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Relatório Final de Pesquisa

Impacto da sobrecarga legal em projetos de pavimentos novos e restaurações – métodos convencionais nacionais e AASHTO 2002 através do software AASHTOware® Pavement ME.

Cliente: Concessionária da Rodovia Osório-Porto Alegre – CONCEPA

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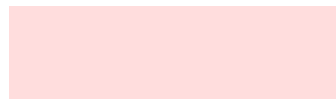
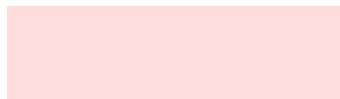
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LISTA DE ABREVIATURAS, SIGLAS E SÍMBOLOS

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

AEMC: Aplicativo de Análise Elástica para Estruturas de Múltiplas Camadas

AET: Autorização Especial de Tráfego

ANP: Agência Nacional do Petróleo, Gás Natural e Biocombustíveis

ATR: Afundamento na Trilha de Roda

B: Base

BGS: Brita Graduada Simples

BL: Camada de Bloqueio

CA: Concreto Asfáltico

CAP: Cimento Asfáltico de Petróleo

CAT: Categoria de Veículo

CBUQ: Concreto Betuminoso Usinado a Quente

CBR (ISC): California Bearing Ratio (Índice de Suporte Califórnia)

CDC: Coordenadoria de Defesa da Concorrência

CML: Carga Máxima Legal

CMT: Capacidade Máxima de Tração

CNT: Confederação Nacional do Transporte

CONTRAN: Conselho Nacional de Trânsito

CTB: Código de Trânsito Brasileiro

CVC's: Combinações de Veículos de Carga

Dadm: Deflexão Admissível

Dc: Deflexão Característica

DENATRAN: Departamento Nacional de Trânsito

DNER: Departamento Nacional de Estradas de Rodagem

DNIT: Departamento Nacional de Infraestrutura e Transportes

Dp: Deflexão de Projeto

ESAL: Equivalent Standard Axle Load

ESRD: Eixo Simples de Rodas Duplas

ESRS: Eixo Simples de Rodas Simples

ESWL: Equivalent Single Wheel Load

ETD: Eixo Tandem Duplo



ETT: Eixo Tandem Triplo
FEC: Fator de Equivalência de Cargas
Fc: Fator de Clima
Fd: Fator de distribuição
Ff: Fator de frota
FGV: Fundação Getúlio Vargas
FHWA: Federal Highway Administration
Fv: Fator de Veículo
GEPOIT: Empresa Brasileira de Planejamento de Transportes
HRB: Highway Research Board
h20: Sub-base
ICMS: Imposto sobre Circulação de Mercadorias e Serviços
IP: Imprimação
IRI: Índice de Rugosidade Internacional
ISP: Índice de Serventia Presente
kN: Quilonewtom
kPa: Quilopascal
LASTRAN: Laboratório de Sistemas de Transportes da UFRGS
Lbs: libras
LDI: Lucros e Despesas Indiretas
MEPDG: Mechanistic-Empirical Pavement Design Guide
MPa: Megapascal
MR: Módulo de Resiliência
MS: Macadame Seco
N: Número N de eixos padrões
NCHRP: National Cooperative Highway Research Program
NRC: National Research Council
PBT: Peso Bruto Total
PBTC: Peso Bruto Total Combinado
PIB: Produto Interno Bruto
PL: Pintura de Ligação
PMF: Pré-misturado a Frio
PMQ: Pré-misturado a Quente



PNLT: Plano Nacional de Logística e Transportes

PSI: Índice de Serventia Atual

P1: Praça de Pedágio

R: Revestimento

Rc: Raio de Curvatura

SC: Sobrecarga

SICRO: Sistema de Custos Rodoviários

SL: Subleito

T.C.: Taxa de Crescimento

Ton (t; tf): Tonelada

TSD: Tratamento Superficial Duplo

UFRGS: Universidade Federal do Rio Grande do Sul

USACE: United States Army Corps of Engineers

VCL's: Veículos Combinados Longos

VDM: Volume Médio Diário

VDMA: Volume Médio Diário Anual

VSA: Valor de Serventia Atual

WIM: Weigh In Motion

ϵ : Deformação

σ : Desvio padrão

ϵ_v : Deformação de compressão no topo do subleito

ϵ_t : Deformação de tração na fibra inferior do revestimento



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1 INTRODUÇÃO

O projeto de pesquisa aqui proposto intitula-se “Impacto da sobrecarga legal em projetos de pavimentos novos e restaurações – métodos convencionais nacionais e AASHTO 2002 através do software *AASHTOware® Pavement ME*”. Este projeto surgiu da demanda da Concessionária proponente, inserida num contexto nacional no mesmo interesse, de entender o impacto das sobrecargas legais nos projetos de pavimentos. Propõem-se um projeto de escopo limitado para curta realização com objetivo de uma aproximação pragmática em 4 meses de trabalho. O estudo buscará a resposta para a pergunta: “Qual o efeito da sobrecarga legal nos veículos rodantes no projeto de pavimentos novos e restaurações”.

Há duas resoluções do Contran que hoje vigoram sobre o tema. A Resolução Nº 210 de 13 de Novembro de 2006 estabelece os limites de carga por eixo e peso bruto total (PBT) dos veículos; a Resolução Nº 258 de 30 de Novembro de 2007 estabelece a tolerância máxima de 5% para PBT e PBTC (Peso Bruto Total Combinado) e também os valores de multa para os excessos de sobrecarga. Ocorre, no entanto, que esta última resolução passou por diversas deliberações em 2009 a 2013 que continuam a liberar o limite em 7,5% de “sobrecarga legal”. Apesar da sobrecarga admissível não poder ser de fato considerada com uma sobrecarga permitida, e sim, como imprecisão dos equipamentos utilizados, o limite acaba por funcionar com um valor de sobrecarga utilizado regularmente por transportadores.

No que se refere aos pavimentos, tal sobrecarga é extremamente danosa. Há no Brasil um consenso na necessidade de atualização nos métodos de fiscalização destas sobrecargas – hoje considerado deficiente – como também nos métodos de dimensionamento – tópico este que é pauta de discussão frequente entre profissionais da área.

Uma vez que não é autorizado pelo Departamento Nacional de Infraestrutura de Transportes – DNIT – o dimensionamento considerando as cargas rodantes nas rodovias, ou seja, com veículos sobrecarregados – estima-se que há uma significativa parcela dos problemas precoces nos pavimentos advindos desta questão. A Figura 1, por exemplo, mostra na estimativa de Pinto e Preussler (2002) que há uma redução de mais da metade da vida de um pavimento para uma sobrecarga de 10%. Considerando uma sobrecarga “legal” de 7,5% haveria uma redução na vida esperada em um pavimento projetado para durar dez anos, para menos de 6 anos – ou seja, mais 4 anos de redução para um horizonte de 10 anos.

Urge, desta forma, que se quantifique este efeito para que seja possível propor mecanismos de “correção” ou mesmo “antecipação” de efeitos – como, por exemplo, rotinas de manutenção.

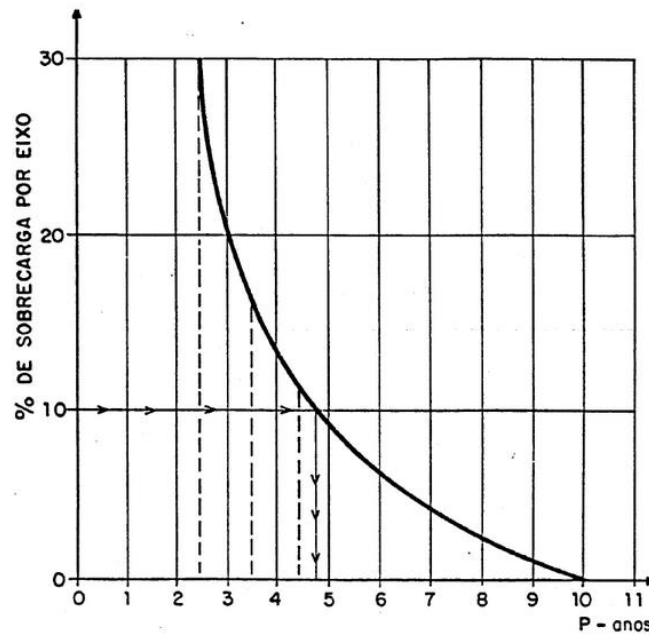


Figura 1 – Curva de sobrecarga por eixo versus a redução da vida útil de pavimentos (Pinto e Preussler, 2002)

1.1 OBJETIVOS

1.1.1 Objetivo geral

Quantificar o impacto nos projetos de pavimentos novos e restaurações de pavimentos em serviço considerando a sobrecarga dita “legal” de veículos conforme Lei de Balanças – Resolução 210 e 258 do Contran. Tal estudo é realizado com base comparativa nos métodos vigentes Brasileiros e também com base no software *AASHTOware® Pavement ME*, que se vale de bases empírico mecanísticas da Guia da AASHTO de 2002.

1.1.2 Objetivos específicos

O presente projeto de pesquisa é conciso e foi de curta duração. Isto não traduz a extensão da problemática envolvida, mas o entendimento de que é necessário atender ao objetivo geral de forma pragmática. Com isto, pretende-se com esta pesquisa atender ao objetivo geral através das seguintes metas específicas:

1. Estabelecer um espectro de cargas padrão com determinação das cargas máximas legais, sobrecarga máxima aceitável considerando as imprecisões de equipamento de medição admissíveis, ou seja, “sobrecarga legal”, e as cargas rodantes do espectro.
2. Identificar os métodos aplicáveis de dimensionamento de pavimentos novos e reabilitações utilizadas no cenário nacional, com ênfase da sua sensibilidade ao impacto da sobrecarga no número N, tradicionalmente usado nos projetos.



3. Utilizar o software da *AASHTOWare® Pavement ME*¹ para dimensionamento e modelagem de performance de pavimentos novos e reabilitados considerando um pavimento típico da região sul do país.

1.2 JUSTIFICATIVA

O país é frequentemente alvo da mídia quanto à qualidade de rolamento das estradas. Sabe-se que a malha rodoviária Brasileira necessita grandes investimentos financeiros para estar nas condições ideais de tráfego. No entanto, com o crescente aumento do fluxo de veículos associado às demandas dos transportadores de carga que se mantém em uma busca incessante por maneiras de reduzir o custo de transporte, acaba por haver um inevitável aumento das cargas dos caminhões transportadores.

As rodovias devem se adequar, assim, à necessidade de transporte atual. Restringir as cargas, apesar de necessário, deve ser feito de forma eficaz tanto para o proprietário da infraestrutura – o Governo / a nação –, quanto para o usuário – o transportador, o motorista. Parece evidente a necessidade então de se elevar as cargas para os quais os pavimentos são projetados; no entanto, para isto é necessário que os manuais de projeto se adequem e considerem a cargas atuais; o que ainda não é uma realidade.

Conhecer desta forma a magnitude do impacto das cargas na performance dos pavimentos poderá deflagrar os pontos a serem considerados para uma adequada manutenção. O fluxograma apresentado na Figura 2 ilustra a sequência lógica de justificativa do estudo.

Importante notar no fluxograma acima que um das problemáticas envolvidas nos valores das sobrecargas referem-se aos valores de multa aplicados. Como discutido na introdução desta proposta de pesquisa, no Item 2, os valores de sobrecarga máximo permitido para não aplicação de multa até 2013 era de 7,5%, com redução prevista para 5% neste ano. A Tabela 1 abaixo mostra os valores de multa aplicáveis conforme os valores de excesso segundo a Resolução 258 do CONTRAN.

A Tabela 2 demonstra os valores de sobrecarga em quilos para os vários tipos de eixos dos veículos comerciais. Com base nela é possível verificar as multas que seriam aplicáveis para o excesso até o percentual estabelecido. Com base na Tabela 3 é possível se identificar que um típico eixo simples de rodas duplas – ESRD, sobrecarregado com 7,5% deveria pagar uma multa de R\$127,69. Deste valor pergunta-se: o valor proposto seria coerente com o dano causado? Não seria o baixo valor que vigora uma “motivação” às sobrecargas? Considerando que a legislação que vigorou até início do ano não aplicava multa até 7,5% de sobrecarga, este valor seria em última análise se quer cobrado.

¹ 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>

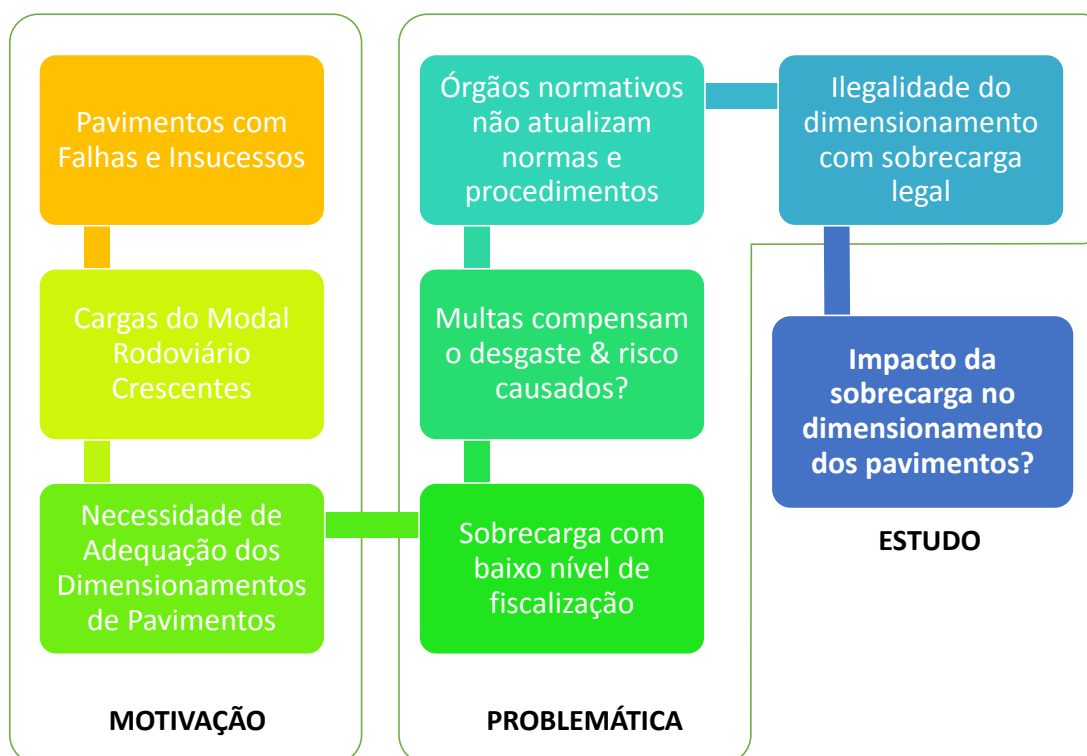


Figura 2 – Fluxograma do trabalho proposto

Tabela 1 – Valores de multa por sobrecarga conforme Resolução 258 do CONTRAN (11/2007)

	Multa		Adicional por 200kg	
Até 600kgs	R\$	85,13	R\$	5,32
601 - 800kgs	R\$	85,13	R\$	10,64
801 - 1000kgs	R\$	85,13	R\$	21,28
1001 - 3000 kgs	R\$	127,69	R\$	31,92
3001 - 5000 kgs	R\$	127,69	R\$	42,56
> 5001 kgs	R\$	127,69	R\$	53,30

Tabela 2 – Valores de sobrecarga para os eixos de rodagem de veículos de carga

	Peso Eixo (kgs)	5%	7.50%	10%	15%
ESRS	6000	300	450	600	900
ESRD	10000	500	750	1.000	1.500
ETD	17000	850	1.275	1.700	2.550
ETT	25500	1.275	1.913	2.550	3.825

ESRS – Eixo Simples de Rodas Simples; ESRD – Eixo Simples de Rodas Duplas;
ETD – Eixo Tandem Duplo; ETT – Eixo Tandem Triplo.



Tabela 3 – Valores de multas em função das sobrecargas

Peso Eixo (kgs)	5%	<u>7.50%</u>	10%	15%
6000	R\$ 95,77	R\$ 101,09	R\$ 101,09	R\$ 191,53
10000	R\$ 101,09	R\$ 127,69	R\$ 191,53	R\$ 383,05
17000	R\$ 191,53	R\$ 351,13	R\$ 414,97	R\$ 542,65
25500	R\$ 351,13	R\$ 446,89	R\$ 542,65	R\$ 978,89

Para dificultar ainda mais este cenário, recentemente, através da Resolução 489 do Contran, publicada no Diário Oficial da União em 06/06/2014, houve um aumento para 10% do limite de peso por eixo como margem para aplicação de multa dos veículos que trafegarem sobrecarregados. O limite vale para caminhões e carretas que não ultrapassem o limite de 5% do PBT ou PBTC.

É por conta destes vários elementos que as sobrecargas hoje acabam por ser mais frequentes do que se gostaria. Quantificar seu impacto nos projetos de pavimentos é necessário para que se consiga contornar adequadamente os problemas frequentes que se enfrentam nas rodovias. Apesar deste projeto de pesquisa não ousar fazer, seria ainda necessário quantificar o valor do dano para verificar se os valores das multas são coerentes. Seguramente o trabalho será um bom ponto de partida para esta engenharia de valor ainda não realizada.

1.3 DESENVOLVIMENTO DO PROJETO

Existem muitas metodologias e abordagens, tanto de avaliação quanto de dimensionamento de reforço em uso no Brasil. Entre as mais utilizadas estão duas metodologias consagradas, normalizadas, e amplamente difundidas no meio rodoviário brasileiro, são elas:

- DNER-PRO 011/79 – Avaliação estrutural de pavimentos flexíveis – Procedimento B
- DNER-PRO 269/94 – Projeto de restauração de pavimentos flexíveis – TECNAPAV

O DNIT – Departamento Nacional de Infraestrutura de Transportes – atualmente tem utilizado em seus contratos de manutenção e restauração (CREMA2) o PRO11, o qual foi ampliado e é apresentado nos editais em forma de árvore de decisão. Para ambos os métodos a aproximação dos carregamentos são feitas através do Número N.

Será com base nos fatores de equivalência de carga – FEC, que será possível quantificar o impacto das sobrecargas nos projetos de pavimentos novos e restaurações. Para o primeiro será considerado o tradicional método do Engenheiro Murilo Lopes de Souza – IPR719; para o segundo serão considerados os procedimentos acima descritos.

Uma das limitações dos procedimentos acima é sua incapacidade de prever o desempenho dos pavimentos. Toda a lógica do dimensionamento é feita com base no comportamento estrutural inicial e não funcional ao longo da vida do pavimento. Para melhor conhecer este comportamento, foi selecionado o que hoje se considera a metodologia mais avançada de dimensionamento de pavimentos empírico-mecânico: Guia da AASHTO 2002.



Esta metodologia está empacotada em conjunto de operações computacionais que iniciou com o conhecido ME-PDG (*Mechanistic-Empirical Pavement Design Guide*) e evoluiu para o chamado *AASHTOware® Pavement ME*. O ME-PDG no entanto, não apenas não se encontra mais disponível para uso como também não possuiu rotinas de dimensionamento, apenas de análise de comportamento para uma dada condição, sem a habilidade de realizar as análises de forma iterativa de forma a possibilitar o dimensionamento de uma estrutura frente a um dado cenário.

O *AASHTOware® Pavement ME* se mostra com grande potencial para realizar a análise deste estudo uma vez que considera o espectro de cargas real da via; ao invés de usar como dado de entrada um número N composto a partir dos fatores de equivalência de carga, o *AASHTOware® Pavement ME* permite a consideração de cada tipo de eixo com seu carregamento em suas várias condições – carga variável – para avaliação mecânica dos pavimentos. Isto permitirá uma melhor avaliação do impacto do sobrecarga padrão também no desempenho dos pavimentos. 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 são sugeridas em acordo com os métodos e técnicas descritos anteriormente:

1. Breve revisão dos métodos de dimensionamento de pavimentos novos e reabilitações utilizados no Brasil, apontando os dados de entrada e sua sensibilidade às cargas dos veículos, bem como as tendências de novos projetos.
2. Determinar os fatores de equivalência de carga correntemente utilizado nos projetos de pavimentação.
3. Identificar um cenário de espectro de cargas típicos rodantes nas rodovias do (a partir de pesquisa previamente realizada), com cargas padrão e rodantes de forma a compor um fluxo de veículos.
4. Compilar as leis que em vigor sobre as sobrecargas de veículos comerciais identificando as máximas cargas rodantes e os valores de sobrecarga máximo considerados para imprecisão de pesagens.
5. Compor o número N para o projeto a ser analisado, tanto em termos de um projeto de restauração, quanto em termos de pavimentos novos.
6. Validar o novo software *AASHTOware® Pavement ME* lançado em 2013, para uso nos projetos de pavimentos novos e restauração considerando o espectro de cargas determinados em (Etapa 3).
7. Montagem de um Cenário A – Pavimento novo – utilizado como referência considerando um tráfego de projeto com e sem sobrecarga legal.
8. Montagem de um Cenário B – Reabilitação de pavimentos - utilizado como referência considerando um tráfego de projeto com e sem sobrecarga legal.
9. Comparação dos métodos nos Cenários montados e discussão sobre o efeito da sobrecarga legal nos projetos de pavimentos novos e reabilitados.
10. Discussão do efeito da sobrecarga legal nos projetos de pavimentos novos e reabilitados.
11. Considerações sobre a performance dos pavimentos com uso de modelos do *AASHTOware® Pavement ME*.
12. Elaboração de relatório final e apresentação à Concessionária de resultados.



2 REVISÃO DE LITERATURA

2.1 TRÁFEGO RODOVIÁRIO

O tráfego rodoviário é formado por veículos de diferentes configurações e magnitudes de cargas. O conhecimento adequado de suas características é muito importante para o estudo do comportamento de pavimentos, tanto rígidos como flexíveis, e os danos causados a essa estrutura. Essas informações podem contribuir também para a interpretação das causas da deterioração dos pavimentos, ilustrando as tendências gerais das propagações de defeitos tipicamente causados pela ação do tráfego. Portanto, abordar-se-á aqui os veículos comerciais que circulam nas rodovias, bem como a ação da carga que os mesmos provocam nos pavimentos.

2.1.1 Volume de tráfego

Segundo Fontenele (2011), o volume de tráfego é definido como “o número de veículos que atravessam uma determinada seção transversal de uma via numa unidade de tempo” e para sua determinação é essencial conhecer a composição do tráfego, ou seja, a proporção de cada tipo de veículo na corrente de tráfego visto a diferença existente entre as configurações dos caminhões e ônibus.

O Volume Diário Médio (VDM) geralmente é obtido com base no cálculo de 365 dias para considerar toda a variação do tráfego, em termos semanais e mensais, que utiliza a via englobando todos os veículos em ambos os sentidos desta. Este volume é então definido como VDM anual (VDMA). A melhor maneira de quantificar os volumes de veículos é através das contagens em campo (contagens classificatórias e volumétricas), mas apenas quando as vias já existem. Tais contagens são realizadas, geralmente, em períodos de sete dias, durante 24 horas, com uso de equipamentos automatizados instalados na pista ou simplesmente de forma visual com registro em formulário específico (DNIT, 2006).

Atualmente, além de contagens manuais, há métodos para realização de contagens automatizadas. Nos equipamentos utilizados para coletas de dados de carregamentos de tráfego os dados relativos ao volume e à distribuição das cargas de tráfego podem ser obtidos a partir de equipamentos de pesagem em movimento – *Weigh in motion* (WIM).

Em função de o WIM gerar um maior custo de aquisição, além uma maior dificuldade de instalação e operação, outra técnica também tem sido utilizada para coleta dos dados de tráfego, como os sensores dispostos no pavimento. Os sensores que monitoram o tráfego acima ou na lateral da estrada e tem como principal vantagem de não estarem sujeitos ao impacto das cargas dos veículos ou das tensões resultantes da interação do pavimento-ambiente. Porém esse método traz limitações, sendo a principal a maior dificuldade de detectar e contar os eixos dos veículos (HALLENBECK e WEINBLATT, 2004).

O *Texas Department of Transportation* apoiou uma pesquisa realizada por Harrison et al. (1998) cujo objetivo foi coletar e analisar as informações sobre o tipo predominante de veículo de carga e o valor das cargas por eixo no transporte rodoviário na fronteira México



– Texas. Os dados foram coletados por meio do sistema WIM e, constatou-se, que o veículo 3S2 (veículo trator com 3 eixos + semirreboque com 2 eixos) é o predominante na frota de carga e que as quantidades de veículos com excesso de carga foram entre 25% e 30% nos veículos 3S2 e entre 80% e 87% nos veículos 3S3 (veículo trator com 3 eixos + semirreboque com 3 eixos).

Devidos aos altos valores de excesso de carga, o *Texas Department Transportation* confinou o tráfego dos veículos 3S3 a estradas de uma determinada região e iniciou aplicação de multas, reduzindo assim, em pouco tempo, a níveis mínimos de sobrecarga.

Analogamente, Brito et al (2013) verificaram através da implantação de um WIM na BR-290/RS, que aproximadamente 25% da frota de veículos comerciais foram classificados como veículos tipo 2C e outros 25% como 3C. Naquele espectro de cargas, apenas 1,2% foi de veículos tipo 3S2; foram mais expressivos veículos articulados tipo 2S2 com 11,2% e 2S3 com 11,2% de frequência. No mesmo estudo, Brito relata que durante o período de coleta de dados, do total de veículos monitorados (107387 veículos) 9,63% apresentavam alguma sobrecarga em algum eixo, sendo que o maior percentual de sobrecarga ocorreu no segundo eixo (3,48% dos veículos apresentaram uma sobrecarga média de 14,7% neste eixo).

2.1.2 Tipos de veículos

Pelo fato da pesquisa estar relacionada com a análise dos efeitos sobre os pavimentos através dos espectros de carga por eixo dos veículos de carga, apresenta-se a classificação de veículos brasileiros, em função do local do estudo, e dos veículos americanos, em função da origem do método da AASHTO (2002).

De acordo com DNIT (2005) são cinco os tipos básicos de veículos para efeito de projeto viário:

- Veículo de passageiros (VP): representa os veículos leves, similares em termos geométricos e operacionais como o automóvel, incluem-se nessa classificação vans, utilitários, pick-ups e similares;
- Veículo comercial rígido (CO): são os veículos não articulados compostos por uma unidade tratora simples, abrangendo os caminhões e ônibus convencionais de dois eixos e seis rodas;
- Ônibus de longo percurso (O): este grupo representa os veículos comerciais rígidos de maiores dimensões. Incluem-se neste grupo os ônibus de turismo e caminhões longos, geralmente de três eixos e dimensões superiores ao veículo tipo CO;
- Semirreboques (SR): grupo dos veículos rodoviários de carga articulados, compostos de unidade tratora simples e um semirreboque;
- Reboques (RE): representa os veículos rodoviários de carga com reboque; é composto por uma unidade tratora simples, um semirreboque e um reboque.

O sistema de classificação adotado pelo DNIT (2006) atribui a cada classe de veículo de carga um código alfanumérico. O primeiro algarismo significa o número de eixos do veículo simples ou unidade tratora, enquanto o segundo, caso exista, representa a quantidade de eixo da(s) unidade(s) rebocada(s).



De acordo com DNIT (2006) as letras significam:

- C: veículo simples (caminhão ou ônibus) ou veículo trator + reboque;
- S: veículo trator (cavalo mecânico) + semirreboque;
- I: veículo trator + semirreboque com distância entre eixos maior que 2,40 m (eixos isolados);
- J: veículo trator + semirreboque com um eixo isolado e outro em tandem;
- D: combinação dotada de 2 (duas) articulações;
- T: combinação dotada de 3 (três) articulações;
- Q: combinação dotada de 4 (quatro) articulações;
- X: veículos especiais (usados para transportar cargas excepcionais em peso ou dimensões, possuem mais de 9 eixos, necessitando, portanto, de uma Autorização Especial de Tráfego – AET);
- B: ônibus.

A Federal Highway Administration (FHWA) desenvolveu uma classificação que divide o tráfego em 13 categorias, onde as classes de 4 a 13 fazem parte os veículos rodoviários de carga. As categorias consideradas por este órgão são apresentadas por Hellenbeck (1991) e Smith e Diefenderfer (2009):

- Classe 1: motocicletas (todos os veículos motorizados de duas ou três rodas);
- Classe 2: carros de passageiros (sedans, *station wagon*, carros de passageiros rebocando trailers recreacionais e leves);
- Classe 3: veículos unitários de dois eixos, quatro pneus (*pick ups*, vans, motor homes, ambulâncias, carros fúnebres, e outros rebocando trailers recreacionais e leves);
- Classe 4: ônibus (esta categoria inclui somente ônibus tradicionais de passageiros, incluindo ônibus escolar; ônibus modificados deverão ser classificados como caminhões e de modo apropriado);
- Classe 5: caminhões unitários de dois eixos, seis pneus (todo caminhão de chassi único, incluindo caminhões, veículos de camping e recreacionais, e motor homes, que têm dois eixos e duas rodas traseiras);
- Classe 6: caminhões unitários de três eixos (todo caminhão de chassi único, incluindo caminhões, veículos de camping e recreacionais, e motor homes, que têm três eixos);
- Classe 7: caminhões unitários de quatro ou mais eixos;
- Classe 8: todos os veículos de quatro ou menos eixos que são formados por duas unidades;
- Classe 9: todos os veículos de cinco eixos que são formados por duas unidades;
- Classe 10: todos os veículos de seis ou mais eixos que são formados por duas unidades;
- Classe 11: todos os veículos de cinco ou menos eixos que são formados por três ou mais unidades;
- Classe 12: todos os veículos de seis eixos que são formados por três ou mais unidades;
- Classe 13: todos os veículos de sete ou mais eixos que são formados por três ou mais unidades.



De acordo com as definições de FHWA e do DNIT apresentadas, percebe-se que dentro de uma mesma classe a configuração de eixos pode mudar o que dificulta a equivalência entre as classes de veículos para a aplicação no método empírico-mecanístico AASHTO (2002).

2.1.3 Cargas sobre os pavimentos

As cargas repetidas aplicadas pelos veículos rodoviários são as principais causadoras da deterioração dos pavimentos, e como consequência, os mesmos precisam ser, muitas vezes, precocemente restaurados. Os caminhões, em geral, apresentam danos desiguais em cada passagem pelo pavimento, sendo os seguintes fatores causadores dos danos: tipo de veículo, carga por eixo, frequência, tipo e localização de eixos, tipo de suspensão, tipo e pressão dos pneus, tempo de aplicação da carga (velocidade) e ponto de aplicação da carga (FERNANDES JR., 1994).

Além dos fatores já mencionados, outras também são as causas de danos nos pavimentos, como por exemplo, o comportamento dos materiais constituintes das camadas, condições operacionais de tráfego, clima, etc.

Mas sendo os caminhões os principais agentes deterioradores dos pavimentos, sabe-se que com o passar dos anos, em conjunto com as inovações tecnológicas da modalidade rodoviária, novas configurações de veículos de cargas tem entrado no mercado, isso faz entender que os efeitos considerados antigamente não são mais os mesmos, já que essas novas configurações trazem veículos comerciais com mais eixos e maior capacidade de carga. Esse conjunto de informações leva a crer que os danos causados pelos caminhões têm apresentado um aumento considerável.

No Brasil, os dados e informações dos excessos de cargas são muito escassos. Além da pequena quantidade de postos de pesagem, verifica-se uma inexistência de investimento nos equipamentos para coleta de dados ao longo das rodovias, mesmo que para efeitos únicos de pesquisa e não de fiscalização/punição, ou seja, fora dos postos de pesagem obrigatórios. Não apenas a questão relacionada à quantidade de postos em operação deve ser observada, mas também se deve levar em consideração a adequada localização desses postos. Muitos postos têm seus dados comprometidos pela existência da possibilidade (e utilização) de rotas de fuga, assunto este comprovado por Chou (1996). O autor aponta que as cargas excedentes afetam tanto o cumprimento da lei como também a precisão dos fatores de carga dos veículos e, conseqüentemente, a equivalência de carga por eixo padrão, item primordial para o dimensionamento de pavimentos.

Fernandes Jr. (1994) comentou em seu trabalho que nos primeiros estudos relativos à pesagem no Brasil, realizado pelo GEIPOT entre 1976 e 1981, ficou evidenciado que, na época, os caminhões trafegavam com cargas de 10% a 30% acima dos limites. O percentual de excesso em cada tipo de eixo foi: 3% dos ESRS estavam com excesso; os ESRD correspondiam a 25%; os ETD a 15% e os ETT a 30%.

Martins e Serravalle (2007) realizaram um estudo nas rodovias federais e estaduais da Bahia, onde foi constatado que 85% dos veículos estavam com excesso de peso por eixo e os veículos com maior frequência de infrações eram os do tipo 2C, 3C, 3S3. Cabe lembrar



que o estudo foi anterior à entrada em vigor da Resolução nº 258/2007 que permitiu a multa por excesso de carga nos eixos.

DNIT e LATRANS (2007) realizaram um trabalho, onde indicaram como as causas da limitação da efetividade das estações de pesagem como sendo as questões relativas à facilidade com que os postos fixos de pesagem são contornados, à falta de recursos para fiscalização (custo de instalação e operação) e à limitação de horários de funcionamento e rotas monitoradas. Dessa forma, em virtude das limitações reportadas, veículos sobrecarregados trafegam pela maioria das rodovias sem serem punidos pelo dano que causam na operação e ao pavimento.

De acordo com o estabelecimento no AASTHO e reforçado por Chou (1996), a relação entre a carga do tráfego e a deterioração do pavimento obedece a Lei da quarta potência, ou seja, um eixo de carga duas vezes mais carregado que outro causará 16 vezes mais danos ao mesmo pavimento. Para melhor exemplificar o efeito da sobrecarga no pavimento, Widmer (2002) afirma que o aumento de carga de 20% acima dos limites atuais implicará na redução da vida útil da estrutura em 50% e Albano (2004) ressalta que os 2,5% a mais na tolerância sobre a carga por eixo, estabelecida desde a Resolução 104/99 do CONTRAN, é responsável por uma redução de 10 a 15 % na vida de projeto prevista para o pavimento.

Tendo em vista que o efeito do excesso de peso é exponencial, é válido ressaltar que é muito importante a limitação de cargas por eixo. Martins e Serravalle (2007) apontam tal importância e salientam que o desgaste produzido gera a necessidade de restauração muito antes do prazo previsto, ou seja, precocemente. De uma forma geral, os autores listam como impactos do excesso de peso nas rodovias: “deterioração de toda a estrutura, causando danos irreparáveis pela simples manutenção; surgimento de fissuras e trincas; e aumento do número de acidentes”.

Fekpe, Clayton e Haas (1995) afirmam que os comerciantes que trafegam com caminhões com excesso de carga provocam a redução do tempo de vida útil do pavimento e não reembolsam ao público o prejuízo originado disso, além de estarem competindo de forma injusta com os outros que estão com os veículos dentro dos limites de carga regulamentadas. Os autores relatam ainda que a falta de fiscalização e controle dos pesos e dimensões dos veículos de carga e a deficiência em manter os caminhões com excesso de carga fora do sistema rodoviário, tem como efeitos negativos o mau uso dos recursos públicos, além de proporcionar a falta de segurança aos usuários (acidentes com caminhões pesados).

Os valores de limites de carga para superiores àqueles usados anteriormente tem um efeito mais ou tão significativo quanto os excedentes aos limites legais, em vista que a malha rodoviária projetada anteriormente à alteração sofrerá com tensões superiores àquelas que o pavimento foi dimensionado para suportar sua vida em serviço.

No Brasil, infelizmente os limites legais de cargas não são observados por parte dos transportadores, por fabricantes de veículos e nem pelas autoridades responsáveis em aprovar projetos de novos veículos. Fernandes Jr. et al. (1995) indicam que os fabricantes de implementos, para se tornarem mais competitivos nos mercados, admitem a construção de reforços nos veículos, produzindo veículos com capacidade de carga acima dos limites legais.



A deterioração de um pavimento por fadiga caracteriza-se pelo rompimento da camada de concreto asfáltico (CA) quando esta é solicitada continuamente por cargas que provocam tensões menores do que a resistência à tração do revestimento. As trincas surgem inicialmente na fibra inferior da camada de CA e propagam-se progressivamente para a superfície, dando a impressão, num estágio final de evolução, semelhante ao couro de crocodilo (Albano, 2005).

A publicação *Truck Weight Limits* (National Research Council, 1990 apud ALBANO 1998), apresenta uma análise da influência de veículos pesados sobre a durabilidade dos pavimentos. O trabalho ressalta que as condições e o desempenho dos pavimentos não dependem somente do número de veículos pesados e da carga por eixo a que os pavimentos estão sujeitos. Outros fatores também devem ser considerados:

- Adequação das espessuras das diversas camadas constituintes do pavimento;
- Qualidade dos materiais empregados na construção;
- Procedimentos construtivos adotados;
- Condições de manutenção da rodovia;
- Propriedades do subleito existente;
- Condições ambientais, principalmente, destacando-se a precipitação pluviométrica, umidade do ar e a variação da temperatura.

Liu et al. (1998) referem que vibração causada pela quantidade das forças dinâmicas verticais e horizontais sobre a estrutura do pavimento podem provocar sua deterioração. Ainda sobre a questão de forças dinâmicas e o efeito do tipo de suspensão dos veículos sobre os pavimentos, a Organization for Economic Co-operation and Development (1998) relata que as suspensões mecânicas, constituídas por feixes de molas, são pelos menos 15% mais rígidas do que as pneumáticas. Os autores ainda afirmam que as suspensões mecânicas produzem forças dinâmicas com o dobro de magnitude do que as pneumáticas.

Com todos os fatores intervenientes pelo uso contínuo torna-se evidente que a durabilidade de um pavimento é limitada. Logo, depois de transcorrido algum tempo, o pavimento deverá sofrer uma ação de “rejuvenescimento”. Waston (1989) explica que, segundo estudos desenvolvidos na Inglaterra, o melhor momento para intervenção ocorre quando as trilhas de rodas estiverem com profundidade de 10 mm ou houver fissuras sobre as trilhas de roda – para o DNIT (2006) na ordem de 20% - mesmo antes de ocorrer esta profundidade. O autor ainda define que a vida útil, para um projeto de pavimento novo, é o período de tempo provável no qual deverá ocorrer esta condição crítica e, conclui relatando que quando são considerados os custos de construção e manutenção, um período de vida útil de 20 anos é o de adoção mais adequada.

Timm e Newcomb (2002 apud ALBANO, 2005) comentam que projetar pavimentos para mais de 20 anos não é aconselhável por se tratar de um período muito longo. Durante este período poderão ocorrer desenvolvimentos na fabricação e nos implementos dos veículos de carga e as autoridades e transportadores poderão negociar mudanças nos limites máximos legais de carga, além de que, haverá alterações nas taxas de crescimento da população e veículos e modificações em uma série de fatores que tendem a alterar as características de fluxo de tráfego previsto. Dessa forma, os autores ressaltam que projeções para um longo período de tempo poderão se tornar inadequadas e ser a principal causa do surgimento prematuro de defeitos nos pavimentos.



No Brasil, o Método de Projeto de Pavimentos Flexíveis do DNER (1981) considera que um pavimento será dimensionado em função do número equivalente N de operações de um eixo padrão, durante um período de projeto escolhido. Em geral, os órgãos rodoviários definem períodos de projeto de até 10 anos. No caso de dimensionamento de camadas de reforço também há uma relação entre a vida útil do pavimento e o decorrente número N.

Martins e Miranda (1995) referem que a consequência imediata da destruição dos pavimentos, com base em levantamentos no Estado de Mato Grosso, é o aumento imediato dos custos de transporte, estimado em até 58% no excesso do consumo de combustível, 30% no desgaste da frota e 100% no tempo de percurso. Os autores exemplificam o excesso de carga com base nos dados colhidos no posto de pesagem dinâmica da BR 174 em Cáceres e na BR 163. No primeiro identificou-se um excesso de carga em 20% nos eixos pesados e no segundo 30% dos eixos apresentavam excesso de carga.

Na rodovia concedida BR 290, Osório – Eldorado do Sul, com o início das pesagens no final do primeiro semestre de 1999, verificou-se que 30% dos veículos pesados trafegavam sobrecarregados. Após algumas semanas de fiscalização, verificou-se uma estabilização dos excessos no intervalo de 4 a 5% (CONCEPA, 2000).

Segundo a PRIME (2013), em um estudo realizado na BR 290/RS, utilizando o sistema WIM, foi possível definir um panorama referente ao sobrepeso dos veículos comerciais monitorados. Foi constatado que, durante o período de coleta de dados, do total de veículos monitorados (107387 veículos) 9,63% apresentavam alguma sobrecarga em algum eixo, sendo que o maior percentual de sobrecarga ocorreu no segundo eixo (3,48% dos veículos apresentaram uma sobrecarga média de 14,7% neste eixo). Outro fato importante a ser destacado foi a segunda maior sobrecarga, sendo esta encontrada no primeiro eixo (2,08% dos veículos apresentaram uma sobrecarga média de 12,93% neste eixo). Cabe ressaltar que a sobrecarga no primeiro eixo é mais crítica para o pavimento, pois apresenta em sua configuração apenas dois pneumáticos (ESRS), fato este que acaba concentrando as cargas de maneiras mais significativas (maior concentração de carga por pneumático).

Fernandes Jr. (1994), referindo a pesquisa sobre o inter-relacionamento dos Custos Rodoviários desenvolvida entre 1976 e 1981 pela Empresa Brasileira de Planejamento de Transportes (GEIPOT, 1997), relata que foram levantados os seguintes dados (Tabela 4):

Tabela 4 – Excesso de peso por eixo praticado no Brasil. Fonte: GEIPOT (1997)

Tipo de Eixo	Veículos com Excesso de Peso (%)	Valor da Sobrecarga	
		Excesso/Limite Legal (kN)	% de Excesso
Dianteiro	3,0	3,0/60,0	5,0
Simplex (roda dupla)	25,0	20,0/100,0	20,0
Tandem Duplo	15,0	85,0/170,0	50,0
Tandem Triplo	30,0	115,0/225,0	45,0



2.1.4 Peso bruto total combinado

O Peso Bruto Total (PBT) de um veículo é considerado, aquele proveniente da soma da tara e da carga deste, sendo o Peso Bruto Total Combinado (PBTC) o resultante da soma dos pesos brutos das unidades que compõem o veículo.

Segundo Fernandes Jr. (1994) a causa da deterioração dos pavimentos é a carga por eixo, não havendo uma relação direta entre o Peso Bruto Total Combinado (PBTC) e o desempenho dos pavimentos. Veículos pesados podem ser pouco danosos aos pavimentos, desde que a carga total seja distribuída adequadamente por um número suficiente de eixos. A utilização de veículos com elevado PBTC e baixa carga por eixo considera simultaneamente dois conceitos: o primeiro trata de menor deterioração dos pavimentos, quanto maior for o número de eixos e o segundo diz a respeito da maior eficiência, quanto maior for a composição rodoviária da carga. Os Veículos Combinados Longos (VCLs) não necessariamente acarretam maior deterioração aos pavimentos, se comparado aos veículos rodoviários convencionais. Para exemplificar, Hussain e Parker (2006) verificaram que os veículos com 2 eixos danificam mais que os veículos de 3 e 5 eixos.

Além dos pavimentos, cabe lembrar que o tráfego de veículos comerciais é responsável pelo impacto mais severo nas pontes e viadutos. A sobrecarga inflige graves danos às estruturas e superfícies pavimentadas, reduzindo significativamente seu ciclo de vida útil, podendo, inclusive, no caso de pontes e viadutos, levar ao colapso.

2.1.5 Tipos de eixos

Os tipos de eixos de veículos rodoviários de carga podem ser de dois tipos: o isolado, chamado de eixo simples; e os em conjunto, denominados de eixos em tandem. Os eixos tandem podem ser dotados apenas de uma roda na extremidade (roda simples) ou duas rodas (rodas duplas). É importante ressaltar que existem combinações de eixos simples de rodas simples com eixos simples de rodas duplas em ônibus, o que não configura um eixo tipo tandem duplo.

O DNIT (2007) chama a atenção para os conjuntos de 2 ou 3 eixos onde as distâncias entre eixos forem maiores que 2,40 metros, pois nesse caso serão considerados isolados. Na Figura 3 os tipos de eixos de veículos rodoviários que circulam nas rodovias brasileiras são apresentados.

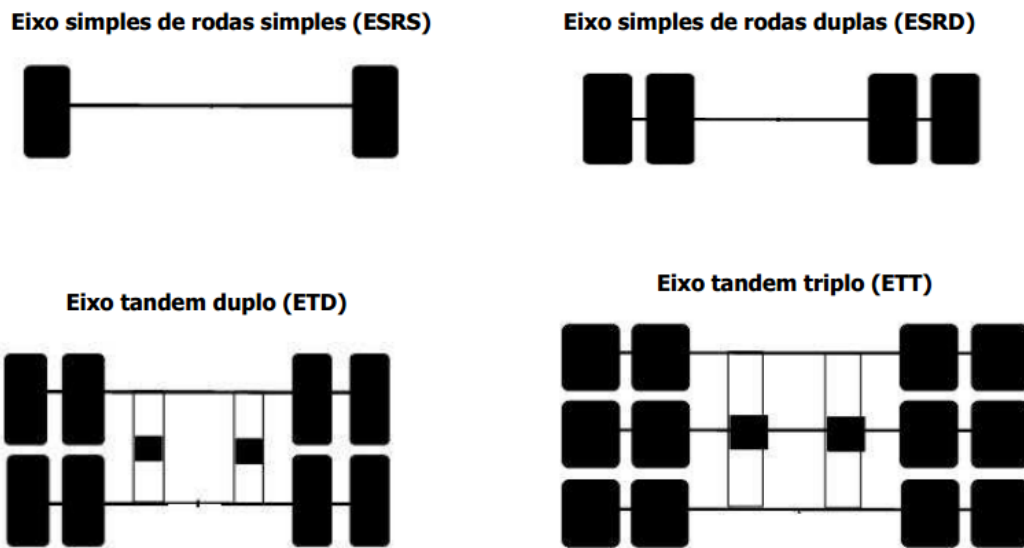


Figura 3 – Tipos de eixos de veículos rodoviários de carga brasileiros. Fonte: DNIT (2007)

2.1.6 Cargas por eixo

Fernandes Jr. (1994) cita em seu trabalho que a carga por eixo, independente dos fatores ambientais, do comportamento dos materiais constituintes da estrutura do pavimento e das ações combinadas de outros fatores de tráfego, é a que mais afeta a deterioração dos pavimentos.

Como citado anteriormente, existe uma relação exponencial entre as cargas por eixo e a deterioração dos pavimentos. Como resultados da pista experimental da AASHO (atual AASHTO), no final da década de 50, indicaram um valor próximo a 4 para esse expoente, passou-se utilizar a expressão “lei da quarta potência” para representar os efeitos relativos de diferentes cargas por eixo sobre o desempenho dos pavimentos. Independentemente do valor exponencial pode-se afirmar que existe um relevante aumento na deterioração dos pavimentos quando ocorrem acréscimos nas cargas por eixo.

Fernandes Jr. (1994) destaca que existem quatro tipos de eixo utilizados pelos veículos de carga que trafegam nas rodovias brasileiras que são:

- Eixos Simples de Roda Simples (ESRS), com carga legal máxima de 6,0 tf;
- Eixos Simples de Roda Dupla (ESRD), com carga legal máxima de 10,0 tf;
- Eixos Tandem-Duplo (ETD), com carga legal máxima de 17,0 tf;
- Eixos Tandem-Triplo (ETT), com carga legal máxima de 25,5 tf.

Cabe lembrar que, quanto aos testes experimentais realizados na pista da AASHO, não se utilizava o ETT, que até hoje tem sua utilização, em muitos países, limitada à mesma carga por eixo do ETD.

Segundo Göktan e Mitschke (1995 apud ALBANO, 2005) os limites de cargas em alguns países da Europa são apresentados no Tabela 5.



Tabela 5 – Limites de cargas em alguns países da Europa. Fonte: Göktan e Mitschke (1995 apud ALBANO, 2005)

País	Carga por Eixo (kN)			PBT ou PBTC (kN)			
	Eixo dianteiro	Eixo simples	Eixo tandem duplo	2 eixos	3 eixos	Semi-reboque	Trator e reboque
Alemanha	100	100	110-200	170	240	400-440	400
Áustria	100	100	160	160	220	380	380
Bélgica	100	100	190-200	190	260	440	440
Bulgária	60	100	130-200	160	260	380	420
Dinamarca	100	100	160-200	180	240	480	480
Finlândia	80	100	180	170	250	440	560
França	130	130	210	190	260	400-440	400
Grécia	70	100-130	200	190	260	380	380
Holanda	100	110	115-190	200	300	500	500
Hungria	100	100	160	200	240	400	400
Inglaterra	92	105	105-203,4	170	243,9	380	352,2
Itália	120	120	200	180	240	400-440	400-440
Iugoslávia	100	100	160	180	240	400	400
Suécia	100	100	160	170	290	375-514	375-514
Suíça	100	100	180	160	190	280	280

No Tabela 6, adaptada dos trabalhos de Albano (2005), FHWA (2013), Michael Paine e Paul Wild (2006) e Regulamento de Pesos e Dimensões de Veículos no Canadá (2006), é mostrada uma comparação entre os limites de carga máximas autorizadas na Europa, Estados Unidos da América, Austrália e Canadá, sem considerar tolerâncias, com as do Brasil.

Tabela 6 – Comparação dos limites de cargas do Brasil, com Europa, EUA, Argentina, Austrália e Canadá. Fonte: adaptada de Peterlini (2006)

Situação	Brasil (t)	EUA ¹ (t)	Europa ² (t)	Argentina (t)	Austrália (t)	Canadá (t)
Eixo simples dianteiro	6,0	-	10,0	10,5	6,0	5,5
Eixo simples rodado duplo	10,0	8,9	10,0	10,5	9,0	9,1
Tandem-duplo	17,0	15,2	16,0	18,0	16,5	18,0
Tandem-tríplo	25,5	-	-	25,5	20,0	26,0
PBT	57,0	35,6	44,0	45,0	-	49,5

¹ Na maioria dos Estados

² Na maioria dos Países

2.1.7 Tipos de pneus

Albano (1998) define pneus como estruturas com borracha natural ou sintética, cuja finalidade é suportar e distribuir o Peso Bruto Total (PBT) e viabilizar a tração e a frenagem de veículos rodoviários através de forças que se desenvolvem na interface de contato com a superfície de rolamento. Os pneus, também designados como pneumáticos, são montados em aros metálicos formando a roda. Os pneus desmontáveis foram produzidos a partir de 1895 pelos irmãos Michelin, na França.

Já Fernandes Jr. (1994) cita que os pneus suportam, impulsionam e controlam os veículos rodoviários por intermédio das forças que se desenvolvem na interface pneu-pavimento, cumprindo as seguintes funções:



- Suportar as cargas que atuam nos eixos;
- Distribuir as cargas verticais dos veículos sobre uma superfície de contato relativamente pequena, diminuindo o atrito e minimizando a resistência de rolamento;
- Fazer parte do sistema de suspensão dos veículos, ajudando a aumentar o conforto das viagens e a reduzir a deterioração dos pavimentos;
- Transmitir aos pavimentos as forças horizontais que se desenvolvem quando da tração, frenagem e mudança de trajetória dos veículos.

Segundo Albano (1998), os dois tipos de pneus mais utilizados são: diagonal e radial. Os pneus diagonais foram os primeiros a ser fabricados e têm sido utilizados desde o início da indústria automotiva, porém a evolução da tecnologia com utilização de materiais resistentes e otimização de projetos eles vêm sendo substituídos, desde a década de 70, pelos radiais, estes são capazes de suportar maiores cargas e maiores pressões de enchimento.

Segundo Michelin (2004), o pneu é chamado diagonal ou convencional quando a carcaça é composta de lonas sobrepostas e cruzadas umas em relação às outras. Os cordoneis que compõem essas lonas são fibras têxteis. Neste tipo de pneus, os flancos são solidários à banda de rodagem. Quando o pneu roda, cada flexão dos flancos é transmitida à banda de rodagem, conformando-se ao solo ou pavimento.

De acordo com a fabricante (MICHELIN, 2004) as principais características dos pneus diagonais são:

- Desgaste mais rápido com menor quilometragem;
- Consumo de combustível mais elevado;
- Aquecimento muito grande, lixando com o solo, fricção entre lonas e a má condução de calor do material têxtil;
- Aderência não muito boa, menor área de contato pneu/pavimento, deformações da banda de rodagem;
- Estabilidade prejudicada, perda da trajetória causada pelas deformações da banda de rodagem;
- Maior possibilidade de cortes/furos, carcaça rígida e material têxtil.

Ainda segundo Michelin (2004), o pneu é chamado radial, quando os cabos da carcaça estão dispostos em aços perpendiculares ao plano de rodagem e orientados em direção ao centro do pneu. A estabilização do piso é obtida através de 3 ou 4 lonas de aço sobrepostas. Por ser uma carcaça única, não existe fricção entre lonas, apenas flexão, o que evita a elevação da temperatura interna do pneu.

As principais características dos pneus radiais são (MICHELIN, 2004):

- Desgaste mais lento, aumento na quilometragem e diminuição no consumo de combustível;
- Redução do aquecimento, não existe fricção entre lonas da carcaça, diminui o lixamento com o solo e o aço é um excelente condutor de calor – maior aderência, área de contato pneu/pavimento é maior e constante;
- Estabilidade favorecida com a redução das deformações da banda de rodagem, o pneu segue uma trajetória definida;

- Menor possibilidade de corte/furos, carcaça mais flexível e com uma “alma de aço”.

A Figura 4 mostra um desenho esquemático de uma seção transversal de um pneu do tipo diagonal ou convencional. Já a Figura 5 mostra um desenho esquemático de uma seção transversal de um pneu tipo radial.

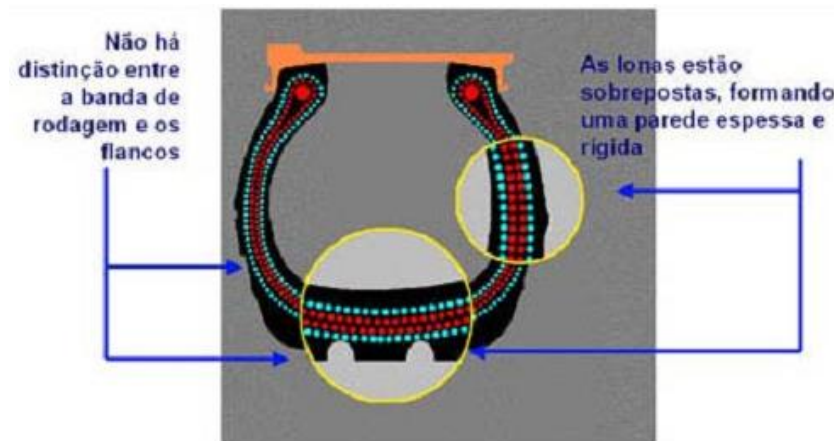


Figura 4 – Corte transversal de um pneu diagonal. Fonte: Michelin, 2004

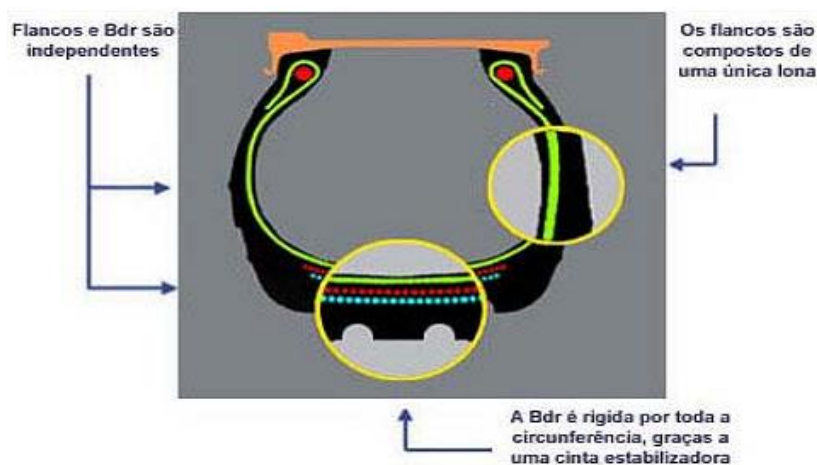


Figura 5 – Corte transversal de um pneu radial. Fonte: Michelin, 2004

Na literatura existem poucos trabalhos conclusivos de comparação entre os efeitos provocados pelo pneu diagonal e o radial. Eliot, Selvan e Mun (1991 apud FERNANDES JR., 1994), estudaram os pneus extralargos e concluíram que os mesmos resultam em maior carga transportadora (menor tara), maior facilidade de manutenção, menor custo (em relação dos pneus convencionais), economia de combustível (menor resistência de rolamento), menor desgaste e menor durabilidade.

Outra discussão ainda limitada no Brasil é sobre a utilização de pneus extra largos ao invés de eixo com rodas duplas. De grande uso nos EUA e Europa, a maioria dos sistemas de avaliação de cargas, não considera a classificação dos eixos com rodas duplas – a exemplo



do próprio Paveware que une os eixos simples de rodas simples com eixos simples de rodas duplas na mesma categoria – como será visto no Capítulo 3, a seguir.

2.1.8 Pressão dos pneus

As cargas do tráfego são transmitidas ao pavimento por meio de rodas pneumáticas dos veículos, as quais exercem uma pressão numa área aproximadamente elíptica e de distribuição parabólica com pressão máxima no centro da área carregada. Assim, embora geralmente se refira a cargas por eixo, as pressões a serem admitidas são referidas às cargas de rodas.

No processo de interação pneu/pavimento a pressão de inflação do pneu desempenha um papel fundamental, sendo considerada como muito importante no mecanismo de surgimento das trincas por fadiga do tipo top-down. Se a carga de um eixo/roda é mantida constante, ao aumentar a pressão de inflação do pneu pode-se reduzir a área de contato, proporcionando um aumento na pressão de contato entre pneu/pavimento. Com isso, há um aumento nos esforços atuantes no revestimento asfáltico e, conseqüentemente, o pavimento se torna mais propício a fatores danosos de maiores intensidades.

Segundo Fernandes Jr. (1994), a importância do tipo de pneu para que se possa analisar o desempenho do pavimento está associada à pressão de enchimento que ele pode suportar, além da distribuição da pressão na superfície de contato pneu/pavimento que se distribui irregularmente sobre uma superfície aproximadamente elíptica.

O mesmo autor, Fernandes Jr. (1994), ressalta ainda que a distribuição da pressão de contato pneu/pavimento varia em função da rigidez do pneu, sendo que esta depende da rigidez da carcaça e das cintas e a própria pressão de enchimento. O pleno conhecimento da distribuição da pressão de contato permite respostas estruturais mais precisas dos pavimentos.

A National Research Council (1990 apud ALBANO, 1998), em pesquisas realizadas em sete estados norte-americanos, entre 1984 e 1986, constatou que 75% a 80% dos pneus usados em caminhões eram do tipo radiais e que a pressão de enchimento média era de 100 psi.

Albano e Lindau (1998) realizaram pesquisas de campo junto ao Posto do Pedágio da Rodovia Estadual RS-240, no município de Portão, Estado do Rio Grande do Sul. Informações de pressão de enchimento dos pneus integrantes de uma amostra representativa de 275 caminhões e dados foram coletados de 1815 pneus. Os valores confirmaram as tendências de aumento da pressão de inflação. Os principais resultados são os seguintes: pressão média na amostra de pneus dianteiros 95 psi (6,7 kg/cm²) e 104 psi (7,3 kg/cm²) na amostra dos demais pneus. Foi constatado no conjunto de pneus uma incidência de 62% de pneus radiais.

Albano (2005) cita que os pneus utilizados na pista experimental da AASHO eram representativos daqueles que estavam em uso no final dos anos 50. Eram os tradicionais pneus de lonas (pneus diagonais) com pressão de enchimento da ordem de 517 kPa a 552 kPa (75 a 80 psi). Desde então os fabricantes introduziram no mercado pneus radiais com melhores condições de suportar maiores cargas e pressões.



Middleton et al. (1986) realizaram um levantamento de dados em rodovias no Estado do Texas e constataram que os pneus radiais em média tiveram uma pressão média de 83 a 145 kPa (12 a 21 psi) mais em relação aos de lona ou convencionais. Além disso, os autores comprovaram as evidências de que acréscimos na pressão dos pneus resultam em aparecimento precoce de trincas por fadiga e também maiores deformações permanentes nas trilhas de rodas.

O Guia AASHTO (1993) comenta que a pressão de inflação, utilizada em veículos pesados, tem aumentado na medida em que os fabricantes de pneus estão melhorando a tecnologia de fabricação. Além disso, as montadoras estão avaliando as vantagens de adoção de maiores pressões inflação nos pneus. Porém, o Guia relata que ainda não se conhece qual o efeito concreto das maiores pressões de enchimento dos pneus sobre os pavimentos.

Albano (2005) relata que a pressão de inflação dos pneus tem significativo efeito nos valores da deformação de tração na fibra inferior do concreto asfáltico, sendo não só para o valor, mas também na localização da deformação máxima de tração relativa à largura de contato do pneu/pavimento. Quanto mais inflados os pneus, maiores deformações ocorrem próximas ao centro do pneu e pressões mais baixas provocam deformações máximas junto as bordas laterais.

Em sua tese de doutorado, Albano (2005), utilizou o Simulador de Tráfego da UFRGS/DAER para ensaios em que utilizou pressões variadas de inflação de 552 kPa (80 psi), 620 kPa (90 psi) e 689 kPa (100 psi) e de intensidade das cargas de 82 kN (8,2 tf), 100 kN (10,0 tf) e 120 kN (12,0 tf) em dois tipos de pavimento, um deles delgado com revestimento em tratamento superficial duplo com 2,5cm de espessura, base e sub-base de macadame seco com 21,0 cm de espessura, e o outro, espesso com revestimento em concreto asfáltico com 9,0 cm de espessura, base de brita graduada simples com 12,0 cm de espessura, sub-base de macadame seco com 16,0 cm de espessura, ambos assentes sobre subleito de argila de comportamento laterítico. Os resultados apresentados pelo autor mostraram que a variação da deflexão recuperável entre os diversos níveis de pressão de inflação para cada nível de carga por eixo é pequena. No caso de pavimento delgado tem algum efeito, mas no espesso as variações são ainda menores, quase que insignificantes. As variações das deflexões foram mais significativas quando as cargas aplicadas sobre os pavimentos eram variadas. São representadas duas tabelas que reproduzem os valores médios da deflexão para cada combinação de fatores (pressão de inflação de pneus e cargas por eixo), calculados para os pavimentos espesso e delgado. A Tabela 7 mostra as variações no pavimento delgado e a Tabela 8 no pavimento espesso.

Tabela 7 – Deflexões médias medidas no pavimento delgado (0,01 mm). Fonte: Albano, 2005

Pressão de inflação de pneus kPa (psi)	Carga por eixo (kN)		
	82	100	120
552 (80)	54,25	69,25	75,25
620 (90)	55,00	71,25	77,75
689 (100)	51,50	63,00	76,00



Tabela 8 – Deflexões médias medidas no pavimento espesso (0,01 mm). Fonte: Albano, 2005

Pressão de inflação de pneus kPa (psi)	Carga por eixo (kN)		
	82	100	120
552 (80)	43,00	45,25	48,50
620 (90)	38,50	43,75	52,00
689 (100)	39,50	47,75	52,25

Por fim, em seu trabalho, Albano (2005) conclui que, em ambos os pavimentos estudados, quanto maior é o nível de carga por eixo, mais pronunciado é o valor da deflexão para cada nível de pressão de inflação considerado, evidenciando assim a conhecida influência da carga por eixo sobre os pavimentos, ou seja, a potencialidade do surgimento de danos ao pavimento é maior quanto maior for a carga e a deflexão. A variação da deflexão entre os diversos níveis de pressão de inflação para cada nível de carga por eixo é pequena. No caso do pavimento espesso as variações são ainda menores que no pavimento delgado. Para os dois níveis de espessura de pavimento estudos, no caso do nível de carga por eixo é de 120 kN, a variação entre os valores de deflexão é mínima para todos os níveis de pressão de inflação.

Kim et al. (1989) sustentam que o transporte de carga apresenta uma tendência de crescimento do PBT dos caminhões. Assim, com o aumento de carga por eixo, a utilização de maiores pressões nos pneus tem se tornado mais usual no contexto do transporte pesado. Na verdade, dentro de um conjunto de circunstâncias, destacam-se dois fatores simultâneos: a tração pelo aumento de carga por eixo é responsável pelas melhores características dos pneus radiais. Outro fator importante é o transportador, responsável pelo aumento da pressão de enchimento dos pneus.

Vale ressaltar que os fabricantes dos pneus fornecem tabelas com o valor de pressão recomendado em função da carga atuante por roda simples e dupla e para cada tamanho de pneumático.

Vários estudos teóricos e experimentais anteriormente desenvolvidos confirmam que a pressão de contato não é igual a pressão de enchimento e nem se distribui uniformemente sobre uma superfície circular. Fernandes Jr. (1994) informa que a superfície de contato aproxima-se da elipse para pneus de lonas e de um retângulo para pneus radiais a medida que a carga por eixo aumenta ou a pressão diminui. Já Souza (1980) relata que a área de contato entre um pneu carregado e uma superfície pavimentada é aproximadamente elíptica quando os pneus são novos e com pressão de enchimento e carga máxima recomendadas. Já para pneumáticos usados e com cargas além da máxima recomendada, a área de contato é aproximadamente retangular.

Porém, por outro lado sabe-se que a forma, o valor e a distribuição da pressão de contato é uma questão com certo grau de complexidade e de difícil generalização, pois são muitos os fatores que influenciam as seguintes determinações: carga por eixo, pressão de enchimento, tipo e tamanho do pneu, velocidade, entre outras.



A maioria dos pesquisadores adota o FEC (Fator de Equivalência de Cargas) para medir os efeitos da variação da pressão de enchimento sobre o desempenho dos pavimentos. Via de regra, quando é utilizado o critério do trincamento da camada de revestimento por fadiga, considera-se como resposta estrutural a deformação horizontal na fibra inferior do CA provocada por tensões de tração. No critério da deformação permanente devido à trilha de rodas, a resposta do pavimento é a deformação vertical no topo do subleito provocada por tensões de compressão.

Fernandes Jr., Paes e Pereira (2007) também estudaram os efeitos das solicitações do tráfego sobre o desempenho de pavimentos flexíveis brasileiros e portugueses. Os autores verificaram, a partir dos cálculos de fatores de equivalência de carga empírico-mecânico, apontando que o FEC aumenta conforme aumentam-se pressões, tendo como consequência um aumento nas deformações horizontais de tração na elevação de pressão de 80 psi (573 kPa) para a de 120 psi (844 kPa), o que pode corresponder a uma variação de até 50% nos fatores de equivalência de carga.

Quando considerada a fadiga do revestimento asfáltico, aumentando-se a pressão de inflação de 563 kPa (80 psi) para 844 kPa (120 psi), pode haver uma variação de até duas vezes no FEC, ou seja, a vida de um pavimento reduz-se à metade (FERNANDES JR., 1994).

Machemehl, Wang e Prozzi (2005) estudaram os possíveis efeitos das pressões de inflação dos pneus nos pavimentos flexíveis as cargas de rodas de 20, 24, 28 e 31 kN e as pressões de 483, 586, 690, 793 e 896 kPa foram utilizadas no estudo. Os autores encontraram que as pressões de enchimento dos pneus têm uma forte relação com as deformações horizontais de tração na fibra inferior do revestimento e com tensões próximas a superfície do revestimento. Isso aconteceu tanto para pavimentos delgados como espessos, verificando-se que quanto maior a pressão de enchimento, maior o dano causado. No entanto, os efeitos da pressão de enchimento nas deformações de compressão no topo do subleito são menores, principalmente nos pavimentos espessos.

Os mesmos autores, Machemehl, Wang e Prozzi (2005), comentaram que em função dos reforços nas laterais dos pneus as deflexões laterais são restringidas deformando mais linearmente na direção longitudinal, fazendo com que a área de contato seja mais retangular do que circular, isso acaba por gerar diferenças nas tensões/deformações nas direções longitudinais e transversais. Os autores ainda ressaltam que o método convencional subestima os resultados a baixa pressão de enchimento e superestima a altas pressões.

Nos trabalhos de Wang (2005) e Wang e Machmehl (2006) foram realizadas comparações entre as respostas estruturais obtidas pelas duas formas de consideração de distribuição e área das pressões de contato. As respostas dos pavimentos sob as pressões de contato não uniformes para diferentes tipos de pneus e pressões de enchimento foram calculadas por um programa de elementos finitos (o ANSYS) considerando os ESRS, ESRD e ETD. Os resultados obtidos pelos autores mostraram que o modelo tradicional (pressão de contato uniformemente distribuída e igual à pressão de enchimento dos pneus, sobre superfície circular) tende a superestimar as deformações horizontais de tração na fibra inferior do revestimento e subestimar a deformação vertical de compressão no topo do subleito, o que são intensificadas pelo aumento de pressão de enchimento do pneu, além de mais significantes para pavimento delgados que espessos e para ESRD e ETD do que para ESRS.



Nesta pesquisa, o valor considerado da pressão de inflação foi o padrão preconizado pelo software Paveware (827,4 kPa – equivalente a 120psi), que conforme relatado nas bibliografias acima, está dentro dos valores esperados no Brasil.

2.2 FATOR DE EQUIVALÊNCIA DE CARGAS

O conceito de equivalência entre cargas surgiu da observação que em estruturas semelhantes de pavimentos, os efeitos destrutivos ocasionados por diferentes veículos ao longo do tempo são iguais, emergindo um critério comparativo entre veículos. Ao efeito destrutivo pontual a cada passagem de uma carga individual atribui-se a terminologia de dano, sendo que a ruptura do pavimento será ocasionada pelo efeito do acúmulo de uma dada quantidade de danos – Hipótese de Miner (MINER, 1945 apud MEDINA, 1997).

Balbo (1997) conclui que os métodos de dimensionamento que adotam diferentes critérios de ruptura de um pavimento implicam em conceitos de danos diferentes, refletindo em suas equações de dimensionamento de pavimentos flexíveis e rígidos, que apresenta diferentes valores para os fatores de equivalência de entre cargas. O autor ainda ressalta que os efeitos destrutivos de uma carga podem ser chamados de dano, sendo que a ruptura do pavimento, encarada através de algum critério definido seu fim de vida útil, ocorrerá por efeito do acúmulo de uma dada quantidade de danos ocorridos.

Albano (1998) cita que medição dos danos causados pelo excessivo carregamento de veículos pode ser avaliada pelo FEC. Estudos desenvolvidos na pista experimental da AASHO no final da década de 50 levaram à conclusão que os efeitos de cargas por eixo sobre pavimentos podiam ser referidos aos provocados por uma carga de eixo simples com rodado duplo de 8,2 tf.

O Manual de Reabilitação de Pavimentos Asfálticos (DNER, 1998) enfatiza que as cargas do tráfego causam deflexões nas camadas do pavimento e alteram o estado de tensões e deformações. Cada carga provoca um efeito destrutivo e reduz a vida remanescente do pavimento. Portanto, diferentes configurações e cargas produzem deflexões diferenciadas, que reduzem a vida do pavimento de diversas maneiras. Os FEC são utilizados para fazer conversões de equivalência entre as várias possibilidades de carga por eixo.

Albano (2005) cita que o tráfego que se desloca sobre o pavimento é o carregamento a ser considerado nas metodologias de dimensionamento tanto empíricos como empírico-mecanísticos. Dessa forma, existe necessidade de modelar o tráfego, pois na realidade, o mesmo apresenta-se de forma bastante complexa: veículos diferentes, cargas aleatórias, inúmeras configurações de eixos e rodas, velocidades variáveis, etc.

Buscando quantificar os danos causados ao pavimento Yoder e Witczak (1975) indicaram que os Fatores de Equivalência de Cargas (FEC) definem o dano causado pela passagem de um veículo em relação ao dano causado por um eixo considerado como padrão, num mesmo tipo de pavimento.

A partir do conceito de equivalência de carga, a definição e quantificação desses efeitos foi o principal objetivo da AASHO, estabelecendo como eixo equivalente padrão o eixo simples de duas rodas de 8,2 tf (82 kN), espaçados de 300 mm (cada conjunto de rodas



duplas), desenvolvendo, de acordo com HRB (1962), o conceito conhecido como Equivalente de carga por eixo padrão (*Equivalent Standard Axle Load – ESAL*).

No estudo da AASHO, de acordo com HRB (1962), estabeleceu-se que o dano ao pavimento devido à passagem de cada eixo de carga simples individual pode ser estimado pela Lei da Quarta Potência. Essa lei diz a respeito de que o dano causado ao pavimento aumenta exponencialmente com o aumento da carga por eixo, conforme é expresso pela Equação 1:

$$FEC = \left(\frac{x_i}{L_s}\right)^m \quad (1)$$

Onde:

- x_i : peso da carga por eixo no i -ésimo lote;
- L_s : carga por eixo padrão com o mesmo número de eixos de x_i (80,1 kN para eixo simples e 151,2 kN para eixos tandem duplo);
- m : potência que detona o dano relativo ao pavimento por uma dada carga x_i .

As verificações da AASHO de todas suas limitações relativas à evolução dos materiais empregados na pavimentação, dos veículos, das cargas e etc., ainda hoje, após mais de 50 anos, os FEC normalmente utilizados nos dimensionamentos de rodovias são de base semi-empírica, não permitindo extrapolações para condições distintas àquelas nas quais eles foram criados. Dessa forma, Fernandes Jr. (1994) e Fernandes Jr. e Sória (1996) enfatizam que FEC empírico-mecanísticos resultantes da análise estrutural dos pavimentos e da consideração de modelos de previsão do desempenho deste são os mais indicados para refletir a situação em campo. Os FEC empírico-mecanísticos assumem a forma da equação 2.

$$FEC_i = \left(\frac{\rho_i}{\rho_0}\right)^b \quad (2)$$

Onde:

- ρ_i é a resposta estrutural correspondente à solicitação em análise;
- ρ_0 é a resposta estrutural à solicitação padrão;
- b é o expoente associado à forma de deterioração, à resposta estrutural considerada, ao tipo de ensaio e à estrutura analisada.

Por meio de estudos desenvolvidos pela pista experimental da AASHO cujos ensaios de campo duraram 25 meses (novembro/1958 e dezembro/1960), definiu-se um eixo padrão, o qual consiste em um eixo simples com rodado duplo com carga de 18.000 lbs (8,2 tf) e com pressão de inflação de pneus de 80 psi (5,6 kg/cm²). Os efeitos destrutivos de cargas por eixos sobre pavimentos podem ser referidos ao provocado por um determinado número de passagens do eixo padrão. Pode-se relacionar cada tipo de eixo ou conjunto de eixos ao eixo padrão através do FEC. Desta forma, o tráfego previsto, para um pavimento é definido em função do número equivalente de operações do eixo padrão, durante o



período de projeto. Esta quantidade de passagens do eixo padrão é denominado número N.

A carga por eixo padrão adotada é de 18.000 lbs (8,2 tf) por eixo simples de roda dupla – ESRD, ou seja, 9.000 lbs (4,2 tf) por rodas duplas. Todas as cargas por eixo previstas em projeto para circular pela via serão relacionadas à carga do eixo padrão. A somatória das relações de equivalência destrutivas fornece um parâmetro, denominado número N, que representa o número de passagens da carga de eixo padrão (8,2 tf), equivalente ao efeito das cargas do tráfego diversificado que realmente vai passar pela via no período de projeto.

Os modelos de obtenção dos FEC da AASHTO e da USACE são descritos a seguir.

2.2.1 Fator de equivalência de cargas do corpo de engenheiros do exército dos Estados Unidos (USACE)

Albano (2005) cita que os FEC/USACE são os adotados pelo DNIT (2006) para cálculo do número N e tem com origem o trabalho de Turnbull et al. (1962) para eixo simples e duplo. A referência do dano no pavimento é o afundamento plástico no subleito, considerado a 70 cm de profundidade (PEREIRA, 1985), tendo como limite o padrão de uma polegada de afundamento.

Pereira (1985) cita que os fatores de Equivalência concebidos pela USACE, em 1962, definiram o “ESWL” – “*Equivalent Single Wheel Load*” e tem como critério de degradação para equivalência, a deformação vertical de compressão no topo do subleito. Primeiramente, a preocupação era com a deformação permanente da camada de fundações do pavimento. Segundo o autor, foi observado que o próprio método de dimensionamento de pavimentos flexíveis (DNER, 1981) limitava-se a relacionar os valores numéricos assumidos para os fatores em questão, não fornecendo indicações esclarecedoras o bastante sobre a sua gênese e, por consequência, também sobre o seu real significado. O autor também lamenta que os textos dos trabalhos desenvolvidos por Turnbull et al. (1962) sejam insuficientes para que se possa apenas através da leitura fazer um julgamento preciso da procedência do uso simplificado dos fatores referidos na resolução dos problemas de dimensionamento de pavimentos destinados a rodovias brasileiras de tráfego pesado.

Na realidade, Pereira (1985) faz uma tentativa de dissipar as dúvidas do sentido de aumentar as poucas informações que se tinha e tentar melhor caracterizar, detalhadamente, os atributos das cargas em rodovias, possibilitando a obtenção de fomentar as análises críticas desses fatores, que, além de induzir as diversas conclusões, resultou no conhecimento das respectivas limitações, bem como na proposição de procedimentos capazes de adequá-los às condições de rodovias de tráfego pesado.

Pereira (1992) cita que a derivação dos FEC adotados pelo Corpo de Engenheiros do Exército dos Estados Unidos foi baseada na equação (3) básica de dimensionamento de pavimentos flexíveis de aeroportos elaborada a partir do acervo de dados experimentais acumulado pelo órgão até início da década de 60.



$$e = \sqrt{P \left[\frac{1}{8,2.ISC} - \frac{1}{pi.\pi} \right]} \quad (3)$$

Onde:

- e = espessura total do pavimento (polegadas);
- pi = pressão de inflação do pneumático (libras por polegada ao quadrado);
- P = carga de roda simples (libras);
- ISC = Índice de Suporte Califórnia (CBR%) do subleito;

Segundo Pereira (1985), a carga de roda simples equivalente é definida como sendo a carga que atuando sobre uma área de contato análoga à de uma das rodas do conjunto, produzindo na superfície do subleito uma deflexão máxima igual à resultante da ação combinada das rodas que integram o referido conjunto. São admitidas as seguintes hipóteses:

- A carga total incidente sobre o conjunto de rodas múltiplas é distribuída equitativamente sobre as rodas que o compõem;
- As áreas de contato entre os pneus e a superfície do pavimento são consideradas circulares;
- A pressão atuante na área de contato pneu/pavimento (pressão de contato) é supostamente uniforme e igual à pressão de inflação do pneu (pi);
- A área de contato A entre cada pneu e a superfície do pavimento é igual à razão entre a carga incidente sobre a roda e a pressão de contato;
- O conjunto pavimento/subleito é assimilado a um semi-espaço constituído por único material perfeitamente elástico, homogêneo e isotrópico (modelo de Boussinesq);
- O coeficiente de Poisson (μ) do conjunto pavimento/subleito é invariável com profundidade sendo igual a 0,50.

A pressão de contato equivalente (peq) é obtida dividindo-se a carga da roda simples equivalente (Peq) pela área de contato A, ou seja: $peq = Peq/A$

Então se o carregamento corresponde a um eixo ou conjunto de eixos de rodas múltiplas, P e pi são substituídos tornando a equação de dimensionamento (4):

$$e = \sqrt{Peq \left[\frac{1}{8,2.ISC} - \frac{1}{peq.\pi} \right]} \quad (4)$$

Os valores de Peq e peq dependem da espessura “e” do pavimento, sendo assim o uso da equação acima para a determinação da espessura total do pavimento requerido sobre um subleito de Índice de Suporte Califórnia (ISC) conhecido implica em um procedimento iterativo.

Pereira (1985) em seu trabalho destacou os seguintes comentários:

- O critério adotado é o da máxima deflexão no topo do subleito;
- A espessura implícita de 34,3 cm é de modo geral inferior a de pavimentos flexíveis no Brasil destinados a tráfego pesado;



- O conjunto pavimento/subleito é associado a um semi-espço de Boussinesq, com $\mu = 0,50$. O modelo em questão afasta-se bastante da hipótese mais simples aceitável para pavimentos reais, a qual consistiria em assemelhar a estrutura a um sistema elástico estratificado, com diversas camadas possuidoras de valores modulares e coeficientes de Poisson distintos.
- A pressão de inflação dos pneus, assumidos como sendo igual a 70 psi (4,9 kg/cm²), foi admitida como constante e independente da configuração de eixos e da carga incidente. Esse valor se considerado com os praticados nos dias atuais pode ser considerado como bastante conservador.
- Conclui-se que as curvas de projeto foram desenvolvidas com o nítido objetivo de assegurar proteção às camadas mais profundas do pavimento, em particular ao subleito contra deformações permanentes. Implica, portanto, que sua aplicação não é adequada para resolução de problemas ligados à estimativa da vida de camadas betuminosas no que se refere à fadiga.

Sales et al. (1987) citam que em 1962 a USACE propôs os FEC para eixos simples com rodas simples ou duplas, eixos tandem-duplos e eixos tandem-triplos, conforme a Tabela 9.

As equações originais dos FEC/USACE estão contidas no Manual de Reabilitação de Pavimentos Asfálticos do DNIT (2006), conforme a Tabela 10.

Tabela 9 – FEC/USACE – Eixos: simples, tandem-duplos e tandem-triplos

Peso por eixo (tf)	Simple	Tandem-duplo	Tandem-triplo
3,0	0,020	0,007	-
5,0	0,100	0,050	0,020
7,0	0,500	0,170	0,060
8,2	1,000	-	Eixo-padrão
9,0	2,000	0,500	0,130
11,0	6,000	1,500	0,235
13,0	15,000	3,500	0,435
15,0	35,000	7,000	0,750
17,0	80,000	14,000	1,210
19,0	-	25,000	1,985
21,0	-	40,000	4,030
23,0	-	60,000	5,850
25,0	-	100,000	7,955
27,0	-	150,000	12,350
29,0	-	150,000	17,810
31,0	-	-	30,550
33,0	-	-	43,550
35,0	-	-	53,300
37,0	-	-	75,400



Tabela 10 – Equações do FEC/USACE. Fonte: DNIT, 2006

Tipo de eixo	Faixa de cargas (tf)	FEC (P em tf)
Dianteiros simples e traseiros simples	0 – 8	$FEC = 2,0782 \times 10^{-4} \times P^{4,0175}$
	≥ 8	$FEC = 1,8320 \times 10^{-6} \times P^{6,2542}$
Tandem-duplo	0 – 11	$FEC = 1,592 \times 10^{-4} \times P^{3,472}$
	≥ 11	$FEC = 1,528 \times 10^{-6} \times P^{5,484}$
Tandem-triplo	0 – 18	$FEC = 8,0359 \times 10^{-5} \times P^{3,3549}$
	≥ 18	$FEC = 1,3229 \times 10^{-7} \times P^{5,5789}$
P = Carga por eixo		

2.2.2 Fator de equivalência de cargas da AASHTO

Pereira (1992) cita que o grande esforço despendido ao longo das atividades da pista experimental da AASHTO teve como objetivo principal estabelecer relações entre o comportamento dos pavimentos estudados, as respectivas estruturas e as cargas de tráfego aplicadas.

Conforme DNER (1998), o conceito de comportamento está ligado nas premissas de que um pavimento deve proporcionar ao usuário: conforto e segurança. Sua concepção está baseada em um procedimento no qual o usuário se julga servido pelo pavimento. O conceito de serventia está ligado à capacidade de um pavimento tem de possuir um rolamento suave, confortável e seguro, o que, em última análise, é a finalidade para a qual foi construído. É também a habilidade de um pavimento de servir ao tráfego com elevados volumes e altas velocidades.

A medição da serventia diz respeito diretamente ao usuário, que é influenciado por diversos atributos dos pavimentos, entre os quais:

- Resposta ao movimento caracterizado pela integração pavimento-veículo-homem para uma determinada velocidade;
- Resposta e aparência caracterizada por certos fatores como trincamentos, remendos, condições de acostamentos, etc.
- Avaliações foram realizadas na pista experimental do órgão norte-americano por grupo de indivíduos que, trafegando em seções pavimentadas, conferiam graus em uma escala variável de notas variando de cinco (muito bom) a zero (muito fraco) conforme alguns procedimentos:



- Das avaliações feitas pelos avaliadores em número de cinco, a média dos valores atribuídos por cada membro do grupo foi designada como sendo o Índice de Serventia Presente (ISP);
- Os avaliadores percorriam o segmento rodoviário da avaliação, em um veículo de passeio médio, a uma velocidade próxima da velocidade estabelecida (60 km/h); e
- As condições climáticas na ocasião do levantamento eram favoráveis. Conforme citado, as notas subjetivas variáveis no intervalo de 0 a 5, foram designadas como sendo um Valor de Serventia Atual (VSA) de acordo com os conceitos inseridos na Tabela 11.

Tabela 11 – Valores da Serventia Atual (VSA). Fonte: DNER, 1998

Valor de Serventia Atual (VSA)	Conceitos
0 a 1	Péssimo
1 a 2	Ruim
a 3	Regular
a 4	Bom
4 a 5	Ótimo

- Os segmentos avaliados tiveram extensões menores do que dois quilômetros. O VSA adotado foi a média dos resultados obtidos por avaliadores que ignoraram a análise, problemas geométricos, bem como problemas ligados à resistência de derrapagem, recalques em aterros e bueiros. Posteriormente, procurou-se estabelecer, através da análise de regressão múltipla, correlações entre os resultados da avaliação subjetiva efetuada e certos atributos medidos objetivamente, inerentes às condições de superfície dos pavimentos inspecionados.

Sales et al. (1987) observaram que a AASHTO, em 1974, formulou equações que representavam o fator de equivalência de uma carga P correspondente ao tipo de eixo. Estas equações são apresentadas a seguir.

Equações obtidas experimentalmente pela AASHTO (1974):

Eixo simples de roda simples:

$$nss = \left(P_{ss} / 7,77 \right)^{4,32} \quad (5)$$

Eixo tandem-duplo:

$$ntd = \left(P_{td} / 15,08 \right)^{4,14} \quad (6)$$



Equações obtidas por Treybirg e Von Quintus (1976 apud SALES et al., 1987):

Eixo simples de roda duplas:

$$nsd = \left(P_{sd} / 8,17 \right)^{4,32} \quad (7)$$

Eixo tandem-triplo:

$$ntt = \left(P_{tt} / 22,95 \right)^{4,22} \quad (8)$$

Balbo (1997) observou que não existe um critério universalmente aceito para o cálculo dos FEC, pois o pavimento pode apresentar ruptura determinada por diversos fatores. A utilização dos danos com base nas solicitações de tração nas fibras inferiores de camadas betuminosas e cimentadas, no que se refere à fadiga, pode resultar FEC entre cargas superiores aos tradicionais fatores tanto da metodologia da USACE como da AASHTO.

Balbo (1997) ainda ressalta que o FEC da AASHTO procura sanar tal aspecto por meio da diferenciação entre os FEC para pavimentos com diferentes Números Estruturais (SN) que na verdade não resolve por completo o problema, pois todos os fatores giram em torno da lei de quarta potência, não sendo muito diferentes entre si.

Albano (2005) cita que os FEC obtidos da equação geral de comportamento das pistas da AASHTO são influenciados pela estrutura do pavimento e, no caso da USACE, pela estrutura do pavimento e suporte do subleito.

Pinto e Preussler (2002) comentam que o FEC/AASHTO baseia-se na variação de serventia, dependendo do tipo de pavimento e do número estrutural (SN). Já o FEC/USACE avalia os efeitos do carregamento considerando a deformação permanente (afundamento das trilhas de roda).

As maiores críticas ao cálculo do número N ocorrem devido aos procedimentos altamente empíricos nos quais está fundamentada a determinação dos FEC, expresso em dano relativo à configuração de um eixo padrão de 8,2 tf (TIMM E NEWCOMB, 2002 apud ALBANO, 2005). Os autores afirmam que pesquisas desenvolvidas em inúmeras pistas experimentais indicam que os FEC são dependentes do tipo de pavimento (flexível ou rígido), espessura do pavimento, tipo do conjunto de eixos e do valor da carga por eixo, pressão de inflação e condições ambientais.

Segundo Pinto e Preussler (2002) um pavimento bem projetado, apresenta ao usuário, após sua conclusão, um alto grau de serventia traduzido por 2 fatores: conforto e segurança. Com passar do tempo, sob efeito do tráfego e das intempéries, o pavimento vai diminuindo sua serventia, devido ao aparecimento de:

- Deformações no seu perfil longitudinal e transversal devido a afundamentos de trilhas de roda.
- a presença de remendos que, num bom serviço de conservação corretiva rotineira vão substituindo as inevitáveis fissuras, afundamentos localizados e painelas.



2.3 FATOR DE VEÍCULOS

Balbo (1997), define que a somatória dos valores $(p_i \times FEC_{i,p})$ computados fornece o valor chamado FV ou fator de caminhão ou equivalência de operações, relativo ao perfil de tráfego verificado em pesagens por 100 veículos da amostra. O valor absoluto do fator de veículo será:

$$FV = \frac{\sum_{i=1}^n (p_i \times FEC_{i,p})}{100} \quad (9)$$

Onde:

- p_i é o valor da percentagem de eixos tabulados em relação ao número total de veículos e $FEC_{i,p}$ é o cômputo do produto para cada percentagem de eixo indicada.

Senço (1997) o define como sendo um fator que transforma o tráfego real, no sentido dominante, no período de projeto, em um tráfego equivalente de eixos padrão, podendo-se considerar que, para um FV, relativo ao veículo, e sendo p_i a percentagem com que esse veículo contribui para o tráfego total V_t , o FV será:

$$FV_t = \frac{[\sum p_i \times FV_j]}{100} \quad (10)$$

Pinto e Preussler (2002) citam que a determinação de solicitação do tráfego para a vida de projeto pode ser obtida a partir do cálculo dos FV. Conhecendo-se os FV individuais (FV_j), para as diferentes categorias de veículos, determinados numa estação de pesagem representativa da região, e das percentagens P_j com que estas categorias de veículos que ocorrem na estrada que está sendo considerada, tem-se que:

$$FV = \frac{\sum (P_j \times FV_j)}{100} \quad (11)$$

Os FV_j para automóveis e caminhões leves, não são tão relevantes, interessando, especialmente os FV_j para caminhões médios, pesados, reboques e semi-reboques.

Albano (2005) cita que o FV deve ser interpretado como o número equivalente de operações do eixo padrão provocado pelo deslocamento de um veículo médio representativo da frota. O FV representa também uma grandeza proporcional ao dano ou consumo provocado pela ação do tráfego sobre o pavimento, podendo se entender que as modificações importantes no FV de uma frota podem indicar uma alteração no desempenho esperado do pavimento devido a ações do tráfego não previstas.

2.4 CARGAS MÁXIMAS LEGAIS

Tratar-se-á neste item das cargas máximas permitidas para trânsito de veículos comerciais definidas pelas legislações pertinentes.



2.4.1 Histórico

A atual legislação referente à pesagem de veículos em vigor no Brasil é constituída por uma série de artigos cuja origem é o Decreto nº 62.127/68 que aprovou o Código Nacional de Trânsito. A partir deste, uma série de decretos e leis introduziram modificações na legislação original. Em um breve resumo a legislação específica sobre o assunto teve a seguinte evolução histórica:

- Decreto nº. 62.127 de 16/01/1968 que aprovou o Regulamento do Código Nacional de Trânsito e estabeleceu as condicionantes para o transporte de cargas rodoviárias conforme mencionado acima esse Decreto ficou conhecido como a Lei da Balança (BRASIL, 1968).
- Lei nº. 7.408 de 25/11/1985 que estabeleceu uma tolerância máxima de 5% sobre o Peso Bruto Total (PBT) e Peso Bruto Transmitido por Eixo (BRASIL, 1985).
- Decreto nº. 98.933 de 07/02/1990 que alterou o limite do Peso Bruto Total Transmitido pelo ESRS e regulamentou o ETD constituído por dois eixos com seis rodas (BRASIL, 1990).
- Resolução nº. 12 de 06/02/98 que estabeleceu limites de peso e dimensões para veículos por vias terrestres (CONTRAN, 1998a).
- Resolução nº.62 de 21/05/98 que regulamentou o uso de pneus extralargos em eixos tandem de semi-reboques e reboques de suspensão pneumática (CONTRAN, 1998b).
- Resolução nº. 68 de 23/09/98 que estabeleceu os requisitos de segurança necessários à circulação de Composição de Veículos de Cargas (CONTRAN, 1998c).
- Resolução nº. 102 de 31/08/99 que estabeleceu os requisitos necessários à circulação de CVC's (CONTRAN, 1999a).
- Resolução nº. 104 de 21/12/99 que dispôs sobre a tolerância máxima de peso bruto de veículos e estabeleceu critério do PBT para aplicação de multas (CONTRAN, 1999b).

Pela importância dessa Resolução (nº 104/99), os seguintes artigos são transcritos:

Artigo 1º - “Enquanto não estiverem concluídos os estudos e pesquisas e atualização dos limites de peso por eixo, bem como não for fixada a metodologia de aferição de peso de veículos, serão adotados os critérios de Peso Bruto Total e Peso Bruto Total Combinado para aferição do peso para aplicação de multa isentando-se de multa os excessos de peso verificados nos eixos isolados ou conjunto de eixos.”

Artigo 2º - “Os limites de Peso Bruto Total e Peso por Eixo permanecem sendo aqueles estabelecidos na Resolução nº 12/98 do CONTRAN”.

Artigo 3º - “O percentual de tolerância de 7,5% no Peso por Eixo permanecerá como o estabelecido na Resolução nº 102/99 do CONTRAN e o percentual de tolerância de 5% para o Peso Bruto Total e Peso Bruto Total Combinado permanece como estabelecido na Lei nº 7.408/85”.

Artigo 4º - “A fiscalização dos limites de peso, por meio do peso declarado na nota fiscal, será exercida somente naquelas rodovias desprovidas de equipamentos de pesagem”.



Artigo 5º - “Quando o peso aferido estiver igual ou inferior ao Peso Bruto Total ou Peso Bruto Total Combinado estabelecidos para o veículo acrescido da tolerância de 5% embora havendo excesso de peso em alguns dos eixos ou conjuntos de eixo, não será aplicada a multa. Nesse caso a carga deverá ser remanejada ou ser efetuado transbordo, de modo a que os excessos por eixo sejam eliminados”,

Parágrafo único – O veículo somente poderá prosseguir viagem depois de sanada a irregularidade.

Artigo 6º - “Quando o peso aferido estiver acima do Peso Bruto Total ou Peso Bruto Total Combinado estabelecido para veículo, acrescido da tolerância de 5%, aplicar-se-á multa correspondente com peso excedente a parcela relativa à tolerância”.

Parágrafo único – O veículo somente poderá prosseguir viagem depois de efetuado o transbordo.

Artigo 7º - “Nos casos de impossibilidade de remanejamento ou transbordo da carga será aplicado o disposto no artigo 275 e seu parágrafo único e demais dispositivo do Código de Trânsito Brasileiro aplicáveis ao assunto”.

- Resolução nº. 108 de 21/12/99 que dispôs sobre a responsabilidade pelos pagamentos de multas (CONTRAN, 1999c).
- Resolução nº. 144/2000 de 05/05/2000 que complementou a Resolução nº 104/99 e autorizou uma tolerância de 5,0% sobre o peso bruto declarado na Nota Fiscal (CONTRAN, 2000).
- Resolução nº. 164/04 de 10/09/2004 que estabeleceu dispensas de Autorização Especial de Trânsito (AET), para os veículos com Peso Bruto Total Combinado (PBTC) superior a 45 toneladas e até 57 toneladas, desde que tenham no máximo 7 eixos e comprimento máximo de 19,80 m e mínimo de 17,50 m (CONTRAN, 2004).
- Resolução nº. 185/05 de 21/10/2005 que alterou as Resoluções 12/98 e 68/98 e que de acordo com o item b do Inciso I do Artigo 2º permitiu CVC com PBTC de até 57 toneladas, com duas ou mais unidades, incluída a unidade tratora (CONTRAN, 2005).

A Tabela 12 mostra uma síntese da evolução das cargas máximas admissíveis no Brasil, de acordo com Decretos, Leis e Resoluções do CONTRAN.

Esta alteração da configuração legal, que ordena as relações e regras de trânsito no país, ainda está em processo de adaptação pela população de usuários do sistema através de mudanças nos hábitos dos condutores de veículos, pedestres e autoridades, seguramente direcionados no sentido de uma necessária diminuição dos conflitos existentes.

Por último, no ano (2014) a CONTRAN regulamentou, através da Resolução nº. 489, de 5 de junho de 2014, novas regras para o carregamento de veículos comerciais. Na nova resolução, a tolerância de sobrecarga por eixo passa a ser de 10%, isso quando o veículo está dentro dos 5% de limite para o peso bruto total (PBT). Quando o veículo estiver acima deste limite, a tolerância é 7,5%.

É importante lembrar que o veículo pode ser autuado duas vezes em uma única passagem pela balança rodoviária, uma pelo excesso de peso do Peso Bruto Total (PBT) e outra pelo excesso nos eixos. Para melhor interpretação da nova resolução é apresentado na Tabela 13.



Tabela 12 – Resumo da evolução das cargas máximas admissíveis no Brasil

Tipos de Eixos	Decreto 62.127/68	Lei 7.408/85	Decreto 98.933/90	Resolução 104/90	Resolução 164/04
	Cargas Máximas (kg)	Cargas Máximas (kg) 5% tolerância PBT e eixos (c/ multa)	Cargas Máximas (kg)	Cargas Máximas (kg) 5% tolerância PBT (c/ multa) e 7,5% eixos (s/ multa)*	Cargas Máximas (kg)
Simplex de Roda Simplex (direcional)	5.000	5.250	6.000	6.450	
Simplex de Roda Dupla c/ 4 pneus	10.000	10.500	10.000	10.750	
Tandem Duplo c/ 8 pneus $1,20m < d \leq 2,40m$	17.000	17.850	17.000	18.275	
Não em tandem $1,20m < d \leq 2,40m$			15.000	16.125	
Dois eixos (6 pneus) 1 eixo com 4 pneus 1 eixo com 2 pneus $1,20m < d \leq 2,40m$			13.500	14.512	
Tandem Triplo $1,20m < d \leq 2,40m$	25.500	26.780	25.500	27.413	
PBT	45.000	47.250	45.000	47.250	57.000**

* Acima desse limite torna-se obrigatório transbordo de carga

** Acima desse limite somente com Autorização Especial de Trânsito

Tabela 13 – Limites da Resolução nº. 489/2014 da CONTRAN

PBT, PBTC ou CMT	Tolerância por eixo	
Abaixo de 5,0% não será autuado	Tolerância de 10,0%	Abaixo de 10,0% não será autuado
		Acima de 10,0% será autuado
Acima de 5,0% será autuado	Tolerância de 7,5%	Abaixo de 7,5% não será autuado
		Acima de 10,0% será autuado pela segunda vez

Por exemplo, se um veículo comercial, com capacidade de carga de 23,00 toneladas, pesar 24,15 toneladas na balança, ele está dentro dos 5% de tolerância. Então, seu eixo dianteiro, que pode levar até 6,00 ton, não é multado se pesar até 6,60 toneladas (10% a mais). Para os traseiros, que levam 17 ton, o limite fica em 18,70 toneladas. Ou seja, é perceptível que não pode-se considerar o limite para colocar carga extra, pois se somar 6,60 + 18,70, tem-se 25,30 ton, logo o peso total passa dos 5%.

Se o mesmo veículo estiver com 25 toneladas, ele já ultrapassa a tolerância de 5%, então o limite por eixo baixa para 7,5%, ou seja, 6,45 toneladas no dianteiro e 18,27 toneladas nos traseiros.

A resolução atesta ainda que para quem estiver com até 5% de excesso em peso bruto, só haverá transbordo ou remanejamento a partir de 12,5% de excesso nos eixos. Até este limite, o veículo será apenas multado. Para quem estiver com excesso acima de 5% de peso bruto, valem as regras antigas.



No que se refere à área de legislação, particularmente sobre o transporte de cargas, encontra-se uma literatura técnica ampla dentre a qual destacam-se, além do texto da Lei 9.503/97, as seguintes publicações com informações e comentários: Coletânea de Legislação de Trânsito (PORTÃO, 2000) e Código de Trânsito Brasileiro (1997).

2.4.2 Código de trânsito brasileiro

Em 23/09/1997, após longa tramitação no Congresso Nacional, foi sancionada pelo Presidente da República a Lei nº. 9503/1997 que institui o novo Código de Trânsito Brasileiro (CTB), que entrou em vigor em 22/01/98, transcorrido cento dias de sua publicação no Diário Oficial da União (BRASIL, 1997). Essa alteração da configuração legal que ordenou as relações do trânsito no Brasil, objetivou mudanças no sentido óbvio de melhorar o sistema anteriormente vigente.

Segundo as resoluções vigentes em âmbito nacional, a Tabela 14 mostra os limites de cargas no Brasil.

Tabela 14 – Limites de cargas no Brasil. Fonte: Resoluções 104/90 e 164/04 do CONTRAN

Limite Máximo de PBT.	57,0 tf
Limite máximo de peso bruto por eixo simples com roda simples (ESRS).	6,0 tf
Limite máximo de peso bruto por eixo simples com roda dupla (ESRD).	10,0 tf
Limite máximo de peso bruto por eixo tandem duplo, quando a distância entre dois planos verticais que contenham os centros da roda for superior a 1,20 m ou inferior a 2,40 m.	17,0 tf
Limite máximo de peso bruto por eixo tandem triplo (somente do tipo semi-reboque), quando a distância entre três planos verticais que contenham os centros da roda for superior a 1,20 m ou inferior a 2,40 m.	25,5 tf

Observações:

- Os limites máximos de carga por eixo tandem equipado com pneu extralargo são de 17,0 tf e 25,5 tf, respectivamente, para eixos tandem-duplos e tandem-triplos.
- Nenhum veículo ou combinação de veículo poderá transitar com PBT ou PBTC superior ao fixado pelo fabricante, nem ultrapassar a capacidade máxima de tração da unidade tratora.

Uma das características do Código de Trânsito Brasileiro que tem recebido maior destaque nas discussões da sociedade, principalmente nos primeiros anos de vigência, é em relação ao rigor das penalidades, não só pelo valor pecuniário das multas, mas também por outras consequências, como a pontuação que pode implicar na suspensão do direito de dirigir.



Pode-se admitir que o CTB ainda está em processo de aperfeiçoamento, necessitando maiores discussões por especialistas e pela sociedade. Como exemplo pode-se citar a necessidade de regulamentação e implementação da inspeção veicular. A missão do CTB é boa, pois sem legislação nada pode se fazer no sentido de melhorar o sistema. Observa-se, na exposição de motivos ao presidente da República feita pelo Ministro da Justiça (BRASIL, 1993) quando do encaminhamento do projeto de Lei, que o novo Código, além de dar novas atribuições, poderes e responsabilidade aos órgãos responsáveis pelo trânsito, visa a segurança uma vez que está focado no seguinte princípio: “o trânsito seguro passa a ser um direito de cidadania”.

A legislação aponta os seguintes conceitos e limites de carga com interesse para o presente trabalho:

- Peso Bruto Total é o peso máximo que o veículo pode transmitir ao pavimento, considerando a tara mais a lotação (carga máxima útil);
- Peso Bruto Total Combinado (PBTC) e/ou Capacidade Máxima de Tração (CMT) é o peso máximo que pode ser transmitido ao pavimento pela combinação de um caminhão trator mais seu semirreboque ou de caminhão trator mais seu reboque;
- São considerados eixos tandem, dois ou mais eixos que constituam em conjunto integral de suspensão, podendo ou não qualquer deles ser motriz;
- O limite máximo do PBT ou PBTC é de 450 kN (45tf);
- O limite máximo do peso bruto por eixo simples isolados, equipado com rodado duplo é de 100 kN (10tf);
- O limite máximo de peso bruto por eixo simples isolado, equipado com rodado simples é de 60 kN (6 tf);
- O limite máximo de peso bruto por eixo tandem duplo, quando a distância entre dois planos verticais que contenham os centros das rodas foi superior a 1,20 m ou inferior (ou igual) a 2,40 m é de 170 kN (17tf);
- O limite máximo do peso bruto por eixo tandem triplo (aplicável somente para semirreboques), quando a distância entre os três planos verticais que contenham os centros das rodas for superior a 1,20 m e inferior (ou igual) a 2,40 m é de 255 kN (25,5 tf);
- Os limites máximos de carga por eixo tandem equipado com pneu extralargo são de 160 kN e 240 kN, respectivamente, para eixos em tandem duplo e triplo.

2.5 MÉTODOS DE DIMENSIONAMENTO DE PAVIMENTOS NOVOS E REFORÇO UTILIZADOS NO BRASIL

2.5.1 Pavimentos novos

O dimensionamento do pavimento obedeceu aos critérios adotados no "Método de Projeto de Pavimentos Flexíveis", do Eng.º Murilo Lopes de Souza. Salienta-se que para uso desta técnica, devem ser seguidas as diretrizes presentes na Norma Rodoviária DNER-ES 282/97 e no Manual de Pavimentação (DNIT, 2006), ao qual destacam-se algumas considerações:

- Na execução do corpo dos aterros não será permitido o uso de solos de baixa capacidade de suporte ($ISC < 2\%$) e expansão maior do que 4%;
- não será permitido o uso de solos com expansão maior do que 2% para a camada final dos aterros;
- no caso de ocorrência de materiais com ISC inferior a 2%, é necessário remover a camada e recompor na espessura de, pelo menos, 1 metro, por material com $ISC > 2\%$; entretanto, para esta finalidade, nesse projeto optou-se por aterro compactado de, no mínimo, $ISC > 10\%$;
- supõe-se sempre, que há uma drenagem superficial adequada e que o lençol d'água subterrâneo foi rebaixado a, pelo menos, 1,50 m em relação ao greide de regularização;
- as espessuras máxima e mínima de compactação das camadas granulares são de 20cm e 10cm, respectivamente. A espessura construtiva mínima para estas camadas é de 15cm; no caso específico do Macadame Seco em que as camadas devem ter entre 16 e 21cm deve ser compatibilizada a espessura do cálculo com a espessura executiva;
- as camadas de base deverão ter $ISC \geq 80\%$ (considerando tráfego $> 1E06$) e as camadas de sub-base $ISC \geq 20\%$;

O método do DNER (atual DNIT) para o dimensionamento de pavimentos flexíveis novos desenvolve-se por meio da seguinte ordem:

(1ª) A partir da observação da Figura 6 devem-se adotar as simbologias apresentadas de modo a determinar a espessura de cada camada do pavimento.

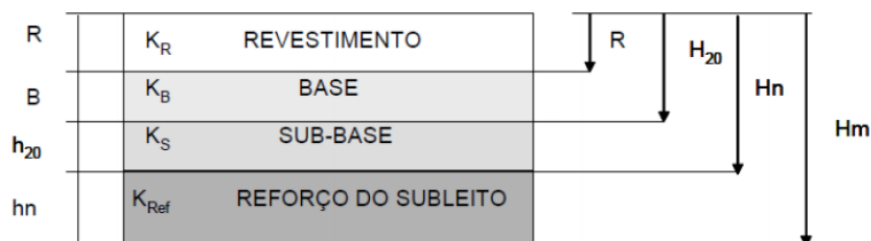


Figura 6 – Espessuras do Pavimento. Fonte: DNIT (2006)

Onde:

- K_R é o coeficiente de equivalência estrutural do pavimento;
- R é a espessura do revestimento;
- K_B é o coeficiente de equivalência estrutural da base;
- B é a espessura da base;
- H_{20} é a espessura de pavimento necessária para proteger a sub-base;
- K_S é o coeficiente de equivalência estrutural da sub-base;
- h_{20} é a espessura da sub-base;
- H_n é a espessura de pavimento necessária para proteger o reforço do subleito;
- K_{Ref} é o coeficiente de equivalência estrutural do reforço do subleito;
- h_n é a espessura do reforço do subleito;
- H_m é a espessura total de pavimento necessária para proteger o subleito.



(2º) A equação 12, apresentada a seguir, tem sua importância na definição das espessuras de H20, Hn e Hm do pavimento. Deve-se ressaltar que os valores obtidos são função direta do número N e do CBR da camada cuja proteção contra a ruptura se quer efetuar.

$$H_t = 77,67 * [N]^{(0,0482)} * [CBR]^{(-0,598)} \quad (12)$$

Onde: N - número equivalente de solicitações do eixo rodoviário de 8,2 tf calculado pela metodologia FEC/USACE.

Observações:

- Aconselha-se a utilização de um CBR igual a 20% para a sub-base, mesmo que na realidade esse valor venha a ser superior. Admite-se tal critério porque a espessura requerida para a segurança da sub-base somente é alcançada com seu CBR em 20%.
- A utilização desta fórmula é recomendada quando o número N atinge valores maiores que $[10]^6$. Distanciando-se desta condição, verifica-se um superdimensionamento dos pavimentos que apresentam número N muito reduzido, da faixa de $N \leq [10]^5$.

(3º) A determinação das espessuras da base (B), sub-base (h20) e reforço do subleito (hn), advém do emprego das inequações 13, 14 e 15 relacionadas na sequência.

$$R * K_R + B * K_B \geq H_{20} \quad (13)$$

$$R * K_R + B * K_B + h_{20} * K_S \geq H_n \quad (14)$$

$$R * K_R + B * K_B + h_{20} * K_S + h_n * K_{ref} \geq H_m \quad (15)$$

Caso ocorra o valor de 40% para o CBR da sub-base concomitantemente a um número $N \leq [10]^6$, deve-se substituir H20 por $H_{20} * 0,8$, enquanto que se o número $N \geq [10]^7$ recomenda-se a substituição de H20 por $H_{20} * 1,20$.

Na intenção de amenizar as causas da ruptura do revestimento e proteger a base dos carregamentos impostos pelo tráfego, adotam-se, em função do número N, as espessuras e os tipos de revestimentos encontrados na tabela apresentada na Tabela 15 – Espessura mínima de revestimento betuminoso. Fonte: DNIT (2006).

Tabela 15 – Espessura mínima de revestimento betuminoso. Fonte: DNIT (2006)

N	Espessura mínima de revestimento betuminoso
$N \leq 10^6$	Tratamento superficial
$10^6 < N \leq 5 \times 10^6$	Revestimento betuminoso com 5,0 cm de espessura
$5 \times 10^6 < N \leq 10^7$	Concreto betuminoso com 7,5 cm de espessura
$10^7 < N \leq 5 \times 10^7$	Concreto betuminoso com 10,0 cm de espessura
$N > 5 \times 10^7$	Concreto betuminoso com 12,5 cm de espessura

Conforme observado nas inequações apresentadas anteriormente, há inseridos nas mesmas, coeficientes de equivalência estrutural no cálculo da espessura de cada camada. O coeficiente de equivalência estrutural, Tabela 16, corresponde a uma relação, em termos de suporte de carga, entre o material escolhido para integrar determinada camada do



pavimento e o material granular padrão. É por meio dessa relação que se tem uma prévia do comportamento estrutural do material selecionado.

Tabela 16 – Coeficientes estruturais para os componentes do pavimento. Fonte: DNIT (2006)

Componentes do pavimento	K
Revestimento de concreto betuminoso – CBUQ	2,00
Revestimento pré- misturado a quente, de graduação densa – PMQ	1,80
Revestimento pré-misturado a frio, de graduação densa – PMF	1,40
Revestimento betuminoso por penetração – PMAF, MB, TSS, TSD, TST	1,20
Camada de materiais granulares – BGS, MH, BC, SB	1,00
Material estabilizado com cimento, resistência a compressão a 7 dias, superior a 45 kg/cm ²	1,70
Material estabilizado com cimento, resistência a compressão a 7 dias, entre 45 kg/cm ² e 28 kg/cm ²	1,40
Material estabilizado com cimento, resistência a compressão a 7 dias, entre 28 kg/cm ² e 21 kg/cm ²	1,20
Material estabilizado com cimento, resistência a compressão a 7 dias, menor que 21 kg/cm ²	1,70
Material estabilizado com cal – Solo-cal	1,70

2.5.2 Cálculo de reforço de pavimento asfálticos

O PRO11/79 tem seus princípios básicos derivados dos trabalhos do Eng. Bolivar Lobo Carneiro, a partir de estudos do Eng. Celestino Ruiz da Argentina. Segundo este método, a evolução das deflexões recuperáveis ao longo da vida de um pavimento pode se dar em três fases, como ilustra a Figura 7, a saber:

- Fase de consolidação – logo após a abertura, a deflexão decresce devido a consolidação adicional provocada pelo tráfego;
- Fase elástica – a deflexão permanece com valores praticamente constantes;
- Fase de fadiga – caracteriza-se por um acelerado crescimento do valor da deflexão devido a perda de capacidade estrutural das camadas do pavimento.

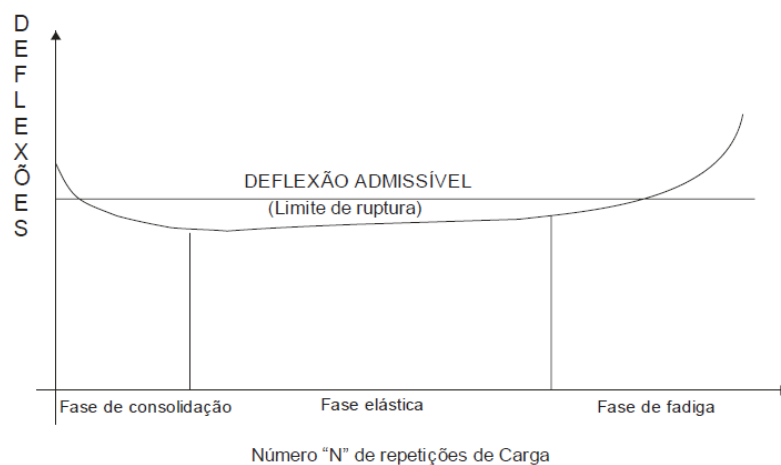


Figura 7 – Fases da vida de um pavimento



Um dos principais parâmetros de entrada, e base para o cálculo do reforço, é a deflexão máxima admissível (D_{adm}) a qual se relaciona ao número N pela equação:

$$\log D_{adm} = 3,01 - 0,0176 \log N \quad (16)$$

No caso deste projeto o N utilizado foi o estimado para 12 anos, para ambos os métodos de cálculo utilizados, com ano de abertura em 2015.

Então, quando se obtém uma deflexão admissível menor que a deflexão de projeto (D_p), haverá necessidade de reforço (h_{cb}), em termos de espessura de concreto betuminoso, determinada pela equação:

$$h_{cb} = 40 \cdot \log \frac{D_p}{D_{adm}} \quad (17)$$

A determinação dos valores de D_p (Deflexão de Projeto ou Deflexão Característica – D_c) para cada subtrecho homogêneo (STH) deve ser determinada a partir de um grupo de dados devidamente tratado estatisticamente (segundo prescrições estritas do PRO 11 – Anexo 1) o qual recomenda que:

$$D_p = Média + \sigma \quad (18)$$

onde é acrescido à média da deflexão do STH o valor do desvio padrão (σ) do respectivo banco de dados, isso significa que o valor adotado de D_p , representa, com nível de confiabilidade adequado, a deflexão do STH em análise.

Com relação à avaliação estrutural, o método apresenta uma tabela (Tabela 17) que traz a partir da comparação dos dados de deflexão admissível (equação 16) e da deflexão de projeto (equação 18) e do raio de curvatura (equação 19) indicativos da qualidade estrutural do pavimento. Os fatores chave são: a) deflexão de projeto < deflexão admissível – pavimento com boa qualidade estrutural; b) deflexão de projeto > deflexão admissível e Raio de curvatura > 100 – pavimento com razoável qualidade estrutural; c) deflexão de projeto > 3. deflexão admissível e/ou e Raio de curvatura > 100 – pavimento com má qualidade estrutural.

$$RC = \frac{6250}{2 \cdot (d_0 - d_{25})} \quad (19)$$

Onde: RC é o Raio de Curvatura, d_0 e d_{25} as deflexões a 0 e 25cm da carga.

O DNIT tem utilizado sistematicamente esta metodologia em forma de árvore de decisão que acompanham os editais do programa CREMA2, os quais estão em anexo. Neste procedimento é necessário que se tenha, de cada STH, os valores de VMD ou N , IRI, IGG e deflexão (admissível e característica) e as soluções vão desde a aplicação de lama asfáltica até a reconstrução do pavimento (ver Anexo 2).

Uma vantagem deste procedimento é que além da espessura de reforço estrutural do PRO11 são indicados procedimentos complementares (como fresagem e solução para acostamentos) além de itens de manutenção como aplicação de Lama Asfáltica. Evidente



que se a experiência acumulada do trecho em estudo permitir, o projetista pode definir tais estratégias.

Para aplicação desta sistemática, os valores de IRI, e IGG foram calculados a partir da média mais o desvio padrão da amostra considerada (de cada STH), conforme recomenda o DNIT.

Tabela 17 – Critérios para avaliação estrutural PRO 11

Hipótese	Dados Deflect. Obtidos	Qualidade Estrutural	Necessidade de Estudos Complementares	Critério Para Cálculo do Reforço	Medidas Corretivas
I	$D_c \leq D_{adm}$ $R \geq 100$	BOA	NÃO		Apenas correções de superfície
II	$D_c > D_{adm}$ $R \geq 100$	Se $D_c \leq 3 D_{adm}$ Regular	NÃO	Deflectométrico	Reforço
III	$D_c \leq D_{adm}$ $R < 100$	Regular para Má	SIM	Deflectométrico e Resistência	Reforço ou Reconstrução
IV	$D_c > D_{adm}$ $R < 100$	Má	SIM	Resistência	Reforço ou Reconstrução
V	—	Má O pavimento apresenta deformações rupturas plásticas generalizadas. (IGG)	SIM	Resistência	Reconstrução

2.5.3 Cálculo de reforço de pavimento asfálticos – PRO 269/94

No ano de 1982 foi proposto pelos Engenheiros Salomão Pinto e Ernesto Preussler um procedimento para projeto de reforço de pavimentos flexíveis que permite considerar explicitamente as propriedades resilientes dos materiais constituintes das estruturas dos pavimentos no Brasil. No decorrer dos anos o método foi validado e oficializado pelo DNER-PRO 269/94 – TECNAPAV (ver Anexo 3).

O procedimento é fundamentado em modelos de fadiga de misturas asfálticas, no comportamento resiliente típico de solos finos e materiais granulares e no cálculo de tensões e deformações considerando a teoria da elasticidade não linear. No caso deste estudo o solo de fundação considerado foi um A-7-5 com 30% passante na #200 e os valores de CBR extraídos do PER.

O cálculo envolve cinco etapas:

- Determinação do tráfego futuro;
- Levantamento de dados acerca do pavimento existente (funcional e estrutural) e determinação da deflexão de projeto - D_p (ou Deflexão Característica – D_c), de cada subtrecho homogêneo;
- Cálculo da espessura efetiva de revestimento betuminoso;

$$h_{ef} = -5,737 + \frac{807,961}{D_c} + 0,972I_1 + 4,101I_2 \quad (20)$$



- Cálculo da deflexão máxima admissível, em função no número N;

$$\log D_{adm} = 3,148 - 0,188 \log N \quad (21)$$

- Determinação da espessura de reforço em concreto asfáltico (HR):

$$HR = -19,015 + \frac{238,14}{\sqrt{D}} - 1,357h_{ef} + 1,016I_1 + 3,893I_2 \quad (22)$$

onde I1 e I2 são constantes relacionadas as características resilientes da terceira camada de estrutura de referência.

2.6 ANÁLISE EMPÍRICO-MECANÍSTICA DE PAVIMENTOS FLEXÍVEIS

O dimensionamento de maneira adequada é fundamental para o bom desempenho de pavimentos asfálticos, a fim de assegurar que a passagem dos eixos dos veículos não venha provocar trincamento excessivo da camada de revestimento dentro do período de projeto, além de garantir que as espessuras e características das camadas que o compõem sejam capazes de minimizar os efeitos gerados pelo afundamento de trilha de roda (FRANCO, 2007).

Atualmente, existem dois métodos de dimensionamento de pavimentos tradicionalmente utilizados, o método semi-empírico e o método empírico-mecanístico, ou seja, o dimensionamento de pavimentos vem tomando novos rumos com o passar dos anos.

O método de dimensionamento do DNER, baseado nos métodos do USACE (*United States Army Corps of Engineers*) e da AASHTO (*American Association of State Highway and Transportation Officials*), dimensiona a estrutura do pavimento com o objetivo de proteger o subleito contra deformações plásticas excessivas durante a vida útil de projeto. Este método, pelo fato de ter extrapolações numéricas, não é considerado puramente empírico, e sim, um método semi-empírico. No Brasil, sua utilização se mostra eficaz pela incomum ocorrência de danos por afundamento de trilha de roda de grande magnitude. No entanto, o método necessita de complementações com análises que considerem no dimensionamento o problema do trincamento por fadiga nas camadas asfálticas de pavimentos flexíveis. Para garantir essa análise com eficiência o procedimento mais adequado é a modelagem empírico-mecanística. Essa nova modelagem além de ser baseada em propriedades mecânicas do solo, ela também traz propriedades dos materiais de pavimentação, possibilitando, dessa forma, a melhoria no dimensionamento da estrutura do pavimento (BRASIL, 2006; HONG, PEREIRA E PROZZI, 2006).

Os resultados da análise estrutural do pavimento (tensões, deformações e deslocamentos), com o uso do sistema empírico-mecanístico, devem ser comparados com critérios pré-definidos, visando garantir que as deformações permanentes e trincamentos por fadiga sejam evitados (BENEVIDES, 2000 apud BERNUCCI et al., 2008; MOTTA, 1991 apud BERNUCCI et al., 2008).



A análise empírico-mecanística busca uma solução mais adequada aos projetos rodoviários, procurando apresentar uma análise o mais real possível da solicitação do tráfego em campo, ou seja, em cada uma das rodovias para qual se pretende executar um novo pavimento ou até mesmo uma restauração.

Medina e Motta (2005) sugerem um roteiro para o dimensionamento empírico-mecanístico, apresentado da seguinte forma:

- Definir o número N de projeto baseado em estudos de tráfego previsto para a via;
- ensaiar os materiais que serão usados no subleito, a fim de obter os módulos de resiliência e as leis de deformação permanente, considerando nos ensaios as variações de umidade;
- definir o módulo de resiliência a ser usado na mistura asfáltica em função da temperatura média esperada na região do projeto;
- depois de estabelecidos os materiais, adotar uma estrutura inicial e estipular espessuras para cada camada de pavimento;
- calcular, através de programas de cálculo empírico-mecanístico, o estado de tensões e deformações atuantes na estrutura, considerando como carga o eixo padrão;
- comparar os valores de tensões e deformações obtidos no cálculo com os critérios de ruptura estabelecidos em função do número N de projeto, usando, entre outros, curvas de fadiga;
- verificar o afundamento de trilha de roda, previsto para o número N, considerando as contribuições de todas as camadas constituintes, comparando com valores admissíveis;
- por fim, se os dois itens anteriores, (f) e (g), forem atendidos, considera-se o pavimento dimensionado. Caso um dos critérios não for atingido, alteram-se as espessuras e refazem-se todos os cálculos

No método empírico-mecanístico, o dimensionamento de pavimentos flexíveis baseia-se pelo diagrama apresentado na Figura 8. O diagrama mostra esquematicamente os dados de entrada (fatores ambientais, tráfego, materiais e técnicas construtivas), o processamento por via empírico-mecanística e os critérios de decisão que devem se integrar de forma a evitar que a degradação por qualquer tipo de ruptura atinja valores maiores que os estabelecidos para o trecho específico, antes de alcançar o número N de projeto. No dimensionamento mostrado no esquema, parte-se das espessuras admitidas e calcula-se o estado de tensões e deformações, os quais são comparados aos valores limites estabelecidos. Por meio de várias interações e tentativas, atinge-se a uma estrutura satisfatória. Cabe lembrar que o procedimento é genérico e pode ser utilizado para qualquer estrutura, sendo que os ajustes particulares são feitos na consideração do tráfego e no método de cálculo das tensões e deformações (MEDINA e MOTTA, 2005).

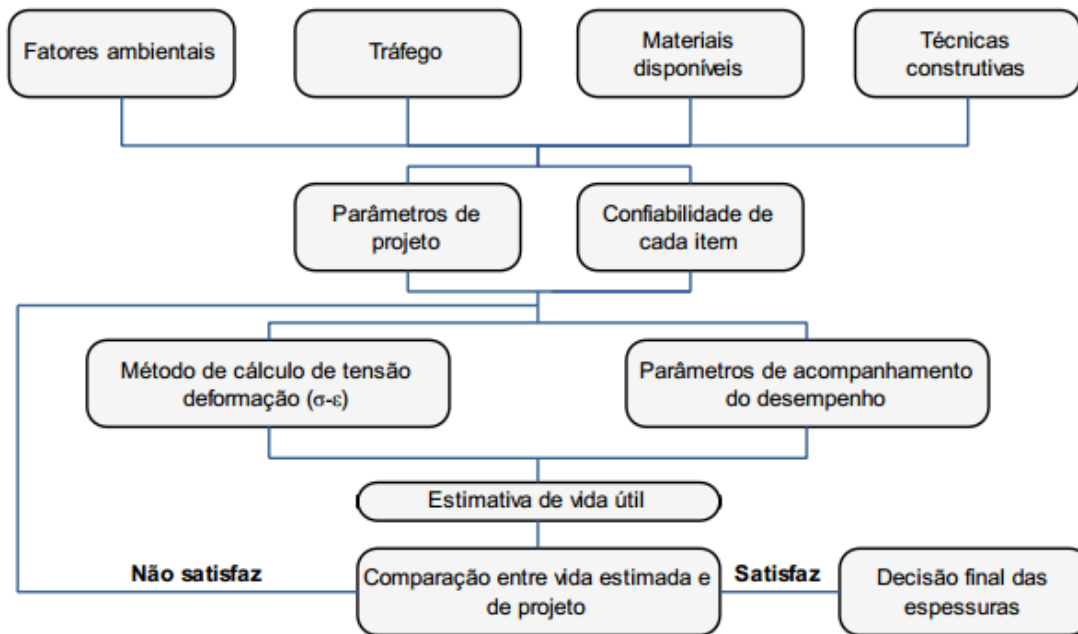


Figura 8 – Fluxograma de dimensionamento empírico-mecanístico de pavimentos. Fonte: Adaptado de MEDINA e MOTTA, 2005

Mesmo com a criação de programas computacionais como Paviflex, SisPav, Guia de Projetos da AASHTO, Pave, etc., que calculam pavimentos por métodos empírico-mecanísticos, a maioria dos projetos realizados atualmente são feitos por meio da análise semi-empírica, com base no CBR. O dimensionamento por métodos empírico-mecanísticos ainda não está muito difundido, principalmente no Brasil, devido haver uma cultura muito grande do uso de métodos semi-empíricos, aliado pela falta de uma metodologia de cálculo de simples compreensão que gere uma percepção confiável de resultados (FRANCO, 2007).

Sabe-se também que, em um projeto de pavimento, o tráfego é um dos principais parâmetros de dimensionamento da espessura das camadas. Em todos os projetos, um estudo de tráfego deve ser realizado a fim de definir a demanda que a via deverá satisfazer com o nível de serviço especificado. Medina e Motta (2005) afirmam isso apontando que uma das dificuldades no dimensionamento de pavimentos é a previsão da evolução do tráfego ao longo do tempo e avaliação do poder de destruição que exercem as várias cargas a diferentes níveis de repetição.

Portanto, a dificuldade de previsão da evolução do tráfego e seu respectivo poder de destruição, em conjunto com a falta de metodologias adequadas de dimensionamento fazem com que o Brasil, cada vez mais, apresente problemas em suas rodovias, gerando desconforto e, principalmente, insegurança aos usuários.

2.6.1 Mecânica dos pavimentos

Um pavimento pode ser definido como um sistema de múltiplas camadas semi-infinitas destinado à: distribuir os esforços verticais e horizontais oriundos do tráfego, proteger as camadas inferiores das intempéries e proporcionar aos usuários uma superfície segura e

regular de maneira a permitir o deslocamento com segurança e economia (MEDINA e MOTTA 2005, PAPAGIANNAKIS e MASSAD, 2008).

Os pavimentos, de maneira geral, são classificados em dois tipos diferentes, em função do seu comportamento estrutural (BALBO, 2007):

a) Flexíveis: é o pavimento no qual a absorção de esforços se dá de forma dividida entre várias camadas, onde as tensões verticais em camadas inferiores concentram-se em regiões próximas da área de aplicação da carga. O termo refere-se ao comportamento do pavimento, pois em termos de tensões, por exemplo, um pavimento semi-rígido apresenta um comportamento flexível à medida que sua camada cimentada degrada;

b) Rígidos: é o pavimento no qual uma camada, absorvendo grande parcela de esforços horizontais solicitantes, gera pressões verticais bastante aliviadas e bem distribuídas sobre camadas inferiores. O termo também se refere ao comportamento. Se um revestimento asfáltico for muito espesso e apresentar módulo de resiliência muito acima dos padrões normais, podendo conceber comportamento rígido ao pavimento;

Balbo (1993) apresenta a diferença de aplicação de carga em pavimento rígido e flexível (Figura 9). A aplicação de cargas em pavimentos flexíveis gera um campo de tensões concentrado nas proximidades da aplicação da carga. Já em pavimentos rígidos, o campo de tensões é mais disperso e a distribuição de cargas é semelhante em toda a dimensão da placa.

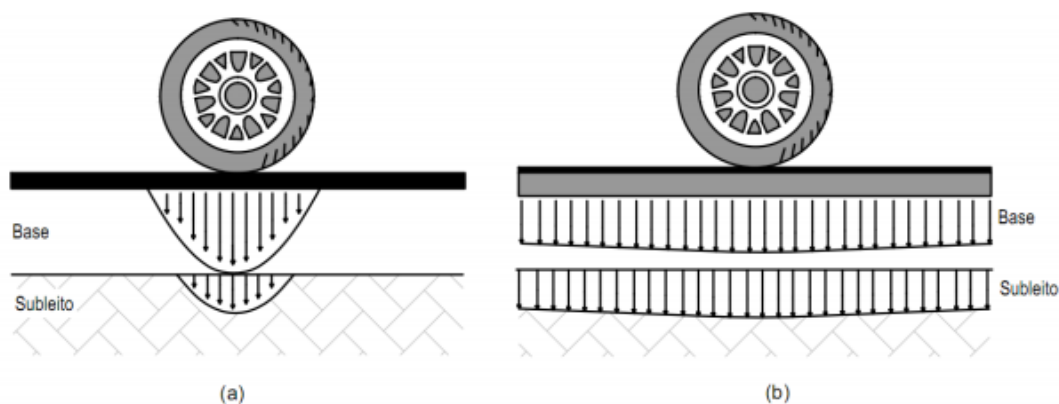


Figura 9 – (a) campo de tensões de pavimento flexível; (b) campo de tensões de pavimento rígido. Fonte: adaptado de Balbo, 1993

É importante para escolha da estrutura a utilizar fazer-se uma análise do tráfego atuante, ou seja, fazer uma análise aprofundada de quais os veículos predominantes no local, avaliando assim de forma mais adequada qual a estrutura para cada situação, visando sempre o bom desempenho e a vida útil do pavimento, evitando-se intervenções precocemente.

Balbo (2007) ressalta que a escolha do tipo de pavimento e dos materiais a serem utilizados é um fator limitante na concepção de um projeto rodoviário para as agências e operadores viários e está diretamente relacionada com a minimização de custos. A boa pesquisa e respectiva escolha de materiais disponíveis na região em conjunto com a dificuldade de



extração e transporte desses materiais são aspectos fundamentais em uma obra de pavimentação.

Segundo Franco (2007, p. 23), “a estrutura de um pavimento asfáltico é representada por um meio estratificado, submetido a um carregamento superficial distribuído em uma área circular podendo ser modelada por meio da teoria da elasticidade”. A figura 7 apresenta a forma mais comum de representação de um pavimento e as principais deformações e deslocamentos atuantes no interior da estrutura.

Outro fator a ser relatado é quanto à deformação permanente, causadora do afundamento de trilha de roda. Dependendo da magnitude das cargas do tráfego e da resistência relativa das camadas do pavimento, a deformação permanente pode ocorrer no subleito, nas camadas de base ou nas camadas asfálticas utilizadas como revestimento. A vulnerabilidade dessas camadas varia nas diferentes épocas do ano. Por exemplo, a deformação permanente no revestimento asfáltico é mais comum durante os meses quentes do verão do que no inverno, enquanto que as camadas granulares de base tornam-se mais susceptíveis aos afundamentos em épocas chuvosas. Outro fator importante é o nível de tensão numa camada individual do pavimento, o qual é função das espessuras das camadas e dos materiais utilizados, e também das cargas aplicadas pelos veículos pesados.

Entretanto, uma causa comum de ATR é a deformação permanente associada à camada de revestimento asfáltico, especialmente em rodovias de tráfego pesado, com elevadas cargas por eixo e alta pressão de pneus. Muitos destes afundamentos podem ser atribuídos à dosagem imprópria da mistura asfáltica (ROBERTS et al., 1996). O emprego de quantidades excessivas de ligante asfáltico é um dos grandes causadores do ATR. Isto se deve ao fato de que o maior volume de asfalto irá agir como lubrificante e reduzir o atrito interno e o intertravamento do esqueleto pétreo da mistura. HOFSTRA e KLOMP (1972) também mostraram que a deformação no concreto asfáltico era maior próximo à superfície solicitada e gradualmente se reduzia com a profundidade. Este decréscimo foi atribuído, na época, ao aumento da tensão confinante com a profundidade, o que resultava em maior resistência ao escoamento plástico, e também à diminuição das tensões cisalhantes. A resistência ao ATR também foi relacionada com a espessura do revestimento asfáltico. UGE e VAN DE LOO (1974) relataram que a deformação nesta camada não cresce com o aumento de sua espessura a partir de um determinado limiar (aproximadamente 13 cm). Em outras palavras, revestimentos asfálticos com espessuras inferiores a 13 cm deformarão mais quanto maior a sua espessura.

No entanto, em revestimentos com espessuras maiores do que este limite, o seu aumento não exerce influência no afundamento. Medidas feitas nas pistas da AASHO mostraram que o ATR apresenta valor máximo em espessuras de aproximadamente 25 cm de concreto asfáltico. Camadas mais espessas, por sua vez, não apresentaram afundamento adicional. Estes resultados sugerem que o aumento de espessura em revestimentos delgados contribui para o desenvolvimento de trilhas de roda, oriundas desta camada.

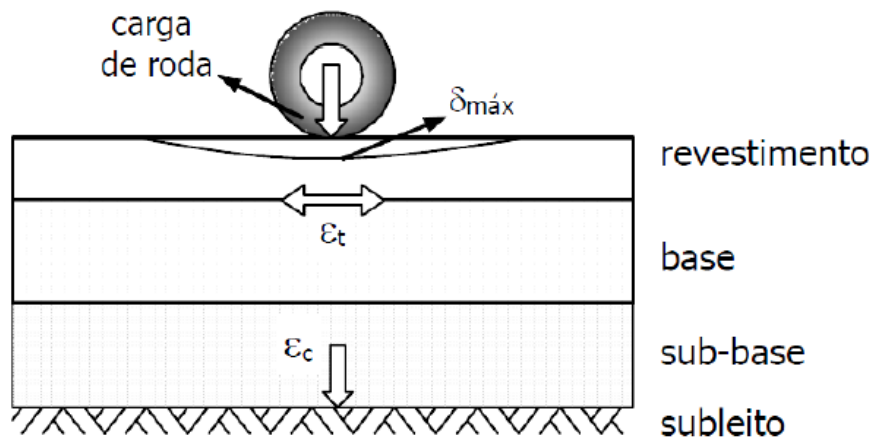


Figura 10 – Tensões, deformações e deslocamentos em um pavimento asfáltico. Fonte: Franco, 2007

Outro fator relevante na estrutura do pavimento é o efeito acumulado de fadiga, o qual começou a ser estudado por Miner. No seu estudo, o pesquisador analisou o efeito acumulado de fadiga de estruturas metálicas utilizadas em aviões (MINER, 1945 apud MEDINA, 1997). A teoria apresentada pelo pesquisador diz que a carga cíclica senoidal foi aplicada nos corpos-de-prova, a diferentes razões de tensões de tração mínimas e máxima, admitindo-se que todo o trabalho aplicado contribui para a fadiga e que o início de uma trinca corresponde a ruptura. O pesquisador aplicou níveis de tensões tais que a ruptura ocorresse a mais de 10^7 ciclos.

Miner (MINER, 1945 apud MEDINA, 1997) estabeleceu que a ruptura da peça solicitada dinamicamente ocorre quando:

$$\sum \frac{n_i}{N_i} = 1 \quad (23)$$

Onde: n_i é o número de ciclos aplicados de tensão máxima e N_i é o número que provoca a ruptura, por meio de uma carga P_i .

Por meio desta teoria pode-se tirar como conclusão que na trilha de roda na fibra inferior do revestimento asfáltico a trinca surja quando se tenha a condição expressa na equação 12. Onde, neste caso, N_i é o número de repetições de carga P_i que causa a ruptura incipiente e n_i é o número de repetições esperado de P_i na vida de projeto. Devido ao módulo de resiliência da mistura asfáltica variar com a temperatura, N_i ficará em função do estado de rigidez no momento da solicitação. Ainda, o estado de tensões varia de posição em função do modo de aplicação da carga (transversal e longitudinal) e com a velocidade do veículo (MONISMITH e DEACON, 1969 apud MEDINA, 1997).

Para aplicação dos modelos para avaliar a deformação permanente e a fadiga é de importância conhecer cada um dos parâmetros utilizados para sua respectiva aplicação, principalmente a metodologia aplicada para o cálculo do número N .

Como exemplo, têm-se os modelos mais utilizados para estas análises como sendo a do Instituto do Asfalto dos Estados Unidos - MS-1, de 1969 e reeditado pela nona vez em 1991, com o objetivo de avaliar a deformação permanente no topo do subleito; e para avaliar a deformação de tração da fibra inferior do revestimento tem-se o modelo da FHWA (Federal



Highway Administration). Em ambos os casos, o número N conhecido para aplicação dos modelos é o calculado pela metodologia FEC da AASHTO, com base na pista experimental da AASHO (atual AASHTO).

O modelo mais difundido no Brasil é o proposto por FRANCO (2007), com a finalidade de analisar a deformação de tração na fibra inferior do revestimento. Este modelo, por ser considerado brasileiro, leva em conta o número N calculado pela metodologia FEC da USACE, mesma utilizada pelo DNIT (2006) para dimensionamento de pavimentos.

2.6.2 Software de dimensionamento de pavimentos – Paveware®

O guia proposto pela AASHTO/2002 é um dos métodos mais conhecido para dimensionamento de pavimentos. Sua abordagem empírico-mecanística permite avaliar o comportamento estrutural dos pavimentos de forma coerente e analítica, sendo isso, fruto da calibração de modelos teóricos com dados experimentais obtidos em campo e laboratório.

De acordo com o relatório do NCHRP (2004), o guia proporciona um conjunto de procedimentos para o dimensionamento de pavimentos novos e reabilitados, tanto do tipo flexível como do tipo rígido. O formato empírico-mecanístico permite trabalhar com uma estrutura para que contínuos melhoramentos sejam feitos no futuro, acompanhando, assim, as mudanças nos veículos, materiais, técnicas de construção, conceitos de projetos, tecnologia de computadores, etc. O guia está dividido em quatro partes distintas e apêndices:

- Parte I: apresenta uma visão global sobre o guia, abrangendo desde os objetivos até a previsão do desempenho do pavimento;
- Parte II: apresenta definições e procedimentos de como obter os dados de entrada necessários para projetos novos ou de reconstrução, bem como de reabilitação;
- Parte III: inclui um material detalhado para auxiliar na compreensão do usuário dos conceitos usados no desenvolvimento do guia e na aplicação adequada dos procedimentos de dimensionamento;
- Parte IV: aborda como o processo empírico-mecanístico pode ser utilizado no dimensionamento de pavimentos sujeitos a baixos volumes de tráfego;
- Apêndices A a D: contém informações detalhadas sobre algumas considerações adicionais de projeto, como por exemplo: lista com diretrizes para comparação de estratégias alternativas de dimensionamento; informações sobre análises econômicas das estratégias e um guia do usuário do software.

Nas últimas décadas a vida útil do pavimento foi verificada em bases semi-empíricas e expressa em termos de número equivalente de solicitações do eixo padrão de 8,2 toneladas, usando a lei da quarta potência para converter o tráfego misto em cargas equivalentes por eixo. Com a tendência de substituição da tradicional base semi-empírica pela empírico-mecanística, vários métodos de dimensionamento foram desenvolvidos sendo o mais conhecido o da AASHTO/2002, proposto pelo *National Cooperative Highway Research Program* (NCHRP) no projeto 1-37A, que introduziu uma nova forma para a caracterização do tráfego: os espectros de carga por eixo (*Axle Load Spectra*).



O método de dimensionamento proposto pelo NCHRP é uma mudança radical do método semi-empírico. O método utiliza a partir da quantificação das características de tráfego usando diretamente todas as cargas por eixo, sendo possível analisar os impactos das variações das cargas de tráfego no pavimento e promover um adequado dimensionamento da estrutura do pavimento (JIANG et al., 2008).

O Guia AASHTO/2002 contém procedimentos para o dimensionamento e análises de todos os tipos de pavimentos, novos ou reabilitados (flexível, rígido e semi-rígido). Quando há possibilidade, as metodologias de dimensionamento para vários tipos de pavimentos são integrados, de forma que o dimensionamento de reforços não favoreça propriamente qualquer tipo de pavimento. Quanto ao dimensionamento de reforços de pavimento, o guia enfatiza da seguinte maneira:

- Procedimentos para avaliação de pavimentos existentes;
- Recomendações nos tratamentos de reabilitação, drenagem superficial e melhorias na fundação;
- Procedimentos nas análises dos custos do ciclo de vida e análises de tráfego;
- Procedimentos de calibração para condições locais;
- Orientação para as instituições desenvolverem manuais de procedimentos;
- Acessos hierárquicos que possam promover múltiplas ações de dimensionamentos, dependendo da classe rodoviária.

Os guias antigos para dimensionamento de estruturas de pavimentos de AASHTO serviram por quase quatro décadas, existindo, então, sérias limitações para continuidade dos seus usos atualmente. Segundo Peterlini (2006), essas limitações podem ser:

- Procedimentos de dimensionamento de reforços não foram considerados na pista experimental na AASHO (atual AASHTO). Atualmente, as necessidades são veementes em termos de dimensionamento de reforços;
- A pista experimental se localizava numa área geográfica específica, Ottawa, Illinois, norte dos Estados Unidos, com dificuldades de simular os efeitos de diferentes condições climáticas de outras regiões nas performances dos pavimentos.
- Somente um tipo de subleito foi usado para todas as seções de testes da pista experimental. Existem muitos outros tipos dentro do próprio Estados Unidos;
- Somente bases granulares densas não-estabilizadas foram incluídas nas principais seções do pavimento. Diferentes tipos de bases são agora usados frequentemente em todo o mundo;
- Veículos, suspensões, configurações de eixos e tipos de pneus eram representativos dos usados no final dos anos 50. Grande maioria está em desuso nos dias de hoje;
- Nenhum sistema de drenagem profunda foi incluído nas seções da pista experimental.

Segundo Peterlini (2006), outra grande diferença entre os procedimentos anteriores da AASHTO com os atuais é a magnitude entre a pista experimental e as modernas rodovias atuais no que se refere ao carregamento. Na pista experimental houve a aplicação de cerca de 10 milhões de carga-eixo; menor do que os carregamentos que sofrem os modernos pavimentos em seus primeiros anos de uso devido ao elevado crescimento do tráfego de veículos nos últimos anos.



As equações básicas originais dos primeiros procedimentos foram baseadas nas análises de regressões estatísticas dos dados da pista experimental. Desse modo, aplicações dos procedimentos para modernos fluxos de tráfego, têm significado aos projetistas, criatividade e experiência muito além dos dados básicos das pesquisas realizadas há muito tempo. Claramente, os resultados têm mostrado que os projetistas têm dimensionado com carregamentos muitos altos, resultando em significativas perdas econômicas (PETERLINI, 2006).

Mais uma grande extrapolação foi sobre a vida de projeto. A pesquisa foi de curta duração, logo, os efeitos de longo prazo das condições climáticas e envelhecimento dos materiais não foram considerados. As pesquisas da pista experimental da AASHTO duraram apenas 1 ano e 1 mês, enquanto vidas de projetos para muitos dos pavimentos atuais são de 20 a 50 anos.

Peterlini (2006) relata em seu trabalho que os procedimentos da AASHTO/1973/1986/1993 relacionam a espessura dos revestimentos para análise de desempenho. Porém, critérios de desempenhos observados nos pavimentos têm revelado que muitos deles necessitam reabilitações pelo fato de não estarem diretamente relacionadas às espessuras do revestimento, como por exemplo, afundamento de trilha de roda, trincas térmicas, etc. A medida primária do desempenho dos pavimentos nos procedimentos anteriores era o Índice de Serventia Atual (PSI) e o fator dominante dessa serventia era, sem dúvida, o tráfego.

Para melhorar a confiabilidade no dimensionamento de pavimentos e encontrar as necessidades de gerenciamento, os critérios devem se ater aos mesmos fatores de desempenho. Para ajudar a diminuir esses problemas se utiliza, por exemplo, o Índice de Rugosidade Internacional (IRI) como um dos critérios de desempenho (PETERLINI, 2006).

O projeto NCHRP além de proporcionar o Guia de Projetos da AASHTO/2002 para dimensionamento de estruturas de pavimentos novos e reabilitados, possui um software computacional, conhecido como *AASHTOWare Pavement*, que é uma evolução do antigo ME-PDG que também foi chamado posteriormente de DARWin-ME e recentemente recebeu o nome de *AASHTOWare® Pavement ME MEPDG (Mechanistic-Empirical Pavement Design Guide)*.

O Paveware® foi lançado em pela AASHTO e é considerado o software para dimensionamento de pavimentos com conhecimento ainda no –“estado-da-arte”. Ele permite o dimensionamento de pavimentos flexíveis novos, reabilitações tipo recape asfáltico sobre pavimento flexível, pavimento rígido, recape flexível sobre pavimento rígido e semi-rígido. A Figura 11 mostra as possíveis estratégias para dimensionamento de pavimentos novos que podem ser simulados do Paveware para pavimentos flexíveis.

A Figura 12 e a Figura 13 mostra a tela de boas vindas da licença adquirida para este projeto, bem como a tela principal na qual se navega entre os vários dados de entrada para dimensionamento/análise dos projetos simulados.

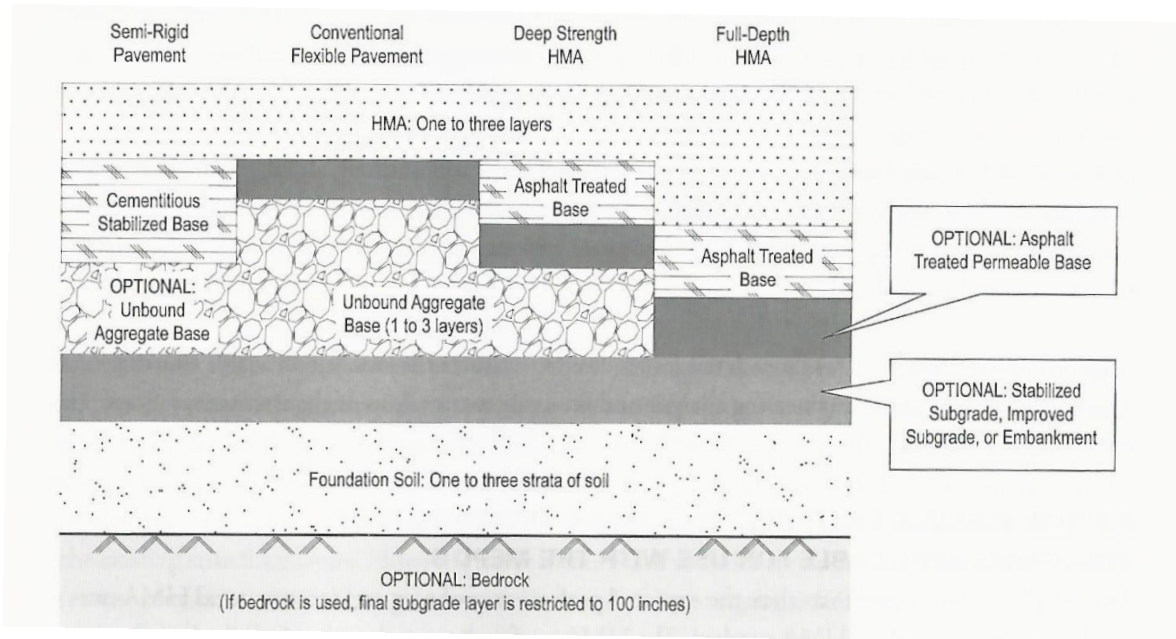


Figura 11 – Estratégias para dimensionamento de pavimentos novos que podem ser simulados do Paveware para pavimentos flexíveis.

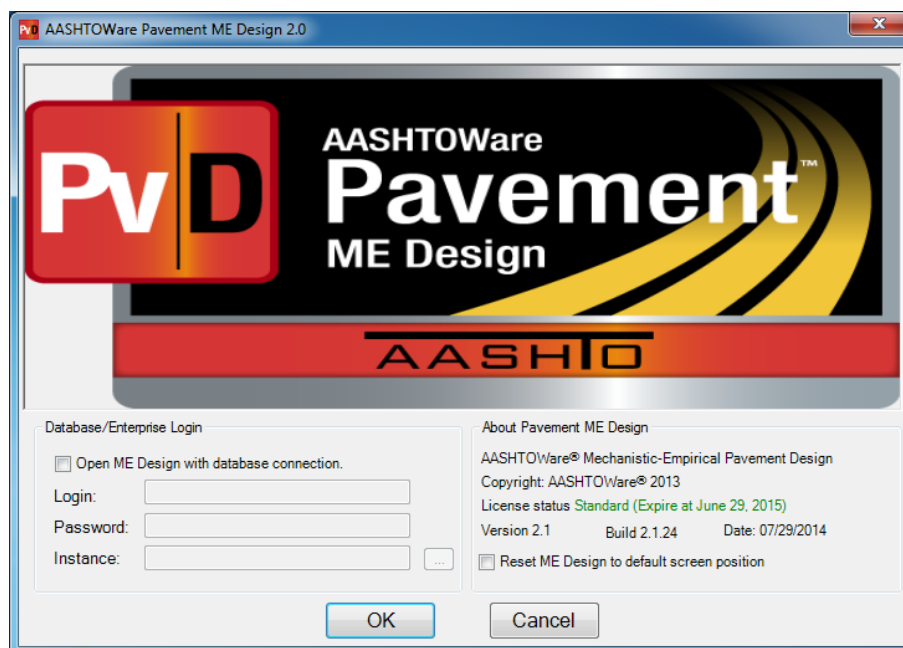


Figura 12 – Tela de entrada do software Paveware – AASHTOWare Pavement ME Design

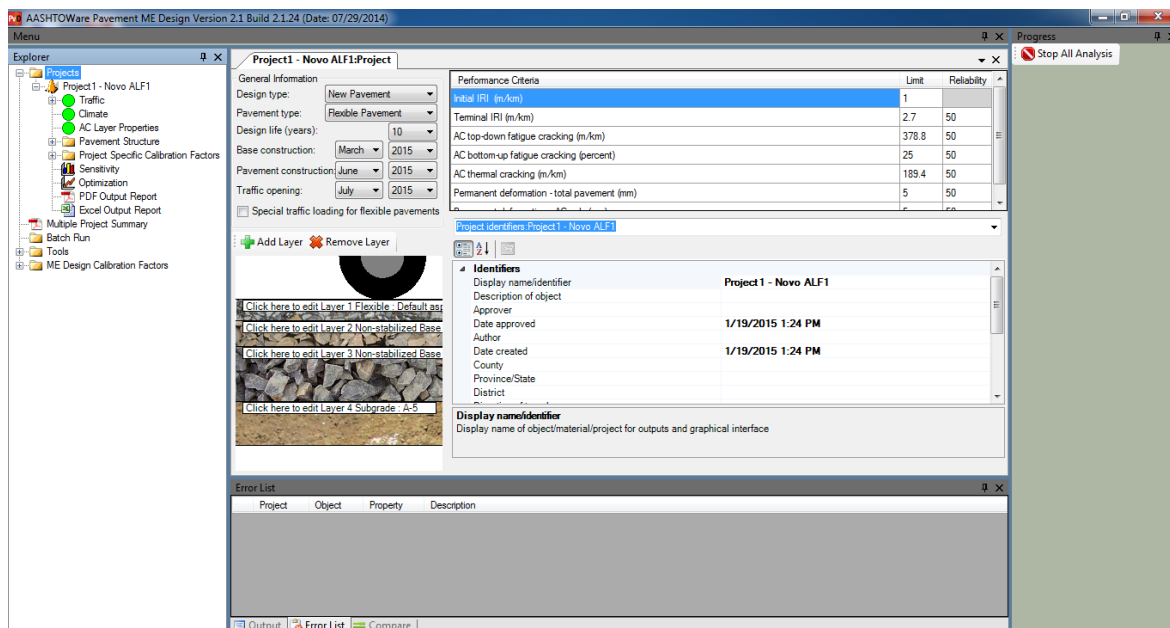


Figura 13 – Tela principal do software Paveware – AASHTOWare Pavement ME Design

A filosofia de funcionamento do novo guia da AASHTO inclui as seguintes doutrinas:

- O guia aplica de uma forma abrangente o conhecimento já validado com tecnologias no estado-da-prática.
- O guia fornece aos projetistas a versatilidade de consideração de uma grande variedade de opções de materiais e projetos.
- O guia proporciona uma base de projeto equitativa do ponto de vista da seleção do tipo de pavimento.
- O guia abrange tanto questões de projeto para pavimentos novos quanto reabilitações.
- O guia e o software associado são de uso/interface amigável.
- O guia compreende três níveis hierárquicos de dados de entrada para o projeto, de maneira a adequar a importância do projeto ao esforço a ele associado. Os níveis de entrada também permitem o uso de procedimentos que podem sofrer melhorias no futuro.

Um dos mais interessantes aspectos deste novo guia é o seu acesso hierárquico, isto é, a consideração de diferentes níveis de precisão dos dados de entrada. O Nível 1, mais elevado, requer do engenheiro-projetista, dados mais acurados, isto é, ensaios dos materiais, pesagens de veículos, etc. O Nível 2 requer ensaios, mas são permitidos correlações de dados, como por exemplo, módulo do subleito estimado através de correlação com o ensaio do CBR. Finalmente o Nível 3, baseado em valores fornecidos pelo programa, na falta de valores locais. Em síntese: Nível 1 – Mais complexo; nível 2 – complexidade intermediária; nível 3 – para projetos que se desconhecem alguns parâmetros de entrada – neste caso são admitidas simplificações sugeridas pelo método.

O Nível 1 de entrada de dados fornecer o maior precisão e menor quantidade de incerteza. Deve notar-se que nem todos os modelos de previsão foram calibrados para níveis mais elevados de entrada. No Nível 1 os dados de entrada são específicos para cada local e exige disponibilidade de dados de laboratório mais extensivo e / ou testes de campo.



O Nível 2 de entrada de dados é menos abrangente. As entradas podem ser selecionadas a partir de um banco de dados e extrapolada a partir destes limites, ou estimado através de correlações.

O Nível 3 entradas fornece o nível mais baixo de precisão. No Nível 3 são considerados insumos típicos e incluem valores padrão para que os testes de materiais sejam mínimos e exija desta forma menos dados coletados.

2.6.3 Outros softwares de dimensionamento de pavimentos

No Brasil, um dos softwares mais conhecidos e de fácil manuseio é o SisPav, criado por FRANCO (2007), na COPPE, no Rio de Janeiro.

O software SisPav (Figura 14) foi desenvolvido com o objetivo de realizar análises e dimensionamentos de estruturas de pavimentos segundo os conceitos relativos ao estado da arte da mecânica dos pavimentos. Um dos critérios definidos foi o de criar uma interface de fácil utilização, com entrada de dados simplificada e com valores sugeridos para fins de anteprojeto.

O SisPav utiliza a teoria da elasticidade, por meio de um programa analítico de Análise Elástica de Múltiplas Camadas – AEMC. A abordagem da análise elástica não linear é realizada de forma simplificada, com a divisão das camadas com este comportamento em três subcamadas.

Duas opções de análise são possíveis de serem realizadas. A primeira delas é o dimensionamento da estrutura propriamente dito, em que o programa analisa os dados de entrada e, por meio um algoritmo similar ao de busca binária em tabela ordenada, encontra a espessura da camada que atenda aos requisitos de projeto. A segunda análise só realiza uma verificação dos dados e requisitos definidos pelo projetista e informa a vida de projeto que a estrutura pode suportar.

Nas duas análises o programa verifica os danos acumulados por fadiga no revestimento asfáltico ou, se for o caso, na base das camadas cimentadas, além da verificação da tensão limite no topo do subleito. O programa fornece também as estimativas de deformação permanente das camadas do pavimento.



CAMADA	MATERIAL	TIPO	ESPESSURA (cm)	MÓDULO (MPa)	COEFICIENTE DE POISSON
1	CONCRETO ASFÁLTICO	Misturas CAP 50/70	7,5	4000	0,33
>> 2 <<	BRITA GRADUADA SIMPLES (BGS)	Projeto	20,0	320	0,35
3	SOLO FINO, SILTOSO OU ARGILOSO	Solo Argiloso LG'(1)	20,0	250	0,35
SL	SUBLEITO	Solo Siltoso NS'	0,0	189	0,35

Figura 14 – Tela Principal do software SispavBR

Há ainda diversos outros softwares que poderiam ser mencionados, mas não está no escopo deste trabalho a exaustão do tema. Alguns que podem ser citados são: Circly, Everpave, Kenpave, entre outros.



3 MÉTODO DA PESQUISA

3.1 DEFINIÇÃO CENÁRIOS DE TRÁFEGO

De forma a cumprir as metas e objetivos propostos, o estudo de tráfego trabalhou com a premissa que da frota total circulante de veículos comerciais (que impactam no dimensionamento de pavimentos) é composta por 80% de veículos carregados e 20% vazios. Seguindo o pressuposto do estudo de LASTRAN e DAER, (2003), define-se que 80% da frota trafega com carga máxima no valor máximo estabelecido pelo CTB, (sem considerar a tolerância) e que 20% dos veículos trafegam vazios na busca de carga ou retornando para as bases.

Outro fato importante a ser relatado é a carga por eixo a ser utilizada. A partir deste, mantém-se constante os veículos vazios e variam-se as porcentagens de veículos com sobrecarga e a sobrecarga nestes veículos. A carga por eixo para os veículos vazios (20%) foi considerada como a carga mínima por eixo apresentada por Balbo (2007), sendo para ESRS = 0,5 tf; ESRD = 1,0 tf; ETD = 4,0 tf; ETT = 5,0 tf. Para os demais veículos (80%) foi considerada a carga máxima legal e acrescida às respectivas sobrecargas nas respectivas porcentagens de veículos (5,0, 7,5 e 10%). Para melhor representar, a Tabela 18 apresenta as cargas e sobrecargas de cada eixo utilizadas no presente estudo.

Tabela 18 – Matrix fatorial das cargas utilizadas

Cargas e Sobrecargas	Eixos			
	ESRS	ESRD	ETD	ETT
CML (tf)	6,0	10,0	17,0	25,5
Carga mínima (tf)	0,5	1,0	4,0	5,0
5,0% SC (tf)	6,3	10,5	17,9	26,8
7,5% SC (tf)	6,5	10,8	18,3	27,4
10,0% SC (tf)	6,6	11,0	18,7	28,1

CML = Carga Máxima Legal, SC =Sobrecarga;

Para a determinação do tráfego de projeto e o espectro de cargas, se fizeram as seguintes opções: o tráfego usado foi aquele apresentado no relatório da pesquisa realizada pela Concessionária com uso da ferramenta WIM e que discutiu o tráfego em detalhe na BR-290/RS no km72 da Pista Sul, relatado no Projeto realizado pela Prime Engenharia em 2013 (Brito e Bock, 2013).

A Tabela 19 mostra a determinação do tráfego equivalente em operação de eixos padrão para um ano considerando o espectro de cargas simplificado usado neste projeto. O efeito do acréscimo de carga e sensível em função do reajustamento dos fatores de equivalência utilizado (USACE). Na Tabela 20 está apresentada a atualização do tráfego de 2013, já que foi utilizada a base do banco de dados do WIM (Brito e Bock, 2013) e a composição do N



para um projeto de 10 anos, considerando-se um crescimento geométrico de 3% da carga. A Tabela 21 resume os valores obtidos e o aumento gerado pelas sobrecargas no número total de operação de eixos padrão previsto. Observa-se que um tráfego de 10^8 é nos dias de hoje ainda elevado, principalmente considerando-se um horizonte de 10 anos. Isto é reflexo do elevado volume de veículos comerciais que trafegam na BR-290/RS.

Tabela 19 – Composição do número N para 1 ano nos cenários com 0% de sobrecarga, 5%, 7,5% e 10% respectivamente.

Classificação DNIT	VDM (Carregado)	VDM (Tara)	N° de Eixos	Configuração				FV		N Equiv.
				ESRS	ESRD	ETD	ETT	DNIT (Carreg.)	DNIT (Tara)	
	80%	20%		0,5	1	4	5			
				6	10	17	25,5			
Classe 5	2C	1708	427	2	1	1		3,567	0,000	6092
Classe 6	3C	1522	381	3	1		1	8,827	0,003	13438
Classe 7	4C	626	156	4	1		1	9,578	0,001	5993
TOTAL										
								N _{día}		25523
								N _{ano}		9,32E+06

Classificação DNIT	VDM (Carregado)	VDM (Tara)	N° de Eixos	Configuração				FV		N Equiv.
				ESRS	ESRD	ETD	ETT	DNIT (Carreg.)	DNIT (Tara)	
	80%	20%		0,5	1	4	5			
				6,3	10,5	17,85	26,775			
Classe 5	2C	1708	427	2	1	1		4,801	0,000	8199
Classe 6	3C	1522	381	3	1		1	11,509	0,003	17522
Classe 7	4C	626	156	4	1		1	12,547	0,001	7851
TOTAL										
								N _{día}		33573
								N _{ano}		1,23E+07

Classificação DNIT	VDM (Carregado)	VDM (Tara)	N° de Eixos	Configuração				FV		N Equiv.
				ESRS	ESRD	ETD	ETT	DNIT (Carreg.)	DNIT (Tara)	
	80%	20%		0,5	1	4	5			
				6,45	10,75	18,275	27,4125			
Classe 5	2C	1708	427	2	1	1		5,542	0,000	9465
Classe 6	3C	1522	381	3	1		1	13,082	0,003	19916
Classe 7	4C	626	156	4	1		1	14,294	0,001	8943
TOTAL										
								N _{día}		38324
								N _{ano}		1,40E+07

Classificação DNIT	VDM (Carregado)	VDM (Tara)	N° de Eixos	Configuração				FV		N Equiv.
				ESRS	ESRD	ETD	ETT	DNIT (Carreg.)	DNIT (Tara)	
	80%	20%		0,5	1	4	5			
				6,6	11	18,7	28,05			
Classe 5	2C	1708	427	2	1	1		6,378	0,000	10892
Classe 6	3C	1522	381	3	1		1	14,825	0,003	22571
Classe 7	4C	626	156	4	1		1	16,235	0,001	10158
TOTAL										
								N _{día}		43620
								N _{ano}		1,59E+07



Tabela 20 – Composição do N para os cenários com 0% de sobrecarga, 5%, 7,5% e 10% respectivamente.

	N _{ano}	N _{acumulado}		N _{ano}	N _{acumulado}		N _{ano}	N _{acumulado}		N _{ano}	N _{acumulado}
2013	9,32E+06		2013	1,23E+07		2013	1,40E+07		2013	1,59E+07	
2014	9,60E+06		2014	1,26E+07		2014	1,44E+07		2014	1,64E+07	
2015	9,88E+06	9,88E+06	2015	1,30E+07	1,30E+07	2015	1,48E+07	1,48E+07	2015	1,69E+07	1,69E+07
2016	1,02E+07	2,01E+07	2016	1,34E+07	2,64E+07	2016	1,53E+07	3,01E+07	2016	1,74E+07	3,43E+07
2017	1,05E+07	3,05E+07	2017	1,38E+07	4,02E+07	2017	1,57E+07	4,59E+07	2017	1,79E+07	5,22E+07
2018	1,08E+07	4,13E+07	2018	1,42E+07	5,44E+07	2018	1,62E+07	6,21E+07	2018	1,85E+07	7,07E+07
2019	1,11E+07	5,25E+07	2019	1,46E+07	6,90E+07	2019	1,67E+07	7,88E+07	2019	1,90E+07	8,97E+07
2020	1,15E+07	6,39E+07	2020	1,51E+07	8,41E+07	2020	1,72E+07	9,60E+07	2020	1,96E+07	1,09E+08
2021	1,18E+07	7,57E+07	2021	1,55E+07	9,96E+07	2021	1,77E+07	1,14E+08	2021	2,02E+07	1,29E+08
2022	1,22E+07	8,79E+07	2022	1,60E+07	1,16E+08	2022	1,83E+07	1,32E+08	2022	2,08E+07	1,50E+08
2023	1,25E+07	1,00E+08	2023	1,65E+07	1,32E+08	2023	1,88E+07	1,51E+08	2023	2,14E+07	1,72E+08
2024	1,29E+07	1,13E+08	2024	1,70E+07	1,49E+08	2024	1,94E+07	1,70E+08	2024	2,20E+07	1,94E+08

Tabela 21 – Tráfego N determinado para cada um dos cenários de sobrecarga

Sobrecarga	N _{10anos}	Aumento
0.0%	1.13E+08	
5.0%	1.49E+08	32%
7.5%	1.70E+08	50%
10.0%	1.94E+08	71%

Para cada um dos cenários de tráfego estabelecidos foram calculados também o número N (Tabela 21), a partir dos Fatores de Equivalência de Carga da USACE (utilizado pelo DNIT). Como é sabido a utilização de FEC tenta normalizar o dano causado por um determinado tipo de veículo (tipo de eixo e carga) em relação a um veículo padrão, neste caso um caminhão com eixo traseiro simples de rodas duplas com 8,2t. Para o FEC da USACE o dano considerado é a deformação plástica no topo do subleito. Nota-se que uma elevação na sobrecarga de 5, 7,5 e 10% eleva o número N em 32, 50 e 71%, respectivamente.

Ainda na Tabela 22 é apresentado, de modo ilustrativo, o cálculo do H_m, que é a espessura total de um pavimento flexível, em termos de material granular, calculado pelo Método de Dimensionamento de Pavimentos Flexíveis do DNIT; nota-se que há pouca sensibilidade do referido procedimento em relação ao cálculo de H_m, um aumento de 10% na sobrecarga representa 71% a mais no número N e apenas 1cm a mais de material granular (k=1), ou 0,5cm de revestimento asfáltico (k=2).

De forma semelhante, foram calculadas as espessuras de reforço pelo Procedimento PRO 11/79 (procedimento usual no cálculo de reforço no âmbito do DNIT) e PRO 269/94, considerando deflexão característica de 50.10⁻²mm. Nota-se que, para o PRO 11, uma elevação de 71% no tráfego causa um incremento de 1,65cm na espessura de concreto asfáltico.



Tabela 22 – Cálculo do número N e impacto em projetos novos e restauração

Sobrecarga	N _{10anos}	Aumento	Solução DNIT – Hm ¹	Solução PRO 11	Solução PRO 269
0,0%	1,13E+08	--	73	4,25	5,16
5,0%	1,49E+08	32%	73	5,10	5,16
7,5%	1,70E+08	50%	74	5,50	5,63
10,0%	1,94E+08	71%	74	5,90	6,10

¹ Hm= espessura total equivalente do pavimento

3.2 MONTAGEM DOS ALF'S

Para a verificação da sensibilidade dos métodos de dimensionamento tradicionais à sobrecarga na frota, foram utilizados os fatores de equivalência de carga, conforme discutidos no subcapítulo anterior. Ocorre que para fazer tal consideração no software Paveware®, é necessário que seja determinado o espectro de carga e sua divisão nas várias categorias existentes.

A Figura 15 mostra como é feito a consideração dos dados conforme o manual da AASHTO usando no Paveware. Observa-se que para avaliações no Nível 1 – dados específicos para o site, é necessário usar o banco de dados obtidos por um sistema WIM que possa ser obtido a distribuição das cargas por eixo (*Axle Load Distribution*). Isto é necessário pois, como pode ser visto na Figura 16, a entrada do tráfego exige que se conheça a distribuição estatística das cargas para cada tipo de eixo: simples, tandem, tridem e quad.

Para tanto, é necessário se valer do banco de dados do WIM e fazer uma coerência entre os vários veículos obtendo-se a distribuição estatística dos mesmos.

Site Specific Traffic Inputs
• Initial Two Way Average Annual Daily Truck Traffic (AADTT) • Percent Trucks in Design Lane • Percent Trucks in Design Direction • Operational Speed • Truck Traffic Growth
WIM Traffic Data
• Axle Load Distribution • Normalized Truck Volume Distribution • Axle Load Configurations • Monthly Distribution Factors • Hourly Distribution Factors
Other Inputs
• Dual Tire Spacing • Tire Pressure • Lateral Wander of Axle Loads

Figura 15 – Dados de entrada no Paveware para o tráfego



Month	Class	Total	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000
January	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	5	100	20	0	0	0	0	0	0	0	0	0	40	0	0
January	6	100	20	0	0	0	0	0	0	0	0	0	80	0	0
January	7	100	20	0	0	0	0	0	0	0	0	0	80	0	0
January	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
January	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	5	100	20	0	0	0	0	0	0	0	0	0	40	0	0
February	6	100	20	0	0	0	0	0	0	0	0	0	80	0	0
February	7	100	20	0	0	0	0	0	0	0	0	0	80	0	0
February	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figura 16 – Padrão do ALF (*Axle Load Fator*) considerado na pesquisa

Para que se pudesse fazer as considerações da sobrecarga, simplificou-se todos os veículos em termos da existência de ESRS, ESRD, ETD e ETT. De posse do VDM relatado para cada veículo e sua silhueta, foi determinado o total de eixos de cada tipo. O número de eixos simples na dianteira dos veículos comerciais, remete a determinação do número de veículos na frota. E o número de cada um dos outros eixos, equacionou o percentual do total de eixos. Isto é necessário para viabilizar a composição da frota e sua segmentação conforme o total de cargas para compor o ALF.

A primeira consideração é que 80% dos veículos foram considerados na carga máxima (ou no valor máximo de sobrecarga proposto na análise) e 20% na sua tara – veículos descarregados, e com a menor carga usual na silhueta.

Posteriormente, se determinou o número de cada tipo de eixo para que pudesse ser feita uma distribuição entre os eixos e com isto se fazer a composição de quatro padrões de *Axle Load Factors* (ALFs):

- ALF 1 – na máxima carga legal (0% de sobrecarga) – considerando espectro simplificado da BR-290/RS km72.
- ALF 2 – com 5% de sobrecarga – considerando espectro simplificado da BR-290/RS km72.
- ALF 3 – com 7,5% de sobrecarga – considerando espectro simplificado da BR-290/RS km72.
- ALF 4 – com 10% de sobrecarga – considerando espectro simplificado da BR-290/RS km72.

O espectro é considerado simplificado, pois não foram considerados veículos em cargas intermediárias. Foram considerados que 20% dos veículos estariam na tara e 80% dos veículos carregados. Isto é compatível com a literatura discutida no Capítulo 2 e permite um melhor controle do efeito dos arquivos ALFs na modelagem, já que o objetivo deste trabalho é justamente conhecer o efeito da sobrecarga num cenário dito padrão. Isto facilita também a análise comparativa e coerência com relação aos valores dos fatores de



equivalência de carga – FECs – utilizado na avaliação do IPR719 para pavimentos novos e PRO 11 e PRO 269 para as restaurações.

3.3 APLICAÇÃO DAS METODOLOGIAS CONSOLIDADAS

Para o cálculo de um pavimento novo e da restauração foi considerado o período de projeto de 10 anos, com previsão de abertura em 2015 e taxa de crescimento geométrico de 3%. O fator de distribuição considerado, imaginando duas faixas de tráfego por sentido e seguindo as recomendações do Manual de estudos de Tráfego do DNIT foi de 48% (para tráfego bidirecional), o que conduziu a um NUSACE de $1,13 \times 10^8$ repetições do eixo padrão.

Para o dimensionamento do reforço foram utilizadas três metodologias, as quais são de uso corrente e disseminado no Brasil, são elas o PRO 11, o PRO 269 e o PRO 11 com aplicação da árvore de decisões do CREMA2. Como elementos de entrada, foram admitidas as seguintes premissas:

- mesmo pavimento dimensionado pelo método do DNER;
- mesmo tráfego calculado para o projeto de pavimentos novos;
- a partir dos limites estabelecidos no PER – Programa de Exploração da Rodovia, como critérios de desempenho a serem atendidos, foram estabelecidos como parâmetros: área trincada de 20%; ATR máximo de 5mm; deflexão máxima de 50.10-2mm e; $QI=35$ (que corresponde a um IRI de 2,69);
- assumiu-se que o pavimento possuía um Raio de Curvatura maior que 100m em que o critério de reforço baseado na deflexão é aceito.

3.4 PARÂMETROS CONSIDERADOS NO AASHTOWARE PAVEMENT

A metodologia aplicada para dimensionamento do AASHTOWare Pavement – Paveware®, é a metodologia aplicada pelo Guia da AASHTO 2002, e discutida brevemente no Capítulo 2, no item 2.6. Afora as questões das estruturas consideradas, a maioria dos outros parâmetros de dimensionamento não foram alterados para que não houvesse desvio das análises dos resultados esperados, já que se tem pouco conhecimento da sensibilidade dos parâmetros de calibração no ambiente nacional, e restrita documentação além do território norte-americano.

Desta foram os parâmetros foram na grande maioria os valores default do sistema, afora aqueles que são objeto de discussão como: módulo de elasticidade das camadas granulares e solo, estrutura do pavimento e tipo de ligante que é considerado no software para avaliação do módulo dinâmico da camada asfáltica – parâmetro necessário na modelagem. Ou seja, as análises foram realizadas considerando o chamado dados de entrada Nível 3, a exceção do tráfego que foi considerado Nível 1 – objetivo desta pesquisa. Uma explicação mais detalhada sobre os níveis está apresentada no item 2.6.2.

O ligante adotado foi um PG 76-22 (Superpave) que equivale, em média, a um ligante modificado 60/85E do DNIT, utilizado em rodovias com este tráfego no Brasil. As demais propriedades das misturas asfálticas foram assumidas os valores default do software. A



Figura 17 mostra as características consideradas pelo software para o referido material asfáltico para uma análise Nível 3.

☒ Superpave Performance Grade

☐ Viscosity Grade

☐ Penetration Grade

Binder type: 76-22

A: 9.715 VTS: -3.208

Creep compliance level 3			
Loading Time(sec)	Low Temp (-20 deg C)	Mid Temp (-10 deg C)	High Temp (0 deg C)
1	0.06793303	0.100242	0.1354411
2	0.07382991	0.115599	0.1689883
5	0.08241795	0.1395685	0.2264134
10	0.08957219	0.1609504	0.2824934
20	0.09734744	0.1856079	0.3524639
50	0.1086711	0.2240937	0.4722371
100	0.1181042	0.2584248	0.5892049

Figura 17 – Parâmetros da mistura asfáltica default do software para um ligante PG76-22

Por falta de dados climáticos no banco de dados do software de qualquer região brasileira foram utilizados os dados climáticos da cidade de Savannah, no estado da Geórgia, Estados Unidos, que no entender dos pesquisadores está próximo, em termos de temperaturas e pluviometria do estado do Rio Grande do Sul. A Figura 18 ilustra os dados climáticos de entrada considerados.

AASHTOWare Pavement ME Design Version 2.1 Build 2.1.24 (Date: 07/29/2014)

Menu

Explorer

- Project1 - Novo ALF1
 - Traffic
 - Single Axle Distribution
 - Tandem Axle Distribution
 - Tridem Axle Distribution
 - Quad Axle Distribution
 - Climate
 - AC Layer Properties
 - Pavement Structure
 - Project Specific Calibration Factors
 - Sensitivity
 - Optimization
 - PDF Output Report
 - Excel Output Report
- Project1 - Novo ALF1_50%
- Multiple Project Summary
- Batch Run
- Tools
- ME Design Calibration Factors

Project1 - Novo ALF1:Climate

Climate Station

Longitude (decimal deg) -81.202

Latitude (decimal deg) 32.119

Elevation (m) 8

Depth of water table (m) Annual(3.048)

Climate station SAVANNAH.GA (03)

Identifiers

Description of object

Approver

Date approved 1/19/2015 1:24 PM

Author

Date created 1/19/2015 1:24 PM

County

Province/State

District

Direction of travel

From station (km)

To station (km)

Highway

Revision Number 0

User defined field 1

User defined field 2

User defined field 3

Display name/Identifier

Display name of object/material/project for outputs and graphical interface

Summary

Hourly climate data

Climate Summary

Mean annual air temperature (deg C) 18.7

Mean annual precipitation (mm) 1123.3

Number of wet days 152.4

Freezing index (deg C - days) 56.6

Average annual number of freeze/thaw cycles 20.8

Monthly Temperatures

Average temperature in January (deg C) 9.5

Average temperature in February (deg C) 11.4

Average temperature in March (deg C) 14.7

Average temperature in April (deg C) 18.5

Average temperature in May (deg C) 22.7

Average temperature in June (deg C) 25.4

Average temperature in July (deg C) 27

Average temperature in August (deg C) 26.5

Average temperature in September (deg C) 24.1

Average temperature in October (deg C) 19.3

Average temperature in November (deg C) 14.8

Average temperature in December (deg C) 9.9

Mean annual air temperature (deg C)

Figura 18 – Dados climáticos considerados nas análises com o Paveware.

4 RESULTADOS E DISCUSSÃO

4.1 DIMENSIONAMENTO DE UM PAVIMENTO NOVO – CENÁRIO A

A Figura 19 apresenta o resultado do dimensionamento pelo método do DNIT, o qual serviu de base para o dimensionamento no software Paveware com os quatro cenários de tráfego apresentados.

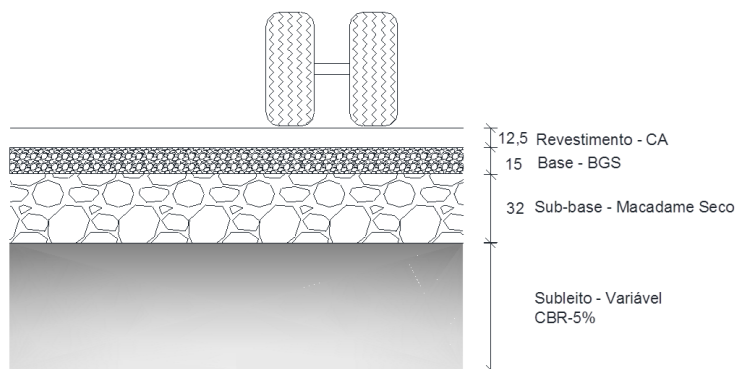


Figura 19 – Pavimento dimensionado pelo método do DNIT

A partir da inserção dos dados no programa, ele calcula, para o período de projeto, se a condição de desempenho é atendida, por exemplo, que o ATR não supere 5mm ou que o IRI não ultrapasse 2,7. Entre a Tabela 23 e a Tabela 26 estão apresentados os resultados sumarizados do projeto do DNIT com os quatro cenários de tráfego considerados (0, 5,0, 7,5 e 10% de sobrecarga).

Como pode ser observado nas referidas Tabelas, os critérios de ruptura (mencionados no item 3.3, ou default do programa) não foram atendidos em nenhum caso. Somente o IRI e a trincamento térmico são atendidos.

De forma a aprofundar as investigações o pavimento dimensionado pelo DNIT foi sendo alterado (para melhor) de forma que se observasse seu comportamento funcional e estrutural frente aos quatro cenários de tráfego considerados. A implementação desta etapa da pesquisa se deu criando, a partir de centenas de análises teste, quatro alternativas, conforme segue:

- Alternativa 1 (CA 12,5cm; BGS 15cm 500MPa; MS 32cm 500MPa; SL 55MPa) – Tabela 27 a Tabela 30;
- Alternativa 2 (CA 12,5cm; BGS 15cm 500MPa; MS 32cm 500MPa; SL 200MPa) – Tabela 31 a Tabela 34;
- Alternativa 3 (CA 20cm; BGS 30cm 500MPa; MS 40cm 500MPa; SL 200MPa) – Tabela 35 e Tabela 38;
- Alternativa 4 (CA 20cm; BGTC 30cm 500MPa; MS 40cm 500MPa; SL 200MPa) – Tabela 39 e Tabela 42;

Ainda, de forma a complementar a análise, foram rodados 4 casos considerando a metade do tráfego, de forma a verificar a influência deste parâmetro no desempenho do pavimento; os resultados estão apresentados entre a Tabela 43 e a Tabela 46.



Projeto Original DNIT (CA 12,5cm PG76-22; BGS 15cm 200MPa; MS 32cm 300MPa; SL 55MPa)

Tabela 23 – Projeto DNIT (CA 12,5cm PG76-22; BGS 15cm 200MPa; MS 32cm 300MPa; SL 55MPa) + 0% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.11	50.00	85.23	Pass
Permanent deformation - total pavement (mm)	5.00	30.38	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	26.00	50.00	47.18	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	645.83	50.00	27.58	Fail
Permanent deformation - AC only (mm)	5.00	14.51	50.00	0.76	Fail

Tabela 24 – Projeto DNIT (CA 12,5cm PG76-22; BGS 15cm 200MPa; MS 32cm 300MPa; SL 55MPa) + 5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.33	50.00	73.16	Pass
Permanent deformation - total pavement (mm)	5.00	34.62	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	41.30	50.00	12.43	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	929.92	50.00	11.34	Fail
Permanent deformation - AC only (mm)	5.00	17.02	50.00	0.34	Fail

Tabela 25 – Projeto DNIT (CA 12,5cm PG76-22; BGS 15cm 200MPa; MS 32cm 300MPa; SL 55MPa) + 7,5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.34	50.00	72.34	Pass
Permanent deformation - total pavement (mm)	5.00	34.87	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	42.70	50.00	10.52	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	903.41	50.00	12.47	Fail
Permanent deformation - AC only (mm)	5.00	16.54	50.00	0.40	Fail

Tabela 26 – Projeto DNIT (CA 12,5cm PG76-22; BGS 15cm 200MPa; MS 32cm 300MPa; SL 55MPa) + 10% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.36	50.00	71.29	Pass
Permanent deformation - total pavement (mm)	5.00	35.20	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	44.10	50.00	8.82	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	905.30	50.00	12.38	Fail
Permanent deformation - AC only (mm)	5.00	16.86	50.00	0.36	Fail

**Alternativa 1 (CA 12,5cm PG76-22; BGS 15cm 500MPa; MS 32cm 500MPa; SL 55MPa)**

Tabela 27 – Alternativa 1 (CA 12,5cm PG76-22; BGS 15cm 500MPa; MS 32cm 500MPa; SL 55MPa) + 0% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.90	50.00	93.56	Pass
Permanent deformation - total pavement (mm)	5.00	28.42	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	6.39	50.00	90.62	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	5.83	50.00	95.66	Pass
Permanent deformation - AC only (mm)	5.00	15.12	50.00	0.62	Fail

Tabela 28 – Alternativa 1 (CA 12,5cm PG76-22; BGS 15cm 500MPa; MS 32cm 500MPa; SL 55MPa) + 5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.04	50.00	88.43	Pass
Permanent deformation - total pavement (mm)	5.00	32.44	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	12.10	50.00	81.94	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	10.97	50.00	92.12	Pass
Permanent deformation - AC only (mm)	5.00	17.74	50.00	0.28	Fail

Tabela 29 – Alternativa 1 (CA 12,5cm PG76-22; BGS 15cm 500MPa; MS 32cm 500MPa; SL 55MPa) + 7,5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.05	50.00	88.12	Pass
Permanent deformation - total pavement (mm)	5.00	32.56	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	12.80	50.00	80.60	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	11.08	50.00	92.06	Pass
Permanent deformation - AC only (mm)	5.00	17.24	50.00	0.32	Fail

Tabela 30 – Alternativa 1 (CA 12,5cm PG76-22; BGS 15cm 500MPa; MS 32cm 500MPa; SL 55MPa) + 10% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.06	50.00	87.55	Pass
Permanent deformation - total pavement (mm)	5.00	32.92	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	13.40	50.00	79.42	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	11.21	50.00	91.98	Pass
Permanent deformation - AC only (mm)	5.00	17.58	50.00	0.29	Fail

**Alternativa 2 (CA 12,5cm PG76-22; BGS 15cm 500MPa; MS 32cm 500MPa; SL 200MPa)**

Tabela 31 – Alternativa 2 (CA 12,5cm PG76-22; BGS 15cm 500MPa; MS 32cm 500MPa; SL 200MPa) + 0% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.69	50.00	98.22	Pass
Permanent deformation - total pavement (mm)	5.00	21.32	50.00	0.01	Fail
AC bottom-up fatigue cracking (percent)	25.00	3.52	50.00	93.86	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	126.33	50.00	73.61	Pass
Permanent deformation - AC only (mm)	5.00	15.63	50.00	0.53	Fail

Tabela 32 – Alternativa 2 (CA 12,5cm PG76-22; BGS 15cm 500MPa; MS 32cm 500MPa; SL 200MPa) + 5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.84	50.00	95.31	Pass
Permanent deformation - total pavement (mm)	5.00	24.78	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	10.90	50.00	84.08	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	428.03	50.00	45.54	Fail
Permanent deformation - AC only (mm)	5.00	18.09	50.00	0.25	Fail

Tabela 33 – Alternativa 2 (CA 12,5cm PG76-22; BGS 15cm 500MPa; MS 32cm 500MPa; SL 200MPa) + 7,5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.83	50.00	95.41	Pass
Permanent deformation - total pavement (mm)	5.00	24.56	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	11.40	50.00	83.21	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	409.09	50.00	47.24	Fail
Permanent deformation - AC only (mm)	5.00	17.57	50.00	0.29	Fail

Tabela 34 – Alternativa 2 (CA 12,5cm PG76-22; BGS 15cm 500MPa; MS 32cm 500MPa; SL 200MPa) + 10% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.85	50.00	95.10	Pass
Permanent deformation - total pavement (mm)	5.00	24.90	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	11.90	50.00	82.31	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	414.77	50.00	46.73	Fail
Permanent deformation - AC only (mm)	5.00	17.91	50.00	0.27	Fail

**Alternativa 3 (CA 20cm PG76-22; BGS 30cm 500MPa; MS 40cm 500MPa; SL 200MPa)**

Tabela 35 – Alternativa 3 (CA 20cm PG76-22; BGS 30cm 500MPa; MS 40cm 500MPa; SL 200MPa) + 0% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.62	50.00	99.11	Pass
Permanent deformation - total pavement (mm)	5.00	19.30	50.00	0.03	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.71	50.00	100.00	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	72.73	50.00	79.27	Pass
Permanent deformation - AC only (mm)	5.00	14.57	50.00	0.74	Fail

Tabela 36 – Alternativa 3 (CA 20cm PG76-22; BGS 30cm 500MPa; MS 40cm 500MPa; SL 200MPa) + 5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.70	50.00	98.20	Pass
Permanent deformation - total pavement (mm)	5.00	22.32	50.00	0.01	Fail
AC bottom-up fatigue cracking (percent)	25.00	1.36	50.00	100.00	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	128.98	50.00	73.36	Pass
Permanent deformation - AC only (mm)	5.00	17.07	50.00	0.34	Fail

Tabela 37 – Alternativa 3 (CA 20cm PG76-22; BGS 30cm 500MPa; MS 40cm 500MPa; SL 200MPa) + 7,5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.69	50.00	98.30	Pass
Permanent deformation - total pavement (mm)	5.00	22.06	50.00	0.01	Fail
AC bottom-up fatigue cracking (percent)	25.00	1.43	50.00	100.00	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	119.51	50.00	74.30	Pass
Permanent deformation - AC only (mm)	5.00	16.57	50.00	0.39	Fail

Tabela 38 – Alternativa 3 (CA 20cm PG76-22; BGS 30cm 500MPa; MS 40cm 500MPa; SL 200MPa) + 10% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.70	50.00	98.18	Pass
Permanent deformation - total pavement (mm)	5.00	22.38	50.00	0.01	Fail
AC bottom-up fatigue cracking (percent)	25.00	1.51	50.00	100.00	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	119.89	50.00	74.25	Pass
Permanent deformation - AC only (mm)	5.00	16.89	50.00	0.36	Fail

**Alternativa 4 (CA 20cm PG76-22; S-C 30cm 500MPa; MS 40cm 500MPa; SL 200MPa)**

Tabela 39 – Alternativa 4 (CA 20cm PG76-22; S-C 30cm 500MPa; MS 40cm 500MPa; SL 200MPa) + 0% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.63	50.00	98.99	Pass
Permanent deformation - total pavement (mm)	5.00	19.31	50.00	0.07	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.00	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.14	-	-	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	365.53	50.00	51.22	Pass
Permanent deformation - AC only (mm)	5.00	16.74	50.00	0.37	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.55	-	-	-

Tabela 40 – Alternativa 4 (CA 20cm PG76-22; S-C 30cm 500MPa; MS 40cm 500MPa; SL 200MPa) + 5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.73	50.00	97.74	Pass
Permanent deformation - total pavement (mm)	5.00	22.44	50.00	0.03	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.00	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.14	-	-	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	744.32	50.00	20.91	Fail
Permanent deformation - AC only (mm)	5.00	19.61	50.00	0.17	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.55	-	-	-

Tabela 41 – Alternativa 4 (CA 20cm PG76-22; S-C 30cm 500MPa; MS 40cm 500MPa; SL 200MPa) + 7,5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.72	50.00	97.88	Pass
Permanent deformation - total pavement (mm)	5.00	22.00	50.00	0.03	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.00	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.14	-	-	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	791.67	50.00	18.09	Fail
Permanent deformation - AC only (mm)	5.00	19.04	50.00	0.19	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.53	-	-	-

Tabela 42 – Alternativa 4 (CA 20cm PG76-22; S-C 30cm 500MPa; MS 40cm 500MPa; SL 200MPa) + 10% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.73	50.00	97.70	Pass
Permanent deformation - total pavement (mm)	5.00	22.36	50.00	0.03	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.00	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.14	-	-	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	831.44	50.00	15.92	Fail
Permanent deformation - AC only (mm)	5.00	19.41	50.00	0.18	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.53	-	-	-

**Com 50% do Tráfego – Projeto Novo**Tabela 43 – Projeto DNIT – 50% de Tráfego – (CA 12,5cm PG76-22; BGS 15cm 200MPa; MS 32cm 300MPa; SL 55MPa) + 0% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.89	50.00	94.13	Pass
Permanent deformation - total pavement (mm)	5.00	25.33	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	13.60	50.00	79.01	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	285.98	50.00	58.58	Pass
Permanent deformation - AC only (mm)	5.00	10.41	50.00	3.60	Fail

Tabela 44 – Projeto DNIT – 50% de Tráfego – (CA 12,5cm PG76-22; BGS 15cm 200MPa; MS 32cm 300MPa; SL 55MPa) + 5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.05	50.00	88.19	Pass
Permanent deformation - total pavement (mm)	5.00	28.75	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	24.00	50.00	52.82	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	465.91	50.00	42.17	Fail
Permanent deformation - AC only (mm)	5.00	12.21	50.00	1.74	Fail

Tabela 45 – Projeto DNIT – 50% de Tráfego – (CA 12,5cm PG76-22; BGS 15cm 200MPa; MS 32cm 300MPa; SL 55MPa) + 7,5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.06	50.00	87.54	Pass
Permanent deformation - total pavement (mm)	5.00	29.11	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	25.10	50.00	49.72	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	446.97	50.00	43.84	Fail
Permanent deformation - AC only (mm)	5.00	11.86	50.00	1.98	Fail

Tabela 46 – Projeto DNIT – 50% de Tráfego – (CA 12,5cm PG76-22; BGS 15cm 200MPa; MS 32cm 300MPa; SL 55MPa) + 10% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.08	50.00	86.99	Pass
Permanent deformation - total pavement (mm)	5.00	29.34	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	26.10	50.00	46.90	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	448.86	50.00	43.68	Fail
Permanent deformation - AC only (mm)	5.00	12.09	50.00	1.81	Fail



A partir dos dados apresentados, montou-se a Tabela 47, que traz os valores absolutos de cada caso estudado dos principais parâmetros de desempenho, que no caso em tela, tem relevância e são comumente considerados no Brasil, além de uma comparação (% redução destes parâmetros, quando a sobrecarga de 5, 7,5 e 10% é imposta ao pavimento. Também é apresentado, em vermelho, um comparativo da estrutura de referencia (DNIT, sem sobrecarga) com a alternativa em estudo (também sem sobrecarga).

Como ilustração, com 5% de sobrecarga média na frota, observa-se um aumento de 59% no trincamento por fadiga, 44% no trincamento top-down e 17% de aumento na deformação permanente, sendo que todos os parâmetros mencionados não atendem os requisitos mínimos de projeto.

A alteração da sobrecarga de 5 para 7,5 e 10% tem menor efeito que do caso sem sobrecarga para 5%, isso pode ser consequência da imprecisão nos dados de entrada de tráfego, os veículos são divididos em bandas e nem sempre um aumento de 2,5 ou 5% faz com que o veículo passe de categoria, em termos de carga por eixo.

Outro aspecto a mencionar é que nenhum pavimento (mesmo com 50% da carga) passa em todos os critérios, isso pode ser explicado pelos seguintes motivos:

- o tráfego considerado, comum nas rodovias brasileiras, é muito elevado, na casa de 108 repetições e, segundo o software, soluções em pavimento flexível tem se mostrado inadequadas (com os materiais testados);
- o limite de 5mm de ATR é extremamente severo e mesmo com a alteração para um ligante PG 82, este limite não é satisfeito;
- a camada de concreto asfáltico tem apresentado muita deformação permanente (apesar de utilizar PG 76-22) e talvez, para este tráfego, misturas tipo SMA ou alto módulo pudessem compor as camadas de revestimento.

O conjunto completo dos dados de saída do software encontram-se no Anexo 4.



Tabela 47 – Resumo comparativo dos resultados – Cenário A – Pavimento Novo

Projeto DNIT (CA 12,5cm; BGS 15cm 200MPa; MS 32cm 300MPa; SL 55MPa)				
Parâmetro	Sobrecarga Eixo			
	0,0%	5,0%	7,5%	10,0%
Fadiga (%)	26,0	41,3	42,7	44,1
Top-down (m)	645,8	929,9	903,4	905,3
ATR (mm)	14,5	17,0	16,5	16,9
% de redução				
Fadiga	--	59%	64%	70%
Top-down	--	44%	40%	40%
ATR	--	17%	14%	16%
Alternativa 1 (CA 12,5cm; BGS 15cm 500MPa; MS 32cm 500MPa; SL 55MPa)				
Parâmetro	Sobrecarga Eixo			
	0,0%	5,0%	7,5%	10,0%
Fadiga (%)	6,4	12,1	12,8	13,4
Top-down (m)	5,8	11,0	11,1	11,2
ATR (mm)	15,1	17,7	17,2	17,6
% de redução				
Fadiga	-75%	89%	100%	110%
Top-down	-99%	88%	90%	92%
ATR	4%	17%	14%	16%
Alternativa 2 (CA 12,5cm; BGS 15cm 500MPa; MS 32cm 500MPa; SL 200MPa)				
Parâmetro	Sobrecarga Eixo			
	0,0%	5,0%	7,5%	10,0%
Fadiga (%)	3,5	10,9	11,4	11,9
Top-down (m)	126,3	428,0	409,1	414,8
ATR (mm)	15,6	18,1	17,6	17,9
% de redução				
Fadiga	-86%	210%	224%	238%
Top-down	-80%	239%	224%	228%
ATR	8%	16%	12%	15%
Alternativa 3 (CA 20cm; BGS 30cm 500MPa; MS 40cm 500MPa; SL 200MPa)				
Parâmetro	Sobrecarga Eixo			
	0,0%	5,0%	7,5%	10,0%
Fadiga (%)	0,7	1,4	1,4	1,5
Top-down (m)	72,7	129,0	119,5	119,9
ATR (mm)	14,6	17,1	16,6	16,9
% de redução				
Fadiga	-97%	92%	101%	113%
Top-down	-89%	77%	64%	65%
ATR	0%	17%	14%	16%
Alternativa 4 (CA 20cm ; BGTC 30cm 500MPa; MS 40cm 500MPa; SL 200MPa)				
Parâmetro	Sobrecarga Eixo			
	0,0%	5,0%	7,5%	10,0%
Fadiga (%)	0,0	0,0	0,0	0,0
Top-down (m)	365,5	744,0	791,7	831,4
ATR (mm)	16,7	19,6	19,0	19,4
% de redução				
Fadiga	-100%	0%	0%	0%
Top-down	-43%	104%	117%	127%
ATR	15%	17%	14%	16%
50% do Tráfego - Projeto DNIT				
Parâmetro	Sobrecarga Eixo			
	0,0%	5,0%	7,5%	10,0%
Fadiga (%)	13,6	24	25,1	26,1
Top-down (m)	285,9	465,9	446,9	448,8
ATR (mm)	10,4	12,21	11,8	12,09
% de redução				
Fadiga	-48%	76%	85%	92%
Top-down	-56%	63%	56%	57%
ATR	-28%	17%	13%	16%



4.2 DIMENSIONAMENTO DE REFORÇO DE PAVIMENTO – CENÁRIO B

Conforme estabelecido no projeto, foi dimensionado um reforço estrutural do pavimento, partindo-se das premissas estabelecida de que a trincada estivesse em 20%; ATR máximo de 5mm; deflexão máxima de 50.10^{-2} mm e; $QI=35$ (que corresponde a um IRI de 2,7), através das metodologias consolidadas PRO 11/79, PRO 269/94 e PRO 11/79 + árvore de decisão CREMA 2 e os resultados foram os seguintes:

- Intervenção PRO 11/79: 4,25cm de reforço em concreto asfáltico;
- Intervenção PRO 269/94: 5,16cm de reforço em concreto asfáltico;
- Intervenção PRO 11/79 + árvore de decisão CREMA 2: Fresagem de 5cm (em 5% da área) + 4,25 cm de reforço em concreto asfáltico e acostamento em Tratamento Superficial Duplo.

O tráfego considerado foi o sem sobrecarga com $N=1,13.10^8$ repetições do eixo padrão. Do ponto de vista prático a solução do PRO 11/79 é adotada como solução em projetos correntes do DNIT no programa CREMA2 e desta forma foi adotada referência na presente pesquisa. Como a espessura calculada foi de 4,25cm, na prática adotou-se 5,00, o que está muito próximo da solução do PRO 269/94.

Desta forma foram simuladas, no software AASHTO a condição do pavimento dimensionado pelo DNIT (estrutura bastante comum no Brasil) com 5cm de reforço em concreto asfáltico e os 4 cenários de tráfego em estudo. Entre a Tabela 48 e a Tabela 63 estão apresentados os resultados obtidos. Pode-se observar que nos quatro casos a reflexão de trincas e a deformação permanente não atingem o critério de aceitação e o projeto é reprovado.

De maneira semelhante ao Cenário A – Dimensionamento de Pavimentos Novos, buscou-se compreender o efeito de outras variáveis no desempenho do pavimento. Neste caso de reforço optou-se por aumentar a espessura de reforço asfáltico para 7,5, 10 e 12,5cm, além do caso com 50% do tráfego. Estes resultados estão apresentados entre a Tabela 64 e a Tabela 67.

**Projeto de Reforço PRO-11 (Pavimento Degradado + 5cm de CA Recape)**

Tabela 48 – Projeto Reforço PRO-11 (Pavimento Degradado + 5cm de CA Recape) + 0% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.45	50.00	99.88	Pass
Permanent deformation - total pavement (mm)	19.00	11.38	50.00	99.21	Pass
Total Cracking (Reflective + Alligator) (percent)	15	21.02	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	120.64	50.00	74.18	Pass
Permanent deformation - AC only (mm)	5.00	11.02	50.00	2.78	Fail

Tabela 49 – Projeto Reforço PRO-11 (Pavimento Degradado + 5cm de CA Recape) + 5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.49	50.00	99.78	Pass
Permanent deformation - total pavement (mm)	19.00	12.86	50.00	95.79	Pass
Total Cracking (Reflective + Alligator) (percent)	15	21.90	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	208.33	50.00	65.83	Pass
Permanent deformation - AC only (mm)	5.00	12.85	50.00	1.36	Fail

Tabela 50 – Projeto Reforço PRO-11 (Pavimento Degradado + 5cm de CA Recape) + 7,5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.48	50.00	99.81	Pass
Permanent deformation - total pavement (mm)	19.00	12.44	50.00	97.10	Pass
Total Cracking (Reflective + Alligator) (percent)	15	22.01	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	198.86	50.00	66.72	Pass
Permanent deformation - AC only (mm)	5.00	12.43	50.00	1.59	Fail

Tabela 51 – Projeto Reforço PRO-11 (Pavimento Degradado + 5cm de CA Recape) + 10% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.48	50.00	99.79	Pass
Permanent deformation - total pavement (mm)	19.00	12.72	50.00	96.27	Pass
Total Cracking (Reflective + Alligator) (percent)	15	22.12	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	198.86	50.00	66.72	Pass
Permanent deformation - AC only (mm)	5.00	12.71	50.00	1.43	Fail

**Projeto de Reforço (Pavimento Degradado + 7,5cm de CA Recape)**

Tabela 52 – Projeto Reforço (Pavimento Degradado + 7,5cm de CA Recape) + 0% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.46	50.00	99.86	Pass
Permanent deformation - total pavement (mm)	19.00	11.98	50.00	98.25	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.46	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	21.02	50.00	88.07	Pass
Permanent deformation - AC only (mm)	5.00	11.84	50.00	2.00	Fail

Tabela 53 – Projeto Reforço (Pavimento Degradado + 7,5cm de CA Recape) + 5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.50	50.00	99.73	Pass
Permanent deformation - total pavement (mm)	19.00	13.86	50.00	91.34	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.87	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	37.50	50.00	84.26	Pass
Permanent deformation - AC only (mm)	5.00	13.86	50.00	0.95	Fail

Tabela 54 – Projeto Reforço (Pavimento Degradado + 7,5cm de CA Recape) + 7,5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.49	50.00	99.76	Pass
Permanent deformation - total pavement (mm)	19.00	13.45	50.00	93.39	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.93	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	36.17	50.00	84.51	Pass
Permanent deformation - AC only (mm)	5.00	13.45	50.00	1.09	Fail

Tabela 55 – Projeto Reforço (Pavimento Degradado + 7,5cm de CA Recape) + 10% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.50	50.00	99.74	Pass
Permanent deformation - total pavement (mm)	19.00	13.72	50.00	92.07	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.98	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	36.17	50.00	84.51	Pass
Permanent deformation - AC only (mm)	5.00	13.72	50.00	0.99	Fail

**Projeto de Reforço (Pavimento Degradado + 10cm de CA Recape)**

Tabela 56 – Projeto Reforço (Pavimento Degradado + 10cm de CA Recape) + 0% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.46	50.00	99.84	Pass
Permanent deformation - total pavement (mm)	19.00	12.29	50.00	97.49	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.21	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	2.10	50.00	99.19	Pass
Permanent deformation - AC only (mm)	5.00	12.26	50.00	1.70	Fail

Tabela 57 – Projeto Reforço (Pavimento Degradado + 10cm de CA Recape) + 5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.51	50.00	99.69	Pass
Permanent deformation - total pavement (mm)	19.00	14.37	50.00	88.30	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.40	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	3.79	50.00	97.55	Pass
Permanent deformation - AC only (mm)	5.00	14.37	50.00	0.79	Fail

Tabela 58 – Projeto Reforço (Pavimento Degradado + 10cm de CA Recape) + 7,5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.50	50.00	99.73	Pass
Permanent deformation - total pavement (mm)	19.00	13.96	50.00	90.75	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.43	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	3.73	50.00	97.62	Pass
Permanent deformation - AC only (mm)	5.00	13.96	50.00	0.91	Fail

Tabela 59 – Projeto Reforço (Pavimento Degradado + 10cm de CA Recape) + 10% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.51	50.00	99.70	Pass
Permanent deformation - total pavement (mm)	19.00	14.23	50.00	89.18	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.45	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	3.73	50.00	97.62	Pass
Permanent deformation - AC only (mm)	5.00	14.23	50.00	0.83	Fail

**Projeto de Reforço (Pavimento Degradado + 12,5cm de CA Recape)**

Tabela 60 – Projeto Reforço (Pavimento Degradado + 12,5cm de CA Recape) + 0% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.45	50.00	99.87	Pass
Permanent deformation - total pavement (mm)	19.00	11.78	50.00	98.53	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.09	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	0.12	50.00	100.00	Pass
Permanent deformation - AC only (mm)	5.00	11.78	50.00	2.05	Fail

Tabela 61 – Projeto Reforço (Pavimento Degradado + 12,5cm de CA Recape) + 5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.50	50.00	99.74	Pass
Permanent deformation - total pavement (mm)	19.00	13.81	50.00	91.62	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.18	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	0.21	50.00	100.00	Pass
Permanent deformation - AC only (mm)	5.00	13.81	50.00	0.97	Fail

Tabela 62 – Projeto Reforço (Pavimento Degradado + 12,5cm de CA Recape) + 7,5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.49	50.00	99.77	Pass
Permanent deformation - total pavement (mm)	19.00	13.42	50.00	93.55	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.19	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	0.22	50.00	100.00	Pass
Permanent deformation - AC only (mm)	5.00	13.42	50.00	1.11	Fail

Tabela 63 – Projeto Reforço (Pavimento Degradado + 12,5cm de CA Recape) + 10% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.50	50.00	99.75	Pass
Permanent deformation - total pavement (mm)	19.00	13.68	50.00	92.29	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.21	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	0.24	50.00	100.00	Pass
Permanent deformation - AC only (mm)	5.00	13.68	50.00	1.01	Fail

**Projeto de Reforço PRO-11 – 50% Tráfego – (Pavimento Degradado + 5cm de CA Recape)**

Tabela 64 – Projeto Reforço PRO-11 – 50% Tráfego – (Pavimento Degradado + 5cm de CA Recape) + 0% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.35	50.00	99.97	Pass
Permanent deformation - total pavement (mm)	19.00	7.77	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.51	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	43.75	50.00	83.20	Pass
Permanent deformation - AC only (mm)	5.00	7.49	50.00	14.15	Fail

Tabela 65 – Projeto Reforço PRO-11 – 50% Tráfego – (Pavimento Degradado + 5cm de CA Recape) + 5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.38	50.00	99.96	Pass
Permanent deformation - total pavement (mm)	19.00	8.74	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	20.96	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	77.65	50.00	78.71	Pass
Permanent deformation - AC only (mm)	5.00	8.73	50.00	7.68	Fail

Tabela 66 – Projeto Reforço PRO-11 – 50% Tráfego – (Pavimento Degradado + 5cm de CA Recape) + 7,5% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.37	50.00	99.96	Pass
Permanent deformation - total pavement (mm)	19.00	8.45	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	21.02	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	74.05	50.00	79.13	Pass
Permanent deformation - AC only (mm)	5.00	8.45	50.00	8.81	Fail

Tabela 67 – Projeto Reforço PRO-11 – 50% Tráfego – (Pavimento Degradado + 5cm de CA Recape) + 10% de sobrecarga

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.38	50.00	99.96	Pass
Permanent deformation - total pavement (mm)	19.00	8.64	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	21.07	-	-	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC bottom-up fatigue cracking (percent)	20.00	0.00	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	74.05	50.00	79.13	Pass
Permanent deformation - AC only (mm)	5.00	8.64	50.00	8.04	Fail



De forma a sintetizar os resultados obtidos e permitir uma fácil visualização dos resultados foi construída a Tabela 68 que apresenta os valores absolutos de cada caso estudado com os principais parâmetros de desempenho, que no caso em tela, tem relevância e são comumente considerados no Brasil, além de uma comparação (% redução destes parâmetros, quando a sobrecarga de 5, 7,5 e 10% é imposta ao pavimento. Também é apresentado, em vermelho, um comparativo da estrutura de referencia (DNIT, sem sobrecarga + solução PRO11/79) com a alternativa em estudo (também sem sobrecarga). A partir da análise destes dados desprende-se as seguintes observações:

- a alteração de carregamento de 0 para 5% de sobrecarga tem maior impacto no desempenho que a mudanças entre os níveis de sobrecarga; isso pode estar relacionado a escala de carregamento utilizada na montagem dos ALFs que é especificada pelo software.
- a elevação da espessura de reforço em concreto asfáltico possibilita a redução importante nos trincamentos (*top - down*, principalmente), mas tem efeito inverso no ATR indicando que a camada de revestimento é que está deformando e ultrapassando os 5mm dados como requisito de projeto. O critério de reflexão de trincas de 15%, *default* do programa, também não é alcançado. Um estudo pormenorizado das propriedades da mistura asfáltica e de seu impacto neste caso é relevante;
- o estudo com 50% do tráfego mostra se importantes reduções nos índices de degradação indicando que o software é sensível a isso e valida a presente análise.

Os resultados das análises estão apresentados na íntegra no Anexo 5.



Tabela 68 – Resumo comparativo dos resultados – Cenário B

PRO-11 - Pavimento antigo + 5cm de capa				
Parâmetro	Sobrecarga Eixo			
	0,0%	5,0%	7,5%	10,0%
Reflexão +Fadiga (%)	21,02	21,9	22,01	22,12
Top-down (m)	120,6	208,3	198,8	198,86
ATR (mm)	11,0	12,8	12,4	12,71
% de redução				
Reflexão +Fadiga (%)	--	4%	5%	5%
Top-down	--	73%	65%	65%
ATR	--	16%	13%	16%

Pavimento antigo + 7,5cm de capa				
Parâmetro	Sobrecarga Eixo			
	0,0%	5,0%	7,5%	10,0%
Reflexão +Fadiga (%)	20,5	20,9	20,9	21,0
Top-down (m)	21,0	37,5	36,2	36,2
ATR (mm)	11,8	13,9	13,5	13,7
% de redução				
Reflexão +Fadiga (%)	-3%	2%	2%	3%
Top-down	-83%	78%	72%	72%
ATR	7%	17%	14%	16%

Pavimento antigo + 10cm de capa				
Parâmetro	Sobrecarga Eixo			
	0,0%	5,0%	7,5%	10,0%
Reflexão +Fadiga (%)	20,2	20,4	20,4	20,5
Top-down (m)	2,1	3,8	3,7	3,7
ATR (mm)	12,2	14,4	14,0	14,2
% de redução				
Reflexão +Fadiga (%)	-4%	1%	1%	1%
Top-down	-98%	80%	78%	78%
ATR	11%	18%	14%	17%

Pavimento antigo + 12,5cm de capa				
Parâmetro	Sobrecarga Eixo			
	0,0%	5,0%	7,5%	10,0%
Reflexão +Fadiga (%)	20,1	20,2	20,2	20,2
Top-down (m)	0,1	0,2	0,2	0,2
ATR (mm)	11,8	13,8	13,4	13,7
% de redução				
Reflexão +Fadiga (%)	-4%	0%	0%	1%
Top-down	-100%	75%	83%	100%
ATR	7%	17%	14%	16%

50% do Tráfego				
PRO-11 - Pavimento antigo + 5cm de capa				
Parâmetro	Sobrecarga Eixo			
	0,0%	5,0%	7,5%	10,0%
Reflexão +Fadiga (%)	20,51	20,96	21,02	21,07
Top-down (m)	43,75	77,6	74,05	74,05
ATR (mm)	7,49	8,7	8,45	8,64
% de redução				
Reflexão +Fadiga (%)	-2%	2%	2%	3%
Top-down	-64%	77%	69%	69%
ATR	-32%	16%	13%	15%



5 CONCLUSÕES E SUGESTÕES

5.1 CONCLUSÕES

A partir da realização da pesquisa é possível destacar as seguintes conclusões:

- No que diz respeito a implementação do software *AASHTOWare* a equipe teve dificuldades operacionais pois, apesar de utilizar computadores em língua inglesa os resultados obtidos não condiziam com os testes de referência fornecidos pela AASHTO. A solução de troca do sistema operacional por inglês nativo foi uma decisão acertada da equipe depois de inúmeros contatos telefônicos com a assistência norte americana.
- A carga tem grande impacto tanto no dimensionamento de pavimentos novos quanto em restaurações; o nível de tráfego adotado na pesquisa é bastante severo e as soluções em pavimento flexível parecem não ser as mais indicadas, principalmente para pavimentos novos.
- O impacto determinado pelo uso da metodologia da AASHTO 2002, com base no uso do *AASHTOWare* se mostrou mais sensível às sobrecargas do que a metodologia nacional em uso, tanto para pavimentos novos quanto restaurações.
- Os limites de desempenho mínimo adotados, baseados nos manuais do DNIT e nos Programas de Exploração Rodoviários (quando existentes) são compatíveis com aqueles utilizados no programa, com exceção da deformação permanente. Nesta pesquisa foi adotado o valor de 5mm para o revestimento o que não foi conseguido em nenhum dos casos analisados.
- A tecnologia dos materiais se mostrou na maioria dos cenários simulados mais efetiva na contenção dos mecanismos de degradação do que aumentos de espessura. Apesar dos testes não serem extensivos, foi notável que a tecnologia da mistura, pouco considerada pelos métodos brasileiros disponíveis, é aspecto chave para a previsão de desempenho dos pavimentos.

5.2 SUGESTÕES PARA TRABALHOS FUTUROS

Como sugestões para trabalhos futuros a equipe recomenda:

- Realização de pesquisa para calibração de modelos de desempenho baseados em desempenho de pavimentos brasileiro;
- montagem de cenários de tráfego a partir de WIM para rodovias nacionais de forma a conhecer o espectro de cargas rodante;
- realizar a caracterização avançada de materiais de forma a permitir análises com maior confiabilidade;
- estudo da influência das propriedades das misturas asfálticas no desempenho dos pavimentos novos e reforço.



5.3 CONSOLIDAÇÃO DAS METAS

Com relação aos objetivos e metas estabelecidos no projeto, de forma a sistematizar a análise do relatório, foram listadas primeiramente os objetivos específicos e em seguida as metas com os devidos comentários a respeito dos resultados alcançados.

Dos objetivos específicos:

1. Estabelecer um espectro de cargas padrão com determinação das cargas máximas legais, sobrecarga máxima aceitável considerando as imprecisões de equipamento de medição admissíveis, ou seja, “sobrecarga legal”, e as cargas rodantes do espectro.

Cumprido, apresentado no item 3.1 Definição cenários de tráfego e materializado na montagem dos ALFs.

2. Identificar os métodos aplicáveis de dimensionamento de pavimentos novos e reabilitações utilizadas no cenário nacional, com ênfase da sua sensibilidade ao impacto da sobrecarga no número N, tradicionalmente usado nos projetos.

Cumprido, apresentado no item 3.1 Definição cenários de tráfego.

3. Utilizar o software da AASHTOware® Pavement ME para dimensionamento e modelagem de performance de pavimentos novos e reabilitados considerando um pavimento típico da região sul do país.

Cumprido, foram rodados centenas de casos, os relatórios completos encontram-se nos Anexos 4 e 5.

Das etapas do projeto:

1. Breve revisão dos métodos de dimensionamento de pavimentos novos e reabilitações utilizados no Brasil, apontando os dados de entrada e sua sensibilidade às cargas dos veículos, bem como as tendências de novos projetos.

Cumprido, a revisão do método de dimensionamento de pavimentos do DNIT está apresentada na revisão de literatura, bem como dos métodos de dimensionamento de reforços PRO 11/79, 269 e soluções adotadas no CREMA2. A tendência de novos projetos aparece quando se trata de análise mecânica, lei de Minner e dos softwares como o Paveware e o Sispav.

2. Determinar os fatores de equivalência de carga correntemente utilizado nos projetos de pavimentação.

Cumprido, apresentado na revisão toda a conceituação dos FEC do USCAE e da AASHTO, bem como as equações de cálculo (item 2.2 - Fator de equivalência de cargas).



3. Identificar um cenário de espectro de cargas típicos rodantes nas rodovias do (a partir de pesquisa previamente realizada), com cargas padrão e rodantes de forma a compor um fluxo de veículos.

Cumprido, foram adotados, a partir de pesquisa anterior, para montagem dos ALFs o espectro de carga da rodovia BR 290, dados de coleta de campo a partir da pesagem em movimento (WIM).

4. Compilar as leis que em vigor sobre as sobrecargas de veículos comerciais identificando as máximas cargas rodantes e os valores de sobrecarga máximo considerados para imprecisão de pesagens.

Cumprido, está apresentado na revisão de literatura, item 2.4 - Cargas máximas legais.

5. Compor o número N para o projeto a ser analisado, tanto em termos de um projeto de restauração, quanto em termos de pavimentos novos.

Cumprido, no item 3.1 - Definição cenários de tráfego.

6. Validar o novo software AASHTOware® Pavement ME lançado em 2013, para uso nos projetos de pavimentos novos e restauração considerando o espectro de cargas determinados em (Etapa 3).

Cumprido, o software foi utilizado por mais de uma centena de vezes, foram rodados exemplos e validados, inclusive, com o apoio do suporte norte americano.

7. Montagem de um Cenário A – Pavimento novo – utilizado como referência considerando um tráfego de projeto com e sem sobrecarga legal.

Cumprido, o pavimento foi dimensionado e analisado, item 4.2 - Dimensionamento de um Pavimento Novo – Cenário A.

8. Montagem de um Cenário B – Reabilitação de pavimentos - utilizado como referência considerando um tráfego de projeto com e sem sobrecarga legal.

Cumprido, o pavimento foi dimensionado segundo a metodologia utilizada no Brasil e a mais comum serviu de base para as análises no Paveware. Esta apresentado no item 4.2 - Dimensionamento de Reforço de Pavimento – Cenário B.

9. Comparação dos métodos nos Cenários montados e discussão sobre o efeito da sobrecarga legal nos projetos de pavimentos novos e reabilitados.

Cumprido, apresentado no capítulo dos resultados (4).

10. Discussão do efeito da sobrecarga legal nos projetos de pavimentos novos e reabilitados.

Cumprido, apresentado no capítulo dos resultados (4).

11. Considerações sobre a performance dos pavimentos com uso de modelos do AASHTOware® Pavement ME.



Cumprido, apresentado no capítulo dos resultados e nas conclusões.

12. Elaboração de relatório final e apresentação à Concessionária de resultados.

Cumprido, materializado no presente relatório.



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ANEXO 1 – PRO 11/79

1 OBJETIVO

Esta norma tem por objetivo estabelecer os procedimentos necessários para a avaliação estrutural dos pavimentos flexíveis existentes, apontar as causas de suas deficiências e fornecer elementos para o cálculo da vida restante ou do reforço necessário para um novo número de solicitações de eixos equivalentes ao eixo padrão durante o período considerado (número N).

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DNER-ME 024/94 - Determinação da Deflexões no Pavimento pela Viga Benkelman.

3 CONCEITUAÇÃO E DEFINIÇÕES

Estes procedimentos foram desenvolvidos baseados no critério de deformabilidade dos pavimentos flexíveis, que são expressos na prática pela medida de deflexões recuperáveis, pois, apesar de todas as limitações deste processo, a experiência tem demonstrado que, de uma maneira geral, existe uma correlação entre a magnitude das deflexões (e do raio de curvatura correspondente) e o aparecimento de falhas nos pavimentos flexíveis. Em virtude da grande variação de suporte estrutural que se observa nos pavimentos, inclusive naqueles bem construídos, usa-se critério estatístico para interpretação das medidas.

No Brasil, já existe considerável experiência sobre medida de deflexão, e é corriqueiro entre nós a "auscultação" de um pavimento por intermédio de medidas de deflexão, pelo menos como uma primeira fase, que pode ser também a única, de avaliação estrutural. Assim, se considerar-se o comportamento de um pavimento bem construído, que ao longo de seu período de vida é solicitado não só pelo tráfego, que o submete a esforços diversos de compressão, cisalhamento e flexão, como também pelos fatores de clima, como precipitações pluviométricas e mudanças de temperatura, causando a fadiga de toda a estrutura do mesmo, pode distinguir-se, com respeito à deflexão, as seguintes fases da vida do pavimento, conforme na figura 1.

3.1 Fase de Consolidação

Fase que sucede imediatamente à construção, sendo caracterizada por um decréscimo desacelerado do valor da deflexão, decorrente da consolidação adicional proporcionada pelo tráfego nas diversas camadas do pavimento. O valor da deflexão tende a se estabilizar ao fim desta primeira fase.

3.2 Fase Elástica

Fase que sucede à de consolidação, e ao longo da qual o valor da deflexão do pavimento, a menos das variações sazonais, se mantém aproximadamente constante ou cresce ligeiramente.

Essa fase define a vida útil do pavimento, tendendo a se alongar na produção da diferença verificada entre a deflexão admissível e a deflexão suportada pelo pavimento.

Aprovada pelo Conselho de Administração em 29/01/79

Resolução nº / , Sessão nº CA/ /

Processo nº 20100028446/78

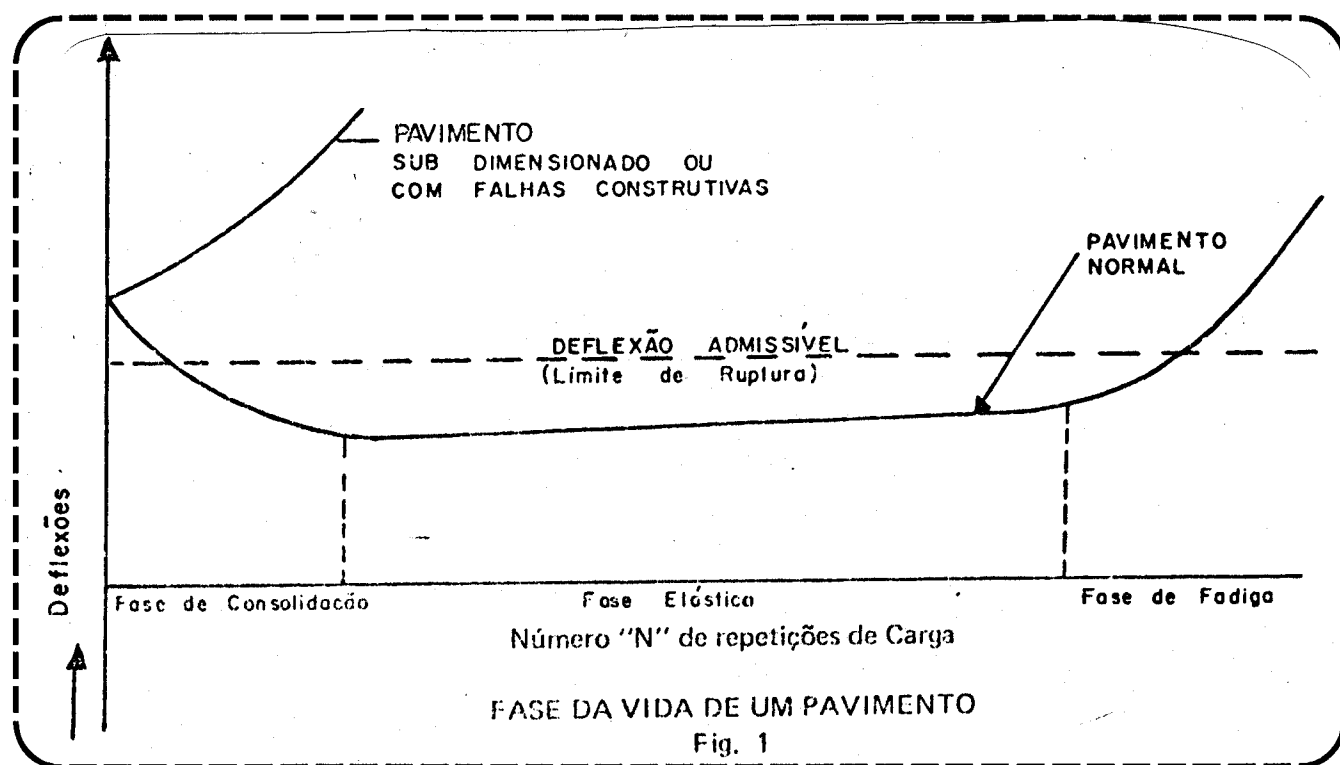
Autor : DNER/DrDTc (IPR) .

3.3 Fase de Fadiga

Fase que sucede à elástica, caracterizando-se por um crescimento acelerado do valor de deflexão do pavimento, na medida em que a estrutura começa a exteriorizar os efeitos da fadiga, representados por fissuras, trincas e acúmulo de deformações permanentes sob cargas repetidas. Caso não se tomem medidas para esforço e recuperação do pavimento, observa-se, geralmente, nesta fase um processo acelerado de degradação do pavimento.

Nota - Evidentemente, um pavimento flexível bem projetado será tanto melhor, técnica e economicamente, quanto maior for a sua fase elástica, que está limitada, de uma maneira geral, pelo número de solicitações das cargas de roda e por diversos fatores que causam deficiências no revestimento e na estrutura do pavimento, dos quais podem destacar-se:

- falhas da fundação, na qual estão incluídas as deficiências do subleito e do próprio corpo dos aterros;
- deficiências de drenagem;
- deficiências de projeto;
- falhas construtivas em uma ou mais camadas do pavimento.



O modo como as solicitações das cargas de roda atuam em um pavimento flexível pode ser ilustrado conforme é mostrado na figura nº 2, que representa esquematicamente um pavimento flexível constituído de revestimento betuminoso, base e sub-base granulares, construído sobre subleito suposto homogêneo. A ação de uma carga de roda, P , aplicada sobre a superfície da estrutura, provocará na face inferior do revestimento o desenvolvimento de uma tensão de tração σ_t , decorrente de deformação de tração ϵ_t , e, na superfície do subleito, uma pressão vertical, P .

Admitindo-se que os materiais integrantes das camadas do pavimento atendem às especificações, no que concerne à respectiva resistência ao cisalhamento, a possibilidade de deformações ou rupturas plásticas restringir-se-ão ao subleito. Tais rupturas são evitadas sempre que o valor da pressão vertical atuante, P , for mantido abaixo do valor da pressão vertical admissível pelo material do subleito, P_{adm} . Para garantir essa condição, o pavimento deve ter uma espessura igual ou superior à indicada, por exemplo, pelo ISC (Índice de Suporte Califórnia) do subleito.

Para que não surjam trincas no revestimento, é necessário manter a deflexão, D , abaixo de um valor máximo, D_{adm} , e o raio de curvatura, R , do pavimento, acima de um certo valor mínimo. Isto garante que a tensão de tração σ_t , correspondente à deformação ϵ_t , na face inferior do revestimento, não ultrapasse um determinado valor, acima do qual o revestimento betuminoso romper-se-á por fadiga.

4 ESTUDOS

Os estudos recomendados para avaliação estrutural dos pavimentos flexíveis e das suas deficiências compreendem os seguintes procedimentos:

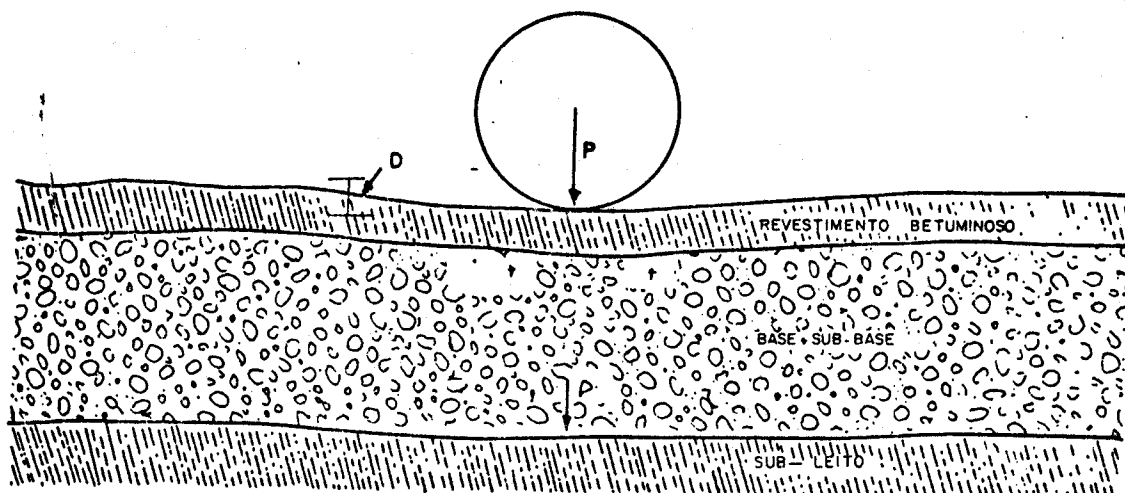
4.1 Estudos Preliminares

Os estudos preliminares do pavimento existente têm como objetivo fornecer uma idéia geral de sua constituição ao longo do trecho, das solicitações por ele já suportadas, bem como do número daqueles que irá suportar durante um novo período de exposição ao tráfego. Estes estudos compreendem:

4.1.1 Levantamento Histórico do Pavimento Existente

O levantamento histórico do pavimento existente deve ser efetuado junto às organizações rodoviárias encarregadas da sua construção e conservação, ou por estudos e reconhecimentos "*in loco*" visando à obtenção das seguintes informações principais:

- a) data de entrega do pavimento existente ao tráfego;
- b) número N de projeto;
- c) tráfego atual e futuro (novos números N);
- d) informações sobre o projeto, incluindo, principalmente, as características do subleito, das diversas camadas do pavimento e dos dispositivos de drenagem, bem como a seção transversal adotada;
- e) informações a respeito da geologia da região;
- f) informações a respeito da hidrologia da região;
- g) informações a respeito do estado de conservação do trecho e dos trabalhos já executados com esse objetivo;
- h) outras informações julgadas procedentes.



EFEITO DA CARGA SOBRE UM PAVIMENTO FLEXÍVEL

Fig. 2

4.1.2 Prospeção Preliminar do Pavimento Existente

A prospeção preliminar deve ser realizada por intermédio da abertura de poços de sondagem, a pá e picareta, localizados nos bordos do revestimento da pista de rolamento, dispostos alternadamente em relação ao eixo, e espaçados longitudinalmente de 2 km. Nos referidos poços deve ser providenciada:

- a identificação expedita e a determinação da espessura das camadas que compõem o pavimento propriamente dito, bem como dos 60 cm superiores do subleito;
- a determinação das umidades naturais e massas específicas aparentes secas "in situ," das camadas granulares do pavimento e das camadas que compõem os 60 cm superiores do subleito;
- a coleta de amostras representativas dos materiais componentes das camadas granulares do pavimento e das camadas que compõem os 60 cm superiores do subleito, para a realização de ensaios de caracterização, compactação e ISC;
- a coleta de amostras representativas dos materiais betuminosos das camadas de ligação (binder) e de revestimento para a realização de ensaios de extração de betume e granulometria.

4.2 Estudos Definitivos

Os estudos definitivos compreendem os seguintes procedimentos:

4.2.1 Demarcação das Estações de Ensaio

Nas rodovias de pista única com duas faixas de tráfego, as estações destinadas à visualização dos locais para determinação das deflexões devem ser demarcadas em ambas as faixas de tráfego, alternadamente, de forma que o espaçamento longitudinal entre duas estações consecutivas localizadas em uma mesma faixa de tráfego seja igual a 40 m, e, conseqüentemente, o afastamento longitudinal entre duas estações consecutivas, consideradas ambas as faixas de tráfego, seja igual a 20 m. Nas rodovias de pista dupla, as estações devem ser demarcadas nas faixas externas de cada pista, com um afastamento longitudinal de 20 m.

4.2.2 Determinação das Deflexões Recuperáveis

Devem ser determinadas as deflexões recuperáveis, na trilha da roda externa, em todas as estações demarcadas ao longo do trecho em estudo, salvo nas que se situem sobre obras de arte especiais. Caso seja julgado necessário, podem ser obtidas também medidas de deflexões nas trilhas das rodas internas. Durante a medida de deflexões devem ser obtidas medidas que possibilitem o cálculo do Raio de Curvatura, de acordo com os métodos já aprovados. Os raios de curvaturas serão determinados com o espaçamento de 200 m, devendo ser feitas determinações adicionais, sempre que ocorrerem valores isolados inferiores a 100 m para o raio de curvatura. Com o objetivo de enriquecer os subsídios proporcionados pelo levantamento das deflexões recuperáveis, podem ser efetuadas também, determinações que possibilitem o delineamento da linha de influência longitudinal inerente à parcela transitória da deformação ocasionada pela carga de prova aplicada à superfície do pavimento (Bacia de Deformação).

Neste particular, a extensão estudada deve ser subdividida em segmentos de cerca de 1 km, devendo ser selecionadas, em cada um deles, duas estações que apresentem, sempre que possível, diversidade no tange ao estado do pavimento.

Nota - A determinação das deflexões do pavimento deve ser executada com a Viga Benkelman pelo método já normalizado pelo DNER, podendo ser usadas outras aparelhagens já normalizadas por aquele órgão, desde que seja estabelecida a devida correlação com as deflexões recuperáveis medidas com a Viga Benkelman.

4.2.3 Inventário do Estado da Superfície do Pavimento Existente

Paralelamente ao levantamento das deflexões recuperáveis, deve ser efetuado um inventário do estado apresentado pela superfície do revestimento da pista de rolamento do pavimento existente.

Este inventário, que é destinado à complementação do levantamento deflectométrico, será feito segundo a metodologia descrita na norma de "Avaliação Objetiva da Superfície de Pavimentos Flexíveis e Semi-Rígidos".

4.2.4 Sondagens Complementares a Pá e Picareta

Conforme o resultado dos estudos precedentes, pode ser verificada a impossibilidade do uso do critério deflectométrico para a avaliação estrutural do pavimento estudado e o cálculo de um novo reforço. Neste caso, devem ser feitos poços de sondagens complementares, com um espaçamento máximo de 200 m, sendo dispensado aos poços em questão o mesmo tratamento concedido aos pertinentes à prospecção preliminar e que foi detalhado no item 4.1.2.

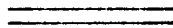
4.2.5 Representação Gráfica dos Resultados dos Estudos

Os resultados dos estudos de deflectometria, de superfície, e das prospecções efetuadas, devem ser representados graficamente em um desenho apropriado (ver figura 3), onde serão incluídas, no mínimo, as seguintes informações:

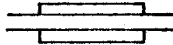
- a) características do subleito do pavimento existente;
- b) elementos referentes à constituição do pavimento existente;
- c) indicações sobre a existência de água freática no subleito;
- d) informes relativos à configuração da terraplenagem;
- e) estanqueamento ou quilometragem;
- f) poligonais representativas da variação das deflexões recuperáveis, obtidas na trilha de roda externa de cada faixa de tráfego;
- g) valores do raio de curvatura;
- h) principais defeitos constatados na superfície da pista de rolamento.

CONVENÇÕES:

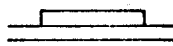
TRECHO EM ATERRO



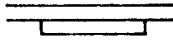
TRECHO EM CORTE



TRECHO EM CORTE A ESQUERDA
E ATERRO A DIREITA



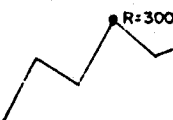
TRECHO EM CORTE A DIREITA
E ATERRO A ESQUERDA



NÍVEL D'ÁGUA



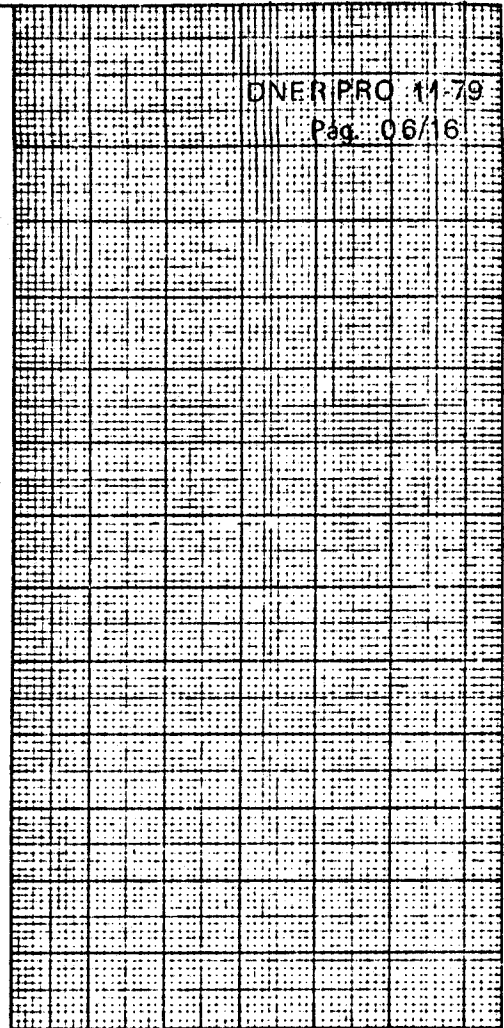
PERFIL DEFLECTOMÉTRICO COM
RAIO DE CURVATURA INDICADO



DEFLEXÃO EM 0,01mm

ESTACA OU Km

SEÇÃO



CONDIÇÕES DA SUPERFÍCIE DO PAVIMENTO

FENDAS PROVENIENTES DE DEFORMAÇÃO PERMANENTE EXCESSIVA OU FADIGA	TRINCAS ISOLADAS	FISSURAS		FI
TRINCAS DE RETRAÇÃO	TRINCA ISOLADA	TRANSVERSAIS	CURTAS	TTC
			LONGAS	TTL
	TRINCAS INTERLIGADAS	LONGITUDINAIS	CURTAS	TLC
			LONGAS	TLL
AFUNDAMENTOS	LOCALS	JACARÉ	S/ EROSAÇÃO	J
			C/ EROSAÇÃO	JE
ONDULAÇÕES TRANSVERSAIS (CORRUGAÇÃO)	NAS TRILHAS DE RODAS	RETRAÇÃO DA BASE OU REVESTIMENTO		TRP
		TIPO BLOCO SEM EROSAÇÃO		TB
		TIPO BLOCO COM EROSAÇÃO		TBE
		FLUÊNCIA PLÁSTICA		ALP
ESCORREGAMENTO DO REVESTIMENTO	REMENDOS	CONSOLIDAÇÃO		ALC
		FLUÊNCIA PLÁSTICA		ATP
		CONSOLIDAÇÃO		ATC
		EXSUDAÇÃO		EX
DESGASTE				D
"PANELAS" (DESAGREGAÇÃO DO REVESTIMENTO E BASE)				P
FALHAS DEVIDAS AO TERRENO DE FUNDAÇÃO				R
AFUNDAMENTO DE CONSOLIDAÇÃO		RUTURA POR CIZALHAMENTO		AC
RUTURA POR CIZALHAMENTO				AH

ESTRUTURA DO PAVIMENTO

ESPESSURA EM CM.

FIG. 3

4.2.6 Definições dos Limites dos Segmentos Homogêneos

A extensão total estudada deve ser subdividida em segmentos que possam ser considerados razoavelmente homogêneos, com vistas às medidas corretivas que estejam a requerer. Esta noção de homogeneidade está, portanto, estreitamente vinculada ao valor residual do pavimento, o qual depende, em grande parte, tanto da constituição da estrutura e do subleito, quanto do seu estado de deterioração.

Considera-se impraticável a proposição de diretrizes rígidas no que diz respeito ao estabelecimento dos limites de tais segmentos, tendo em vista a inevitável subjetividade ditada pela natureza do problema.

Recomenda-se que a tarefa seja executada levando-se em conta, principalmente, os resultados da análise simultânea dos seguintes elementos propiciados pelos estudos precedentes e representados no desenho recomendado no item 4.2.5 (Fig. 3):

- a) a configuração das poligonais representativas da variação da deflexões recuperáveis;
- b) os valores do raio de curvatura;
- c) a constituição do pavimento existente;
- d) os contatos entre as litologias que constituem o subleito;
- e) a natureza e a frequência dos defeitos verificados na superfície do revestimento da pista de rolamento.

Por motivos de ordem construtiva, sempre que possível, deve-se conferir aos segmentos homogêneos uma extensão mínima da ordem de 200 m.

Caso sejam encontrados segmentos menos extensos, ao longo dos quais os níveis de deflexão e/ou o estado da superfície do pavimento se mostrem notoriamente discrepantes, quando comparados com aqueles exibidos pelos segmentos adjacentes, tais segmentos devem ser considerados isoladamente.

Não devem ser tomados segmentos homogêneos com extensão superior a 2000 m.

4.2.7 Análise Estatística das Deflexões Recuperáveis, Avaliação das Deflexões Recuperáveis. Características

Em princípio, devem ser consideradas como pertencentes a um único universo, as deflexões recuperáveis encontradas nas trilhas de roda externa de ambas as faixas de tráfego, em cada segmento homogêneo. Excepcionalmente, a análise simultânea dos quatro elementos relacionados no item 4.2.6 pode conduzir o projetista ao tratamento em separado de cada faixa de tráfego. Em tais condições, a avaliação da superfície, o cálculo das deflexões características e a definição dos parâmetros de tráfego devem ser estabelecidos em separado, por faixa de tráfego.

Nesses casos, a extensão mínima desejável de cada segmento homogêneo passa a ser de 400 m. Para cada uma das distribuições assim definidas, deve-se efetuar o cálculo estatístico da deflexão característica correspondente, adotando-se o seguinte procedimento:

- a) tabulam-se os valores individuais das deflexões recuperáveis encontradas (D_i);
- b) calcula-se a média aritmética, D , dos valores individuais (média da amostra);

$$D = \frac{\sum D_i}{n}$$

onde n representa o número o número de valores individuais computados (número de indivíduos componentes da amostra);

- c) determina-se o valor do desvio-padrão da amostra, σ , através da expressão:

$$\sigma = \sqrt{\frac{\sum (D_i - D)^2}{n - 1}}$$

- d) estabelece-se o intervalo de aceitação para os valores individuais, definindo-o através dos limites $D \pm z \sigma$, onde z será estimado em função de n , mediante o critério constante da tabela apresentada a seguir:

TABELA I

n	z
3	1
4	1,5
5 - 6	2
7 - 19	2,5
≥ 20	3

Nota - Os valores constantes da Tabela I originam-se do "Highway Research Board" - Report 17.

- e) segue-se a eliminação de todos os valores individuais da distribuição situados fora do intervalo anteriormente definido, procedendo-se a novo cálculo de D e σ com os valores remanescentes, bem como a fixação dos novos limites do intervalo de aceitação, $D \pm z \sigma$, para a nova situação. Esse procedimento deve ser repetido, em cada caso, tantas vezes sucessivas quantas forem necessárias para o enquadramento de todos os valores individuais remanescentes no intervalo $D \pm z \sigma$ determinado. Os valores de D e σ assim encontrados são considerados, respectivamente, como a média aritmética e o desvio-padrão da amostra.
- f) o valor do coeficiente de variação (cv) é determinado, para cada uma das distribuições, através da expressão:

$$cv = \frac{\sigma}{D}$$

- g) o valor da deflexão característica é determinado, para cada uma das distribuições, através da expressão:

$$D_c = D + \sigma$$

onde D e σ representam, respectivamente, a média aritmética e o desvio-padrão da amostra.

4.2.8 Deflexão de Projeto - Correção Sazonal

A época mais indicada para a realização das medidas das deflexões é imediatamente após a estação chuvosa, quando o subleito está com o máximo de umidade. Como isto, porém, nem sempre é possível, costuma-se utilizar fatores de correção sazonal para as deflexões obtidas em qualquer época, a fim de corrigi-las para a época mais desfavorável. Estes fatores de correção sazonal dependem de pesquisa regionais, quase inexistentes no Brasil, para serem corretamente aplicados. Desta maneira, sugerem-se os seguintes valores:

TABELA II

Natureza do Subleito	Fator de Correção Sazonal - F_s	
	Estação Seca	Estação Chuvosa
Arenoso e Permeável	1,10 - 1,30	1,00
Argiloso e Sensível à Umidade	1,20 - 1,40	1,00

A escolha do fator de correção sazonal, F_s , mais adequado para a correção das medidas de deflexão, deve ser feita levando-se em conta as seguintes informações:

- a) a distribuição das precipitações mensais médias correspondentes à região onde se acha implantado o trecho em estudo;
- b) as precipitações mensais ocorridas nos meses durante os quais foi efetuado o levantamento deflectométrico, e nos três meses que antecederam o levantamento;
- c) as características da estrutura do pavimento existente e de seu subleito.

A deflexão característica corrigida ou deflexão de projeto (D_p) é calculada pela fórmula:

$$D_p = D_c \times F_s$$

Sendo:

D_p - deflexão característica corrigida ou deflexão de projeto, em 0,01 mm

D_c - deflexão característica obtida para a época do levantamento deflectométrico, em 0,01 mm

F_s - fator de correção sazonal

Nota - Os valores constantes da Tabela II foram adaptados de um relatório do "Centre Experimental de Recherches et d'Etudes du Bâtiment et des Travaux Publics - Paris, France" para reforços dos pavimentos flexíveis na África Tropical e Madagascar, e da publicação nº 428 do IPR "Variação Mensais de Deflexão com a Viga Benkelman" sobre pesquisas realizadas no Estado do Rio Janeiro.

5 DEFLEXÃO ADMISSÍVEL (D_{adm})

Para que não surjam trincas no revestimento, é necessário manter a deflexão do pavimento abaixo de um determinado valor (D_{adm}), denominado deflexão admissível.

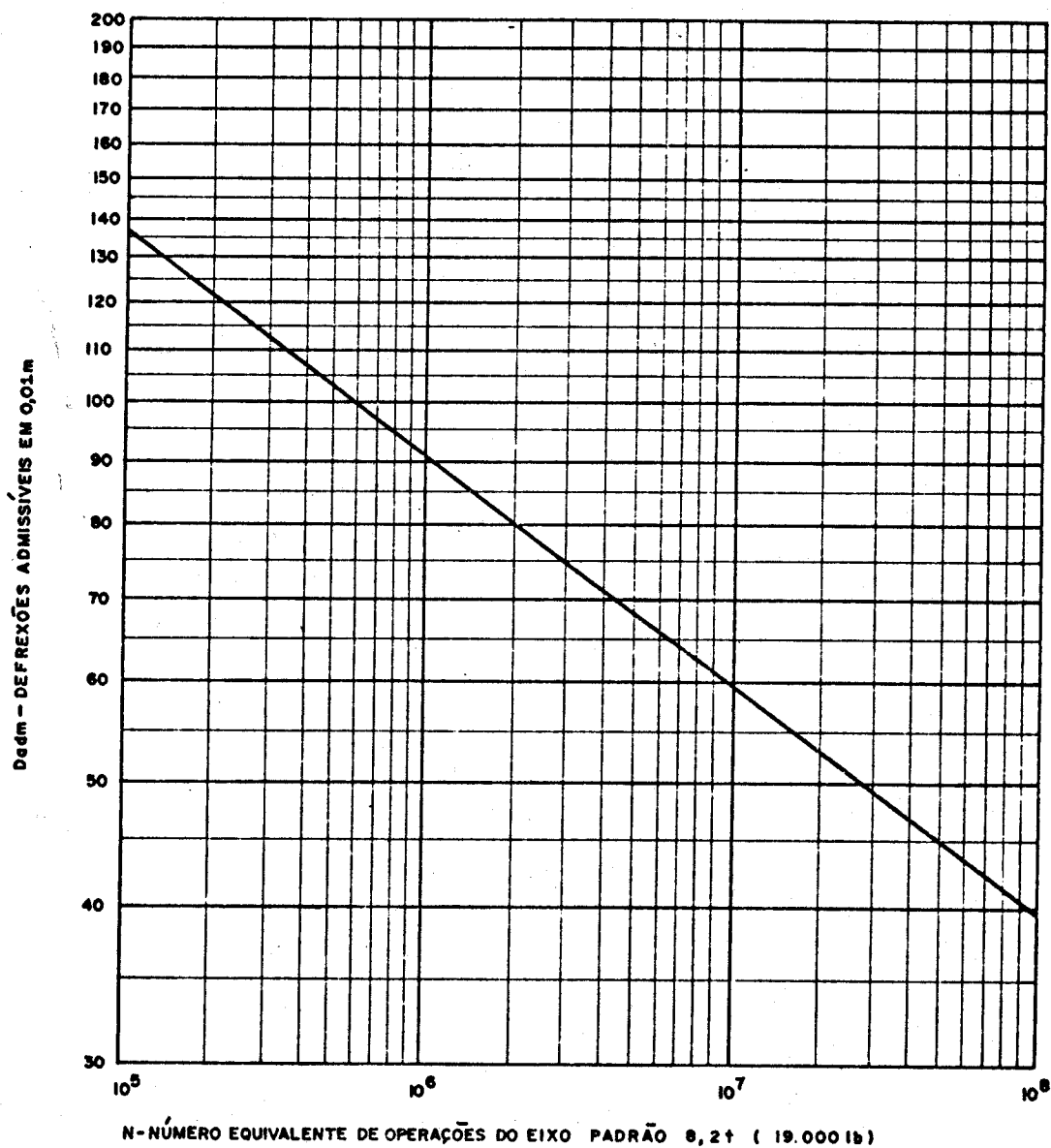
O valor da deflexão admissível depende dos materiais constituintes do revestimento e da base do pavimento, bem como do número N de solicitações de eixos equivalentes ao eixo padrão de 8,2 t.

Para pavimento flexíveis, constituídos de revestimento de concreto betuminoso executado sobre base granular, o valor da deflexão admissível (D_{adm}) em 0,01mm é dado pela seguinte expressão correspondente a deflexões medidas com a carga padrão de 8,2 t por eixo:

$$\log D_{adm} = 3,01 - 0,176 \log N$$

Esta expressão está representada graficamente no ábaco da figura 4.

DEFLEXÃO ADMISSÍVEL PARA CONCRETO BETUMINOSO
(DEFLEXÕES MEDIDAS COM CARGA POR EIXO DE 8,2t)



$$\log D_{adm} = 3,01 - 0,175 \log N$$

N	D _{adm}
10 ⁵	135
10 ⁶	90
10 ⁷	60
10 ⁸	40

FIG. 4

Para pavimentos semi-rígidos, com base de solo-cimento ou base de brita tratada com cimento, que não apresente fissuração exagerada, deve ser adotada como deflexão admissível a metade do valor obtido pela expressão e ábaco apresentados, independentemente do tipo de revestimento.

Para avaliação de pavimento com revestimentos do tipo tratamento superficial, executados sobre base granular, deve ser adotada como deflexão admissível o dobro do valor obtido pela expressão e ábaco apresentados; no caso de ser projetado um reforço com revestimento em CBUQ, a deflexão admissível será a correspondente a este material.

O valor de N a ser considerado na determinação da deflexão admissível, depende do tipo de análise a que se está submetendo o pavimento, como a seguir explicitado.

Para verificar se o pavimento ainda está em sua fase elástica, o número N a ser considerado para a determinação da deflexão admissível é o correspondente às cargas por eixos suportadas pelo pavimento, desde sua abertura ao tráfego, até a data das medidas de deflexão.

Para determinar a deflexão admissível a ser adotada em um determinado projeto de reforço de pavimento, o número N a ser utilizado é o correspondente às cargas por eixo a serem suportadas pelo reforço do pavimento, desde a liberação deste reforço ao tráfego até o final do período de projeto arbitrado para o reforço.

6 ESTIMATIVA DE VIDA RESTANTE DO PAVIMENTO

Quando a deflexão de projeto (D_p) de um determinado pavimento está abaixo da deflexão admissível (D_{adm}), para um determinado valor de N correspondente ao tráfego já suportado pelo pavimento existente, sendo $R \geq 100$ m, este fato indica que o pavimento em estudo ainda não atingiu a fase de fadiga e possui, portanto, um período de vida restante.

O tempo de vida restante pode ser estimado determinando-se a que valor N corresponde a deflexão de projeto (D_p).

Conhecendo-se:

N_s - Número de solicitações correspondentes às cargas por eixos suportadas pelo pavimento desde sua abertura ao tráfego até a data da avaliação;

N_t - Número de solicitações indicadas no Gráfico de Deflexões Admissíveis em correspondente à deflexão característica de projeto (D_p);

tem-se:

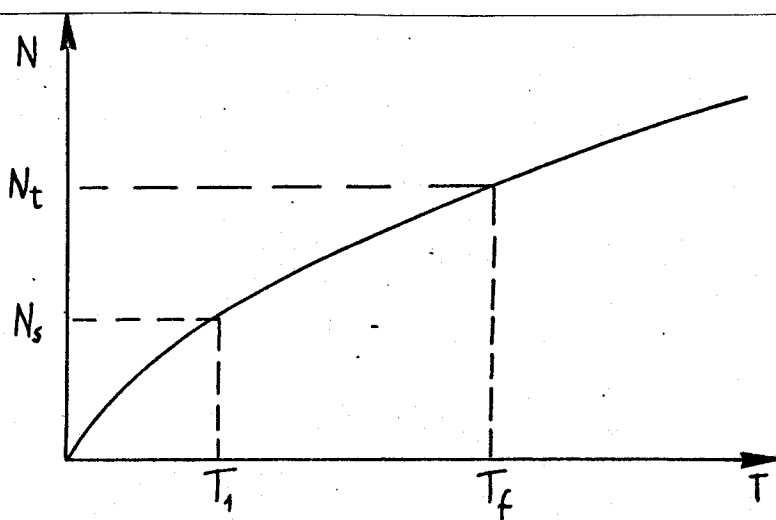
$$N_r = N_t - N_s$$

Sendo:

N_r - Número de solicitações correspondente às cargas por eixo a serem suportadas pelo pavimento desde a data da avaliação até o final do período de vida restante do pavimento.

Conhecendo-se a curva de variação do número N acumulado, em função do tempo de exposição do pavimento ao tráfego, é possível estimar o tempo de vida restante deste pavimento.

Para isto basta determinar na curva (tempo de exposição ao tráfego x N) os tempos T_i , correspondentes a N_s , e o tempo T_f , correspondente a N_t .



O tempo de vida restante estimado para o pavimento em estudo, no que respeita à fadiga, é dado pela expressão:

$$T_r = T_f - T_1$$

7 AVALIAÇÃO ESTRUTURAL

Ainda não se dispõe de critérios universalmente aceites que possibilitem uma fácil tomada de posição com respeito à avaliação estrutural dos pavimentos.

Não há, por exemplo, normas rígidas que permitam definir com precisão, para o projeto de reforços de pavimentos existentes, a fronteira que separa os campos de aplicação dos critérios deflectométrico e de resistência.

Em tese, seria lícito aceitar-se que os métodos de projeto baseados no critério deflectométrico seriam válidos quando a estrutura subjacente ao reforço estivesse funcionando em regime aproximadamente elástico, ou, em outras palavras, quando as cargas incidentes ocasionassem exclusivamente deformações de carácter transitório.

A verificação de deformações plásticas significativas, decorrentes da evolução de processos de ruptura ao cisalhamento, evidenciaria a presença, no pavimento existente, de problemas situados fora do escopo dos métodos de dimensionamento alicerçados no critério deflectométrico.

No que pesem as dificuldades que cercam o problema, propõe-se um critério para a fixação das diretrizes a serem adotadas para efeito da avaliação estrutural dos pavimentos.

Procura-se formular cinco casos típicos, na suposição de que a maioria das situações que ocorrem nos subtrechos homogêneos possa se enquadrar, aproximadamente, em uma das hipóteses formuladas. Para isto, consideram-se os seguintes parâmetros, obtidos durante os estudos executados:

N - número de solicitações de eixos equivalentes ao eixo padrão de 8,2 t;

Dp - deflexão de projeto;

R - raio de curvatura;

Dadm - deflexão admissível;

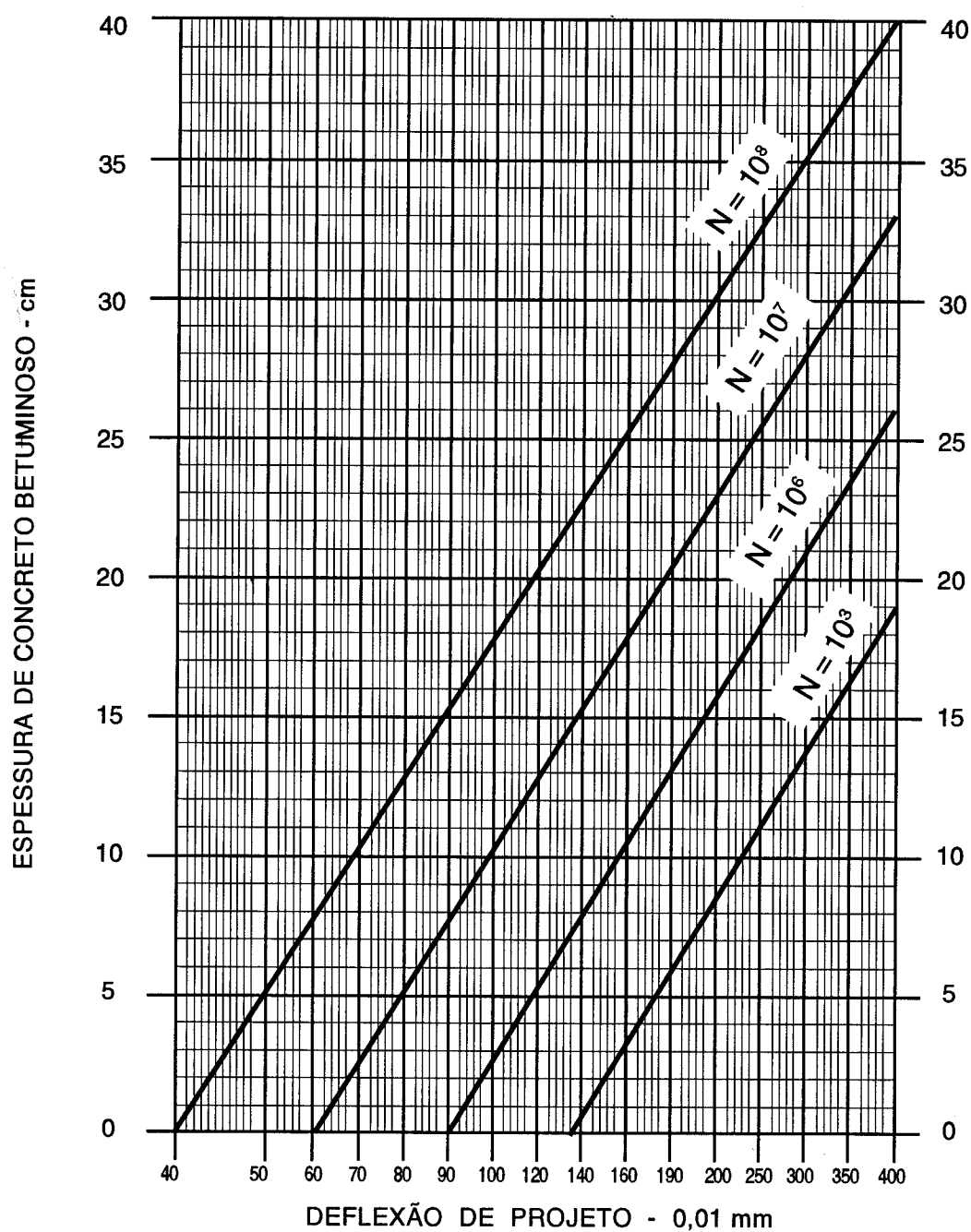
I.G.G. - Índice de Gravidade Global.

Na tabela III, apresentada a seguir, procura-se, em função dos parâmetros citados acima:

TABELA III
Cr terios para Avalia  o Estrutural

Hip�tese	Dados Deflectom�tricos obtidos	Qualidade Estrutural	Necessidade de Estudos Complementares	Cr�terio para C�lculo de Refor�o	Medidas Corretivas
I	$D_p \leq D_{adm}$ $R \geq 100$	BOA	N�O		Apenas corre��es de superf�cie
II	$D_p > D_{adm}$ $R \geq 100$	Se $D_p \leq 3 D_{adm}$ REGULAR	N�O	Deflectom�trico	Refor�o
		Se $D_p > 3 D_{adm}$ M�	SIM	Deflectom�trico e Resist�ncia	Refor�o ou Reconstru��o
III	$D_p \leq D_{adm}$ $R < 100$	REGULAR PARA M�	SIM	Deflectom�trico e Resist�ncia	Refor�o ou Reconstru��o
IV	$D_p > D_{adm}$ $R < 100$	M�	SIM	Resist�ncia	Refor�o ou Reconstru��o
V	—	M� O pavimento apresenta deforma��es permanentes e rupturas pl�sticas generalizadas ($IGG > 180$).	SIM	Resist�ncia	Reconstru��o

ÁBACO PARA DIMENSIONAMENTO DA ESPESSURA DE REFORÇO DO PAVIMENTO EM CONCRETO BETUMINOSO



- a) fixar quando serão necessários estudos complementares;
- b) definir o critério para a avaliação estrutural e o cálculo do reforço;
- c) fazer recomendações quanto às medidas corretivas.

8 DIMENSIONAMENTO DE REFORÇO DO PAVIMENTO

8.1 Critério Deflectométrico ou de Deformabilidade

A espessura necessária de reforço do pavimento deve ser estimada através dos resultados do levantamento deflectométrico executado para a avaliação estrutural, pela expressão ou pelo ábaco apresentado a seguir na figura 6:

$$h = K \cdot \log \frac{D_p}{D_{adm}}$$

onde:

- h - espessura do reforço do pavimento em centímetros;
- D_p - deflexão de projeto determinada para o subtrecho homogêneo, objeto do dimensionamento, em centésimos de milímetro;
- D_{adm} - deflexão admissível após a execução do reforço do pavimento, em centésimos de milímetro;
- K - fator de redução de deflexão, próprio do material usado no reforço.

8.1.1 Dimensionamento do Reforço em Concreto Betuminoso

Para calcular a espessura de reforço do pavimento, h_{cb}, em termos de concreto betuminoso, deve ser usado o valor 40 para K, tendo-se, portanto:

$$h_{cb} = 40 \log \frac{D_p}{D_{adm}}$$

Um valor mais exato, para as características próprias do material empregado no reforço, pode ser determinado pela expressão apresentada a seguir:

$$K = \frac{h}{\log \frac{D_0}{D_r}}$$

onde:

- K - fator de redução de deflexão a ser determinado para o material usado na execução do reforço;
- h - espessura do reforço, em centímetros;
- D₀ - deflexão medida na superfície do pavimento existente, antes da execução do reforço, em centésimos de milímetro;
- D_r - deflexão medida na superfície do reforço, em centésimos de milímetros.

As medidas efetuadas antes e após a execução do reforço do pavimento, devem ser feitas sob as mesmas condições do subleito. As medidas efetuadas sobre o reforço do pavimento, devem ser feitas quando houver certeza de que o novo revestimento não está mais sendo influenciado pela compactação dada pelo tráfego (fase de consolidação).

A espessura do reforço do pavimento pode ser facilmente corrigida, se for constatado que K tem um valor diferente de 40, pela expressão:

$$h_r = \frac{K}{40} \times h_{40}$$

onde:

h_r - espessura do reforço para material $K \neq 40$;

K - fator de redução de deflexão próprio do material usado no reforço do pavimento;

h_{40} - espessura do reforço do pavimento considerando-se $K = 40$.

8.1.2 Dimensionamento de Reforço com Camadas Múltiplas

Devem ser estudadas outras soluções para constituição das camadas inferiores do reforço do pavimento existente sempre que o dimensionamento indicar espessuras de reforço, em termos de concreto betuminoso, superiores a 5 cm.

Para o cálculo das espessuras das camadas não constituídas de concreto betuminoso, devem ser adotados os coeficientes de equivalência estrutural recomendados pelo DNER e transcritos a seguir.

A espessura de concreto betuminoso substituído deve ser multiplicada por:

$$\frac{2,00}{\text{Coef. equiv. estrutural do material utilizado}}$$

TABELA IV

componentes do reforço do pavimento	coeficiente de equivalência estrutural
Concreto Betuminoso	2,00
Pré-misturado a quente de graduação densa	1,70
Pré-misturado a frio de graduação densa	1,40
Macadame betuminoso por penetração	1,20
Brita graduada com ISC > 80	1,10
Material granular com ISC ≥ 60	1,00
Solo-cimento com resistência à compressão a 7 dias superior a 45 kg/cm ²	1,70
Solo-cimento com resistência à compressão a 7 dias entre 45 kg/cm ² e 28 kg/cm ²	1,40
Solo-cimento com resistência à compressão a 7 dias e inferior a 28 kg/cm ²	1,00

8.2 Critério de resistência

Na forma como foi indicado na Tabela III, referente a Critérios para Avaliação Estrutural, há casos em que o projeto de reforço do pavimento existente pode ser também executado utilizando-se os resultados dos estudos complementares e o método de dimensionamento de pavimentos flexíveis do DNER. Para isto, às diversas camadas constituintes do pavimento existente e do reforço projetado devem ser atribuídos coeficientes de equivalência estrutural compatíveis com suas características, determinadas pelos ensaios de campo e de laboratório e pelas observações "in situ", as quais poderão recomendar, inclusive, a execução de outros serviços complementares à execução do reforço, tais como, drenagem, obras nos acostamentos, remoção e reposição de materiais.

9 PALAVRAS-CHAVE

Afundamento, Deflexão, Deformação, Pavimento, Recalque.



ANEXO 2 – ÁRVORE DE DECISÕES DO CREMA 2

CATÁLOGO DE SOLUÇÕES DO PROGRAMA SWAP

Soluções equivalentes a considerar

1 – Reconstrução cimento.	{ Substituição de camadas. Reciclagem c/adição de agregados. Reciclagem c/adição de cal ou Reciclagem c/ adição de espuma de asfalto.
2 - Fresagem e substituição de revestimento (esp. elevada)	{ Reciclagem "in situ" ou em usina.
3 - Reperfilagem	{ Fresagem superficial (e=2cm).
4 – TSD c/polímero	{ Micro revestimento (1,5 cm – duas camadas).
5 - CBUQ	{ TSD pol + micro (uma camada) ou lama, para $e = \leq 4\text{cm}$. CPA (alta pluviosidade, baixa condição de drenagem). SMA (tráfego pesado). Areia asfalto. TSD pol + CBUQ. CBUQ com asfalto modificado.

Obs.: Para a aplicação de qualquer solução considerada tecnicamente equivalente, deverá ser avaliada a sua compatibilidade financeira, quando comparada com a solução básica.

CATÁLOGO DE SOLUÇÕES TÉCNICAS - DNIT
(soluções de reforço calculadas pelo PRO -11/79 10 anos)

Rodovias com revestimento em concreto asfáltico

IRI	VMD	N (USACE)	IRI<=3				3 < IRI <= 4			
			IGG<=20	IGG >20	IGG<=20	IGG >20	IGG<=60	IGG >60	IGG<=60	IGG >60
			Defl<Dadm	Defl>Dadm	Defl<Dadm	Defl>Dadm	Defl<=Dadm	Defl>Dadm	Defl<=Dadm	Defl>Dadm
VMD < 1000		< 6,9E+06	LG	F5(5%) + LG	Hx	F5(5%) + Hx	F5(10%) + Micro(1,5)	F5(20%) + Micro(1,5)	F5(10%) + Hx	F5(20%) + Hx
			TSD		Reest. de base+TSD		Reest. de Base+TSD(10%) TSD(90%)		Reest. de base+TSD	
1000 ≤ VMD < 2000	Acostamentos	≥ 6,9E+06 < 1,43E+07	LG	F5(5%) + LG	Hx	F5(5%) + Hx	F5(10%) + Micro(1,5)	F5(20%) + Micro(1,5)	F5(10%) + Hx	F5(20%) + Hx
			TSD		Reest. de base+TSD		Reest. de Base+TSD(10%) TSD(90%)		Reest. de base+TSD	
2000 ≤ VMD < 3000	Acostamentos	≥ 1,43E+07 < 2,14E+07	LG	F5(5%) + LG	Hx	F5(5%) + Hx	F5(10%) + H3	F5(20%) + H3	F5(10%) + Hx	F5(20%) + Hx
			TSD		Reest. de base+TSD		Reest. de Base+TSD(10%) TSD(90%)		Reest. de base+TSD	
3000 ≤ VMD < 5000	Acostamentos	≥ 2,14E+07 < 3,57E+07	LG	F5(5%) + LG	Hx	F5(5%) + Hx	F5(10%) + H3	F5(20%) + H3	F5(10%) + Hx	F5(20%) + Hx
			TSD		Reest. de base+TSD		Reest. de Base+TSD(10%) TSD(90%)		Reest. de base+TSD	
VMD ≥ 5000	Acostamentos	≥ 3,57E+07	LG	F5(5%) + LG	Hx	F5(5%) + Hx	F5(10%) + H3	F5(20%) + H3	F5(10%) + Hx	F5(20%) + Hx
			TSD		Reest. de base+TSD		Reest. de Base+TSD(10%) TSD(90%)		Reest. de base+TSD	

4 < IRI <= 5,5					IRI > 5,5				
IGG < =100	IGG >100	IGG <=100	IGG >100		IGG < =150	IGG >150	IGG <150	IGG >150	
Defl< =Dadm		Defl>Dadm			Defl< =Dadm		Defl>Dadm		
F5(20%) + REP + Micro(1,5)	F5(30%) + REP + Micro(1,5)	F5(20%) + REP + Hx	F5(30%) + REP + Hx		FR5(100%) + REP + H4	FR5(100%) + REP + TSDpol + H4	FR5(100%) + REP + TSDpol + Hx	REC5	
Reest. de Base+TSD(20%) TSD(80)%		Reest. de base+TSD			Reest. de Base+TSD(30%) TSD(70)%		Reest. de base+ TSD	REC+TSD	
Defl< =Dadm		Defl>Dadm			Defl< =Dadm		Defl>Dadm		
F5(20%) + REP + Micro(1,5)	F5(30%) + REP + Micro(1,5)	F5(20%) + REP + Hx	F5(30%) + REP + Hx		FR5(100%) + REP + H4	FR5(100%) + REP + TSDpol + H4	FR5(100%) + REP + TSDpol + Hx	REC7	
Reest. de Base+TSD(20%) TSD(80)%		Reest. de base+TSD			Reest. de Base+TSD(30%) TSD(70)%		Reest. de base+ TSD	REC+TSD	
Defl< =Dadm		Defl>Dadm			Defl< =Dadm		Defl>Dadm		
F5(20%) + REP + H3	F5(30%) + REP + H3	F5(20%) + REP + Hx	F5(30%) + REP + Hx		FR5(100%) + REP + H5	FR5(100%) + REP + TSDpol + H5	FR5(100%) + REP + TSDpol + Hx	REC8	
Reest. de Base+TSD(20%) TSD(80)%		Reest. de base+TSD			Reest. de Base+TSD(30%) TSD(70)%		Reest. de base+ TSD	REC+TSD	
Defl< =Dadm		Defl>Dadm			Defl< =Dadm		Defl>Dadm		
F5(20%) + REP + H3	F5(30%) + REP + H3	F5(20%) + REP + Hx	F5(30%) + REP + Hx		FR5(100%) + REP + H5	FR5(100%) + REP + TSDpol + H5	FR5(100%) + REP + TSDpol + Hx	REC9	
Reest. de Base+TSD(20%) TSD(80)%		Reest. de base+TSD			Reest. de Base+TSD(30%) TSD(70)%		Reest. de base+ TSD	REC+TSD	
Defl< =Dadm		Defl>Dadm			Defl< =Dadm		Defl>Dadm		
F5(20%) + REP + H3	F5(30%) + REP + H3	F5(20%) + REP + Hx	F5(30%) + REP + Hx		FR5(100%) + REP + H5	FR5(100%) + REP + TSDpol + H5	FR5(100%) + REP + TSDpol + Hx	REC10	
Reest. de Base+TSD(20%) TSD(80)%		Reest. de base+TSD			Reest. de Base+TSD(30%) TSD(70)%		Reest. de base+ TSD	REC+TSD	

Nota:

FR5 = fresagem de 5cm
F5 = fresagem + reposição de 5cm
REP = reperfilagem com massa fina de CBUQ e= 2cm
LG = lama asfáltica grossa
Micro = micro revestimento asfáltico em duas camadas (1,5cm)
TSDpol = tratamento superficial duplo c/ polímero
REC e = reconstrução através de reciclagem de Base+ revestimento com espessura de Reest. de base = reestabilização de base com adição de 10cm de material
TSD = tratamento superficial duplo
Hx = camada de CBUQ com espessura x, onde x = 40 log DP/Dadm

CATÁLOGO DE SOLUÇÕES TÉCNICAS - DNIT
(soluções de reforço calculadas pelo PRO -11/79 10 anos)

Rodovias com revestimento em Tratamento Superficial

IRI	VMD	N (USACE)	IRI<=3				3 < IRI <= 4			
			IGG<=20	IGG >20	IGG<=20	IGG >20	IGG<=60	IGG >60	IGG<=60	IGG >60
			Defl<Dadm		Defl>Dadm		Defl<=Dadm		Defl>Dadm	
VMD < 1000	< 6,9E+06	RP(1%)+ LG	RP(3%)+ LG	RP(1%)+ Hx	RP(3%)+ Hx	RP(3%)+ TSDpol	RP(5%)+ TSDpol	RP(3%)+ Hx	RP(5%)+ Hx	
		TSS		TSD		Reest. base + TSS(10%) TSS (90%)		Reest. base + TSD		
1000 ≤ VMD < 2000	≥ 6,9E+06 < 1,43E+07	RP(1%)+ LG	RP(3%)+ LG	RP(1%)+ Hx	RP(3%)+ Hx	RP(3%)+ TSDpol	RP(5%)+ TSDpol	RP(3%)+ Hx	RP(5%)+ Hx	
		TSS		Reest. base + TSD		Reest. base + TSS(10%) TSS (90%)		Reest. base + TSD		
VMD ≥ 2000	≥ 1,43E+07	RP(1%)+ LG	RP(3%)+ LG	RP(1%)+ Hx	RP(3%)+ Hx	RP(3%)+ TSDpol	RP(5%)+ TSDpol	RP(3%)+ Hx	RP(5%)+ Hx	
		TSS		Reest. base + TSD		Reest. base + TSS(10%) TSS (90%)		Reest. base + TSD		
Acostamentos		TSS		Reest. base + TSD		Reest. base + TSS(10%) TSS (90%)		Reest. base + TSD		

4 < IRI <= 5,5					IRI > 5,5				
IGG < =100	IGG >100	IGG <=100	IGG >100	IGG <=150	IGG >150	IGG <150	IGG >150		
Defl< =Dadm		Defl>Dadm		Defl< =Dadm		Defl>Dadm			
RP(5%) + REP + TSDpol	RP(10%)+ REP + TSDpol	RP(5%) + REP + Hx	RP(10%)+ REP + Hx	RP(10%)+ REP + TSDpol	REC5	RP (15%) + REP + Hx	REC5	REC5	
Reest. base + TSS(20%) TSS (80%)		Reest. base + TSD		Reest. base + TSS(30%) TSS (70%)	REC + TSD	Reest. base + TSD	REC + TSD	REC + TSD	
Defl< =Dadm		Defl>Dadm		Defl< =Dadm		Defl>Dadm			
RP(5%) + REP + TSDpol	RP(10%)+ REP + TSDpol	RP(5%) + REP + Hx	RP(10%)+ REP + Hx	RP(10%)+ REP + TSDpol	REC7	RP (10%) + REP + Hx	REC7	REC7	
Reest. base + TSS(20%) TSS (80%)		Reest. base + TSD		Reest. base + TSS(30%) TSS (70%)	REC + TSD	Reest. base + TSD	REC + TSD	REC + TSD	
Defl< =Dadm		Defl>Dadm		Defl< =Dadm		Defl>Dadm			
RP(5%) + REP + TSDpol	RP(10%)+ REP + TSDpol	RP(5%) + REP + Hx	RP(10%)+ REP + Hx	RP(10%)+ REP + TSDpol	REC8	RP (10%) + REP + Hx	REC8	REC8	
Reest. base + TSS(20%) TSS (80%)		Reest. base + TSD		Reest. base + TSS(30%) TSS (70%)	REC + TSD	Reest. base + TSD	REC + TSD	REC + TSD	

Nota:

RP = reparo profundo
REP = reperfilagem com massa fina de CBUQ e= 2cm
LG = lama asfáltica grossa
TSDpol = tratamento superficial duplo c/ polímero
REC e = reconstrução através de reciclagem de Base+ revestimento com espessura de CBUQ = e
Reest. base = reestabilização de base com adição de 10cm de material
TSS = tratamento superficial simples
TSD = tratamento superficial duplo
Hx = camada de CBUQ com espessura x, onde x = 40 log DP/Dadm



ANEXO 3 – PRO 269/94

MT - DEPARTAMENTO NACIONAL DE ESTRADAS DE RODAGEM**Projeto de restauração de pavimentos flexíveis - TECNAPAV****Norma rodoviária****Procedimento****DNER-PRO 269/94****p.01/17****RESUMO**

Este documento, que é uma norma técnica, define um procedimento a ser utilizado no projeto de restauração de pavimentos flexíveis, apresentando alternativas em concreto asfáltico, em camadas integradas de concreto asfáltico e pré-misturado, em tratamento superficial e em lama asfáltica - Método da Resiliência - TECNAPAV

ABSTRACT

This document presents procedures to be used for rehabilitation of flexible pavements. It is applied to bituminous concret, surface treatment and slurry Seal-Resiliency Method - TECNAPAV.

SUMÁRIO

- 0 Apresentação
- 1 Objetivo
- 2 Referências
- 3 Definições
- 4 Levantamento dos dados do pavimento existente
- 5 Levantamento de campo
- 6 Ensaaios de laboratório
- 7 Cálculo dos parâmetros do trecho
- 8 Divisão do trecho em subtrechos homogêneos
- 9 Projeto de restauração

Anexo informativo**Macrodescriptores MT:** Norma, pavimento, projeto, restauração do pavimento**Microdescriptores DNER:** Pavimento flexível, projeto, restauração do pavimento.**Palavras-chave IRRD/IPR:** Norma (0139), pavimento flexível (2944), recapeamento (2991)**Descritores SINORTEC:** Pavimentos flexíveis, projeto

Aprovada pelo Conselho Administrativo em 14/12/94

Resolução nº 105/94, Sessão nº CA/38/94

Processo nº 51100011226/93.9

Autor e Histórico:

DNER/DrDTc (IPR)

0 APRESENTAÇÃO

Esta Norma apresenta uma alternativa de procedimentos, para projetos de restauração de pavimentos flexíveis, com a designação TECNAPAV.

1 OBJETIVO

Esta Norma define os procedimentos a serem adotados na aplicação do método de projeto de restauração de pavimentos flexíveis, desenvolvido pelos Engenheiros Salomão Pinto e Ernesto S. Preussler, intitulado Método da Resiliência - TECNAPAV.

2 REFERÊNCIAS

2.1 Normas complementares

Na aplicação desta Norma é necessário consultar:

- a) DNER-ME 129/94 - Solos-compactação utilizando amostras não trabalhadas;
- b) DNER-ME 049/94 - Solos - determinação do índice de suporte Califórnia utilizando amostras não trabalhadas;
- c) DNER-ME 024/94 - Pavimento - determinação das deflexões pela viga Benkelman;
- d) DNER-ES 128/83 - Levantamento da condição de superfície de segmentos-testemunha de rodovias de pavimento flexível ou semi-rígido para gerência de pavimentos a nível de rede;
- e) Método de Dimensionamento de Pavimento Flexível do DNER, ed. 1979;
- f) DNER-ME 051/94 - Solos - análise granulométrica;
- g) DNER-PRO 008/94 - Avaliação objetiva da superfície de pavimentos flexíveis e semi-rígidos;
- h) DNER-ME 131/94 - Solos - determinação do módulo de resiliência;
- i) DNER-ME 133/94 - Misturas betuminosas - determinação do módulo de resiliência;
- j) DNER-ME 138/94 - Misturas betuminosas - determinação da resistência a tração por compressão diametral;
- l) ABNT-EB 22/88 (NBR 5734) - Peneiras para ensaio.

2.2 Referências bibliográficas

No preparo desta Norma foram consultados os seguintes documentos:

- a) Proposição de método para projeto de reforço de pavimentos flexíveis, considerando a resiliência- Ernesto Preussler e Salomão Pinto - MT/DNER - Instituto de Pesquisas Rodoviárias - 1982;
- b) Proposição de método para projeto de reforço de pavimentos flexíveis, considerando a resiliência - versão II - Salomão Pinto e Ernesto Preussler - MT/DNER - Instituto de Pesquisas Rodoviárias - 1984;
- c) DNER-PRO 159/85 - Projeto de restauração de pavimentos flexíveis e semi-rígidos.

3 DEFINIÇÕES

Para efeitos desta Norma, são adotadas as seguintes definições:

3.1 Trincamento - TR

A percentagem das áreas contendo trincas não capilares, em uma faixa de tráfego, em relação à área total dessa faixa.

3.2 Espessura efetiva - hef

A espessura equivalente ao revestimento existente, que é considerada no cálculo da camada de recapeamento.

3.3 Número N_p

O número equivalente de operações do eixo padrão simples de 80,12 kN (8,17 tf), correspondente à frota de veículos comerciais atuante em um determinado período.

3.4 Vida de fadiga - N_t

O número de solicitações do eixo padrão simples de 80,12 kN, que leva o revestimento asfáltico à fase de trincamento por fadiga.

3.5 Subtrechos homogêneos

Segmentos da rodovia que apresentam características semelhantes de tráfego, subleito, estrutura do pavimento, condições de sua superfície e deflexão.

3.6 Período de análise

O intervalo de tempo, em anos, correspondente ao número cumulativo de solicitações do eixo padrão simples de 80,12 kN, determinado para o projeto.

3.7 Indicadores de desempenho

Os valores máximos admissíveis para as condições de superfície, em termos de intensidade de defeitos e irregularidade, para que a rodovia seja utilizada em um padrão desejado.

3.8 Restrições econômicas

Compreendem os recursos financeiros máximos que o Órgão Rodoviário dispõe para a restauração do subtrecho, no período de análise.

4 LEVANTAMENTO DOS DADOS DO PAVIMENTO EXISTENTE

Deve ser feito junto aos Órgãos Rodoviários encarregados de sua construção e conservação, para a obtenção dos seguintes elementos:

- a) informações sobre o projeto do pavimento existente, compreendendo as características do subleito, características e espessura das camadas constituintes do pavimento, bem como de eventuais restaurações e a seção transversal tipo do pavimento;

- b) identificação do trecho em relação ao PNV;
- c) custos de conservação diretamente relacionados com o pavimento;
- d) histórico do tráfego;
- e) localização de bueiros;
- f) outras informações julgadas procedentes.

5 LEVANTAMENTO DE CAMPO

5.1 Demarcação do Trecho

O trecho deve ser demarcado a cada 20m, nas bordas da pista de rolamento.

Durante esta etapa, devem ser anotados os seguintes dados:

- a) Início e final de trecho;
- b) início e final de obras-de-arte especiais;
- c) início e final de interseções;
- d) cruzamentos e entrocamentos;
- e) início e final de defeitos refletidos no pavimento, devido à movimentação ou erosão de maciços terrosos do corpo estradal;
- f) outros dados julgados necessários.

5.2 Determinação das deflexões recuperáveis

5.2.1 As deflexões recuperáveis devem ser determinadas em ambas as faixas de tráfego, de conformidade com o estabelecido no Método DNER-ME 024/94 (ver item 2.1.c). As vigas Benkelman utilizadas devem ser isoladas termicamente com isopor.

5.2.2 Nas rodovias de pista única, com duas faixas de tráfego, a demarcação dos pontos de medição é feita alternadamente em ambas as faixas de tráfego, na trilha de roda externa, de forma que o espaçamento longitudinal entre dois pontos consecutivos, localizados em uma mesma trilha de roda, seja igual a 40m e, em consequência, o afastamento longitudinal entre dois pontos consecutivos, consideradas ambas as faixas de tráfego, seja igual a 20m.

5.2.3 Nas rodovias de pista dupla, os pontos devem ser demarcados na trilha de roda externa de cada pista, com afastamento longitudinal de 20m.

5.3 Levantamento da condição do pavimento

5.3.1 O levantamento da condição do pavimento deve incluir a determinação das áreas que apresentam trincas, buracos e remendos, de conformidade com o disposto na Especificação DNER-ES 128/83 (V. item 2.1.d), valendo as seguintes observações:

- 2/
- a) Os segmentos-testemunha devem ter 6m de comprimento e largura igual à da faixa de rolamento, e devem ser espaçados de 20m, centro e centro, e posicionados, alternadamente, em cada uma das faixas de rolamento;
 - b) as trincas classe 1 não devem ser levantadas. Pode ser utilizado também o procedimento DNER-PRO-08/94 (ver item 2.1.g).

5.3.2 A avaliação do estado da condição de superfície pode ser complementada através de medidas de irregularidade em ambas as faixas de tráfego, por meio de aparelhos medidores do tipo resposta, tais como Integrador IPR/USP ou Maysmeter.

5.4 Sondagem a pá e picareta e coleta de amostras

5.4.1 Devem ser feitas sondagens, a pá e picareta, posicionadas alternadamente nas bordas da pista de rolamento, e espaçadas em 2000 m, no máximo, aprofundadas até ser atingido, 0,60m do subleito.

5.4.2 Caso sejam detectadas mudanças nas características do pavimento e/ou do subleito, devem ser realizadas sondagens intermediárias, de modo a caracterizar as extensões de pavimento com características semelhantes.

5.4.3 Independentemente do espaçamento adotado, cada subtrecho homogêneo, definido no Capítulo 8, deve conter pelo menos um poço sondagem.

5.4.4 Todas as camadas componentes do pavimento devem ser classificadas expeditamente, quanto à sua constituição e função na estrutura do pavimento, sendo também determinadas as espessuras respectivas. O mesmo critério deve ser aplicado ao subleito.

5.4.5 De cada camada do pavimento e do subleito, exceto do revestimento, deve ser coletada uma amostra representativa.

5.5 Sondagens rotativas no revestimento e coleta de amostras

5.5.1 Somente nos casos de revestimentos em concreto asfáltico, devem ser realizadas sondagens rotativas, por meio de equipamento dotado de coroa diamantada, com 0,10m de diâmetro.

5.5.2 Os pontos de sondagem devem estar localizados, no centro da trilha de roda externa, na mesma seção transversal das sondagens indicadas no item 5.4. Devem ser espaçadas longitudinalmente em 2000m e dispostos, alternadamente, em cada uma das faixas de tráfego.

5.5.3 Os testemunhos colhidos devem ser examinados, a fim de se definir o número e a espessura das camadas betuminosas presentes na superestrutura do pavimento.

5.5.4 Quando o ponto programado para a sondagem incidir sobre remendo ou "panela", o equipamento de prospecção deve ser deslocado sobre o eixo da trilha de roda externa, devendo o deslocamento imposto ser suficiente para que o testemunho extraído possa representar efetivamente a superestrutura típica da área.

5.5.5 Nos locais onde for impossível a obtenção de testemunho incólume, a natureza das camadas betuminosas e as respectivas espessuras devem ser inferidas a partir de observações efetuadas no furo aberto pela sonda rotativa.

5.6 Caracterização do Tráfego

5.6.1 As contagens volumétricas classificatórias e pesagens de todos os veículos comerciais devem ser feitas no mínimo durante 3 (três) dias consecutivos, em um período de 24 horas diárias para as contagens e de 8 (oito) horas diárias para as pesagens, em local (ou locais) adequado(s) para a caracterização do tráfego do trecho.

5.6.2 Os veículos devem ser classificados conforme preconizado nos estudos de tráfego.

6 ENSAIOS DE LABORATÓRIO

6.1 Índice de Suporte Califórnia e granulometria com sedimentação

6.1.1 Com as amostras coletadas, conforme estabelecido no item 5.4, devem ser realizados ensaios para a determinação do Índice de Suporte Califórnia, segundo o Método DNER-ME 129/94 (ver item 2.1.a) com as seguintes energias de compactação:

- a) material de base - Proctor Modificado;
- b) material de sub-base - Proctor Intermediário;
- c) material de reforço do subleito - Proctor Intermediário;
- d) material de subleito - Proctor Normal.

6.1.2 Os ensaios de granulometria com sedimentação devem ser realizados de acordo com o Método DNER-ME 051/94 (ver item 2.1.f), para os solos contendo mais de 35% em peso passando na peneira de 0,075mm de abertura (nº 200).

6.2 Módulo de Resiliência

Ensaios para a determinação de módulos de resiliência e de resistência à tração por compressão diametral devem ser realizados de acordo com os métodos DNER-ME 133/94, DNER-ME 138/94 e DNER-ME 131/94 (ver itens 2.1.i, 2.1.j e 2.1.h).

7 CÁLCULO DOS PARÂMETROS DO TRECHO

7.1 Deflexão Recuperável

A deflexão recuperável deve ser calculada individualmente, para cada determinação feita, conforme indicado no item 5.2, segundo o Método DNER-ME 024/94 (ver item 2.1.c).

7.2 Trincamento

Nas superfícies de avaliação, analisadas conforme indicado no item 5.3, que apresentarem trincas de classe 2 e/ou 3, deve ser calculado o trincamento através da expressão:

$$TR = \frac{TRI}{S} \times 100$$

onde:

TR = trincamento, em %;

TRI = total das áreas com trincamento de classes 2 e 3, bem como eventuais buracos e remendos contidos na superfície de avaliação, em m²;

S = área da superfície de avaliação, em m²;

7.3 Irregularidade

As medições de irregularidade devem ser convertidas na escala de QI, através da equação de calibração apropriada.

7.4 Índice de Suporte Califórnia

Deve ser adotado o valor do Índice de Suporte Califórnia correspondente à umidade ótima do ensaio de compactação correspondente, segundo as indicações do item 6.1, ou correspondente à umidade e massa específica aparente "in situ".

7.5 Percentagem de silte na fração que passa na peneira de 0,075mm de abertura (nº 200)

A percentagem de silte contida nos solos, segundo as indicações do item 6.1, deve ser calculada a partir do ensaio de granulometria com sedimentação, pela expressão:

$$S = 100 - \frac{P_1}{P_2} \times 100$$

onde:

S = Silte, em %;

P₁ = percentagem, em peso, de material cujas partículas tenham diâmetro inferior a 0,005mm, determinada na curva de distribuição granulométrica;

P₂ = percentagem, em peso, de material cujas partículas tenham diâmetro inferior a 0,075mm, determinada na curva de distribuição granulométrica.

7.6 Classificação dos solos

Os solos devem ser classificados em tres grupos quanto às suas características resilientes em função do valor do Índice de Suporte Califórnia (CBR) e percentagem de silte(S), conforme a Tabela 1 seguinte:

Tabela 1 - Grupos de Solos

CBR %	S%		
	≤ 35	35 a 65	> 65
≥10	I	II	III
6 a 9	II	II	III
2 a 5	III	III	III

7.7 Espessura da camada granular - Hcg

Deve-se considerar, para fins de espessura, como camadas granulares, as de base, sub-base e/ou reforço do subleito, constituídas por materiais granulares, tais como: solo arenoso, pedregulhoso, solo estabilizado granulometricamente, solo brita, brita graduada e macadames, desde que contenham menos de 35% em peso, passando na peneira de abertura de 0,075mm (nº 200).

7.8 Número N

O parâmetro de tráfego utilizado no projeto deve ser calculado de acordo com os fatores de equivalência preconizados no Método de Dimensionamento de Pavimento Flexível do DNER, edição de 1979.

8 DIVISÃO DO TRECHO EM SUBTRECHOS HOMOGÊNEOS

8.1 Os dados obtidos conforme indicado nos itens 5.1, 5.4 e 5.5. e no Capítulo 7 desta Norma devem ser anotados em gráfico próprio, podendo-se adotar o modelo da Figura 1.

8.2 O gráfico deve ser elaborado em papel milimetrado, devendo representar todo o trecho em estudo.

8.3 Inicialmente, o trecho deve ser dividido em segmentos que apresentem valores semelhantes de constituição do pavimento, do tráfego médio diário (TMD) e da deflexão recuperável.

8.4 Procede-se, em seguida, à análise visual dos valores de QI e trincamento, de modo a serem delimitados os segmentos que apresentem valores semelhantes destes parâmetros.

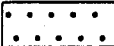
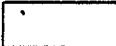
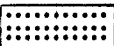
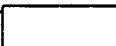
8.5 Os valores individuais do trincamento, que não se enquadrarem na faixa definida pela média aritmética mais ou menos três vezes o desvio padrão, devem ser eliminados da análise. A ocorrência desses pontos extremos deve ser investigada detalhadamente.

8.6 A análise conjunta dos dois grupos de segmentos, obtidos como antes descrito, resultará na divisão do trecho em subtrechos homogêneos.

8.7 Em qualquer fase da análise, a extensão máxima admitida para um subtrecho homogêneo deve ser 7000 m.

8.8 Recomenda-se que a deflexão seja o parâmetro preponderante na divisão do trecho em subtrechos homogêneos.

Figura 1 - Modelo de Gráfico para Divisão do Trecho em Subtrechos Homogêneos

PISTA DE ROLAMENTO	QI QUOCIENTE DE IRREGULARIDADE (Cont / km)																				
	TR TRINCAMENTO (%)																				
	D DEFLEXÃO RECUPERÁVEL (0,01 mm)																				
TMD																					
CONSTITUIÇÃO DO PAVIMENTO *		ESPESSURA (cm)																			
OBSERVAÇÕES																					
ESTAQUEAMENTO																					
SUBTRECHO HOMOGÊNEO																					
* CONVENÇÕES PARA AS CAMADAS DO PAVIMENTO		 PAVIMENTO REVESTIMENTO  SUB-BASE   BASE  																			

9 PROJETO DE RESTAURAÇÃO

A restauração deve ser projetada separadamente, para cada subtrecho homogêneo, definido conforme indicado no Capítulo 8.

9.1 Determinação dos parâmetros de projeto

9.1.1 Pavimento existente

Para cada subtrecho homogêneo devem ser determinados os parâmetros a seguir definidos, a partir dos resultados obtidos segundo estabelecido nos Capítulos 5 e 7:

- a) espessura do revestimento asfáltico existente - obtida a partir dos elementos segundo o item 5.5;
- b) deflexão característica - resultado da soma da média aritmética com o correspondente desvio padrão dos valores individuais da deflexão recuperável, obtidos segundo o indicado no item 7.1;
- c) trincamento - resultado da soma da média aritmética com o respectivo desvio padrão dos valores individuais do trincamento, obtidos conforme estabelecido no item 7.2;
- d) espessura da camada granular - obtida de acordo com o indicado no item 7.7;
- e) tipo de solo - determinado de acordo com o indicado no item 7.6.

9.1.2 Restauração do pavimento

Para o trecho em estudo devem ser estabelecidos os parâmetros a seguir mencionados:

- a) período de análise - deve ser fixado o período de análise, em anos;
- b) taxa de crescimento do tráfego - deve ser determinada em função de dados históricos disponíveis, ou fixada pelo Órgão Rodoviário;
- c) tráfego - previsto para o período de análise;
- d) restrições de construção - fixadas pelo projetista ou Órgão Rodoviário;
- e) restrições econômicas - pode ser fornecida pelo Órgão Rodoviário a disponibilidade de recursos para a manutenção do trecho, ao longo do período de análise;
- f) custos unitários de restauração - compreendem a soma de todos os componentes de custos necessários para a execução de 1km de reforço ou restauração. Devem ser estimados pelo projetista ou fixados pelo Órgão Rodoviário para o início do período de análise (ano zero). O custo unitário de restaurações a serem executadas ao longo do período de análise deve ser calculado a preços referidos ao início do período de análise, pelo uso da expressão:

$$C_0 = \frac{C_n}{(1 + i)^n}$$

onde:

- C_0 - Custo unitário da restauração a ser realizada no ano n, atualizado para o início do período de análise;
- C_n - custo unitário da restauração;
- i - taxa de oportunidade de capital, estimada pelo projetista ou fixada pelo Órgão Rodoviário, em percentagem sobre 100 (%/100);
- n - ano previsto para execução da restauração, considerando o início do período de análise como ano zero.

9.2 Análise da condição do pavimento existente

9.2.1 A análise da condição estrutural e funcional do pavimento existente, a partir do trincamento, irregularidade da superfície, deflexão, e da serventia retratada pelo Índice de Gravidade Global (IGG), reflete um quadro sintomático do grau de deterioração da rodovia.

9.2.2 A partir desses levantamentos (item 9.2.1), é possível definir critérios para o cálculo do recapeamento, fazer recomendações quanto a medidas corretivas e, principalmente, compatibilizar a solução numérica com o estado da condição superficial, adequando-a às restrições de natureza econômica.

9.3 Dimensionamento do reforço do pavimento

A espessura necessária de reforço do pavimento existente deve ser determinada através dos resultados dos levantamentos executados de acordo com as etapas a seguir descritas:

9.3.1 Deflexão de projeto característica:

$$D_c = \bar{D} + \sigma$$

onde:

D_c - deflexão de projeto, 0,01mm;

$\bar{D}$ - média aritmética das deflexões de campo, 0,01mm;

σ - desvio padrão, 0,01mm.

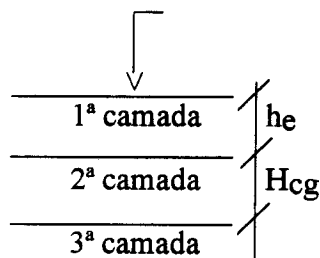
9.3.2 Estrutura de referência

Definir para o subtrecho homogêneo uma estrutura de referência constituída por três camadas, com as respectivas espessuras, ou seja:

1ª camada - camada betuminosa, item 5.5;

2ª camada - camada granular, item 7.7;

3ª camada - camada de solo, item 7.6.



9.3.3 Classificação do solo da 3ª camada

O solo da 3ª camada deve ser classificado de acordo com a Tabela 1, item 7.6, em solo Tipo I ou Tipo II ou Tipo III.

9.3.4 Cálculo da espessura efetiva (hef)

$$hef = - 5,737 + \frac{807,961}{D_c} + 0,972 I_1 + 4,101 I_2$$

onde:

hef - espessura efetiva, em cm;

I_1, I_2 - constantes relacionadas às características resilientes da terceira camada da estrutura de referência.

Caso 1 - Espessura da camada granular (H_{cg}) é menor ou igual a 45cm

3ª camada Tipo I: $I_1 = 0$ $I_2 = 0$

3ª camada Tipo II: $I_1 = 1$ $I_2 = 0$

3ª camada Tipo III: $I_1 = 0$ $I_2 = 1$

Caso 2 - Espessura da camada granular (H_{cg}) é maior do que 45cm, adotar:

$I_1 = 0$ e $I_2 = 1$

Caso 3 - O hef calculado deve estar compreendido entre os intervalos:

$0 \leq \text{hef} \leq h_e$
Se $\text{hef} < 0$, adotar $\text{hef} = 0$
Se $\text{hef} > h_e$, adotar $\text{hef} = h_e$

onde:

h_e - espessura da camada betuminosa existente, em cm.

Caso 4 - Quando o grau de trincamento do revestimento existente for superior a 50% ou o somatório de $FC-2 + FC-3 > 80\%$ e $FC-3 > 30\%$ pode ser conveniente adotar o limite inferior do hef, bem como considerar a solução de recapeamento em camadas integradas de CBUQ e pré-misturado, com a finalidade de minimizar o fenômeno de reflexão de trincas no revestimento projetado.

9.3.5 Critério de fadiga

$$\log \bar{D} = 3,148 - 0,188 \log N_p$$

onde:

$\bar{D}$ - deflexão máxima admissível, 0,01mm;

N_p - número cumulativo de solicitações de eixos equivalentes ao eixo padrão de 80,12 kN (8,17 tf), para o período de projeto.

9.3.6 Cálculo da espessura de reforço em concreto asfáltico

$$HR = -19,015 + \frac{238,14}{\sqrt{\bar{D}}} - 1,357 \text{ hef} + 1,016 I_1 + 3,893 I_2$$

onde:

HR - espessura da camada de reforço em concreto asfáltico, em cm.

9.3.7 Solução de recapeamento

Caso 1: Para $3 < HR \leq 12,5$ cm a subdivisão em camadas integradas de CBUQ e pré-misturado ou camada única de CBUQ (binder e capa), são alternativas que podem ser consideradas a partir das condições de superfície existente, contemplando as características de deformabilidade das misturas betuminosas a serem utilizadas;

Caso 2: Para $12,5 < HR \leq 25$ cm é recomendada a adoção de camadas integradas dos tipos CBUQ e pré-misturado, de acordo com o seguinte procedimento:

$$H_{pm} = 0,60 HR$$

$$H_{CA} = HR - H_{pm}$$

onde:

H_{pm} - espessura de pré-misturado, em cm;

H_{CA} - espessura de concreto asfáltico, em cm;

HR - espessura de reforço em concreto asfáltico, calculada no item 9.3.6, em cm.

Caso 3: Para $HR > 25$ cm as camadas integradas não devem ser constituídas exclusivamente de misturas betuminosas.

Para esta situação, deve-se verificar, também, a necessidade de remoção do revestimento existente ou camadas subjacentes, com a reconstrução da estrutura do pavimento.

Caso 4: Para $HR \leq 3$ cm e a partir da análise da condição do pavimento existente, segundo as indicações do item 9.2, poderão ser contempladas soluções com lama asfáltica ou tratamento superficial.

Caso 5: Se as restrições econômicas condicionarem uma espessura máxima para HR inferior ao valor calculado segundo o item 9.3.6, deve ser avaliada a deflexão $\bar{D}$ e determinado o valor de N_t correspondente, pela expressão:

$$\log N_t = \frac{3,148 - \log \bar{D}}{0,188}$$

A vida fadiga em anos (A) da solução proposta será definida pela condição:

$$\sum_{i=1}^A \frac{N_i}{N_t} \leq 1,0$$

N_i - número anual de solicitações do eixo padrão correspondente ao ano (i).

Neste caso, a solução de recapeamento por etapas requer a consideração, dentro do período de análise de no máximo mais duas soluções sucessivas. A espessura efetiva (hef) nas etapas seguintes será avaliada pelos modelos:

$$V = - \left(\frac{he - hef_1}{TR} \right) 50 + he ; TR > 50\%$$

$$V = - \left(\frac{hef_1}{80 - TR} \right) 50 + hef_1 + \left(\frac{hef_1}{80 - TR} \right) TR ; TR \leq 50\%$$

$$T_i = - \left(\frac{hef_{i-1} + HR_{i-1}}{80} \right) 50 + hef_{i-1} + HR_{i-1} ; i = 2 \text{ e } 3$$

$$hef_2 = \frac{T_2 + V}{2}$$

$$hef_3 = \frac{hef_2 + T_3}{2}$$

onde:

he - espessura do revestimento original (sem reforço);

hef₁ - espessura efetiva do revestimento original (sem reforço);

TR - percentagem de área trincada do pavimento original (sem reforço);

HR_{i-1} - espessura da camada de reforço na etapa anterior (i - 1);

hef₂ - espessura efetiva da primeira camada de reforço;

hef₃ - espessura efetiva da segunda camada de reforço.

9.3.8 De posse do valor de hef correspondente à etapa seguinte, bem como número N restante, ou seja, N_p - N_v, procede-se a análise a partir do item 9.3.5.

9.3.9 O custo unitário da(s) alternativa(s) de estratégia de recapeamento, satisfazendo às condições impostas pelo projetista e/ou Órgão Rodoviário, deve ser avaliado segundo indicações do item 9.1.2, com a finalidade de otimizar os investimentos nos serviços de restauração de pavimentos.

9.4 Considerações complementares

Para deflexões superiores a 1,40mm, onde a 3ª camada for classificado como do Tipo I ou Tipo II devem ser contempladas também soluções de restauração por critérios de resistência, bem como verificada a necessidade de remoção e reconstrução de uma nova estrutura de pavimento. No caso do solo da 3ª camada ser do Tipo III, valem as mesmas considerações anteriores, porém para valores de deflexões superiores a 1,60mm. Nos demais casos a aplicação de critérios de resistência ficará a cargo de considerações do projetista.

9.5 Dimensionamento do reforço do pavimento contemplando a reciclagem

A espessura do revestimento existente a ser reciclada e a de reforço complementar devem ser determinadas de acordo com as etapas a seguir descritas:

9.5.1 Módulo de resiliência efetivo do revestimento existente

$$\log M_{ef} = 11,19 - 2,753 \log D_c - 1,714 \log h_e - 0,0053 I_1 + 0,2766 I_2$$

onde:

$$M_{ef} \geq 1000 \text{ kgf/cm}^2;$$

D_c - deflexão de projeto, 0,01mm, item 9.3.1;

I_1, I_2 - constantes relacionadas às características resilientes da terceira camada da estrutura de referência, item 9.3.4;

h_e - espessura da camada betuminosa existente, cm;

M_{ef} - módulo de resiliência efetivo do revestimento existente, kgf/cm².

9.5.2 Módulo de resiliência da mistura betuminosa reciclada

Deve ser determinado o módulo de resiliência da mistura betuminosa reciclada, dosada em laboratório, segundo as indicações do item 6.2.

9.5.3 Cálculo da relação modular

$$\mu = \frac{MR_c}{M_{ef}}$$

onde:

μ - relação modular;

MR_c - módulo de resiliência da mistura betuminosa reciclada, kgf/cm²;

M_{ef} - módulo de resiliência efetivo do revestimento existente, kgf/cm².

9.5.4 Cálculo da deflexão de projeto característica, após reciclagem

$$\overline{D_c} = D_c \left[\frac{h_c}{h_e} \left(\mu^{\frac{1}{3}} - 1 \right) + 1 \right]^{-1,324}$$

onde:

D_c - deflexão de projeto, 0,01mm, item 9.3.1;

h_e - espessura da camada betuminosa existente, cm;

h_c - espessura da camada betuminosa existente reciclada-espessura de corte, cm;

μ - relação modular, item 9.5.3;

$\bar{D}_0$ - deflexão de projeto característica do pavimento reciclado correspondente à espessura h_c , 0,01mm.

A espessura de corte (h_c) deve satisfazer as seguintes condições:

$$h_c \geq 3,0\text{cm} \quad \text{e,}$$

$$h_c \leq h_e - 2$$

9.5.5 Solução de recapeamento

Caso 1: Para $\mu \leq 1,0$ a solução de restauração deve ser a determinada segundo os itens 9.3 e 9.4, sem reciclagem. Contudo pode ser avaliada a reciclagem com espessura mínima de corte para atender a melhoria das condições de rolamento do revestimento betuminoso, no caso em que $\bar{D}_0 \leq \bar{D}$ ou $HR \leq 3\text{cm}$, itens 9.3.5, 9.3.6 e 9.3.7 (Caso 4).

Caso 2: Para $\mu > 1,0$ adotar o seguinte procedimento:

- calcular $\bar{D}_0$ para diferentes valores de h_c segundo o intervalo de espessuras indicadas no item 9.5.4;
- para $\bar{D}_0 \leq \bar{D}$ a solução por reciclagem com espessura de corte h_c constitui uma alternativa de restauração;
- para $\bar{D}_0 > \bar{D}$ dimensionar a camada de reforço a partir do item 9.3.4, considerando $\bar{D}_0 = \bar{D}$. Esta solução constitui uma alternativa de restauração mista, ou seja, reciclagem com corte de espessura h_c e recapeamento com espessura HR . O projetista deve proceder a uma análise de viabilidade técnico-econômica das alternativas de projeto obtidas.

NOTAS: 1) O módulo de resiliência da mistura reciclada (MRc) pode ser estimado pelo modelo:

$$MRc = 5000 \sigma_R$$

onde:

σ_R - Resistência à tração por compressão diametral, kgf/cm^2 , determinada pelo Método DNER-ME 138/94.

2) HR - Espessura de recapeamento sobre a espessura reciclada (h_c)

Anexo Informativo

Quadro I - Classificação dos Veículos

Símbolo	Configuração	Descrição
		Automóvel
		Utilitário
2C		Ônibus
2C		Caminhão
3C		Caminhão
4C		Caminhão
2S1		Semi-Reboque
2S2		Semi-Reboque
2S3		Semi-Reboque
3S2		Semi-Reboque
3S3		Semi-Reboque
2C2		Reboque
2C3		Reboque

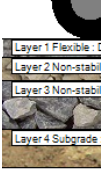


ANEXO 4 – ANÁLISES PAVEWARE – CENÁRIO A: PAVIMENTO NOVO

Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data: 32.119, -81.202
 Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
 Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

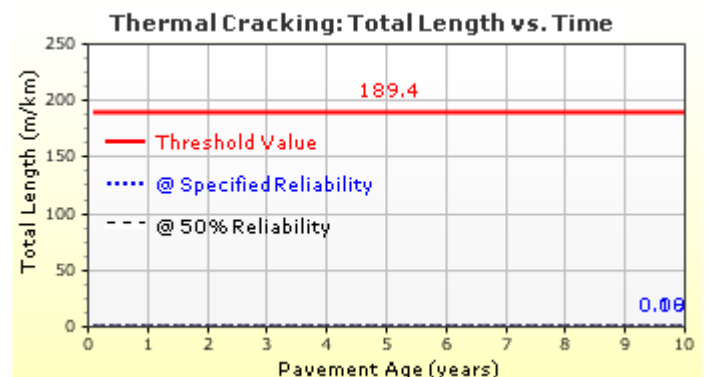
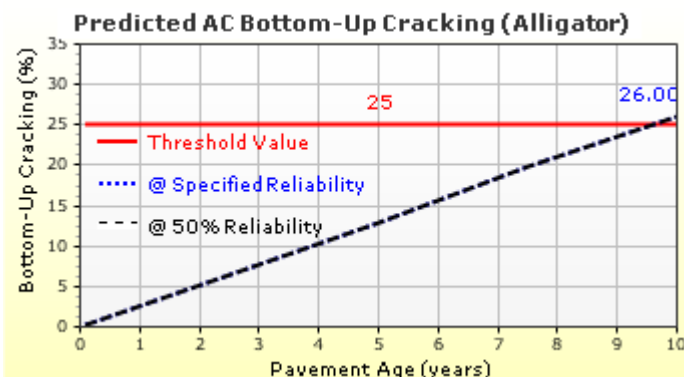
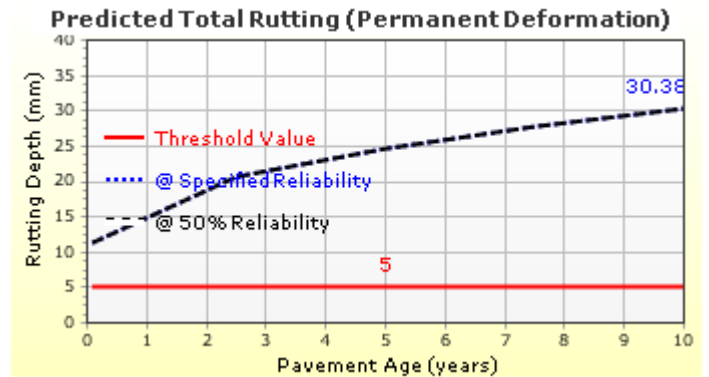
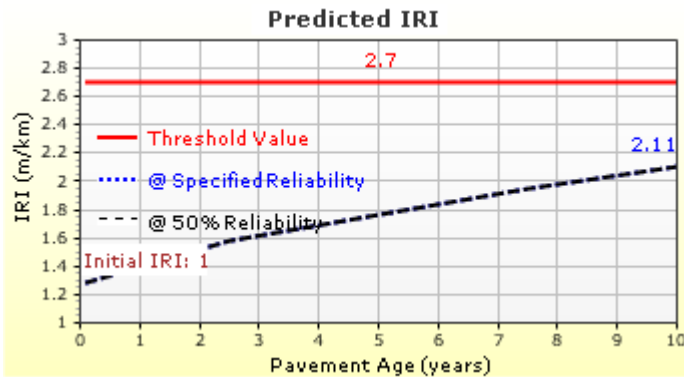
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.11	50.00	85.23	Pass
Permanent deformation - total pavement (mm)	5.00	30.38	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	26.00	50.00	47.18	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	645.83	50.00	27.58	Fail
Permanent deformation - AC only (mm)	5.00	14.51	50.00	0.76	Fail

Distress Charts

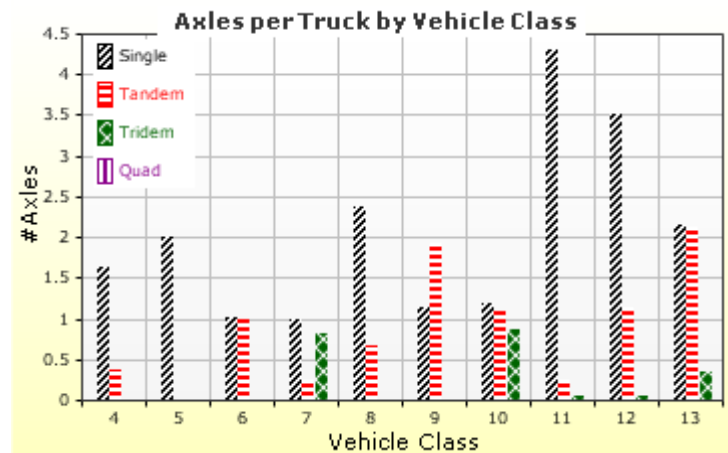
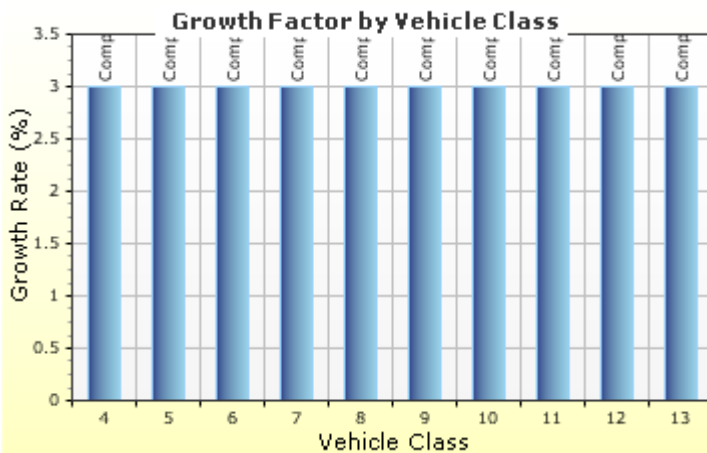
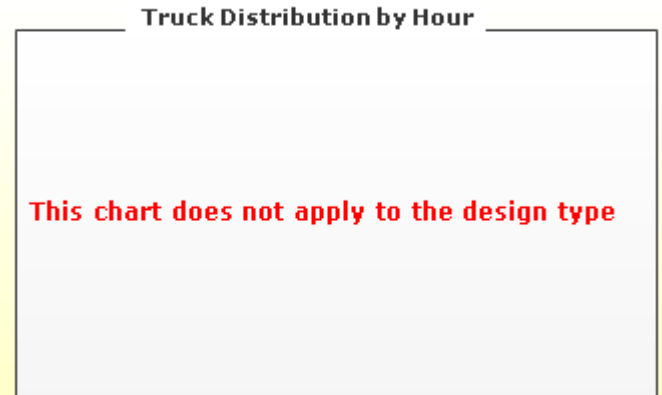
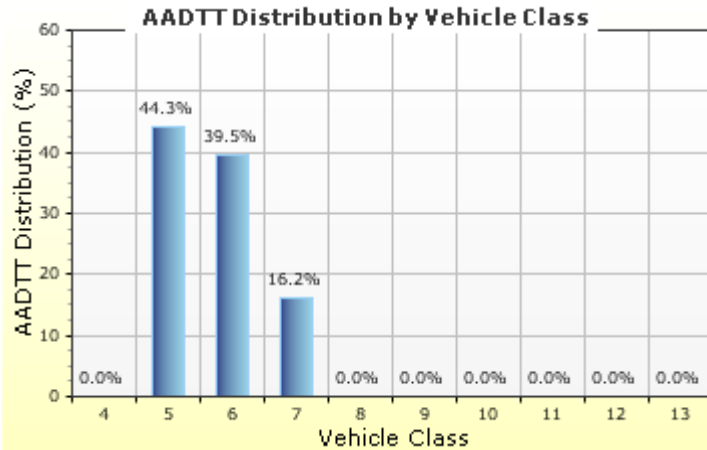


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

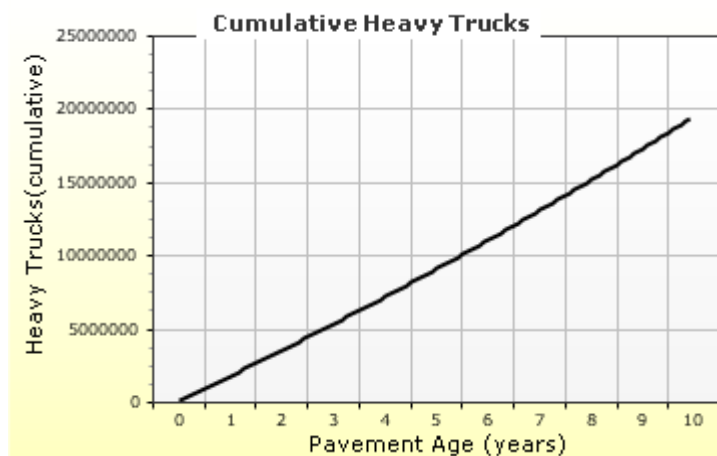
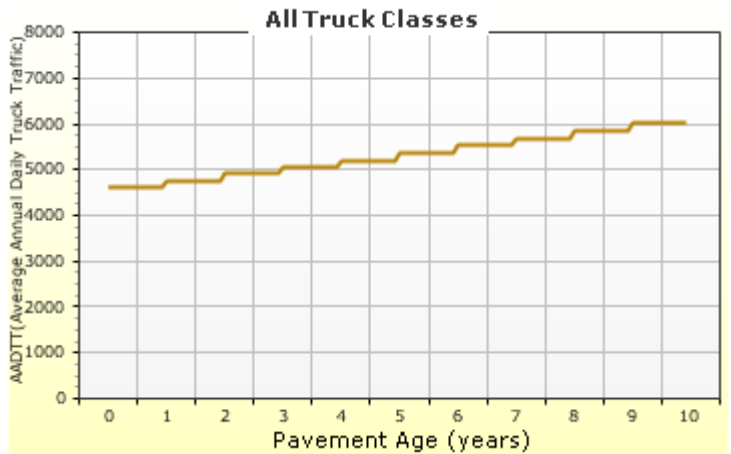
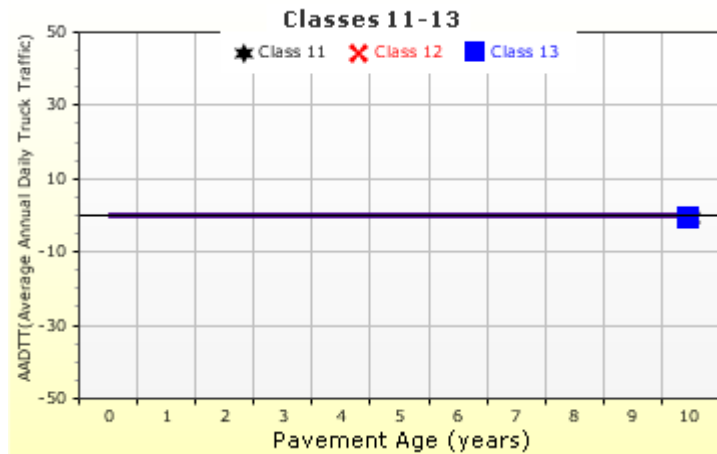
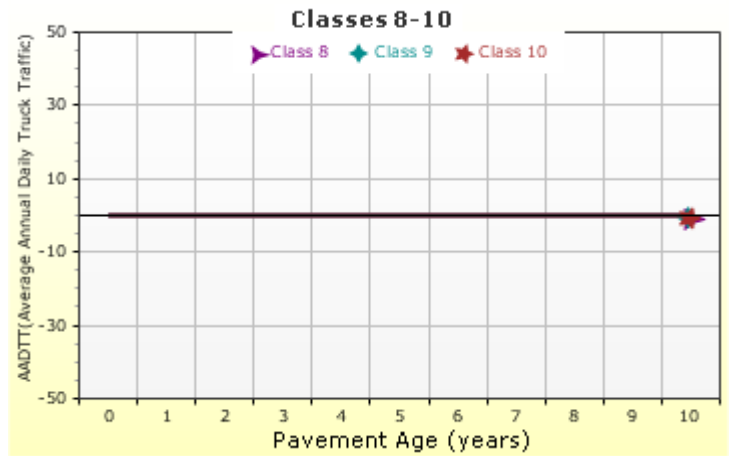
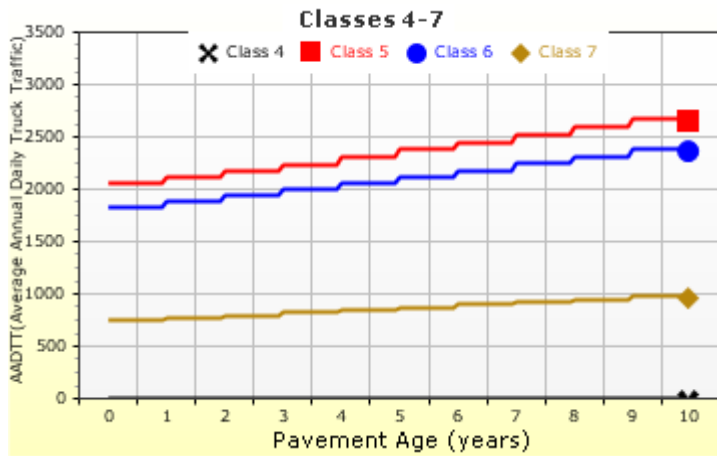
Wheelbase does not apply

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



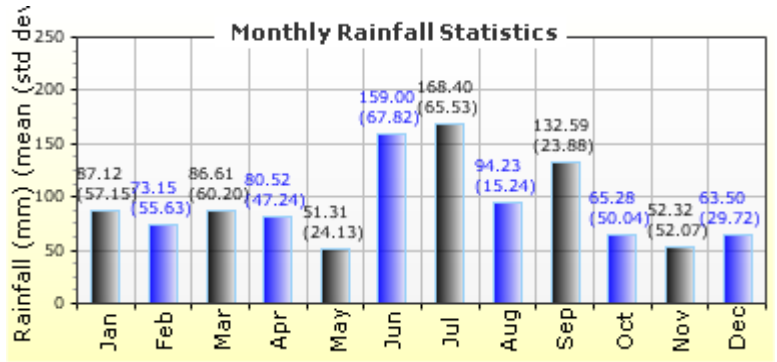
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

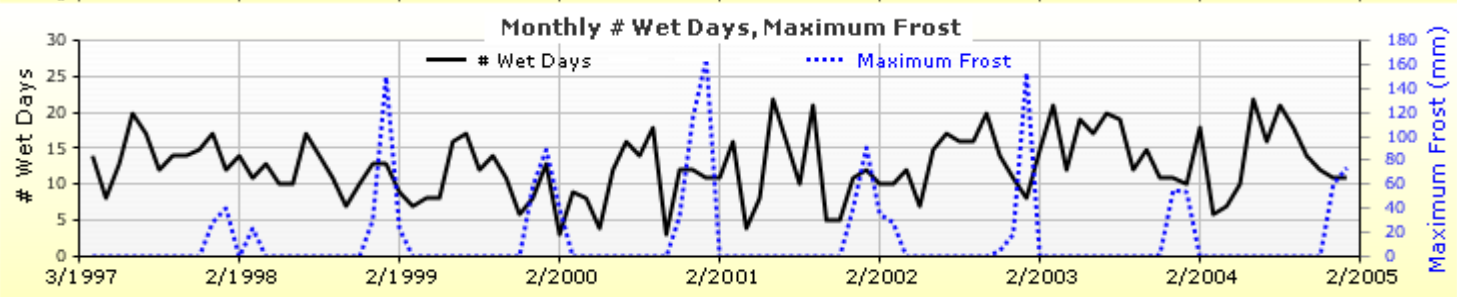
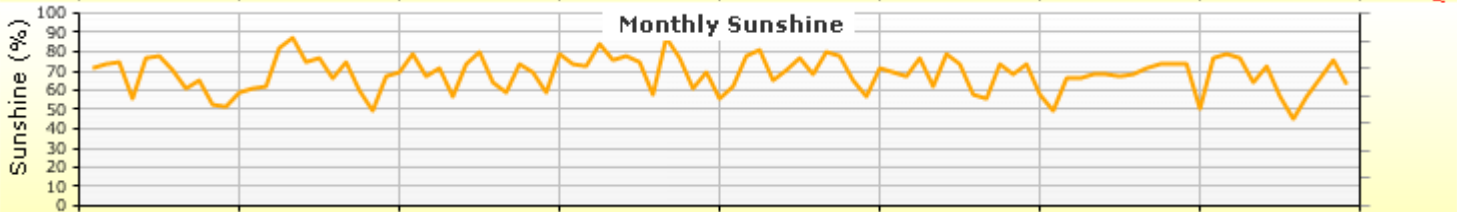
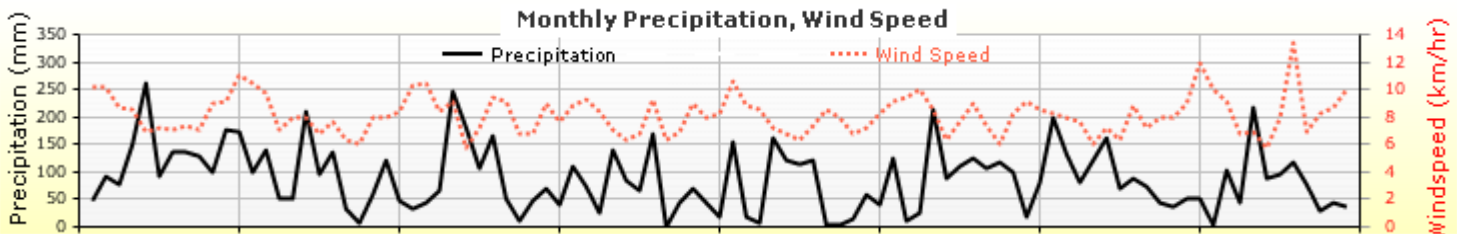
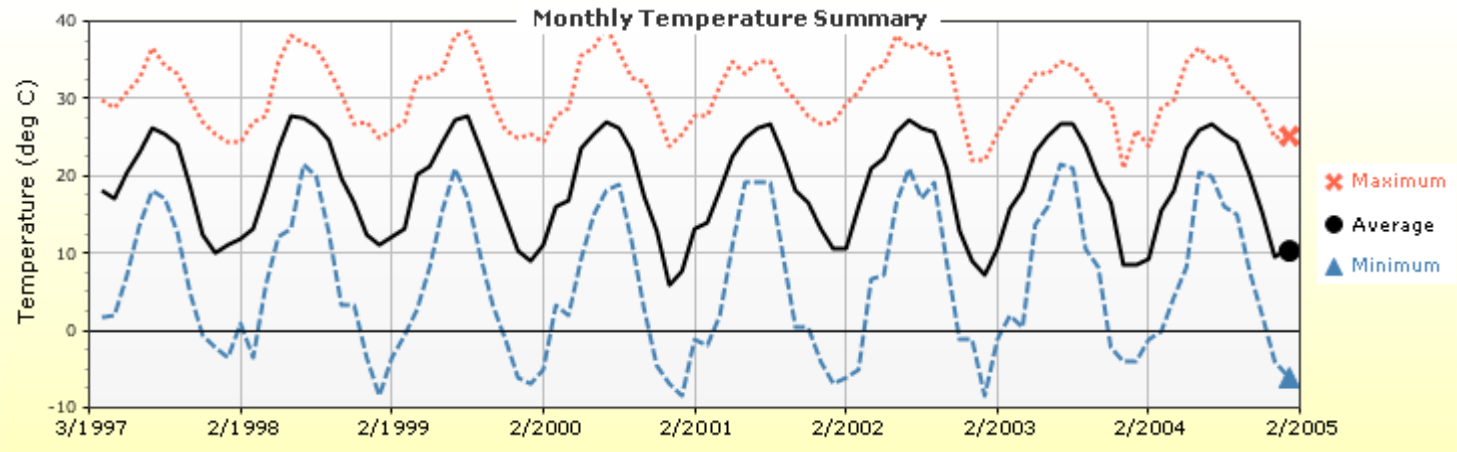
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

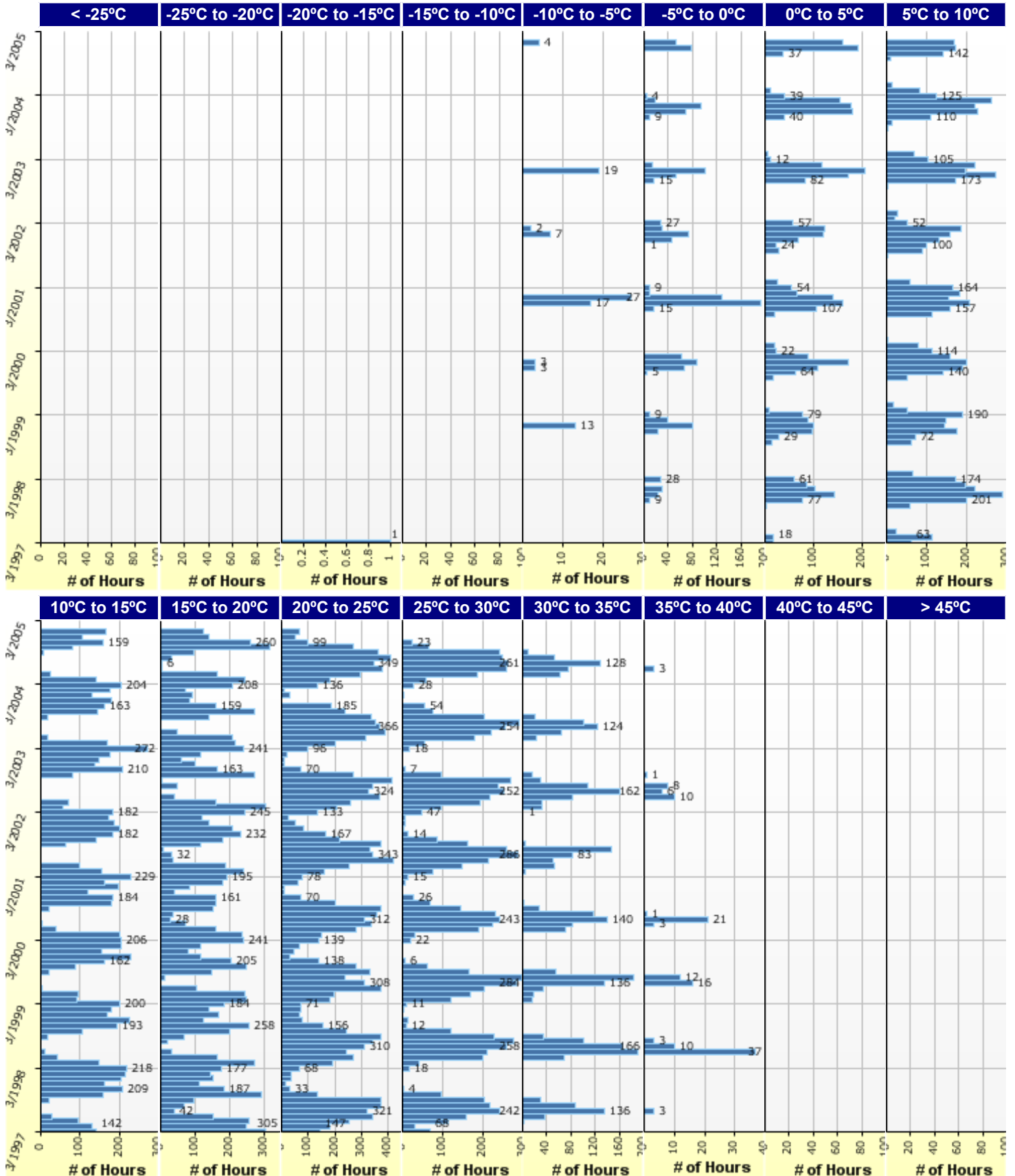


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF1

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1.dgpx



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

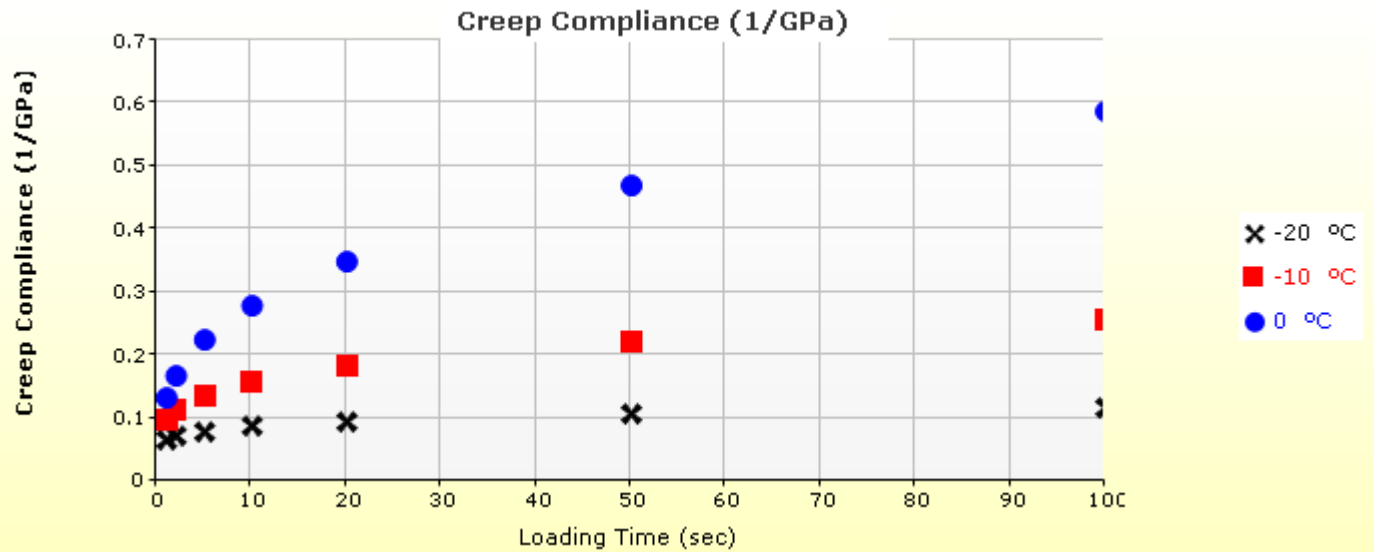
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

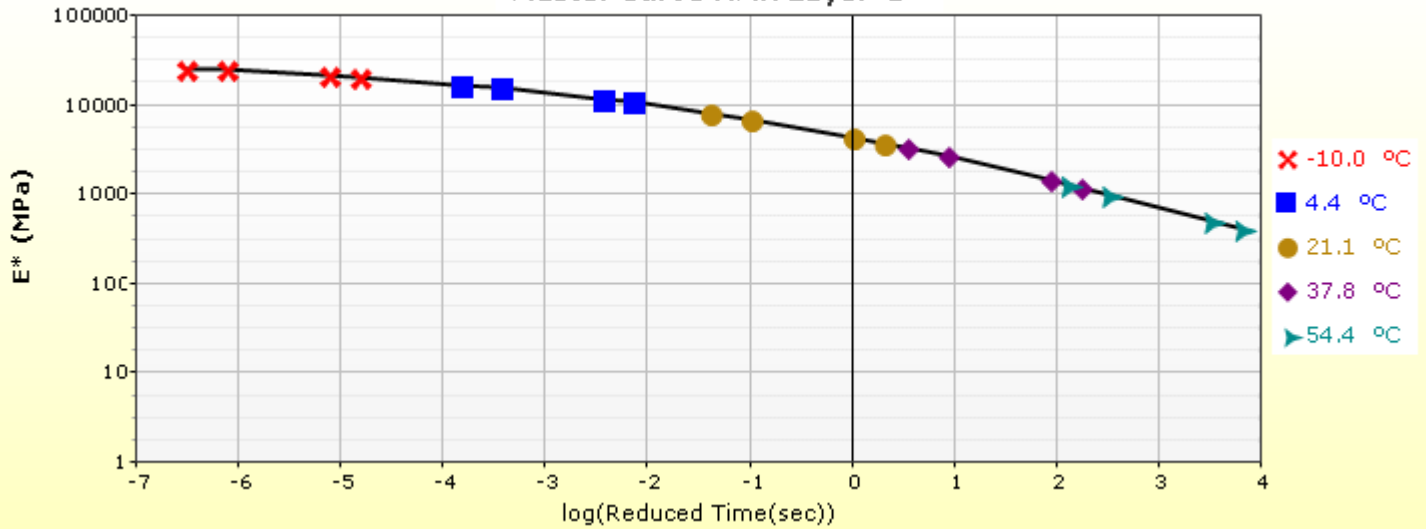
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

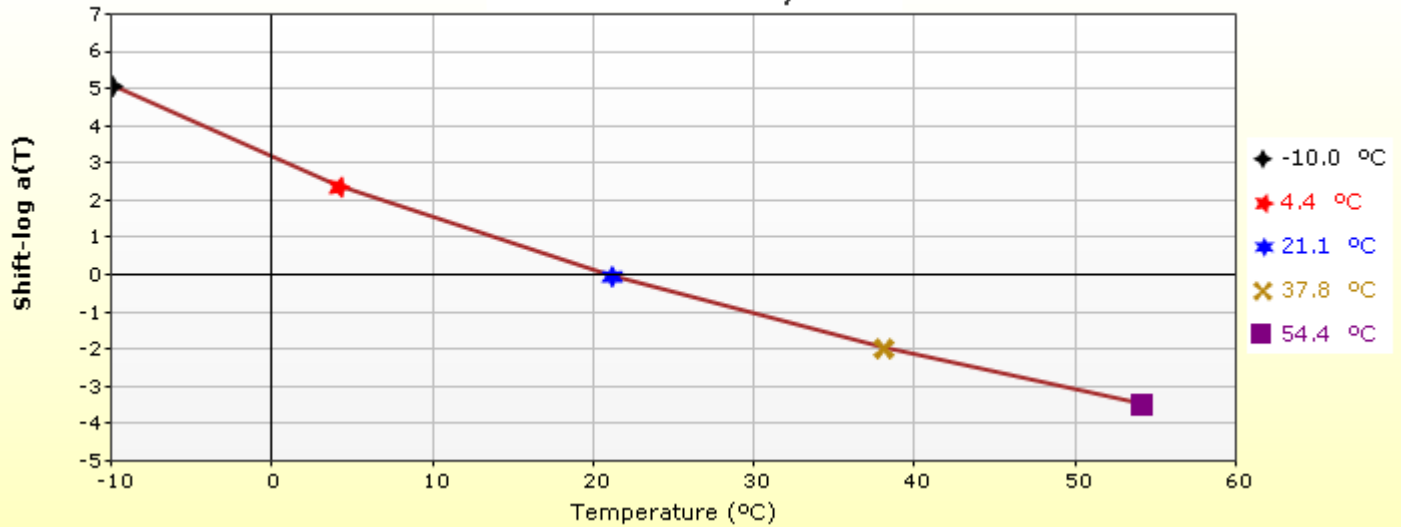


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

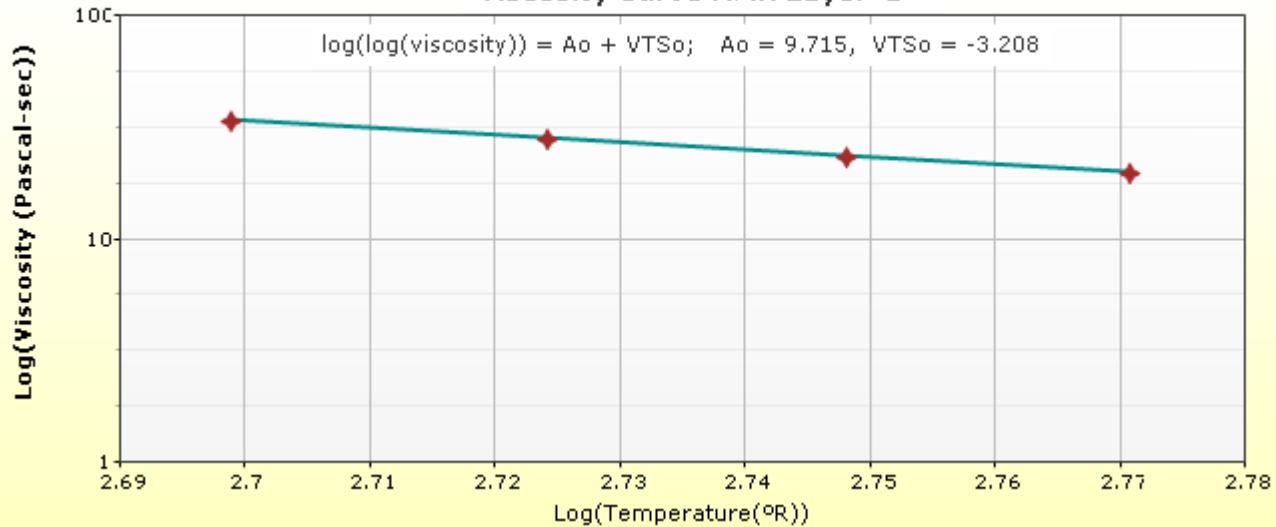
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

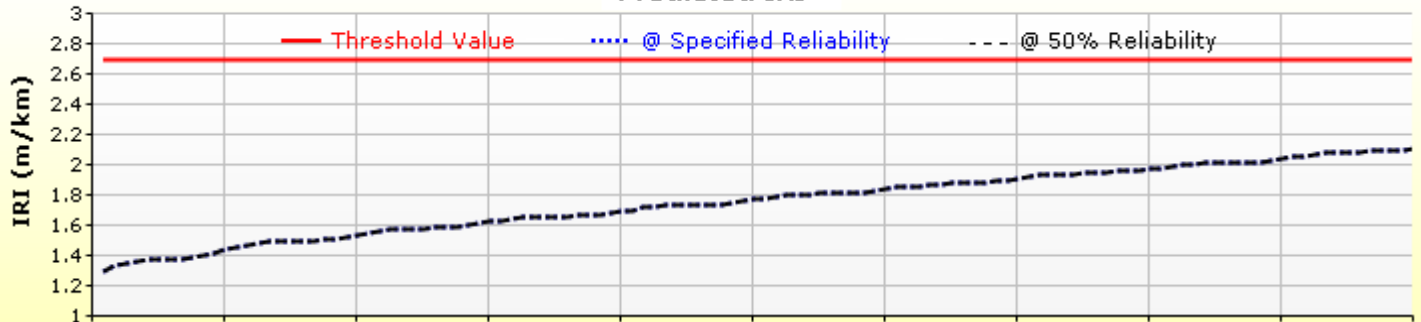


Viscosity Curve HMA Layer 1

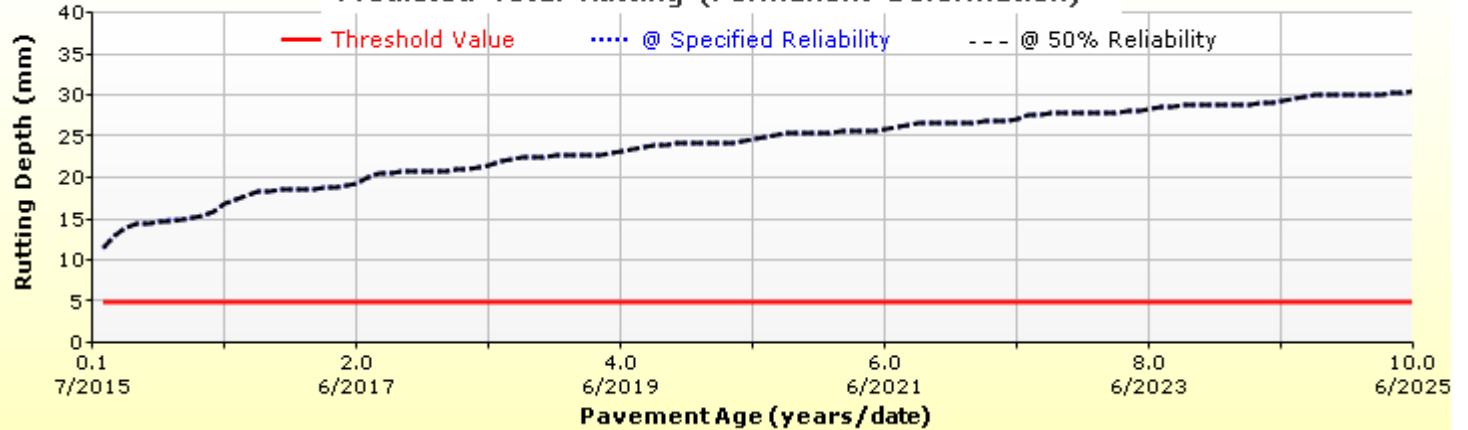


Analysis Output Charts

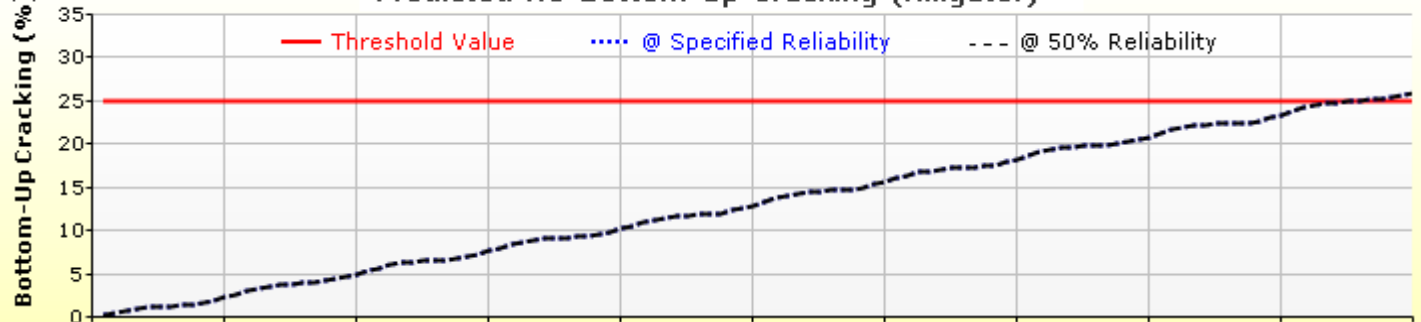
Predicted IRI



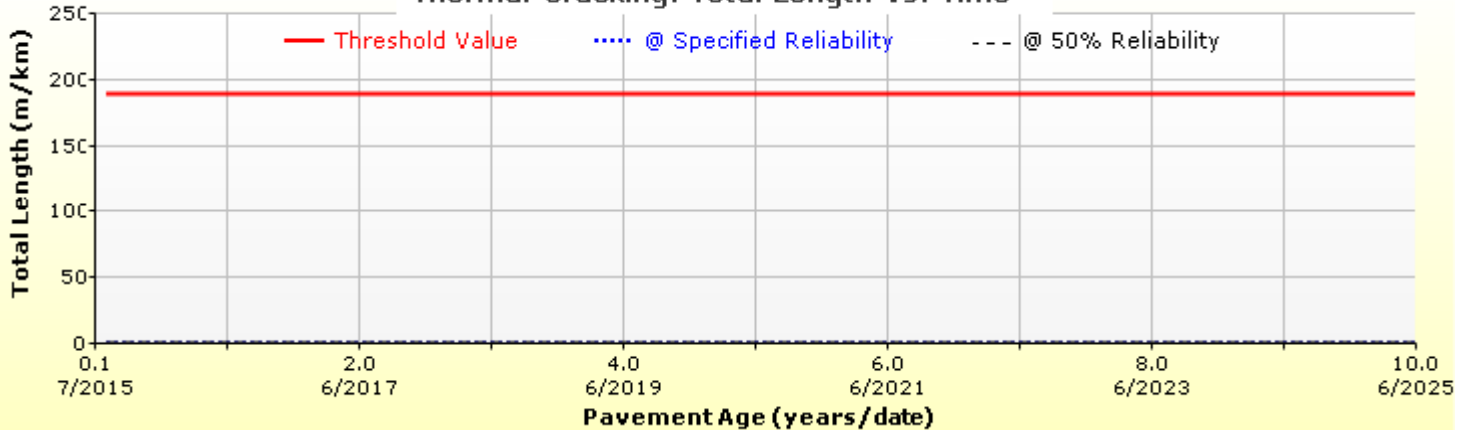
Predicted Total Rutting (Permanent Deformation)



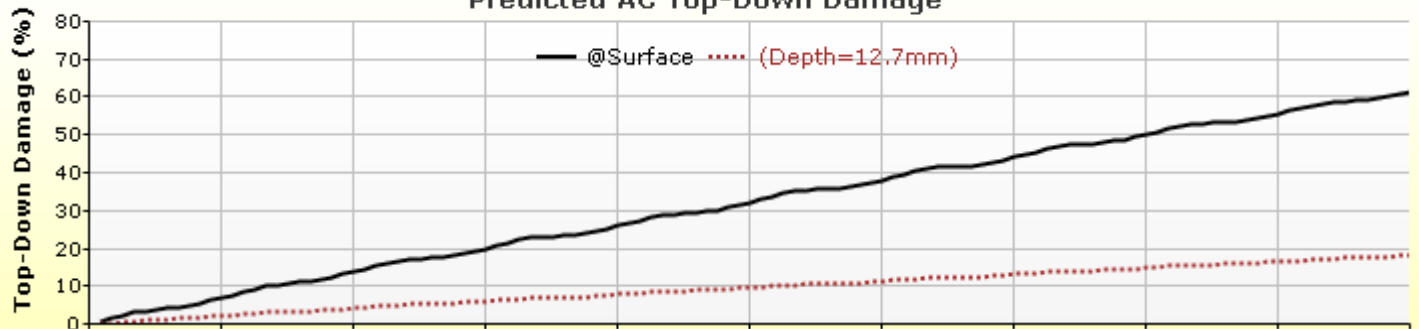
Predicted AC Bottom-Up Cracking (Alligator)



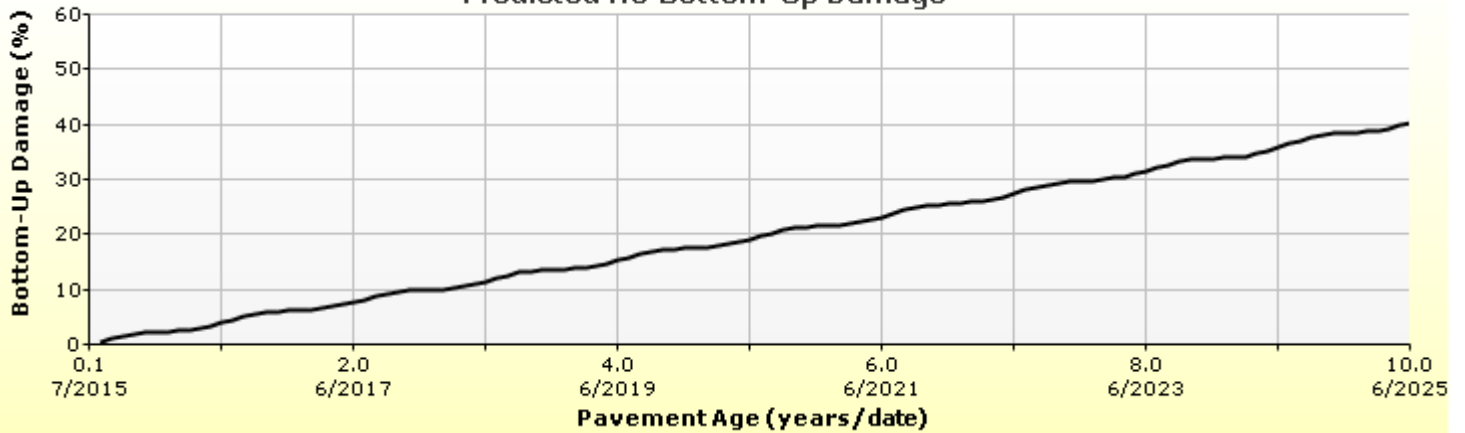
Thermal Cracking: Total Length vs. Time



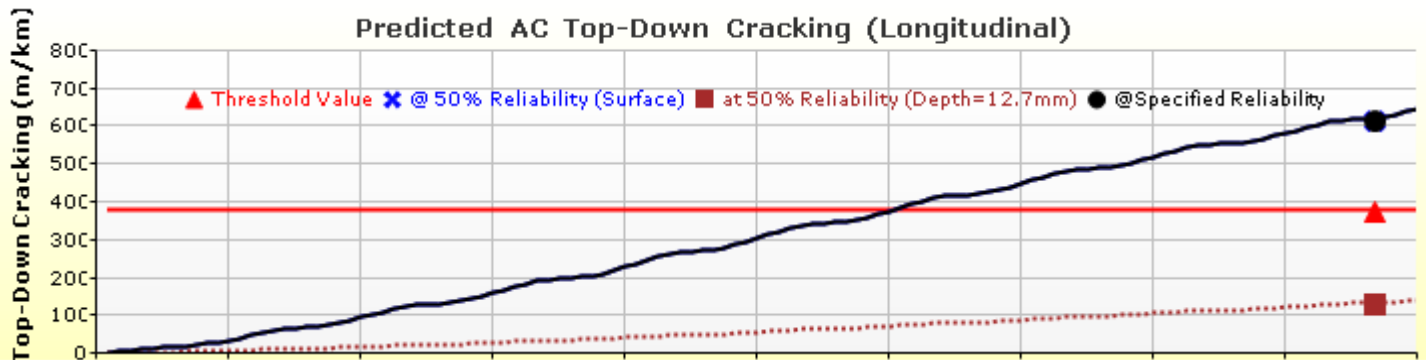
Predicted AC Top-Down Damage



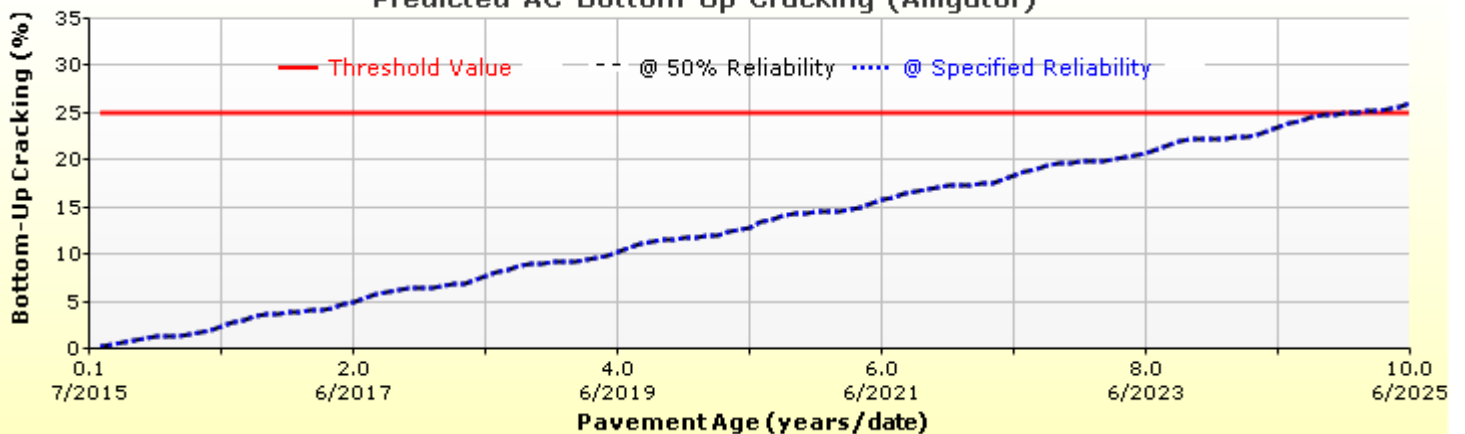
Predicted AC Bottom-Up Damage



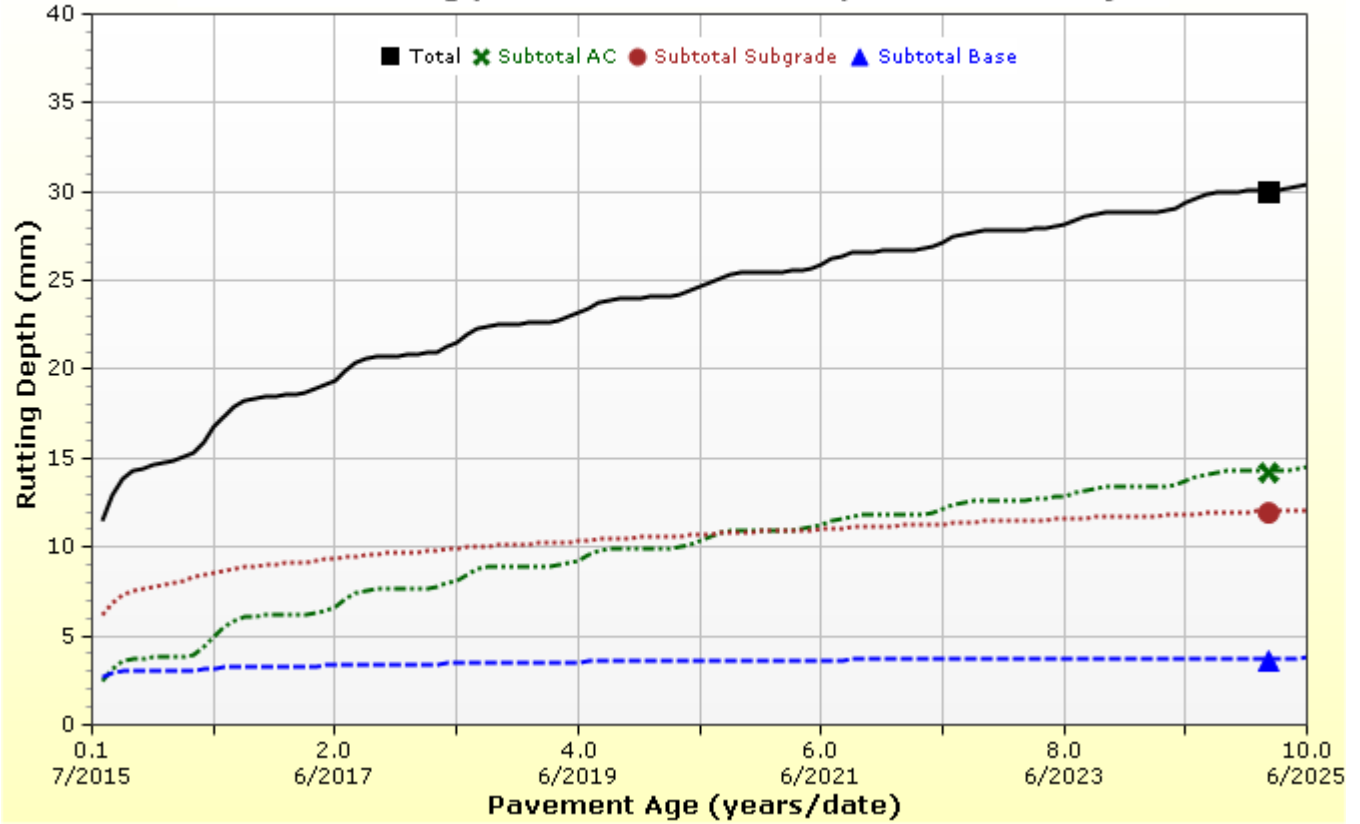
Predicted AC Top-Down Cracking (Longitudinal)

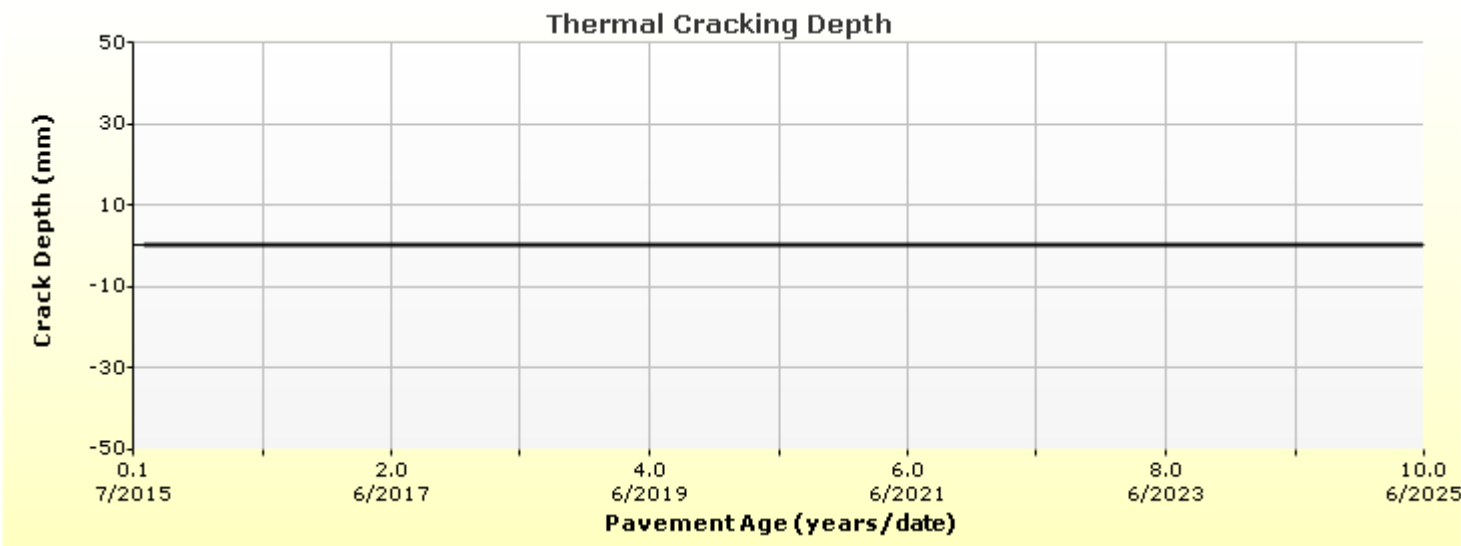
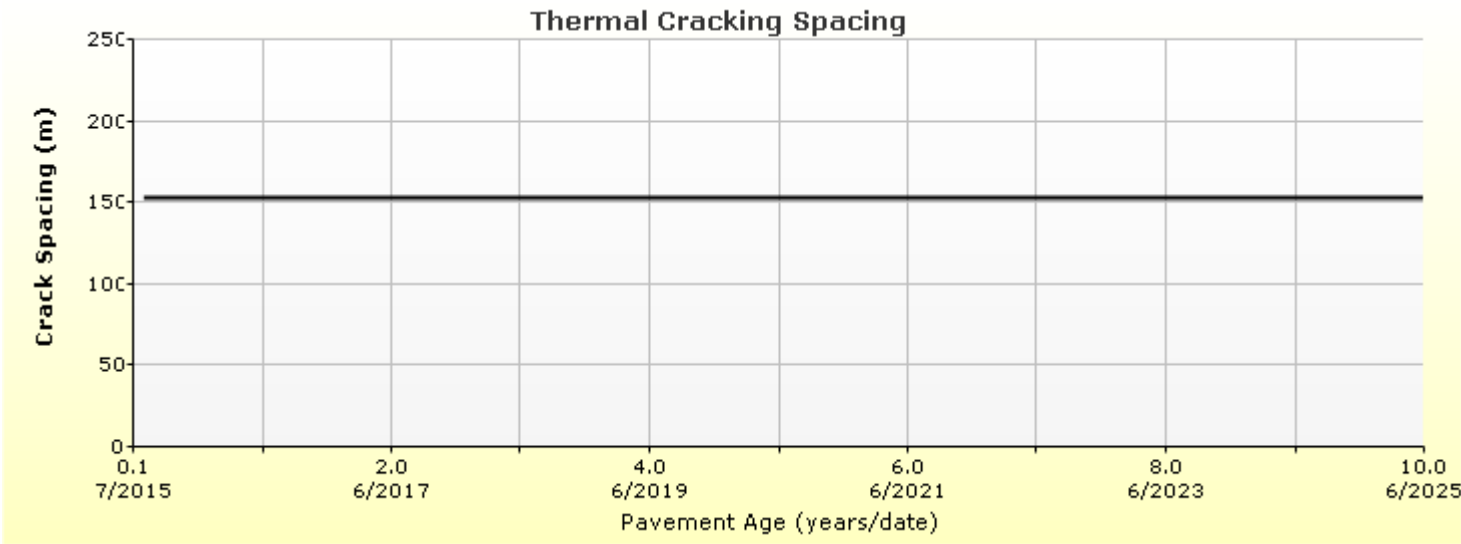


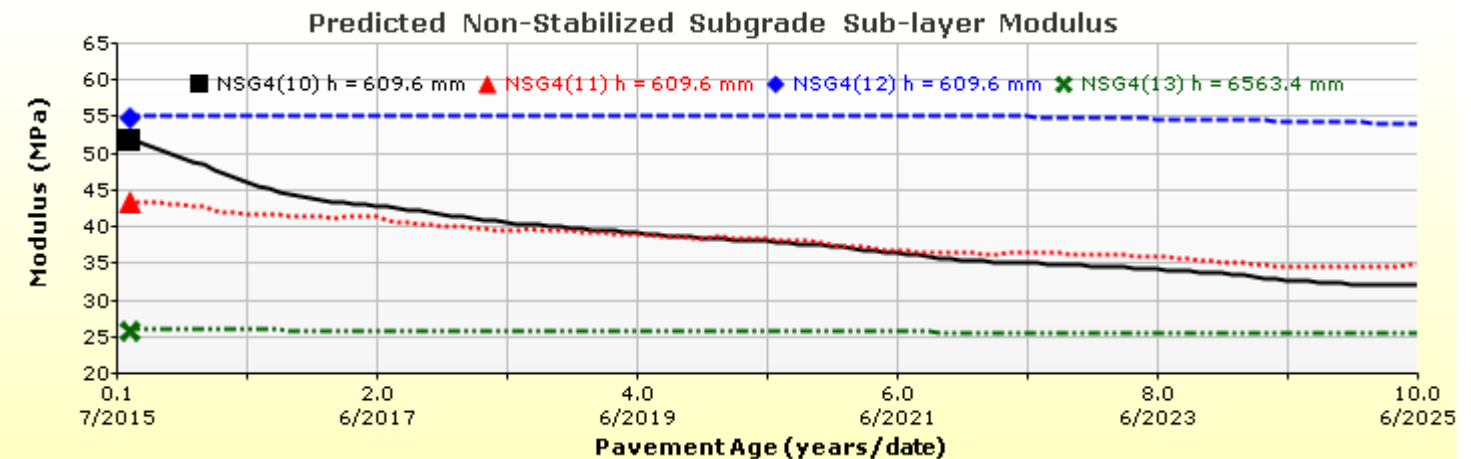
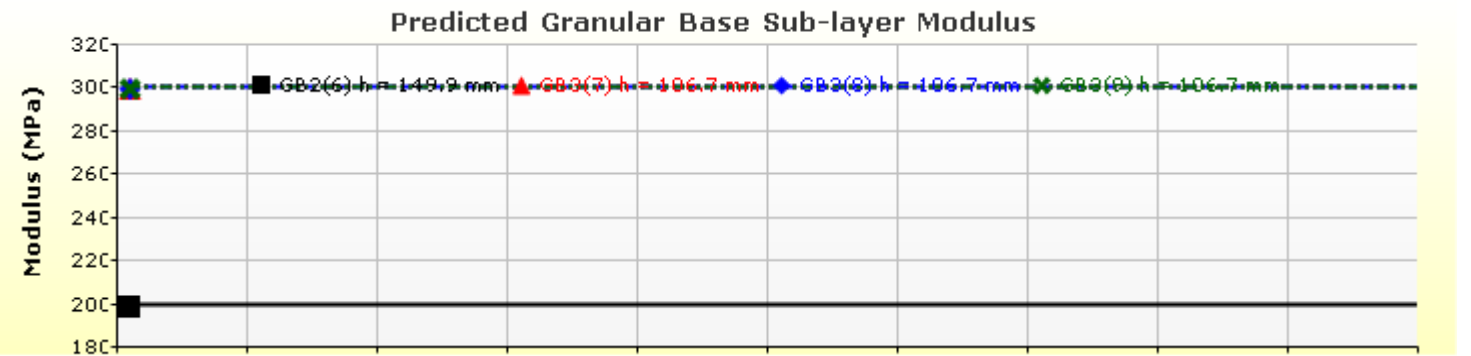
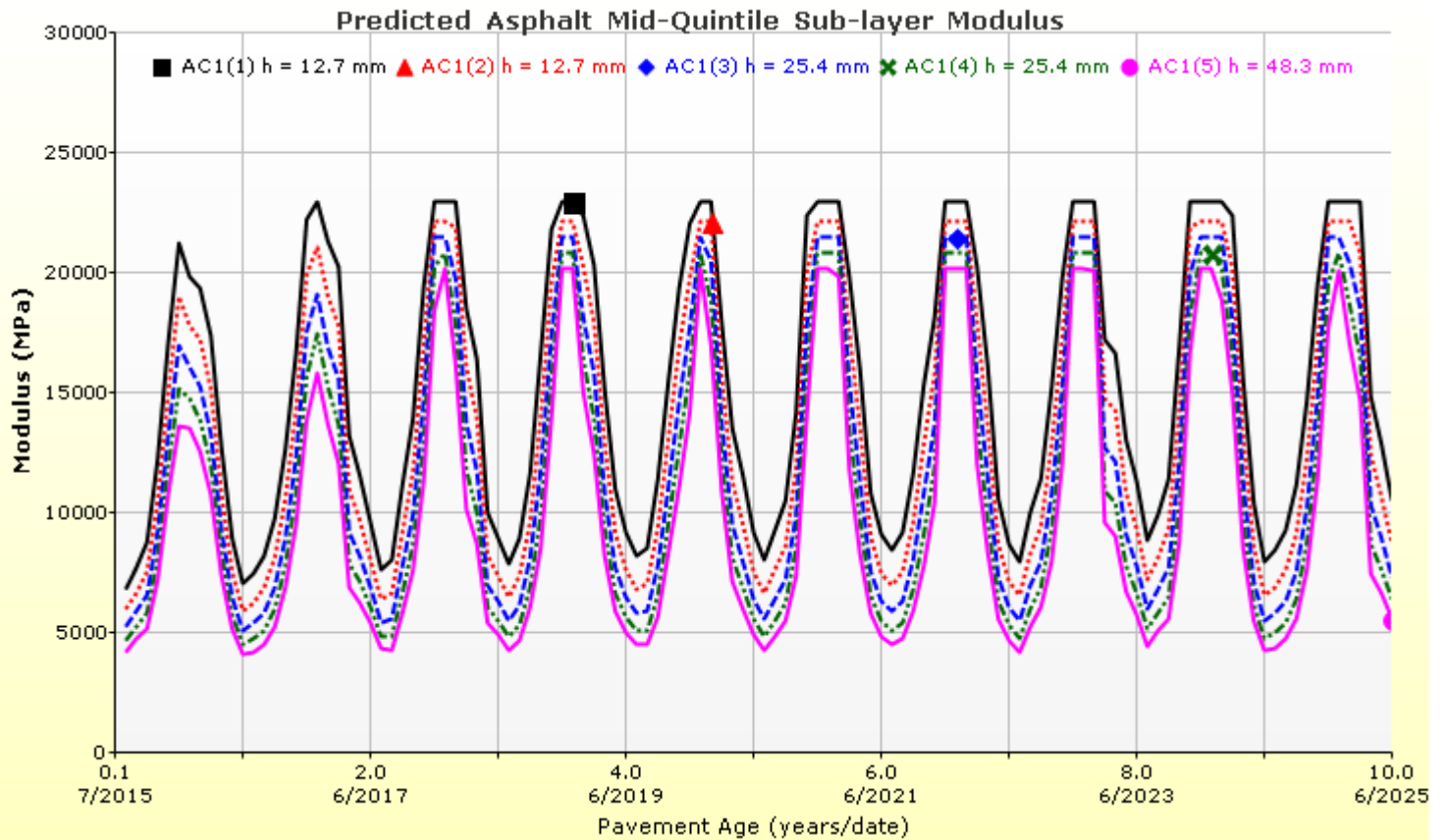
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

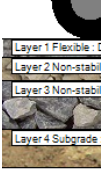
Design Inputs

Design Life: **10 years**
Design Type: **Flexible Pavement**

Base construction: **March, 2015**
Pavement construction: **June, 2015**
Traffic opening: **July, 2015**

Climate Data **32.119, -81.202**
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

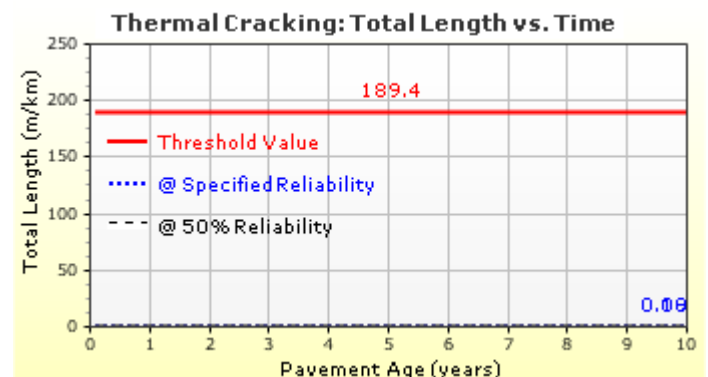
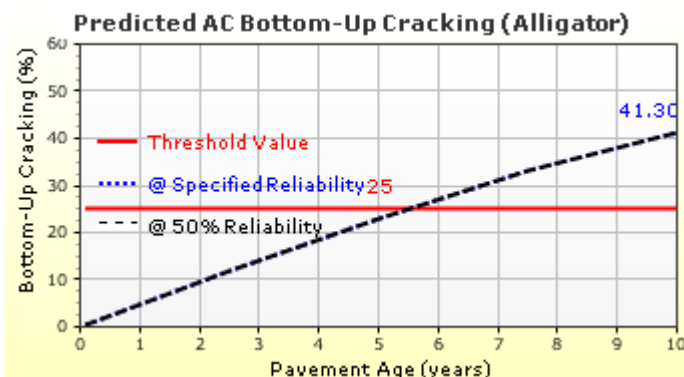
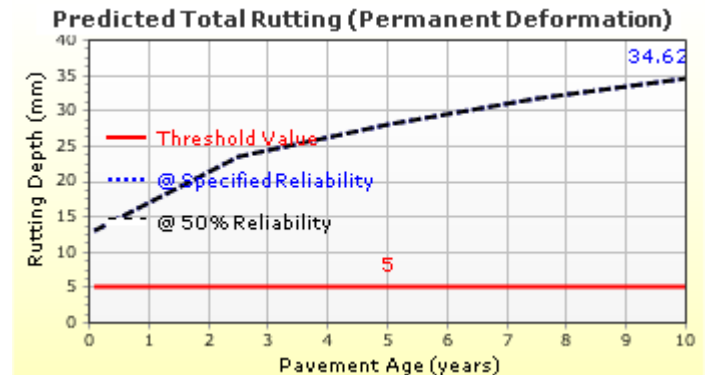
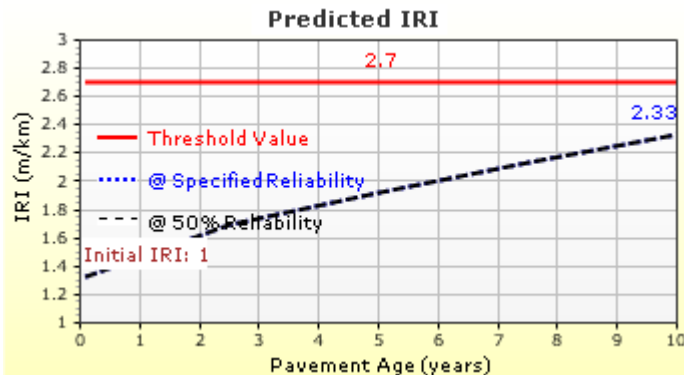
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.33	50.00	73.16	Pass
Permanent deformation - total pavement (mm)	5.00	34.62	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	41.30	50.00	12.43	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	929.92	50.00	11.34	Fail
Permanent deformation - AC only (mm)	5.00	17.02	50.00	0.34	Fail

Distress Charts

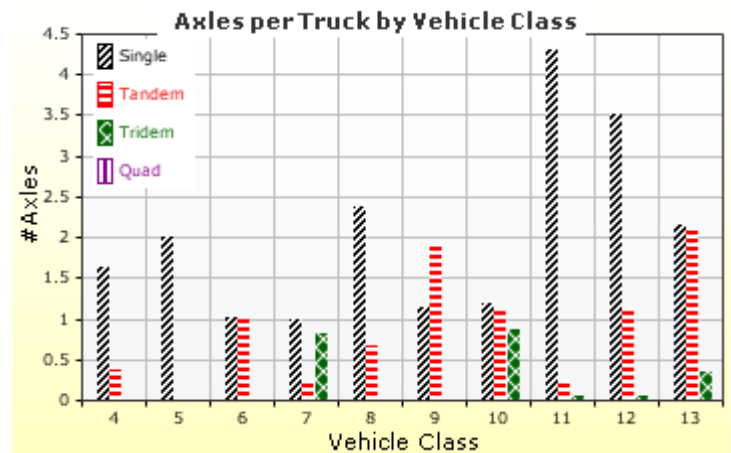
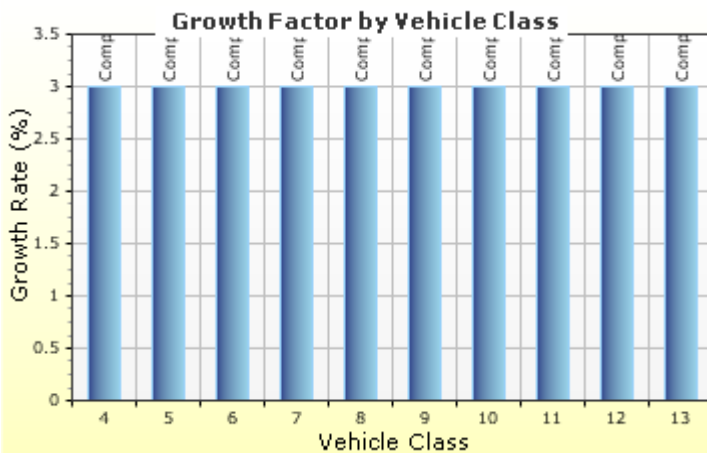
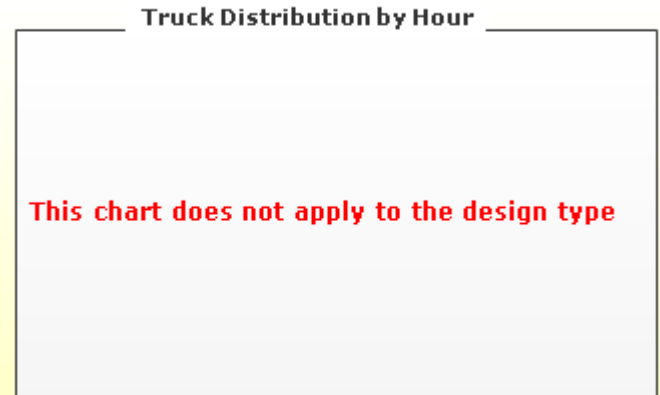
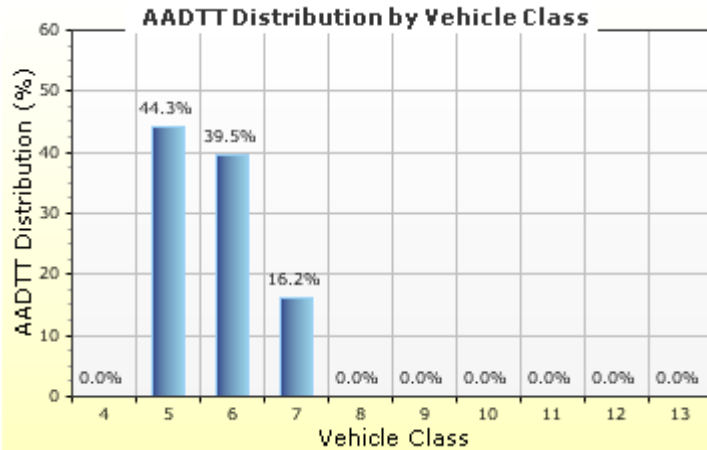


