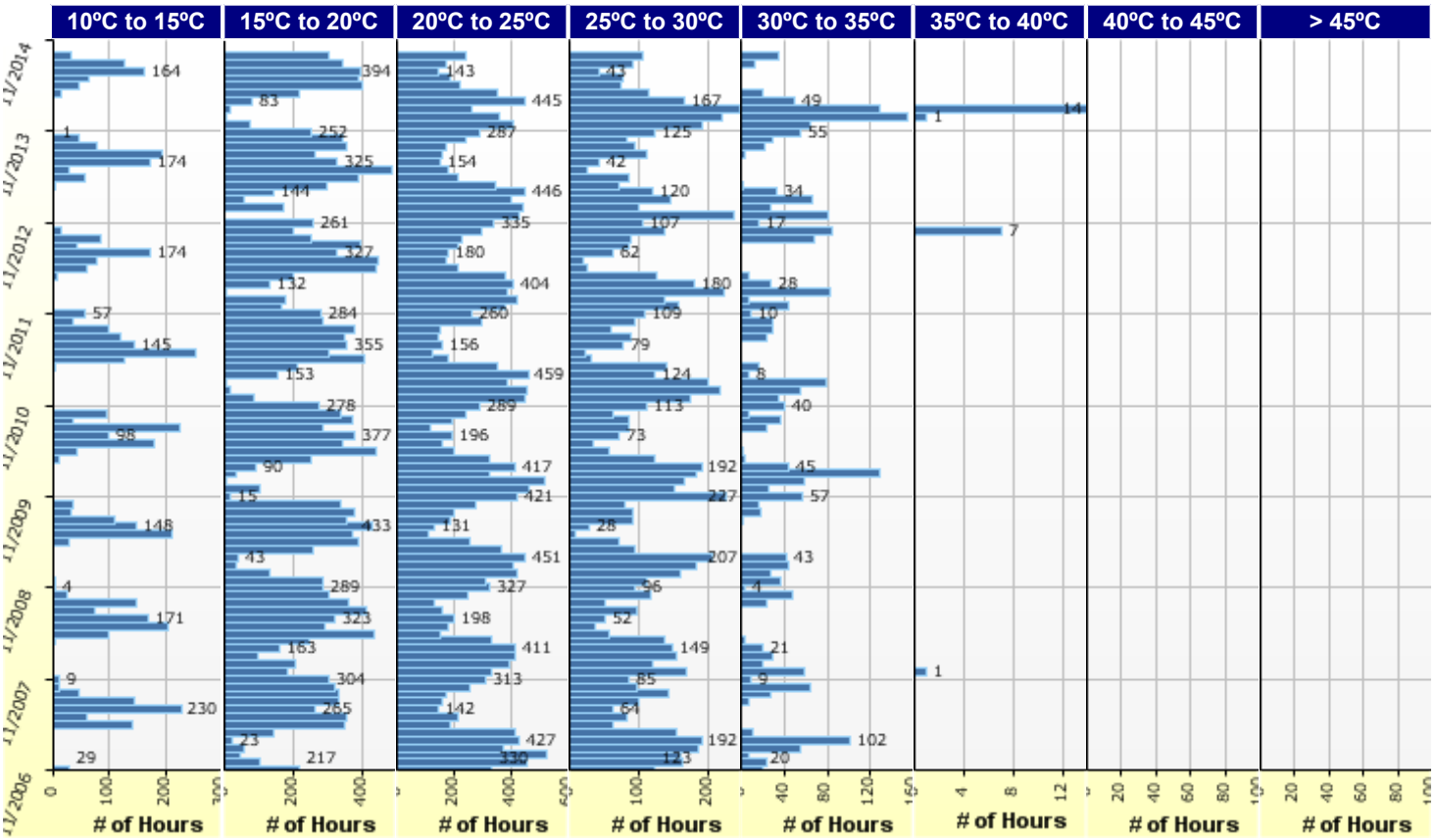






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

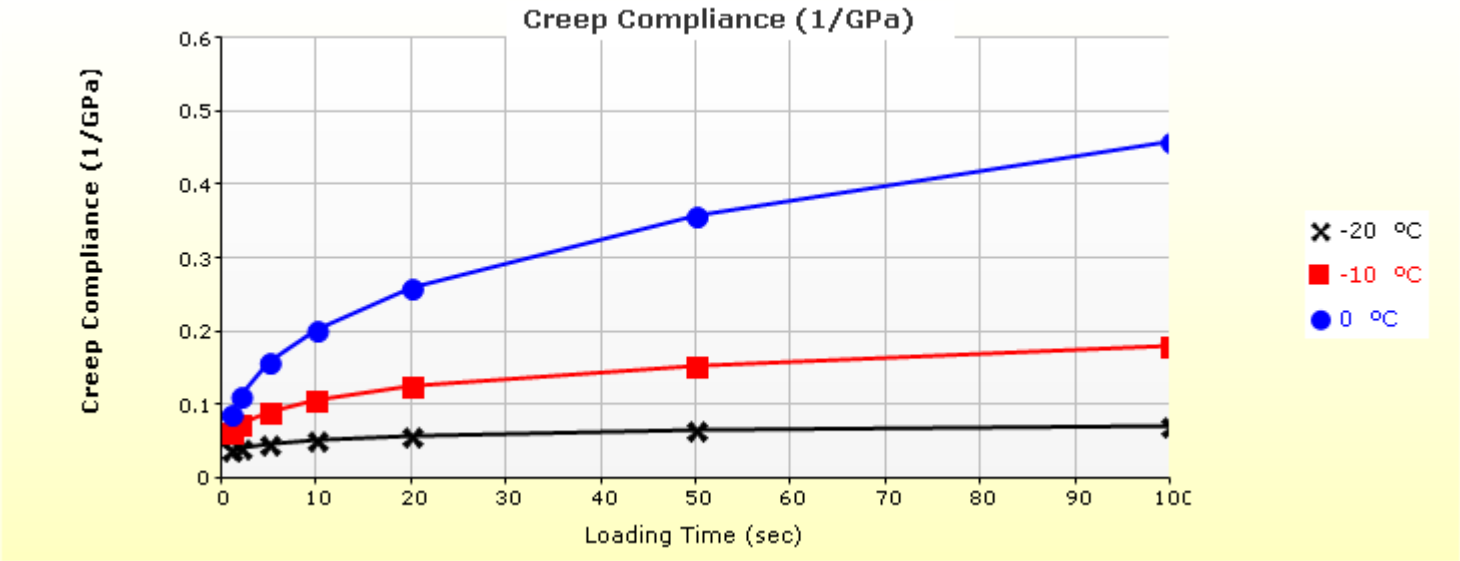
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

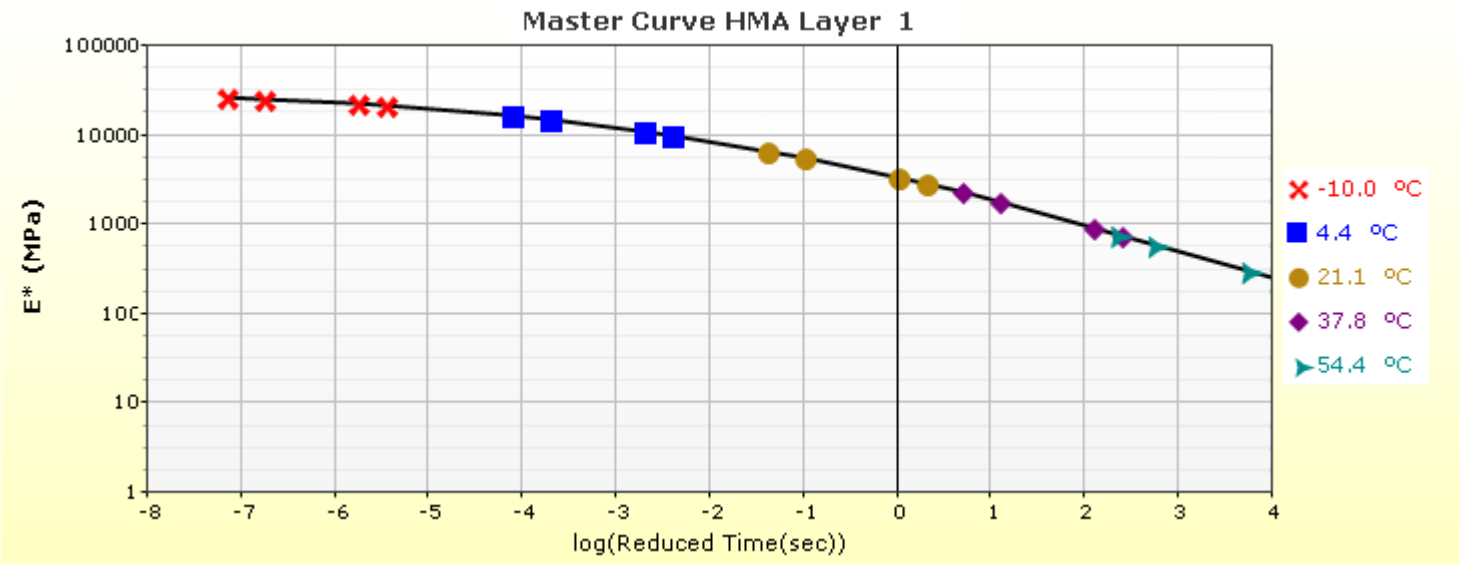
Indirect tensile strength at -10 ºC (MPa)	2.69

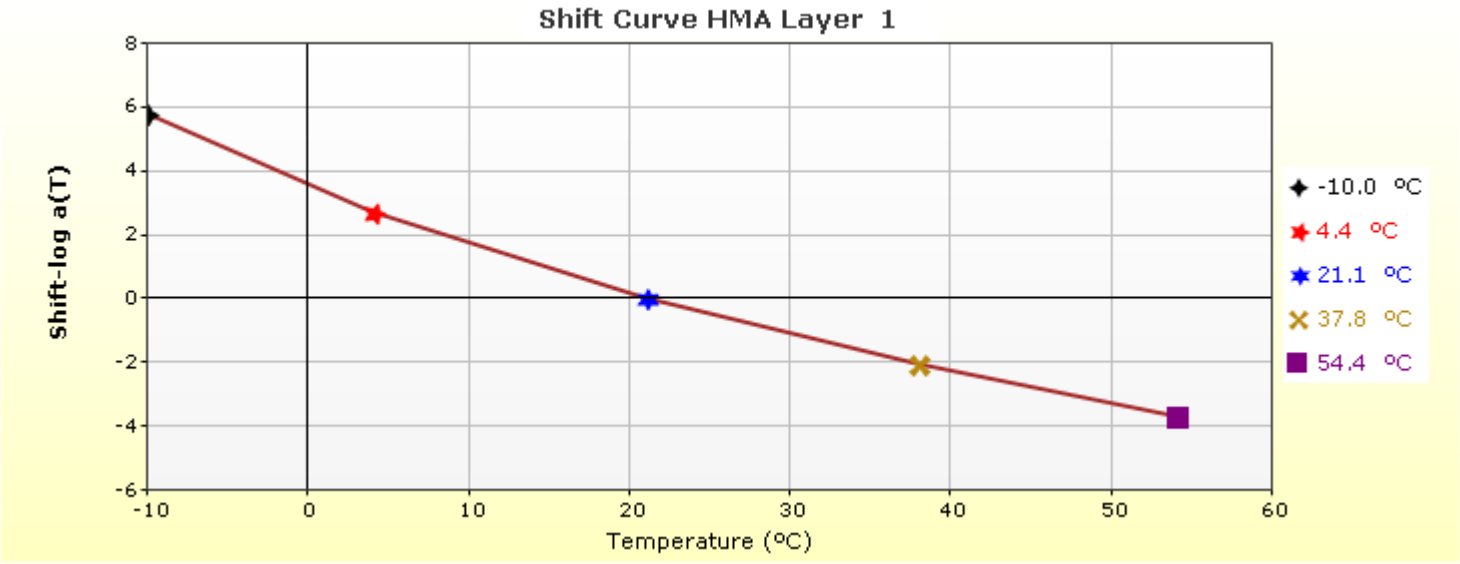
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

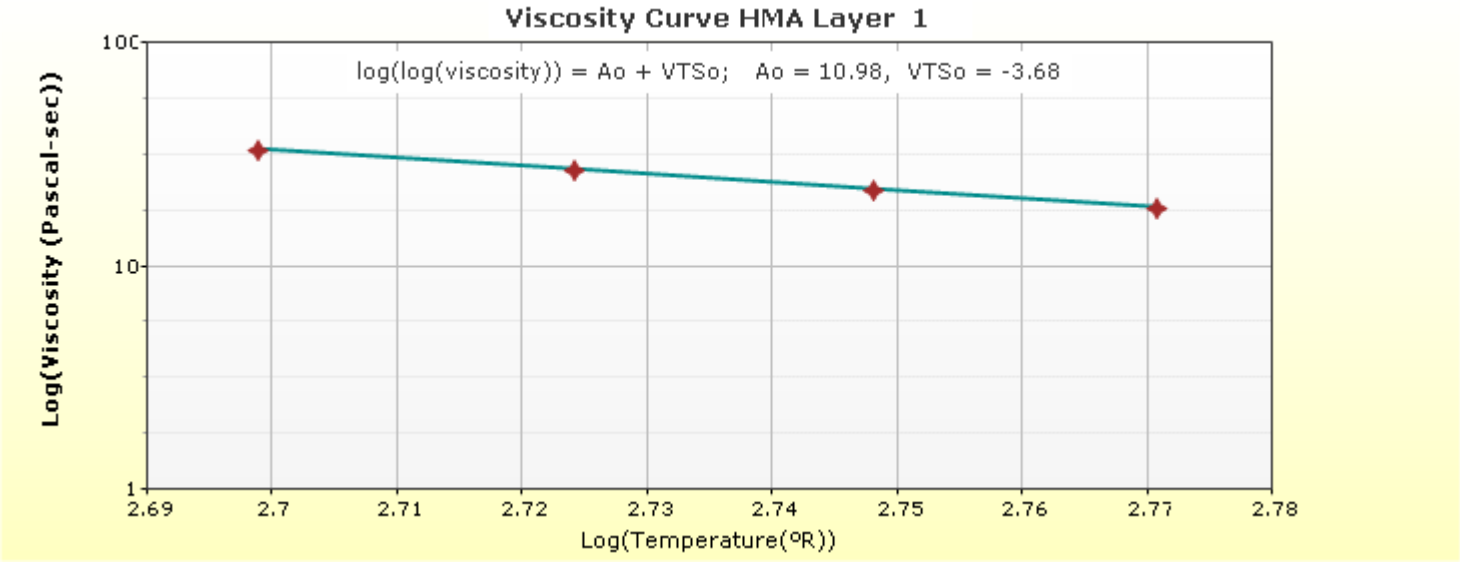
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



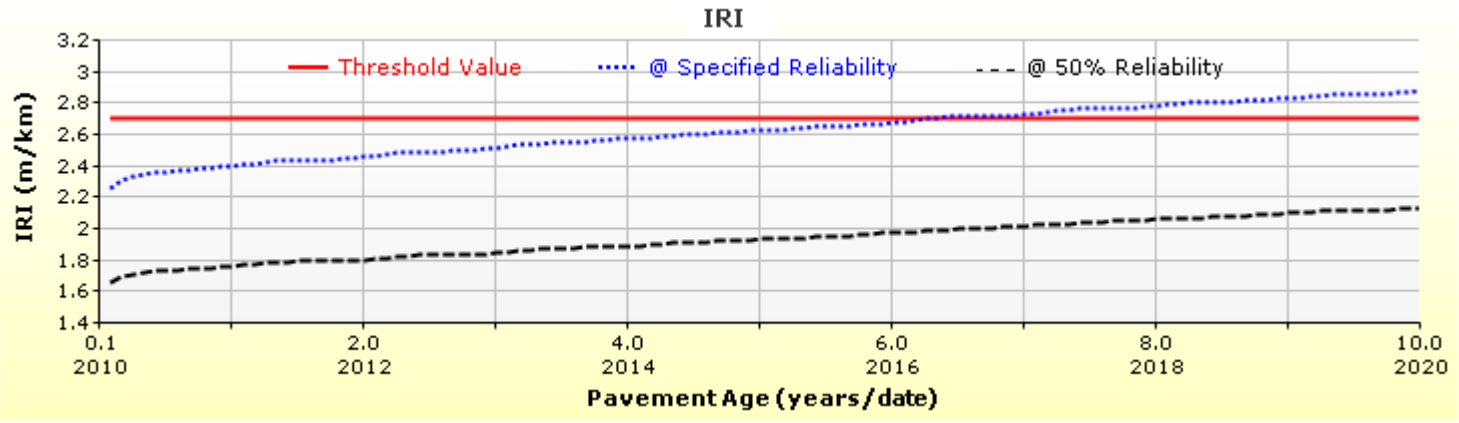
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

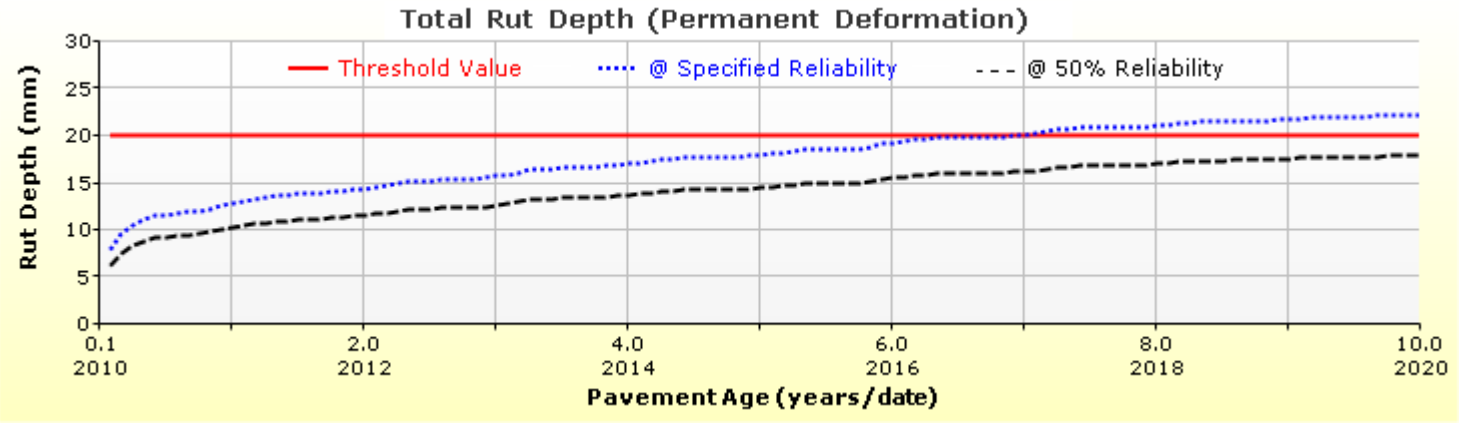


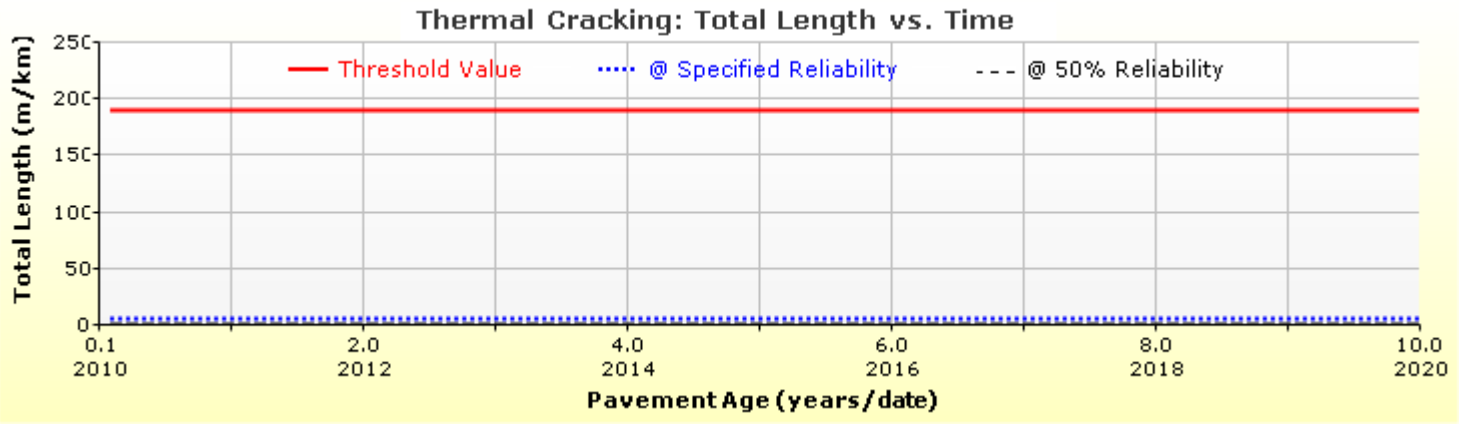


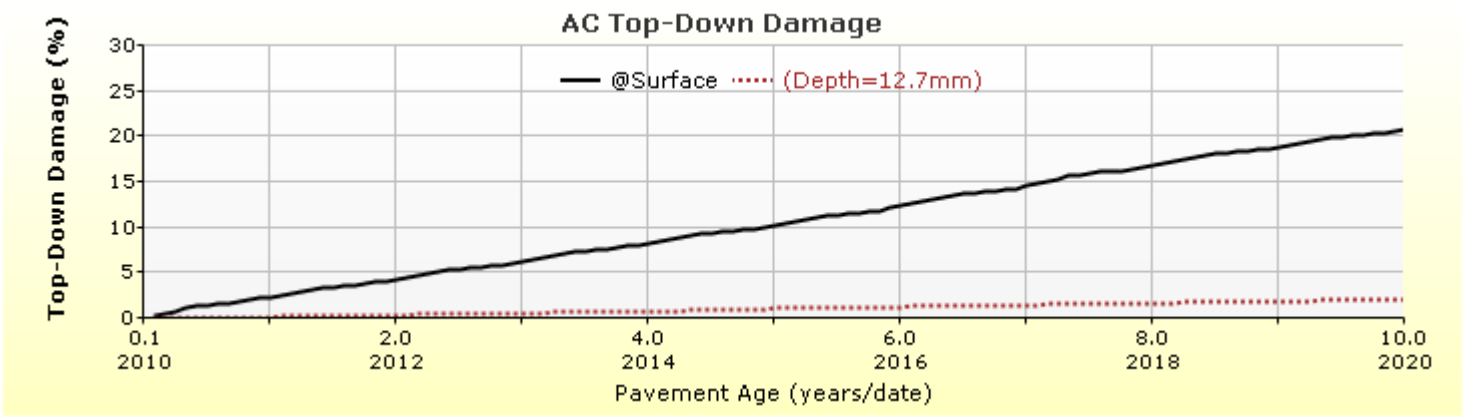


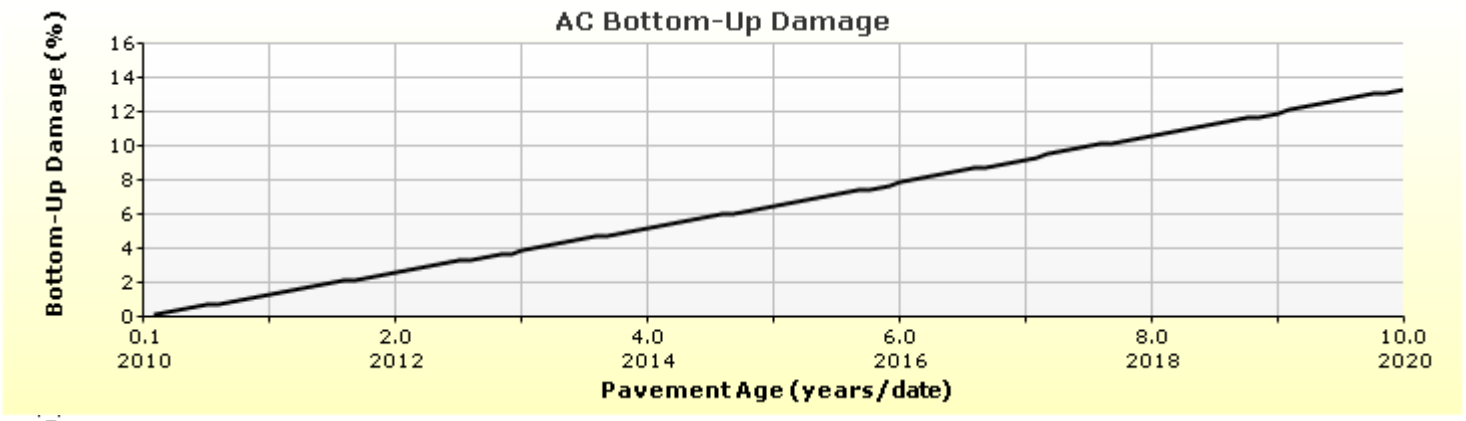
Analysis Output Charts

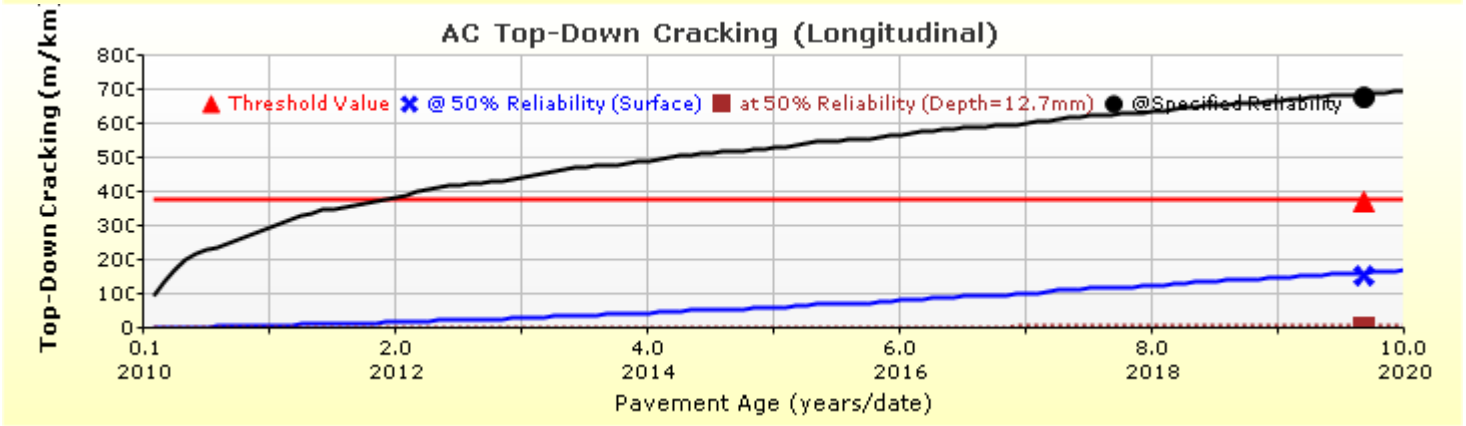


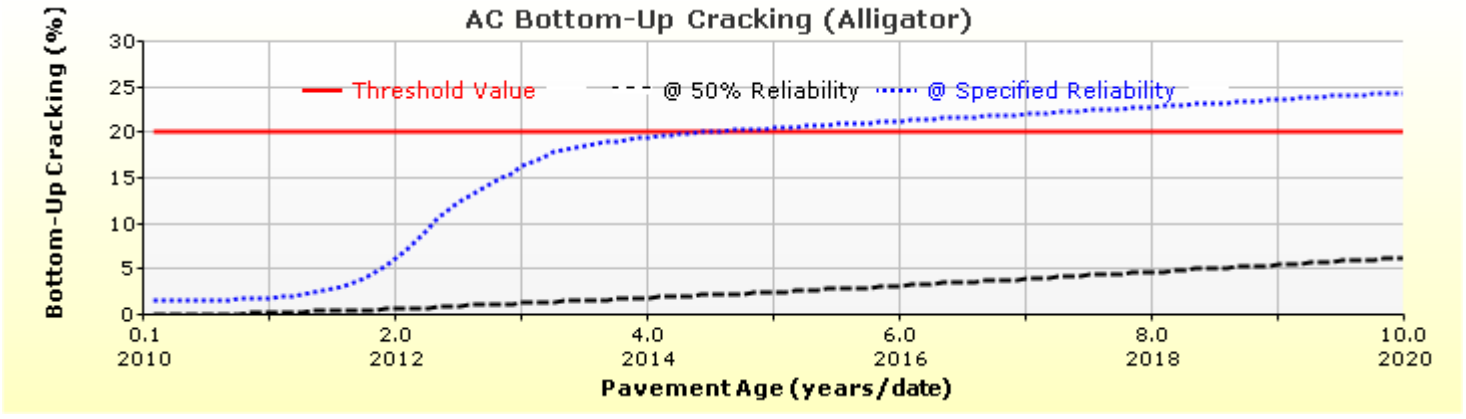


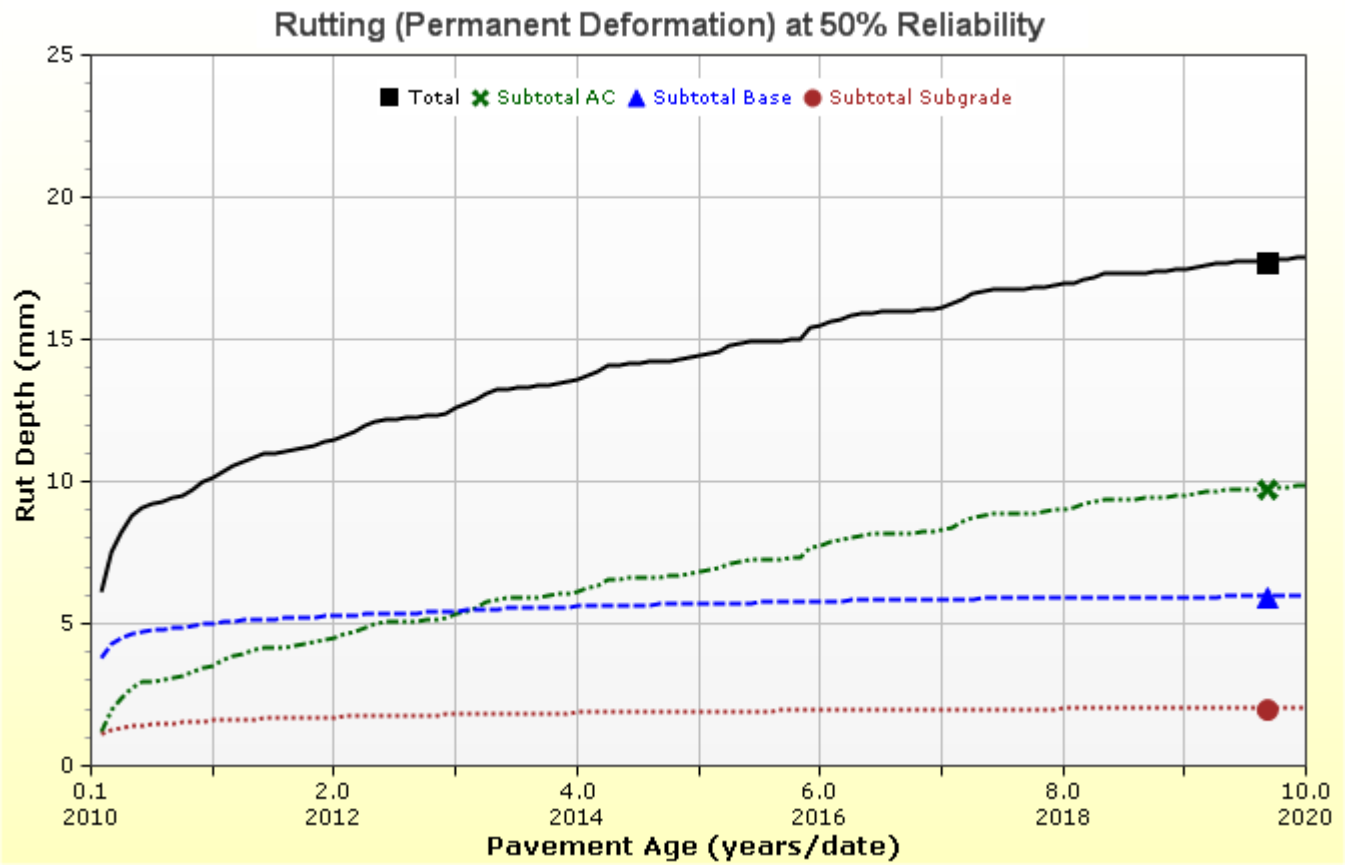


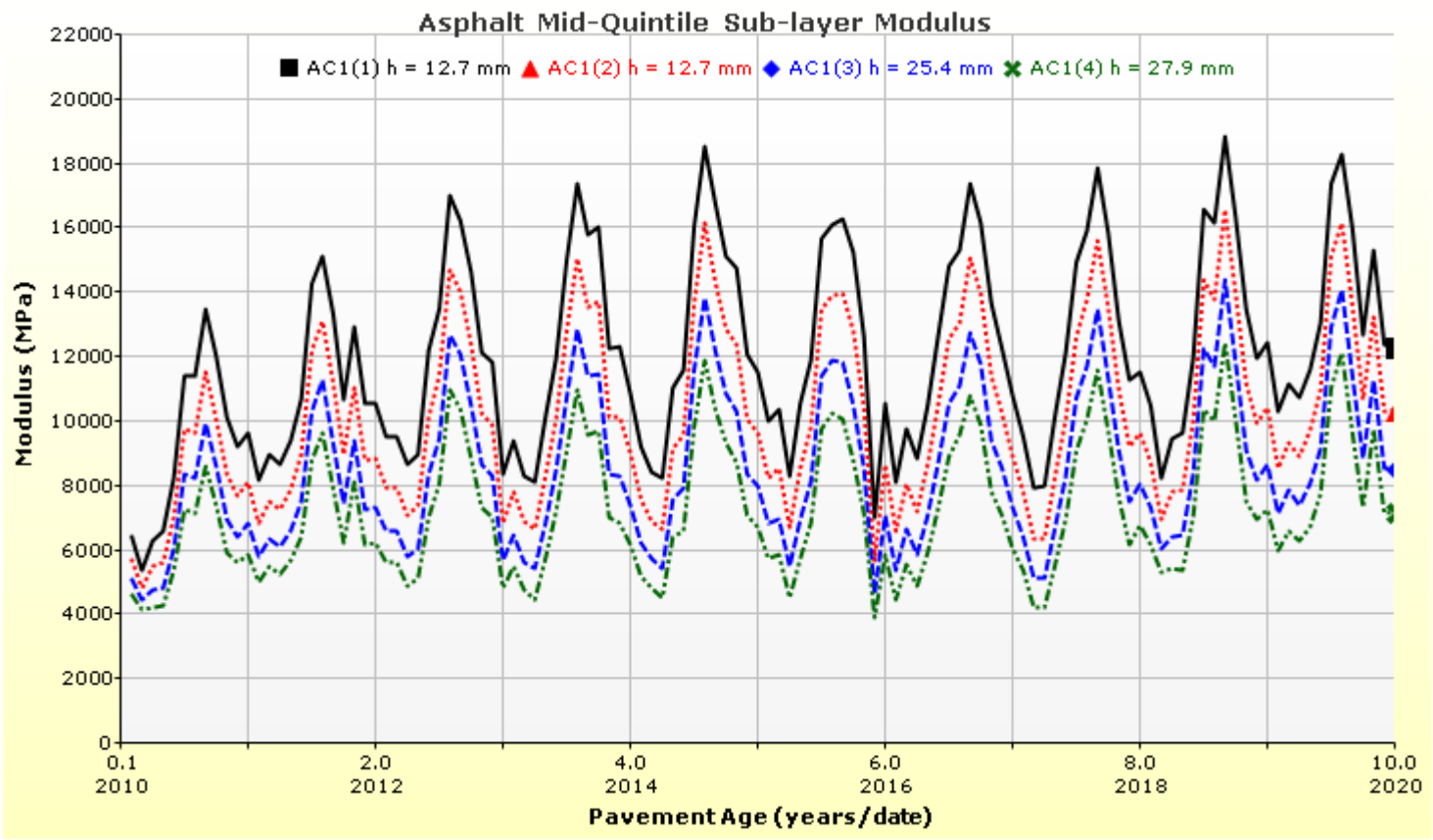

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

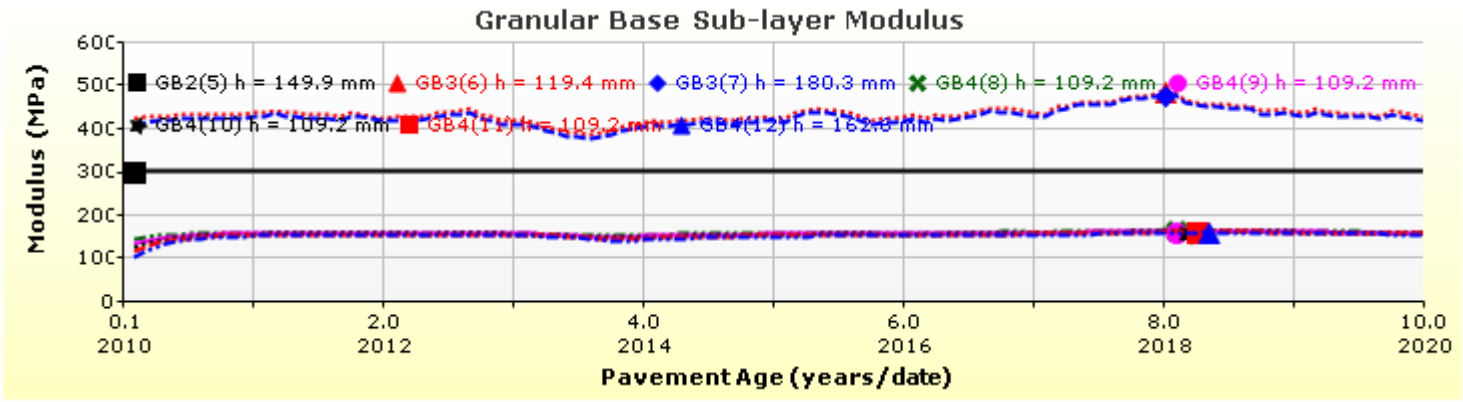

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

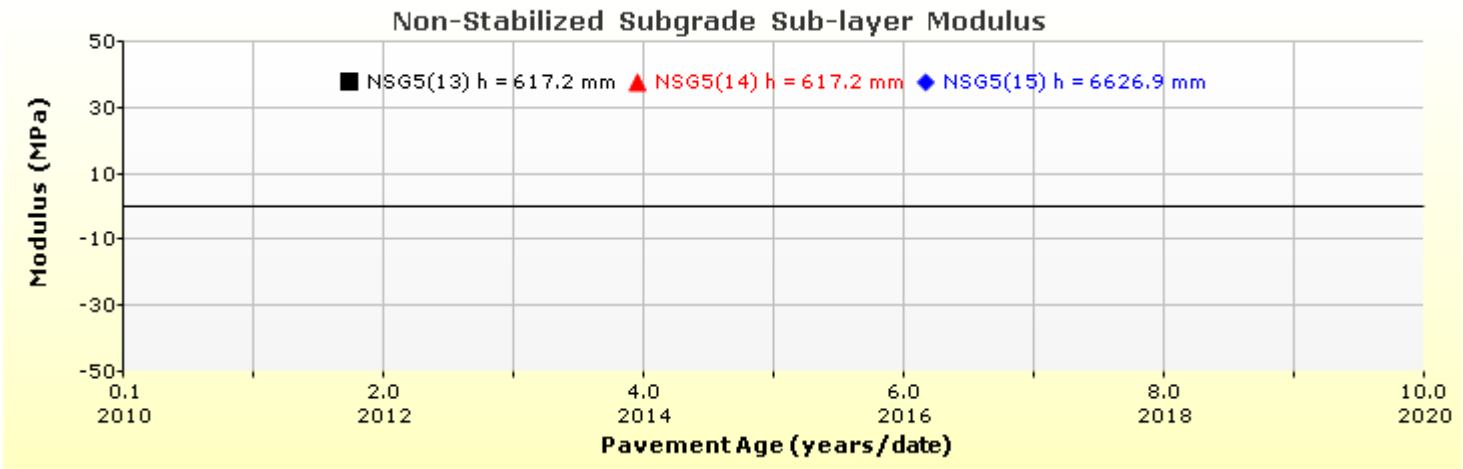

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.8 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 1
Bf2: 1
Bf3: 1

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestSP+4

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestSP+4.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -23.5, -46.62

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

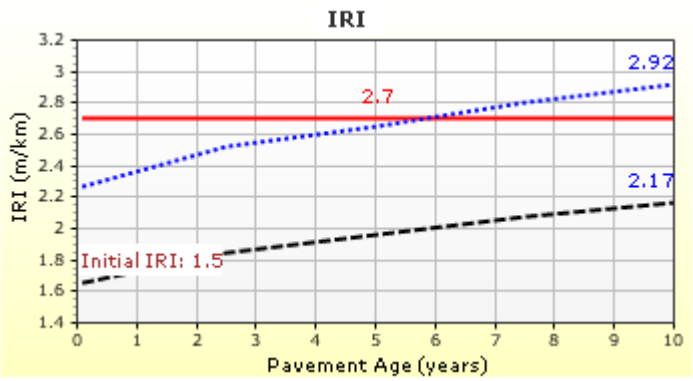
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

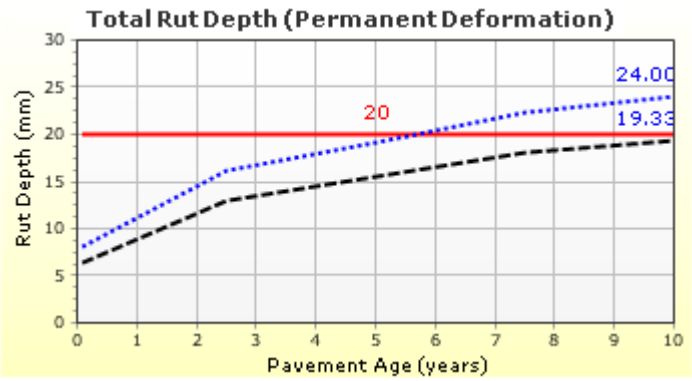
Design Outputs

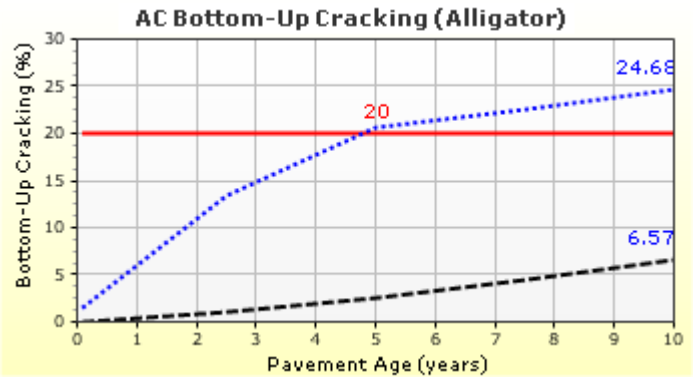
Distress Prediction Summary

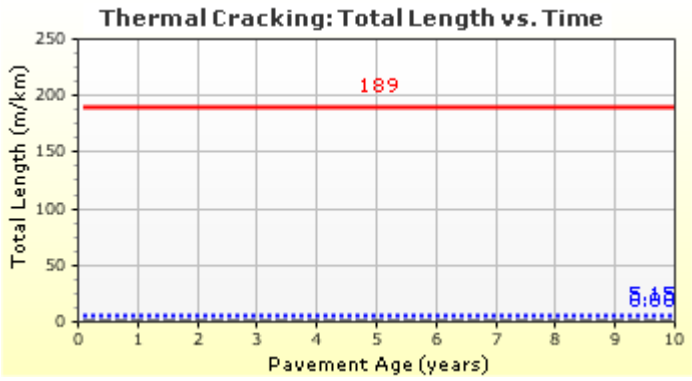
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.92	90.00	81.60	Fail
Permanent deformation - total pavement (mm)	20.00	23.99	90.00	57.20	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.68	90.00	82.91	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	732.58	90.00	66.65	Fail
Permanent deformation - AC only (mm)	5.00	11.32	50.00	2.46	Fail

Distress Charts







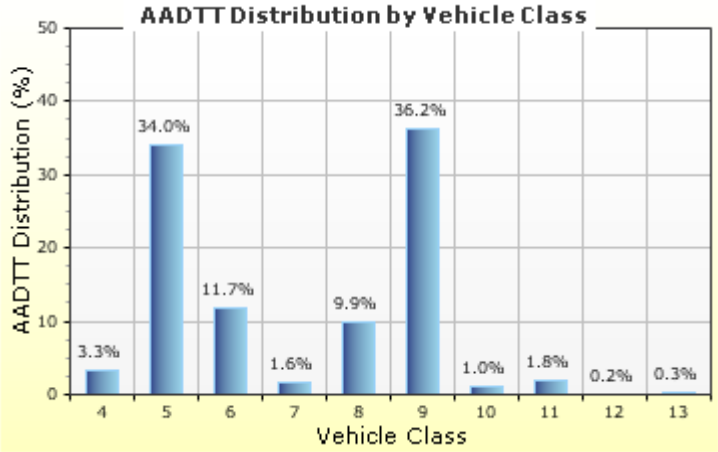


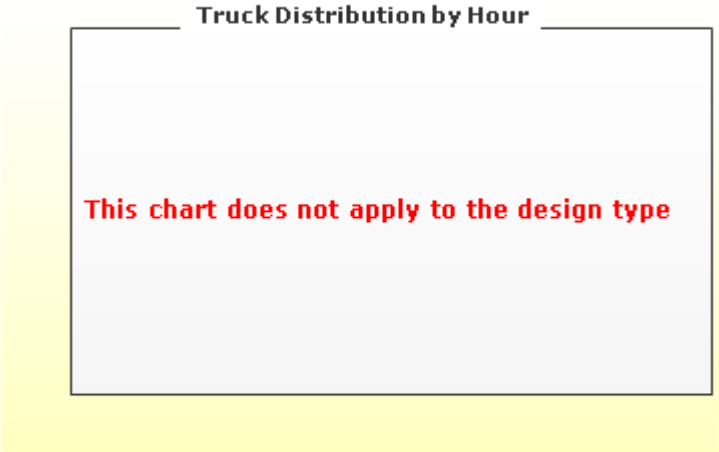


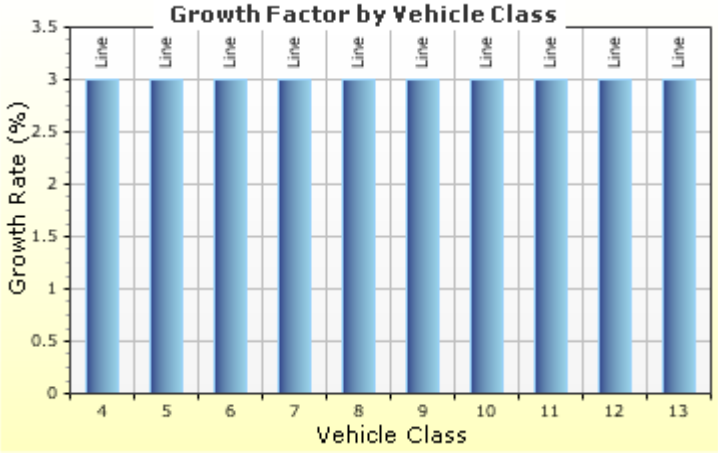
Traffic Inputs

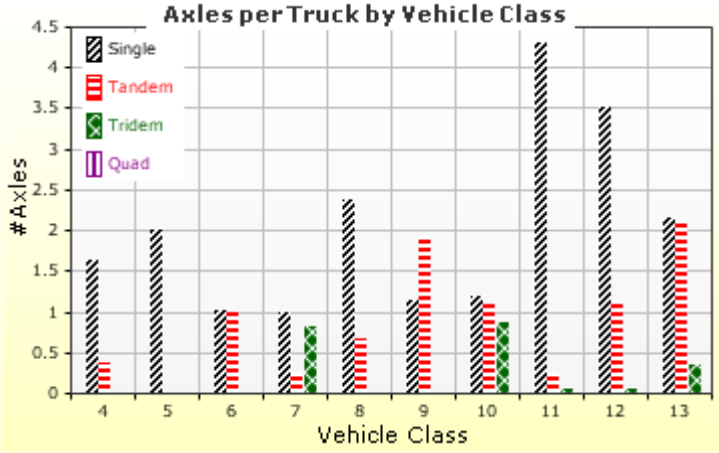
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

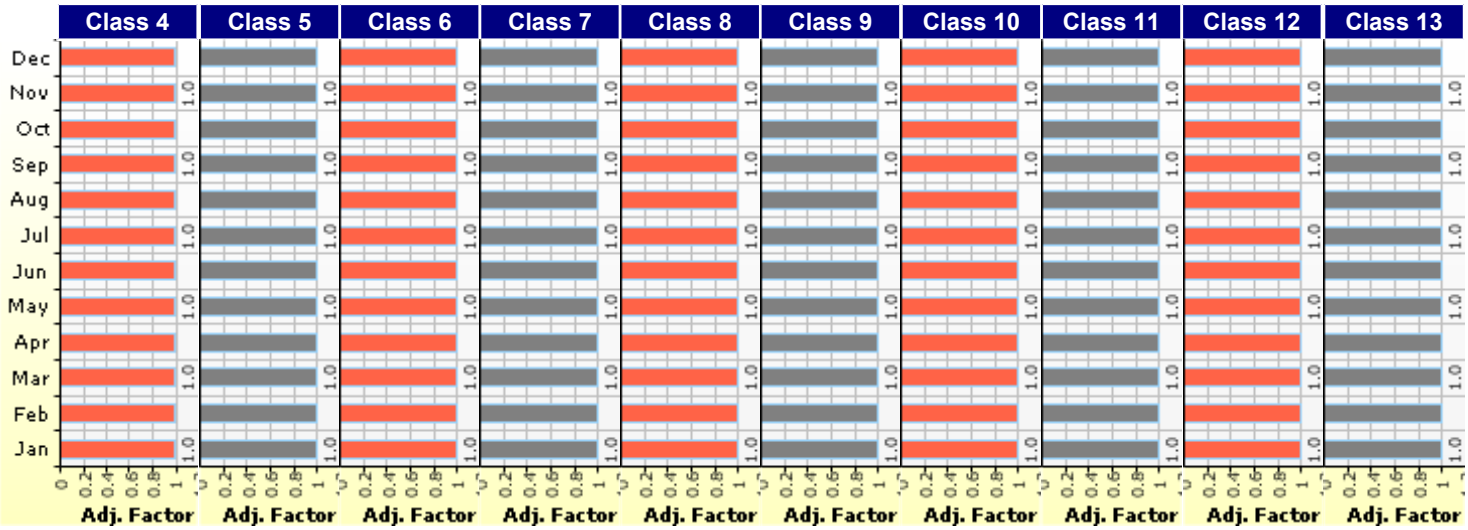








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

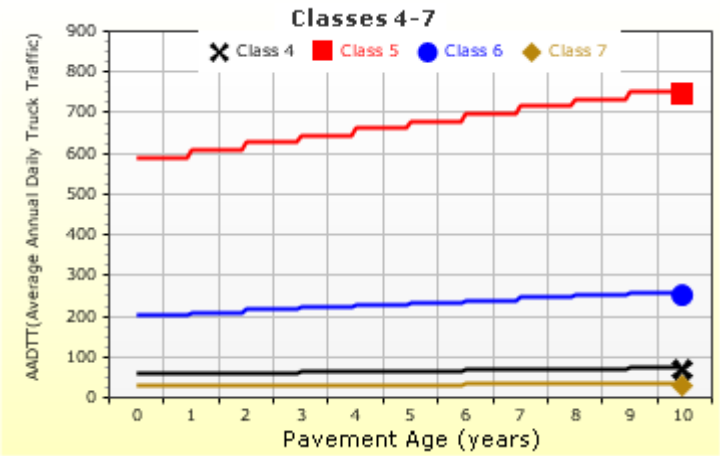
Wheelbase does not apply

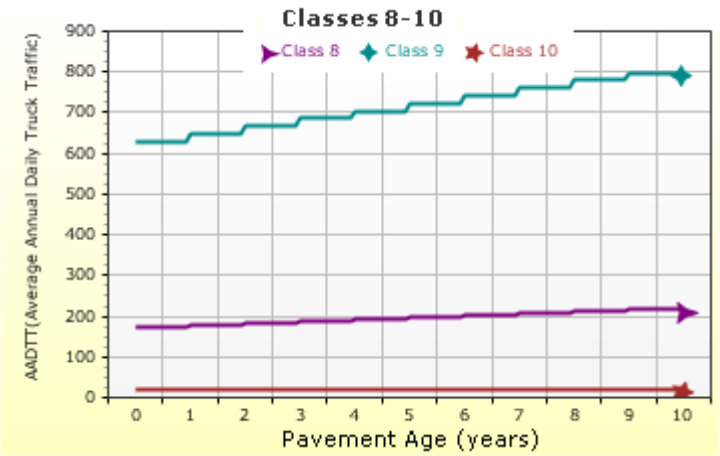
Number of Axles per Truck

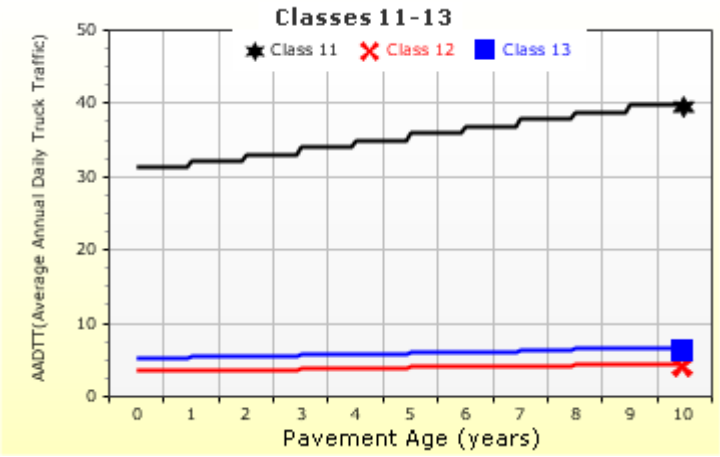
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

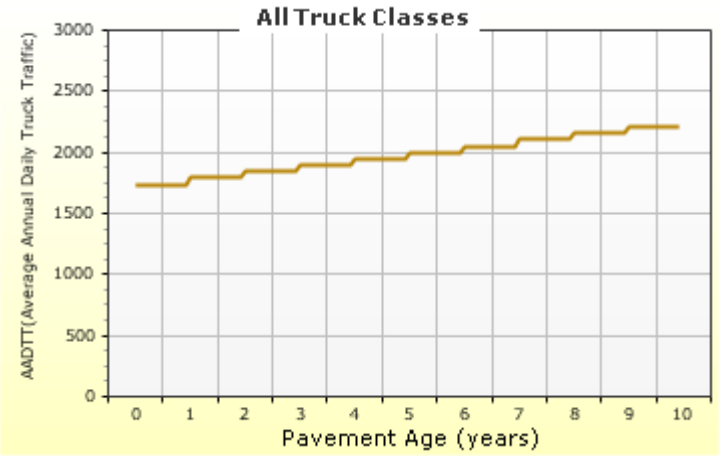
AADTT (Average Annual Daily Truck Traffic) Growth

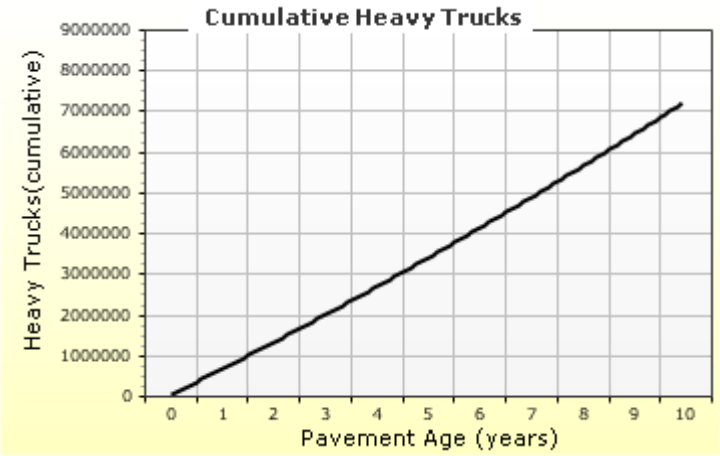
*** Traffic cap is not enforced**







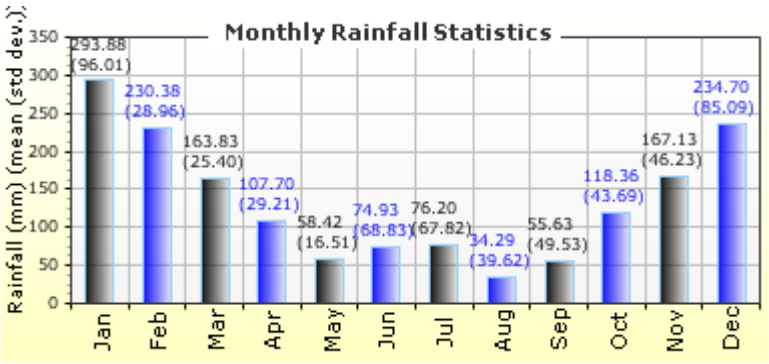




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
SAO PAULO, SP	-23.50000 -46.62000 792

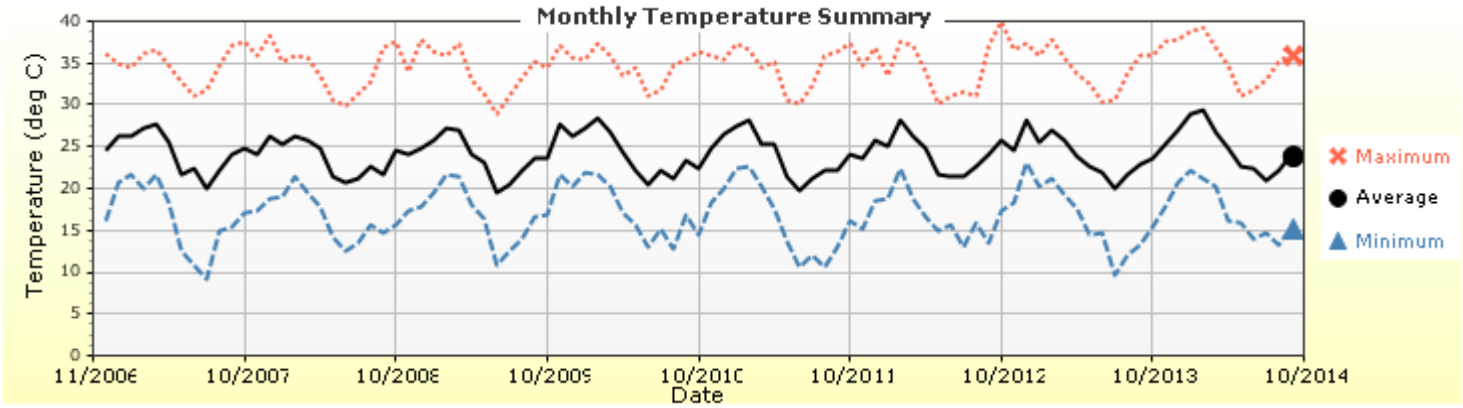


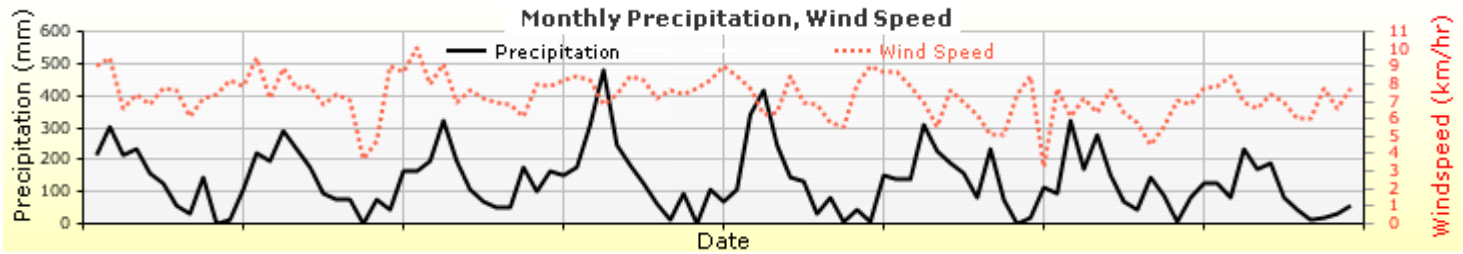
Annual Statistics:

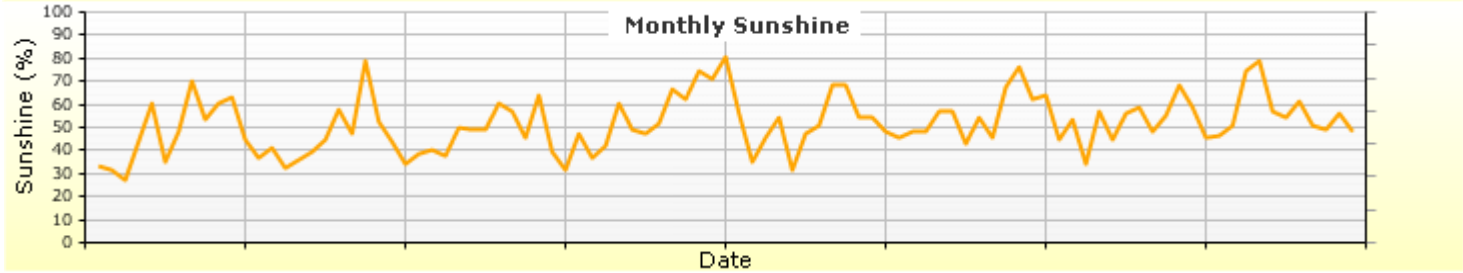
Mean annual air temperature (ºC)	24.15
Mean annual precipitation (mm)	1628.14
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

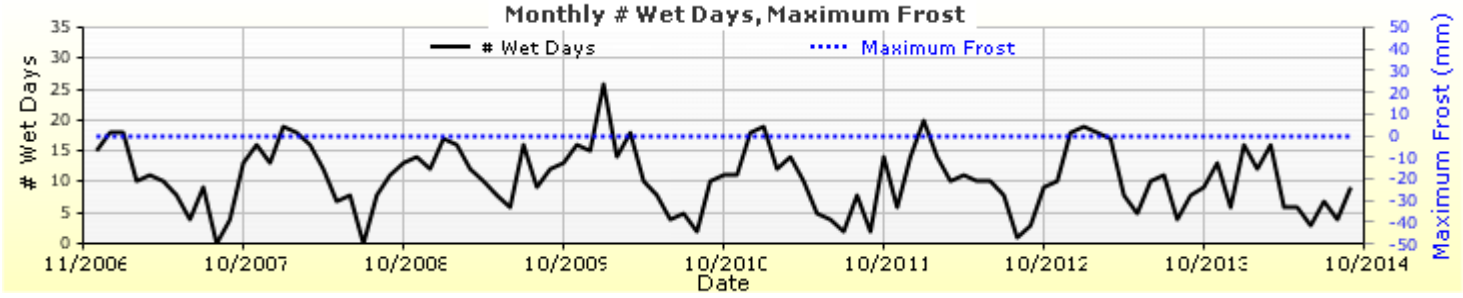
Water table depth (m): 3.05

Monthly Climate Summary:

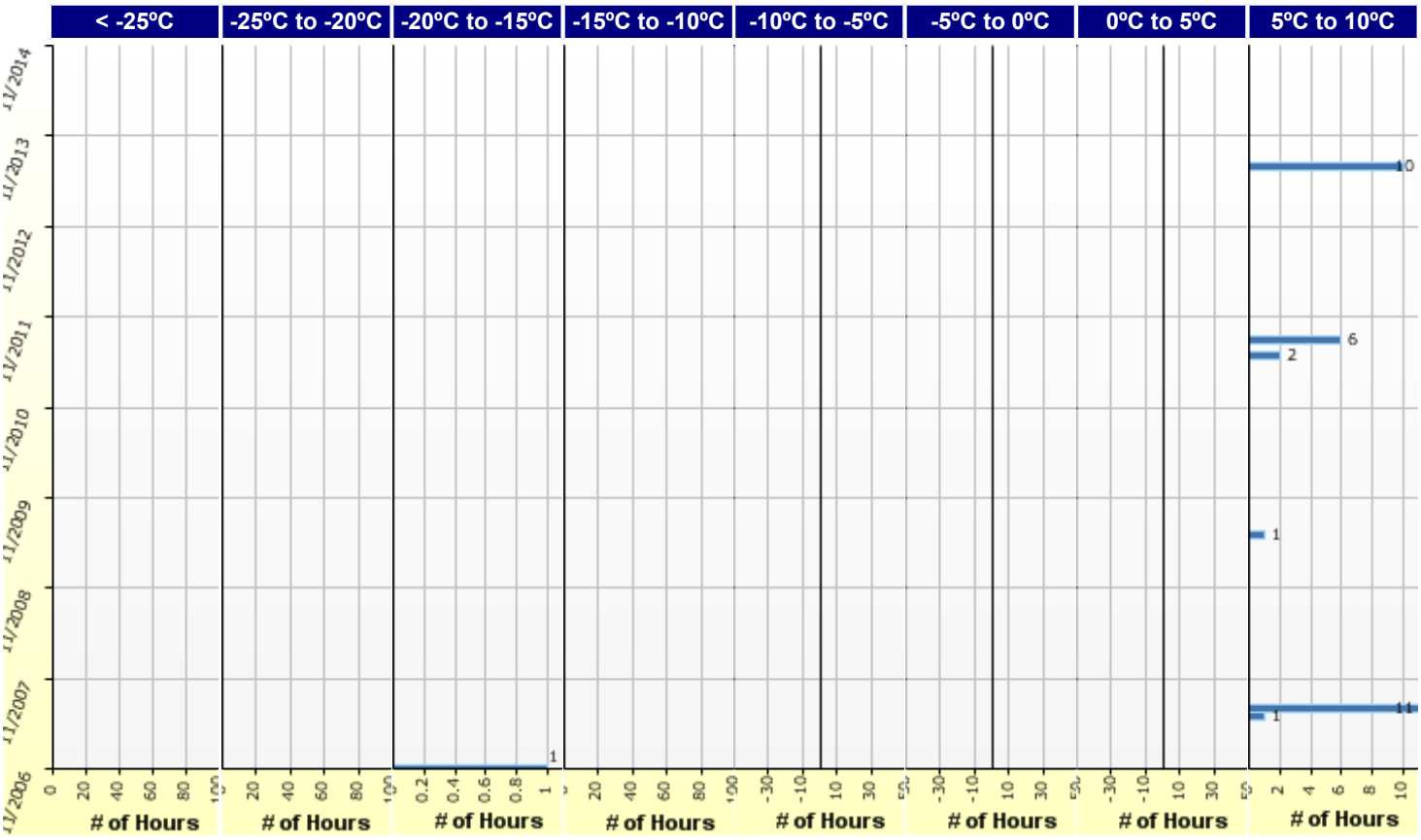


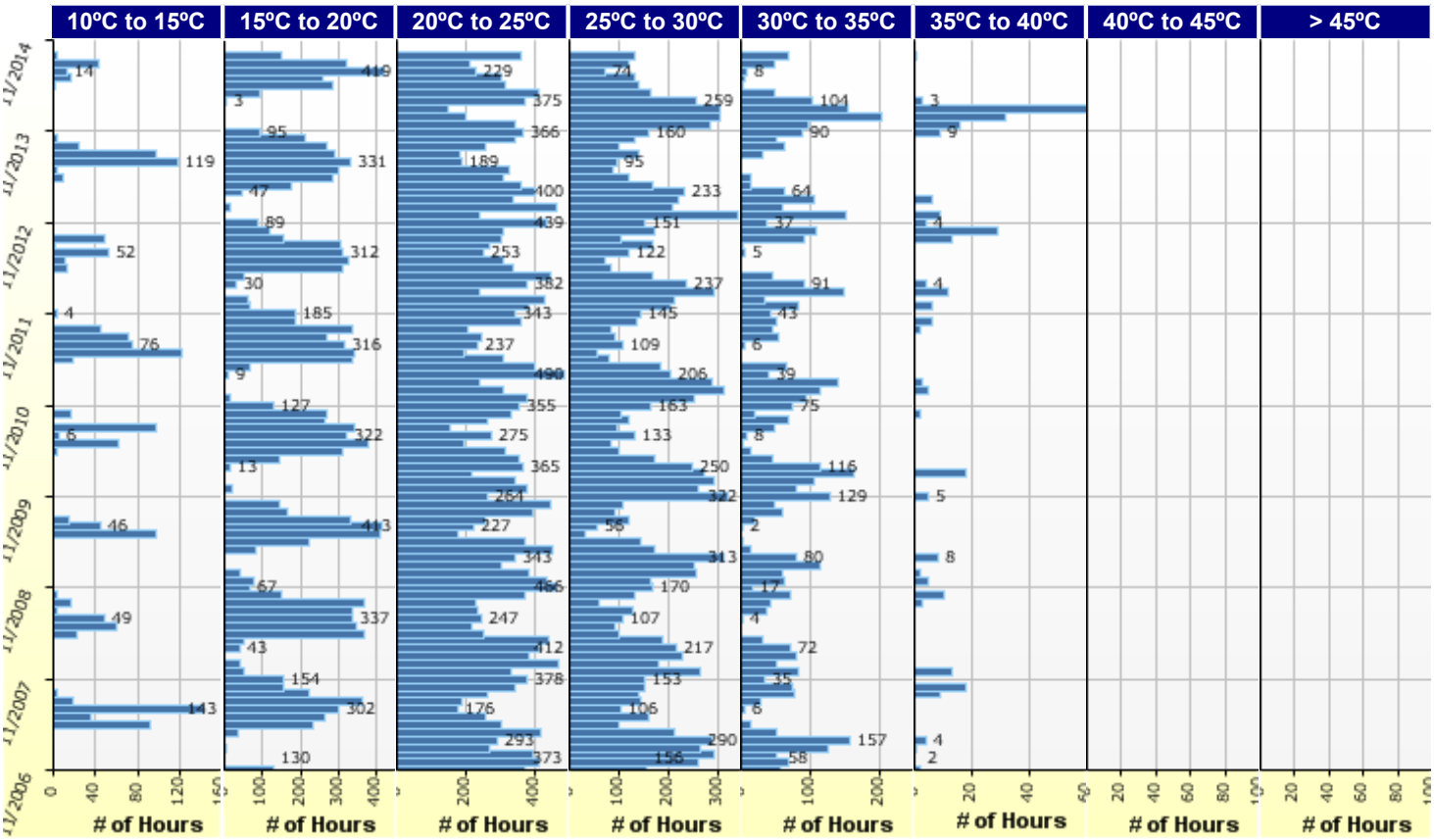






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

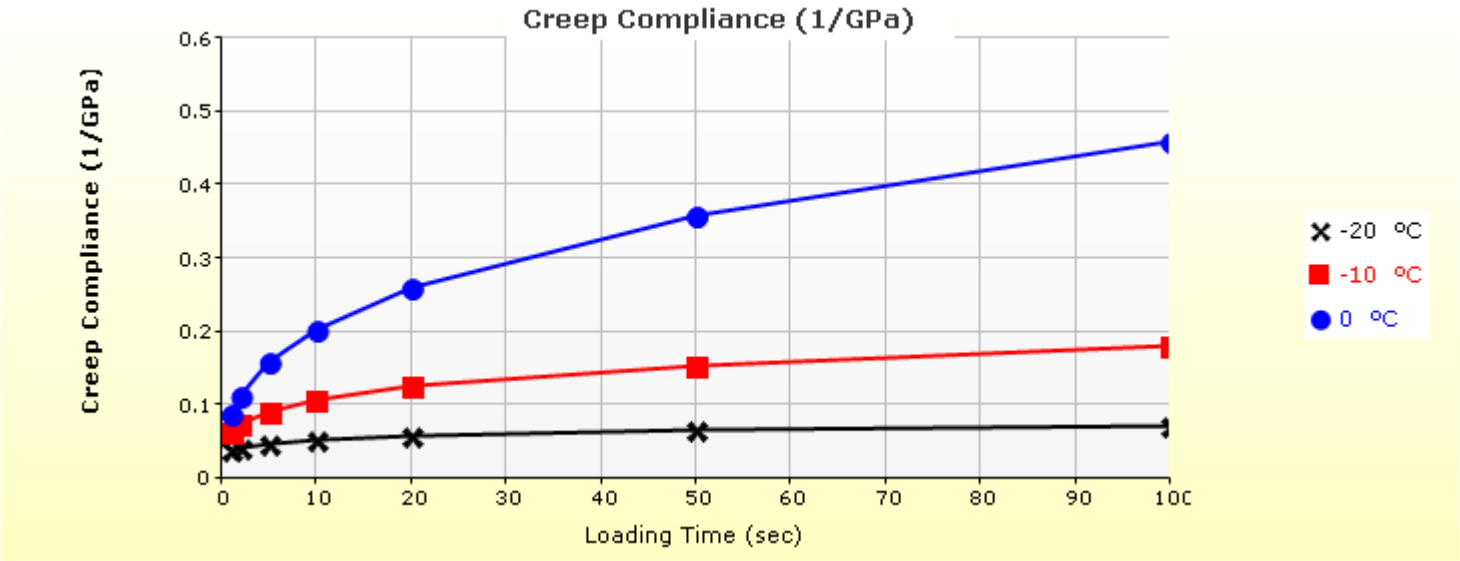
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

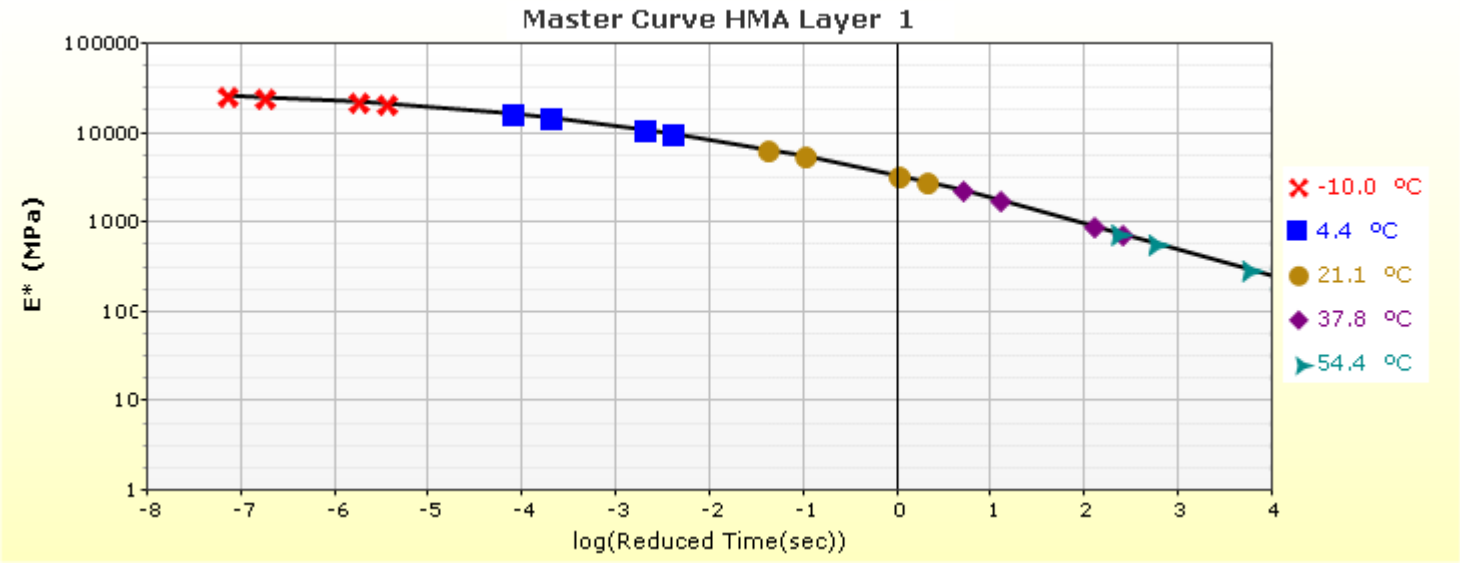
Indirect tensile strength at -10 ºC (MPa)	2.69