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

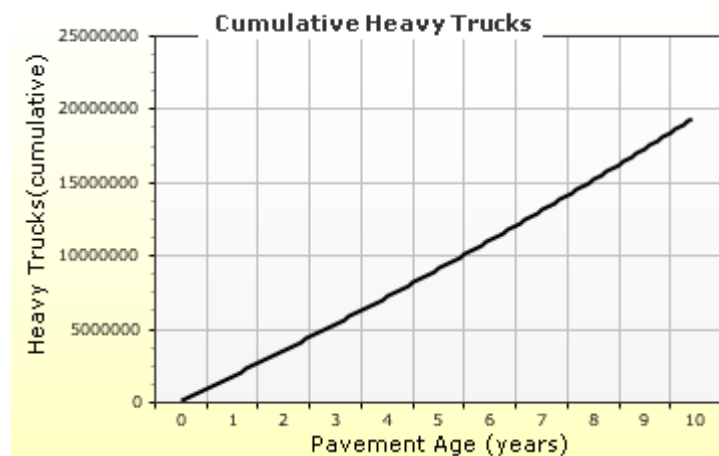
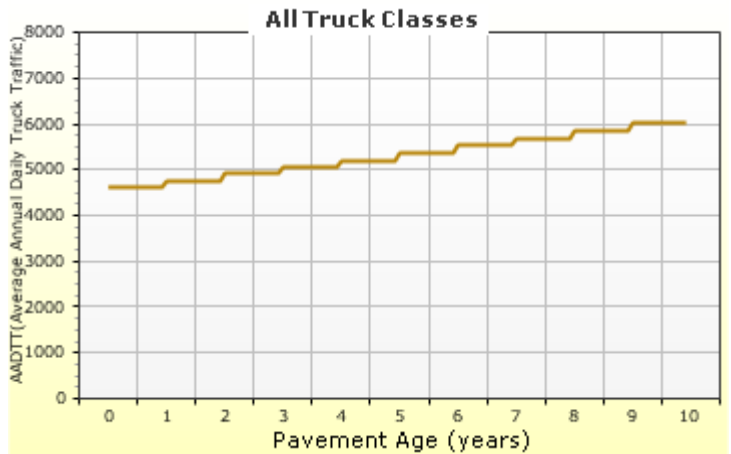
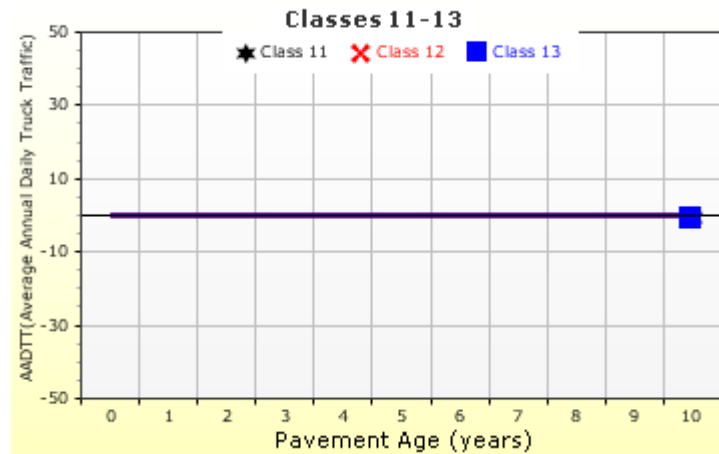
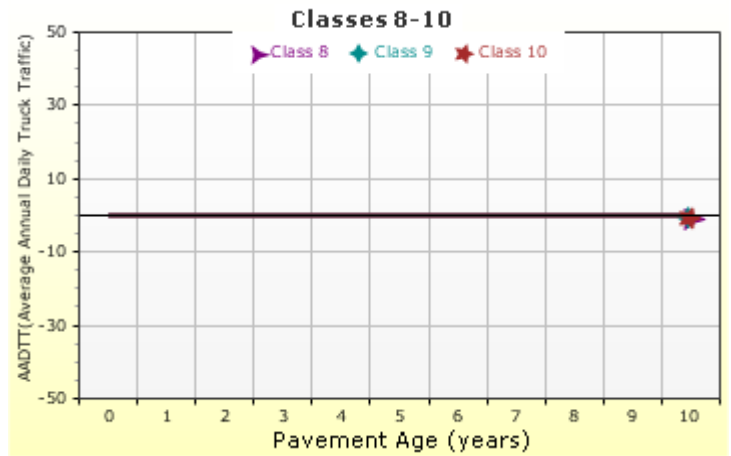
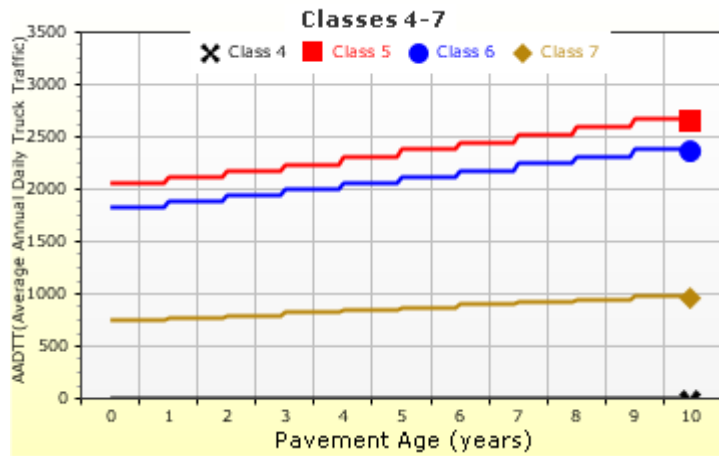
Wheelbase does not apply

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



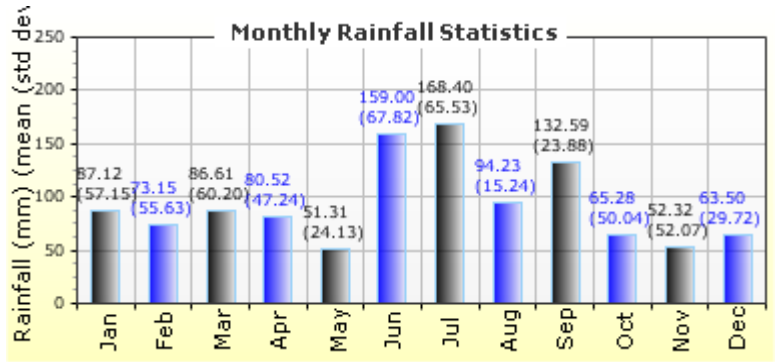
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

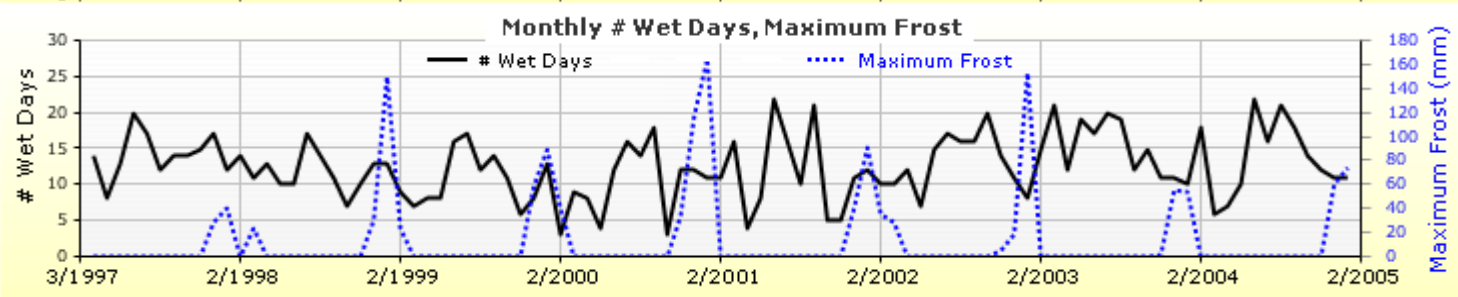
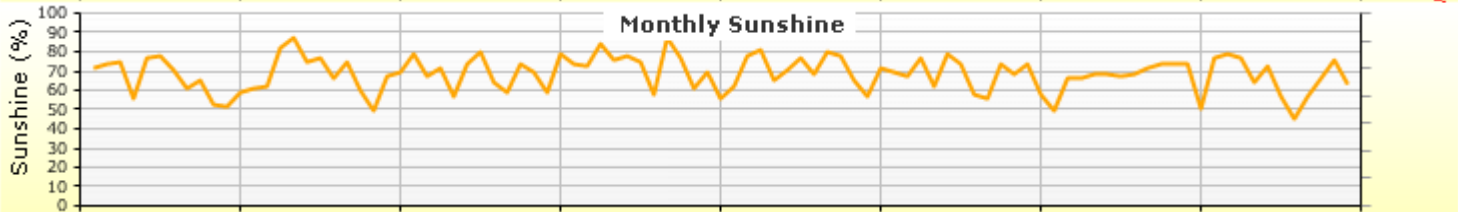
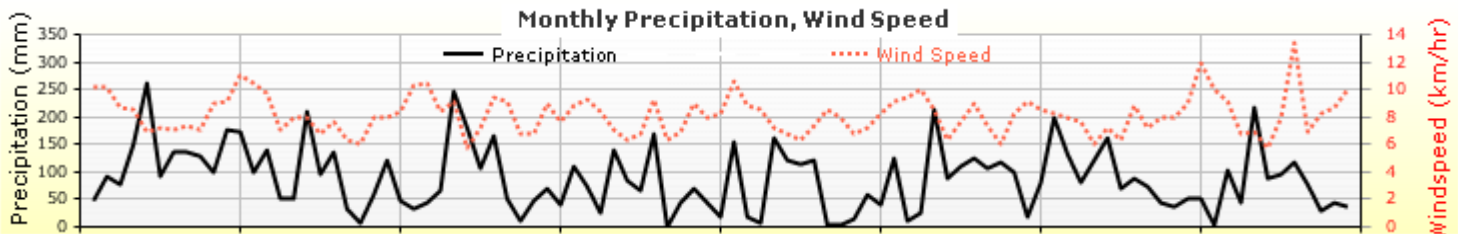
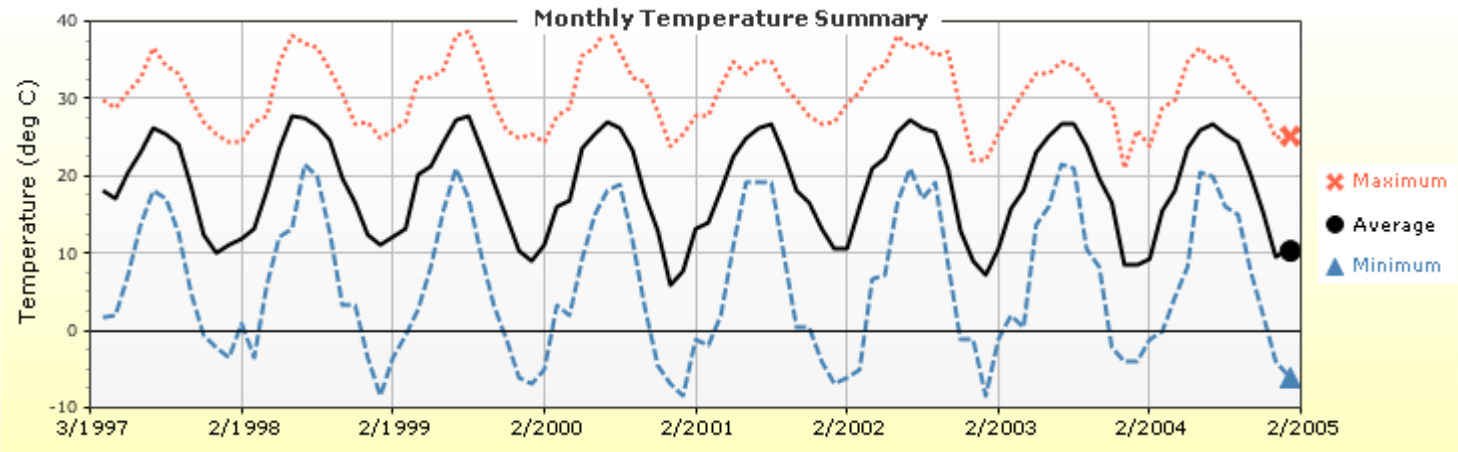
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

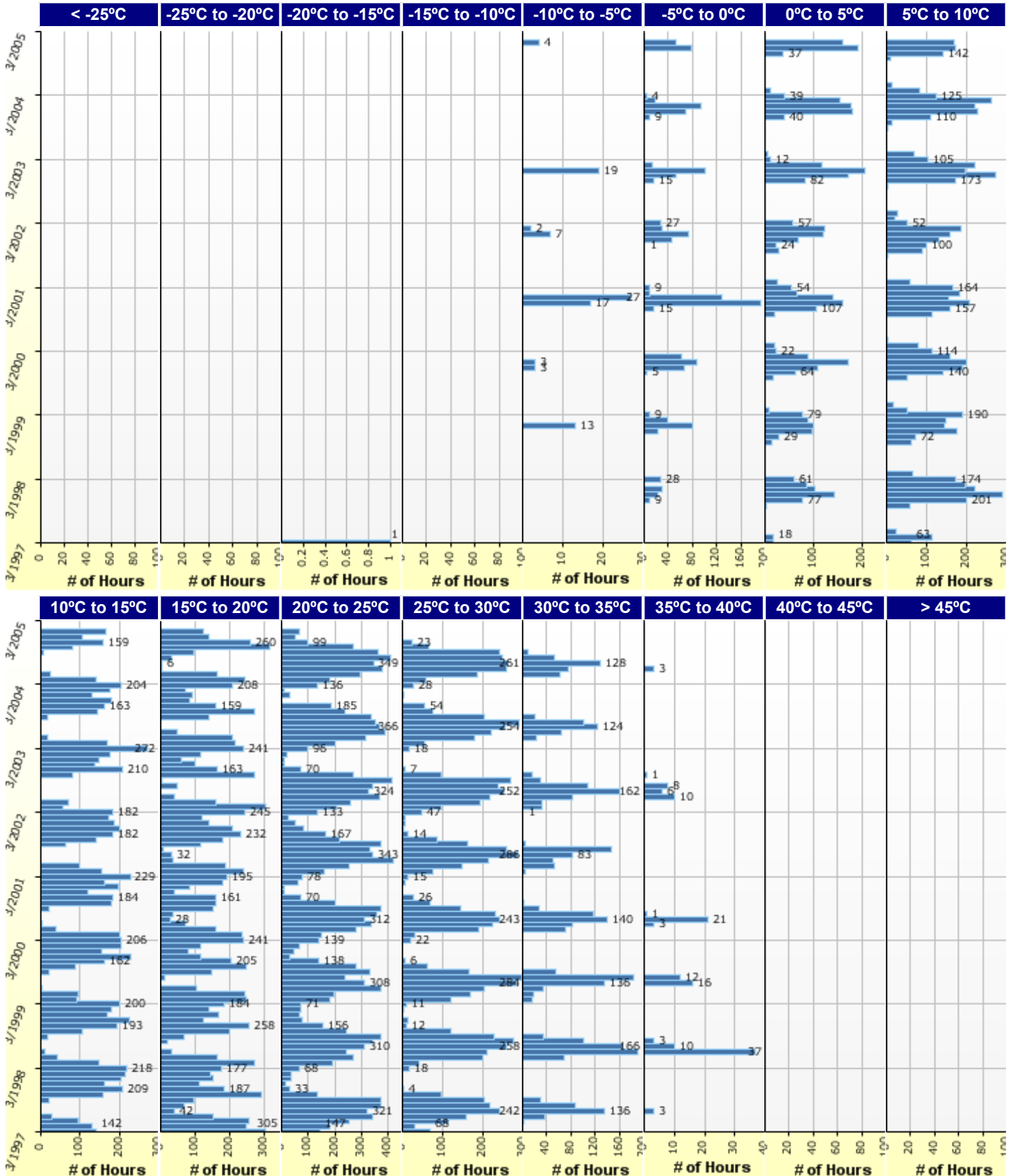


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF2

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF2.dgpx



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

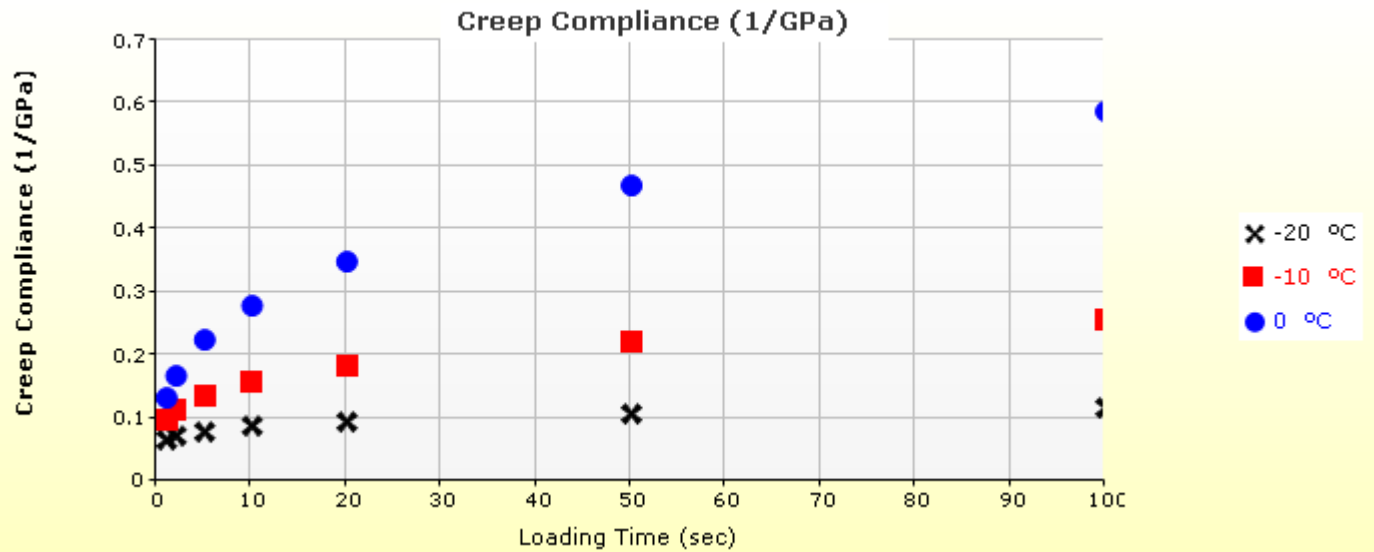
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

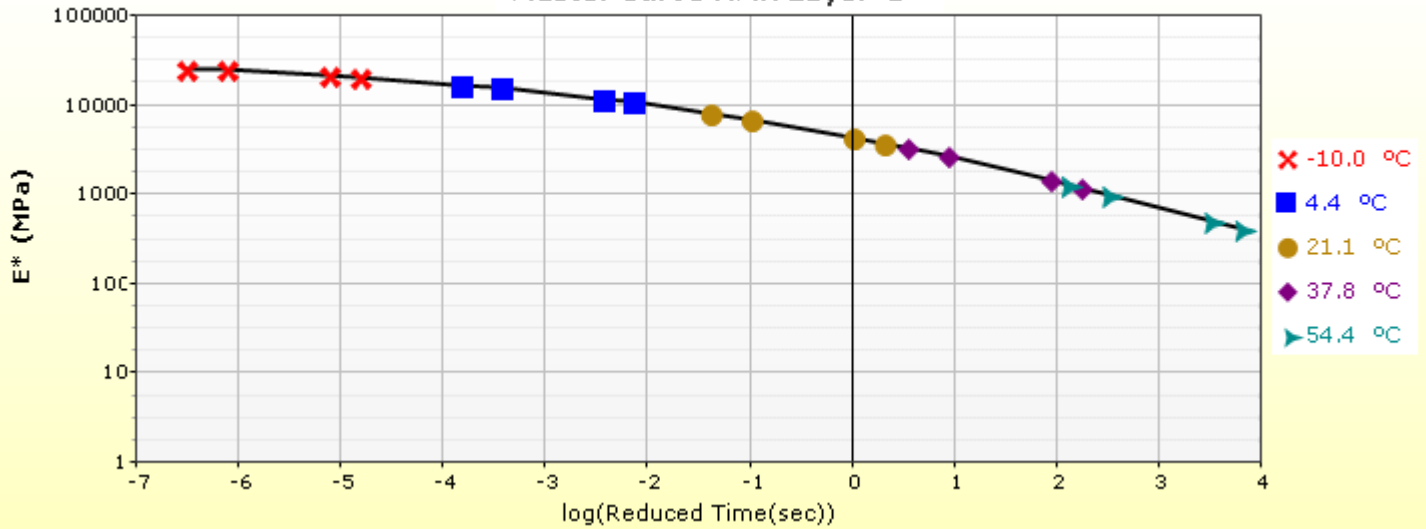
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

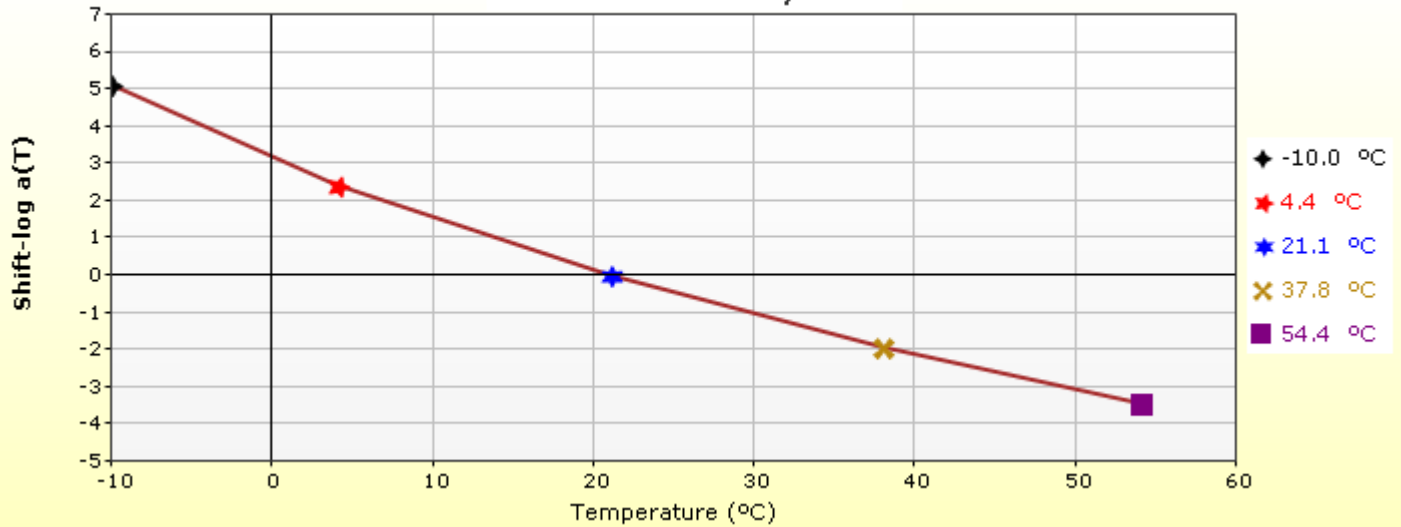


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

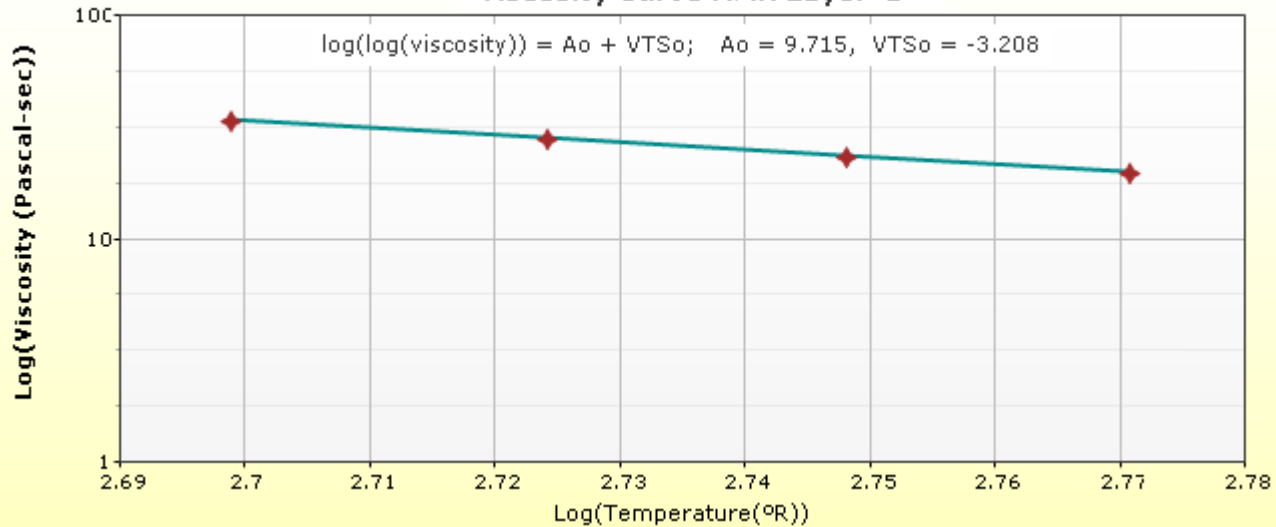
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

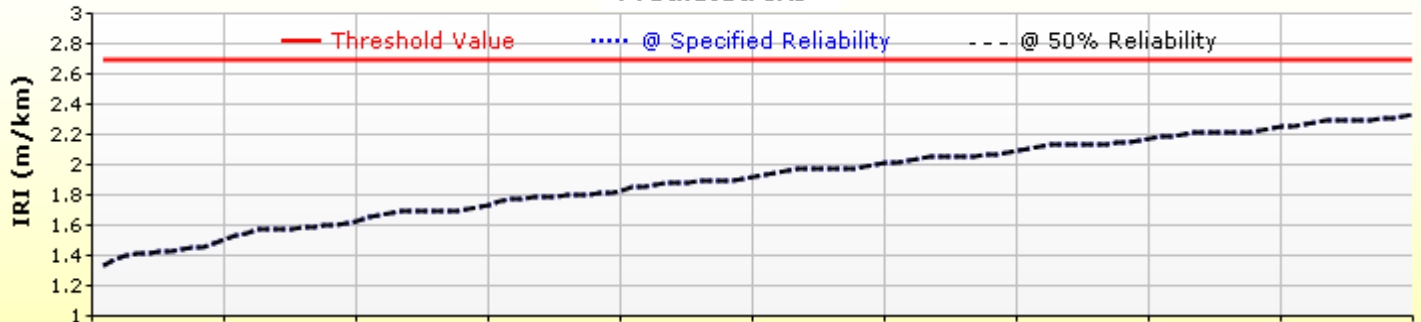


Viscosity Curve HMA Layer 1

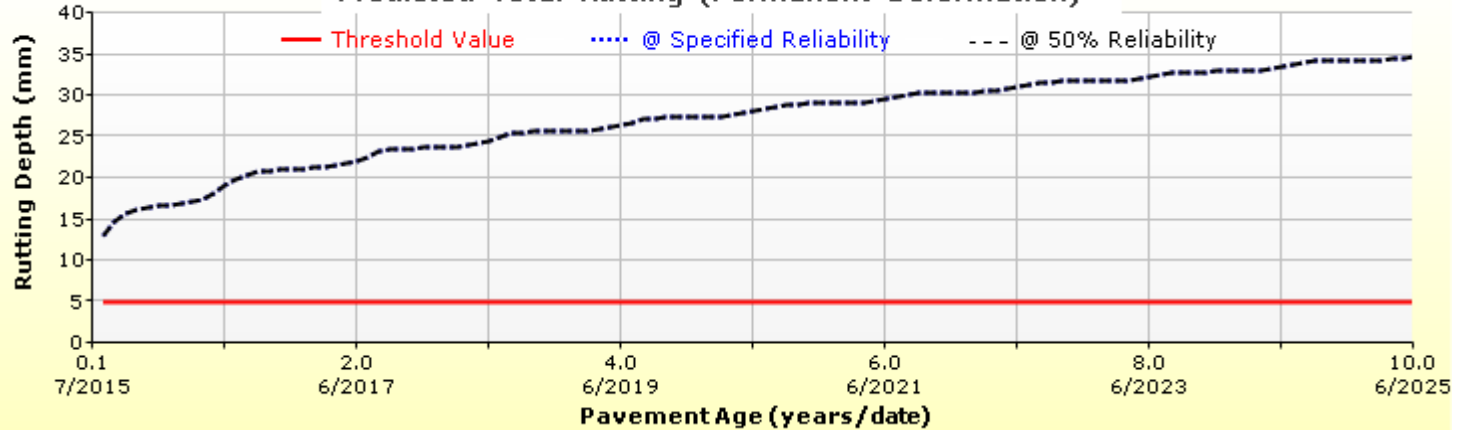


Analysis Output Charts

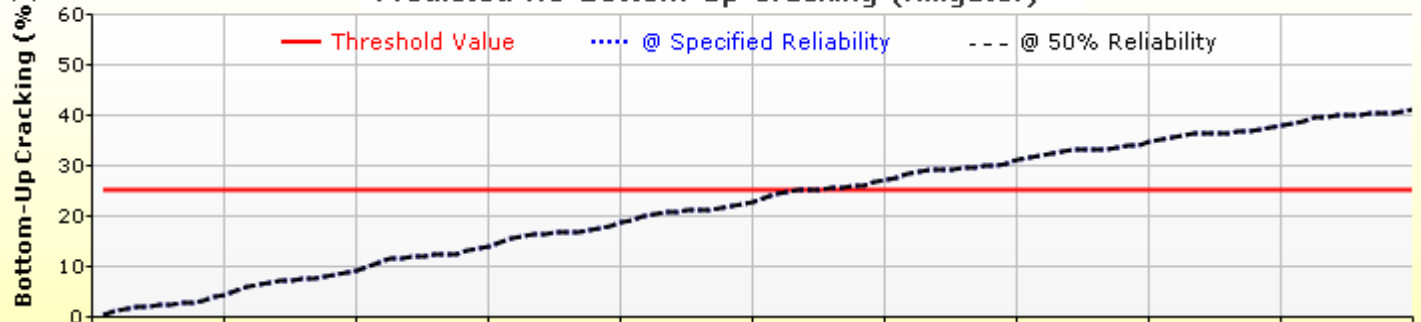
Predicted IRI



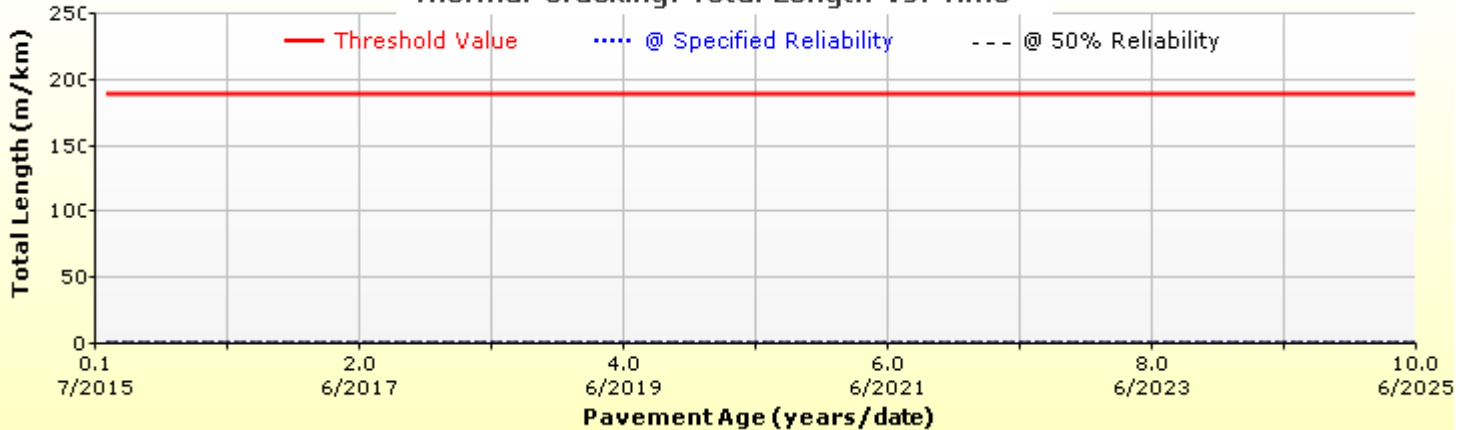
Predicted Total Rutting (Permanent Deformation)

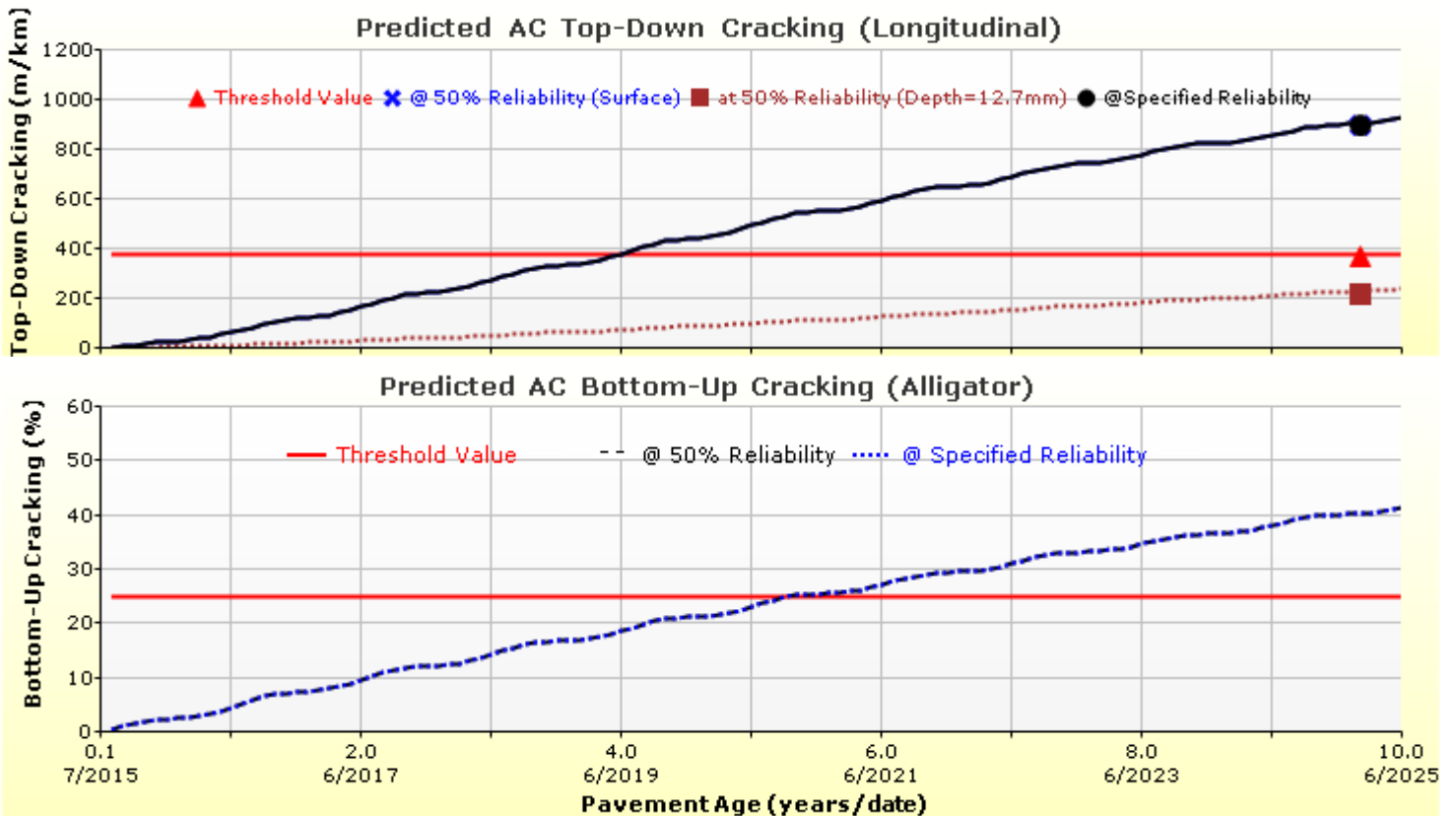
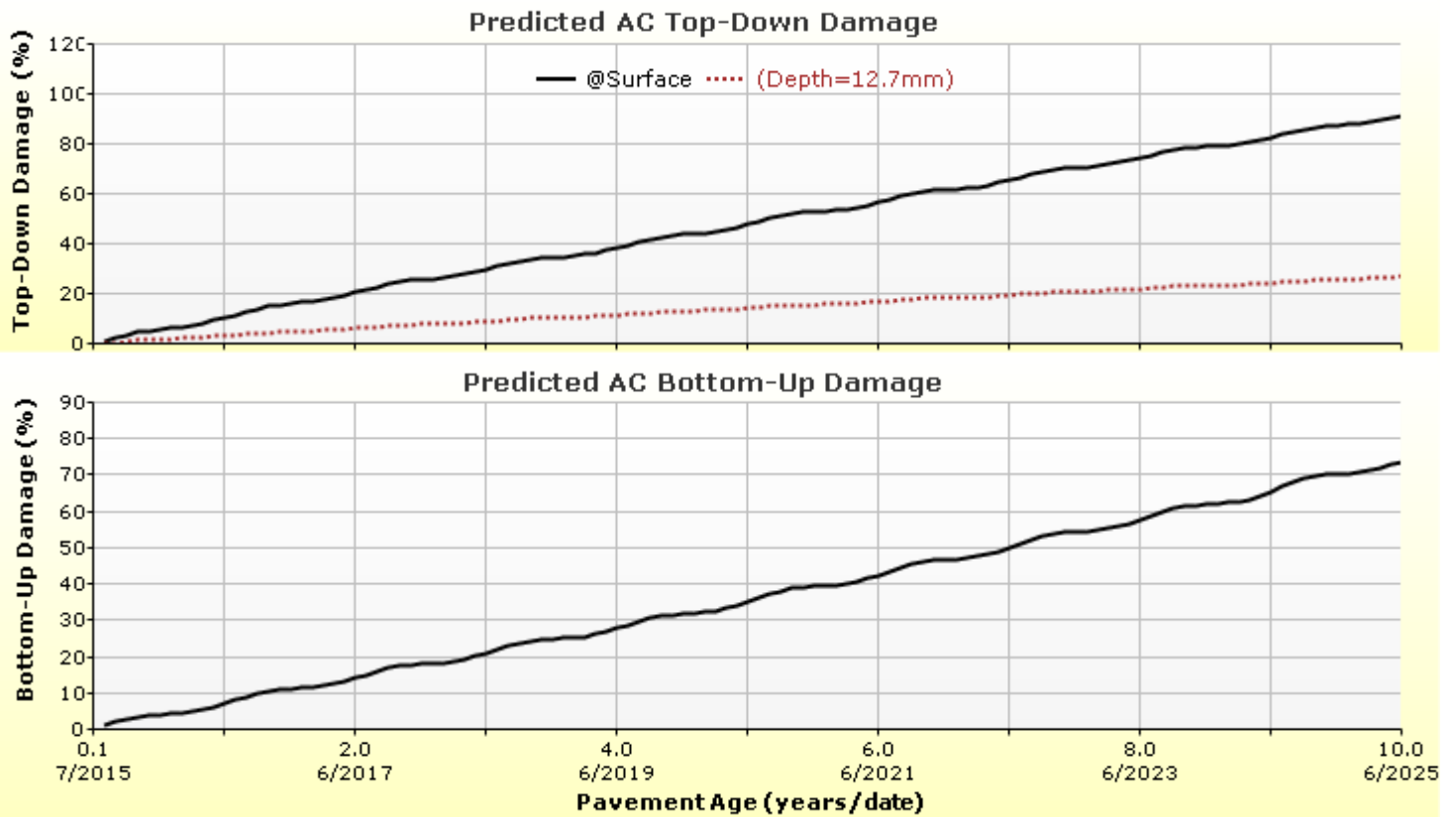


Predicted AC Bottom-Up Cracking (Alligator)

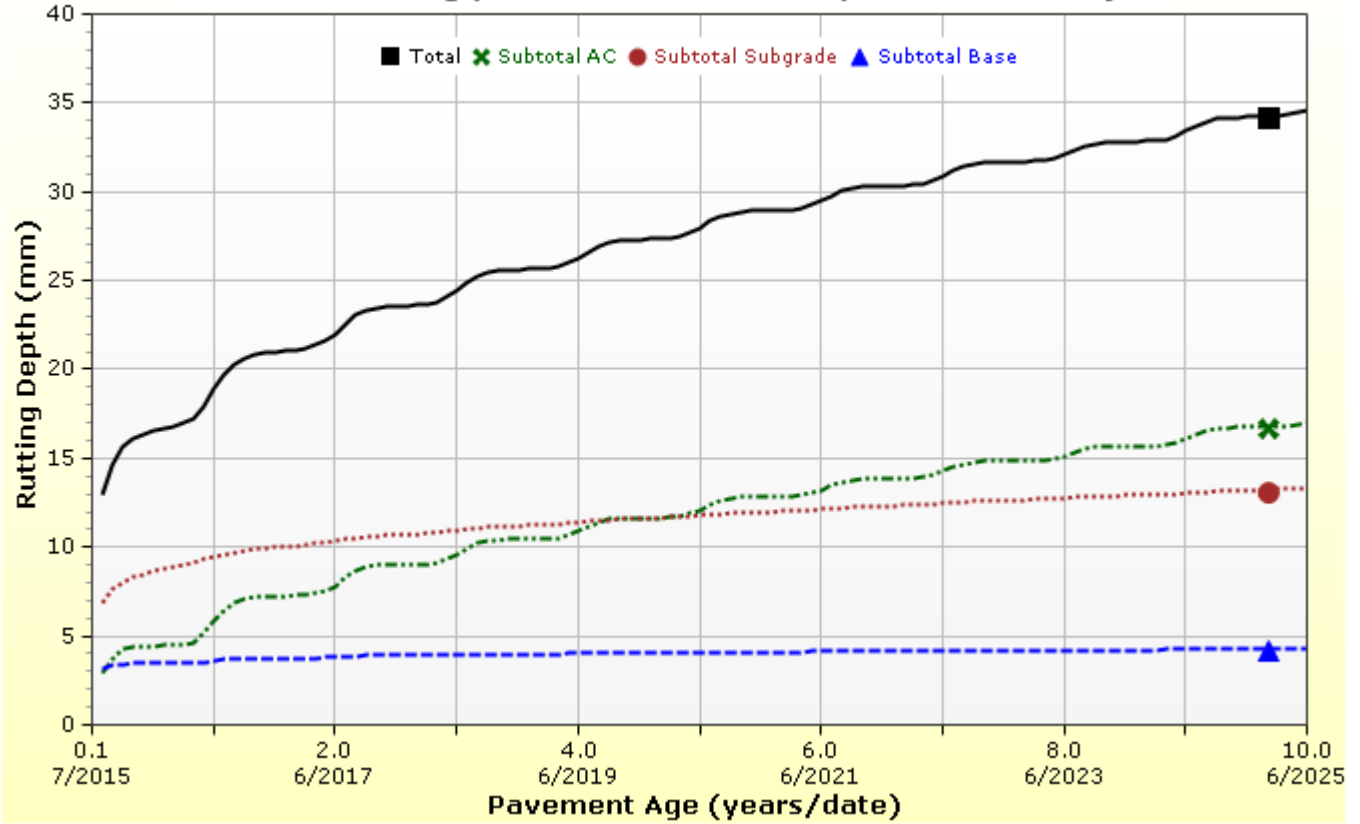


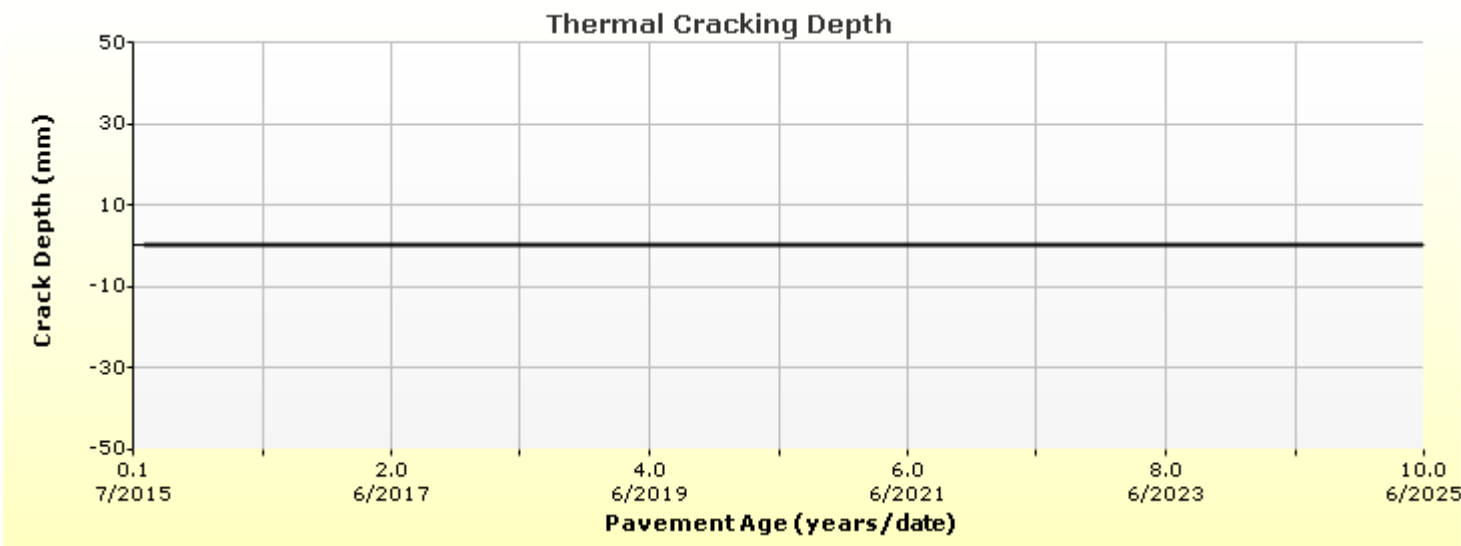
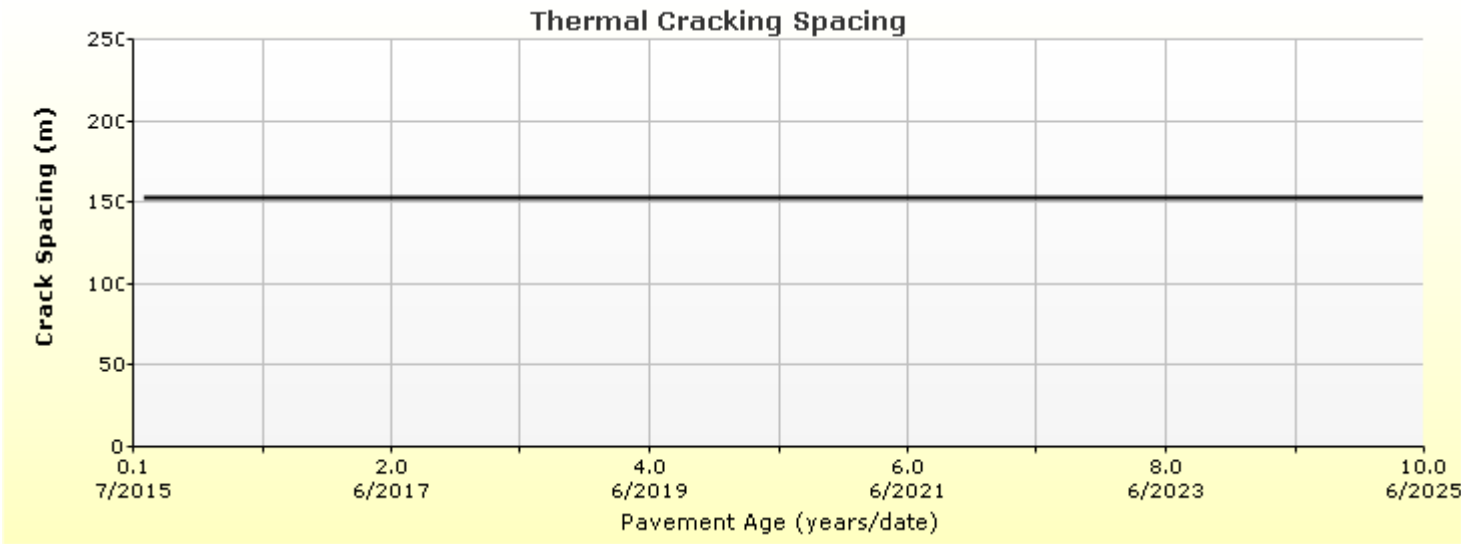
Thermal Cracking: Total Length vs. Time

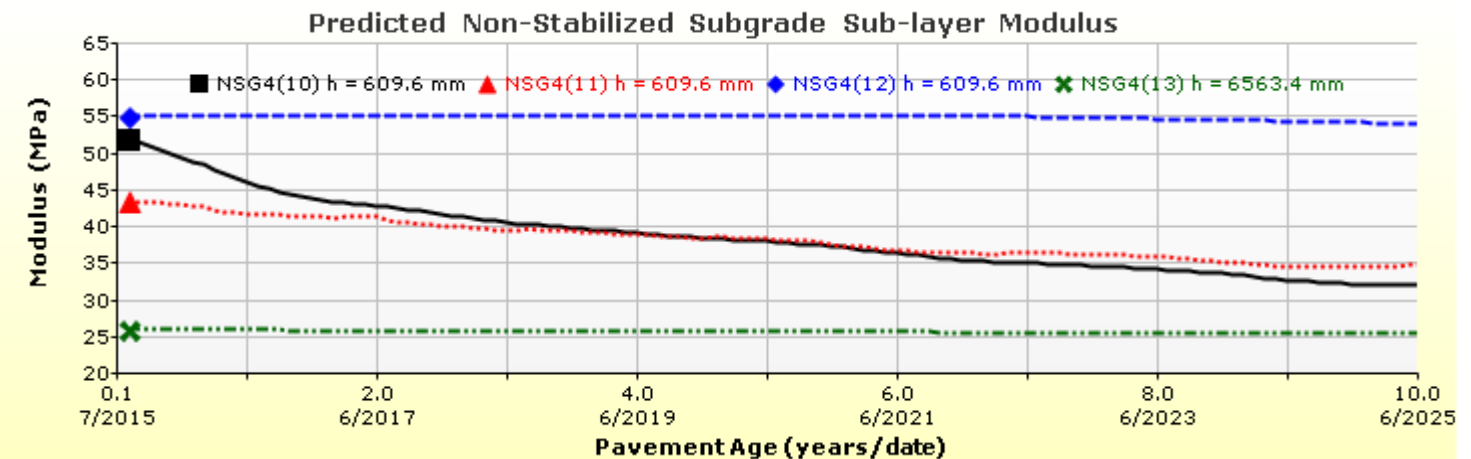
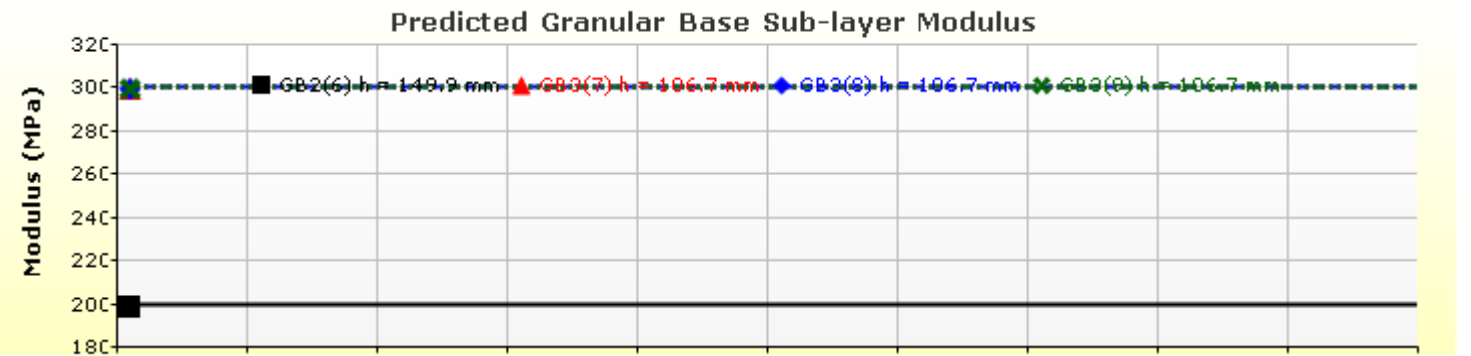
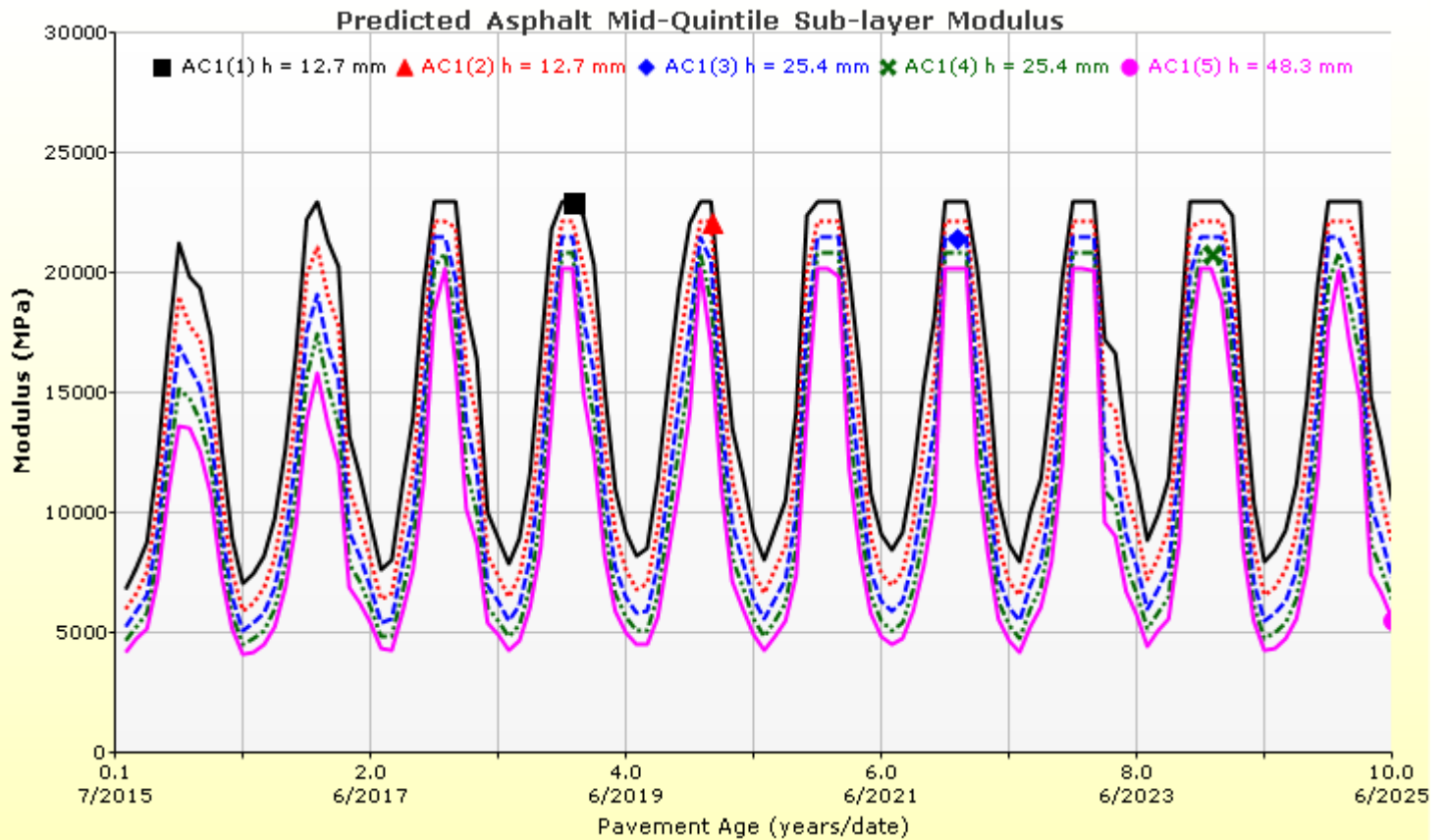




Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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() σ = standard deviation of the log of the depth of cracks in the pavments C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_s = Tensile stress(psi) M_r = modulus of rupture(psi)
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

Standard Deviation (BASERUT)

0.1235*Pow(SUBRUT,0.5012)+0.001

AC Cracking

AC Top Down Cracking

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

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: 7

c2: 3.5

c3: 0

c4: 1000

c1: 1

c2: 1

c3: 6000

AC Cracking Top Standard Deviation

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

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

IRI Flexible Pavements

C1 - Rutting

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

CSM Standard Deviation

CTB*1

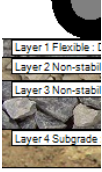
Design Inputs

Design Life: **10 years**
Design Type: **Flexible Pavement**

Base construction: **March, 2015**
Pavement construction: **June, 2015**
Traffic opening: **July, 2015**

Climate Data **32.119, -81.202**
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

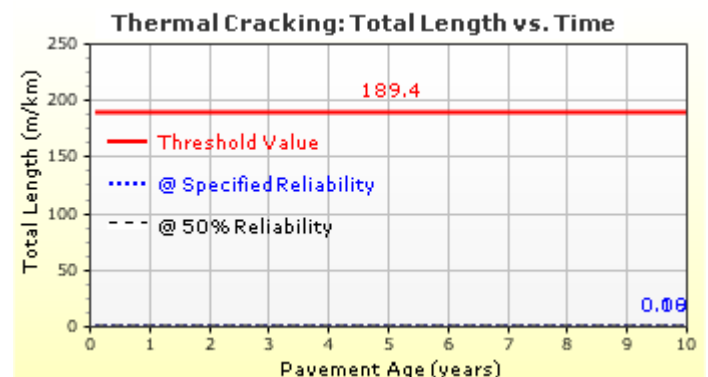
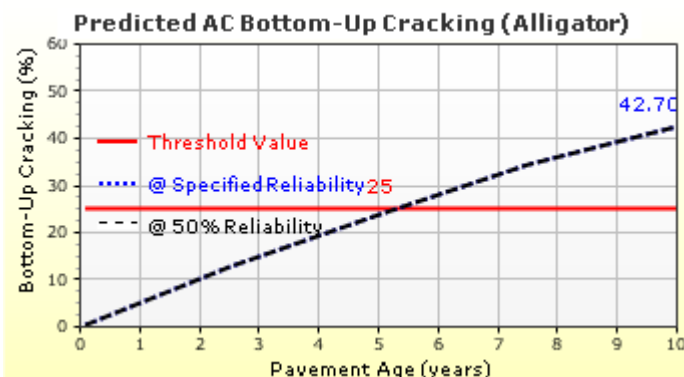
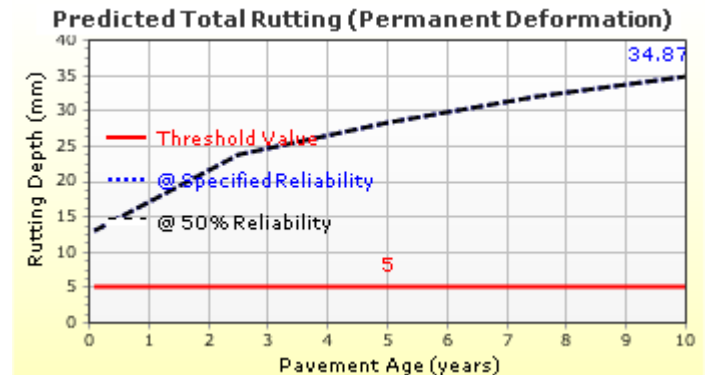
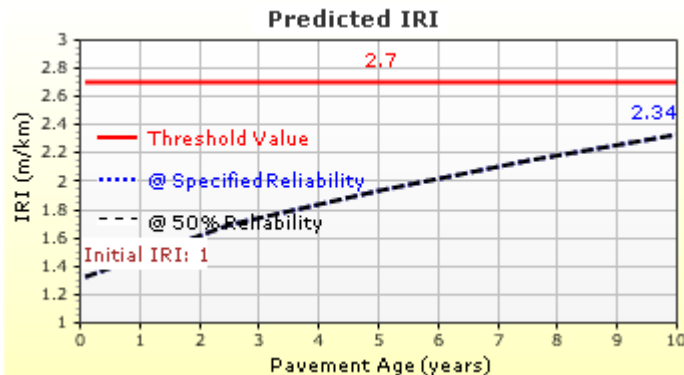
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.34	50.00	72.34	Pass
Permanent deformation - total pavement (mm)	5.00	34.87	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	42.70	50.00	10.52	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	903.41	50.00	12.47	Fail
Permanent deformation - AC only (mm)	5.00	16.54	50.00	0.40	Fail

Distress Charts

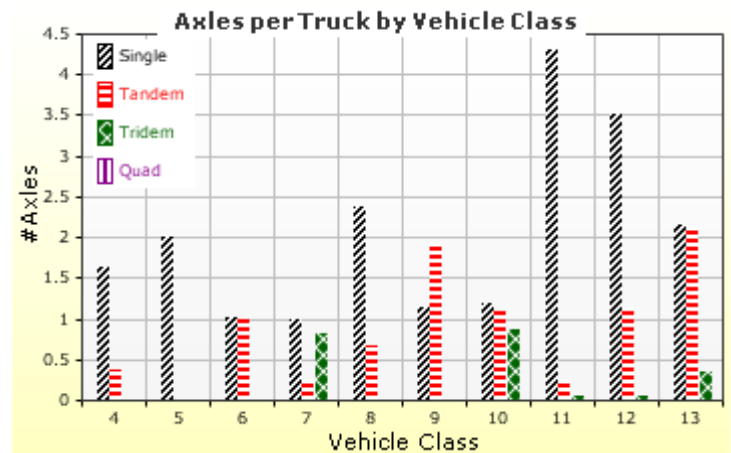
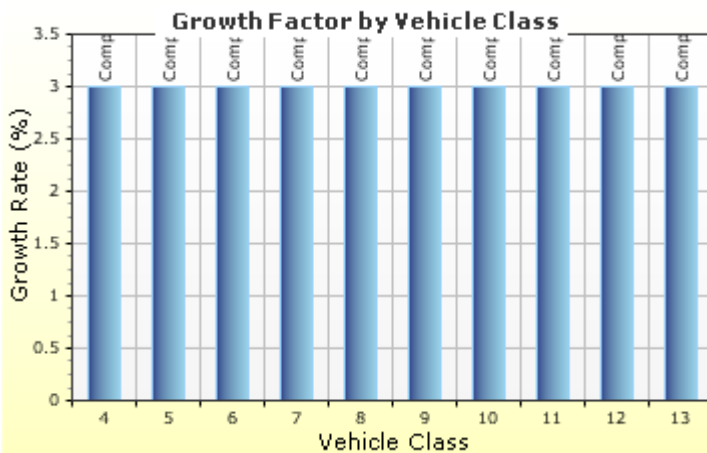
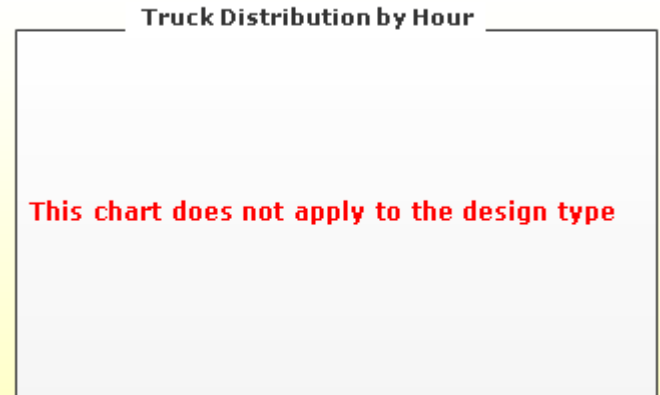
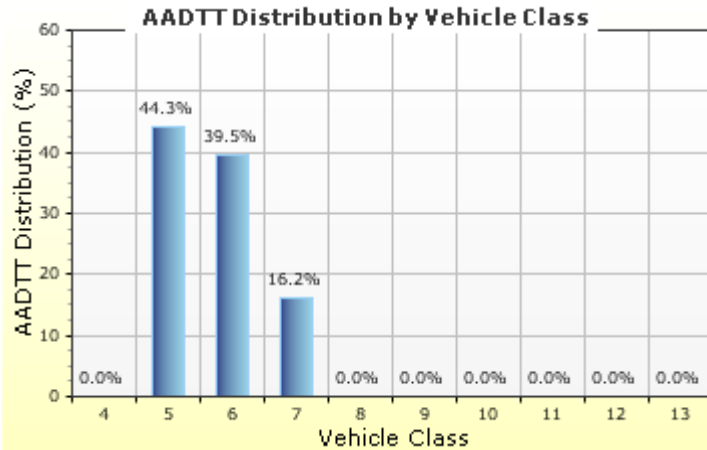


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

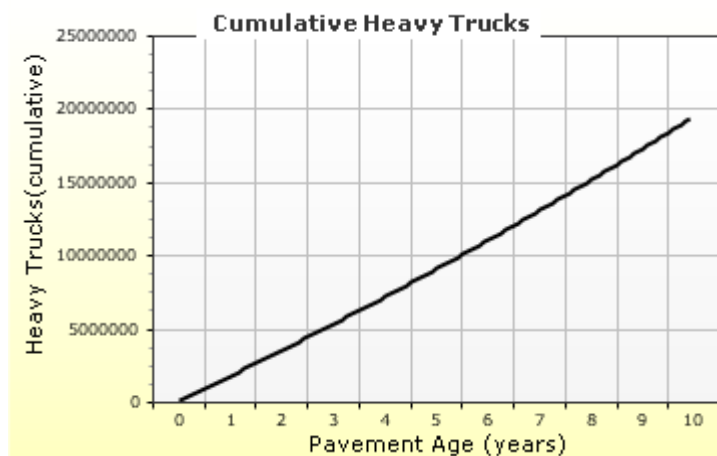
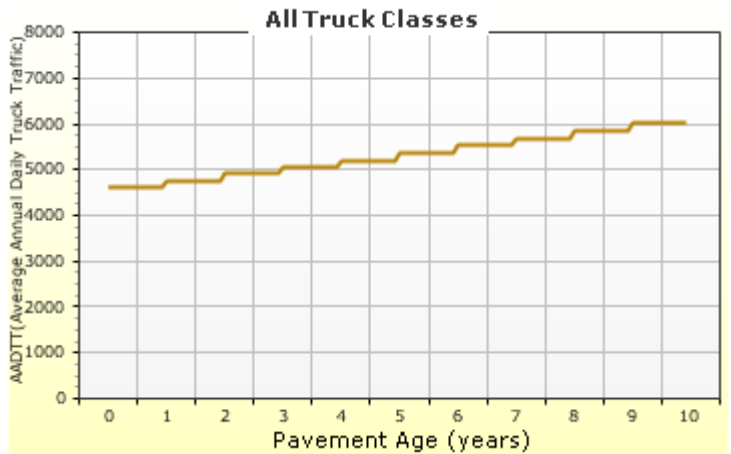
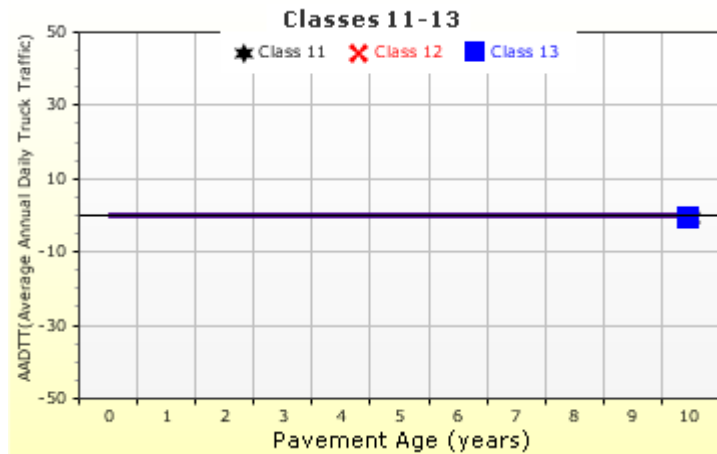
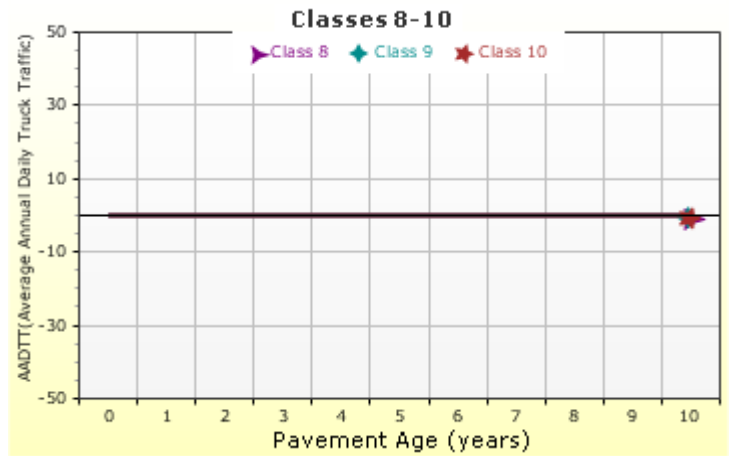
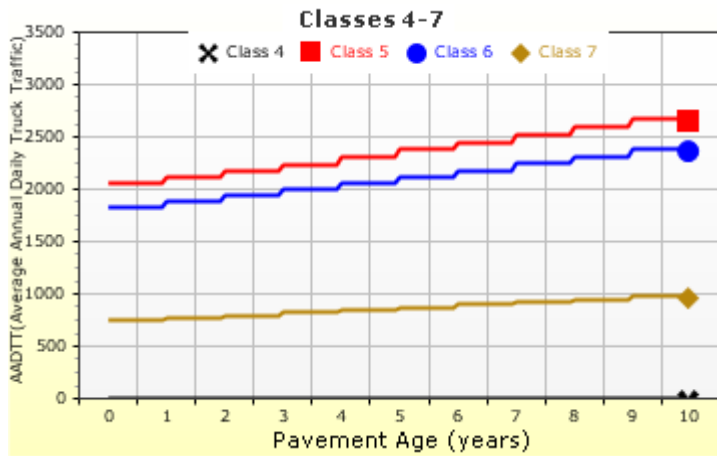
Wheelbase does not apply

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



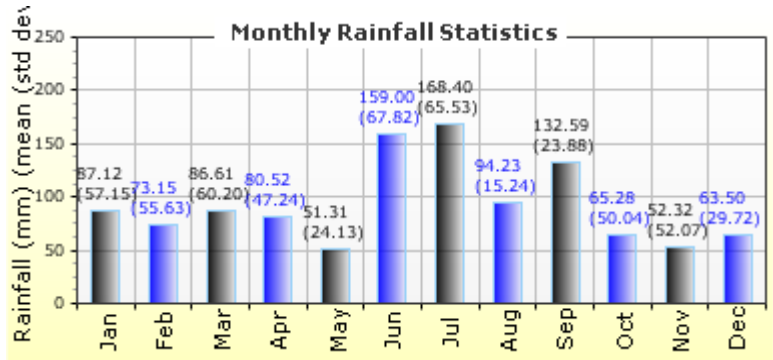
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

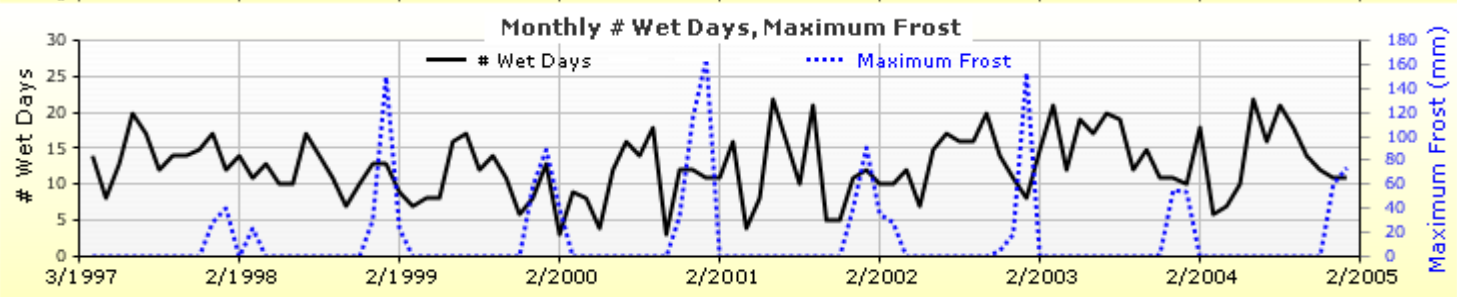
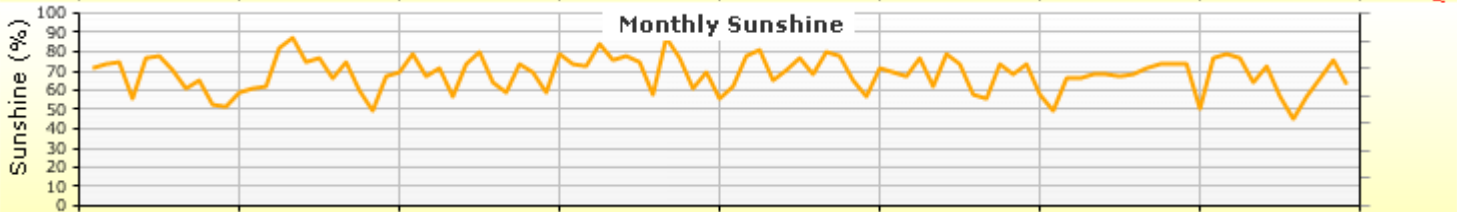
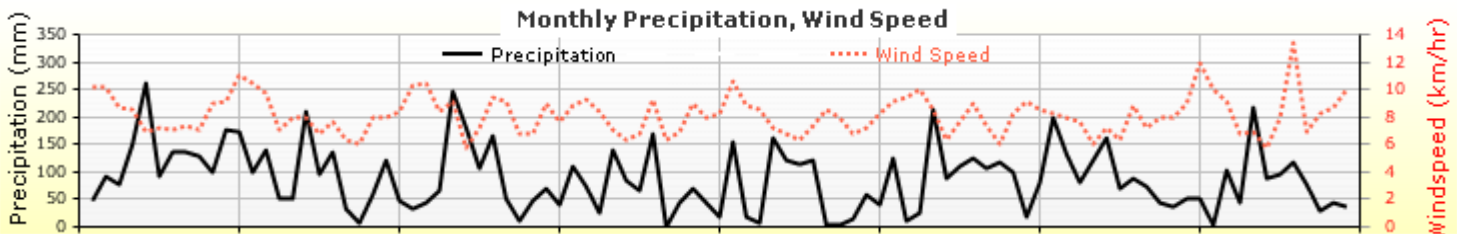
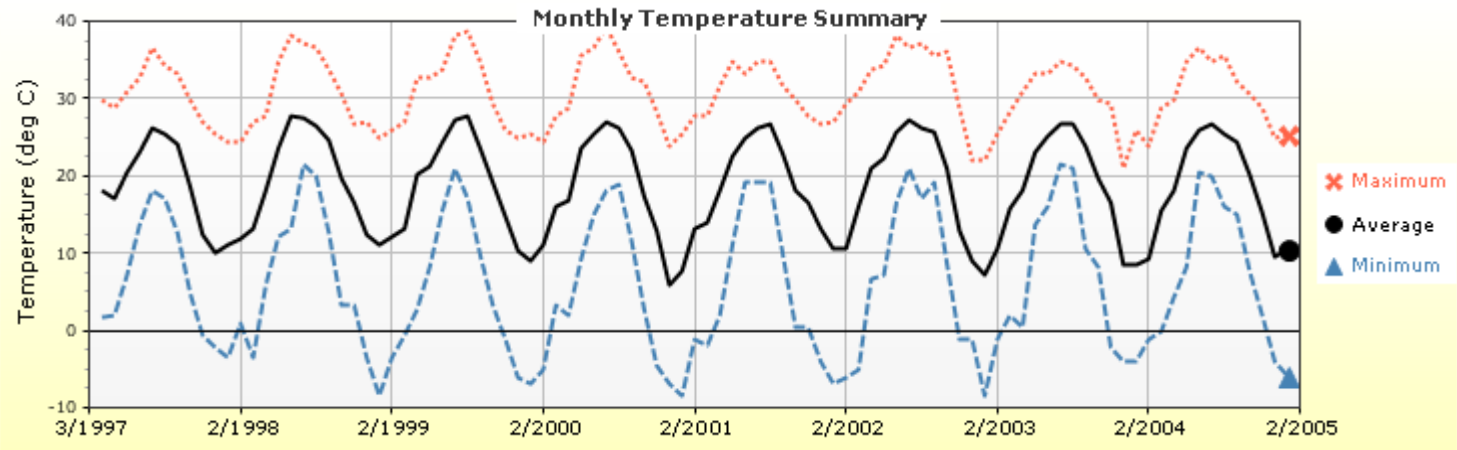
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

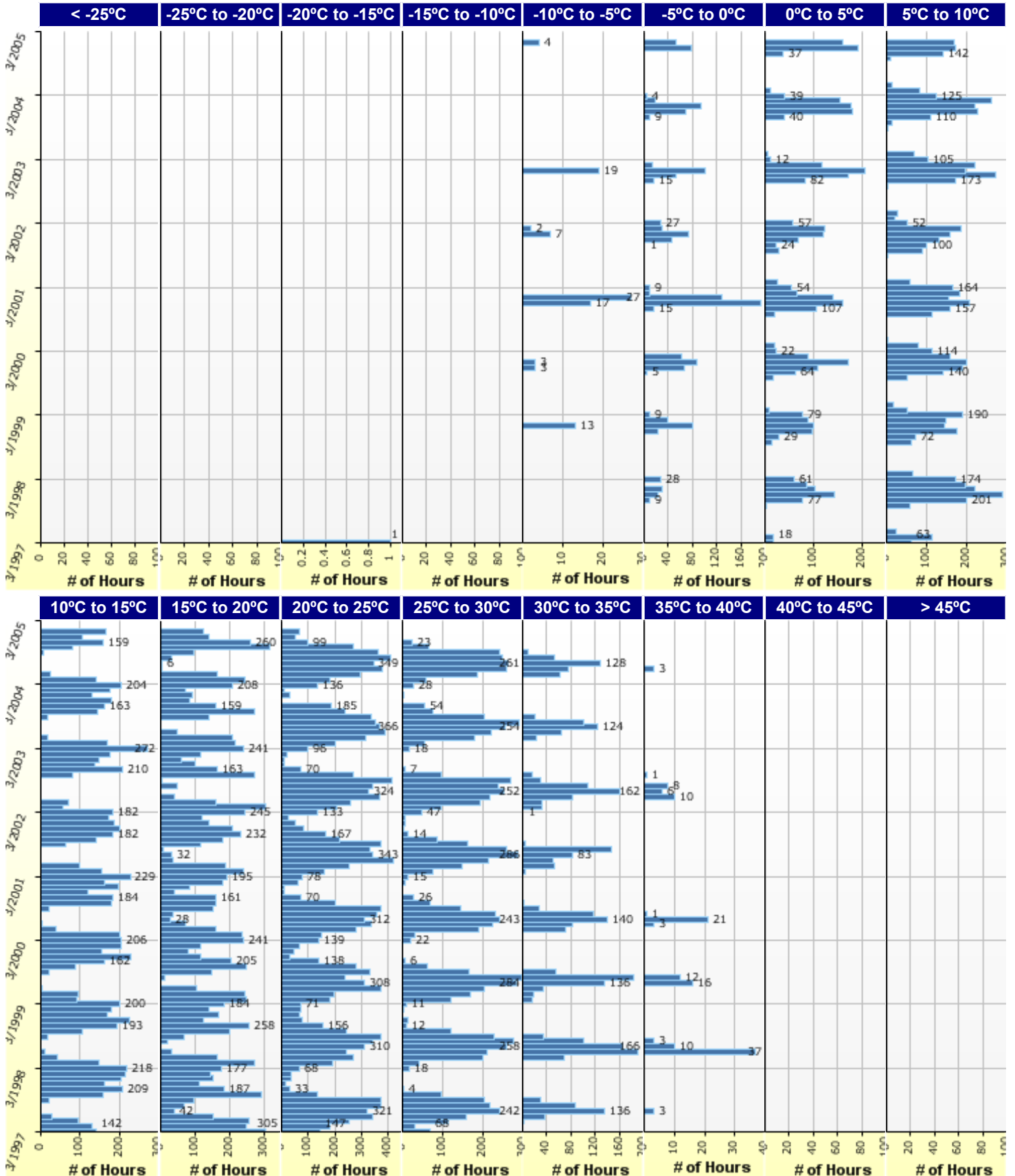


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF3

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF3.dgpx



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

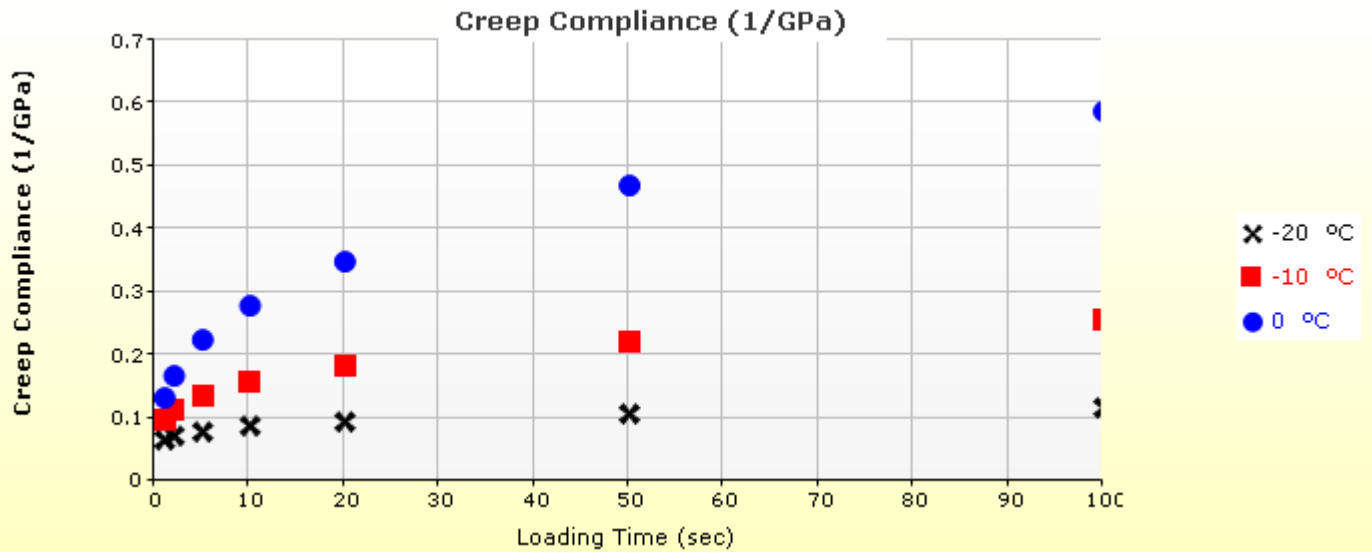
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

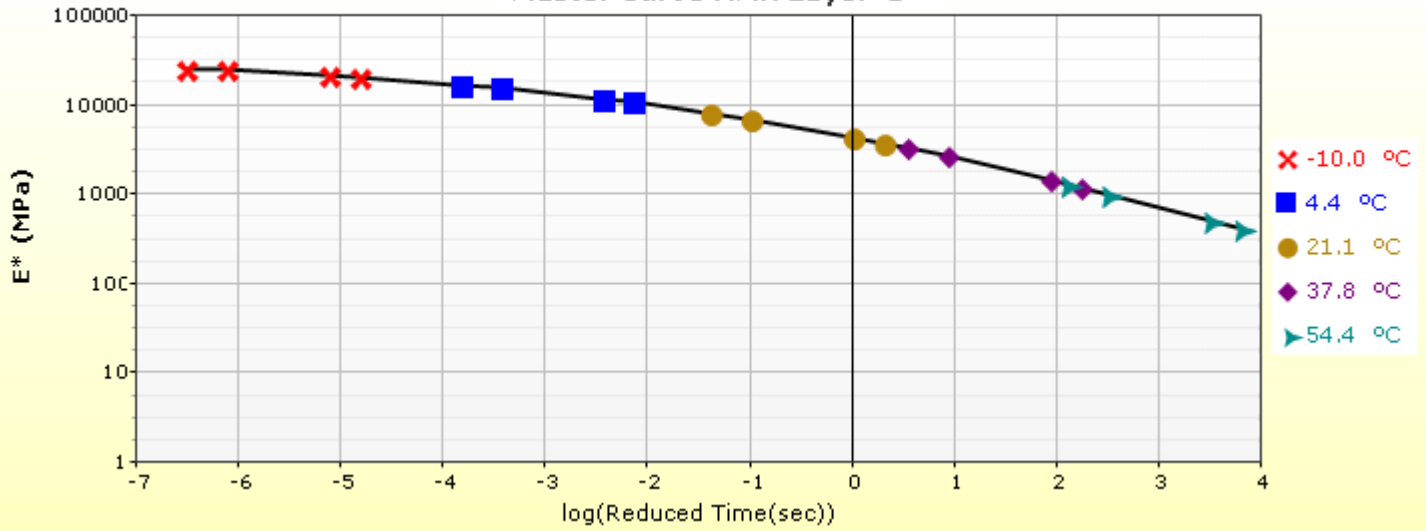
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

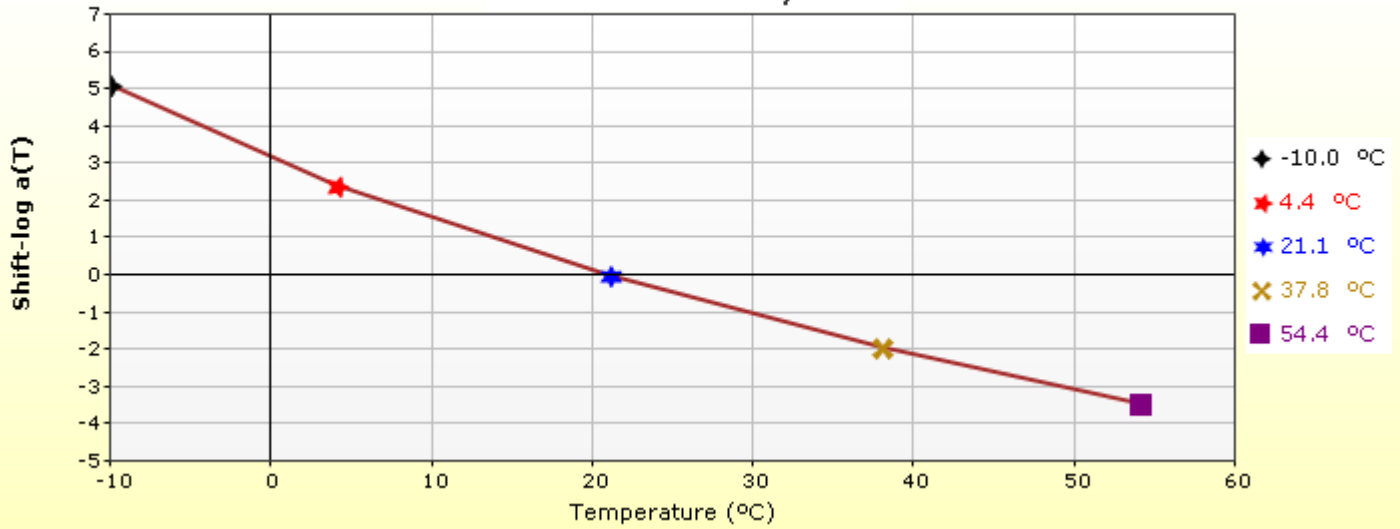


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

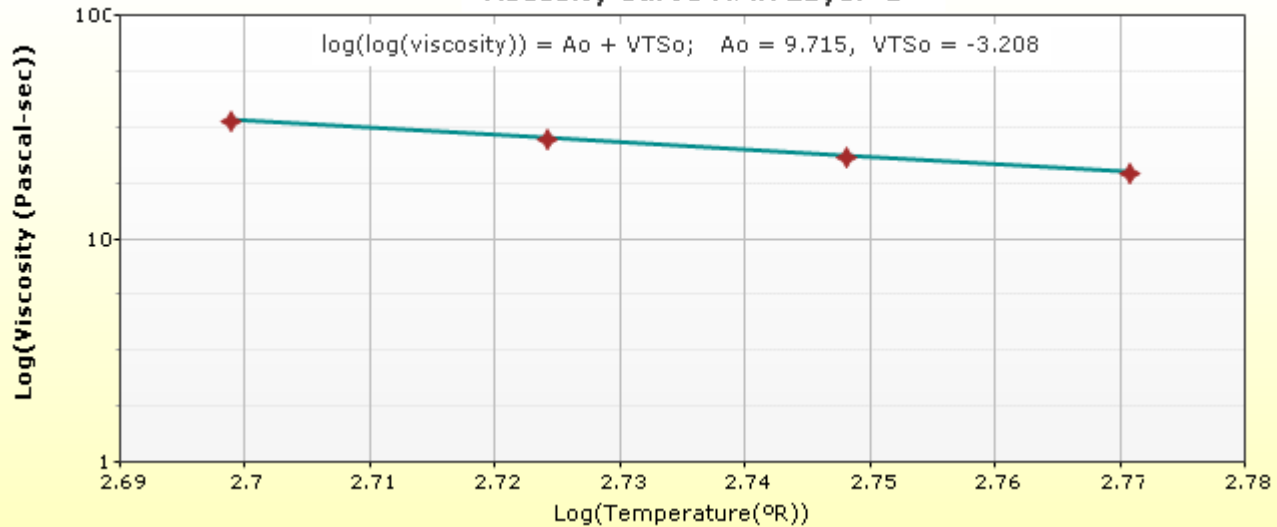
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

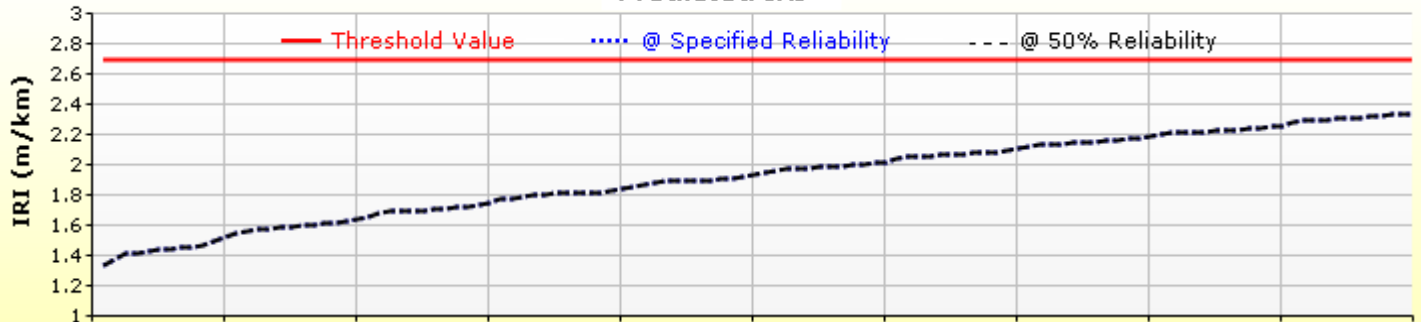


Viscosity Curve HMA Layer 1

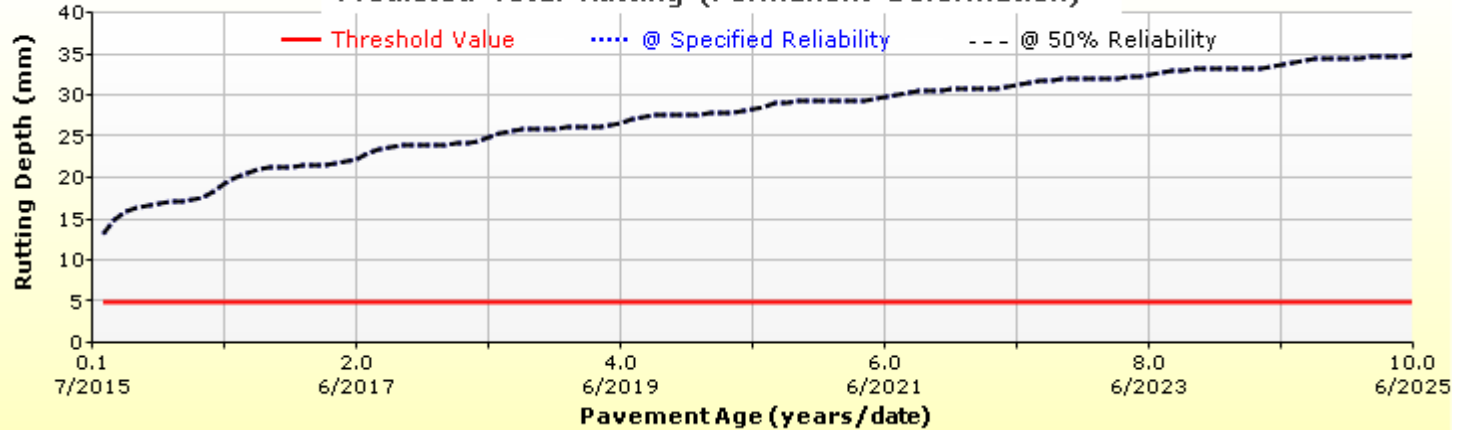


Analysis Output Charts

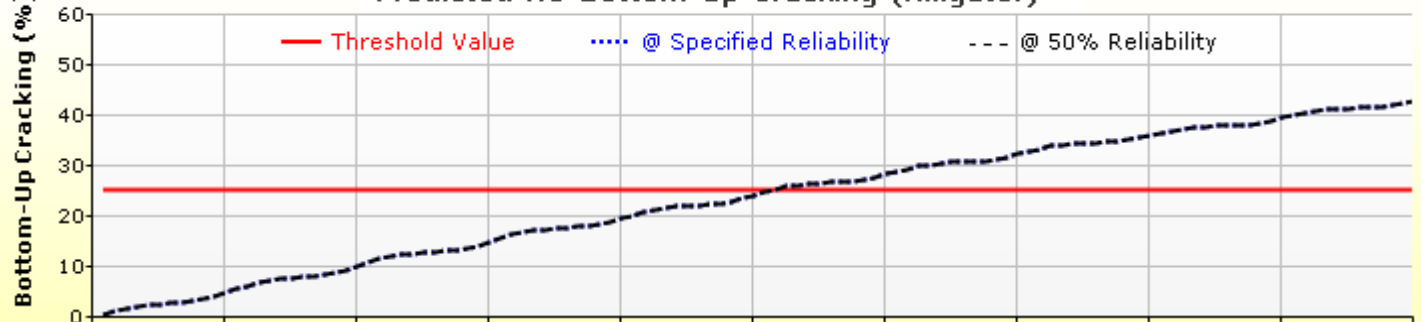
Predicted IRI



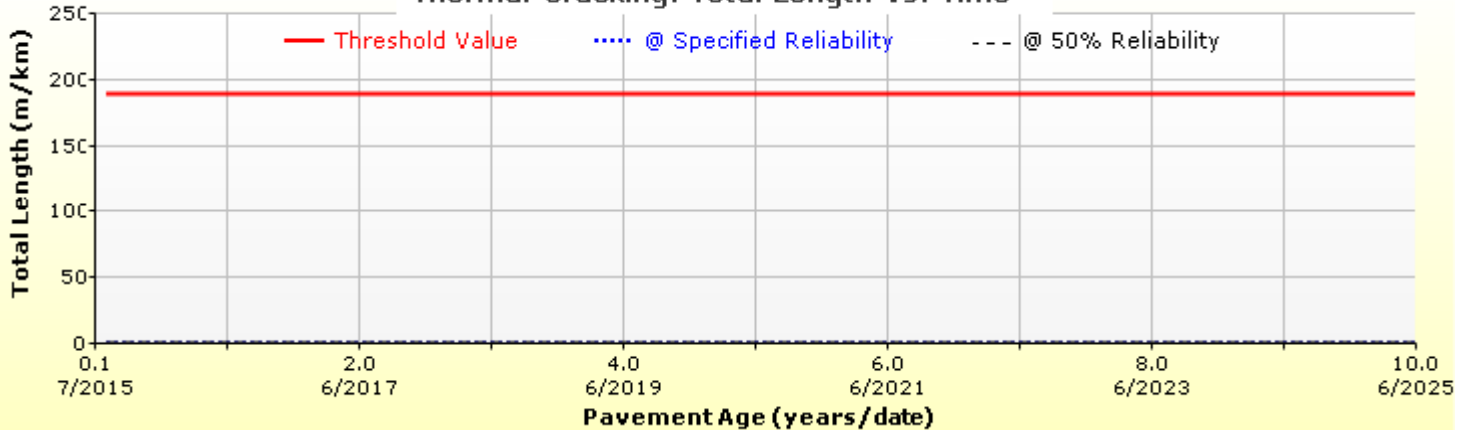
Predicted Total Rutting (Permanent Deformation)

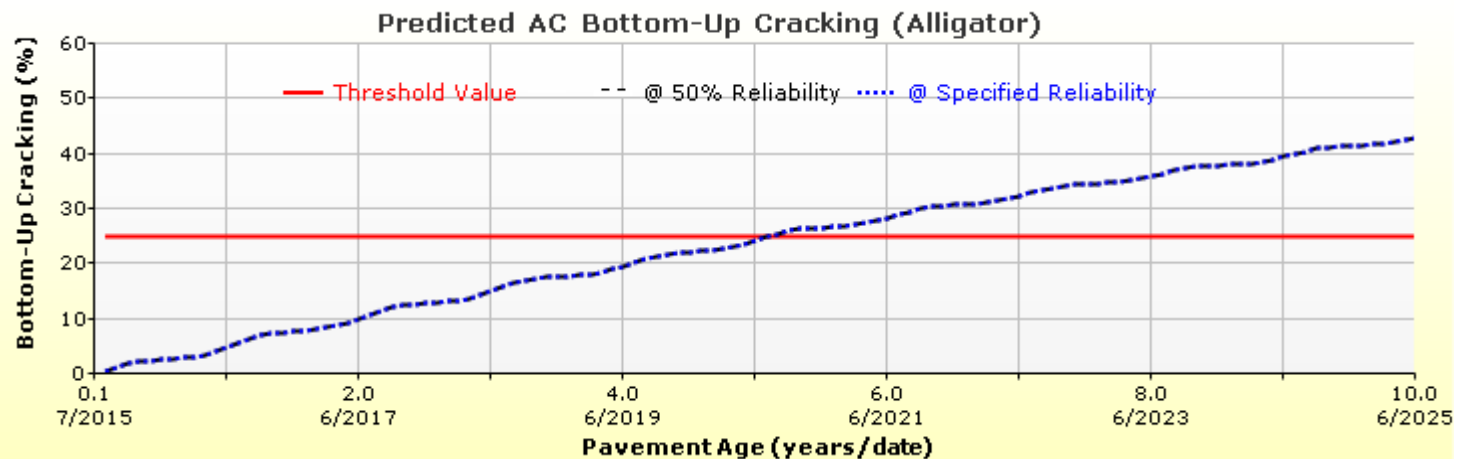
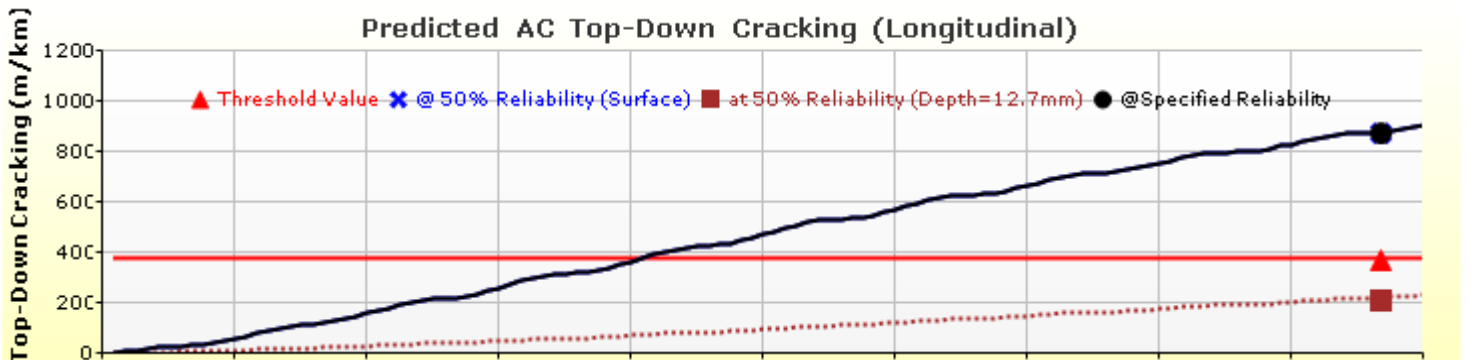
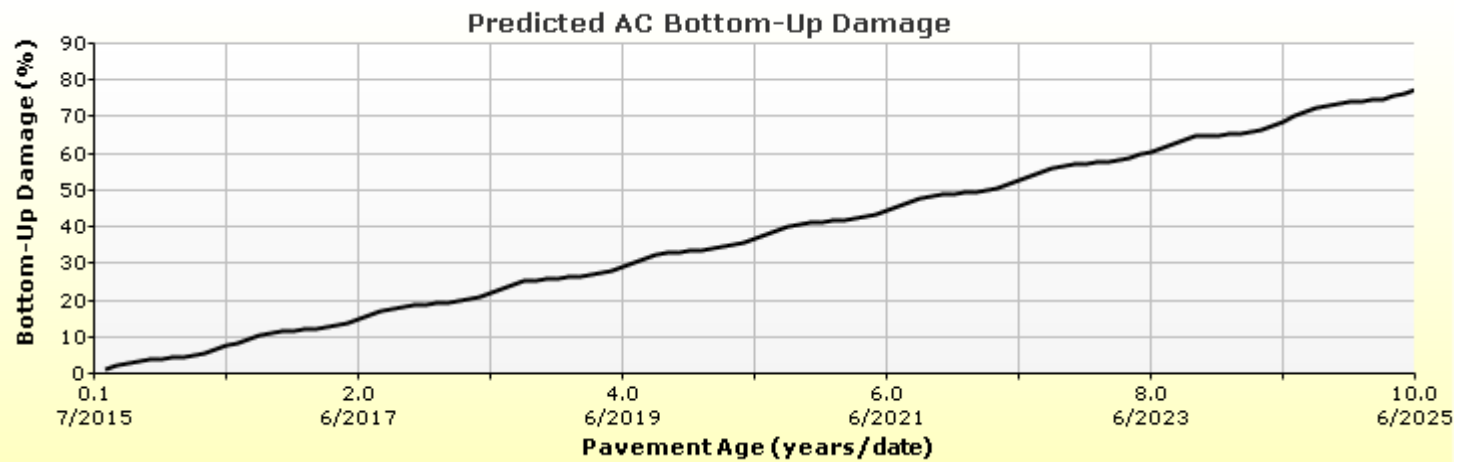
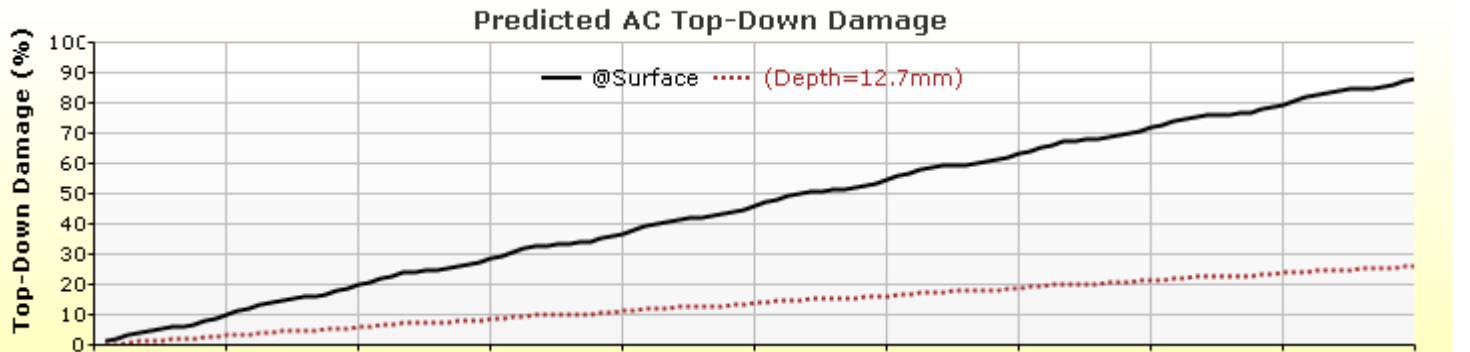


Predicted AC Bottom-Up Cracking (Alligator)

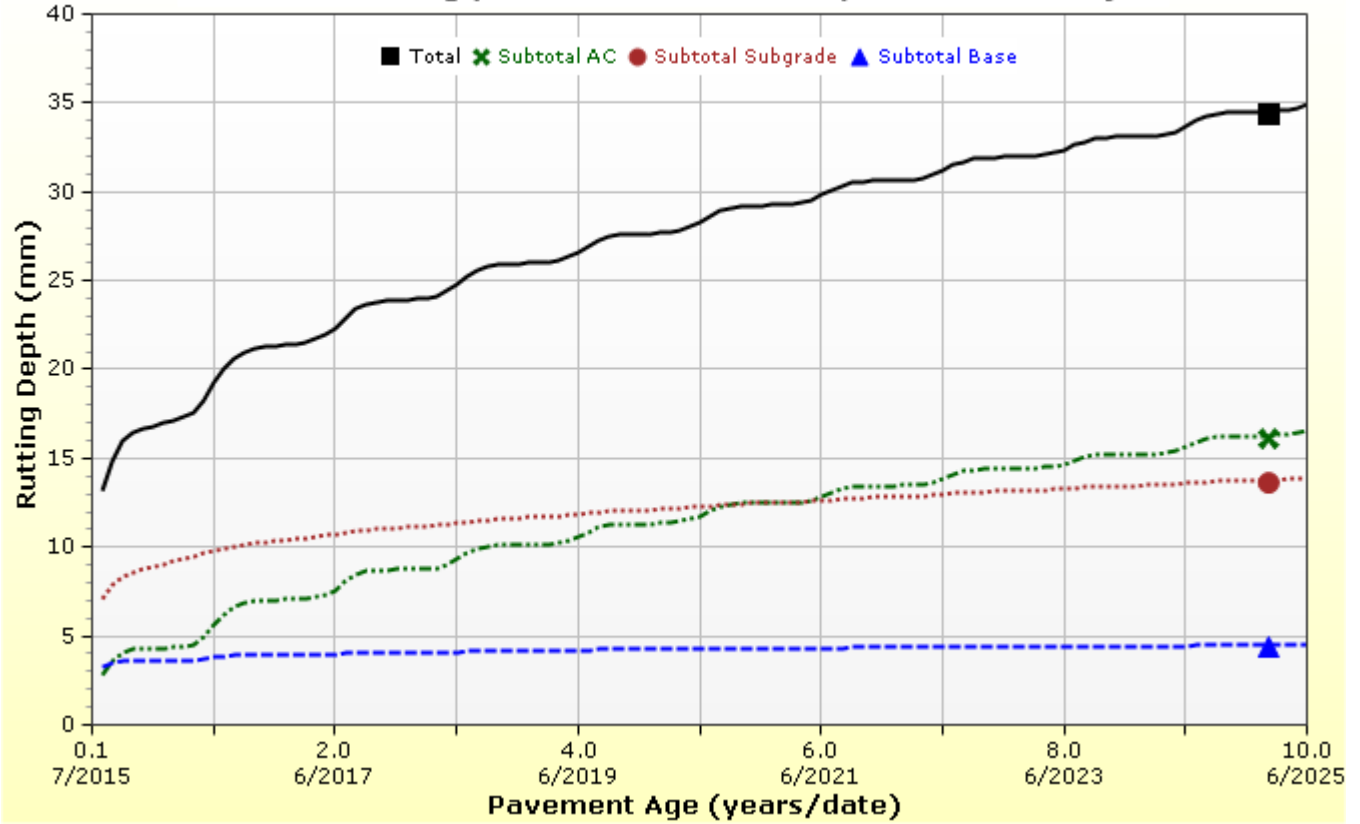


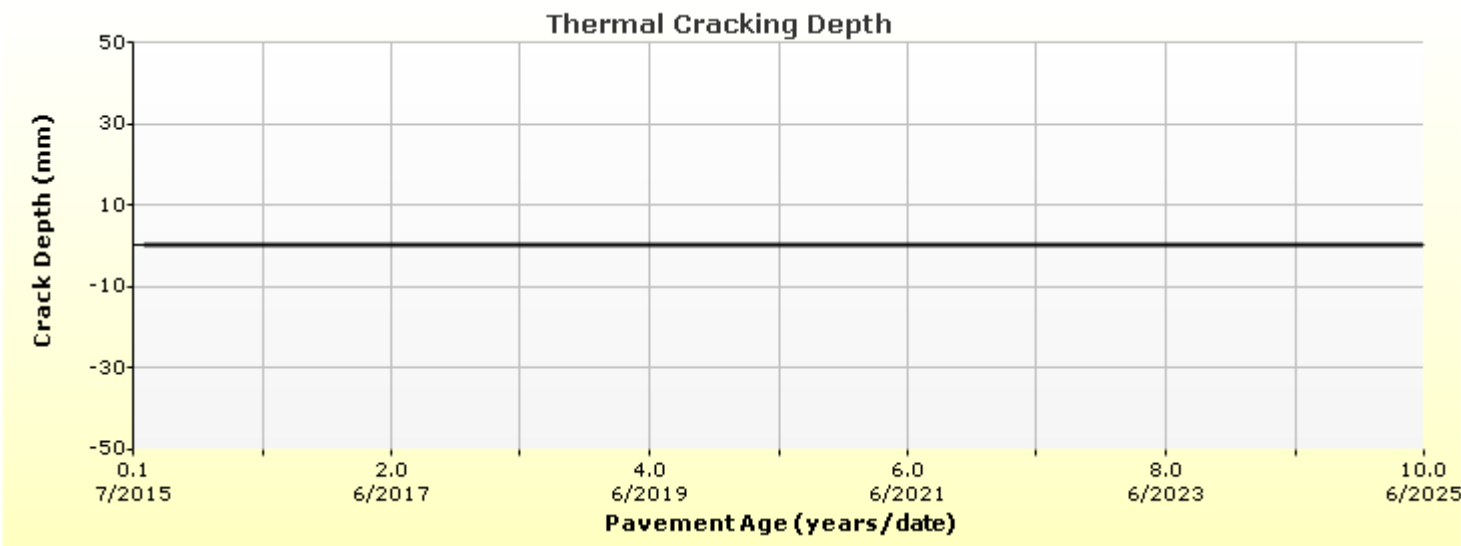
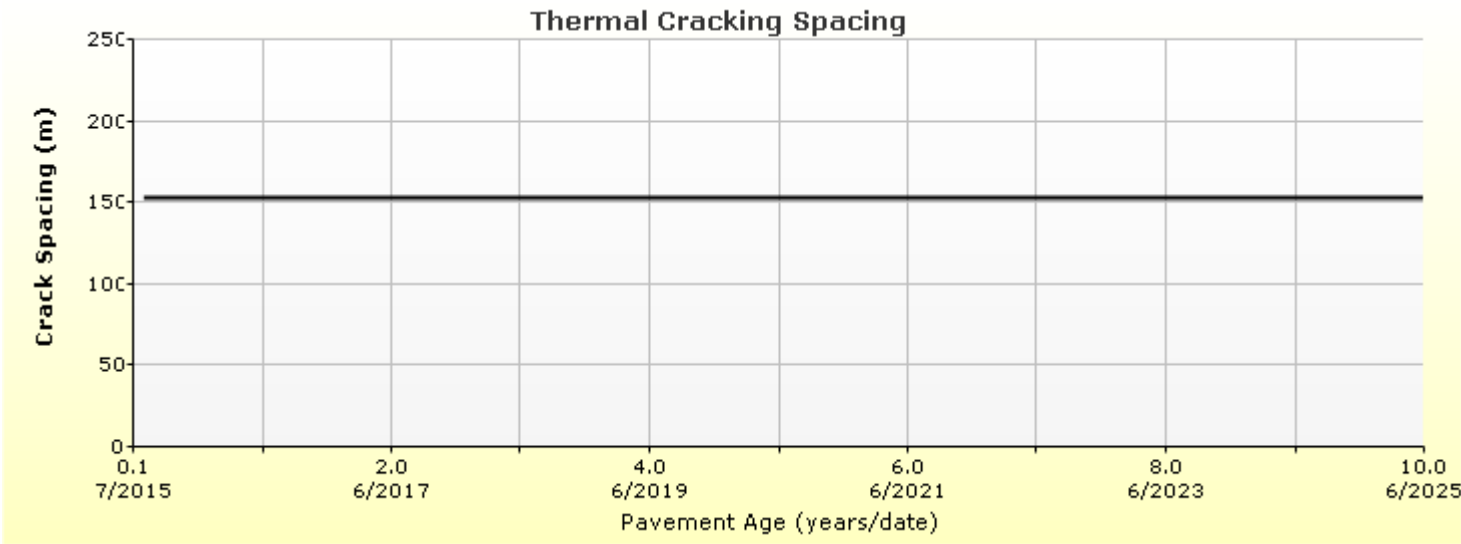
Thermal Cracking: Total Length vs. Time

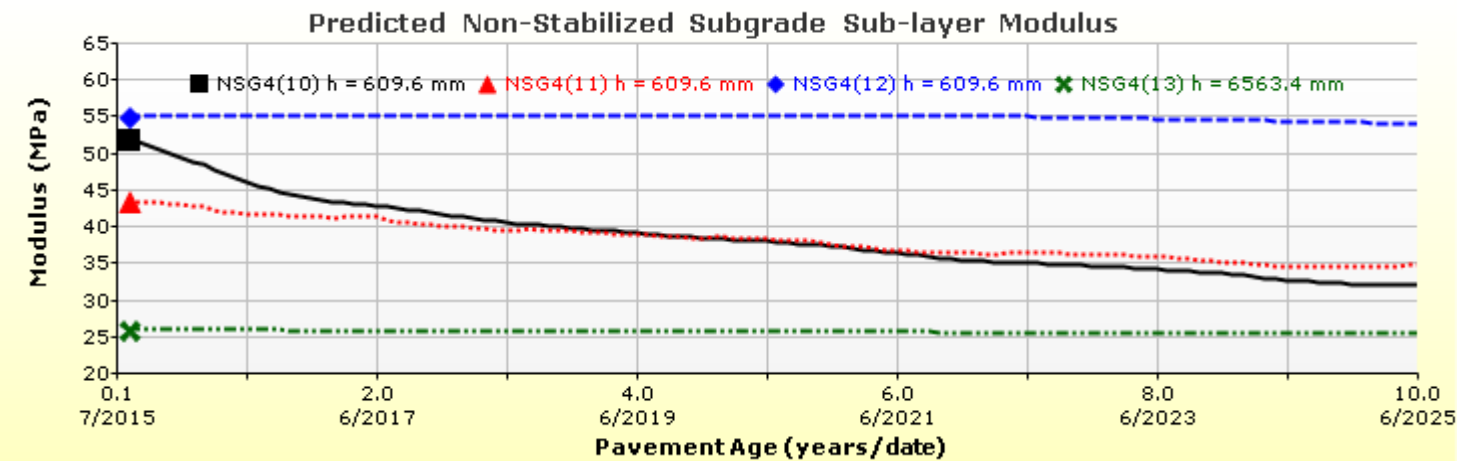
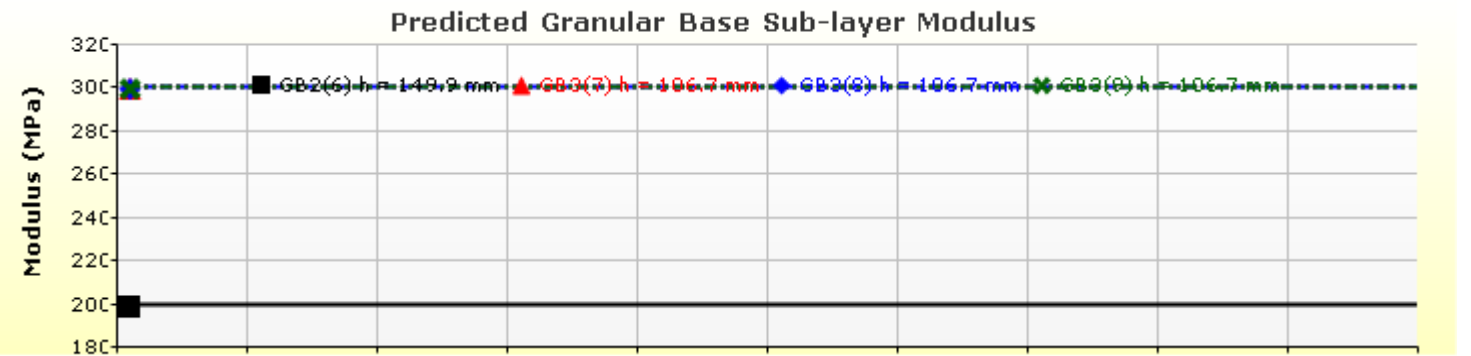
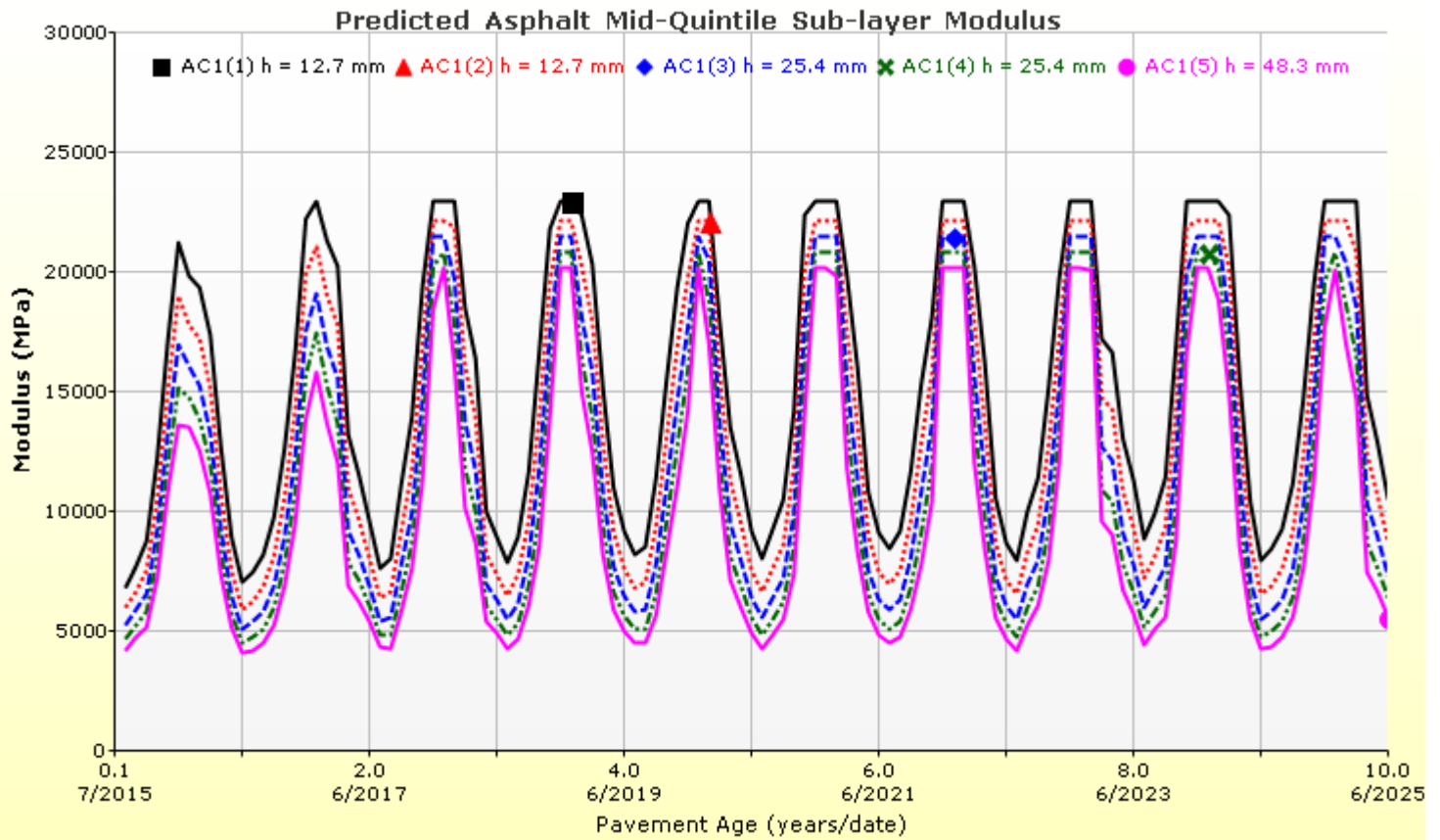




Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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() σ = standard deviation of the log of the depth of cracks in the pavments C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_s = Tensile stress(psi) M_r = modulus of rupture(psi)
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

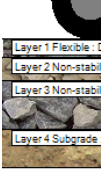
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

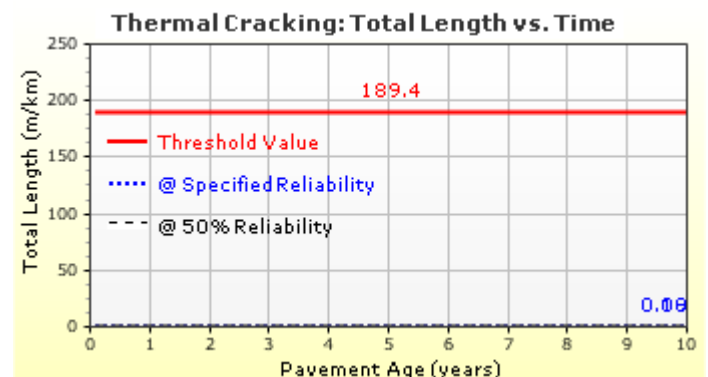
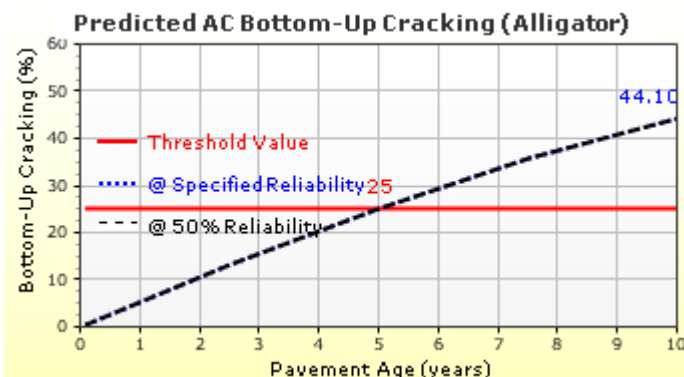
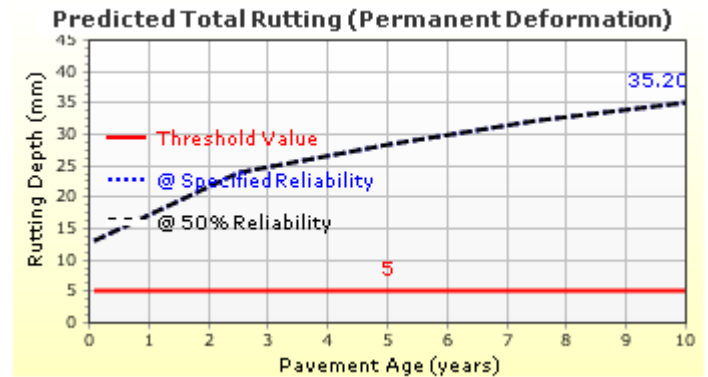
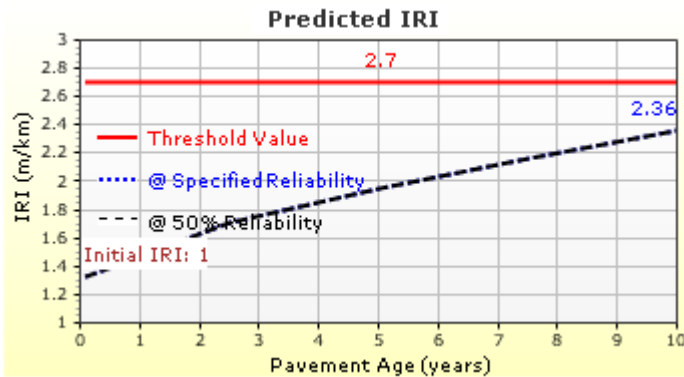
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.36	50.00	71.29	Pass
Permanent deformation - total pavement (mm)	5.00	35.20	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	44.10	50.00	8.82	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	905.30	50.00	12.38	Fail
Permanent deformation - AC only (mm)	5.00	16.86	50.00	0.36	Fail

Distress Charts

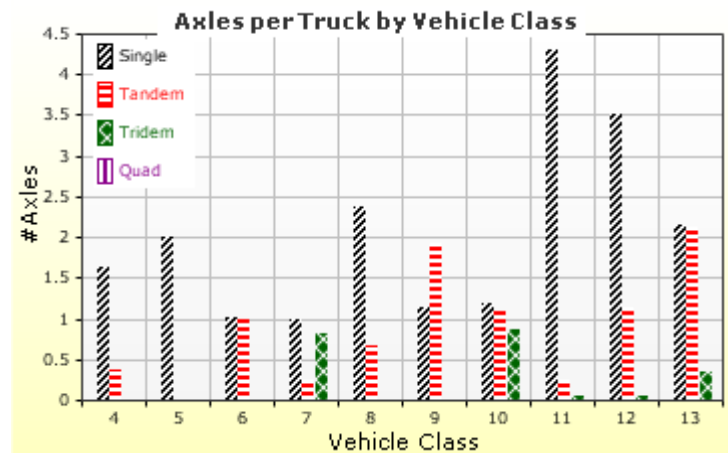
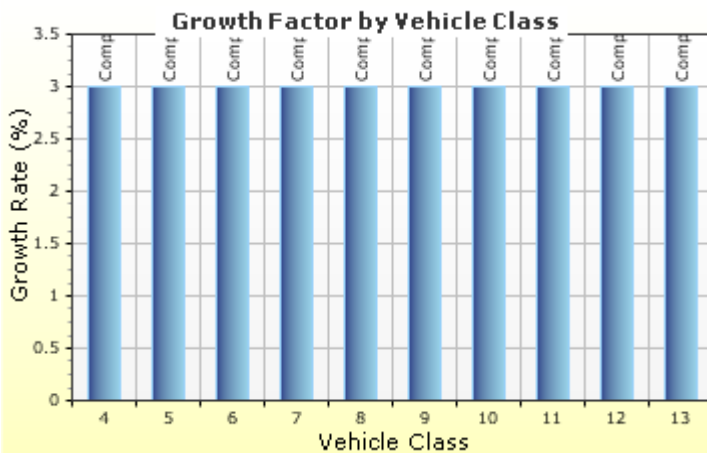
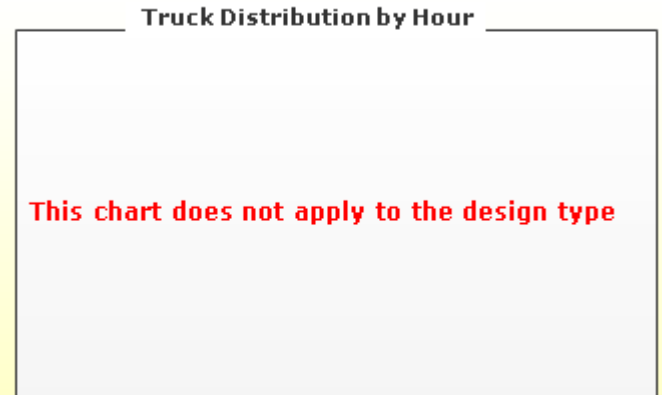
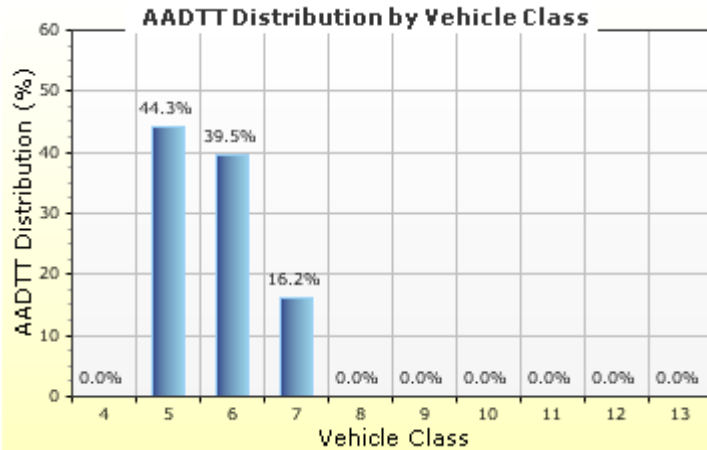


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

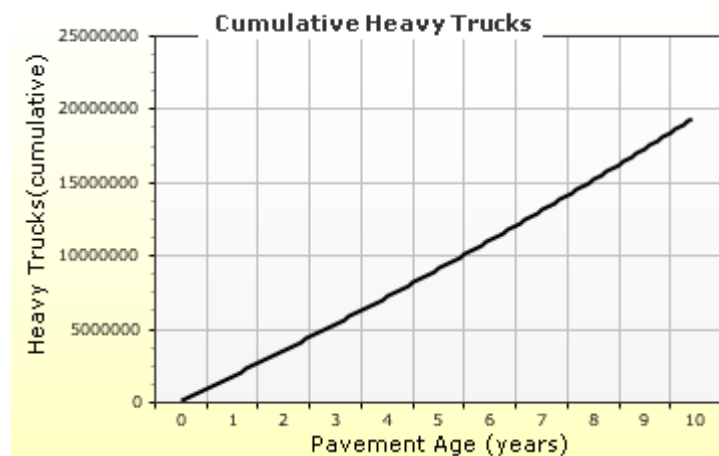
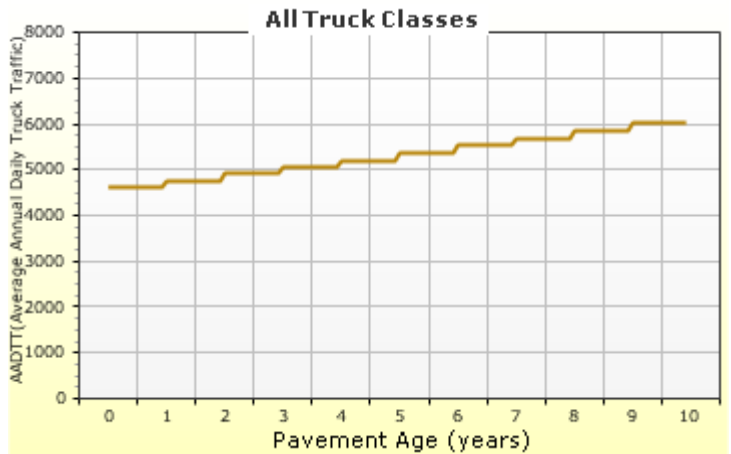
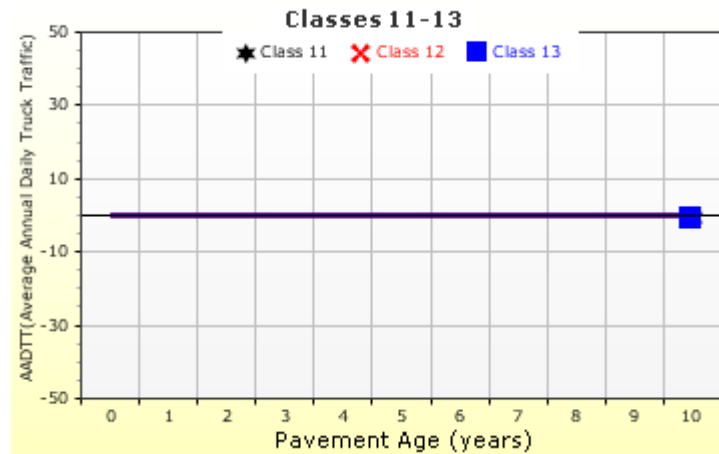
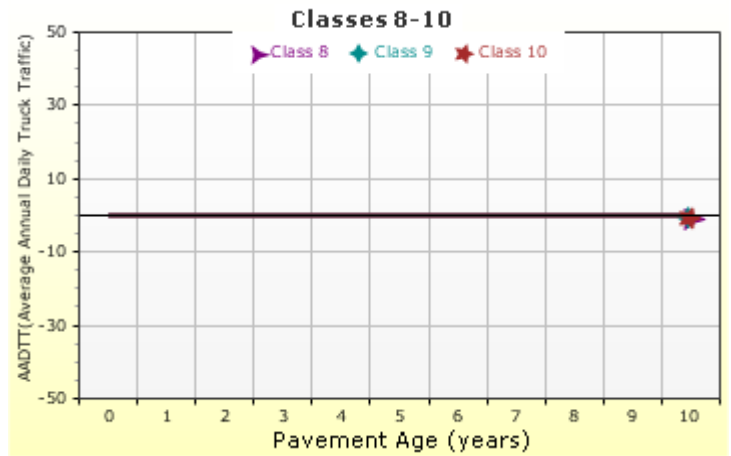
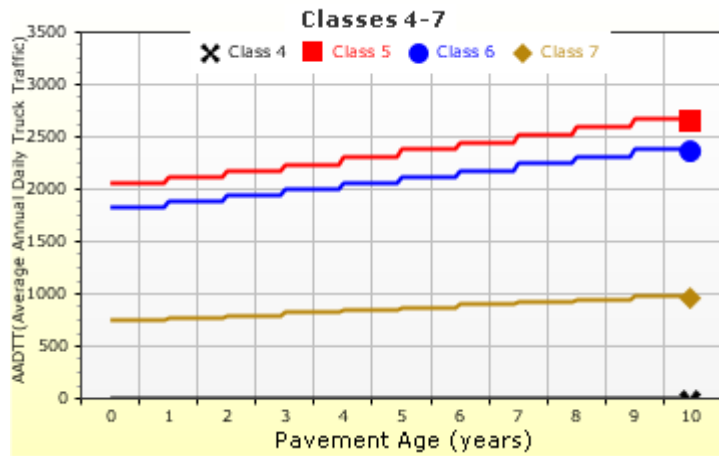
Wheelbase does not apply

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



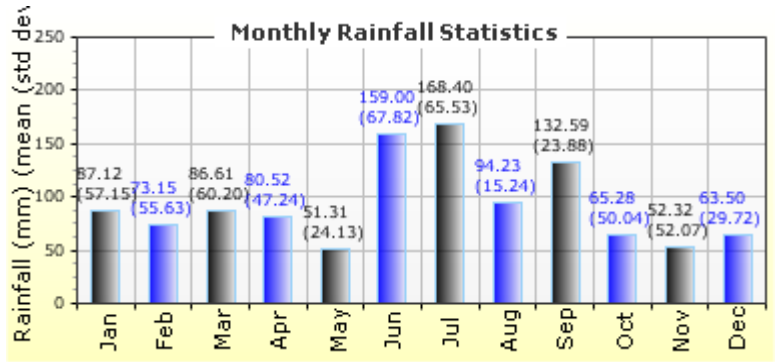
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

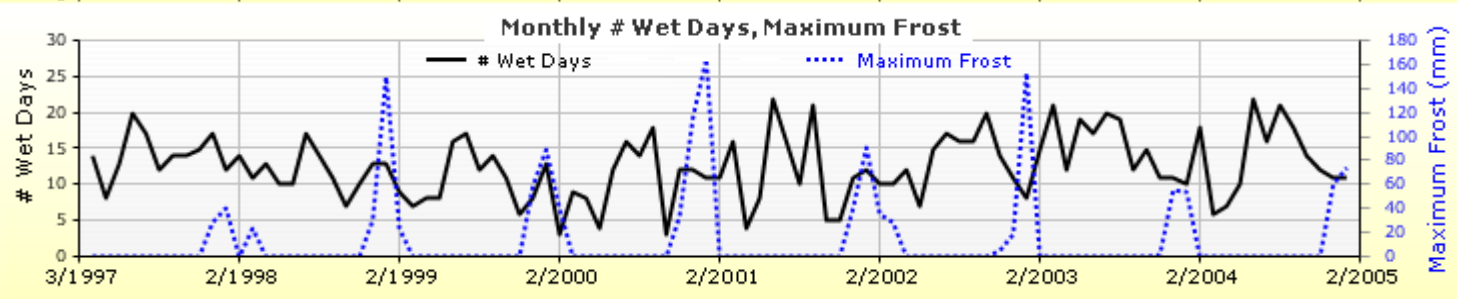
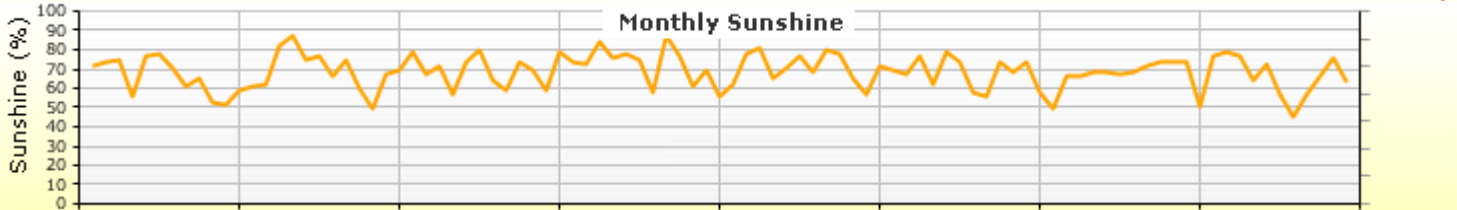
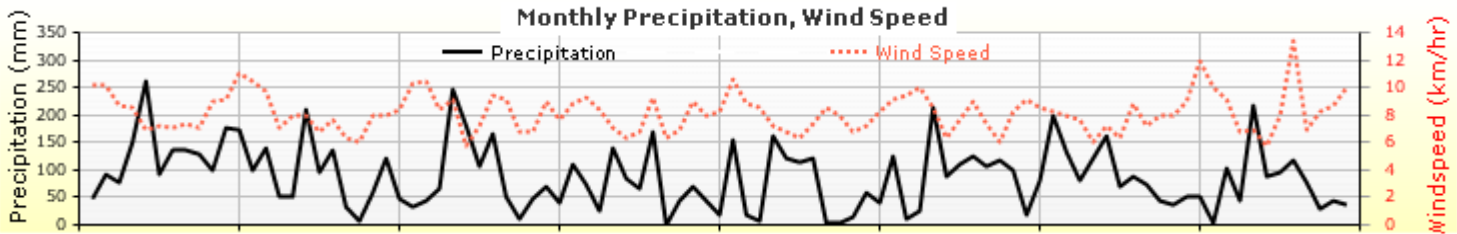
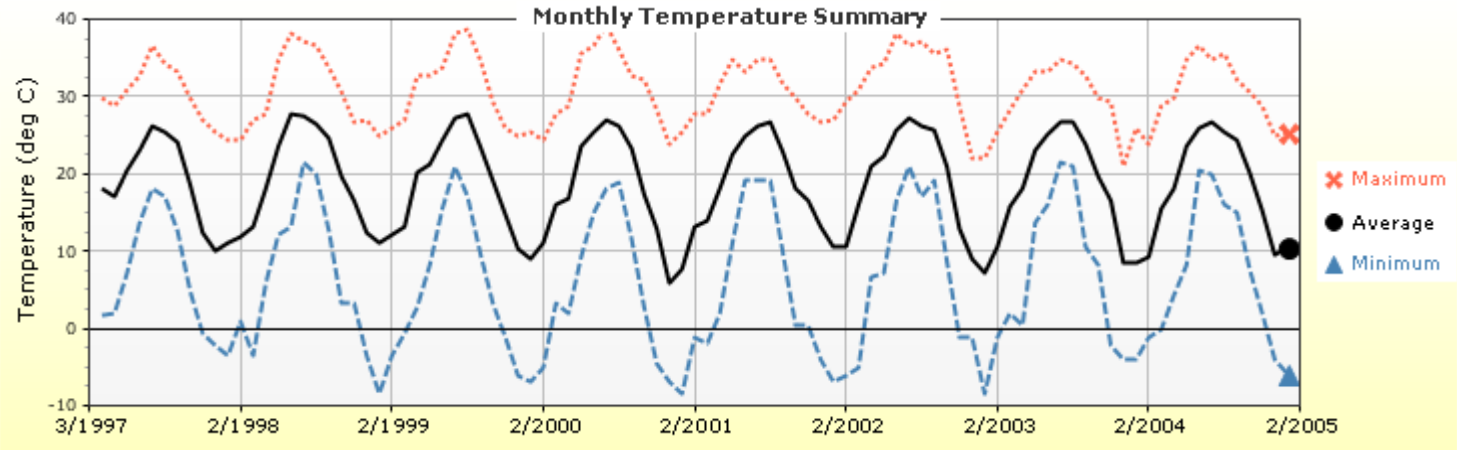
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

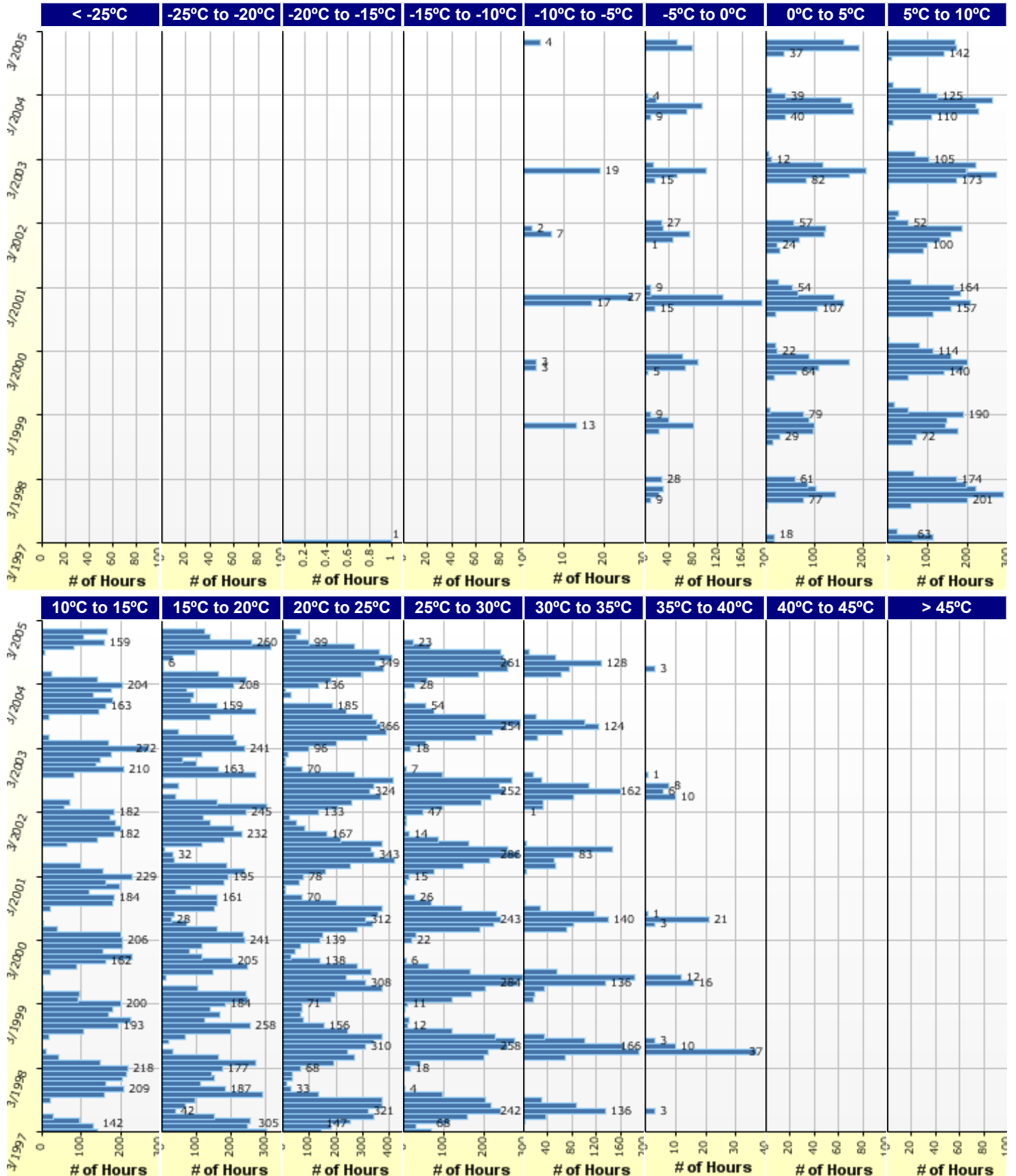


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF4

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF4.dgpx



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

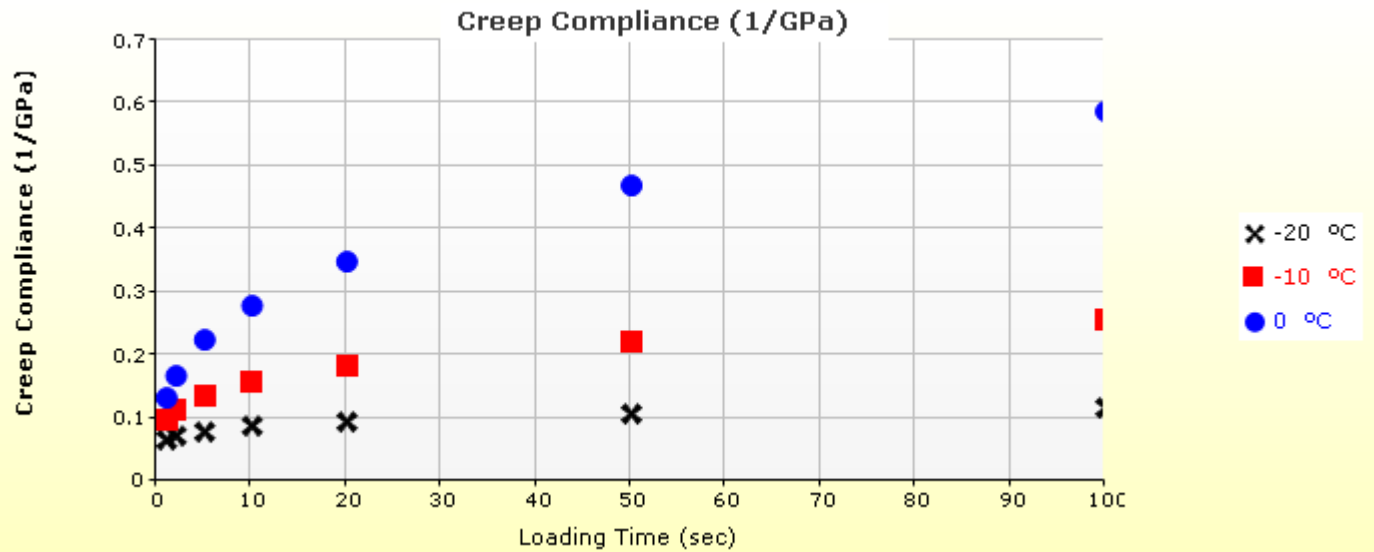
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

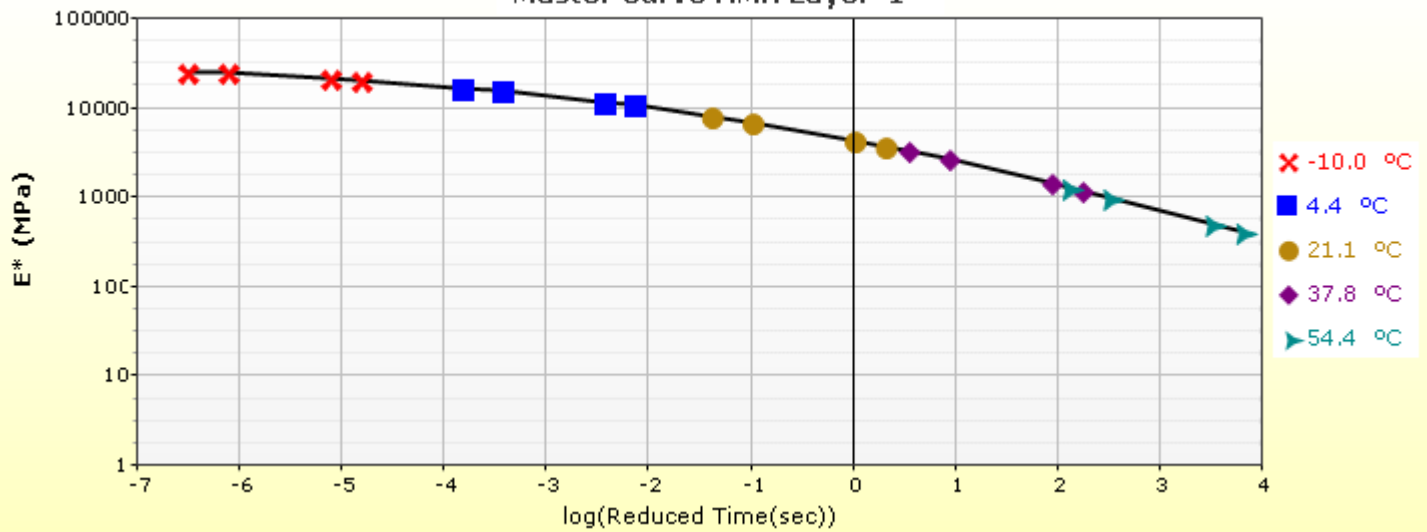
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

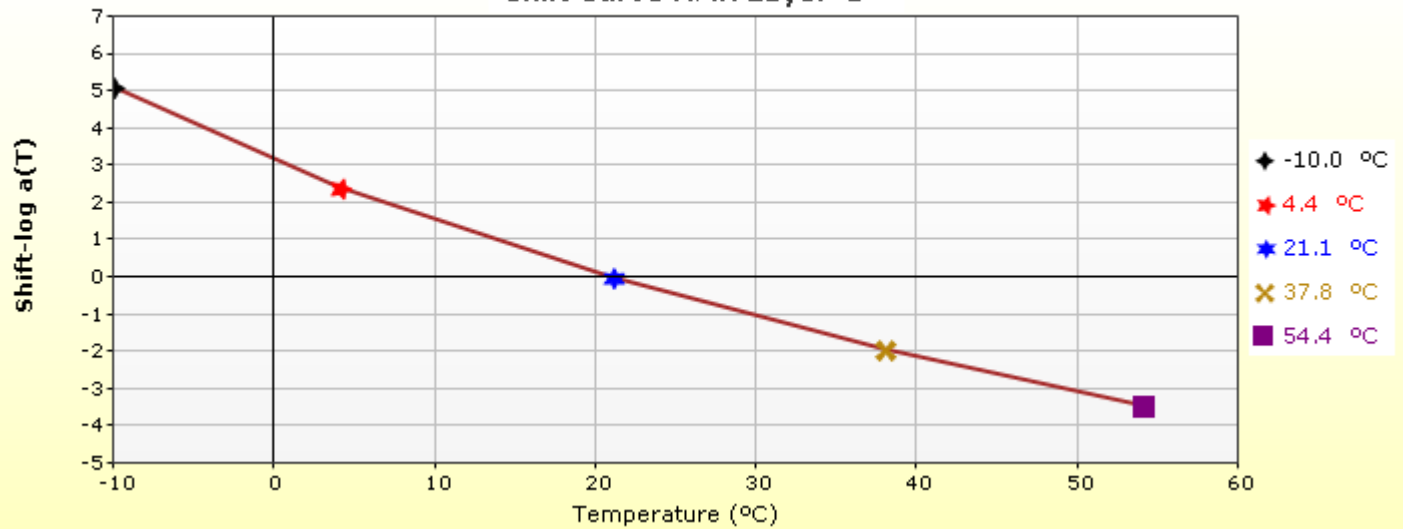


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

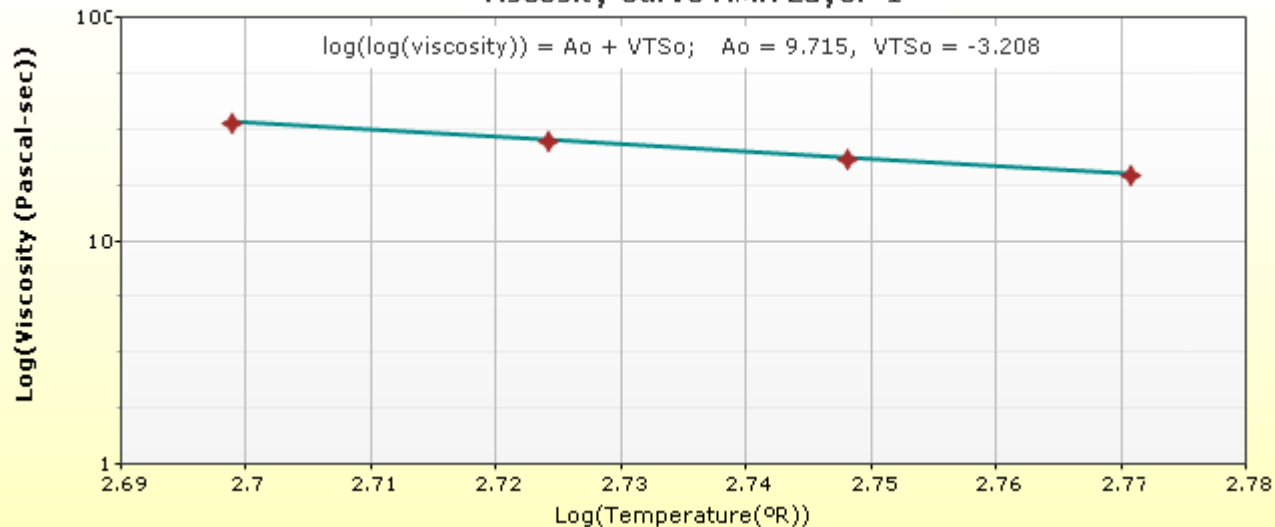
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

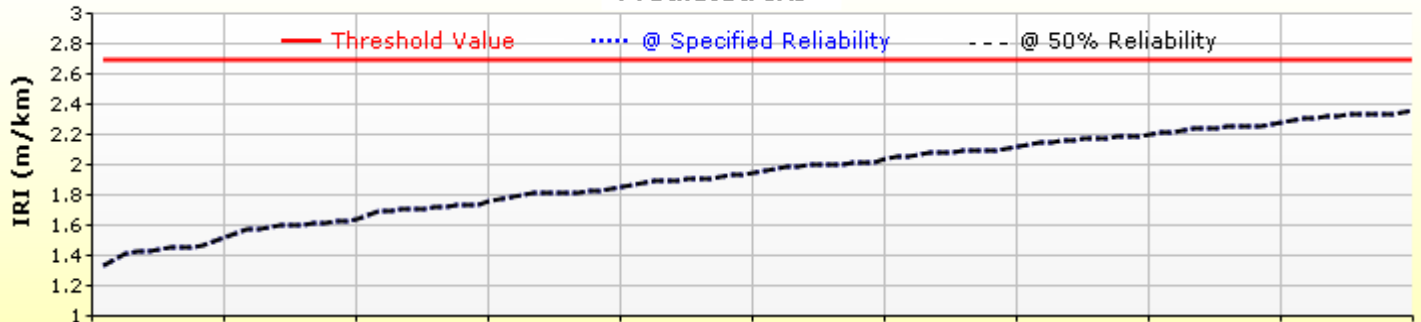


Viscosity Curve HMA Layer 1

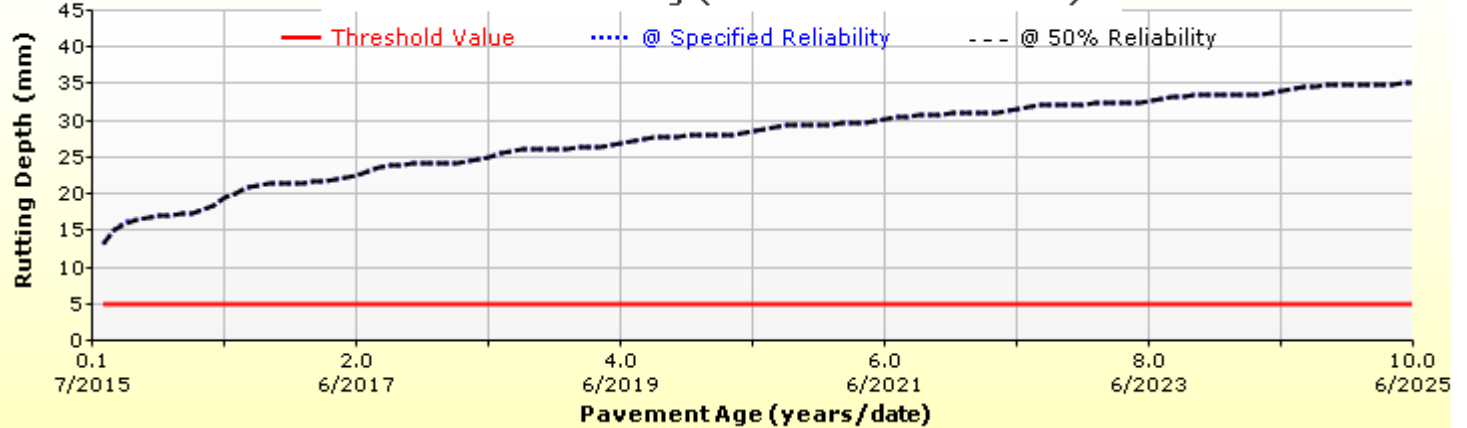


Analysis Output Charts

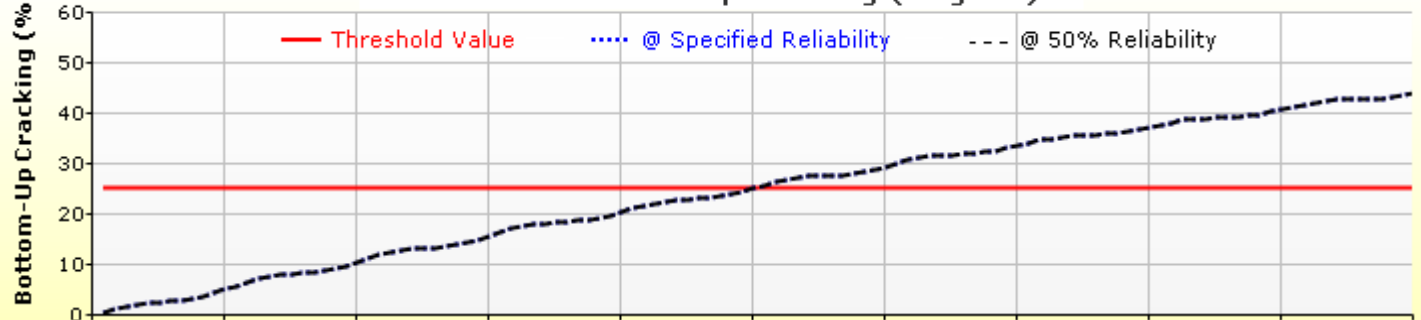
Predicted IRI



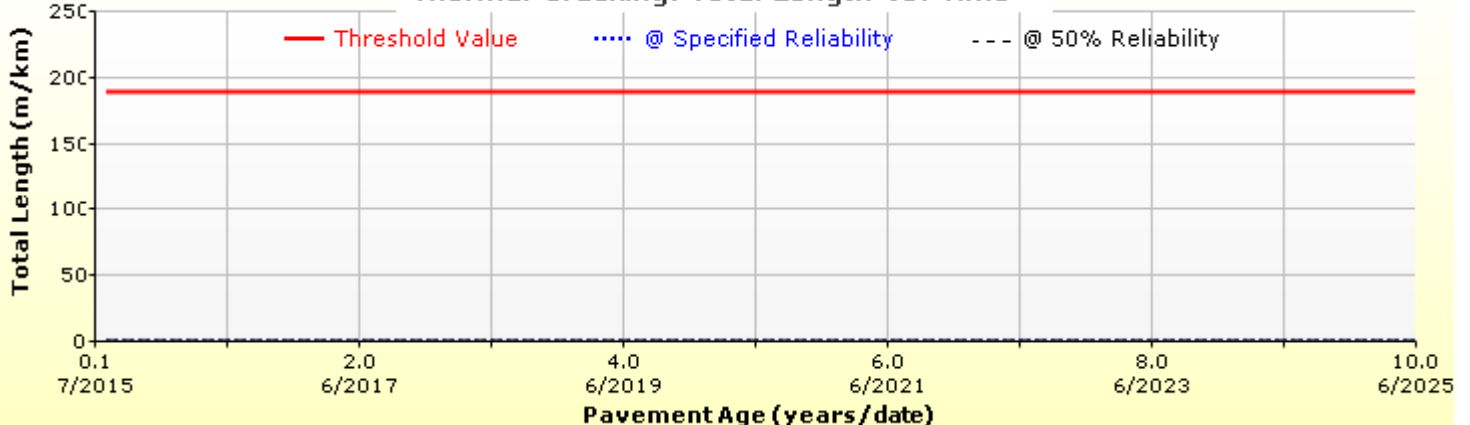
Predicted Total Rutting (Permanent Deformation)

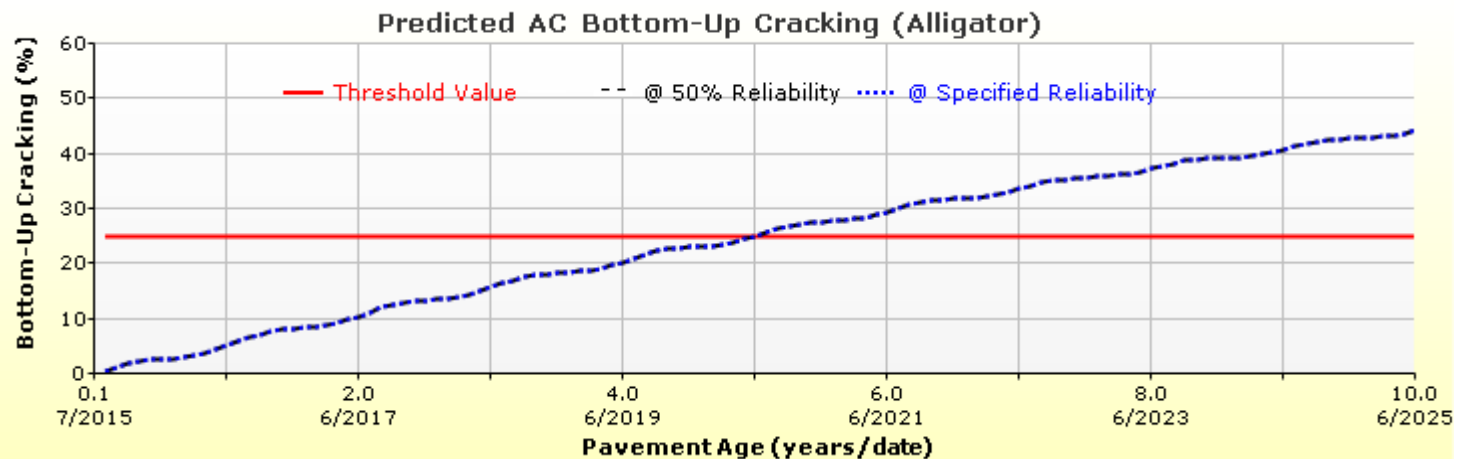
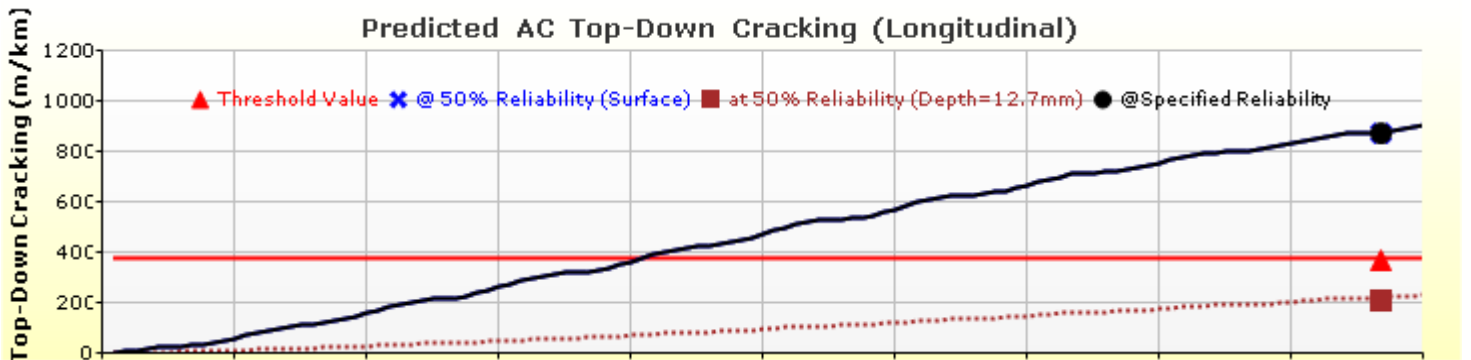
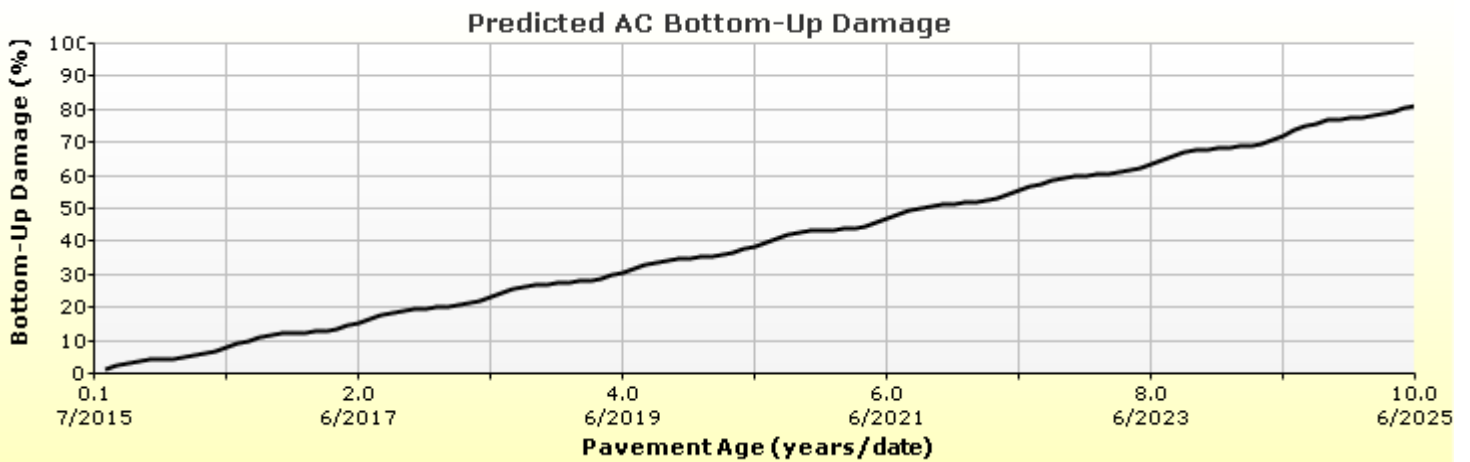
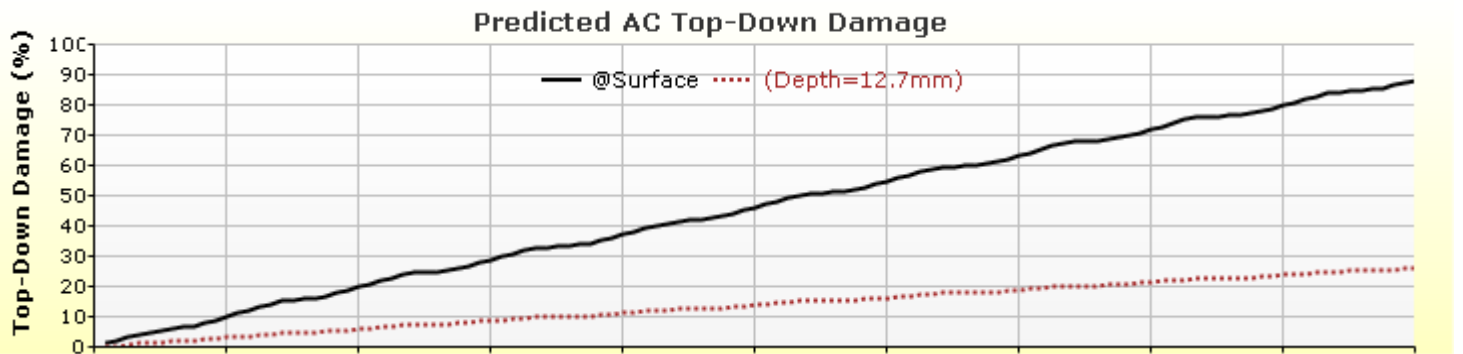


Predicted AC Bottom-Up Cracking (Alligator)

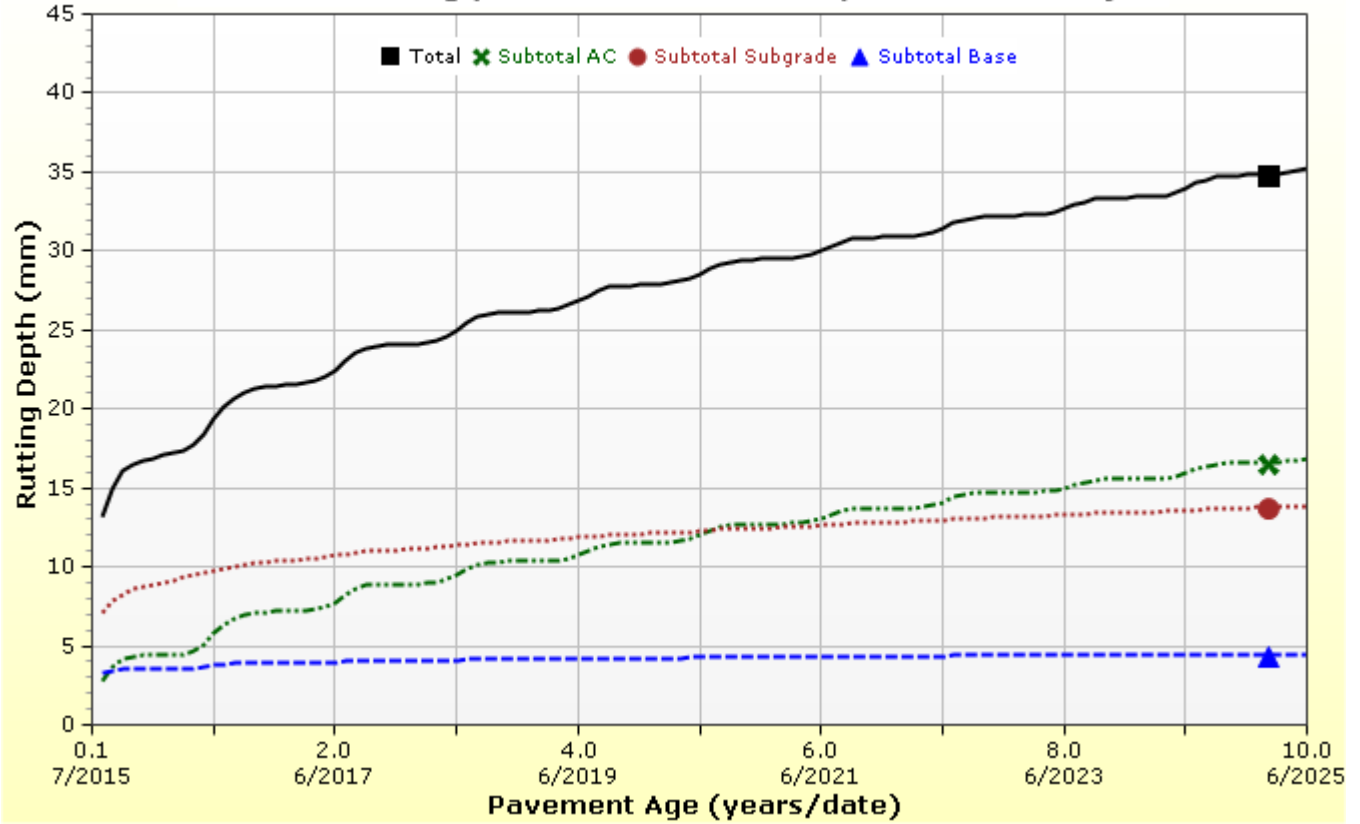


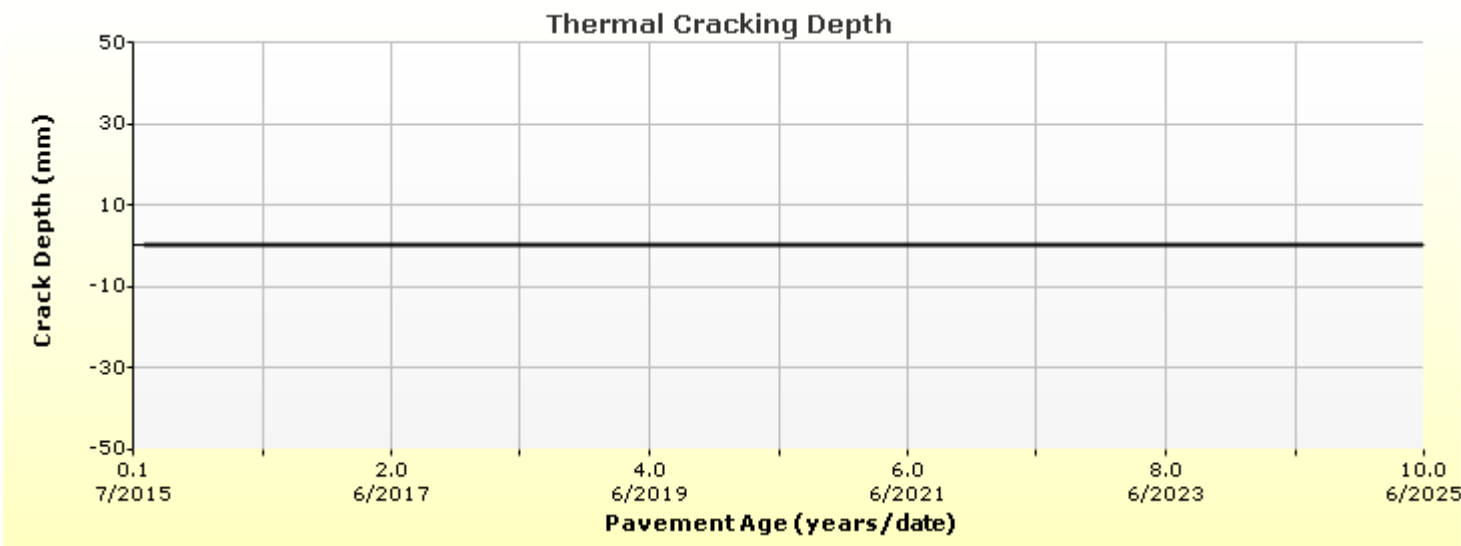
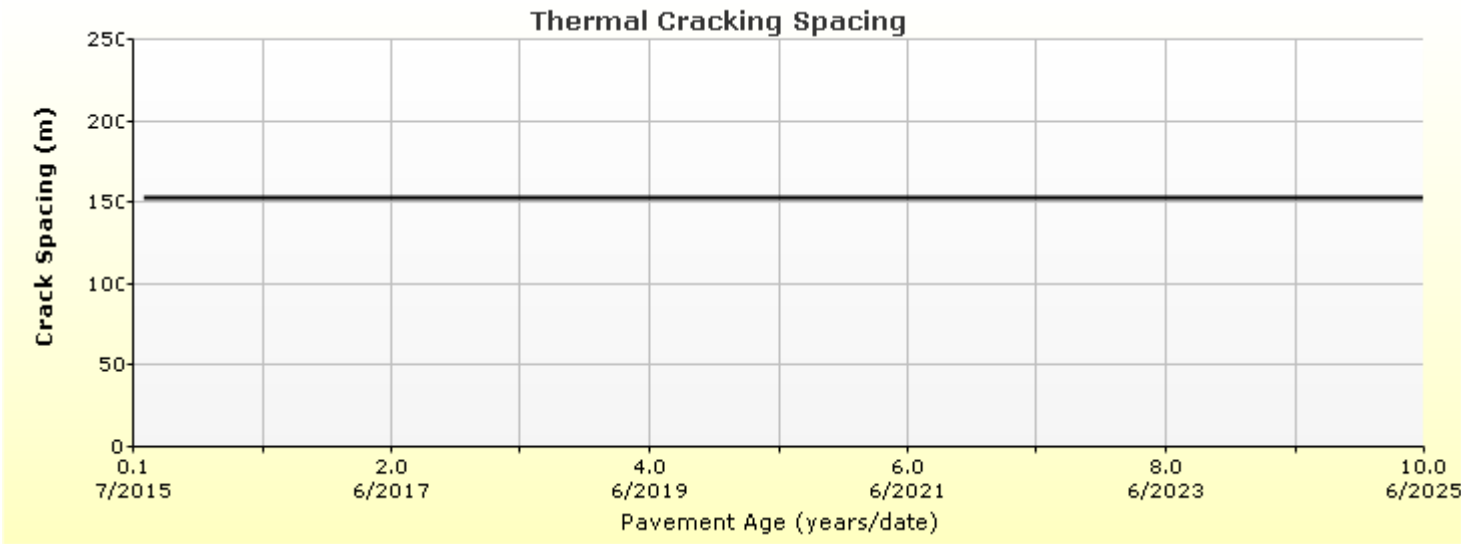
Thermal Cracking: Total Length vs. Time

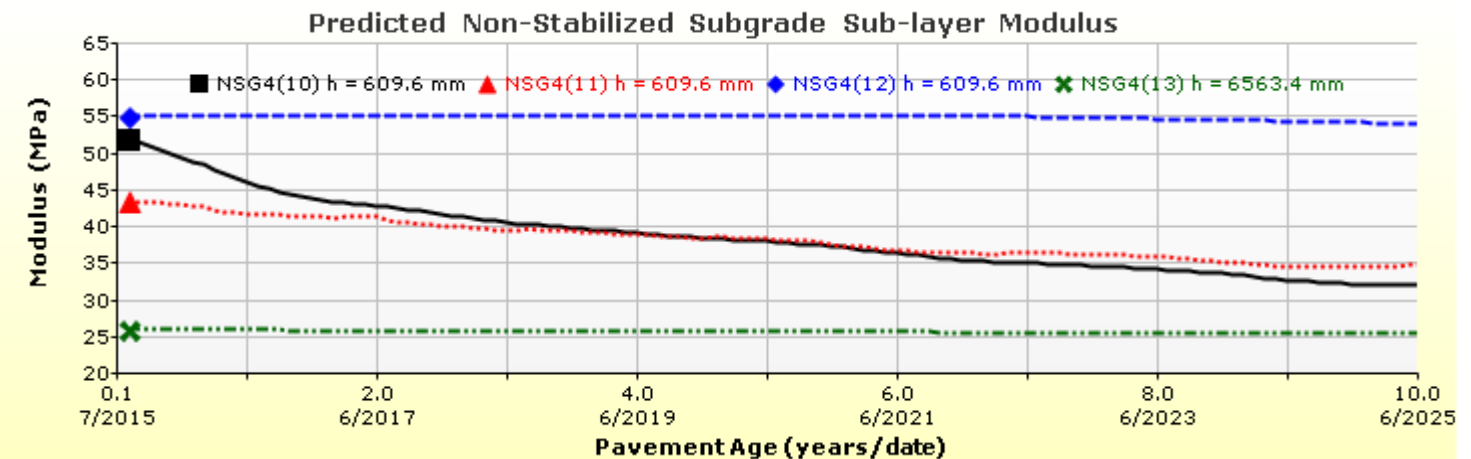
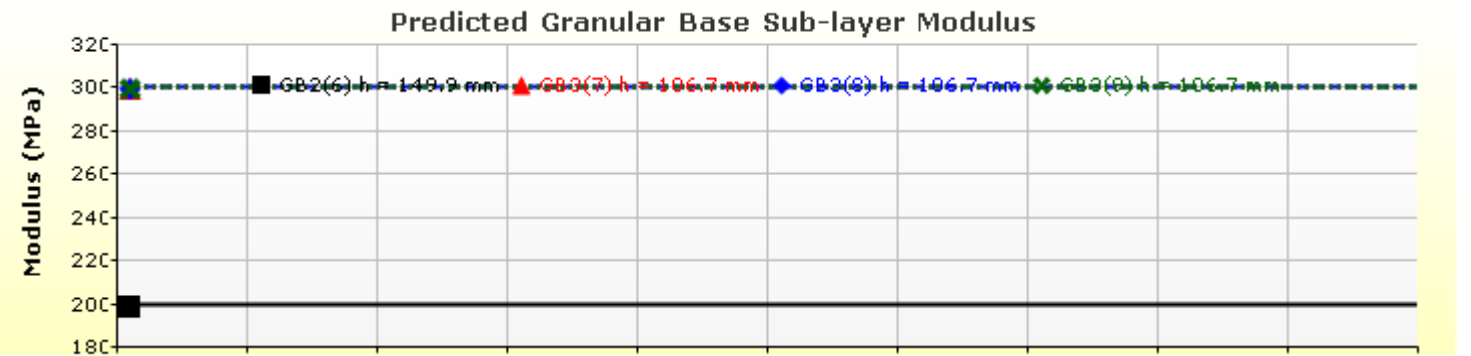
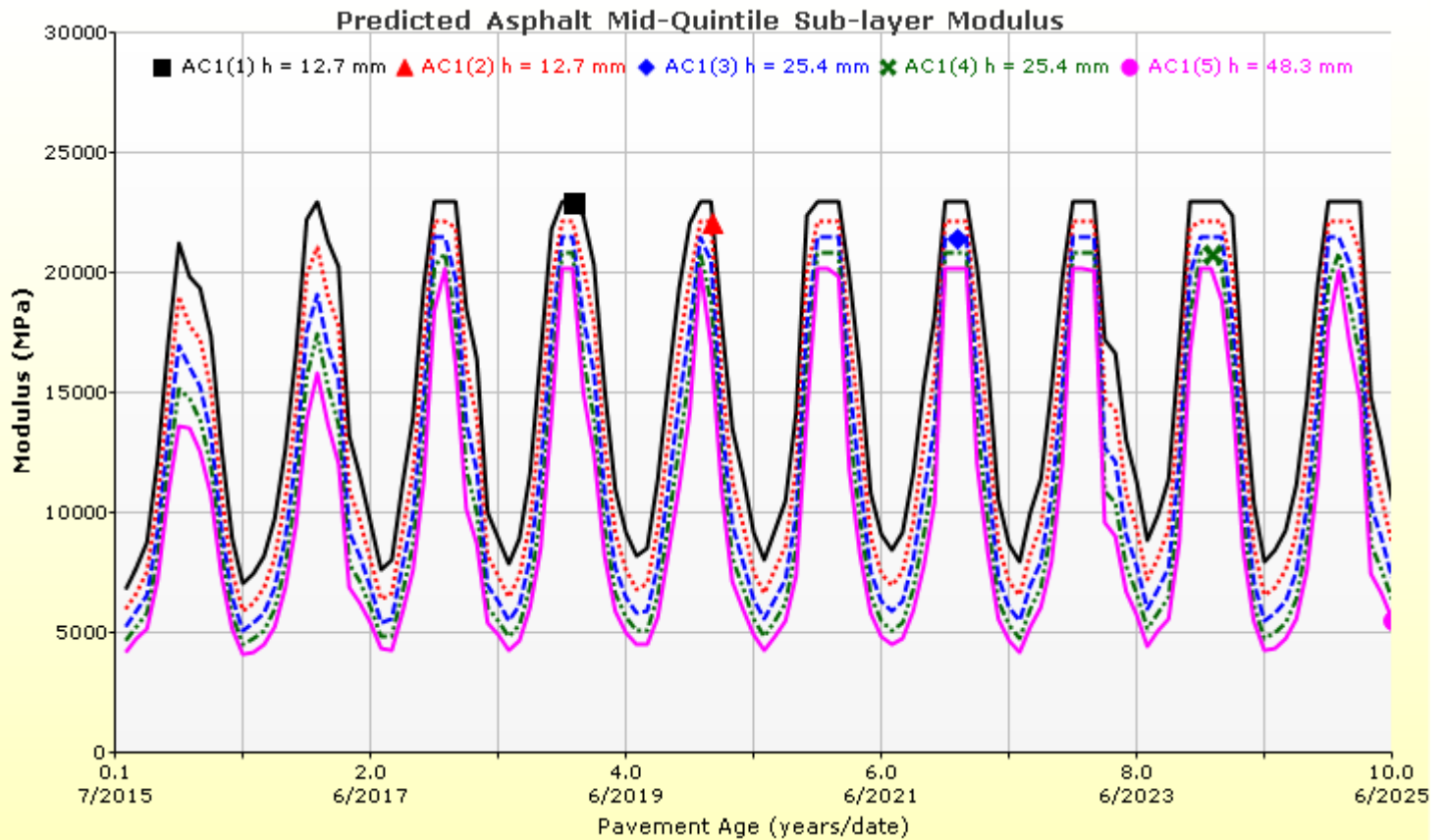




Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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 = regression coefficient determined through field calibration $N()$ = standard normal distribution evaluated at() σ = standard deviation of the log of the depth of cracks in the pavements C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_s = Tensile stress(psi) M_r = modulus of rupture(psi)
k1: 1	k2: 1
Bc1: 1	Bc2: 1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

Standard Deviation (BASERUT)

0.1235*Pow(SUBRUT,0.5012)+0.001

AC Cracking

AC Top Down Cracking

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

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: 7

c2: 3.5

c3: 0

c4: 1000

c1: 1

c2: 1

c3: 6000

AC Cracking Top Standard Deviation

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

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

IRI Flexible Pavements

C1 - Rutting

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

CSM Standard Deviation

CTB*1

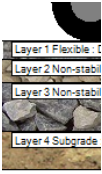
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

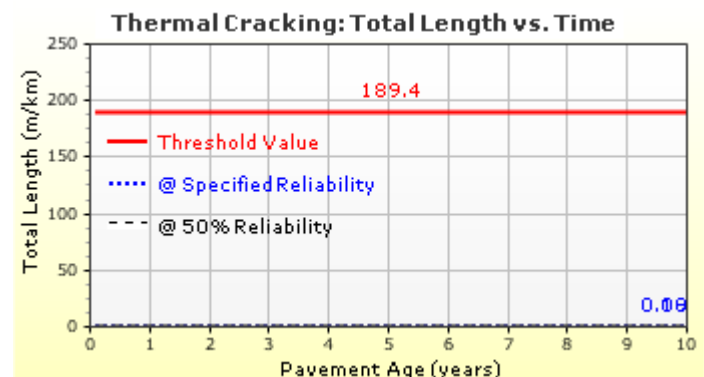
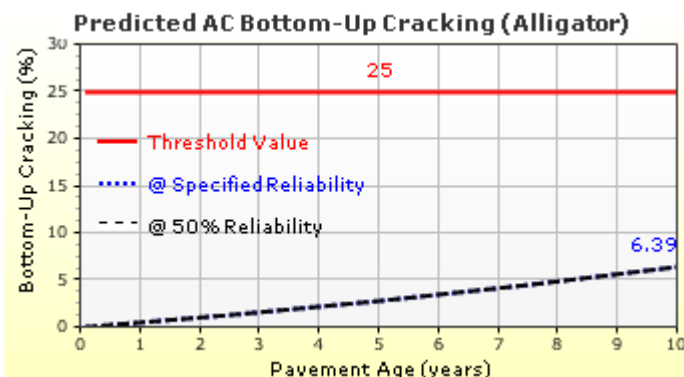
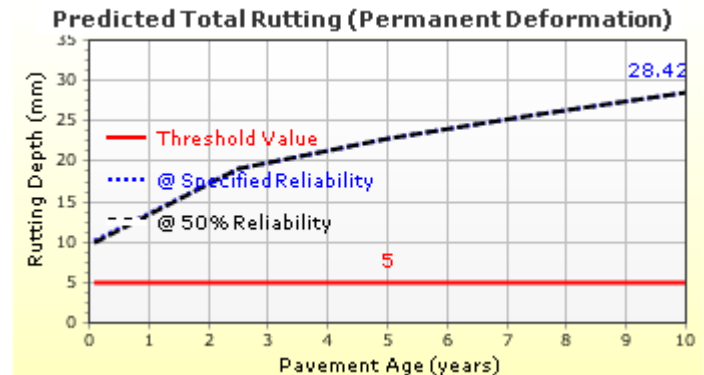
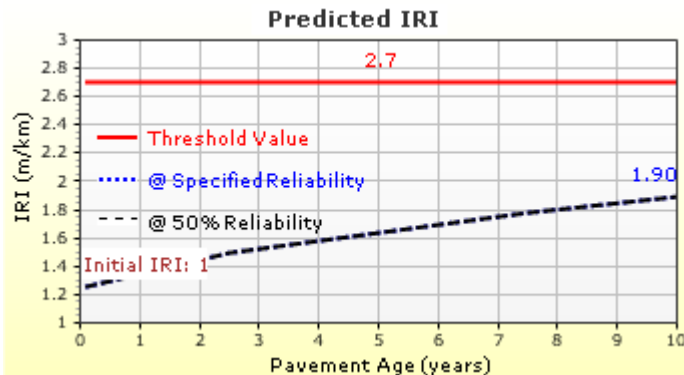
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.90	50.00	93.56	Pass
Permanent deformation - total pavement (mm)	5.00	28.42	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	6.39	50.00	90.62	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	5.83	50.00	95.66	Pass
Permanent deformation - AC only (mm)	5.00	15.12	50.00	0.62	Fail

Distress Charts

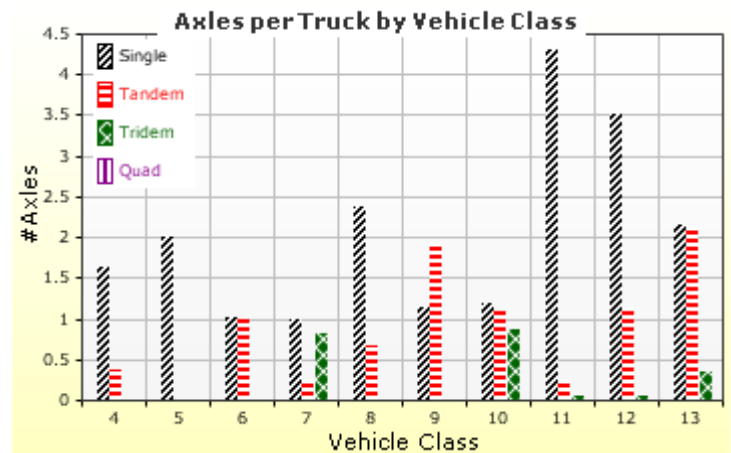
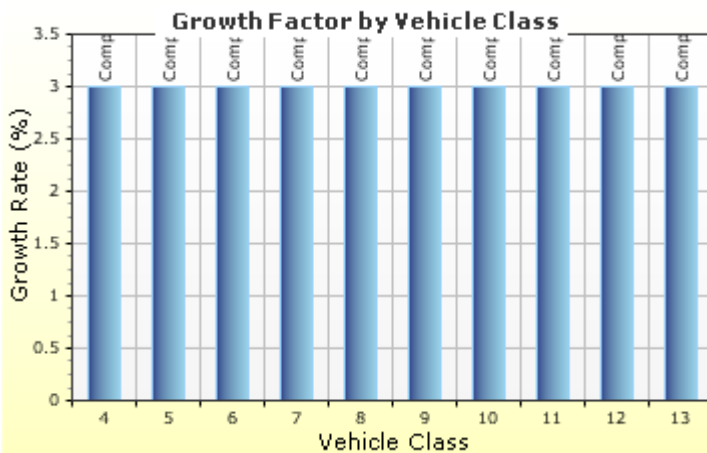
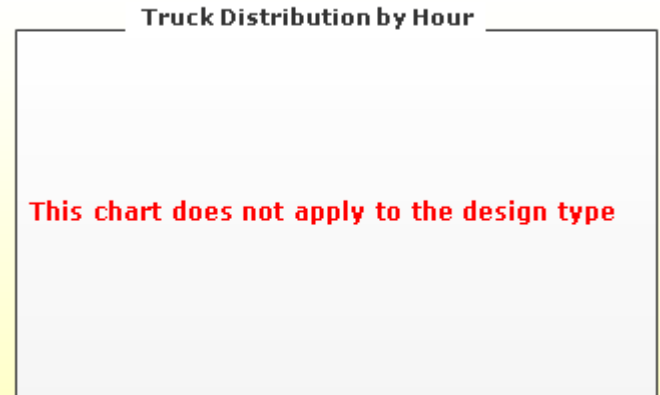
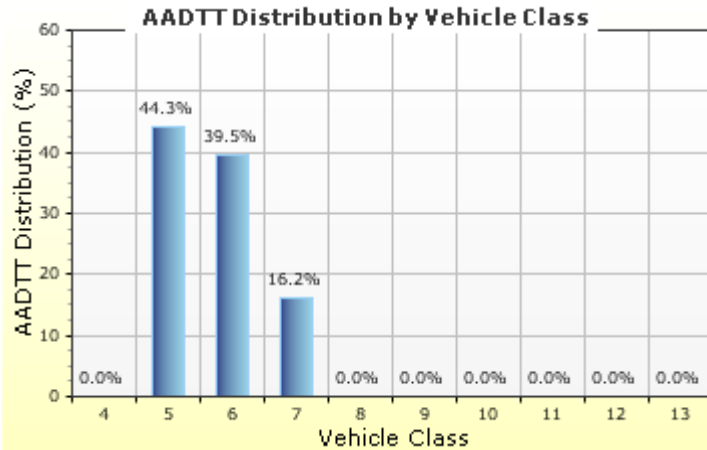


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

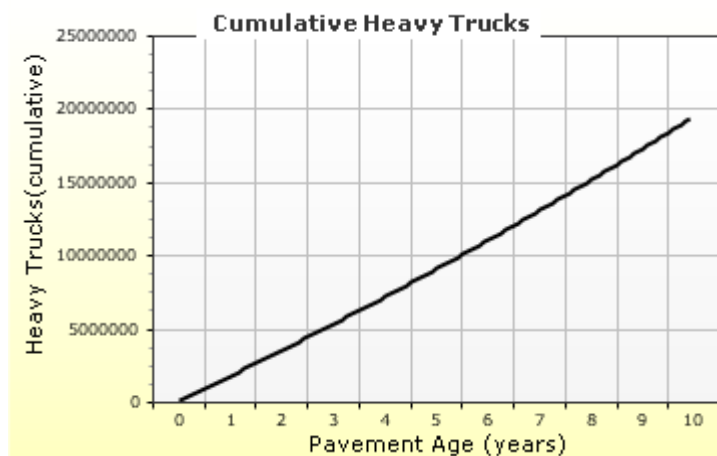
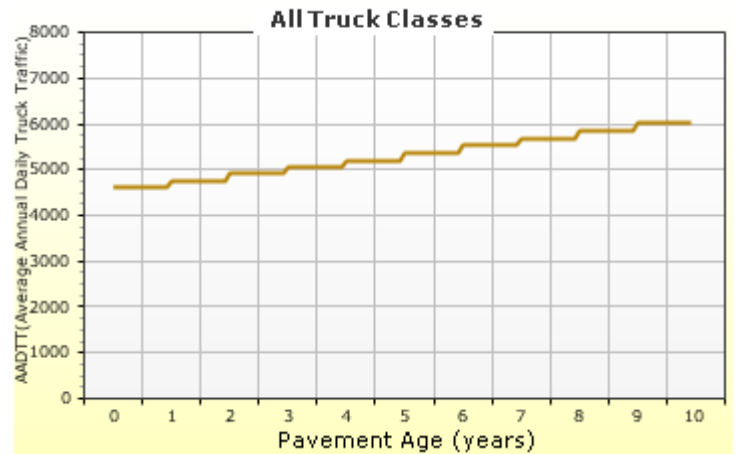
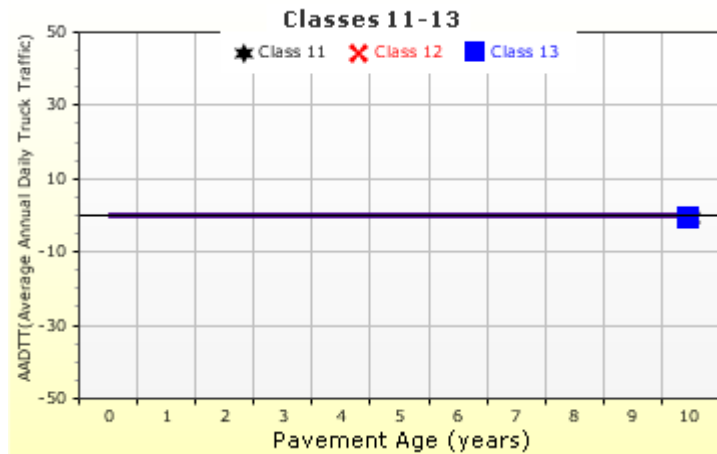
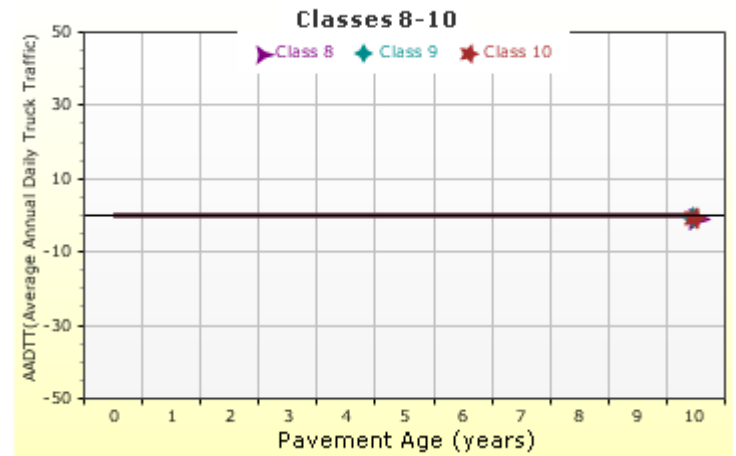
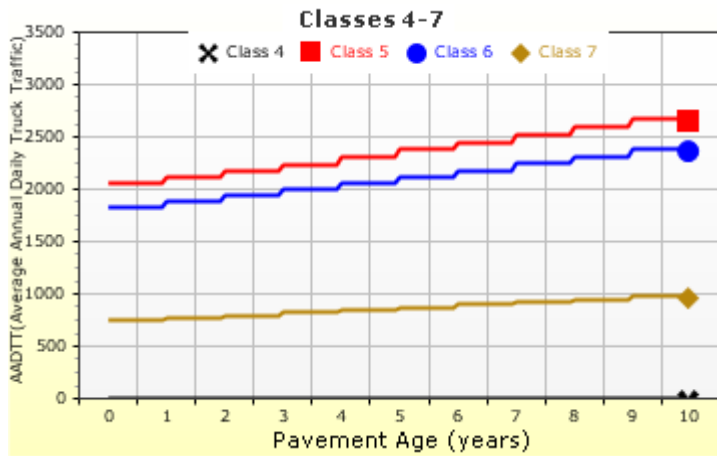
Wheelbase does not apply

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



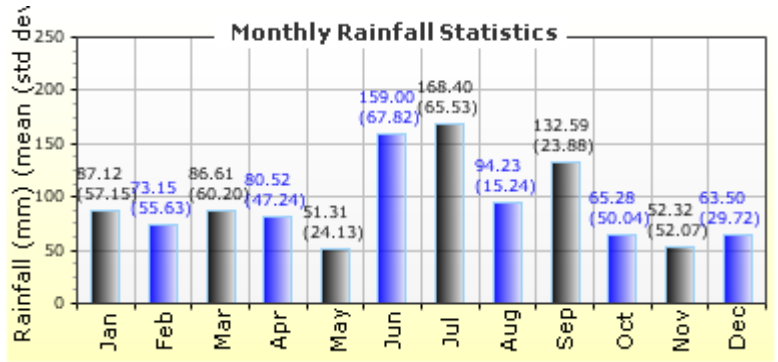
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

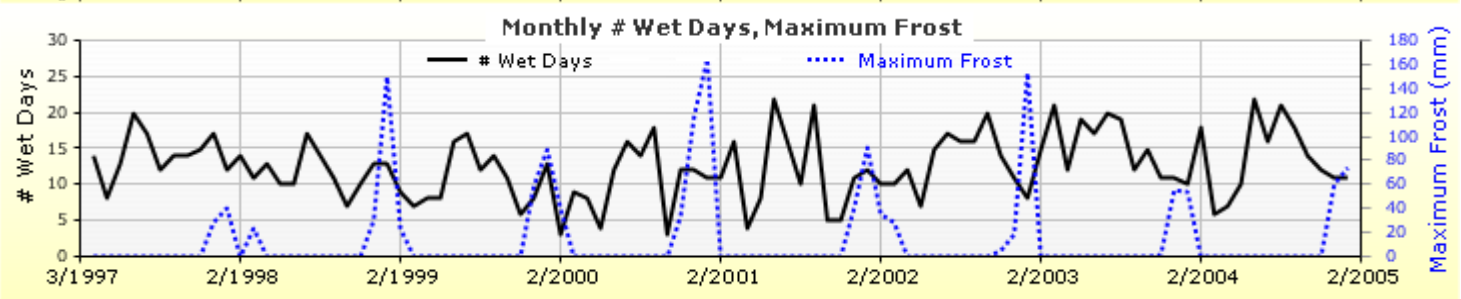
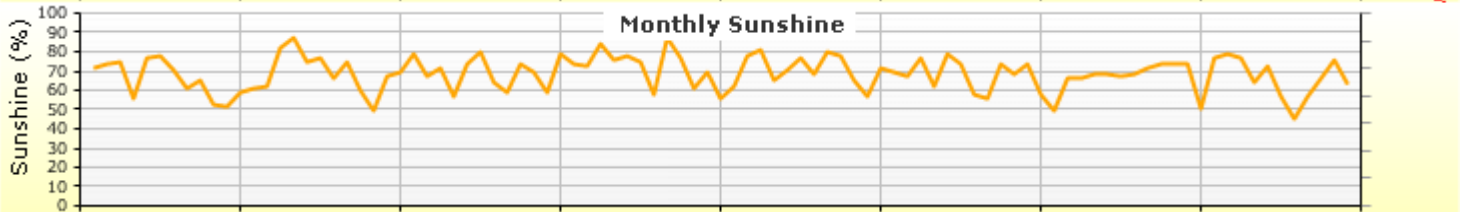
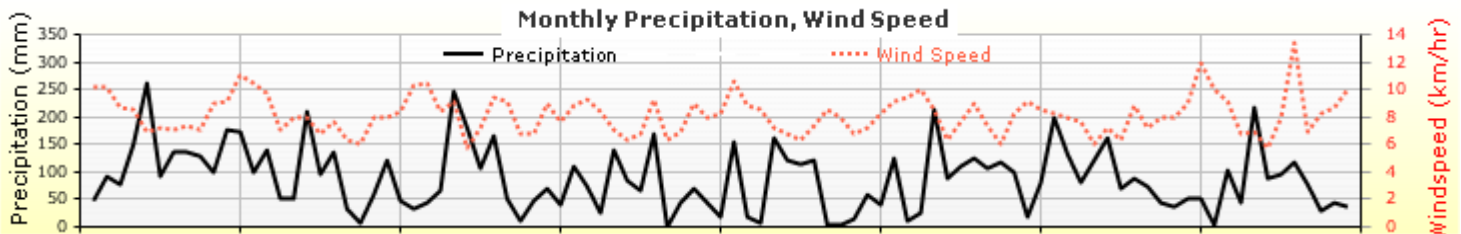
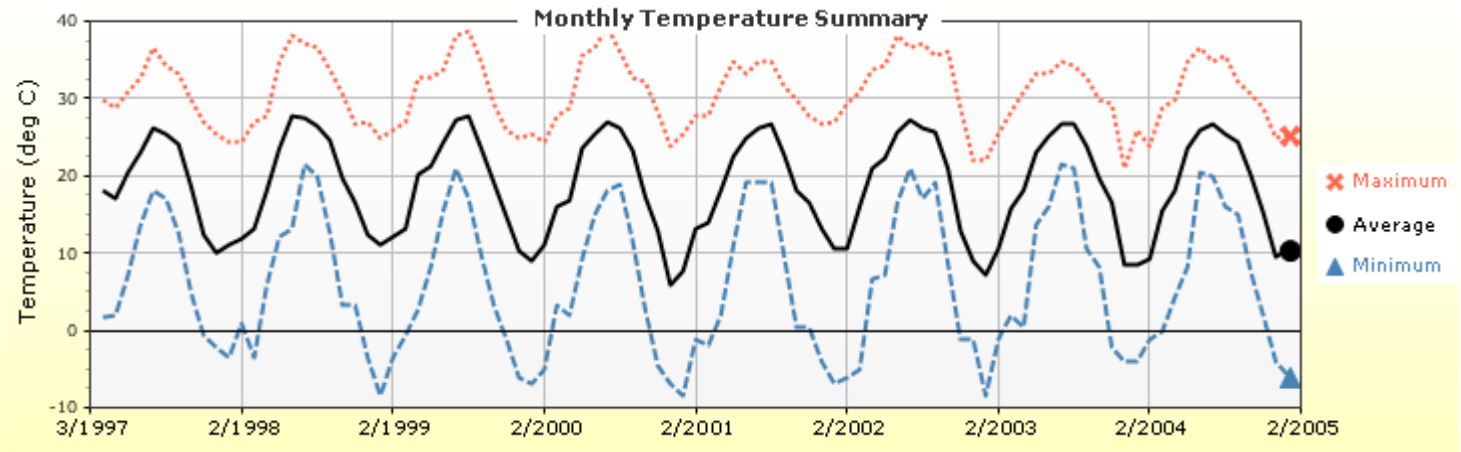
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

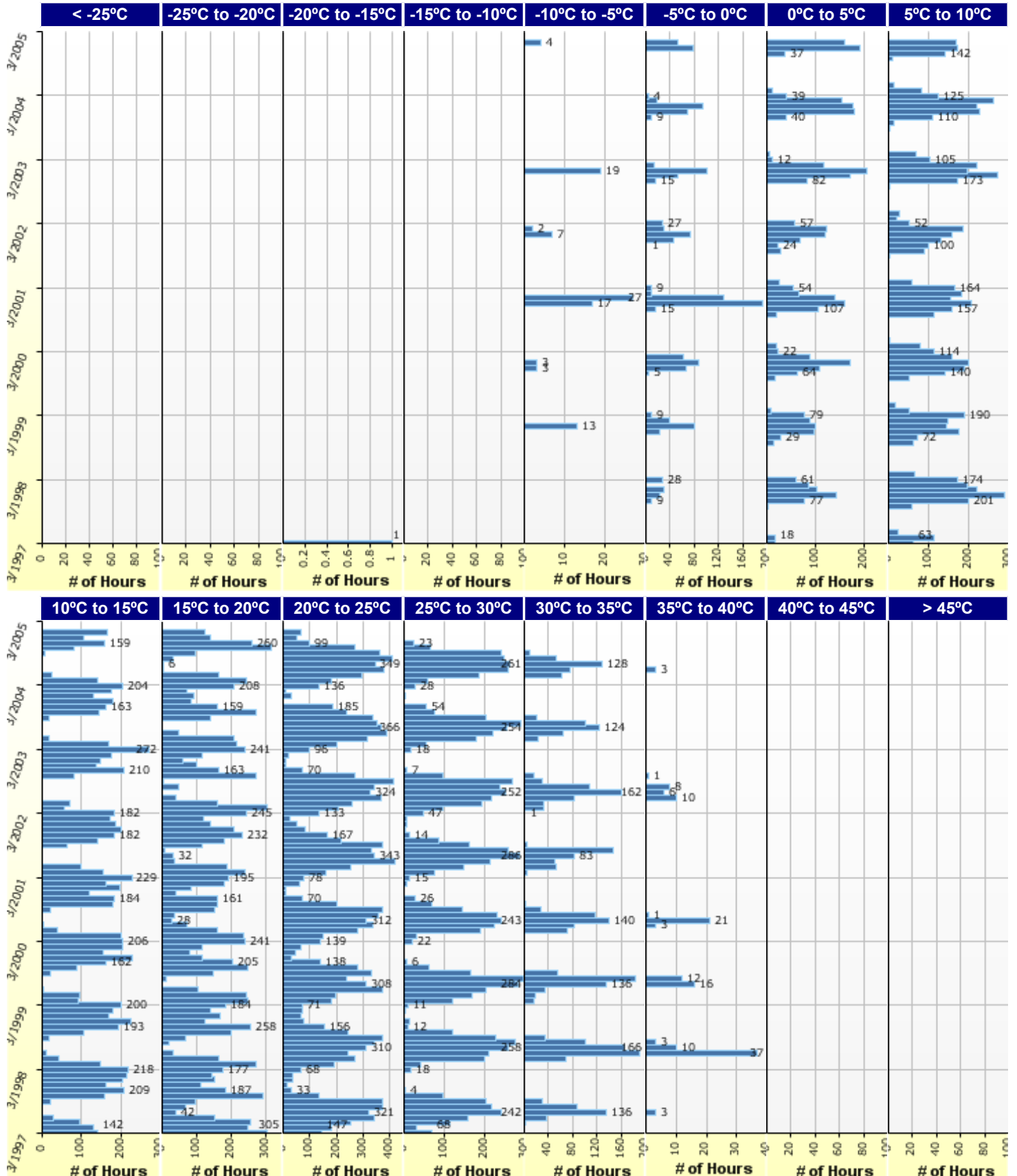


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF1_ALT1

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1_ALT1.dgpx



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

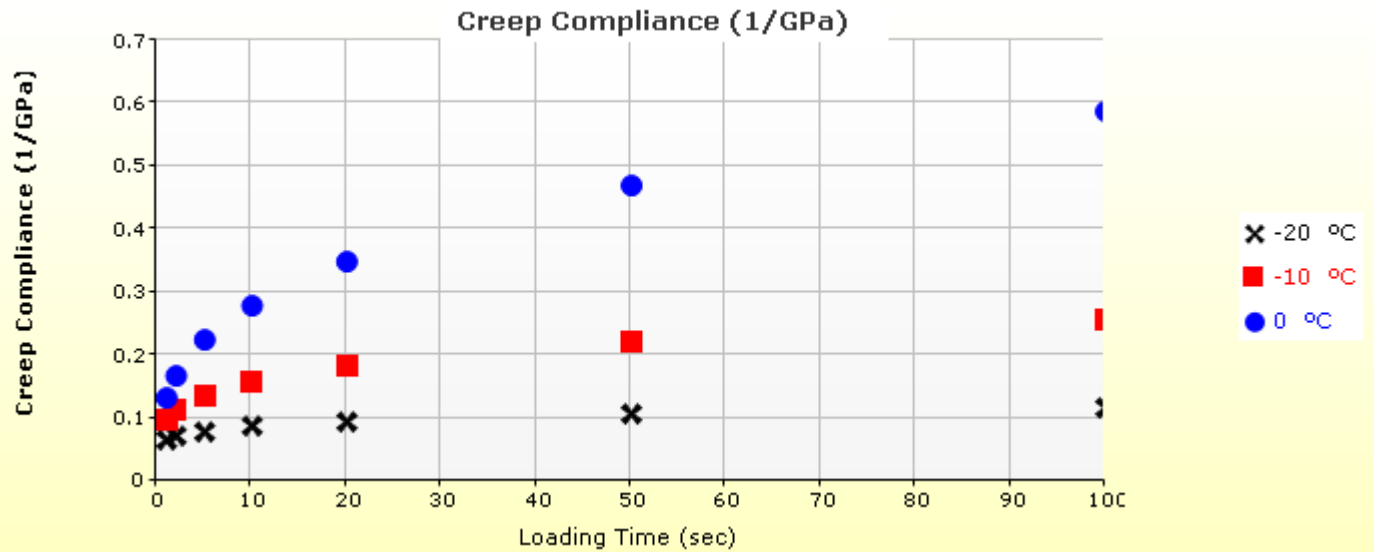
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

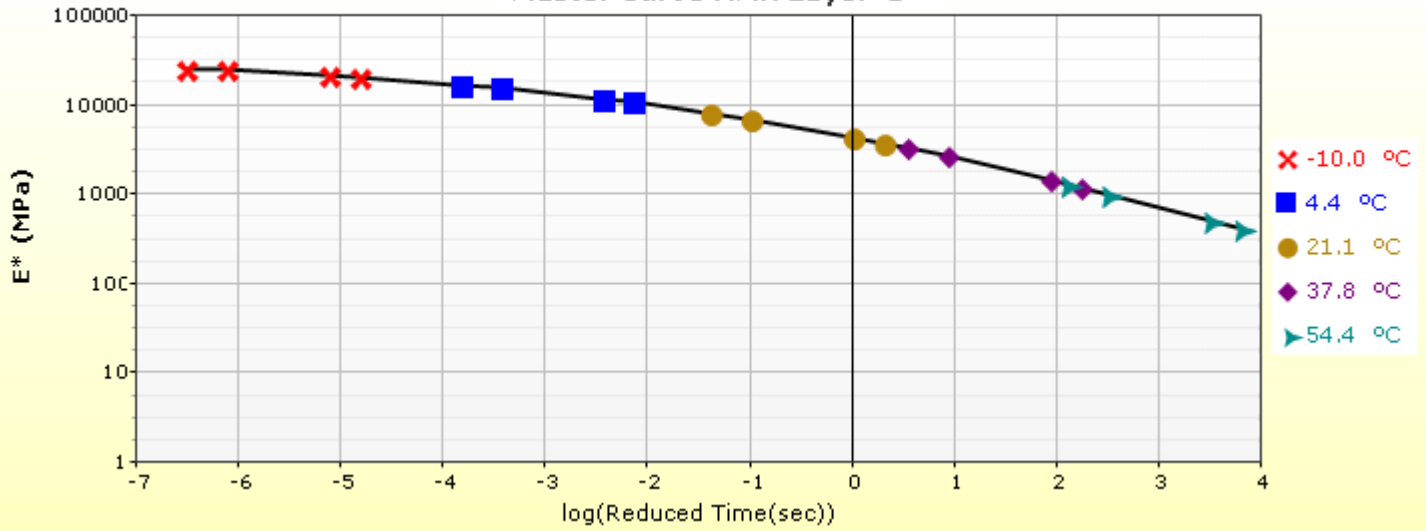
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

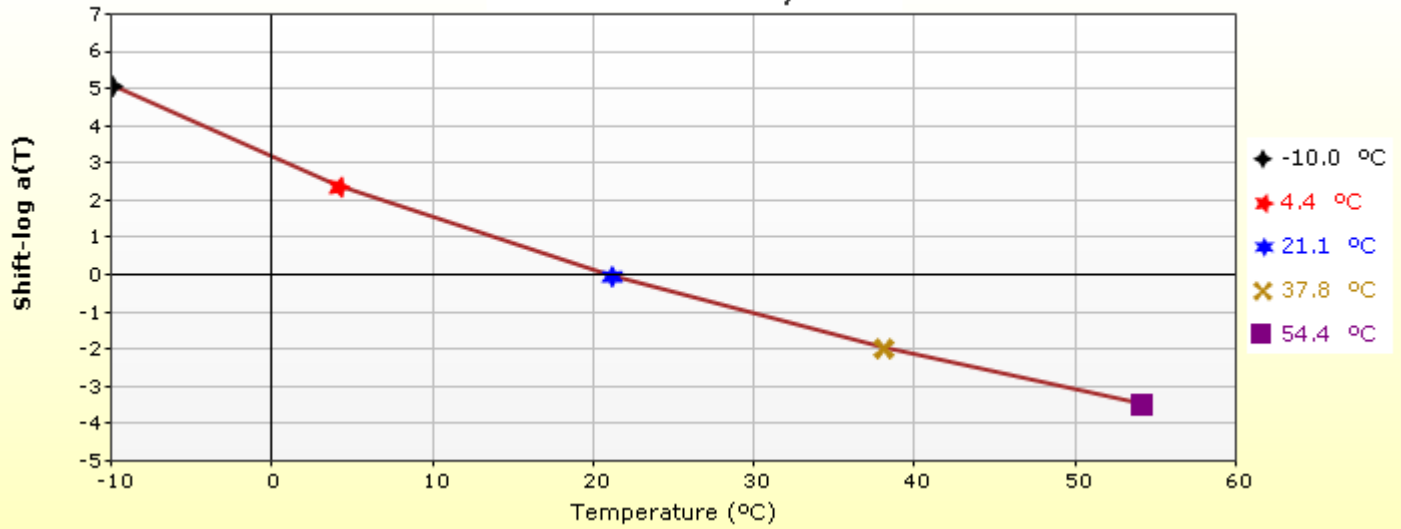


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

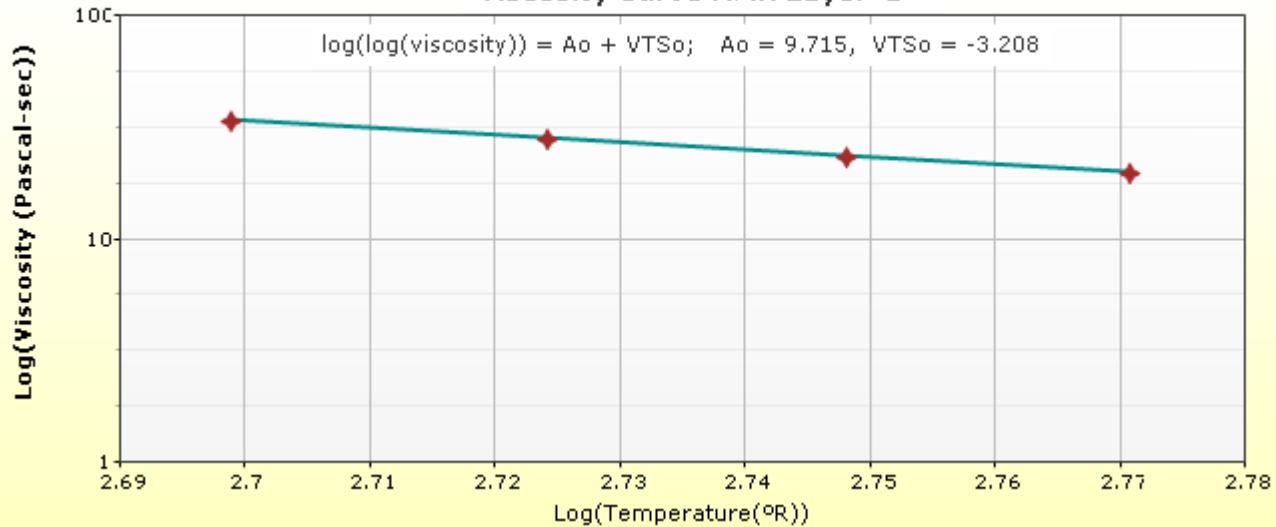
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

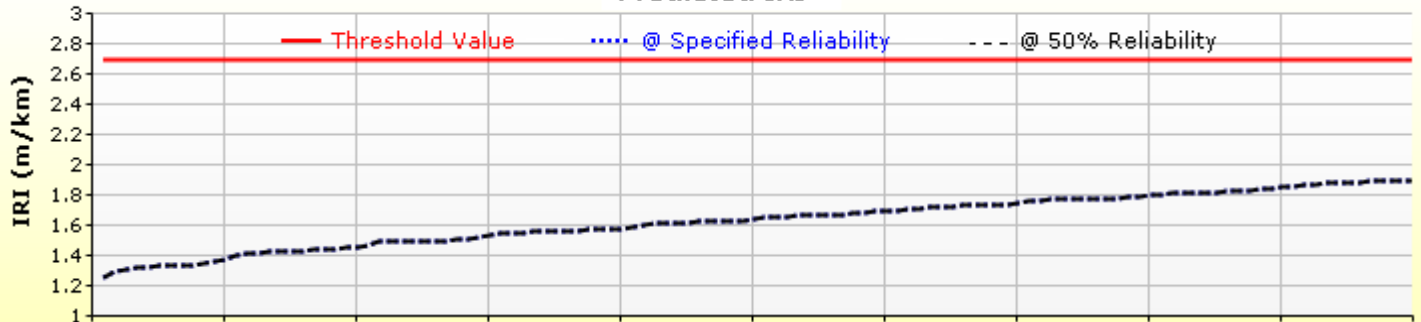


Viscosity Curve HMA Layer 1

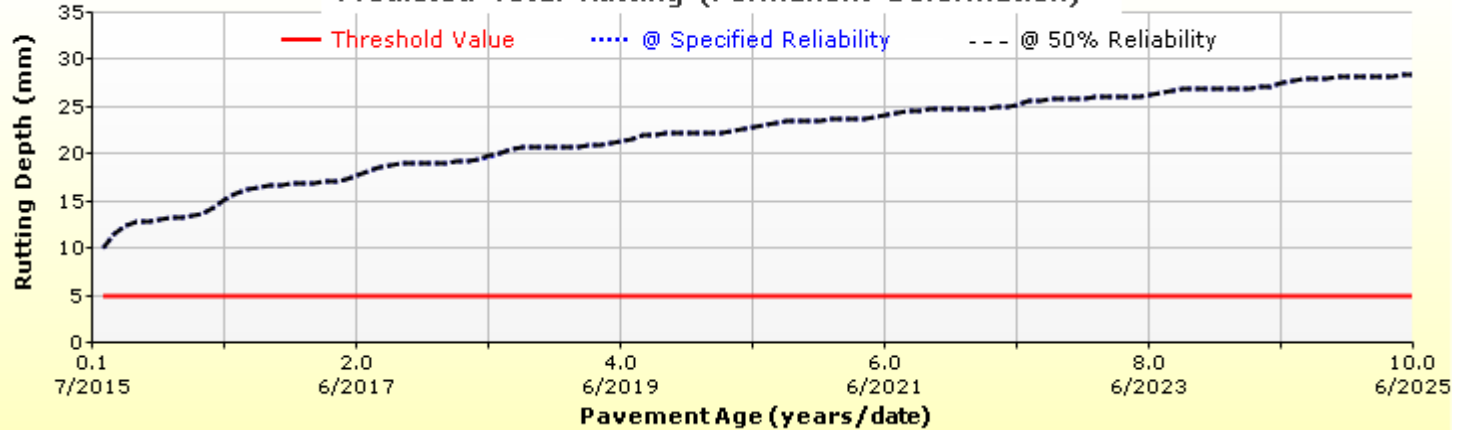


Analysis Output Charts

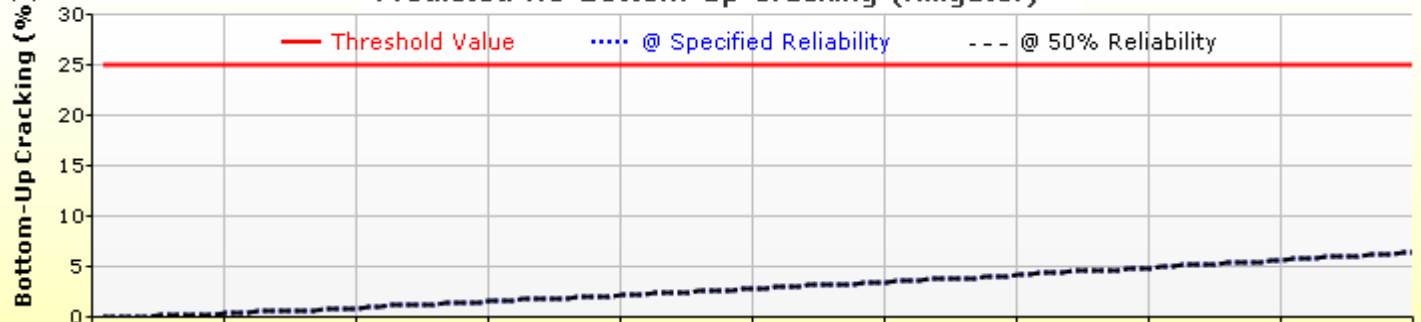
Predicted IRI



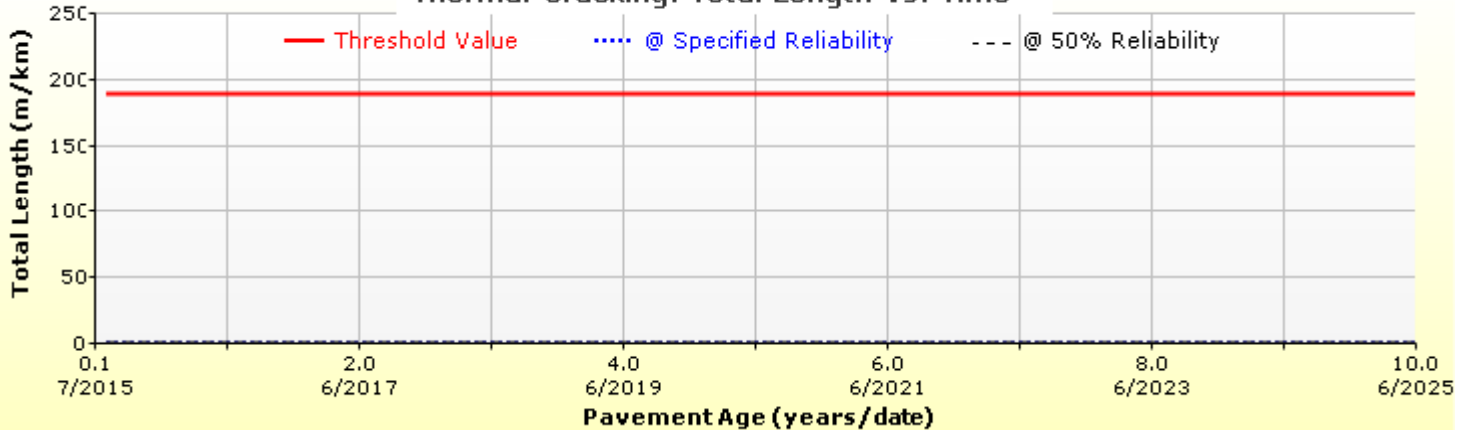
Predicted Total Rutting (Permanent Deformation)

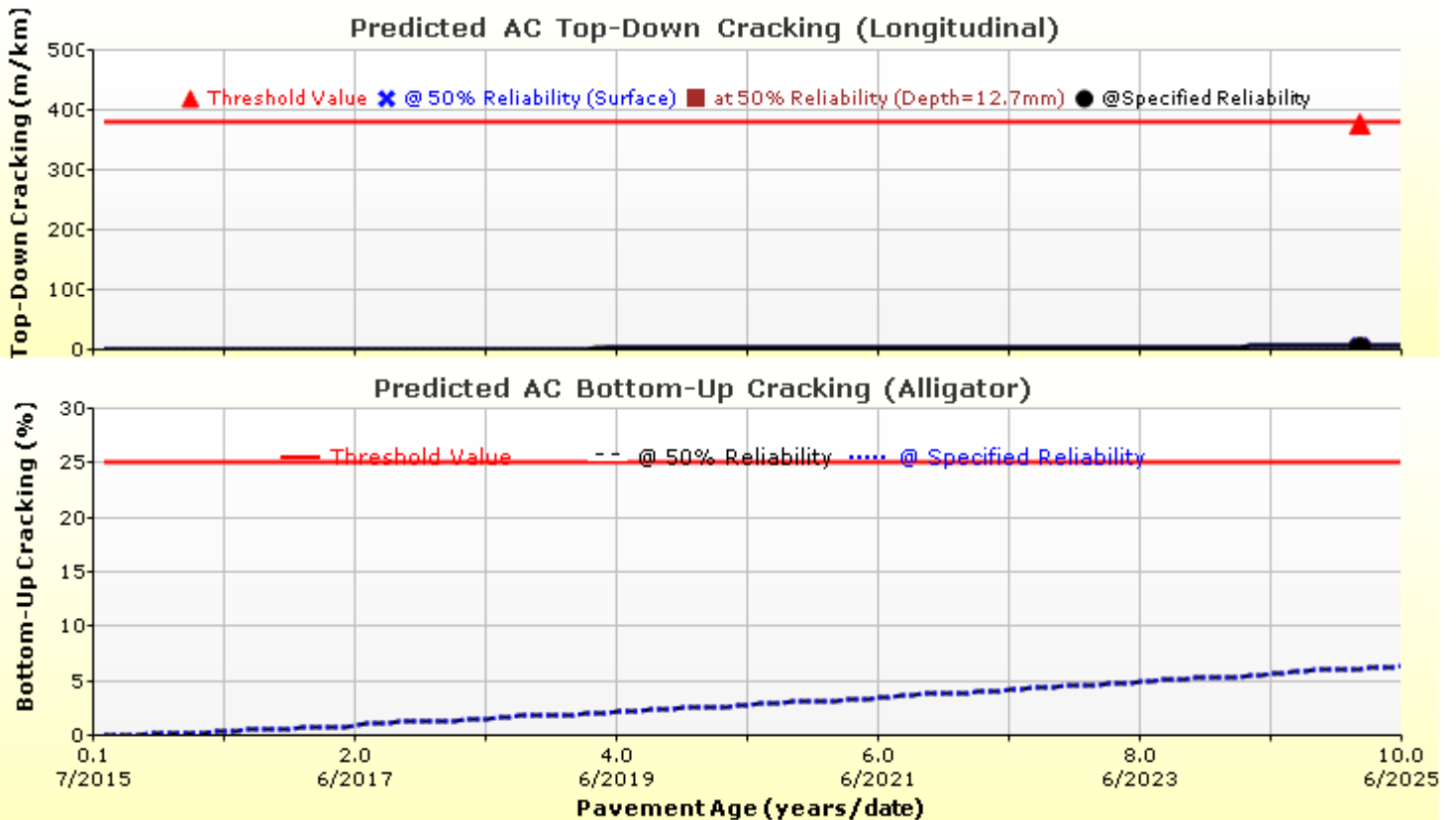
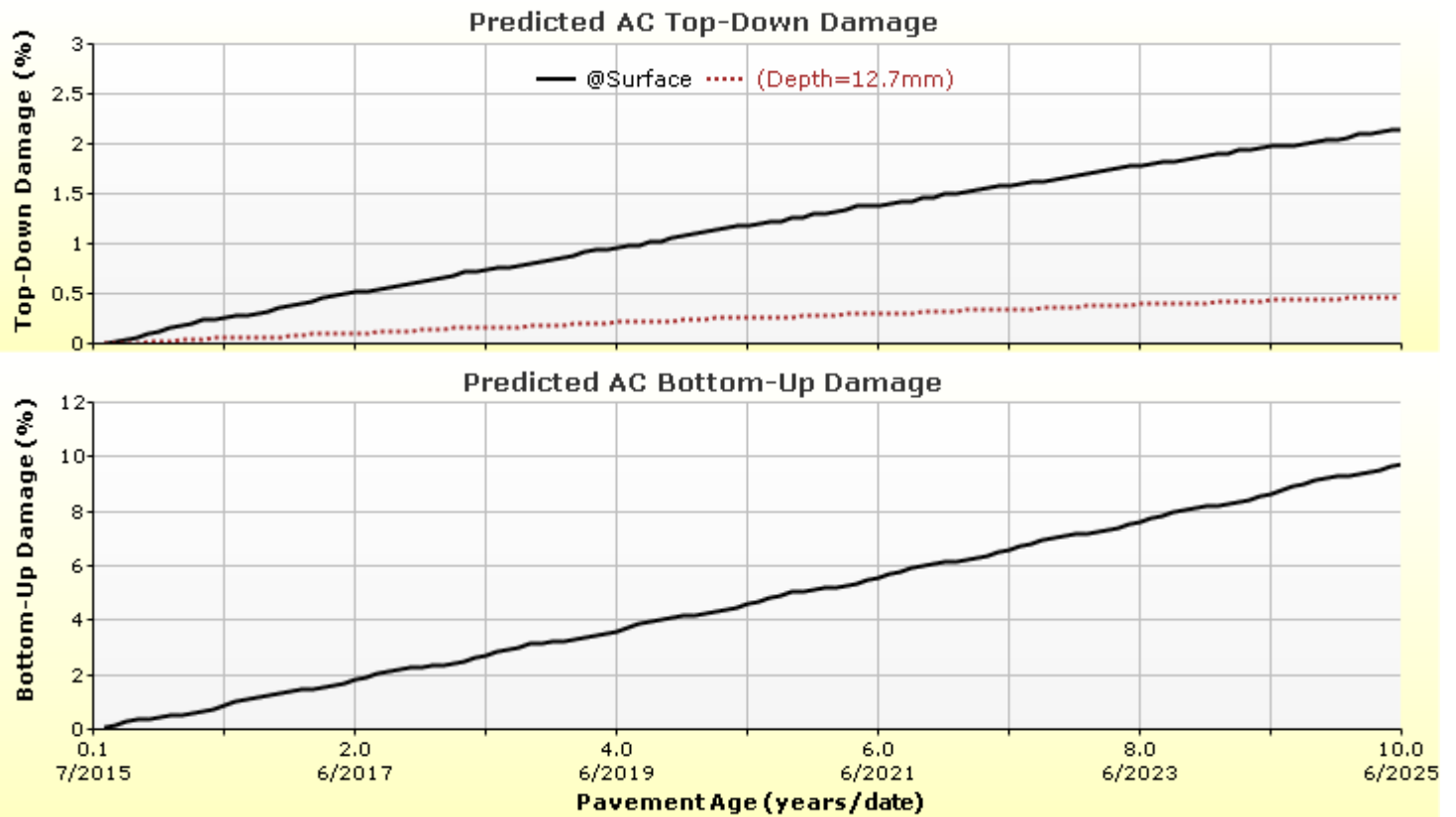


Predicted AC Bottom-Up Cracking (Alligator)

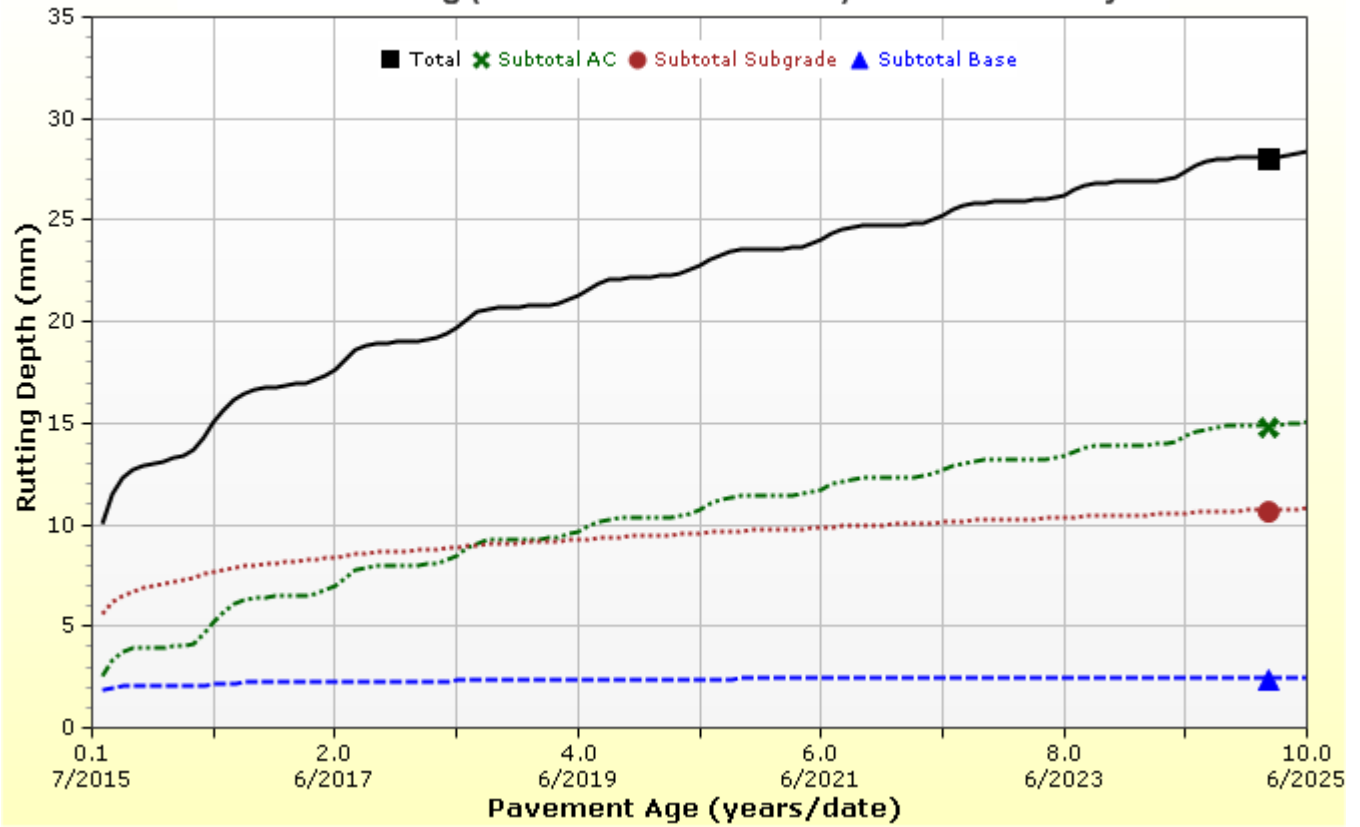


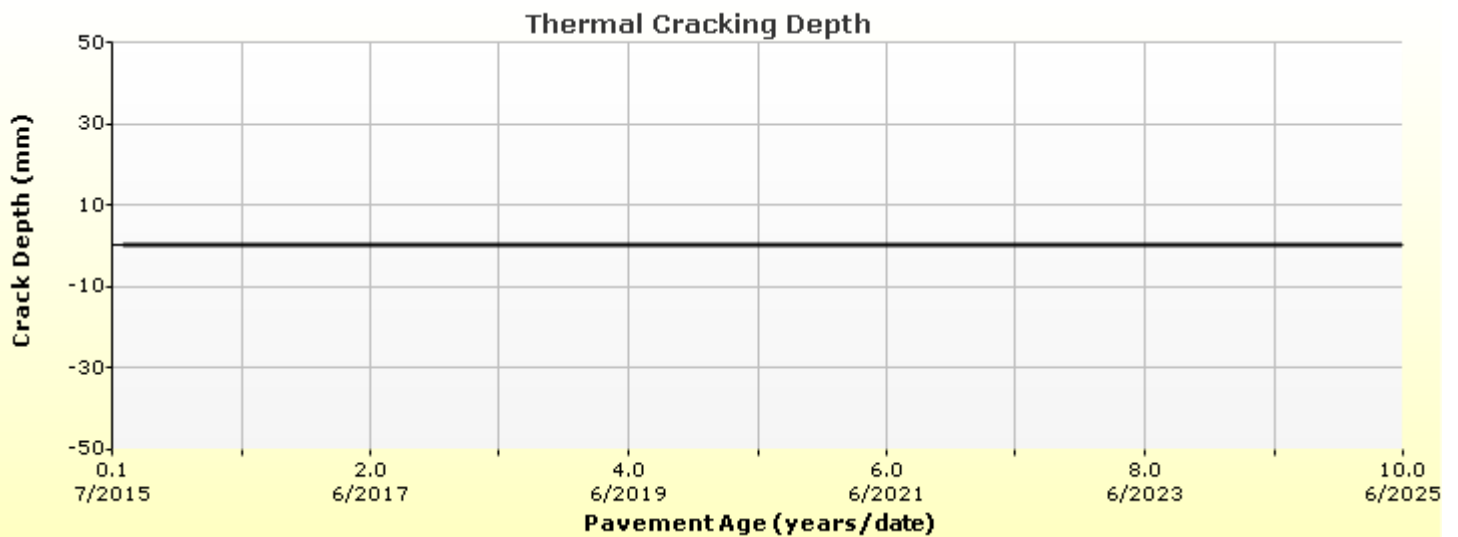
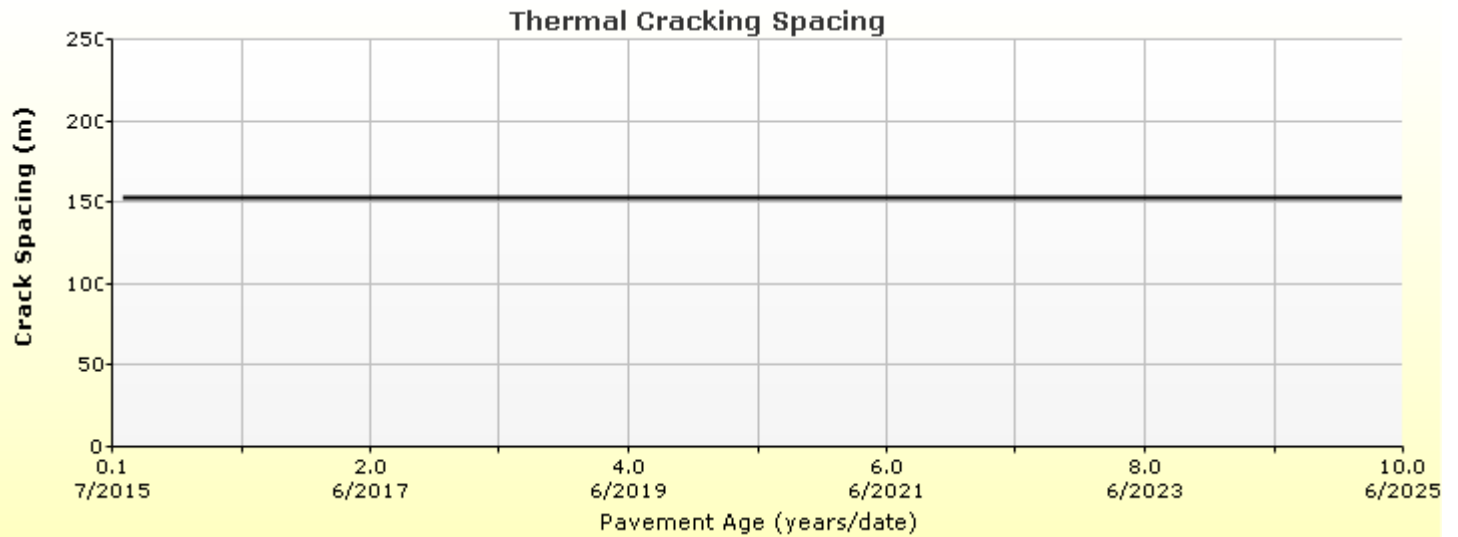
Thermal Cracking: Total Length vs. Time

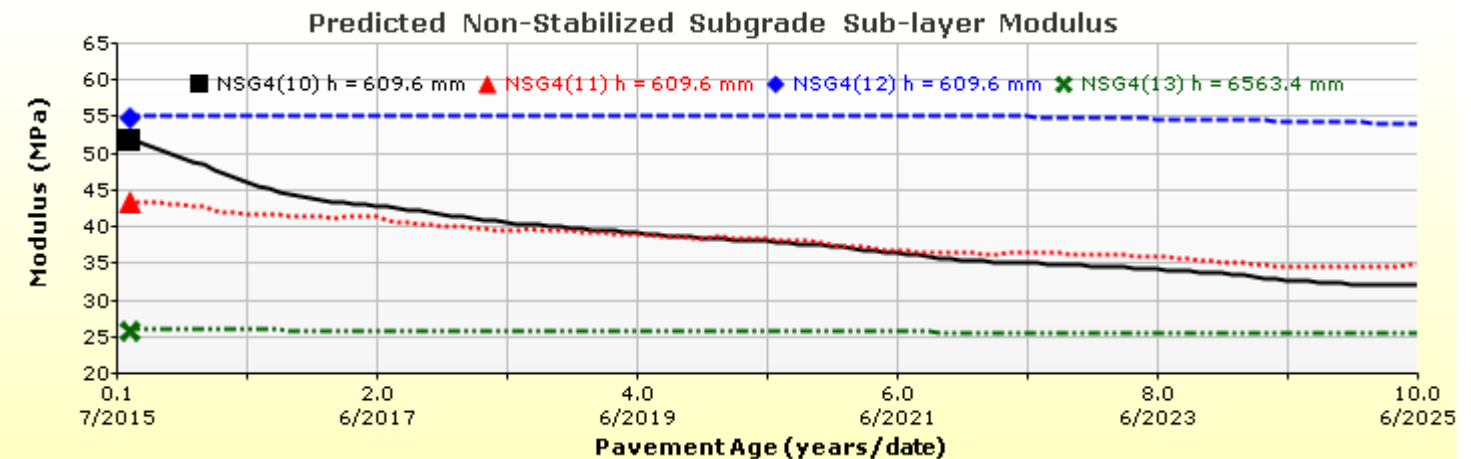
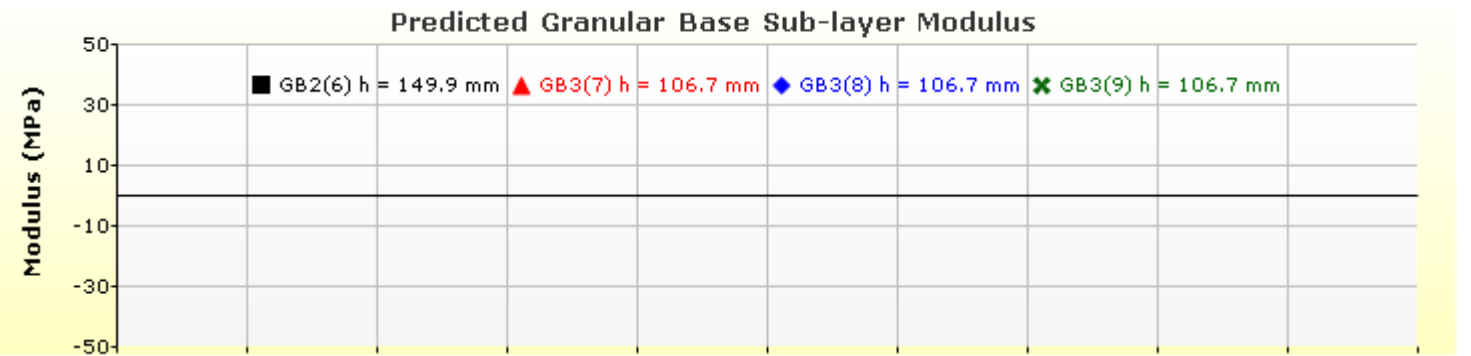
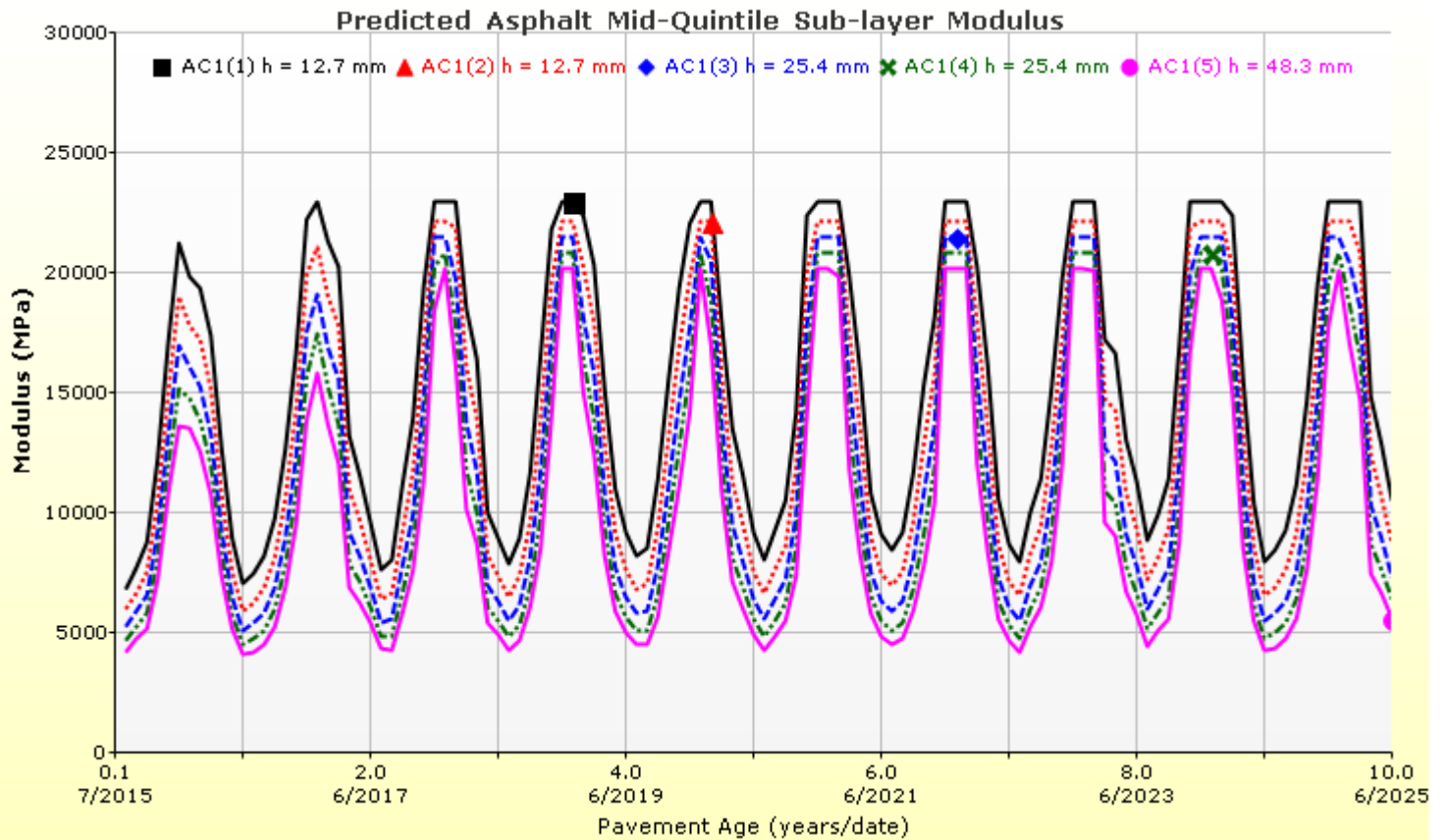




Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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 = regression coefficient determined through field calibration $N()$ = standard normal distribution evaluated at() σ = standard deviation of the log of the depth of cracks in the pavements C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_s = Tensile stress(psi) M_r = modulus of rupture(psi)
k1: 1	k2: 1
Bc1: 1	Bc2: 1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

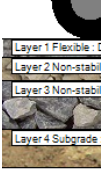
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

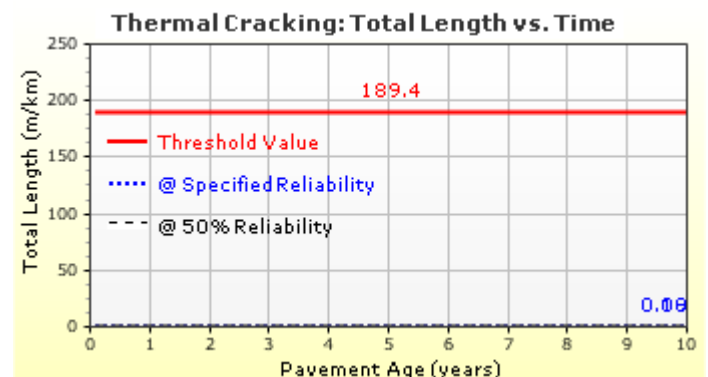
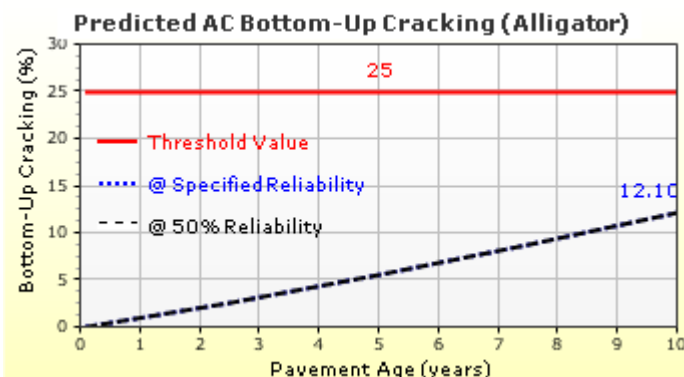
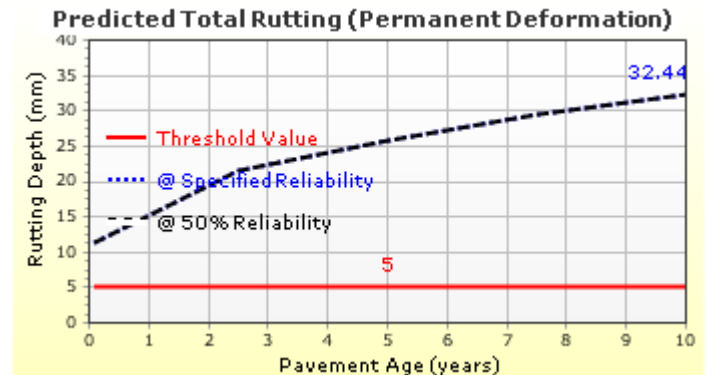
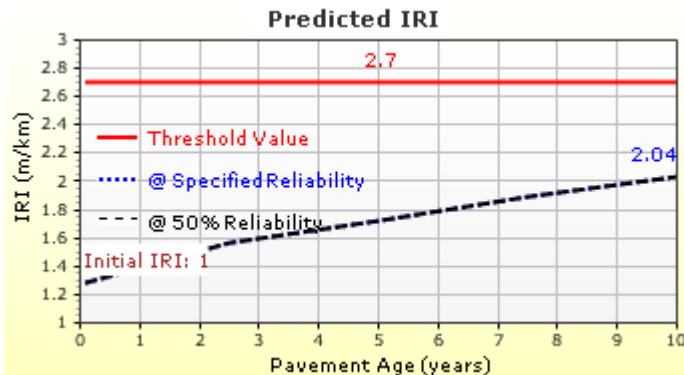
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.04	50.00	88.43	Pass
Permanent deformation - total pavement (mm)	5.00	32.44	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	12.10	50.00	81.94	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	10.97	50.00	92.12	Pass
Permanent deformation - AC only (mm)	5.00	17.74	50.00	0.28	Fail

Distress Charts

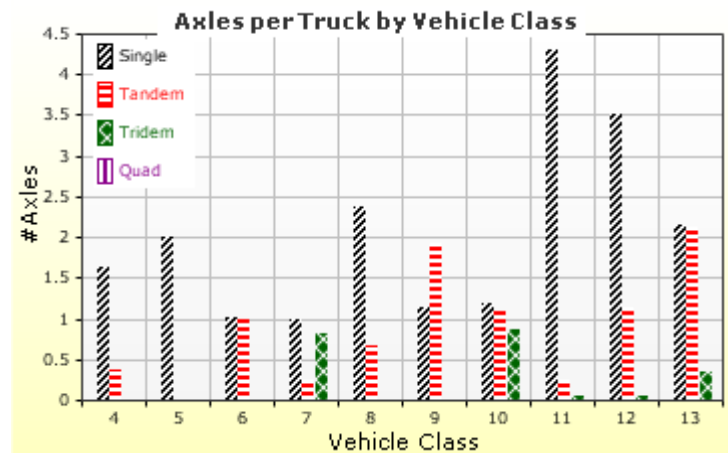
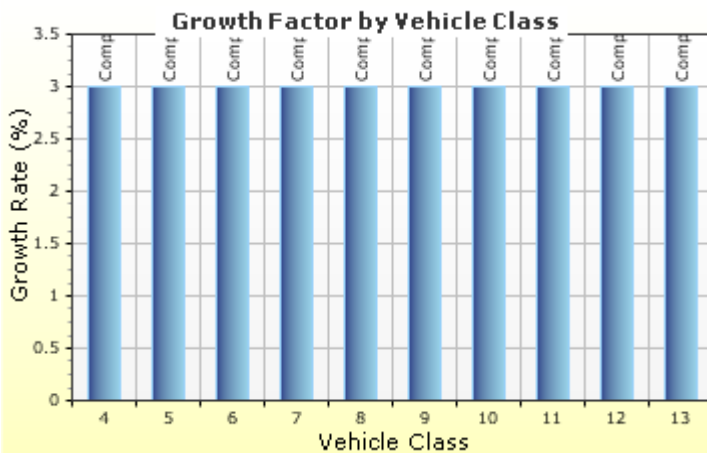
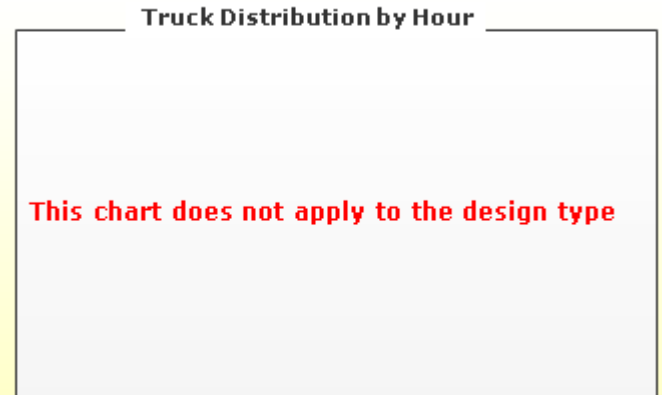
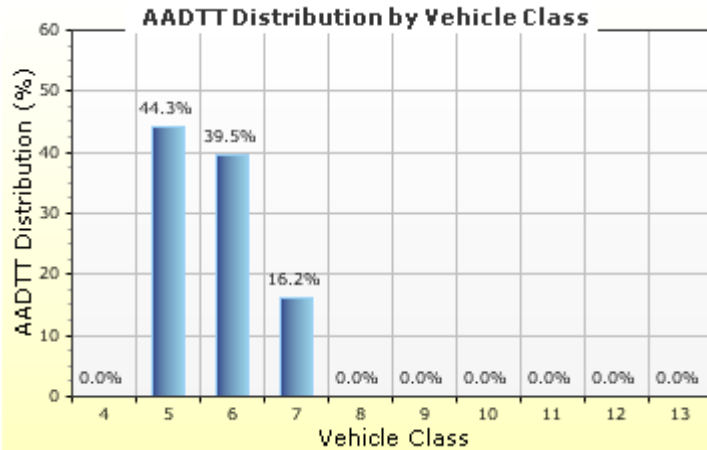


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

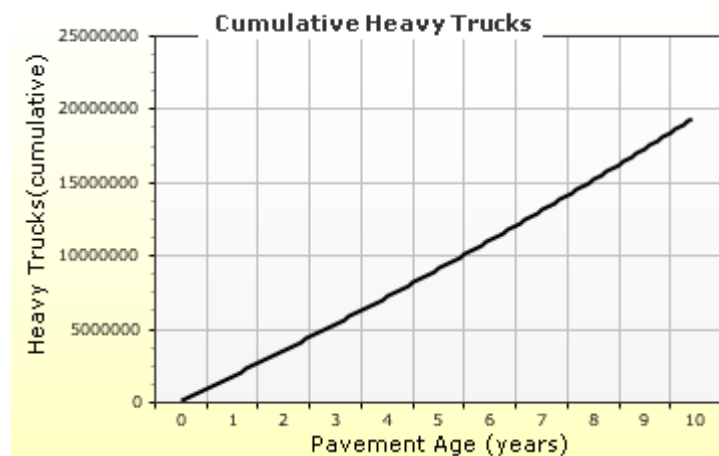
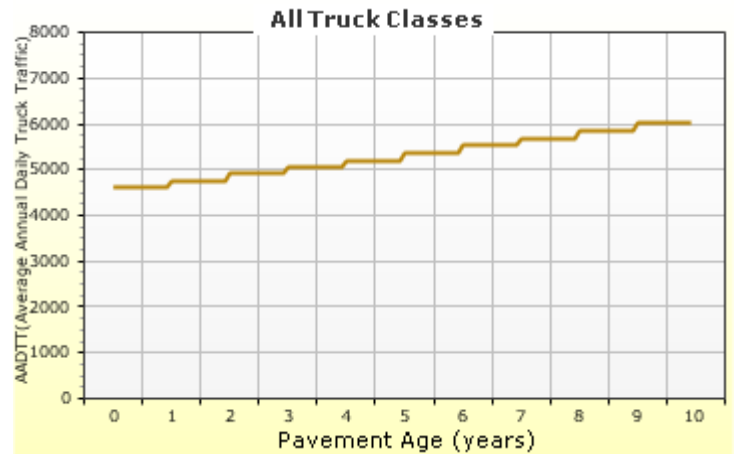
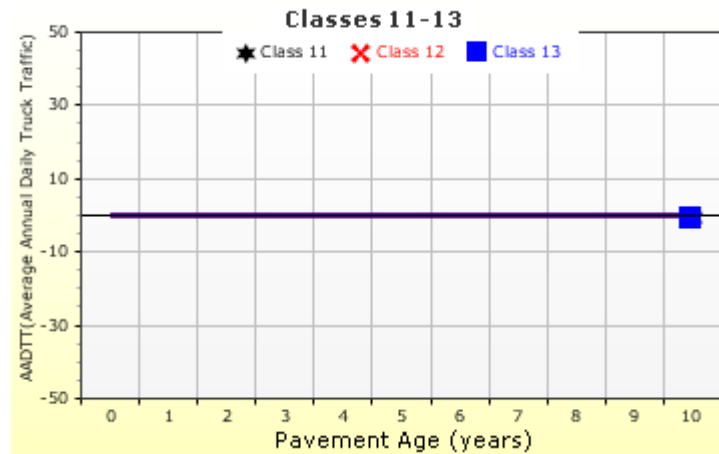
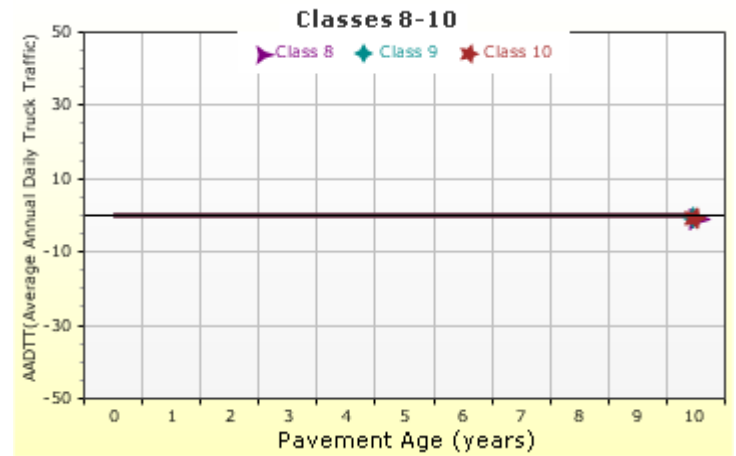
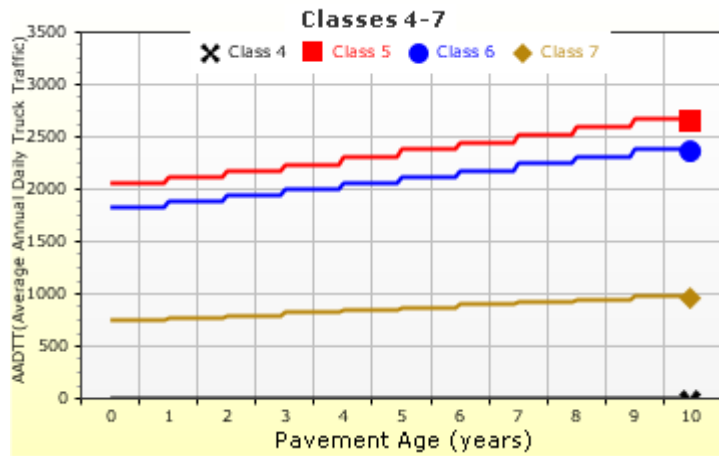
Wheelbase does not apply

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



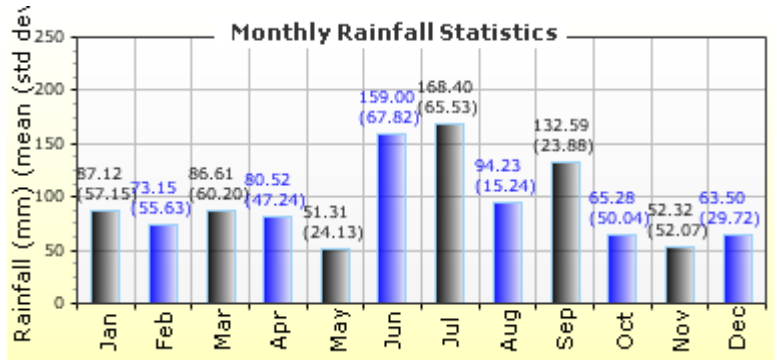
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

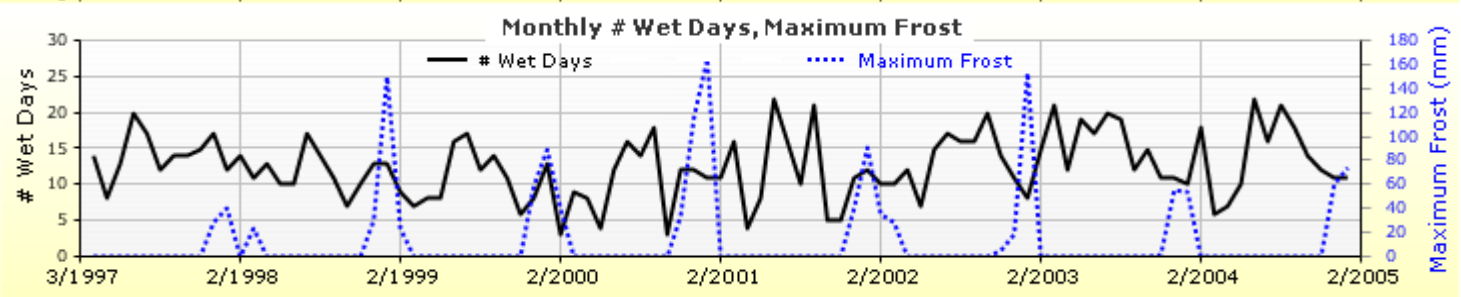
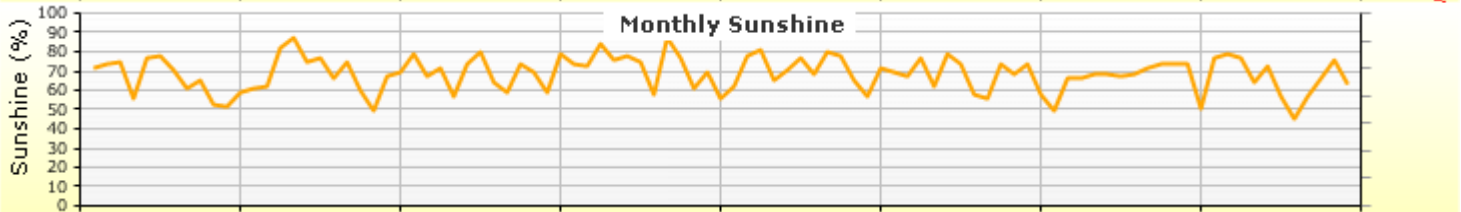
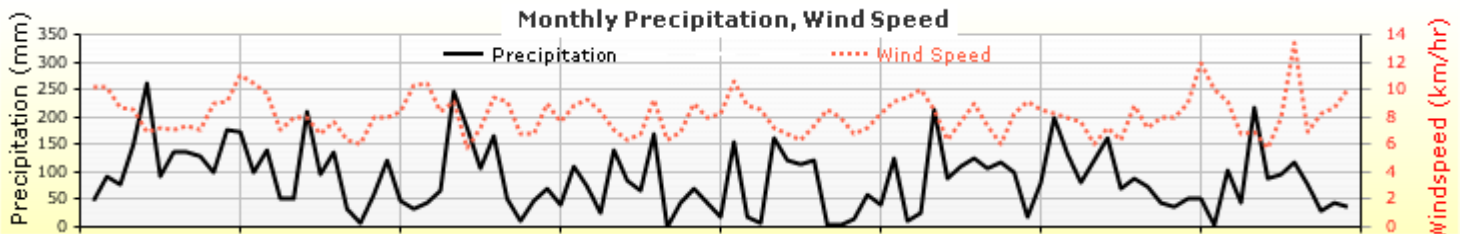
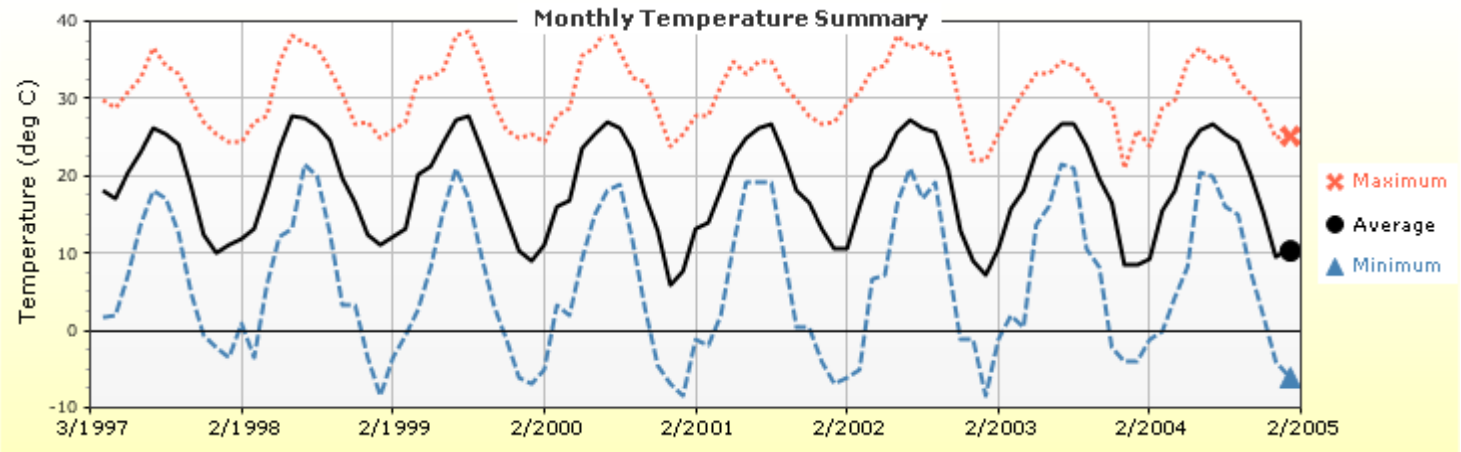
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

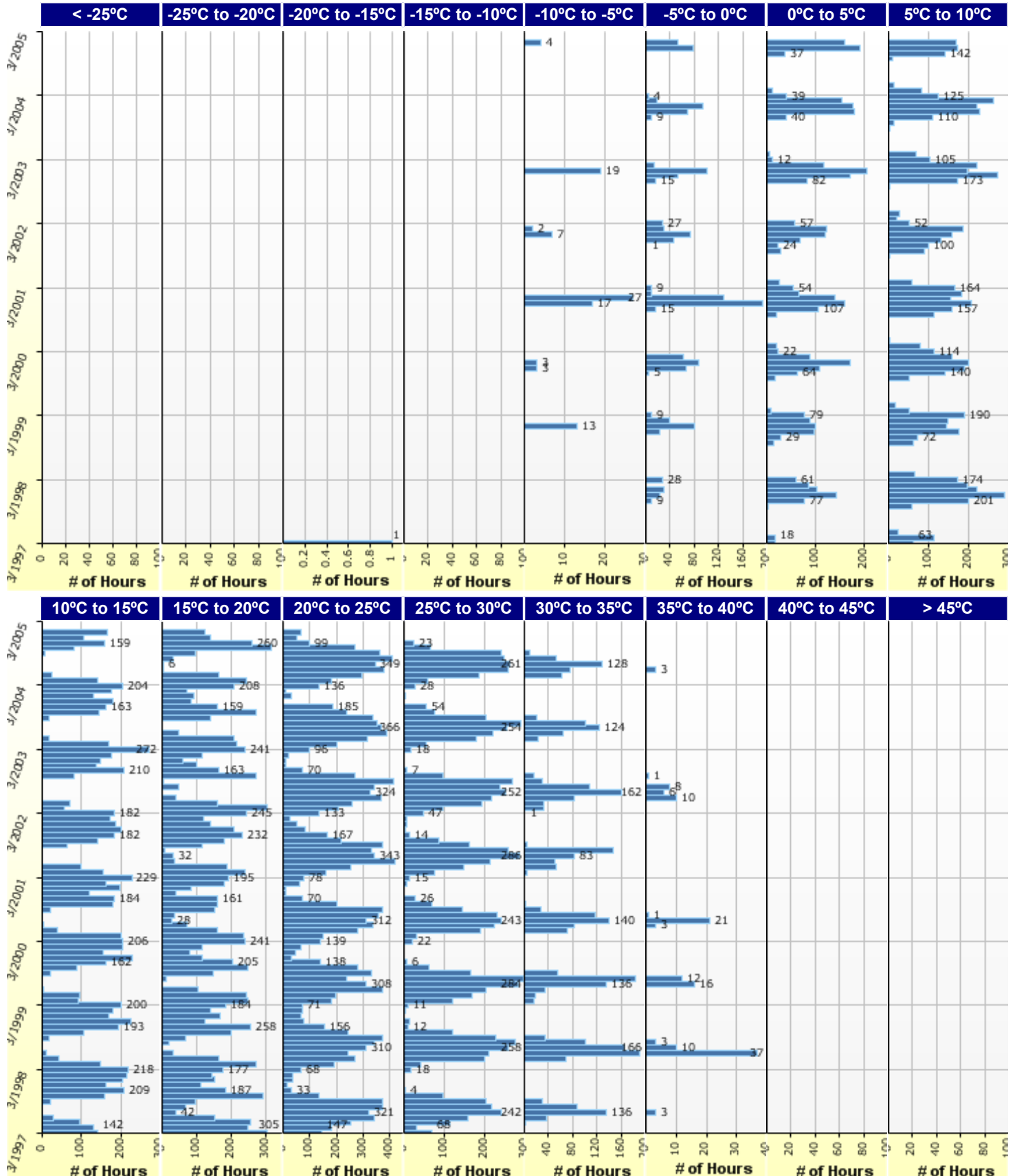


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF2_ALT1

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF2_ALT1.dgpx



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

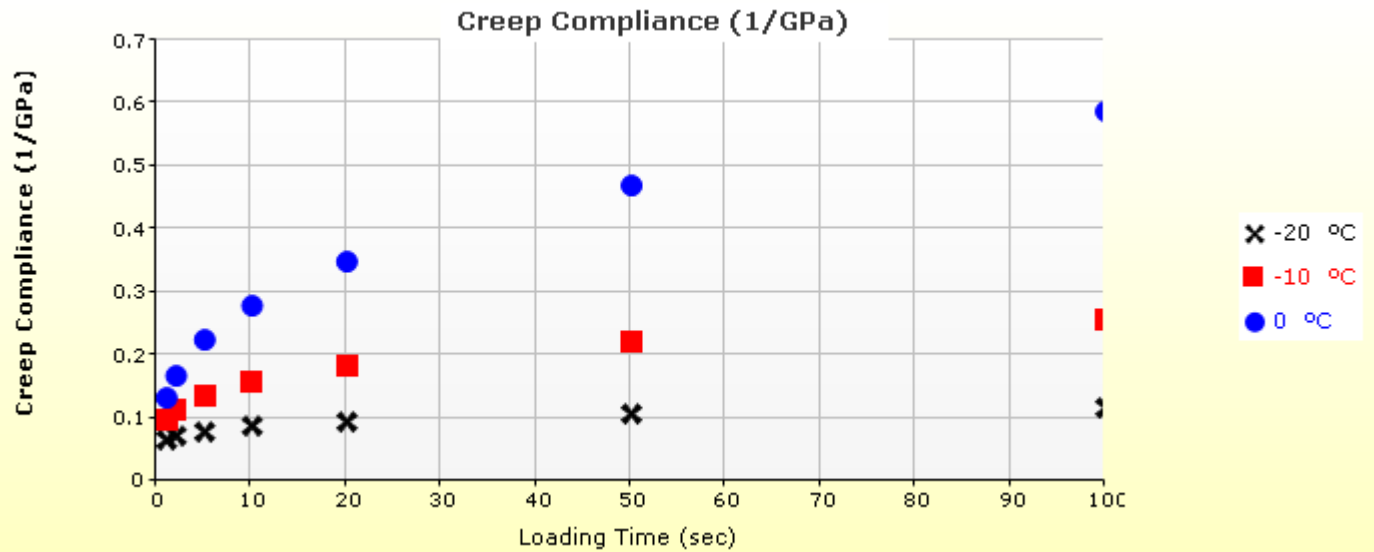
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

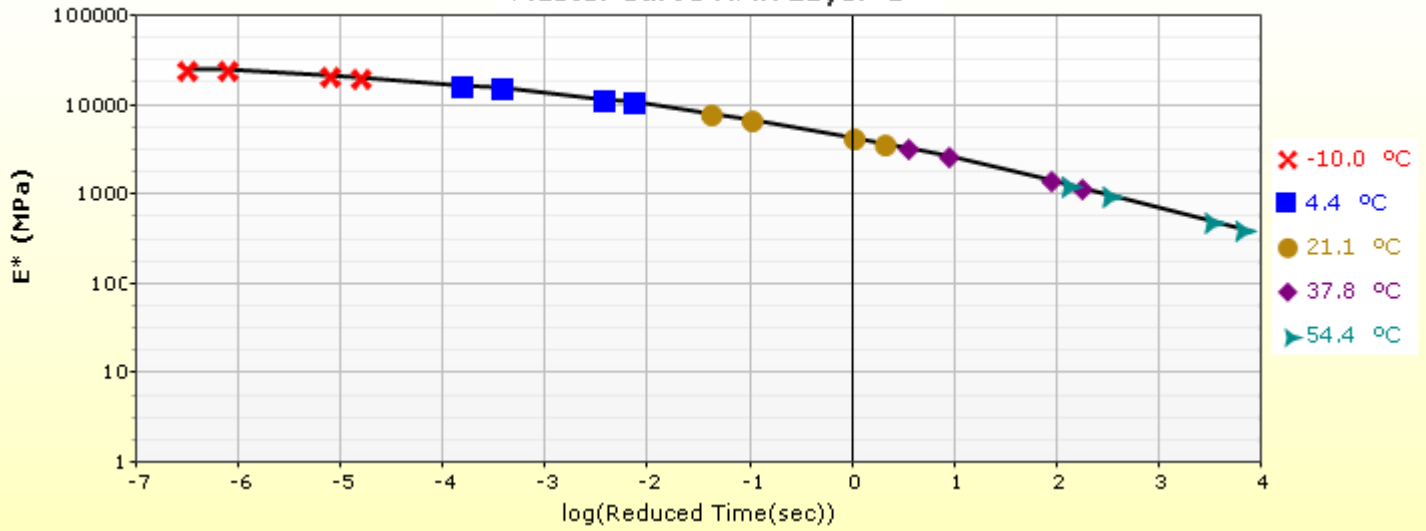
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

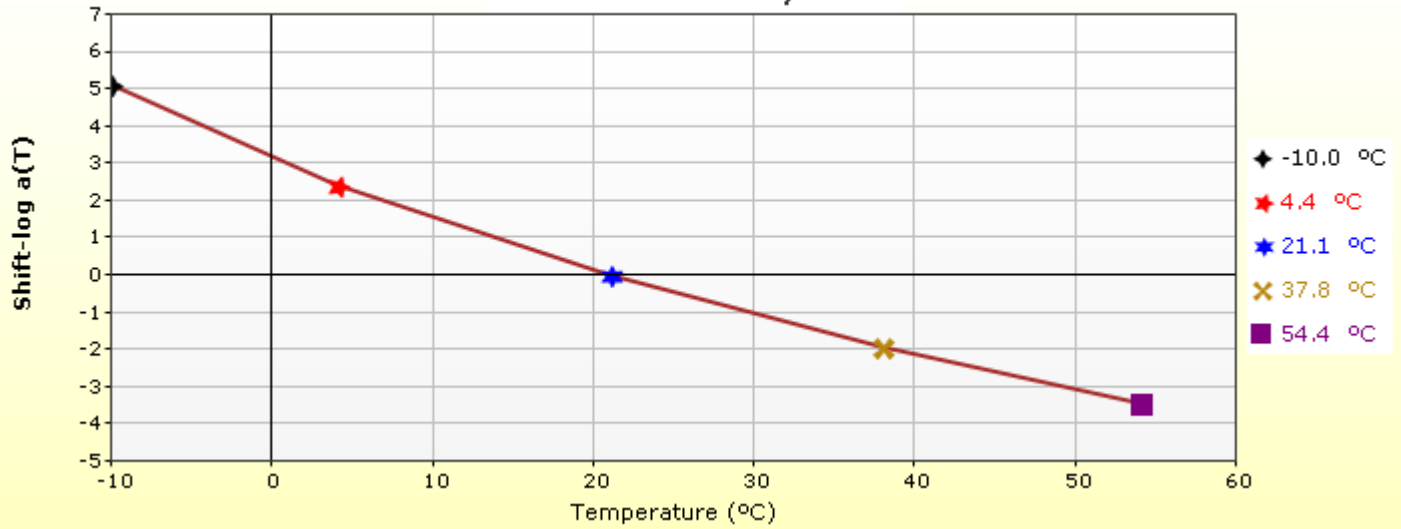


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

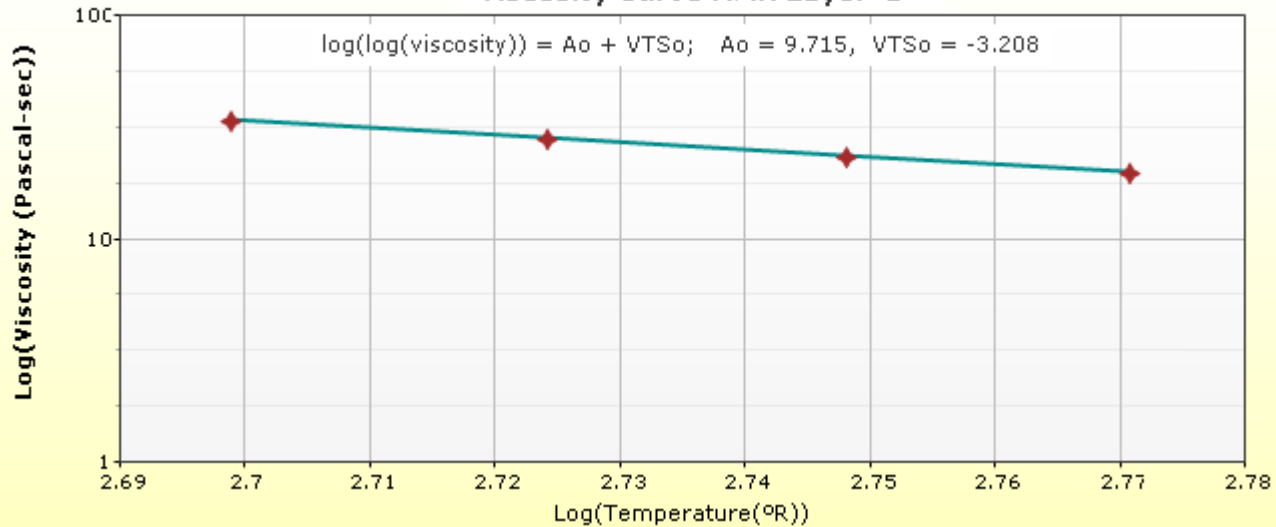
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

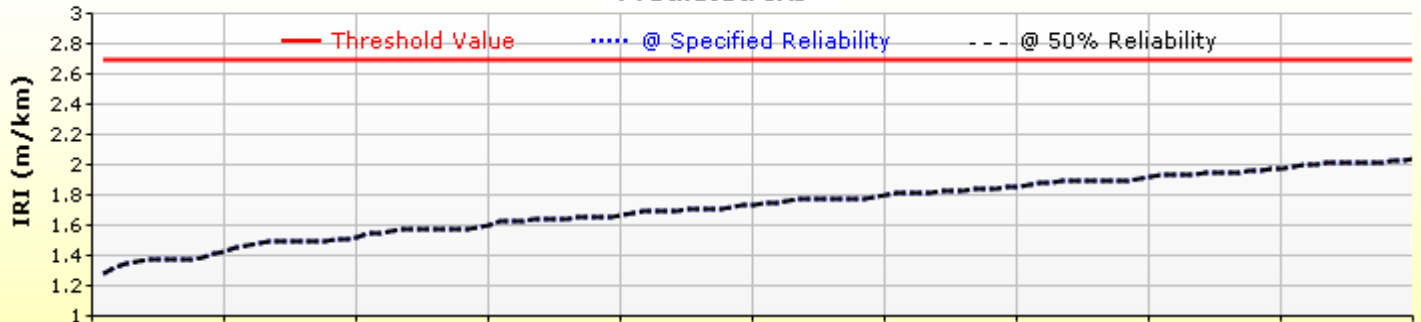


Viscosity Curve HMA Layer 1

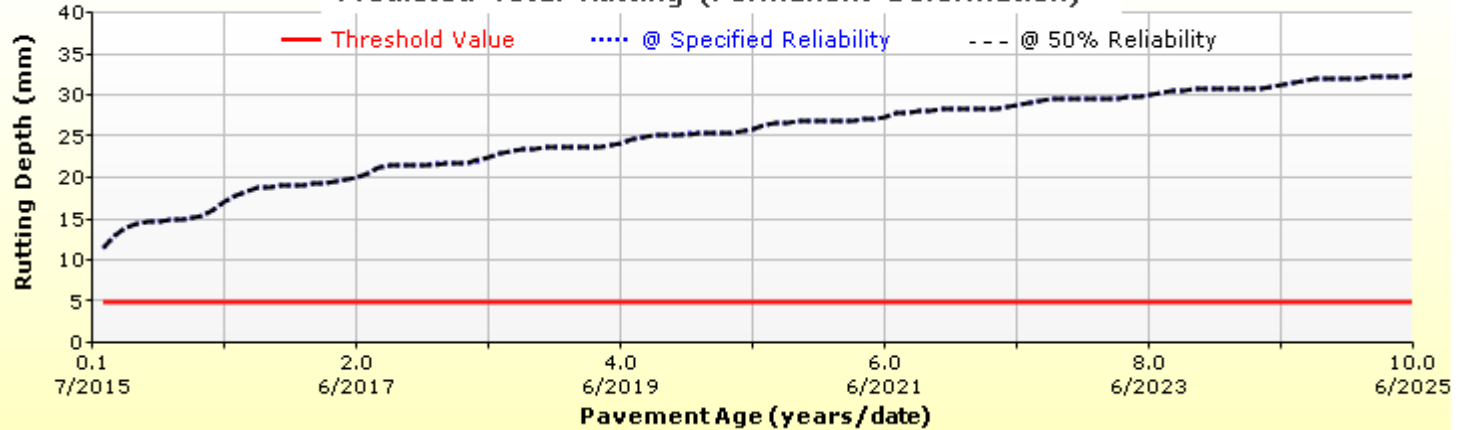


Analysis Output Charts

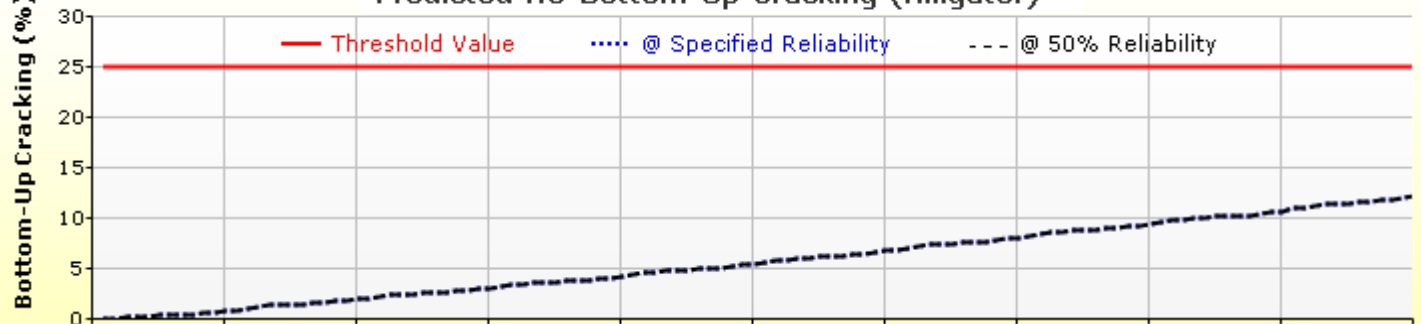
Predicted IRI



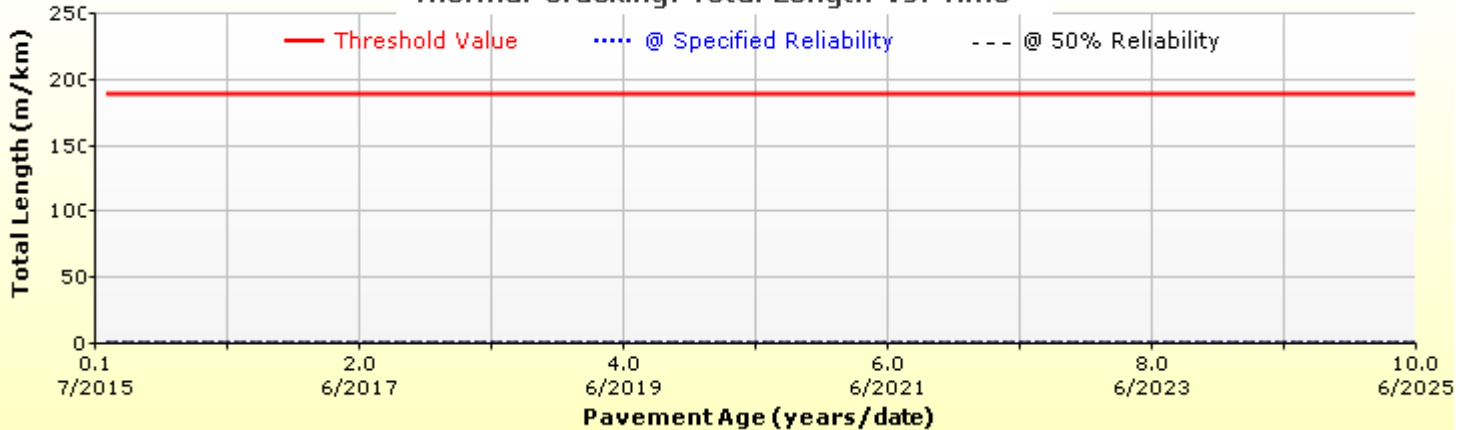
Predicted Total Rutting (Permanent Deformation)

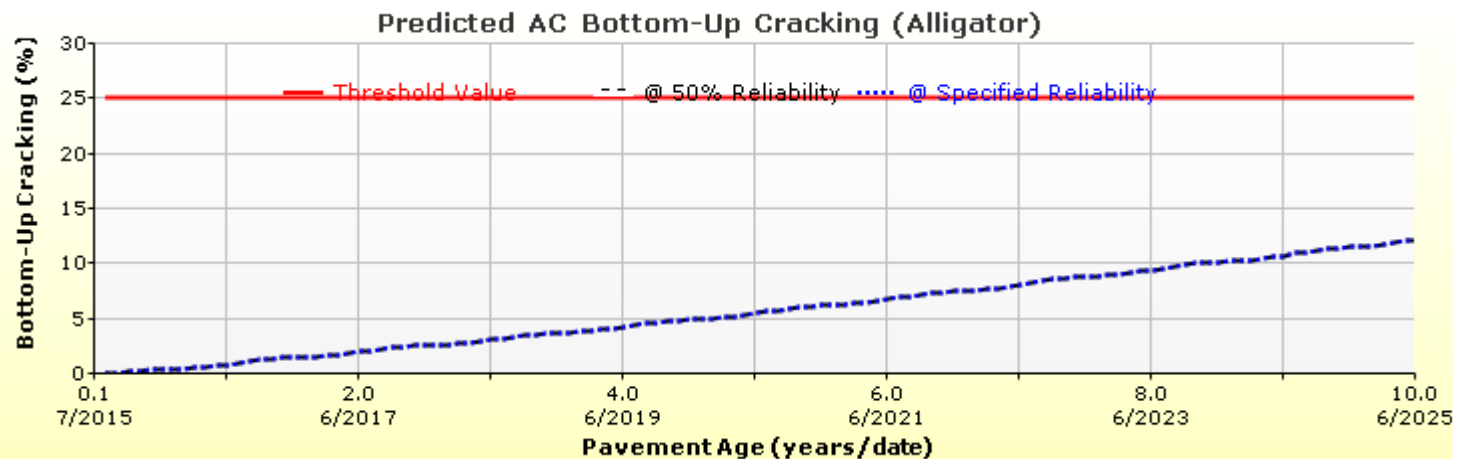
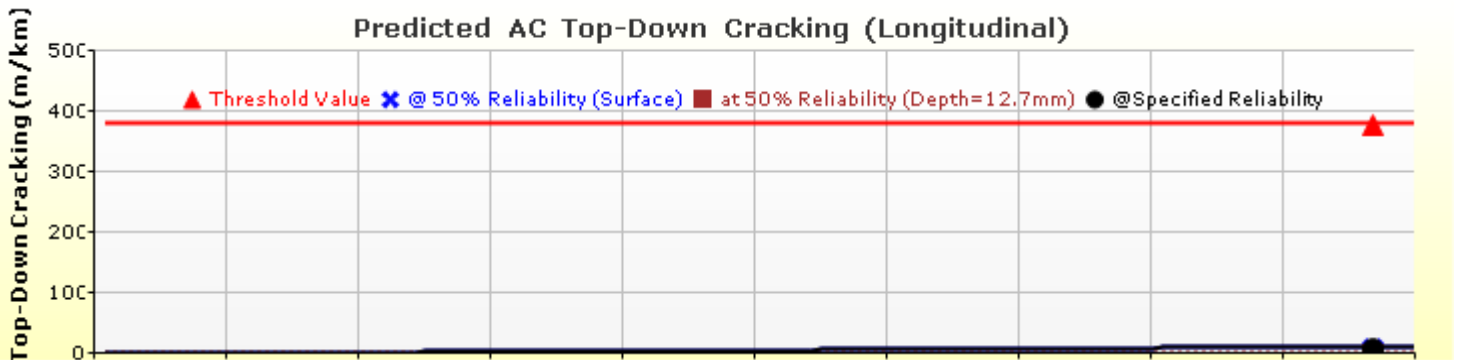
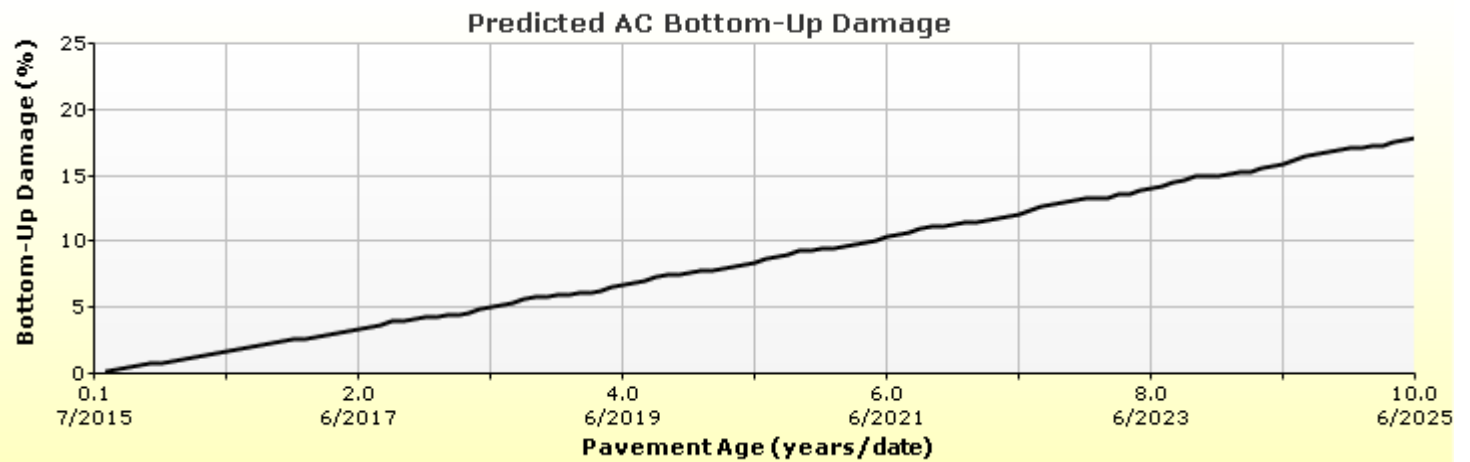
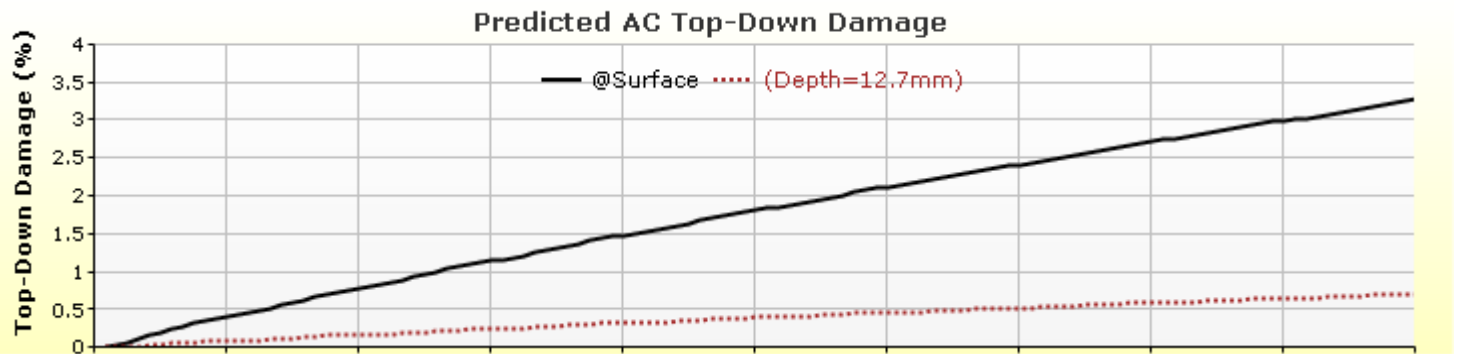


Predicted AC Bottom-Up Cracking (Alligator)

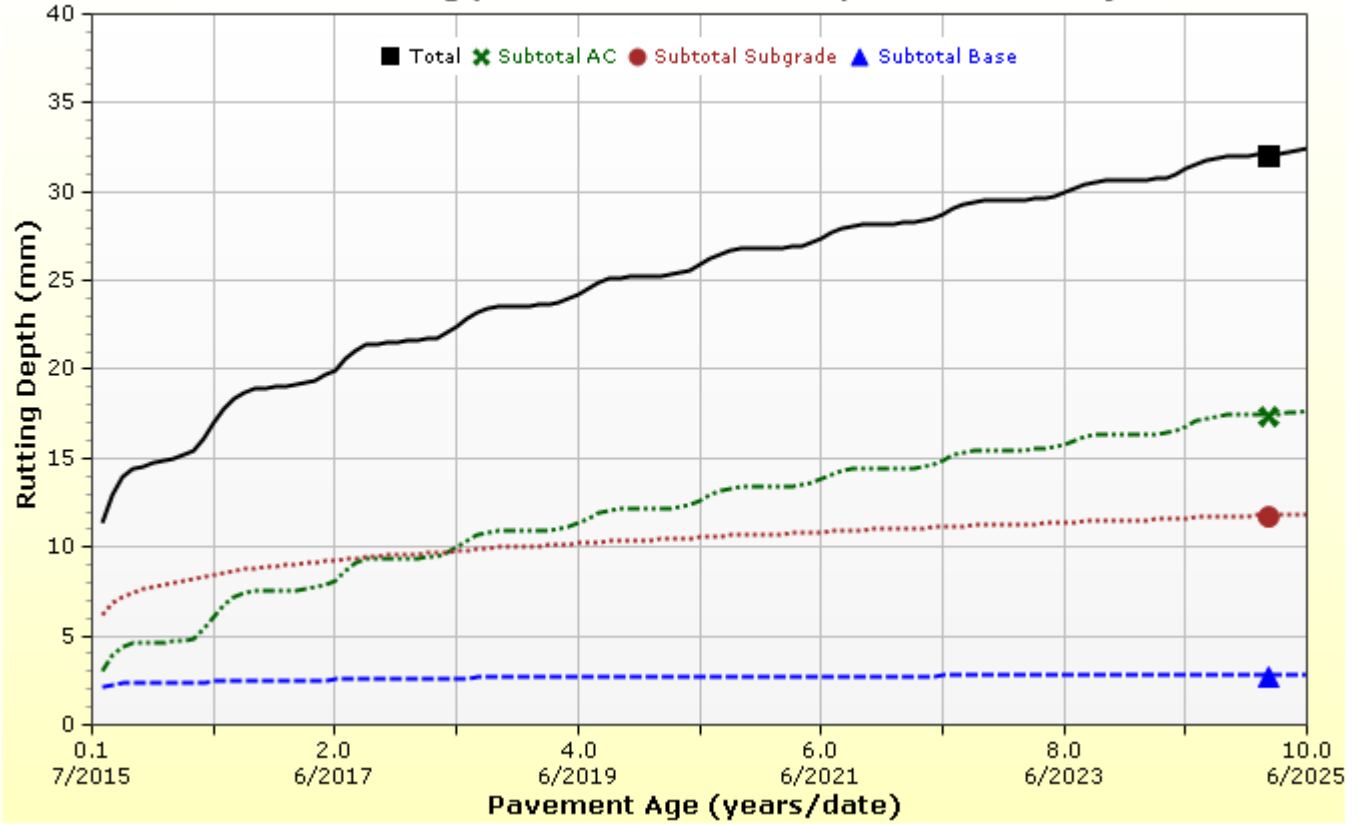


Thermal Cracking: Total Length vs. Time

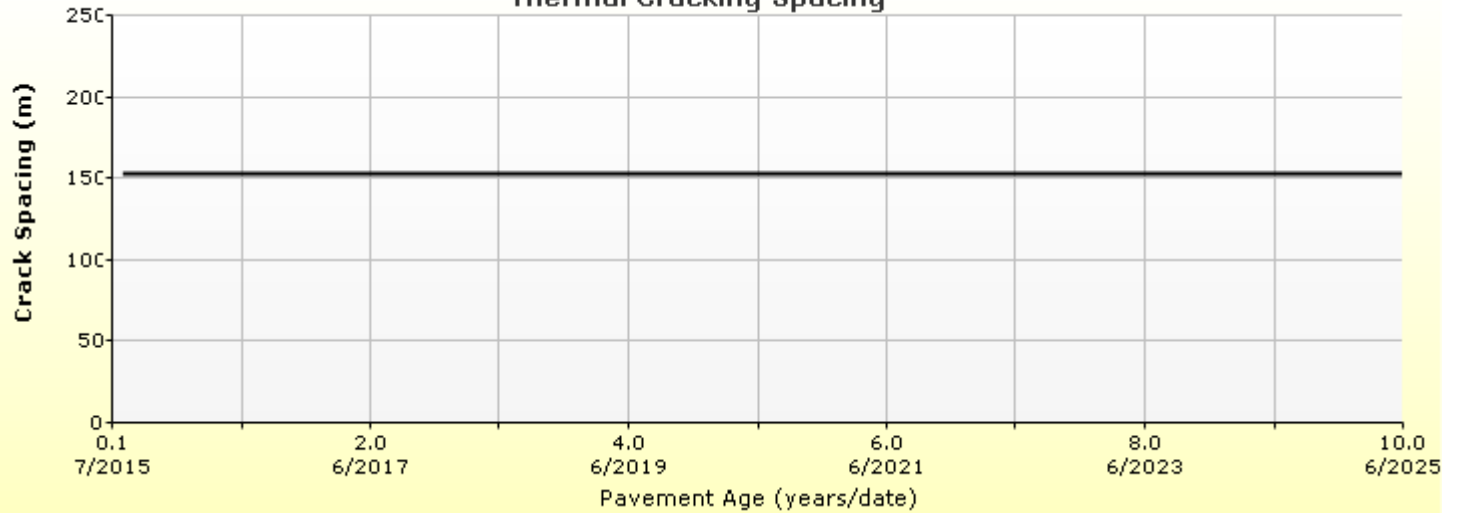




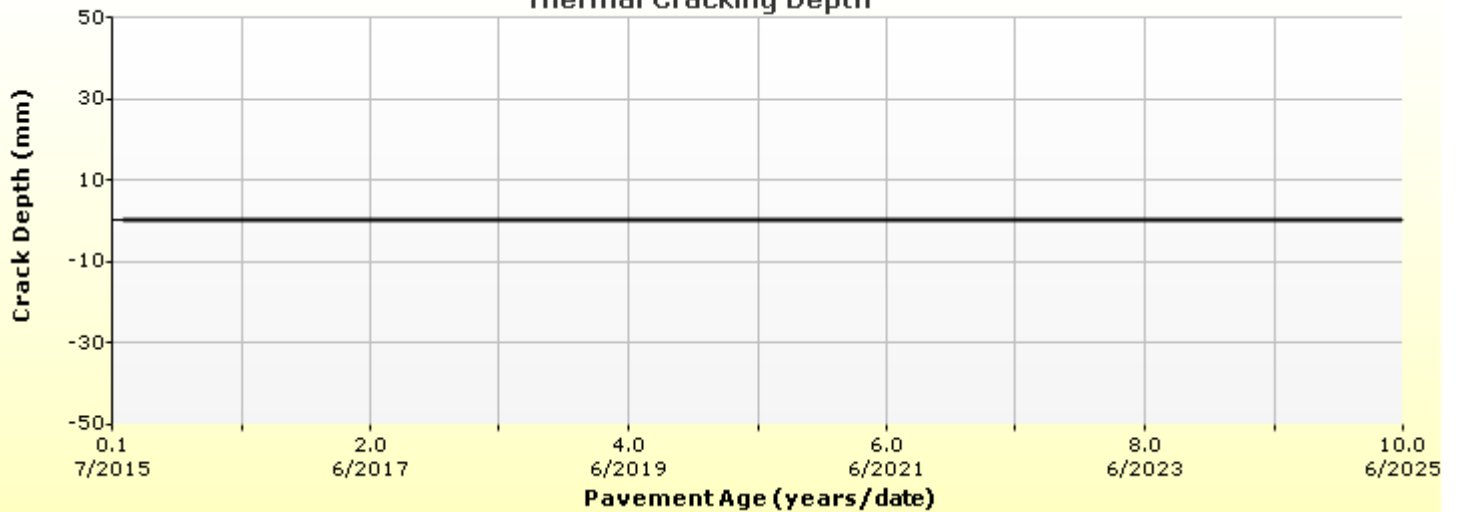
Predicted Rutting (Permanent Deformation) at 50% Reliability

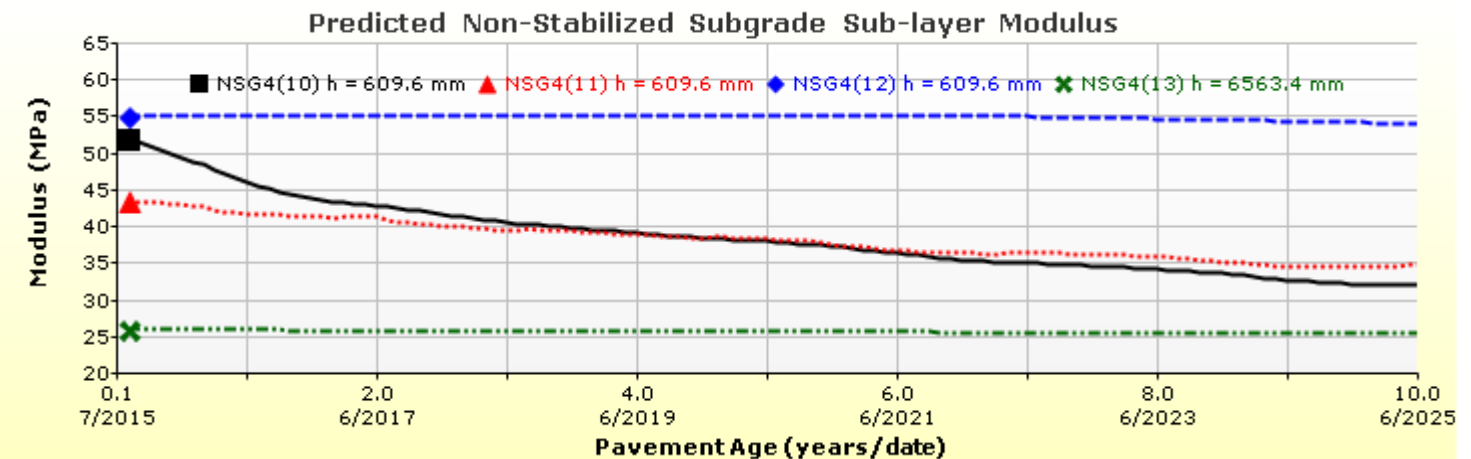
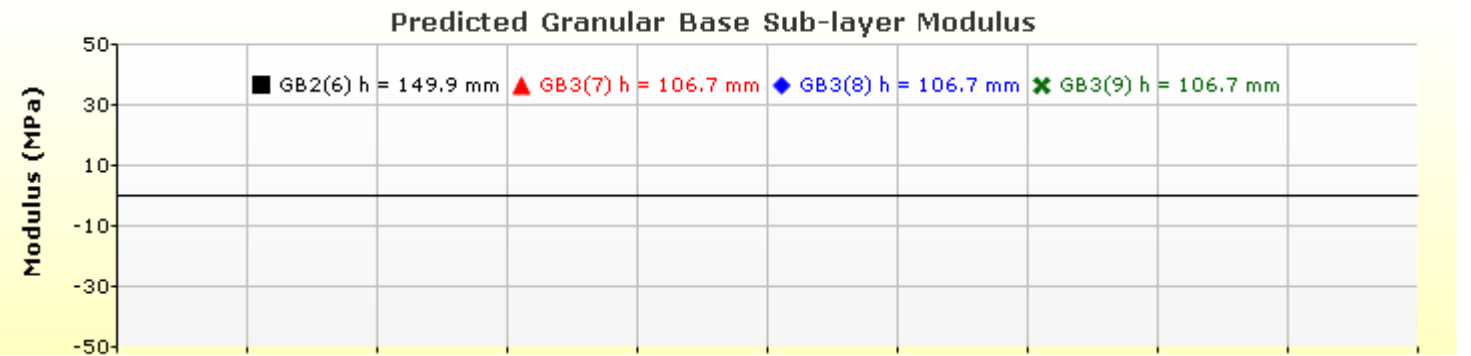
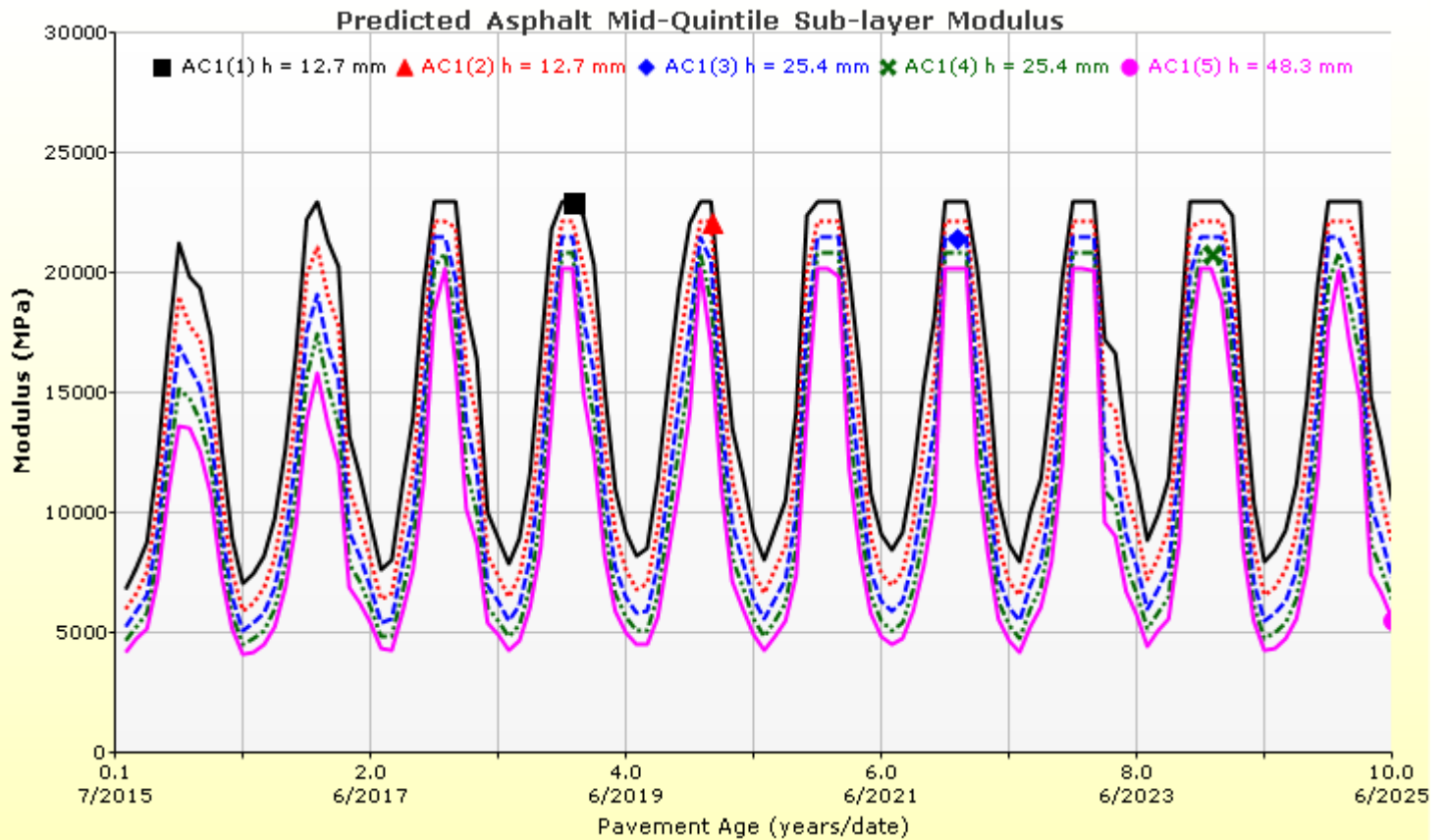


Thermal Cracking Spacing



Thermal Cracking Depth





Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

Standard Deviation (BASERUT)

0.1235*Pow(SUBRUT,0.5012)+0.001

AC Cracking

AC Top Down Cracking

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

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: 7

c2: 3.5

c3: 0

c4: 1000

c1: 1

c2: 1

c3: 6000

AC Cracking Top Standard Deviation

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

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

IRI Flexible Pavements

C1 - Rutting

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

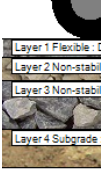
CSM Standard Deviation

CTB*1

Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data: 32.119, -81.202
Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm)	Volumetric at Construction:	
Flexible	Default asphalt concrete	125.0	Effective binder content (%)	11.6
NonStabilized	Crushed stone	150.0	Air voids (%)	7.0
NonStabilized	Crushed stone	320.0		
Subgrade	A-5	Semi-infinite		

Traffic

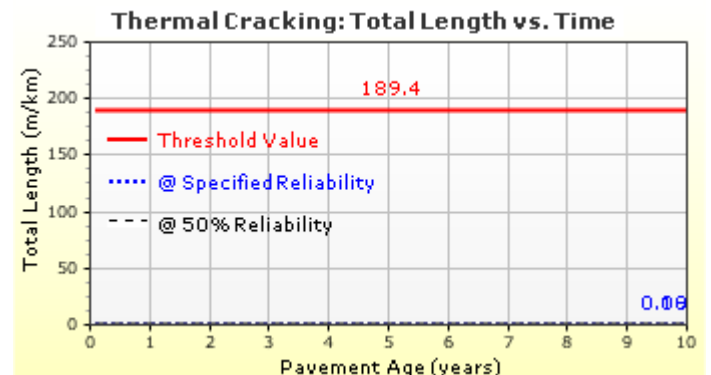
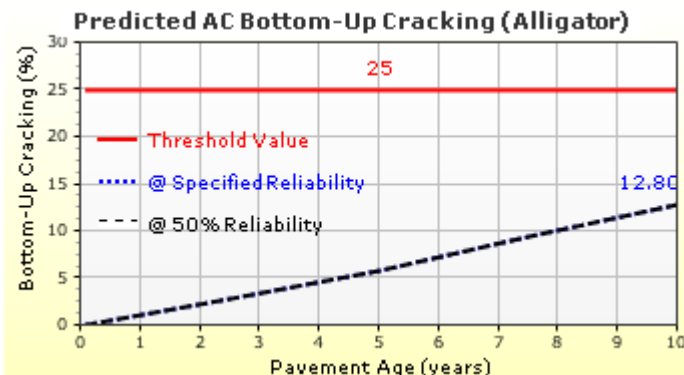
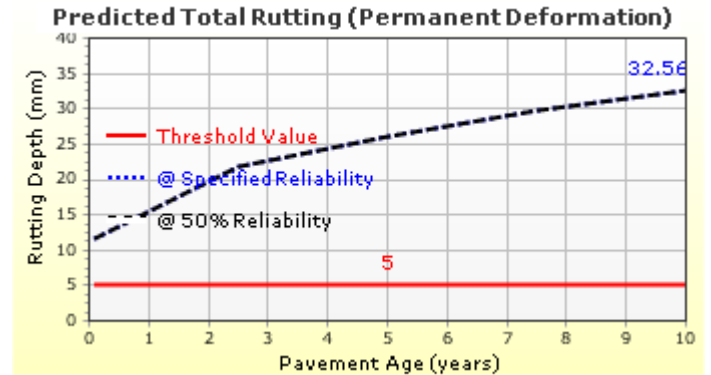
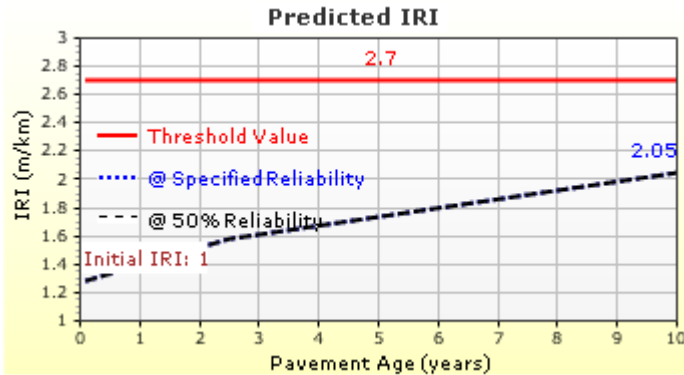
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.05	50.00	88.12	Pass
Permanent deformation - total pavement (mm)	5.00	32.56	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	12.80	50.00	80.60	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	11.08	50.00	92.06	Pass
Permanent deformation - AC only (mm)	5.00	17.24	50.00	0.32	Fail

Distress Charts

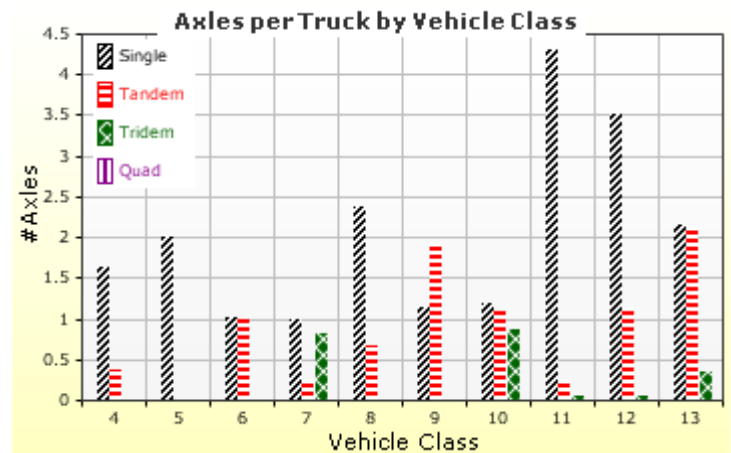
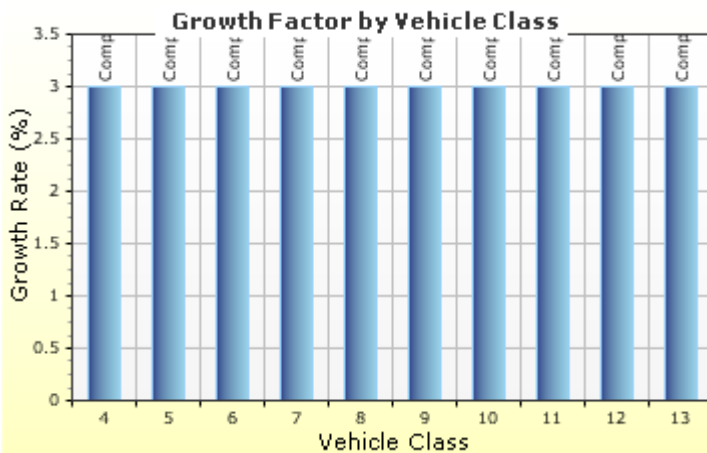
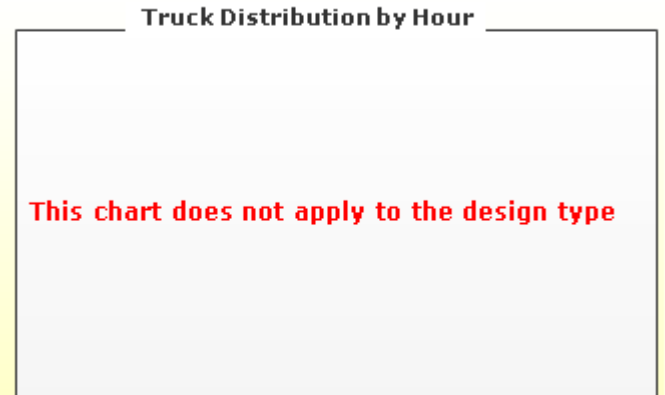
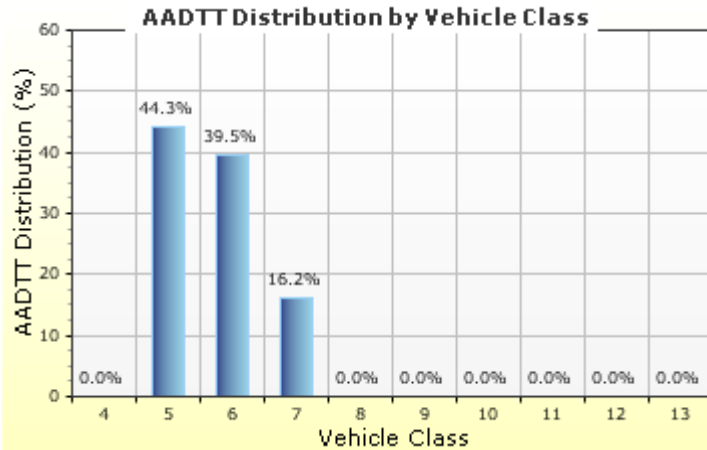


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

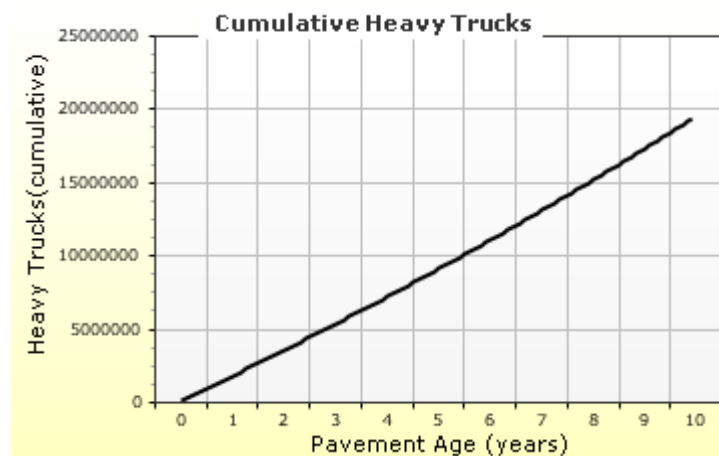
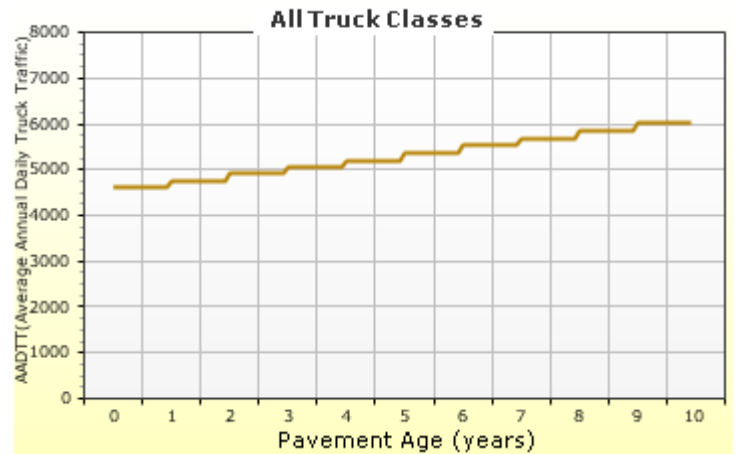
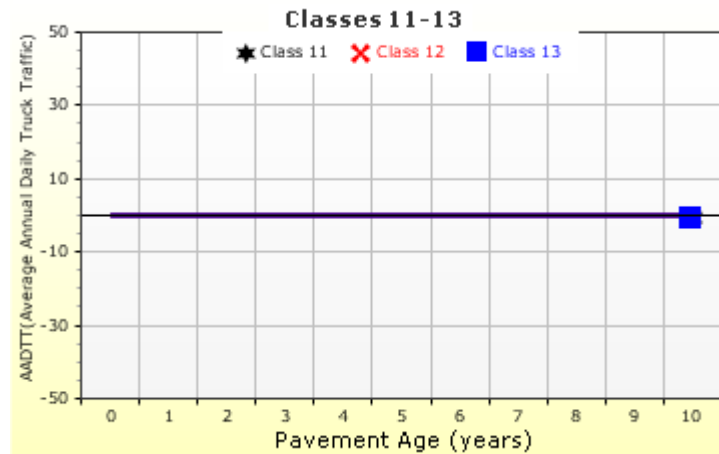
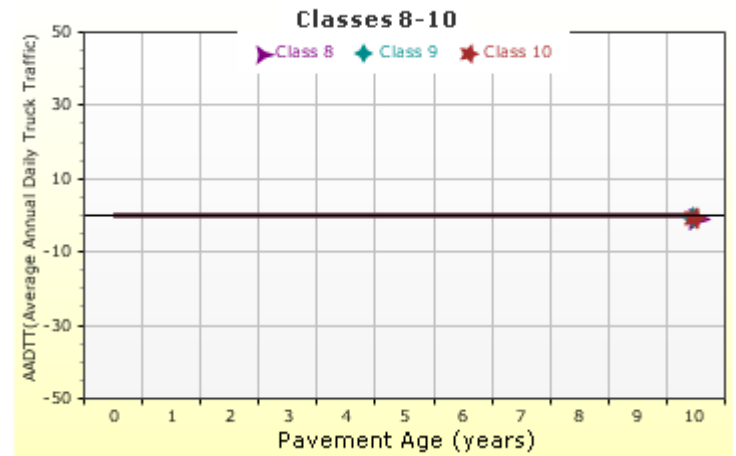
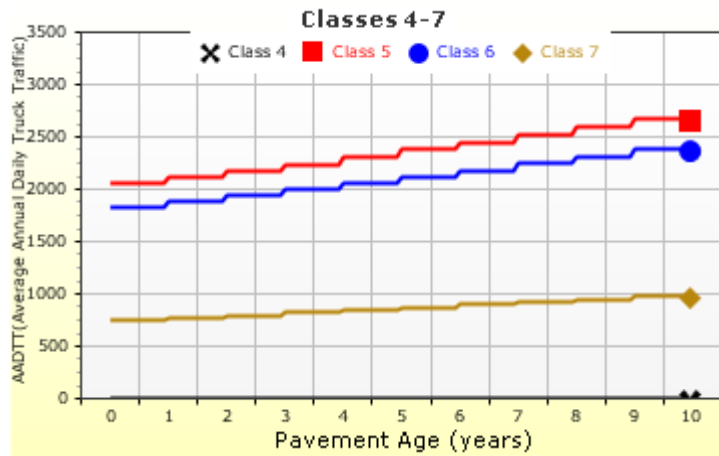
Wheelbase does not apply

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



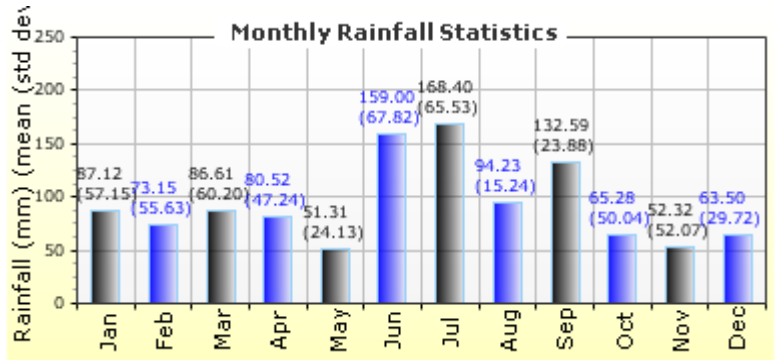
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

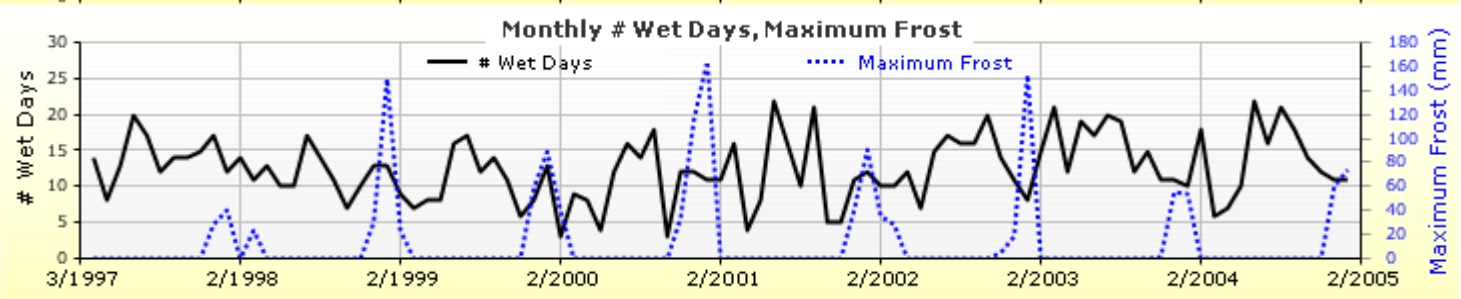
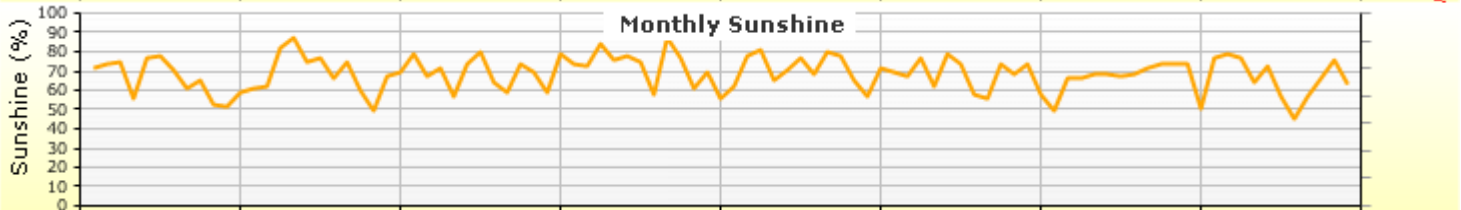
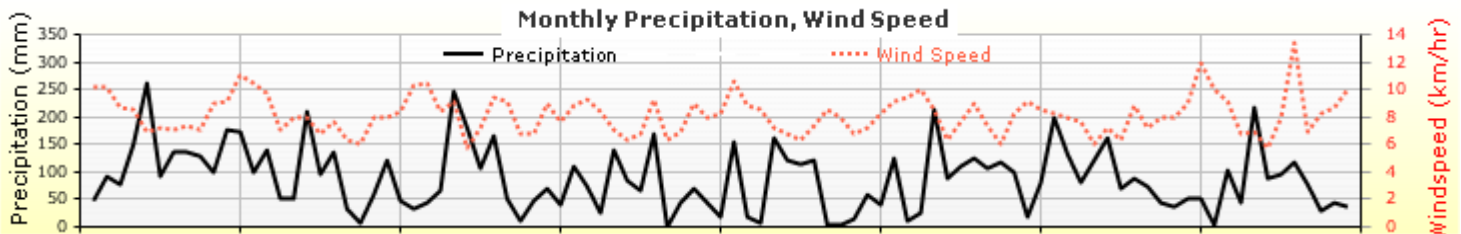
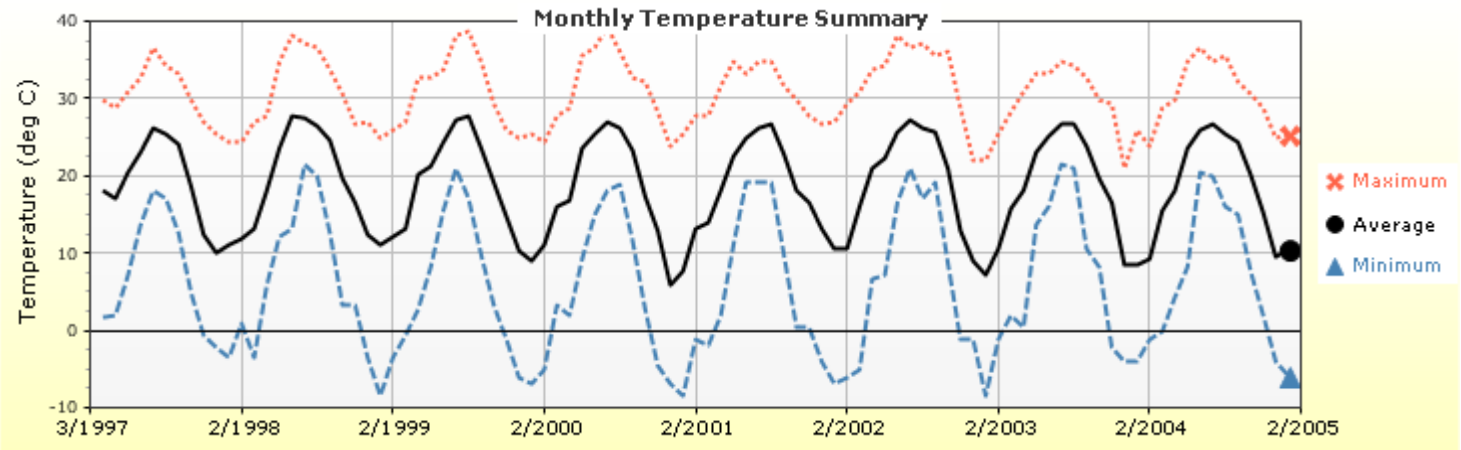
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

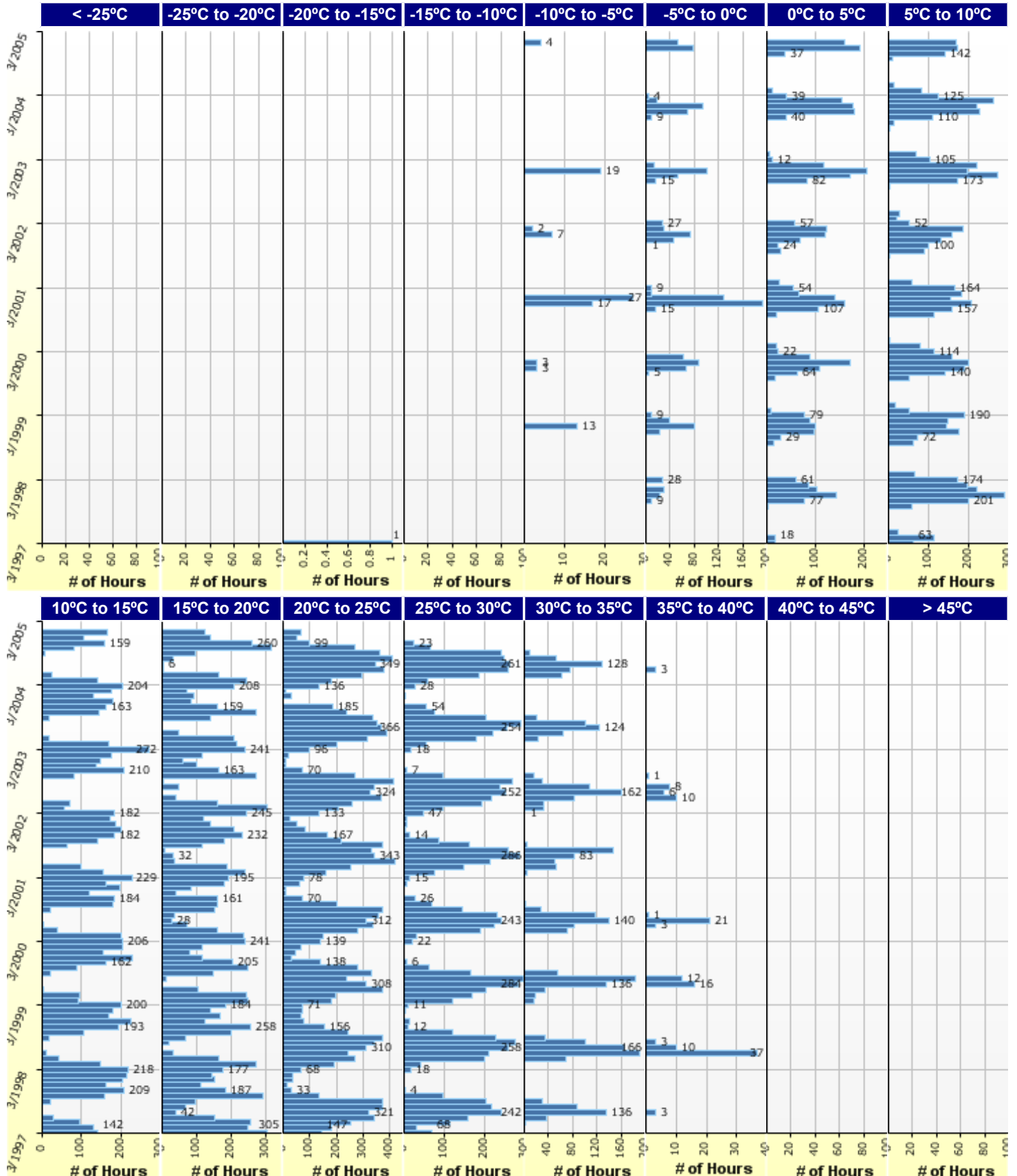


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF3_ALT1

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF3_ALT1.dgpx



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

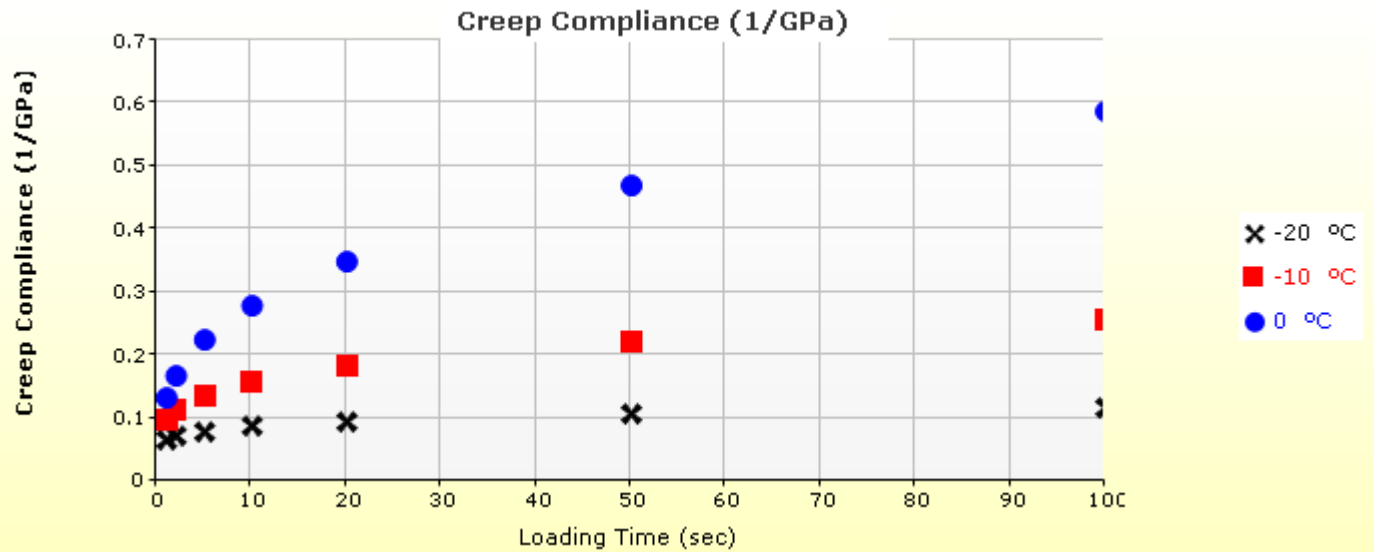
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

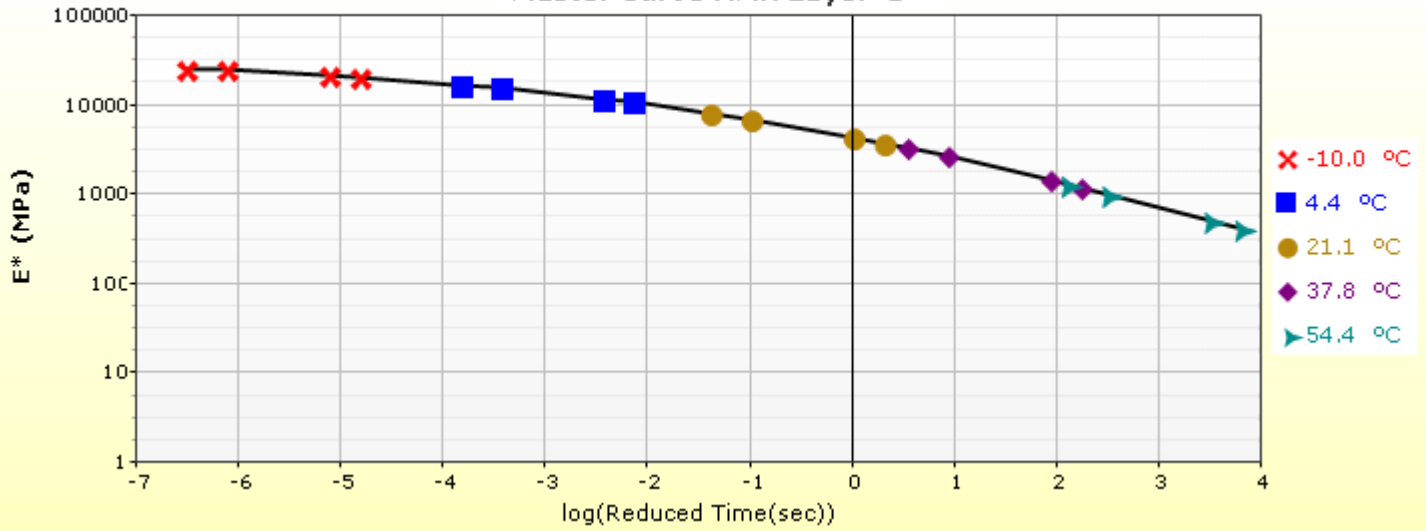
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

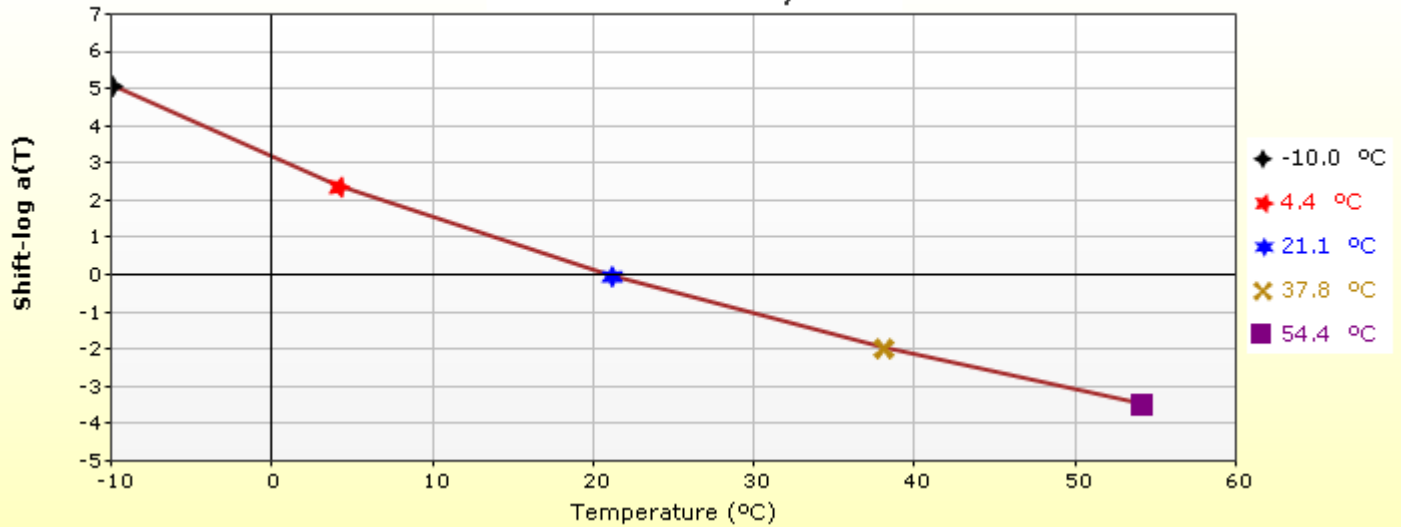


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

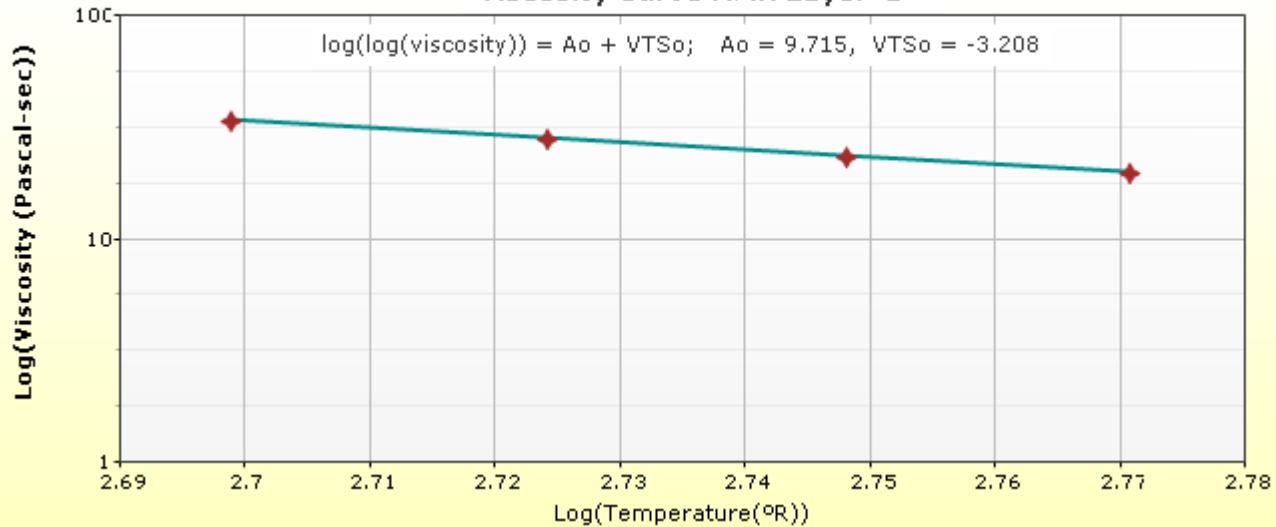
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

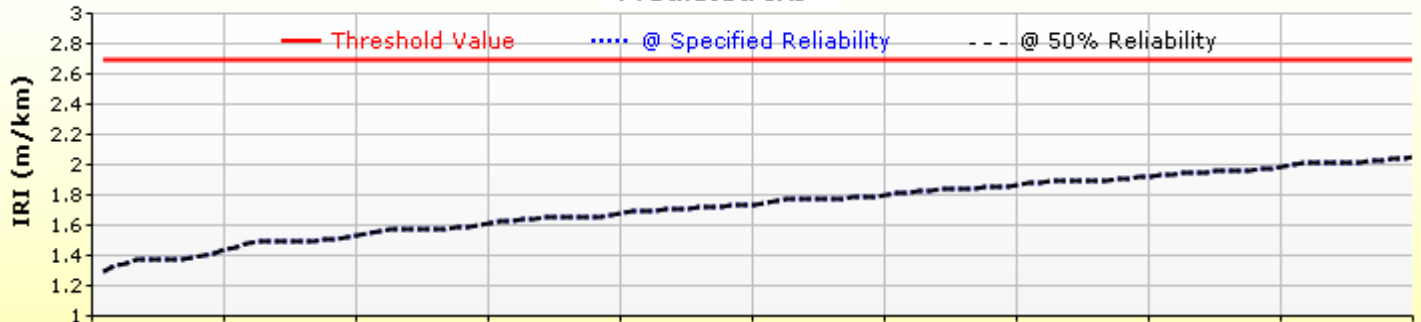


Viscosity Curve HMA Layer 1

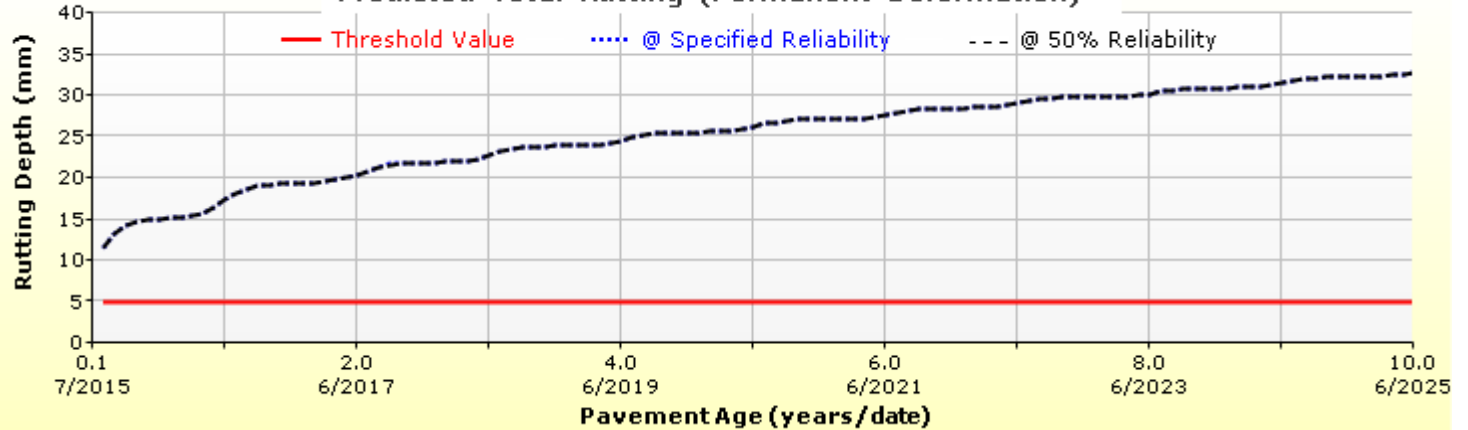


Analysis Output Charts

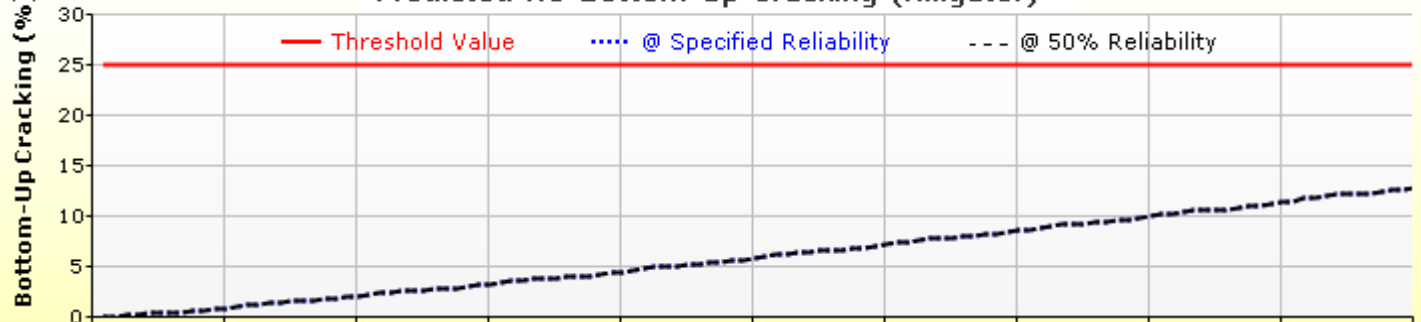
Predicted IRI



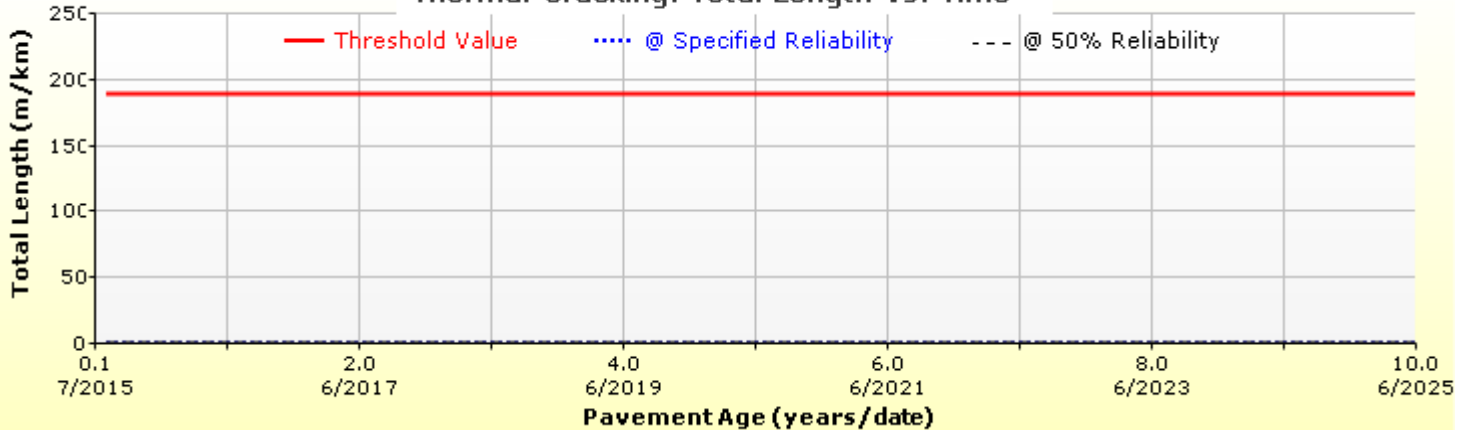
Predicted Total Rutting (Permanent Deformation)

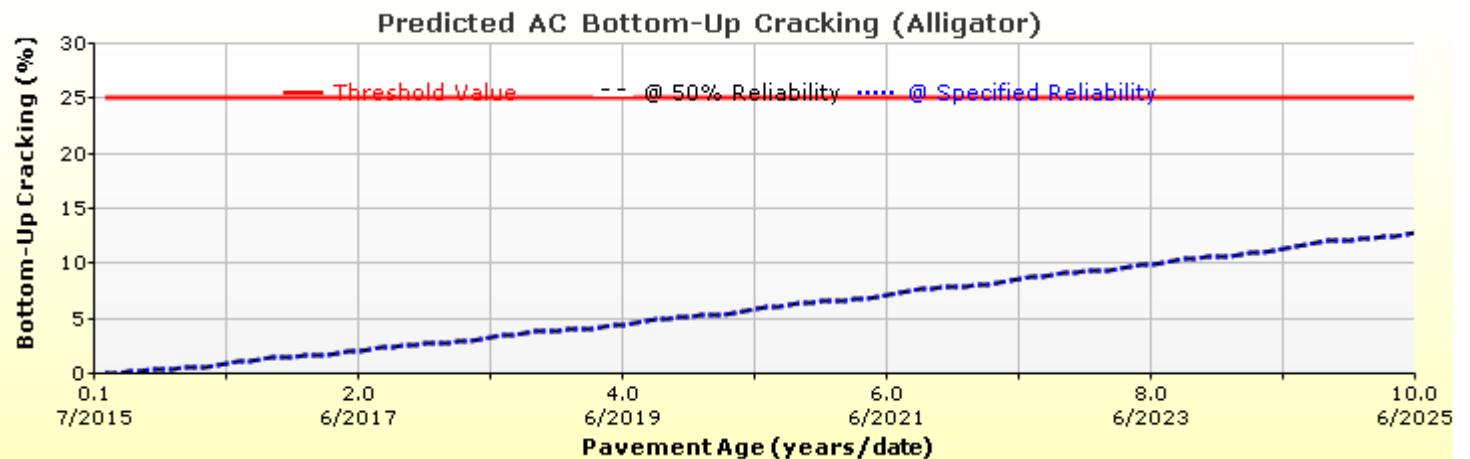
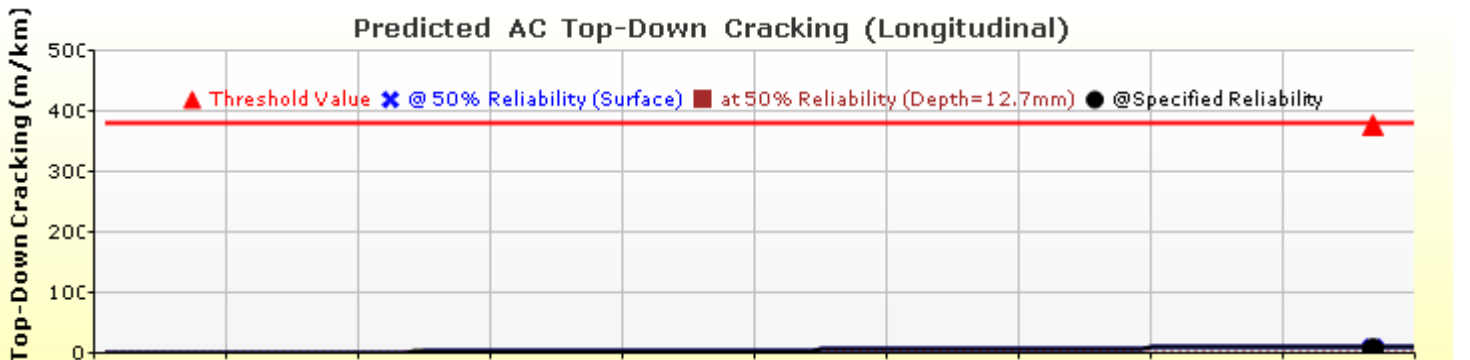
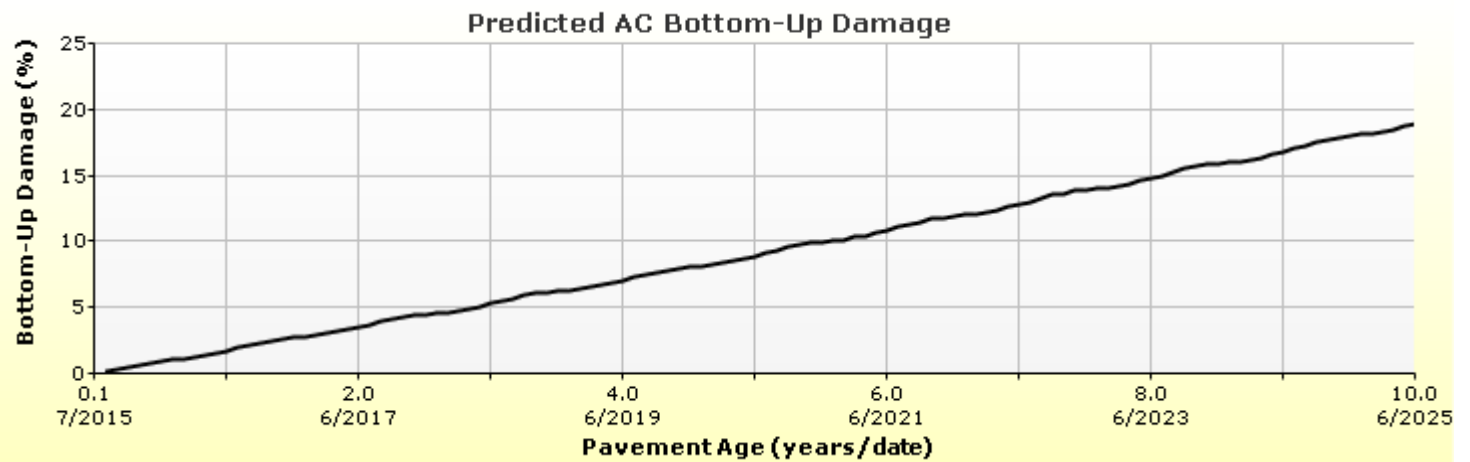
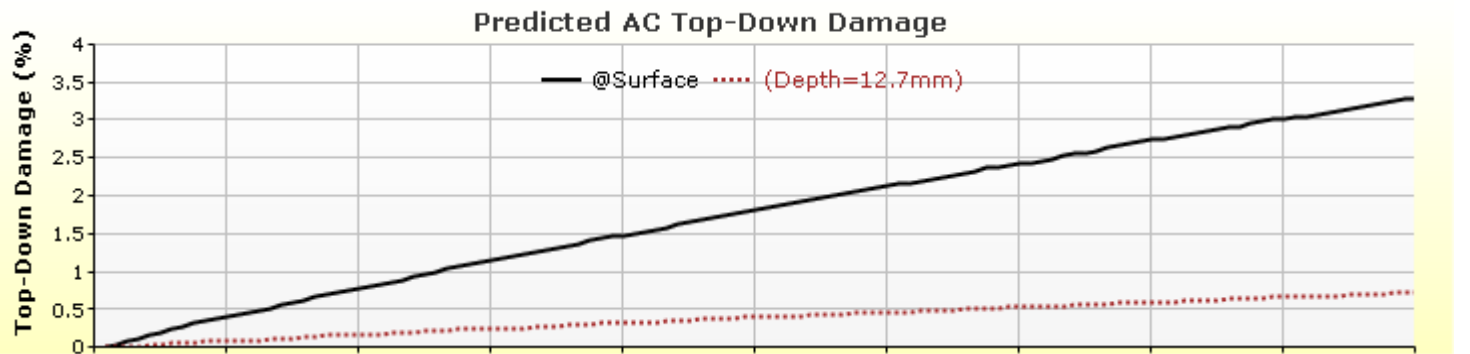


Predicted AC Bottom-Up Cracking (Alligator)

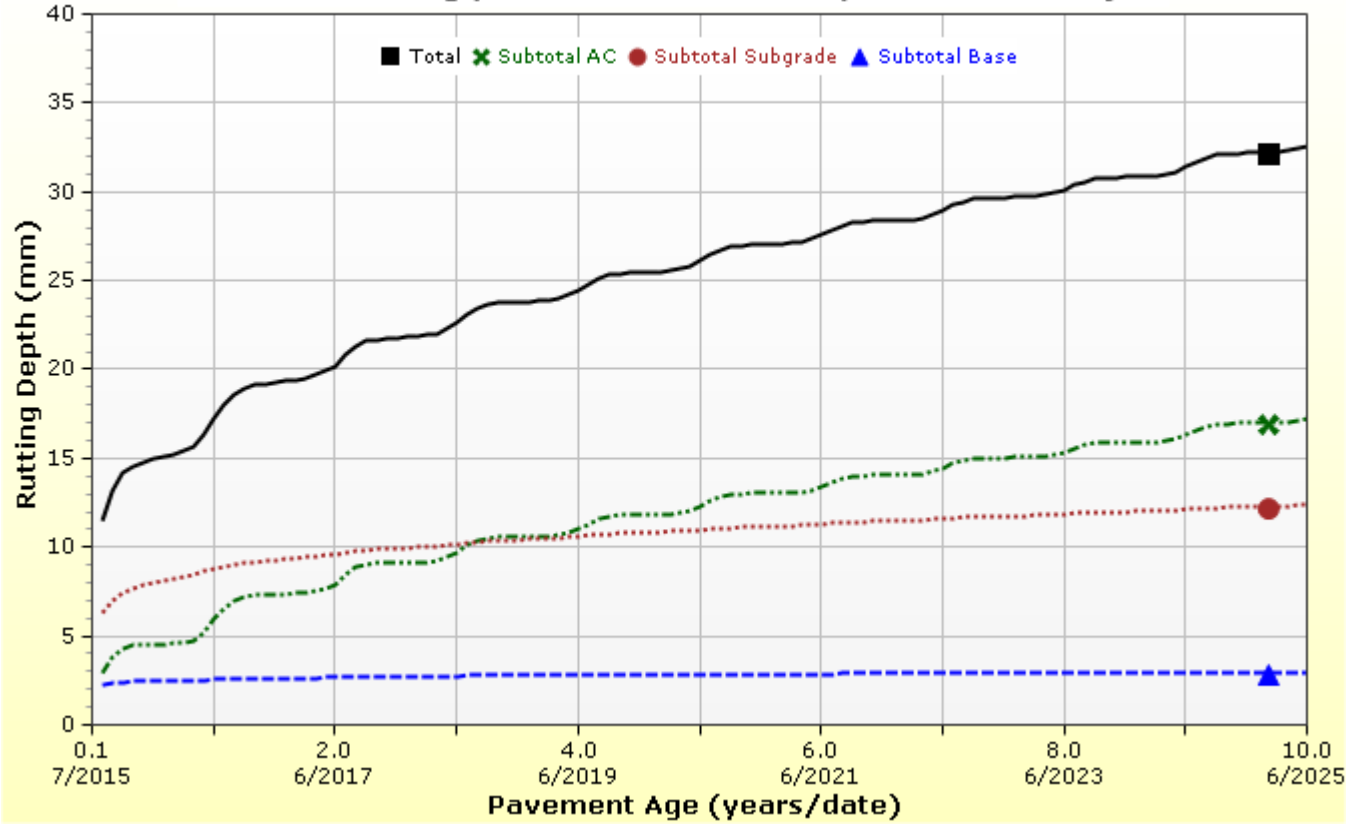


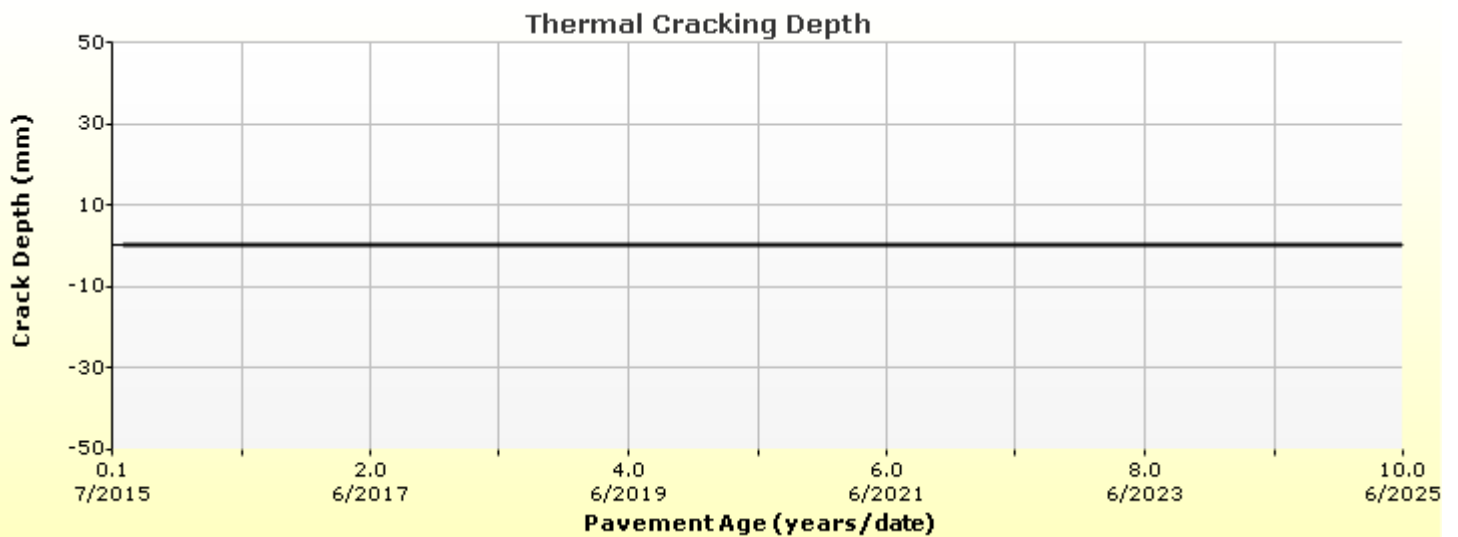
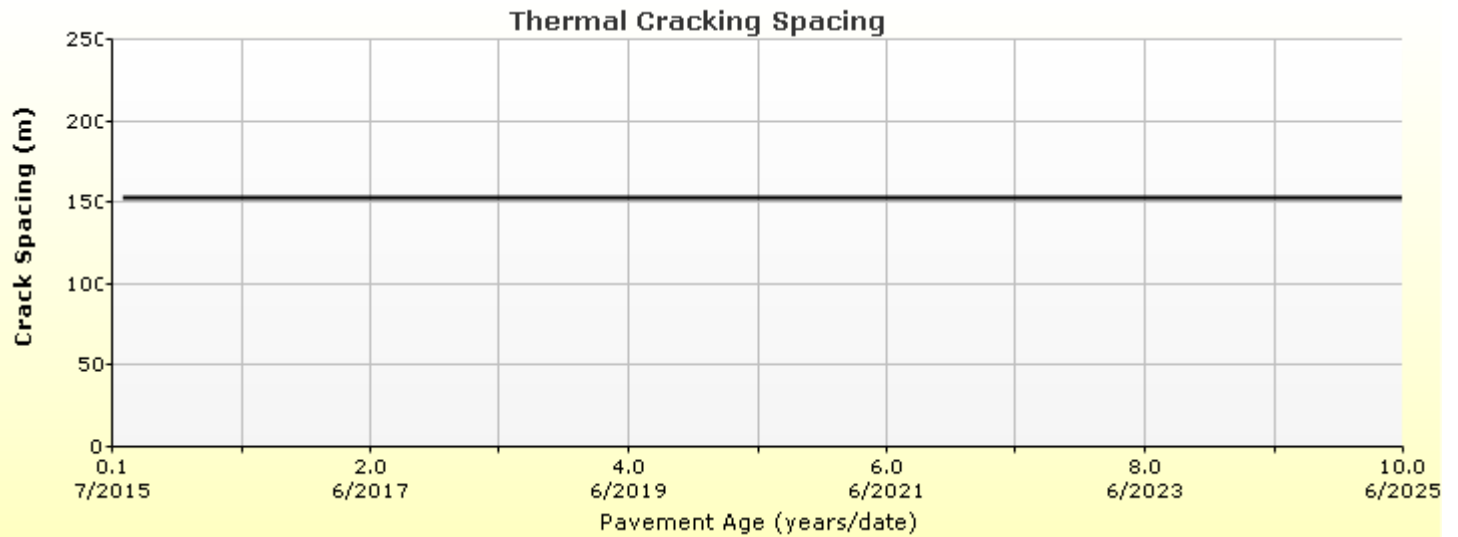
Thermal Cracking: Total Length vs. Time

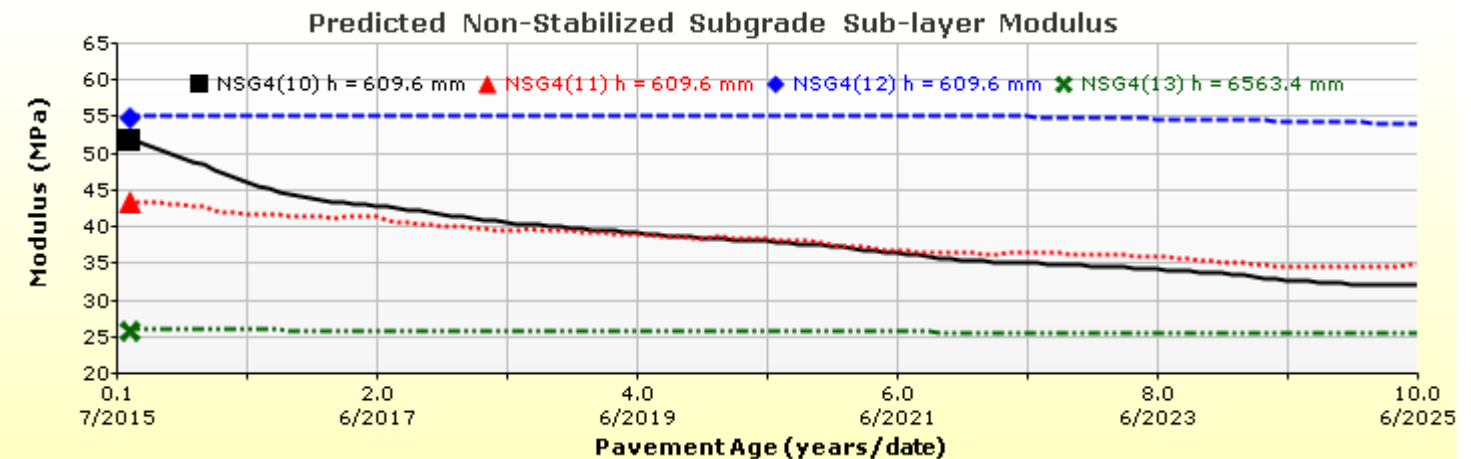
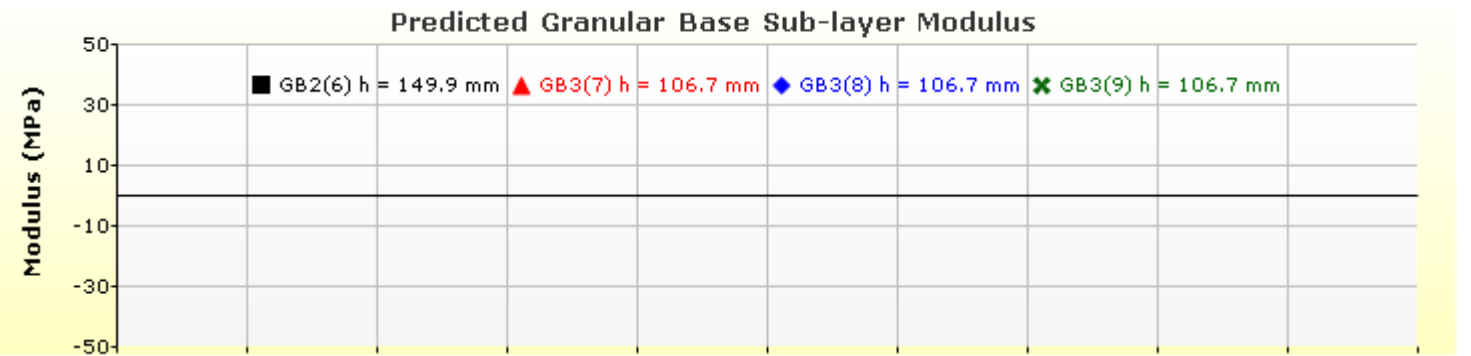
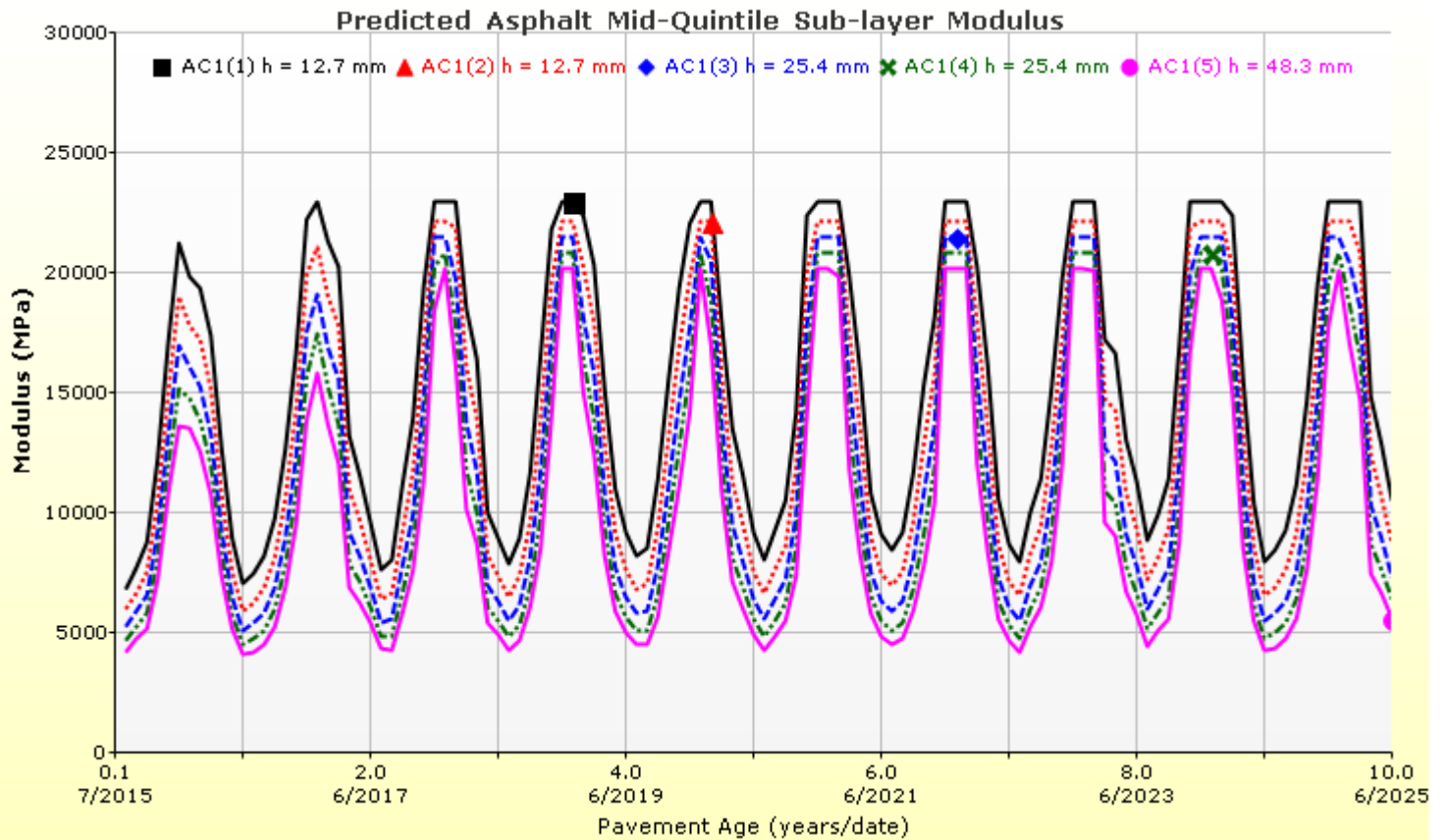




Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

Standard Deviation (BASERUT)

0.1235*Pow(SUBRUT,0.5012)+0.001

AC Cracking

AC Top Down Cracking

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

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: 7

c2: 3.5

c3: 0

c4: 1000

c1: 1

c2: 1

c3: 6000

AC Cracking Top Standard Deviation

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

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

IRI Flexible Pavements

C1 - Rutting

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

CSM Standard Deviation

CTB*1

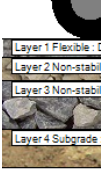
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

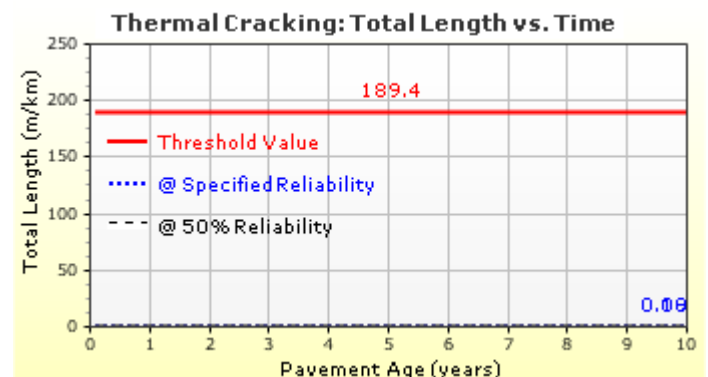
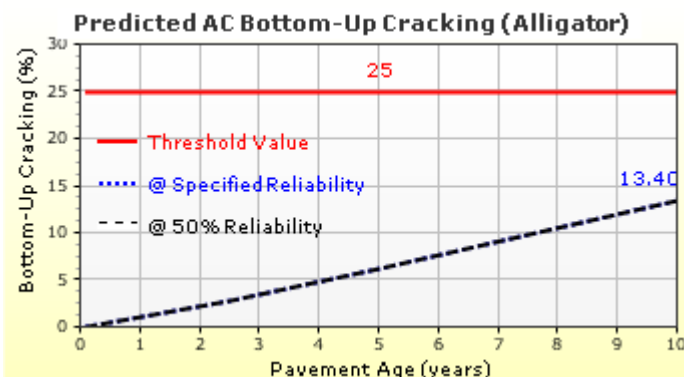
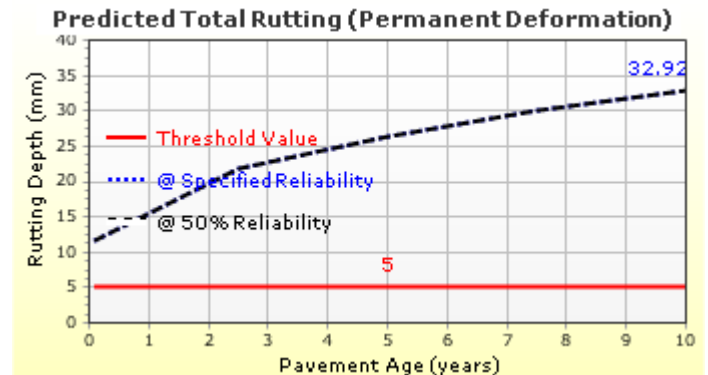
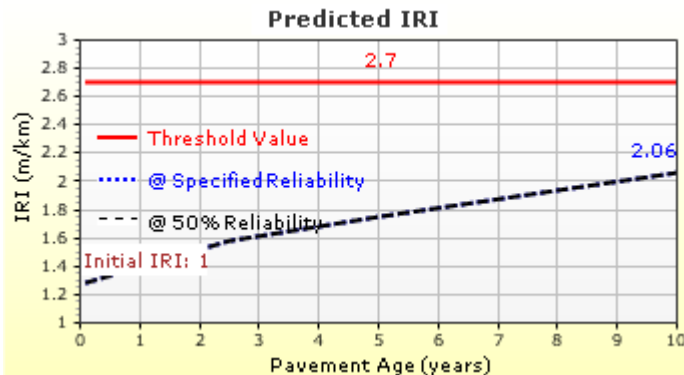
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.06	50.00	87.55	Pass
Permanent deformation - total pavement (mm)	5.00	32.92	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	13.40	50.00	79.42	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	11.21	50.00	91.98	Pass
Permanent deformation - AC only (mm)	5.00	17.58	50.00	0.29	Fail

Distress Charts

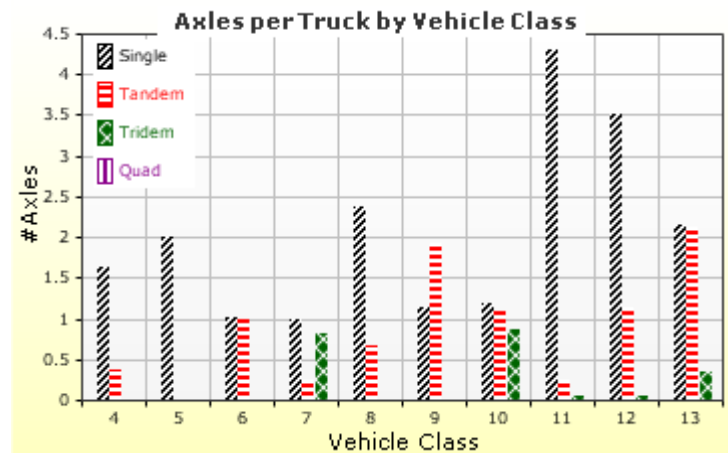
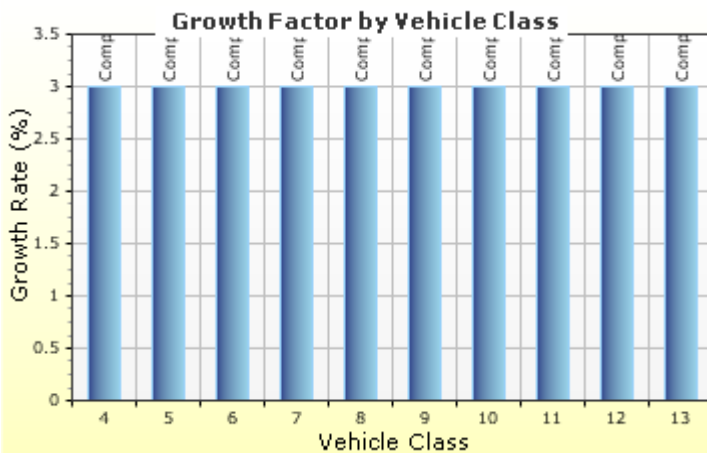
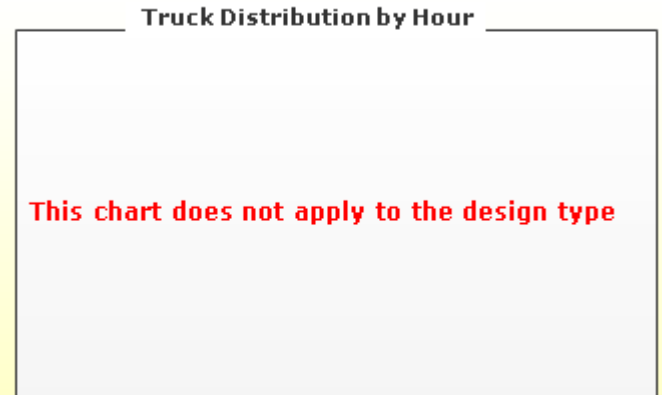
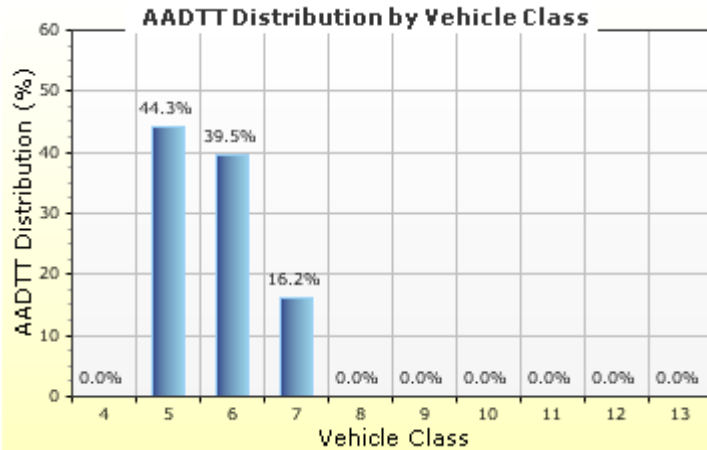


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

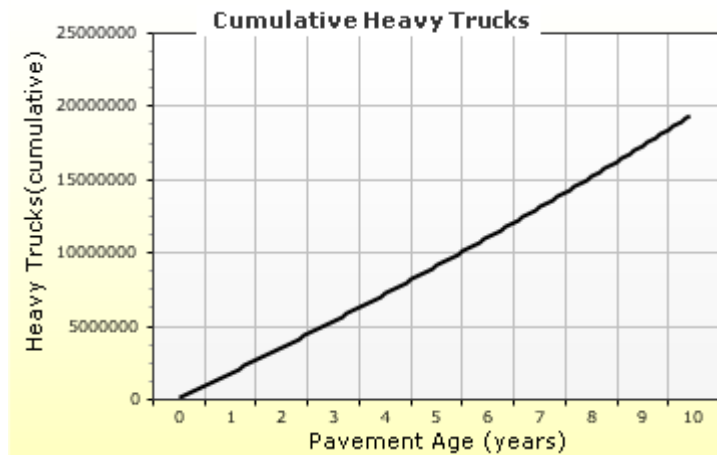
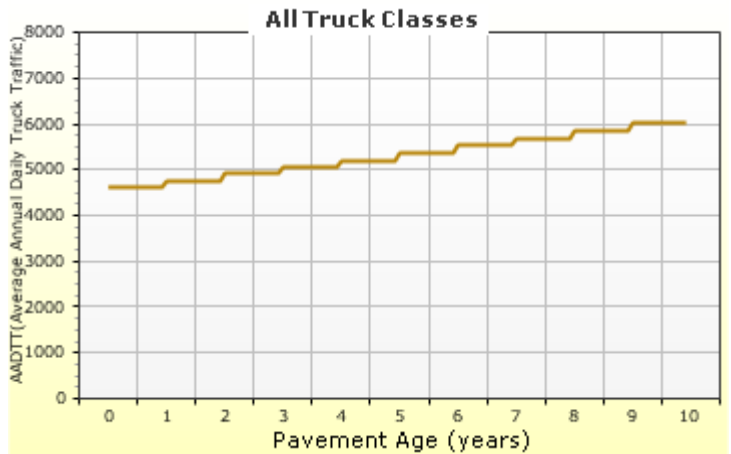
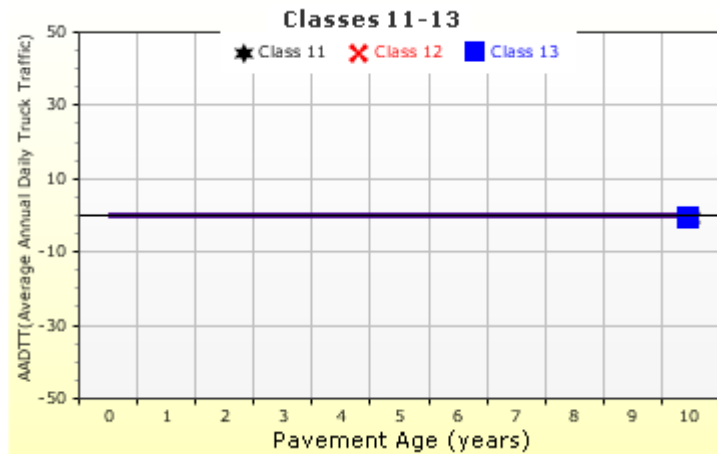
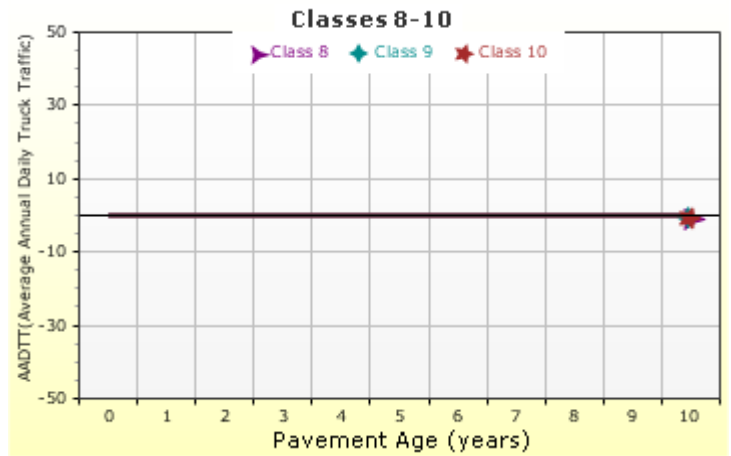
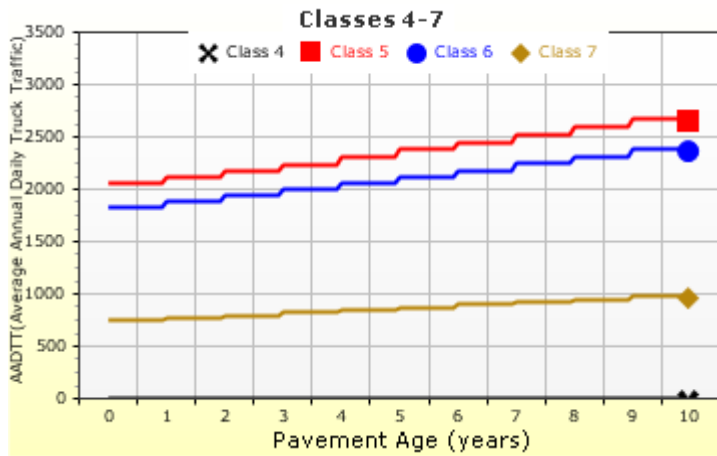
Wheelbase does not apply

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



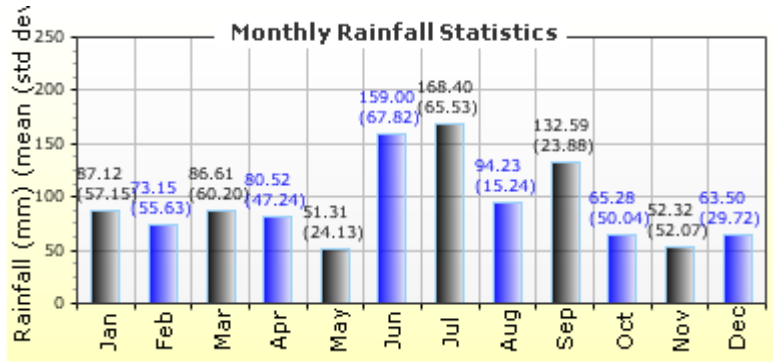
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

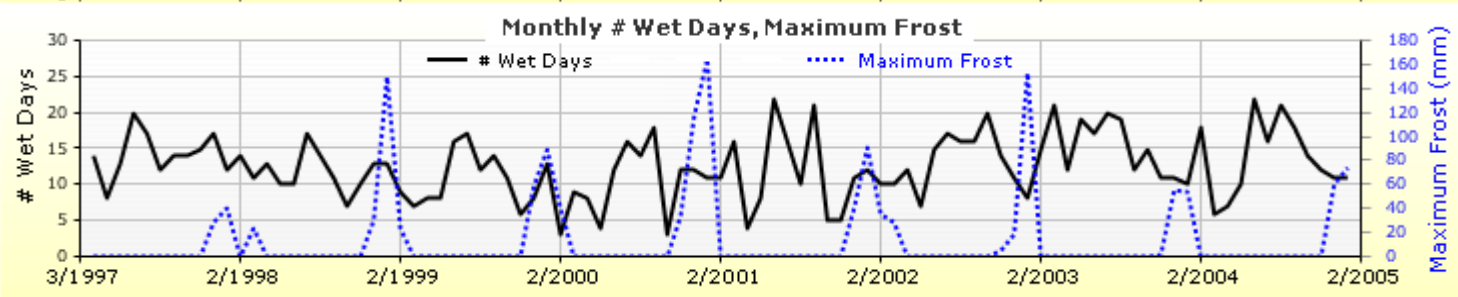
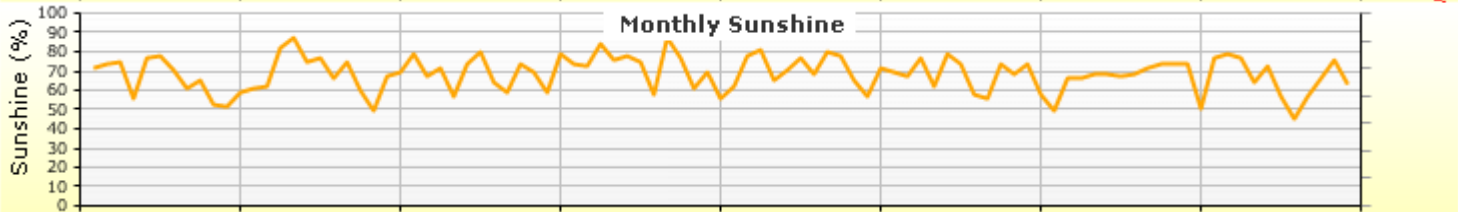
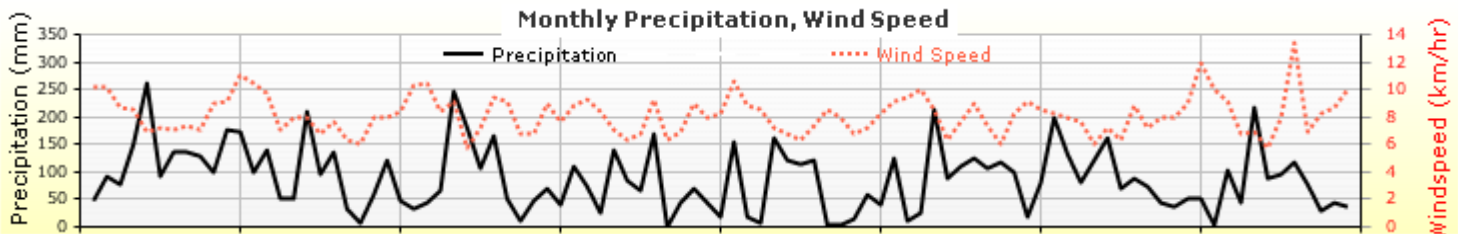
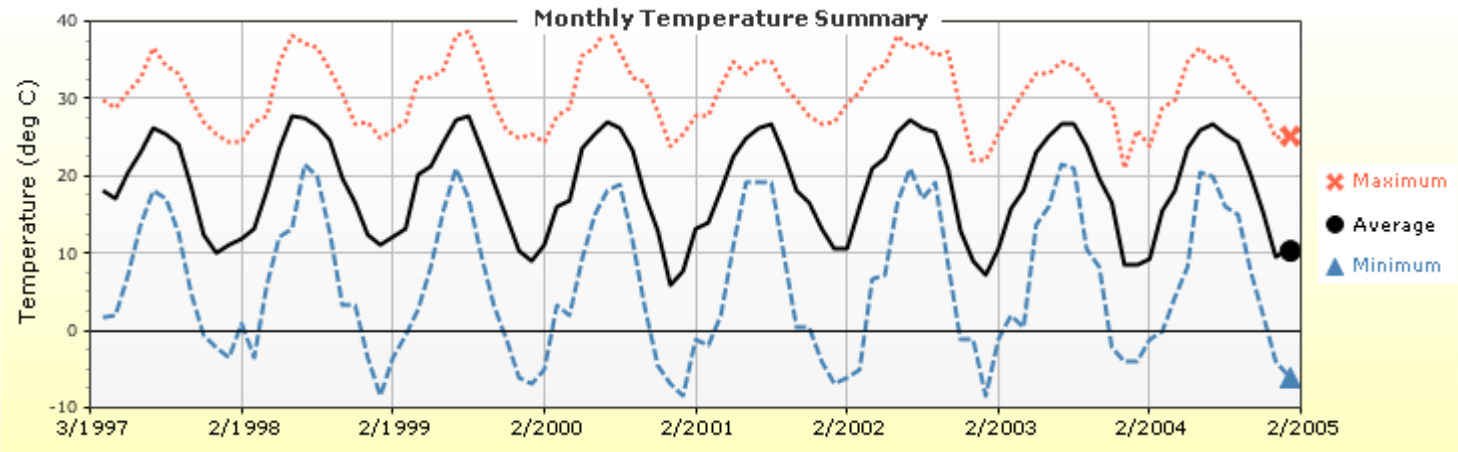
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

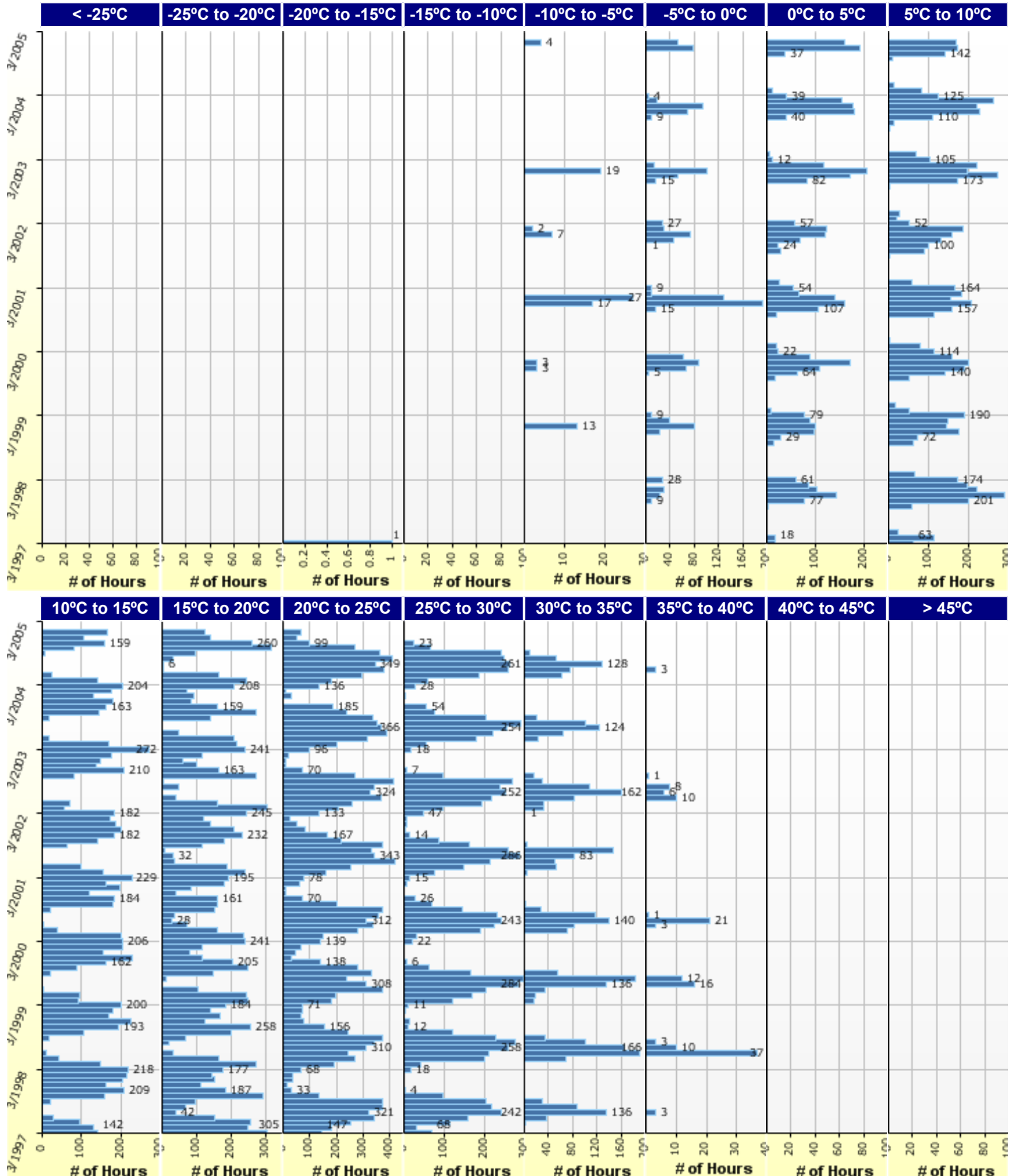


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF4_ALT1

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF4_ALT1.dgpx



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

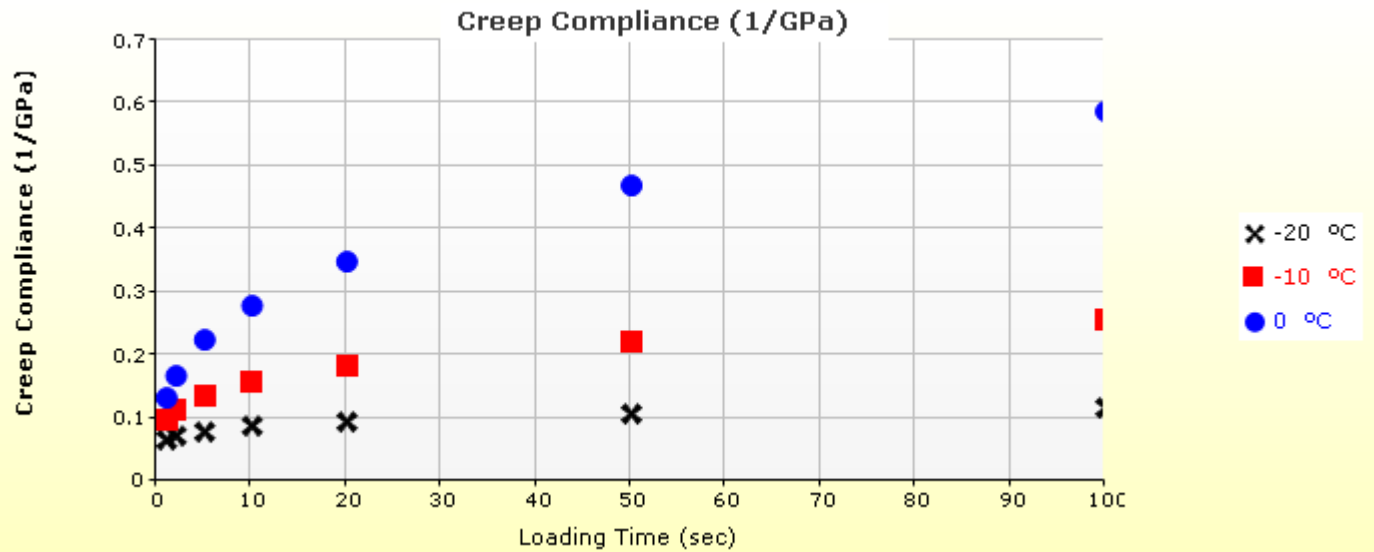
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

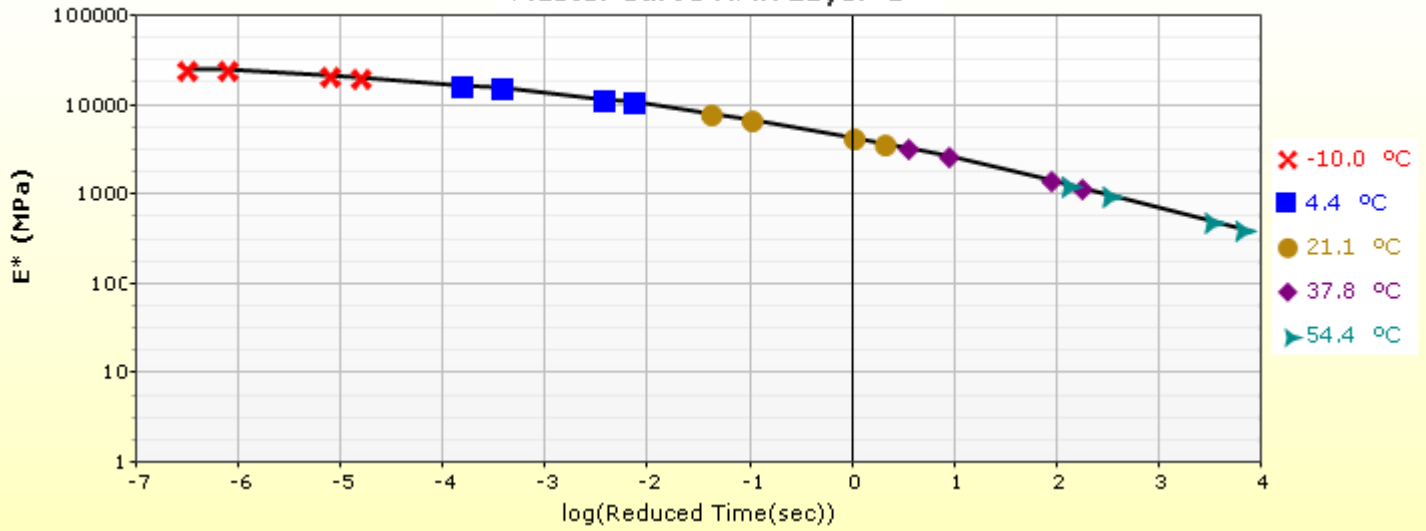
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

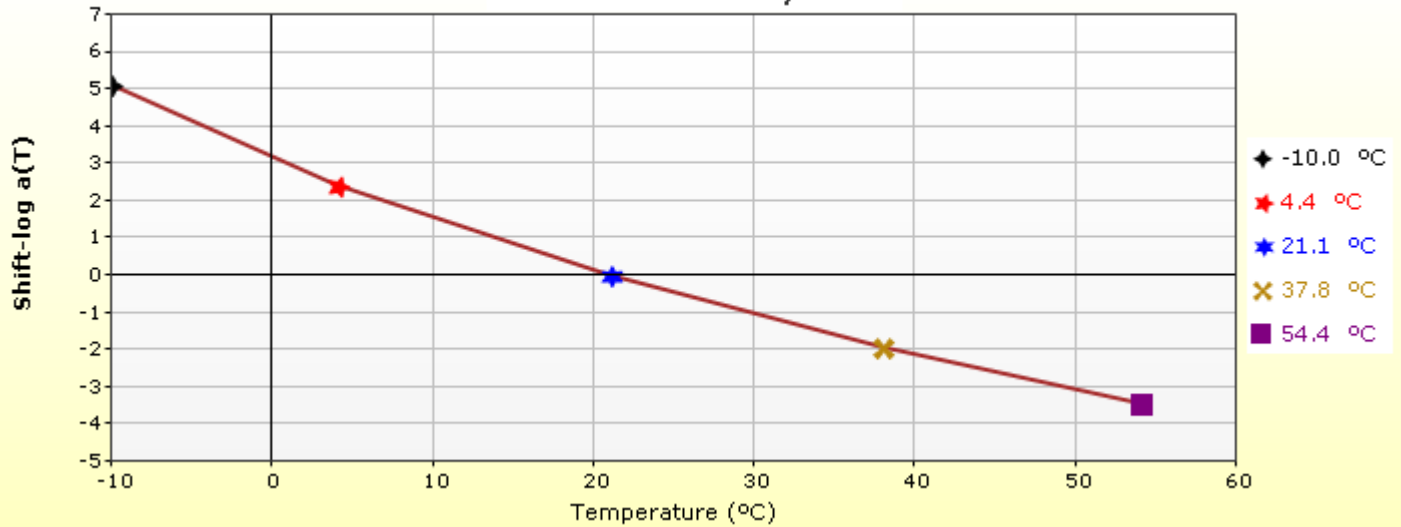


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

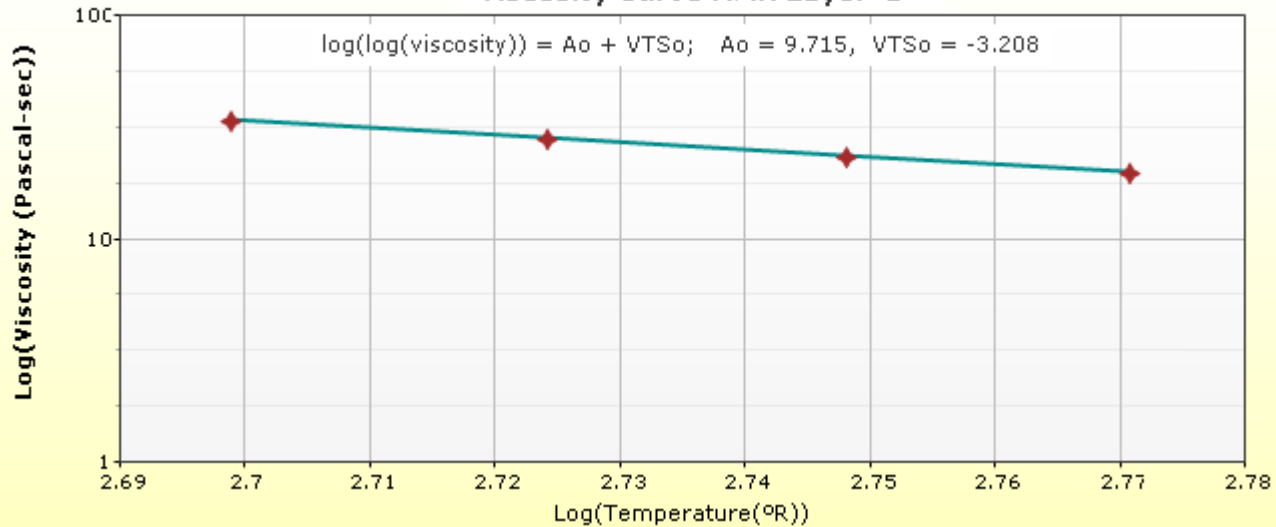
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

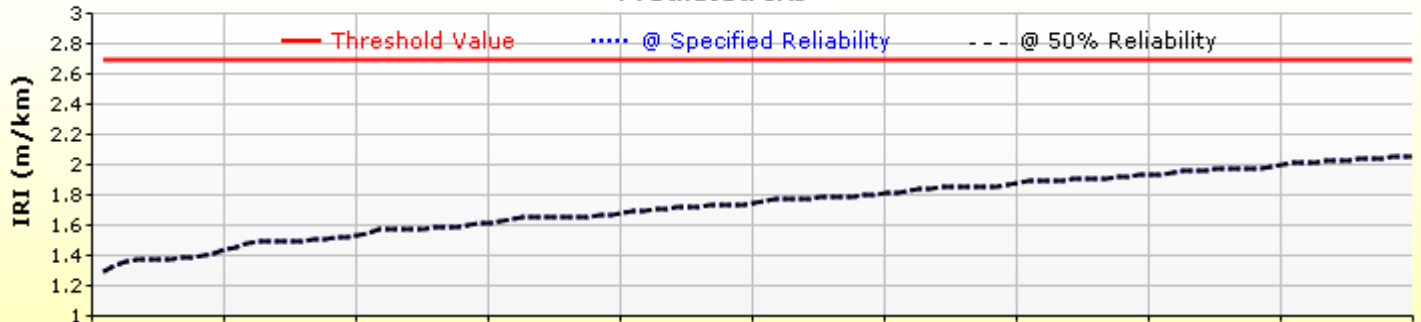


Viscosity Curve HMA Layer 1

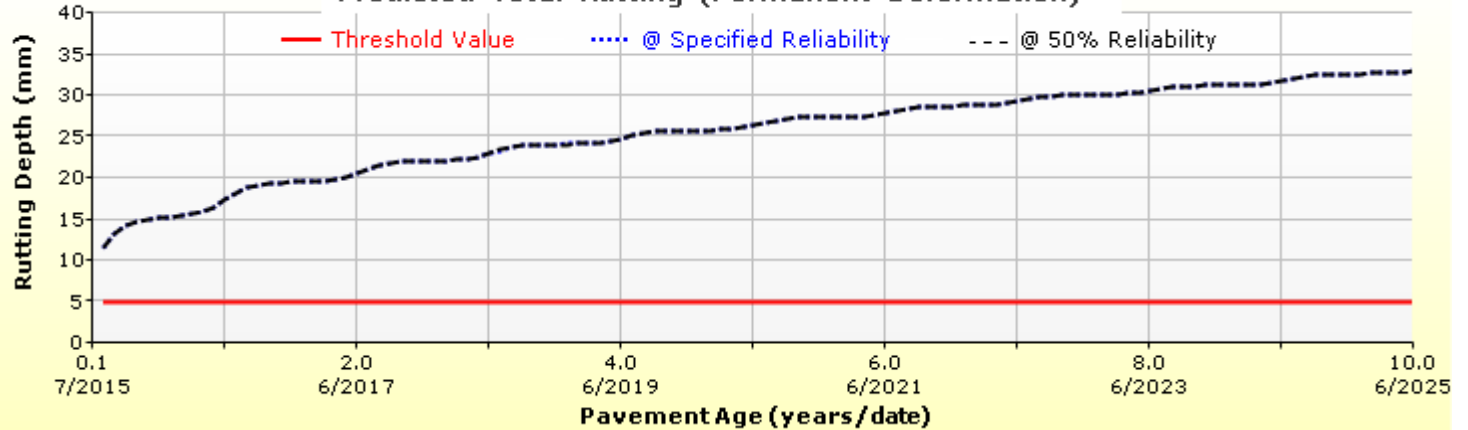


Analysis Output Charts

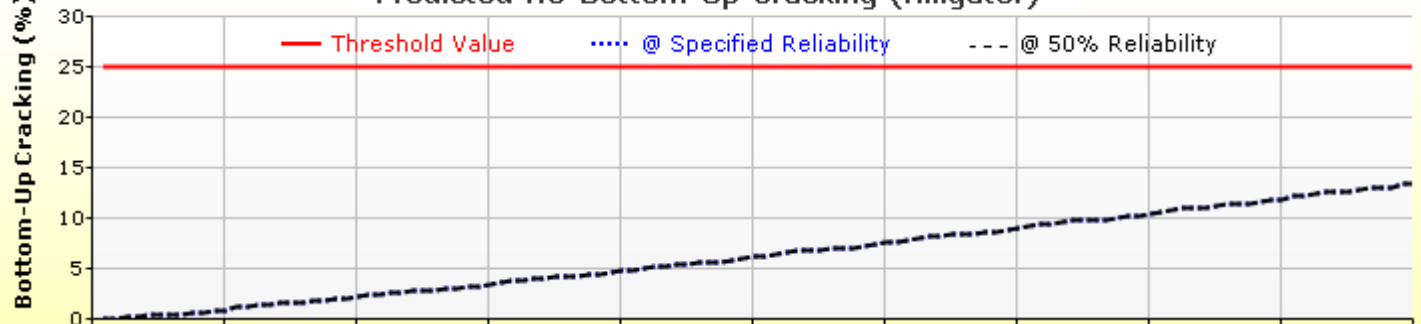
Predicted IRI



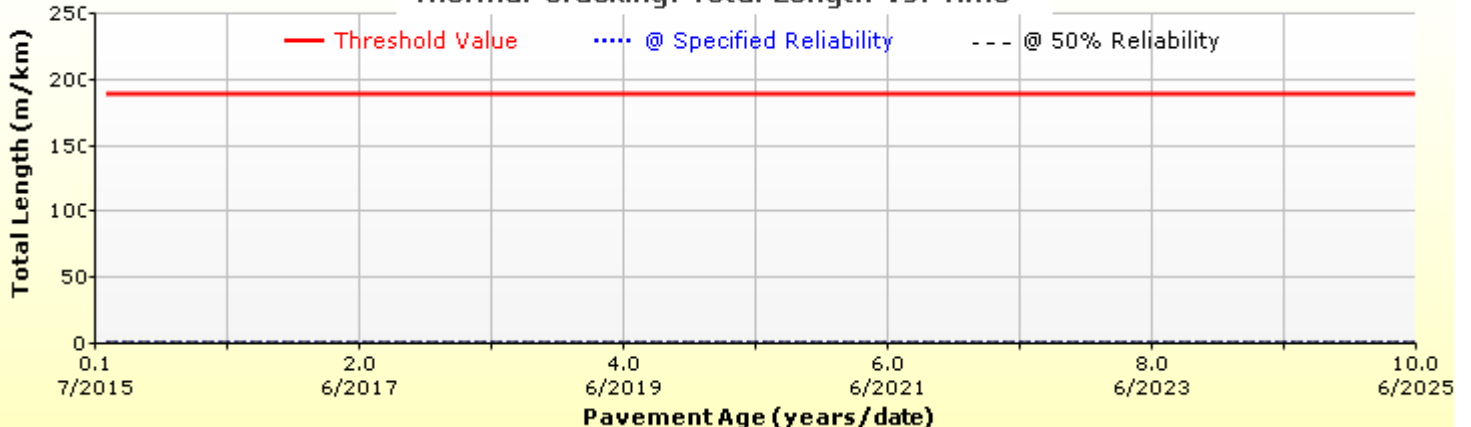
Predicted Total Rutting (Permanent Deformation)



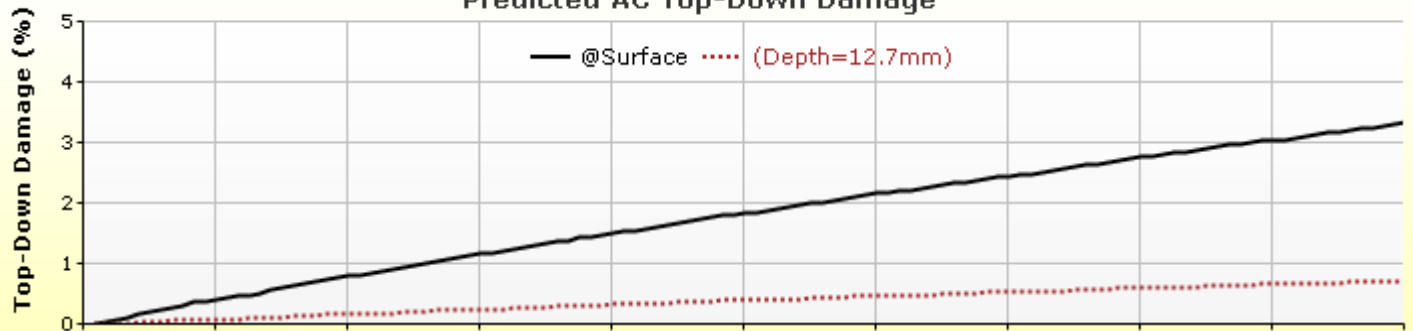
Predicted AC Bottom-Up Cracking (Alligator)



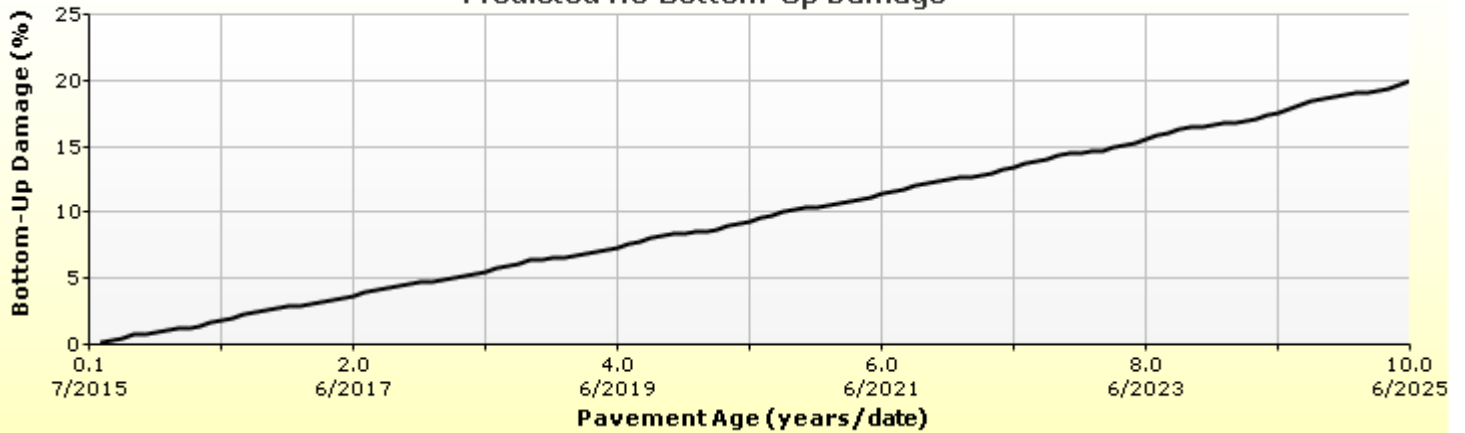
Thermal Cracking: Total Length vs. Time



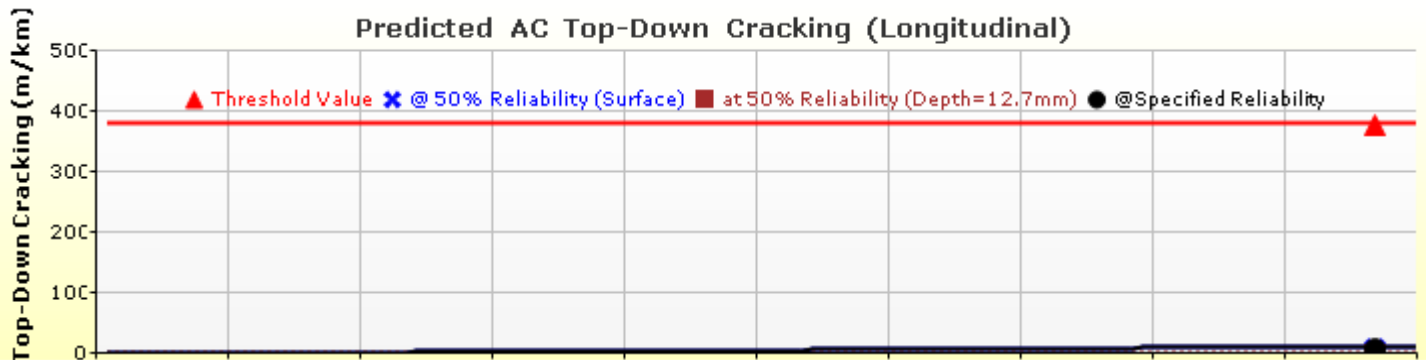
Predicted AC Top-Down Damage



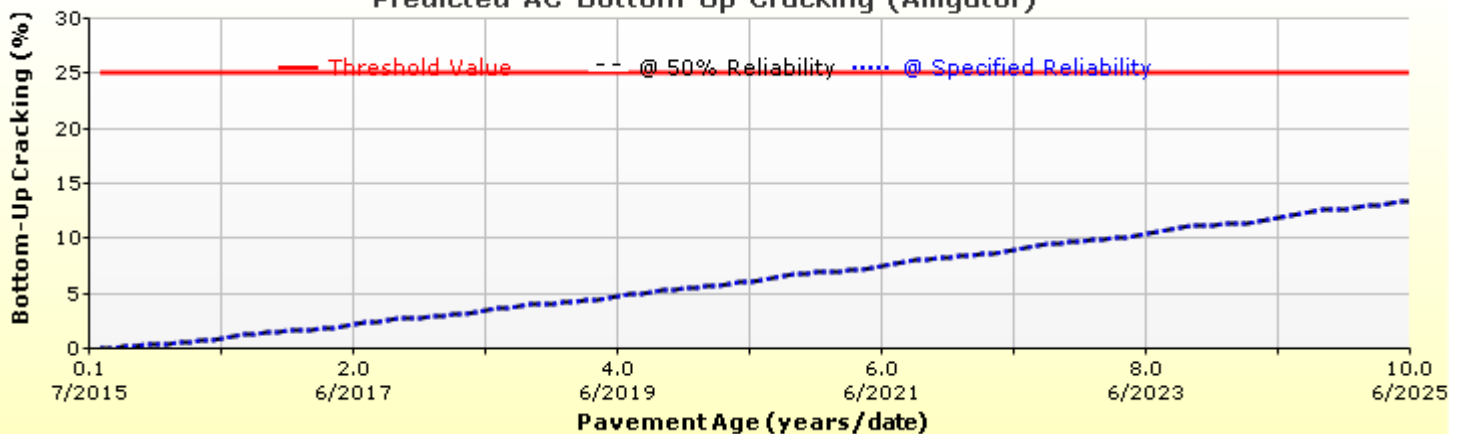
Predicted AC Bottom-Up Damage



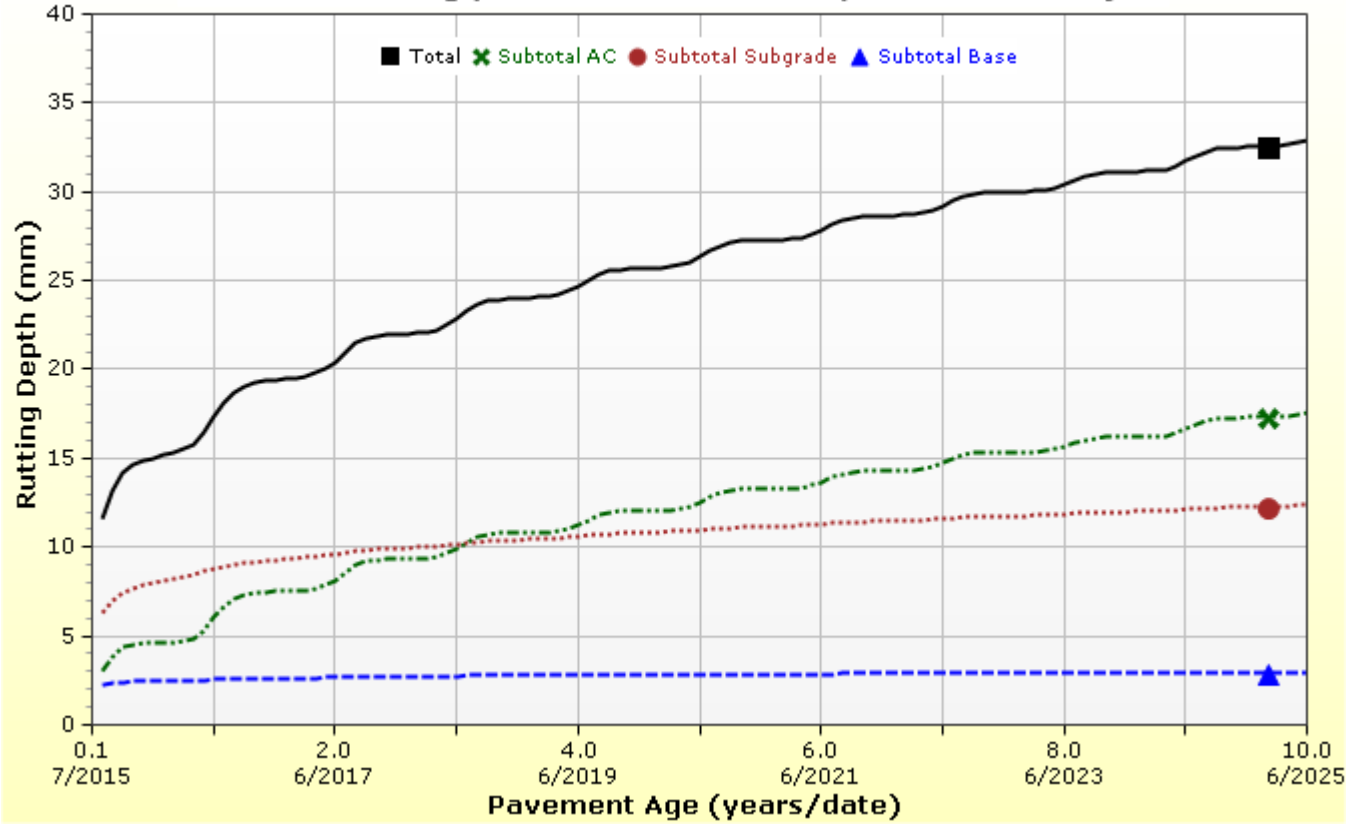
Predicted AC Top-Down Cracking (Longitudinal)



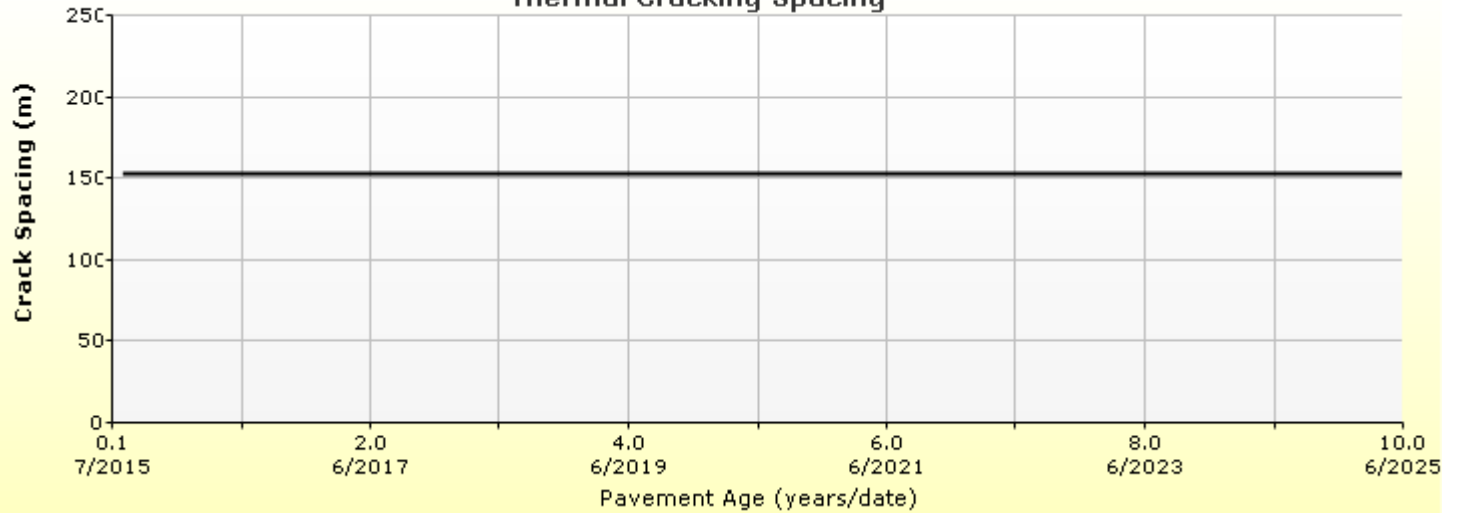
Predicted AC Bottom-Up Cracking (Alligator)



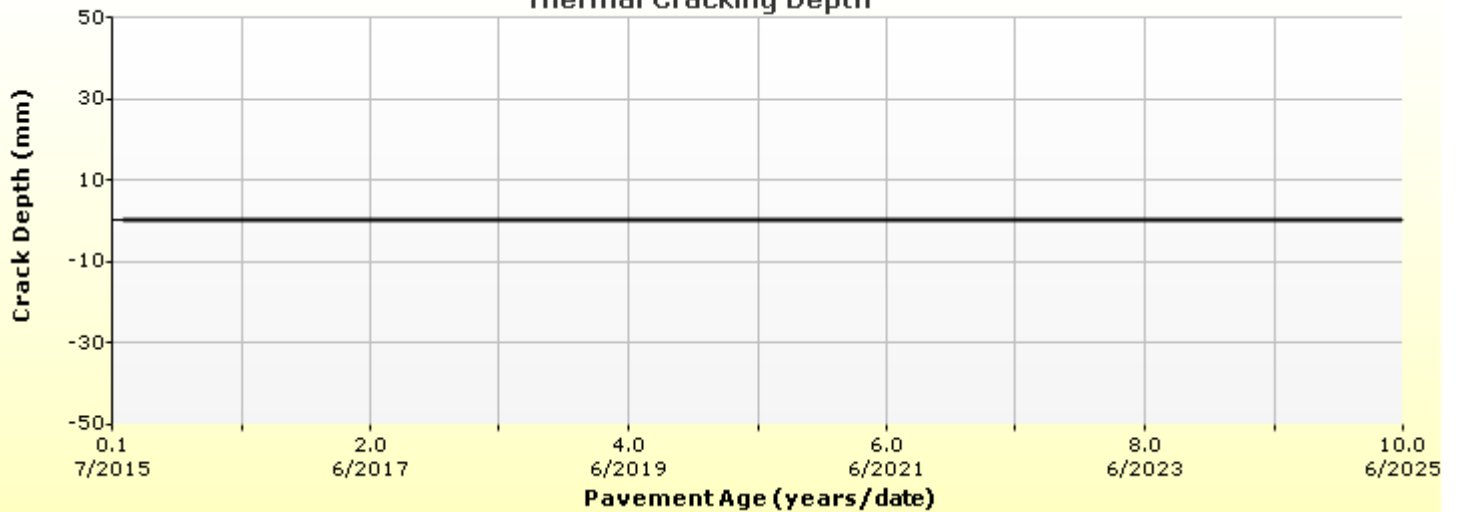
Predicted Rutting (Permanent Deformation) at 50% Reliability

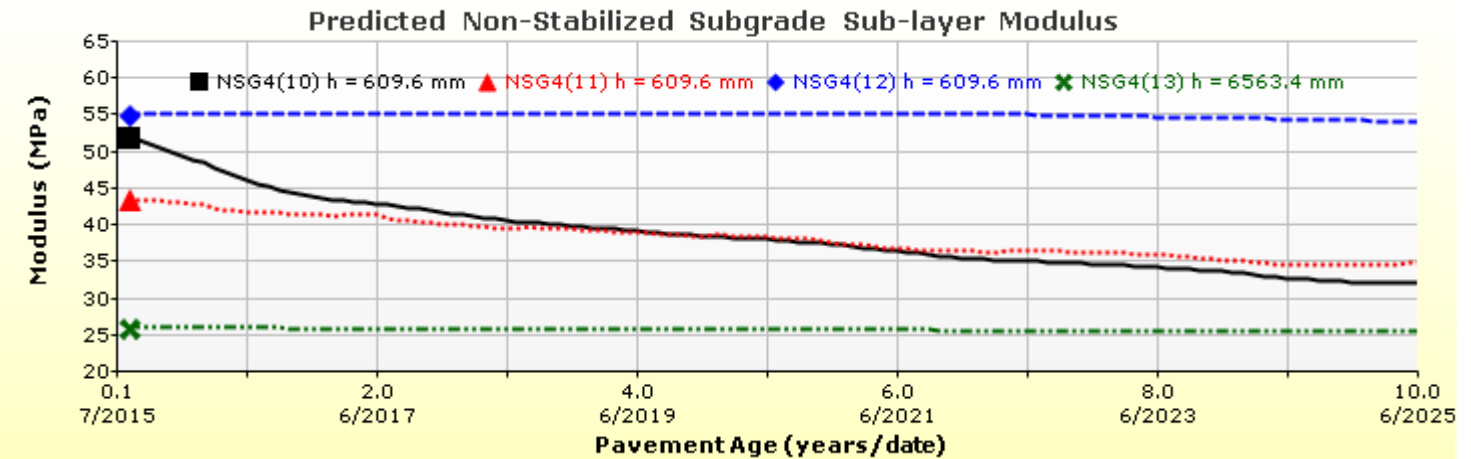
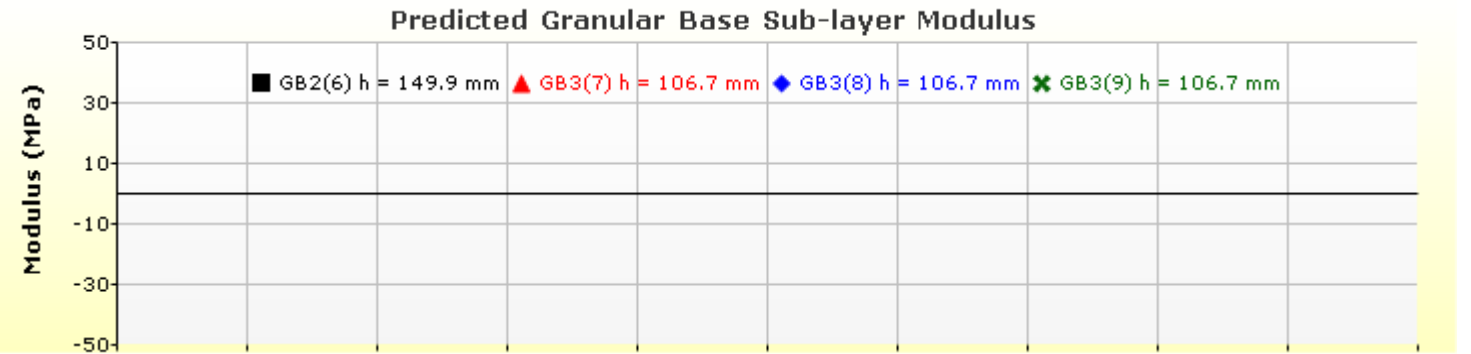
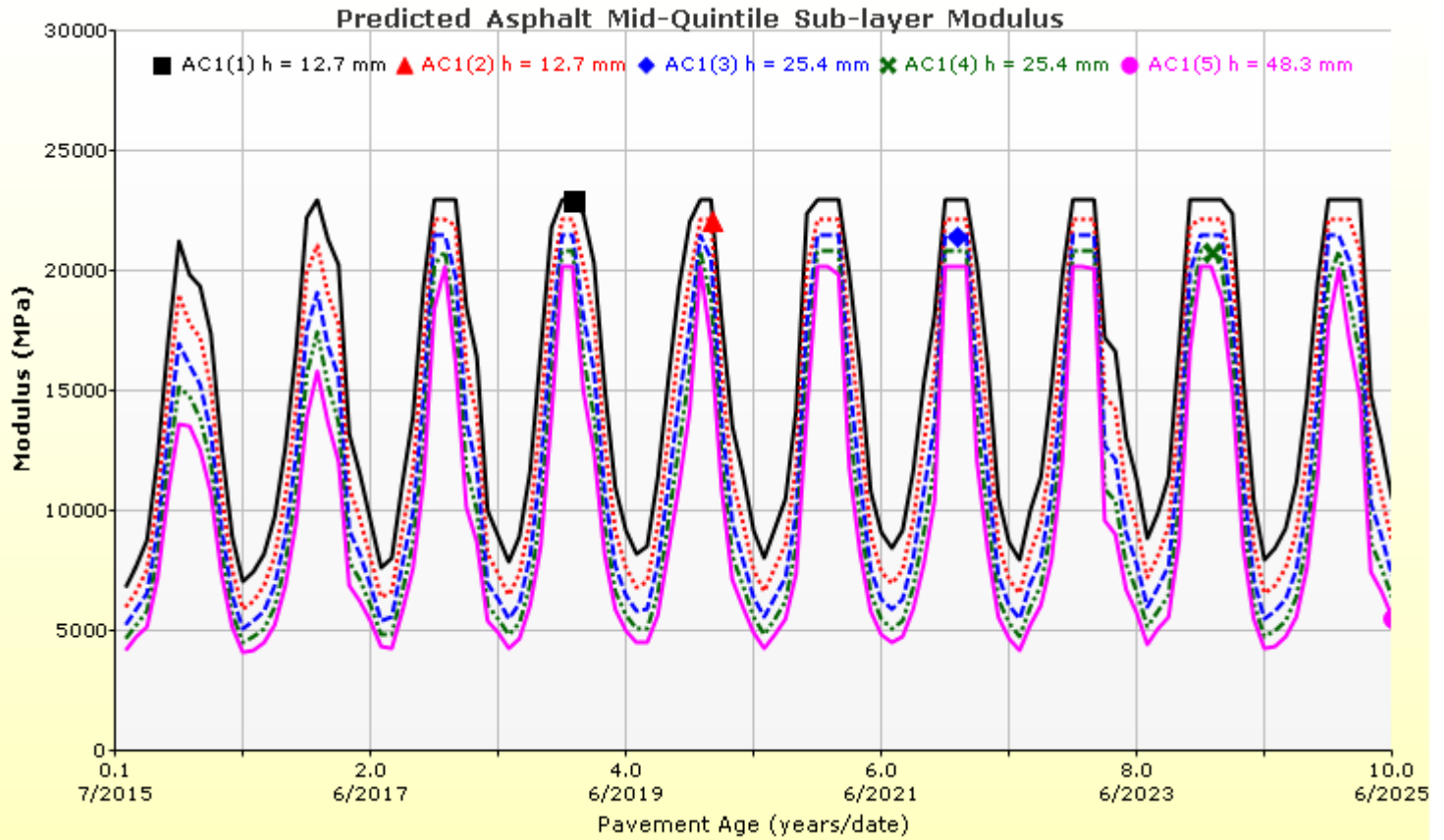


Thermal Cracking Spacing



Thermal Cracking Depth





Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

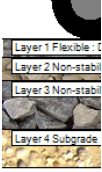
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

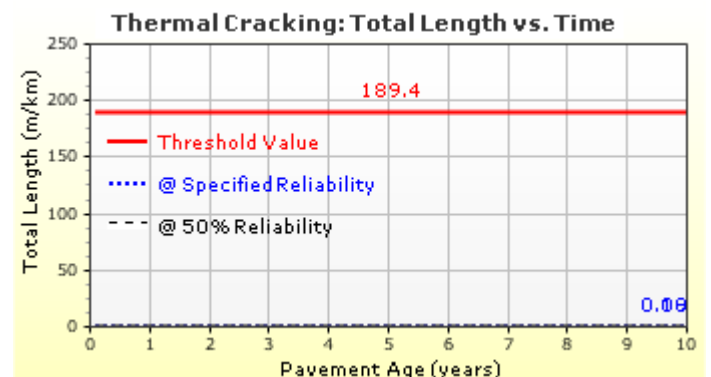
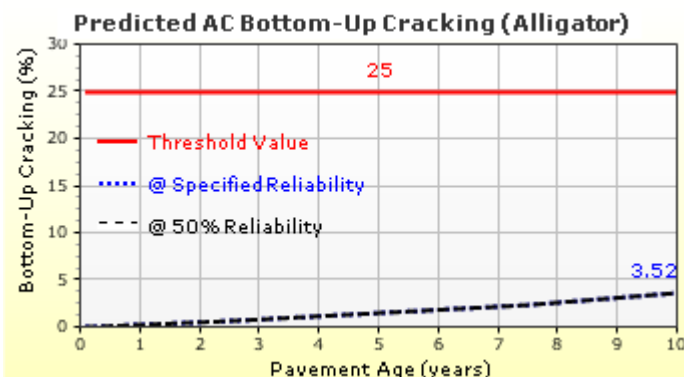
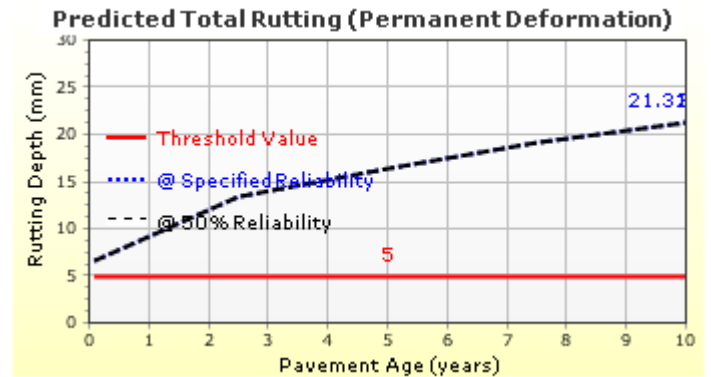
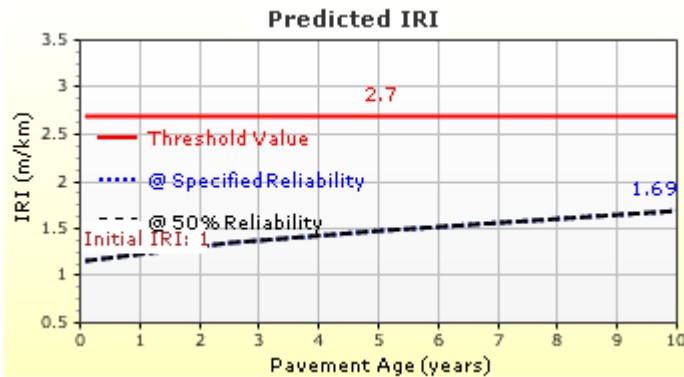
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.69	50.00	98.22	Pass
Permanent deformation - total pavement (mm)	5.00	21.32	50.00	0.01	Fail
AC bottom-up fatigue cracking (percent)	25.00	3.52	50.00	93.86	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	126.33	50.00	73.61	Pass
Permanent deformation - AC only (mm)	5.00	15.63	50.00	0.53	Fail

Distress Charts

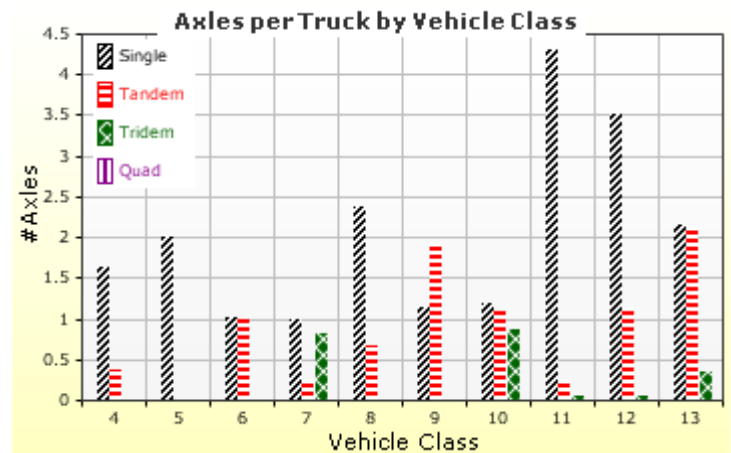
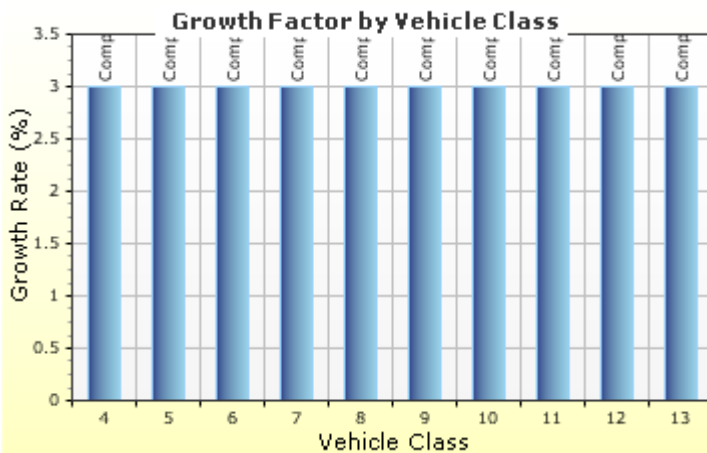
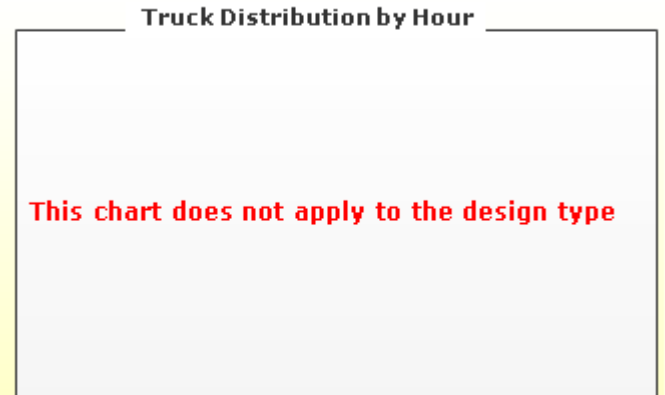
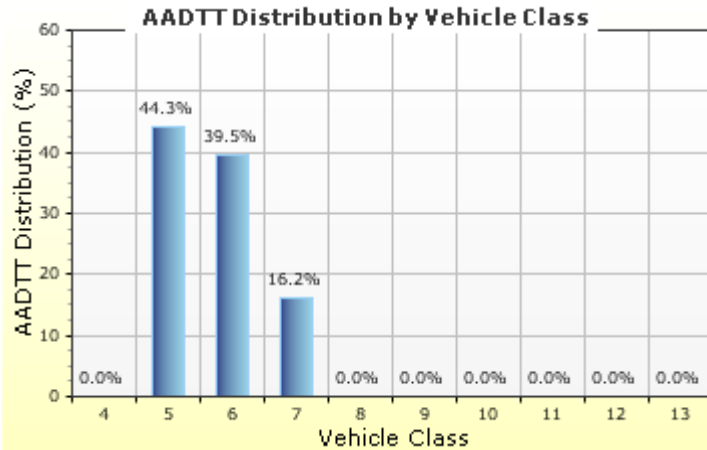


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

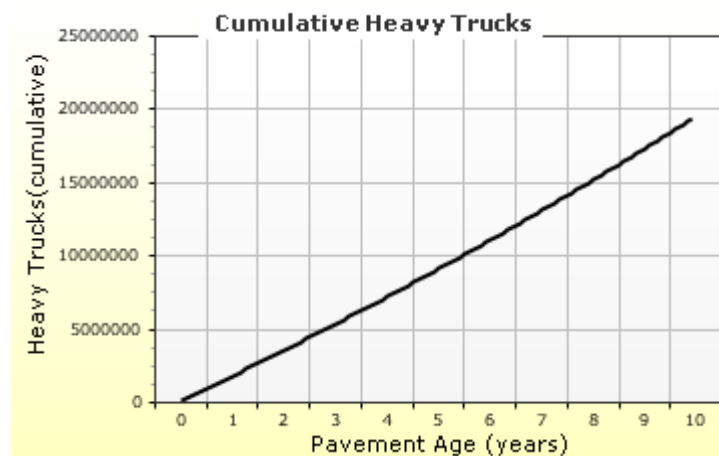
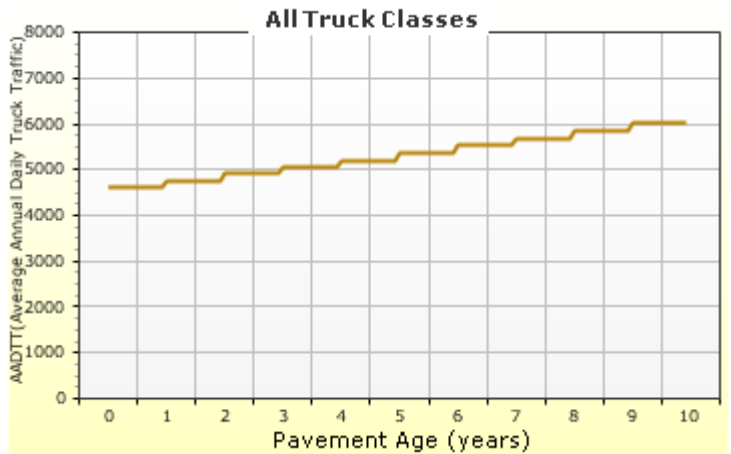
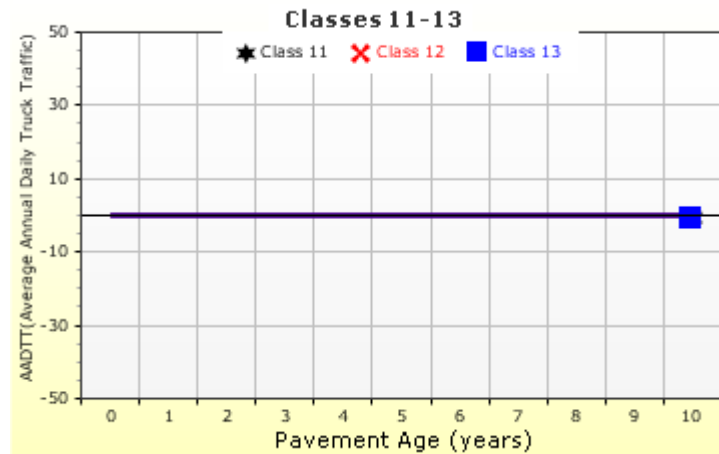
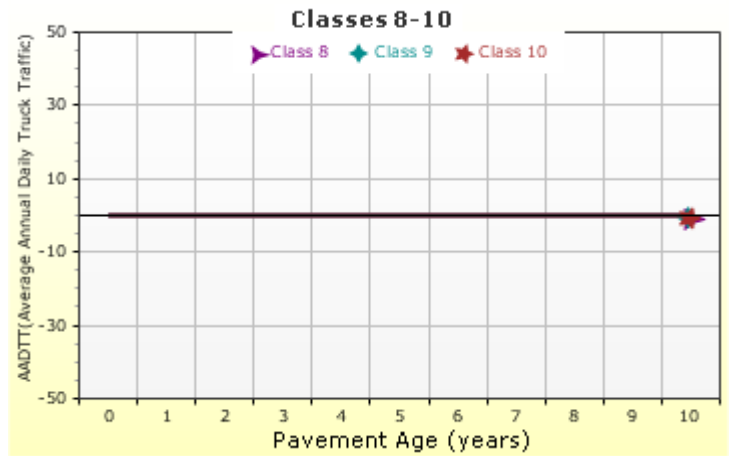
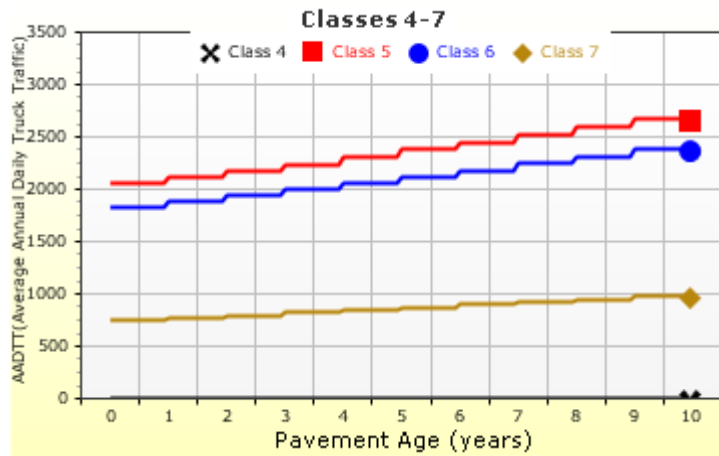
Wheelbase does not apply

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



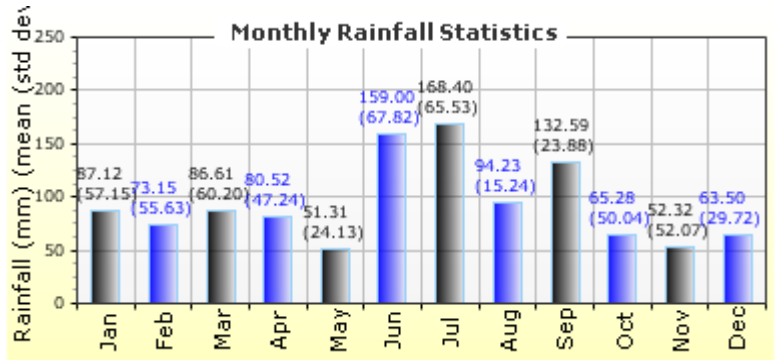
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

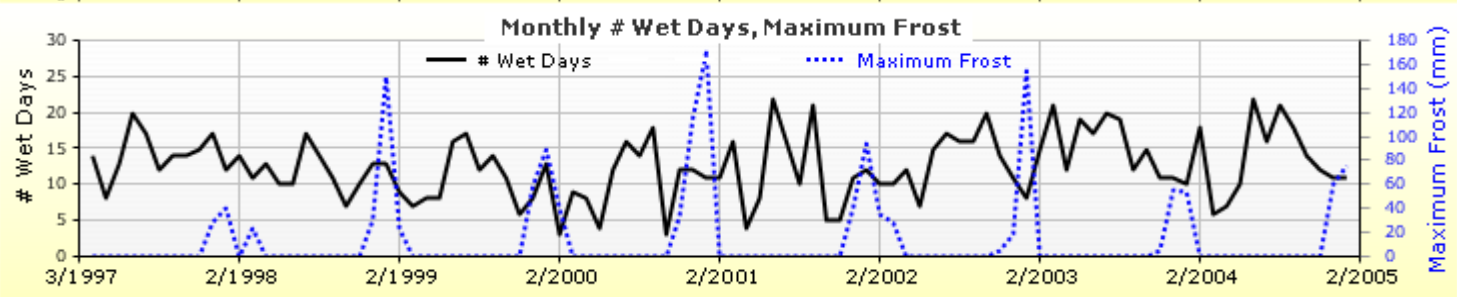
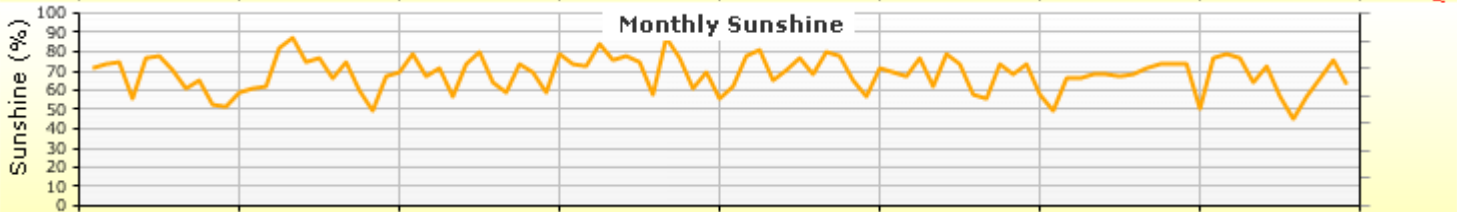
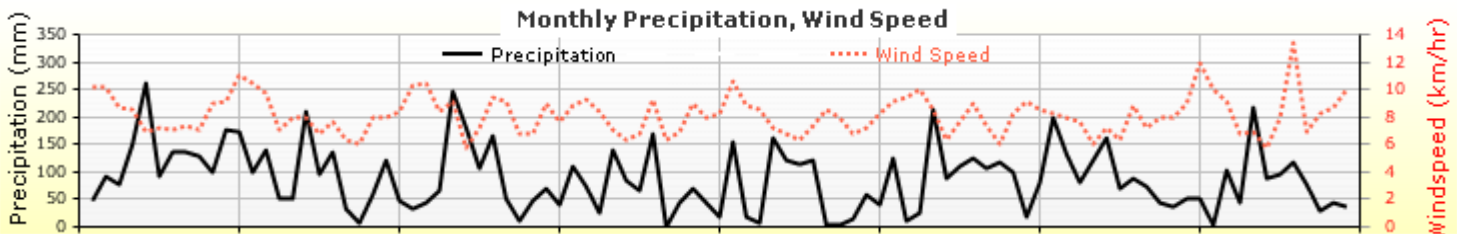
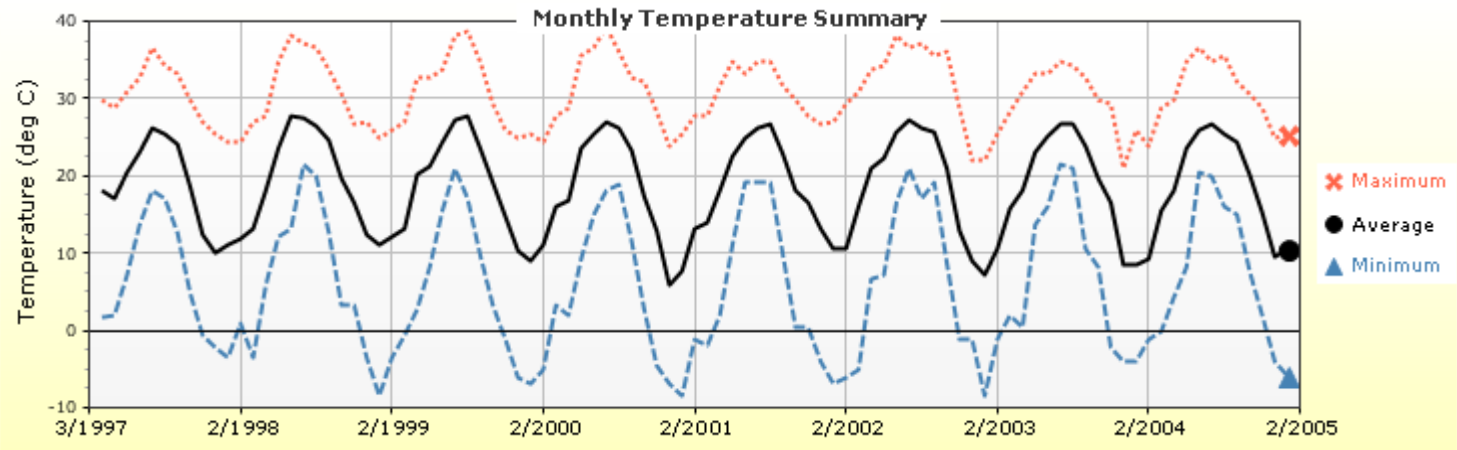
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

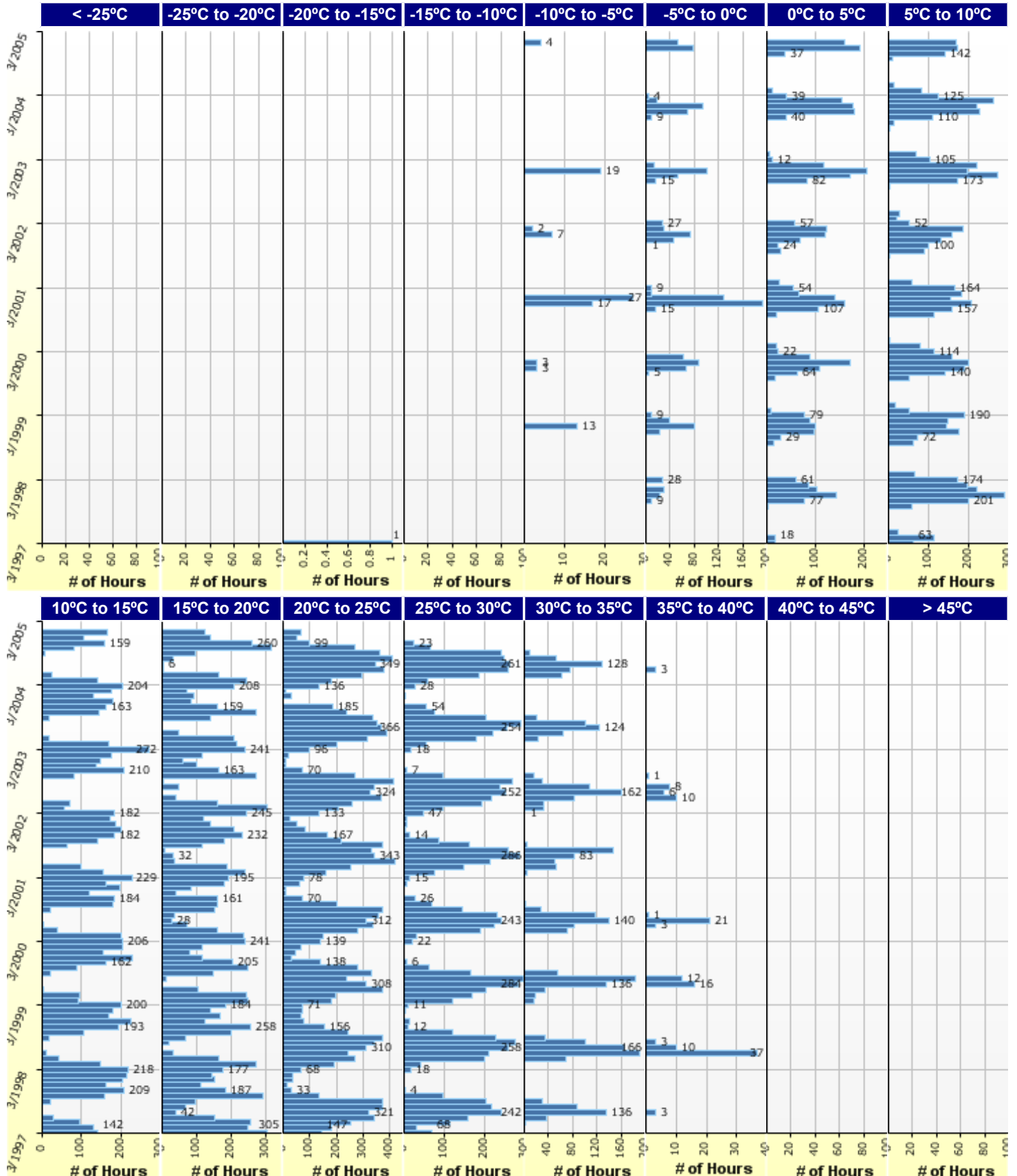


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF1_ALT2

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1_ALT2.dgpx



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

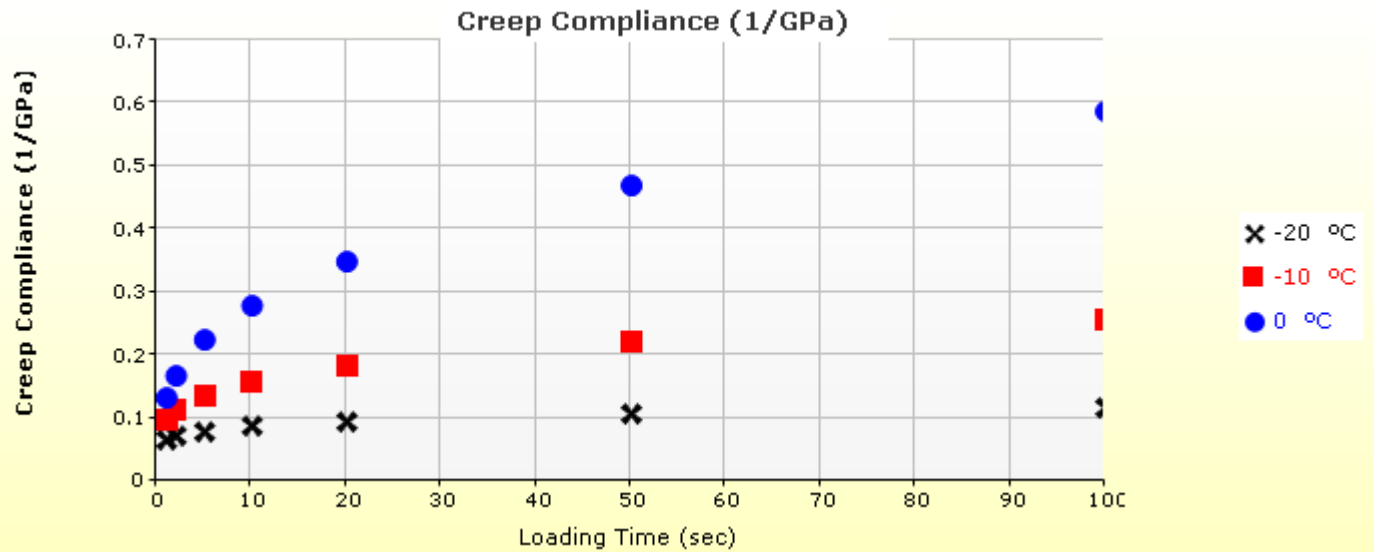
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

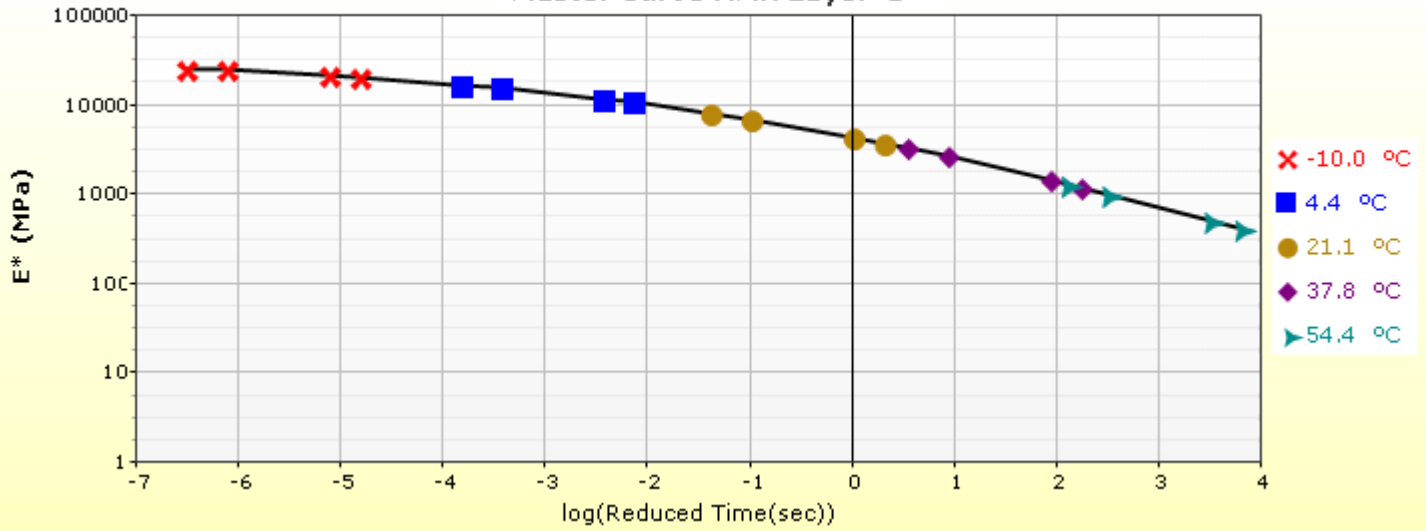
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

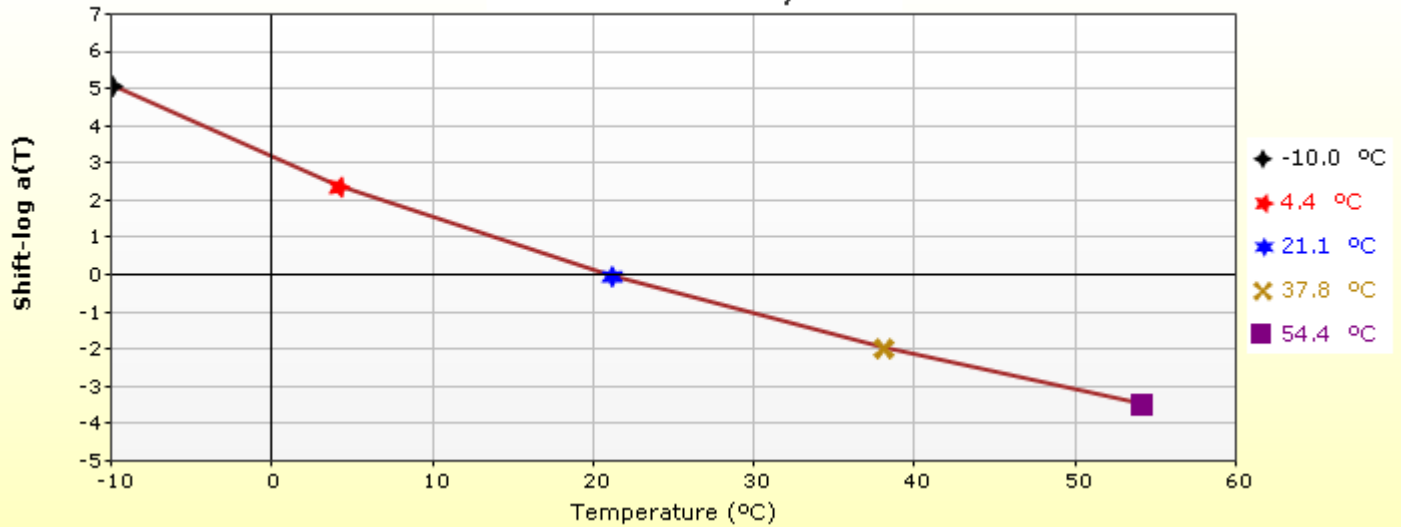


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

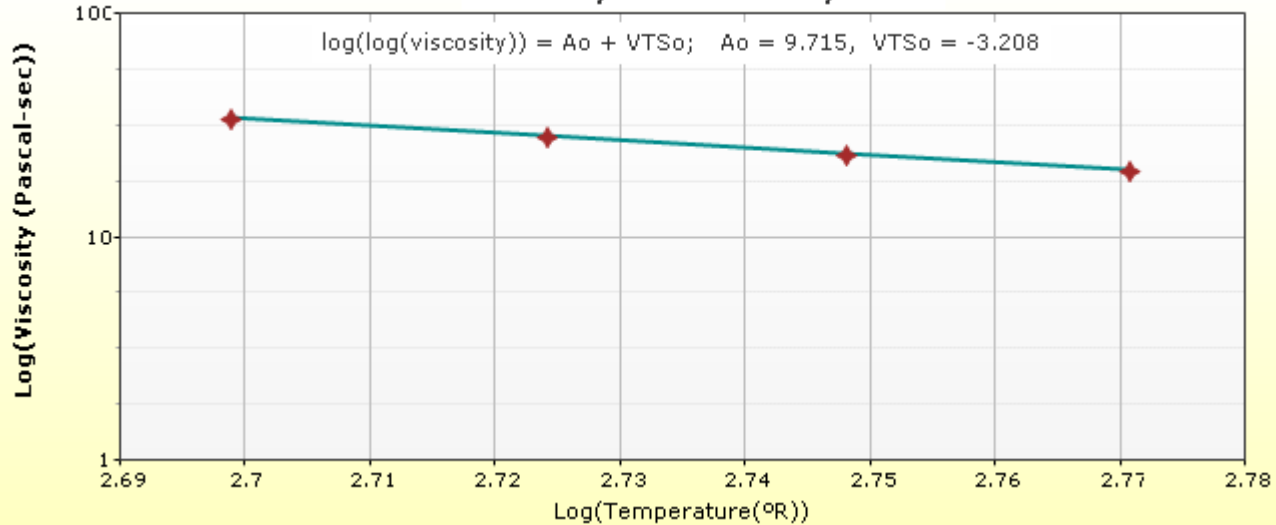
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

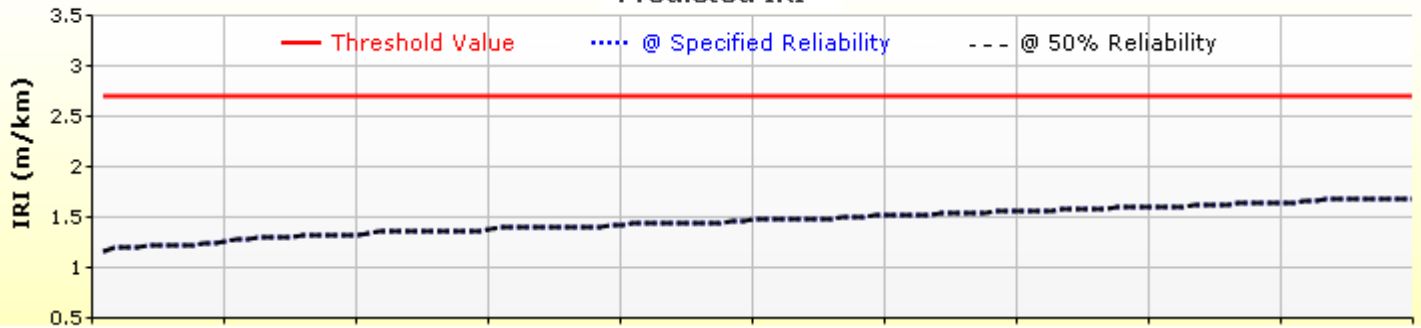


Viscosity Curve HMA Layer 1

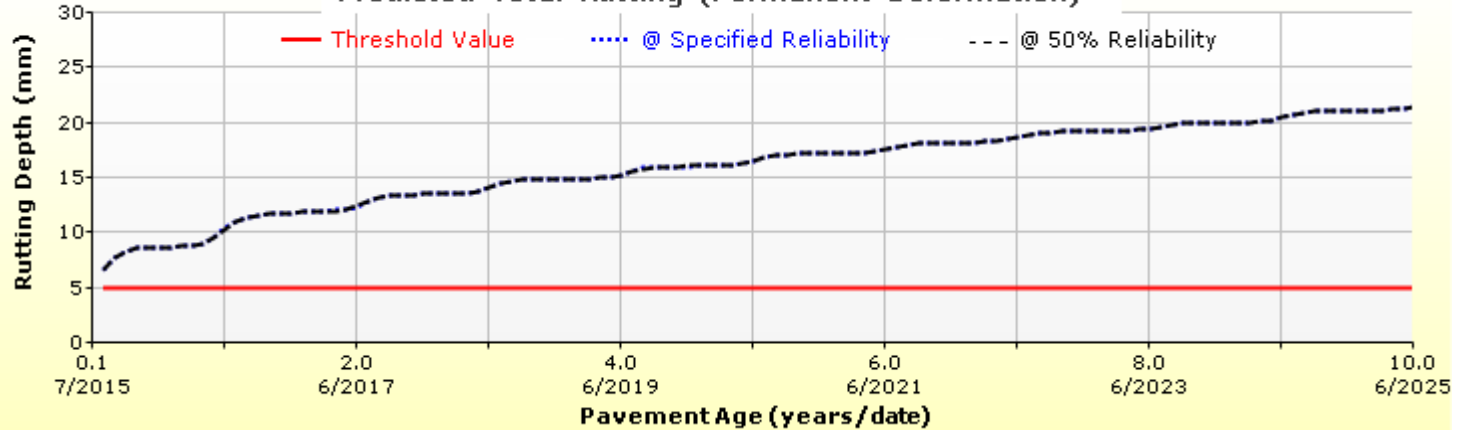


Analysis Output Charts

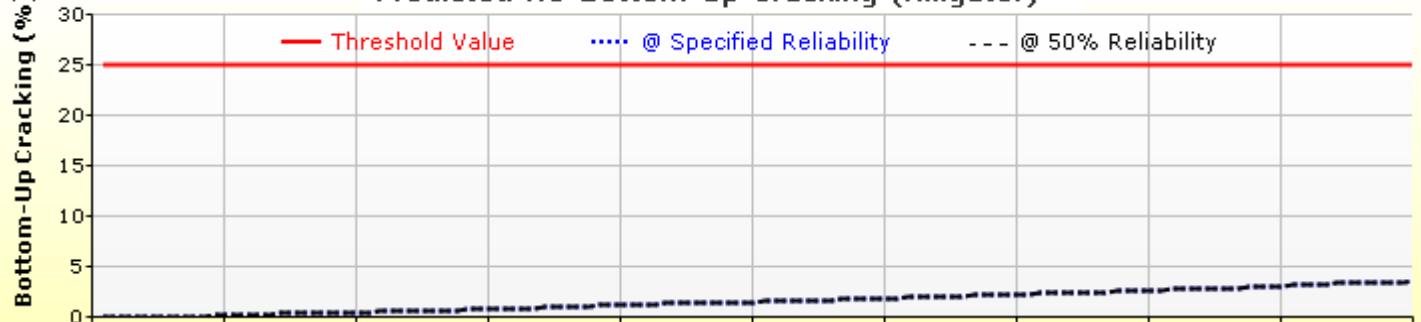
Predicted IRI



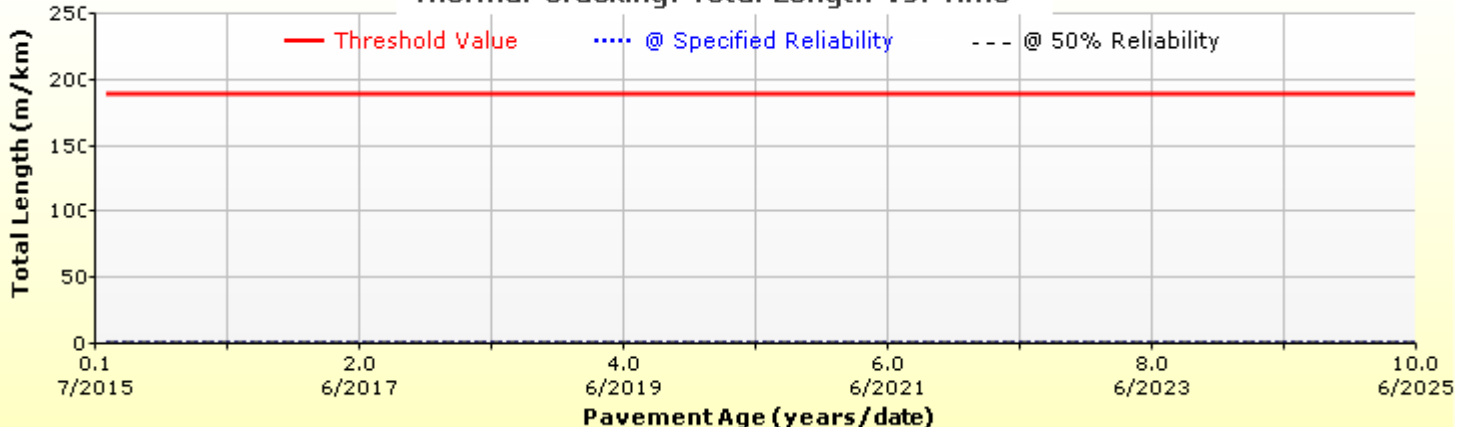
Predicted Total Rutting (Permanent Deformation)



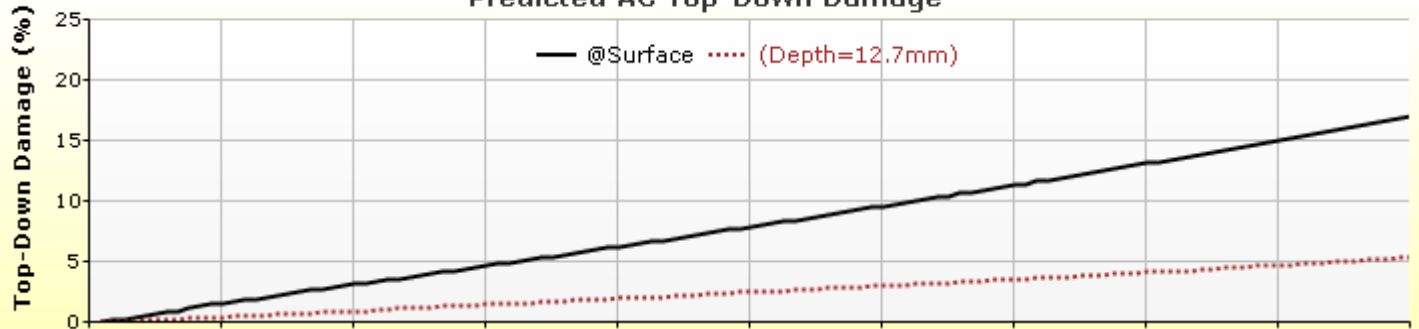
Predicted AC Bottom-Up Cracking (Alligator)



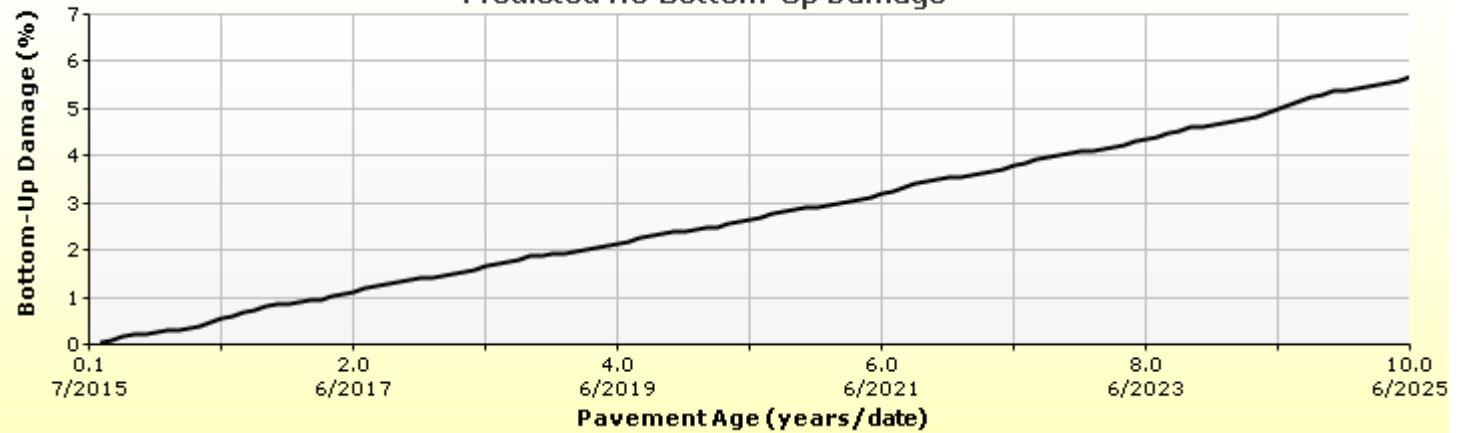
Thermal Cracking: Total Length vs. Time



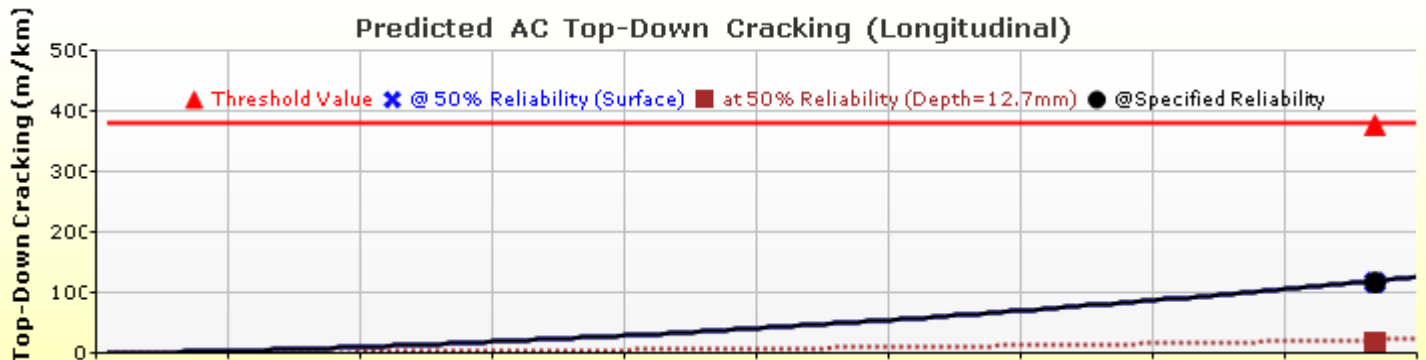
Predicted AC Top-Down Damage



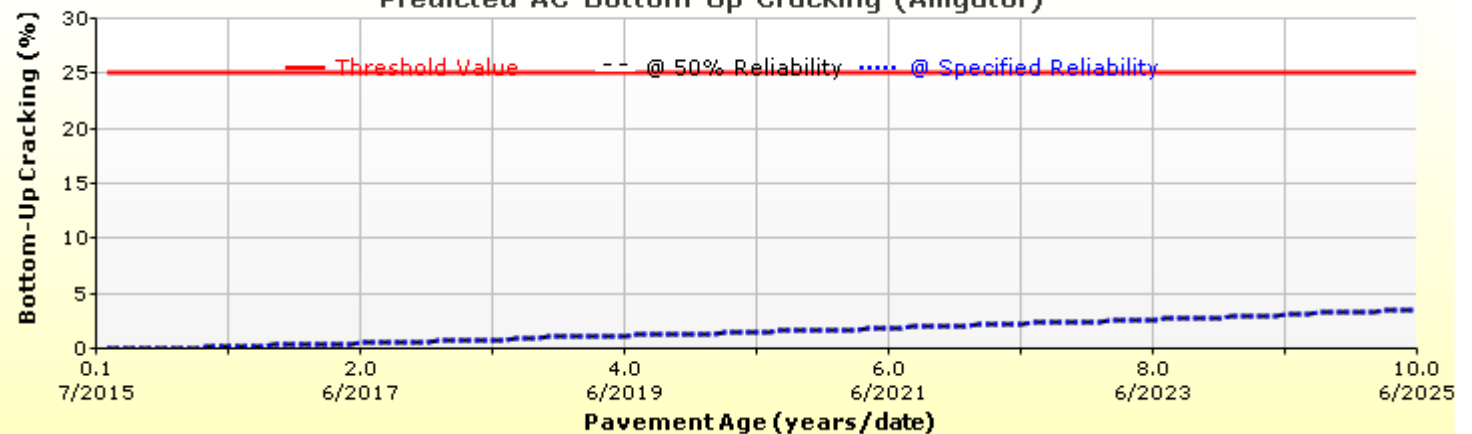
Predicted AC Bottom-Up Damage



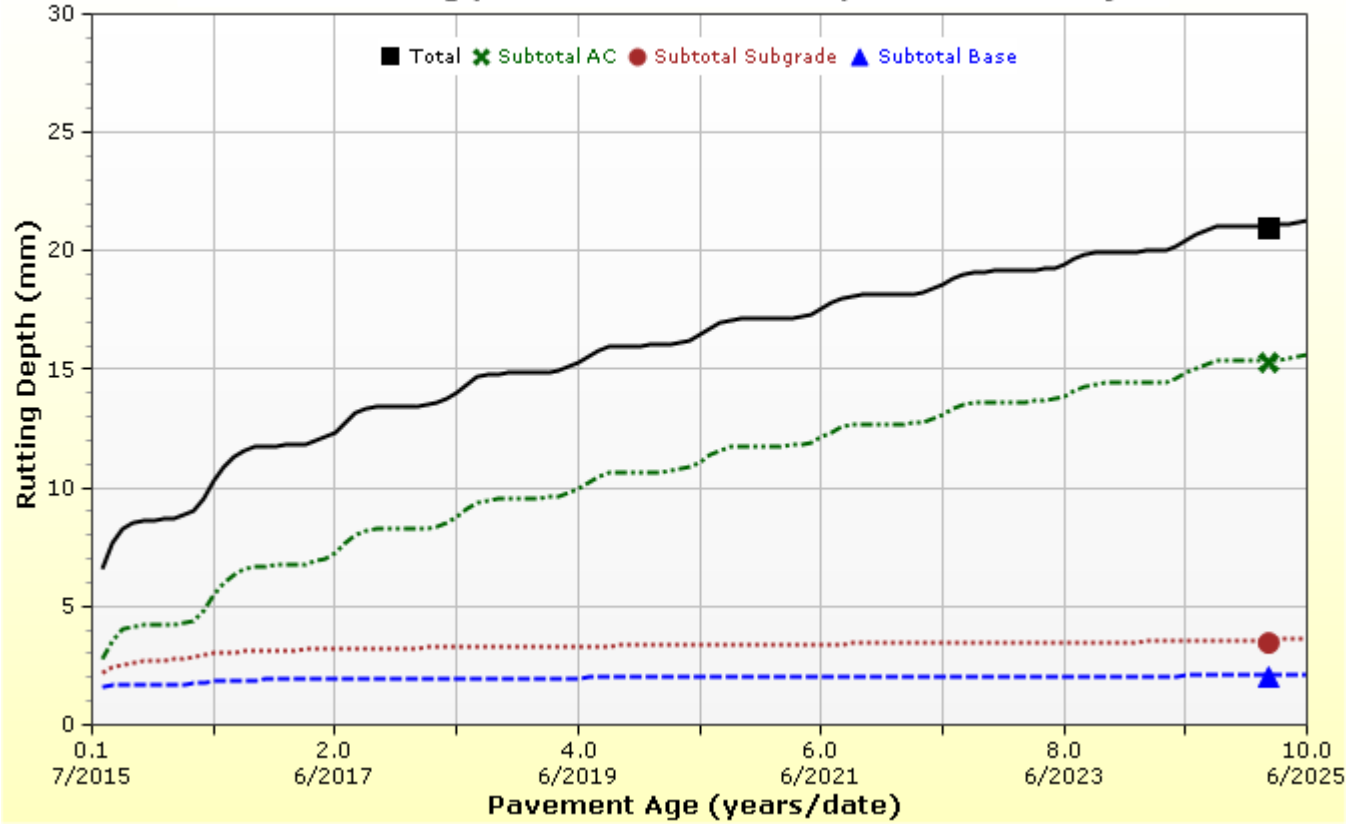
Predicted AC Top-Down Cracking (Longitudinal)

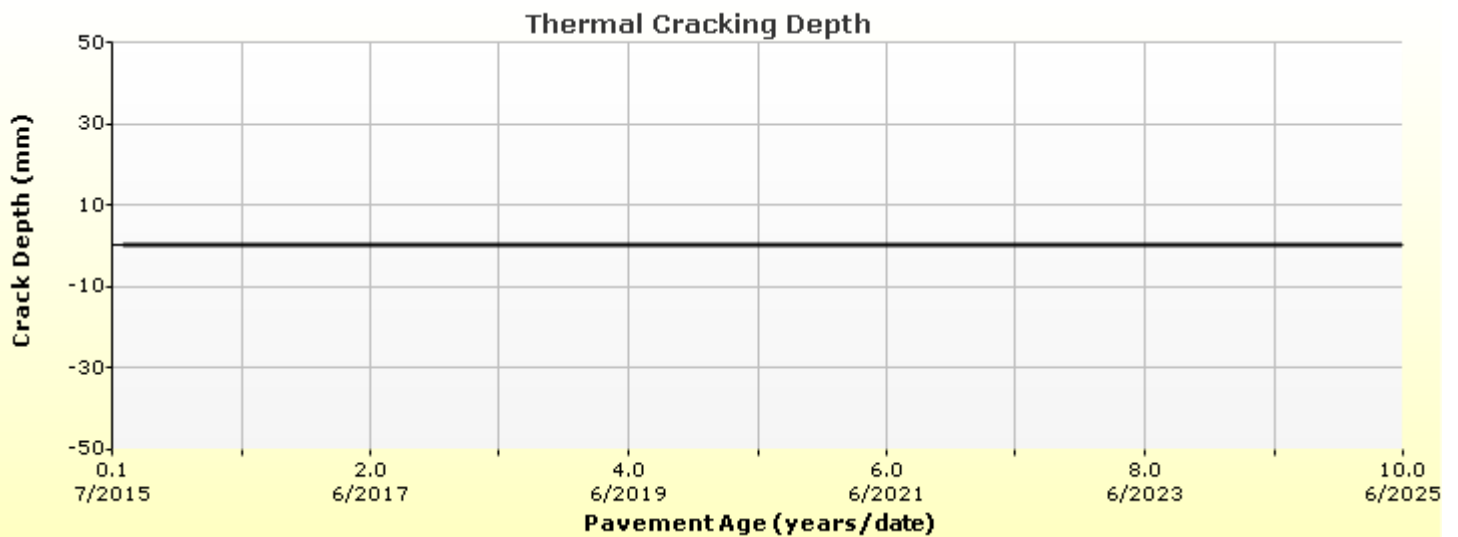
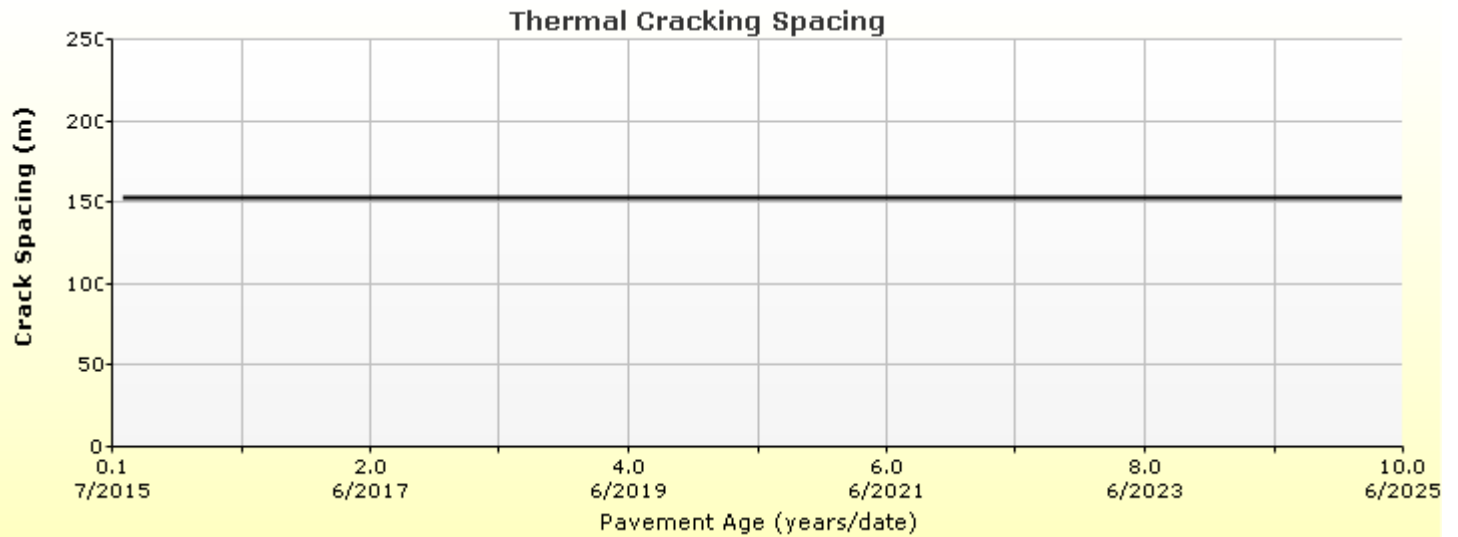


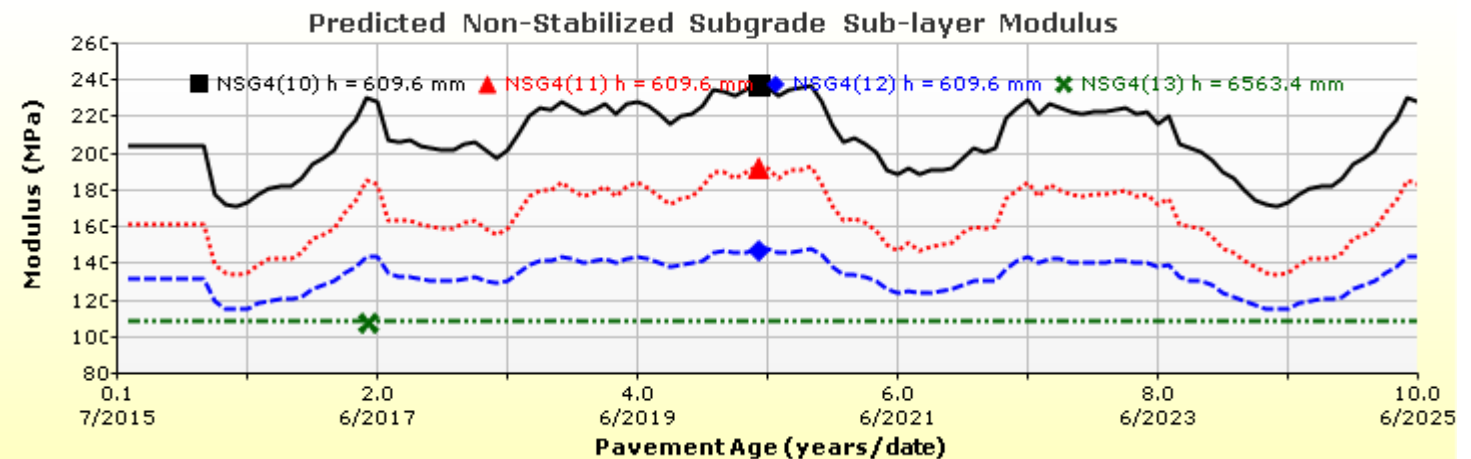
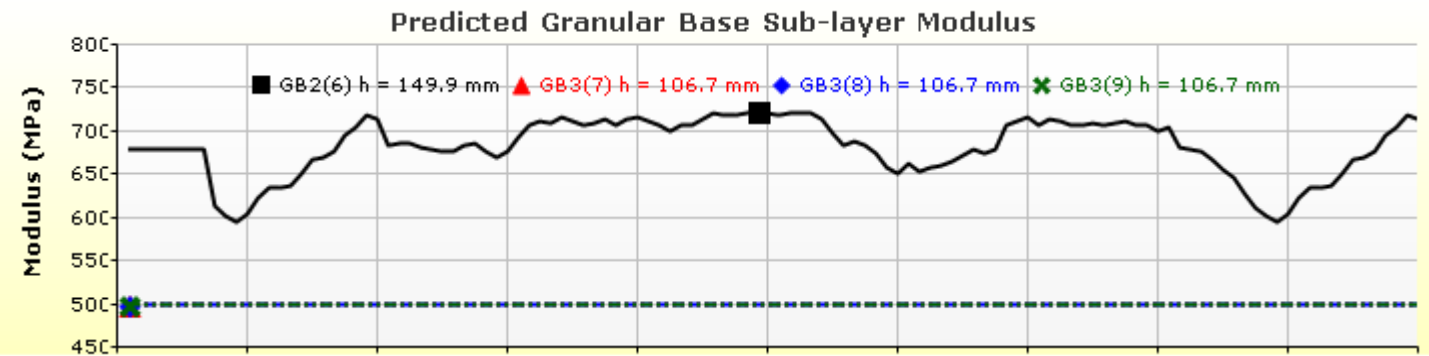
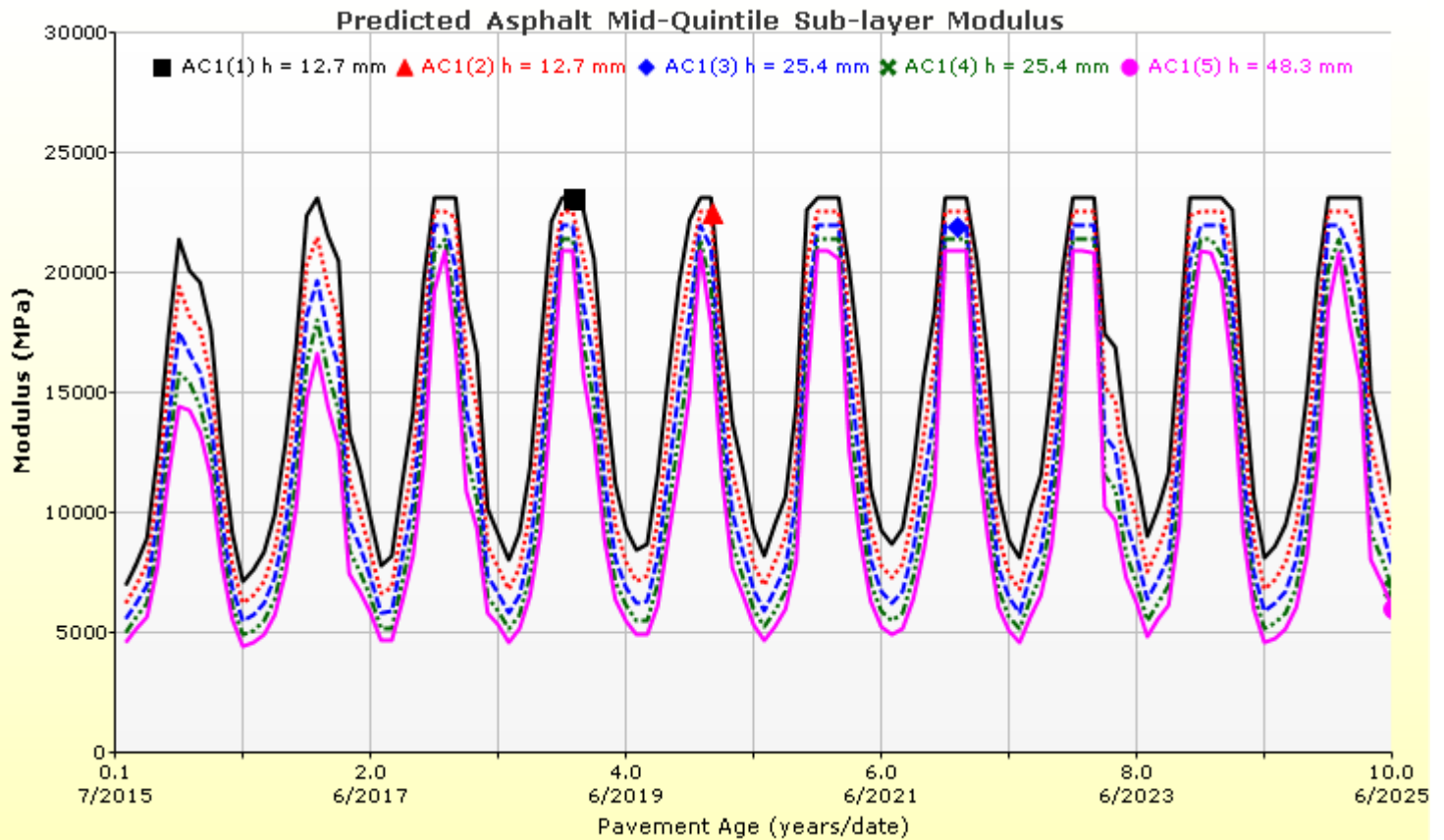
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)
500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

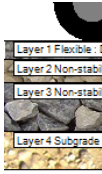
C3: 0.008

C4: 0.015

Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data: 32.119, -81.202
 Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
 Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

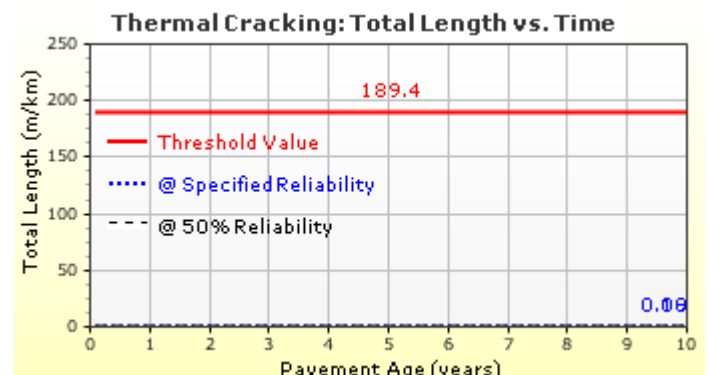
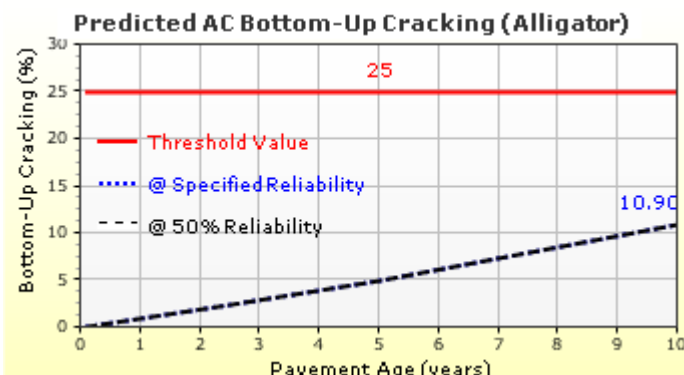
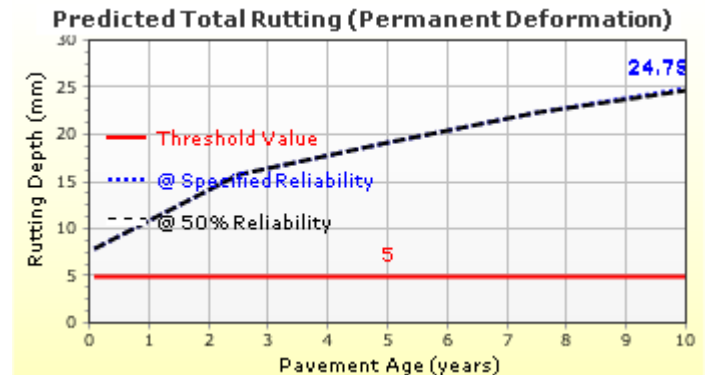
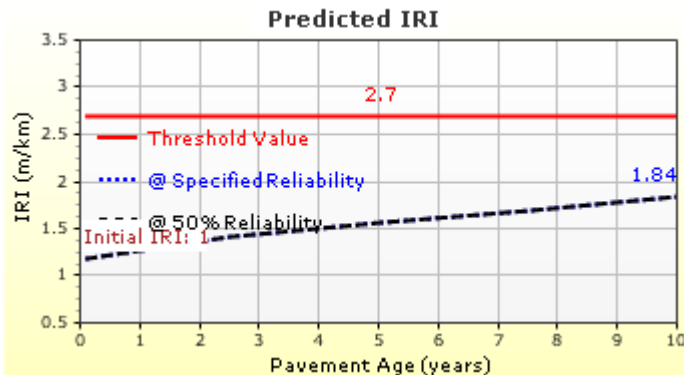
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.84	50.00	95.31	Pass
Permanent deformation - total pavement (mm)	5.00	24.78	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	10.90	50.00	84.08	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	428.03	50.00	45.54	Fail
Permanent deformation - AC only (mm)	5.00	18.09	50.00	0.25	Fail

Distress Charts

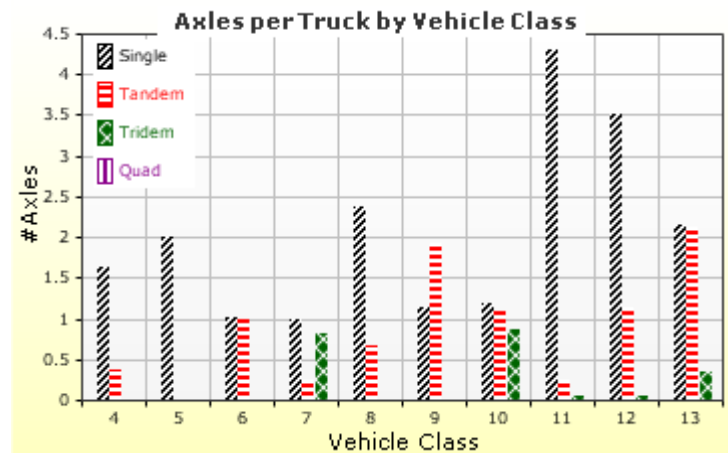
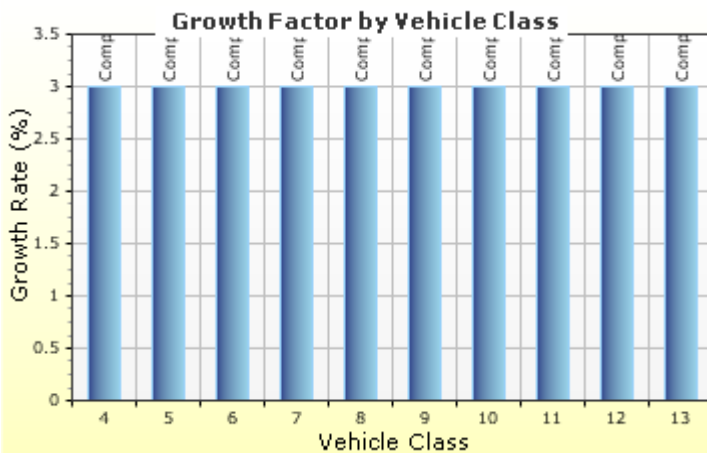
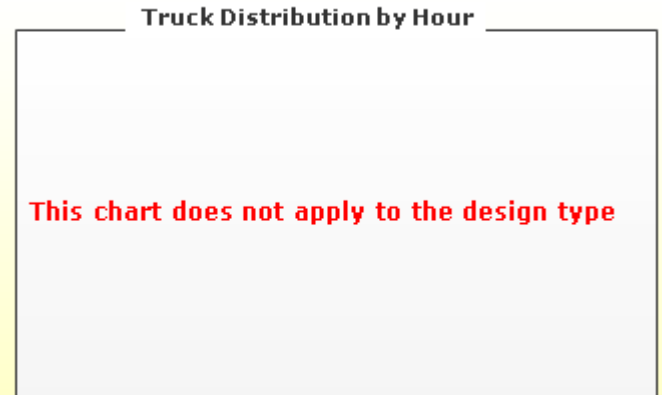
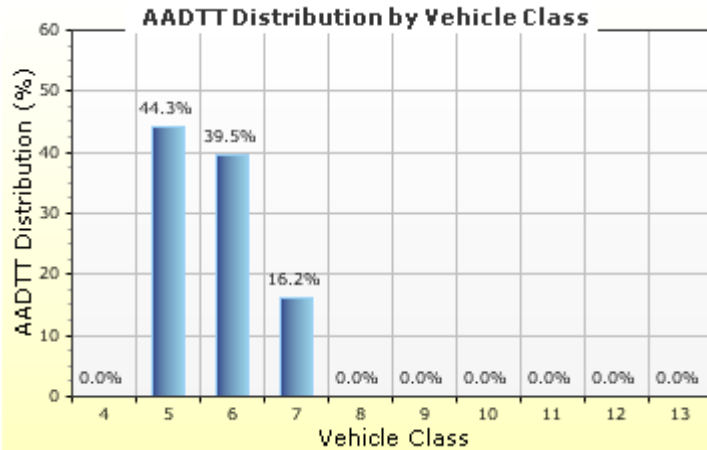


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

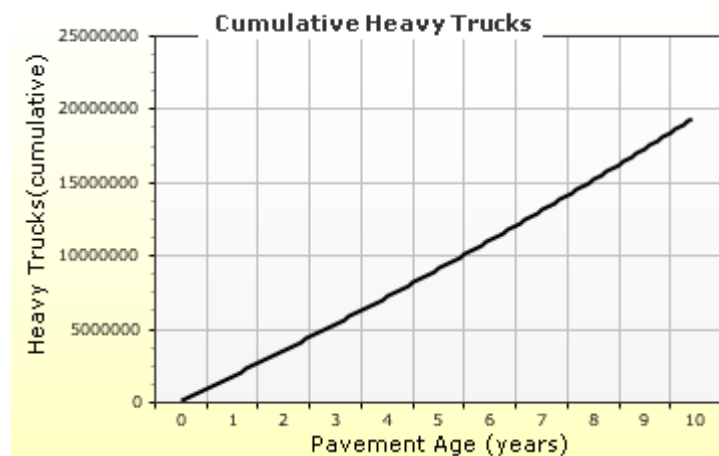
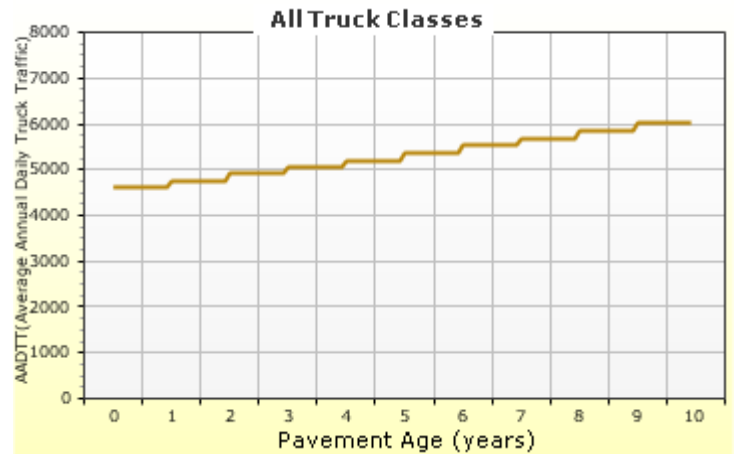
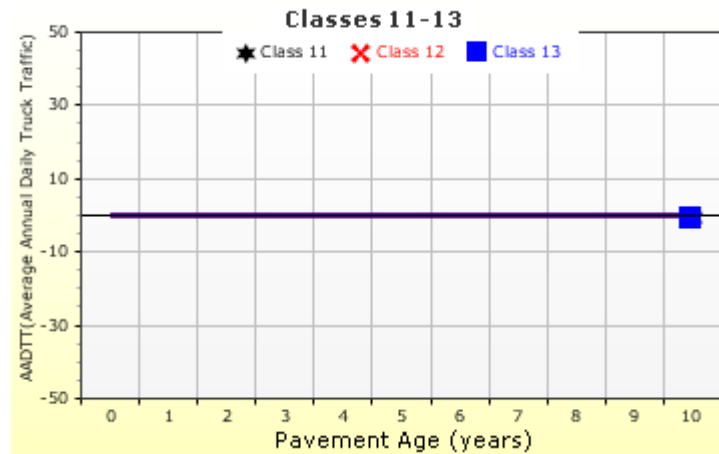
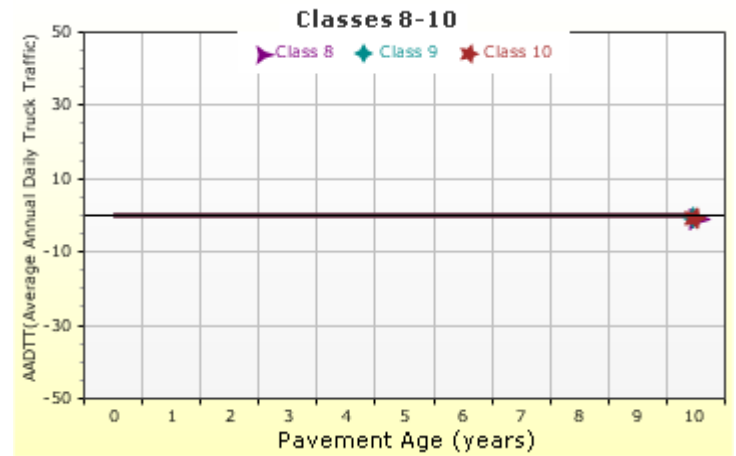
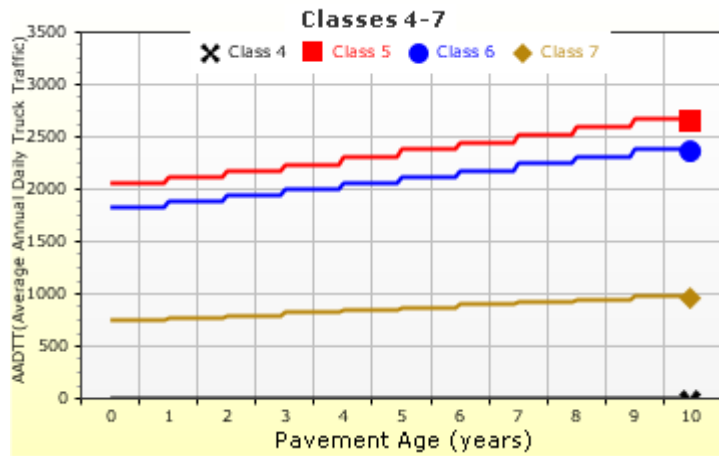
Wheelbase does not apply

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



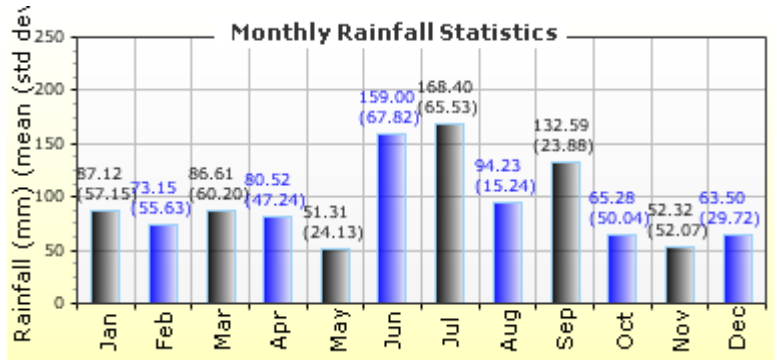
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

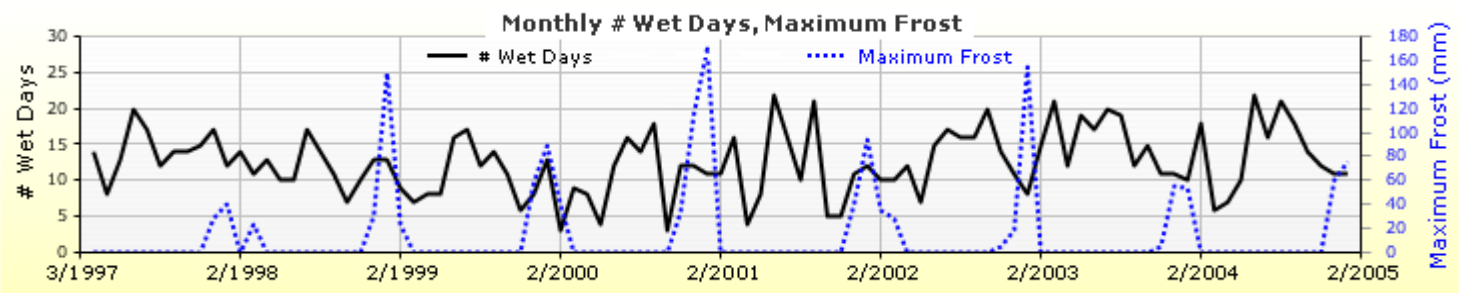
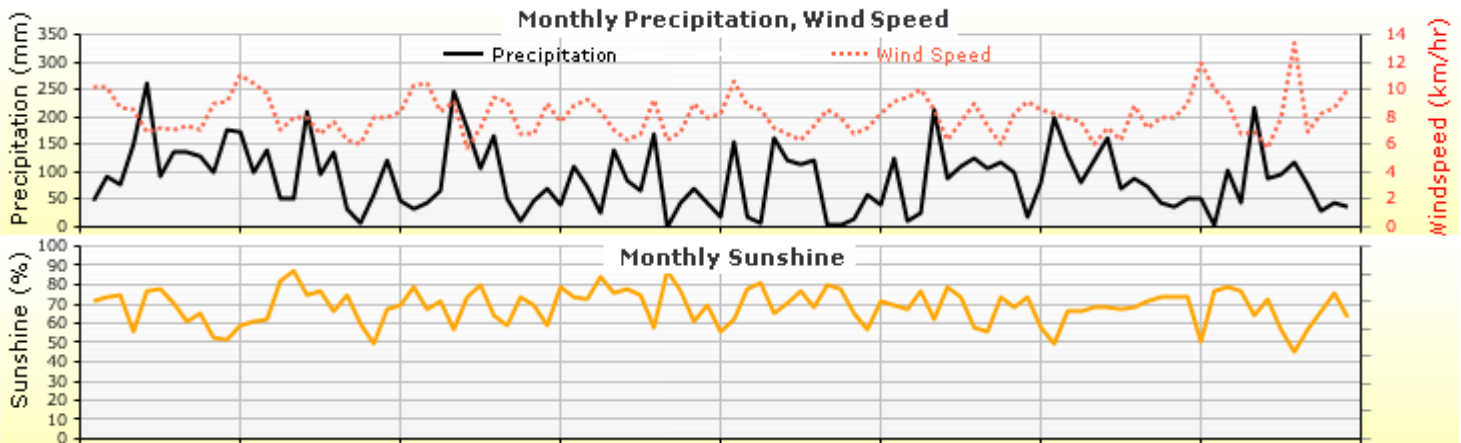
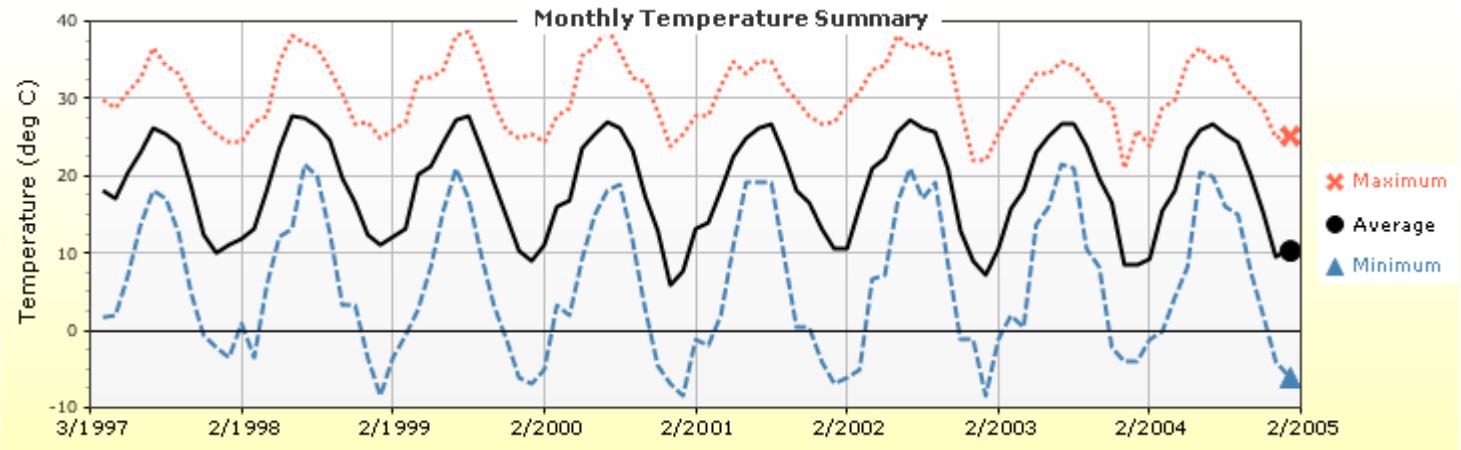
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

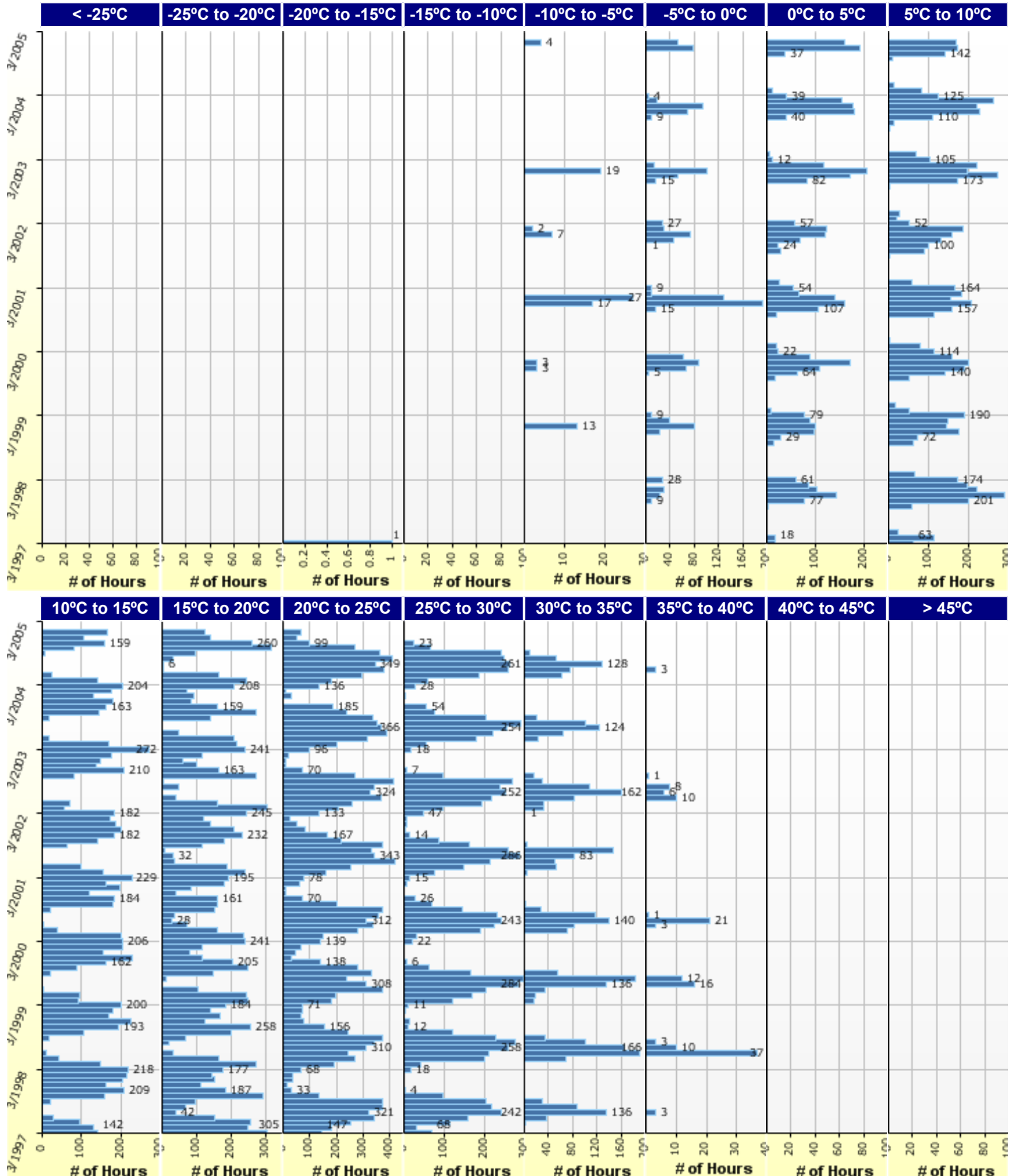


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF2_ALT2

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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

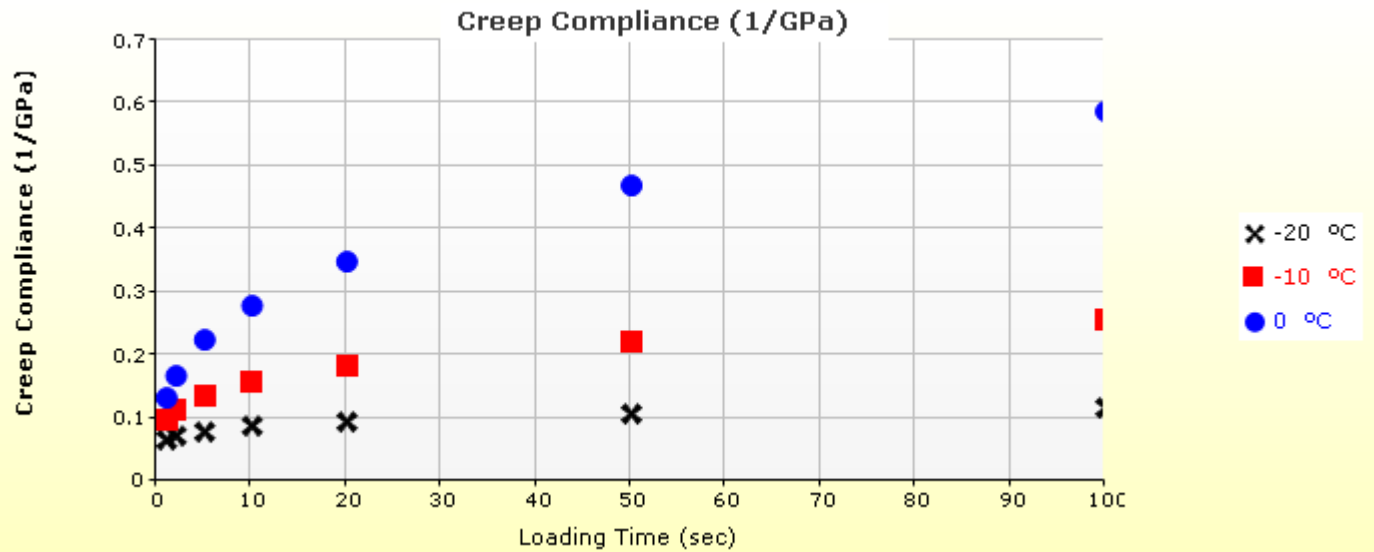
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

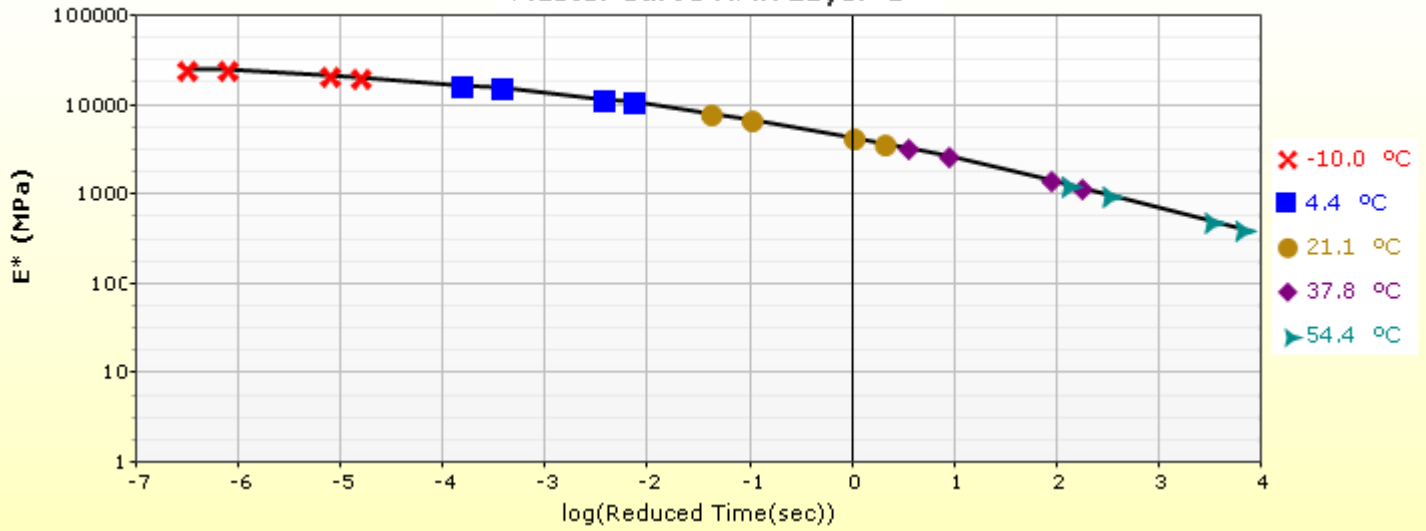
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

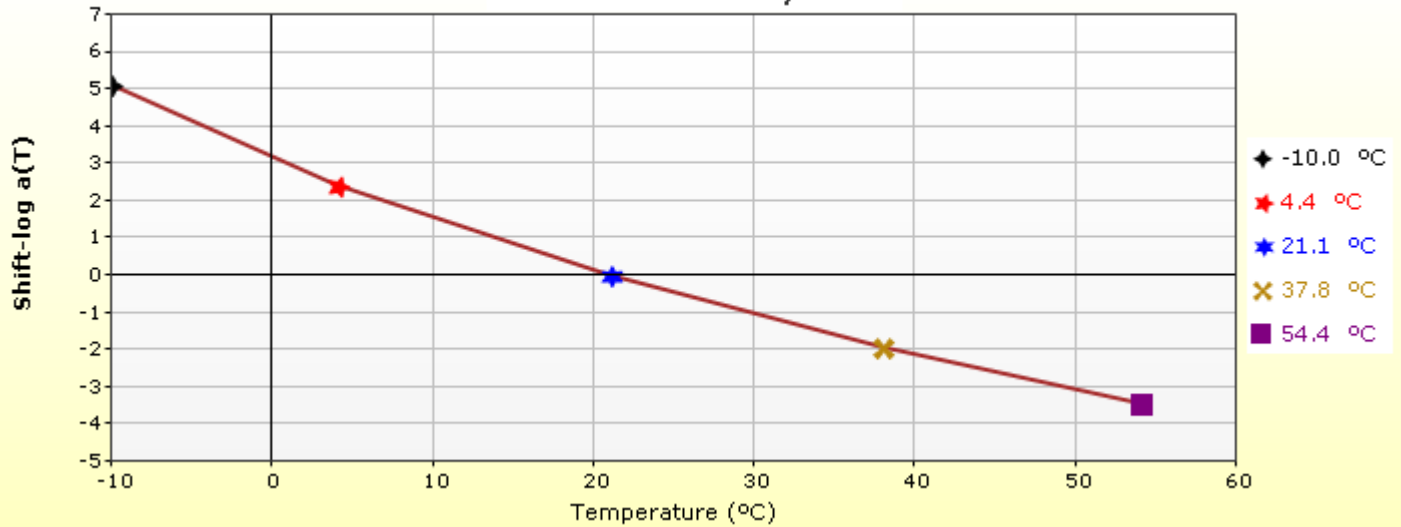


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

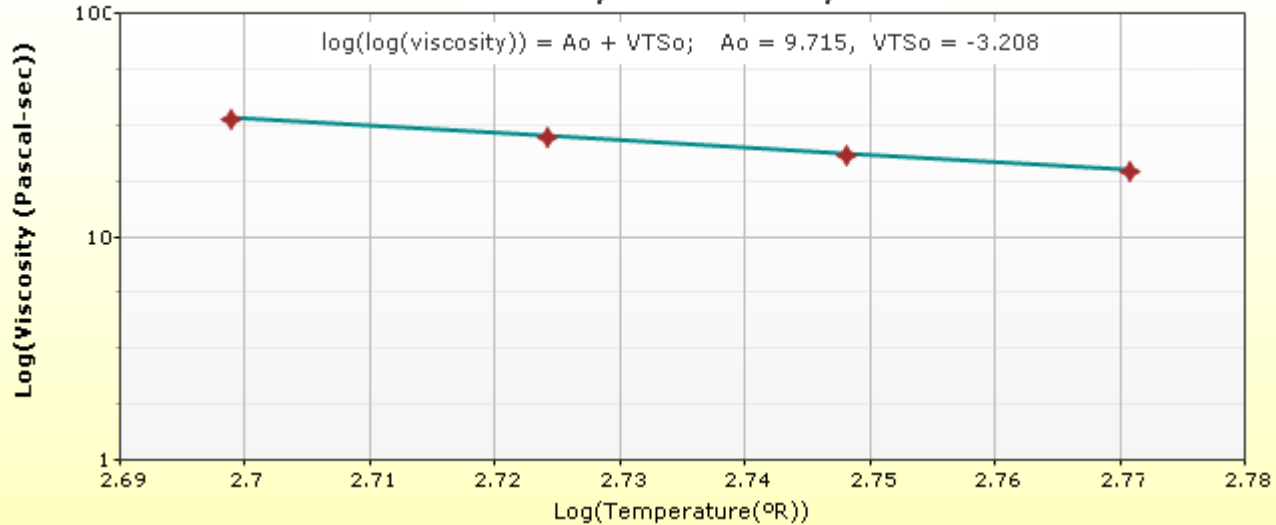
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

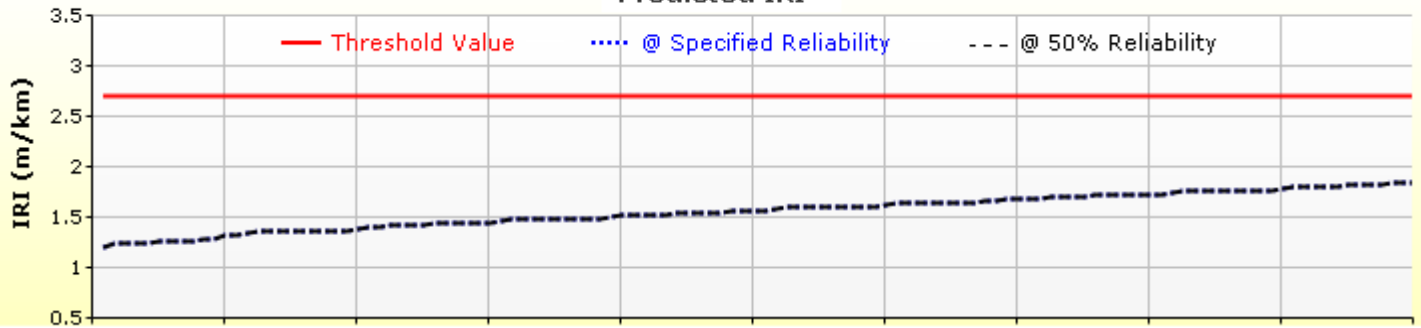


Viscosity Curve HMA Layer 1

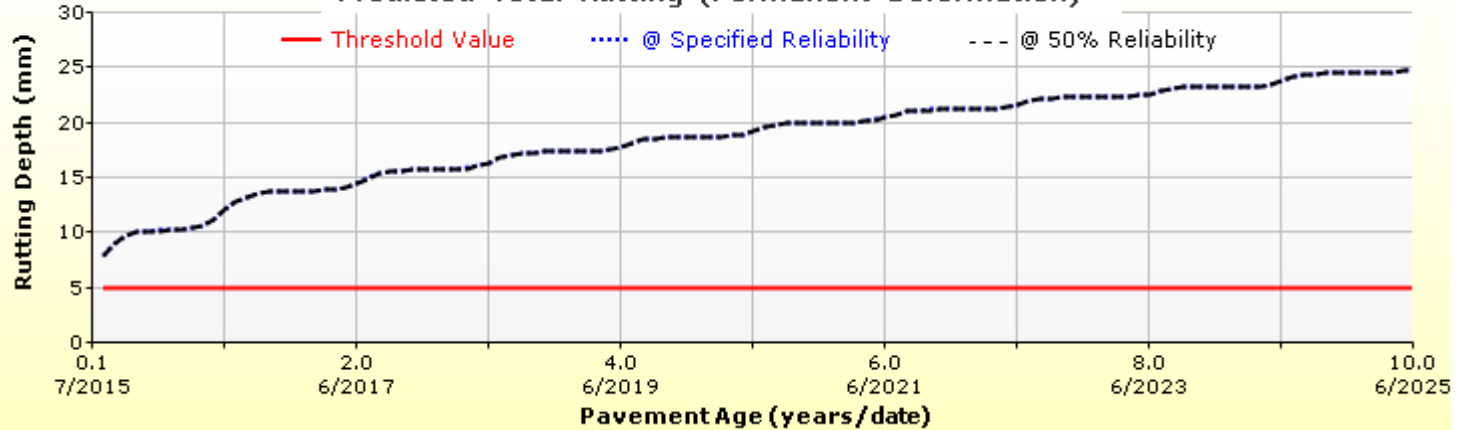


Analysis Output Charts

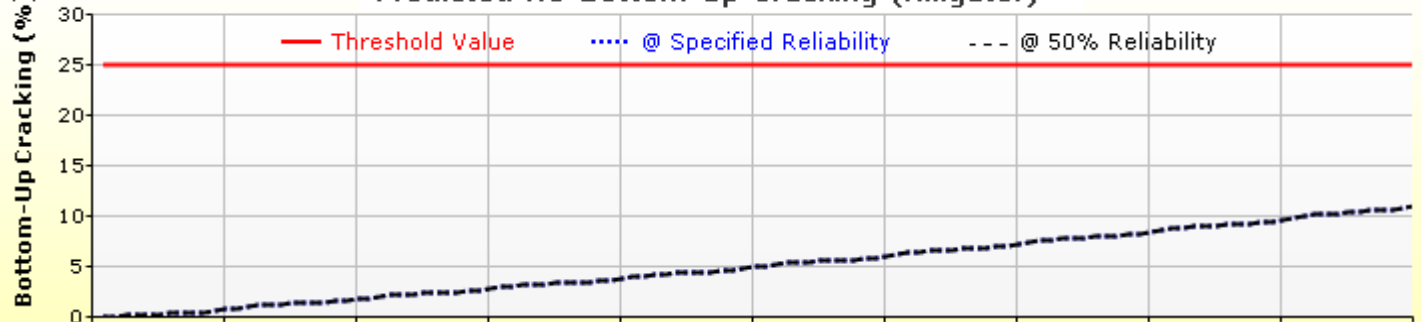
Predicted IRI



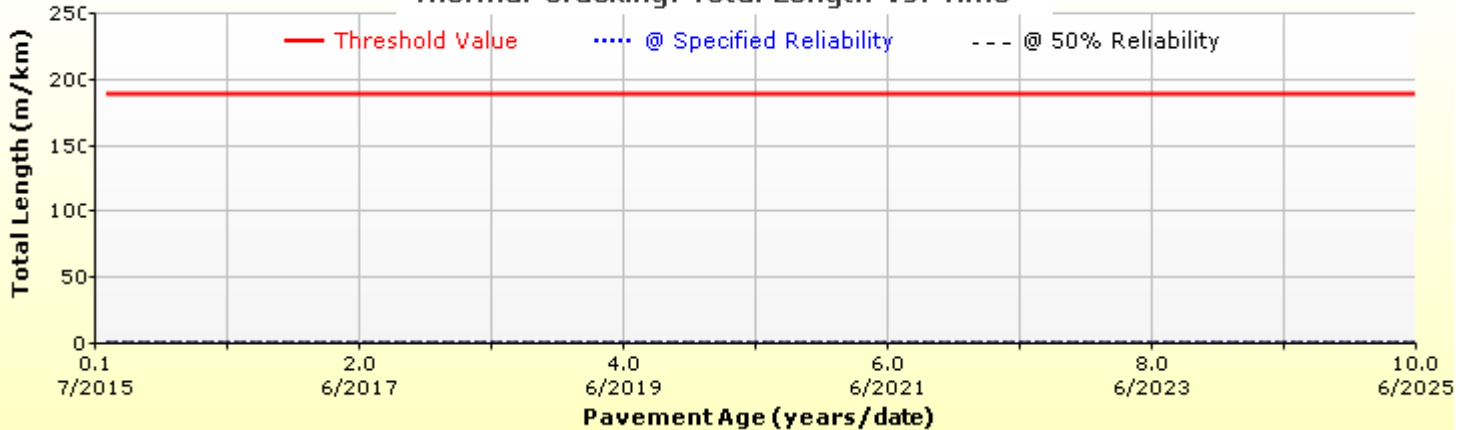
Predicted Total Rutting (Permanent Deformation)



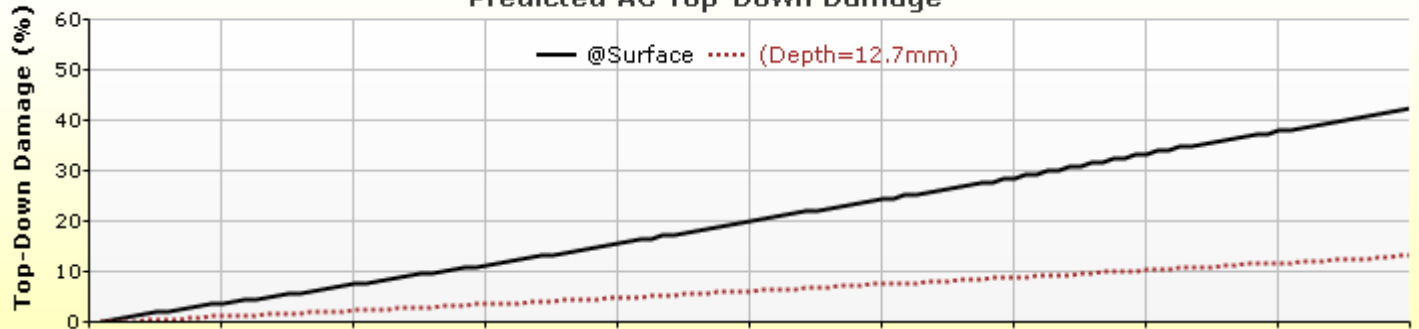
Predicted AC Bottom-Up Cracking (Alligator)



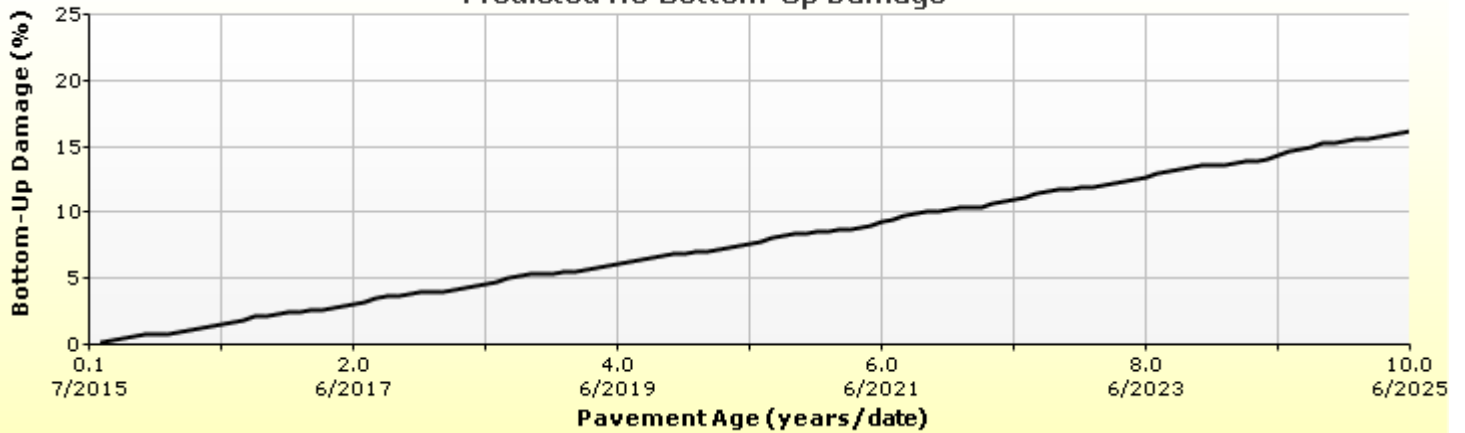
Thermal Cracking: Total Length vs. Time



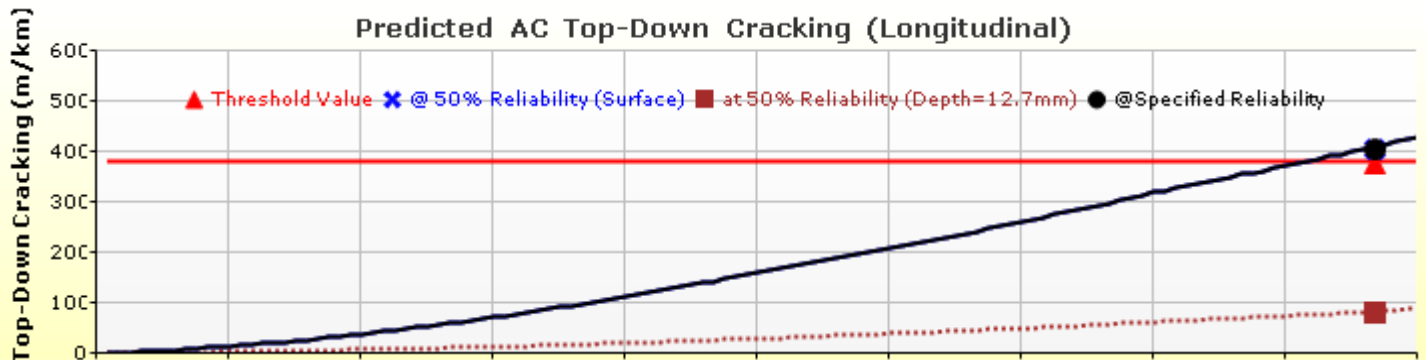
Predicted AC Top-Down Damage



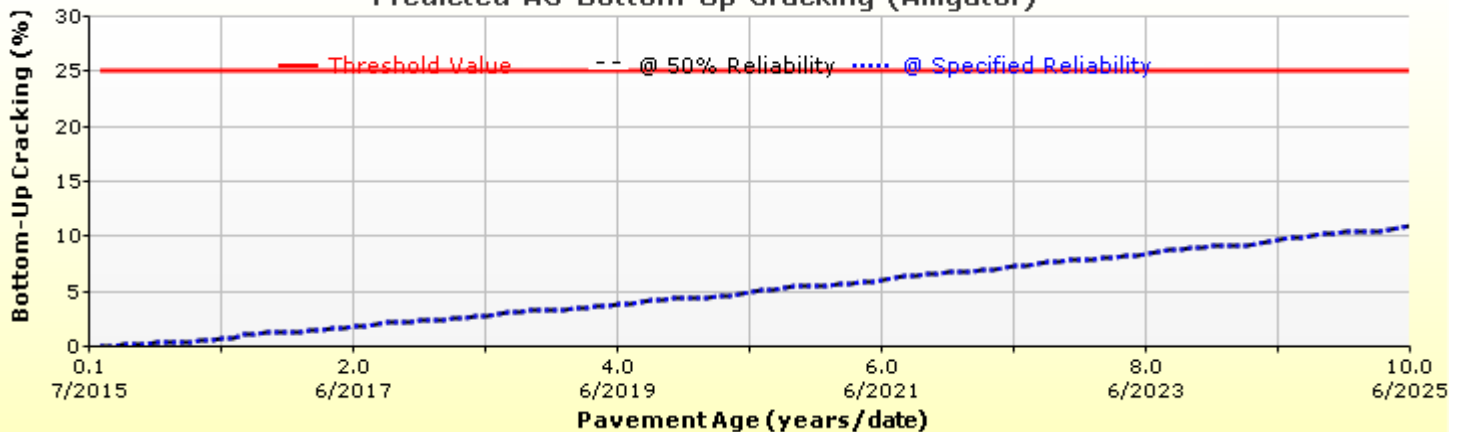
Predicted AC Bottom-Up Damage



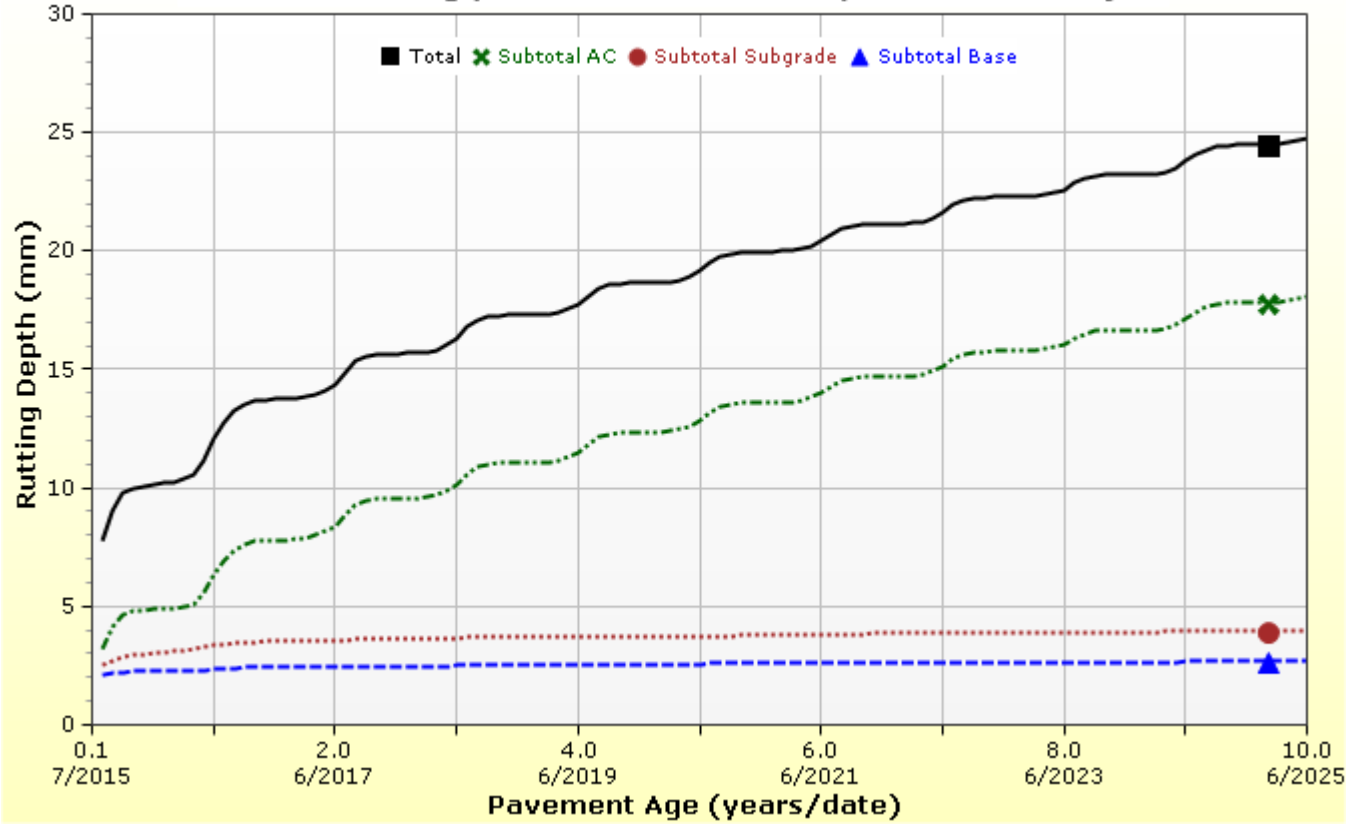
Predicted AC Top-Down Cracking (Longitudinal)

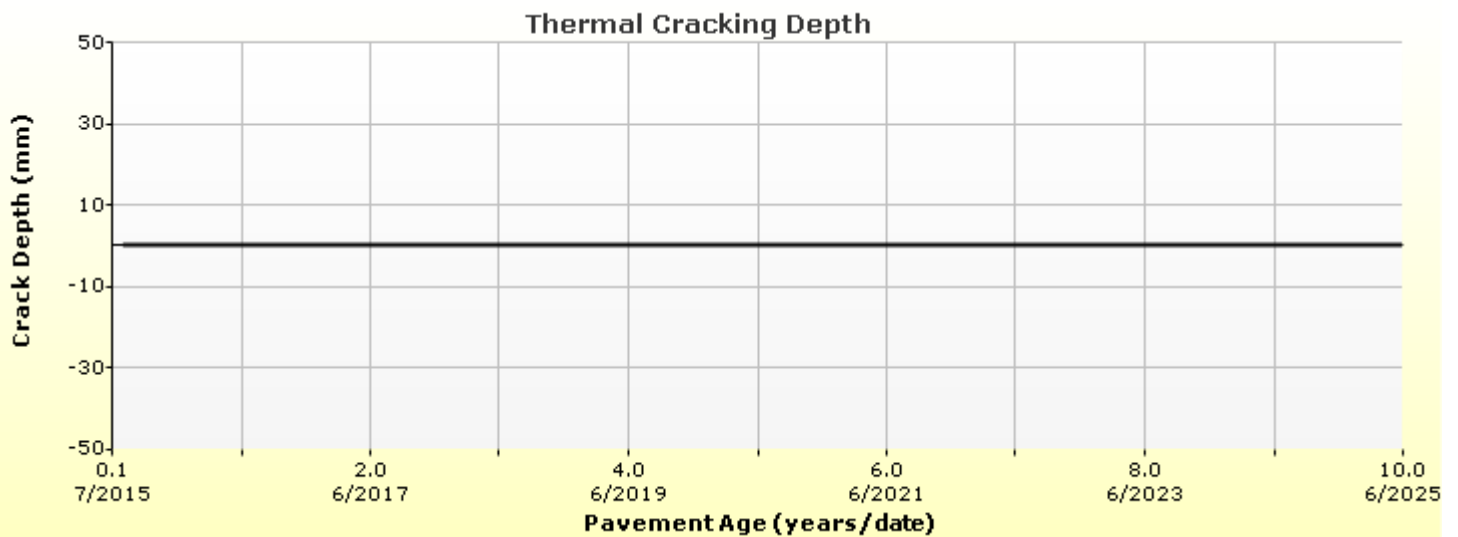
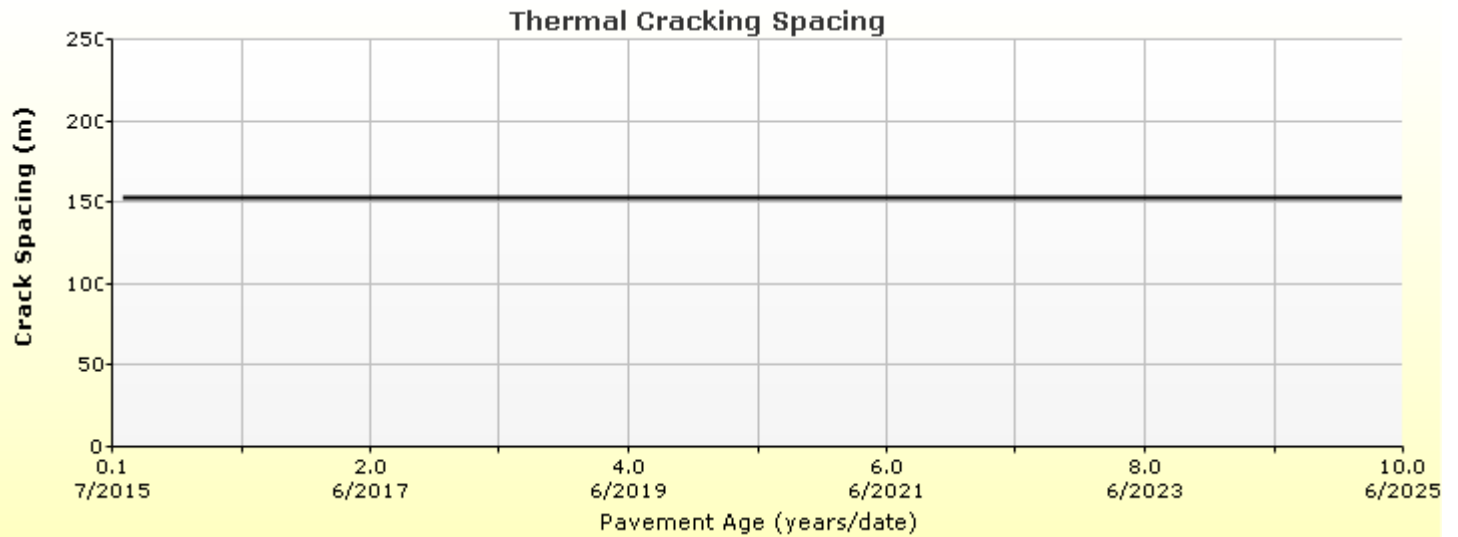


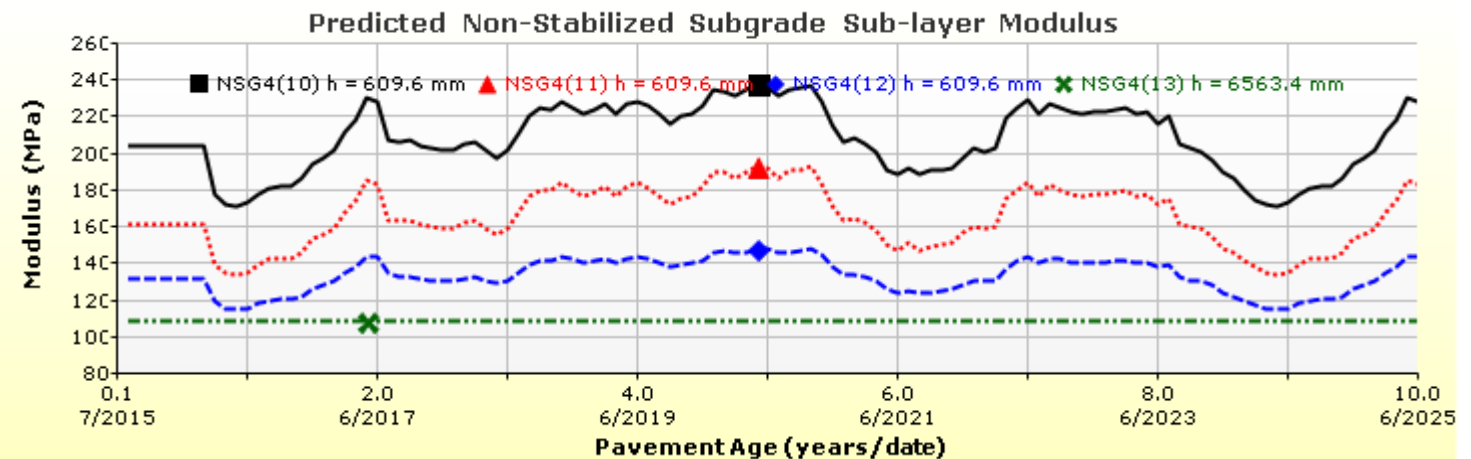
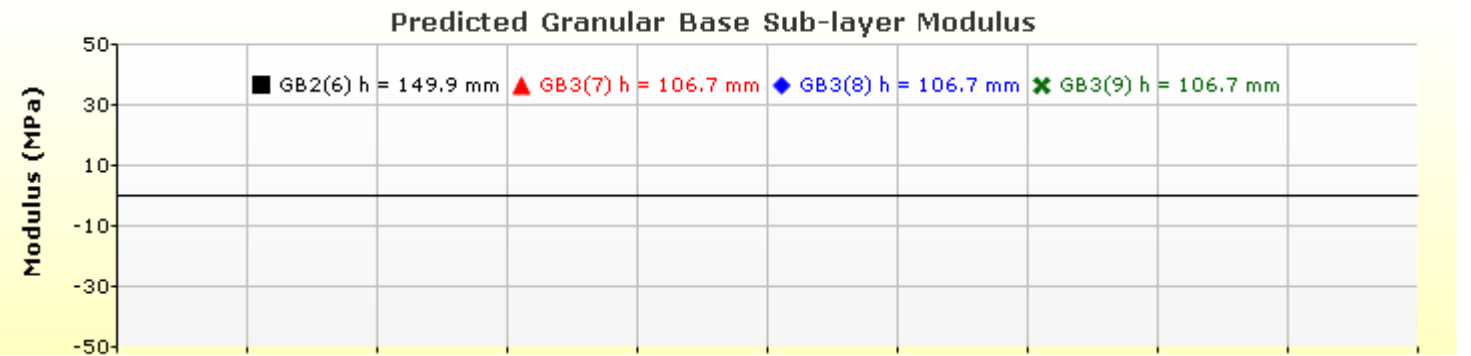
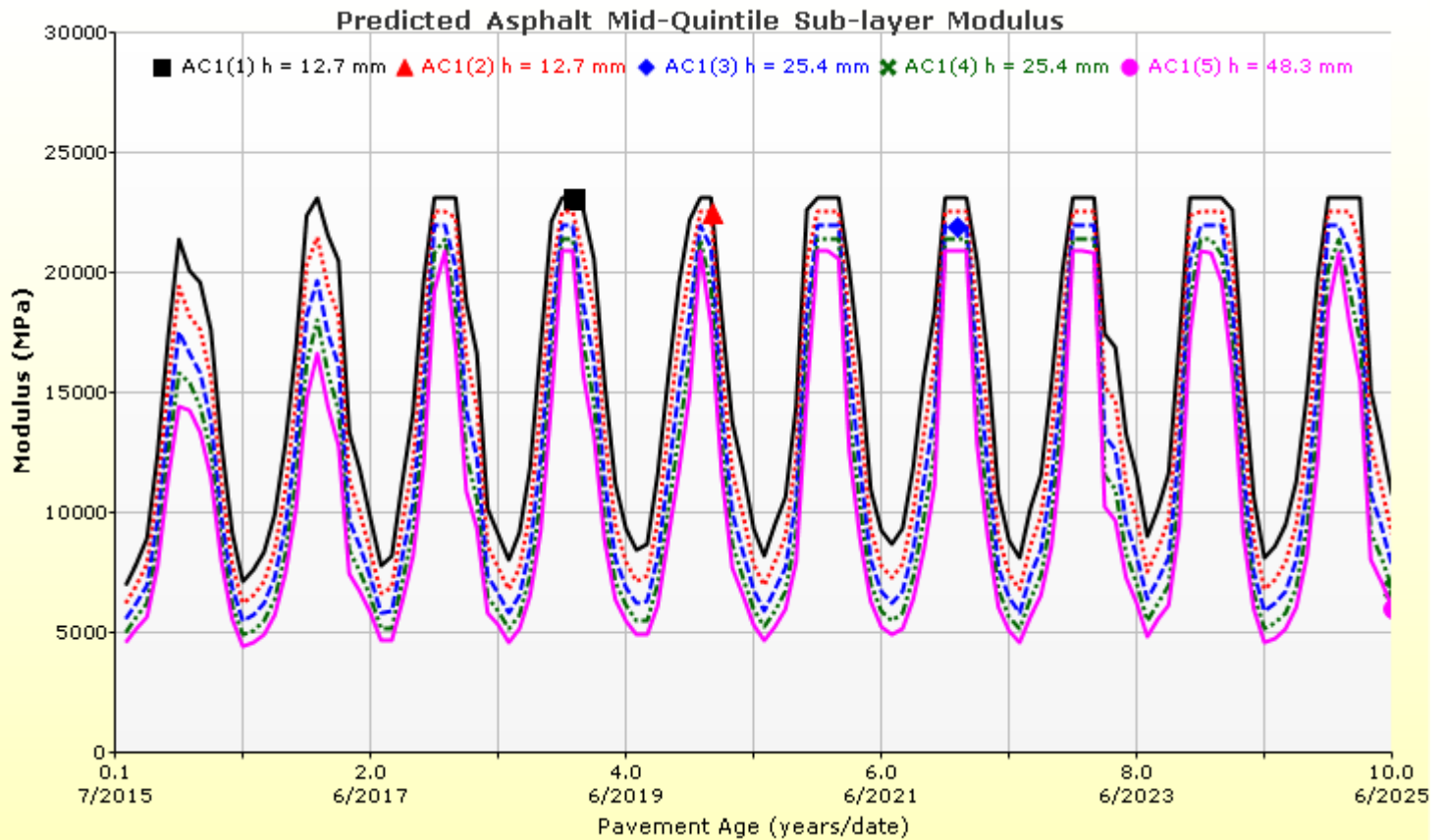
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = number\ of\ repetitions\ to\ fatigue\ cracking$ $\sigma_s = Tensile\ stress(ksi)$ $M_r = modulus\ of\ rupture(ksi)$
k1: 1	k2: 1 Bc1: 1 Bc2: 1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

Standard Deviation (BASERUT)

0.1235*Pow(SUBRUT,0.5012)+0.001

AC Cracking

AC Top Down Cracking

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

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: 7

c2: 3.5

c3: 0

c4: 1000

c1: 1

c2: 1

c3: 6000

AC Cracking Top Standard Deviation

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

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

IRI Flexible Pavements

C1 - Rutting

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

CSM Standard Deviation

CTB*1

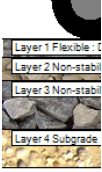
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

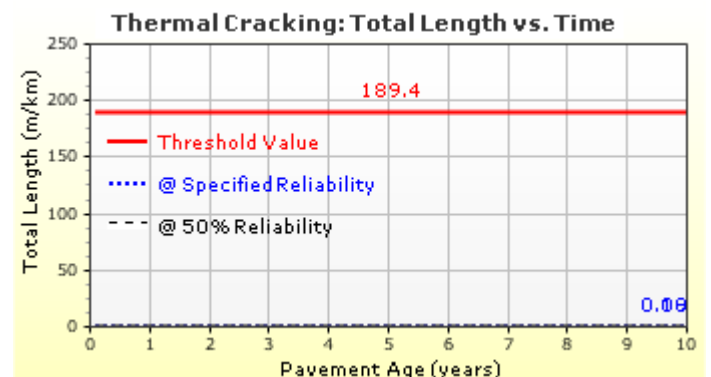
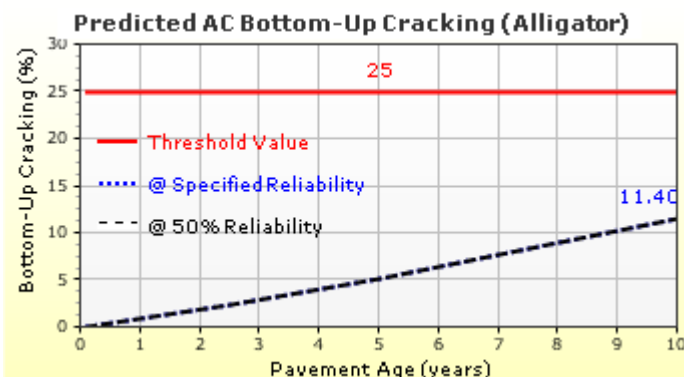
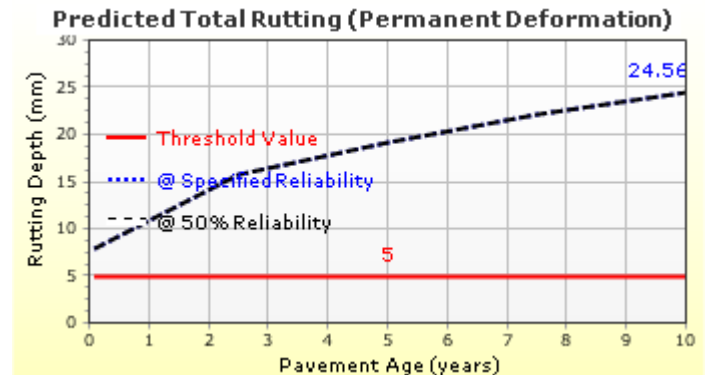
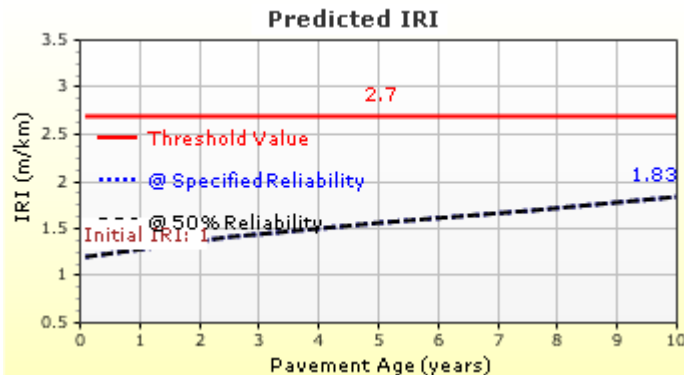
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.83	50.00	95.41	Pass
Permanent deformation - total pavement (mm)	5.00	24.56	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	11.40	50.00	83.21	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	409.09	50.00	47.24	Fail
Permanent deformation - AC only (mm)	5.00	17.57	50.00	0.29	Fail

Distress Charts

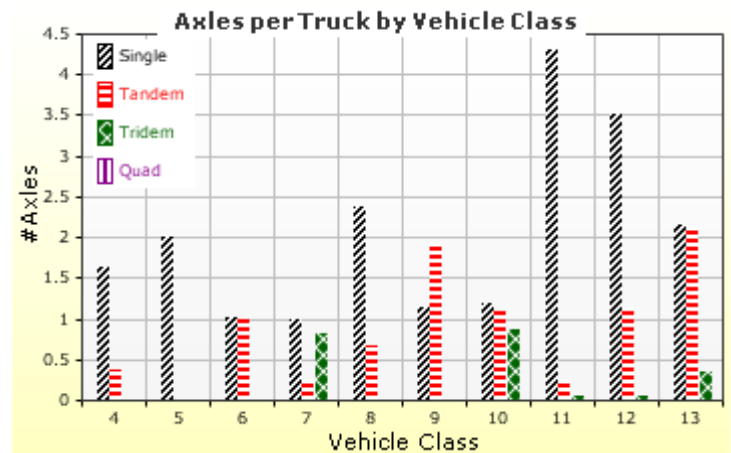
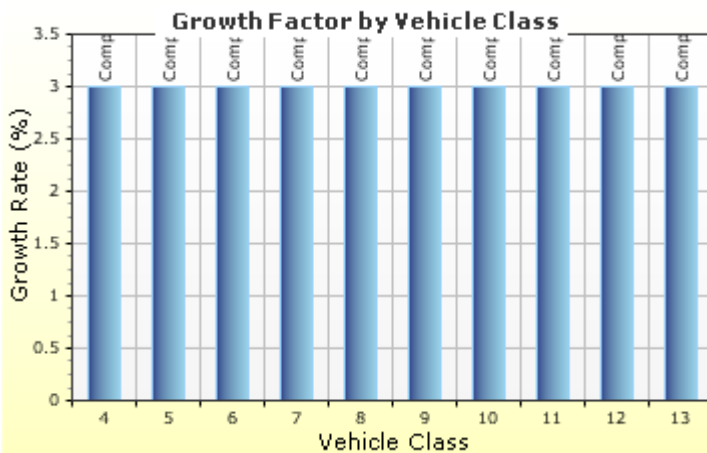
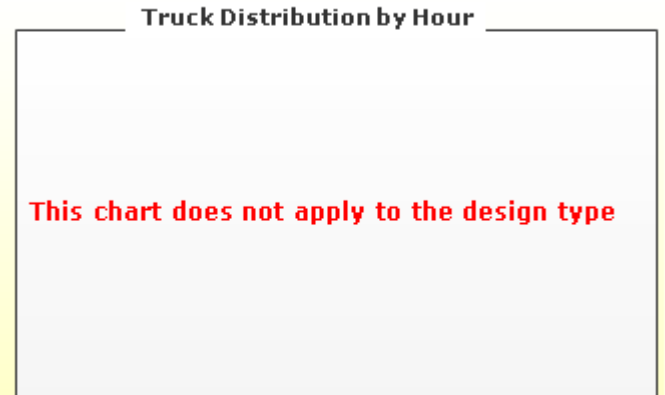
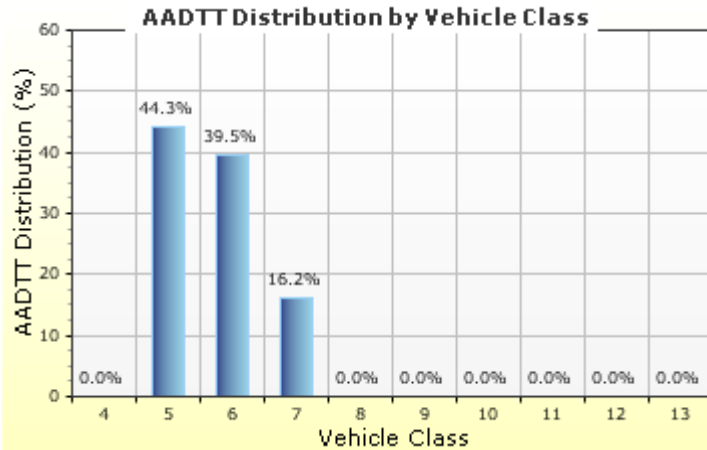


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

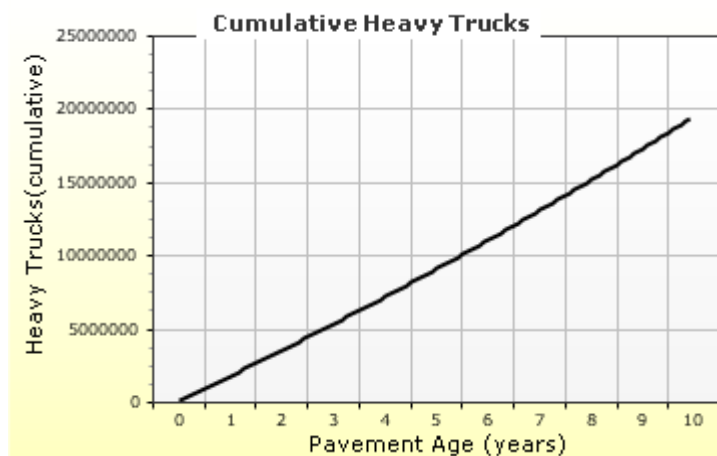
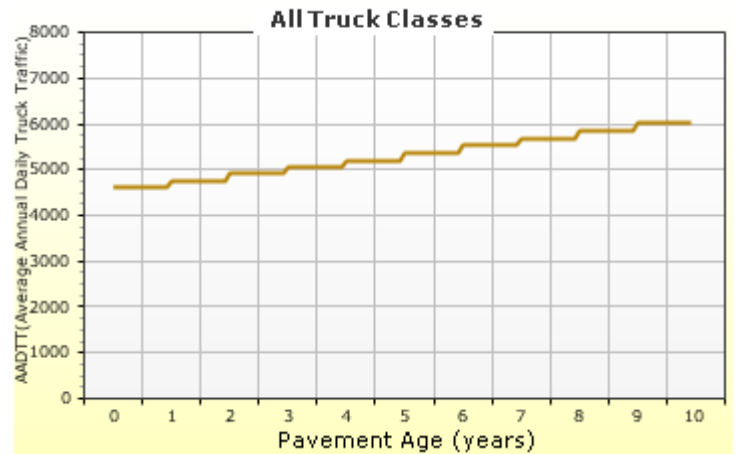
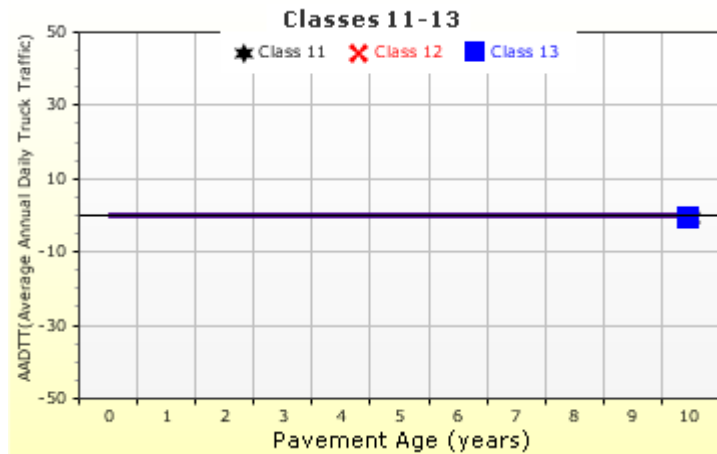
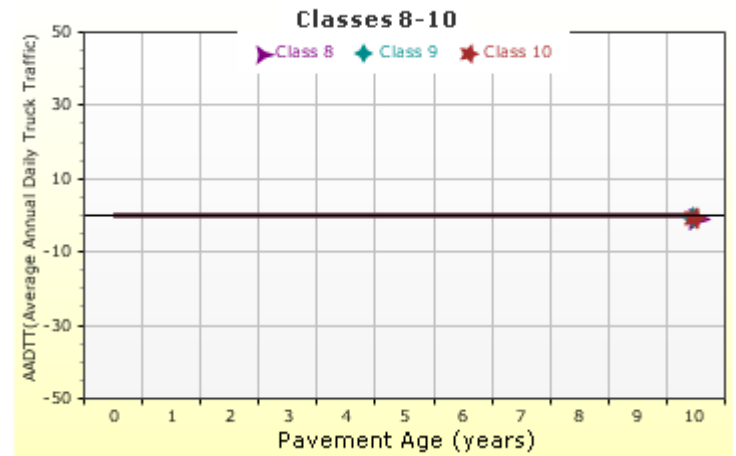
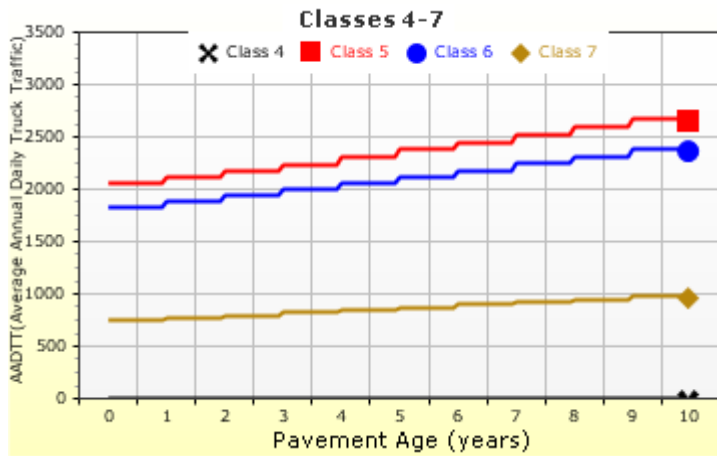
Wheelbase does not apply

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



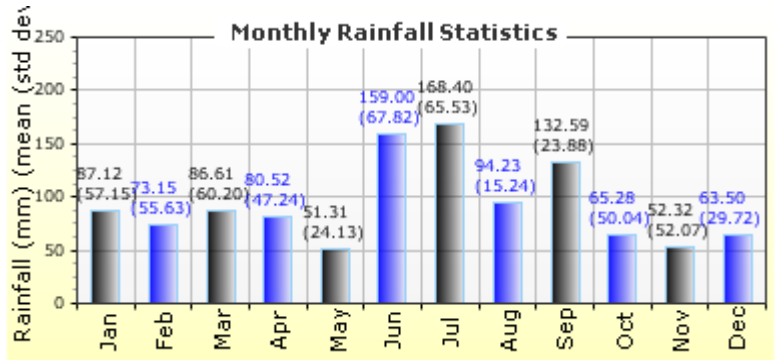
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

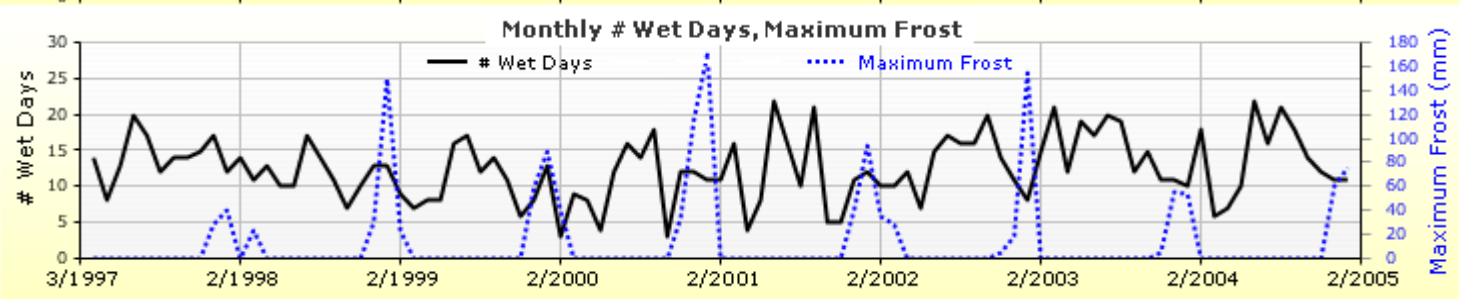
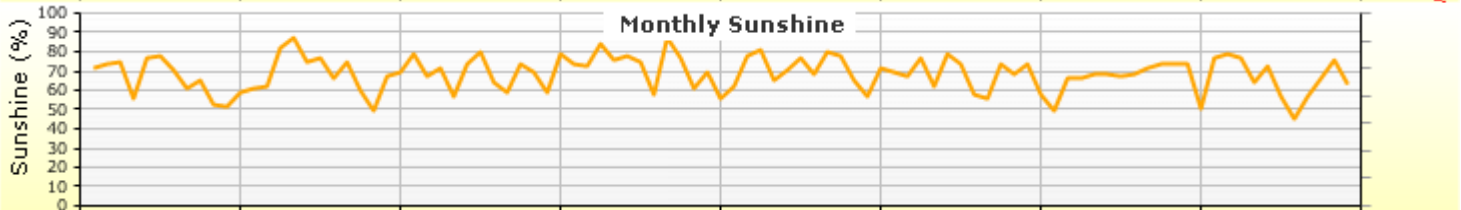
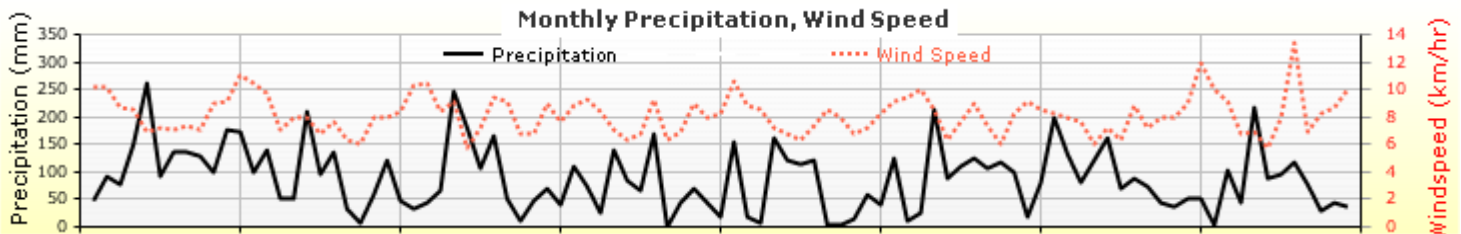
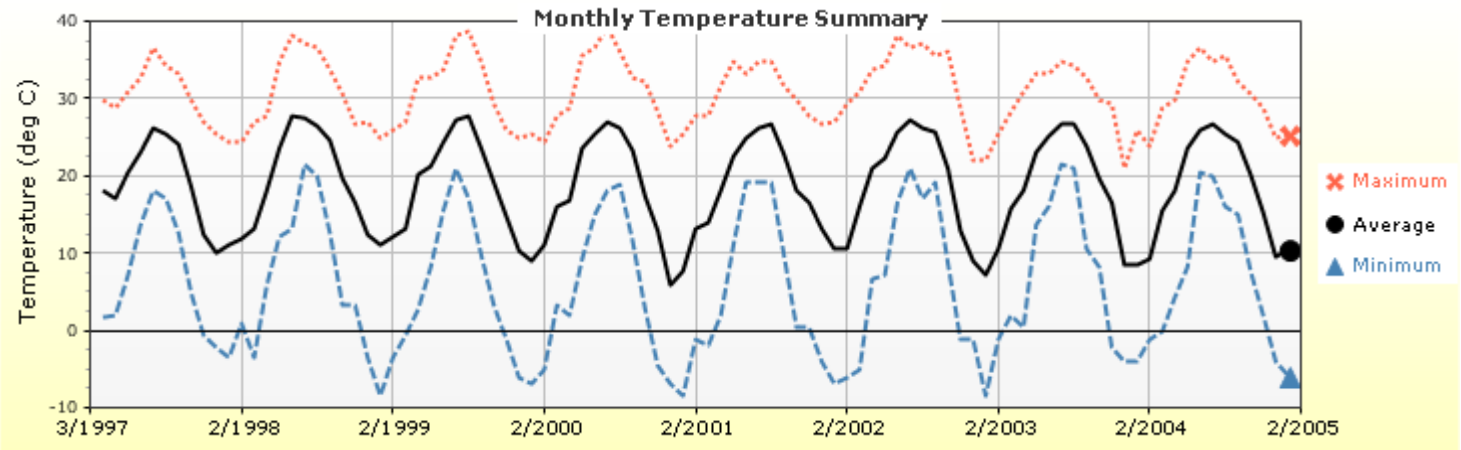
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

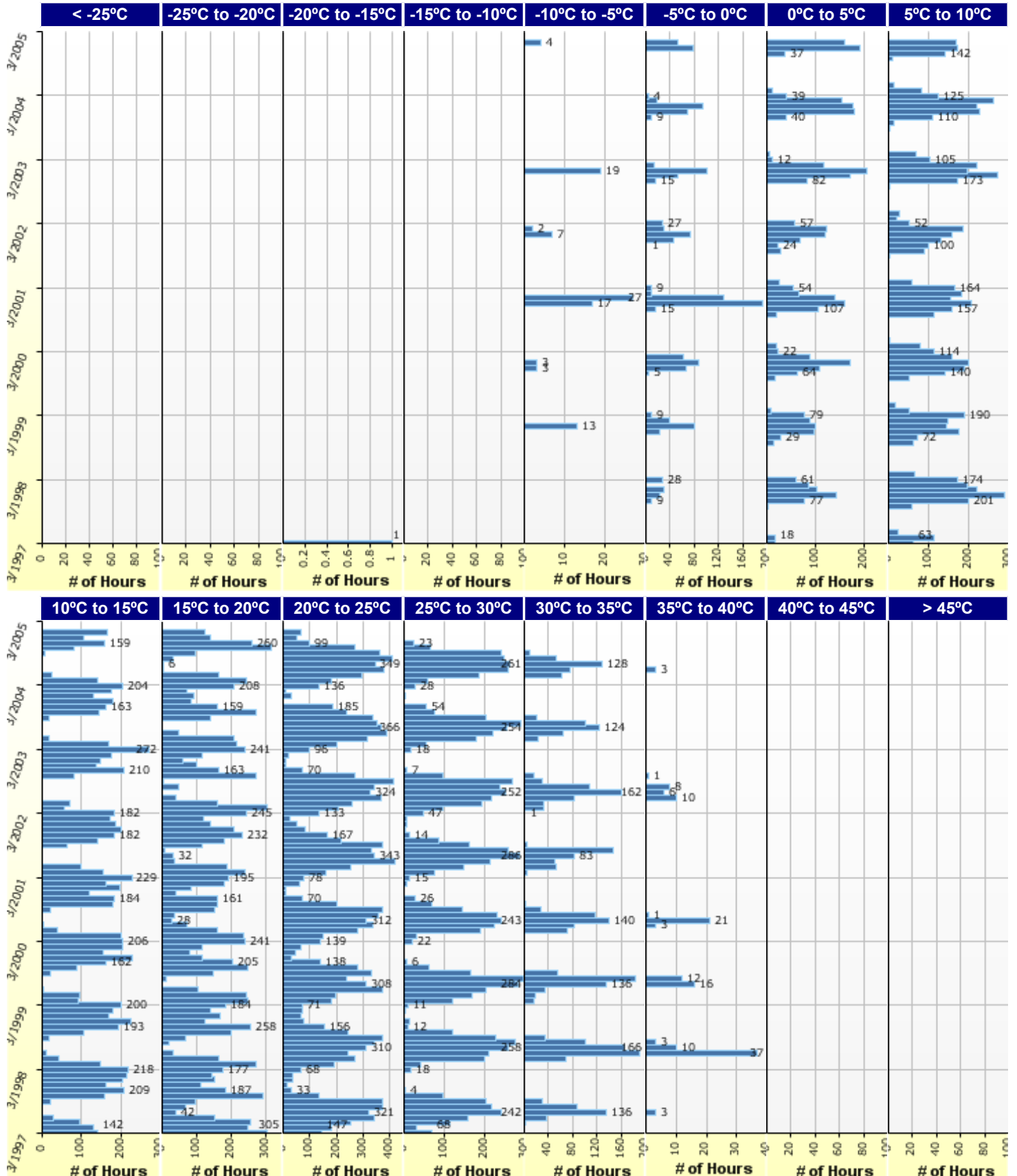


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF3_ALT2

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF3_ALT2.dgpx



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

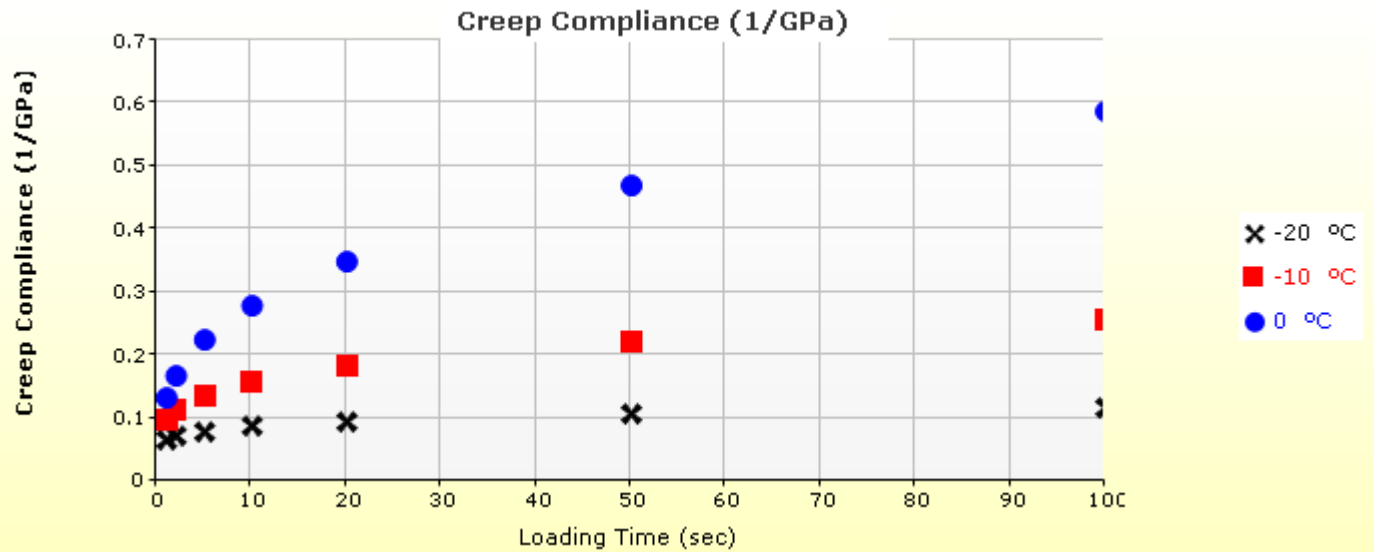
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

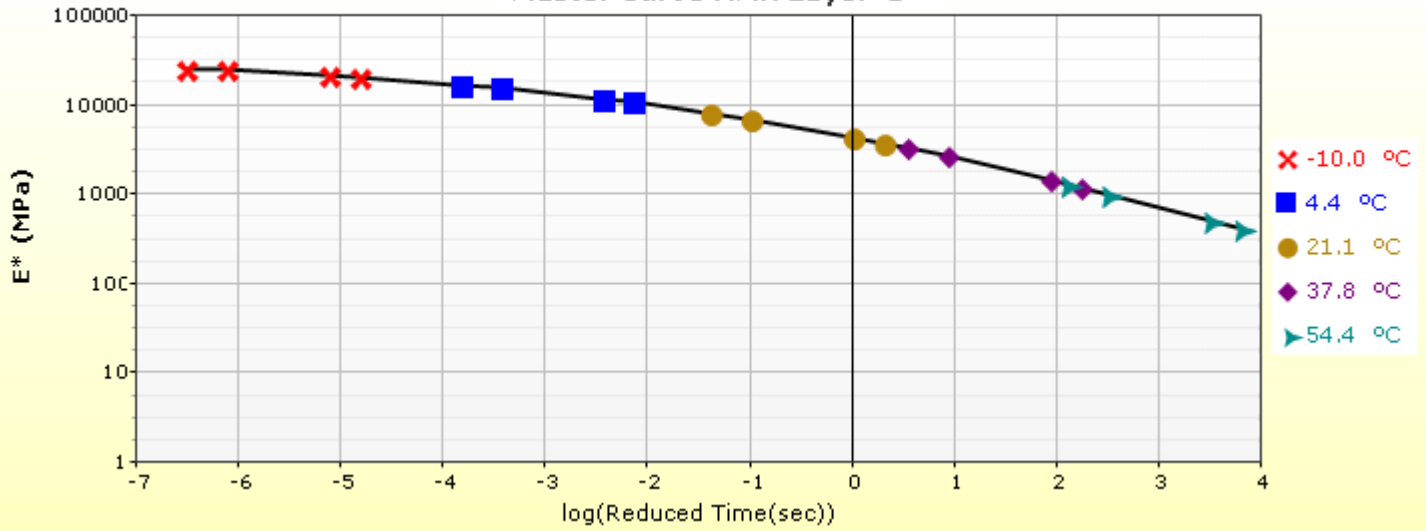
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

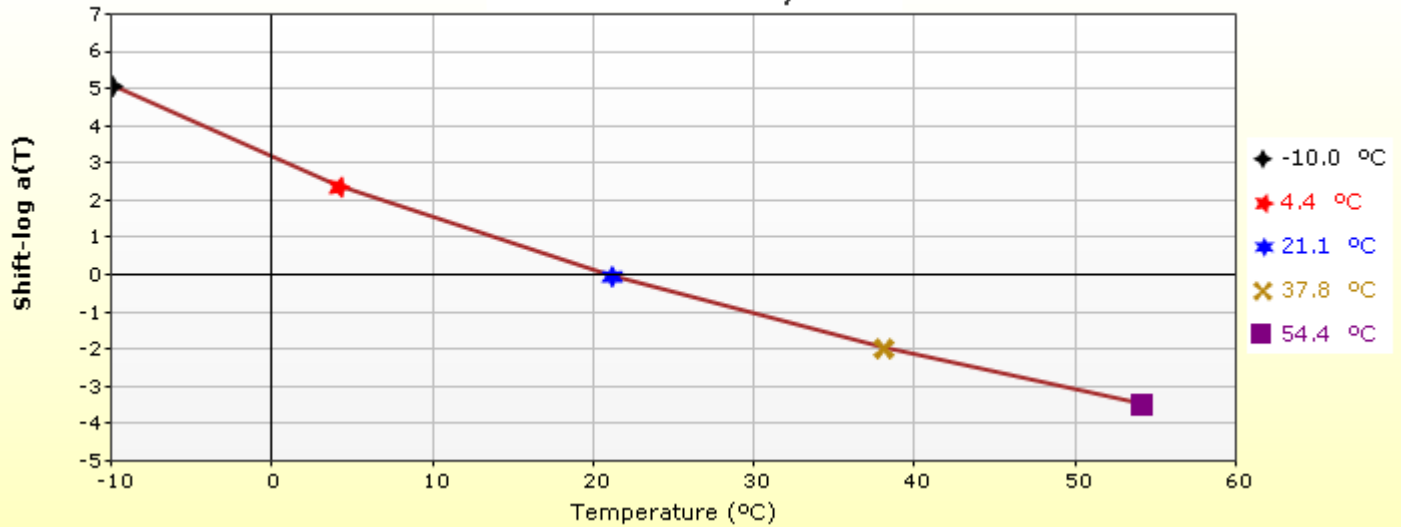


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

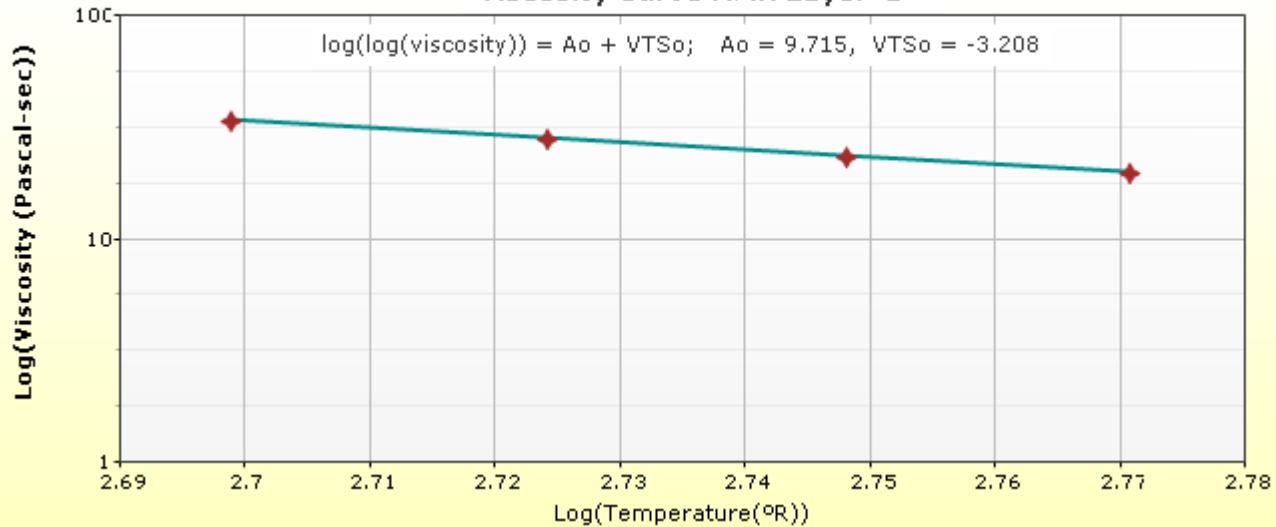
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

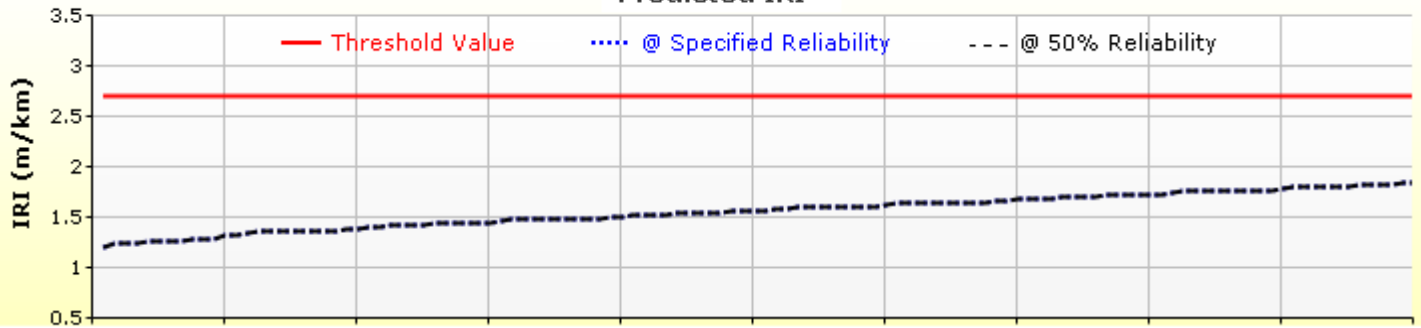


Viscosity Curve HMA Layer 1

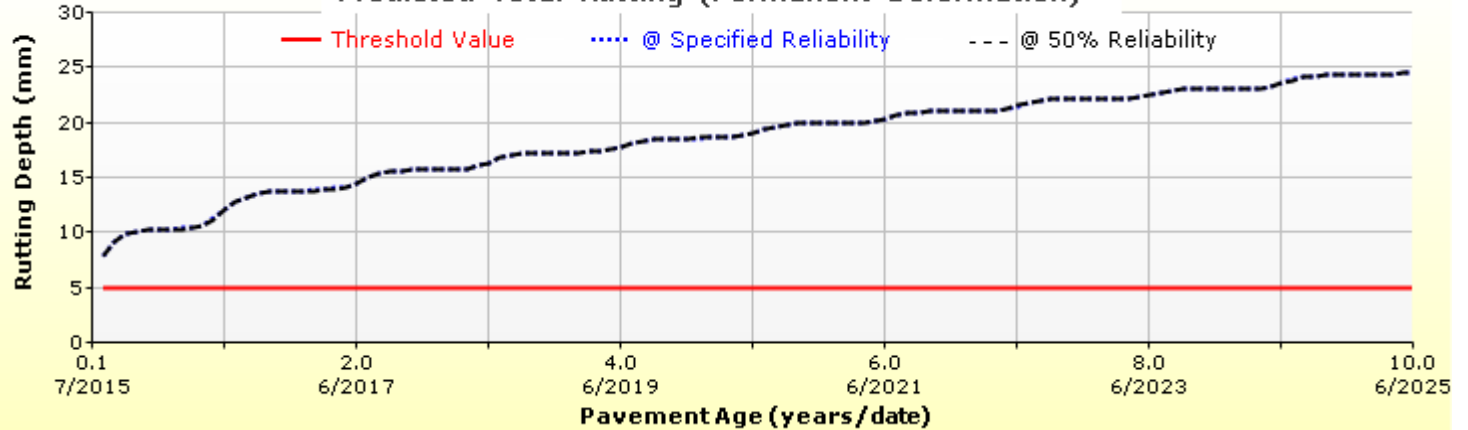


Analysis Output Charts

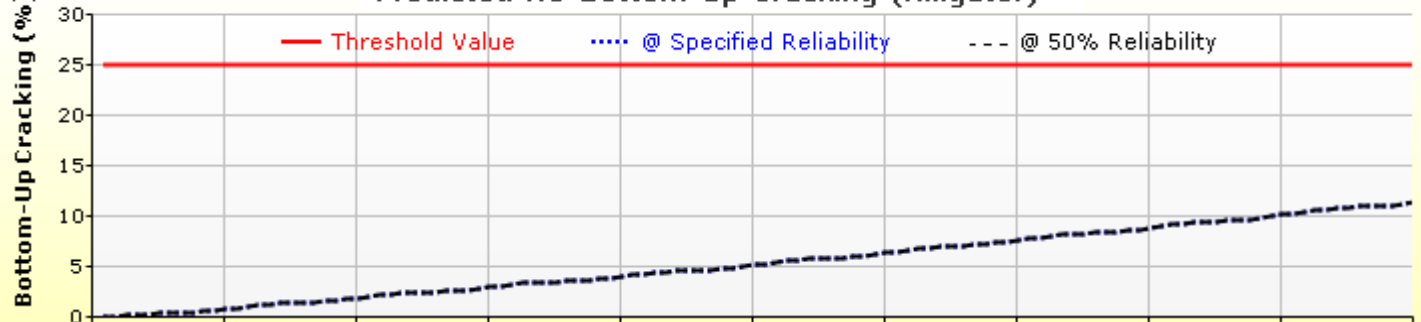
Predicted IRI



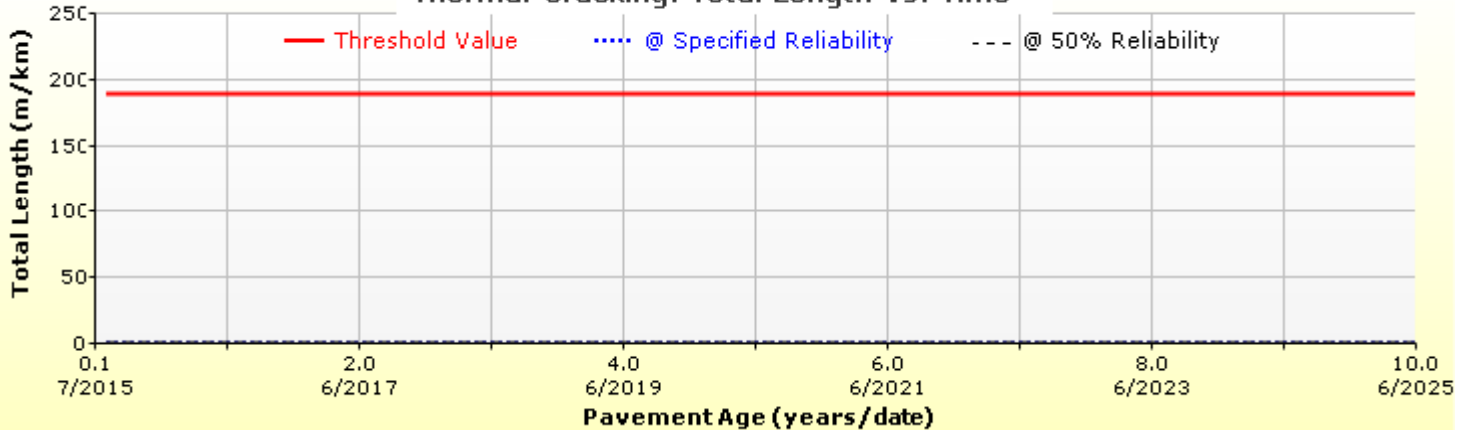
Predicted Total Rutting (Permanent Deformation)



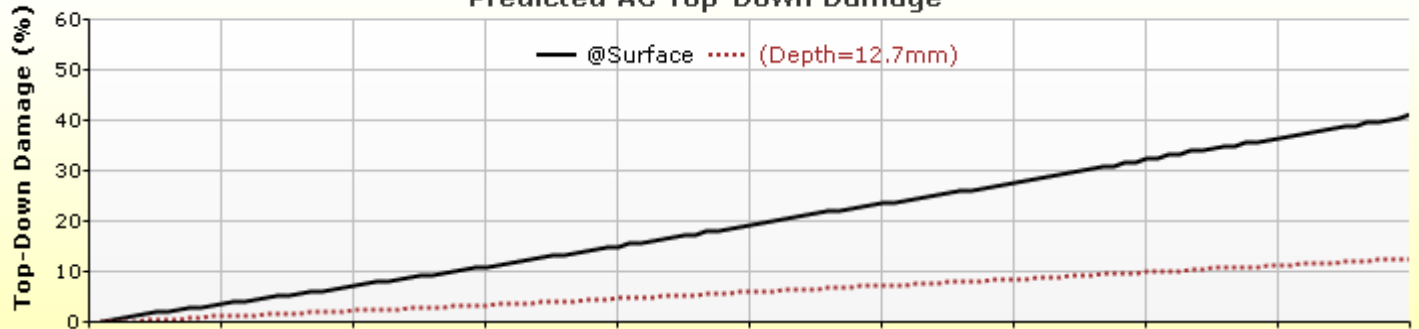
Predicted AC Bottom-Up Cracking (Alligator)



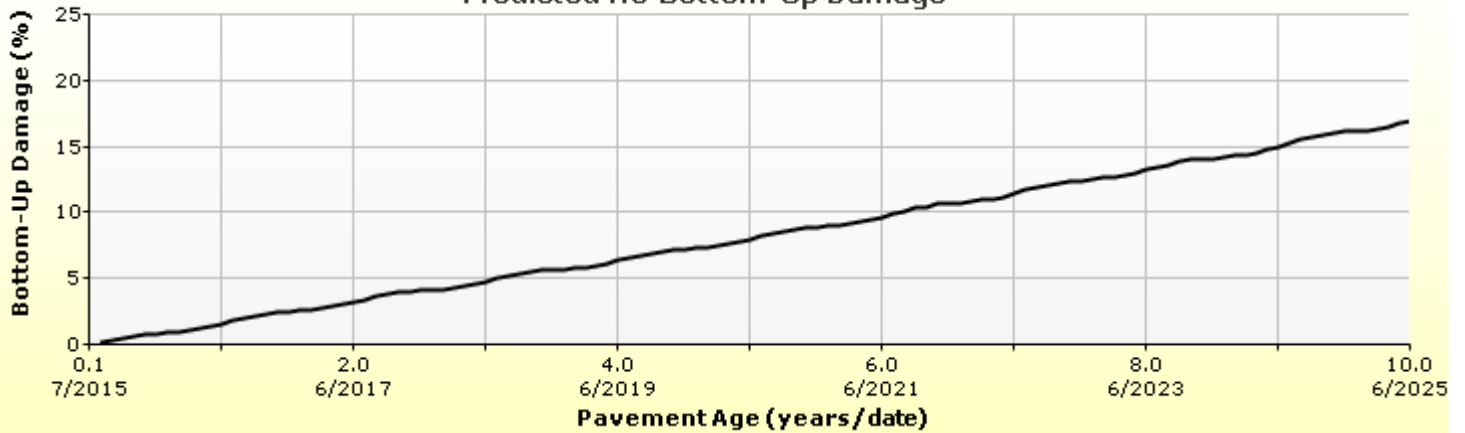
Thermal Cracking: Total Length vs. Time



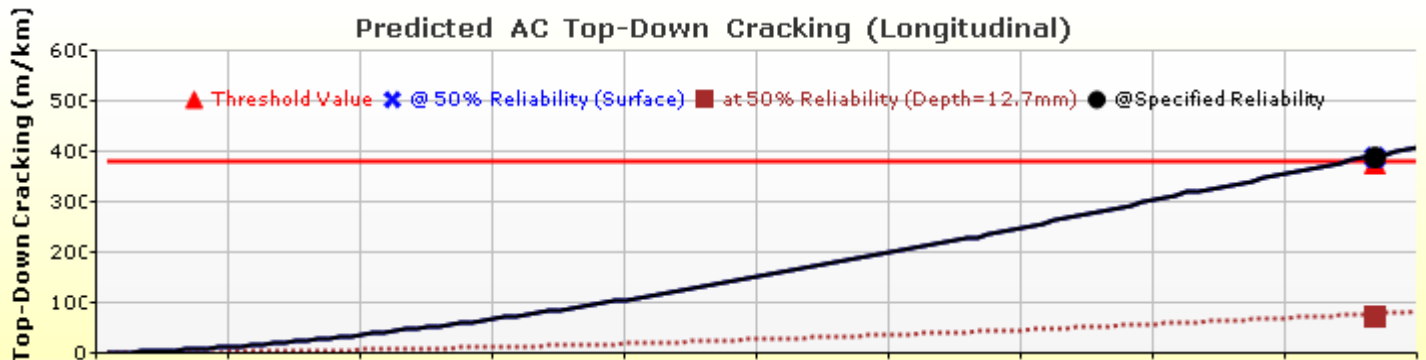
Predicted AC Top-Down Damage



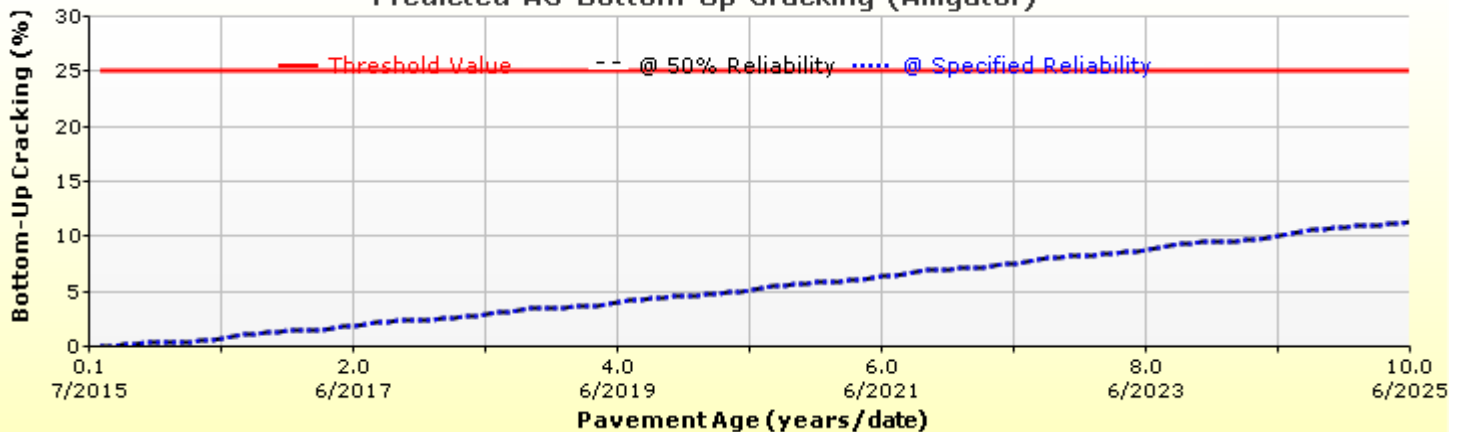
Predicted AC Bottom-Up Damage



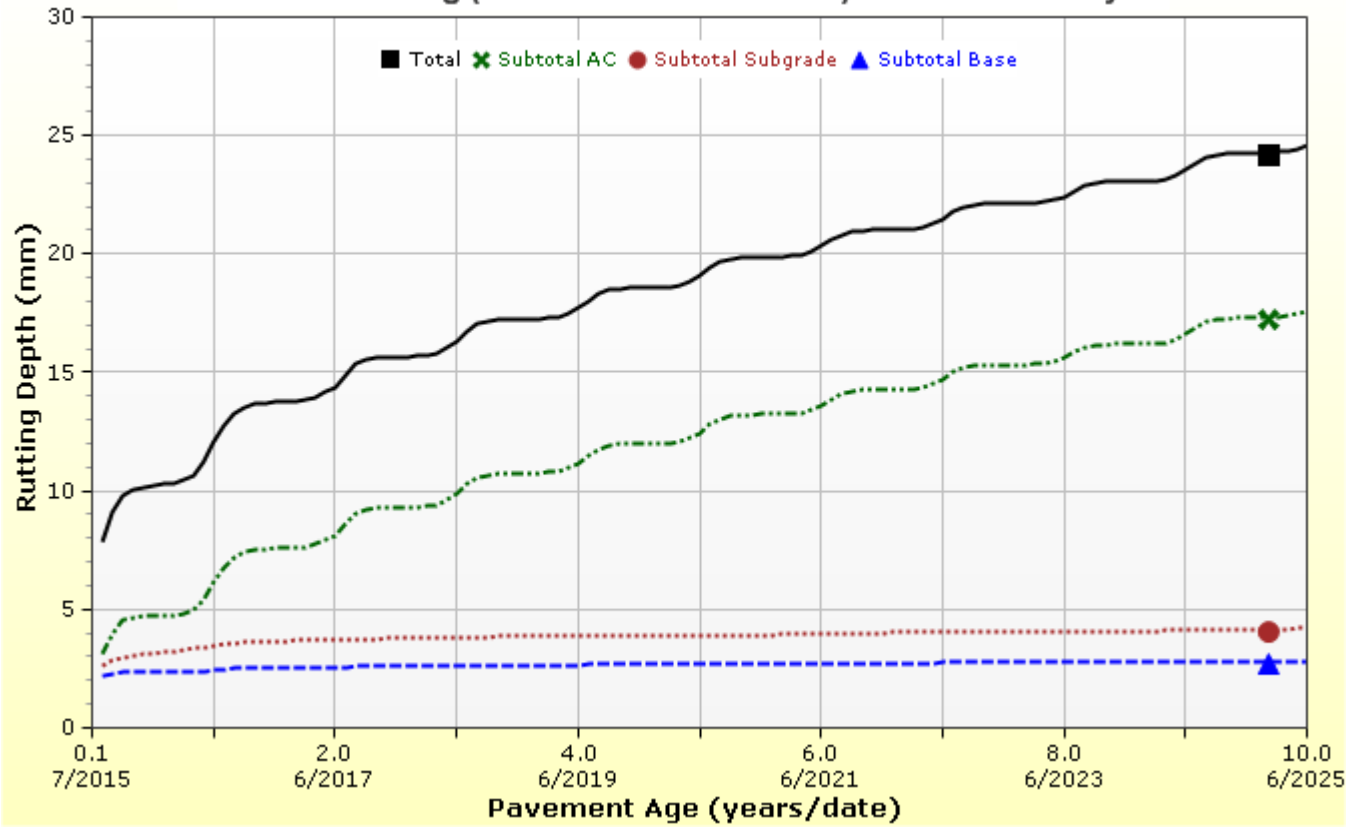
Predicted AC Top-Down Cracking (Longitudinal)

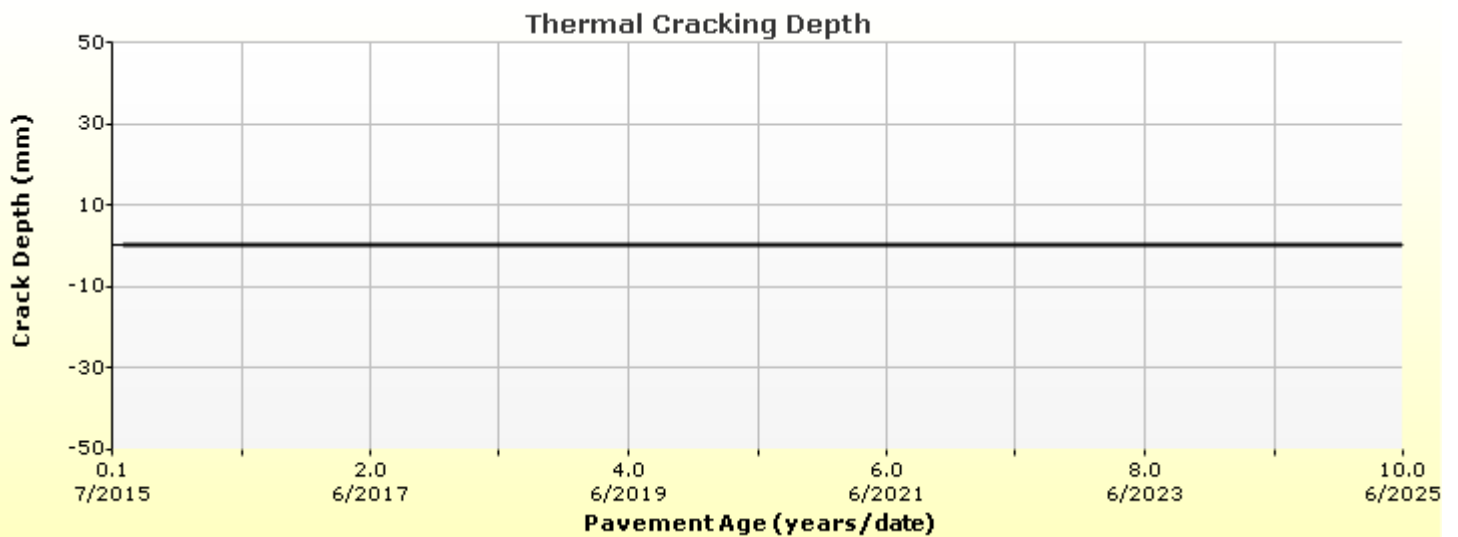
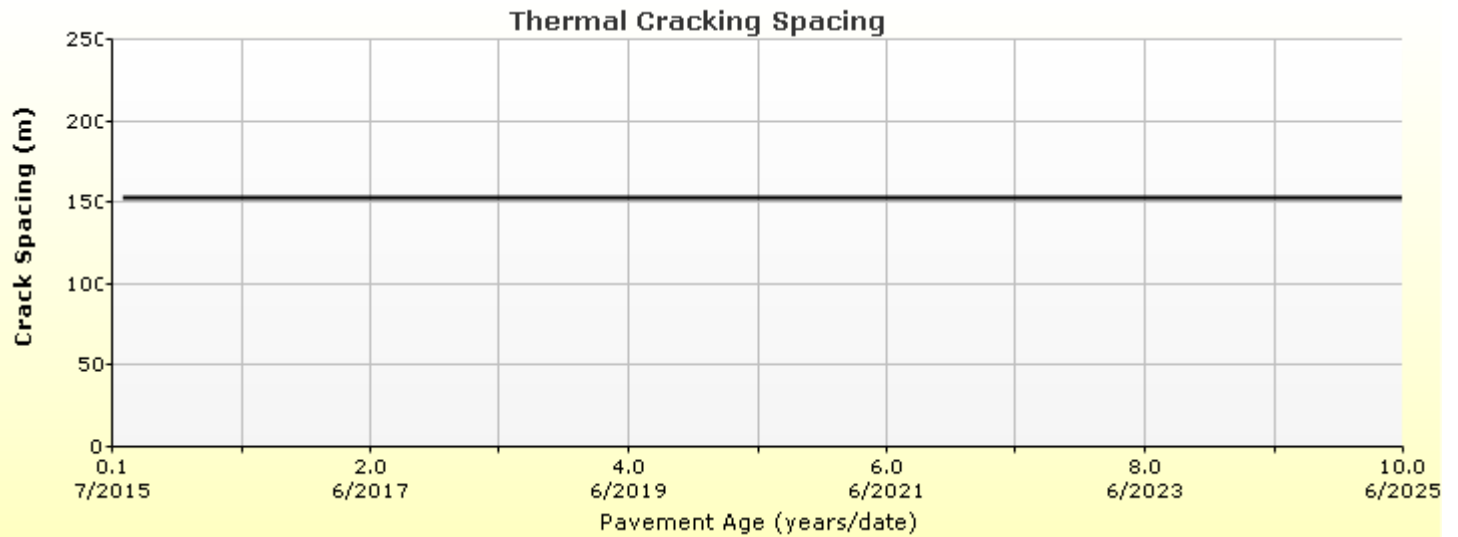


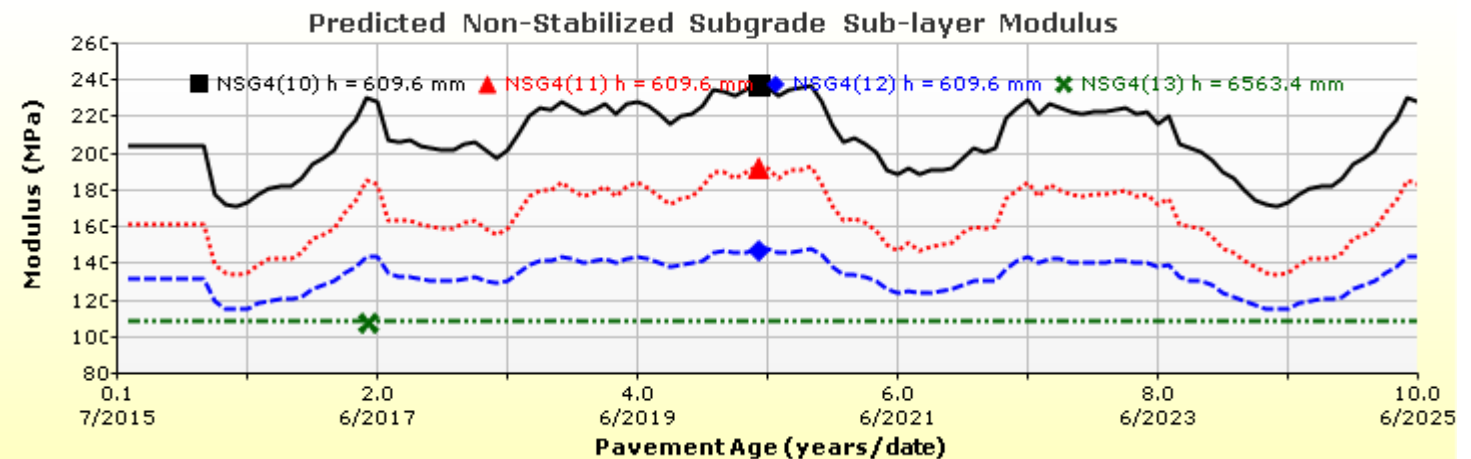
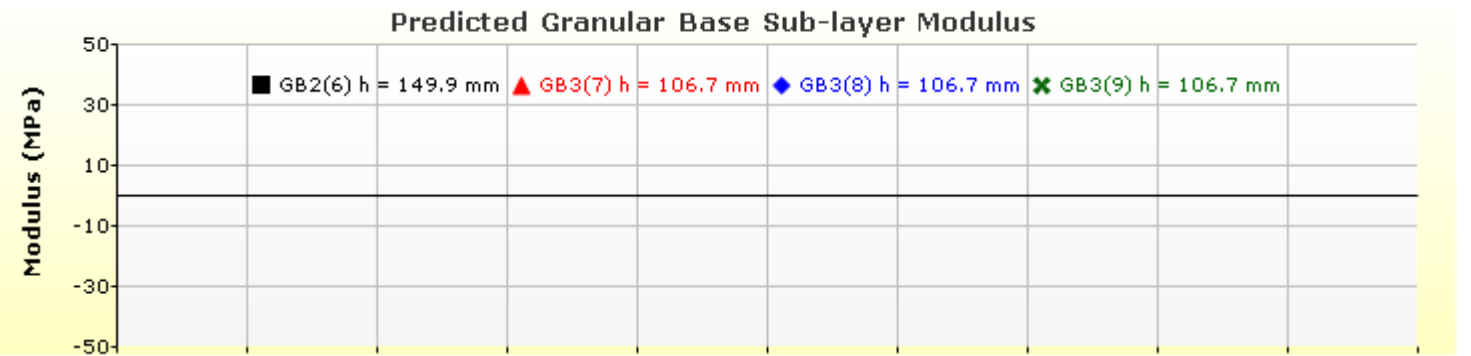
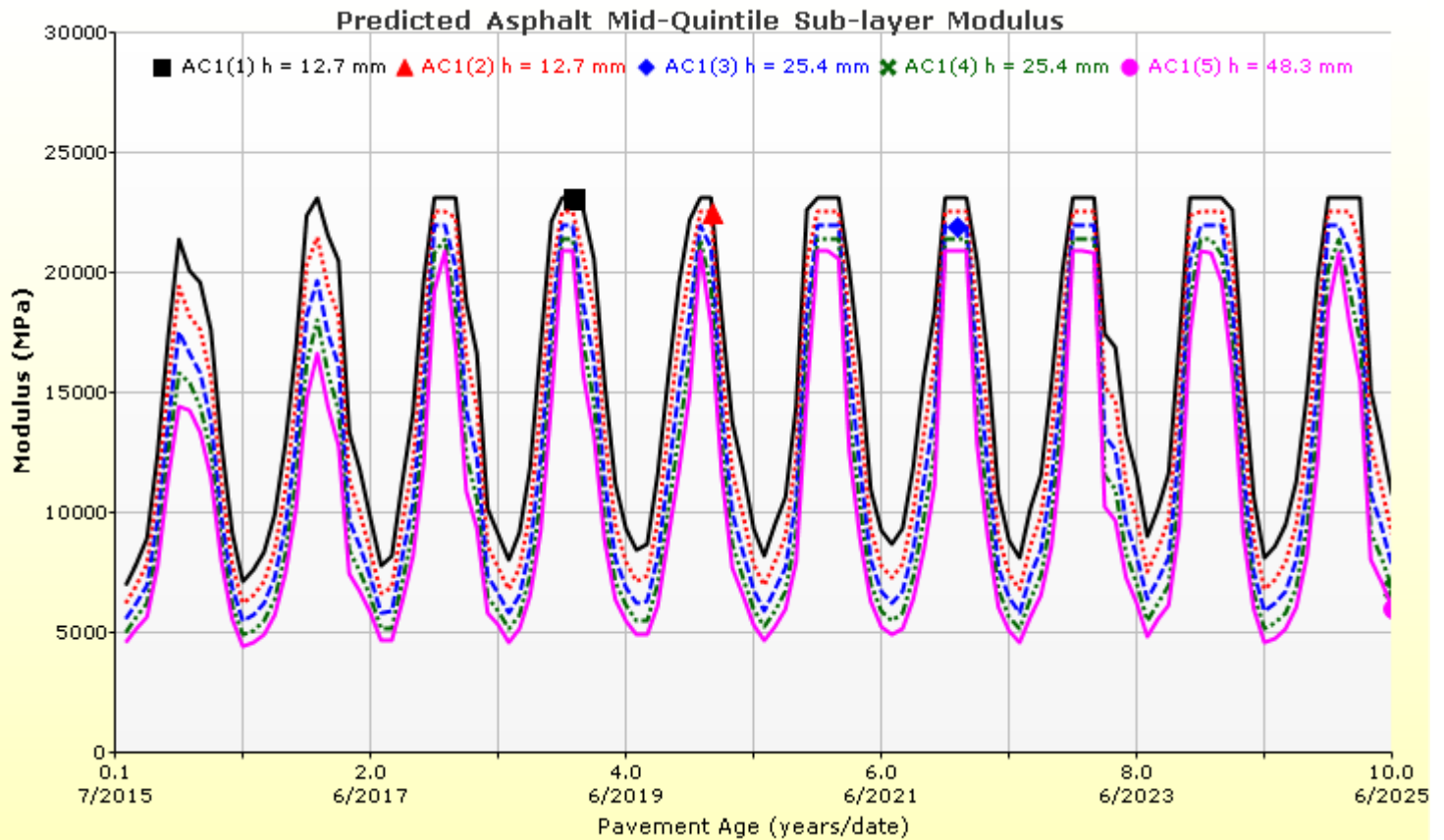
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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() σ = standard deviation of the log of the depth of cracks in the pavments C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_s = Tensile stress(psi) M_r = modulus of rupture(psi)
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

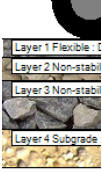
C3: 0.008

C4: 0.015

Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data: 32.119, -81.202
 Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
 Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm)	Volumetric at Construction:	
Flexible	Default asphalt concrete	125.0	Effective binder content (%)	11.6
NonStabilized	Crushed stone	150.0	Air voids (%)	7.0
NonStabilized	Crushed stone	320.0		
Subgrade	A-1-a	Semi-infinite		

Traffic

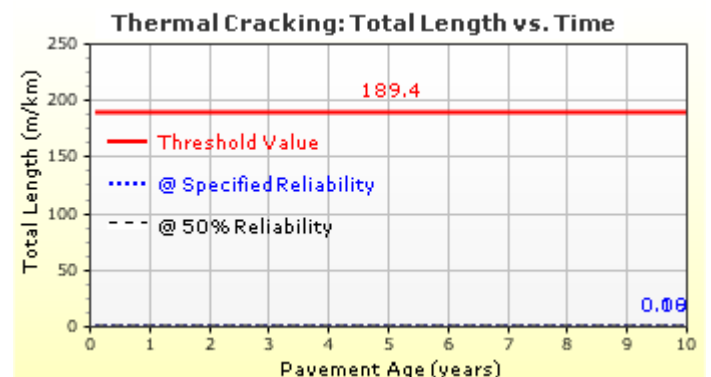
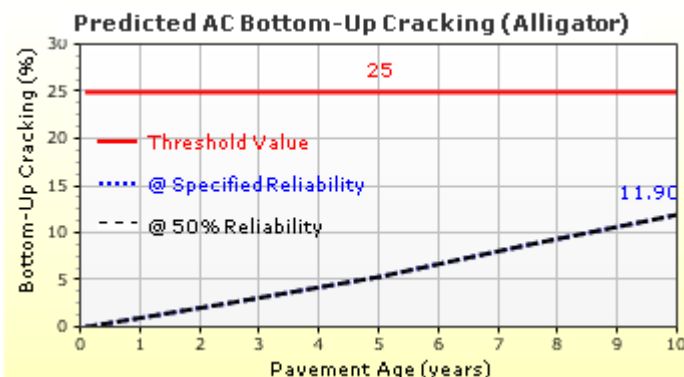
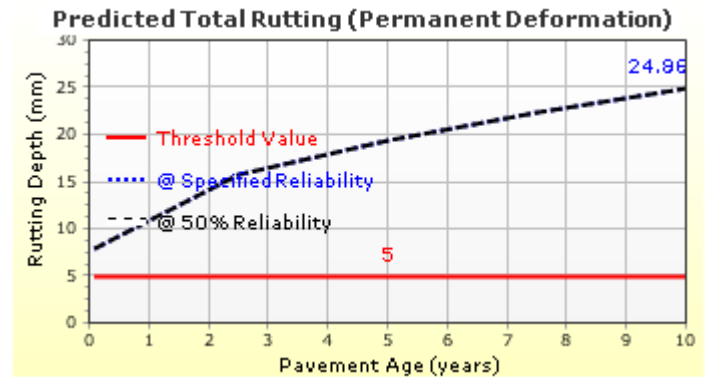
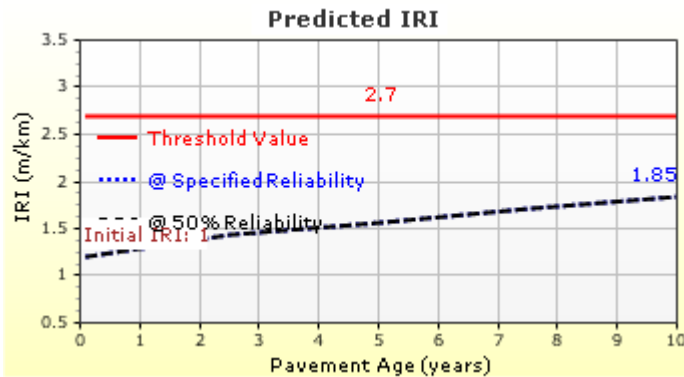
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.85	50.00	95.10	Pass
Permanent deformation - total pavement (mm)	5.00	24.90	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	11.90	50.00	82.31	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	414.77	50.00	46.73	Fail
Permanent deformation - AC only (mm)	5.00	17.91	50.00	0.27	Fail

Distress Charts

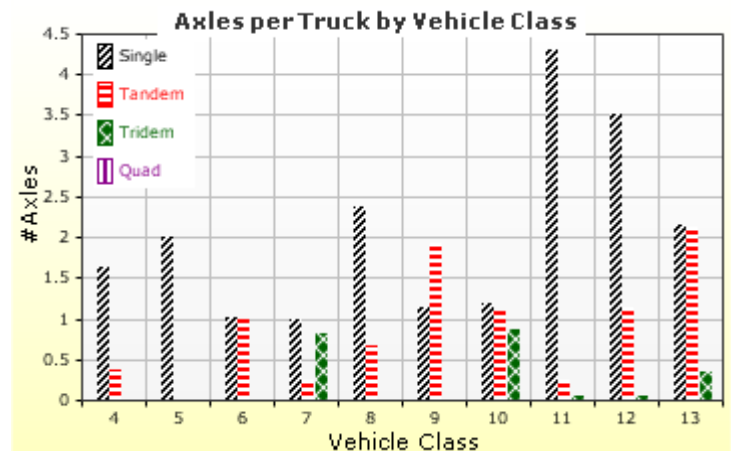
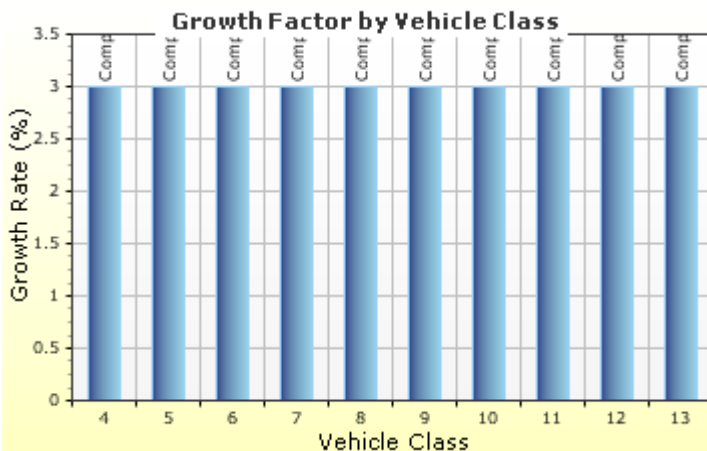
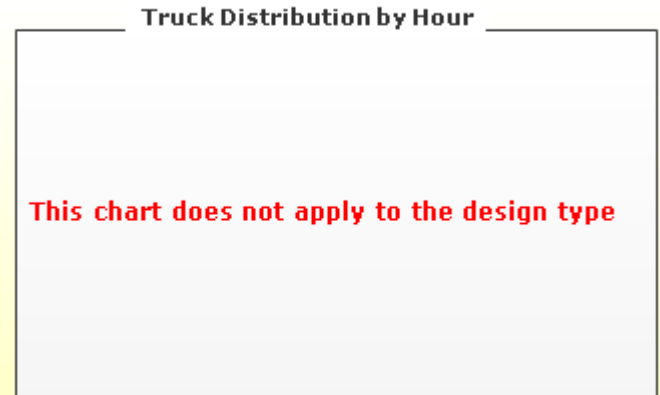
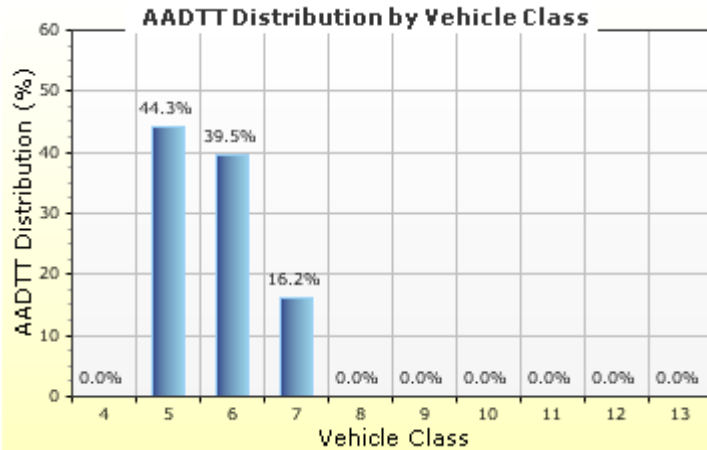


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

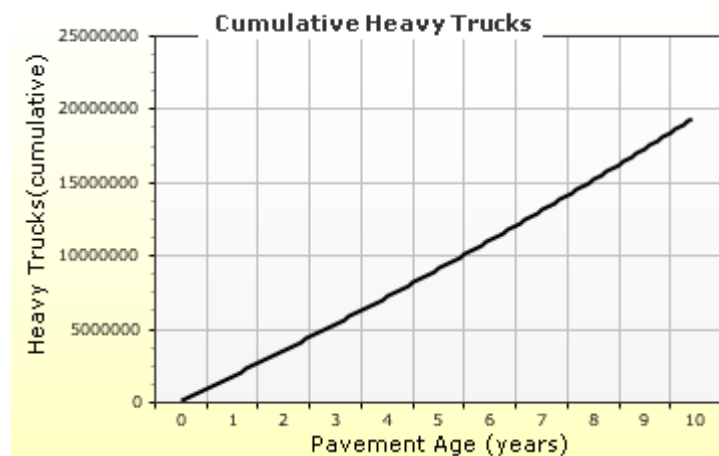
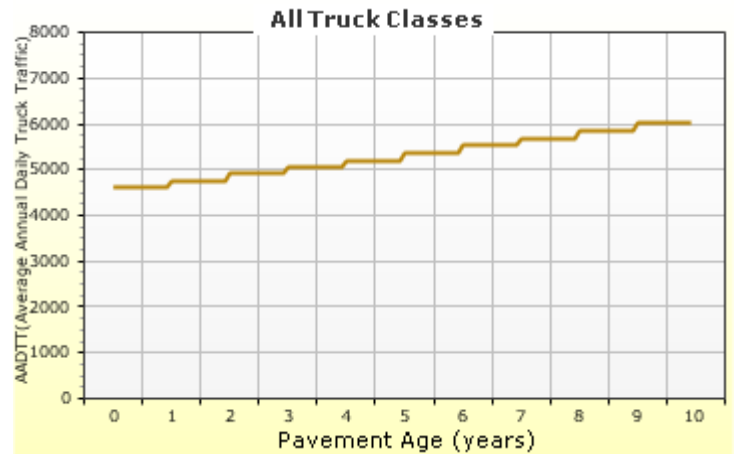
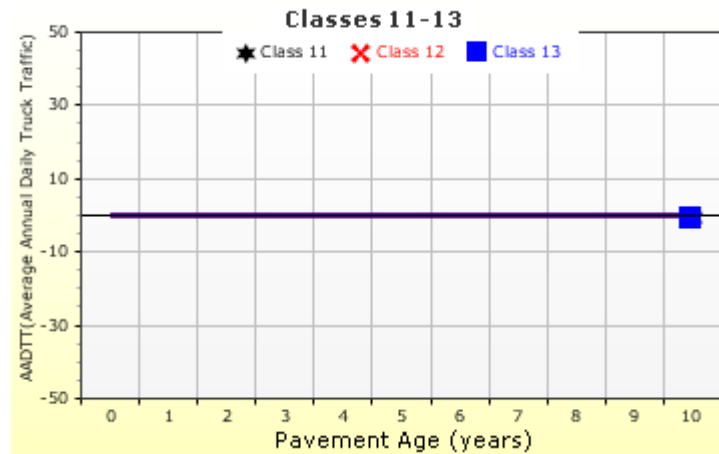
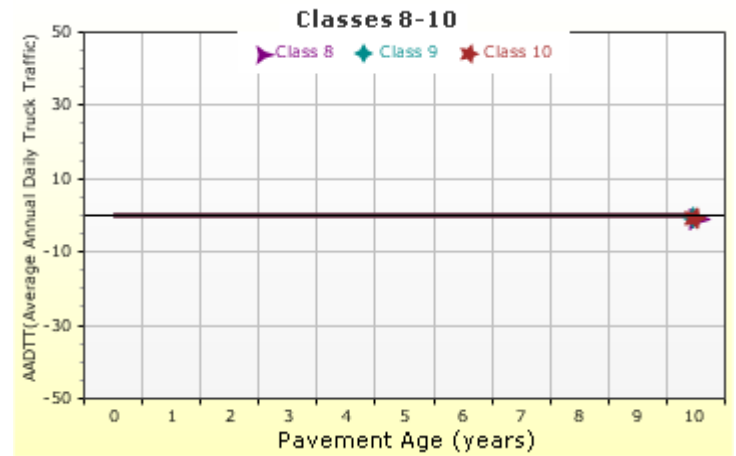
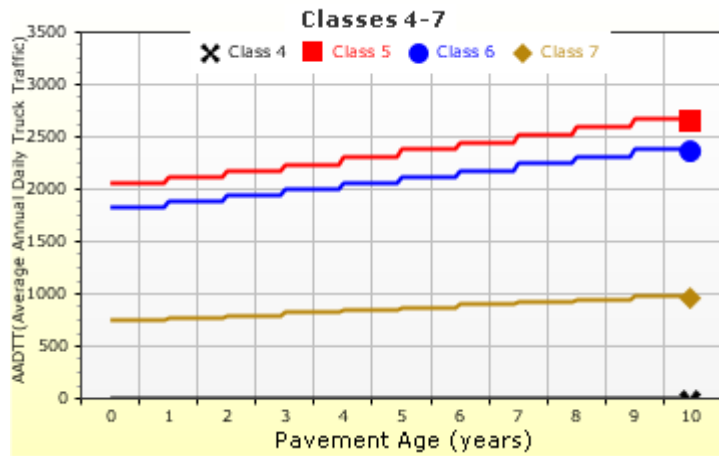
Wheelbase does not apply

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



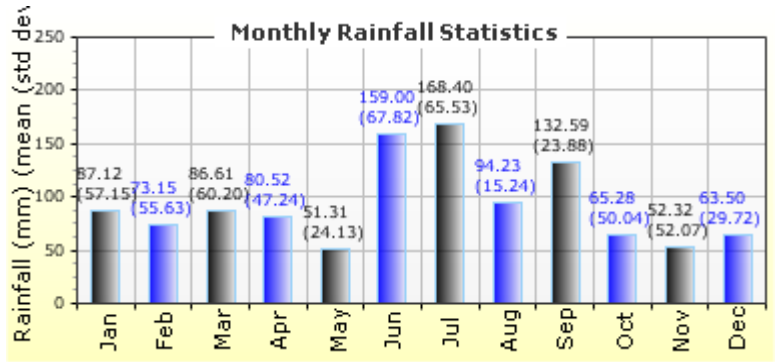
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

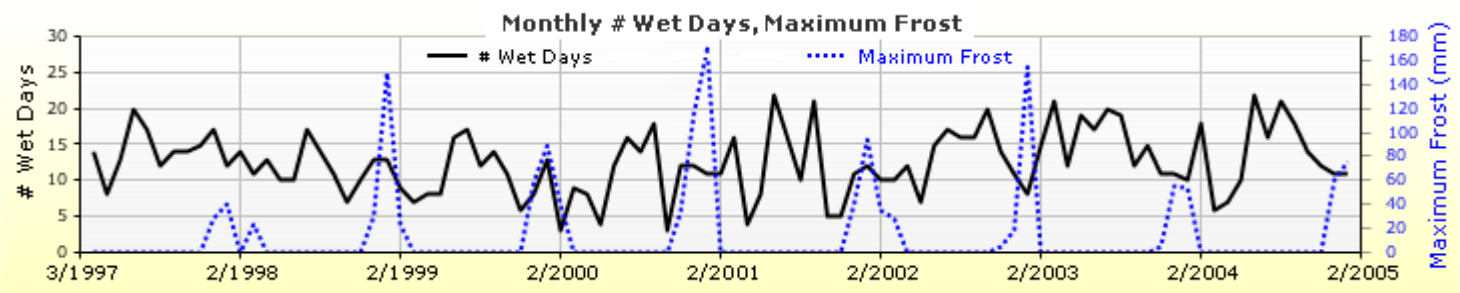
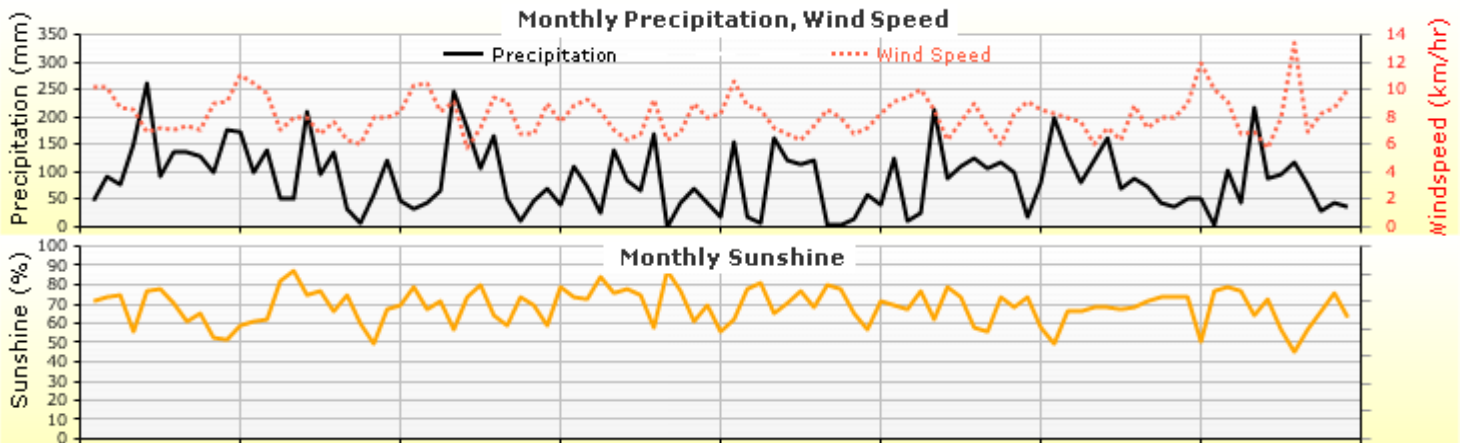
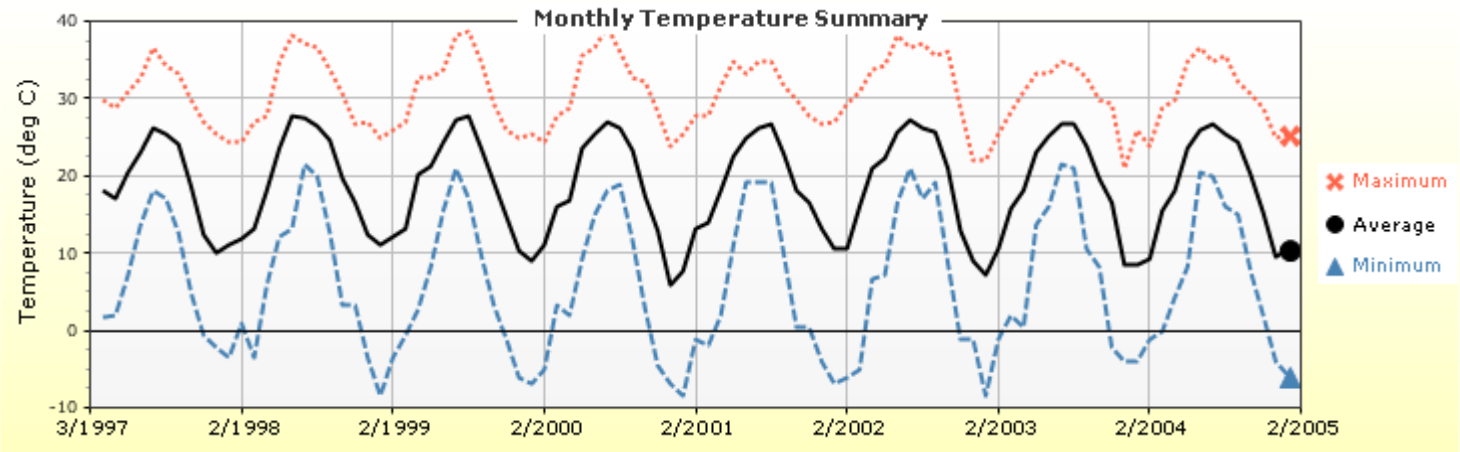
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

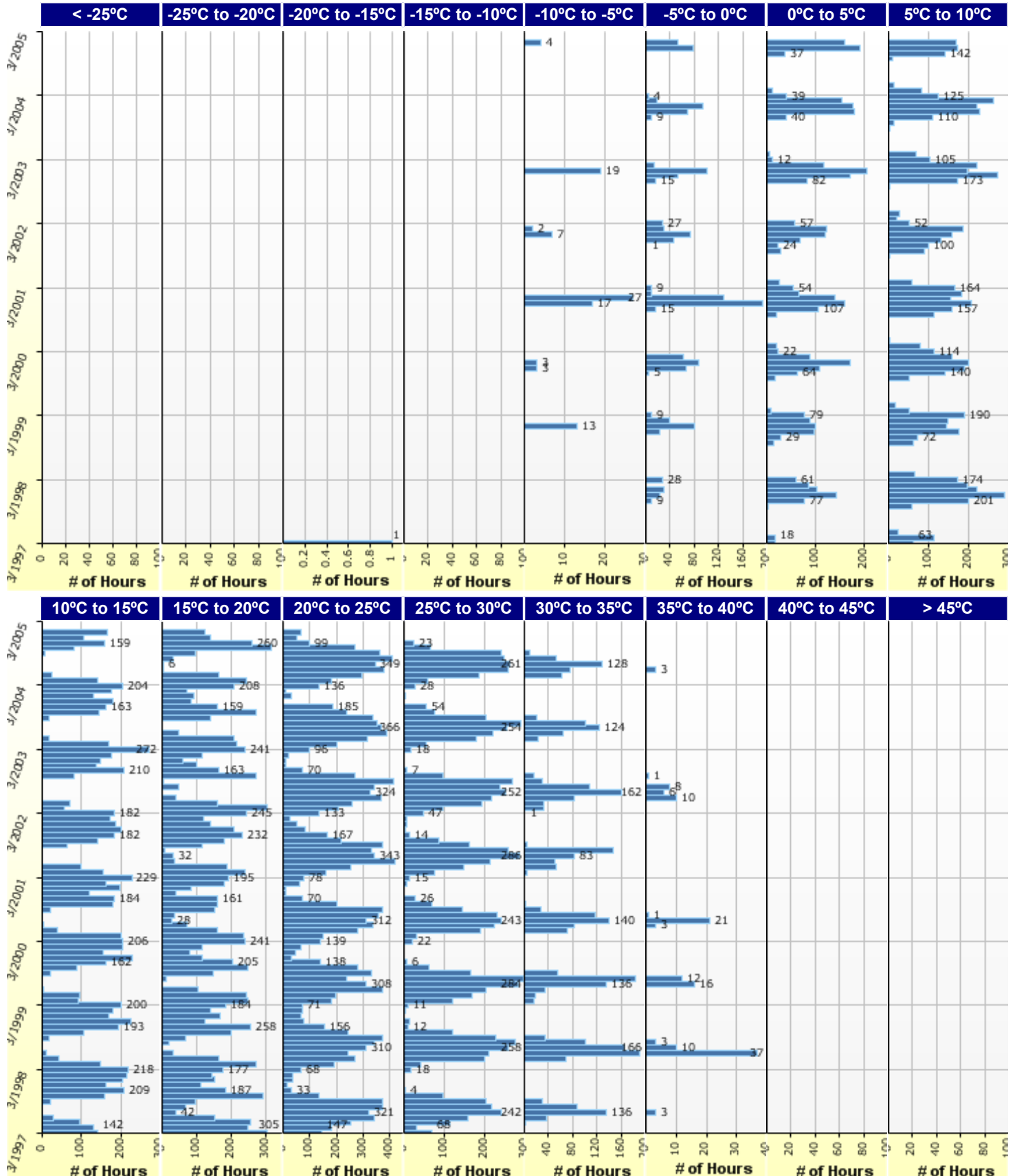


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF4_ALT2

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF4_ALT2.dgpx



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

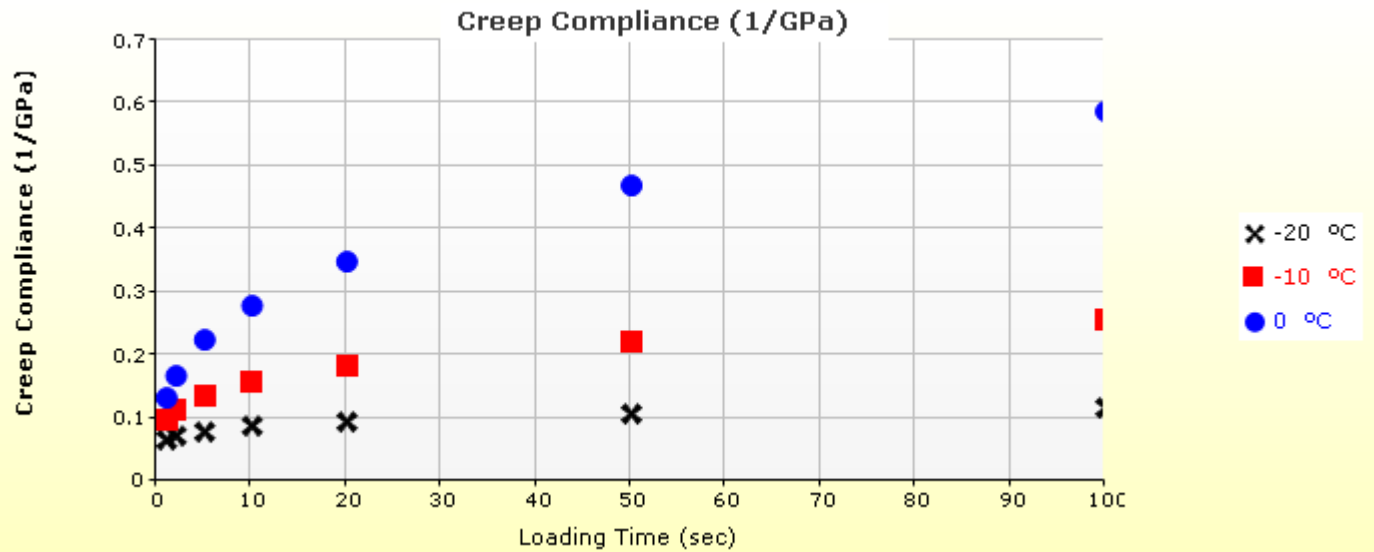
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

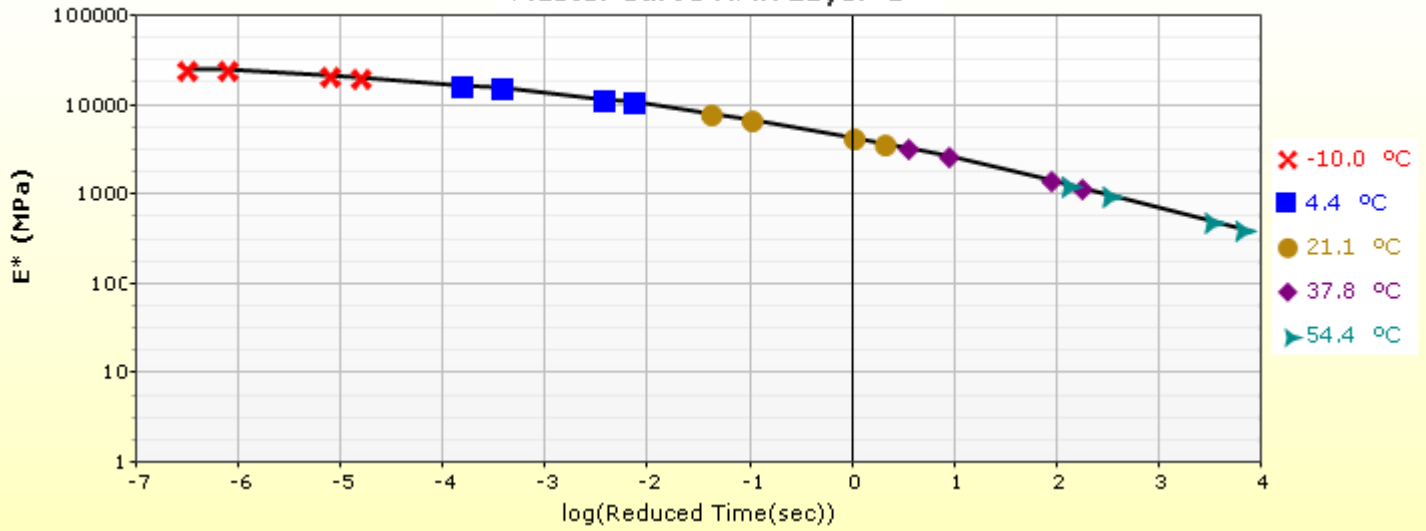
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

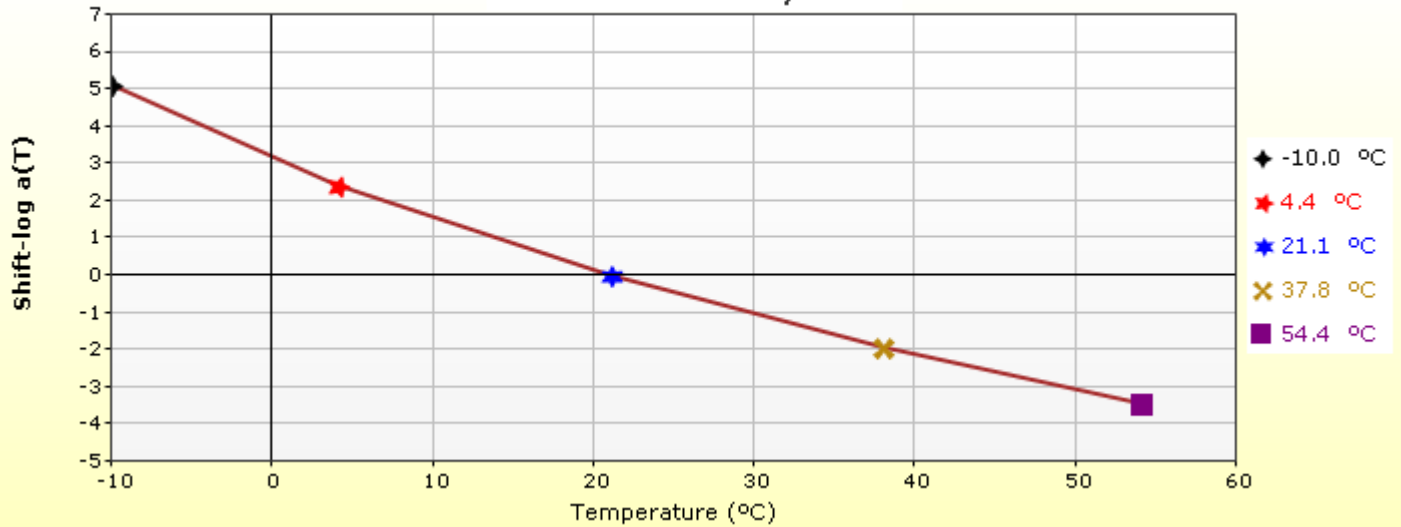


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

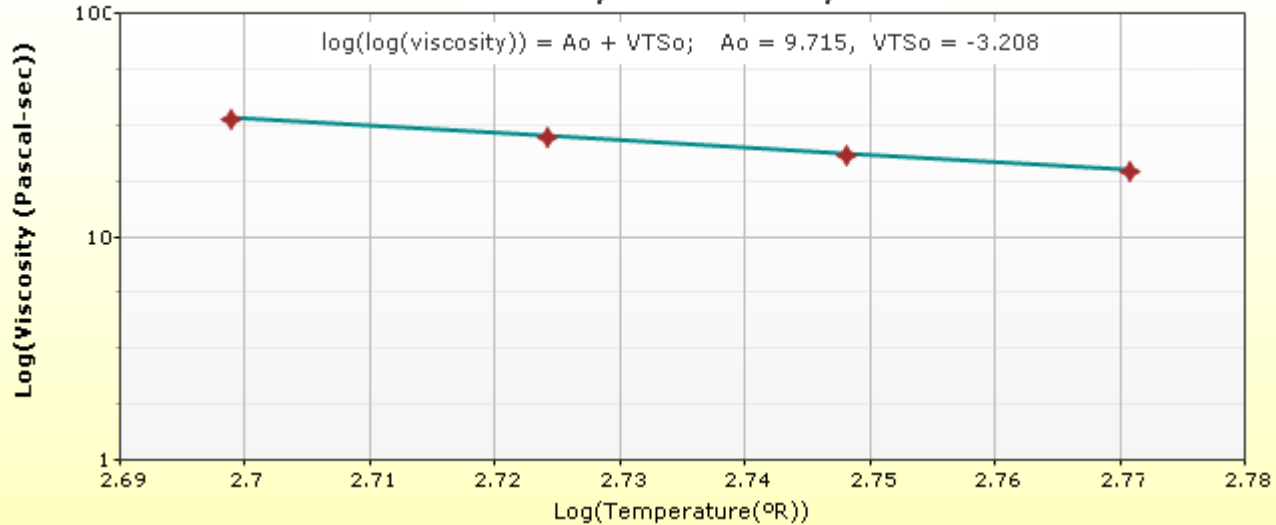
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

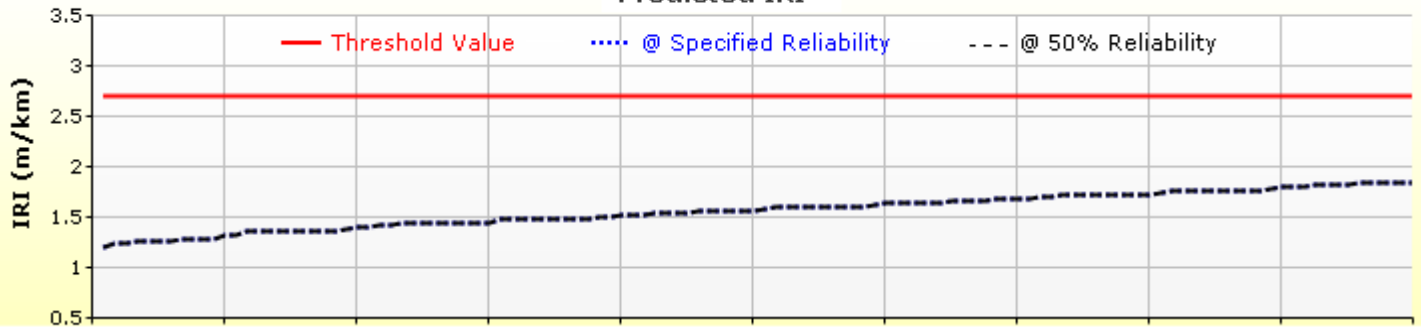


Viscosity Curve HMA Layer 1

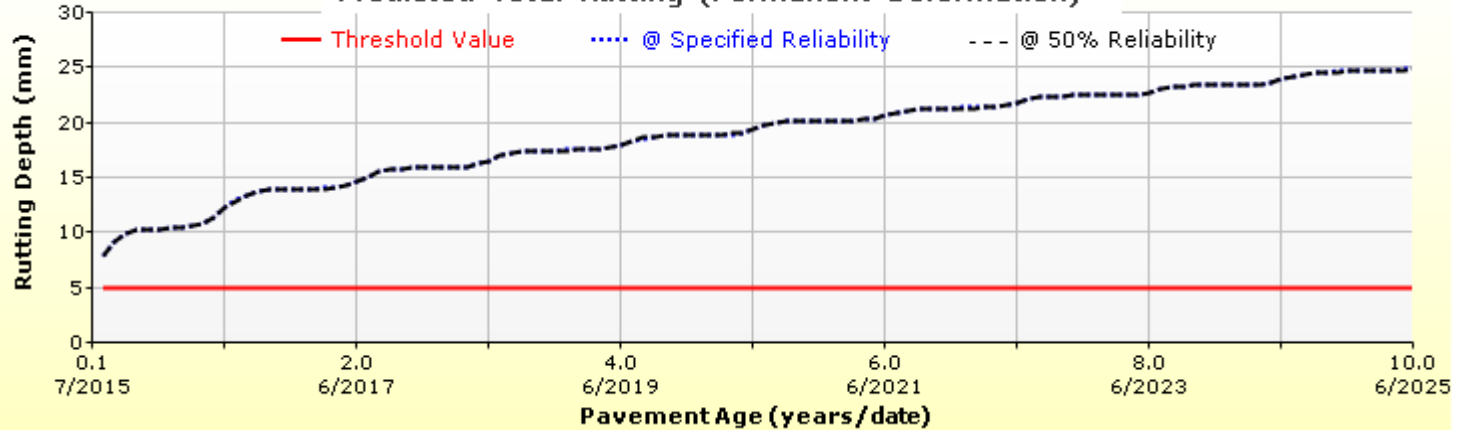


Analysis Output Charts

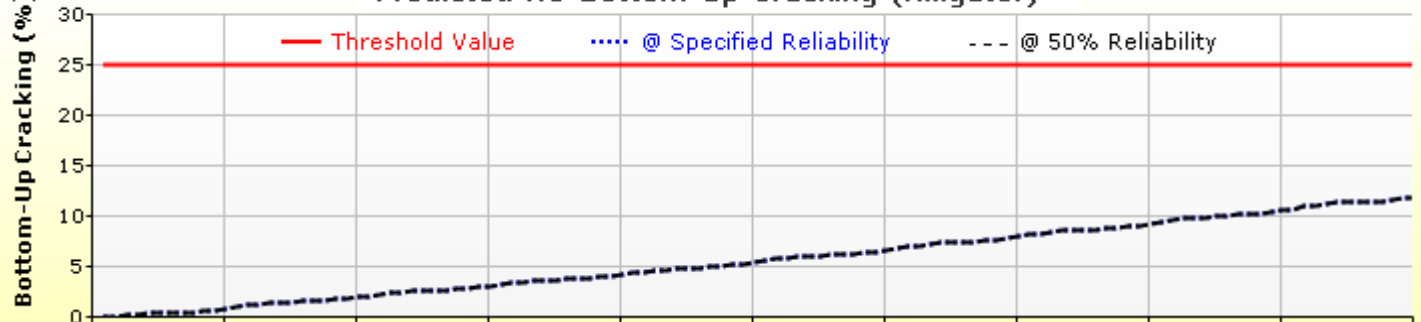
Predicted IRI



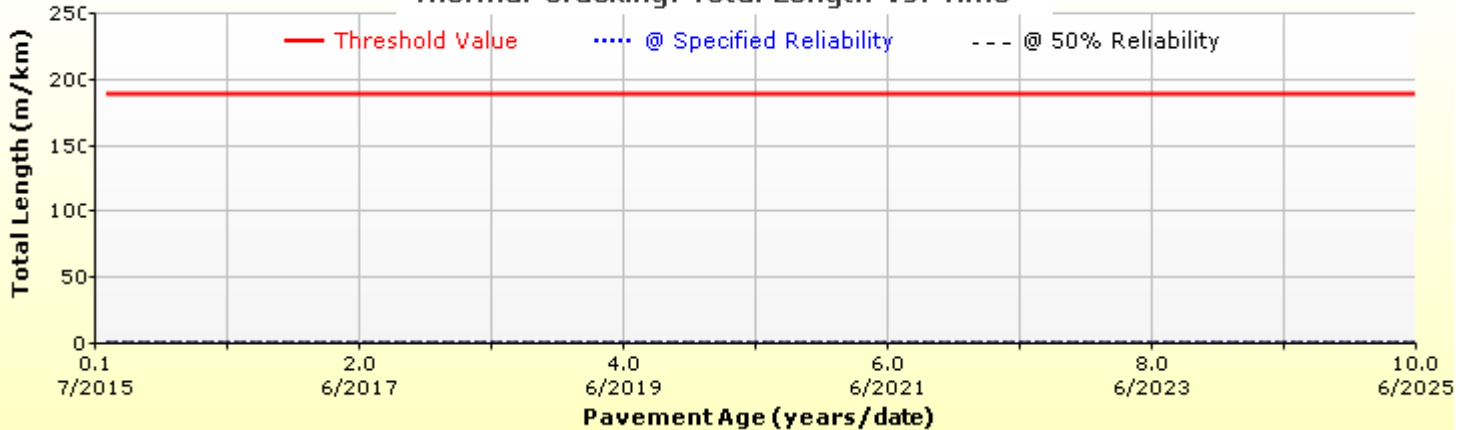
Predicted Total Rutting (Permanent Deformation)



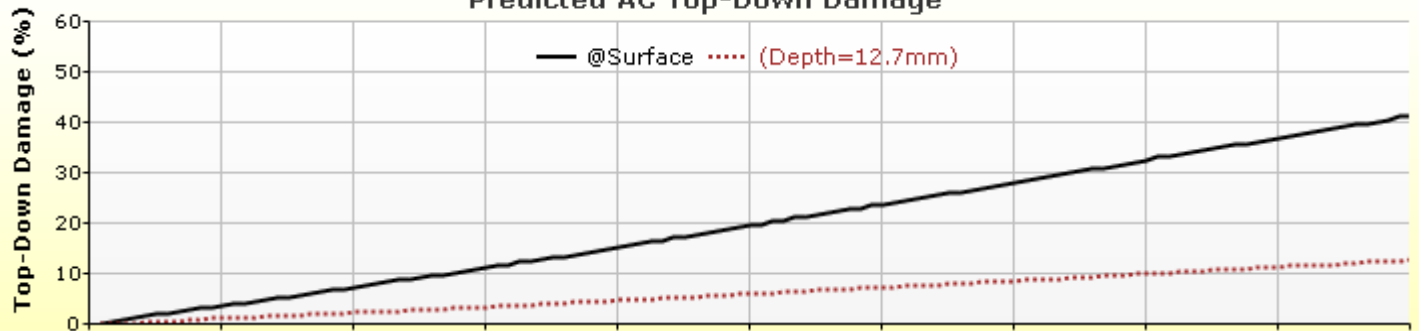
Predicted AC Bottom-Up Cracking (Alligator)



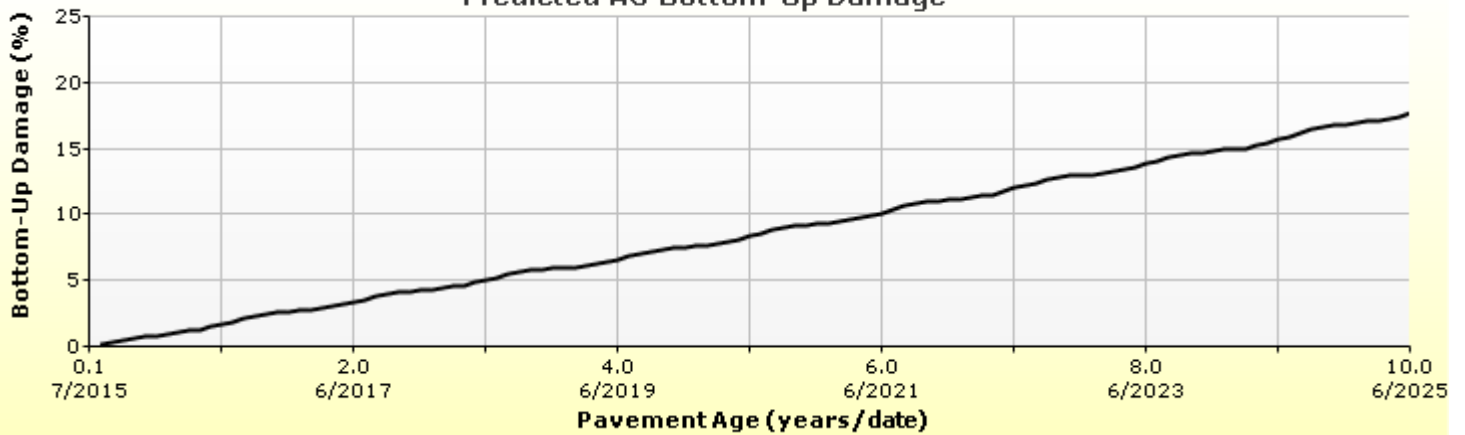
Thermal Cracking: Total Length vs. Time



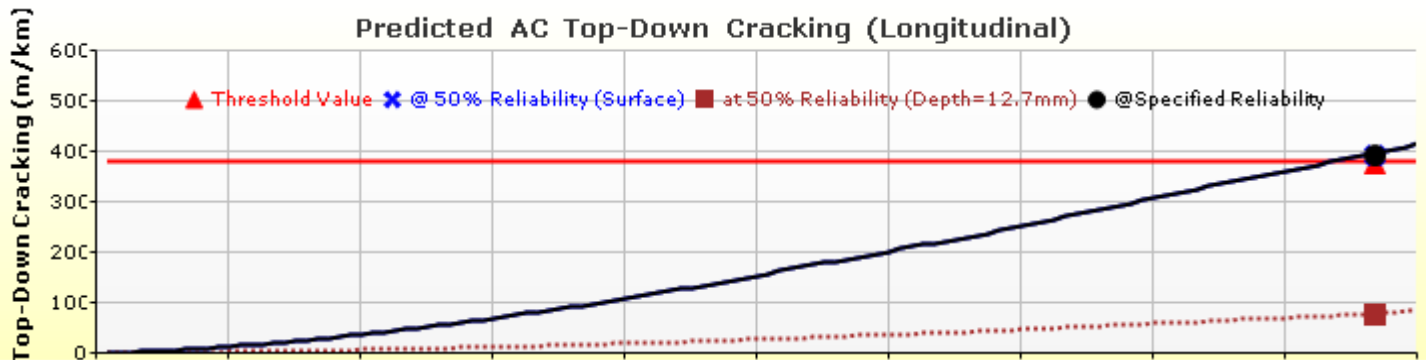
Predicted AC Top-Down Damage



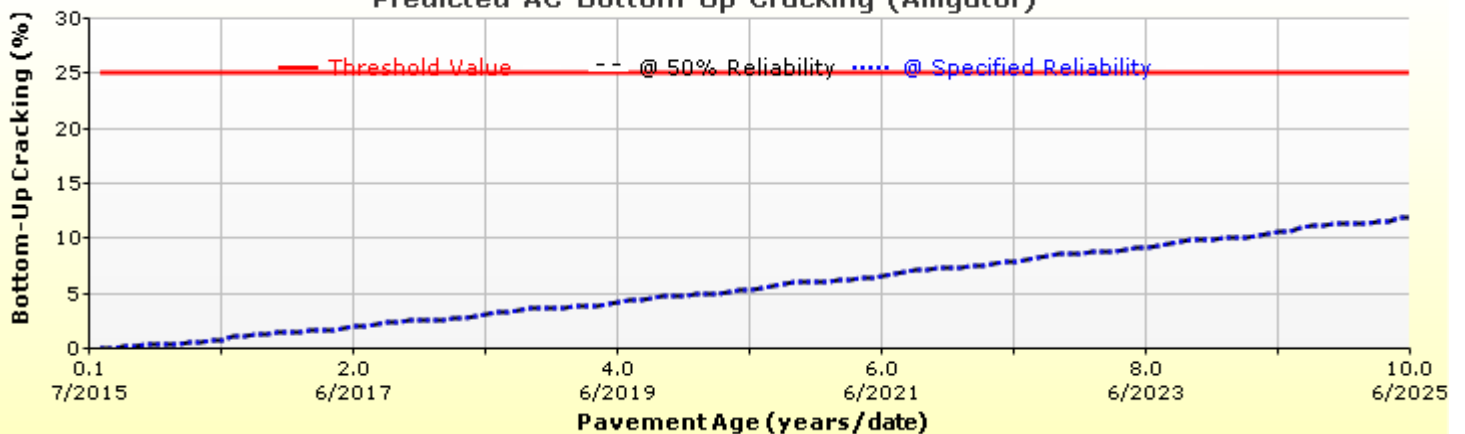
Predicted AC Bottom-Up Damage



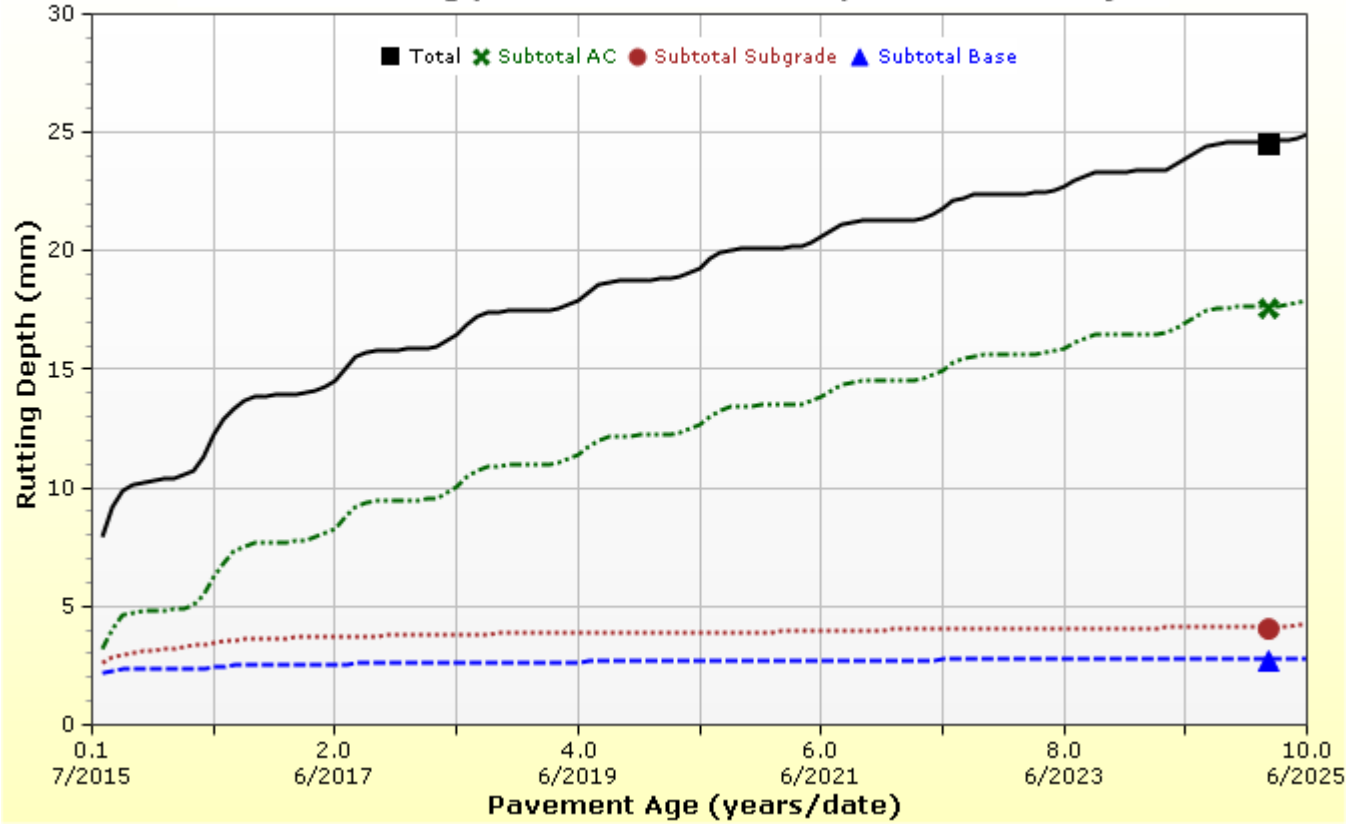
Predicted AC Top-Down Cracking (Longitudinal)



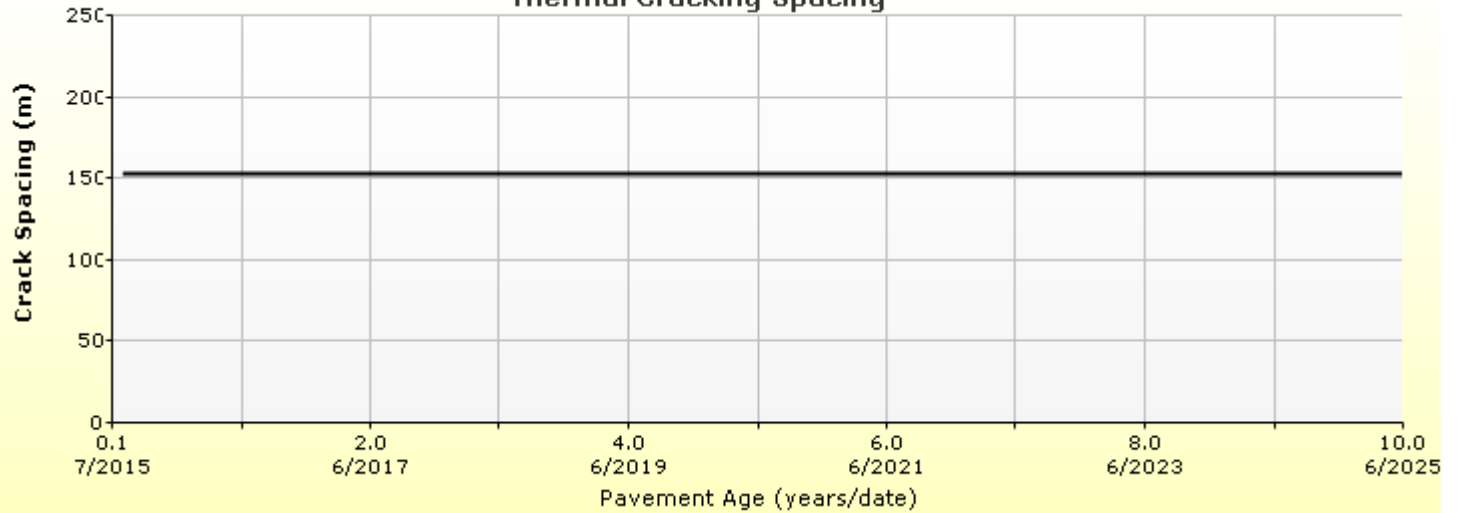
Predicted AC Bottom-Up Cracking (Alligator)



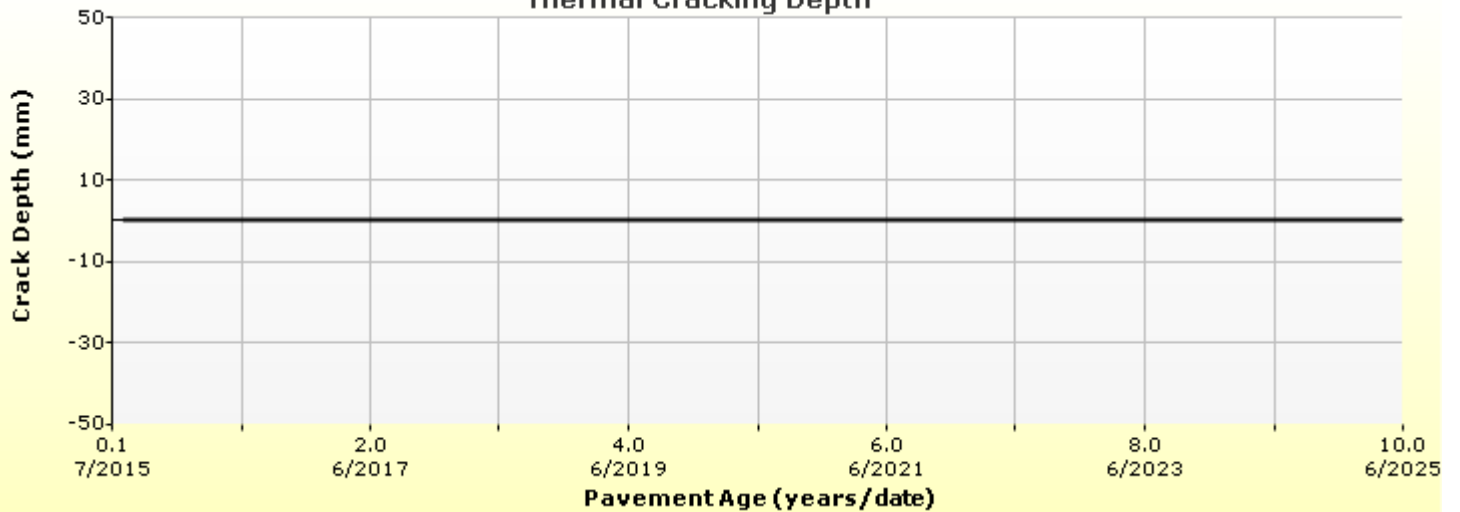
Predicted Rutting (Permanent Deformation) at 50% Reliability

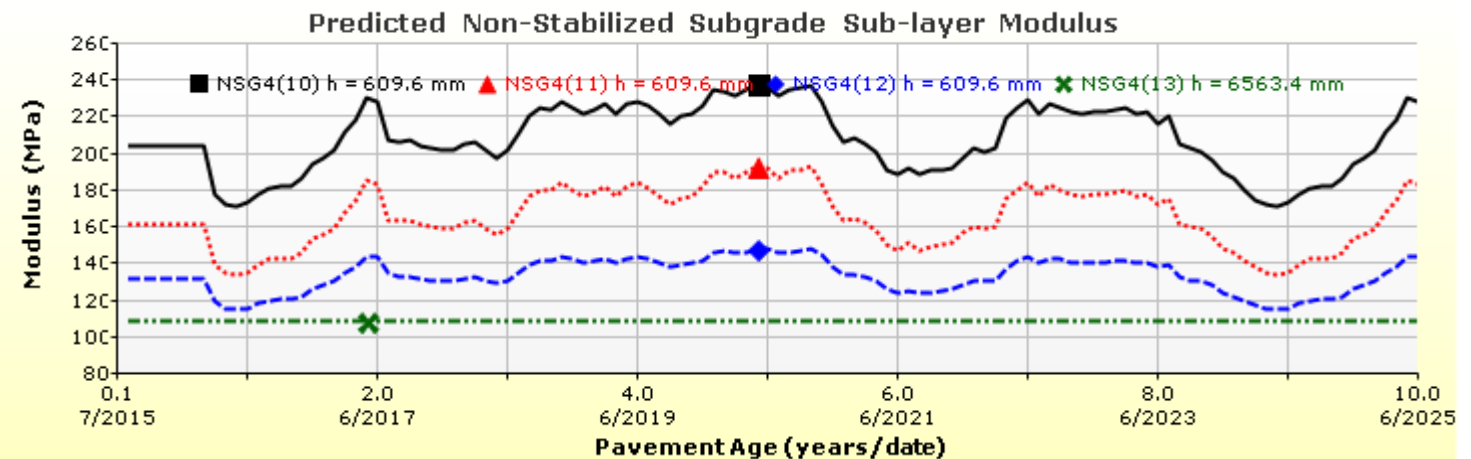
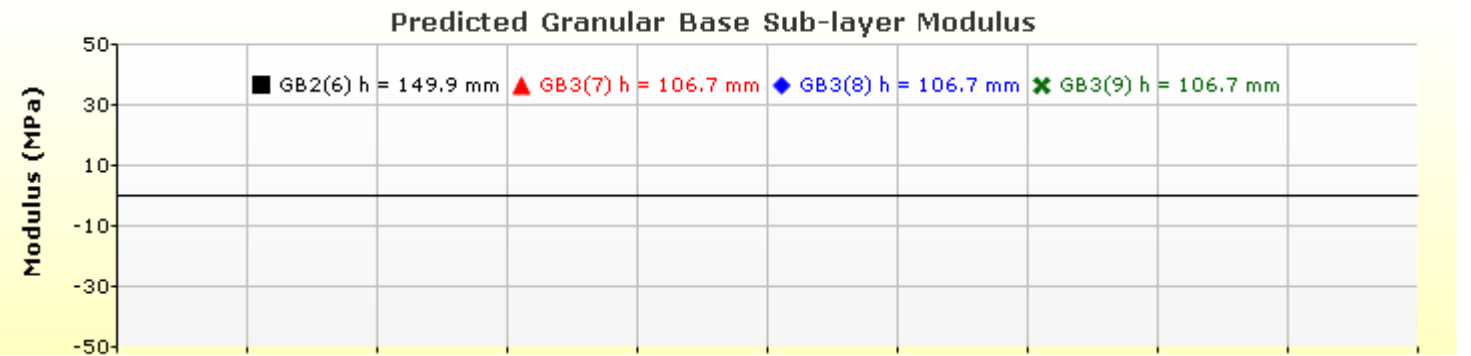
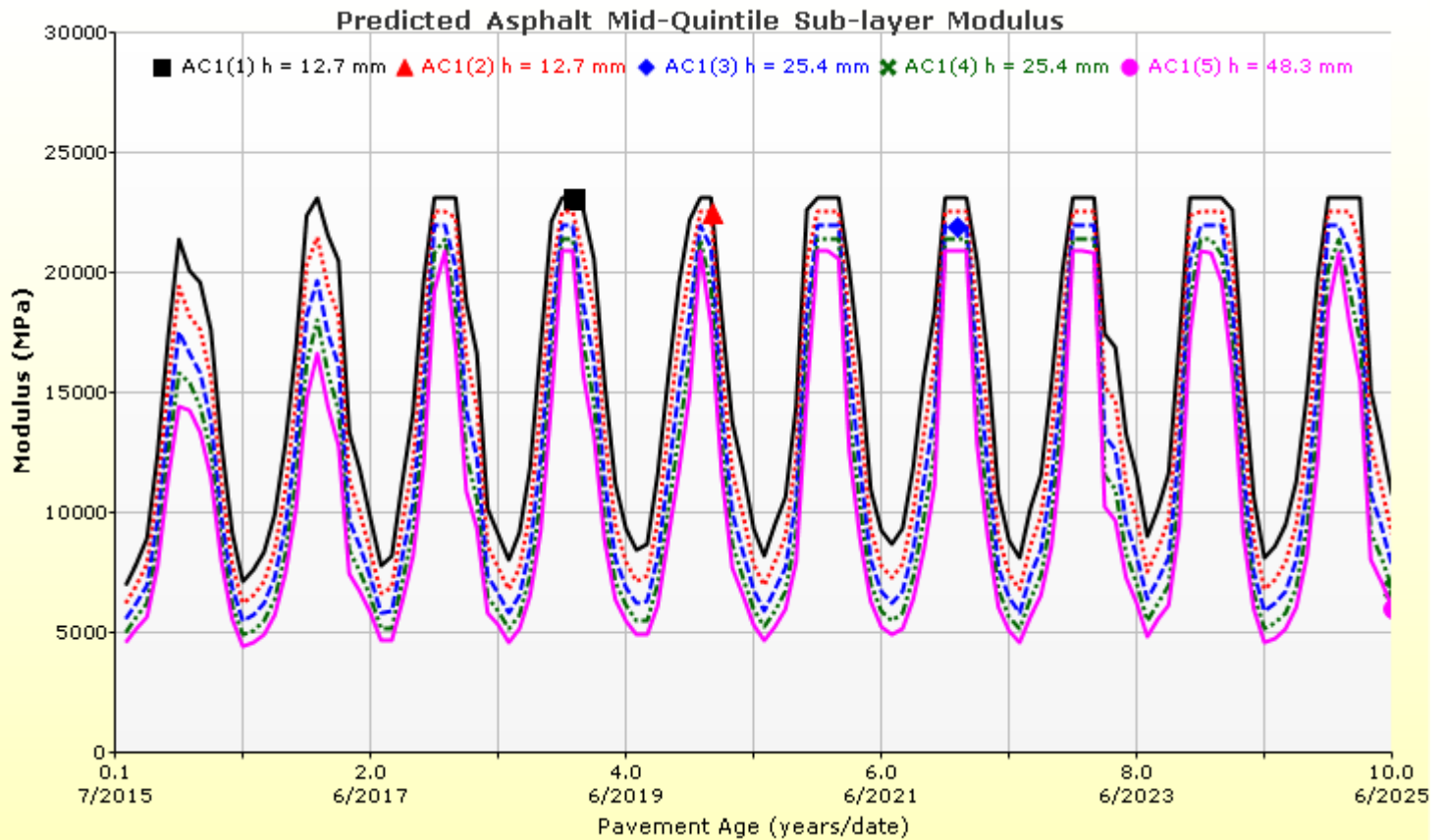


Thermal Cracking Spacing



Thermal Cracking Depth





Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

Standard Deviation (BASERUT)

0.1235*Pow(SUBRUT,0.5012)+0.001

AC Cracking

AC Top Down Cracking

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

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: 7

c2: 3.5

c3: 0

c4: 1000

c1: 1

c2: 1

c3: 6000

AC Cracking Top Standard Deviation

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

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

IRI Flexible Pavements

C1 - Rutting

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

CSM Standard Deviation

CTB*1

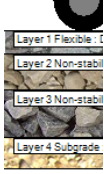
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	200.0
NonStabilized	Crushed stone	300.0
NonStabilized	Crushed stone	400.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

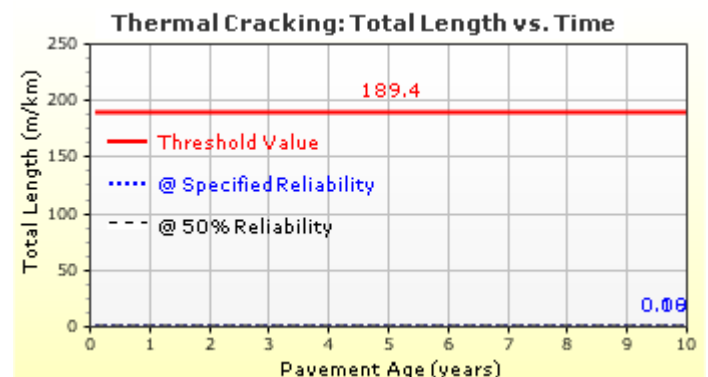
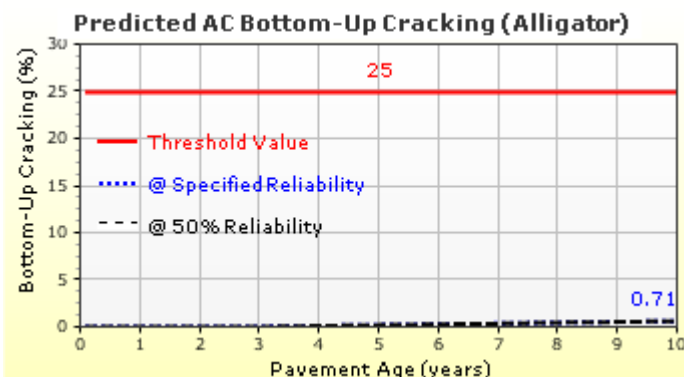
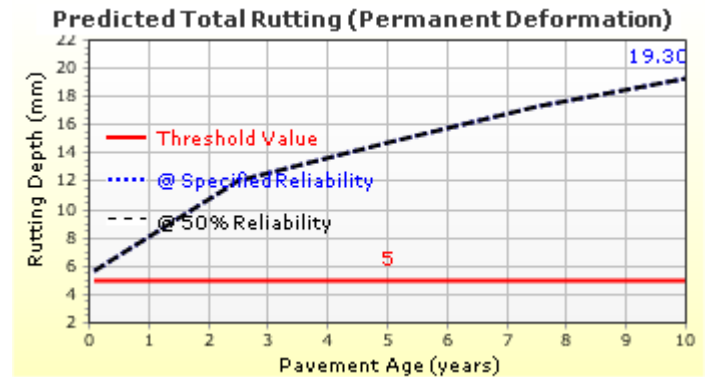
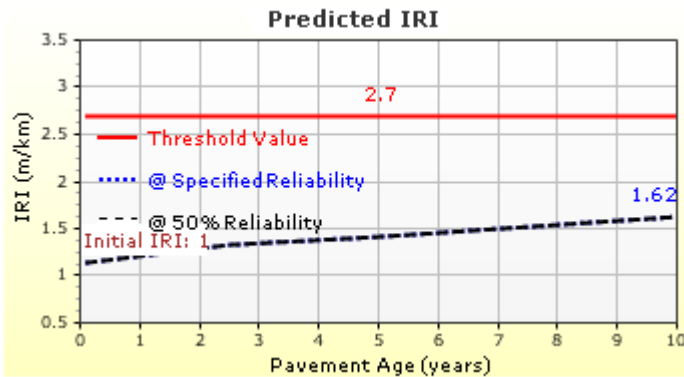
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.62	50.00	99.11	Pass
Permanent deformation - total pavement (mm)	5.00	19.30	50.00	0.03	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.71	50.00	100.00	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	72.73	50.00	79.27	Pass
Permanent deformation - AC only (mm)	5.00	14.57	50.00	0.74	Fail

Distress Charts

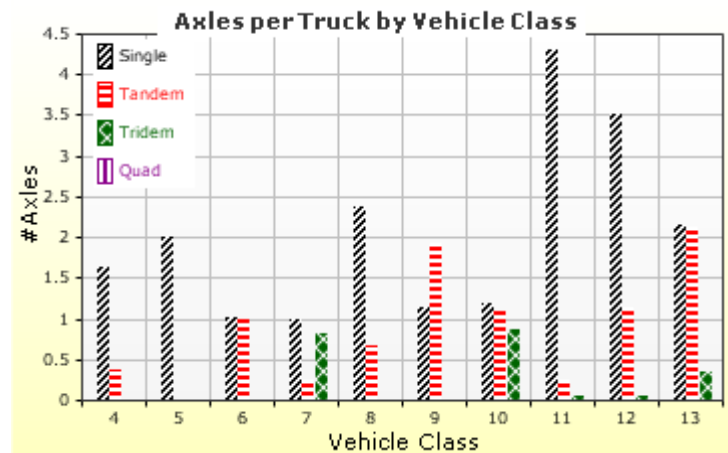
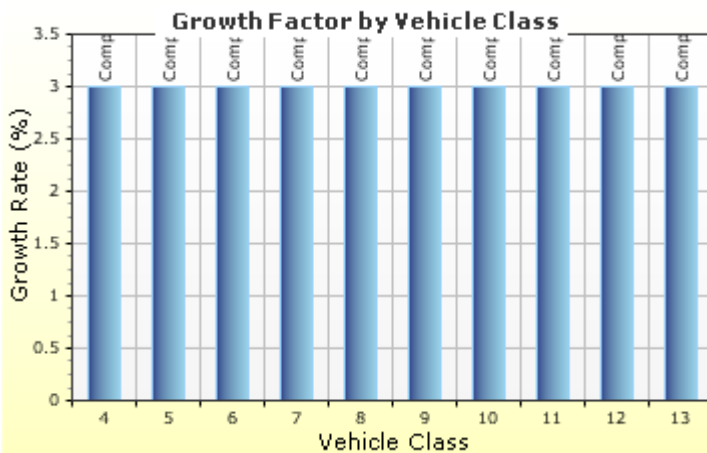
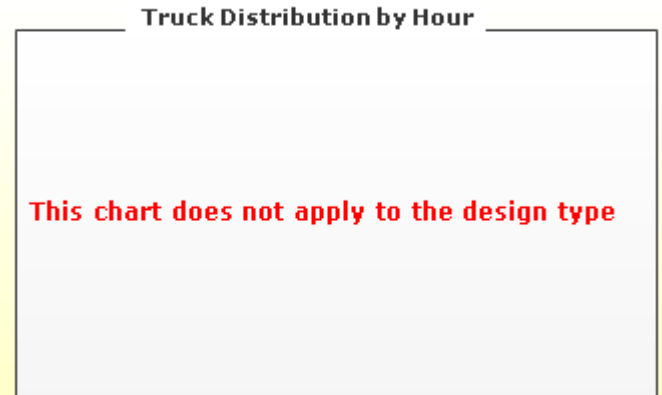
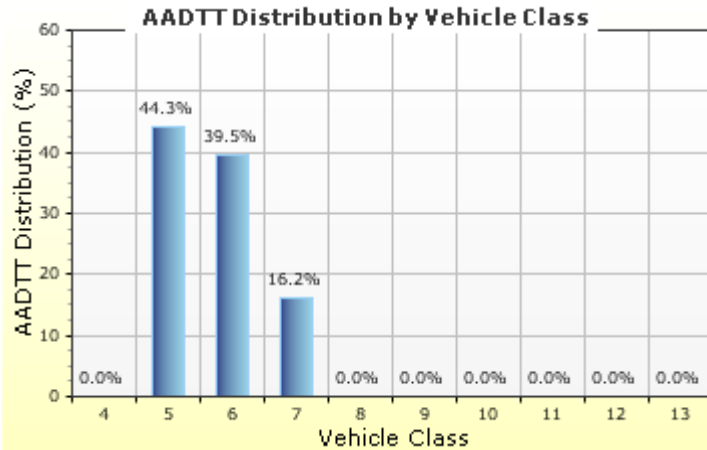


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

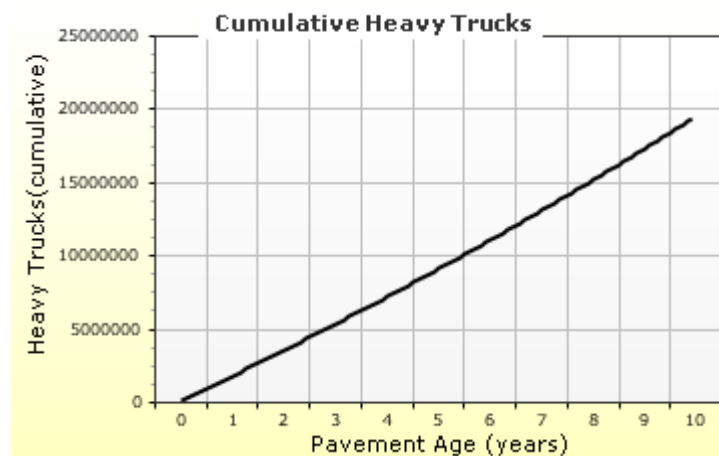
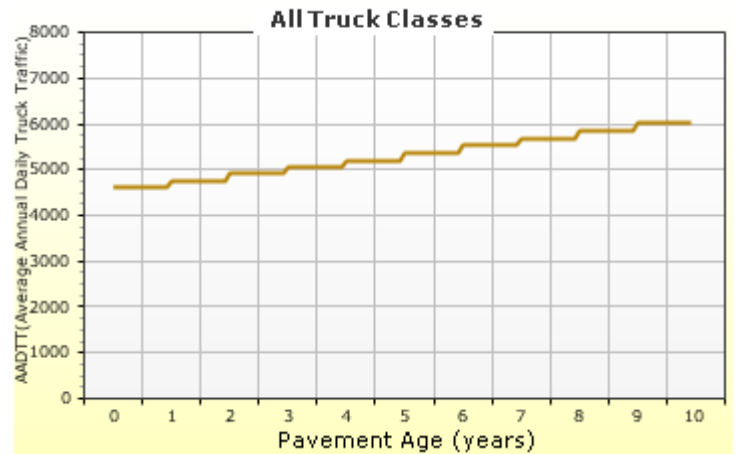
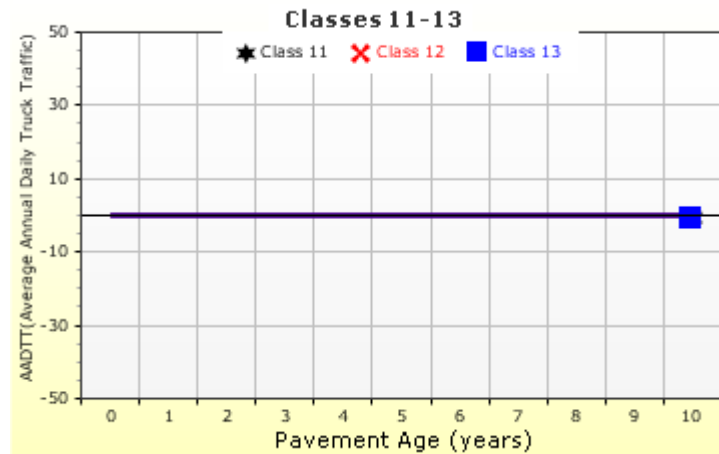
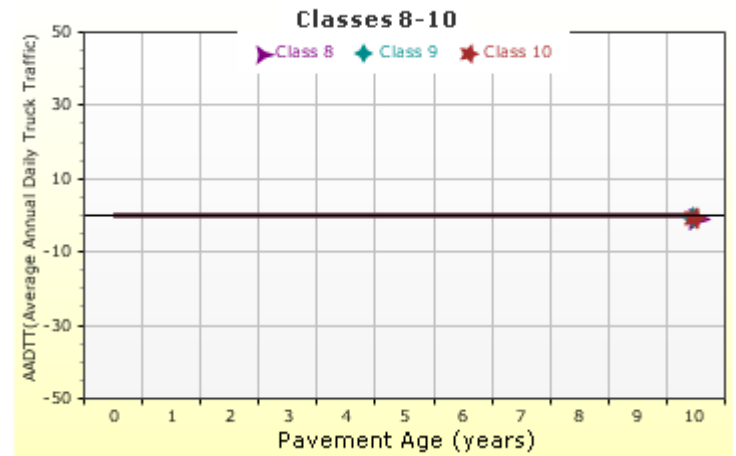
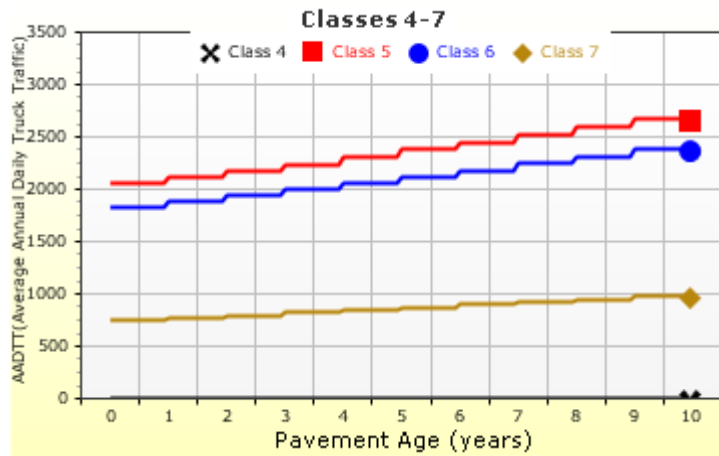
Wheelbase does not apply

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



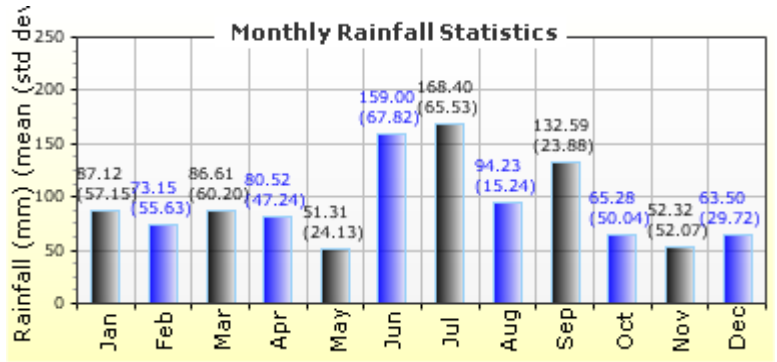
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

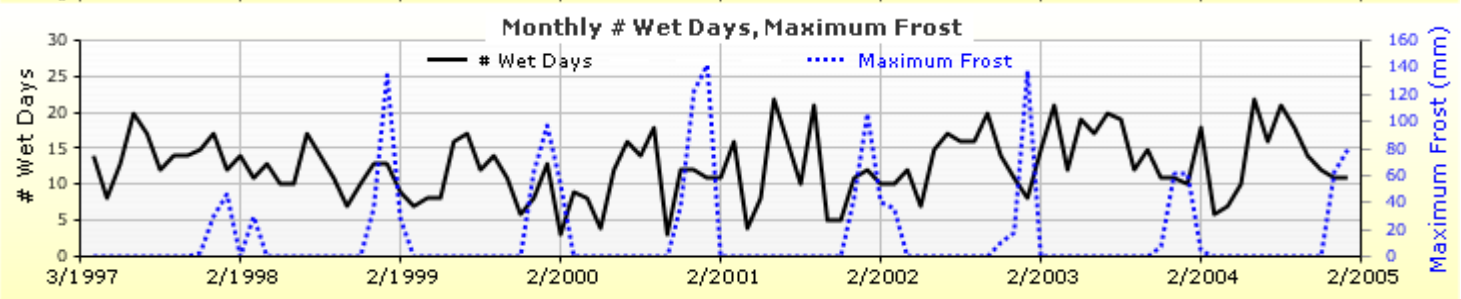
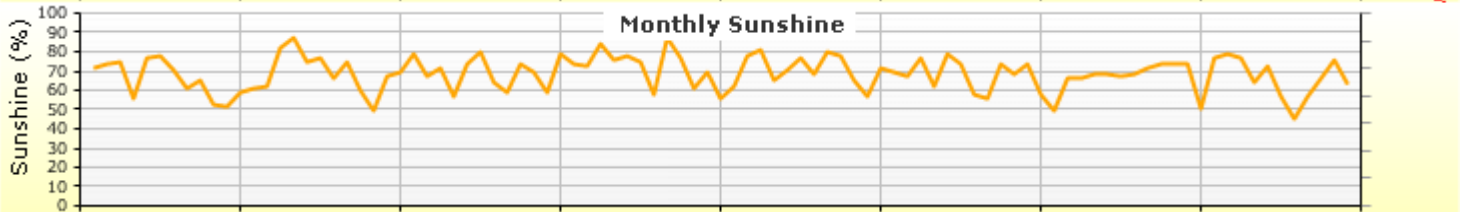
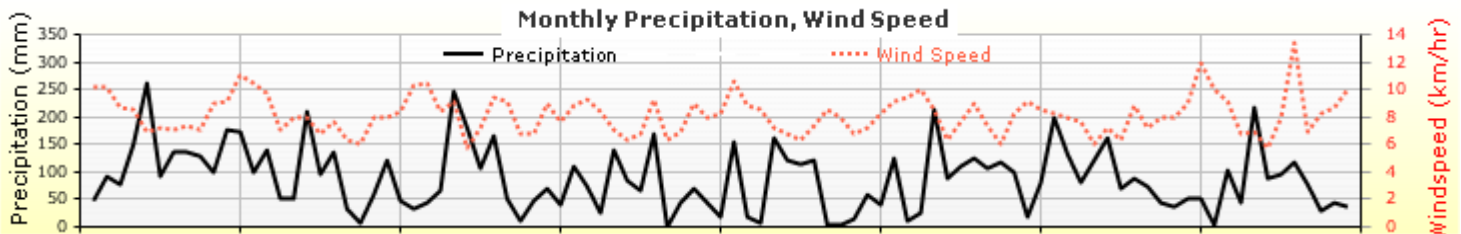
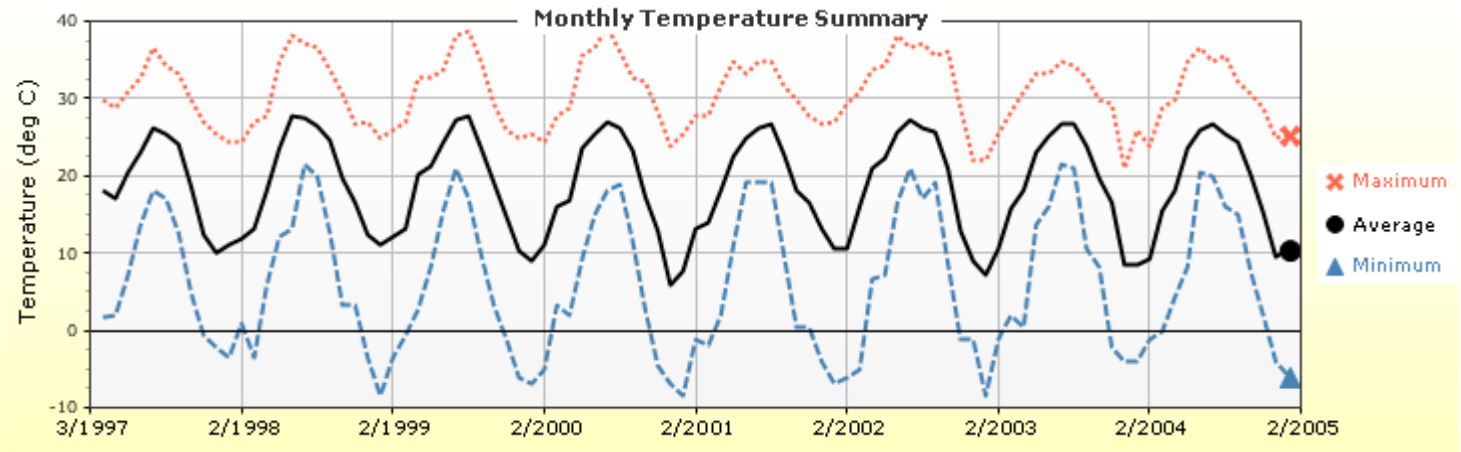
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

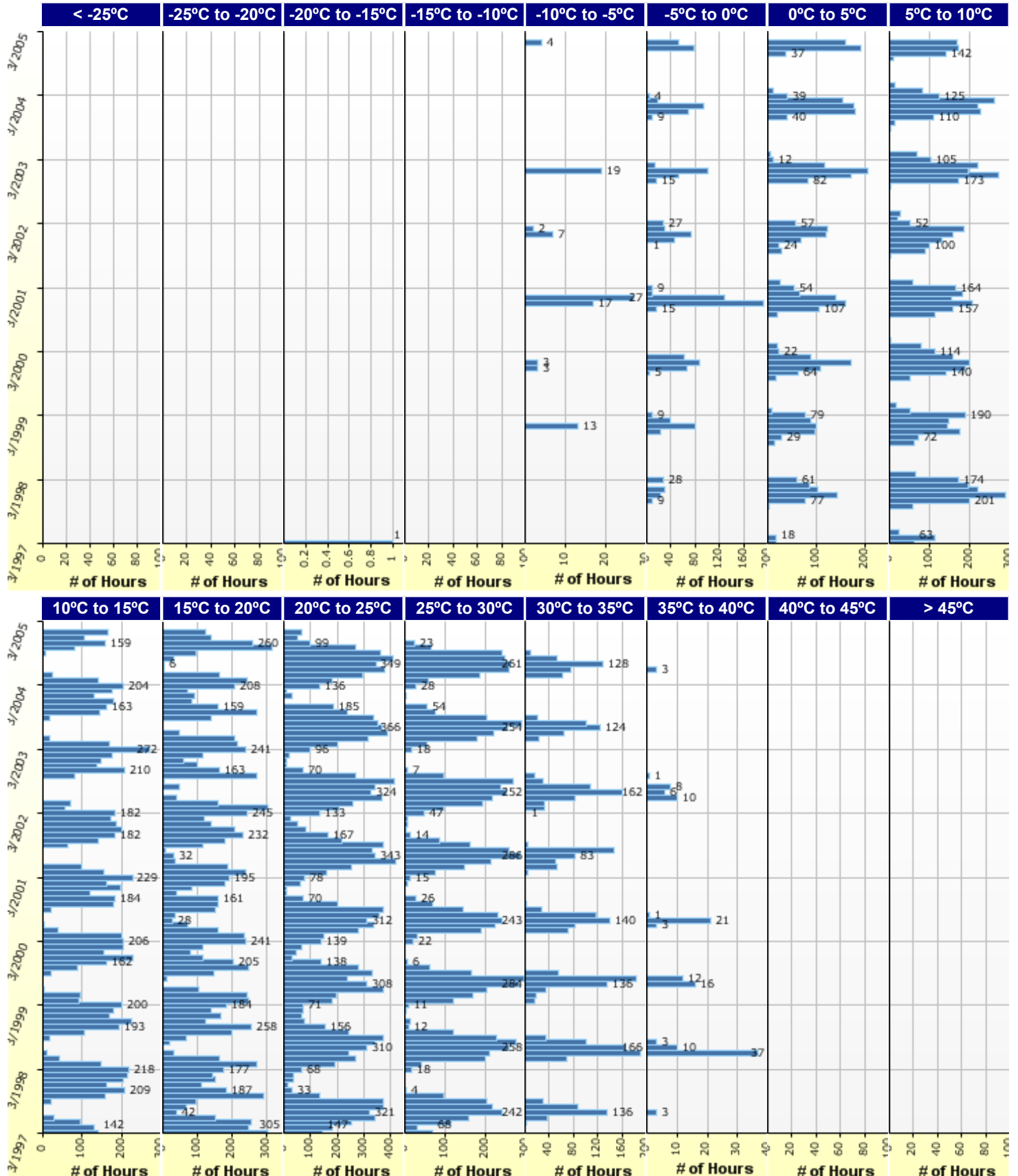


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF1_ALT3

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1_ALT3.dgpx



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

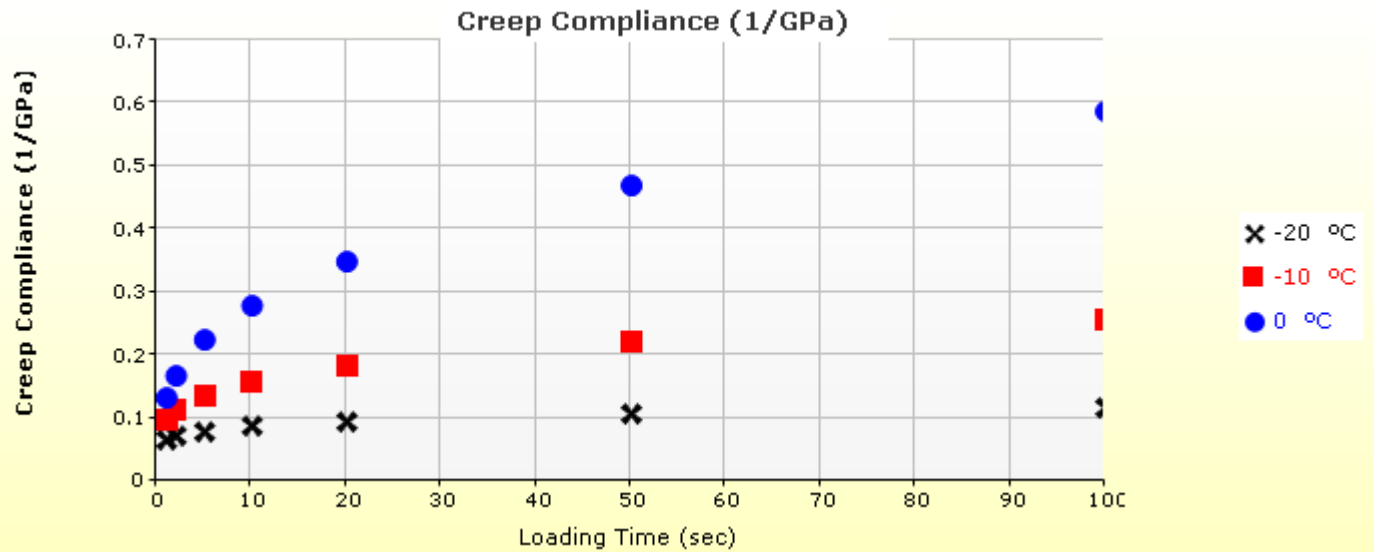
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

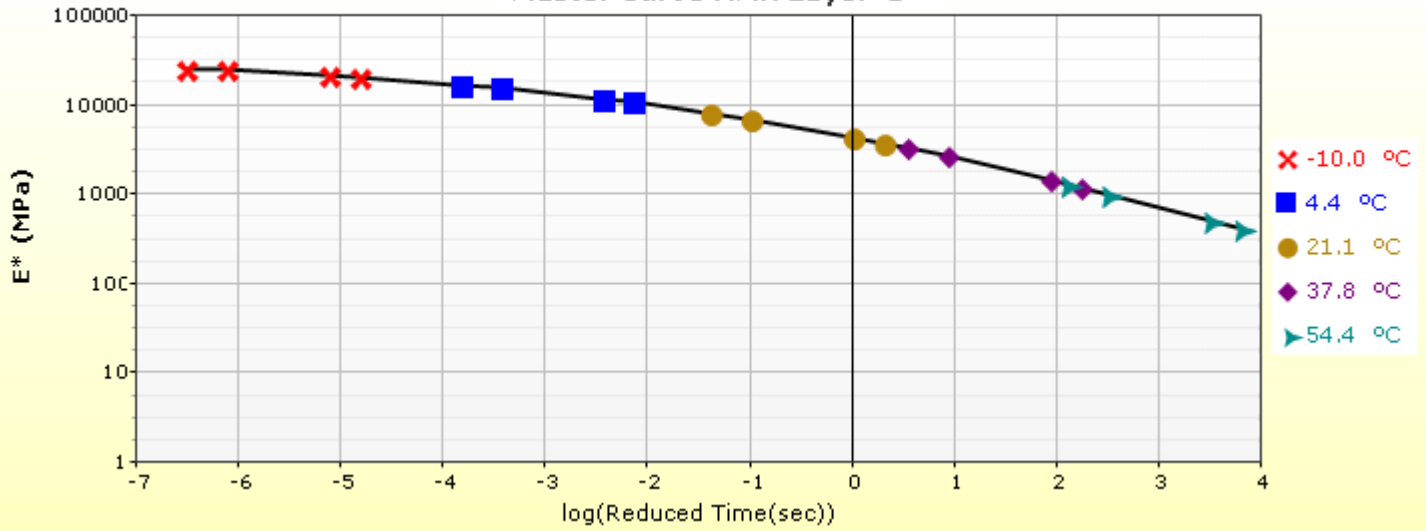
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

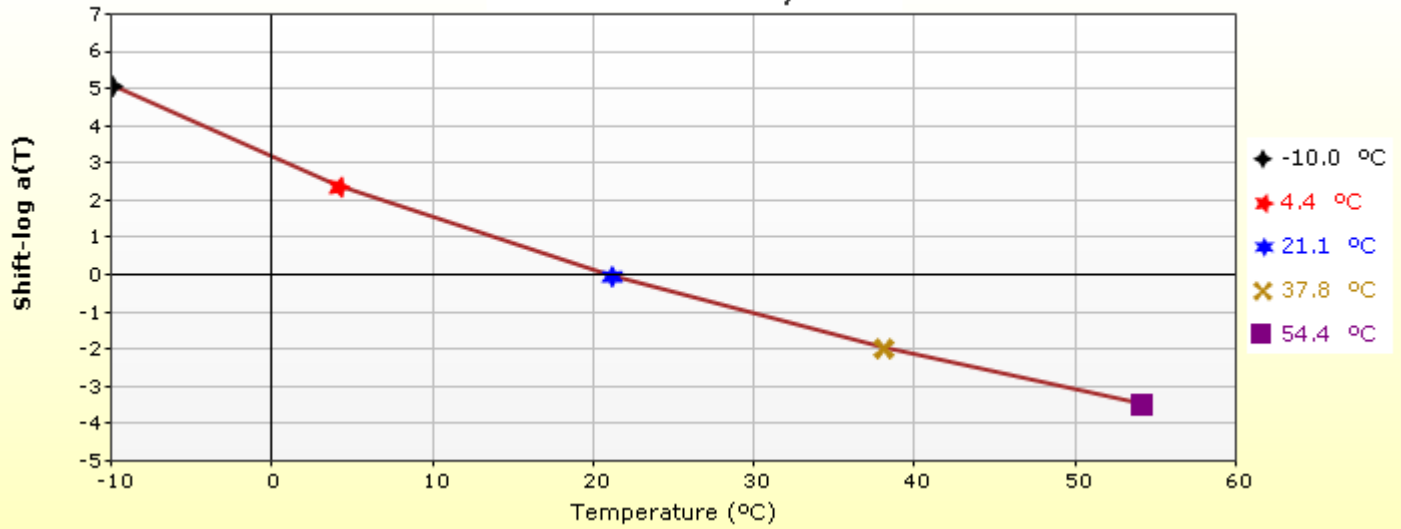


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

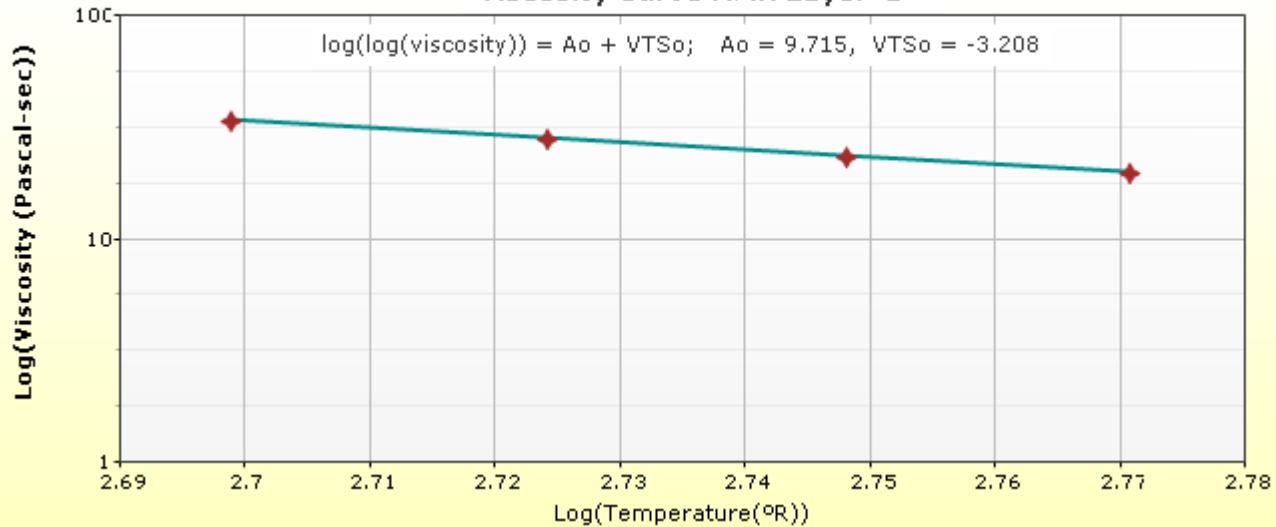
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

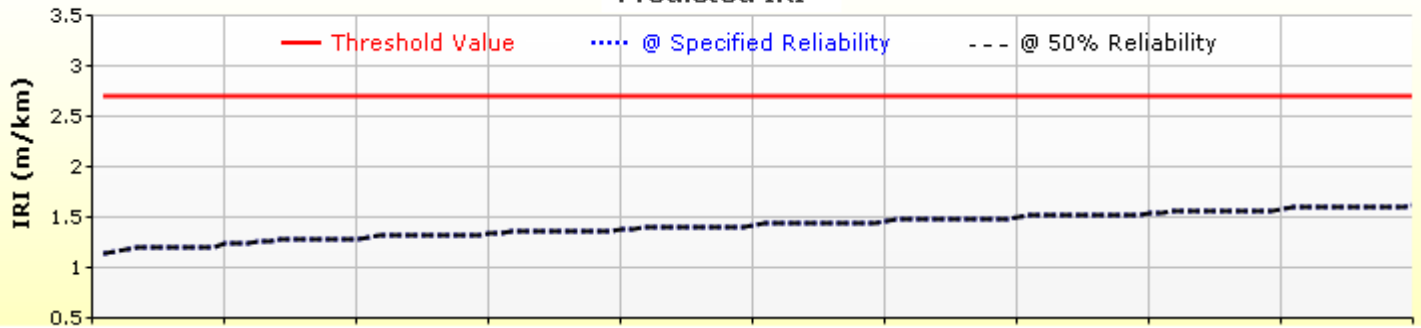


Viscosity Curve HMA Layer 1

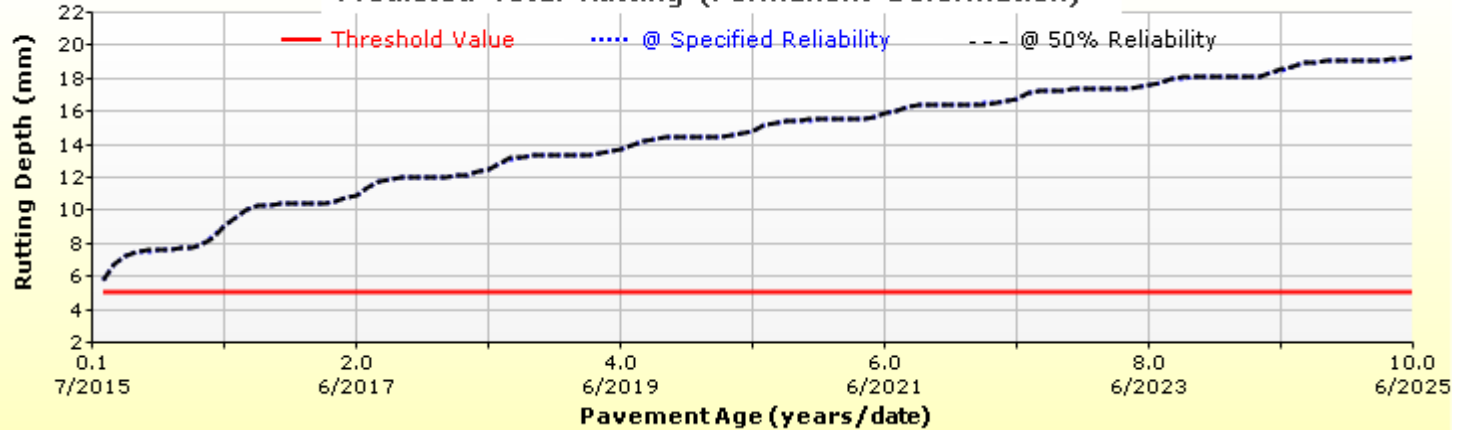


Analysis Output Charts

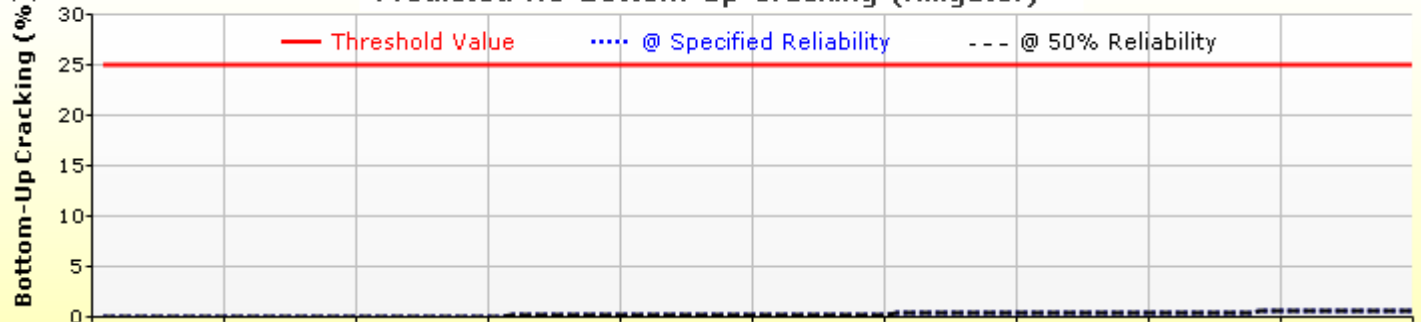
Predicted IRI



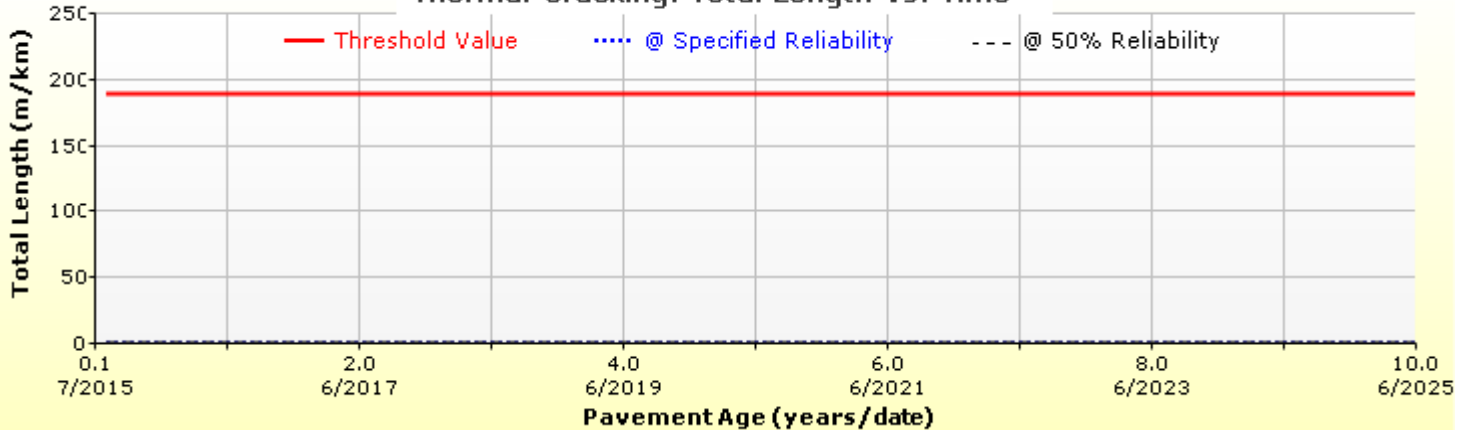
Predicted Total Rutting (Permanent Deformation)



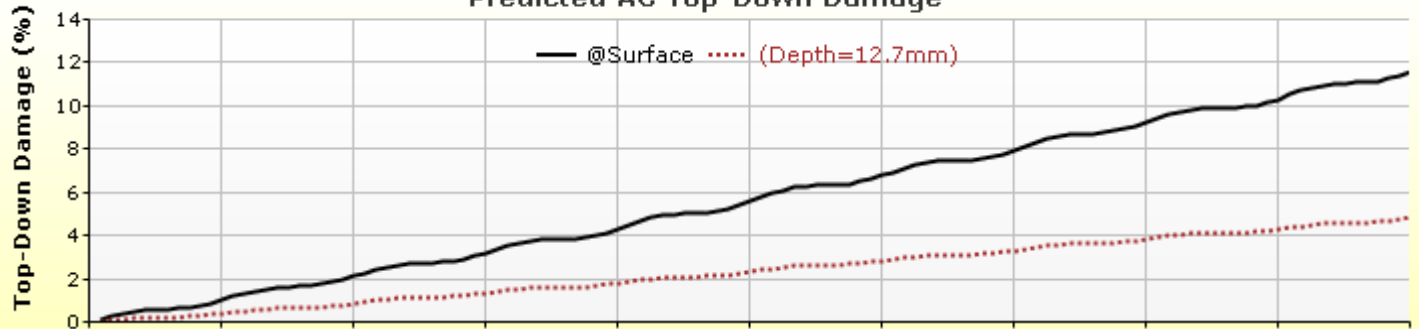
Predicted AC Bottom-Up Cracking (Alligator)



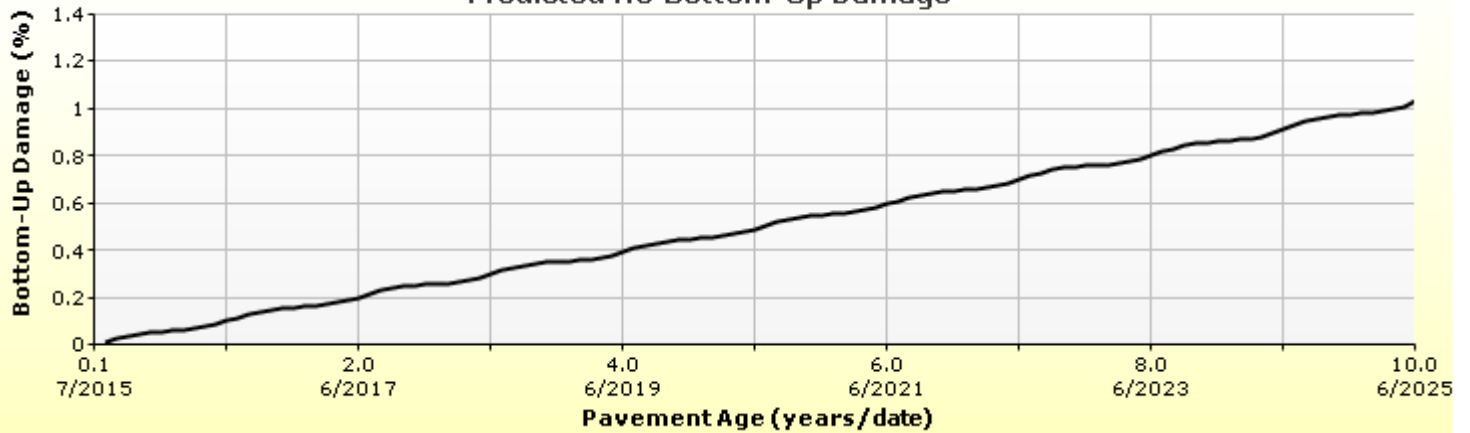
Thermal Cracking: Total Length vs. Time



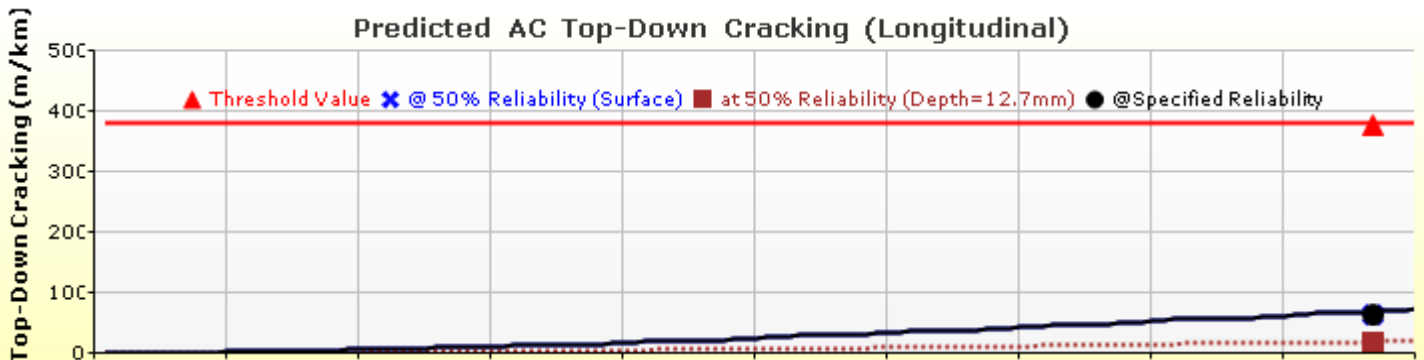
Predicted AC Top-Down Damage



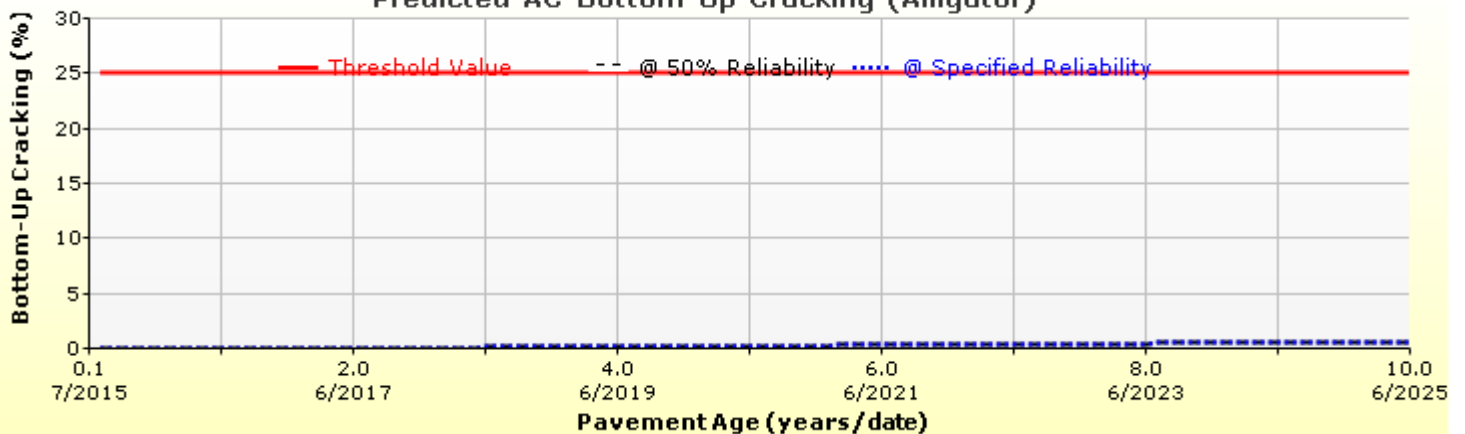
Predicted AC Bottom-Up Damage



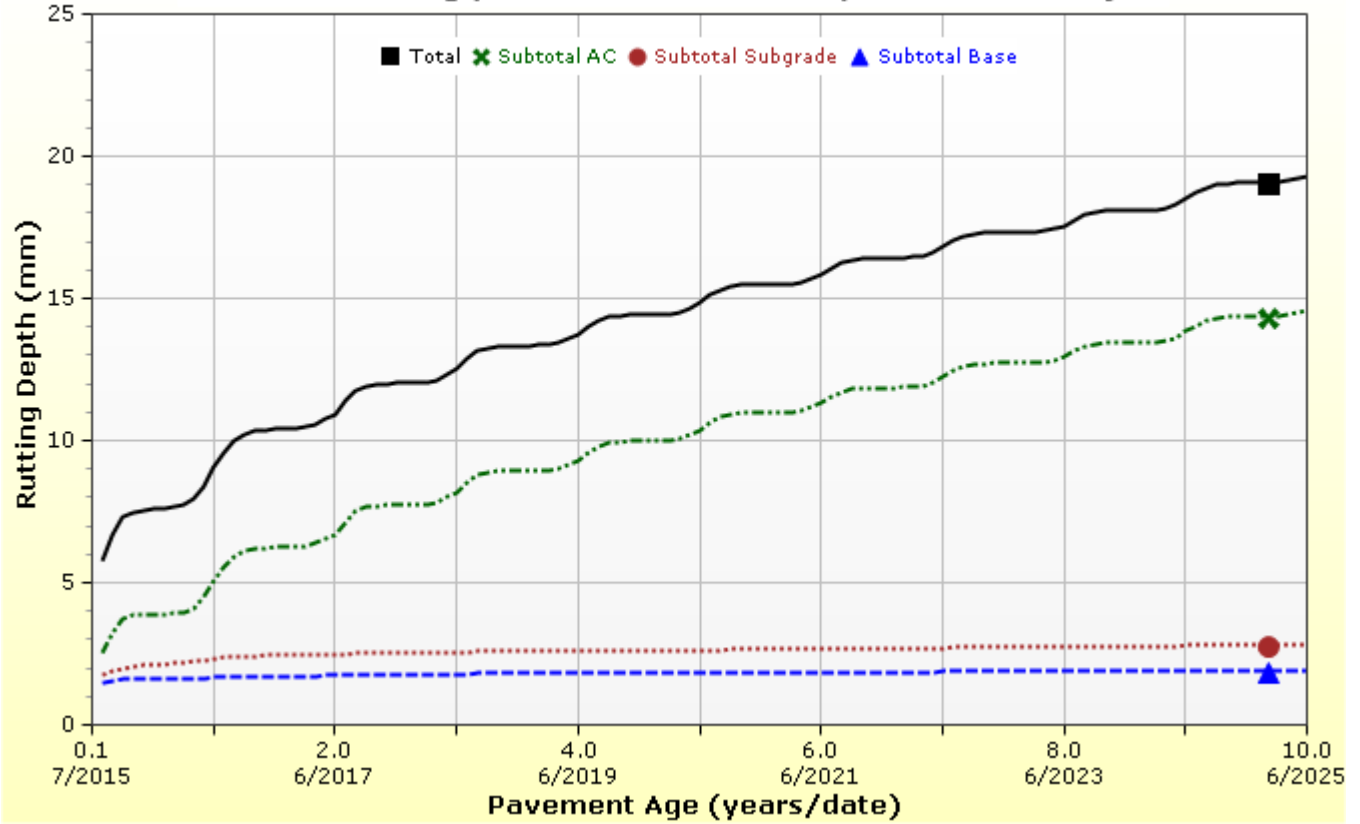
Predicted AC Top-Down Cracking (Longitudinal)



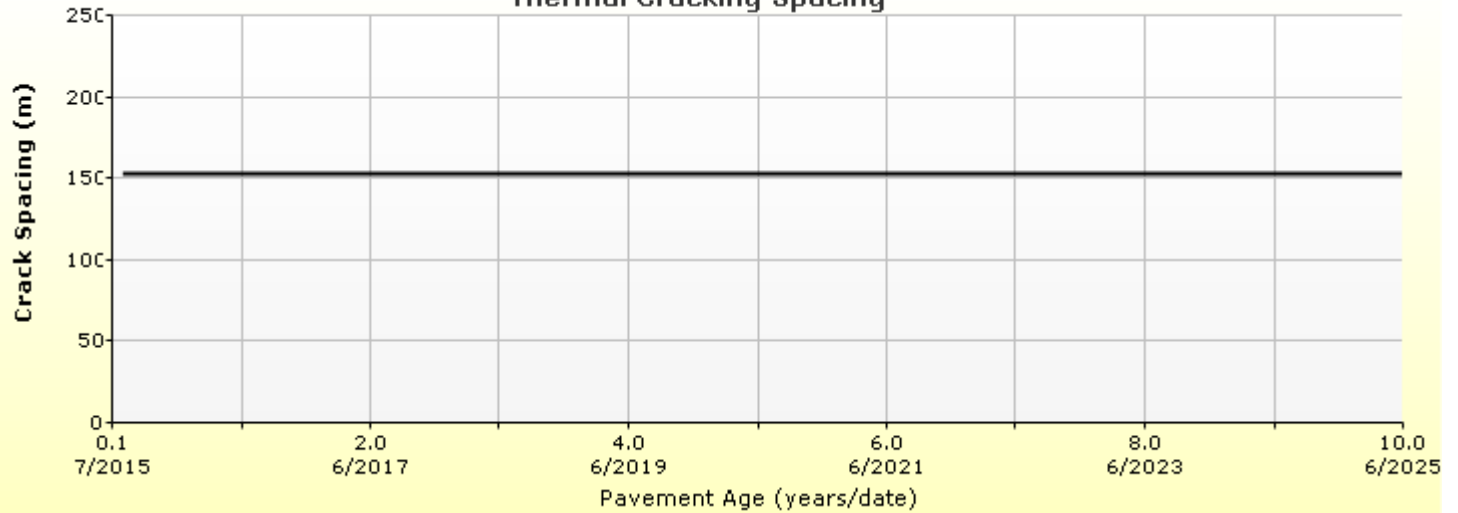
Predicted AC Bottom-Up Cracking (Alligator)



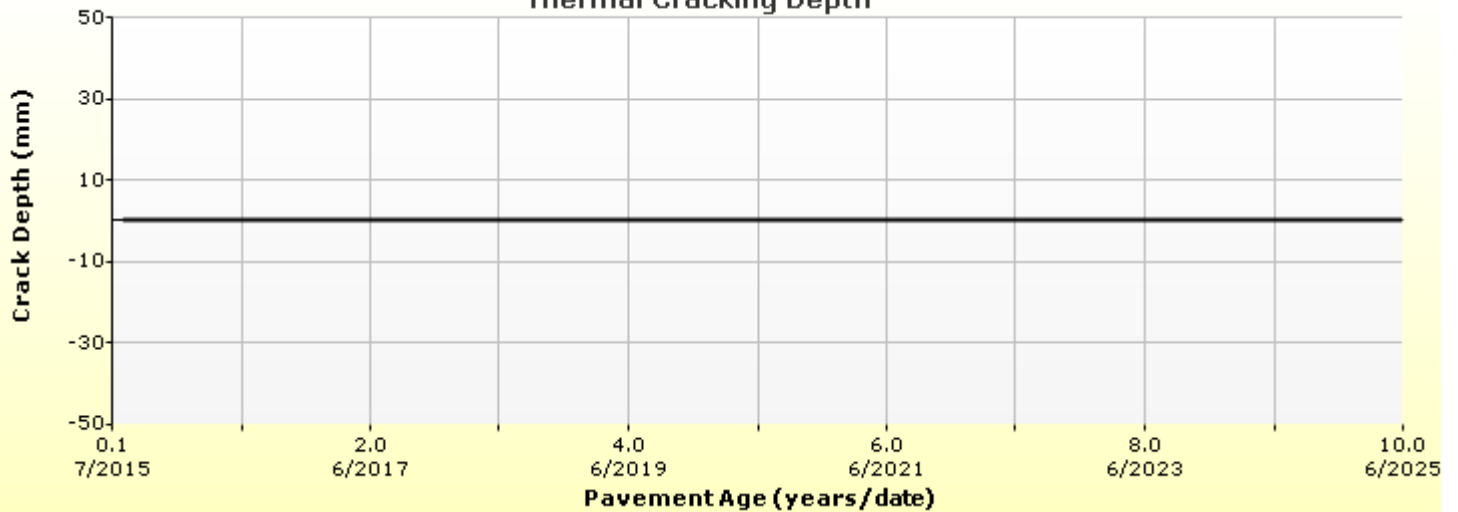
Predicted Rutting (Permanent Deformation) at 50% Reliability