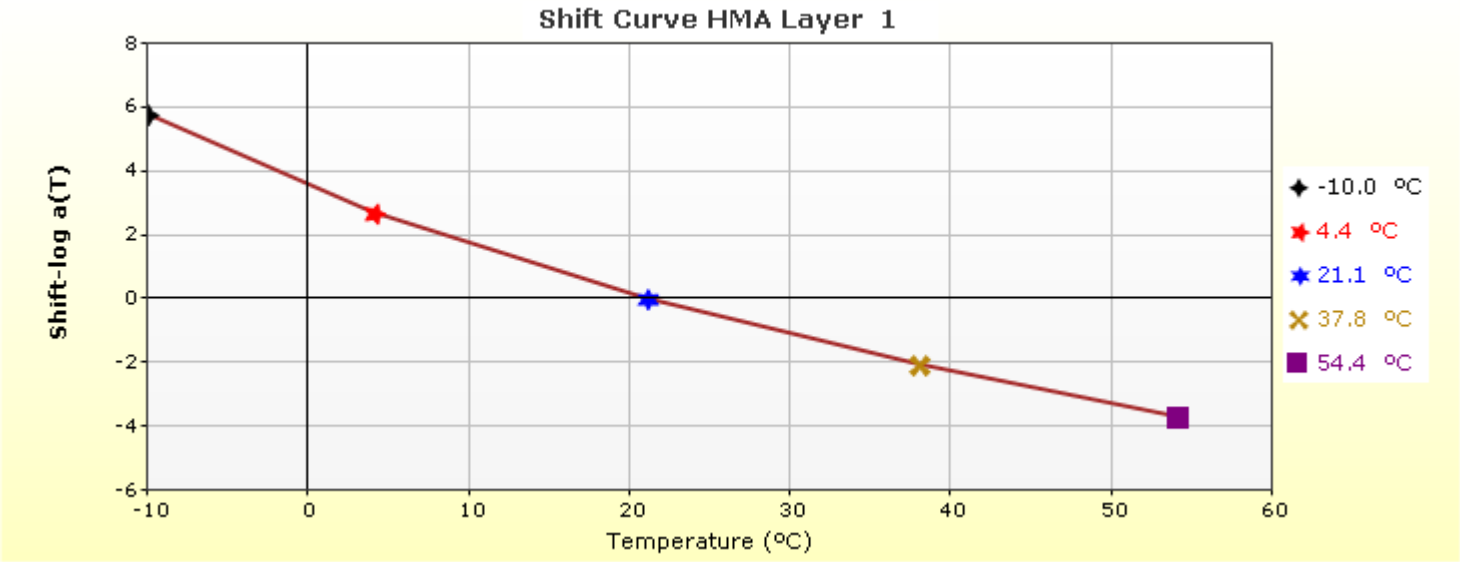
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

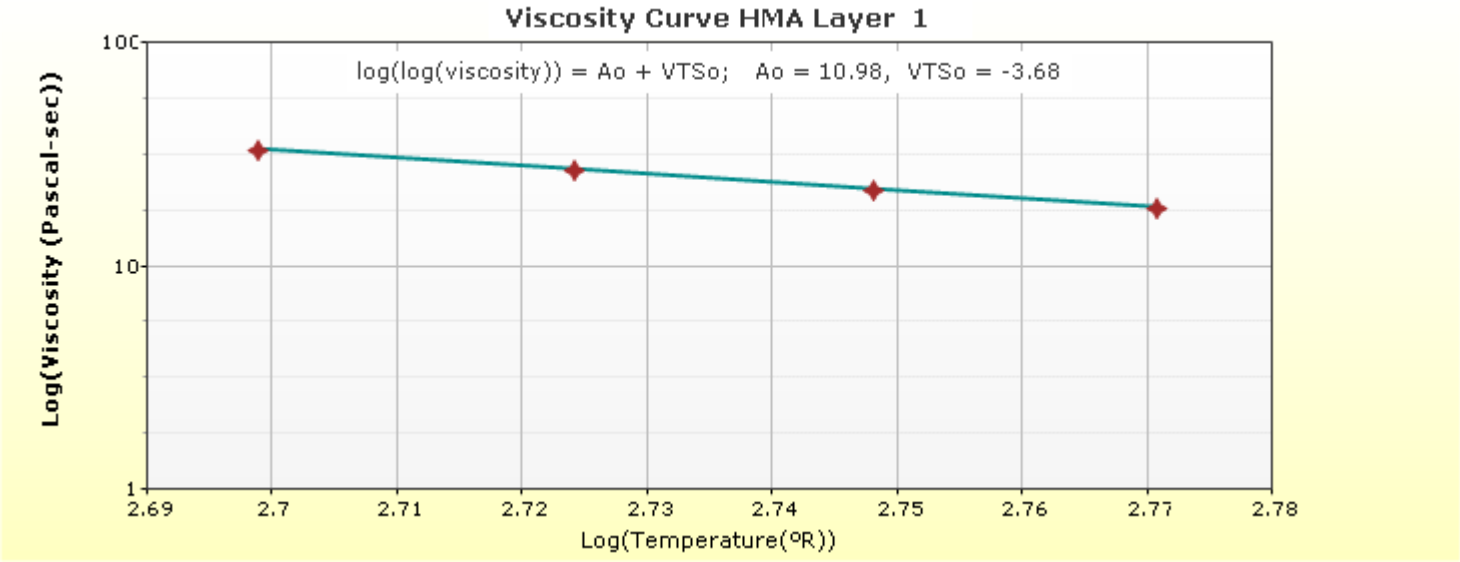
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



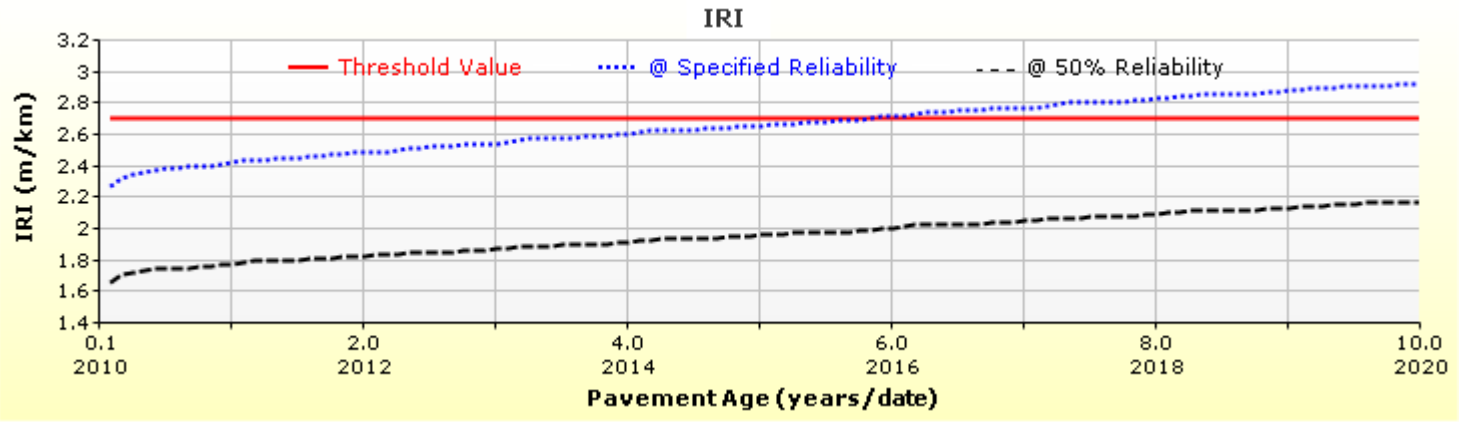
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

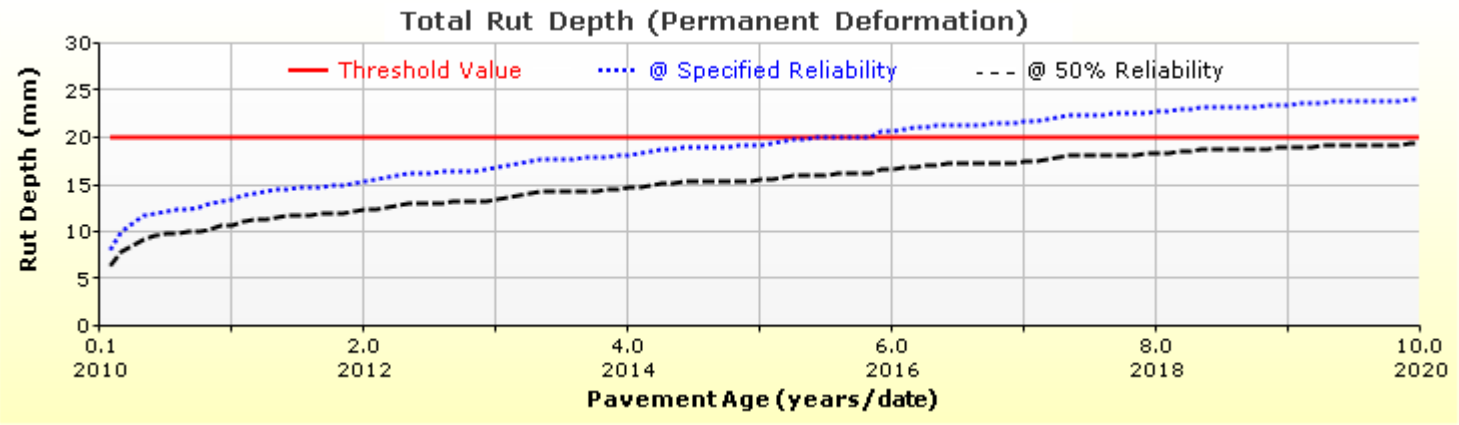


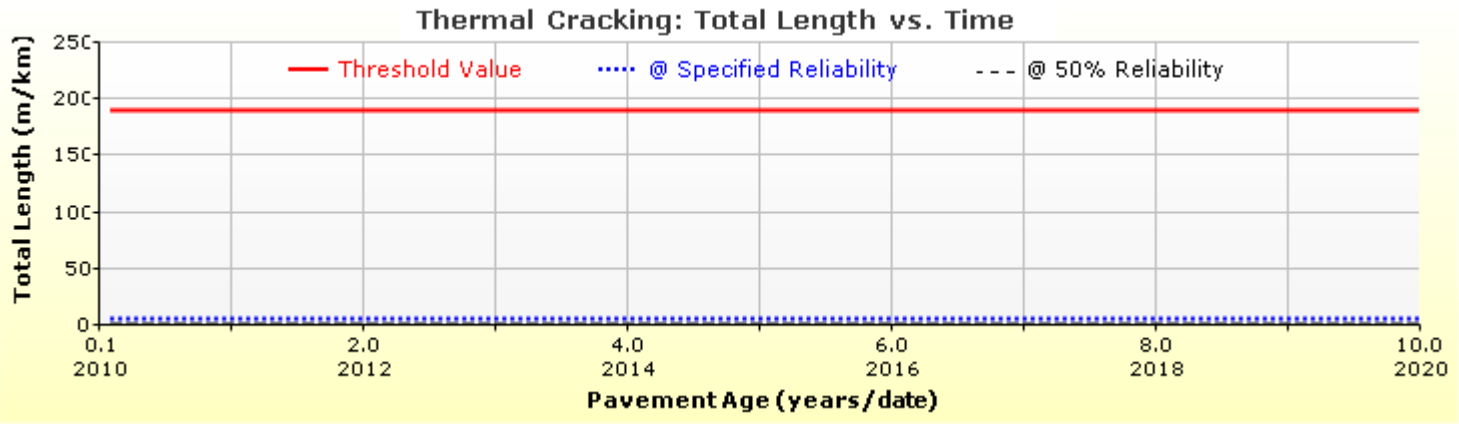


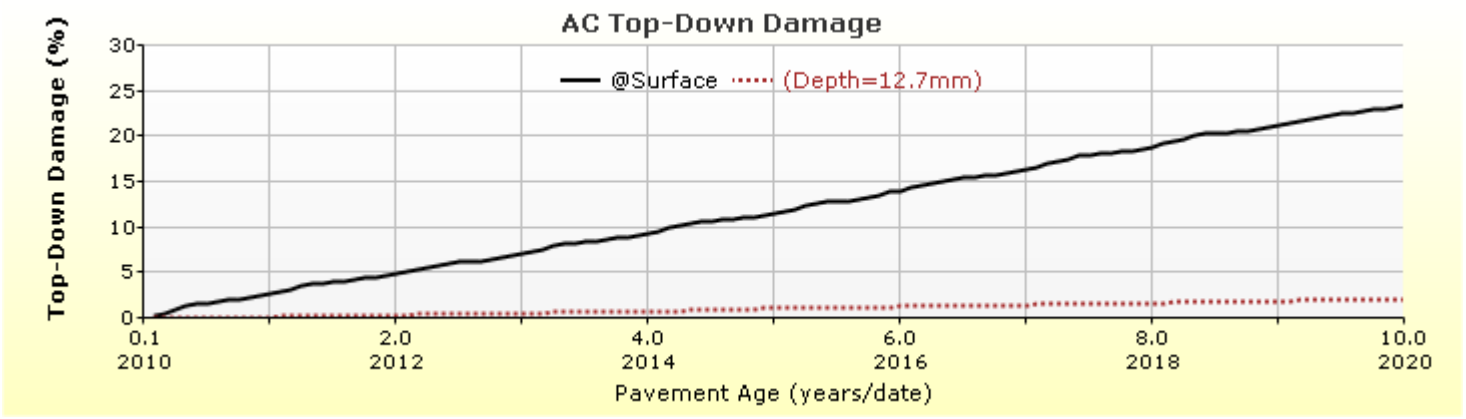


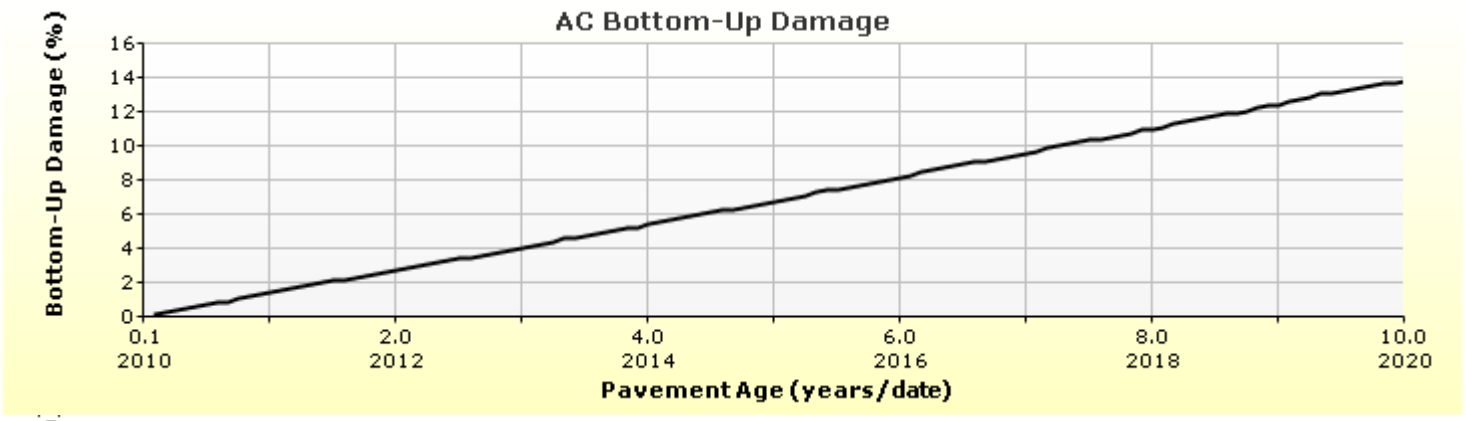
Analysis Output Charts

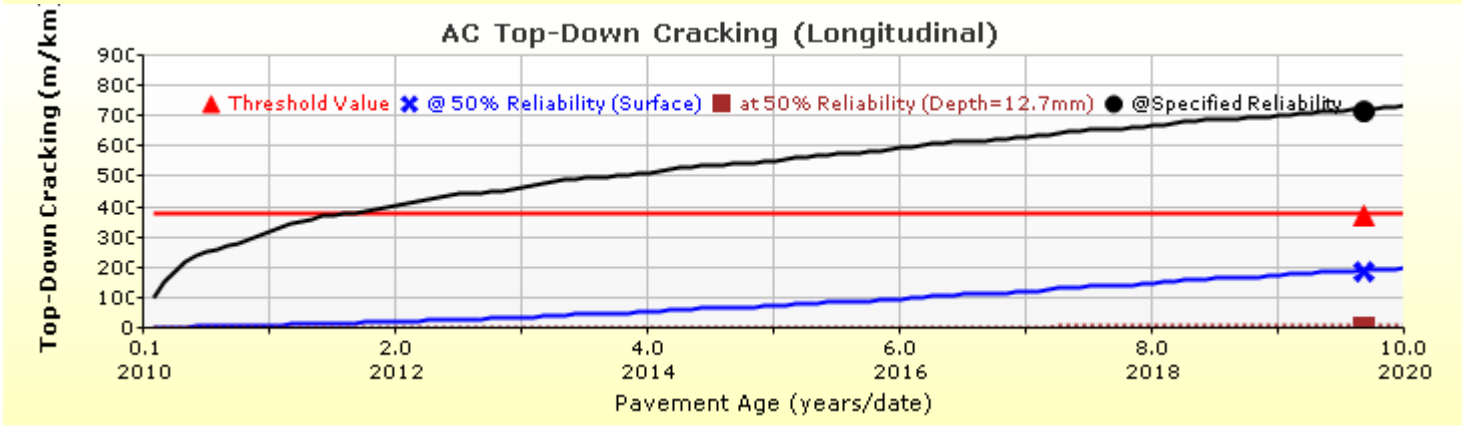


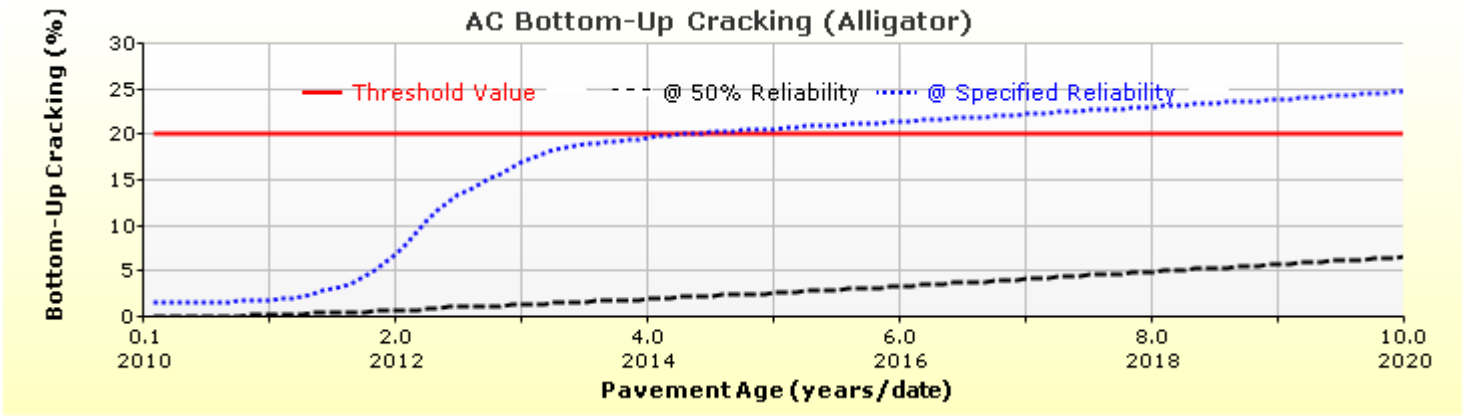


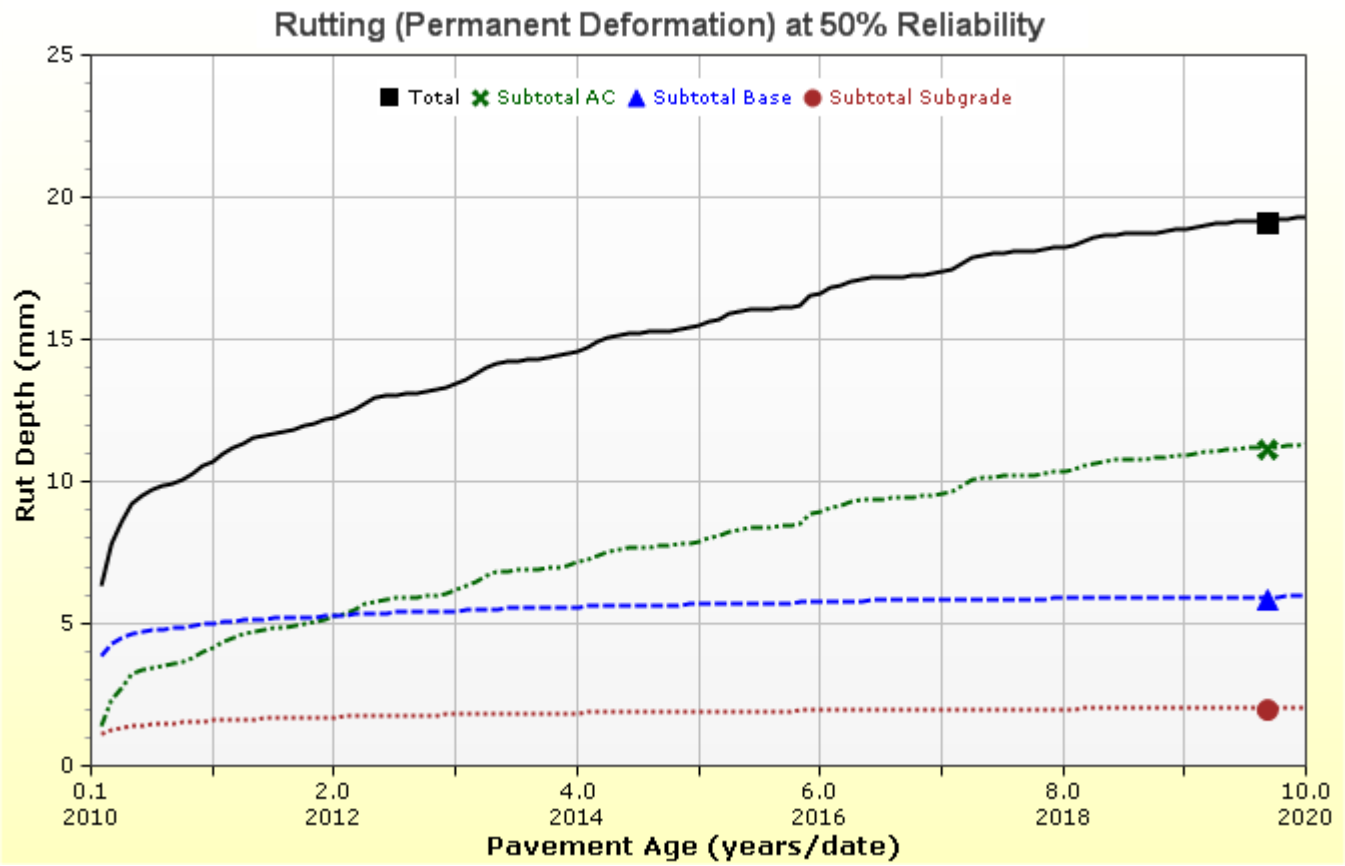


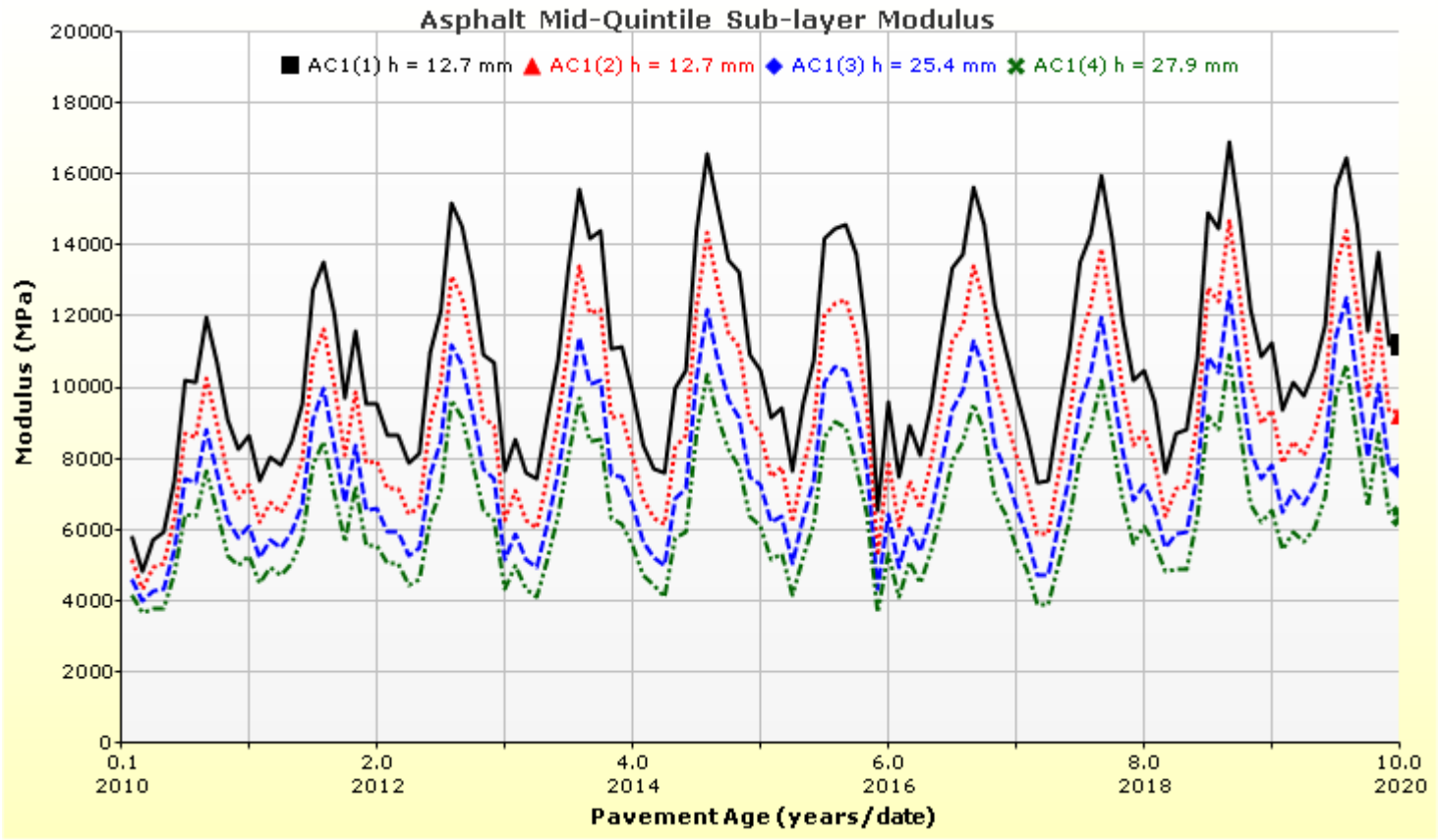

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

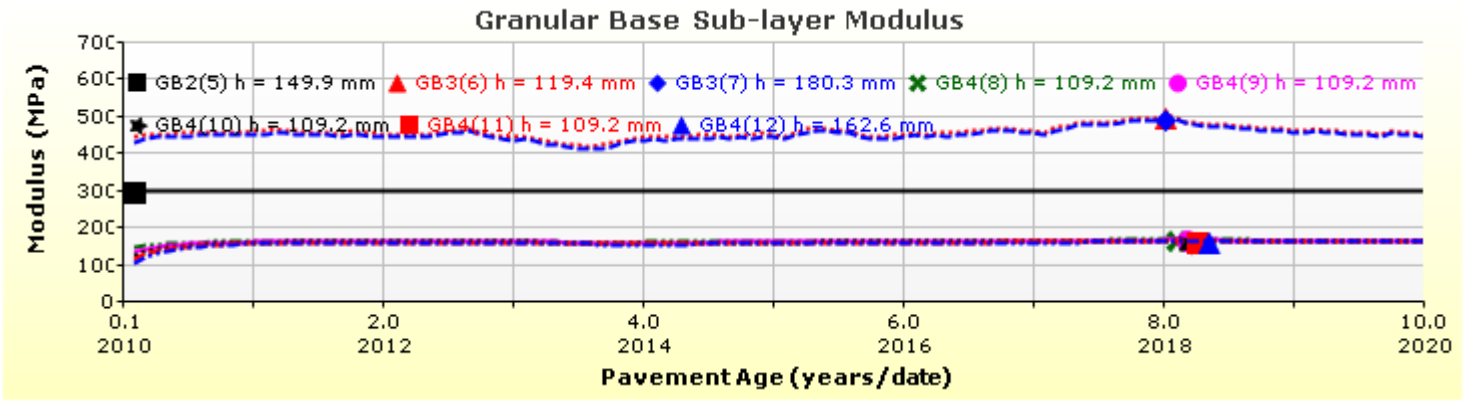

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

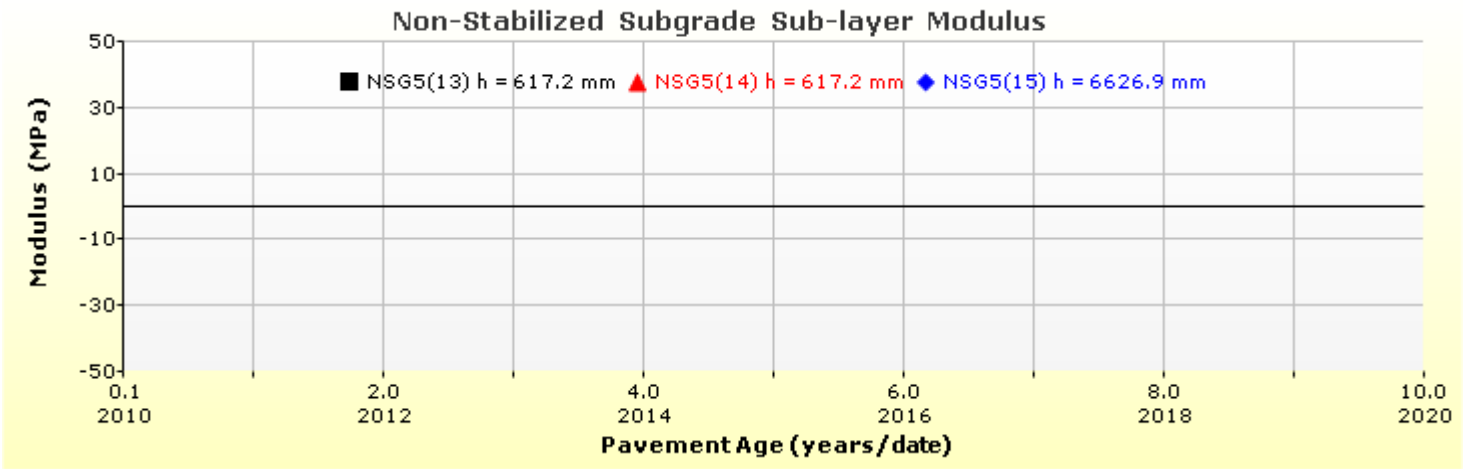

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
900
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
70
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestSP-2

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestSP-2.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -23.5, -46.62

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

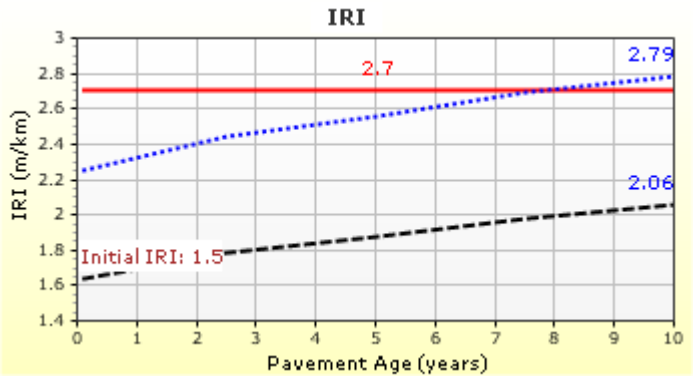
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

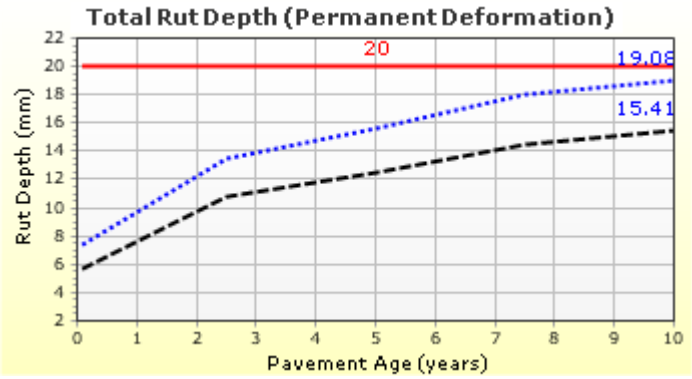
Design Outputs

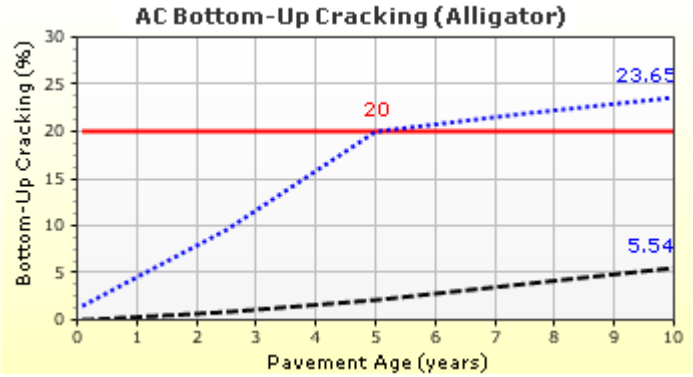
Distress Prediction Summary

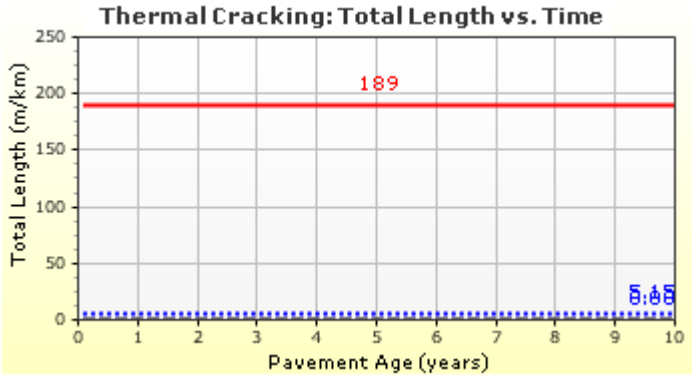
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.79	90.00	86.91	Fail
Permanent deformation - total pavement (mm)	20.00	19.07	90.00	94.58	Pass
AC bottom-up fatigue cracking (percent)	20.00	23.65	90.00	84.70	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	636.55	90.00	73.69	Fail
Permanent deformation - AC only (mm)	5.00	7.36	50.00	15.07	Fail

Distress Charts







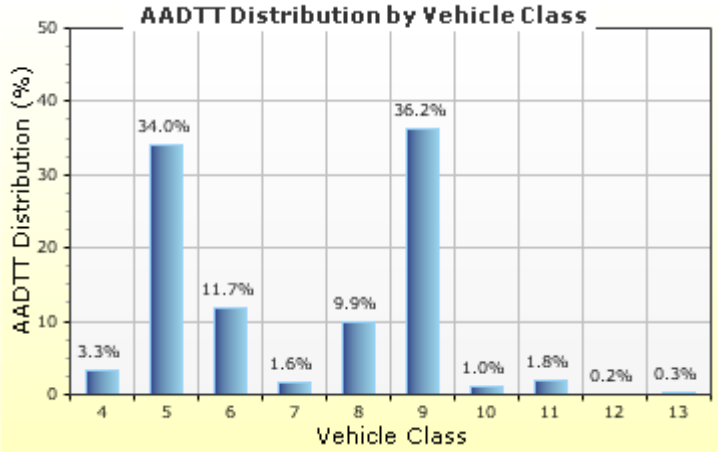


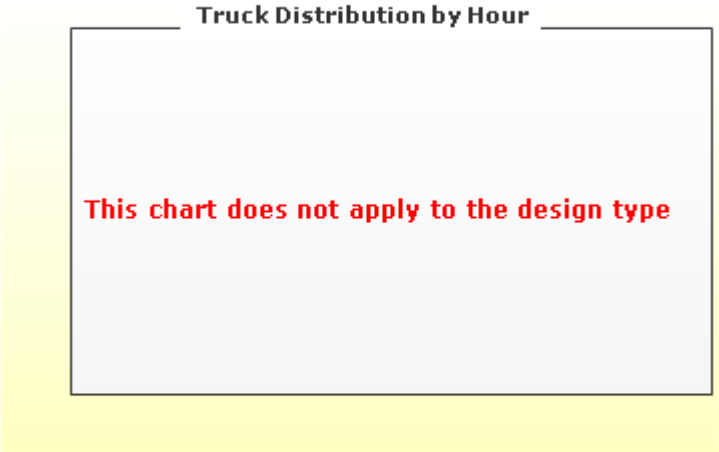


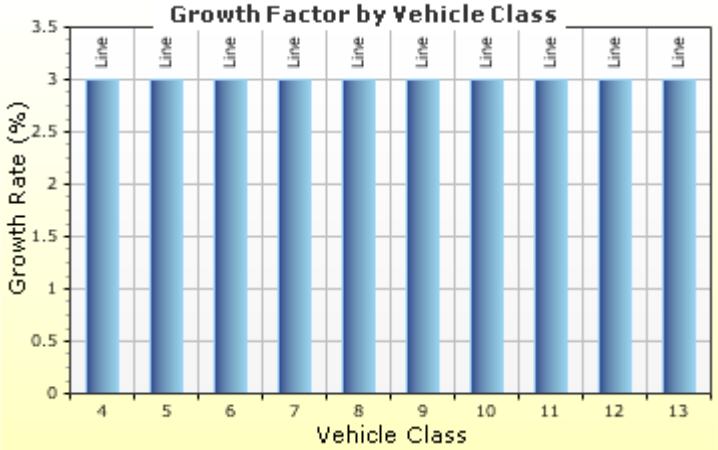
Traffic Inputs

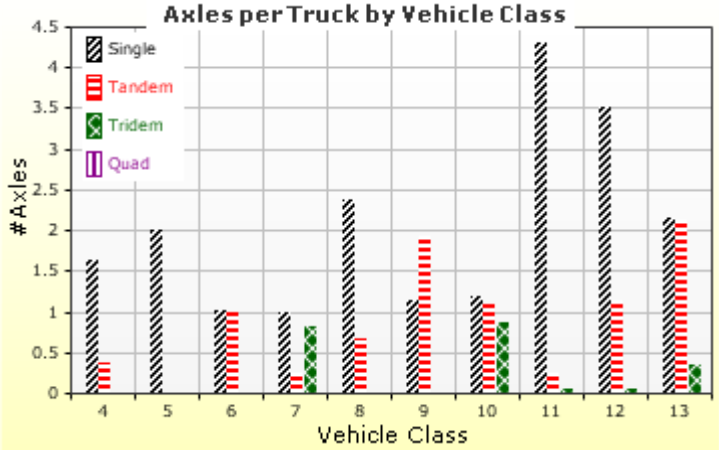
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

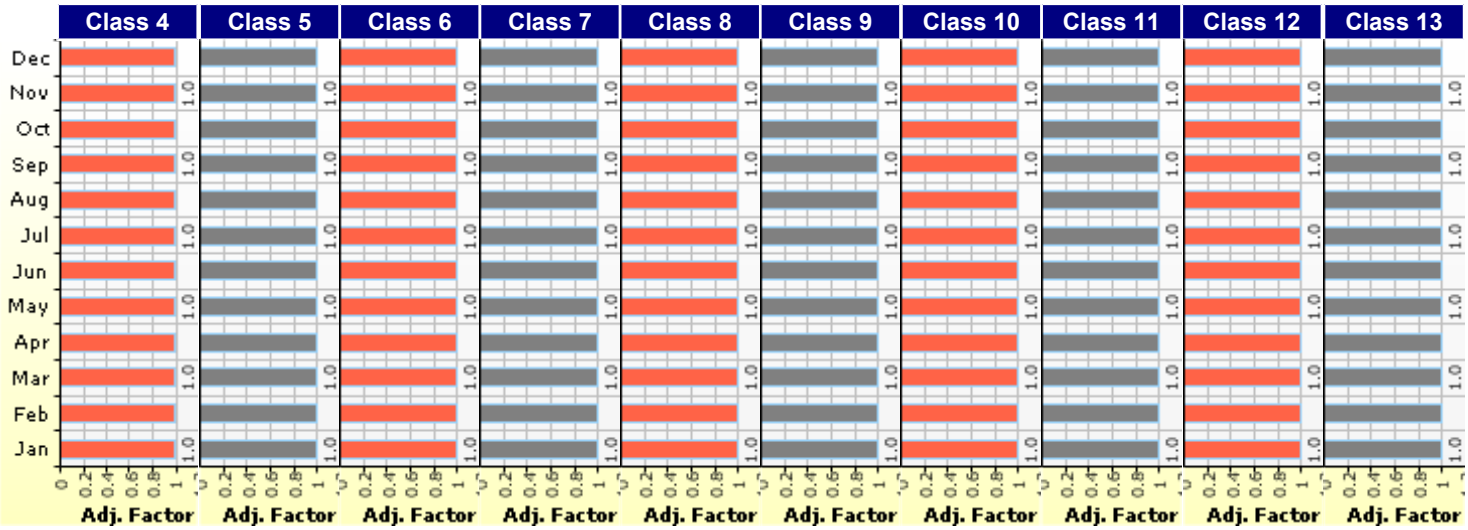








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

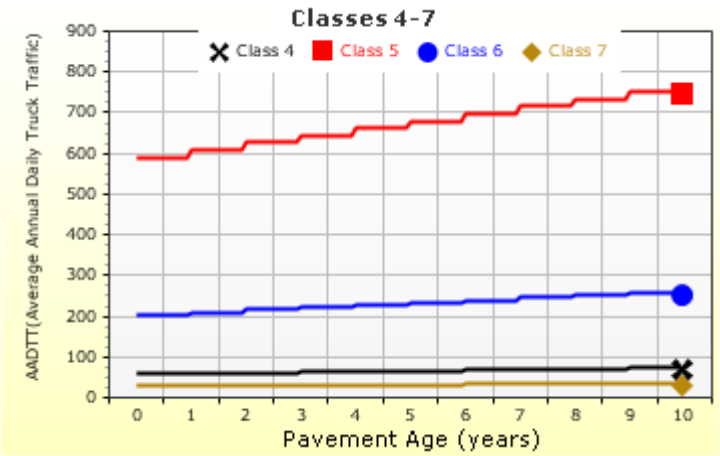
Wheelbase does not apply

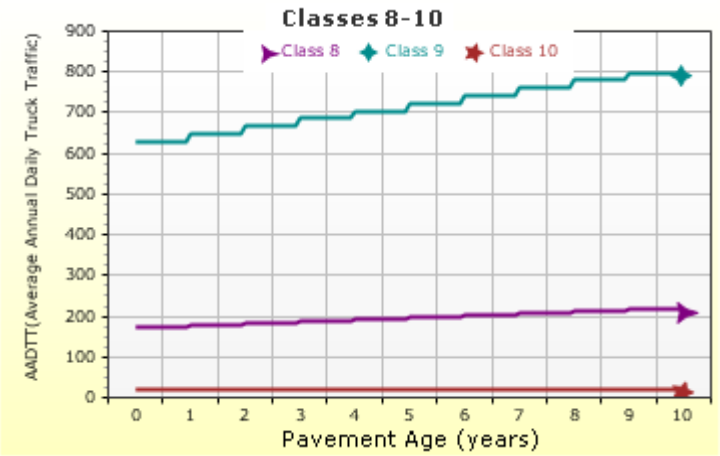
Number of Axles per Truck

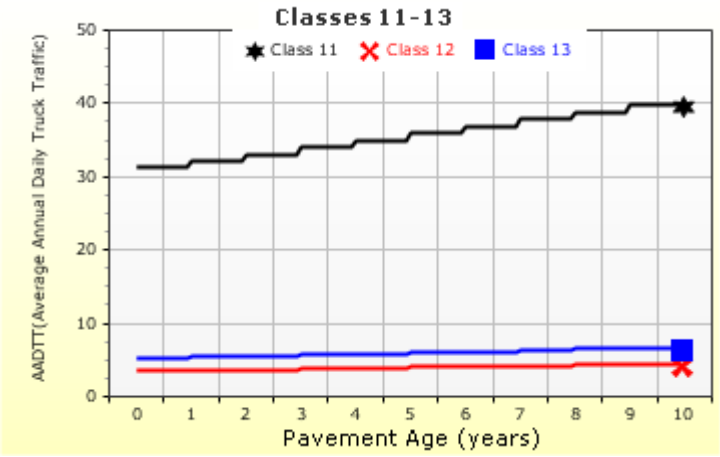
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

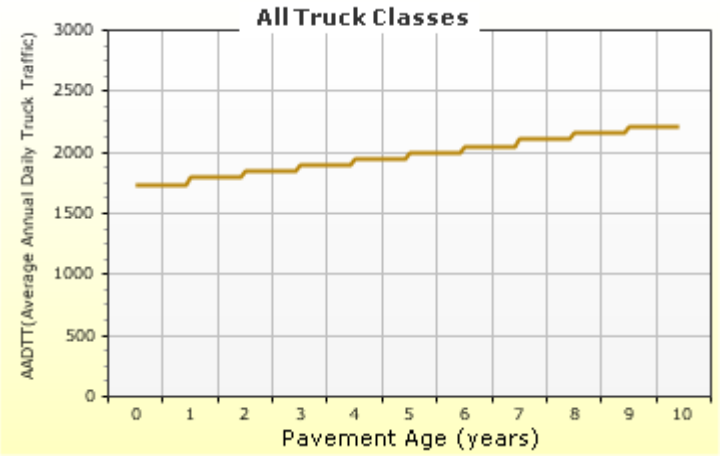
AADTT (Average Annual Daily Truck Traffic) Growth

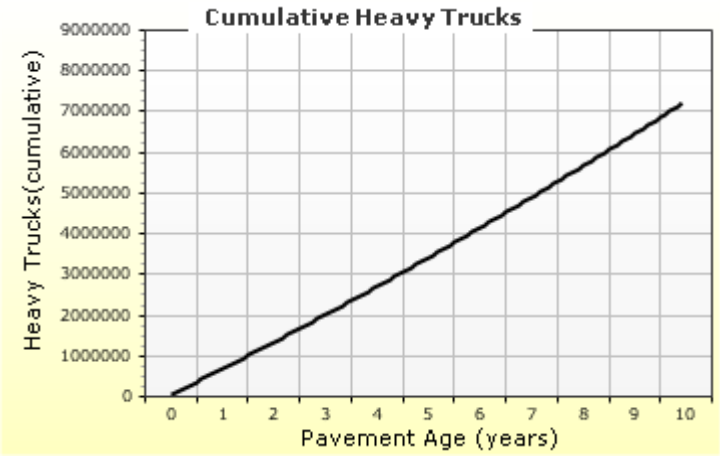
*** Traffic cap is not enforced**







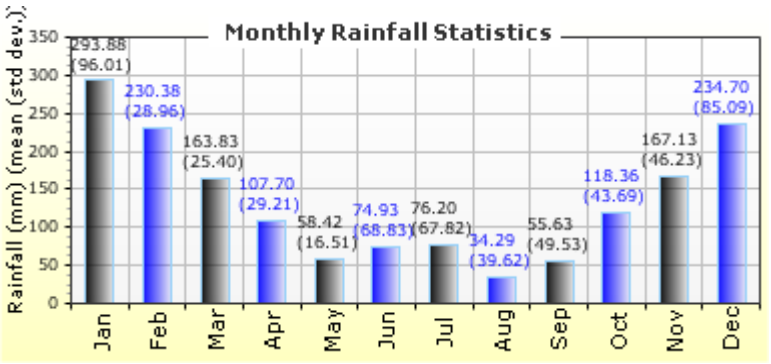




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
SAO PAULO, SP	-23.50000 -46.62000 792

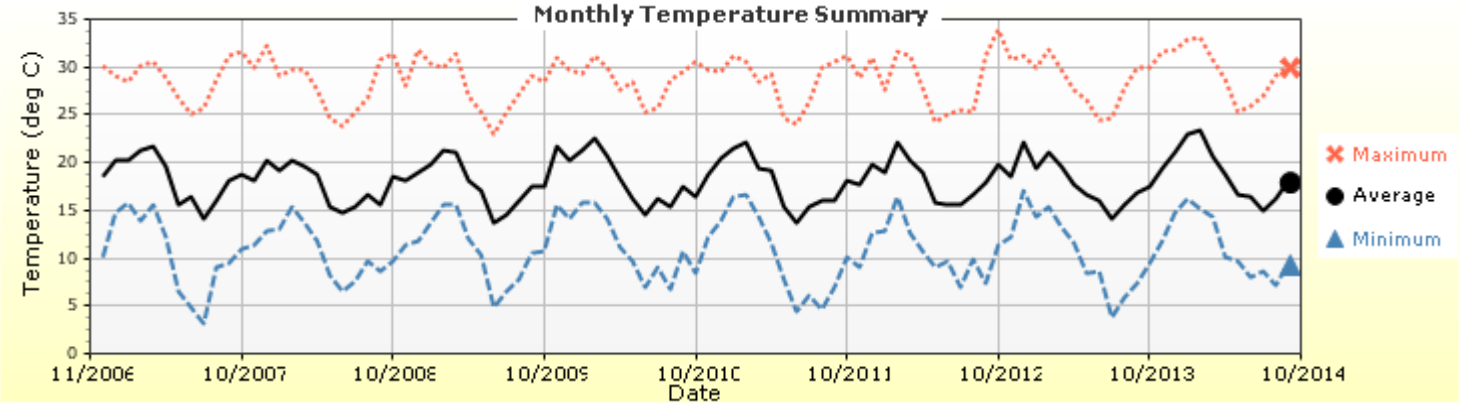


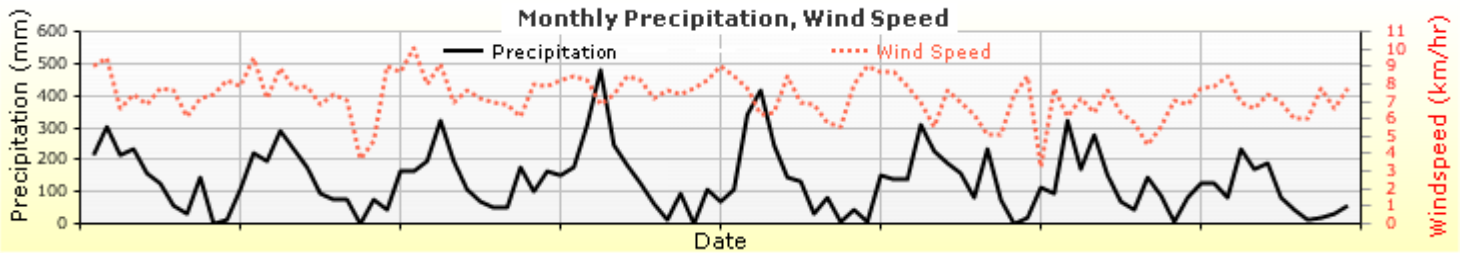
Annual Statistics:

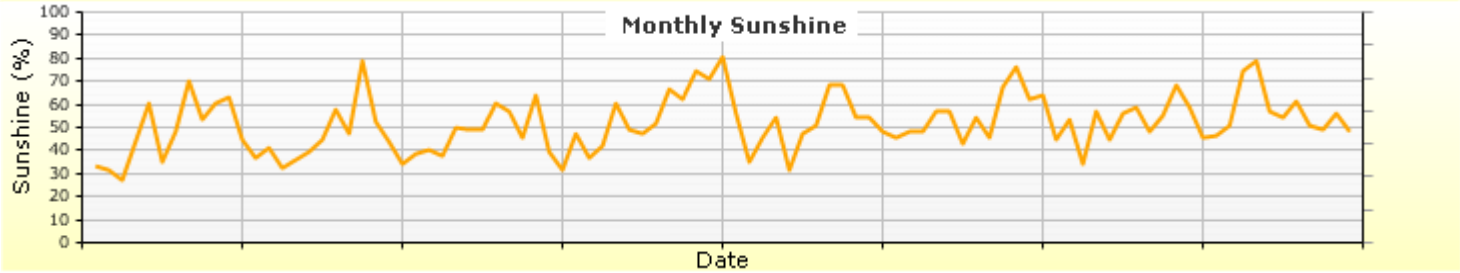
Mean annual air temperature (ºC)	18.15
Mean annual precipitation (mm)	1628.14
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

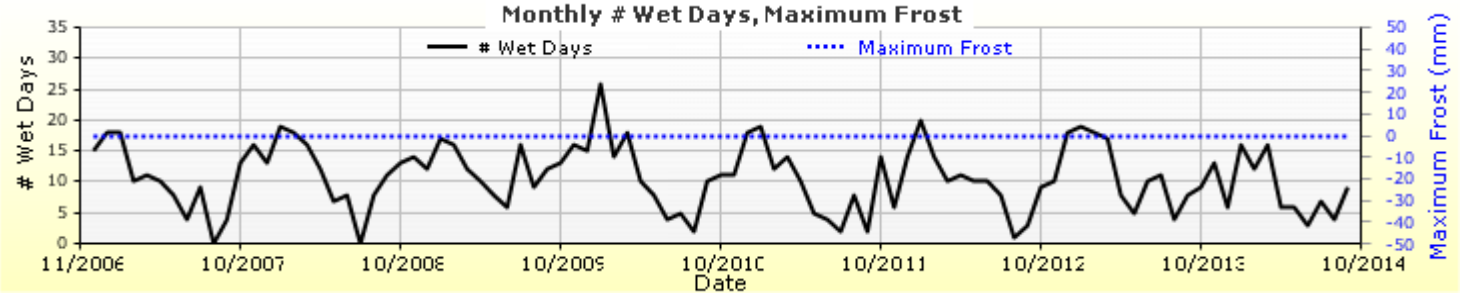
Water table depth (m)	3.05

Monthly Climate Summary:

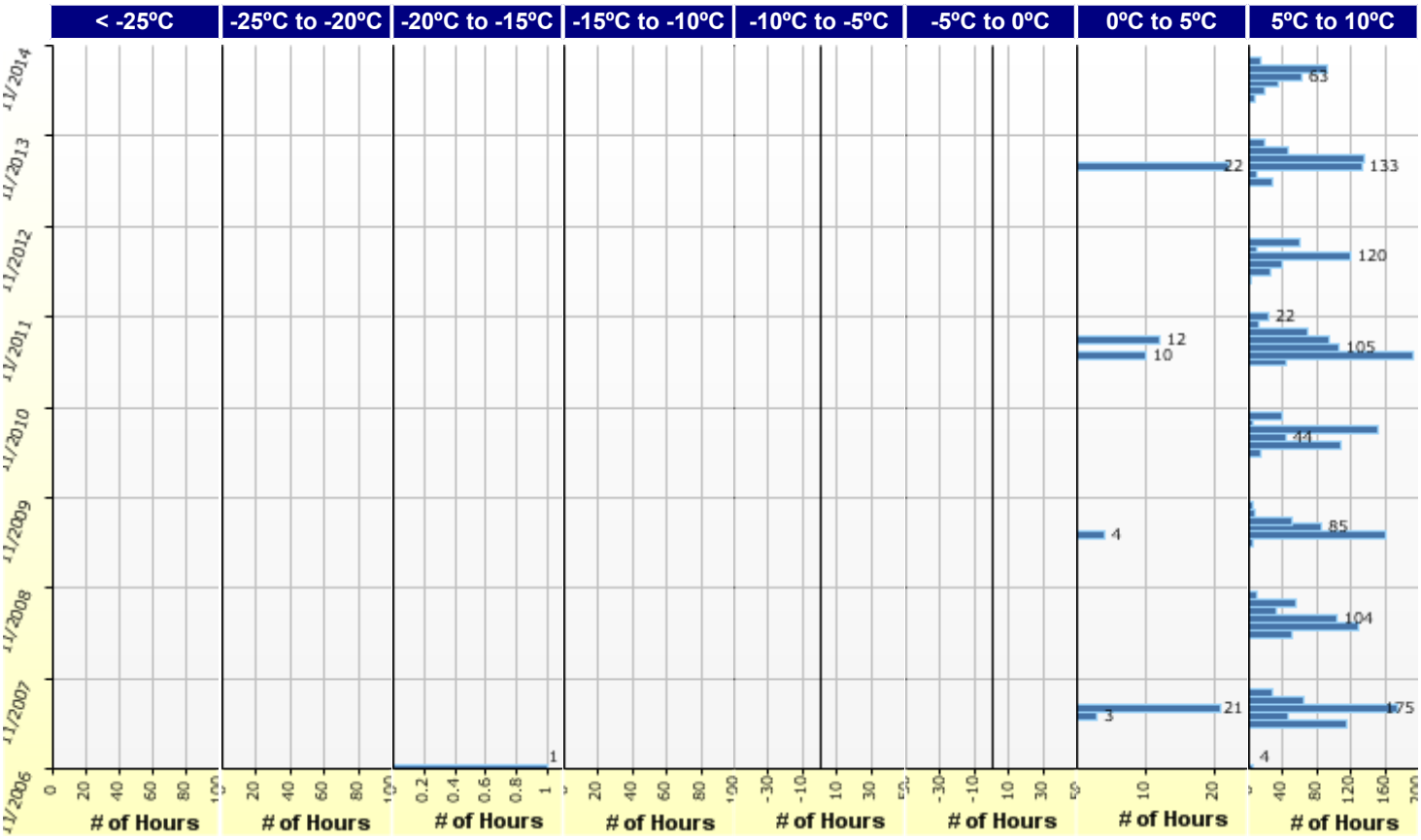


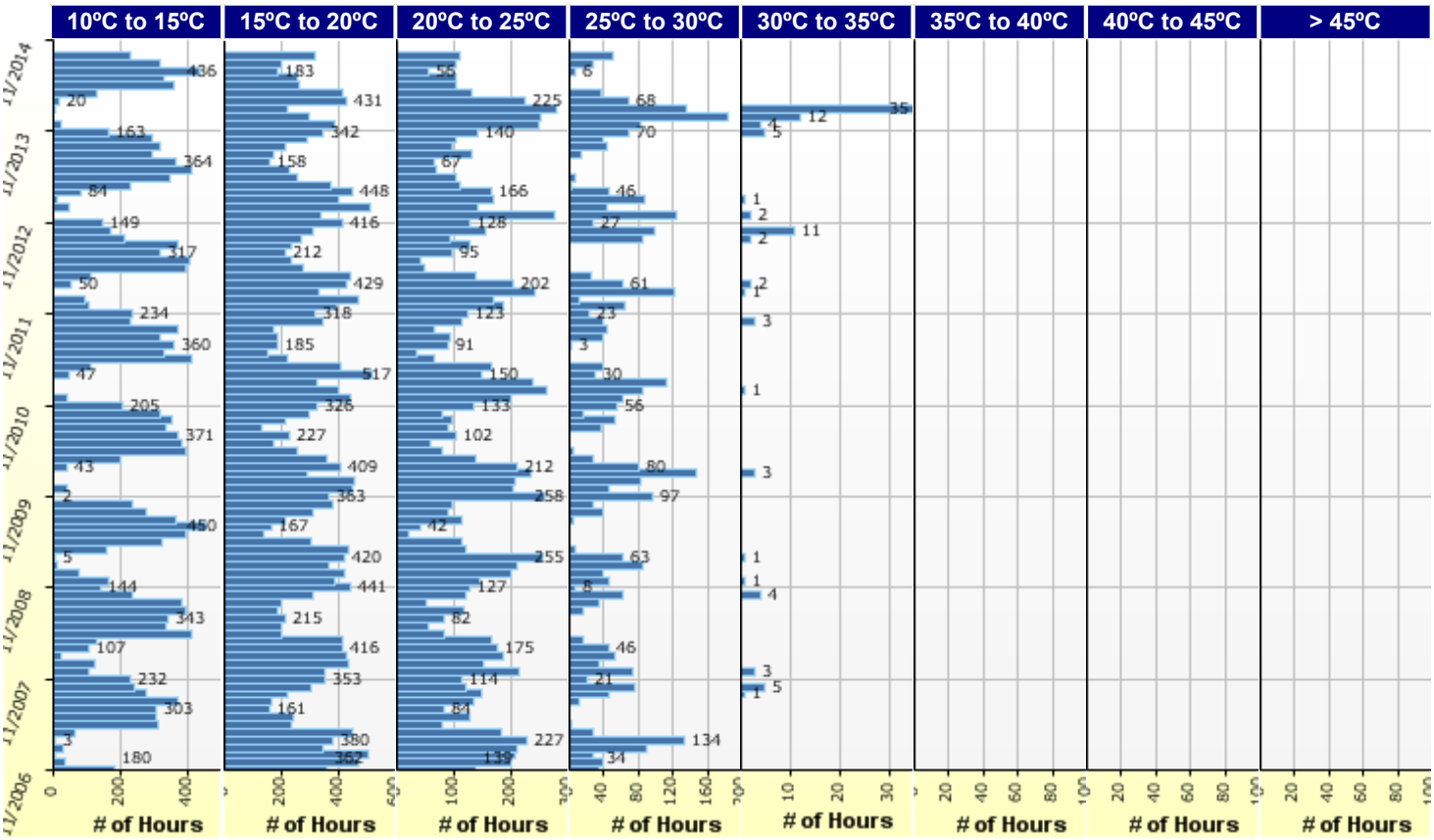






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

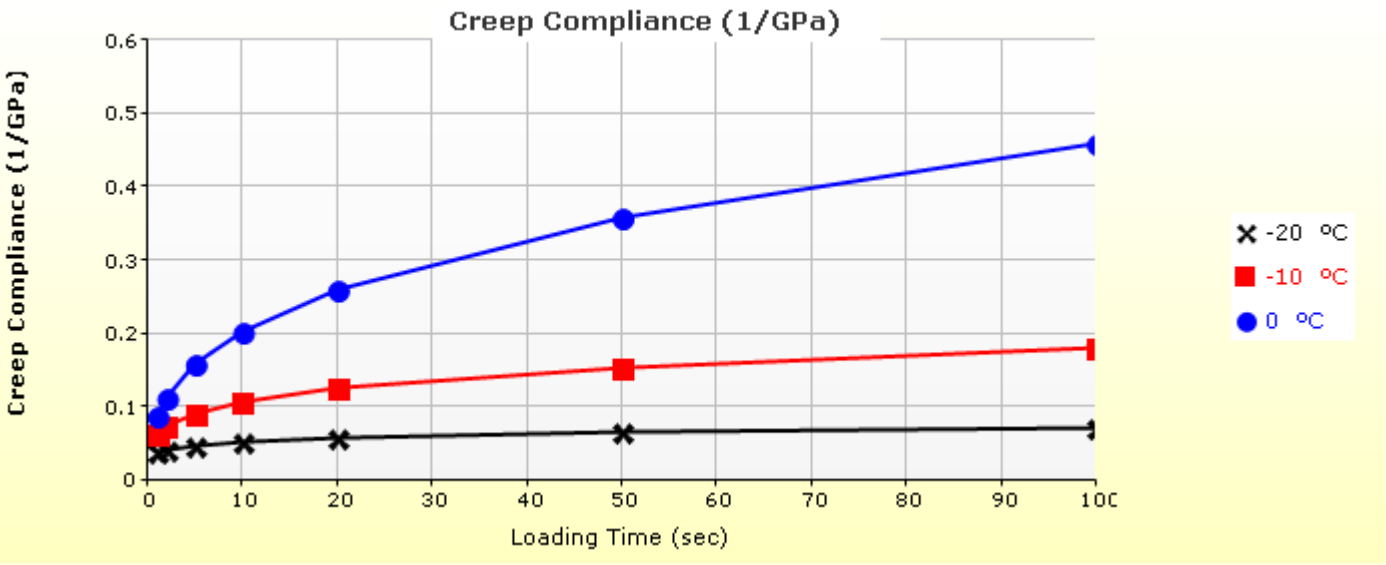
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

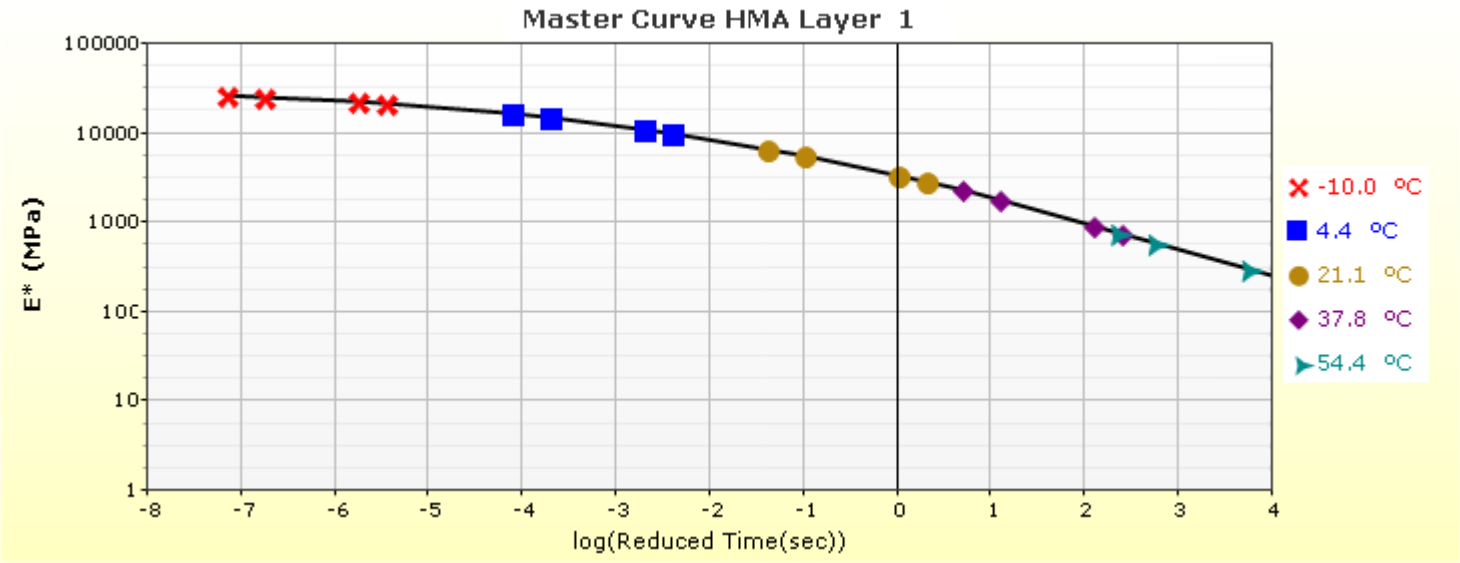
Indirect tensile strength at -10 ºC (MPa)	2.69

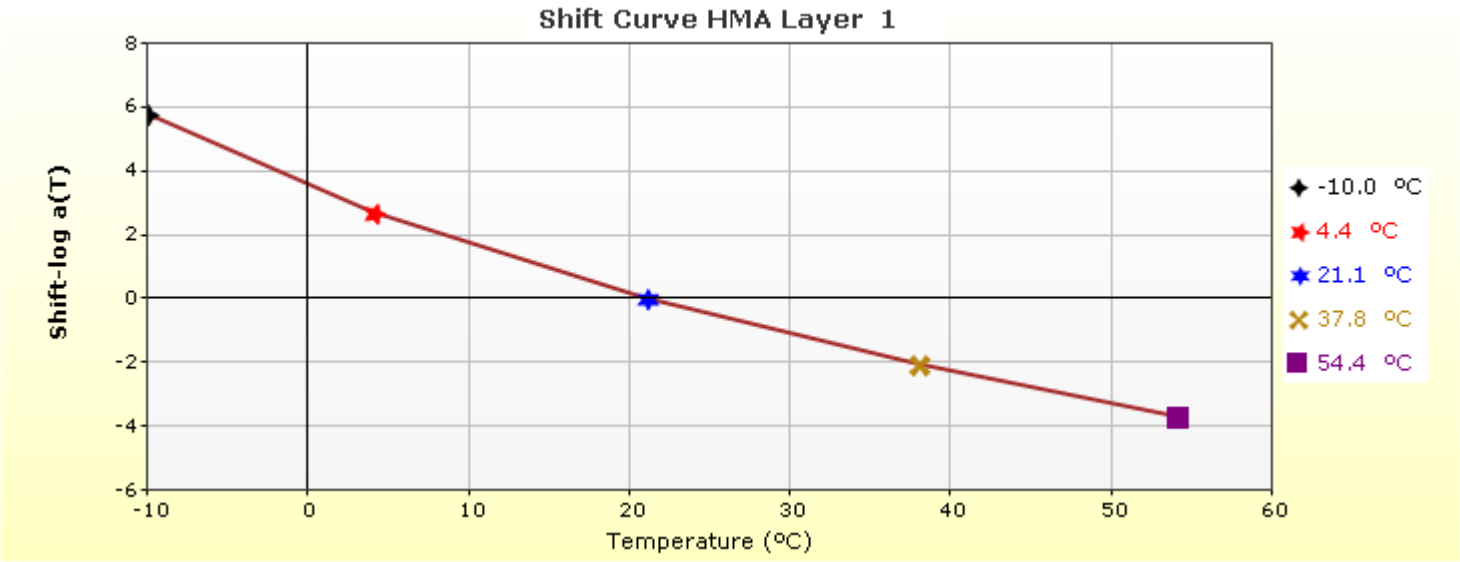
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

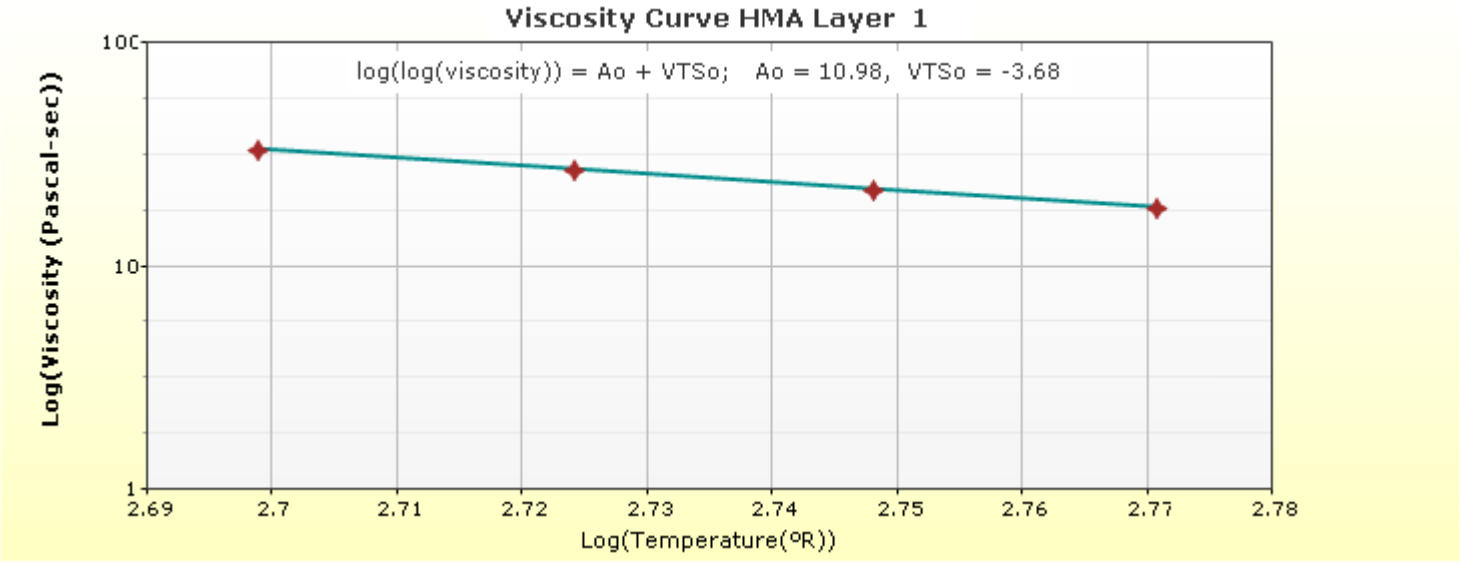
	Creep Compliance (1/GPa)		
Loading time (sec)	**-20 ºC**	**-10 ºC**	**0 ºC**
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



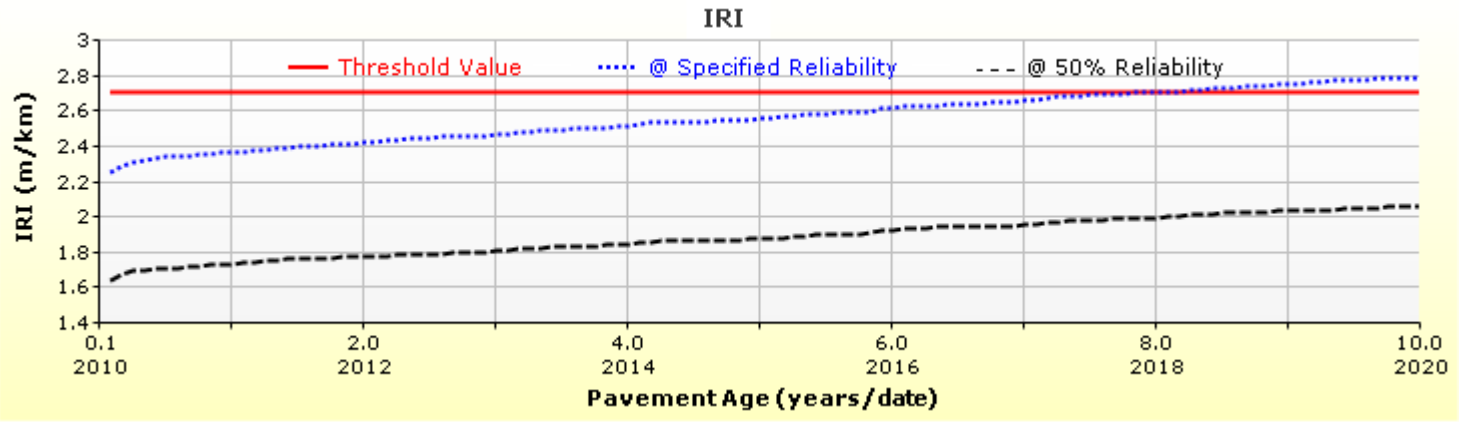
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