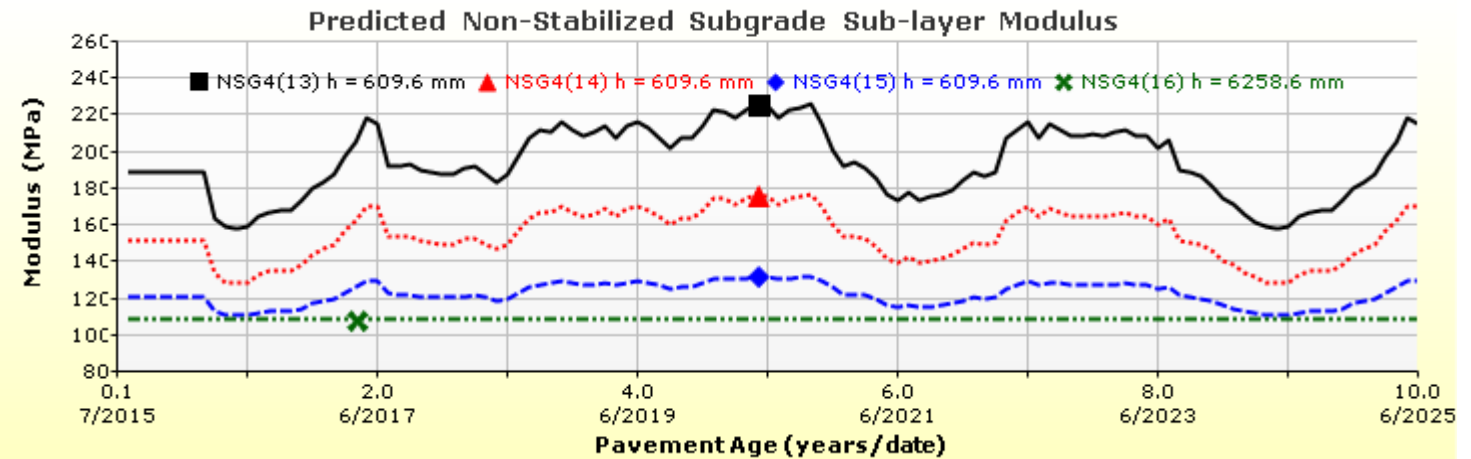
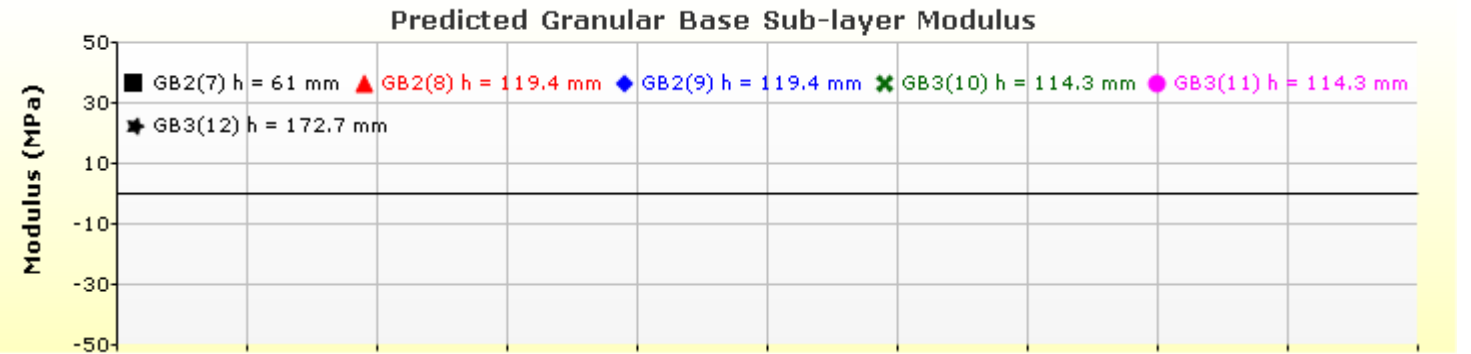
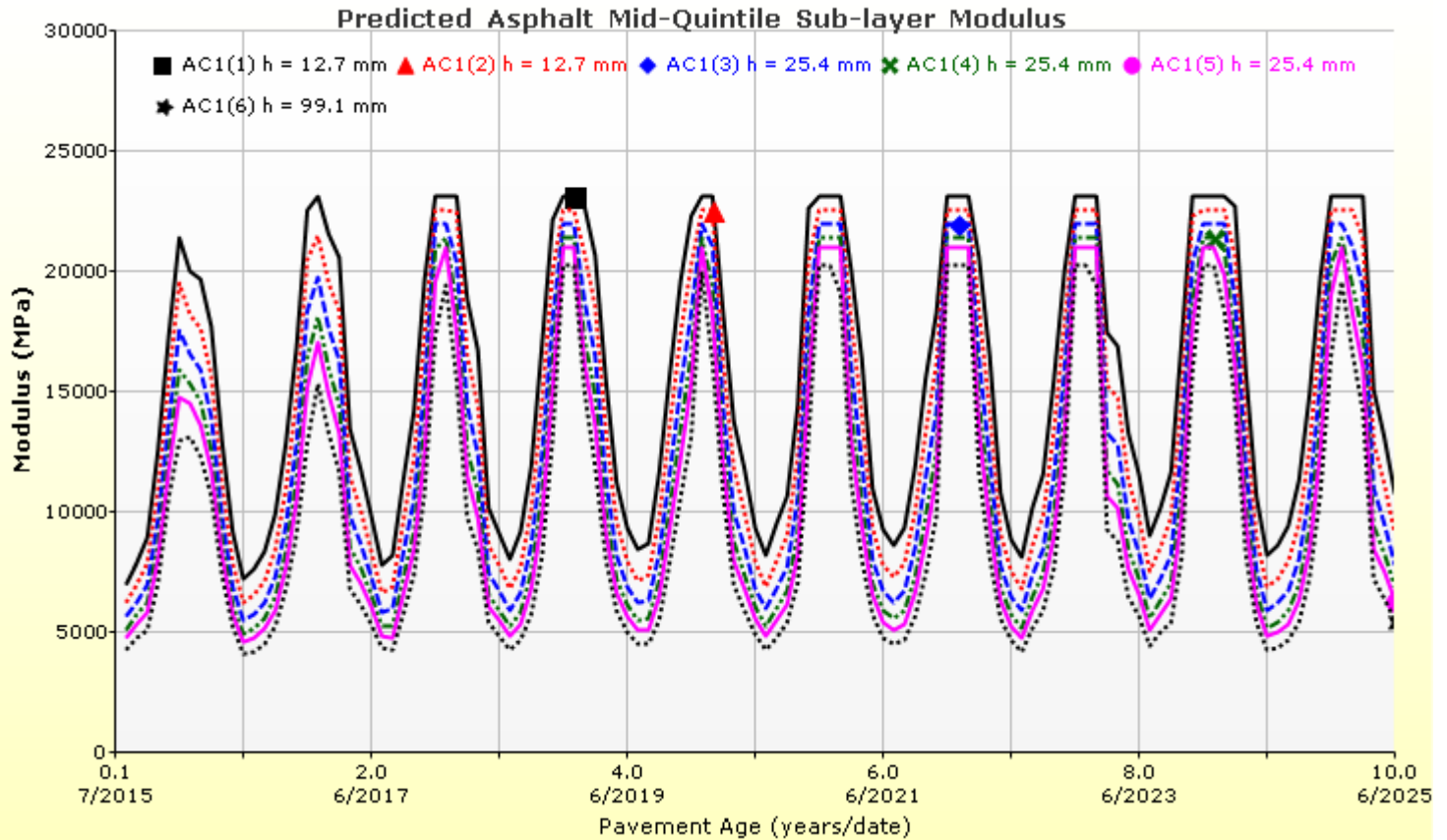


Thermal Cracking Spacing



Thermal Cracking Depth





Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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:	Annual representative values
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	200.0
NonStabilized	Crushed stone	300.0
NonStabilized	Crushed stone	400.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

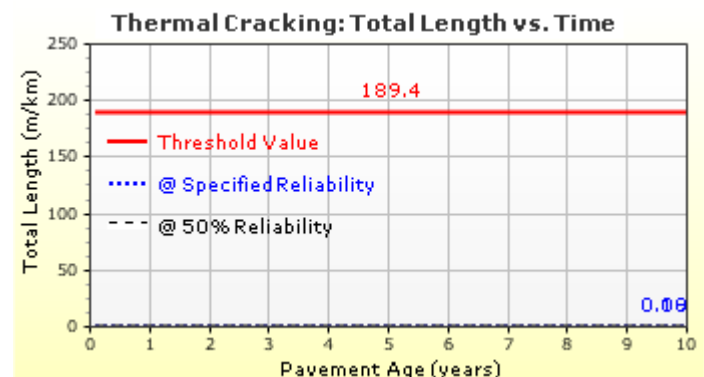
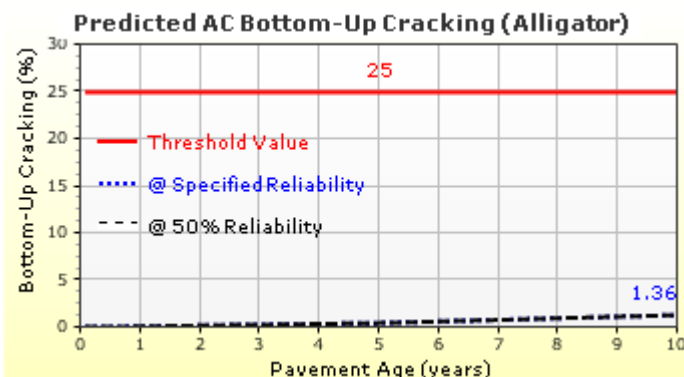
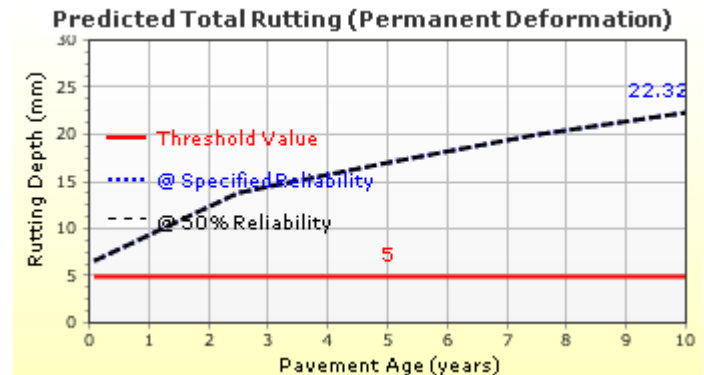
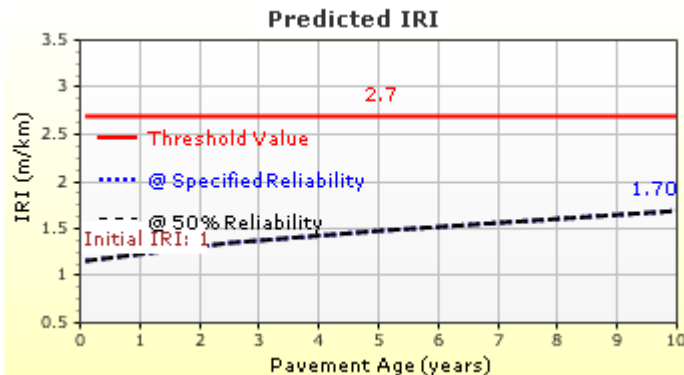
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.70	50.00	98.20	Pass
Permanent deformation - total pavement (mm)	5.00	22.32	50.00	0.01	Fail
AC bottom-up fatigue cracking (percent)	25.00	1.36	50.00	100.00	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	128.98	50.00	73.36	Pass
Permanent deformation - AC only (mm)	5.00	17.07	50.00	0.34	Fail

Distress Charts

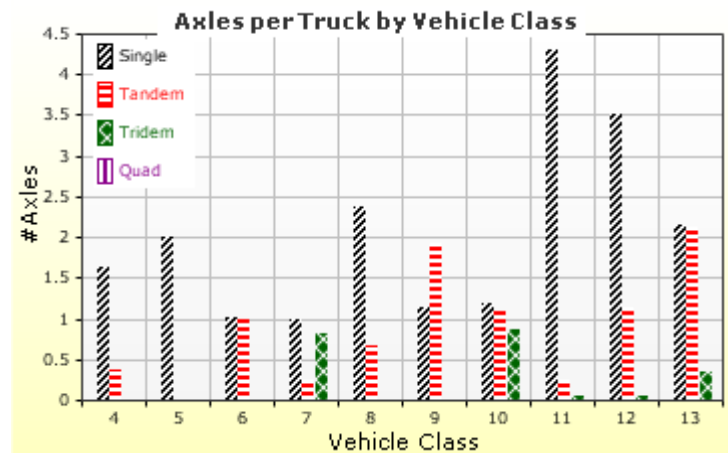
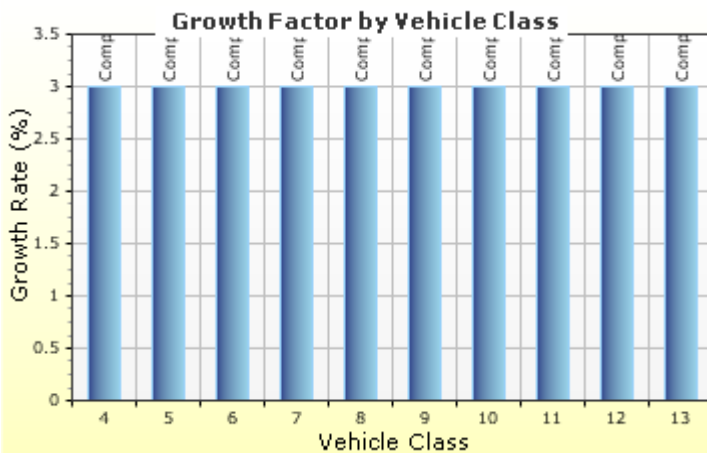
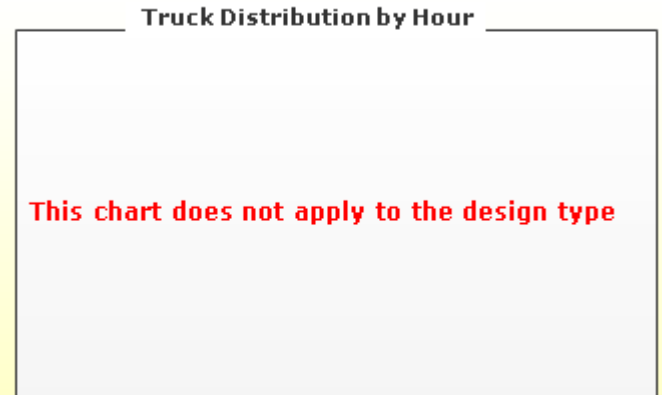
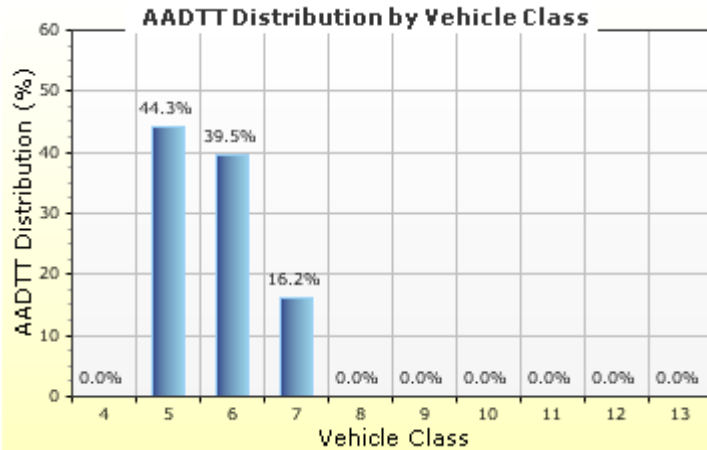


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

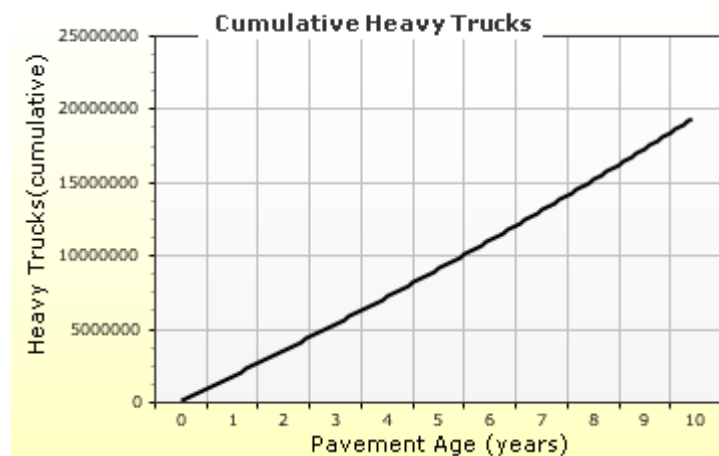
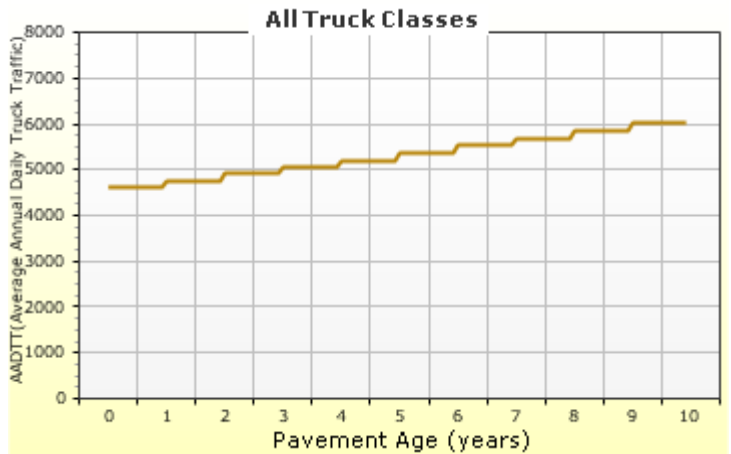
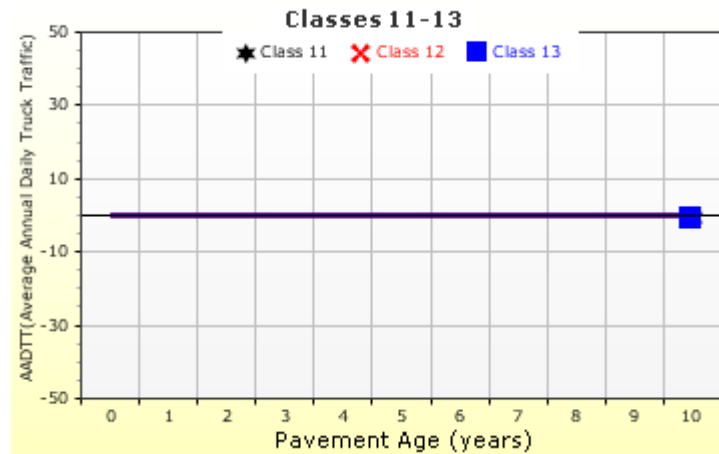
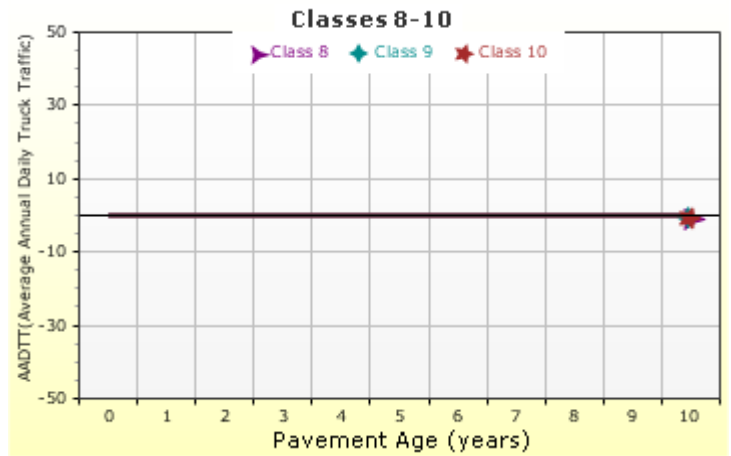
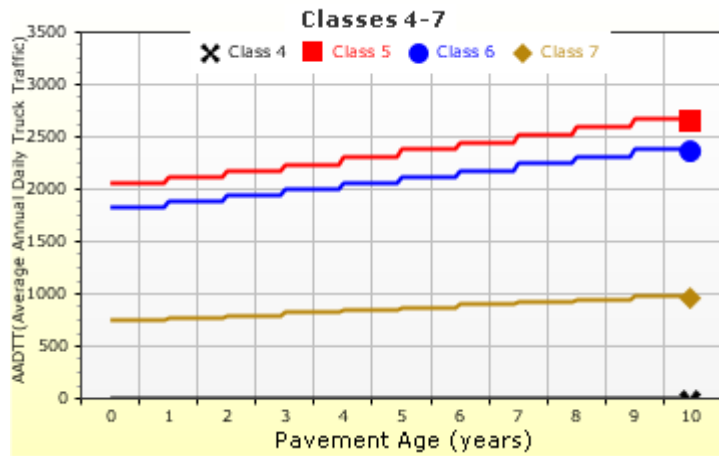
Wheelbase does not apply

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



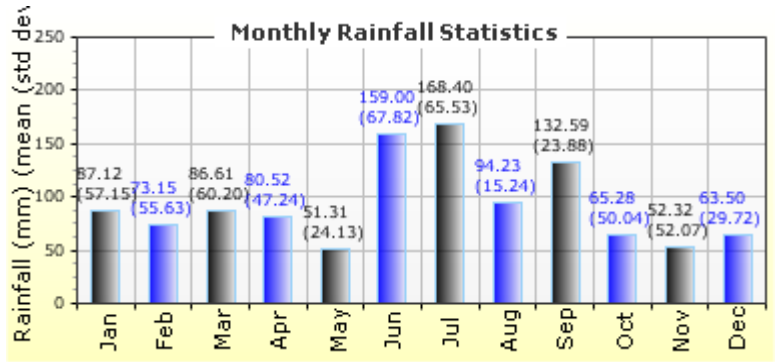
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

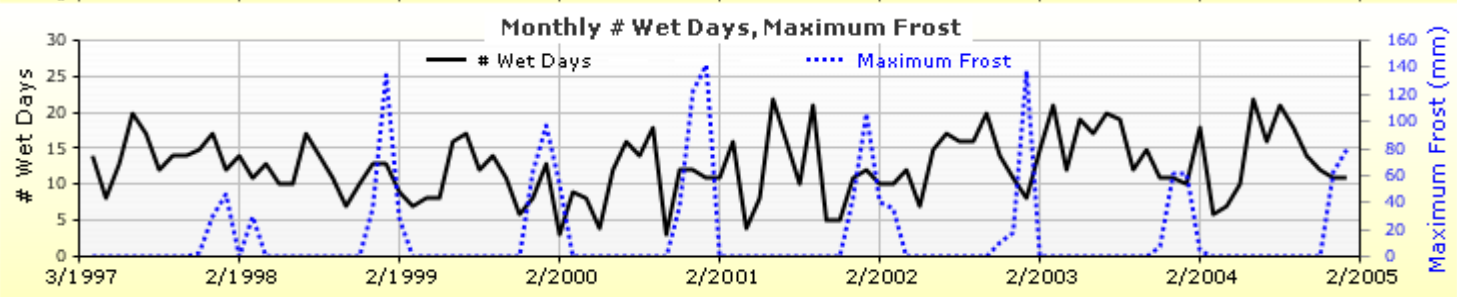
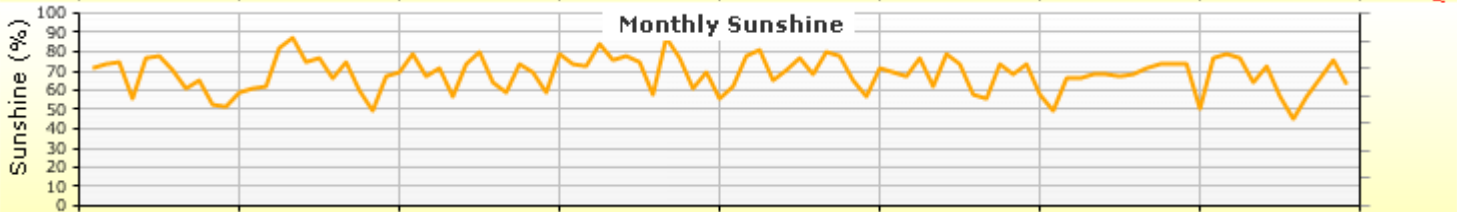
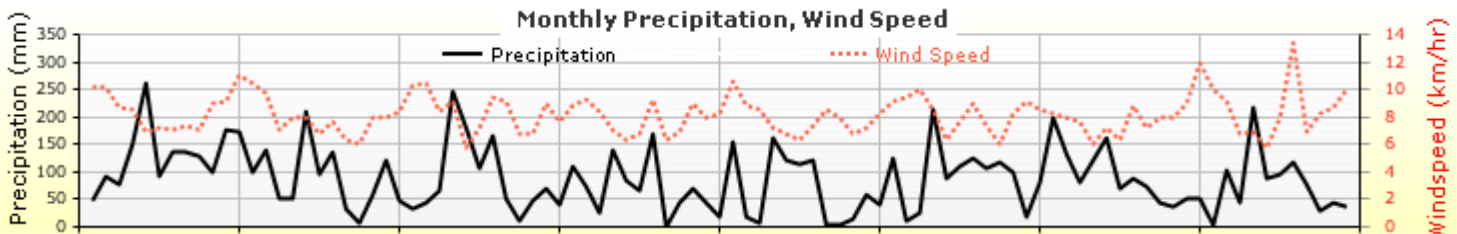
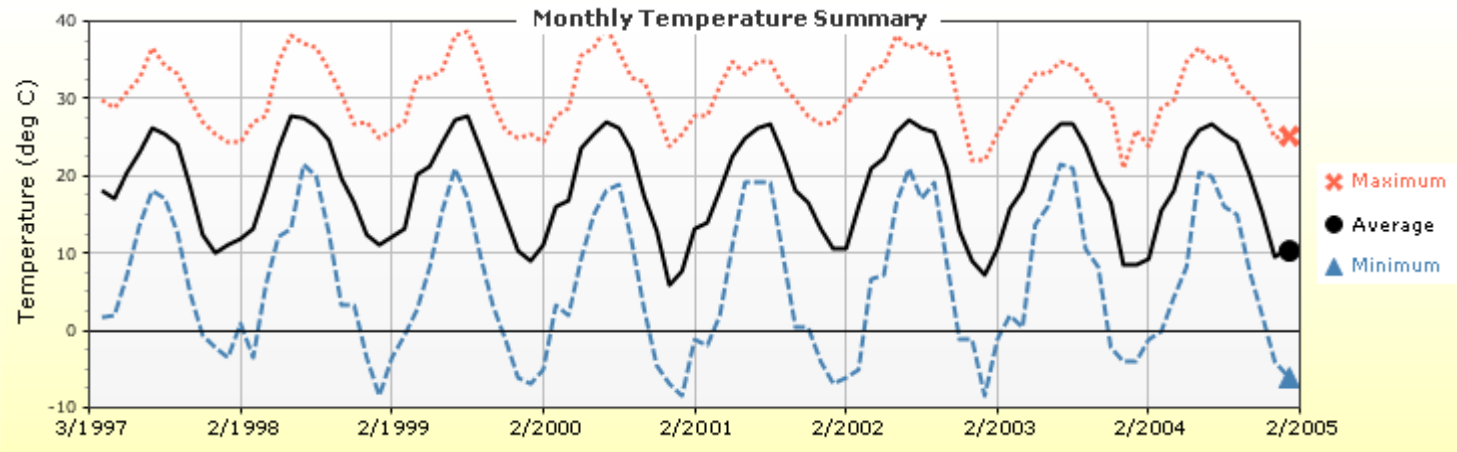
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

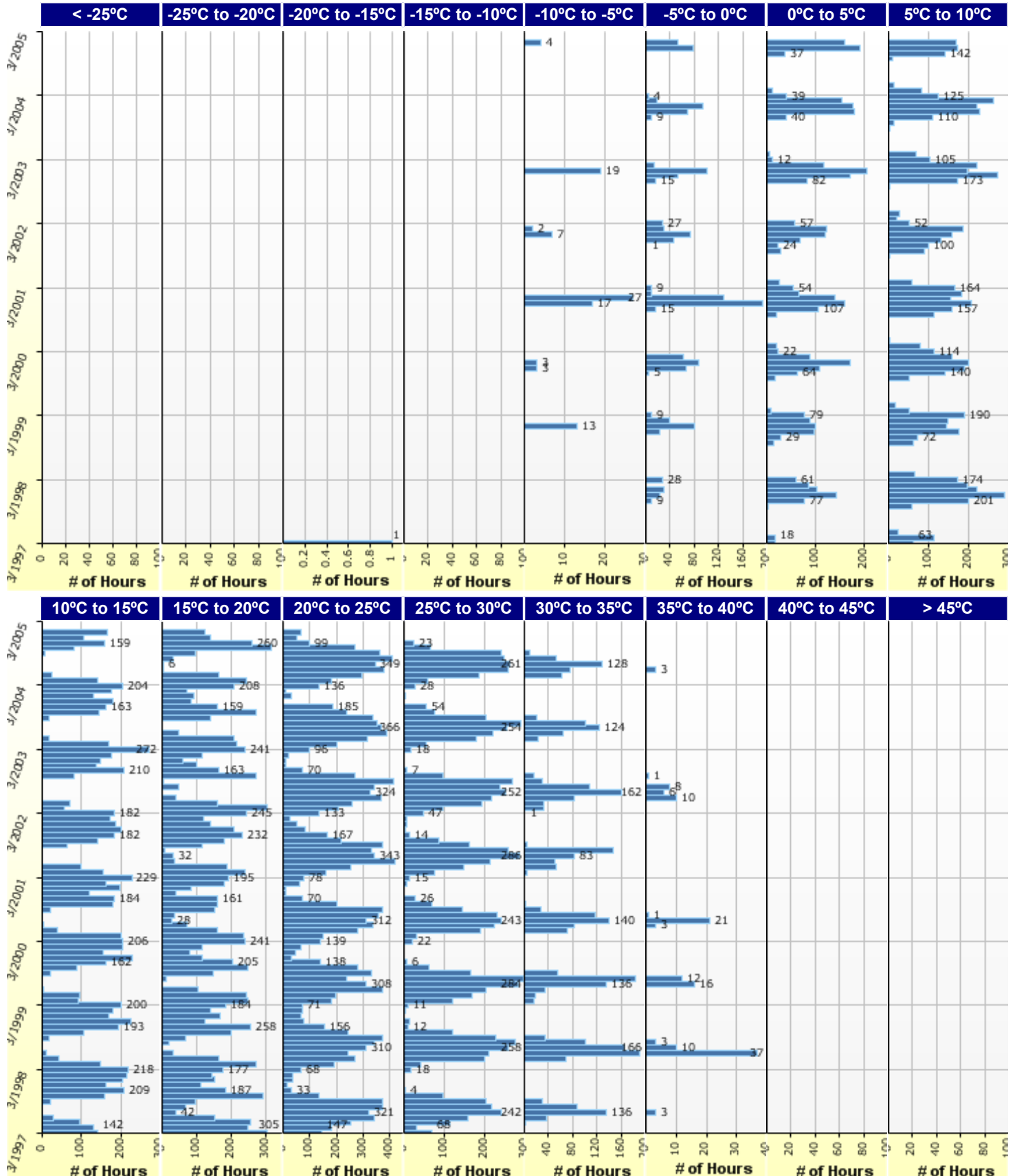


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF2_ALT3

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF2_ALT3.dgpx



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

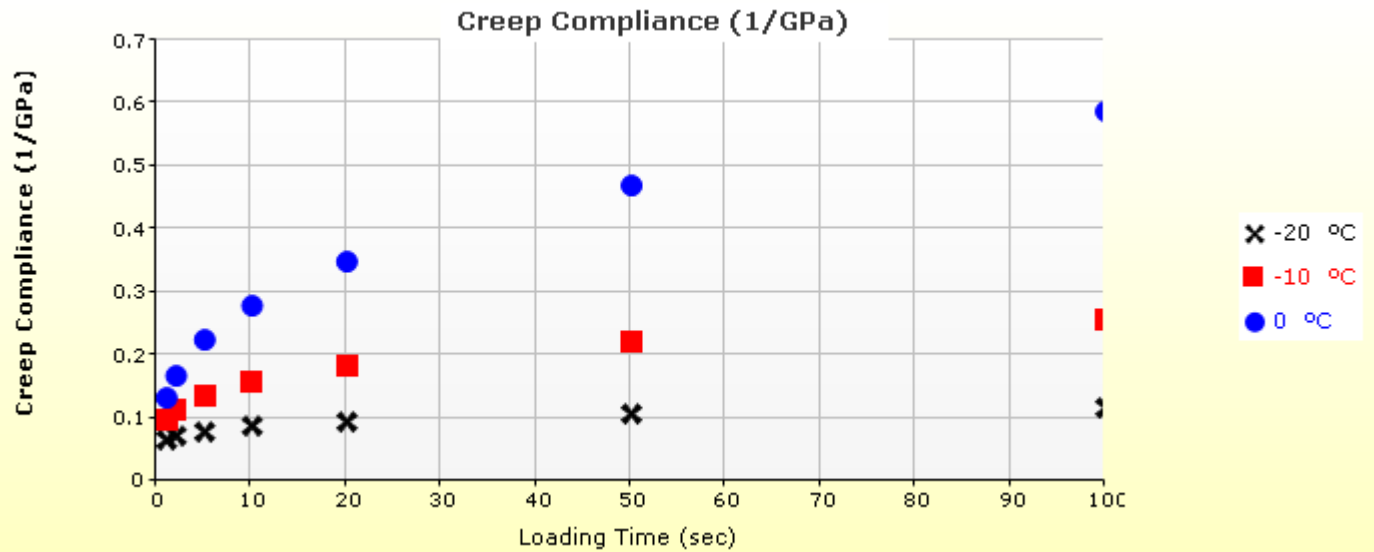
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

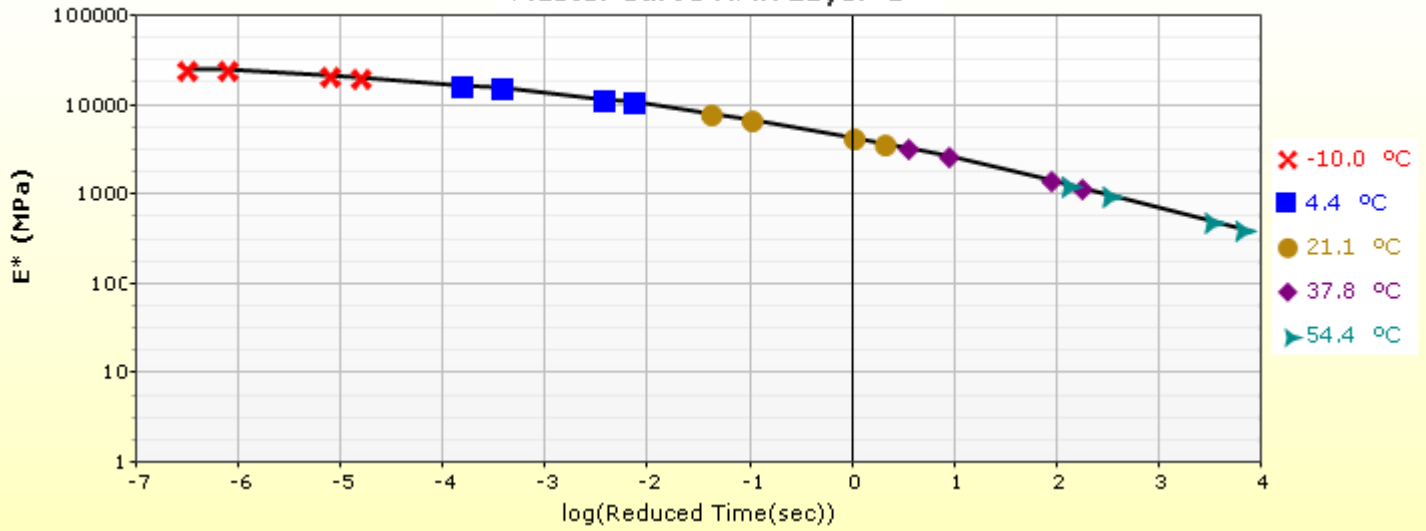
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

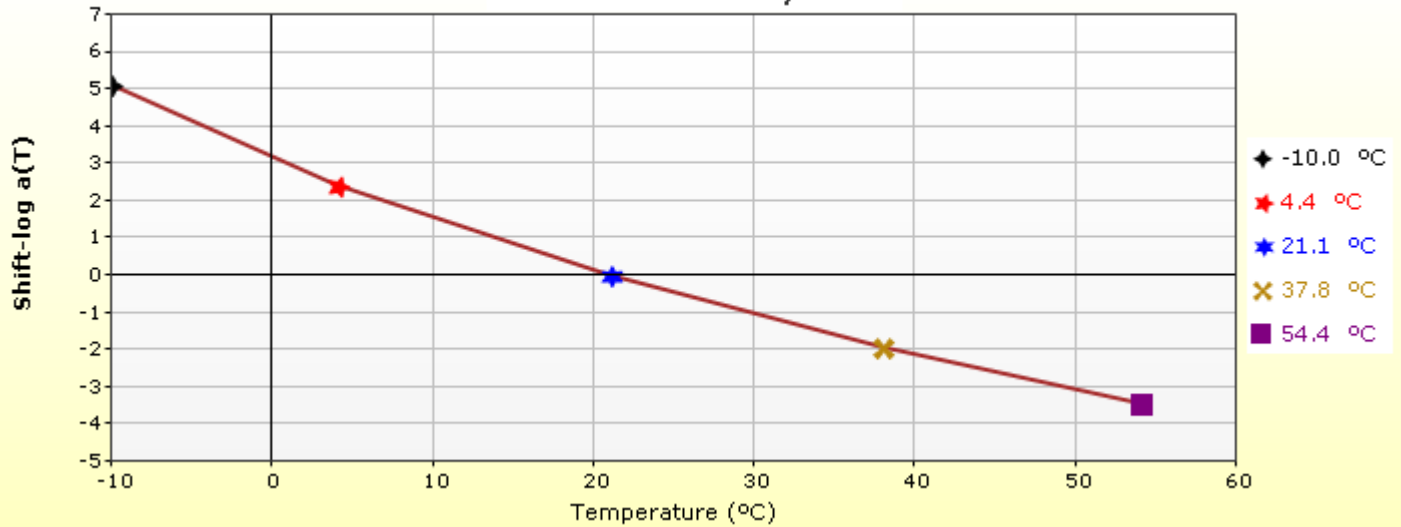


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

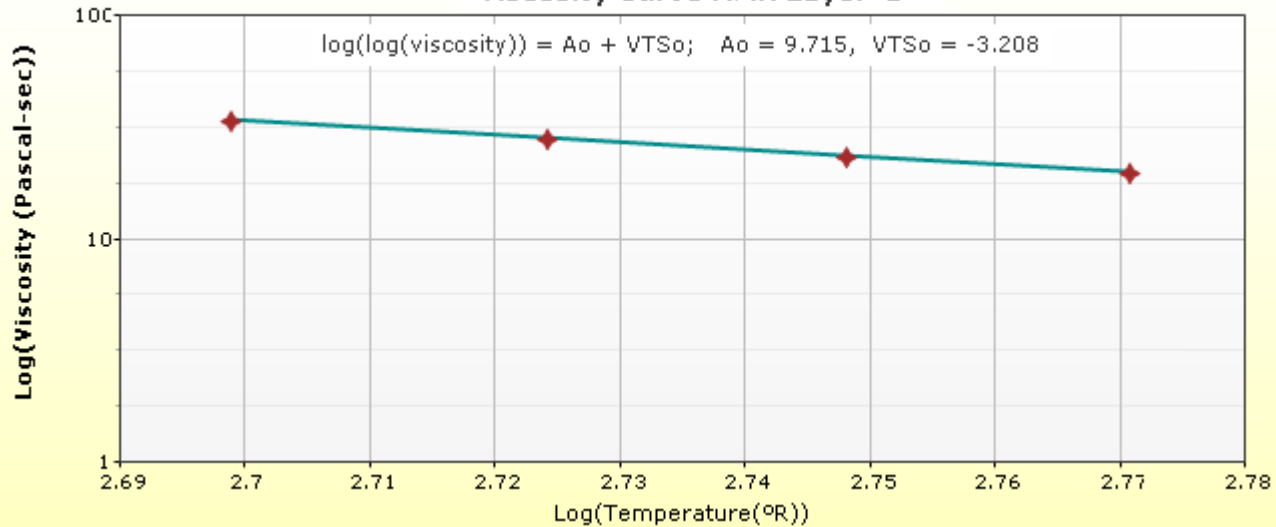
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

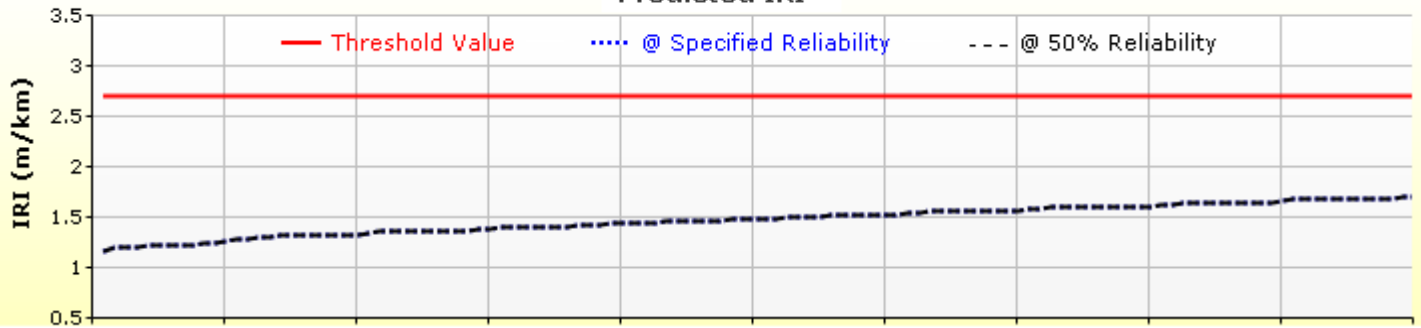


Viscosity Curve HMA Layer 1

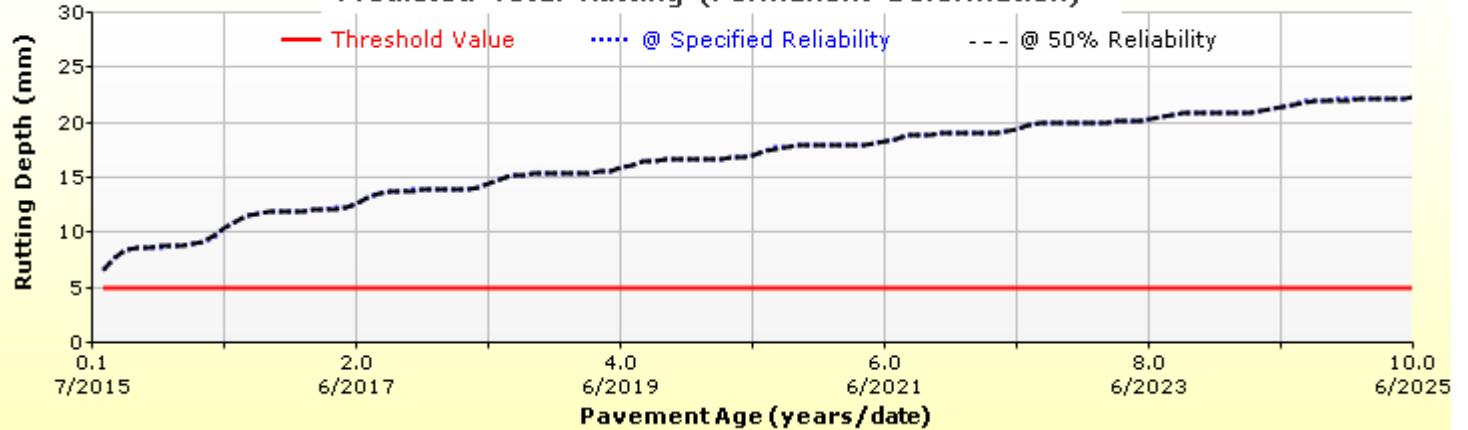


Analysis Output Charts

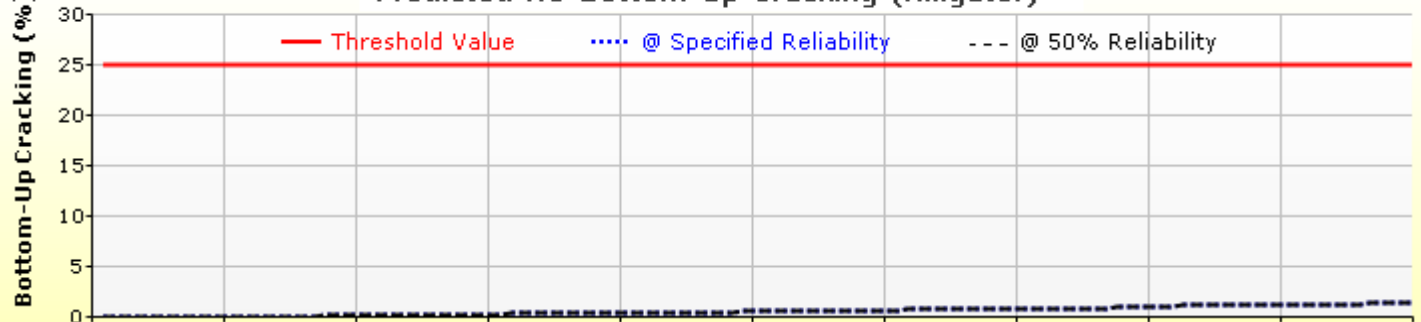
Predicted IRI



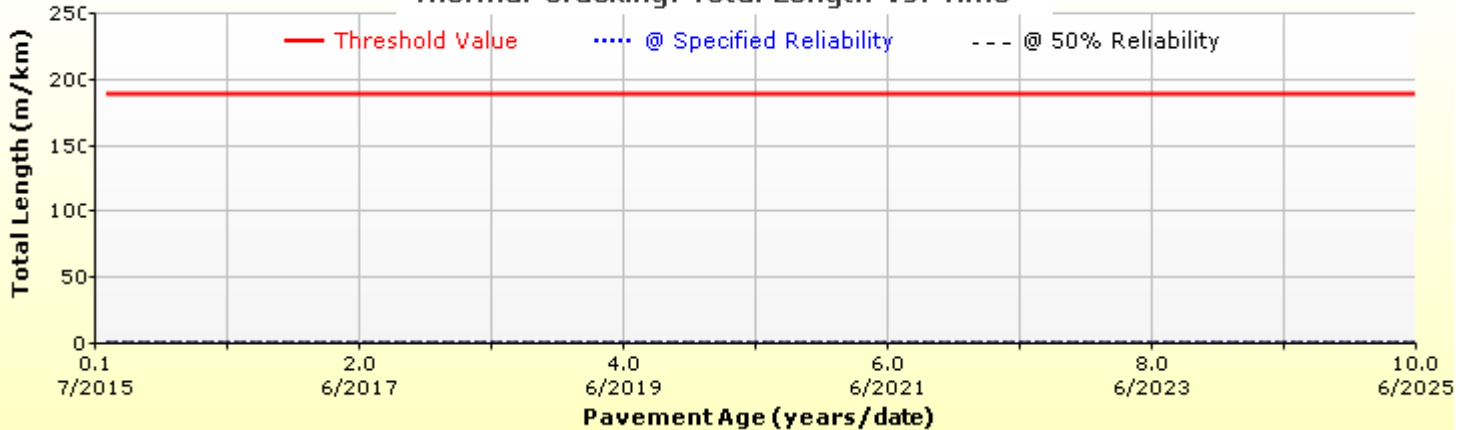
Predicted Total Rutting (Permanent Deformation)



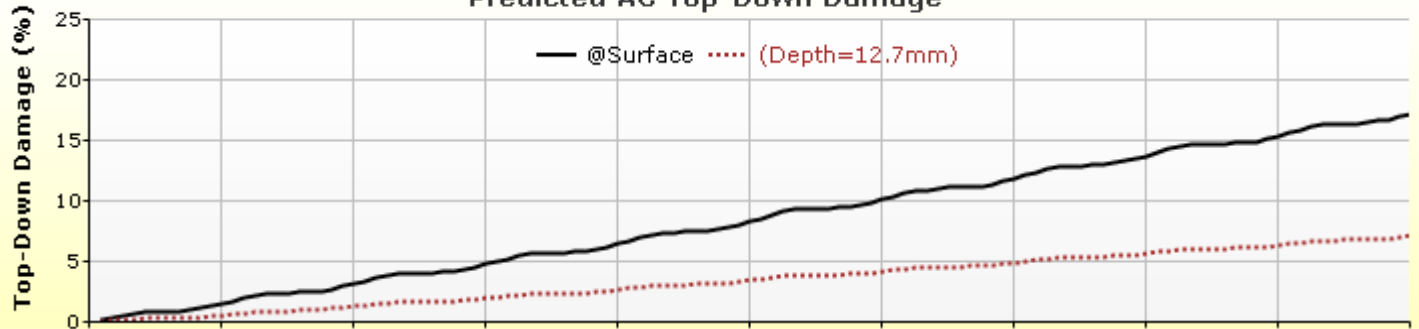
Predicted AC Bottom-Up Cracking (Alligator)



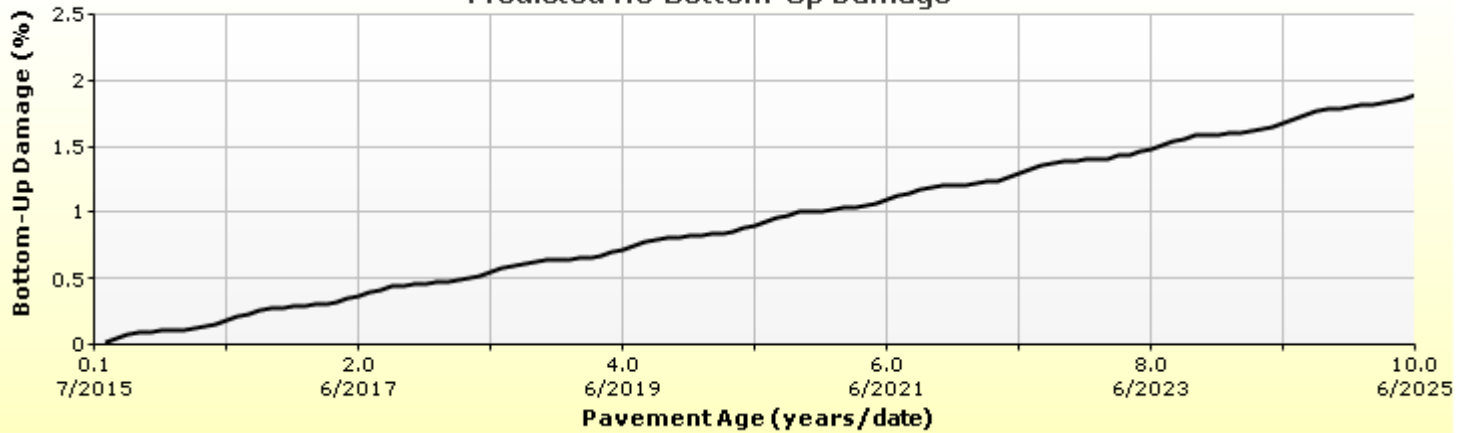
Thermal Cracking: Total Length vs. Time



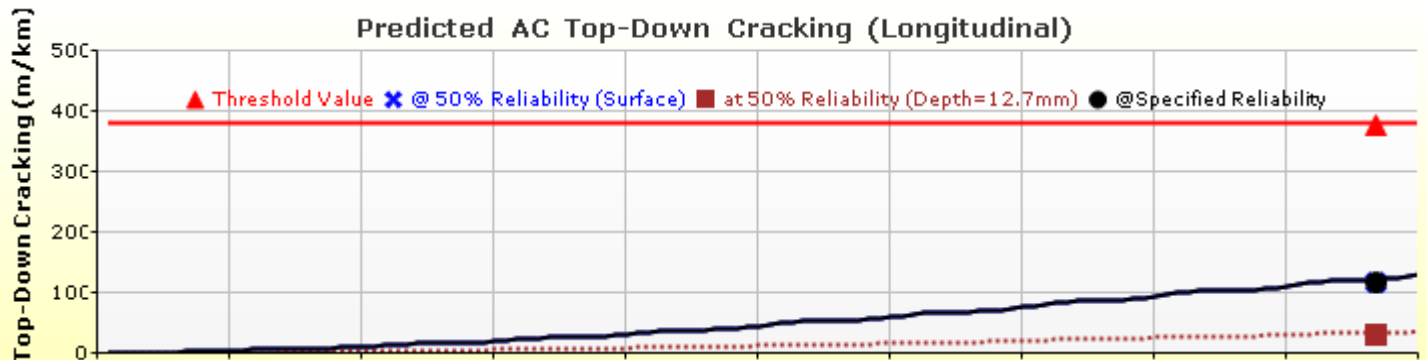
Predicted AC Top-Down Damage



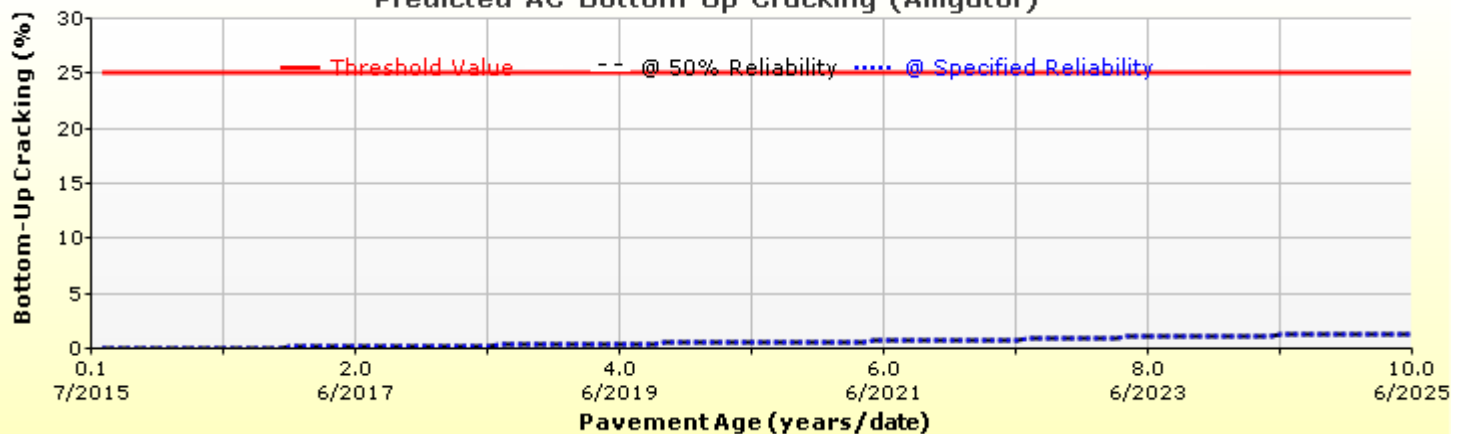
Predicted AC Bottom-Up Damage



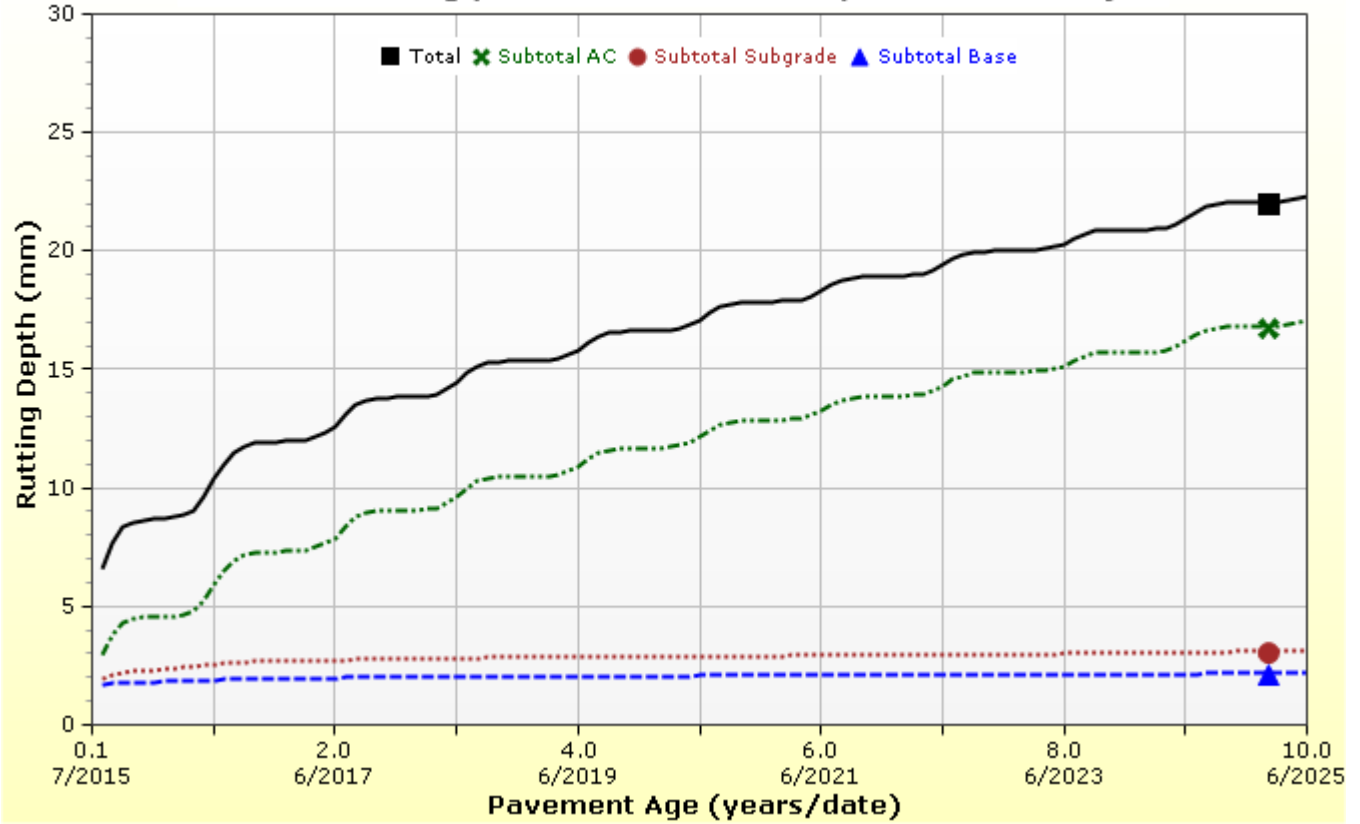
Predicted AC Top-Down Cracking (Longitudinal)



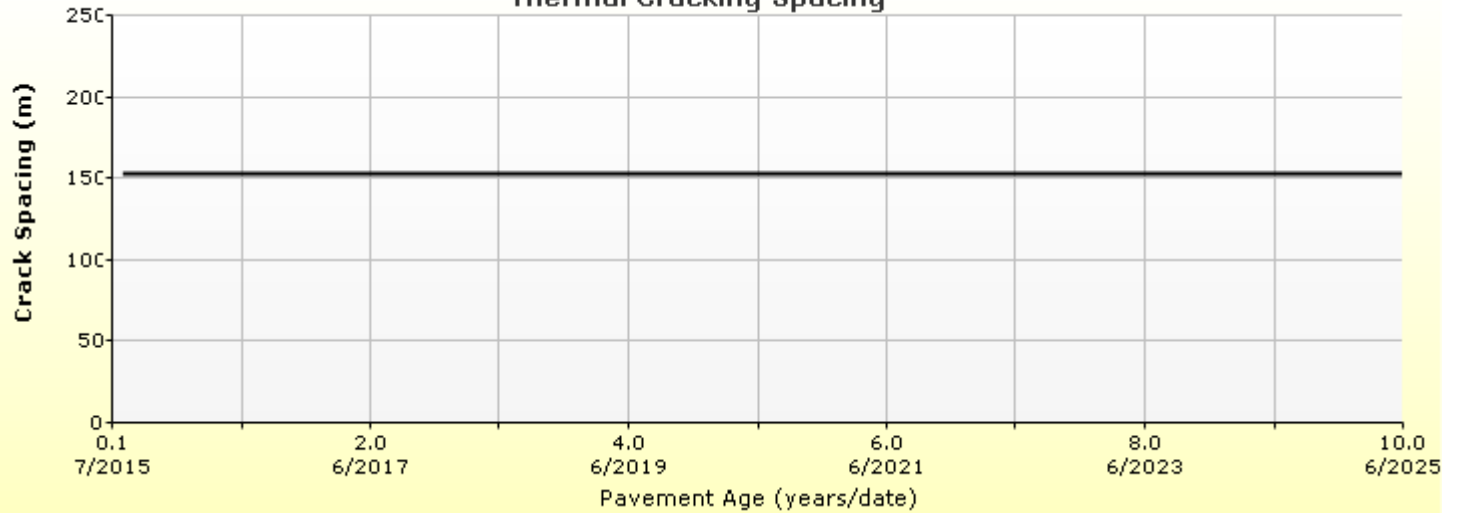
Predicted AC Bottom-Up Cracking (Alligator)



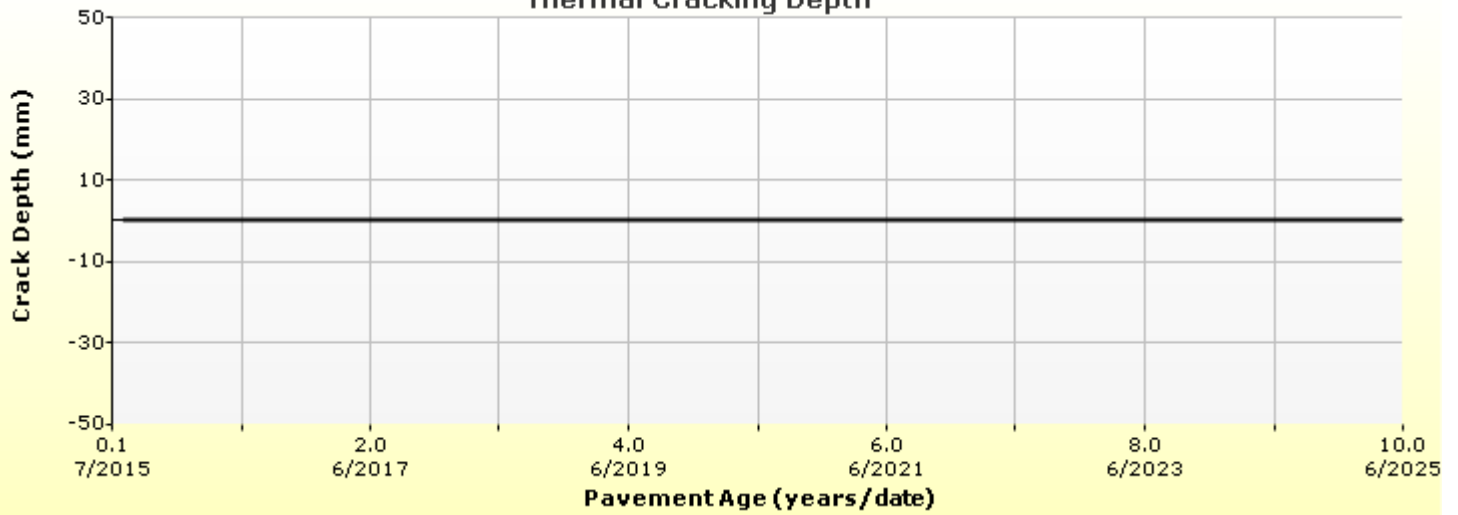
Predicted Rutting (Permanent Deformation) at 50% Reliability

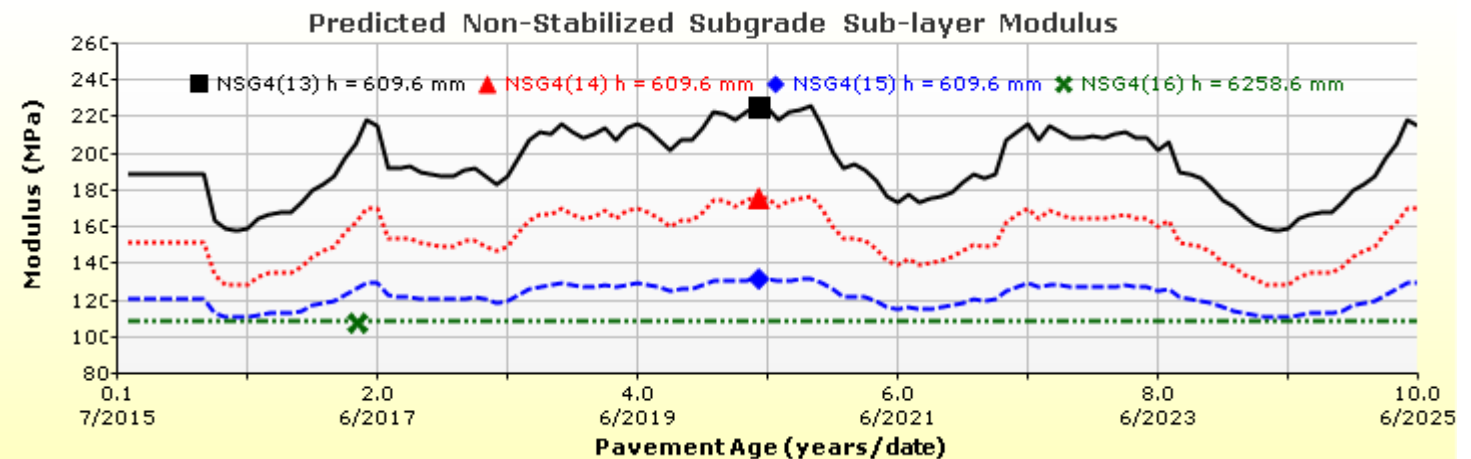
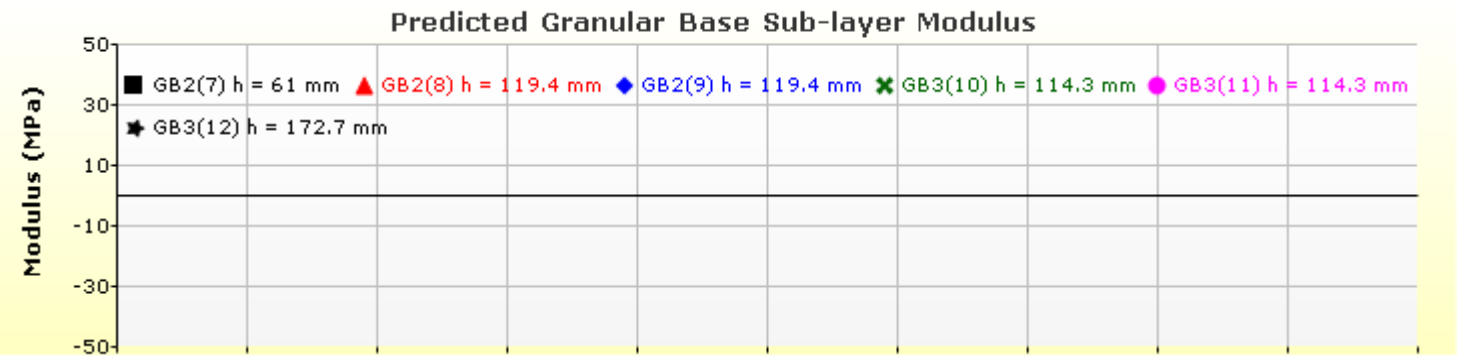
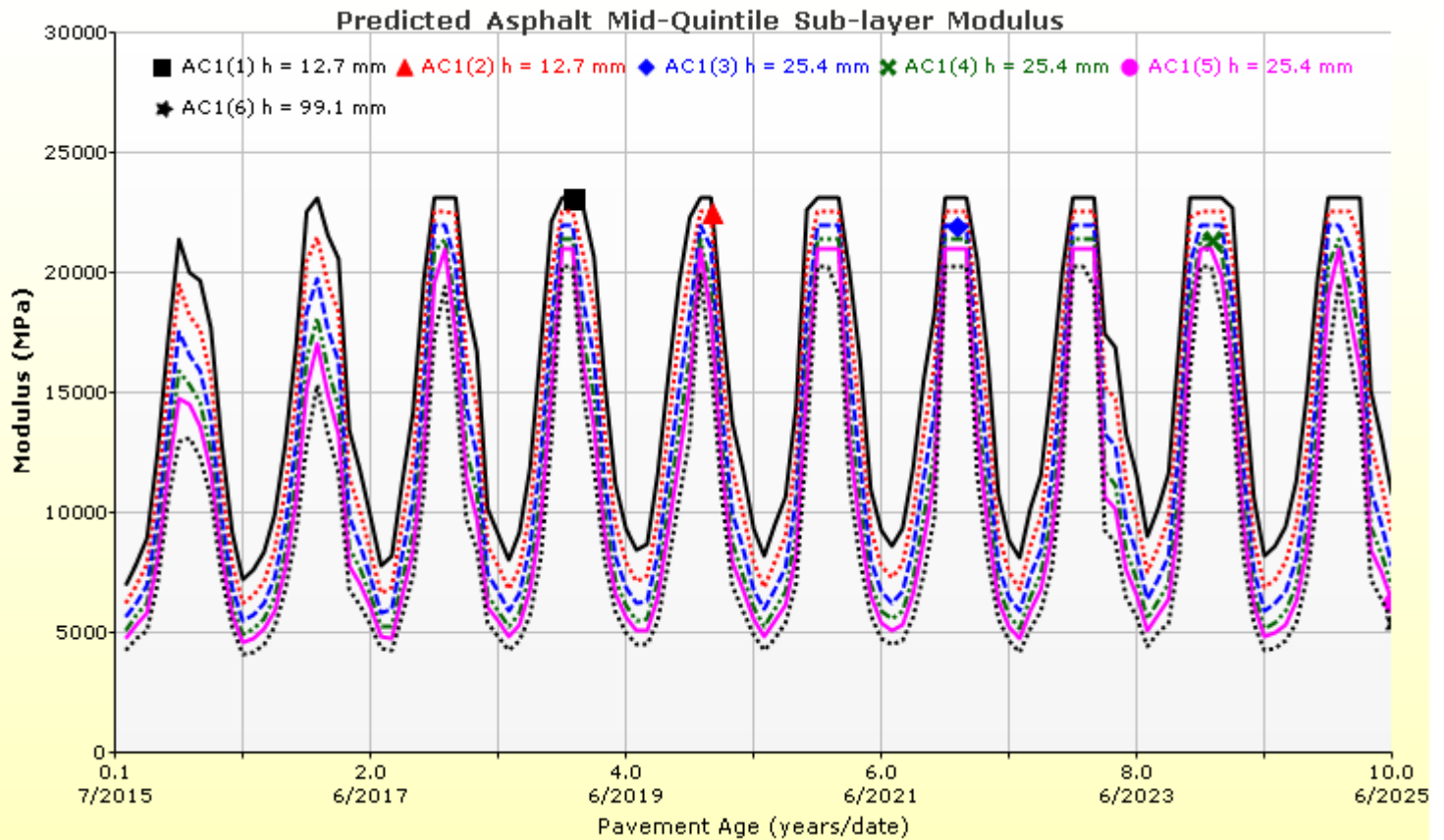


Thermal Cracking Spacing



Thermal Cracking Depth





Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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:	Annual representative values
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

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Plasticity Index	1.0
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Saturated hydraulic conductivity (m/hr)	False	1.54e-02
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Optimum gravimetric water content (%)	False	7.4

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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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

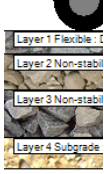
C3: 0.008

C4: 0.015

Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data: 32.119, -81.202
Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	200.0
NonStabilized	Crushed stone	300.0
NonStabilized	Crushed stone	400.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

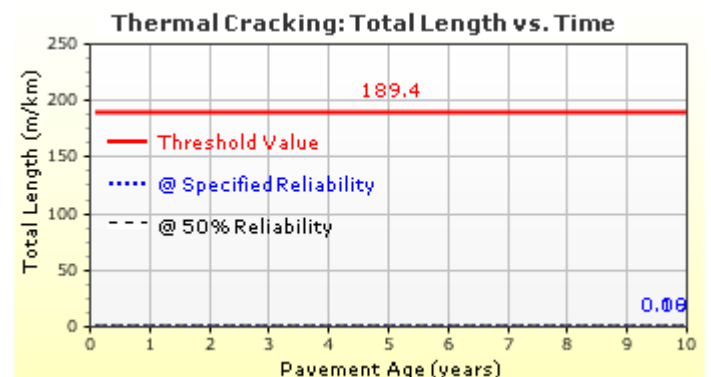
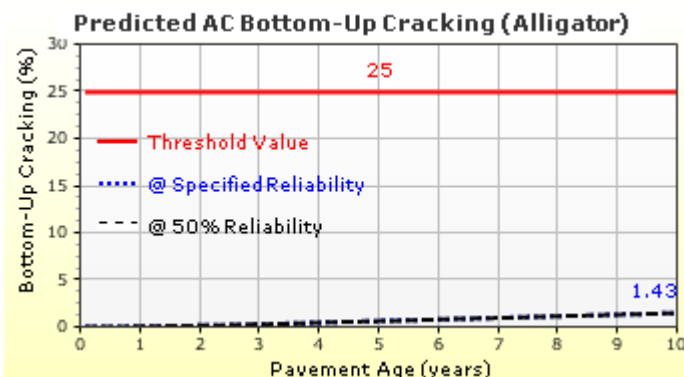
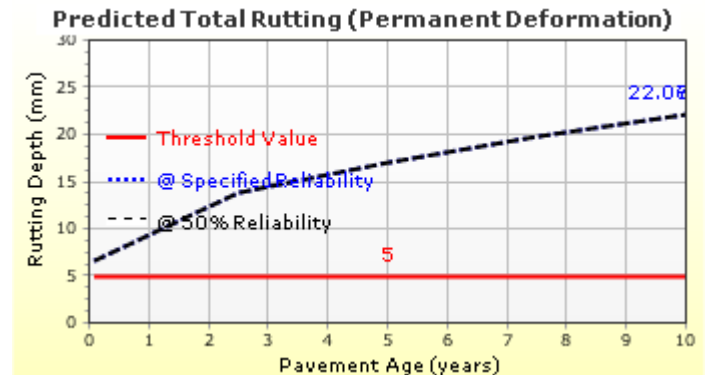
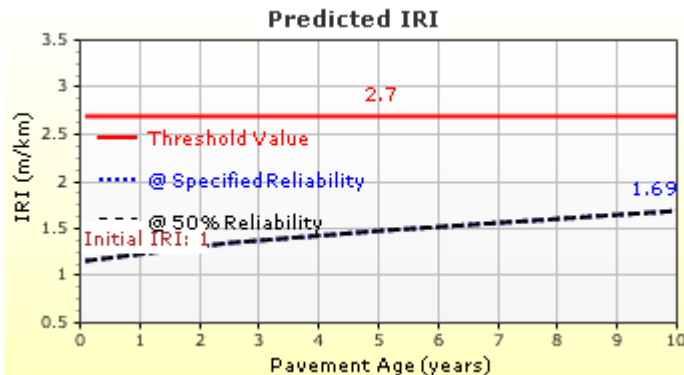
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.69	50.00	98.30	Pass
Permanent deformation - total pavement (mm)	5.00	22.06	50.00	0.01	Fail
AC bottom-up fatigue cracking (percent)	25.00	1.43	50.00	100.00	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	119.51	50.00	74.30	Pass
Permanent deformation - AC only (mm)	5.00	16.57	50.00	0.39	Fail

Distress Charts

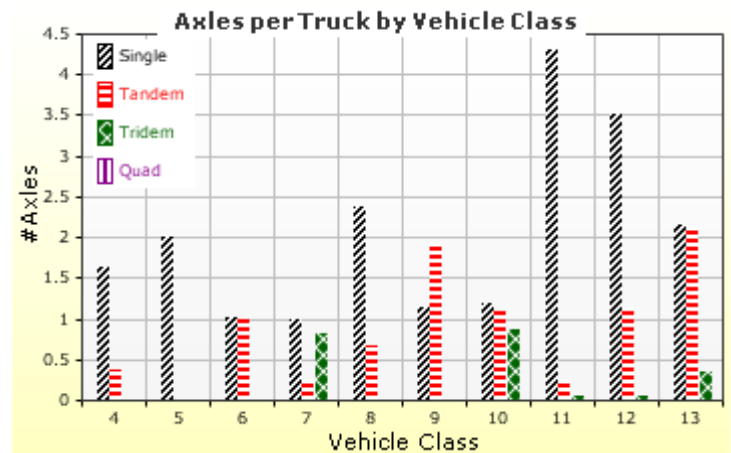
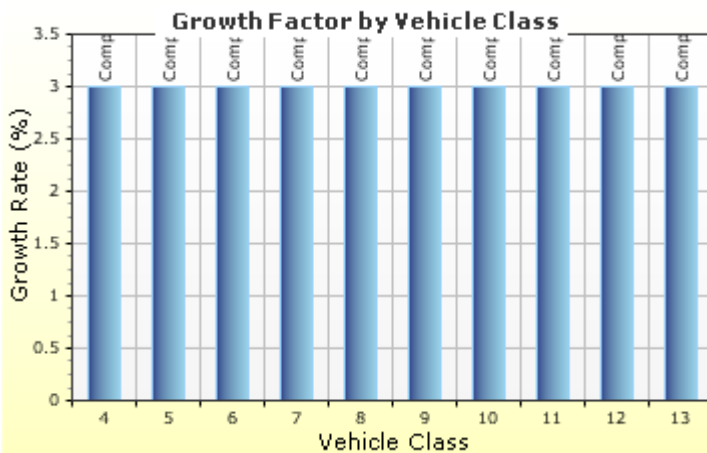
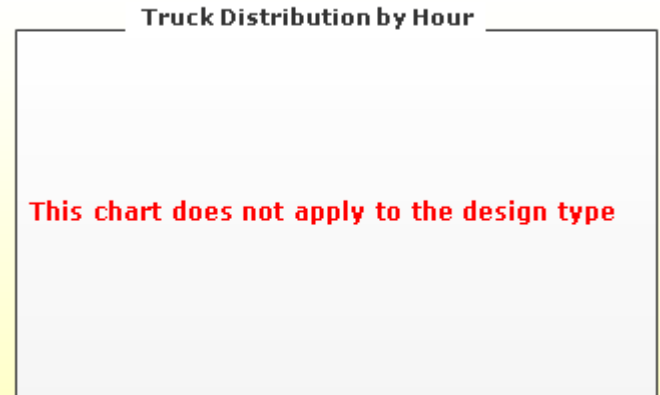
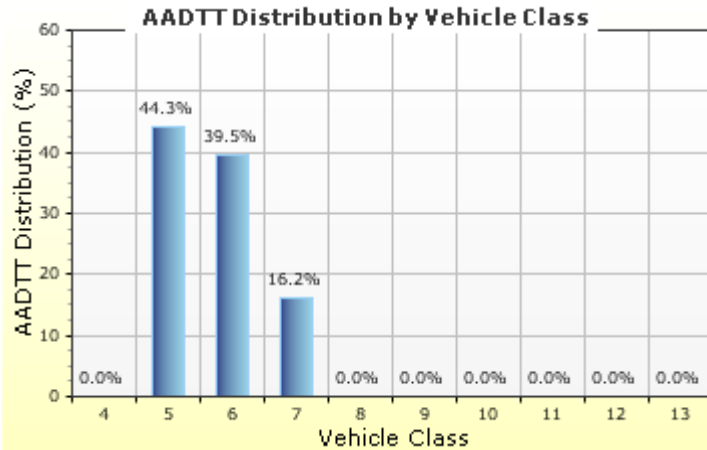


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

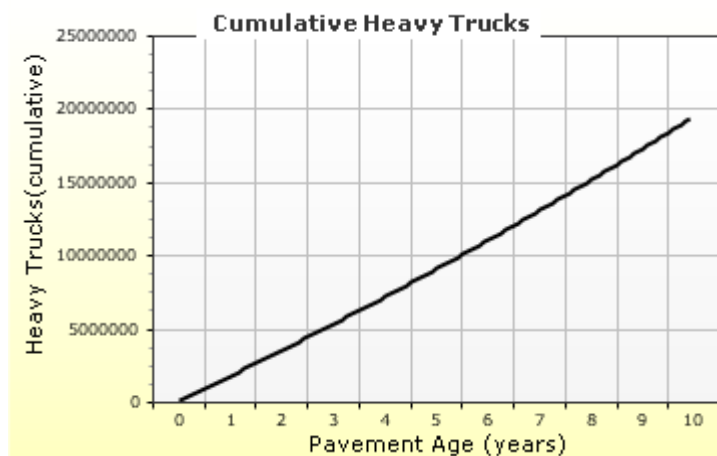
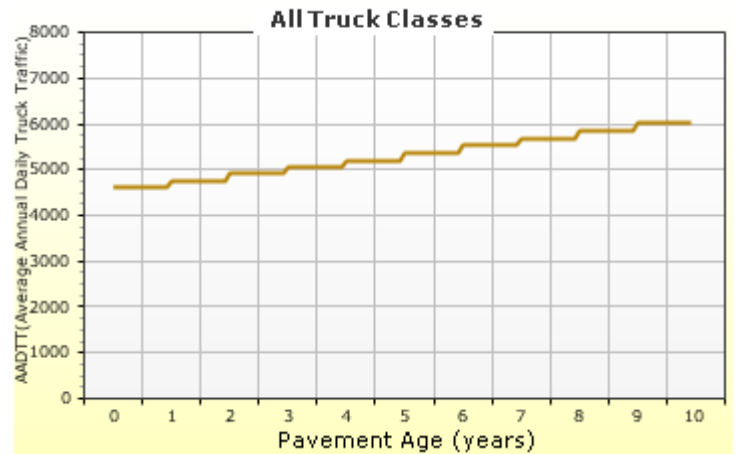
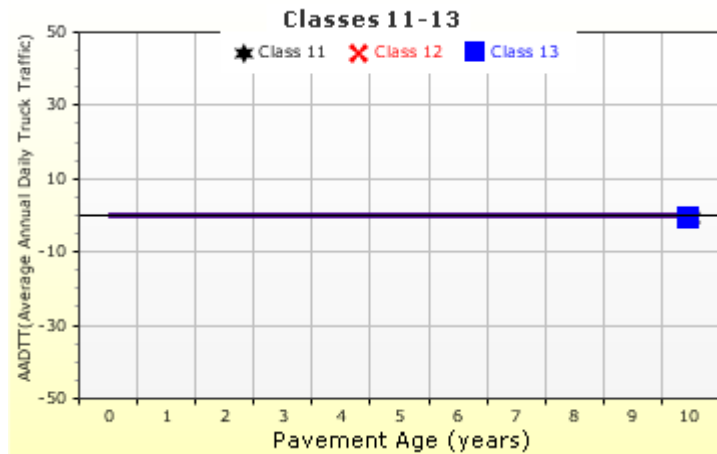
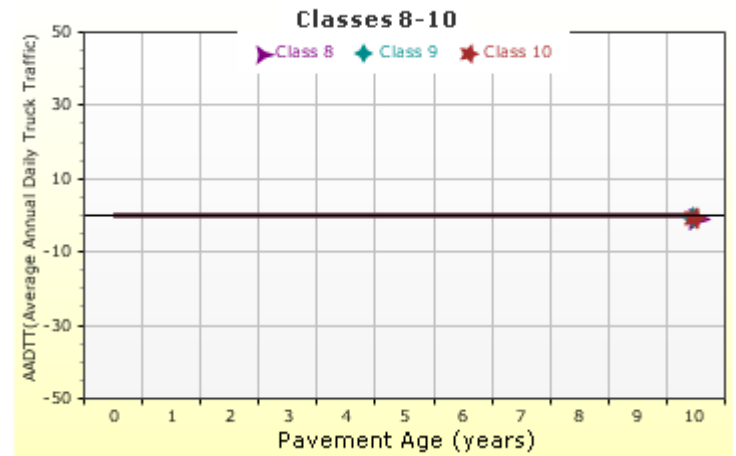
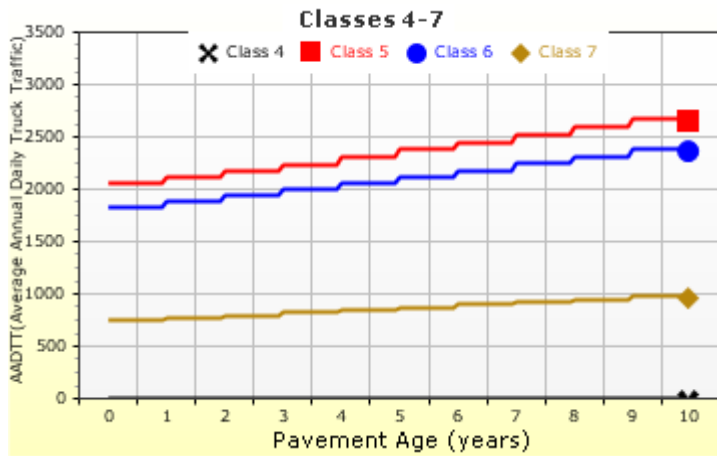
Wheelbase does not apply

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



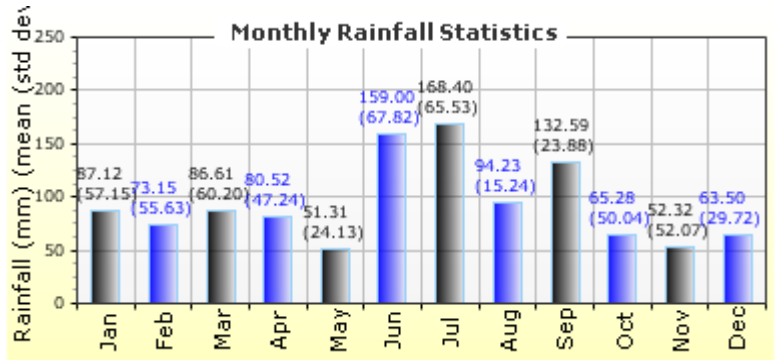
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

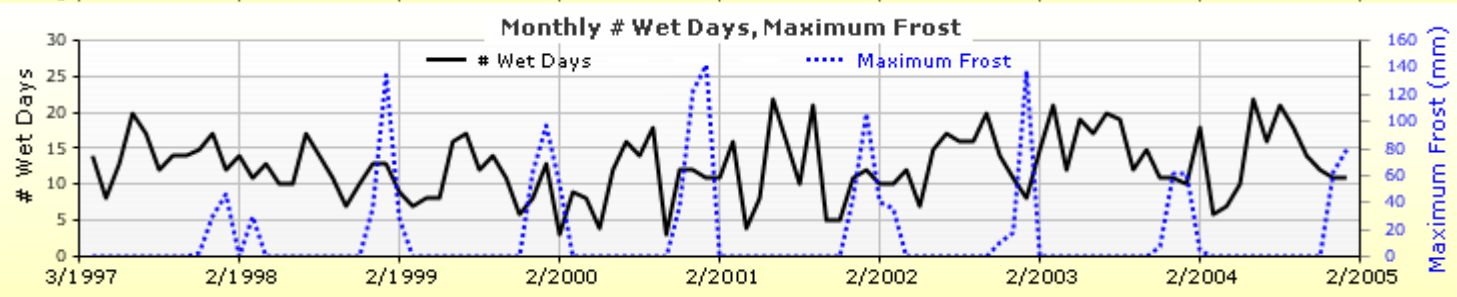
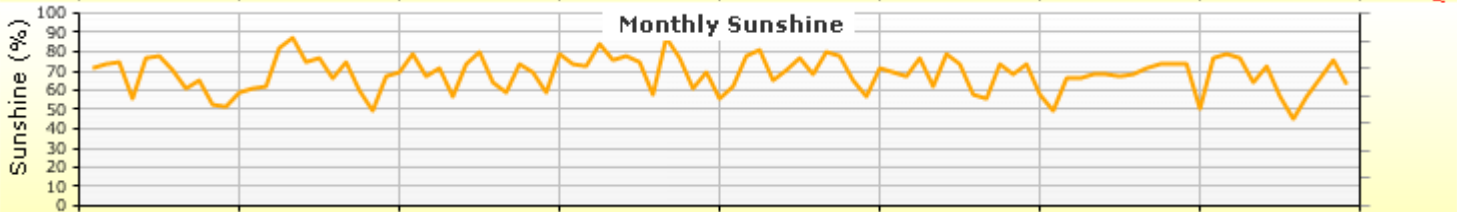
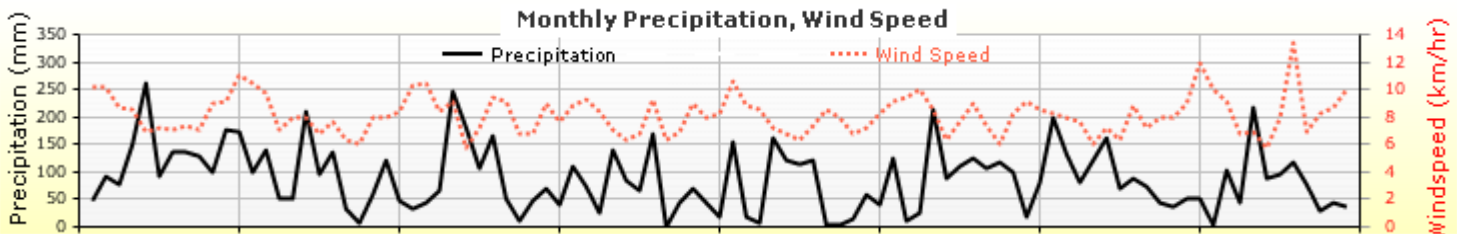
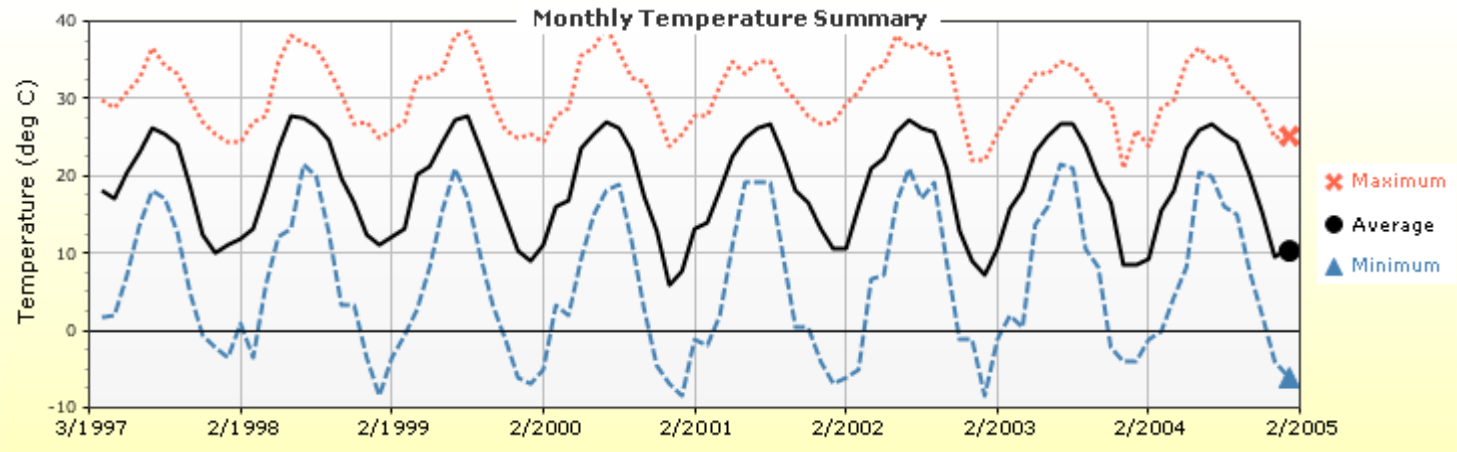
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

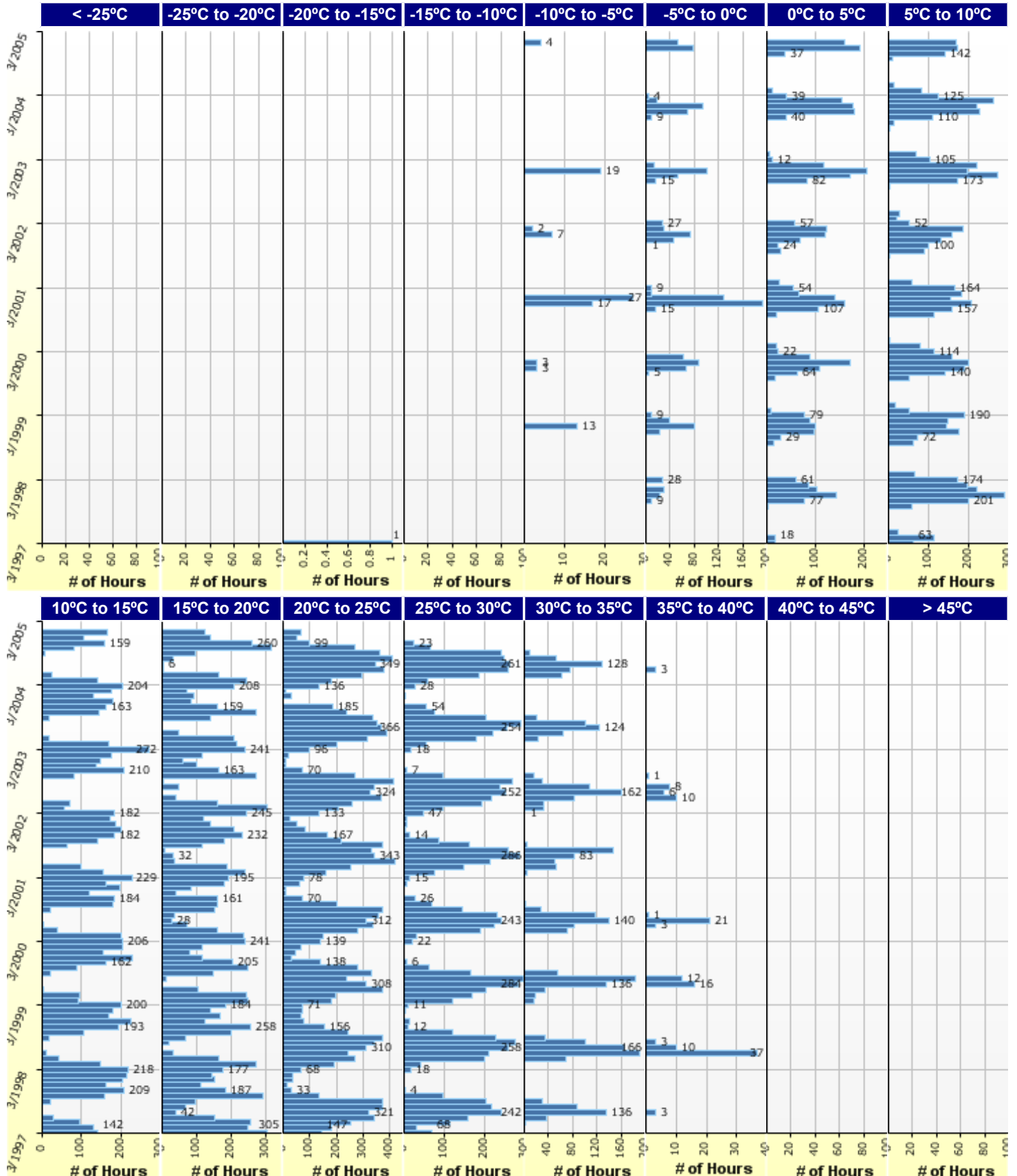


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF3_ALT3

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF3_ALT3.dgpx



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

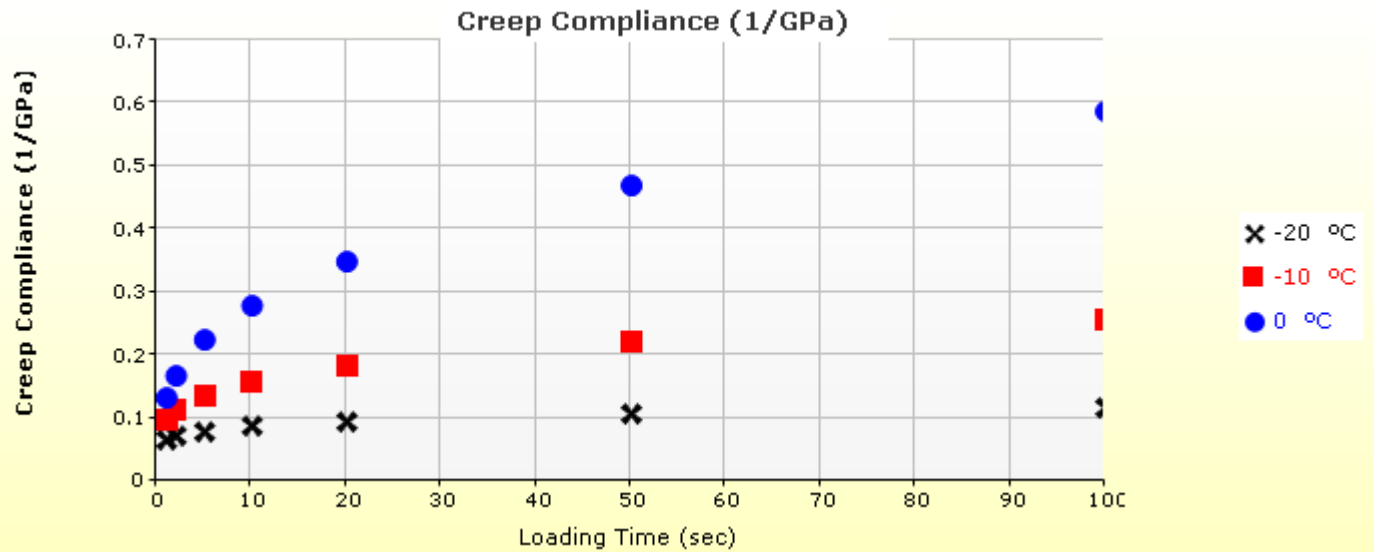
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

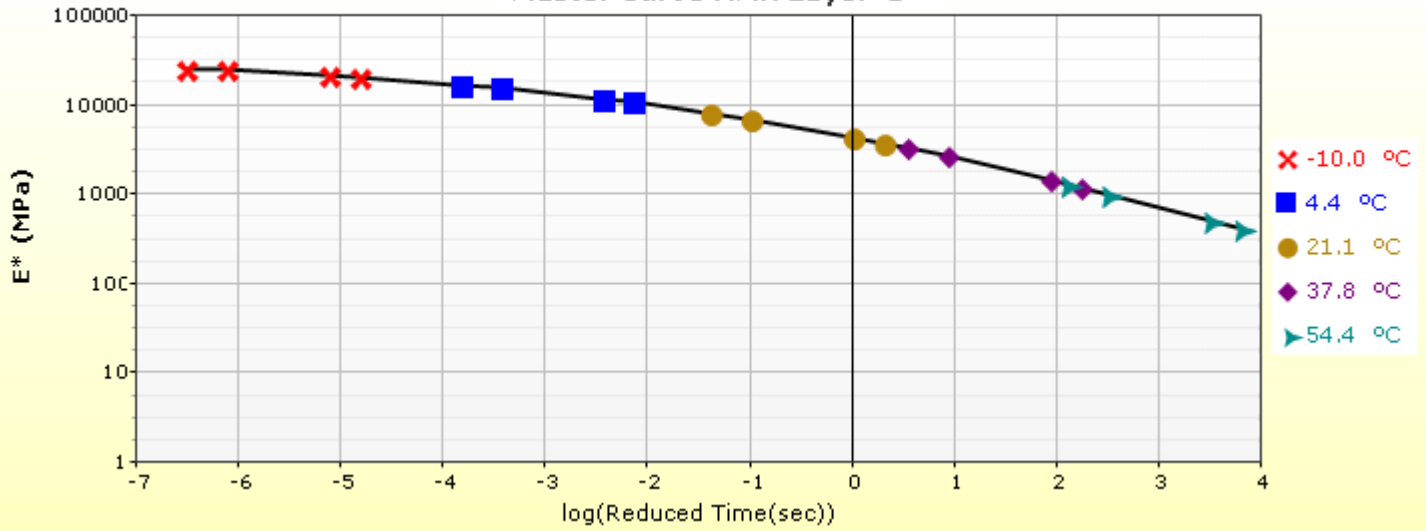
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

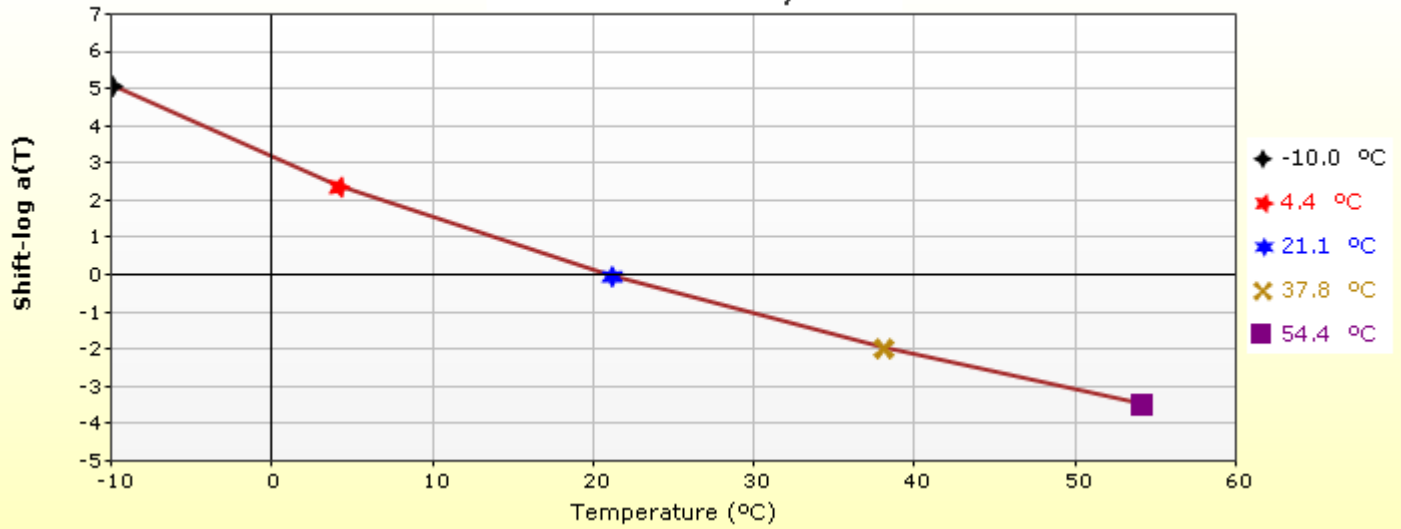


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

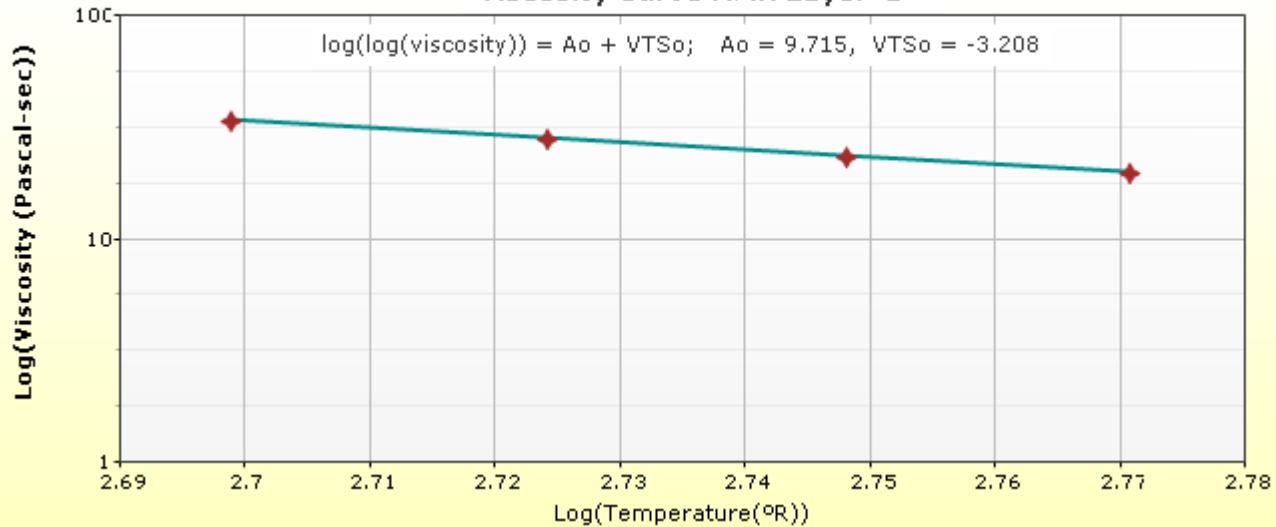
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

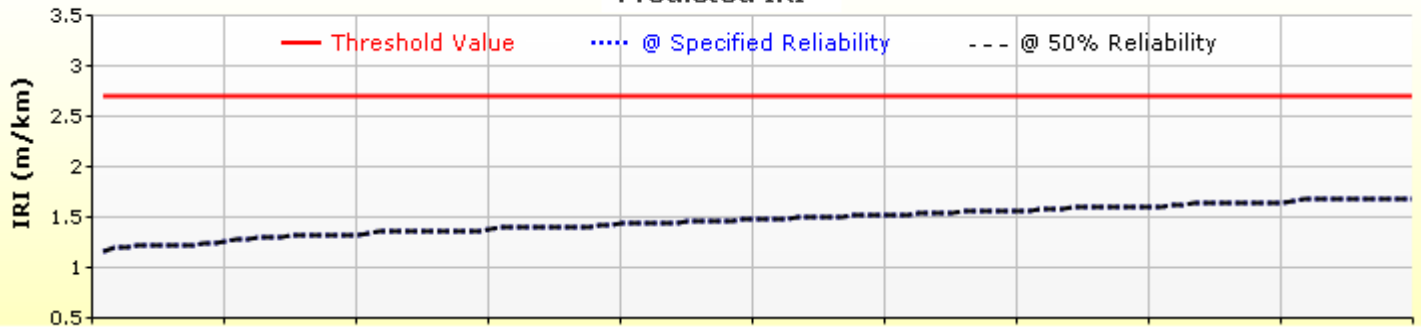


Viscosity Curve HMA Layer 1

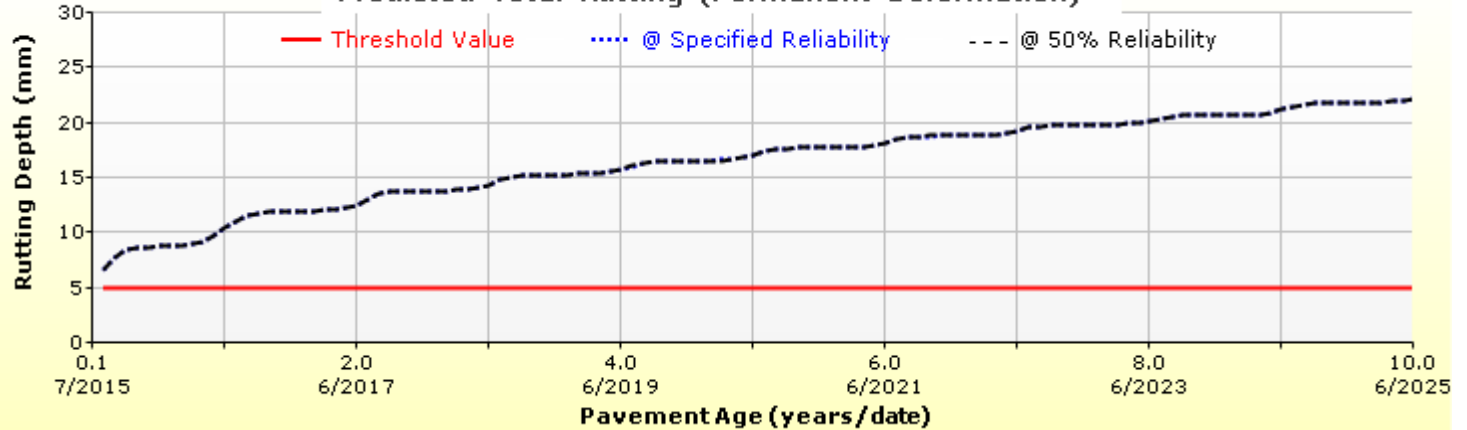


Analysis Output Charts

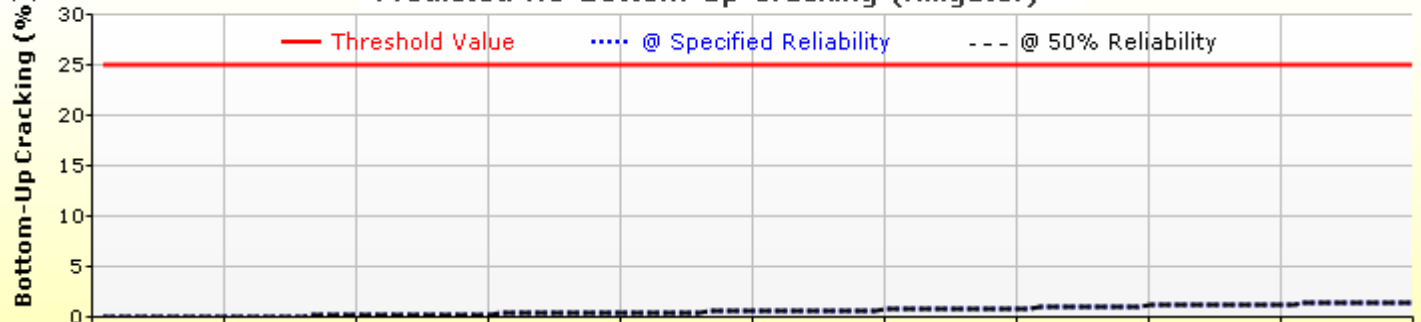
Predicted IRI



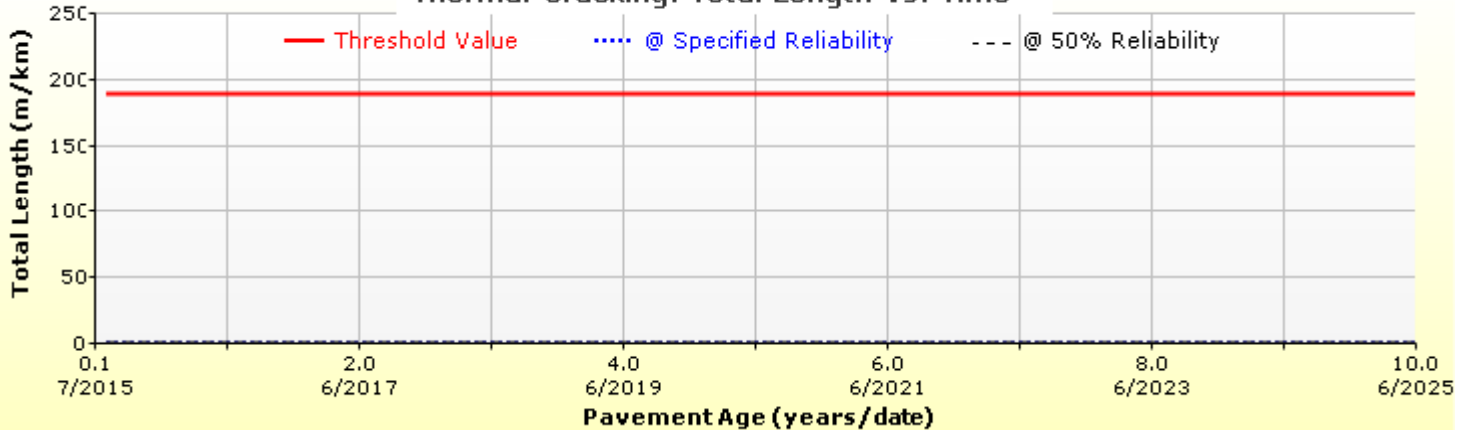
Predicted Total Rutting (Permanent Deformation)



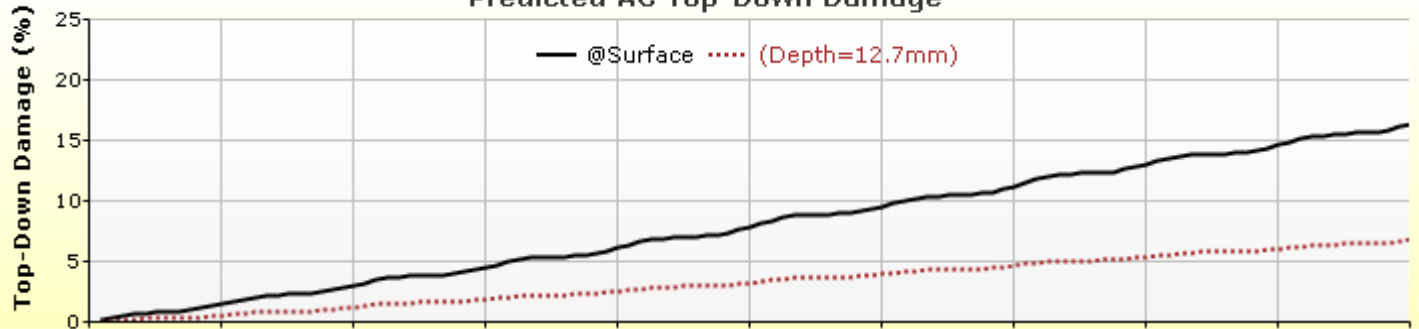
Predicted AC Bottom-Up Cracking (Alligator)



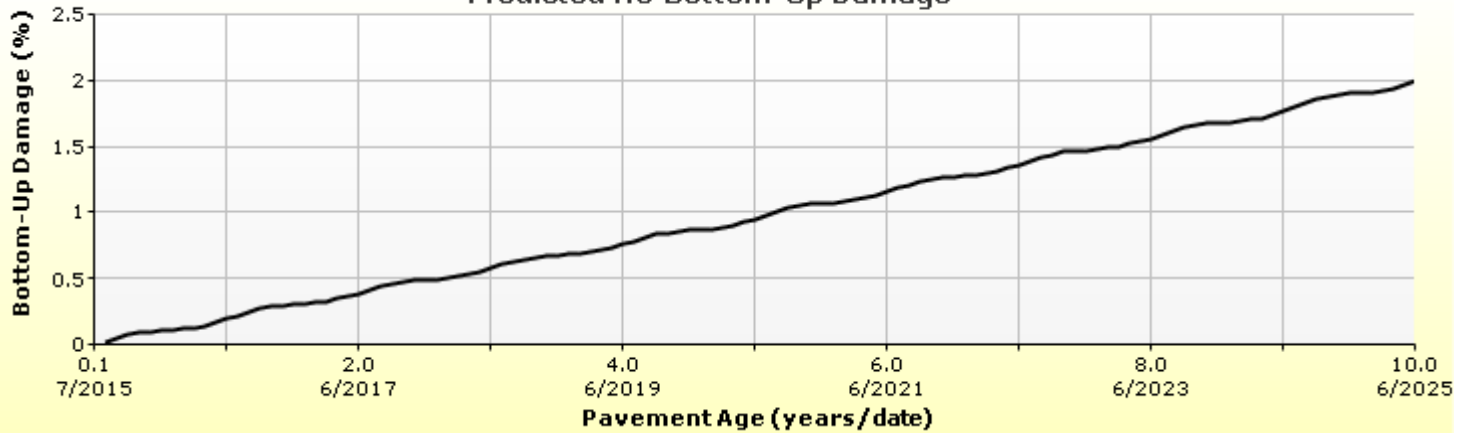
Thermal Cracking: Total Length vs. Time



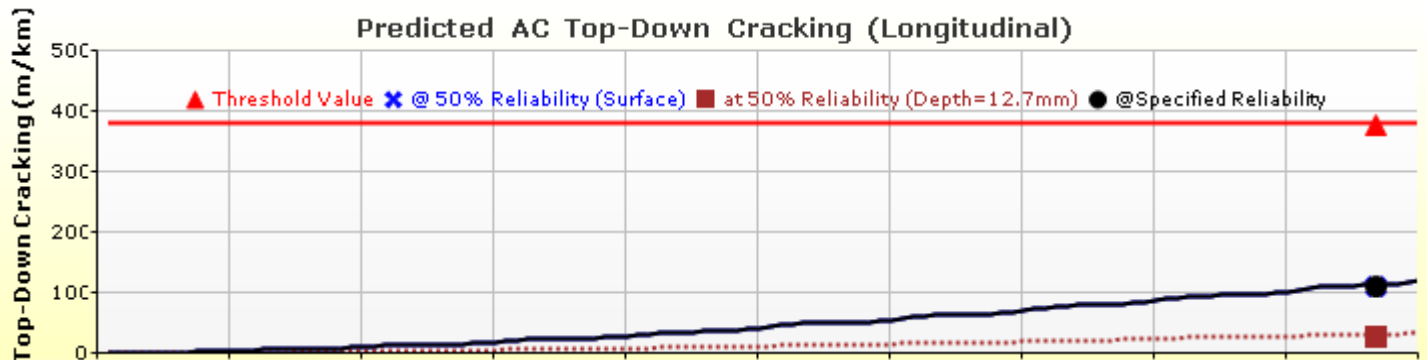
Predicted AC Top-Down Damage



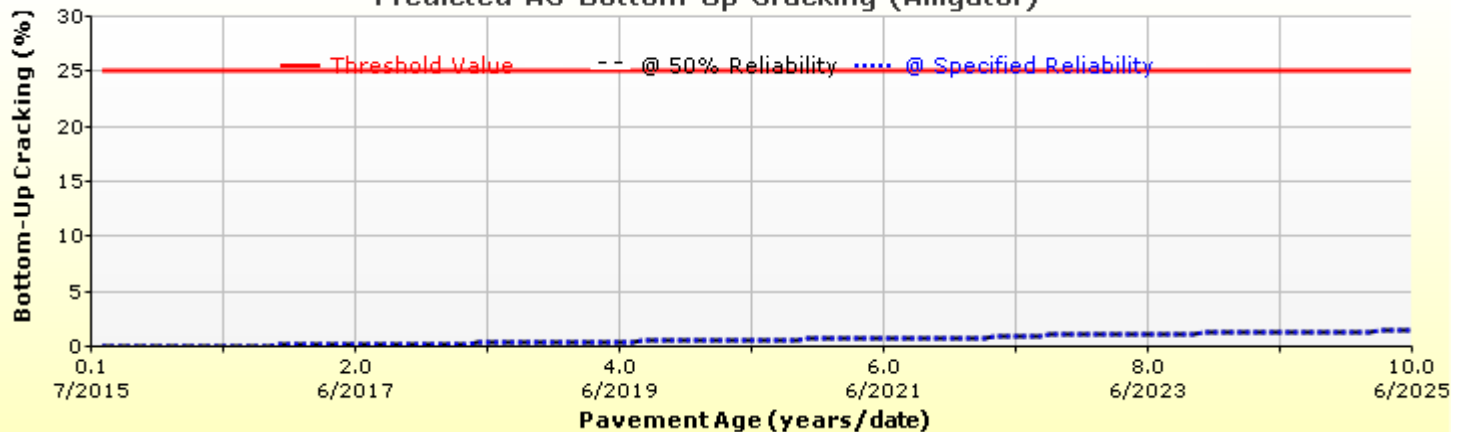
Predicted AC Bottom-Up Damage



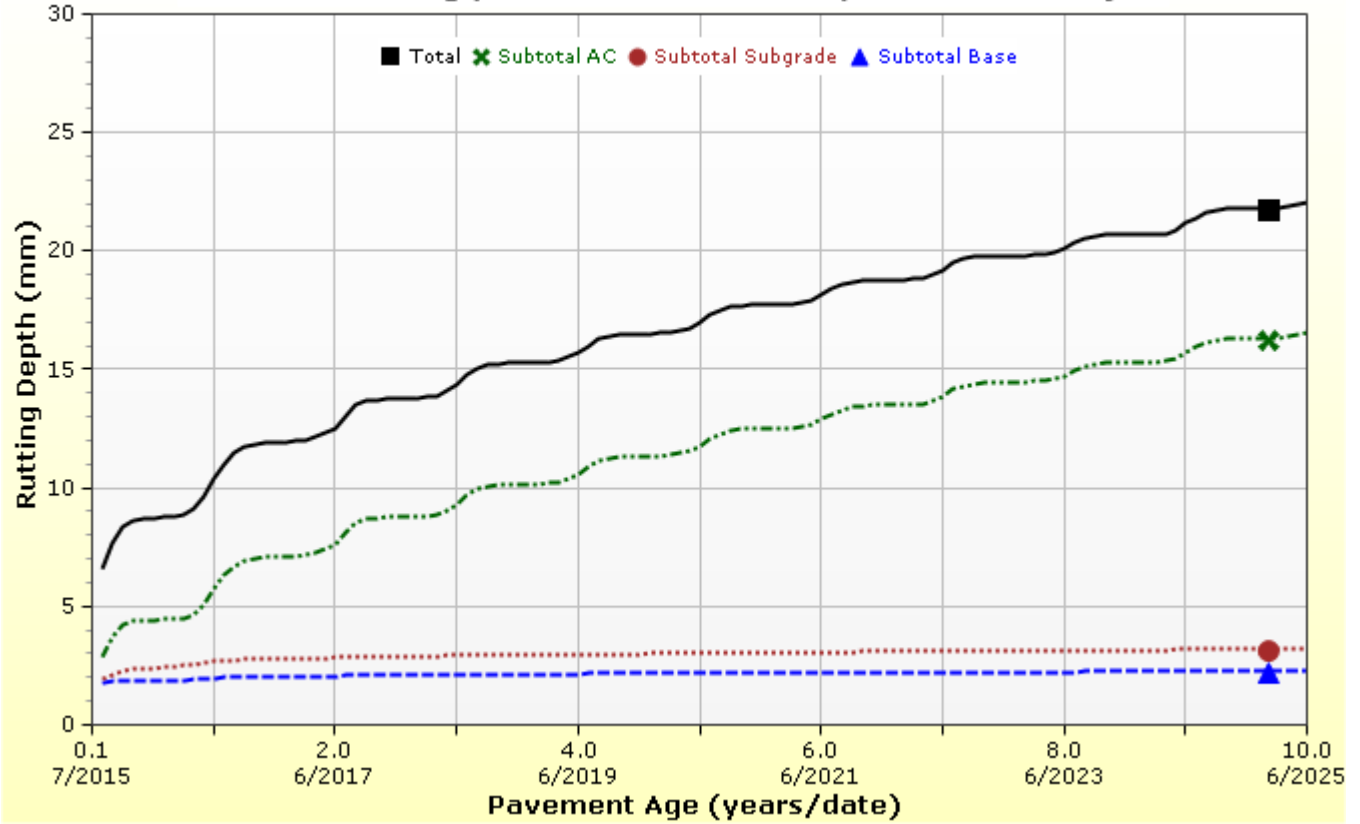
Predicted AC Top-Down Cracking (Longitudinal)

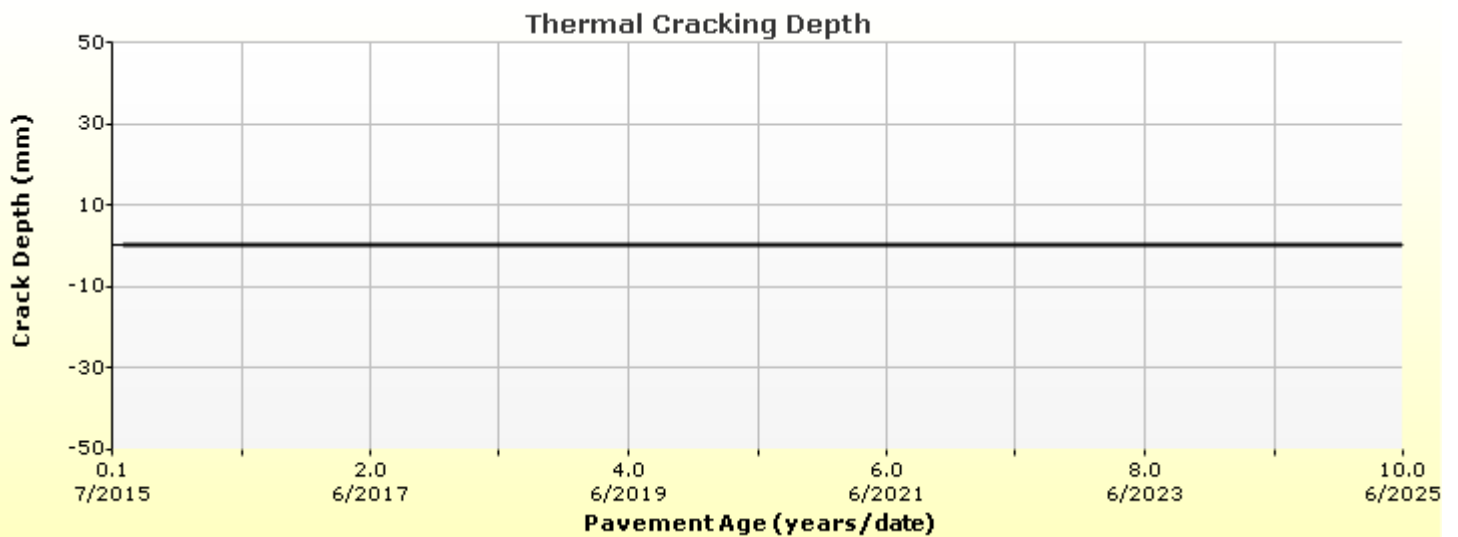
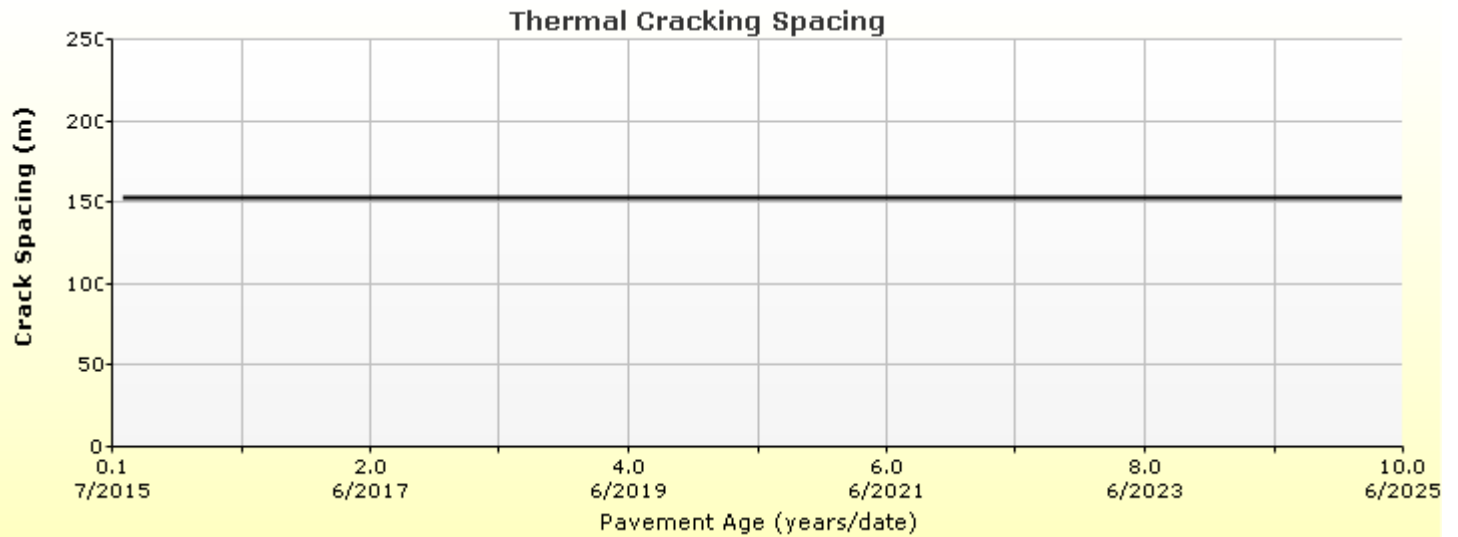


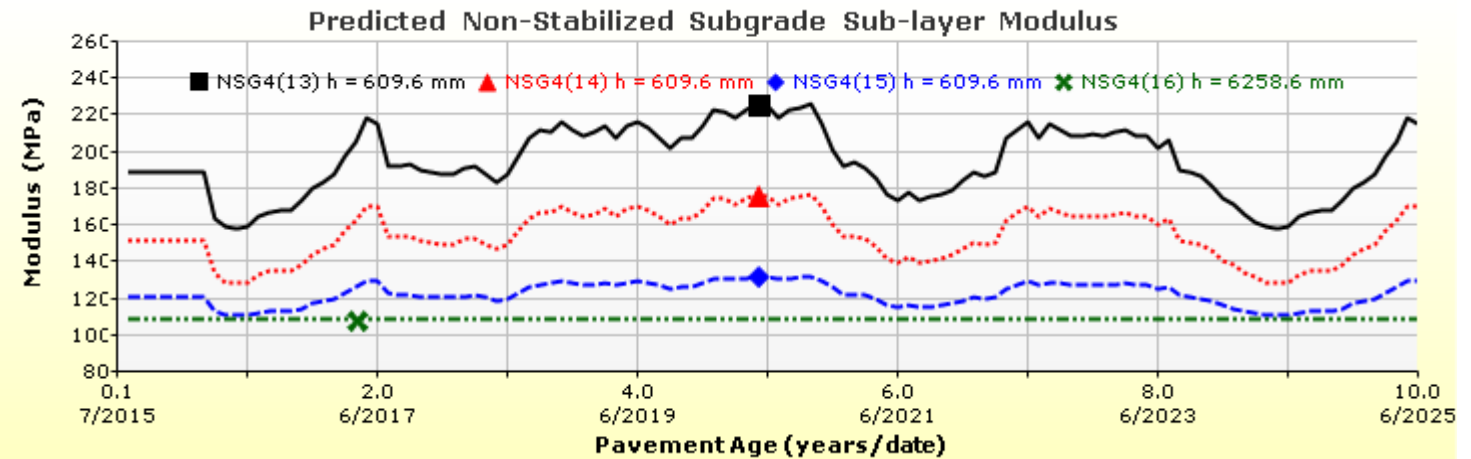
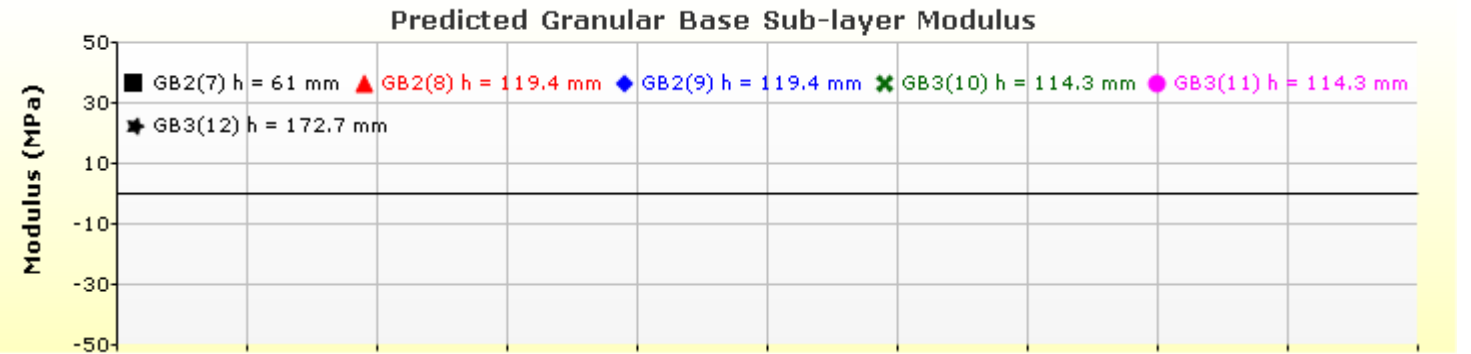
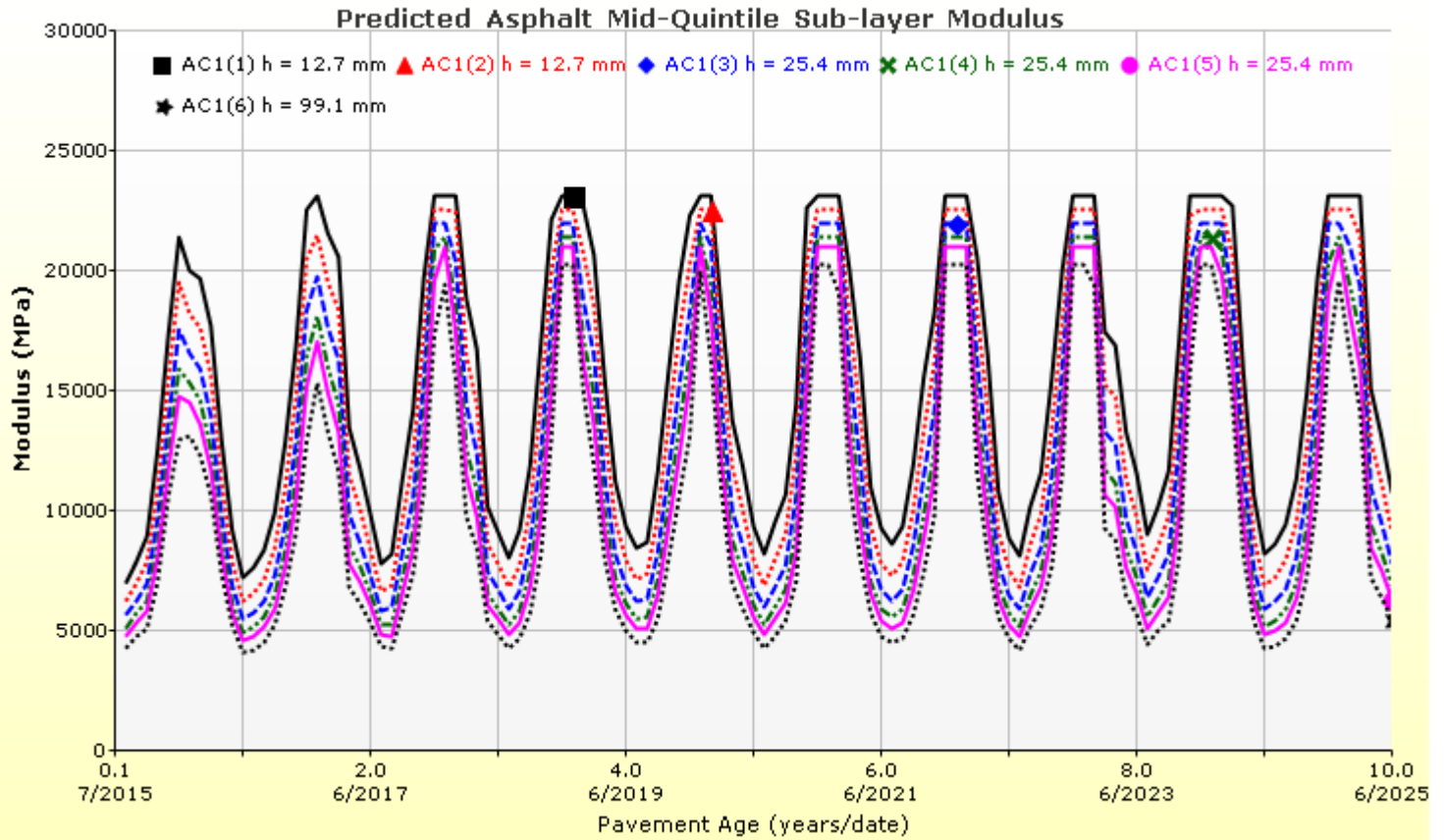
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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:	Annual representative values
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

Standard Deviation (BASERUT)

0.1235*Pow(SUBRUT,0.5012)+0.001

AC Cracking

AC Top Down Cracking

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

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: 7

c2: 3.5

c3: 0

c4: 1000

c1: 1

c2: 1

c3: 6000

AC Cracking Top Standard Deviation

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

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

IRI Flexible Pavements

C1 - Rutting

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

CSM Standard Deviation

CTB*1

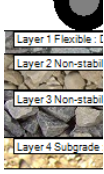
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	200.0
NonStabilized	Crushed stone	300.0
NonStabilized	Crushed stone	400.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

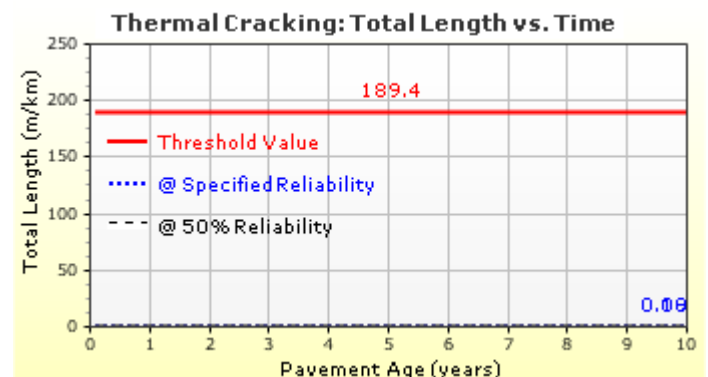
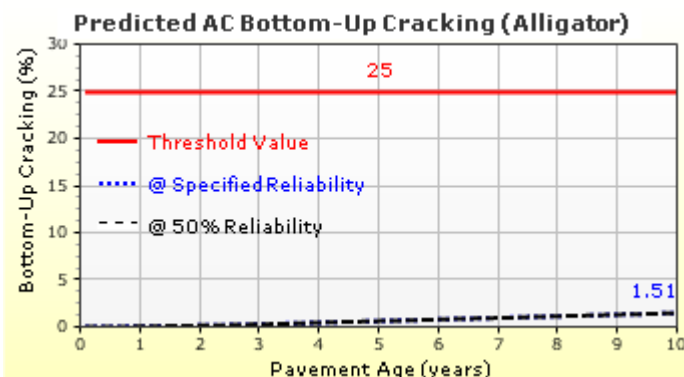
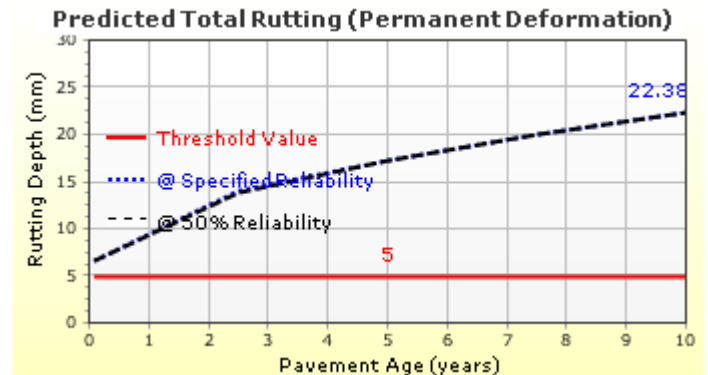
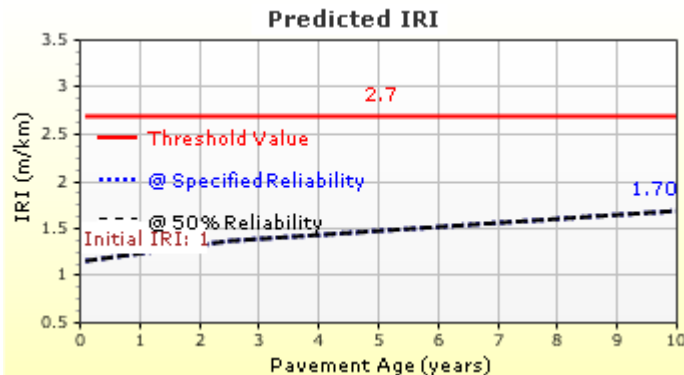
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.70	50.00	98.18	Pass
Permanent deformation - total pavement (mm)	5.00	22.38	50.00	0.01	Fail
AC bottom-up fatigue cracking (percent)	25.00	1.51	50.00	100.00	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	119.89	50.00	74.25	Pass
Permanent deformation - AC only (mm)	5.00	16.89	50.00	0.36	Fail

Distress Charts

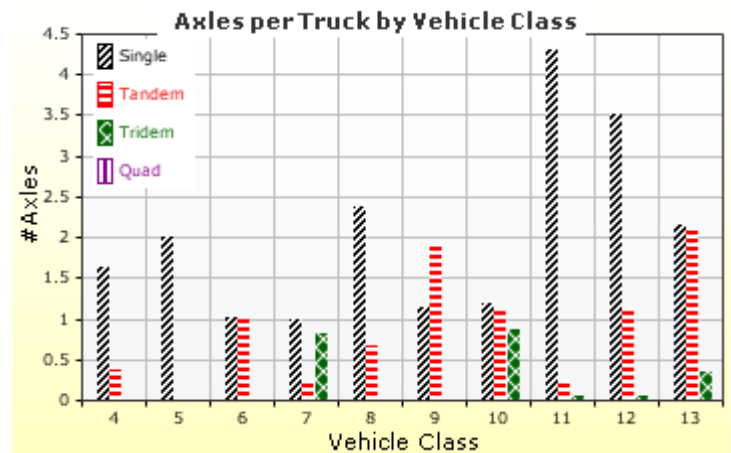
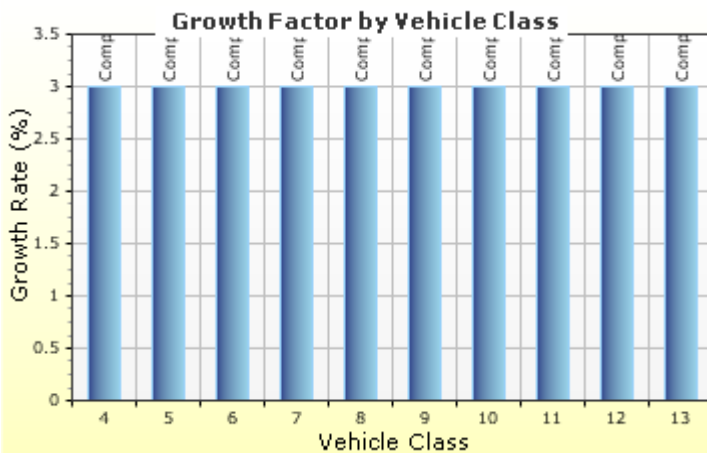
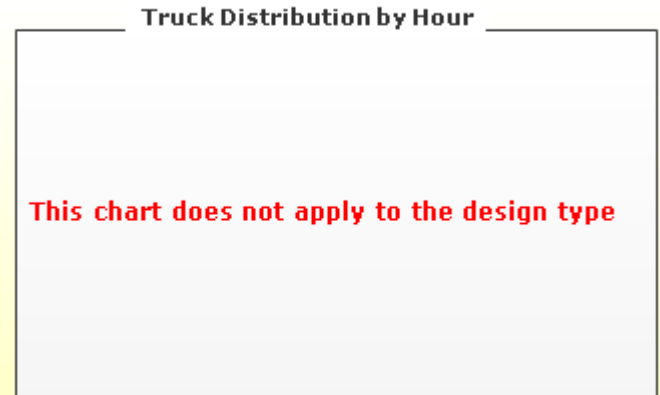
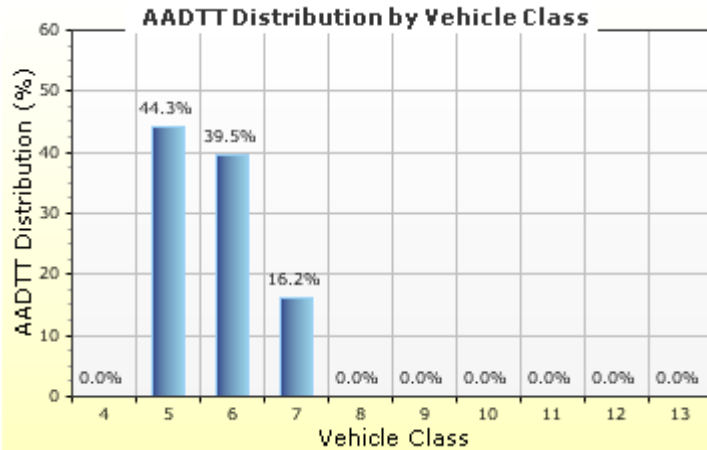


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

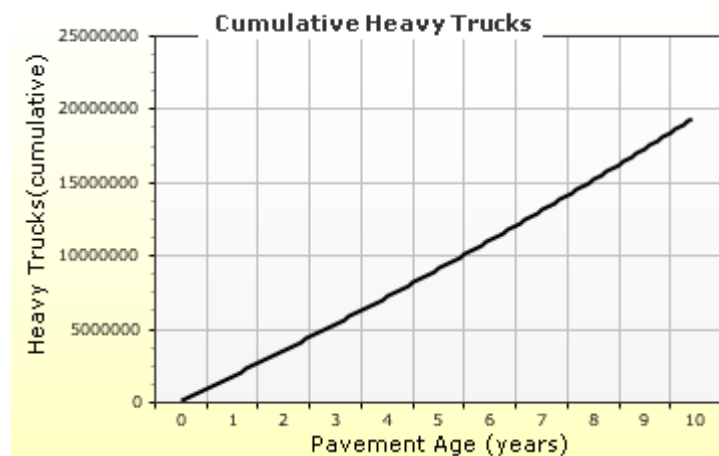
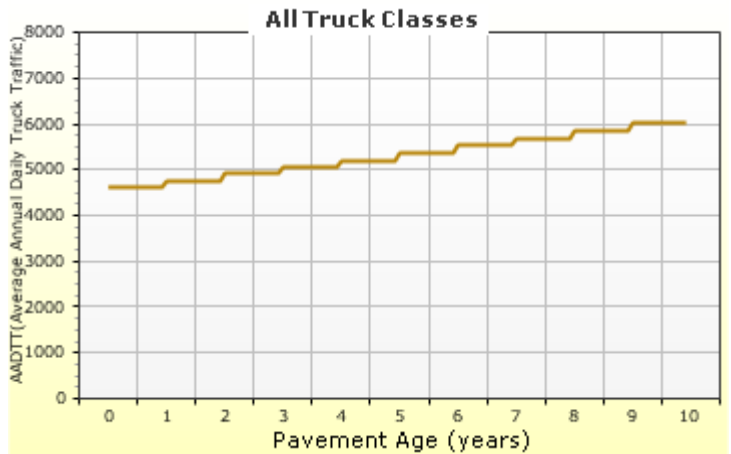
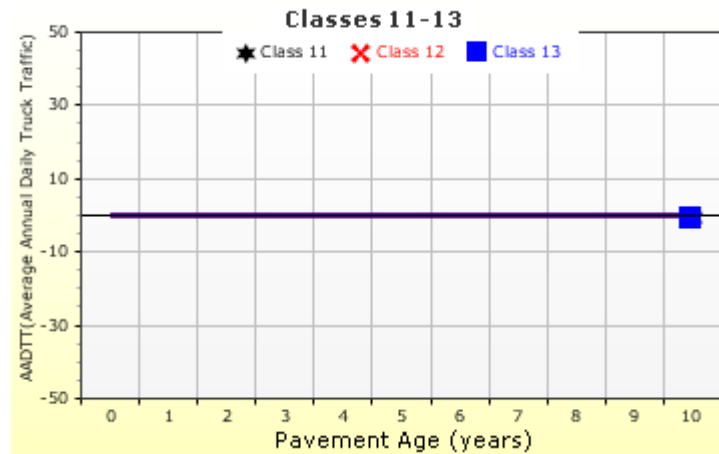
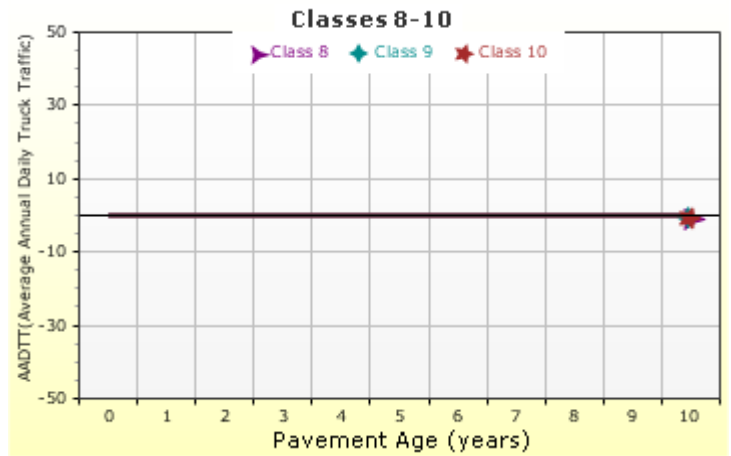
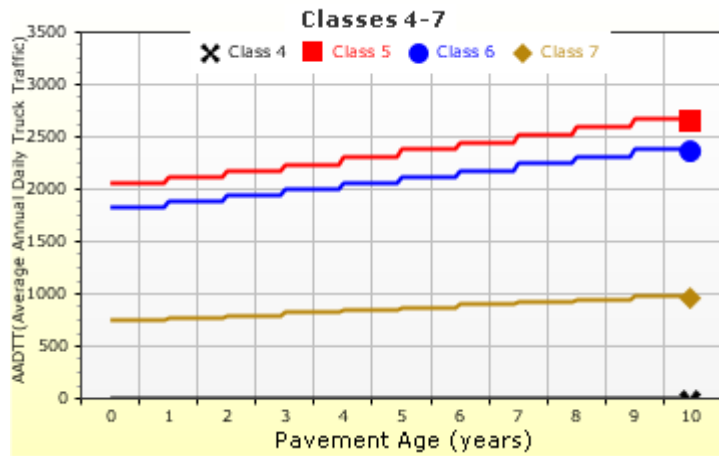
Wheelbase does not apply

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



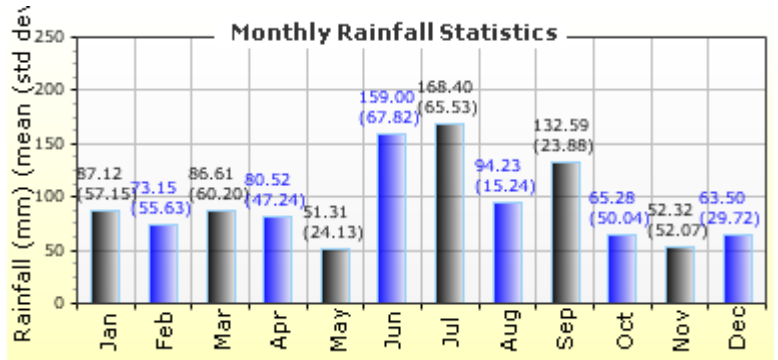
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

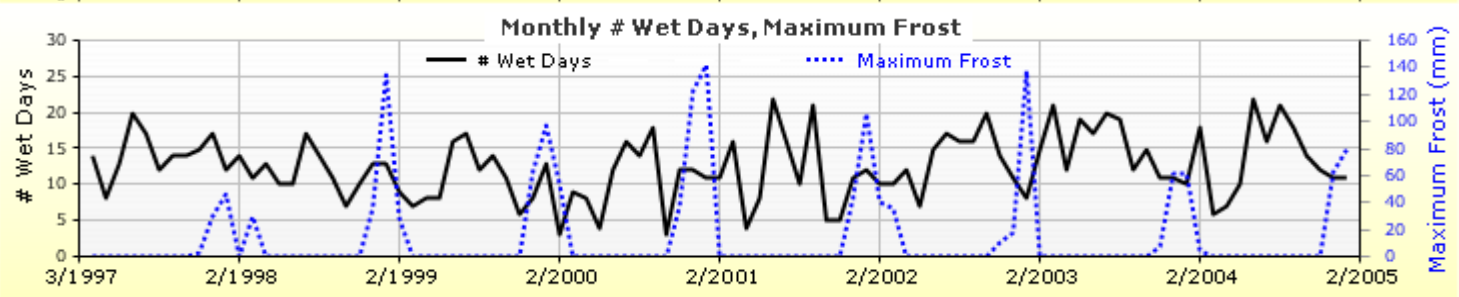
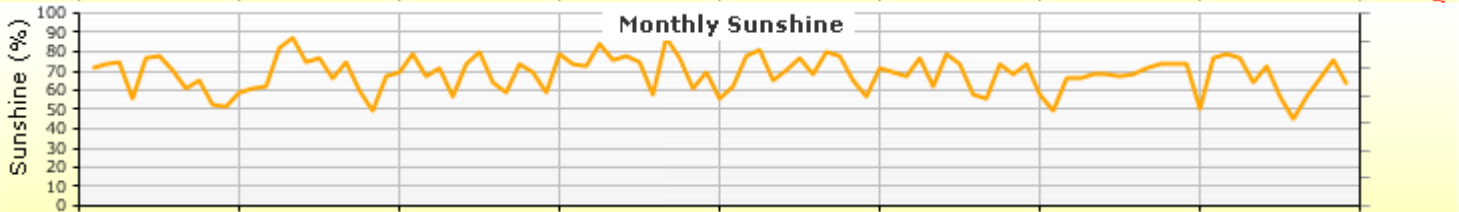
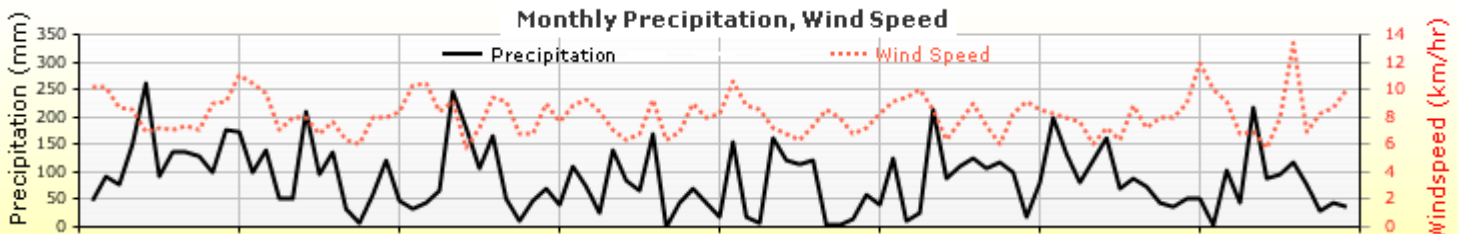
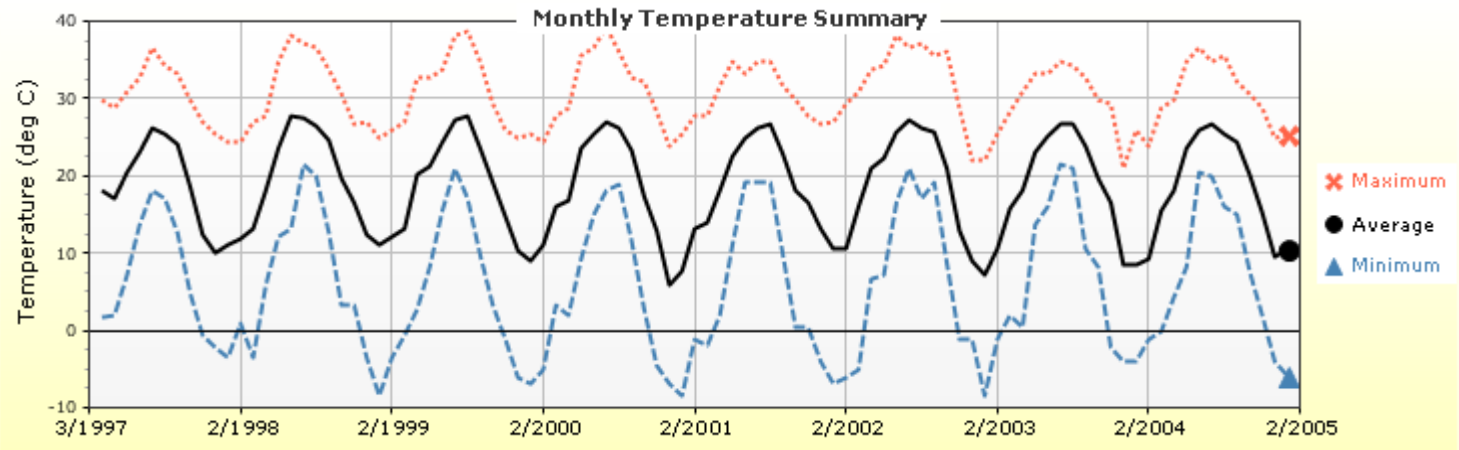
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

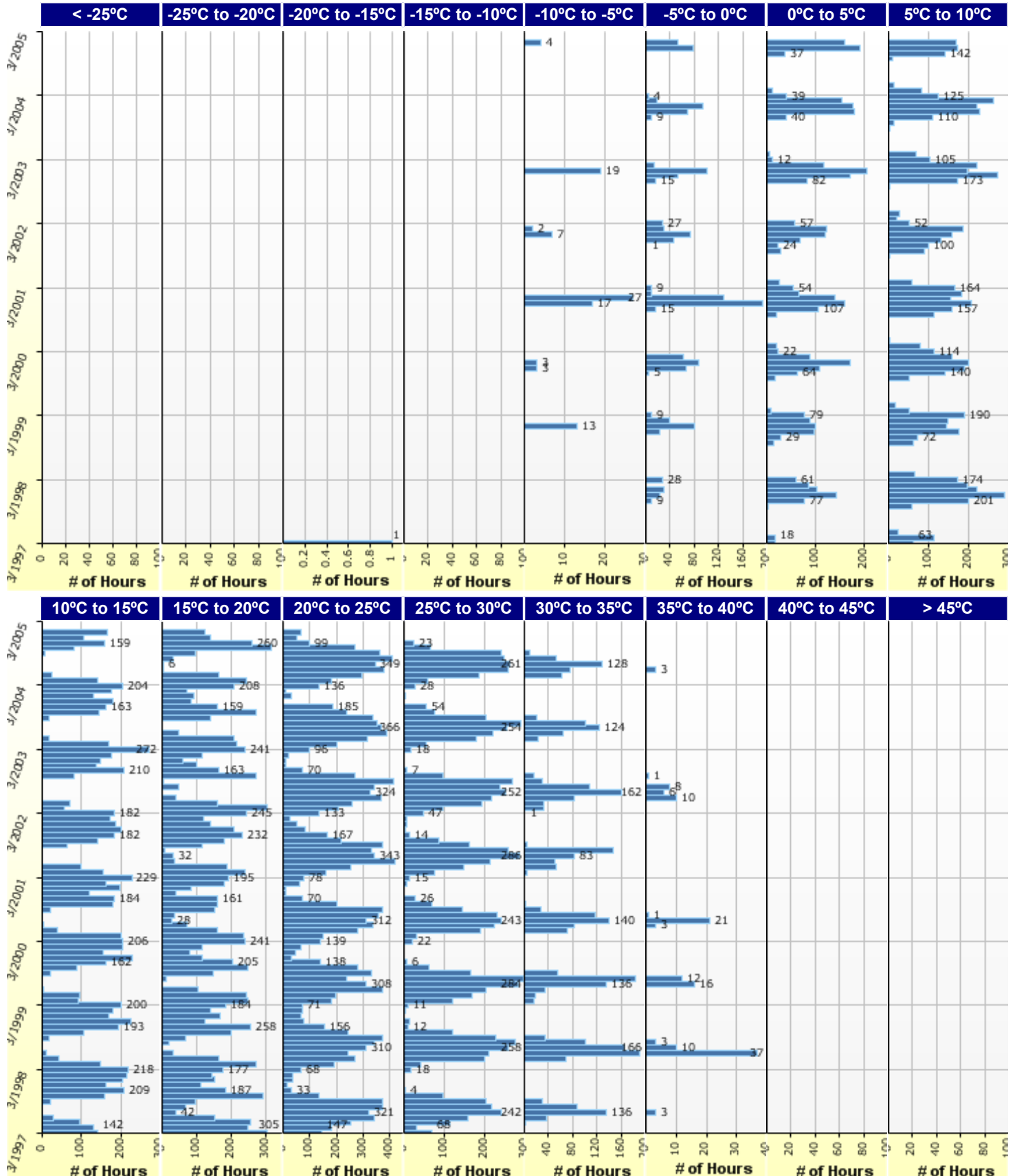


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF4_ALT3

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF4_ALT3.dgpx



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

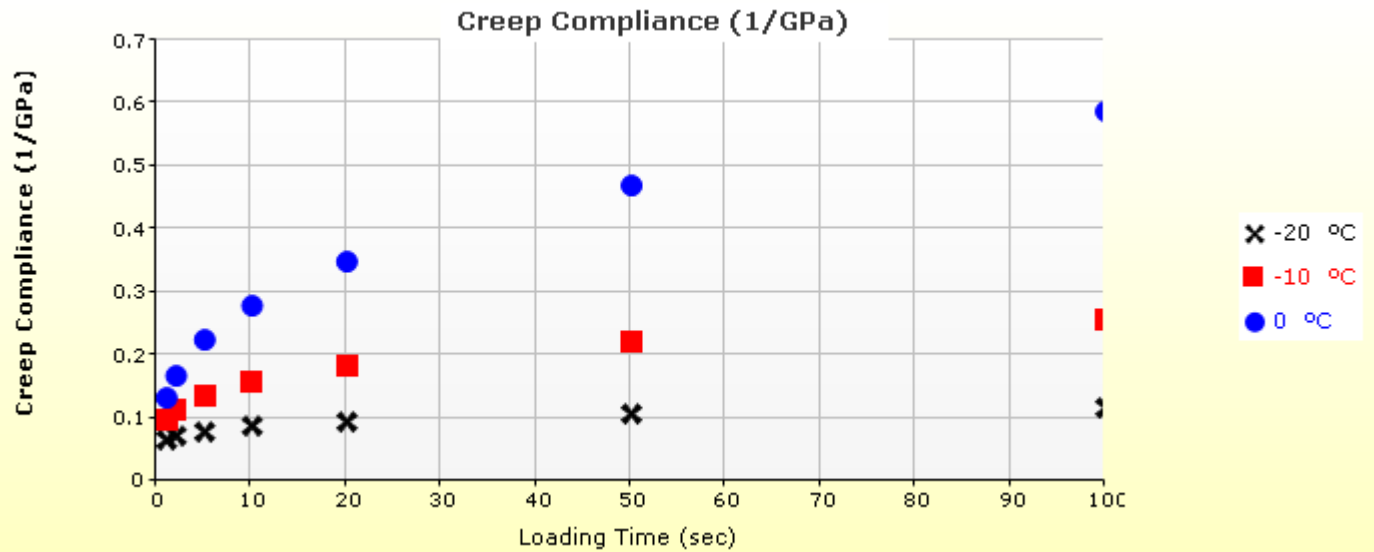
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

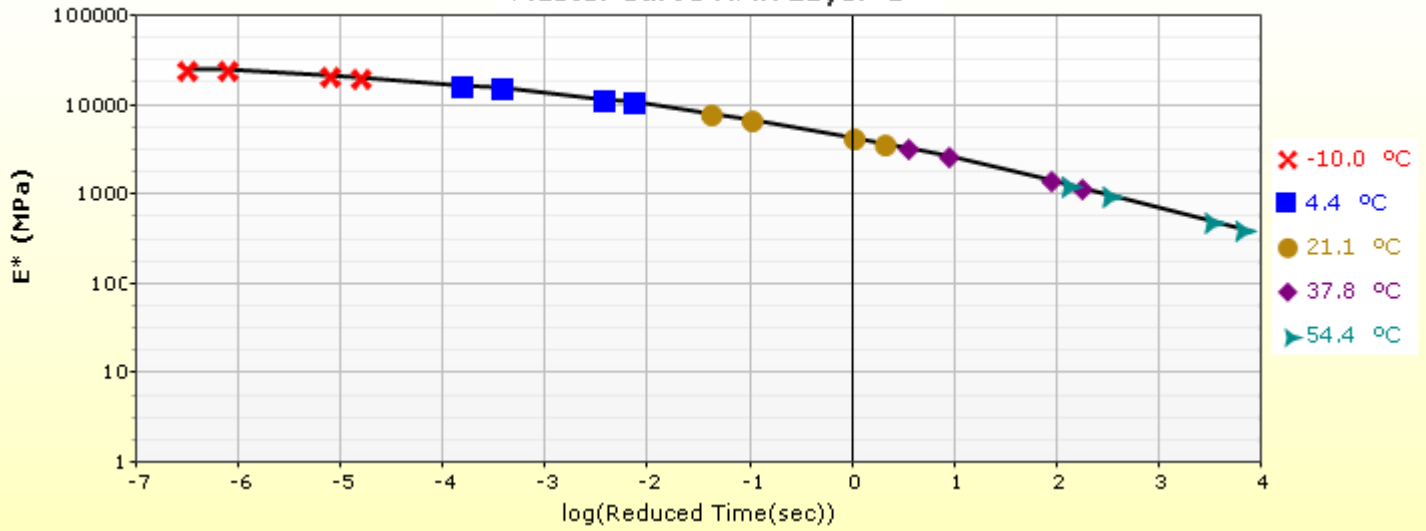
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

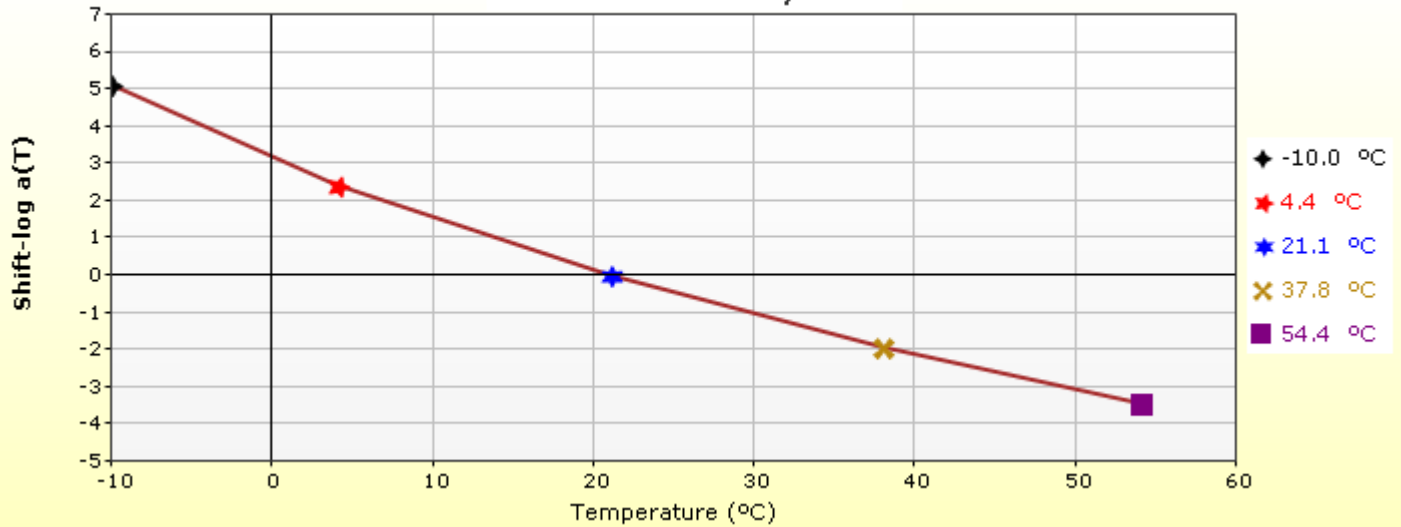


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

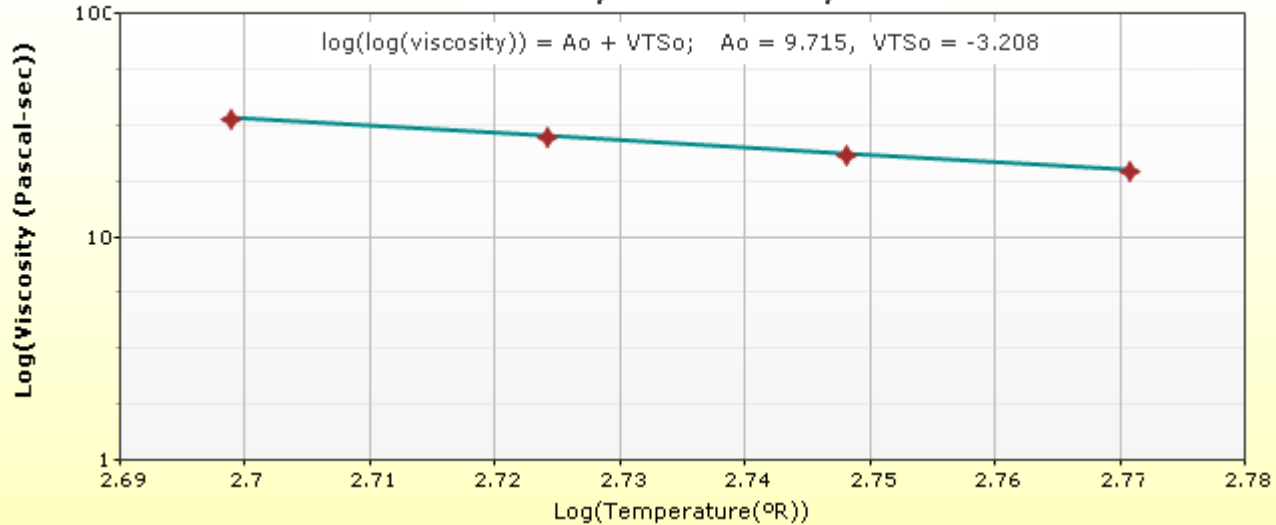
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

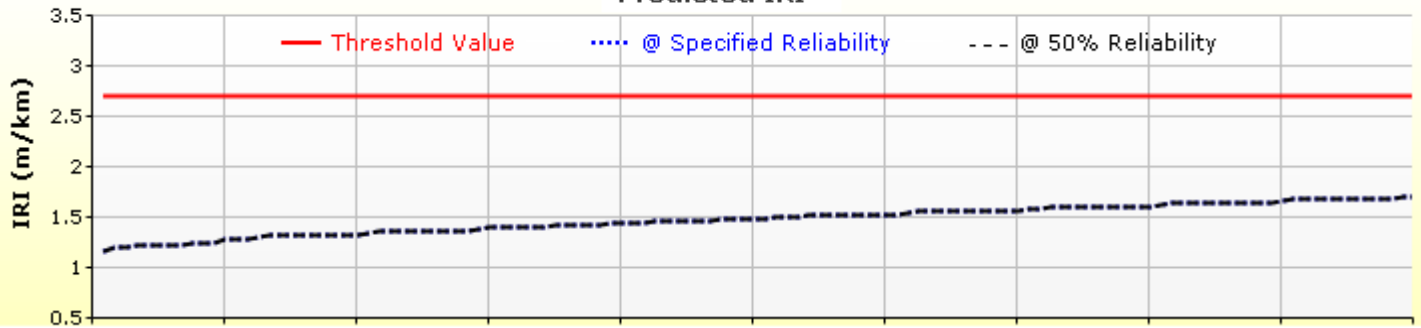


Viscosity Curve HMA Layer 1

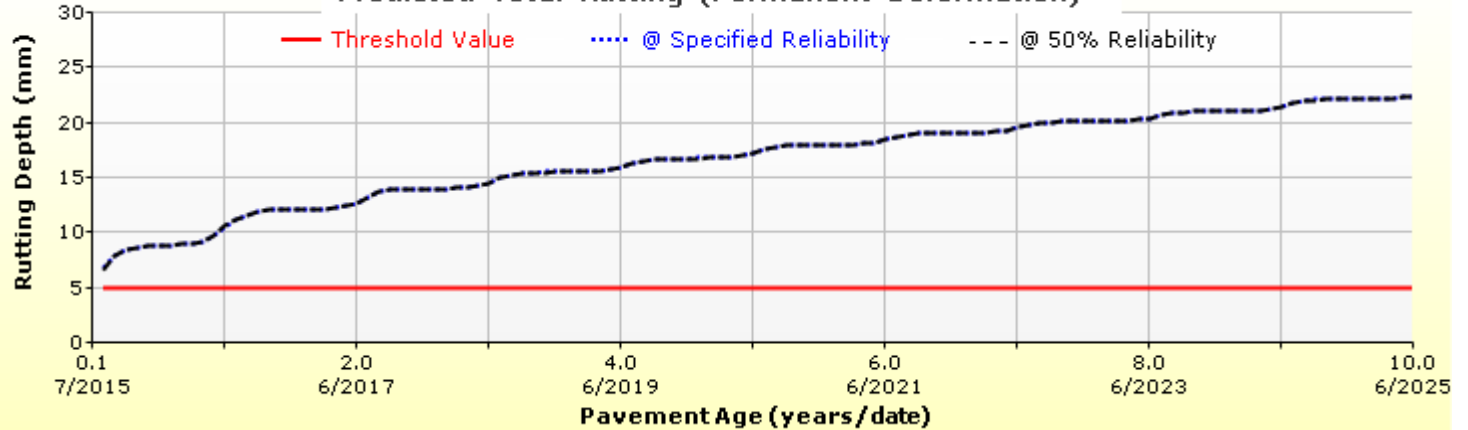


Analysis Output Charts

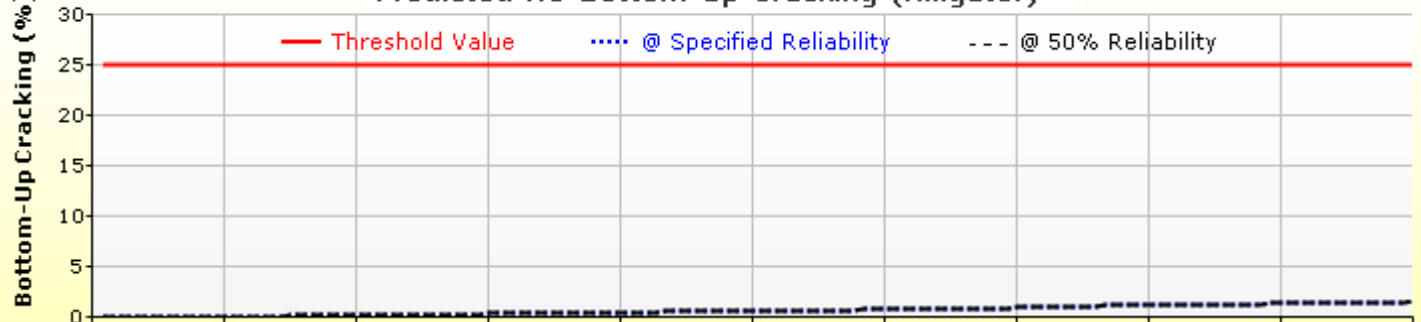
Predicted IRI



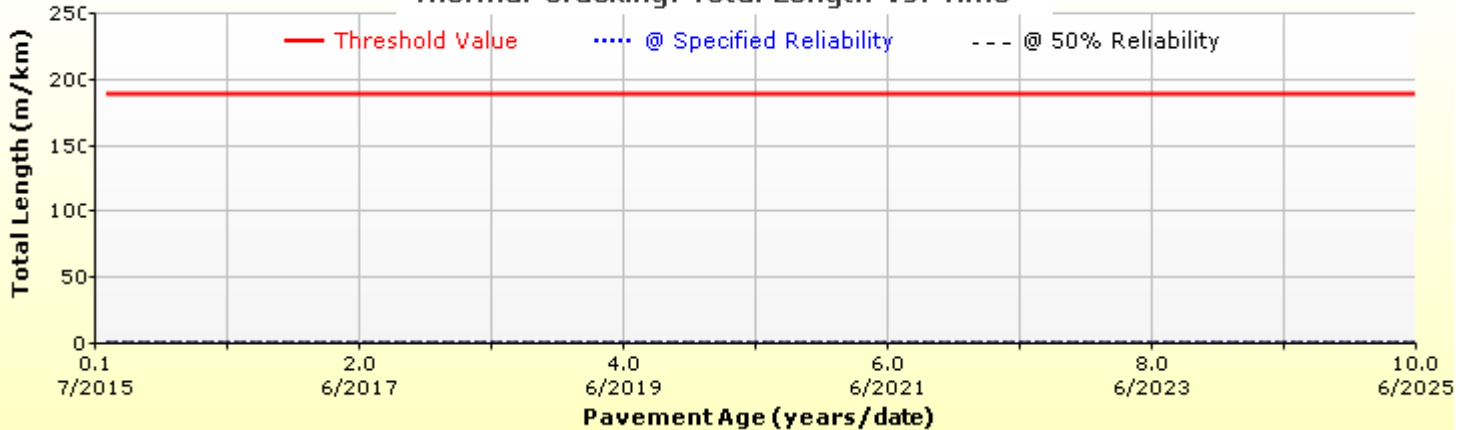
Predicted Total Rutting (Permanent Deformation)



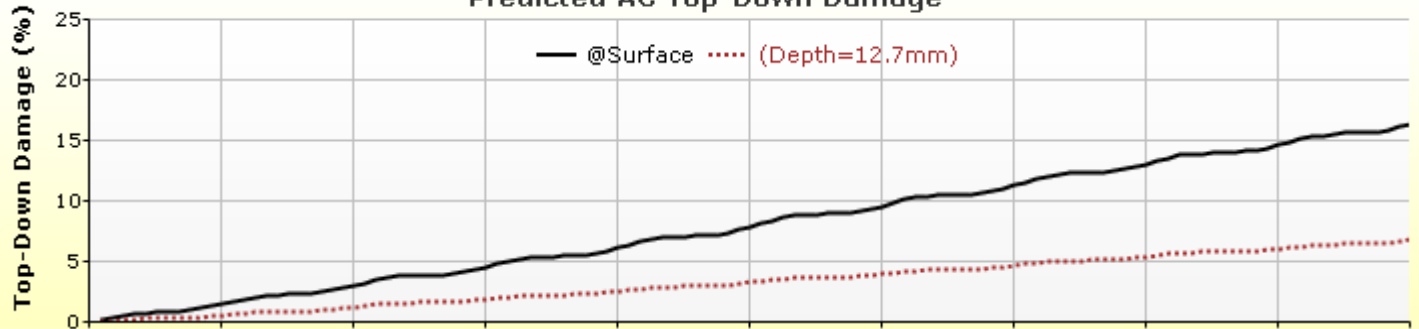
Predicted AC Bottom-Up Cracking (Alligator)



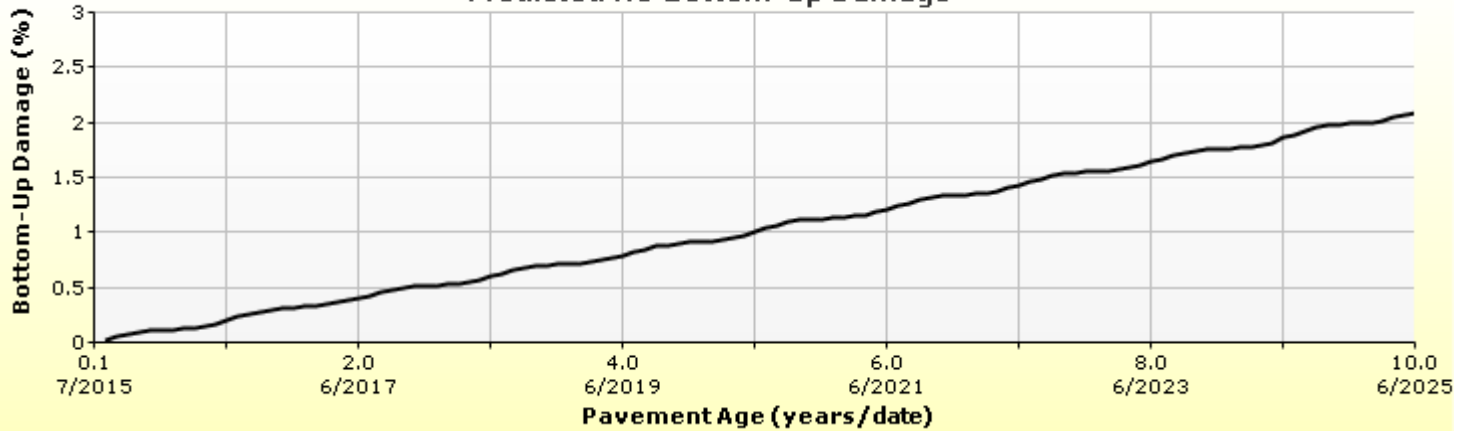
Thermal Cracking: Total Length vs. Time



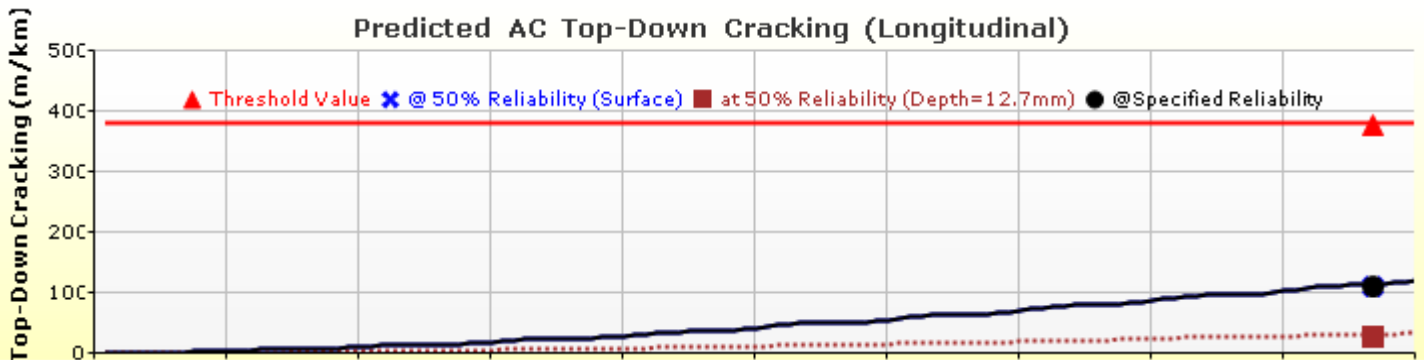
Predicted AC Top-Down Damage



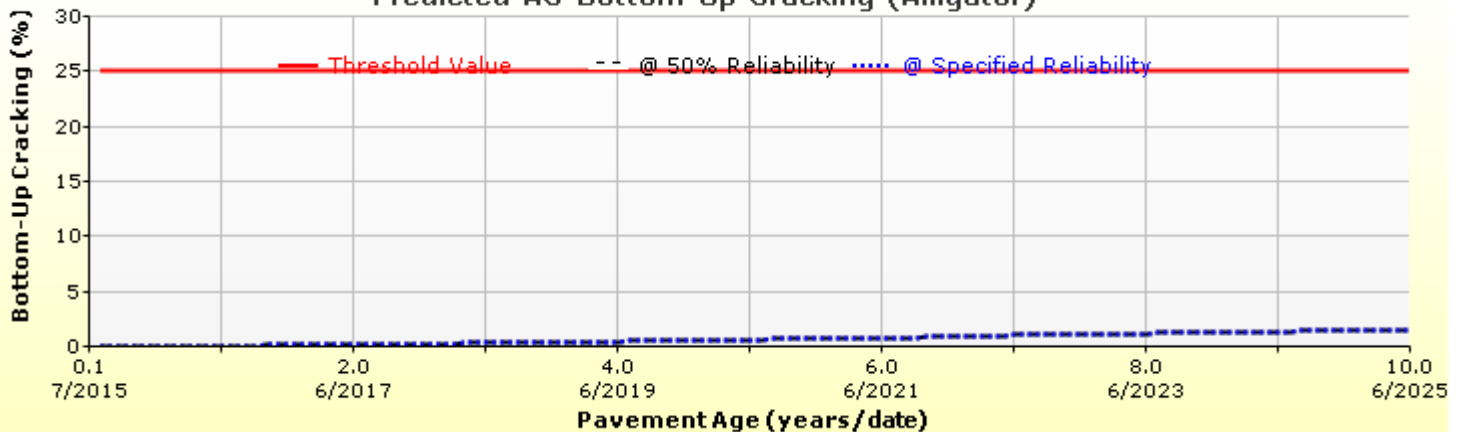
Predicted AC Bottom-Up Damage



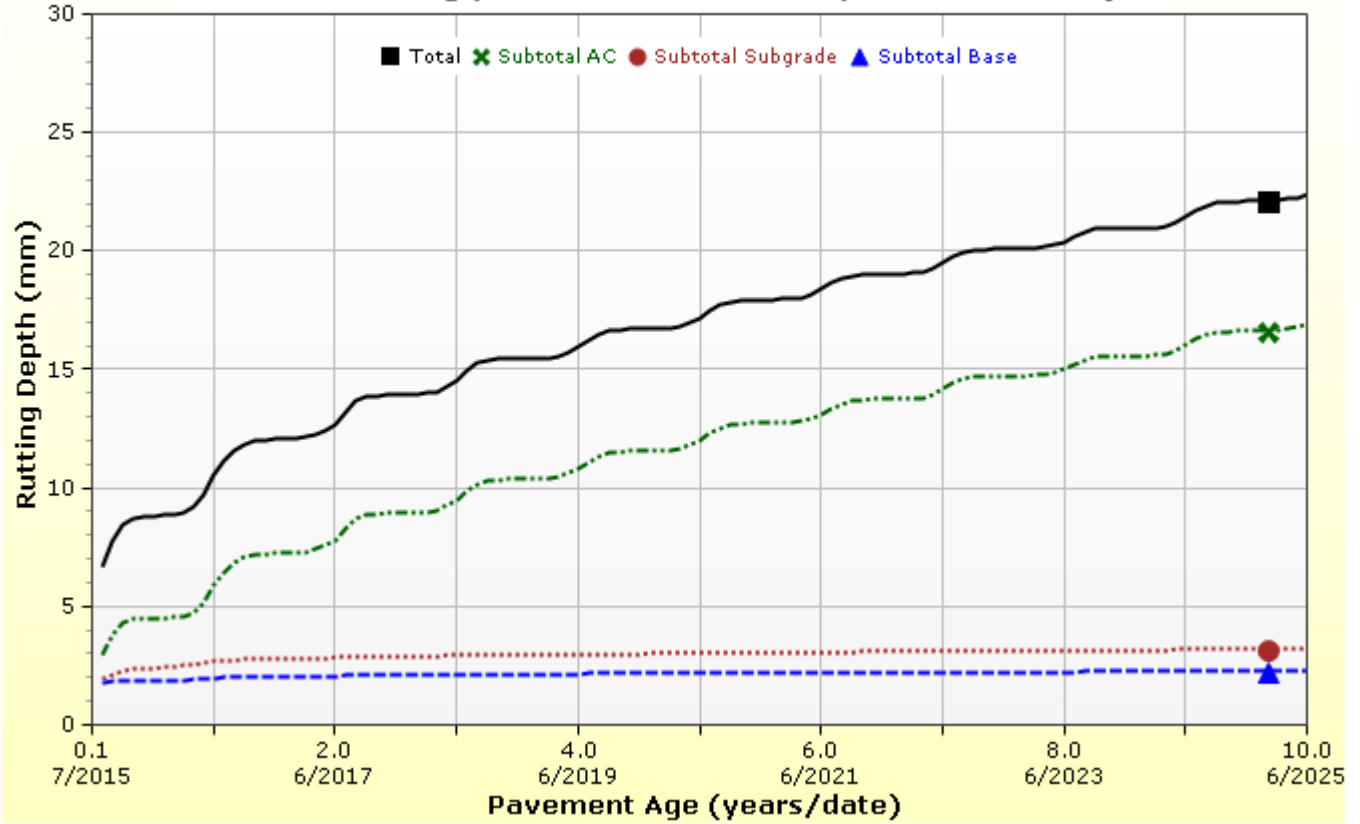
Predicted AC Top-Down Cracking (Longitudinal)



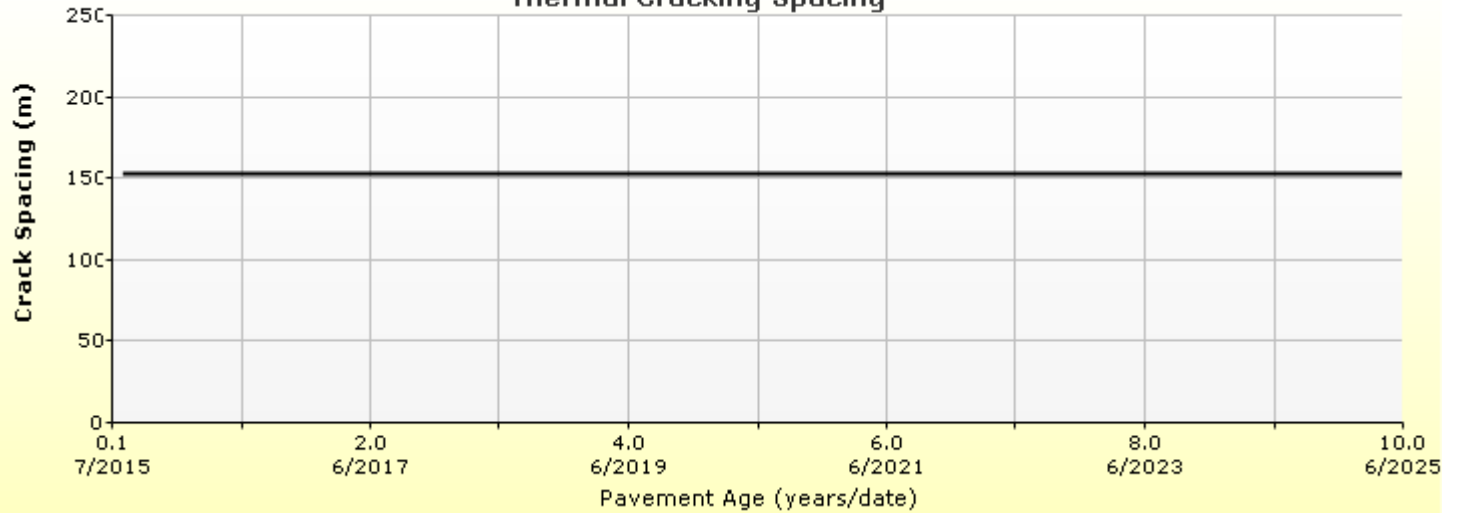
Predicted AC Bottom-Up Cracking (Alligator)



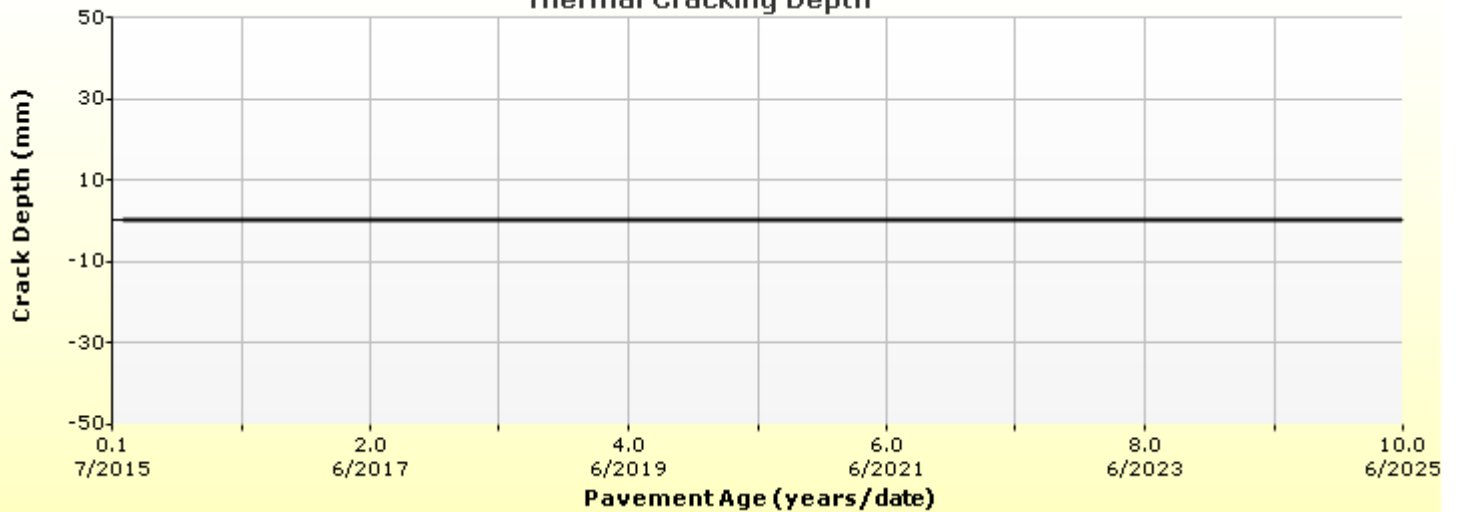
Predicted Rutting (Permanent Deformation) at 50% Reliability

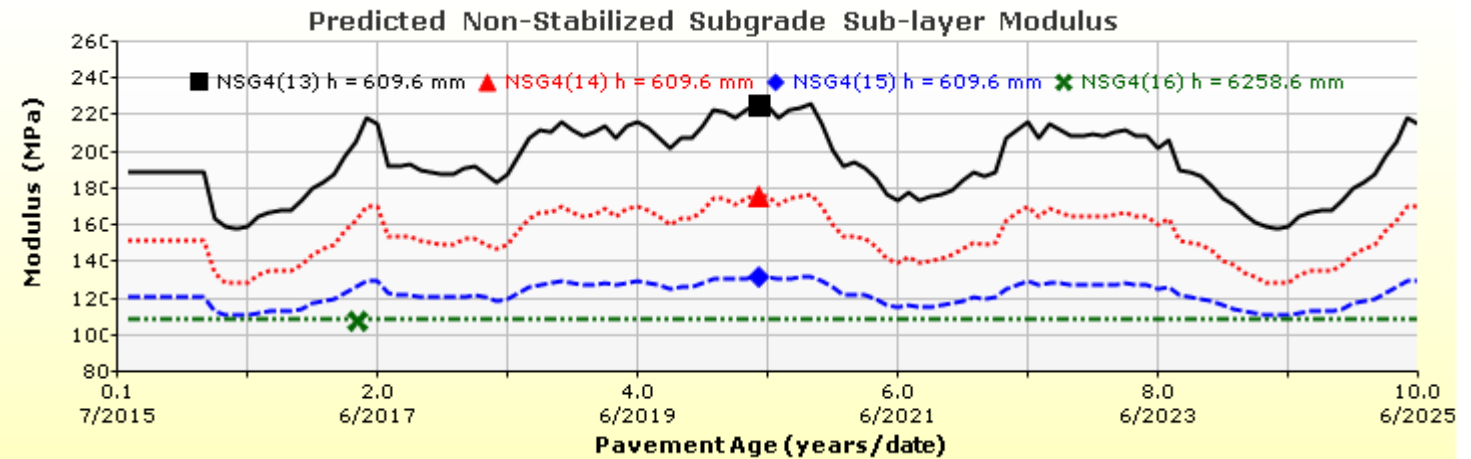
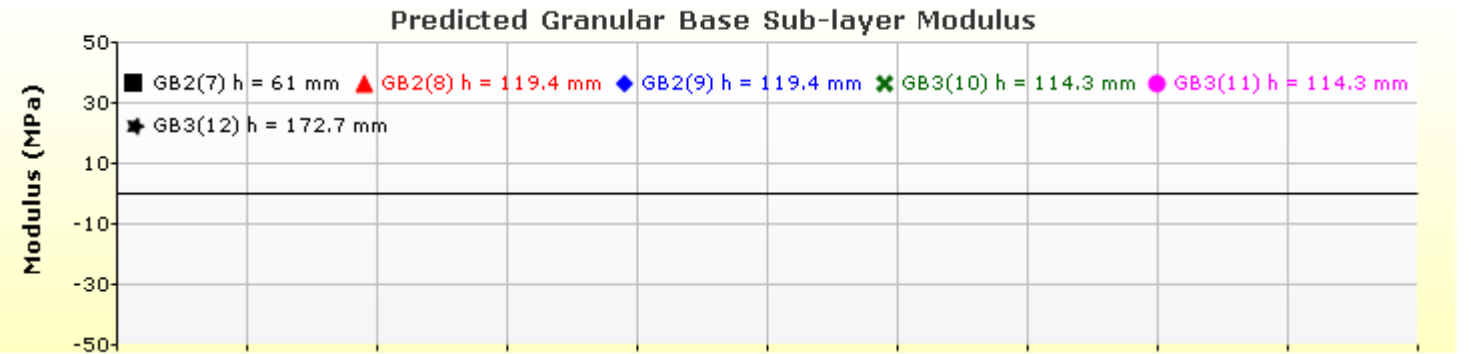
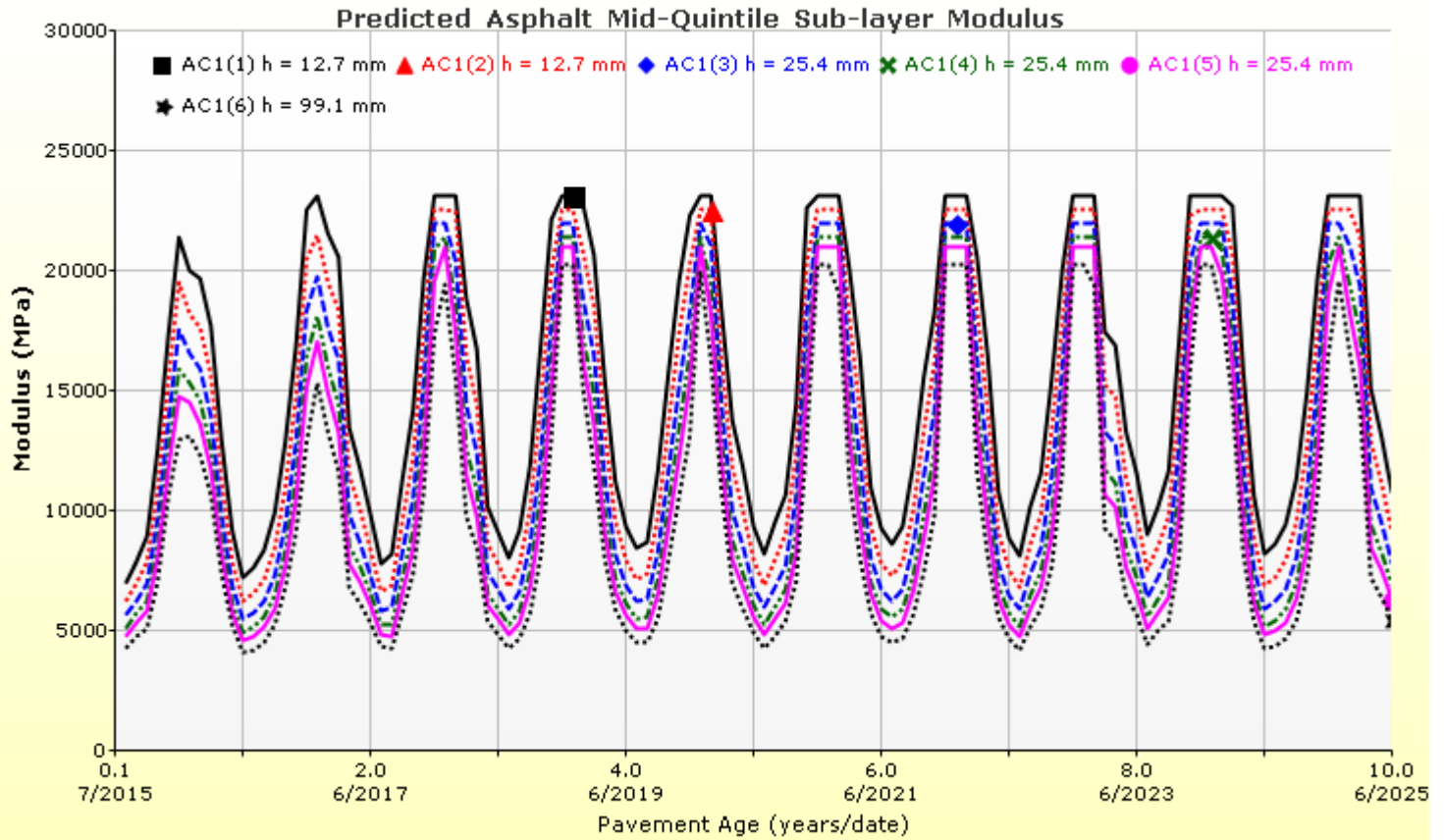


Thermal Cracking Spacing



Thermal Cracking Depth





Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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:	Annual representative values
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

Standard Deviation (BASERUT)

0.1235*Pow(SUBRUT,0.5012)+0.001

AC Cracking

AC Top Down Cracking

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

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: 7

c2: 3.5

c3: 0

c4: 1000

c1: 1

c2: 1

c3: 6000

AC Cracking Top Standard Deviation

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

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

IRI Flexible Pavements

C1 - Rutting

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

CSM Standard Deviation

CTB*1



Project1 - Novo ALF1_ALT4

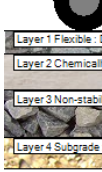
File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1_ALT4.dgpx



Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data 32.119, -81.202
Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm):	Volumetric at Construction:	
Flexible	Default asphalt concrete	200.0	Effective binder content (%)	11.6
Cement_Base	Cement stabilized	300.0	Air voids (%)	7.0
NonStabilized	Crushed stone	400.0		
Subgrade	A-1-a	Semi-infinite		

Traffic

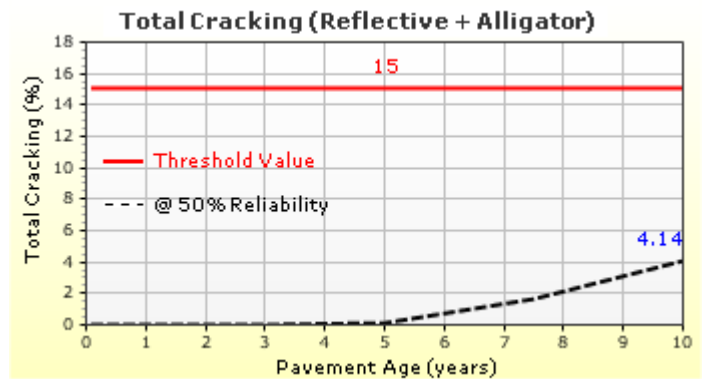
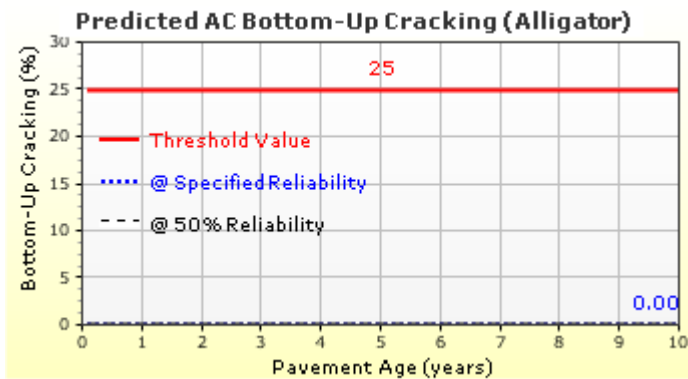
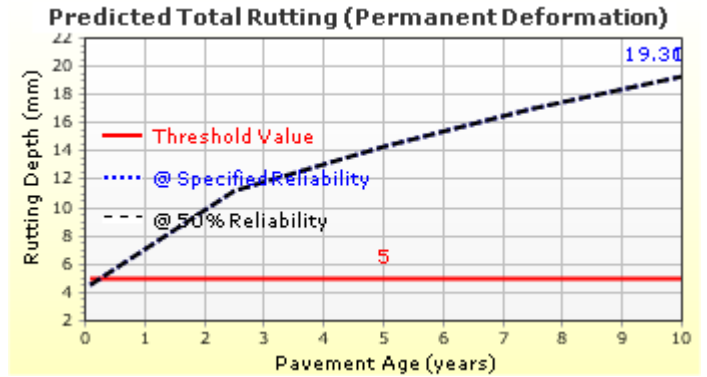
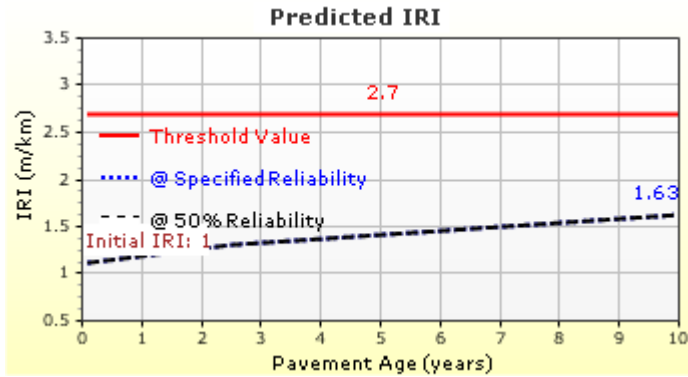
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.63	50.00	98.99	Pass
Permanent deformation - total pavement (mm)	5.00	19.31	50.00	0.07	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.00	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.14	-	-	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	365.53	50.00	51.22	Pass
Permanent deformation - AC only (mm)	5.00	16.74	50.00	0.37	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.55	-	-	-

Distress Charts

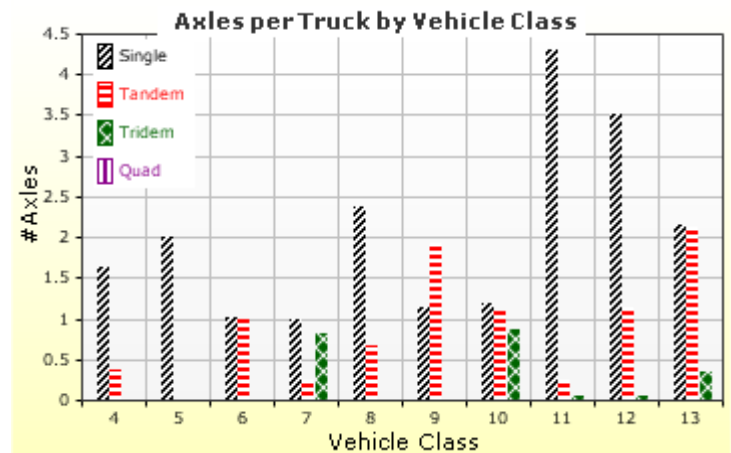
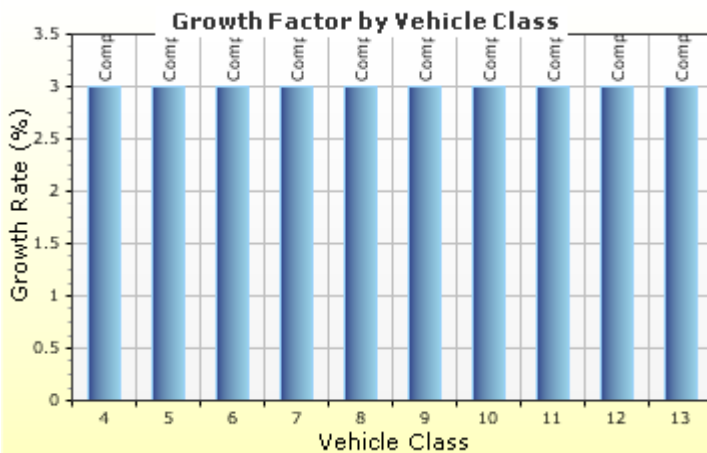
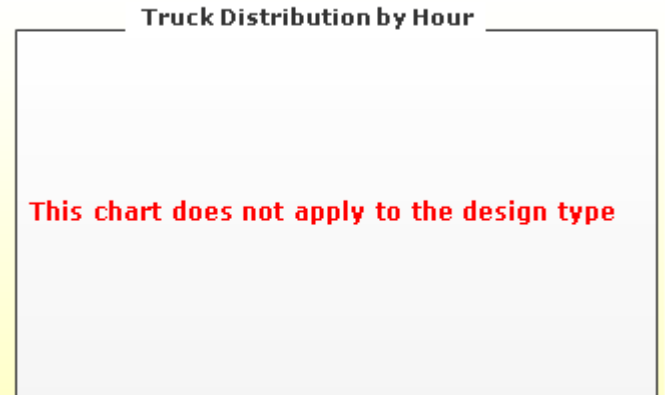
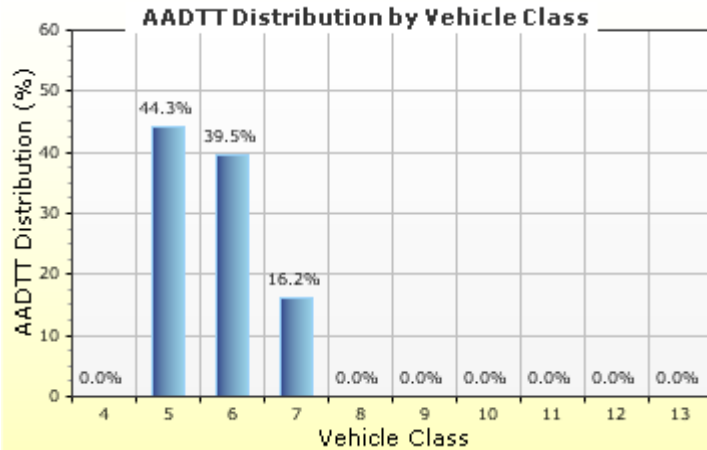


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

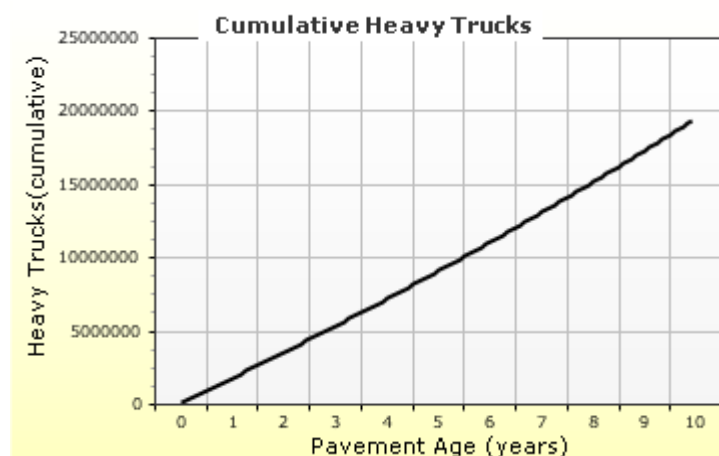
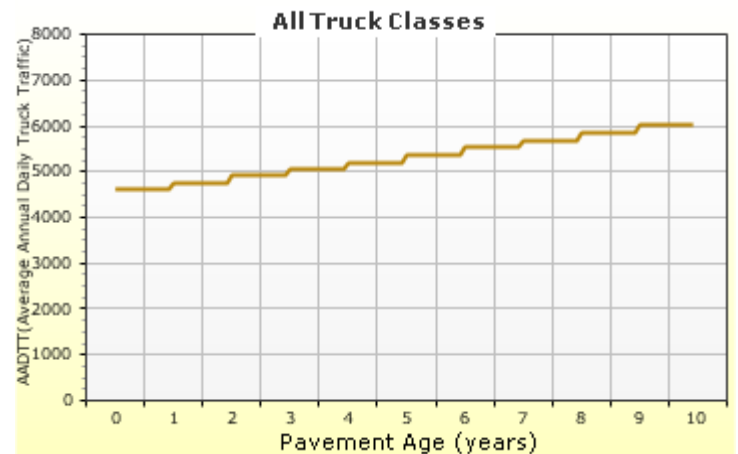
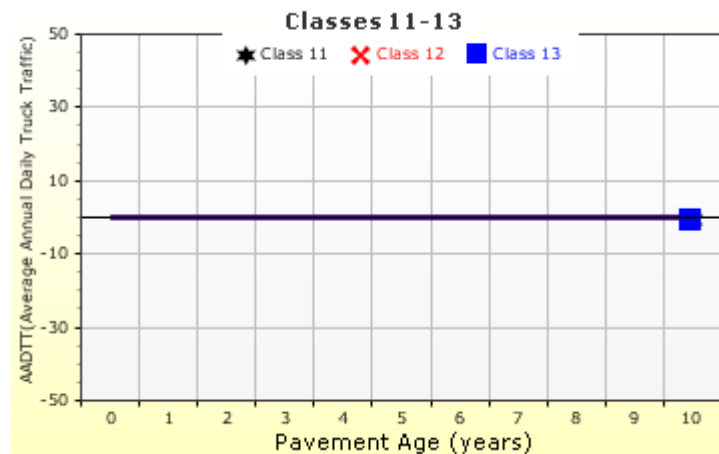
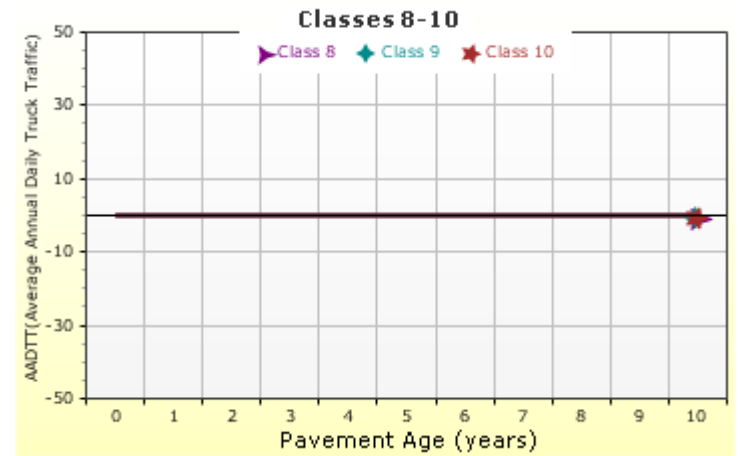
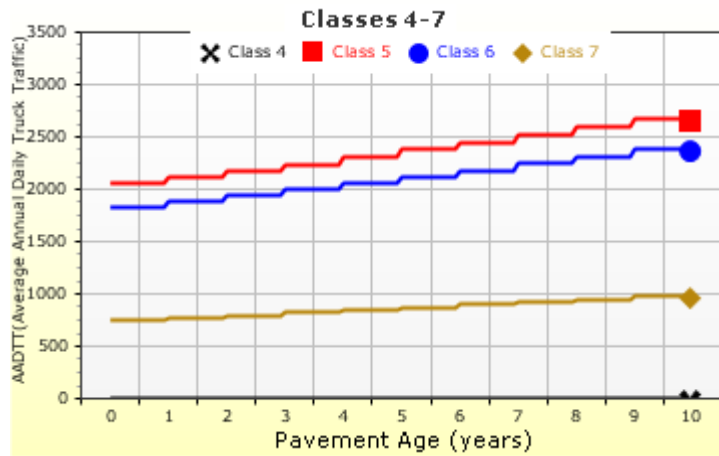
Wheelbase does not apply

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



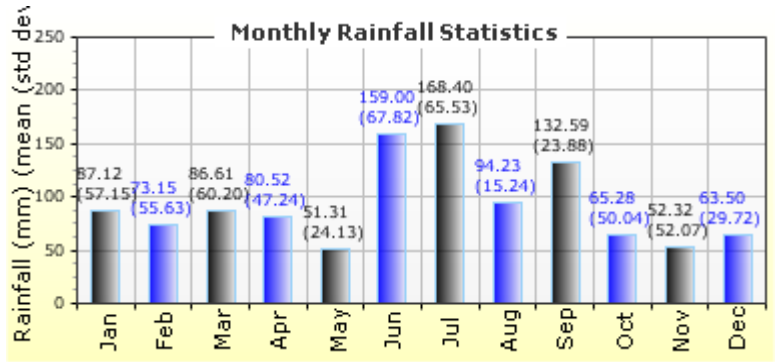
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

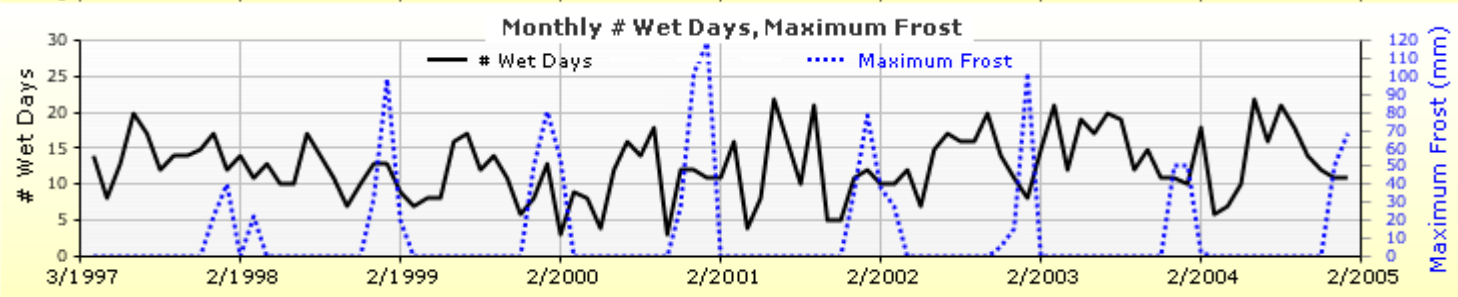
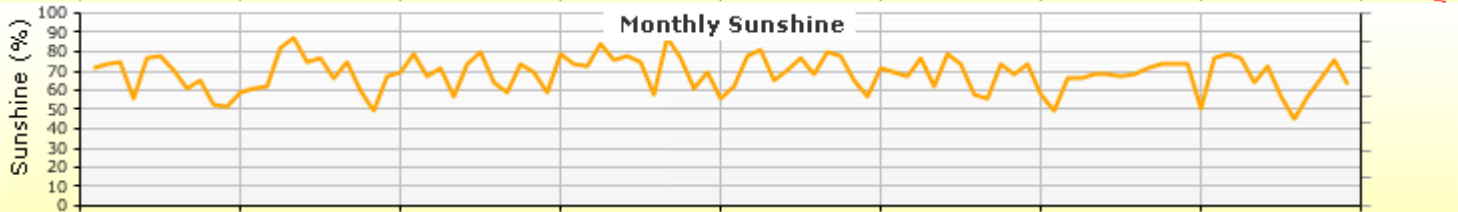
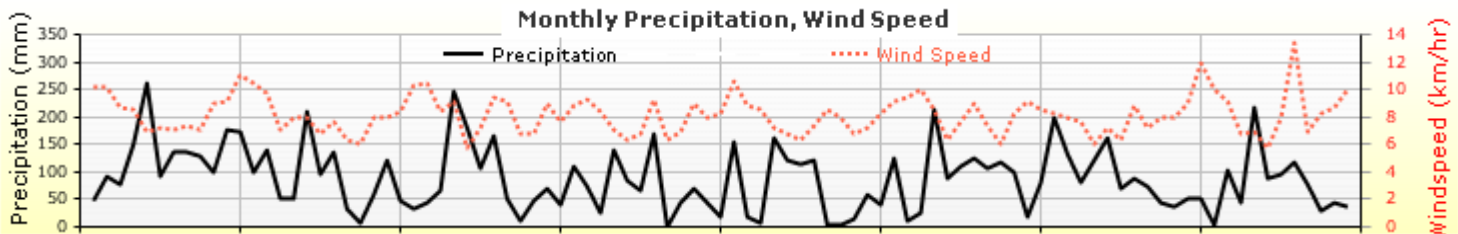
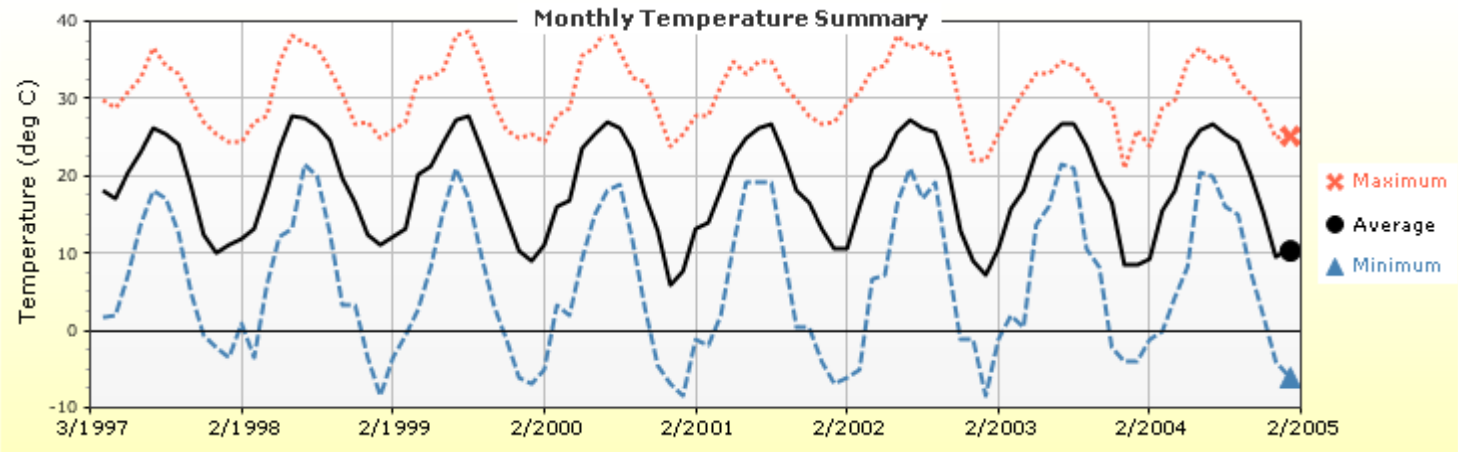
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

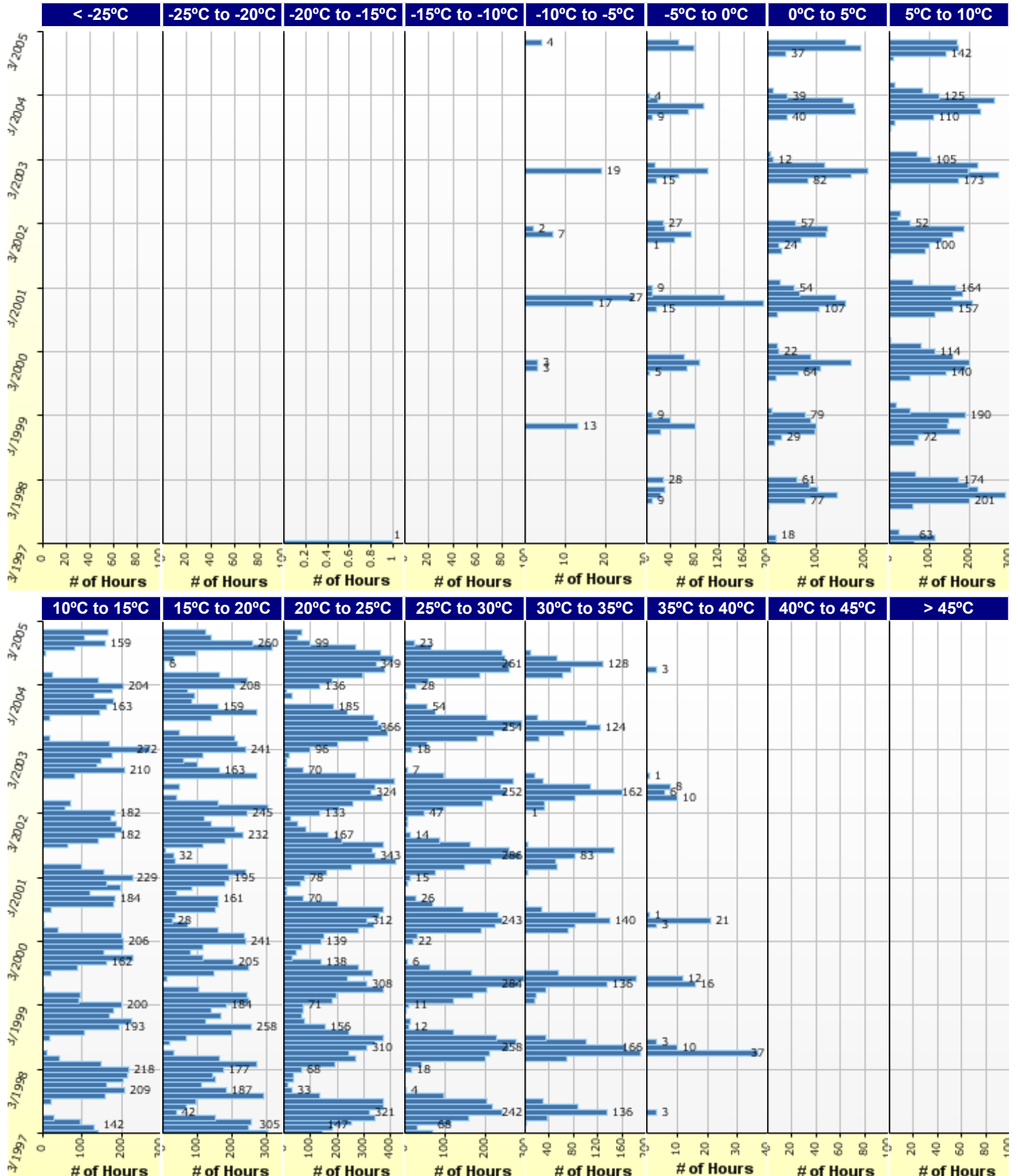


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF1_ALT4

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1_ALT4.dgpx



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

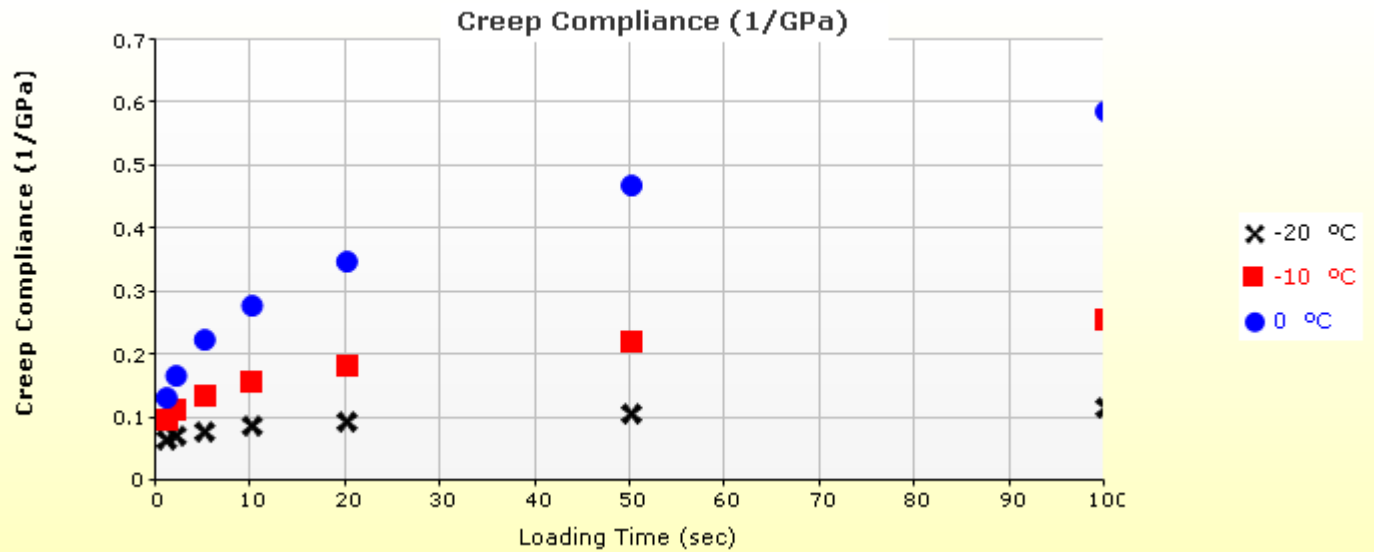
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Chemically Stabilized : Cement stabilized	Chemically Stabilized (2)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

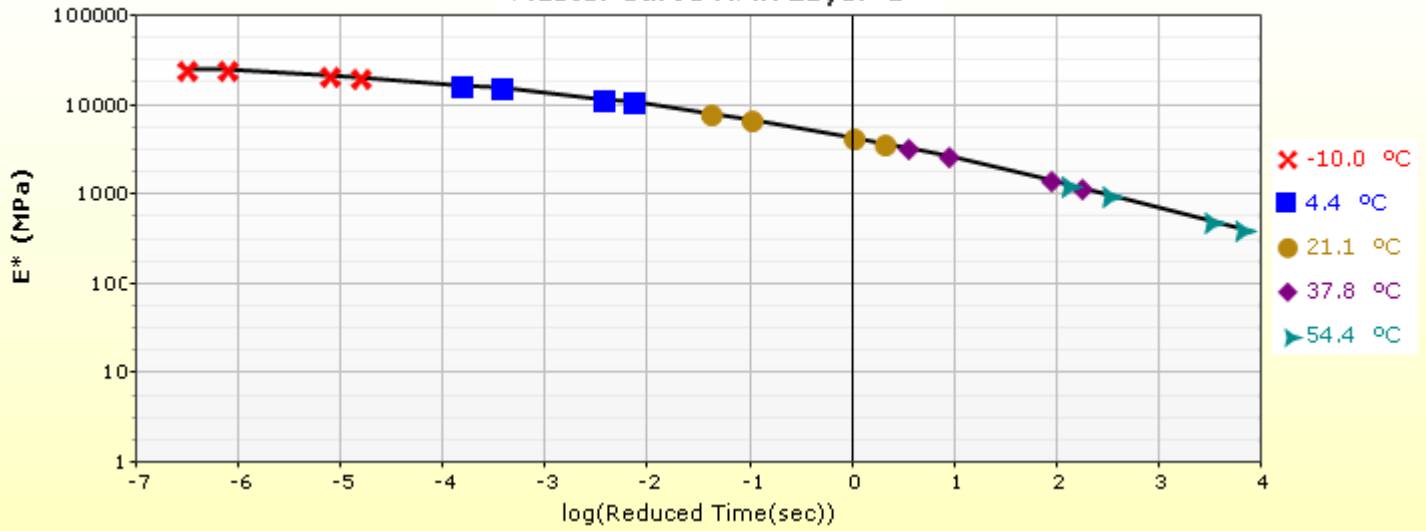
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

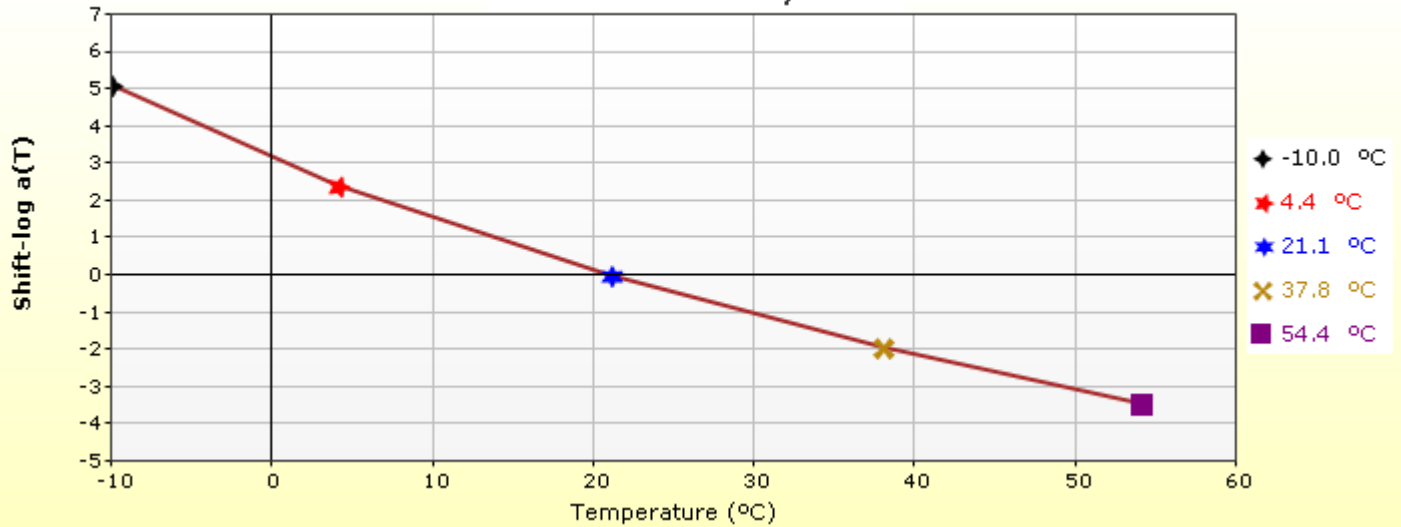


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

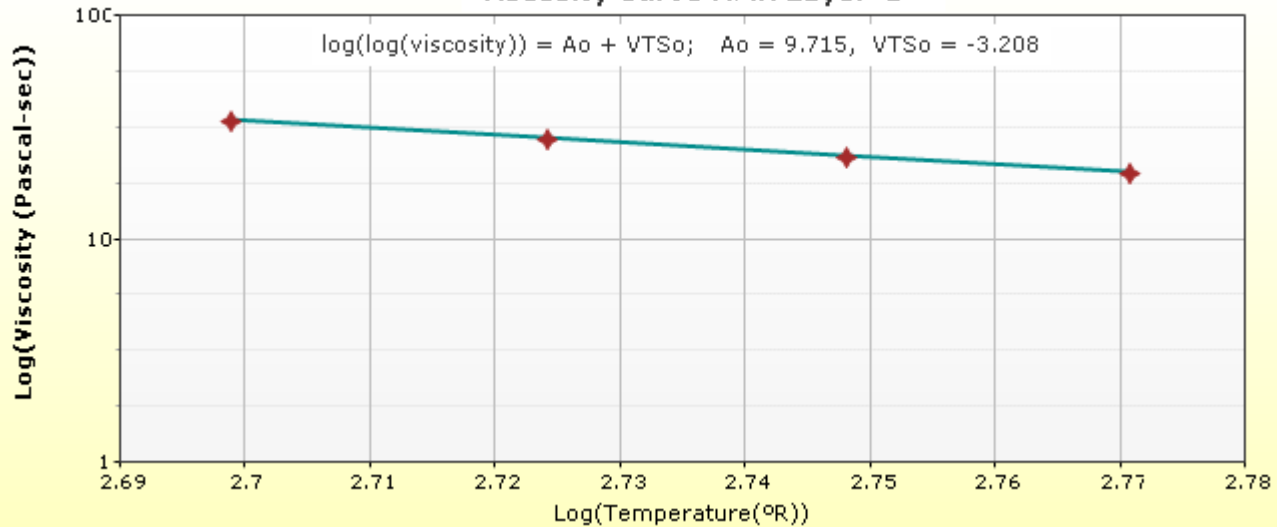
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

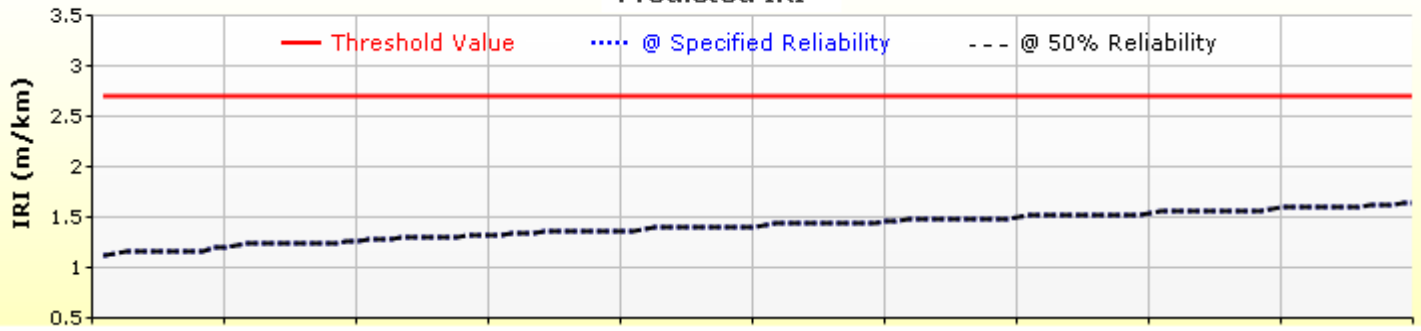


Viscosity Curve HMA Layer 1

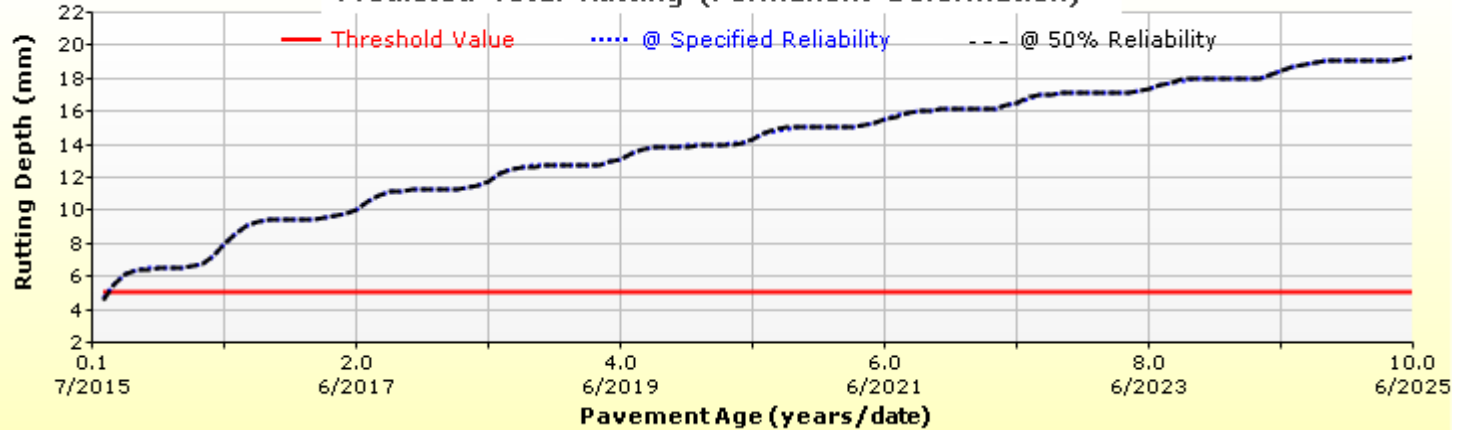


Analysis Output Charts

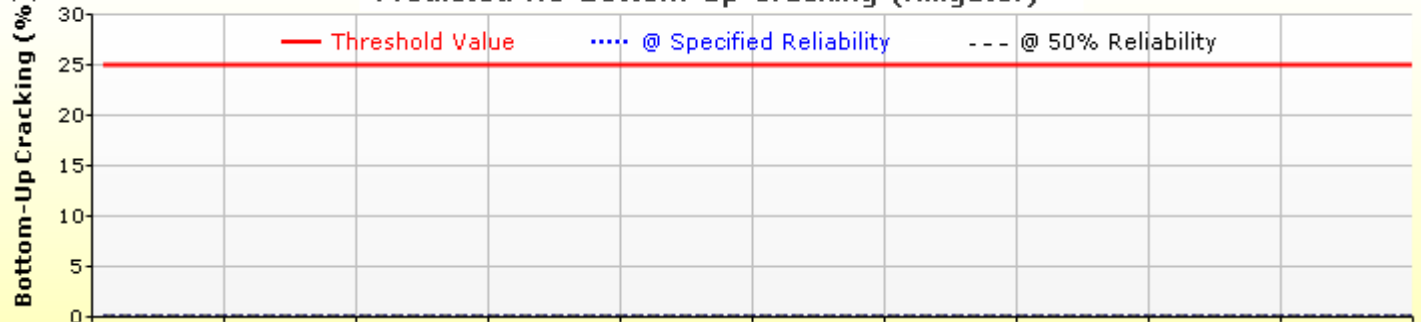
Predicted IRI



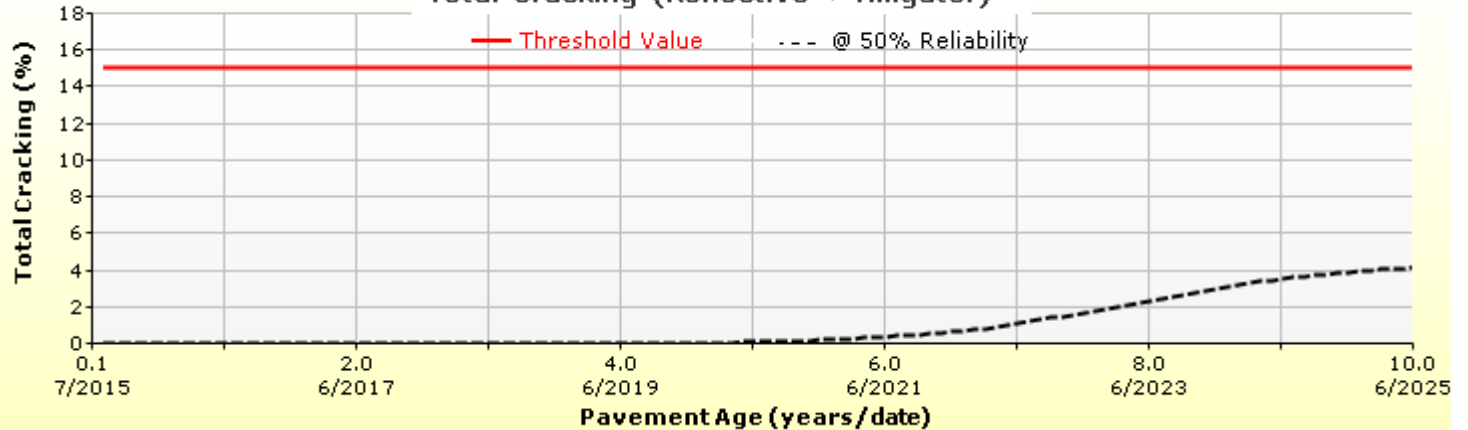
Predicted Total Rutting (Permanent Deformation)

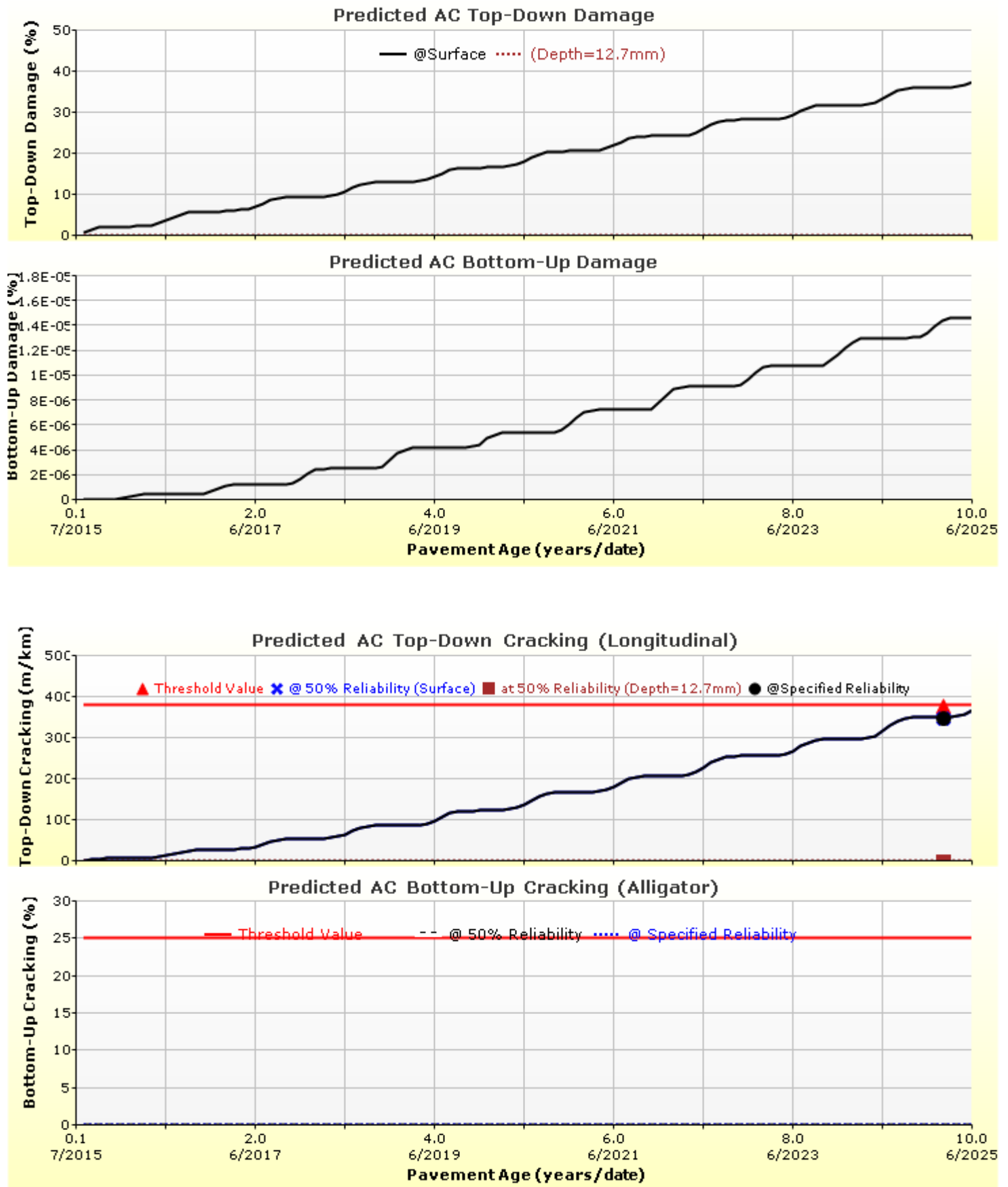


Predicted AC Bottom-Up Cracking (Alligator)

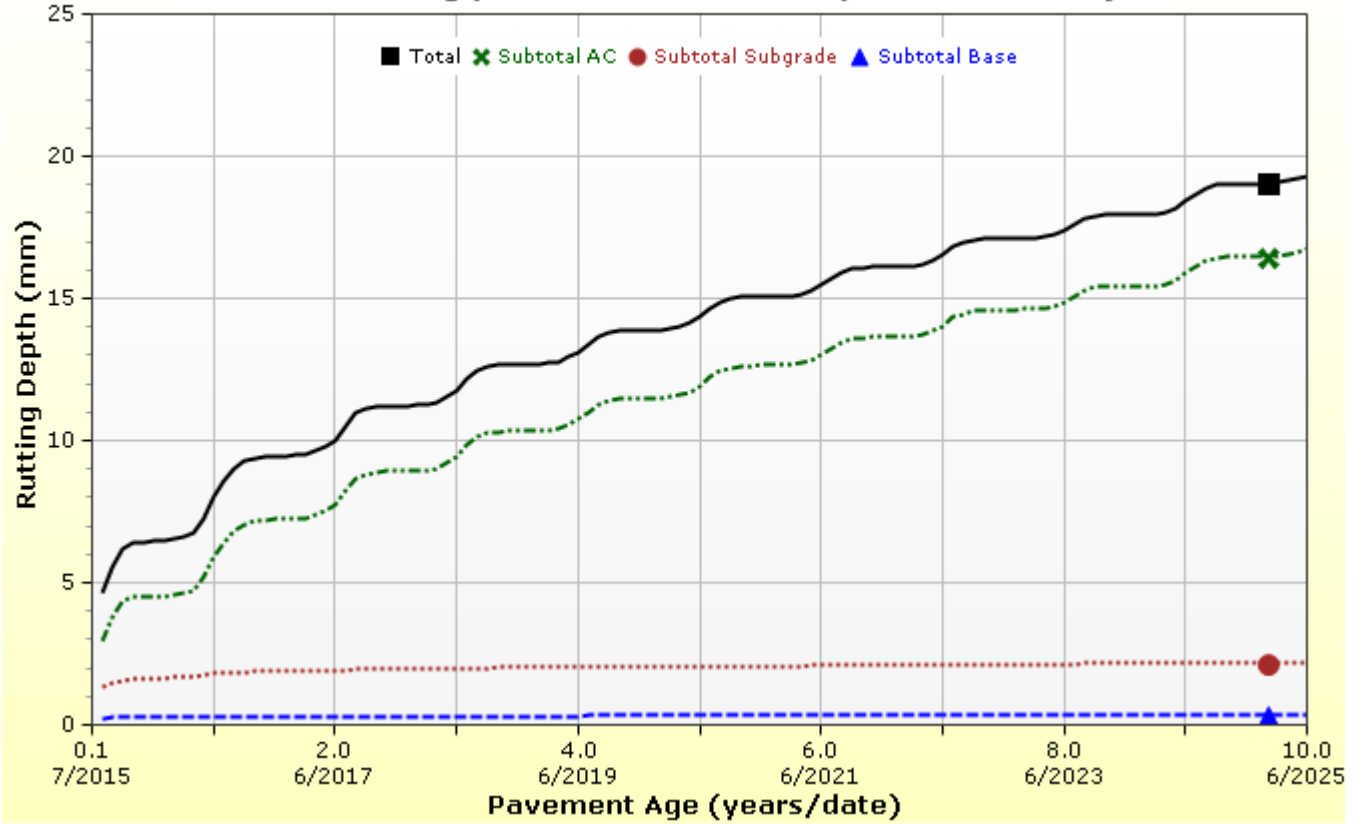


Total Cracking (Reflective + Alligator)

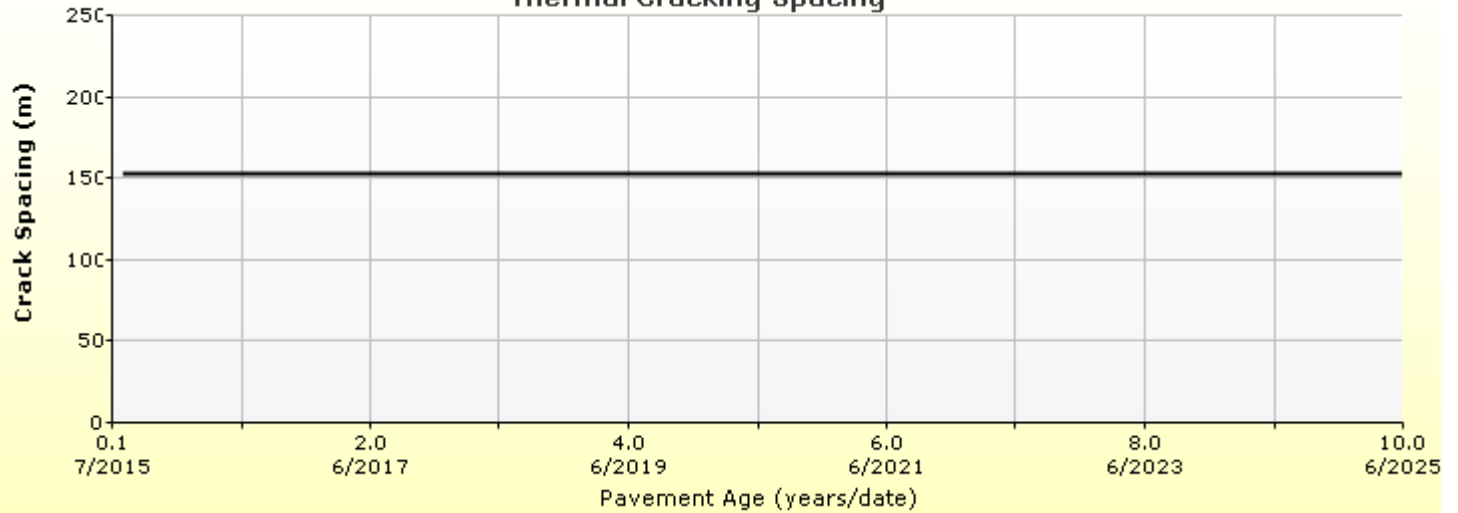




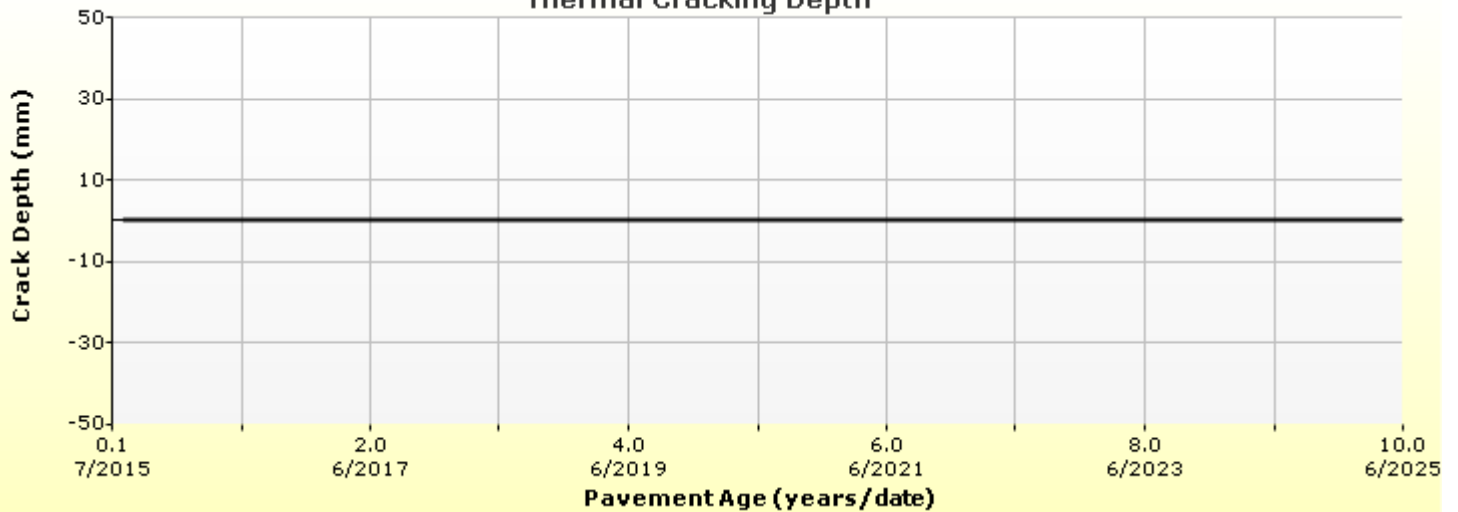
Predicted Rutting (Permanent Deformation) at 50% Reliability

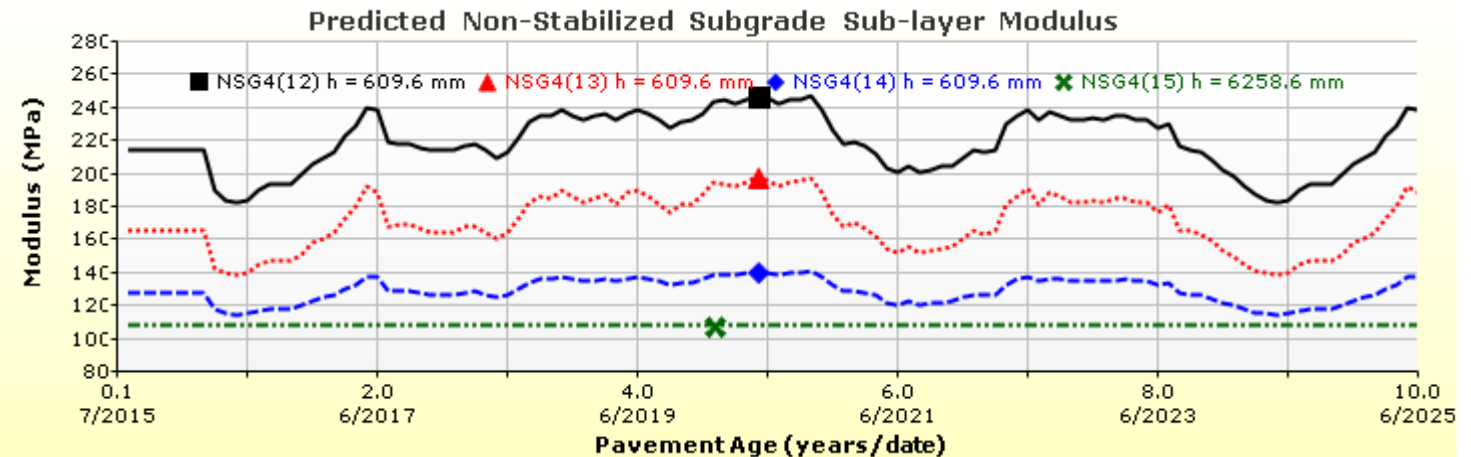
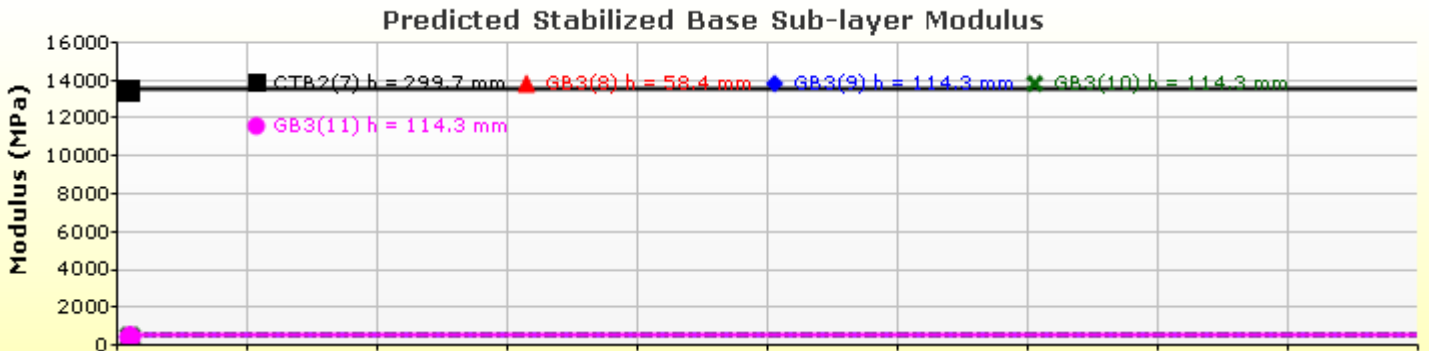
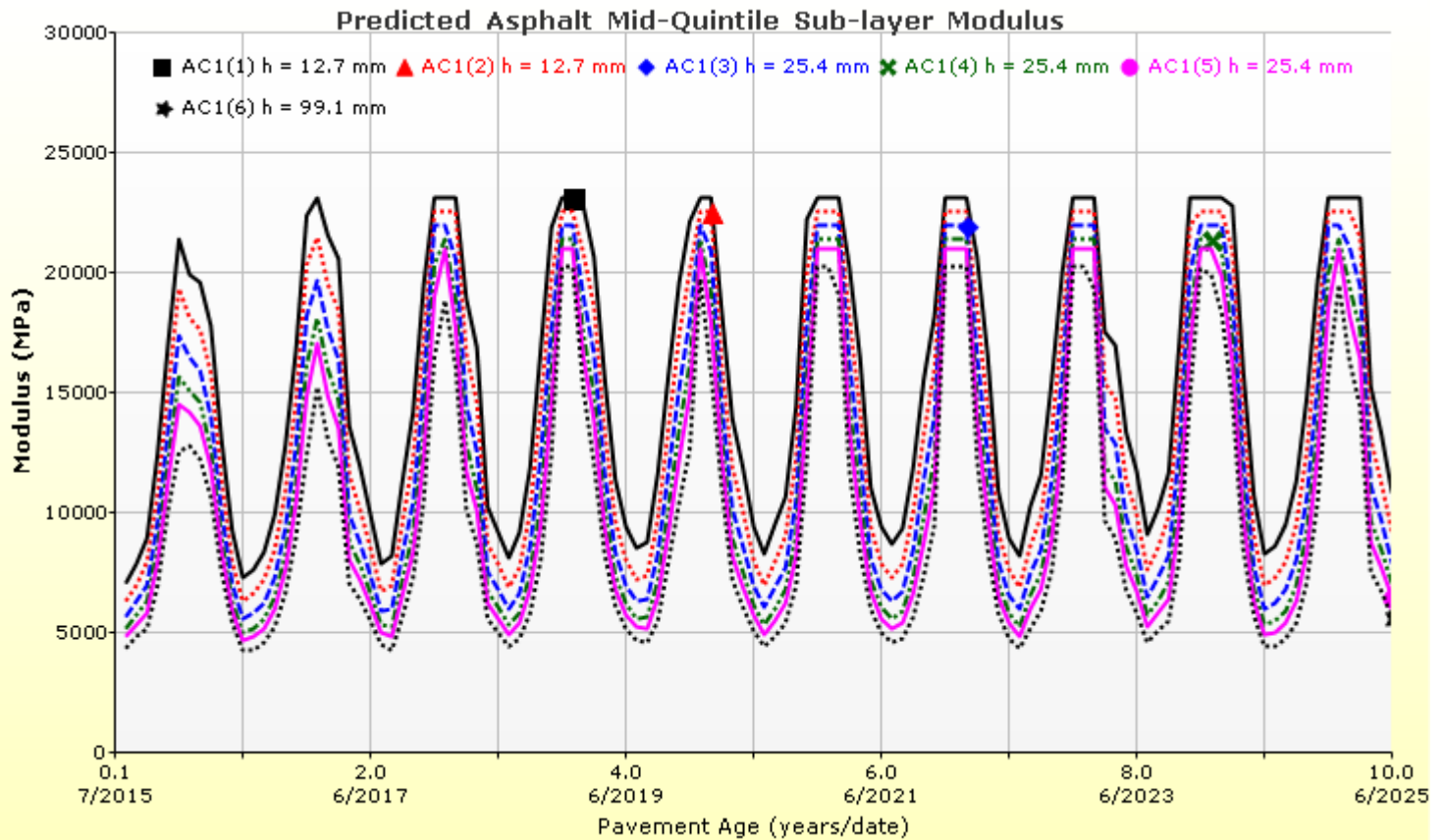


Thermal Cracking Spacing

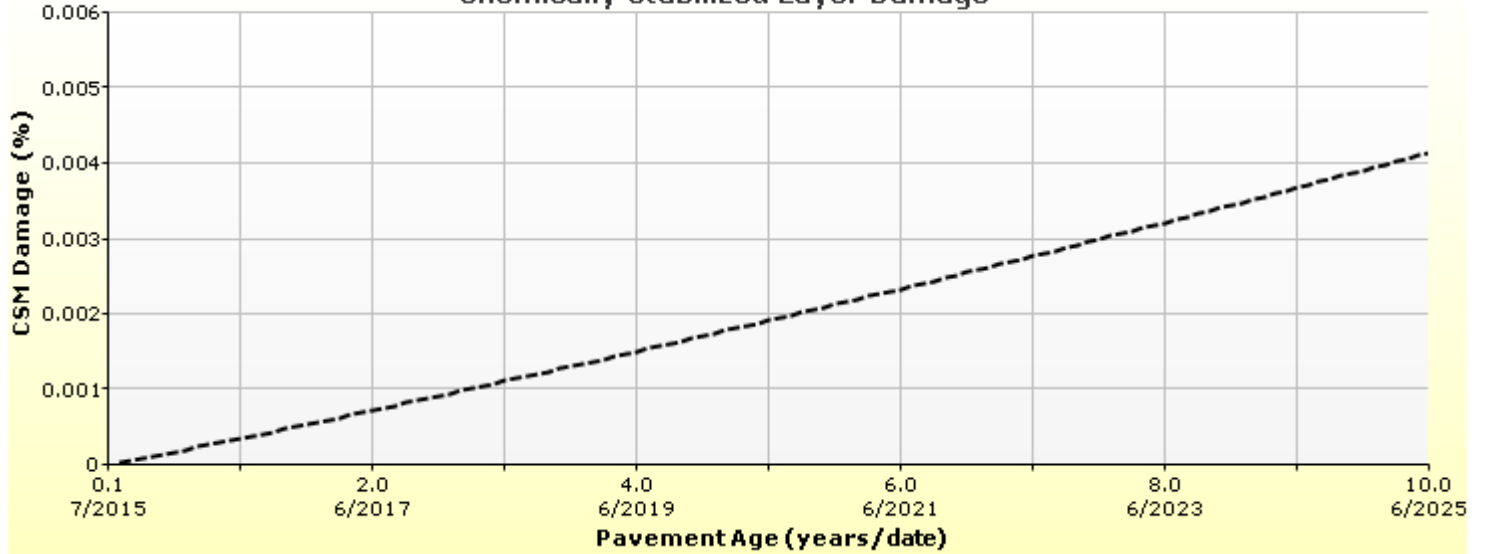


Thermal Cracking Depth

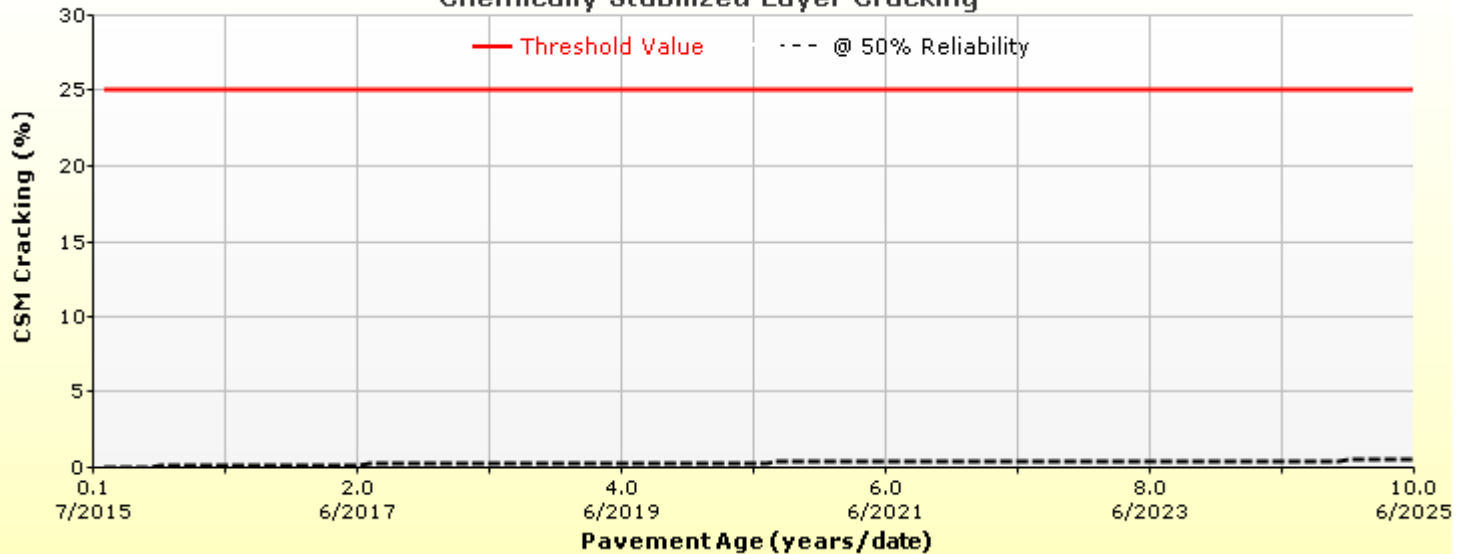




Chemically Stabilized Layer Damage



Chemically Stabilized Layer Cracking



Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 Chemically Stabilized : Cement stabilized

Chemically Stabilized

Layer thickness (mm)	300
Poisson's ratio	0.2
Unit weight (kgf/m ³)	2400

Strength

Elastic/resilient modulus (MPa)	13790

Thermal

Heat capacity (joule/kg-kelvin)	1172.3
Thermal conductivity (watt/meter-kelvin)	2.16

Identifiers

Field	Value
Display name/identifier	Cement stabilized
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 3 Non-stabilized Base : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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() σ = standard deviation of the log of the depth of cracks in the pavments C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_s = Tensile stress(psi) M_r = modulus of rupture(psi)
k1: 1	k2: 1
Bc1: 1	Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015



Project1 - Novo ALF2_ALT4

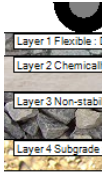
File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF2_ALT4.dgpx



Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data 32.119, -81.202
Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm):	Volumetric at Construction:	
Flexible	Default asphalt concrete	200.0	Effective binder content (%)	11.6
Cement_Base	Cement stabilized	300.0	Air voids (%)	7.0
NonStabilized	Crushed stone	400.0		
Subgrade	A-1-a	Semi-infinite		

Traffic

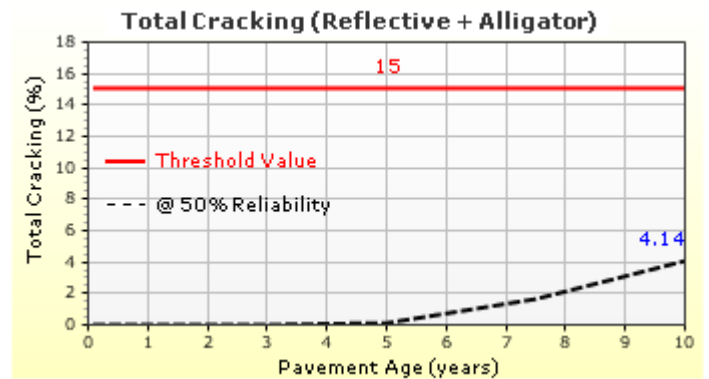
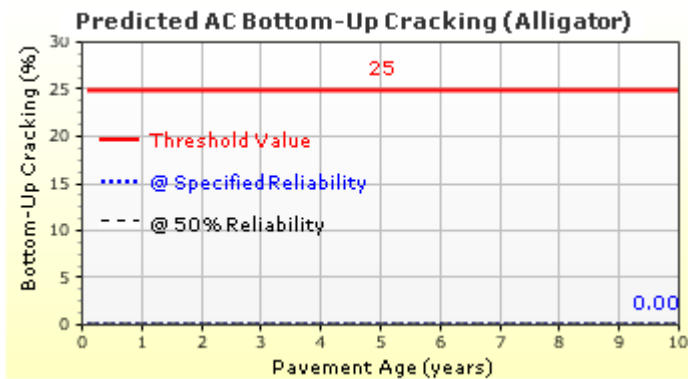
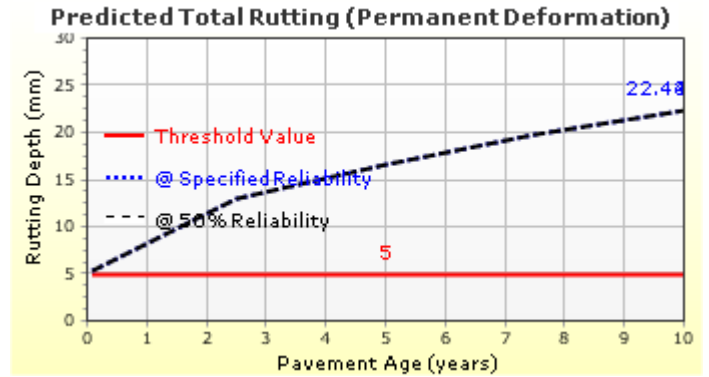
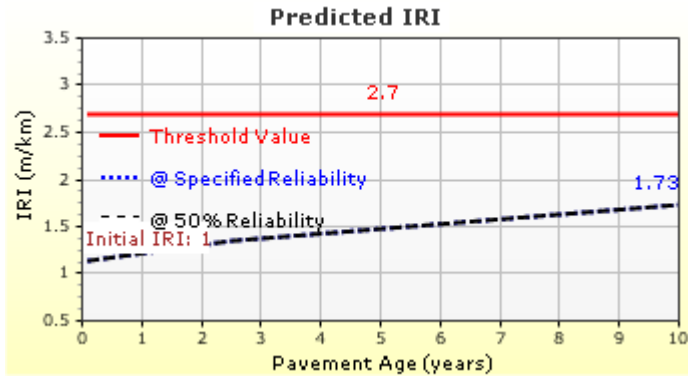
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.73	50.00	97.74	Pass
Permanent deformation - total pavement (mm)	5.00	22.44	50.00	0.03	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.00	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.14	-	-	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	744.32	50.00	20.91	Fail
Permanent deformation - AC only (mm)	5.00	19.61	50.00	0.17	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.55	-	-	-

Distress Charts

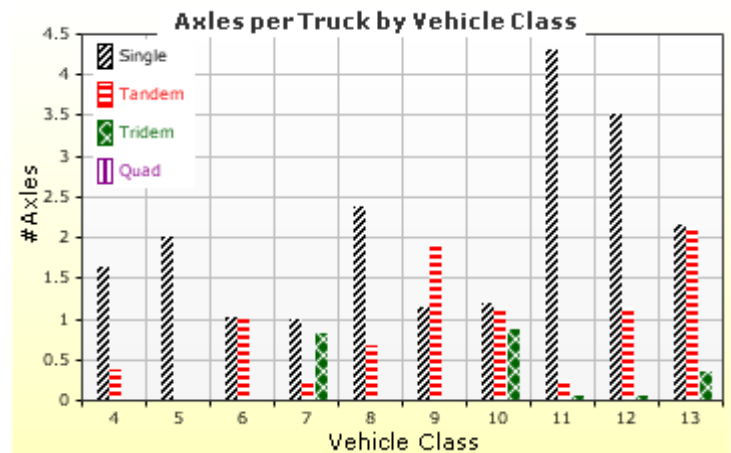
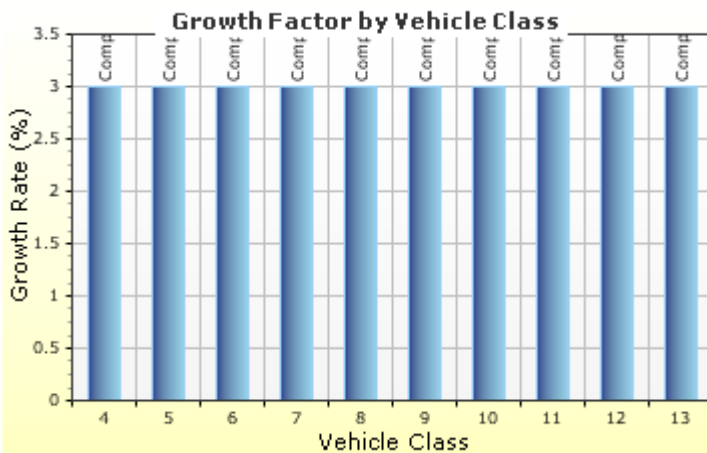
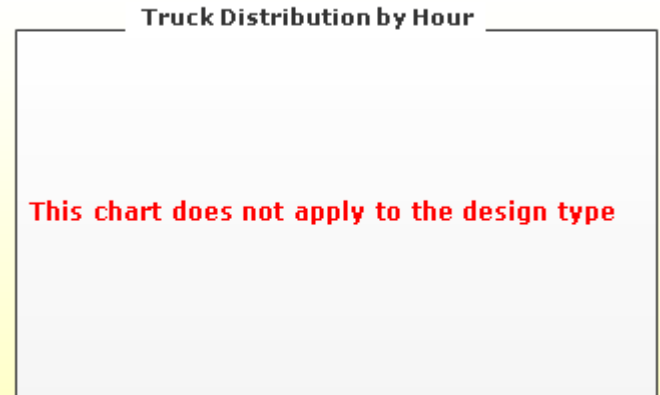
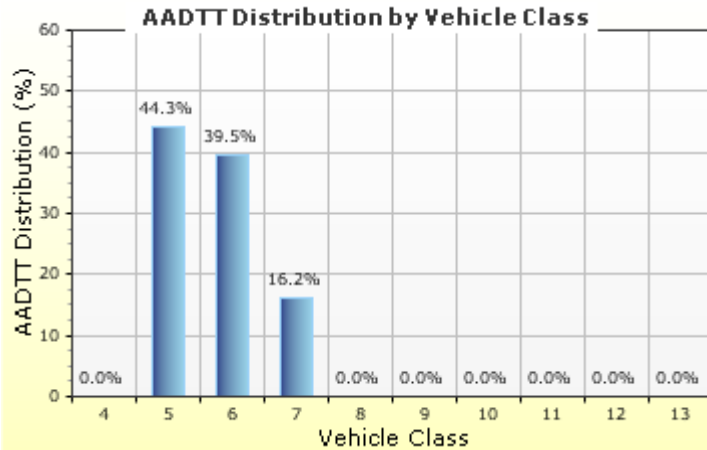


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

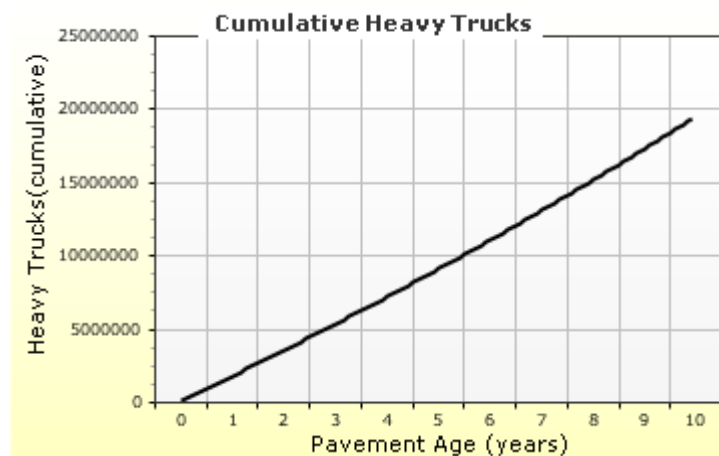
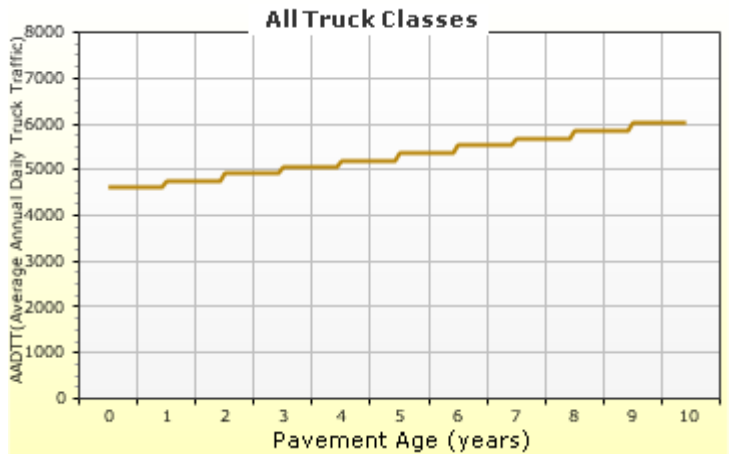
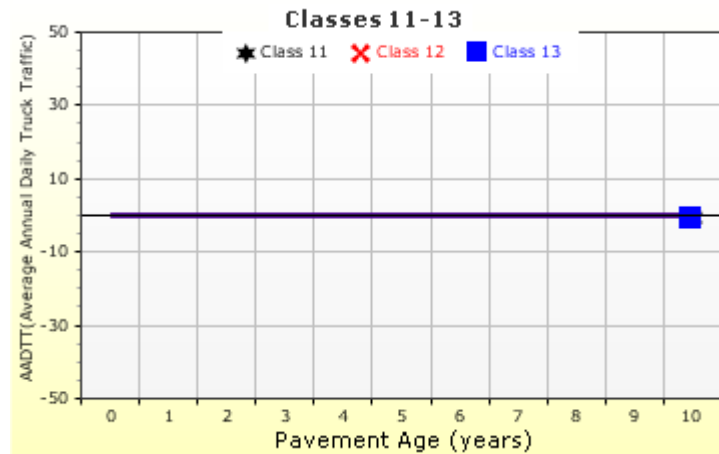
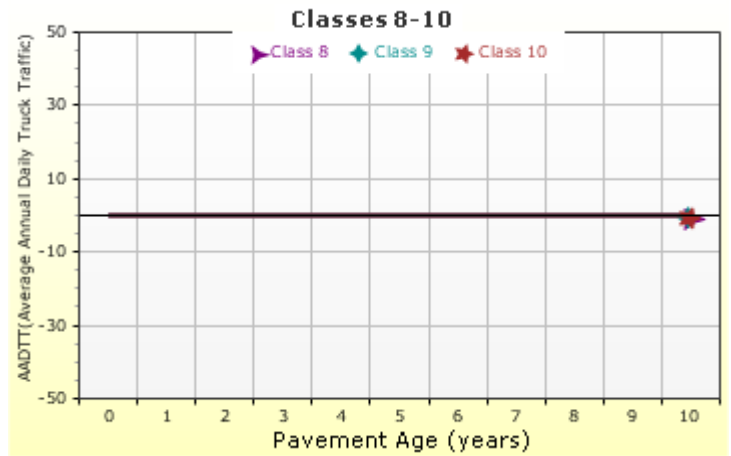
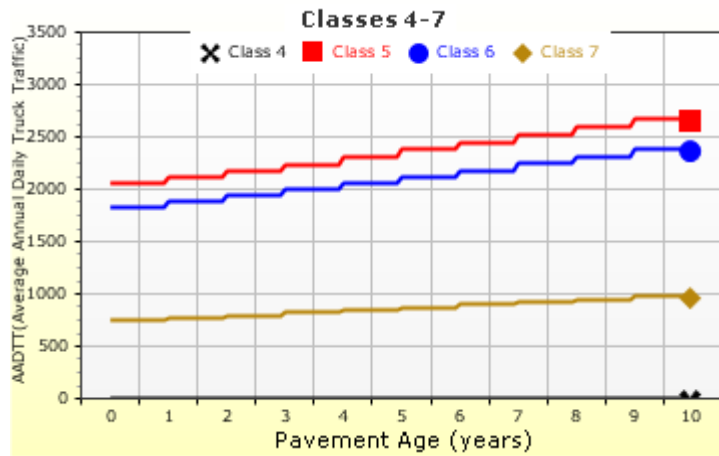
Wheelbase does not apply

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



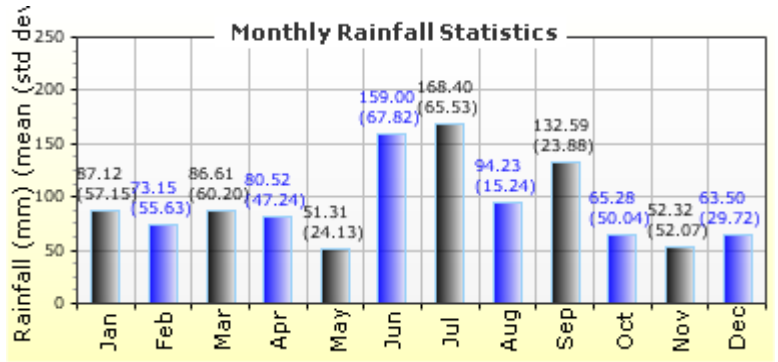
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

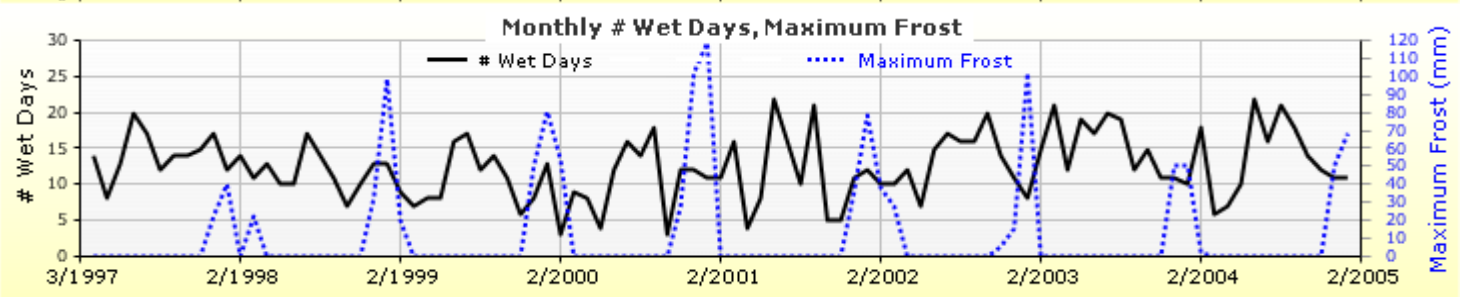
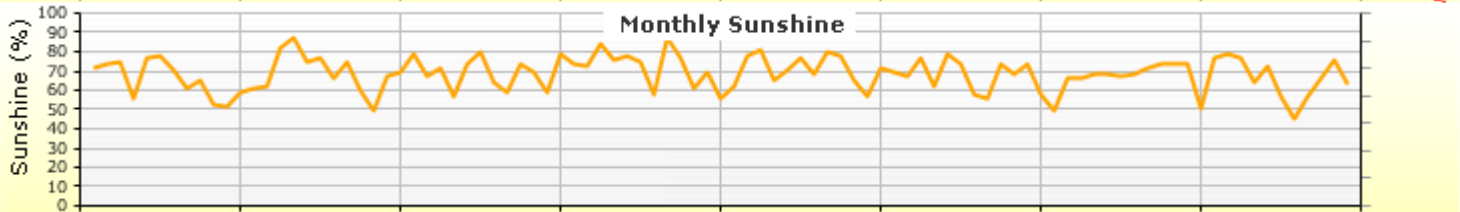
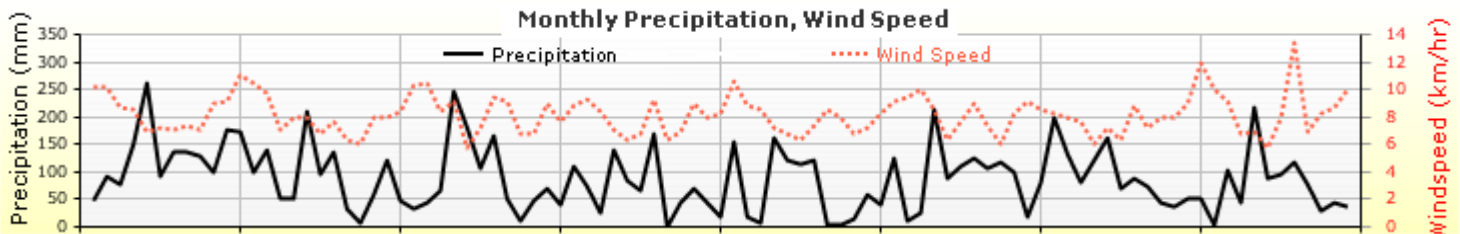
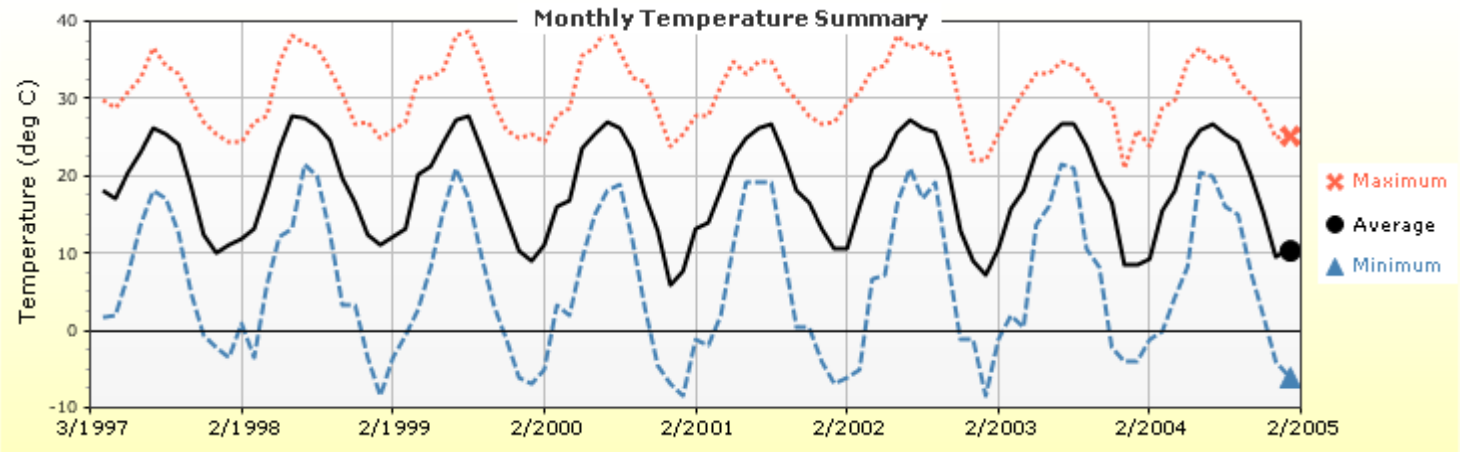
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

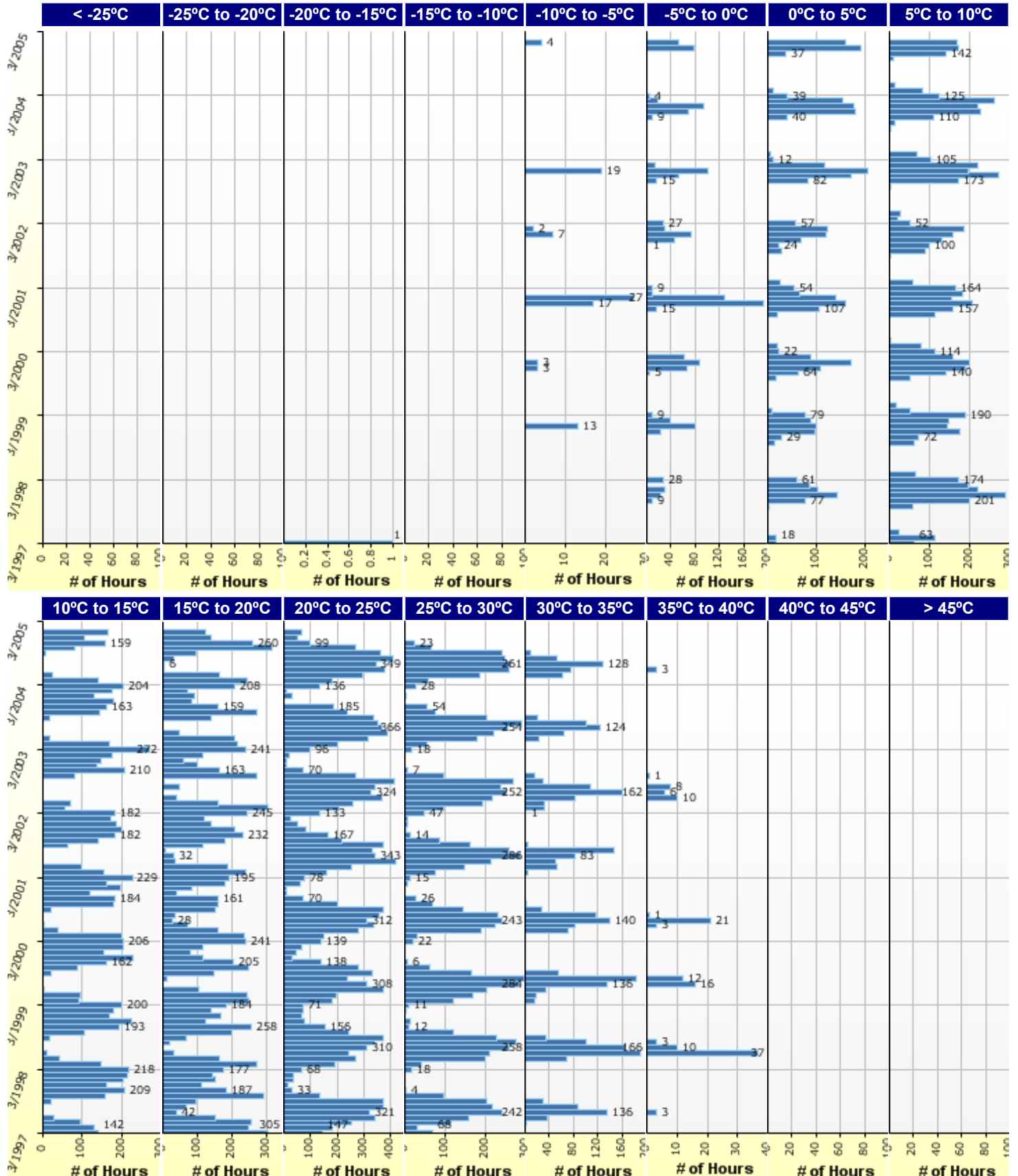


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF2_ALT4

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF2_ALT4.dgpx



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

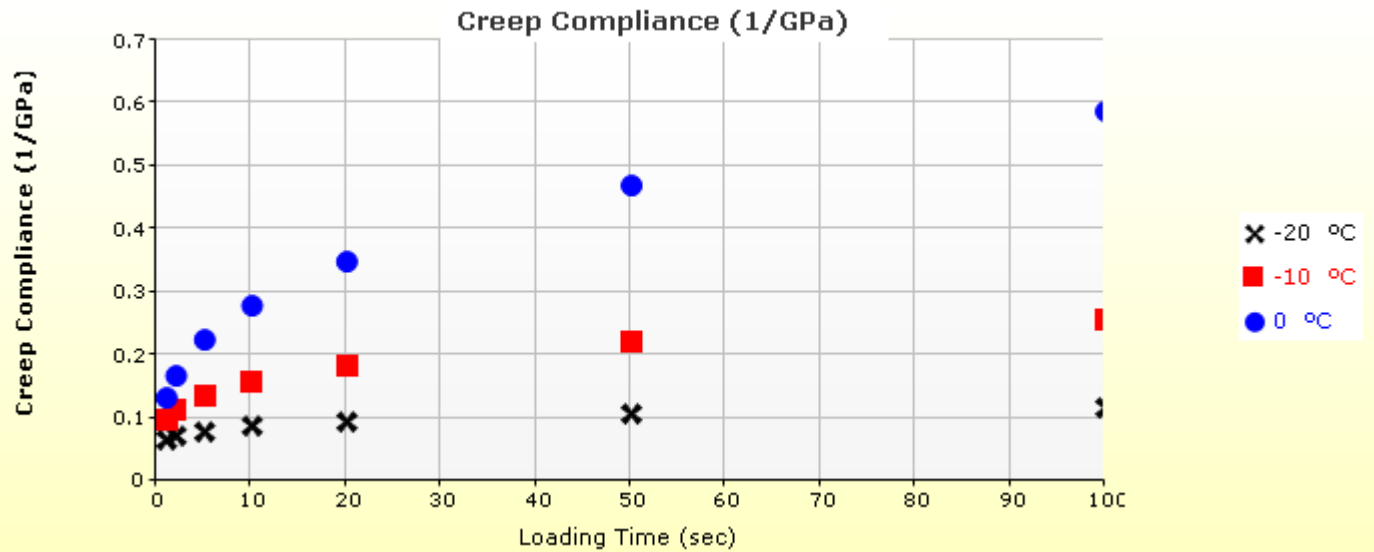
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Chemically Stabilized : Cement stabilized	Chemically Stabilized (2)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

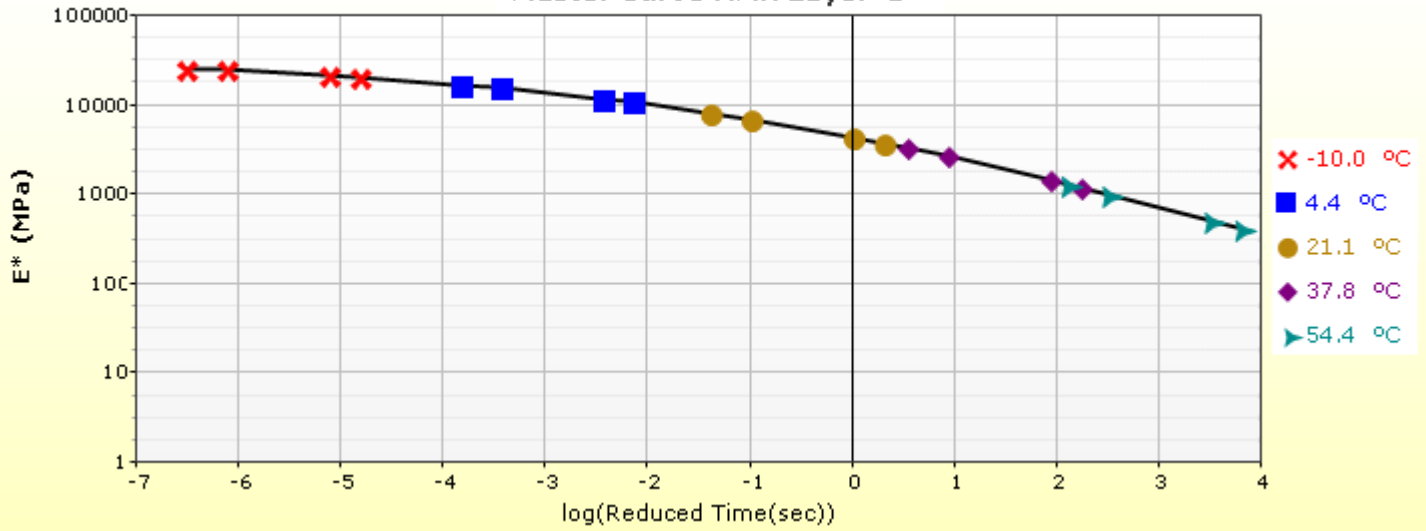
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

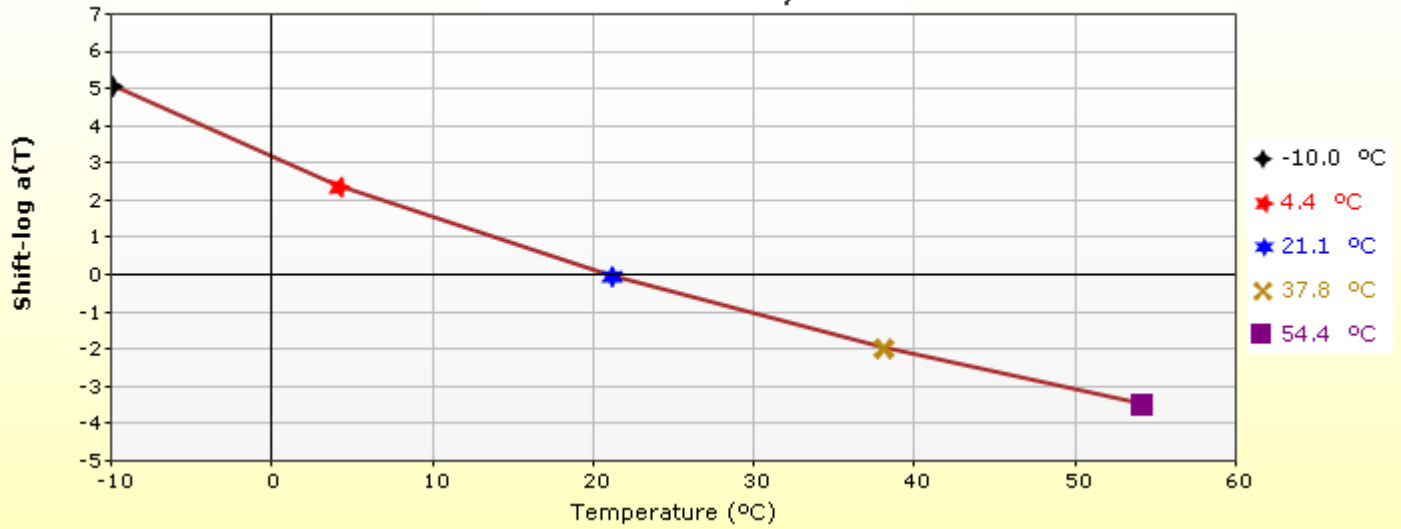


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

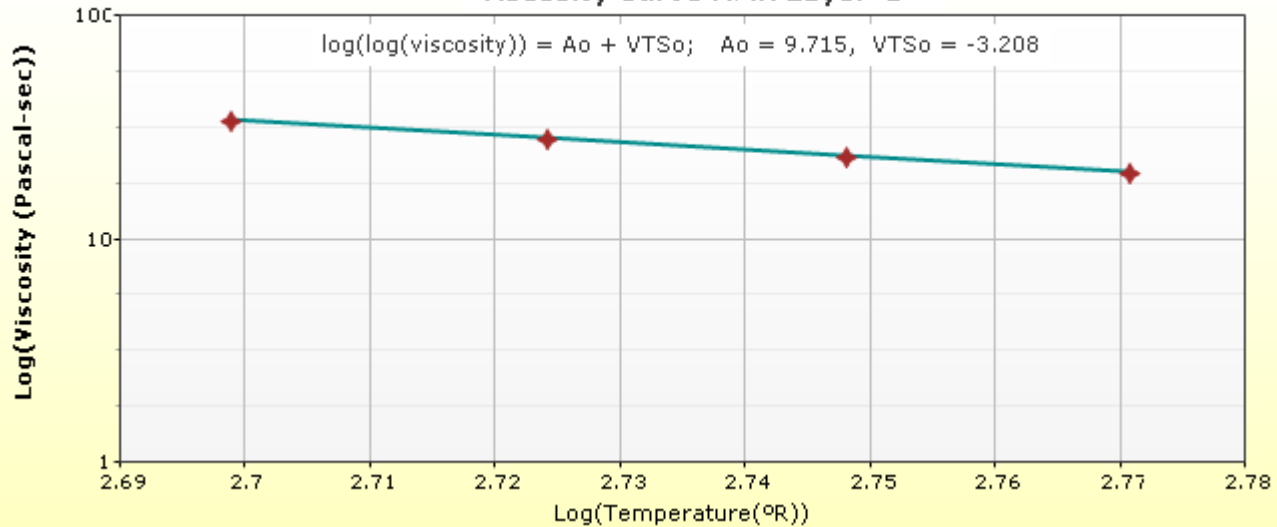
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

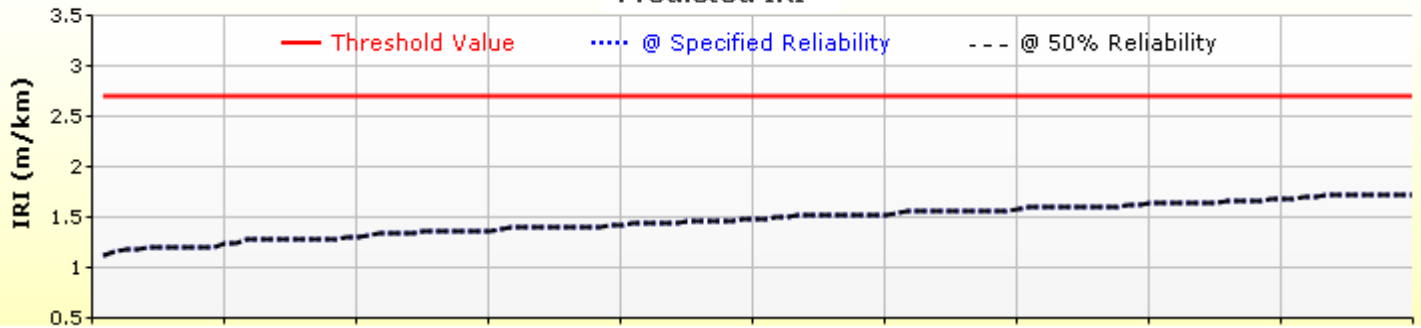


Viscosity Curve HMA Layer 1

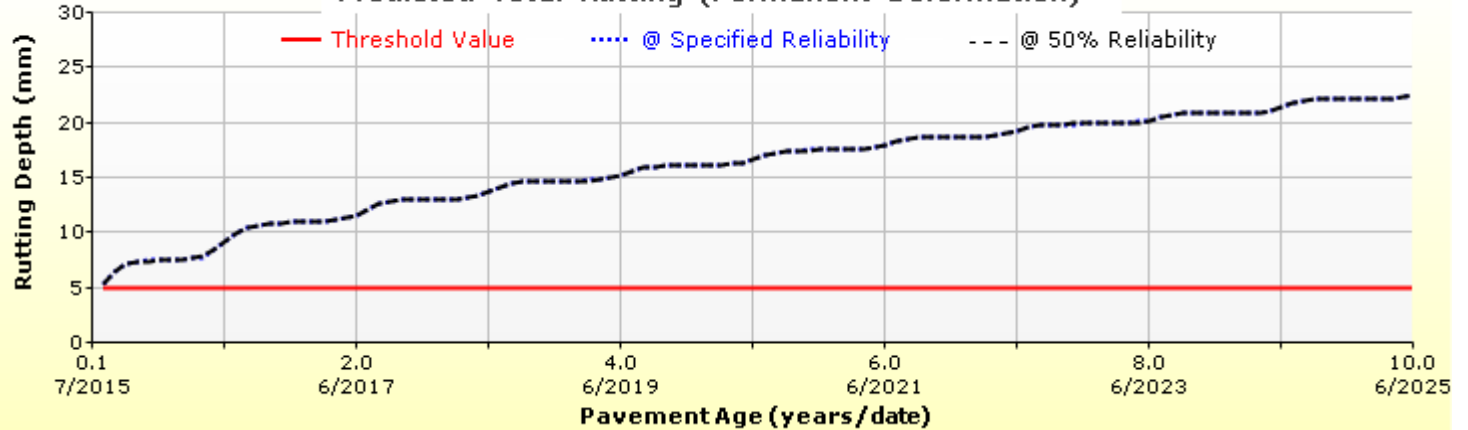


Analysis Output Charts

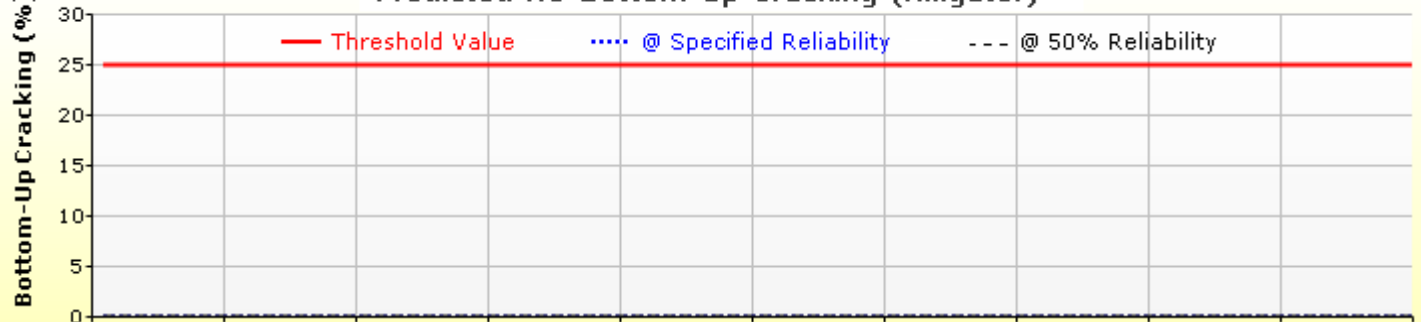
Predicted IRI



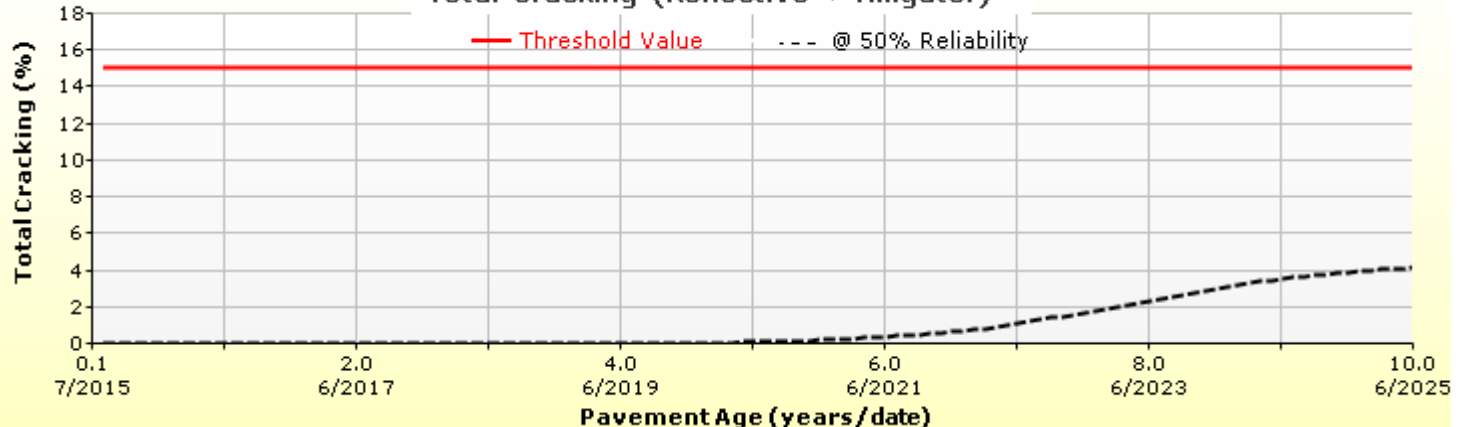
Predicted Total Rutting (Permanent Deformation)

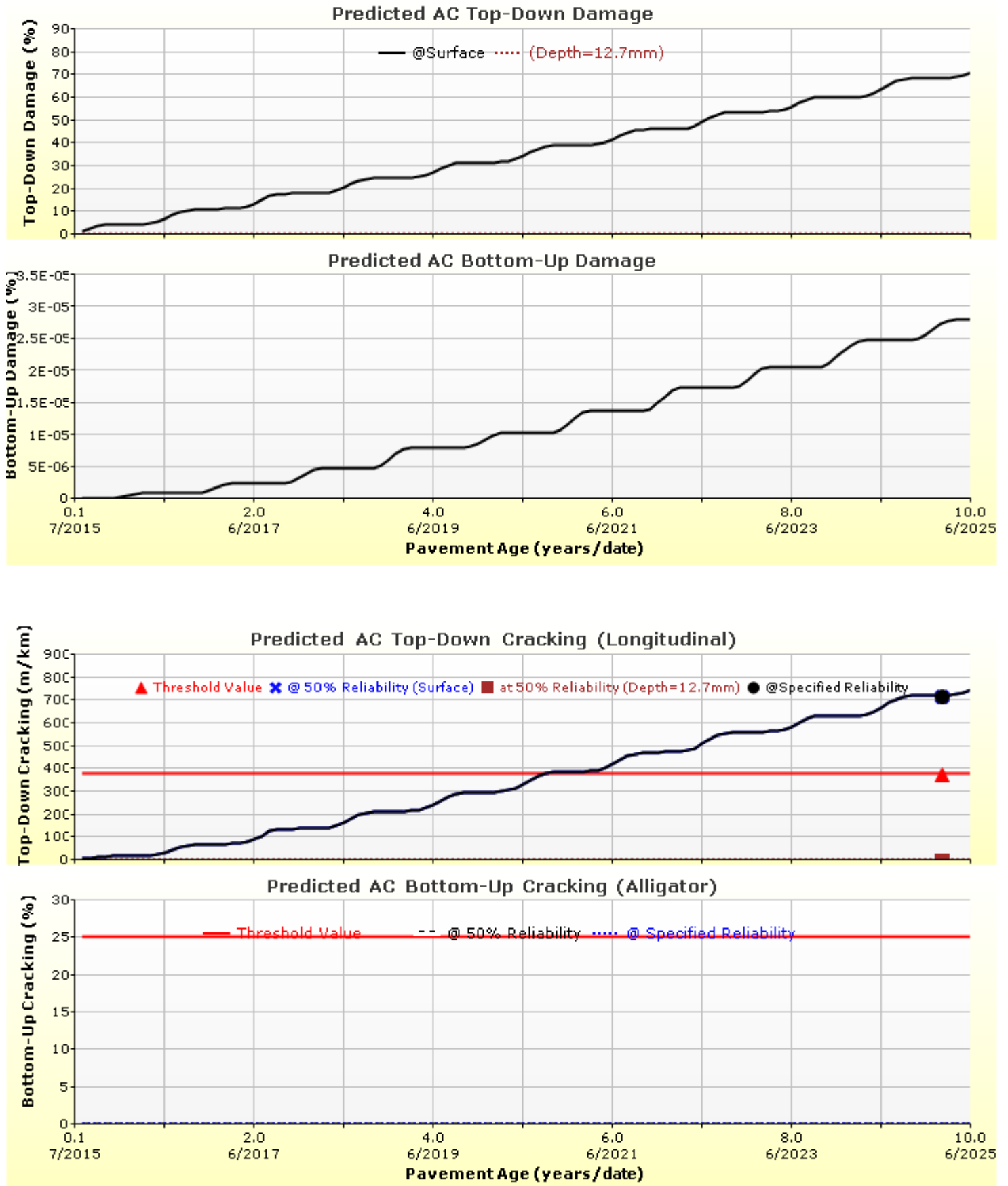


Predicted AC Bottom-Up Cracking (Alligator)

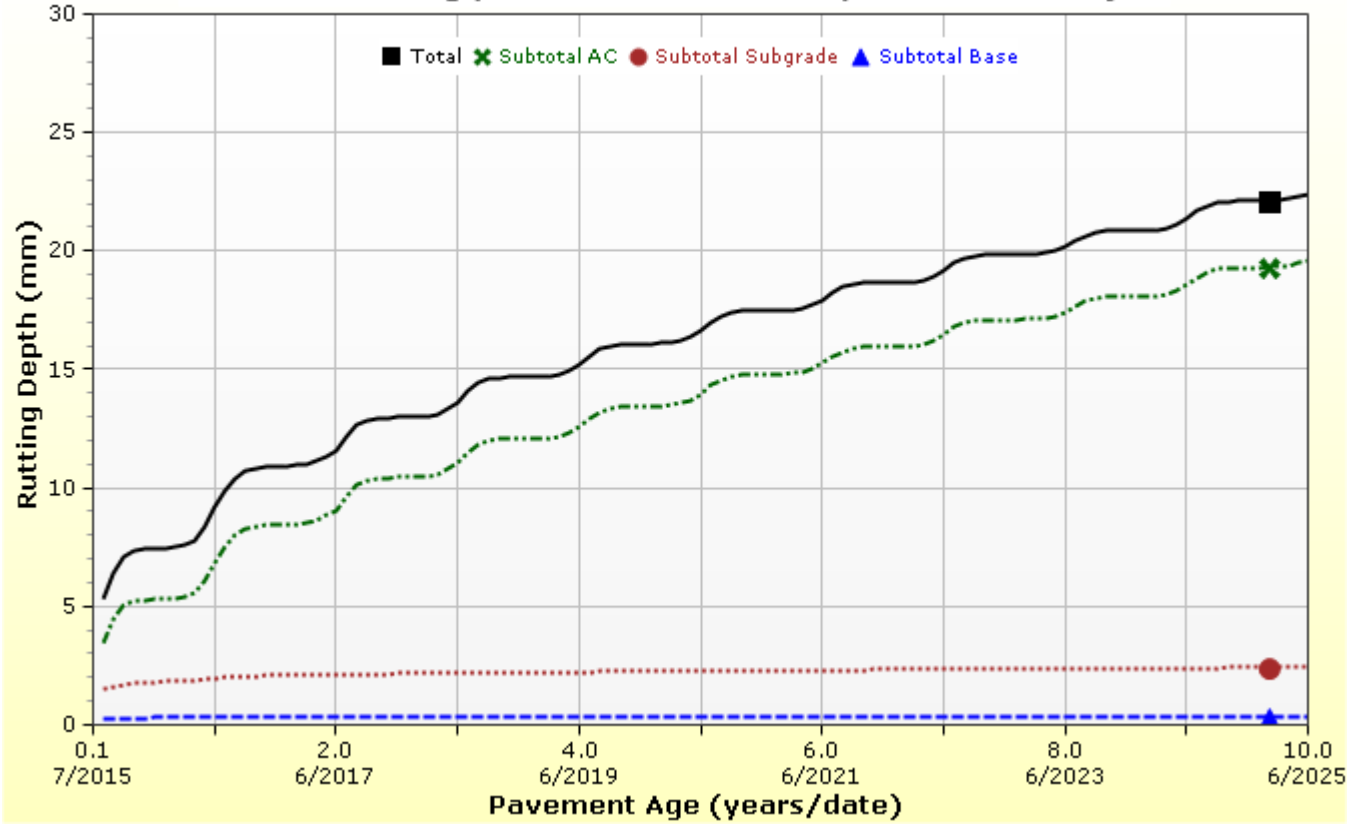


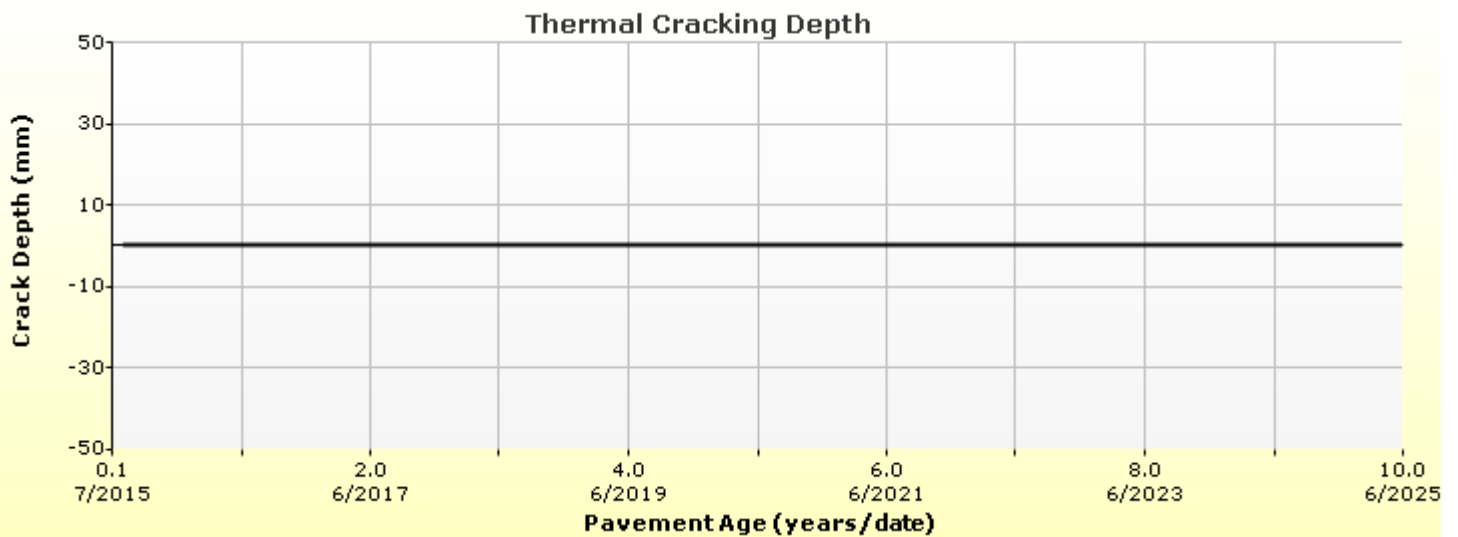
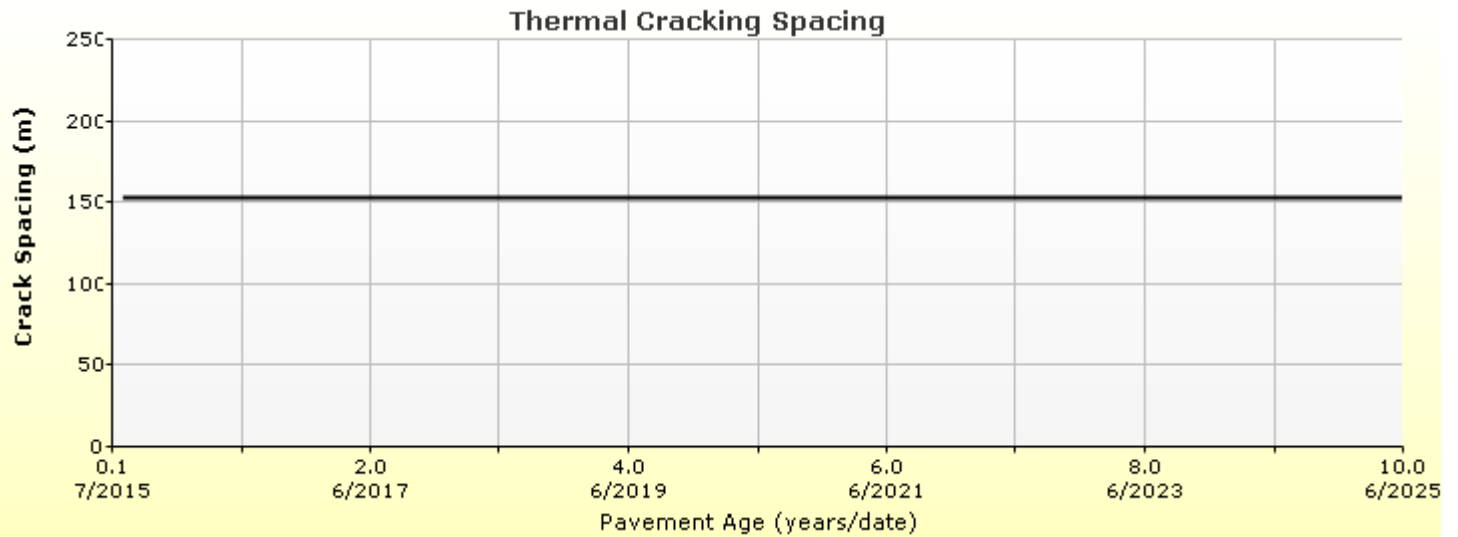
Total Cracking (Reflective + Alligator)

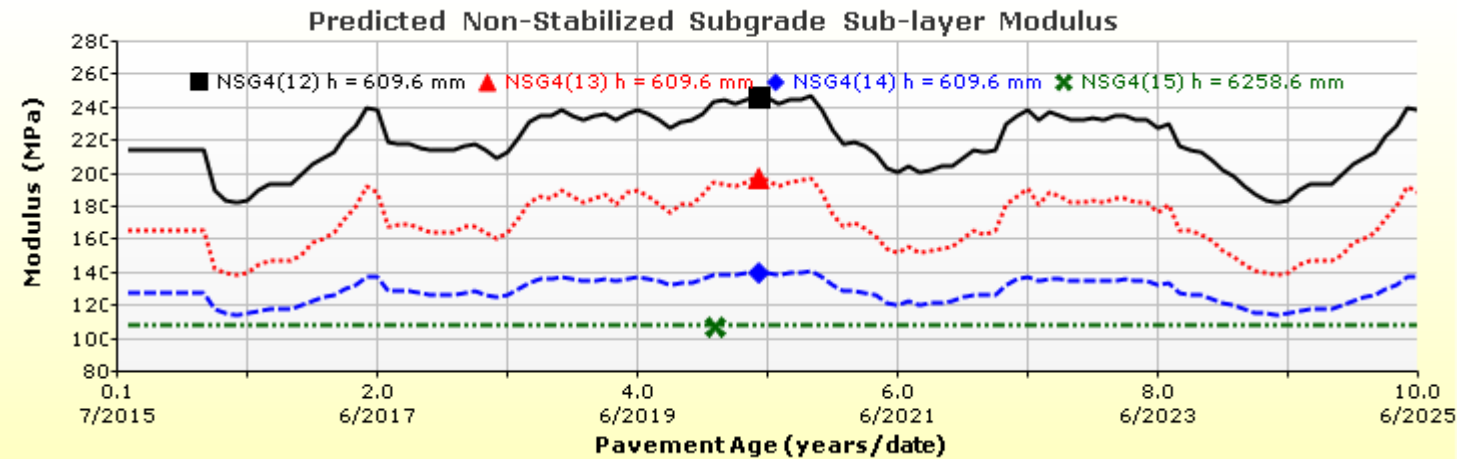
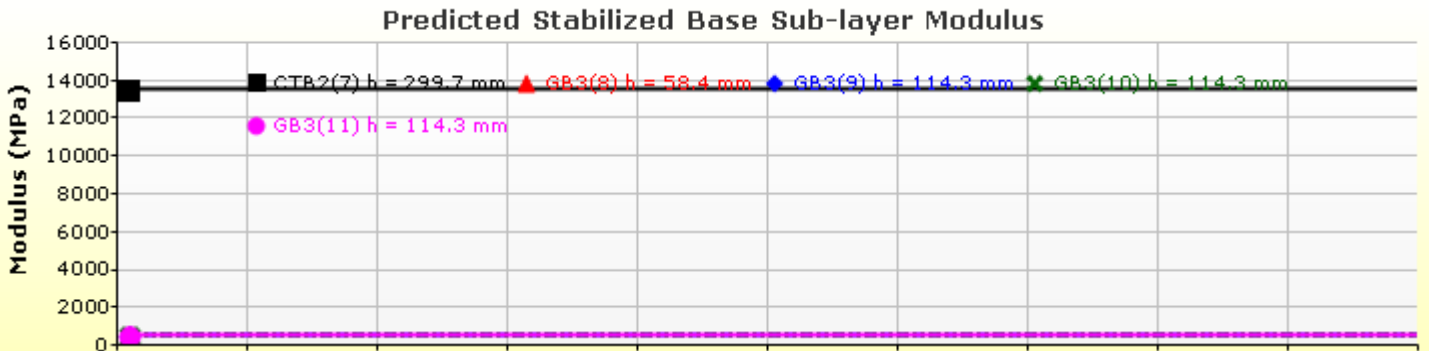
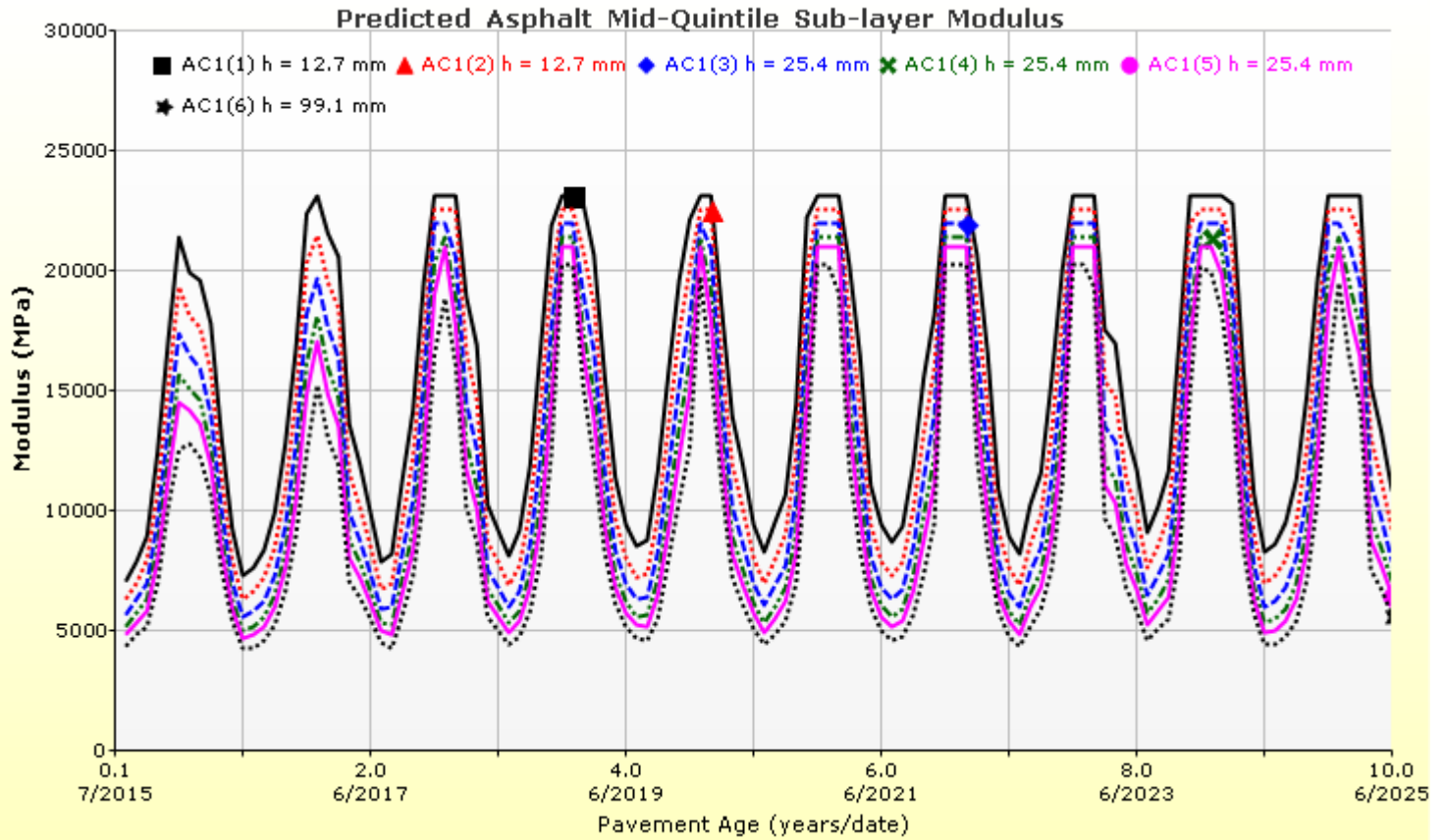




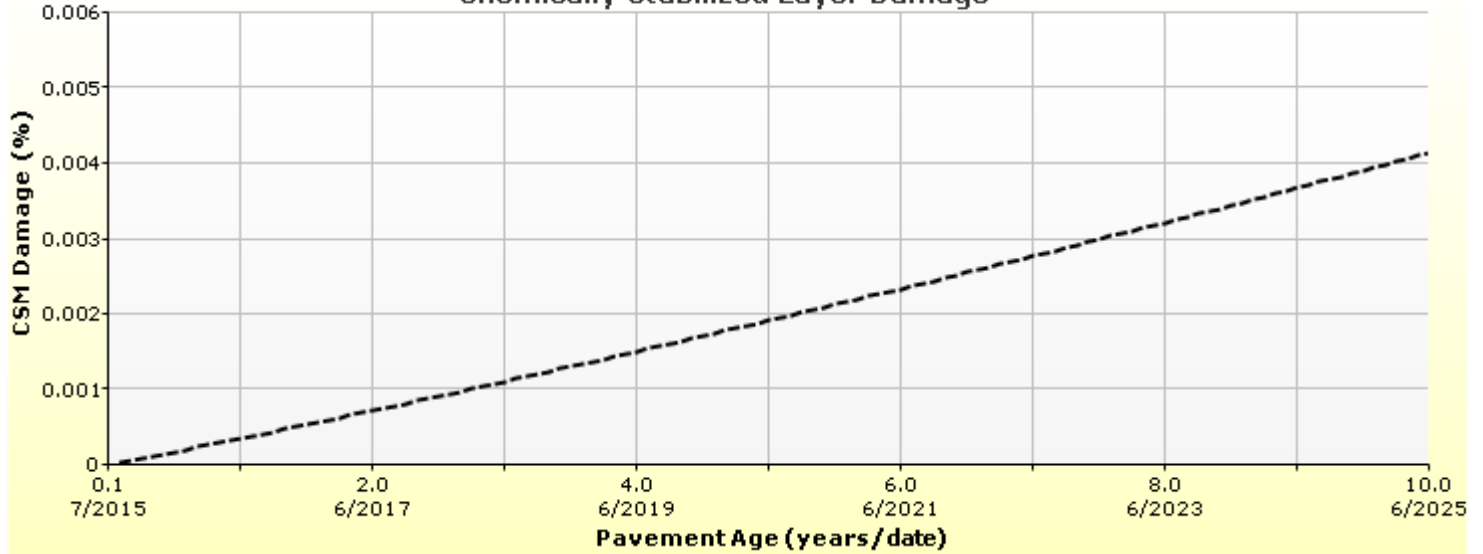
Predicted Rutting (Permanent Deformation) at 50% Reliability



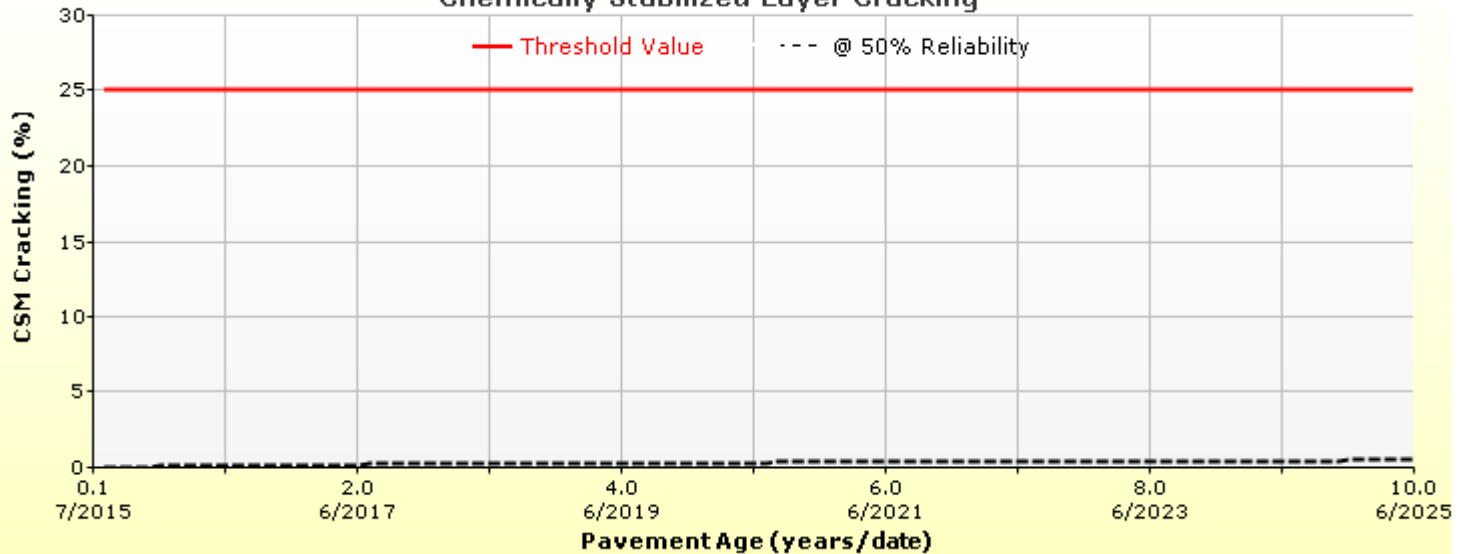




Chemically Stabilized Layer Damage



Chemically Stabilized Layer Cracking



Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 Chemically Stabilized : Cement stabilized

Chemically Stabilized

Layer thickness (mm)	300
Poisson's ratio	0.2
Unit weight (kgf/m ³)	2400

Strength

Elastic/resilient modulus (MPa)	13790

Thermal

Heat capacity (joule/kg-kelvin)	1172.3
Thermal conductivity (watt/meter-kelvin)	2.16

Identifiers

Field	Value
Display name/identifier	Cement stabilized
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 3 Non-stabilized Base : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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 = regression coefficient determined through field calibration $N()$ = standard normal distribution evaluated at() σ = standard deviation of the log of the depth of cracks in the pavements C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_s = Tensile stress(psi) M_r = modulus of rupture(psi)
k1: 1	k2: 1
Bc1: 1	Bc2: 1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

Standard Deviation (BASERUT)

0.1235*Pow(SUBRUT,0.5012)+0.001

AC Cracking

AC Top Down Cracking

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

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: 7

c2: 3.5

c3: 0

c4: 1000

c1: 1

c2: 1

c3: 6000

AC Cracking Top Standard Deviation

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

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

IRI Flexible Pavements

C1 - Rutting

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

CSM Standard Deviation

CTB*1



Project1 - Novo ALF3_ALT4

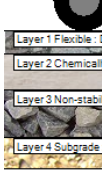
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Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data 32.119, -81.202
Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm):	Volumetric at Construction:	
Flexible	Default asphalt concrete	200.0	Effective binder content (%)	11.6
Cement_Base	Cement stabilized	300.0	Air voids (%)	7.0
NonStabilized	Crushed stone	400.0		
Subgrade	A-1-a	Semi-infinite		

Traffic

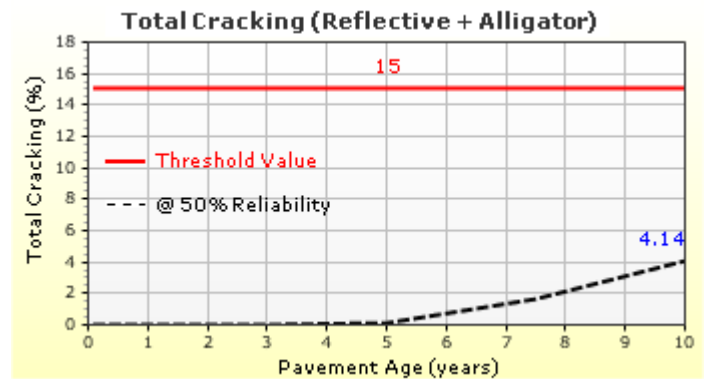
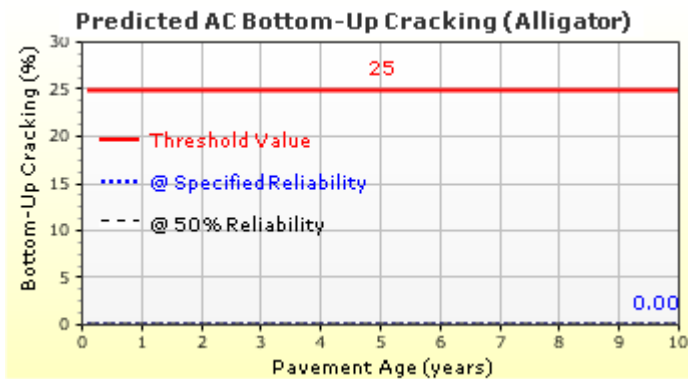
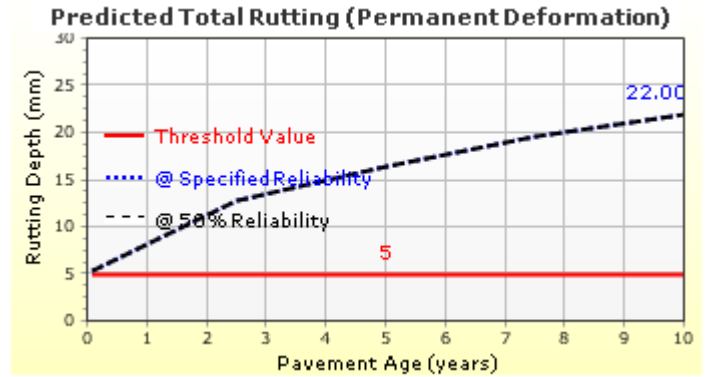
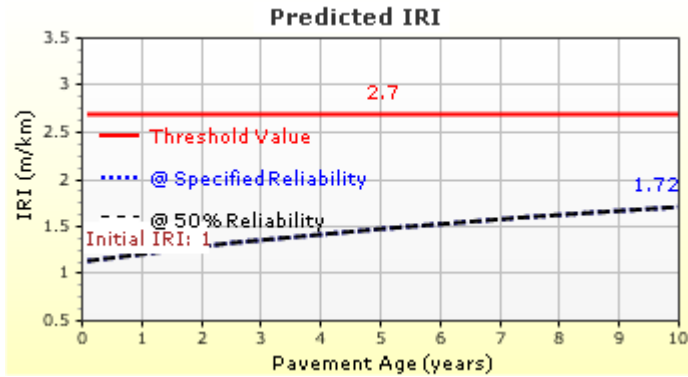
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.72	50.00	97.88	Pass
Permanent deformation - total pavement (mm)	5.00	22.00	50.00	0.03	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.00	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.14	-	-	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	791.67	50.00	18.09	Fail
Permanent deformation - AC only (mm)	5.00	19.04	50.00	0.19	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.53	-	-	-

Distress Charts

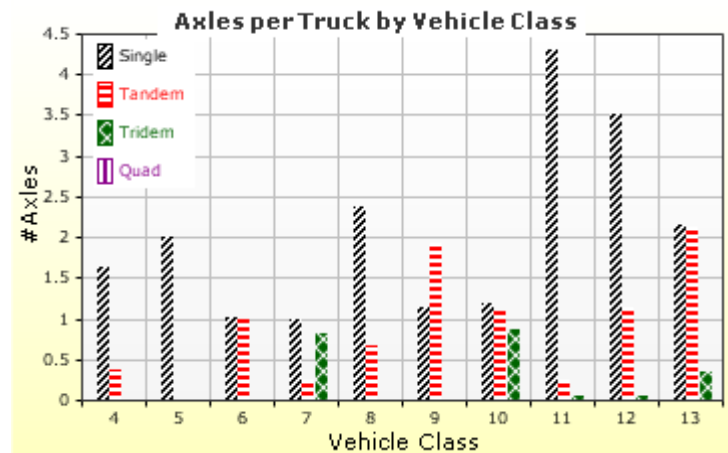
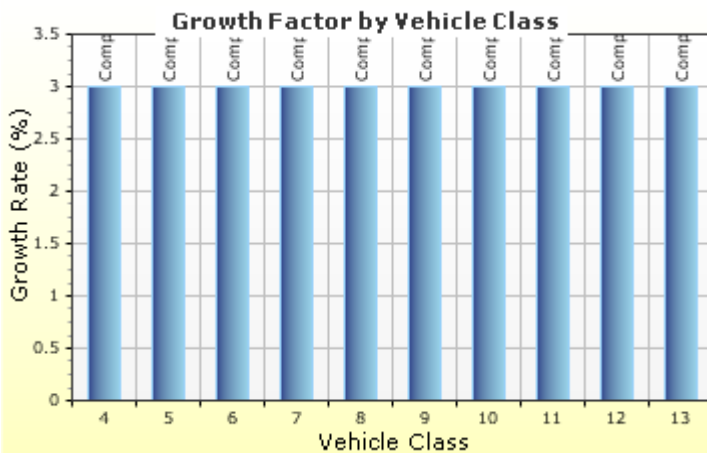
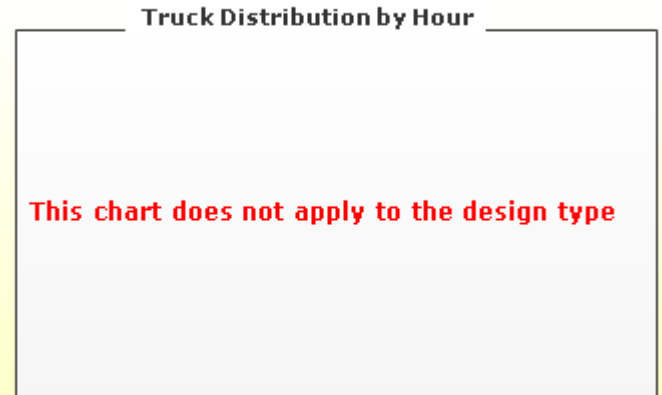
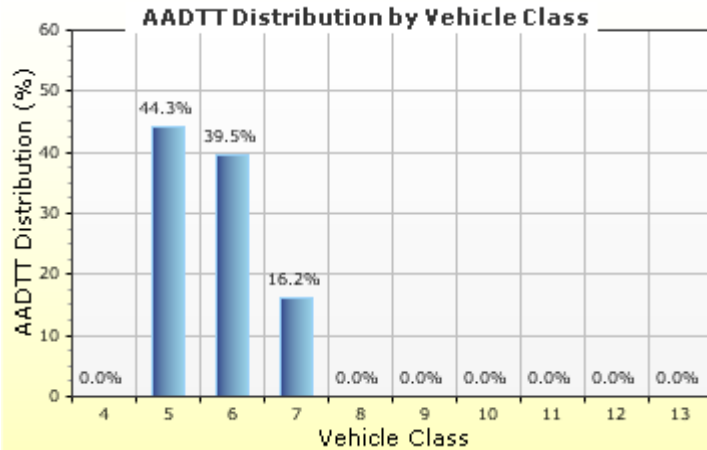


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

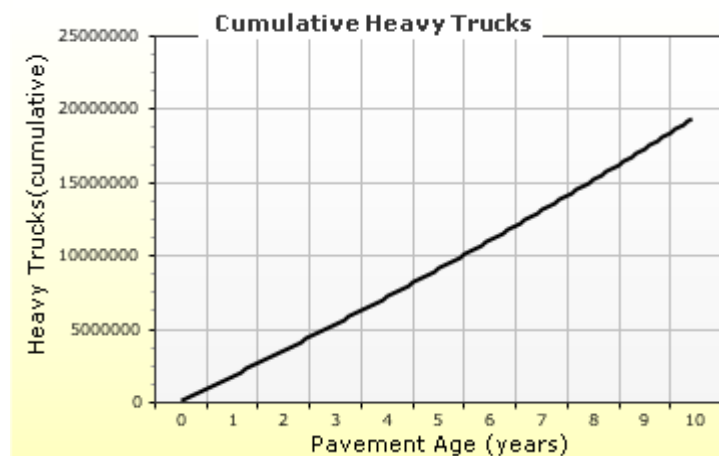
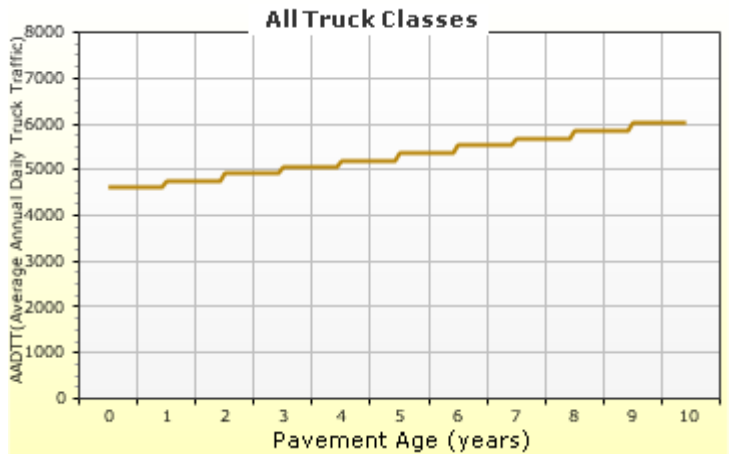
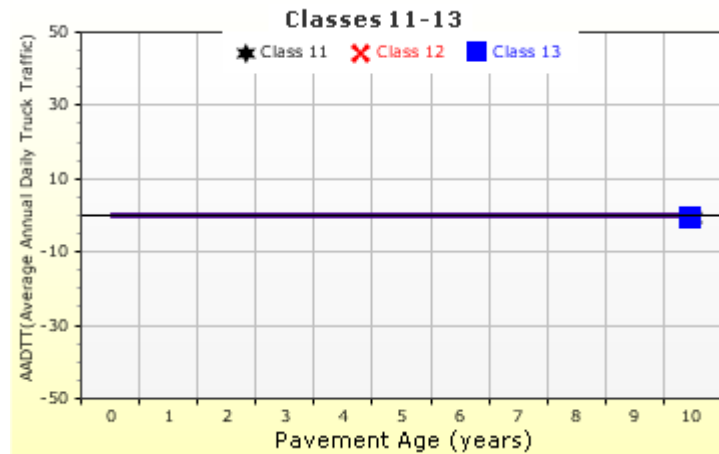
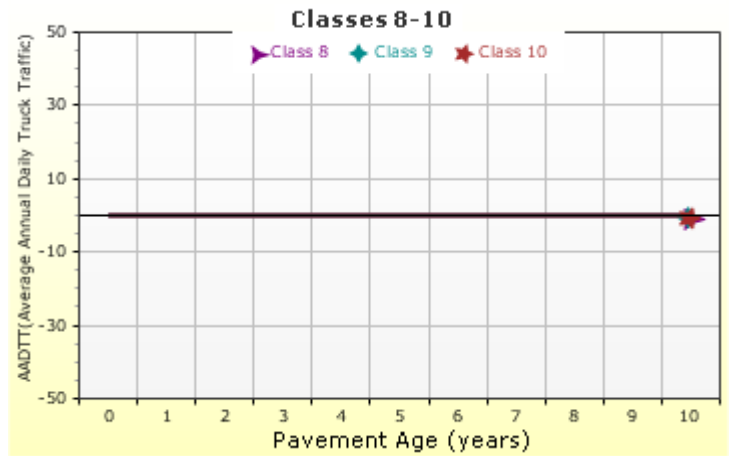
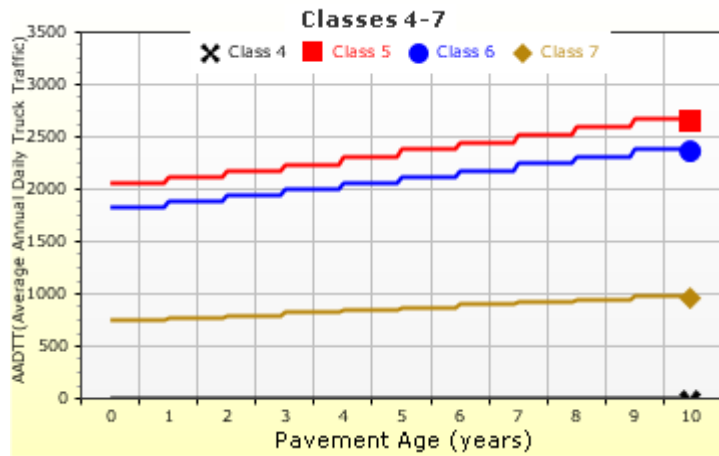
Wheelbase does not apply

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



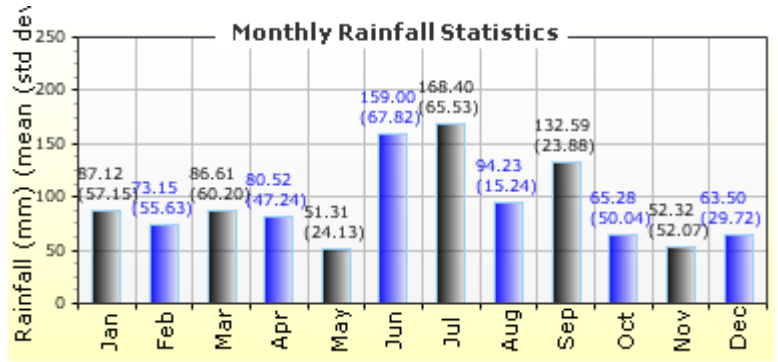
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

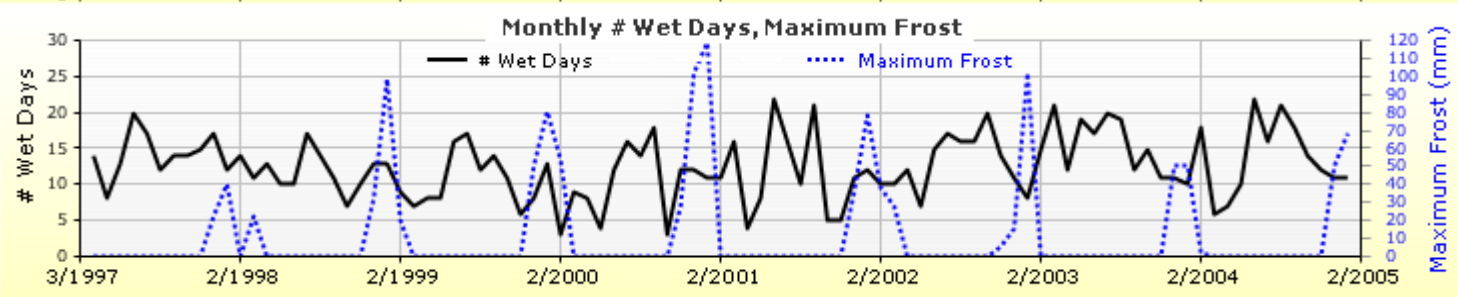
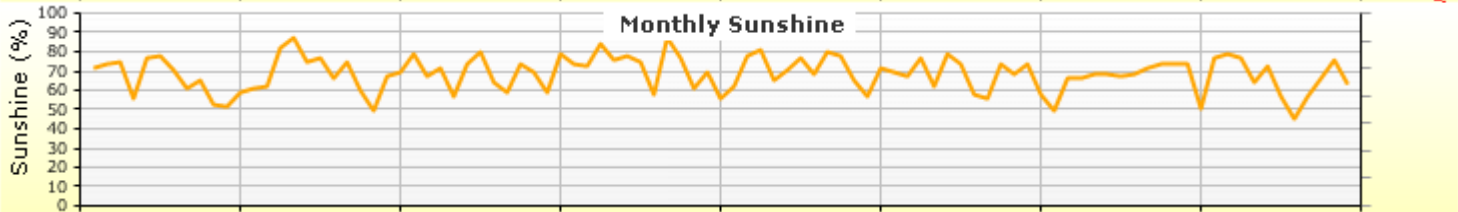
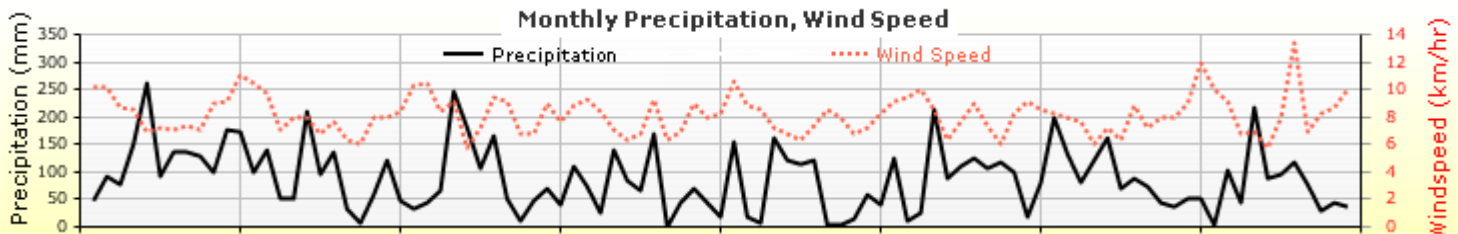
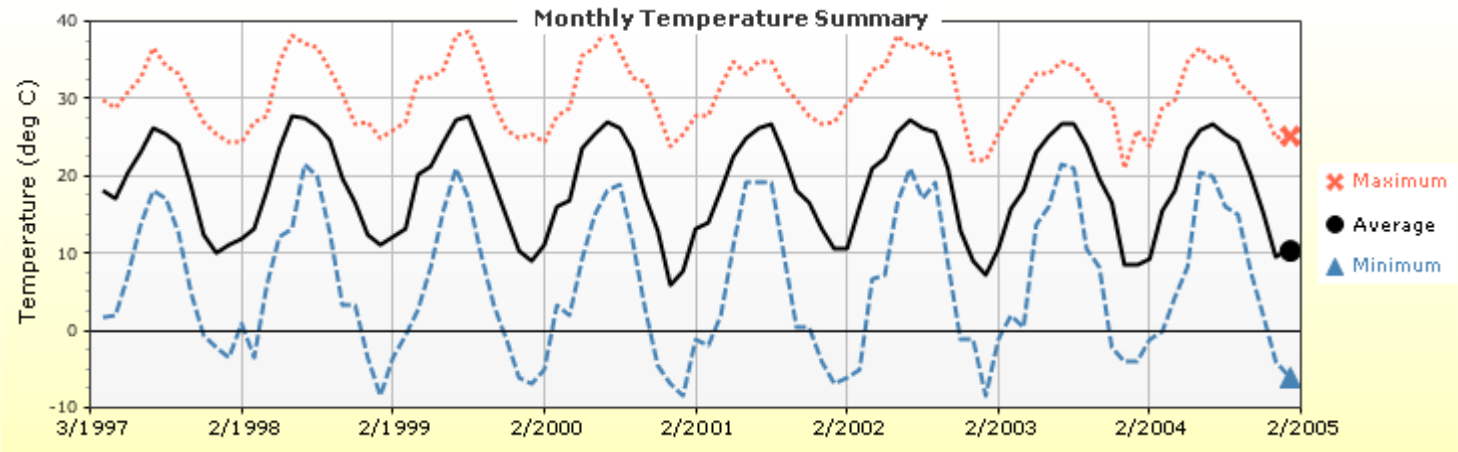
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

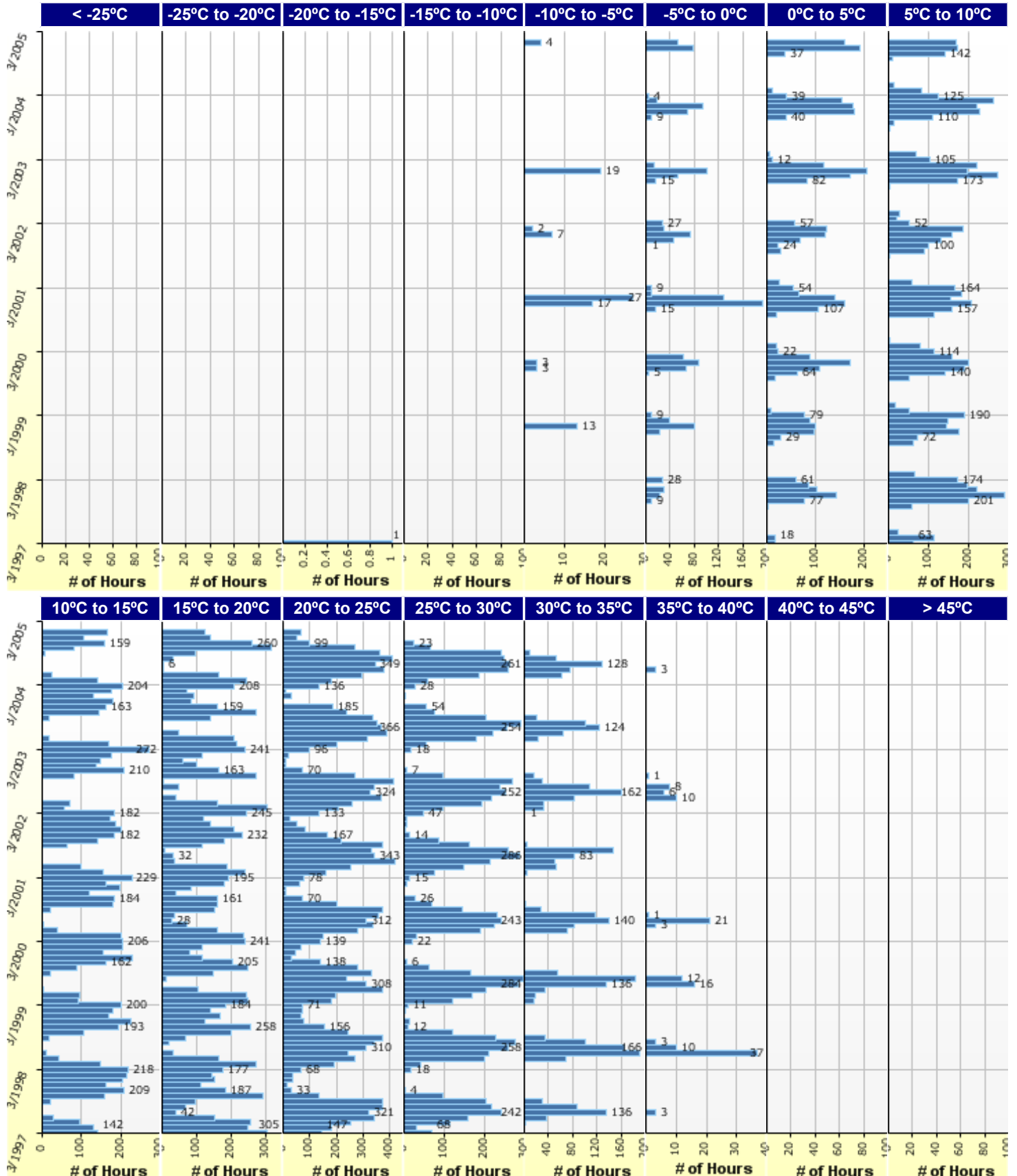


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF3_ALT4

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF3_ALT4.dgpx



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

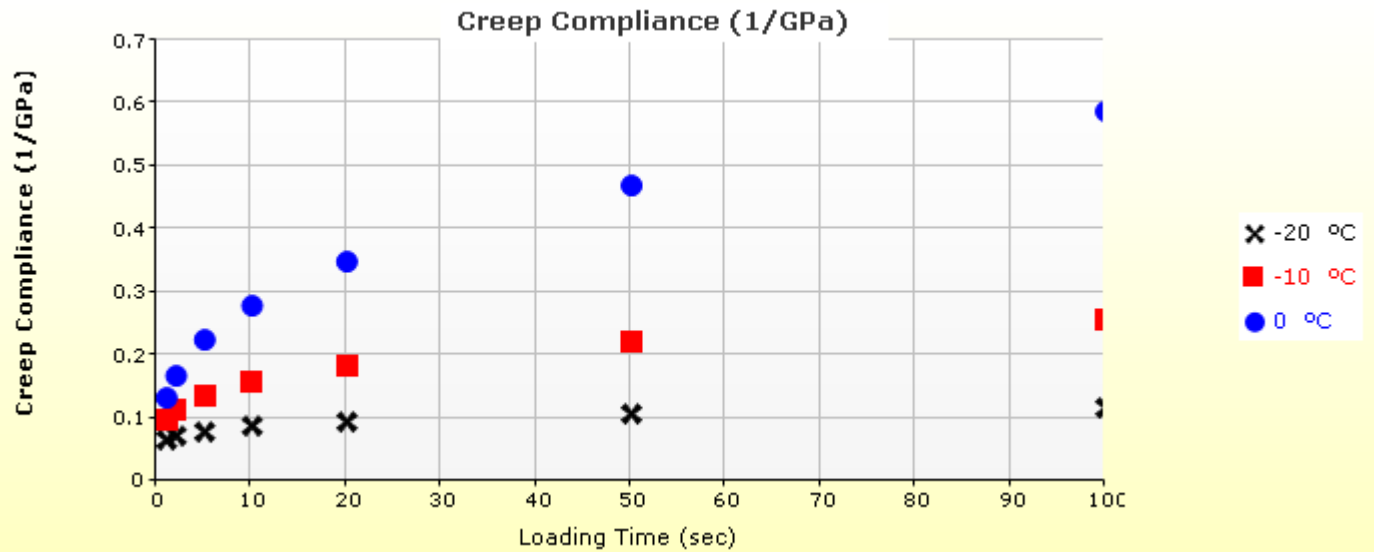
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Chemically Stabilized : Cement stabilized	Chemically Stabilized (2)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

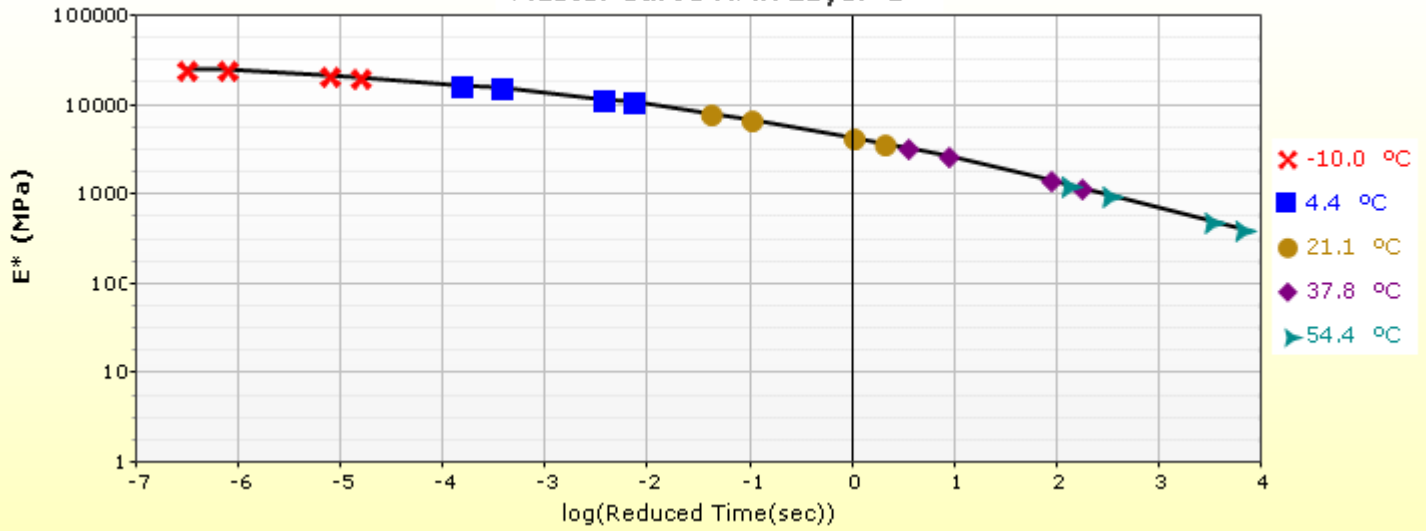
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

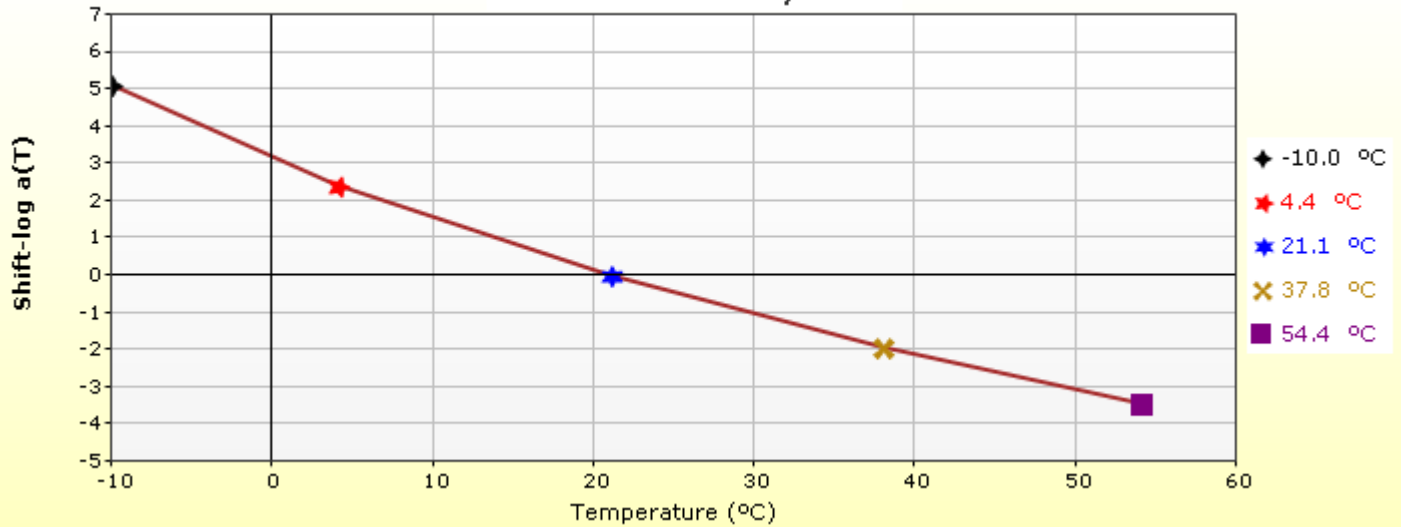


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

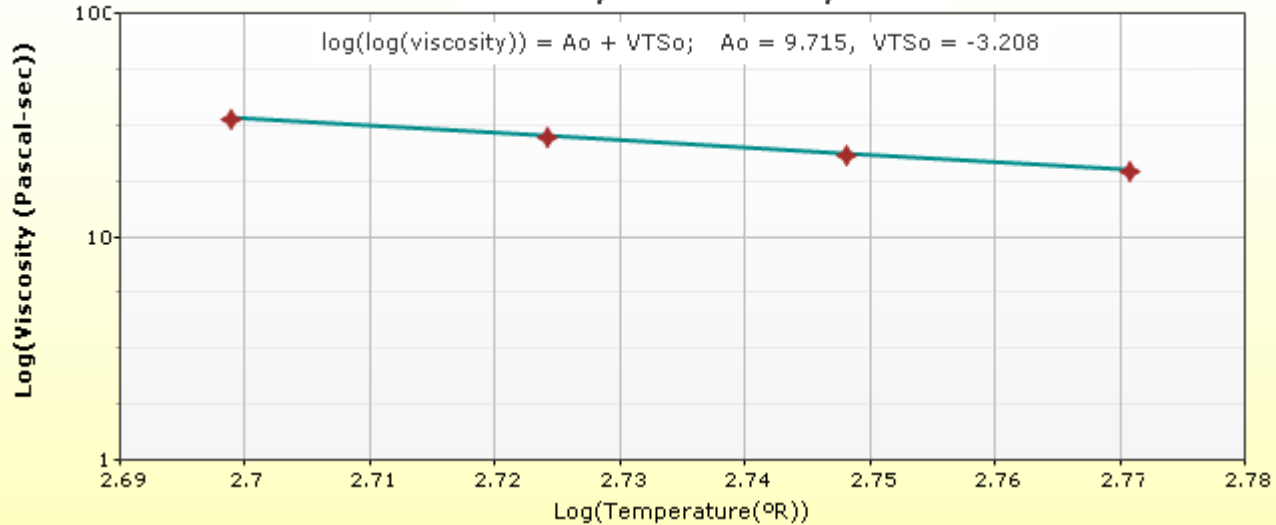
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

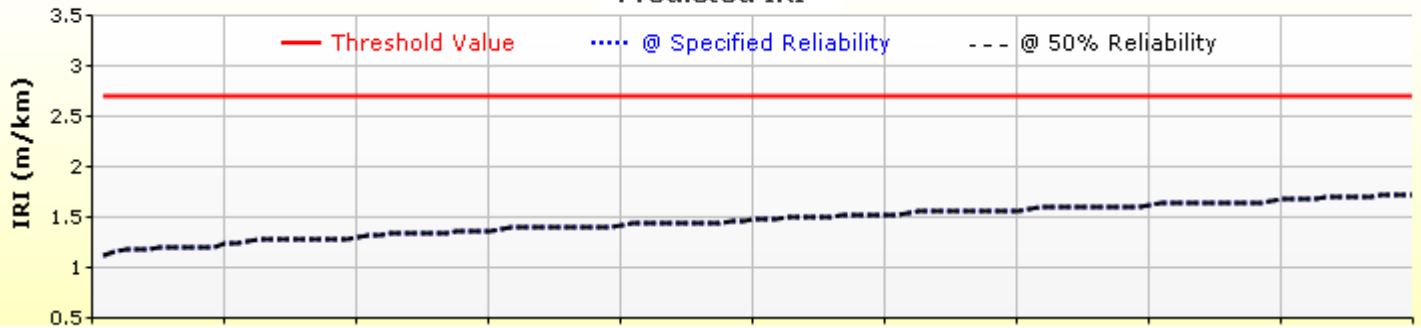


Viscosity Curve HMA Layer 1

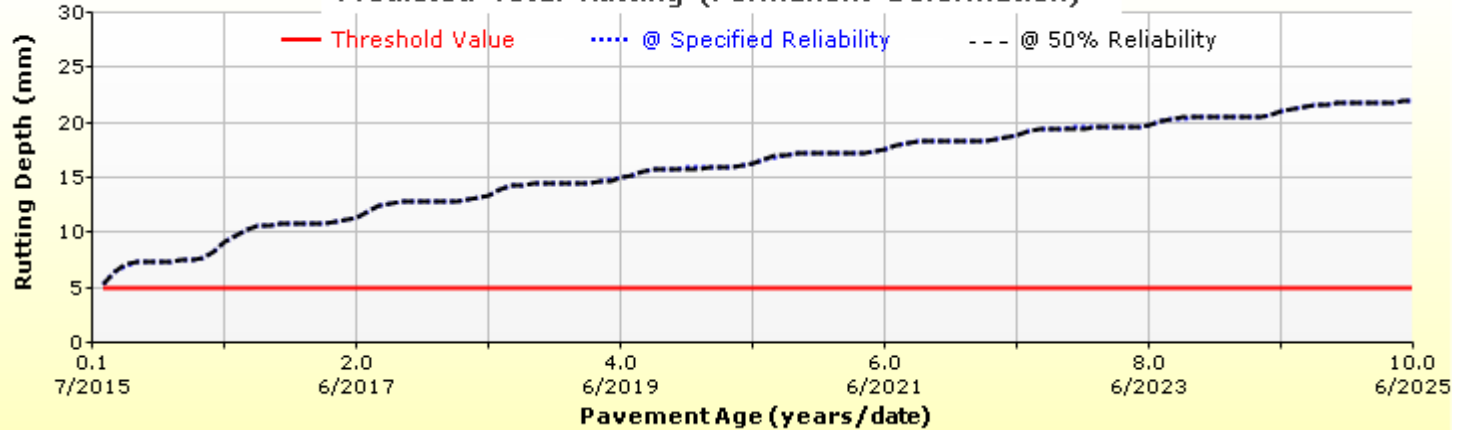


Analysis Output Charts

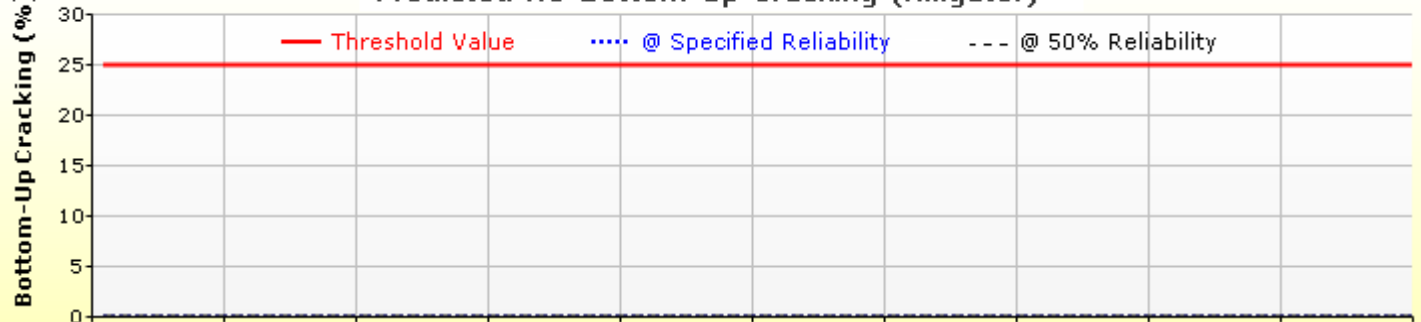
Predicted IRI



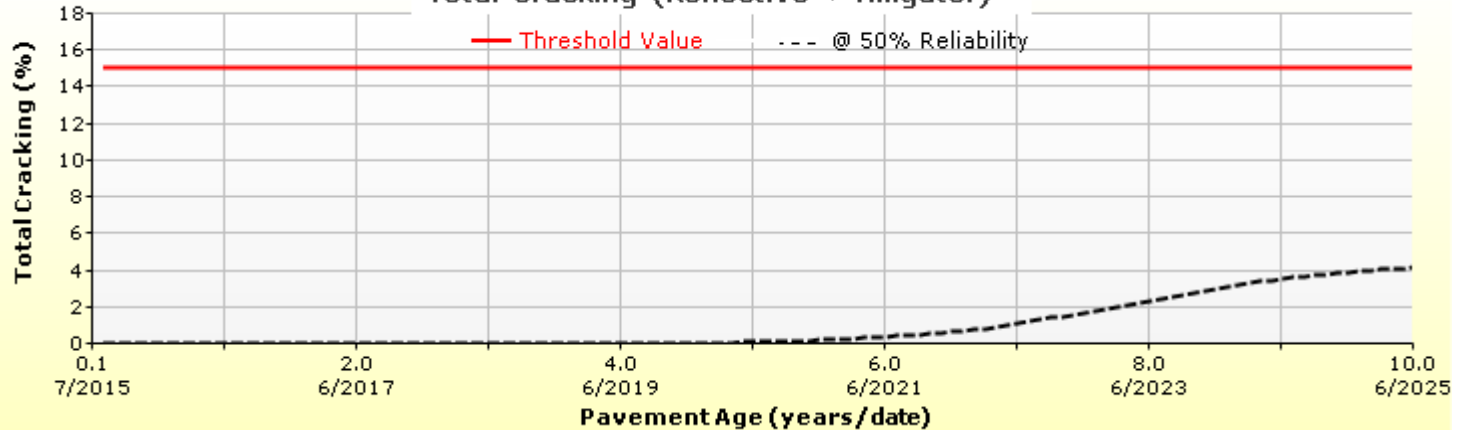
Predicted Total Rutting (Permanent Deformation)



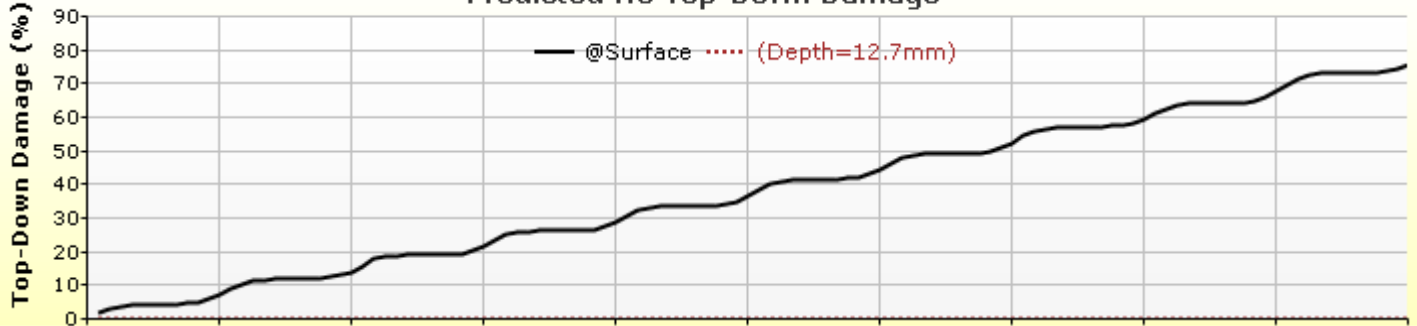
Predicted AC Bottom-Up Cracking (Alligator)



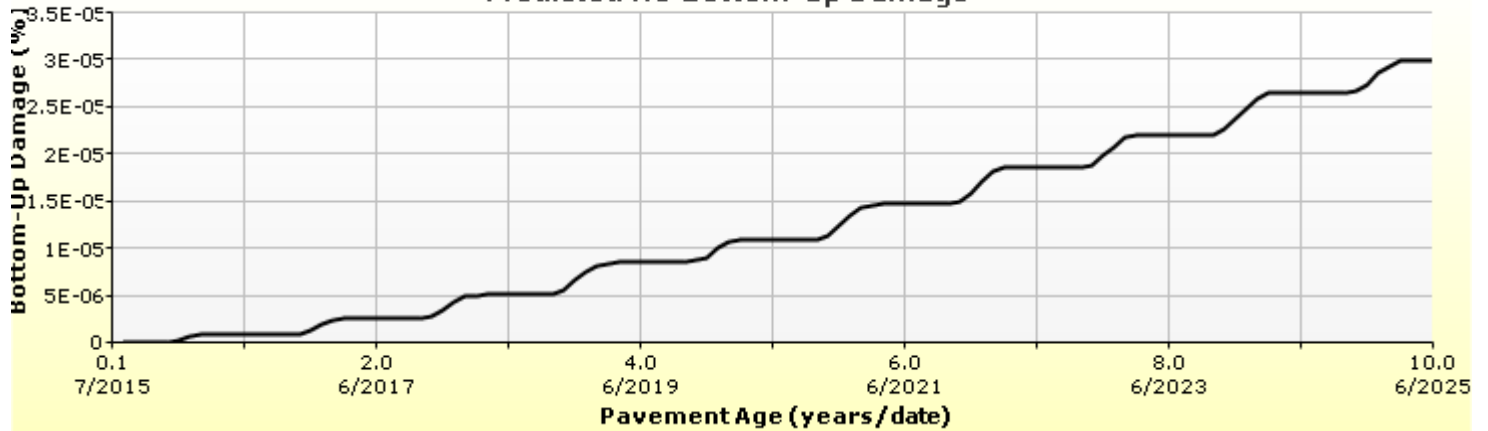
Total Cracking (Reflective + Alligator)



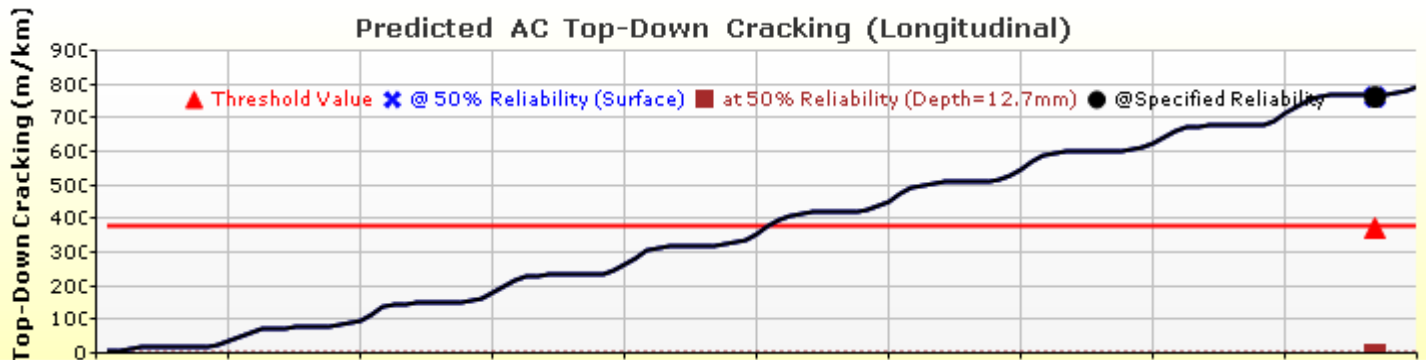
Predicted AC Top-Down Damage



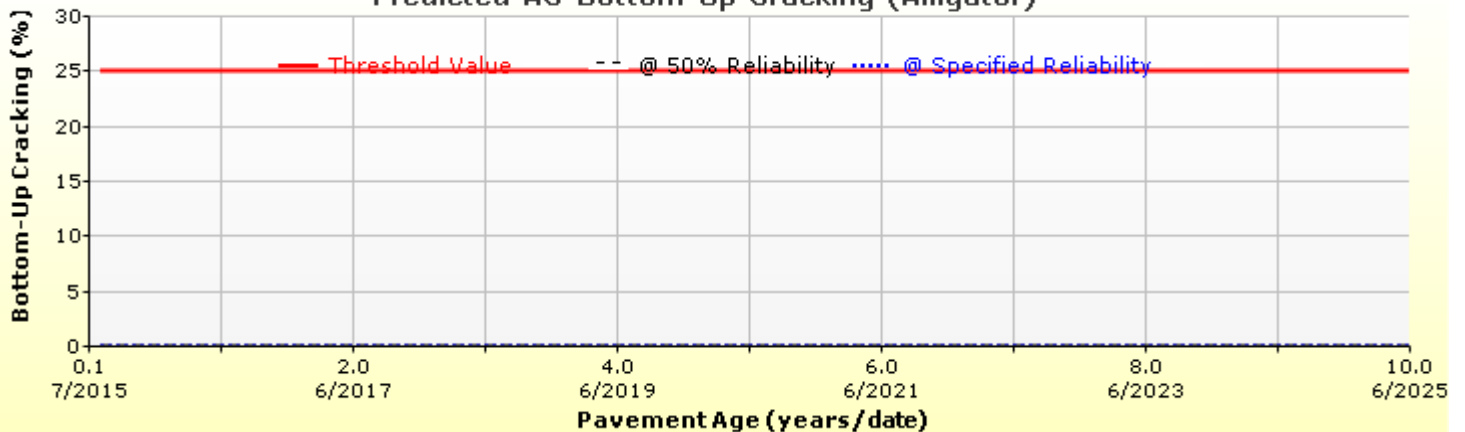
Predicted AC Bottom-Up Damage



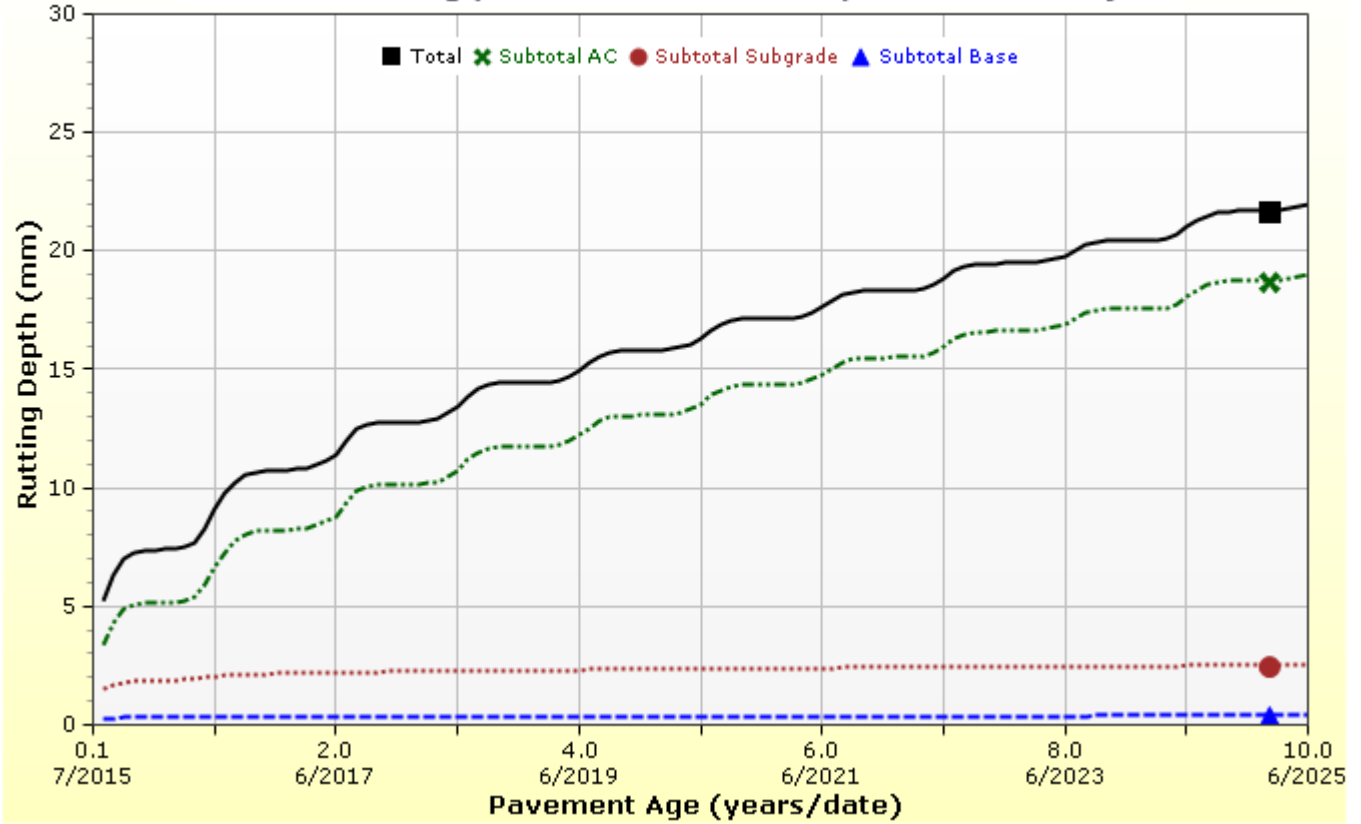
Predicted AC Top-Down Cracking (Longitudinal)

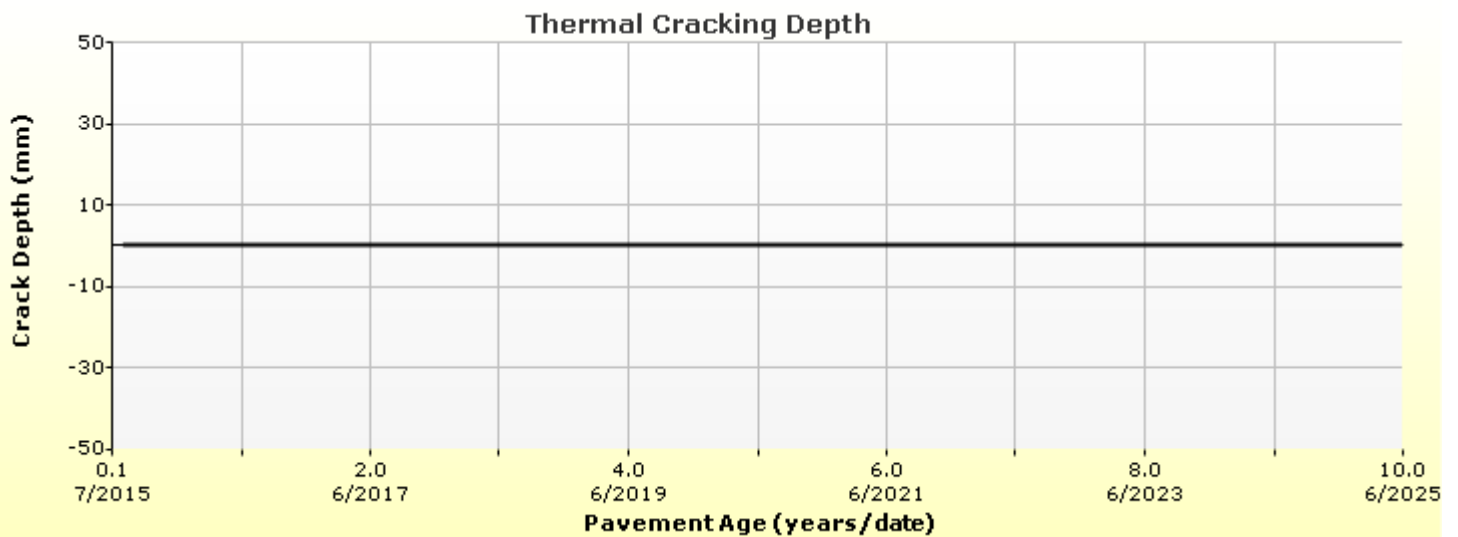
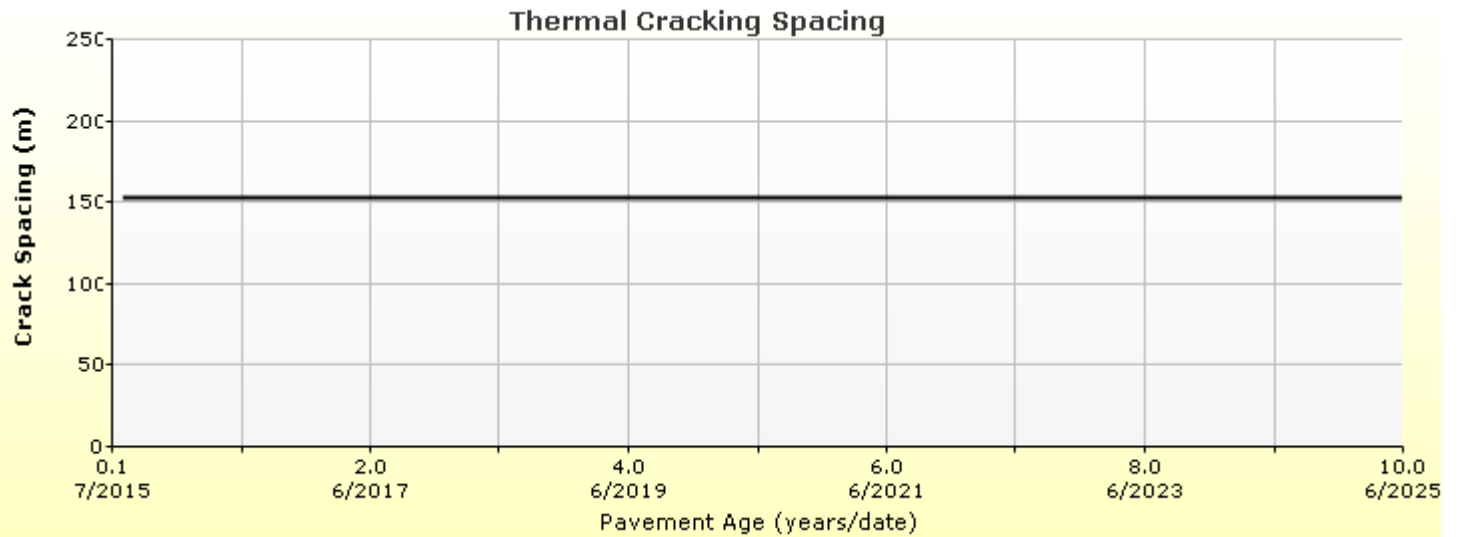


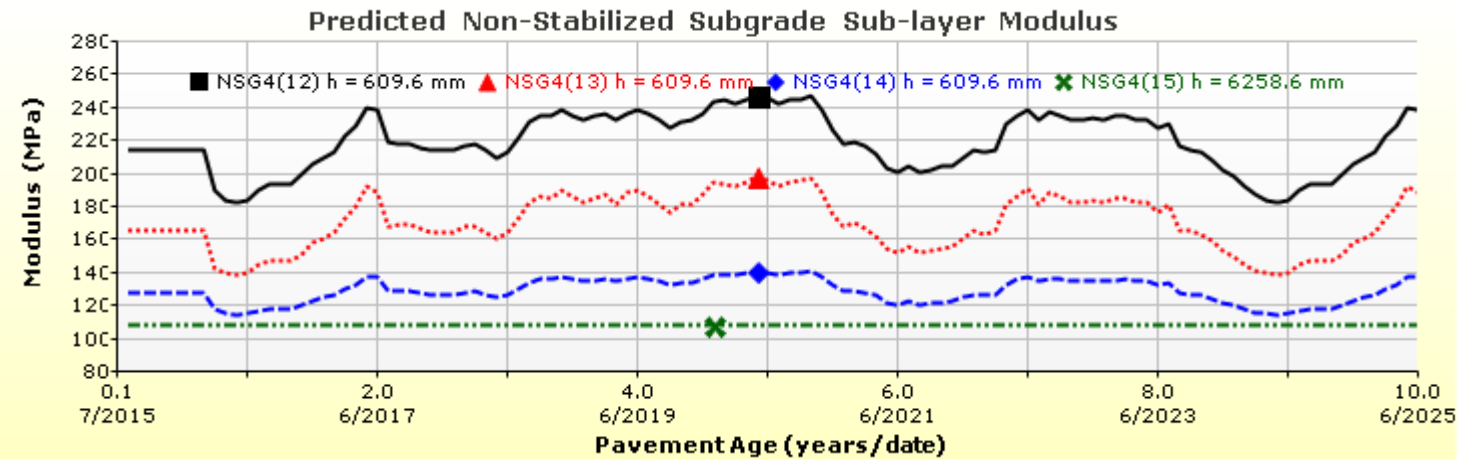
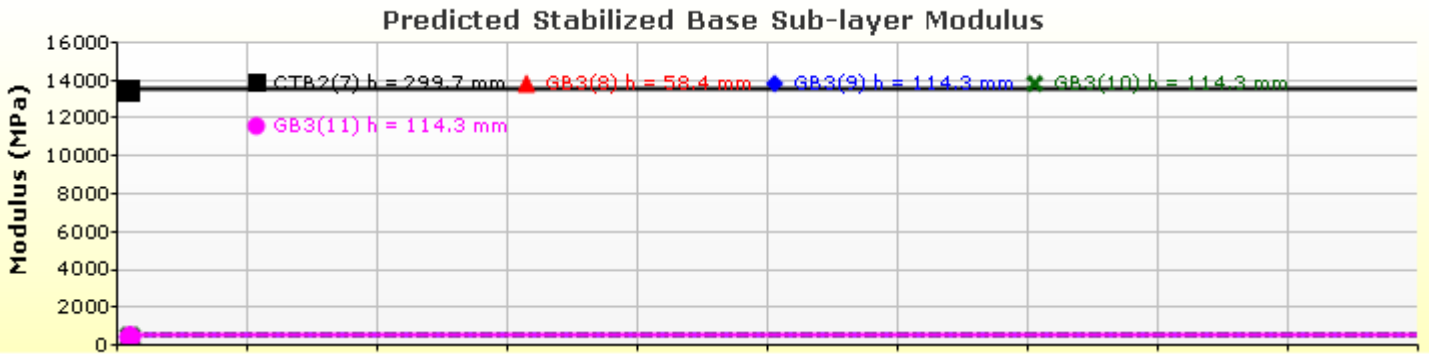
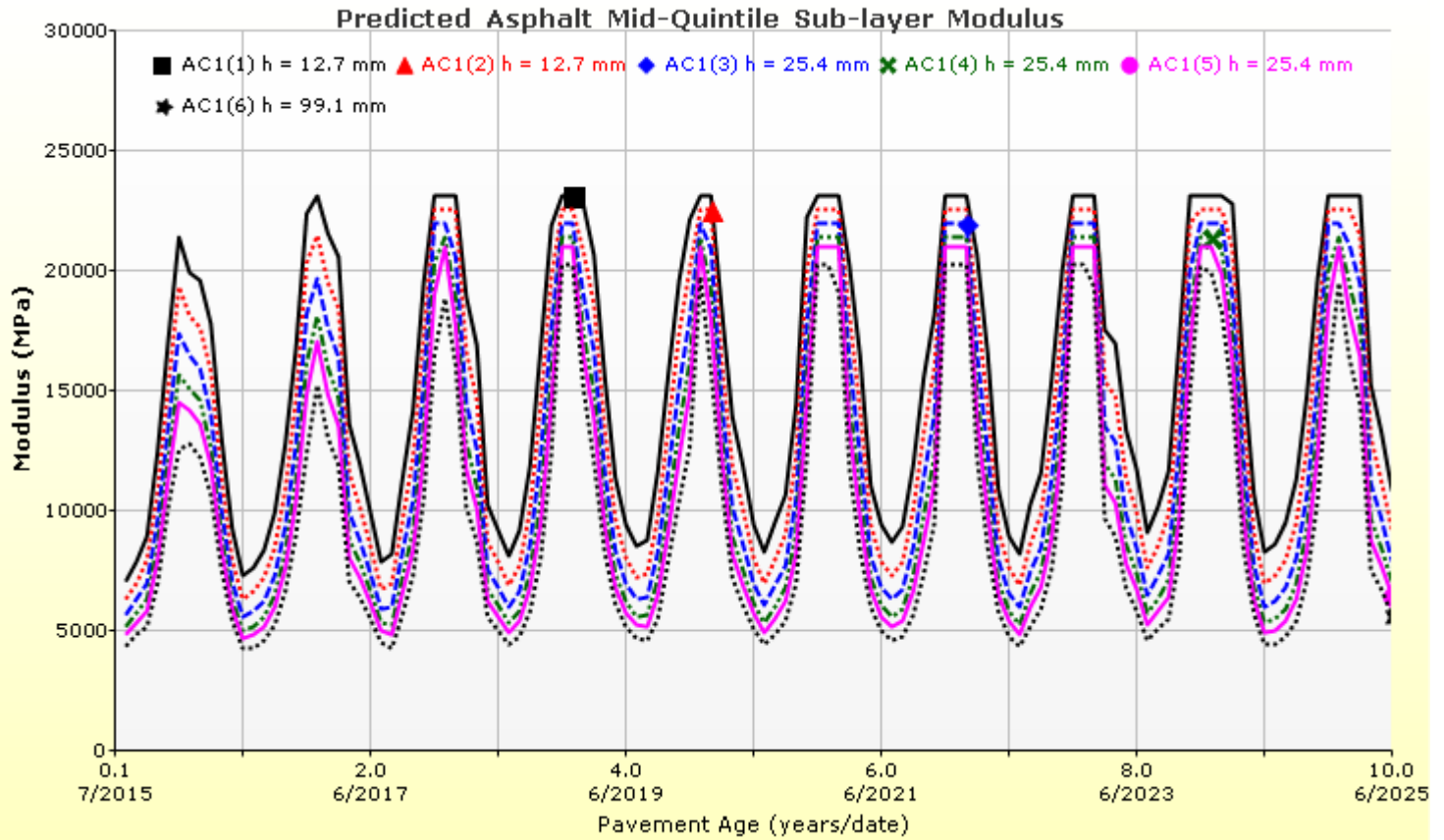
Predicted AC Bottom-Up Cracking (Alligator)



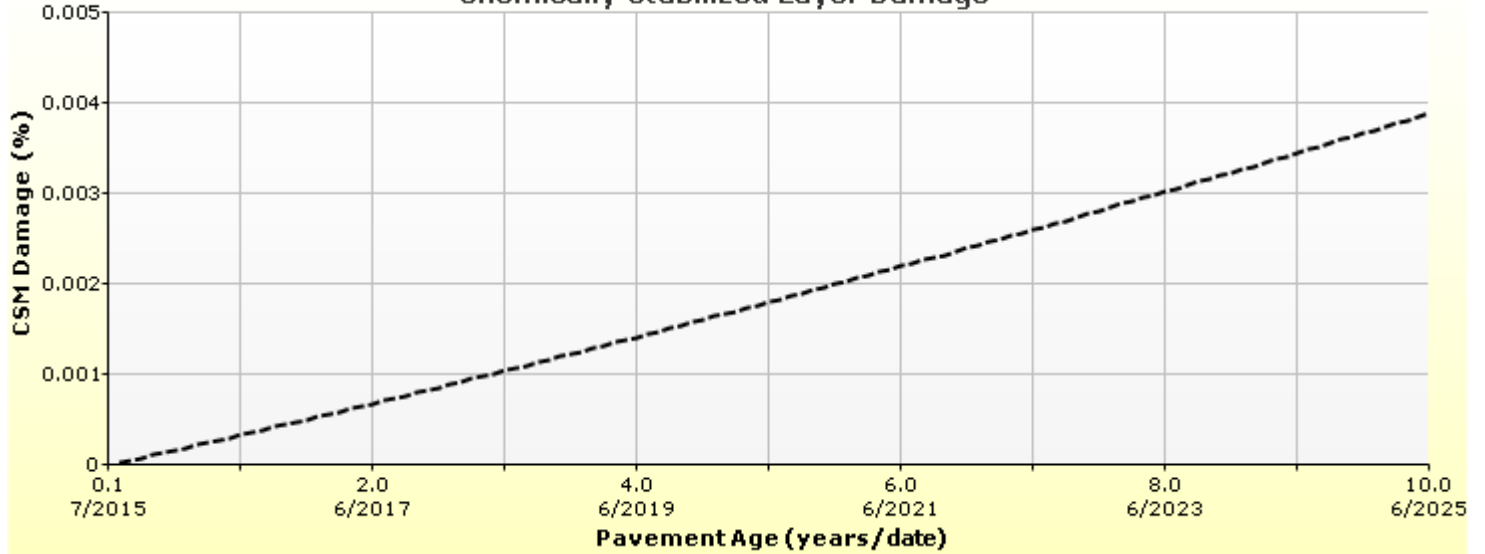
Predicted Rutting (Permanent Deformation) at 50% Reliability



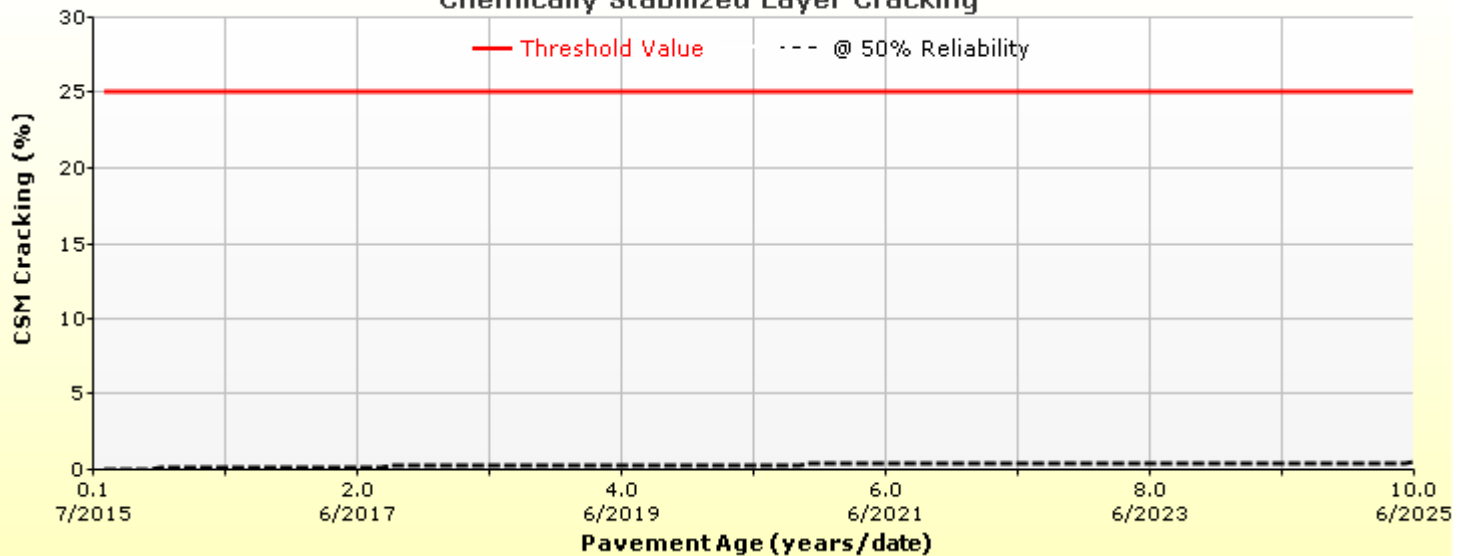




Chemically Stabilized Layer Damage



Chemically Stabilized Layer Cracking



Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 Chemically Stabilized : Cement stabilized

Chemically Stabilized

Layer thickness (mm)	300
Poisson's ratio	0.2
Unit weight (kgf/m ³)	2400

Strength

Elastic/resilient modulus (MPa)	13790

Thermal

Heat capacity (joule/kg-kelvin)	1172.3
Thermal conductivity (watt/meter-kelvin)	2.16

Identifiers

Field	Value
Display name/identifier	Cement stabilized
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 3 Non-stabilized Base : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

Standard Deviation (BASERUT)

0.1235*Pow(SUBRUT,0.5012)+0.001

AC Cracking

AC Top Down Cracking

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

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: 7

c2: 3.5

c3: 0

c4: 1000

c1: 1

c2: 1

c3: 6000

AC Cracking Top Standard Deviation

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

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

IRI Flexible Pavements

C1 - Rutting

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

CSM Standard Deviation

CTB*1



Project1 - Novo ALF4_ALT4

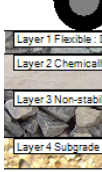
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Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data 32.119, -81.202
Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm):	Volumetric at Construction:	
Flexible	Default asphalt concrete	200.0	Effective binder content (%)	11.6
Cement_Base	Cement stabilized	300.0	Air voids (%)	7.0
NonStabilized	Crushed stone	400.0		
Subgrade	A-1-a	Semi-infinite		

Traffic

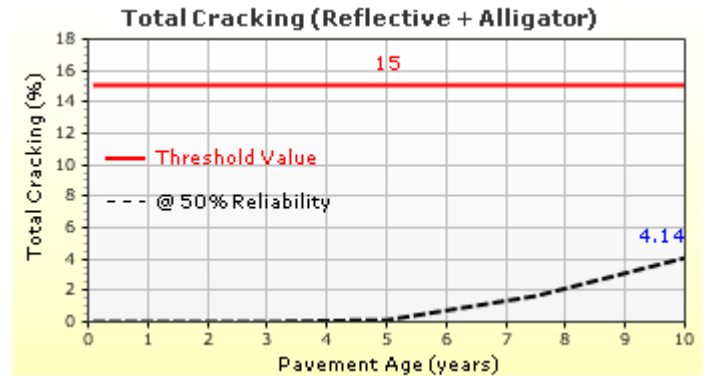
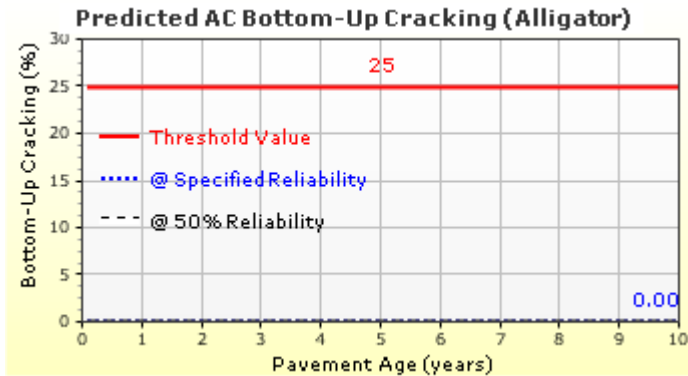
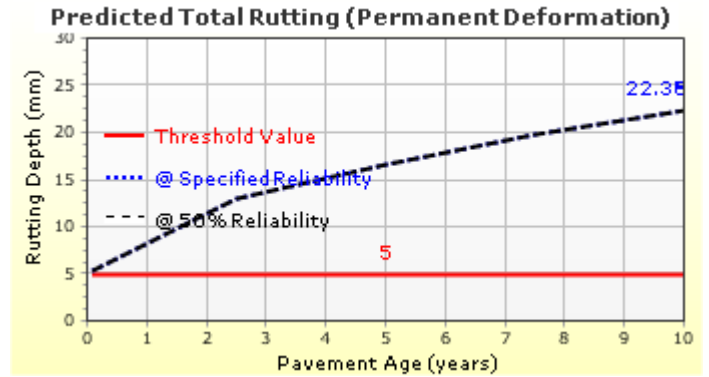
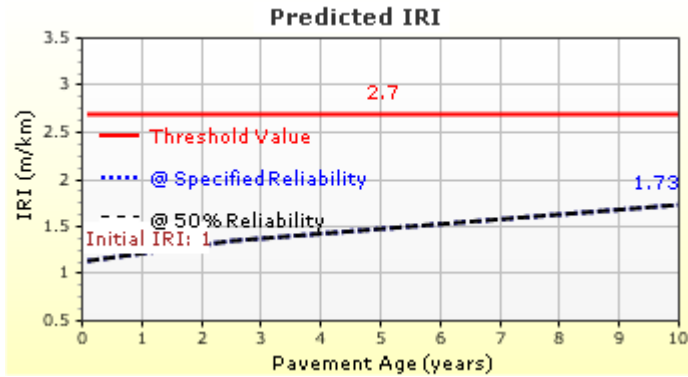
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.73	50.00	97.70	Pass
Permanent deformation - total pavement (mm)	5.00	22.36	50.00	0.03	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.00	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.14	-	-	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	831.44	50.00	15.92	Fail
Permanent deformation - AC only (mm)	5.00	19.41	50.00	0.18	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.53	-	-	-

Distress Charts

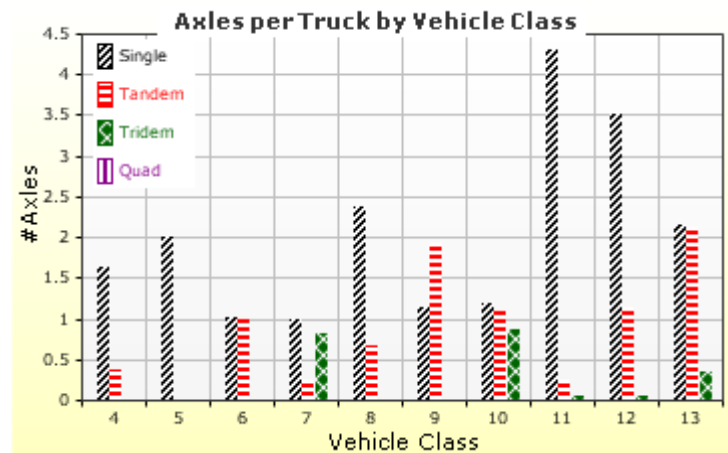
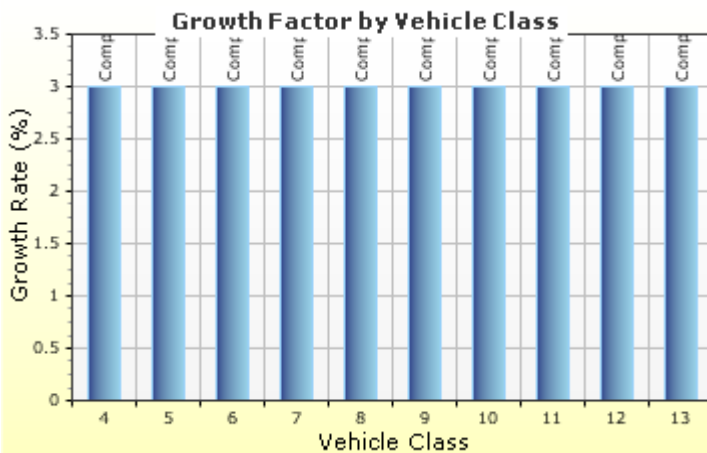
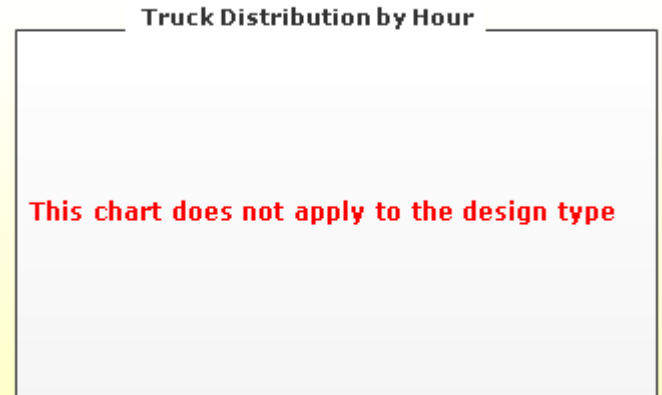
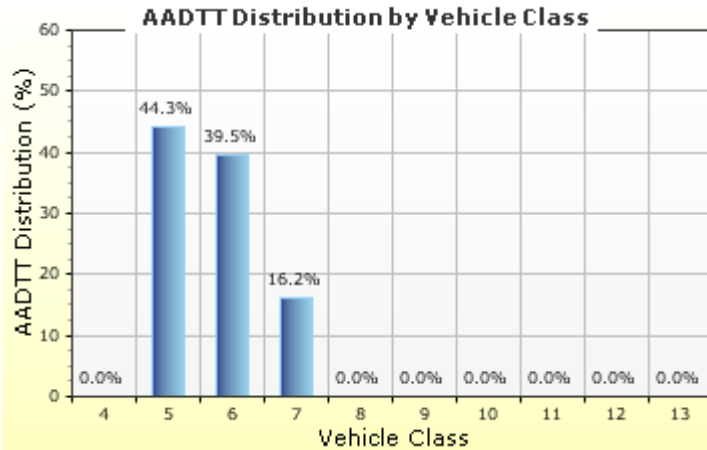


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

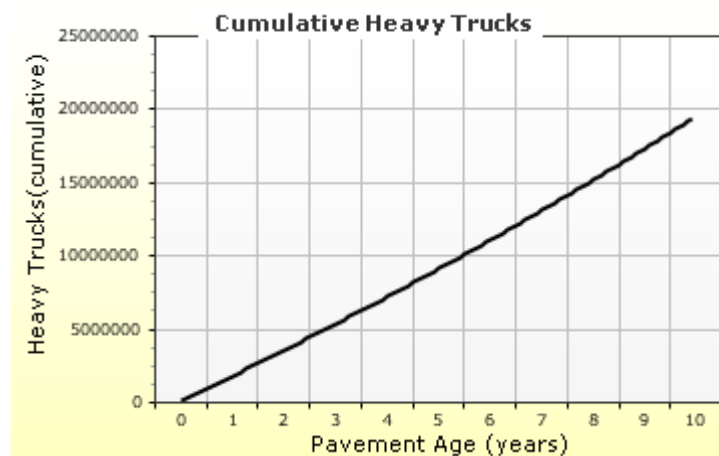
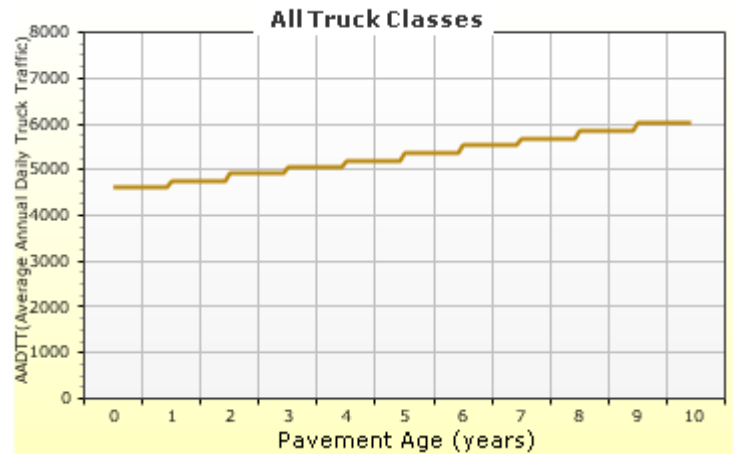
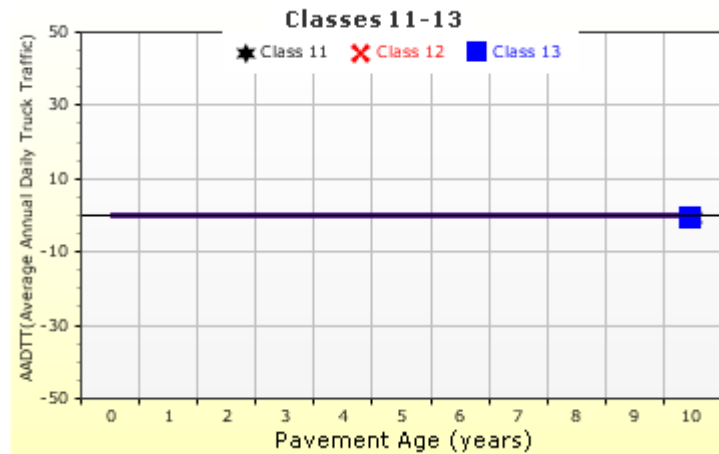
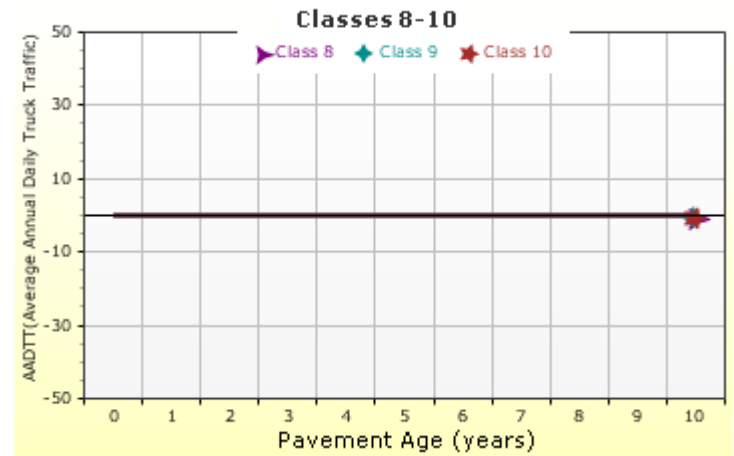
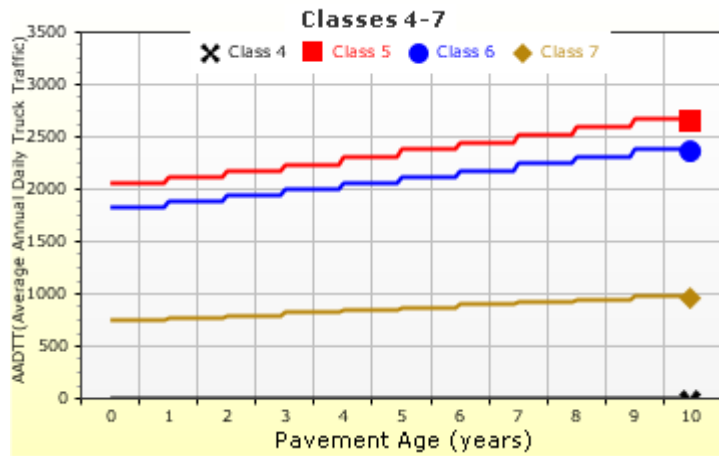
Wheelbase does not apply

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



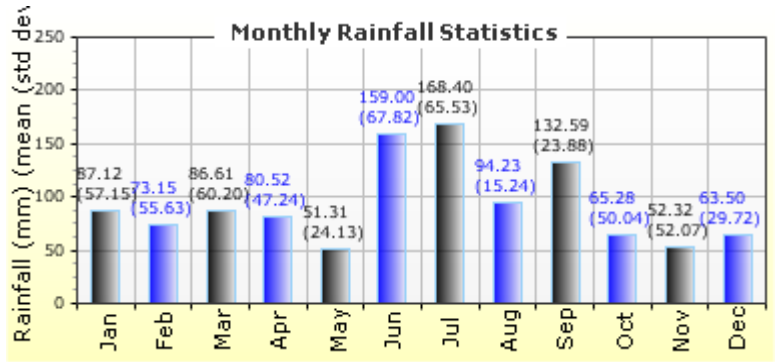
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

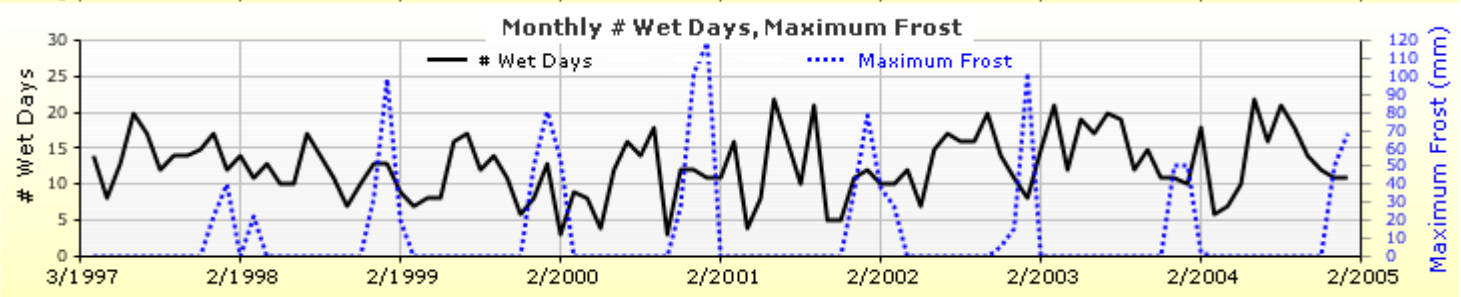
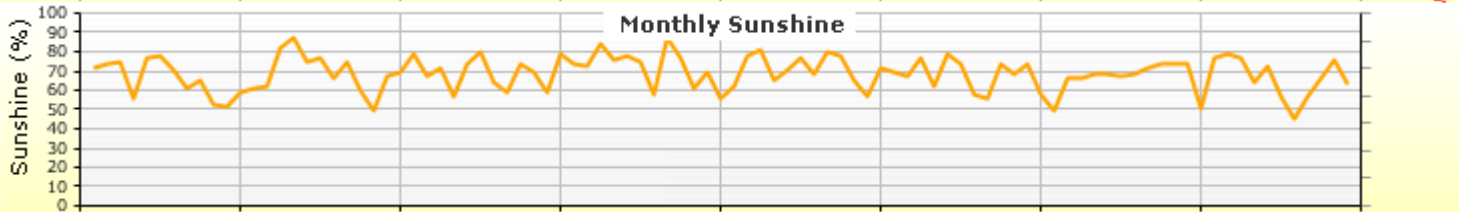
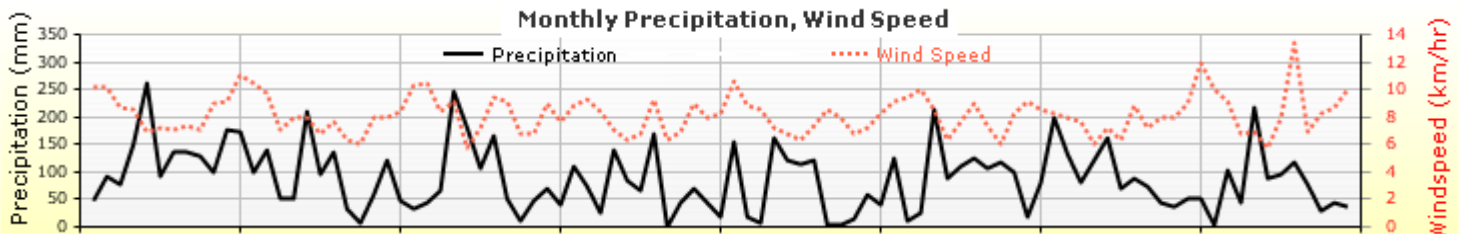
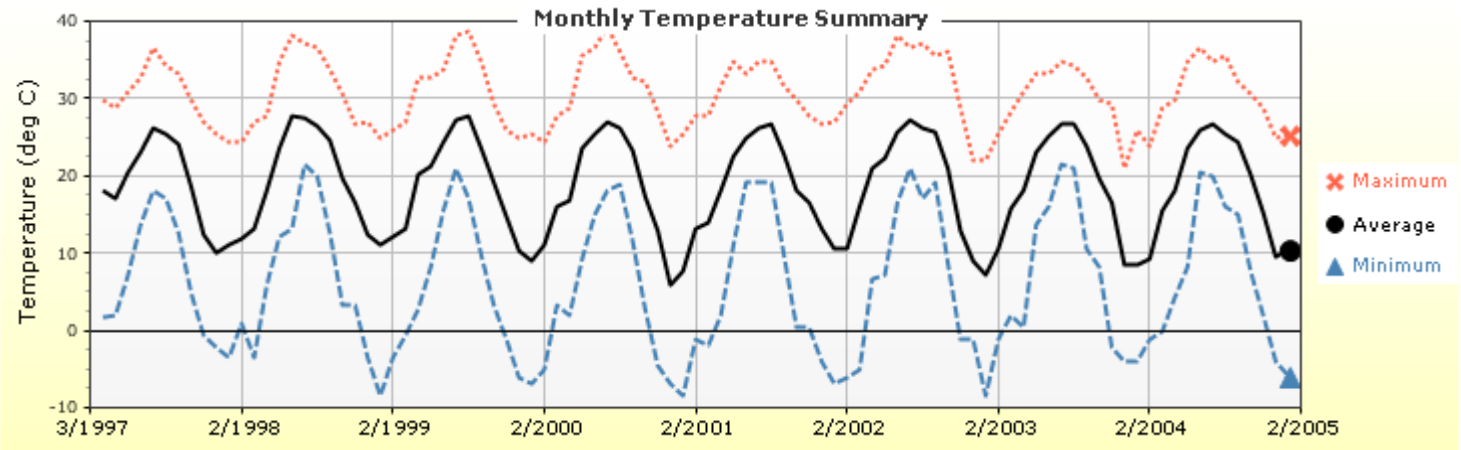
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

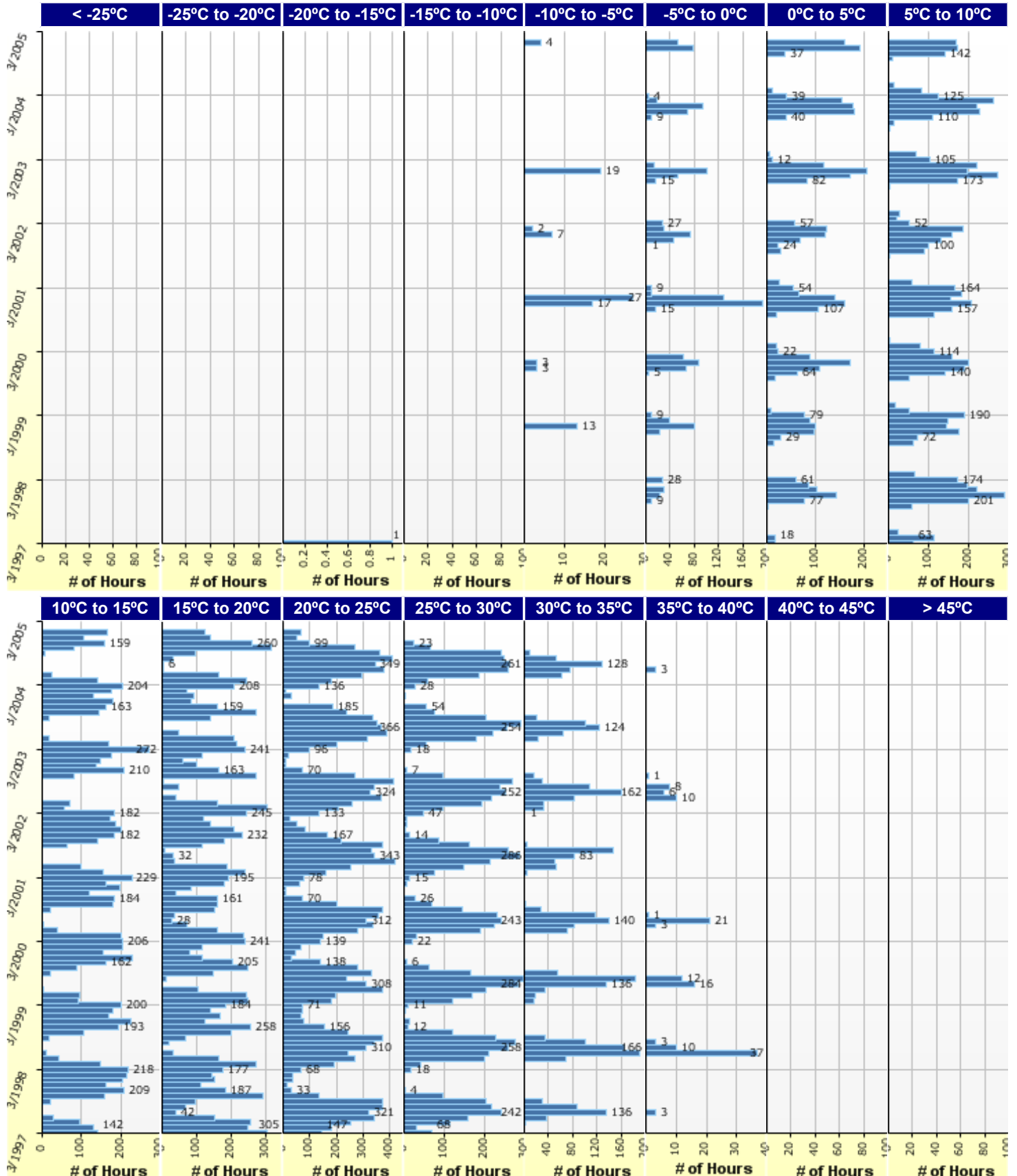


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF4_ALT4

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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

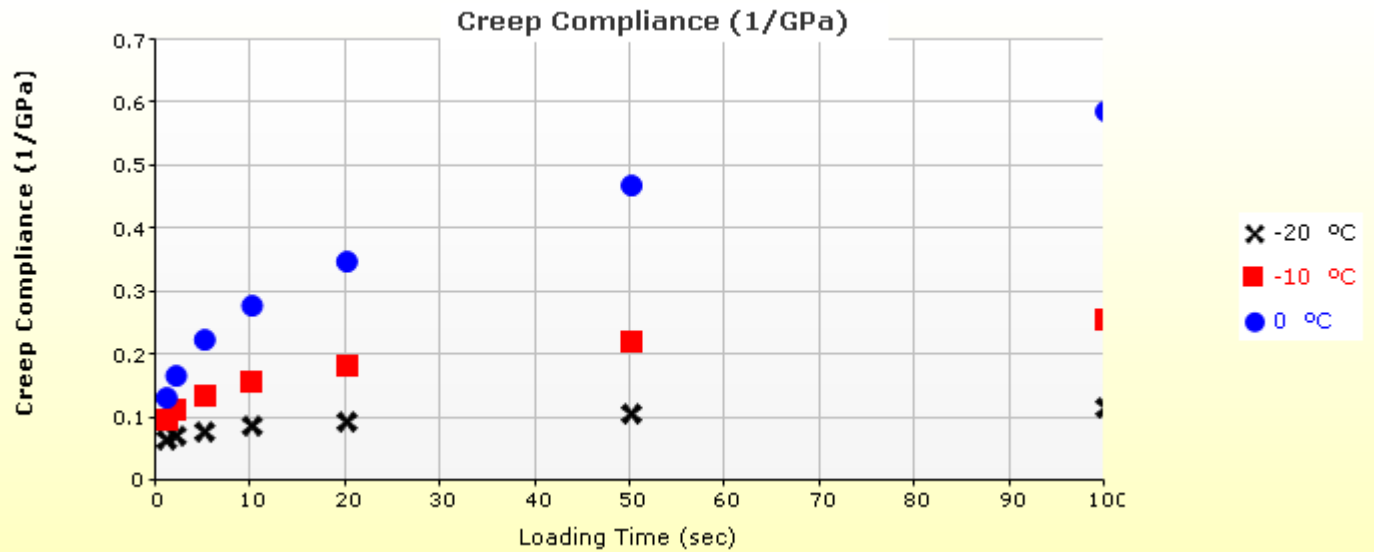
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Chemically Stabilized : Cement stabilized	Chemically Stabilized (2)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

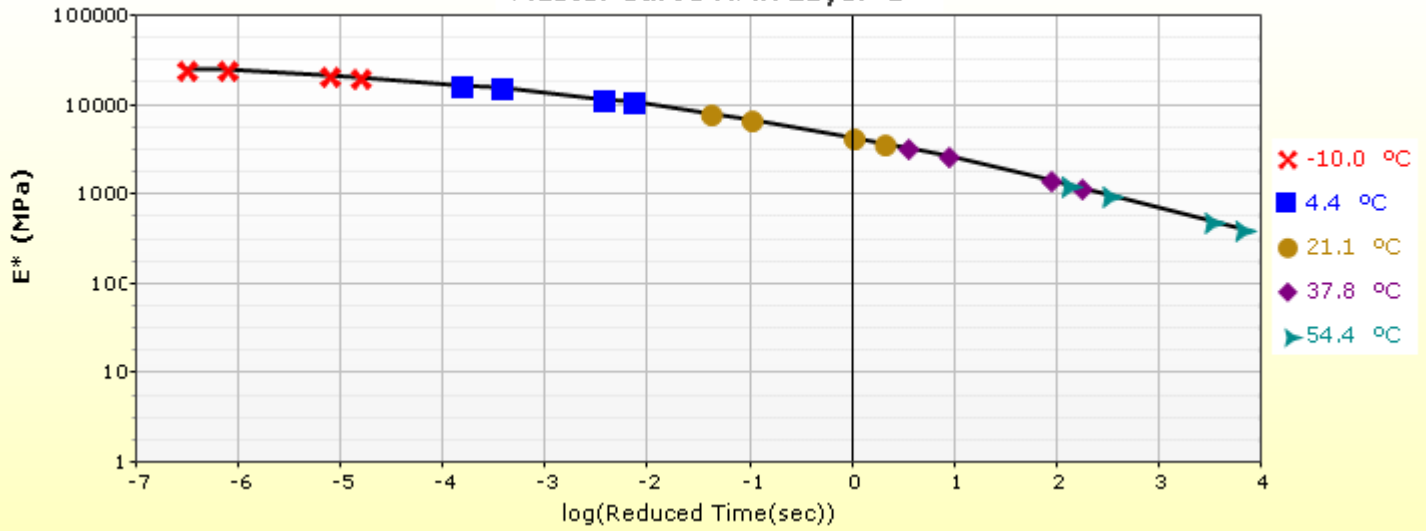
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

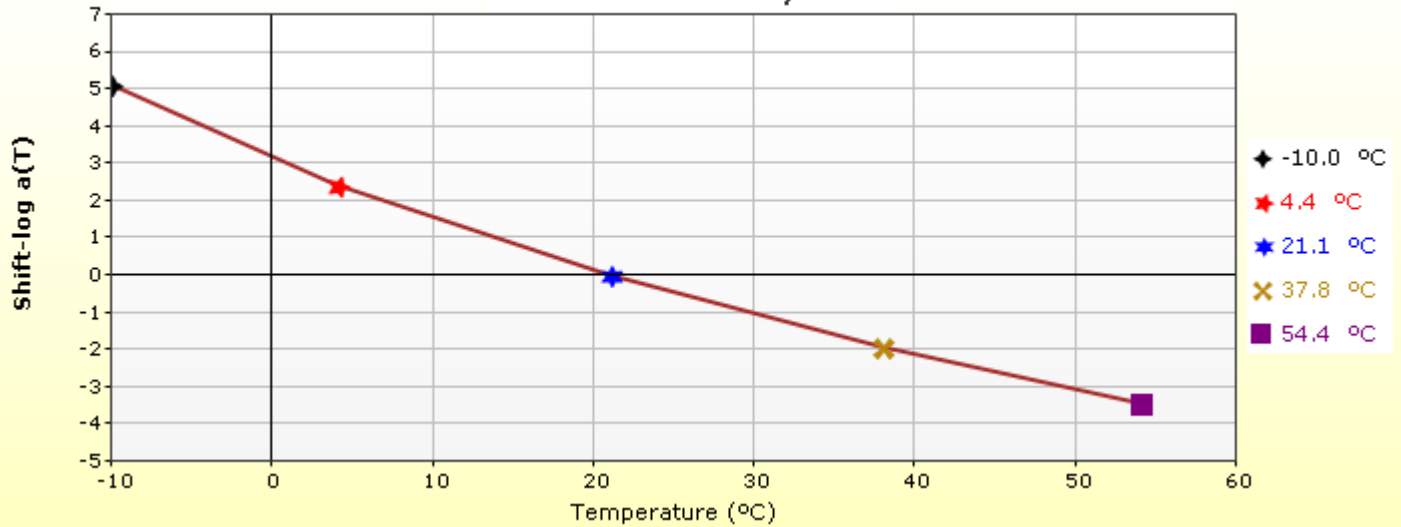


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

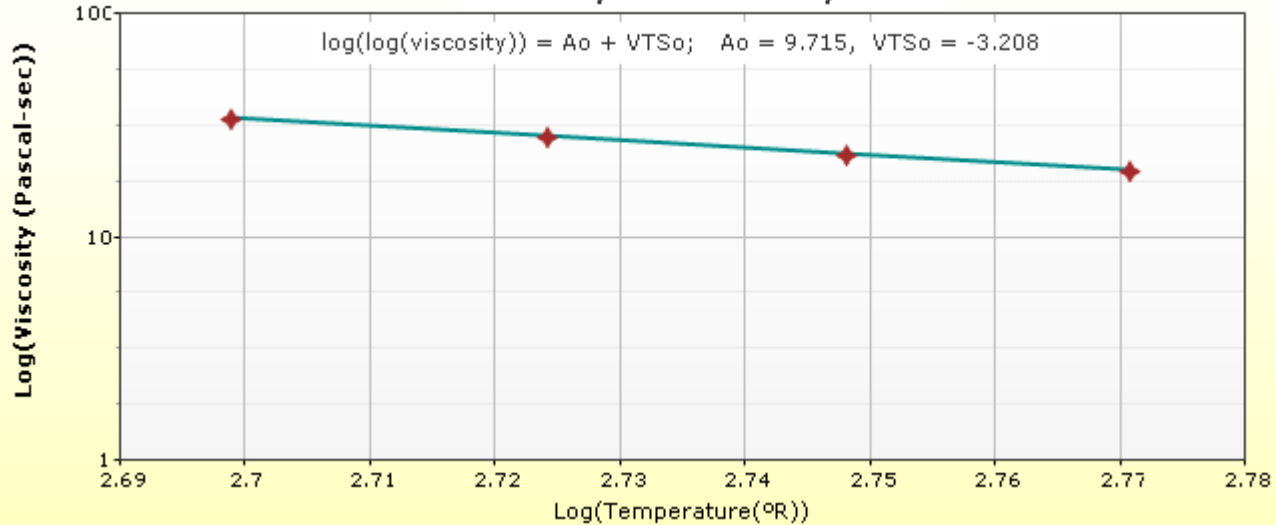
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

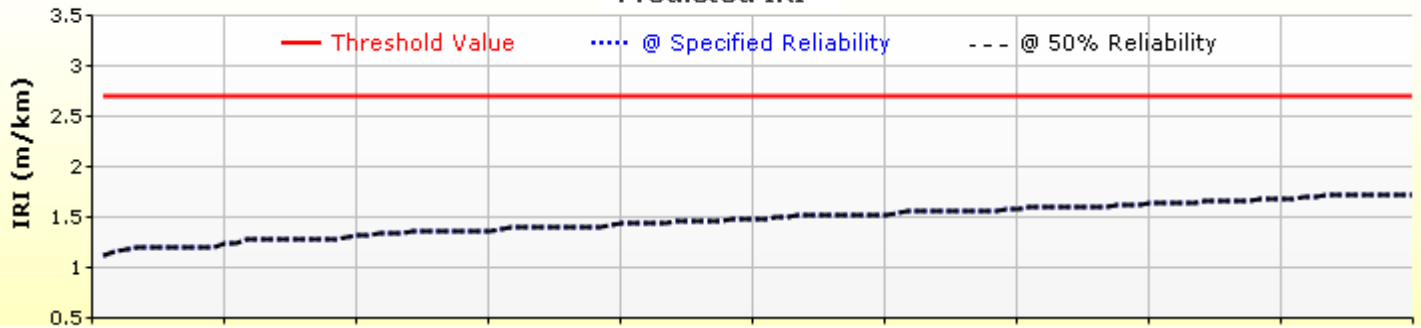


Viscosity Curve HMA Layer 1

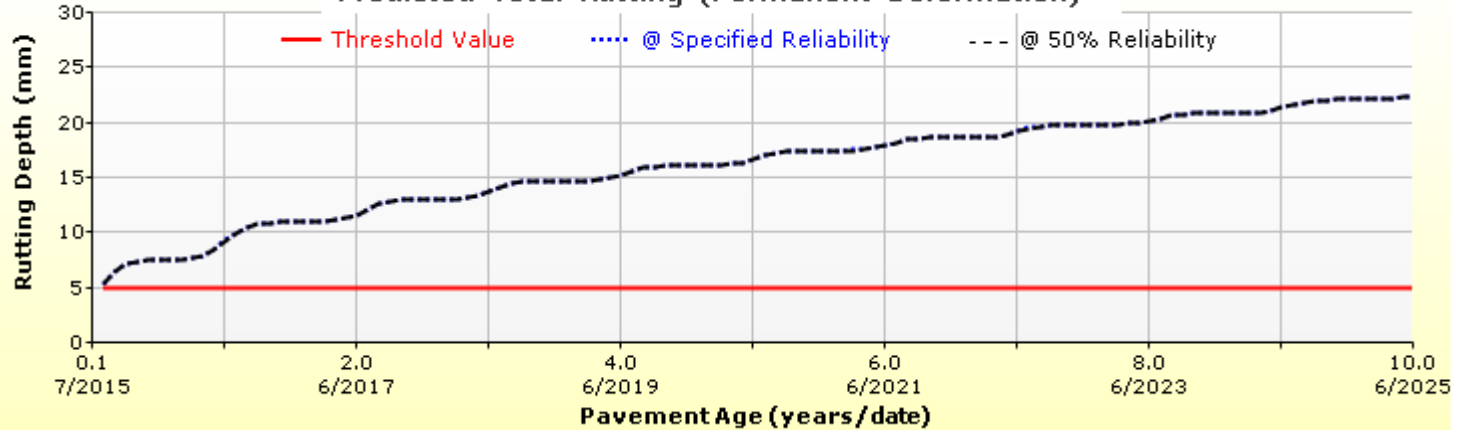


Analysis Output Charts

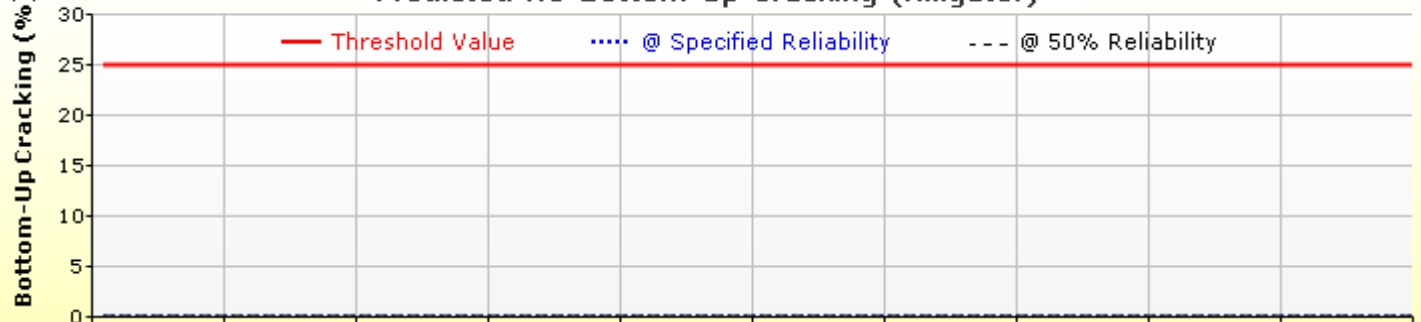
Predicted IRI



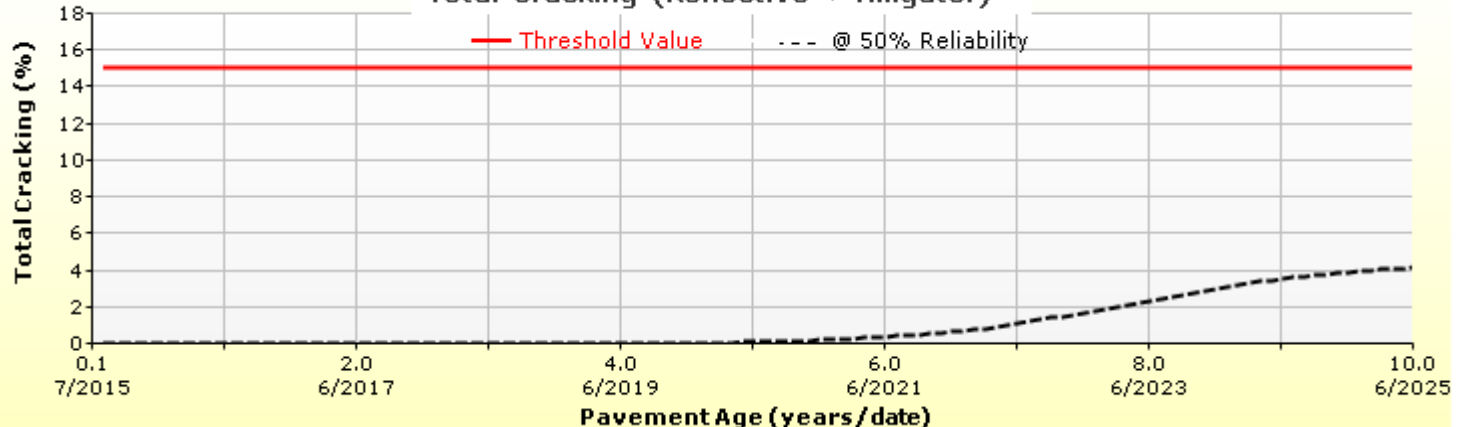
Predicted Total Rutting (Permanent Deformation)

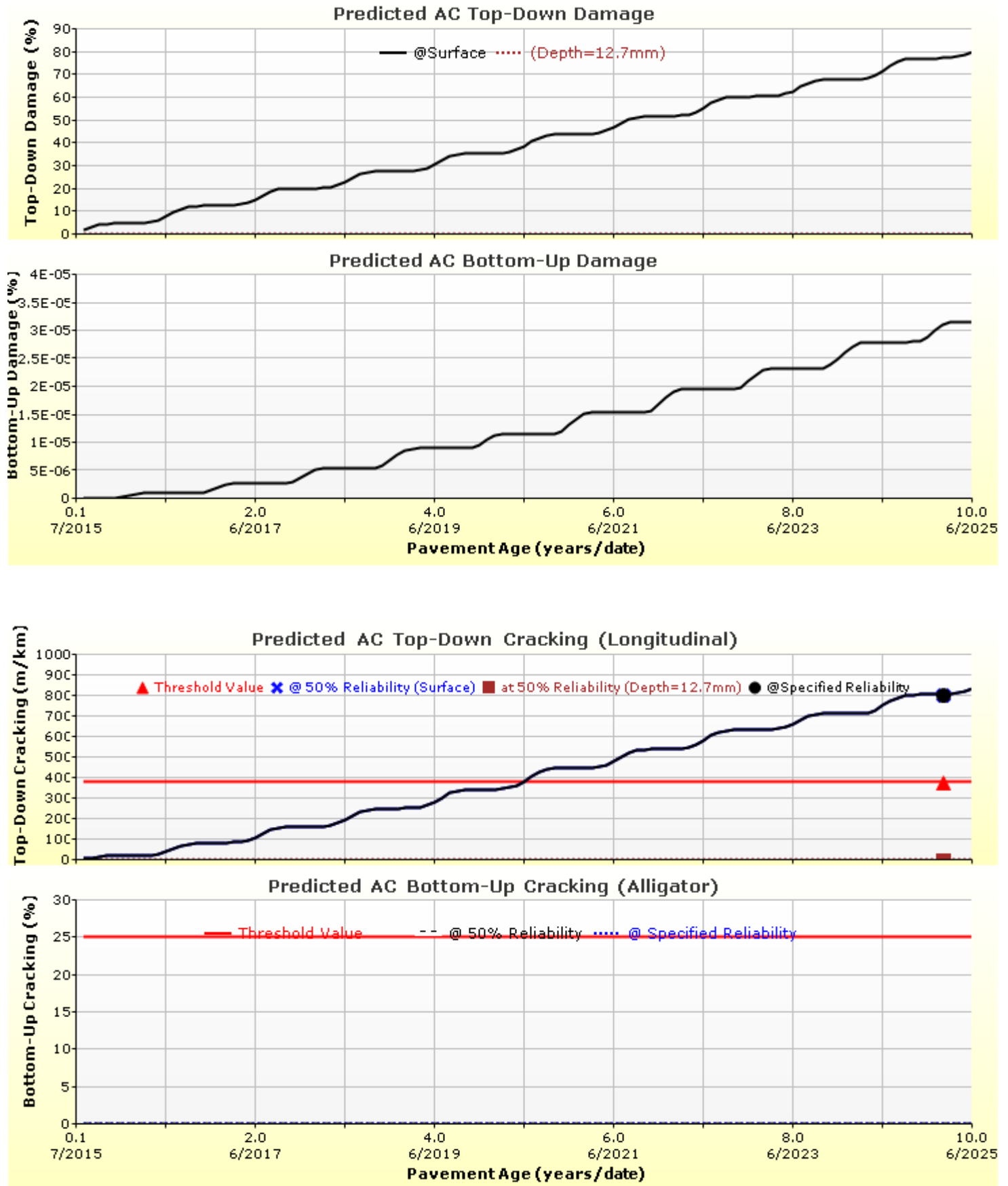


Predicted AC Bottom-Up Cracking (Alligator)

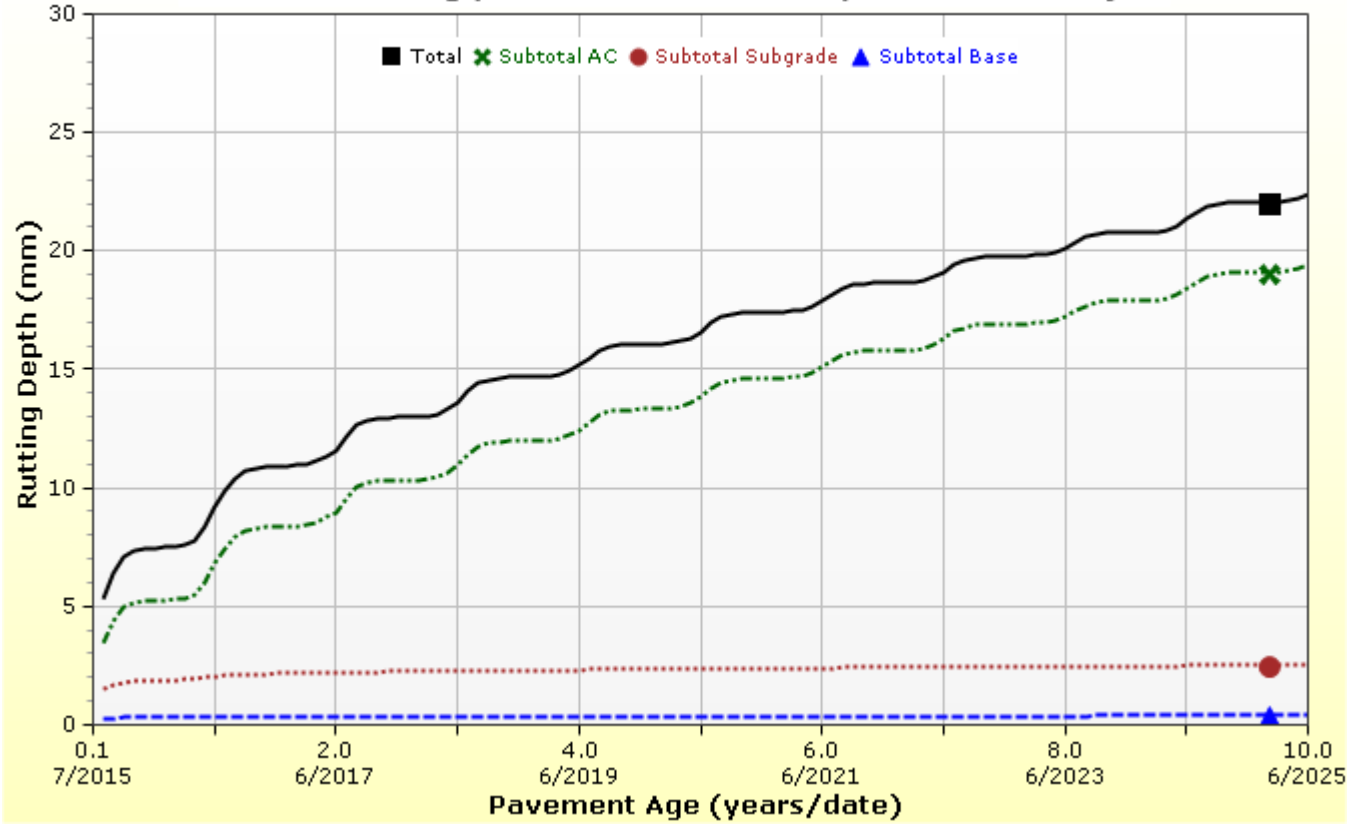


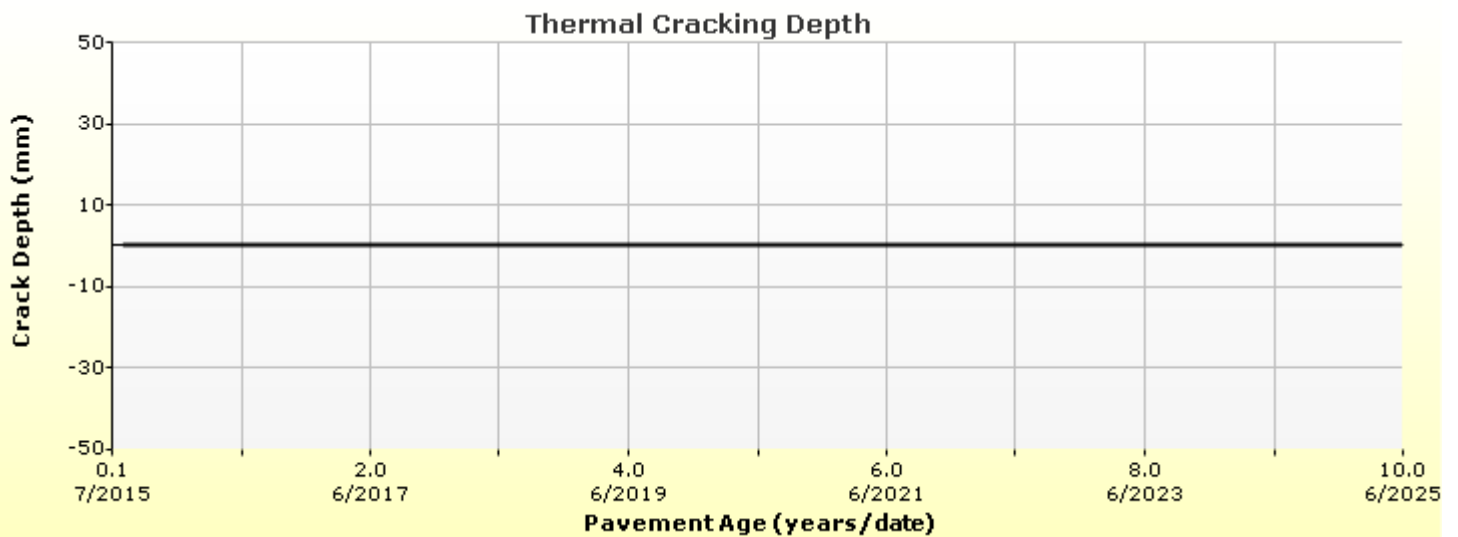
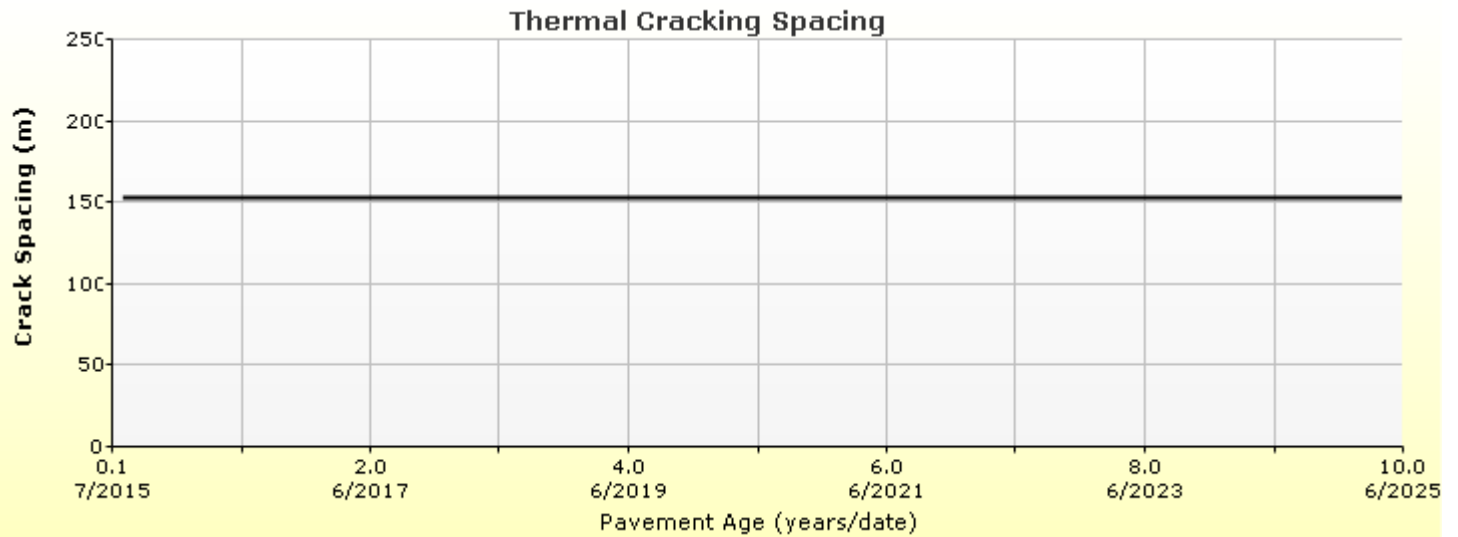
Total Cracking (Reflective + Alligator)

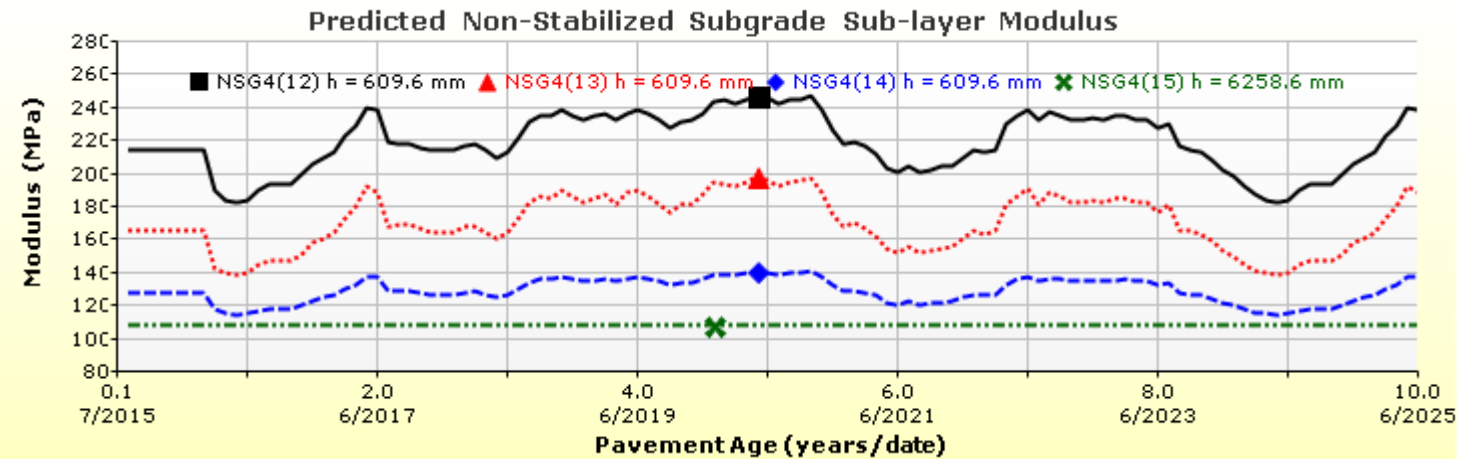
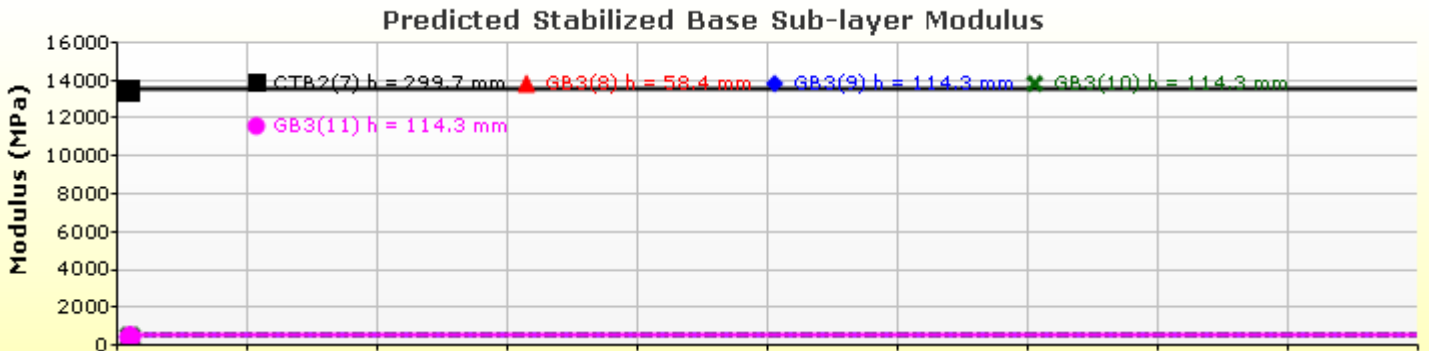
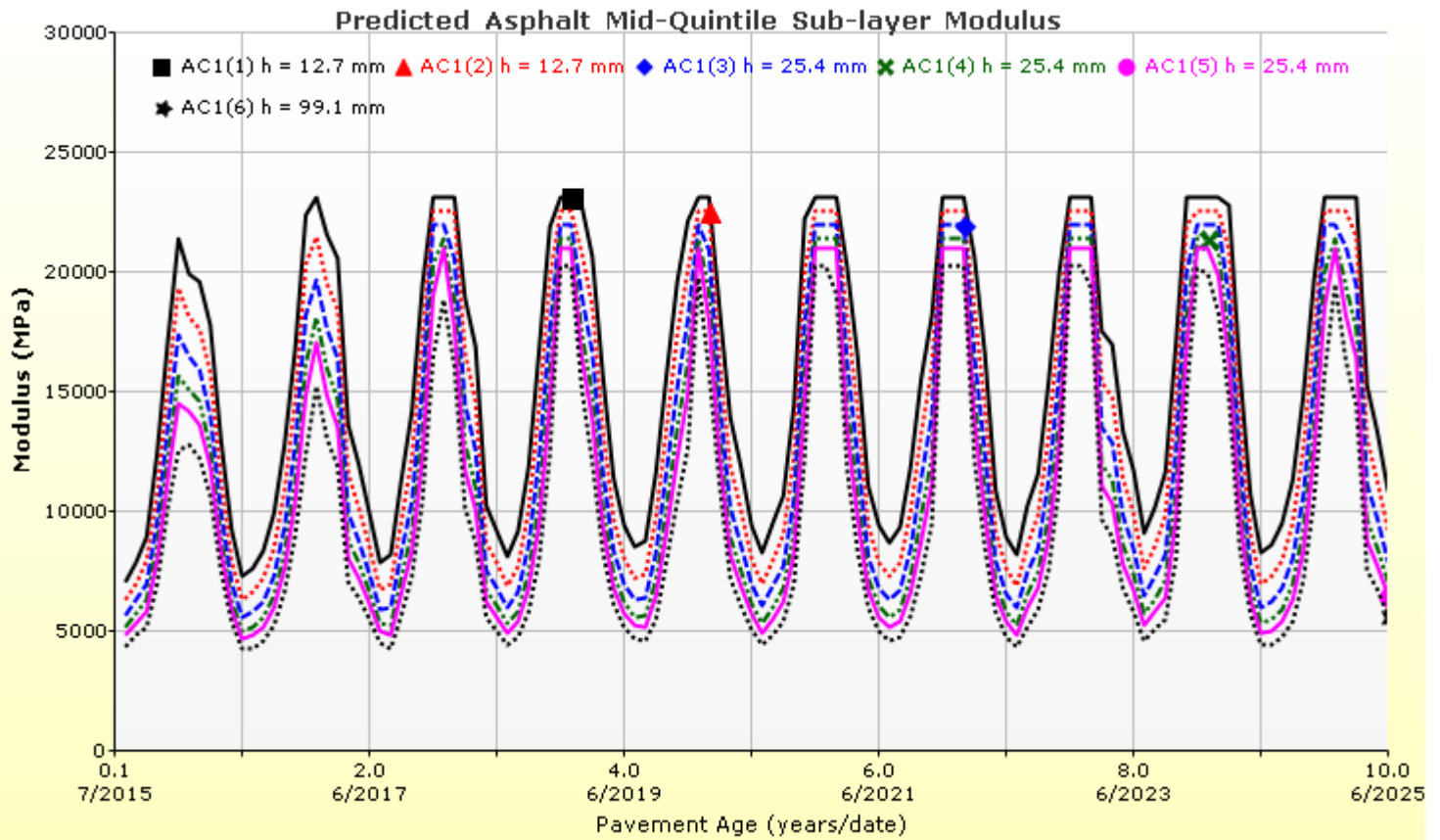




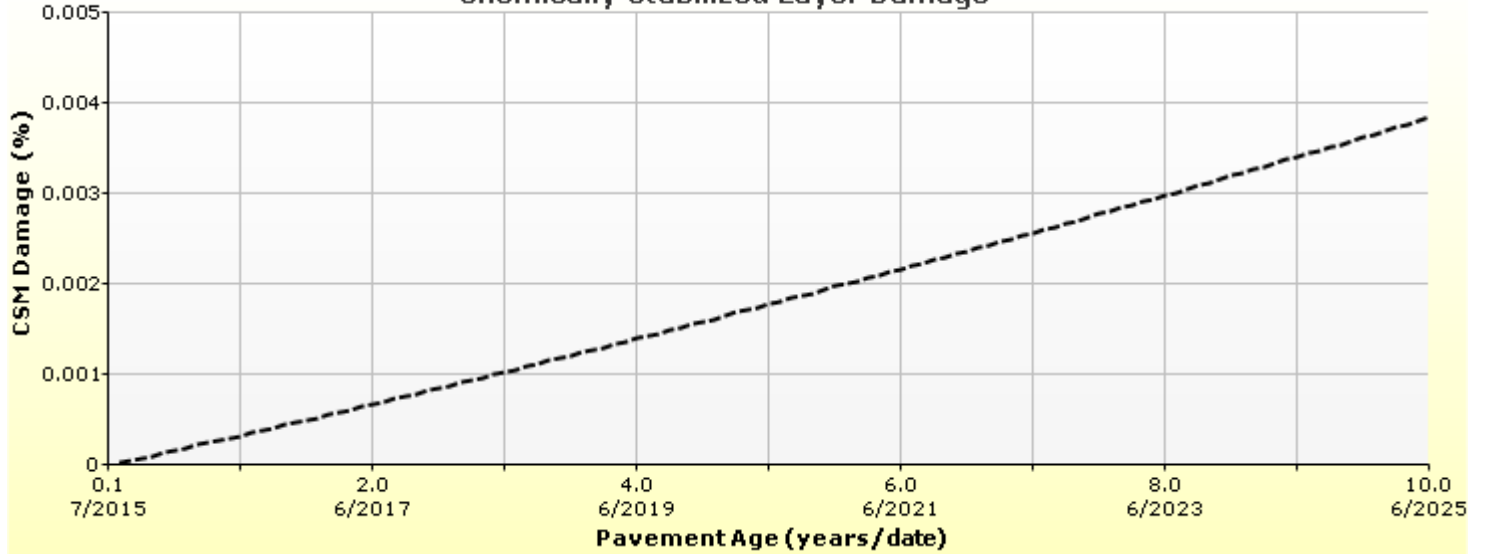
Predicted Rutting (Permanent Deformation) at 50% Reliability



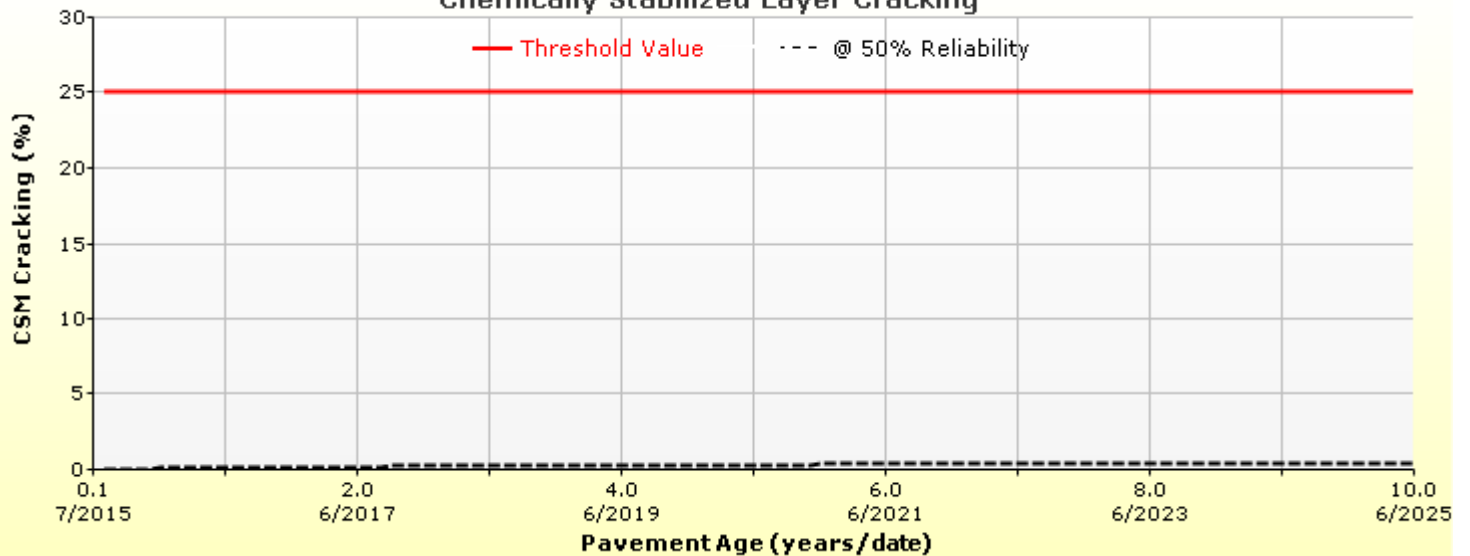




Chemically Stabilized Layer Damage



Chemically Stabilized Layer Cracking



Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 Chemically Stabilized : Cement stabilized

Chemically Stabilized

Layer thickness (mm)	300
Poisson's ratio	0.2
Unit weight (kgf/m ³)	2400

Strength

Elastic/resilient modulus (MPa)	13790

Thermal

Heat capacity (joule/kg-kelvin)	1172.3
Thermal conductivity (watt/meter-kelvin)	2.16

Identifiers

Field	Value
Display name/identifier	Cement stabilized
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 3 Non-stabilized Base : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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 = regression coefficient determined through field calibration $N()$ = standard normal distribution evaluated at() σ = standard deviation of the log of the depth of cracks in the pavements C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_s = Tensile stress(psi) M_r = modulus of rupture(psi)
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

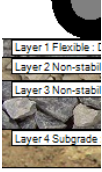
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

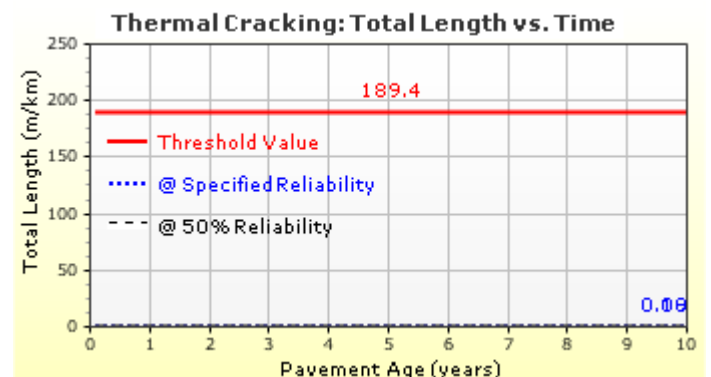
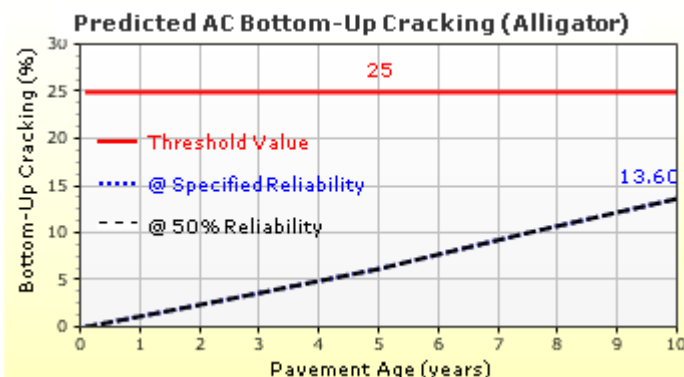
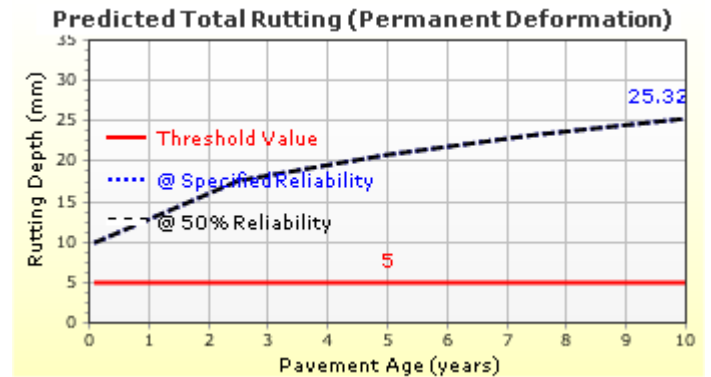
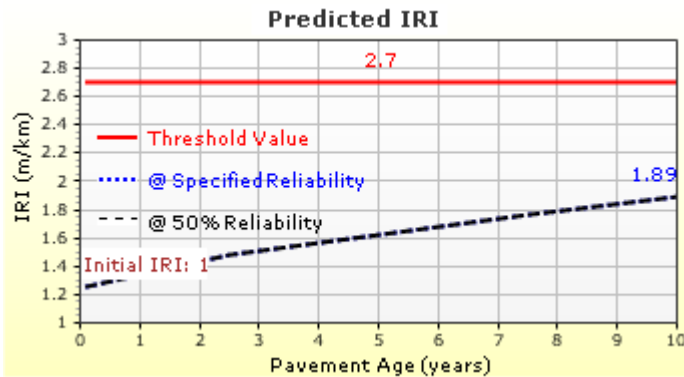
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	4,820
2020 (5 years)	4,486,440
2025 (10 years)	9,687,460

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.89	50.00	94.13	Pass
Permanent deformation - total pavement (mm)	5.00	25.33	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	13.60	50.00	79.01	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	285.98	50.00	58.58	Pass
Permanent deformation - AC only (mm)	5.00	10.41	50.00	3.60	Fail

Distress Charts

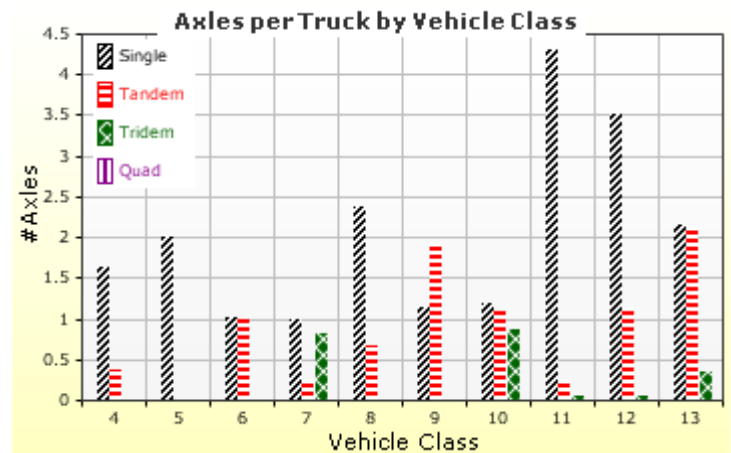
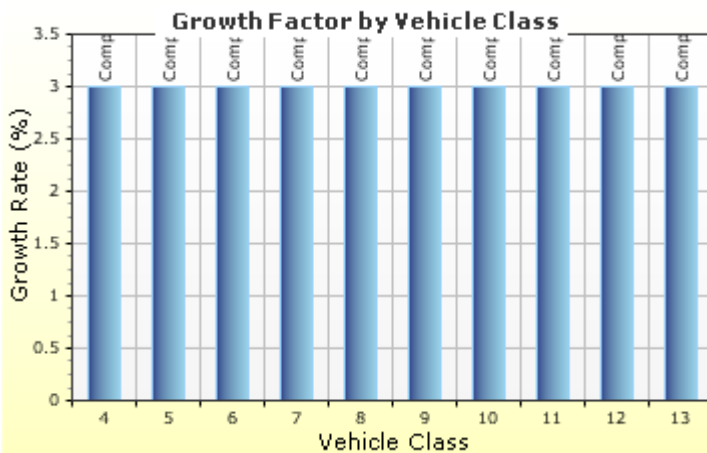
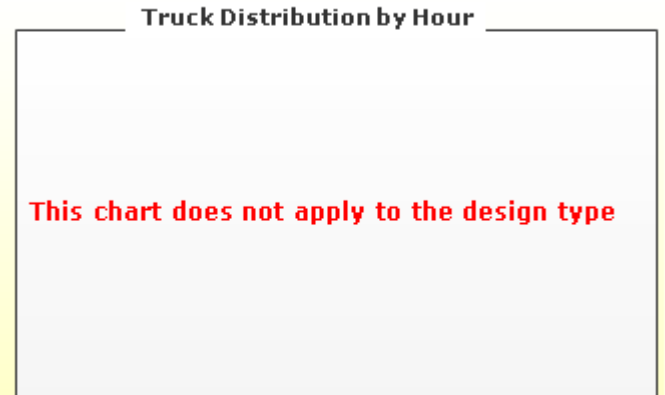
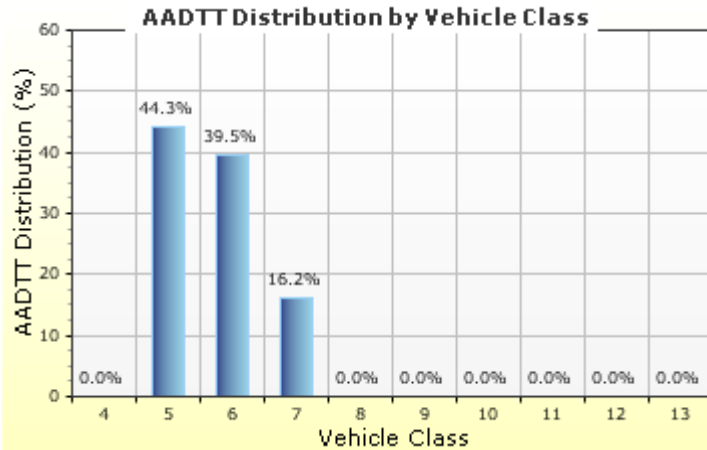


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 4,820
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

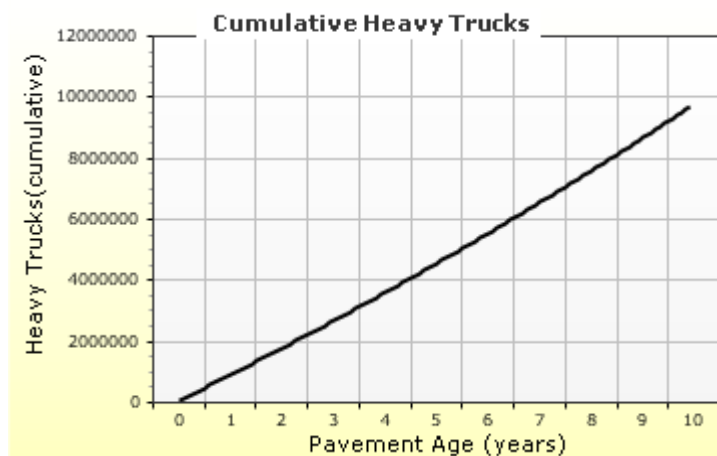
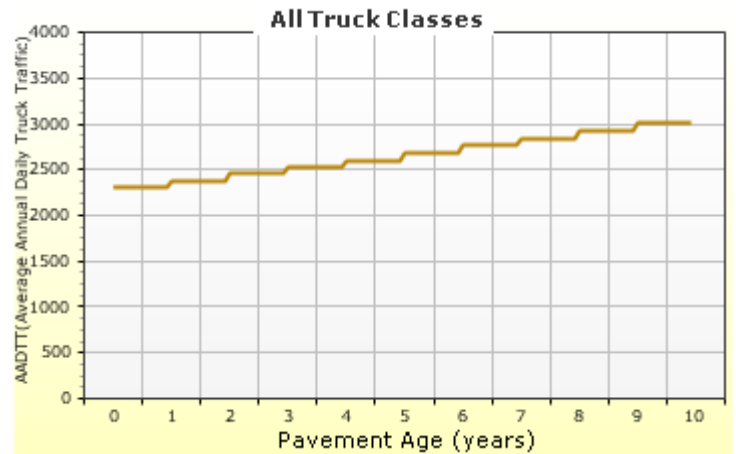
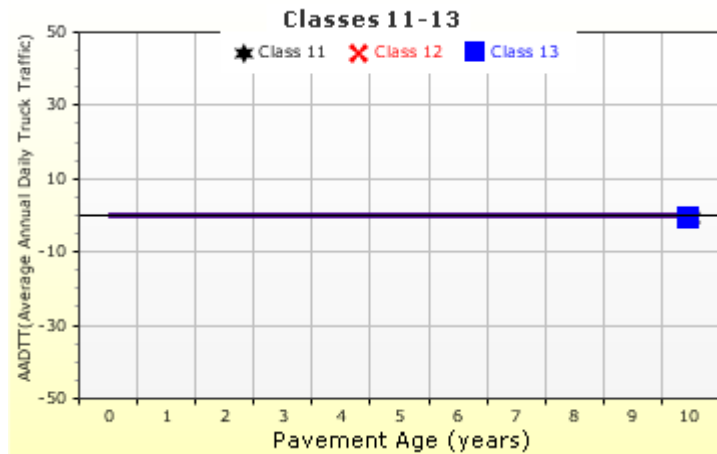
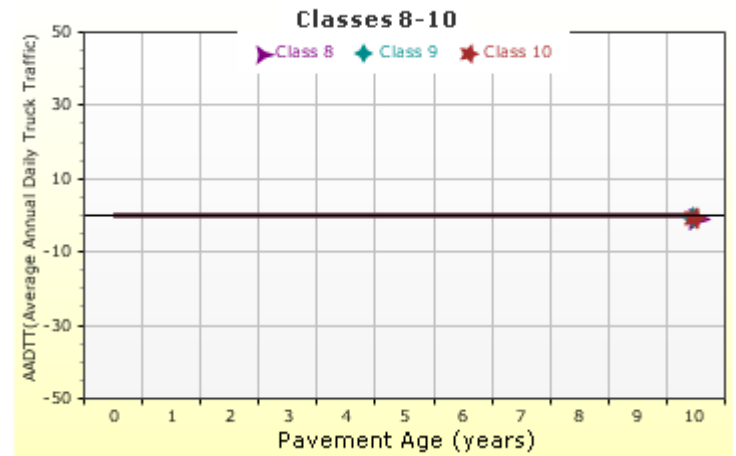
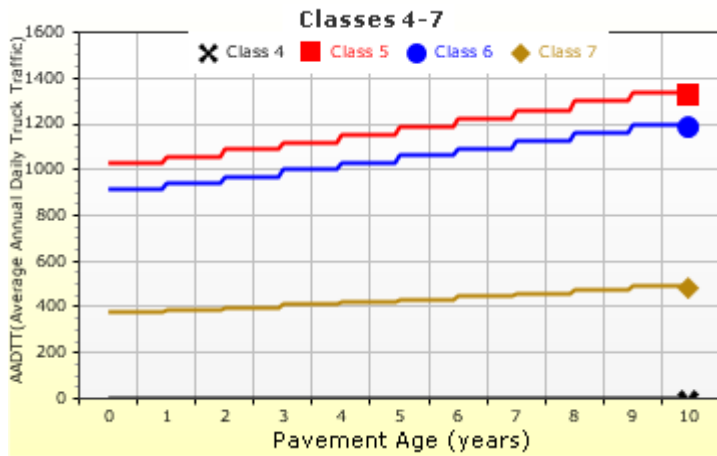
Wheelbase does not apply

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



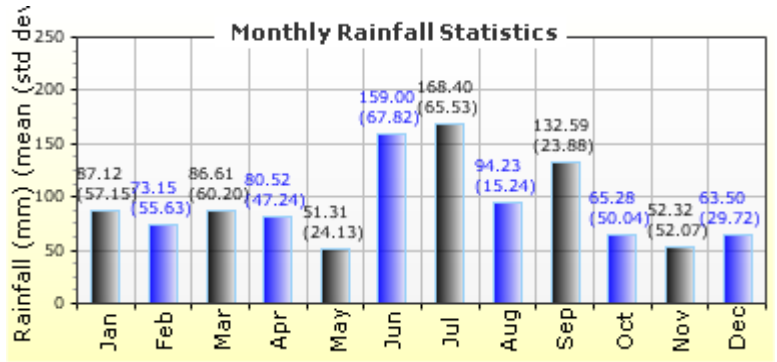
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

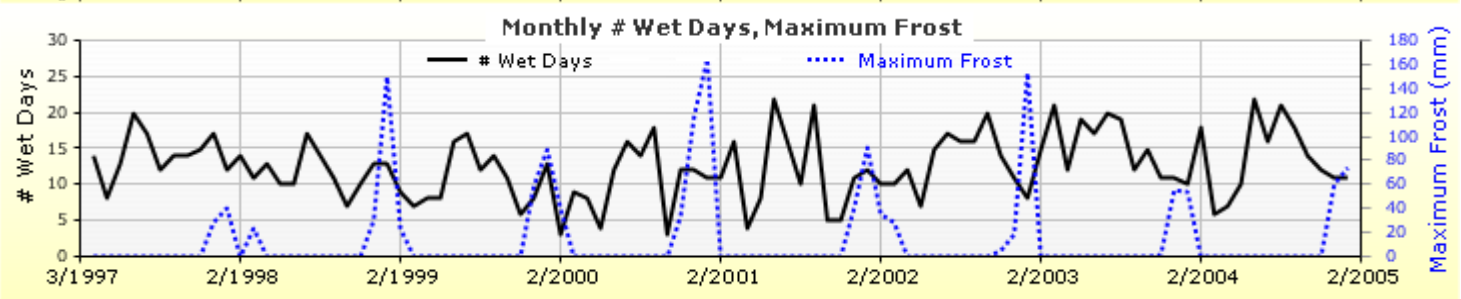
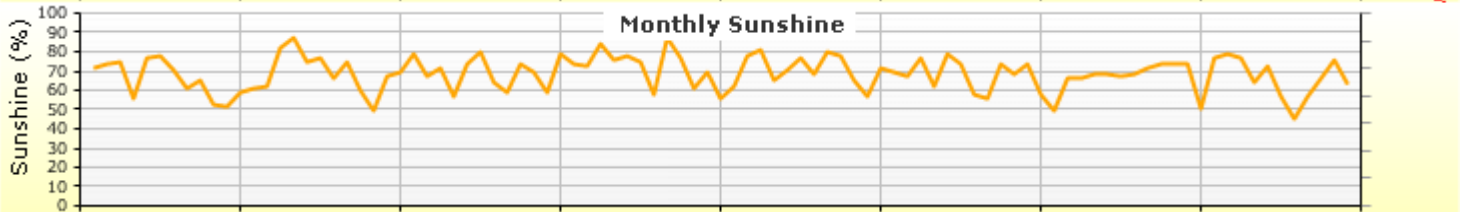
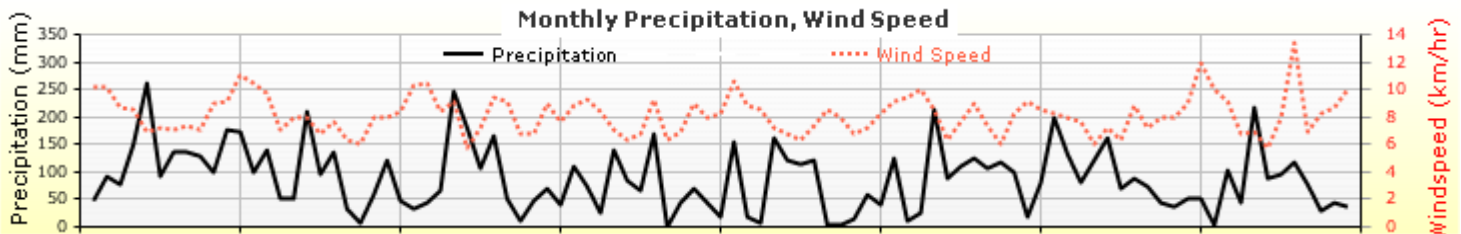
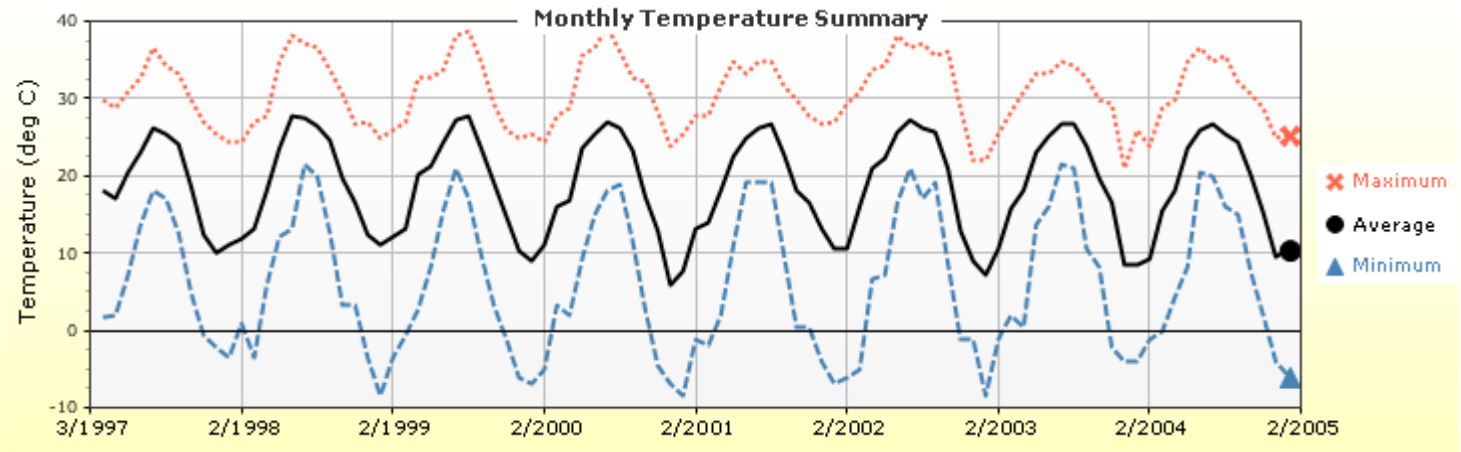
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

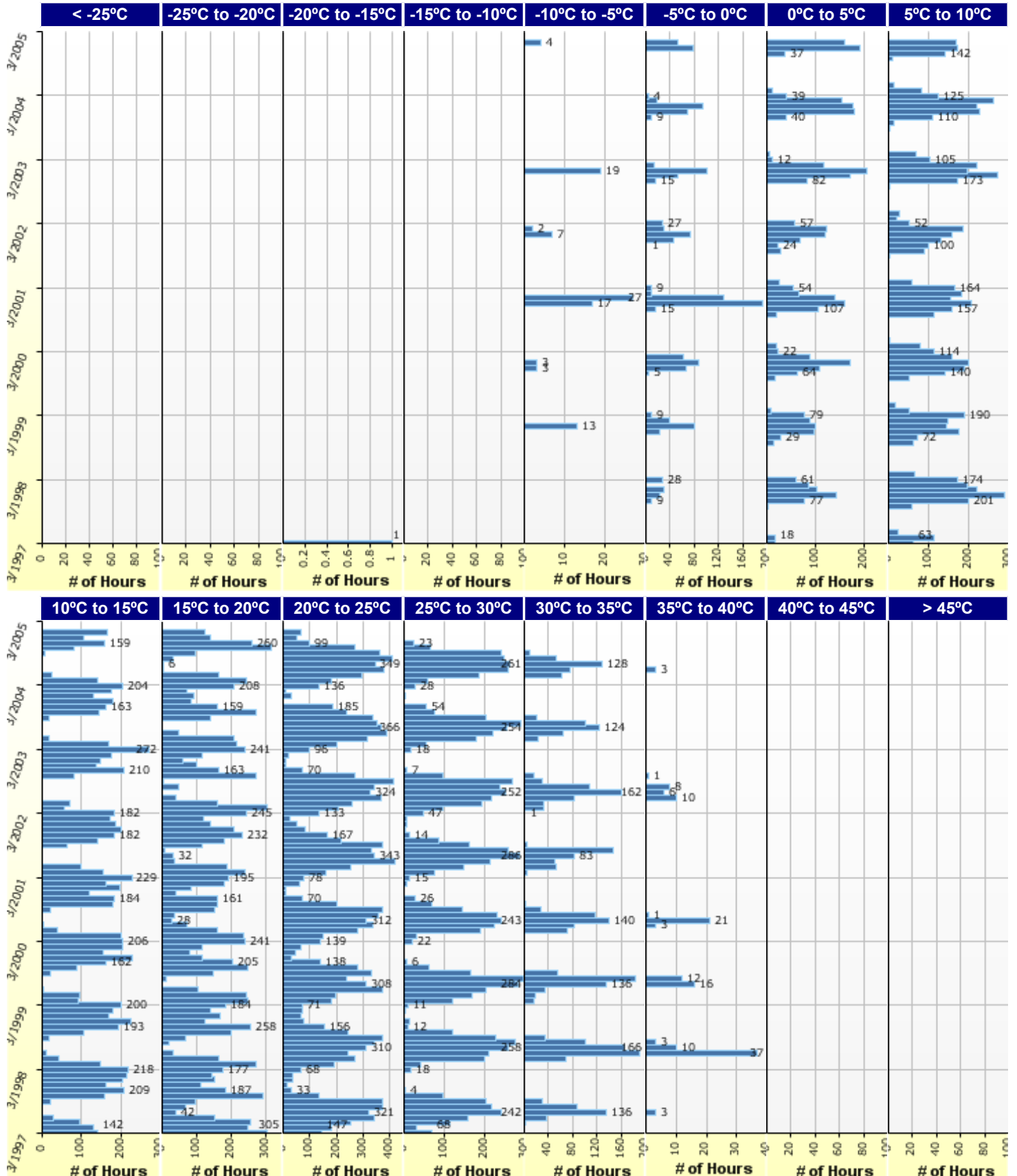


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF1_50%

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1_50%.dgp



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

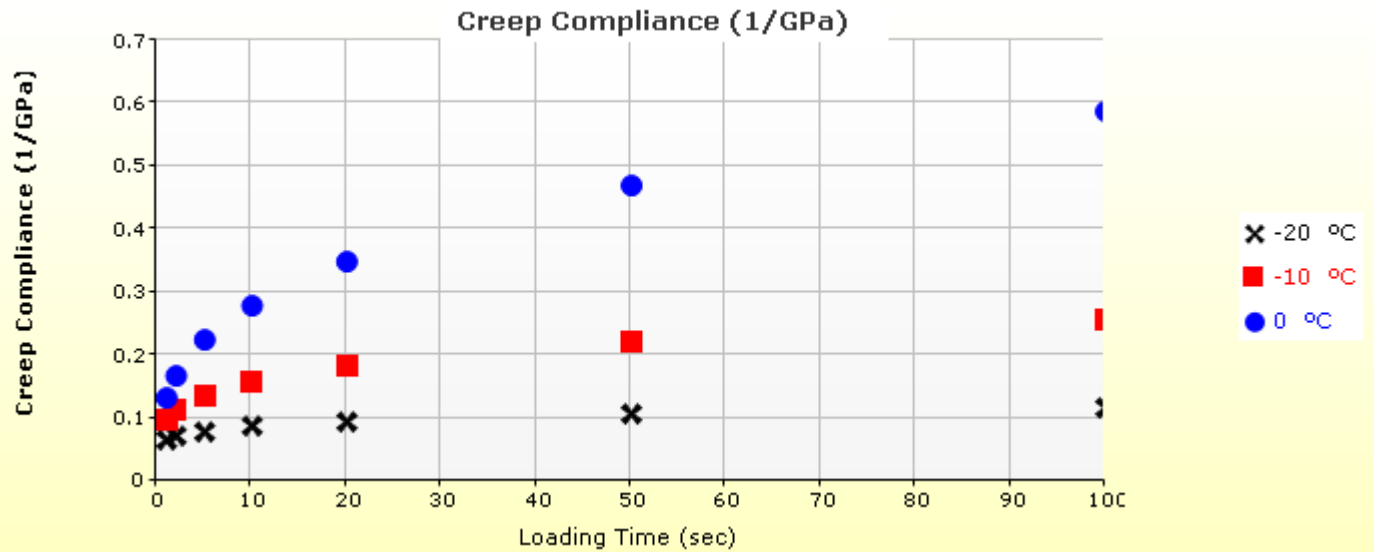
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

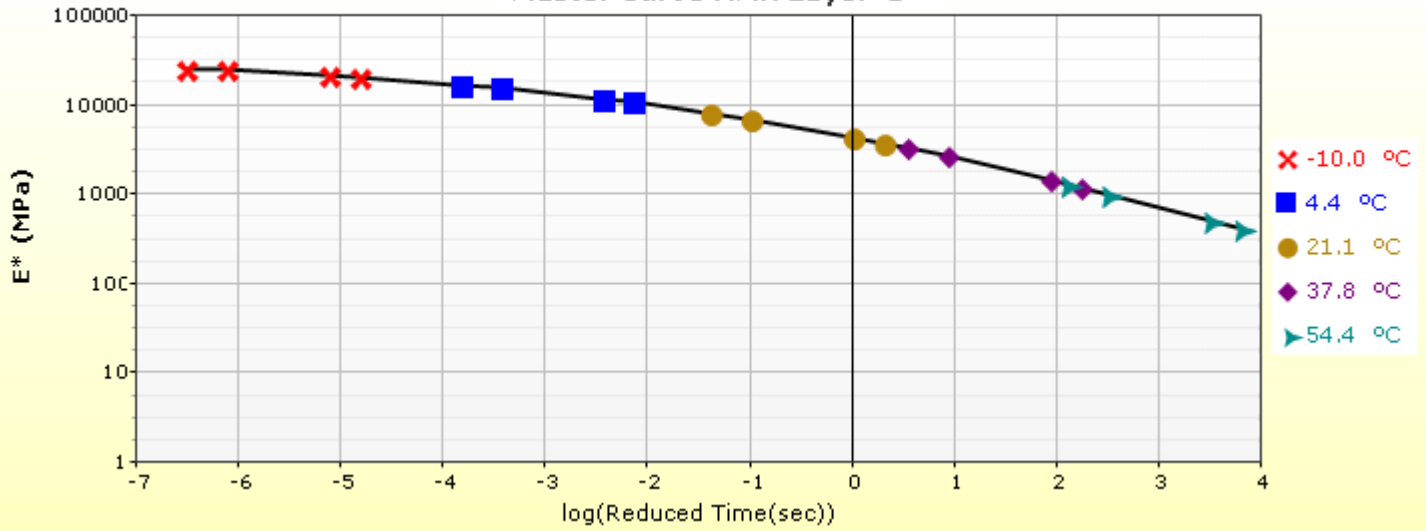
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

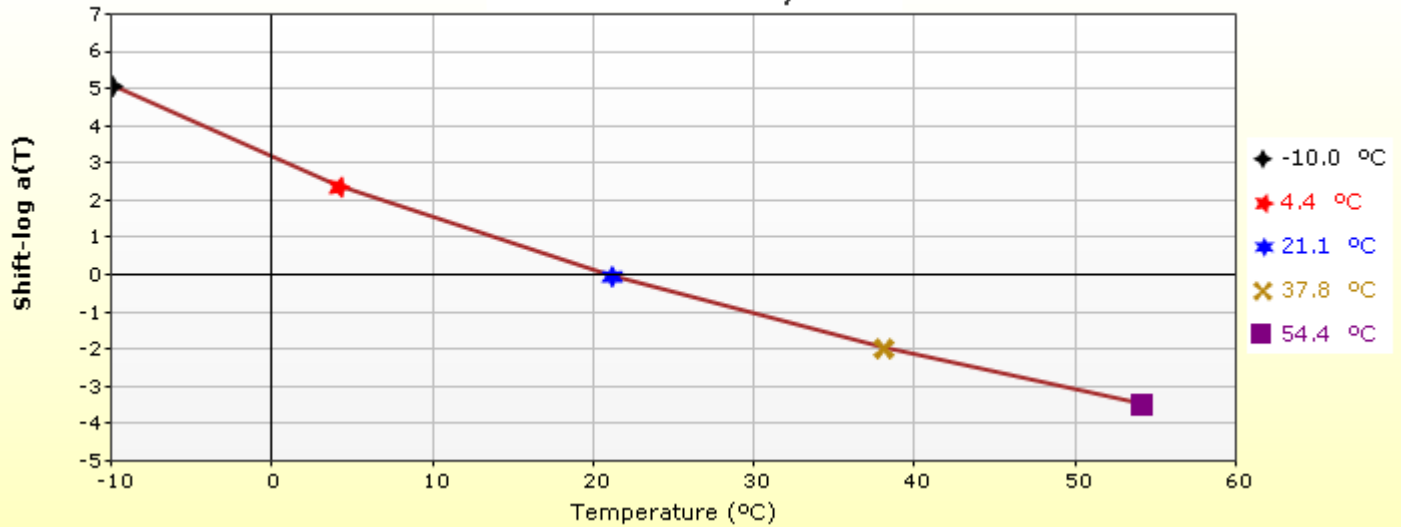


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

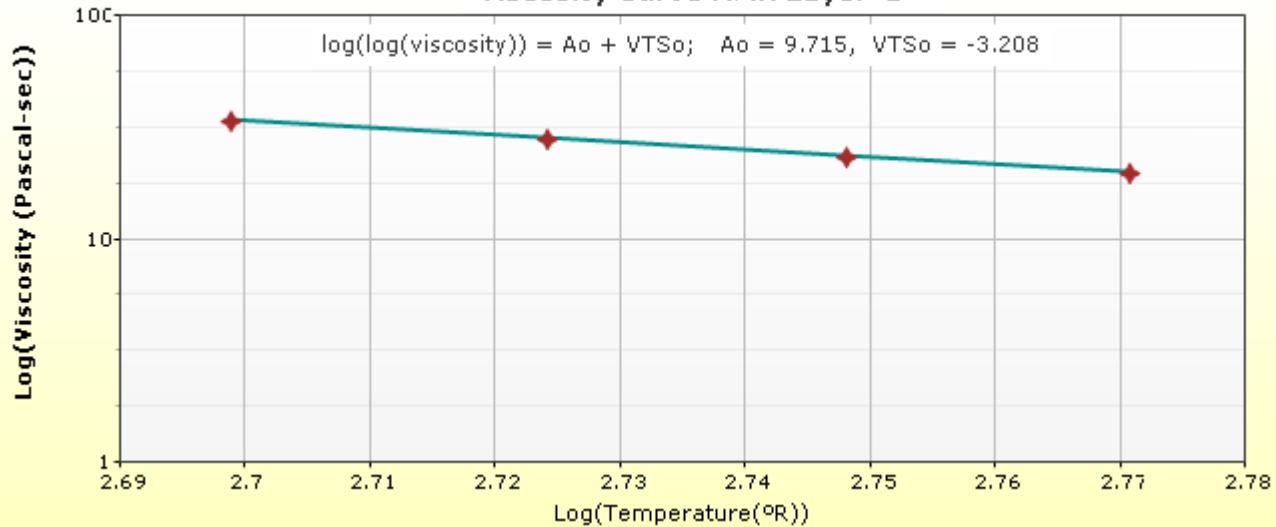
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

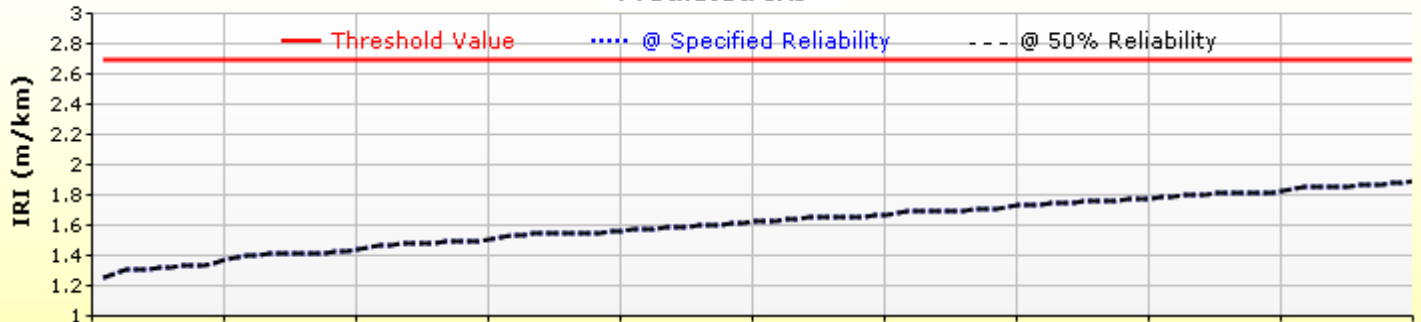


Viscosity Curve HMA Layer 1

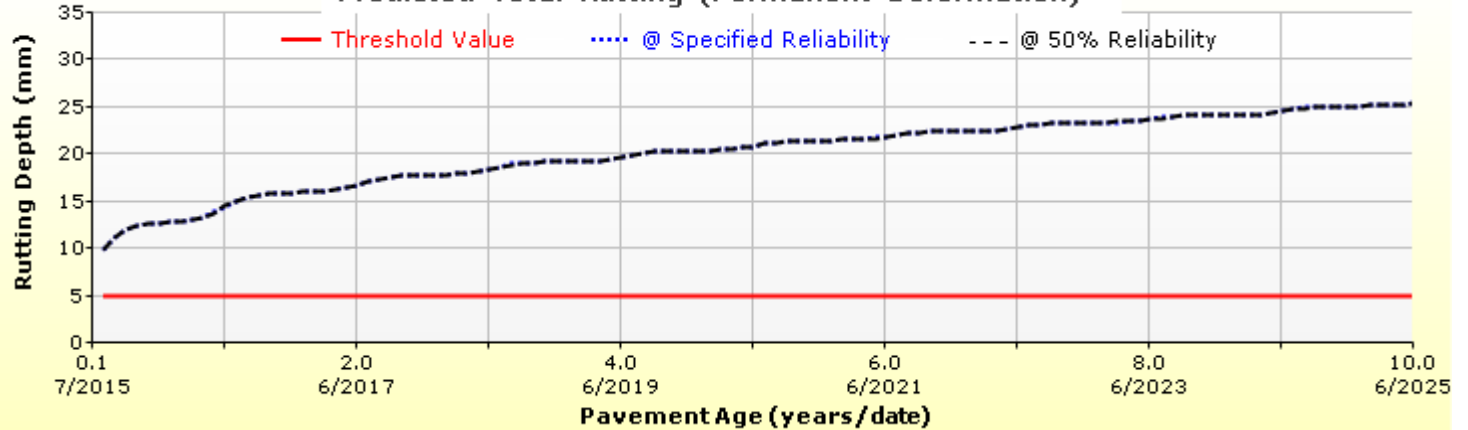


Analysis Output Charts

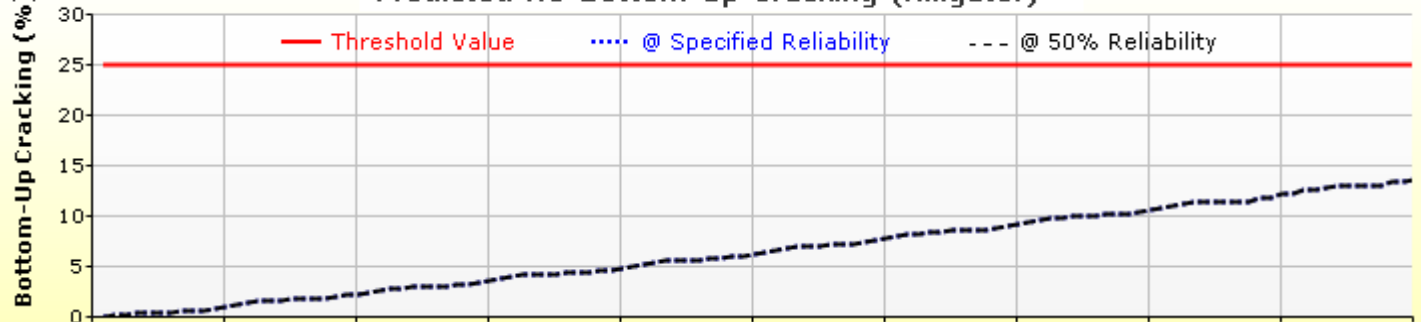
Predicted IRI



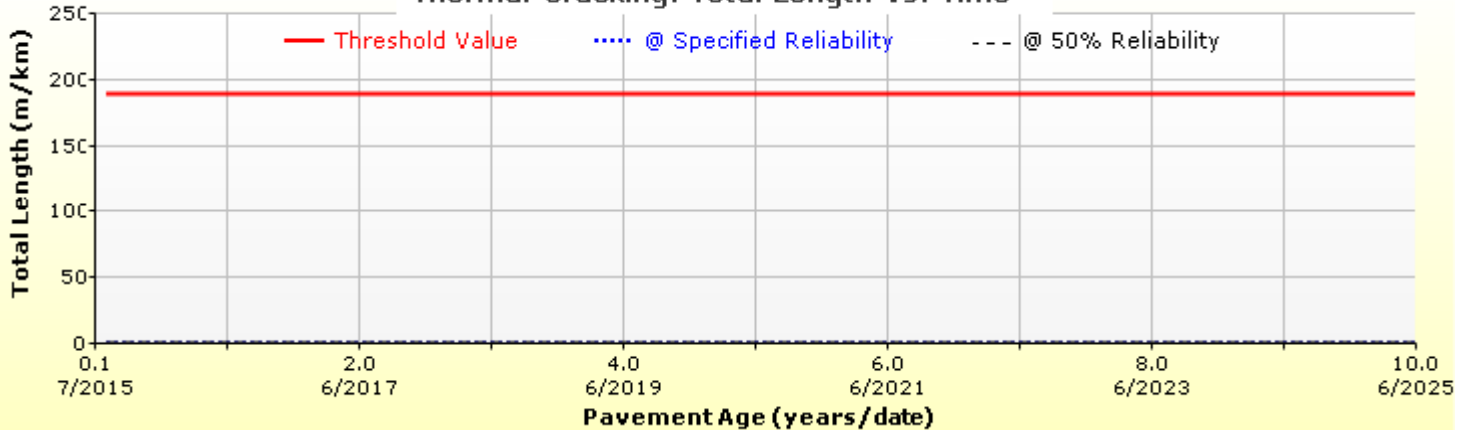
Predicted Total Rutting (Permanent Deformation)



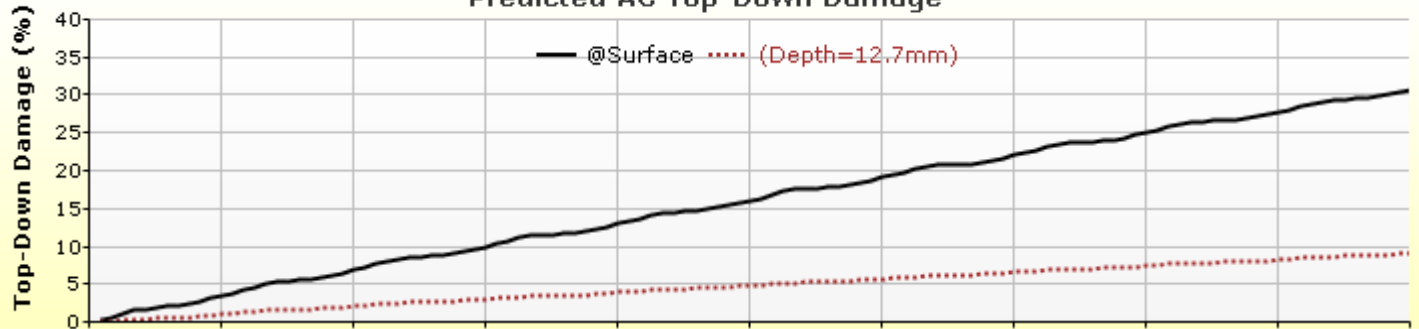
Predicted AC Bottom-Up Cracking (Alligator)



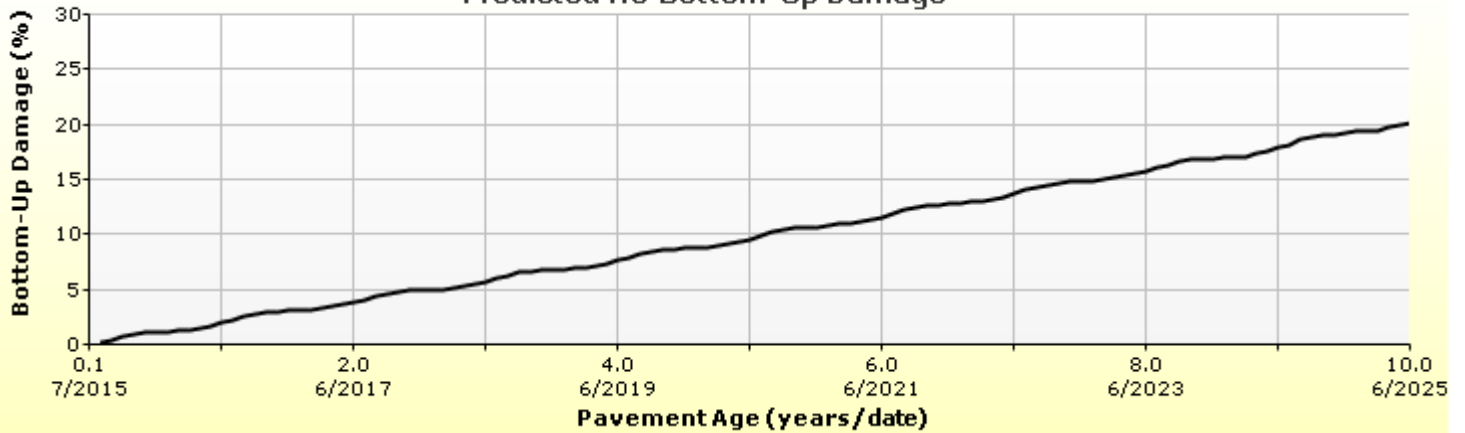
Thermal Cracking: Total Length vs. Time



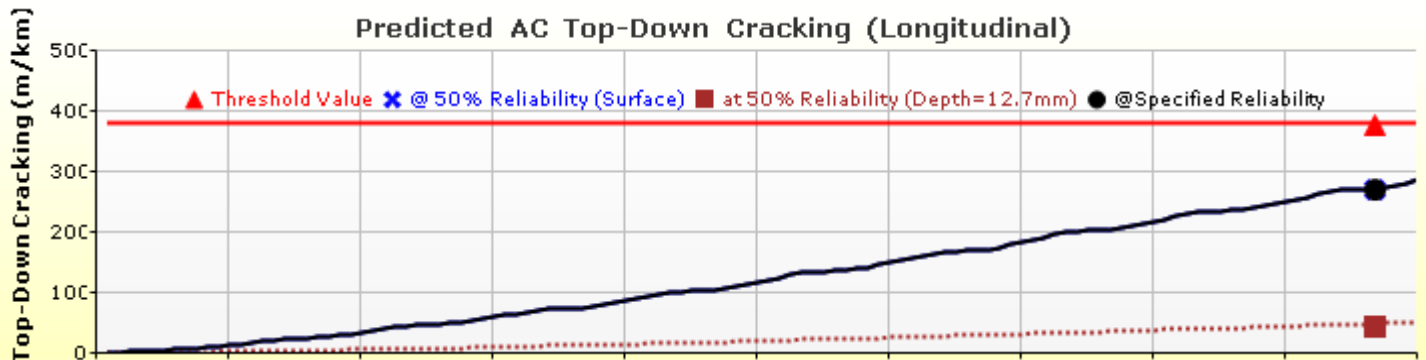
Predicted AC Top-Down Damage



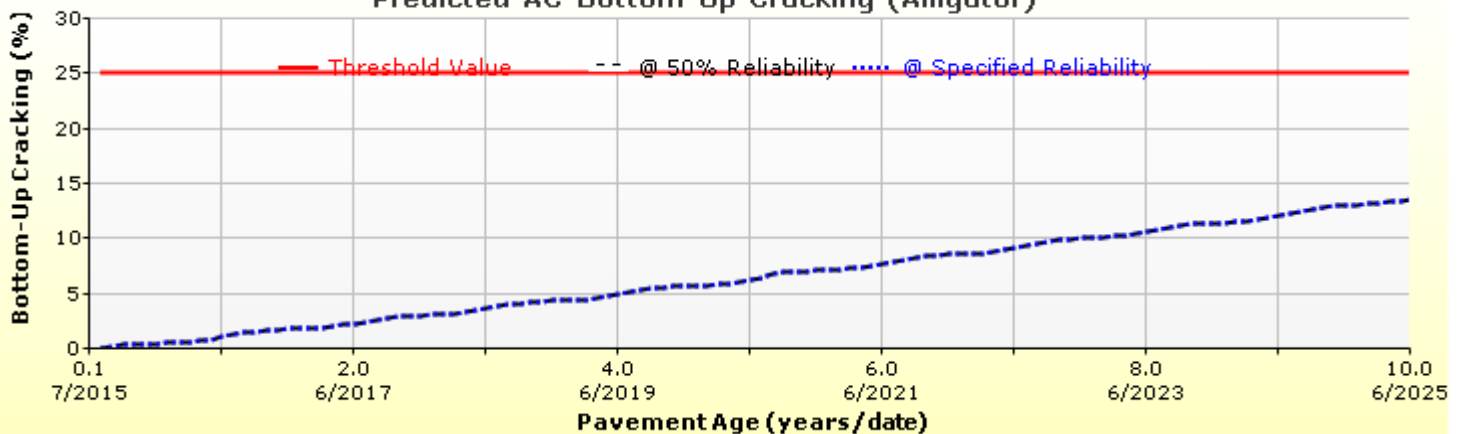
Predicted AC Bottom-Up Damage



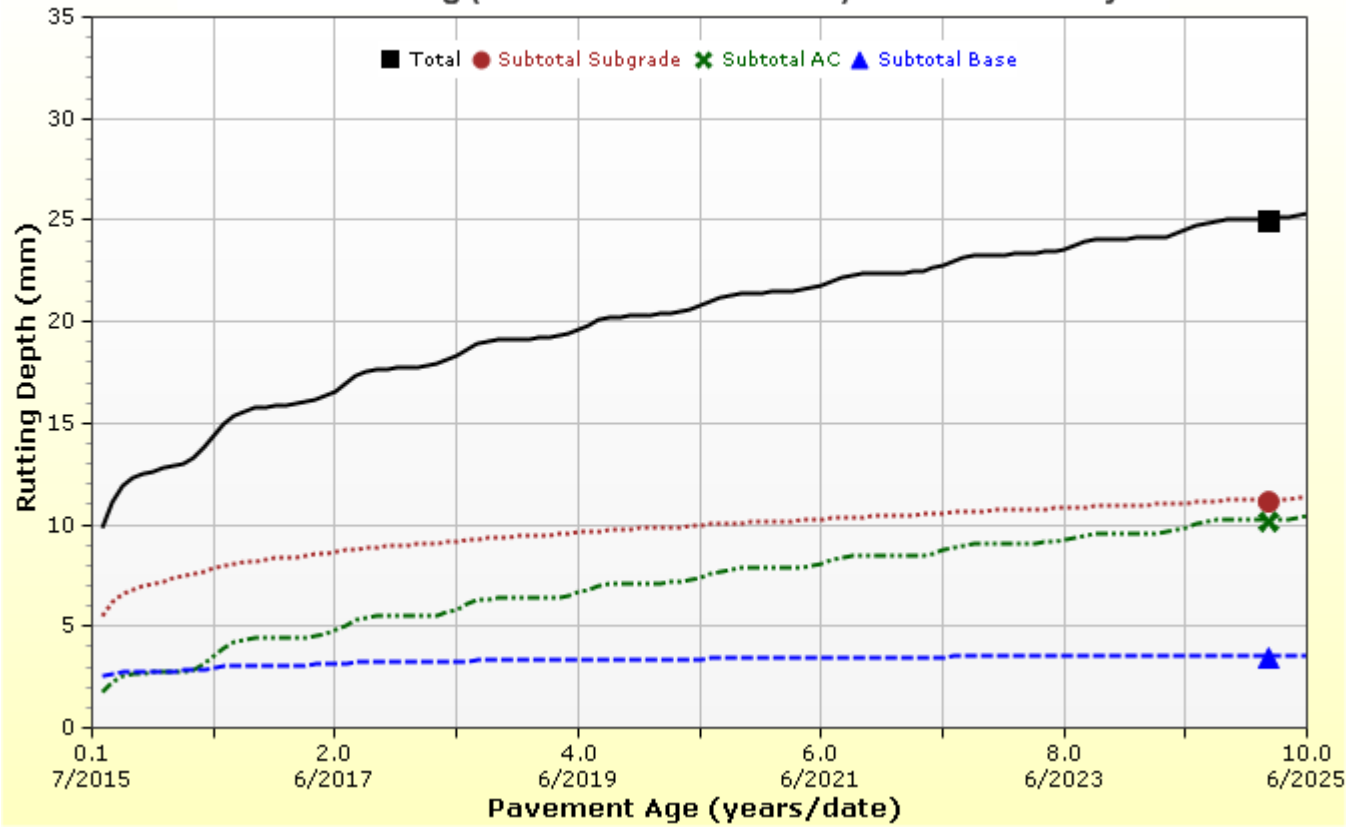
Predicted AC Top-Down Cracking (Longitudinal)

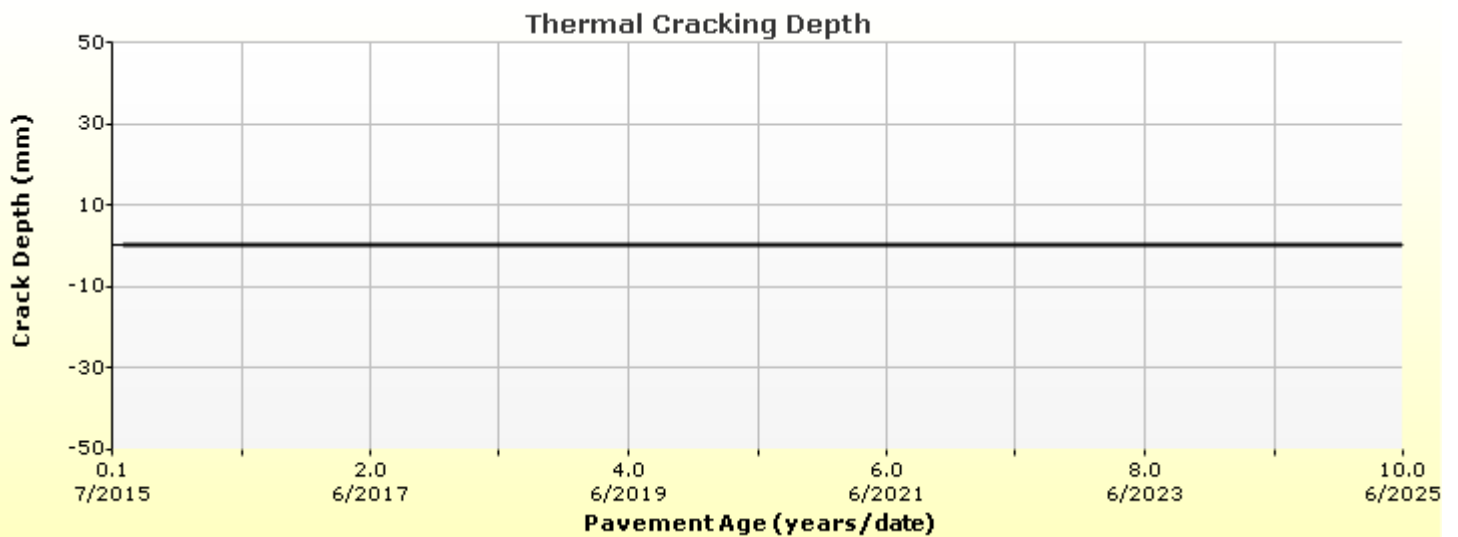
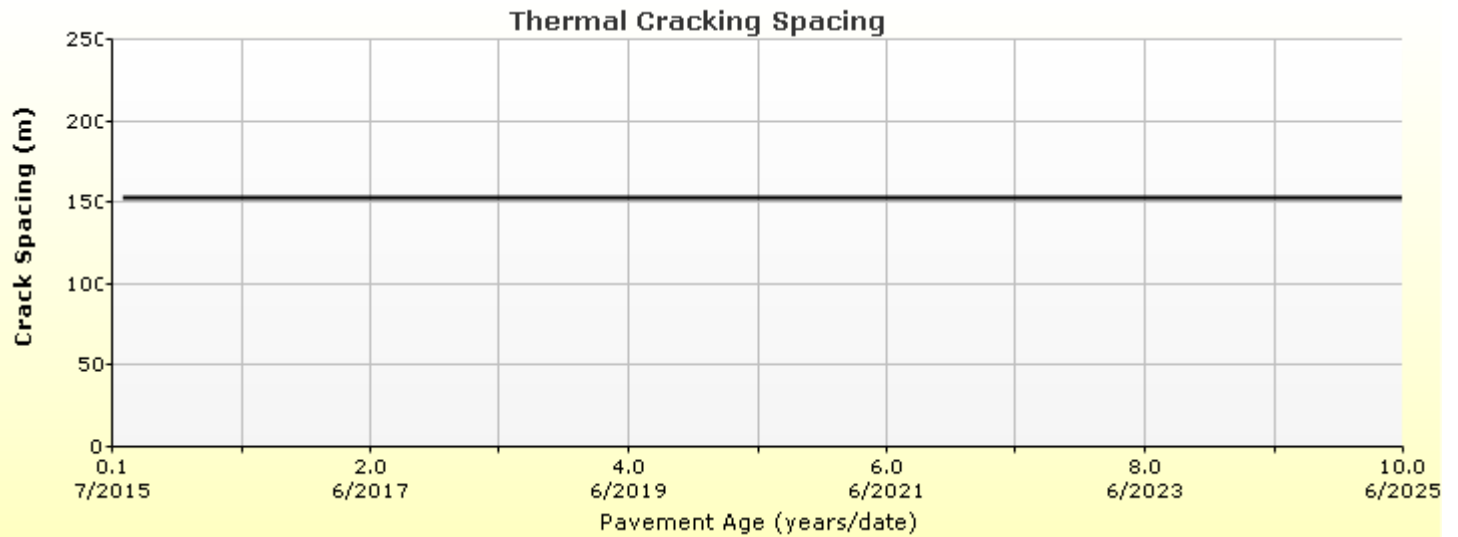


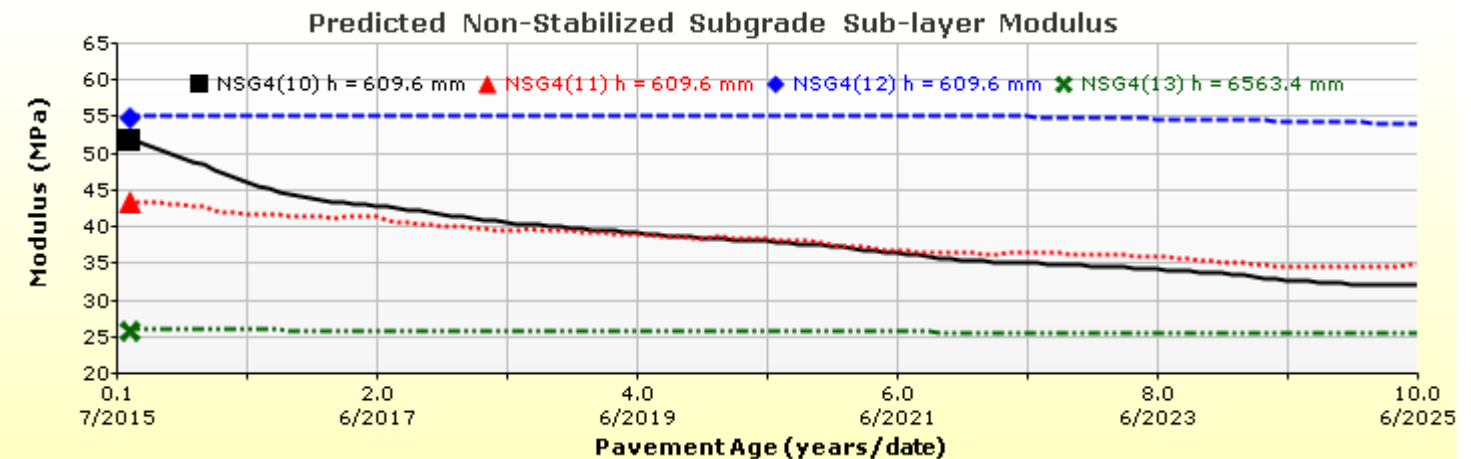
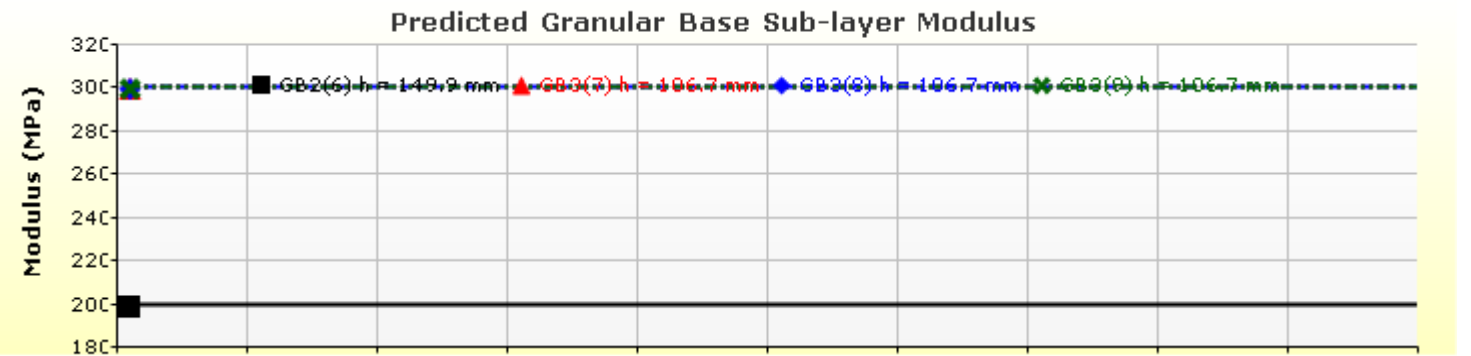
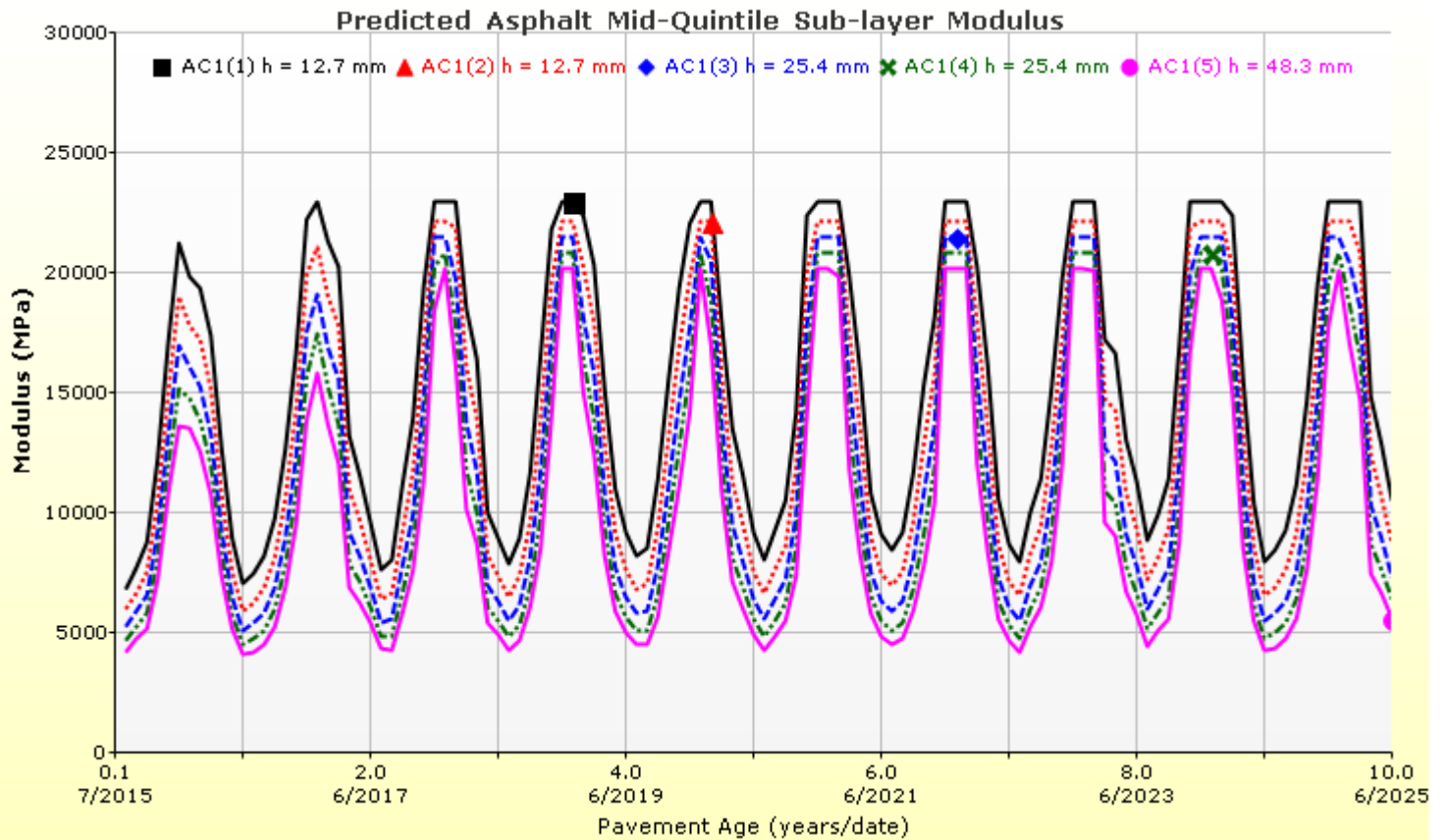
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

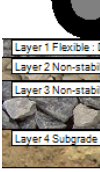
C3: 0.008

C4: 0.015

Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data: 32.119, -81.202
 Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
 Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

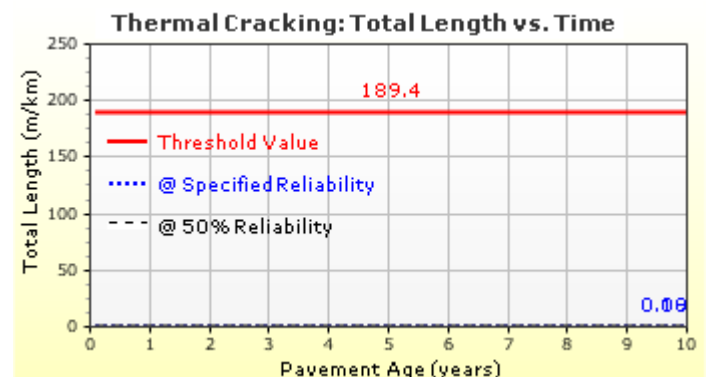
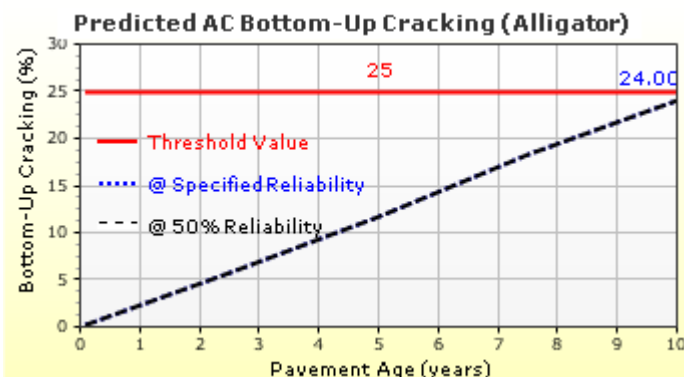
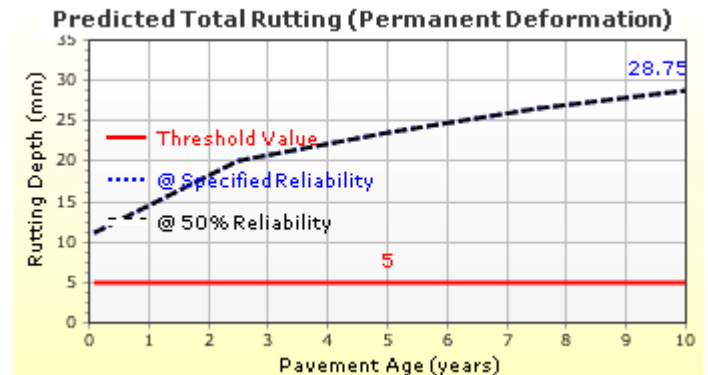
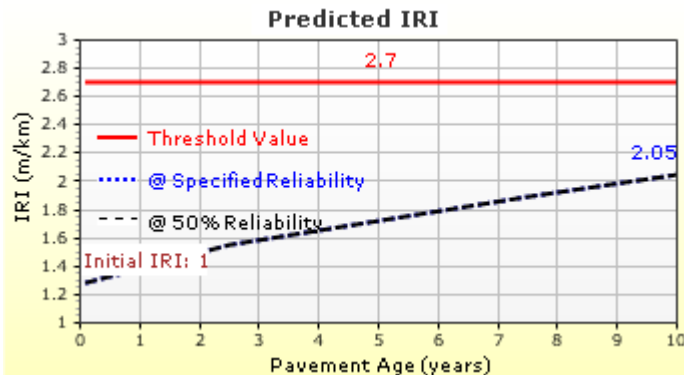
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	4,820
2020 (5 years)	4,486,440
2025 (10 years)	9,687,460

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.05	50.00	88.19	Pass
Permanent deformation - total pavement (mm)	5.00	28.75	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	24.00	50.00	52.82	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	465.91	50.00	42.17	Fail
Permanent deformation - AC only (mm)	5.00	12.21	50.00	1.74	Fail

Distress Charts

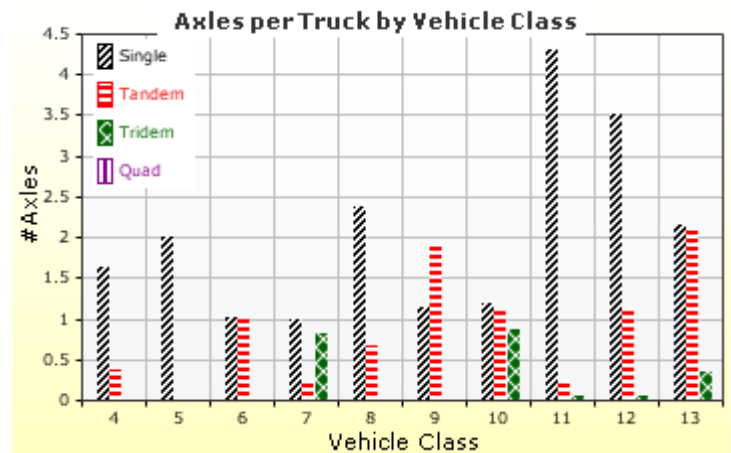
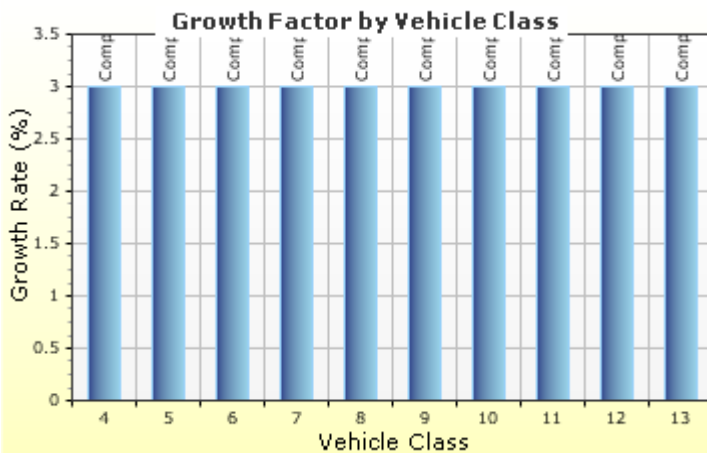
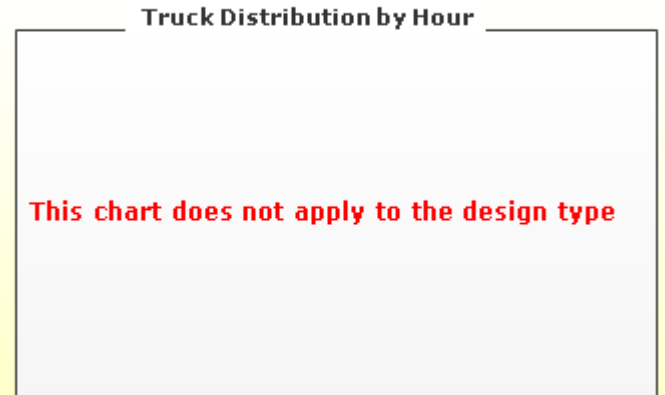
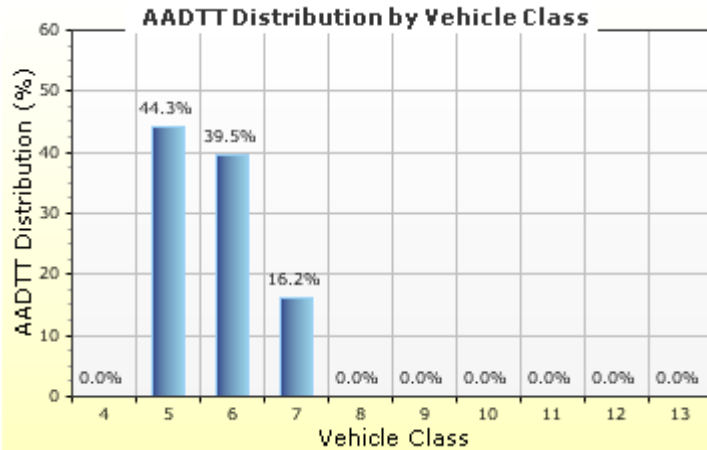


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 4,820
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

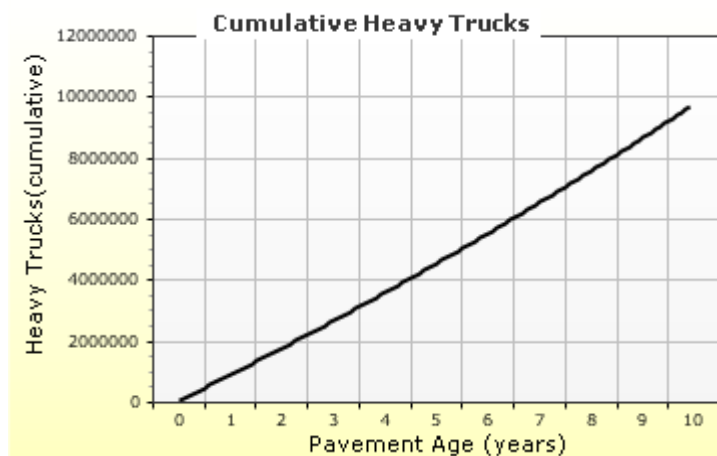
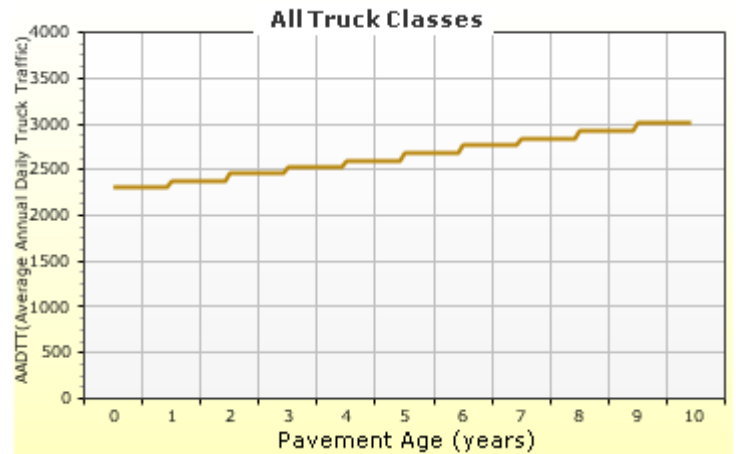
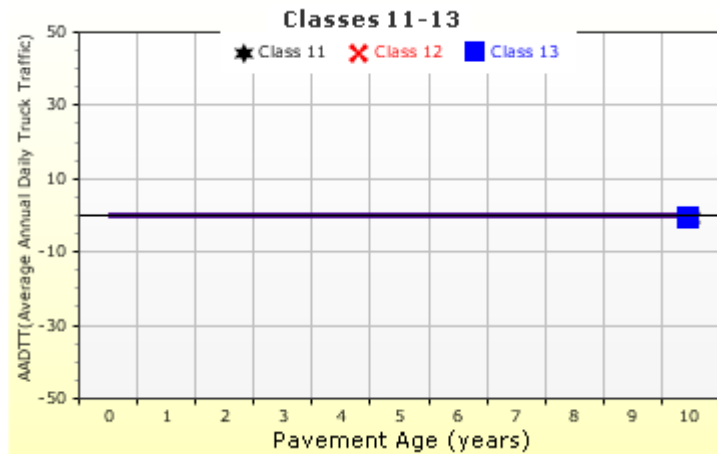
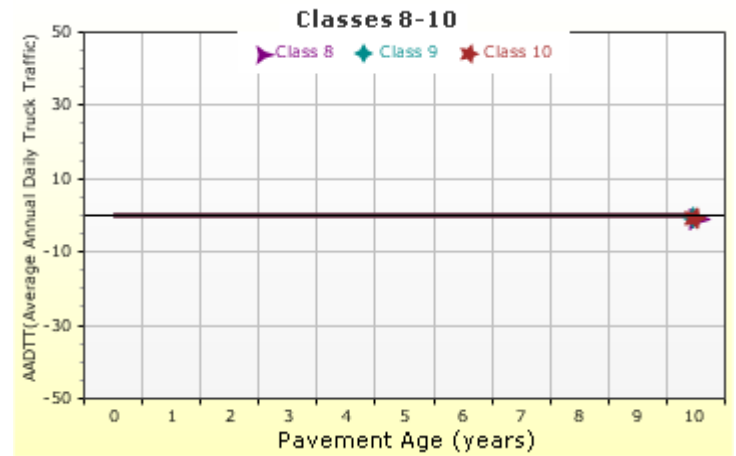
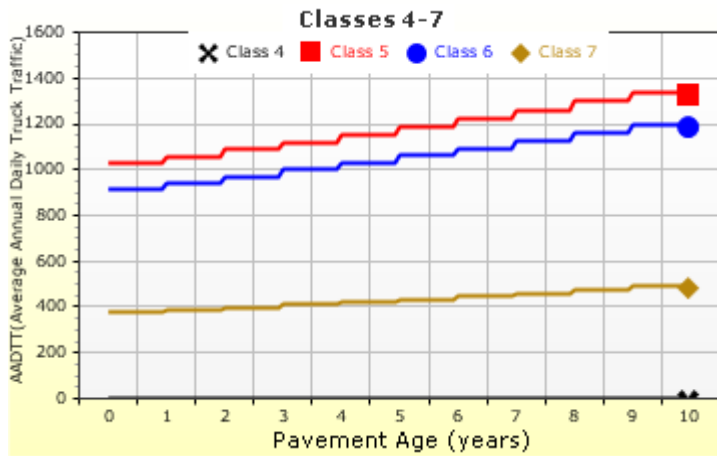
Wheelbase does not apply

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



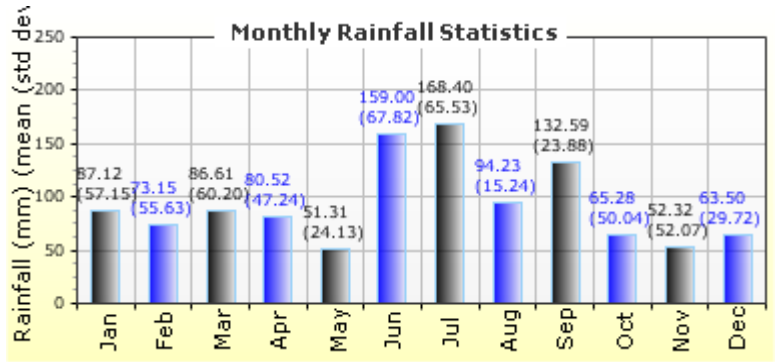
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

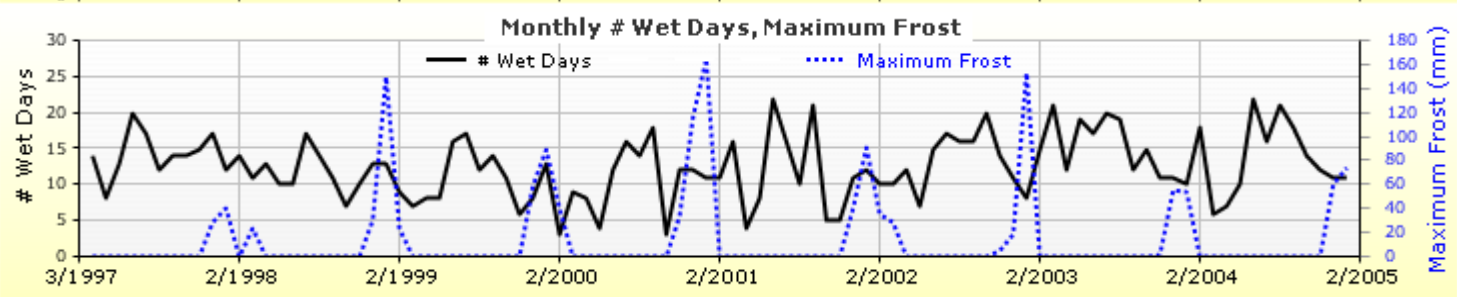
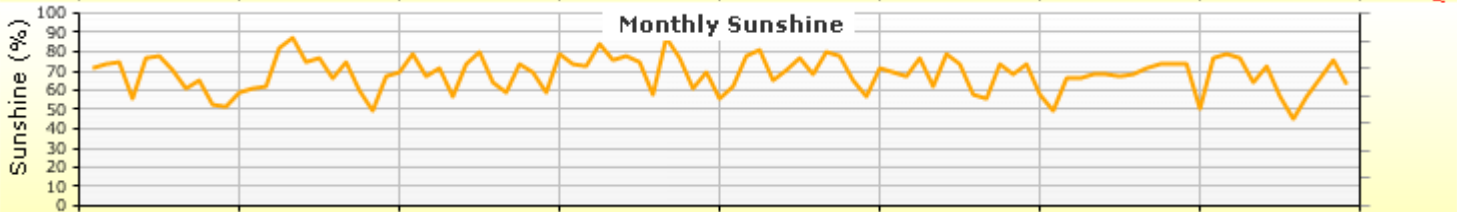
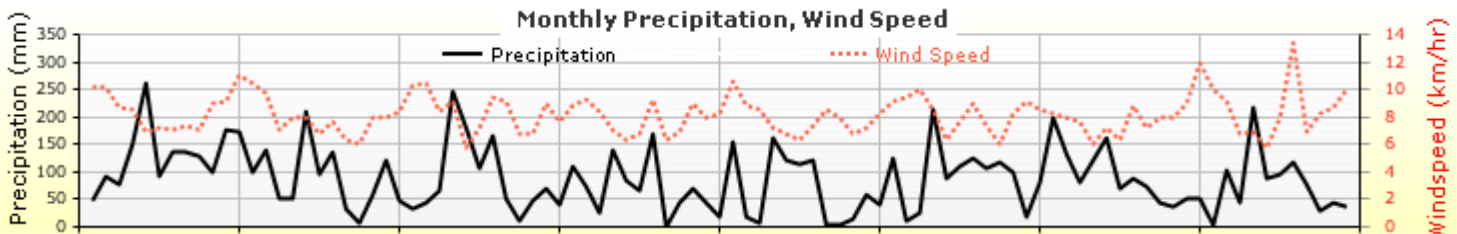
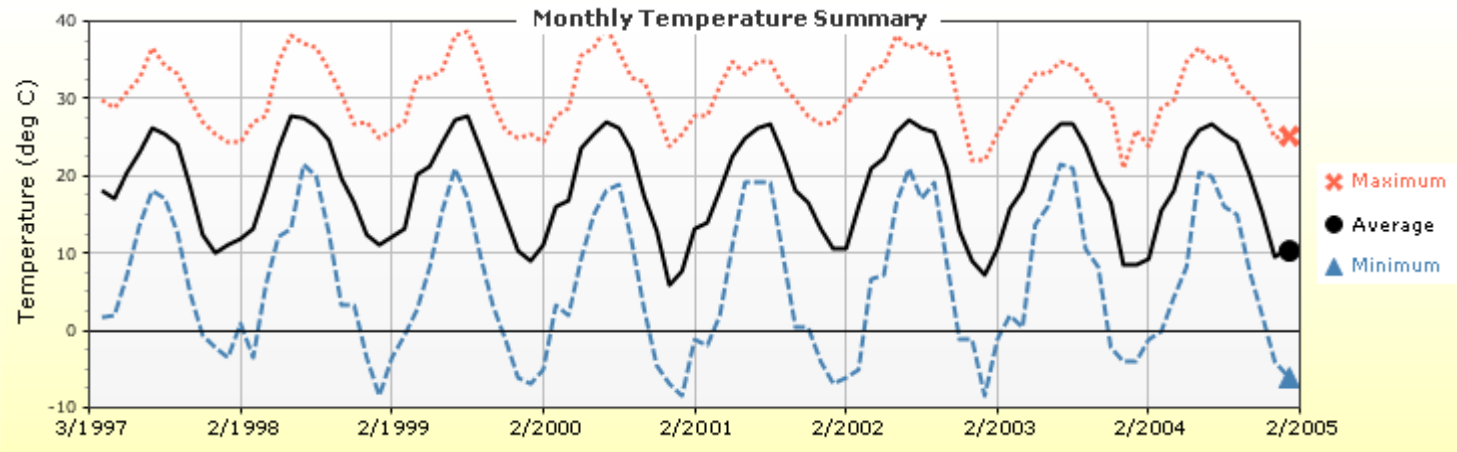
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

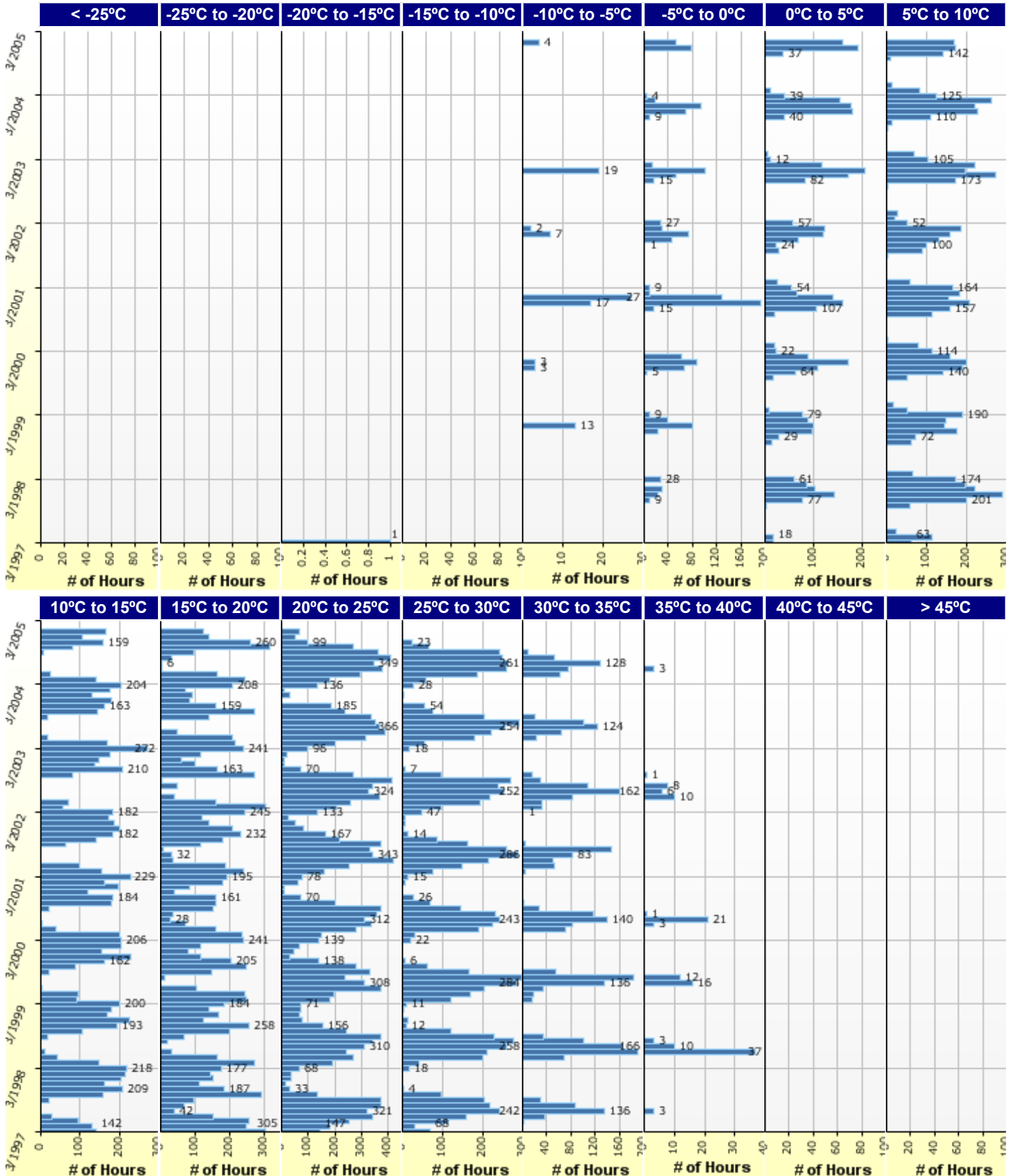


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF2_50%

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF2_50%.dgp



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

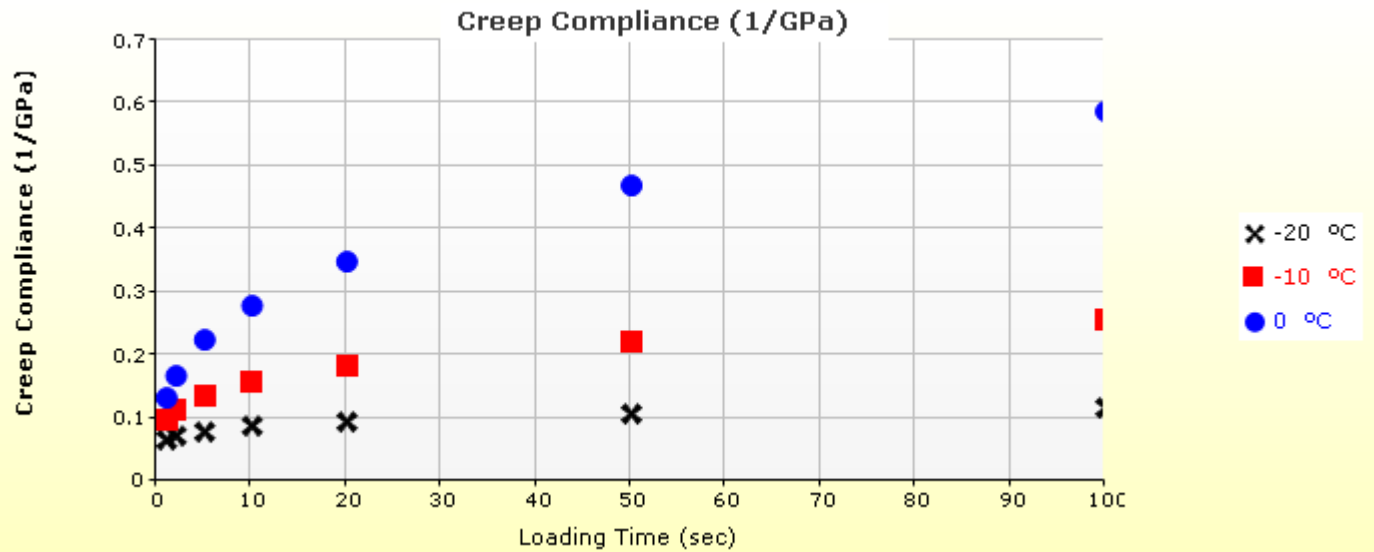
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

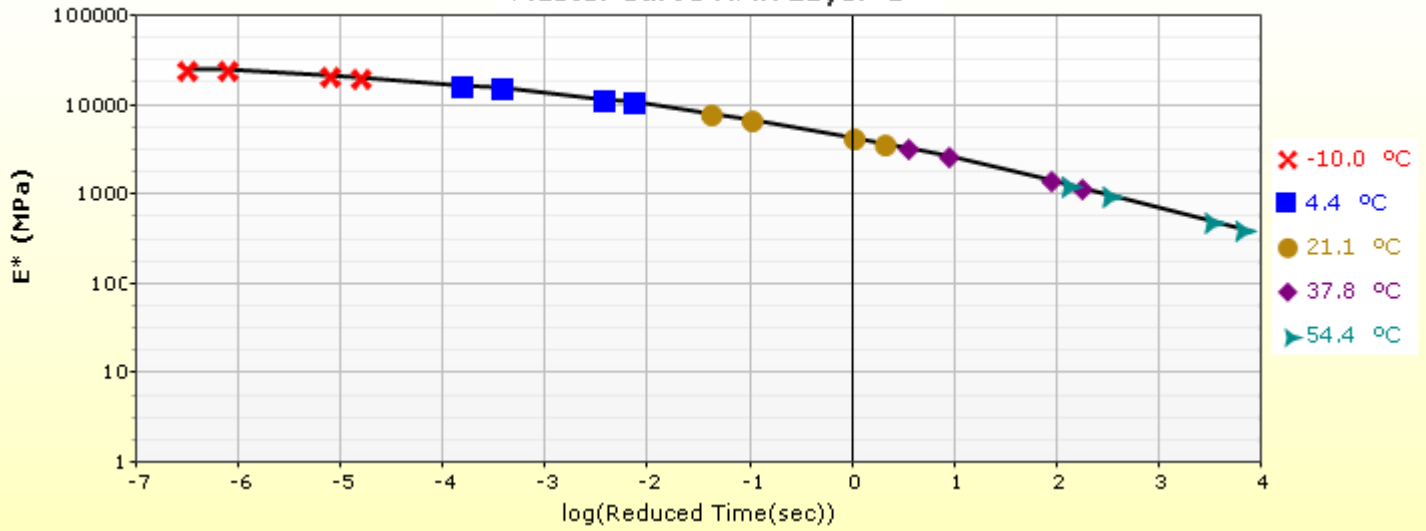
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

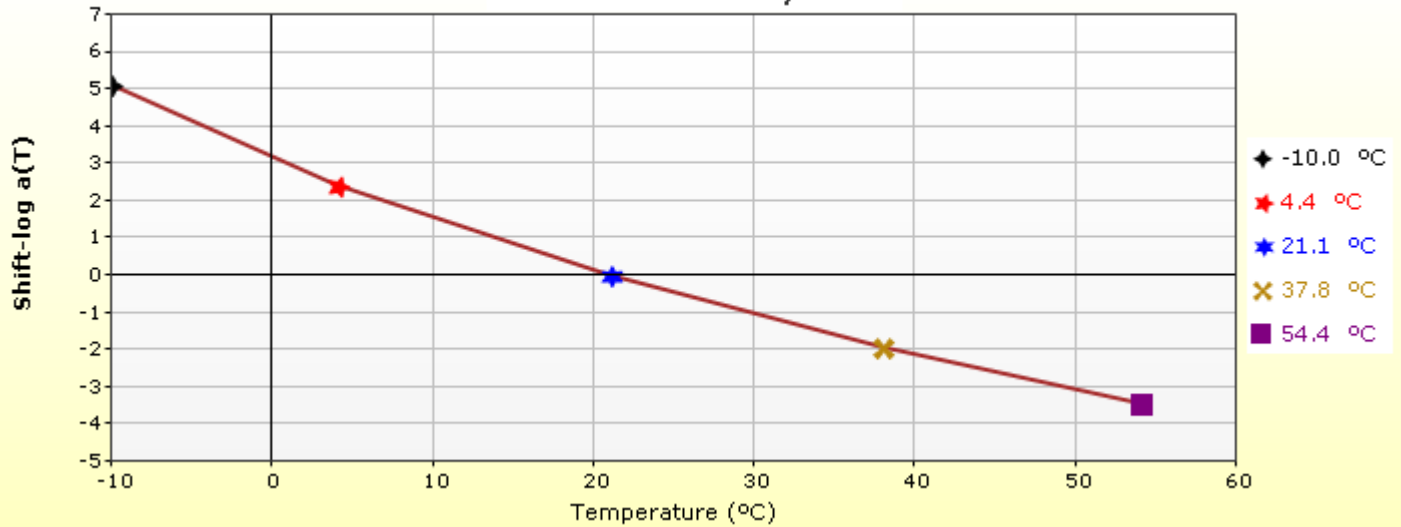


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

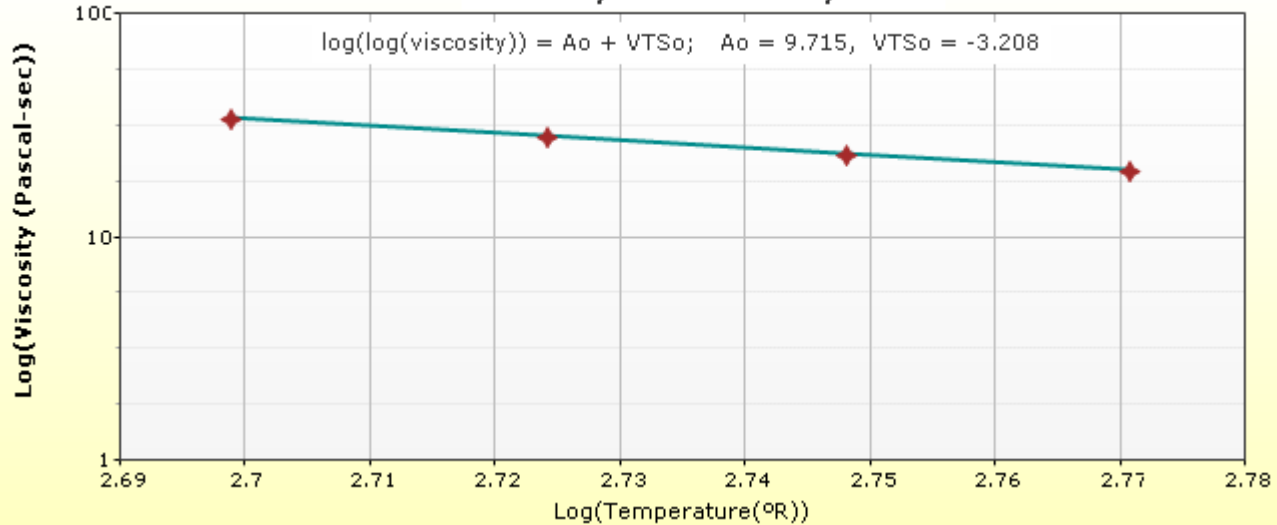
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

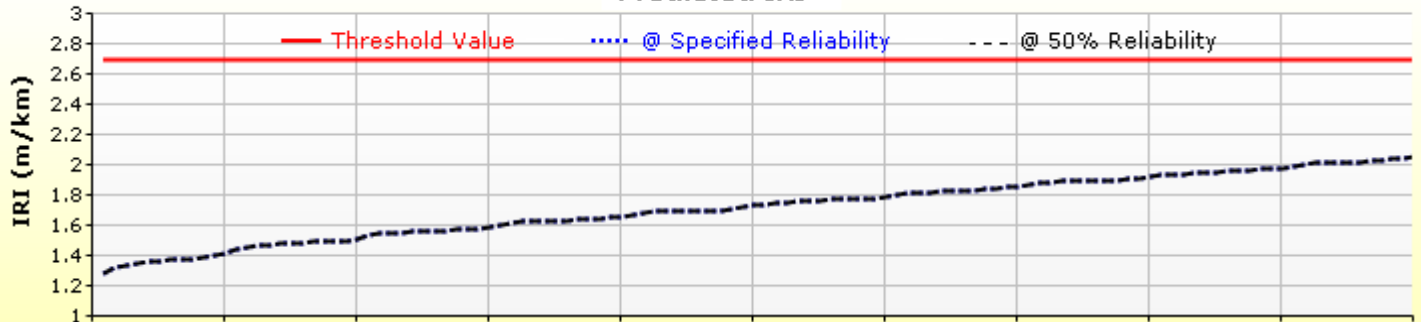


Viscosity Curve HMA Layer 1

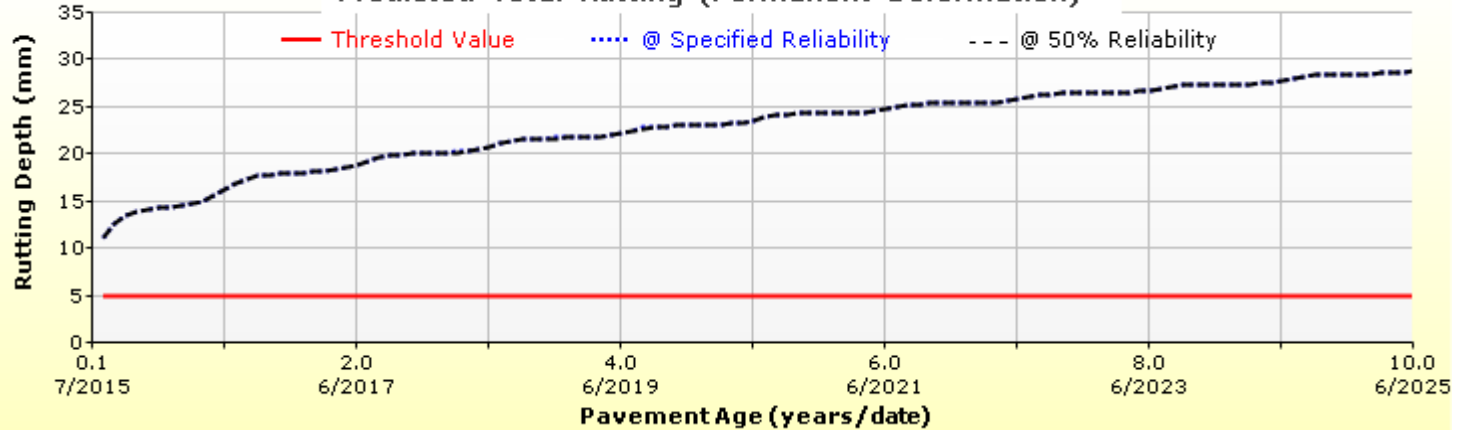


Analysis Output Charts

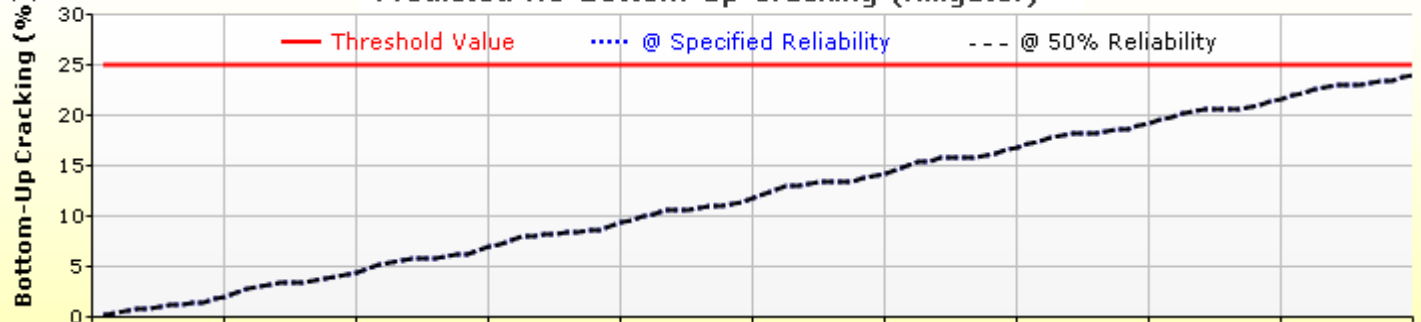
Predicted IRI



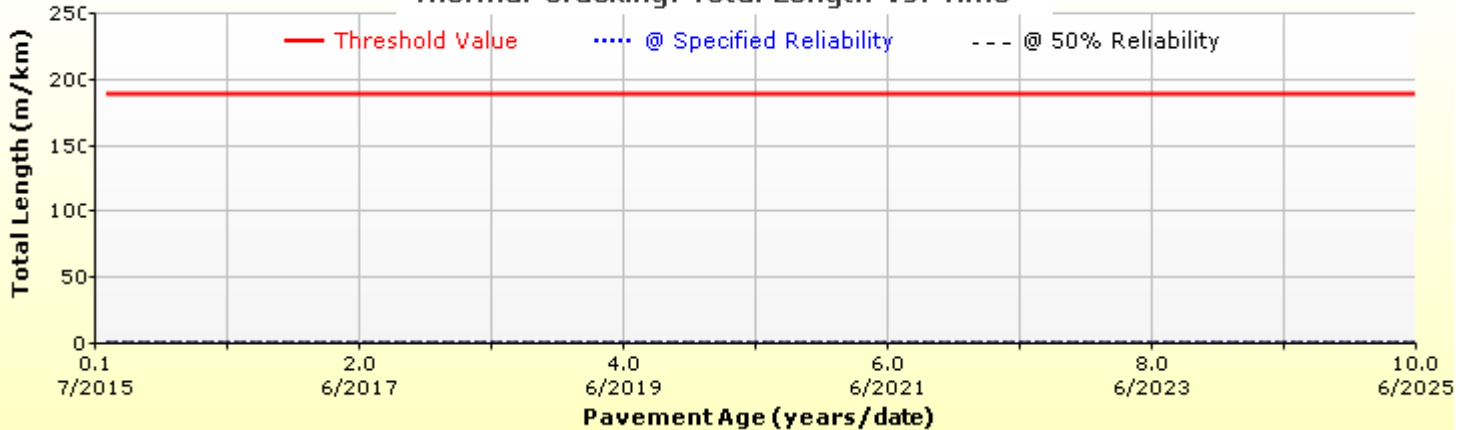
Predicted Total Rutting (Permanent Deformation)



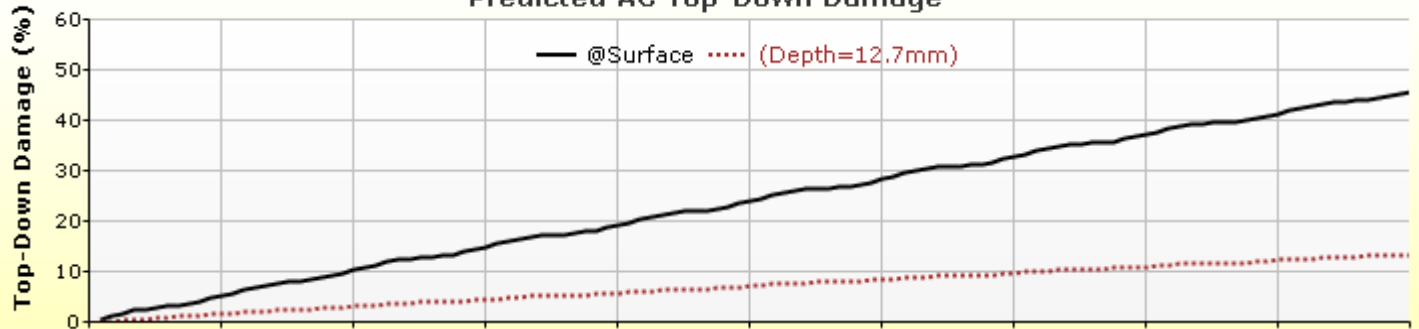
Predicted AC Bottom-Up Cracking (Alligator)



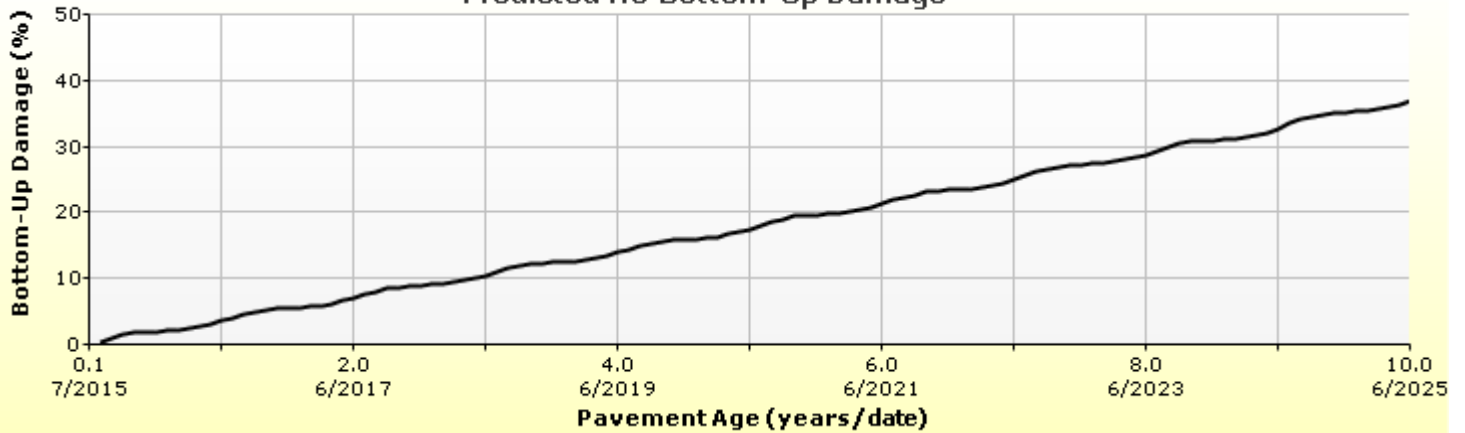
Thermal Cracking: Total Length vs. Time



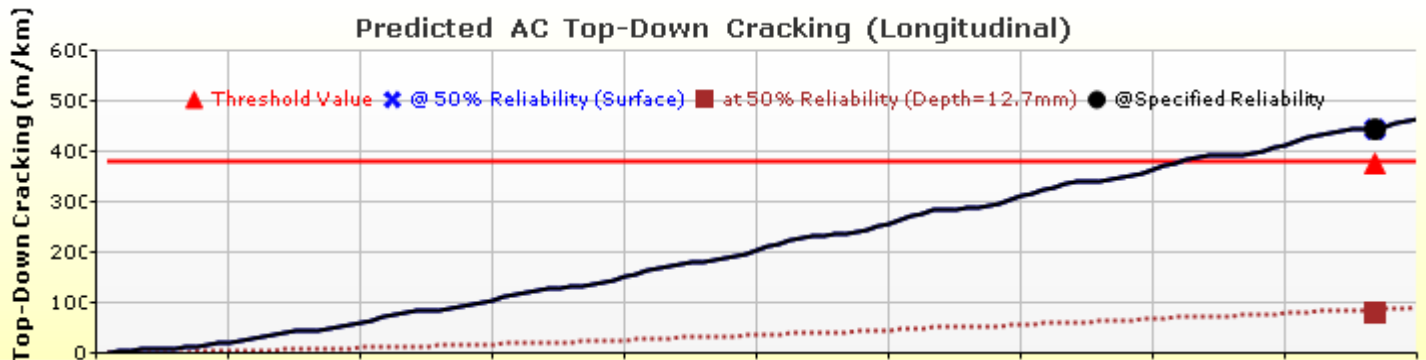
Predicted AC Top-Down Damage



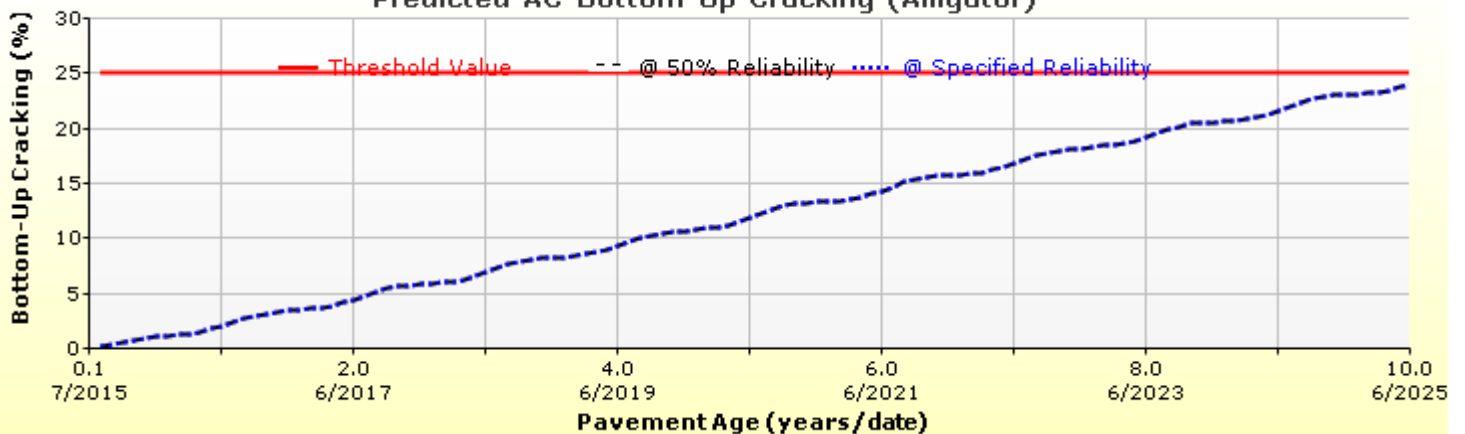
Predicted AC Bottom-Up Damage



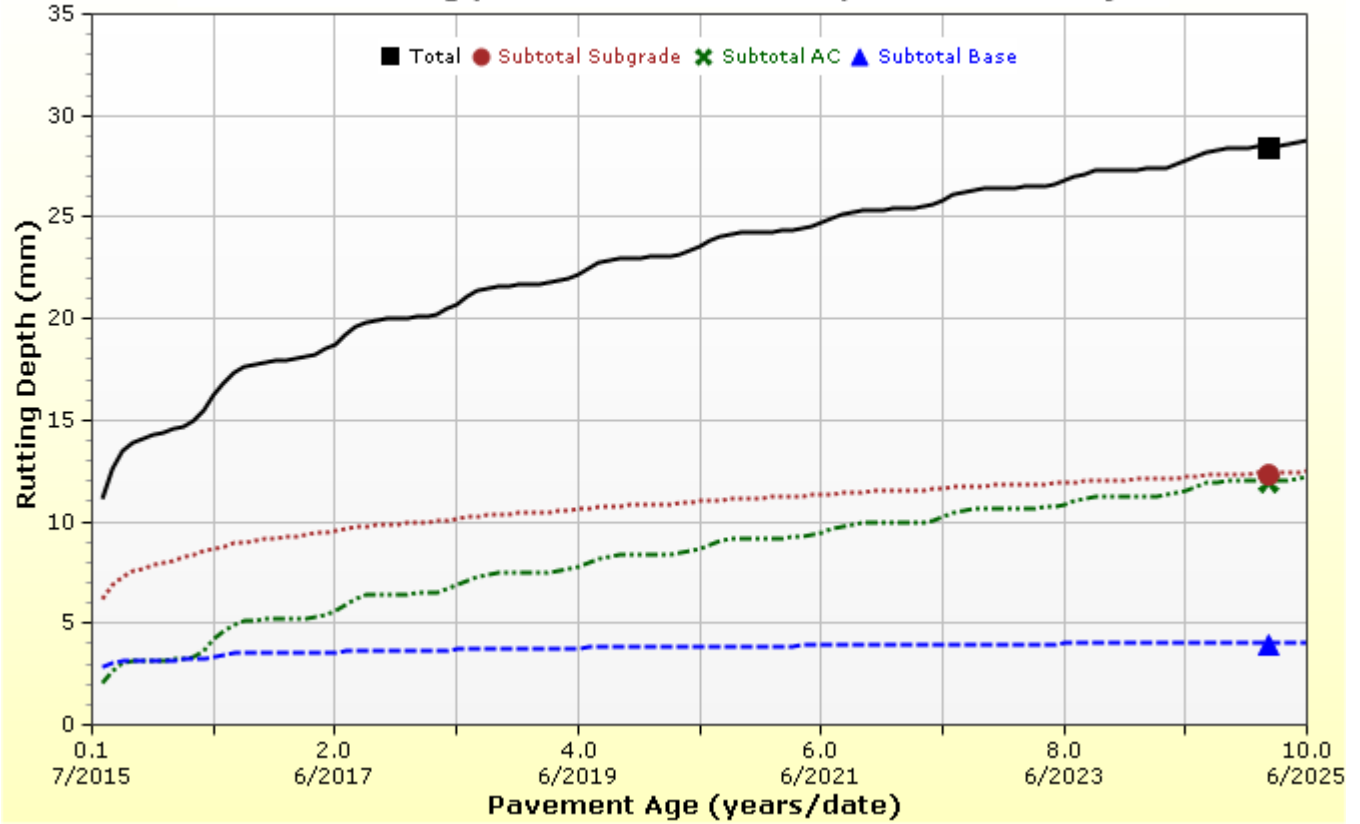
Predicted AC Top-Down Cracking (Longitudinal)

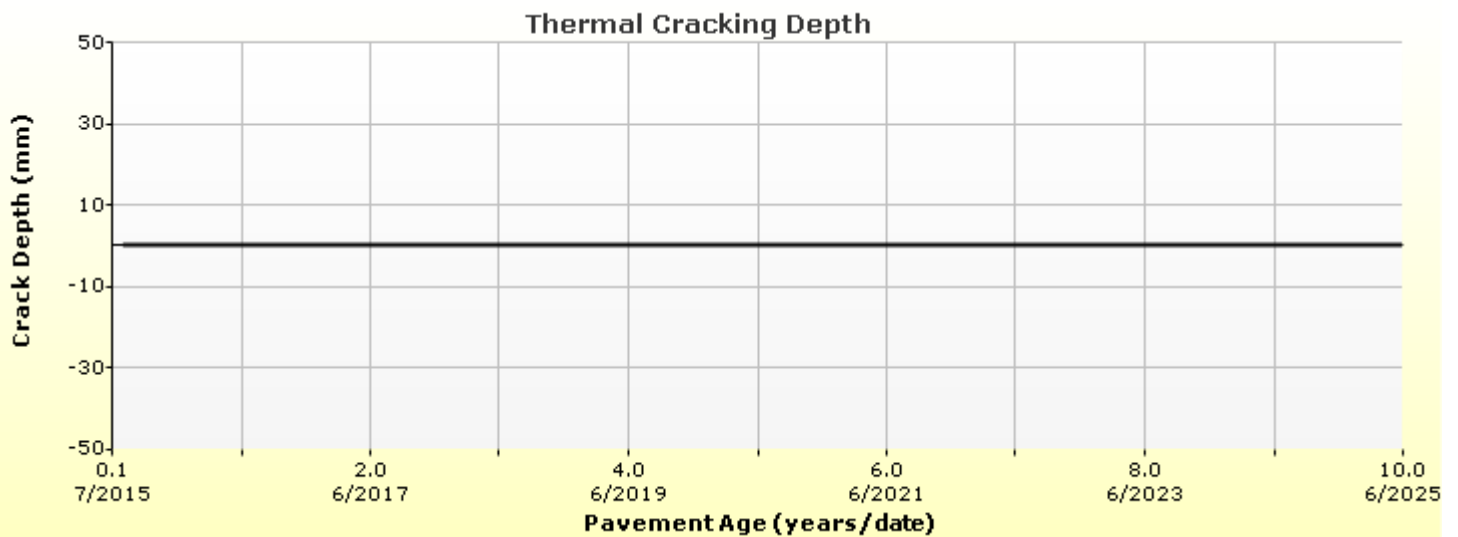
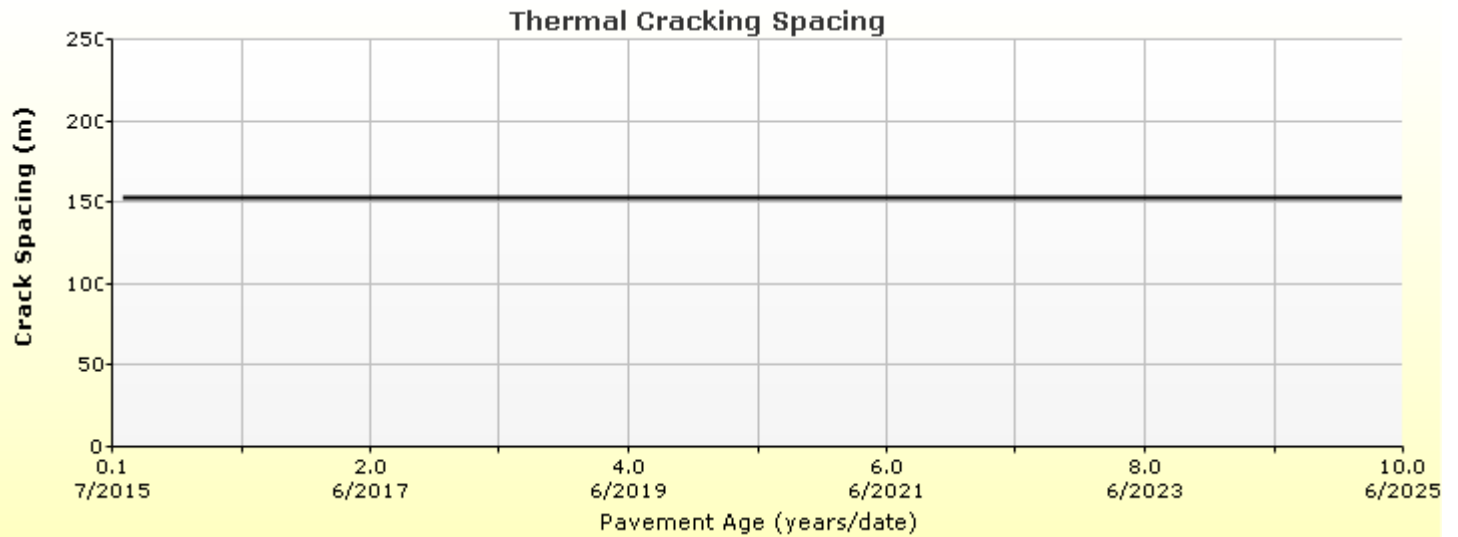


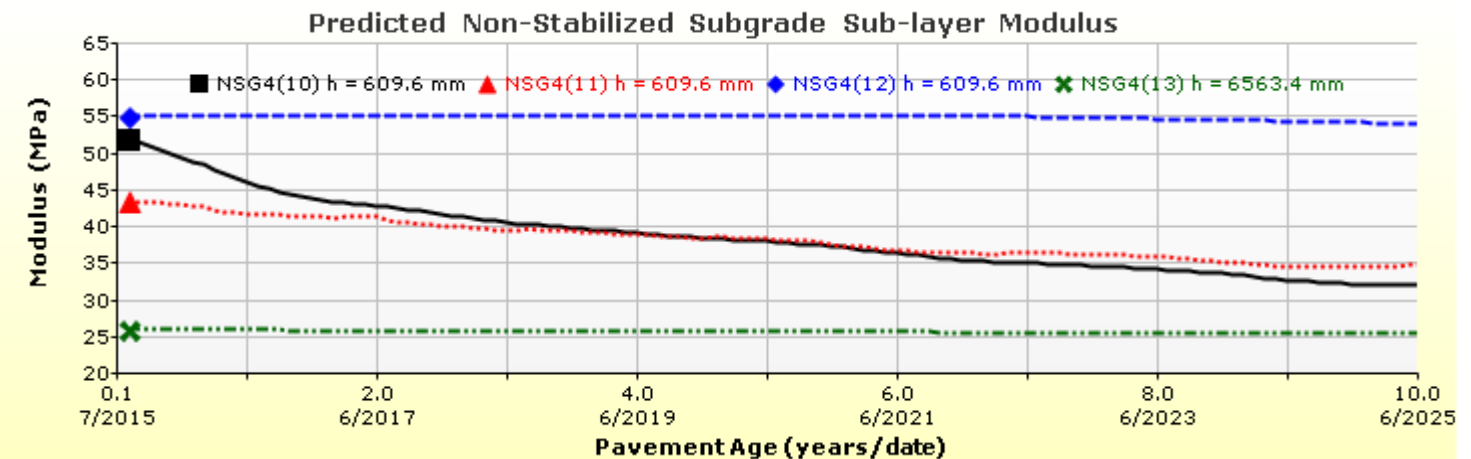
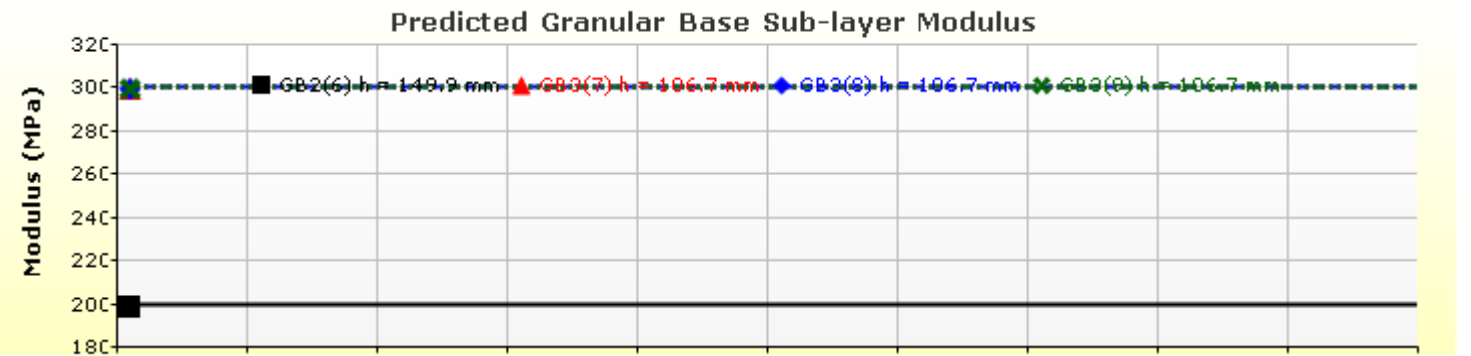
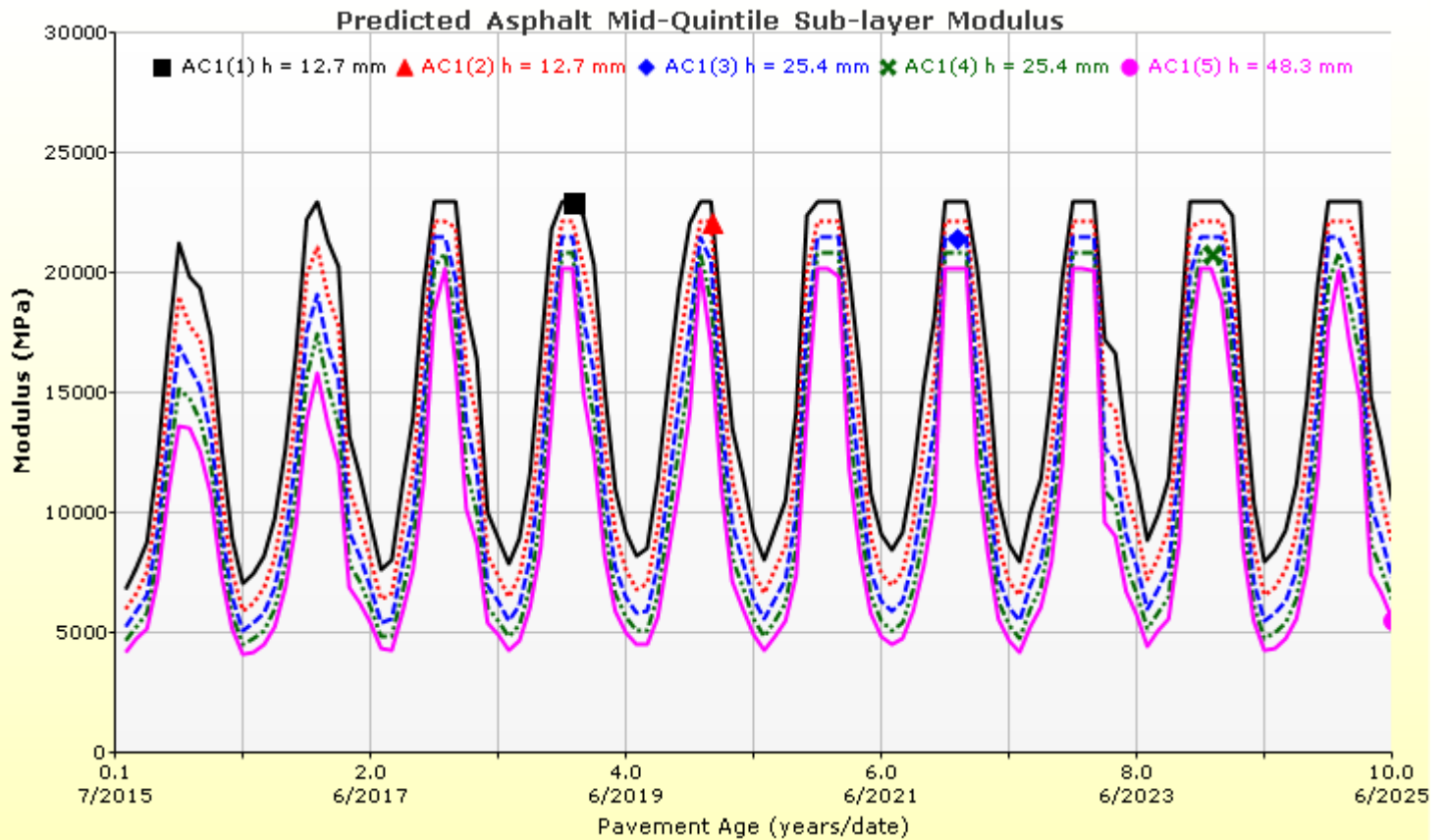
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
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 $		δ_a = permanent deformation for the layer N = number of repetitions ε_v = average vertical strain(in/in) $\varepsilon_0, \beta, \rho$ = material properties ε_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		AC Bottom Up Cracking	
$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 \log_{10}(Damage))}} \right) * 10.56$		$FC = \left(\frac{6000}{1 + e^{(C_1 * C'_1 + C_2 * C'_2 \log_{10}(D * 100))}} \right) * \left(\frac{1}{60} \right)$ $C'_2 = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$ $C'_1 = -2 * C'_2$	
c1: 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 Cracking Bottom Standard Deviation 1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))	

CSM Cracking		IRI Flexible Pavements	
$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$		C1 - Rutting C3 - Transverse Crack C2 - Fatigue Crack C4 - Site Factors	
C1: 1	C2: 1	C3: 0	C4: 1000
CSM Standard Deviation CTB*1		C1: 40	C2: 0.4
		C3: 0.008	C4: 0.015

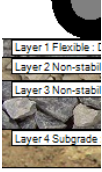
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

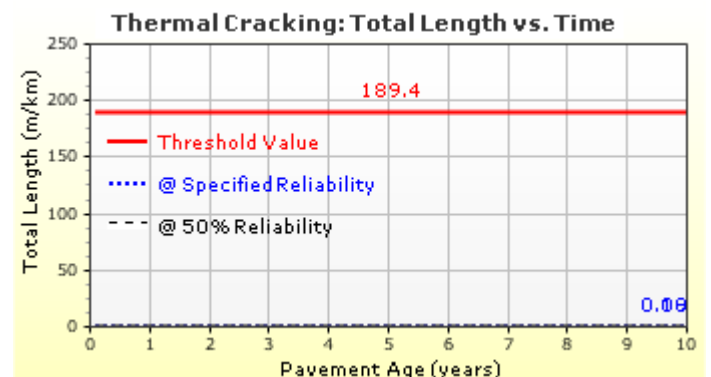
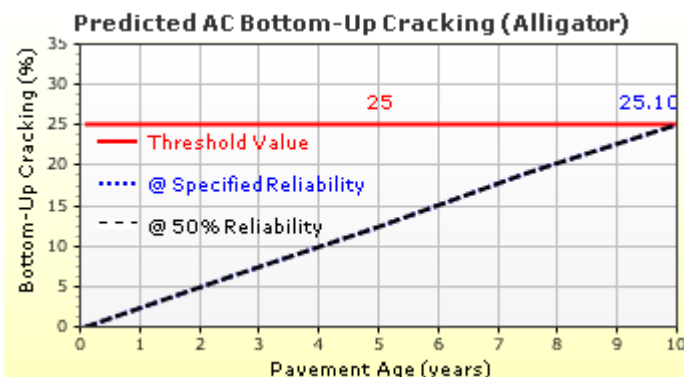
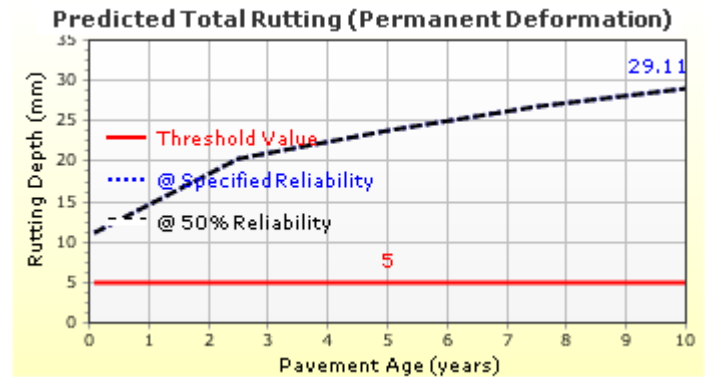
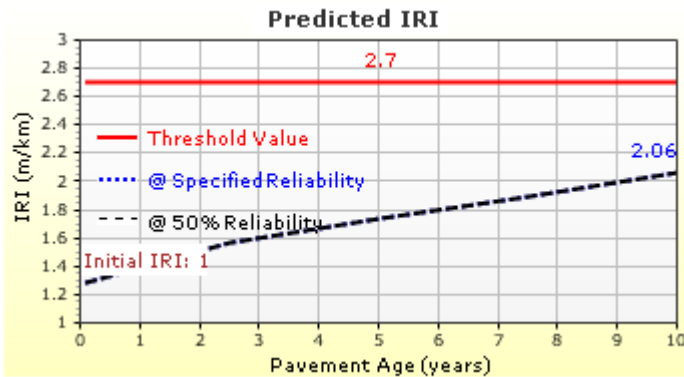
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	4,820
2020 (5 years)	4,486,440
2025 (10 years)	9,687,460

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.06	50.00	87.54	Pass
Permanent deformation - total pavement (mm)	5.00	29.11	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	25.10	50.00	49.72	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	446.97	50.00	43.84	Fail
Permanent deformation - AC only (mm)	5.00	11.86	50.00	1.98	Fail

Distress Charts

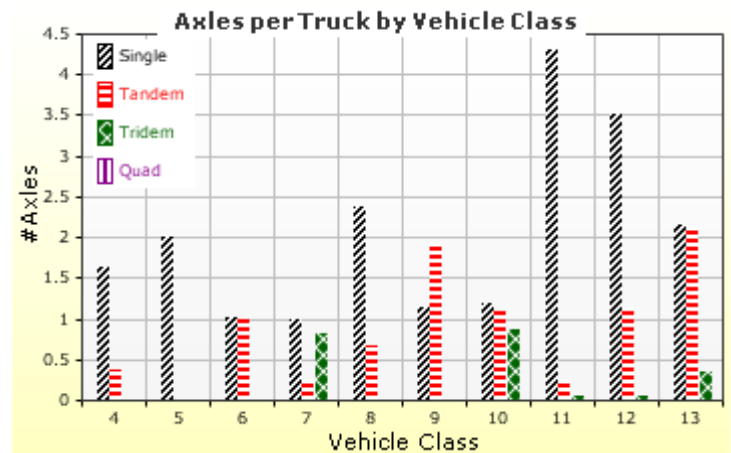
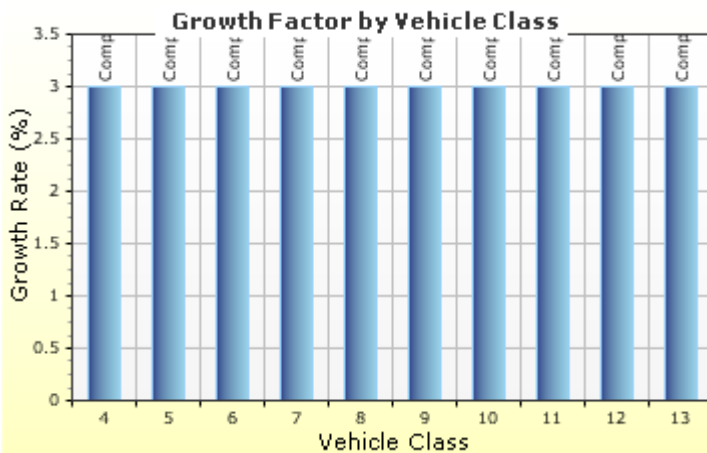
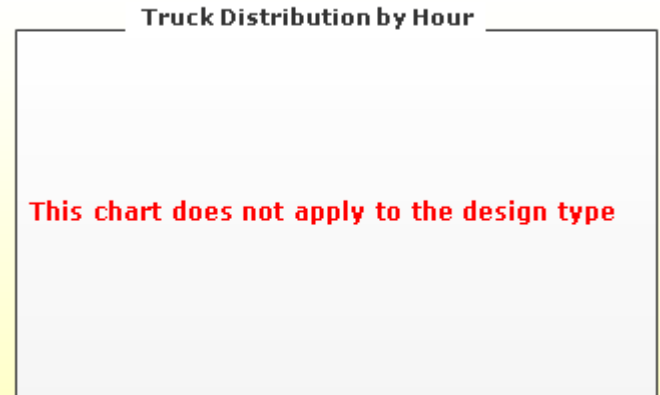
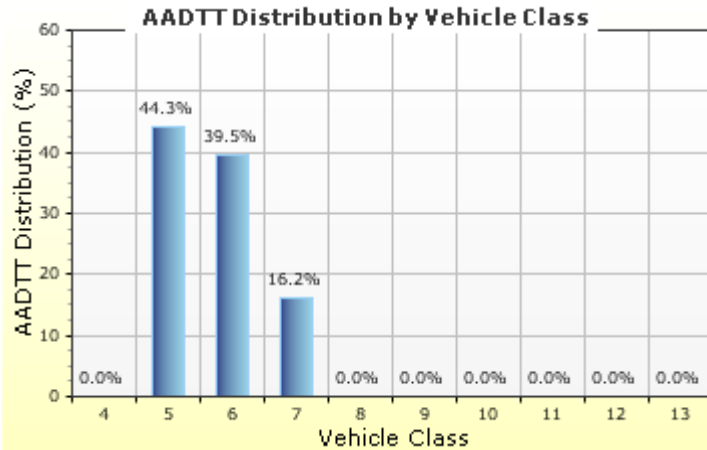


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 4,820
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

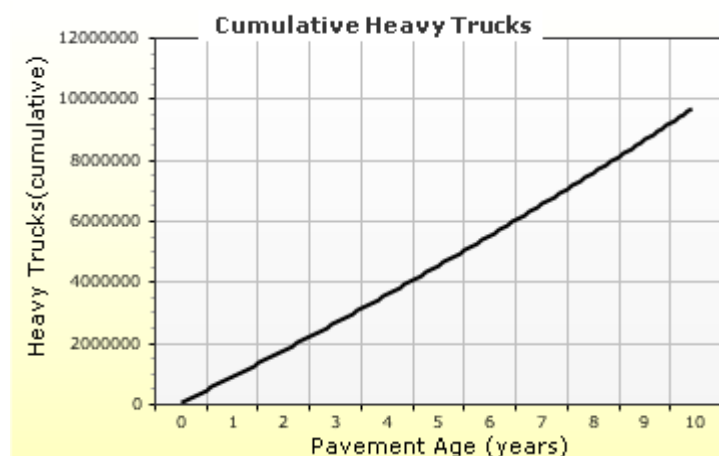
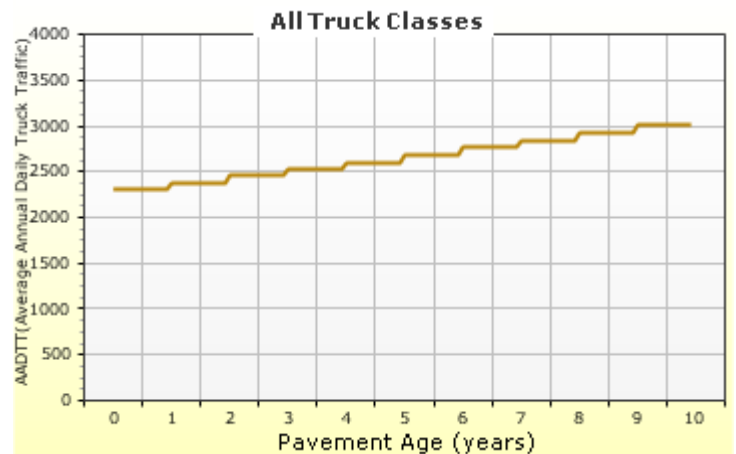
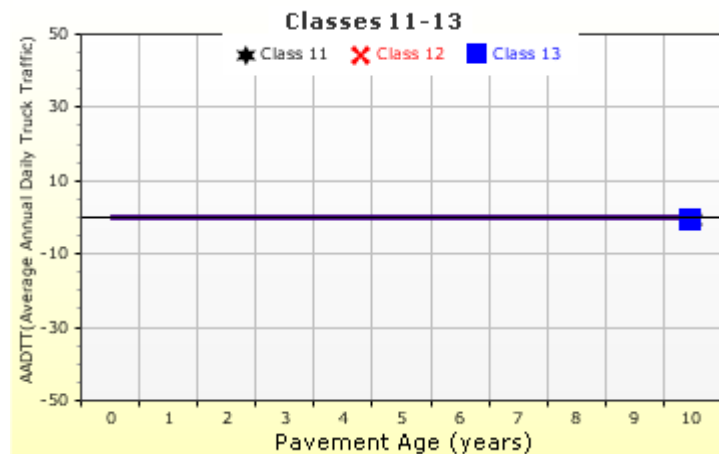
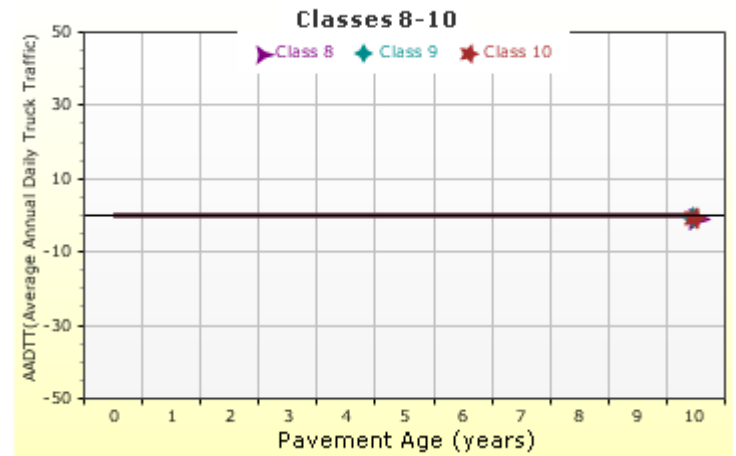
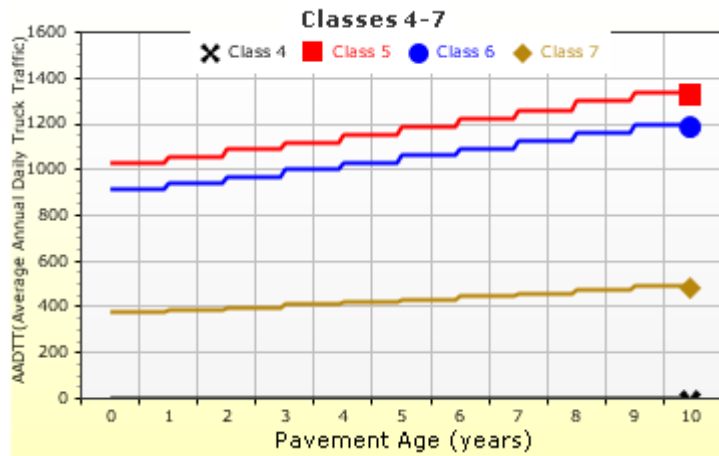
Wheelbase does not apply

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



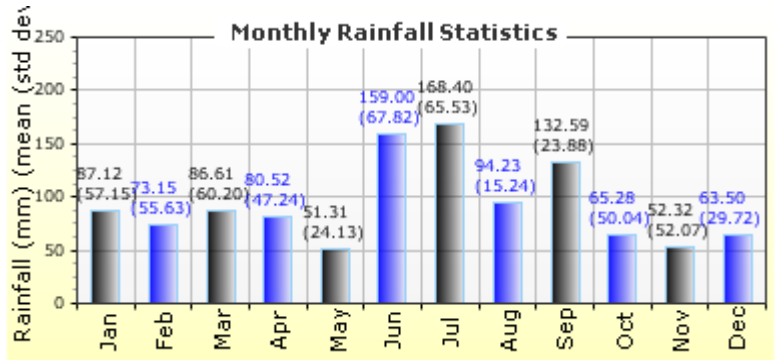
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

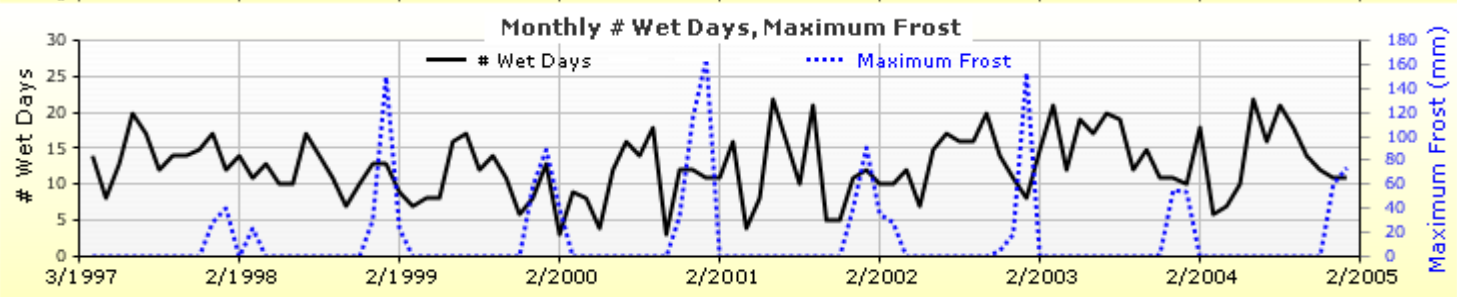
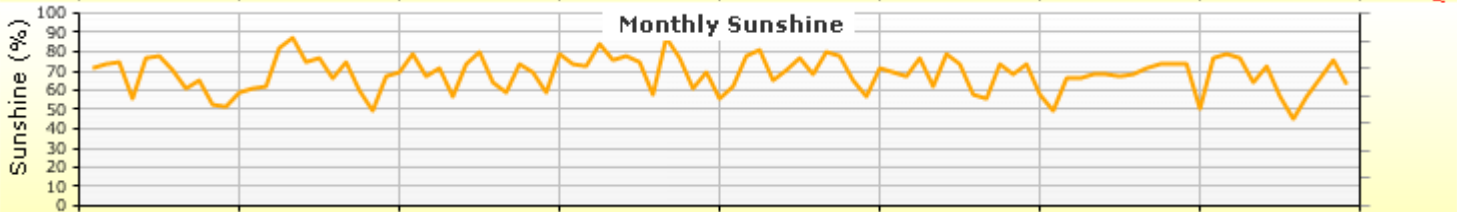
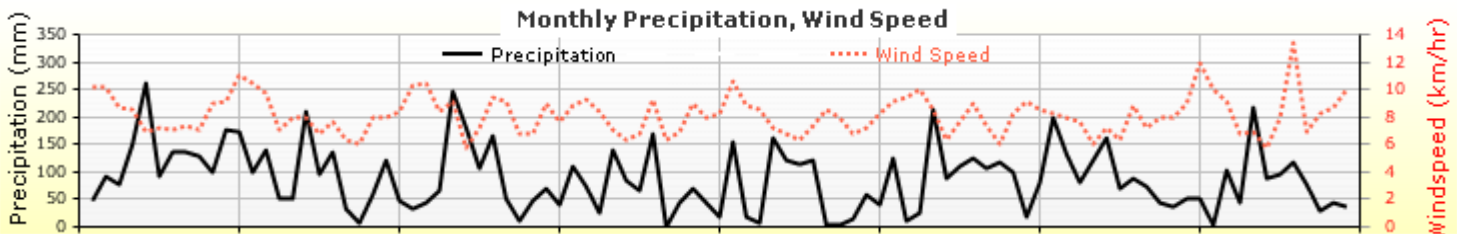
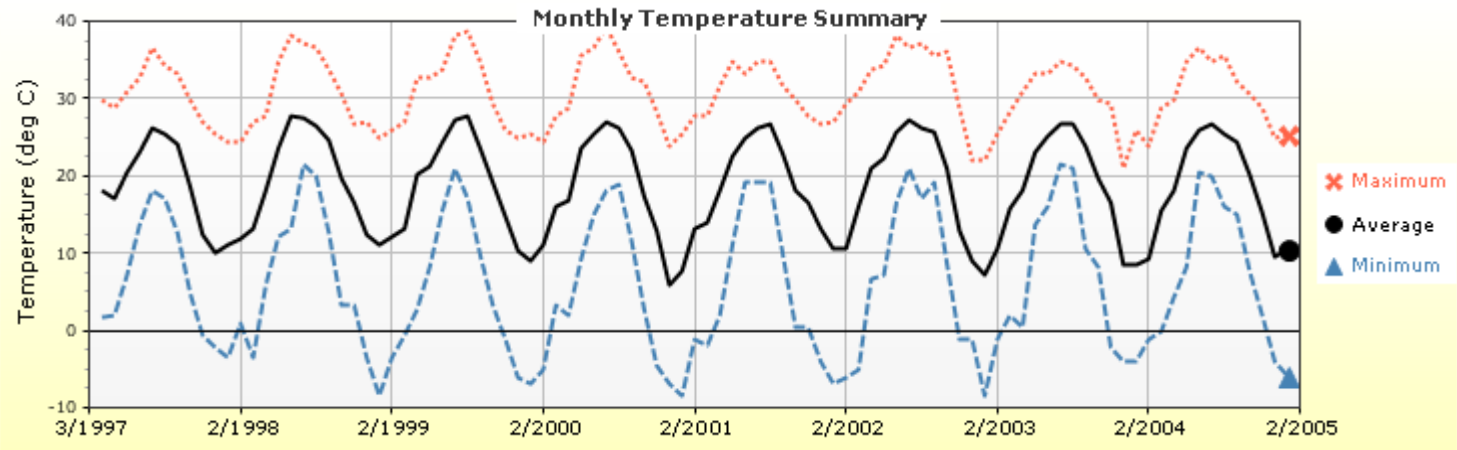
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

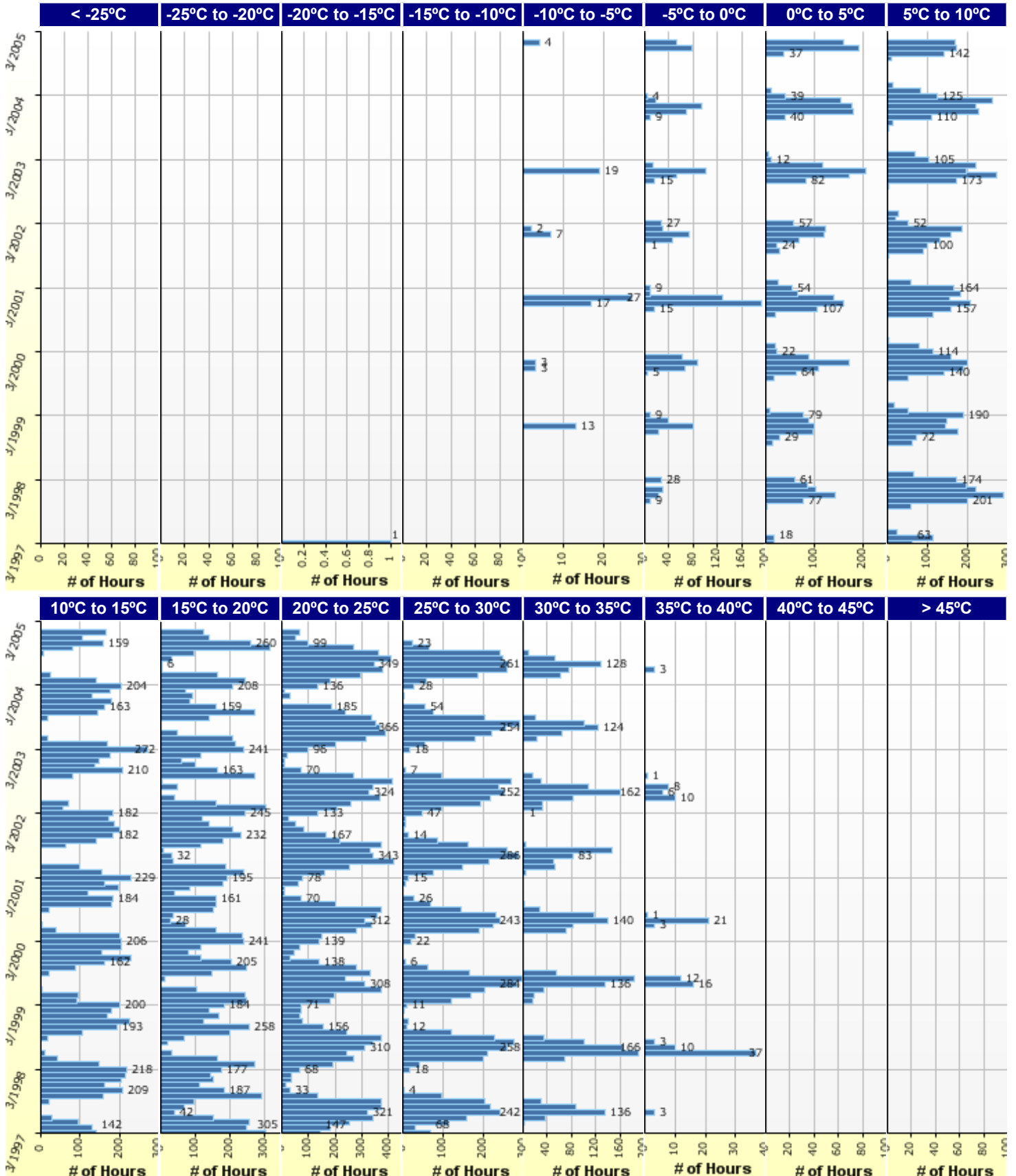


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF3_50%

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF3_50%.dgp



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

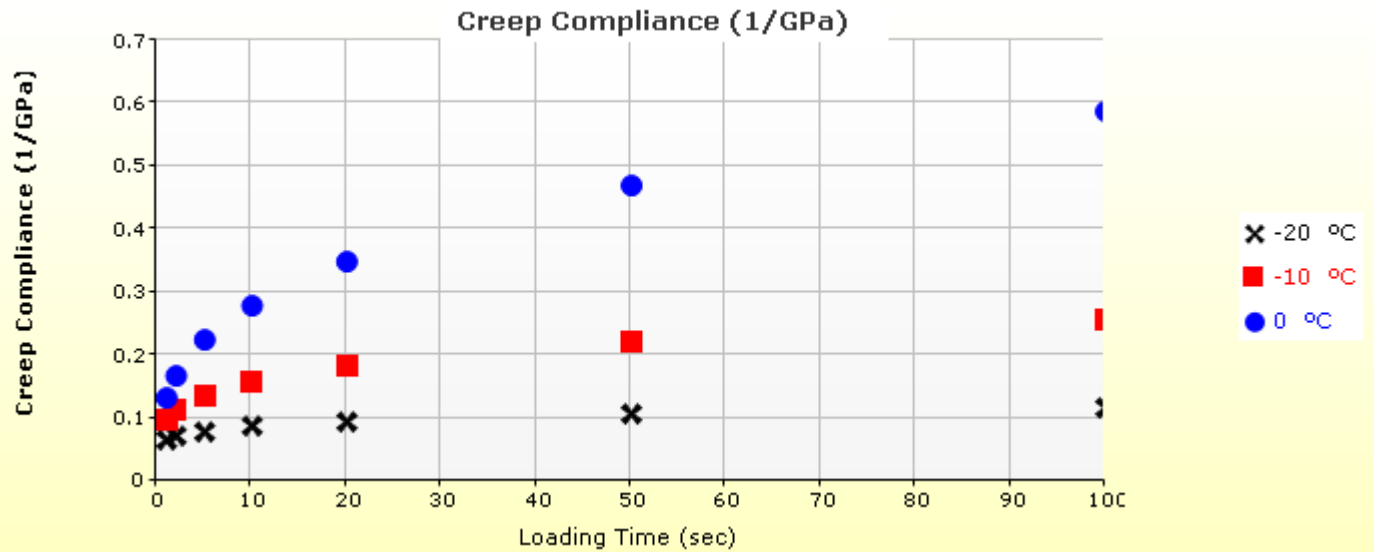
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

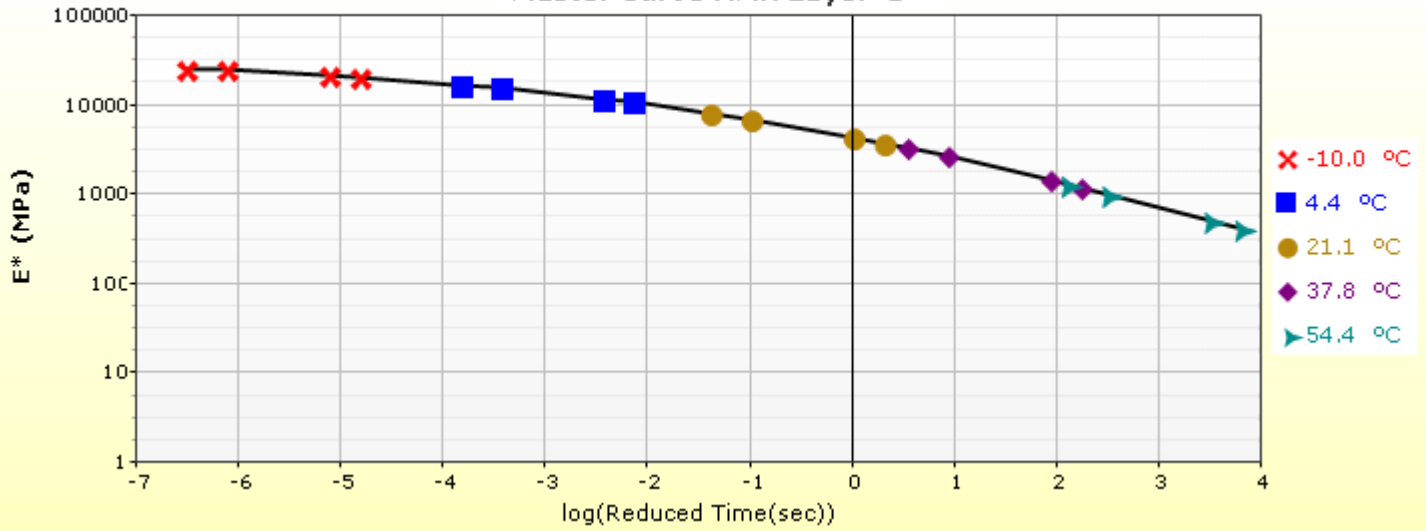
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

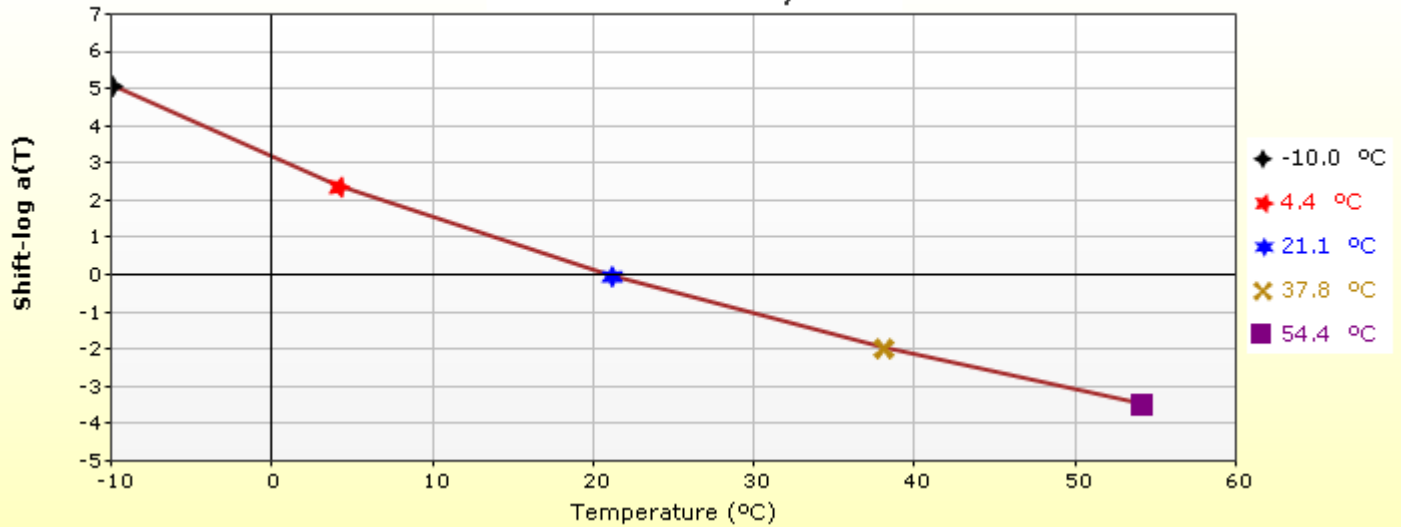


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

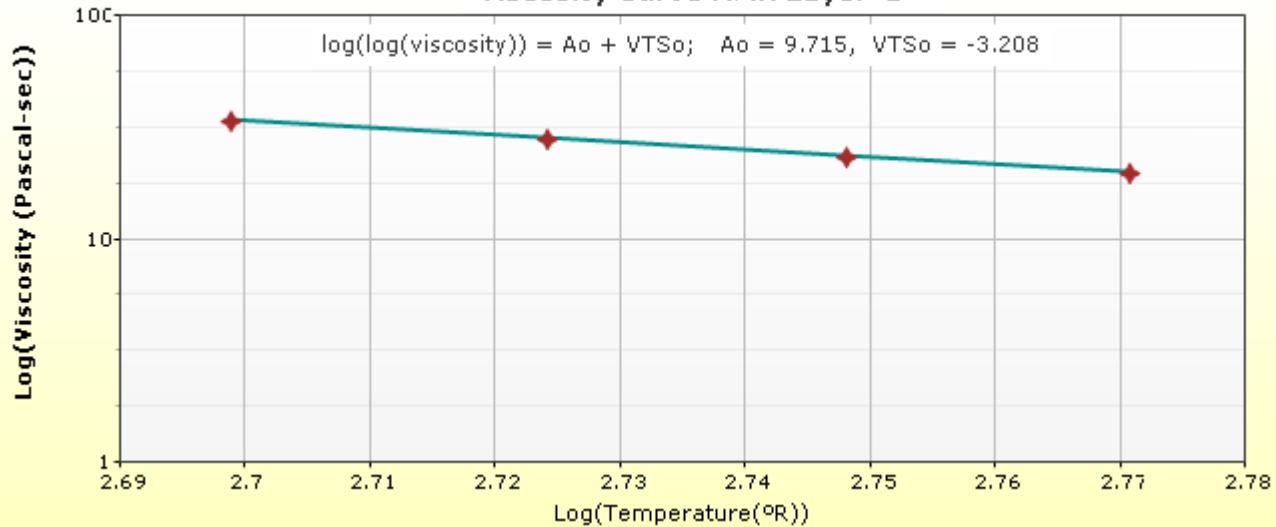
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

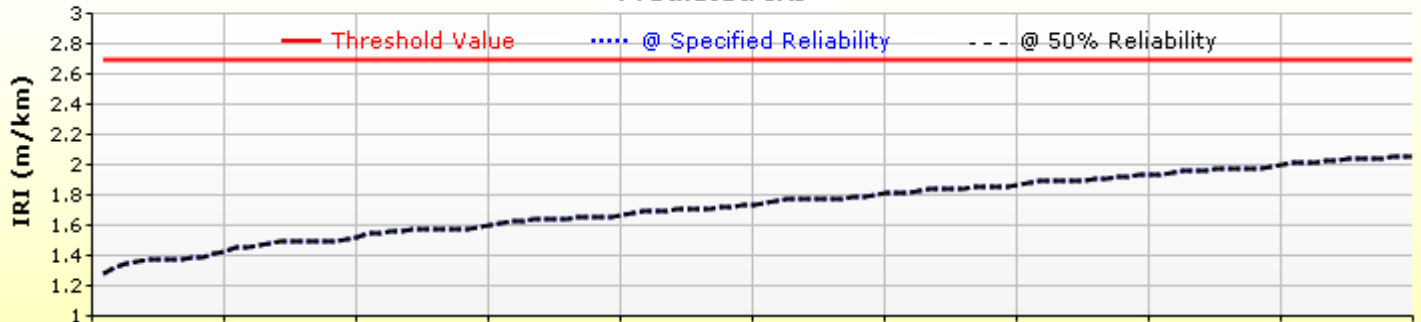


Viscosity Curve HMA Layer 1

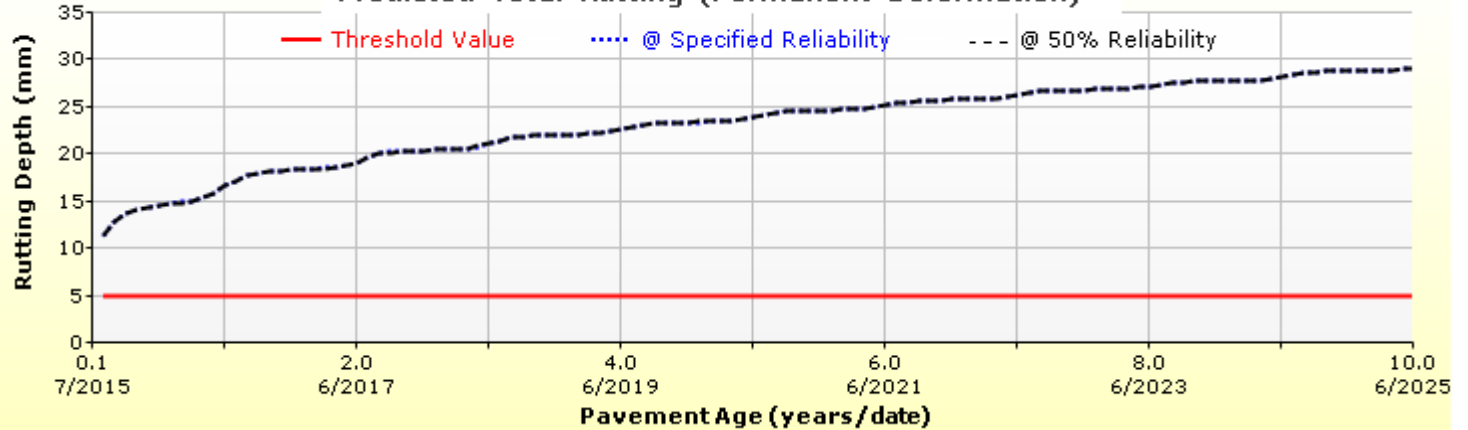


Analysis Output Charts

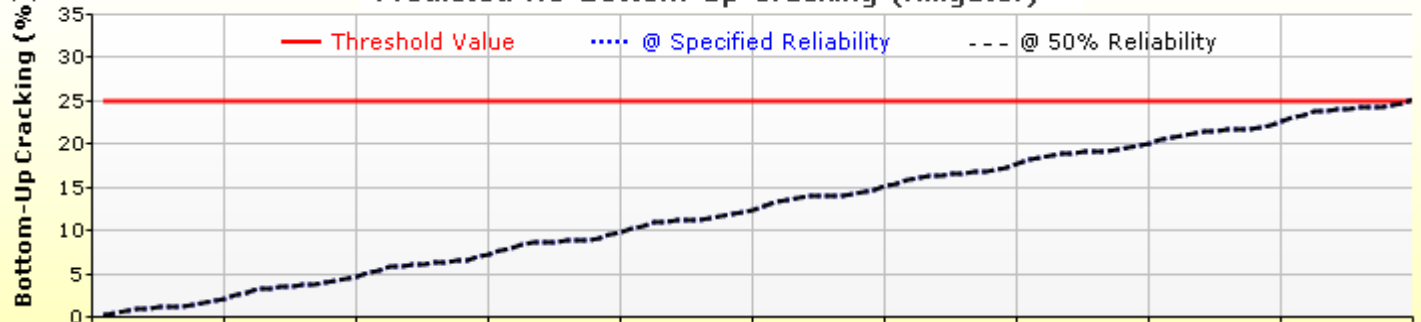
Predicted IRI



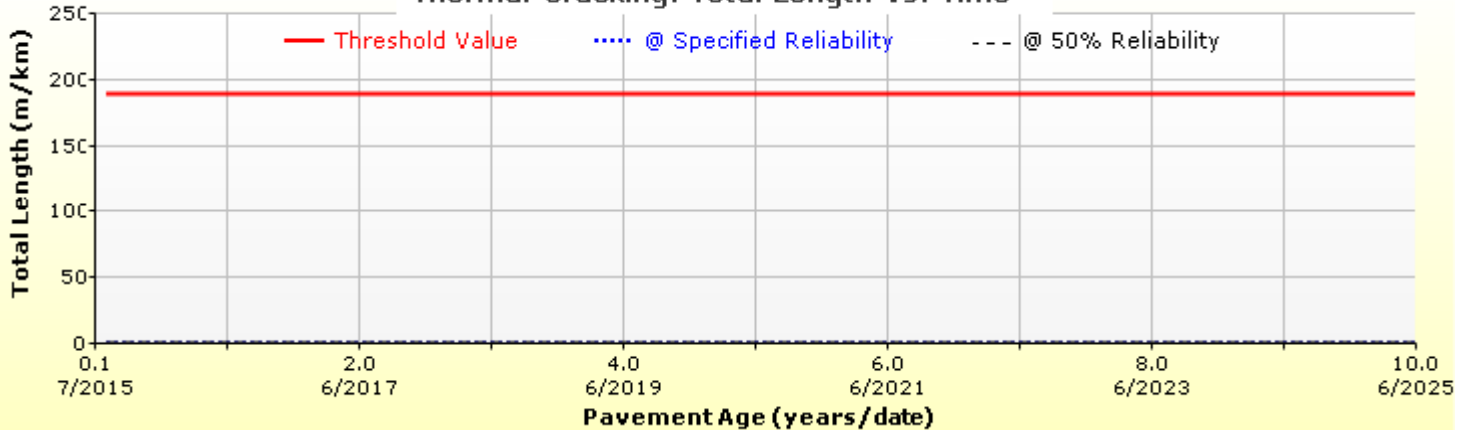
Predicted Total Rutting (Permanent Deformation)



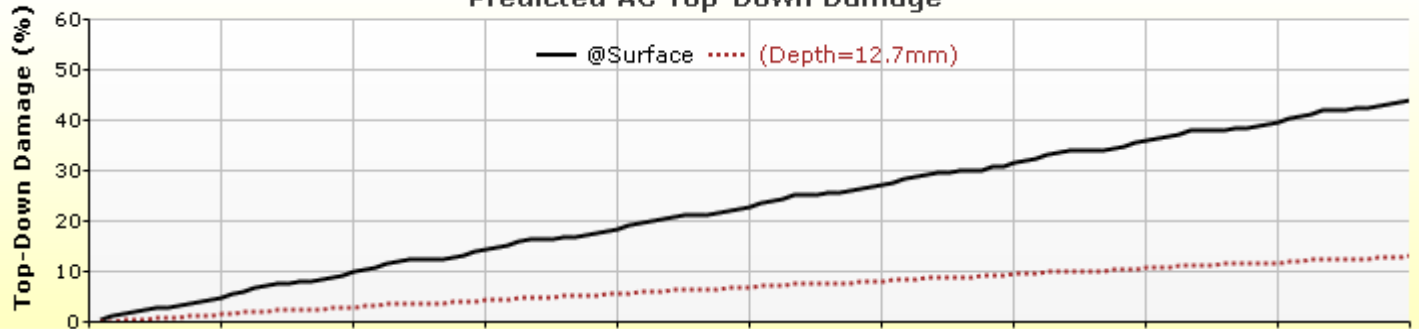
Predicted AC Bottom-Up Cracking (Alligator)



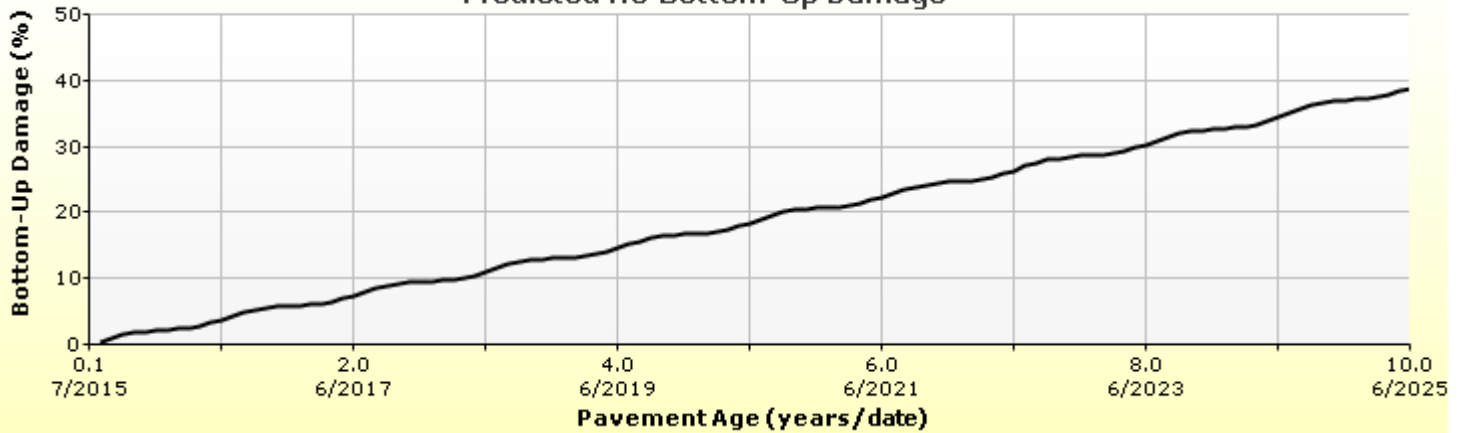
Thermal Cracking: Total Length vs. Time



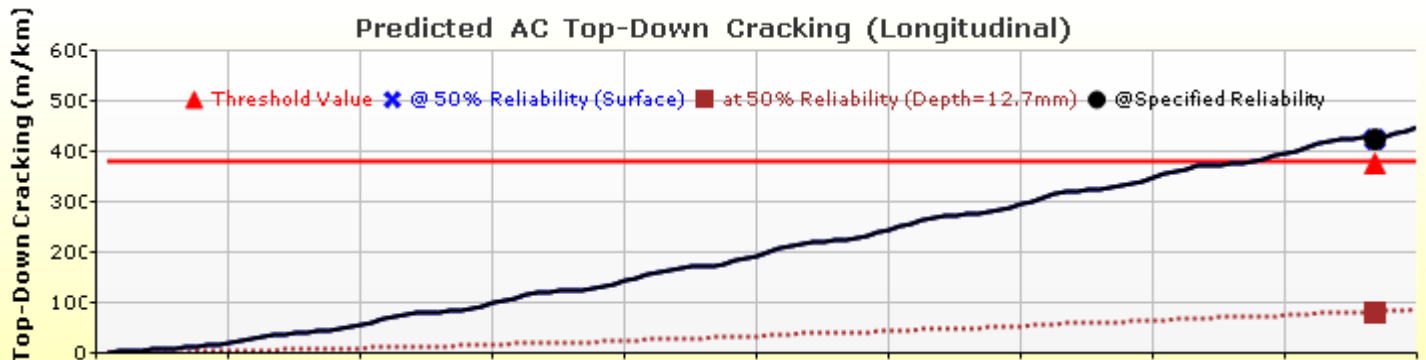
Predicted AC Top-Down Damage



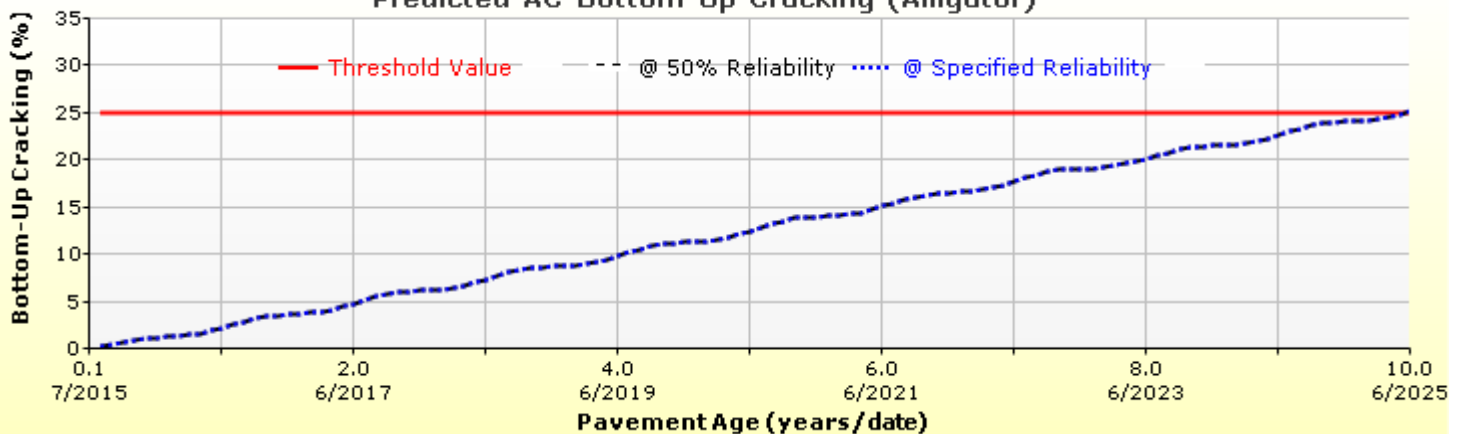
Predicted AC Bottom-Up Damage



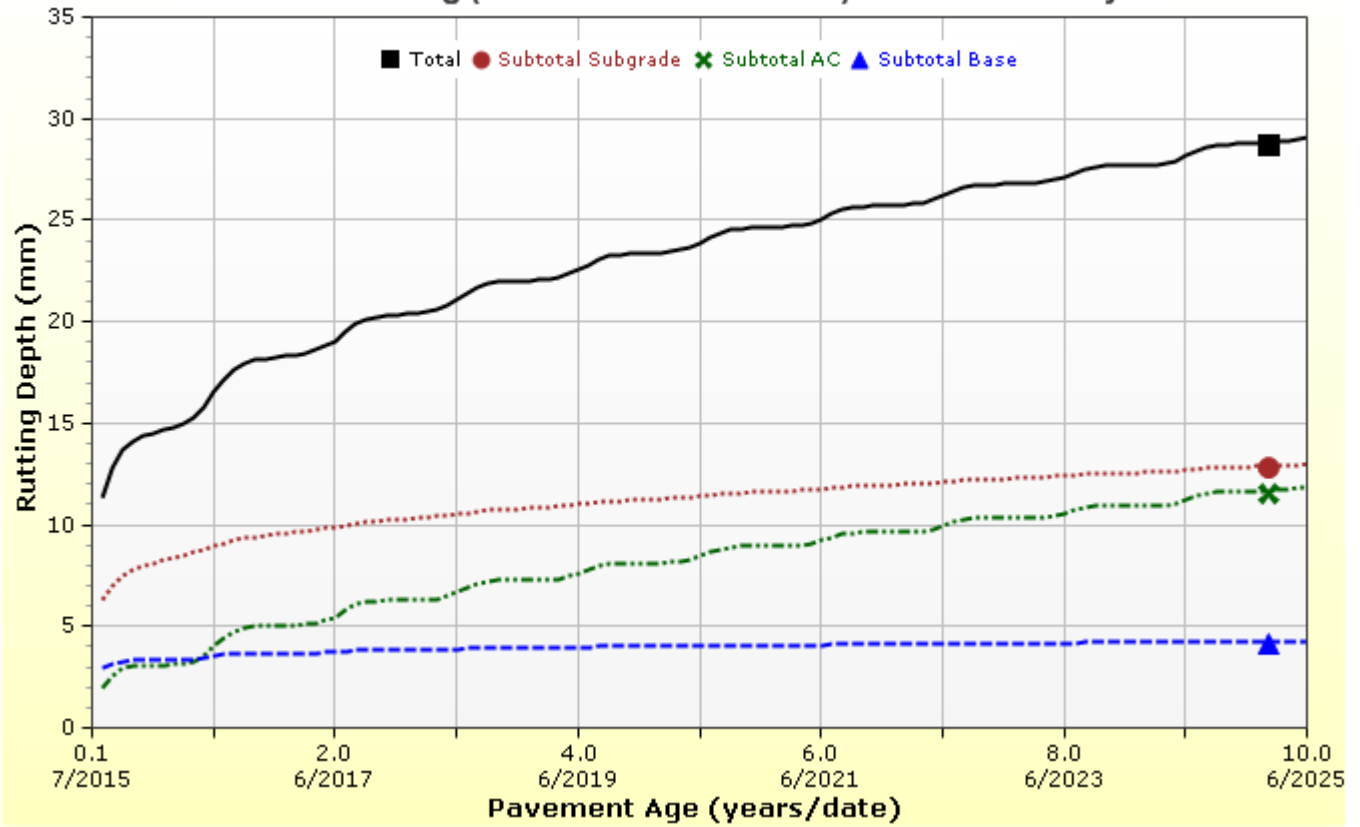
Predicted AC Top-Down Cracking (Longitudinal)

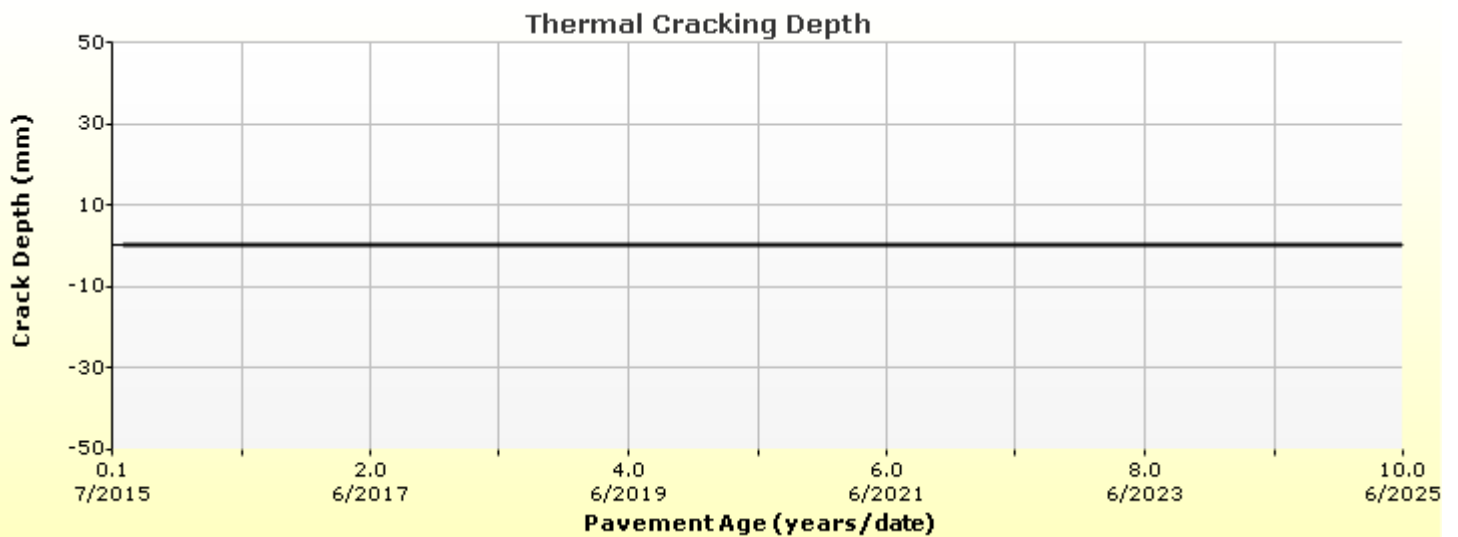
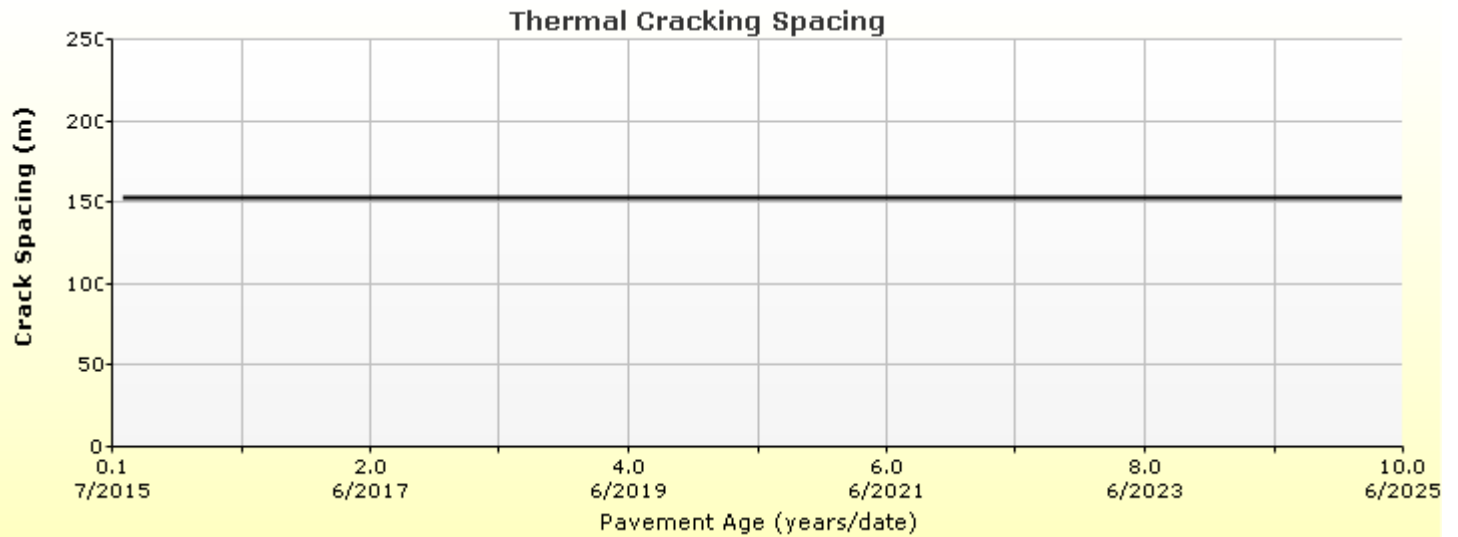


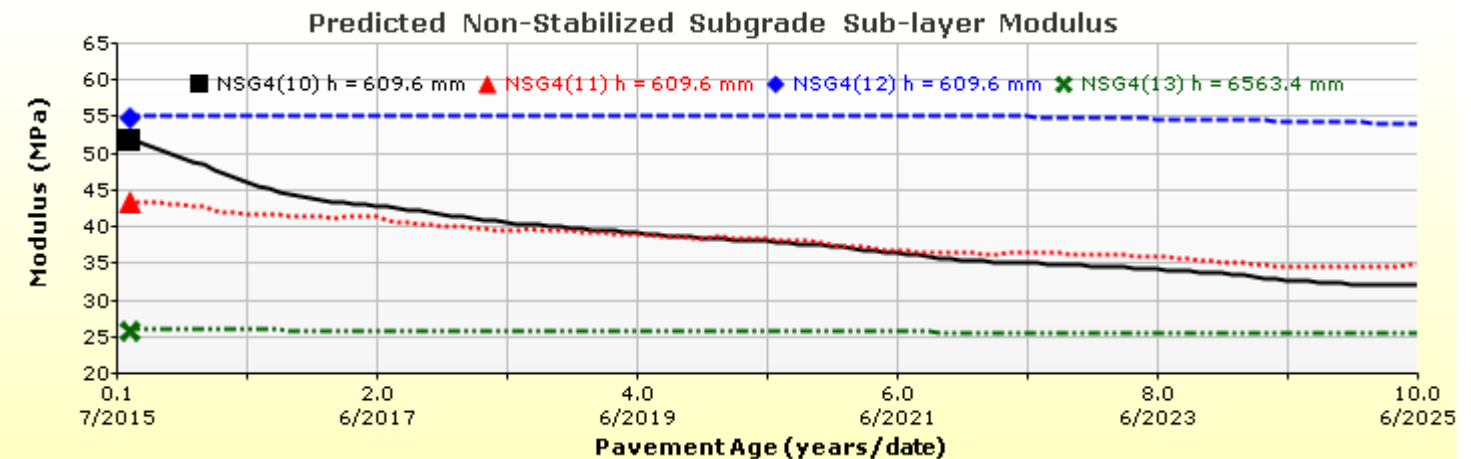
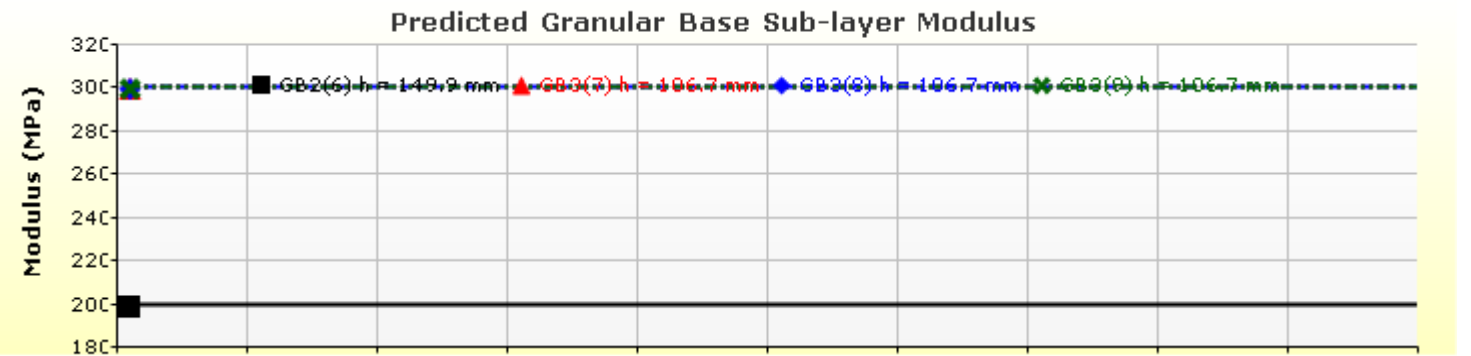
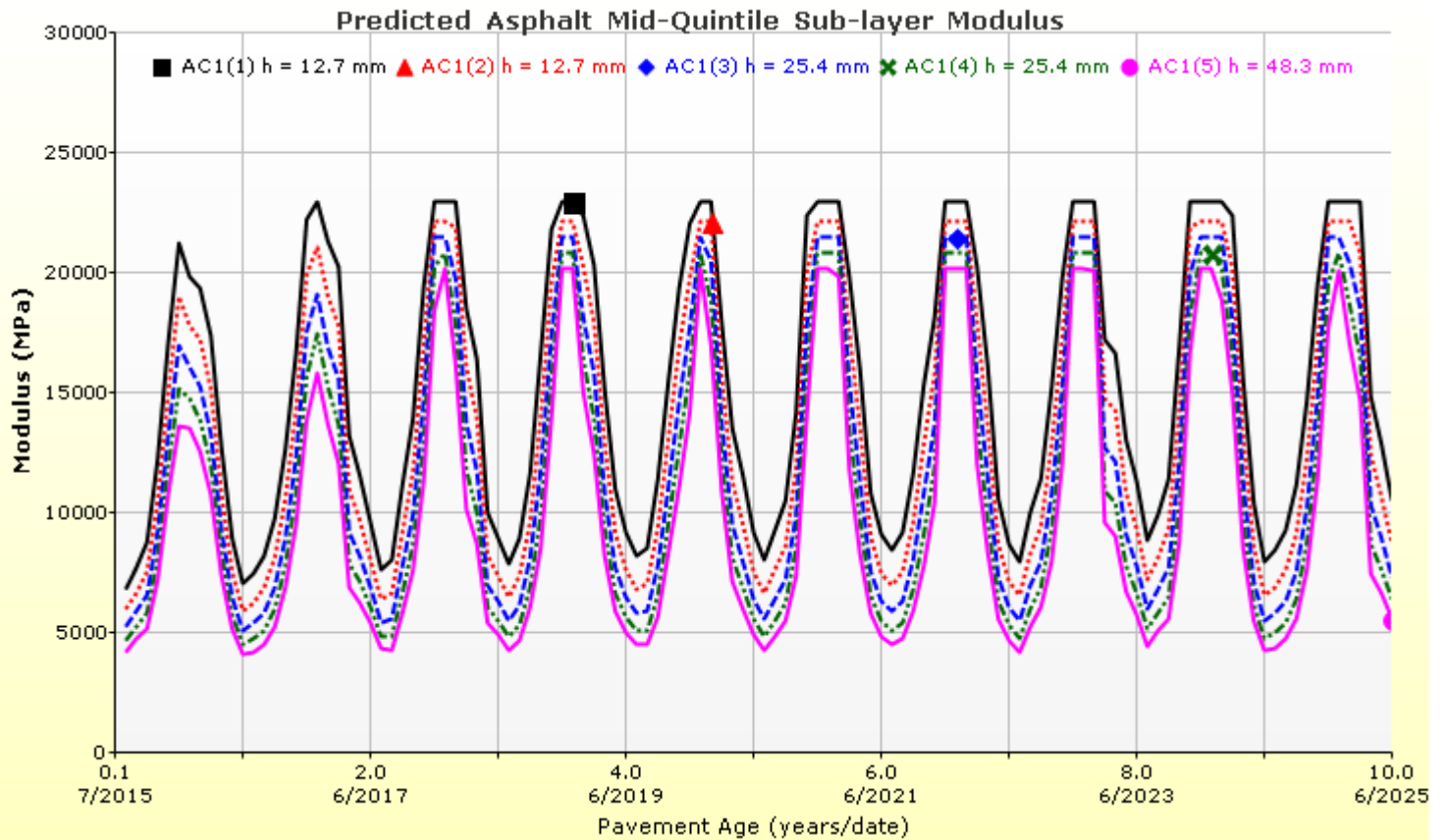
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

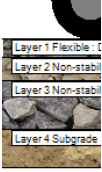
C3: 0.008

C4: 0.015

Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data: 32.119, -81.202
 Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
 Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm)	Volumetric at Construction:	
Flexible	Default asphalt concrete	125.0	Effective binder content (%)	11.6
NonStabilized	Crushed stone	150.0	Air voids (%)	7.0
NonStabilized	Crushed stone	320.0		
Subgrade	A-5	Semi-infinite		

Traffic

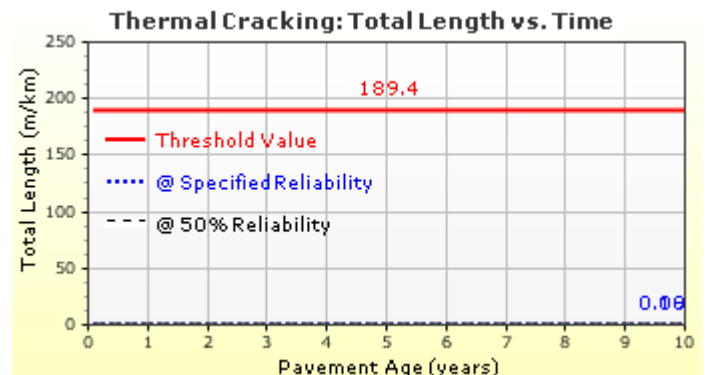
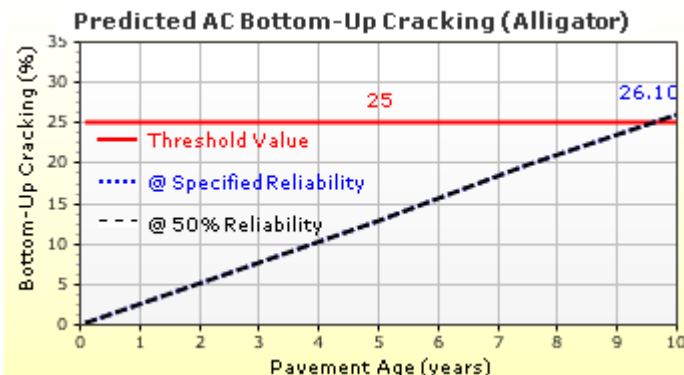
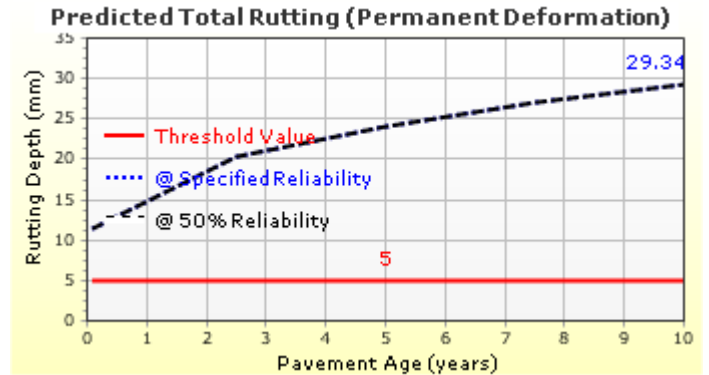
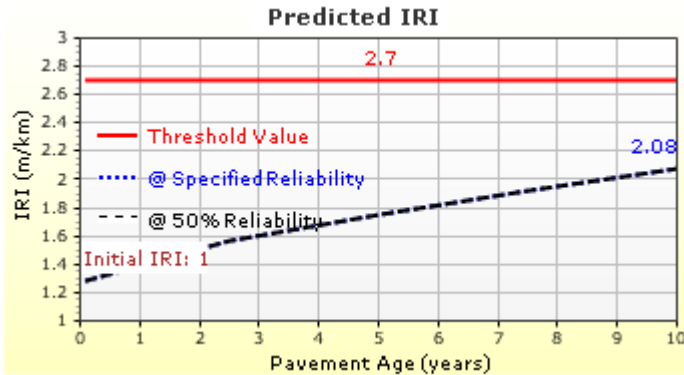
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	4,820
2020 (5 years)	4,486,440
2025 (10 years)	9,687,460

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.08	50.00	86.99	Pass
Permanent deformation - total pavement (mm)	5.00	29.34	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	26.10	50.00	46.90	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	448.86	50.00	43.68	Fail
Permanent deformation - AC only (mm)	5.00	12.09	50.00	1.81	Fail

Distress Charts

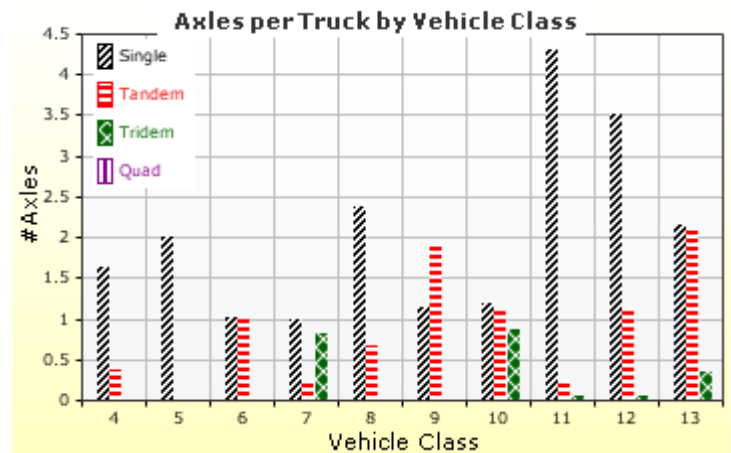
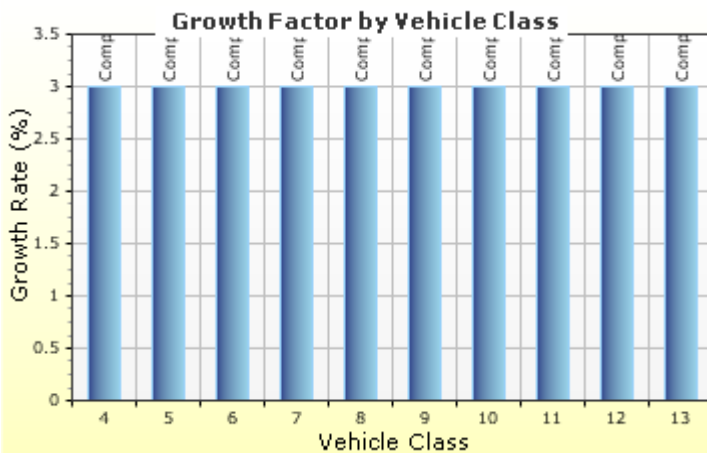
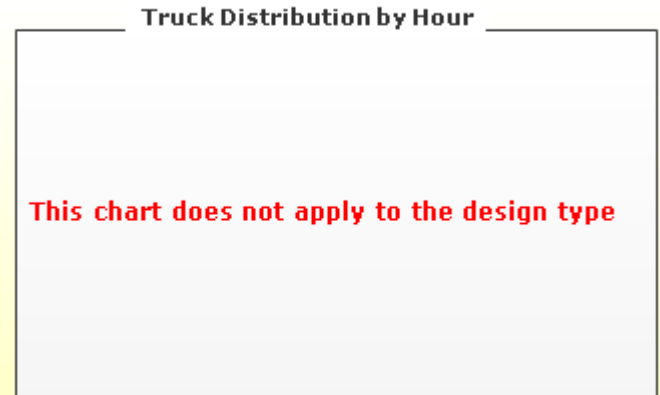
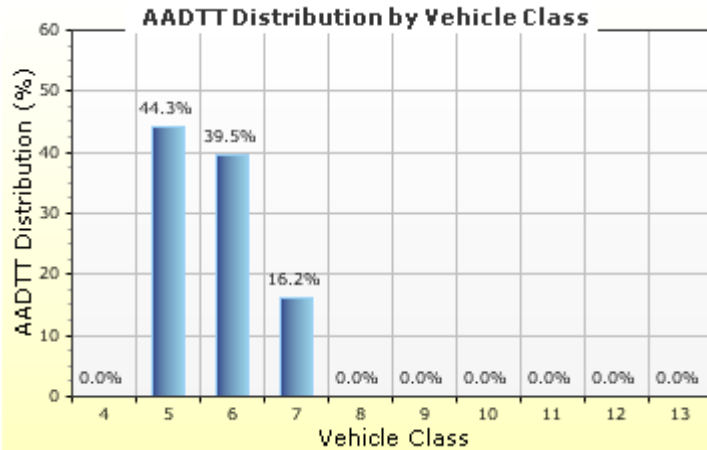


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 4,820
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

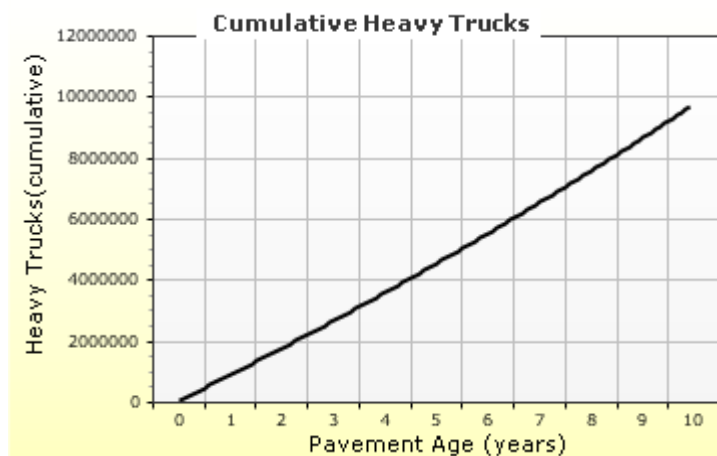
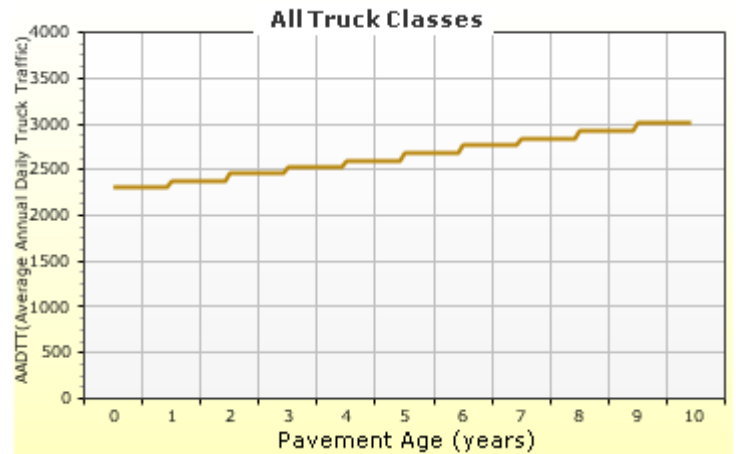
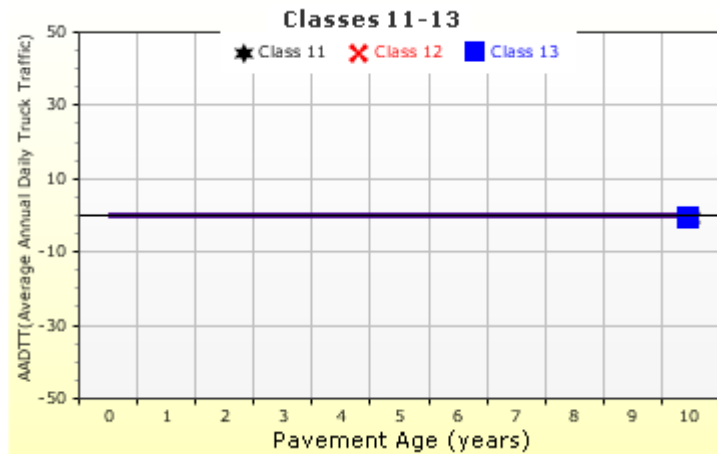
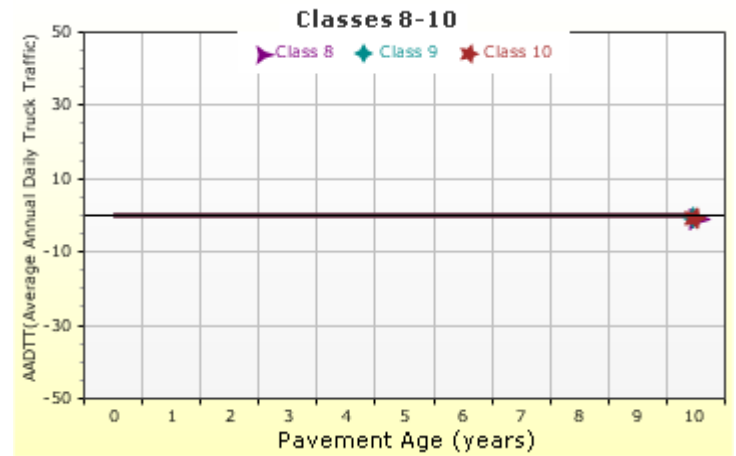
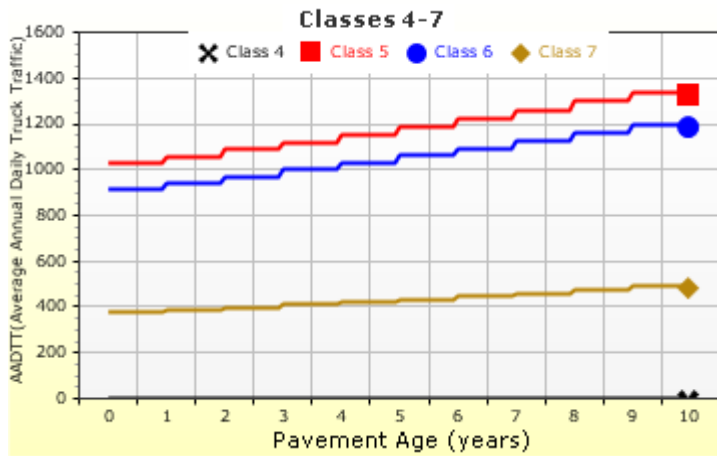
Wheelbase does not apply

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



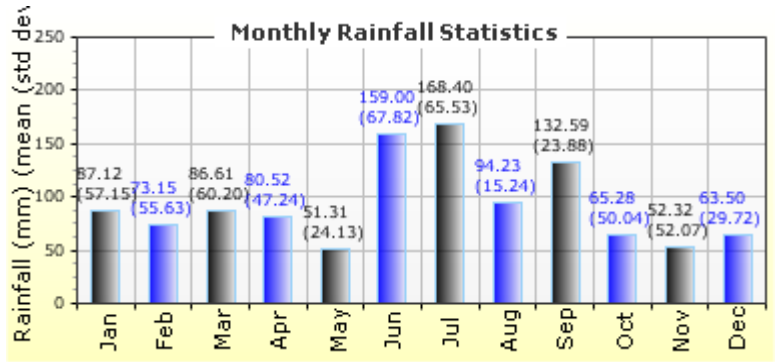
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

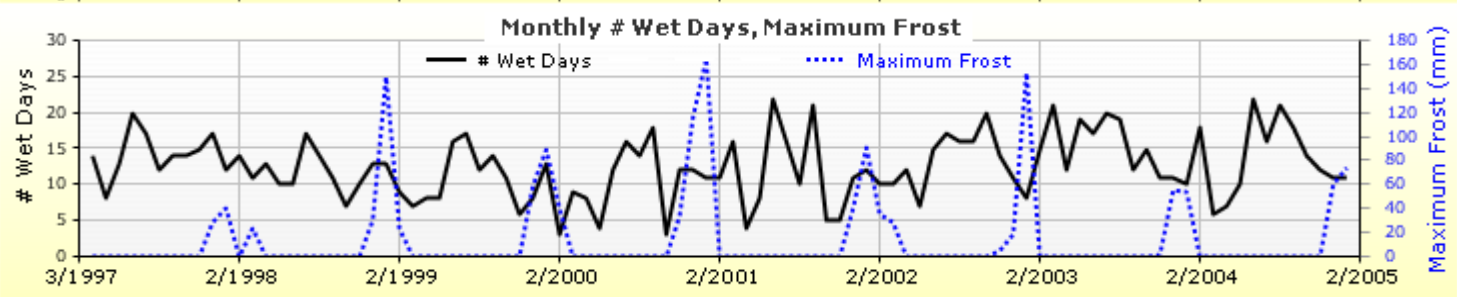
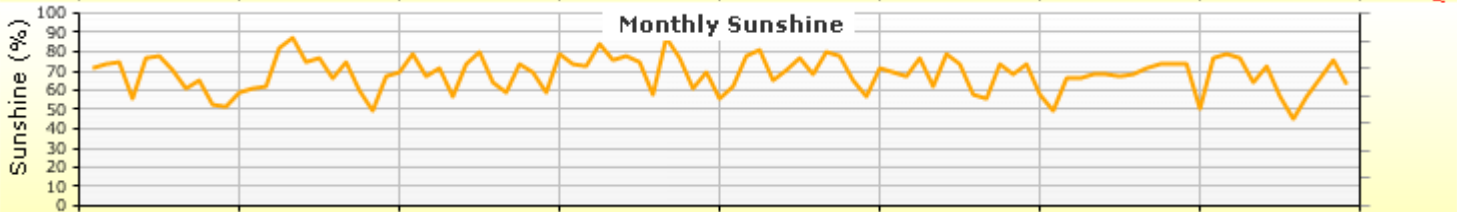
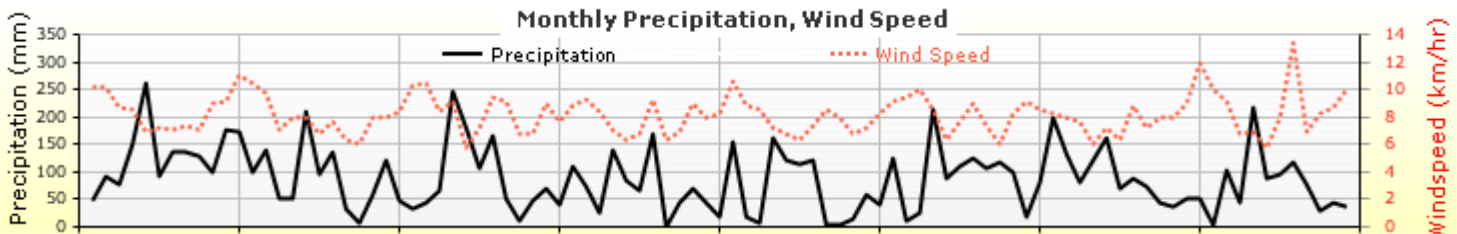
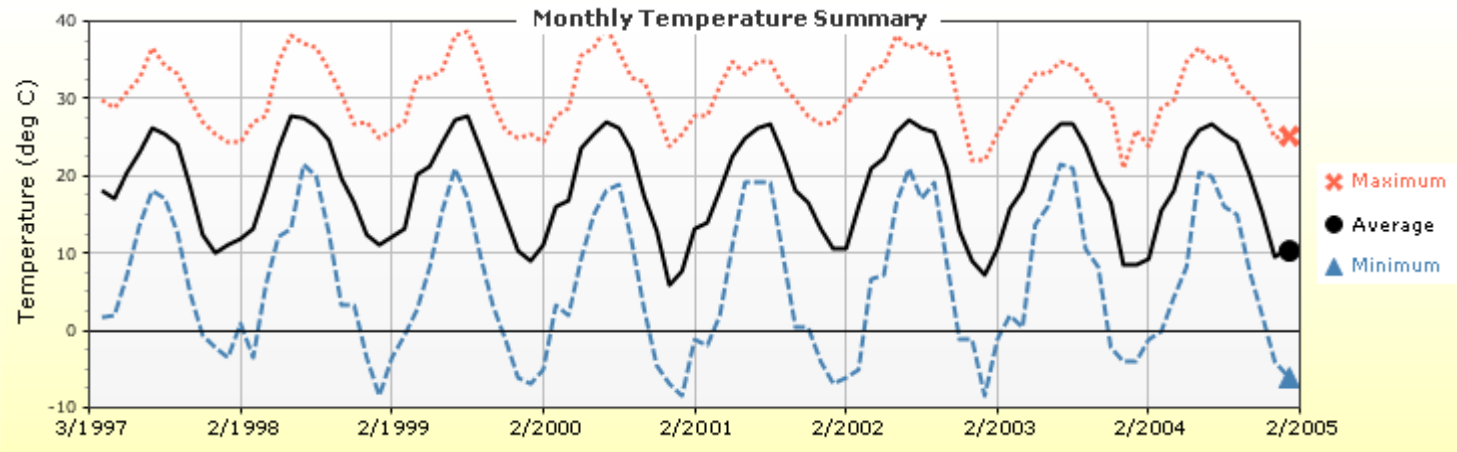
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

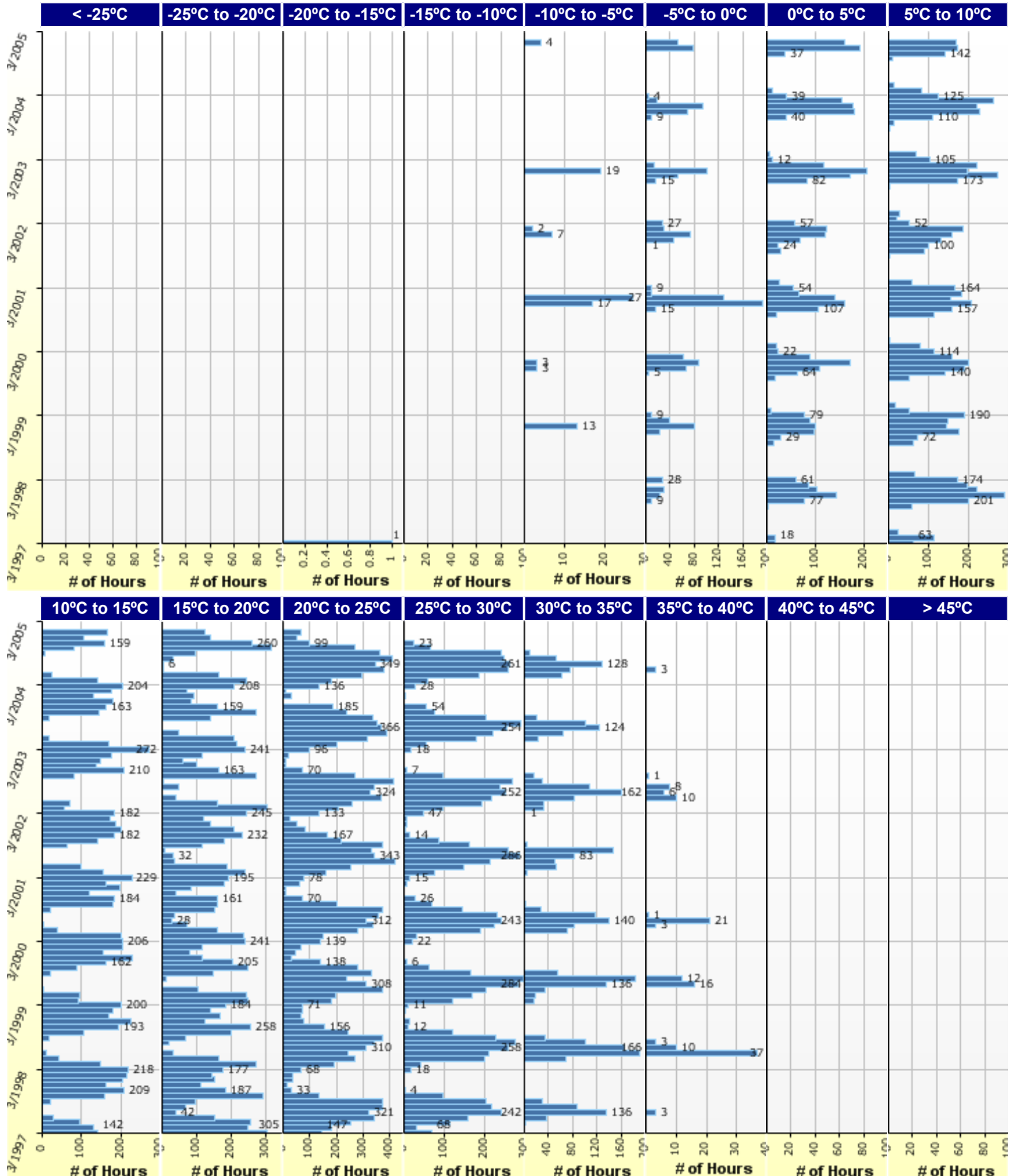


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF4_50%

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF4_50%.dgp



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

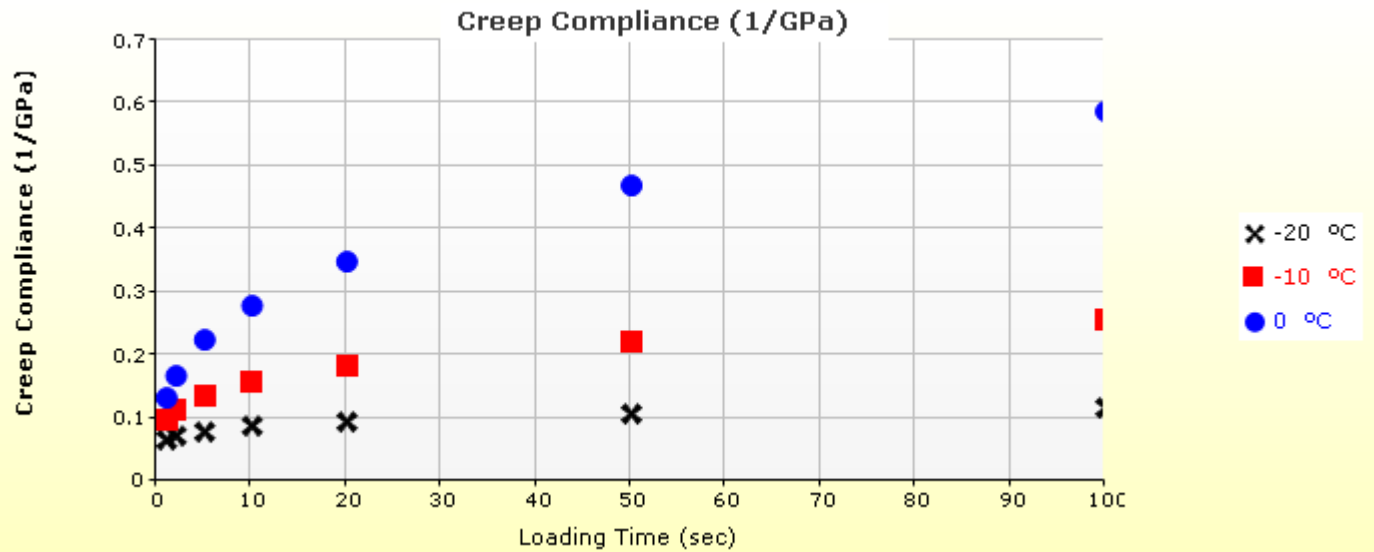
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

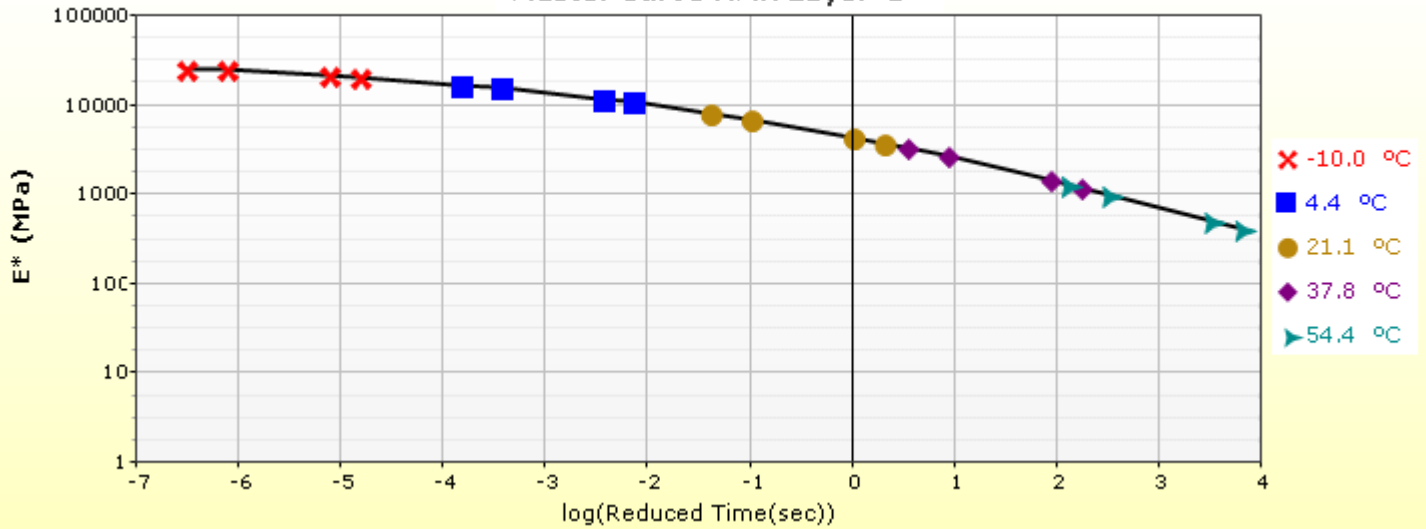
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

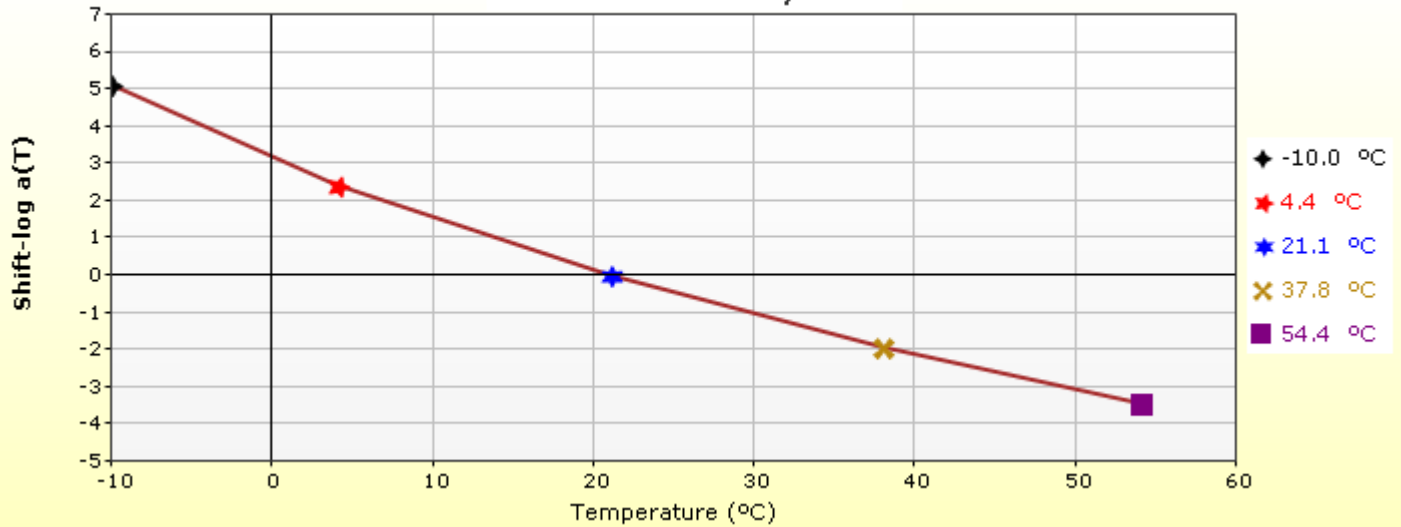


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

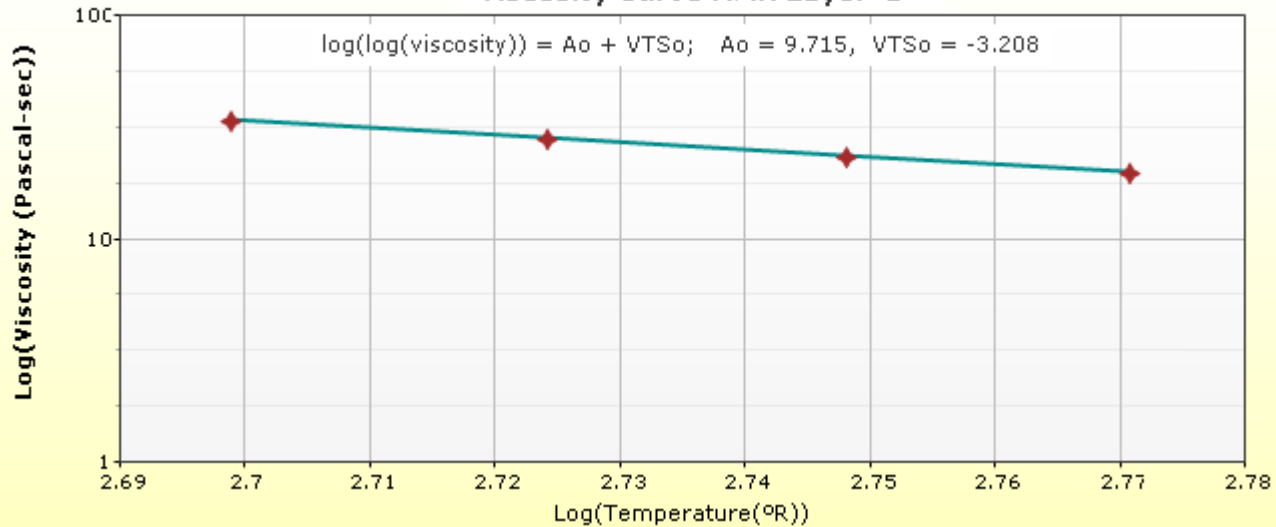
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

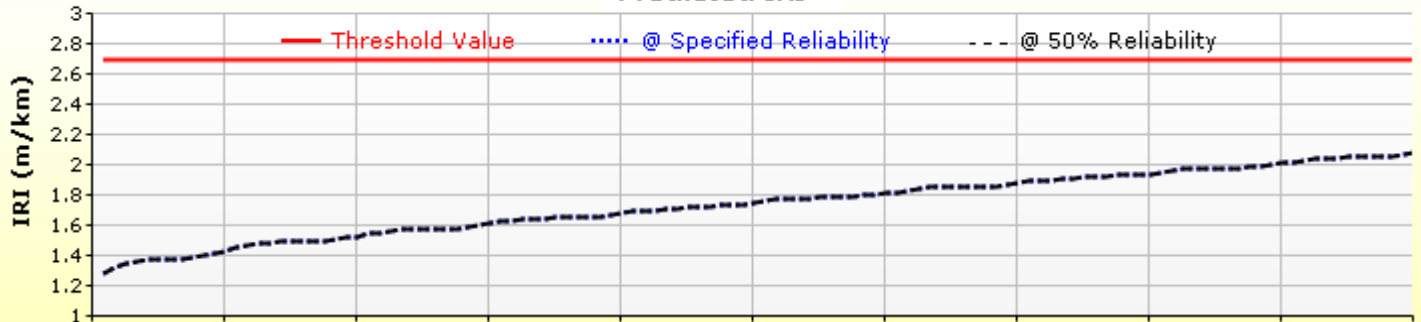


Viscosity Curve HMA Layer 1

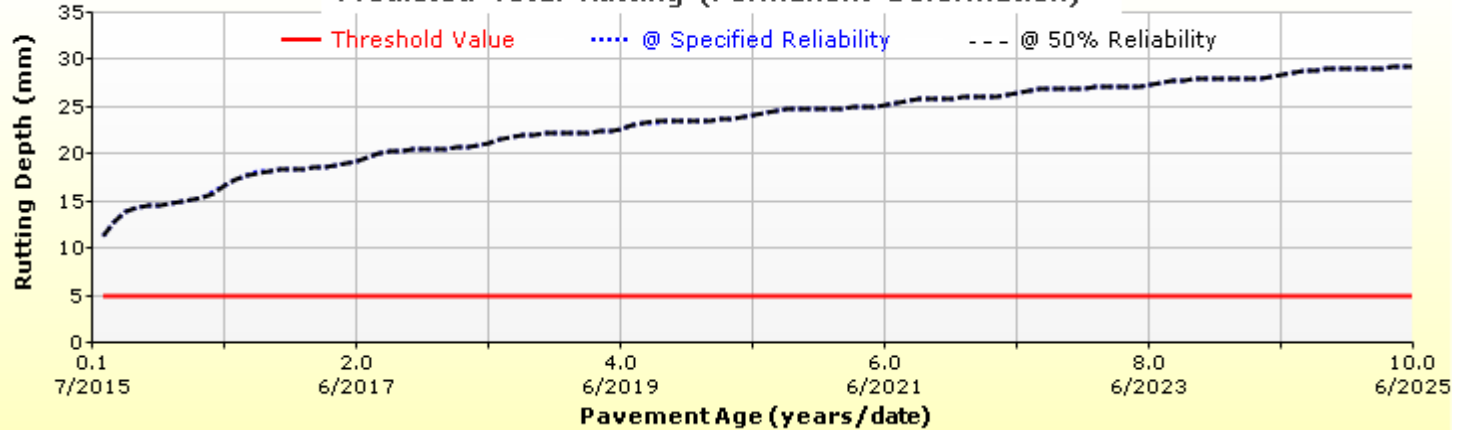


Analysis Output Charts

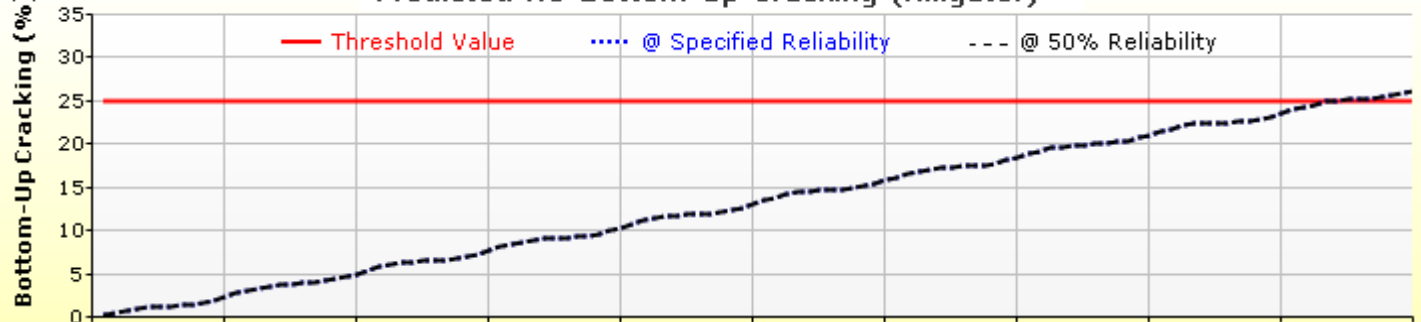
Predicted IRI



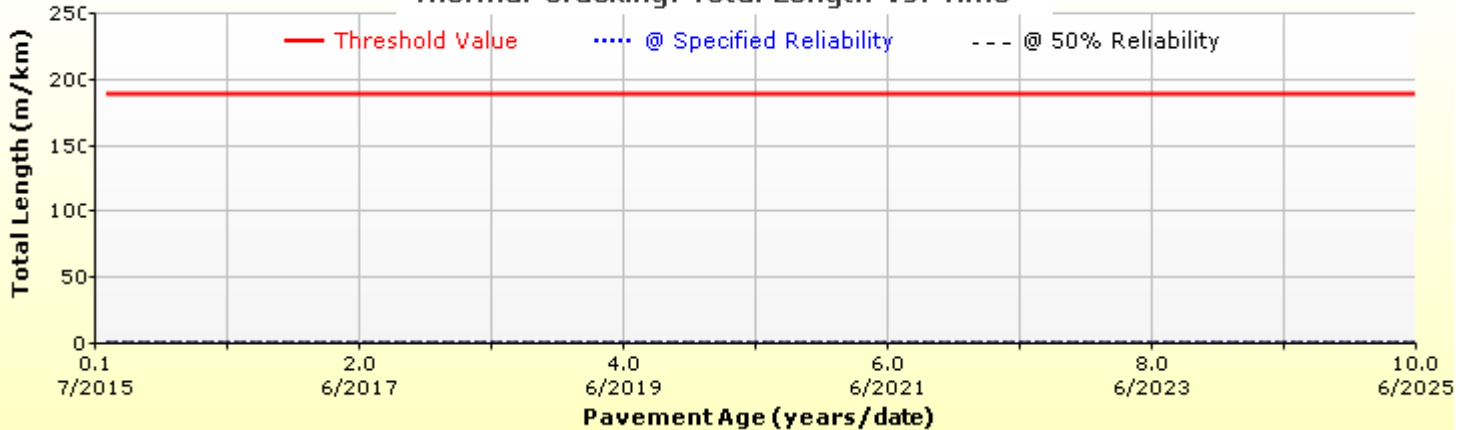
Predicted Total Rutting (Permanent Deformation)



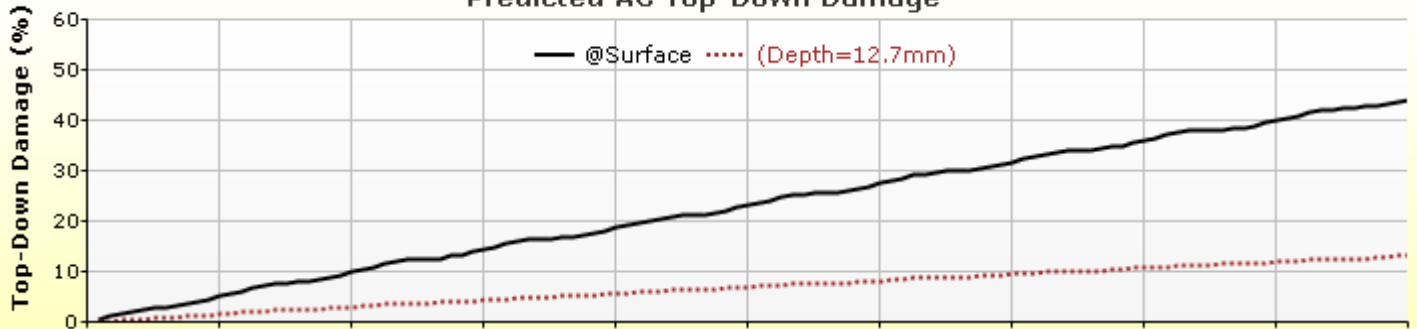
Predicted AC Bottom-Up Cracking (Alligator)



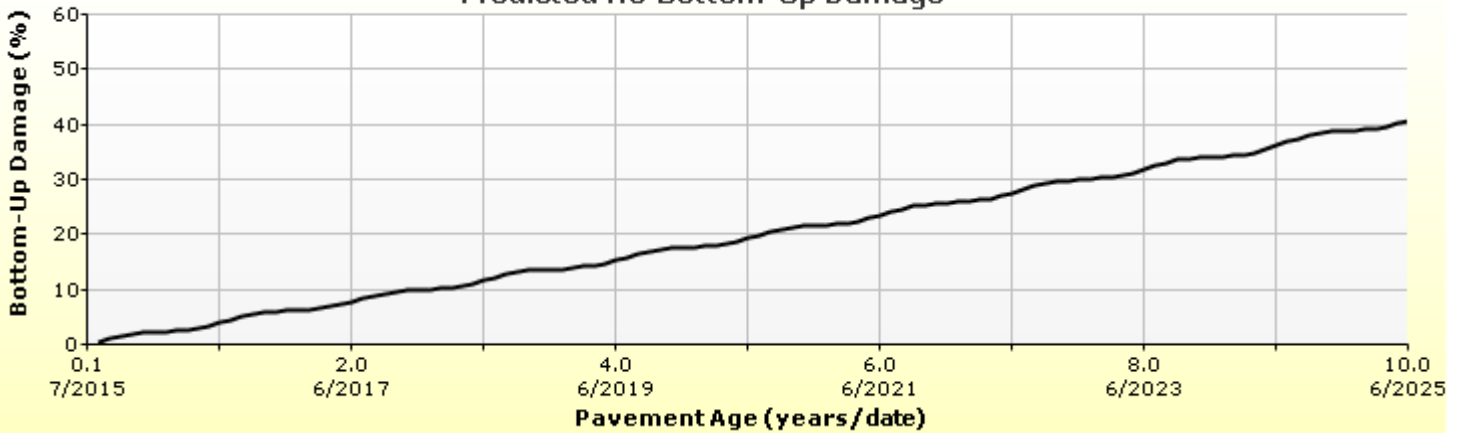
Thermal Cracking: Total Length vs. Time



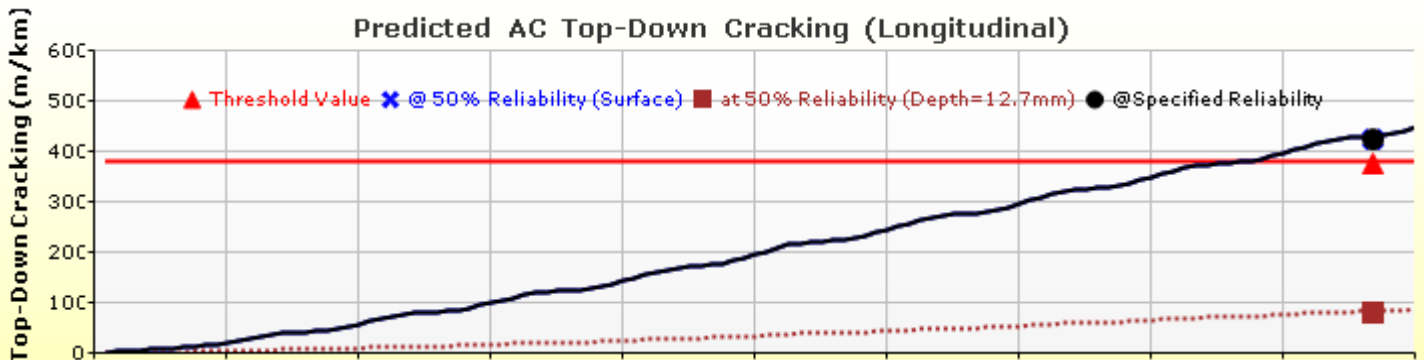
Predicted AC Top-Down Damage



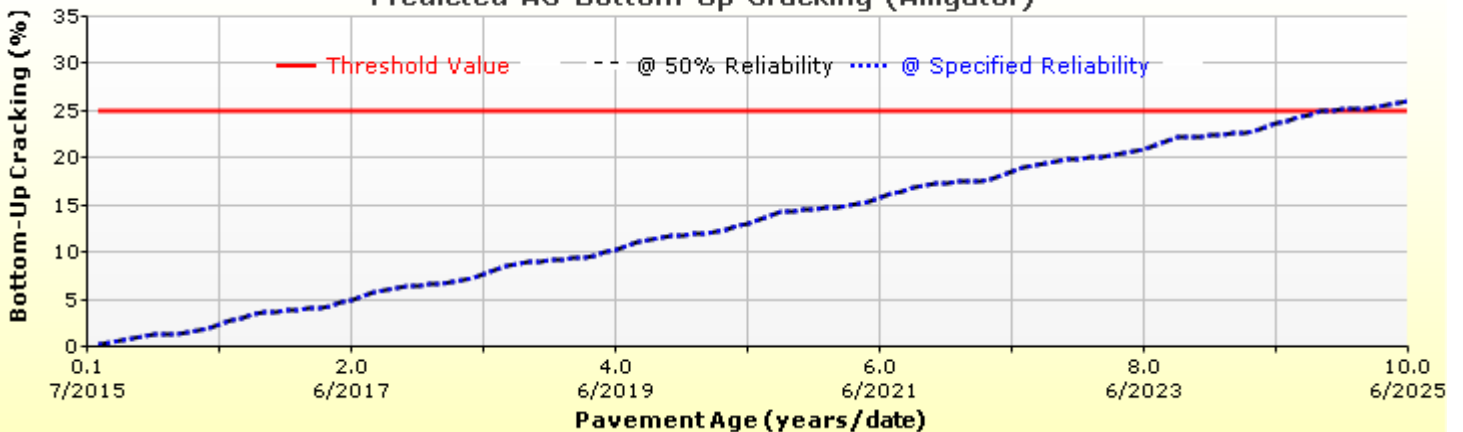
Predicted AC Bottom-Up Damage



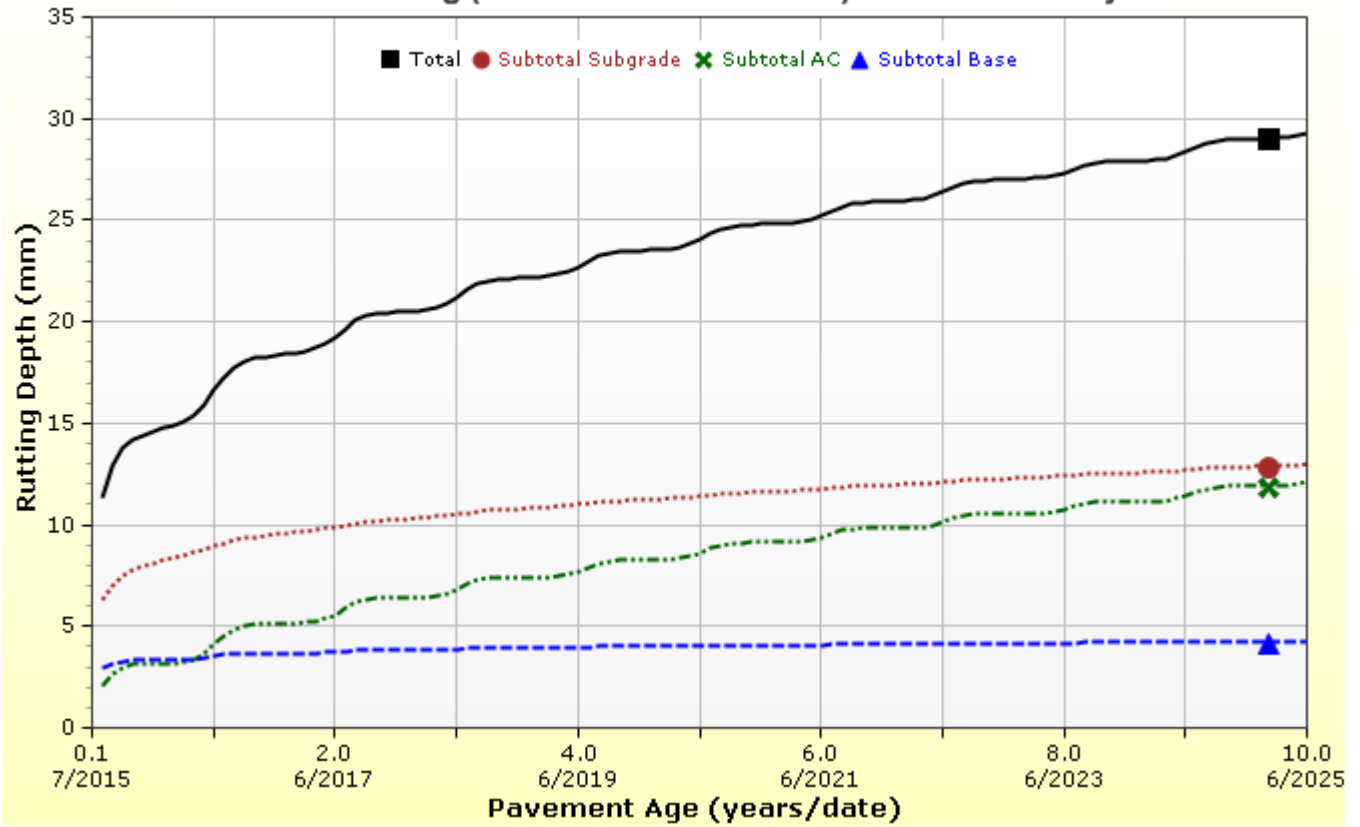
Predicted AC Top-Down Cracking (Longitudinal)

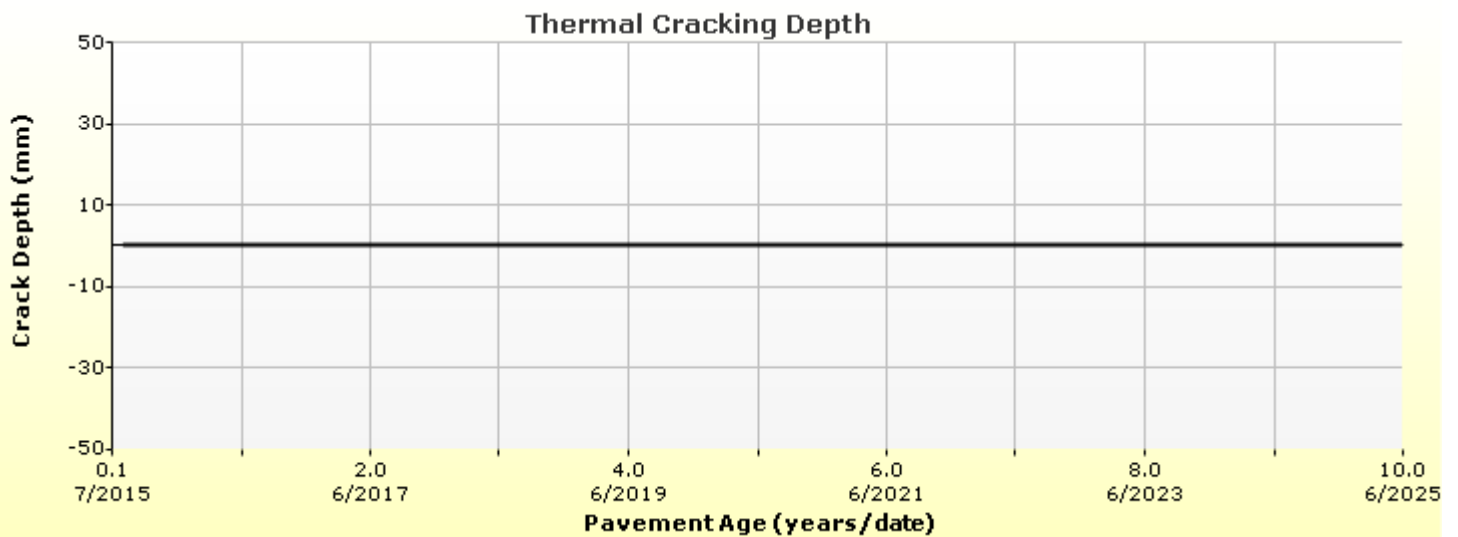
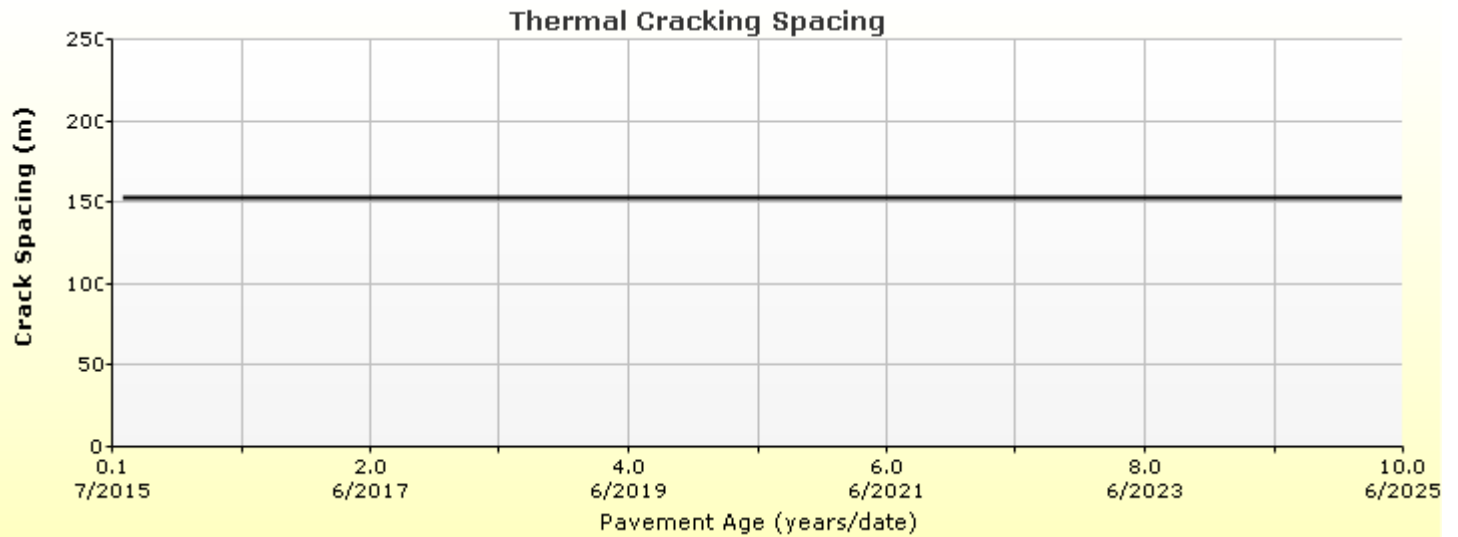


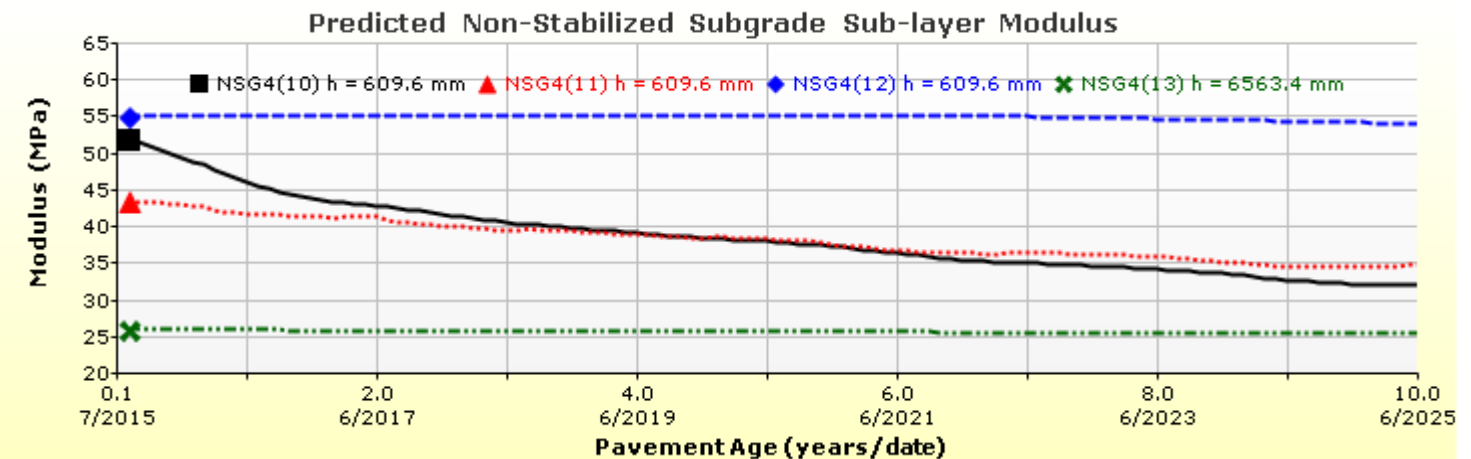
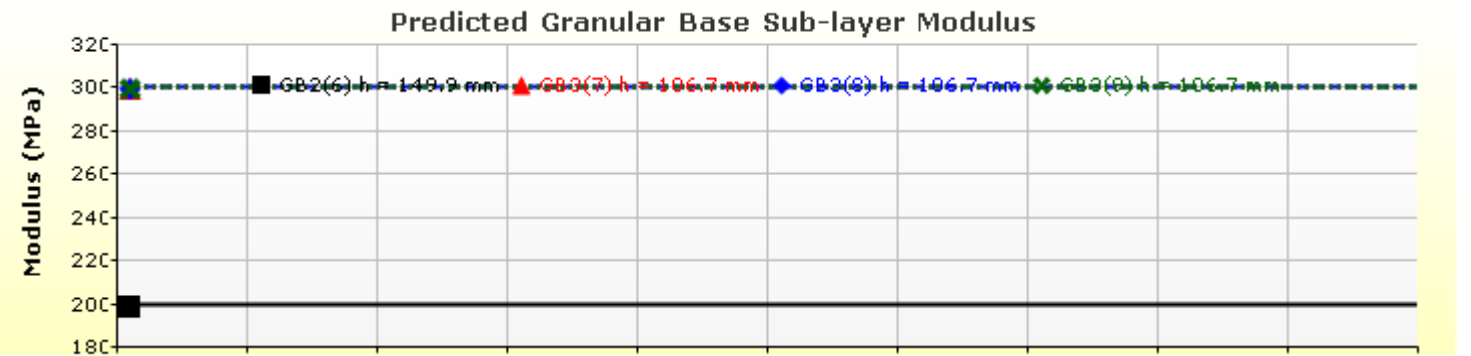
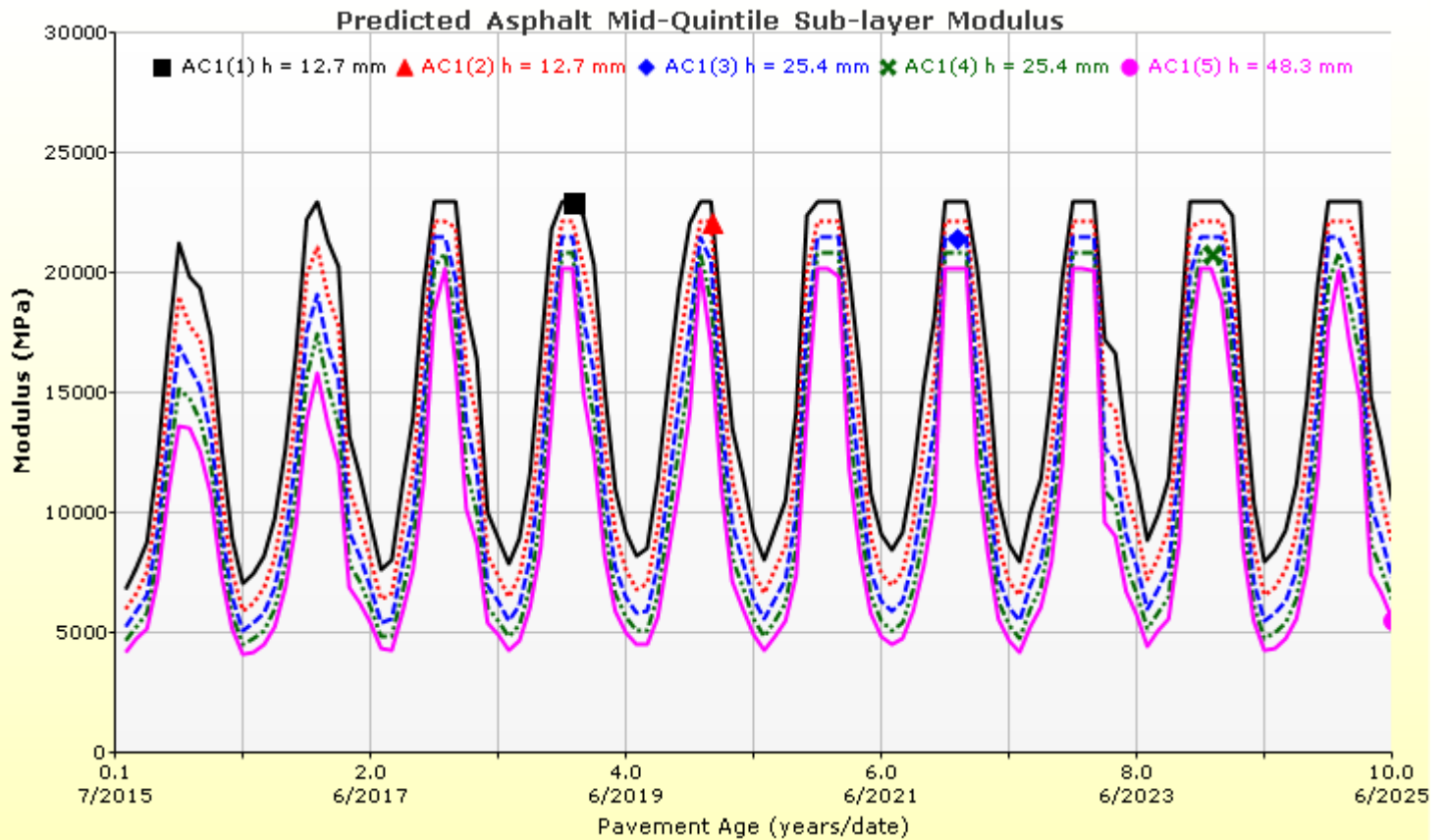
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015



ANEXO 5 – ANÁLISES PAVEWARE – CENÁRIO B: RESTAURAÇÃO

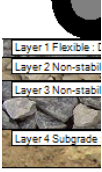
Design Inputs

Design Life: **10 years**
Design Type: **Flexible Pavement**

Base construction: **March, 2015**
Pavement construction: **June, 2015**
Traffic opening: **July, 2015**

Climate Data **32.119, -81.202**
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

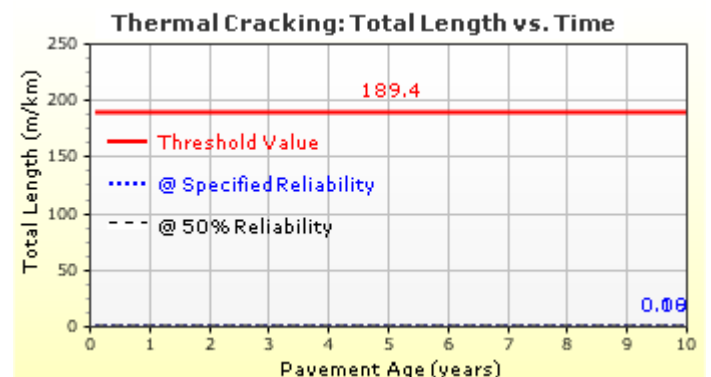
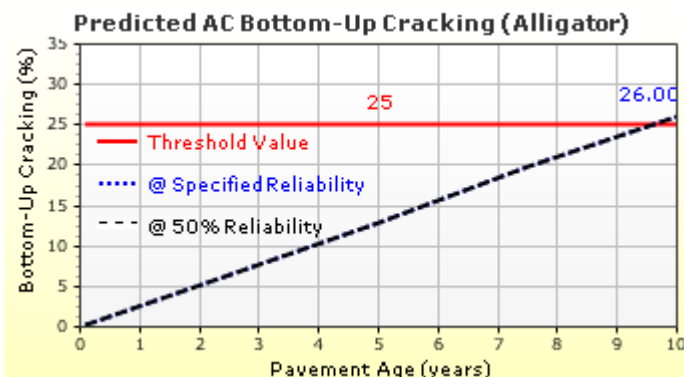
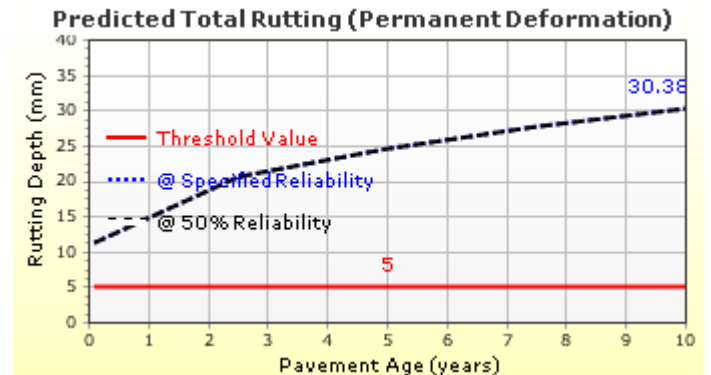
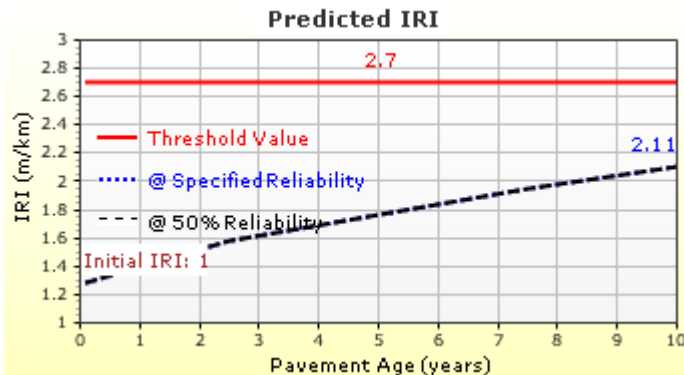
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.11	50.00	85.23	Pass
Permanent deformation - total pavement (mm)	5.00	30.38	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	26.00	50.00	47.18	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	645.83	50.00	27.58	Fail
Permanent deformation - AC only (mm)	5.00	14.51	50.00	0.76	Fail

Distress Charts

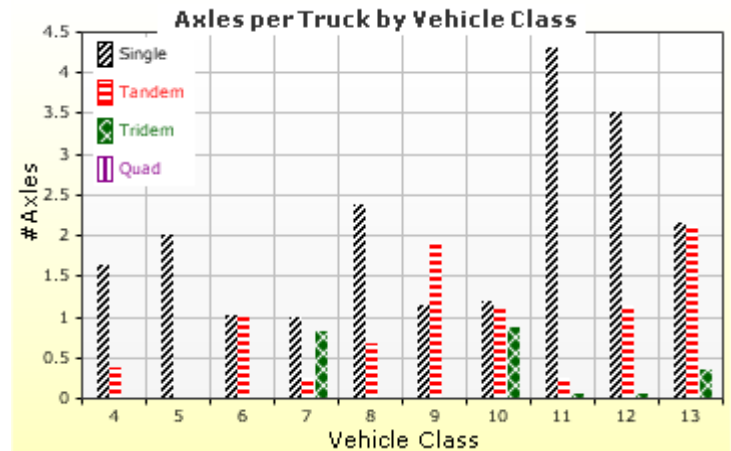
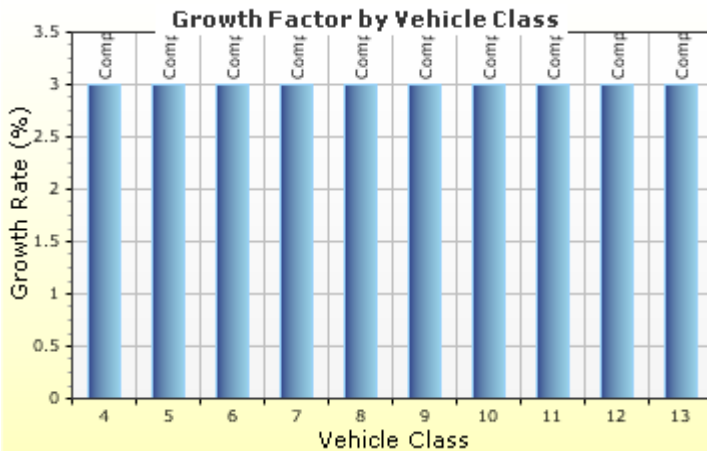
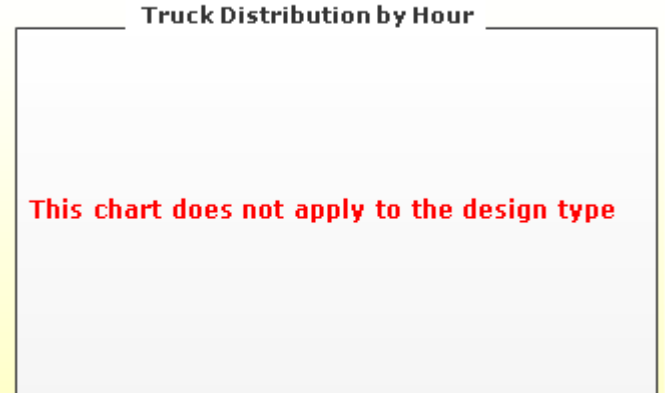
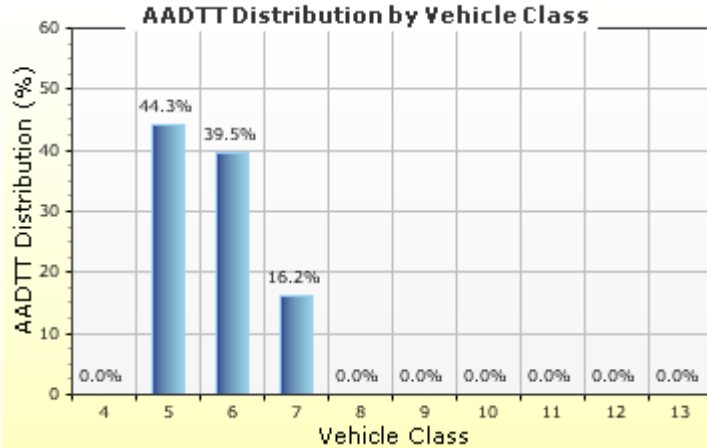


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

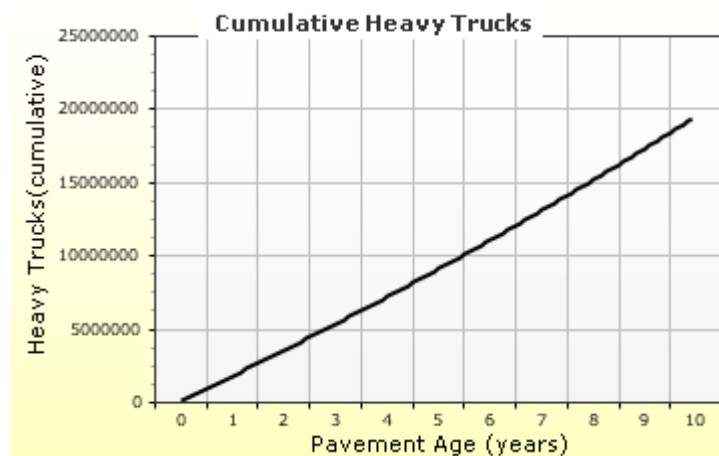
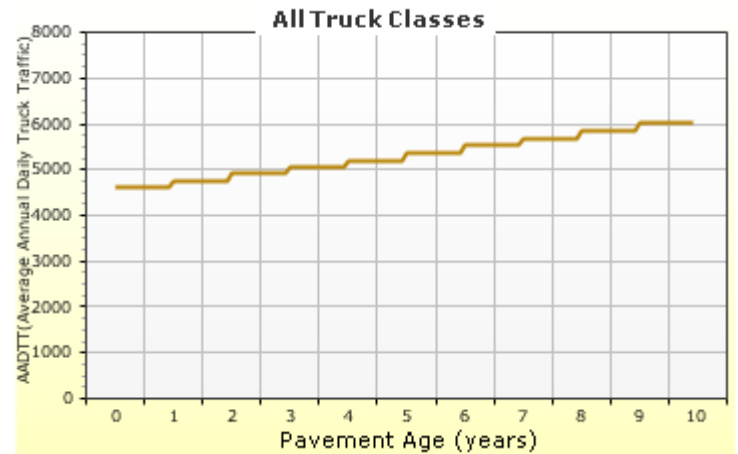
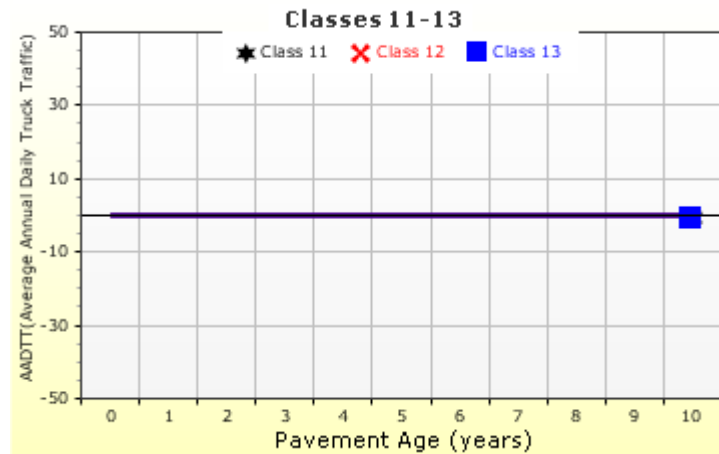
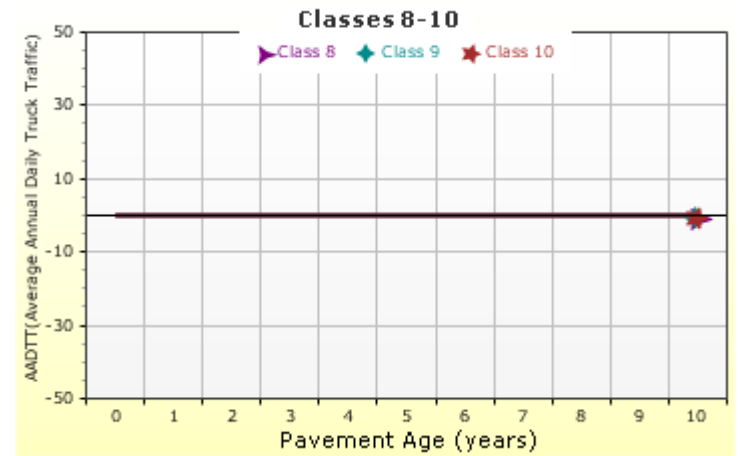
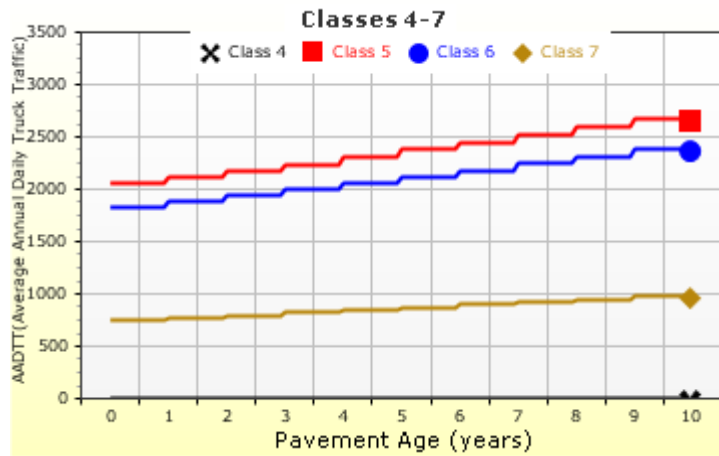
Wheelbase does not apply

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



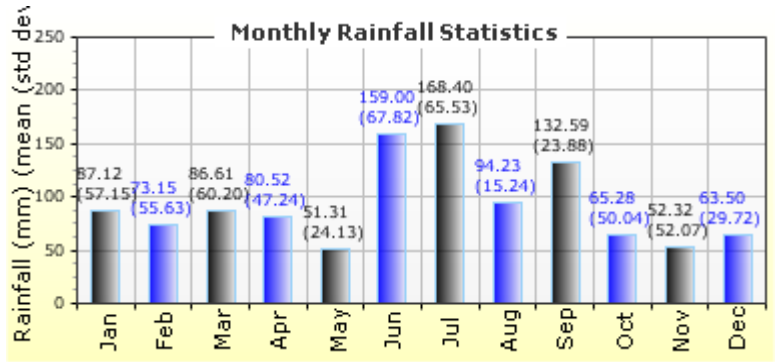
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

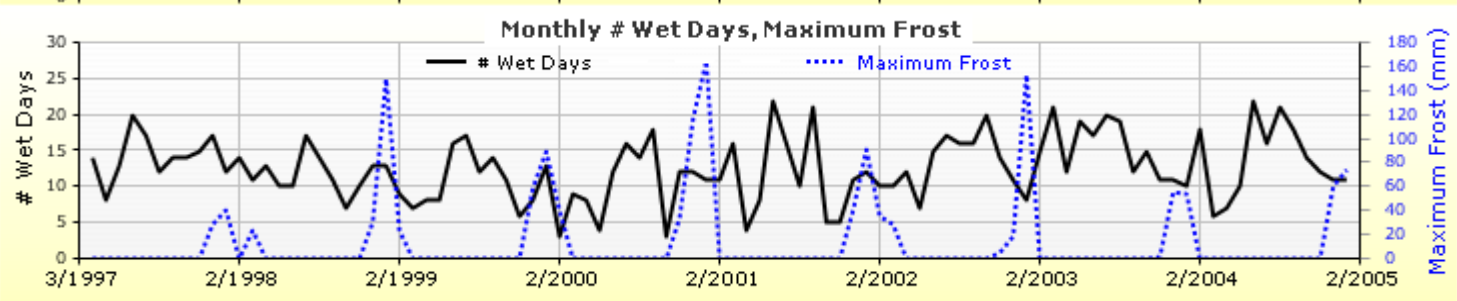
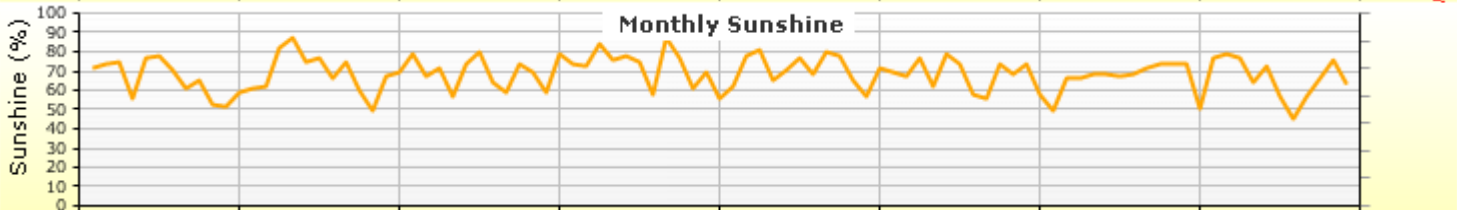
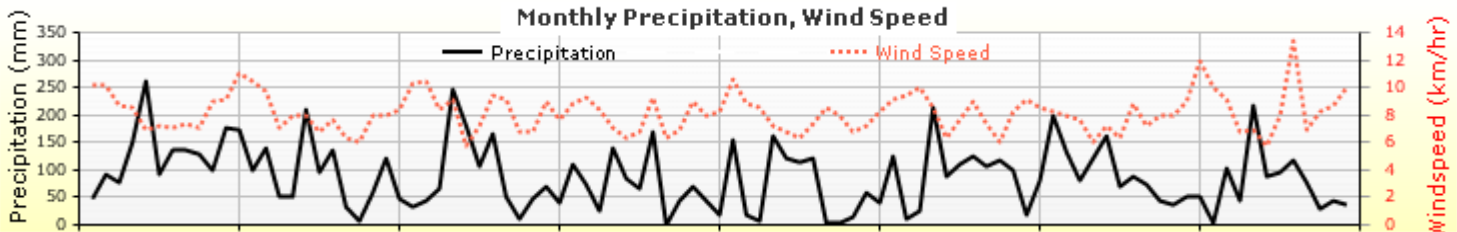
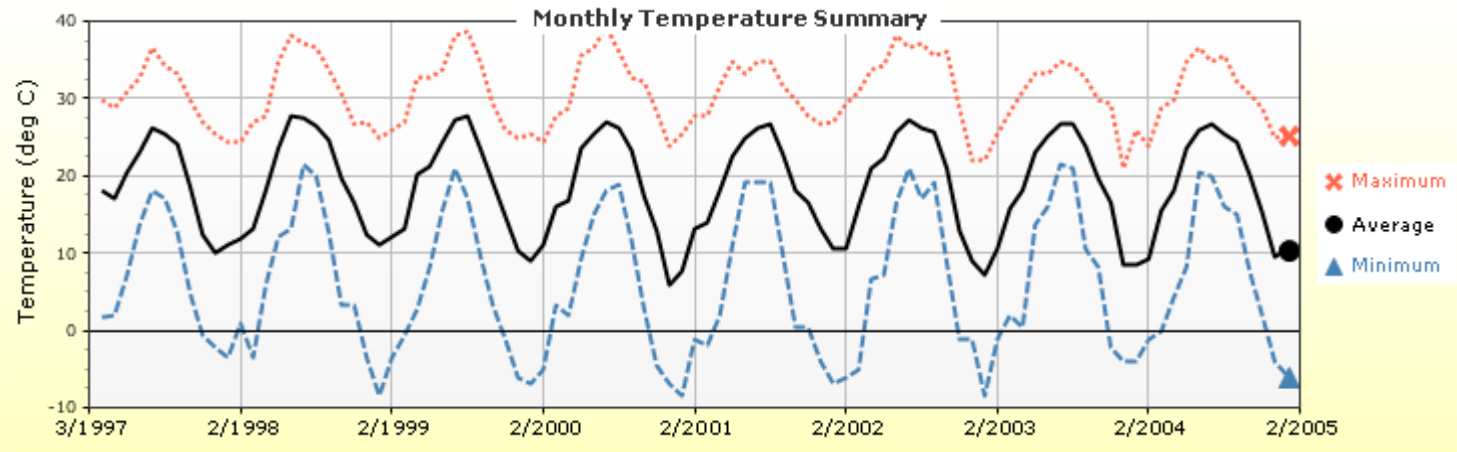
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

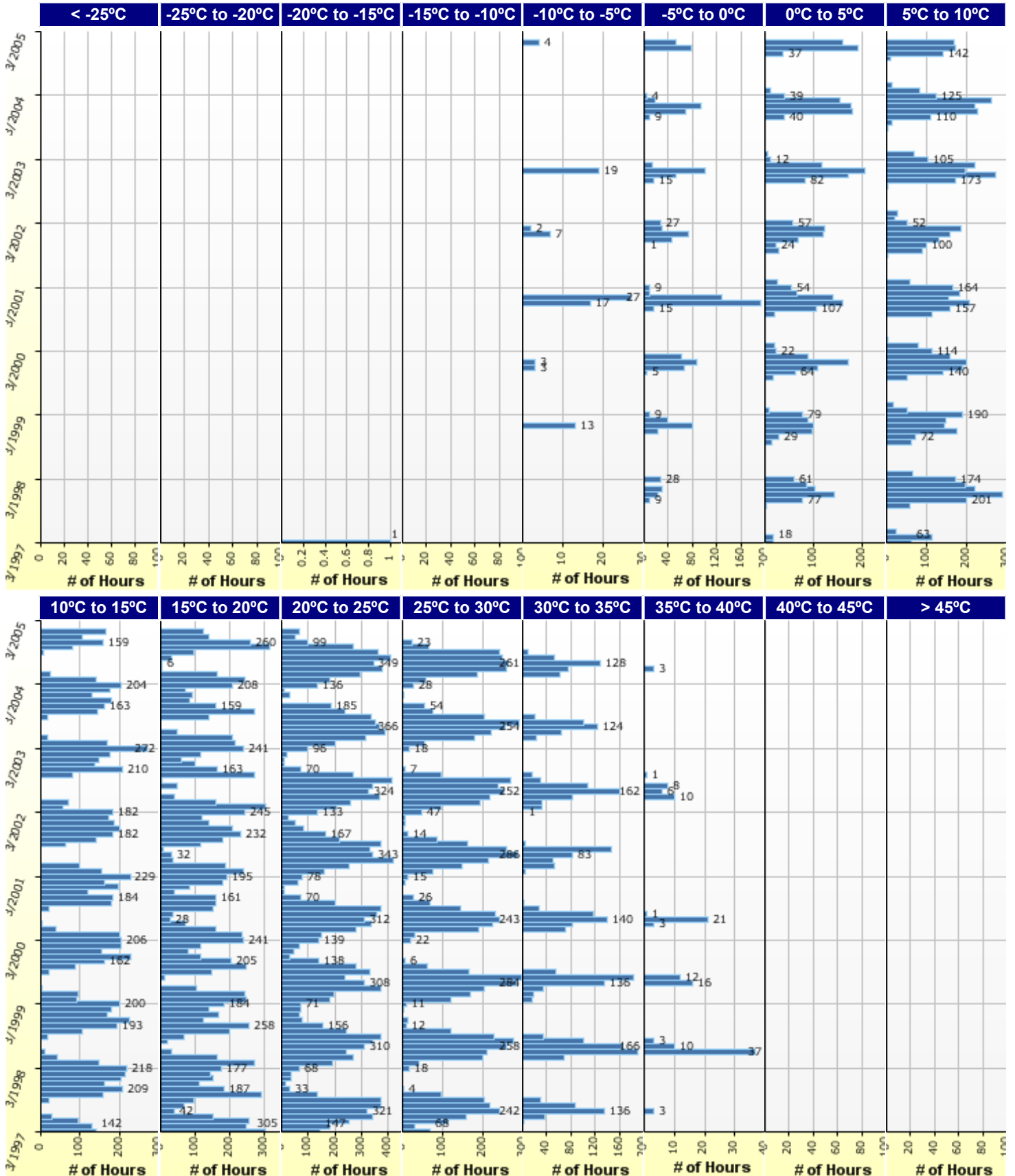


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF1

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1.dgpx



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

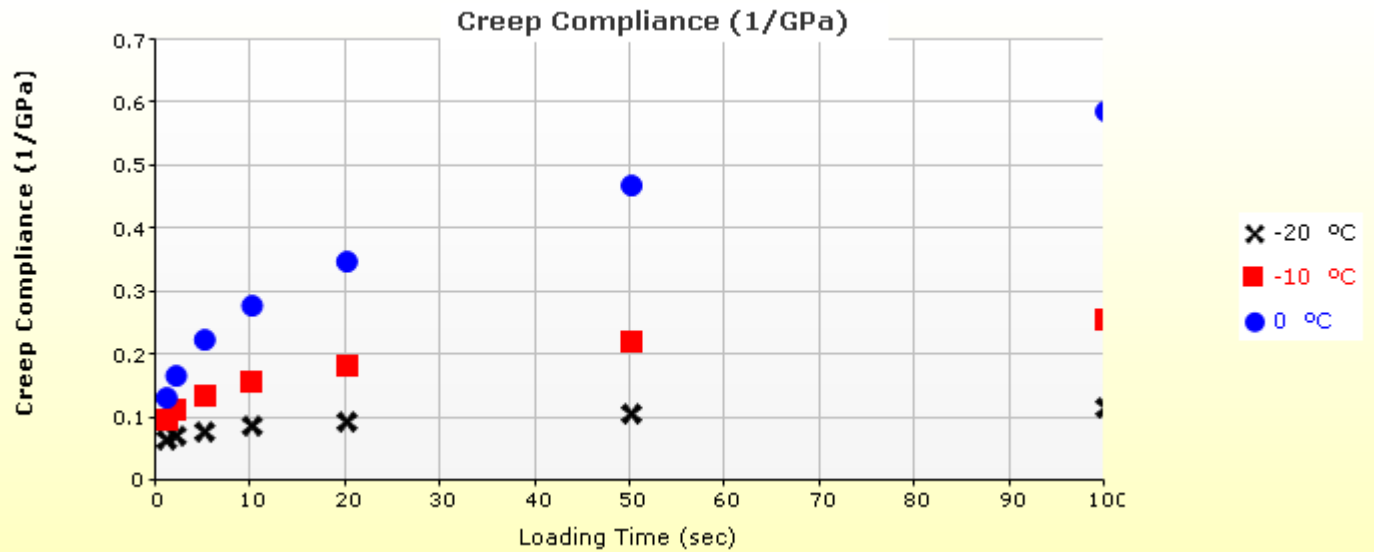
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

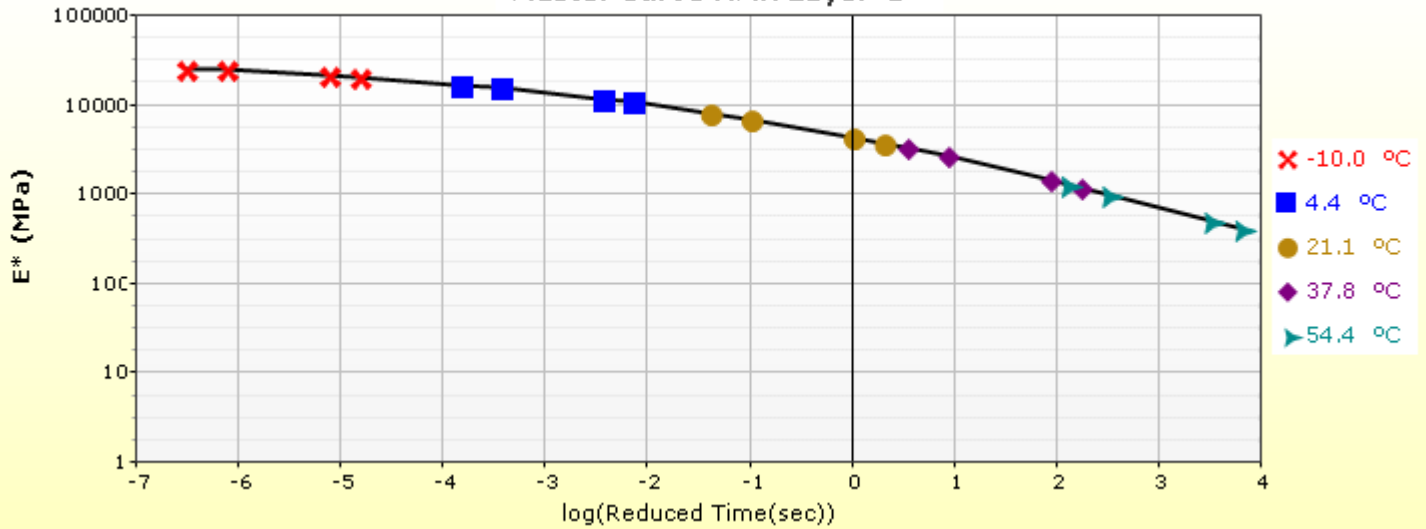
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