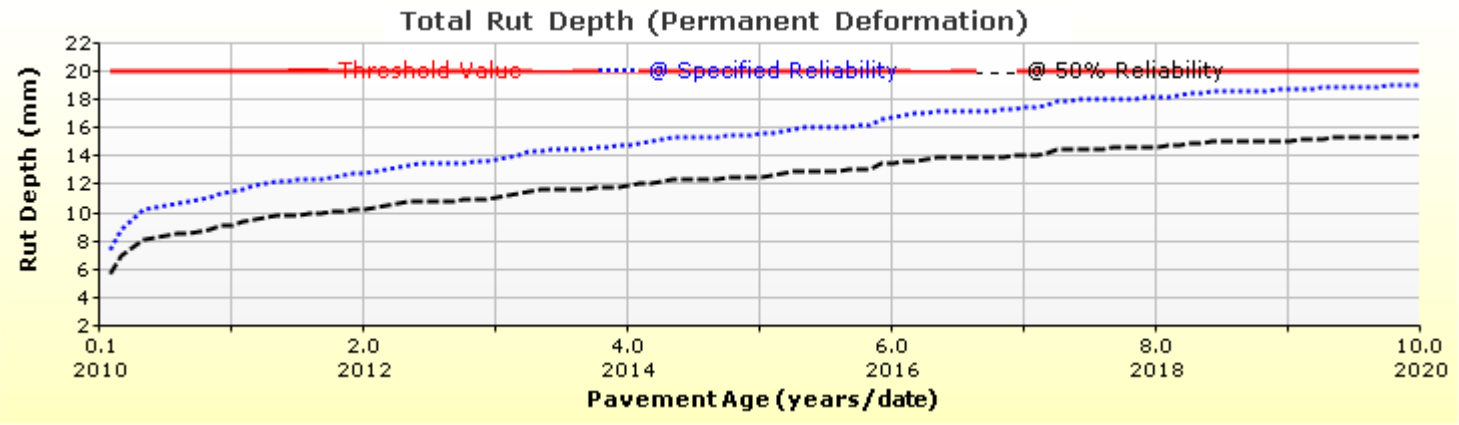


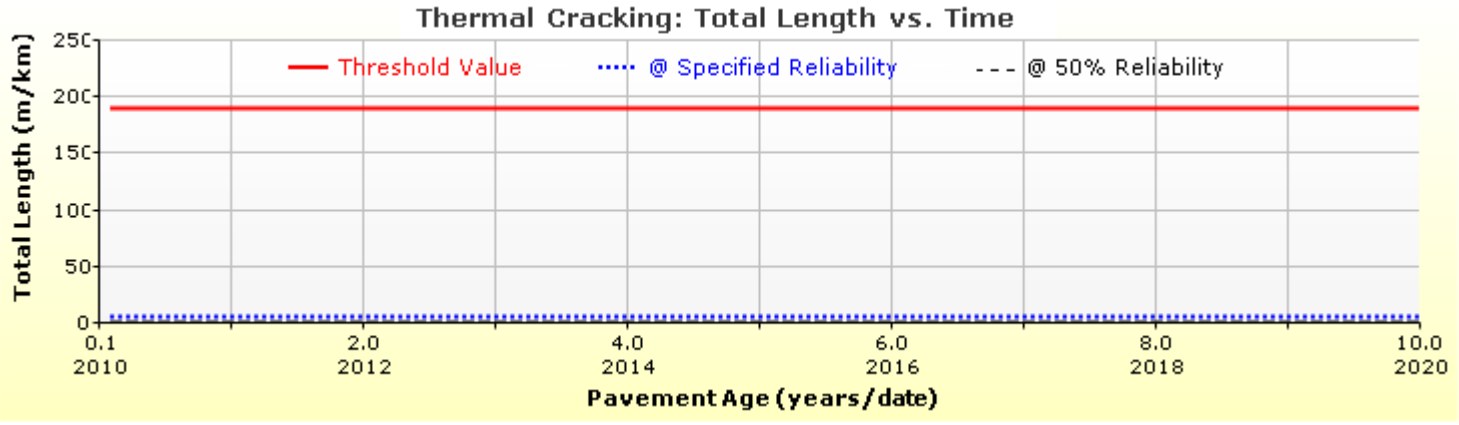


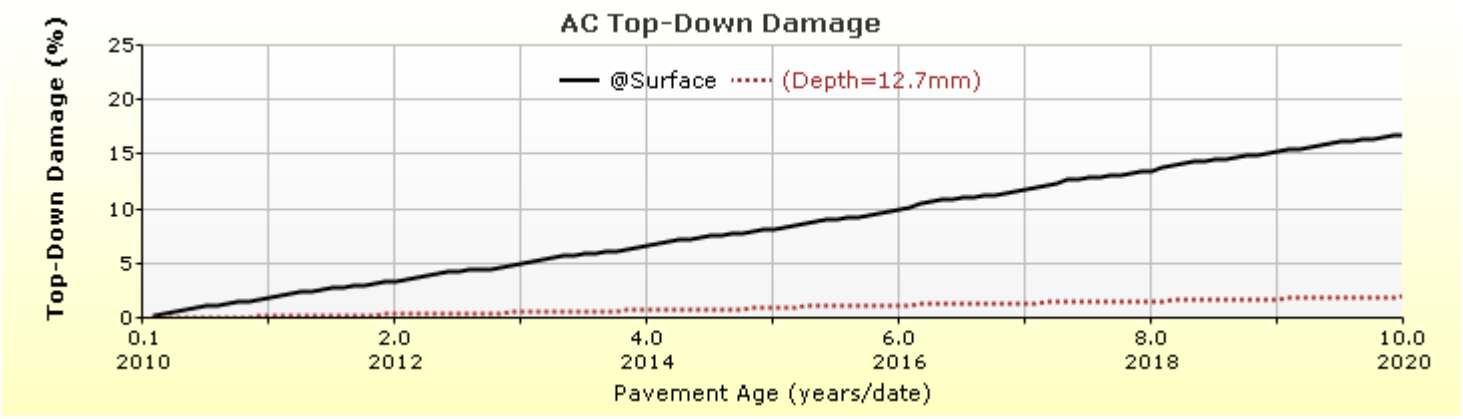


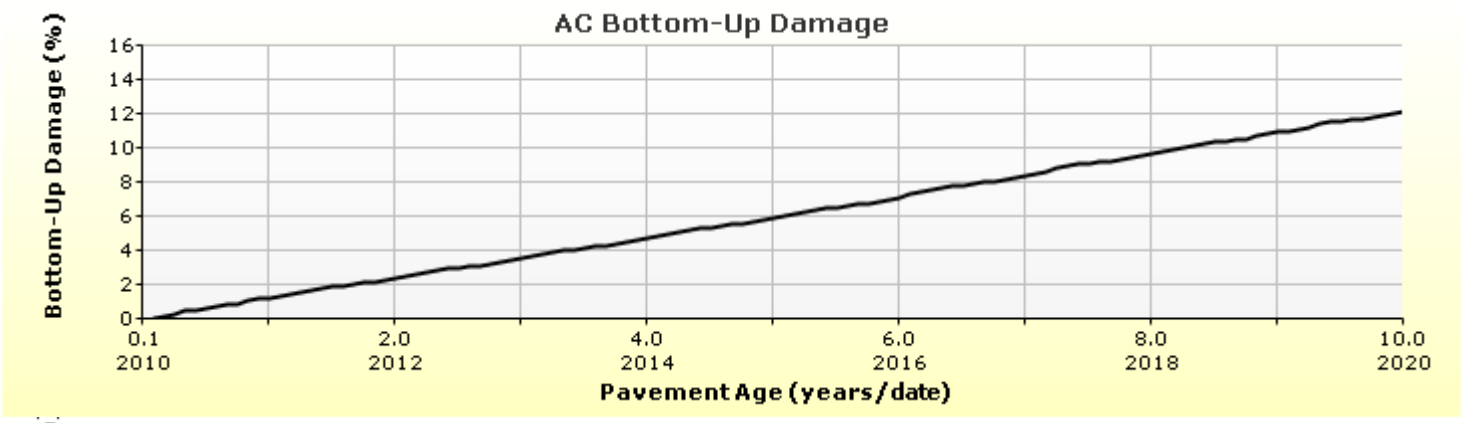
Analysis Output Charts

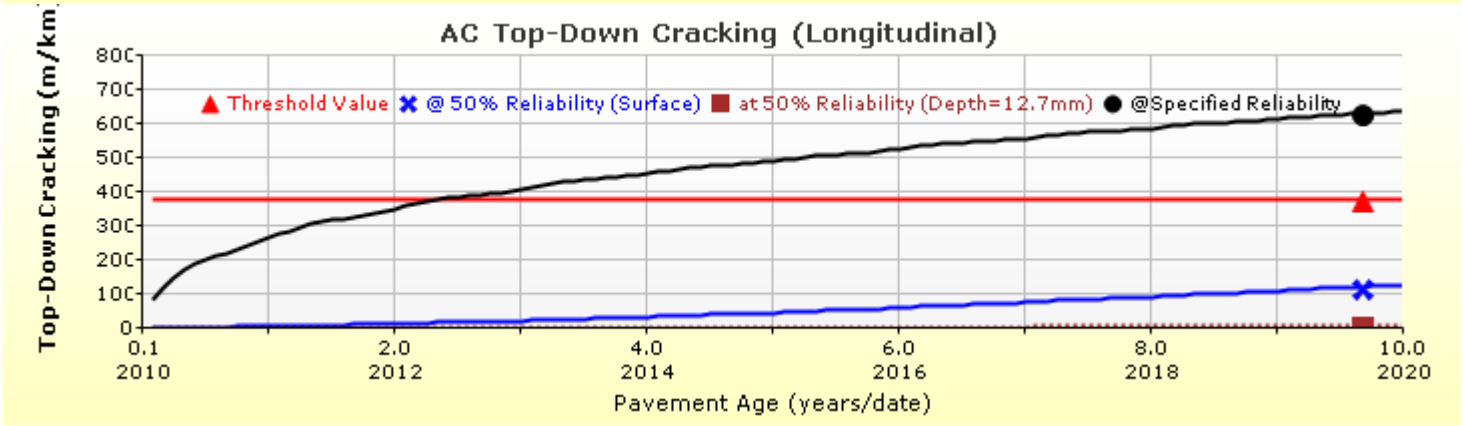


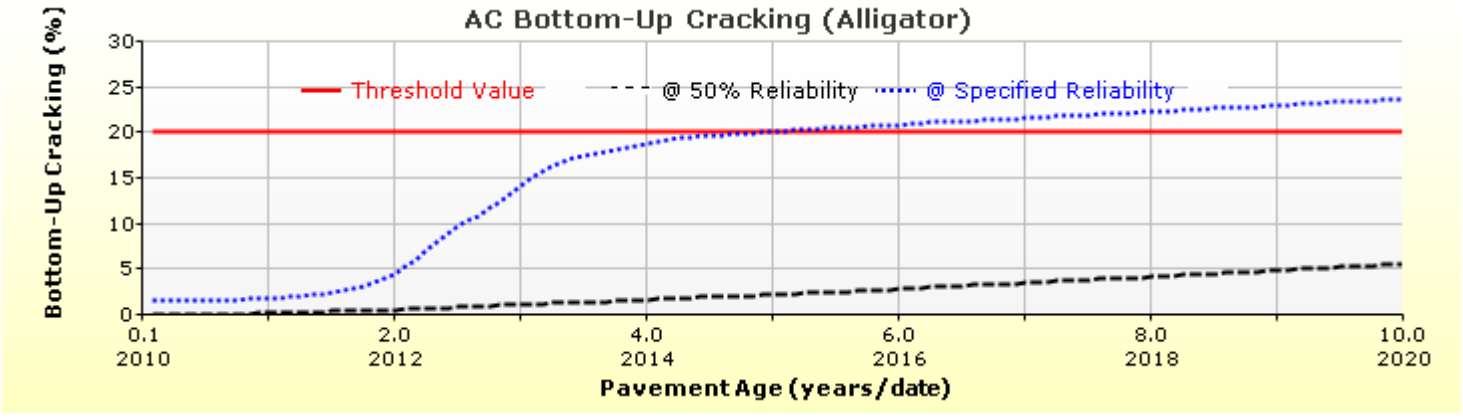


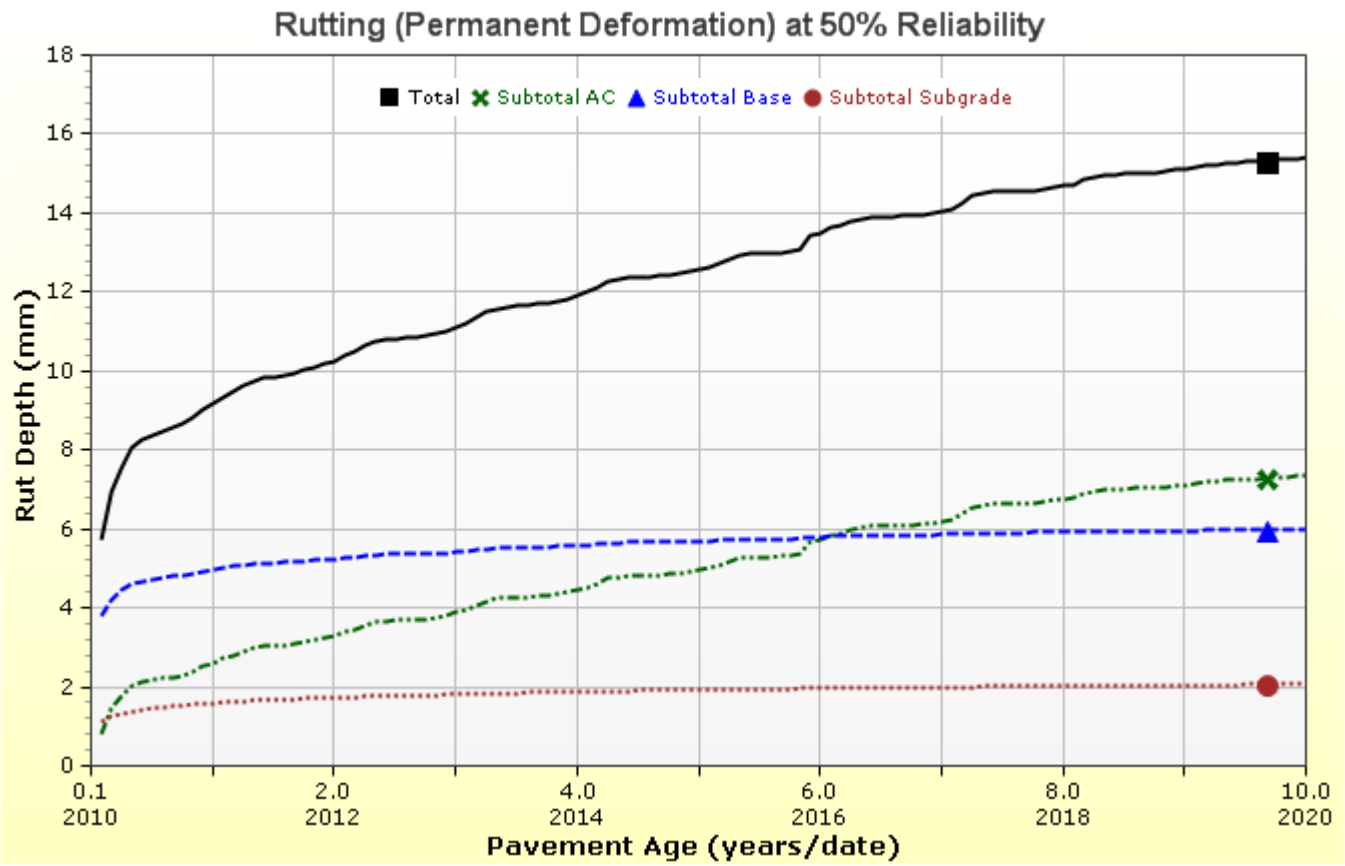


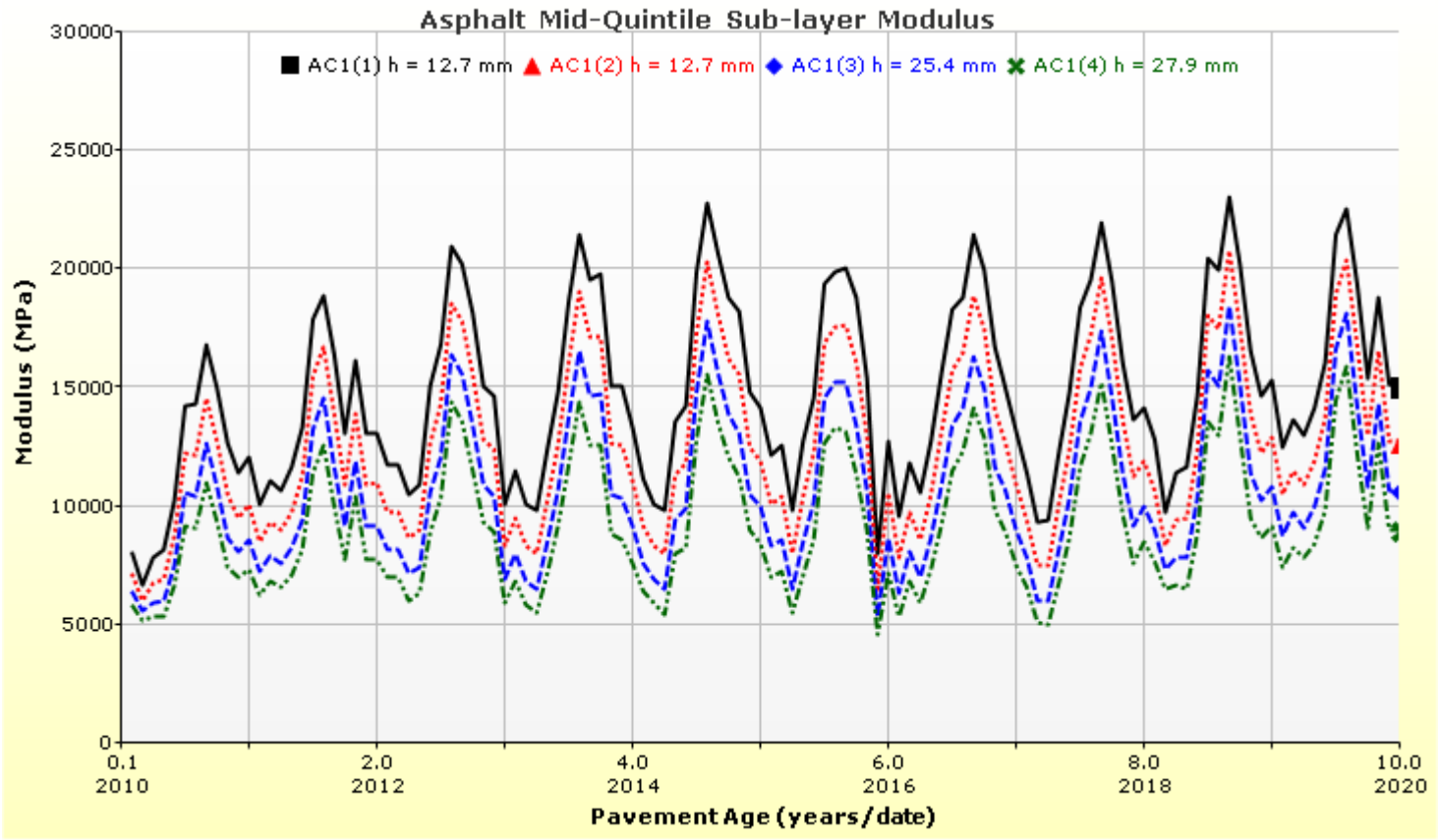

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

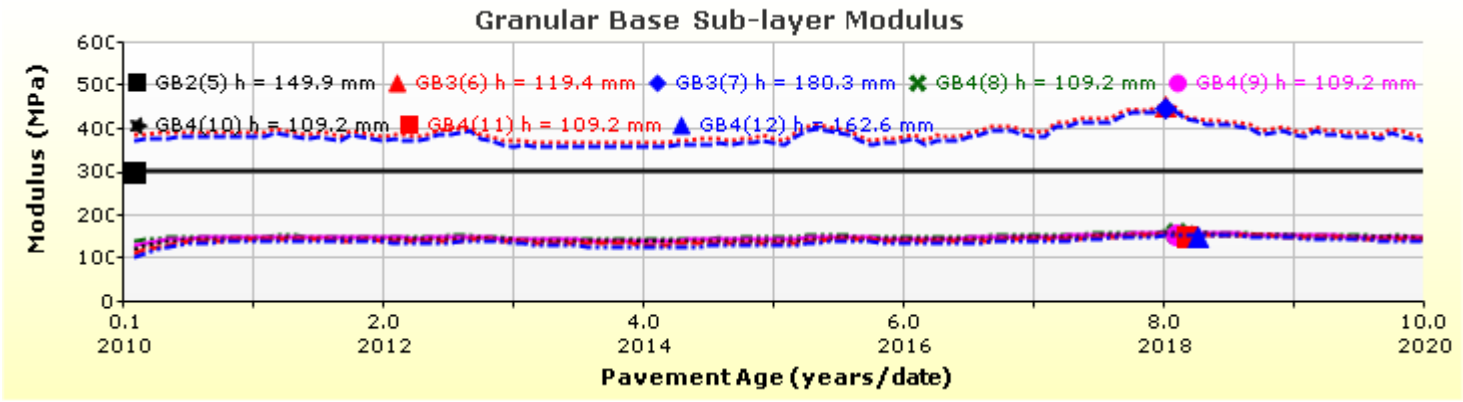

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

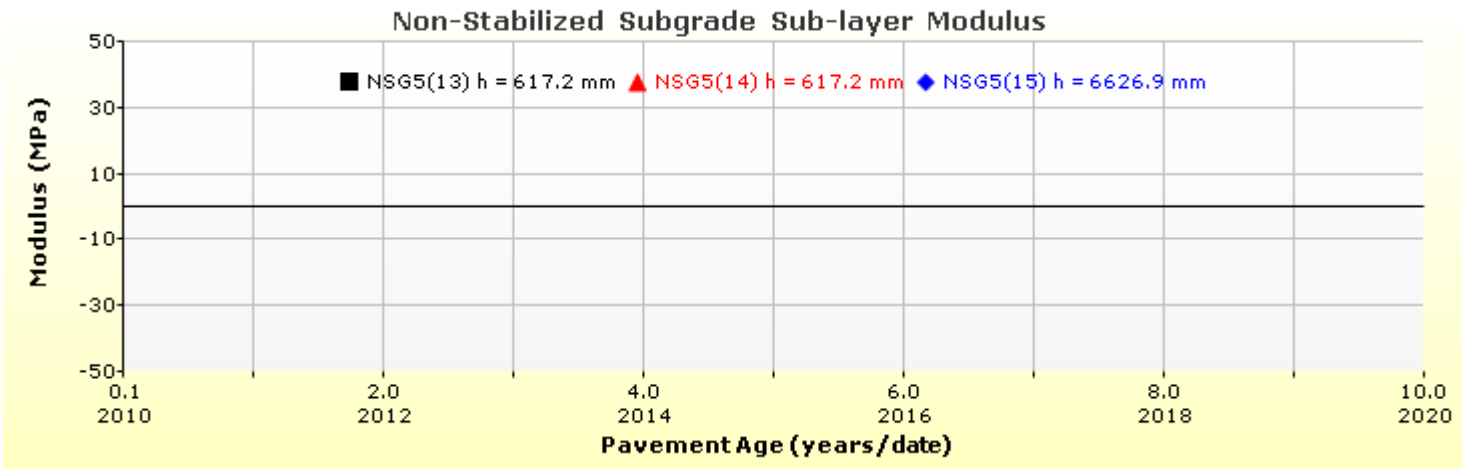

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2\beta_{r2}} N^{k_3 B_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left({}^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left({}^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestSP-4

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestSP-4.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -23.5, -46.62

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

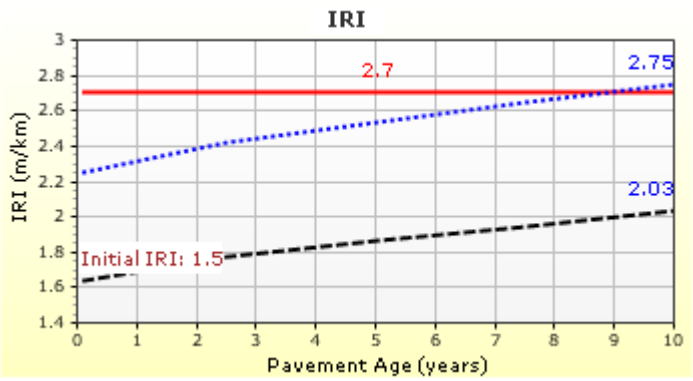
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

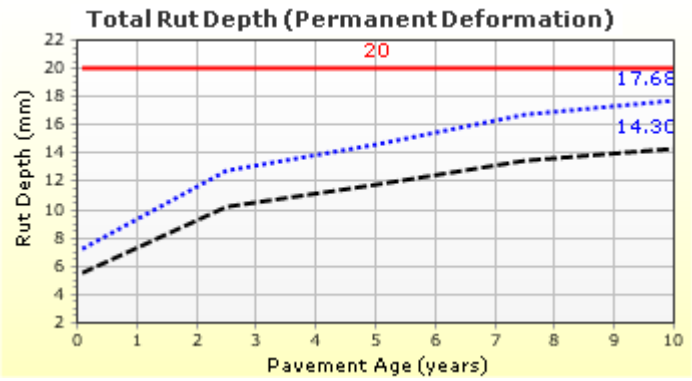
Design Outputs

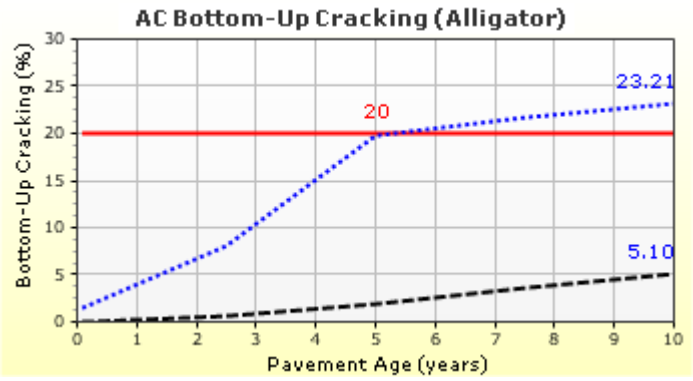
Distress Prediction Summary

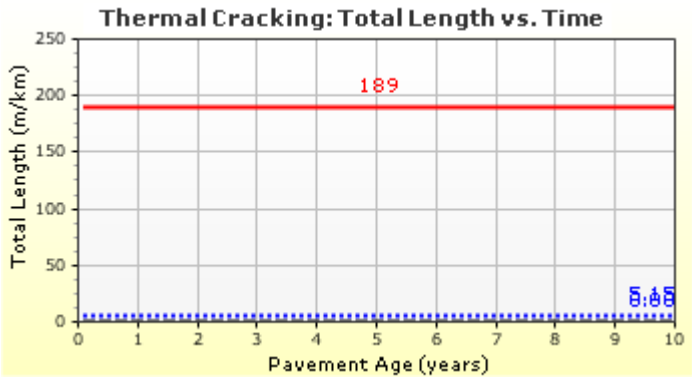
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.75	90.00	88.29	Fail
Permanent deformation - total pavement (mm)	20.00	17.69	90.00	98.44	Pass
AC bottom-up fatigue cracking (percent)	20.00	23.21	90.00	85.42	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	613.30	90.00	75.29	Fail
Permanent deformation - AC only (mm)	5.00	6.28	50.00	26.27	Fail

Distress Charts







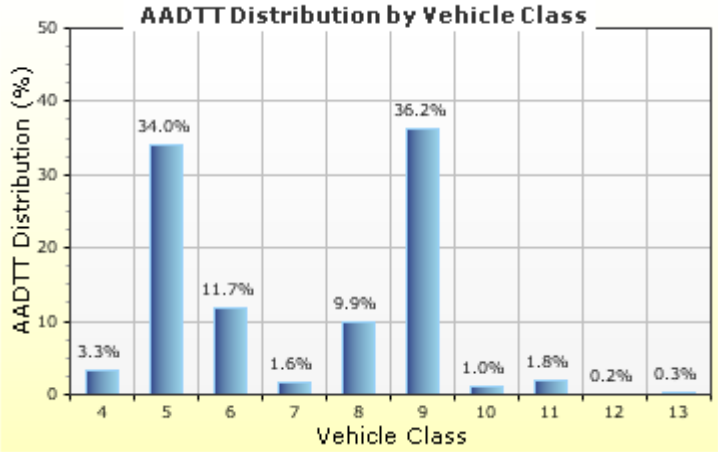


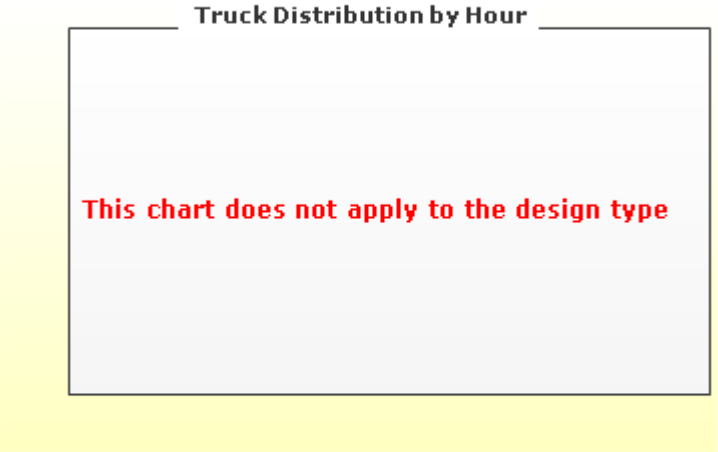
Threshold Value ····· @ Specified Reliability - - - @ 50% Reliability

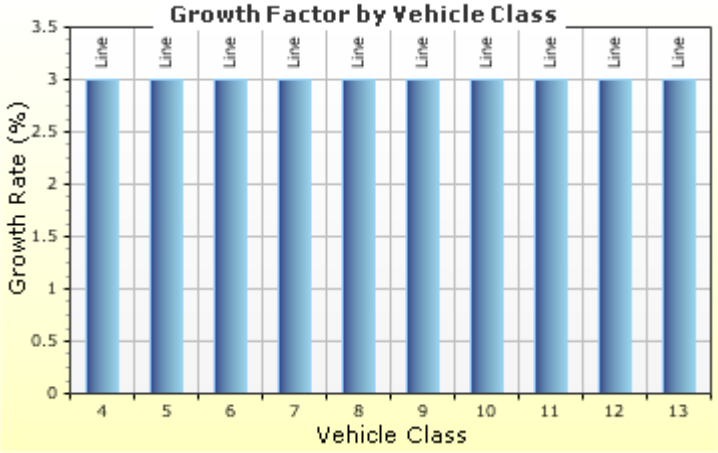
Traffic Inputs

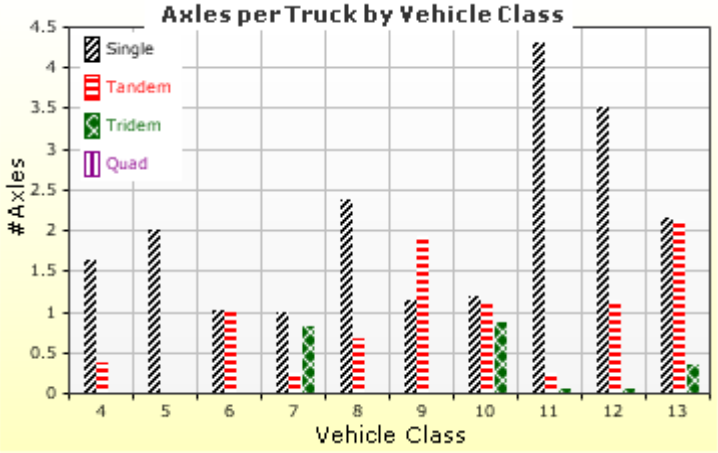
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

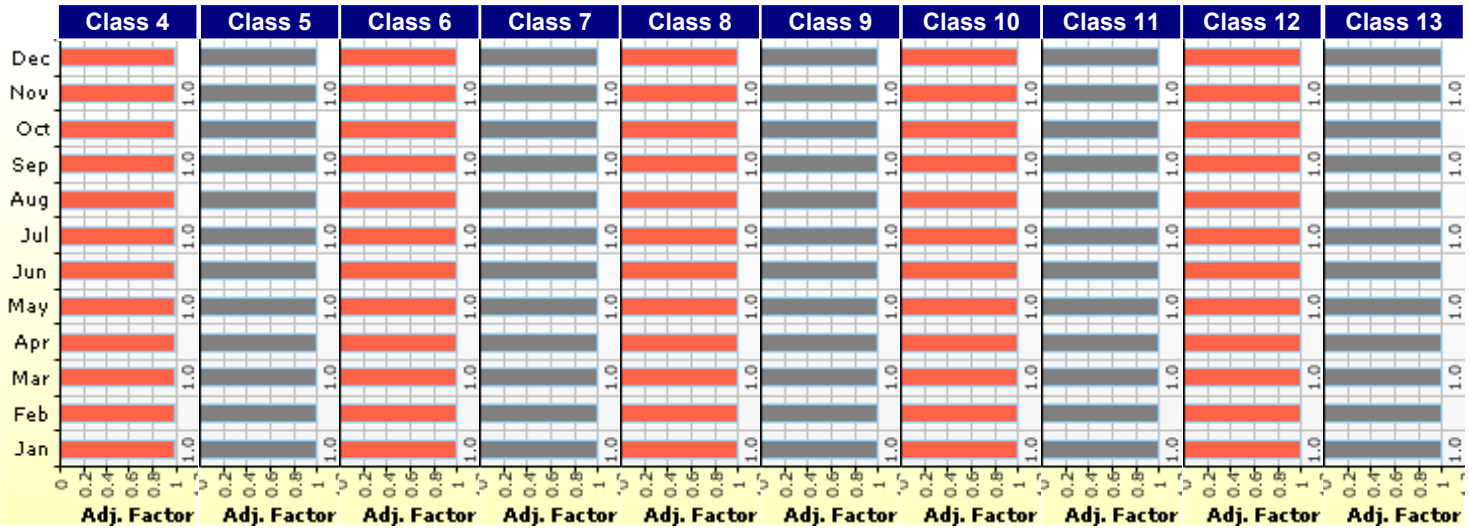








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

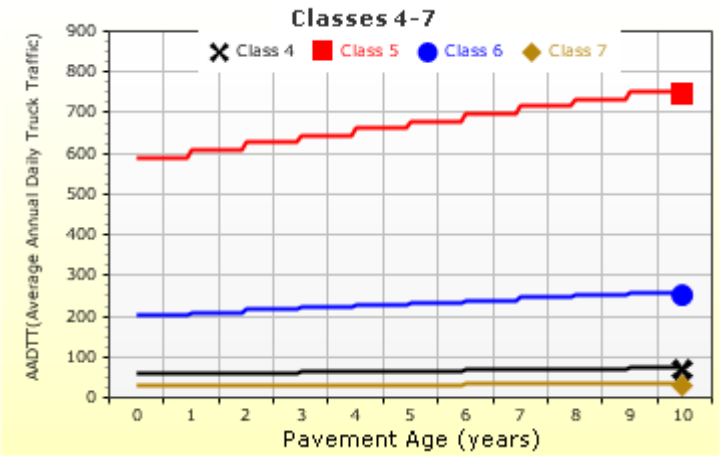
Wheelbase does not apply

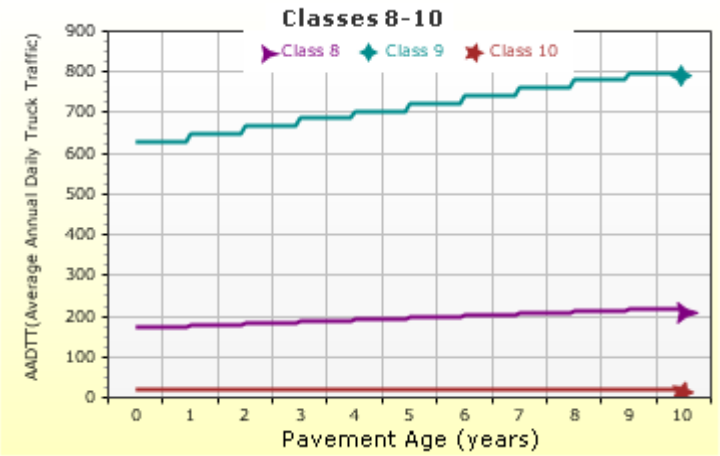
Number of Axles per Truck

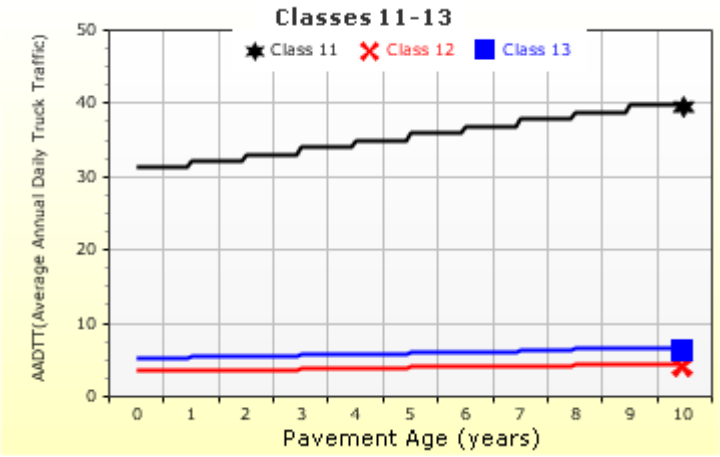
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

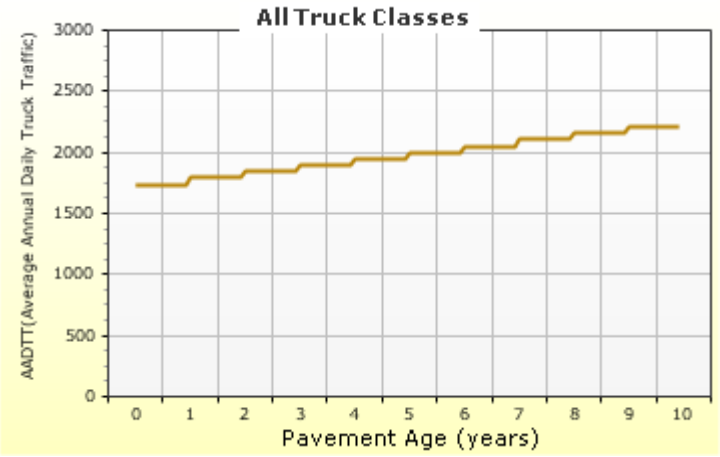
AADTT (Average Annual Daily Truck Traffic) Growth

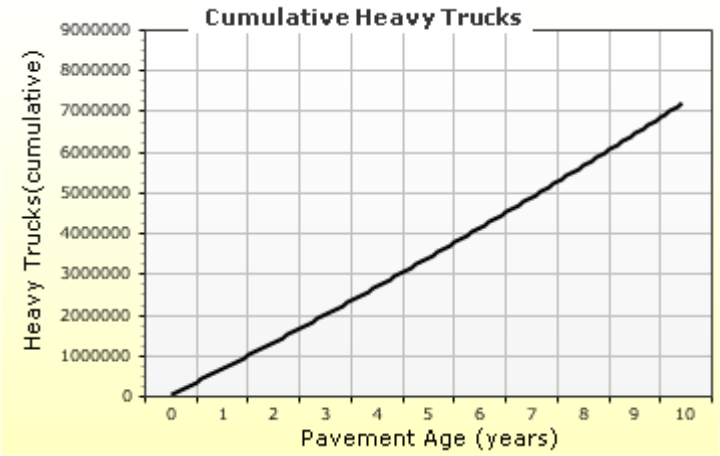
*** Traffic cap is not enforced**







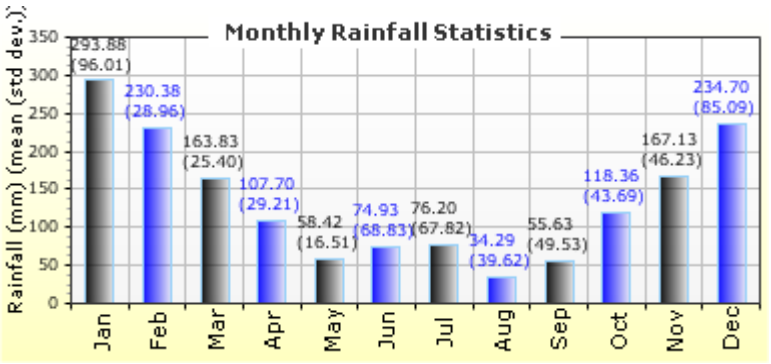




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
SAO PAULO, SP	-23.50000 -46.62000 792

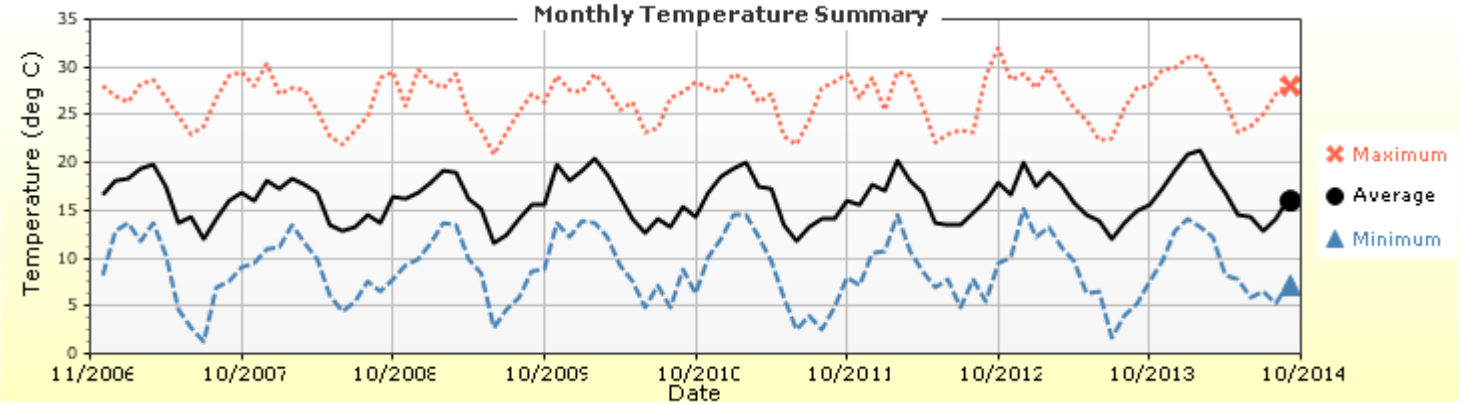


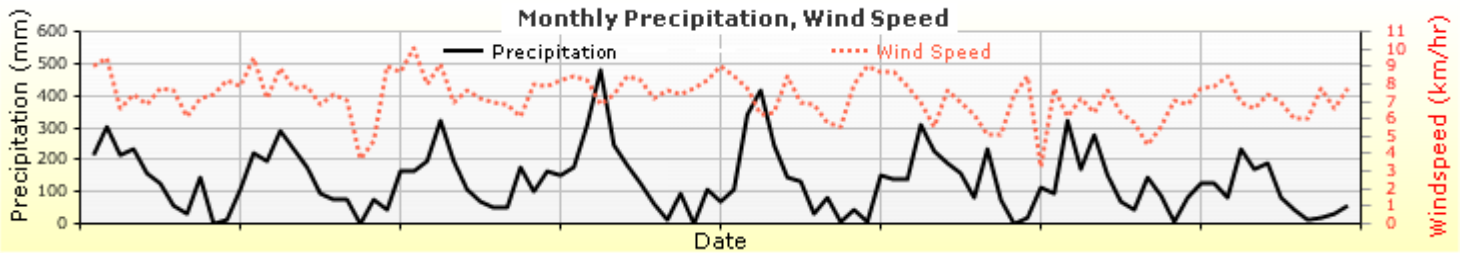
Annual Statistics:

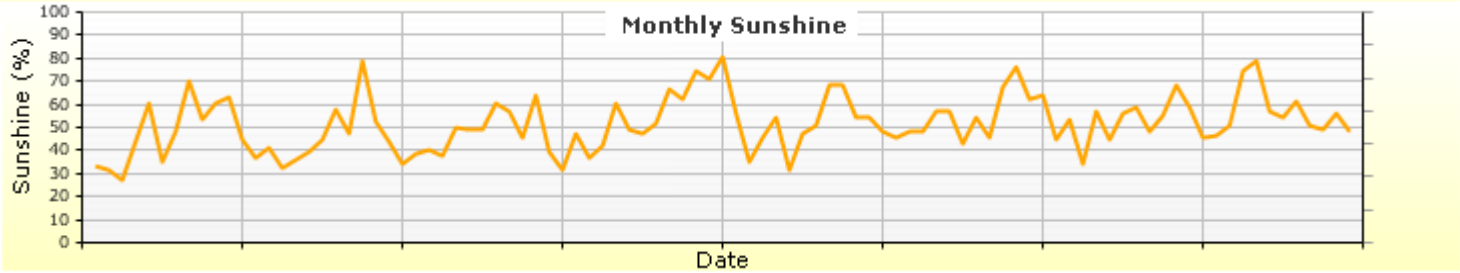
Mean annual air temperature (ºC)	16.15
Mean annual precipitation (mm)	1628.14
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

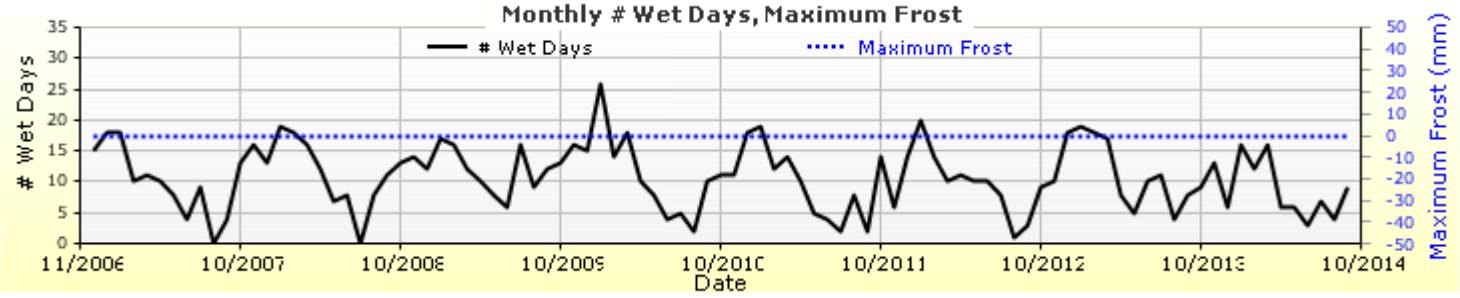
Water table depth (m): 3.05

Monthly Climate Summary:

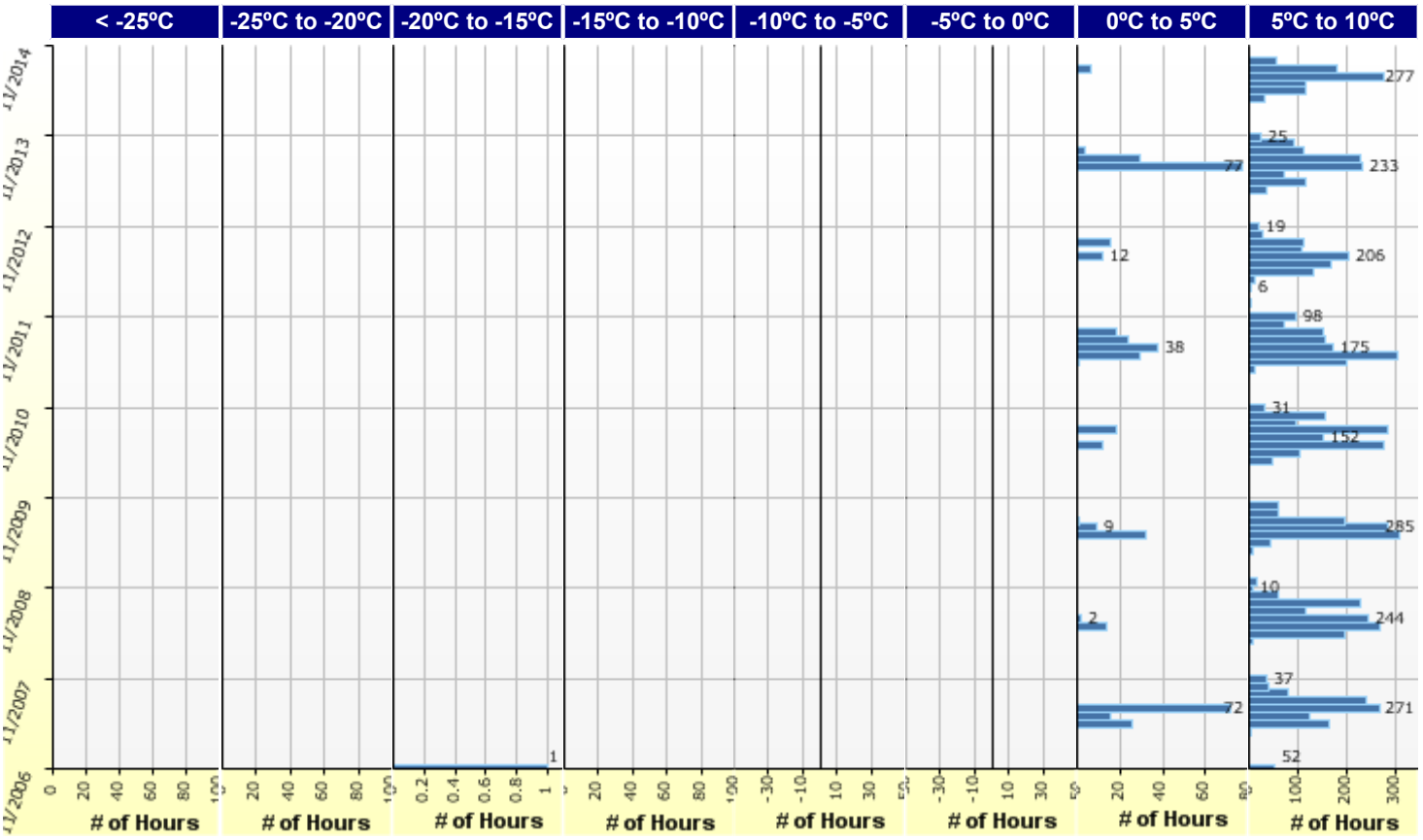


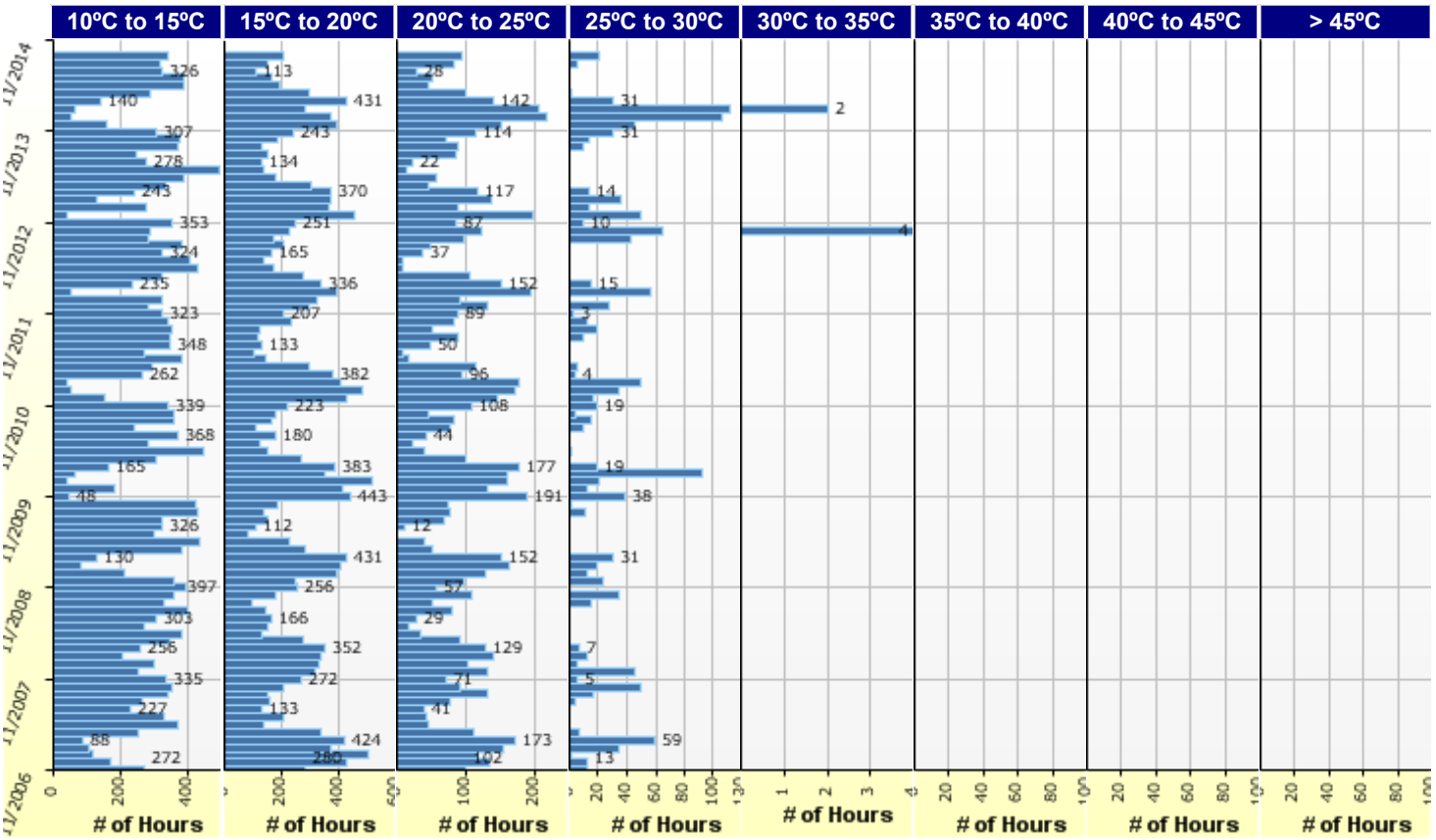






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

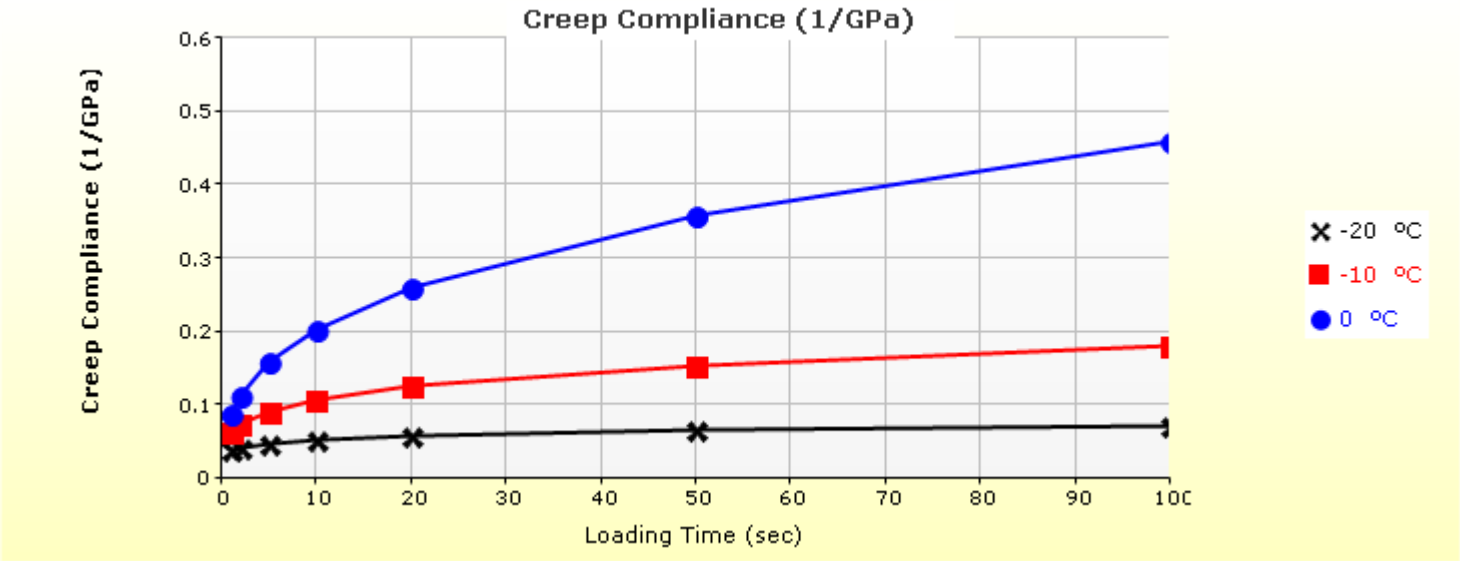
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

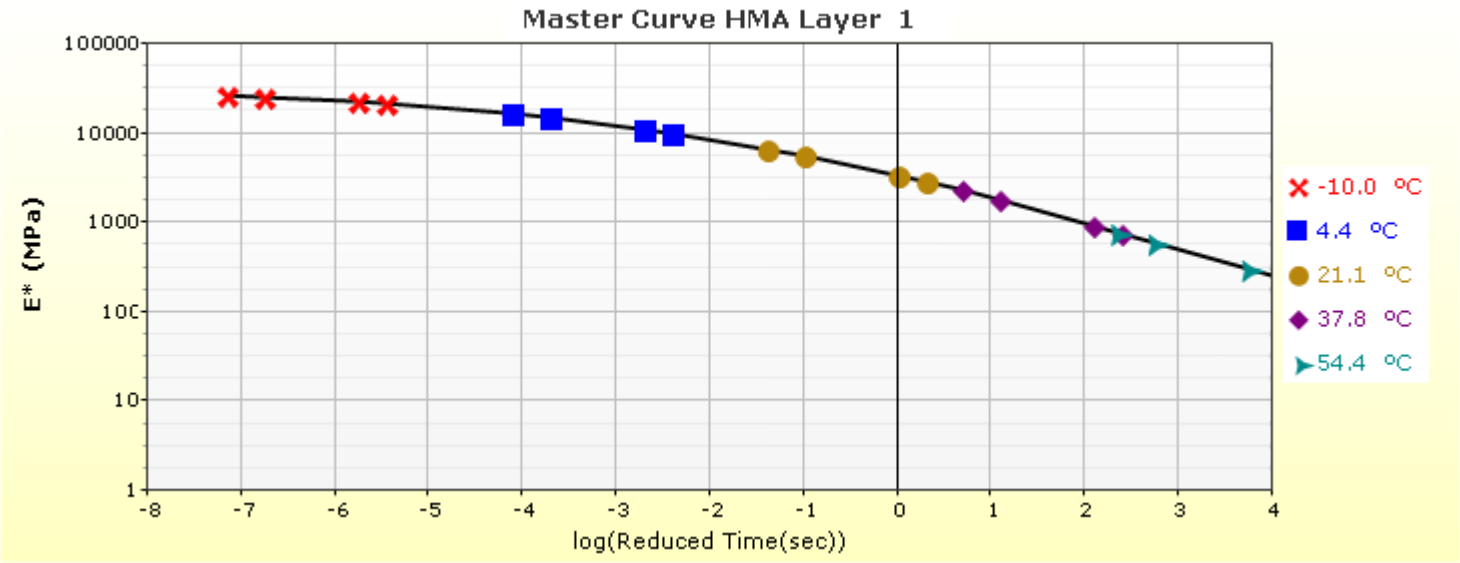
Indirect tensile strength at -10 ºC (MPa)	2.69

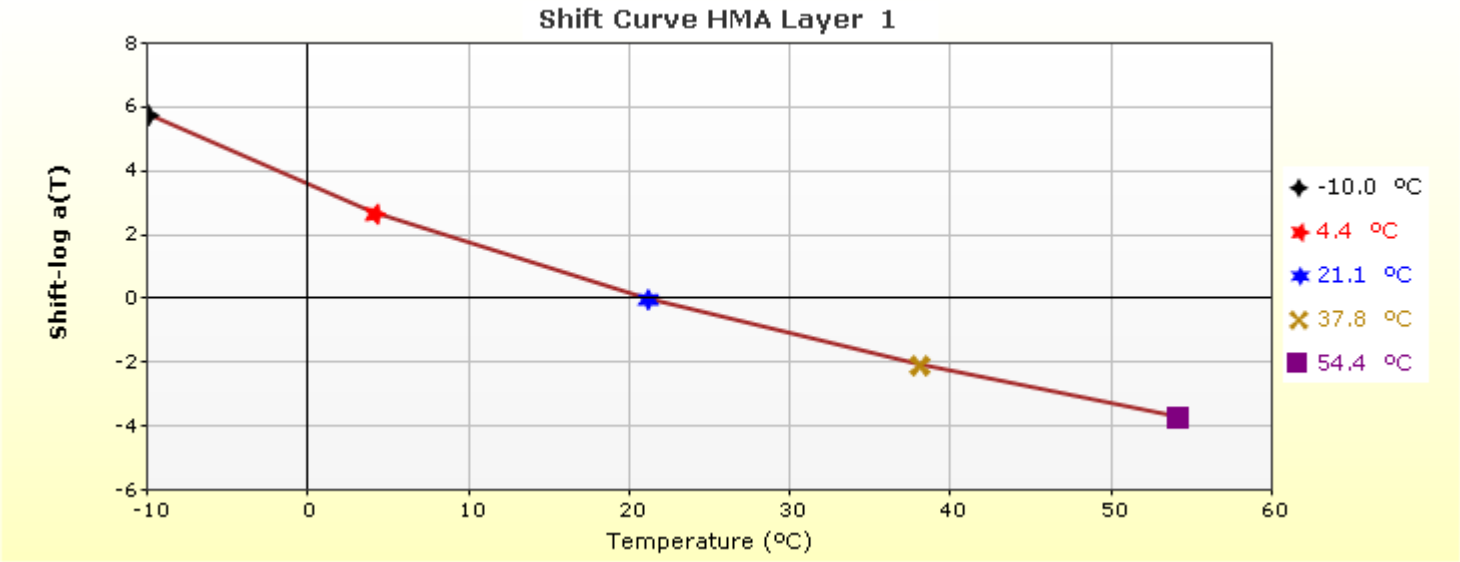
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

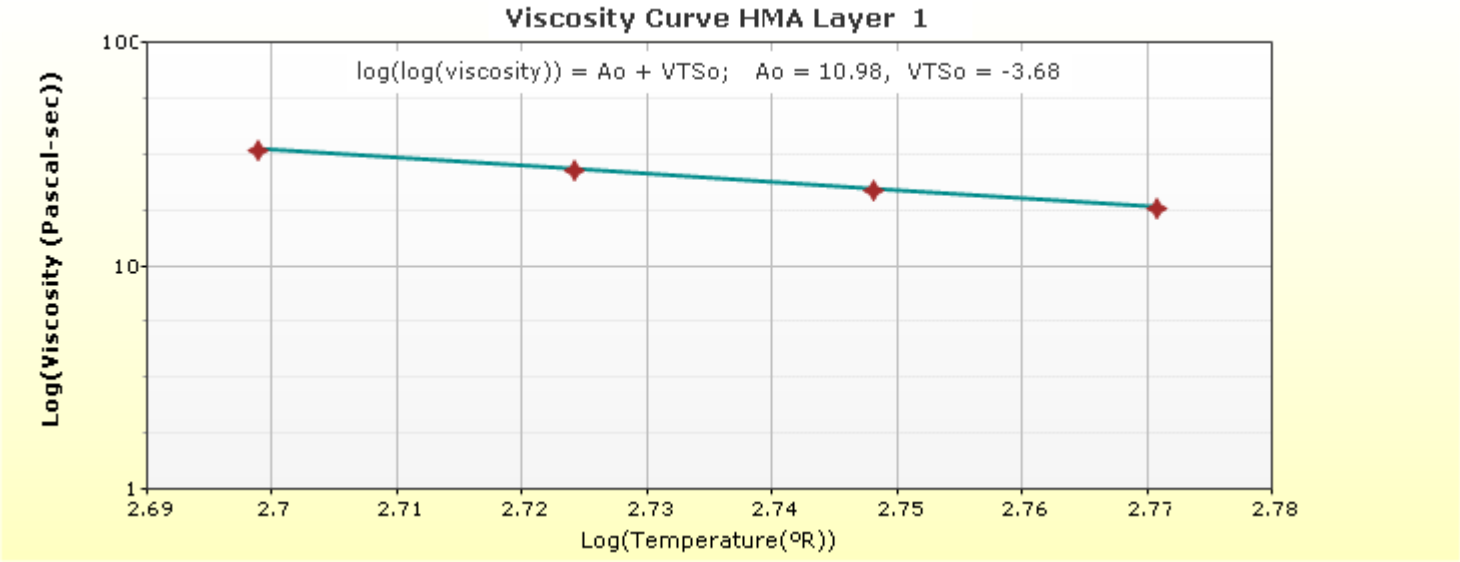
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



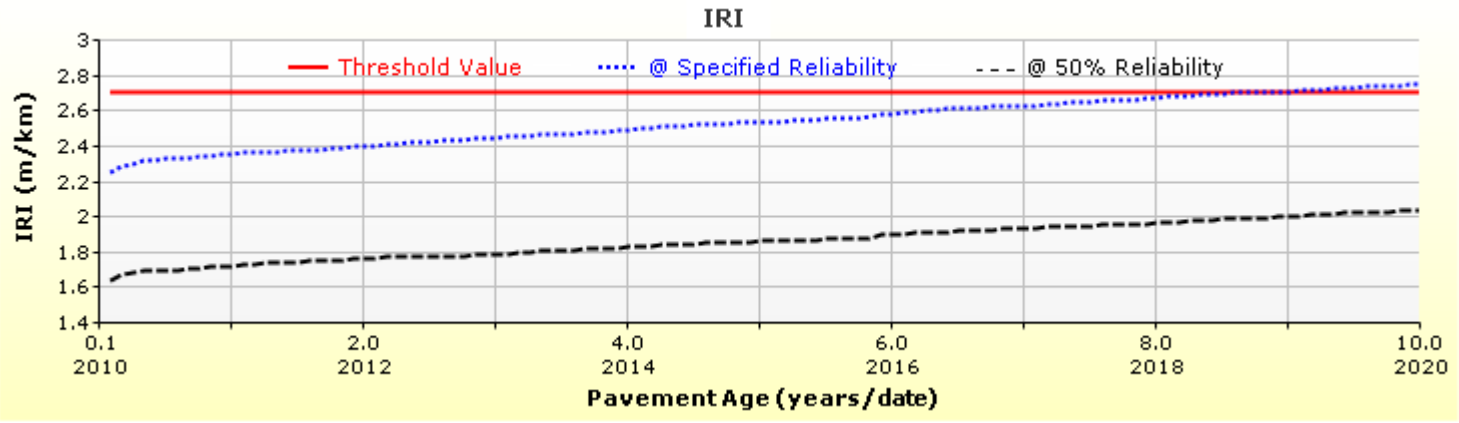
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