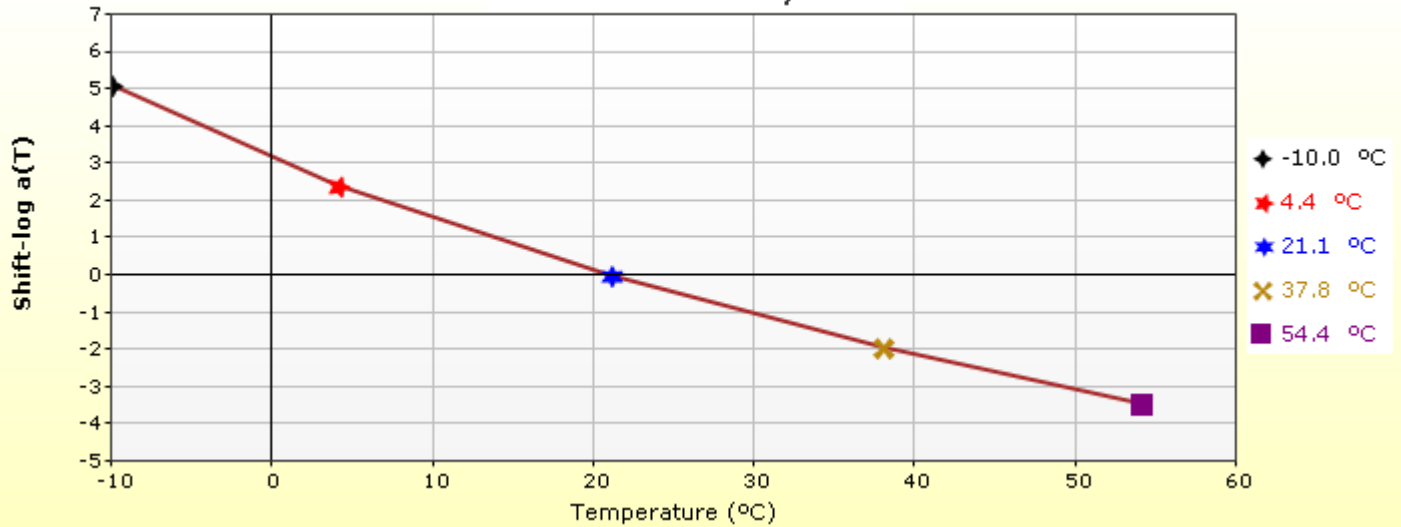


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

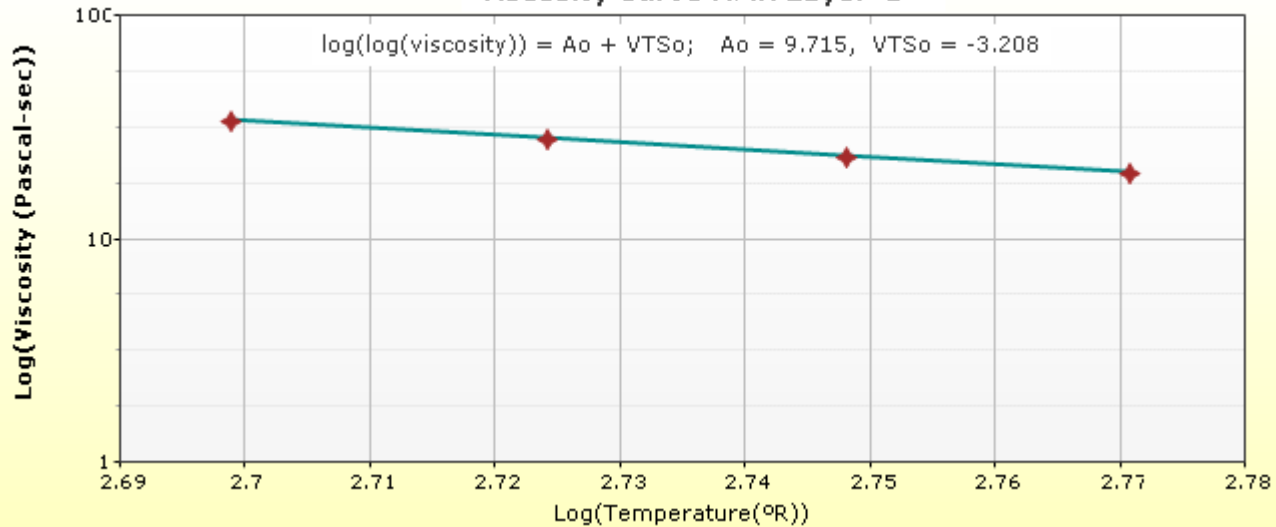
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

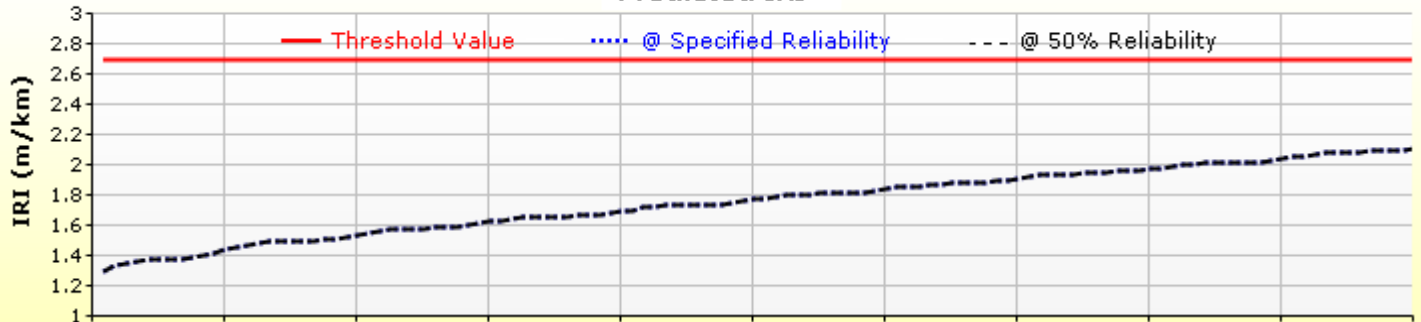


Viscosity Curve HMA Layer 1

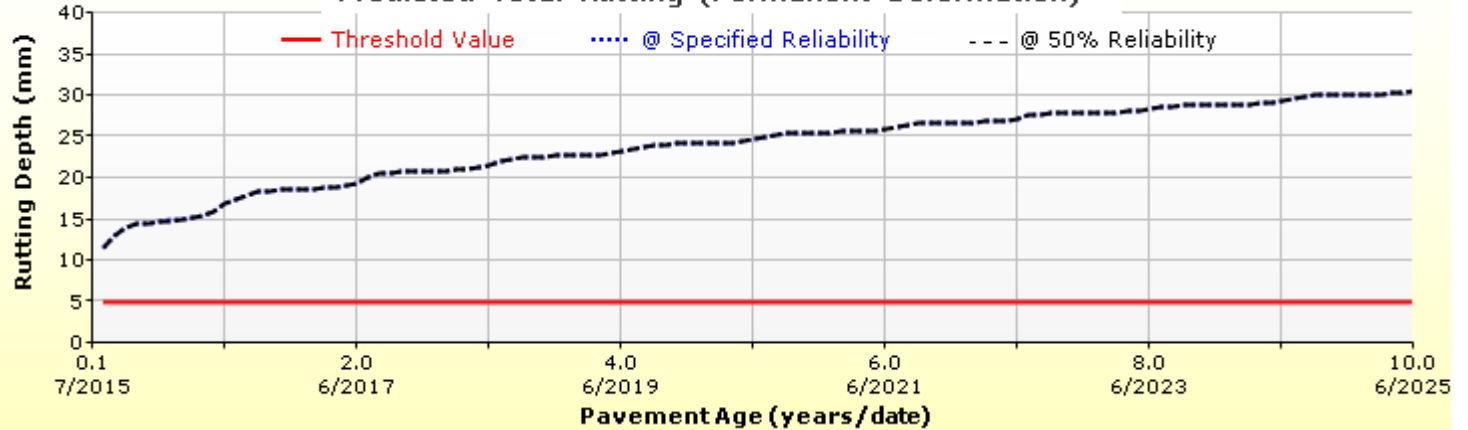


Analysis Output Charts

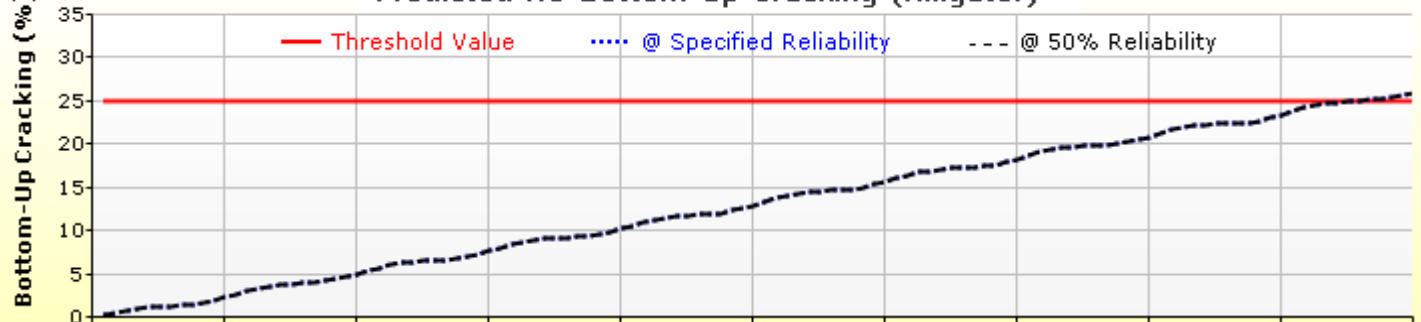
Predicted IRI



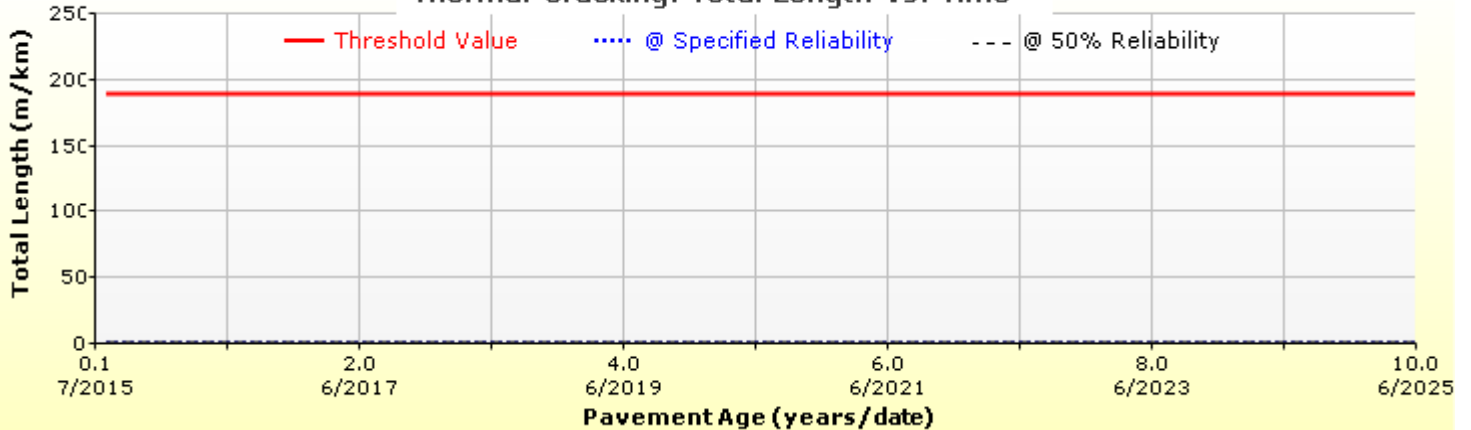
Predicted Total Rutting (Permanent Deformation)



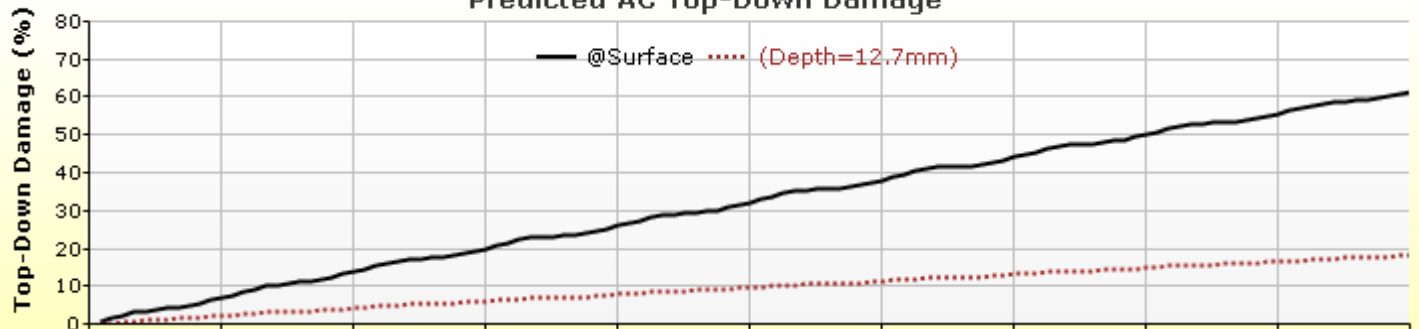
Predicted AC Bottom-Up Cracking (Alligator)



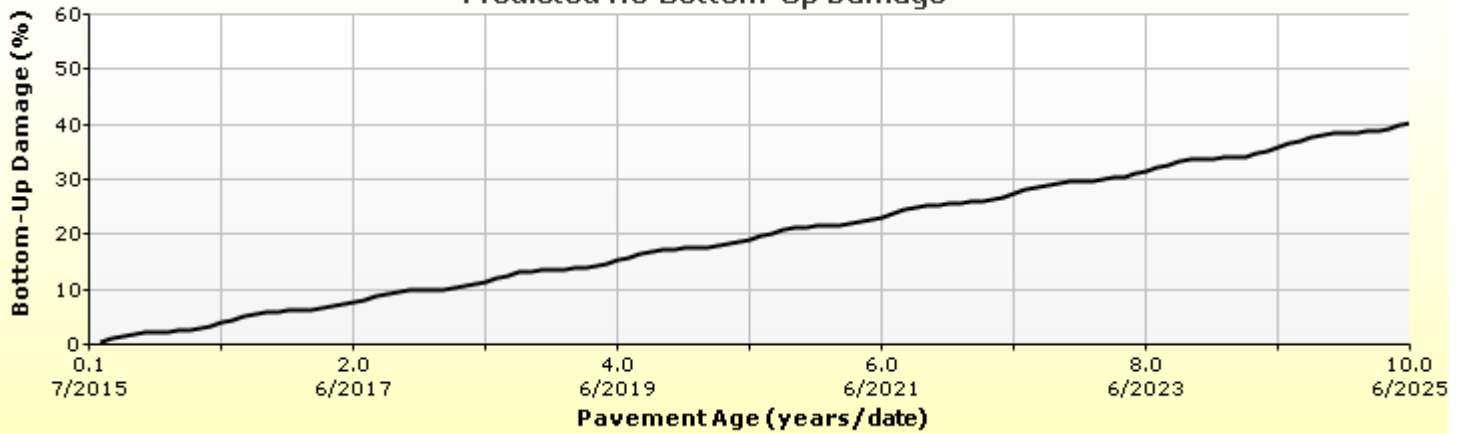
Thermal Cracking: Total Length vs. Time



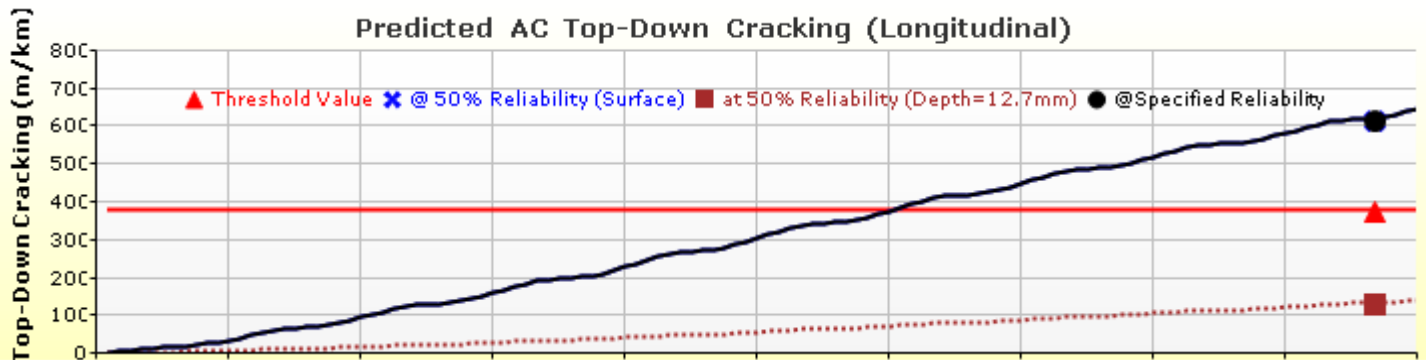
Predicted AC Top-Down Damage



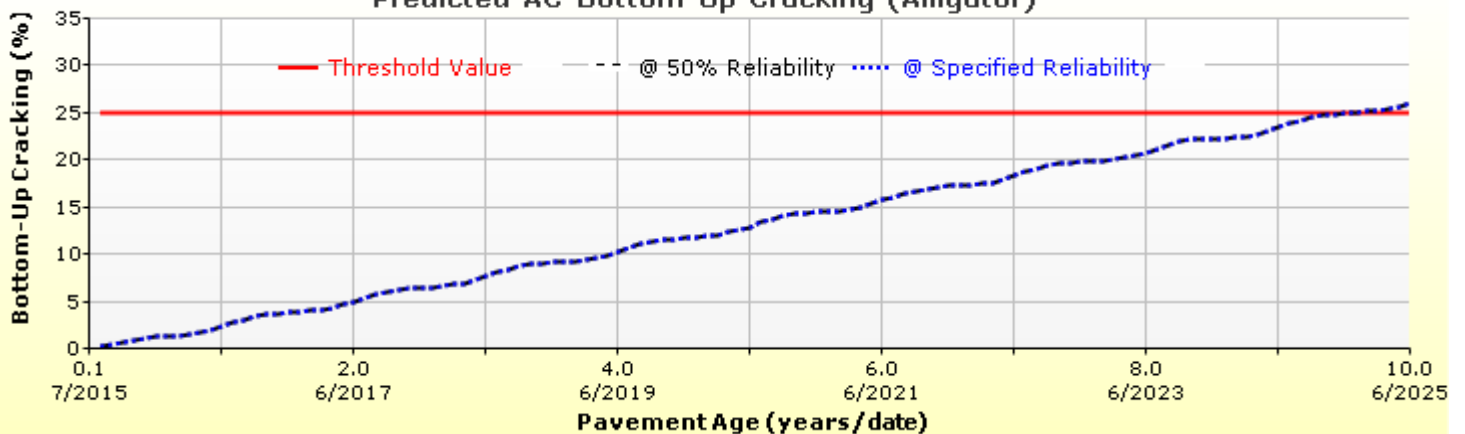
Predicted AC Bottom-Up Damage



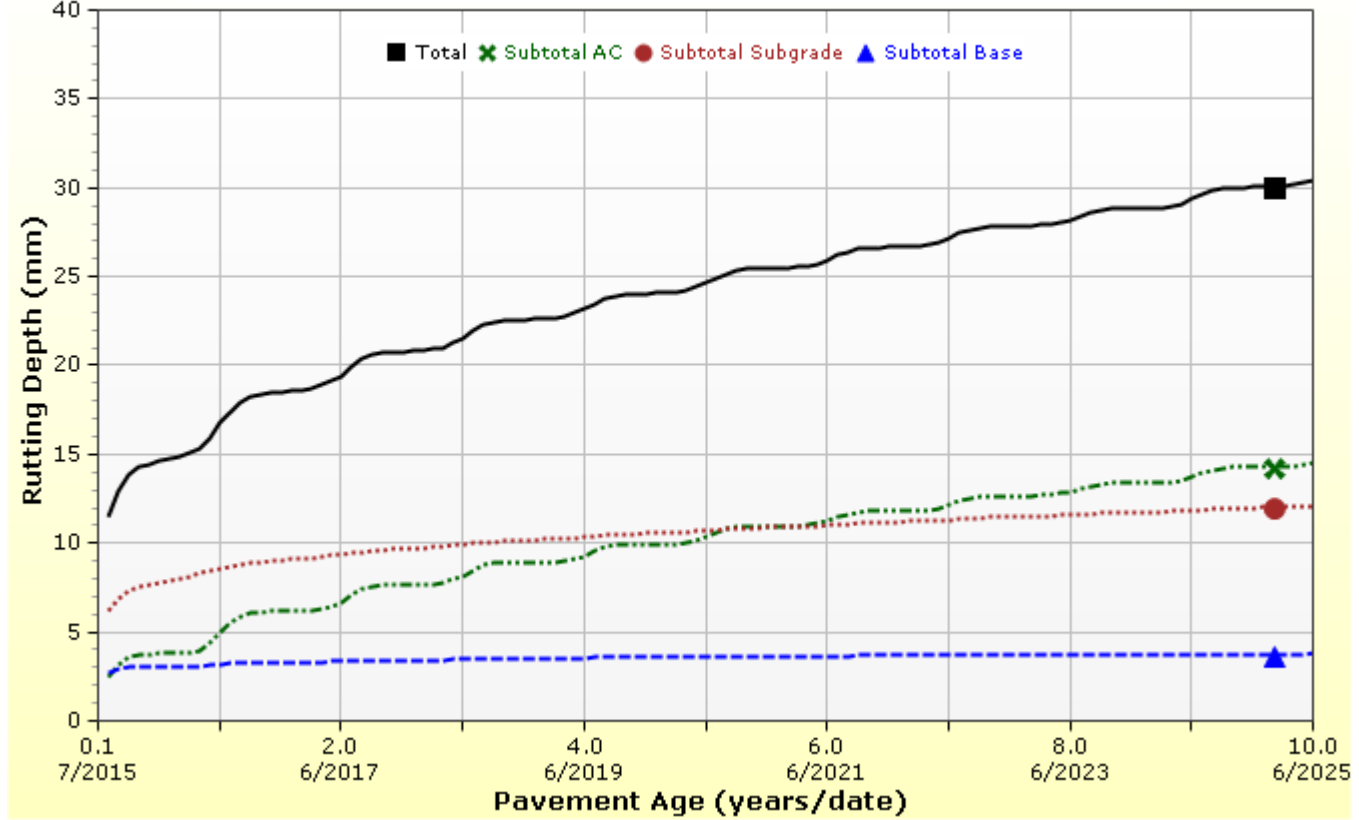
Predicted AC Top-Down Cracking (Longitudinal)

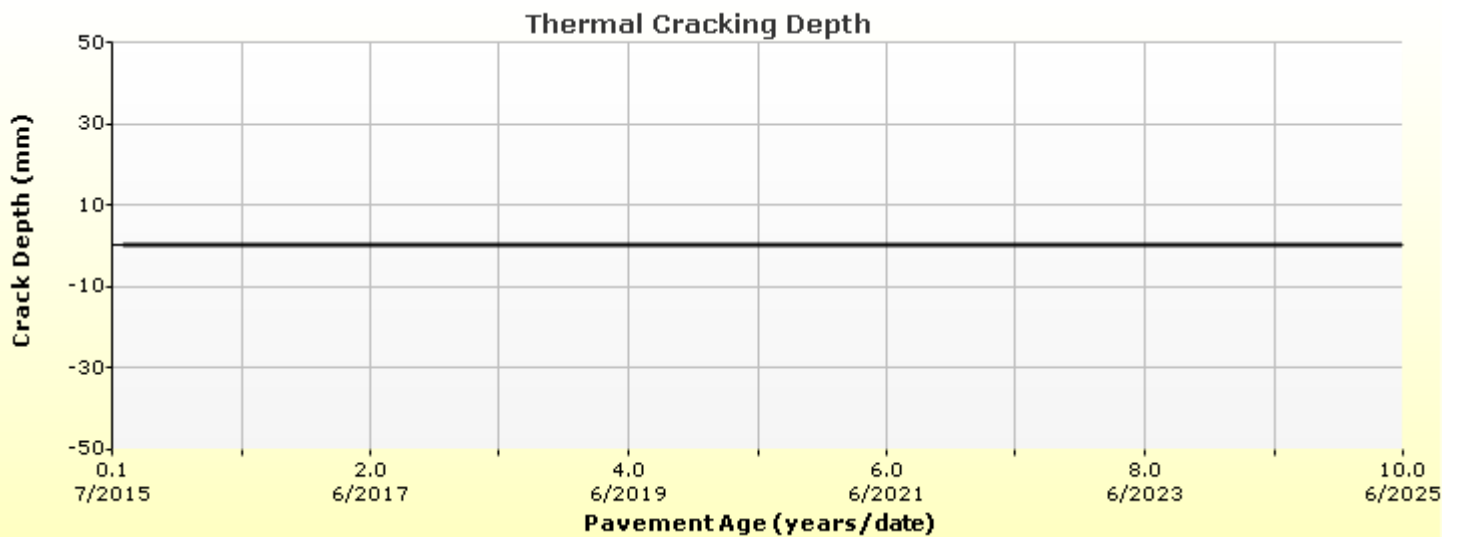
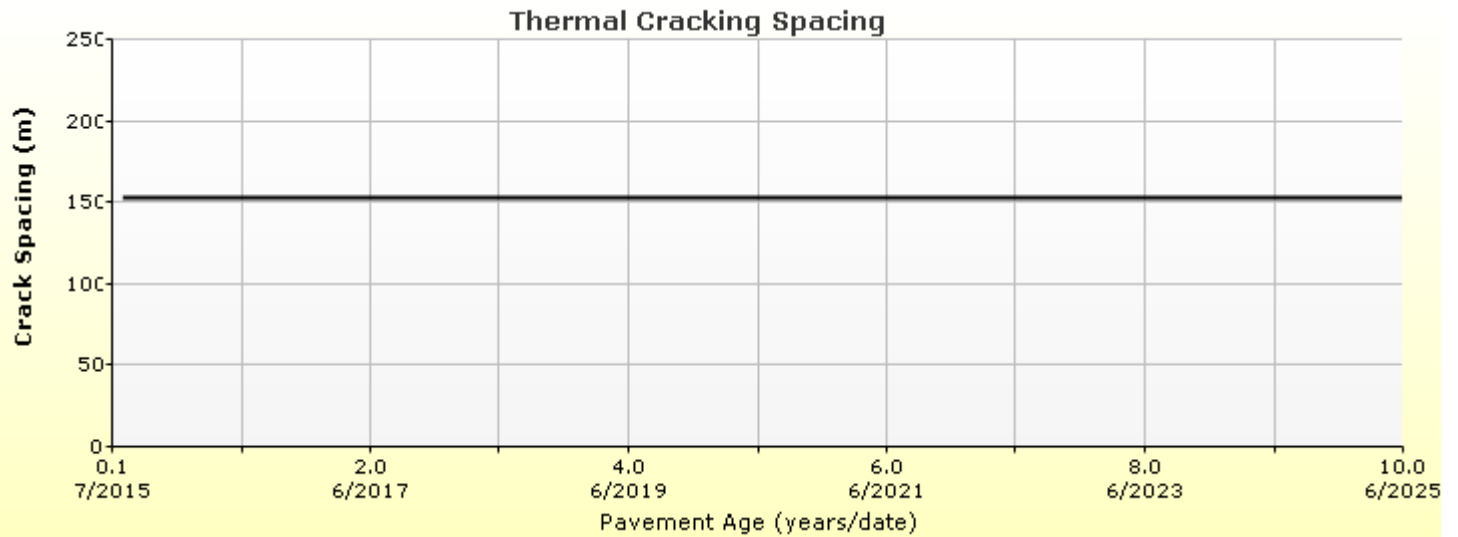


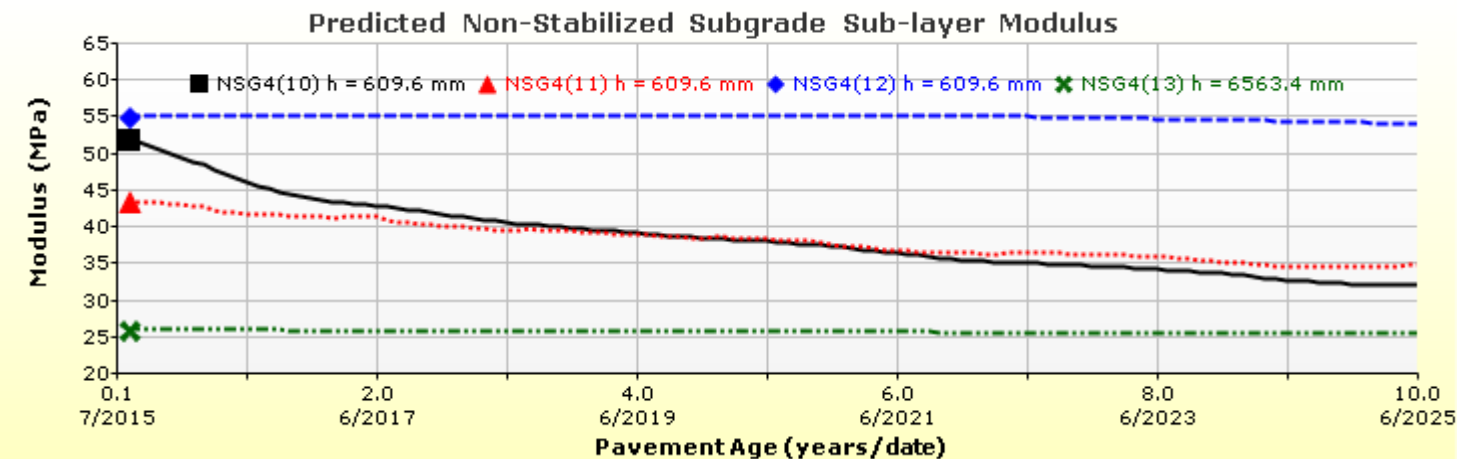
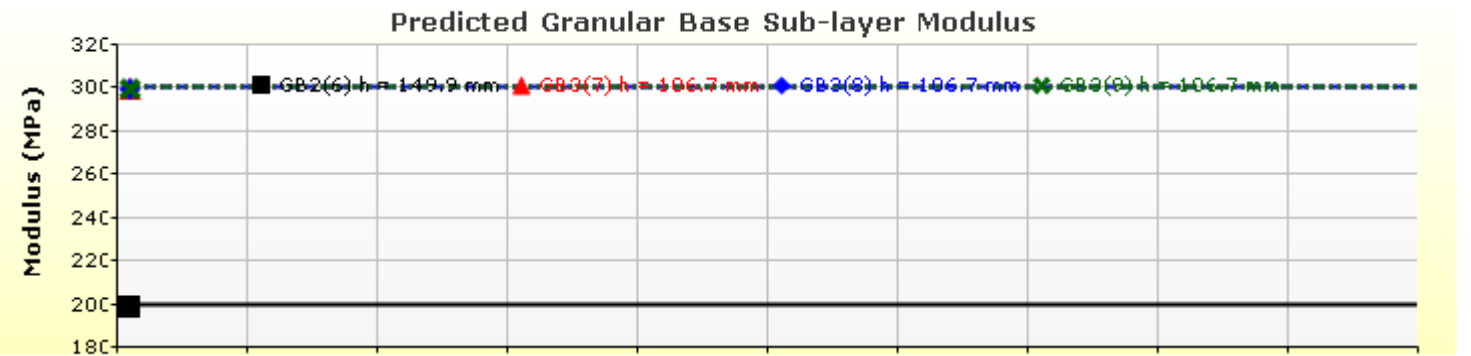
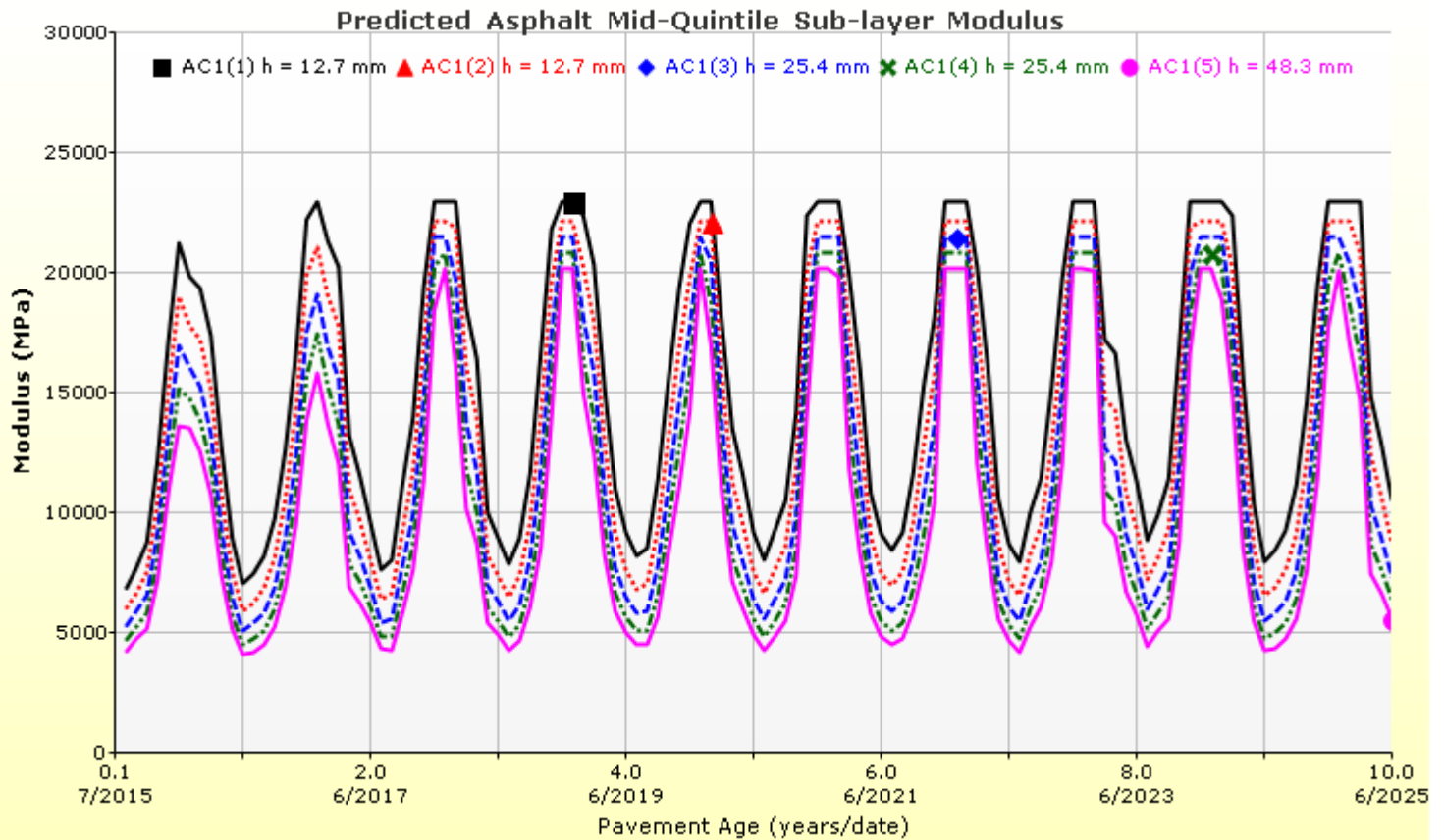
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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 $		δ_a = permanent deformation for the layer N = number of repetitions ε_v = average vertical strain(in/in) $\varepsilon_0, \beta, \rho$ = material properties ε_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		AC Bottom Up Cracking	
$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * \log_{10}(Damage))}} \right) * 10.56$		$FC = \left(\frac{6000}{1 + e^{(C_1 * C'_1 + C_2 * C'_2 * \log_{10}(D * 100))}} \right) * \left(\frac{1}{60} \right)$ $C'_2 = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$ $C'_1 = -2 * C'_2$	
c1: 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 Cracking Bottom Standard Deviation 1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))	

CSM Cracking		IRI Flexible Pavements	
$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$		C1 - Rutting C3 - Transverse Crack C2 - Fatigue Crack C4 - Site Factors	
C1: 1	C2: 1	C3: 0	C4: 1000
CSM Standard Deviation CTB*1		C1: 40	C2: 0.4
		C3: 0.008	C4: 0.015

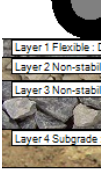
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

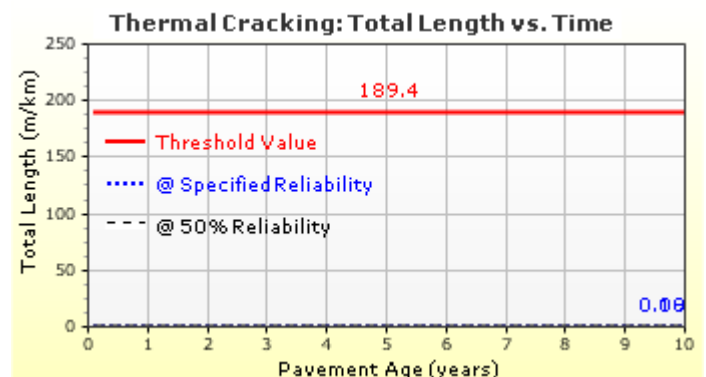
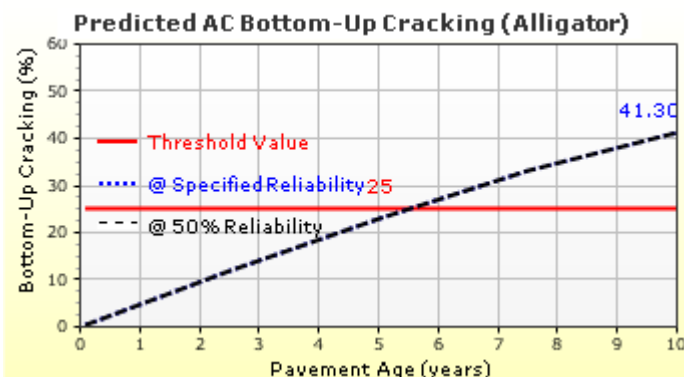
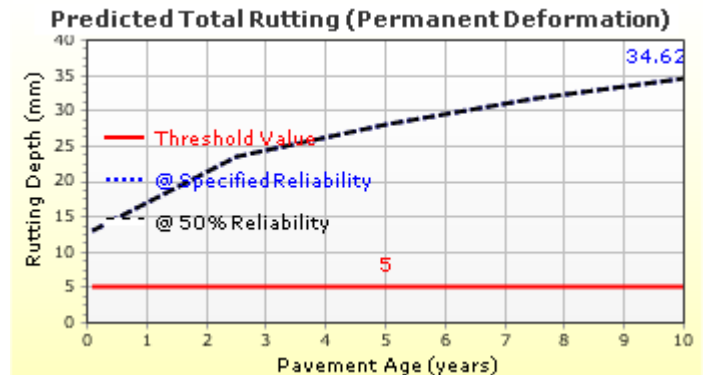
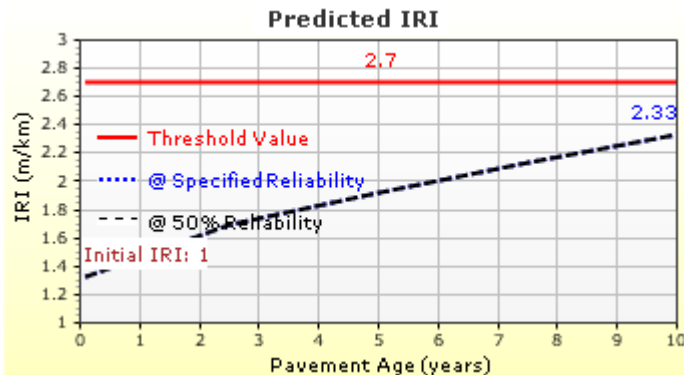
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.33	50.00	73.16	Pass
Permanent deformation - total pavement (mm)	5.00	34.62	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	41.30	50.00	12.43	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	929.92	50.00	11.34	Fail
Permanent deformation - AC only (mm)	5.00	17.02	50.00	0.34	Fail

Distress Charts

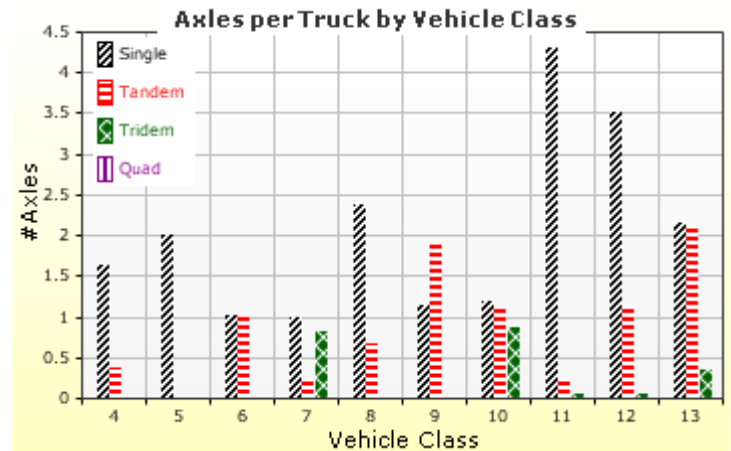
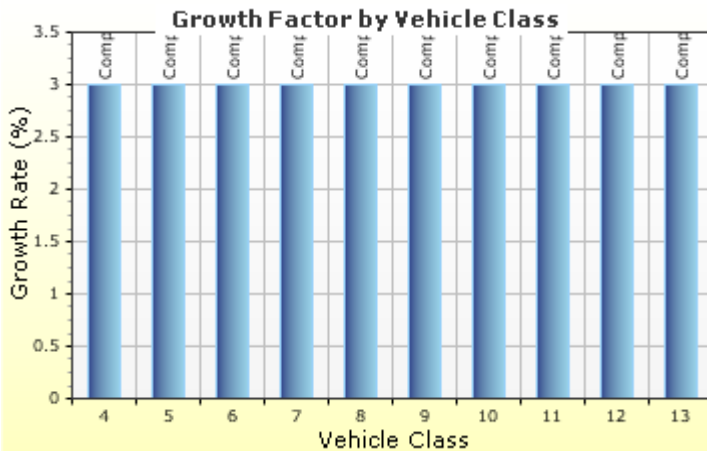
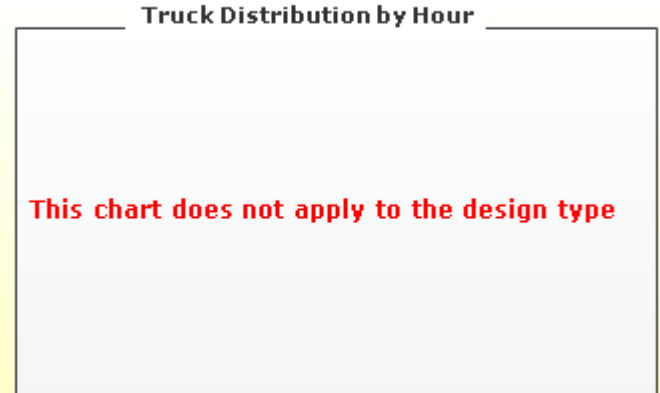
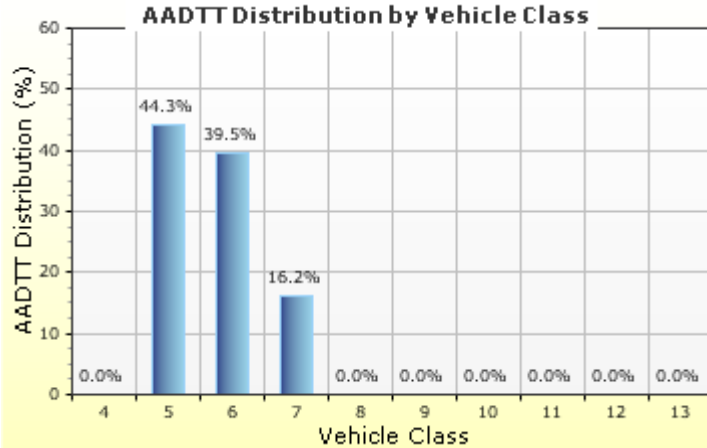


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

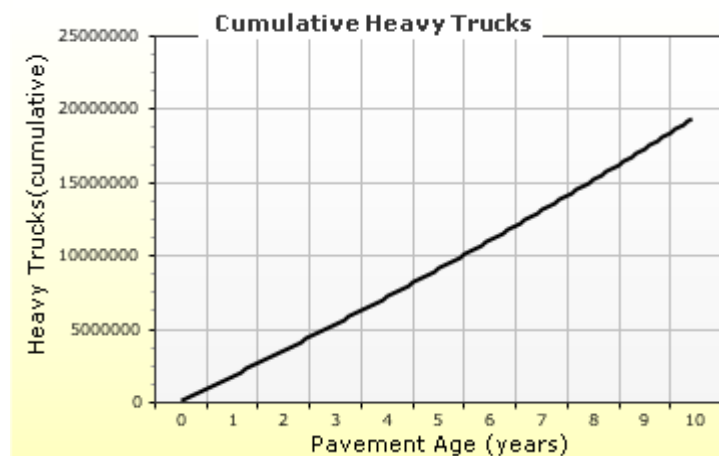
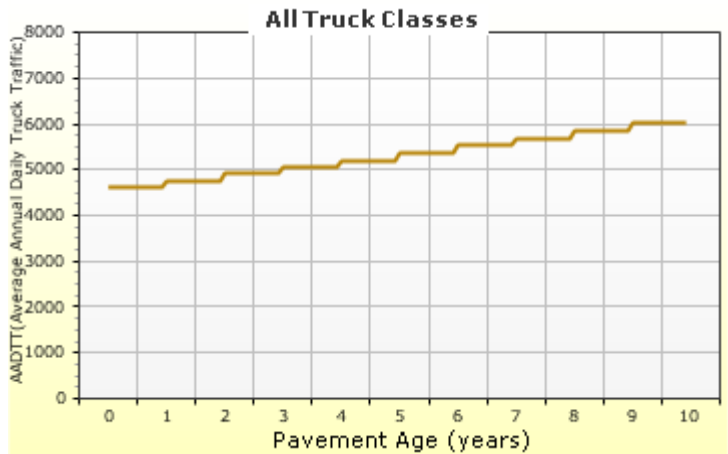
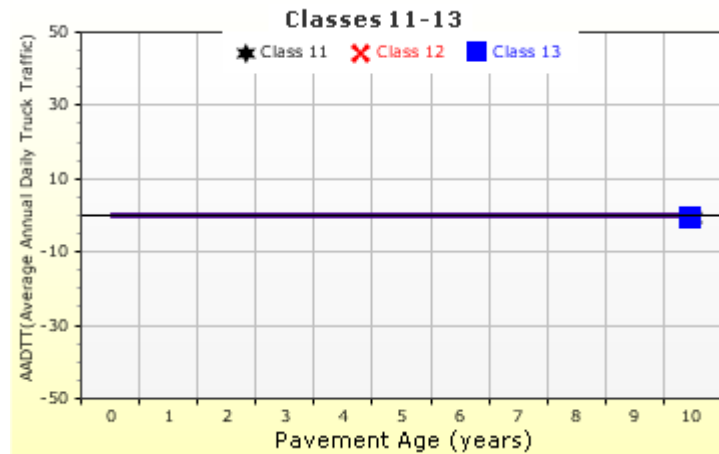
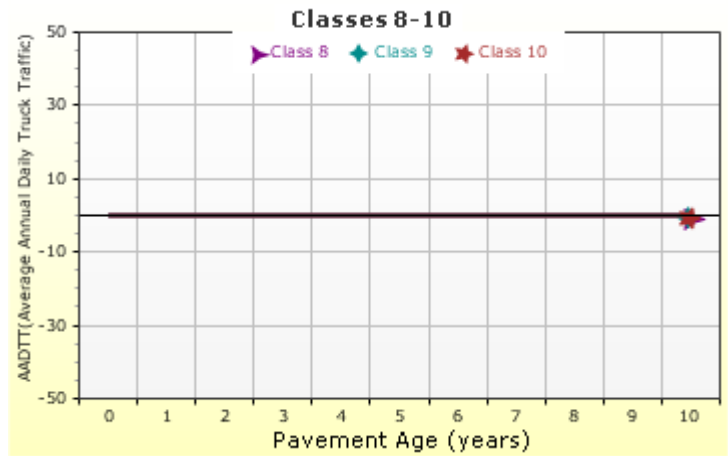
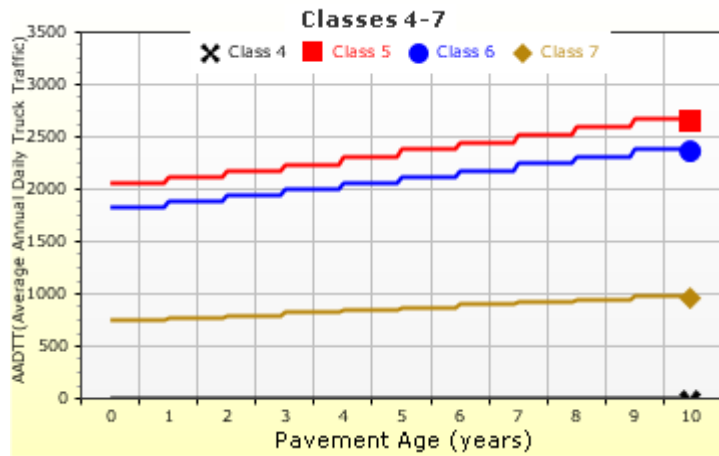
Wheelbase does not apply	

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



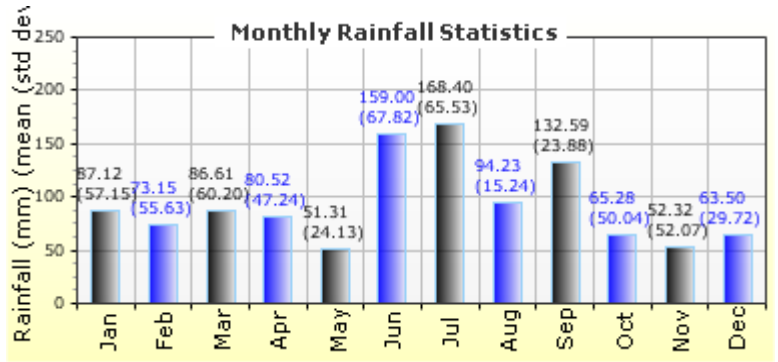
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

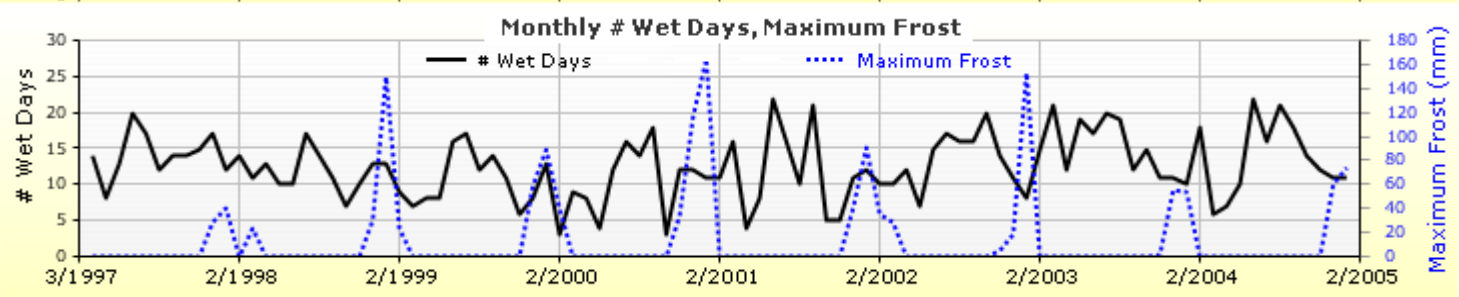
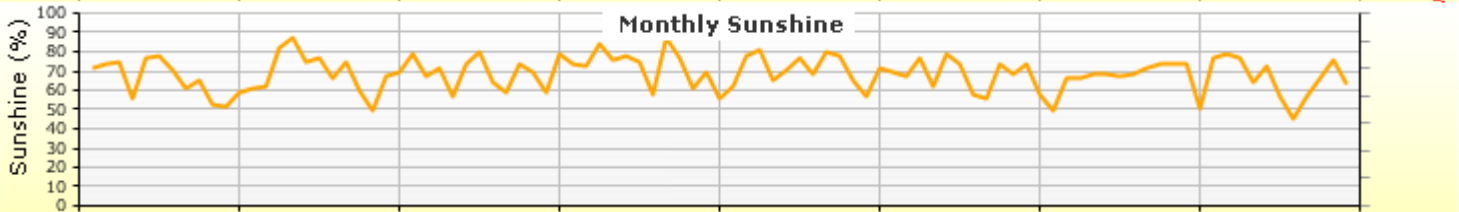
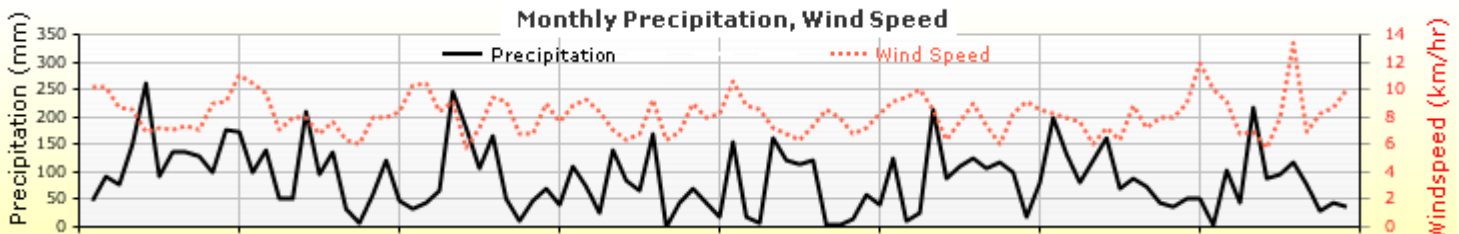
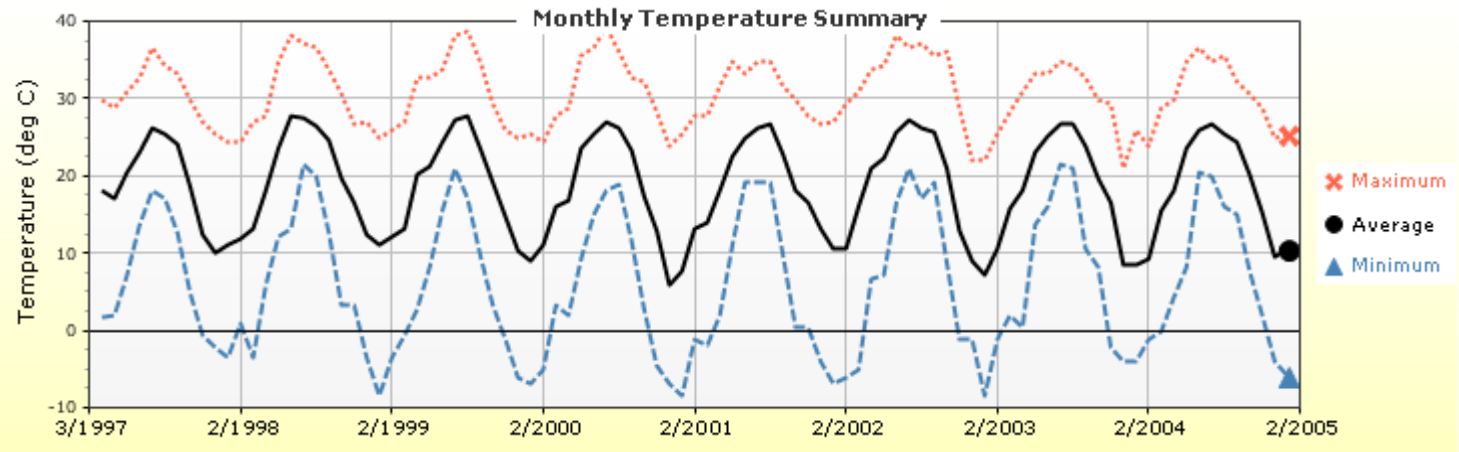
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

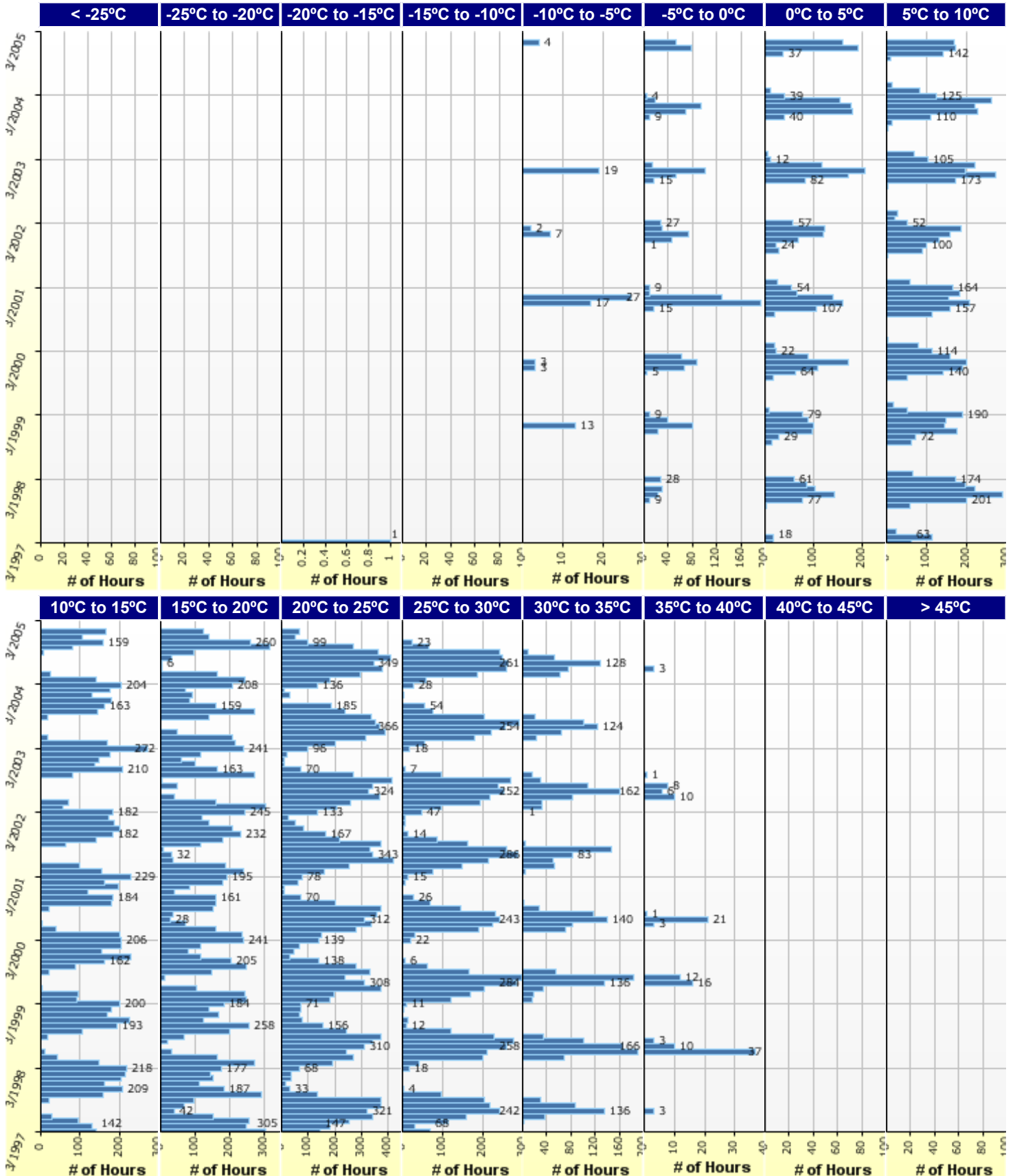


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF2

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF2.dgpx



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

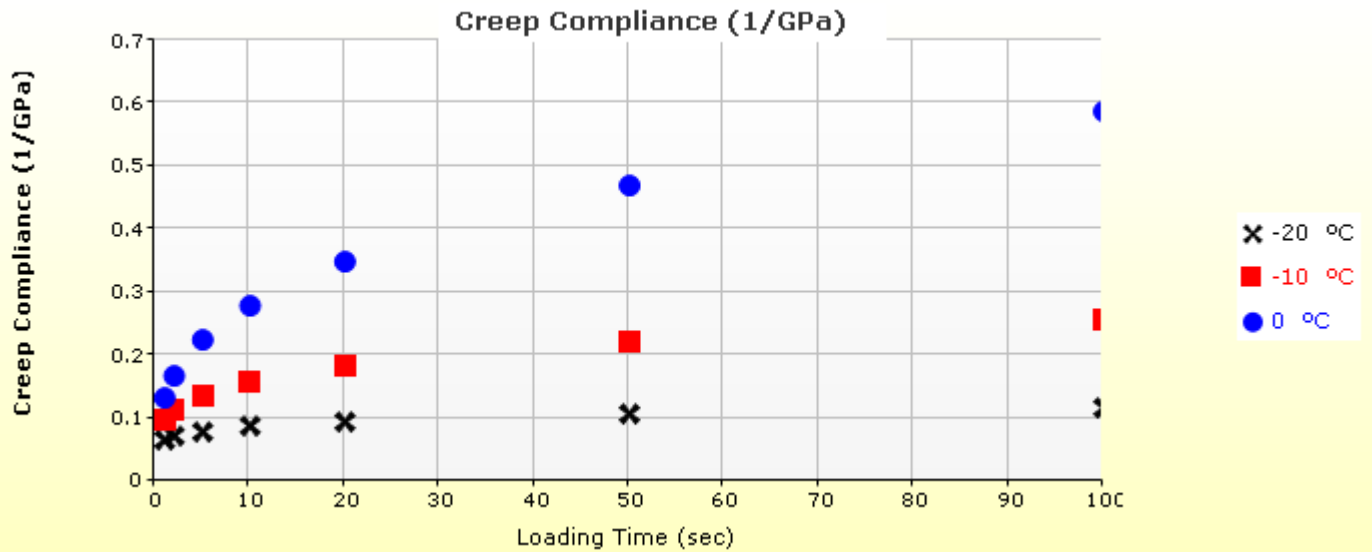
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

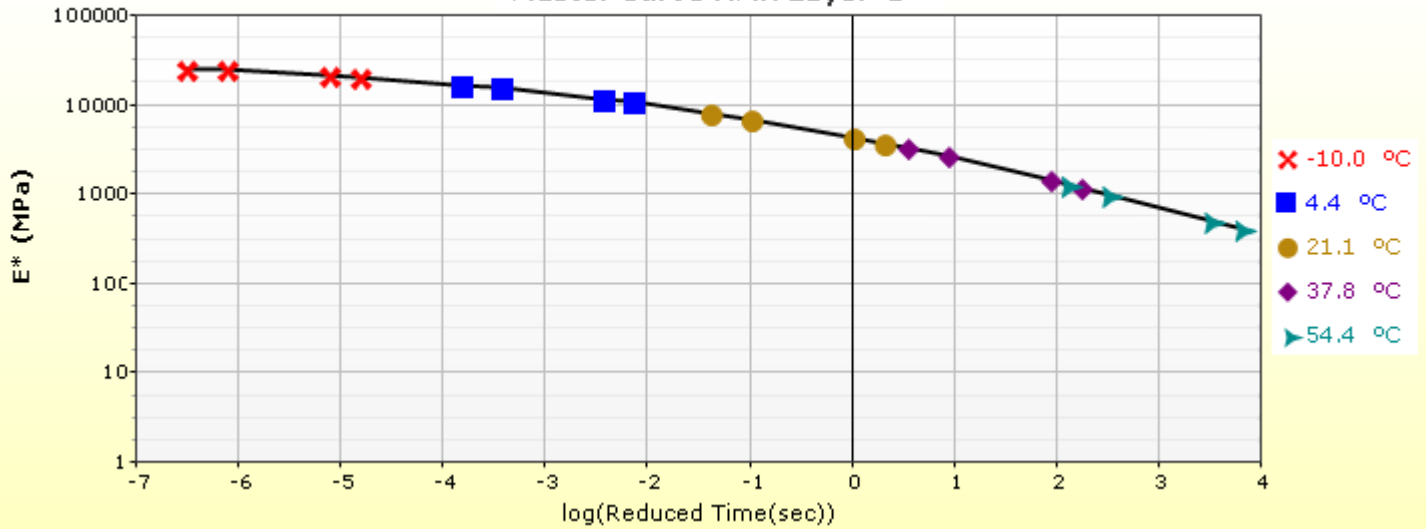
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

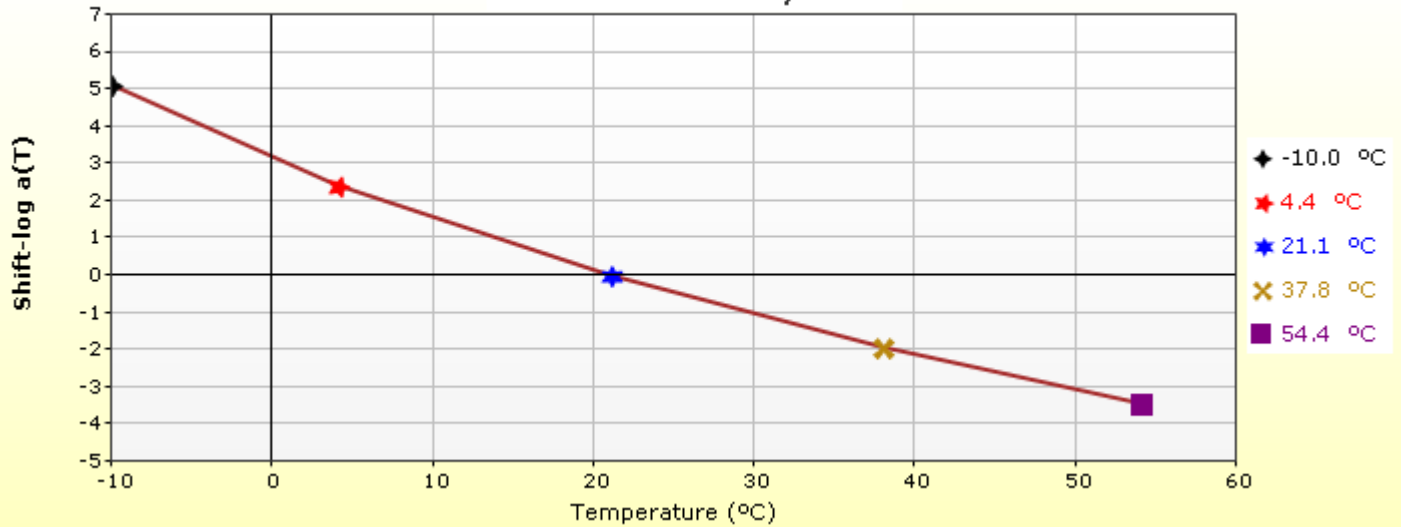


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

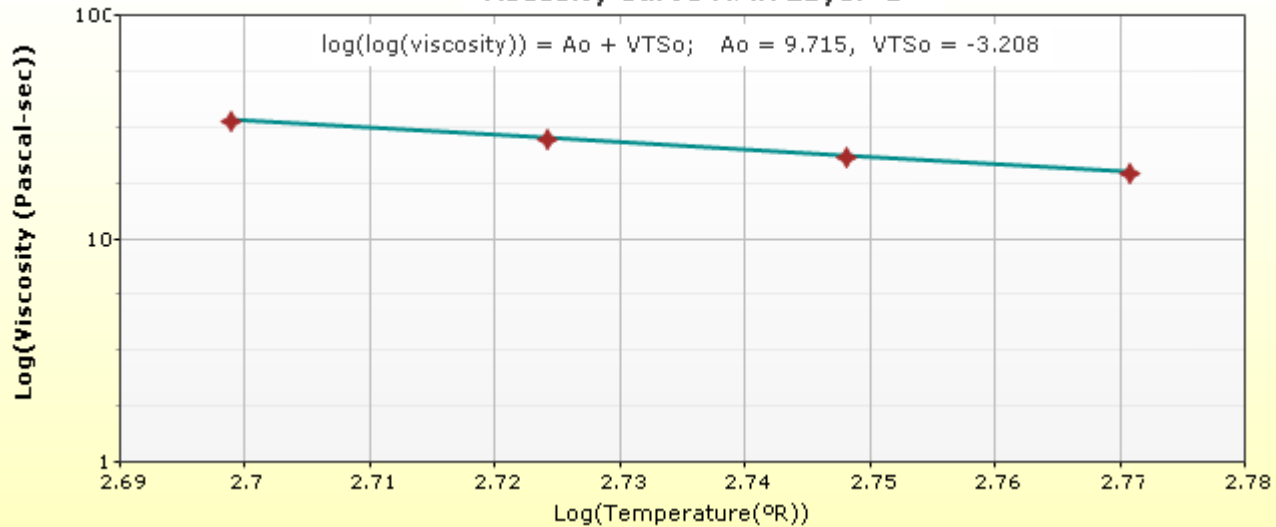
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

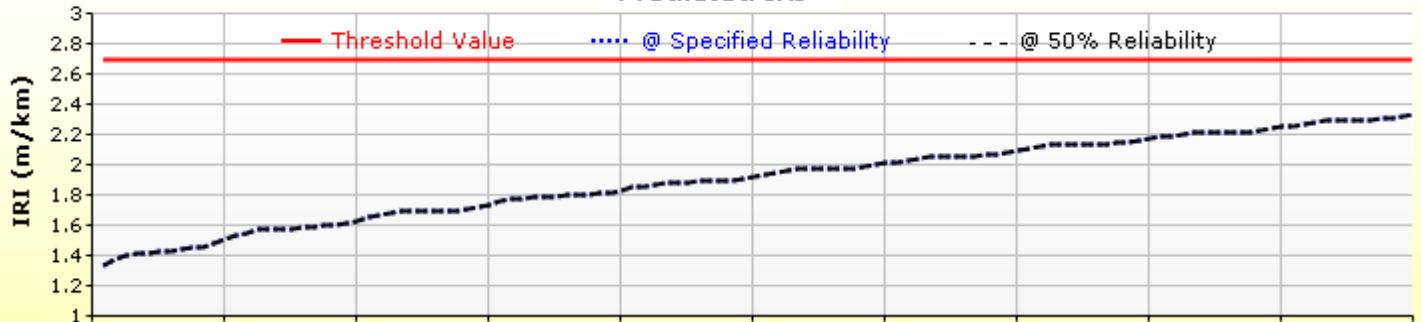


Viscosity Curve HMA Layer 1

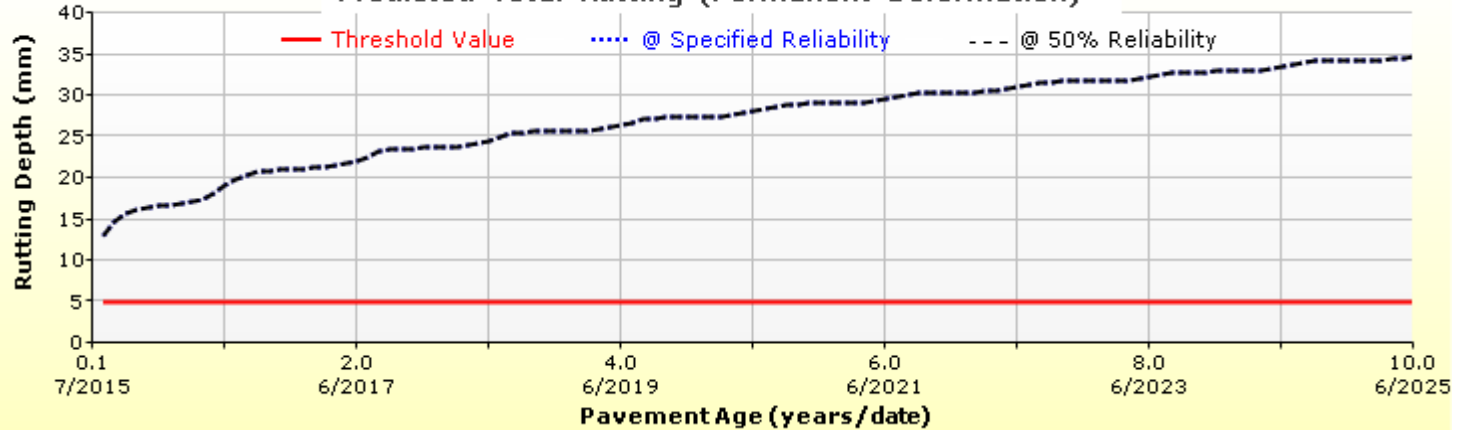


Analysis Output Charts

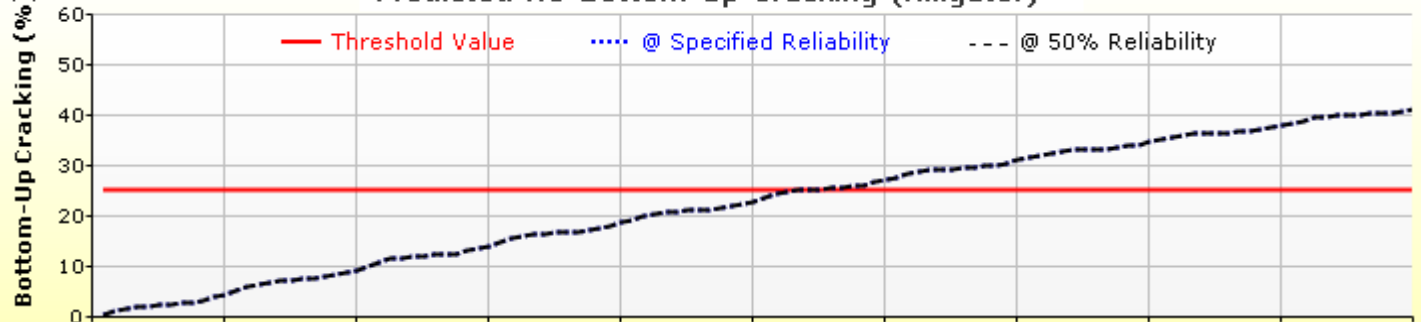
Predicted IRI



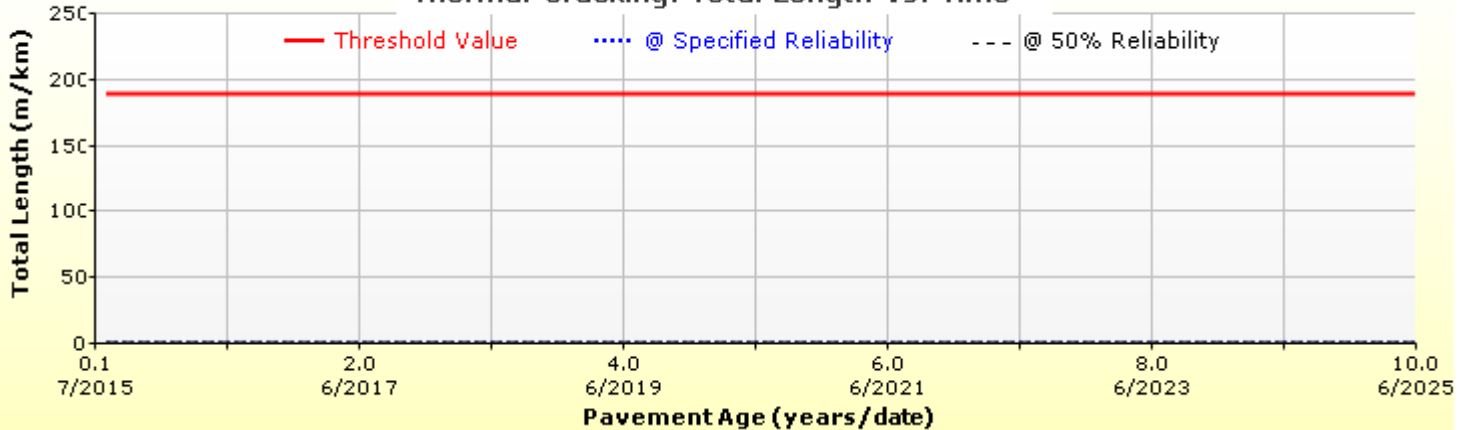
Predicted Total Rutting (Permanent Deformation)

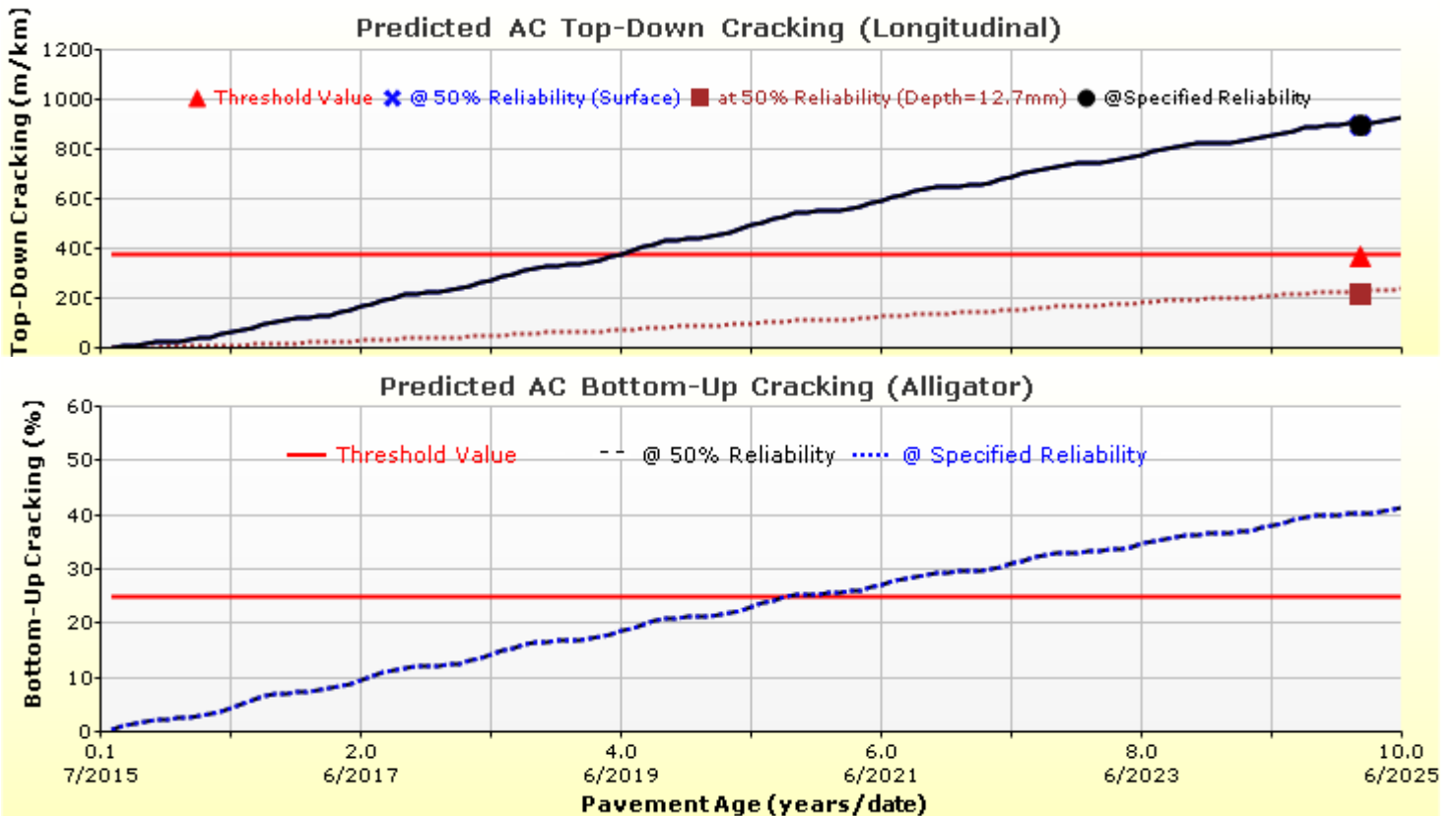
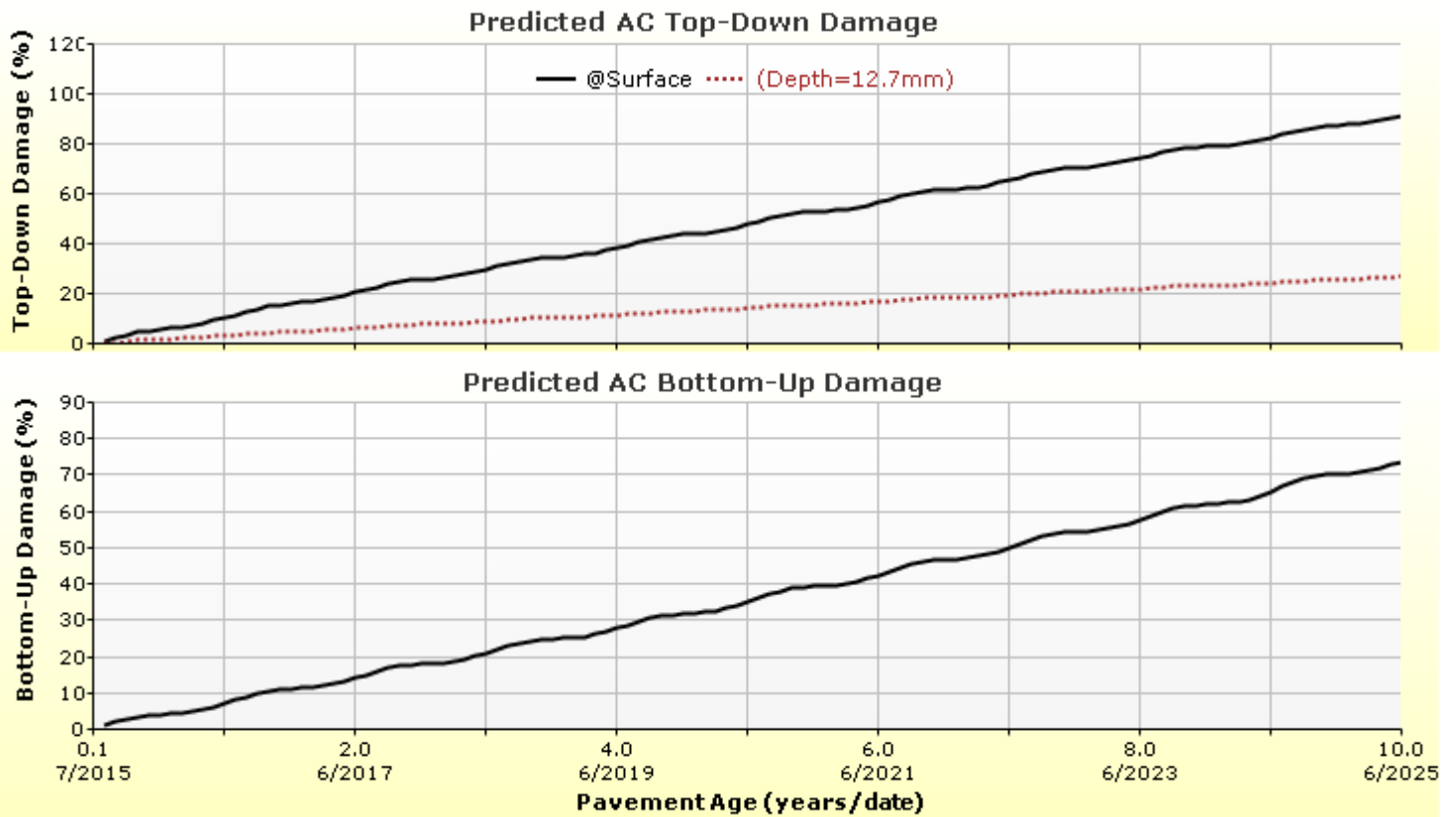


Predicted AC Bottom-Up Cracking (Alligator)

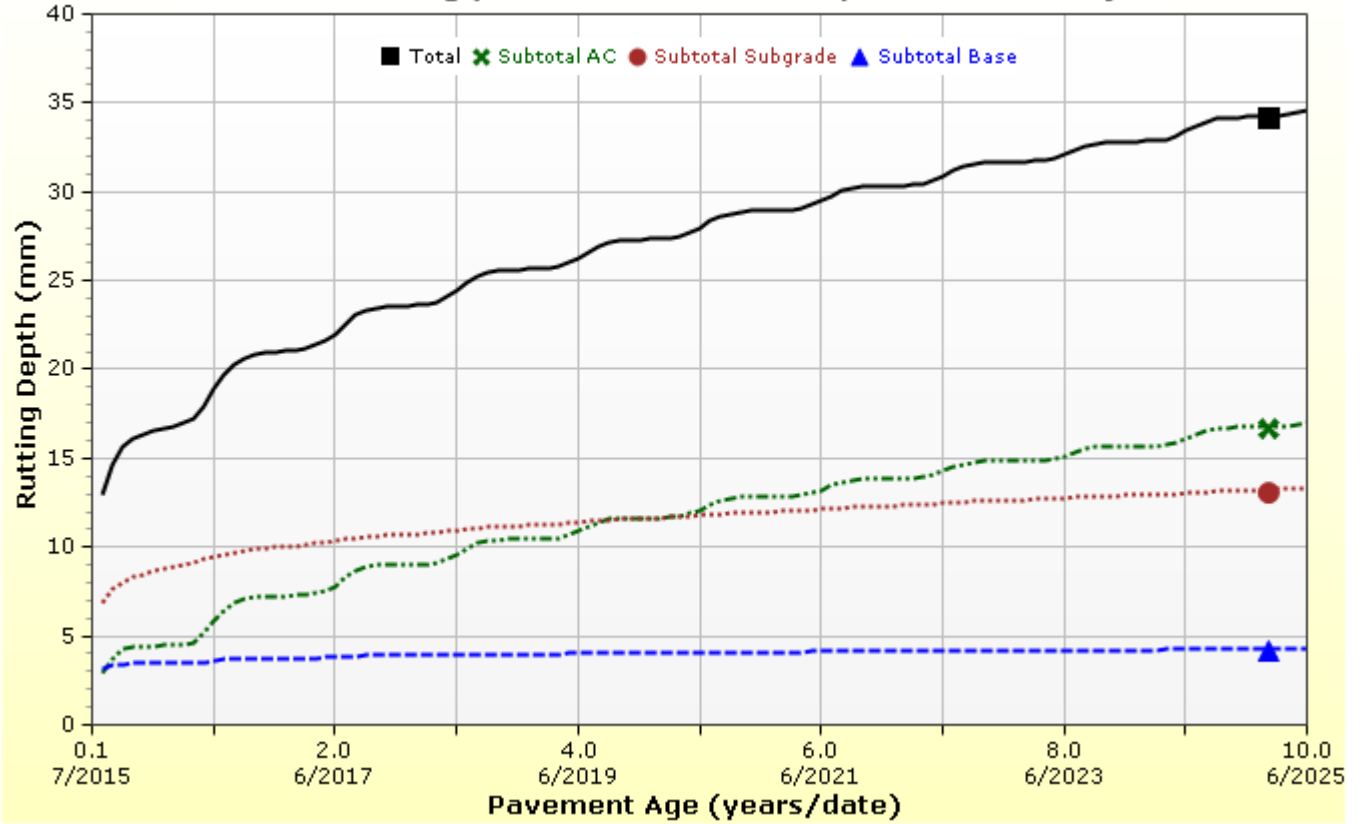


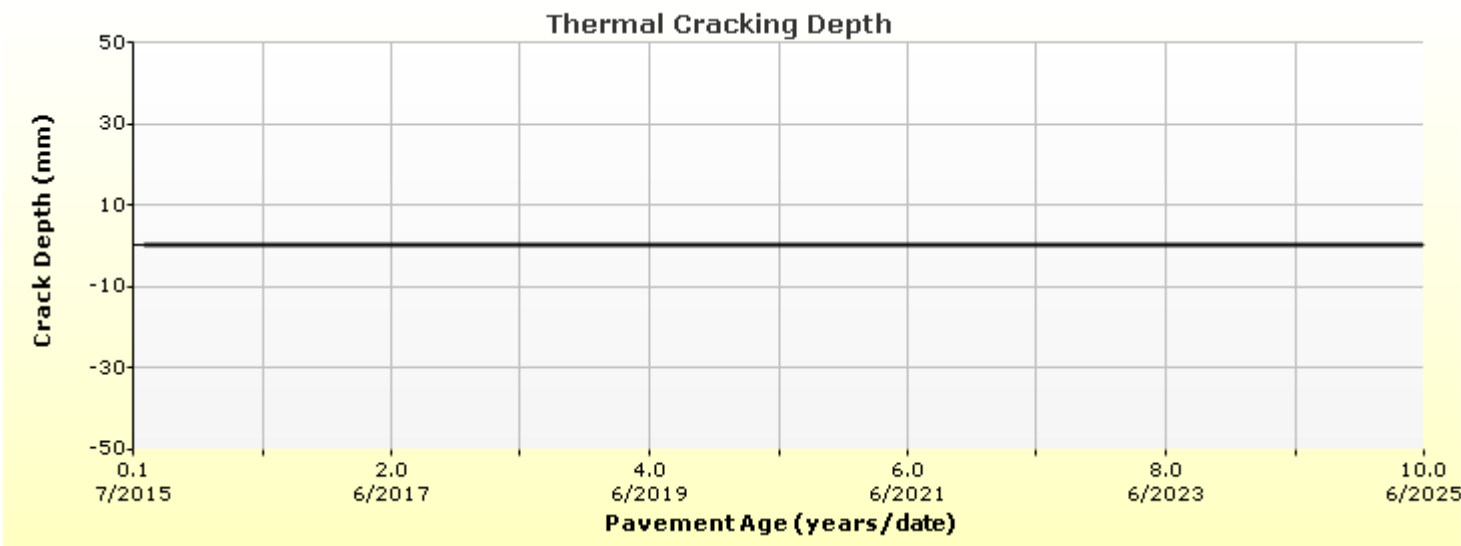
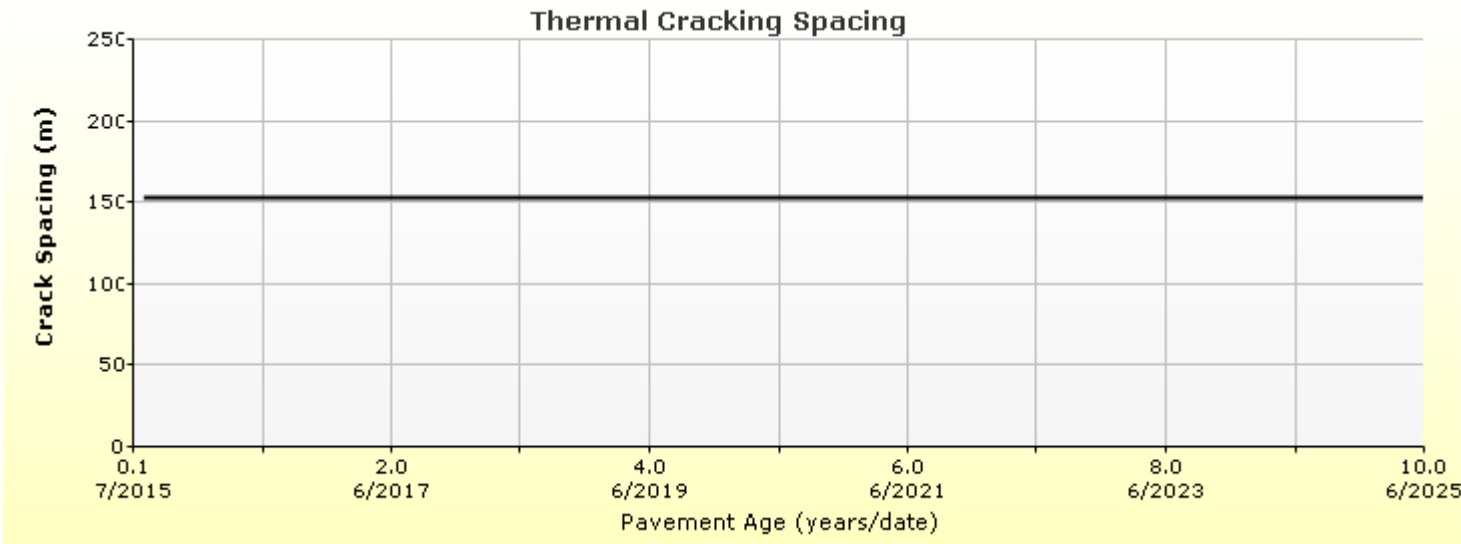
Thermal Cracking: Total Length vs. Time

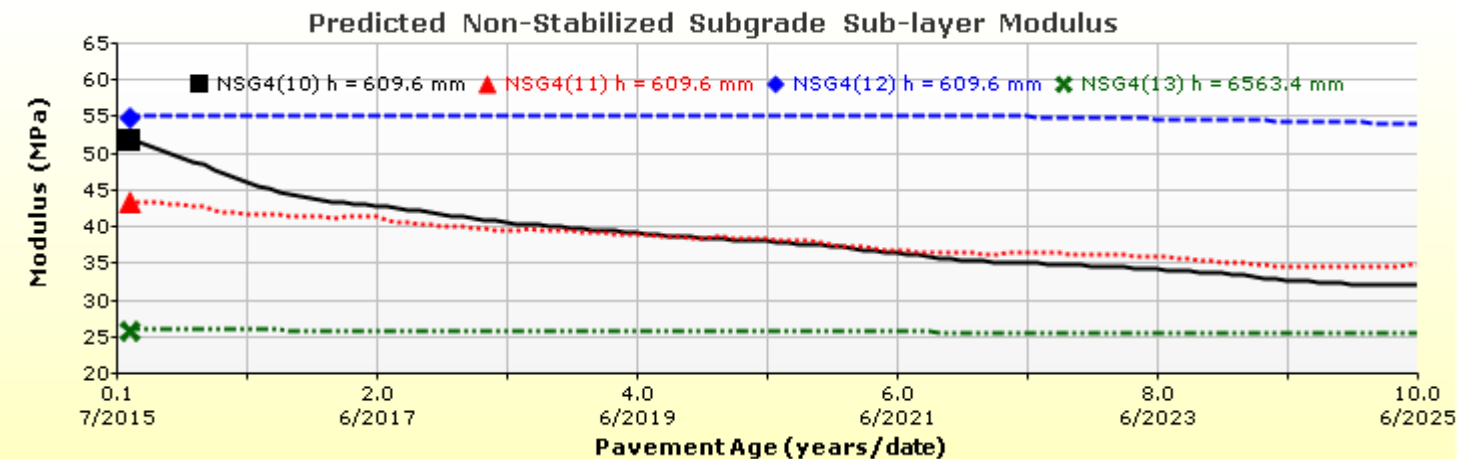
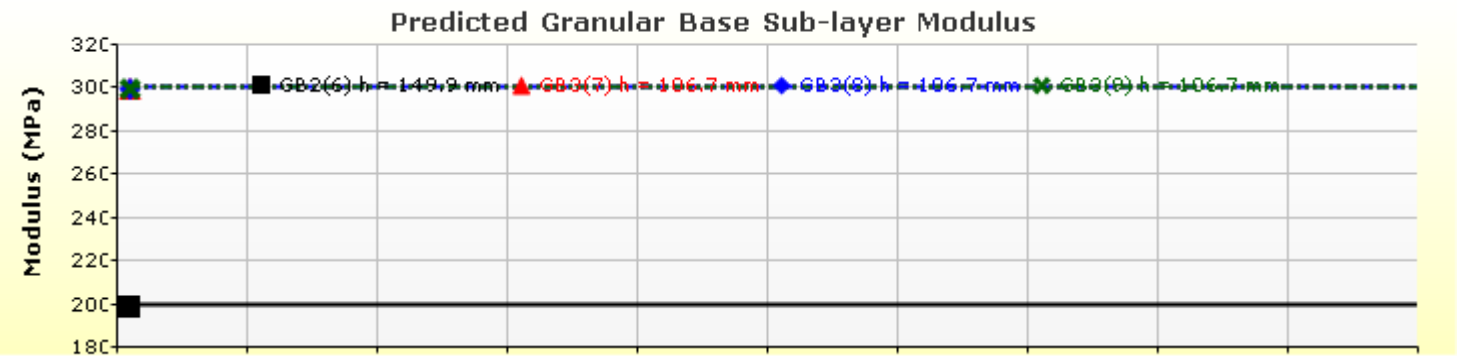
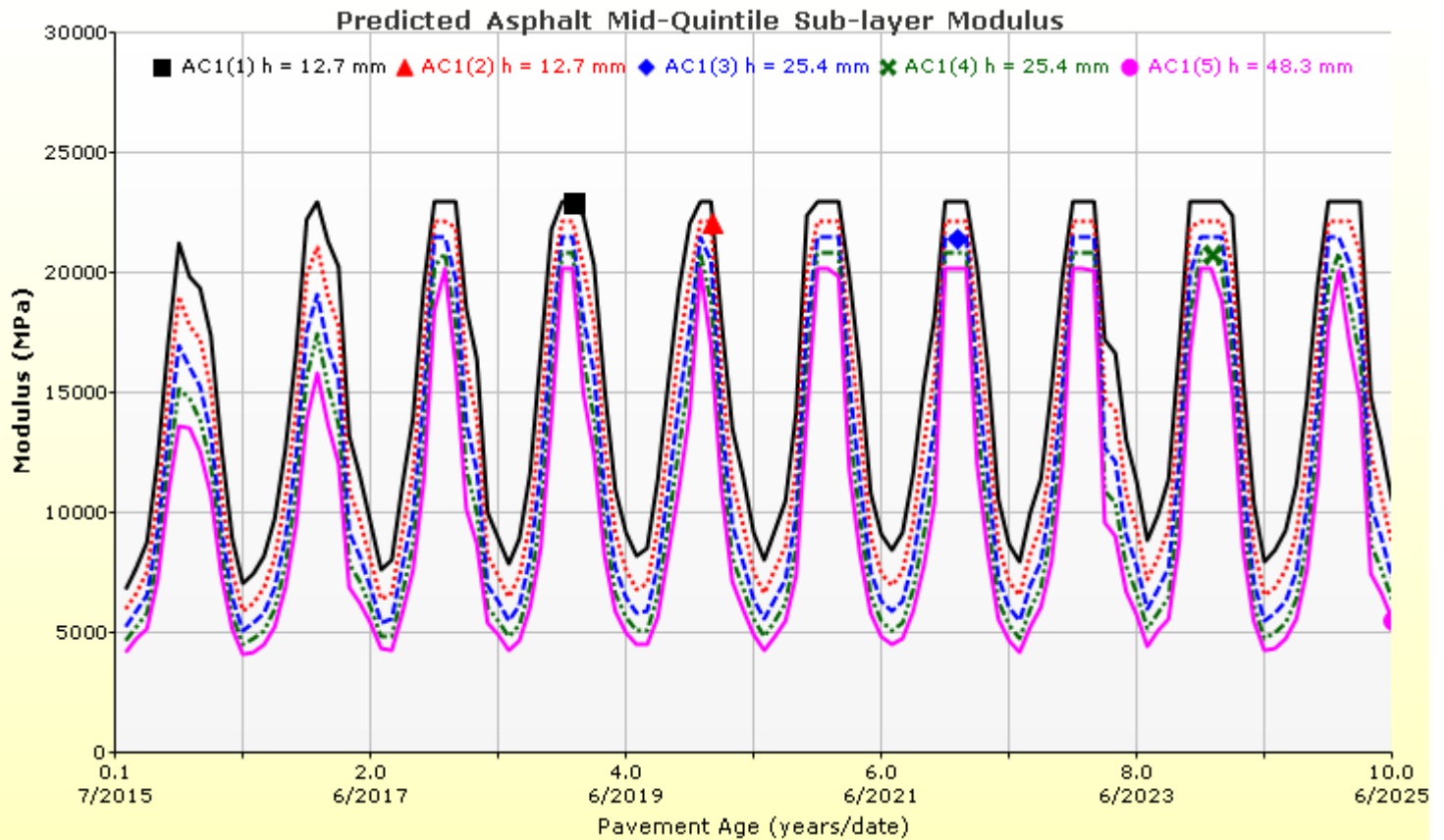




Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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() σ = standard deviation of the log of the depth of cracks in the pavments C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_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 $		δ_a = permanent deformation for the layer N = number of repetitions ε_v = average vertical strain(in/in) $\varepsilon_0, \beta, \rho$ = material properties ε_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		AC Bottom Up Cracking	
$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * \log_{10}(Damage))}} \right) * 10.56$		$FC = \left(\frac{6000}{1 + e^{(C_1 * C'_1 + C_2 * C'_2 * \log_{10}(D * 100))}} \right) * \left(\frac{1}{60} \right)$ $C'_2 = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$ $C'_1 = -2 * C'_2$	
c1: 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 Cracking Bottom Standard Deviation 1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))	

CSM Cracking		IRI Flexible Pavements	
$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$		C1 - Rutting C3 - Transverse Crack C2 - Fatigue Crack C4 - Site Factors	
C1: 1	C2: 1	C3: 0	C4: 1000
CSM Standard Deviation CTB*1		C1: 40	C2: 0.4
		C3: 0.008	C4: 0.015

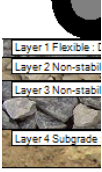
Design Inputs

Design Life: **10 years**
Design Type: **Flexible Pavement**

Base construction: **March, 2015**
Pavement construction: **June, 2015**
Traffic opening: **July, 2015**

Climate Data **32.119, -81.202**
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

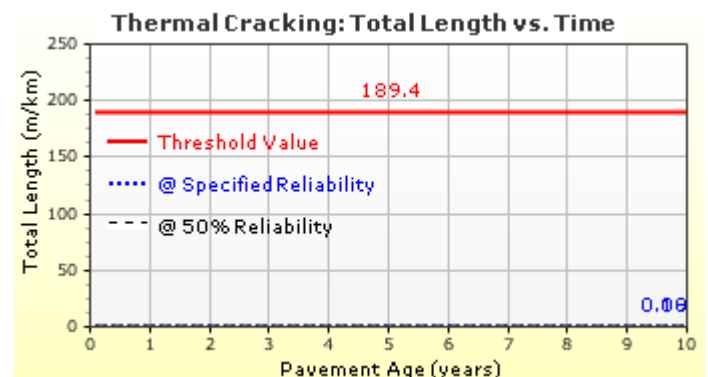
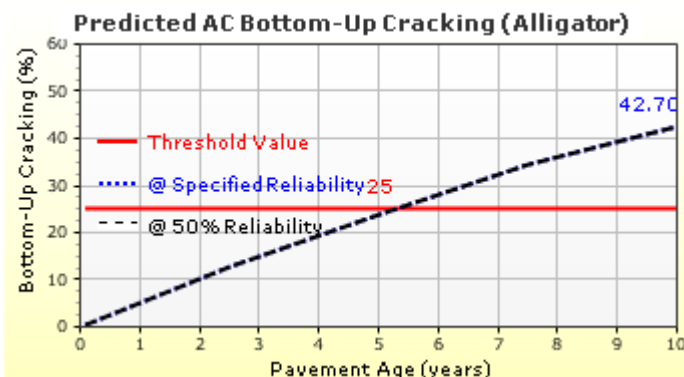
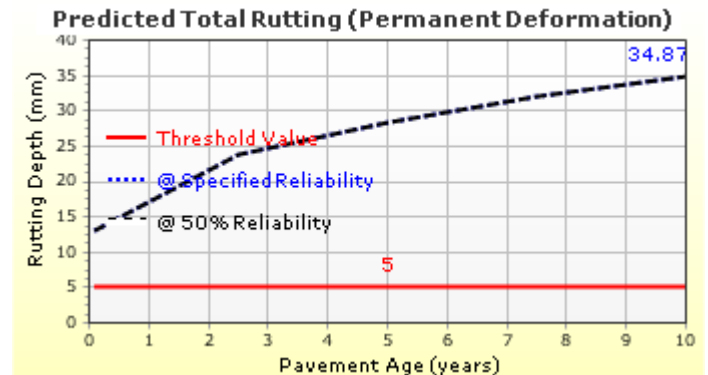
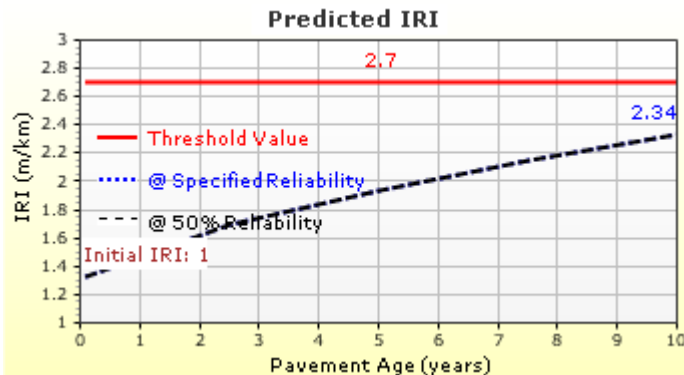
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.34	50.00	72.34	Pass
Permanent deformation - total pavement (mm)	5.00	34.87	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	42.70	50.00	10.52	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	903.41	50.00	12.47	Fail
Permanent deformation - AC only (mm)	5.00	16.54	50.00	0.40	Fail

Distress Charts

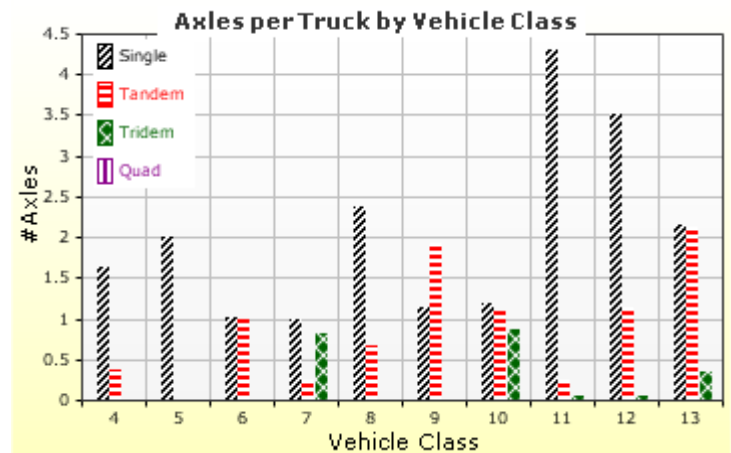
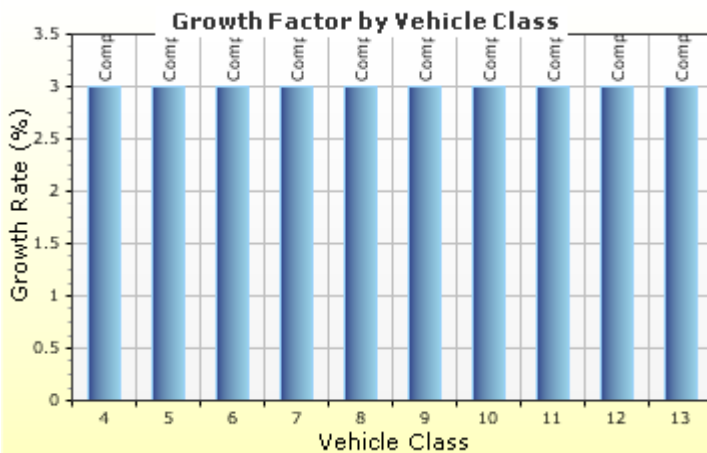
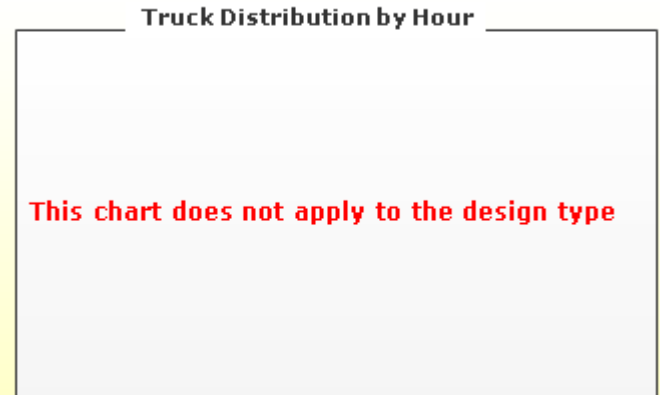
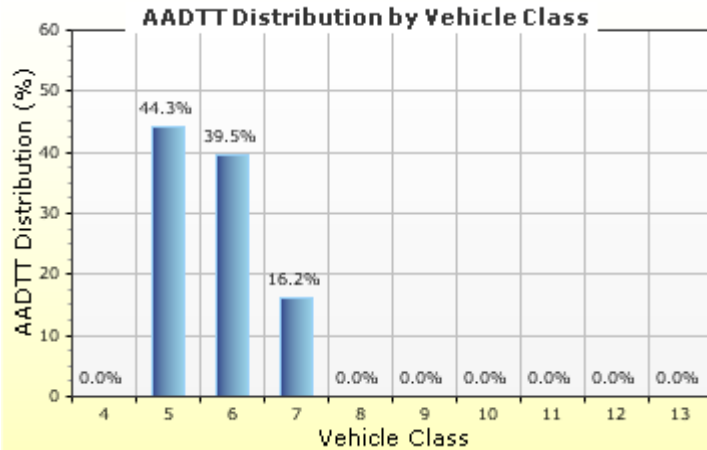


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

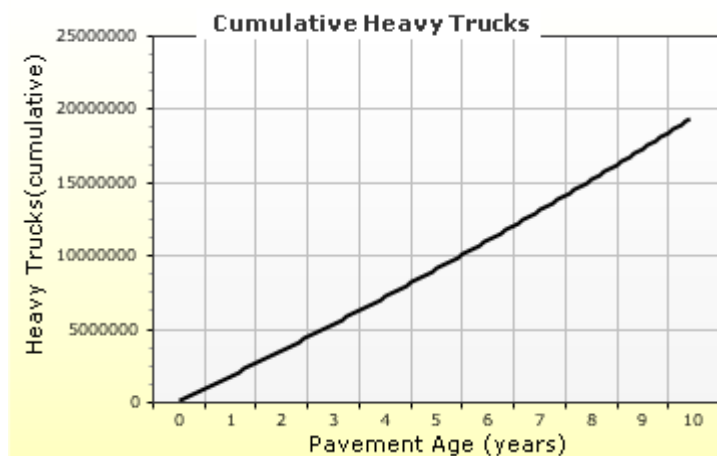
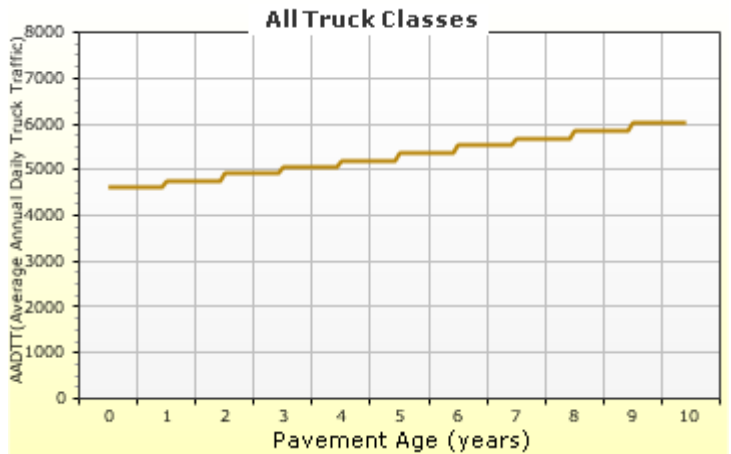
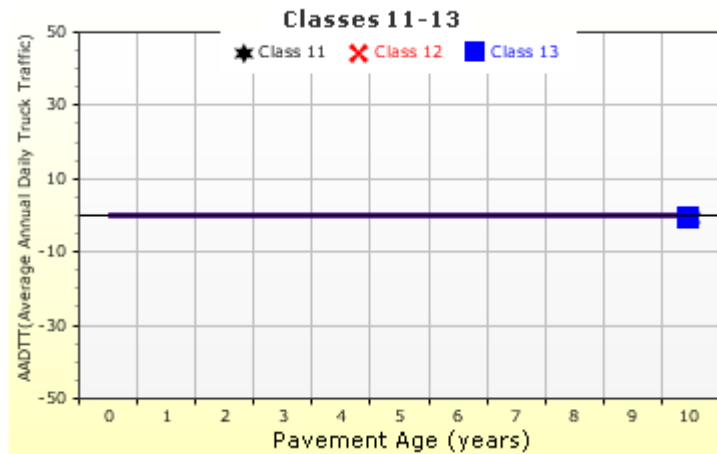
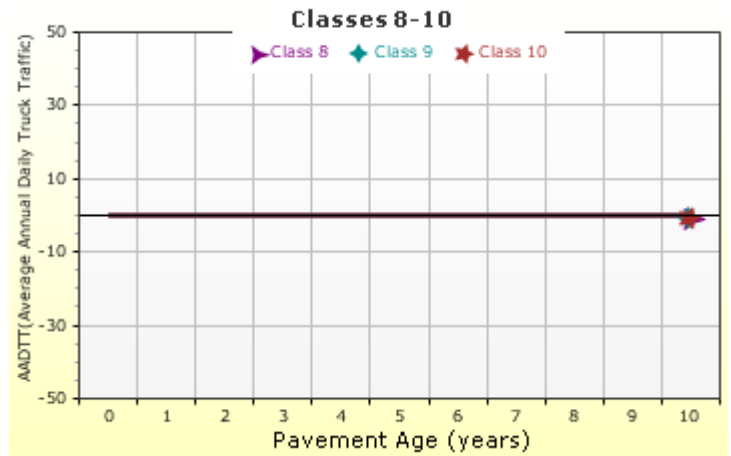
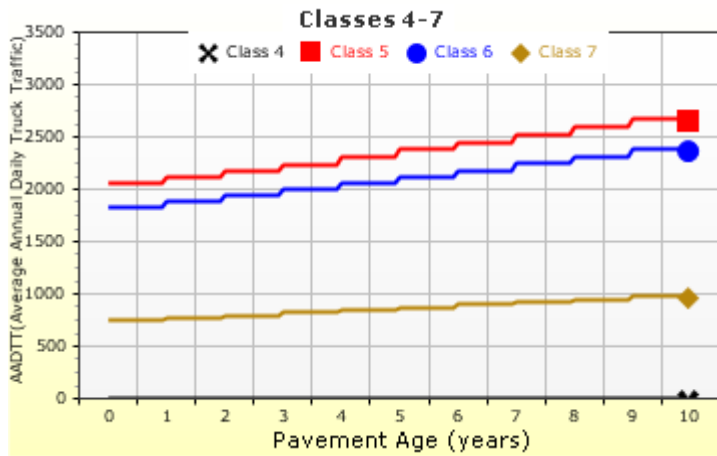
Wheelbase does not apply

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



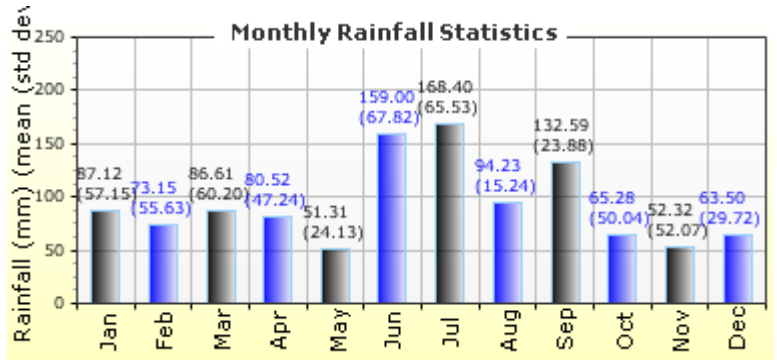
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

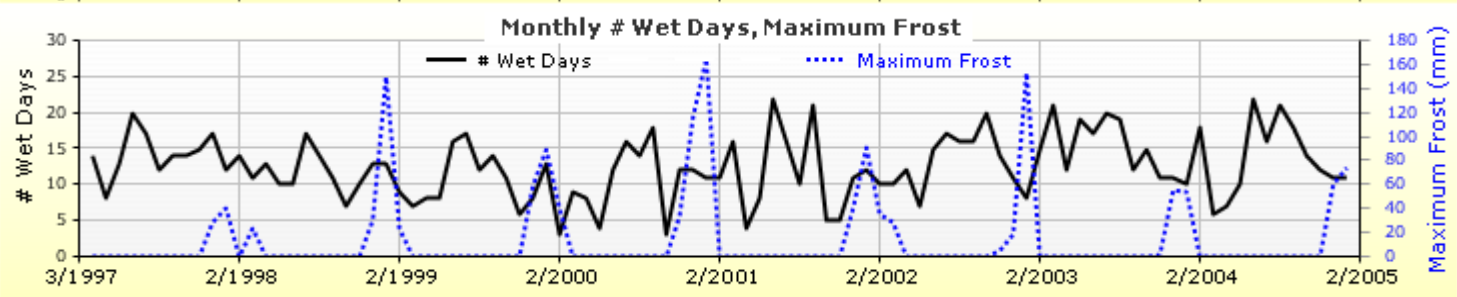
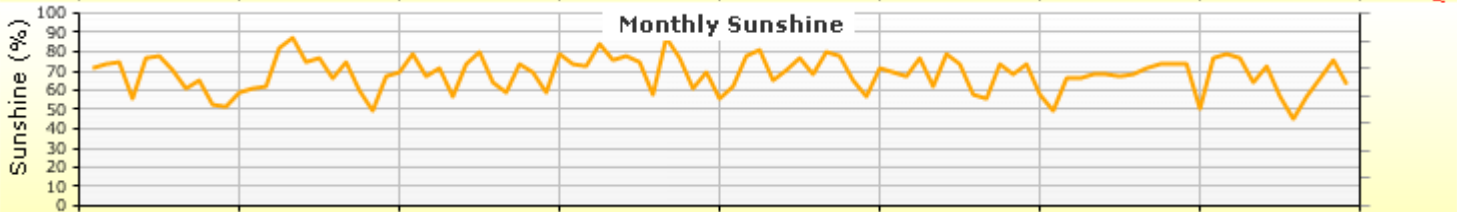
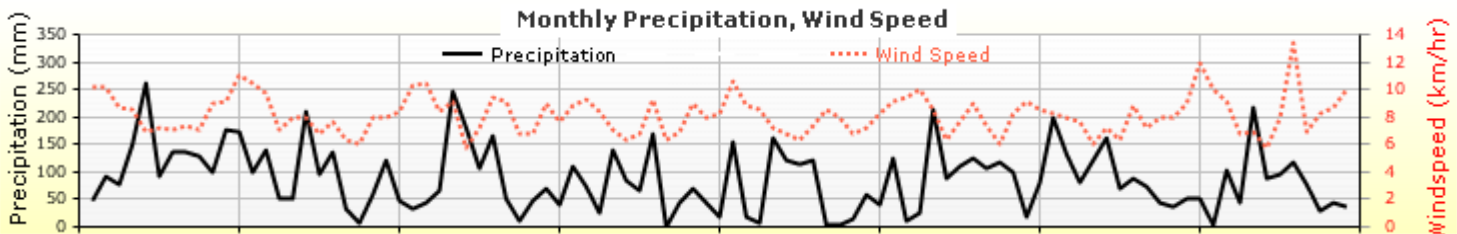
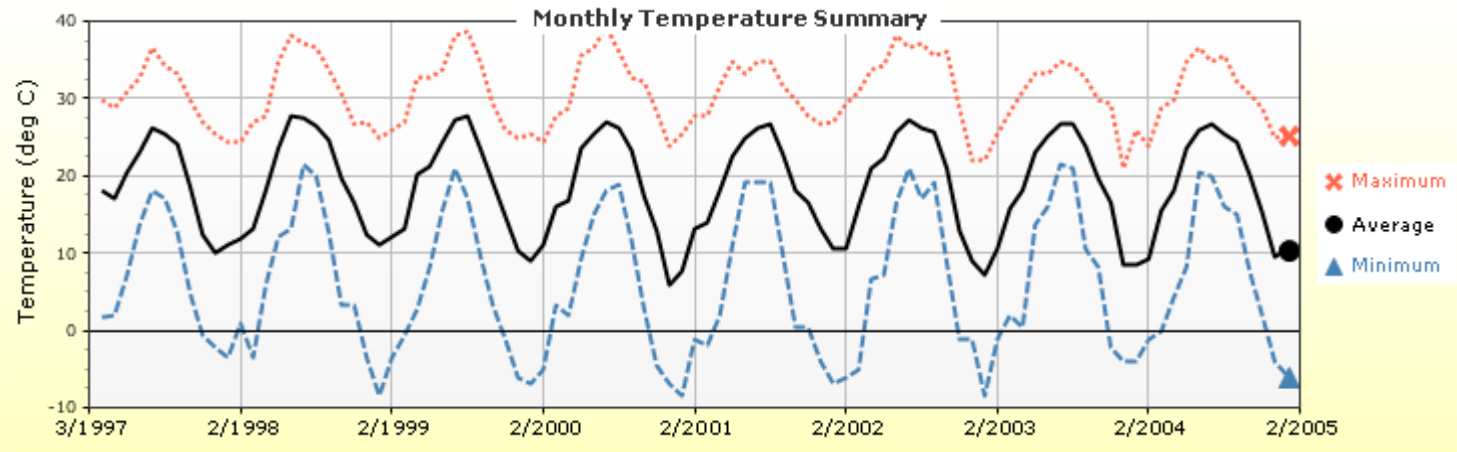
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

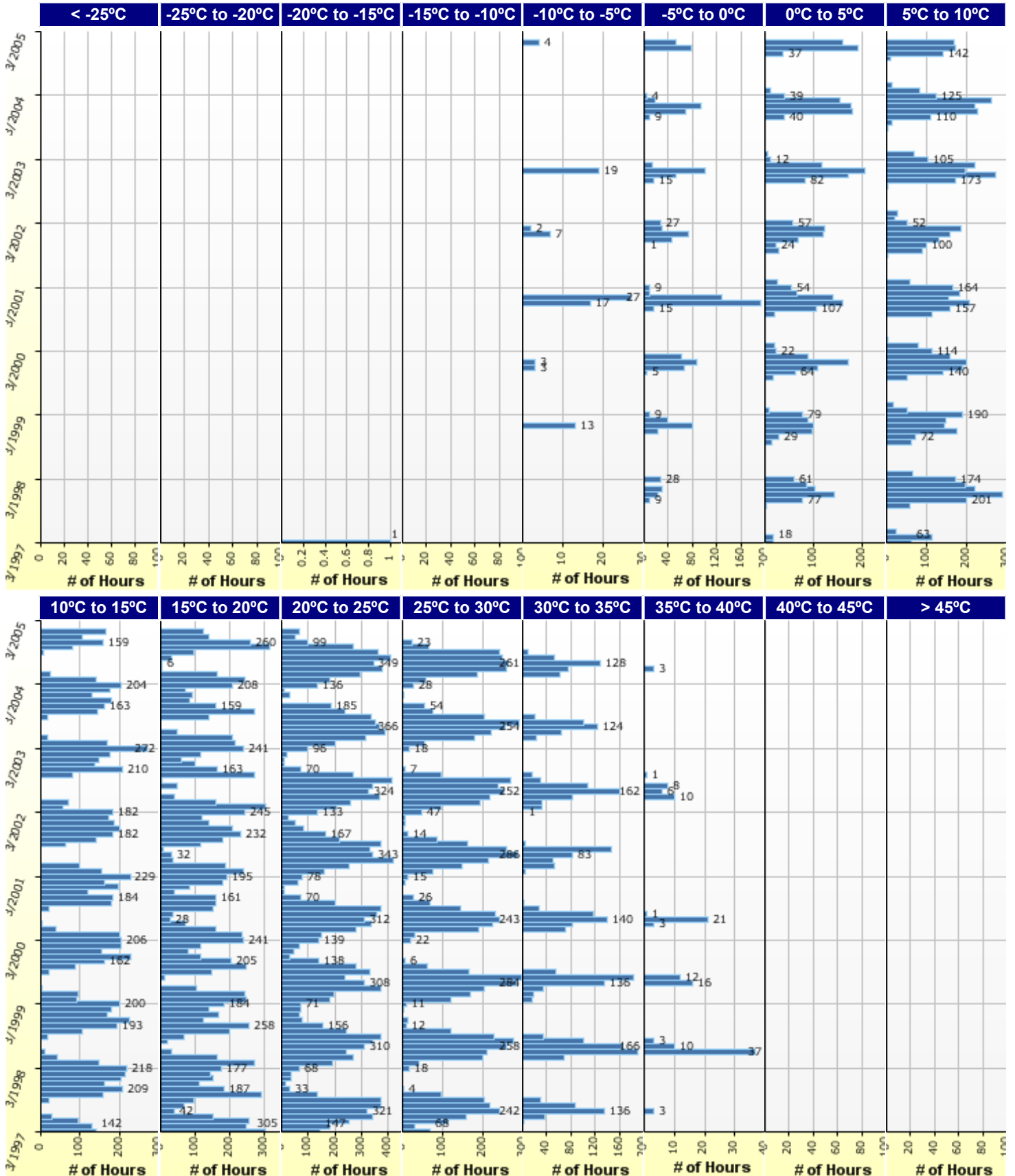


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF3

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF3.dgpx



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

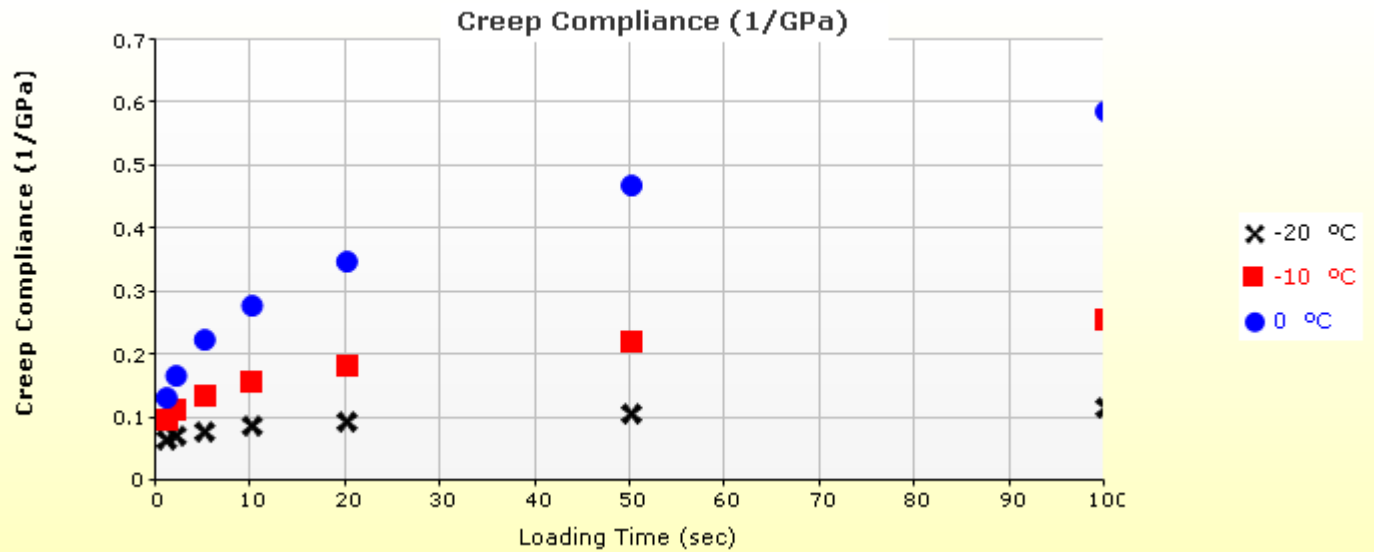
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

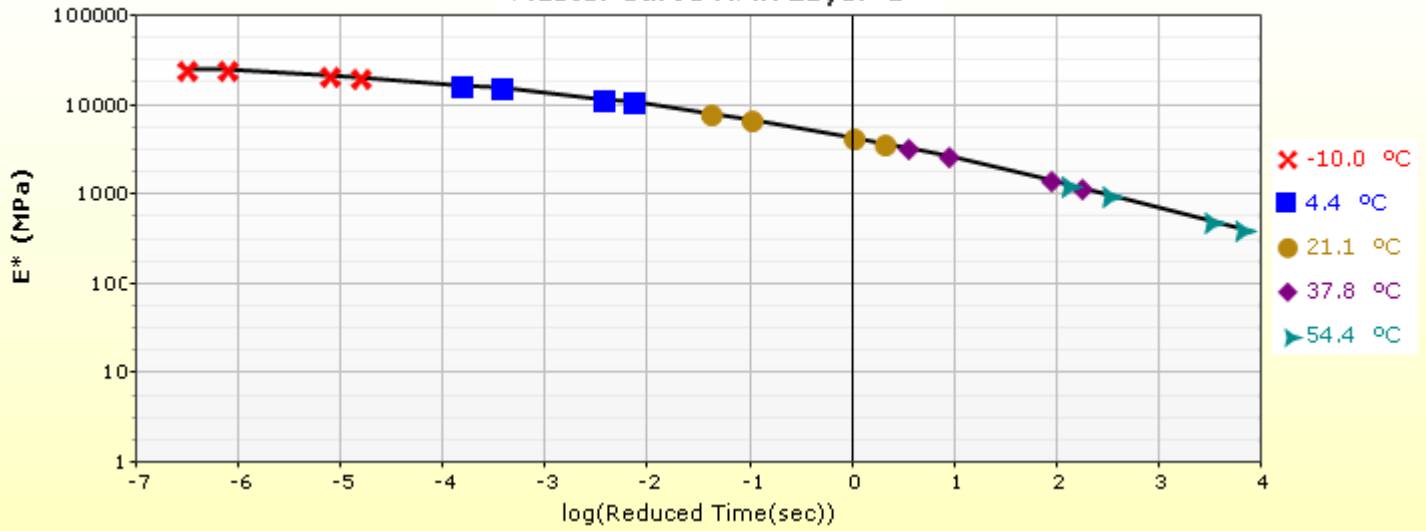
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

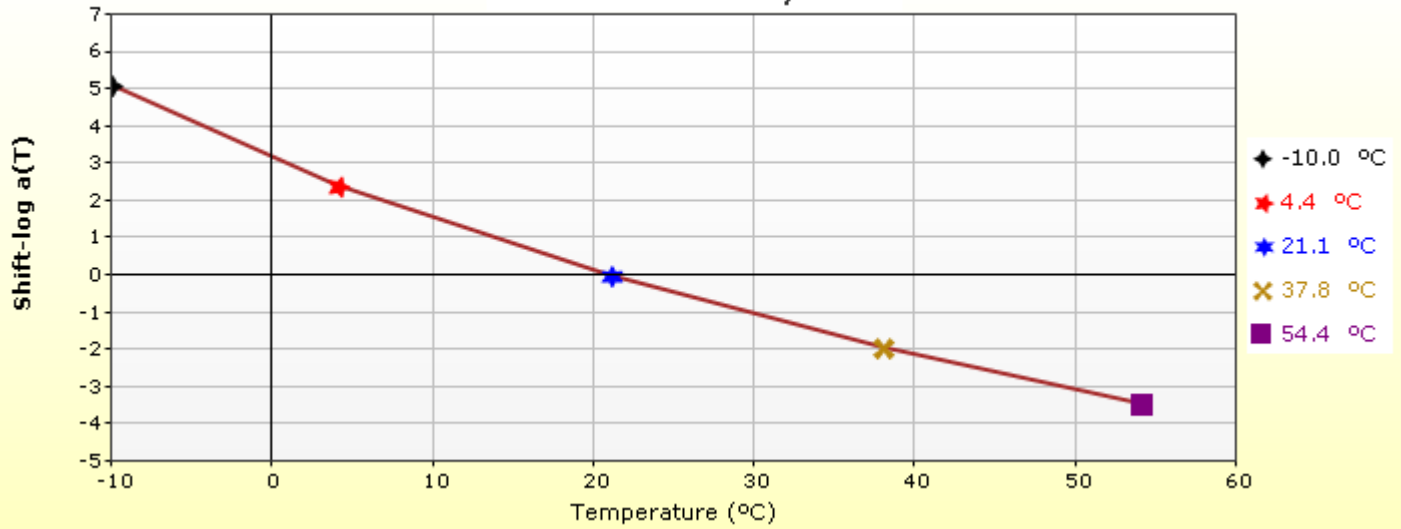


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

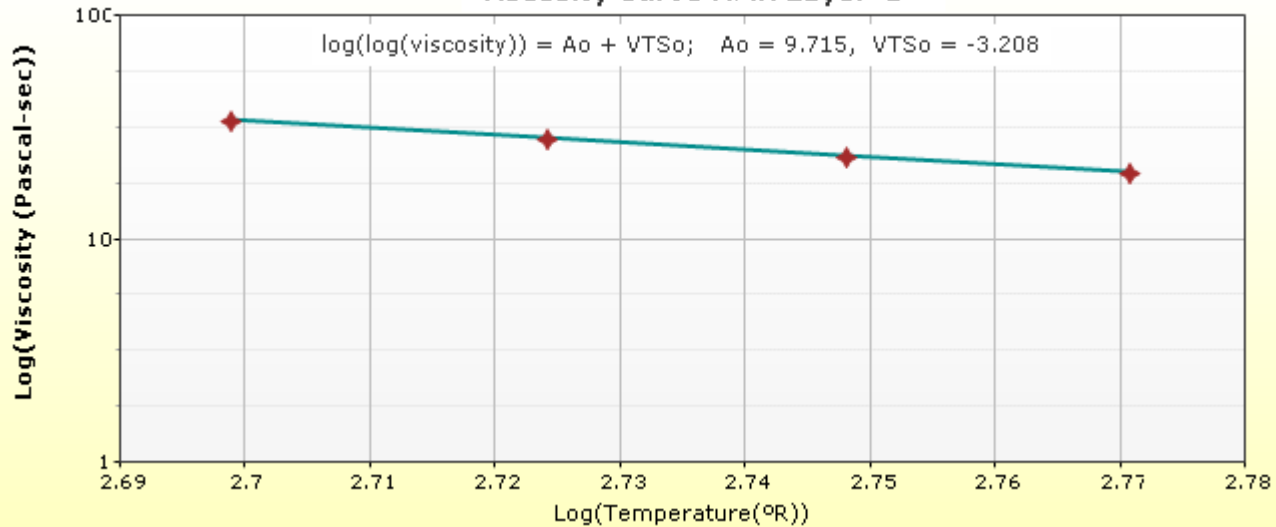
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

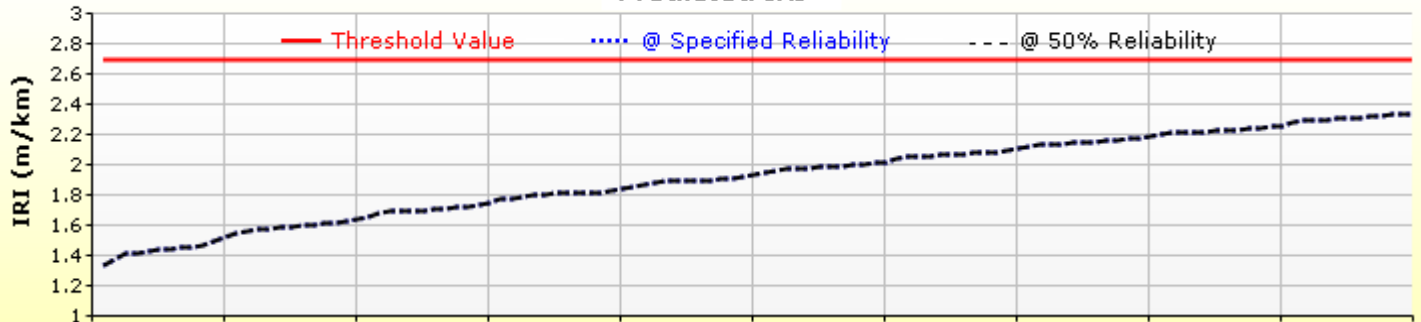


Viscosity Curve HMA Layer 1

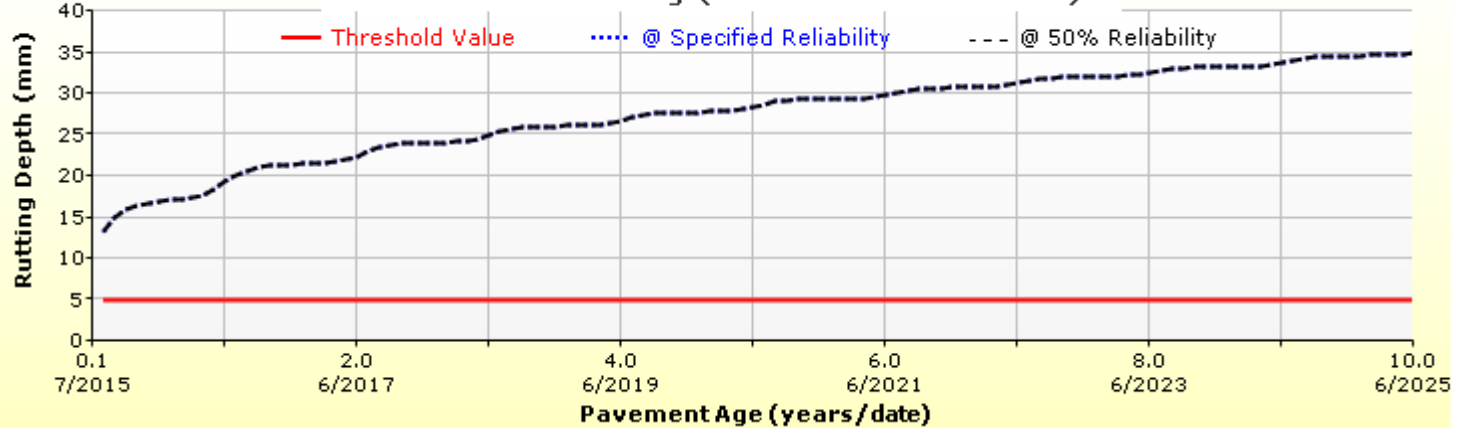


Analysis Output Charts

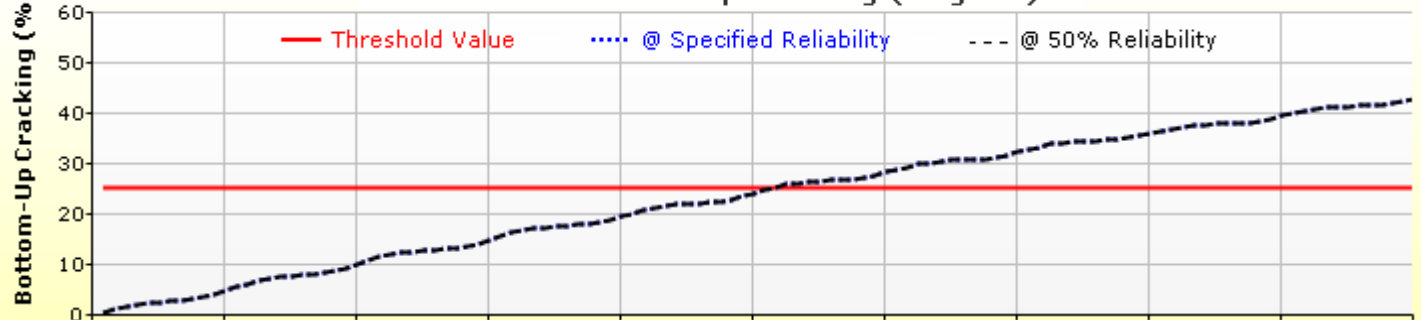
Predicted IRI



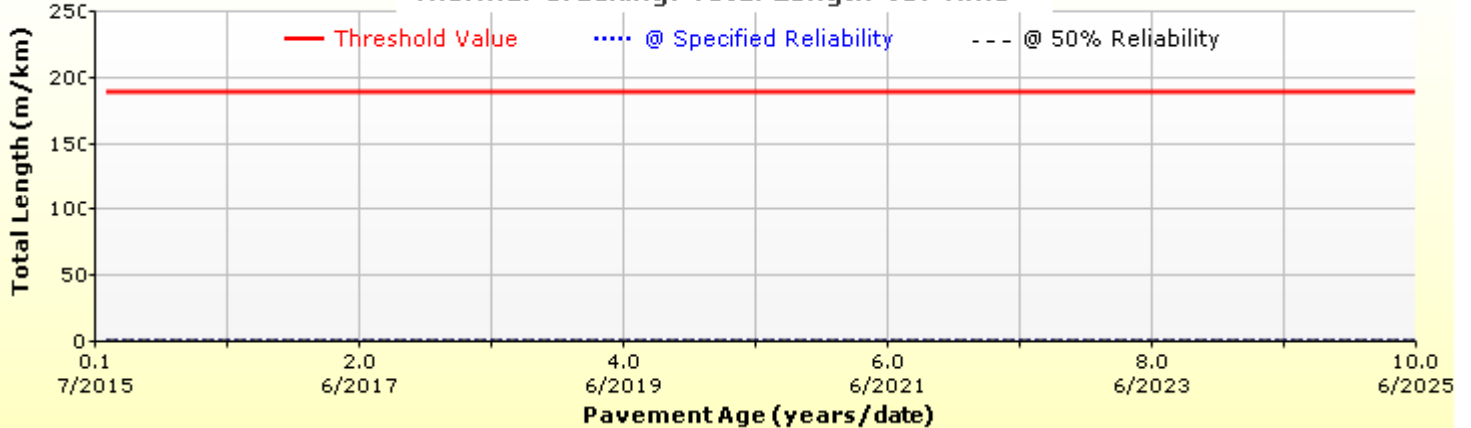
Predicted Total Rutting (Permanent Deformation)

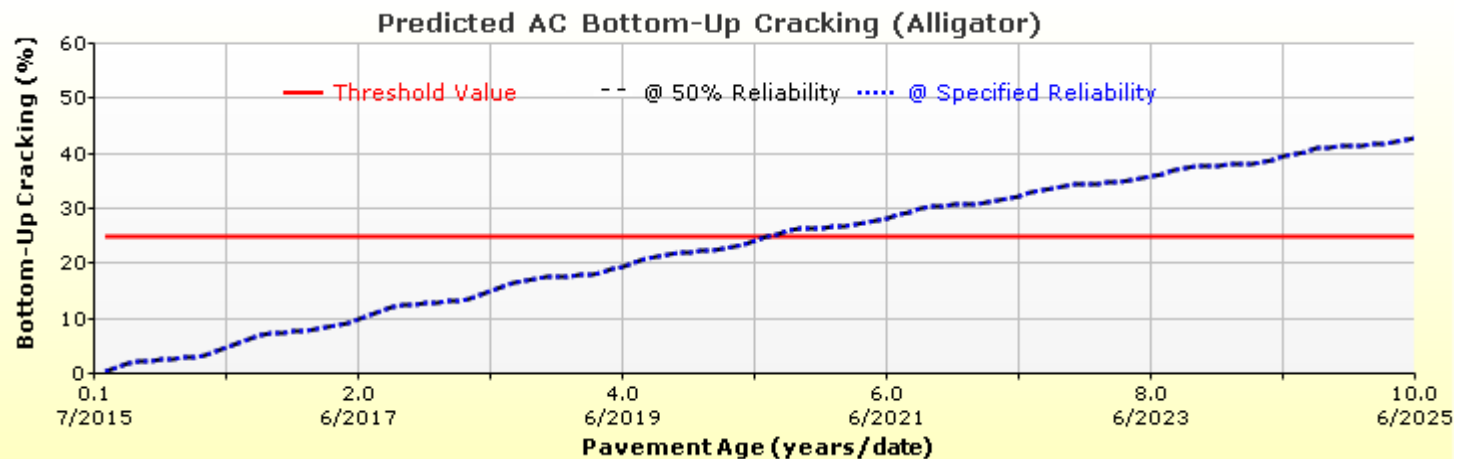
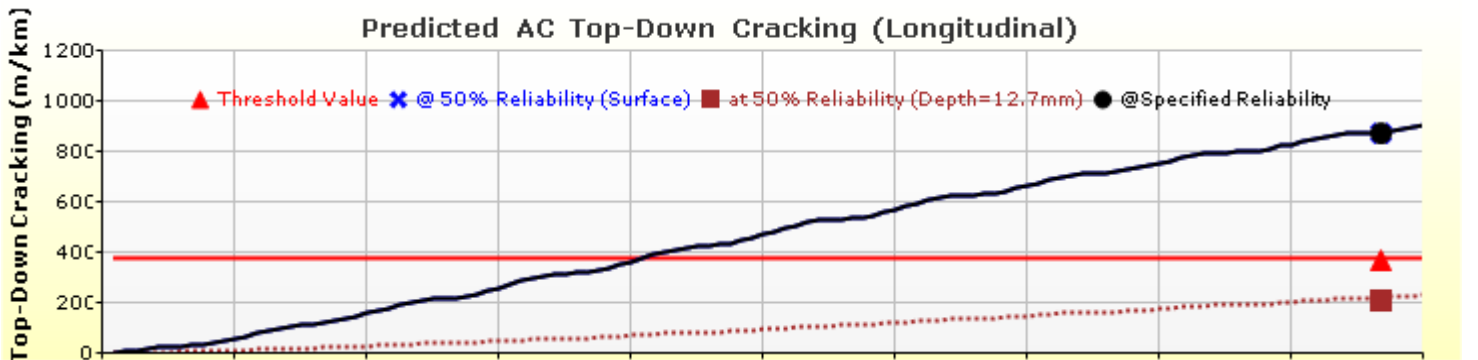
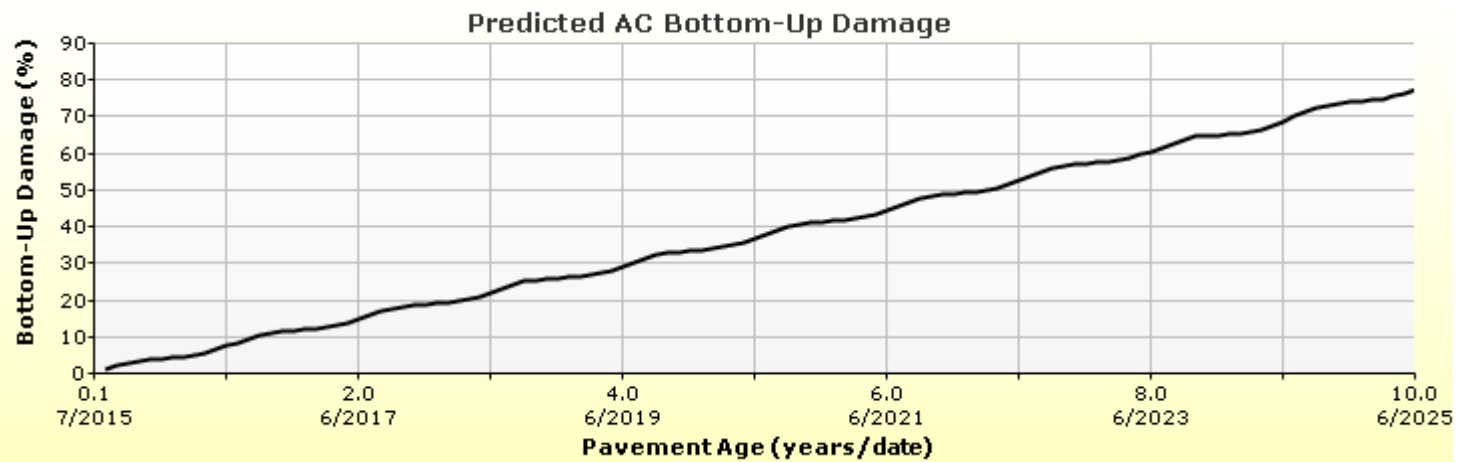
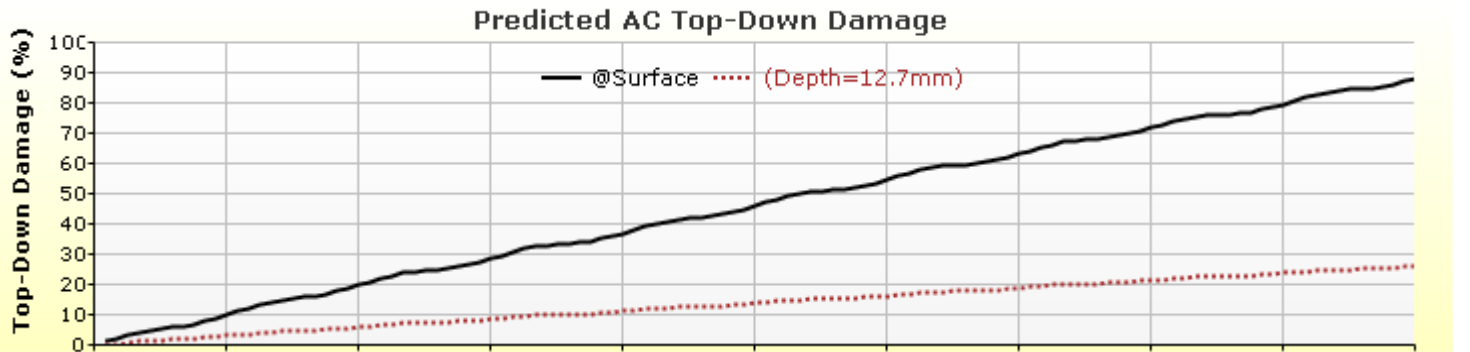


Predicted AC Bottom-Up Cracking (Alligator)

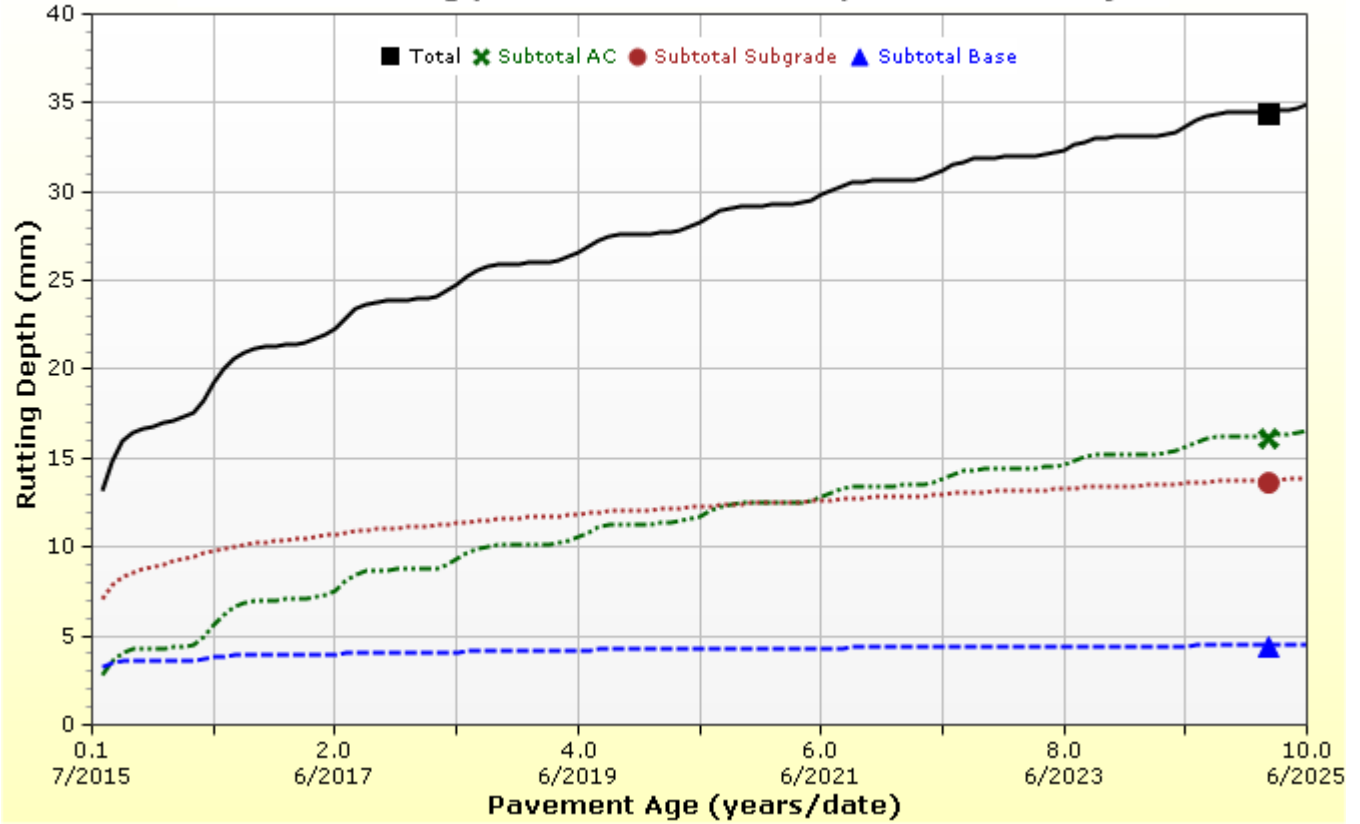


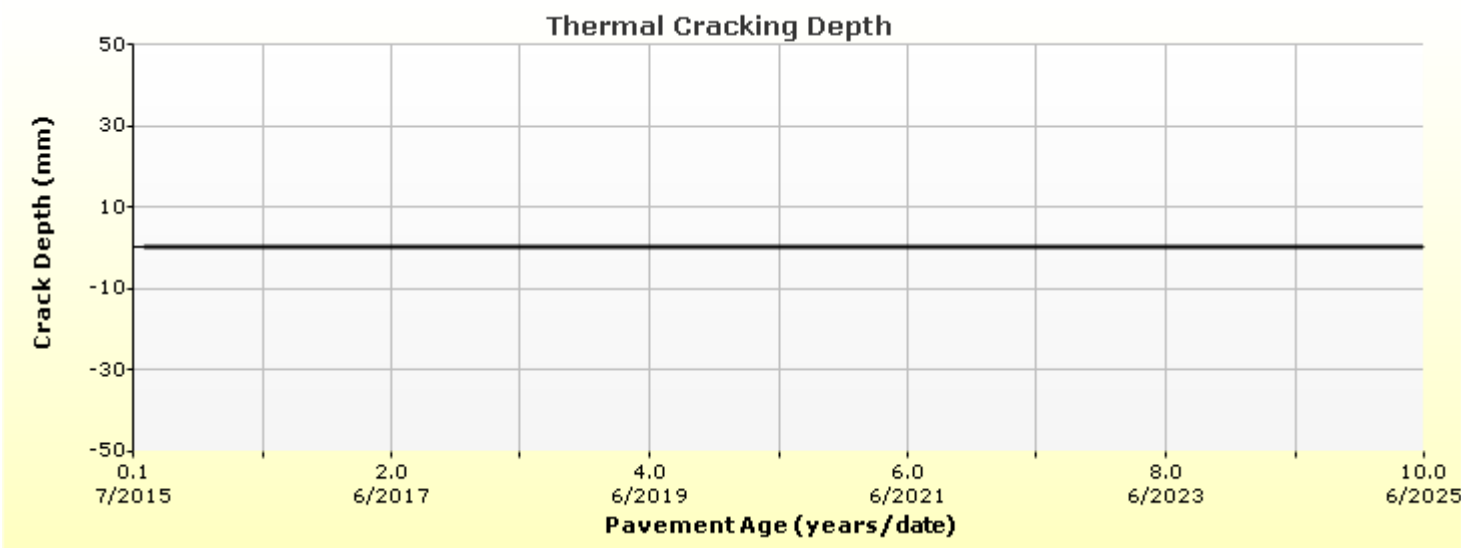
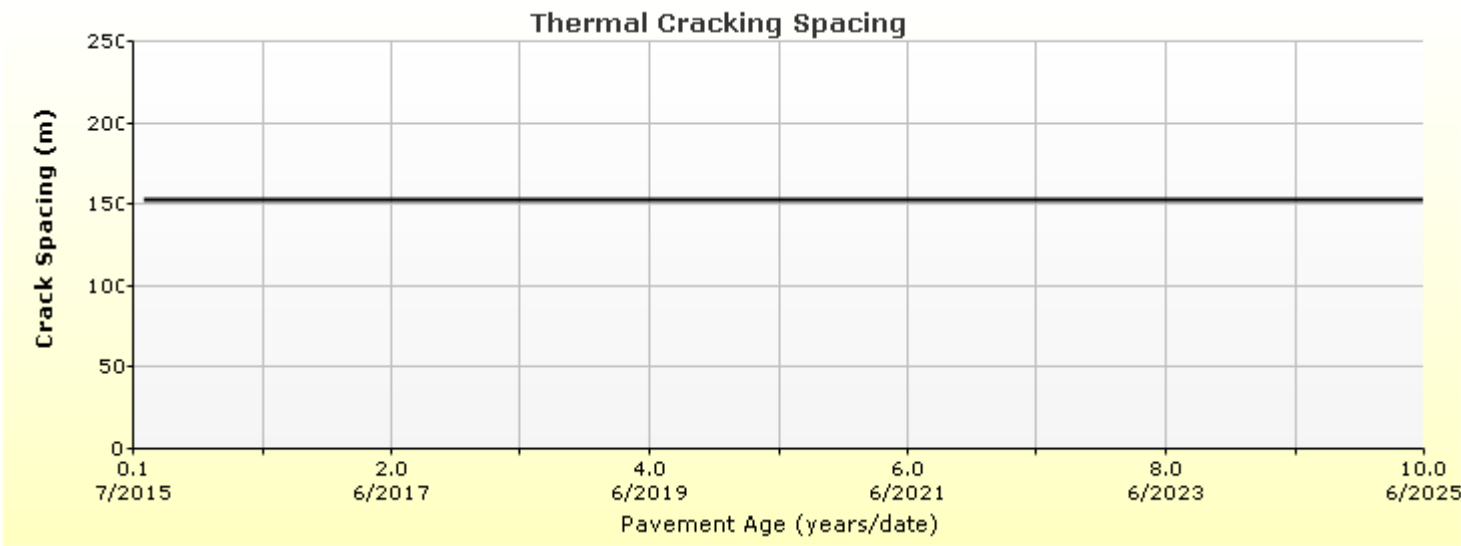
Thermal Cracking: Total Length vs. Time

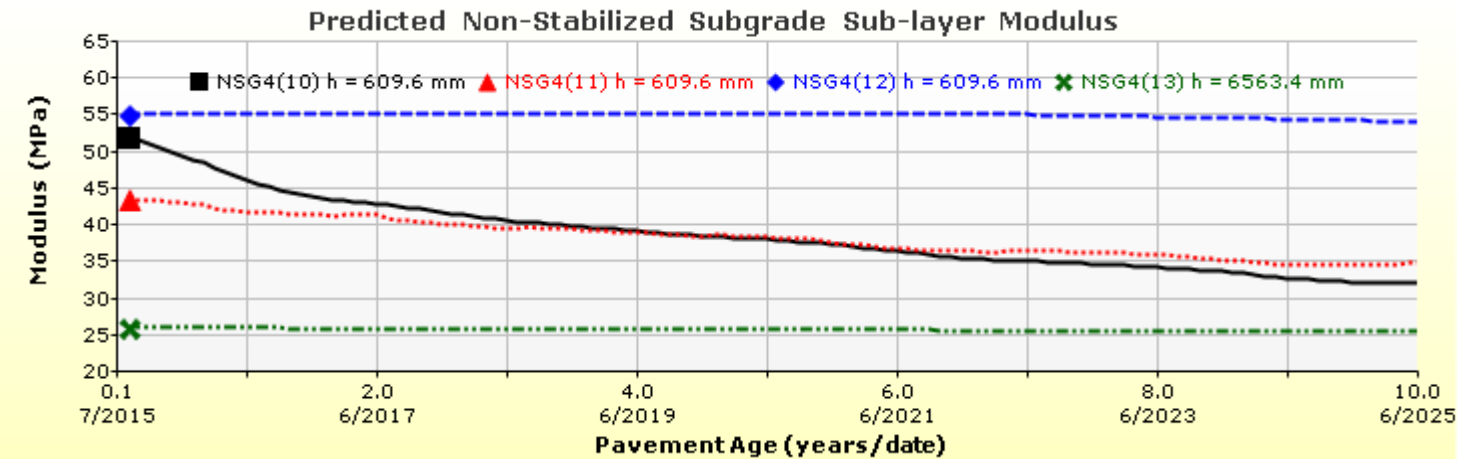
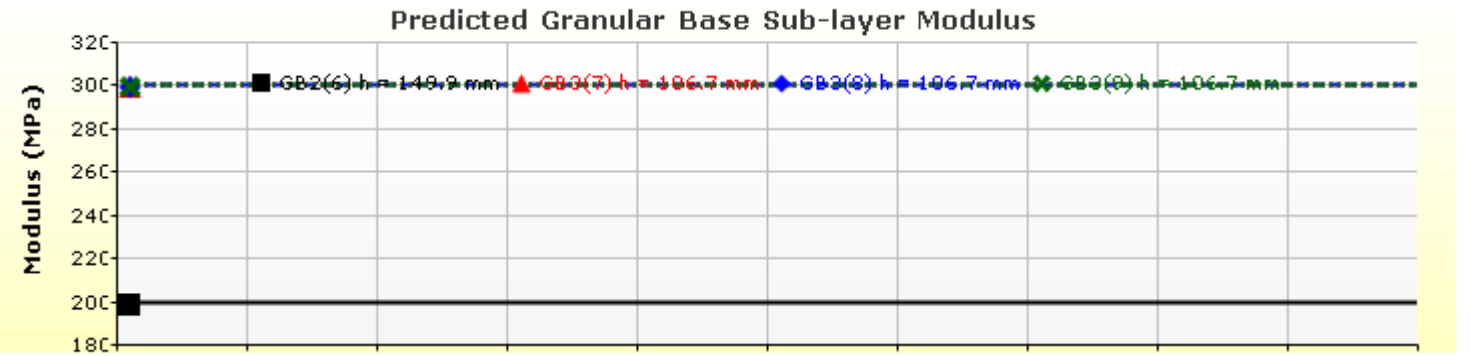
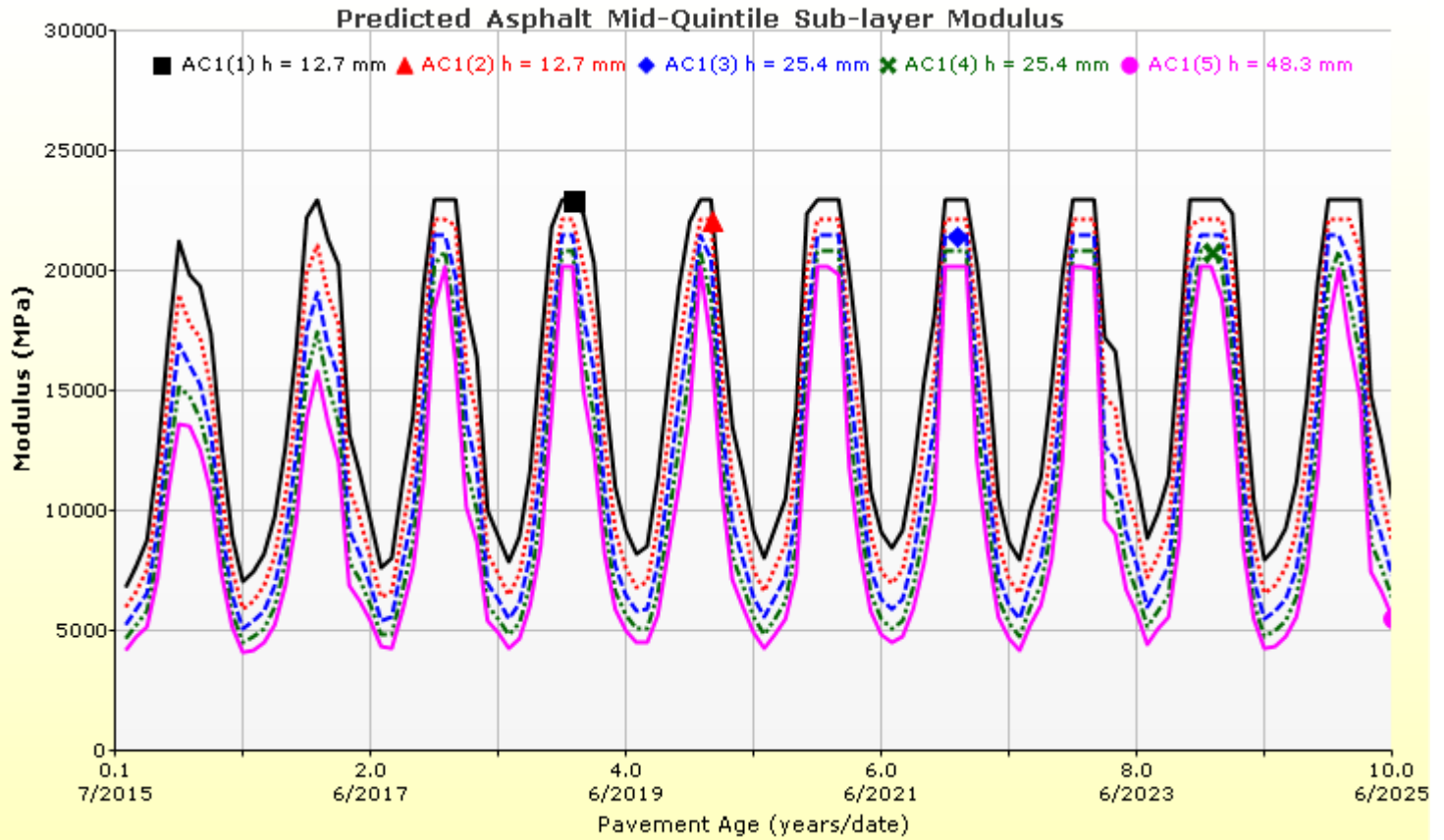




Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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() σ = standard deviation of the log of the depth of cracks in the pavments C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_s = Tensile stress(psi) M_r = modulus of rupture(psi)
k1: 1	k2: 1
Bc1: 1	Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

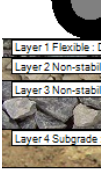
Design Inputs

Design Life: **10 years**
Design Type: **Flexible Pavement**

Base construction: **March, 2015**
Pavement construction: **June, 2015**
Traffic opening: **July, 2015**

Climate Data **32.119, -81.202**
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

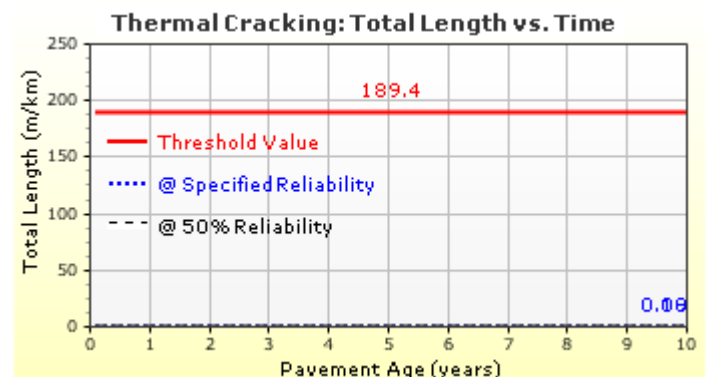
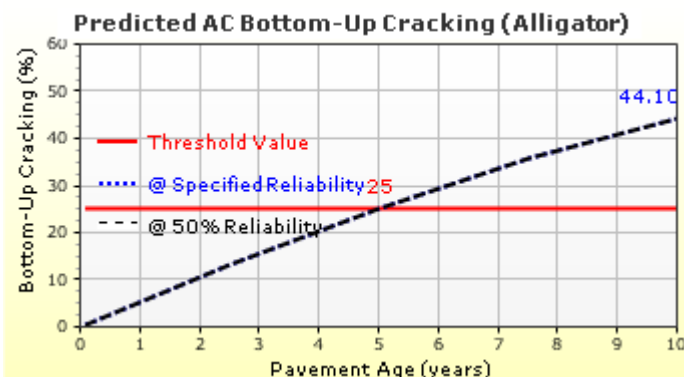
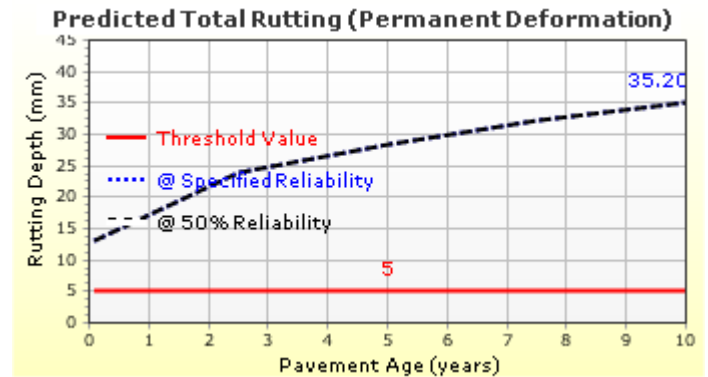
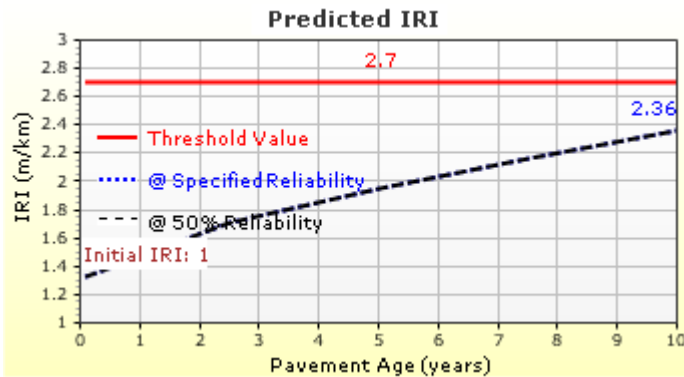
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.36	50.00	71.29	Pass
Permanent deformation - total pavement (mm)	5.00	35.20	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	44.10	50.00	8.82	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	905.30	50.00	12.38	Fail
Permanent deformation - AC only (mm)	5.00	16.86	50.00	0.36	Fail

Distress Charts

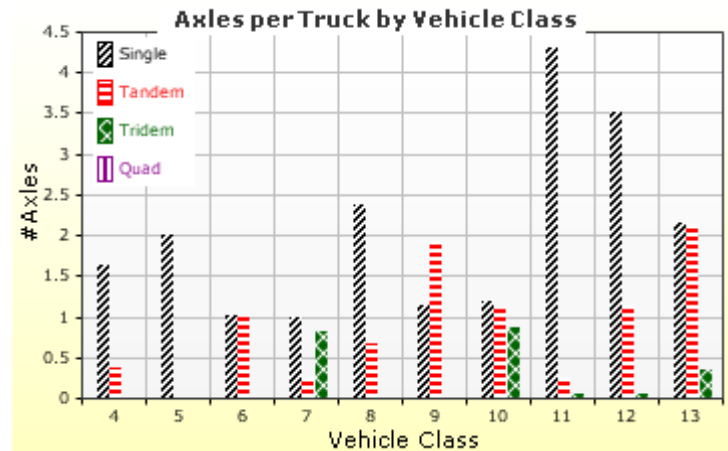
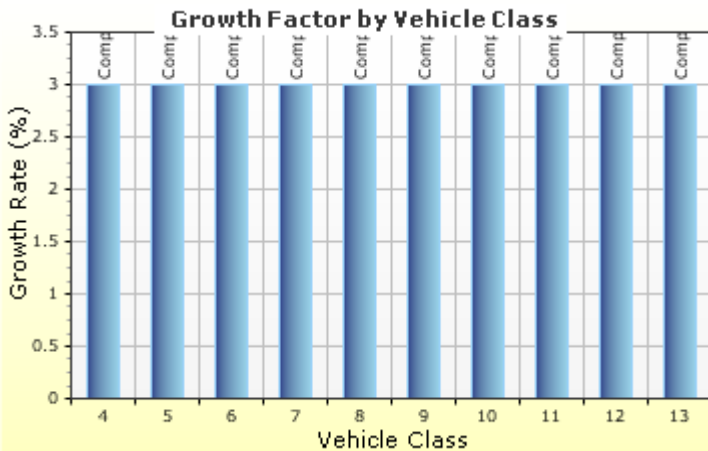
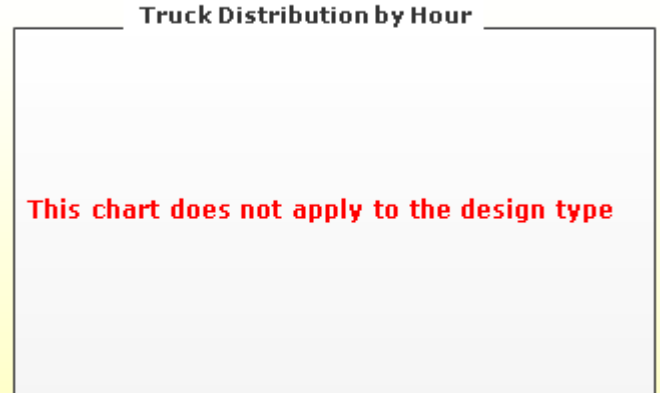
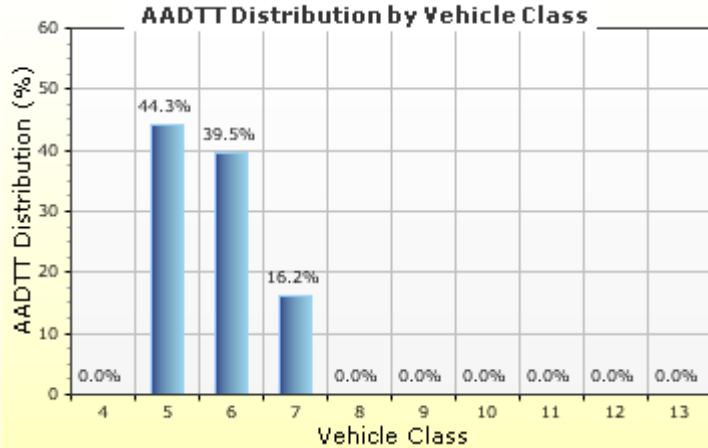


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

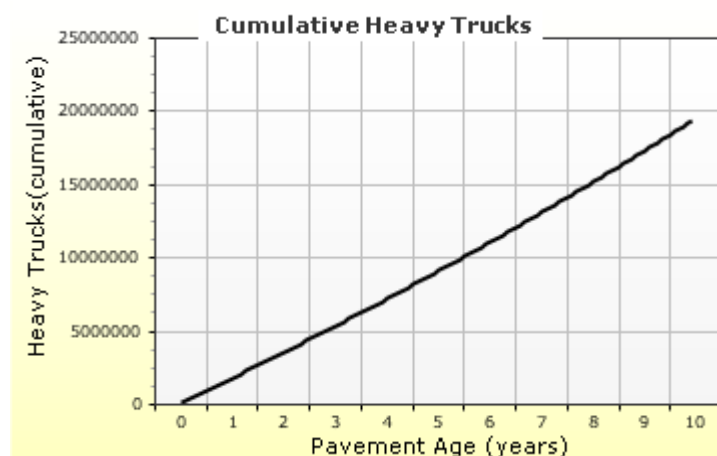
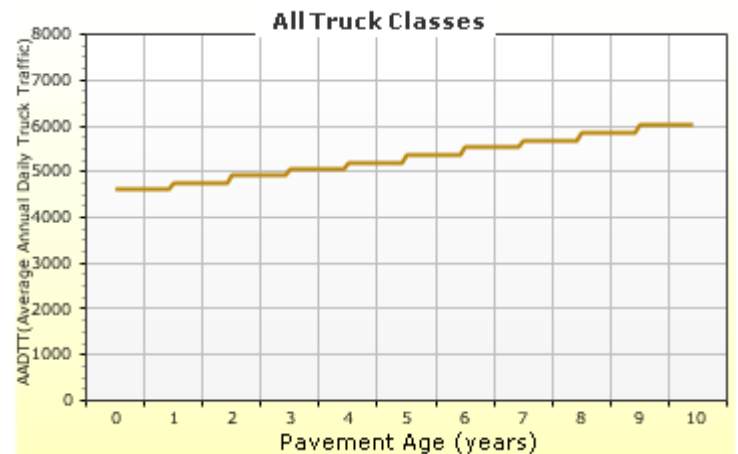
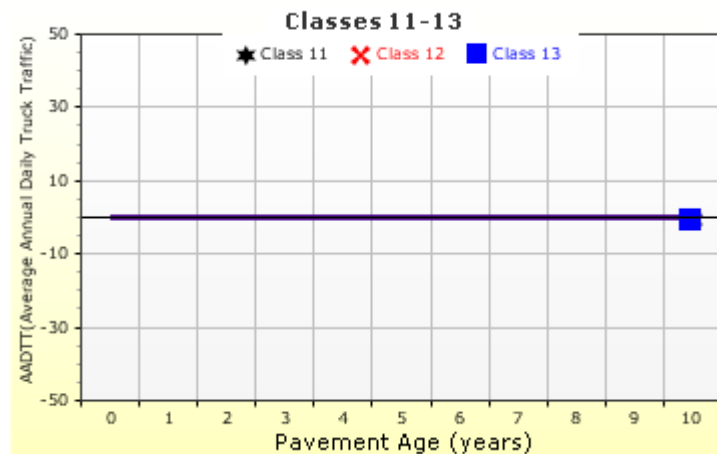
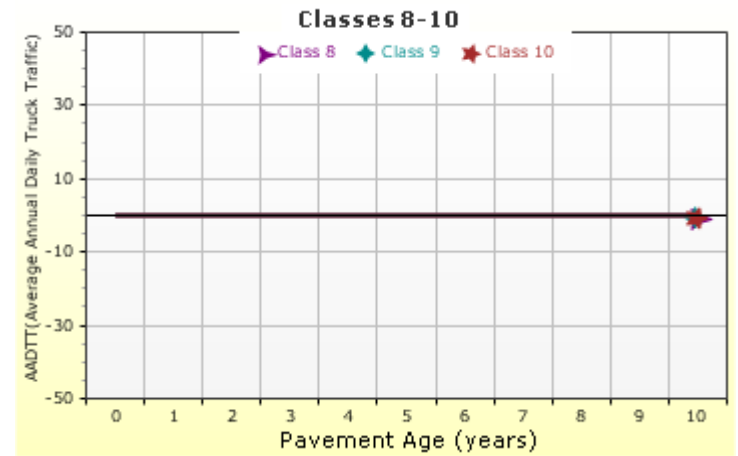
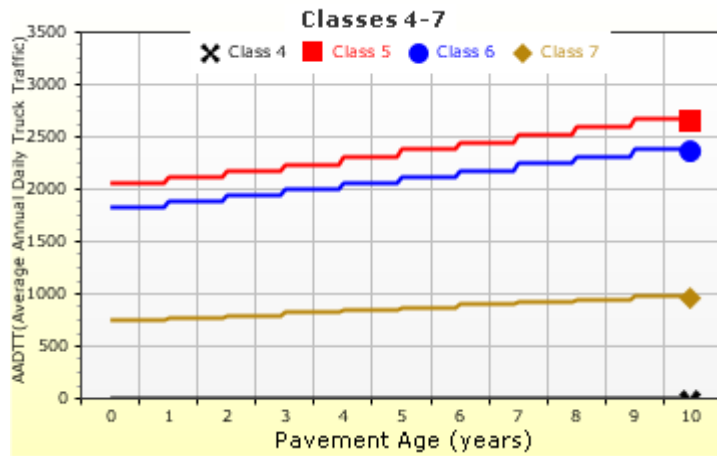
Wheelbase does not apply

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



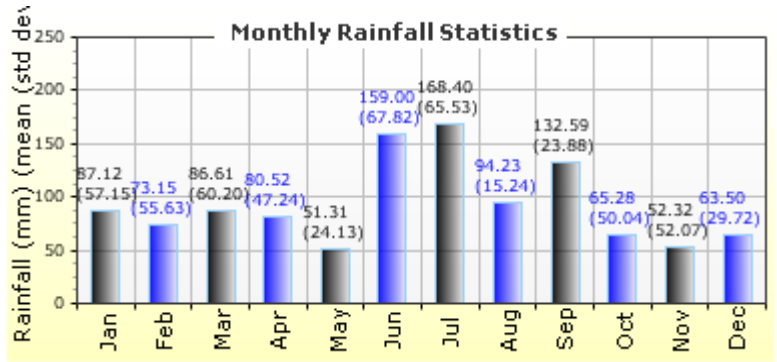
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

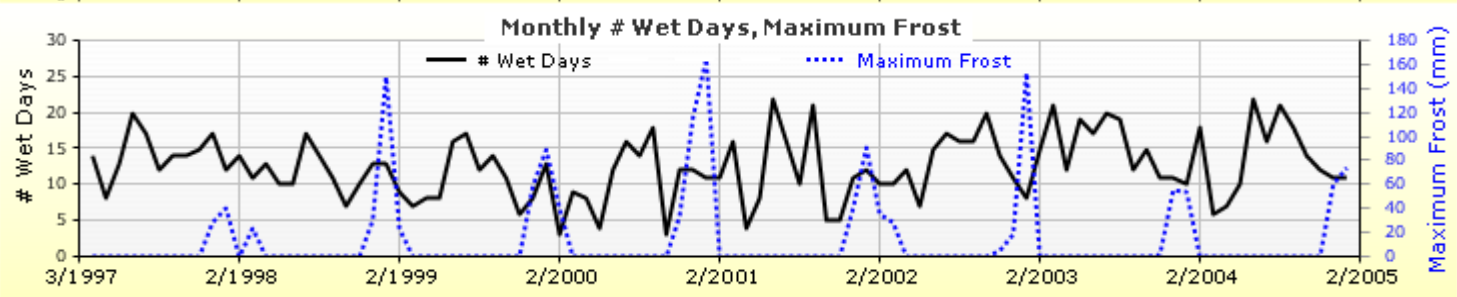
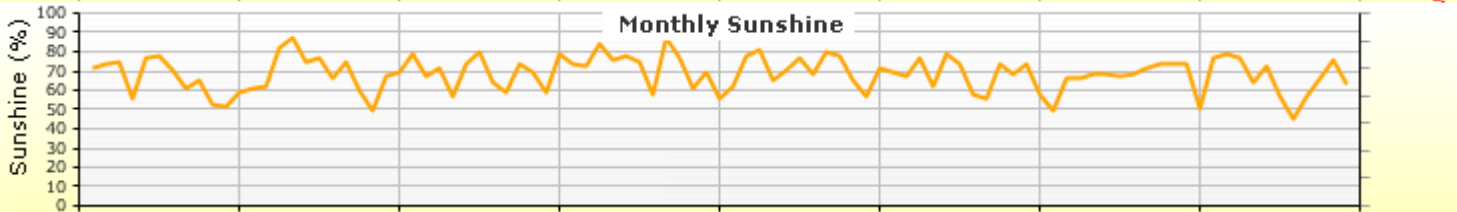
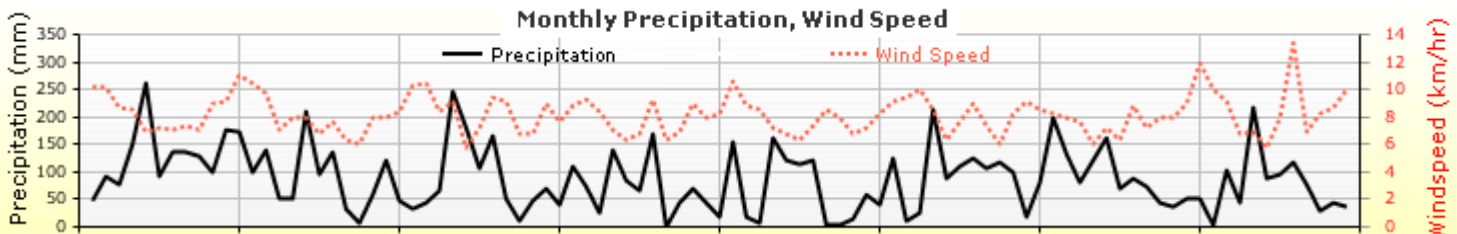
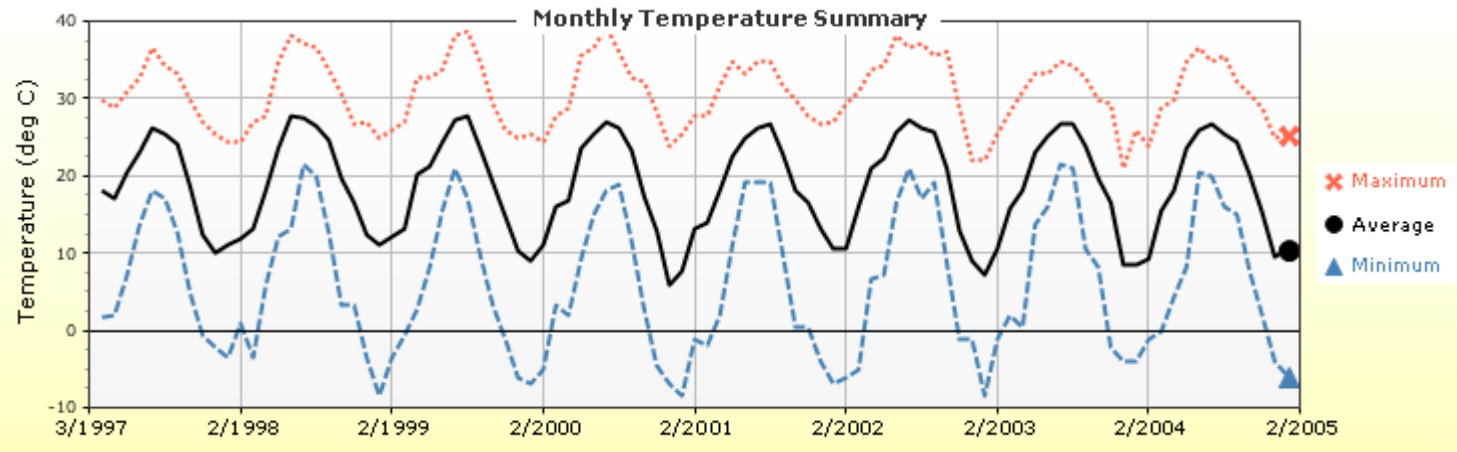
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

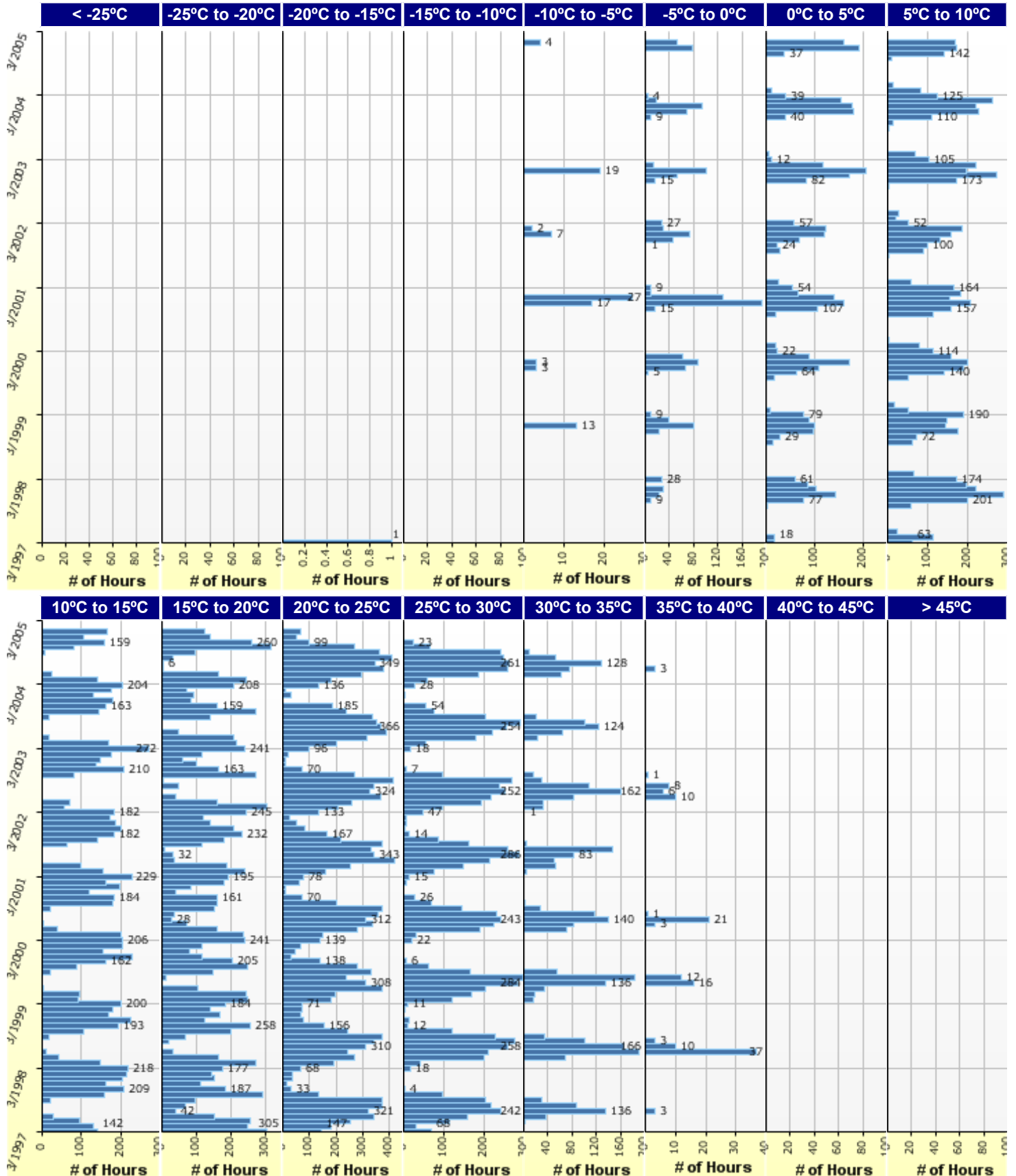


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF4

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF4.dgpx



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

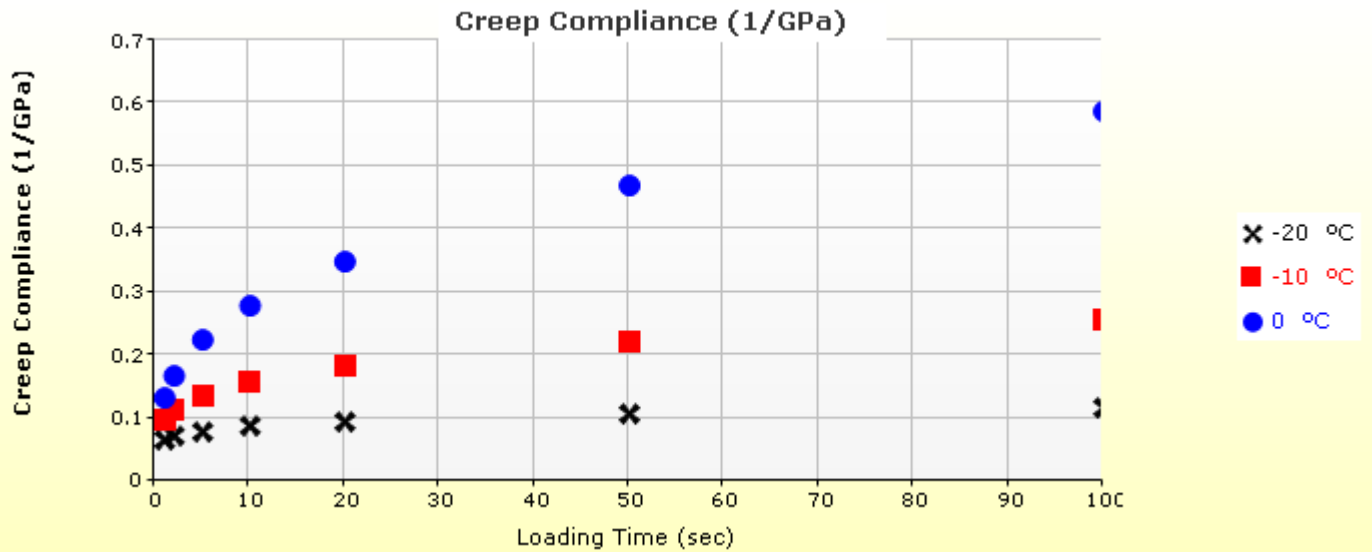
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

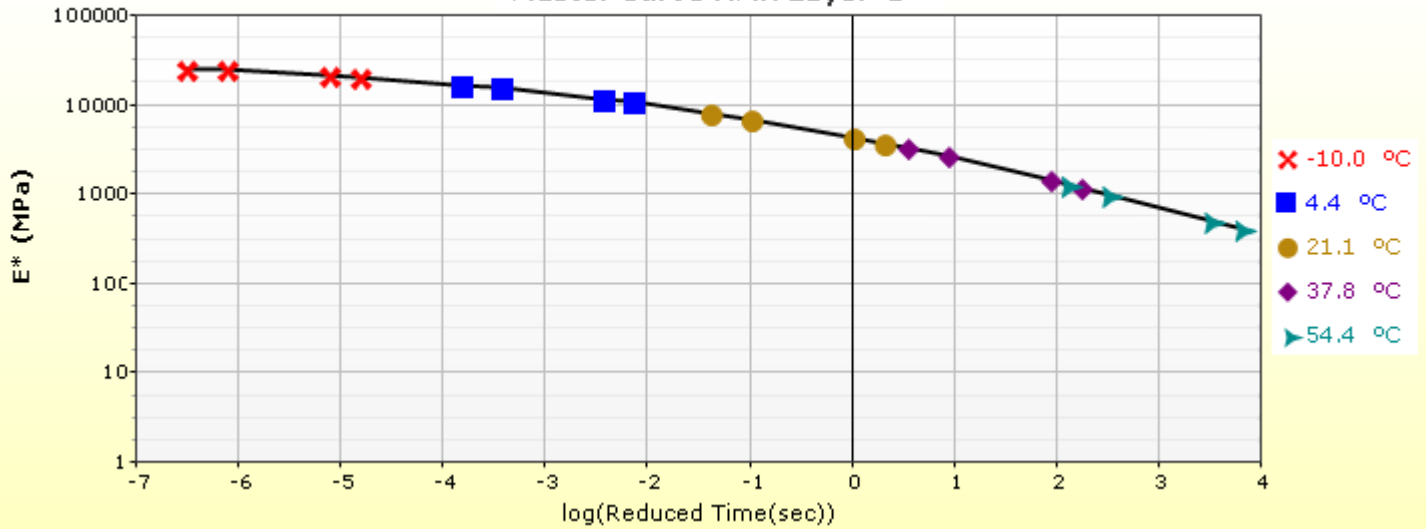
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

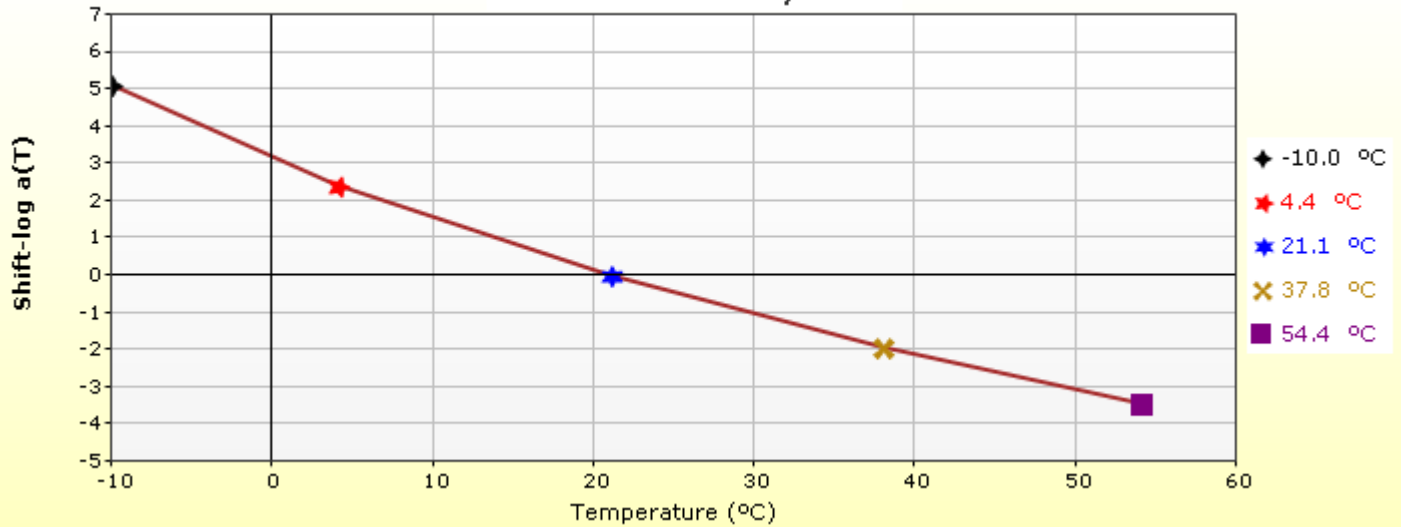


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

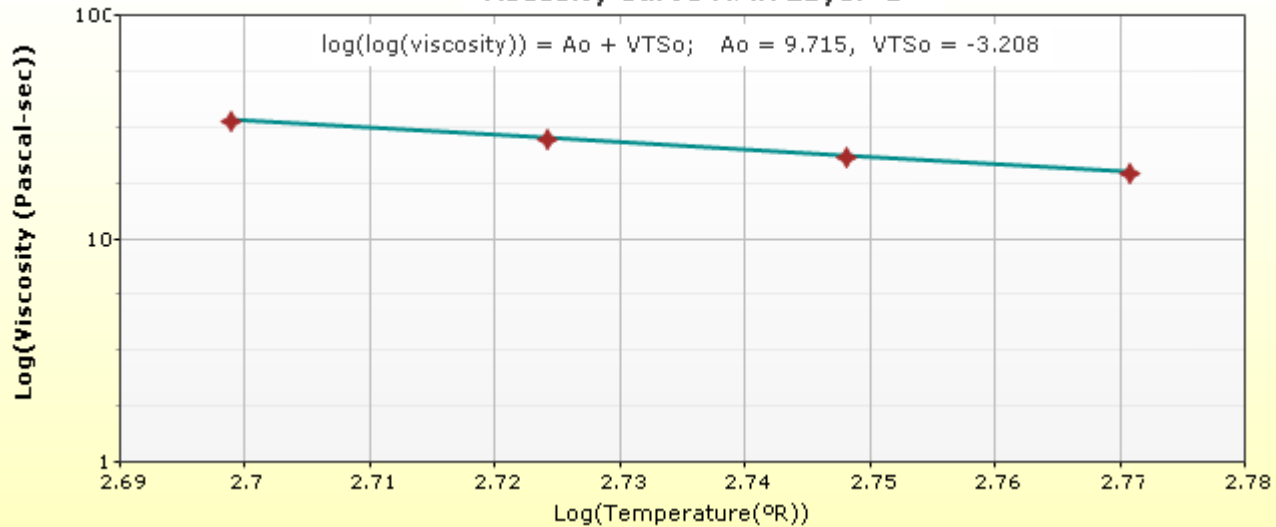
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

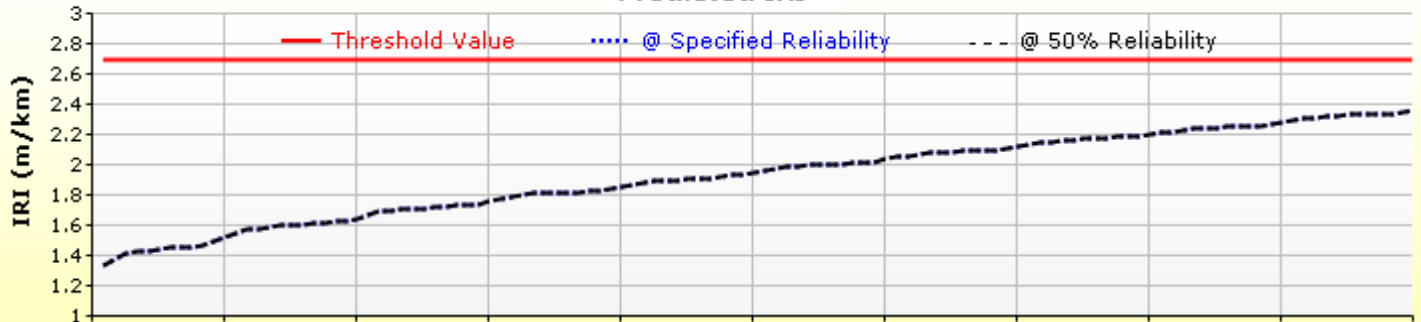


Viscosity Curve HMA Layer 1

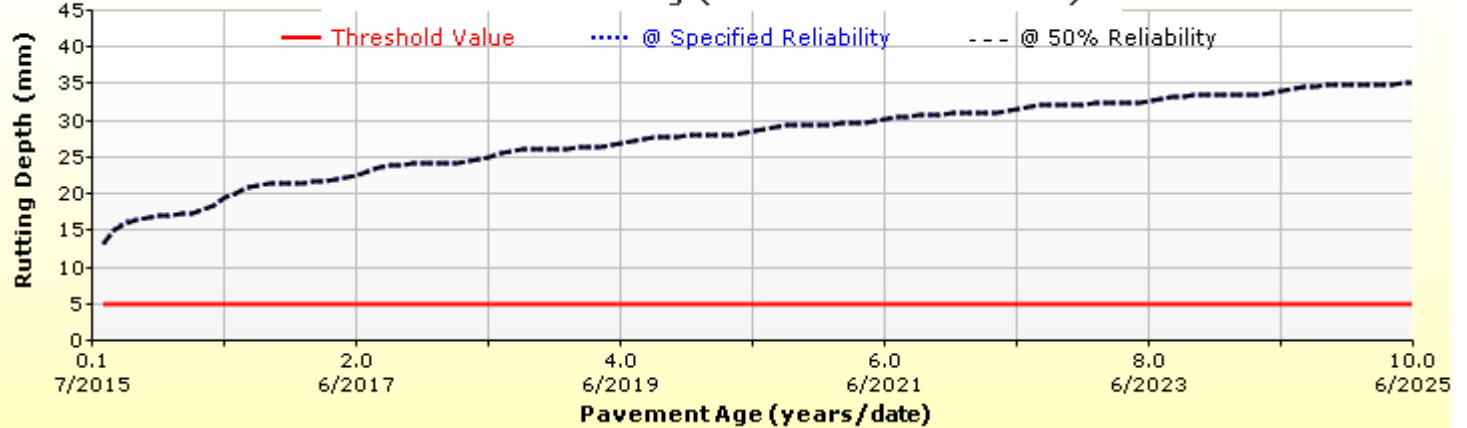


Analysis Output Charts

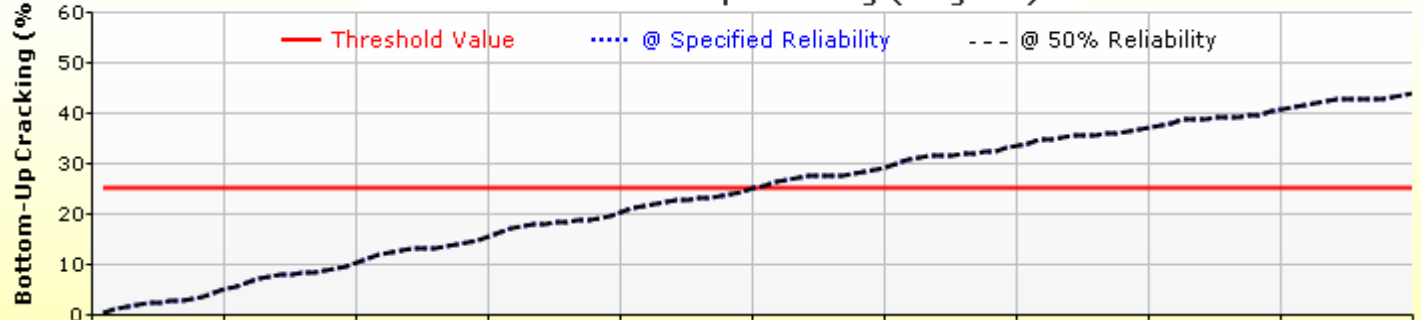
Predicted IRI



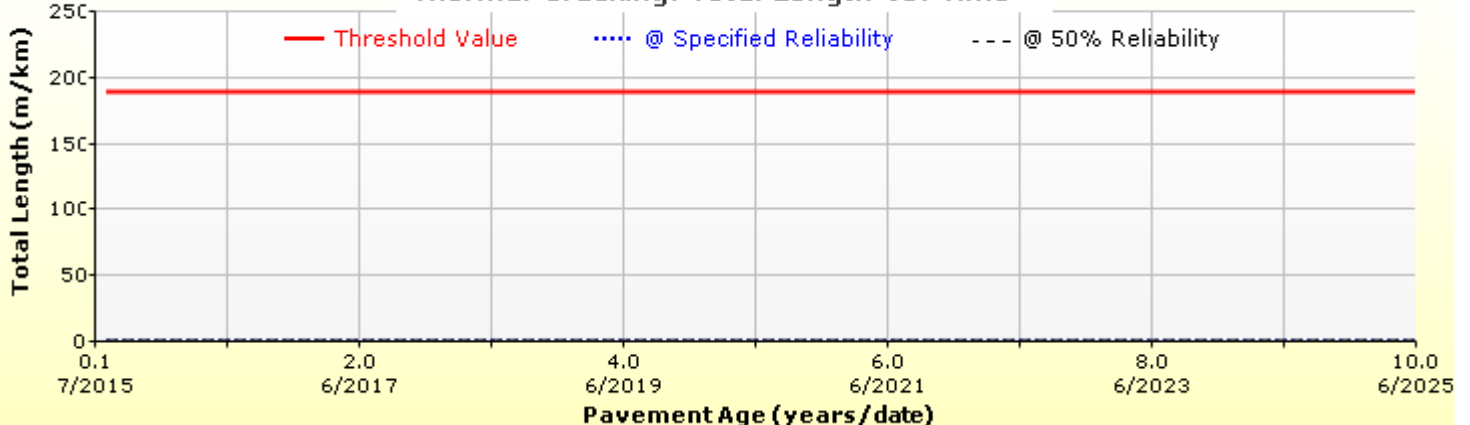
Predicted Total Rutting (Permanent Deformation)

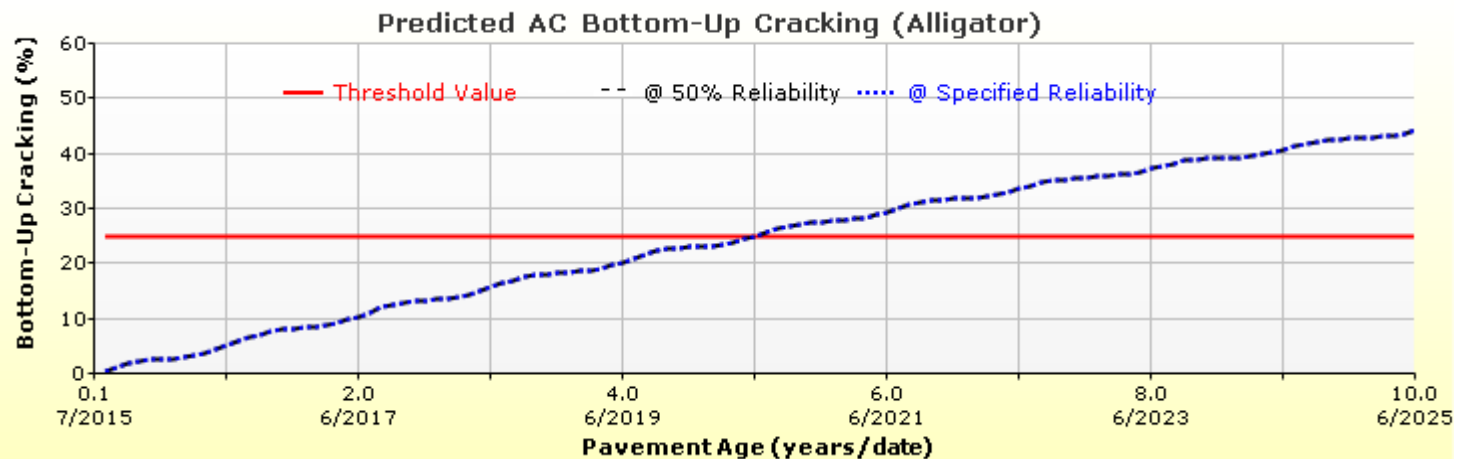
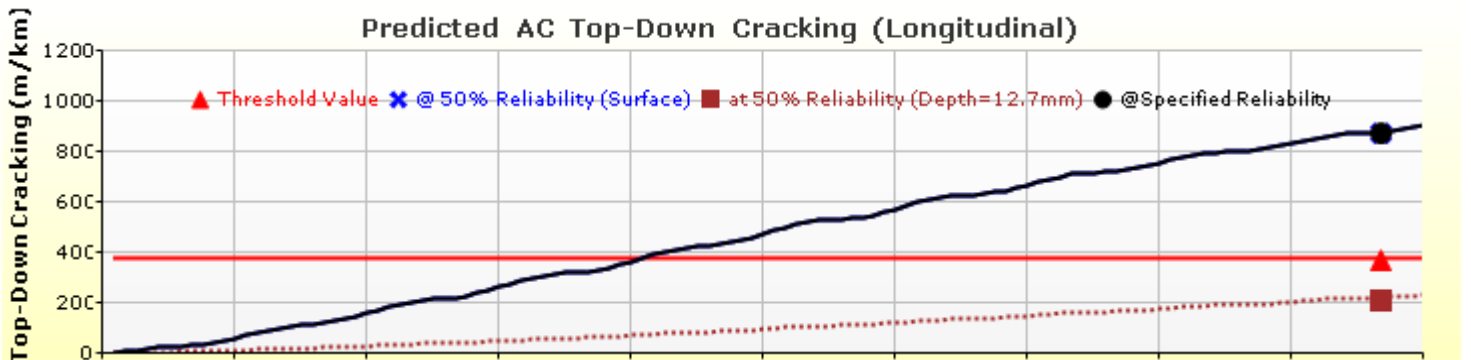
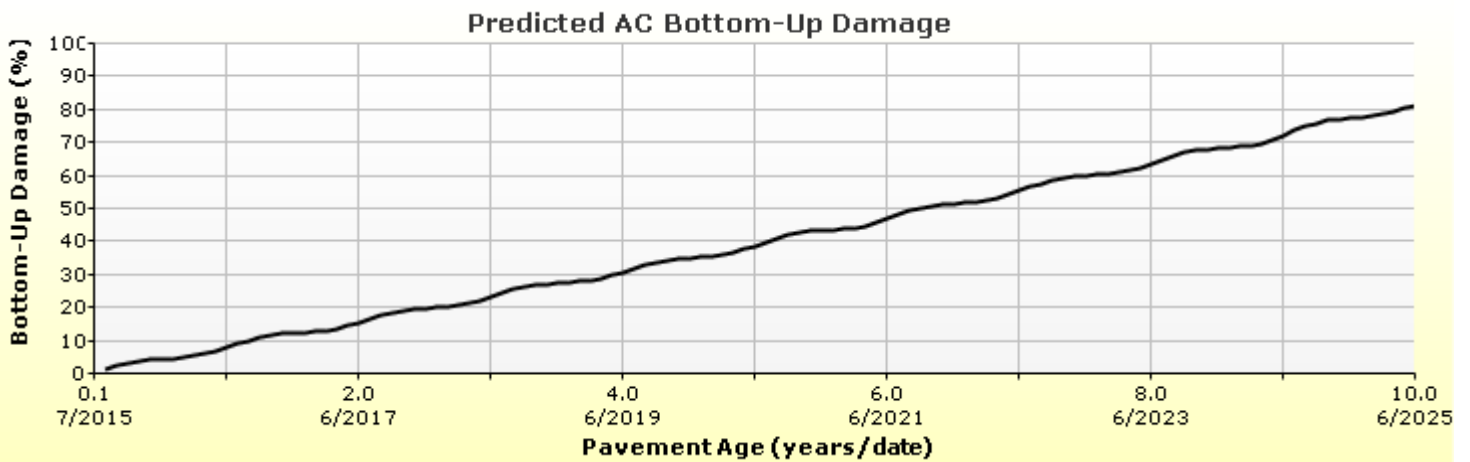
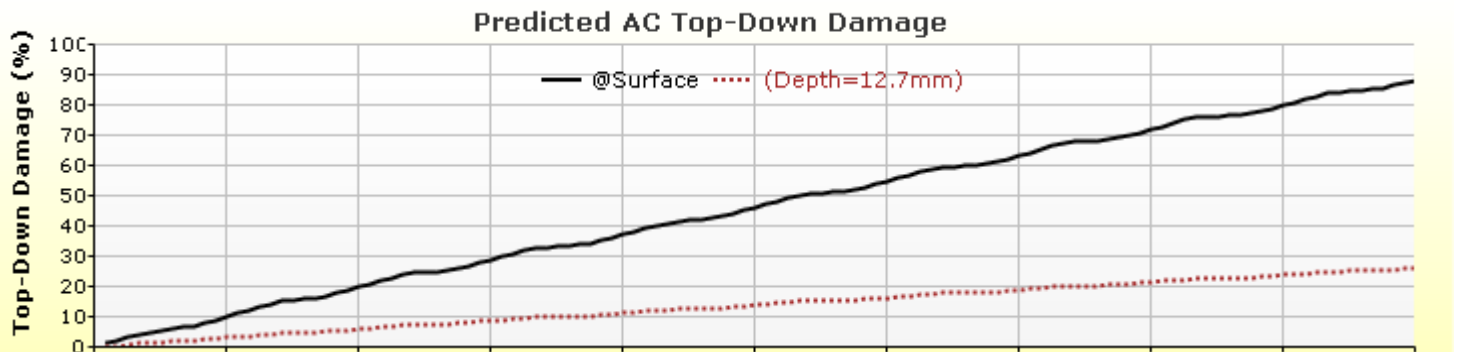


Predicted AC Bottom-Up Cracking (Alligator)

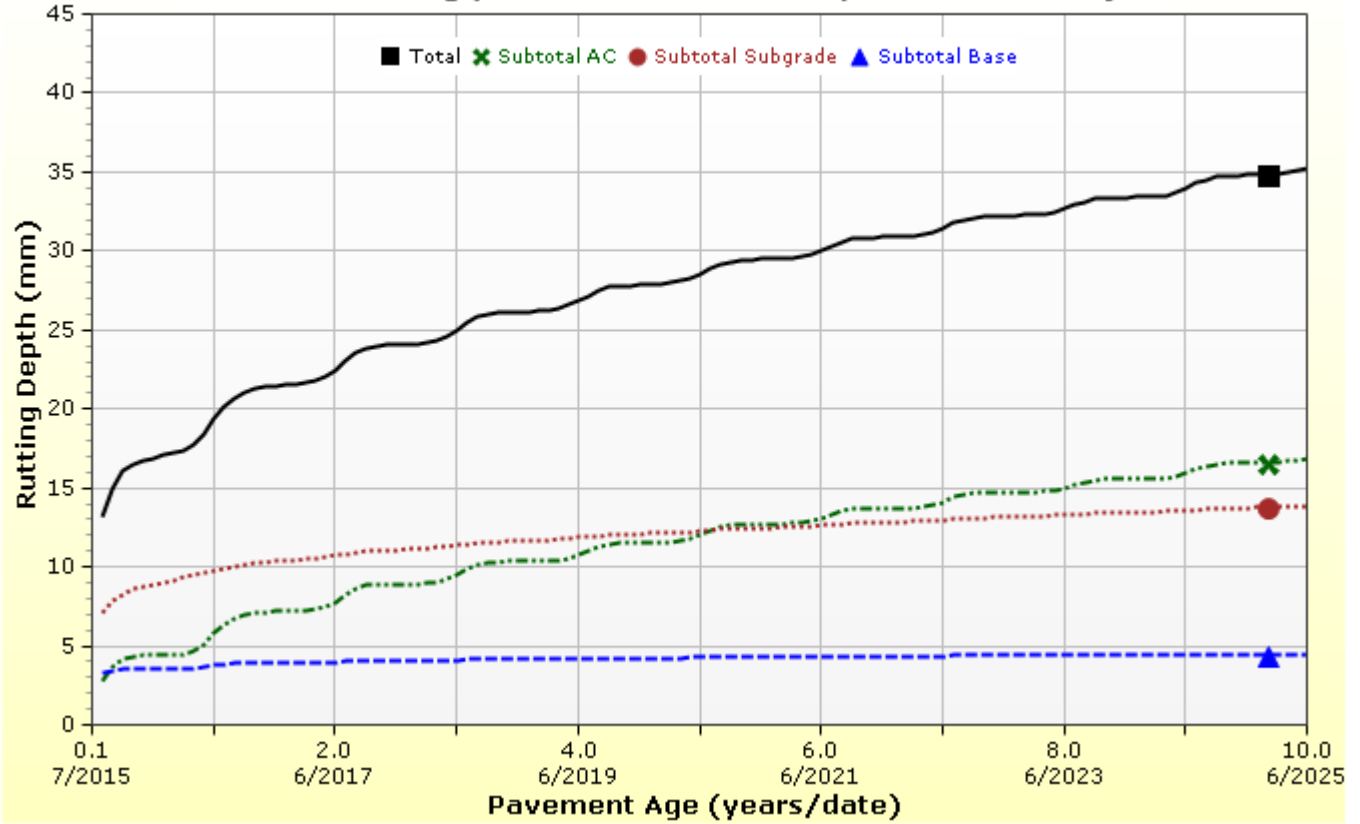


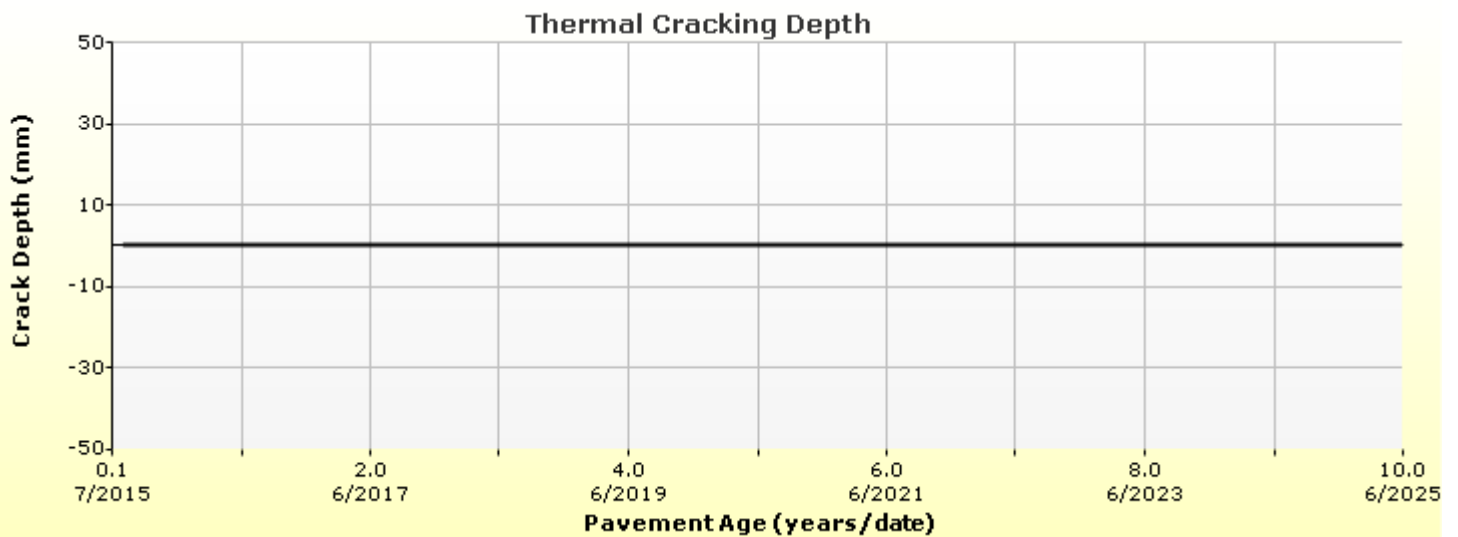
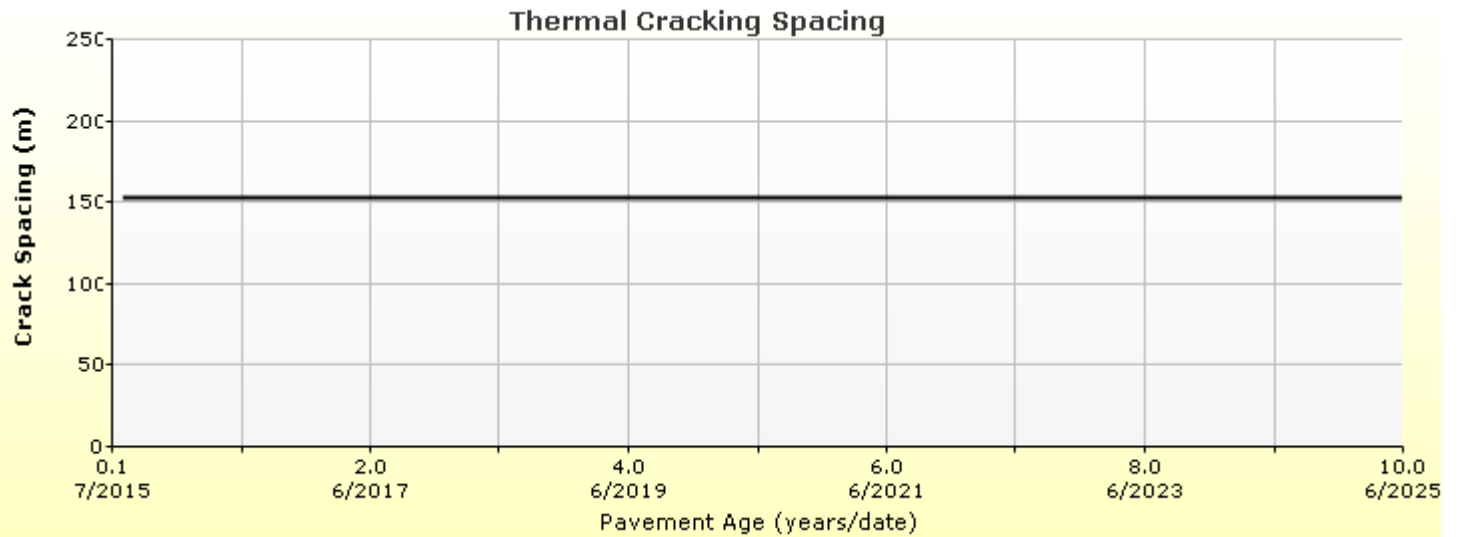
Thermal Cracking: Total Length vs. Time

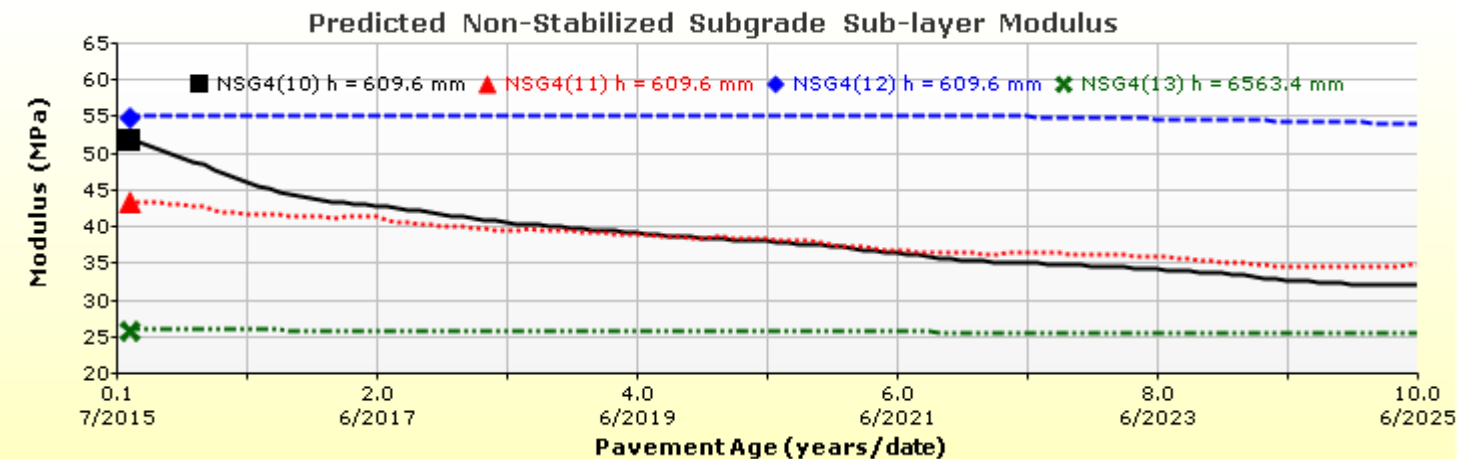
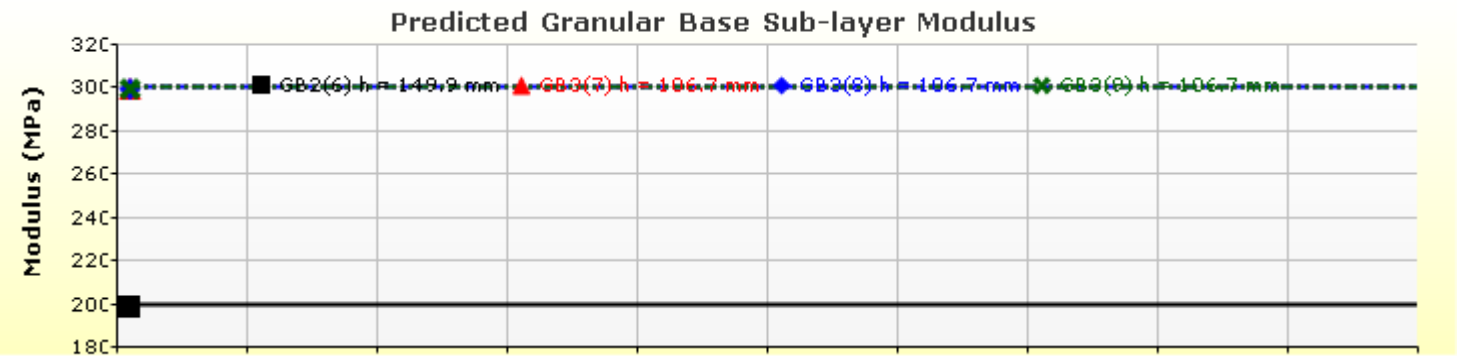
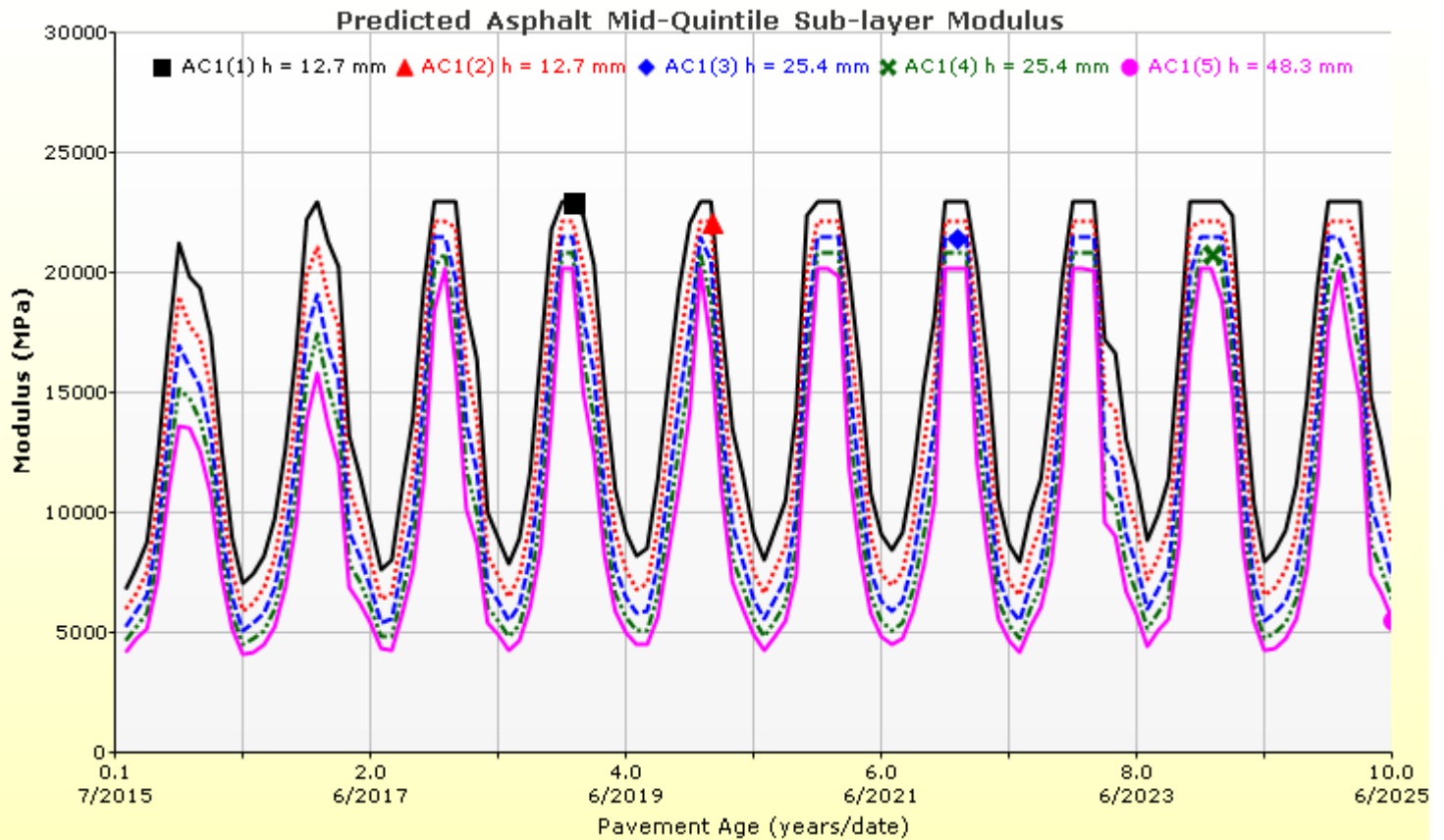




Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

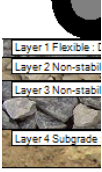
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

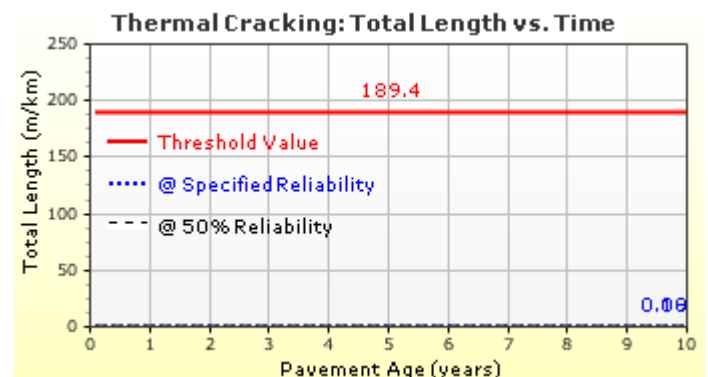
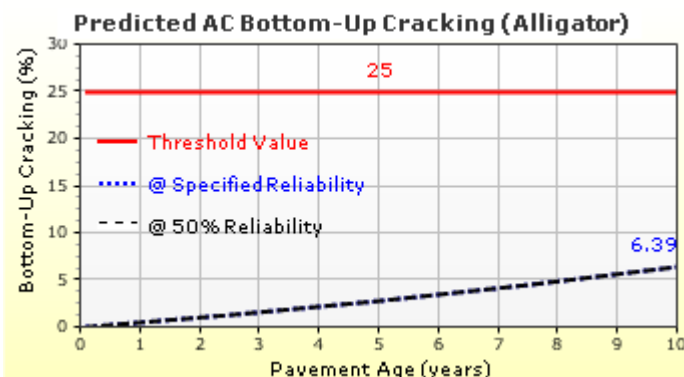
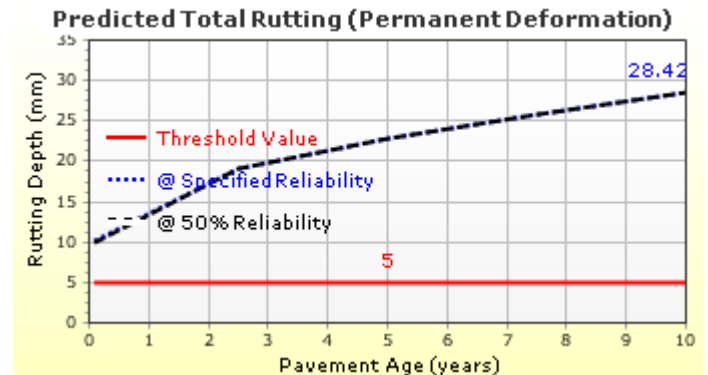
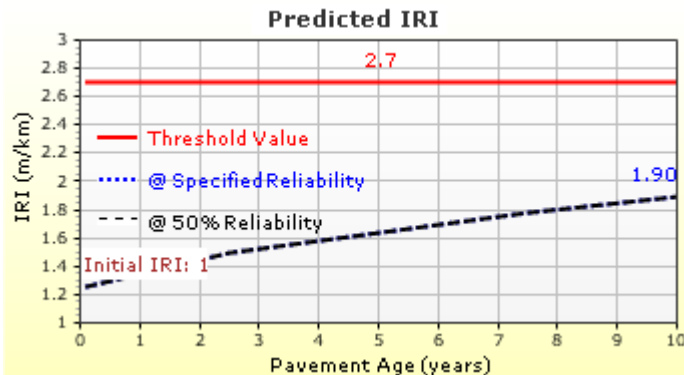
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.90	50.00	93.56	Pass
Permanent deformation - total pavement (mm)	5.00	28.42	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	6.39	50.00	90.62	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	5.83	50.00	95.66	Pass
Permanent deformation - AC only (mm)	5.00	15.12	50.00	0.62	Fail

Distress Charts

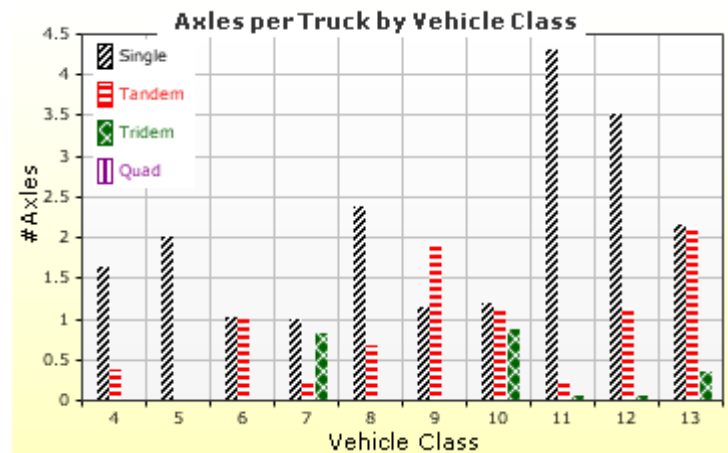
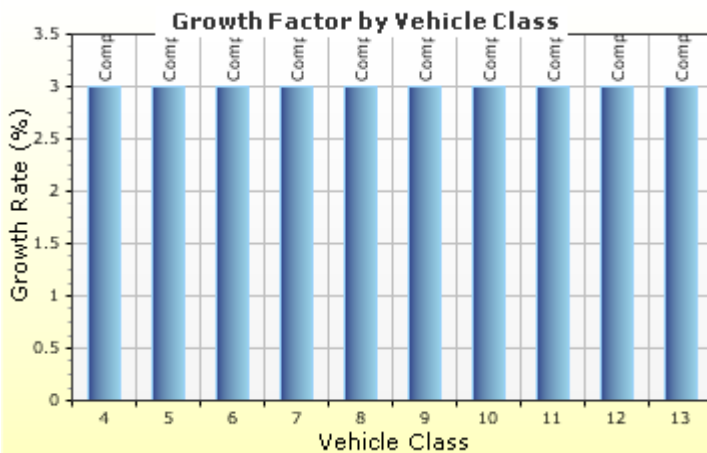
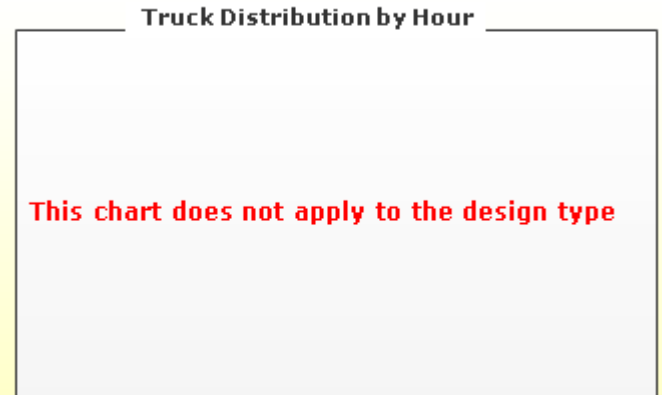
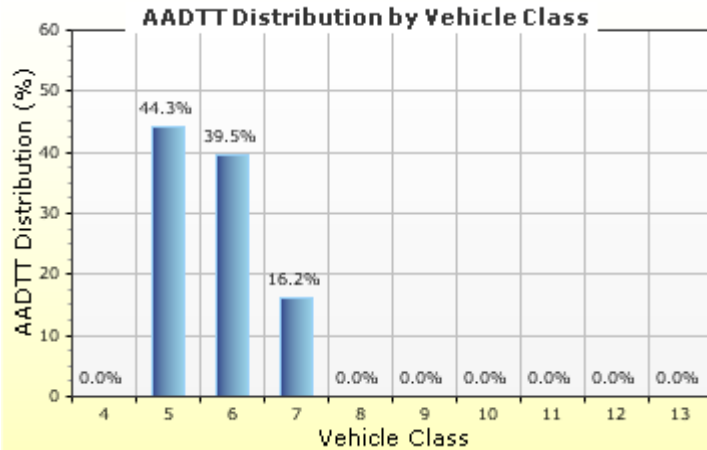


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

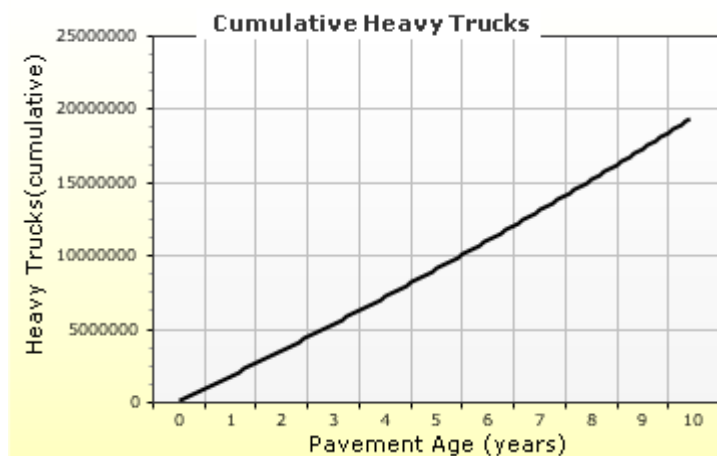
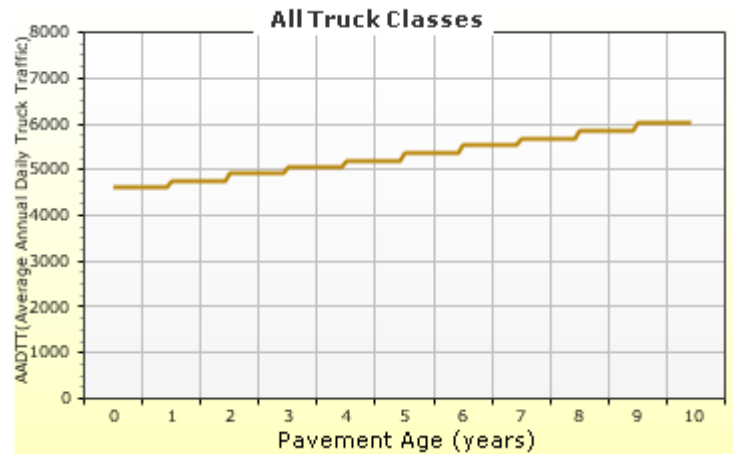
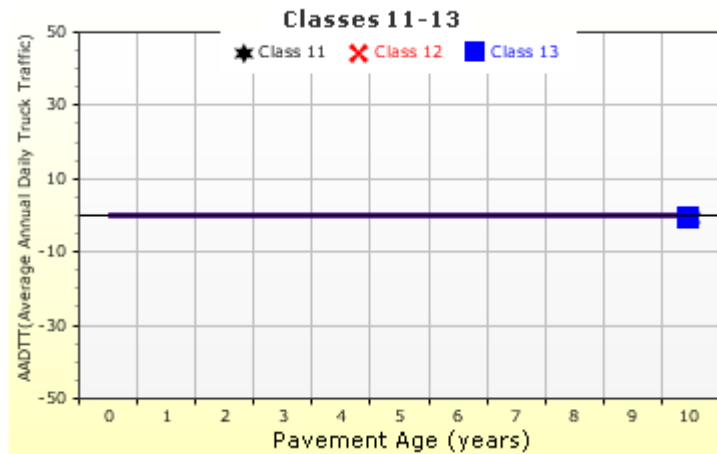
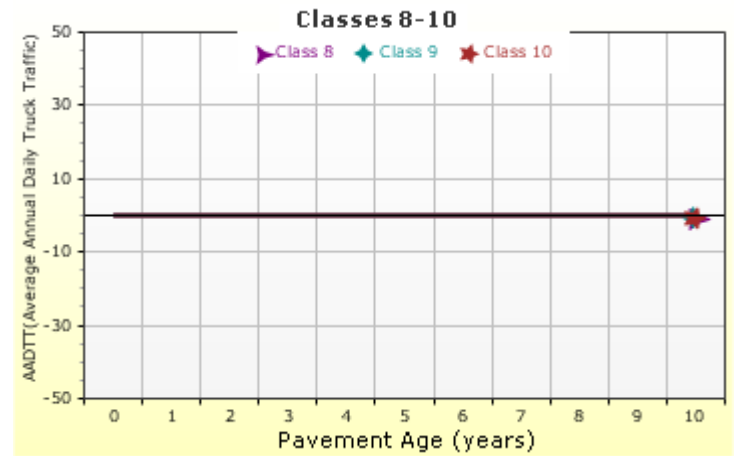
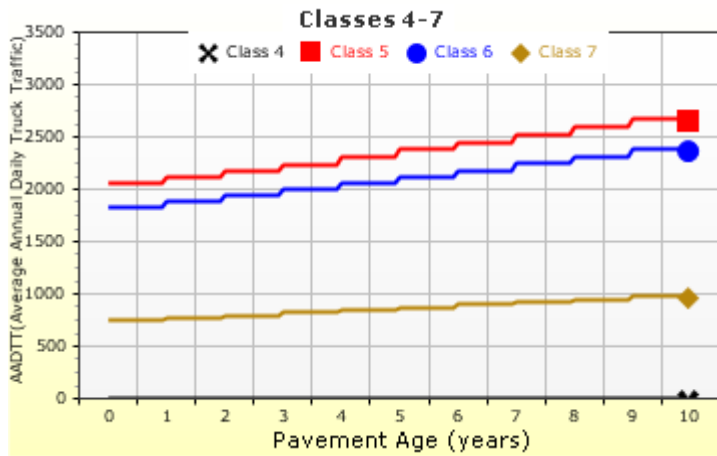
Wheelbase does not apply

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



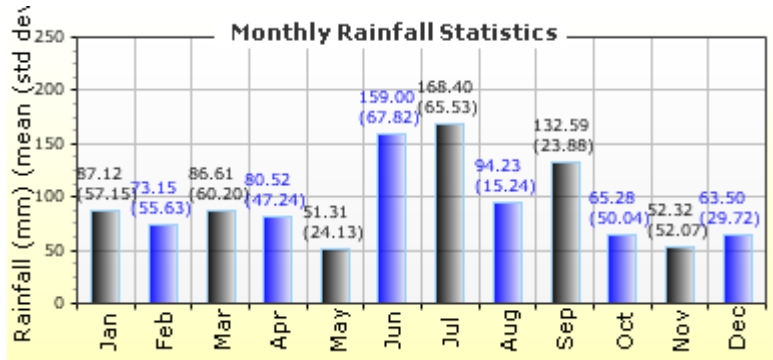
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

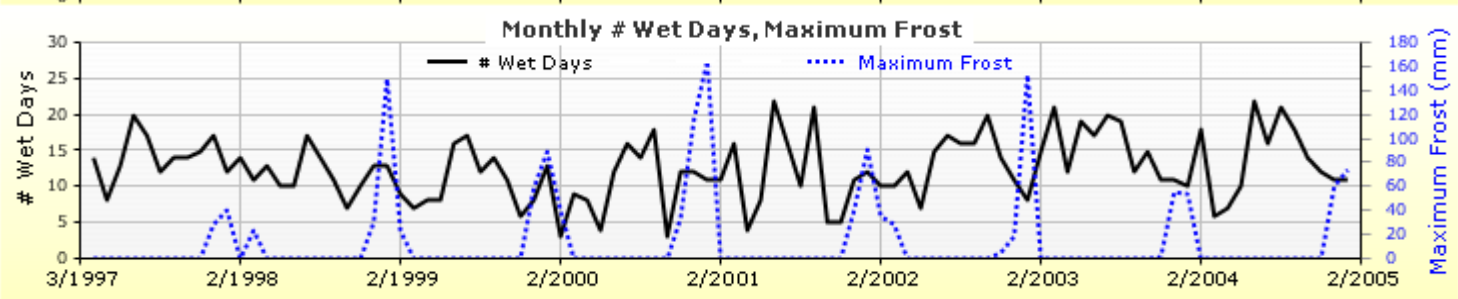
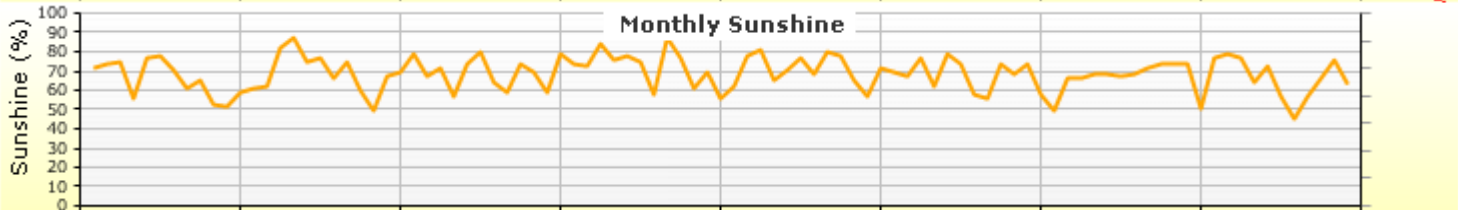
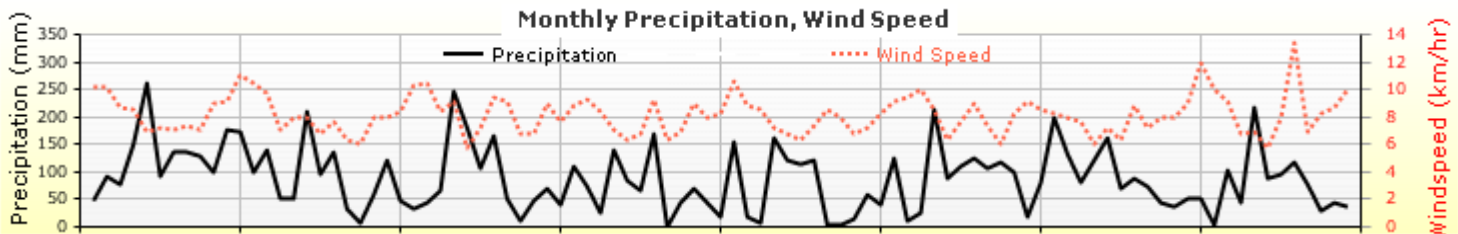
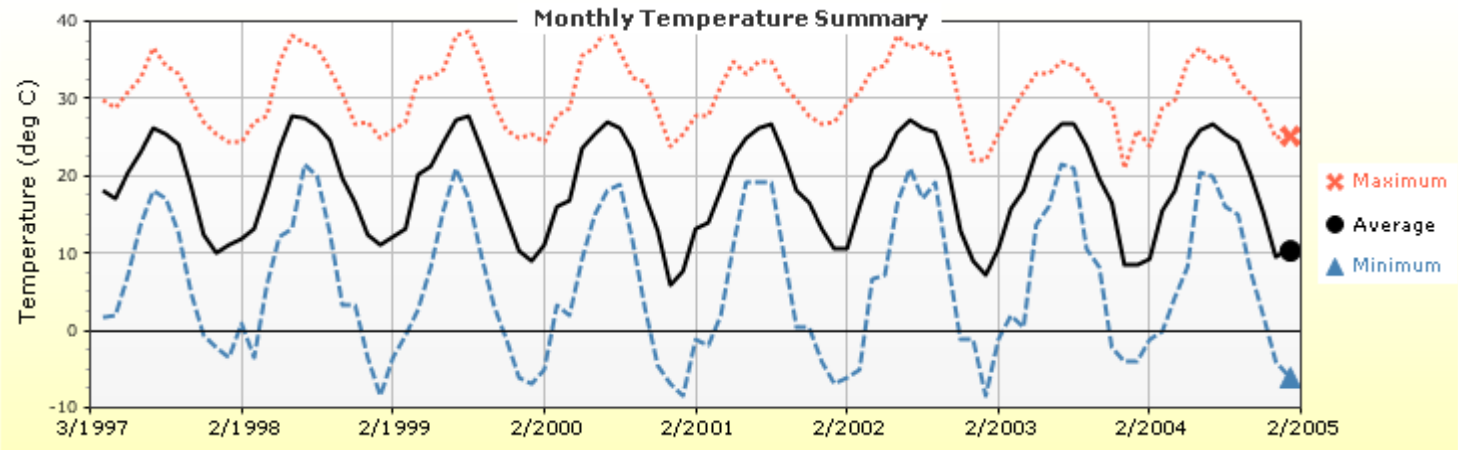
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

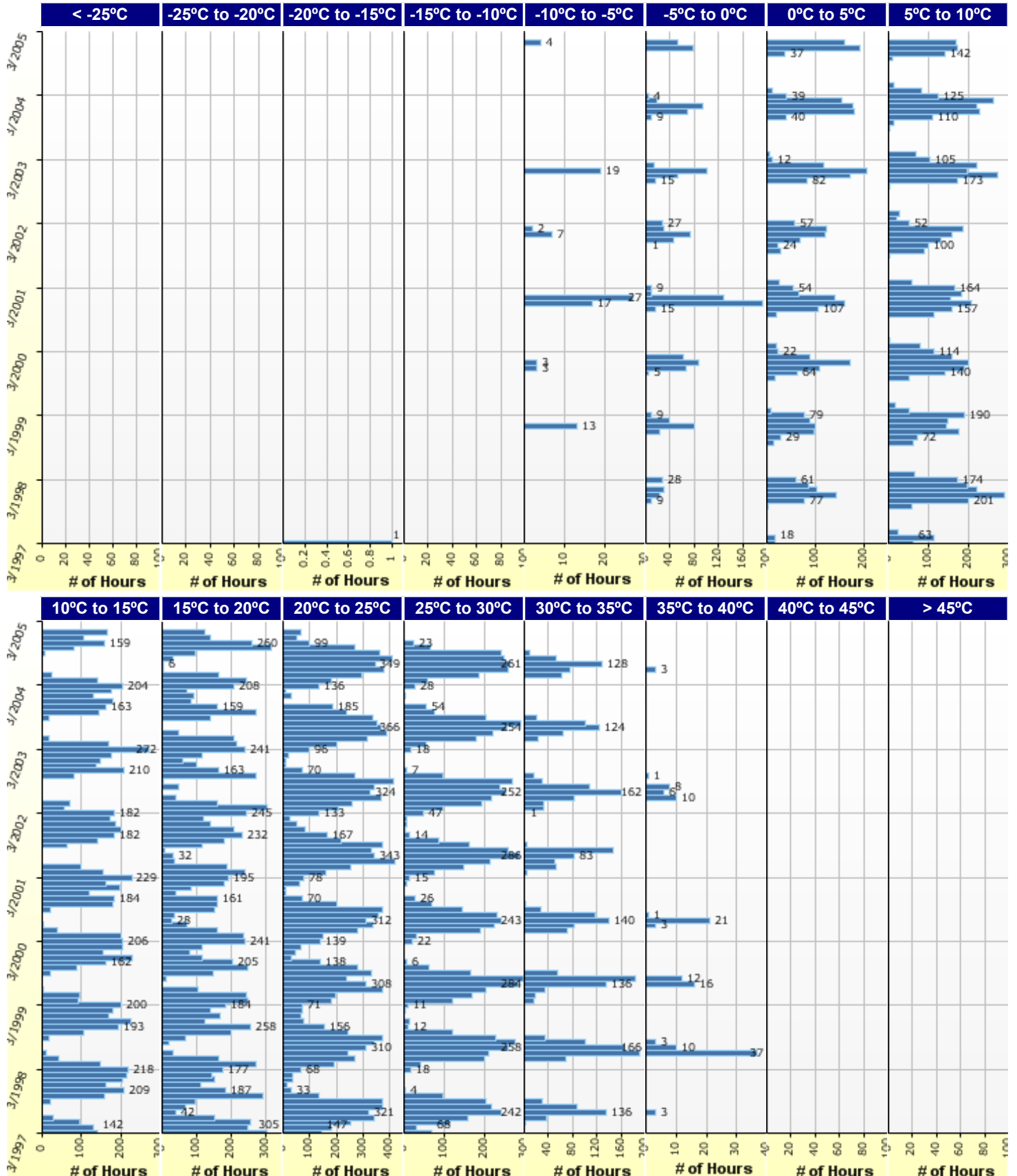


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF1_ALT1

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1_ALT1.dgpx



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

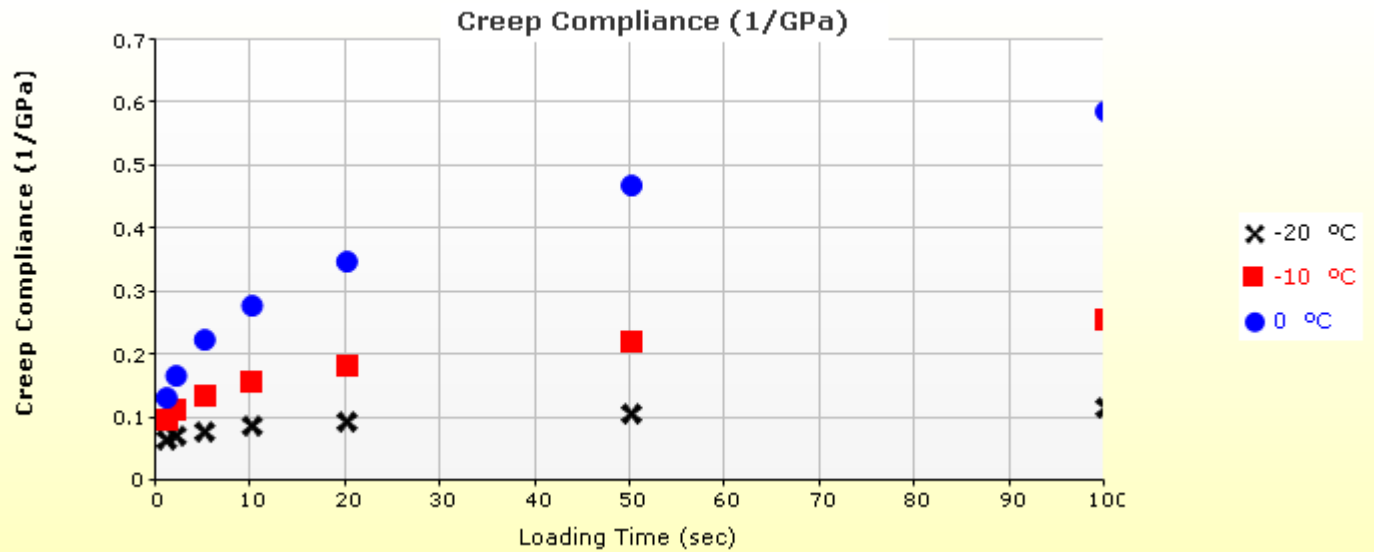
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

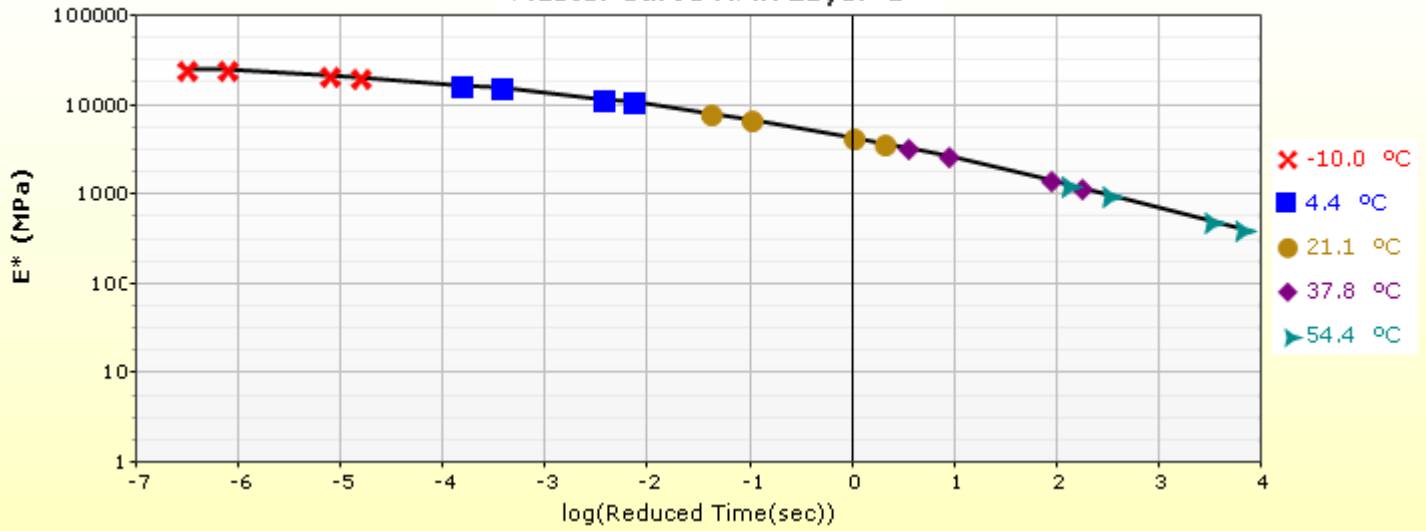
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

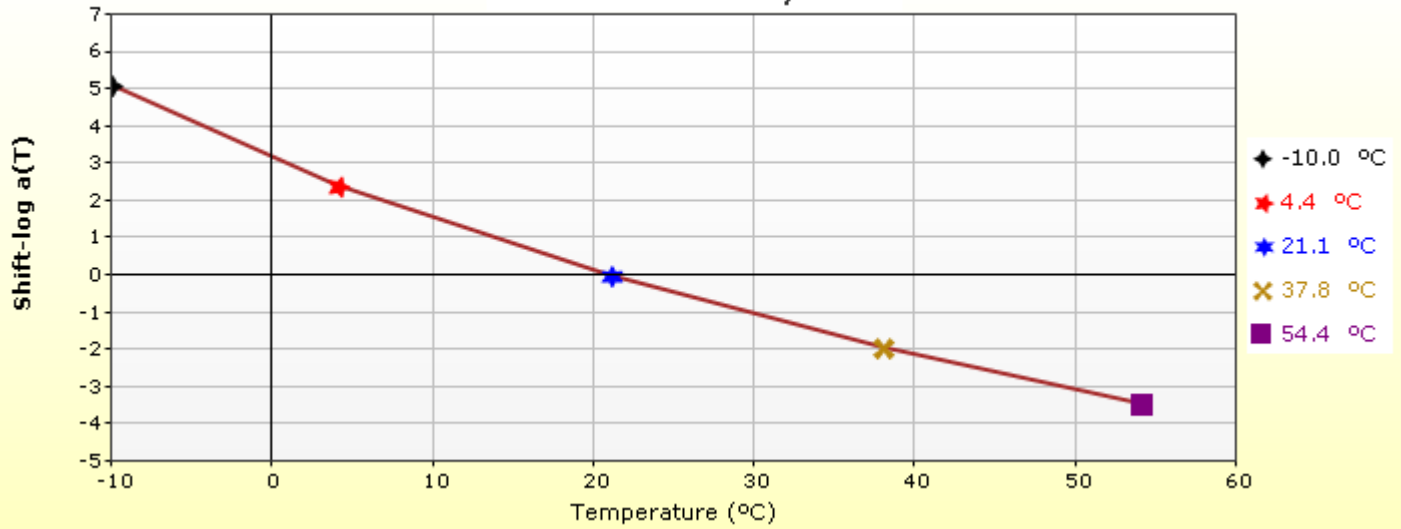


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

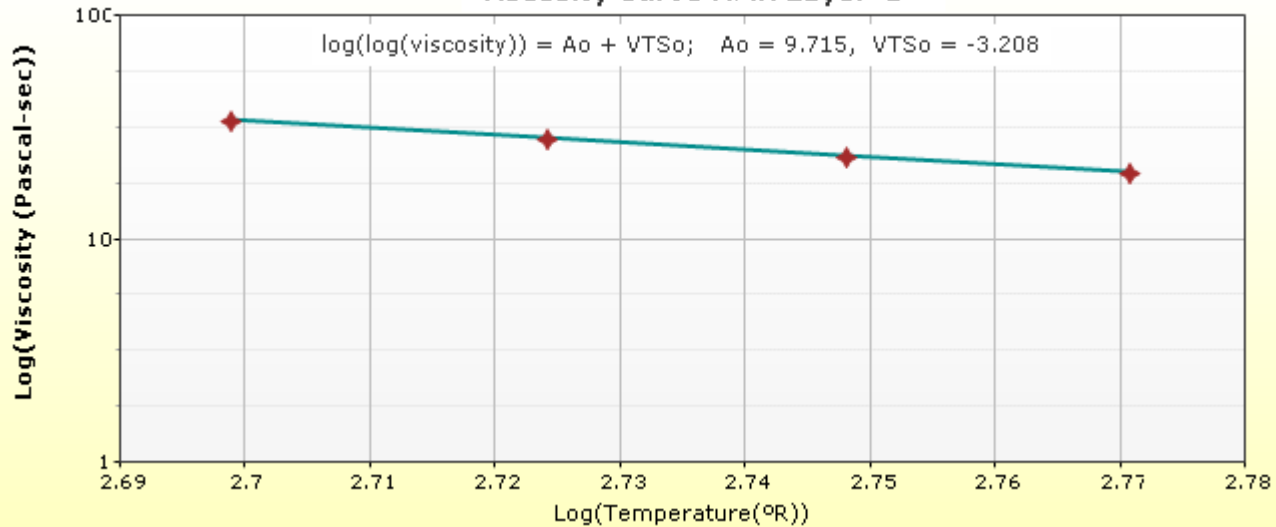
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

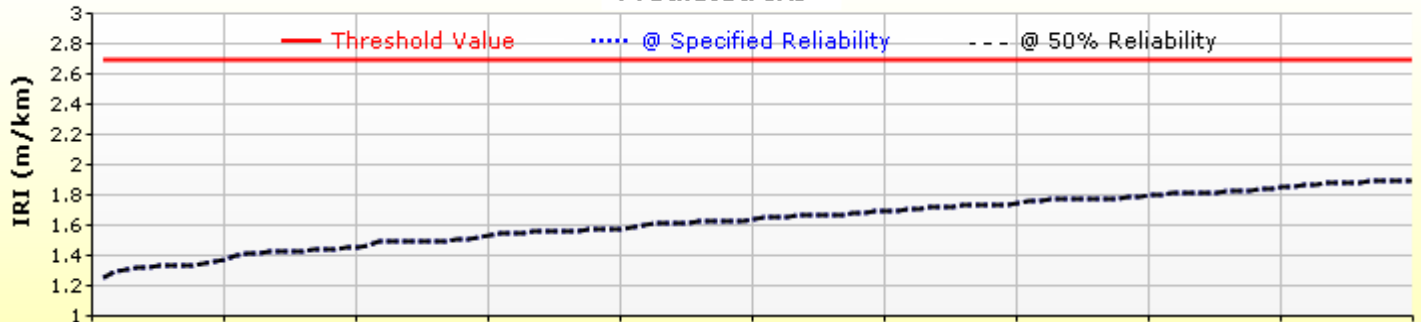


Viscosity Curve HMA Layer 1

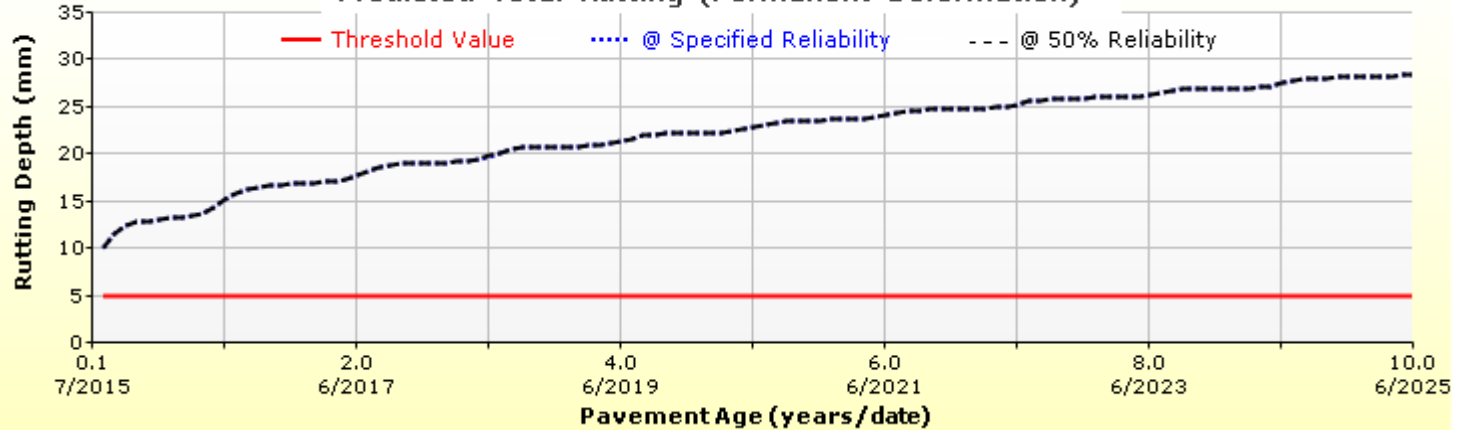


Analysis Output Charts

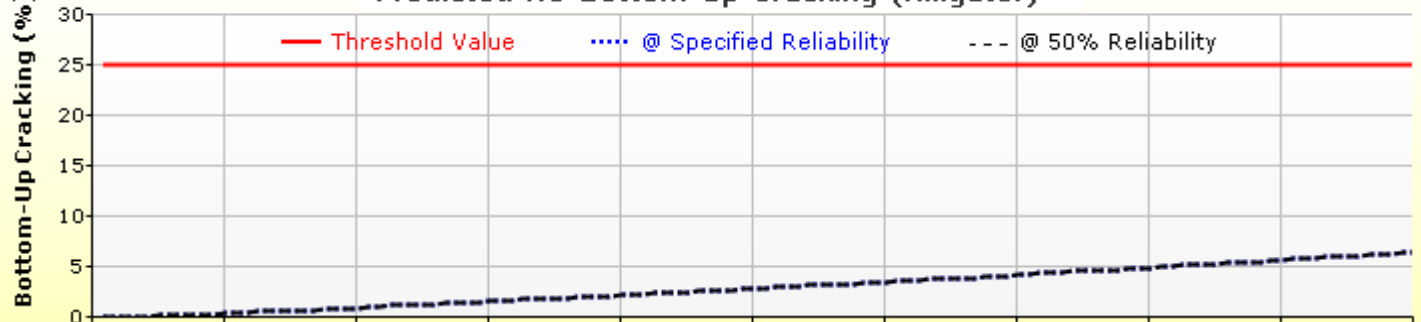
Predicted IRI



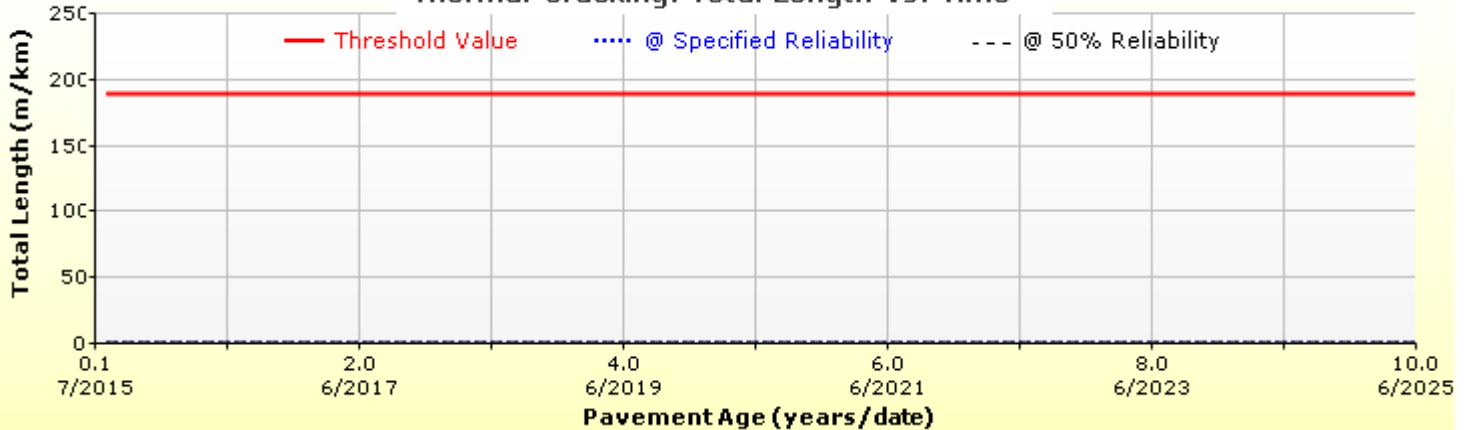
Predicted Total Rutting (Permanent Deformation)

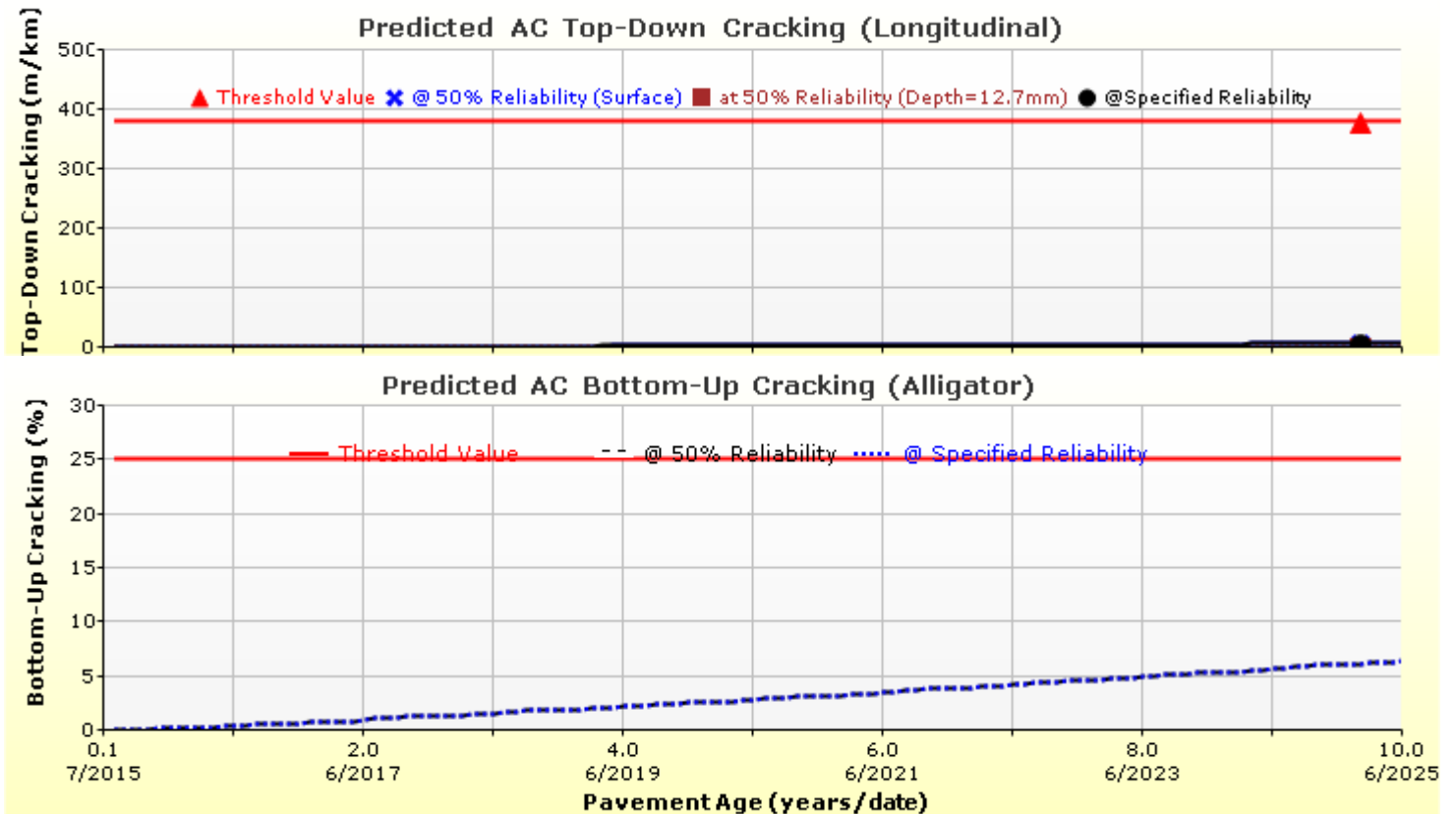
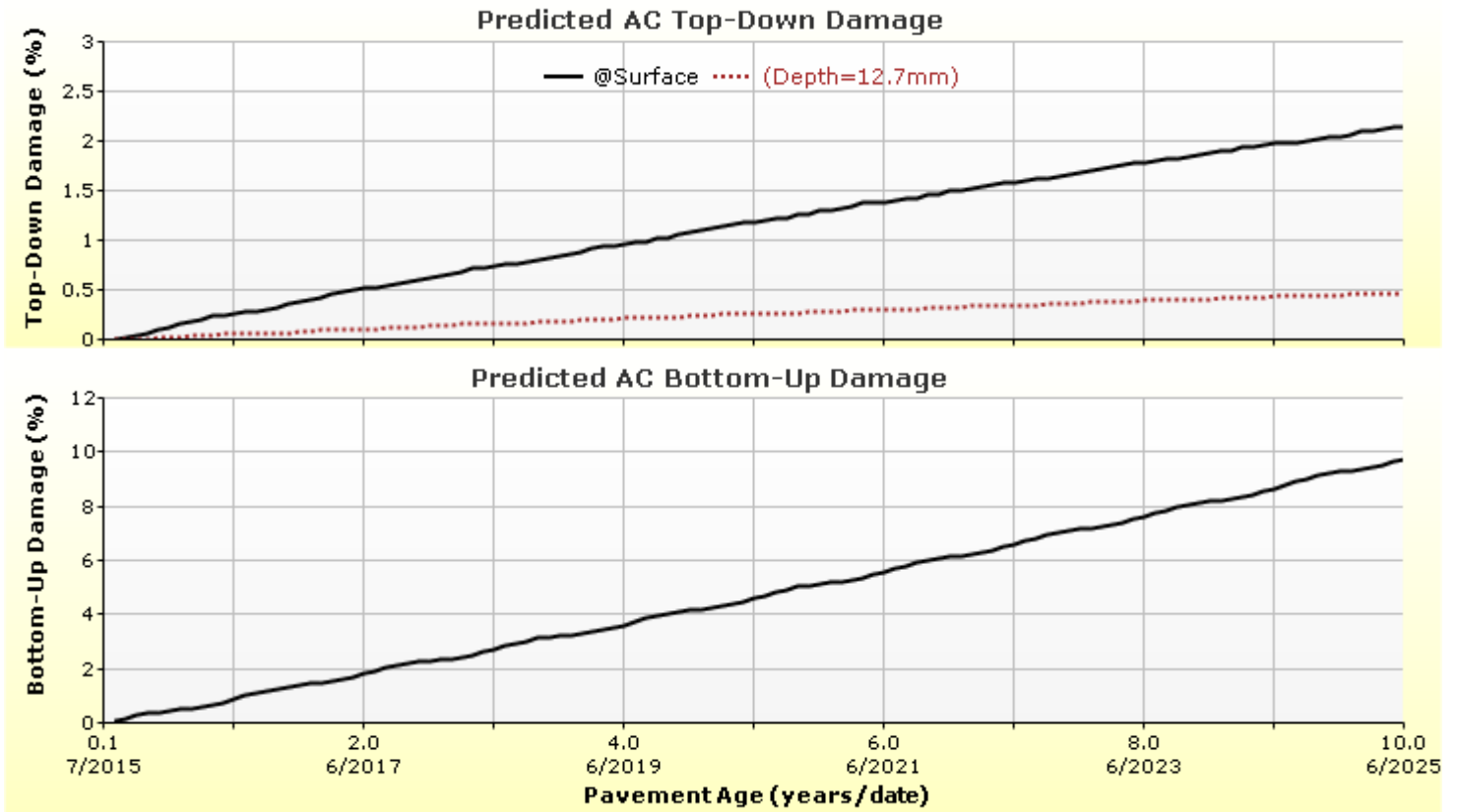


Predicted AC Bottom-Up Cracking (Alligator)

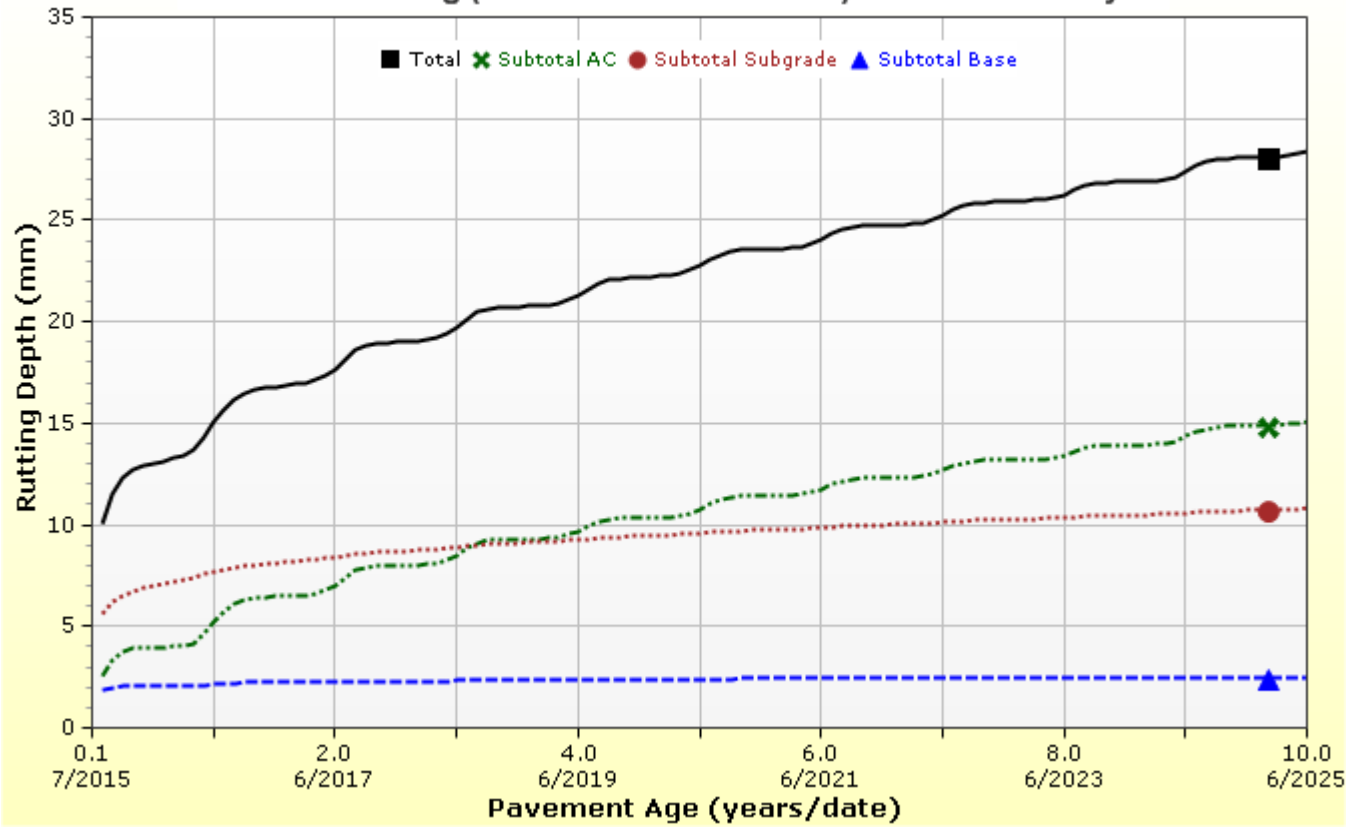


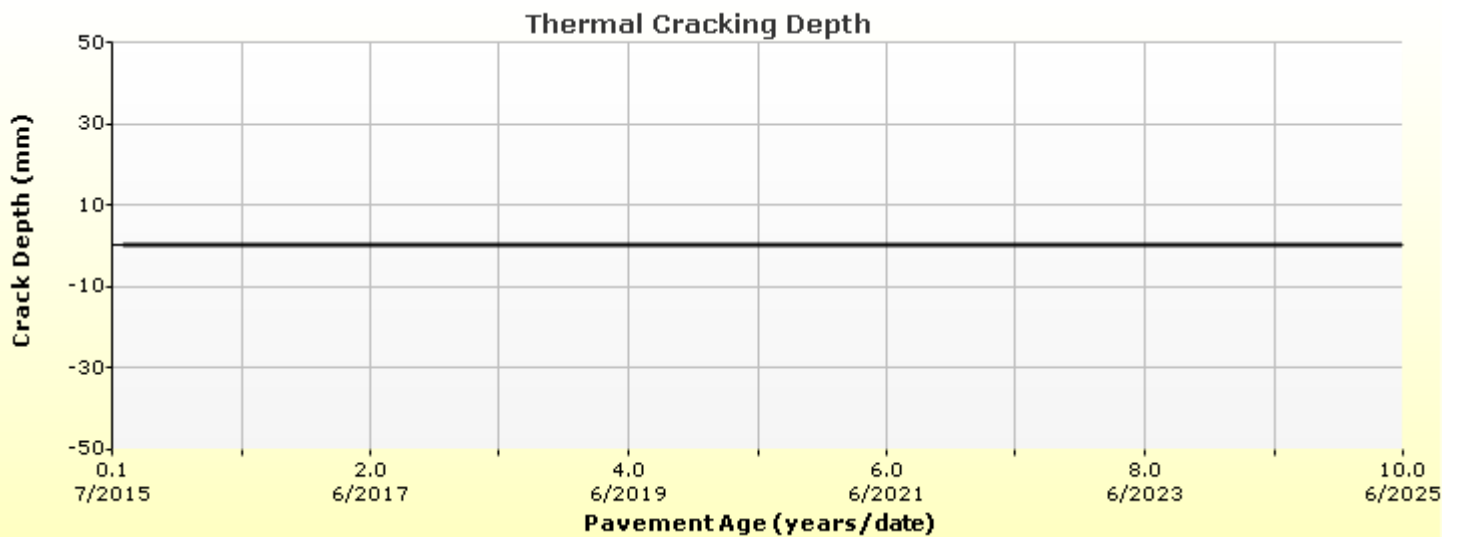
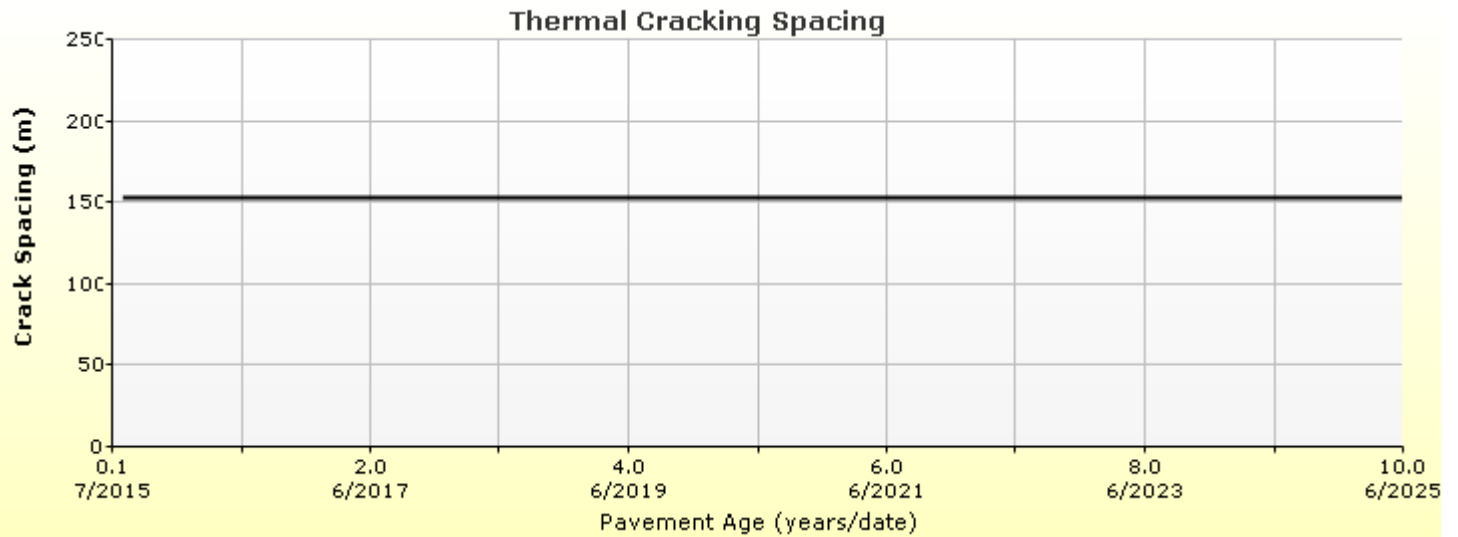
Thermal Cracking: Total Length vs. Time

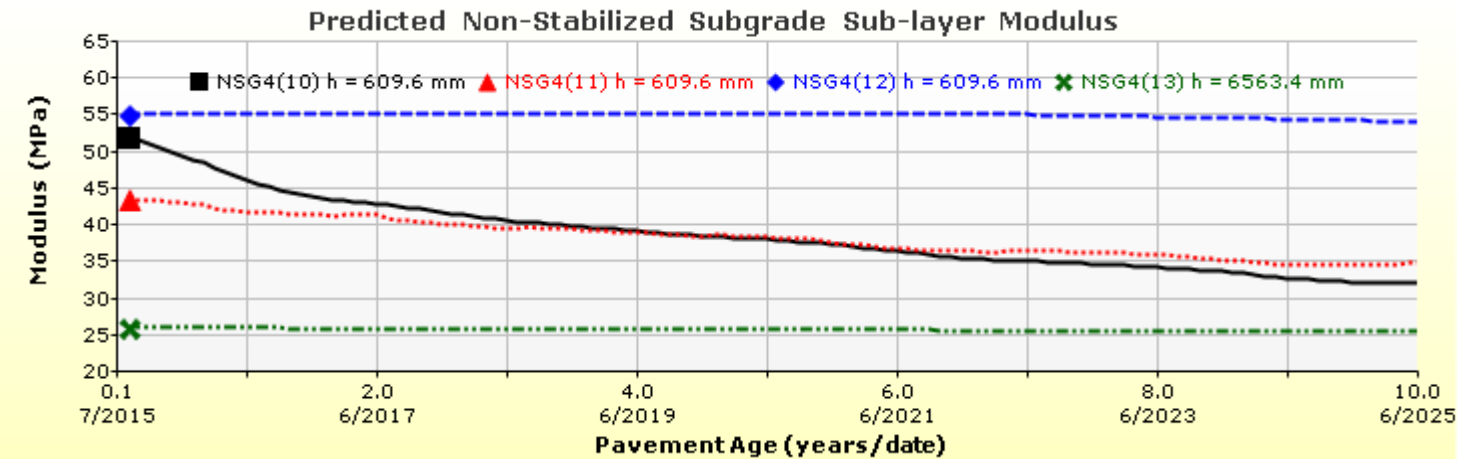
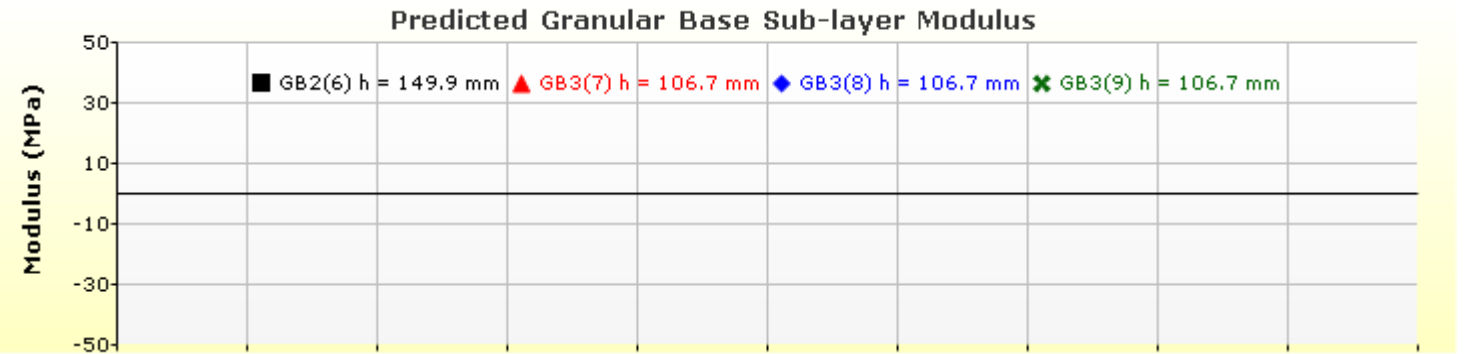
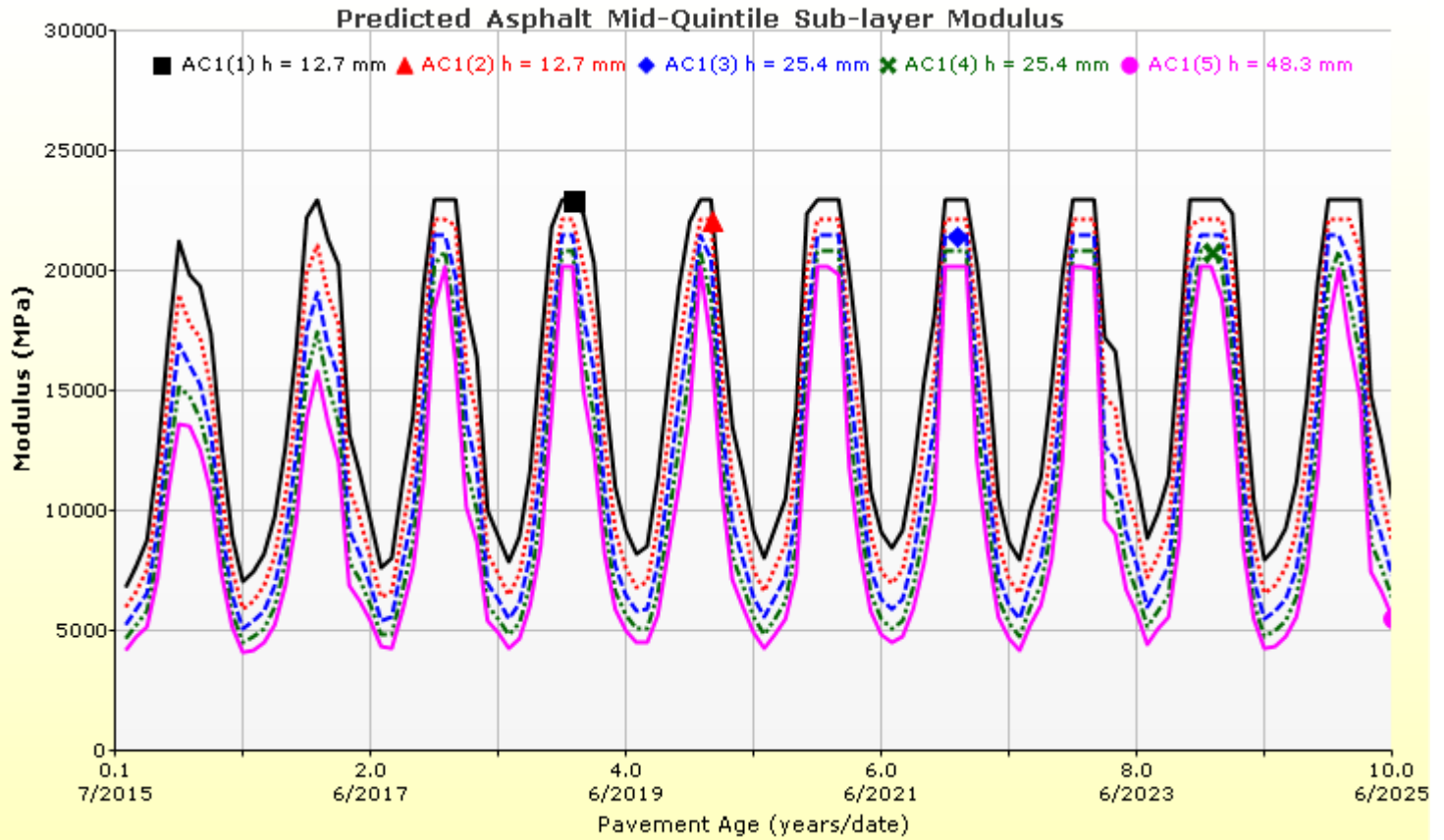




Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

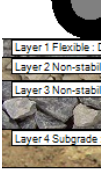
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)	Volumetric at Construction:	
Flexible	Default asphalt concrete	125.0	Effective binder content (%)	11.6
NonStabilized	Crushed stone	150.0	Air voids (%)	7.0
NonStabilized	Crushed stone	320.0		
Subgrade	A-5	Semi-infinite		

Traffic

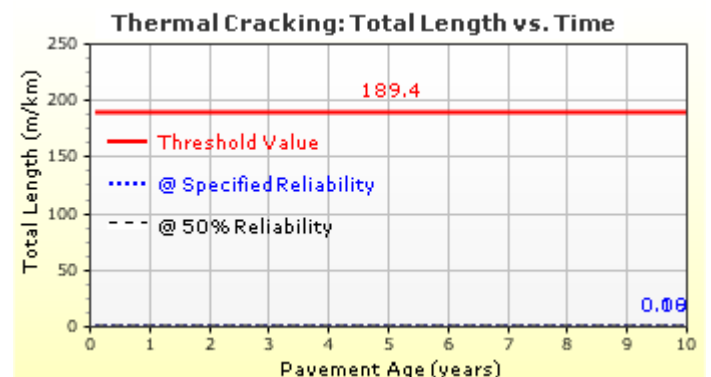
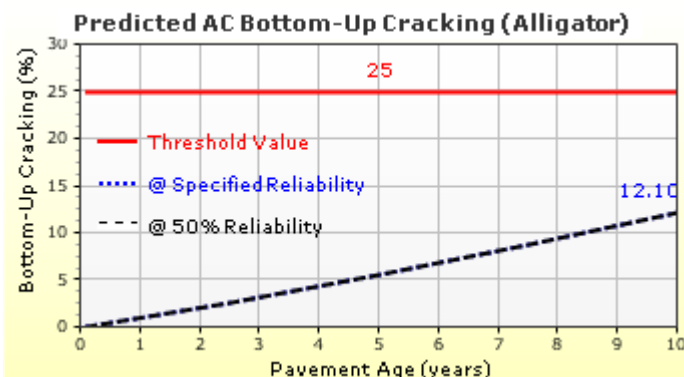
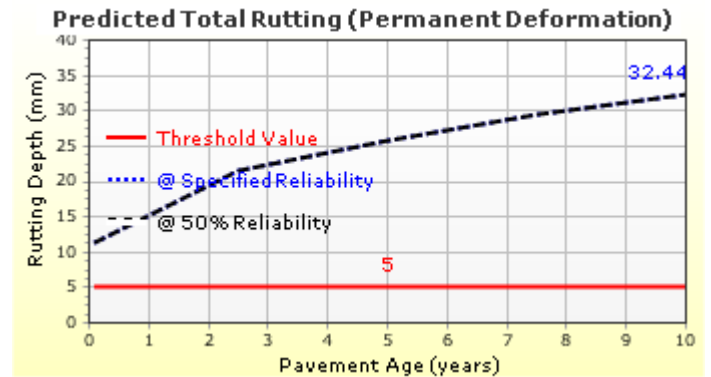
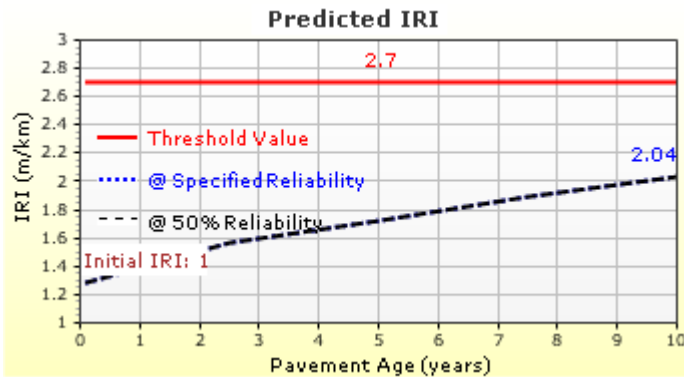
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.04	50.00	88.43	Pass
Permanent deformation - total pavement (mm)	5.00	32.44	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	12.10	50.00	81.94	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	10.97	50.00	92.12	Pass
Permanent deformation - AC only (mm)	5.00	17.74	50.00	0.28	Fail

Distress Charts

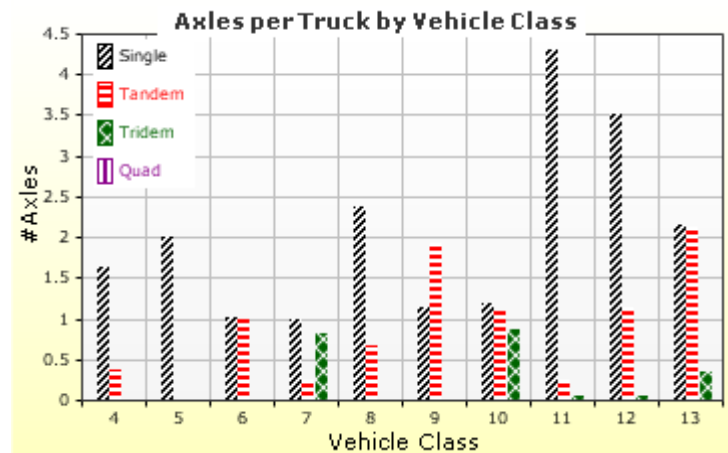
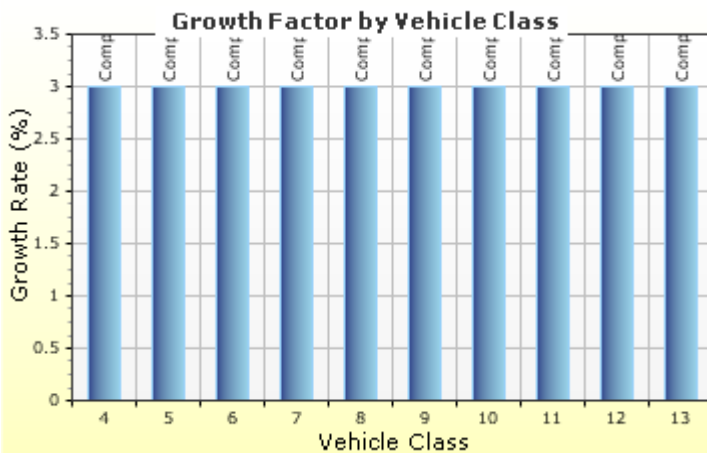
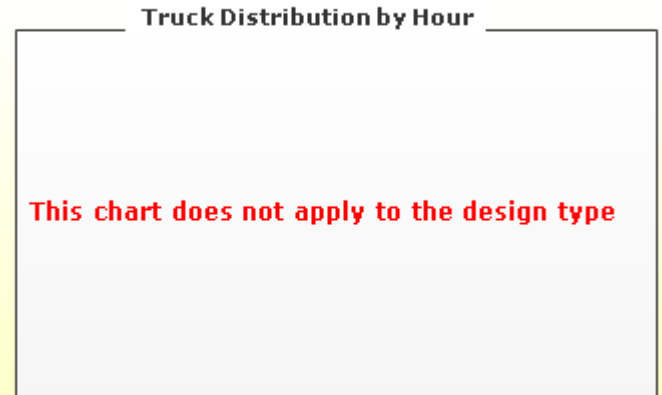
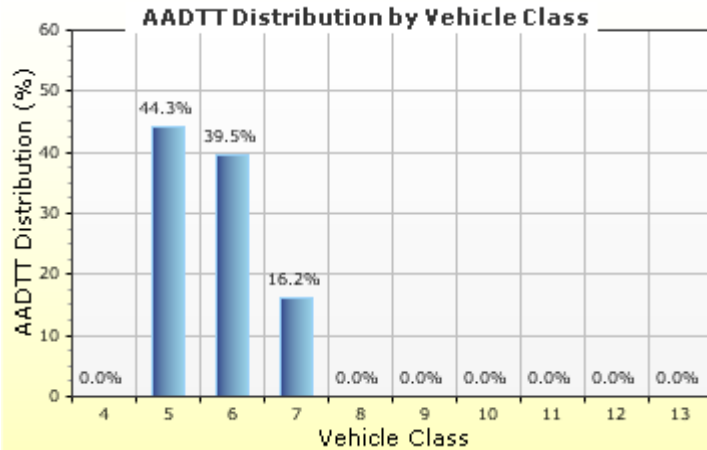


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

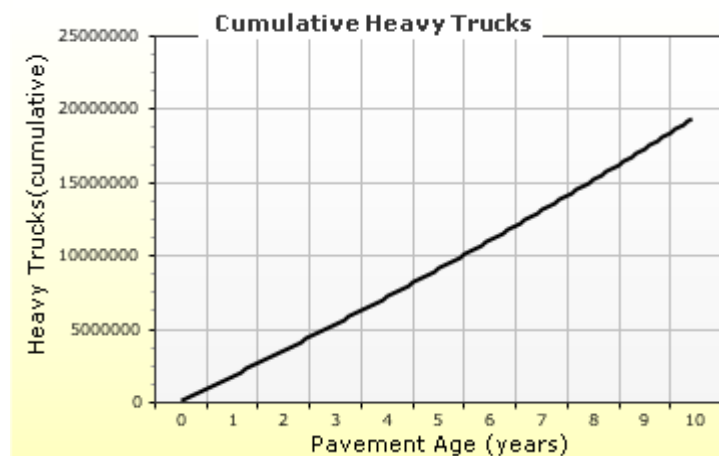
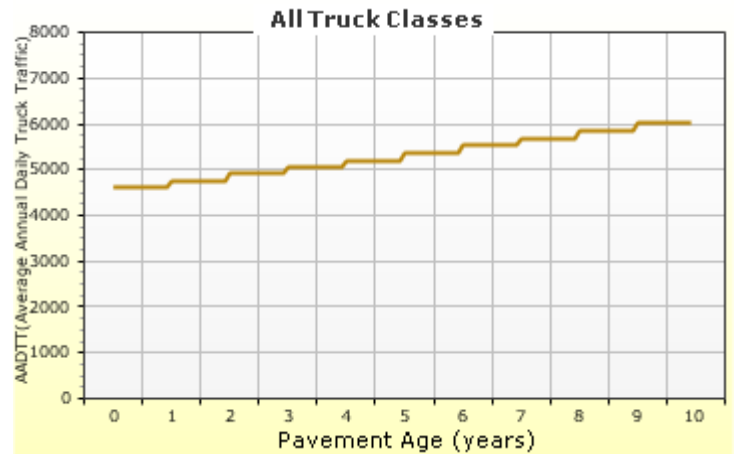
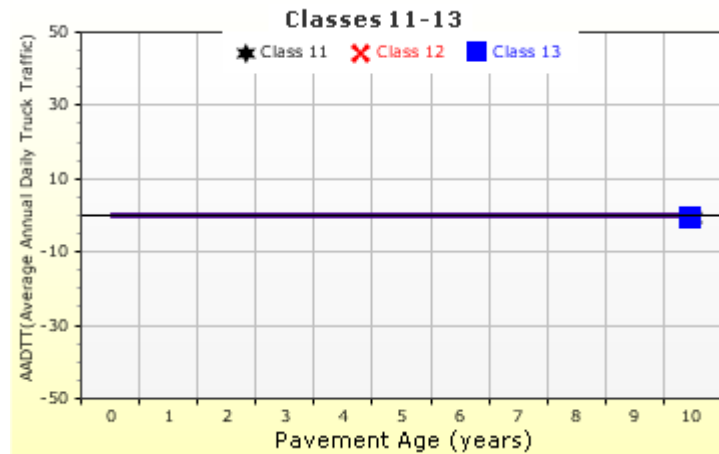
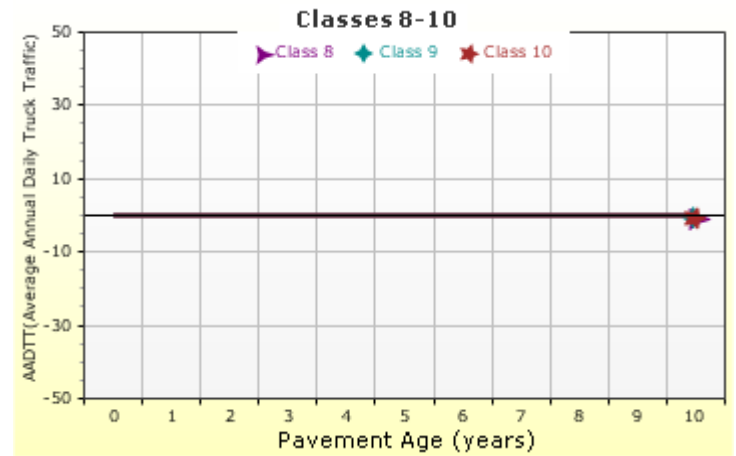
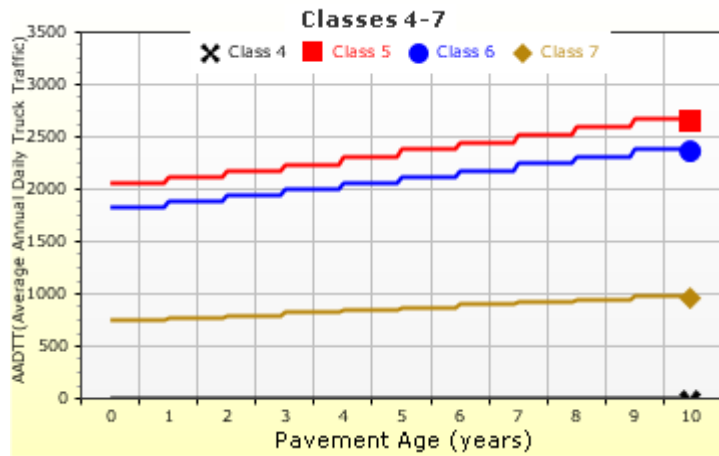
Wheelbase does not apply

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



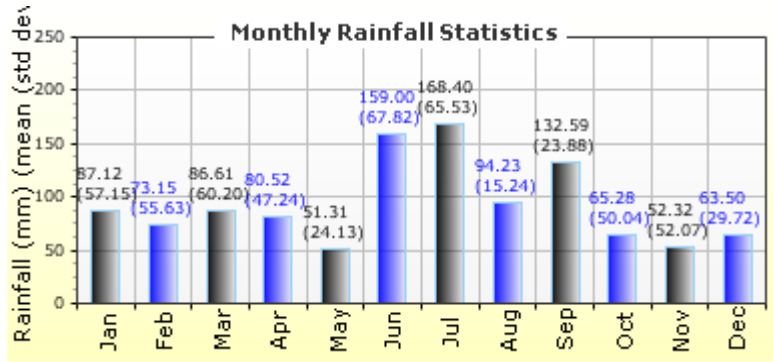
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

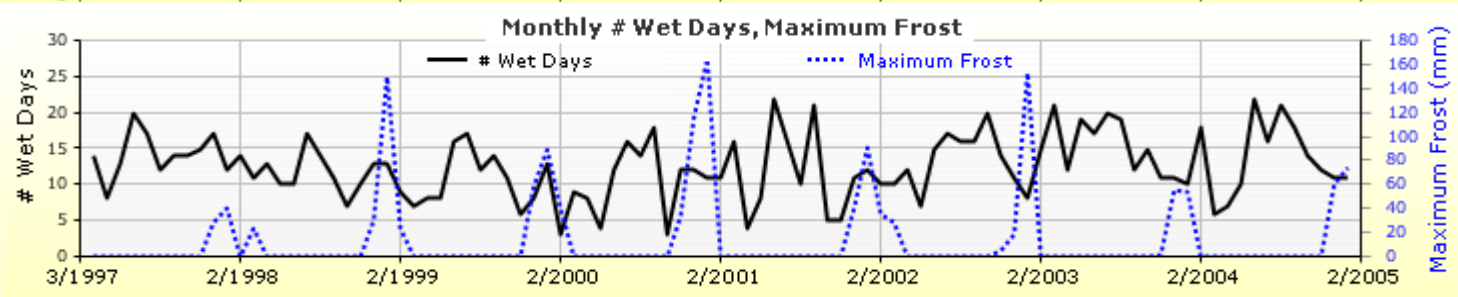
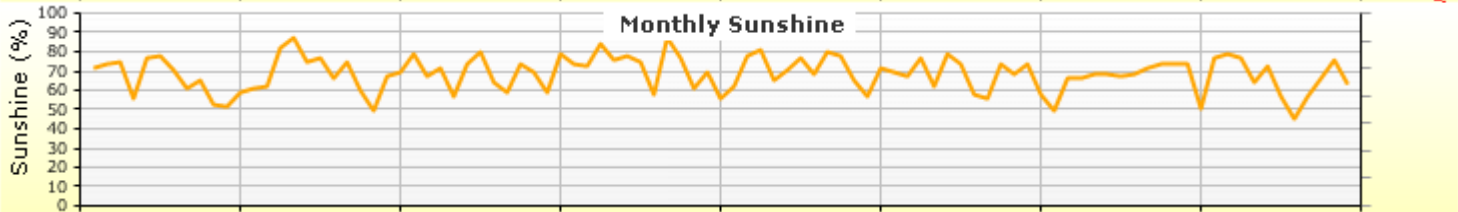
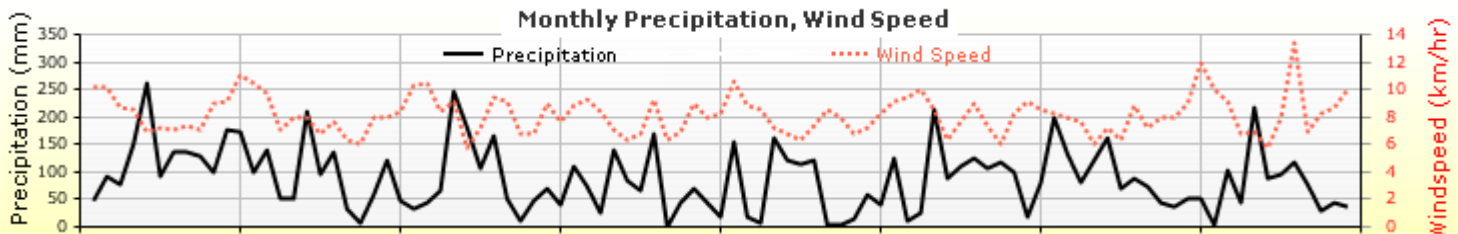
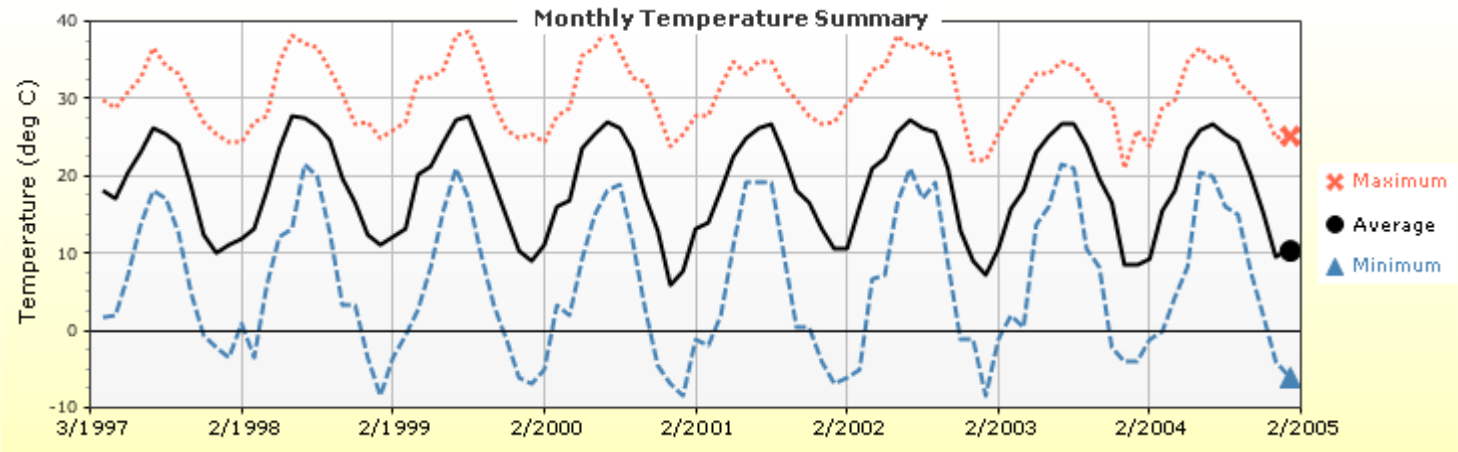
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

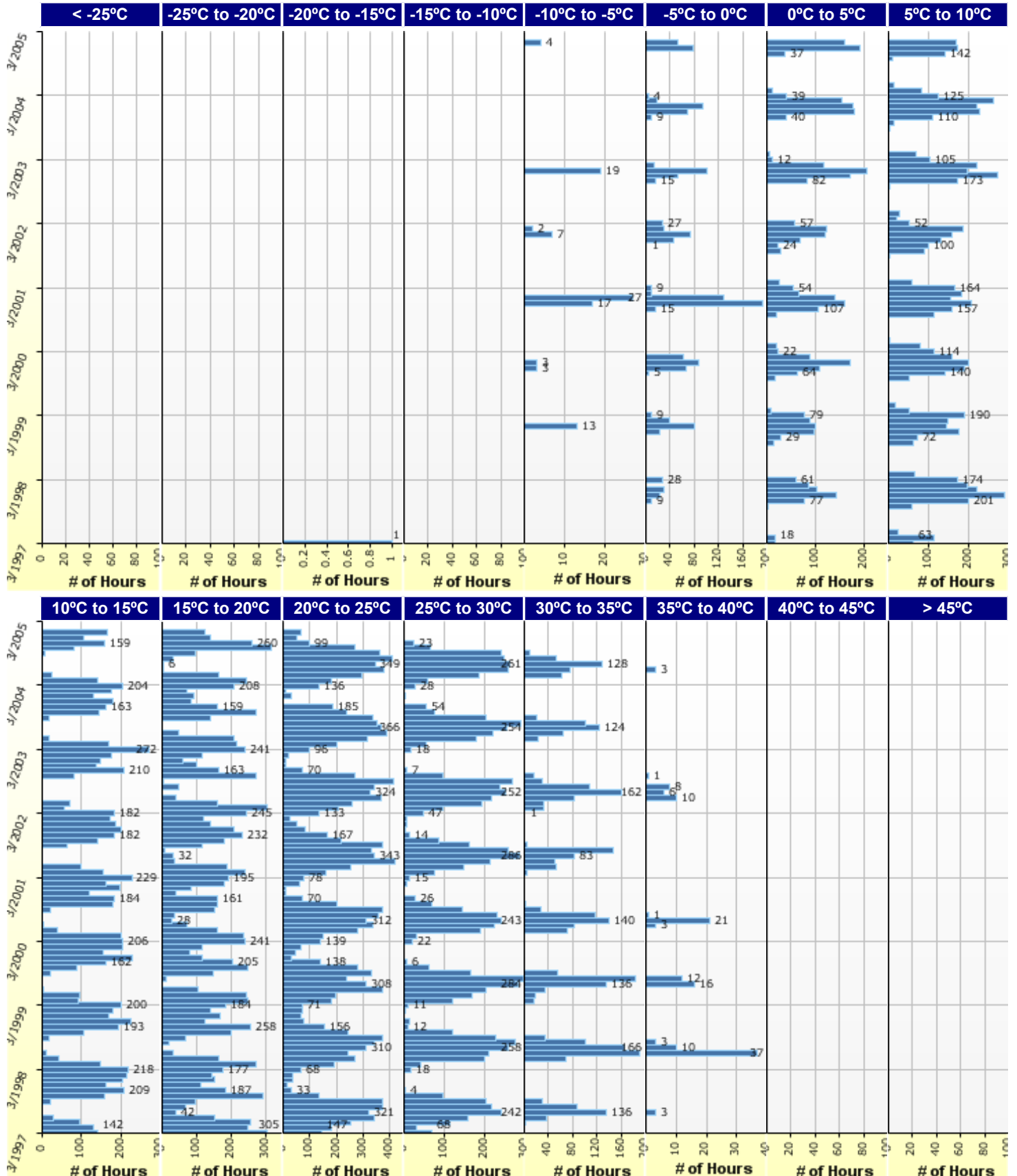


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF2_ALT1

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF2_ALT1.dgpx



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

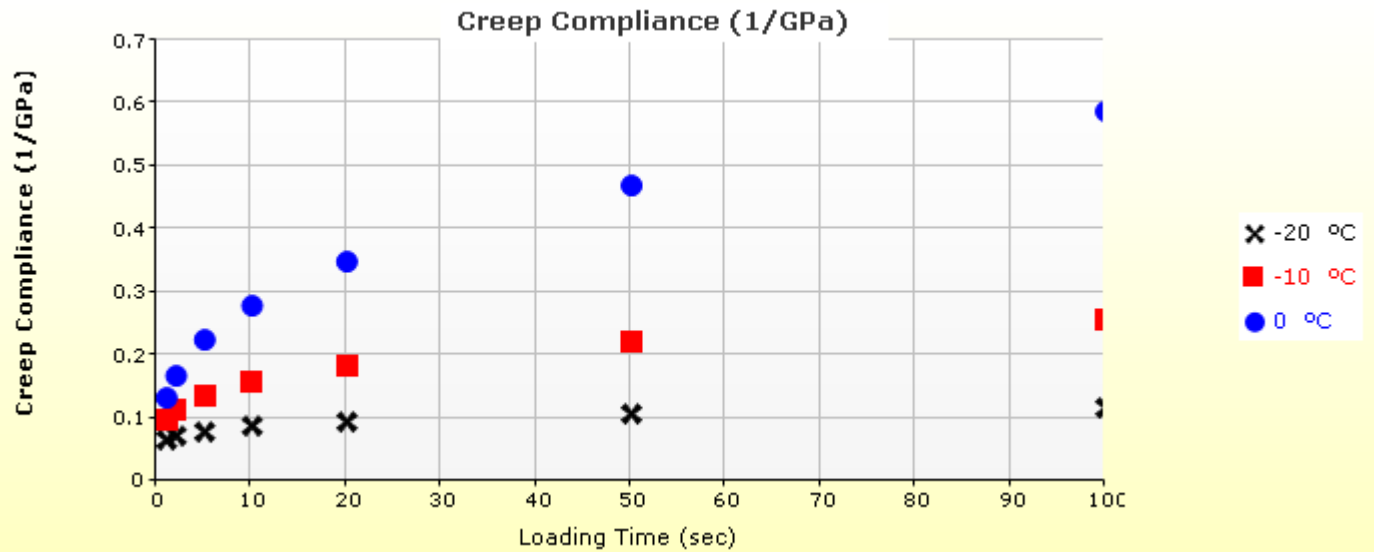
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

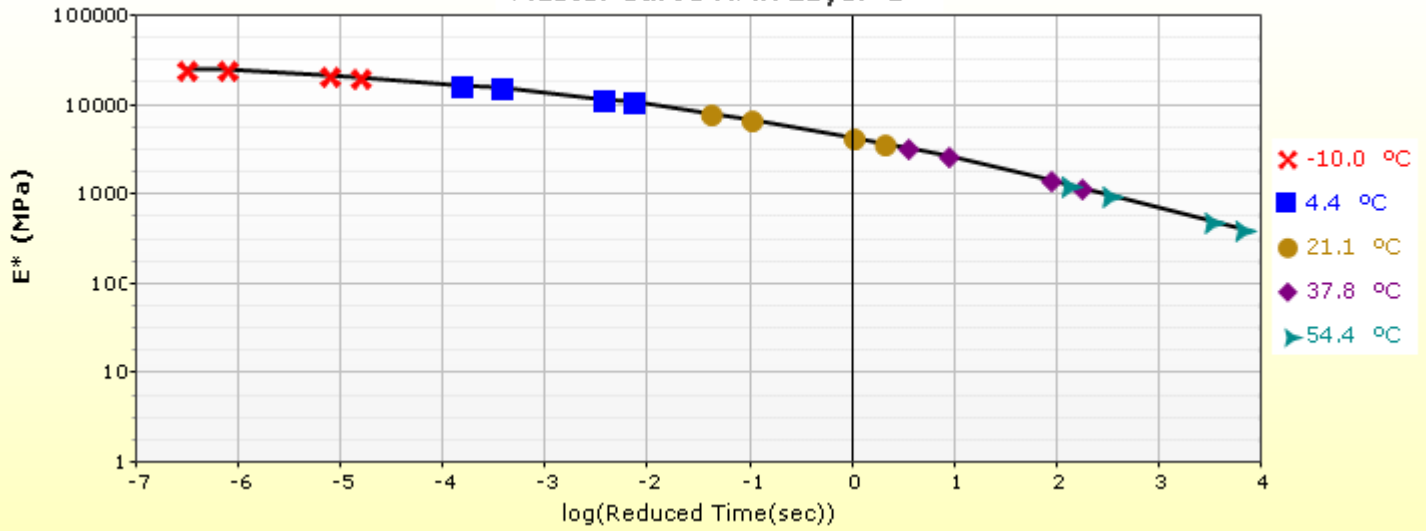
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

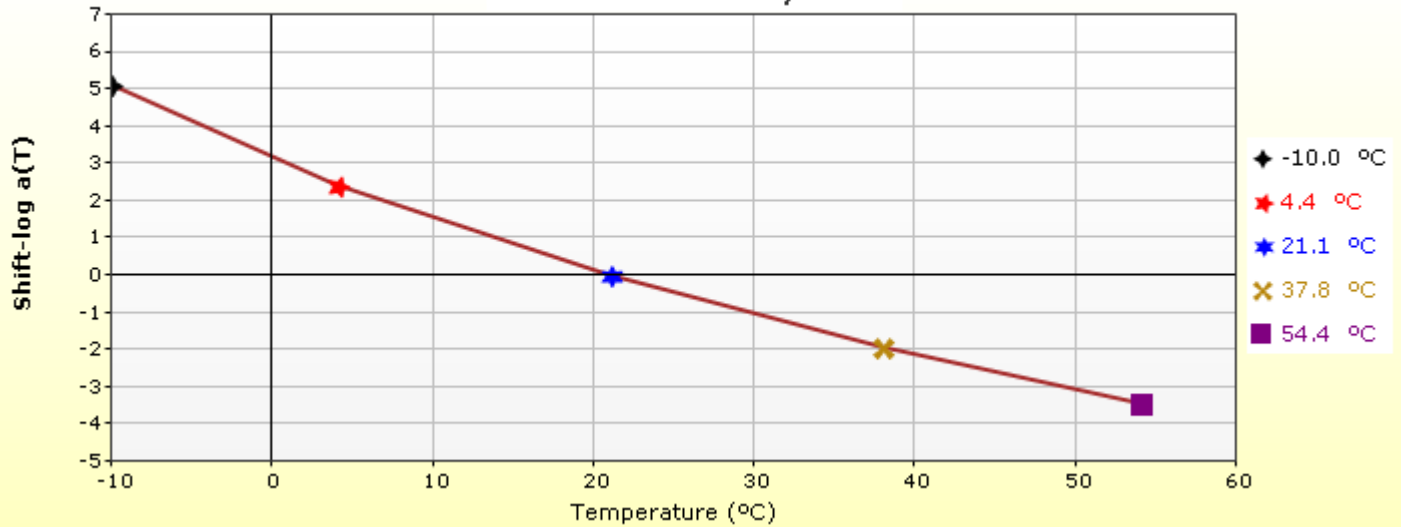


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

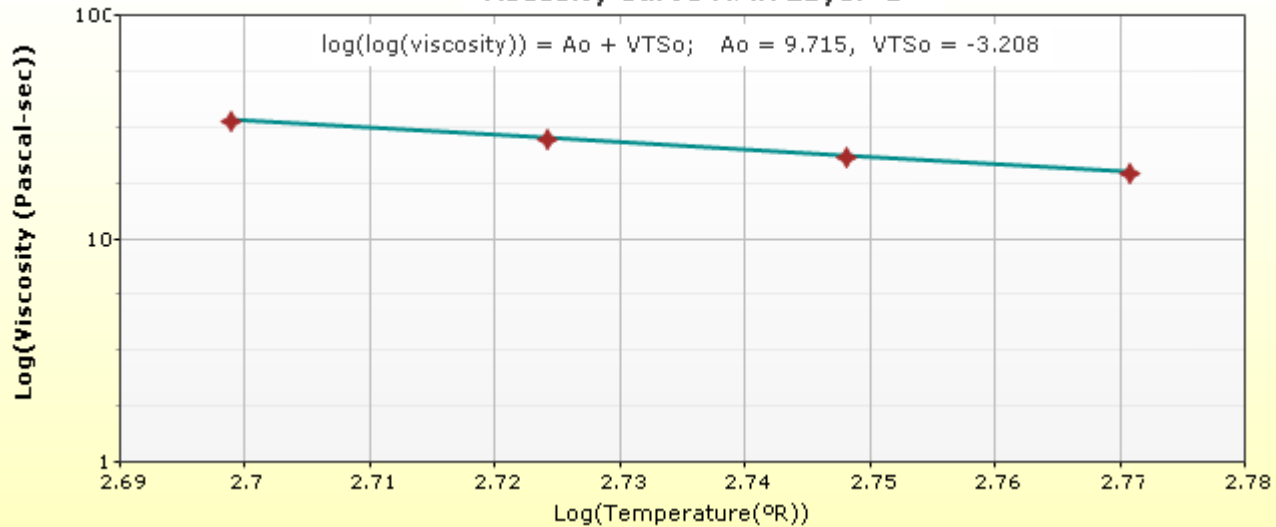
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

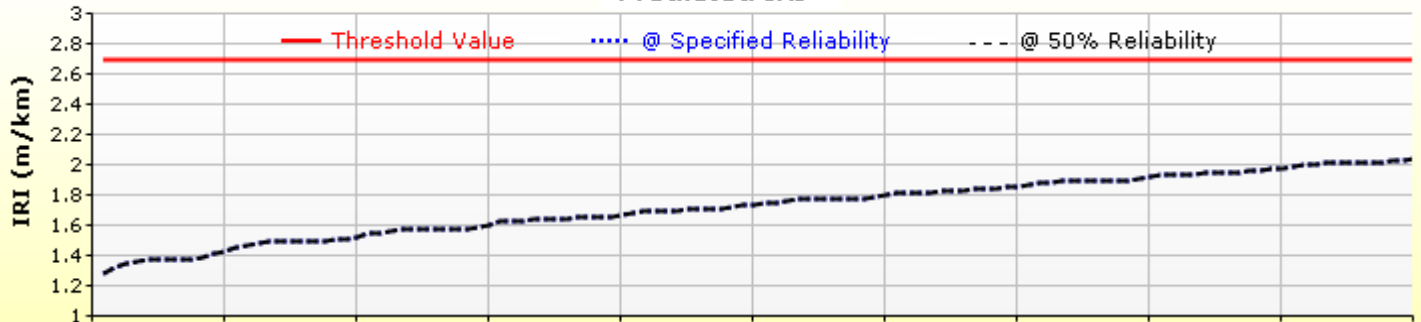


Viscosity Curve HMA Layer 1

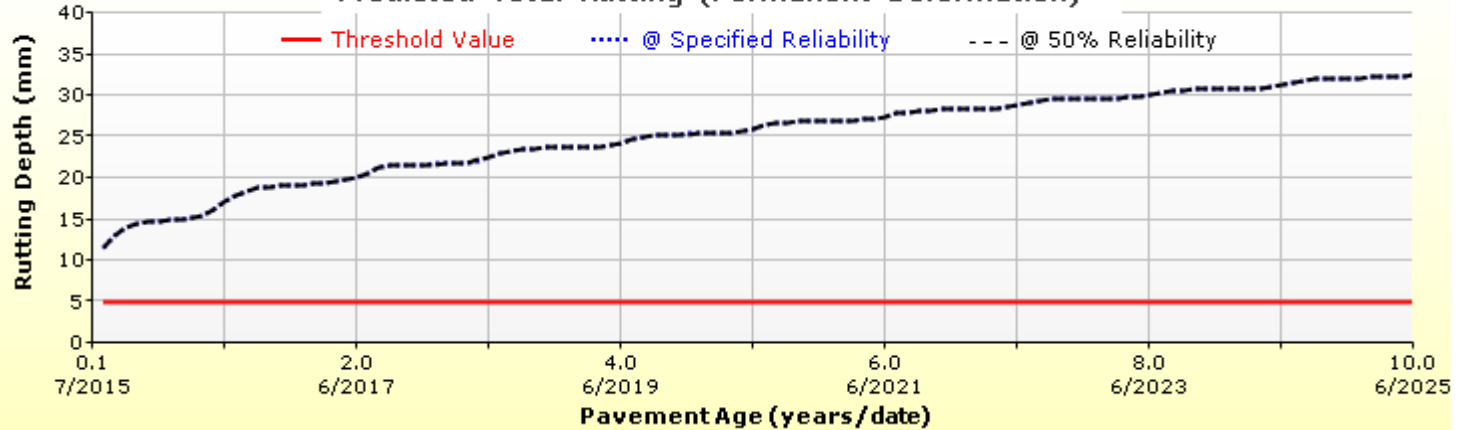


Analysis Output Charts

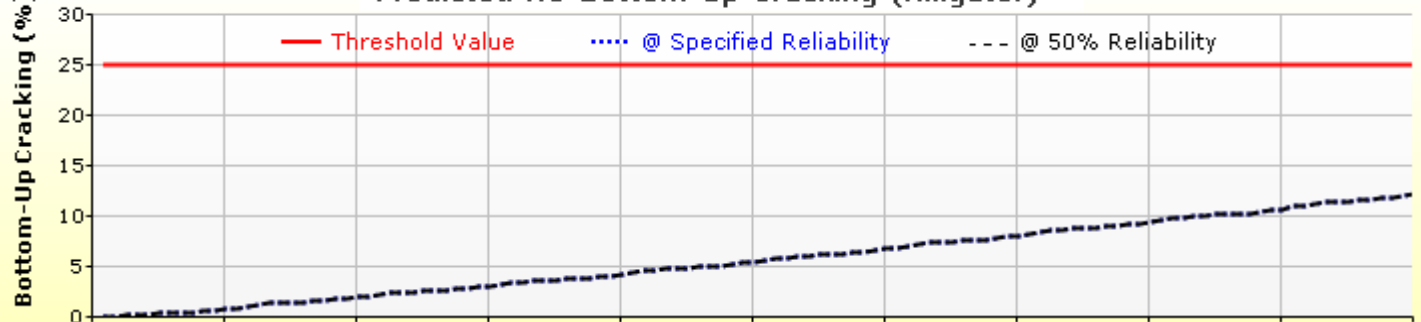
Predicted IRI



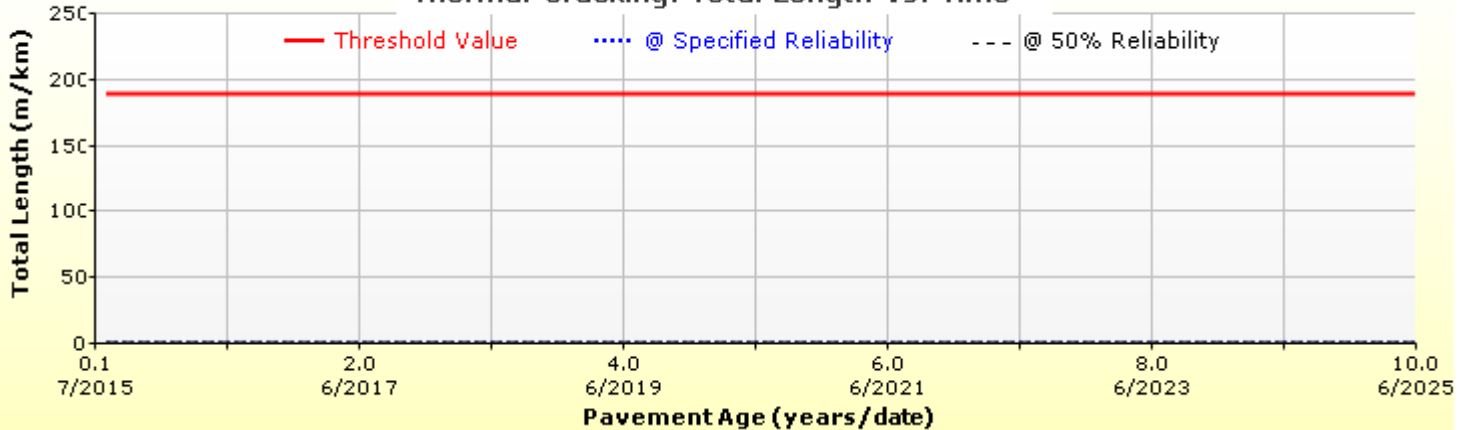
Predicted Total Rutting (Permanent Deformation)

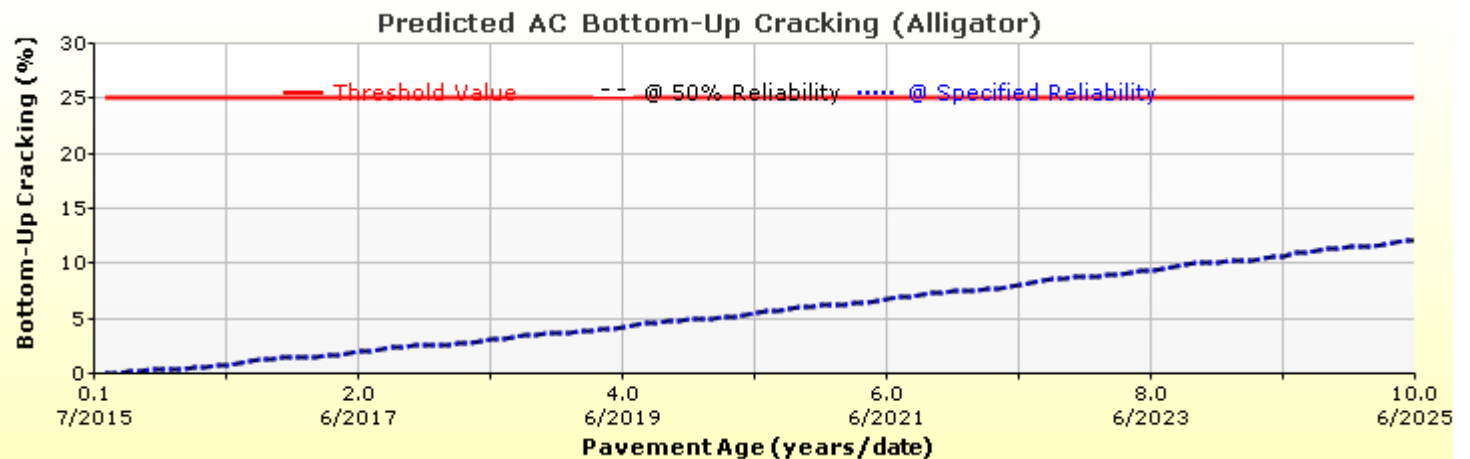
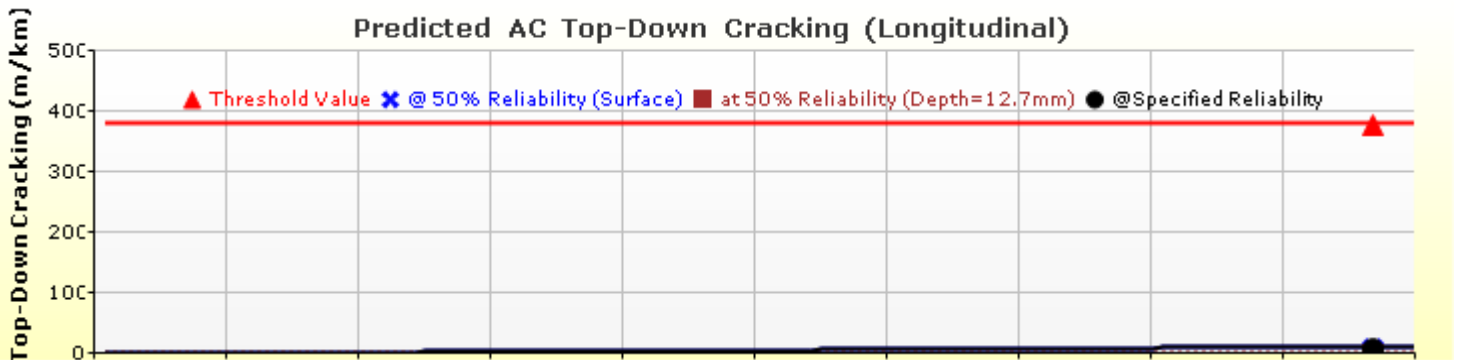
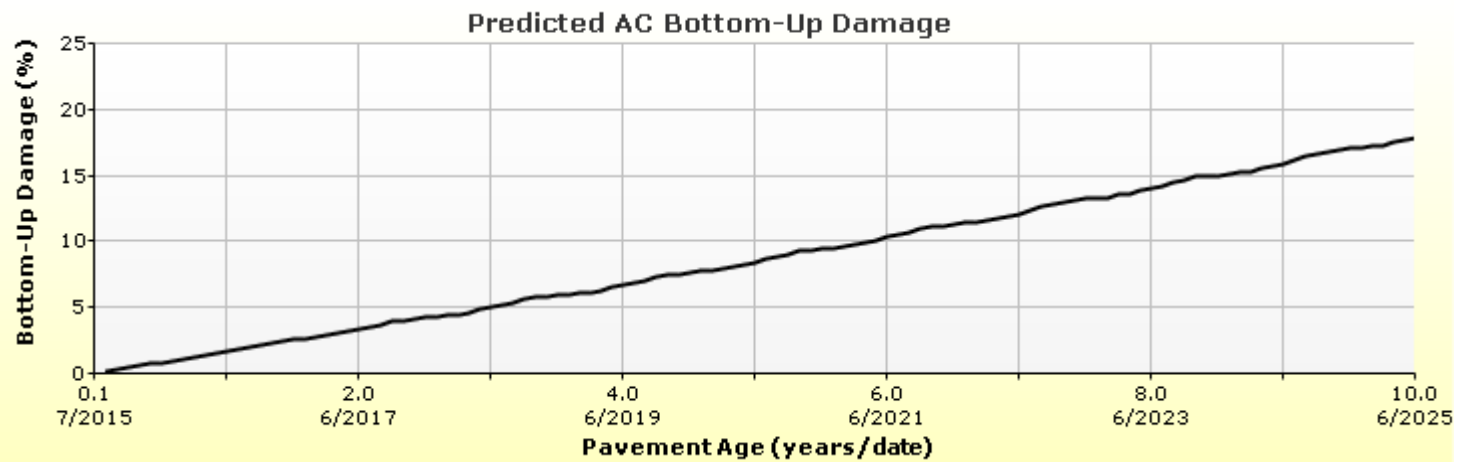
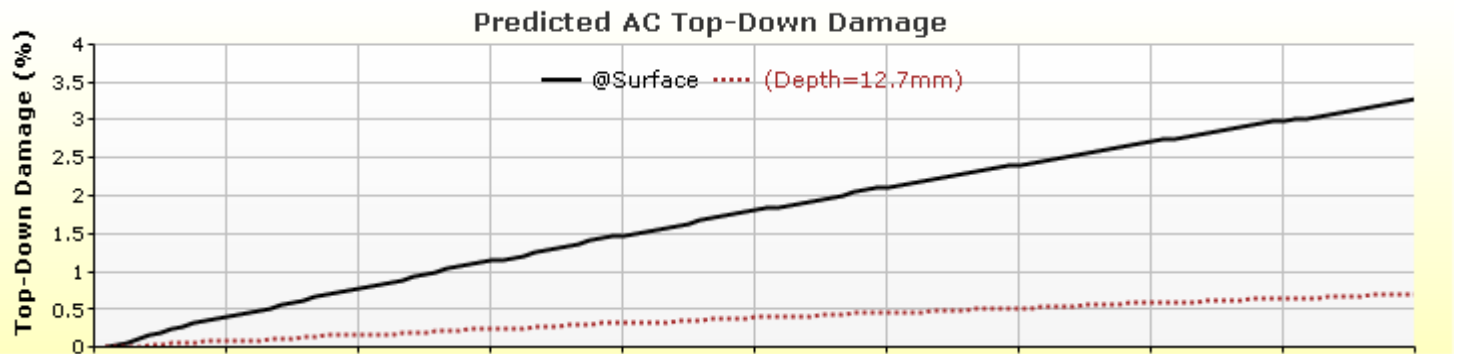


Predicted AC Bottom-Up Cracking (Alligator)

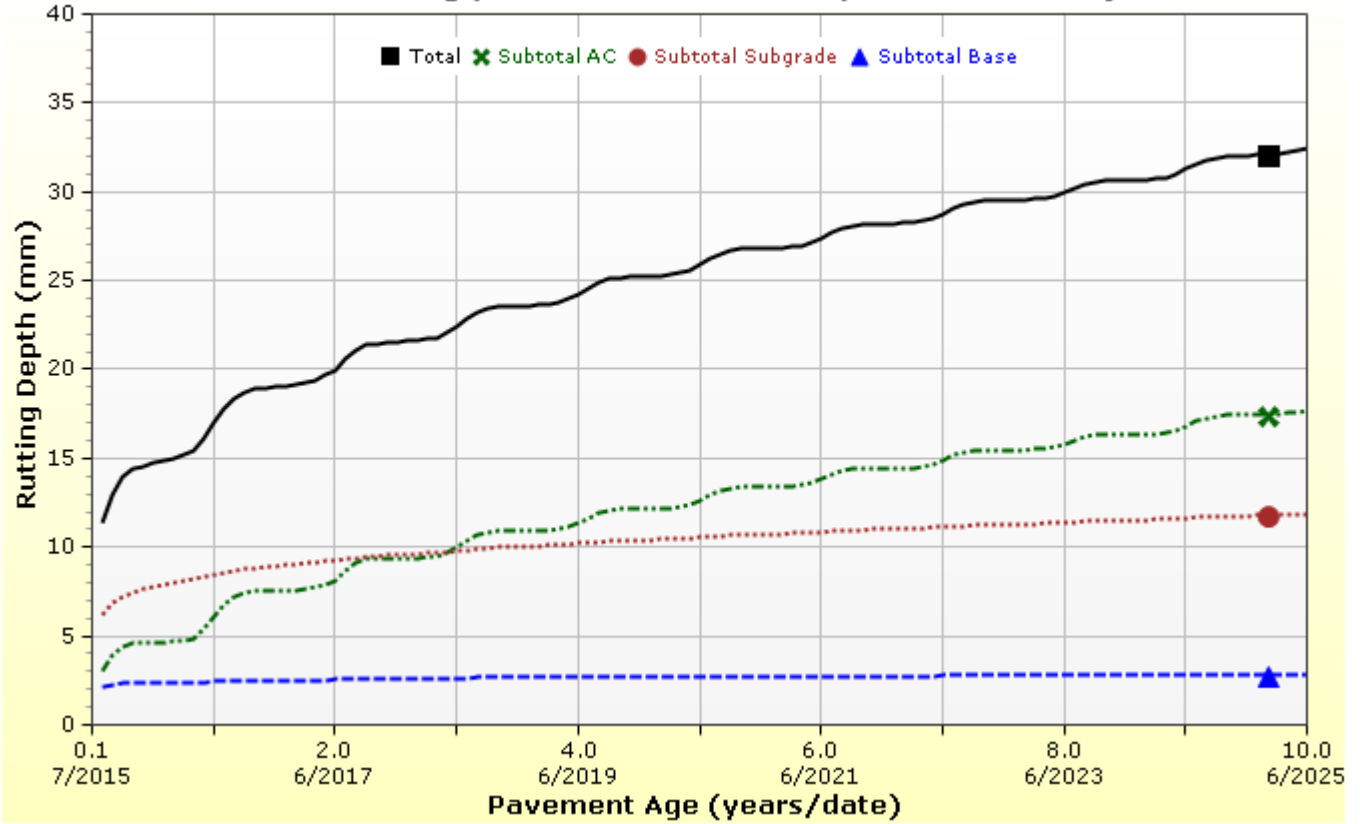


Thermal Cracking: Total Length vs. Time

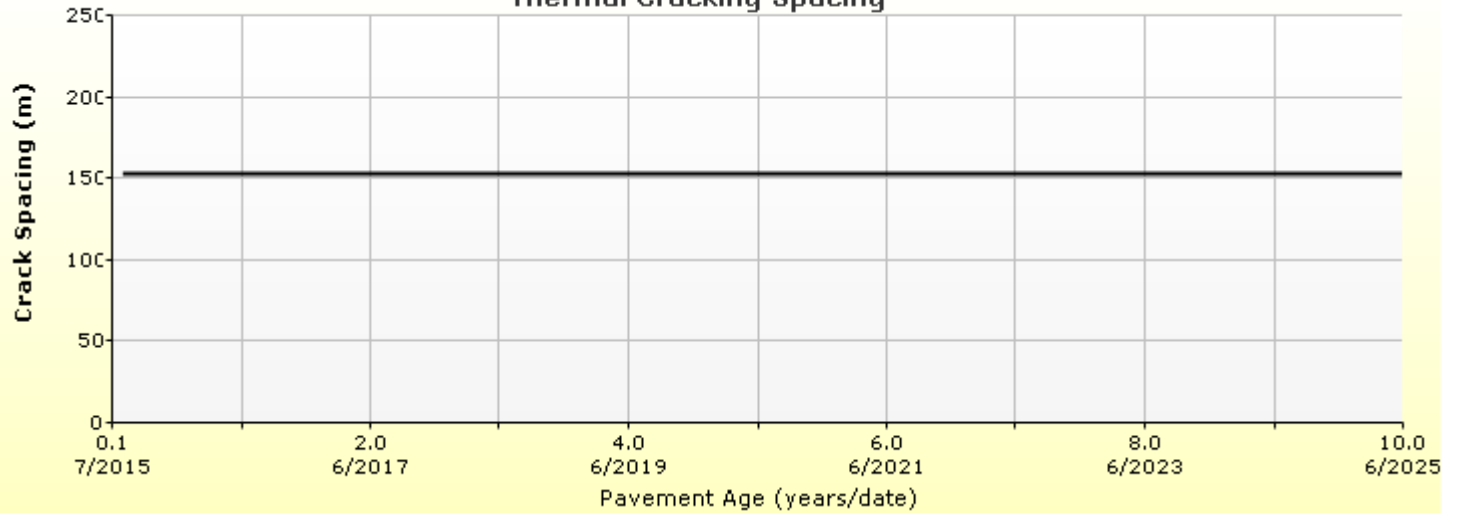




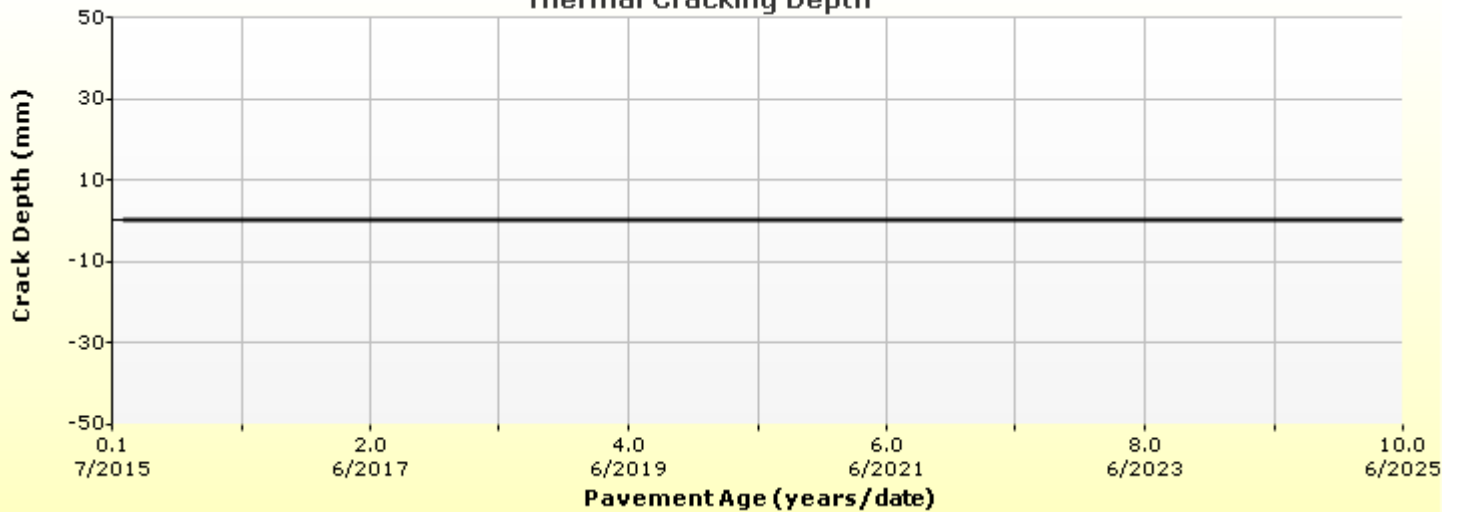
Predicted Rutting (Permanent Deformation) at 50% Reliability

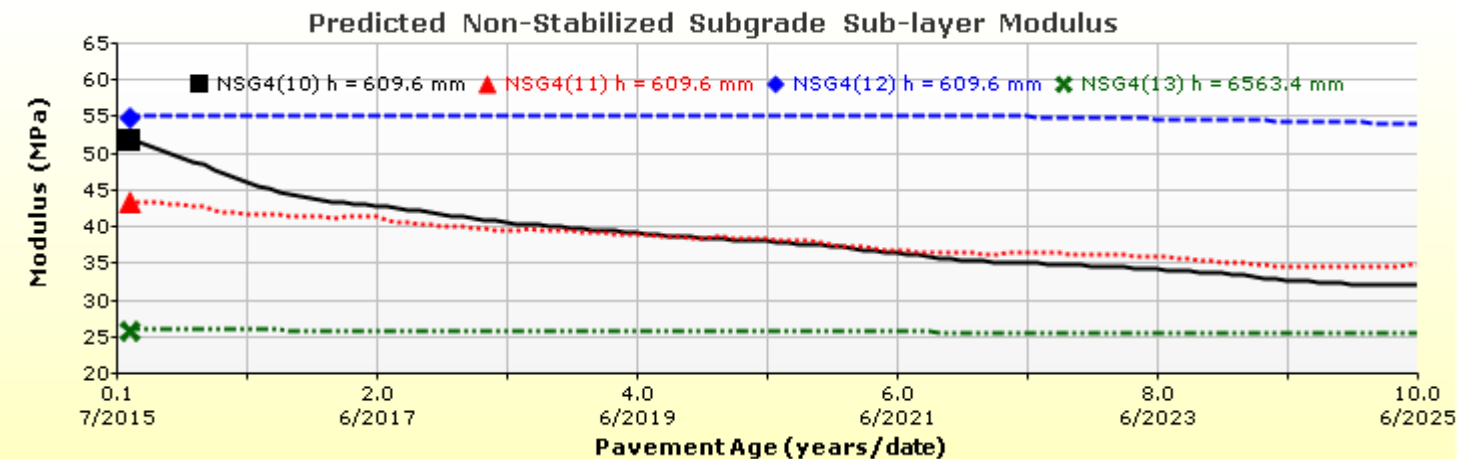
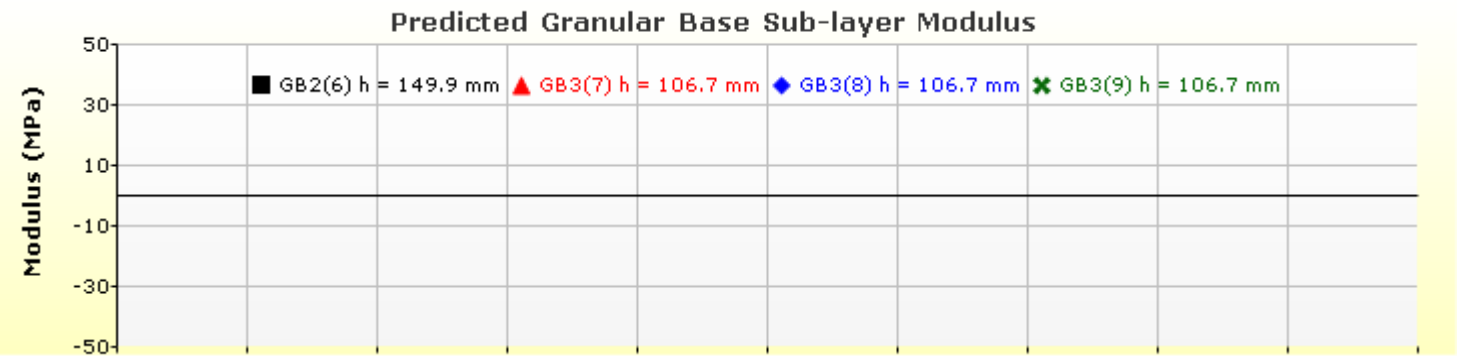
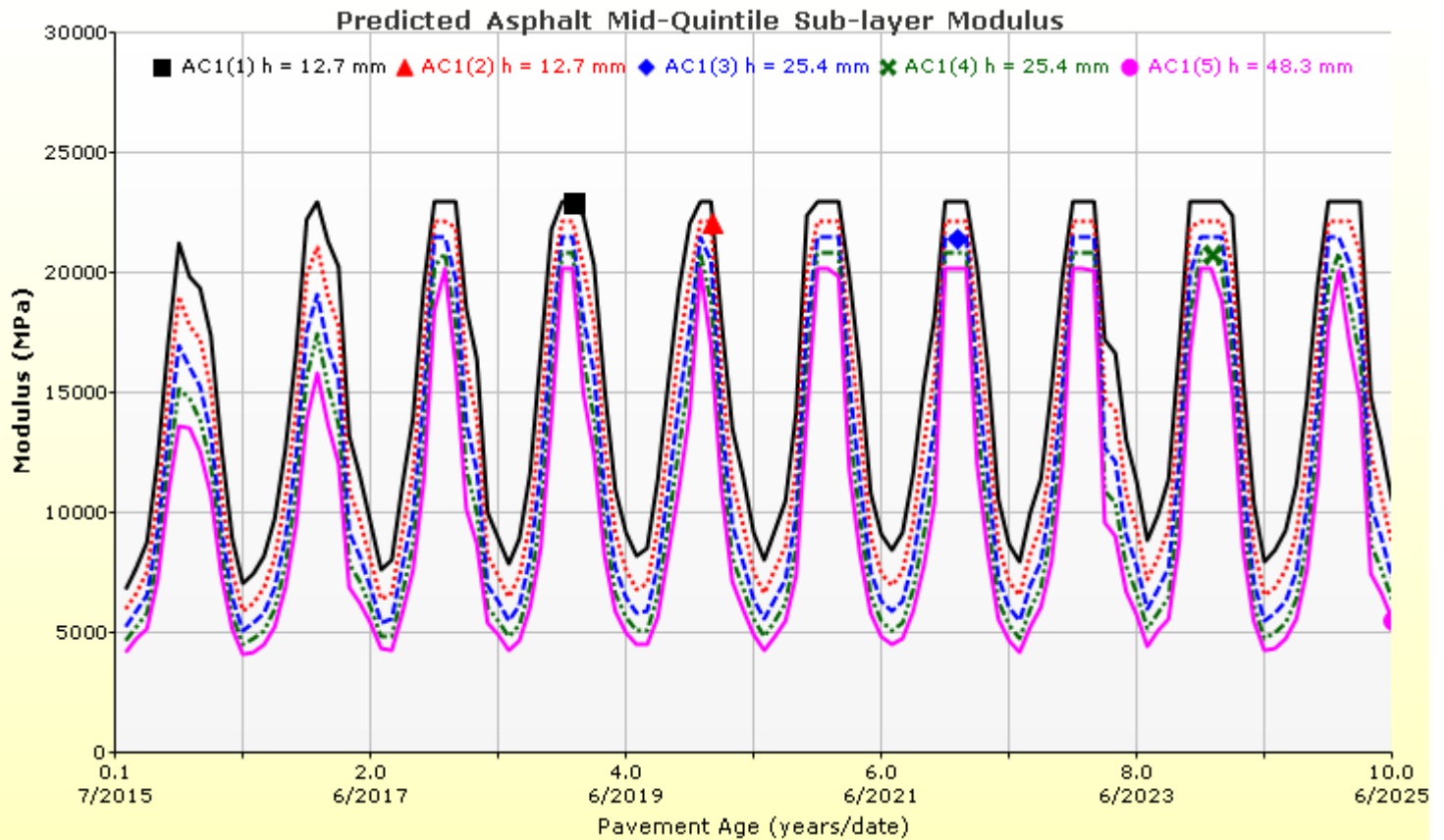


Thermal Cracking Spacing



Thermal Cracking Depth





Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
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 $		δ_a = permanent deformation for the layer N = number of repetitions ε_v = average vertical strain(in/in) $\varepsilon_0, \beta, \rho$ = material properties ε_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		AC Bottom Up Cracking	
$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * \log_{10}(Damage))}} \right) * 10.56$		$FC = \left(\frac{6000}{1 + e^{(C_1 * C'_1 + C_2 * C'_2 * \log_{10}(D * 100))}} \right) * \left(\frac{1}{60} \right)$ $C'_2 = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$ $C'_1 = -2 * C'_2$	
c1: 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 Cracking Bottom Standard Deviation 1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))	

CSM Cracking		IRI Flexible Pavements	
$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$		C1 - Rutting C3 - Transverse Crack C2 - Fatigue Crack C4 - Site Factors	
C1: 1	C2: 1	C3: 0	C4: 1000
CSM Standard Deviation CTB*1		C1: 40	C2: 0.4
		C3: 0.008	C4: 0.015

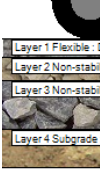
Design Inputs

Design Life: **10 years**
Design Type: **Flexible Pavement**

Base construction: **March, 2015**
Pavement construction: **June, 2015**
Traffic opening: **July, 2015**

Climate Data **32.119, -81.202**
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)	Volumetric at Construction:	
Flexible	Default asphalt concrete	125.0	Effective binder content (%)	11.6
NonStabilized	Crushed stone	150.0	Air voids (%)	7.0
NonStabilized	Crushed stone	320.0		
Subgrade	A-5	Semi-infinite		

Traffic

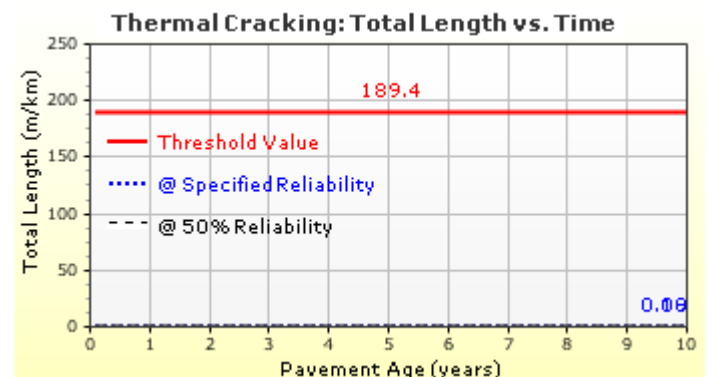
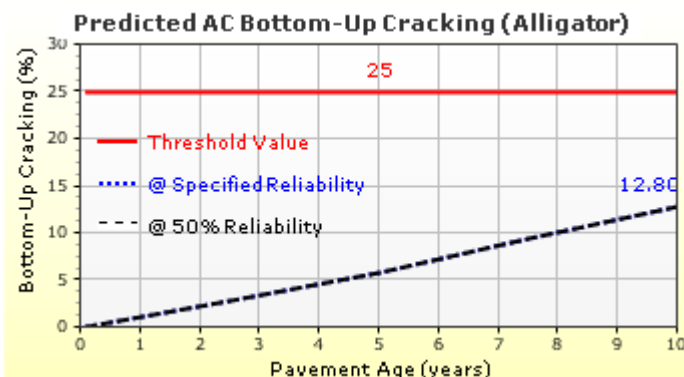
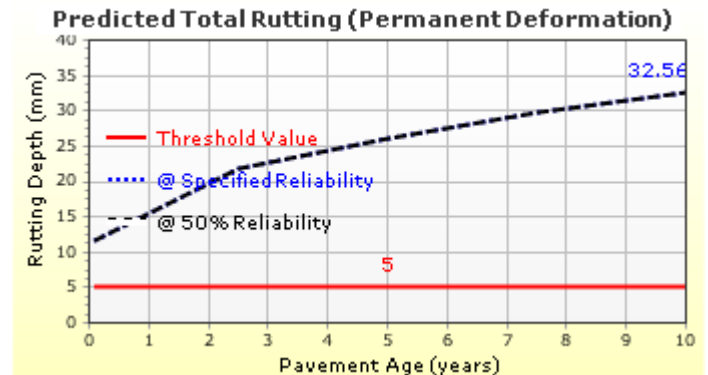
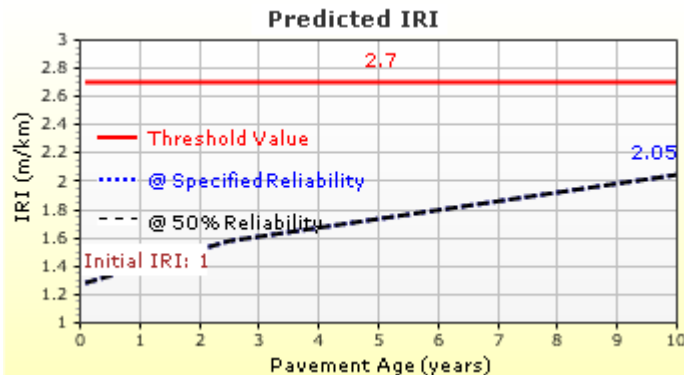
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.05	50.00	88.12	Pass
Permanent deformation - total pavement (mm)	5.00	32.56	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	12.80	50.00	80.60	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	11.08	50.00	92.06	Pass
Permanent deformation - AC only (mm)	5.00	17.24	50.00	0.32	Fail

Distress Charts

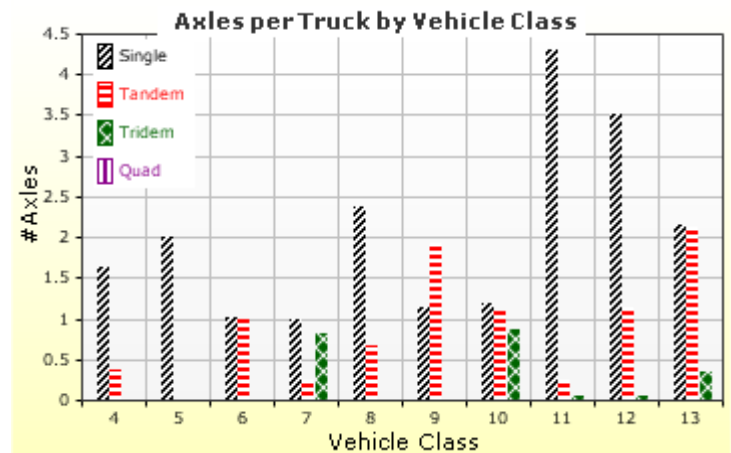
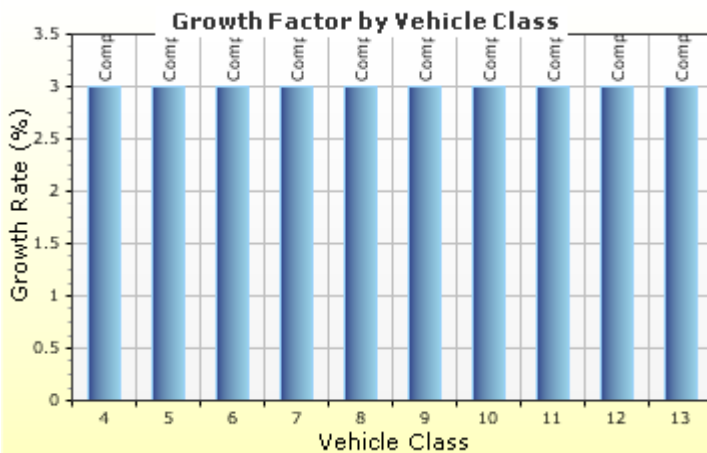
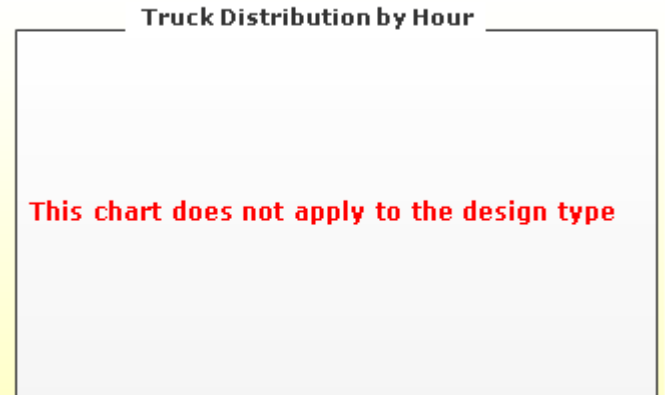
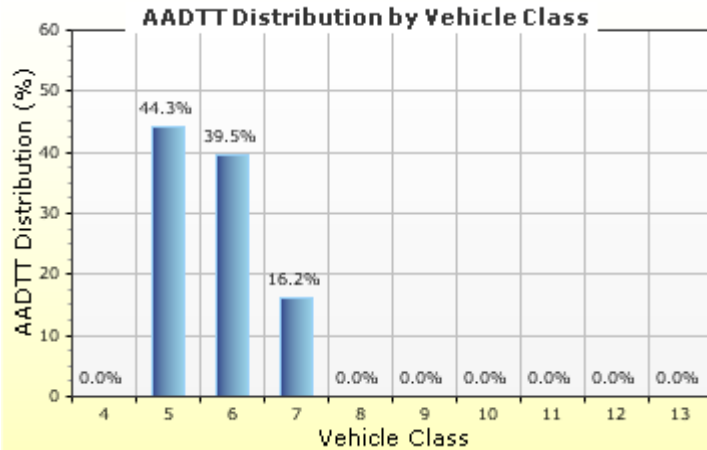


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

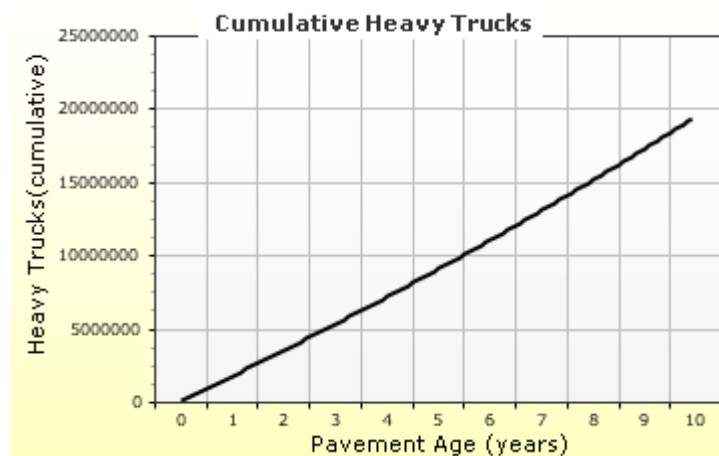
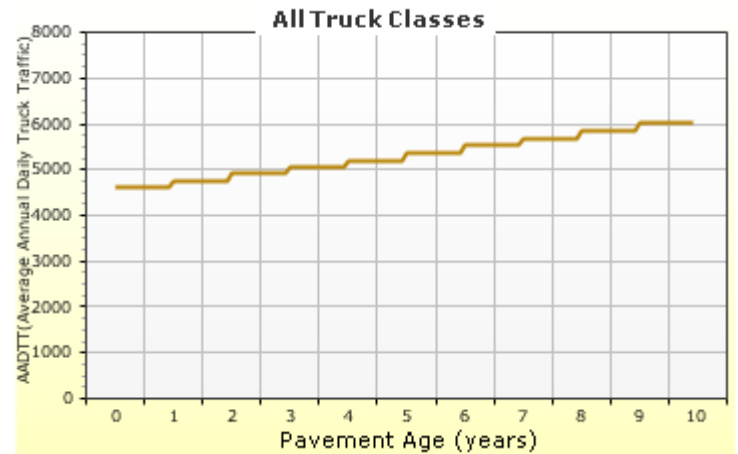
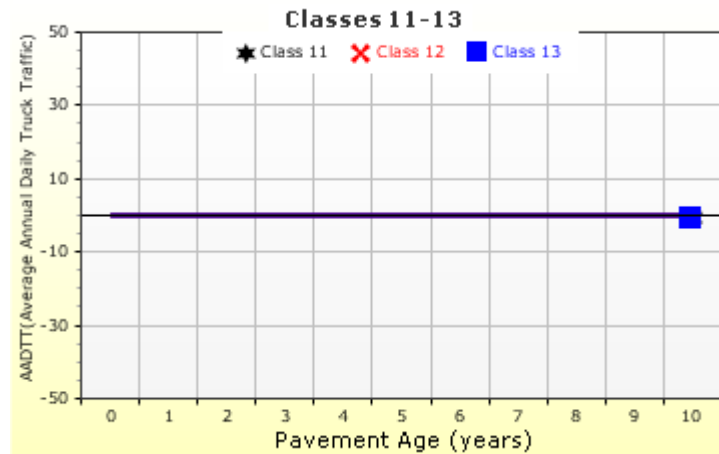
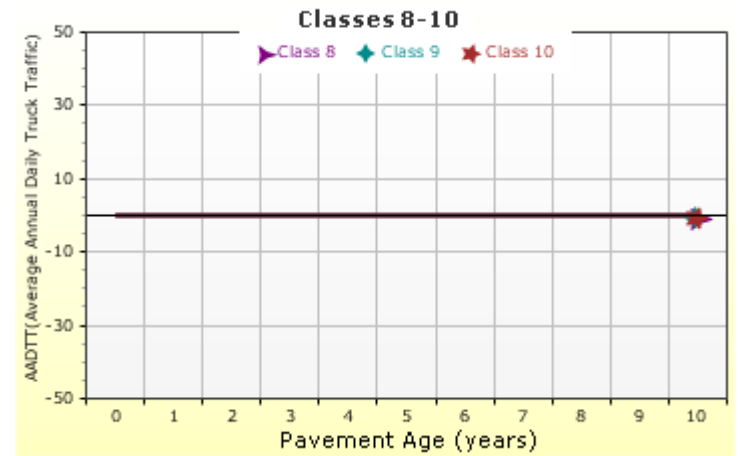
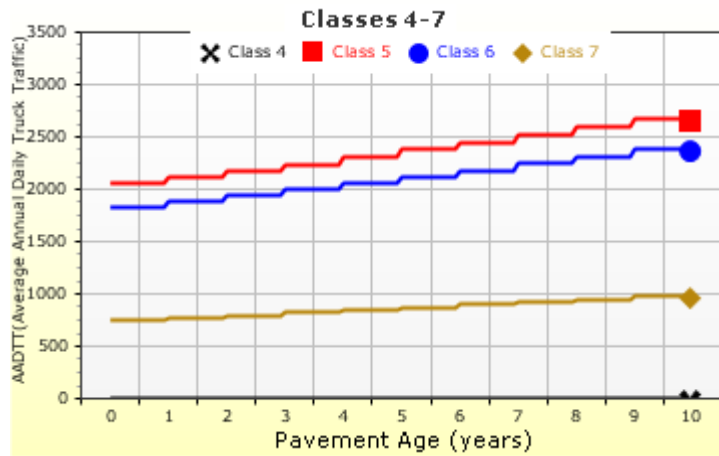
Wheelbase does not apply

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



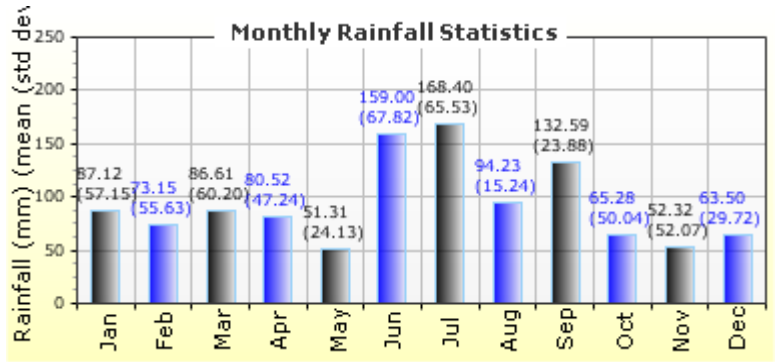
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

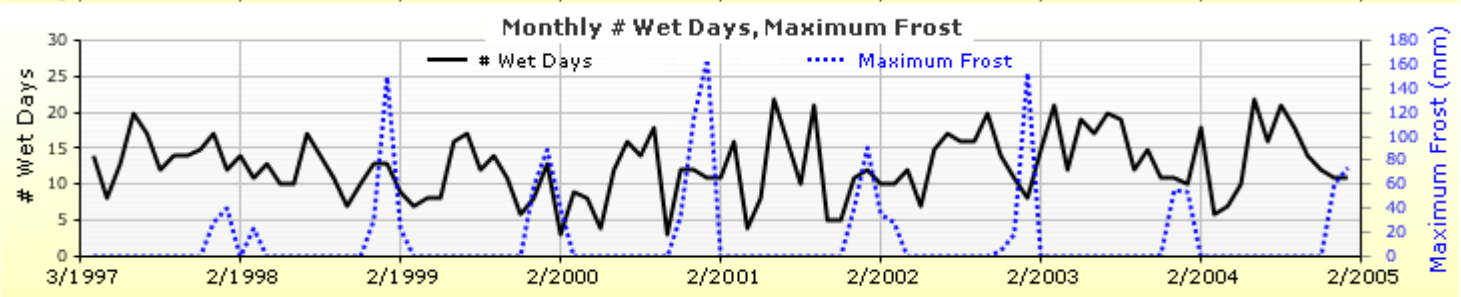
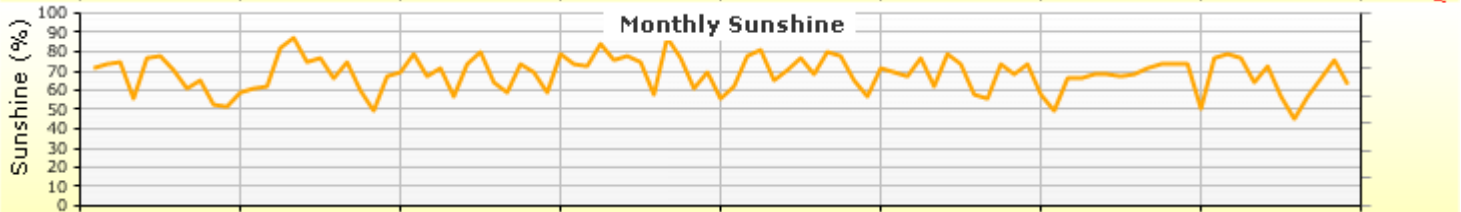
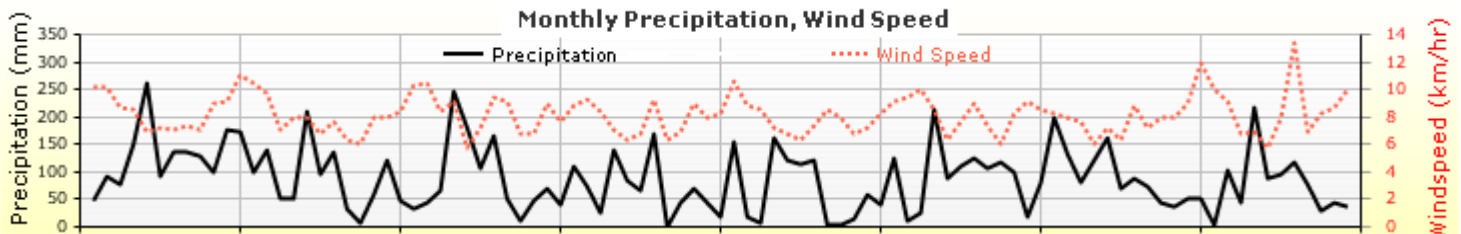
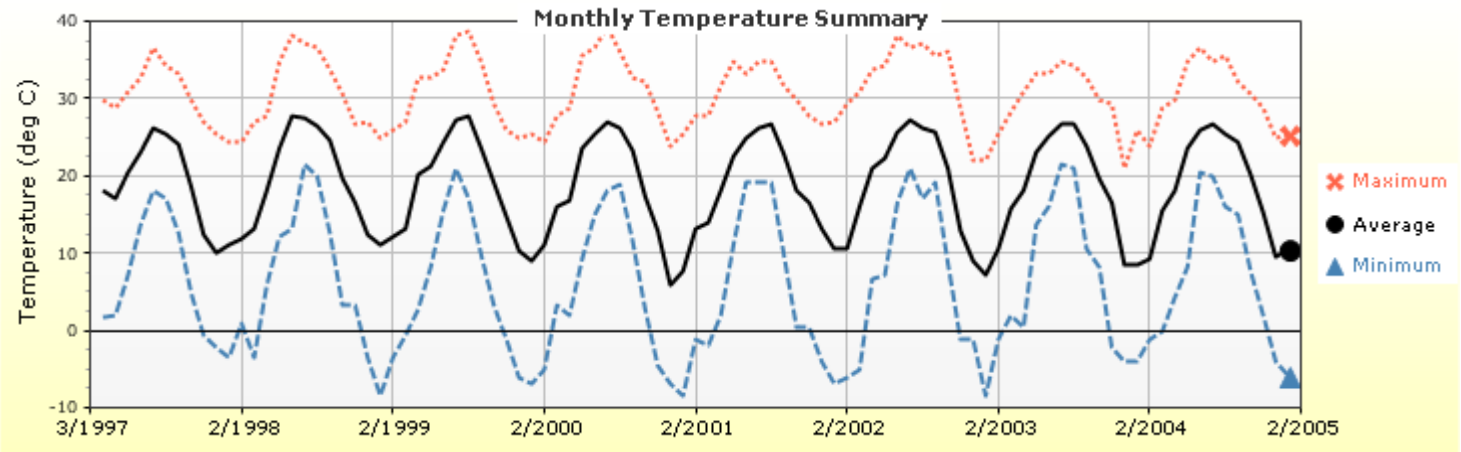
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

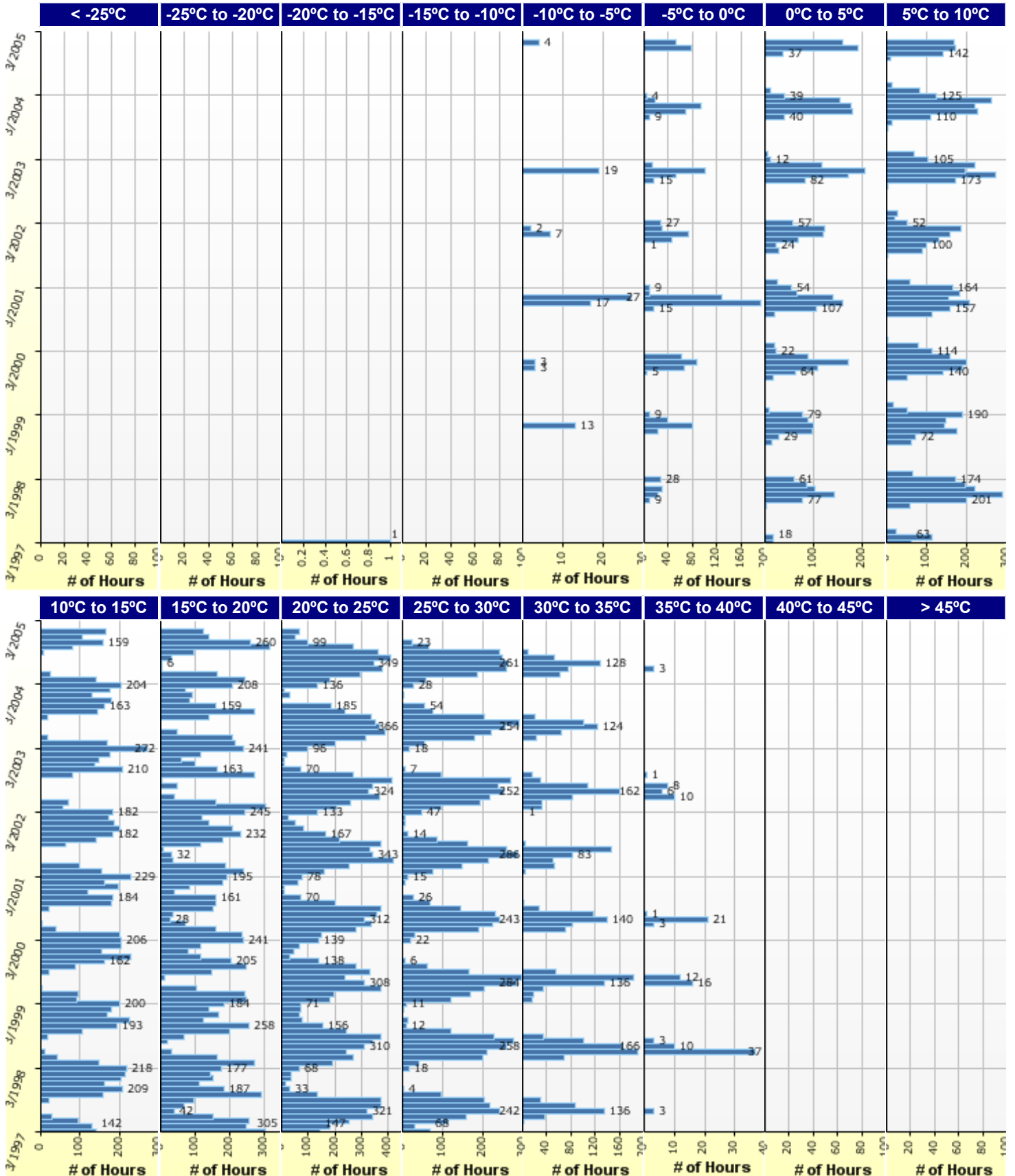


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF3_ALT1

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF3_ALT1.dgpx



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

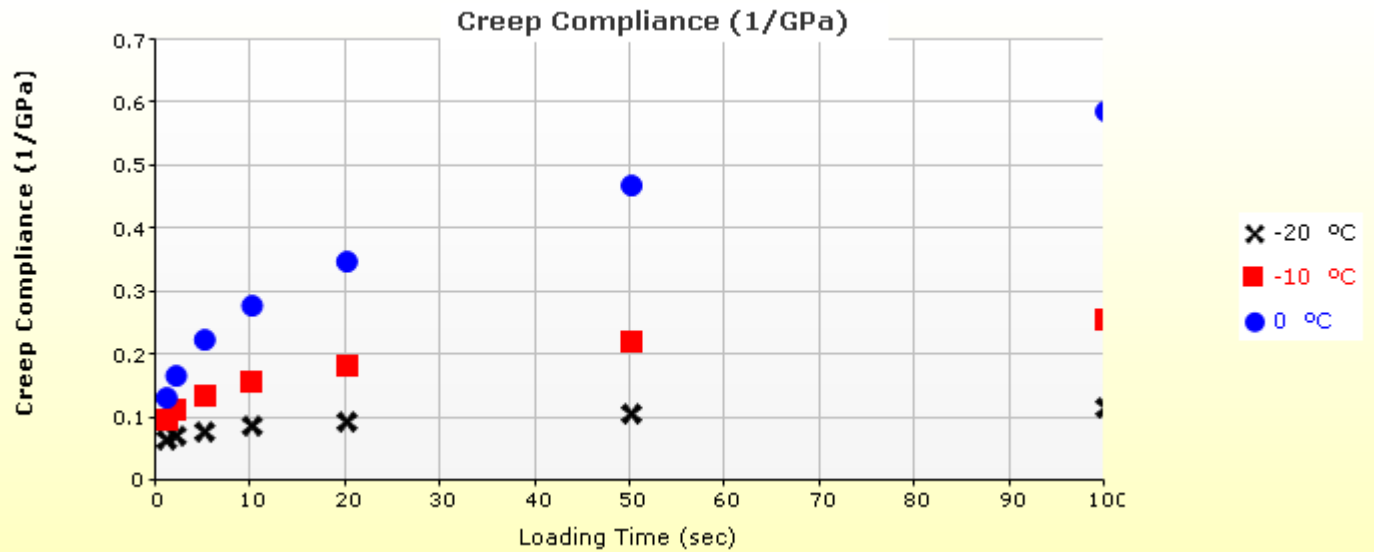
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

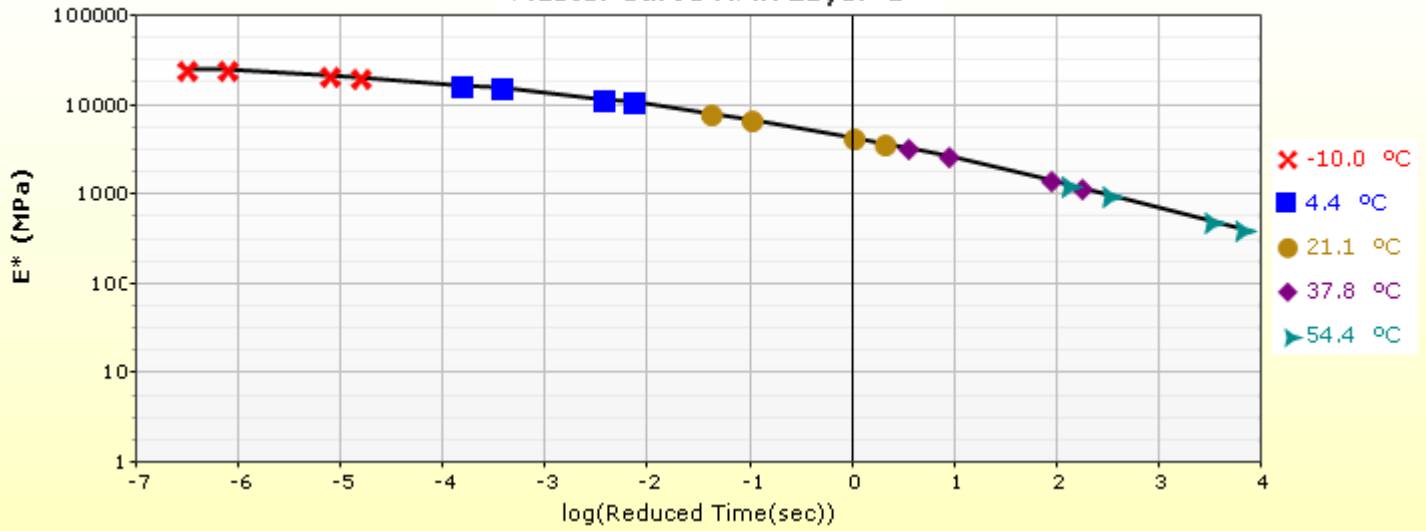
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

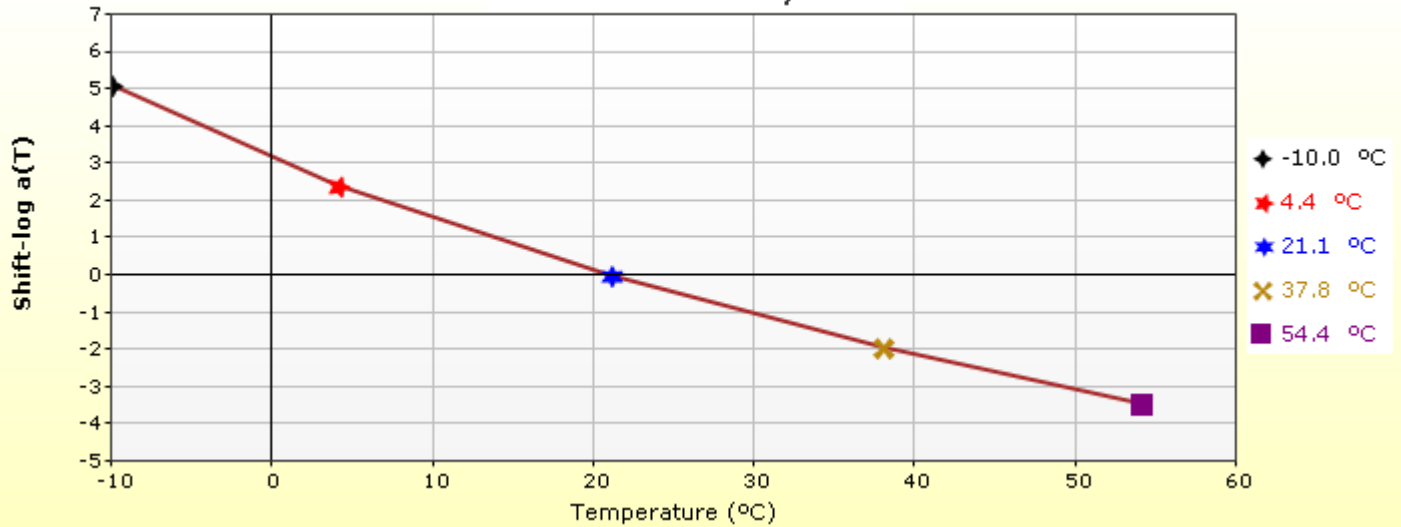


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

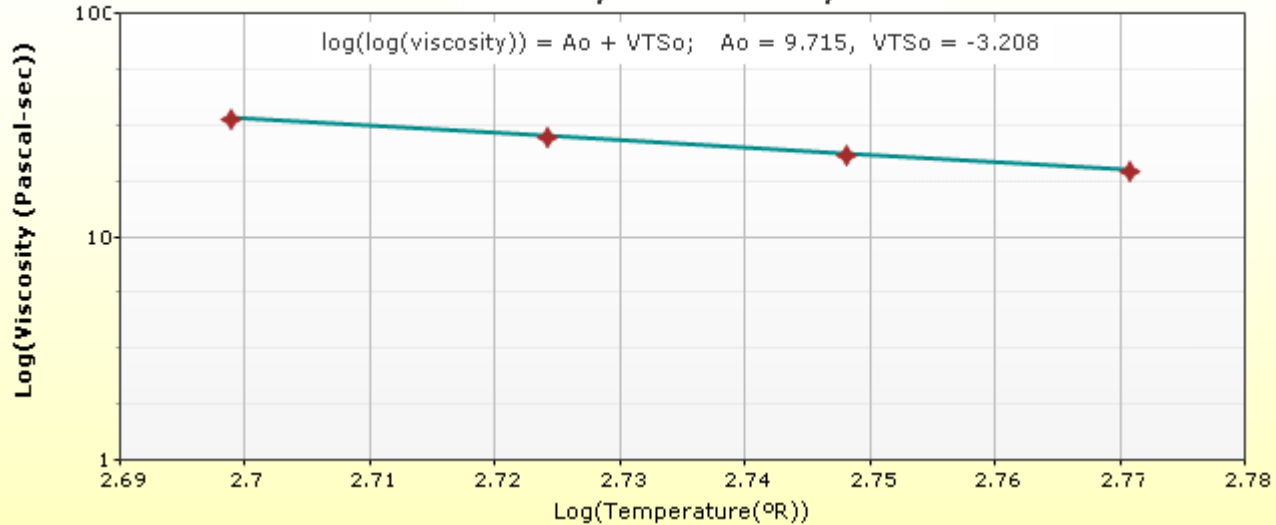
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

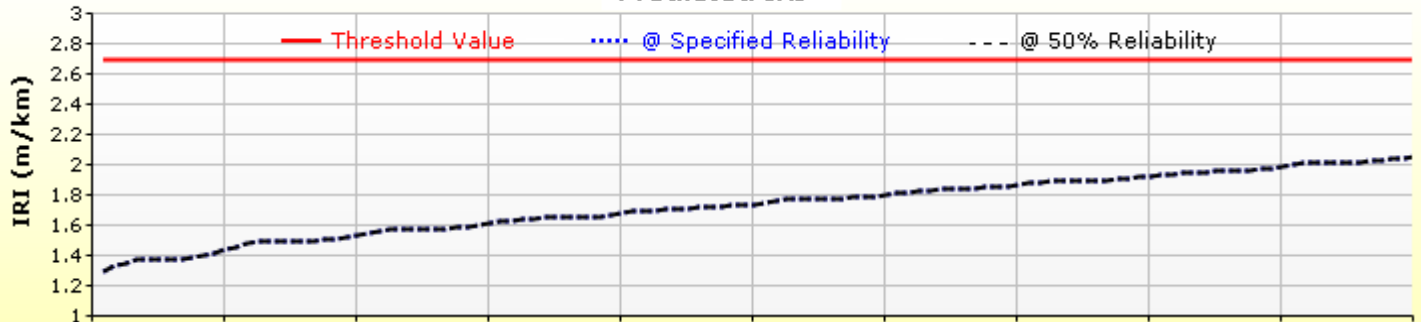


Viscosity Curve HMA Layer 1

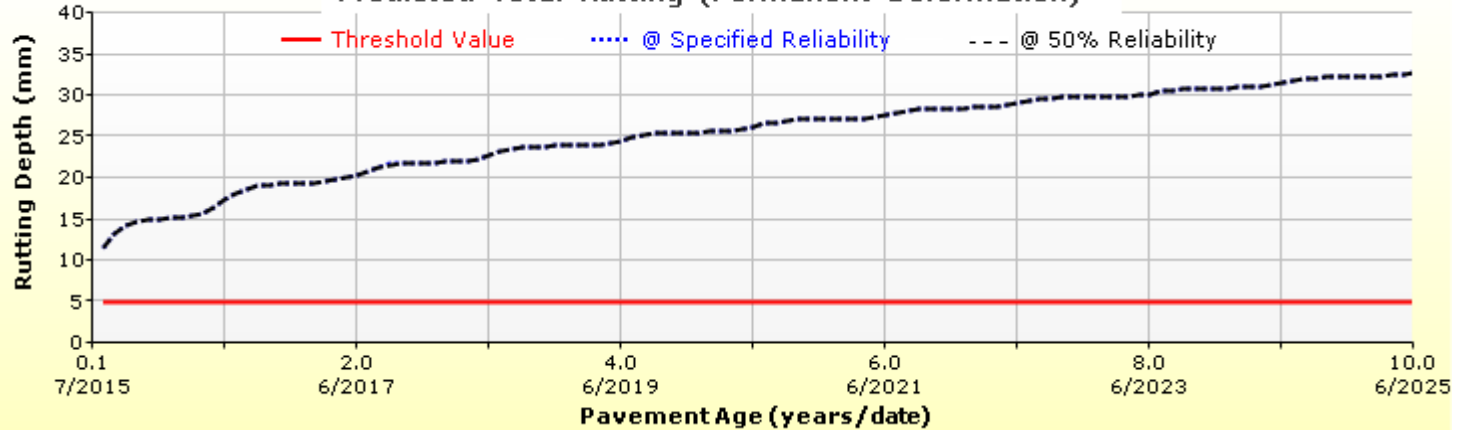


Analysis Output Charts

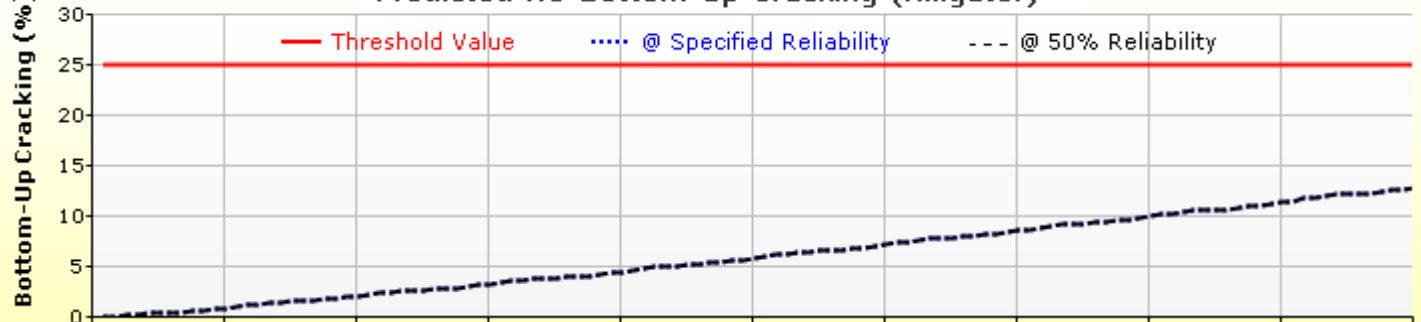
Predicted IRI



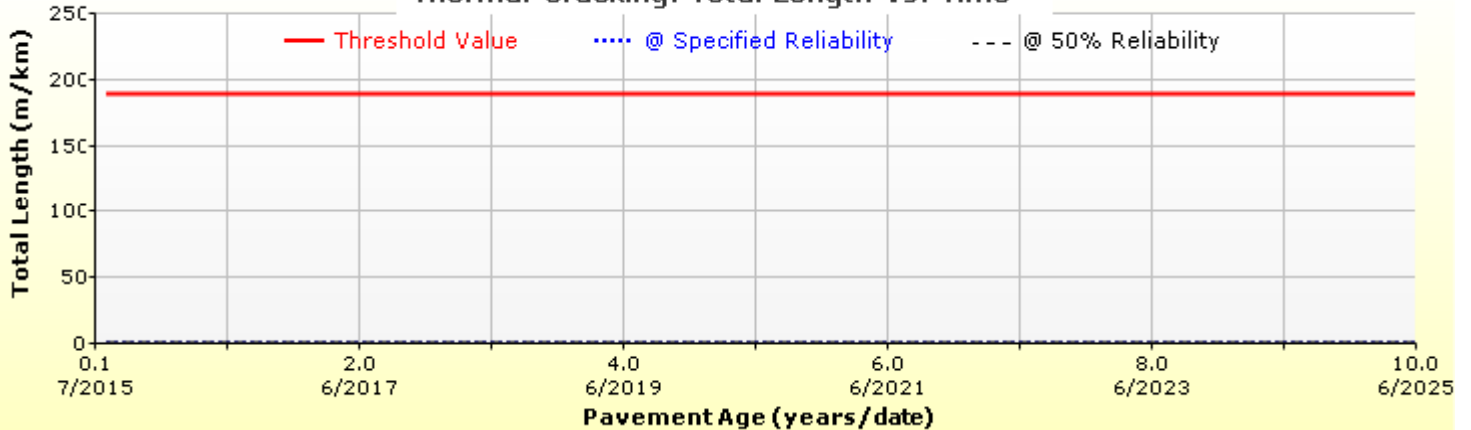
Predicted Total Rutting (Permanent Deformation)

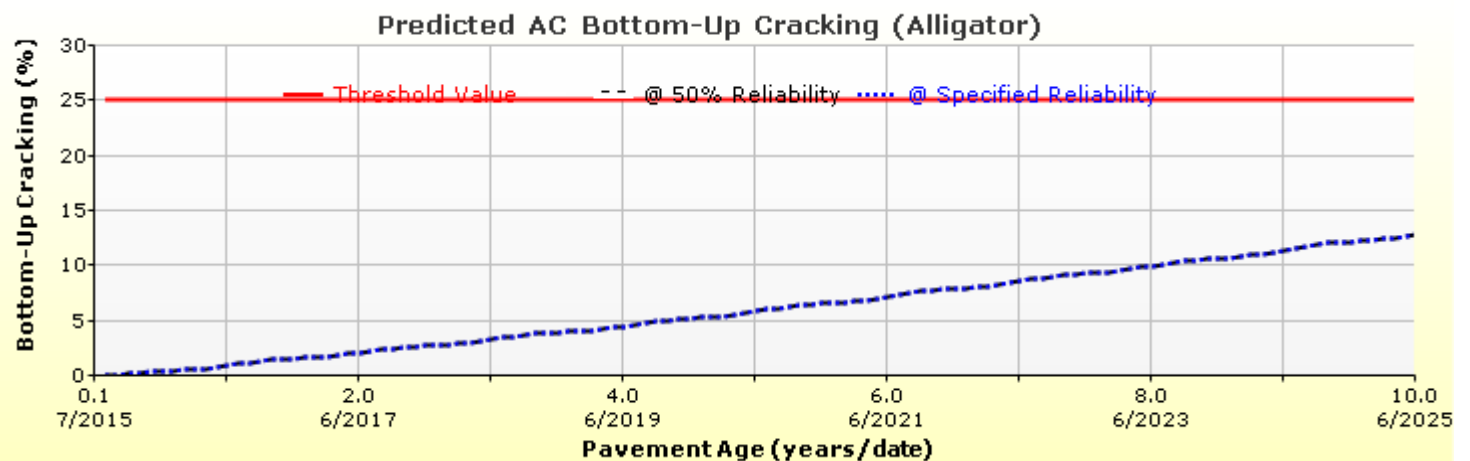
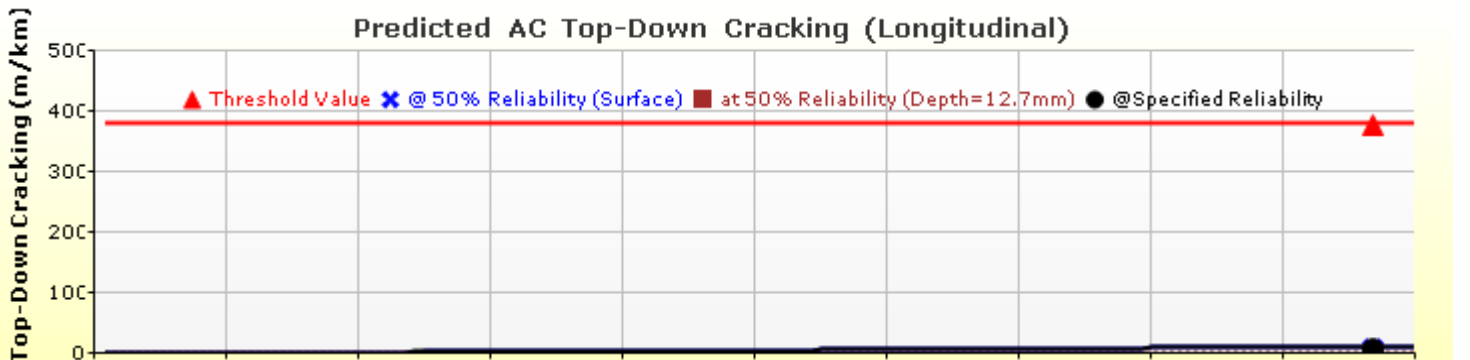
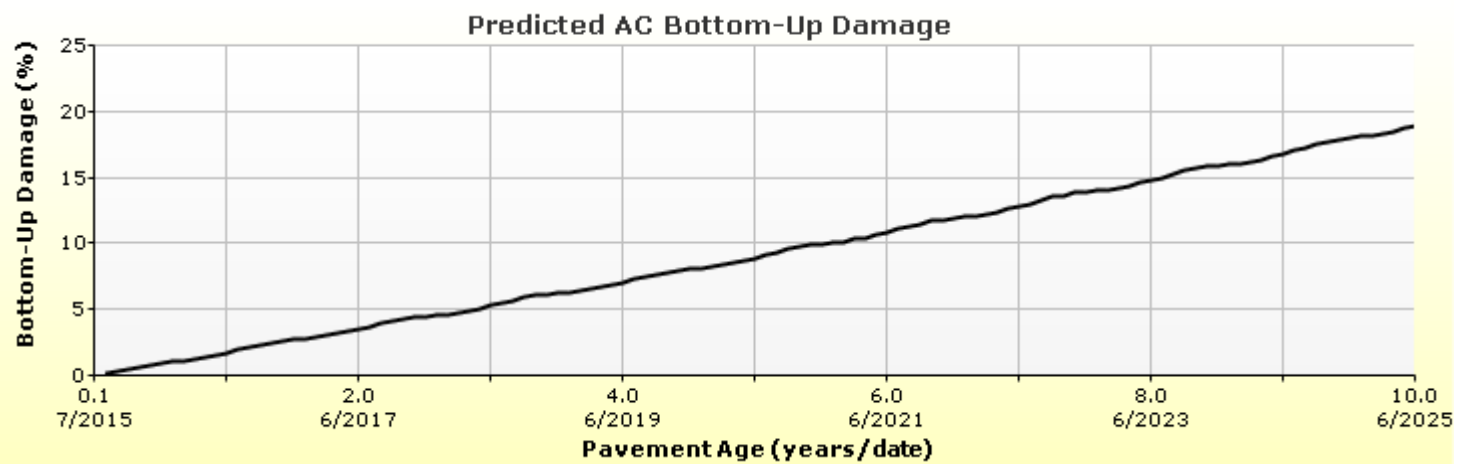
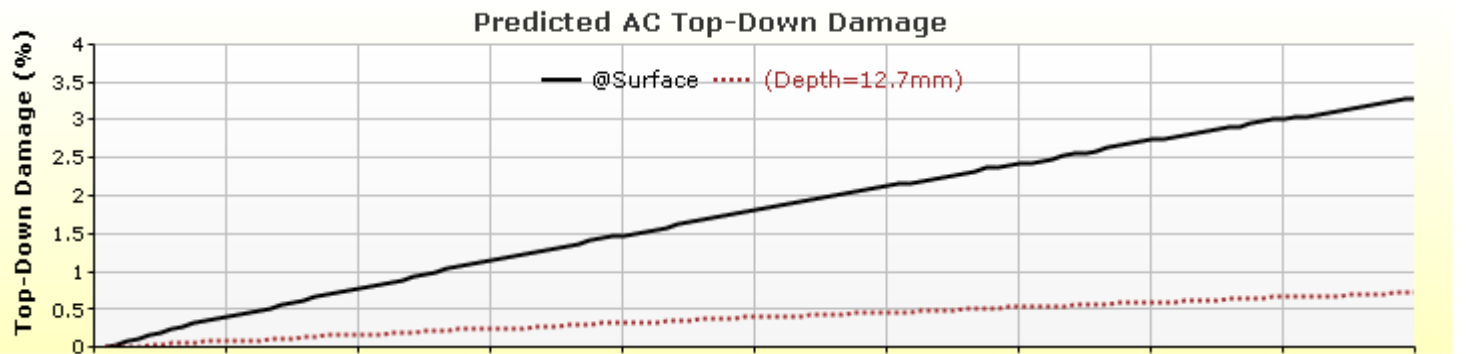


Predicted AC Bottom-Up Cracking (Alligator)

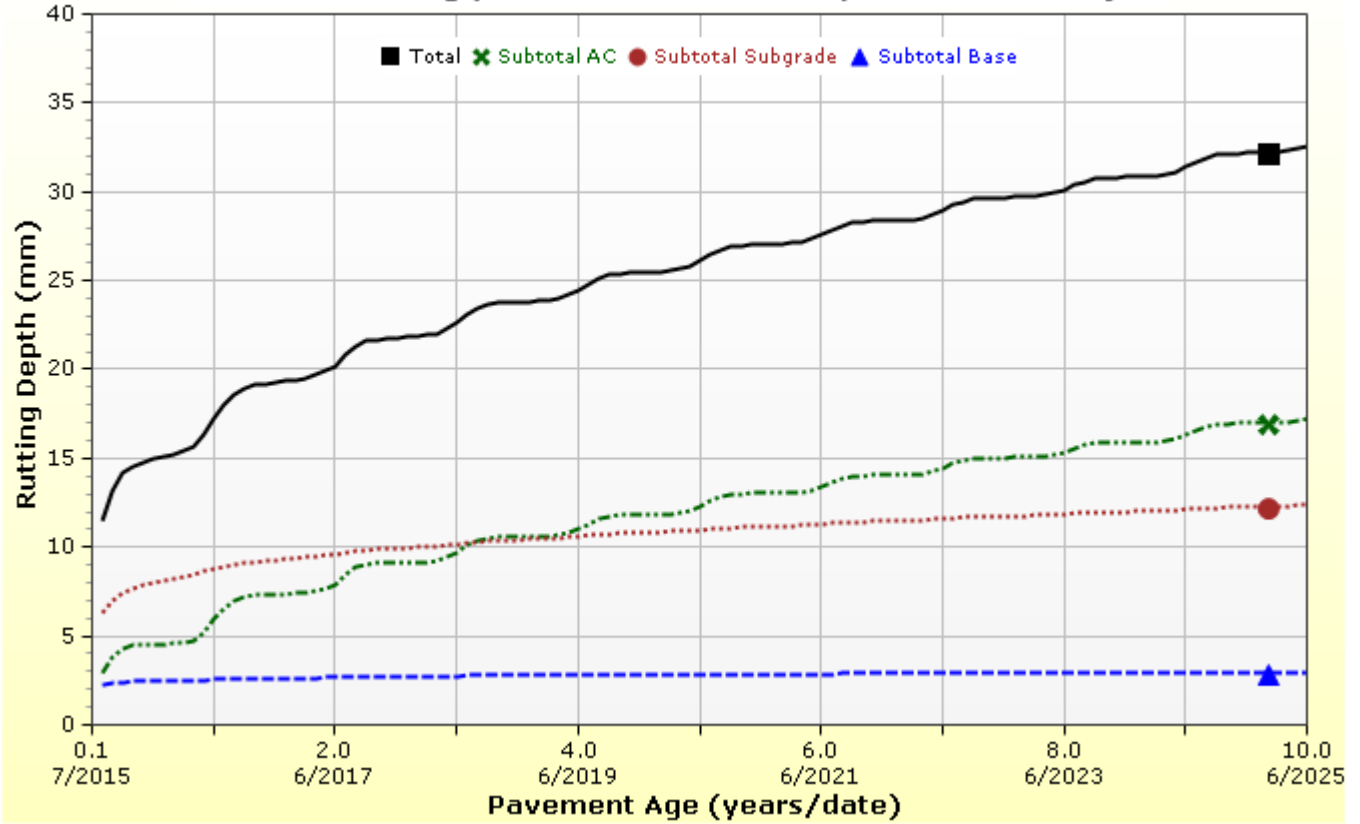


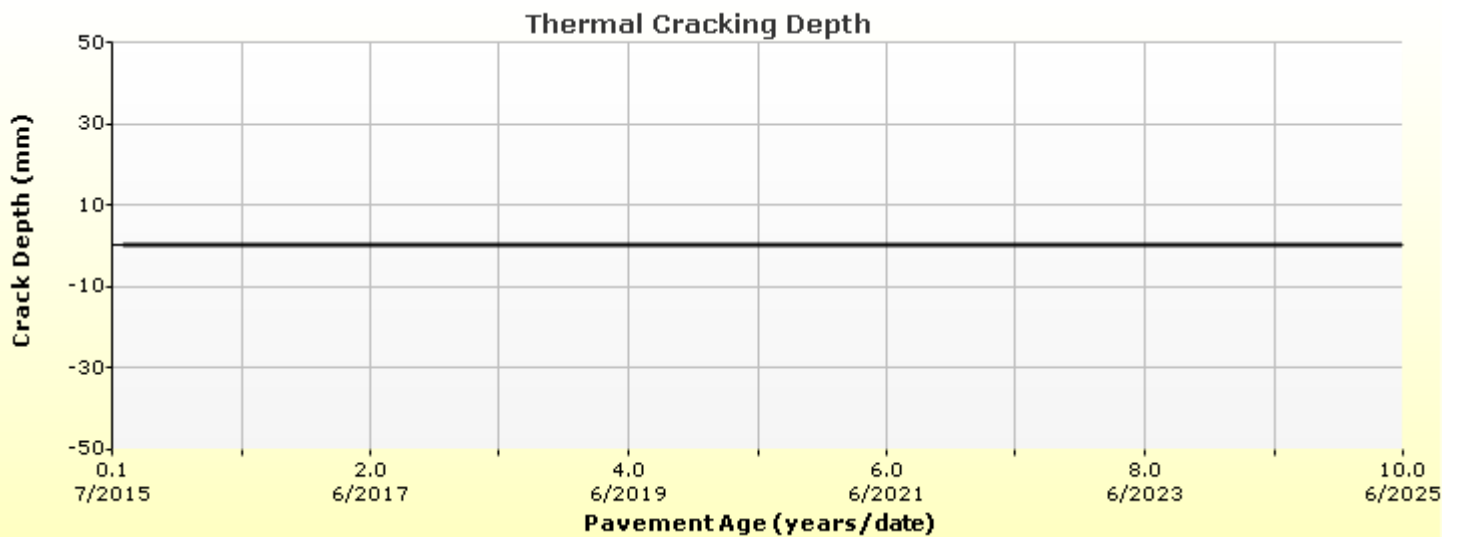
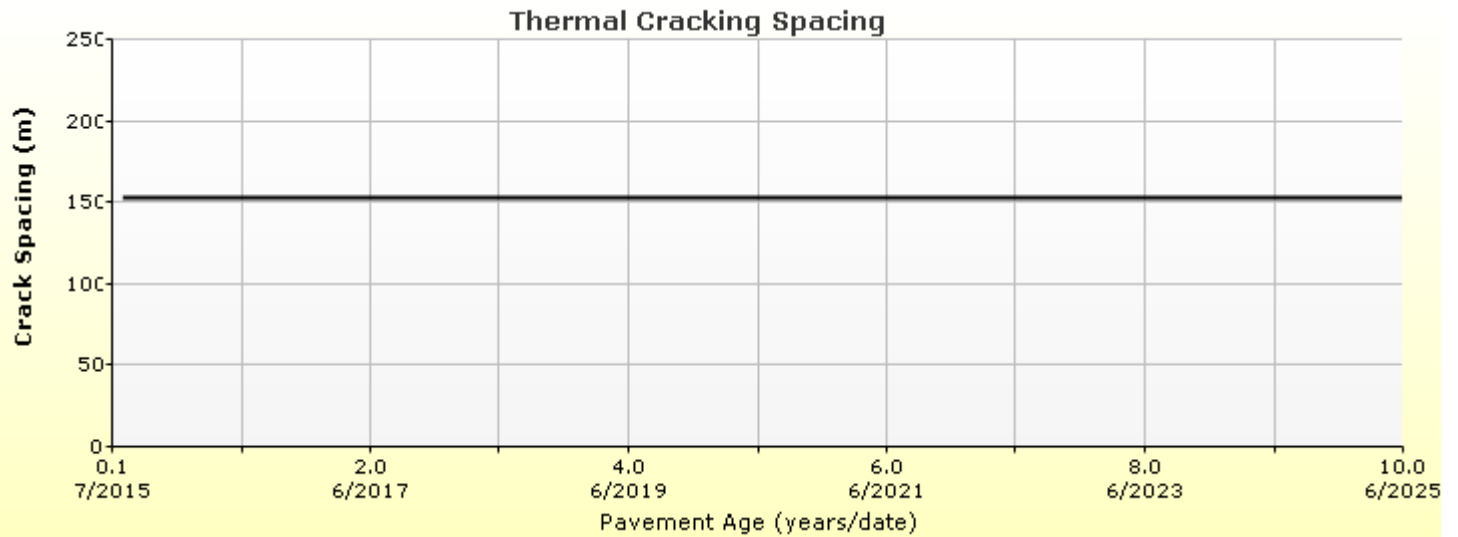
Thermal Cracking: Total Length vs. Time

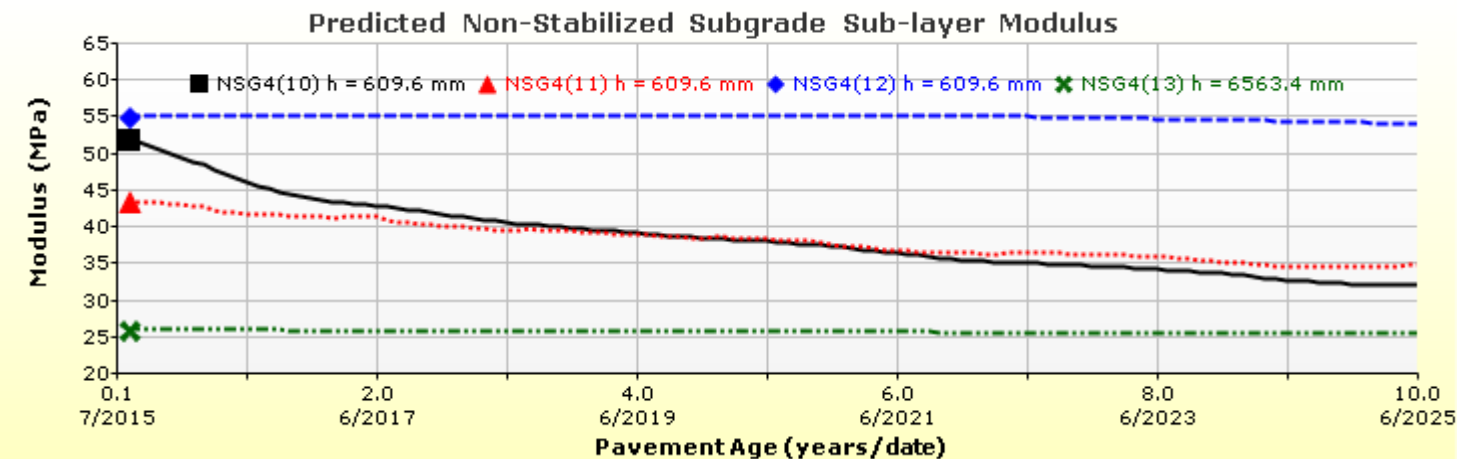
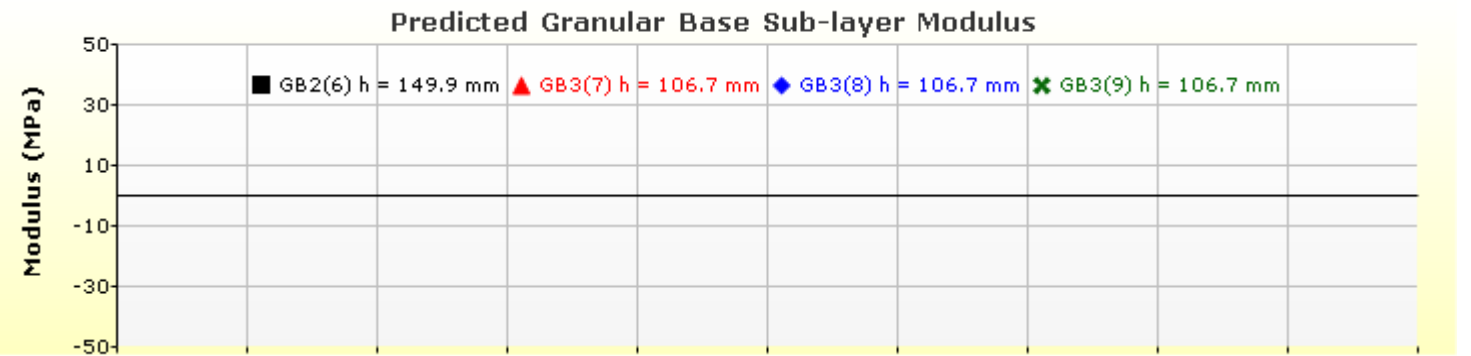
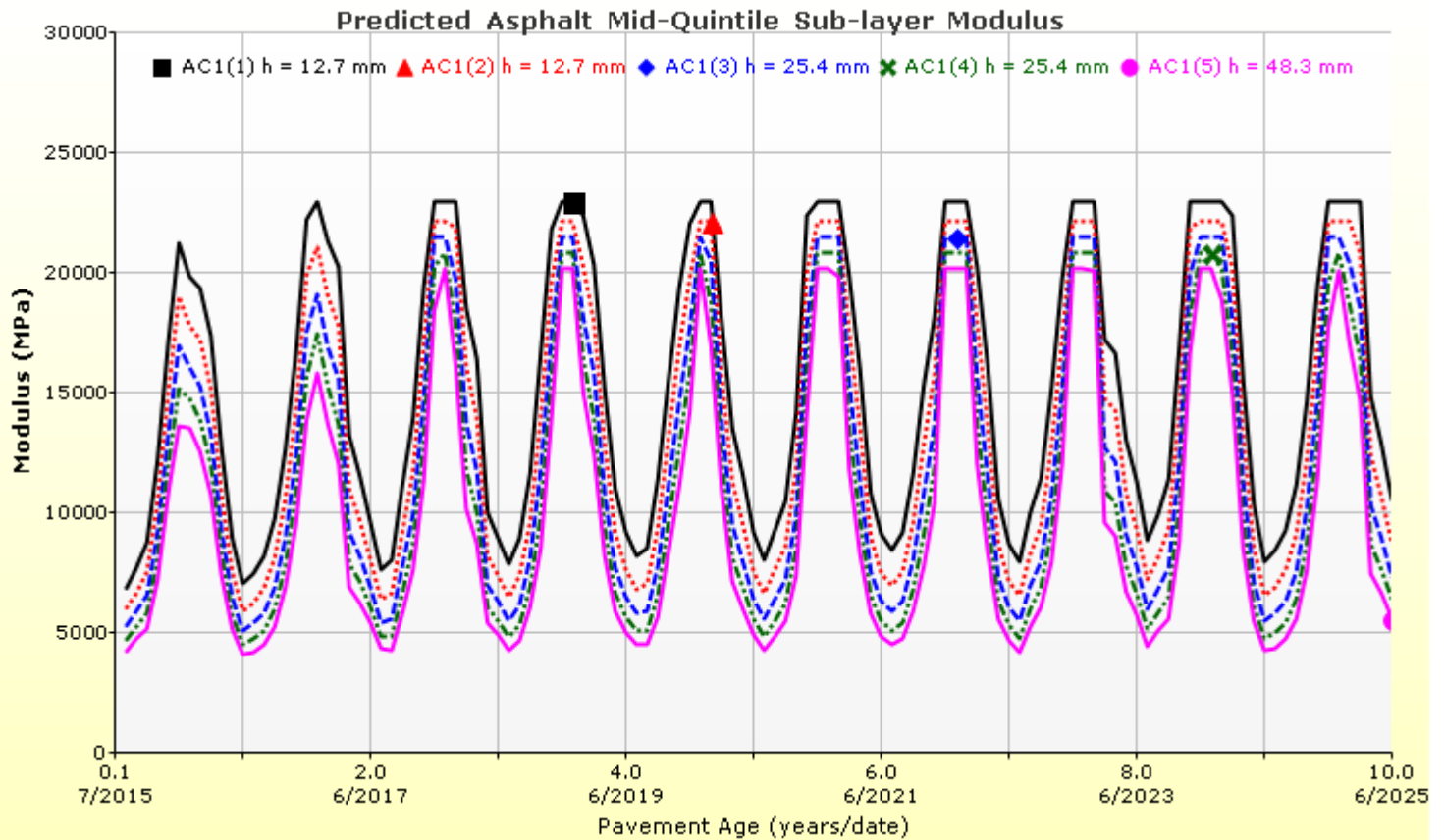




Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

Standard Deviation (BASERUT)

0.1235*Pow(SUBRUT,0.5012)+0.001

AC Cracking

AC Top Down Cracking

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

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: 7

c2: 3.5

c3: 0

c4: 1000

c1: 1

c2: 1

c3: 6000

AC Cracking Top Standard Deviation

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

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

IRI Flexible Pavements

C1 - Rutting

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

CSM Standard Deviation

CTB*1

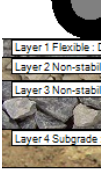
Design Inputs

Design Life: **10 years**
Design Type: **Flexible Pavement**

Base construction: **March, 2015**
Pavement construction: **June, 2015**
Traffic opening: **July, 2015**

Climate Data **32.119, -81.202**
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)	Volumetric at Construction:	
Flexible	Default asphalt concrete	125.0	Effective binder content (%)	11.6
NonStabilized	Crushed stone	150.0	Air voids (%)	7.0
NonStabilized	Crushed stone	320.0		
Subgrade	A-5	Semi-infinite		

Traffic

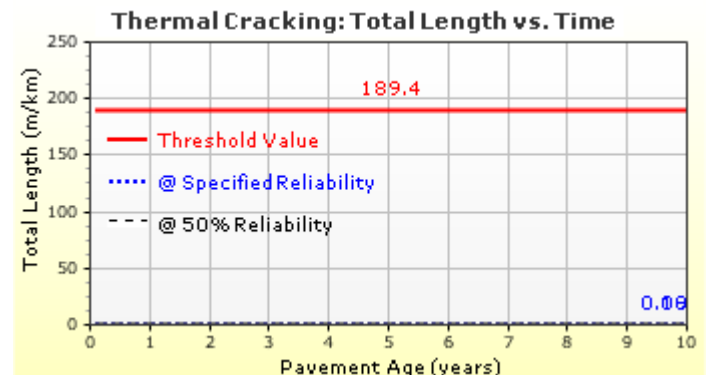
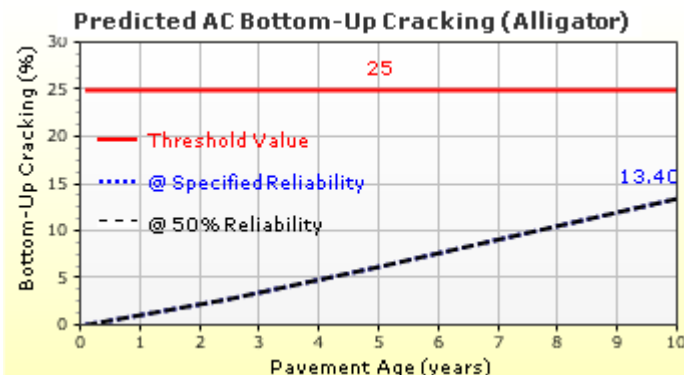
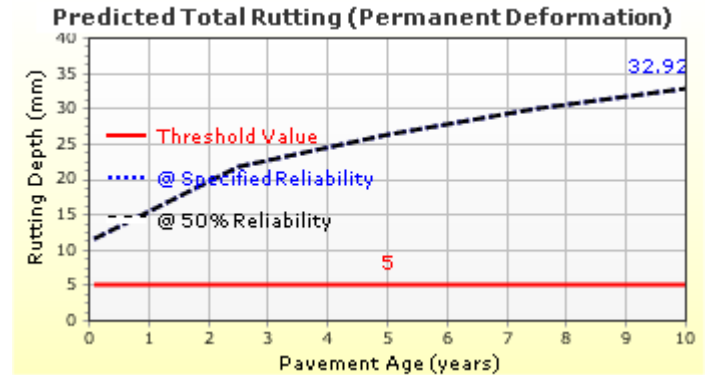
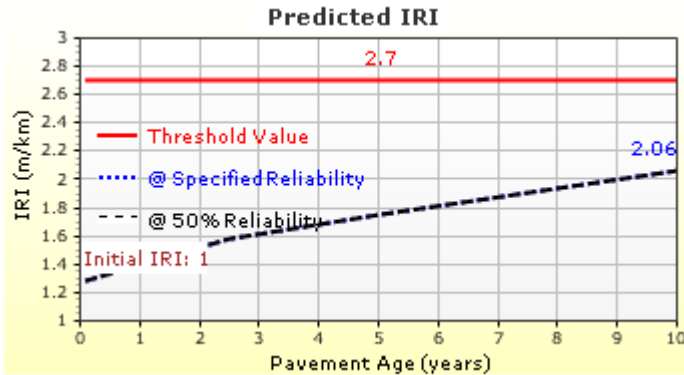
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.06	50.00	87.55	Pass
Permanent deformation - total pavement (mm)	5.00	32.92	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	13.40	50.00	79.42	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	11.21	50.00	91.98	Pass
Permanent deformation - AC only (mm)	5.00	17.58	50.00	0.29	Fail

Distress Charts

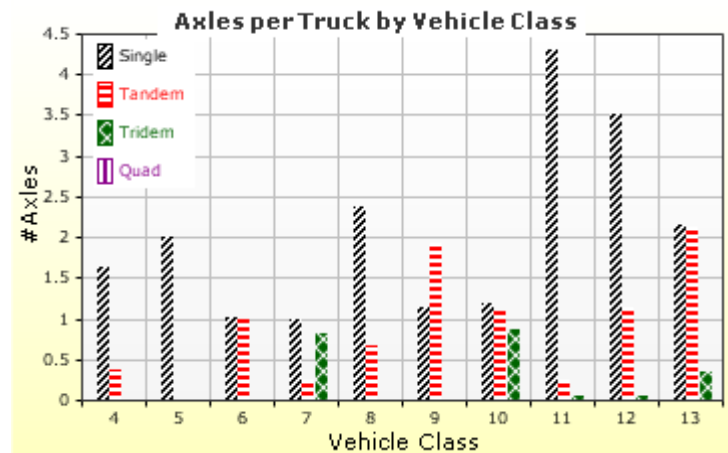
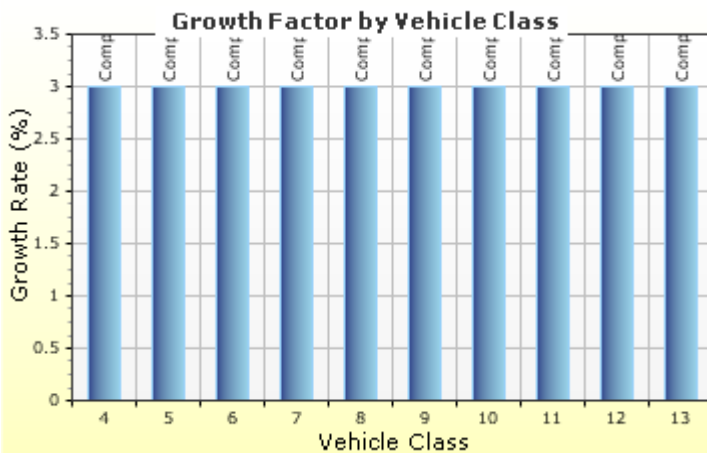
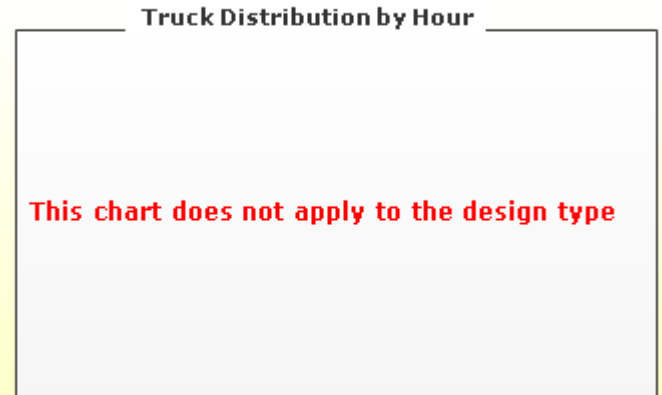
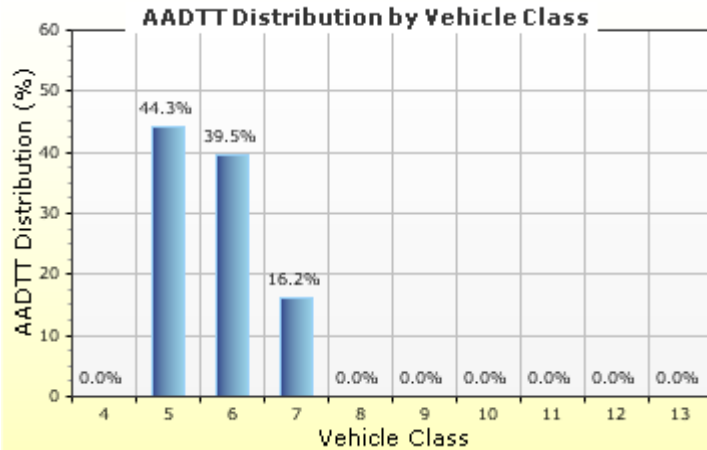


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

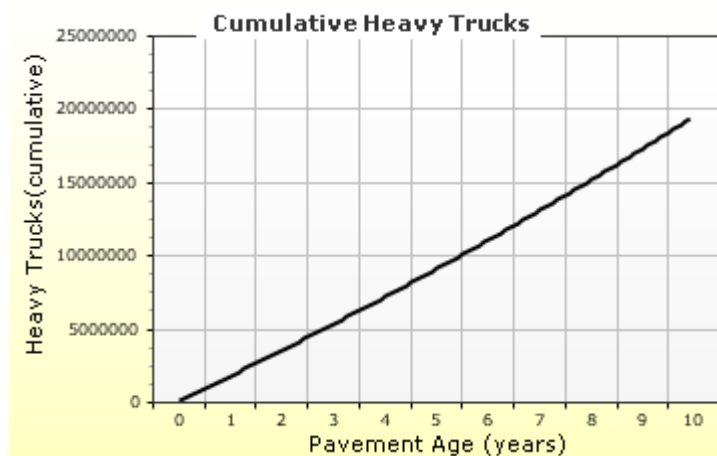
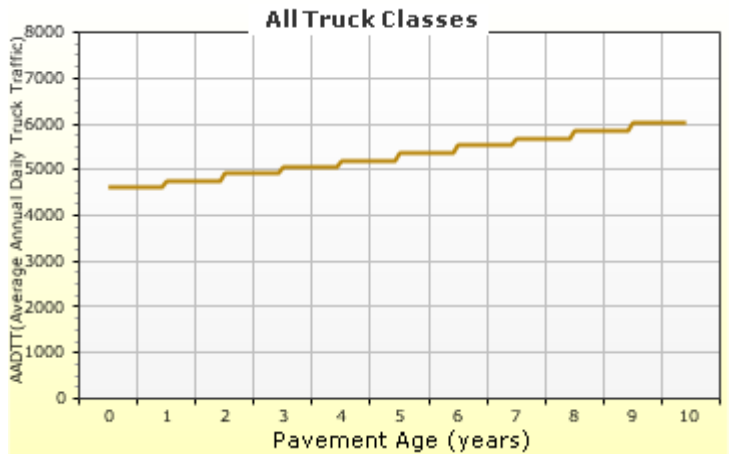
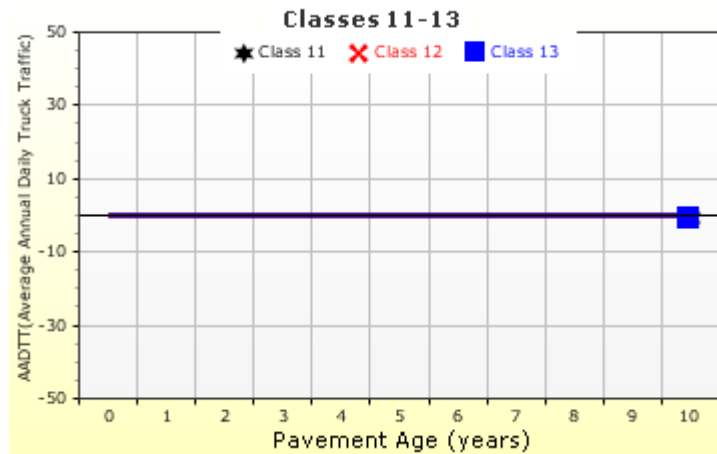
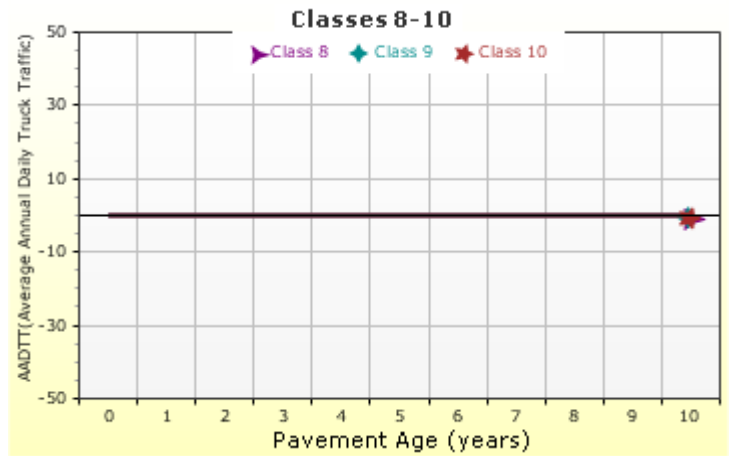
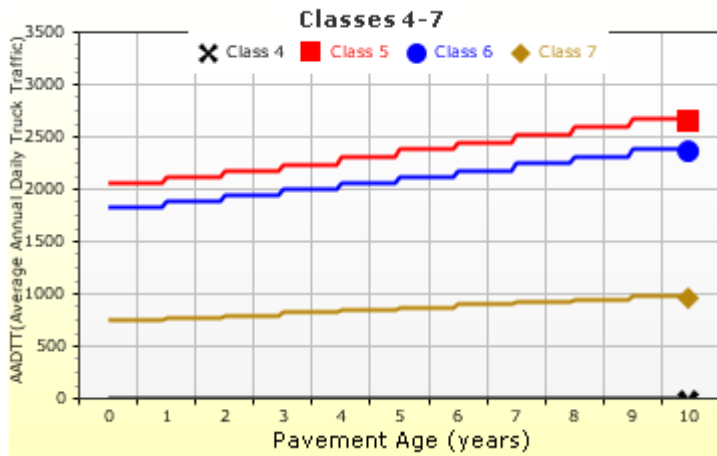
Wheelbase does not apply

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



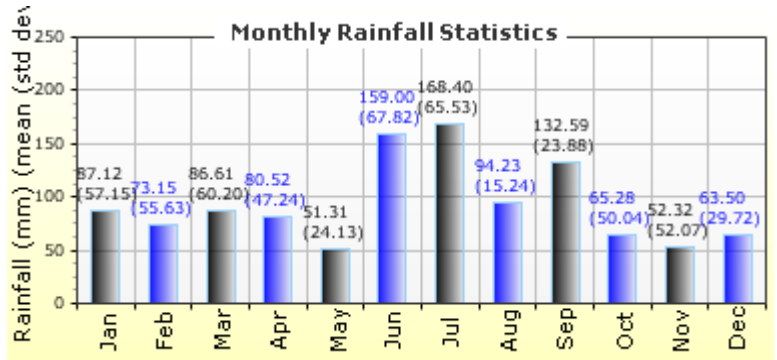
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

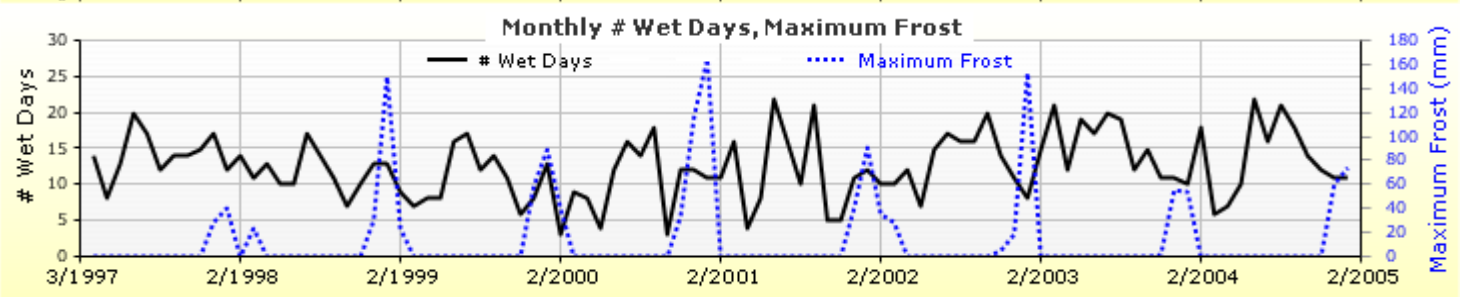
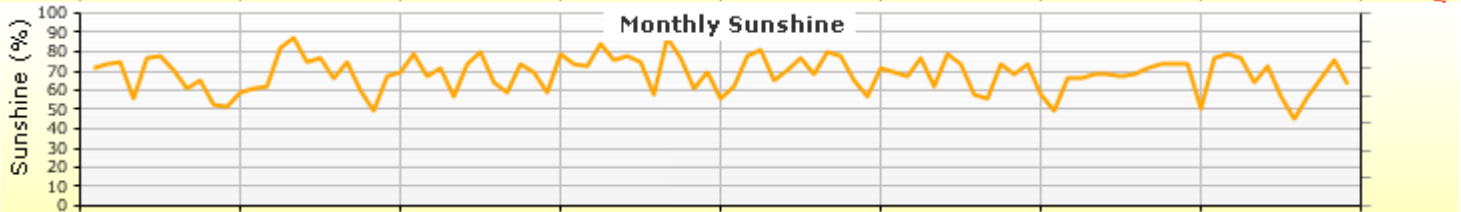
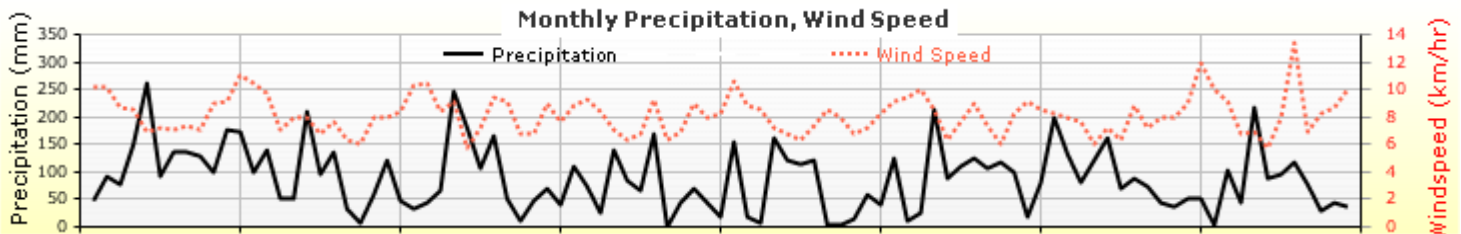
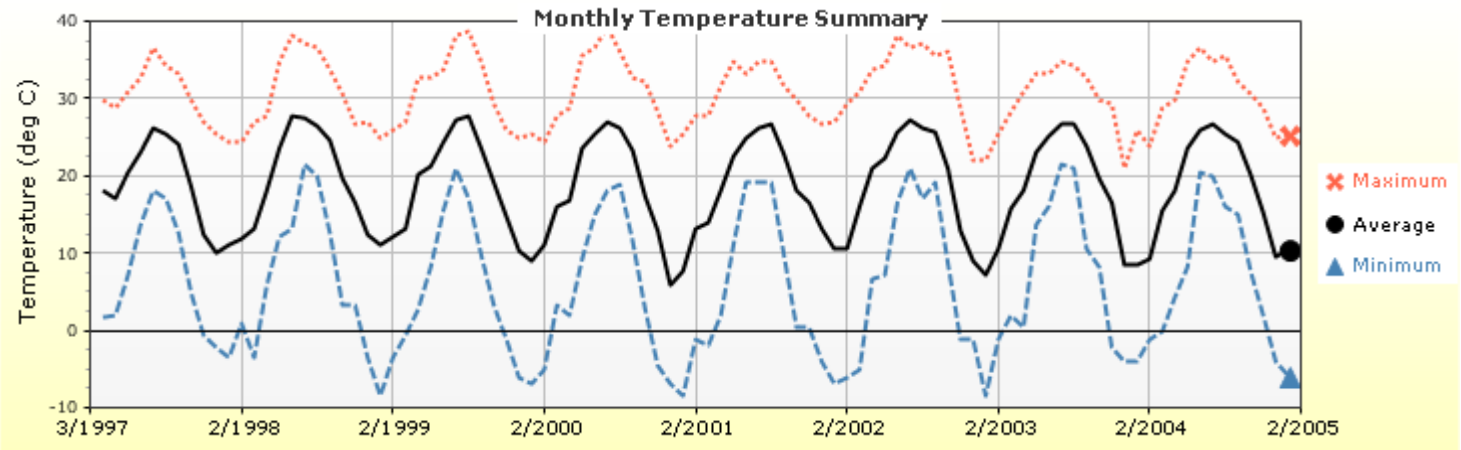
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

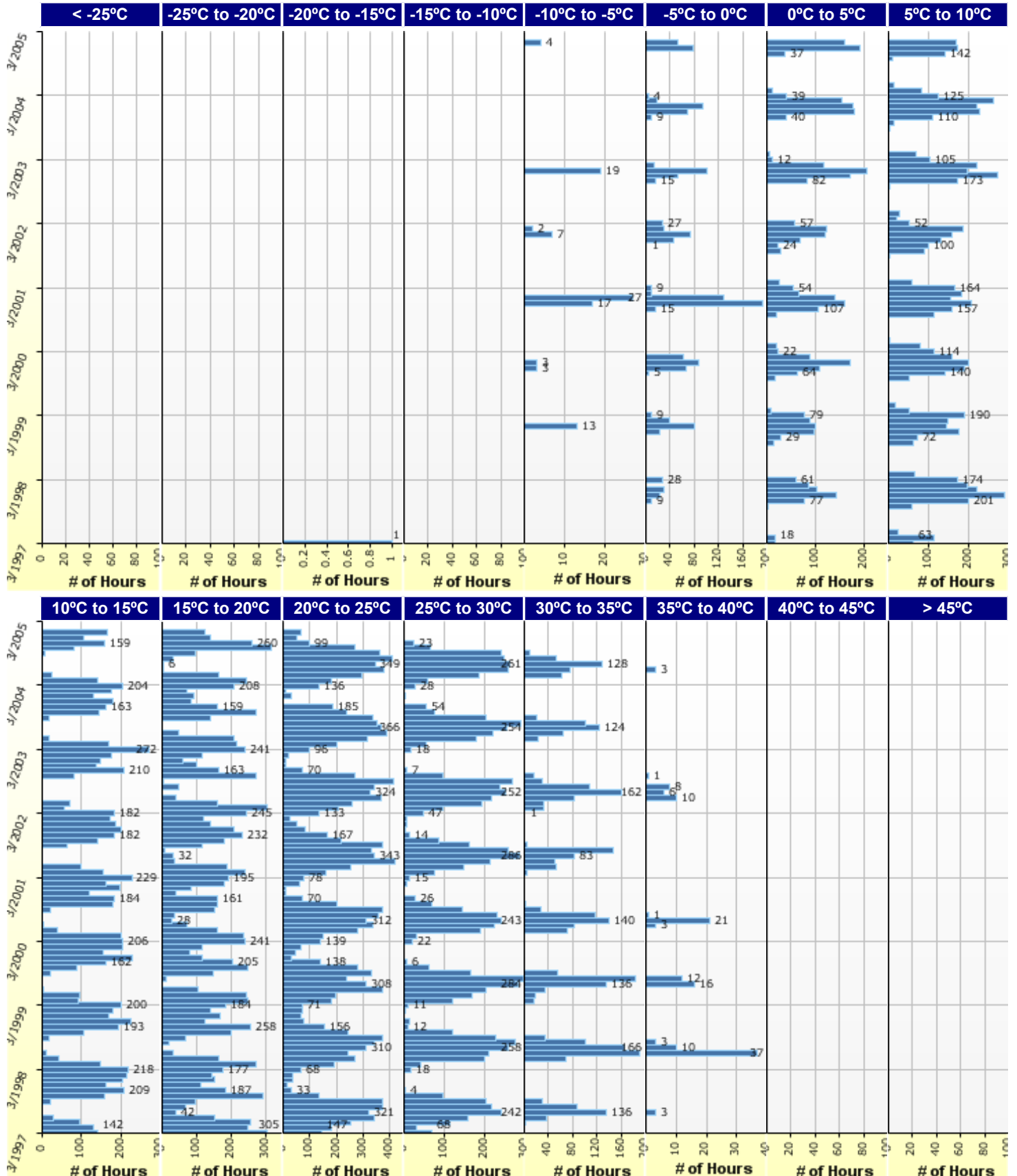


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF4_ALT1

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF4_ALT1.dgpx



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

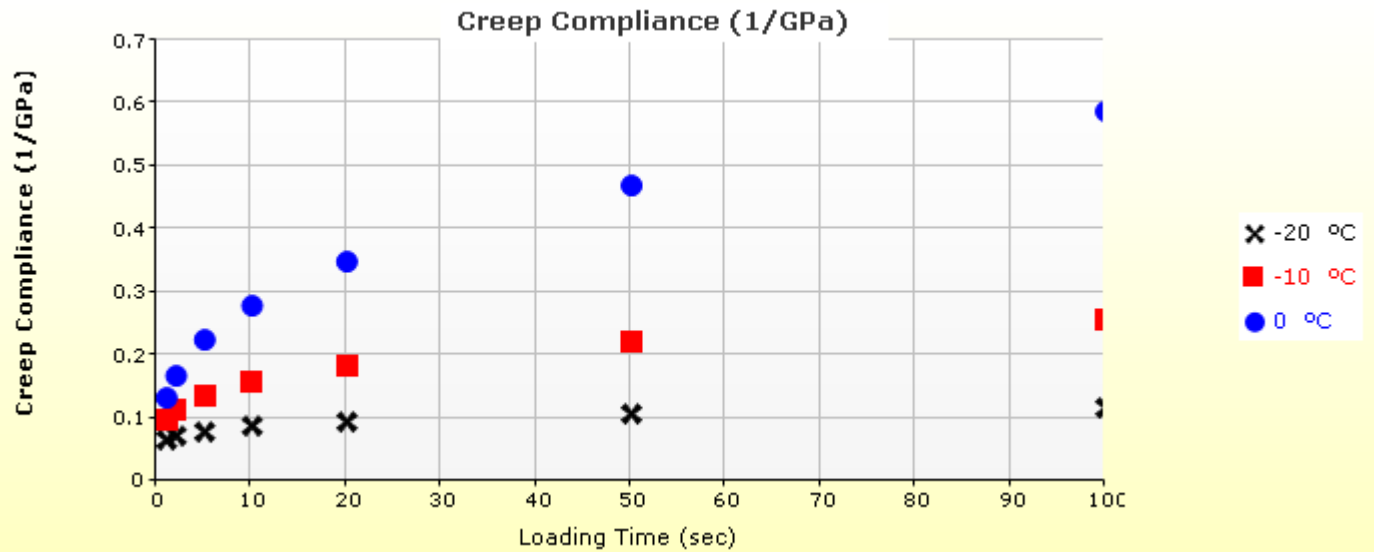
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

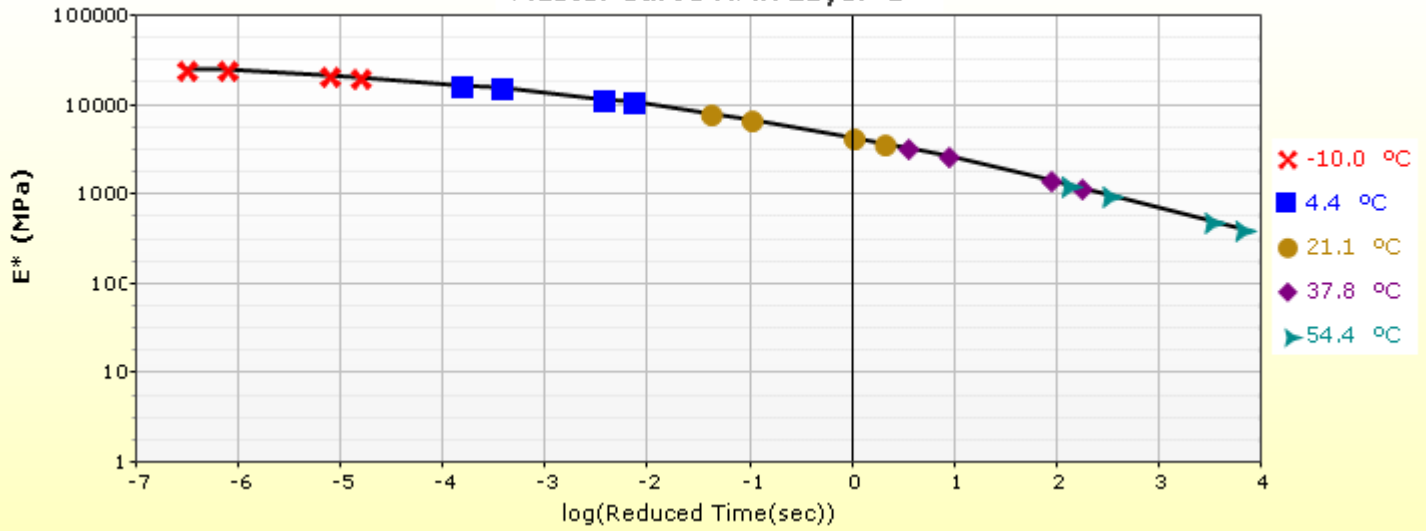
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

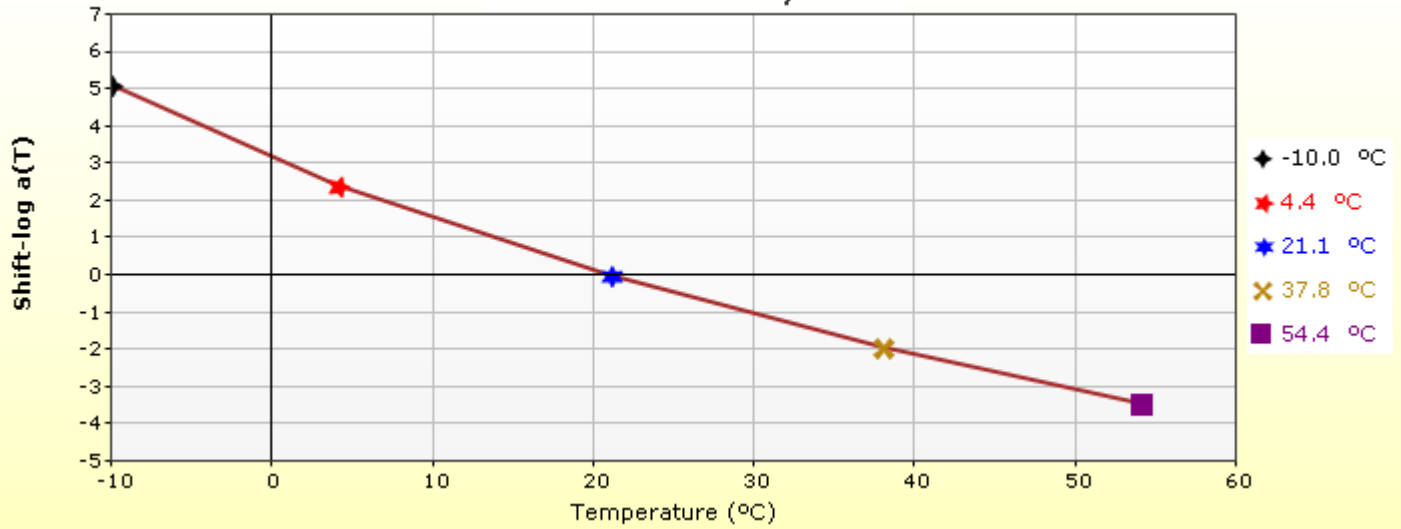


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

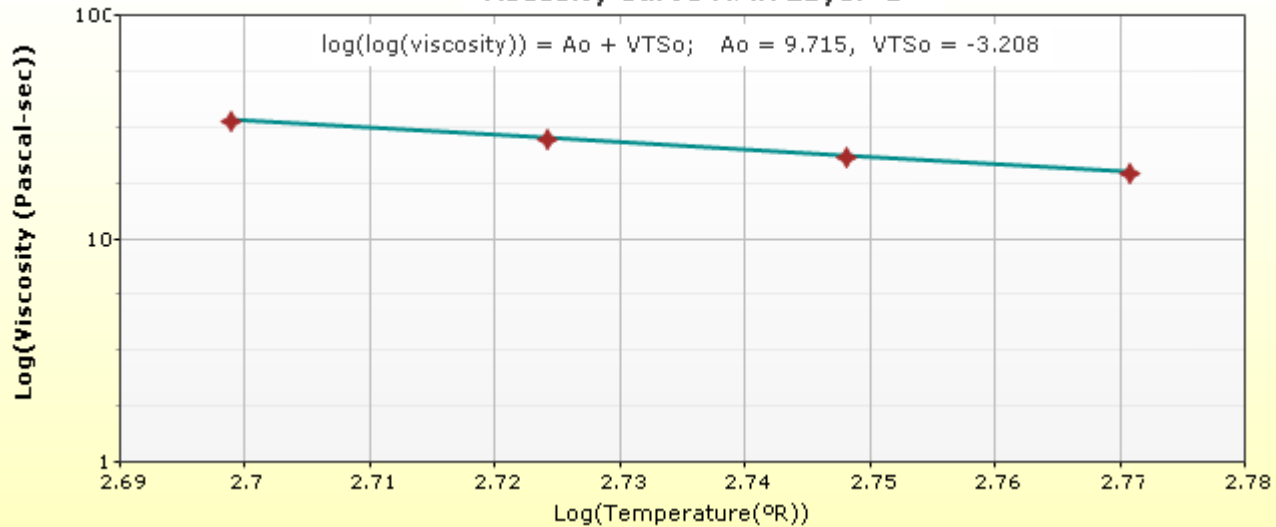
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

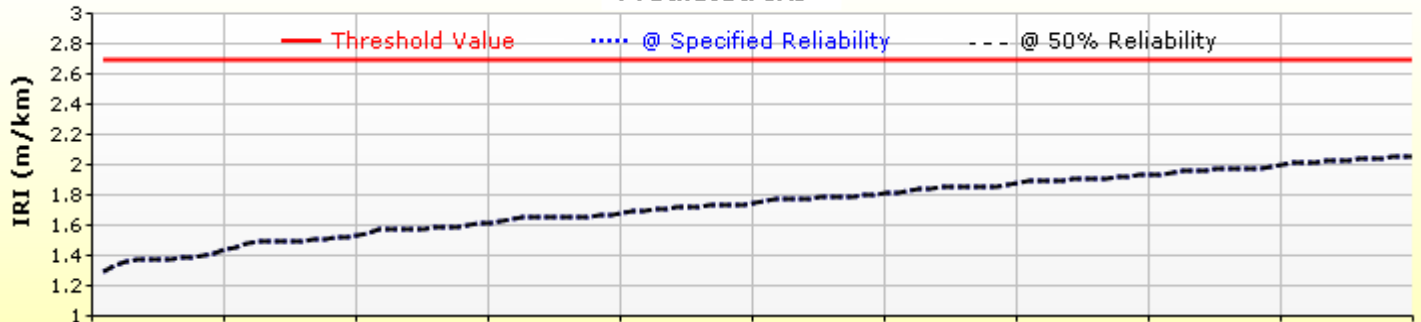


Viscosity Curve HMA Layer 1

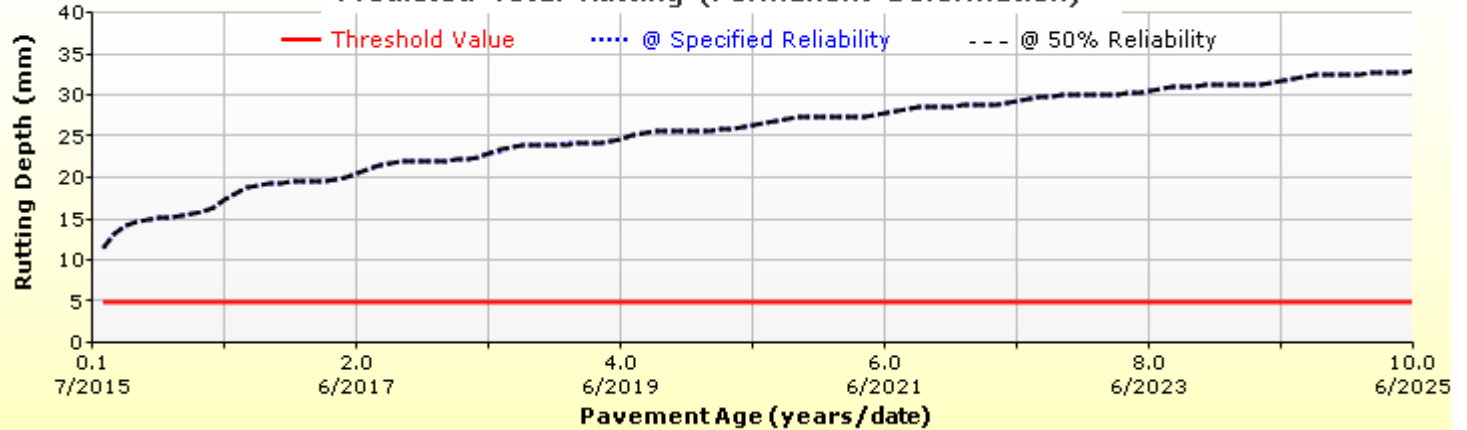


Analysis Output Charts

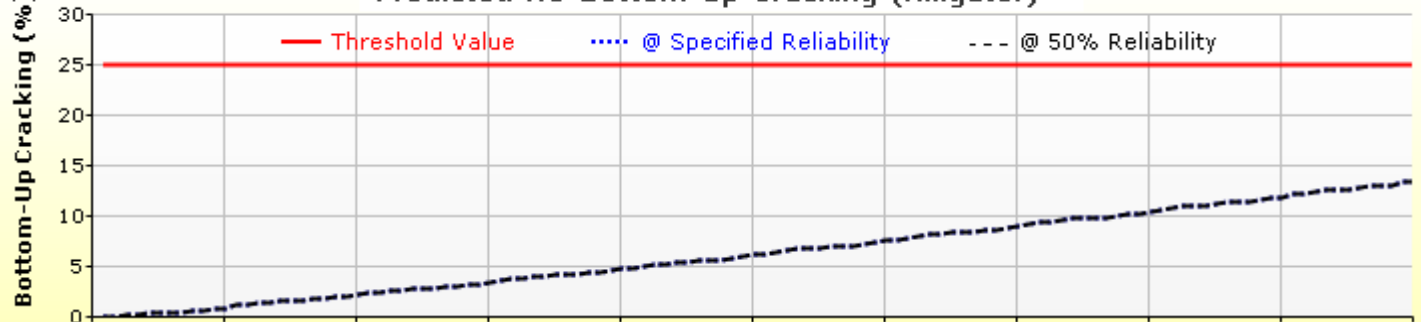
Predicted IRI



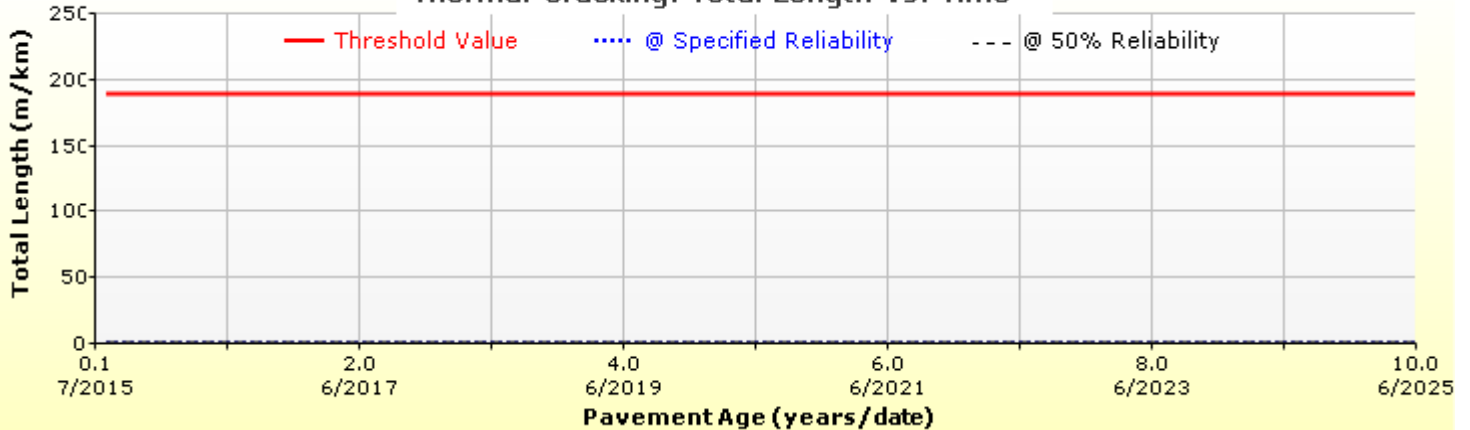
Predicted Total Rutting (Permanent Deformation)



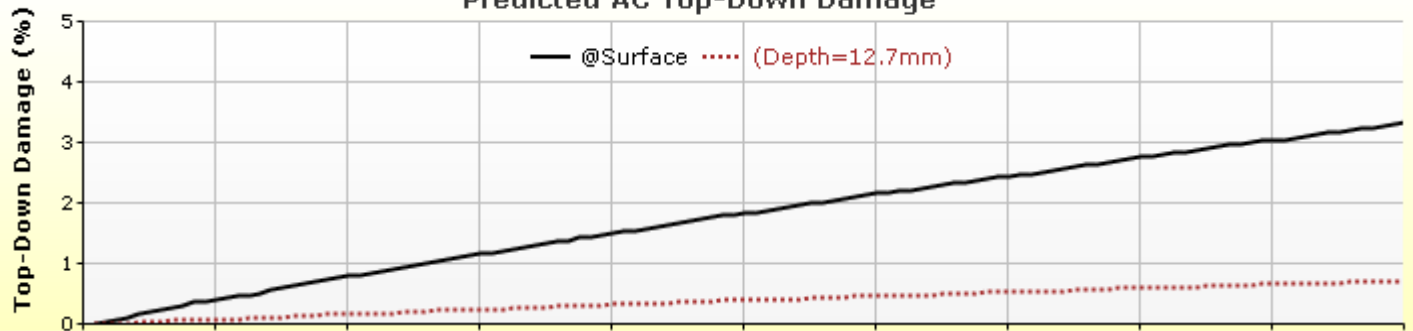
Predicted AC Bottom-Up Cracking (Alligator)



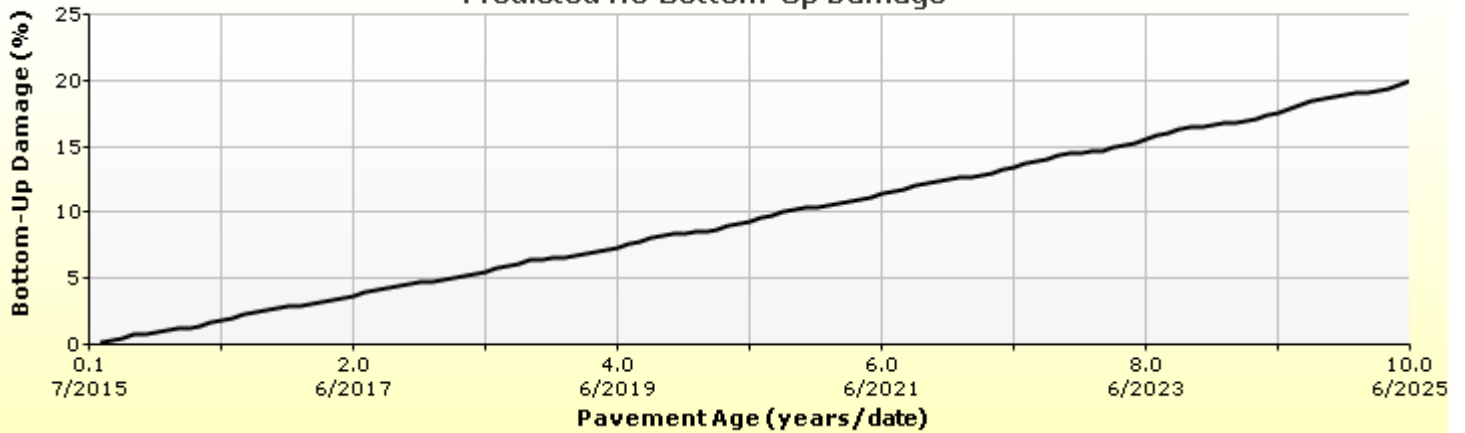
Thermal Cracking: Total Length vs. Time



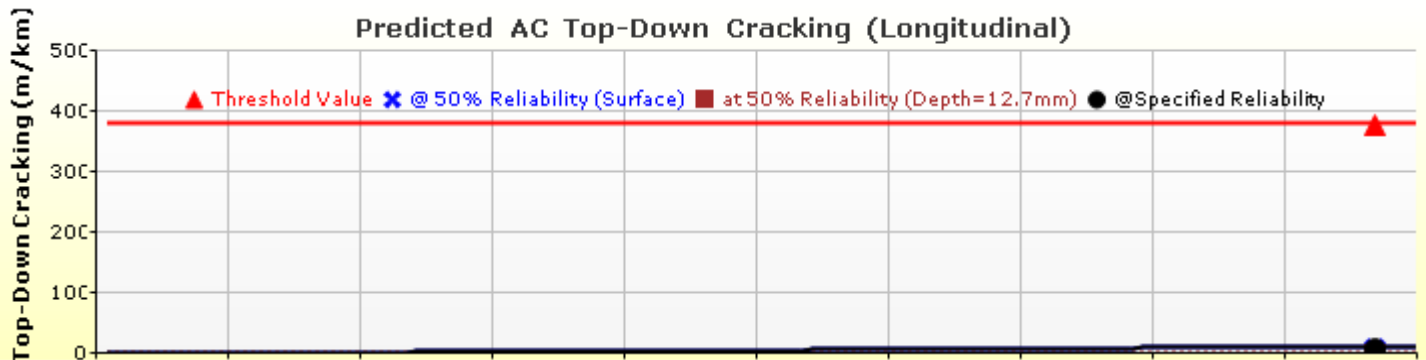
Predicted AC Top-Down Damage



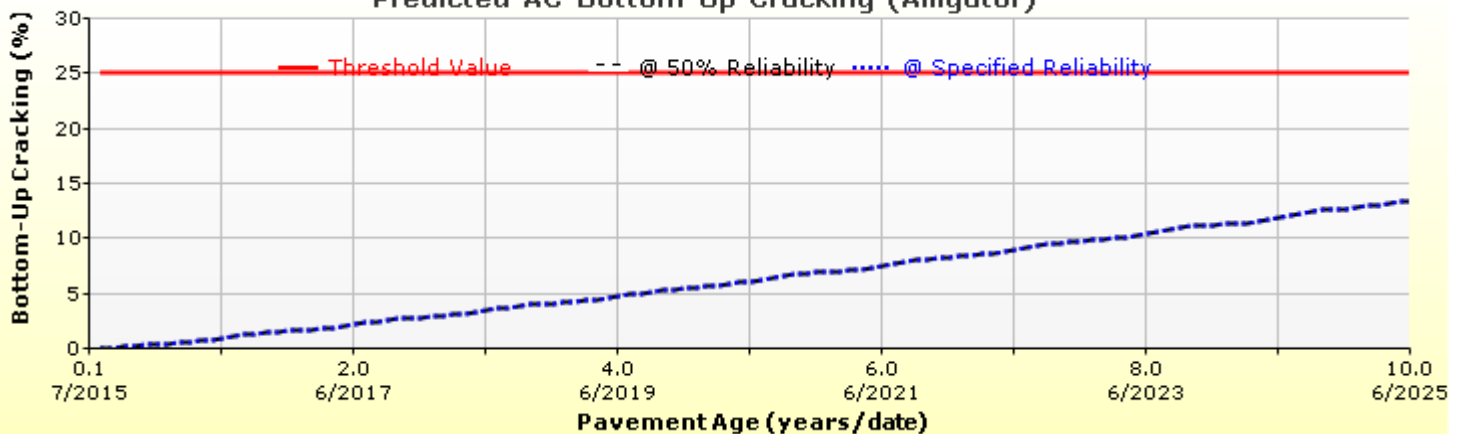
Predicted AC Bottom-Up Damage



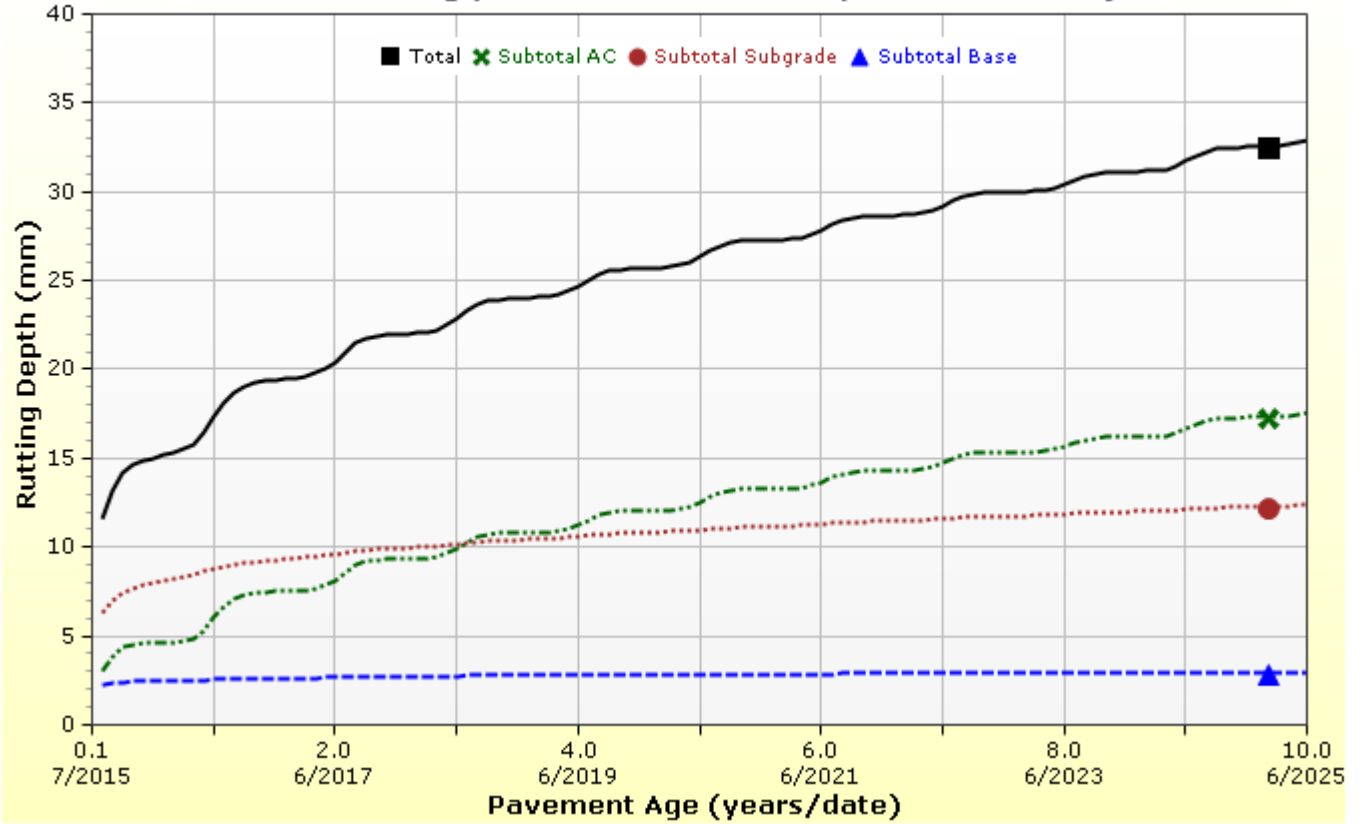
Predicted AC Top-Down Cracking (Longitudinal)

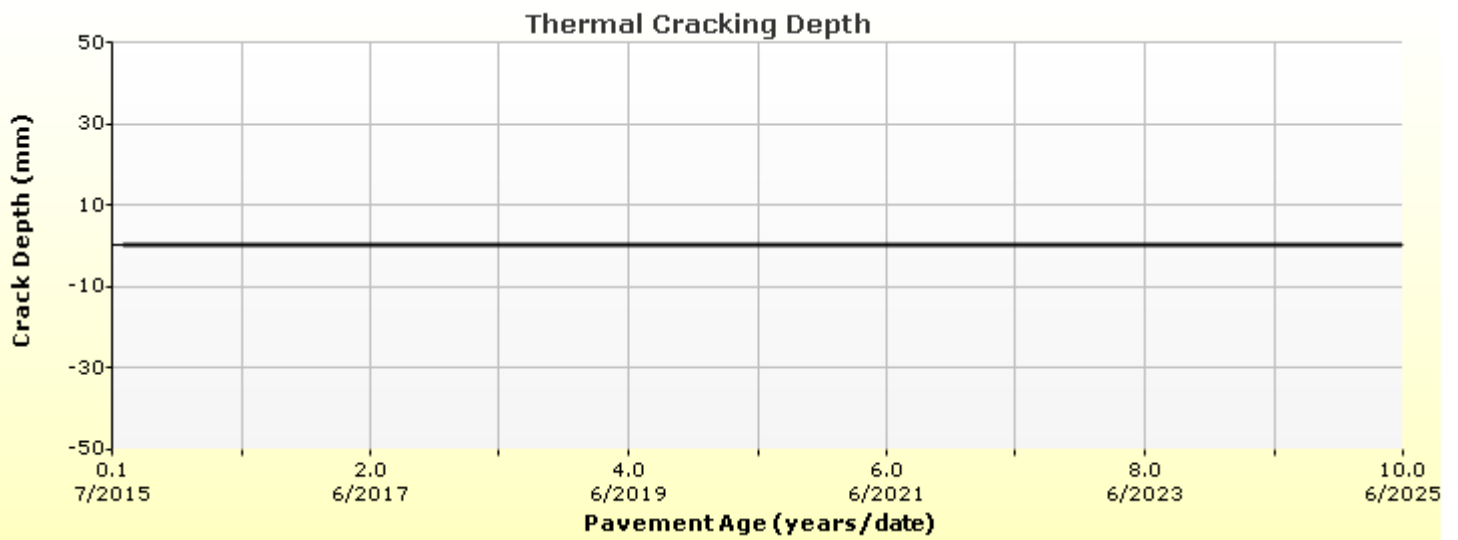
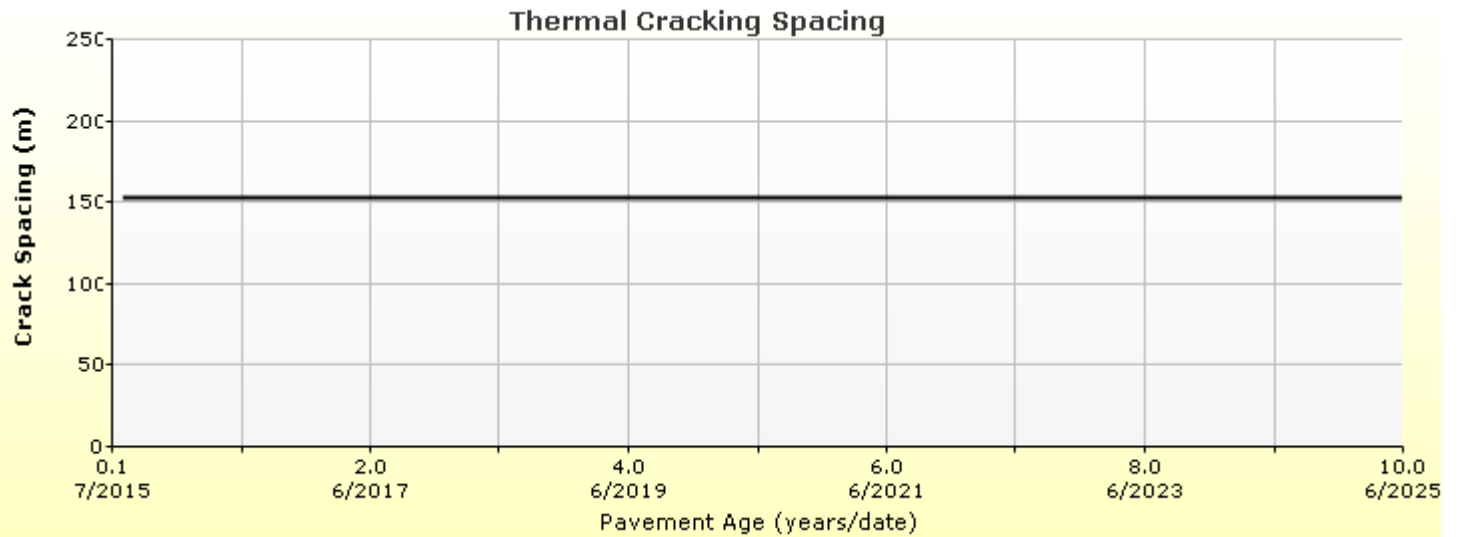


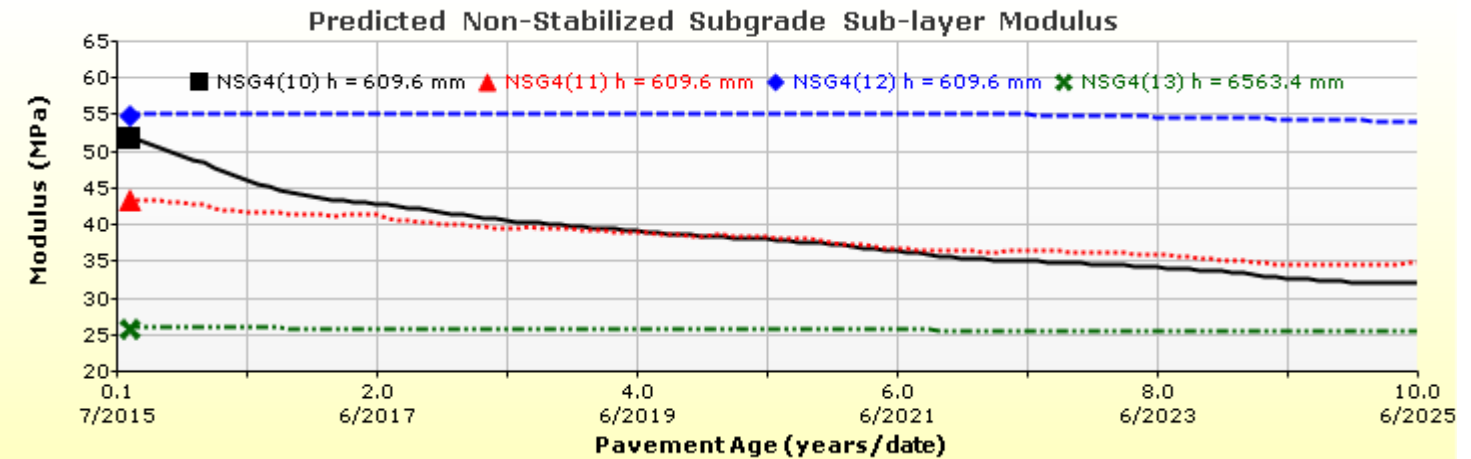
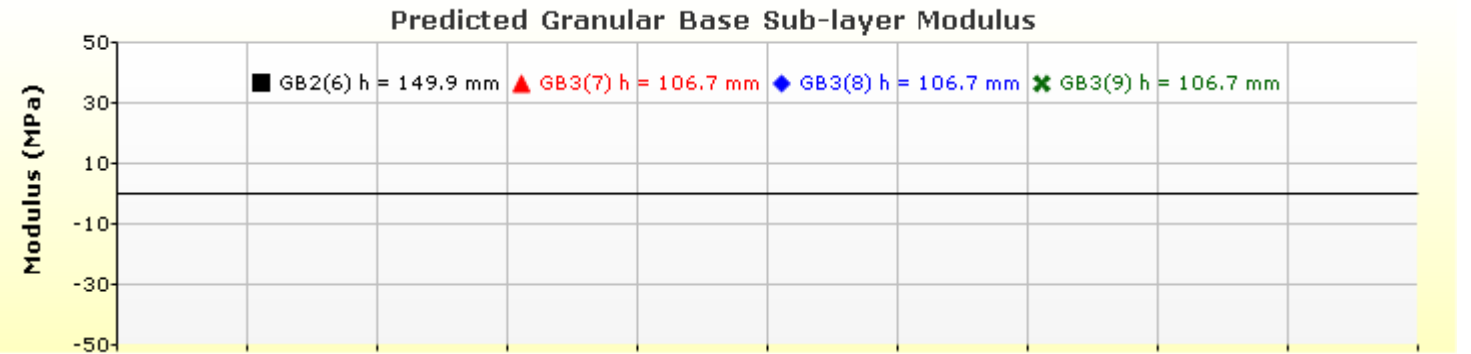
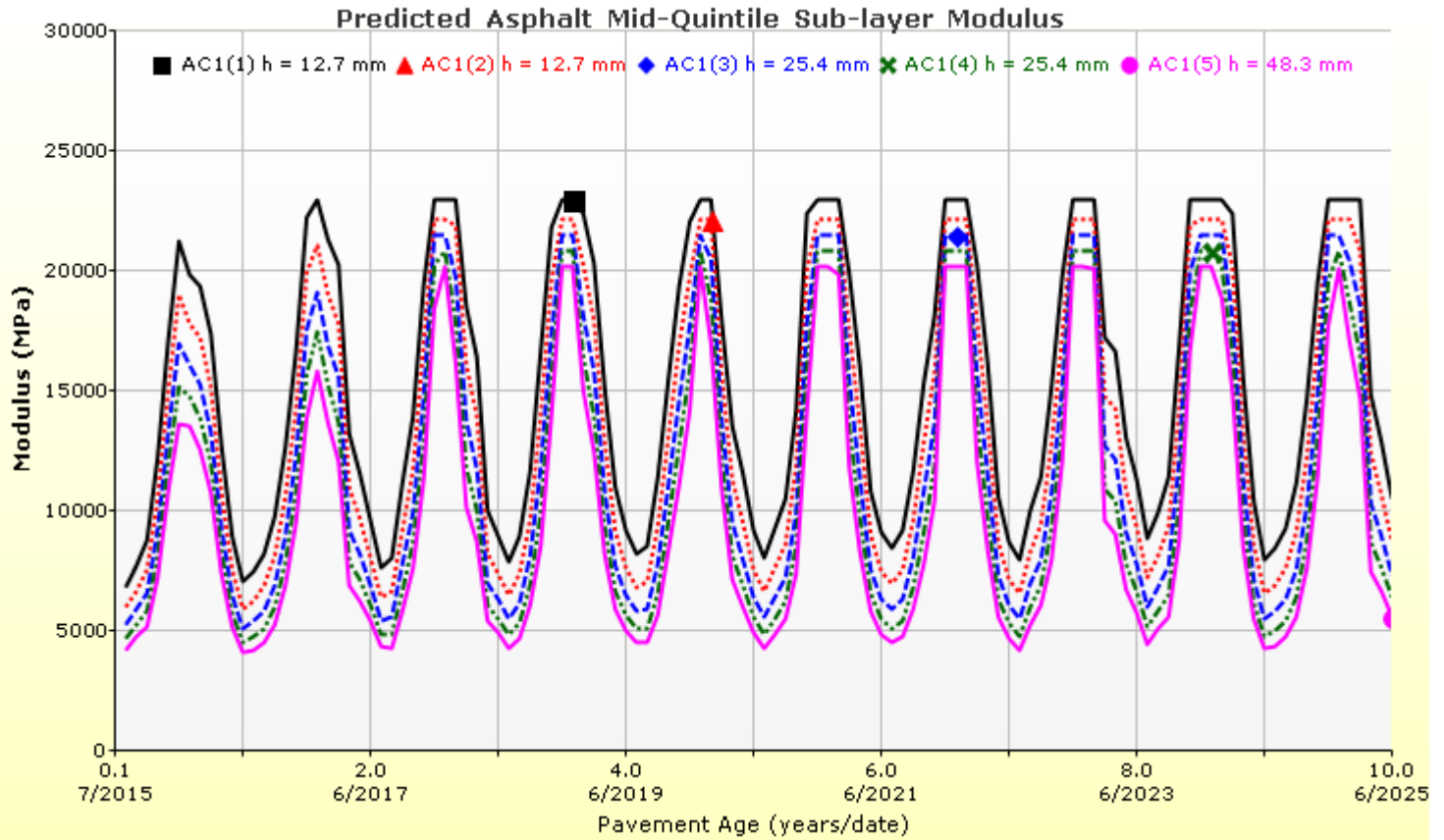
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

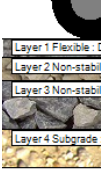
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

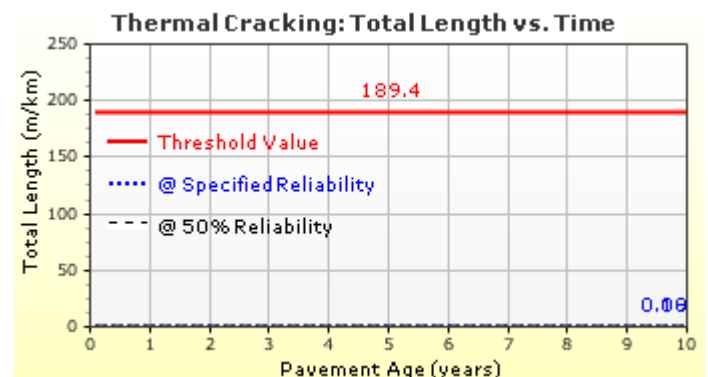
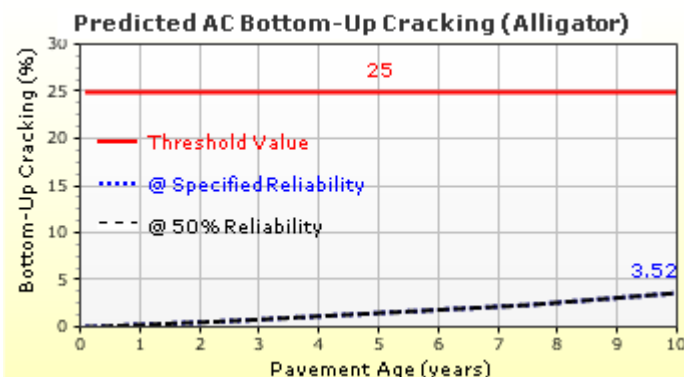
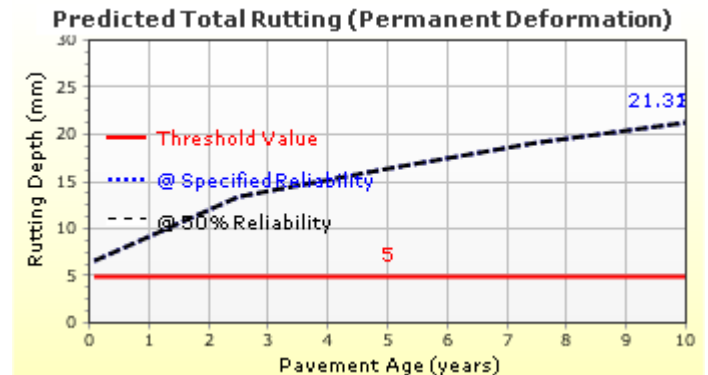
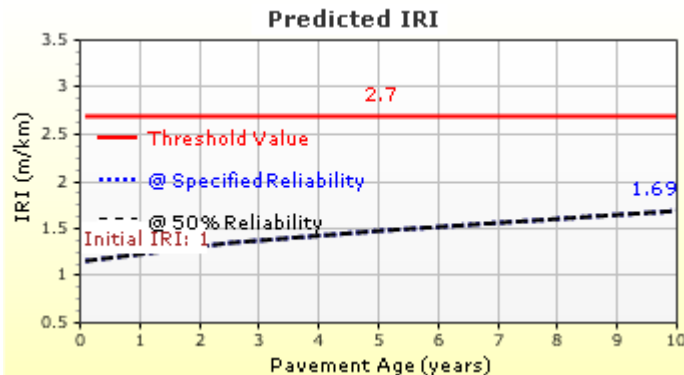
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.69	50.00	98.22	Pass
Permanent deformation - total pavement (mm)	5.00	21.32	50.00	0.01	Fail
AC bottom-up fatigue cracking (percent)	25.00	3.52	50.00	93.86	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	126.33	50.00	73.61	Pass
Permanent deformation - AC only (mm)	5.00	15.63	50.00	0.53	Fail

Distress Charts

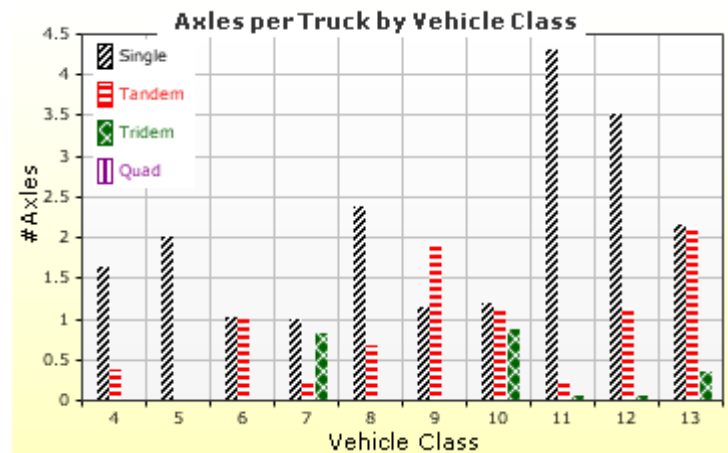
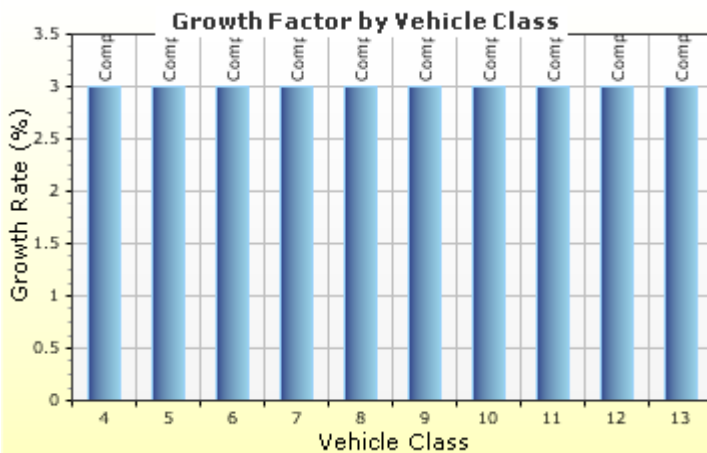
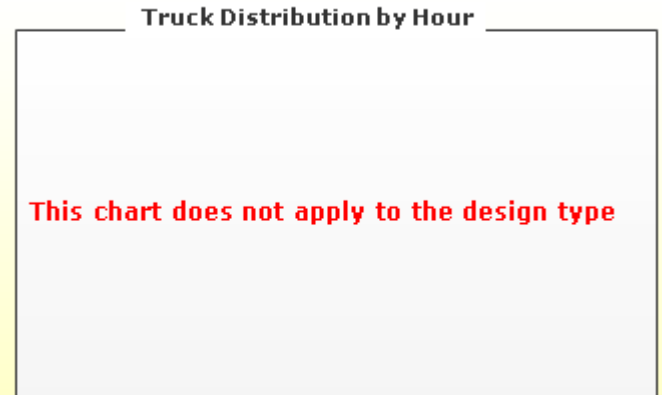
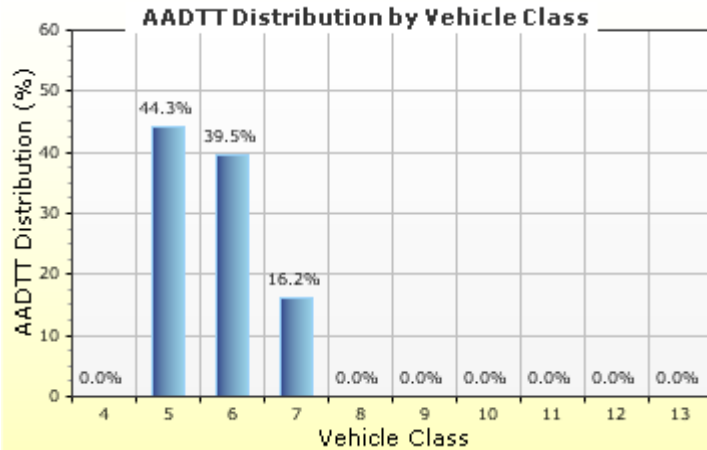


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

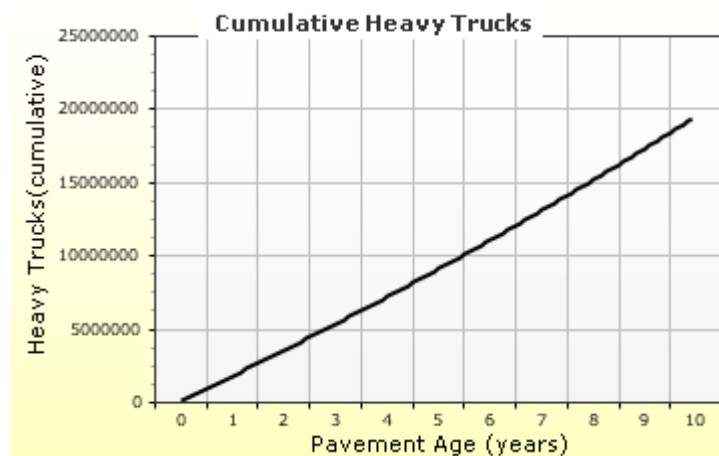
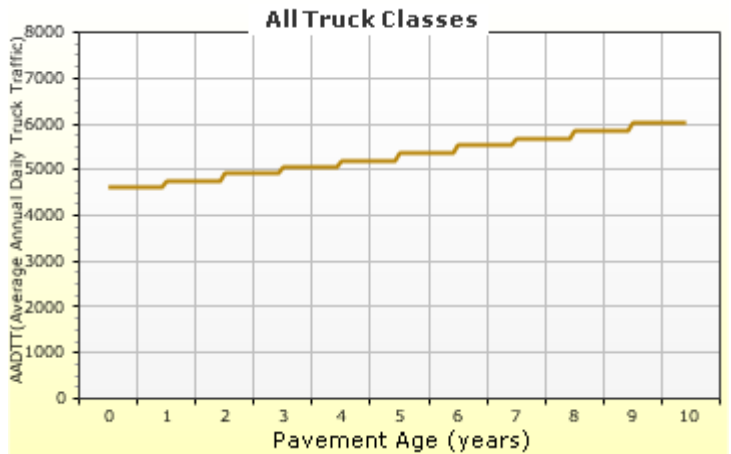
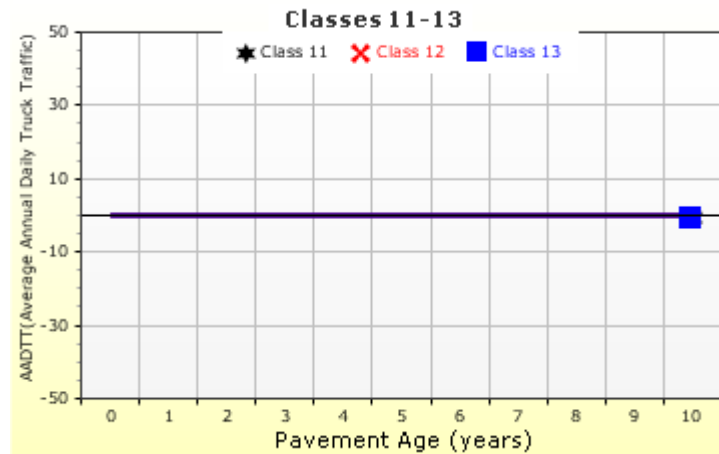
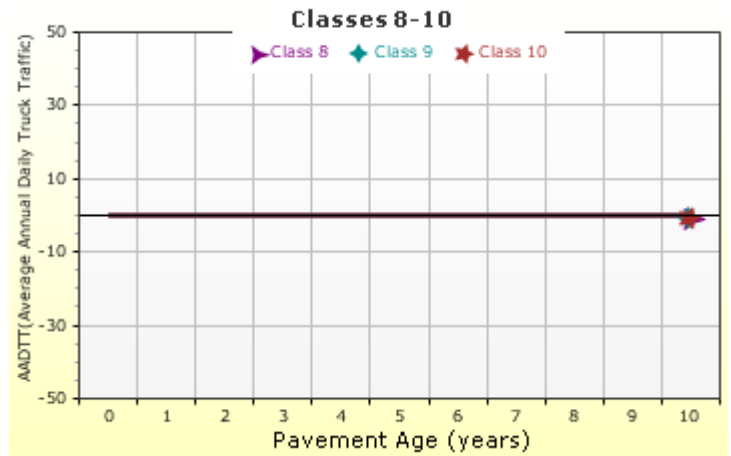
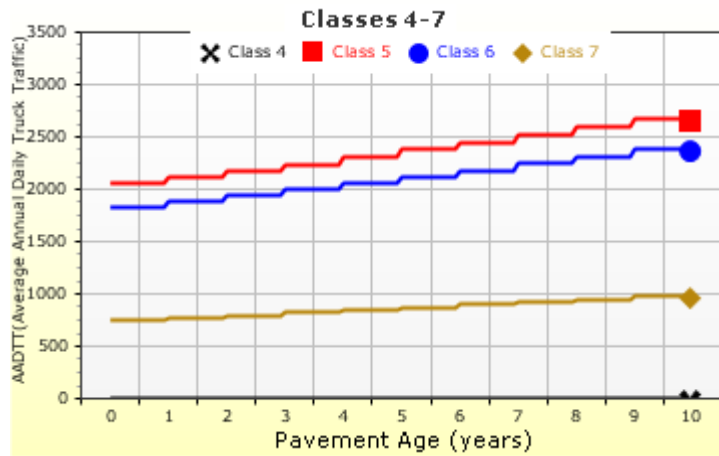
Wheelbase does not apply

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



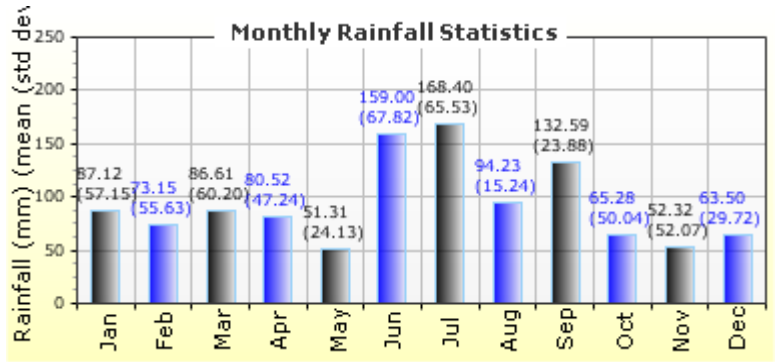
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

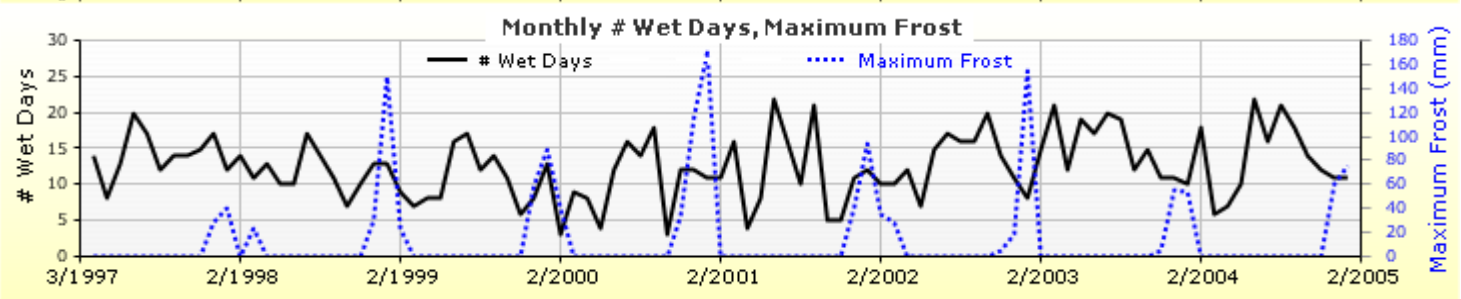
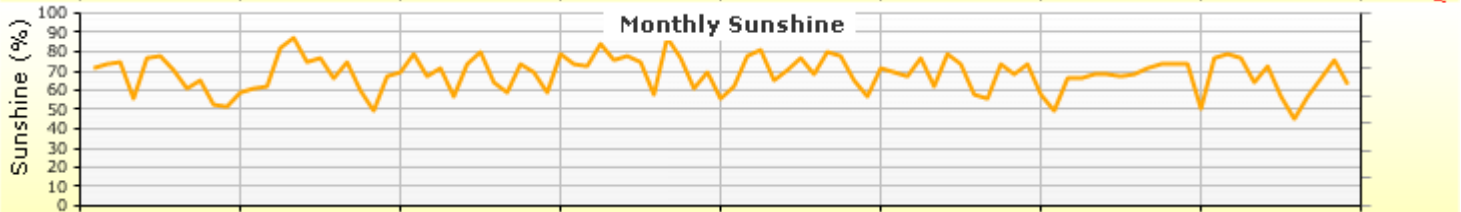
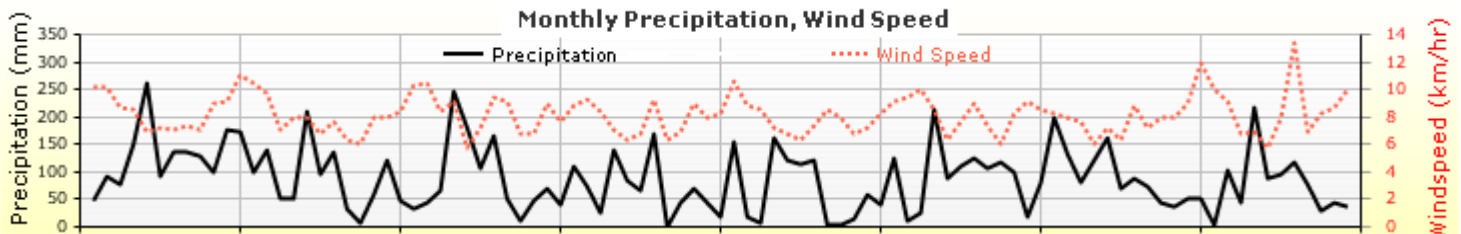
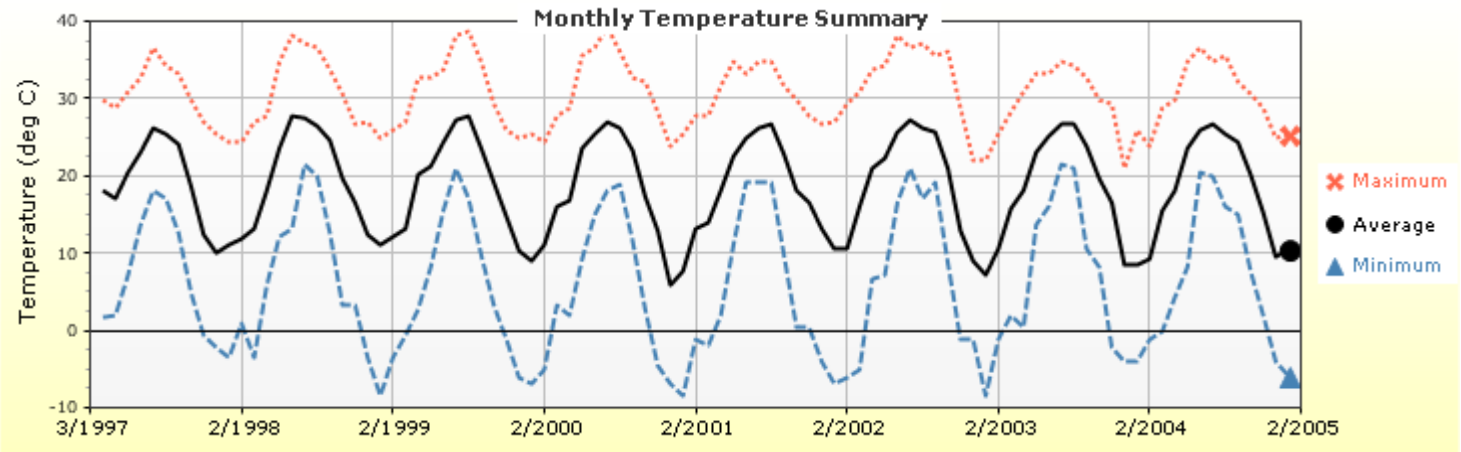
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

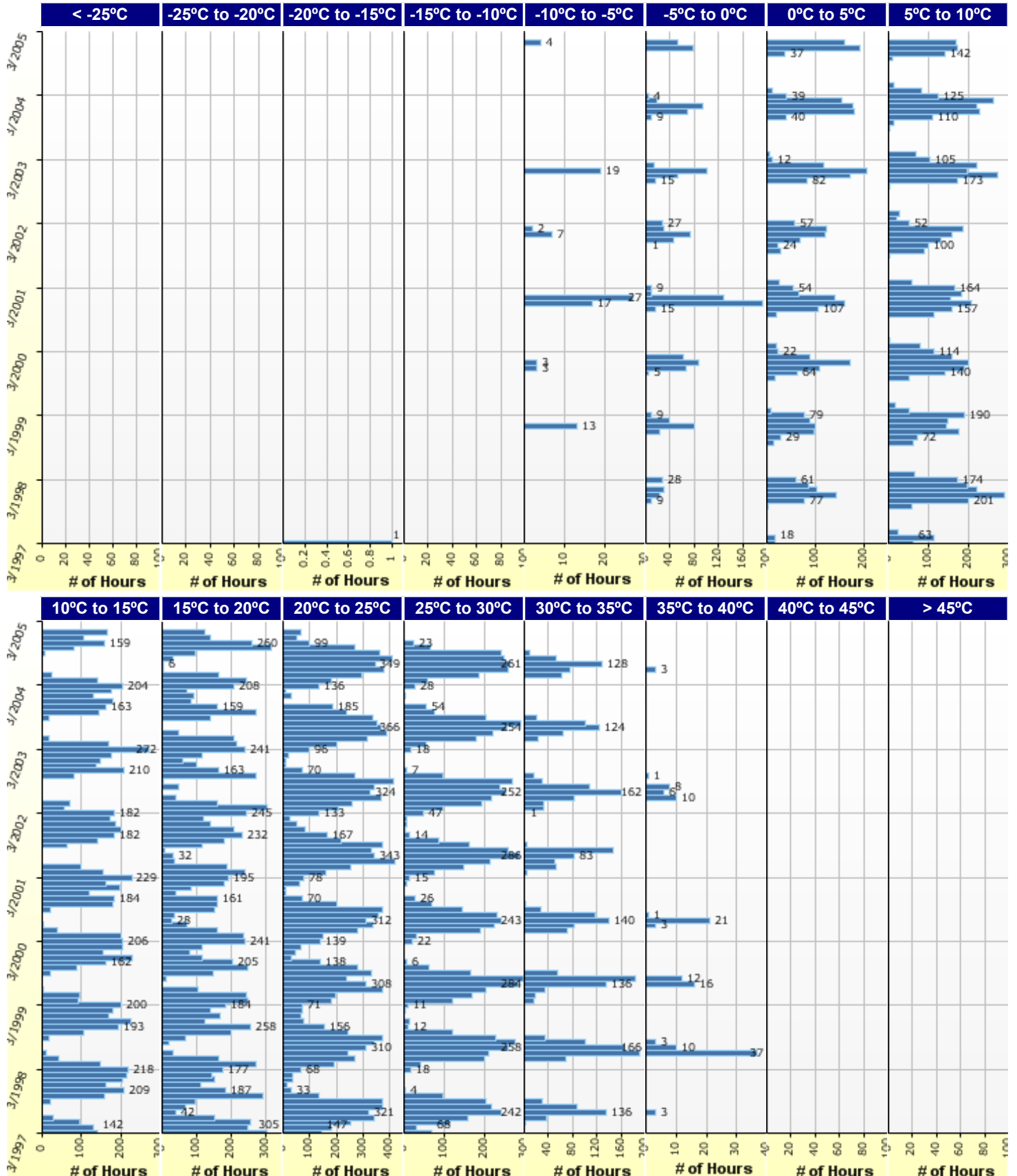


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF1_ALT2

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1_ALT2.dgpx



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

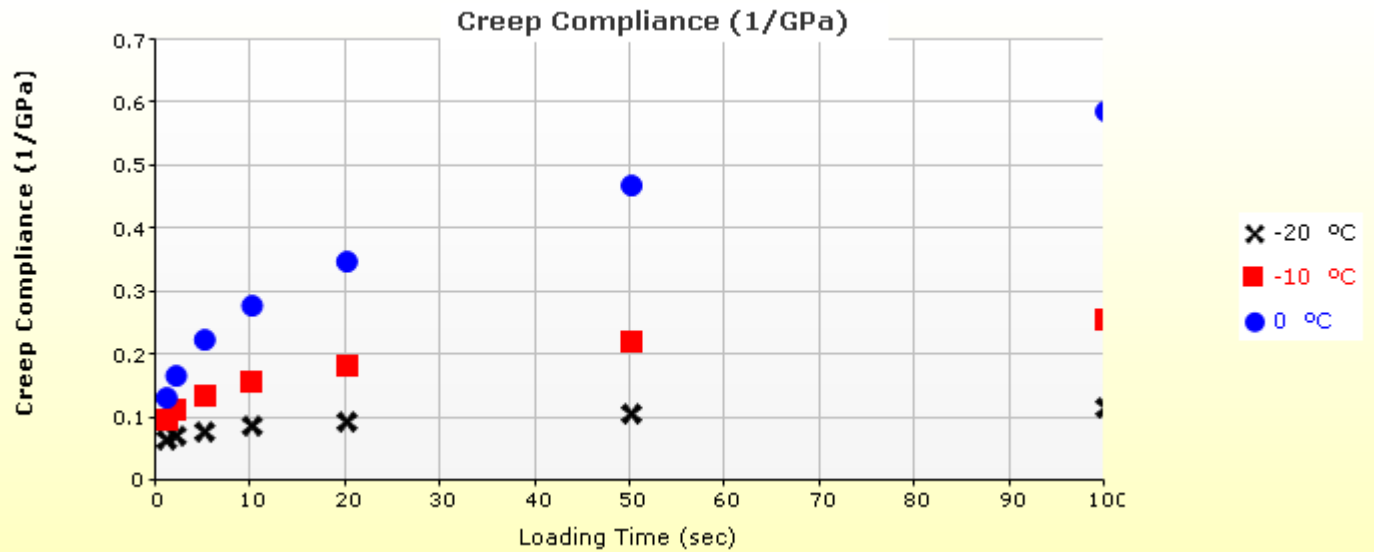
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

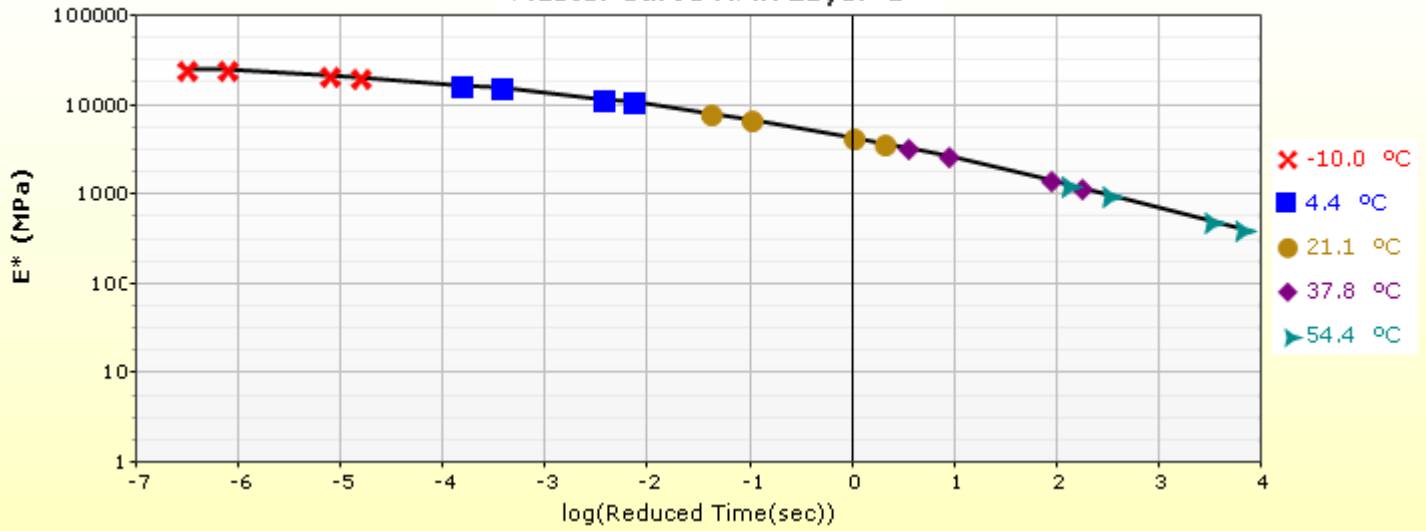
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

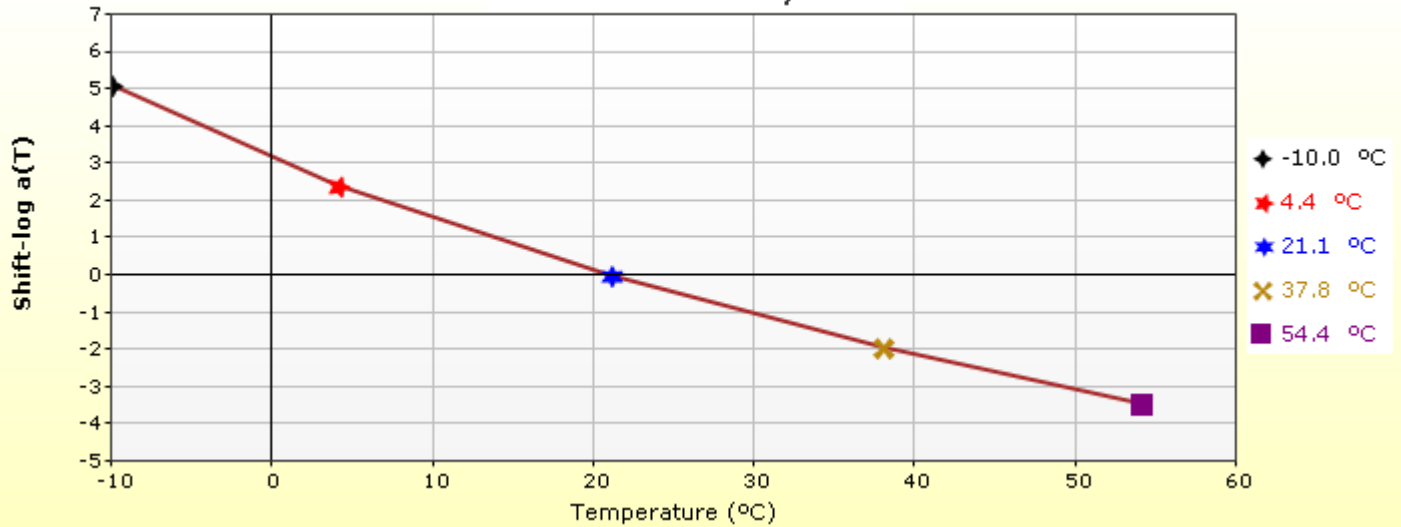


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

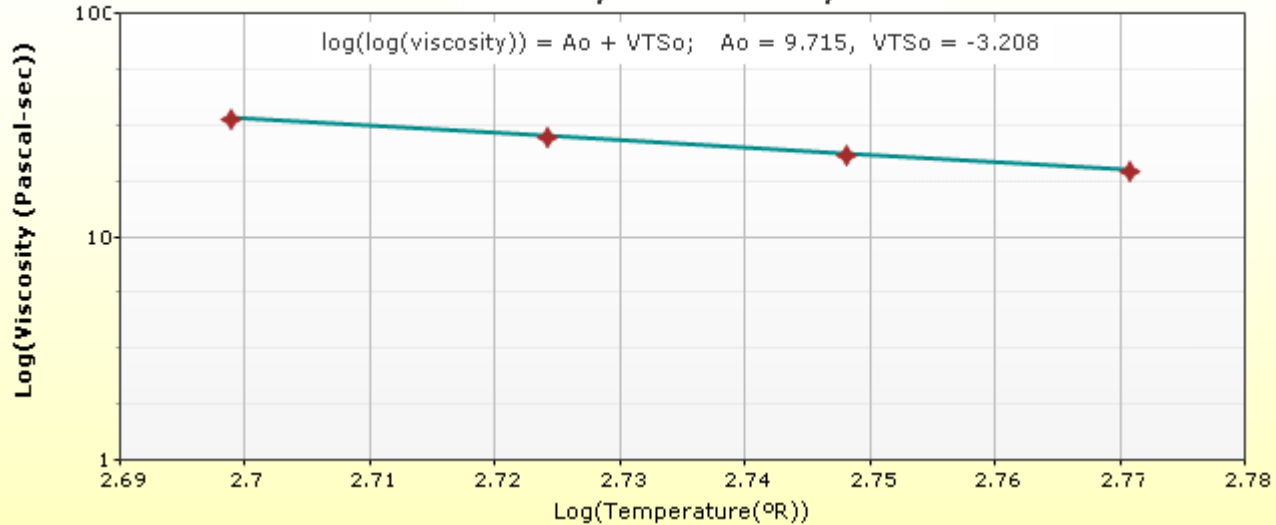
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

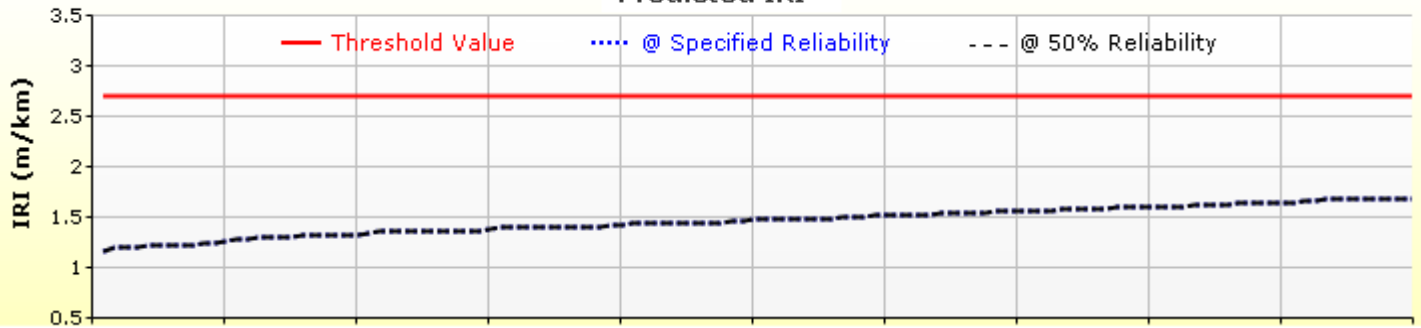


Viscosity Curve HMA Layer 1

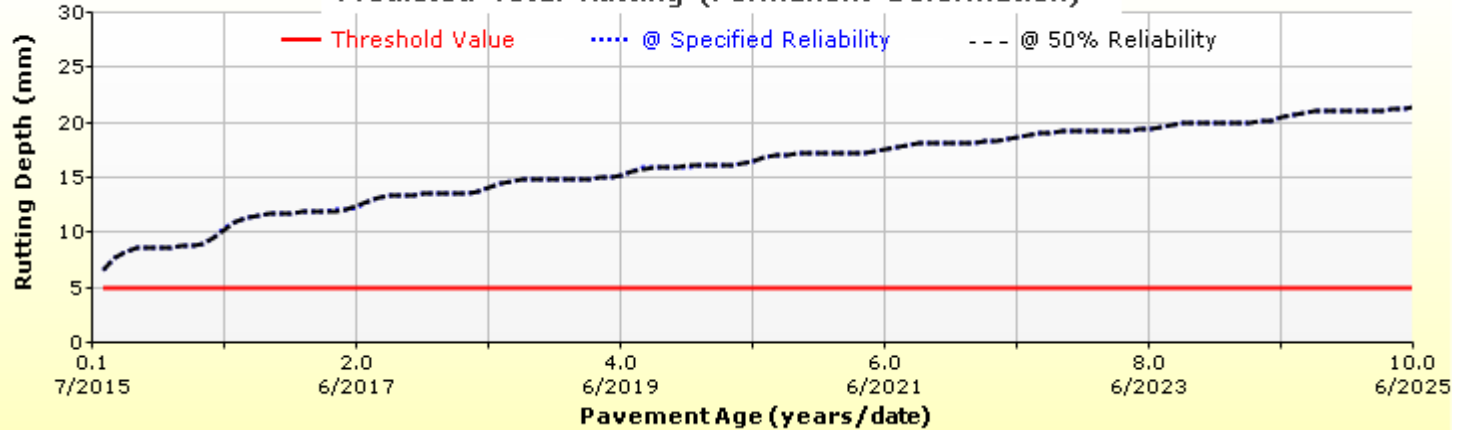


Analysis Output Charts

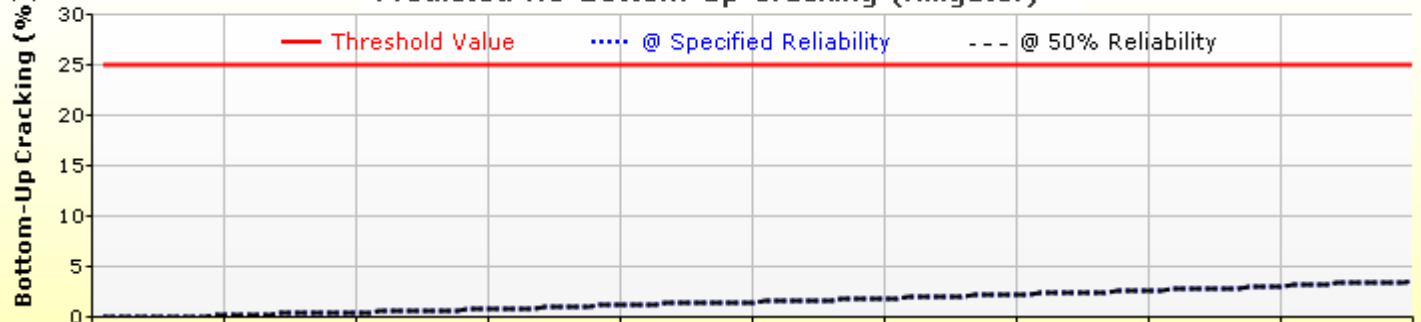
Predicted IRI



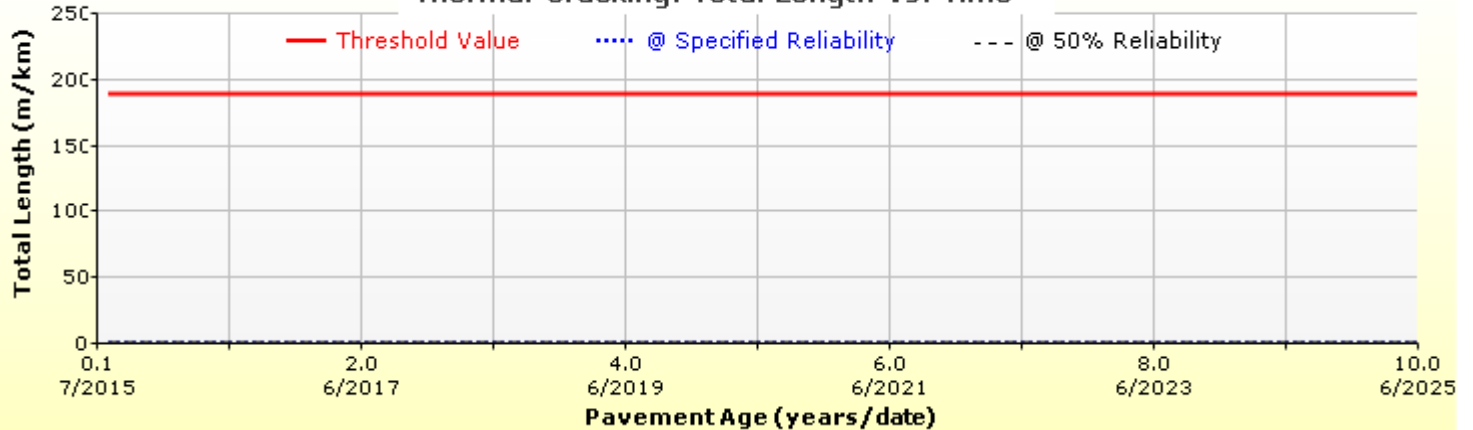
Predicted Total Rutting (Permanent Deformation)



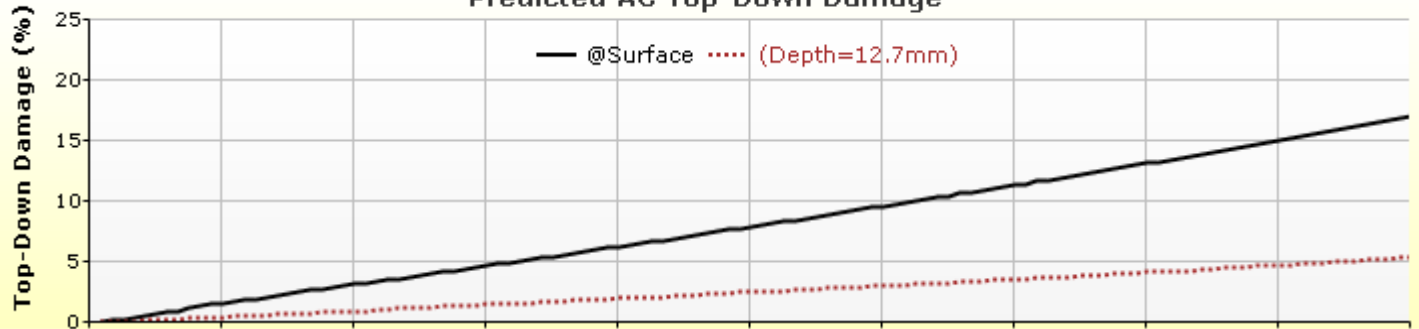
Predicted AC Bottom-Up Cracking (Alligator)



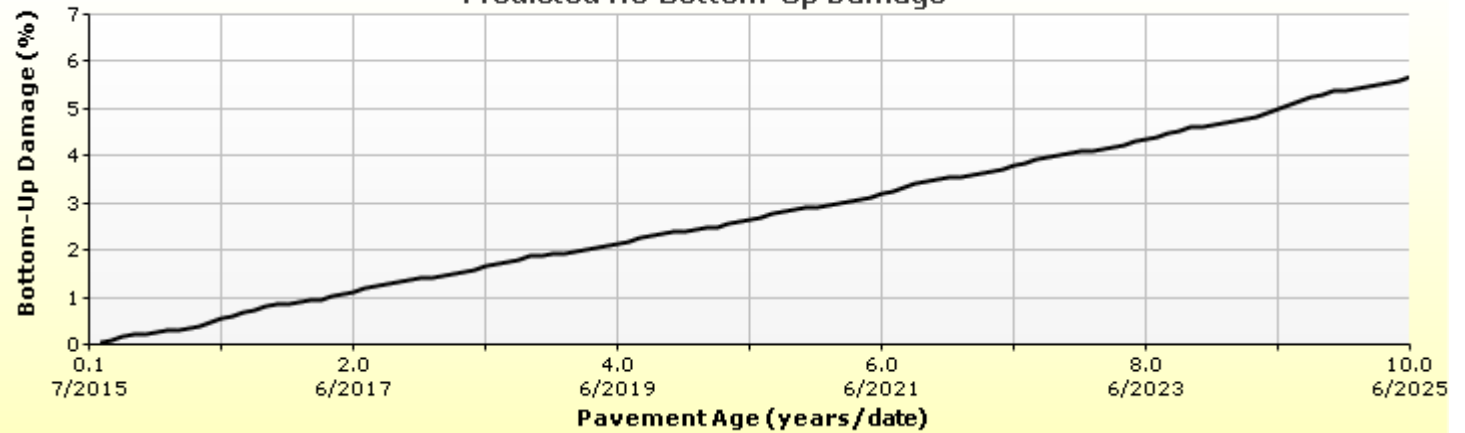
Thermal Cracking: Total Length vs. Time



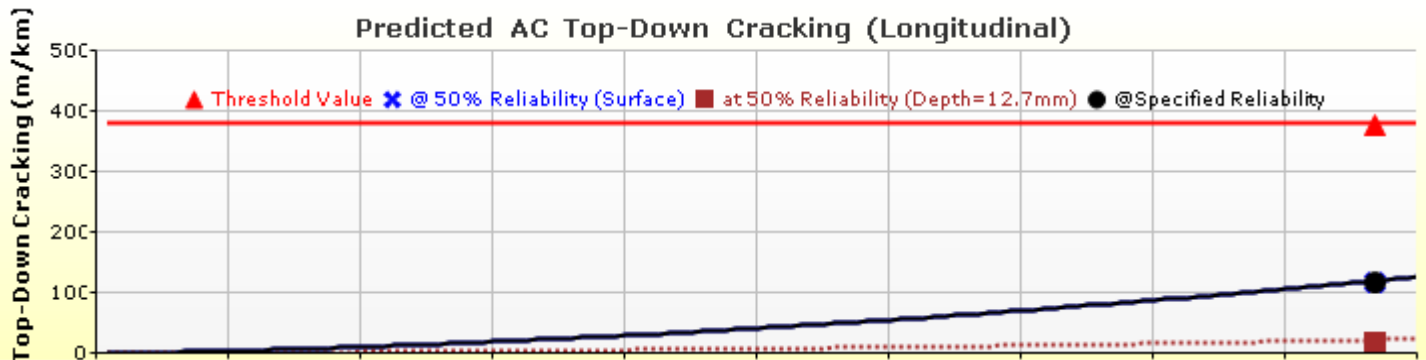
Predicted AC Top-Down Damage



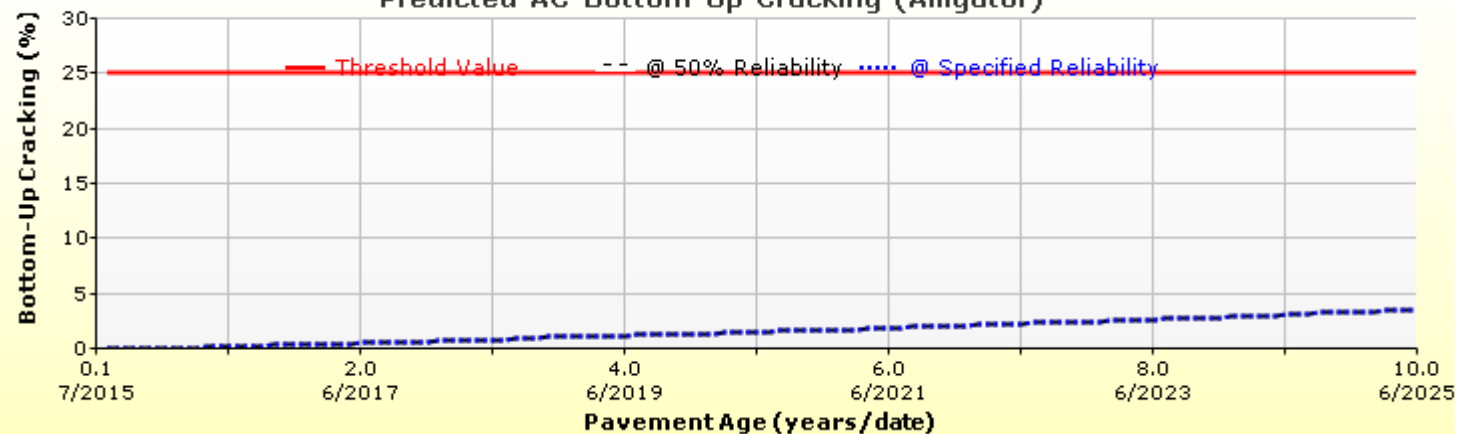
Predicted AC Bottom-Up Damage



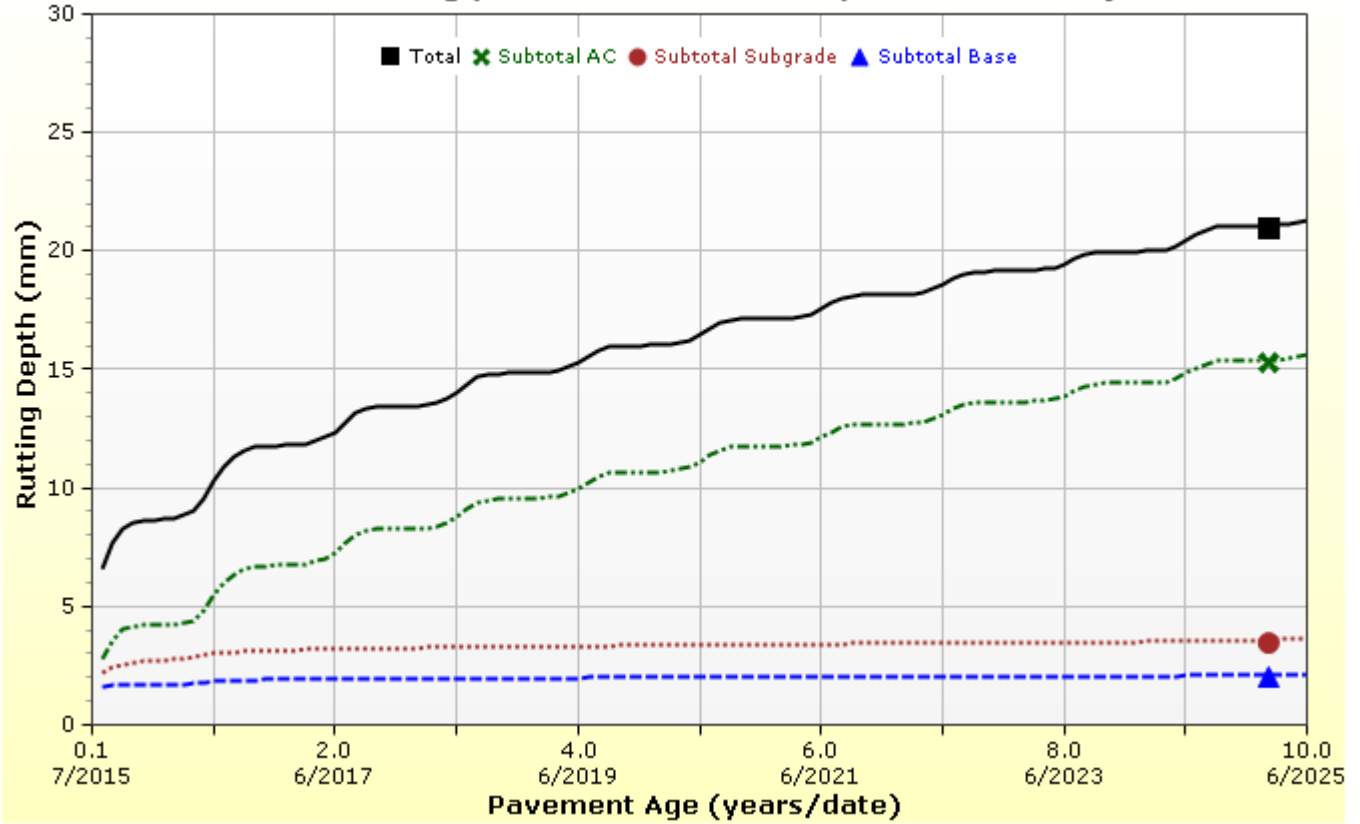
Predicted AC Top-Down Cracking (Longitudinal)

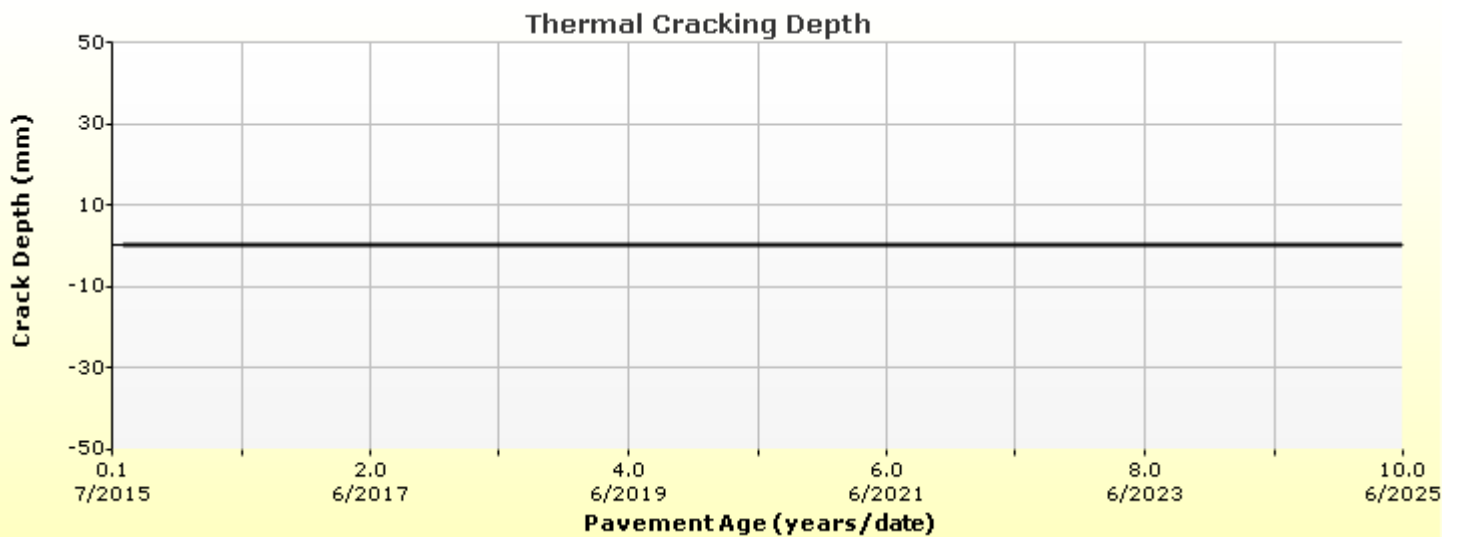
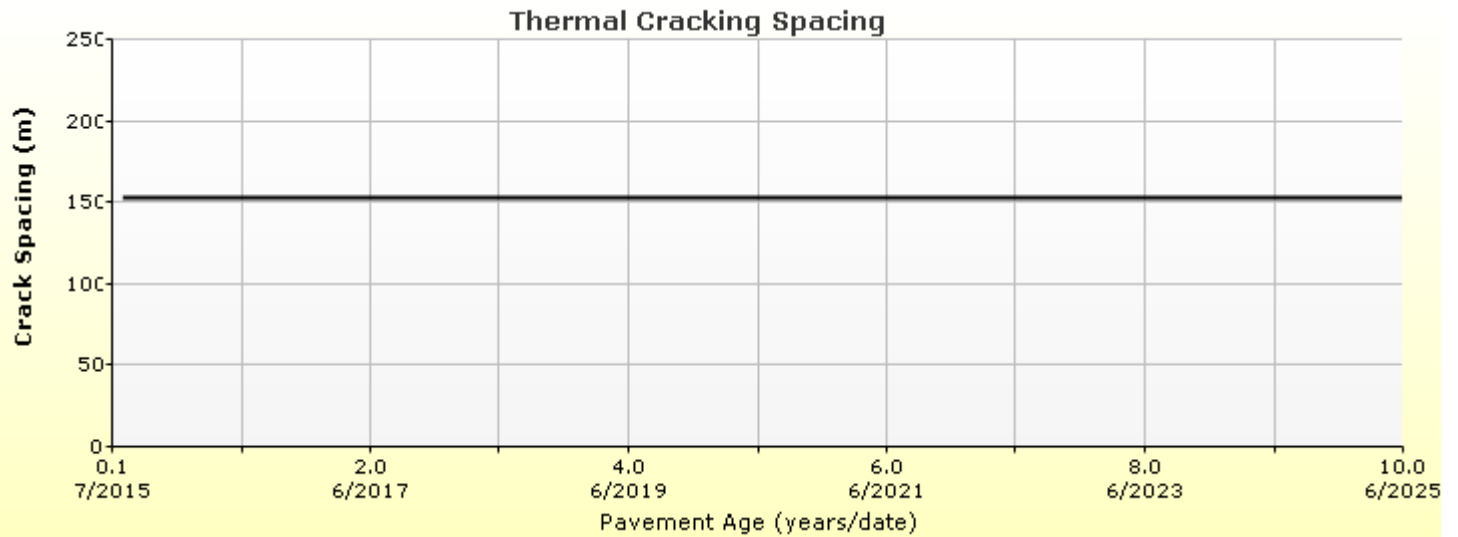


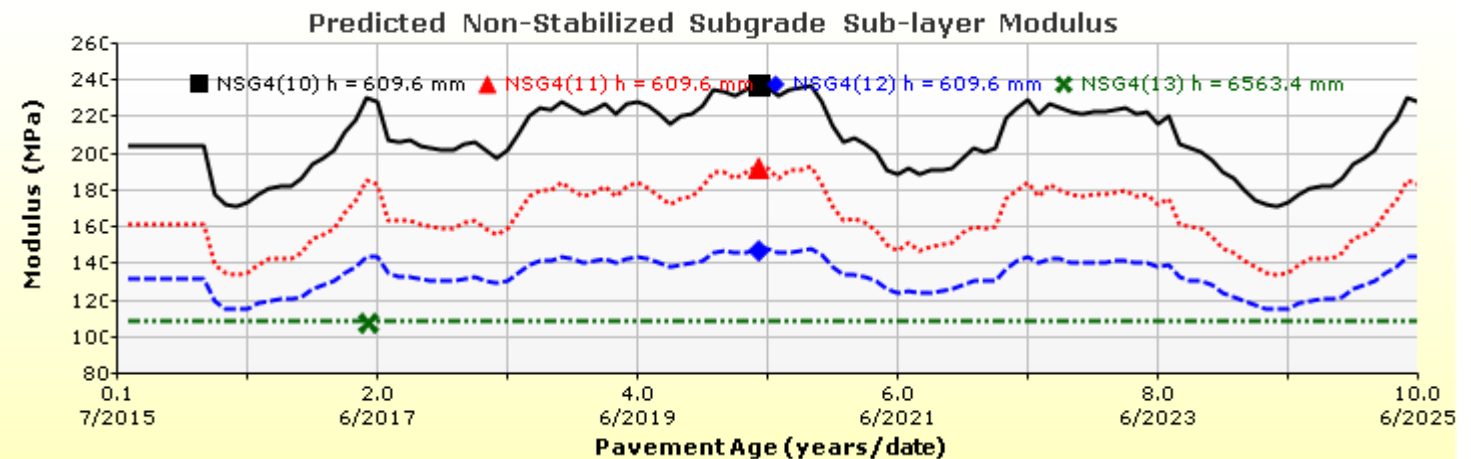
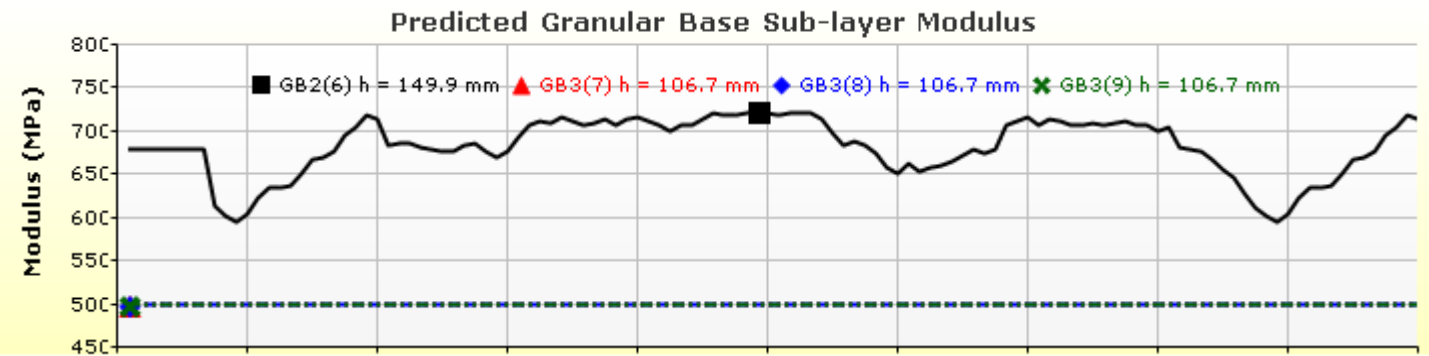
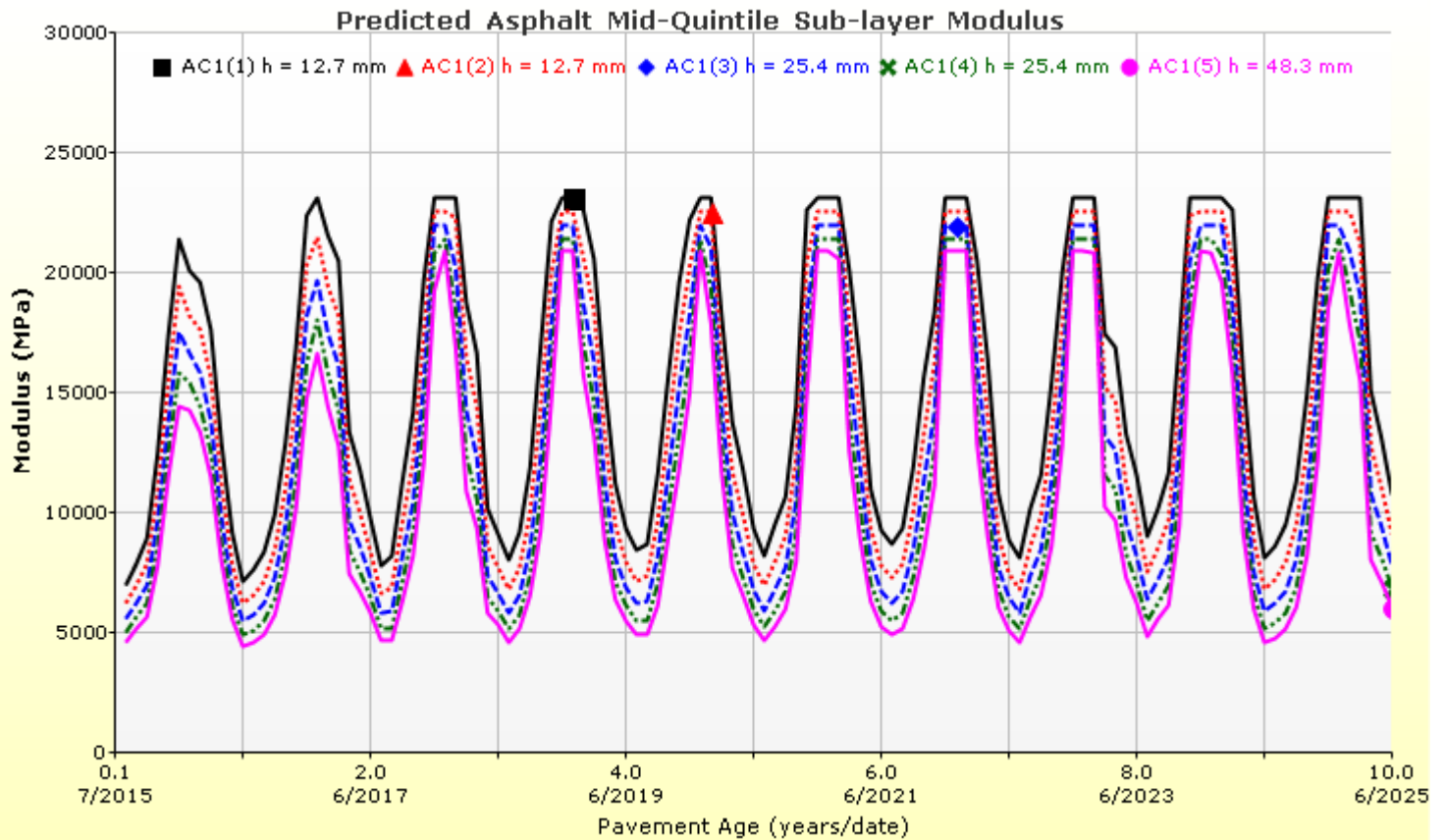
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)
500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

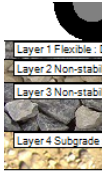
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)	Volumetric at Construction:	
Flexible	Default asphalt concrete	125.0	Effective binder content (%)	11.6
NonStabilized	Crushed stone	150.0	Air voids (%)	7.0
NonStabilized	Crushed stone	320.0		
Subgrade	A-1-a	Semi-infinite		

Traffic

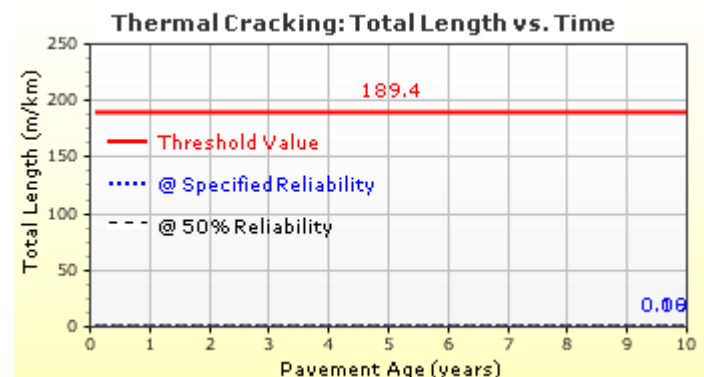
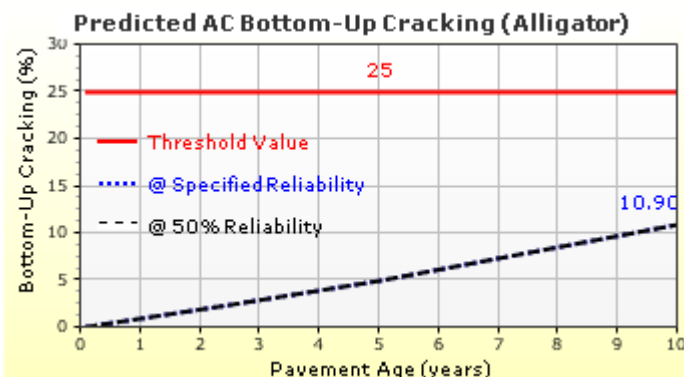
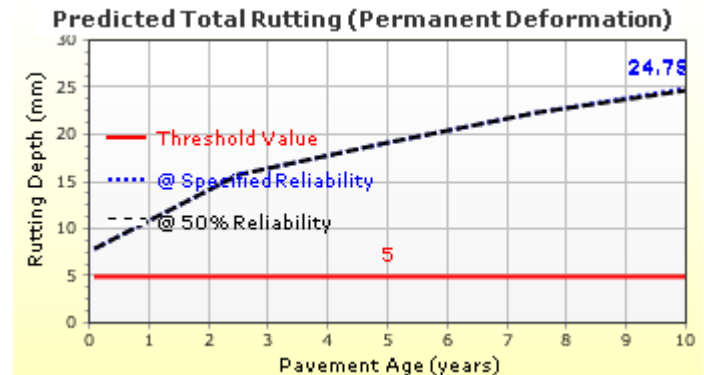
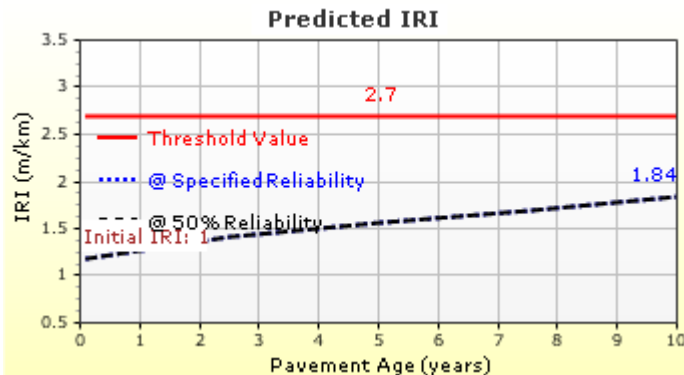
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.84	50.00	95.31	Pass
Permanent deformation - total pavement (mm)	5.00	24.78	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	10.90	50.00	84.08	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	428.03	50.00	45.54	Fail
Permanent deformation - AC only (mm)	5.00	18.09	50.00	0.25	Fail

Distress Charts

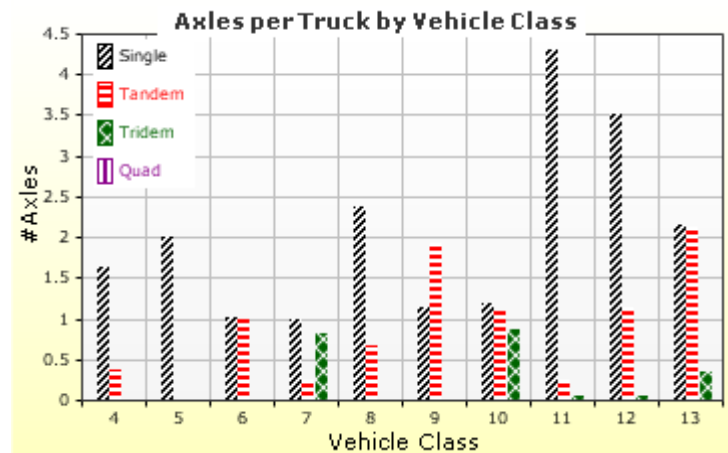
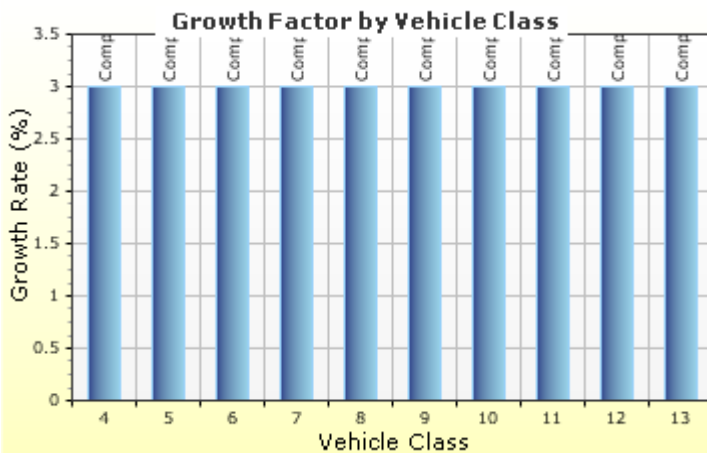
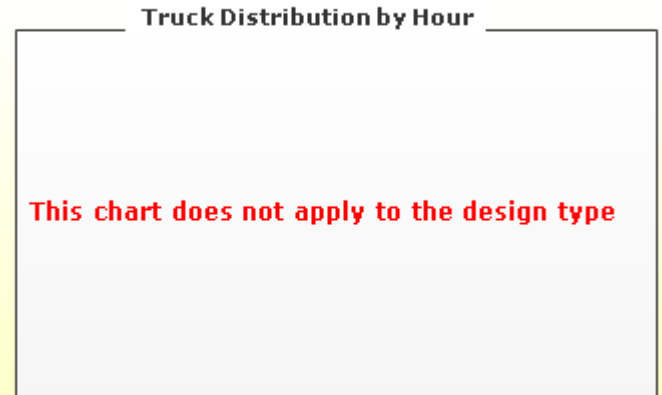
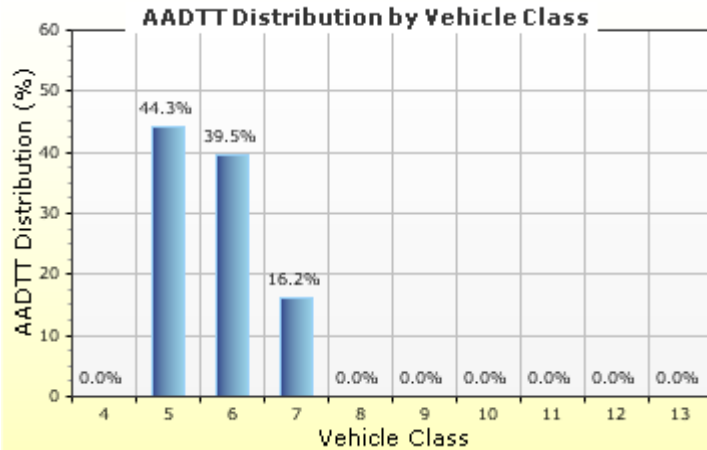


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

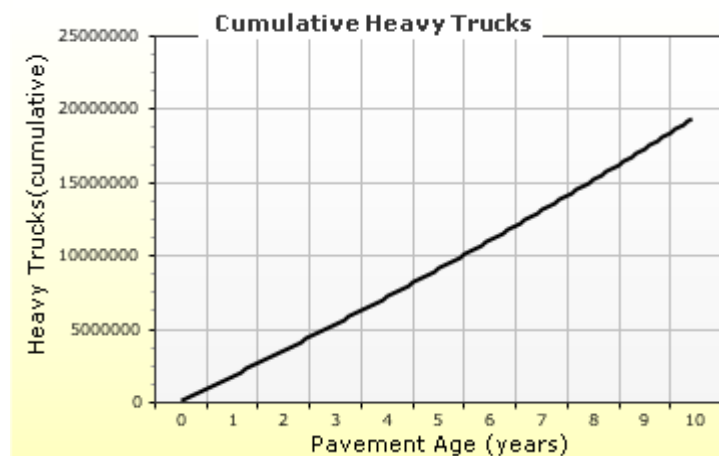
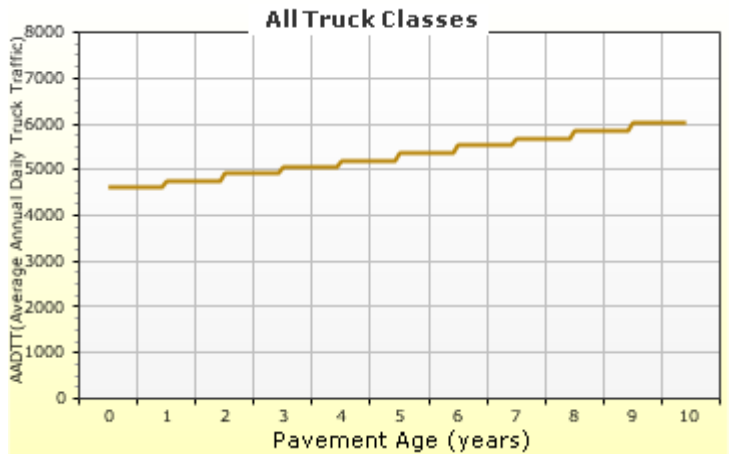
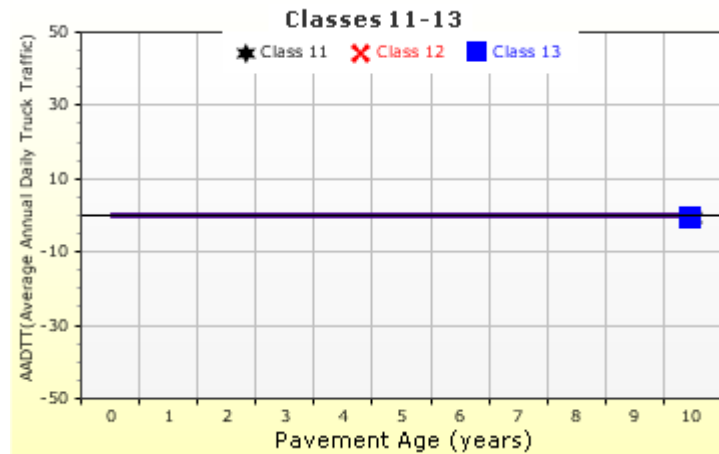
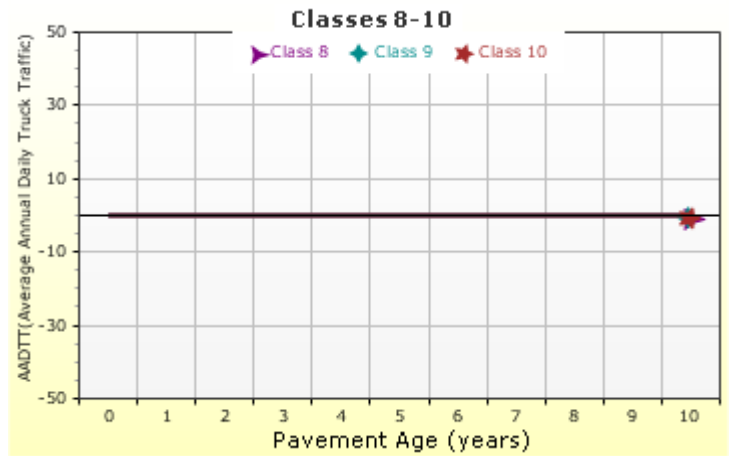
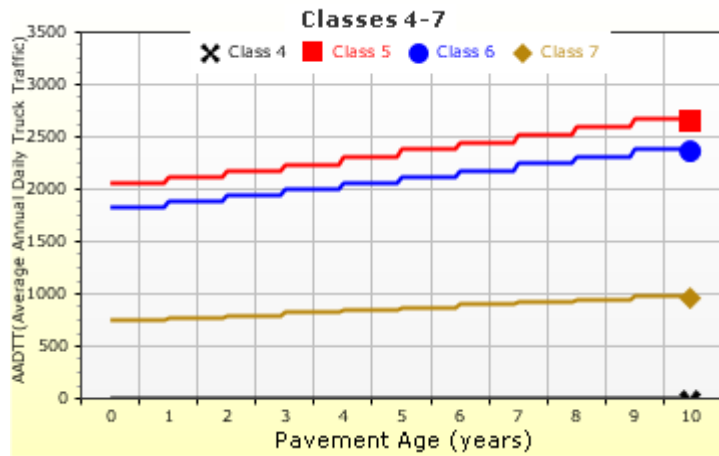
Wheelbase does not apply

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



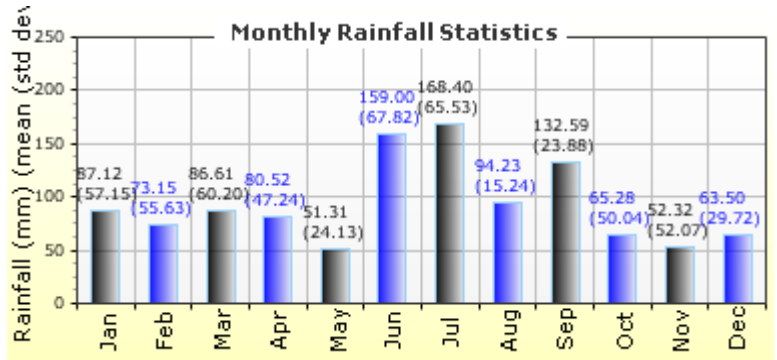
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

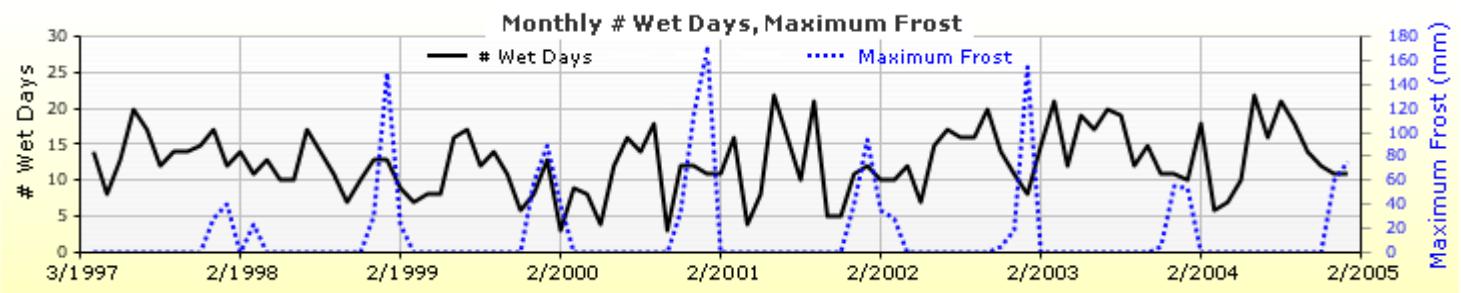
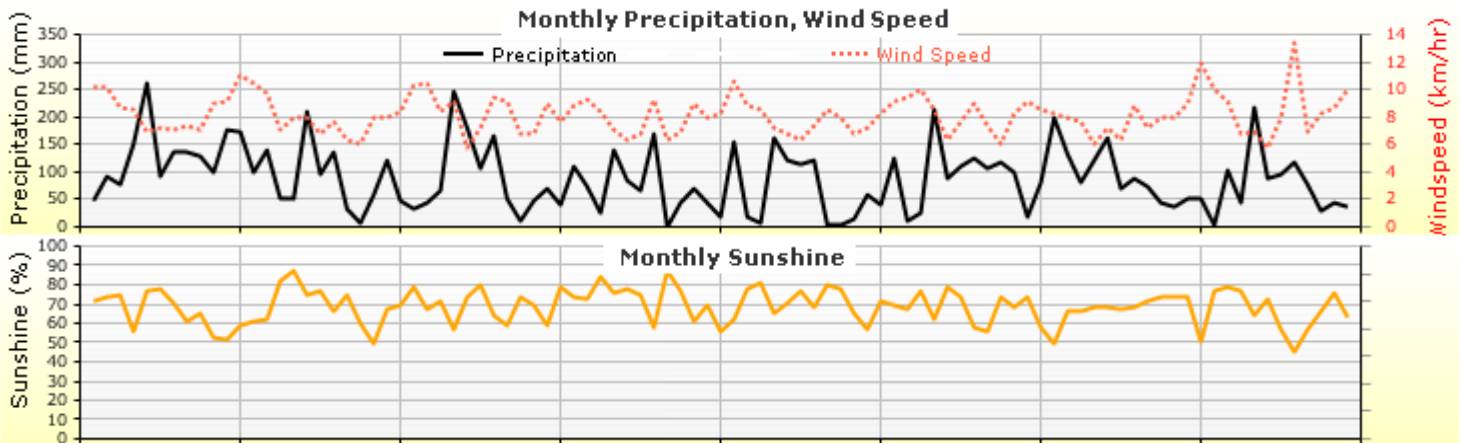
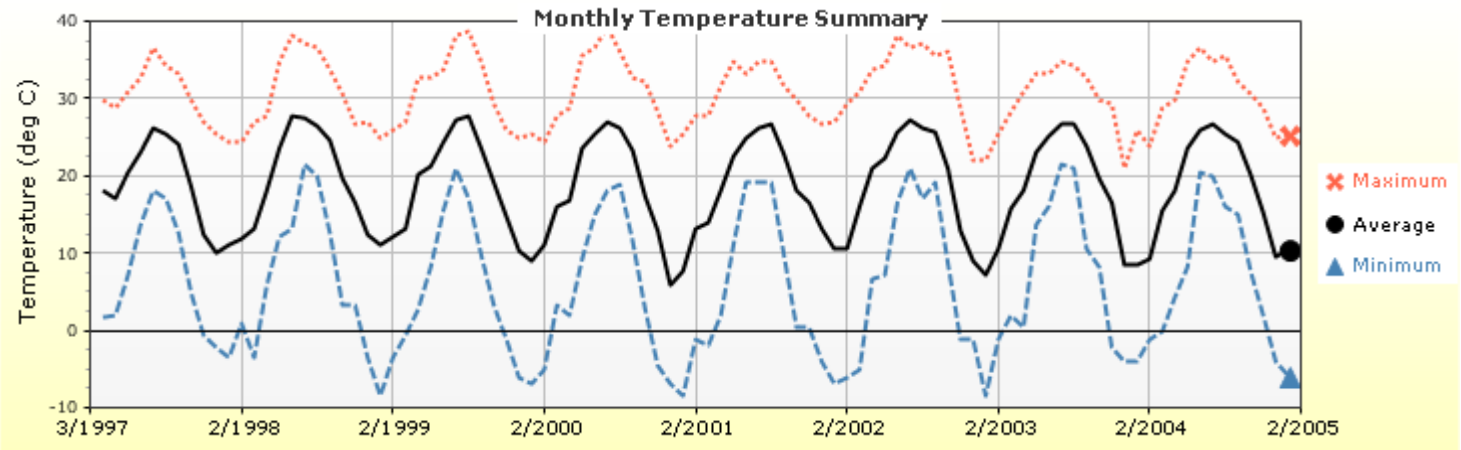
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

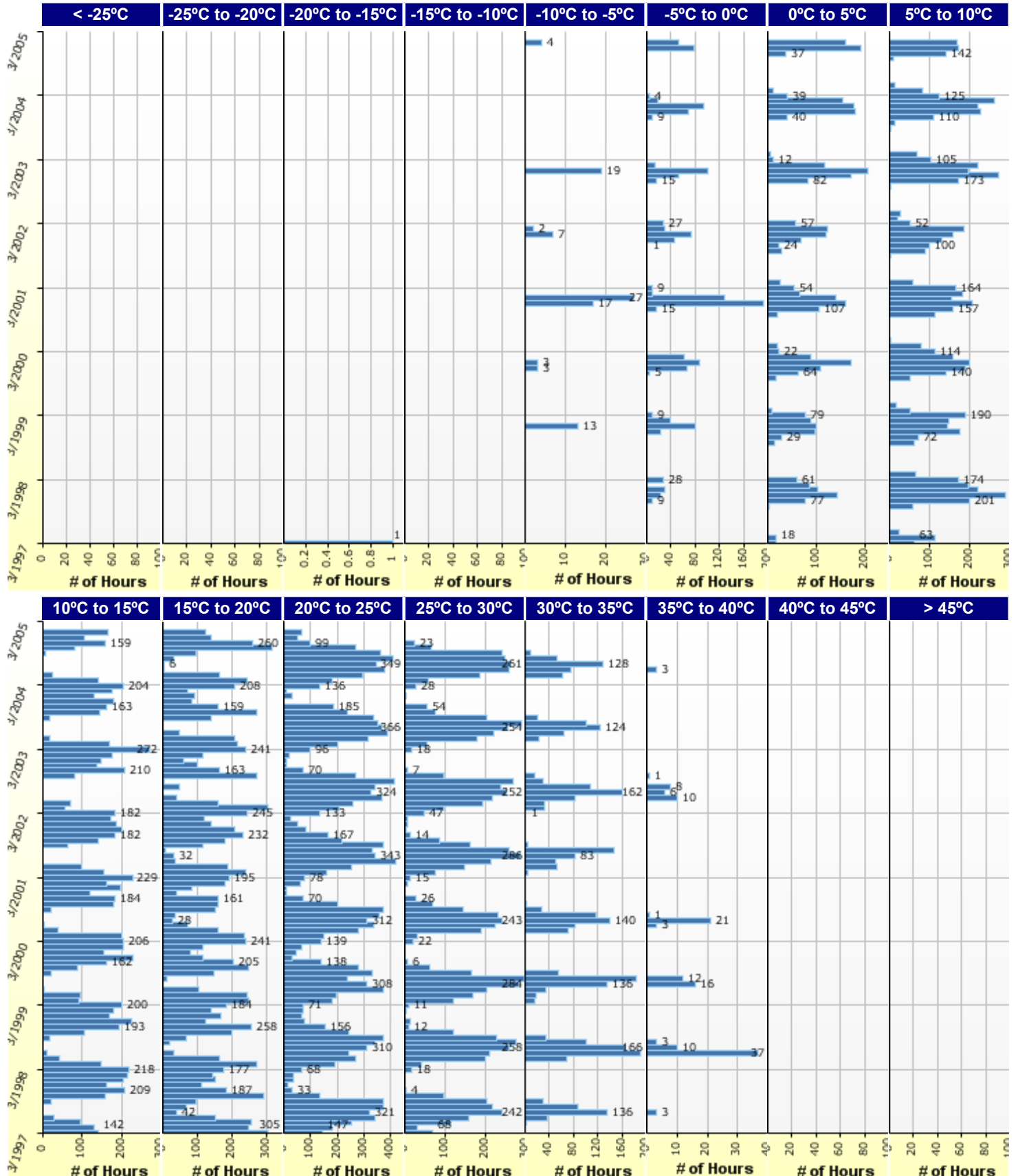


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF2_ALT2

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF2_ALT2.dgpx



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

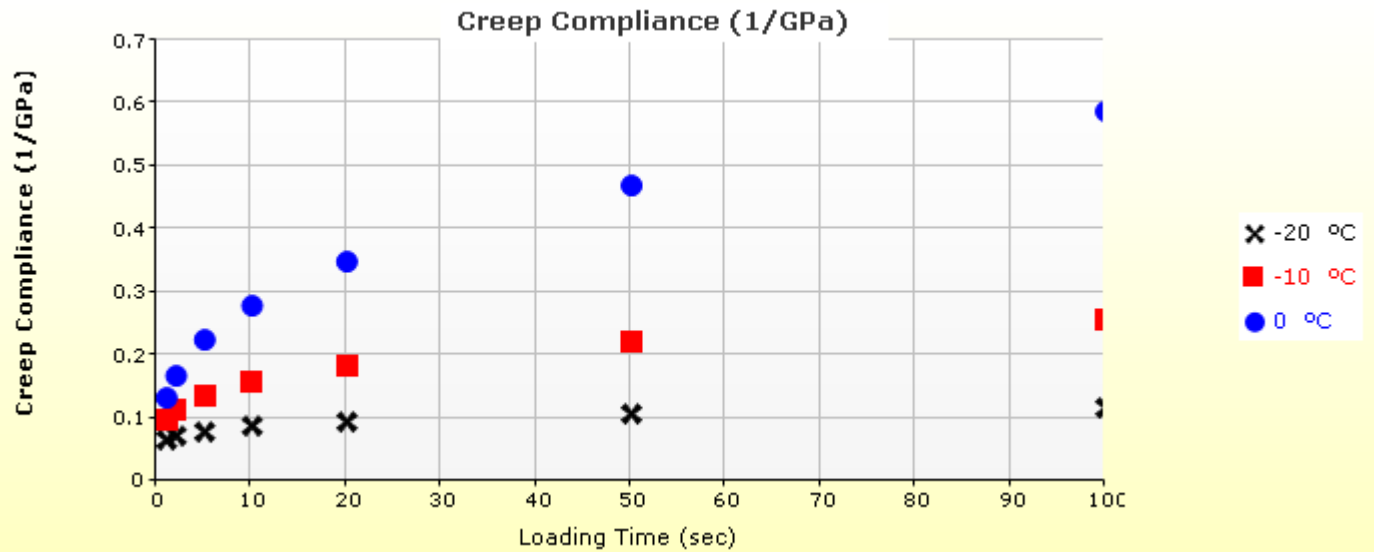
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

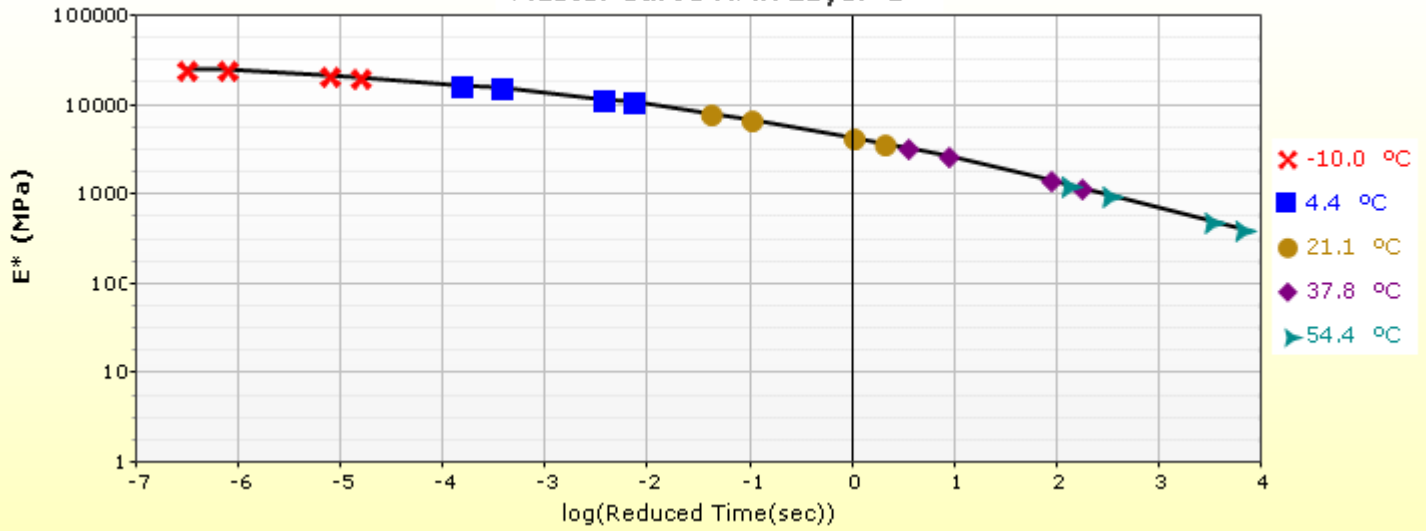
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

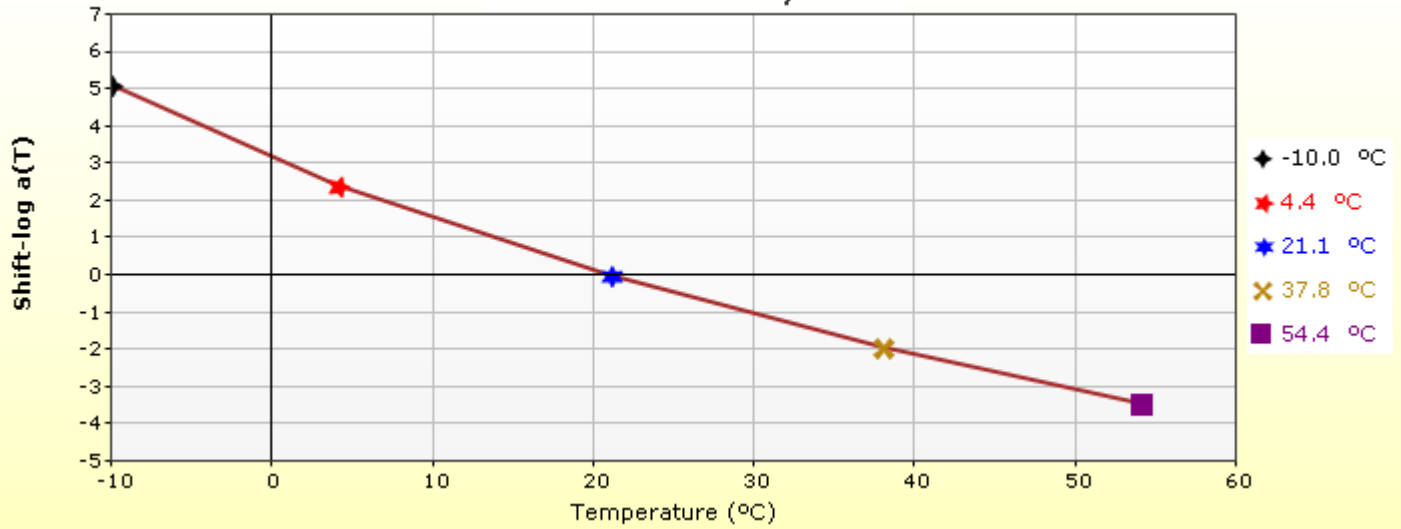


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

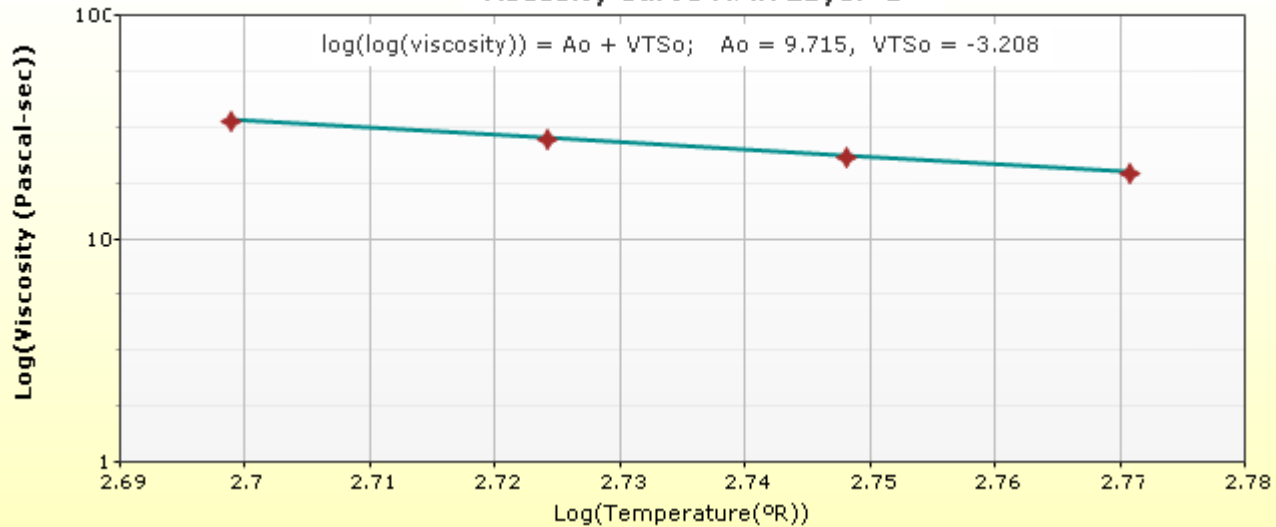
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

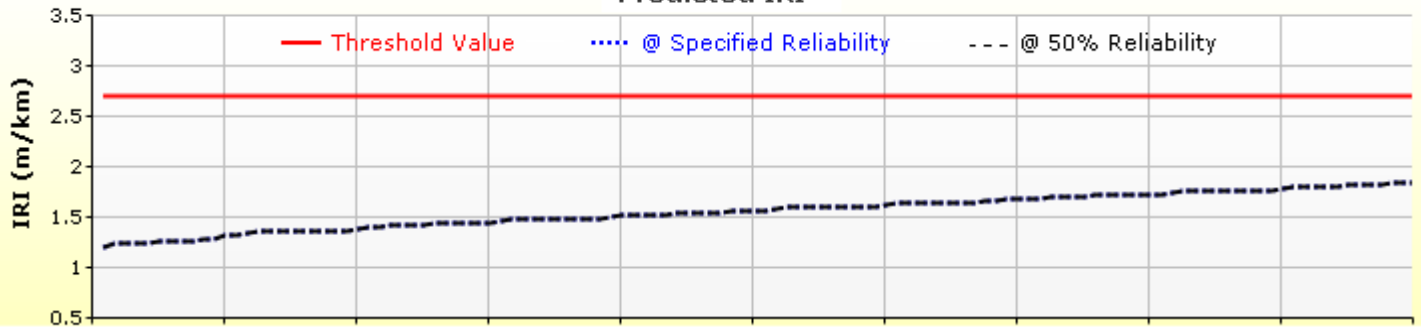


Viscosity Curve HMA Layer 1

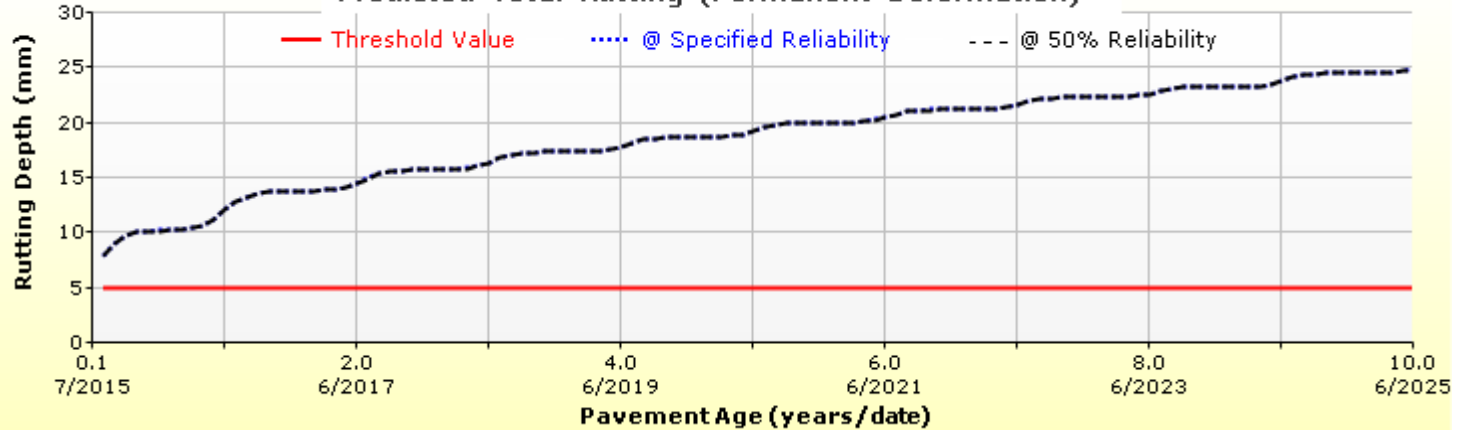


Analysis Output Charts

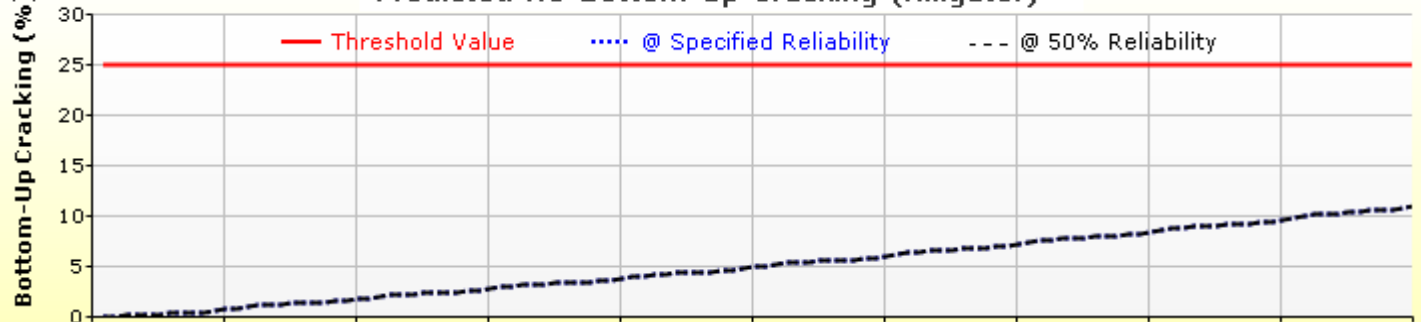
Predicted IRI



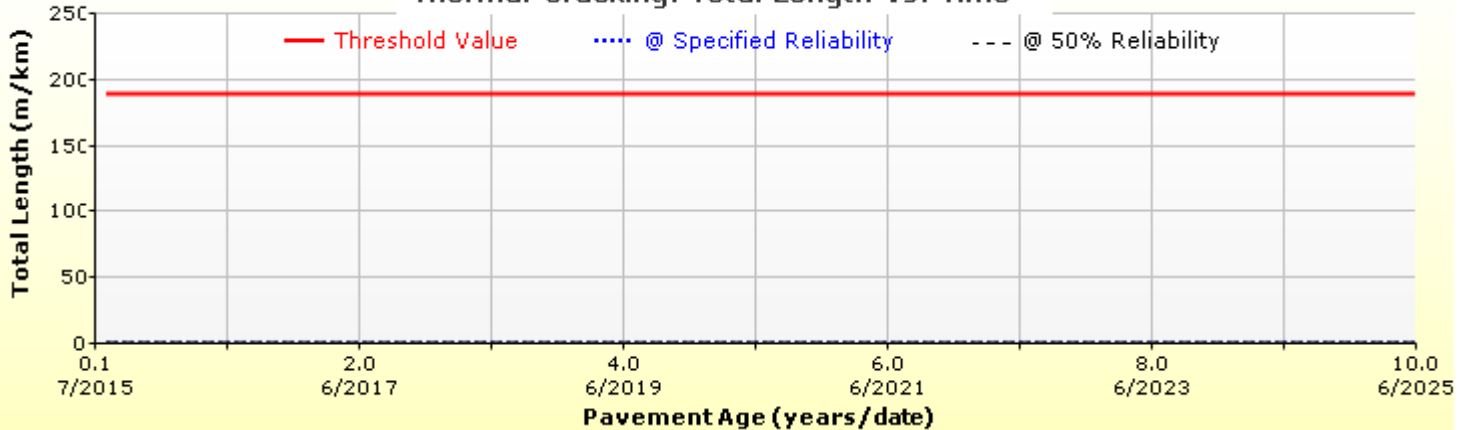
Predicted Total Rutting (Permanent Deformation)



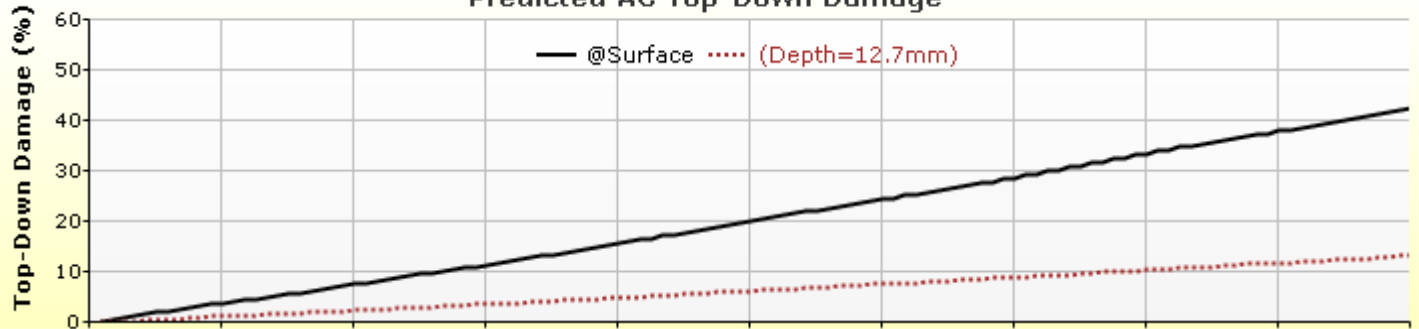
Predicted AC Bottom-Up Cracking (Alligator)



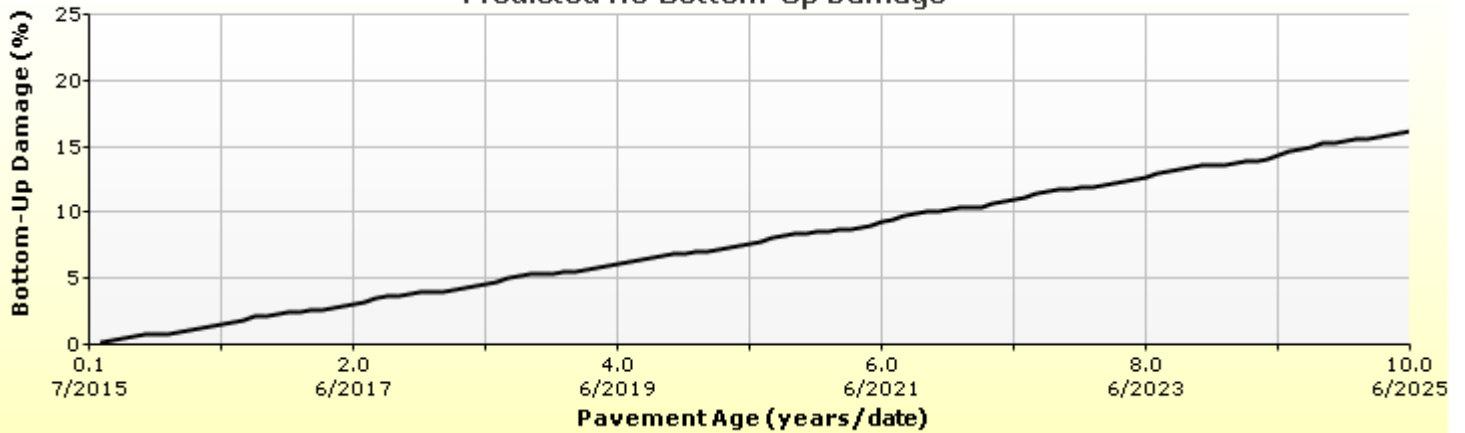
Thermal Cracking: Total Length vs. Time



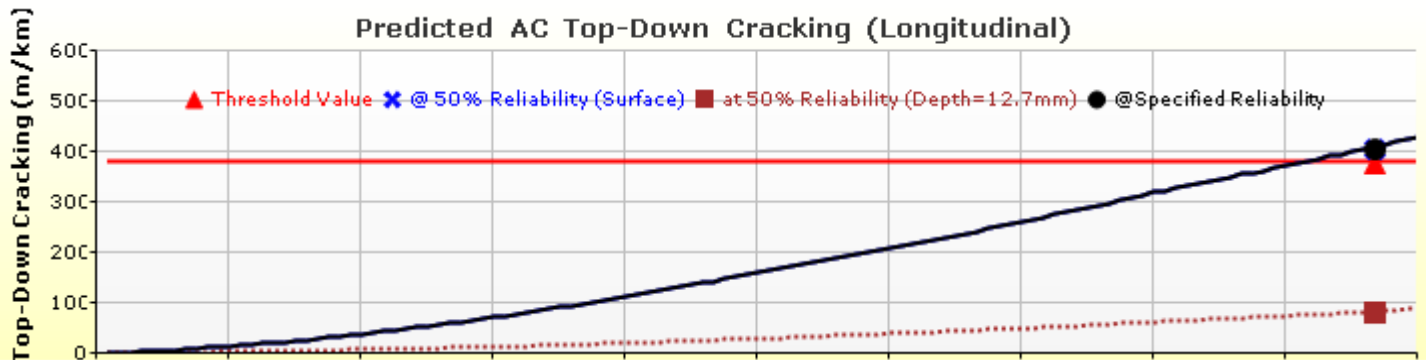
Predicted AC Top-Down Damage



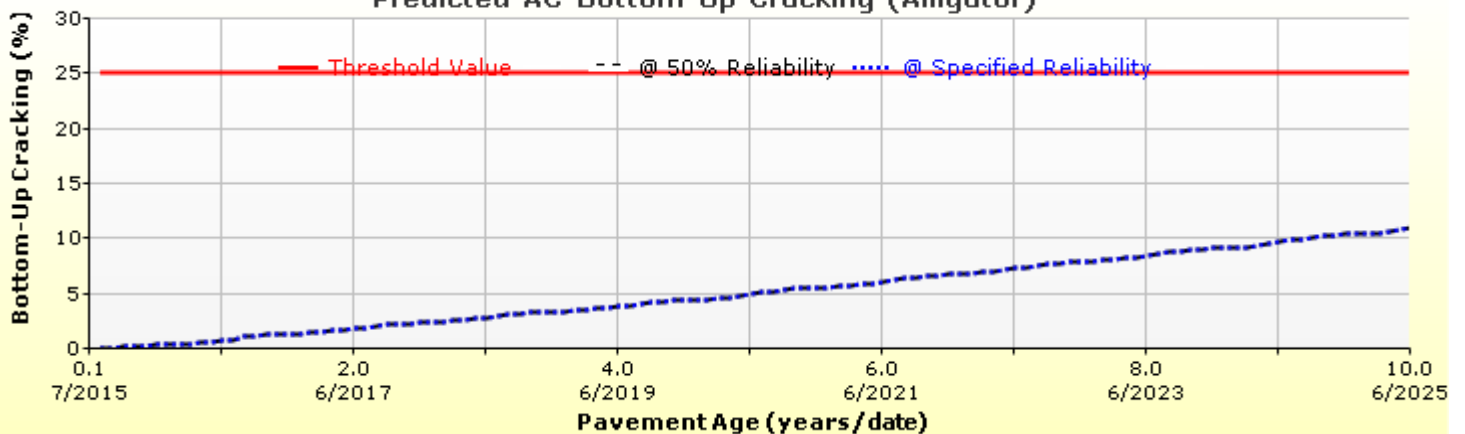
Predicted AC Bottom-Up Damage



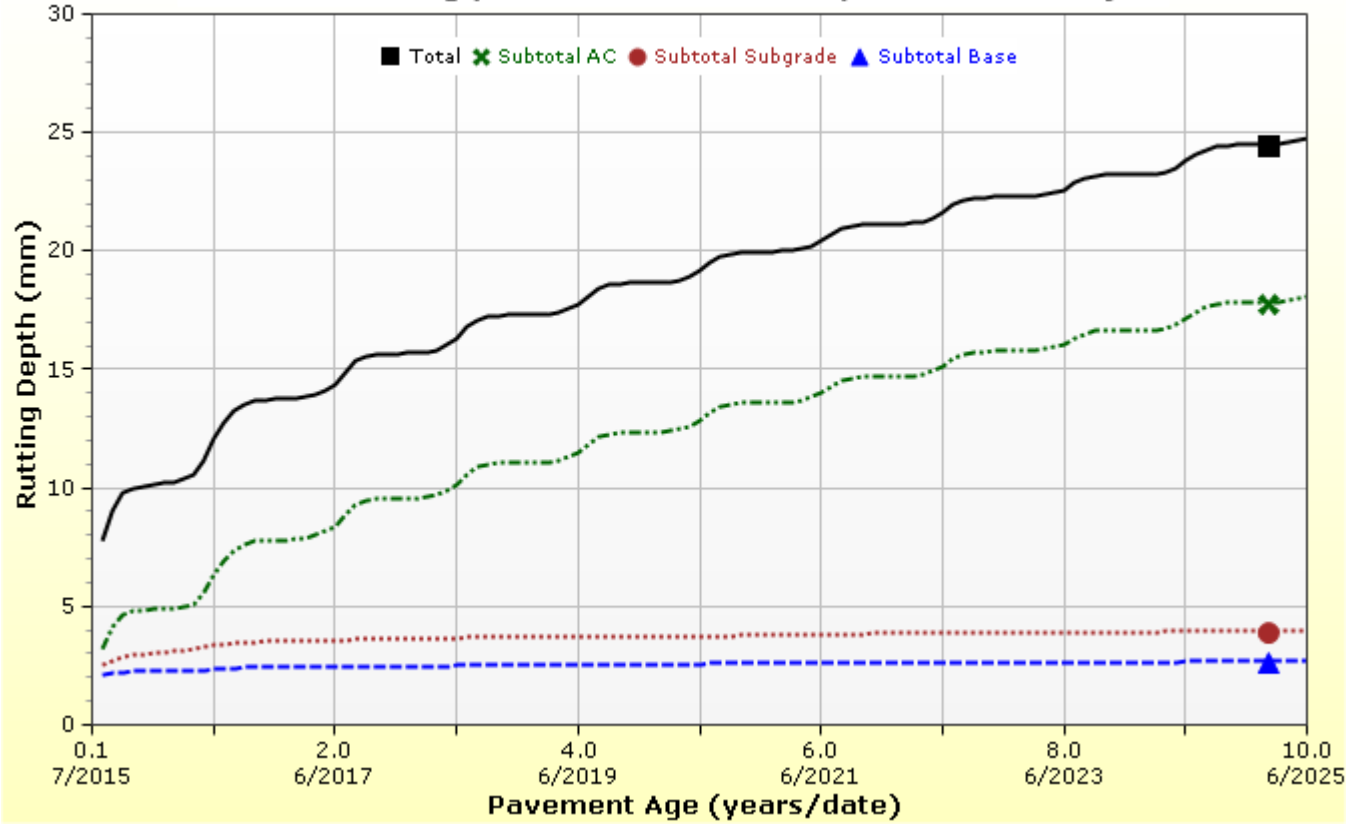
Predicted AC Top-Down Cracking (Longitudinal)



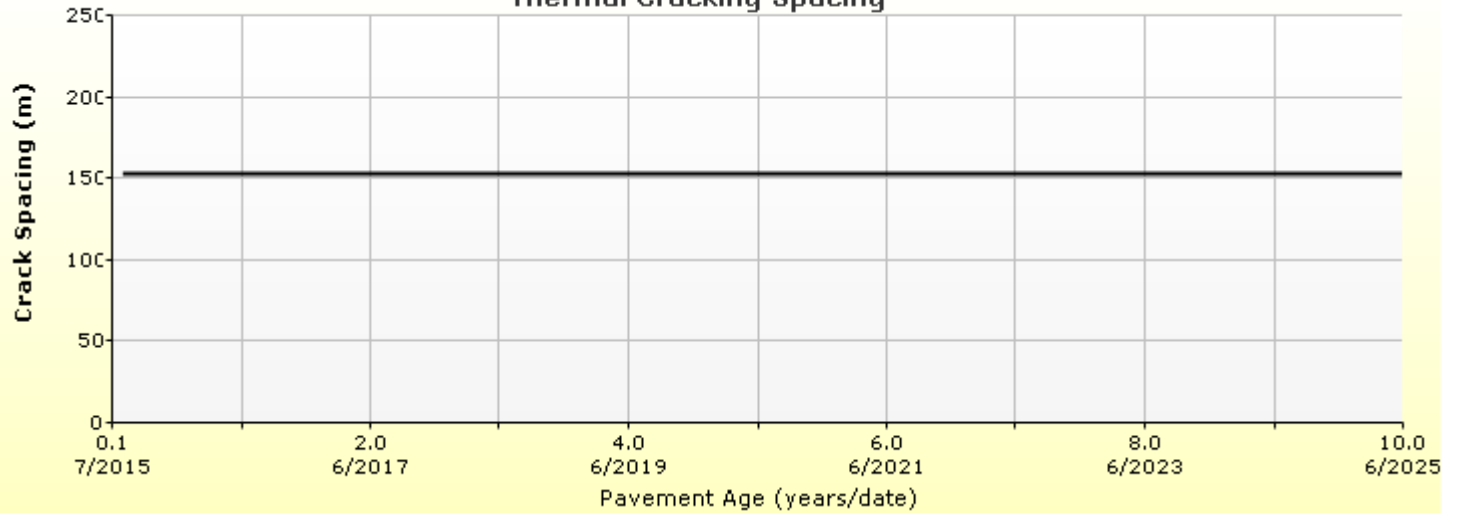
Predicted AC Bottom-Up Cracking (Alligator)



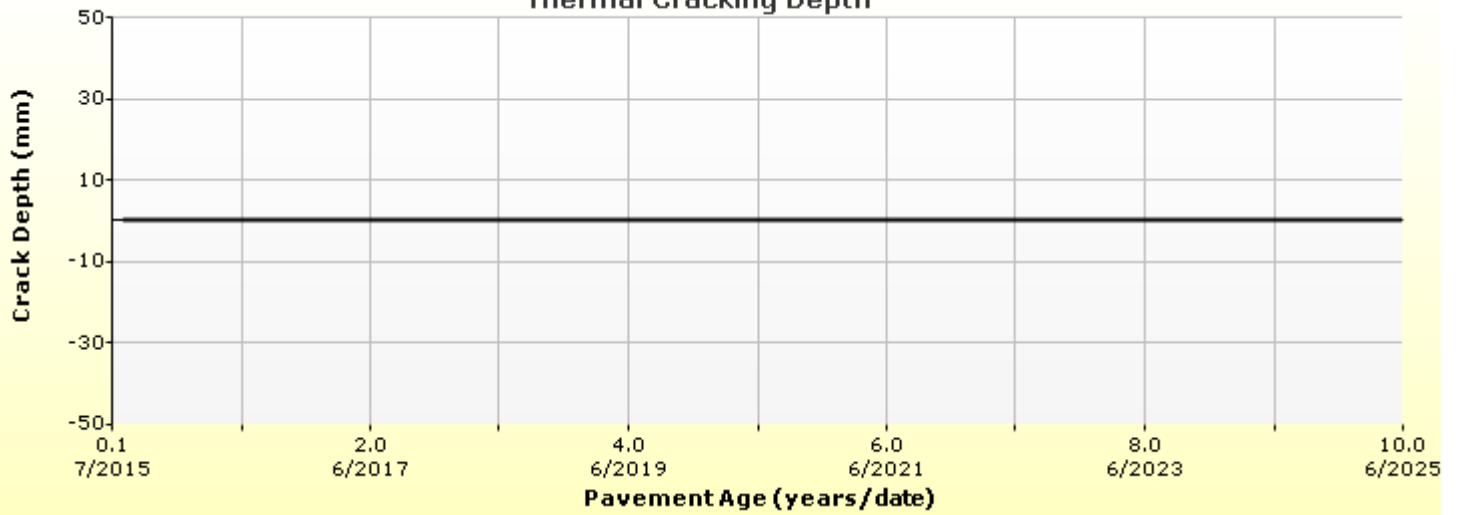
Predicted Rutting (Permanent Deformation) at 50% Reliability

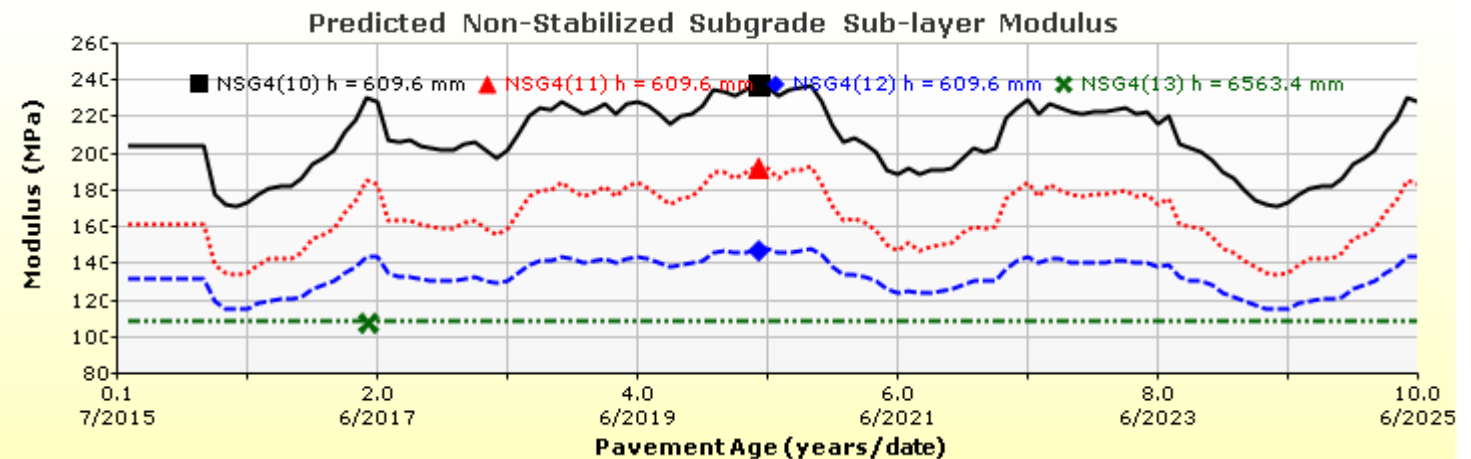
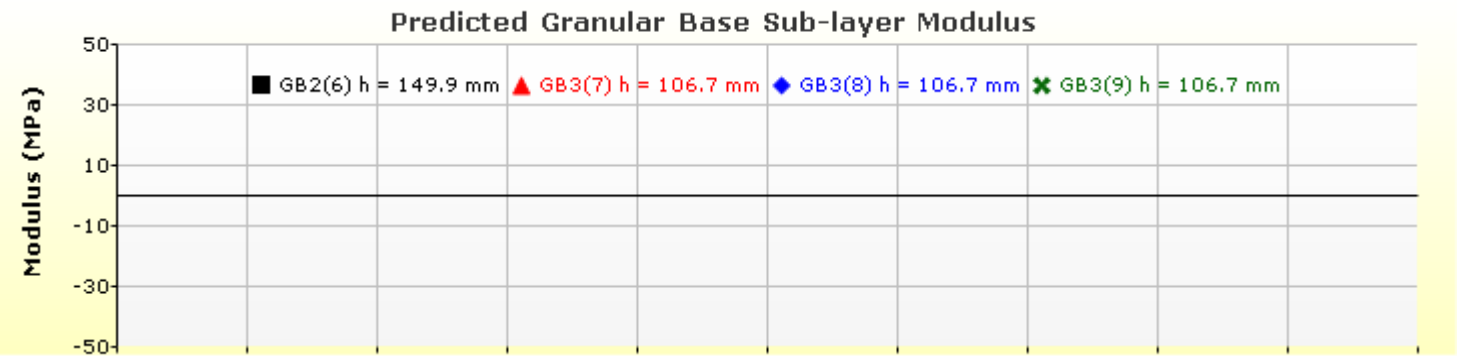
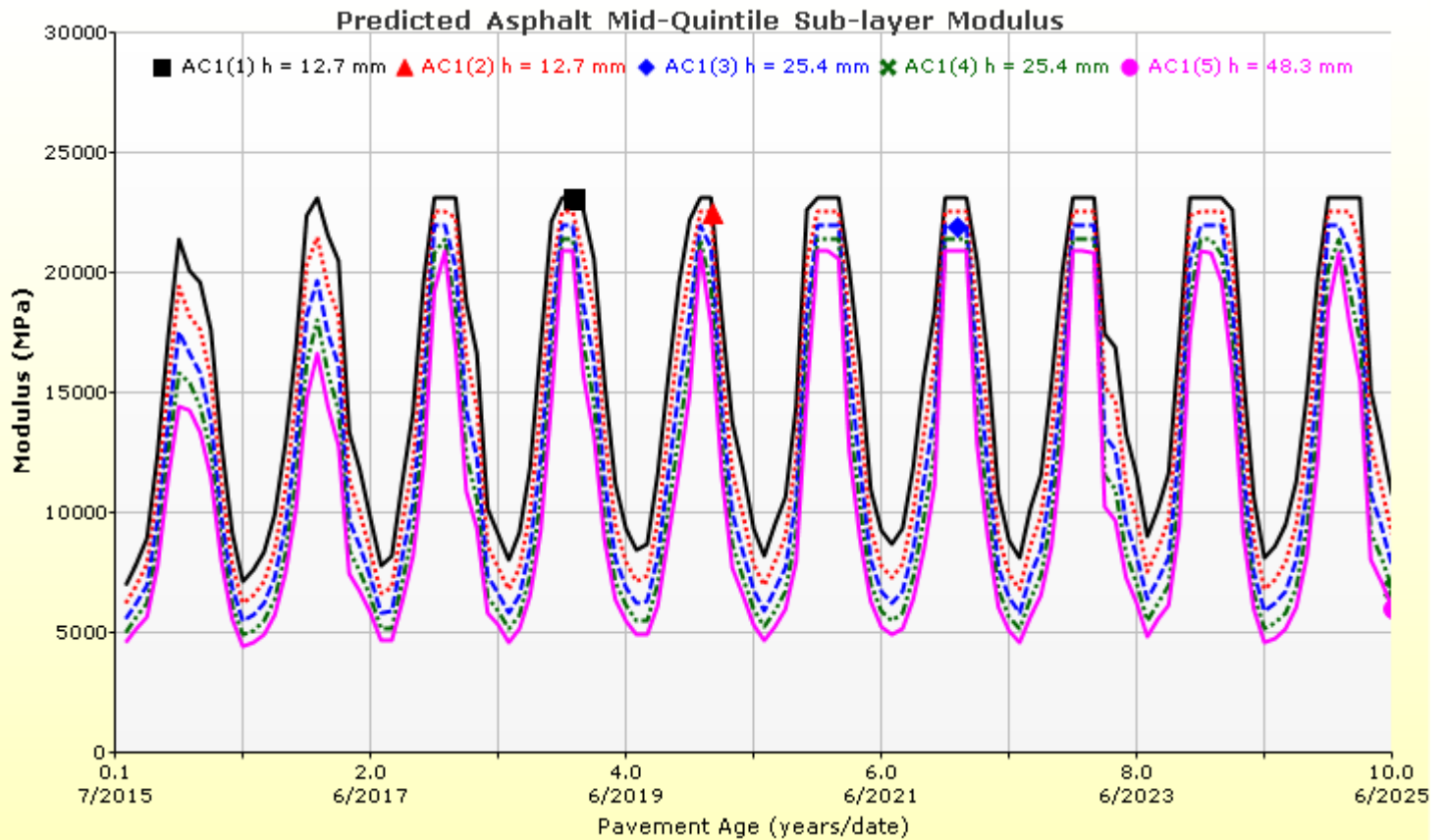


Thermal Cracking Spacing



Thermal Cracking Depth





Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

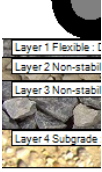
C3: 0.008

C4: 0.015

Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data: 32.119, -81.202
 Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
 Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

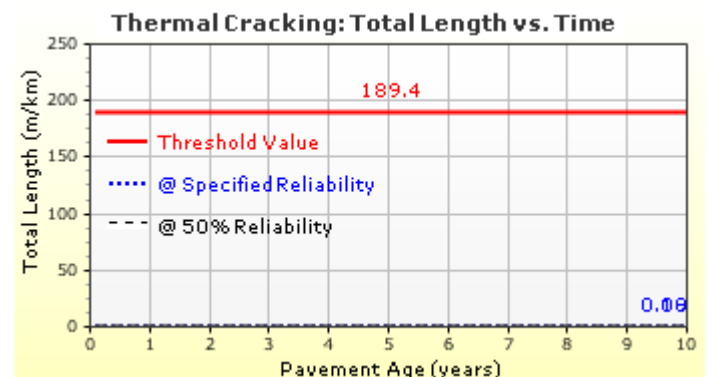
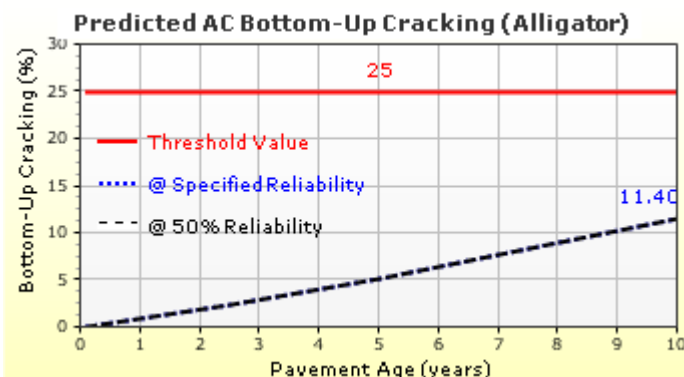
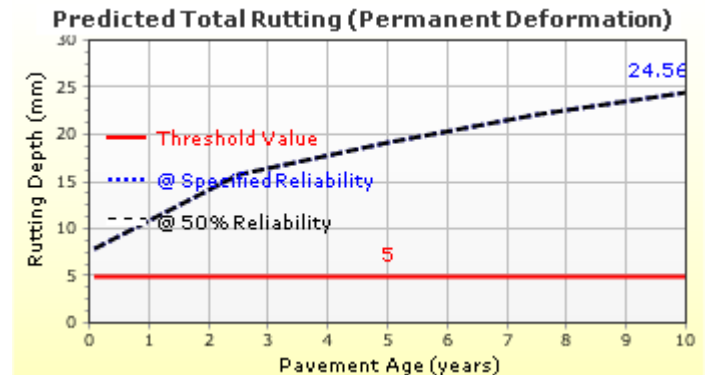
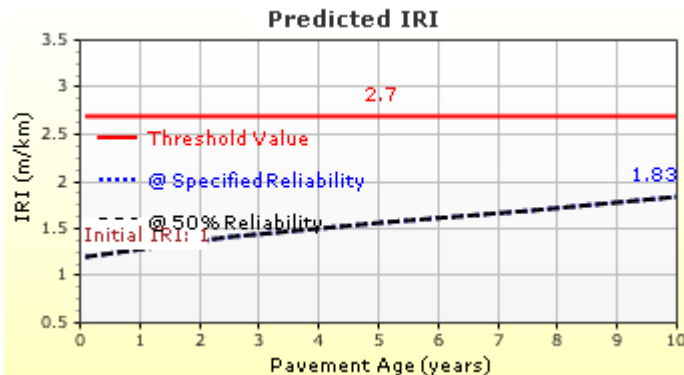
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.83	50.00	95.41	Pass
Permanent deformation - total pavement (mm)	5.00	24.56	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	11.40	50.00	83.21	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	409.09	50.00	47.24	Fail
Permanent deformation - AC only (mm)	5.00	17.57	50.00	0.29	Fail

Distress Charts

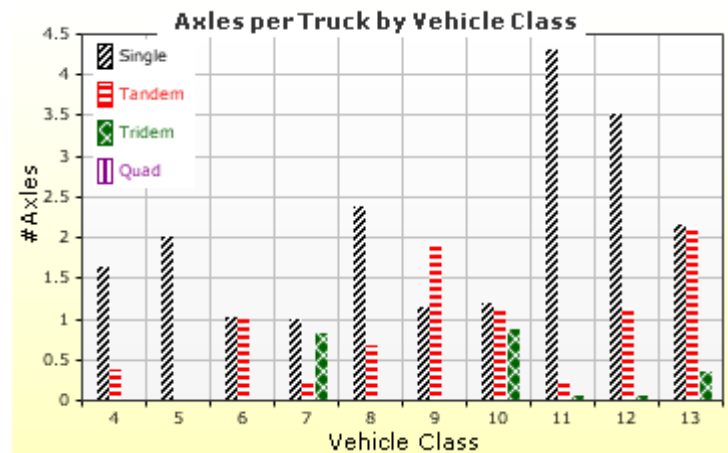
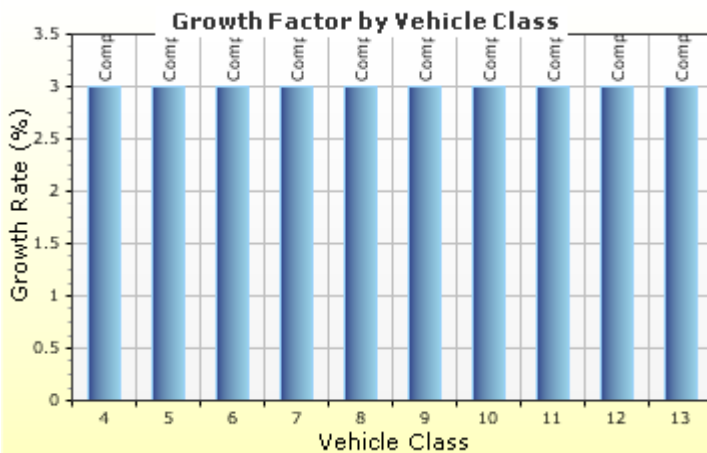
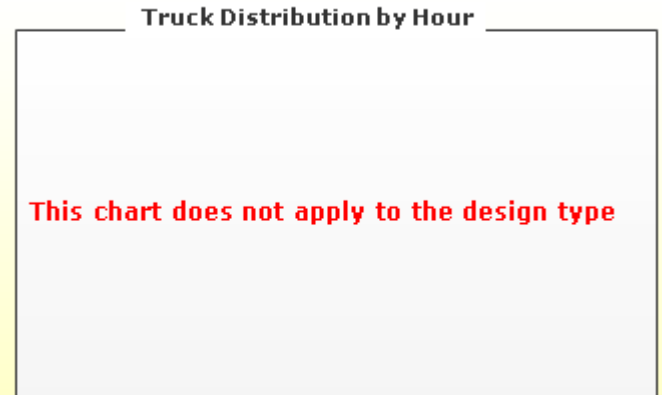
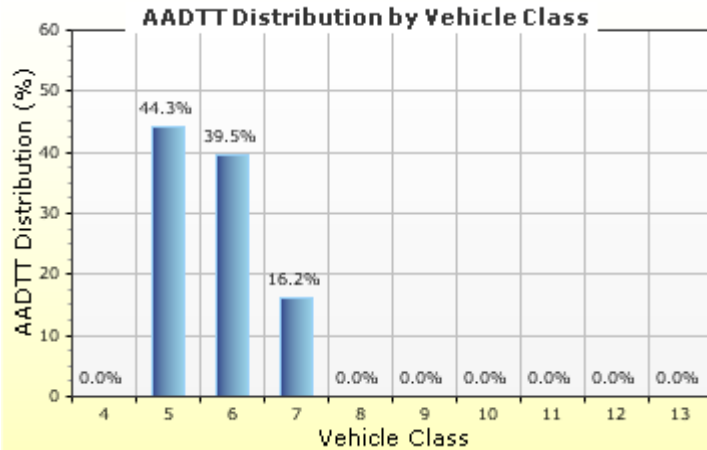


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

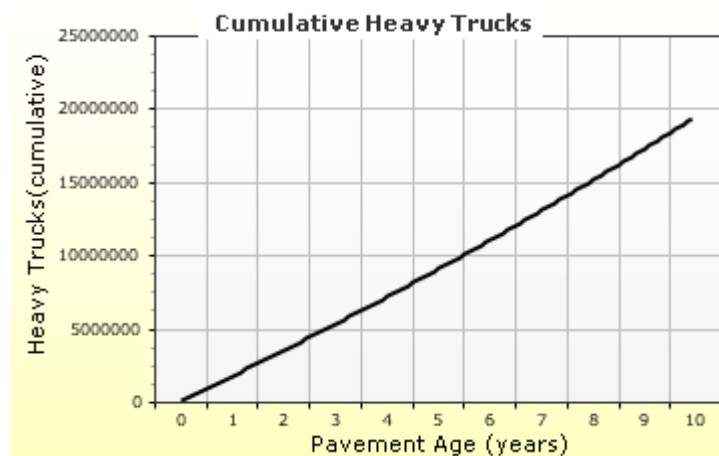
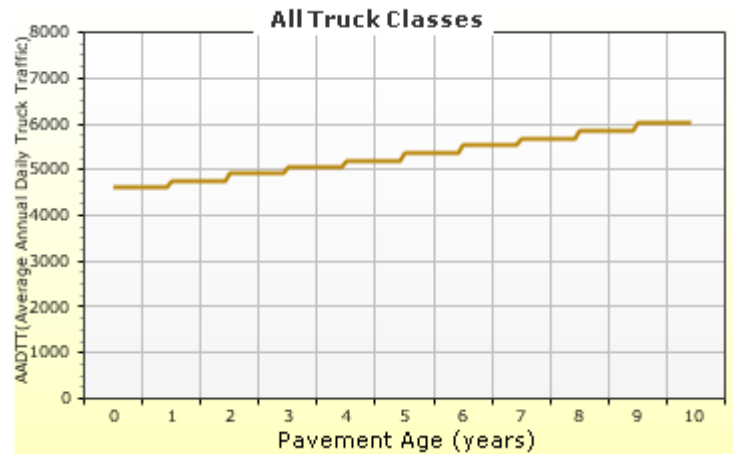
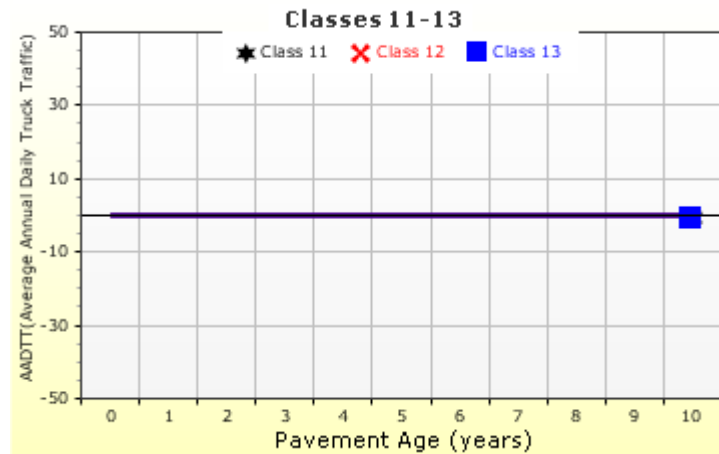
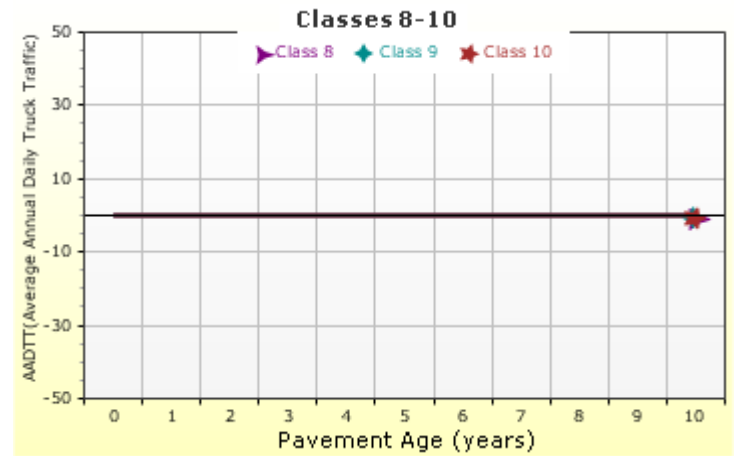
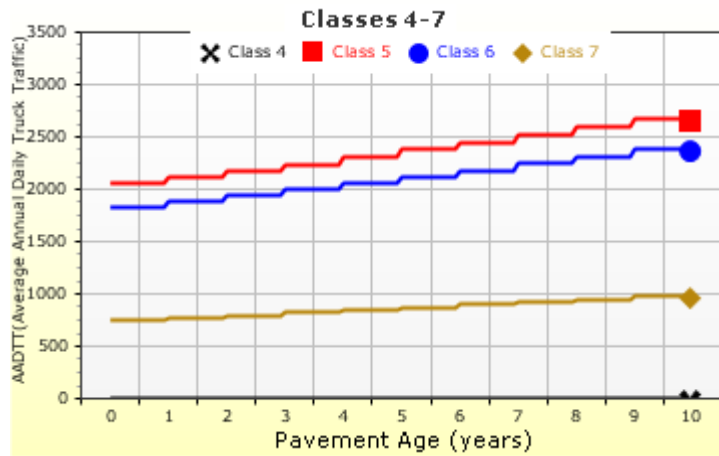
Wheelbase does not apply

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



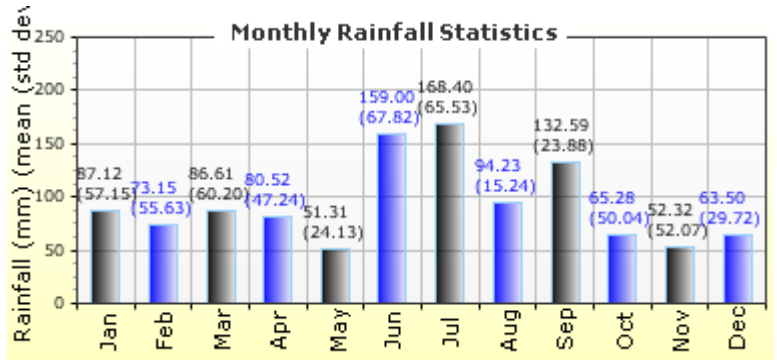
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

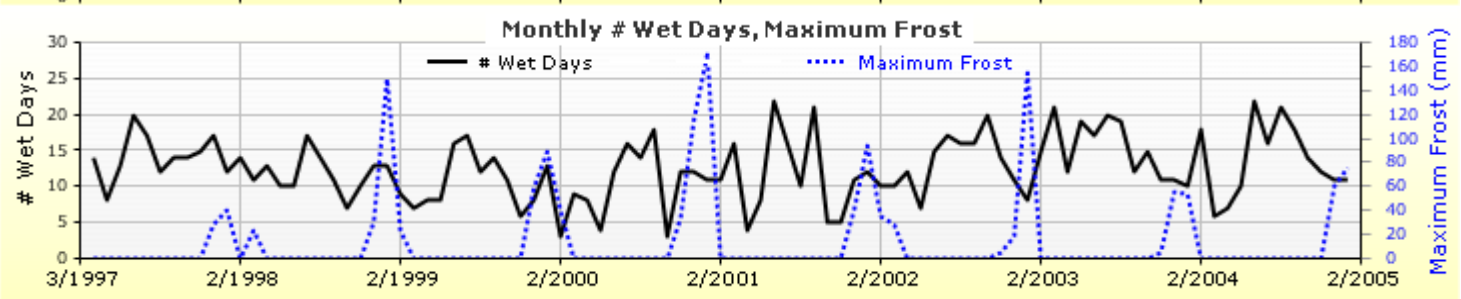
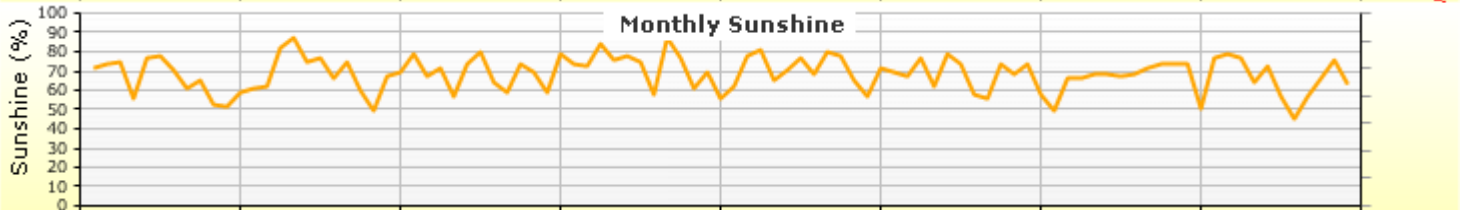
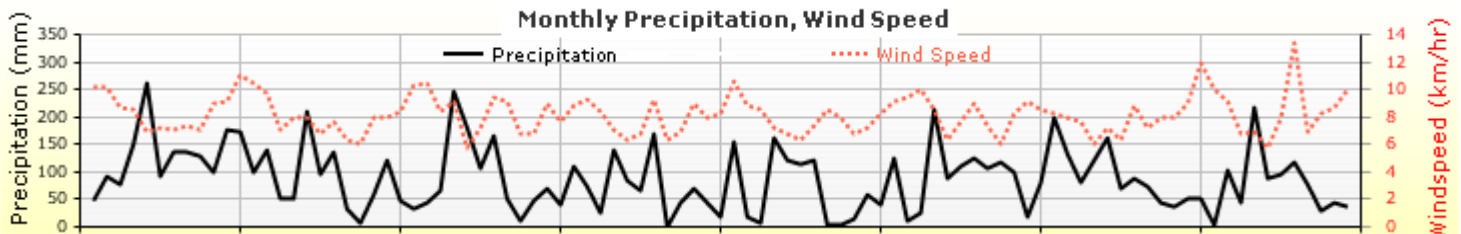
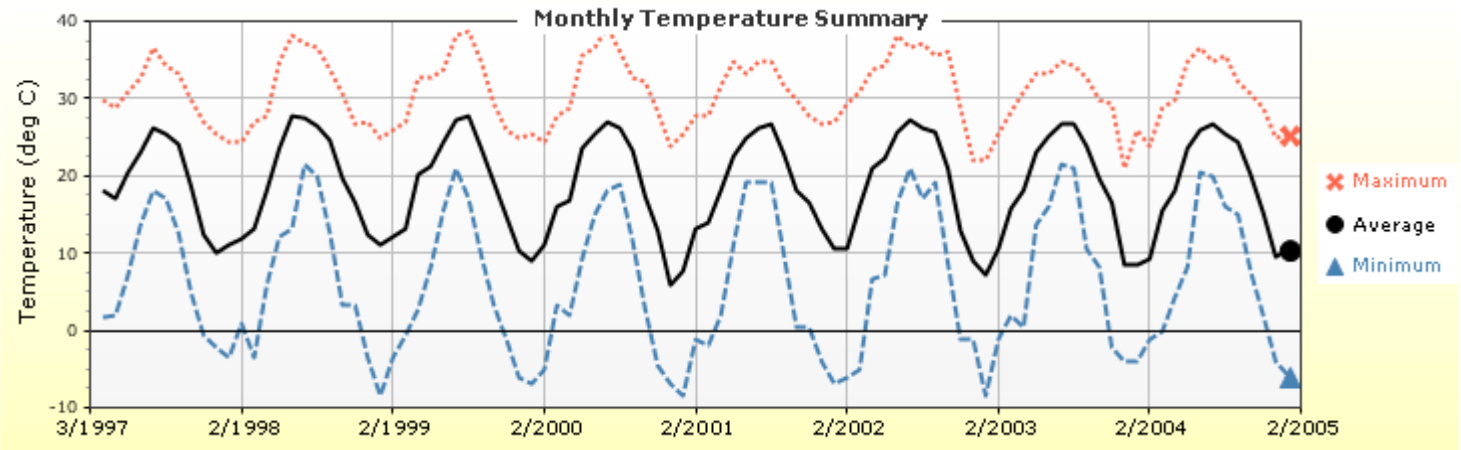
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

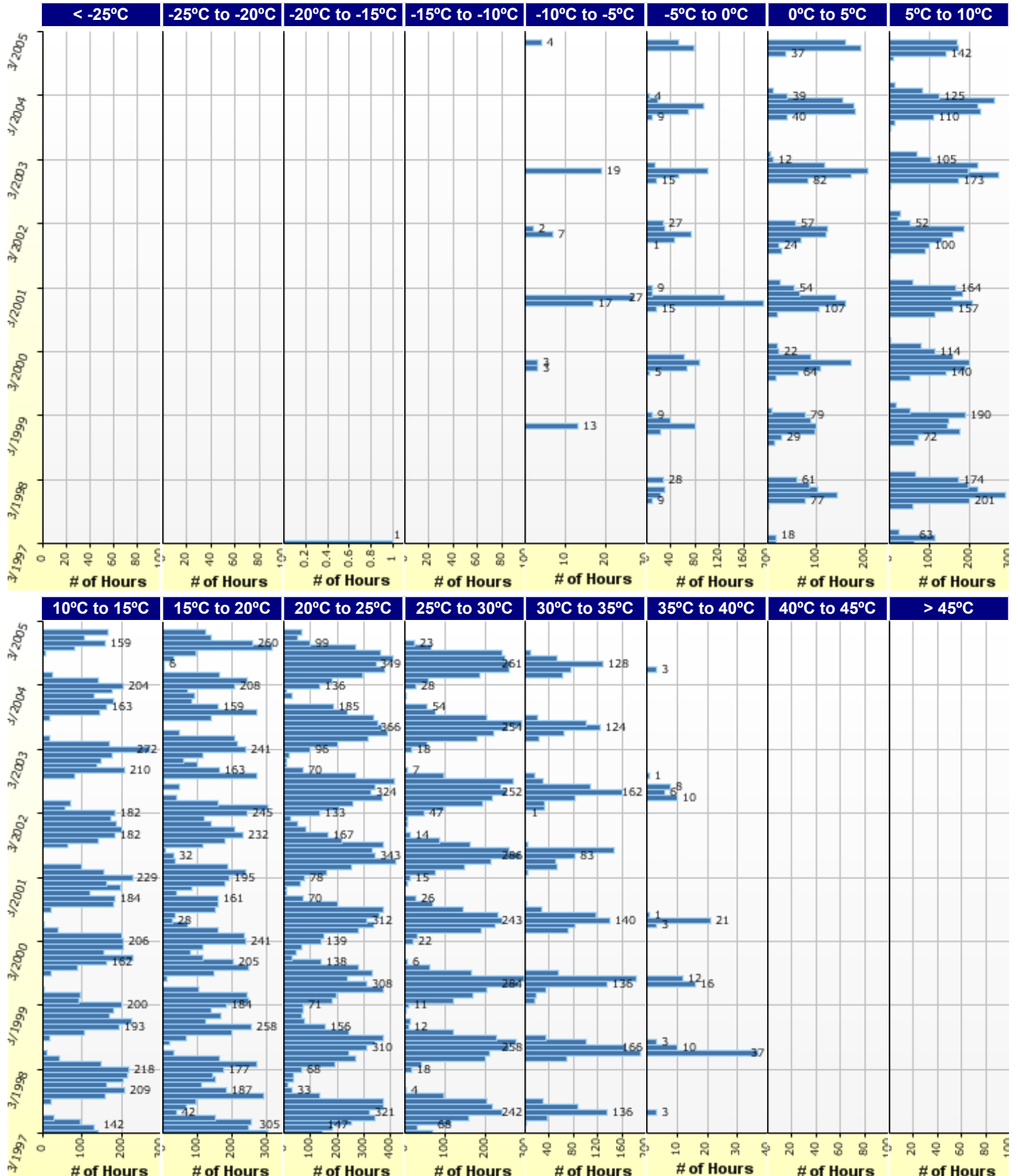


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF3_ALT2

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF3_ALT2.dgpx



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

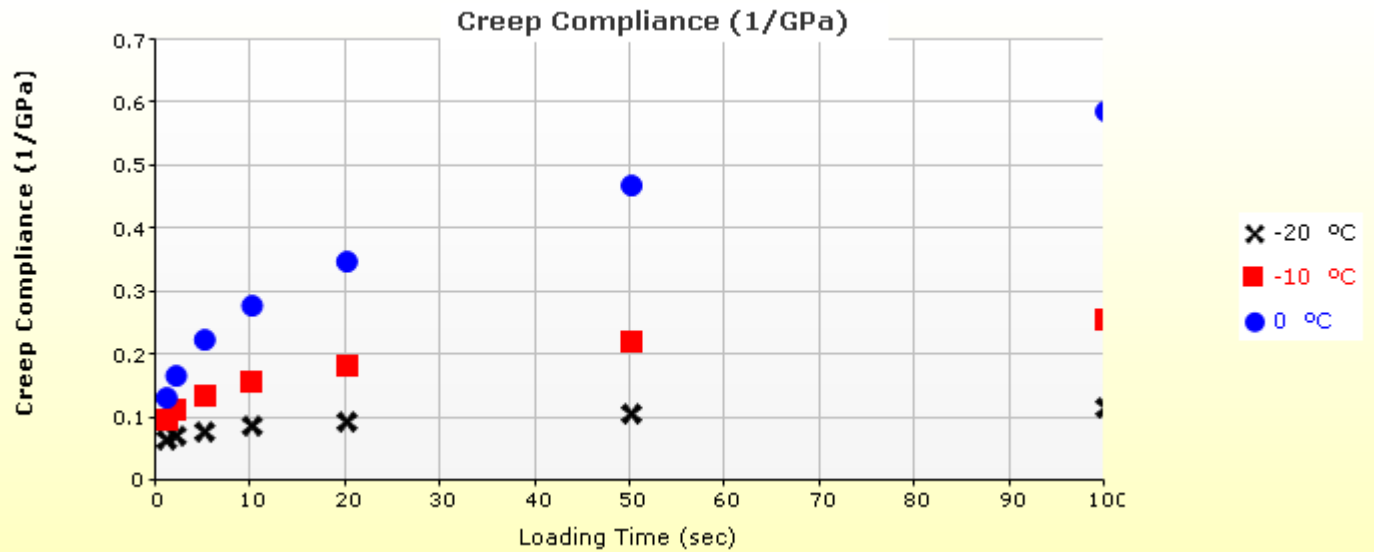
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

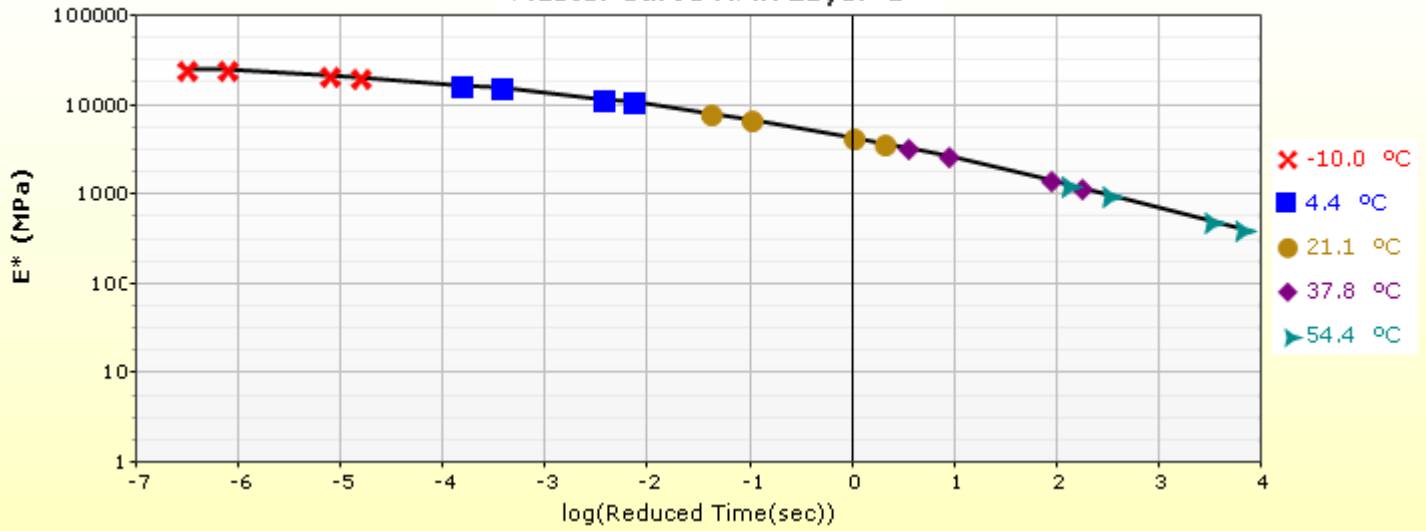
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

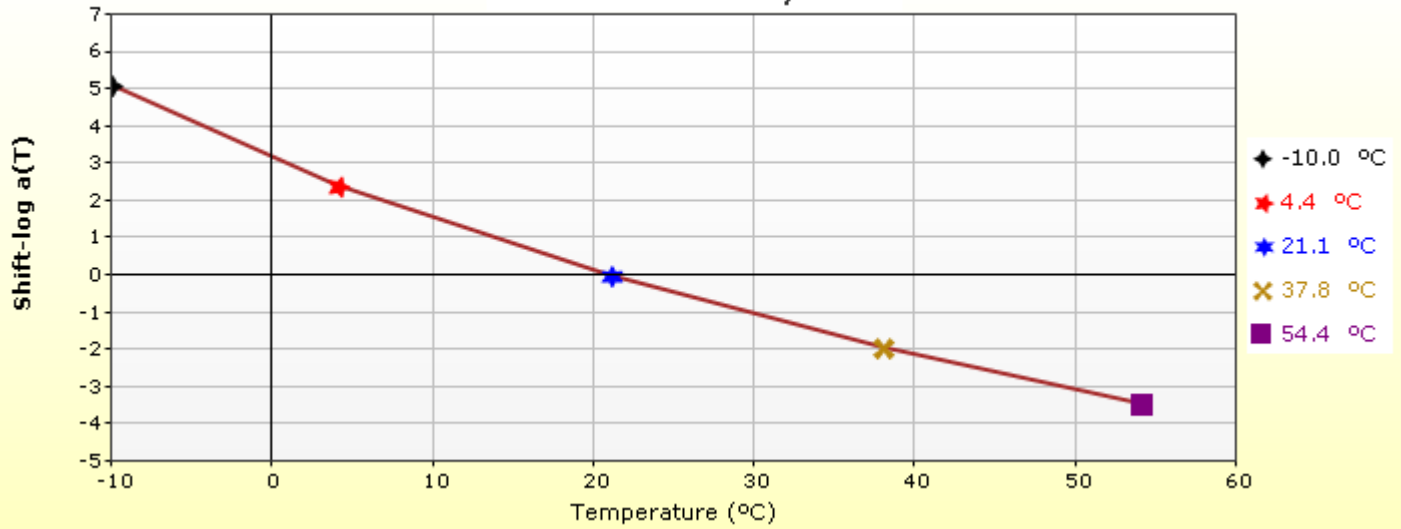


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

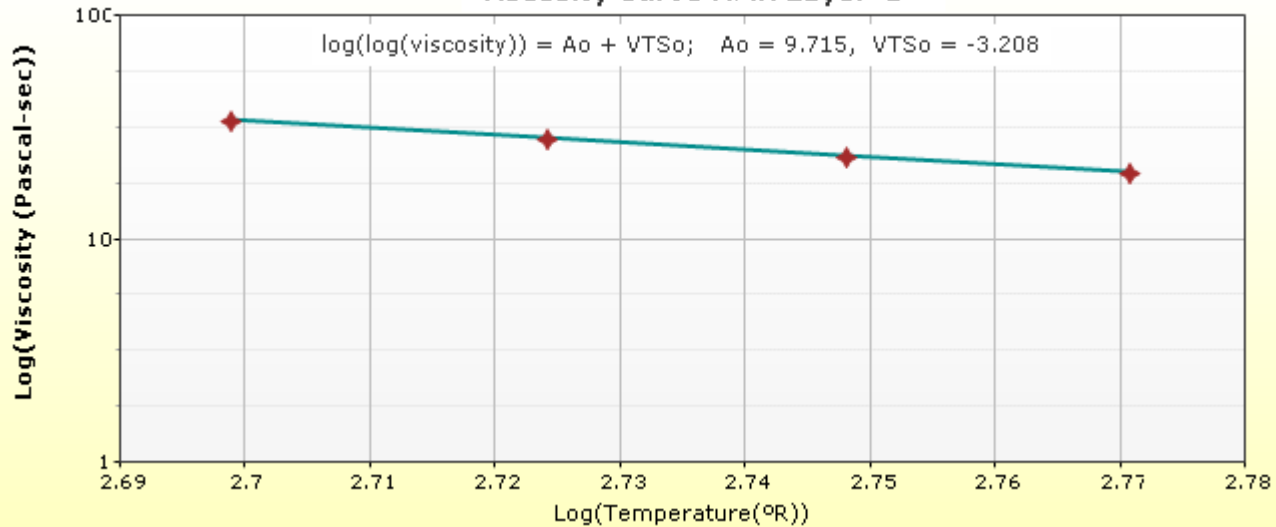
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

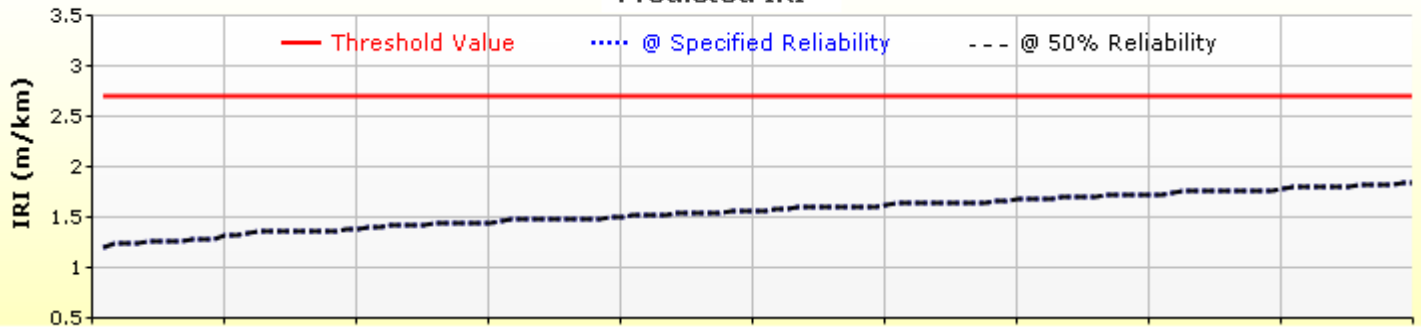


Viscosity Curve HMA Layer 1

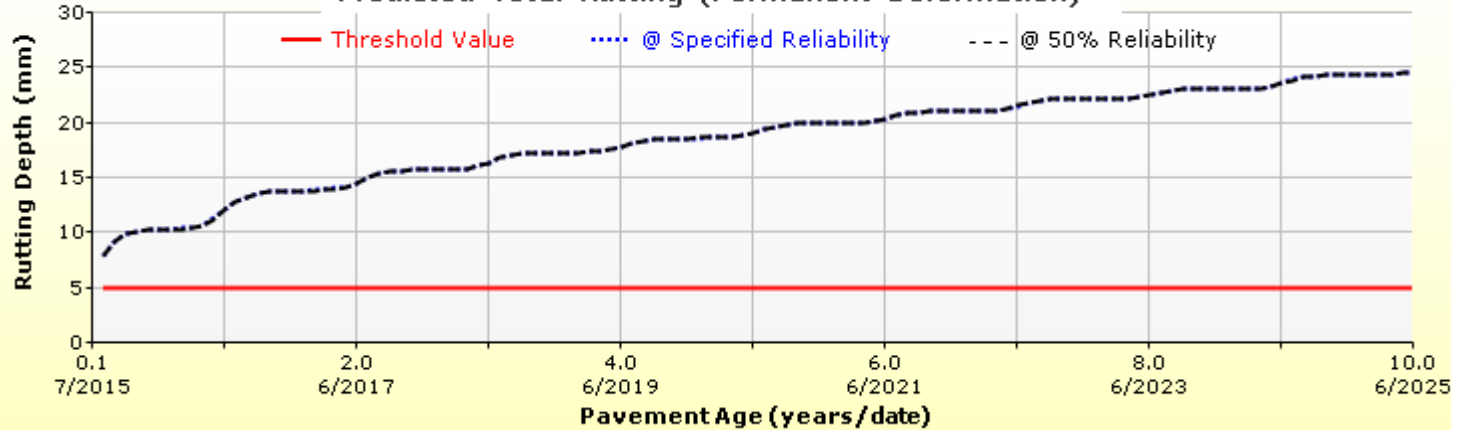


Analysis Output Charts

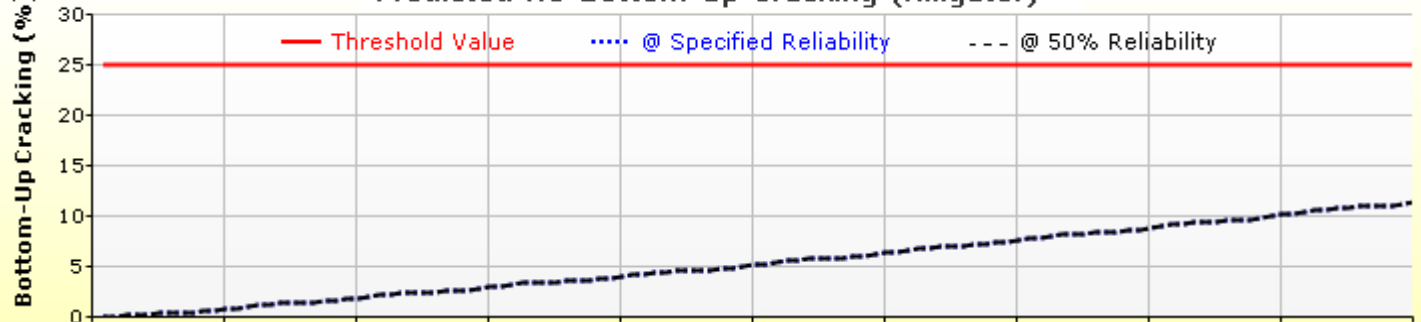
Predicted IRI



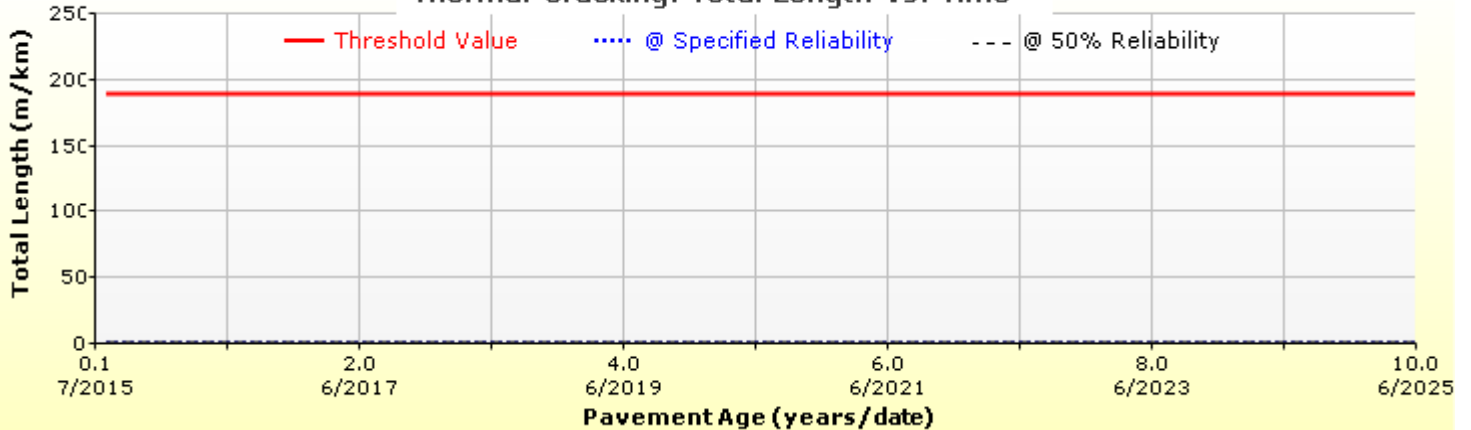
Predicted Total Rutting (Permanent Deformation)



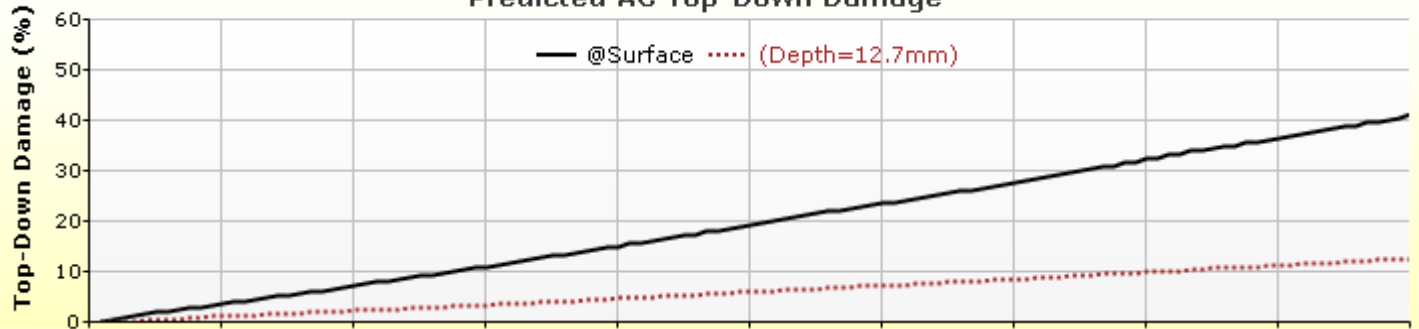
Predicted AC Bottom-Up Cracking (Alligator)



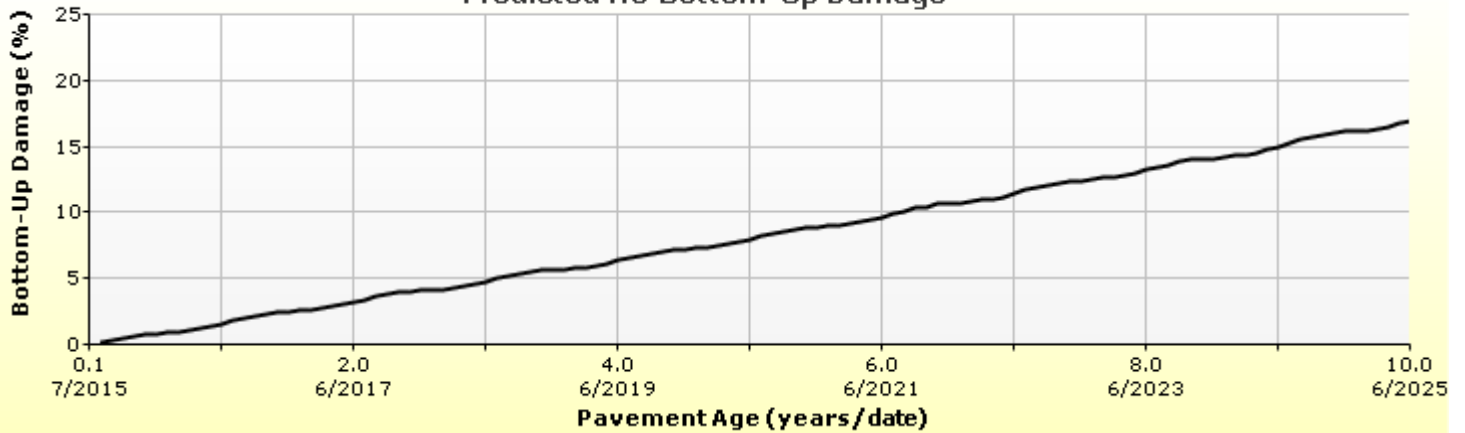
Thermal Cracking: Total Length vs. Time



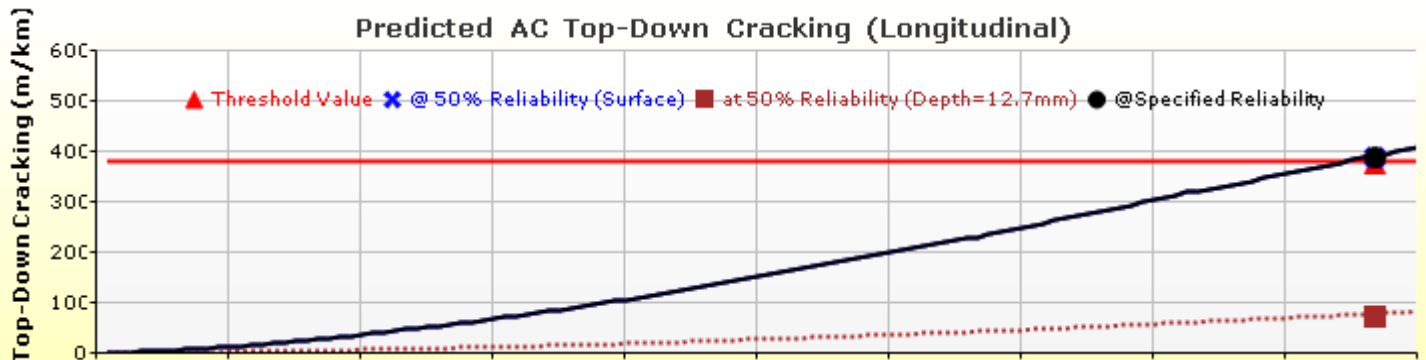
Predicted AC Top-Down Damage



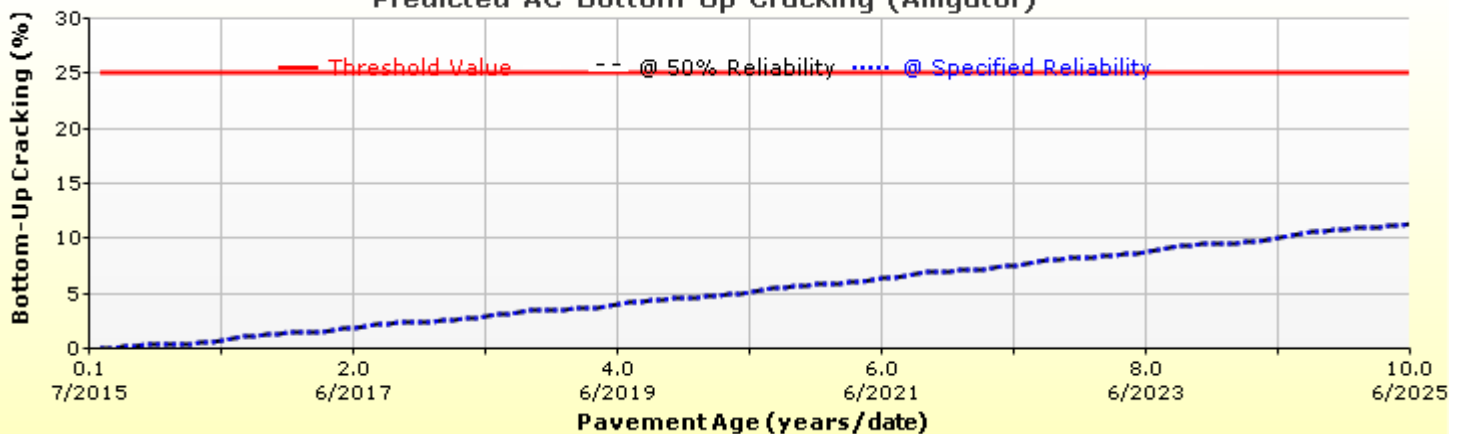
Predicted AC Bottom-Up Damage



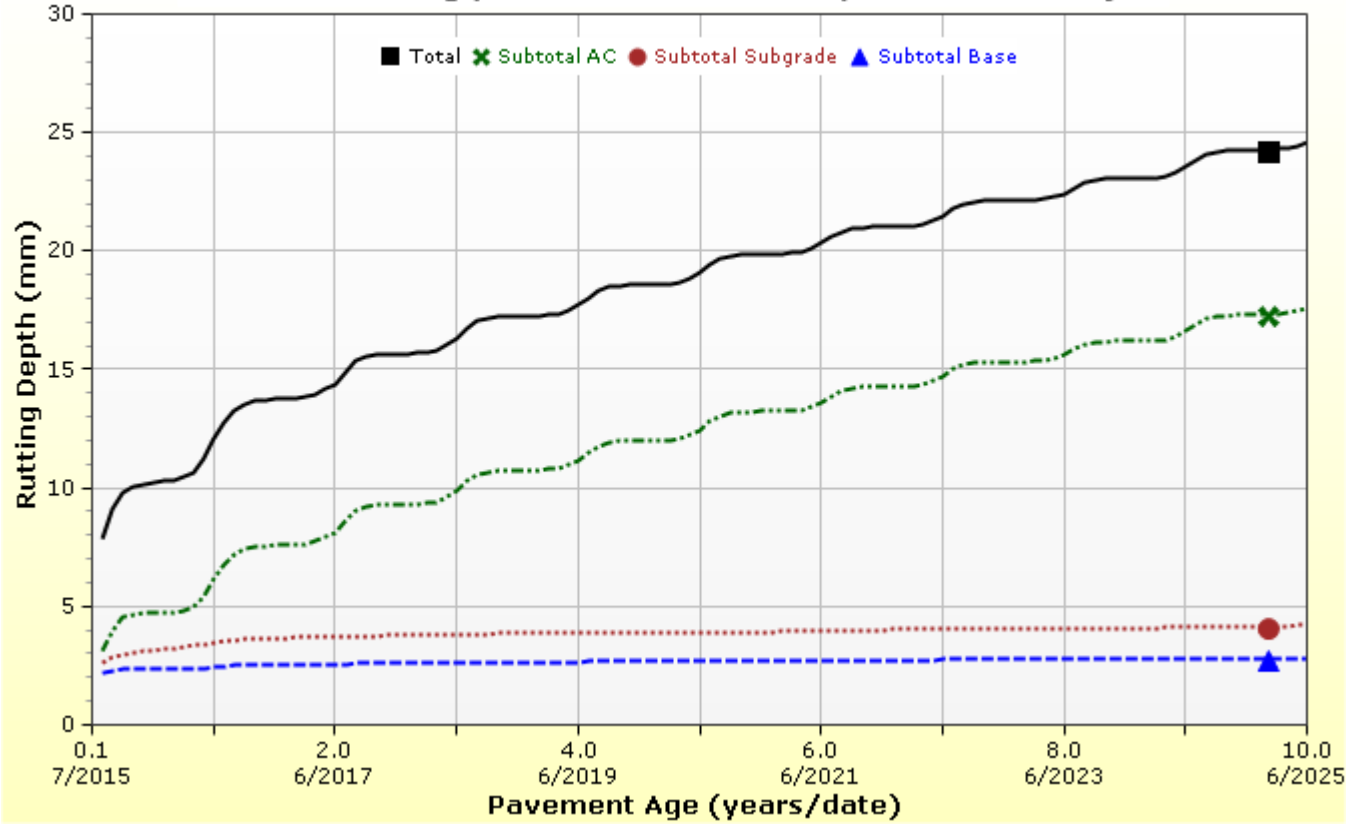
Predicted AC Top-Down Cracking (Longitudinal)

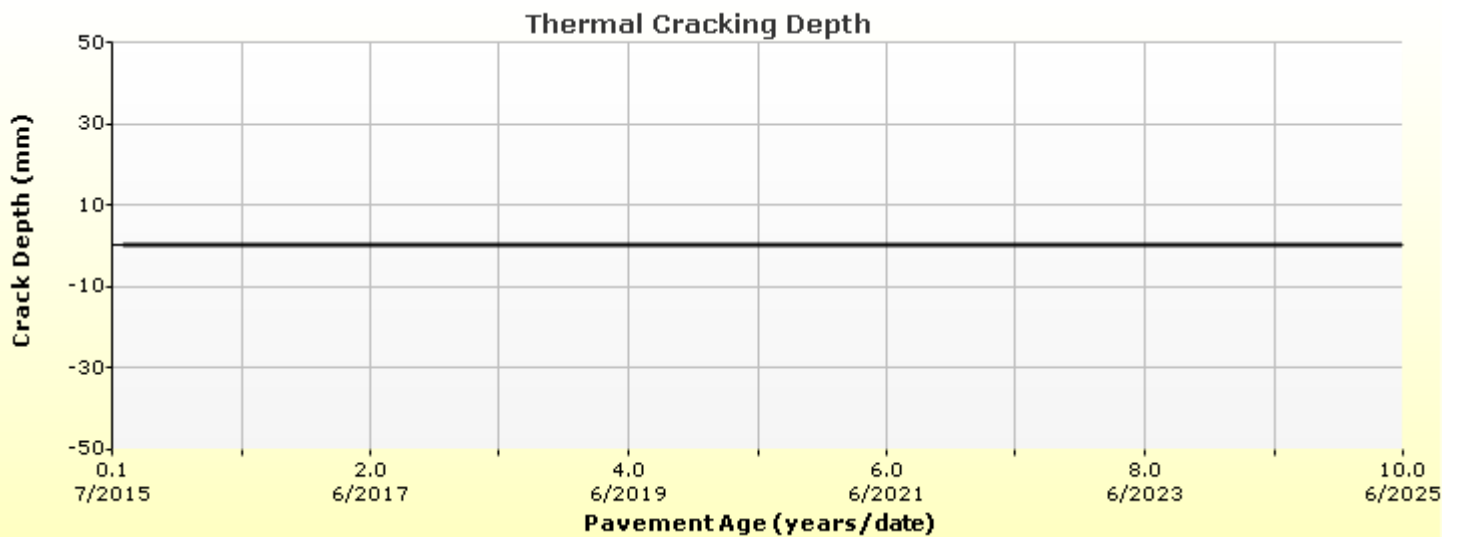
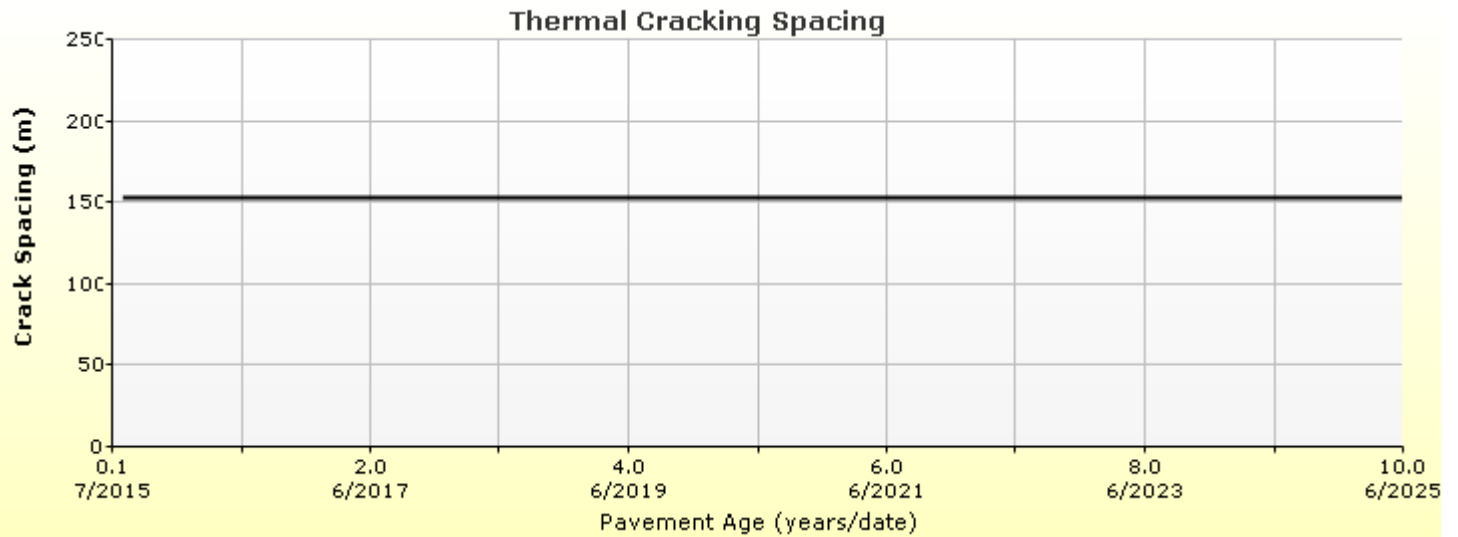


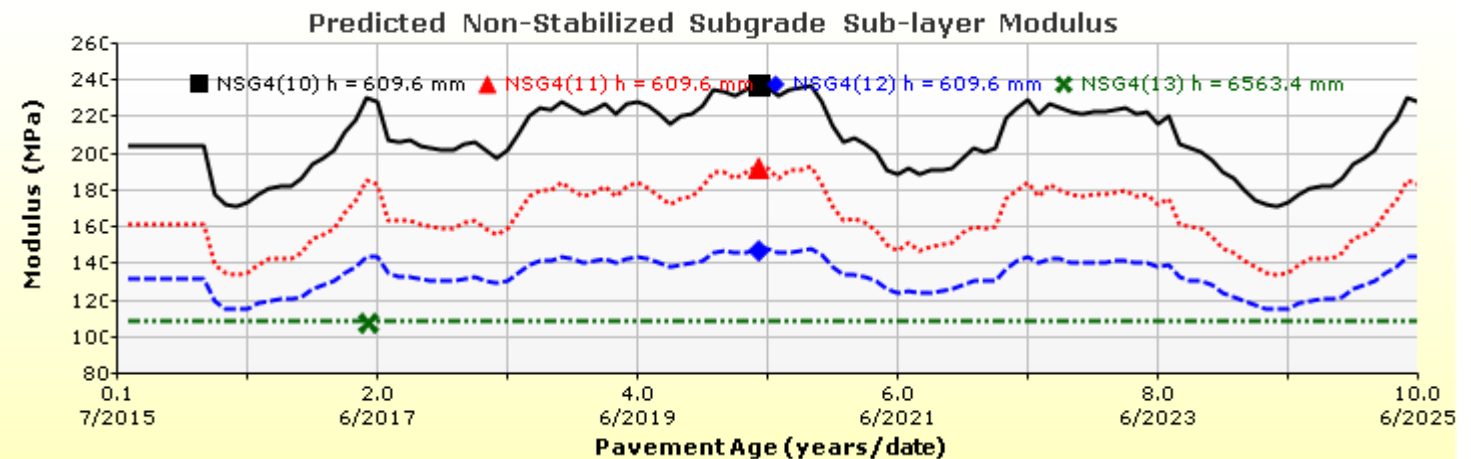
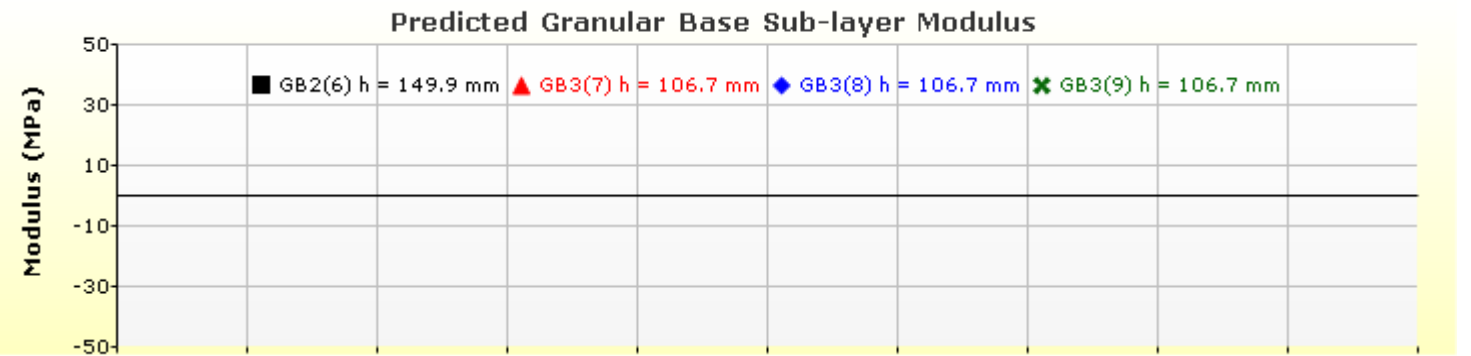
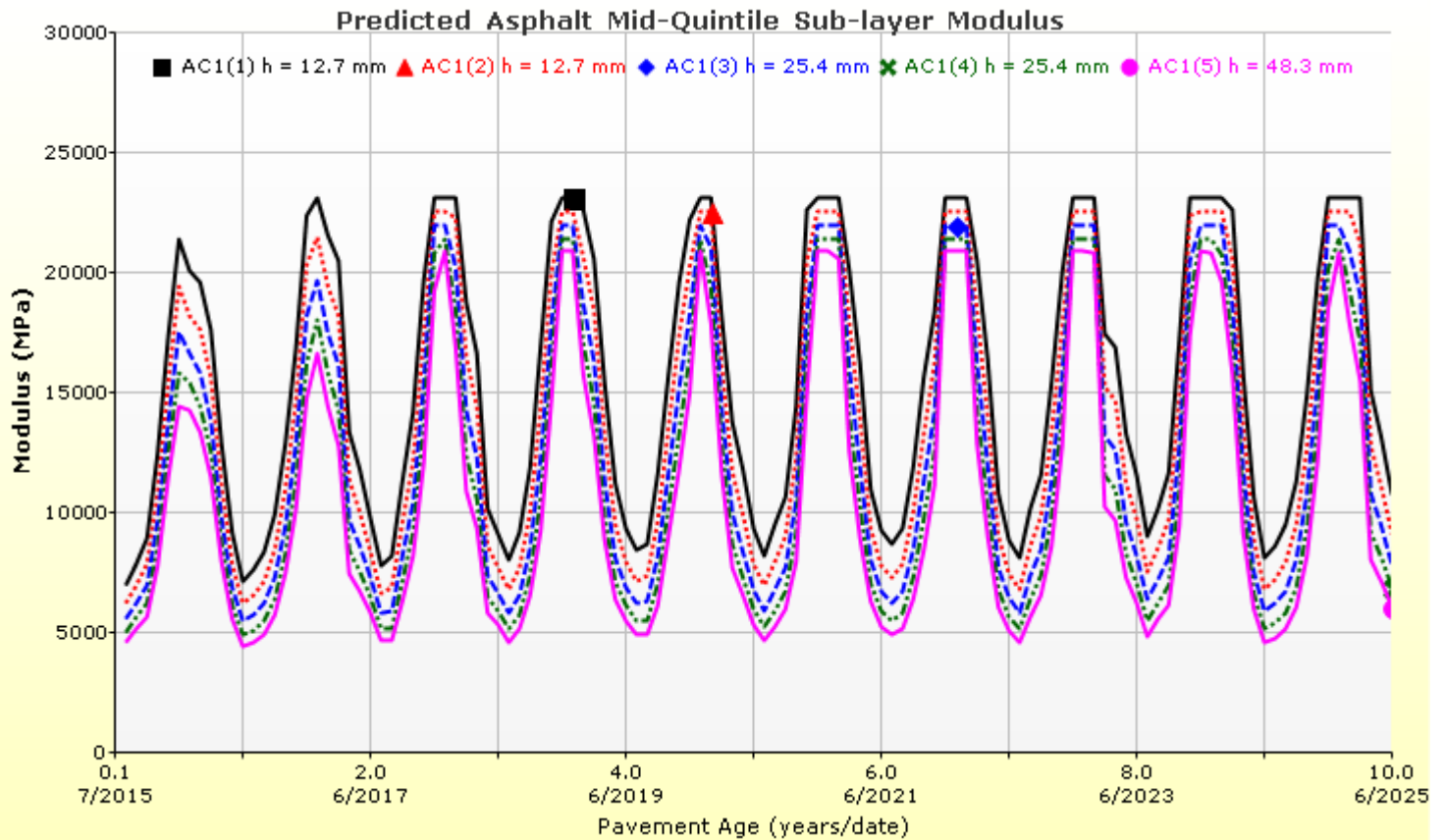
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)
500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

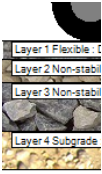
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)	Volumetric at Construction:	
Flexible	Default asphalt concrete	125.0	Effective binder content (%)	11.6
NonStabilized	Crushed stone	150.0	Air voids (%)	7.0
NonStabilized	Crushed stone	320.0		
Subgrade	A-1-a	Semi-infinite		

Traffic

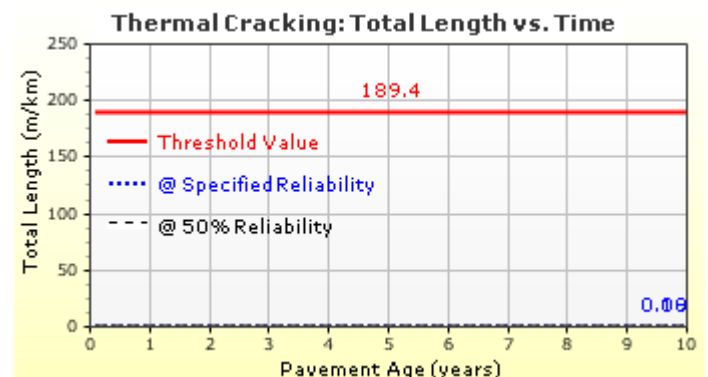
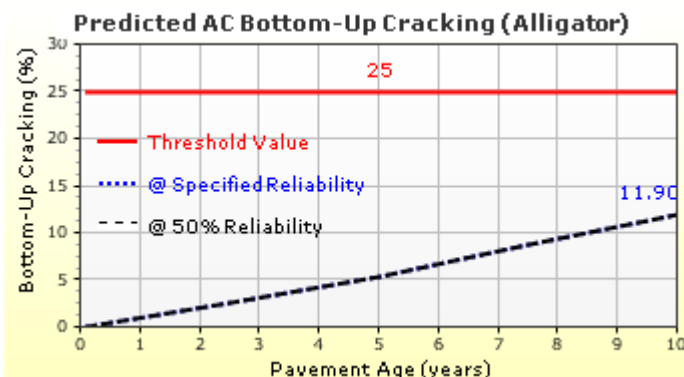
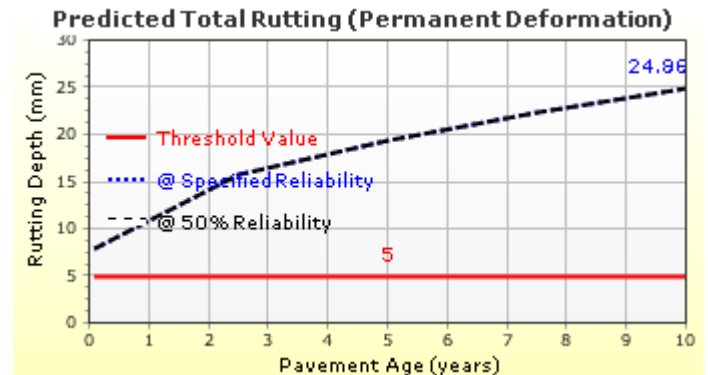
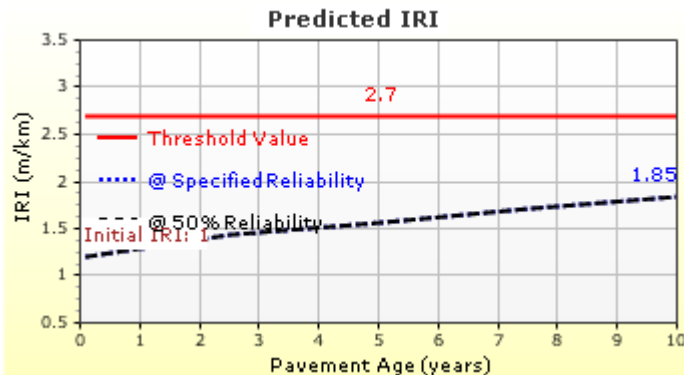
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.85	50.00	95.10	Pass
Permanent deformation - total pavement (mm)	5.00	24.90	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	11.90	50.00	82.31	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	414.77	50.00	46.73	Fail
Permanent deformation - AC only (mm)	5.00	17.91	50.00	0.27	Fail

Distress Charts

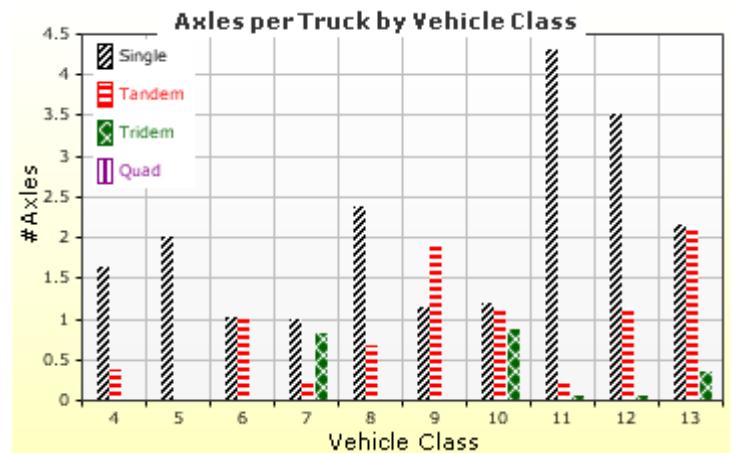
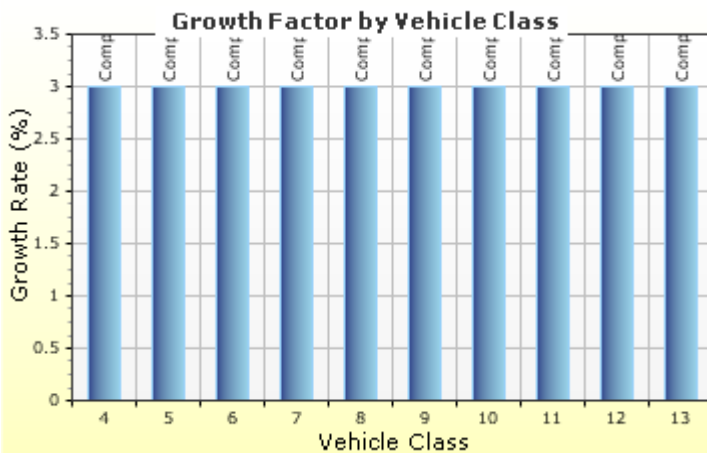
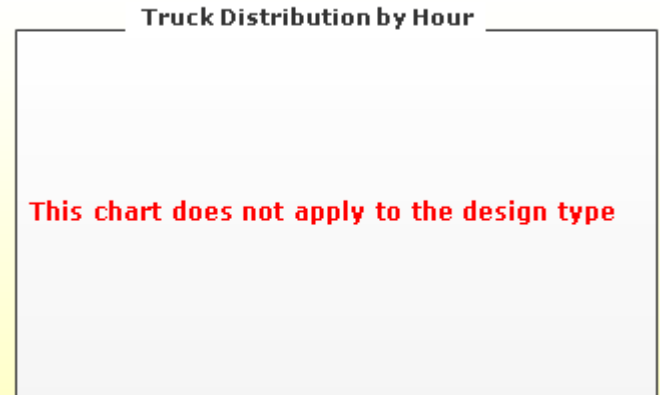
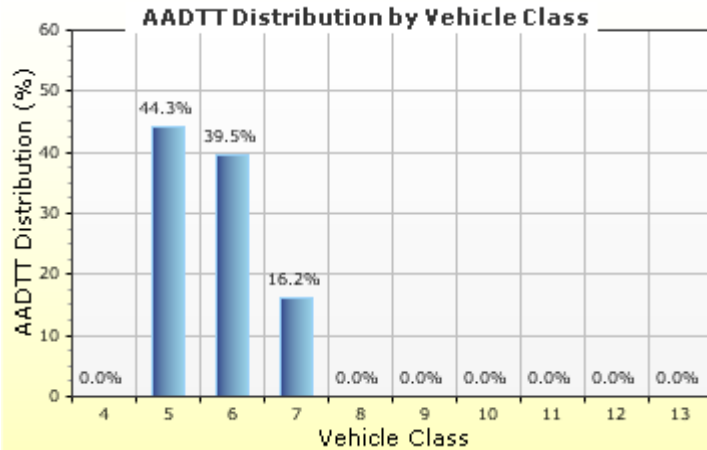


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

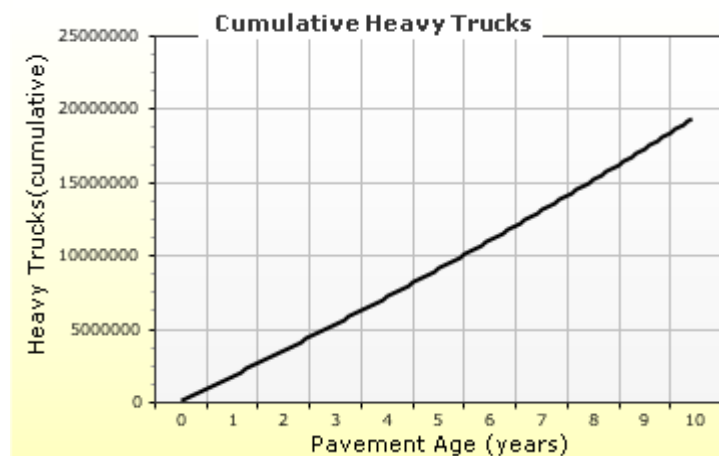
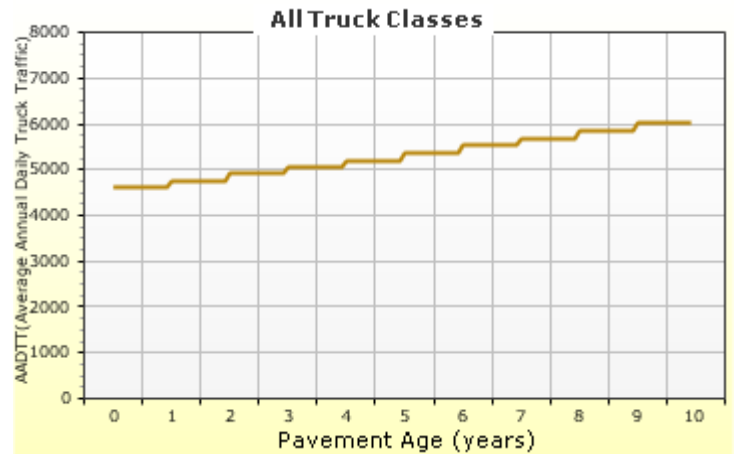
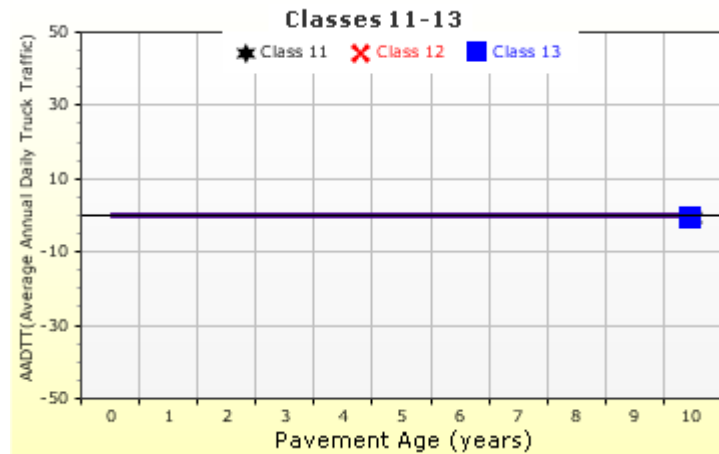
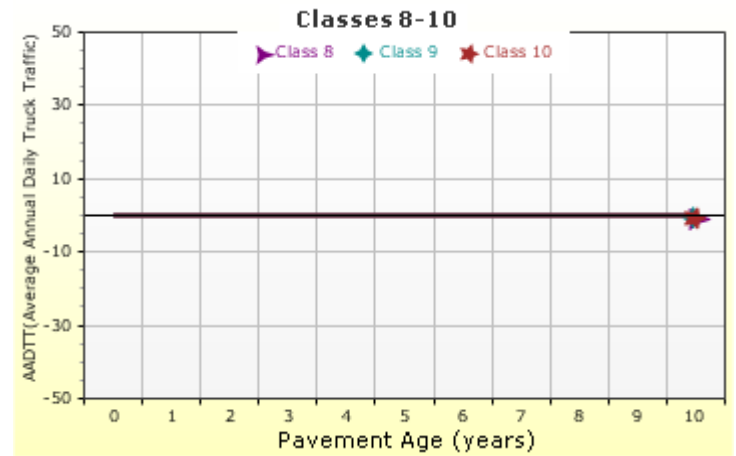
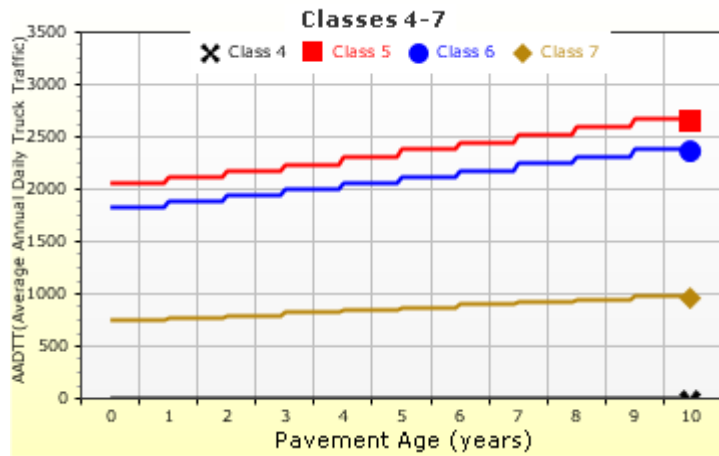
Wheelbase does not apply

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



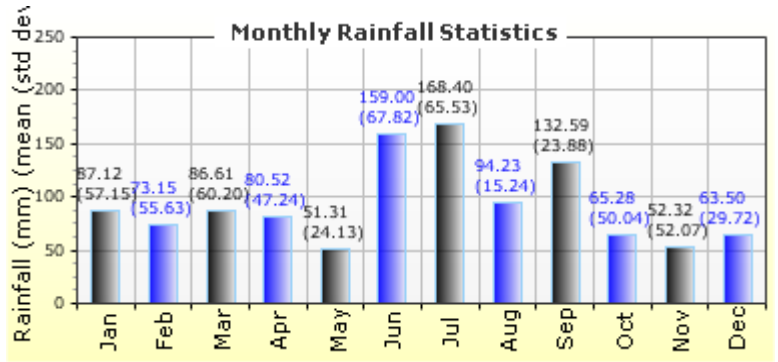
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

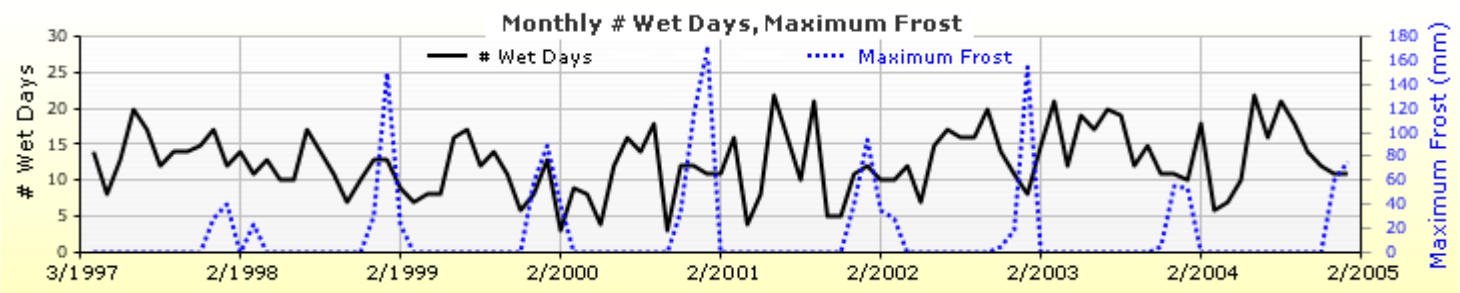
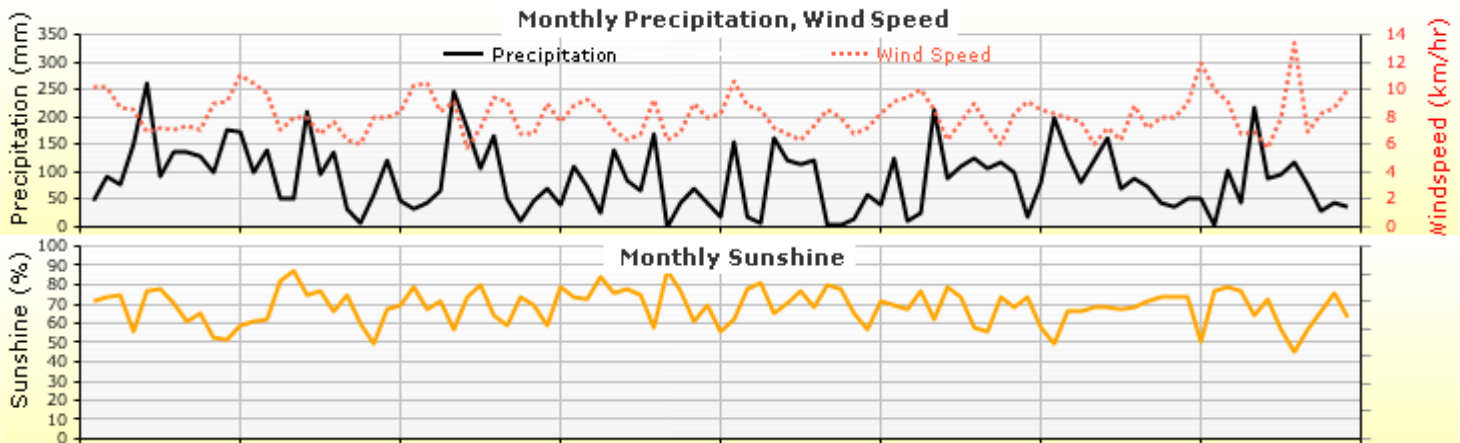
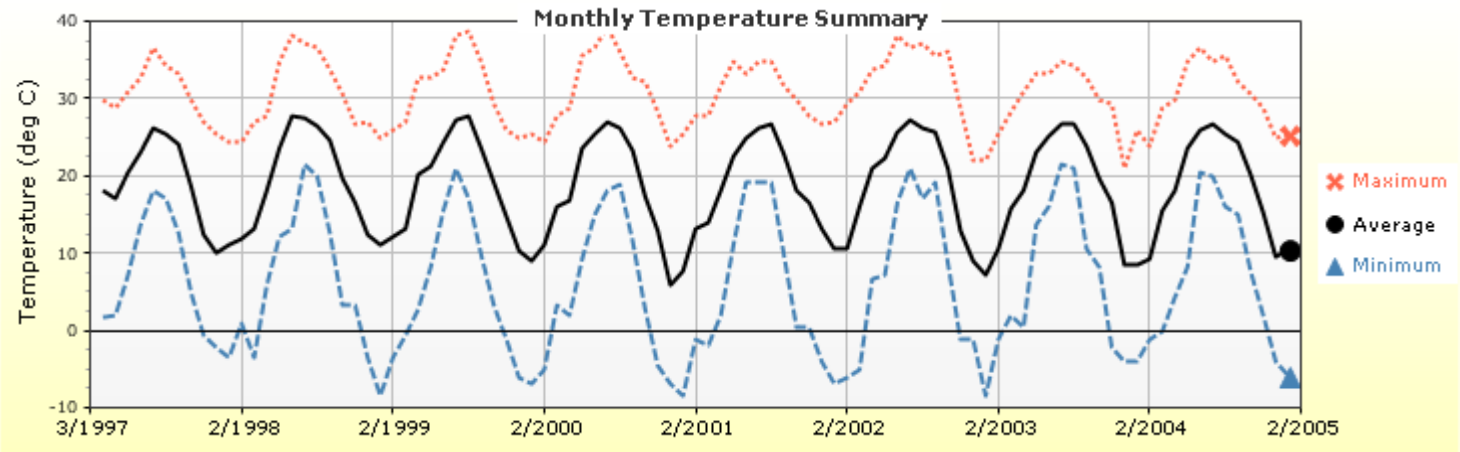
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

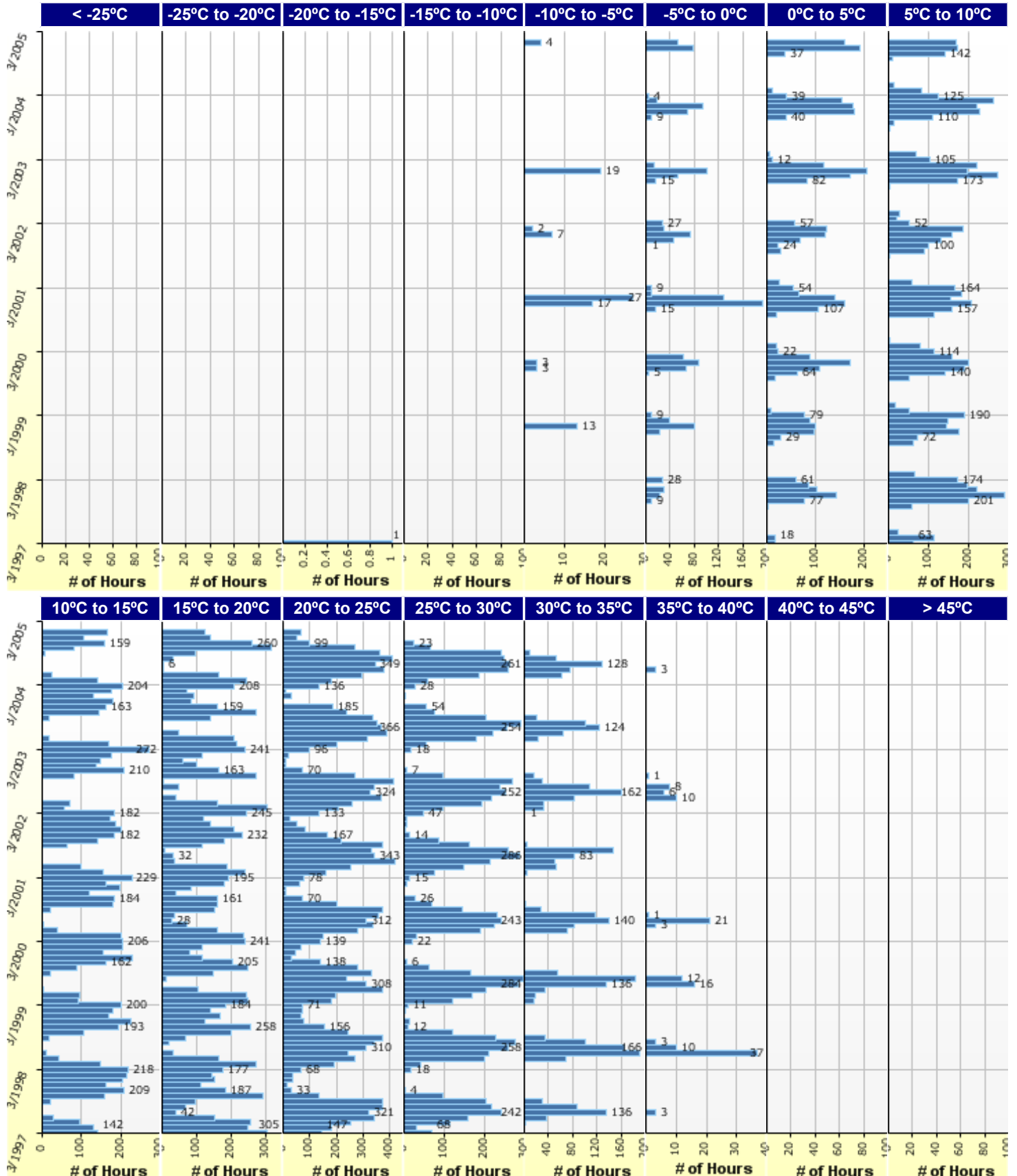


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF4_ALT2

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF4_ALT2.dgpx



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

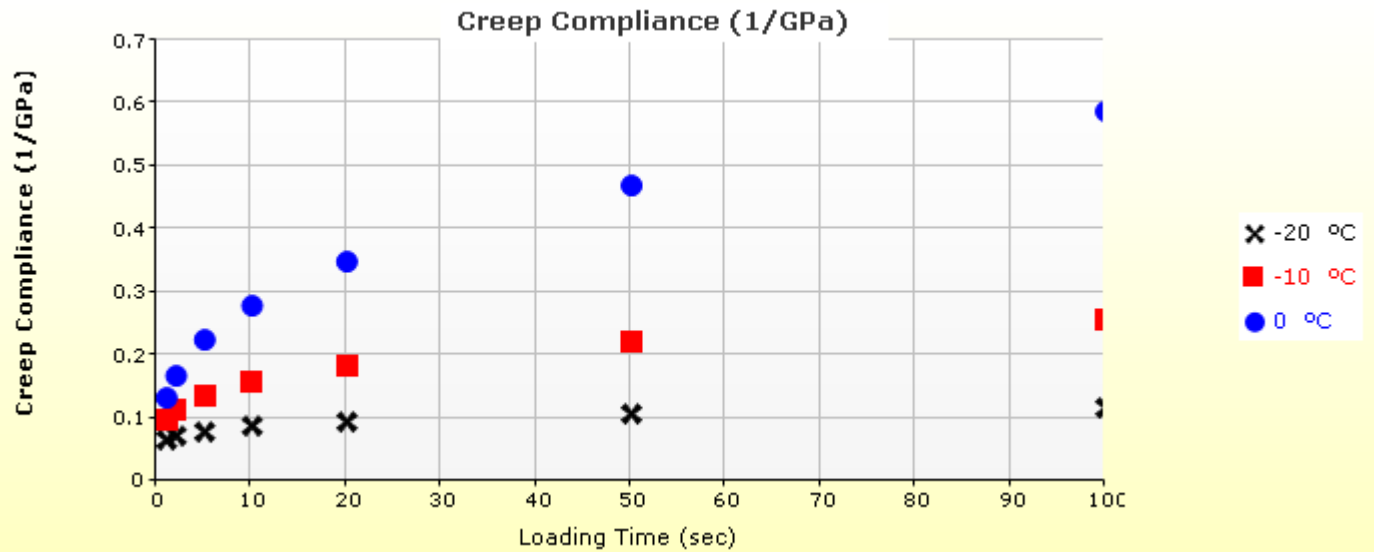
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

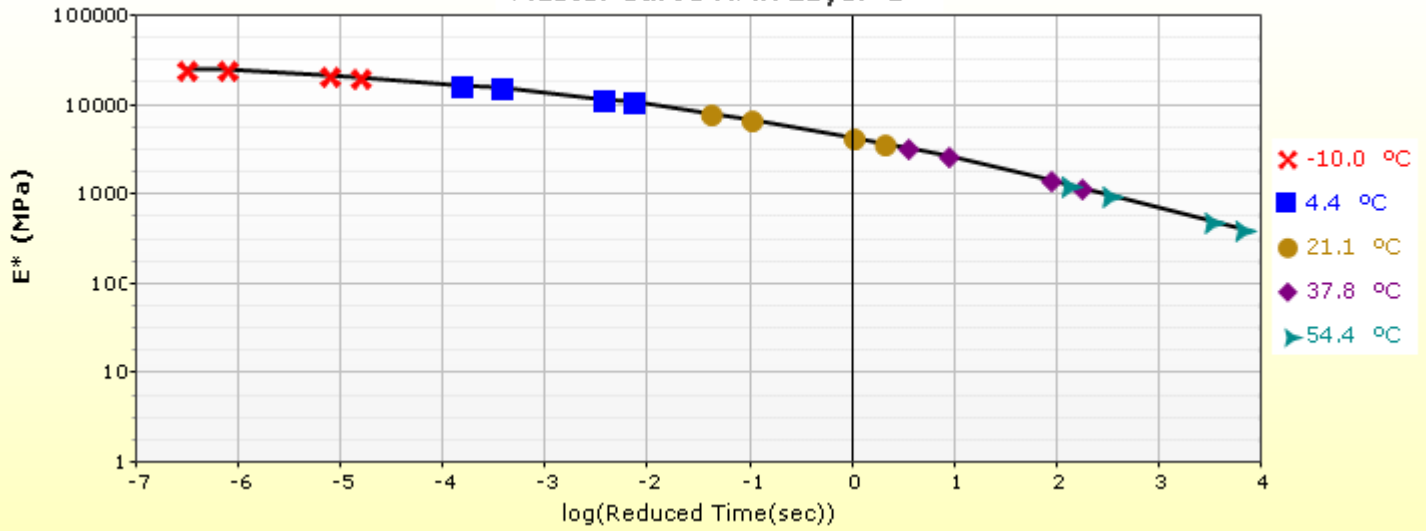
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

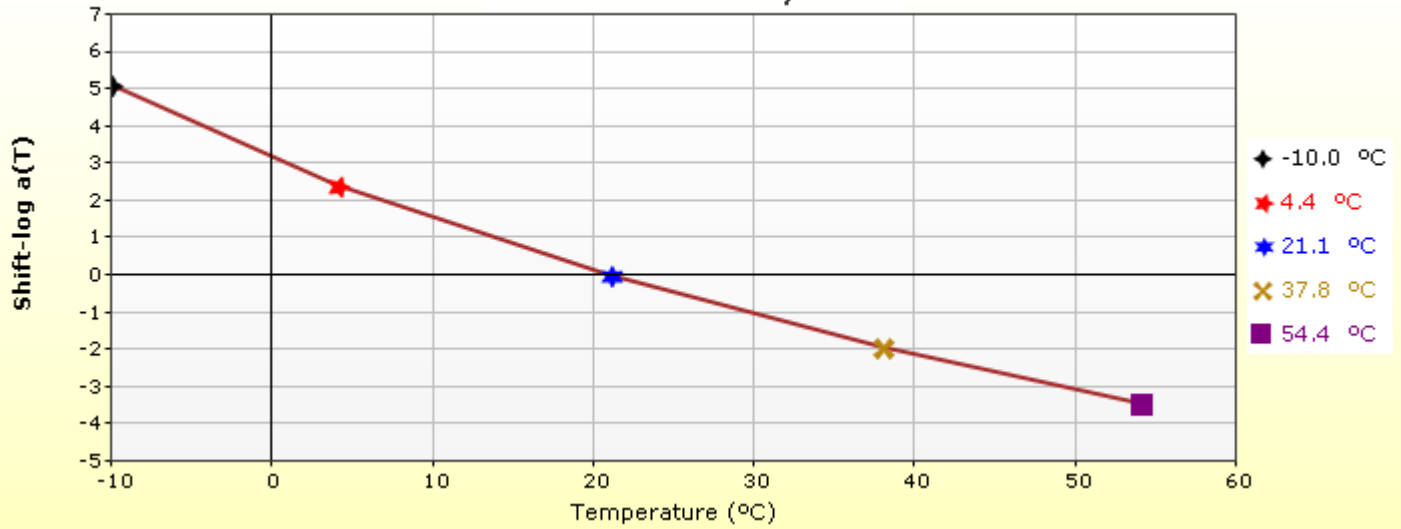


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

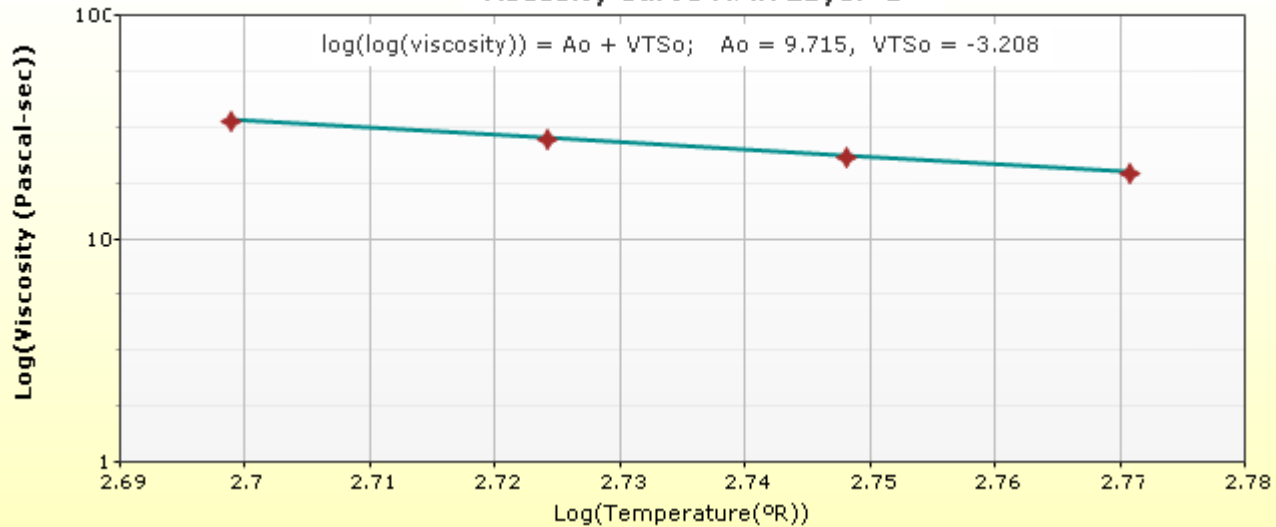
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

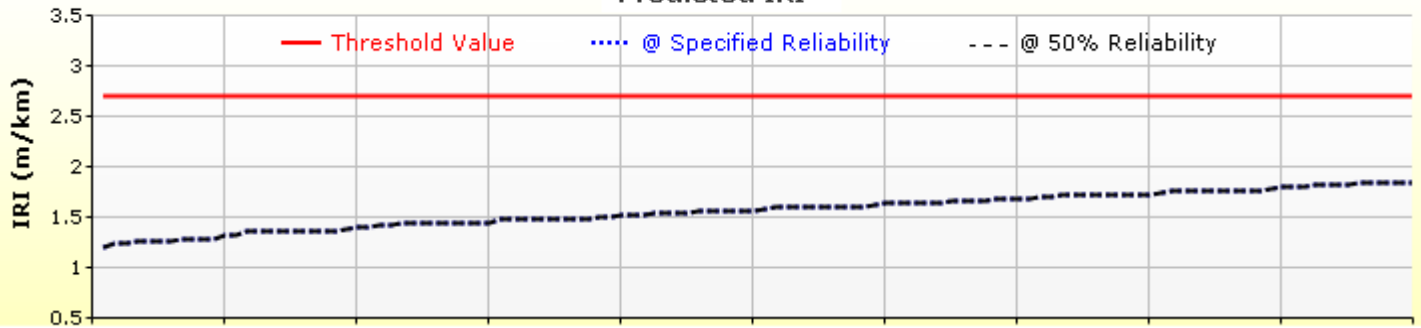


Viscosity Curve HMA Layer 1

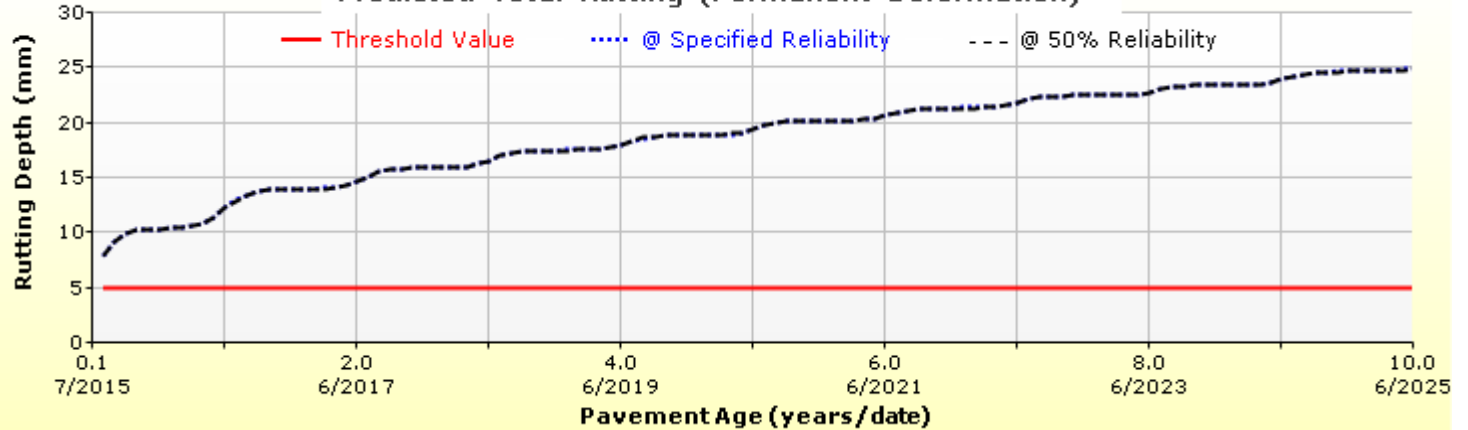


Analysis Output Charts

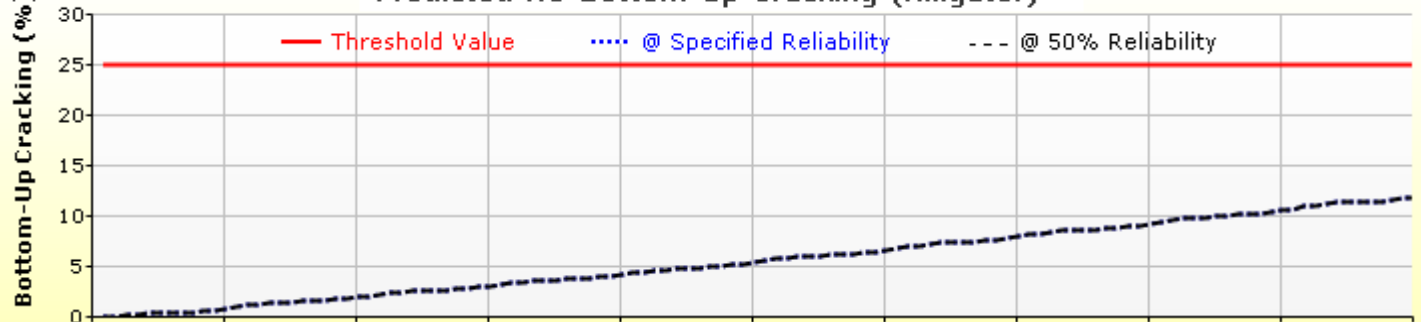
Predicted IRI



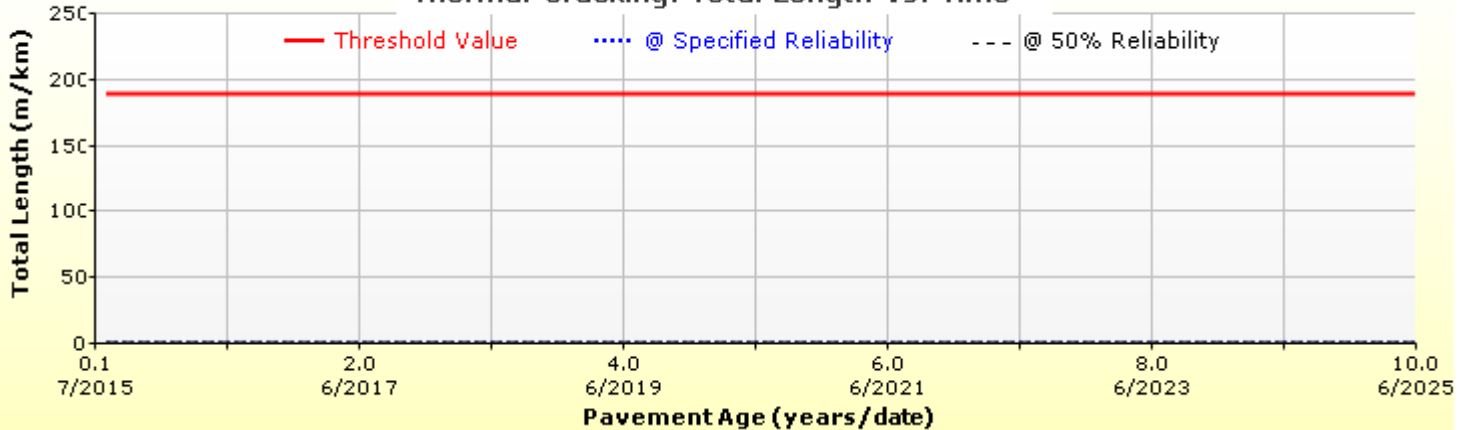
Predicted Total Rutting (Permanent Deformation)



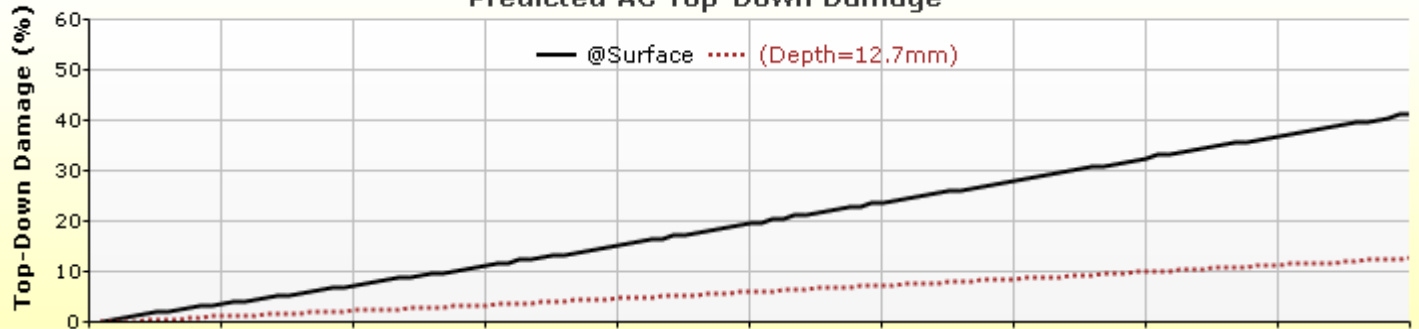
Predicted AC Bottom-Up Cracking (Alligator)



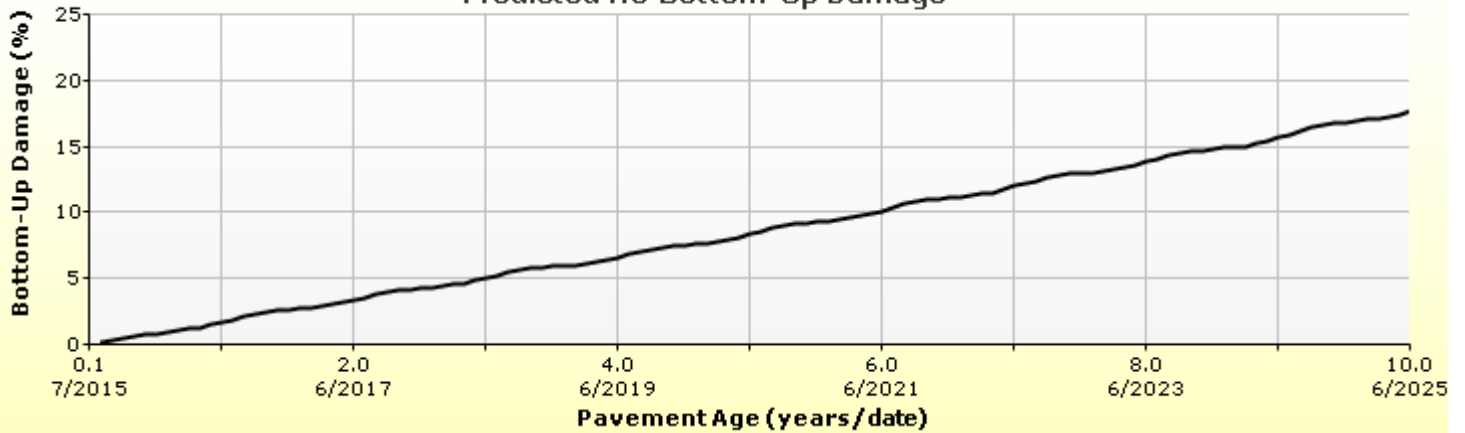
Thermal Cracking: Total Length vs. Time



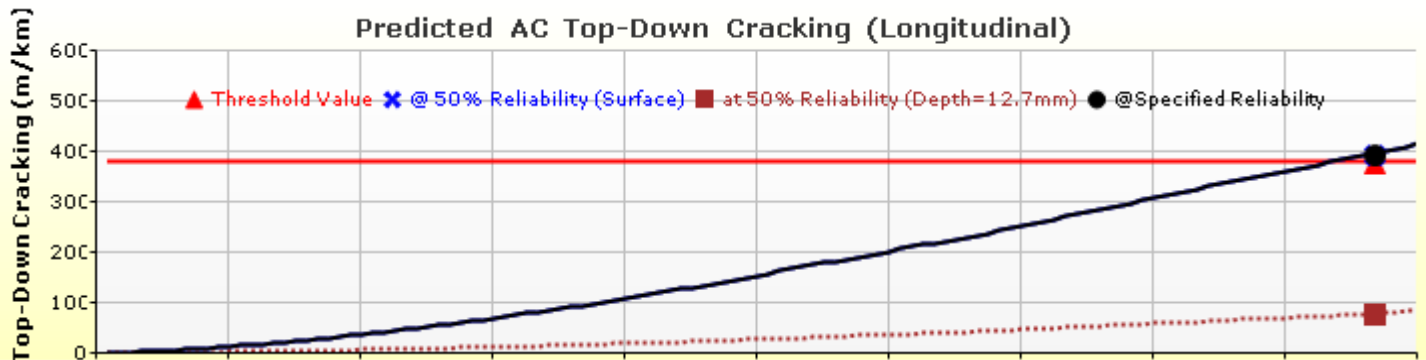
Predicted AC Top-Down Damage



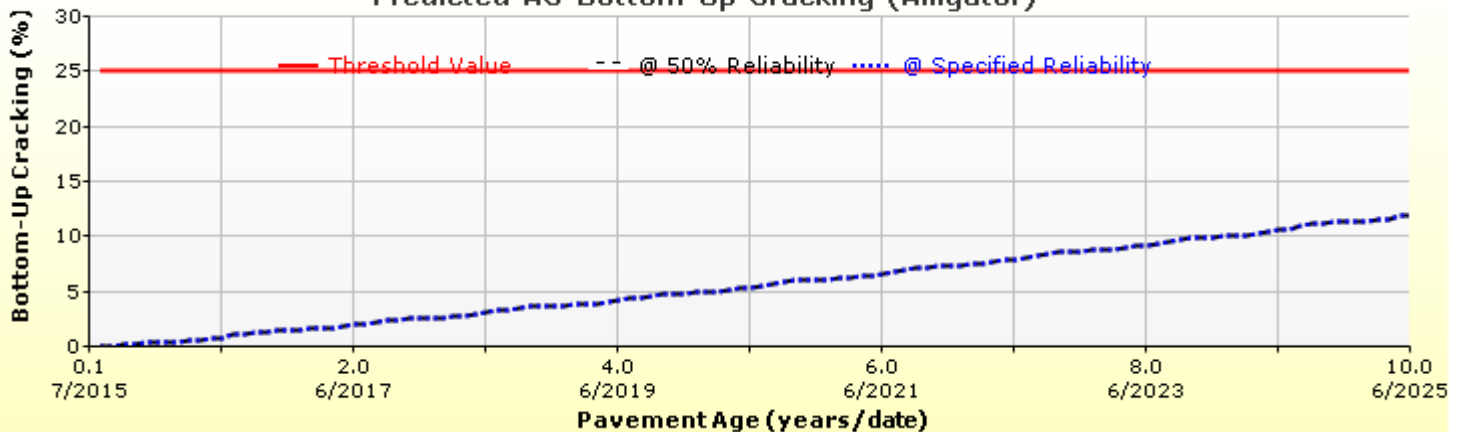
Predicted AC Bottom-Up Damage



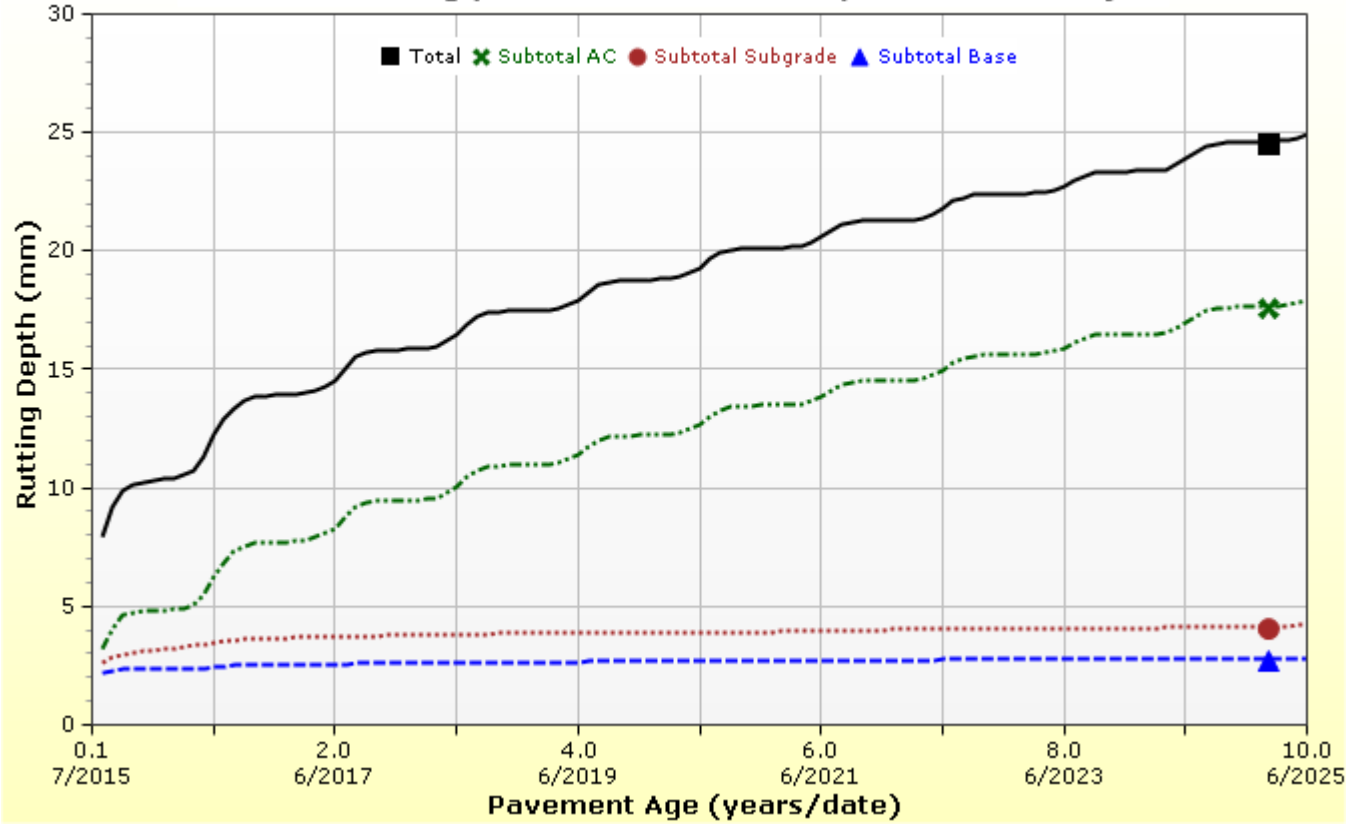
Predicted AC Top-Down Cracking (Longitudinal)

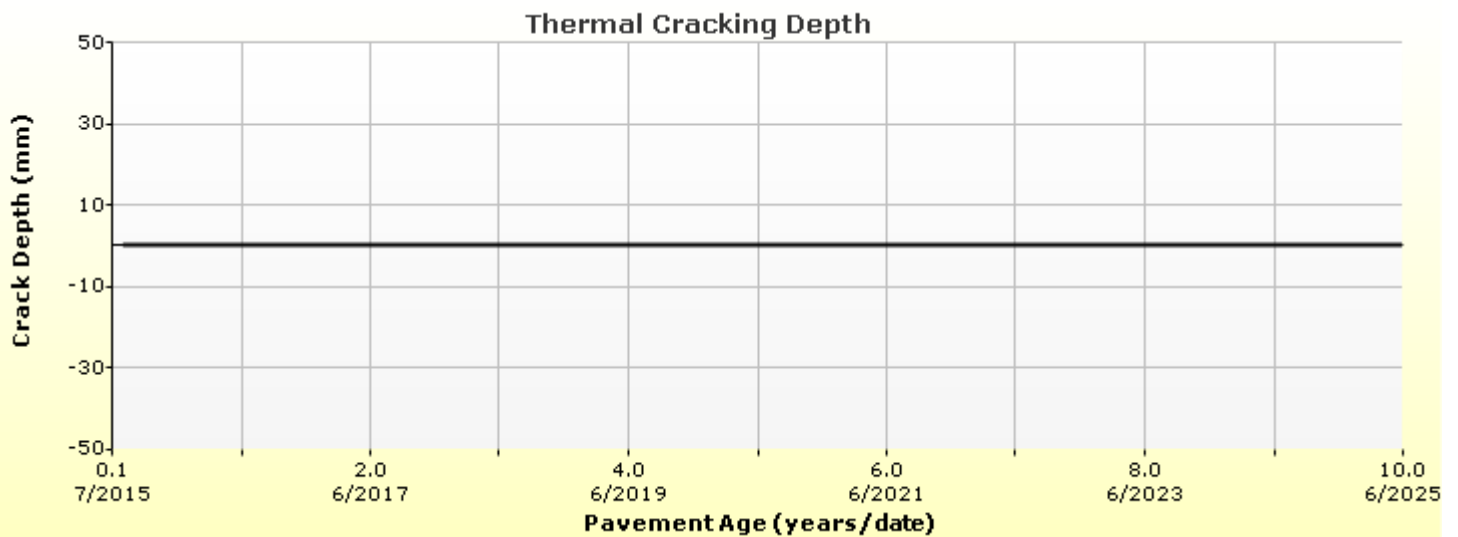
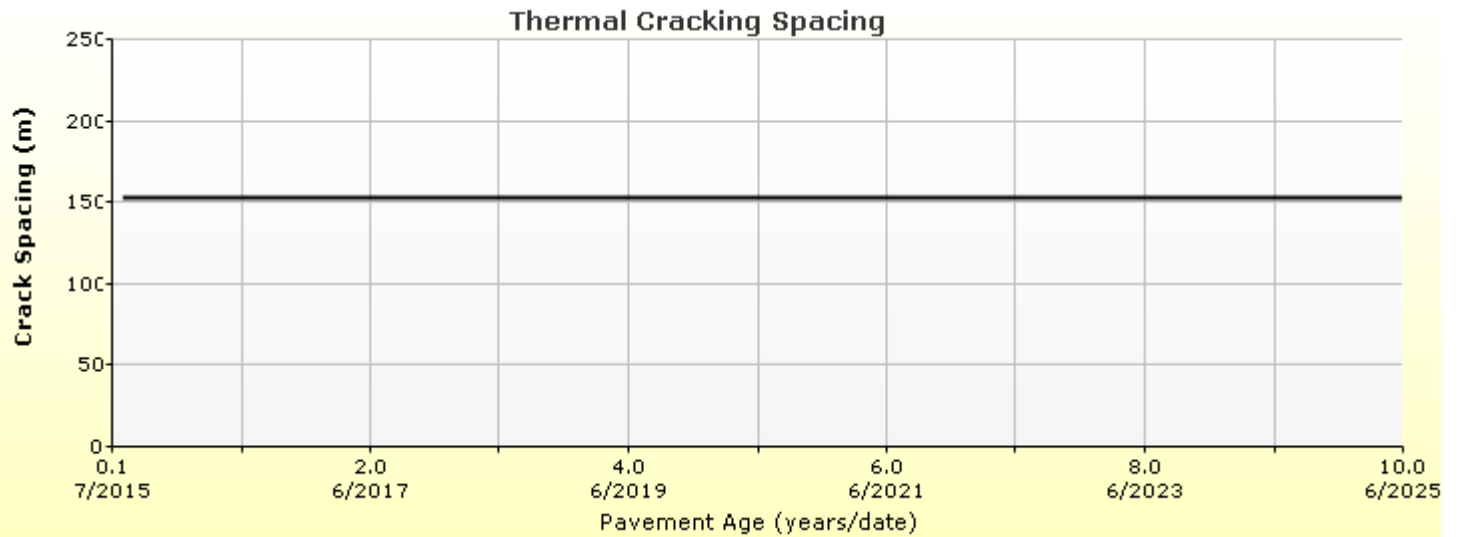


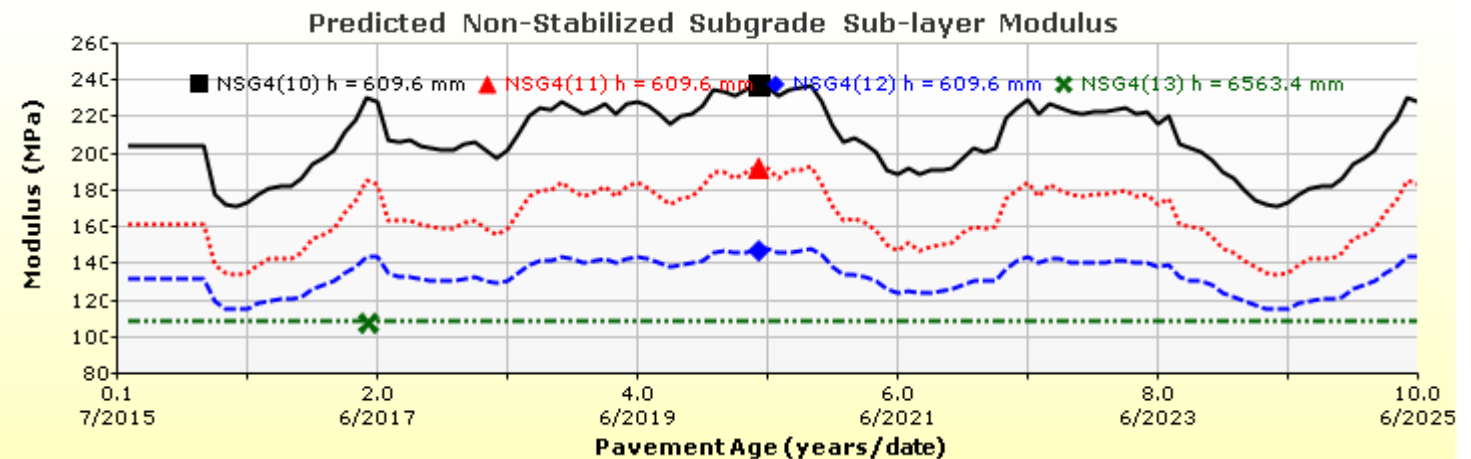
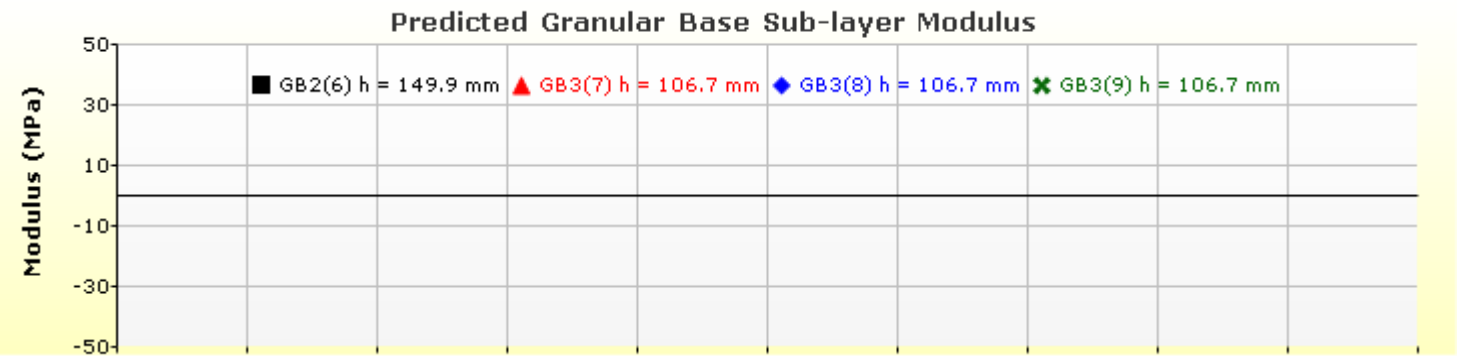
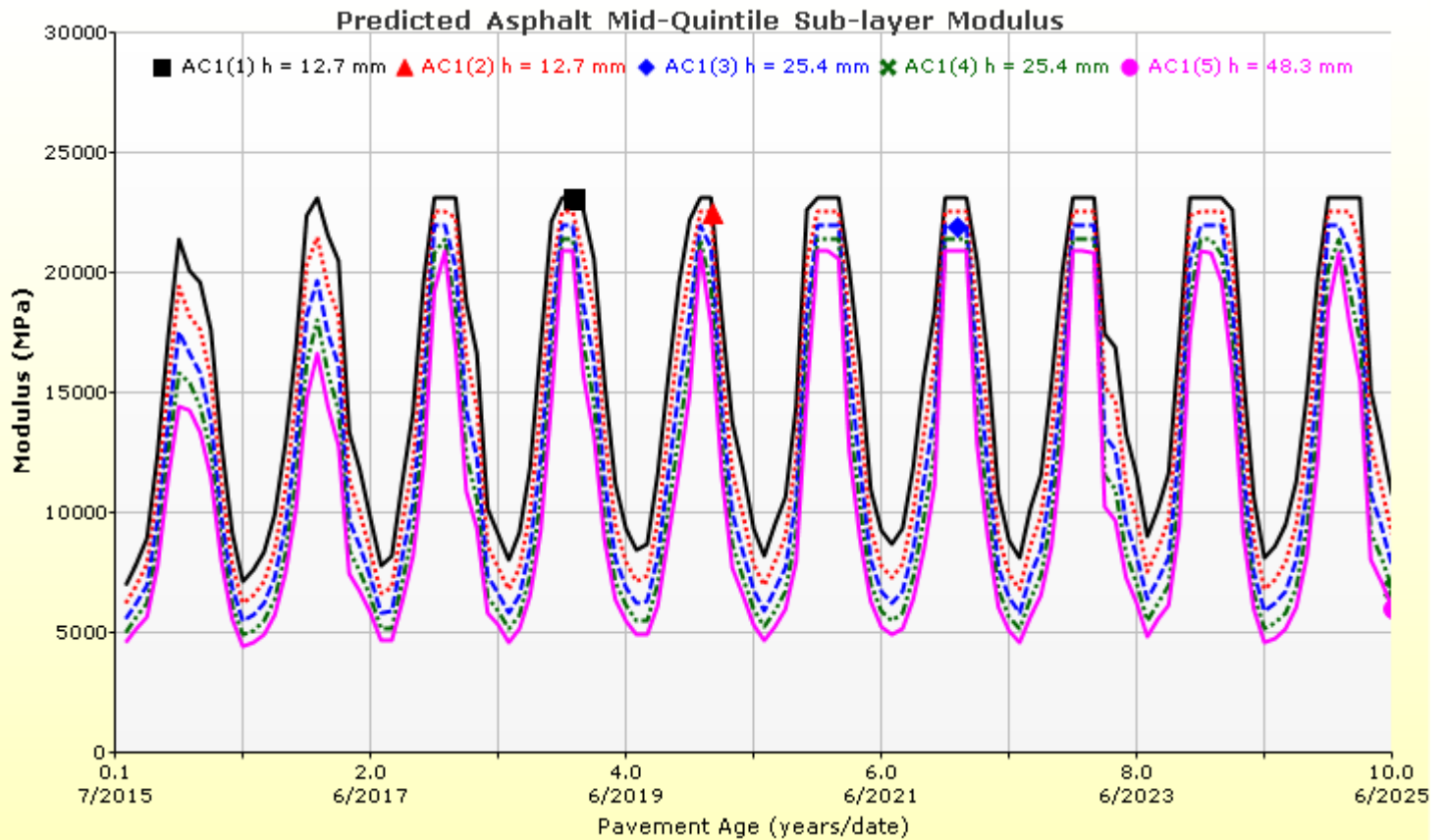
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

Standard Deviation (BASERUT)

0.1235*Pow(SUBRUT,0.5012)+0.001

AC Cracking

AC Top Down Cracking

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

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: 7

c2: 3.5

c3: 0

c4: 1000

c1: 1

c2: 1

c3: 6000

AC Cracking Top Standard Deviation

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

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

IRI Flexible Pavements

C1 - Rutting

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

CSM Standard Deviation

CTB*1

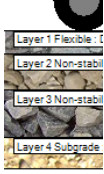
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	200.0
NonStabilized	Crushed stone	300.0
NonStabilized	Crushed stone	400.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

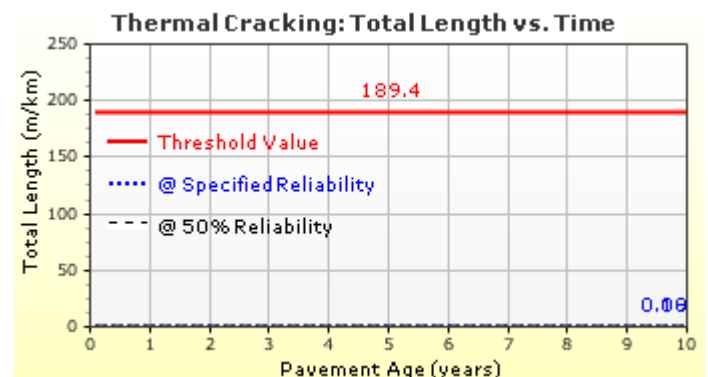
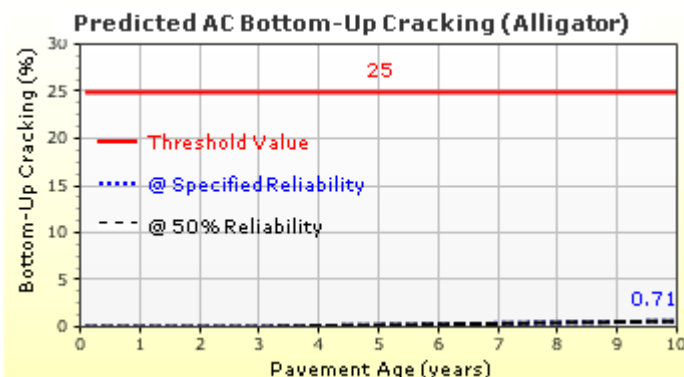
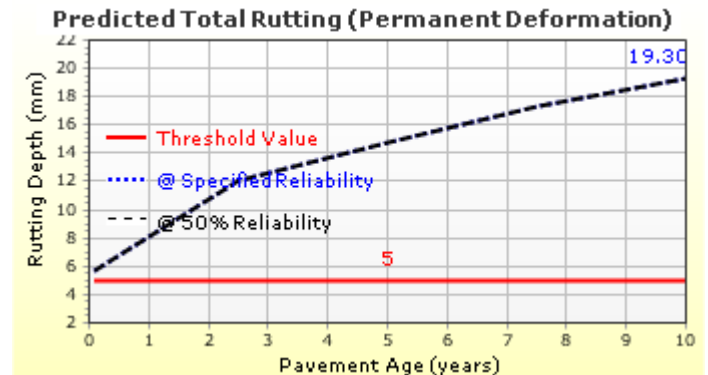
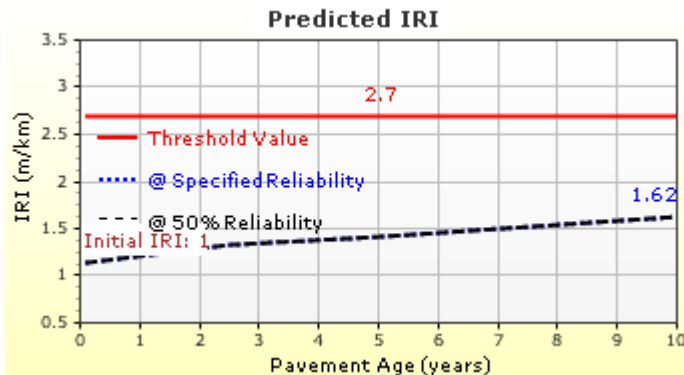
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.62	50.00	99.11	Pass
Permanent deformation - total pavement (mm)	5.00	19.30	50.00	0.03	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.71	50.00	100.00	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	72.73	50.00	79.27	Pass
Permanent deformation - AC only (mm)	5.00	14.57	50.00	0.74	Fail

Distress Charts

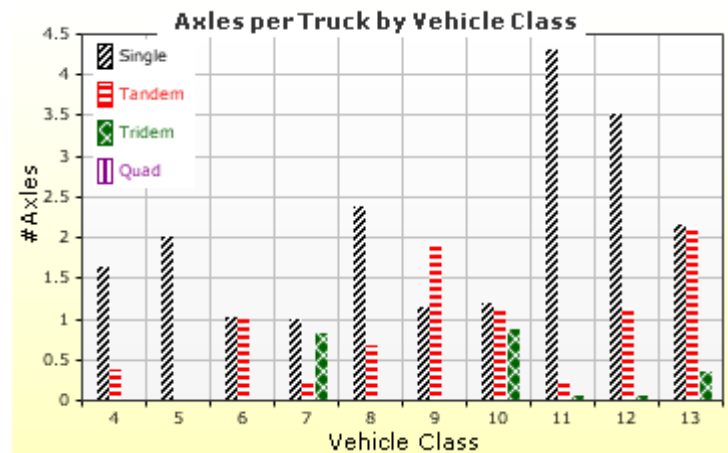
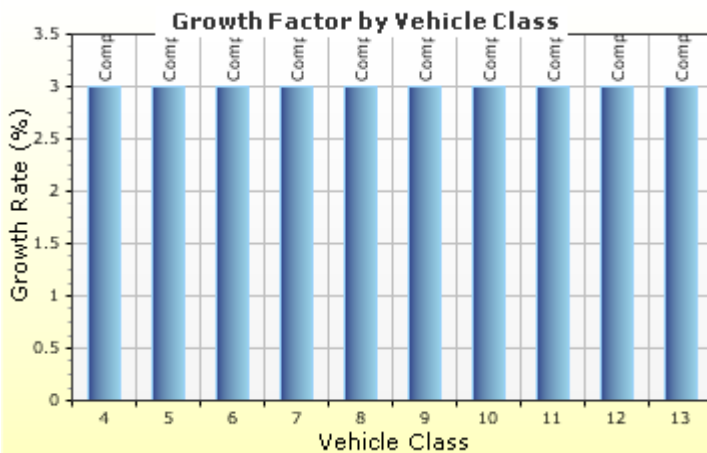
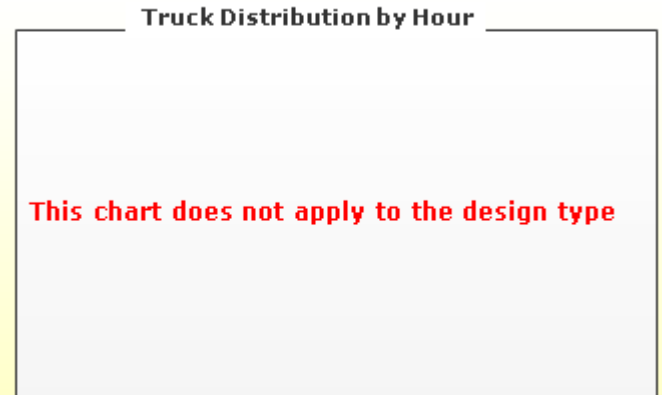
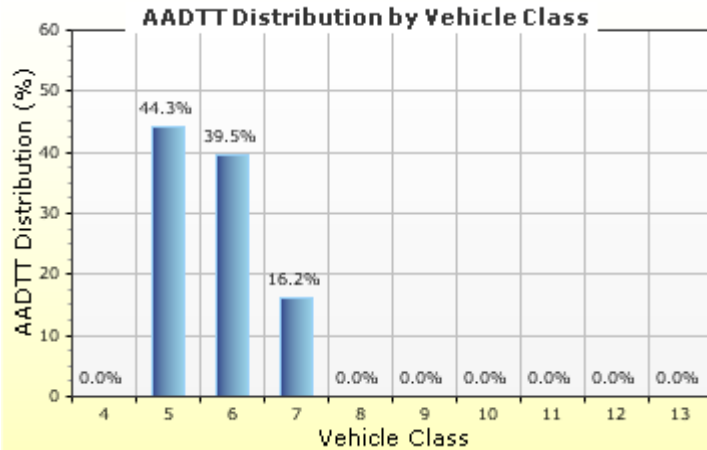


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

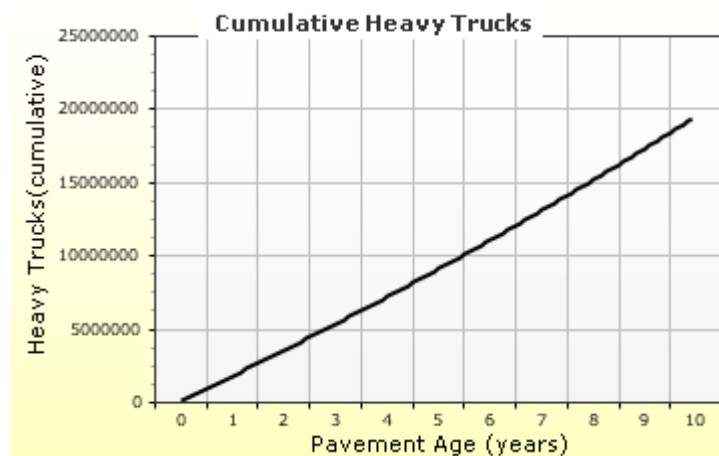
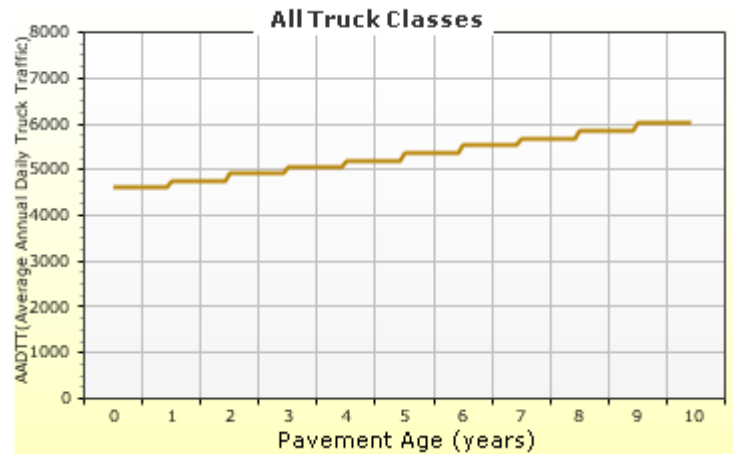
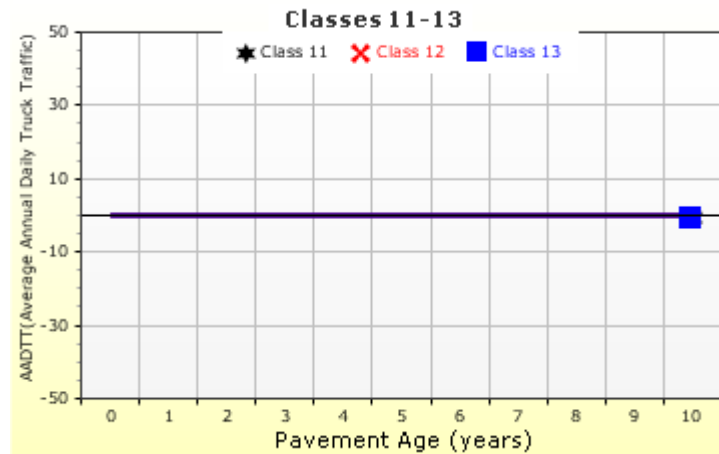
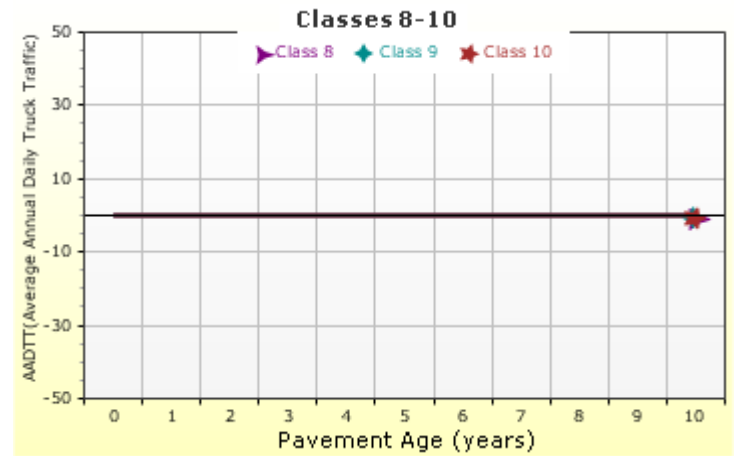
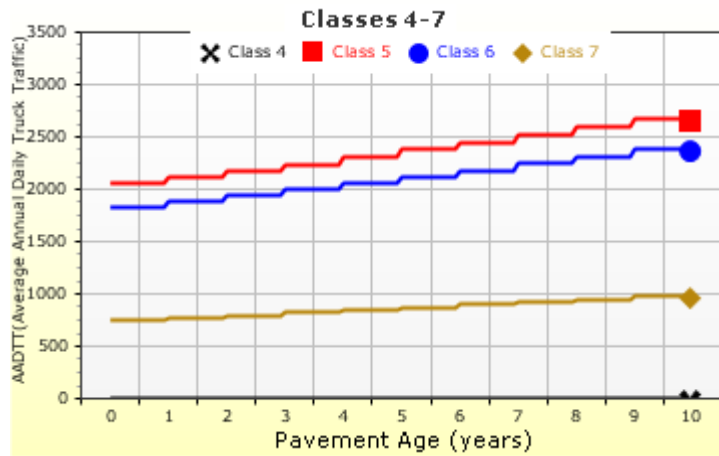
Wheelbase does not apply	

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



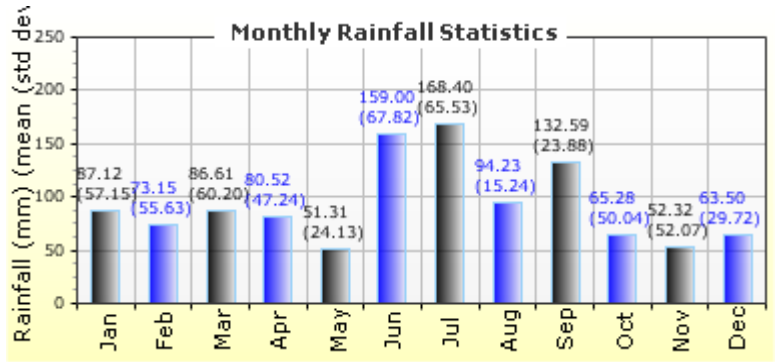
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