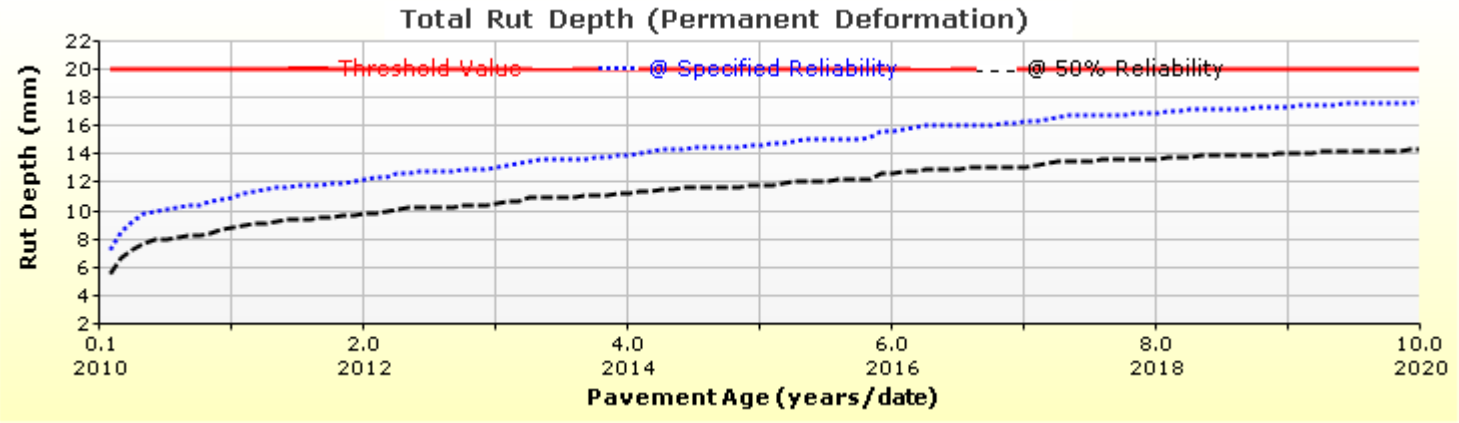


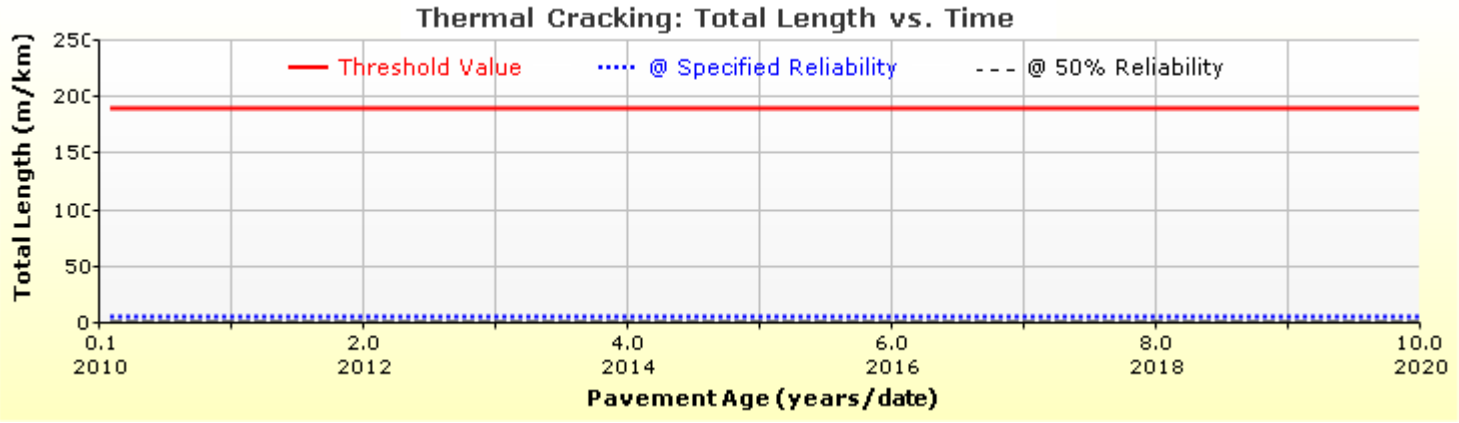


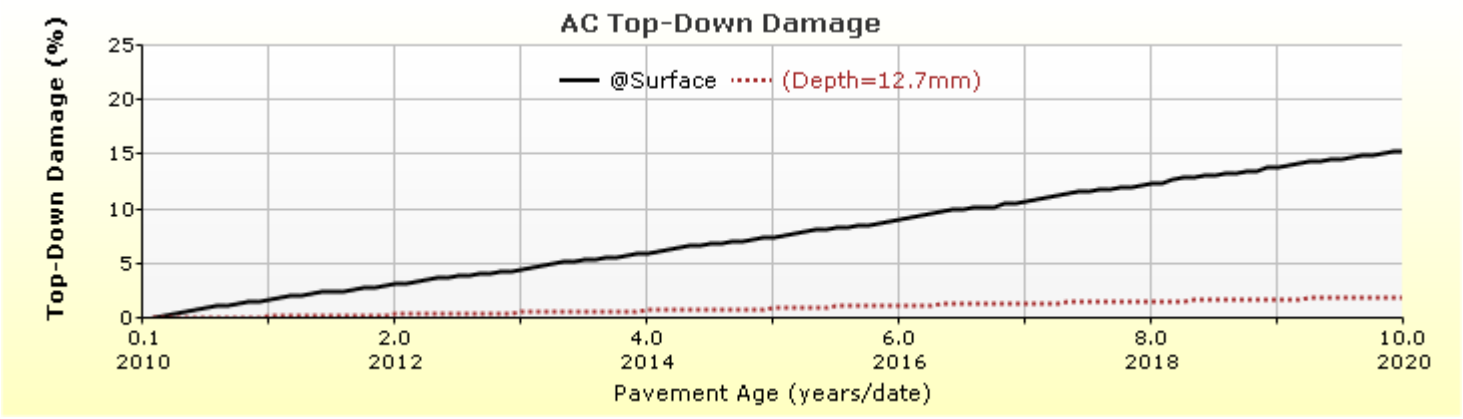


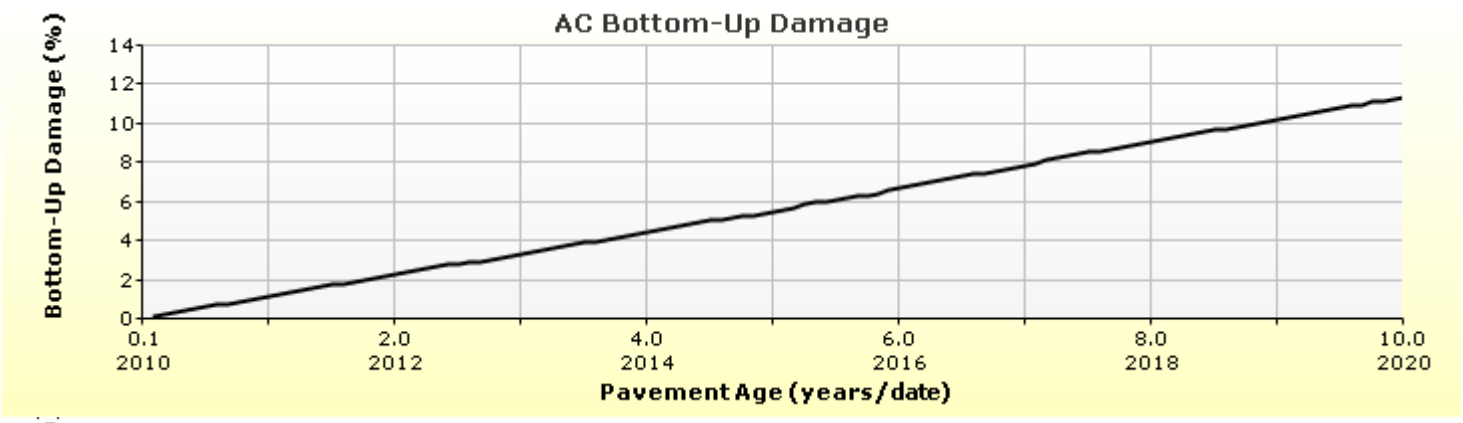
Analysis Output Charts

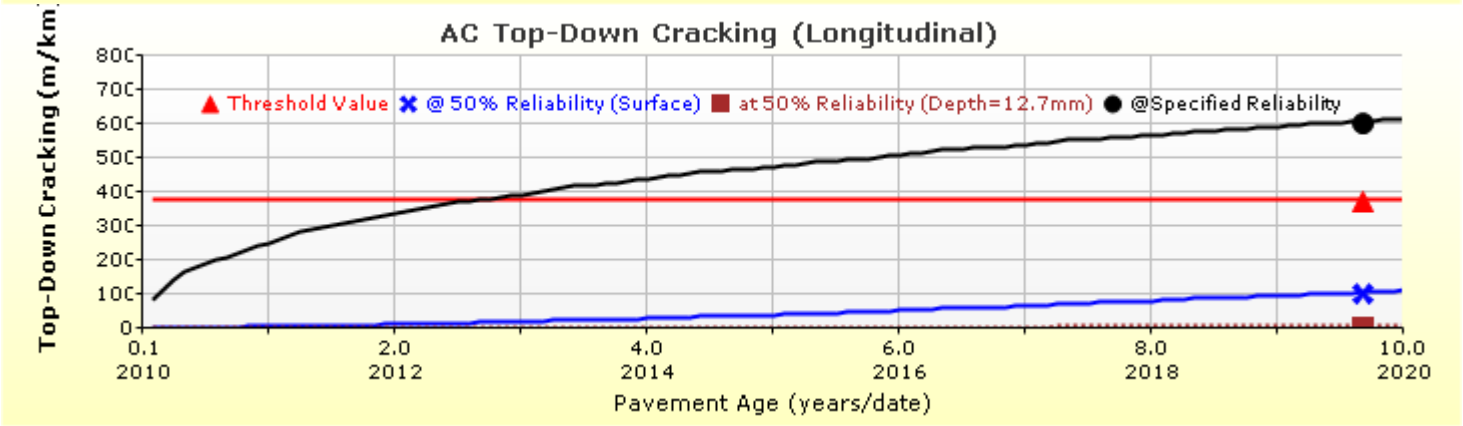


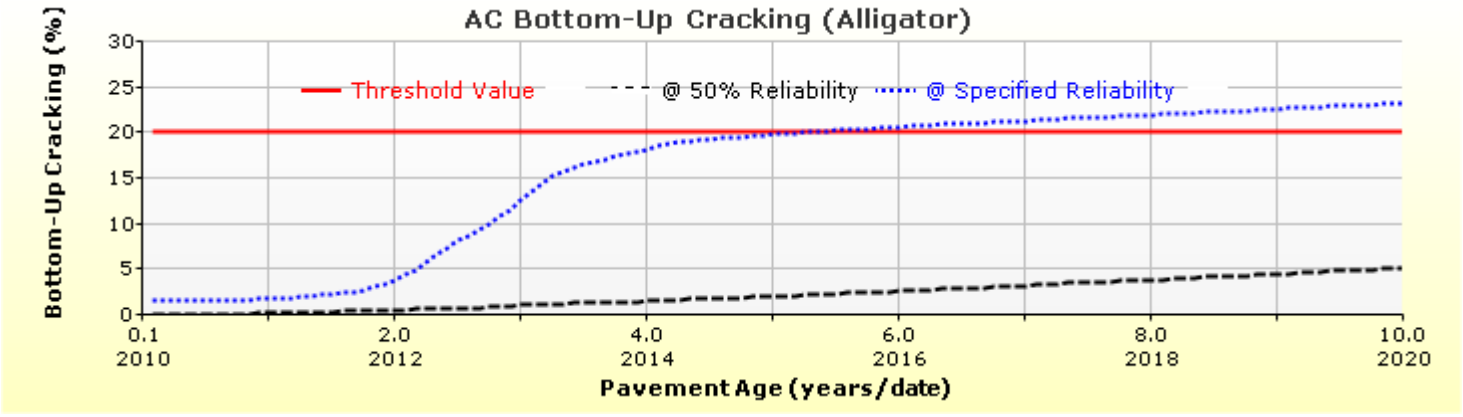


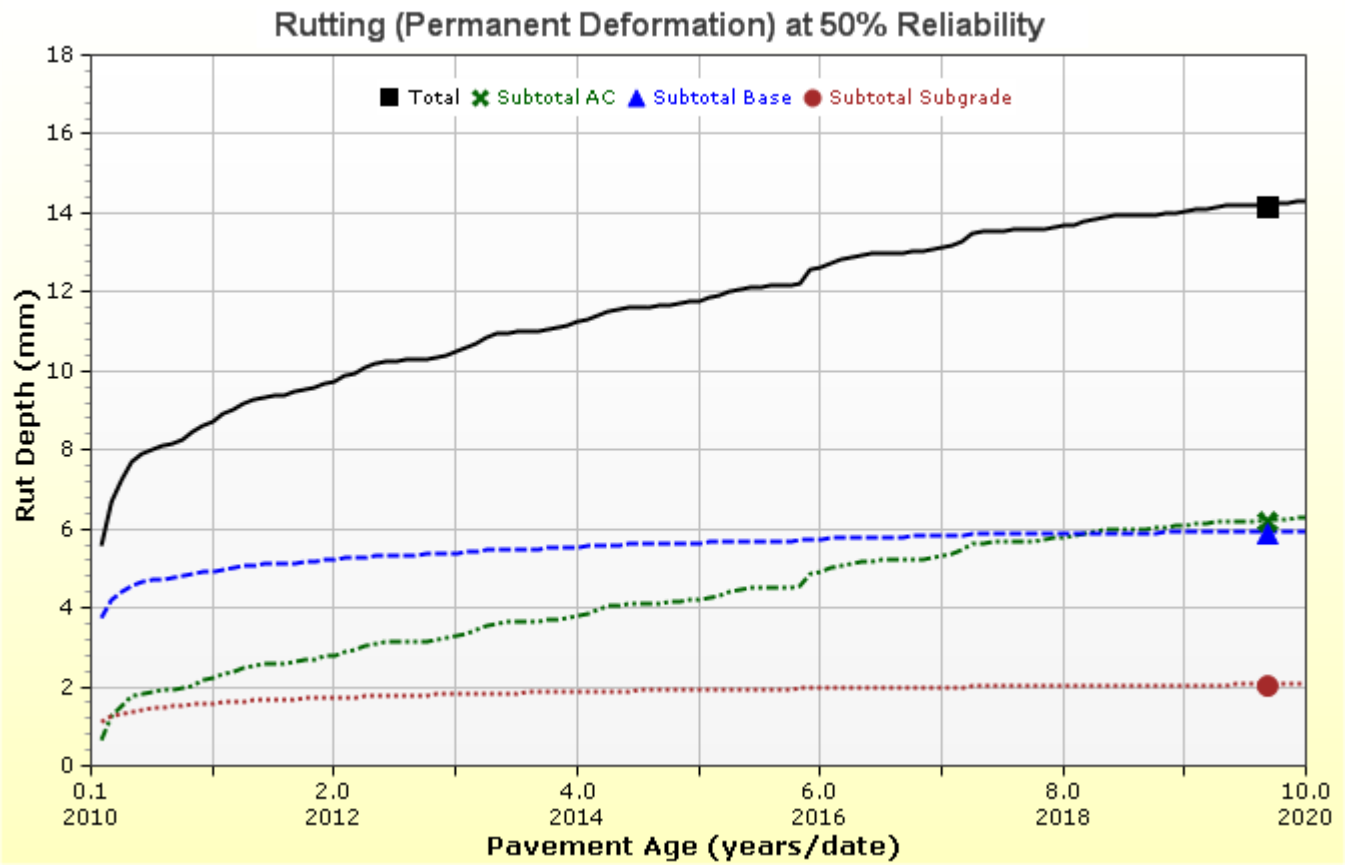


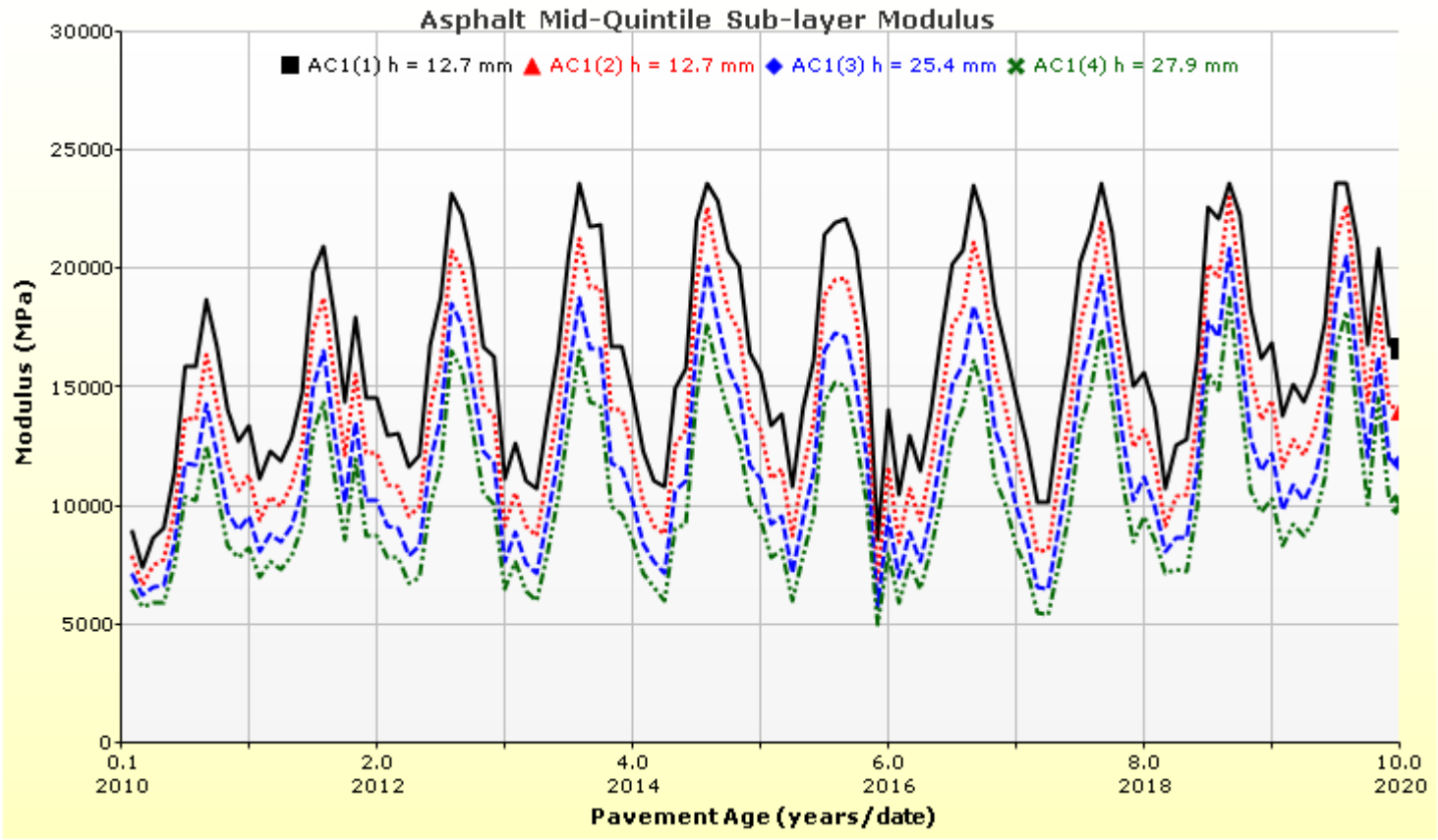

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

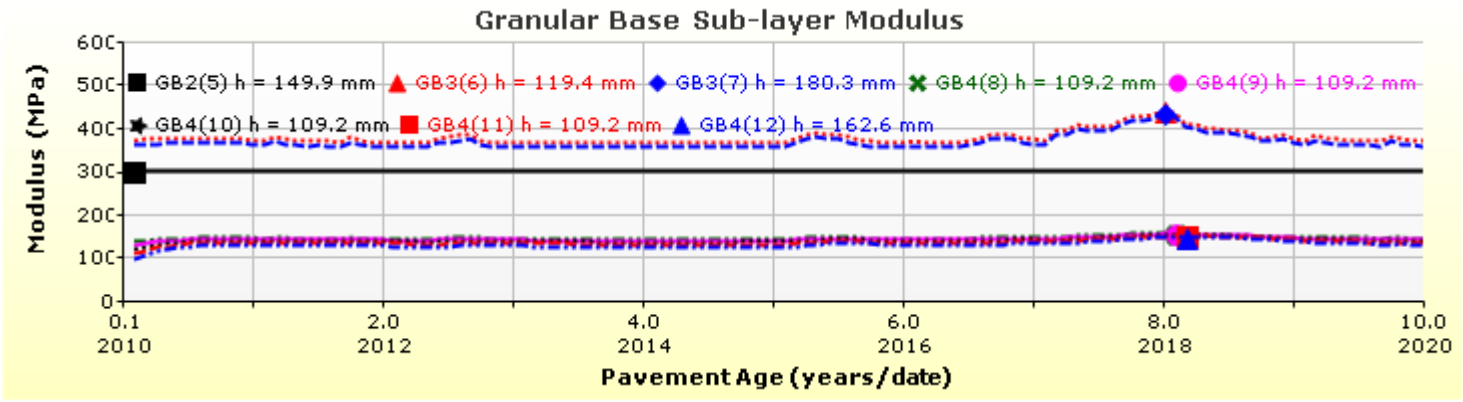

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

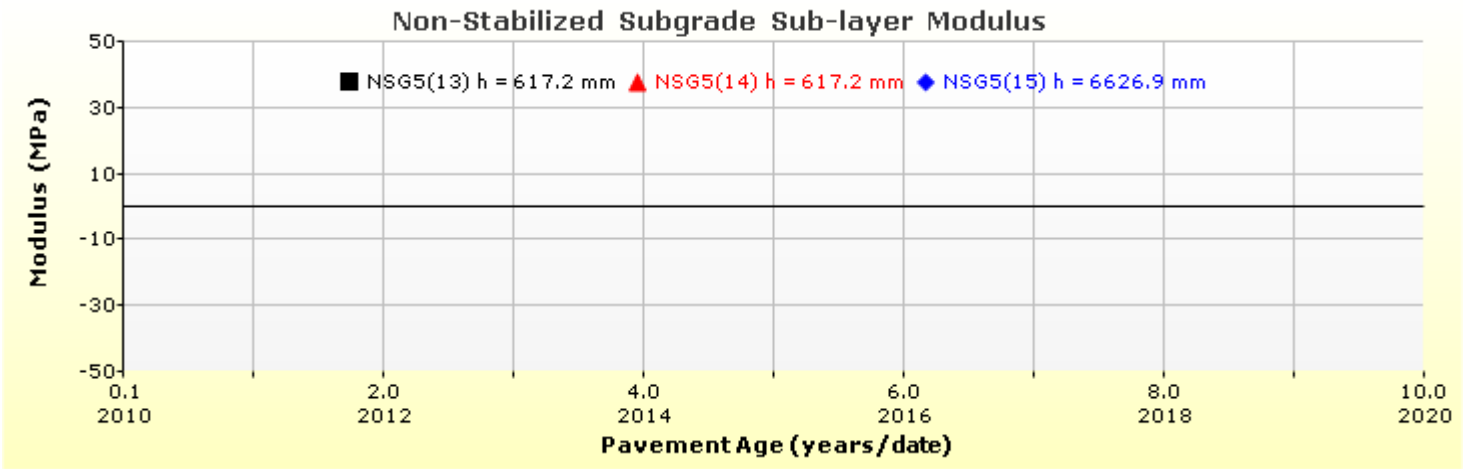

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
0
2
4
6
8
10
12
14
16
18
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestSP_cobertura

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestSP_cobertura.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -23.5, -46.62

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

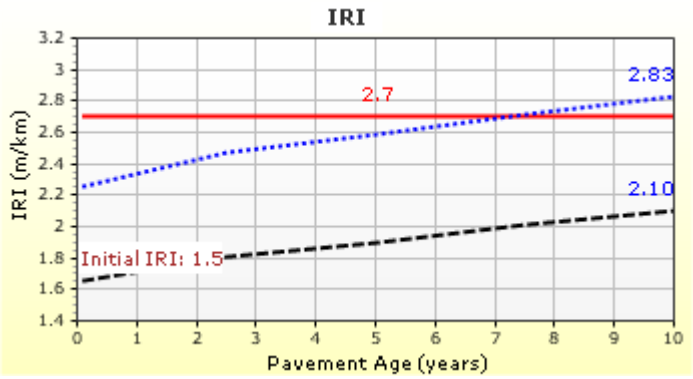
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

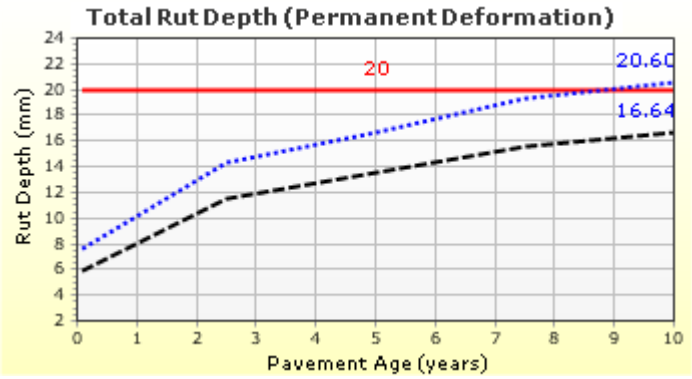
Design Outputs

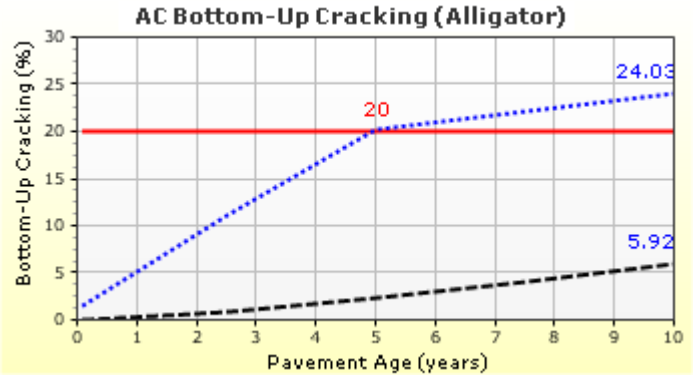
Distress Prediction Summary

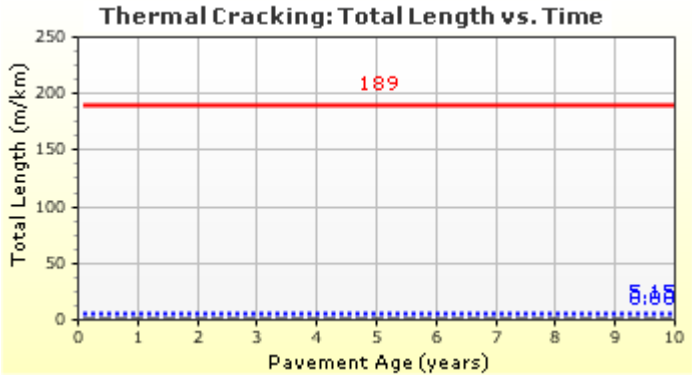
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.83	90.00	85.33	Fail
Permanent deformation - total pavement (mm)	20.00	20.61	90.00	86.06	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.03	90.00	84.05	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	663.94	90.00	71.76	Fail
Permanent deformation - AC only (mm)	5.00	8.59	50.00	8.22	Fail

Distress Charts







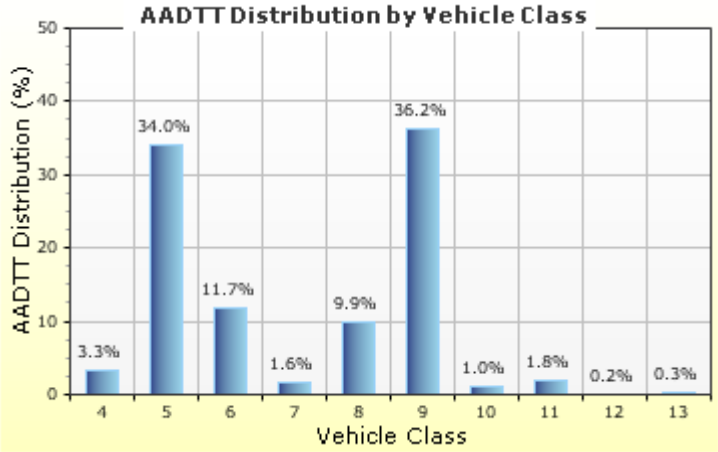


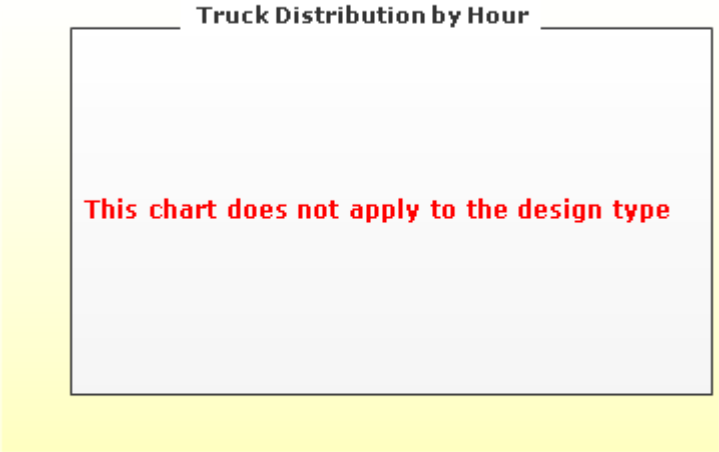


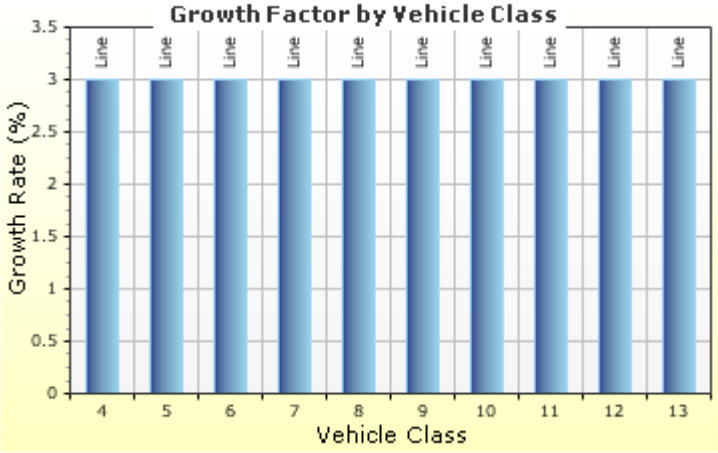
Traffic Inputs

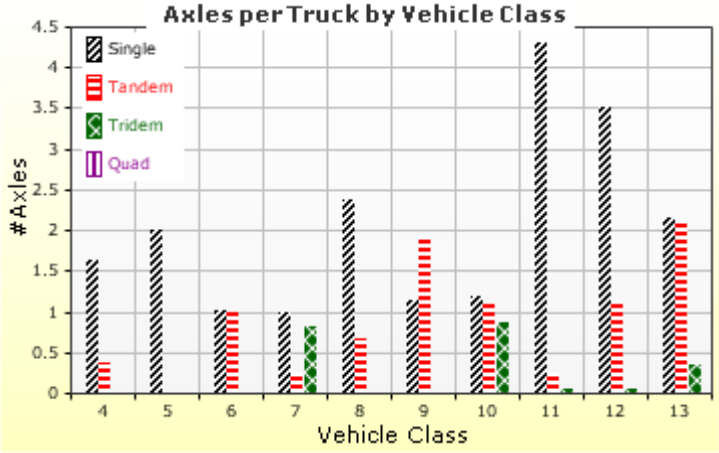
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

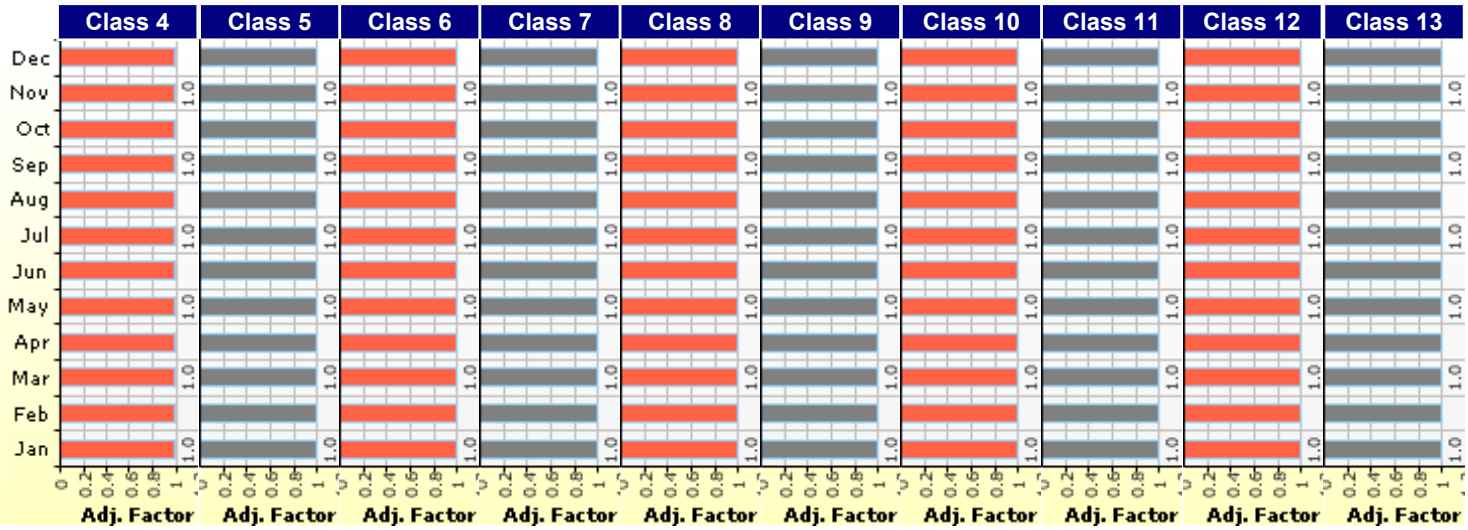








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

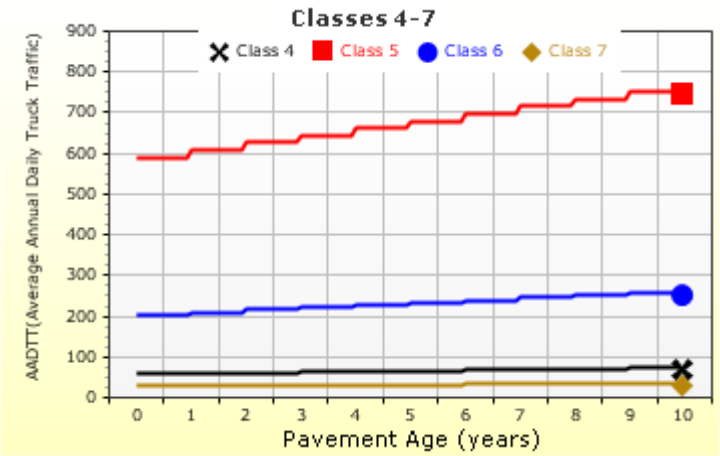
Wheelbase does not apply

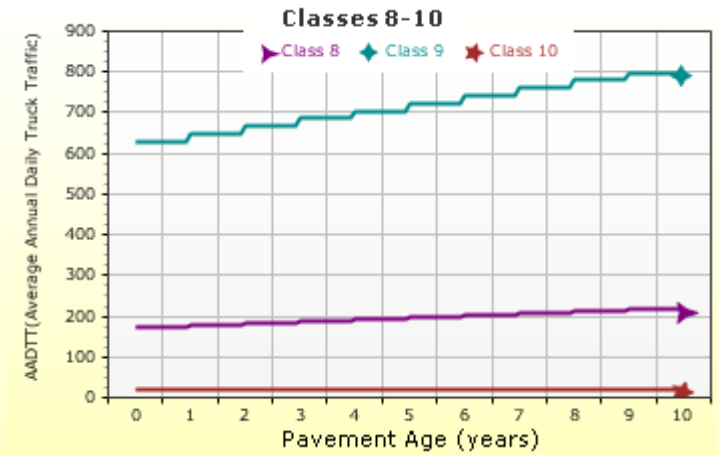
Number of Axles per Truck

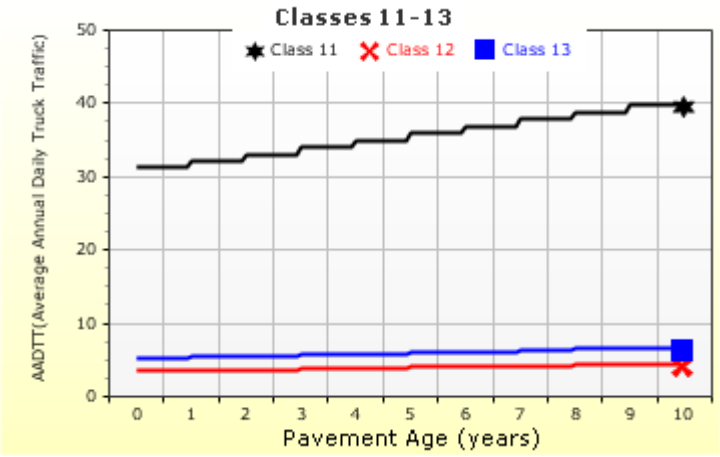
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

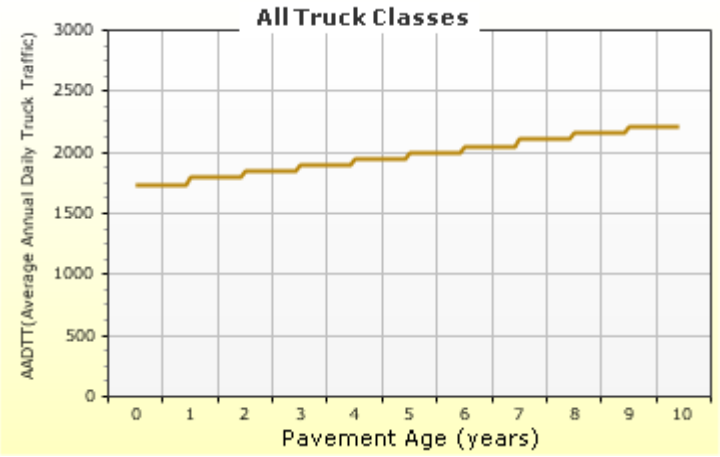
AADTT (Average Annual Daily Truck Traffic) Growth

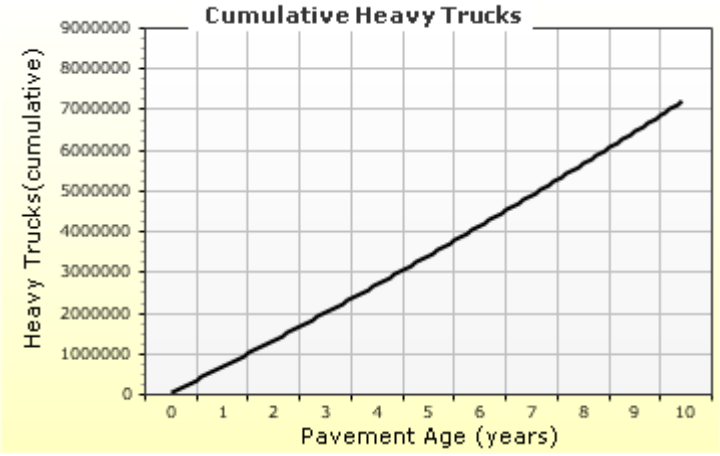
*** Traffic cap is not enforced**







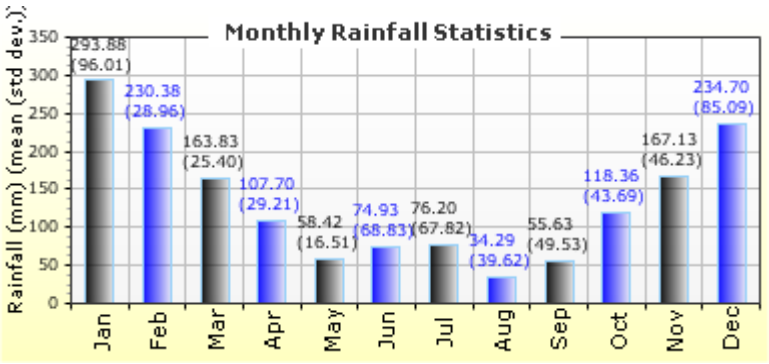




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
SAO PAULO, SP	-23.50000 -46.62000 792

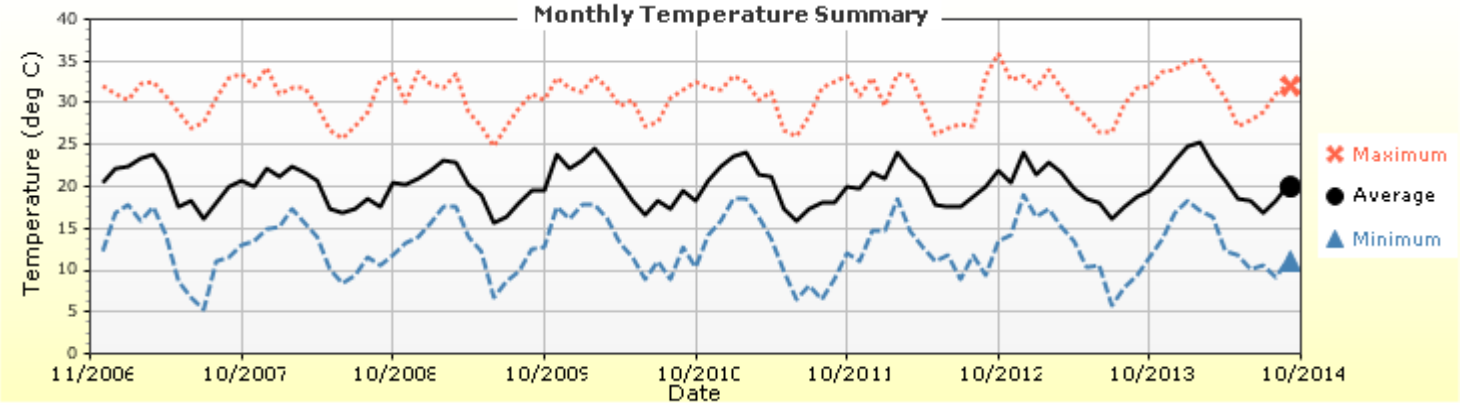


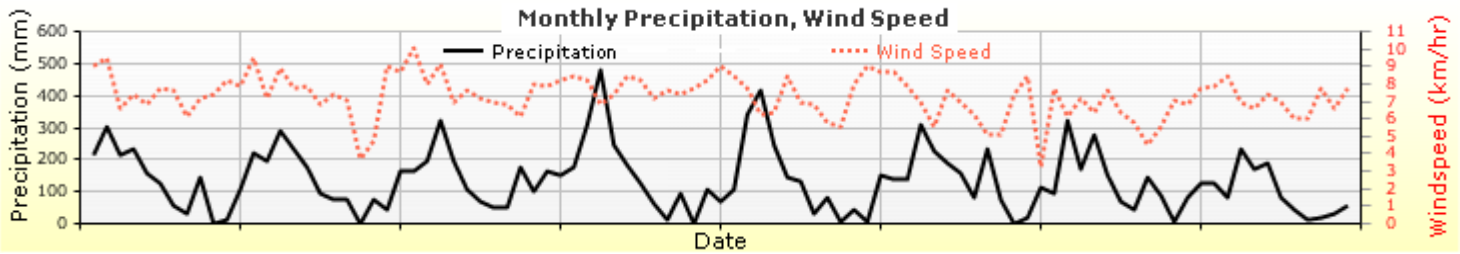
Annual Statistics:

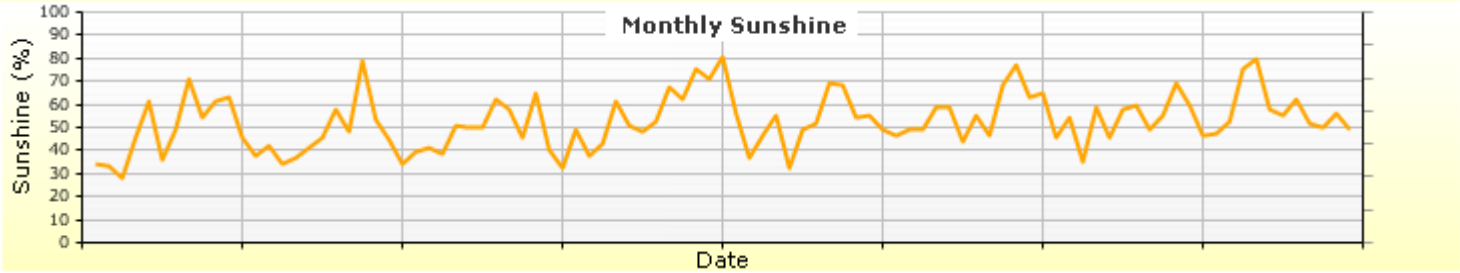
Mean annual air temperature (ºC)	20.15
Mean annual precipitation (mm)	1628.14
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

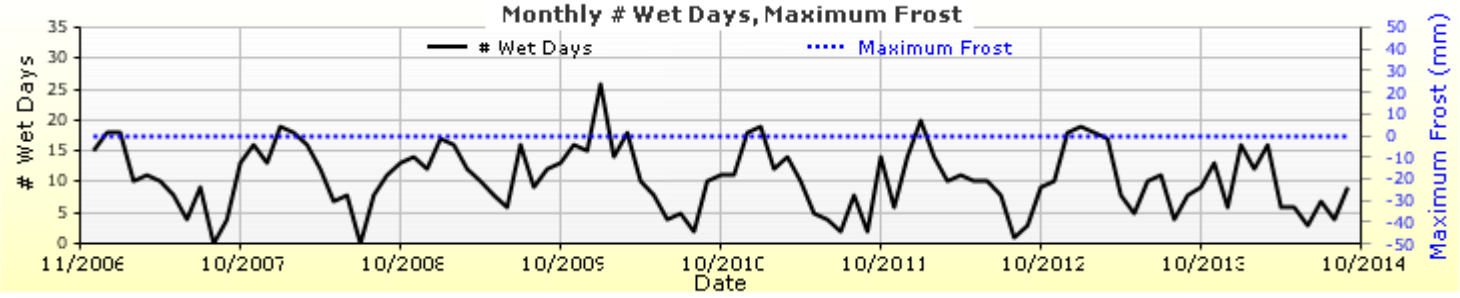
Water table depth (m): 3.05

Monthly Climate Summary:

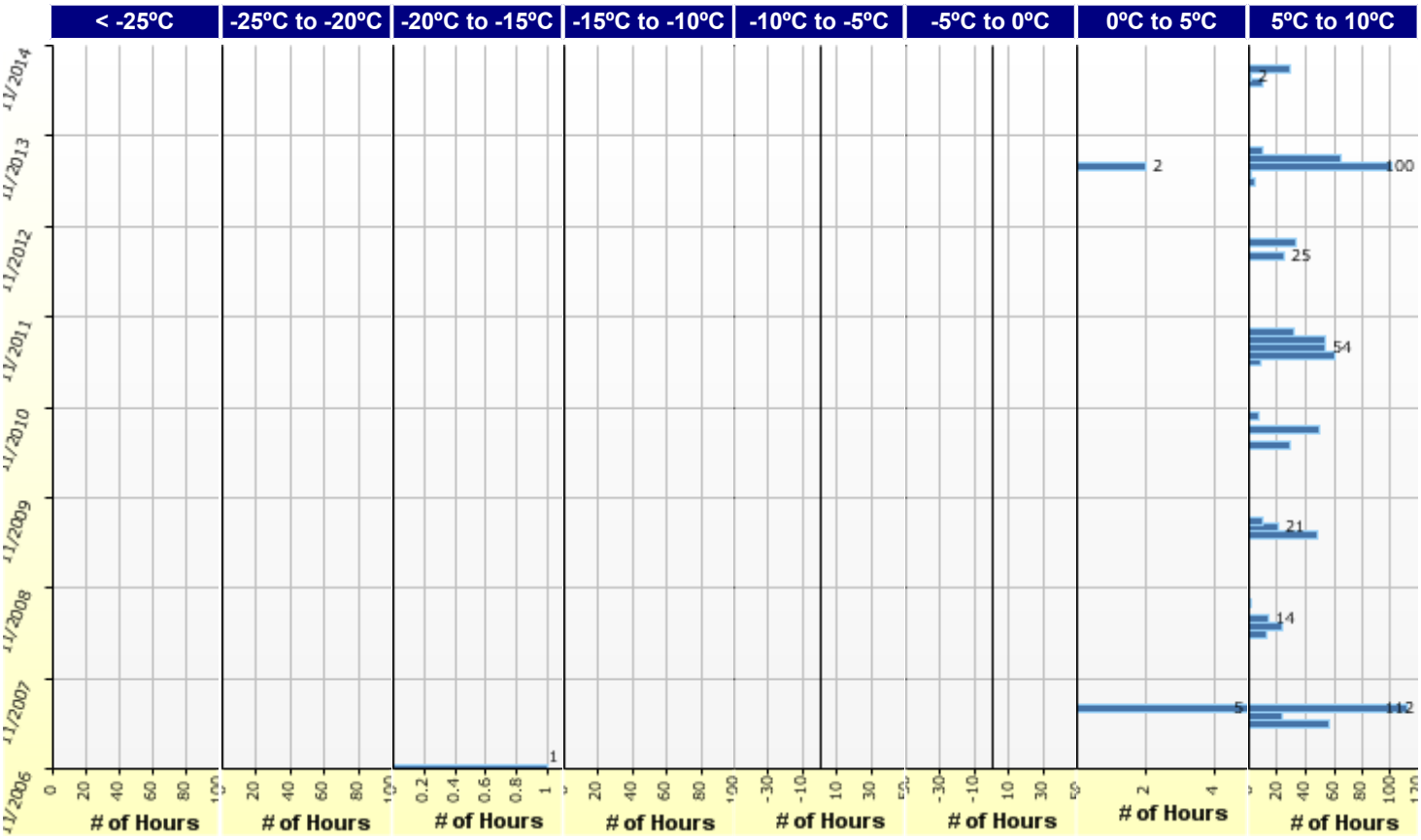


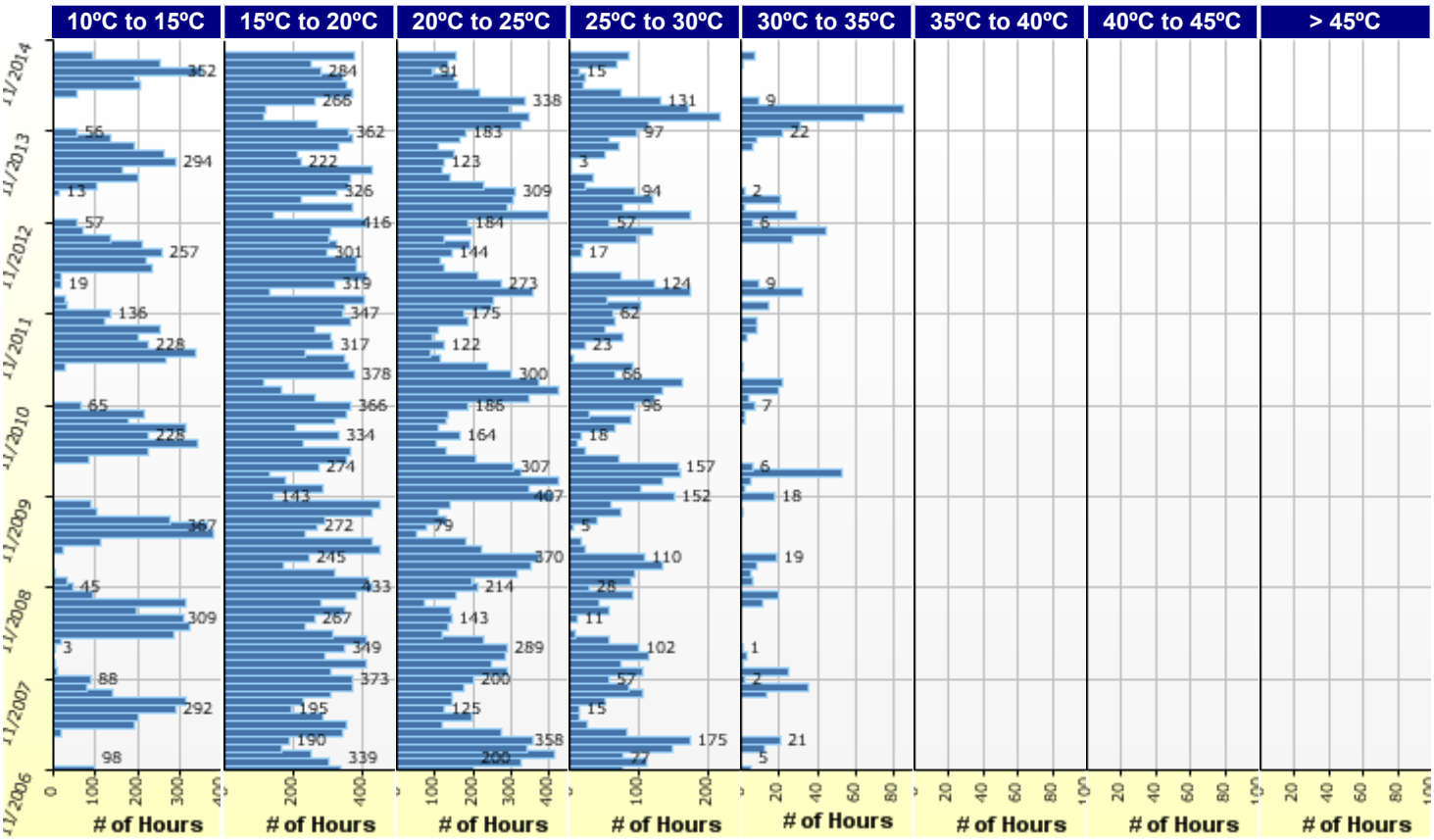






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

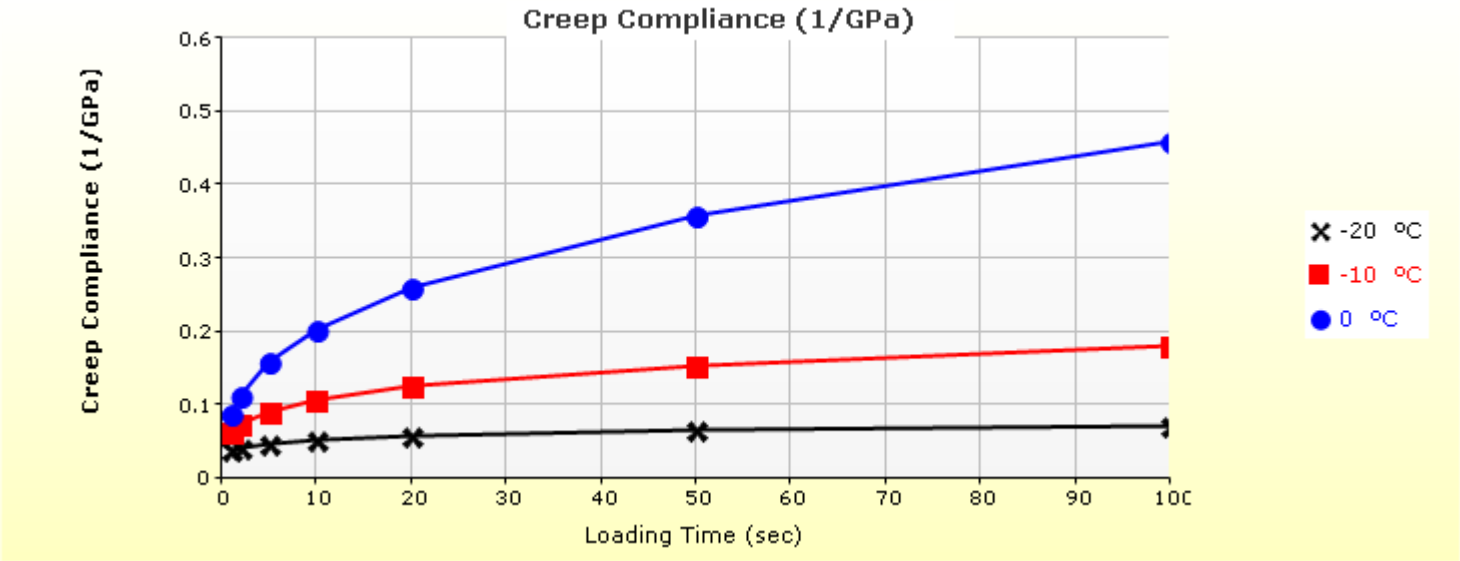
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

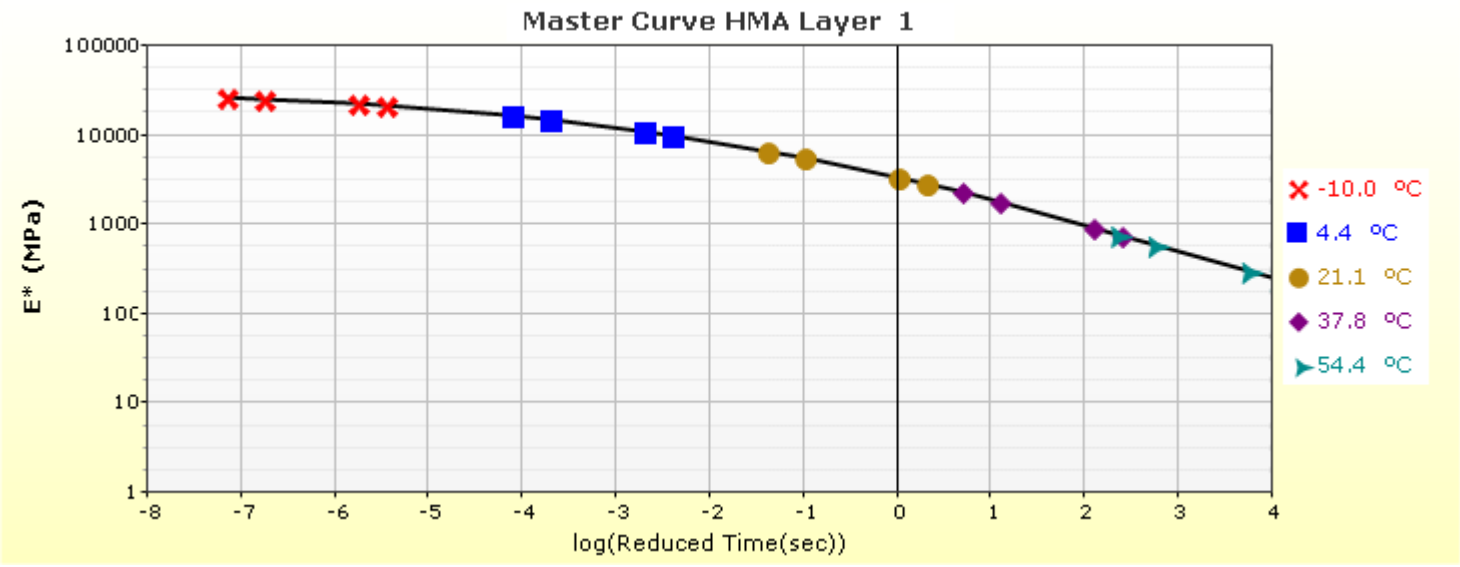
Indirect tensile strength at -10 ºC (MPa)	2.69

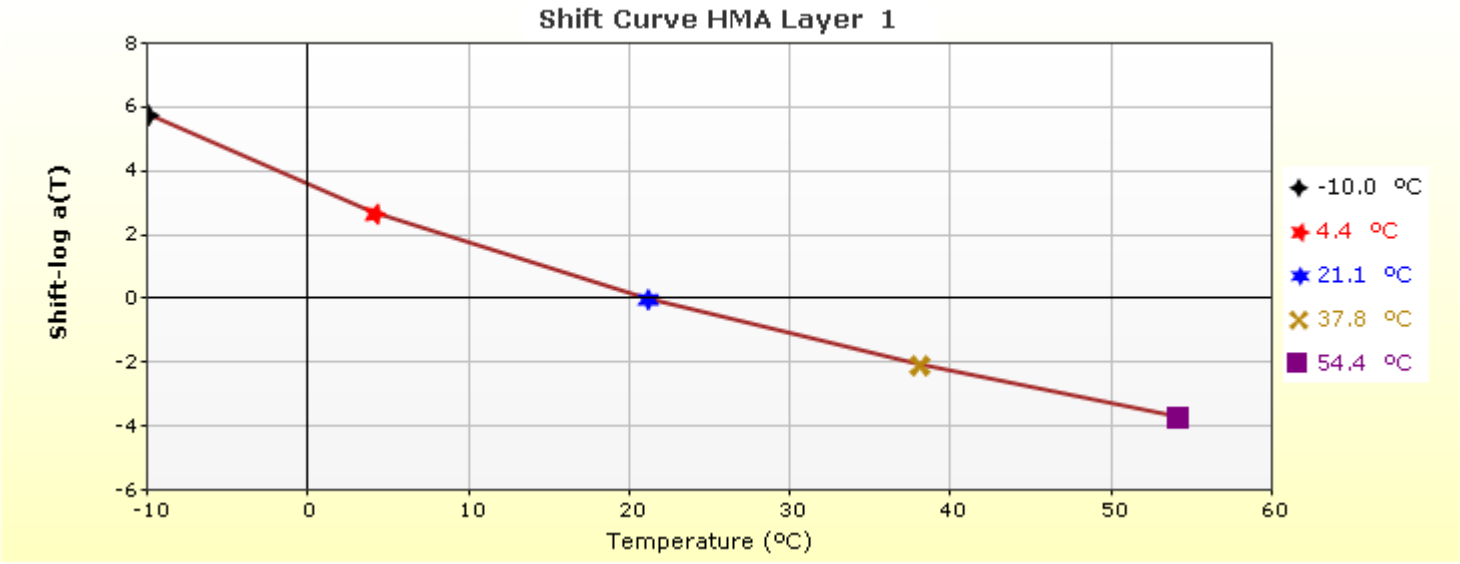
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

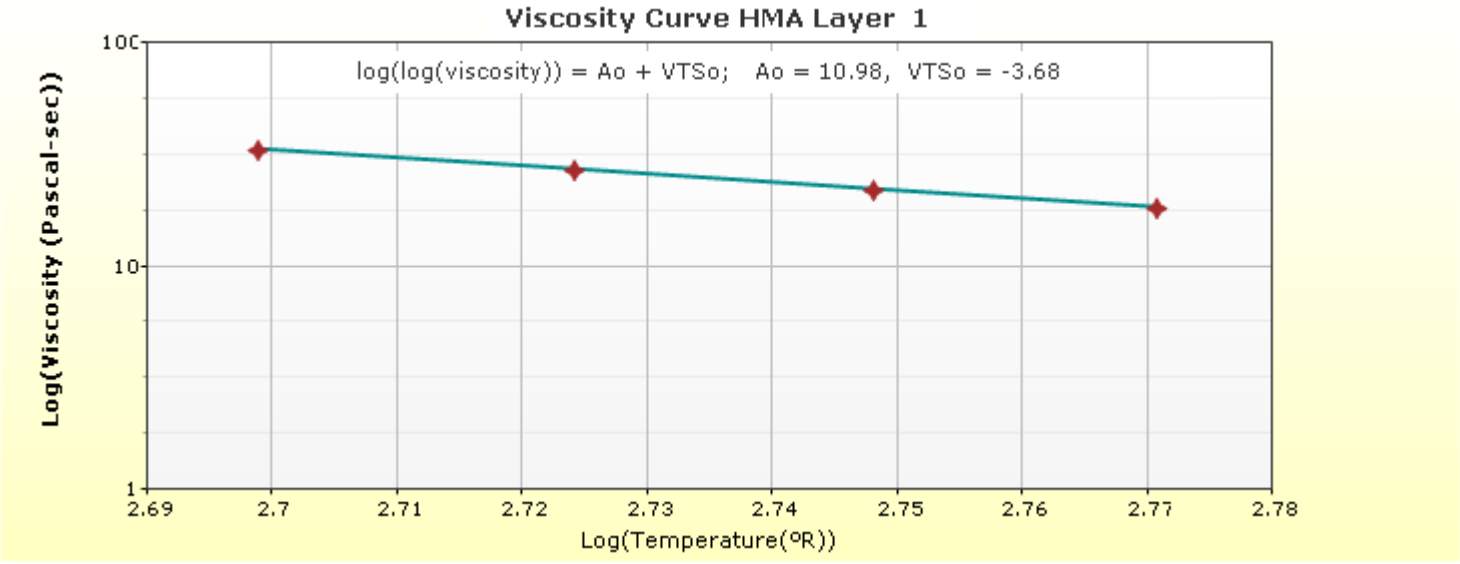
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



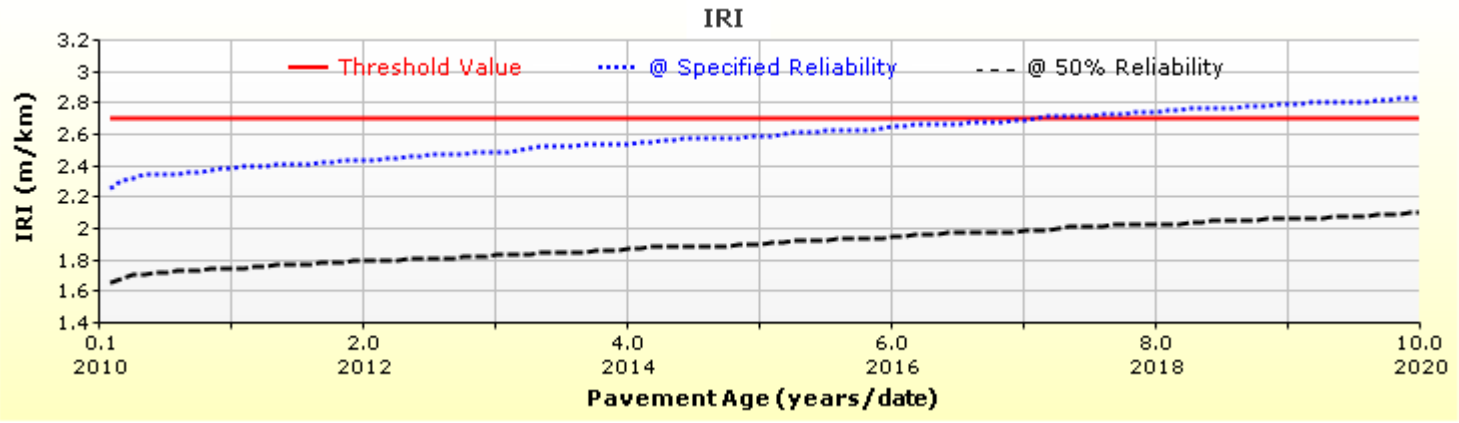
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

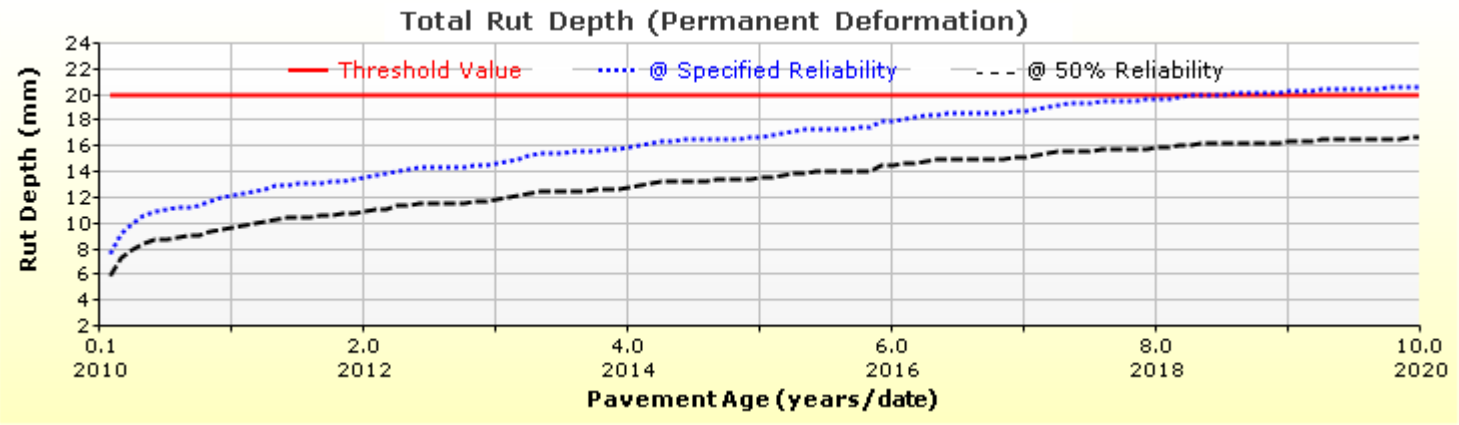


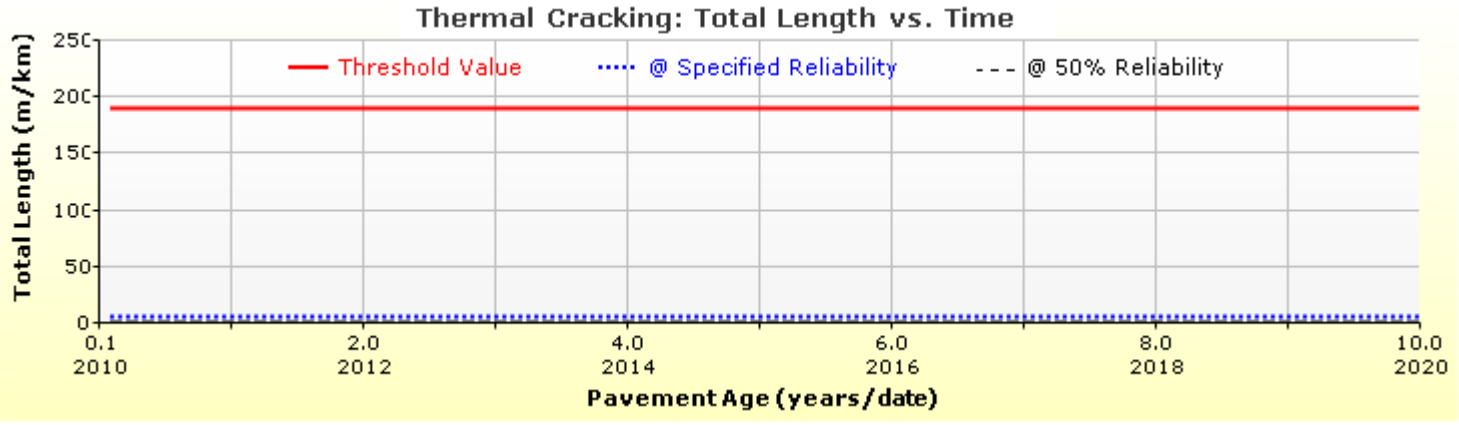


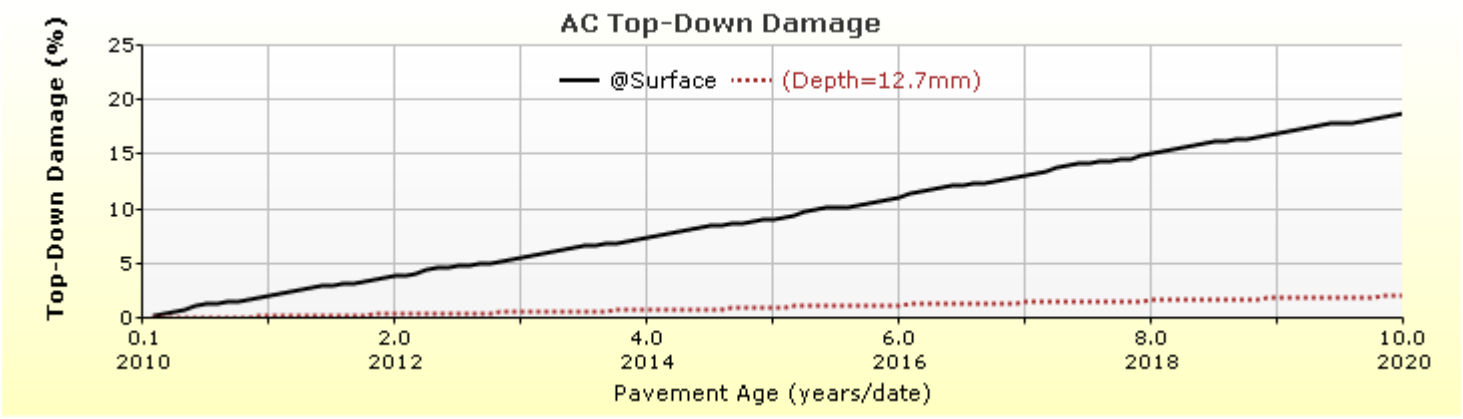


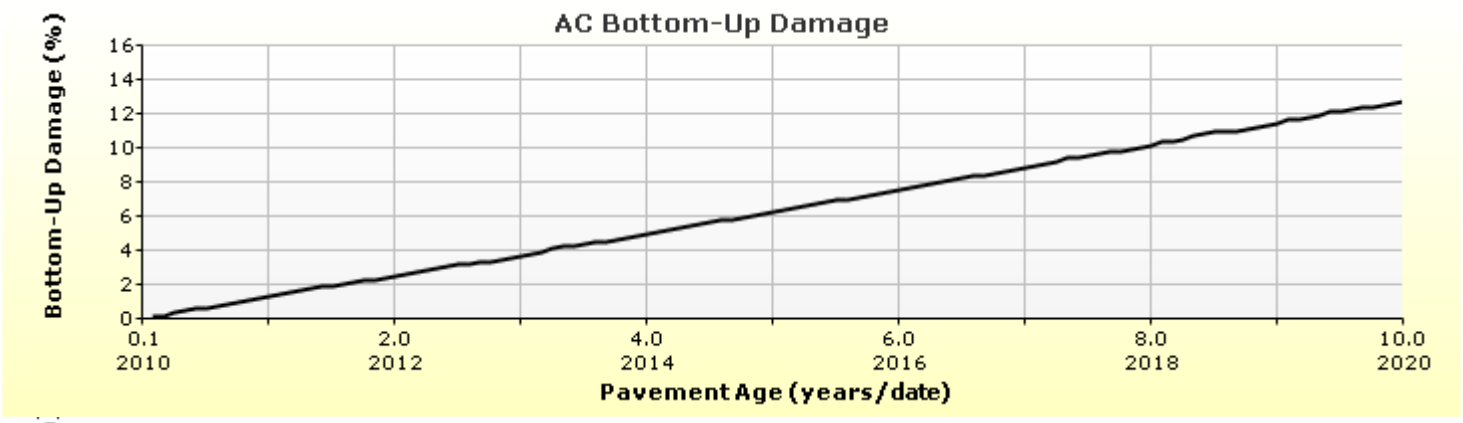
Analysis Output Charts

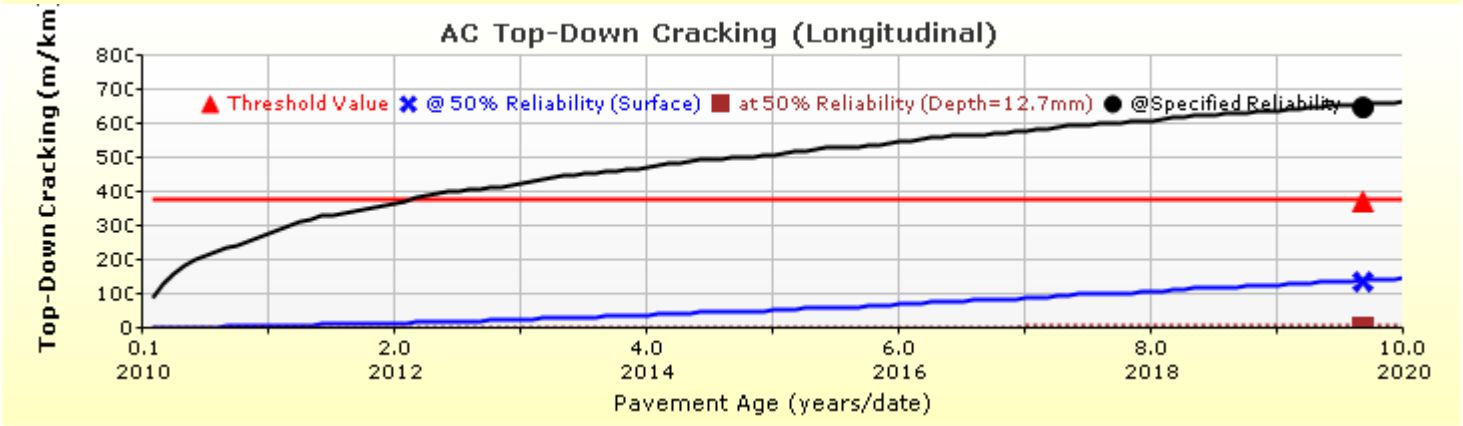


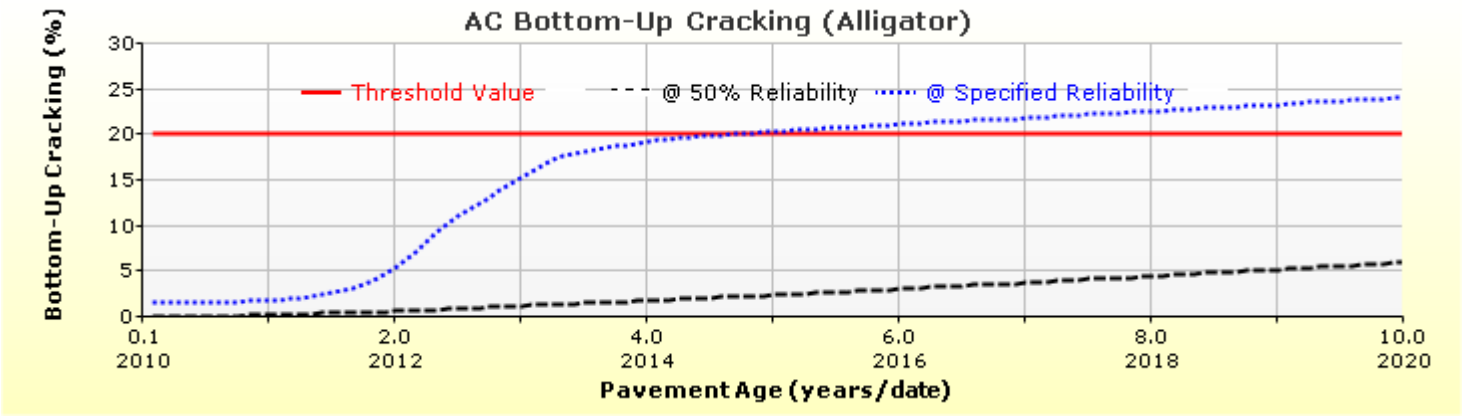


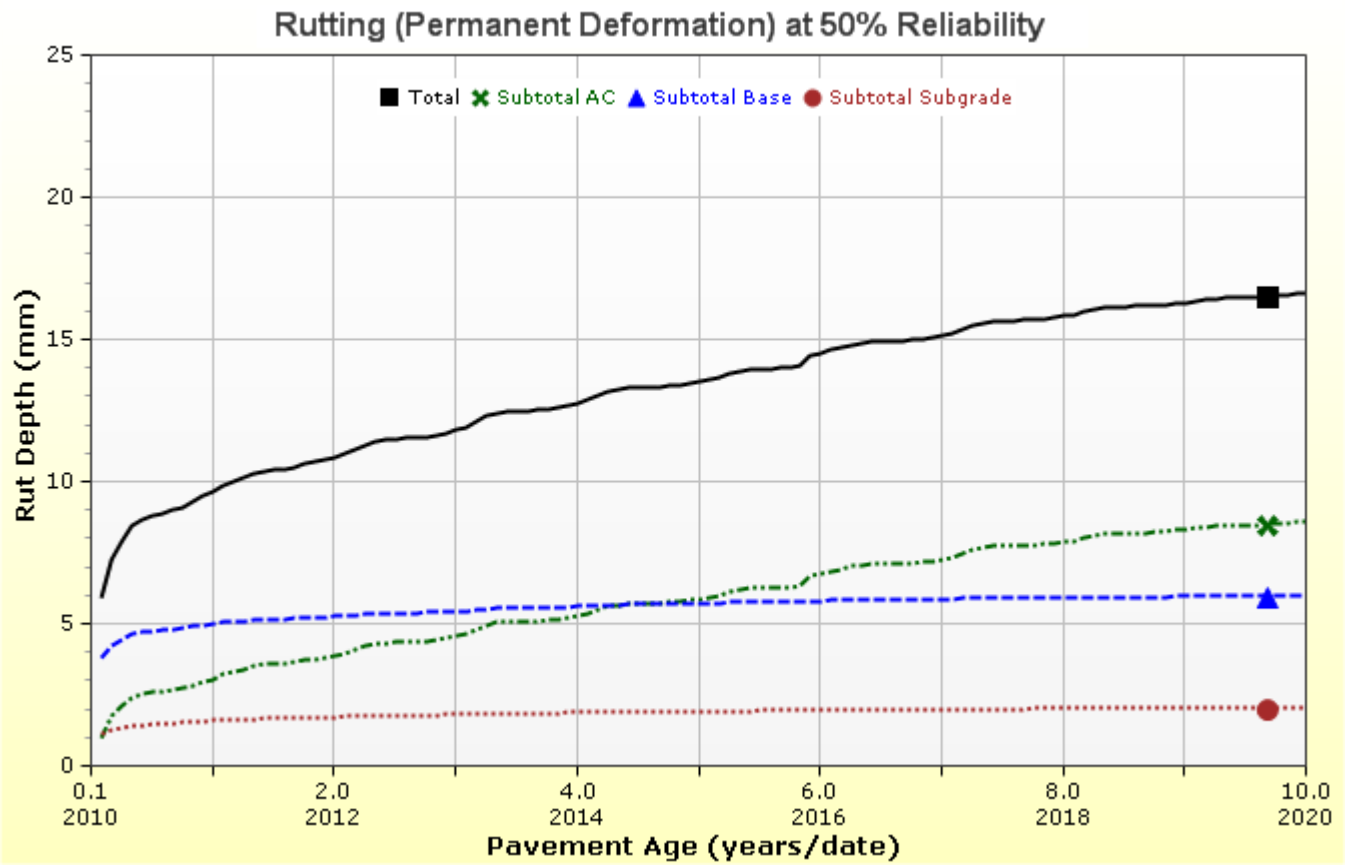


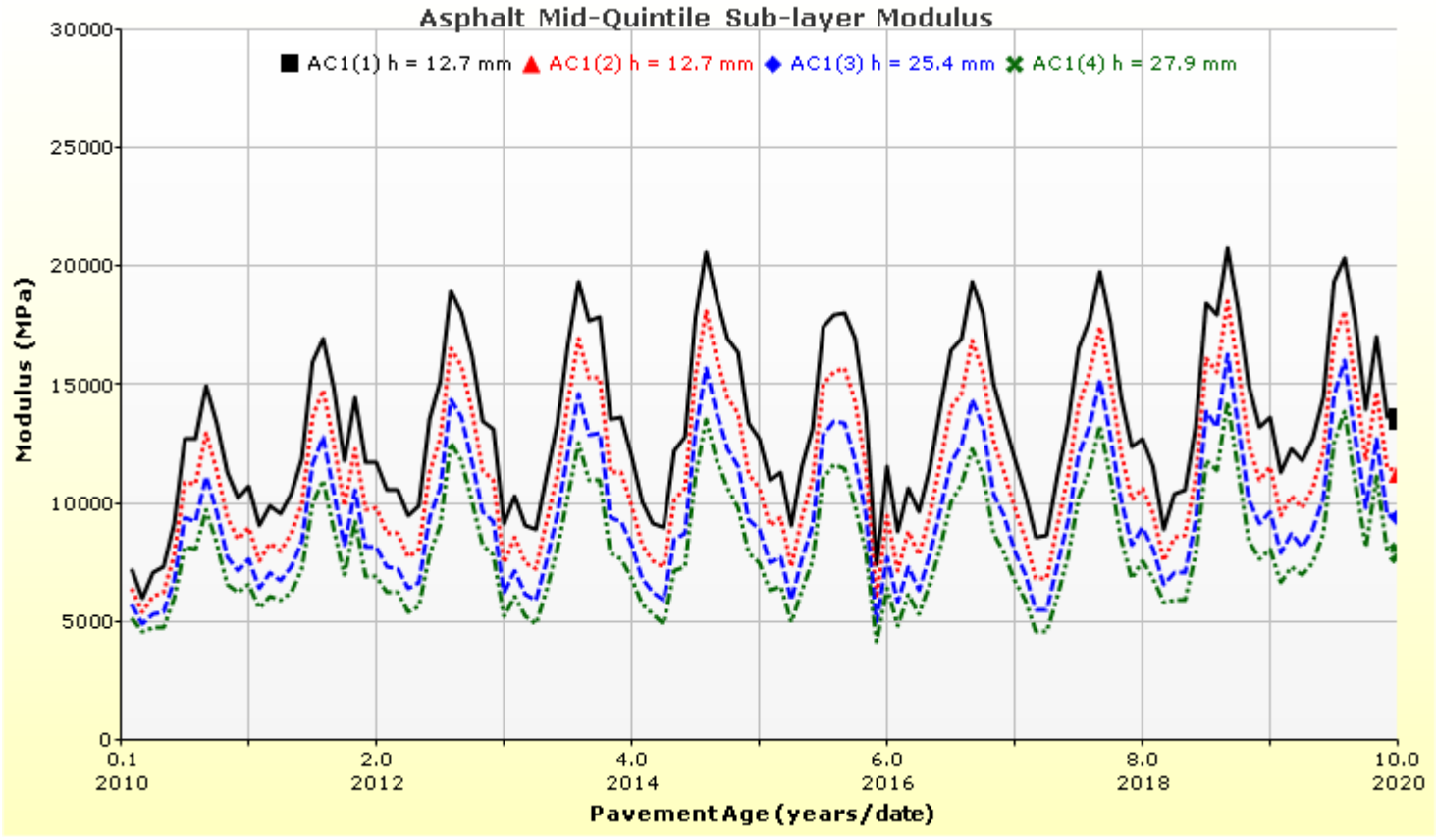

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

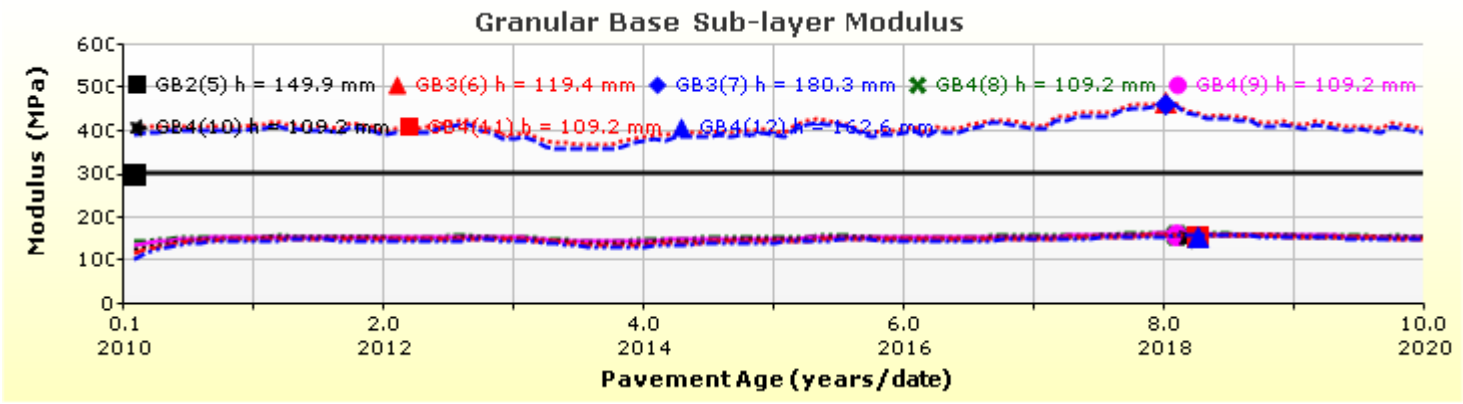

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

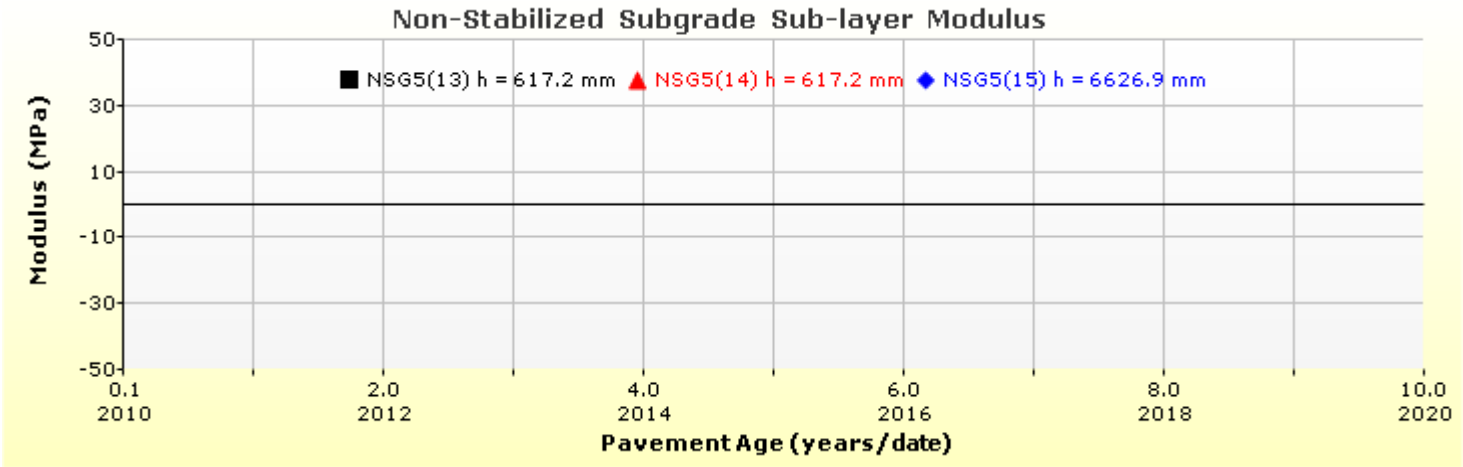

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2\beta_{r2}} N^{k_3 B_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_\alpha^2 + 2.4868 * H_\alpha - 17.342$$

$$C_2 = 0.0172 * H_\alpha^2 - 1.7331 * H_\alpha + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestSP_precip

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestSP_precip.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -23.5, -46.62

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

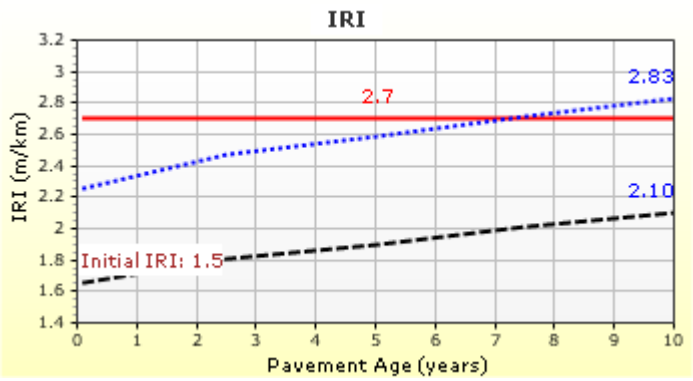
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

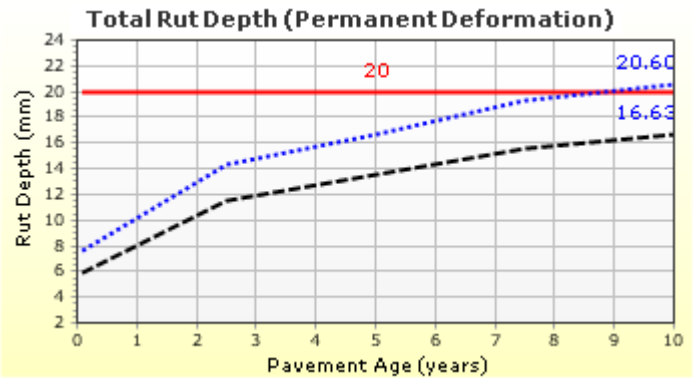
Design Outputs

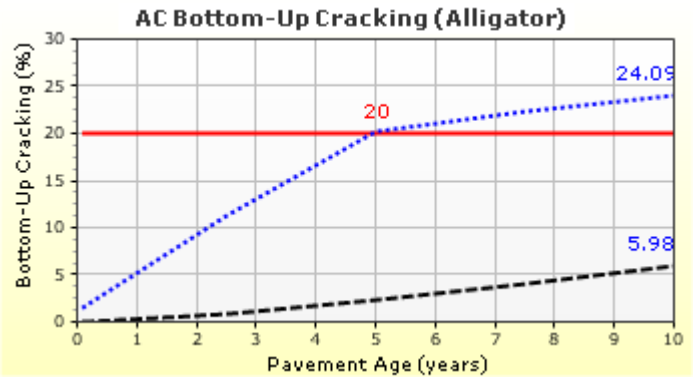
Distress Prediction Summary

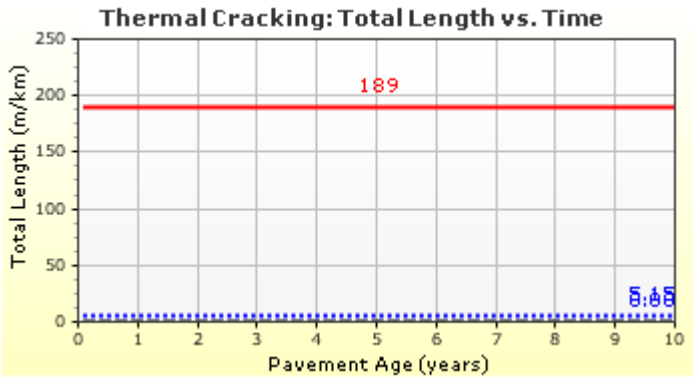
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.83	90.00	85.28	Fail
Permanent deformation - total pavement (mm)	20.00	20.60	90.00	86.11	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.09	90.00	83.95	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	664.13	90.00	71.75	Fail
Permanent deformation - AC only (mm)	5.00	8.56	50.00	8.35	Fail

Distress Charts







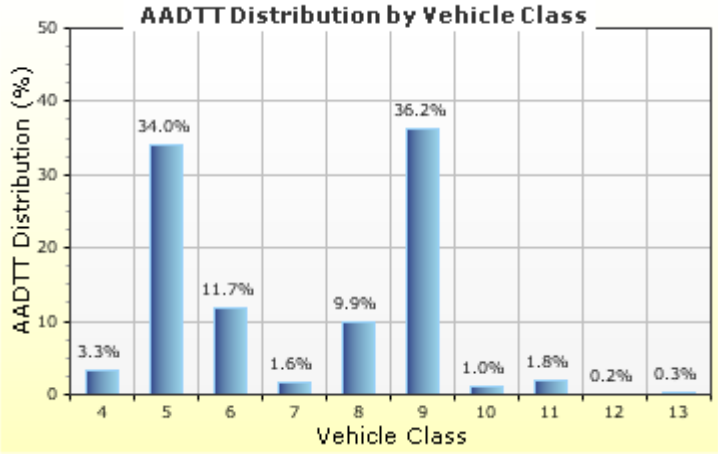


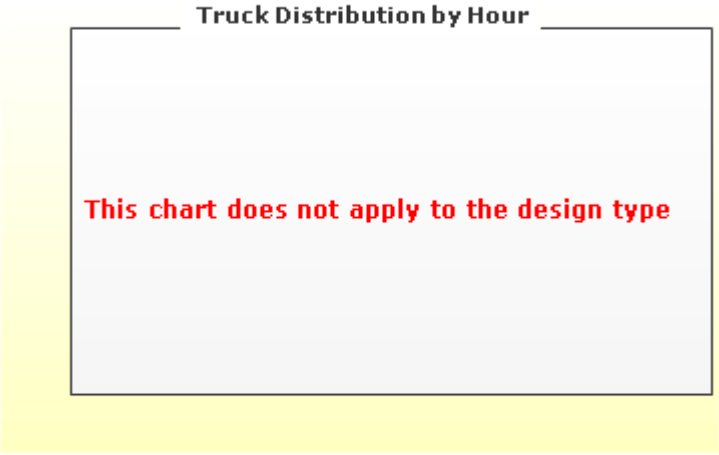


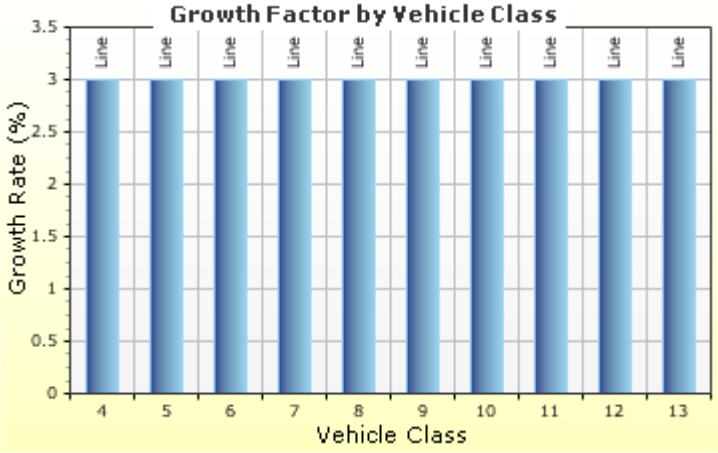
Traffic Inputs

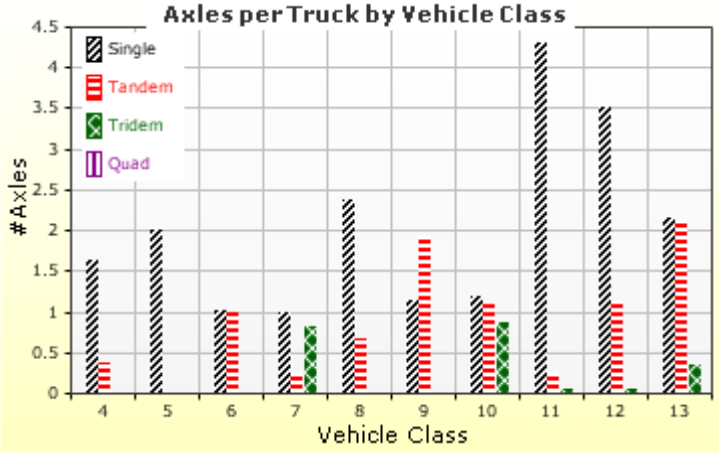
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

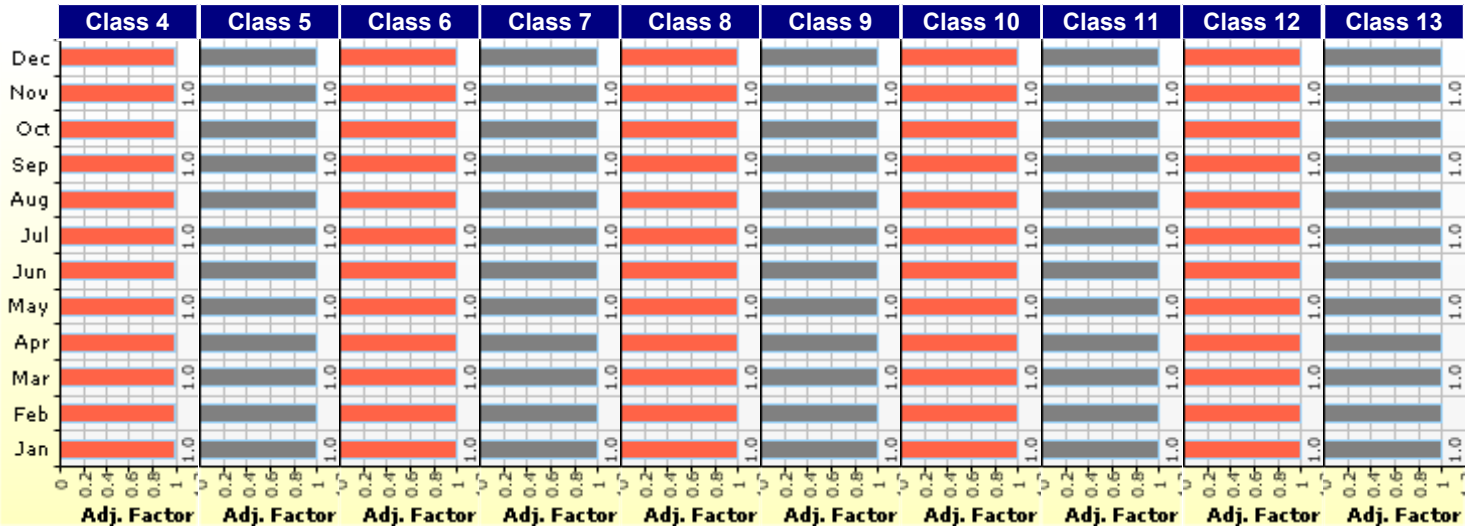








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

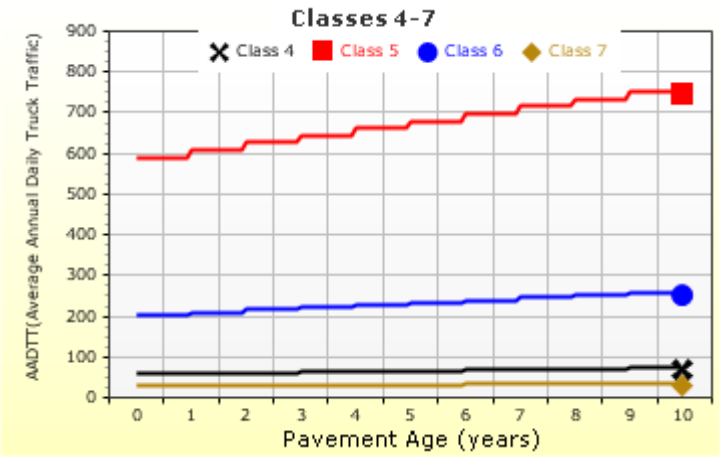
Wheelbase does not apply

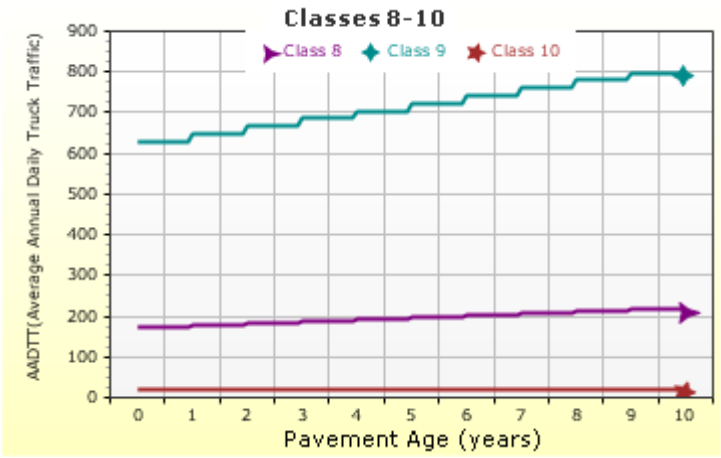
Number of Axles per Truck

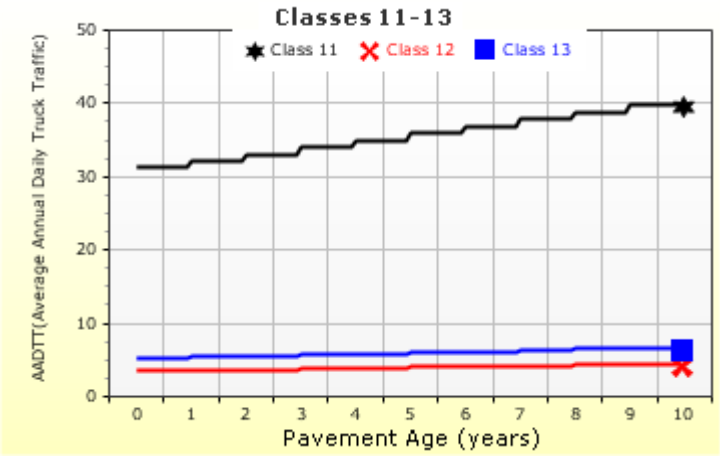
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

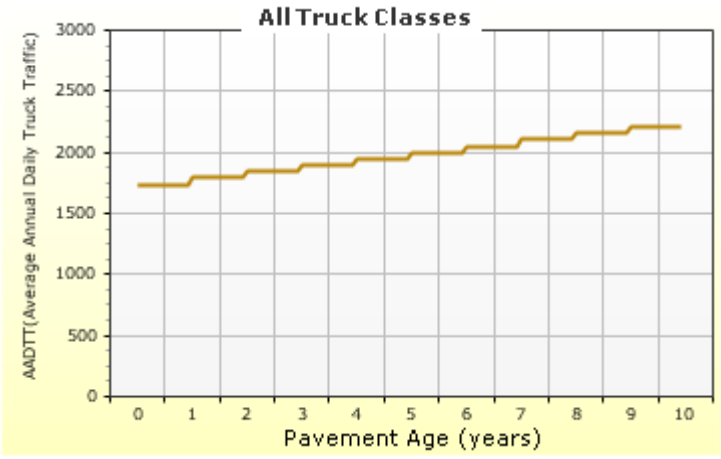
AADTT (Average Annual Daily Truck Traffic) Growth

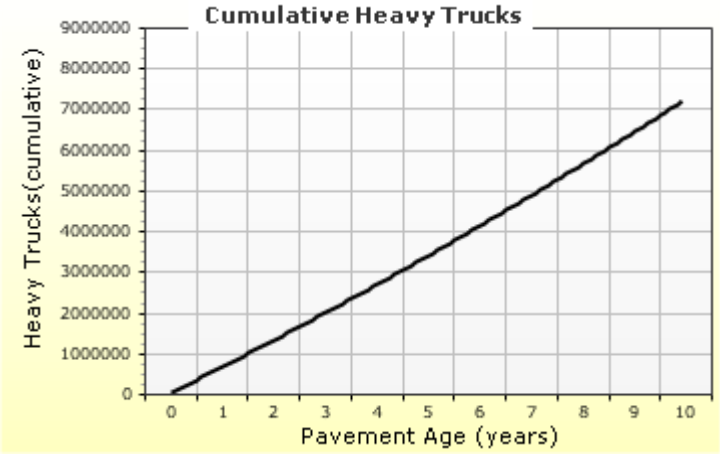
*** Traffic cap is not enforced**







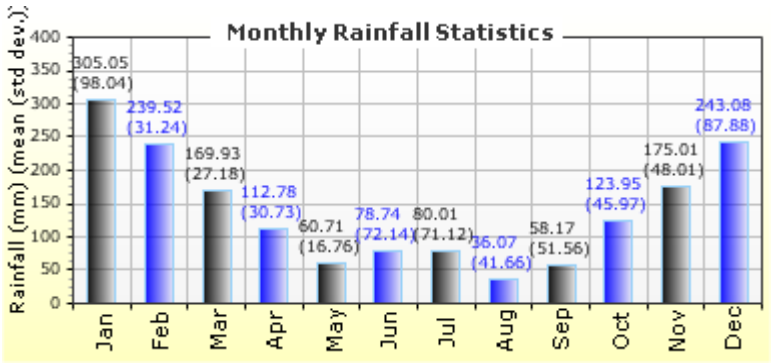




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
SAO PAULO, SP	-23.50000 -46.62000 792

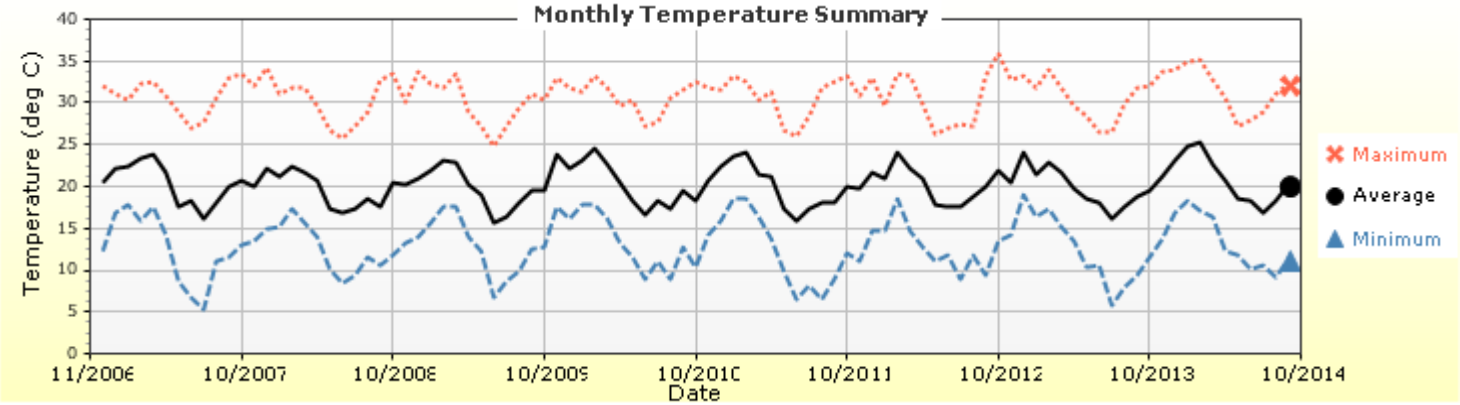


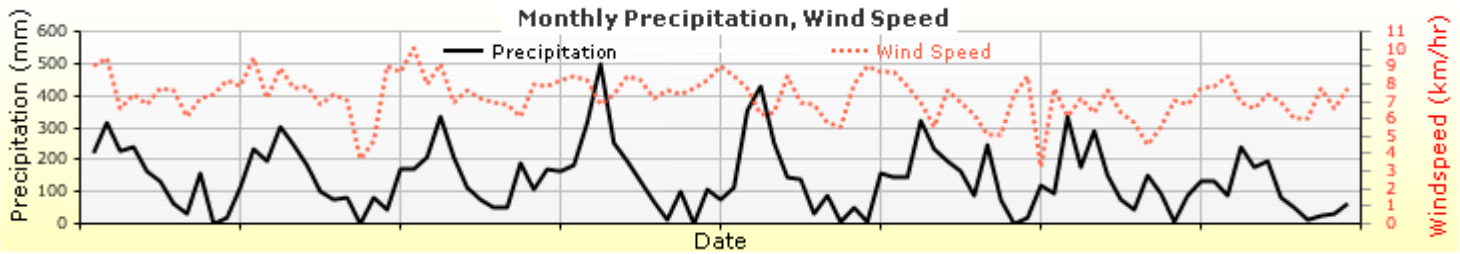
Annual Statistics:

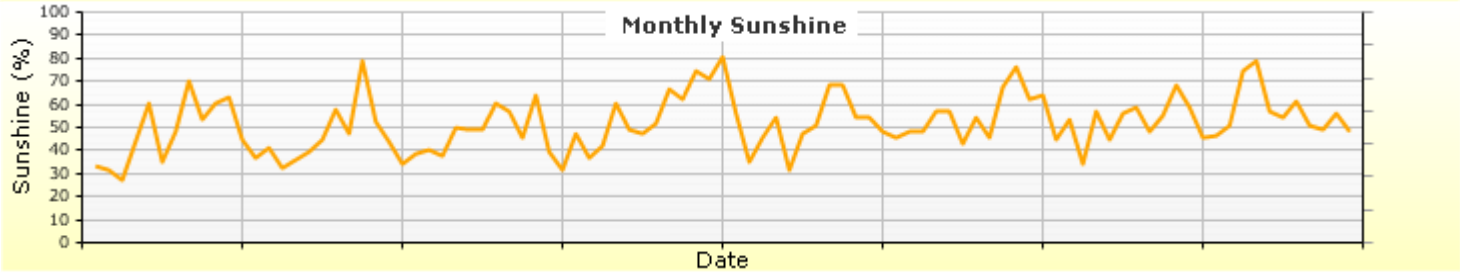
Mean annual air temperature (ºC)	20.15
Mean annual precipitation (mm)	1696.21
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

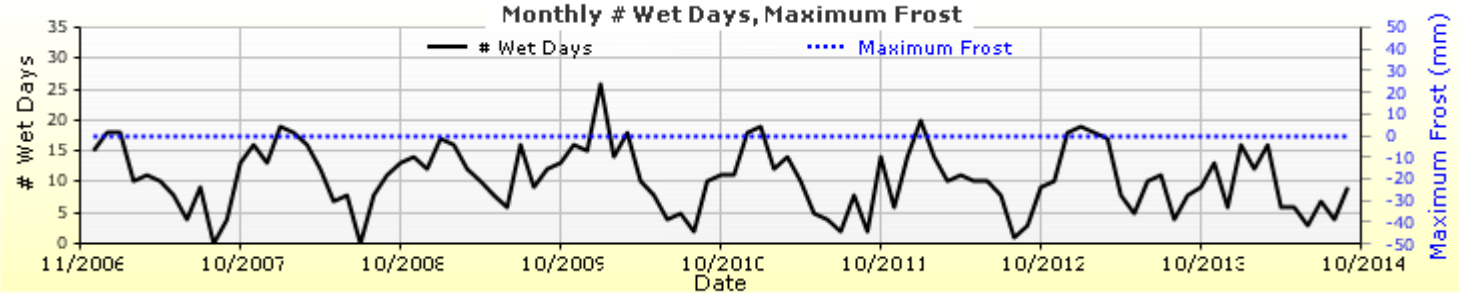
Water table depth (m)	3.05

Monthly Climate Summary:

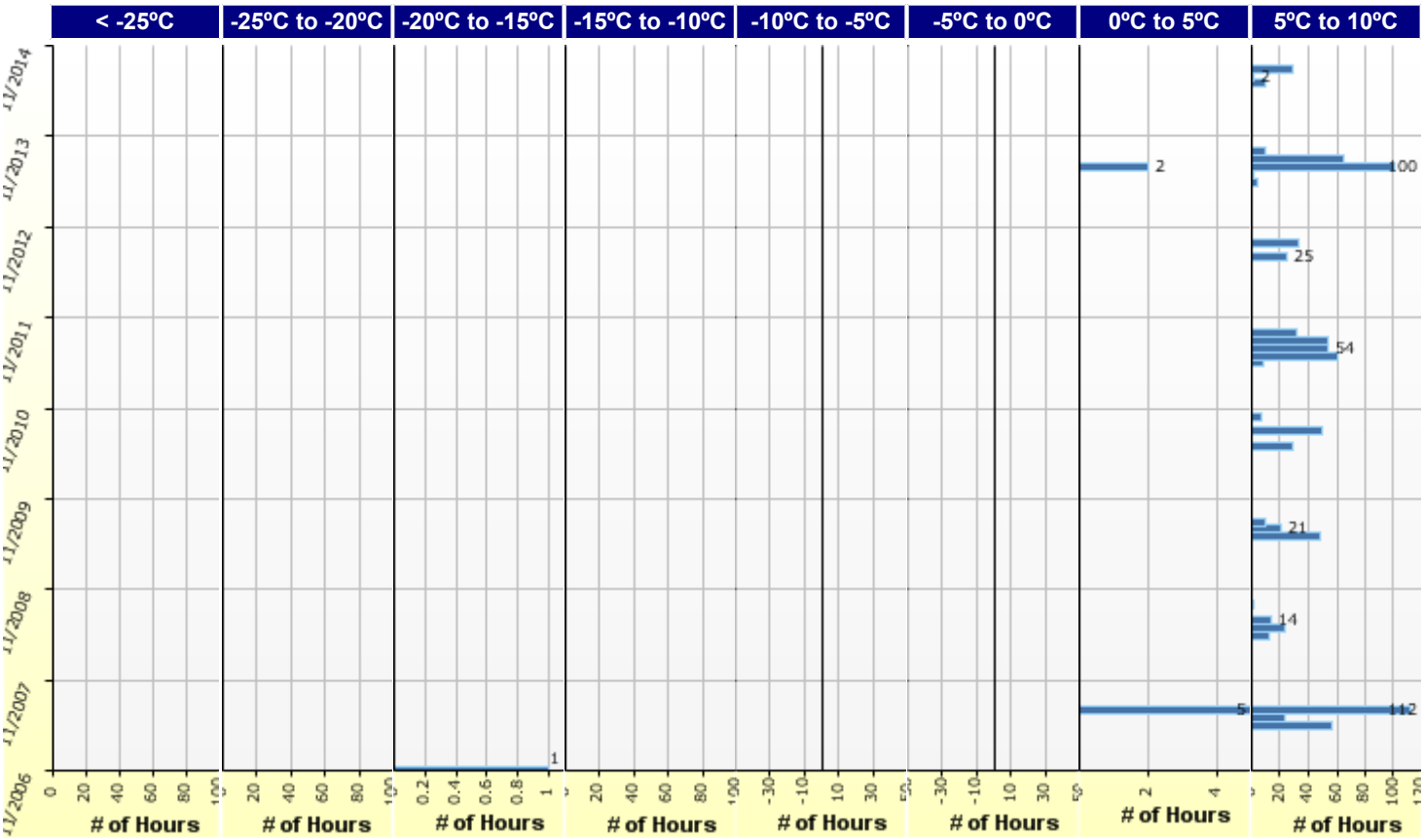


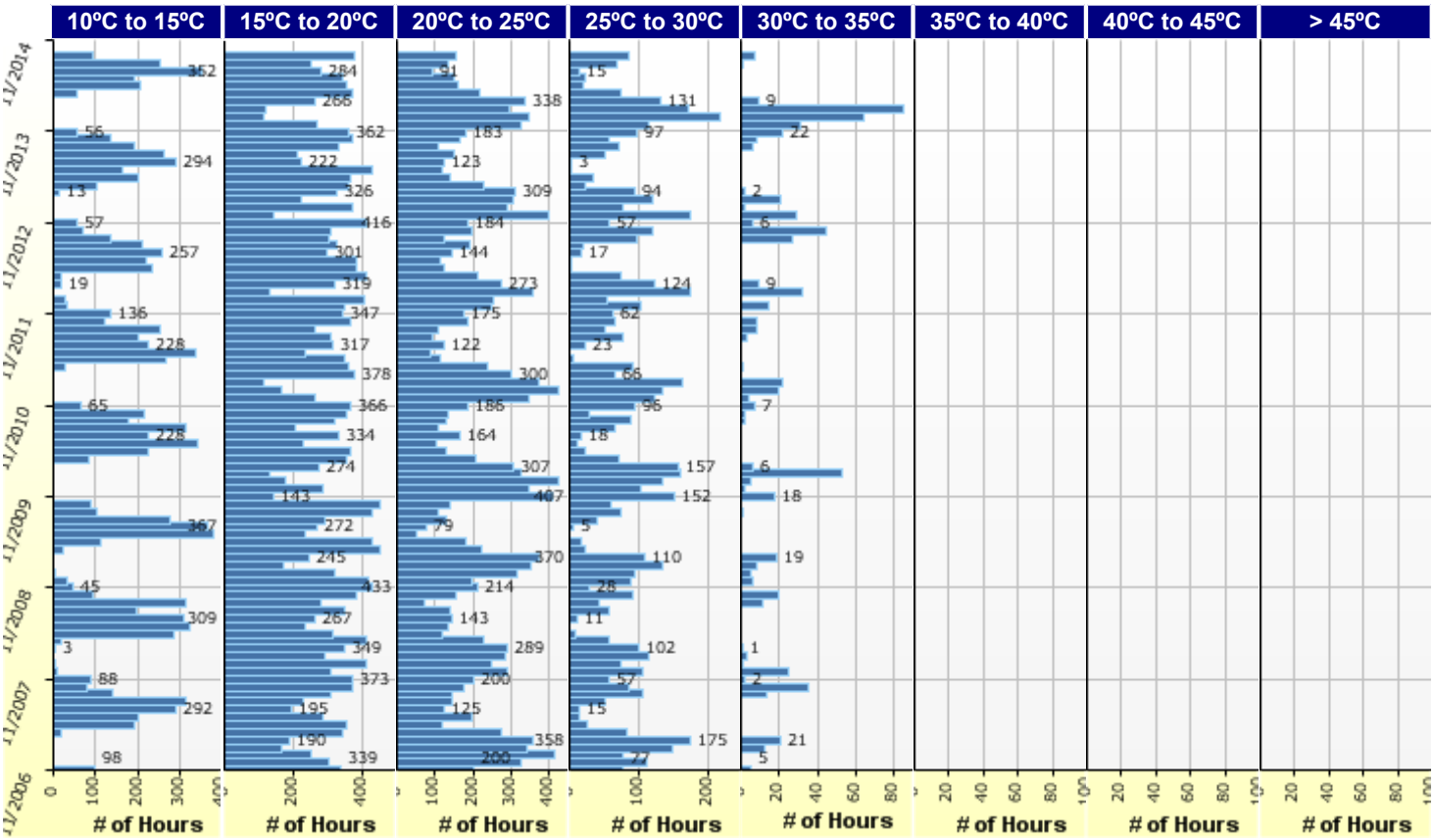






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

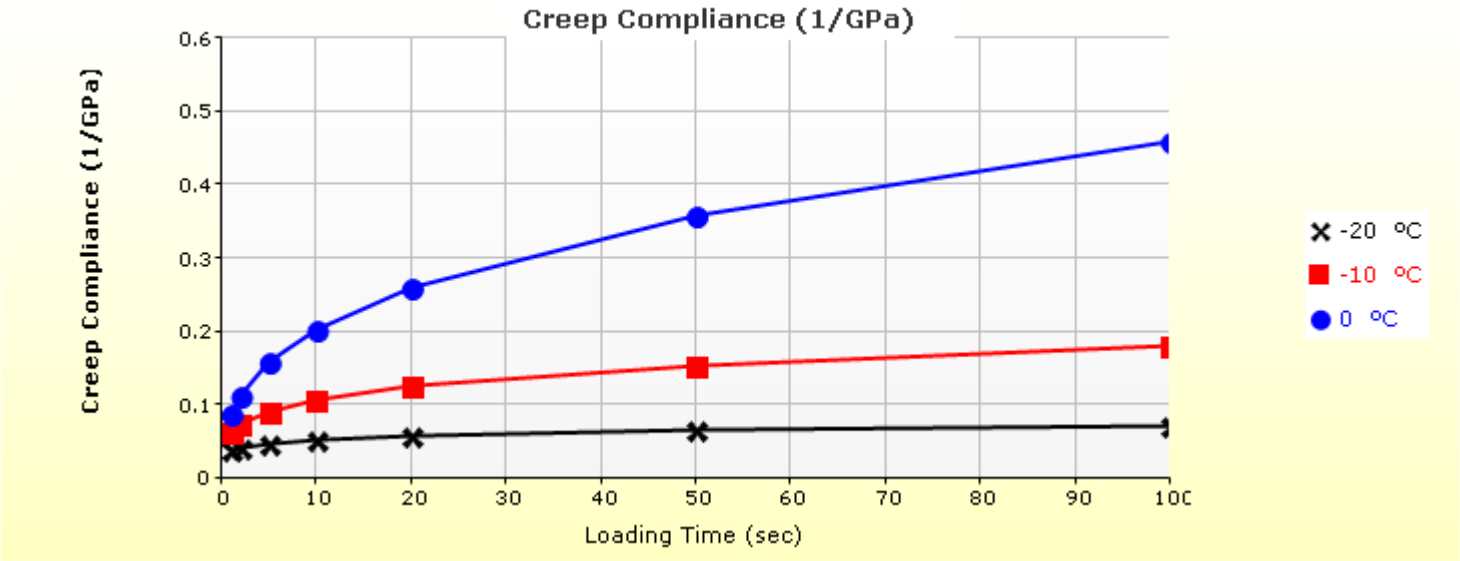
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

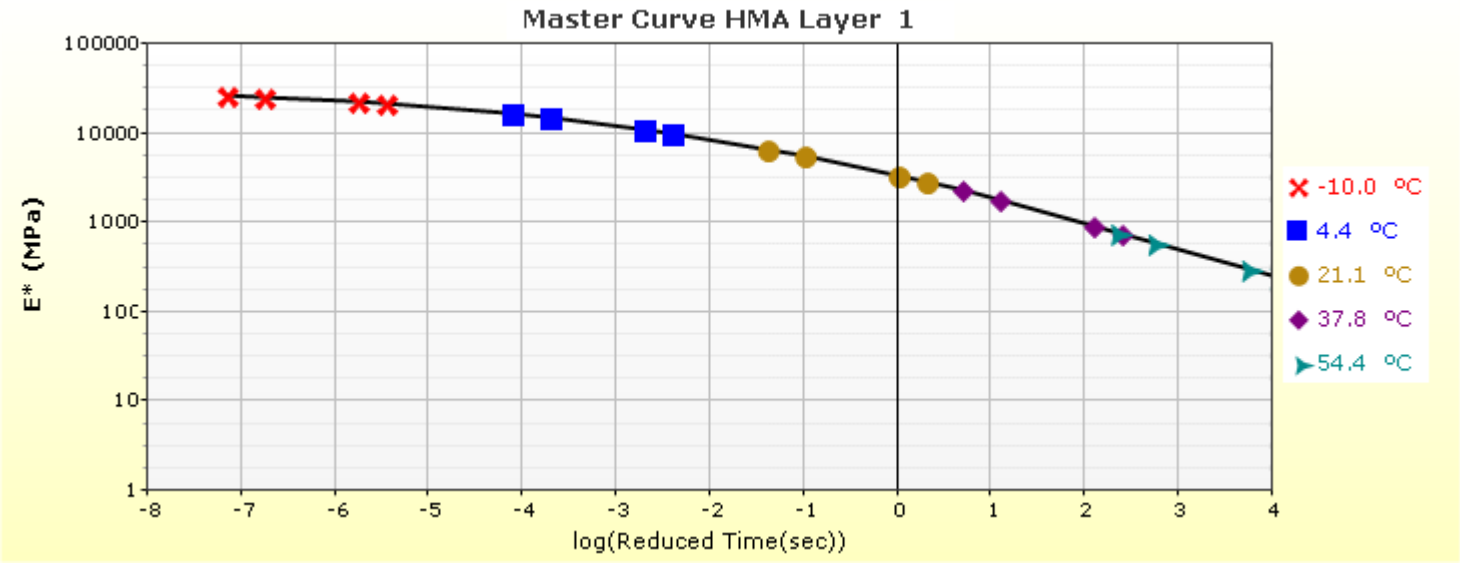
Indirect tensile strength at -10 ºC (MPa)	2.69

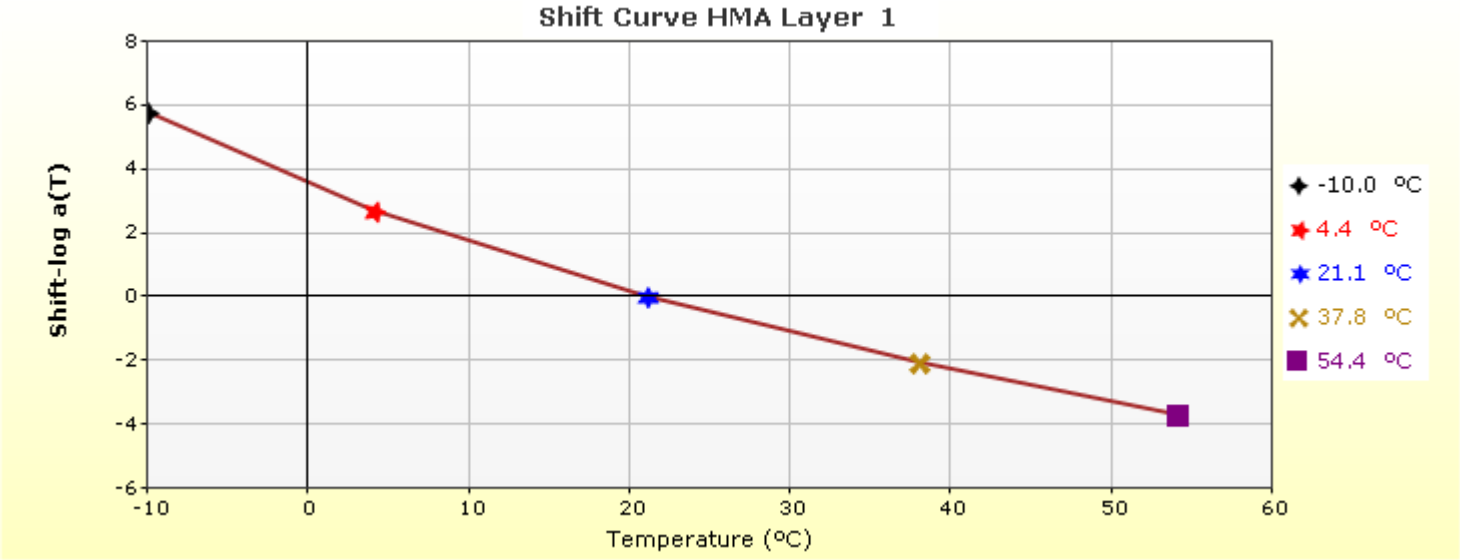
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

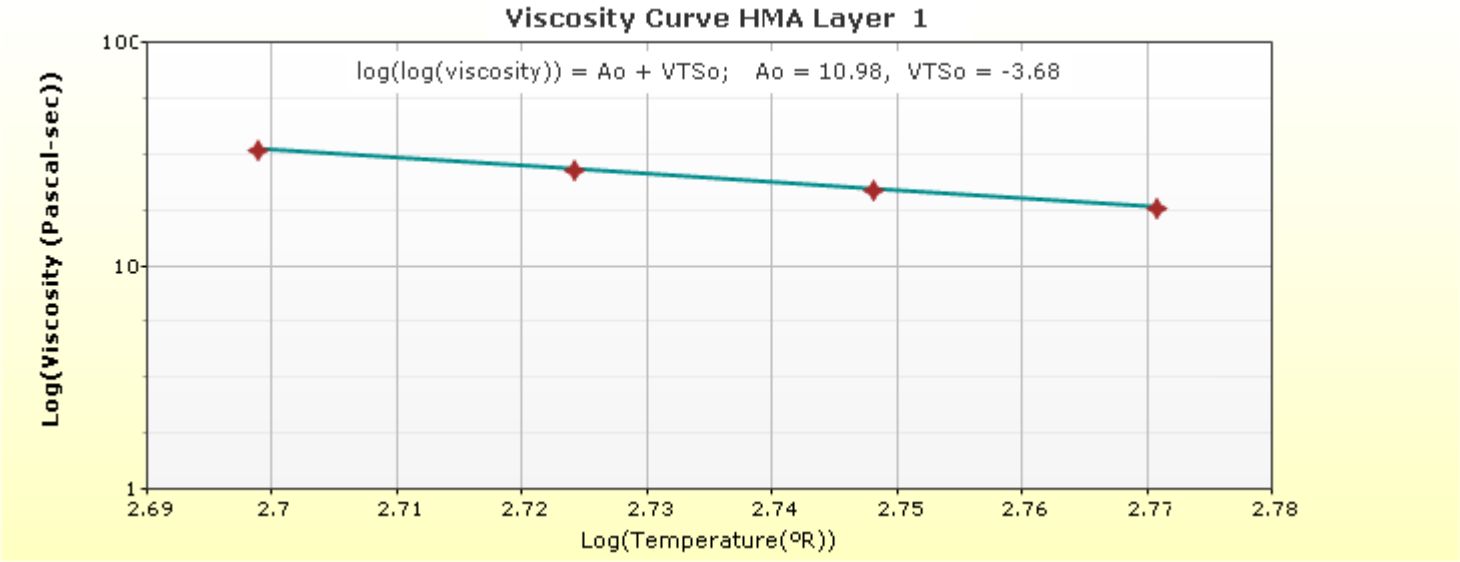
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



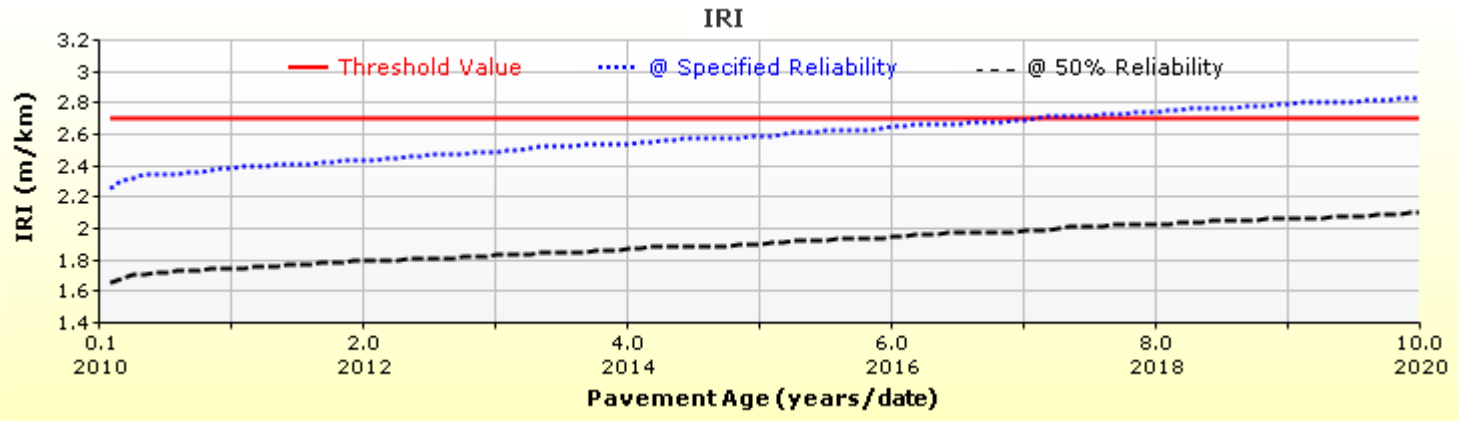
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

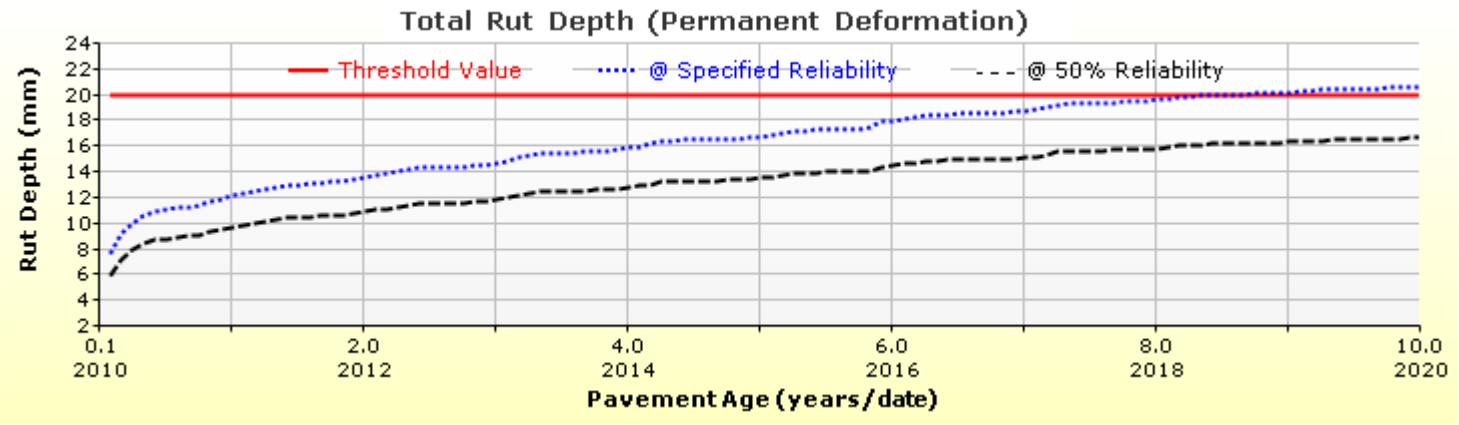


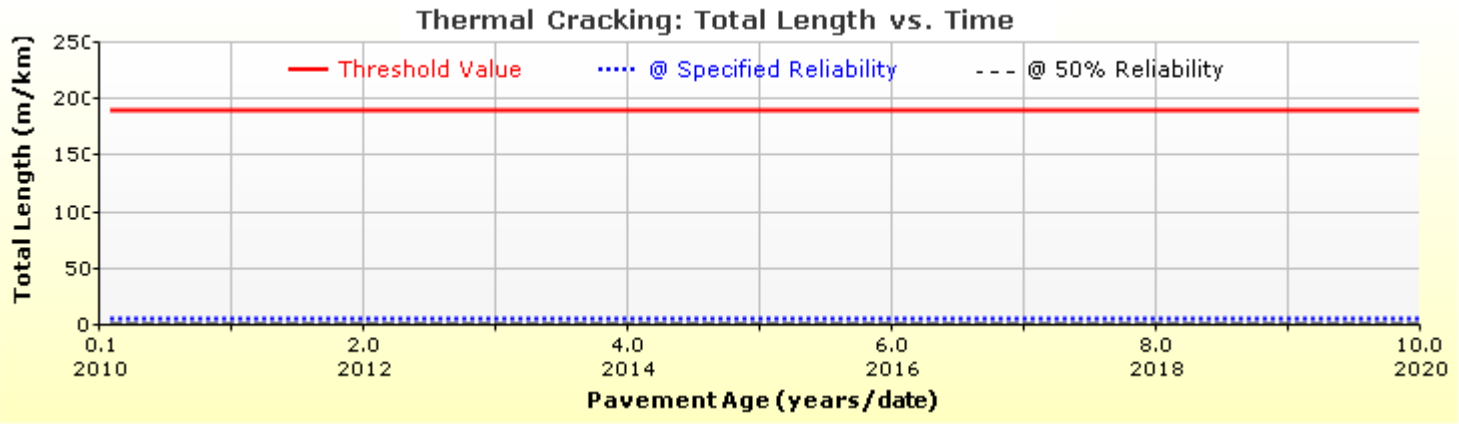


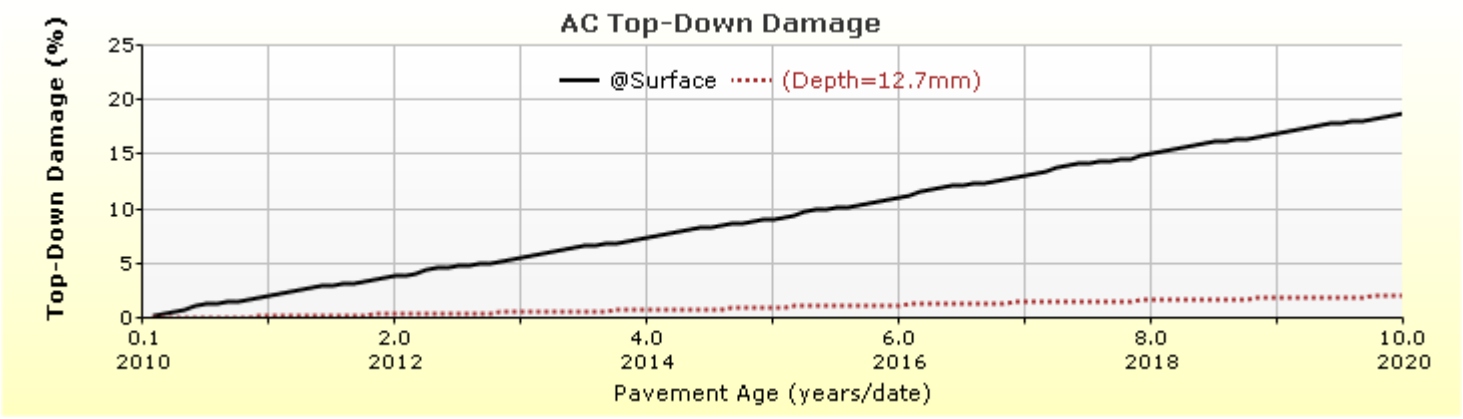


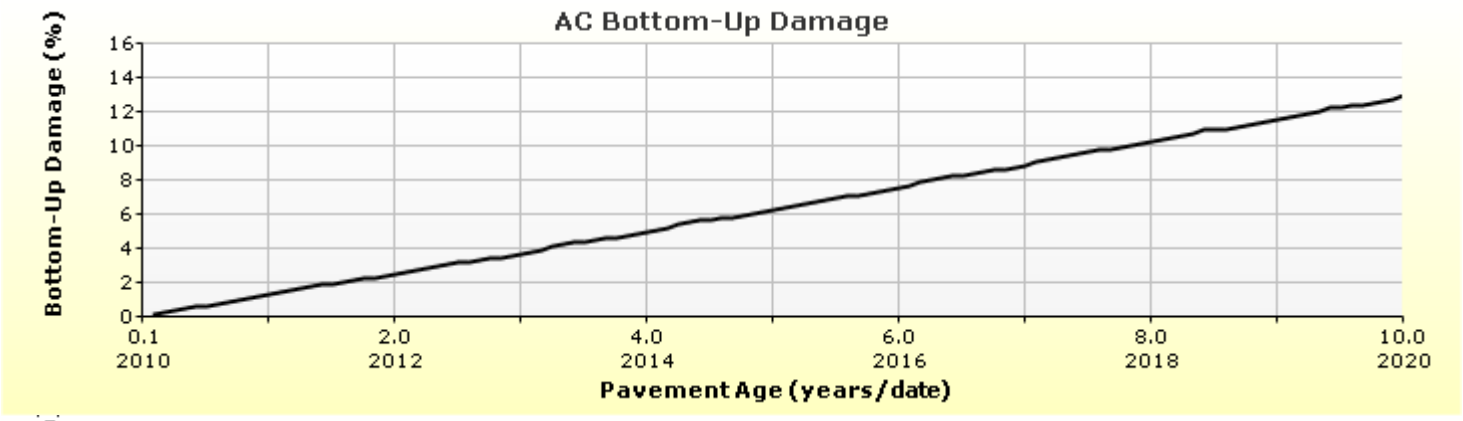
Analysis Output Charts

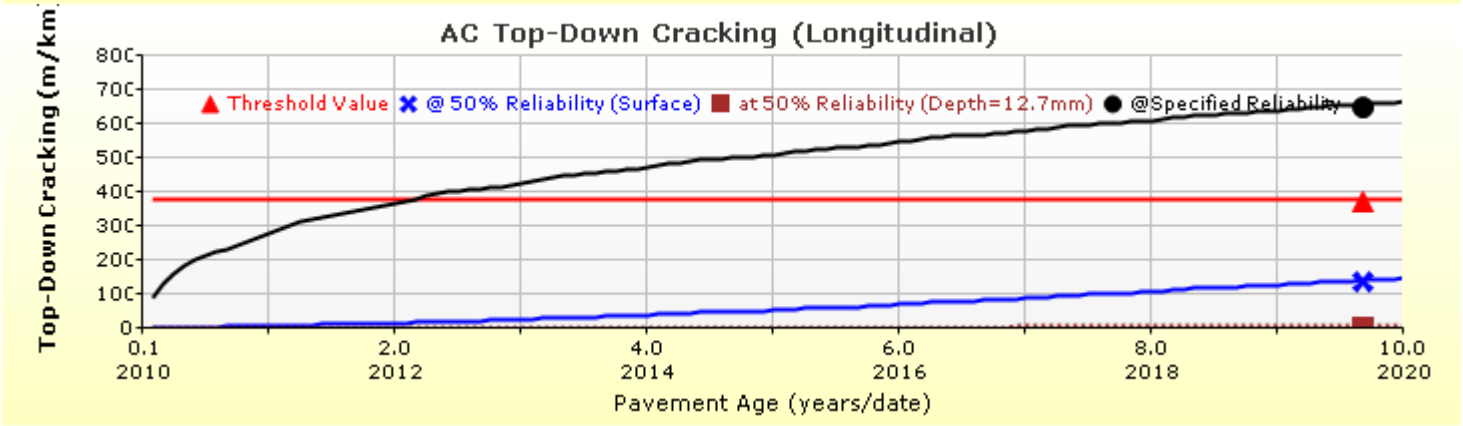


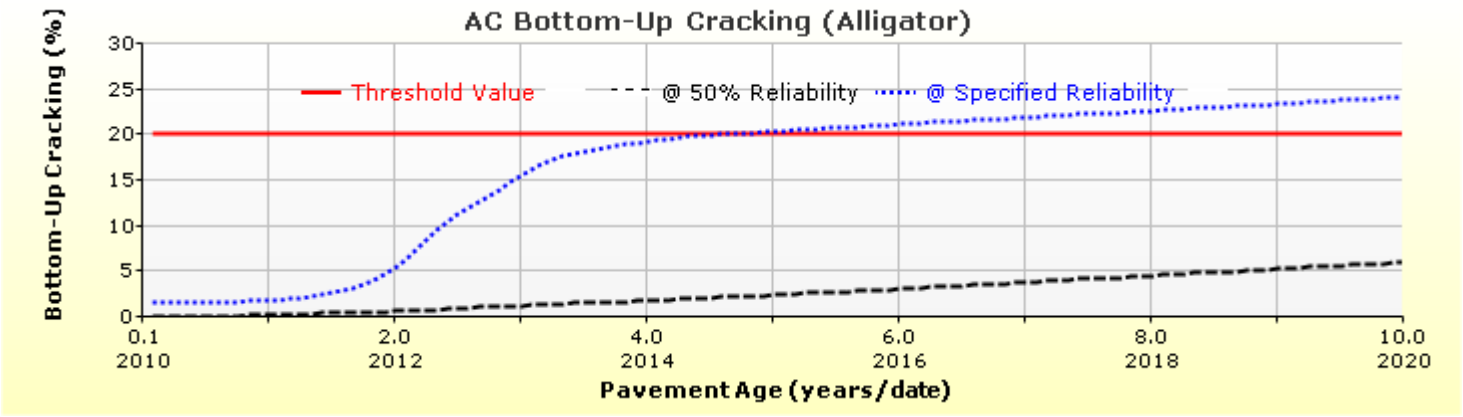


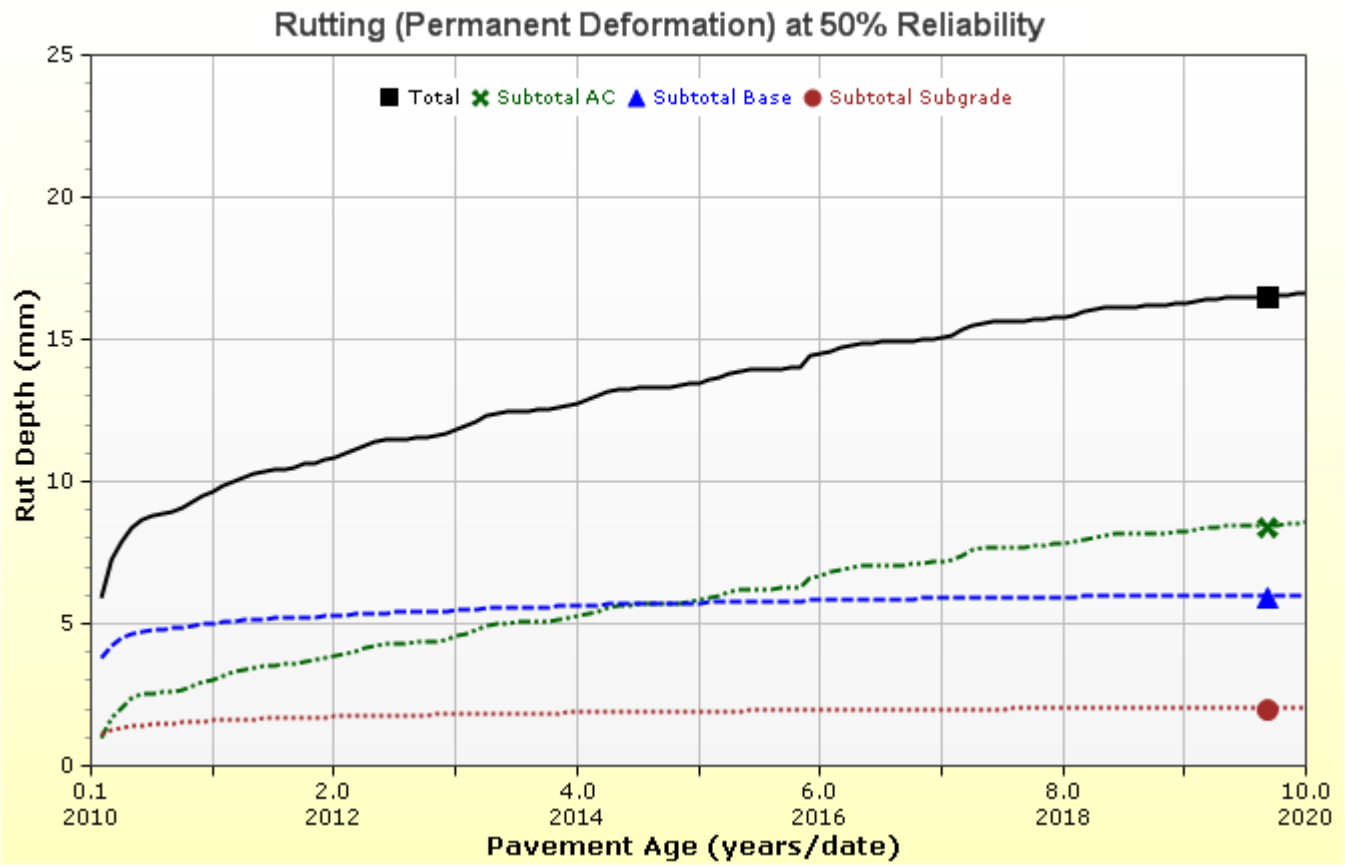


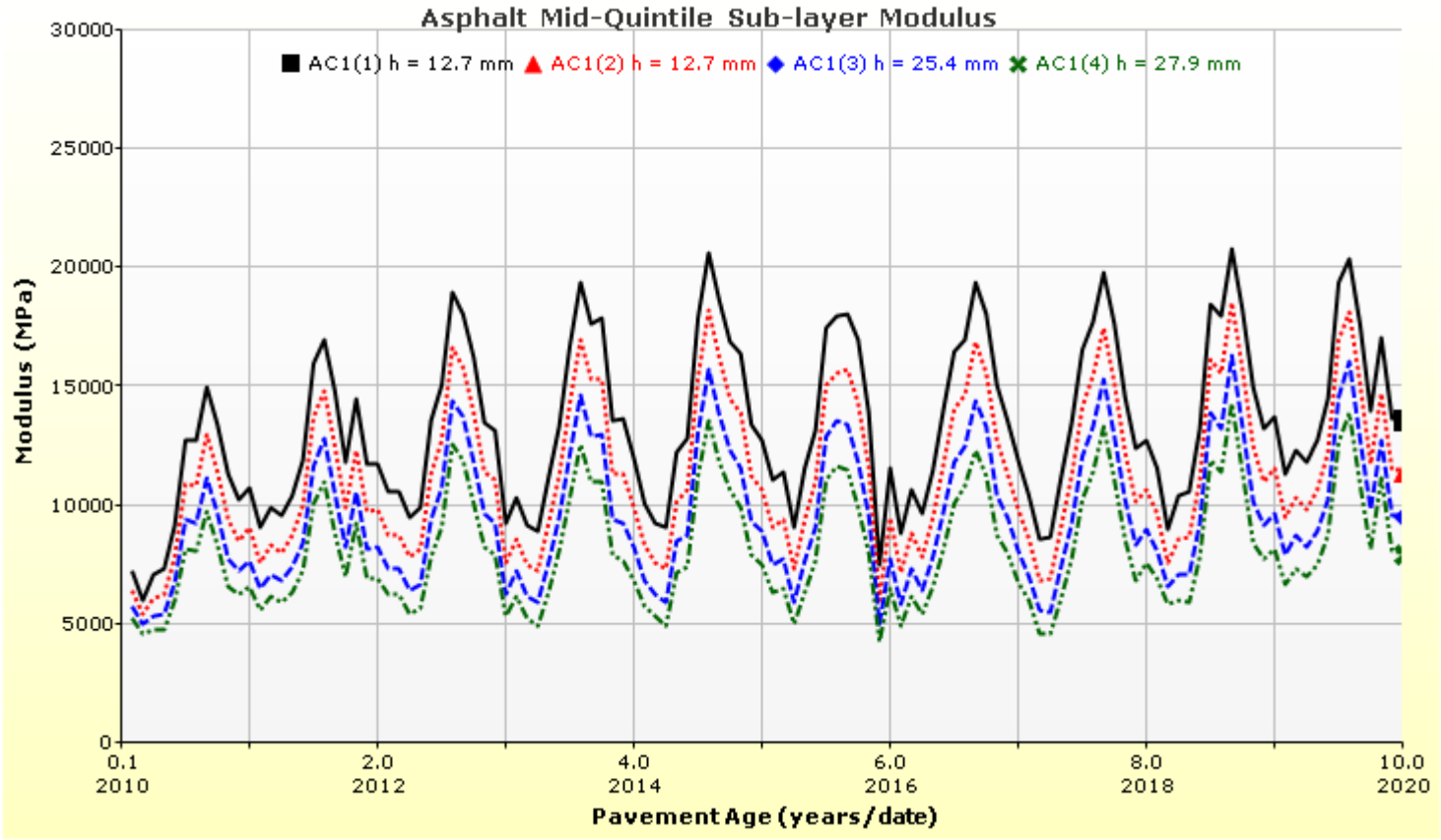

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

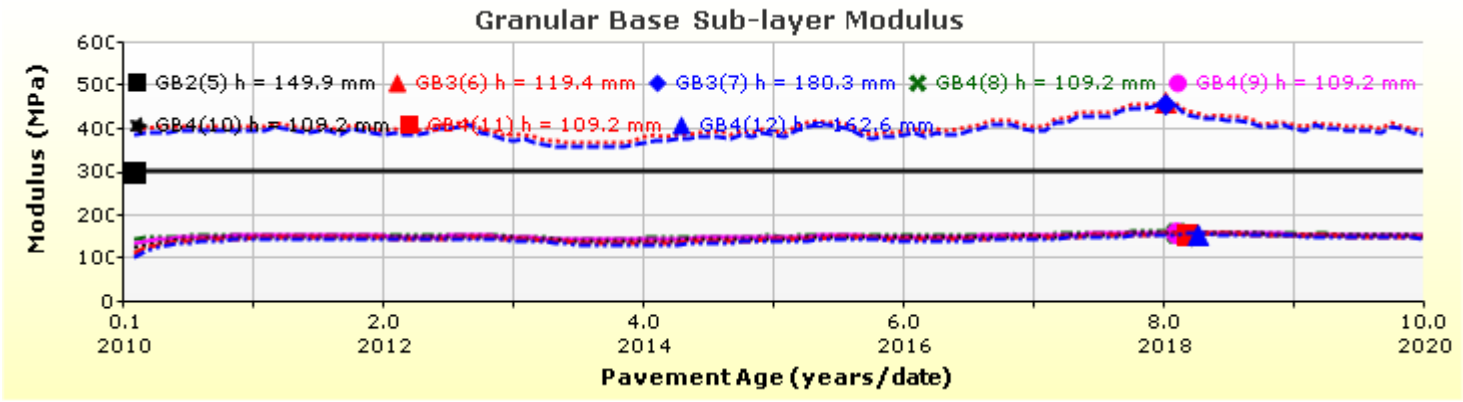

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

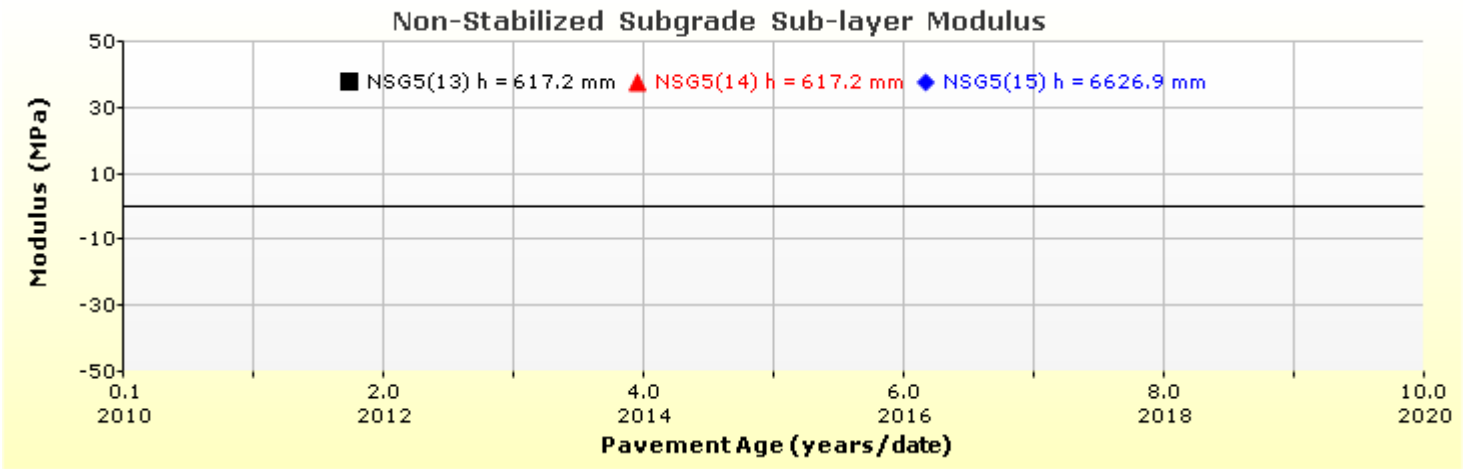

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60000
50000
40000
30000
20000
10000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$

$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$

$T = layer\ temperature(^{\circ}F)$

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestSP_Temp

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestSP_Temp.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -23.5, -46.62

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

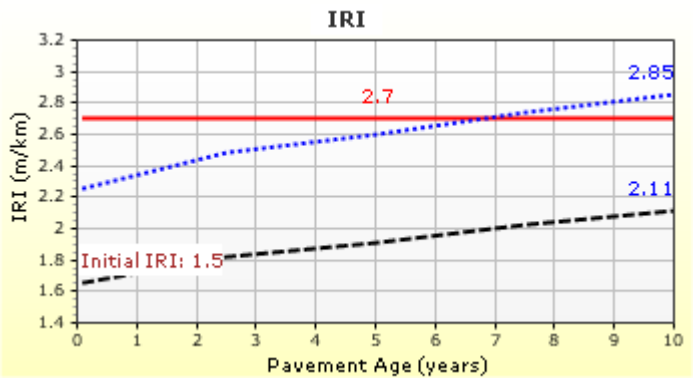
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

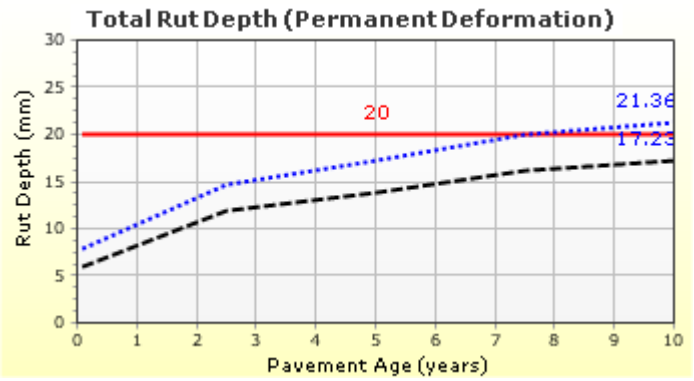
Design Outputs

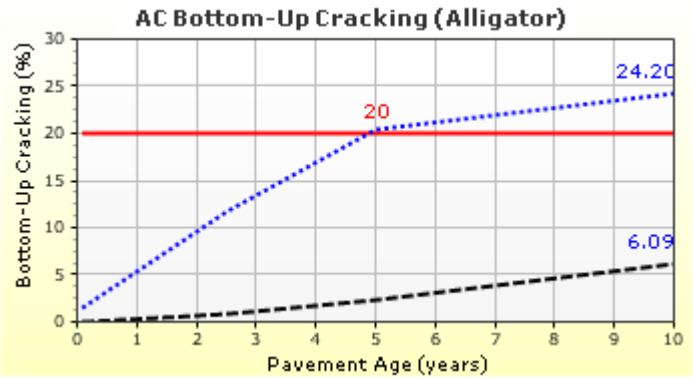
Distress Prediction Summary

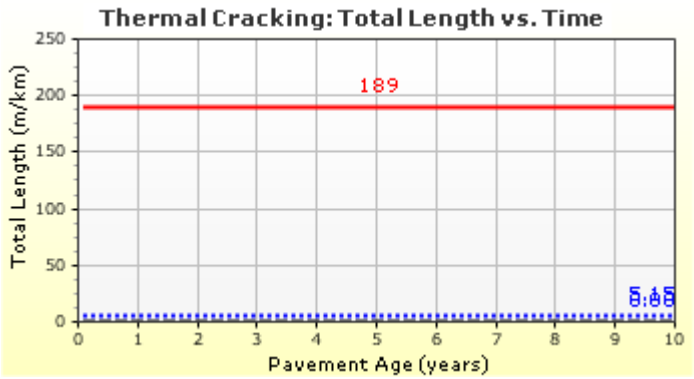
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.85	90.00	84.53	Fail
Permanent deformation - total pavement (mm)	20.00	21.35	90.00	80.47	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.20	90.00	83.76	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	678.49	90.00	70.71	Fail
Permanent deformation - AC only (mm)	5.00	9.19	50.00	6.18	Fail

Distress Charts







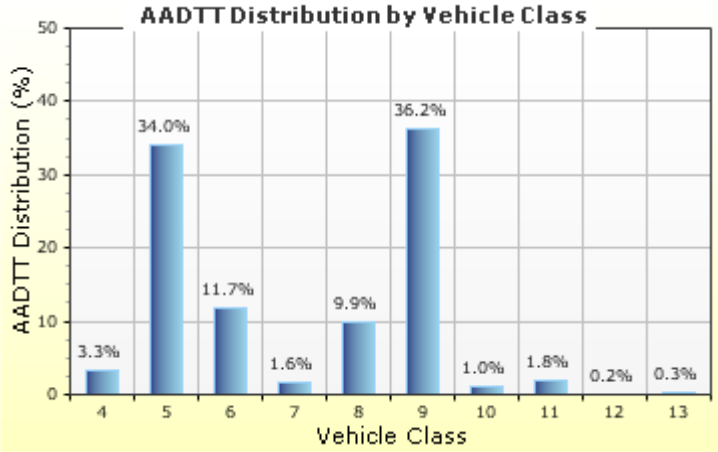


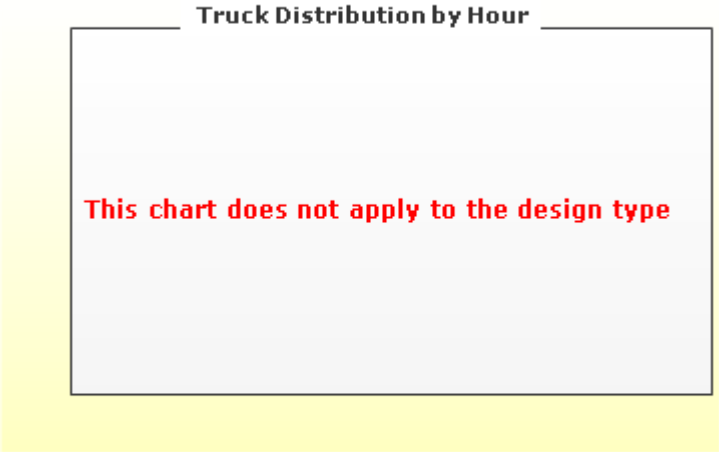


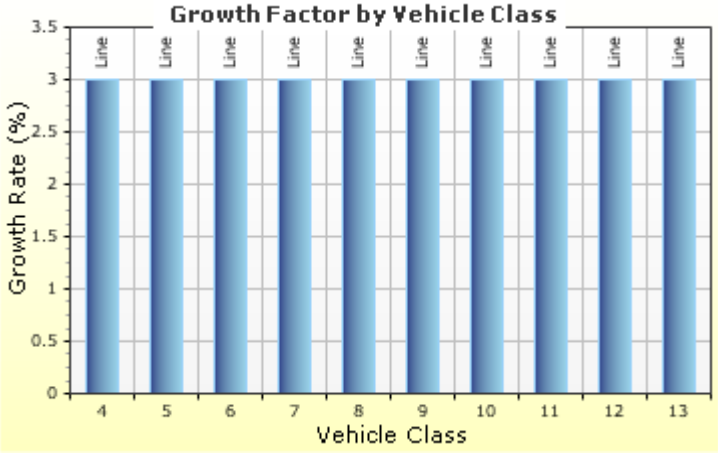
Traffic Inputs

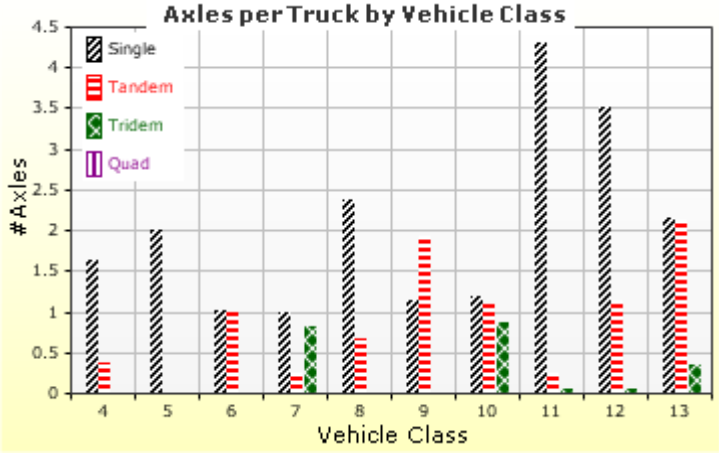
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

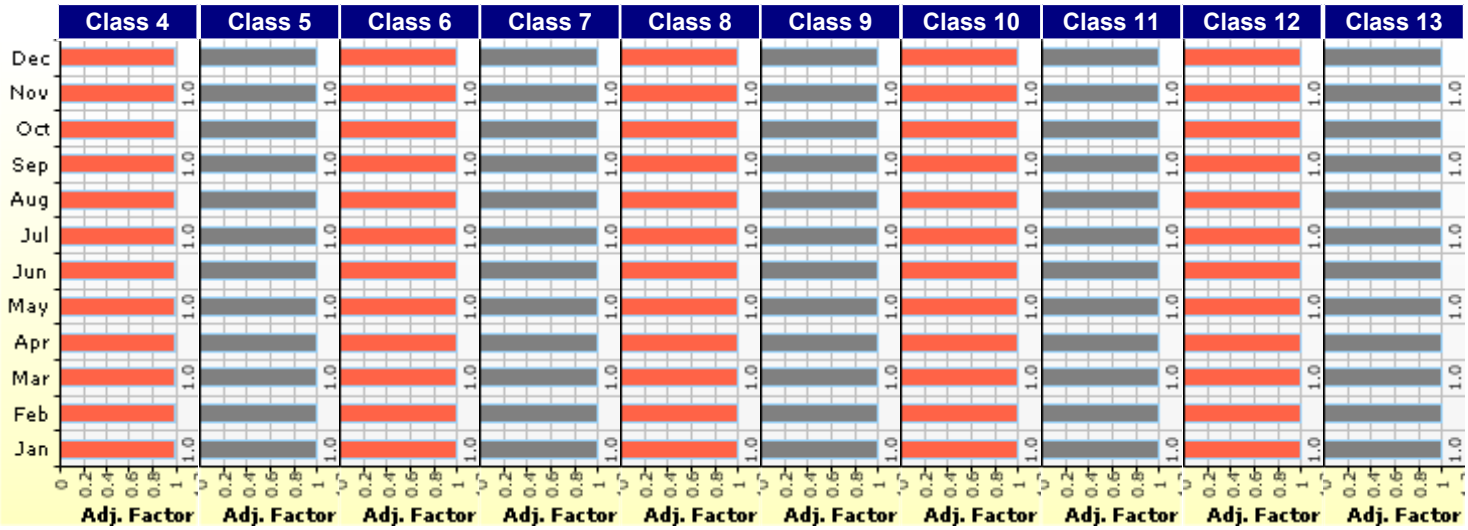








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

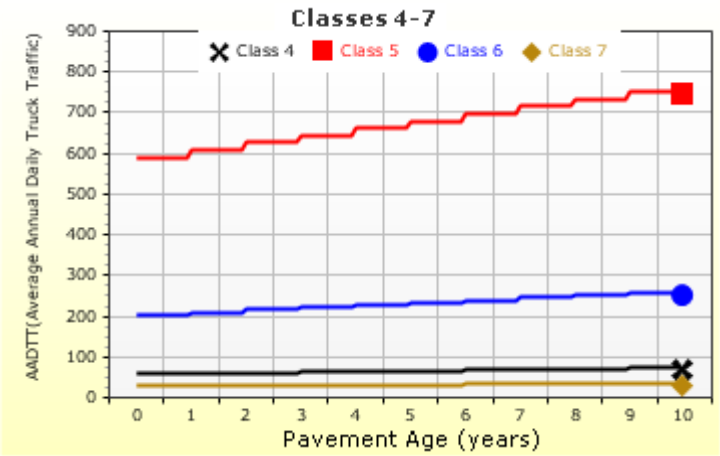
Wheelbase does not apply

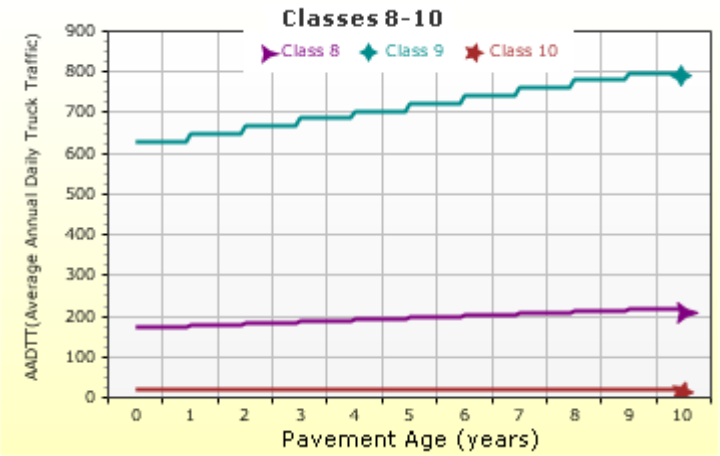
Number of Axles per Truck

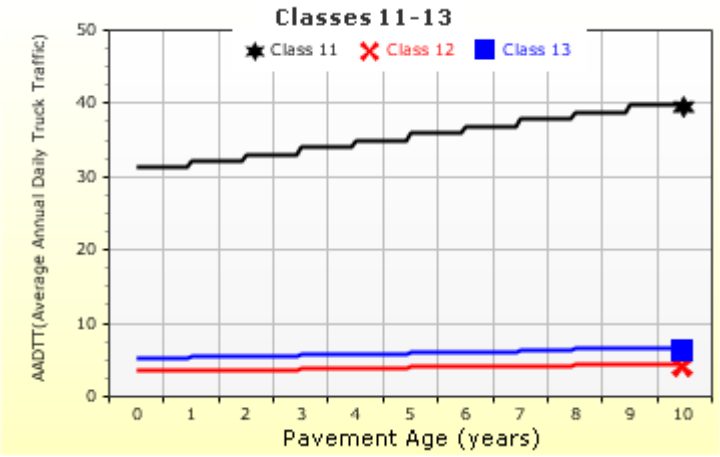
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

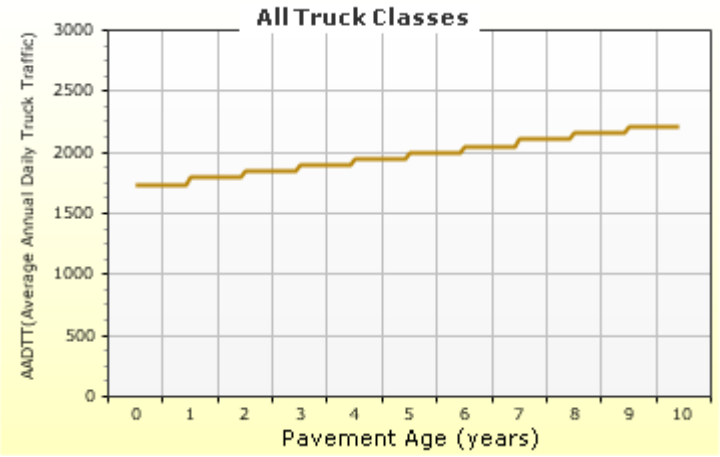
AADTT (Average Annual Daily Truck Traffic) Growth

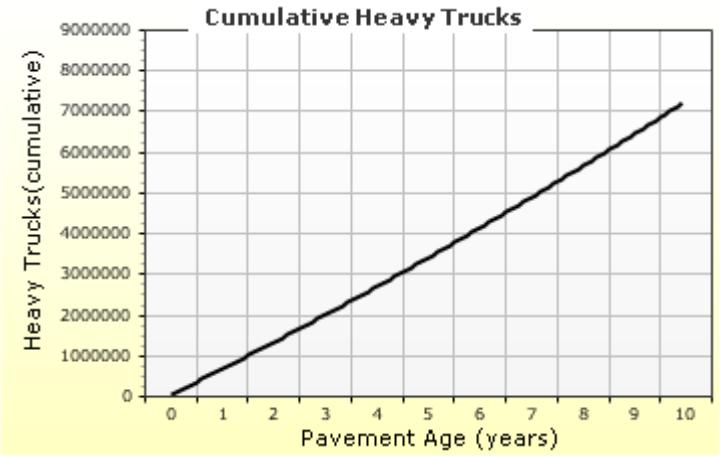
*** Traffic cap is not enforced**







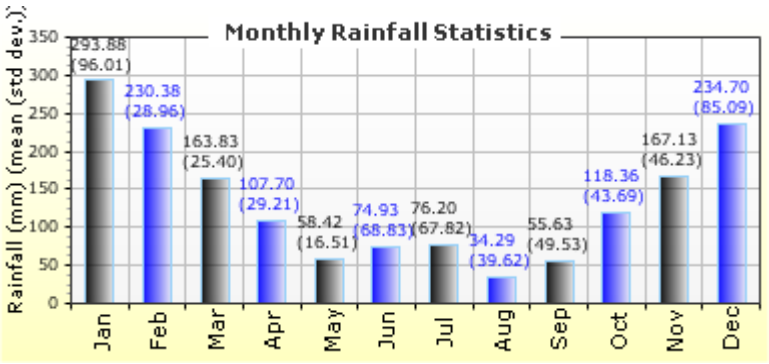




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
SAO PAULO, SP	-23.50000 -46.62000 792

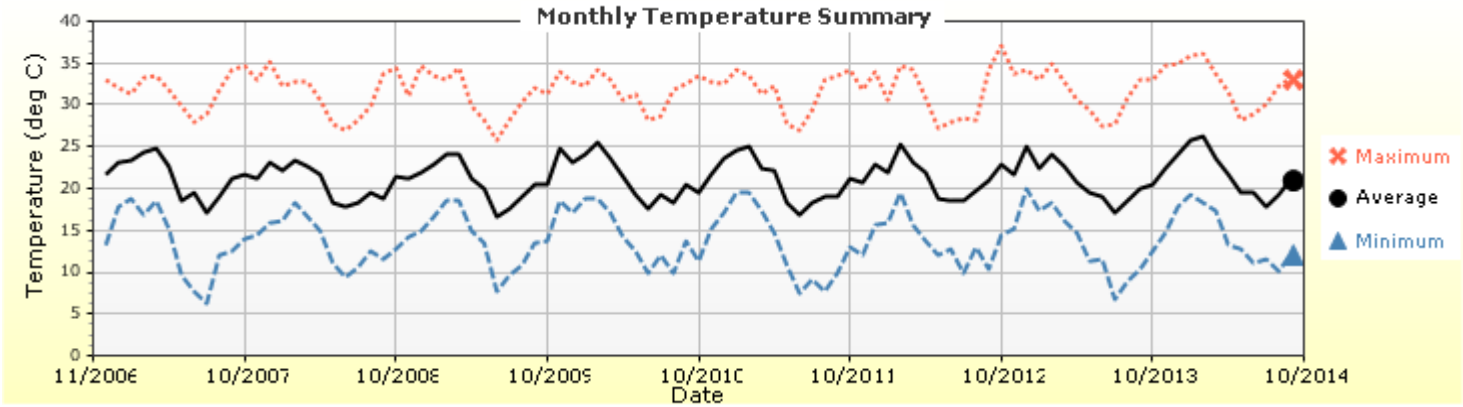


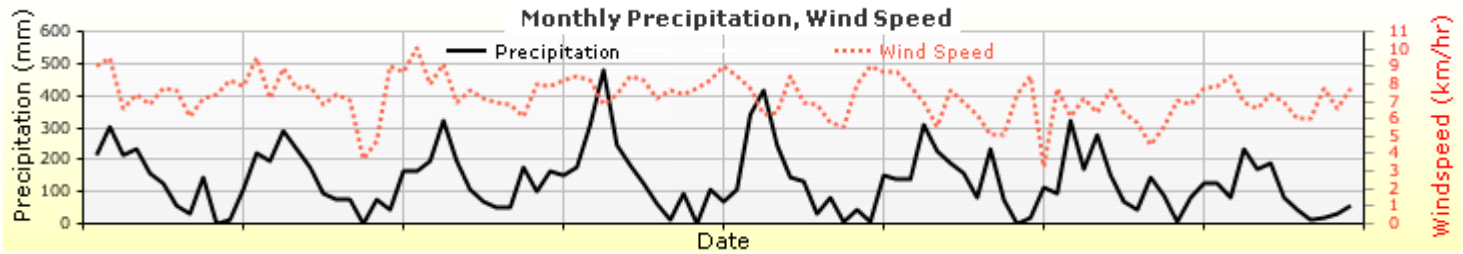
Annual Statistics:

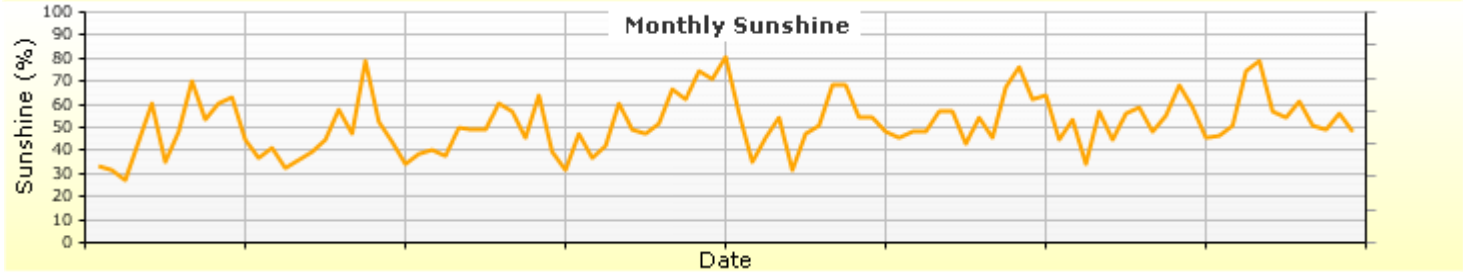
Mean annual air temperature (ºC)	21.15
Mean annual precipitation (mm)	1628.14
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

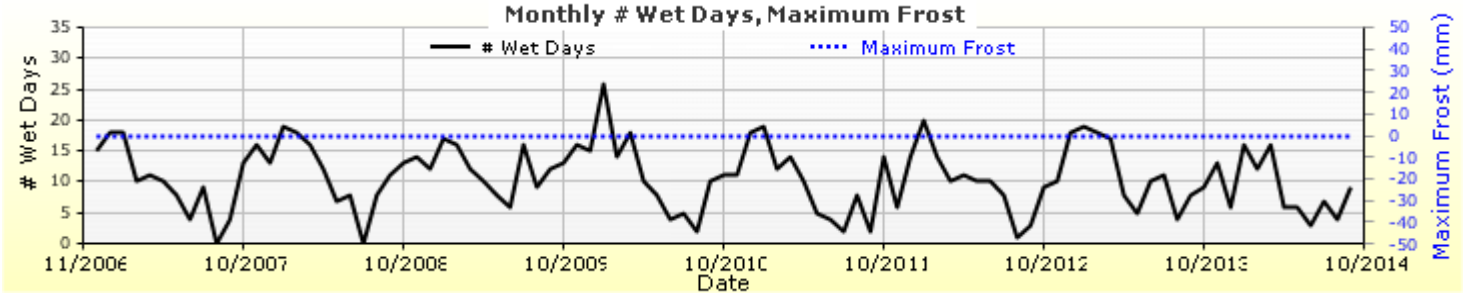
Water table depth (m): 3.05

Monthly Climate Summary:

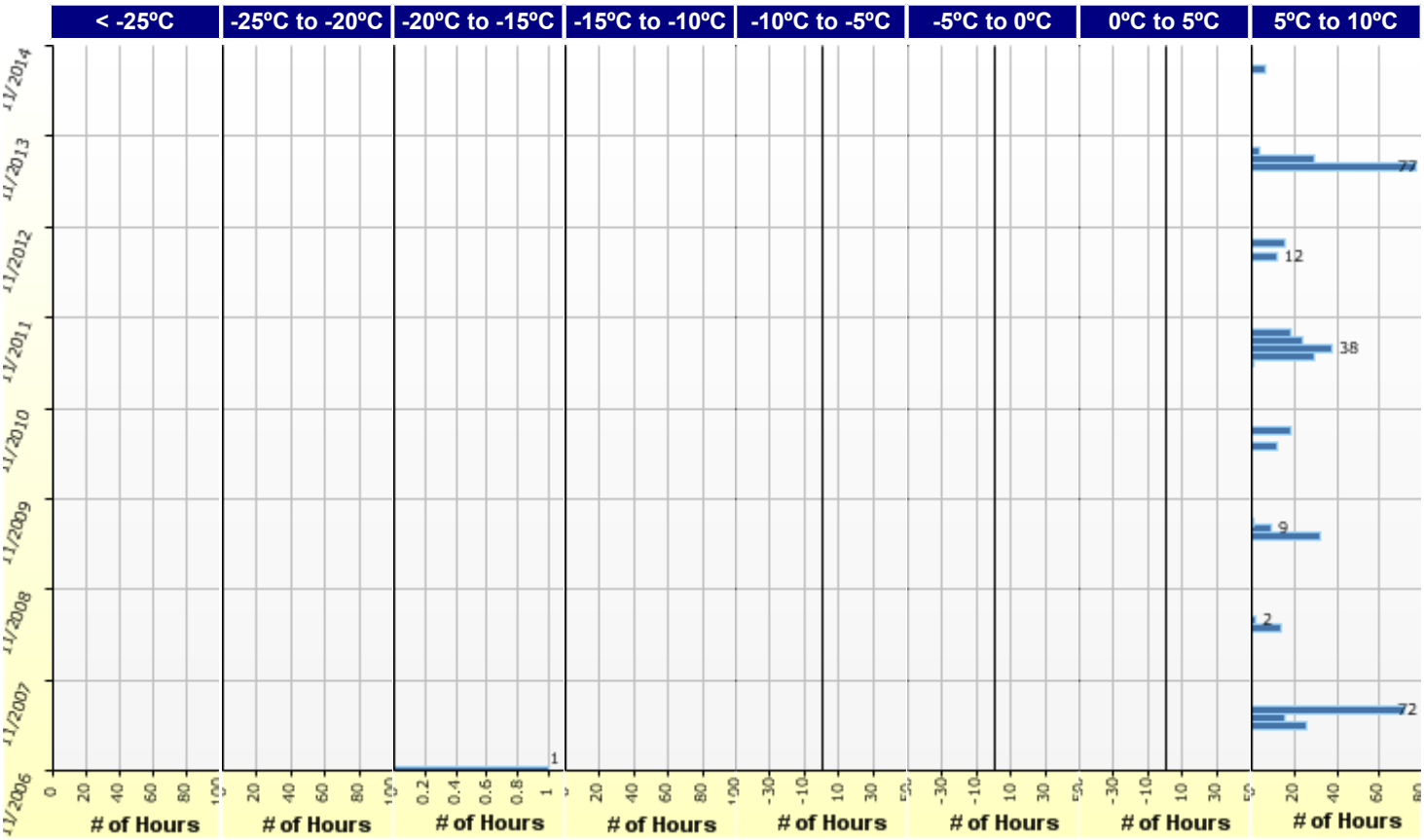


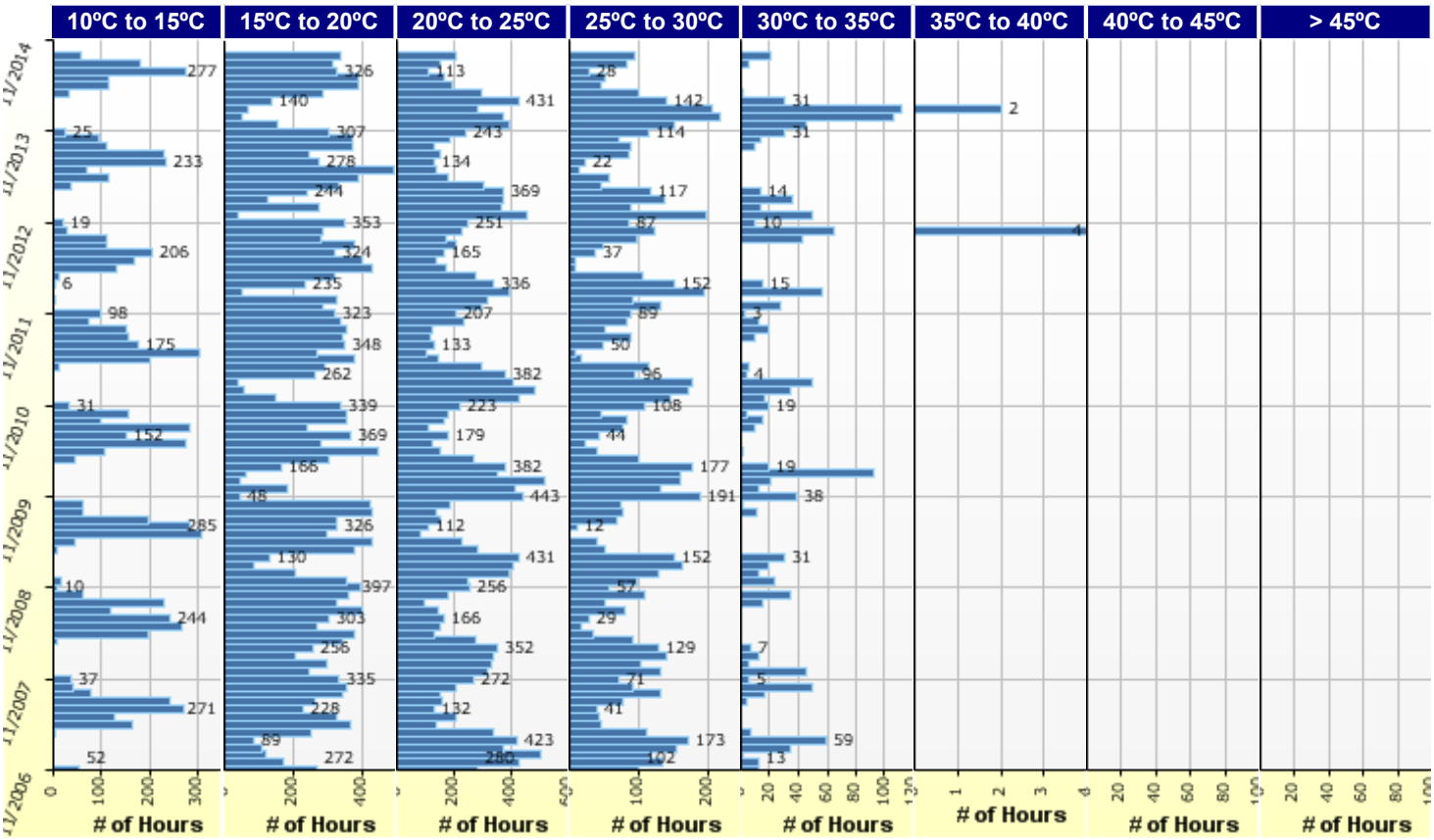






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

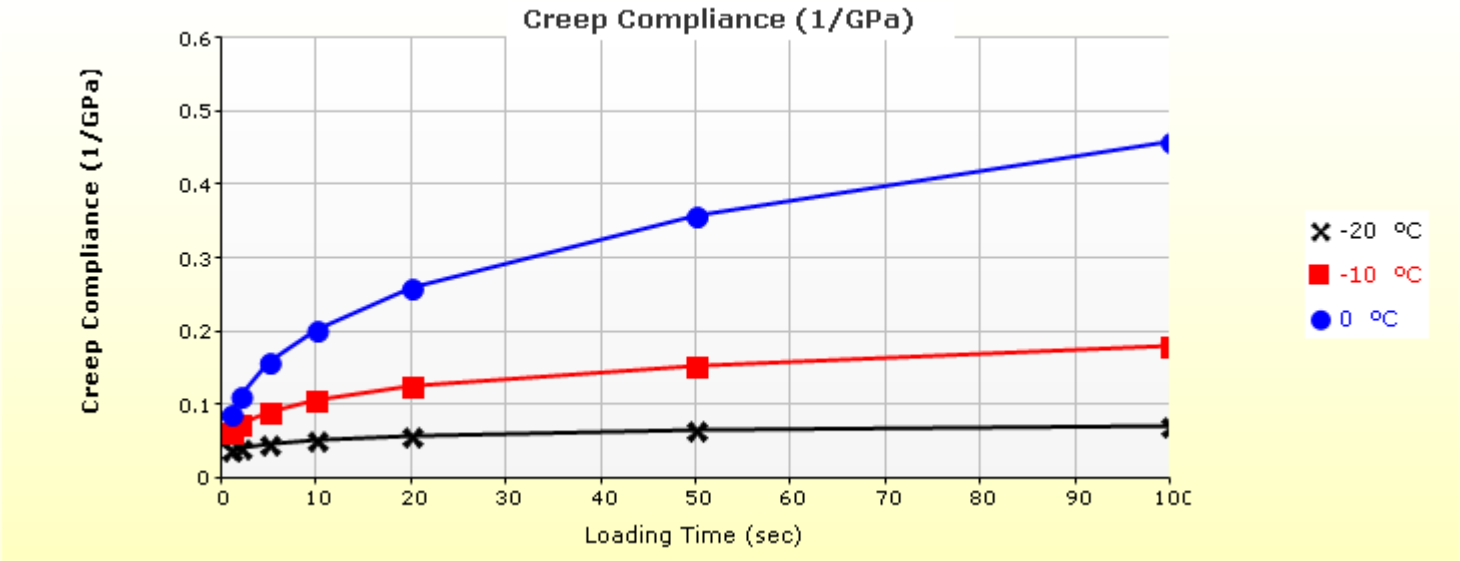
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

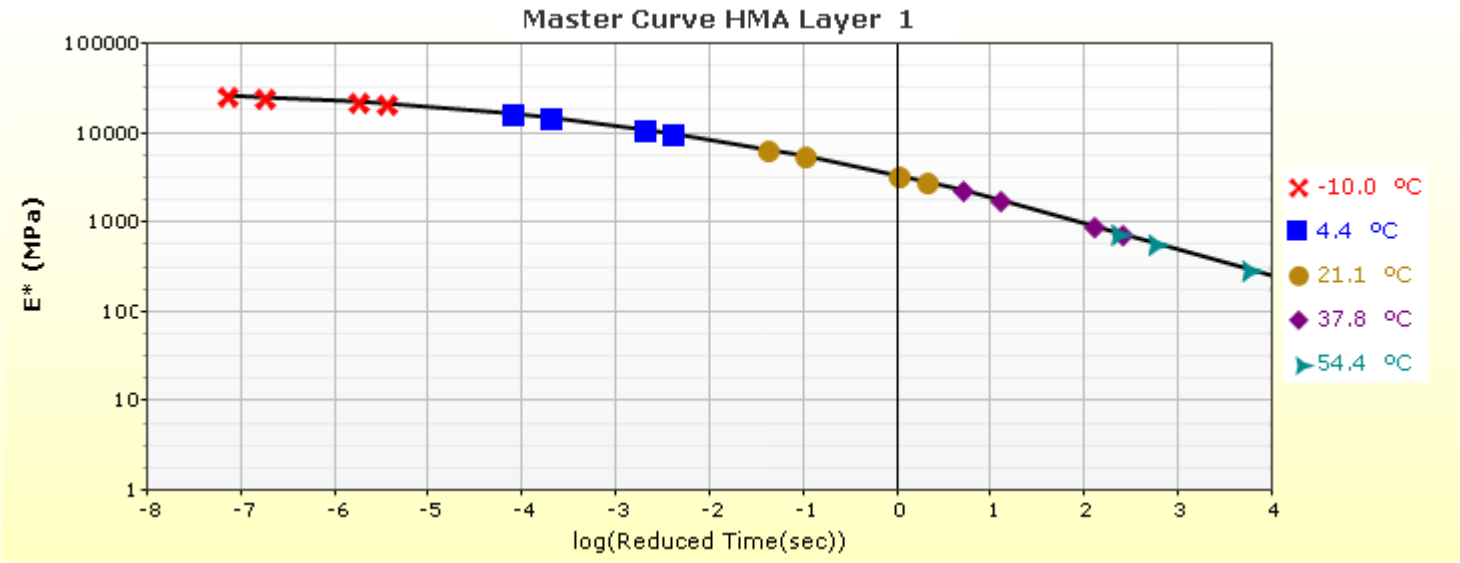
Indirect tensile strength at -10 ºC (MPa)	2.69

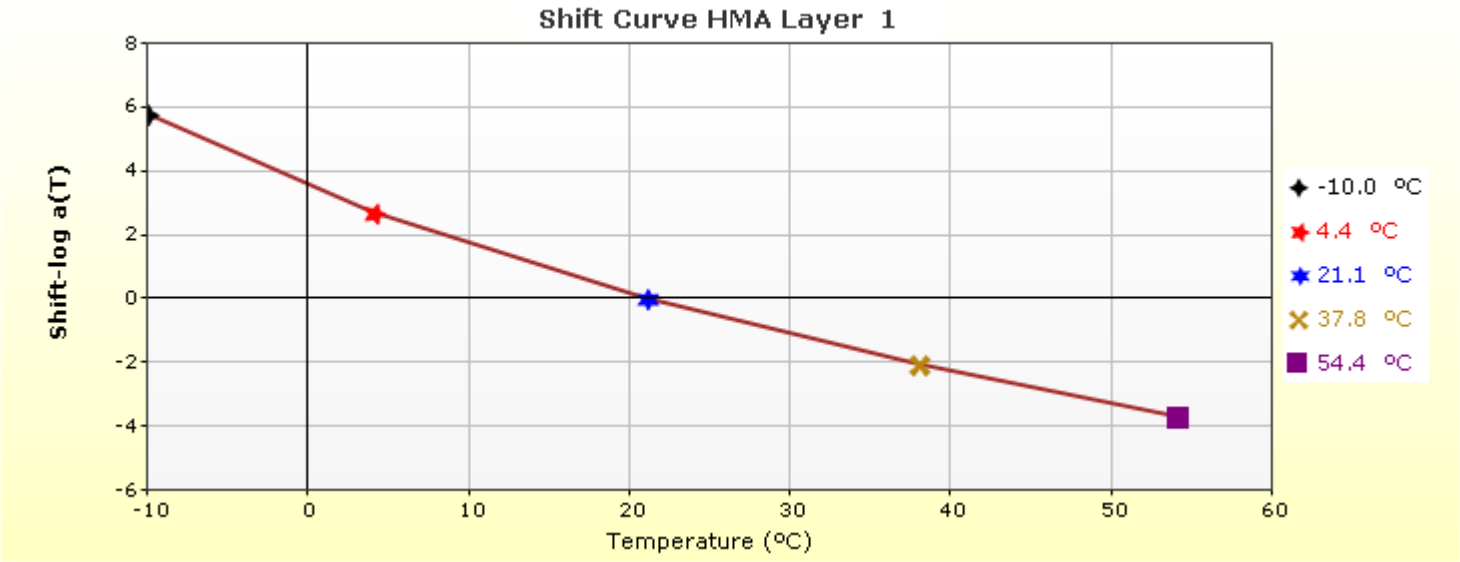
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

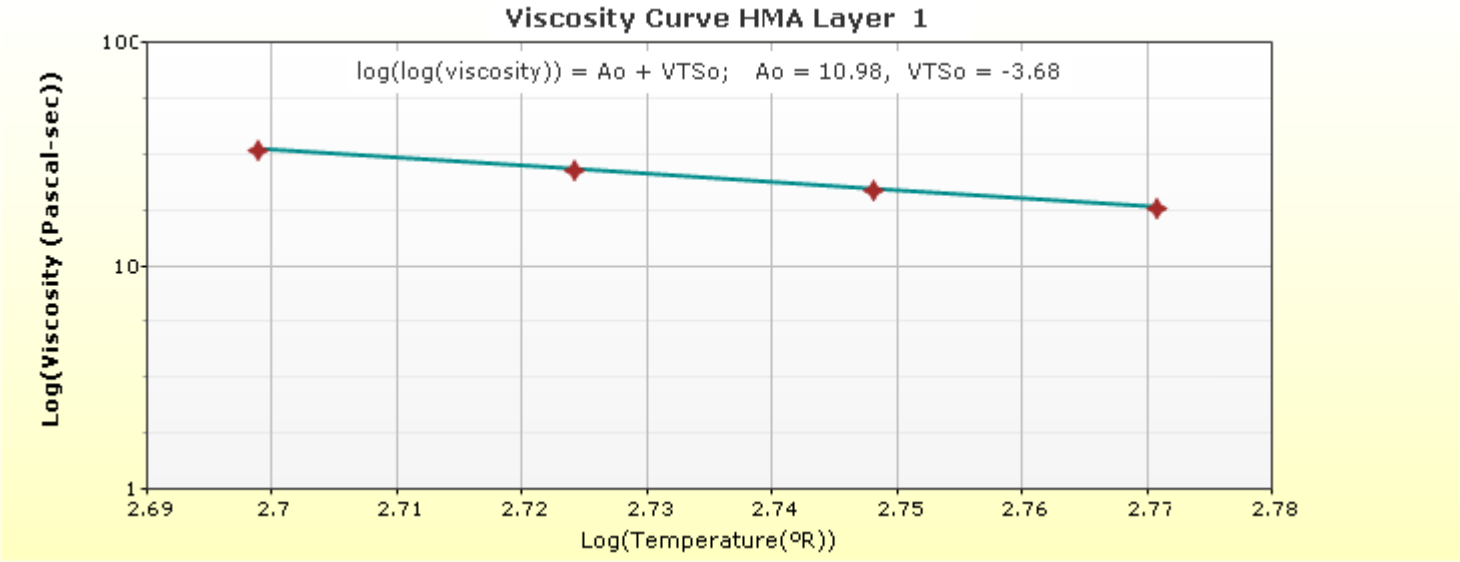
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



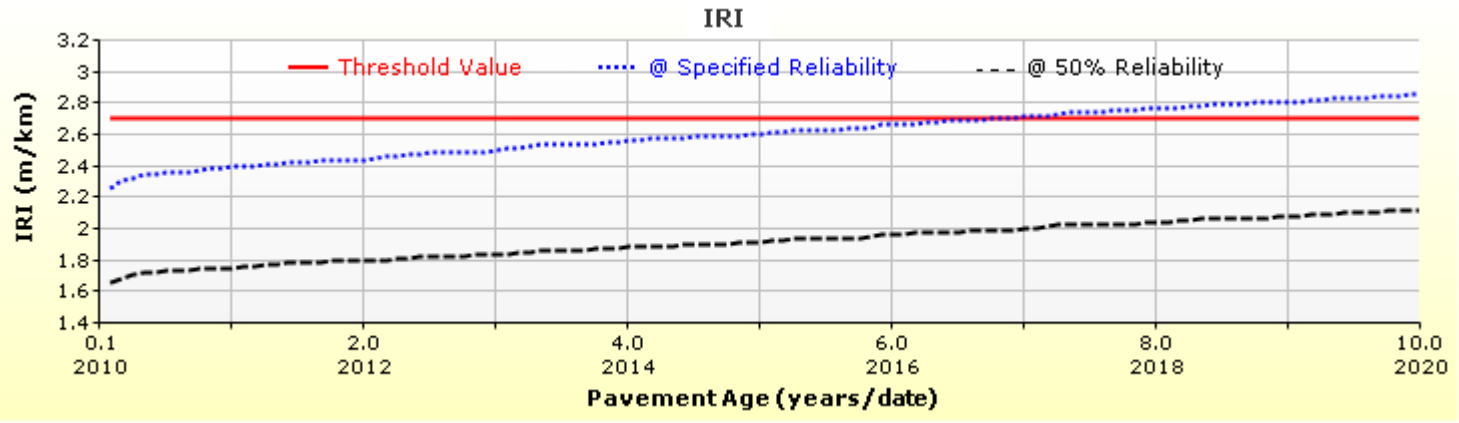
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

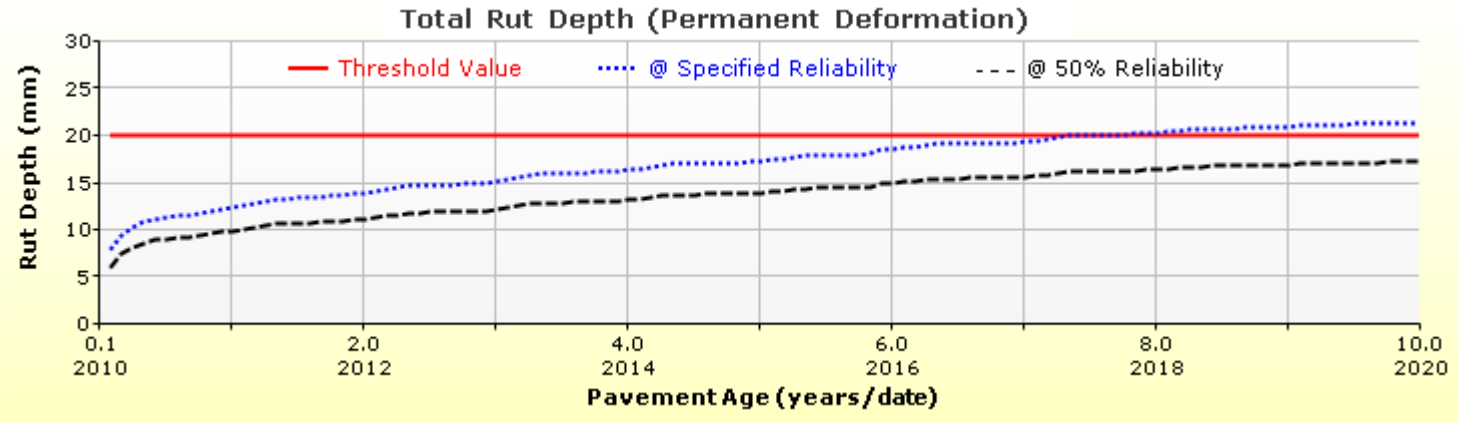


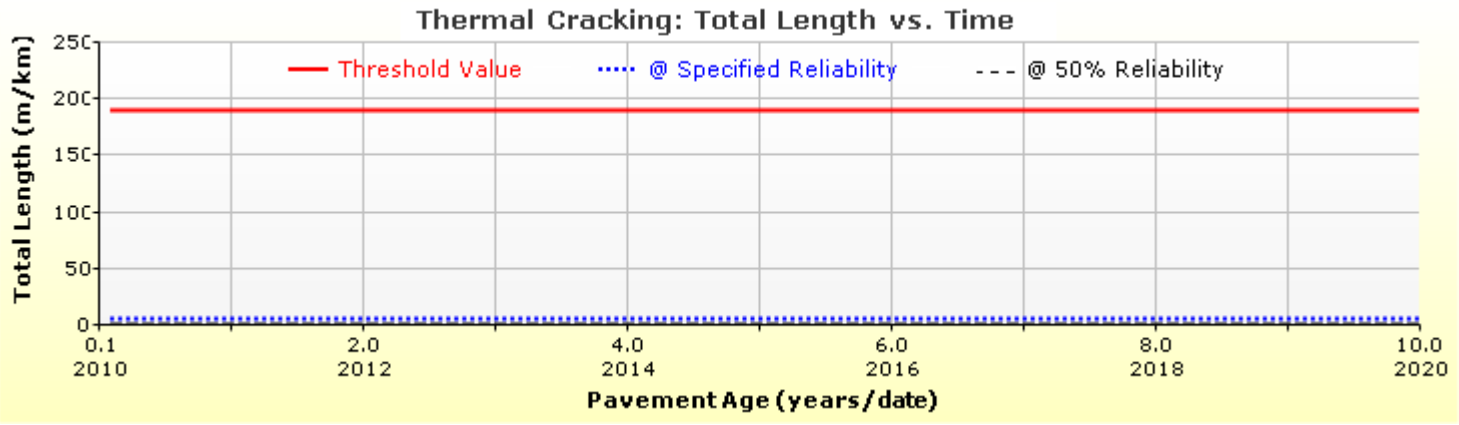


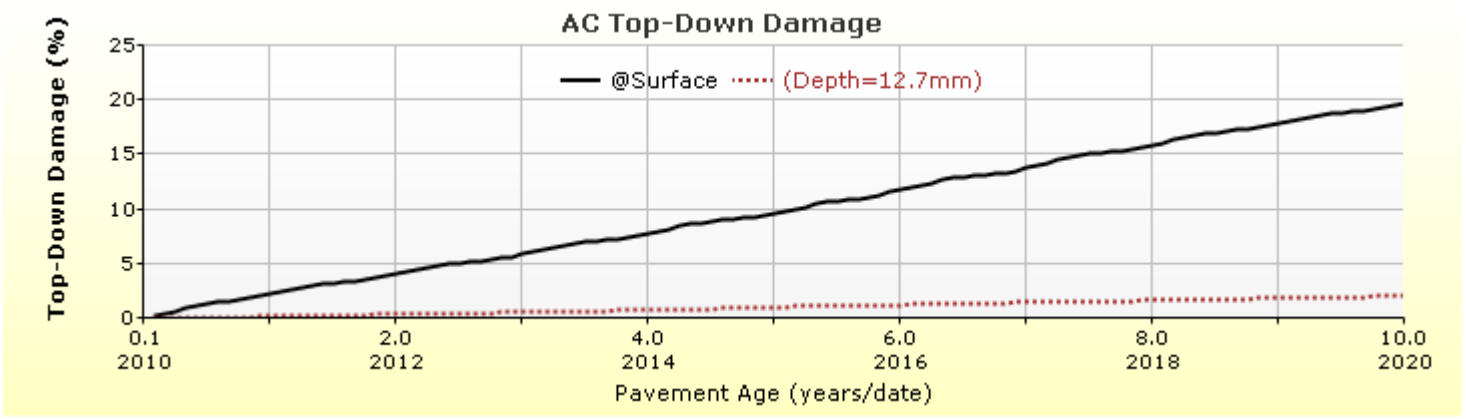


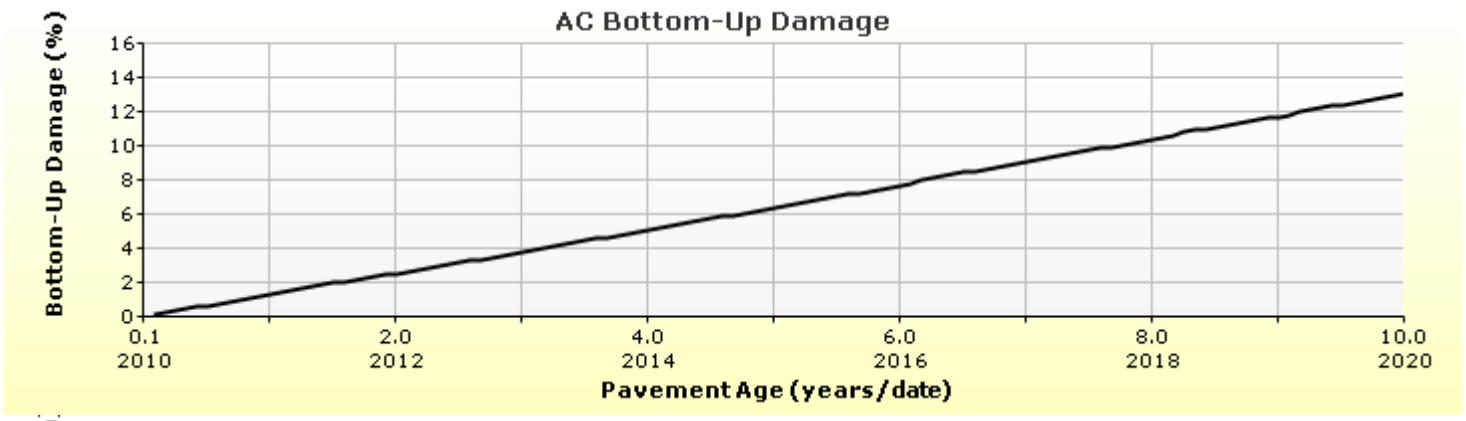
Analysis Output Charts

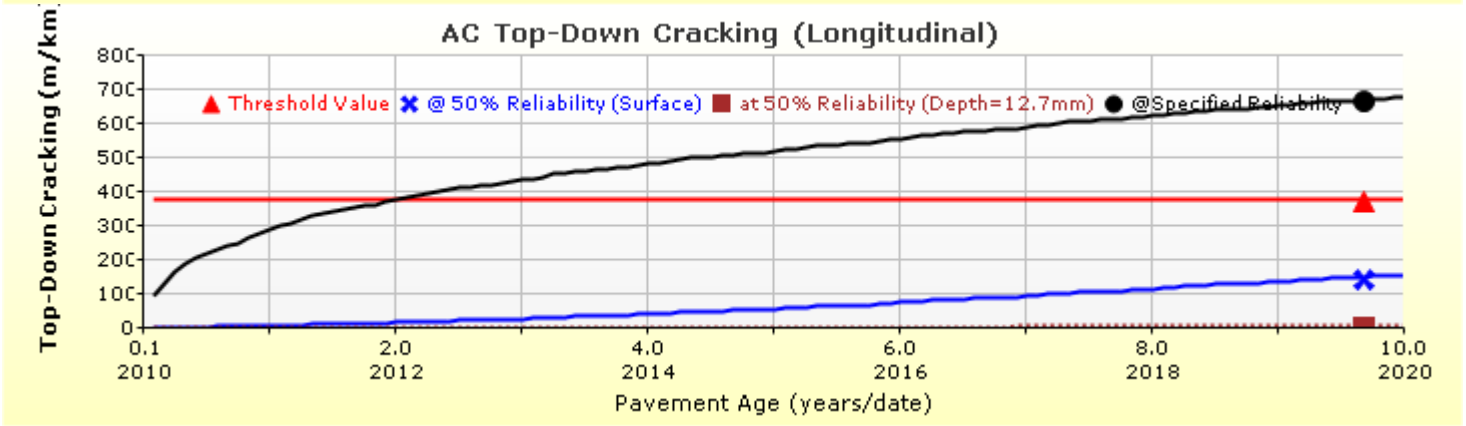


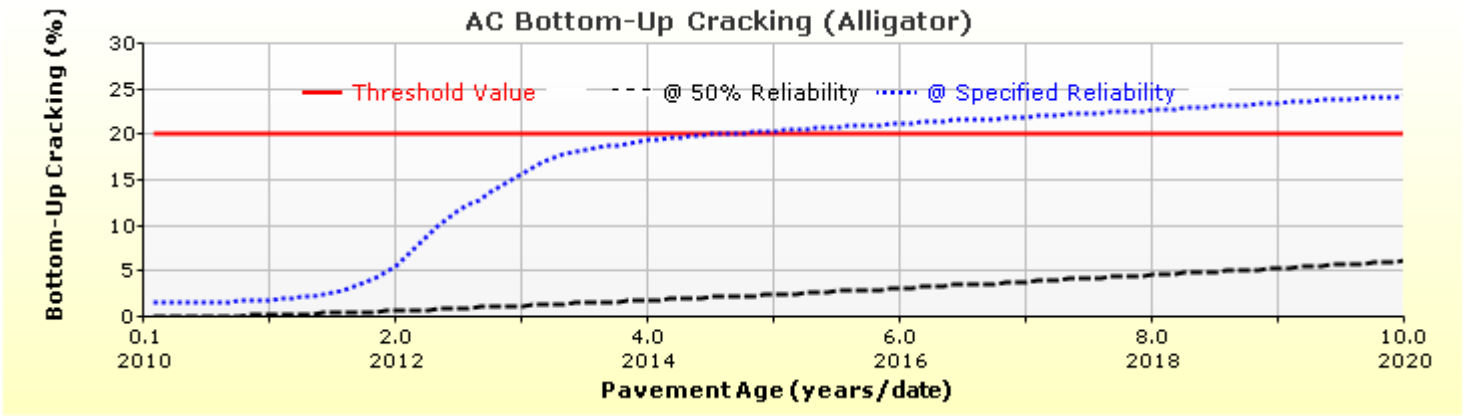


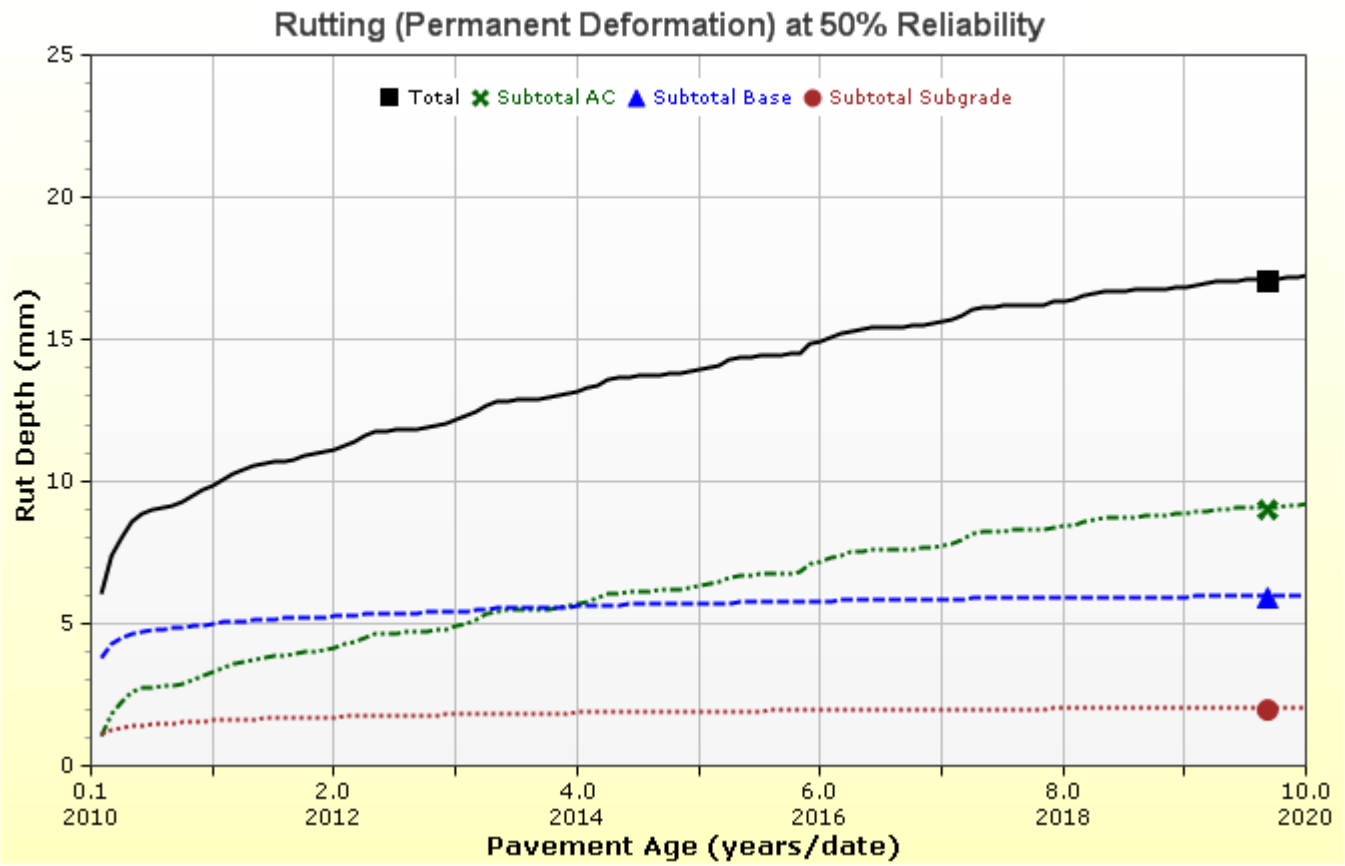


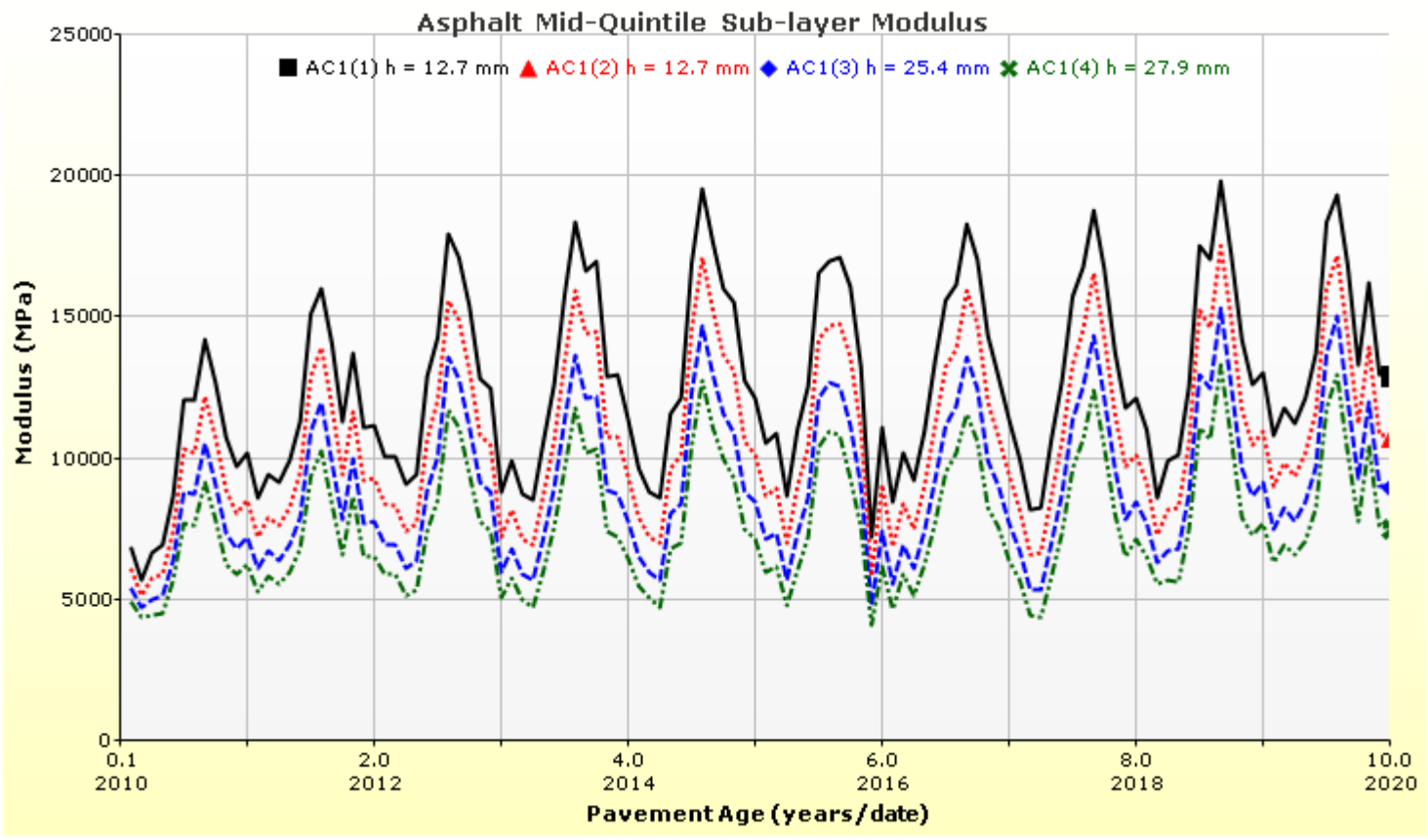

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

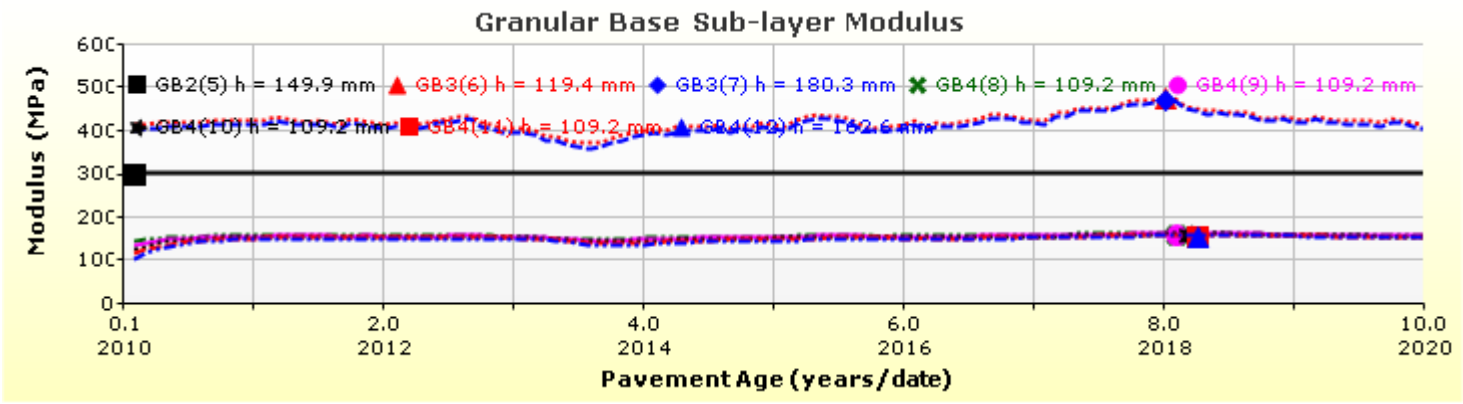

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

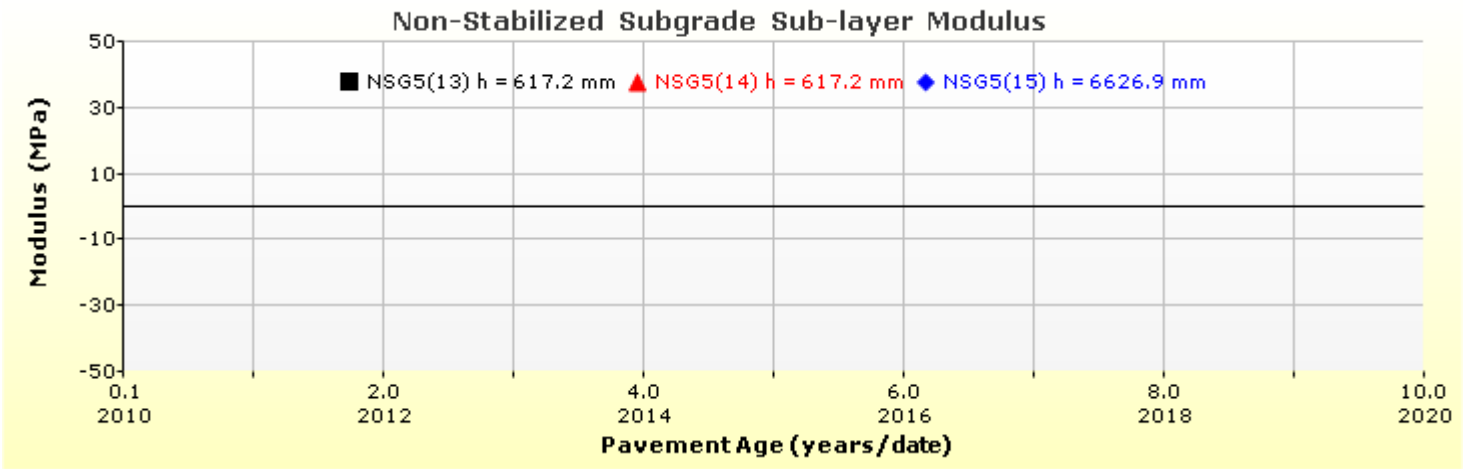

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566
k2: 3.9492
k3: 1.281
Bf1: 1
Bf2: 1
Bf3: 1

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2\beta_{r2}} N^{k_3\beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{\alpha}^2 + 2.4868 * H_{\alpha} - 17.342$$

$$C_2 = 0.0172 * H_{\alpha}^2 - 1.7331 * H_{\alpha} + 27.428$$

Where:

$$H_{ac} = total\ AC\ thickness(in)$$

$\varepsilon_p = plastic\ strain\left({}^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left({}^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestSP_Temp5

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestSP_Temp5.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -23.5, -46.62

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

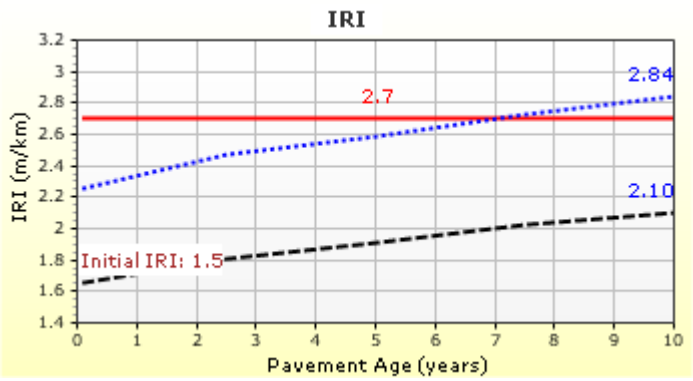
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

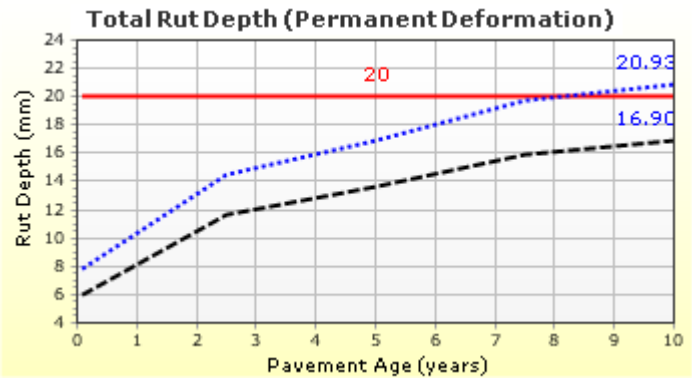
Design Outputs

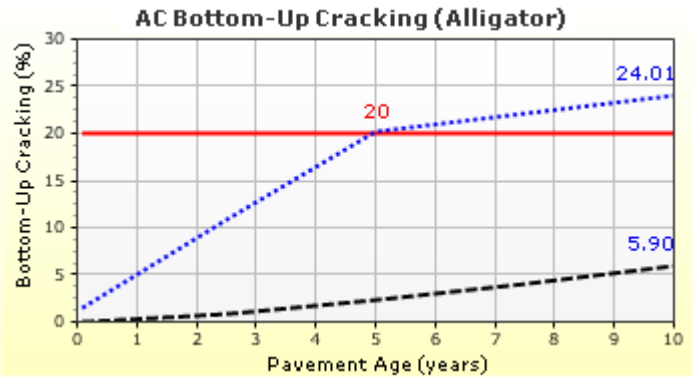
Distress Prediction Summary

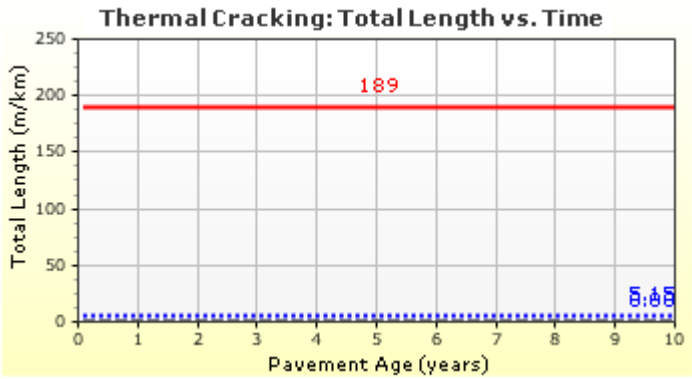
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.84	90.00	85.02	Fail
Permanent deformation - total pavement (mm)	20.00	20.93	90.00	83.72	Fail
AC bottom-up fatigue cracking (percent)	20.00	24.01	90.00	84.08	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	667.14	90.00	71.53	Fail
Permanent deformation - AC only (mm)	5.00	8.85	50.00	7.27	Fail

Distress Charts







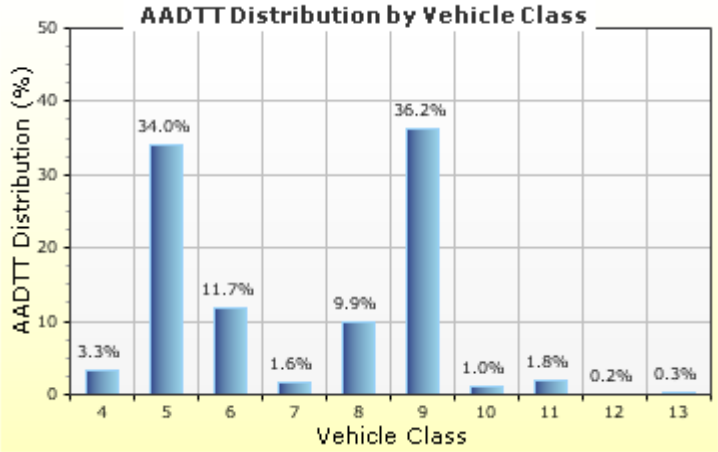


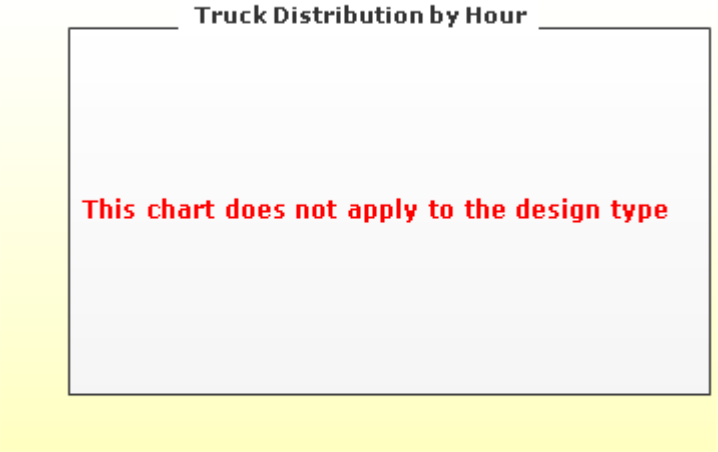


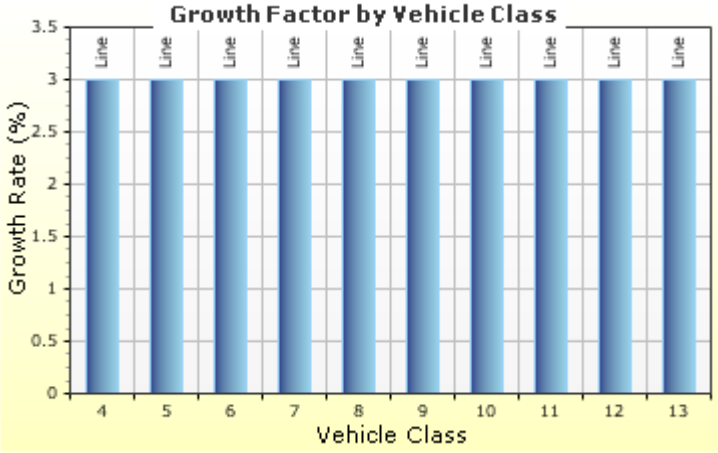
Traffic Inputs

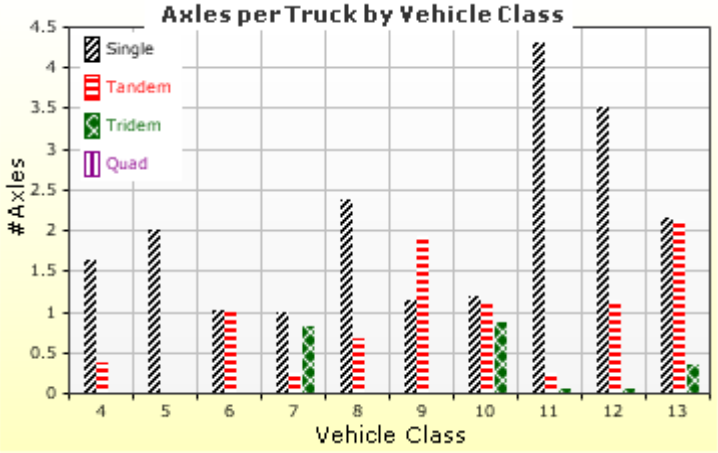
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

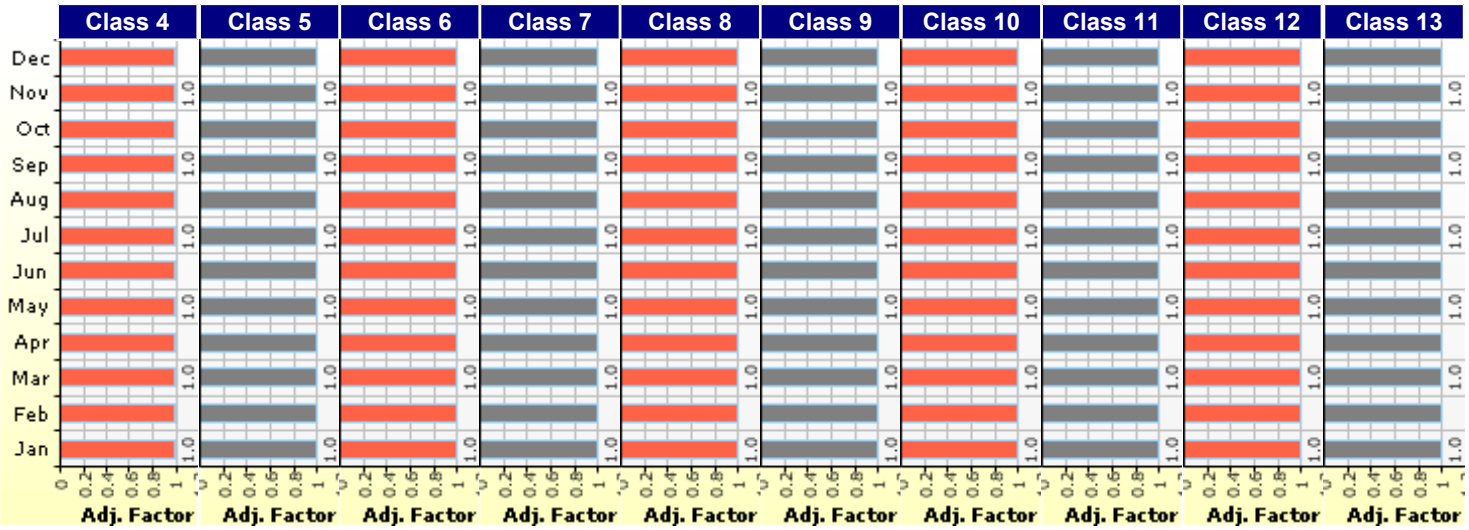








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

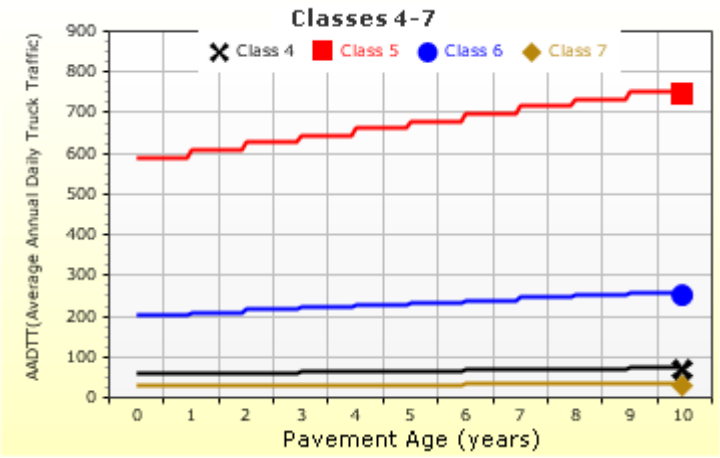
Wheelbase does not apply

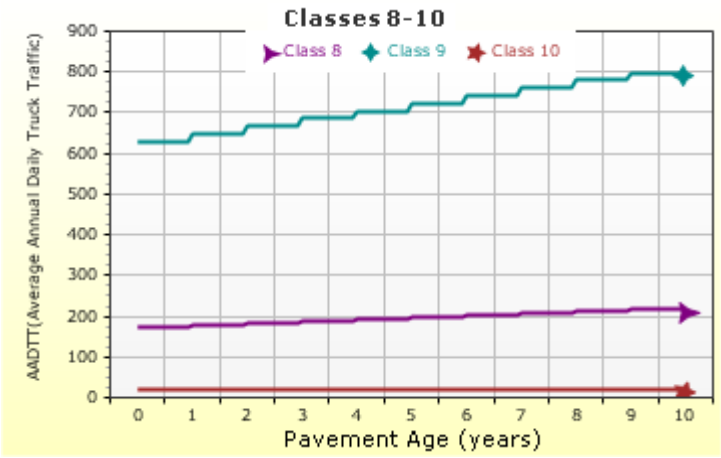
Number of Axles per Truck

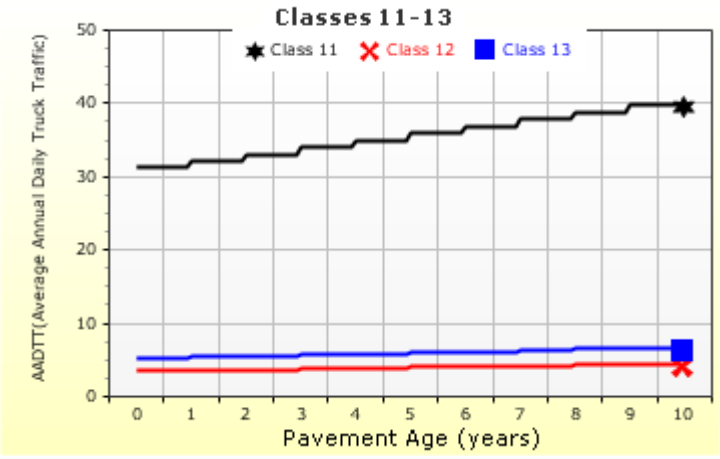
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

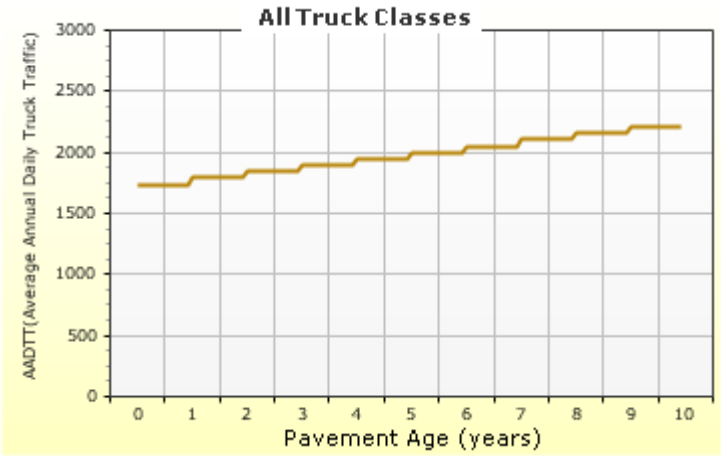
AADTT (Average Annual Daily Truck Traffic) Growth

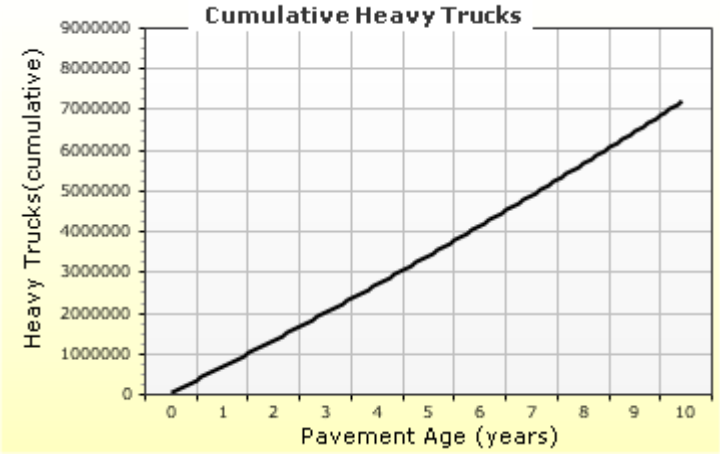
*** Traffic cap is not enforced**







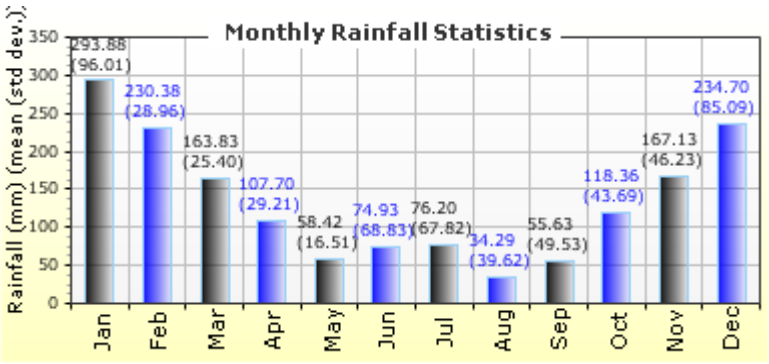




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
SAO PAULO, SP	-23.50000 -46.62000 792

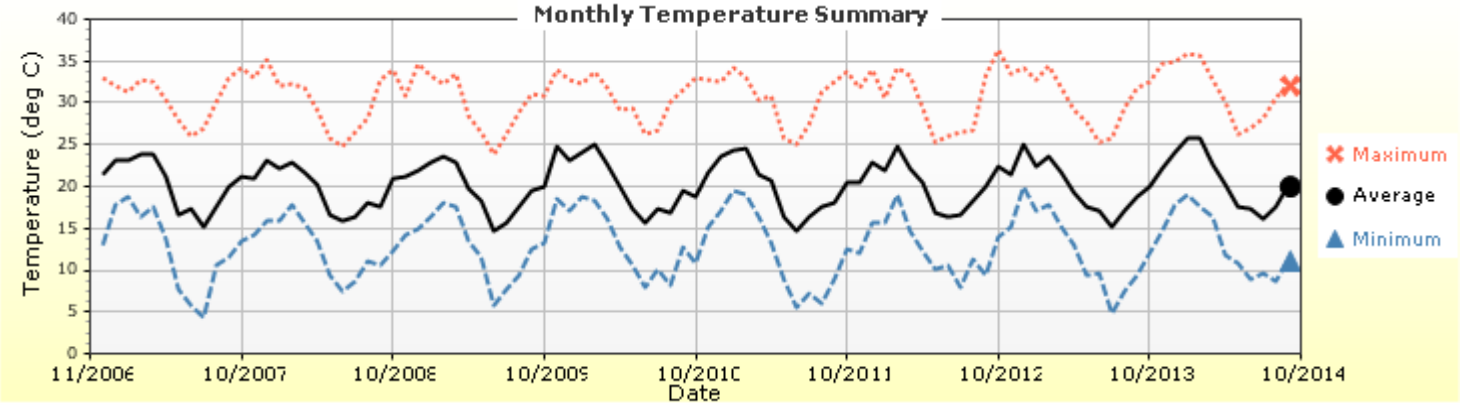


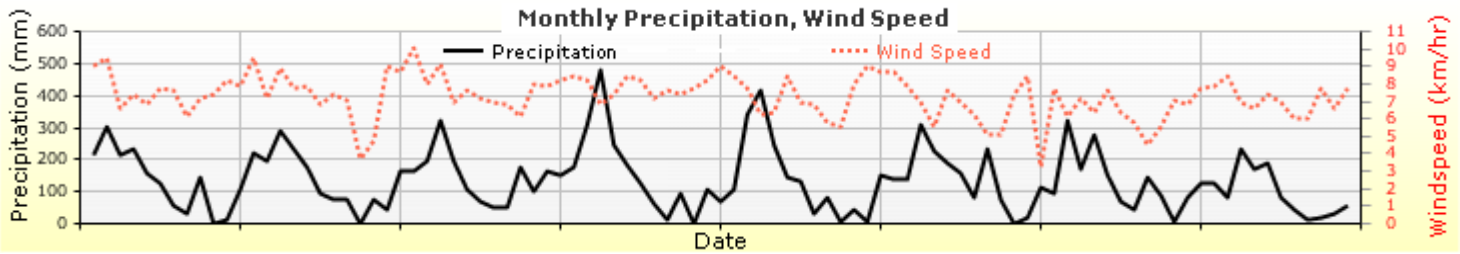
Annual Statistics:

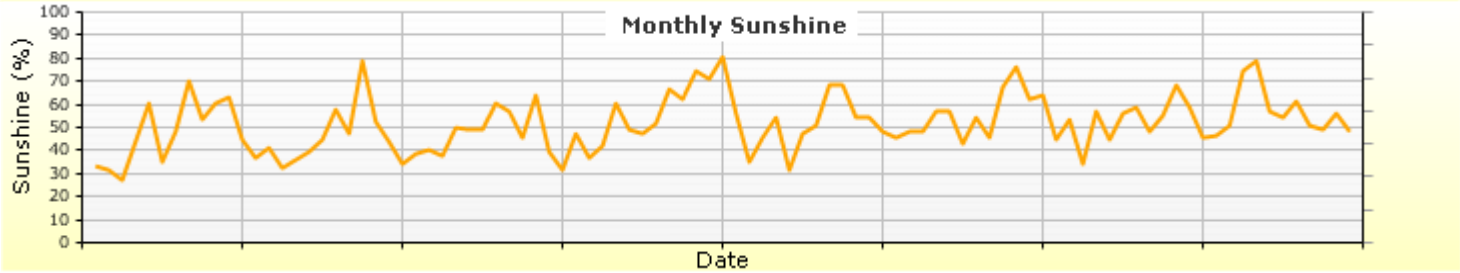
Mean annual air temperature (ºC)	20.17
Mean annual precipitation (mm)	1628.14
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

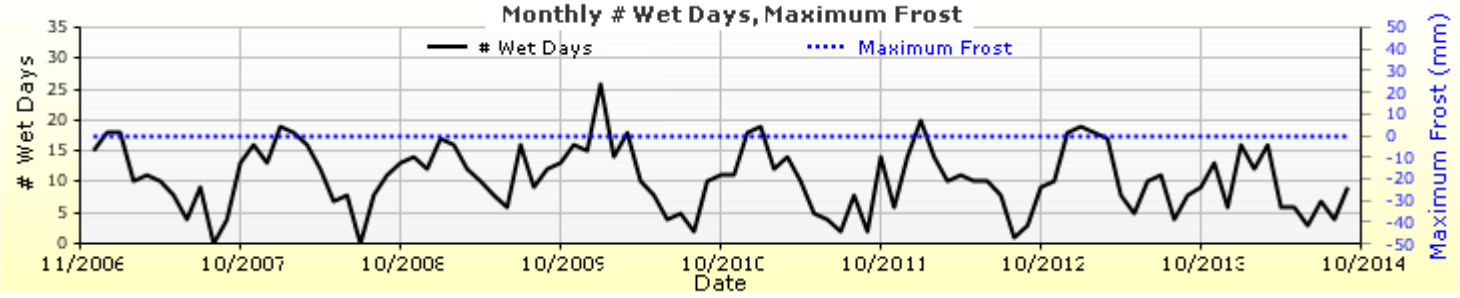
Water table depth (m): 3.05

Monthly Climate Summary:

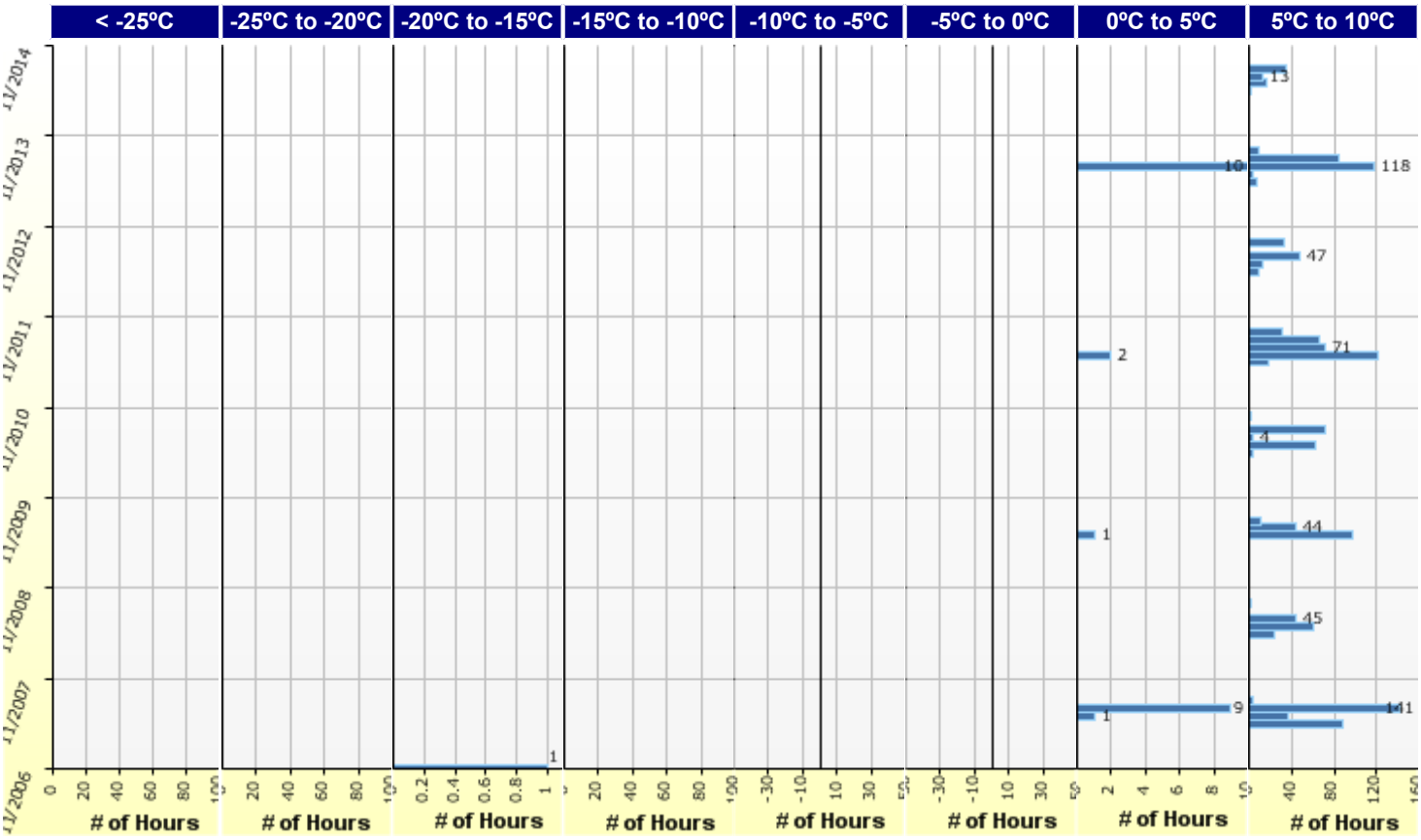


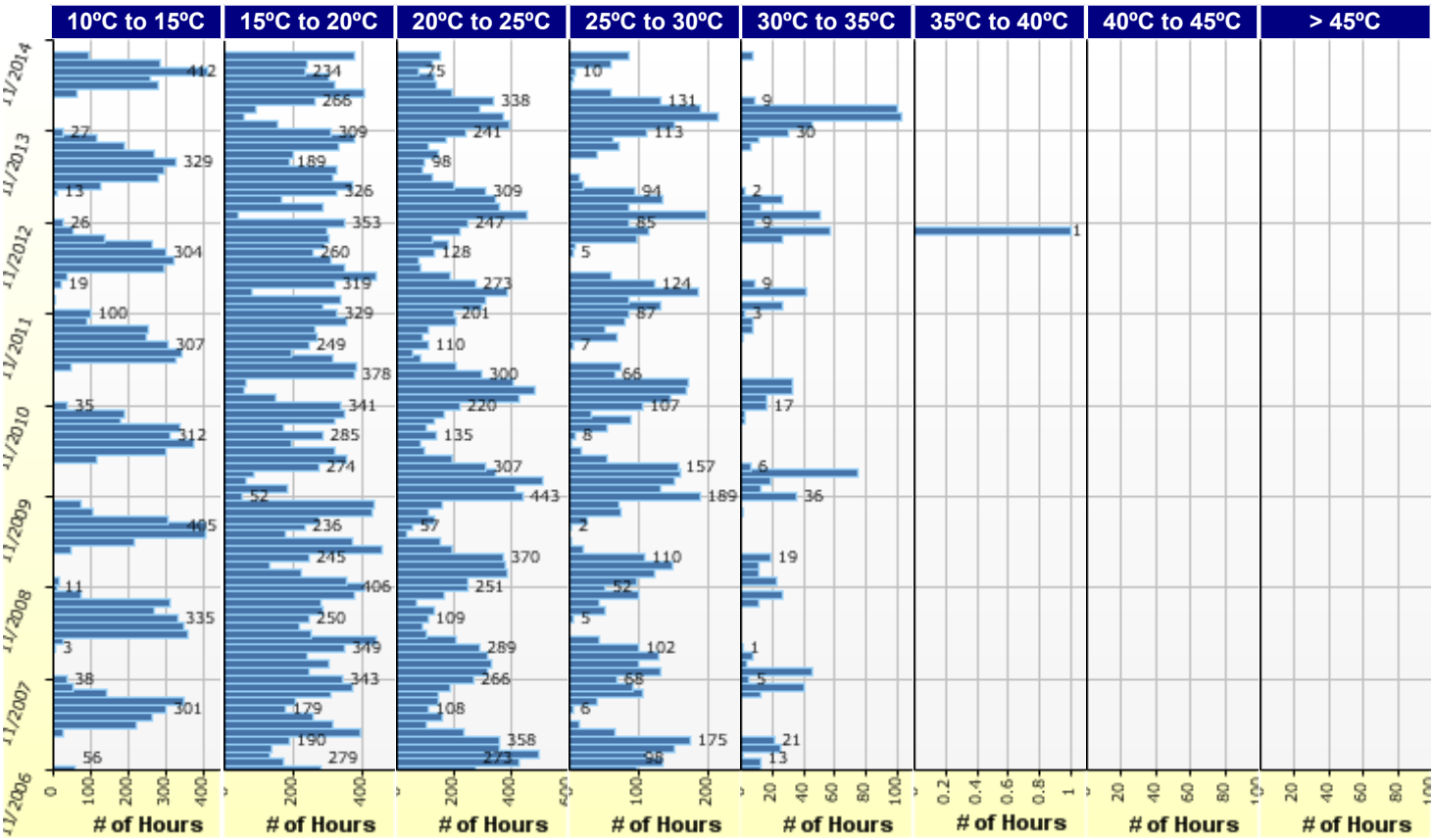






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

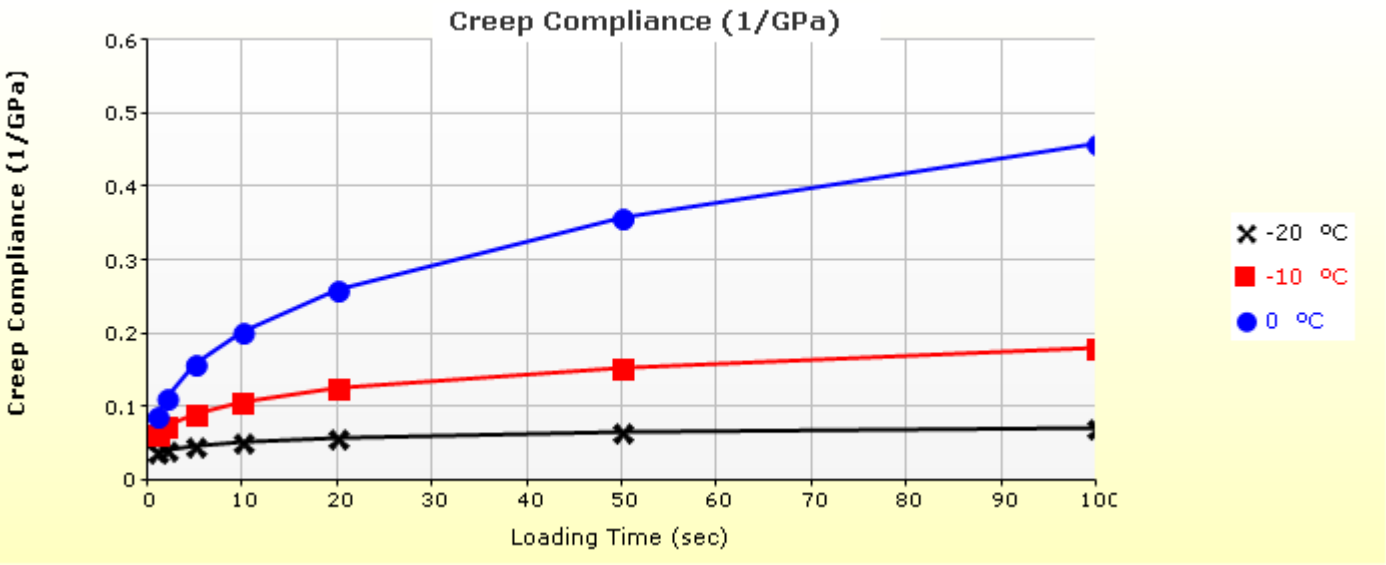
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

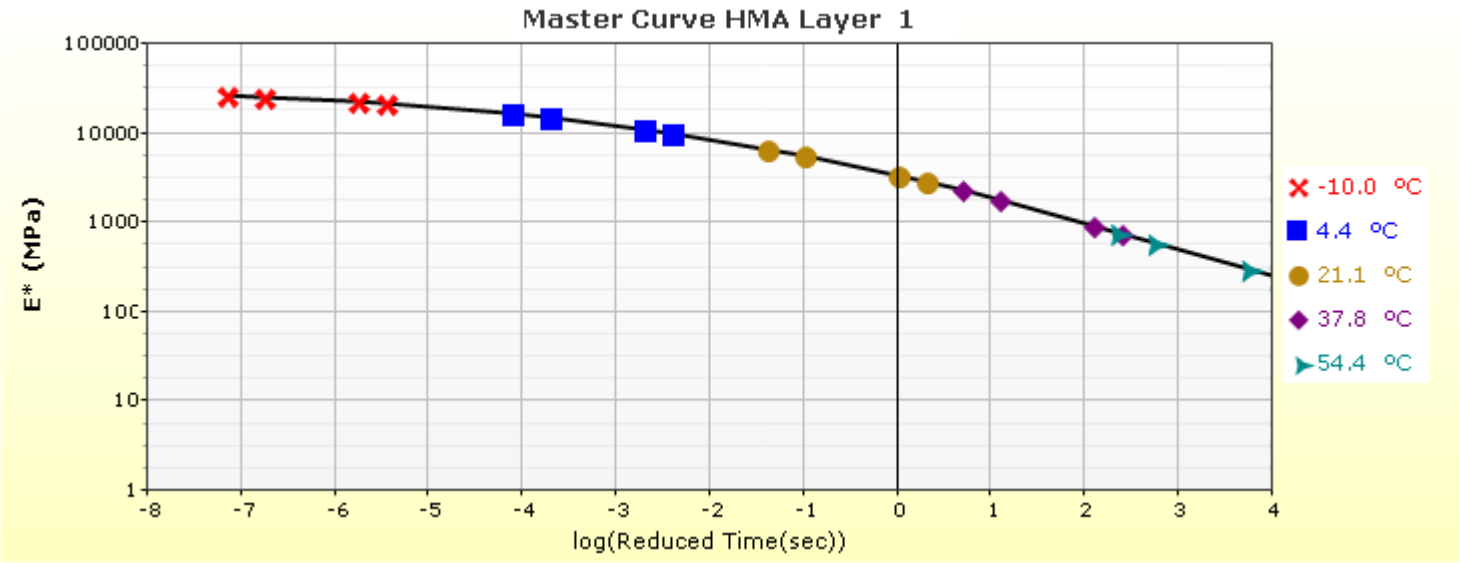
Indirect tensile strength at -10 ºC (MPa)	2.69

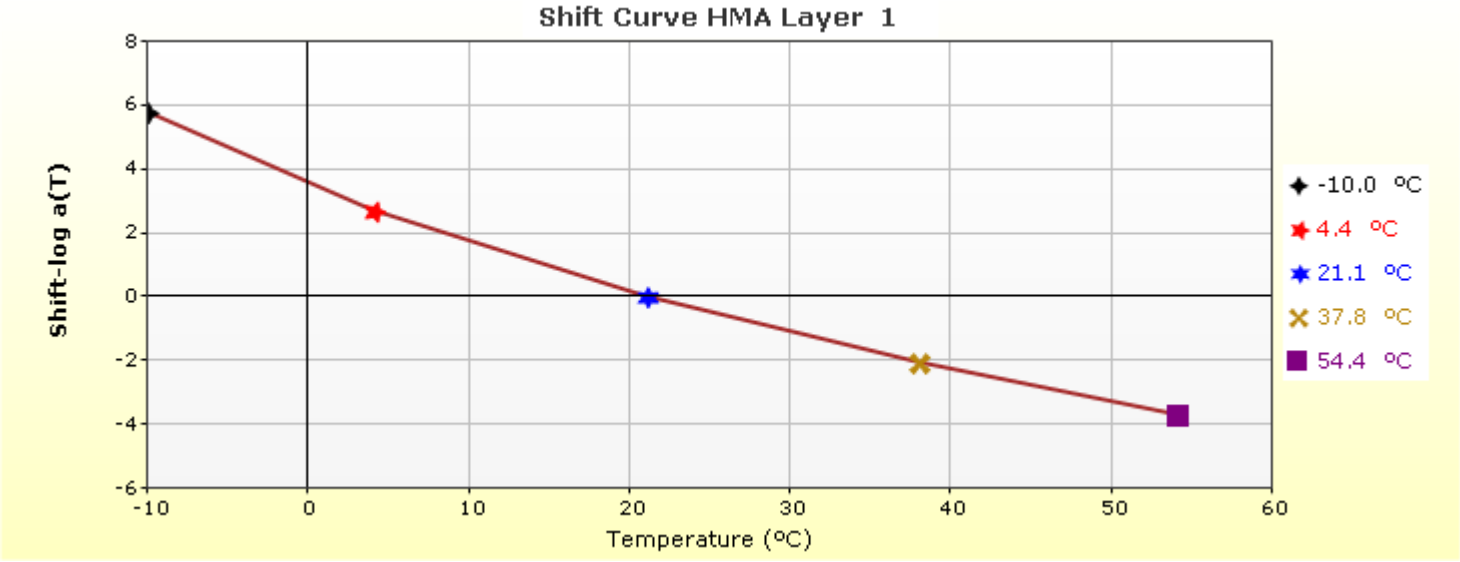
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

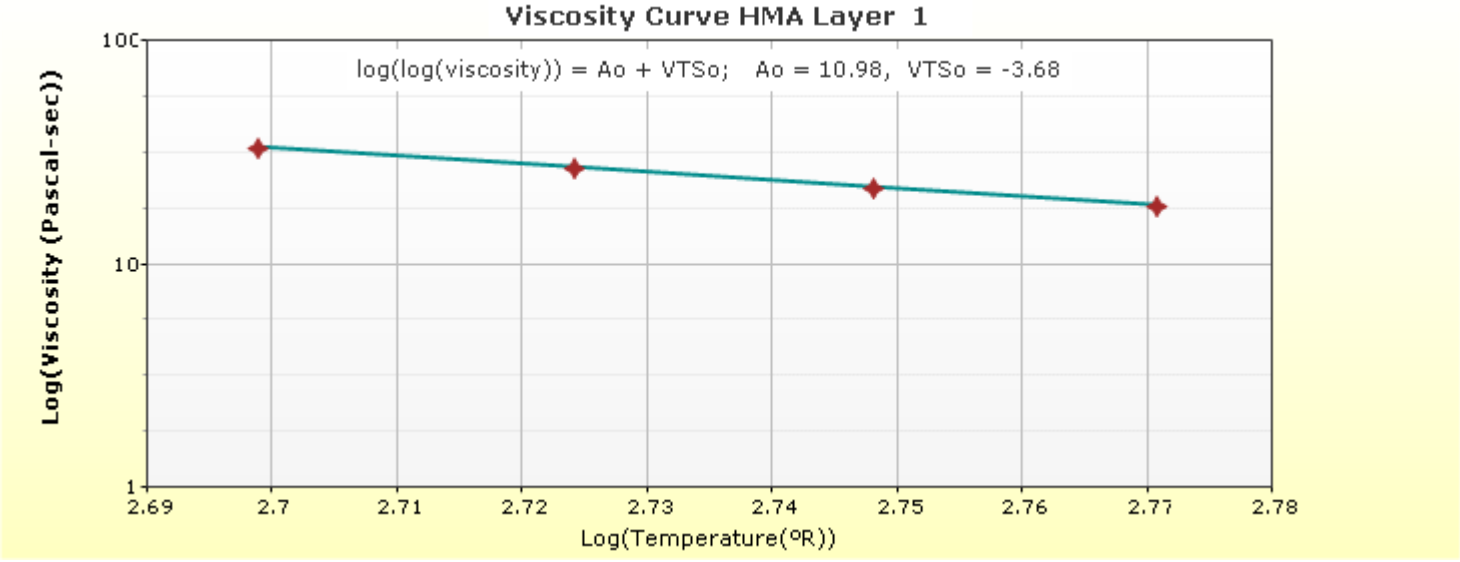
	Creep Compliance (1/GPa)		
Loading time (sec)	**-20 ºC**	**-10 ºC**	**0 ºC**
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



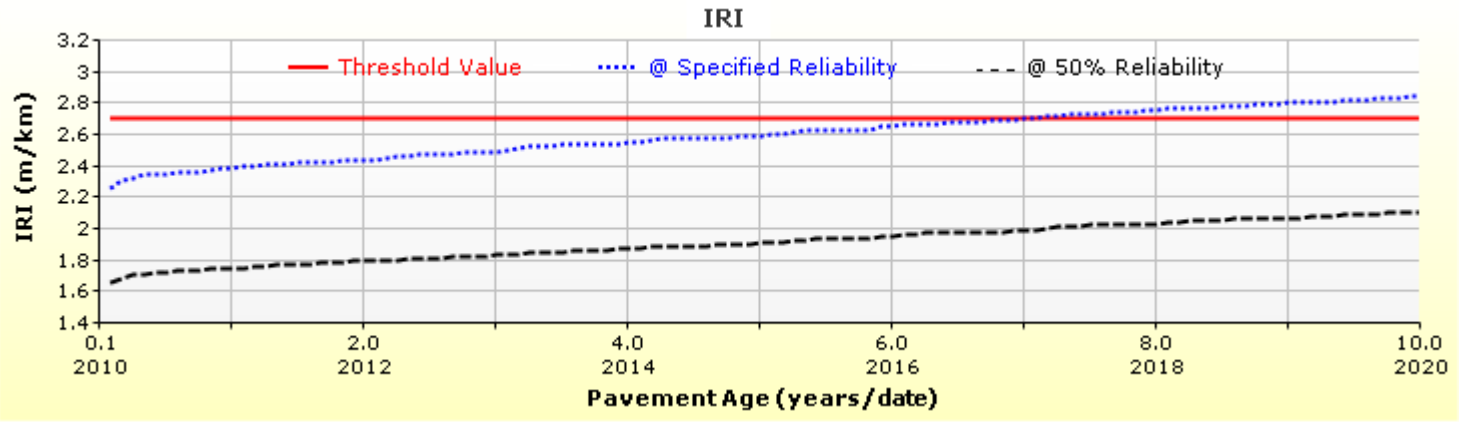
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

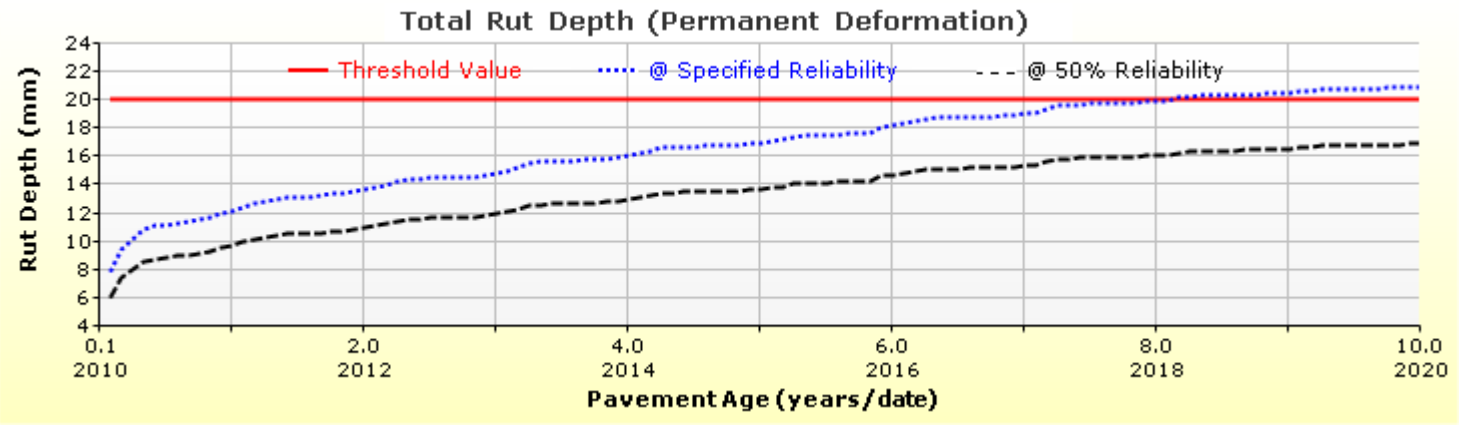


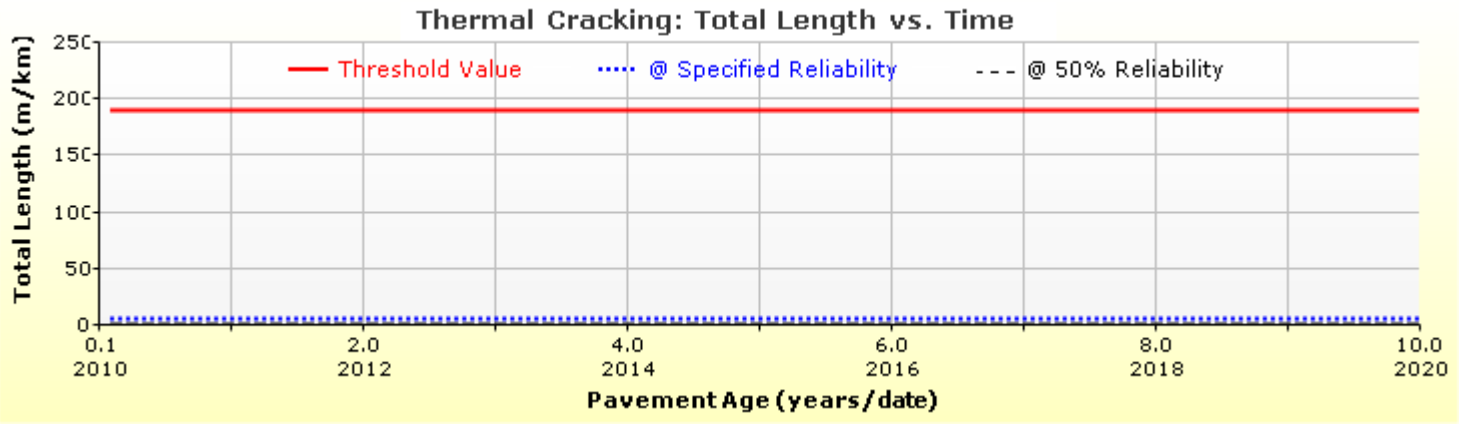


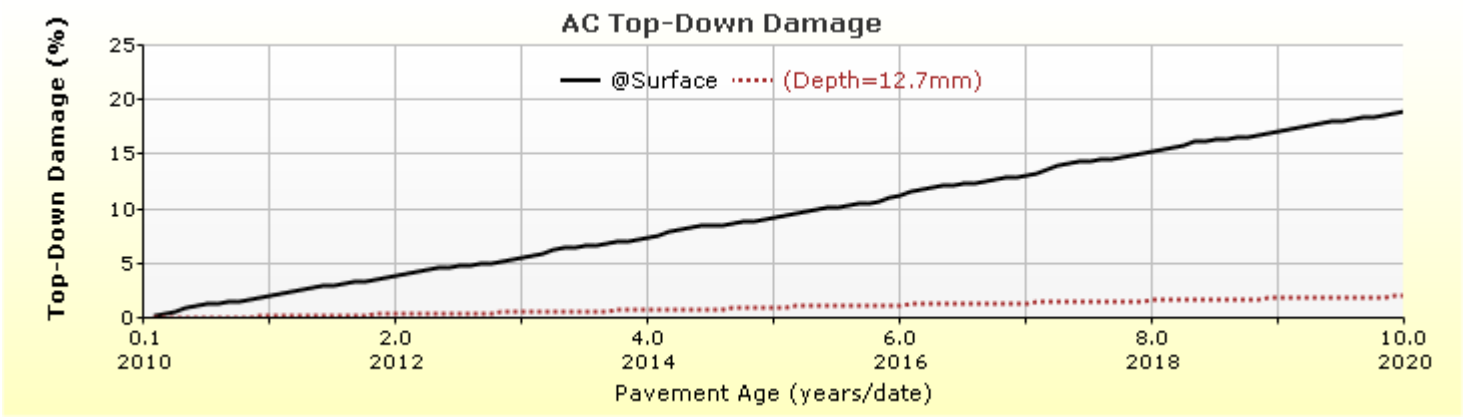


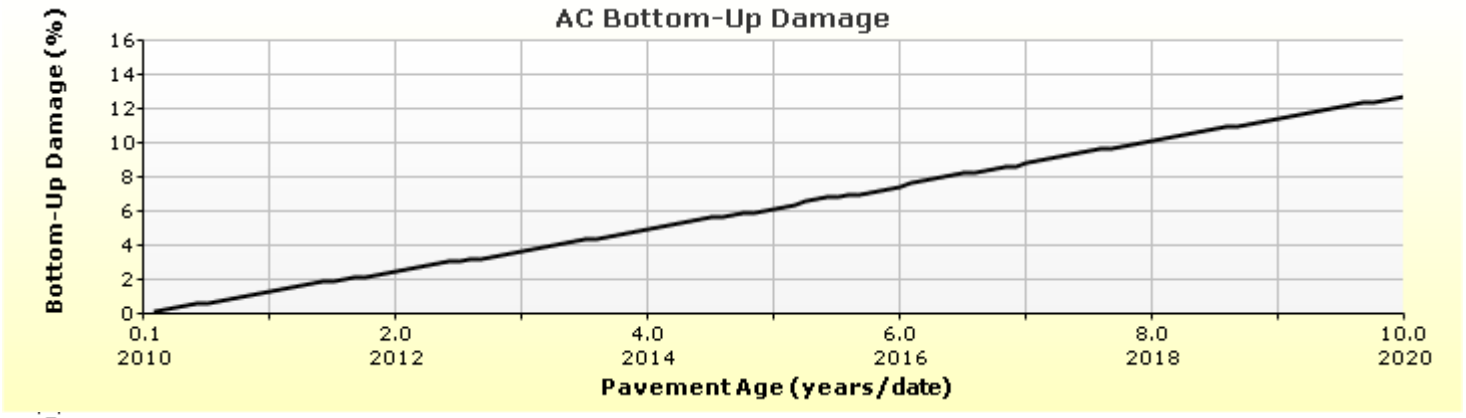
Analysis Output Charts

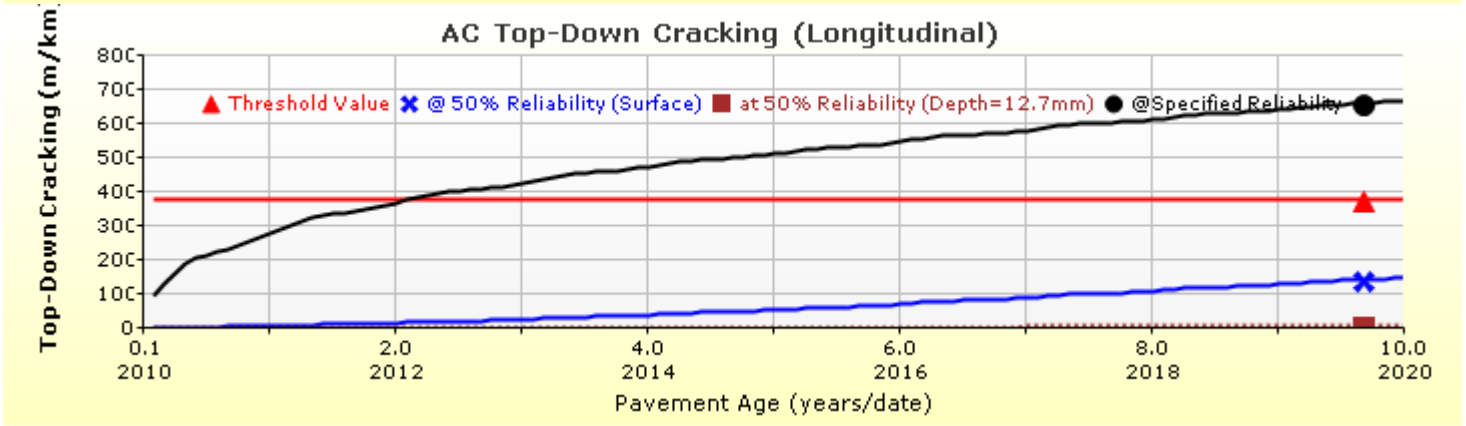


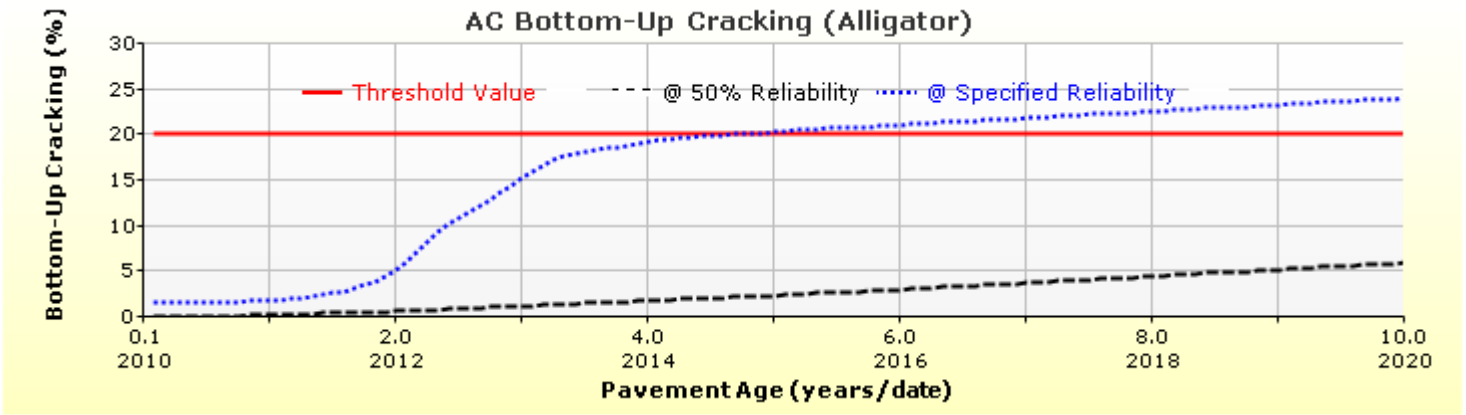


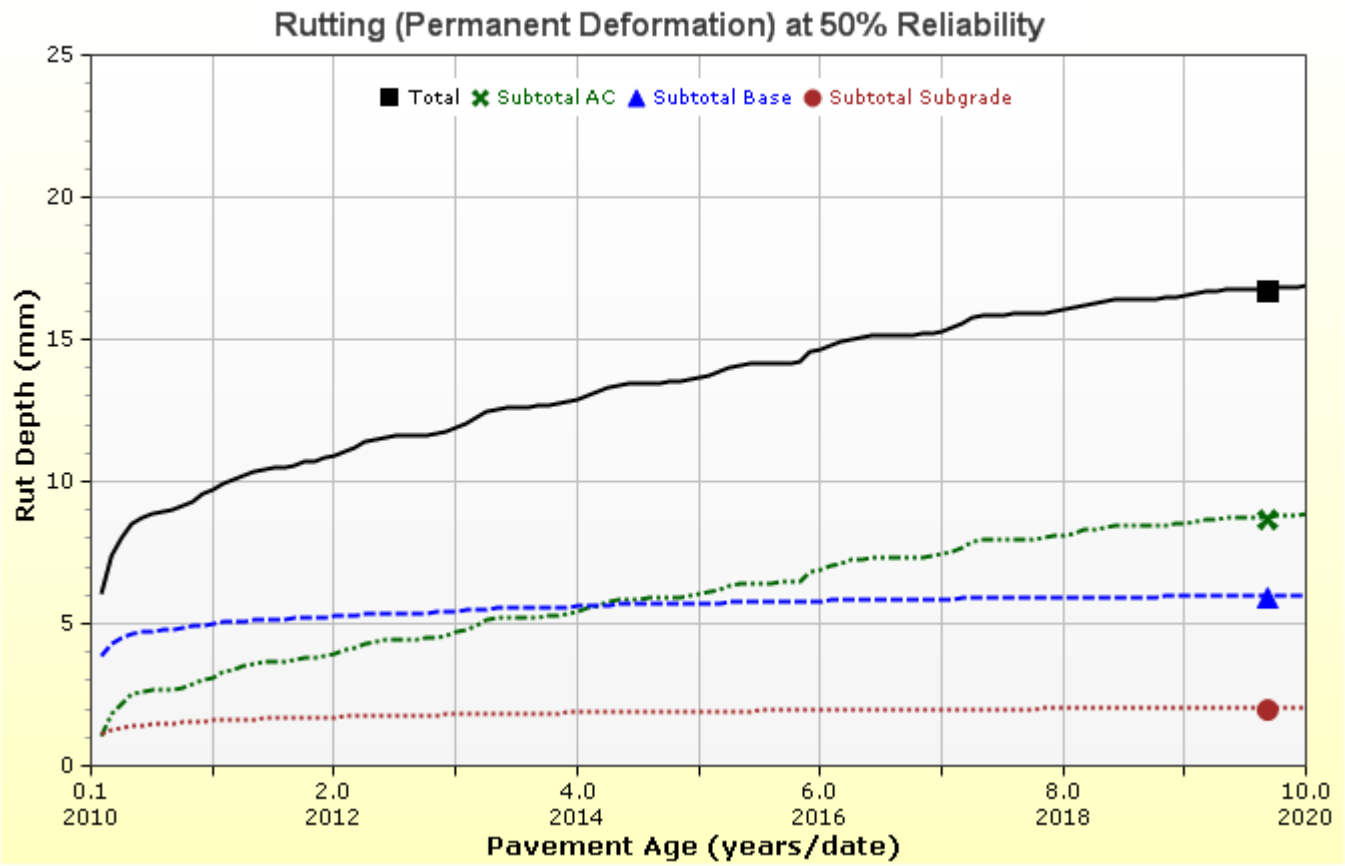


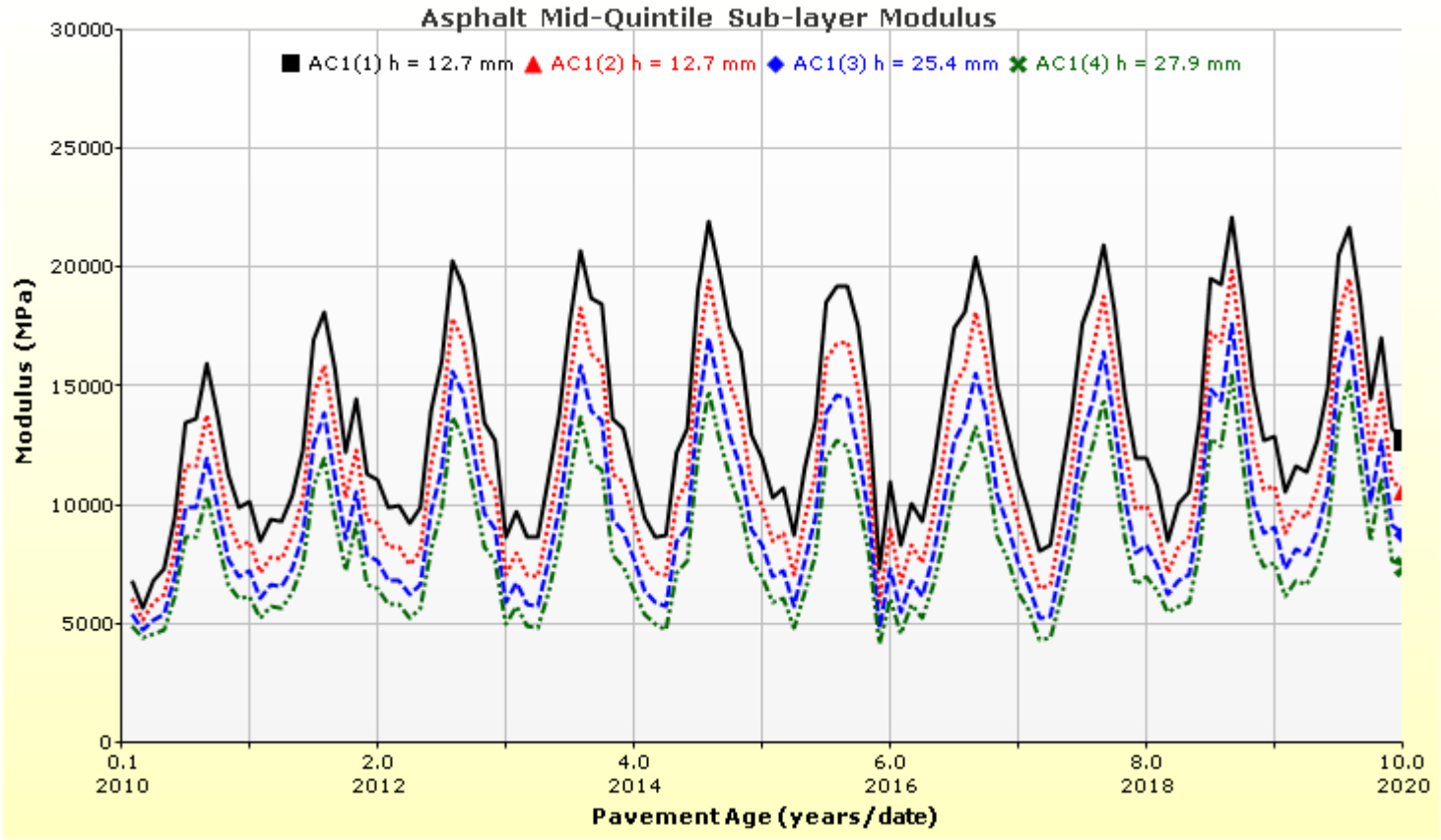

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

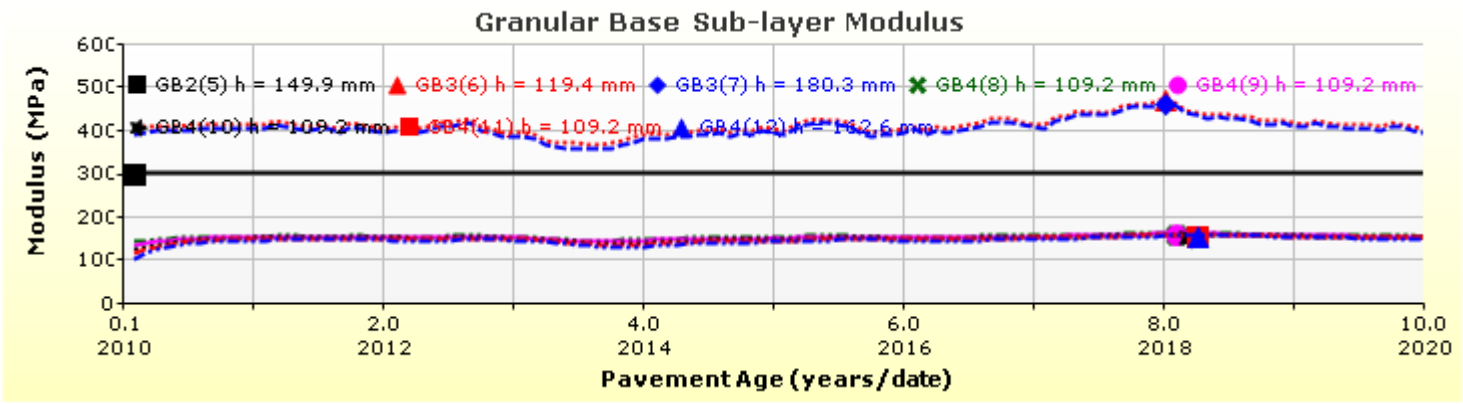

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

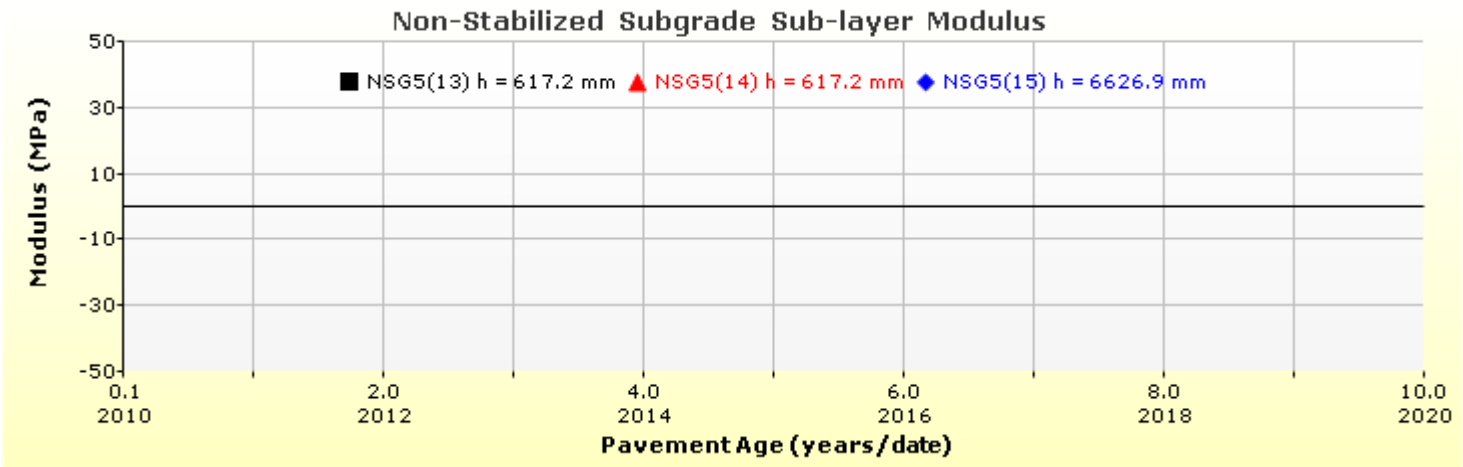

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60
50
40
30
20
10
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{ac}^2 + 2.4868 * H_{ac} - 17.342$$

$$C_2 = 0.0172 * H_{ac}^2 - 1.7331 * H_{ac} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$

$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$

$T = layer\ temperature(^{\circ}F)$

$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10(TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

TestSP_vento

File Name: C:\Users\Lelio Brito\My ME Design\Projects\TestSP_vento.dgpx

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: November, 2010
Pavement construction: November, 2010
Traffic opening: December, 2010

Climate Data Sources (Lat/Lon): -23.5, -46.62

Design Structure

Layer type	Material Type	Thickness(mm)
Flexible	Concreto Asfáltico	80.0
NonStabilized	Base Brita Graduada	150.0
NonStabilized	Macadame Seco	300.0
NonStabilized	Areia A-3	600.0
Subgrade	Subleito Local	Semi-infinite

Volumetric at Construction:	
Effective binder content (%)	11.0
Air voids (%)	7.0

Traffic

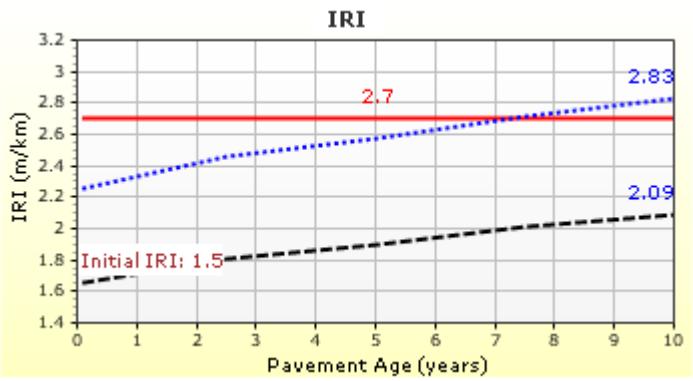
Age (year)	Heavy Trucks (cumulative)
2010 (initial)	5,216
2015 (5 years)	3,362,390
2020 (10 years)	7,200,590

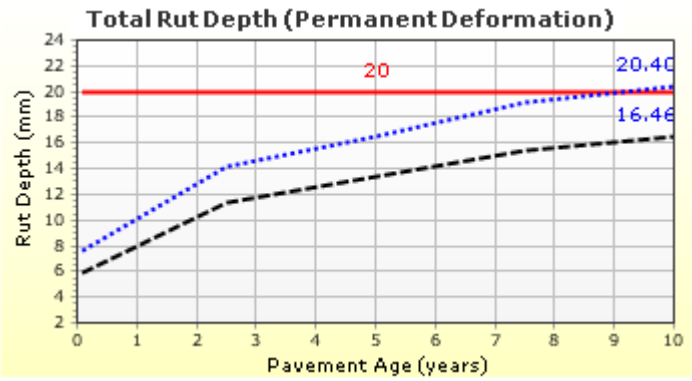
Design Outputs

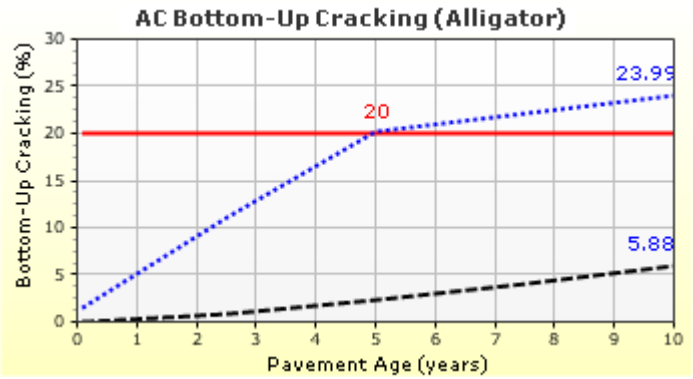
Distress Prediction Summary

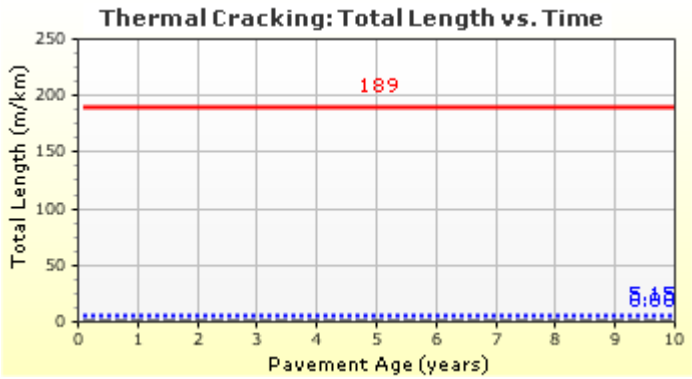
Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.83	90.00	85.56	Fail
Permanent deformation - total pavement (mm)	20.00	20.39	90.00	87.53	Fail
AC bottom-up fatigue cracking (percent)	20.00	23.99	90.00	84.12	Fail
AC thermal cracking (m/km)	189.00	5.15	90.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.00	660.16	90.00	72.03	Fail
Permanent deformation - AC only (mm)	5.00	8.43	50.00	8.88	Fail

Distress Charts







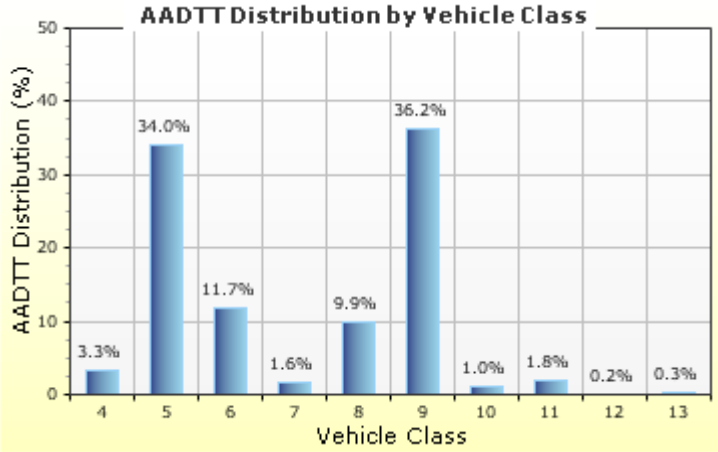


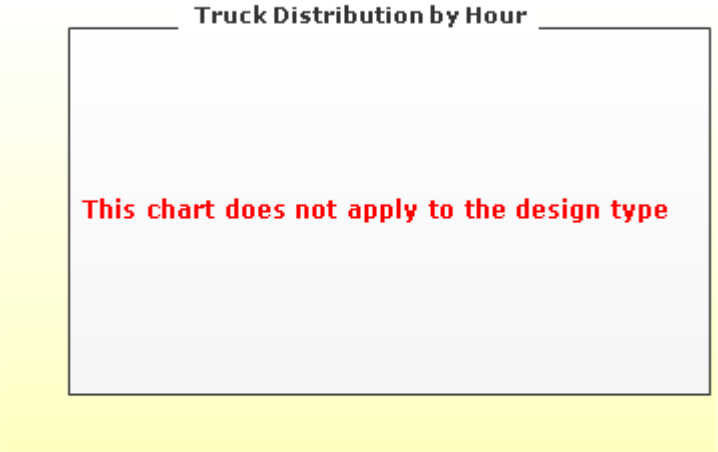


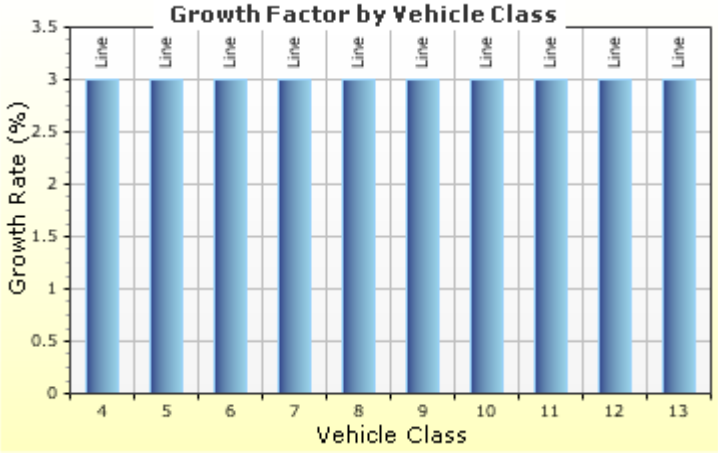
Traffic Inputs

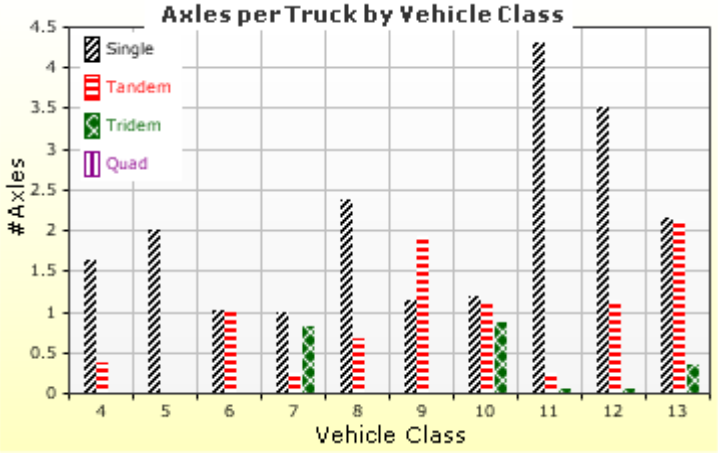
Graphical Representation of Traffic Inputs

Initial two-way AADTT:	5,216	Percent of trucks in design direction (%):	50.0
Number of lanes in design direction:	2	Percent of trucks in design lane (%):	66.6
		Operational speed (kph)	90.0

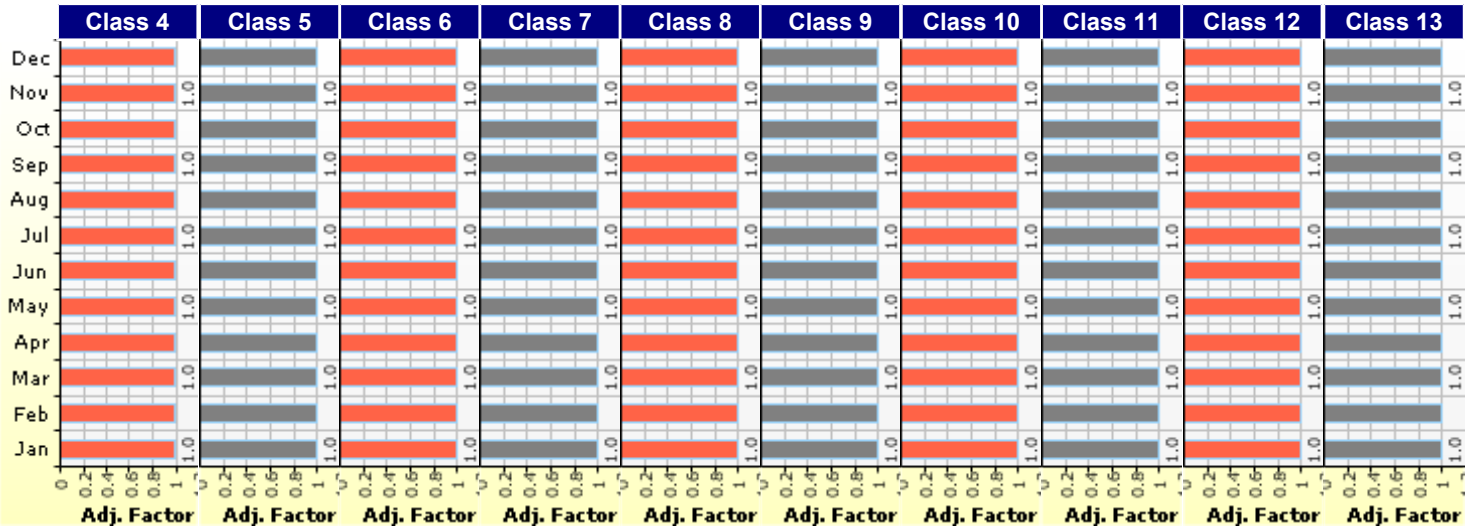








Traffic Volume Monthly Adjustment Factors



Tabular Representation of Traffic Inputs

Volume Monthly Adjustment Factors

Level 3: Default MAF

Month	Vehicle Class									
	4	5	6	7	8	9	10	11	12	13
January	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
February	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
March	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
April	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
May	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
June	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
July	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
August	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
September	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
October	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
November	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
December	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Distributions by Vehicle Class

Truck Distribution by Hour does not apply

Vehicle Class	AADTT Distribution (%) (Level 3)	Growth Factor	
		Rate (%)	Function
Class 4	3.3%	3%	Linear
Class 5	34%	3%	Linear
Class 6	11.7%	3%	Linear
Class 7	1.6%	3%	Linear
Class 8	9.9%	3%	Linear
Class 9	36.2%	3%	Linear
Class 10	1%	3%	Linear
Class 11	1.8%	3%	Linear
Class 12	0.2%	3%	Linear
Class 13	0.3%	3%	Linear

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460.0
Traffic wander standard deviation (mm)	254.0
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.6
Dual tire spacing (mm)	305.0
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.3
Tridem axle spacing (m)	1.3
Quad axle spacing (m)	1.3

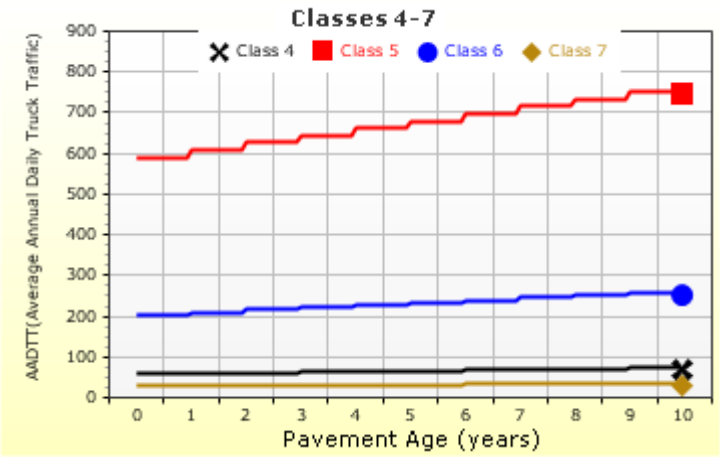
Wheelbase does not apply

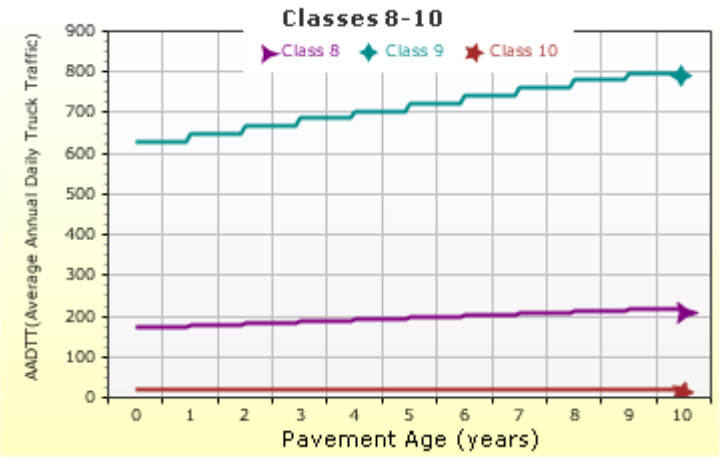
Number of Axles per Truck

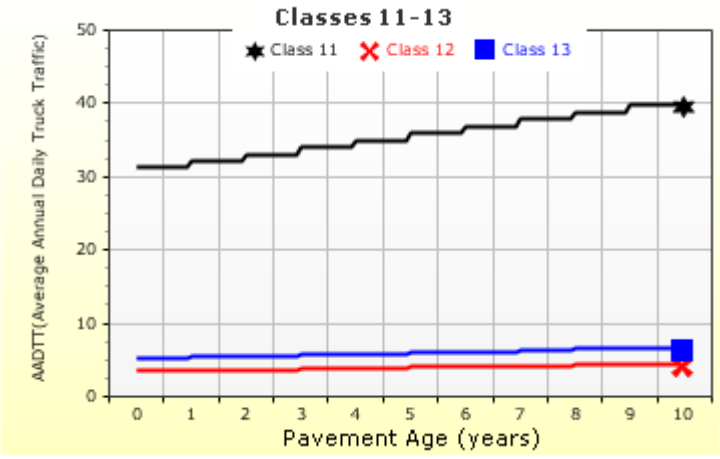
Vehicle Class	Single Axle	Tandem Axle	Tridem Axle	Quad Axle
Class 4	1.62	0.39	0	0
Class 5	2	0	0	0
Class 6	1.02	0.99	0	0
Class 7	1	0.26	0.83	0
Class 8	2.38	0.67	0	0
Class 9	1.13	1.93	0	0
Class 10	1.19	1.09	0.89	0
Class 11	4.29	0.26	0.06	0
Class 12	3.52	1.14	0.06	0
Class 13	2.15	2.13	0.35	0

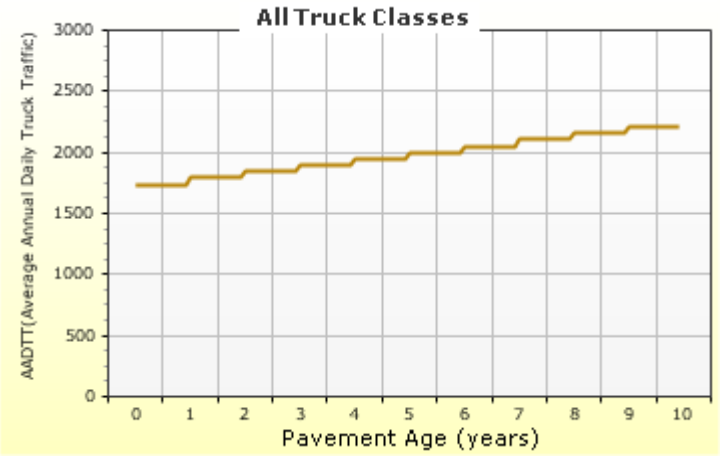
AADTT (Average Annual Daily Truck Traffic) Growth

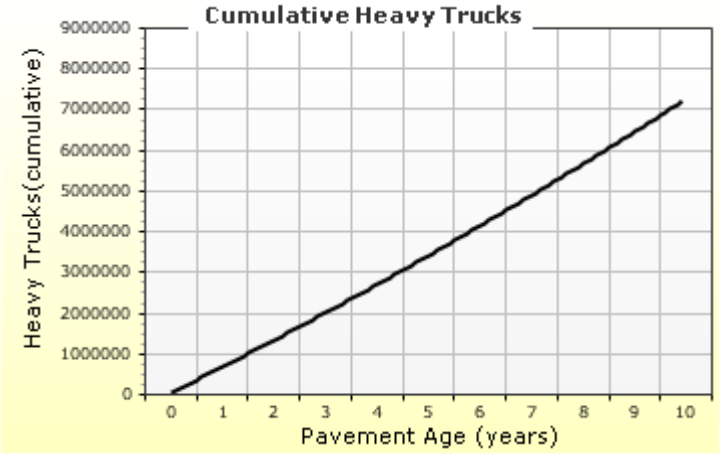
*** Traffic cap is not enforced**







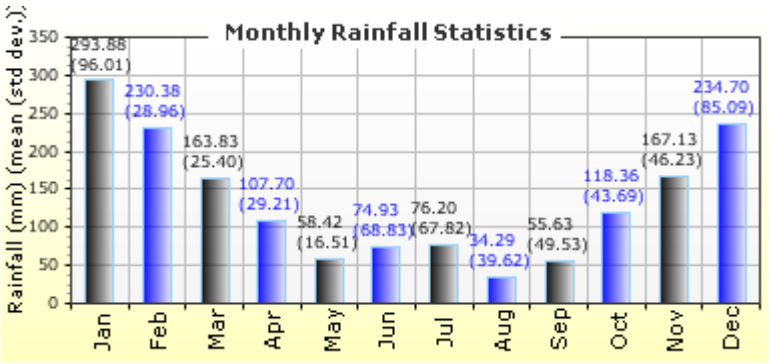




Climate Inputs

Climate Data Sources:

Climate Station Cities:	Location (lat lon elevation(m))
SAO PAULO, SP	-23.50000 -46.62000 792

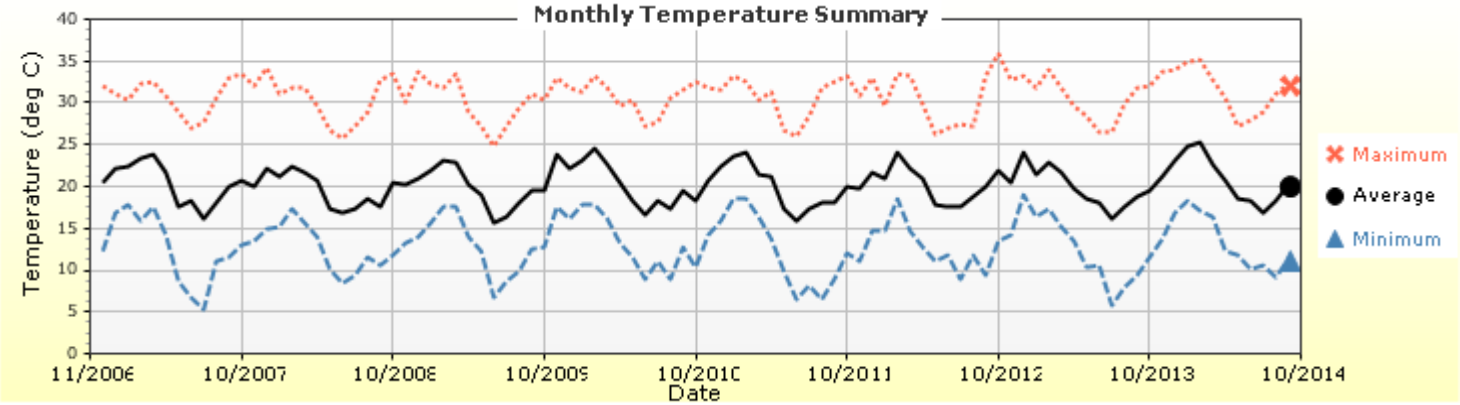


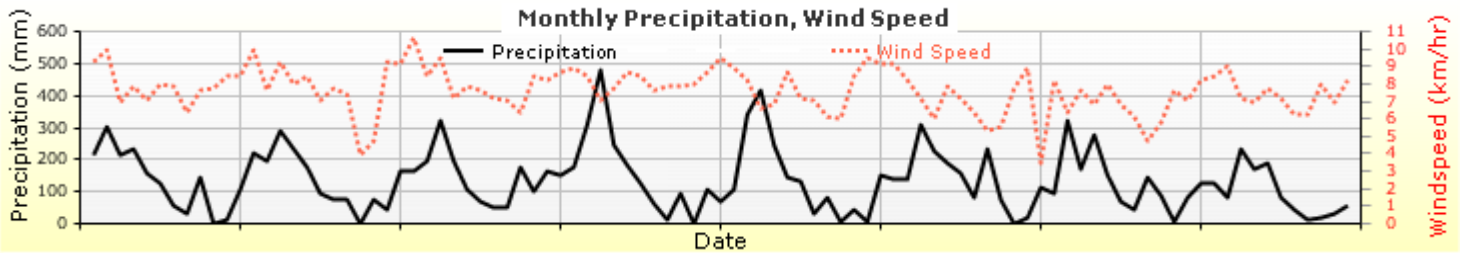
Annual Statistics:

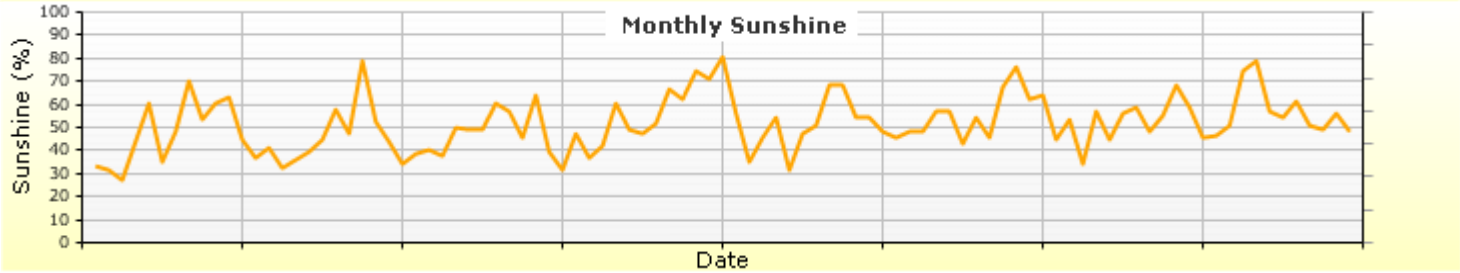
Mean annual air temperature (ºC)	20.15
Mean annual precipitation (mm)	1628.14
Freezing index (ºC - days)	0
Average annual number of freeze/thaw cycles:	0.00

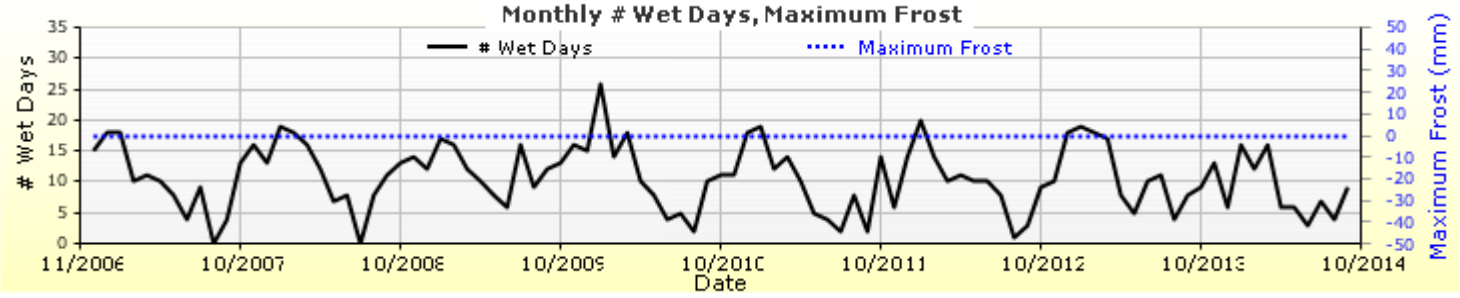
Water table depth (m): 3.05

Monthly Climate Summary:

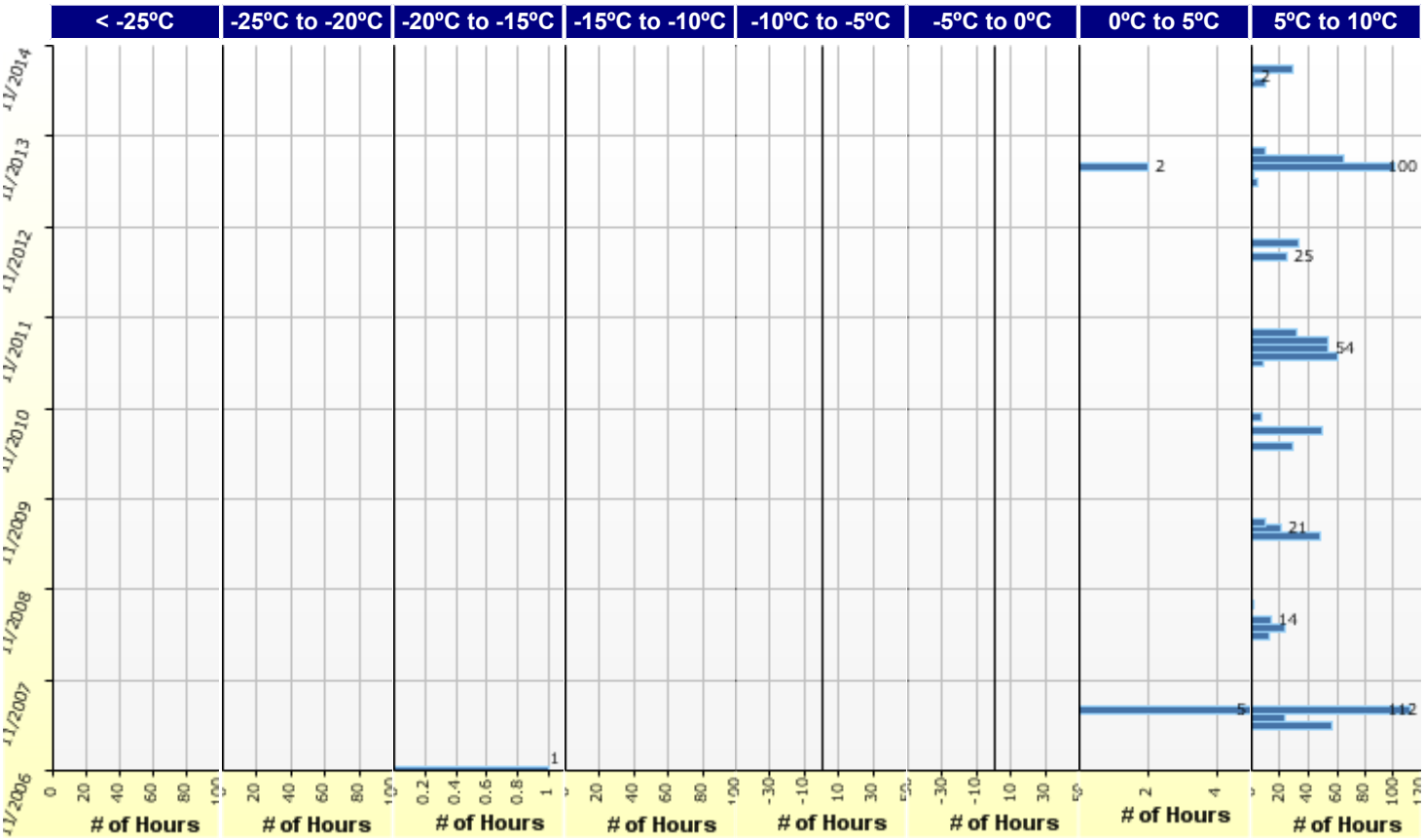


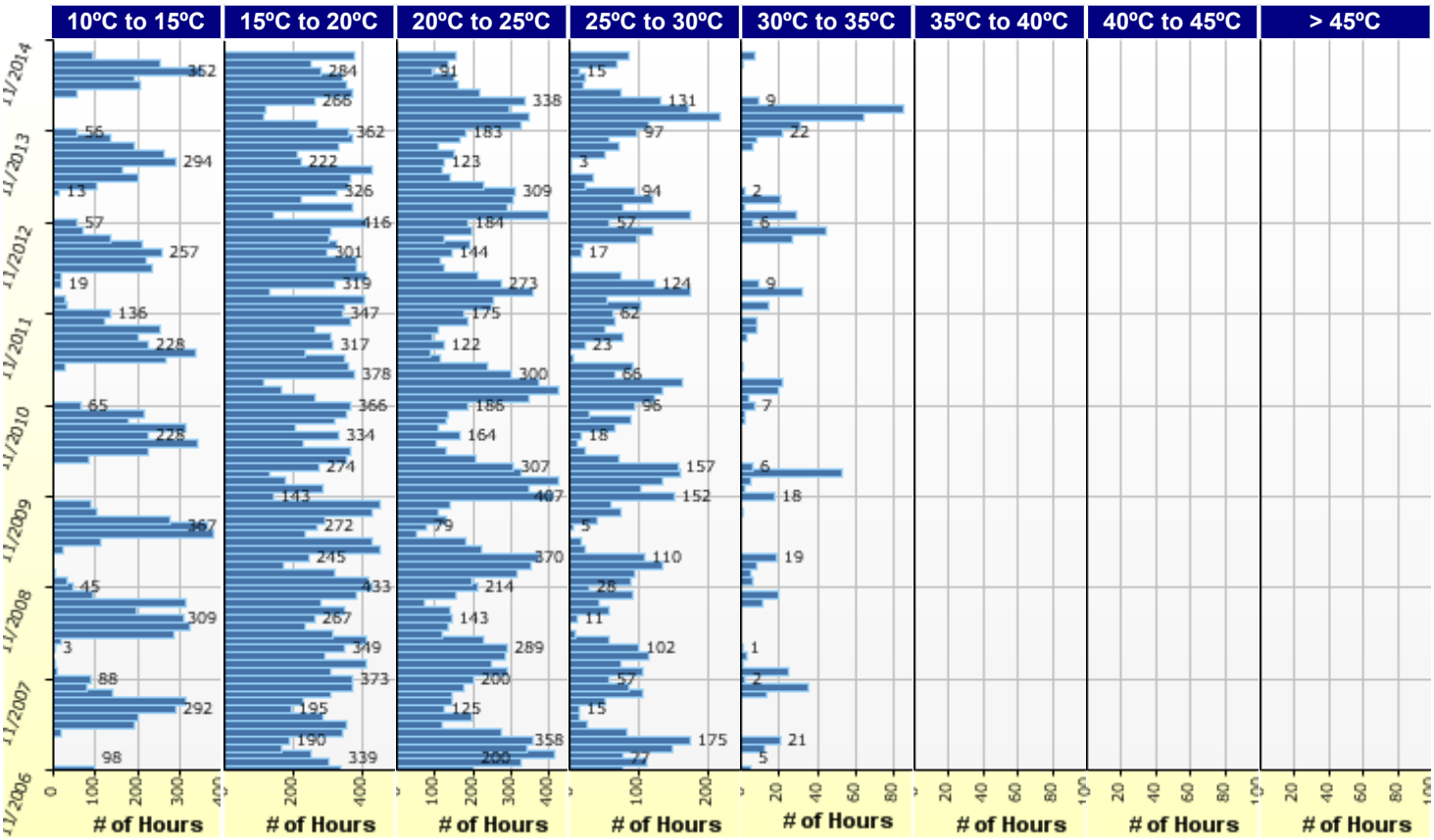






Hourly Air Temperature Distribution by Month:





Design Properties

HMA Design Properties

Use Multilayer Rutting Model	False
Using G* based model (not nationally calibrated)	False
Is NCHRP 1-37A HMA Rutting Model Coefficients	True
Endurance Limit	-
Use Reflective Cracking	True

Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

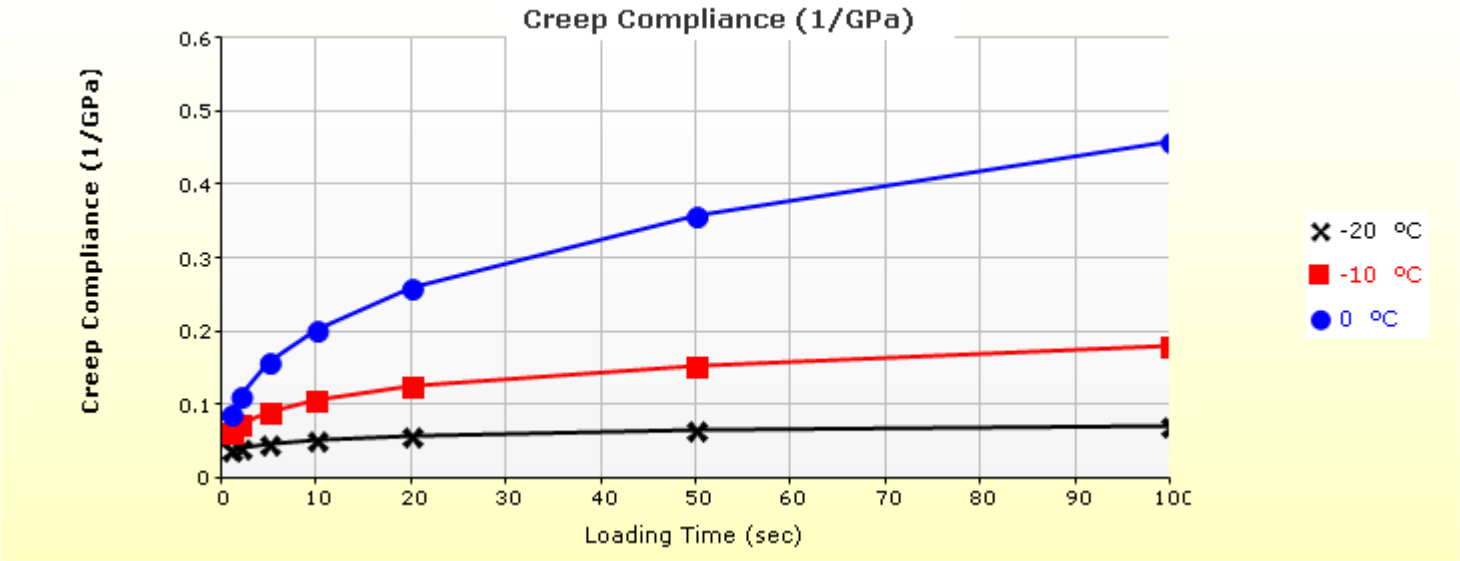
Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Concreto Asfáltico	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Base Brita Graduada	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Macadame Seco	Non-stabilized Base (4)	1.00
Layer 4 Non-stabilized Base : Areia A-3	Non-stabilized Base (4)	1.00
Layer 5 Subgrade : Subleito Local	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

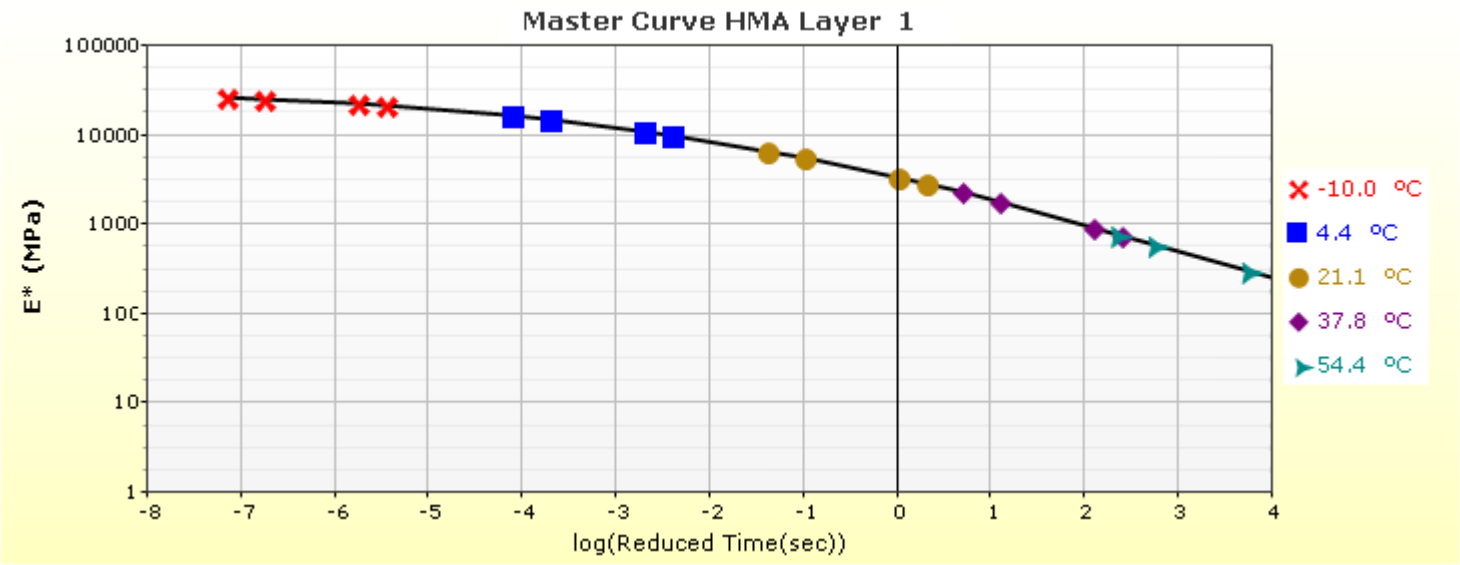
Indirect tensile strength at -10 ºC (MPa)	2.69

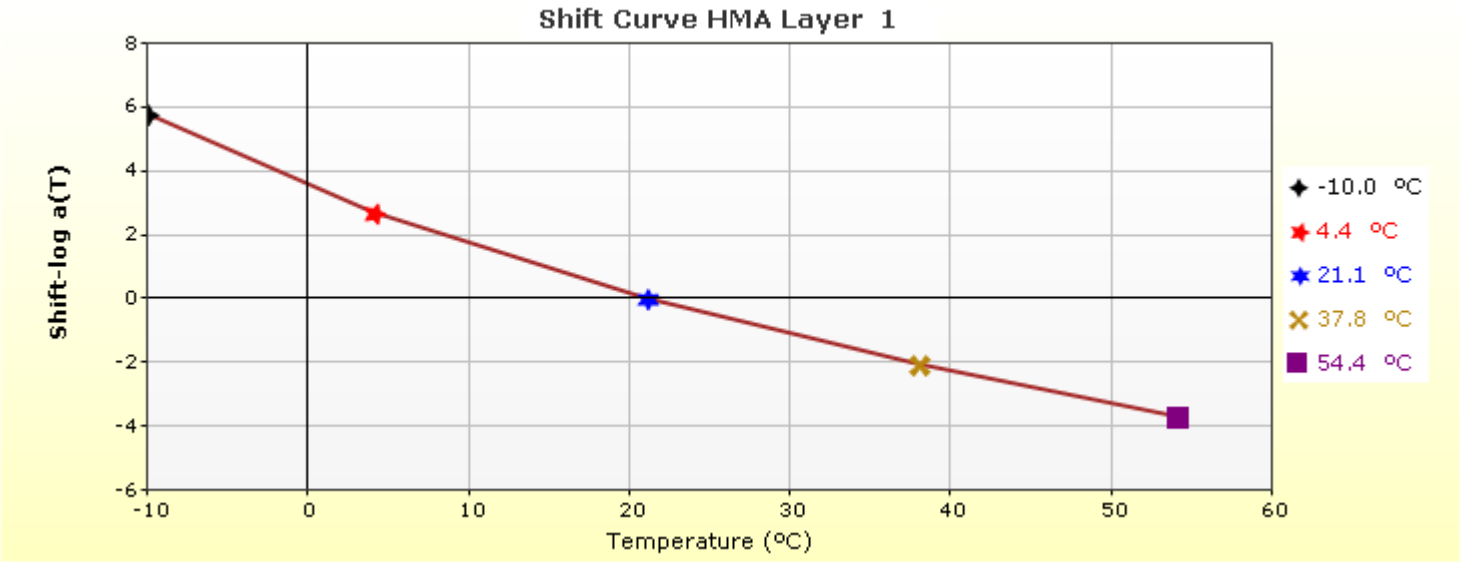
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/ºC)	-
Aggregate coefficient of thermal contraction (mm/mm/ºC)	9.0e-006
Voids in Mineral Aggregate (%)	18.0

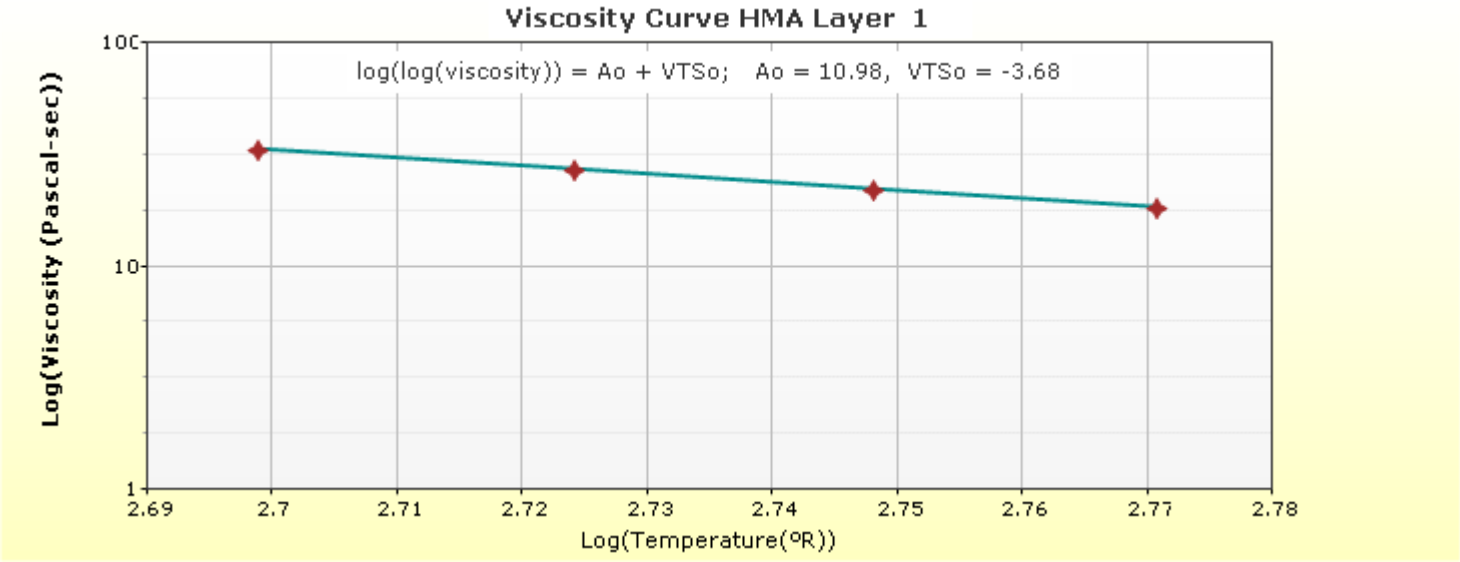
	Creep Compliance (1/GPa)		
Loading time (sec)	-20 ºC	-10 ºC	0 ºC
1	3.89e-002	6.47e-002	8.94e-002
2	4.27e-002	7.55e-002	1.14e-001
5	4.84e-002	9.26e-002	1.58e-001
10	5.32e-002	1.08e-001	2.03e-001
20	5.84e-002	1.26e-001	2.59e-001
50	6.62e-002	1.55e-001	3.59e-001
100	7.27e-002	1.81e-001	4.59e-001



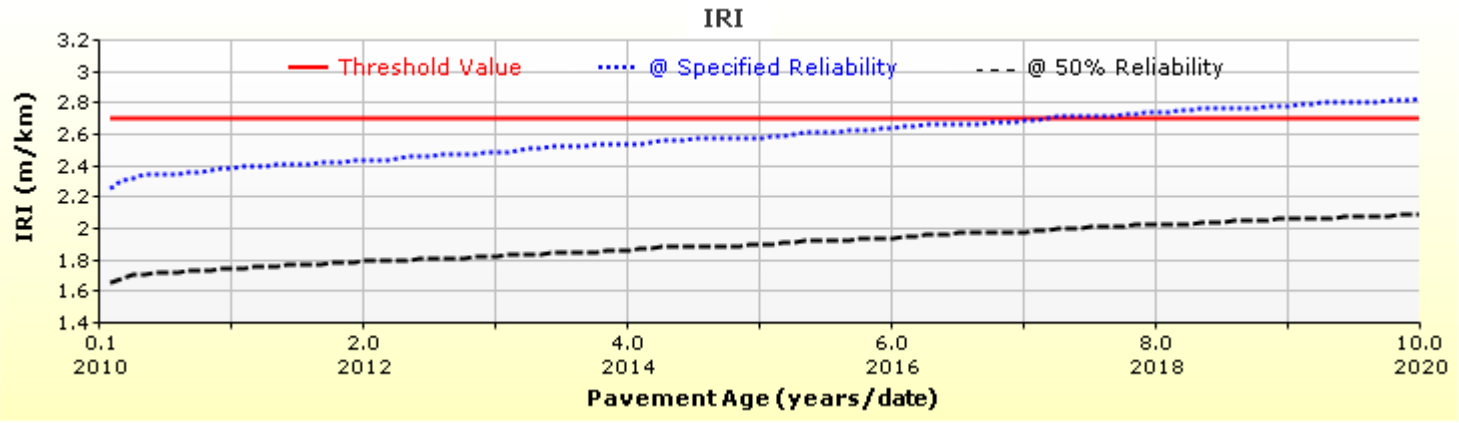
HMA Layer 1: Layer 1 Flexible : Concreto Asfáltico

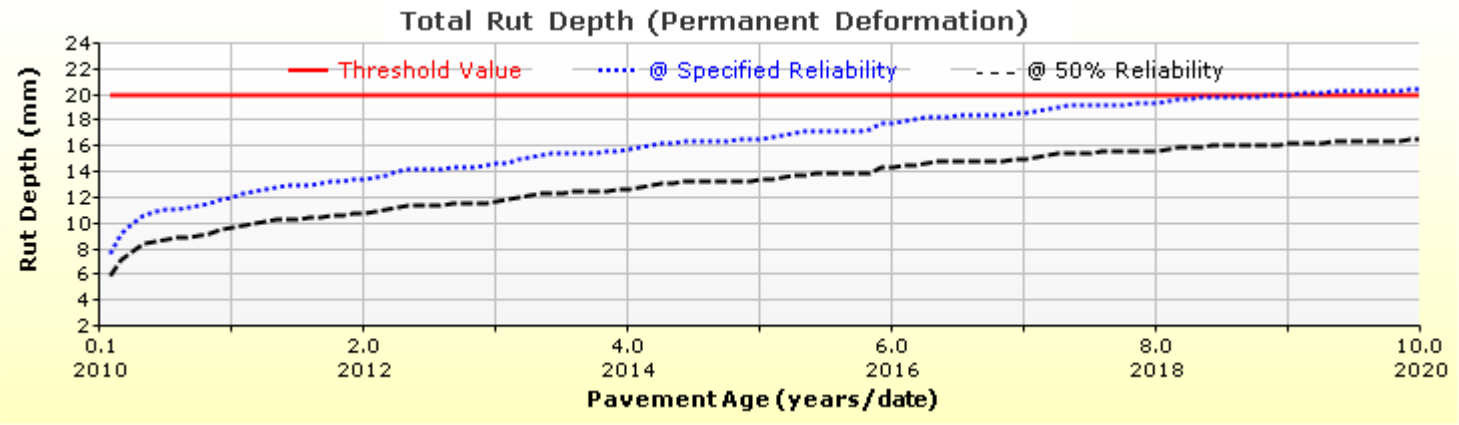


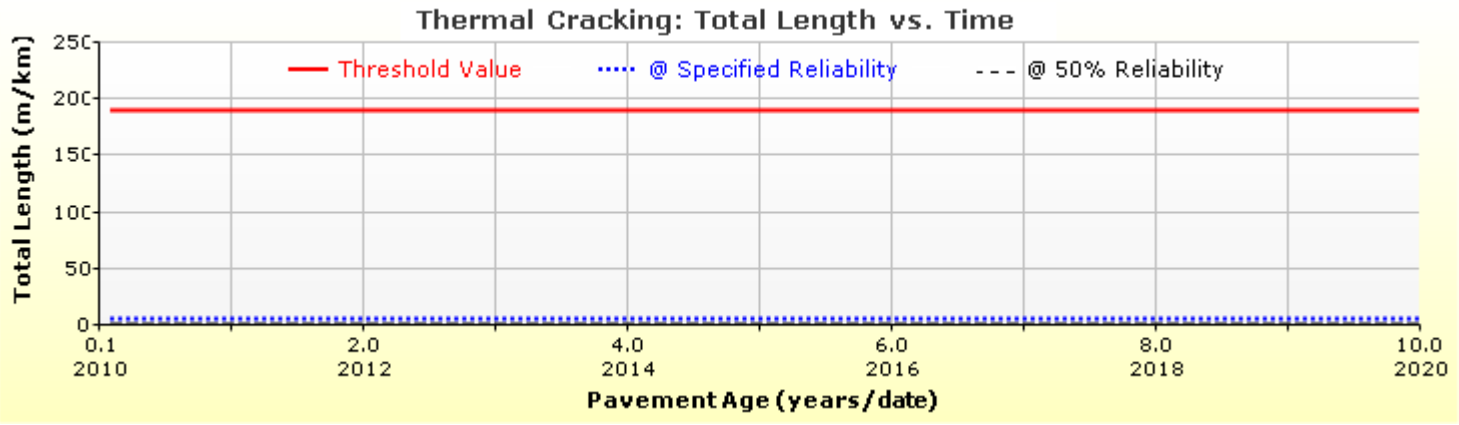


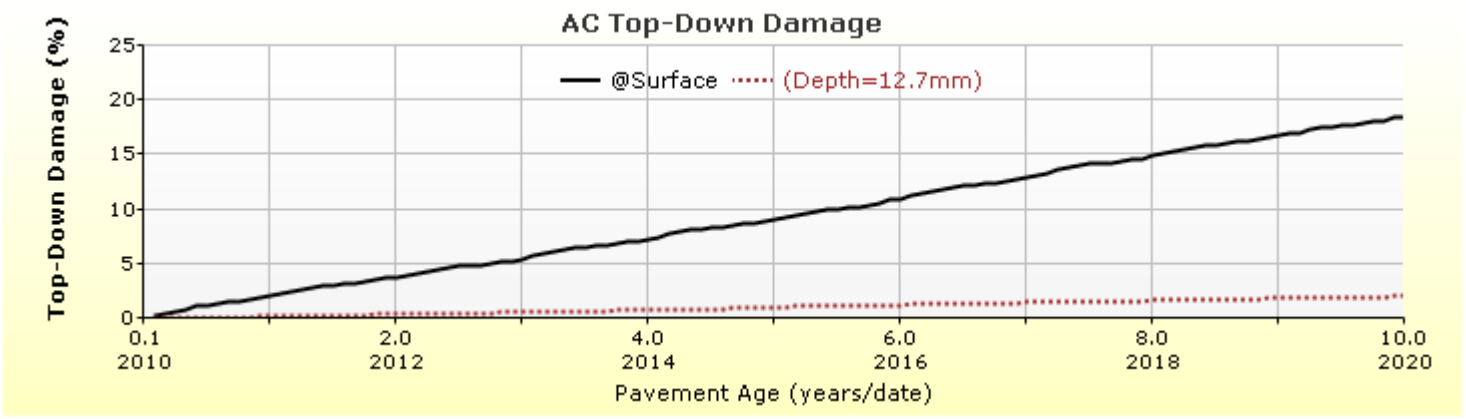


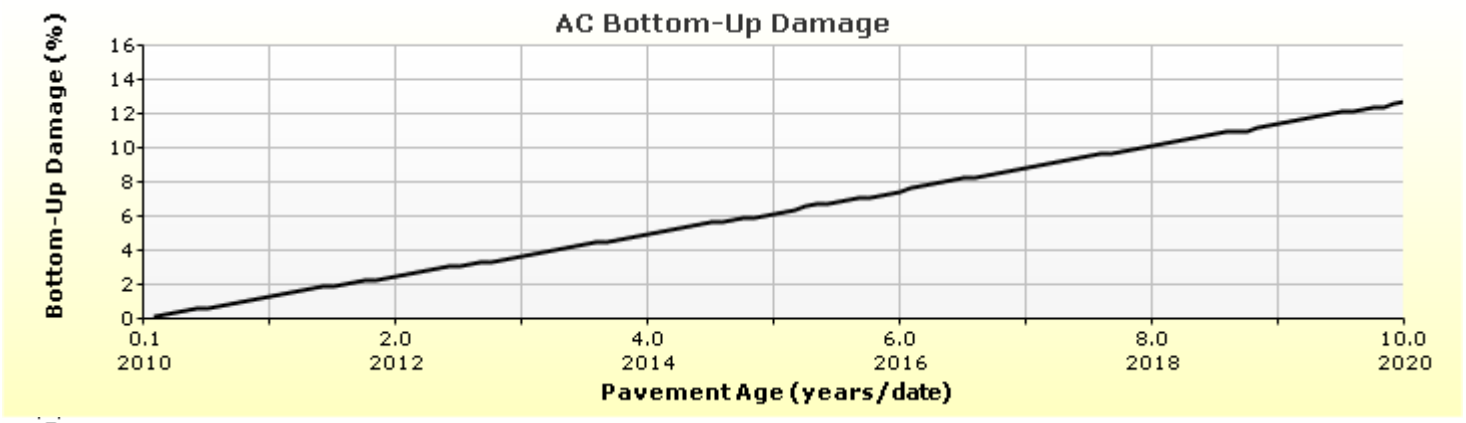
Analysis Output Charts

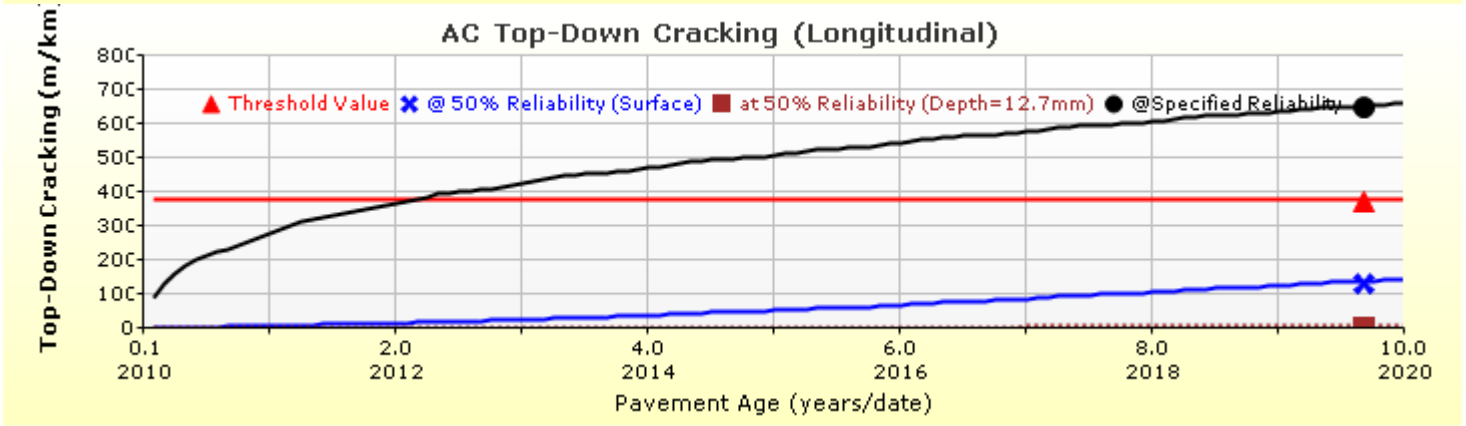


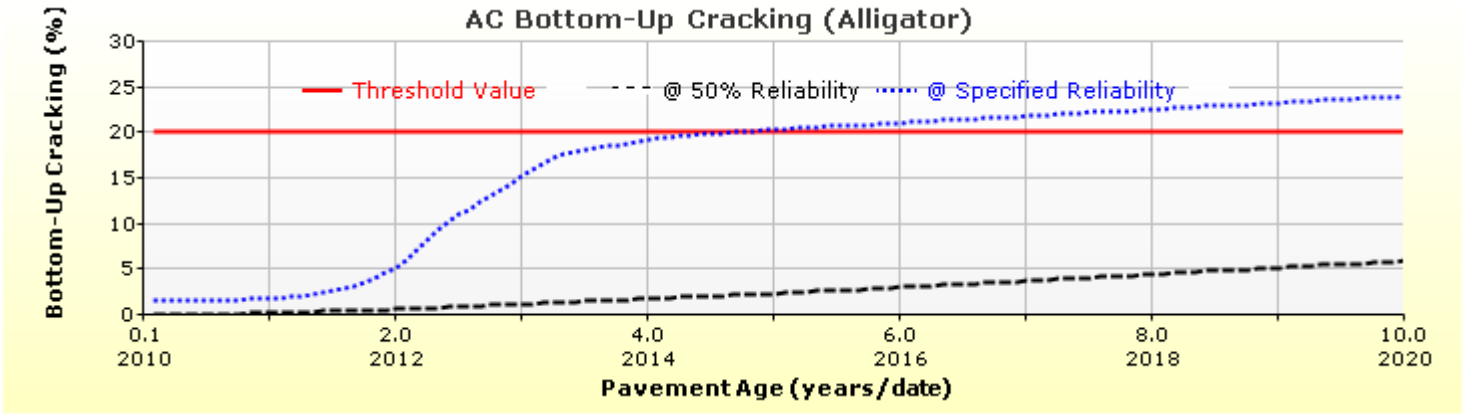


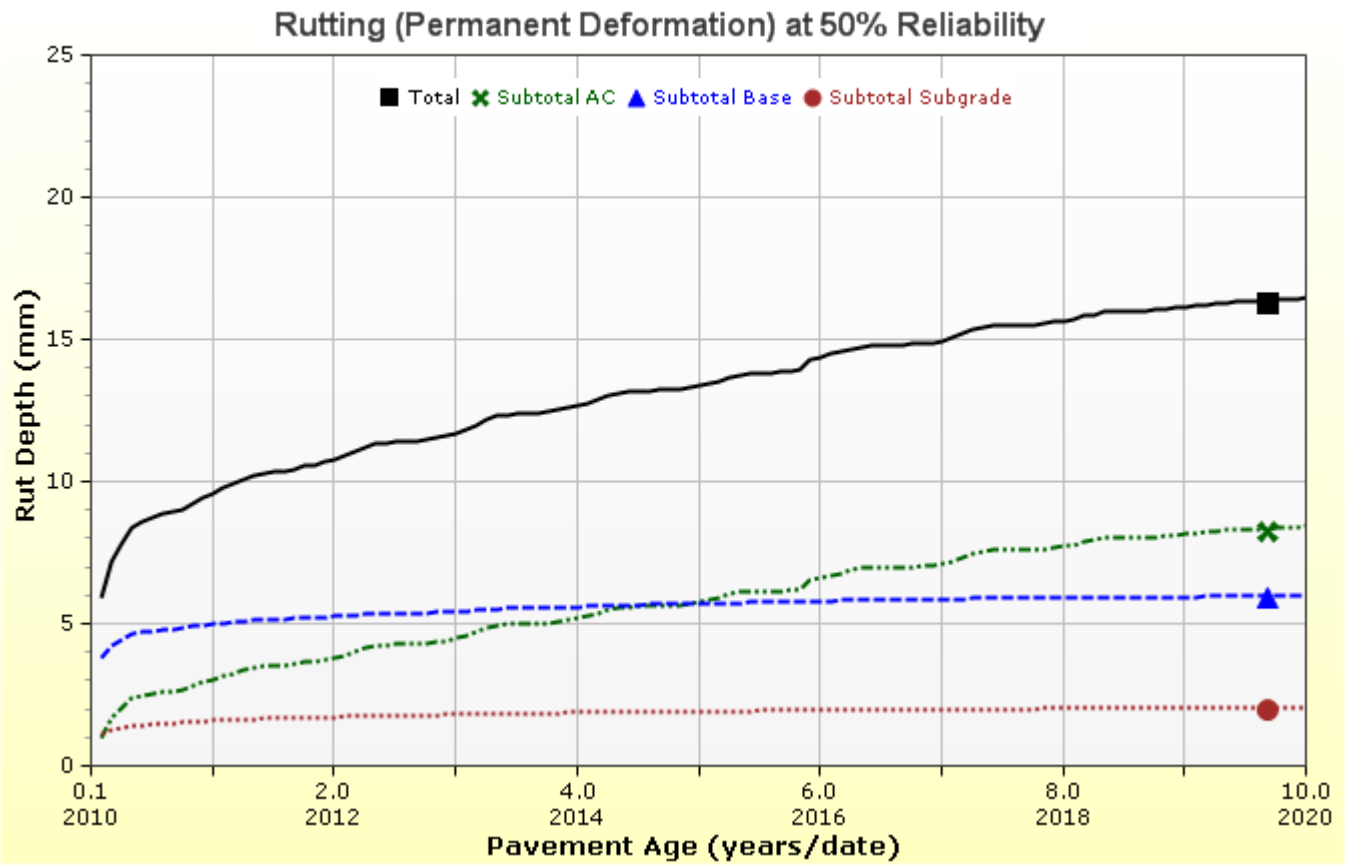


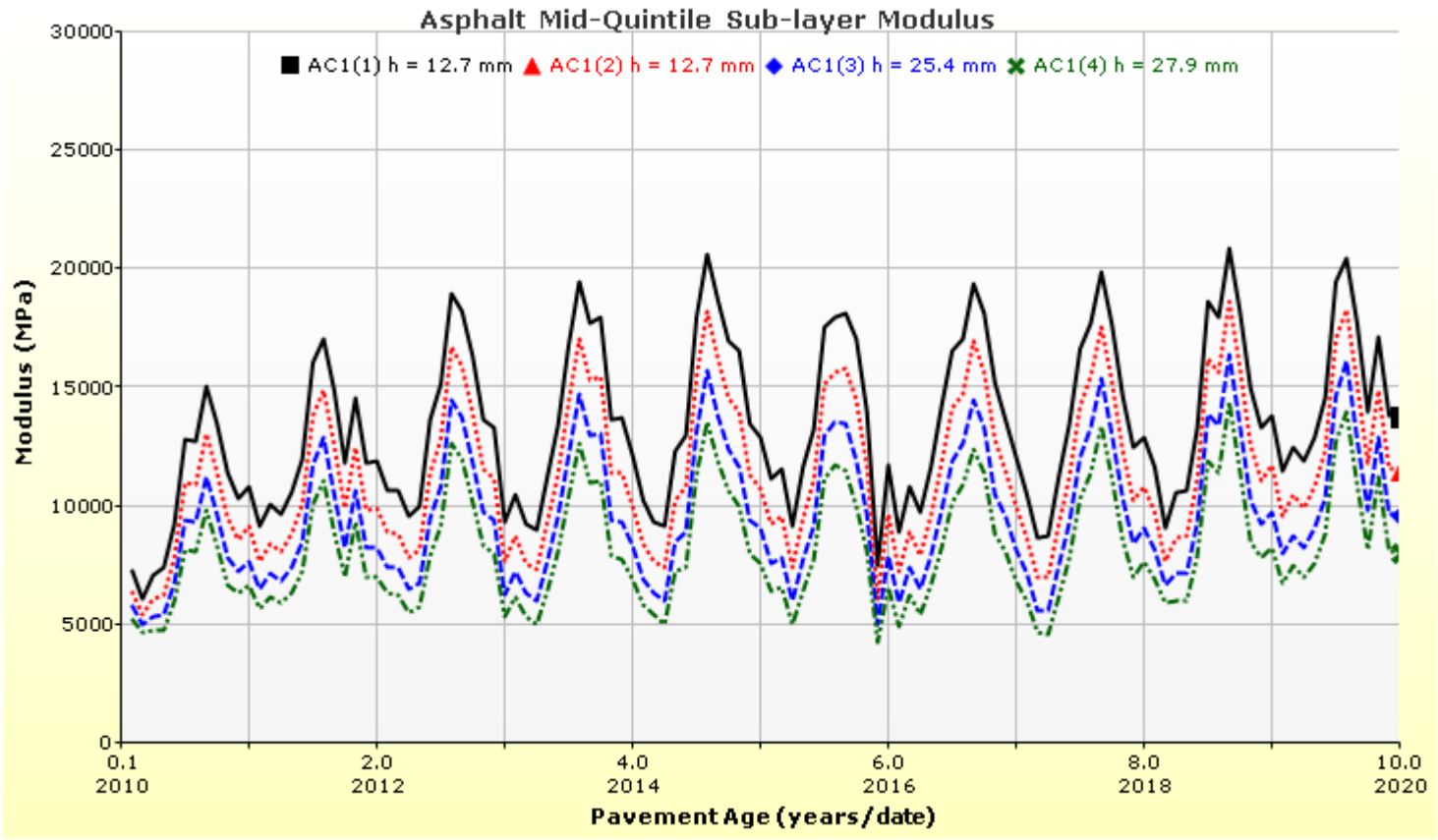

AC Top-Down Damage
Top-Down Damage (%)
@Surface
(Depth=12.7mm)
0
5
10
15
20
25
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

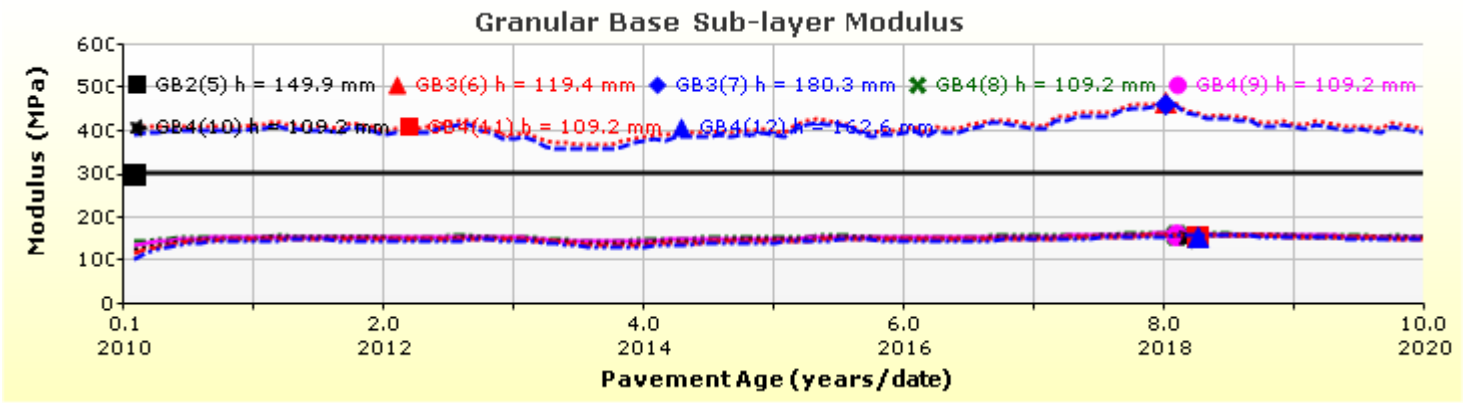

AC Bottom-Up Damage
Bottom-Up Damage (%)
0
2
4
6
8
10
12
14
16
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

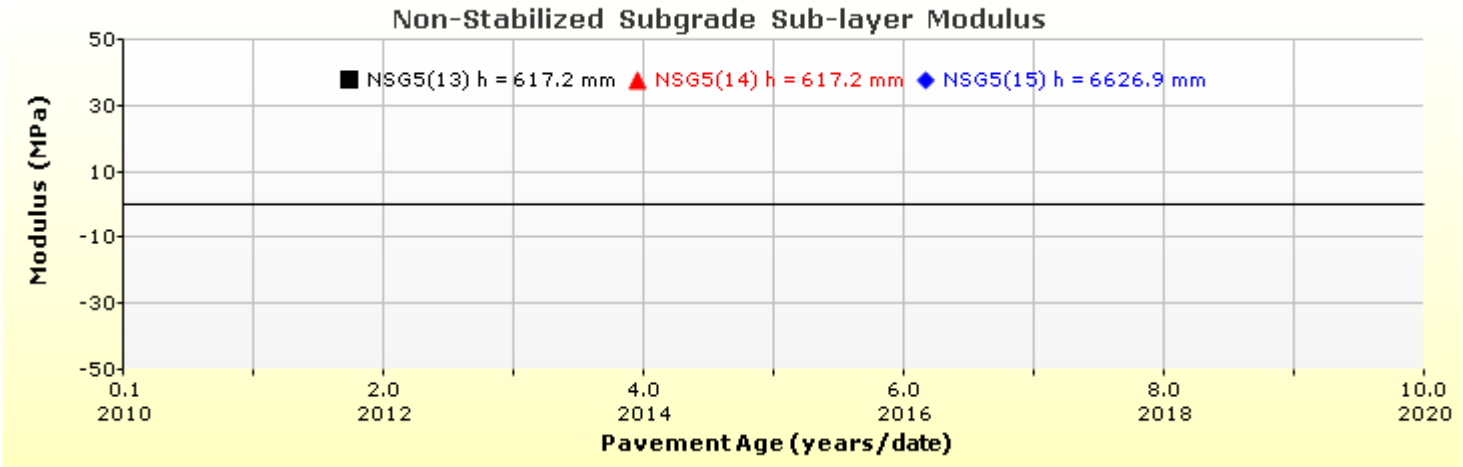

AC Top-Down Cracking (Longitudinal)
Top-Down Cracking (m/km)
Threshold Value
@ 50% Reliability (Surface)
at 50% Reliability (Depth=12.7mm)
@Specified Reliability
0
100
200
300
400
500
600
700
800
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


AC Bottom-Up Cracking (Alligator)
Bottom-Up Cracking (%)
Threshold Value
@ 50% Reliability
@ Specified Reliability
0
5
10
15
20
25
30
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Rutting (Permanent Deformation) at 50% Reliability
Total
Subtotal AC
Subtotal Base
Subtotal Subgrade
Rut Depth (mm)
25
20
15
10
5
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Asphalt Mid-Quintile Sub-layer Modulus
AC1(1) h = 12.7 mm
AC1(2) h = 12.7 mm
AC1(3) h = 25.4 mm
AC1(4) h = 27.9 mm
Modulus (MPa)
30000
25000
20000
15000
10000
5000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Granular Base Sub-layer Modulus
GB2(5) h = 149.9 mm
GB3(6) h = 119.4 mm
GB3(7) h = 180.3 mm
GB4(8) h = 109.2 mm
GB4(9) h = 109.2 mm
GB4(10) h = 109.2 mm
GB4(11) h = 109.2 mm
GB4(12) h = 162.6 mm
Modulus (MPa)
60000
50000
40000
30000
20000
10000
0
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)


Non-Stabilized Subgrade Sub-layer Modulus
NSG5(13) h = 617.2 mm
NSG5(14) h = 617.2 mm
NSG5(15) h = 6626.9 mm
Modulus (MPa)
50
30
10
-10
-30
-50
0.1
2010
2.0
2012
4.0
2014
6.0
2016
8.0
2018
10.0
2020
Pavement Age (years/date)

Layer Information

Layer 1 Flexible : Concreto Asfáltico

Asphalt		
Thickness (mm)	80.0	
Unit weight (kgf/m^3)	2400.0	
Poisson's ratio	Is Calculated?	False
	Ratio	0.35
	Parameter A	-
	Parameter B	-

Asphalt Dynamic Modulus (Input Level: 3)

Gradation	Percent Passing
19 mm-inch sieve	100
9.5 mm sieve	77
4.75 mm sieve	60
0.075mm sieve	6

Asphalt Binder

Parameter	Value
Grade	Superpave Performance Grade
Binder Type	64-22
A	10.98
VTS	-3.68

General Info

Name	Value
Reference temperature (ºC)	21.1
Effective binder content (%)	11
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Concreto Asfáltico
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Layer 2 Non-stabilized Base : Base Brita Graduada

Unbound	
Layer thickness (mm)	150.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
300.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Base Brita Graduada
Description of object	BGS
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2045.8
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 3 Non-stabilized Base : Macadame Seco

Unbound	
Layer thickness (mm)	300.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
350.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Macadame Seco
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	6.0
Plasticity Index	1.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	2038.2
Saturated hydraulic conductivity (m/hr)	False	1.54e-02
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	7.2555
bf	1.3328
cf	0.8242
hr	117.4000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	8.7
0.150mm	
0.180mm	12.9
0.250mm	
0.300mm	
0.425mm	20.0
0.600mm	
0.850mm	
1.18mm	
2.0mm	33.8
2.36mm	
4.75mm	44.7
9.5mm	57.2
12.5mm	63.1
19.0mm	72.7
25.0mm	78.8
37.5mm	85.8
50.0mm	91.6
63.0mm	
75.0mm	
90.0mm	97.6

Layer 4 Non-stabilized Base : Areia A-3

Unbound	
Layer thickness (mm)	600.0
Poisson's ratio	0.35
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Modify input values by temperature/moisture
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
100.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Areia A-3
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	11.0
Plasticity Index	0.0
Is layer compacted?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	True	1922.2
Saturated hydraulic conductivity (m/hr)	False	3.777e-03
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	7.3

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	4.7572
bf	2.8814
cf	0.8694
hr	100.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	5.2
0.150mm	
0.180mm	33.0
0.250mm	
0.300mm	
0.425mm	76.8
0.600mm	
0.850mm	
1.18mm	
2.0mm	93.4
2.36mm	
4.75mm	95.3
9.5mm	96.6
12.5mm	97.1
19.0mm	98.0
25.0mm	98.6
37.5mm	99.2
50.0mm	99.7
63.0mm	
75.0mm	
90.0mm	99.9

Layer 5 Subgrade : Subleito Local

Unbound	
Layer thickness (mm)	Semi-infinite
Poisson's ratio	0.4
Coefficient of lateral earth pressure (k0)	0.5

Modulus (Input Level: 3)

Analysis Type:	Annual representative values
Method:	Resilient Modulus (psi)

Resilient Modulus (psi)
140.0

Use Correction factor for NDT modulus?	-
NDT Correction Factor:	-

Identifiers

Field	Value
Display name/identifier	Subleito Local
Description of object	
Author	
Date Created	1/1/0001 12:00:00 AM
Approver	
Date approved	1/1/0001 12:00:00 AM
State	
District	
County	
Highway	
Direction of Travel	
From station (km)	
To station (km)	
Province	
User defined field 2	
User defined field 3	
Revision Number	0

Sieve

Liquid Limit	45.0
Plasticity Index	5.0
Is layer compacted?	False

	Is User Defined?	Value
Maximum dry unit weight (kgf/m^3)	False	1908.9
Saturated hydraulic conductivity (m/hr)	False	2.821e-07
Specific gravity of solids	False	2.7
Optimum gravimetric water content (%)	False	11.4

User-defined Soil Water Characteristic Curve (SWCC)	
Is User Defined?	False
af	65.2333
bf	1.0338
cf	0.4994
hr	500.0000

Sieve Size	% Passing
0.001mm	
0.002mm	
0.020mm	
0.075mm	54.3
0.150mm	
0.180mm	66.2
0.250mm	
0.300mm	
0.425mm	74.3
0.600mm	
0.850mm	
1.18mm	
2.0mm	82.6
2.36mm	
4.75mm	86.9
9.5mm	90.2
12.5mm	91.9
19.0mm	94.1
25.0mm	95.9
37.5mm	97.5
50.0mm	98.5
63.0mm	
75.0mm	
90.0mm	99.5

Calibration Coefficients

AC Fatigue

$$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2\beta_{f2}} \left(\frac{1}{E}\right)^{k_3\beta_{f3}}$$

$$C = 10^M$$

$$M = 4.84\left(\frac{V_b}{V_a + V_b} - 0.69\right)$$

k1: 0.007566	
k2: 3.9492	
k3: 1.281	
Bf1: 1	
Bf2: 1	
Bf3: 1	

AC Rutting

$$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1} T^{k_2\beta_{r2}} N^{k_3\beta_{r3}}$$

$$k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$$

$$C_1 = -0.1039 * H_{\alpha}^2 + 2.4868 * H_{\alpha} - 17.342$$

$$C_2 = 0.0172 * H_{\alpha}^2 - 1.7331 * H_{\alpha} + 27.428$$

Where:

$H_{ac} = total\ AC\ thickness(in)$

$\varepsilon_p = plastic\ strain\left(^{in}/_{in}\right)$
$\varepsilon_r = resilient\ strain\left(^{in}/_{in}\right)$
$T = layer\ temperature(^{\circ}F)$
$N = number\ of\ load\ repetitions$

AC Rutting Standard Deviation	0.24*Pow(RUT,0.8026)+0.001	
AC Layer	K1:-3.35412 K2:1.5606 K3:0.4791	Br1:1 Br2:1 Br3:1

Thermal Fracture

$$C_f = 400 * N\left(\frac{\log C / h_{ac}}{\sigma}\right)$$

$$\Delta C = (k * \beta t)^{n+1} * A * \Delta K^n$$

$$A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$$

$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$
$k = refression\ coefficient\ determined\ through\ field\ calibration$
$N() = standard\ normal\ distribution\ evaluated\ at()$
$\sigma = standard\ deviation\ of\ the\ \log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$
$C = crack\ depth(in)$
$h_{ac} = thickness\ of\ asphalt\ layer(in)$
$\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$
$\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$
$A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$
$E = mixture\ stiffness$
$\sigma_M = Undamaged\ mixture\ tensile\ strength$
$\beta_t = Calibration\ parameter$

Level 1 K: 1.5	Level 1 Standard Deviation: 0.1468 * THERMAL + 65.027
Level 2 K: 0.5	Level 2 Standard Deviation: 0.2841 *THERMAL + 55.462
Level 3 K: 1.5	Level 3 Standard Deviation: 0.3972 * THERMAL + 20.422

CSM Fatigue

$$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$$

$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$
$\sigma_s = Tensile\ stress(psi)$
$M_r = modulus\ of\ rupture(psi)$

k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

$$\delta_a(N) = \beta_{s_1} k_1 \varepsilon_v h \left(\frac{\varepsilon_0}{\varepsilon_r}\right) \left| e^{-\left(\frac{\rho}{N}\right)^{\beta}} \right|$$

$\delta_a = permanent\ deformation\ for\ the\ layer$
$N = number\ of\ repetitions$
$\varepsilon_v = average\ veritcal\ strain(in/in)$
$\varepsilon_0, \beta, \rho = material\ properties$
$\varepsilon_r = resilient\ strain(in/in)$

Granular		Fine	
k1: 2.03	Bs1: 1	k1: 1.35	Bs1: 1
Standard Deviation (BASERUT) 0.1477*Pow(BASERUT,0.6711)+0.001		Standard Deviation (BASERUT) 0.1235*Pow(SUBRUT,0.5012)+0.001	

AC Cracking

AC Top Down Cracking

$$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * log_{10}(Damage))}}\right) * 10.56$$

c1: 7	c2: 3.5	c3: 0	c4: 1000

AC Cracking Top Standard Deviation

200 + 2300/(1+exp(1.072-2.1654*LOG10 (TOP+0.0001)))

AC Bottom Up Cracking

$$FC = \left(\frac{6000}{1 + e^{(C_1 * C_1' + C_2 * C_2' log_{10}(D * 100))}}\right) * \left(\frac{1}{60}\right)$$

$$C_2' = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$$

$$C_1' = -2 * C_2'$$

c1: 1	c2: 1	c3: 6000

AC Cracking Bottom Standard Deviation

1.13+13/(1+exp(7.57-15.5*LOG10 (BOTTOM+0.0001)))

CSM Cracking

$$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$$

C1: 1	C2: 1	C3: 0	C4: 1000

CSM Standard Deviation

CTB*1

IRI Flexible Pavements

C1 - Rutting
C2 - Fatigue Crack
C3 - Transverse Crack
C4 - Site Factors

C1: 40	C2: 0.4	C3: 0.008	C4: 0.015

ANEXO B – APRESENTAÇÃO CONCEPA-ANTT 29/02/2016



Pesquisas de Desenvolvimento Tecnológico
RDT – ANTT – Concepa - Prime
Porto Alegre, 29 de Fevereiro de 2016

PESQUISAS REALIZADAS

- 2013-2015 - Uso da tecnologia de Weigh-in-Motion (WIM) para avaliação de desempenho de pavimentos asfálticos da BR 290/RS – Freeway. Lélio Brito
- 2014-2015 - Impacto da sobrecarga legal em projetos de pavimentos novos e restaurações – métodos convencionais nacionais e AASHTO 2002 através do software AASHTOware® Pavement ME. Lélio Brito & Luciano Specht
- 2016 - Influência da temperatura no comportamento de Pavimentos Flexíveis – uma análise direcionada às ilhas de calor. Lélio Brito & Lucas Heller
- 2016 - Instrumentação *insitu* de um Segmento da BR-290 - Estudo Comparativo do Efeito Laboratório-Campo da Fadiga
  Equipe UFRGS: Jorge Ceratti, Gracieli Colpo, Fernando Cronst
  Equipe PRIME: Lélio Brito, Dionísio Doering



Pesquisas de Desenvolvimento Tecnológico
RDT – ANTT – Concepa - Prime
Porto Alegre, 29 de Fevereiro de 2016

Influência da temperatura no comportamento de Pavimentos Flexíveis – uma análise direcionada às ilhas de calor.

Prof. Lélio Brito, PhD Eng.
Eng. Lucas Heller



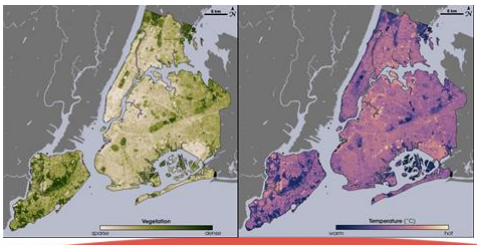
Pesquisas de Desenvolvimento Tecnológico
RDT – ANTT – Concepa - Prime
Porto Alegre, 29 de Fevereiro de 2016

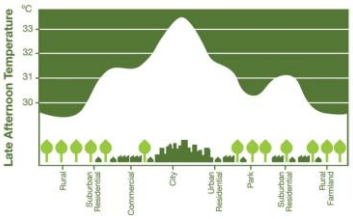
Objetivo: Compilar os dados climáticos em formato de arquivos tipo ICM (Integrated Climatic Models) de maneira a viabilizar uma análise da performance dos pavimentos devido às variações climáticas geradas pelo efeito de “Ilha de Calor Urbana” (ICU).



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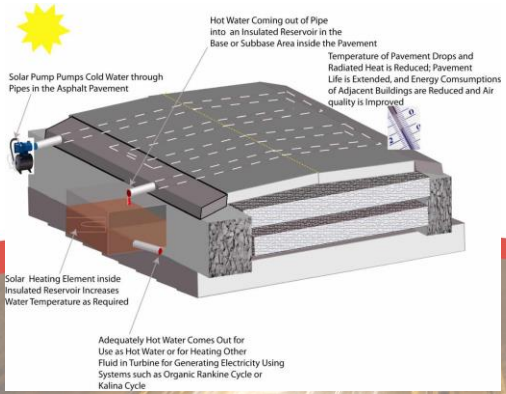
A ilha de calor urbana é um fenômeno causado principalmente pelas superfícies impermeáveis das cidades em detrimento a vegetação natural, aumentando a temperatura nos centros urbanos comparada a zona rural.



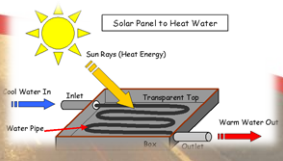


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Com a presença desse fenômeno pode-se usar pavimentos especiais para menor aumento de temperatura, ou através de sistemas coletores para captar essa energia, como por exemplo, dutos com fluídos para captar o calor.



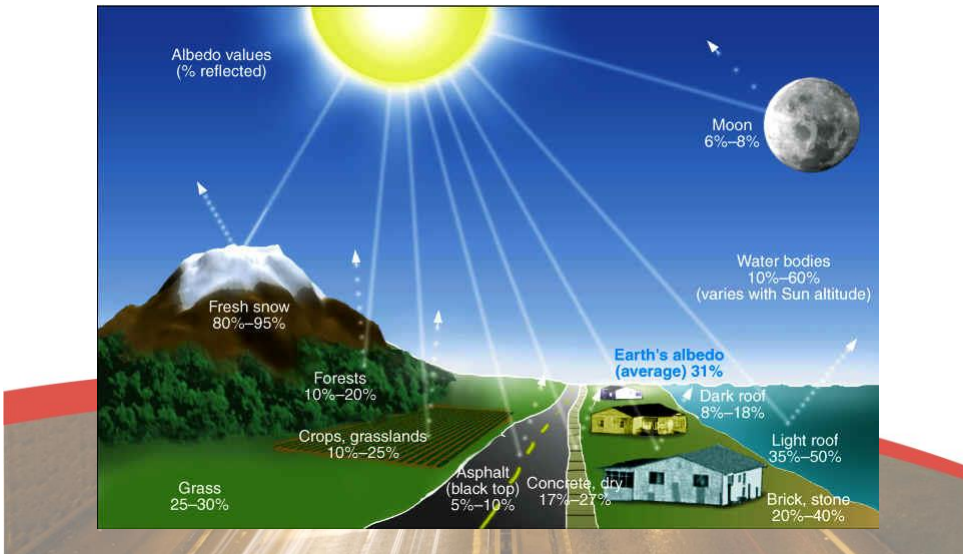




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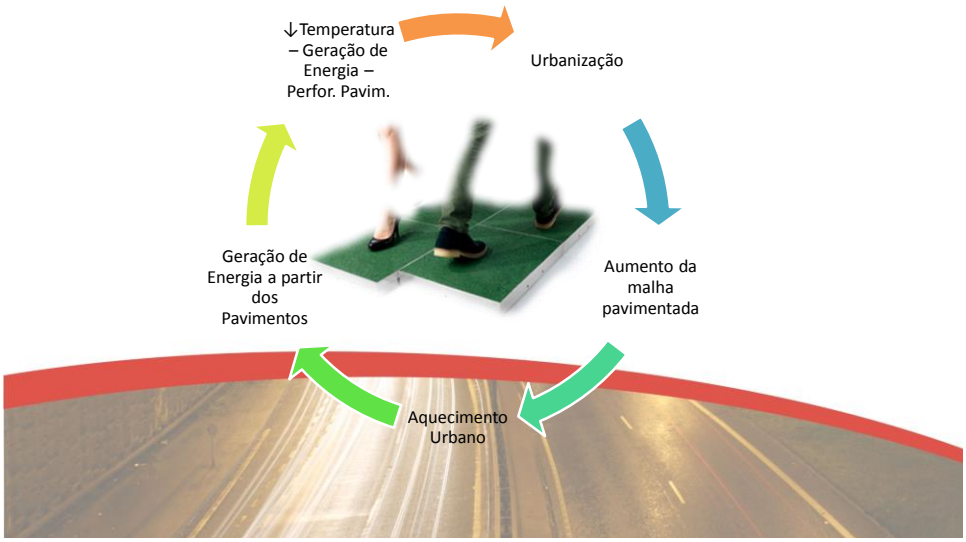
Albedo é um coeficiente de refletância, expressando o quanto da radiação recebida é refletida de volta. Essa propriedade é modificada em casos de pavimentos reflexivos na tentativa de absorver menos energia.

A medição do albedo é feita através de piranômetros que medem a radiação solar. Usualmente é utilizado 2 piranômetros, sendo um para a medição da radiação solar incidente e outro para a radiação solar refletida. A relação entre ambos é feita e o resultado é o Albedo do material medido.

Alguns estudos recentes indicam a possibilidade de uma medida aproximada do albedo através de fotografias digitais.



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Os dados climáticos serão obtido através do INMET, via solicitação direta, e através do CPTEC/INPE(Centro de Previsão do Tempo e Estudos Climáticos/Instituto Nacional de Pesquisas Espaciais).

É esperado a obtenção dos HCD (Hourly Climatic Data) das cidades de São Paulo, Rio de Janeiro, Brasília e Fortaleza, além da cidade de Porto Alegre, proposta inicialmente.



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Maiores temperaturas em pavimentos tendem a gerar maiores deformações e diminuição da vida útil.
Esse comportamento pode ser observado nas tabelas abaixo, resultado de experimentos prévios.

Critério de Desempenho – Alternativa 1	Normal	Frio	Calor
IRI Final (cm/km)	205,54	195,75	210,59
Trincas Longitudinais (m/km):	1,84	0,89	2,37
Trincamento por fadiga (%):	3,00	2,70	3,20
Deformação Permanente (Apenas CA) (cm):	2,03	1,65	2,21
Deformação Permanente (Total) (cm):	3,05	2,67	3,23

Critério de Desempenho – Alternativa 2	Normal	Frio	Calor
IRI Final (cm/km)	199,85	195,43	202,22
Trincas Longitudinais (m/km):	116,69	144,35	112,33
Trincamento por fadiga (%):	17,30	16,90	17,90
Deformação Permanente (Apenas CA) (cm):	1,02	0,84	1,09
Deformação Permanente (Total) (cm):	2,84	2,67	2,92

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