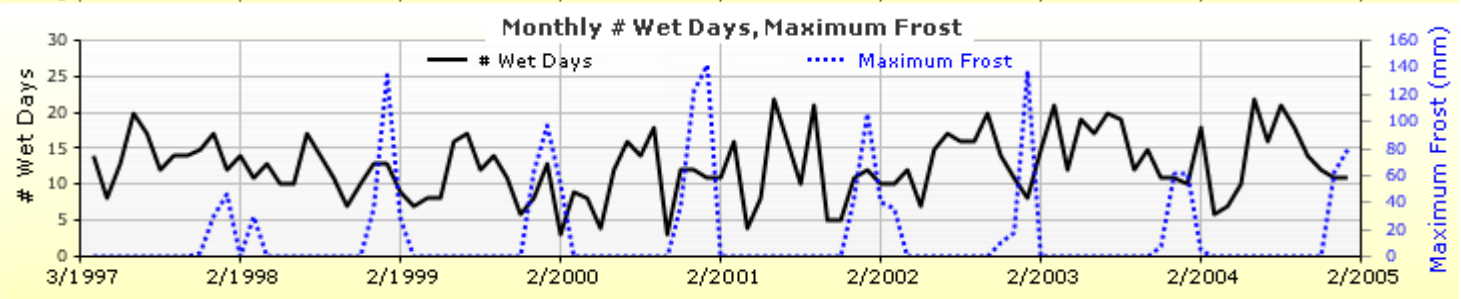
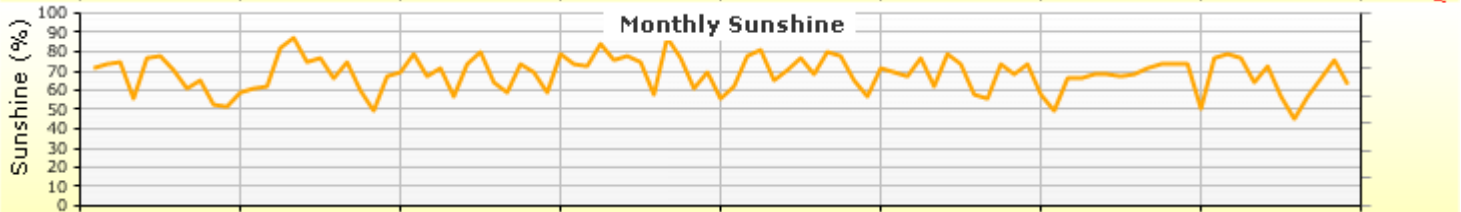
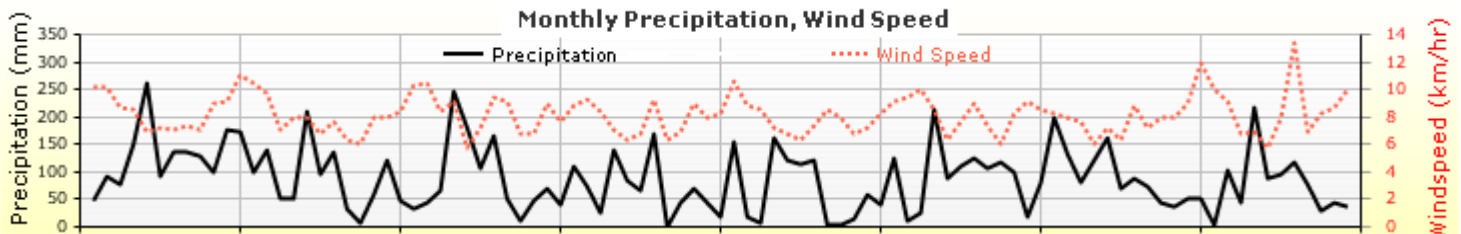
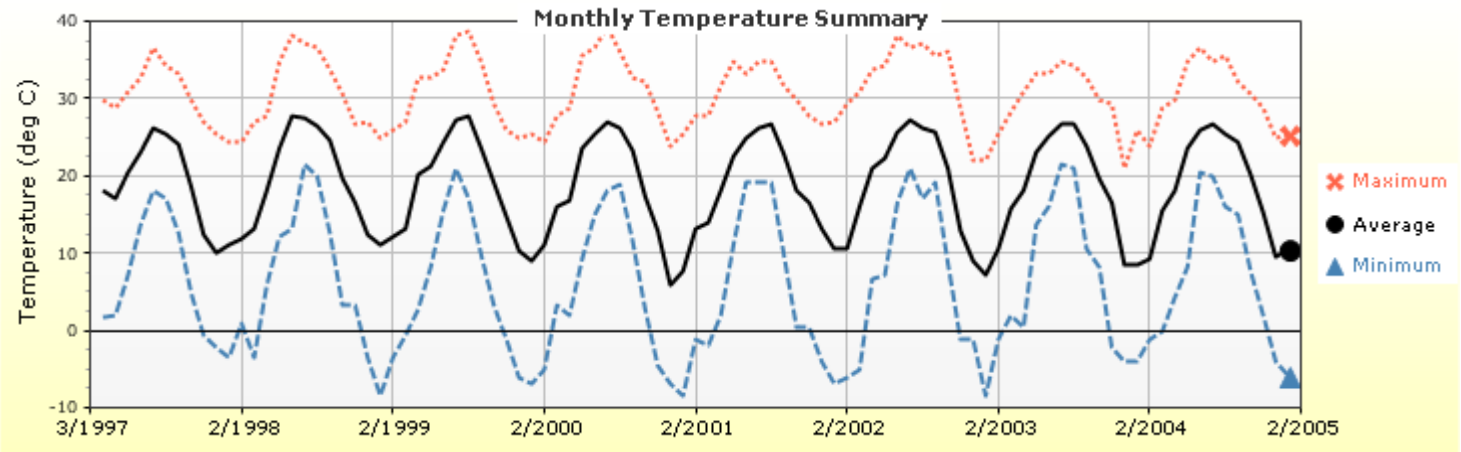
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

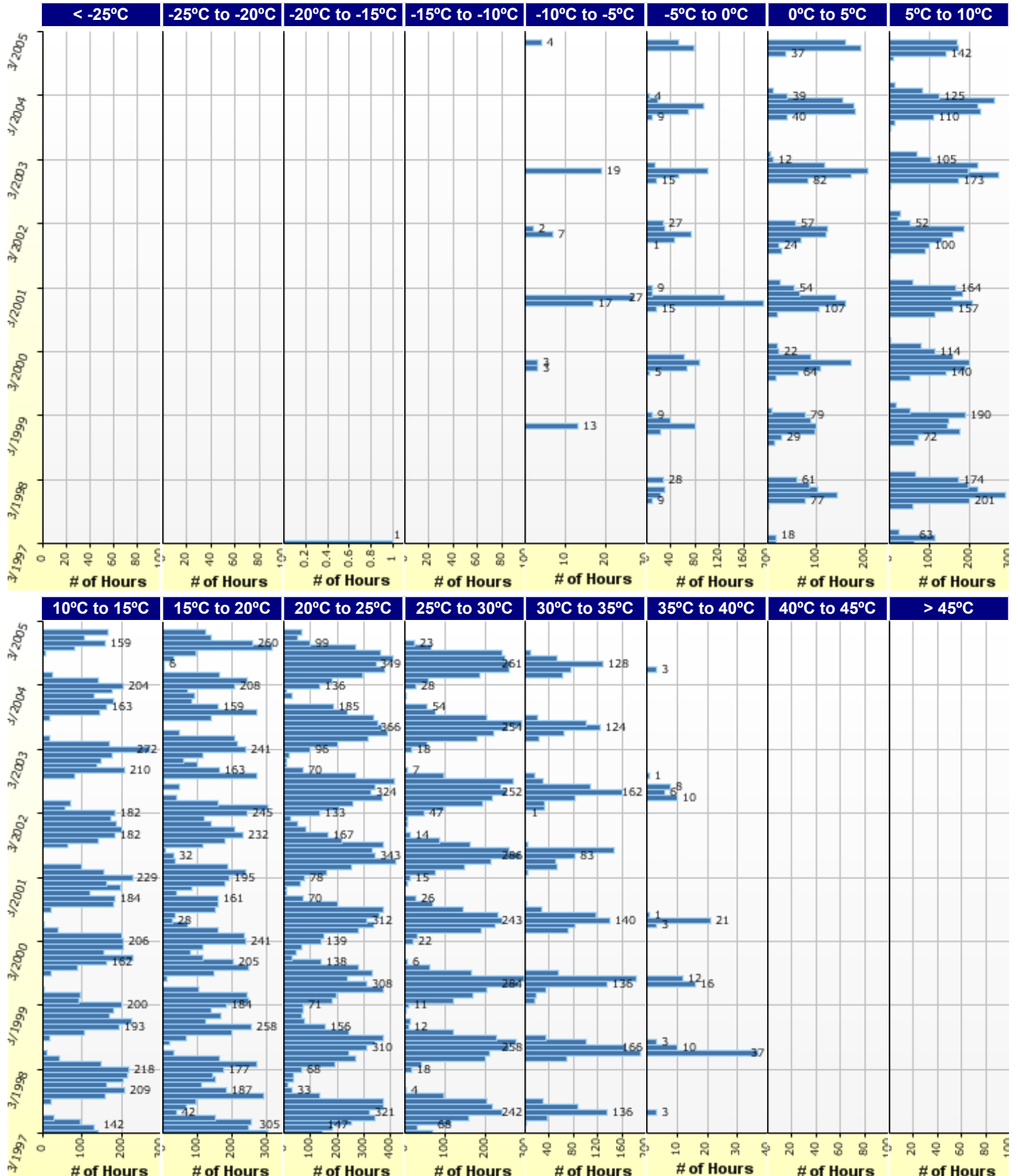


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF1_ALT3

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1_ALT3.dgpx



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

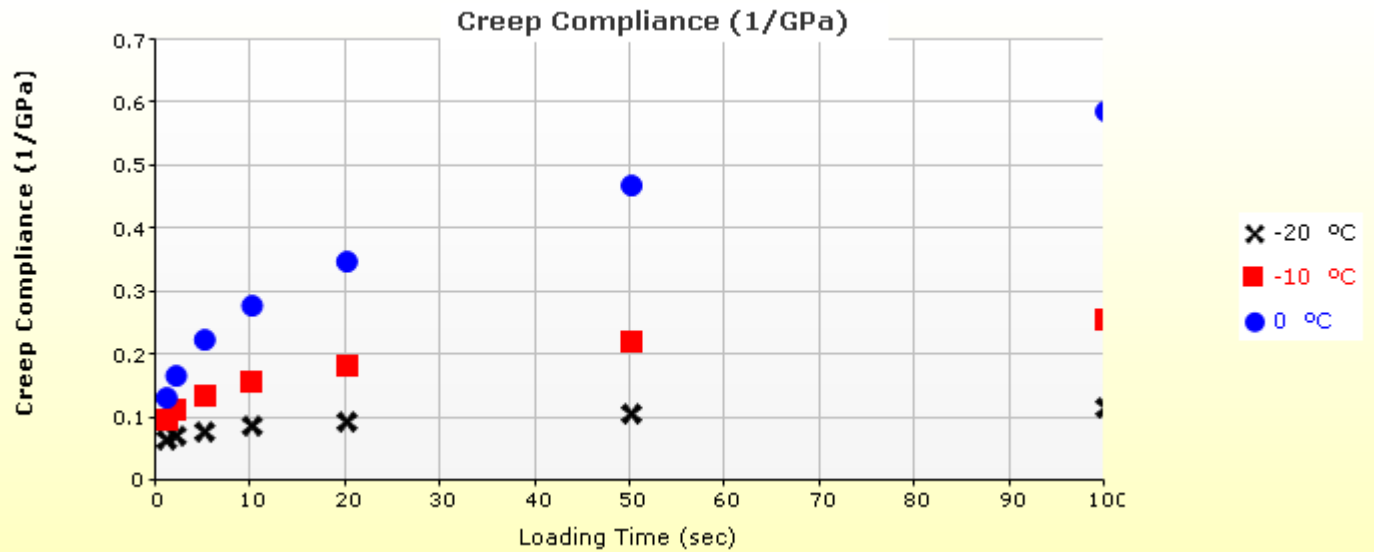
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

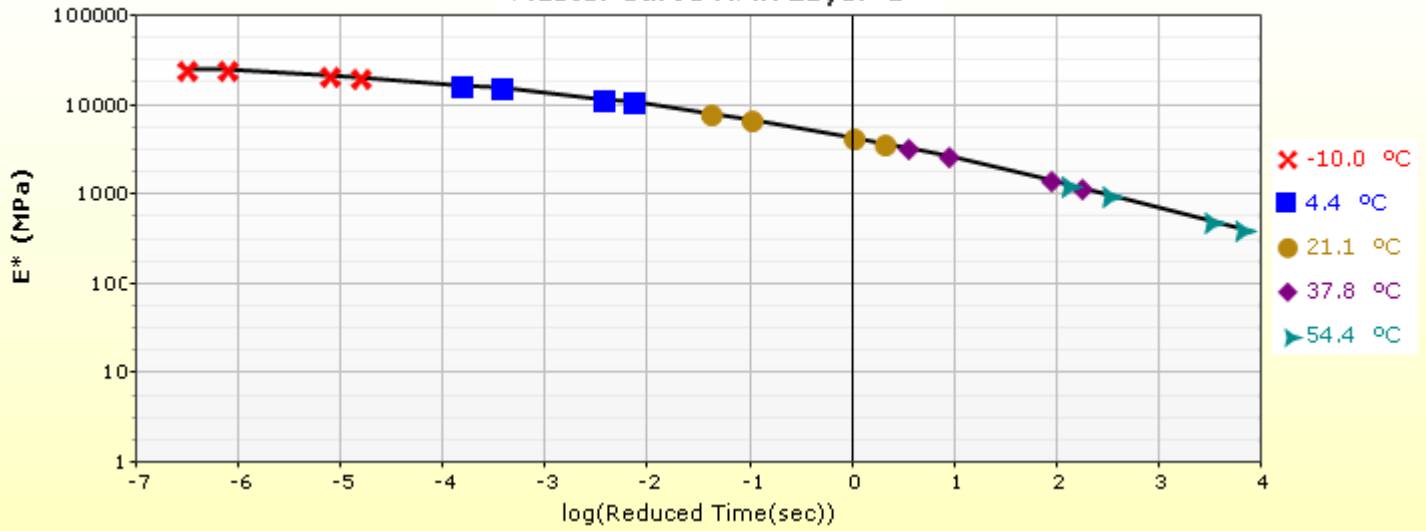
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

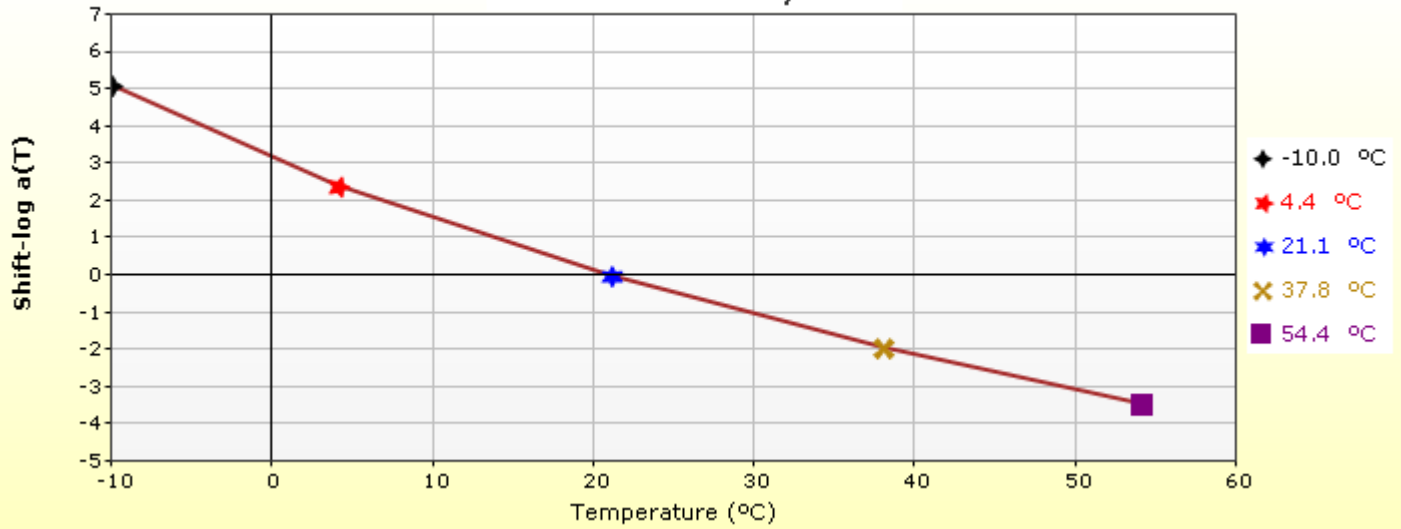


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

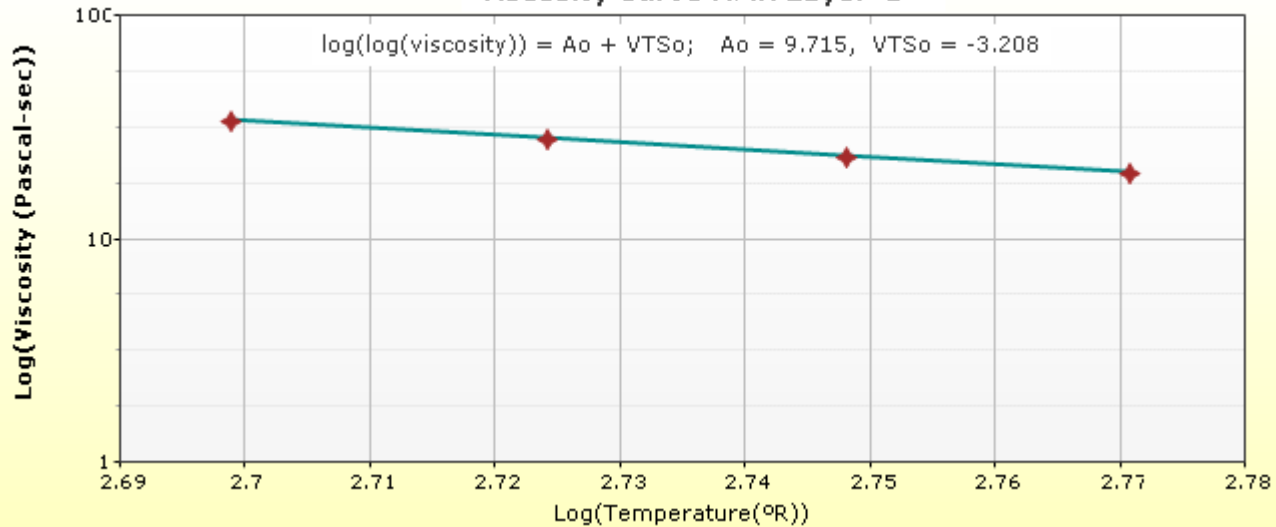
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

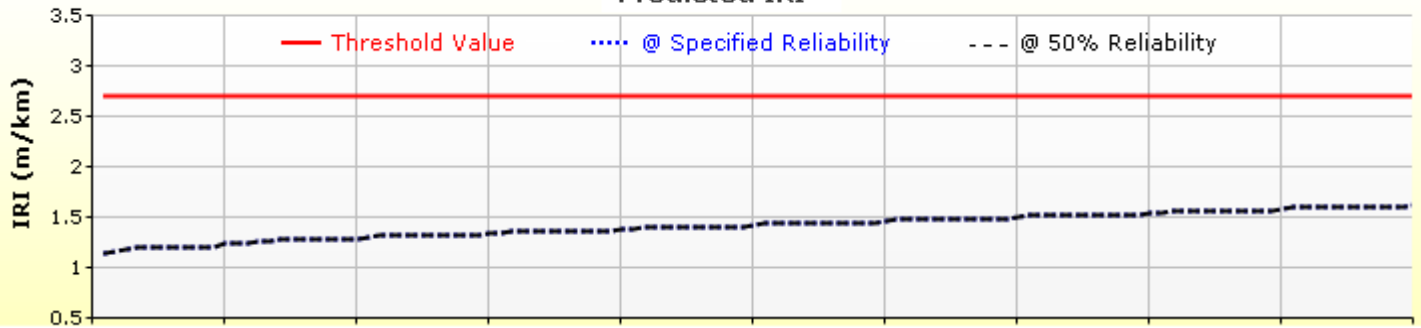


Viscosity Curve HMA Layer 1

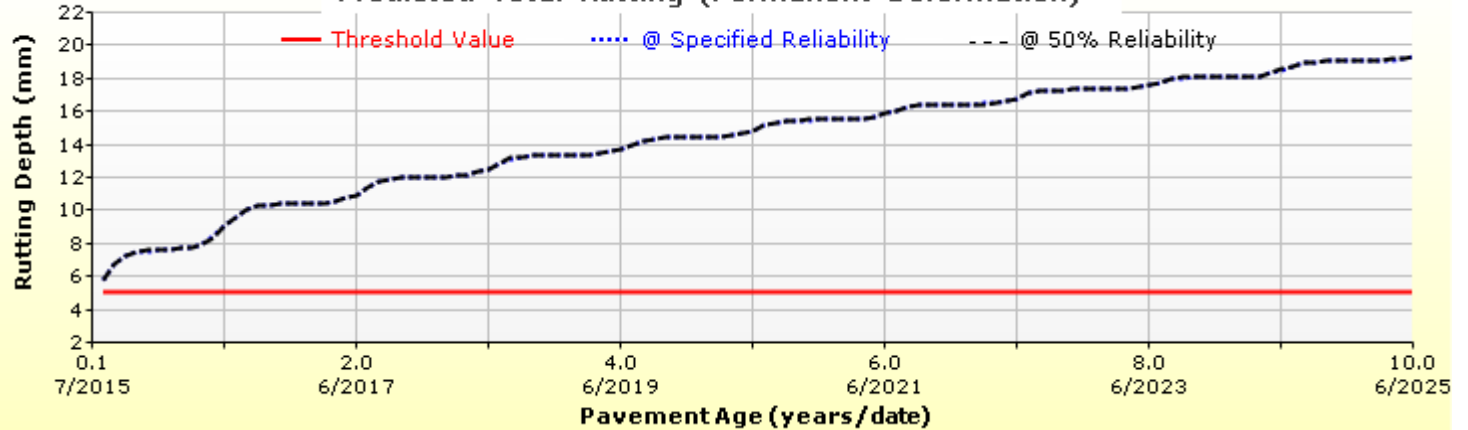


Analysis Output Charts

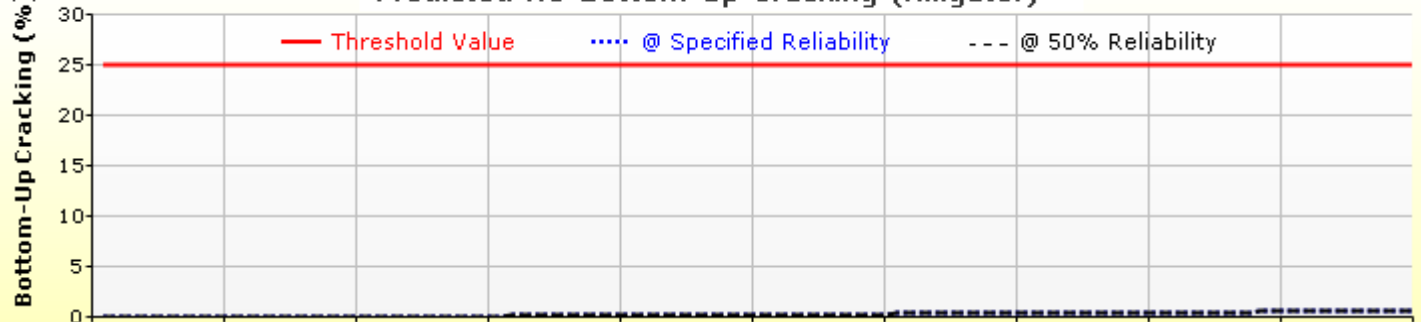
Predicted IRI



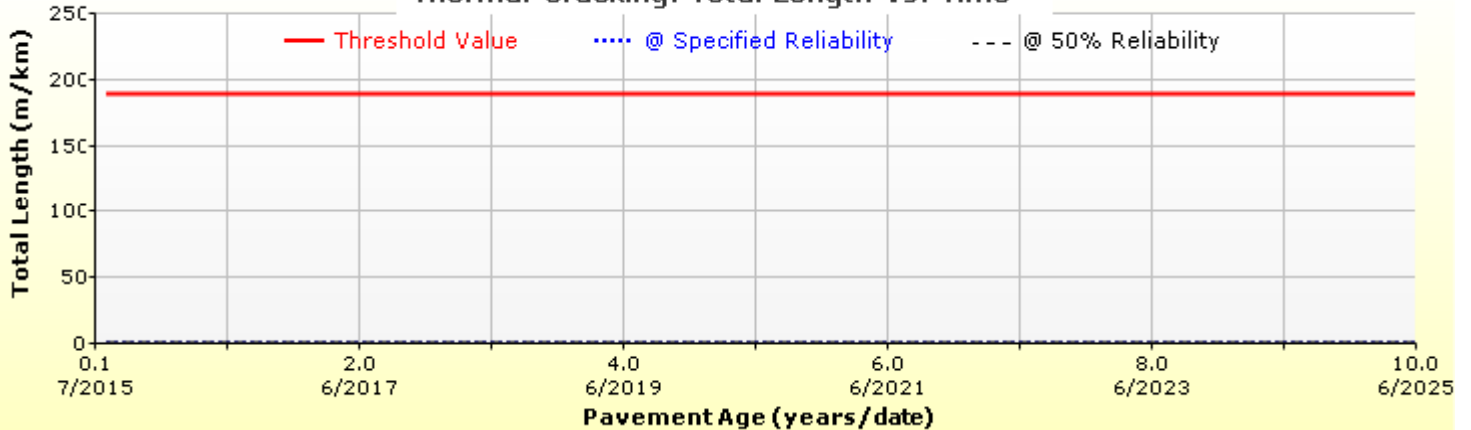
Predicted Total Rutting (Permanent Deformation)



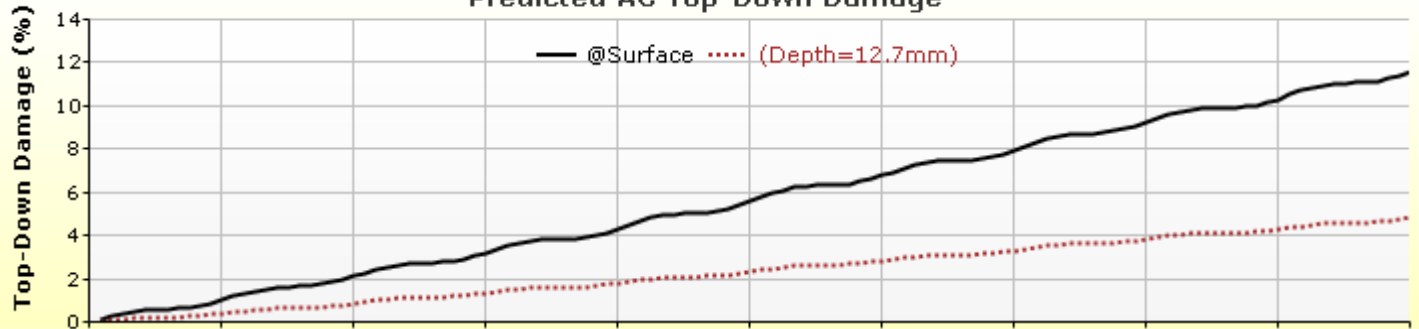
Predicted AC Bottom-Up Cracking (Alligator)



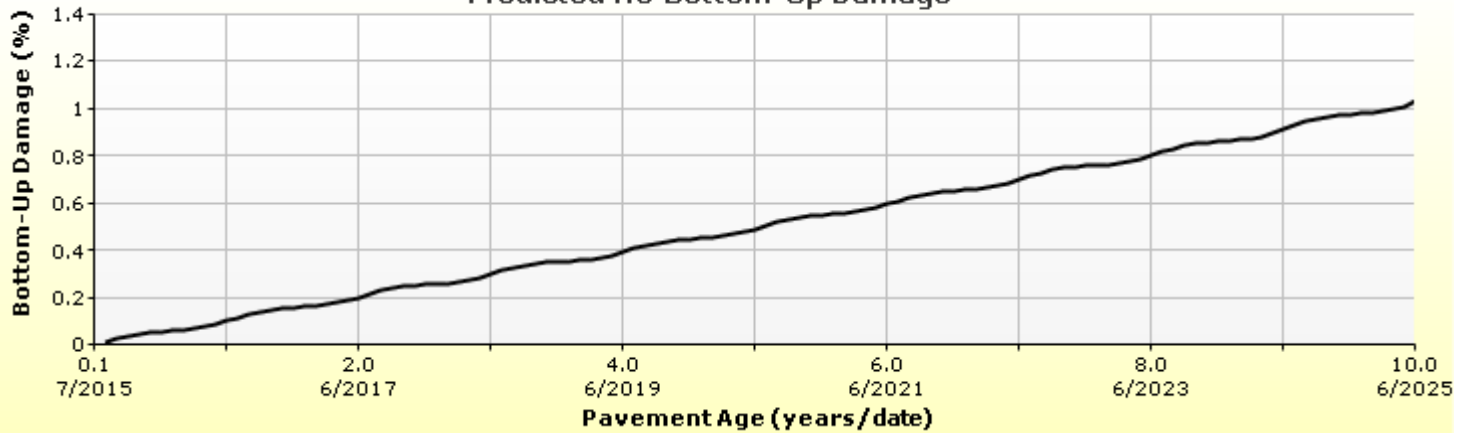
Thermal Cracking: Total Length vs. Time



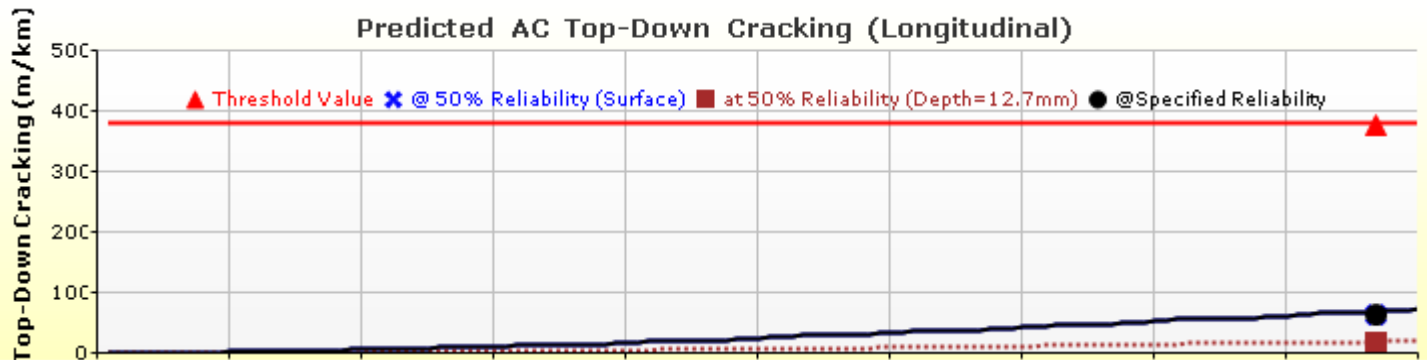
Predicted AC Top-Down Damage



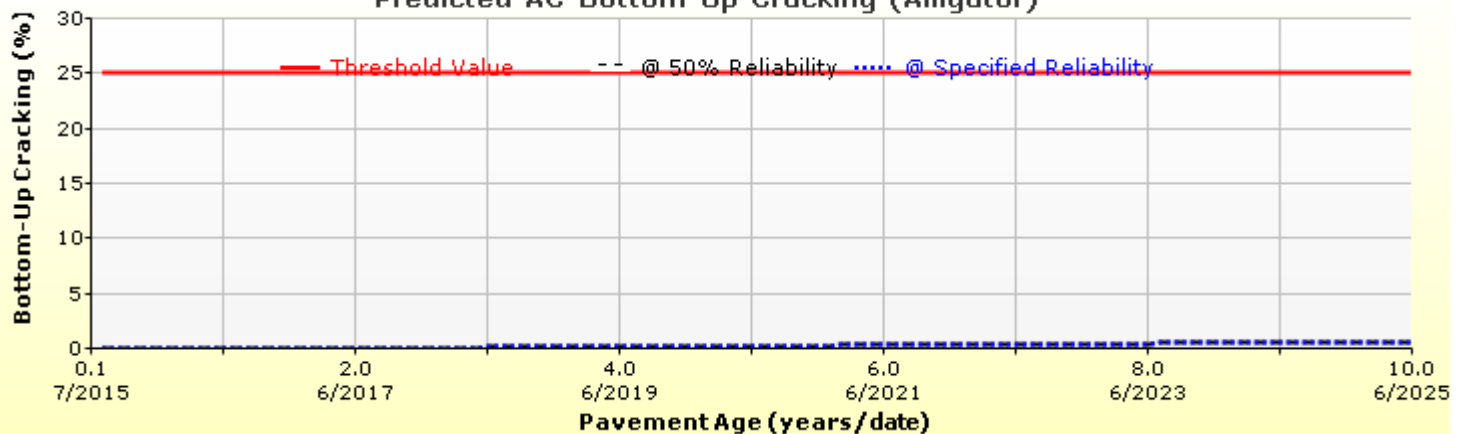
Predicted AC Bottom-Up Damage



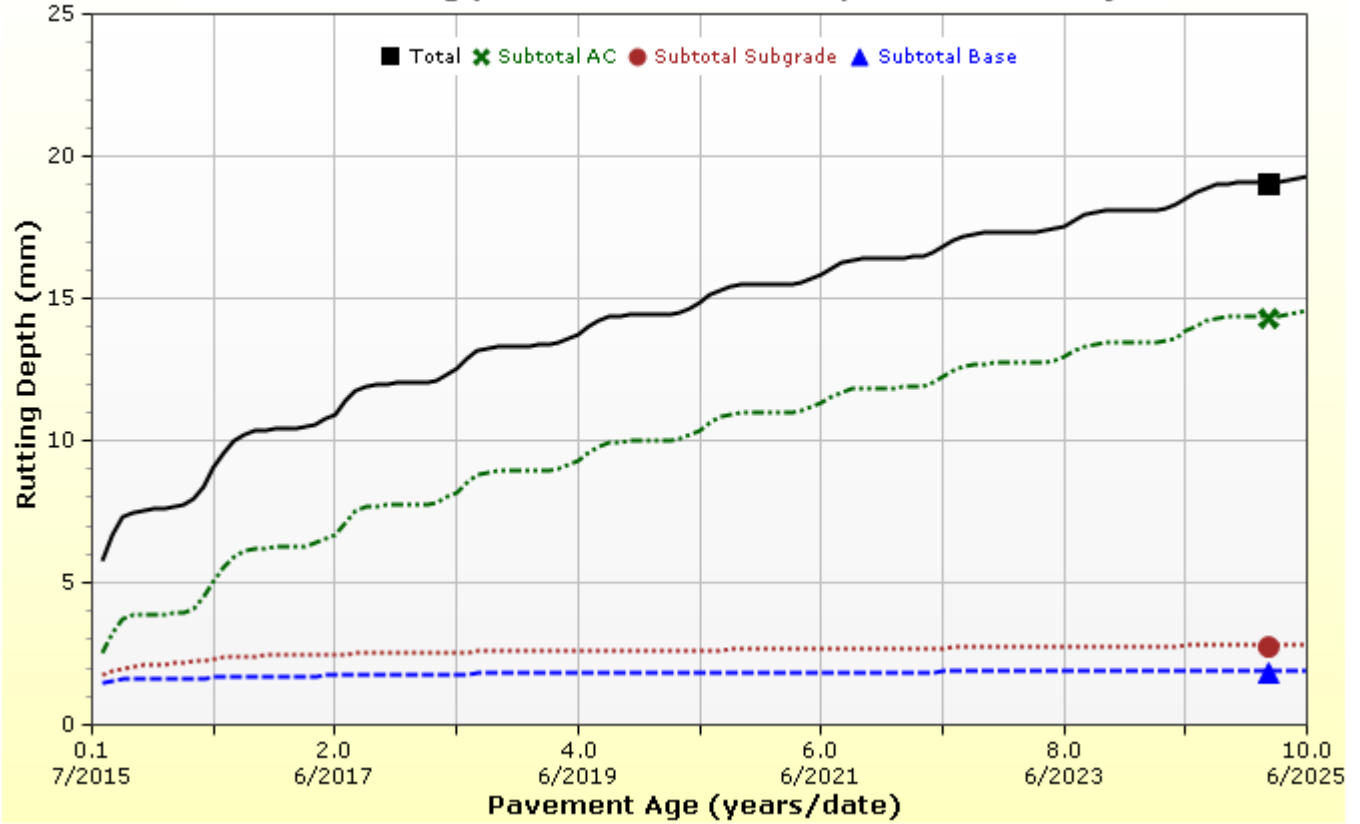
Predicted AC Top-Down Cracking (Longitudinal)



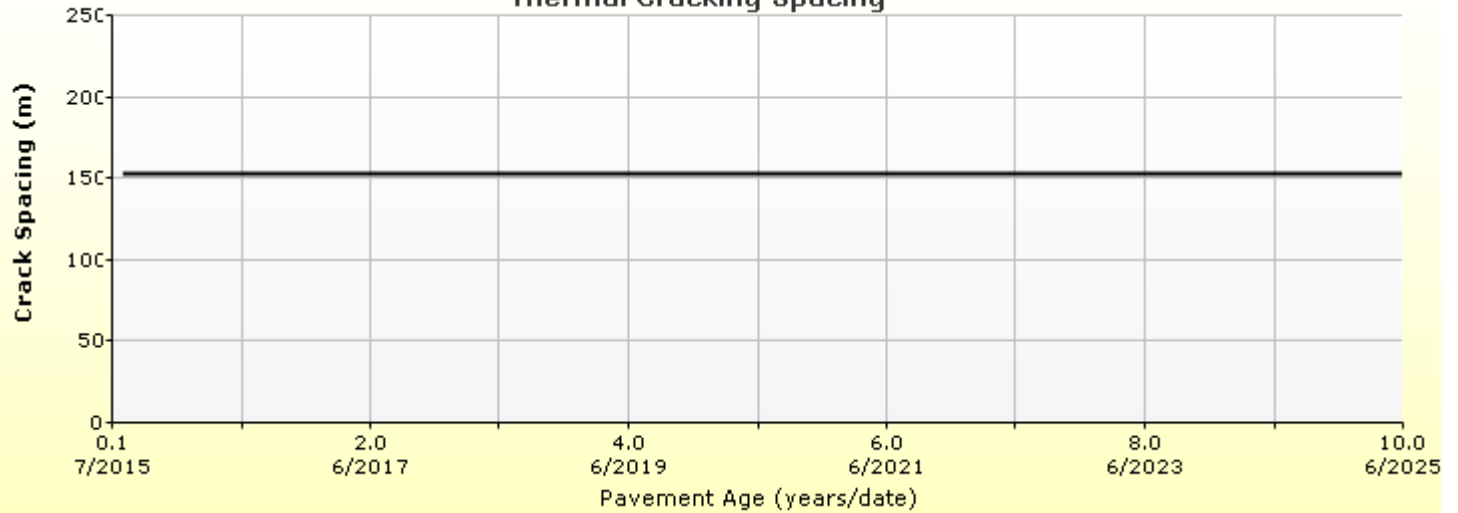
Predicted AC Bottom-Up Cracking (Alligator)



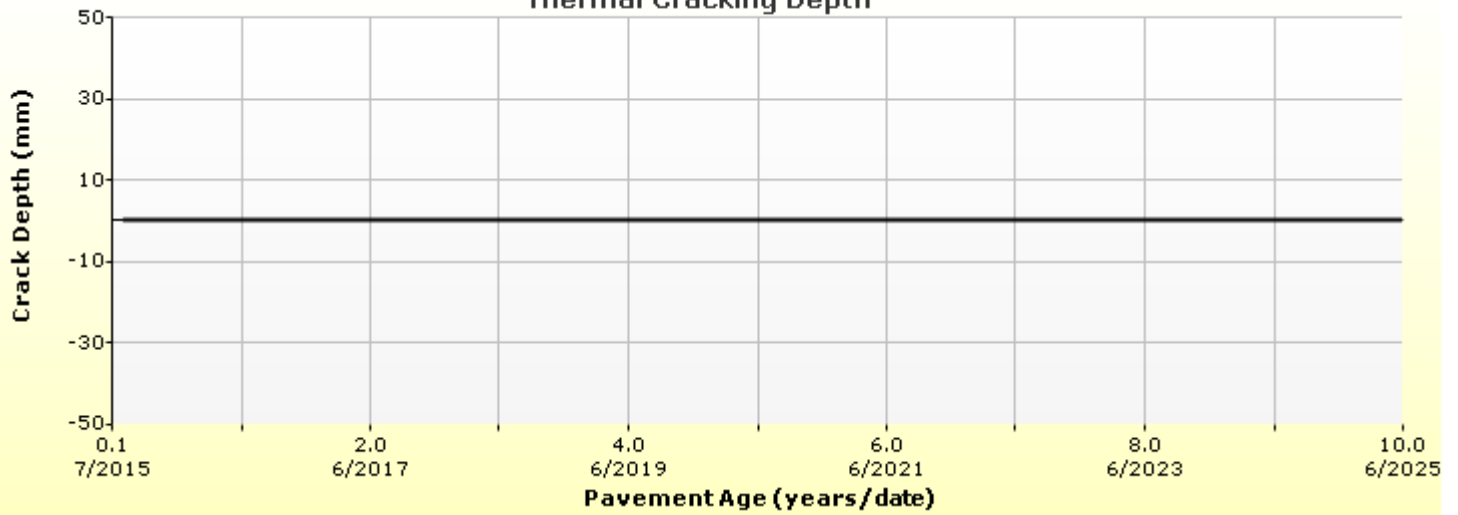
Predicted Rutting (Permanent Deformation) at 50% Reliability

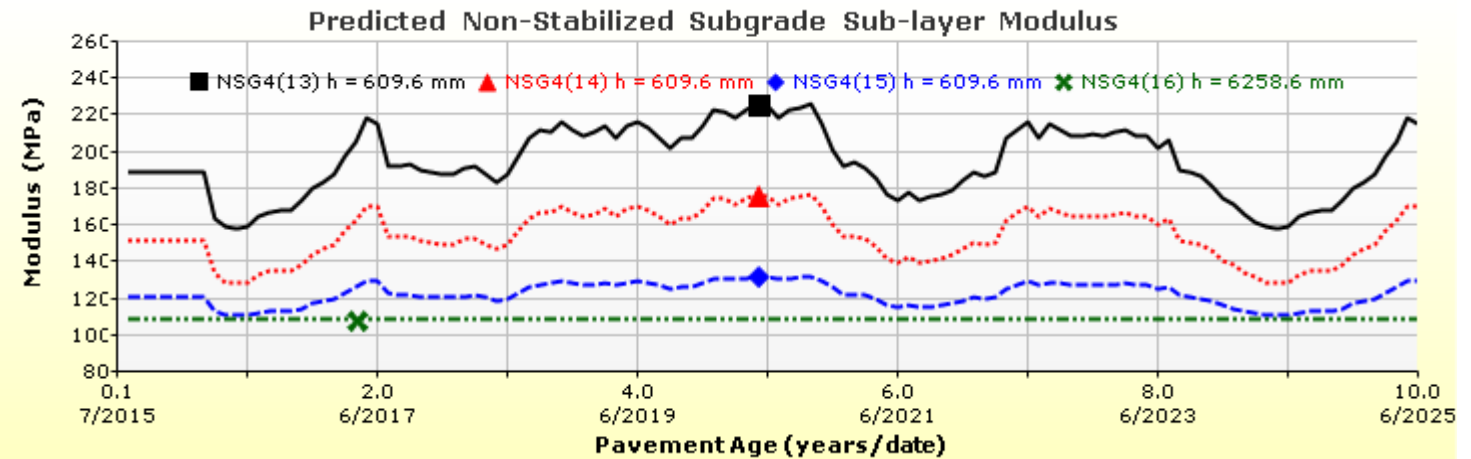
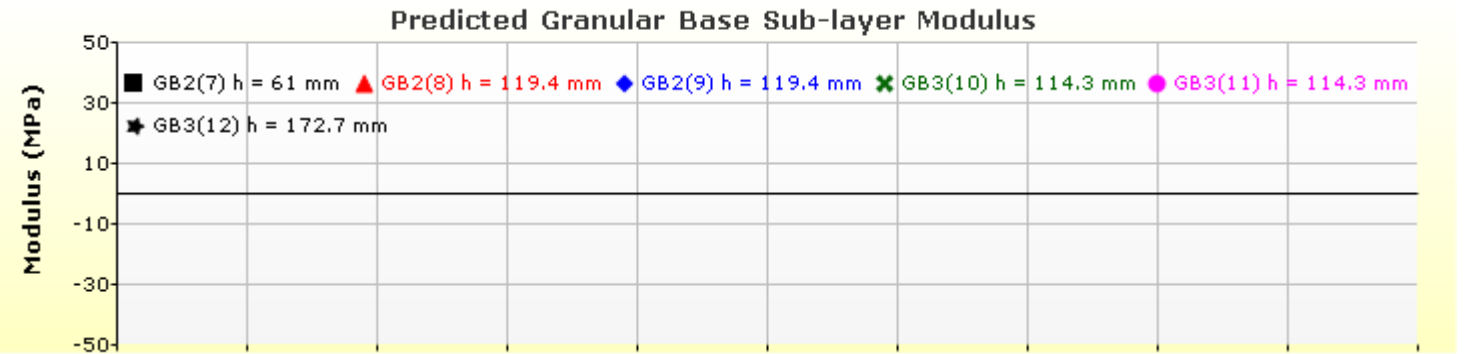
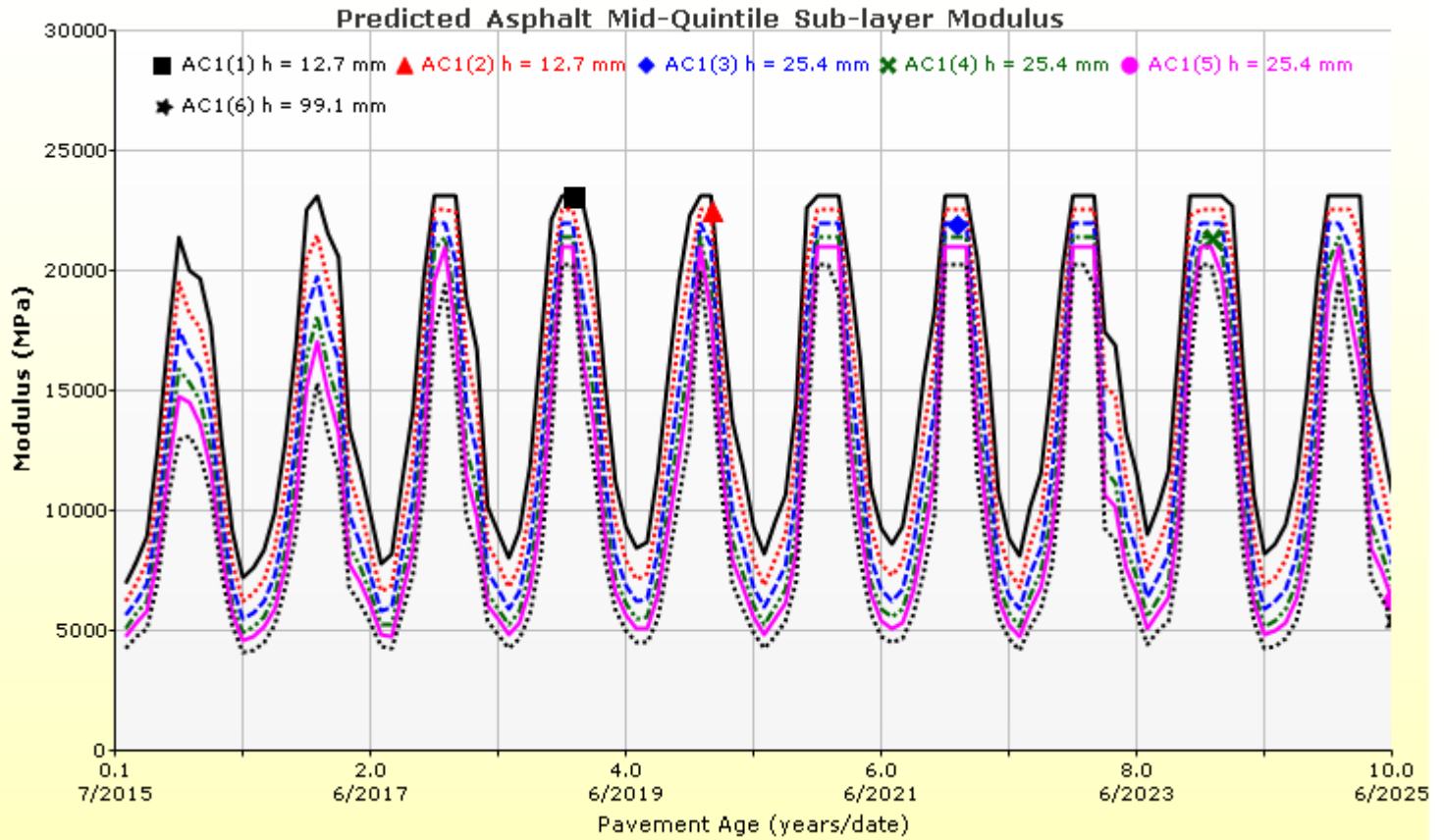


Thermal Cracking Spacing



Thermal Cracking Depth





Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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:	Annual representative values
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	200.0
NonStabilized	Crushed stone	300.0
NonStabilized	Crushed stone	400.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

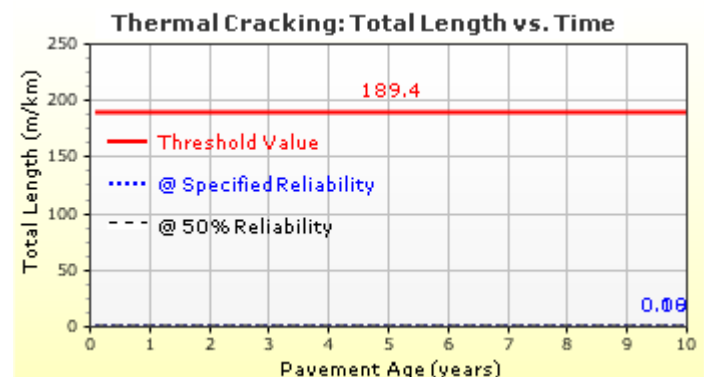
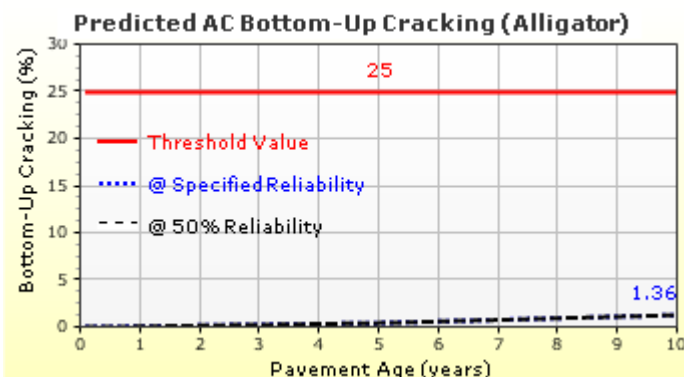
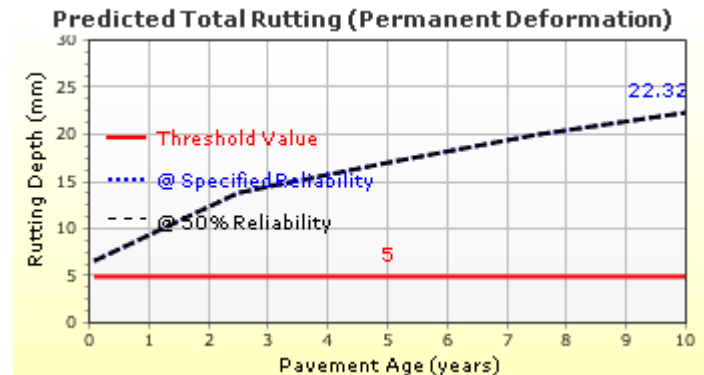
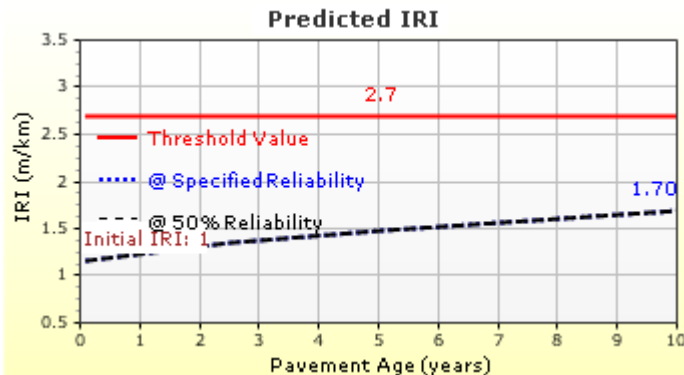
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.70	50.00	98.20	Pass
Permanent deformation - total pavement (mm)	5.00	22.32	50.00	0.01	Fail
AC bottom-up fatigue cracking (percent)	25.00	1.36	50.00	100.00	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	128.98	50.00	73.36	Pass
Permanent deformation - AC only (mm)	5.00	17.07	50.00	0.34	Fail

Distress Charts

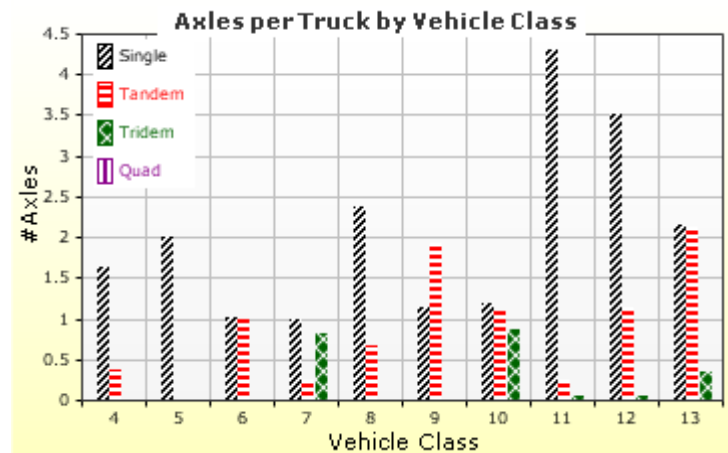
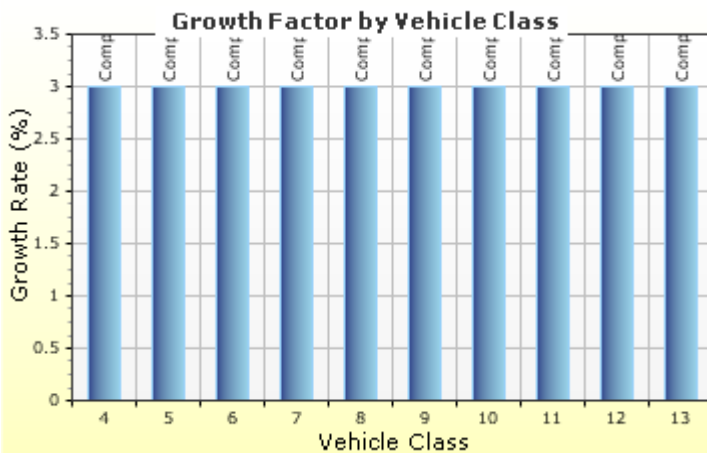
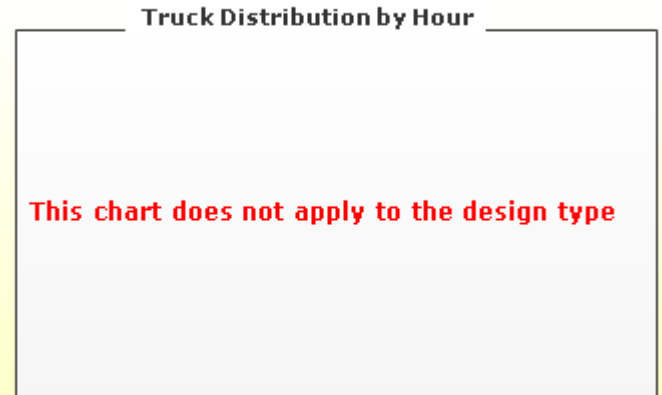
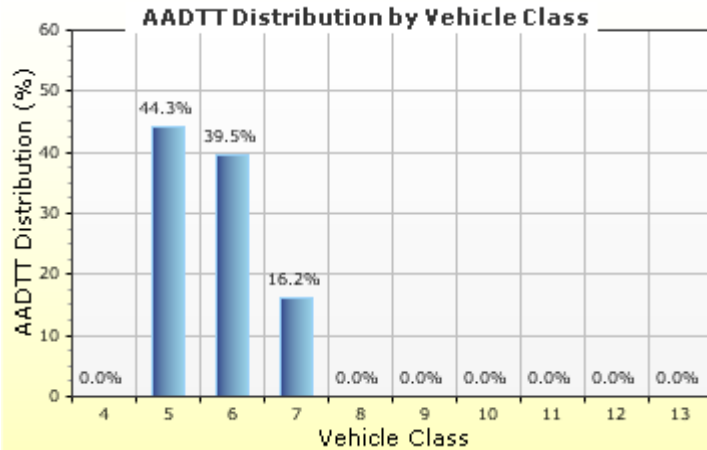


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

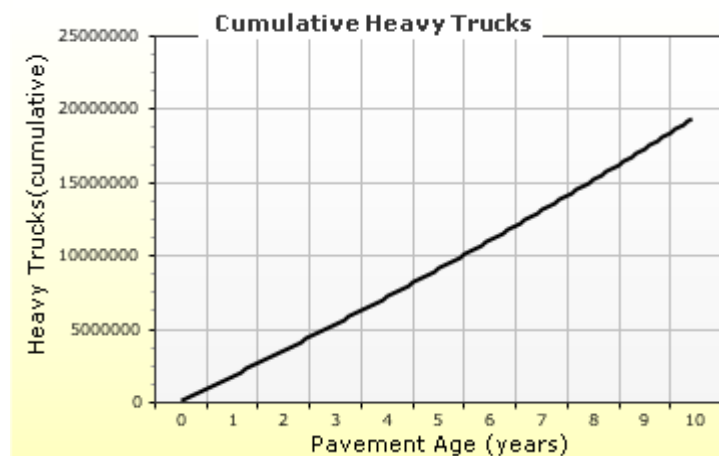
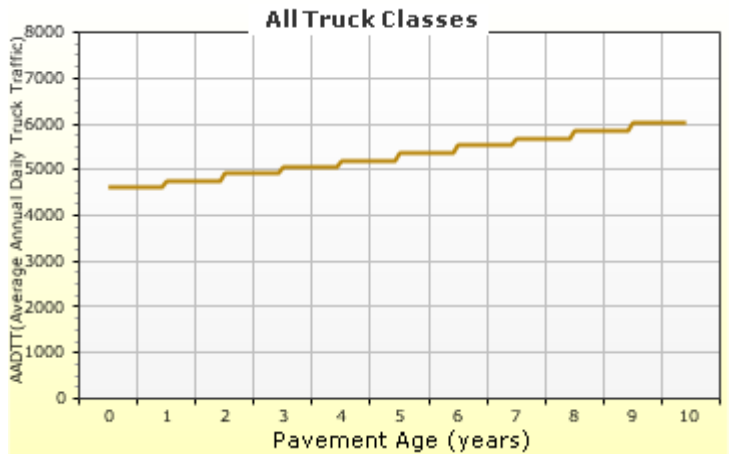
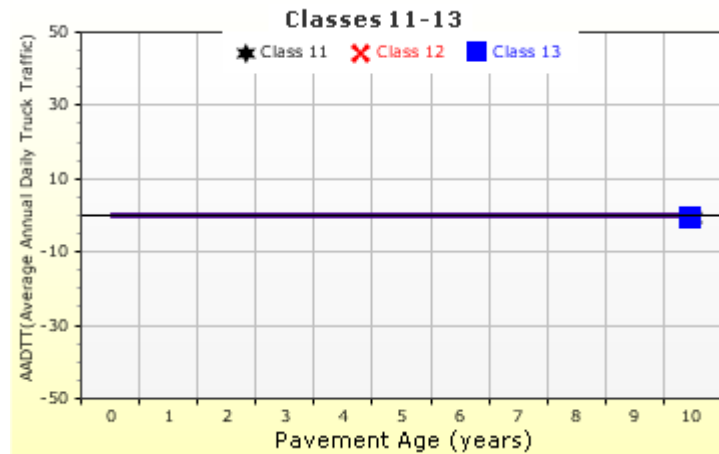
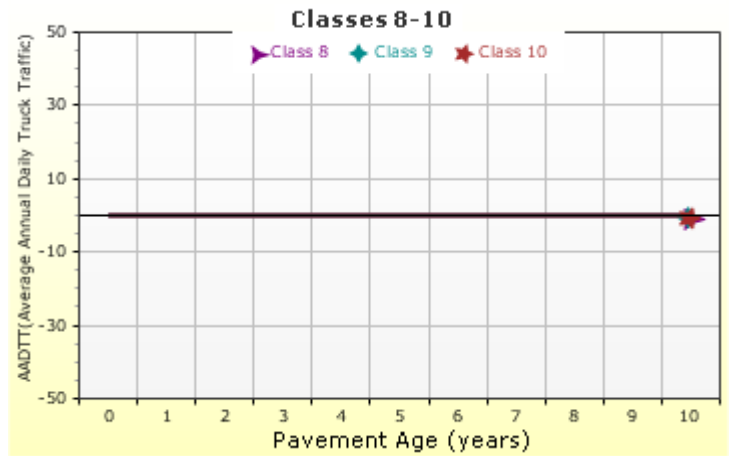
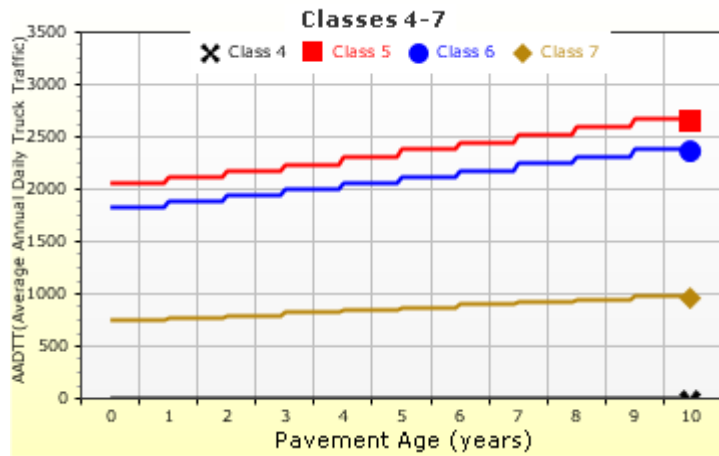
Wheelbase does not apply

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



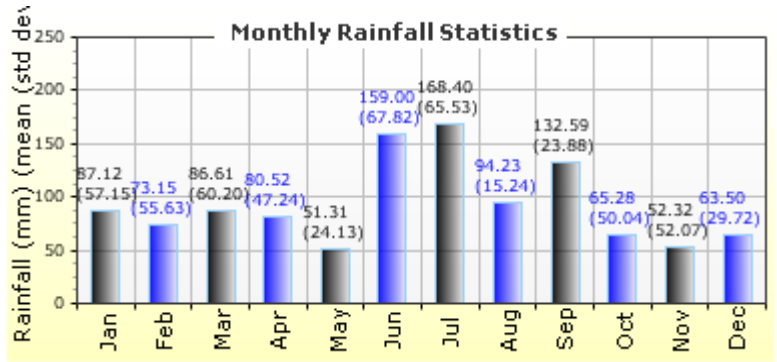
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

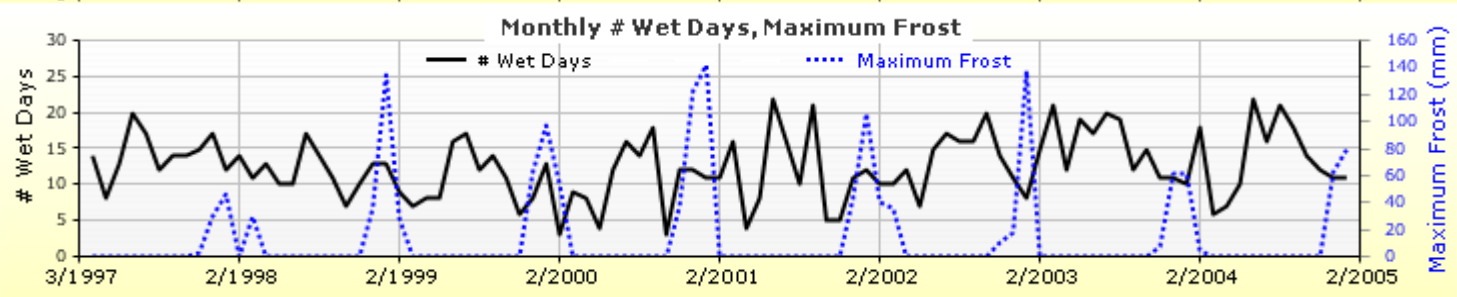
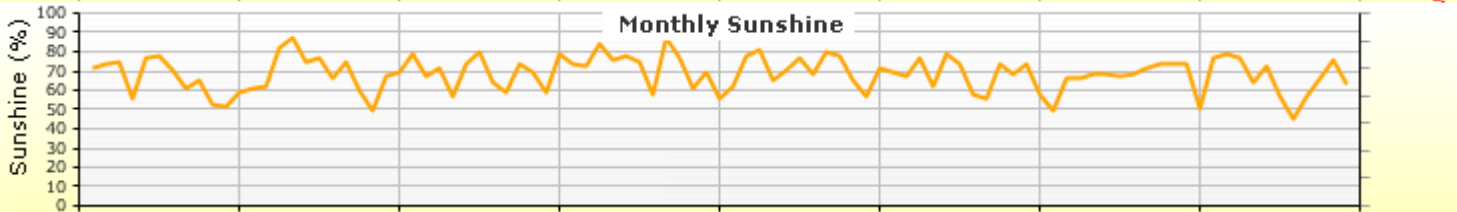
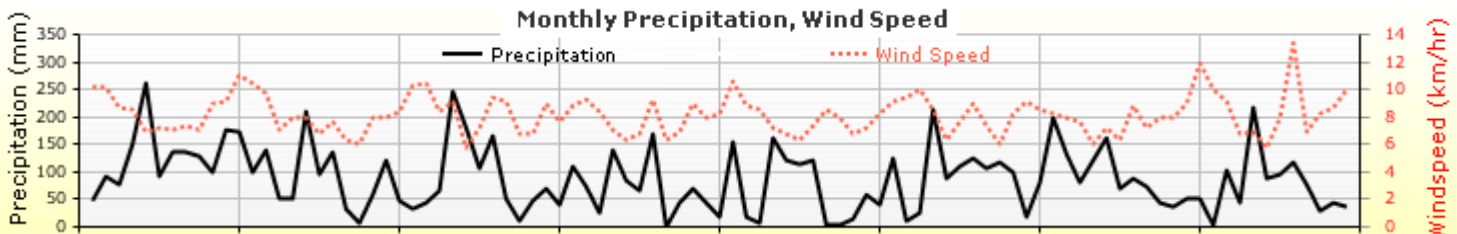
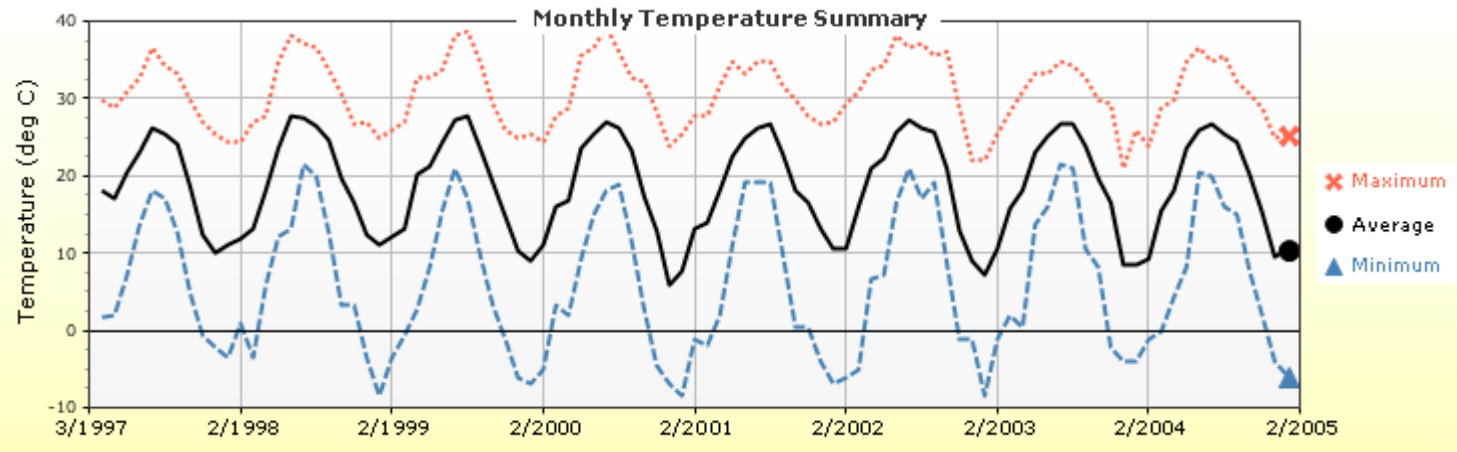
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

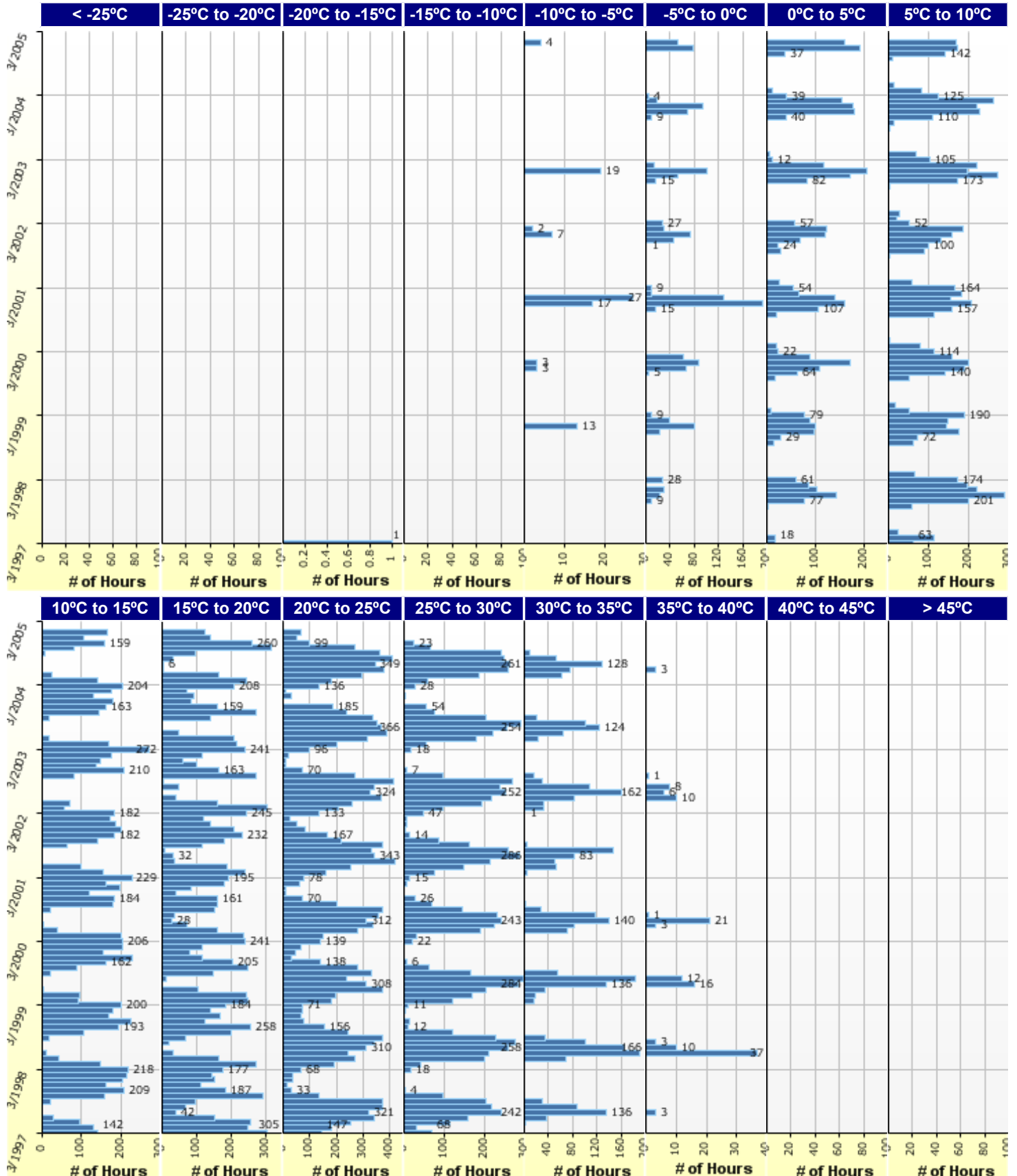


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF2_ALT3

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF2_ALT3.dgpx



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

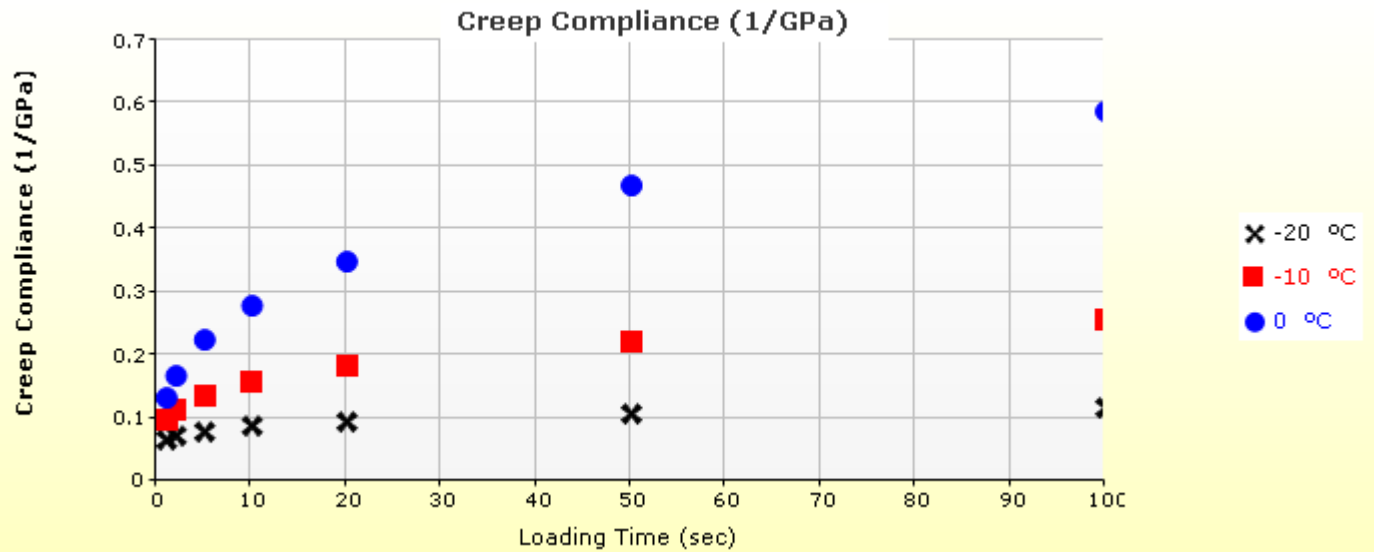
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

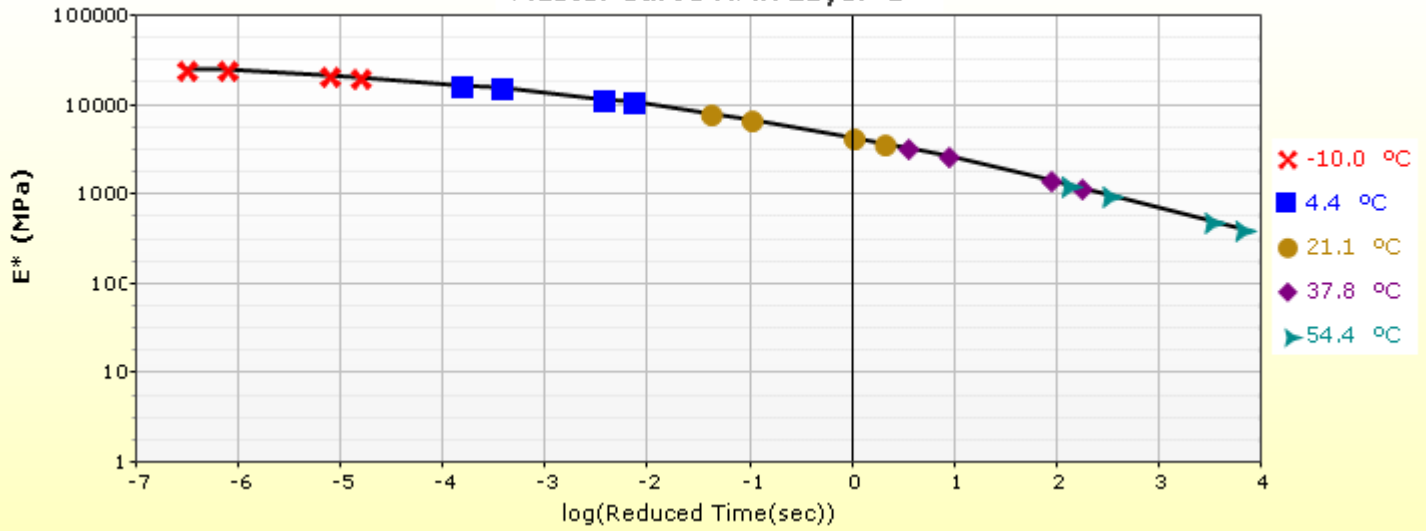
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

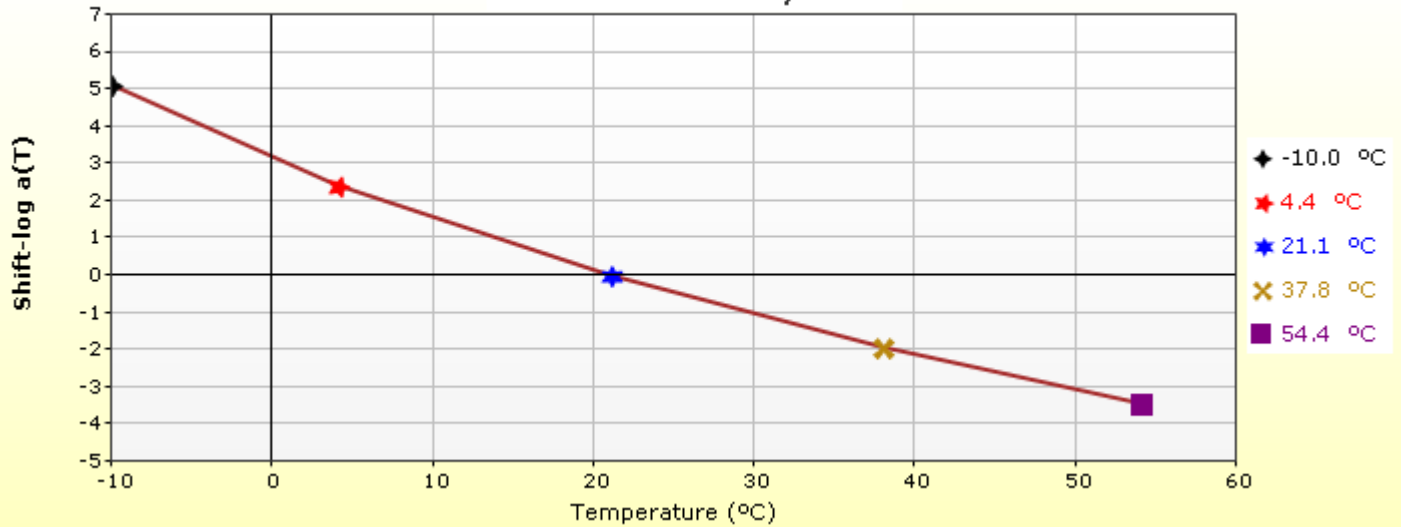


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

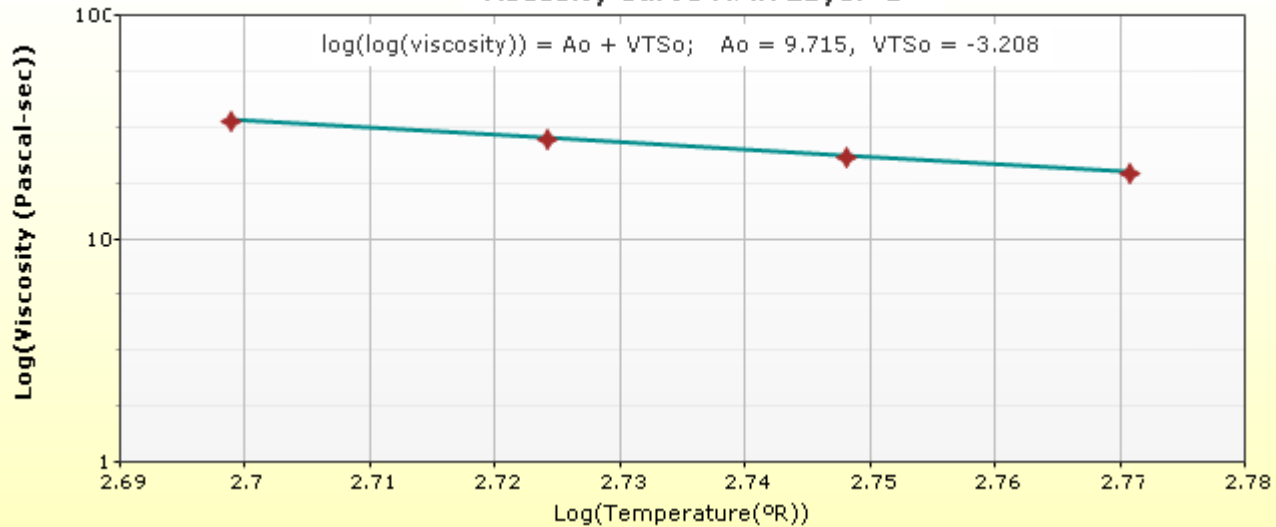
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

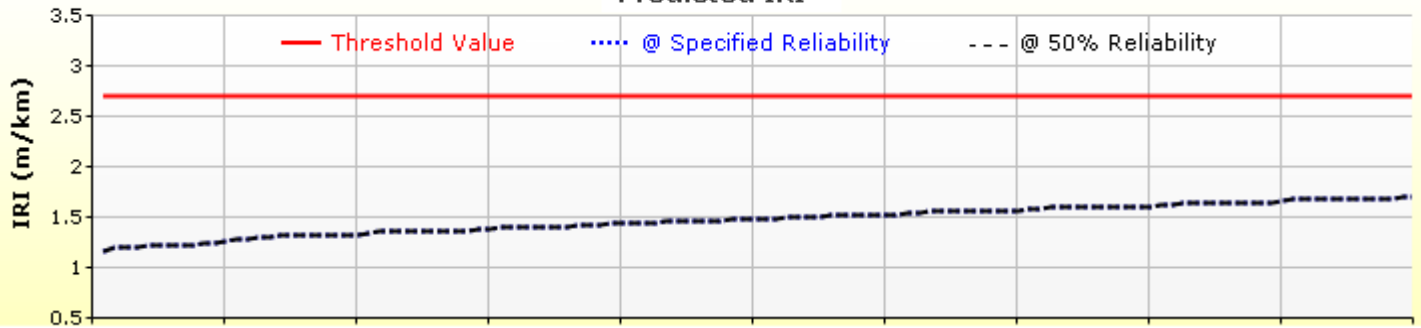


Viscosity Curve HMA Layer 1

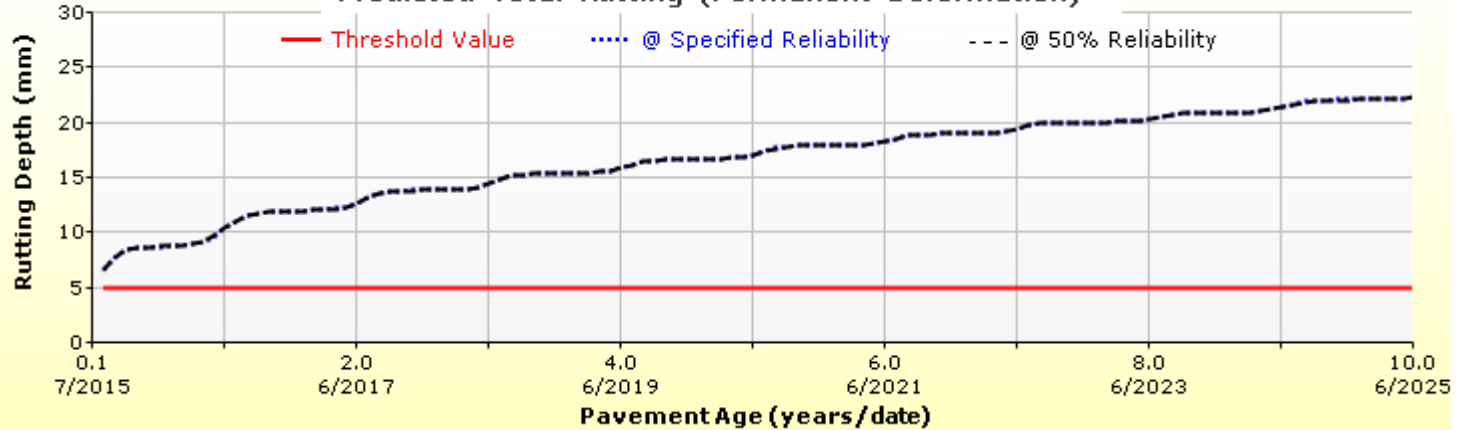


Analysis Output Charts

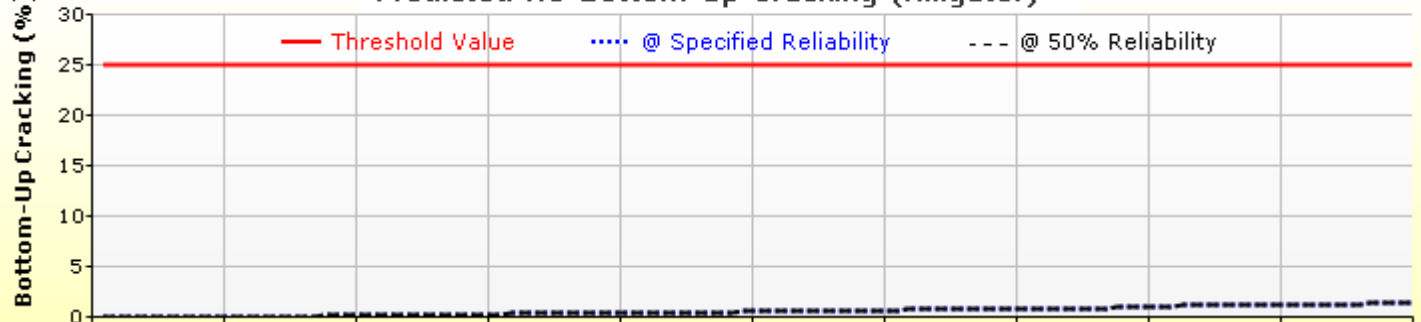
Predicted IRI



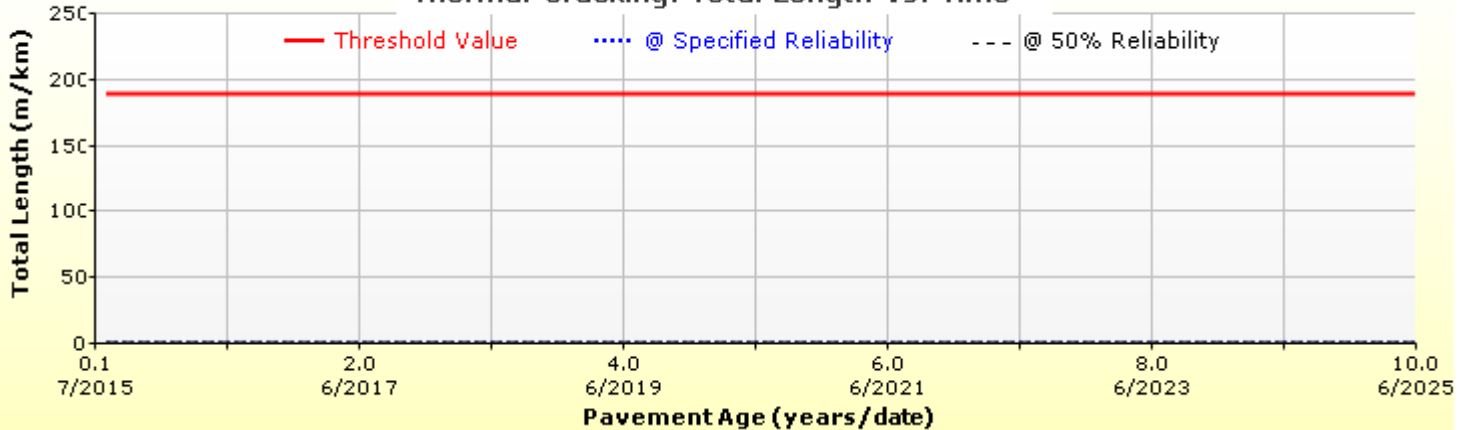
Predicted Total Rutting (Permanent Deformation)



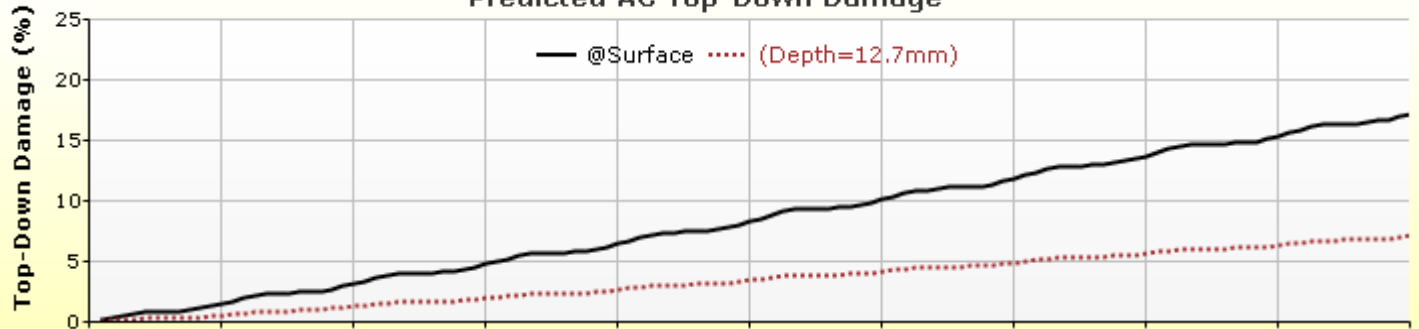
Predicted AC Bottom-Up Cracking (Alligator)



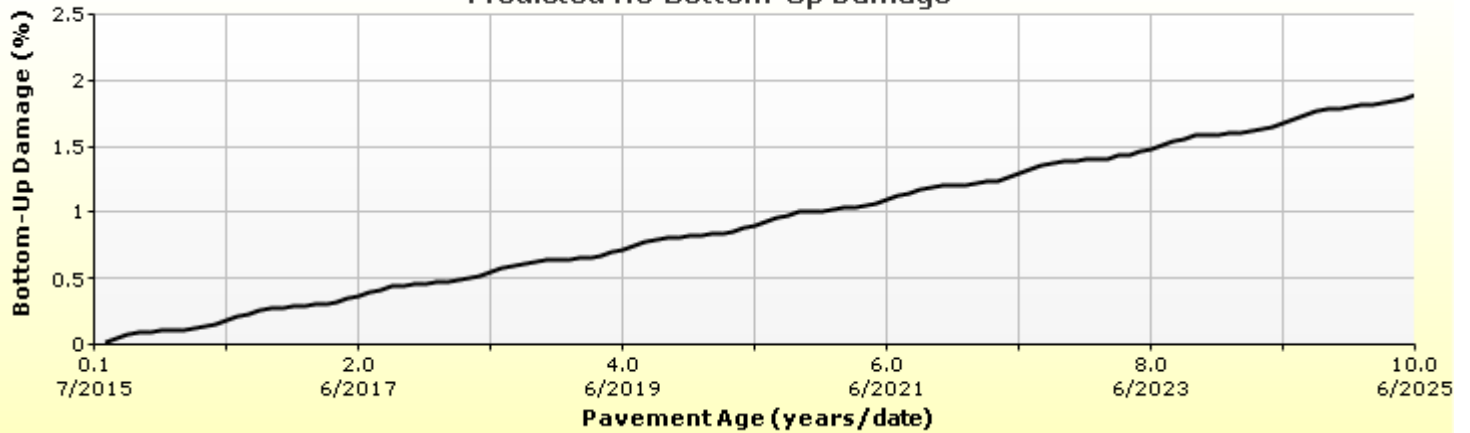
Thermal Cracking: Total Length vs. Time



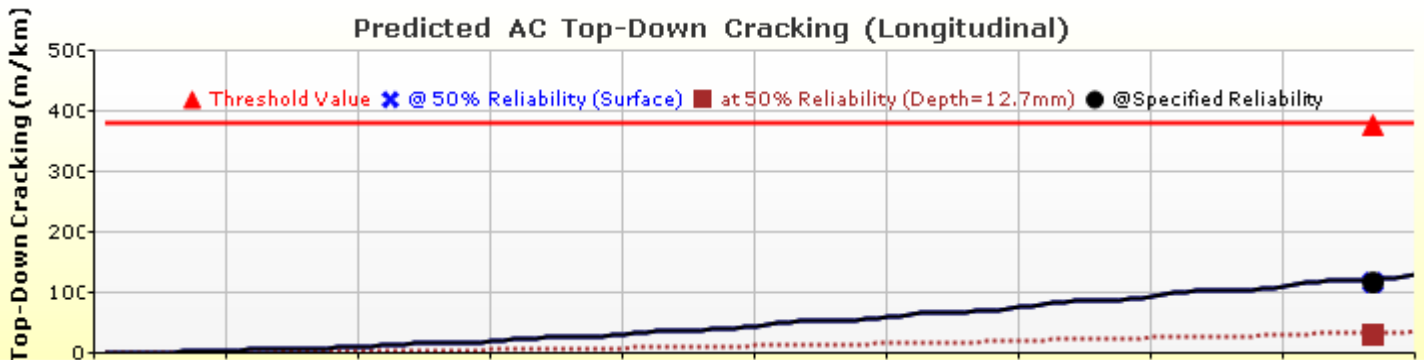
Predicted AC Top-Down Damage



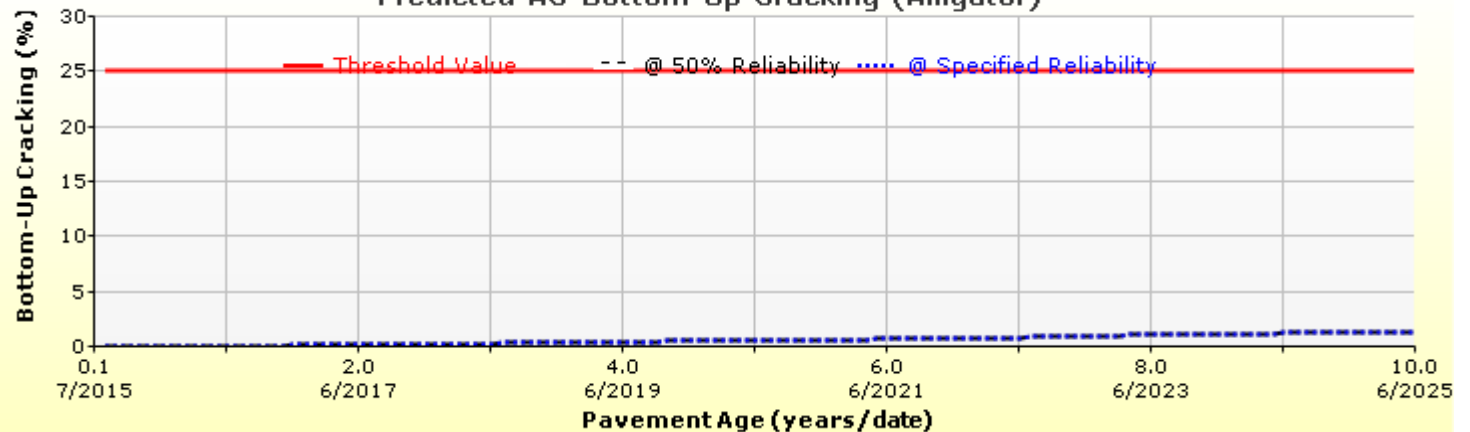
Predicted AC Bottom-Up Damage



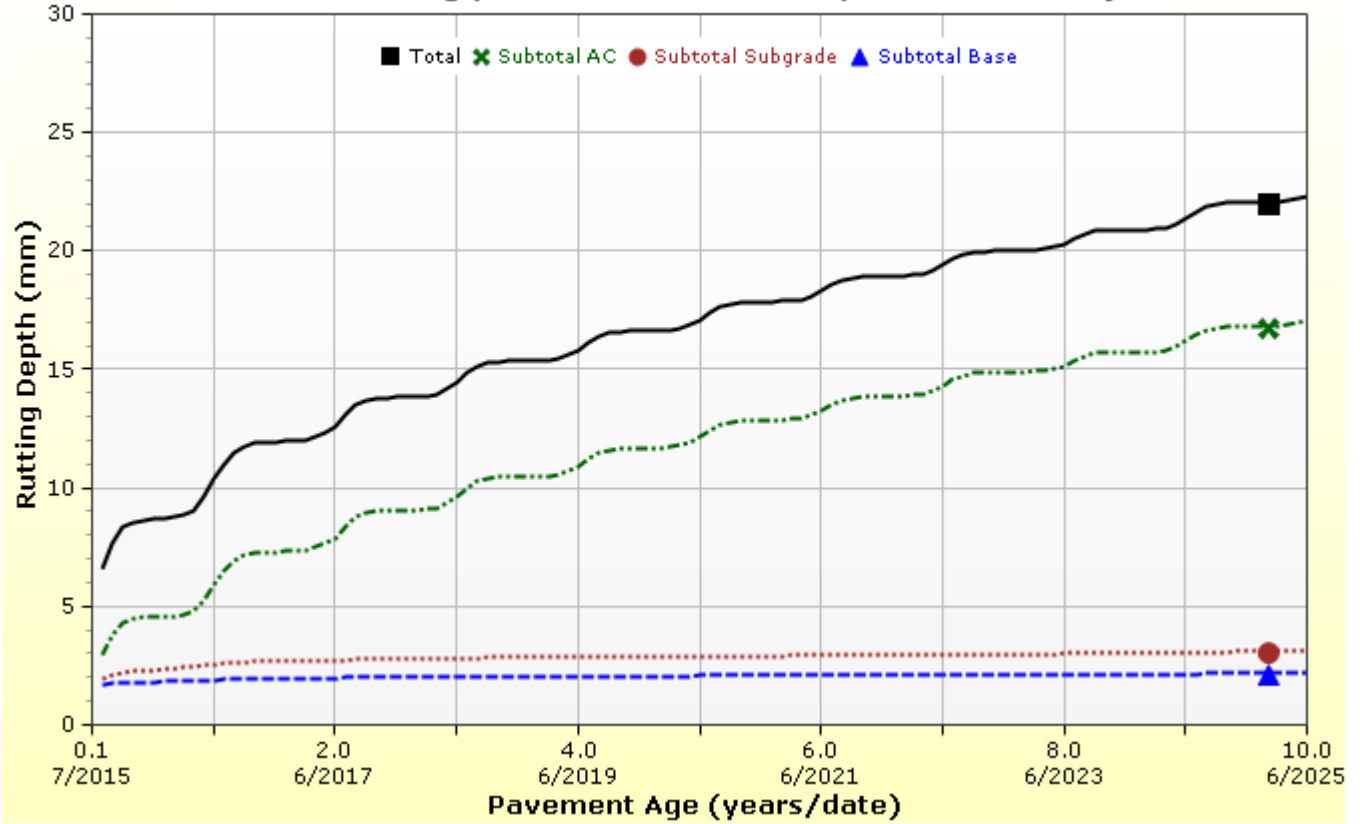
Predicted AC Top-Down Cracking (Longitudinal)



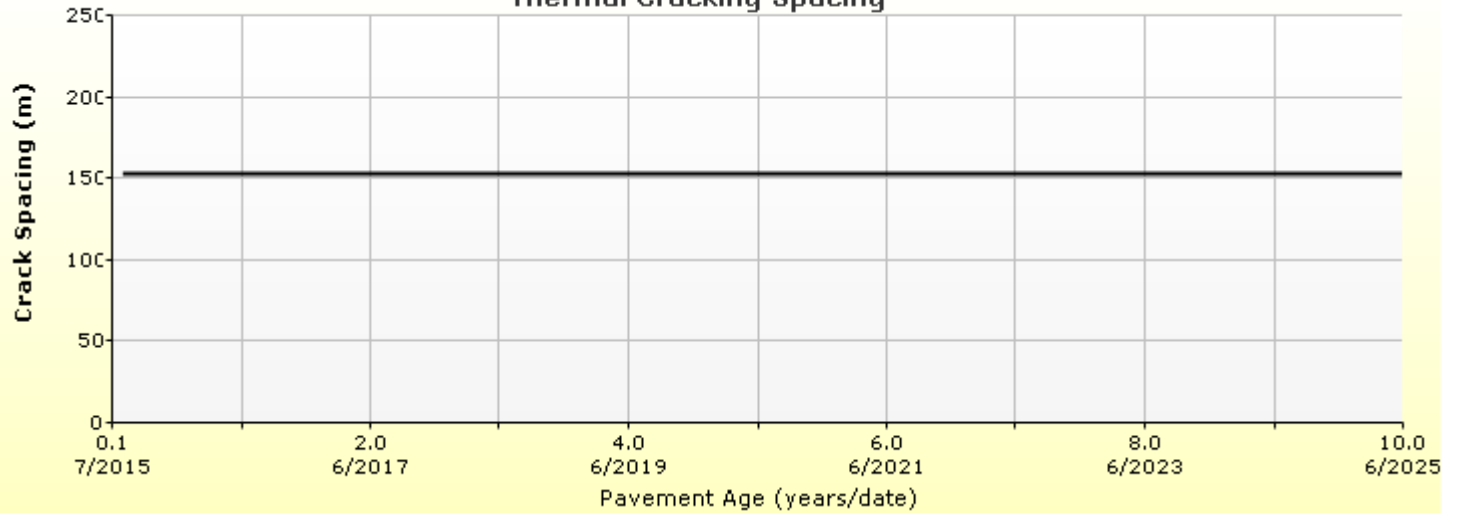
Predicted AC Bottom-Up Cracking (Alligator)



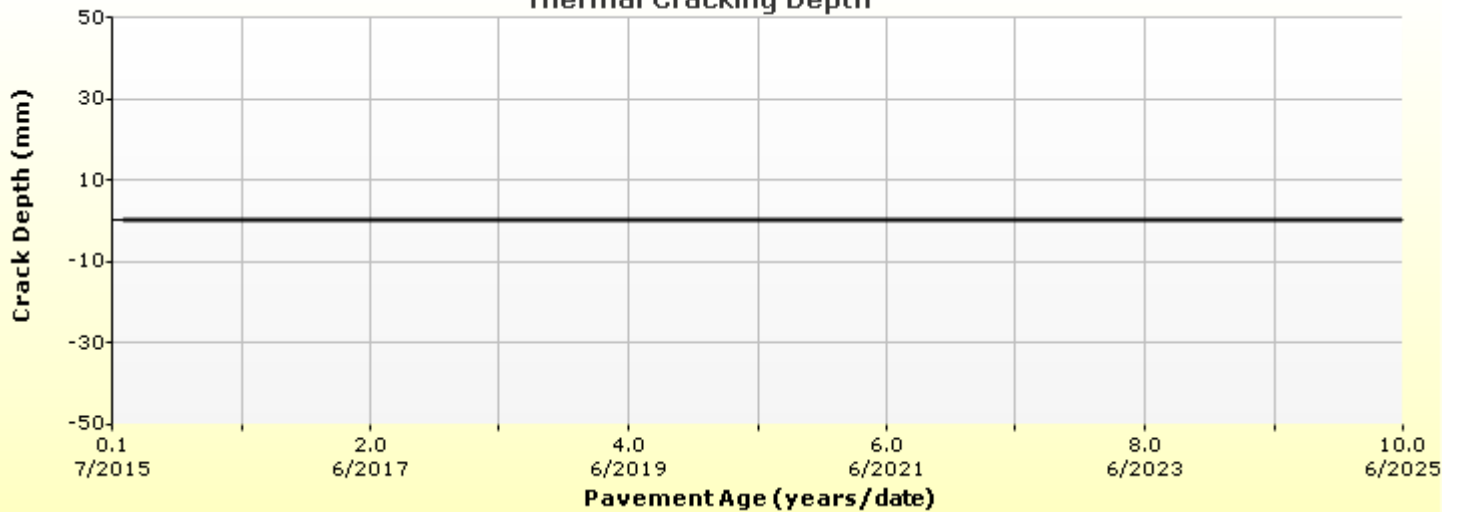
Predicted Rutting (Permanent Deformation) at 50% Reliability

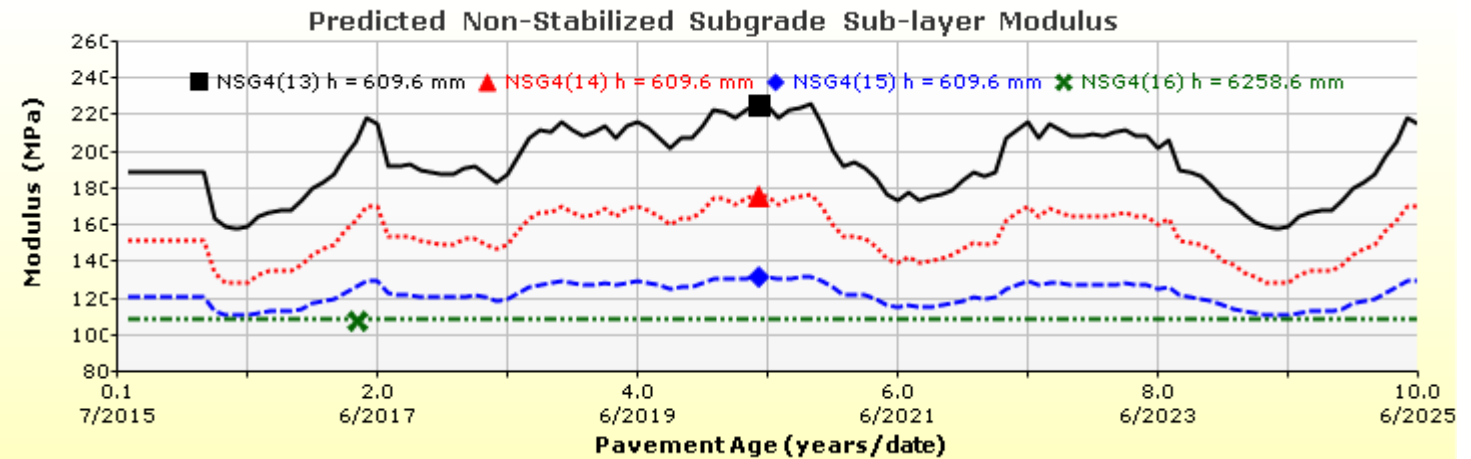
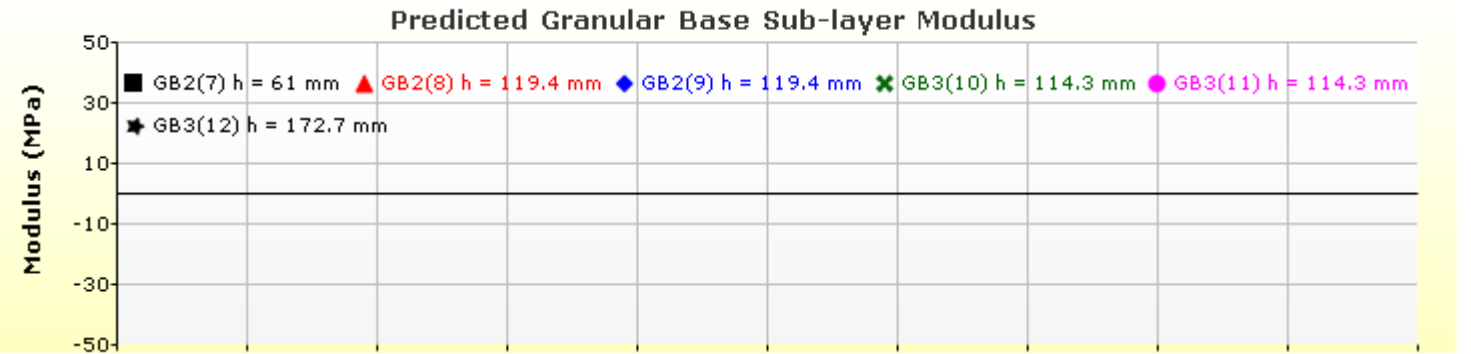
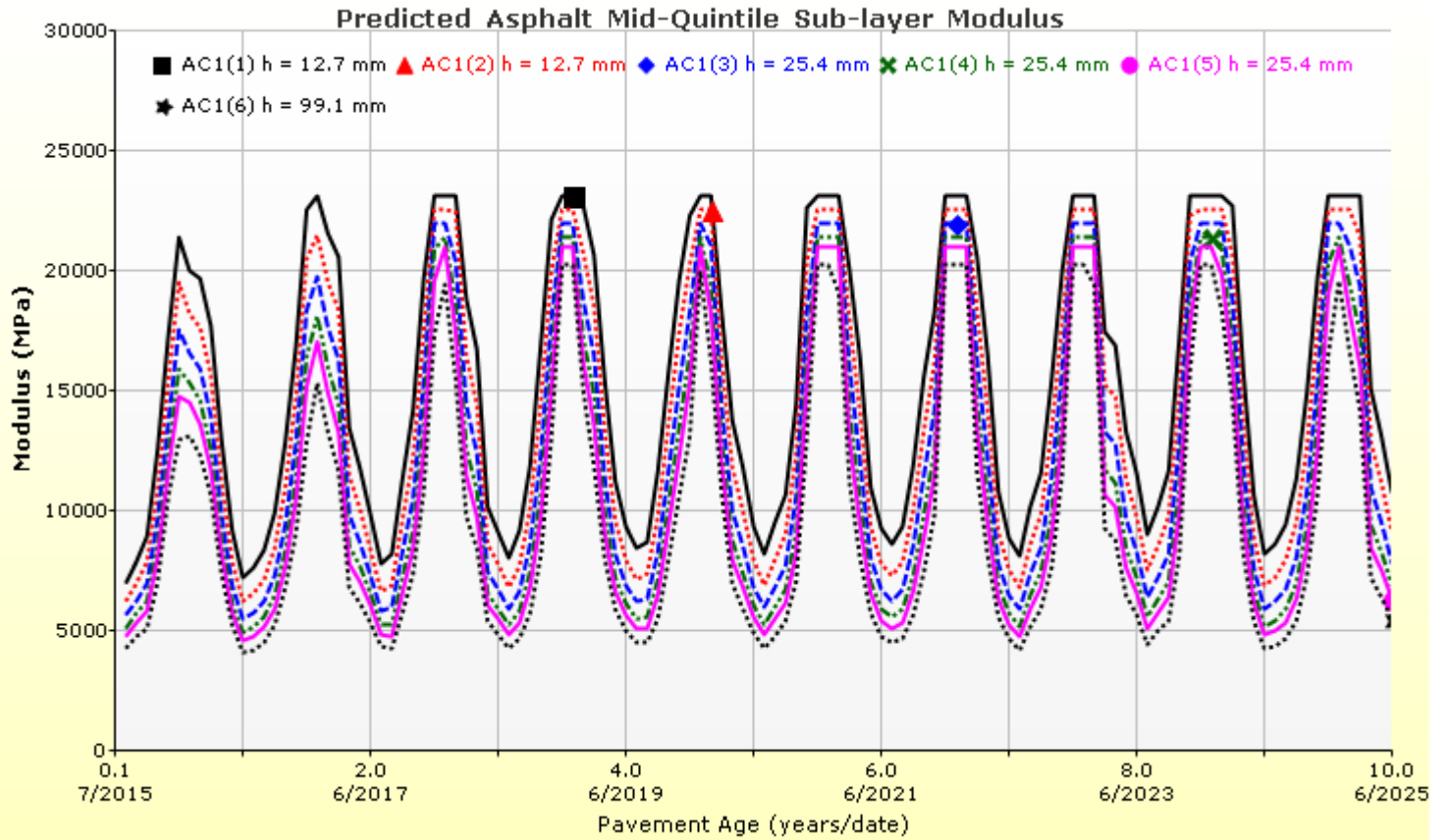


Thermal Cracking Spacing



Thermal Cracking Depth





Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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:	Annual representative values
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

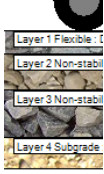
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	200.0
NonStabilized	Crushed stone	300.0
NonStabilized	Crushed stone	400.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

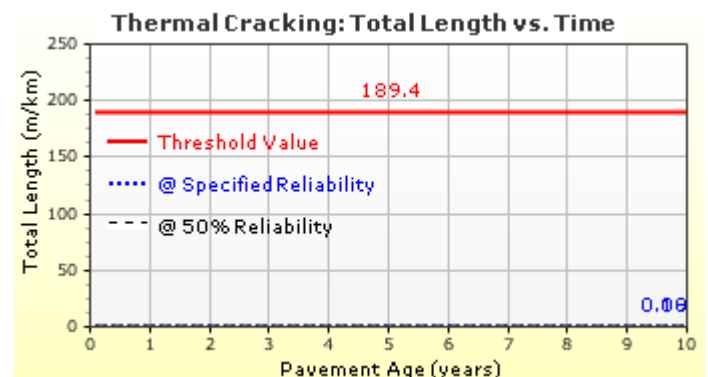
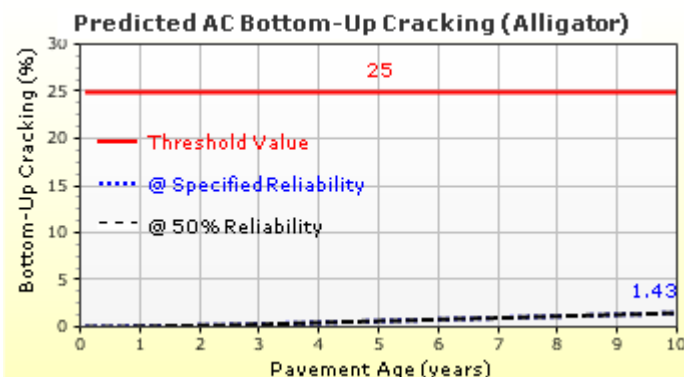
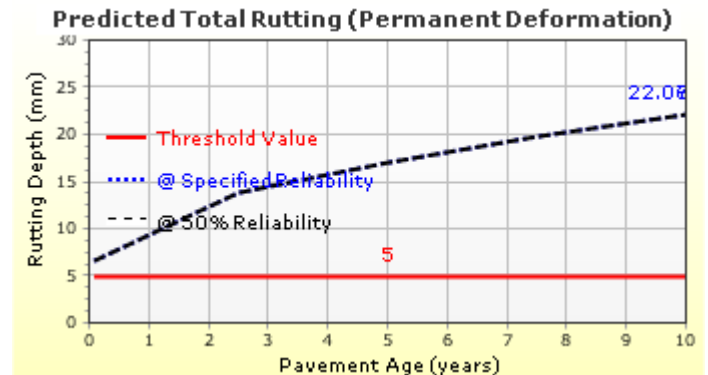
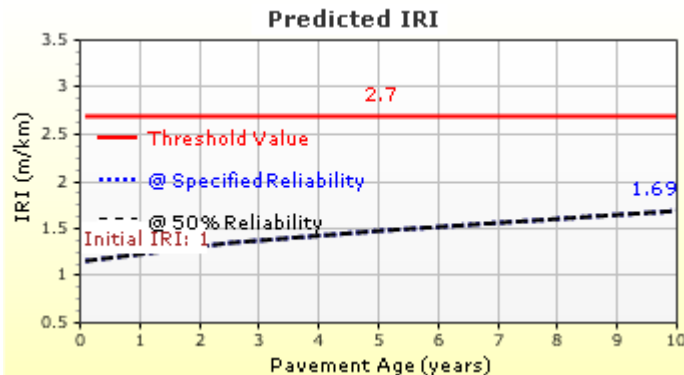
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.69	50.00	98.30	Pass
Permanent deformation - total pavement (mm)	5.00	22.06	50.00	0.01	Fail
AC bottom-up fatigue cracking (percent)	25.00	1.43	50.00	100.00	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	119.51	50.00	74.30	Pass
Permanent deformation - AC only (mm)	5.00	16.57	50.00	0.39	Fail

Distress Charts

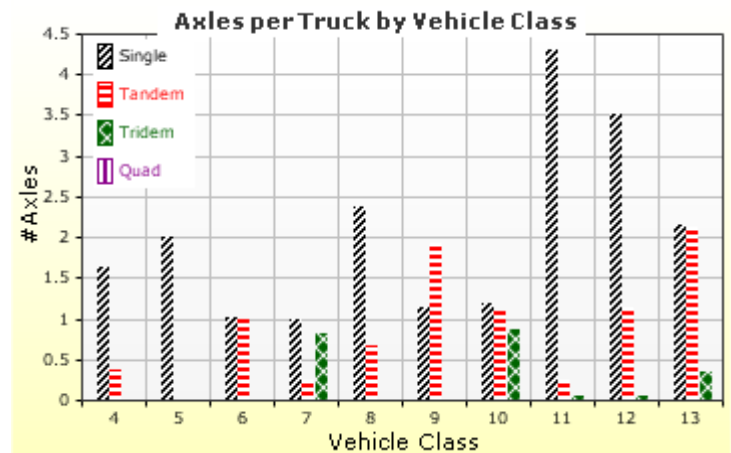
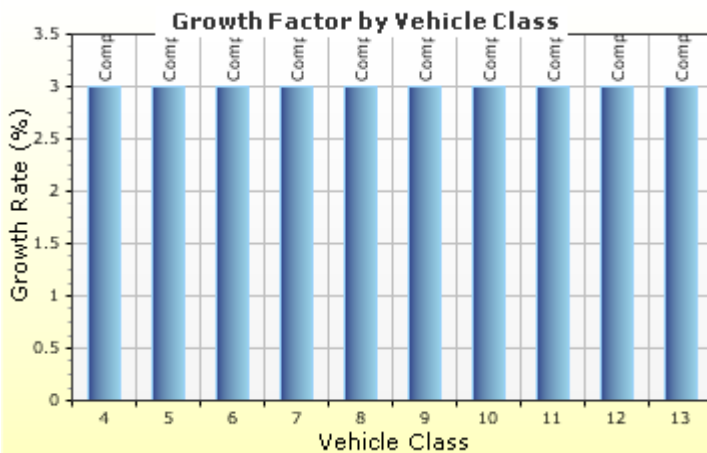
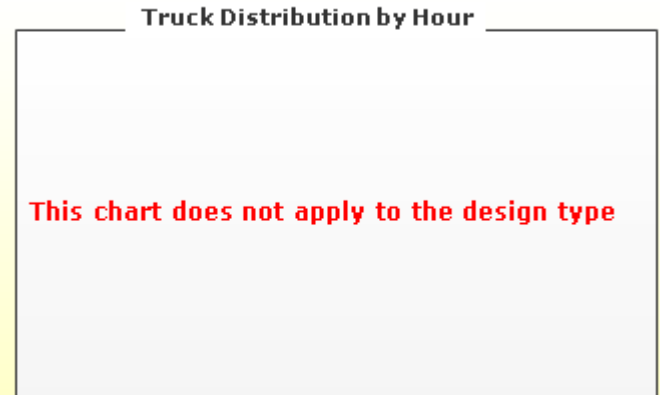
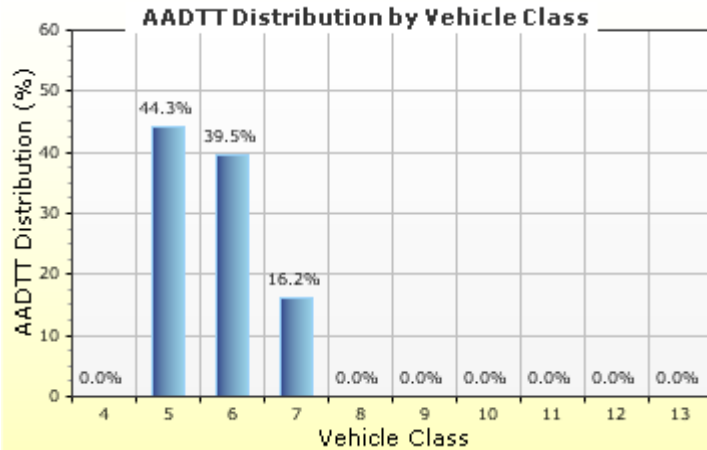


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

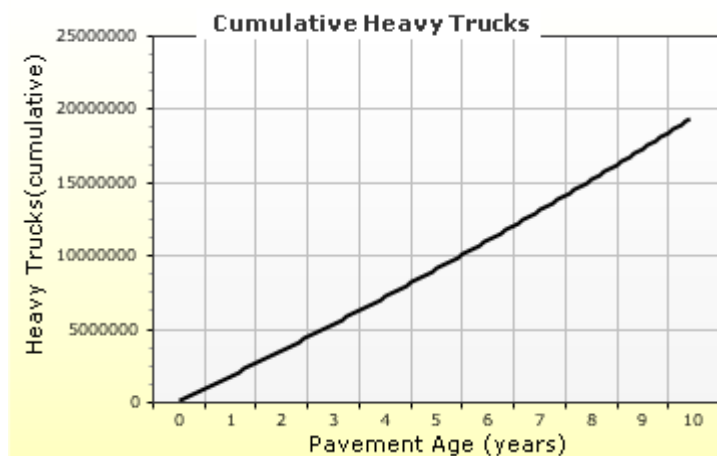
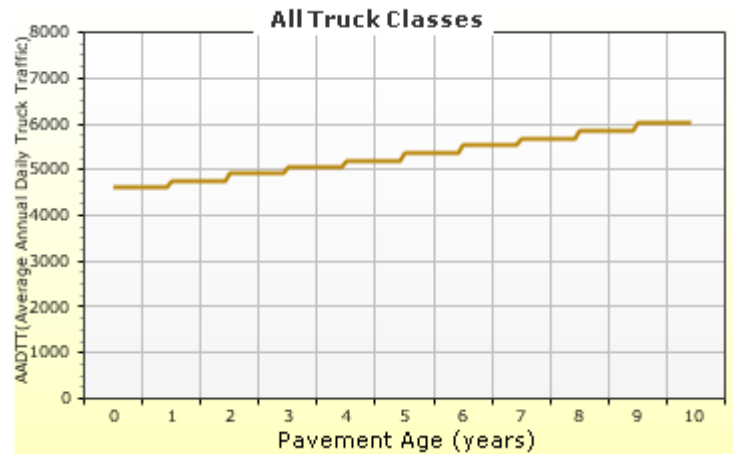
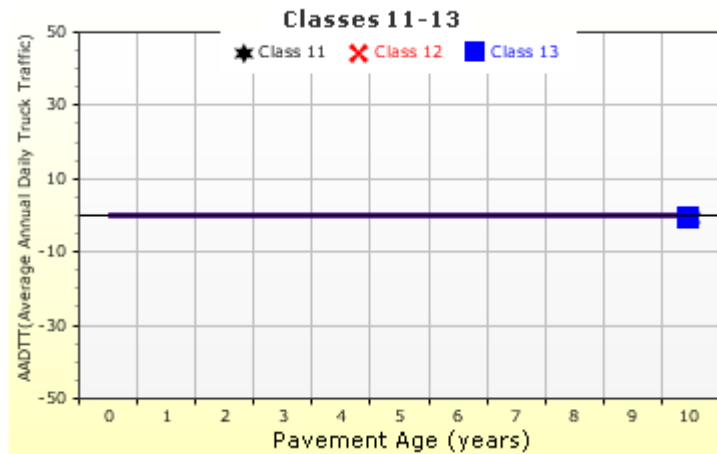
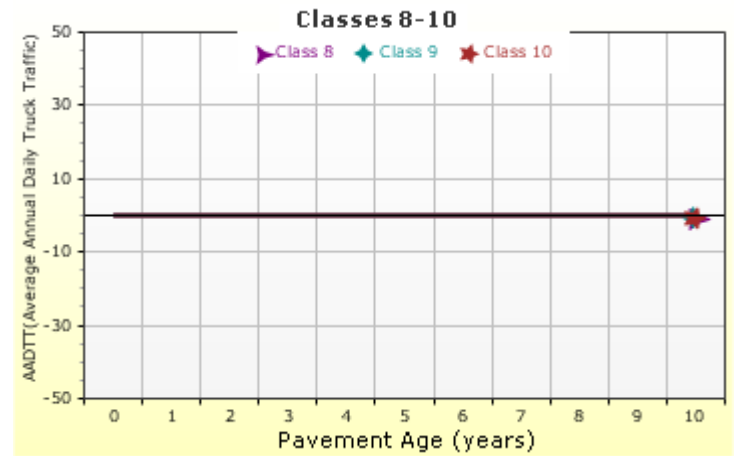
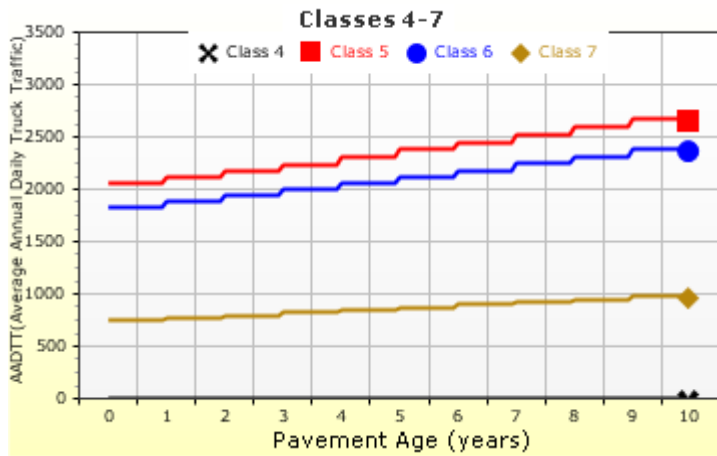
Wheelbase does not apply

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



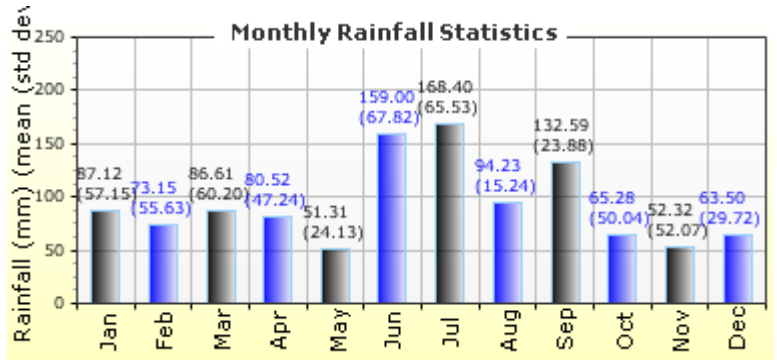
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

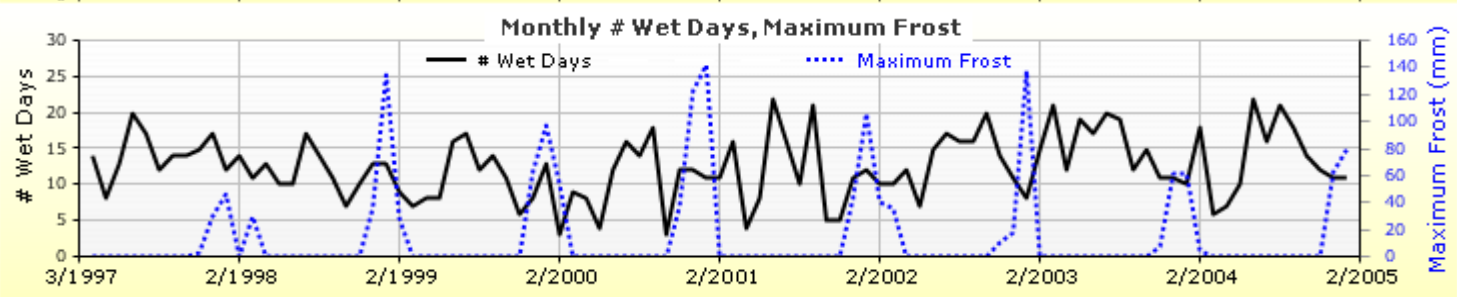
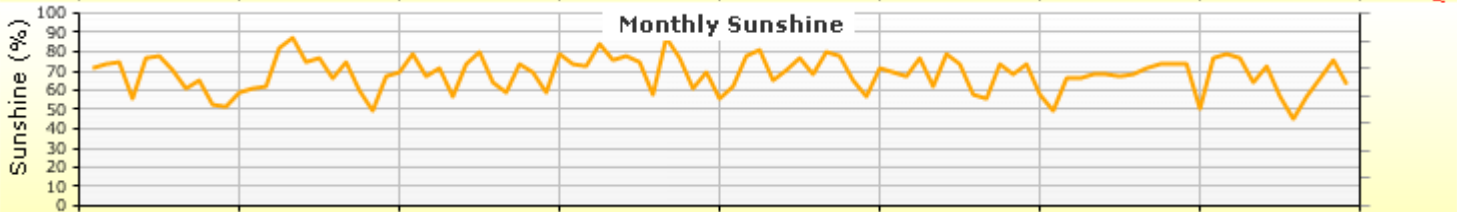
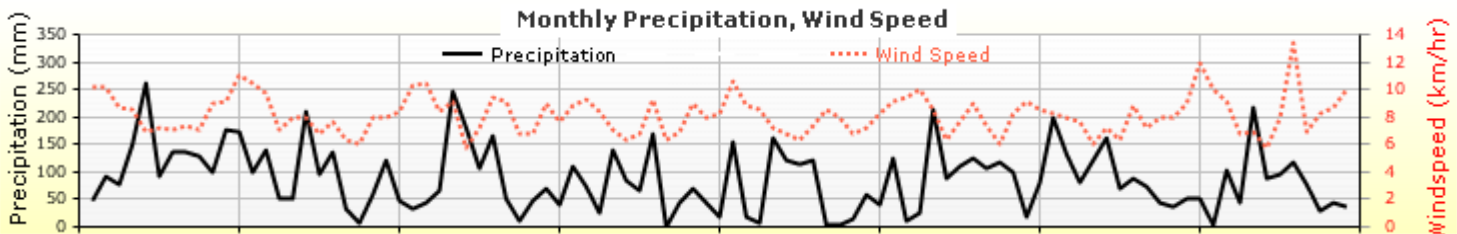
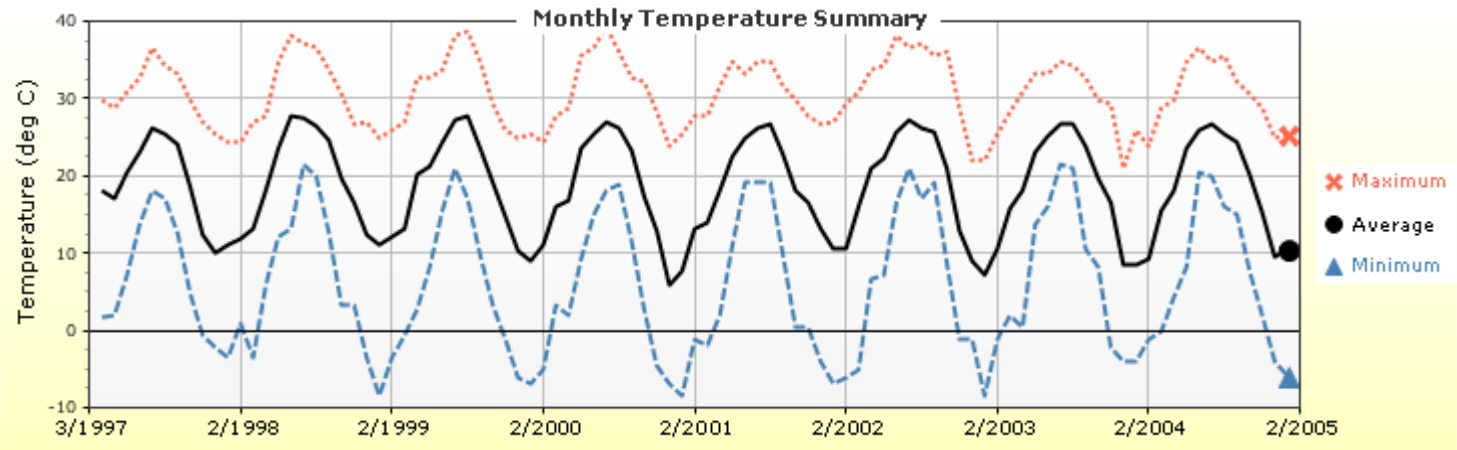
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

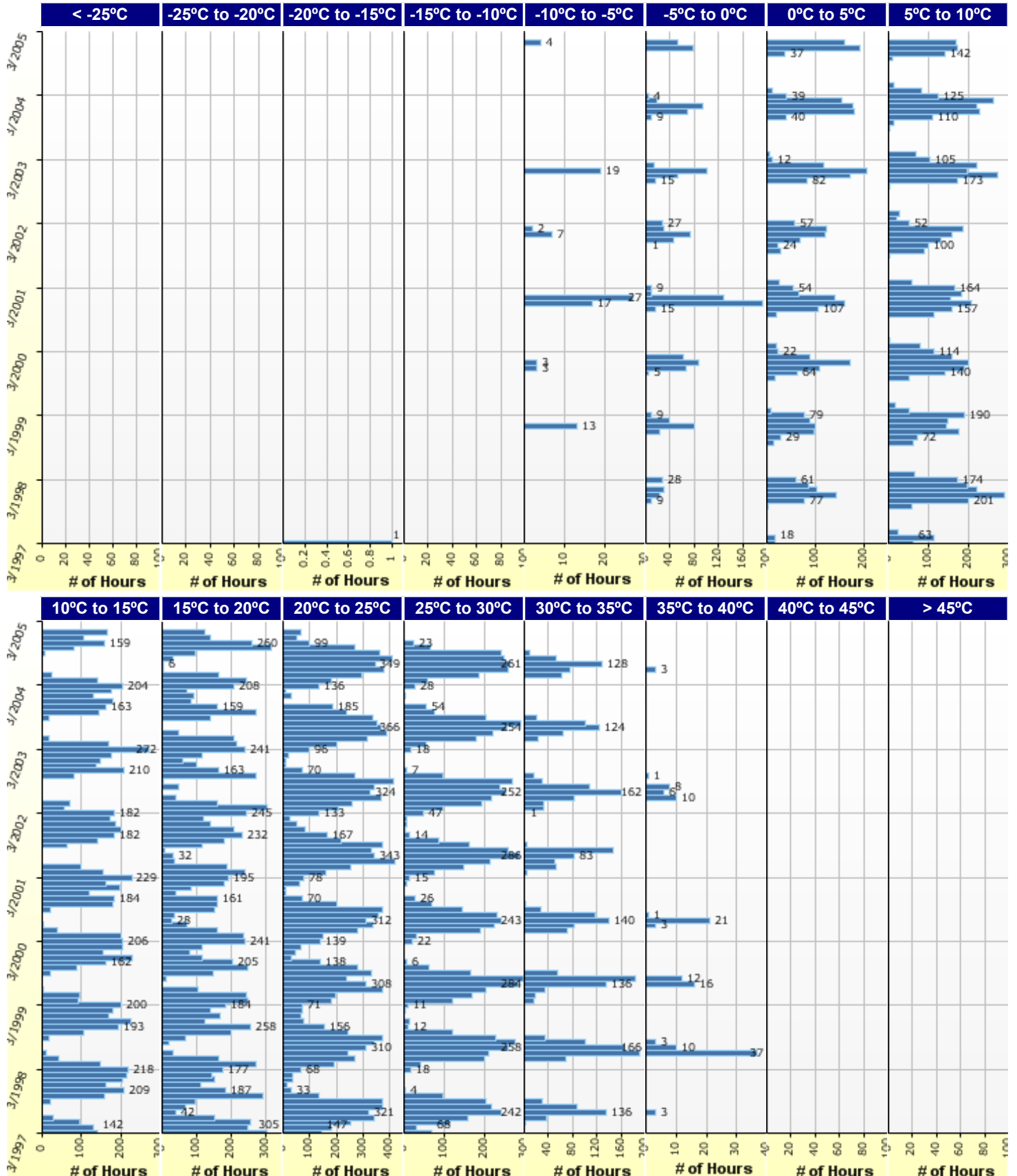


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF3_ALT3

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF3_ALT3.dgpx



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

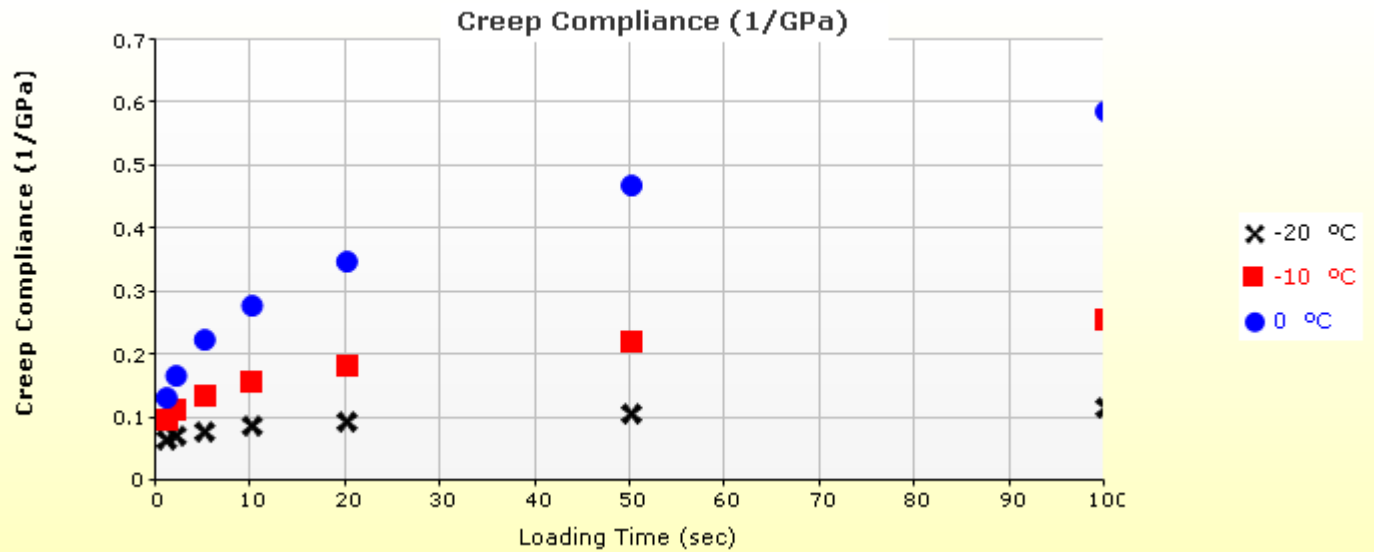
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

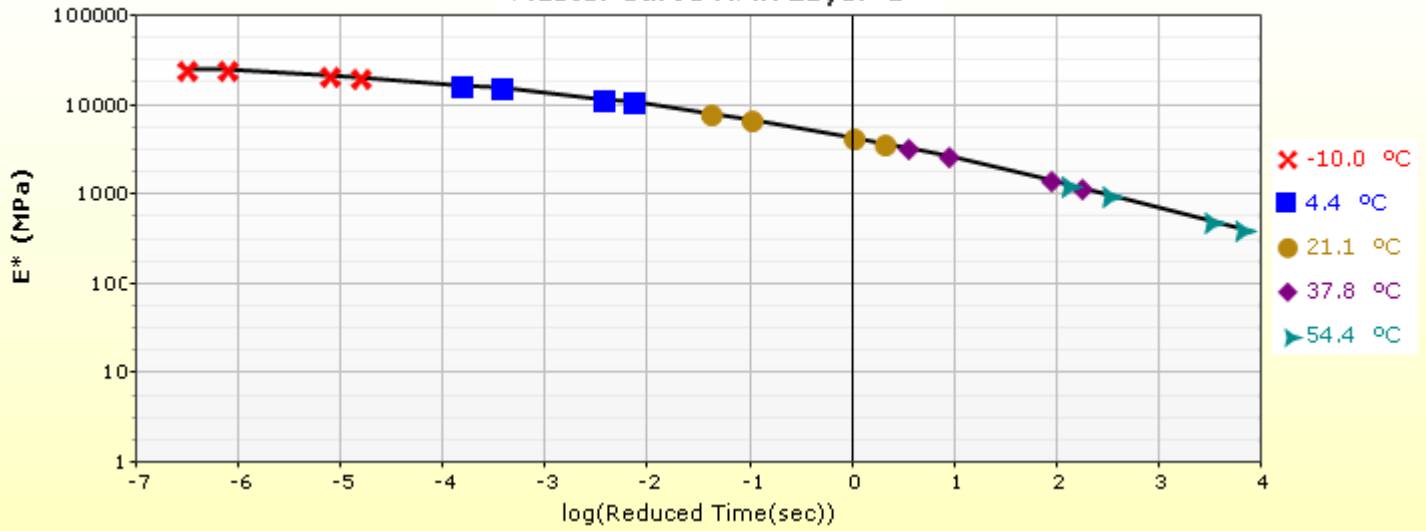
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

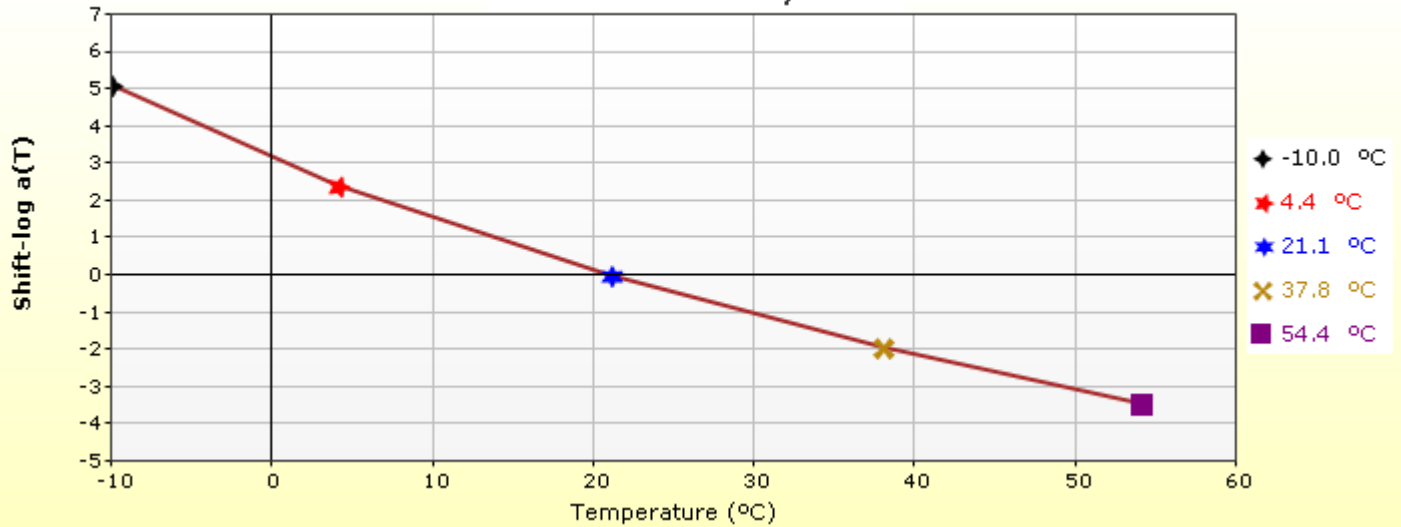


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

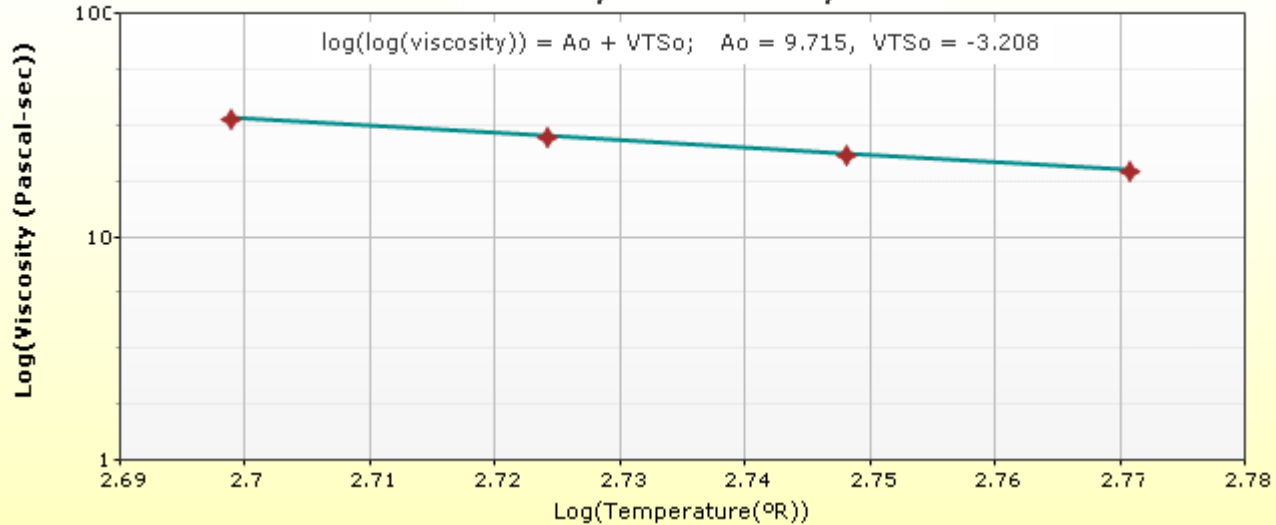
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

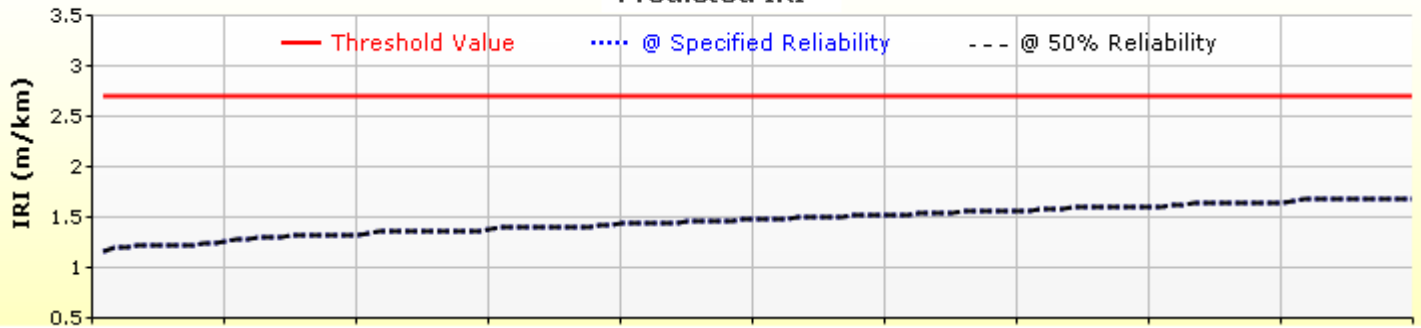


Viscosity Curve HMA Layer 1

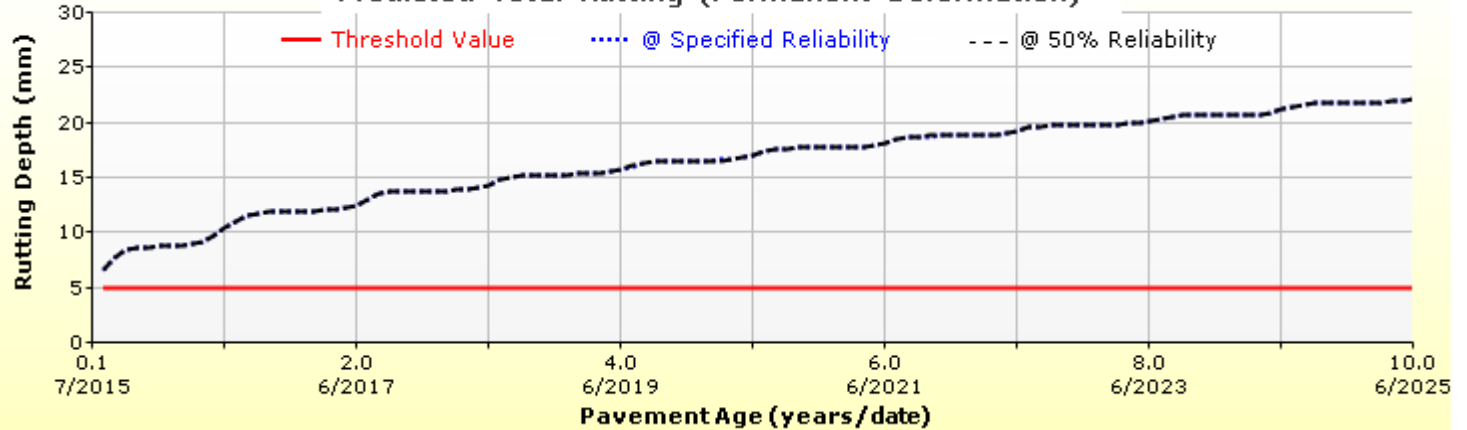


Analysis Output Charts

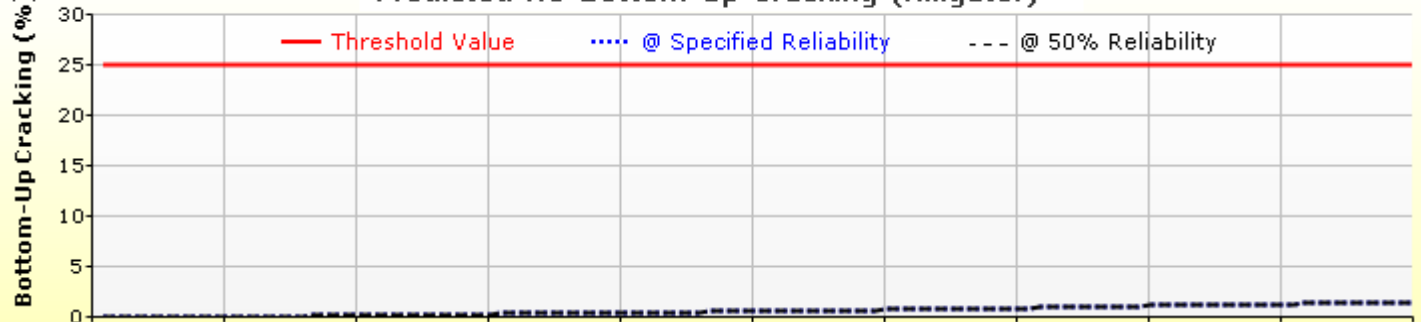
Predicted IRI



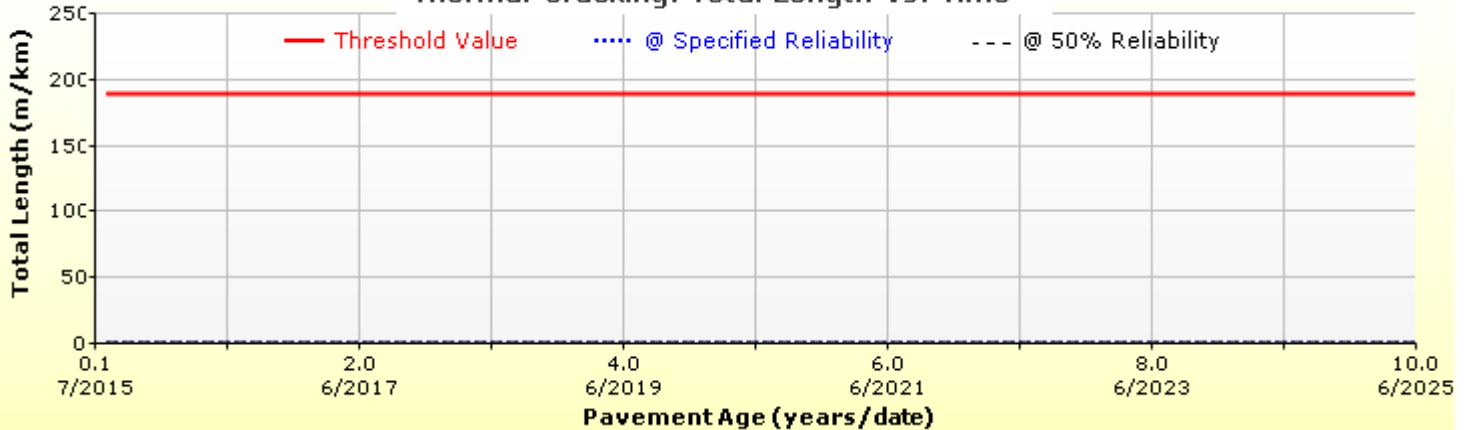
Predicted Total Rutting (Permanent Deformation)



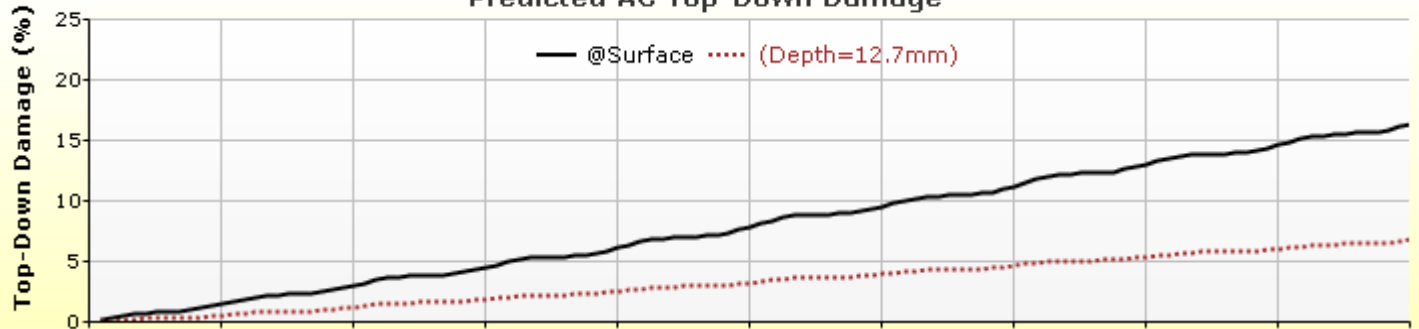
Predicted AC Bottom-Up Cracking (Alligator)



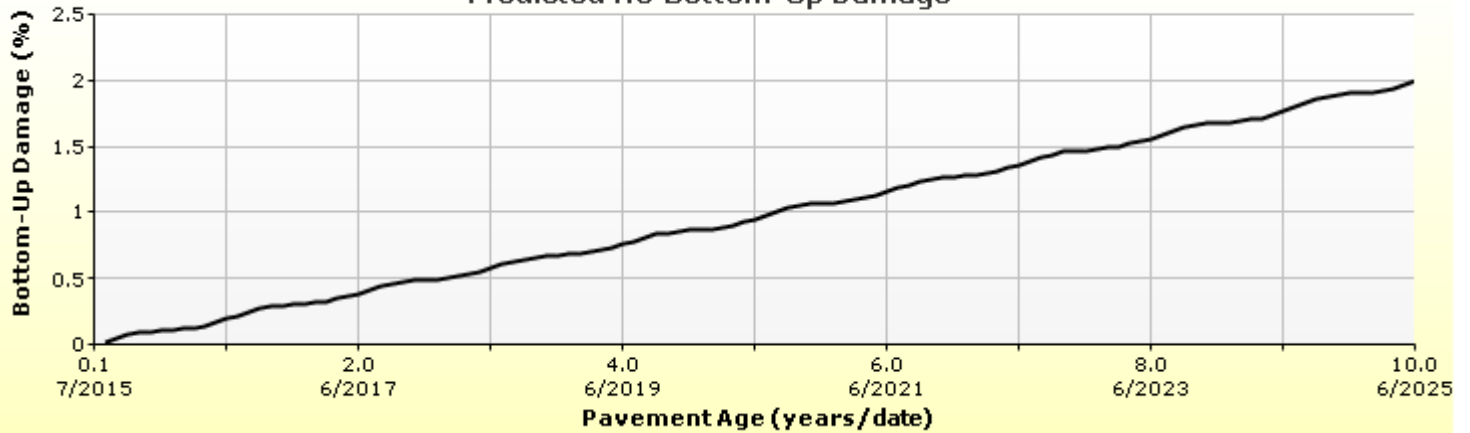
Thermal Cracking: Total Length vs. Time



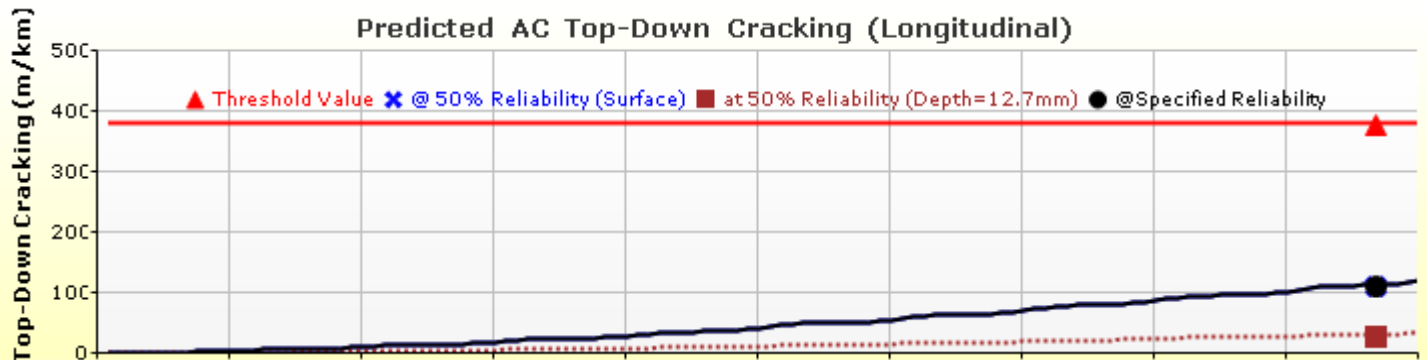
Predicted AC Top-Down Damage



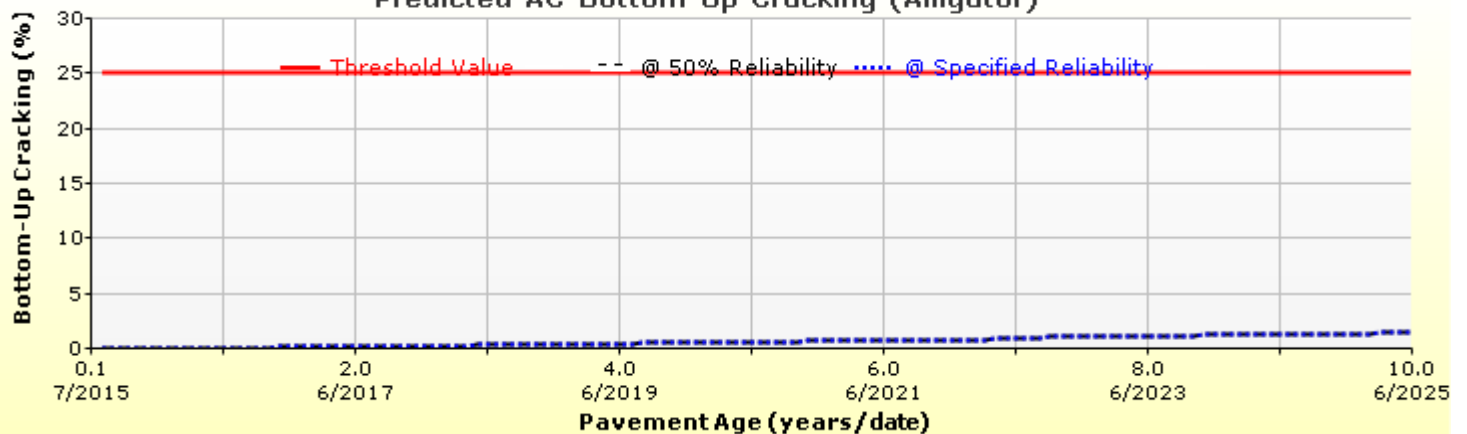
Predicted AC Bottom-Up Damage



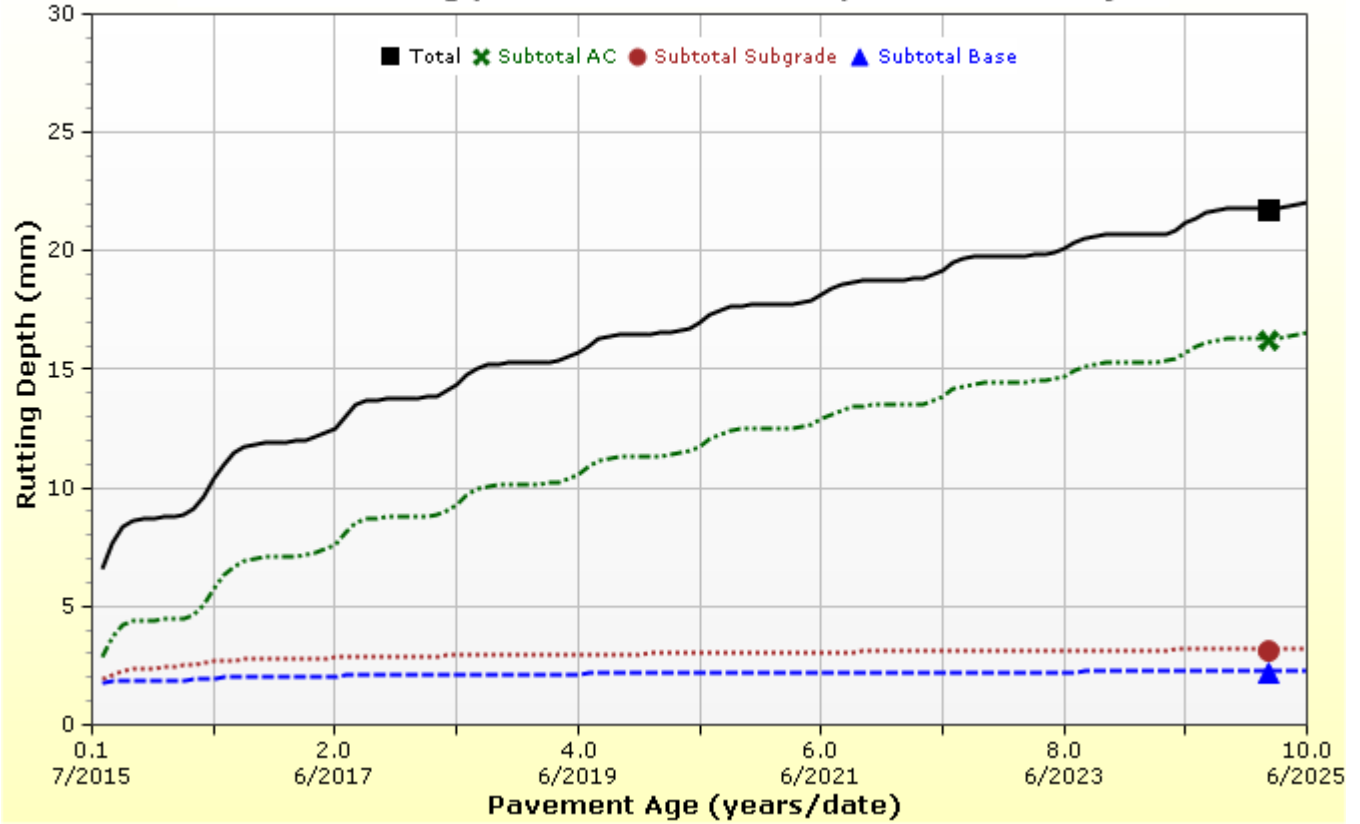
Predicted AC Top-Down Cracking (Longitudinal)



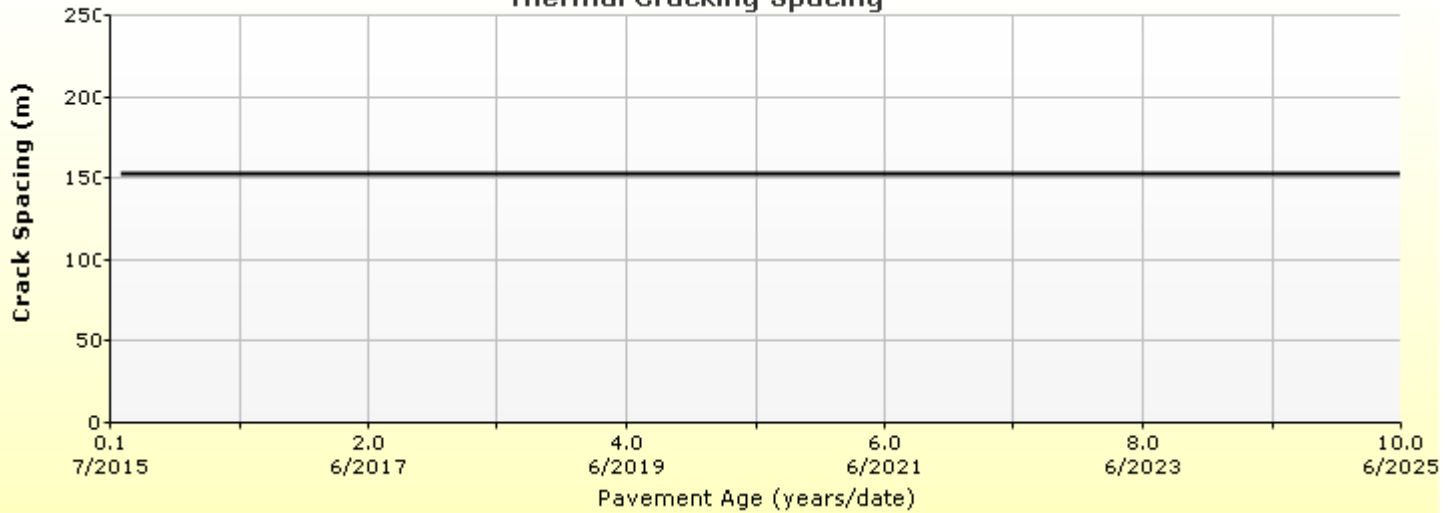
Predicted AC Bottom-Up Cracking (Alligator)



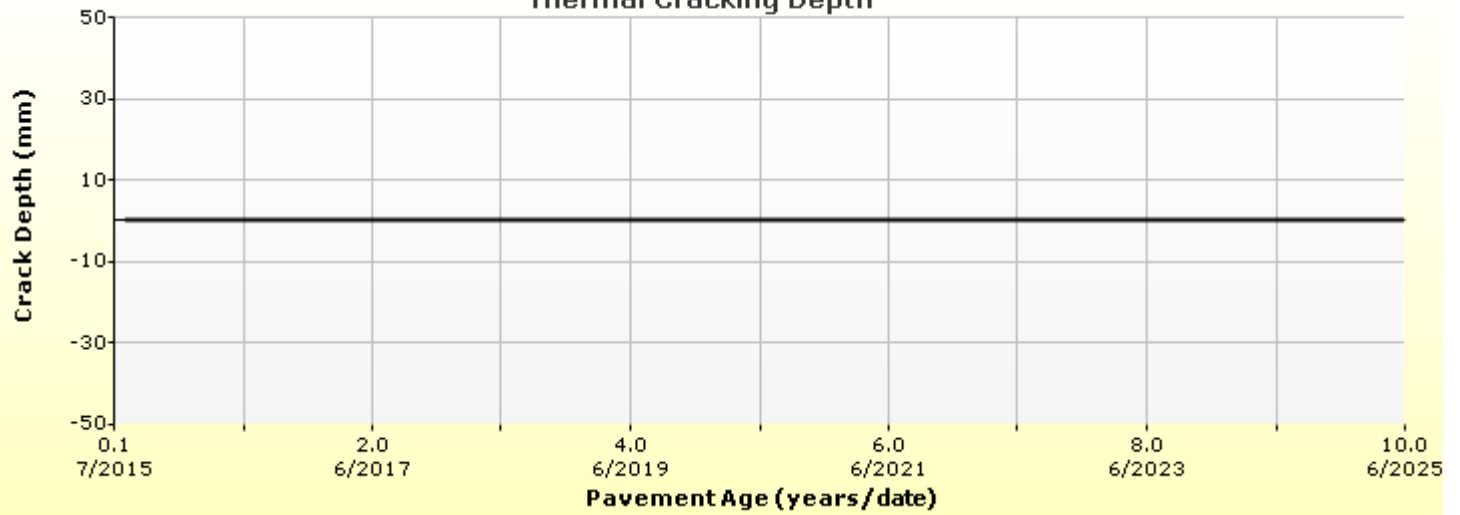
Predicted Rutting (Permanent Deformation) at 50% Reliability

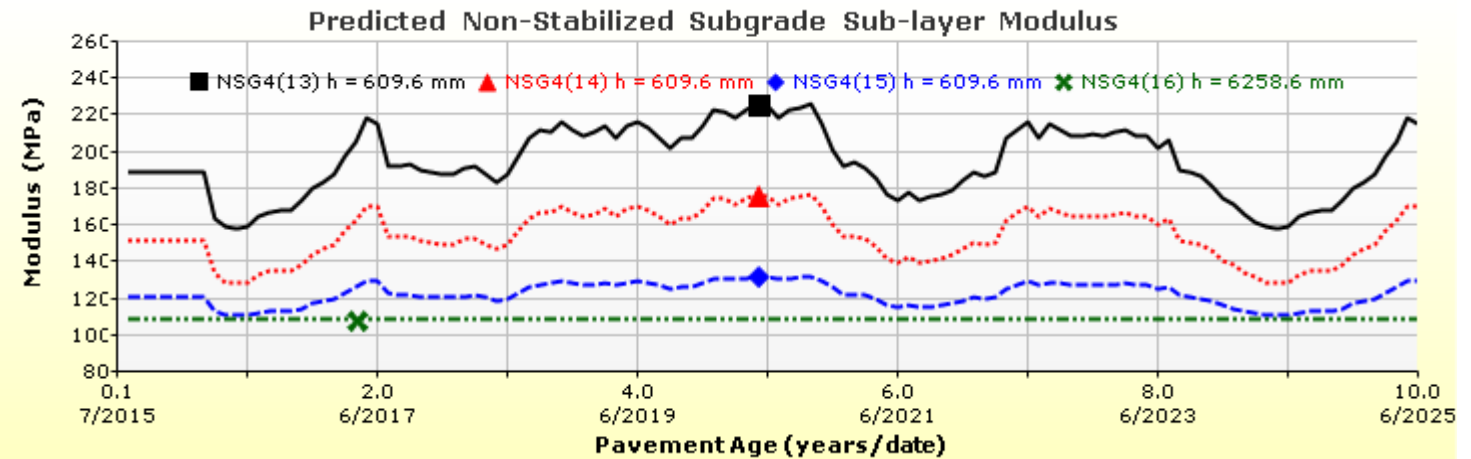
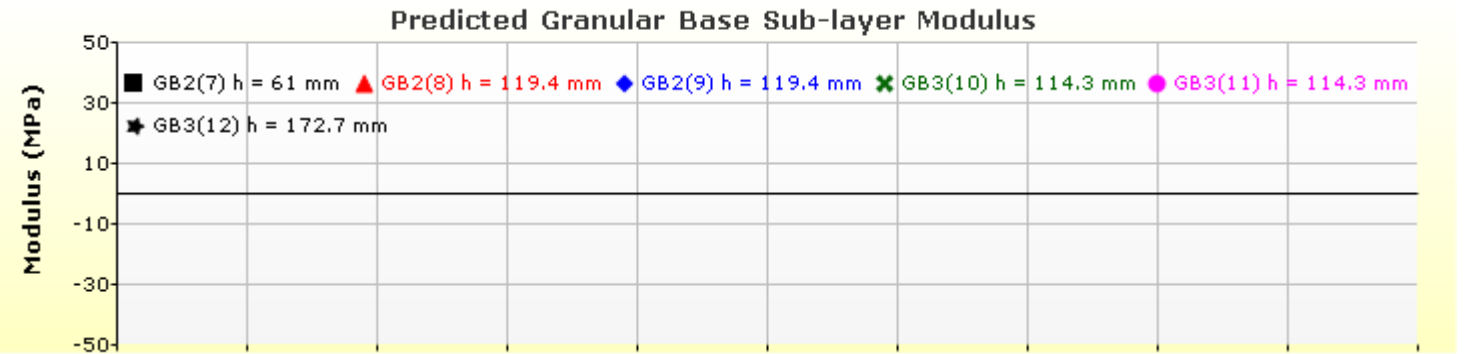
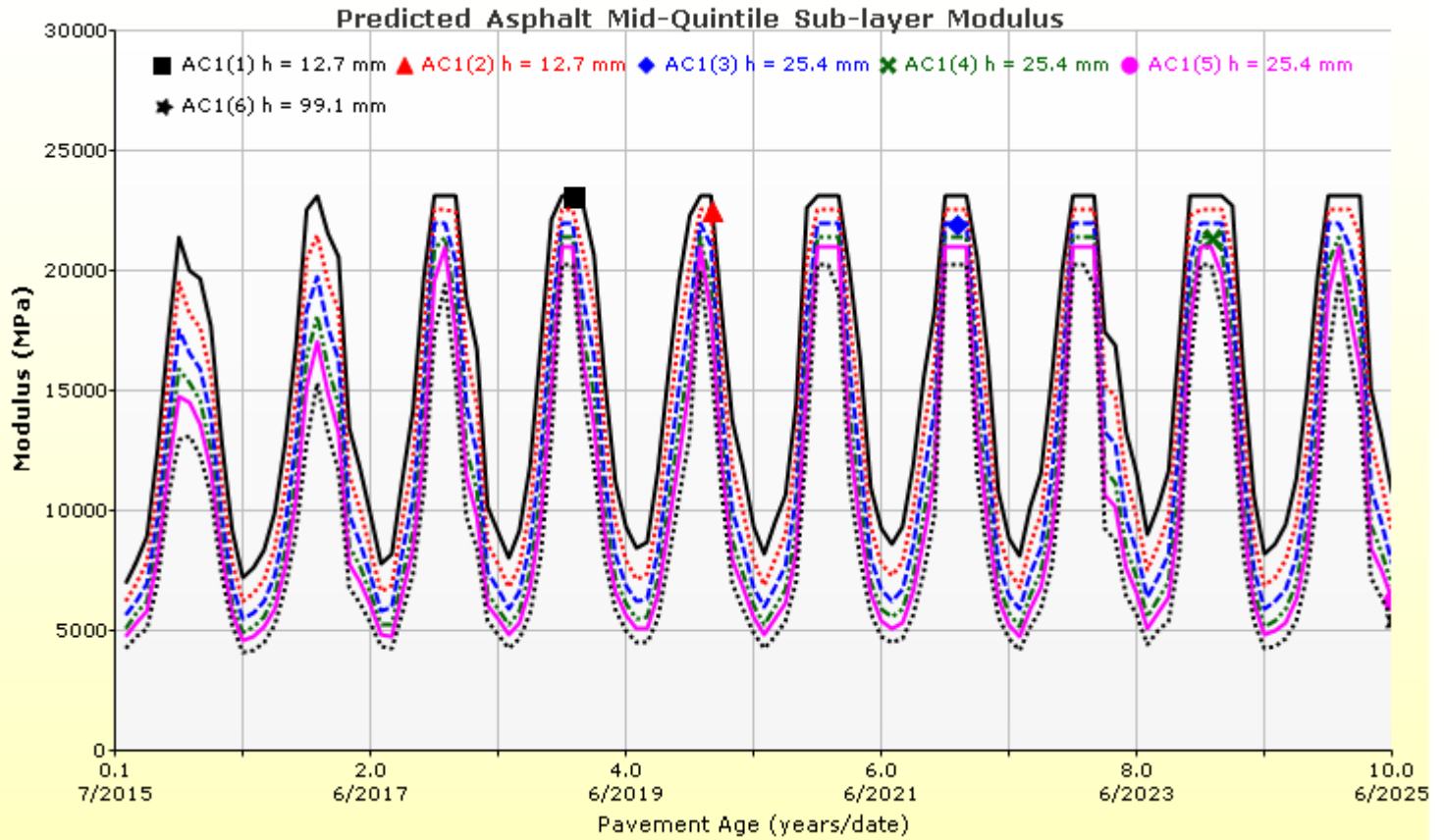


Thermal Cracking Spacing



Thermal Cracking Depth





Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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:	Annual representative values
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)
500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	200.0
NonStabilized	Crushed stone	300.0
NonStabilized	Crushed stone	400.0
Subgrade	A-1-a	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

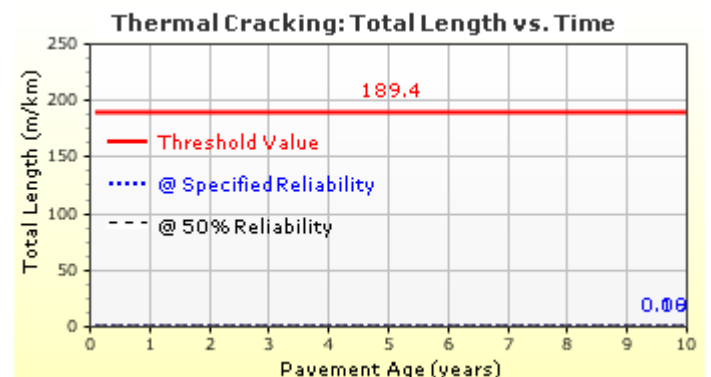
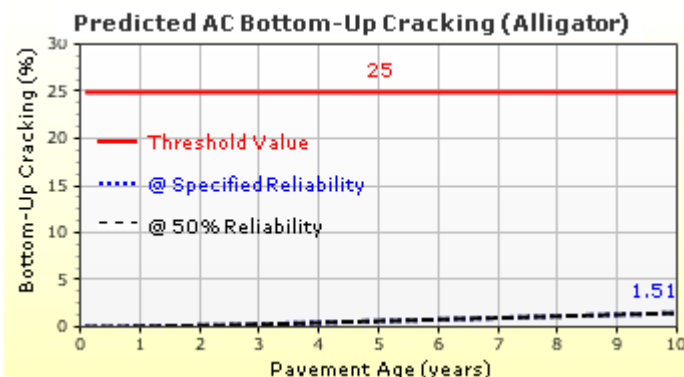
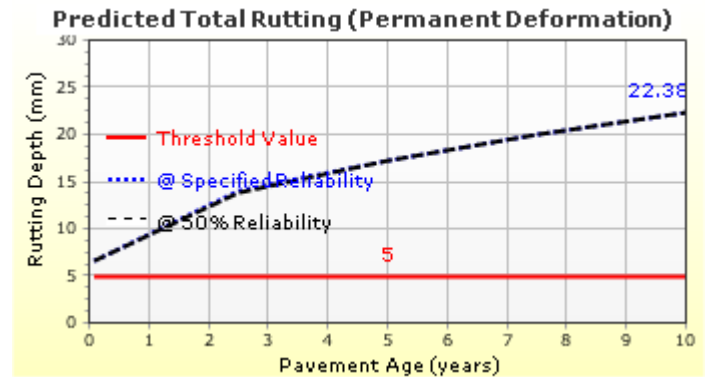
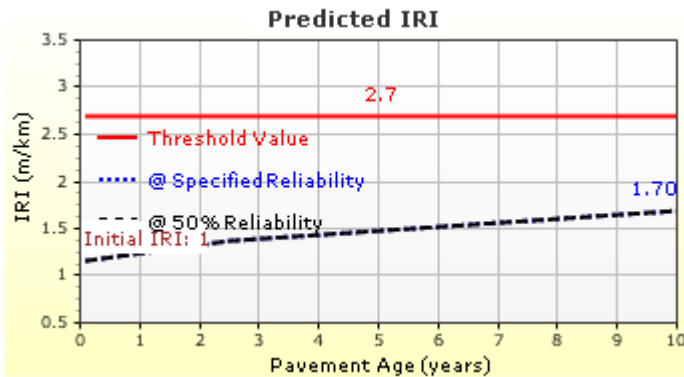
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.70	50.00	98.18	Pass
Permanent deformation - total pavement (mm)	5.00	22.38	50.00	0.01	Fail
AC bottom-up fatigue cracking (percent)	25.00	1.51	50.00	100.00	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	119.89	50.00	74.25	Pass
Permanent deformation - AC only (mm)	5.00	16.89	50.00	0.36	Fail

Distress Charts

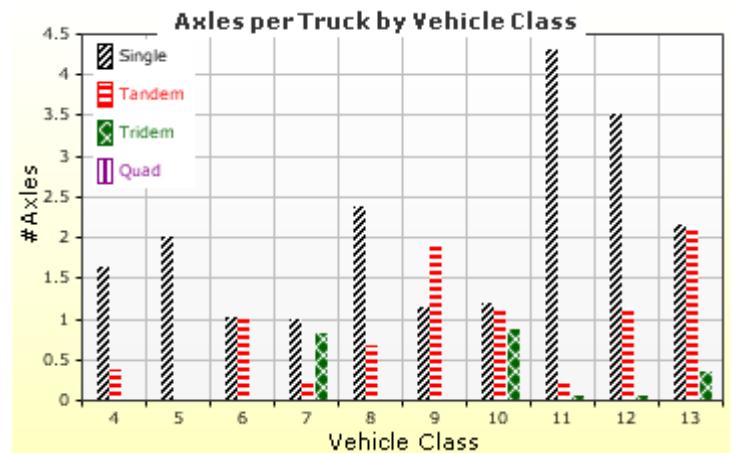
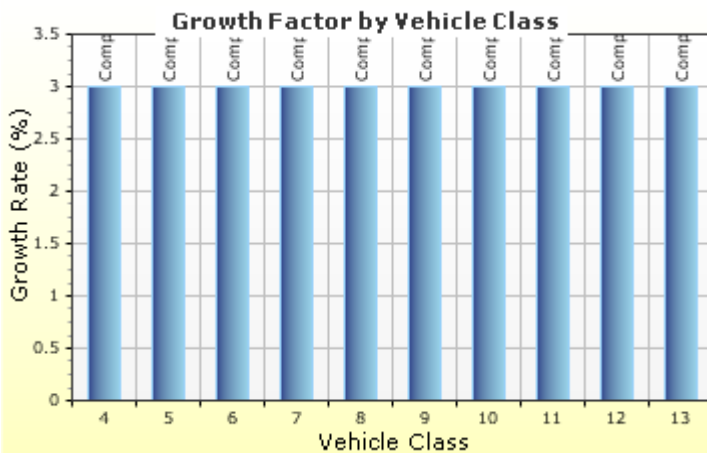
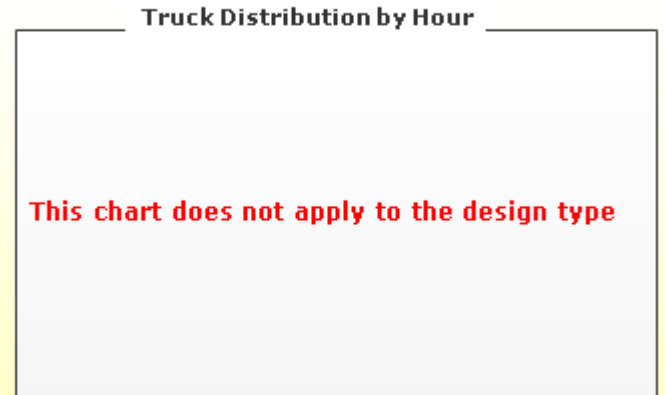
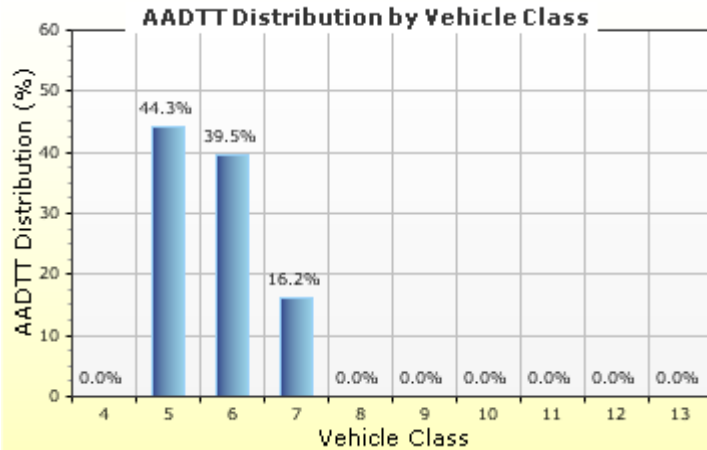


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

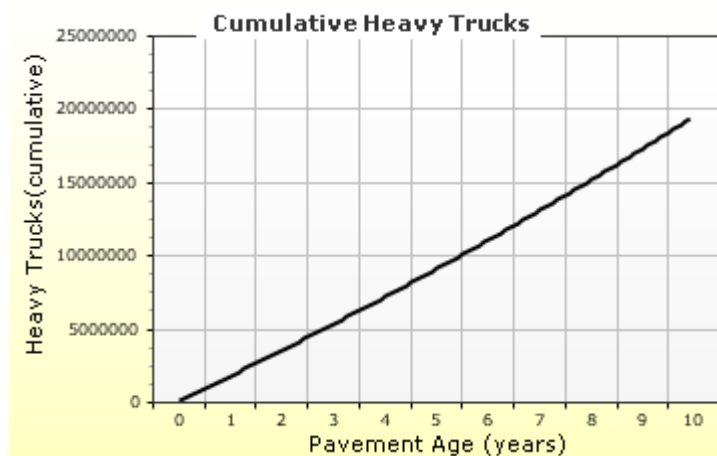
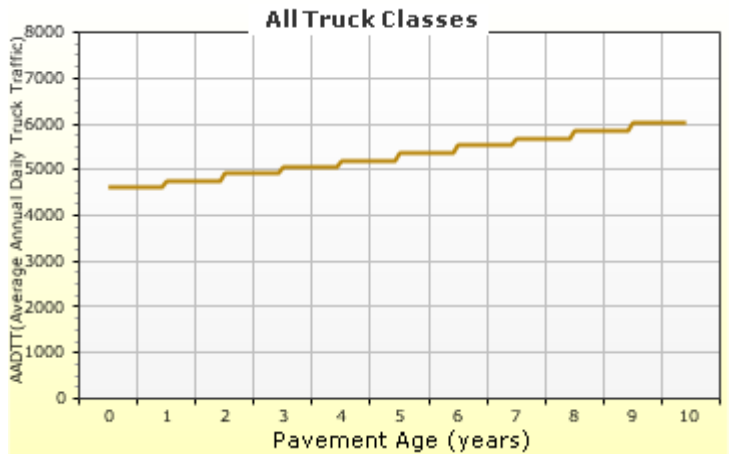
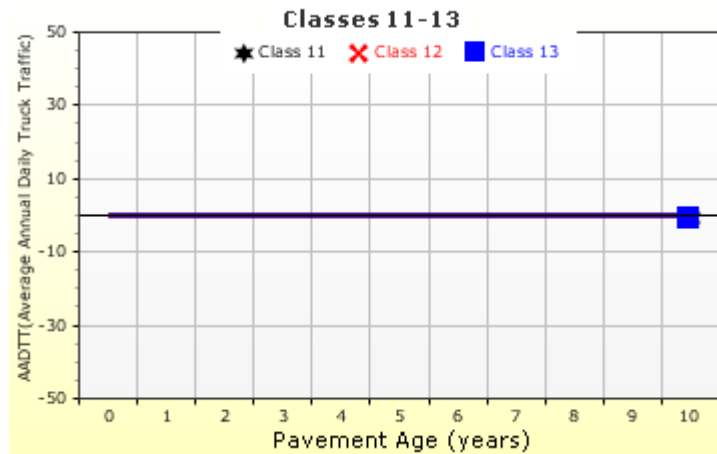
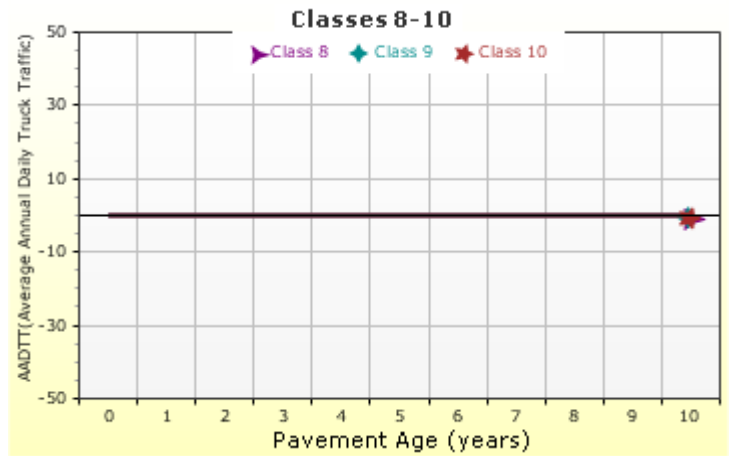
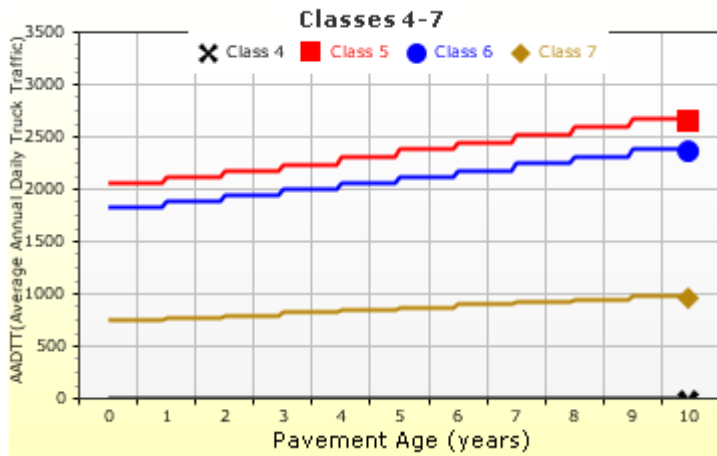
Wheelbase does not apply

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



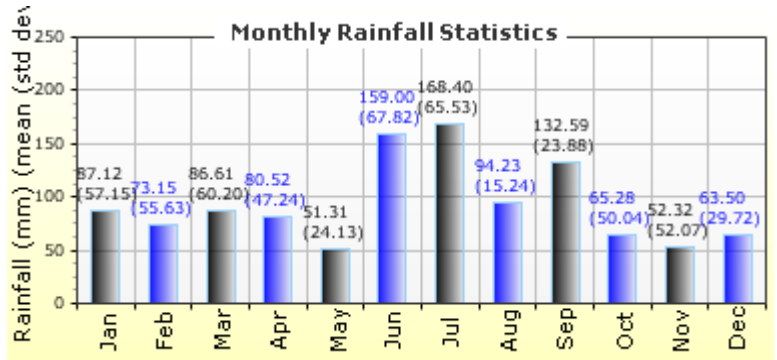
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

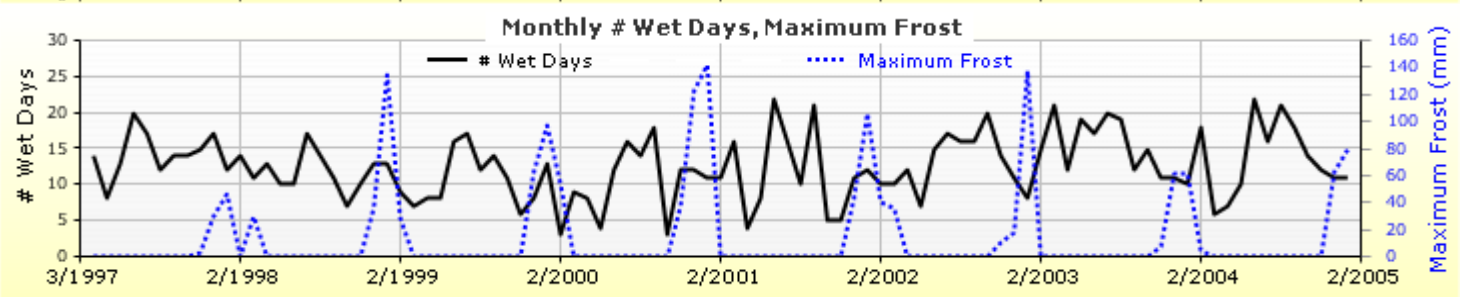
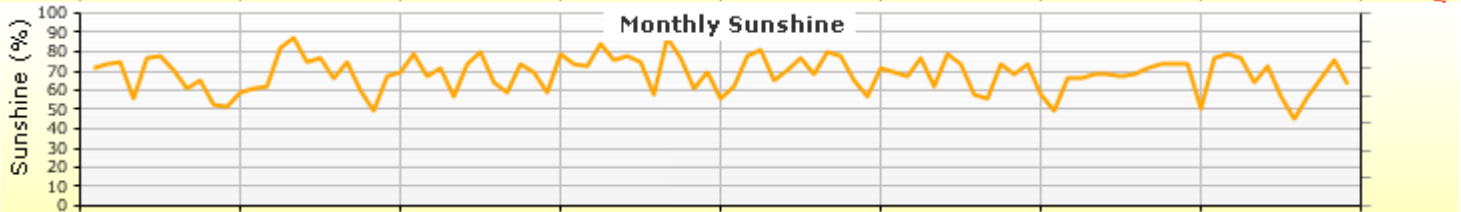
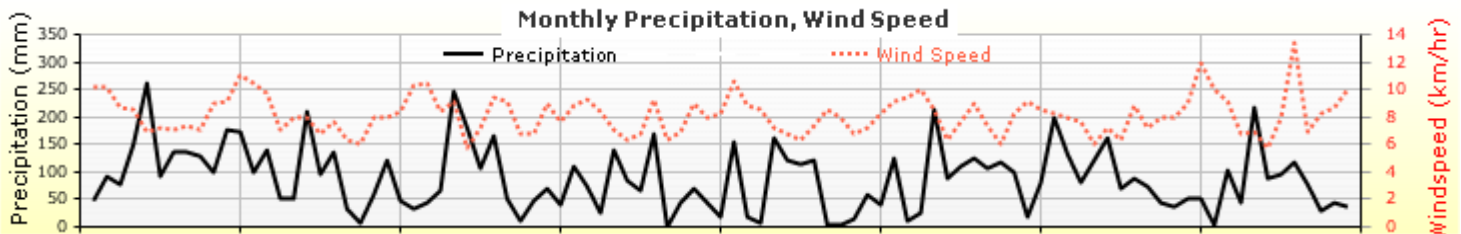
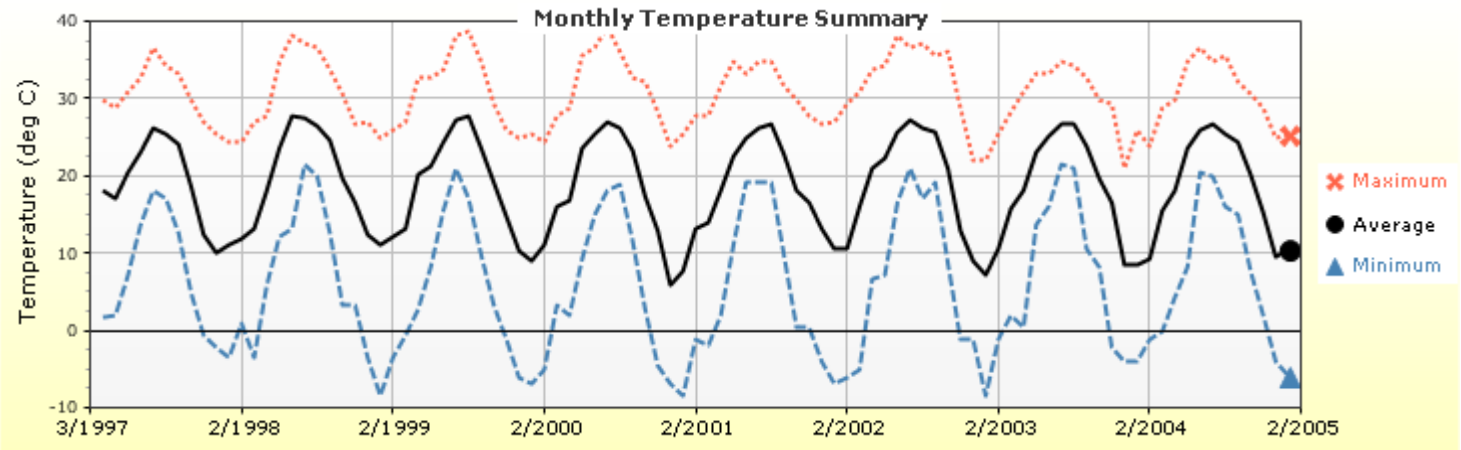
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

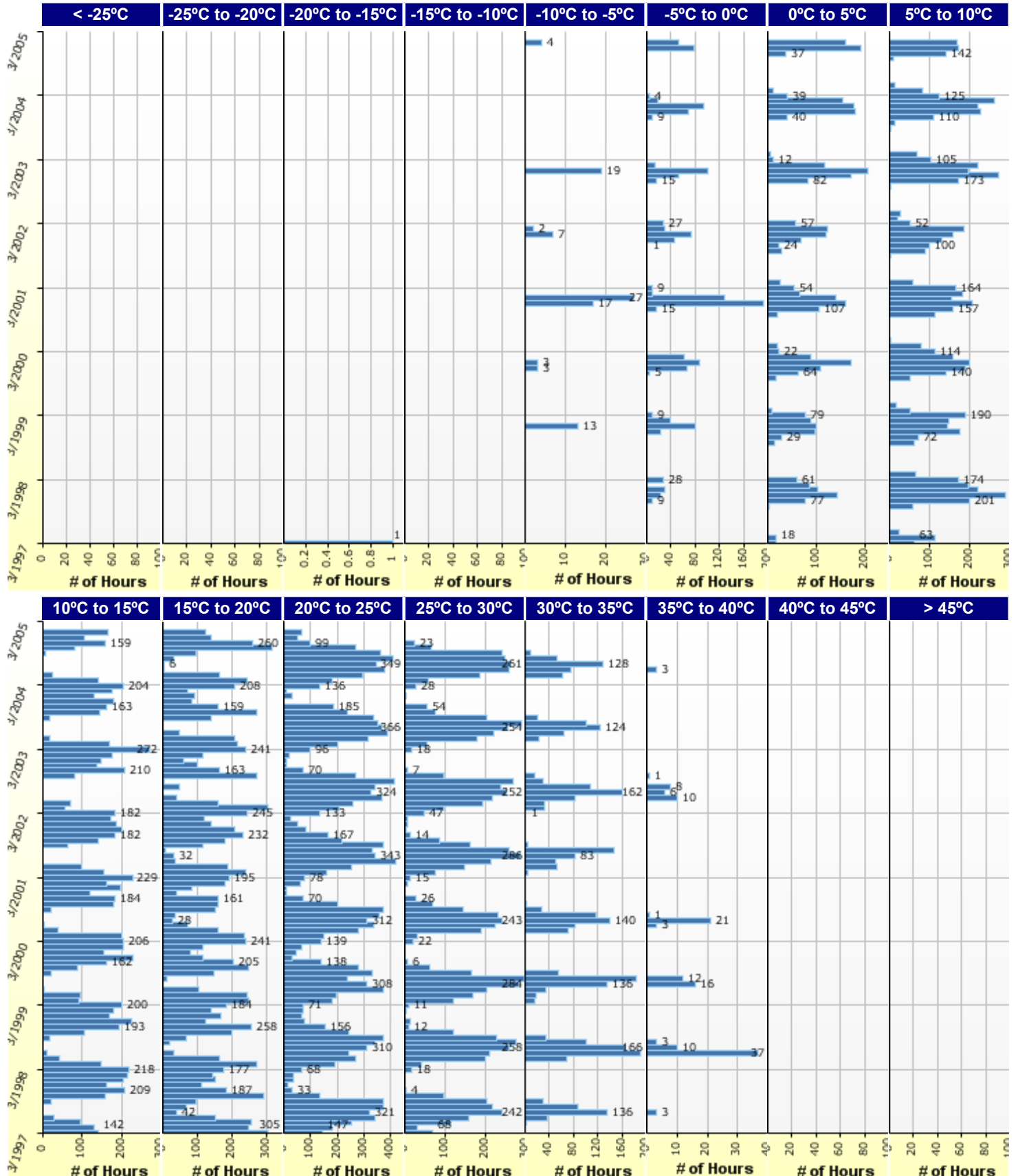


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF4_ALT3

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF4_ALT3.dgpx



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

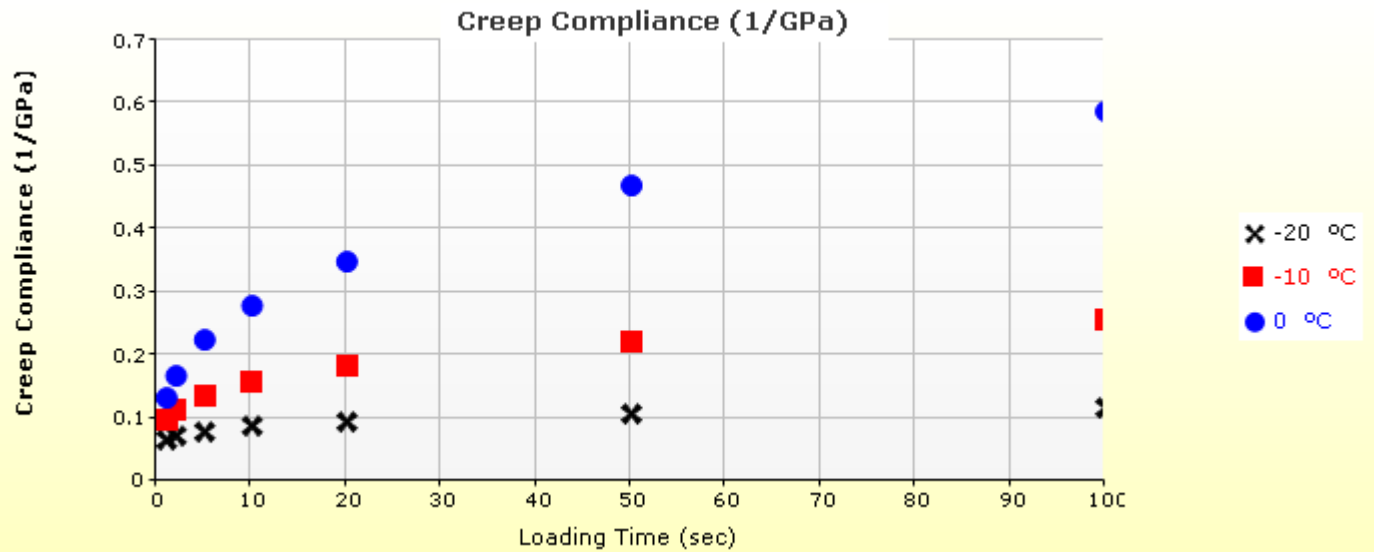
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

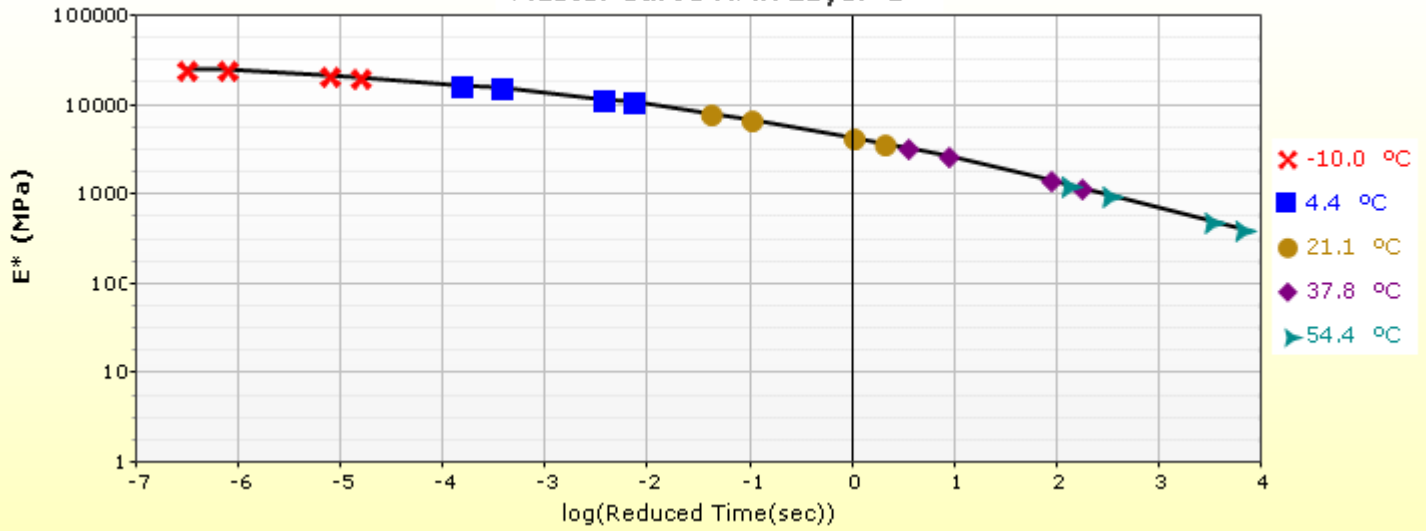
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

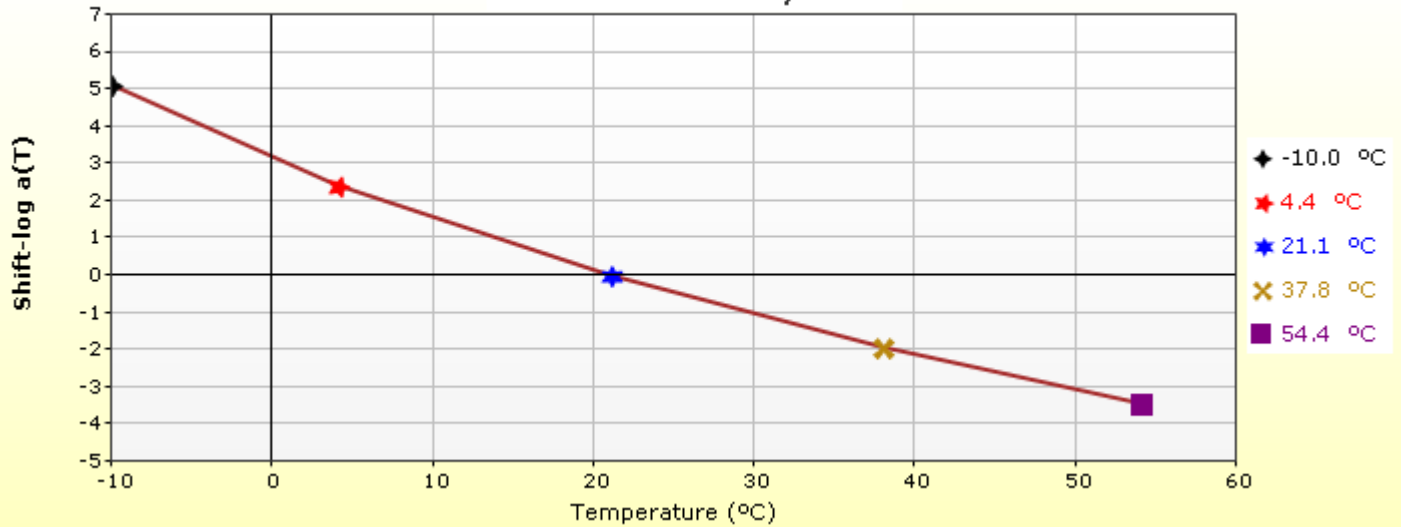


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

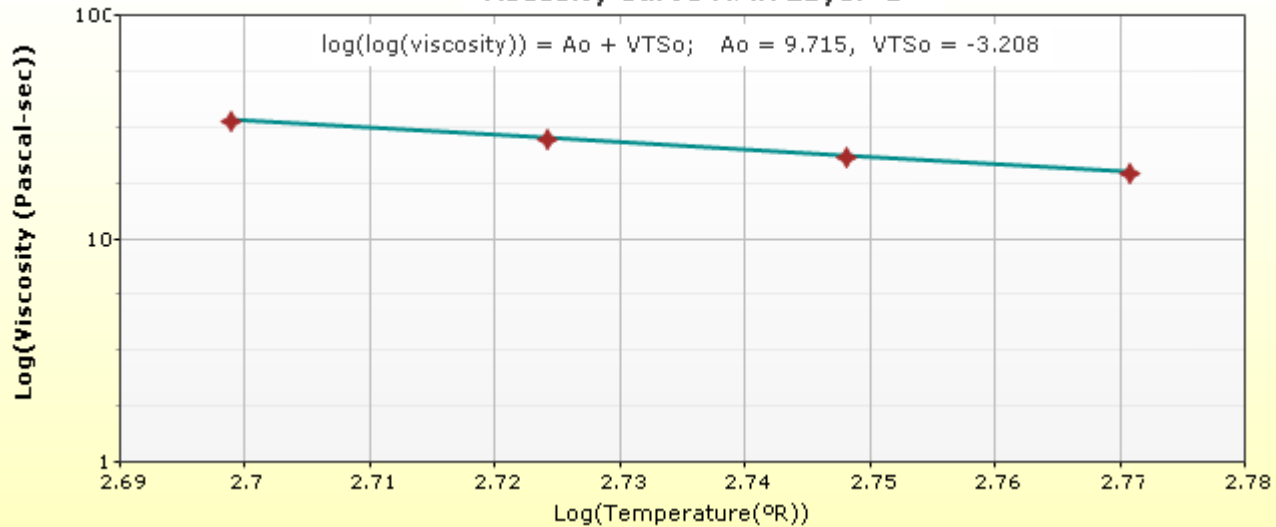
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

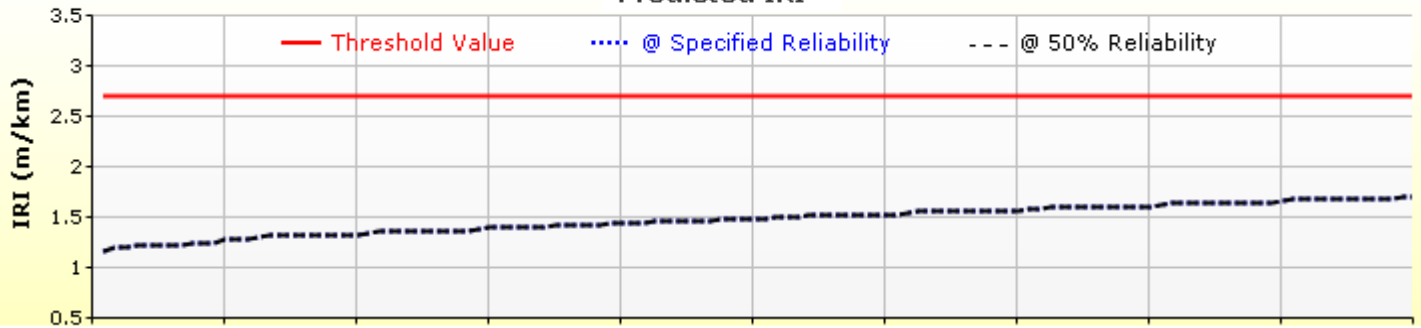


Viscosity Curve HMA Layer 1

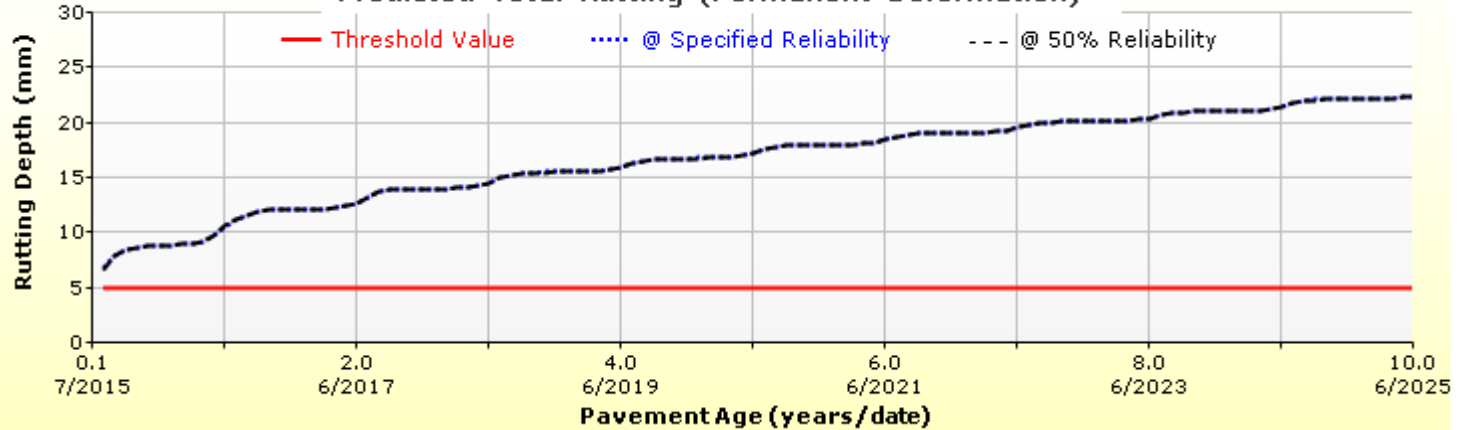


Analysis Output Charts

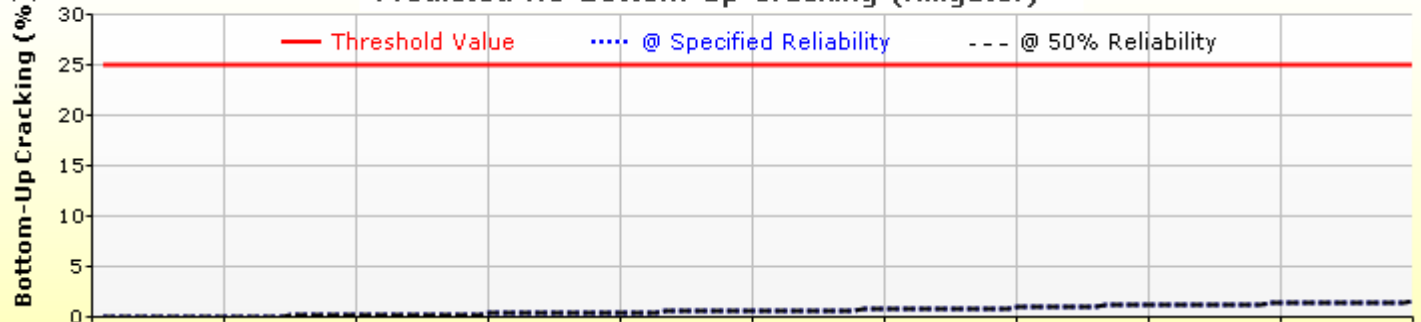
Predicted IRI



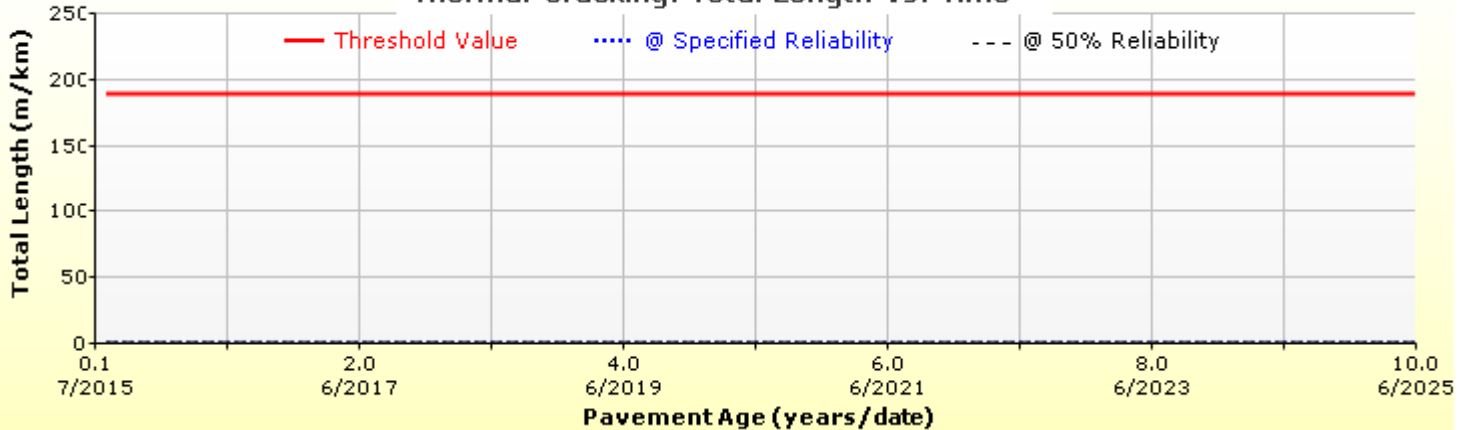
Predicted Total Rutting (Permanent Deformation)



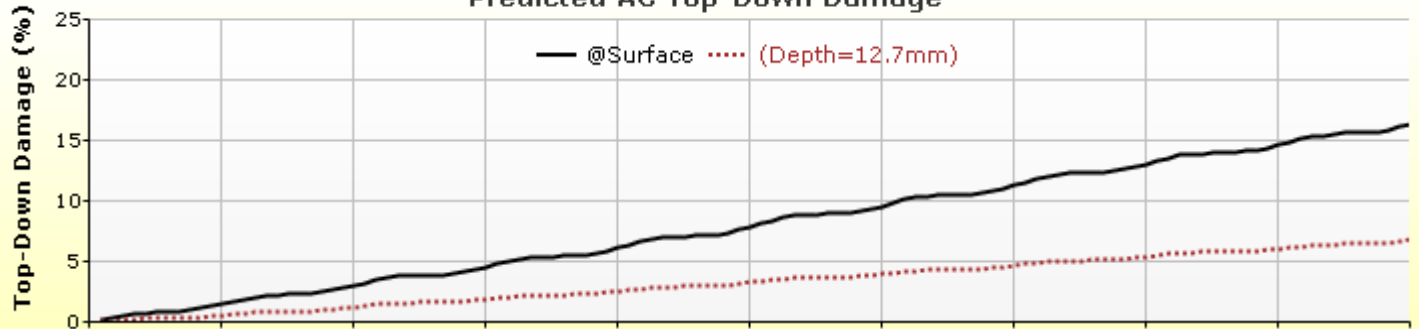
Predicted AC Bottom-Up Cracking (Alligator)



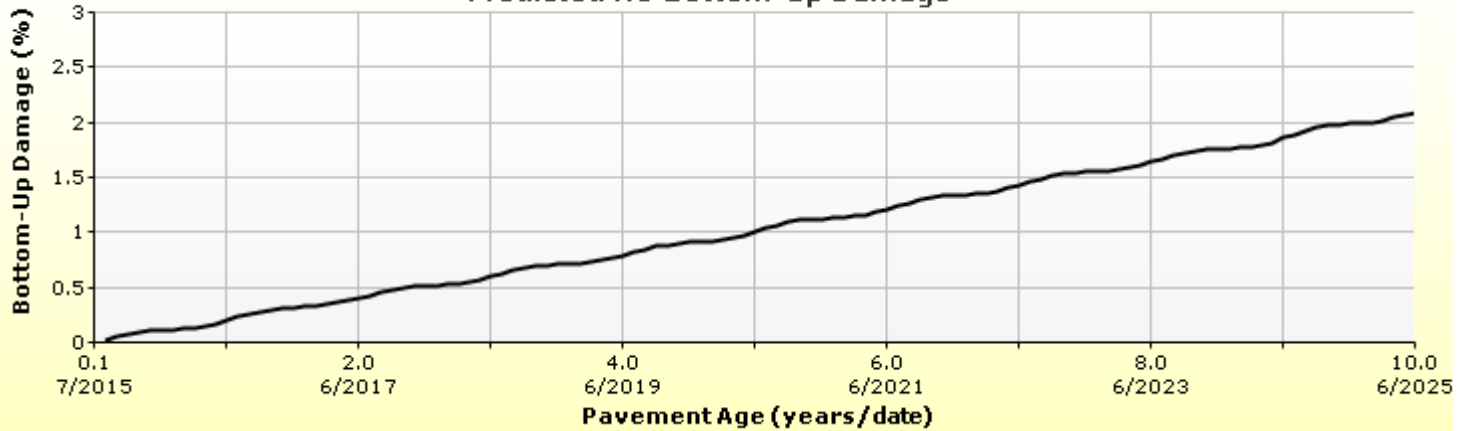
Thermal Cracking: Total Length vs. Time



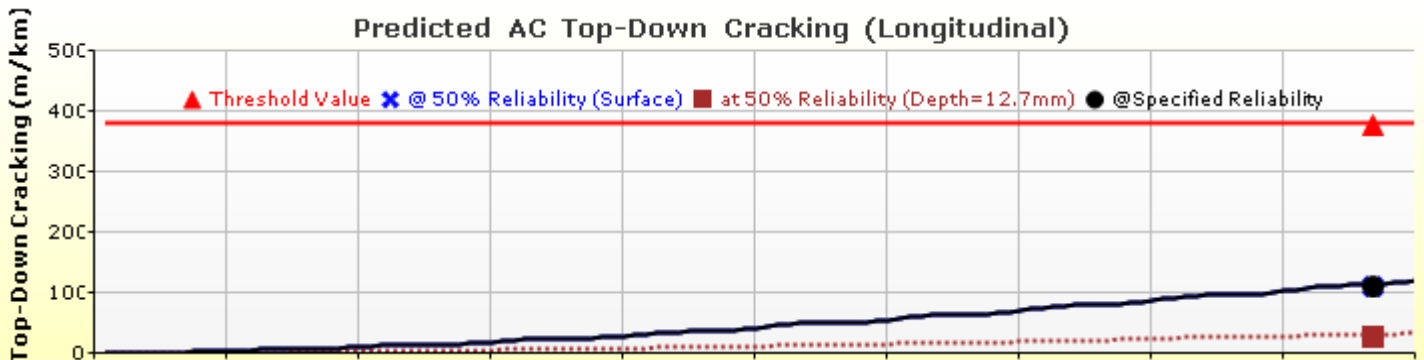
Predicted AC Top-Down Damage



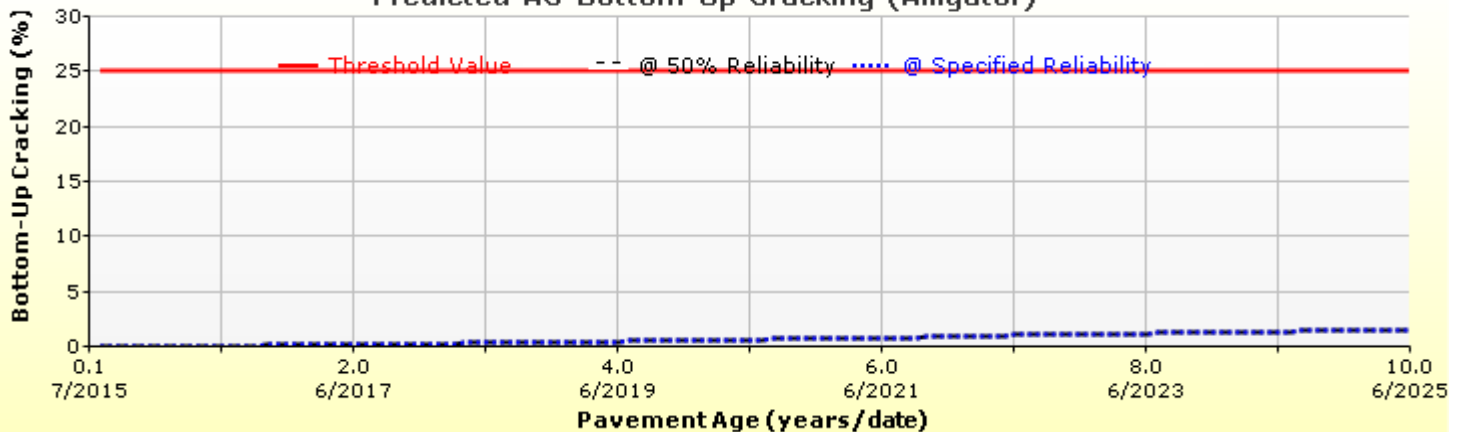
Predicted AC Bottom-Up Damage



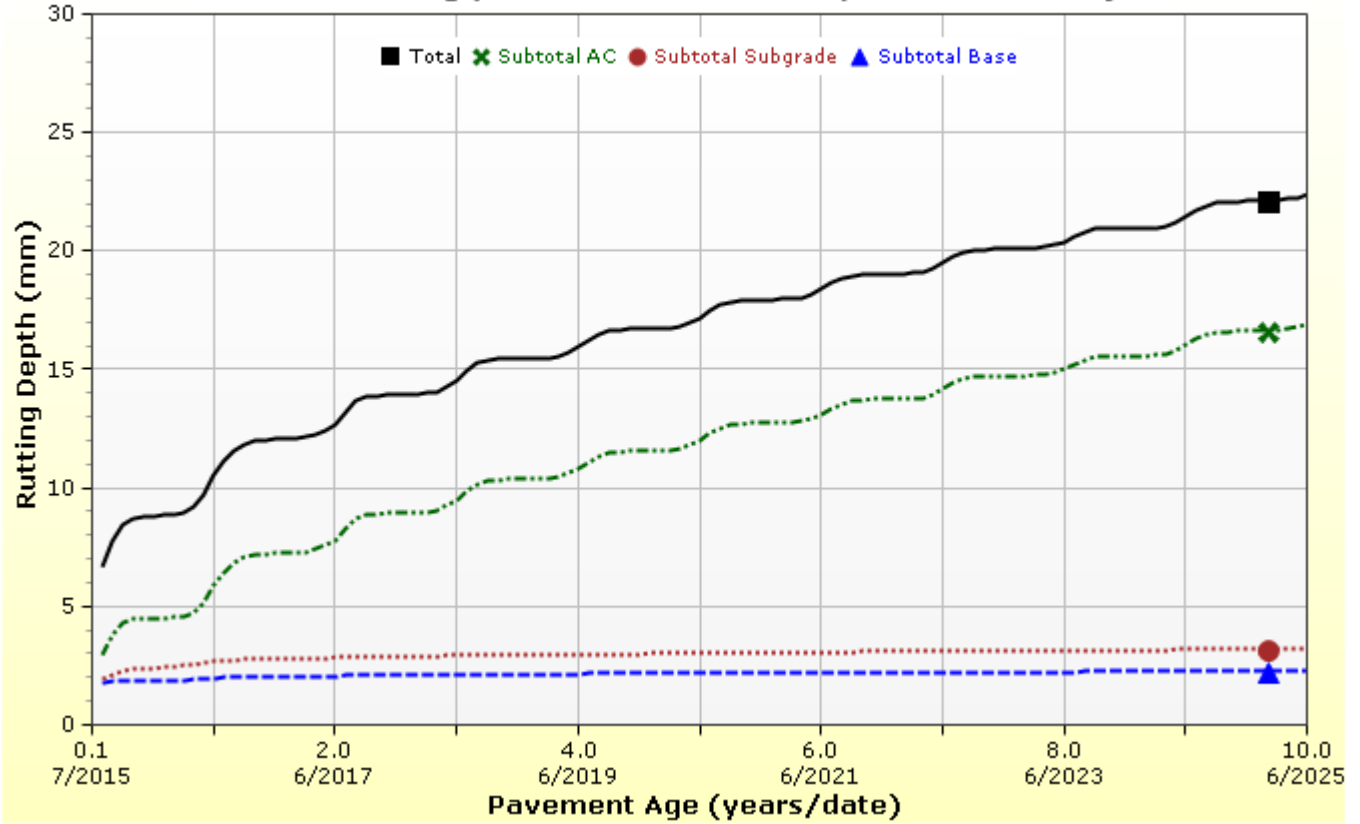
Predicted AC Top-Down Cracking (Longitudinal)

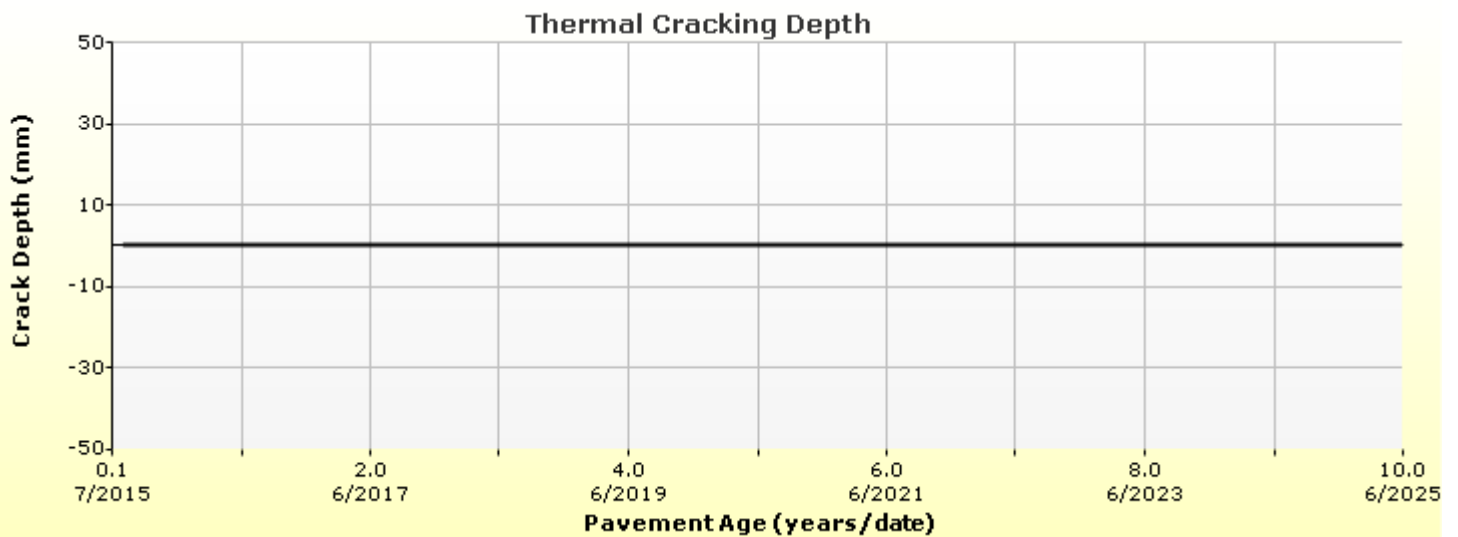
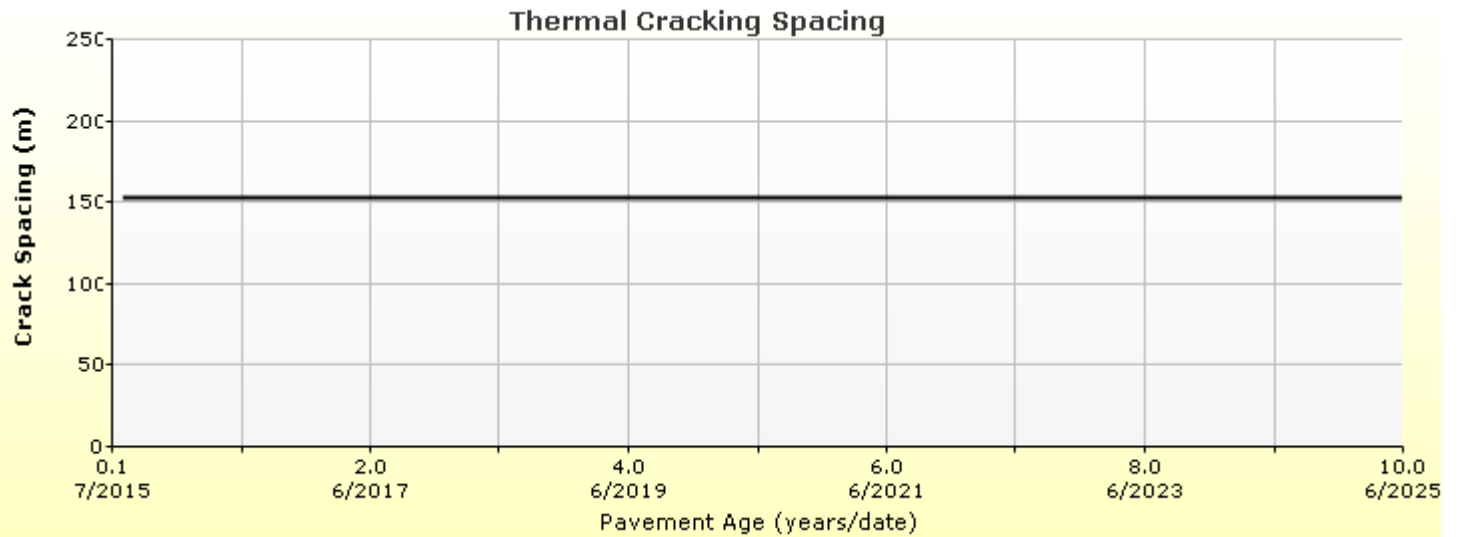


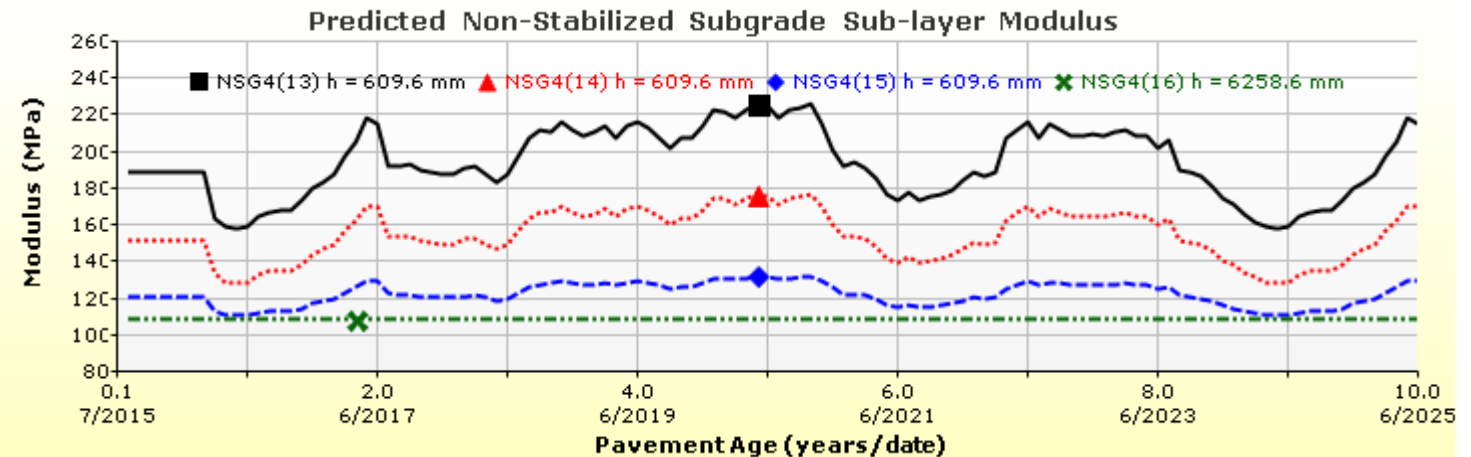
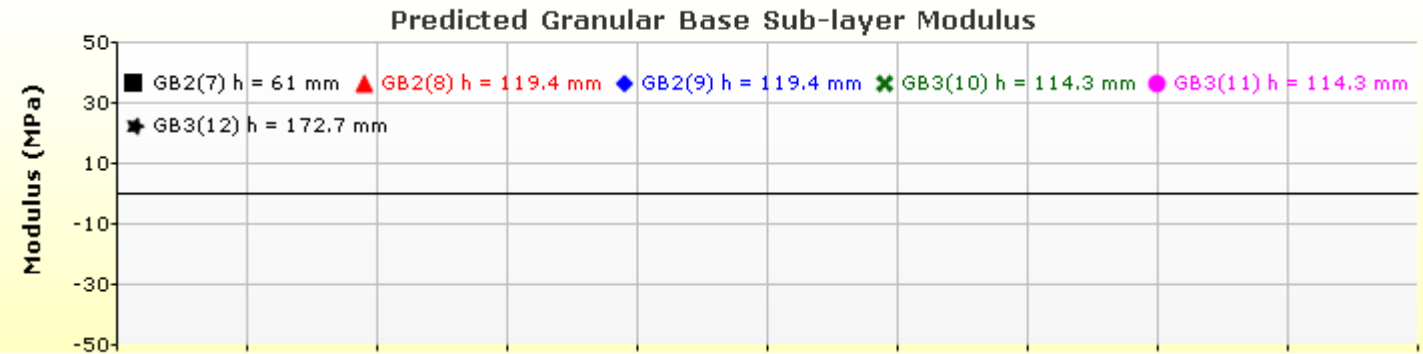
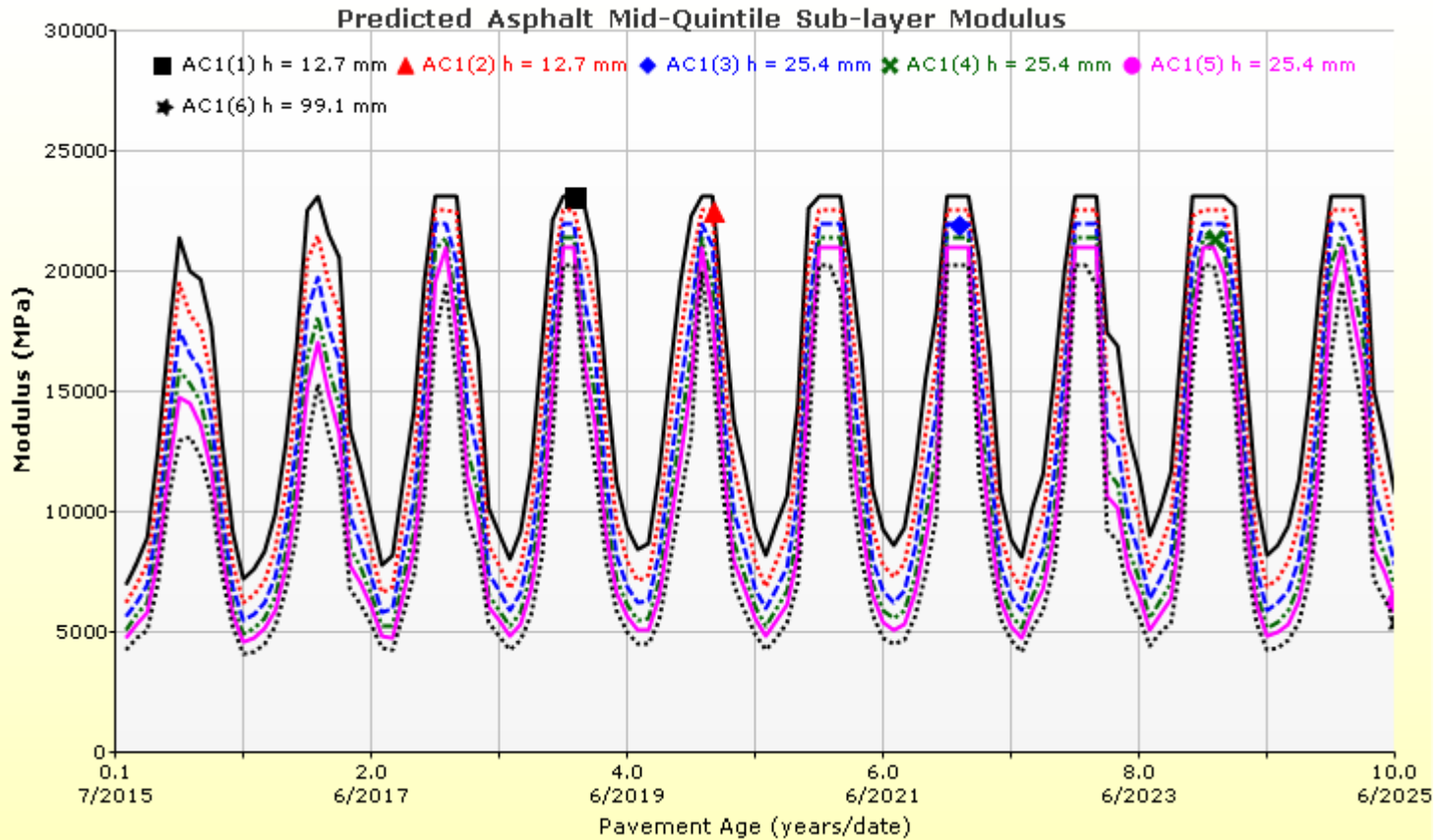
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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:	Annual representative values
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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() σ = standard deviation of the log of the depth of cracks in the pavments C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$		$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$	
k1: 1	k2: 1	Bc1: 1	Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015



Project1 - Novo ALF1_ALT4

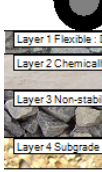
File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1_ALT4.dgpx



Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data 32.119, -81.202
Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm):	Volumetric at Construction:	
Flexible	Default asphalt concrete	200.0	Effective binder content (%)	11.6
Cement_Base	Cement stabilized	300.0	Air voids (%)	7.0
NonStabilized	Crushed stone	400.0		
Subgrade	A-1-a	Semi-infinite		

Traffic

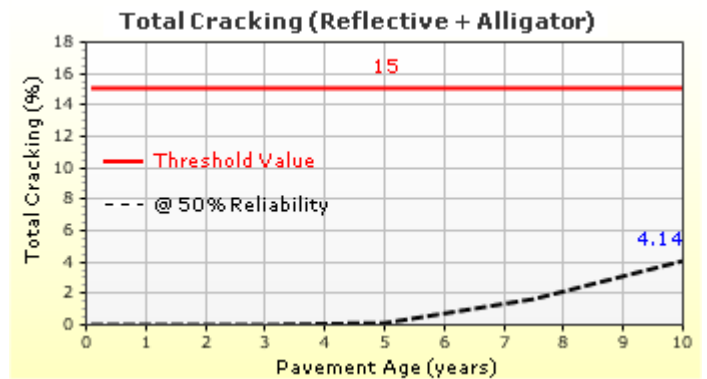
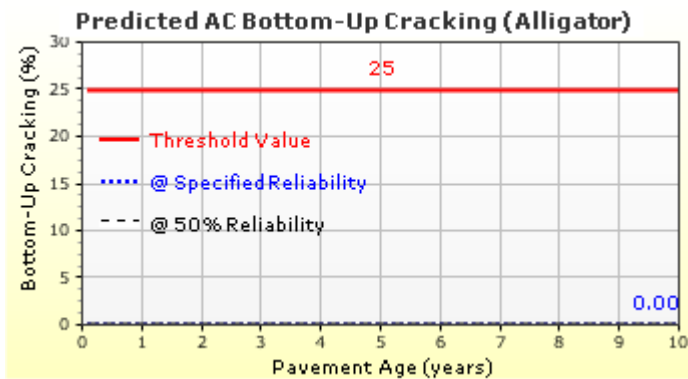
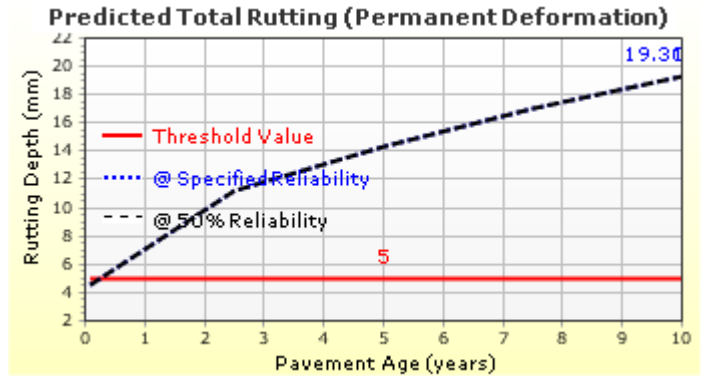
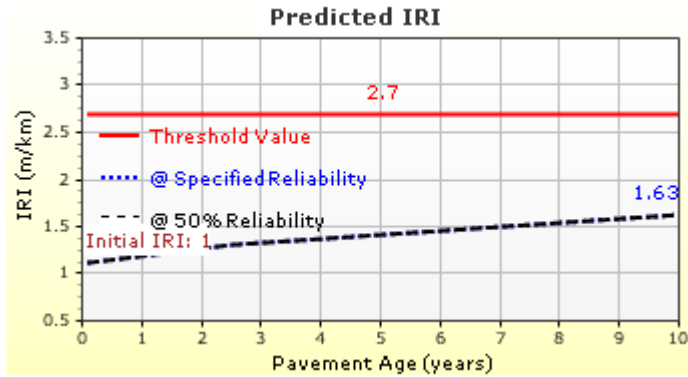
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.63	50.00	98.99	Pass
Permanent deformation - total pavement (mm)	5.00	19.31	50.00	0.07	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.00	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.14	-	-	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	365.53	50.00	51.22	Pass
Permanent deformation - AC only (mm)	5.00	16.74	50.00	0.37	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.55	-	-	-

Distress Charts

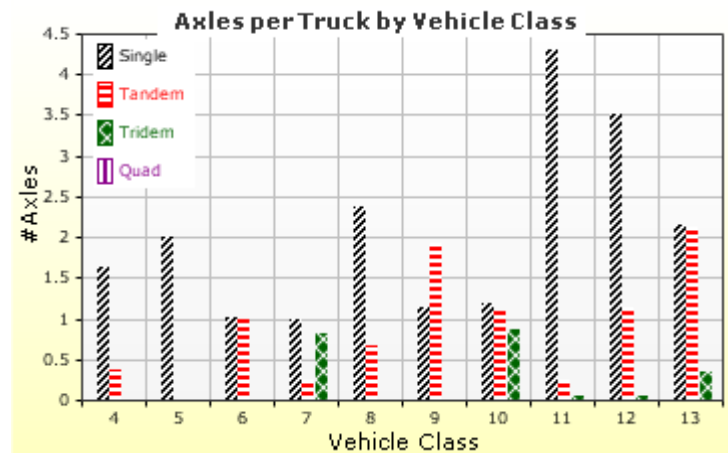
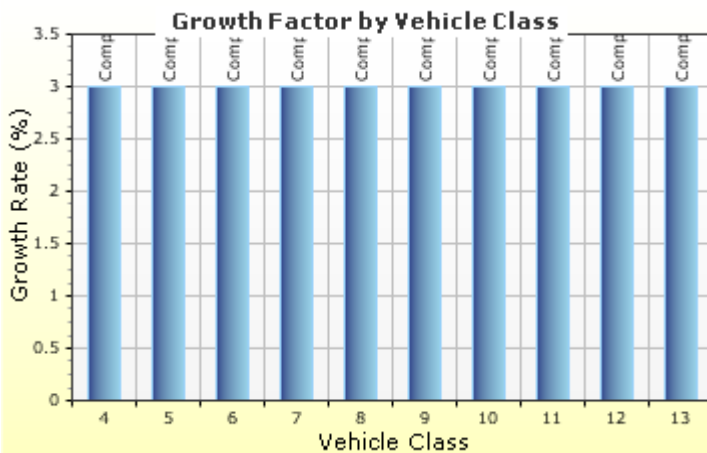
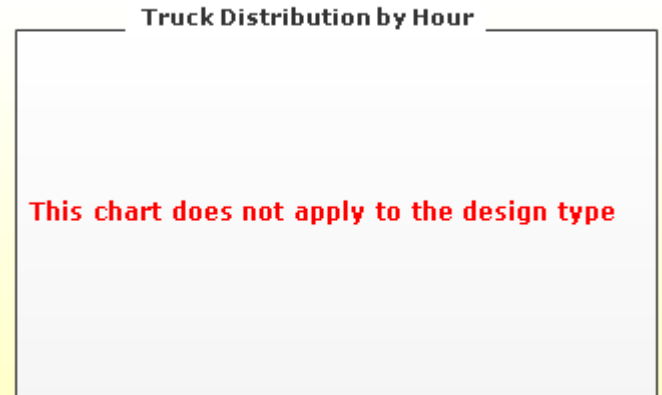
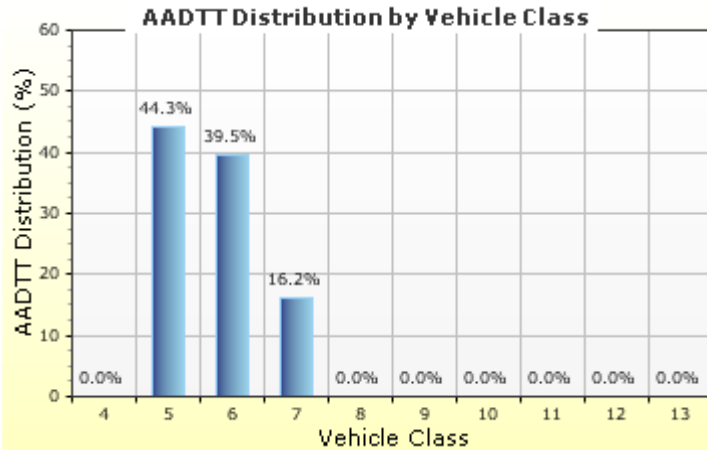


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

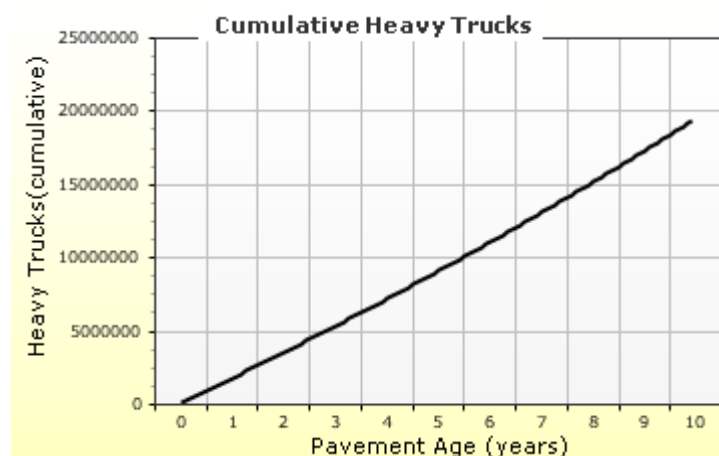
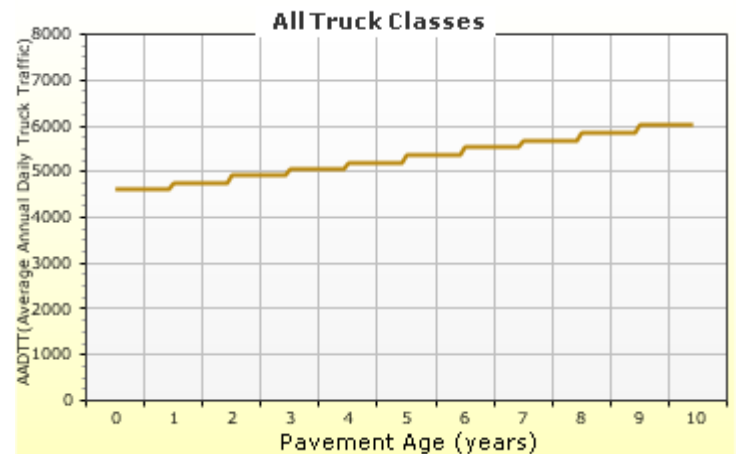
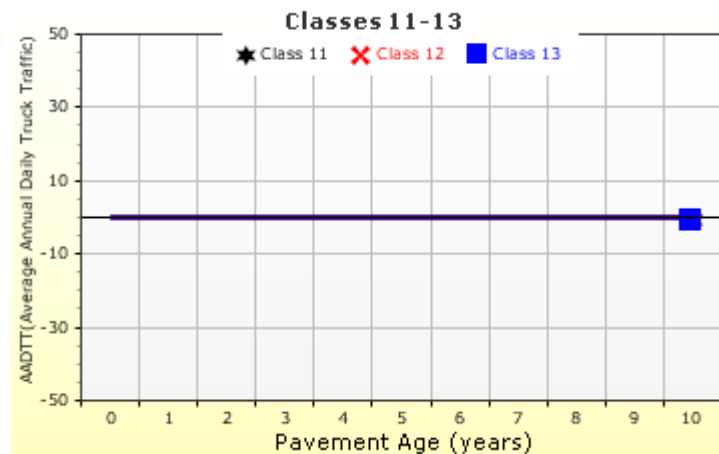
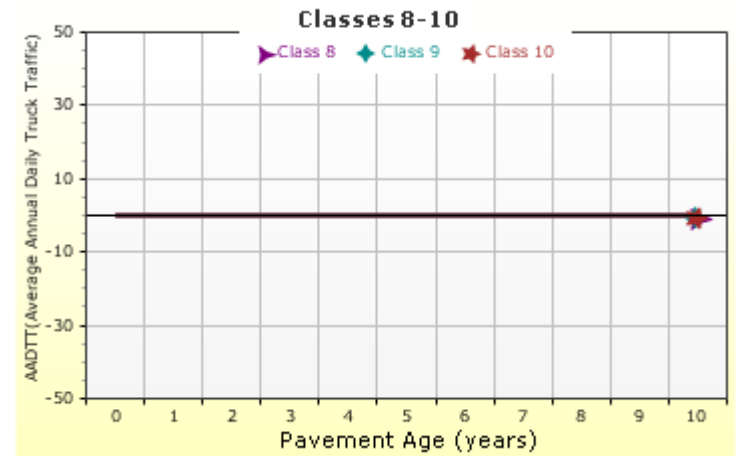
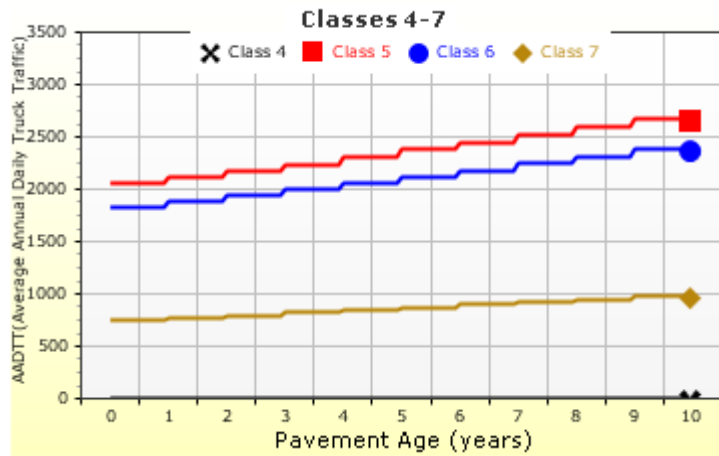
Wheelbase does not apply

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



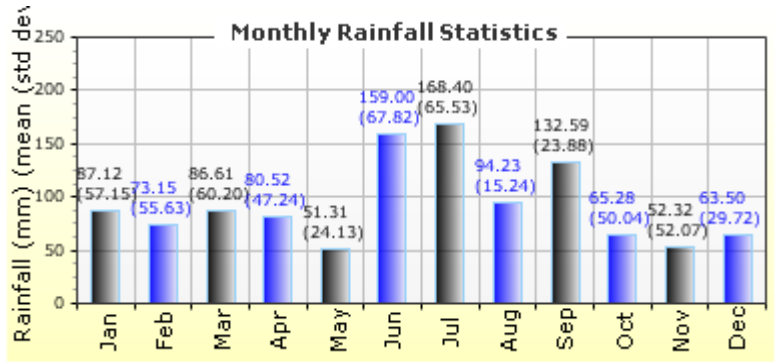
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

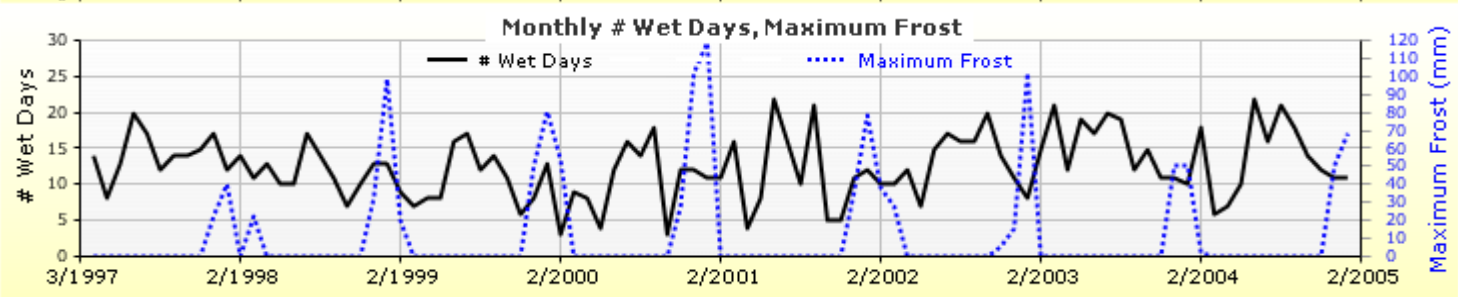
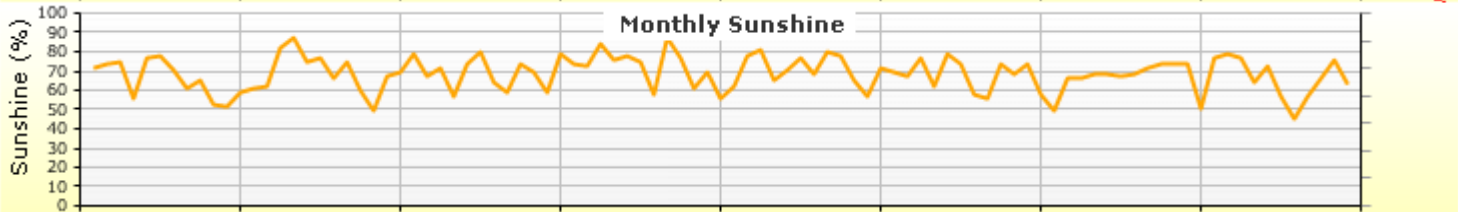
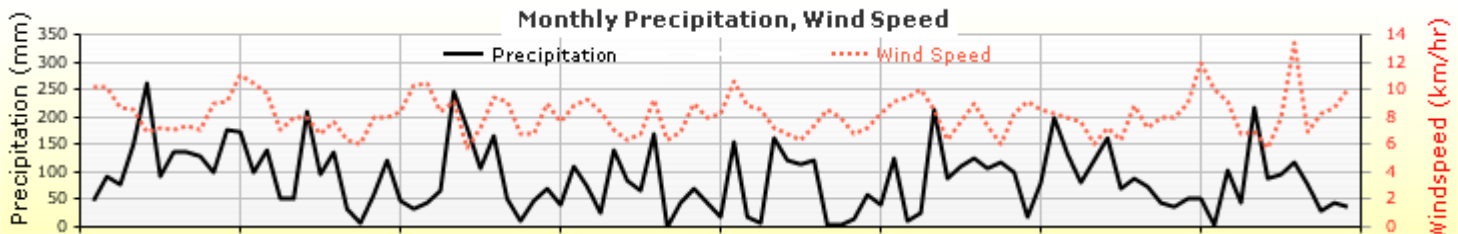
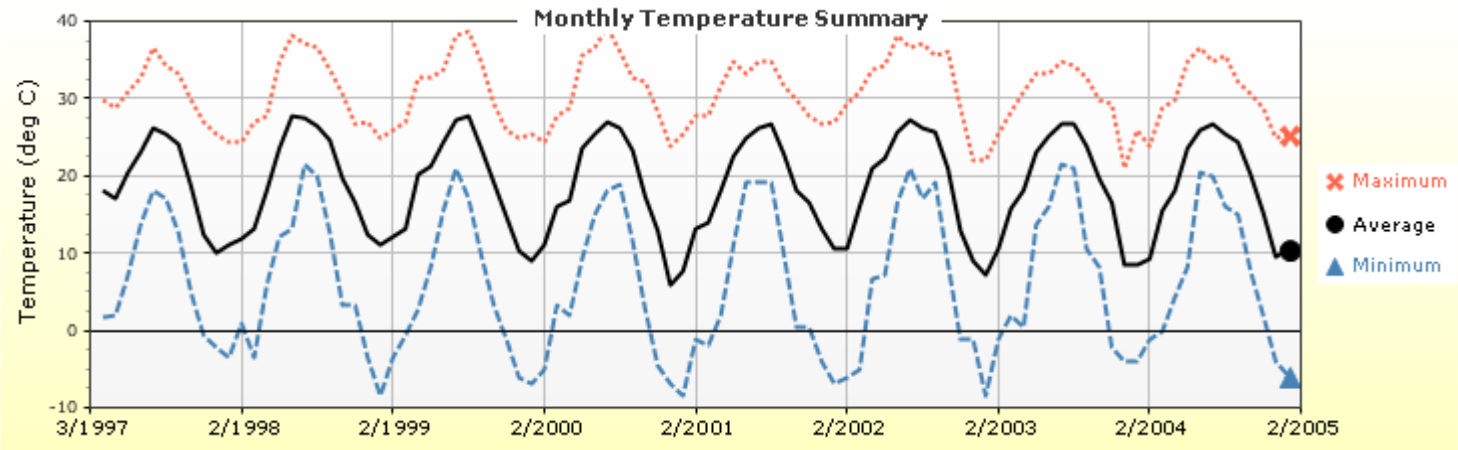
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

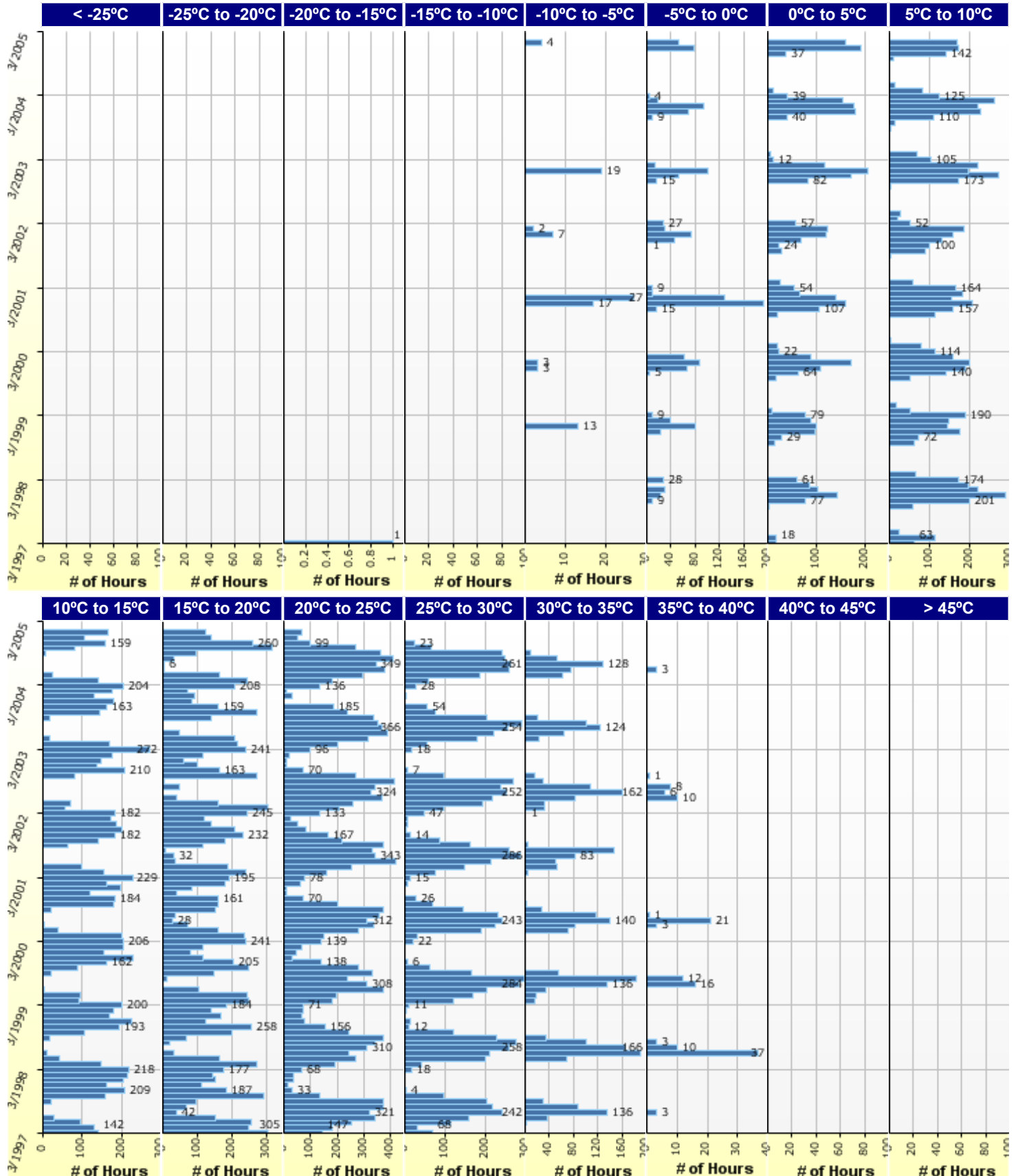


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF1_ALT4

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1_ALT4.dgpx



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

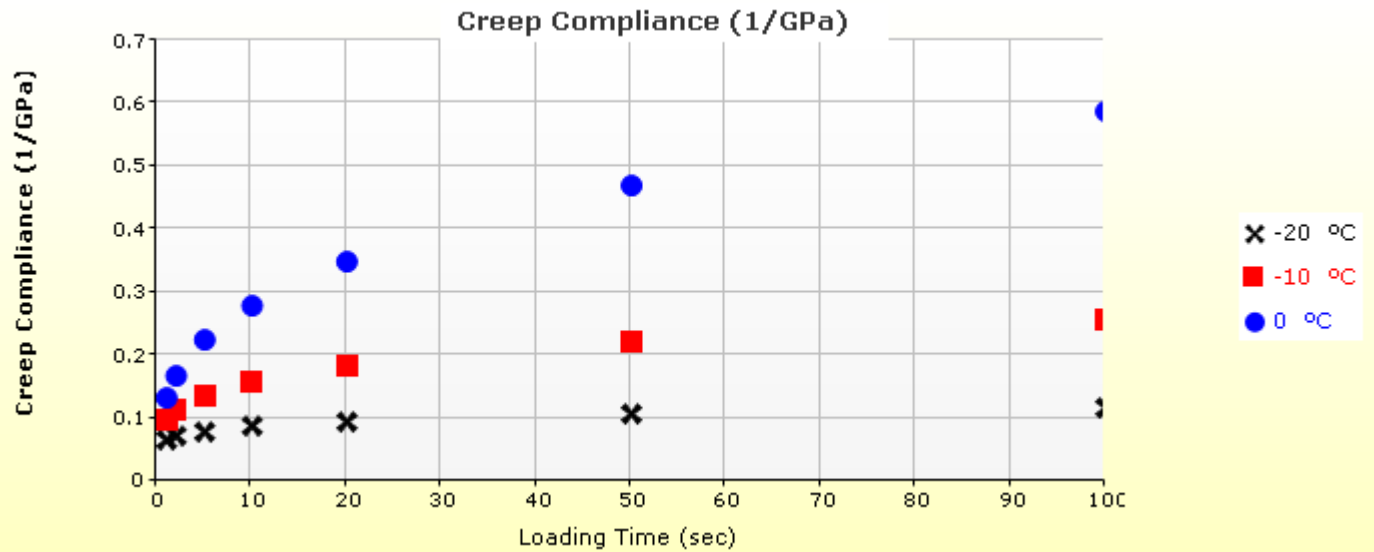
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Chemically Stabilized : Cement stabilized	Chemically Stabilized (2)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

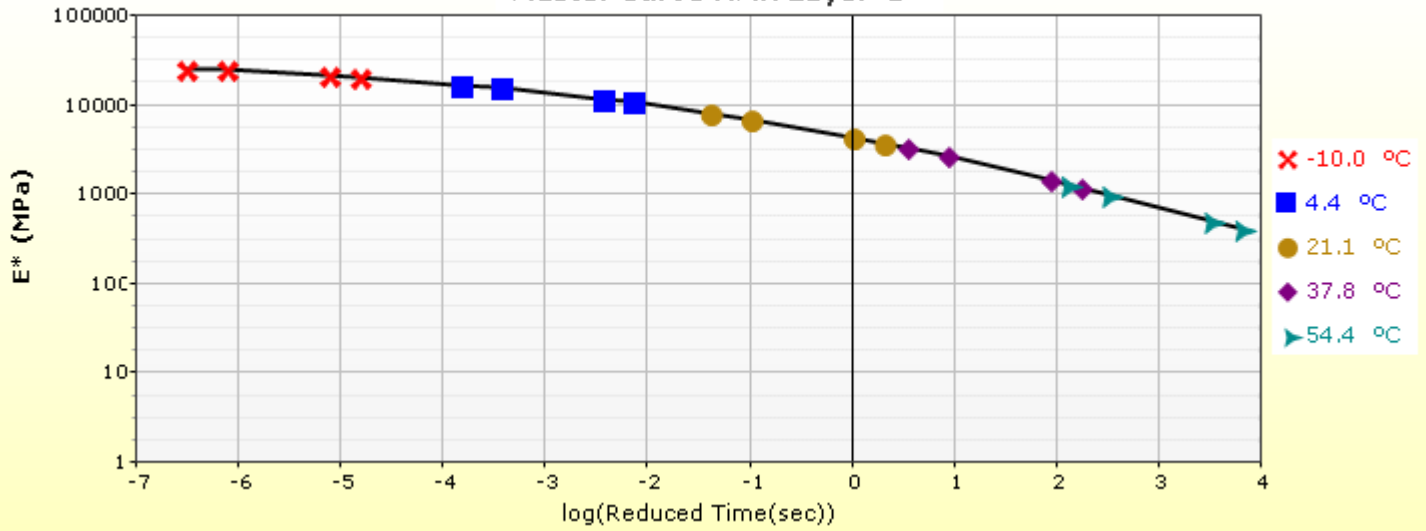
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

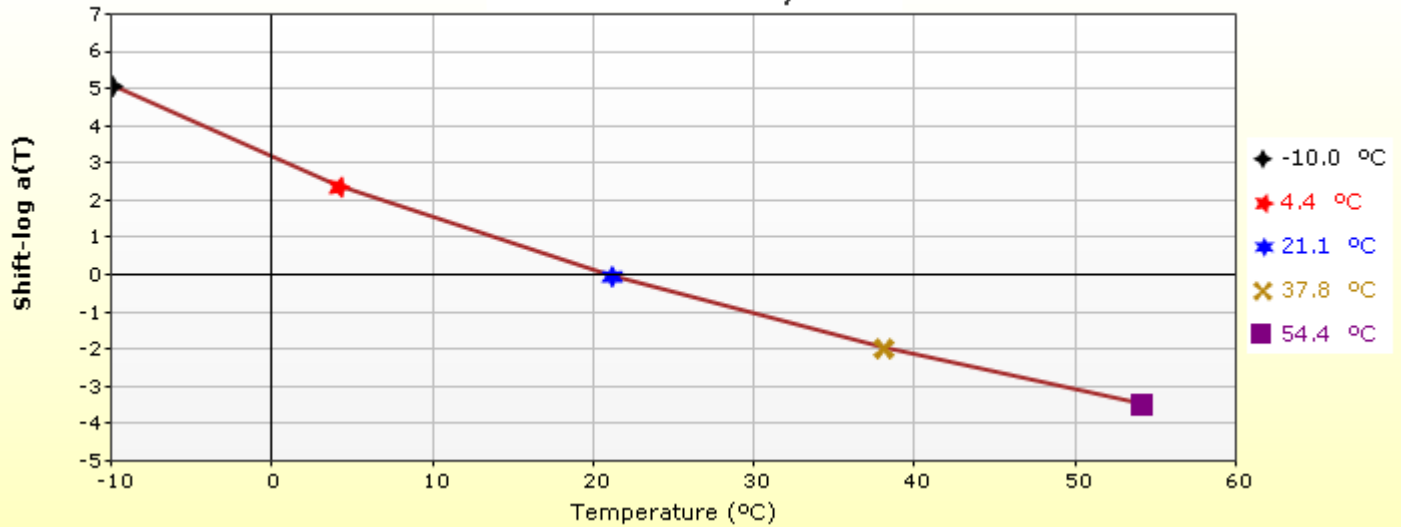


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

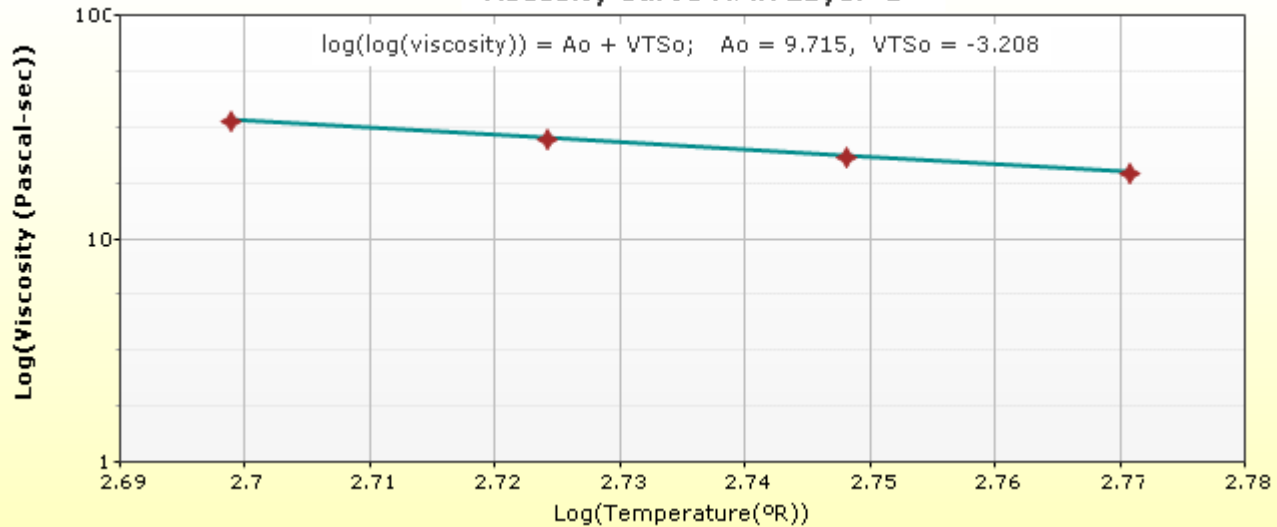
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

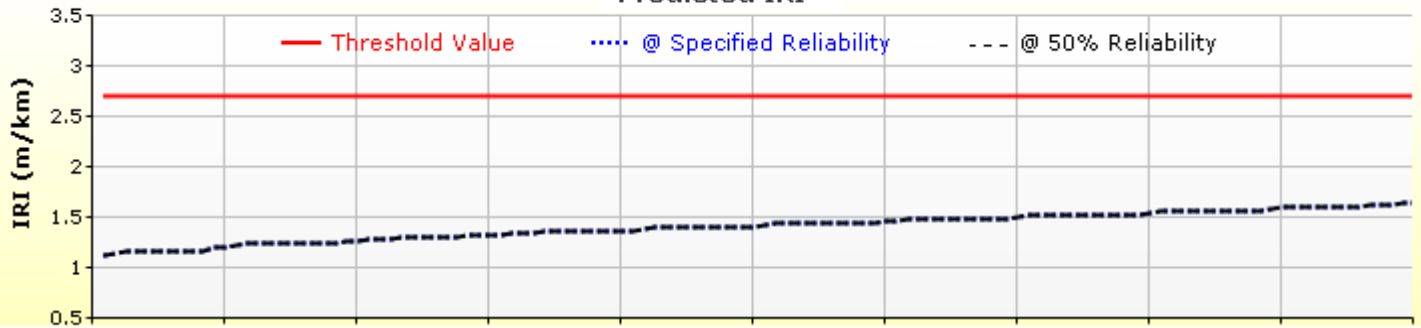


Viscosity Curve HMA Layer 1

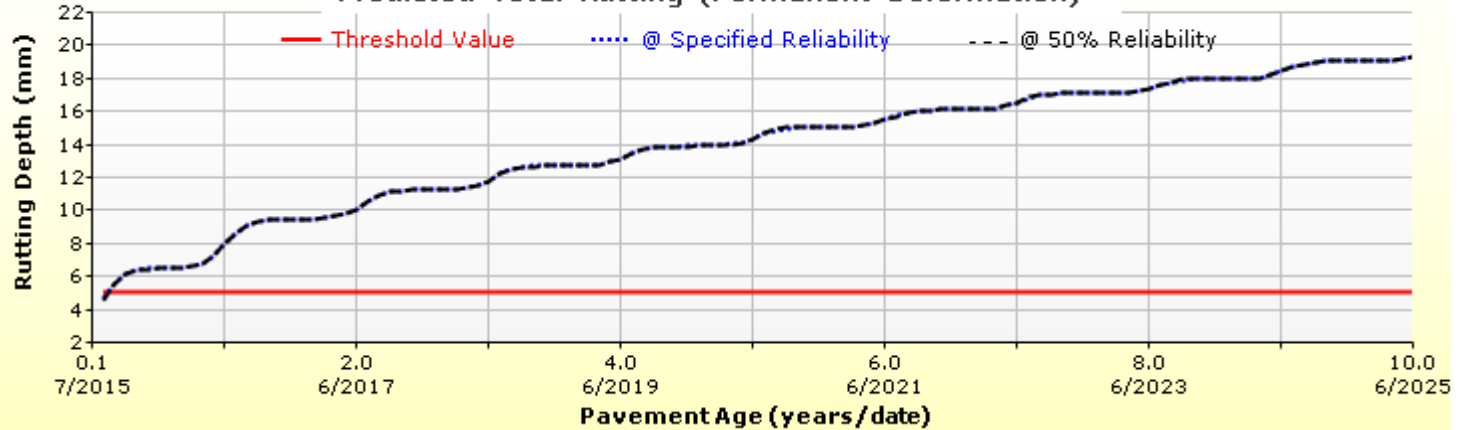


Analysis Output Charts

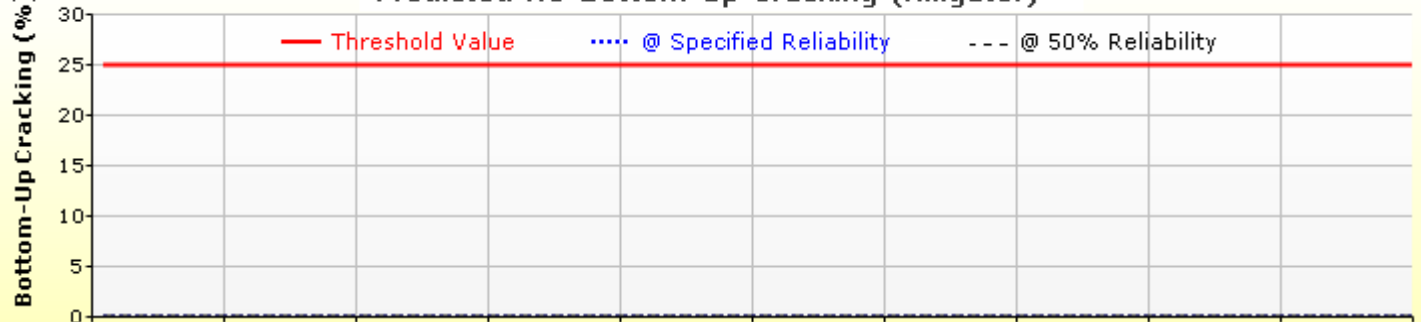
Predicted IRI



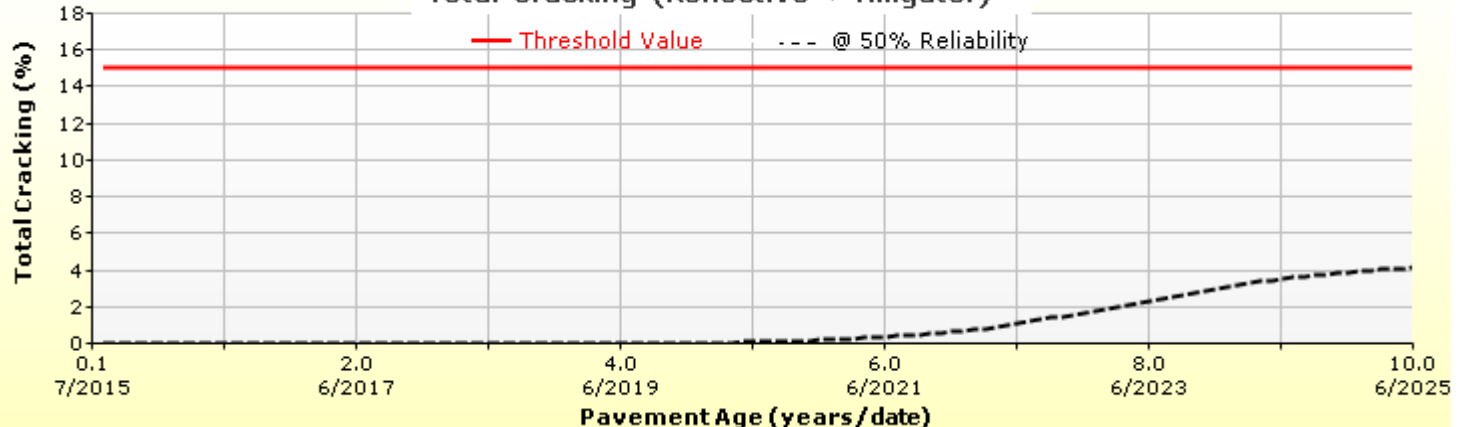
Predicted Total Rutting (Permanent Deformation)

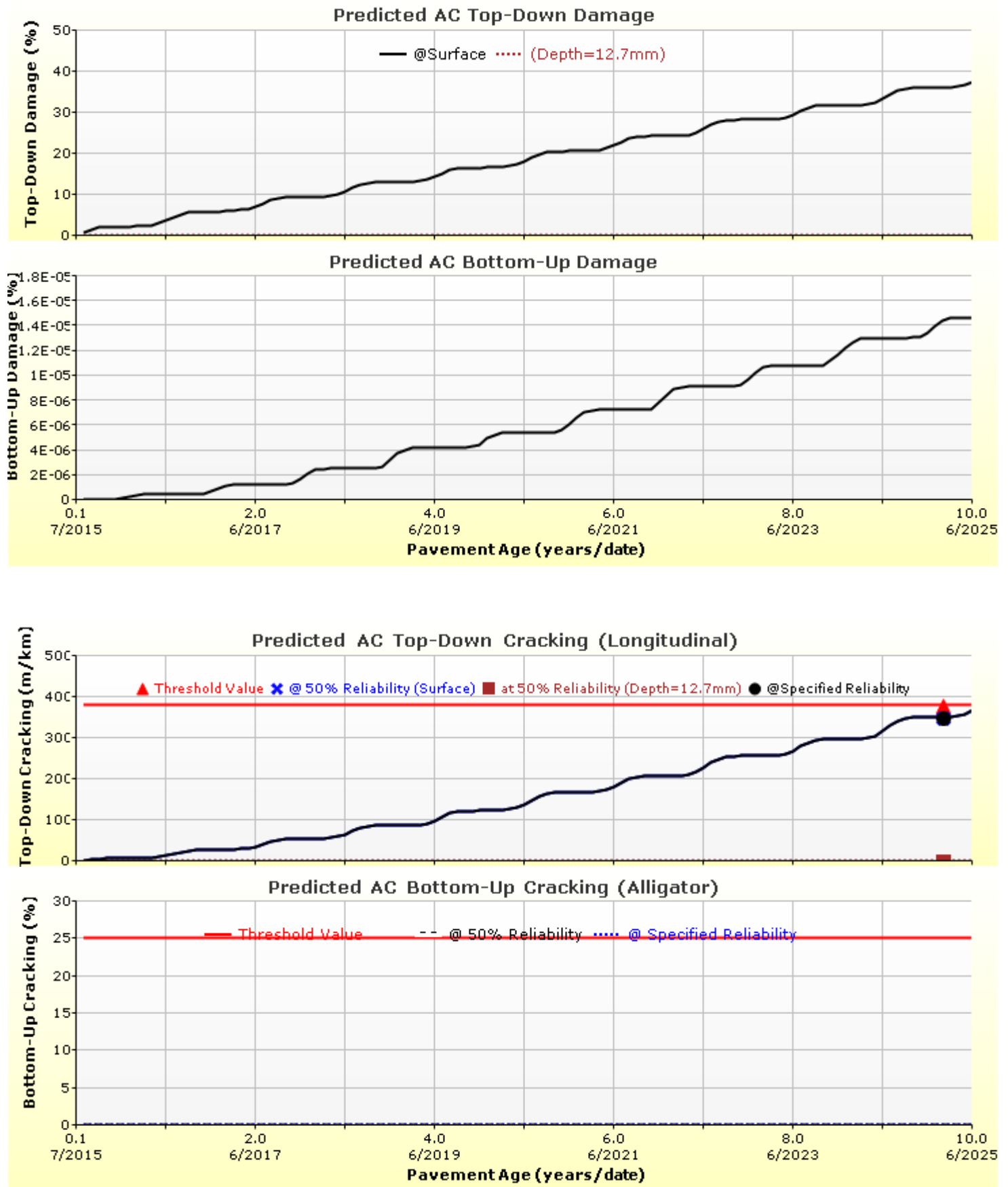


Predicted AC Bottom-Up Cracking (Alligator)

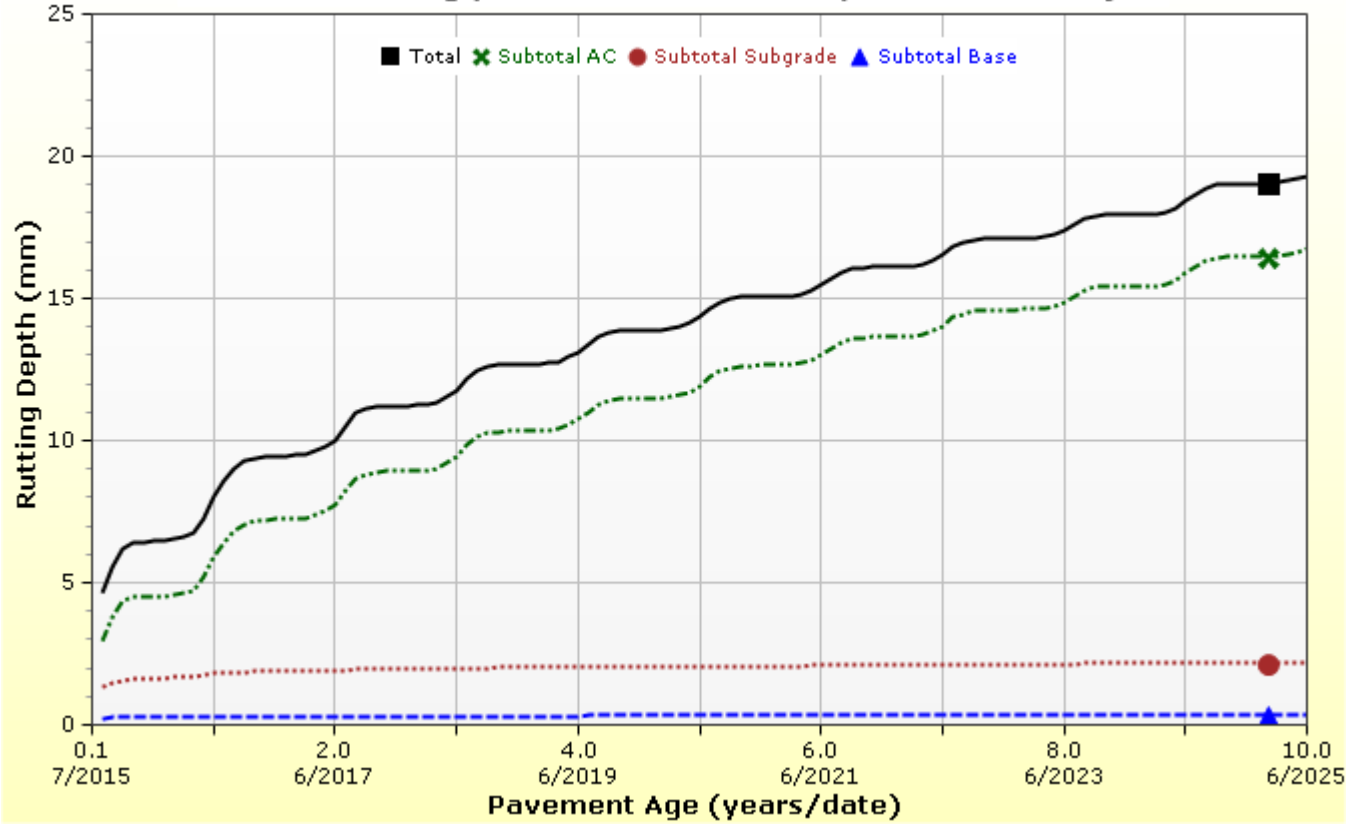


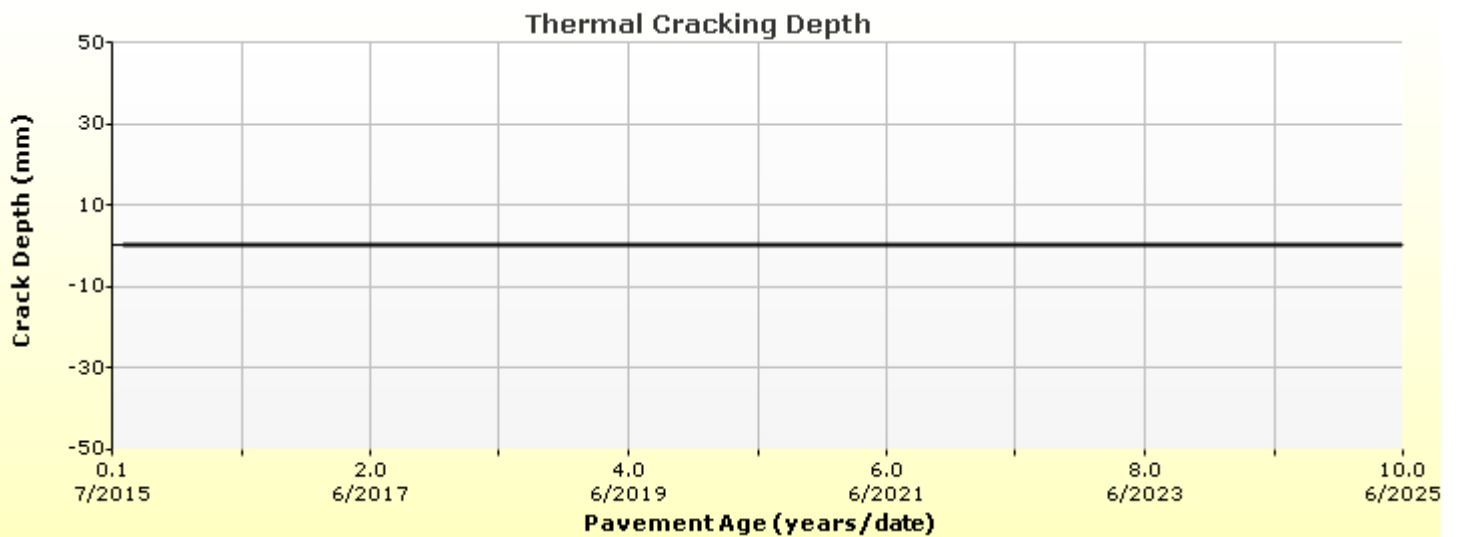
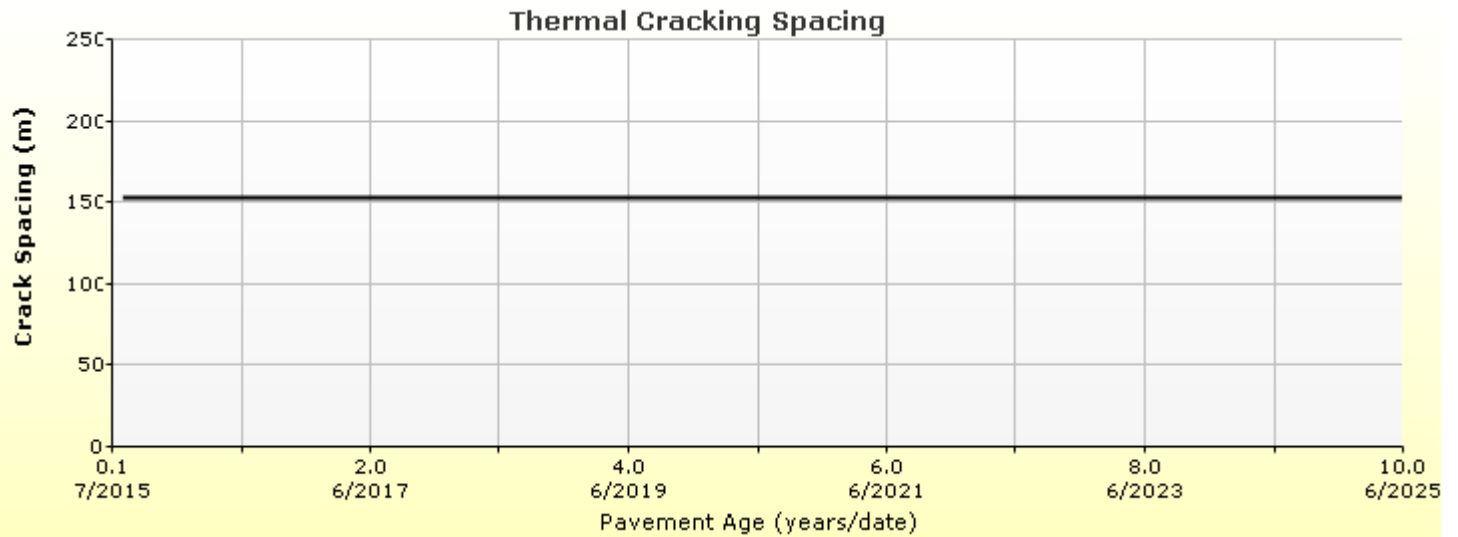
Total Cracking (Reflective + Alligator)

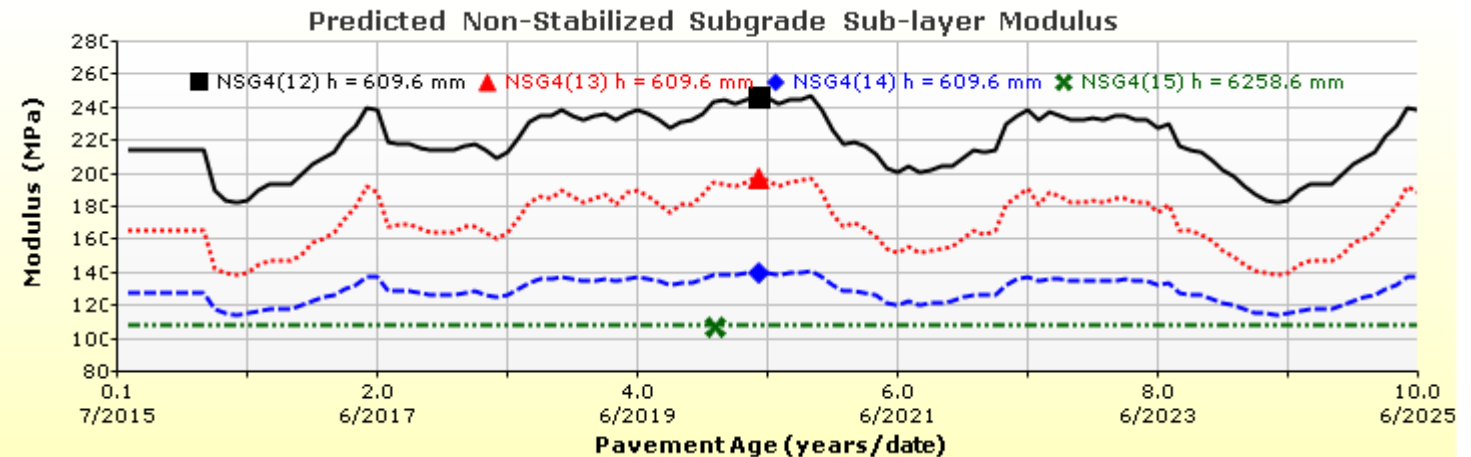
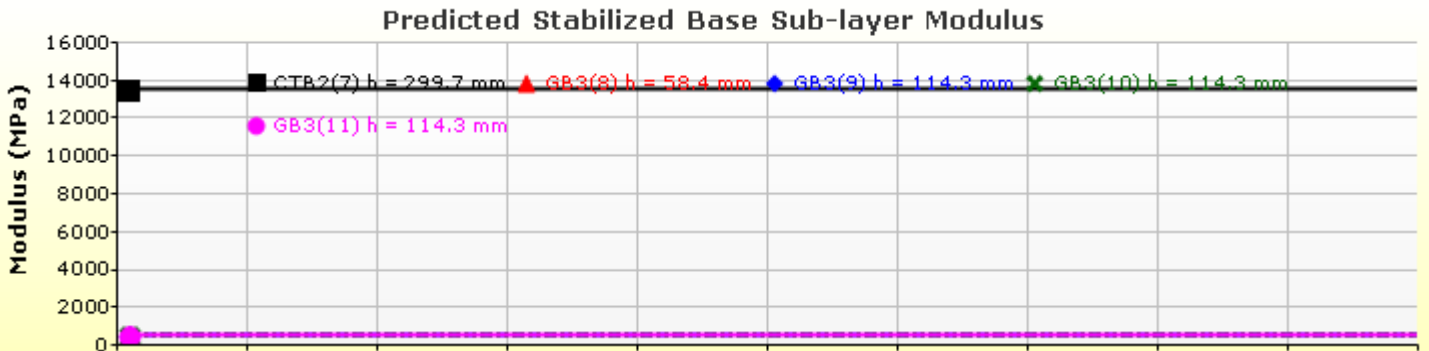
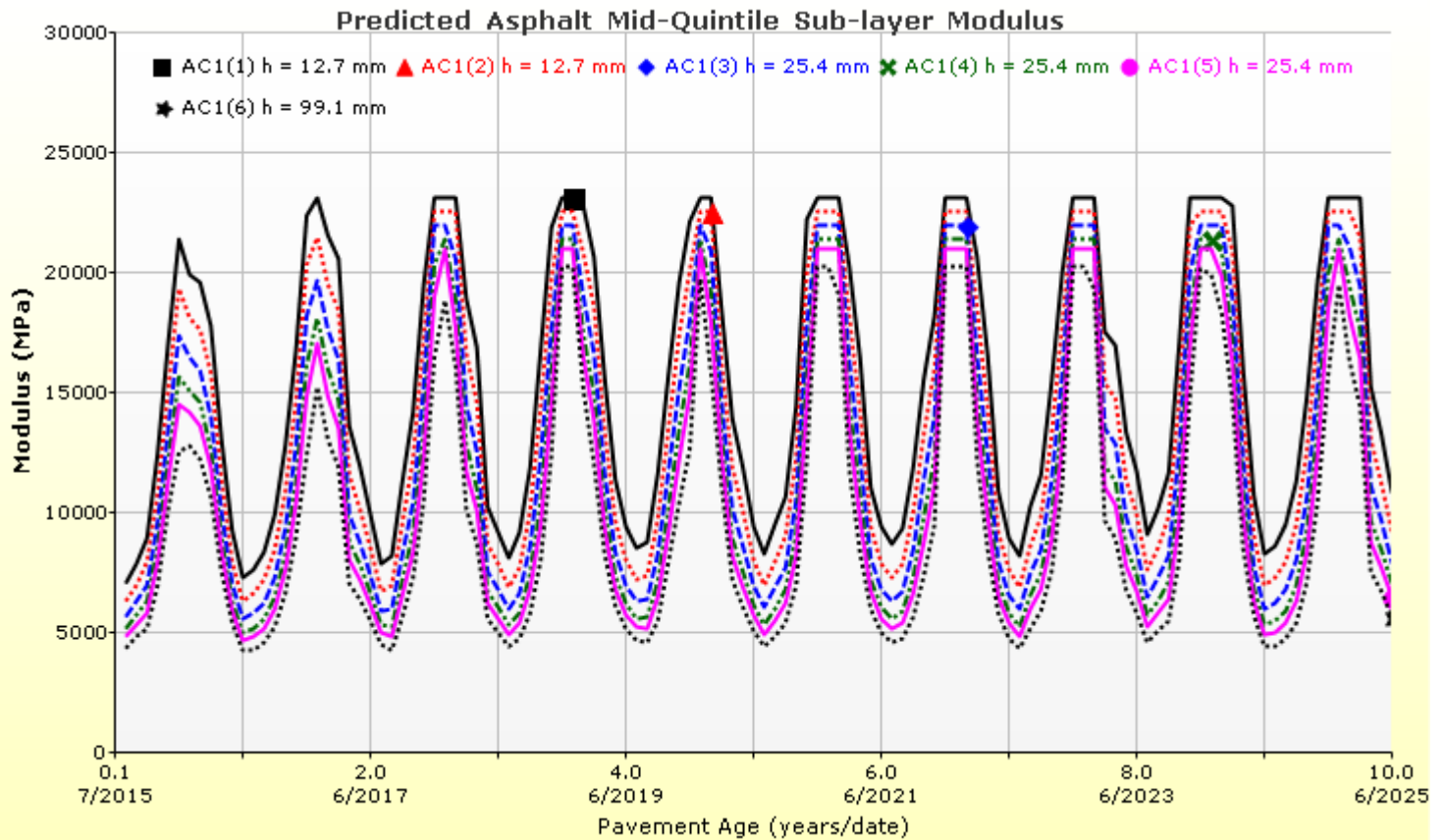




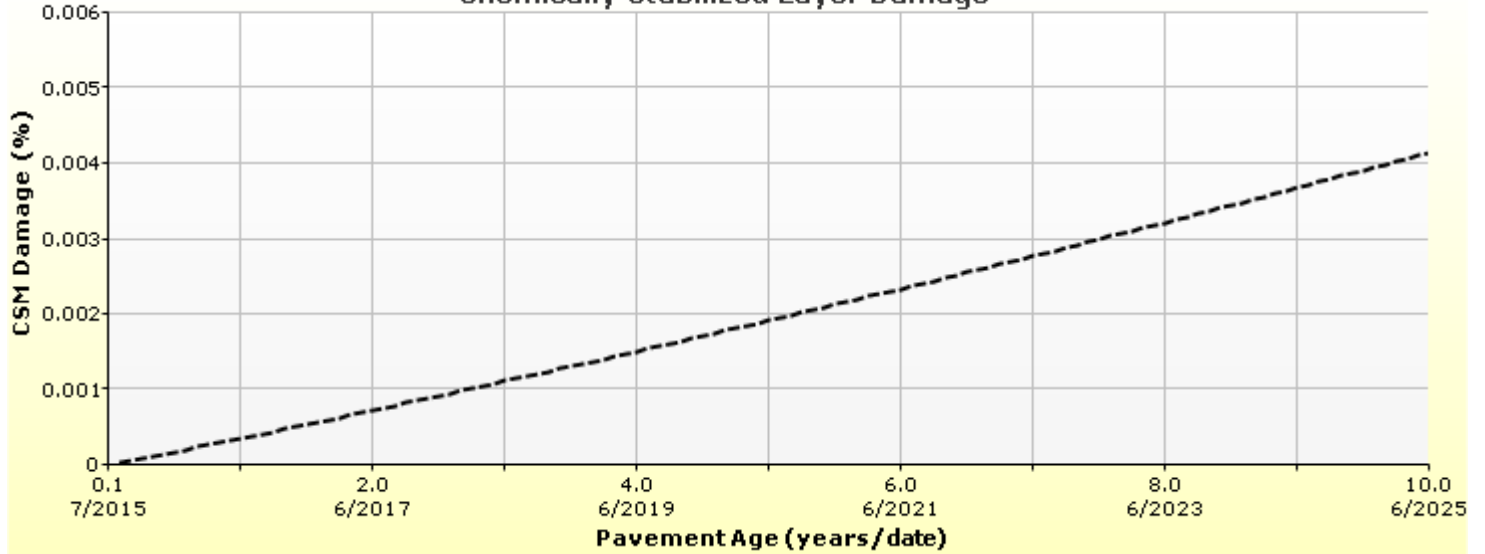
Predicted Rutting (Permanent Deformation) at 50% Reliability



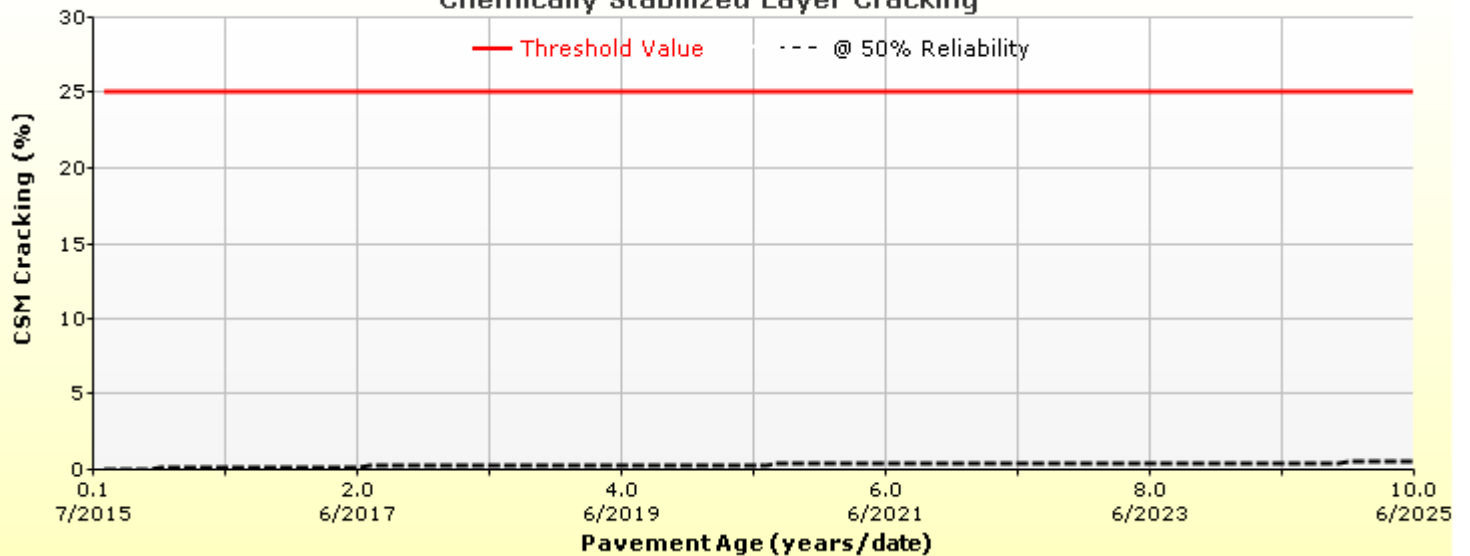




Chemically Stabilized Layer Damage



Chemically Stabilized Layer Cracking



Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 Chemically Stabilized : Cement stabilized

Chemically Stabilized

Layer thickness (mm)	300
Poisson's ratio	0.2
Unit weight (kgf/m^3)	2400

Strength

Elastic/resilient modulus (MPa)	13790

Thermal

Heat capacity (joule/kg-kelvin)	1172.3
Thermal conductivity (watt/meter-kelvin)	2.16

Identifiers

Field	Value
Display name/identifier	Cement stabilized
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 3 Non-stabilized Base : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r} \right)}{k_2 \beta_{c2}} \right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015



Project1 - Novo ALF2_ALT4

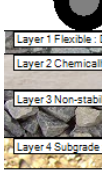
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Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data 32.119, -81.202
Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm):	Volumetric at Construction:	
Flexible	Default asphalt concrete	200.0	Effective binder content (%)	11.6
Cement_Base	Cement stabilized	300.0	Air voids (%)	7.0
NonStabilized	Crushed stone	400.0		
Subgrade	A-1-a	Semi-infinite		

Traffic

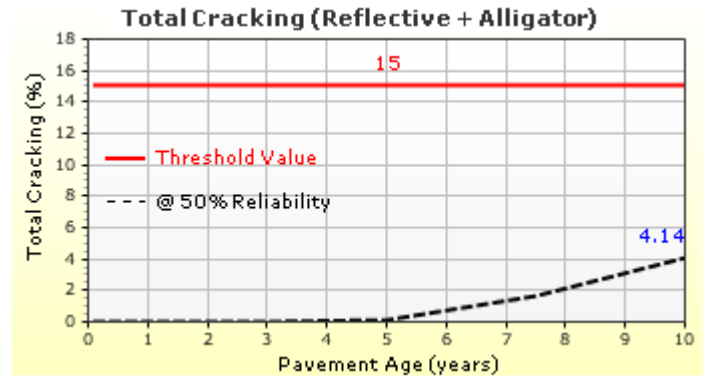
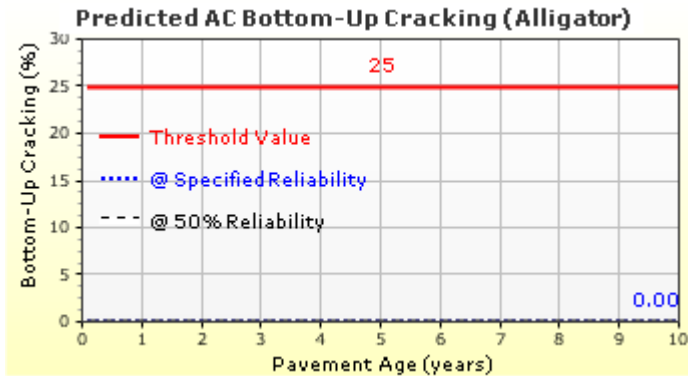
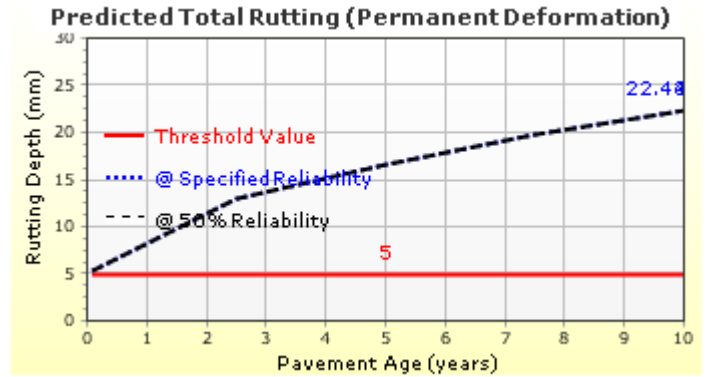
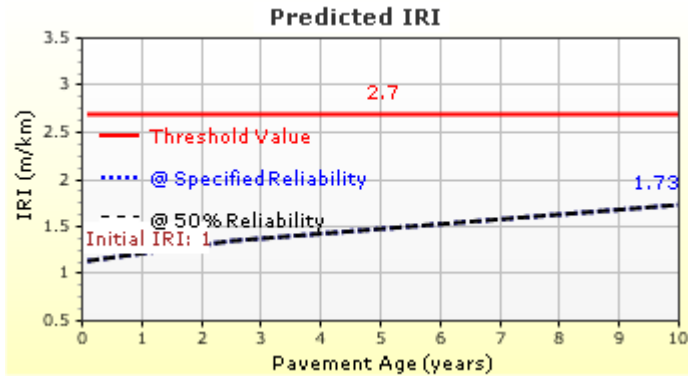
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.73	50.00	97.74	Pass
Permanent deformation - total pavement (mm)	5.00	22.44	50.00	0.03	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.00	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.14	-	-	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	744.32	50.00	20.91	Fail
Permanent deformation - AC only (mm)	5.00	19.61	50.00	0.17	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.55	-	-	-

Distress Charts

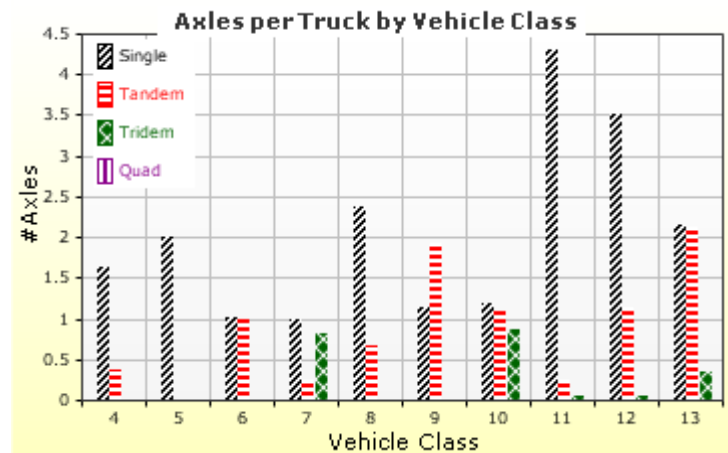
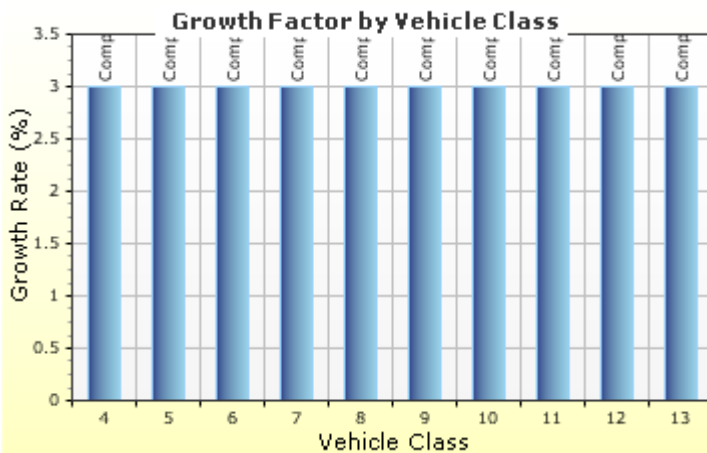
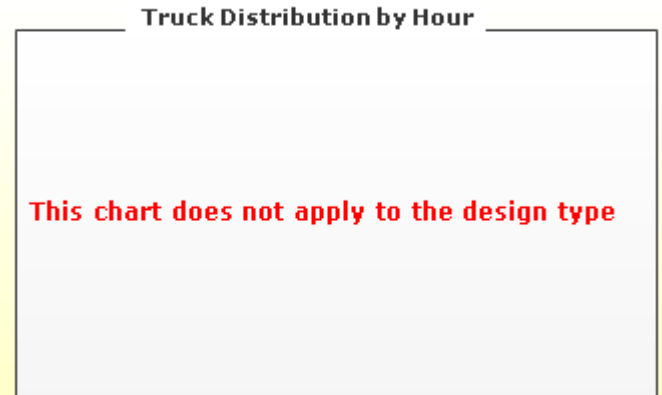
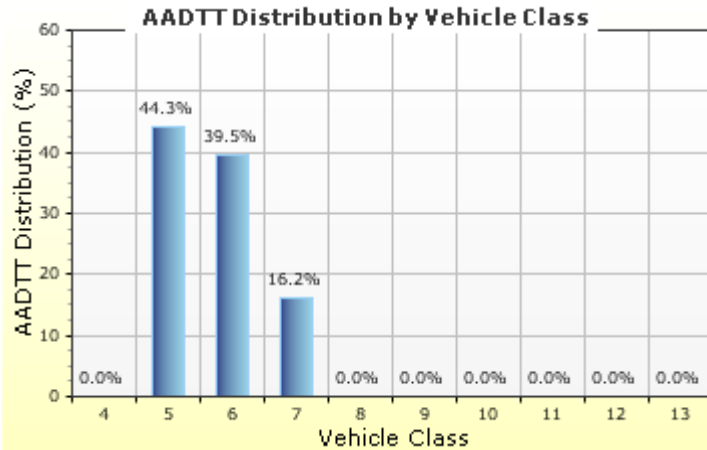


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

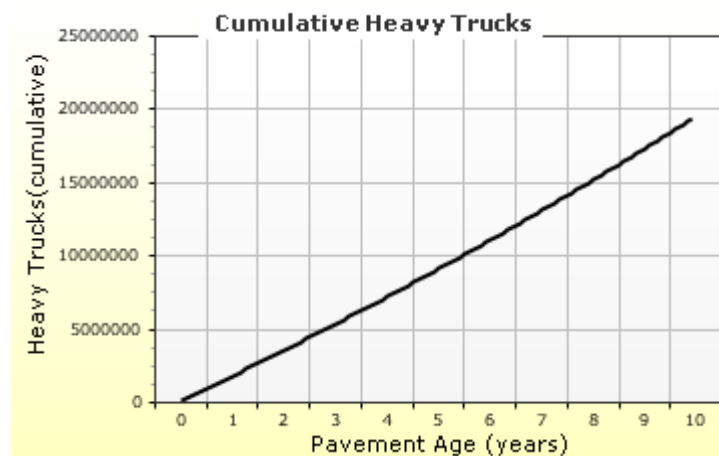
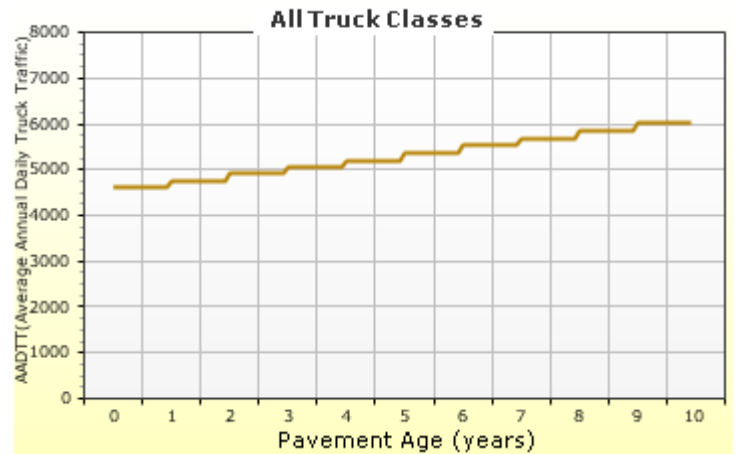
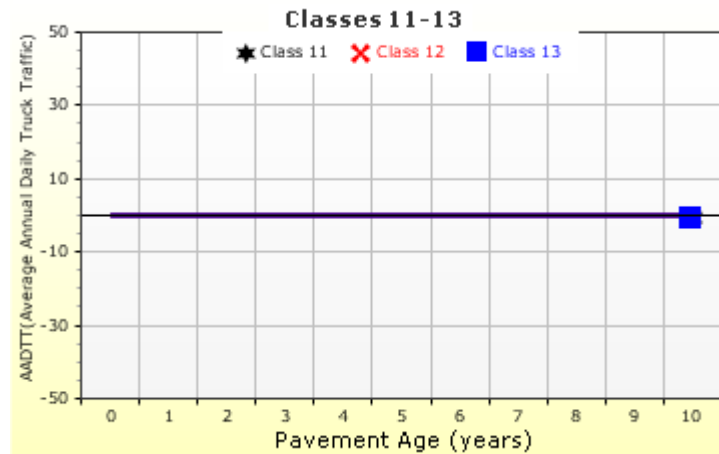
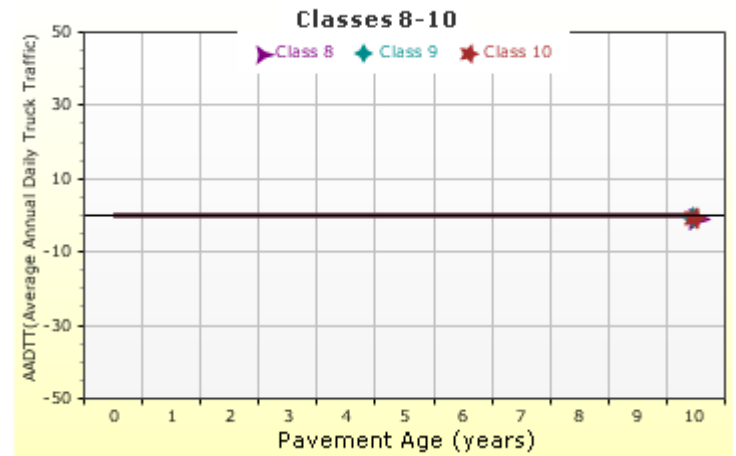
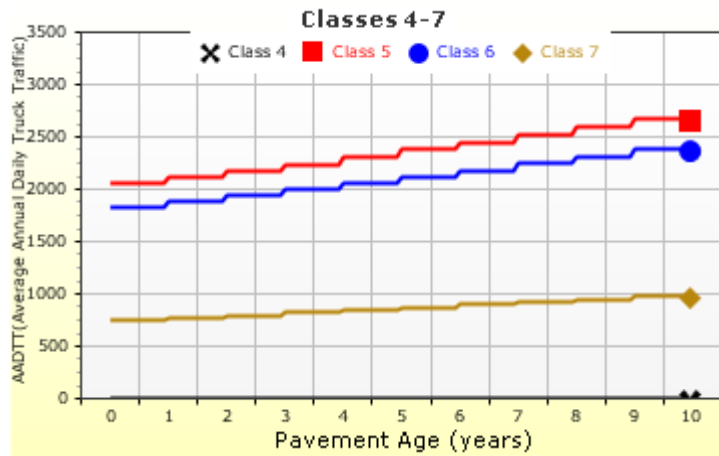
Wheelbase does not apply

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



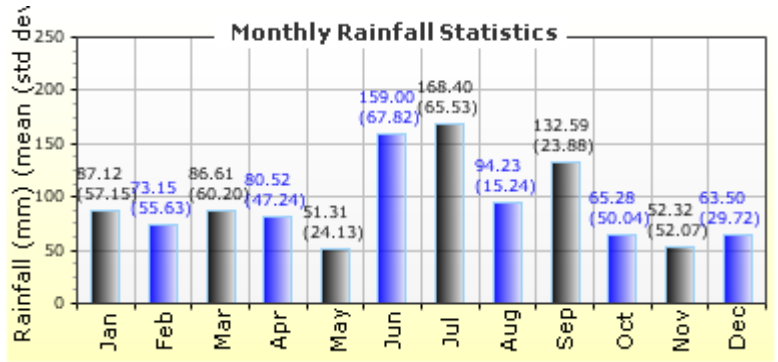
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

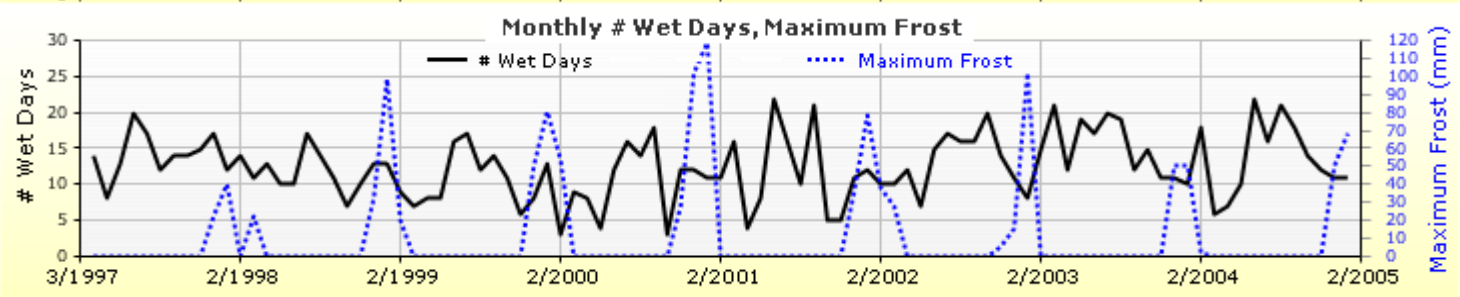
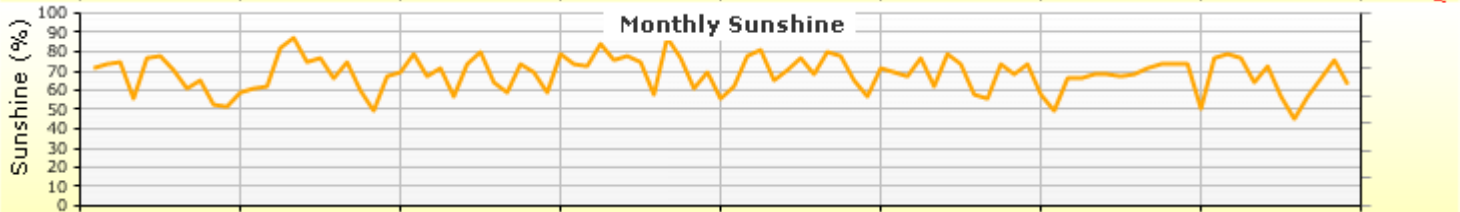
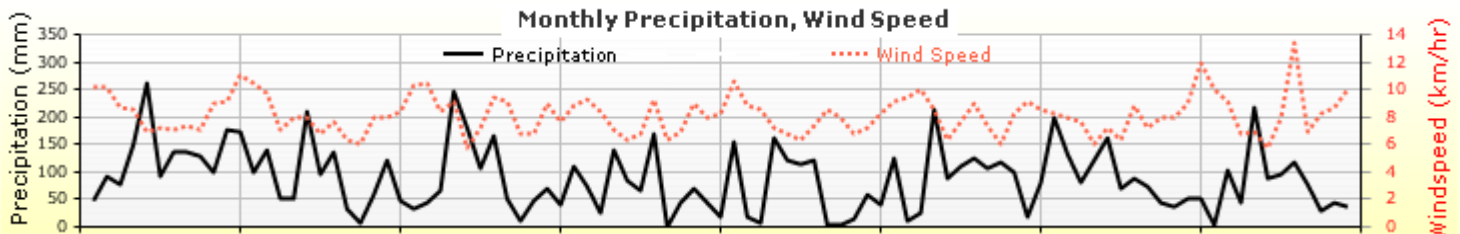
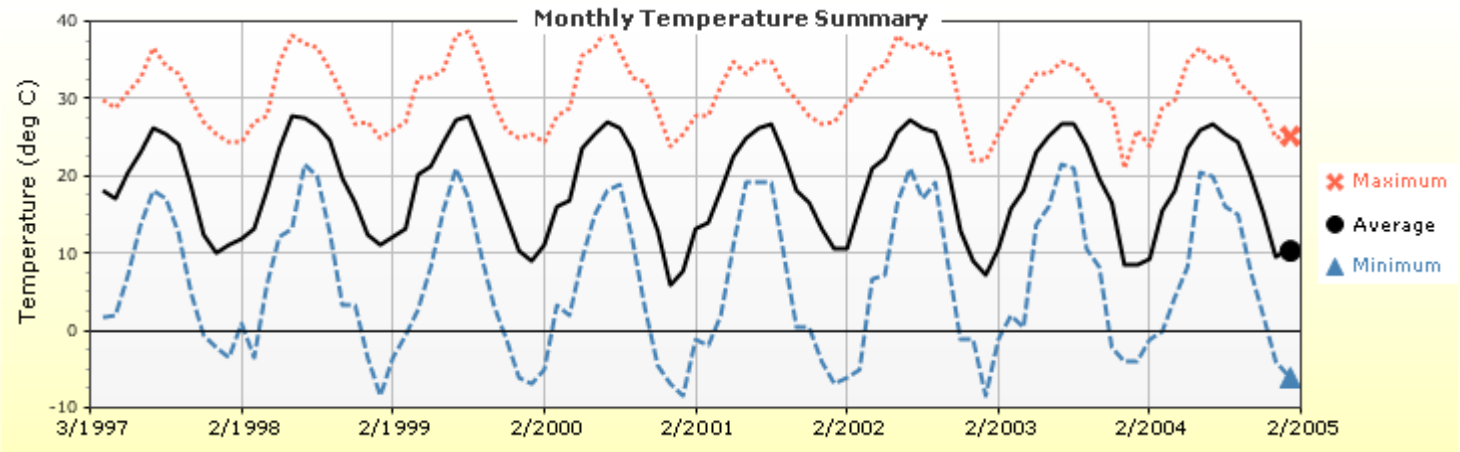
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

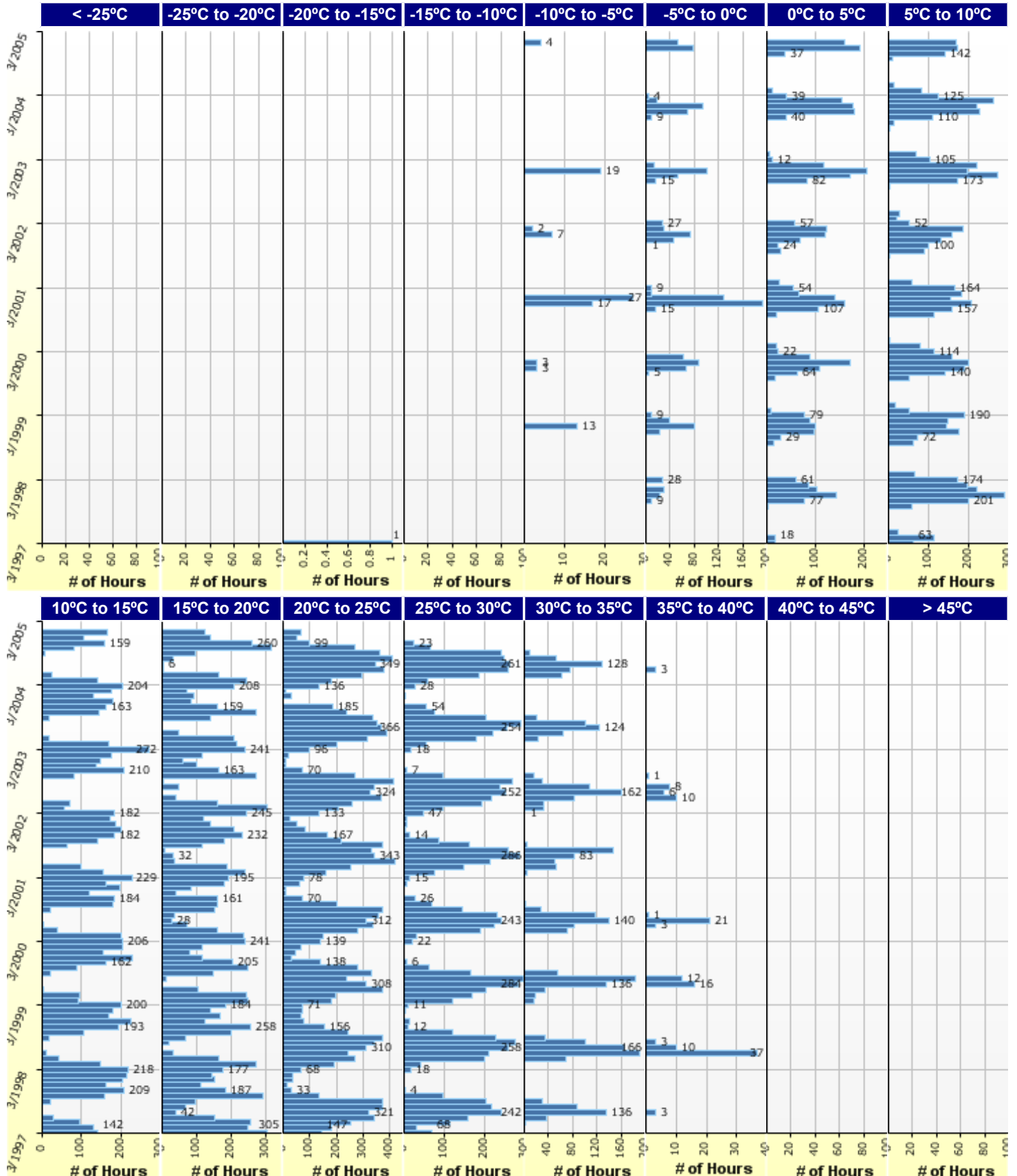


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF2_ALT4

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF2_ALT4.dgpx



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

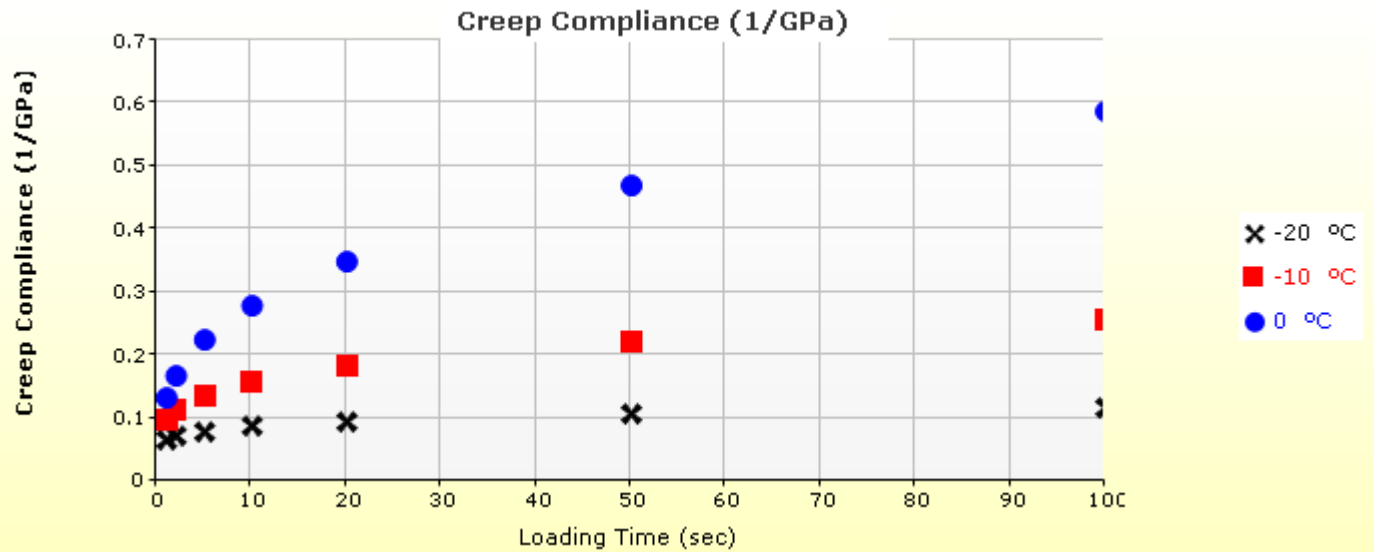
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Chemically Stabilized : Cement stabilized	Chemically Stabilized (2)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

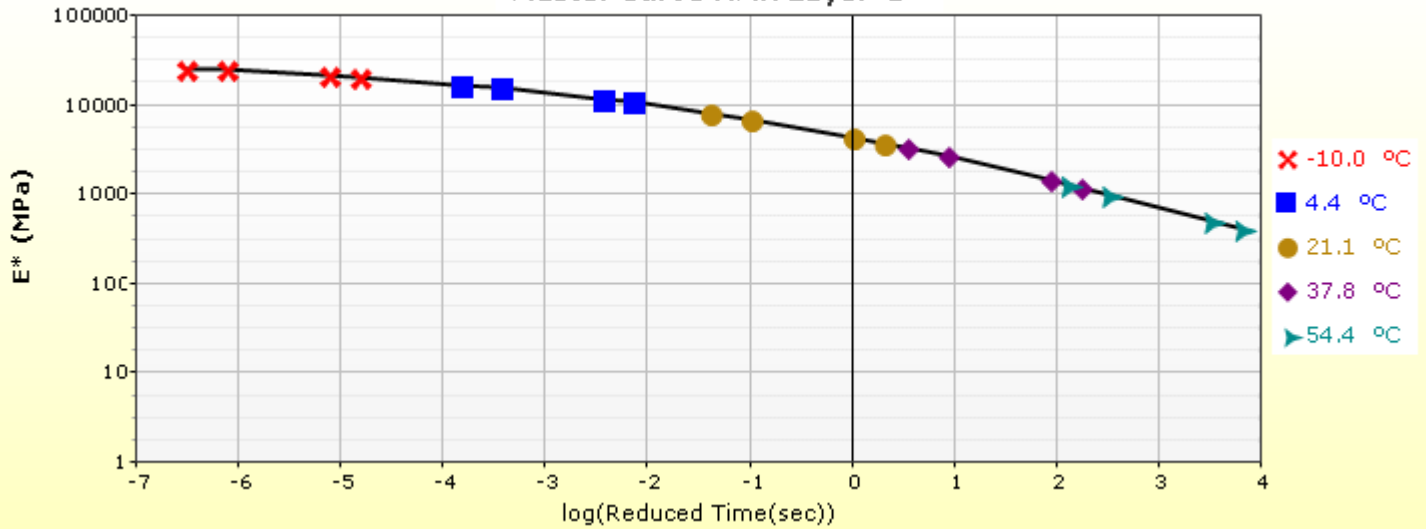
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

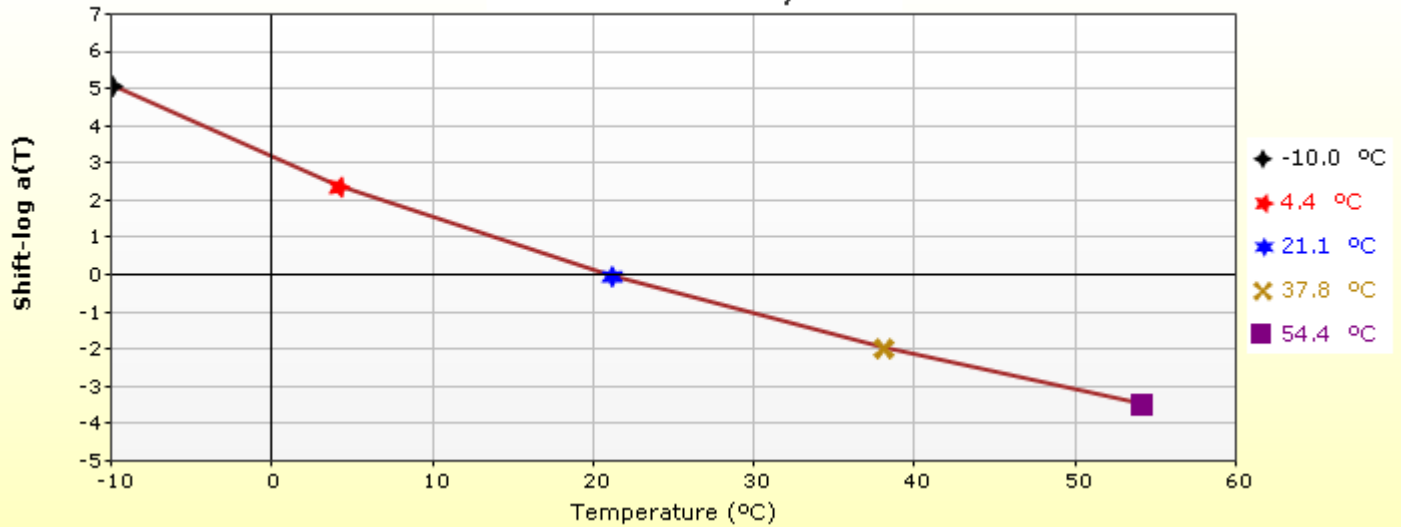


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

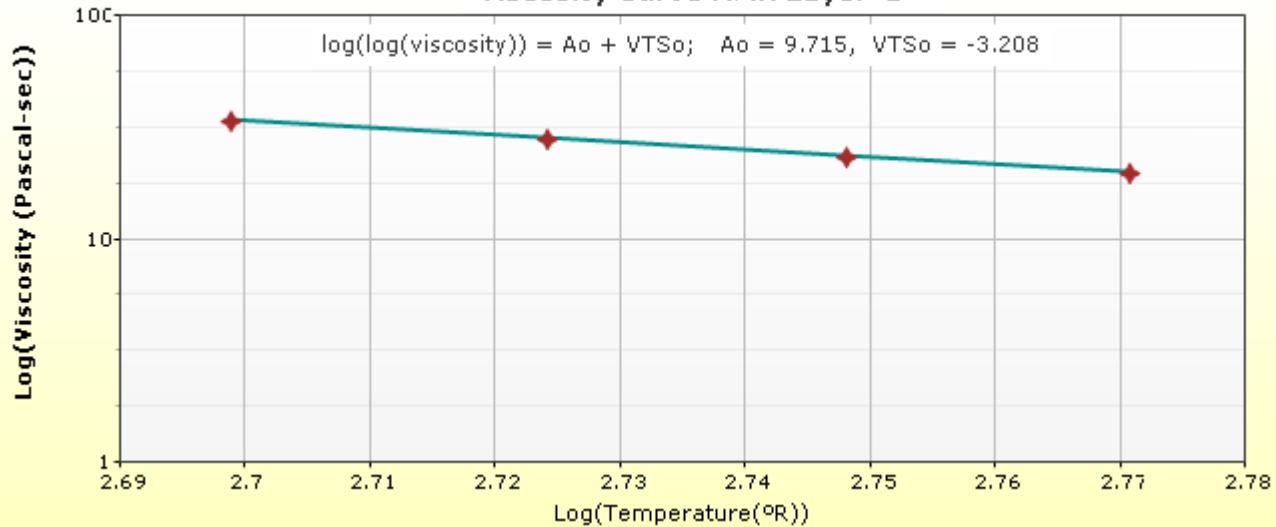
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

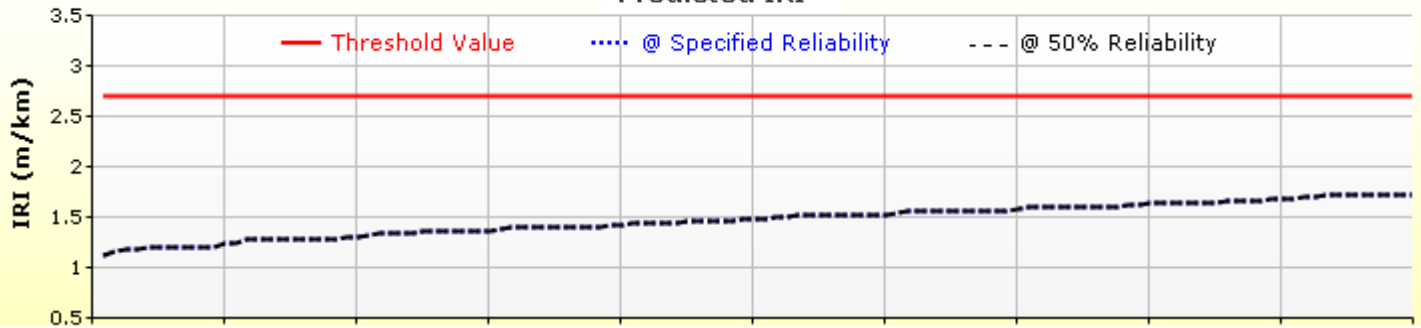


Viscosity Curve HMA Layer 1

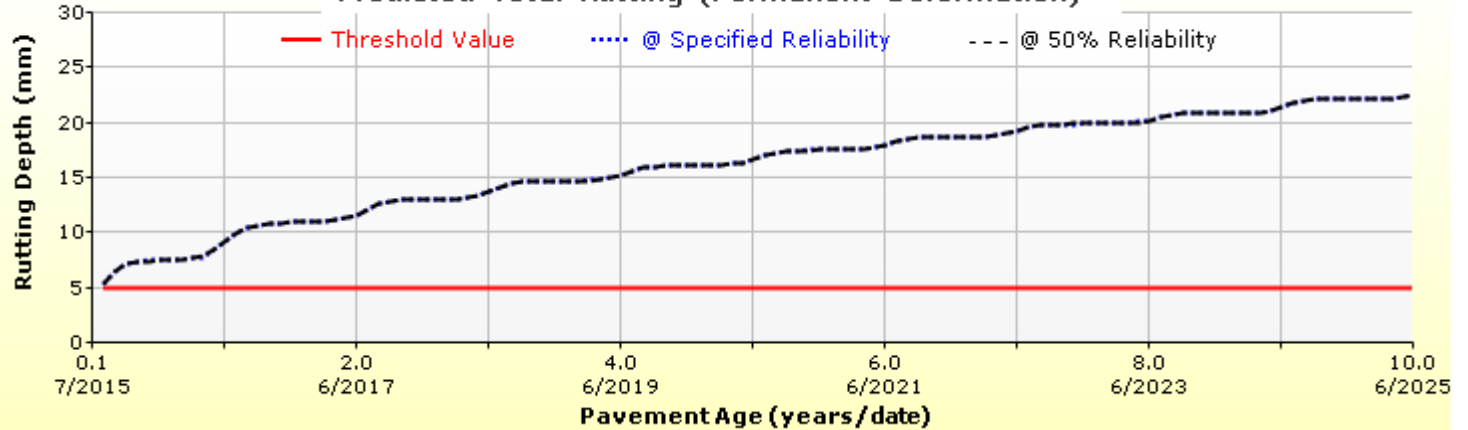


Analysis Output Charts

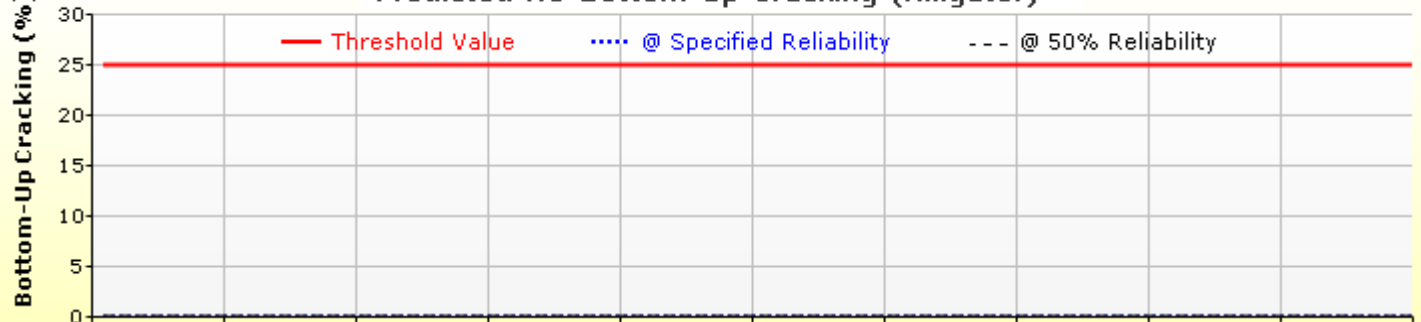
Predicted IRI



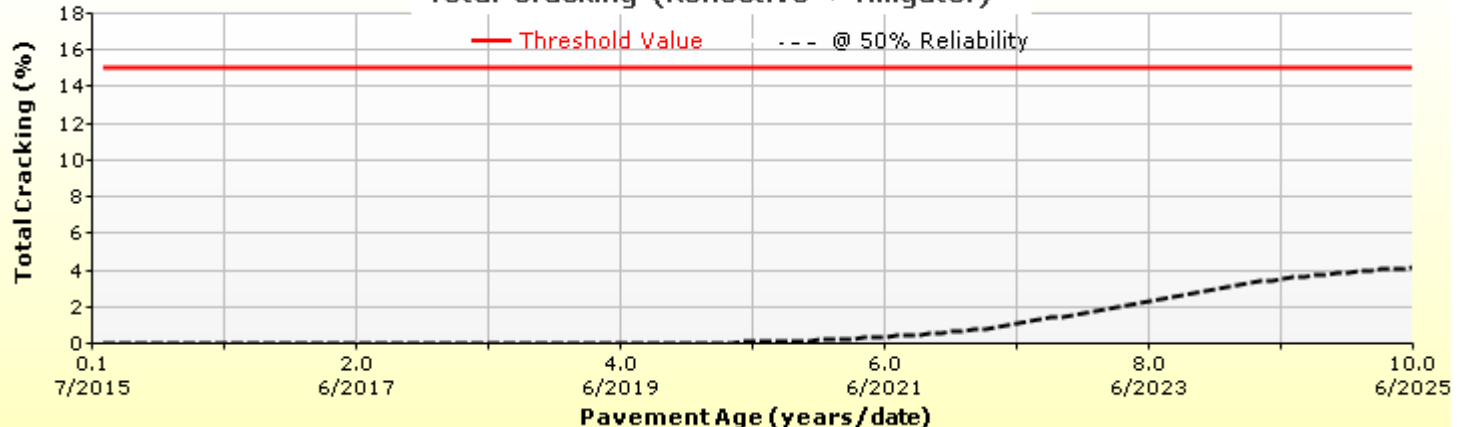
Predicted Total Rutting (Permanent Deformation)

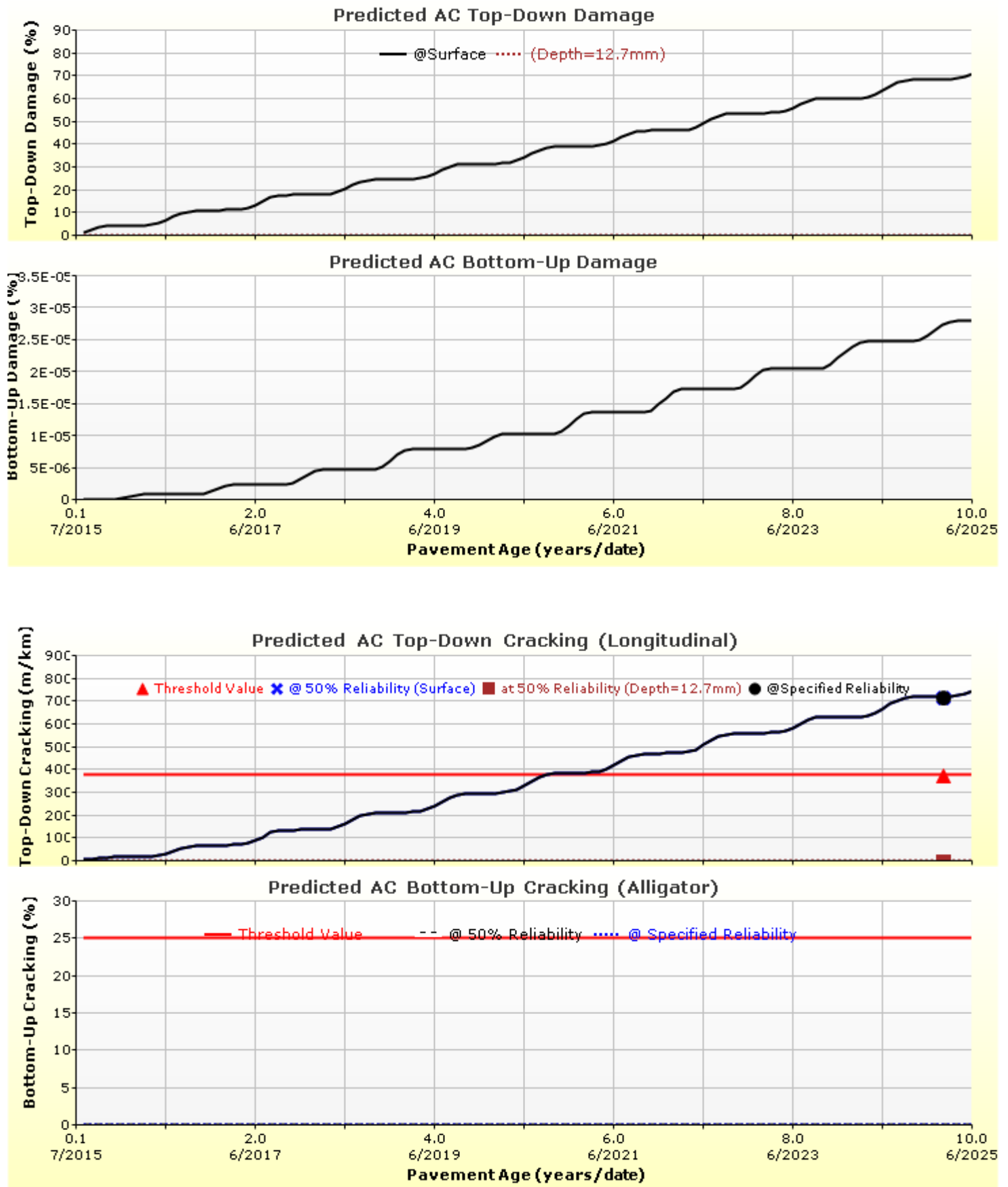


Predicted AC Bottom-Up Cracking (Alligator)

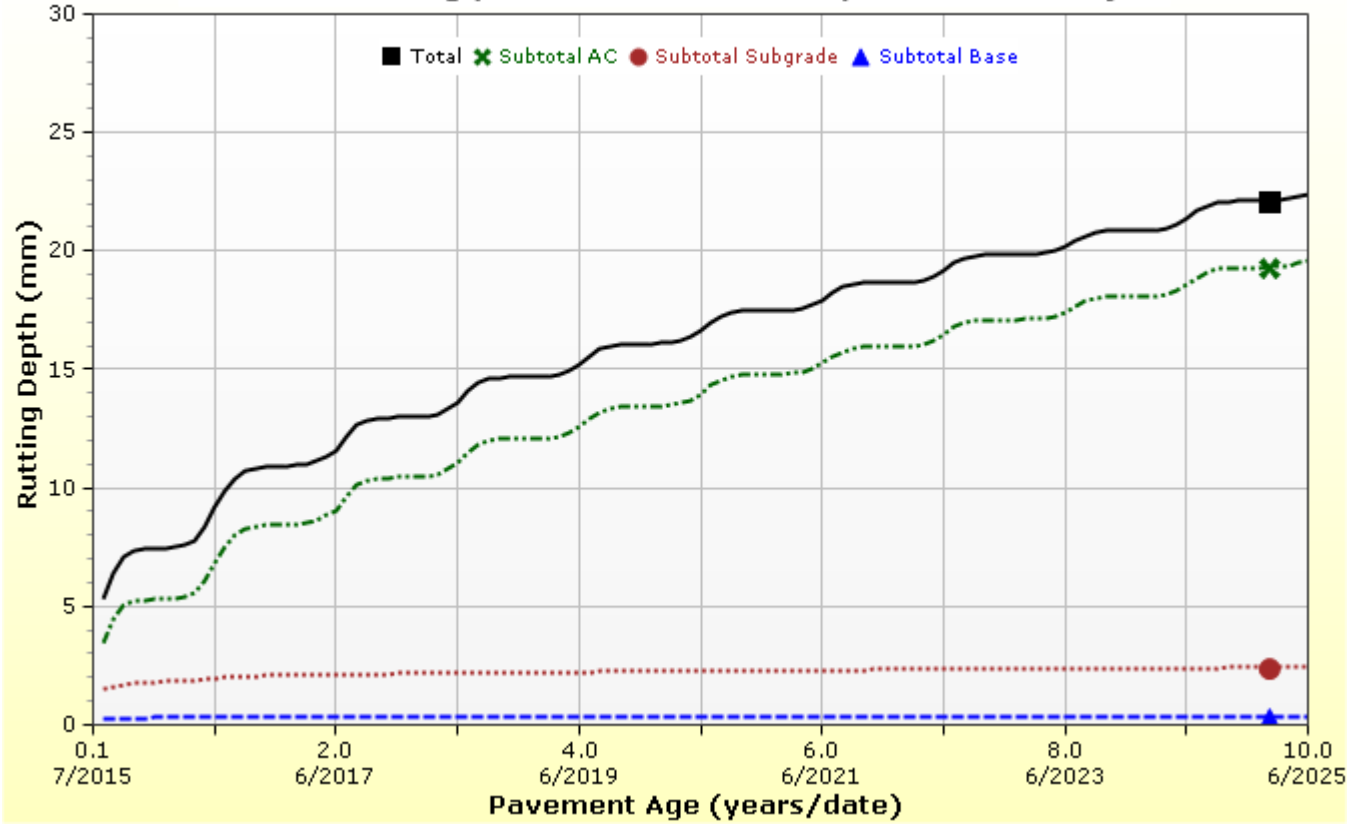


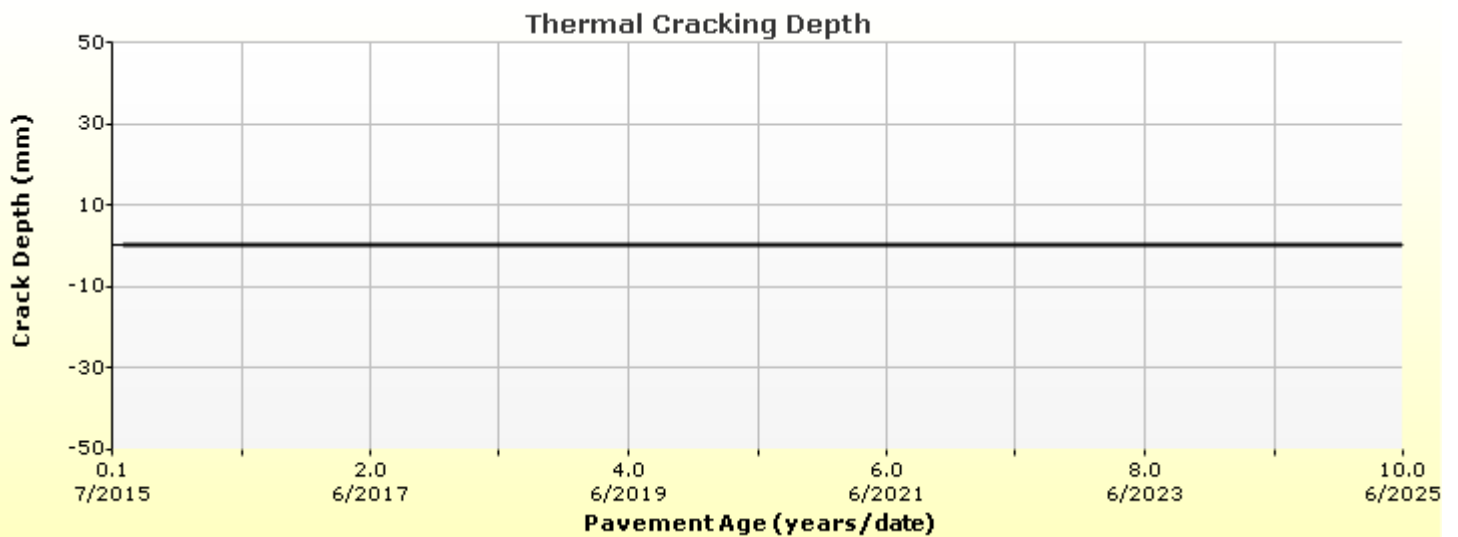
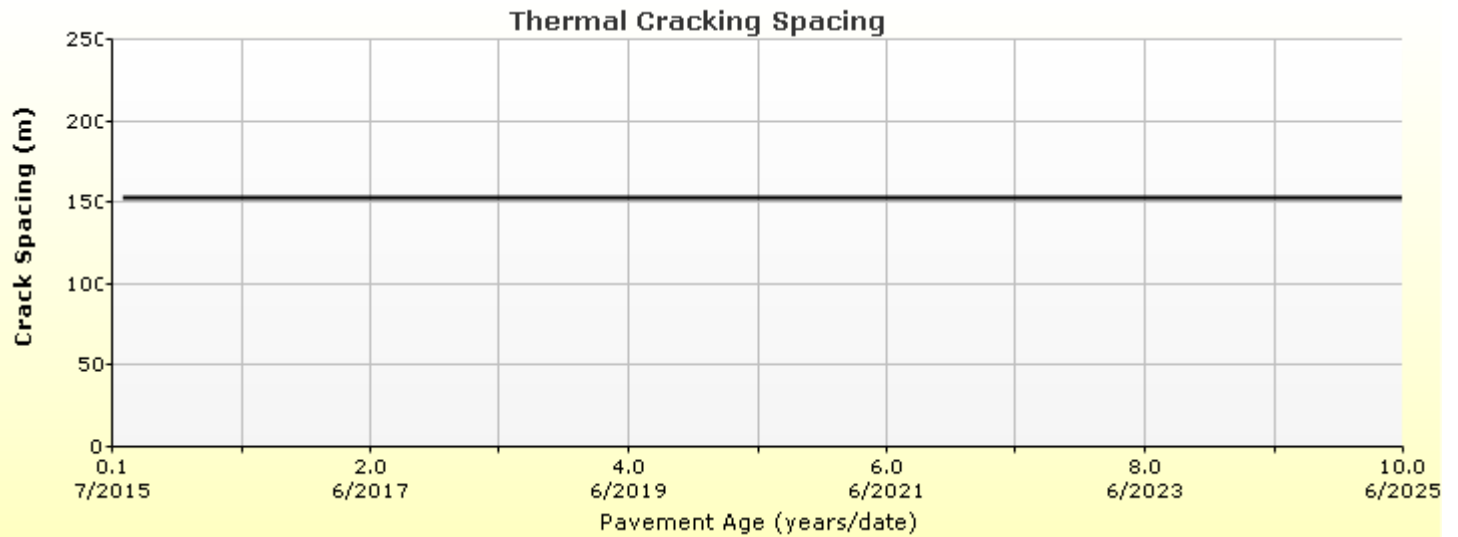
Total Cracking (Reflective + Alligator)

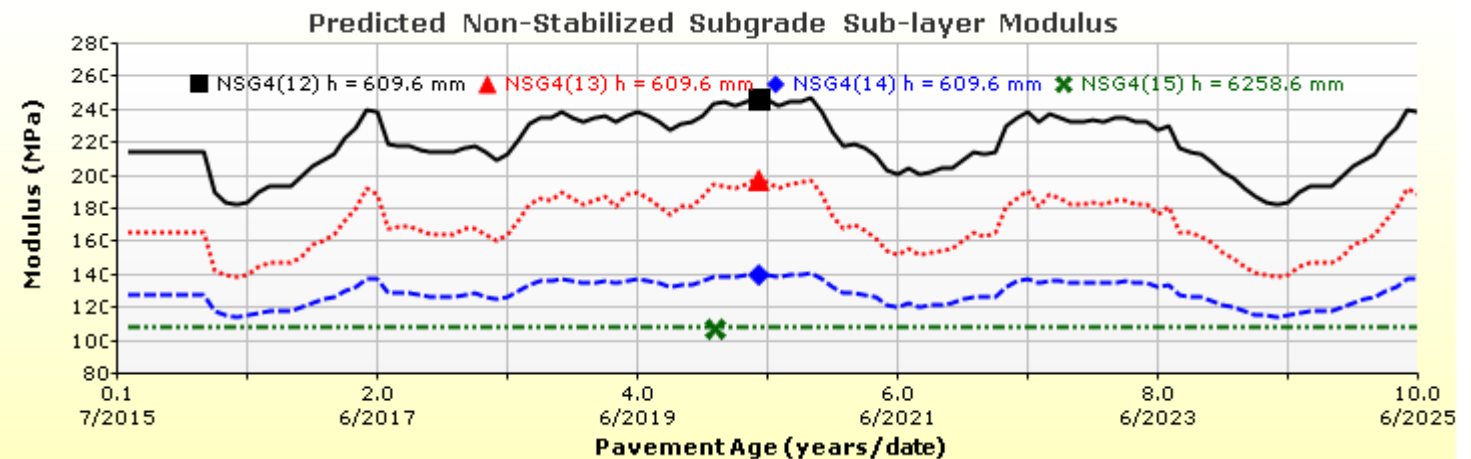
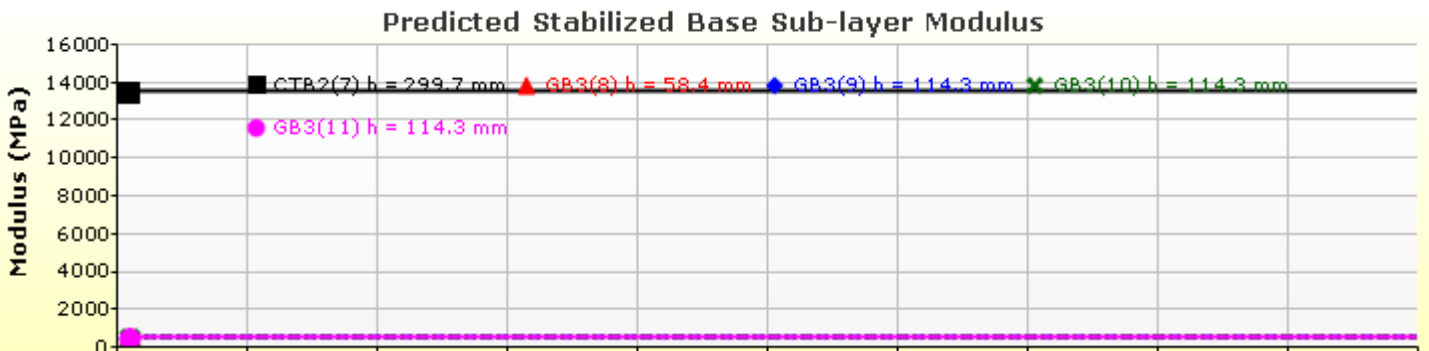
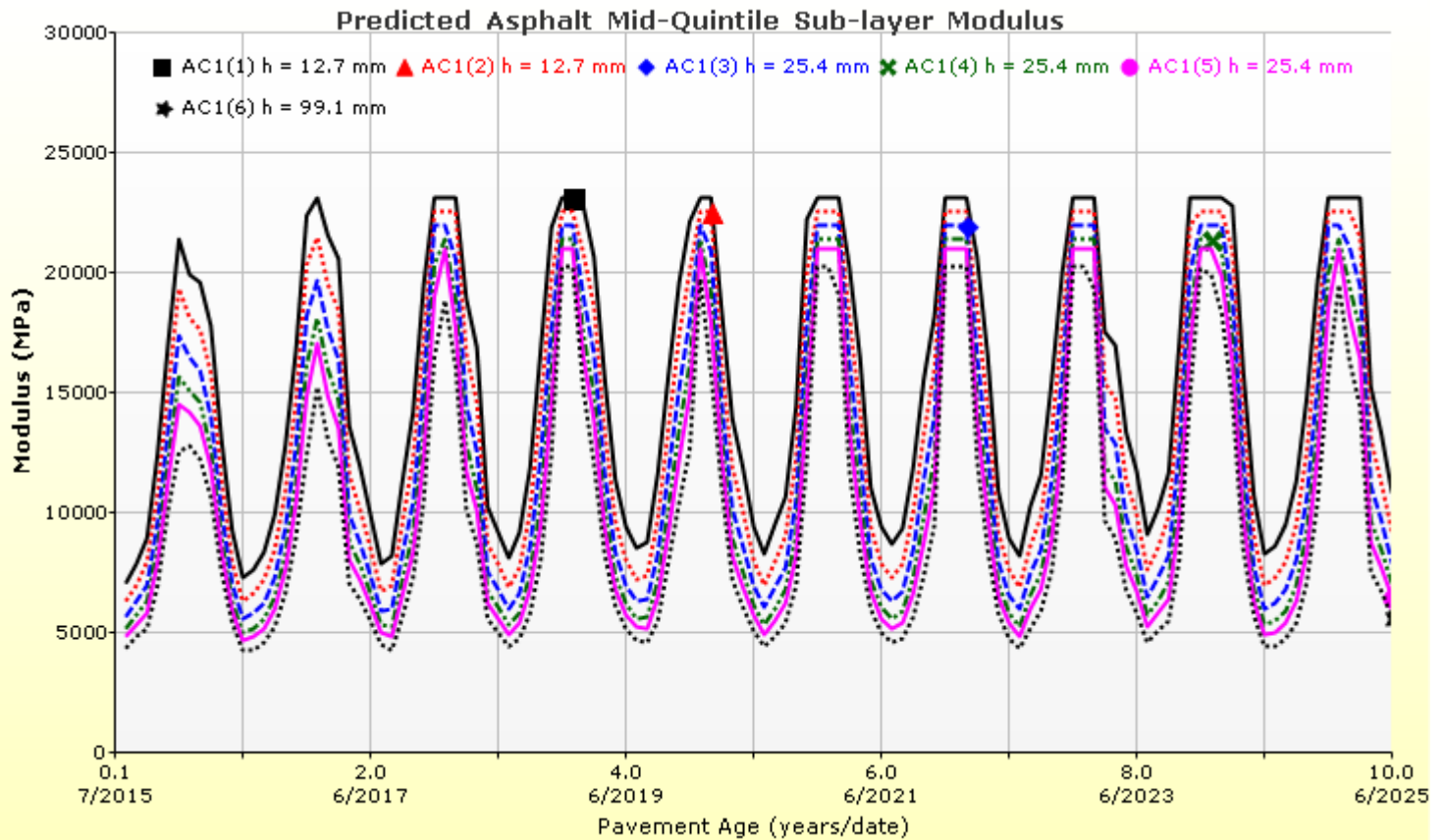




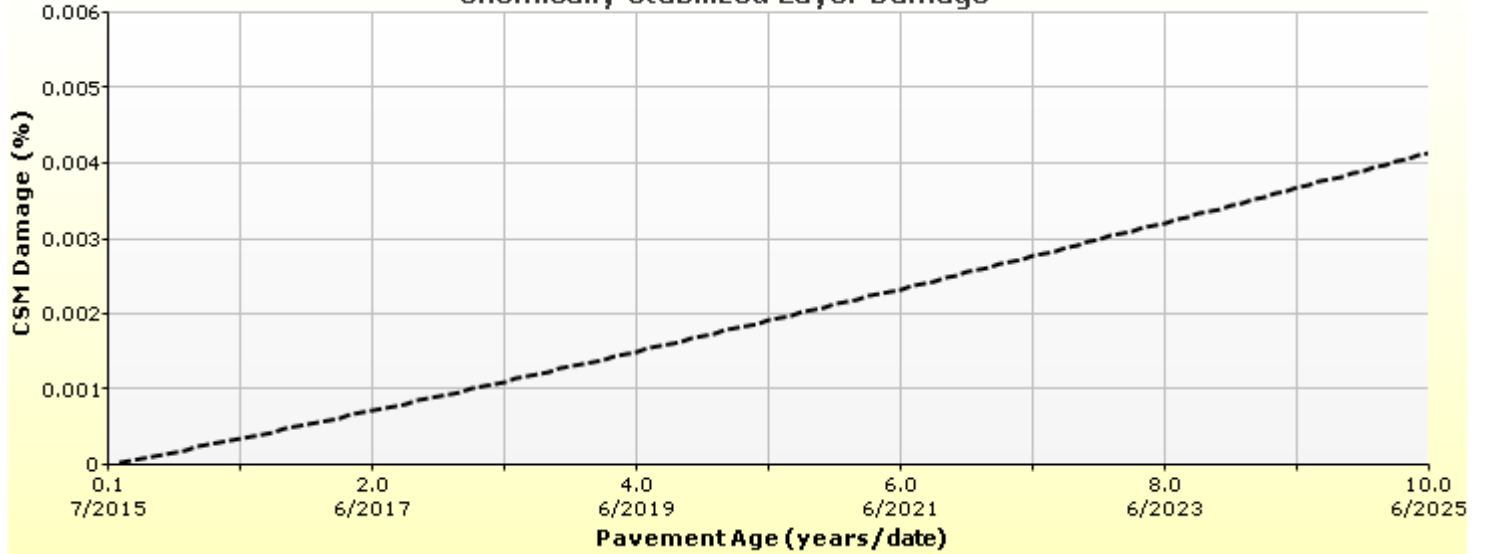
Predicted Rutting (Permanent Deformation) at 50% Reliability



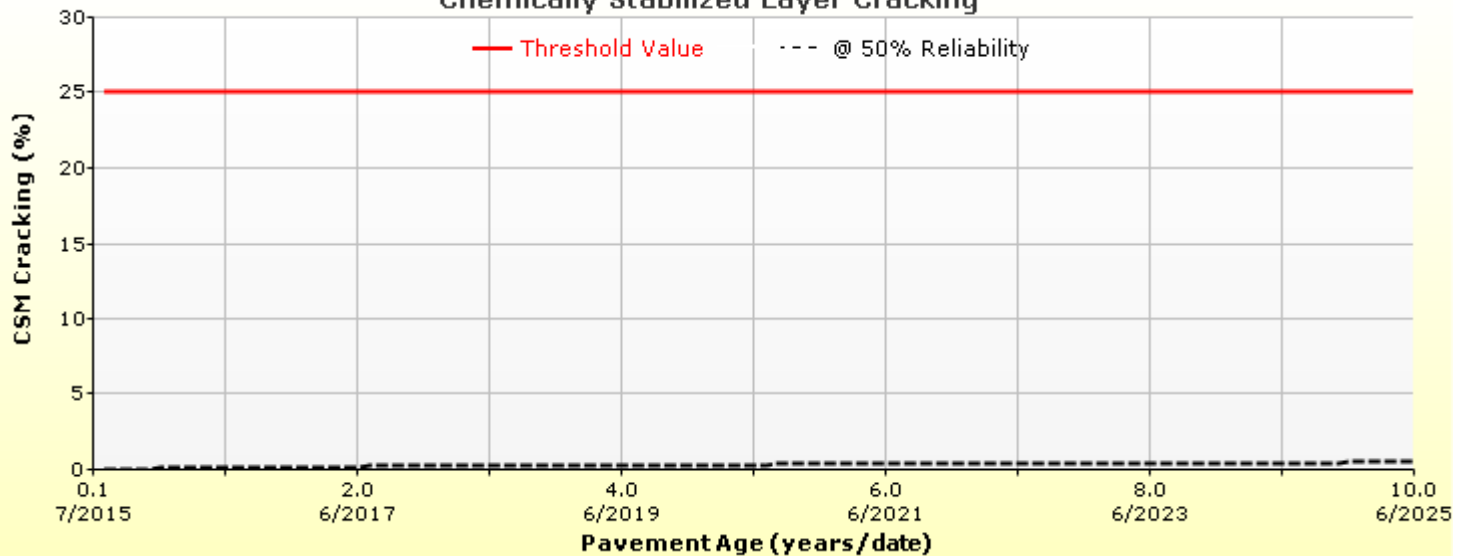




Chemically Stabilized Layer Damage



Chemically Stabilized Layer Cracking



Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 Chemically Stabilized : Cement stabilized

Chemically Stabilized

Layer thickness (mm)	300
Poisson's ratio	0.2
Unit weight (kgf/m ³)	2400

Strength

Elastic/resilient modulus (MPa)	13790

Thermal

Heat capacity (joule/kg-kelvin)	1172.3
Thermal conductivity (watt/meter-kelvin)	2.16

Identifiers

Field	Value
Display name/identifier	Cement stabilized
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 3 Non-stabilized Base : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015



Project1 - Novo ALF3_ALT4

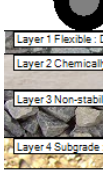
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Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data 32.119, -81.202
Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm):	Volumetric at Construction:	
Flexible	Default asphalt concrete	200.0	Effective binder content (%)	11.6
Cement_Base	Cement stabilized	300.0	Air voids (%)	7.0
NonStabilized	Crushed stone	400.0		
Subgrade	A-1-a	Semi-infinite		

Traffic

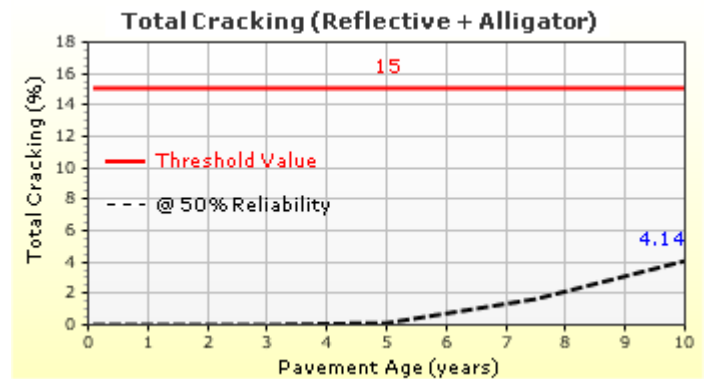
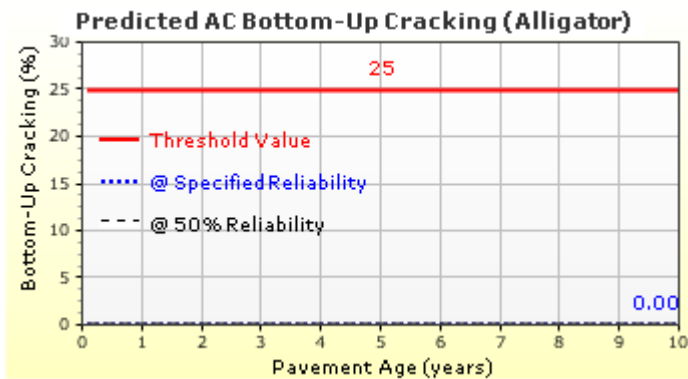
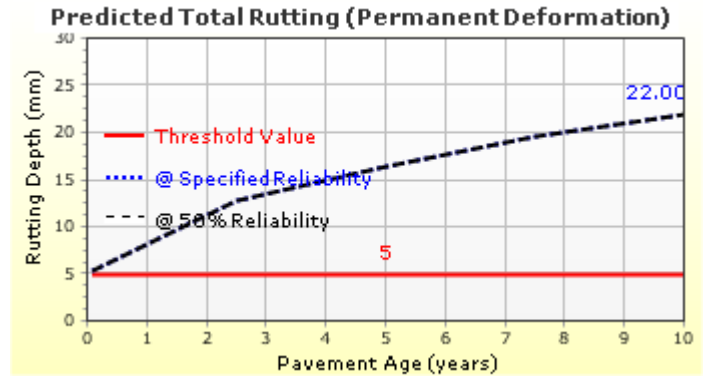
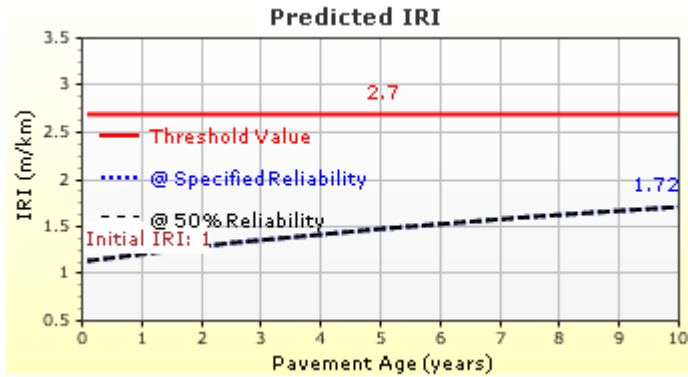
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.72	50.00	97.88	Pass
Permanent deformation - total pavement (mm)	5.00	22.00	50.00	0.03	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.00	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.14	-	-	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	791.67	50.00	18.09	Fail
Permanent deformation - AC only (mm)	5.00	19.04	50.00	0.19	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.53	-	-	-

Distress Charts

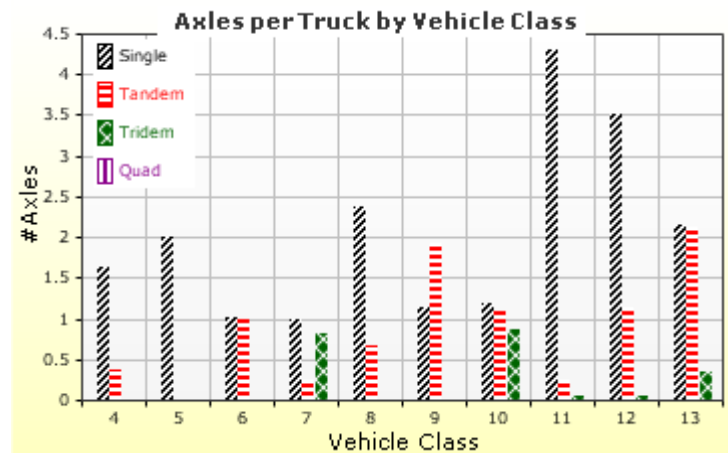
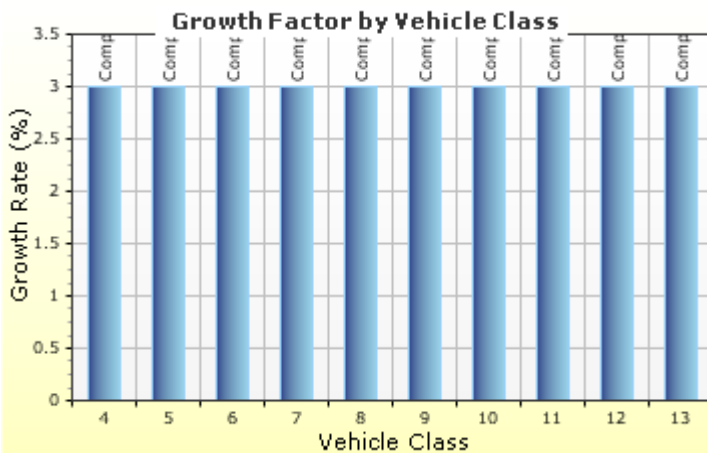
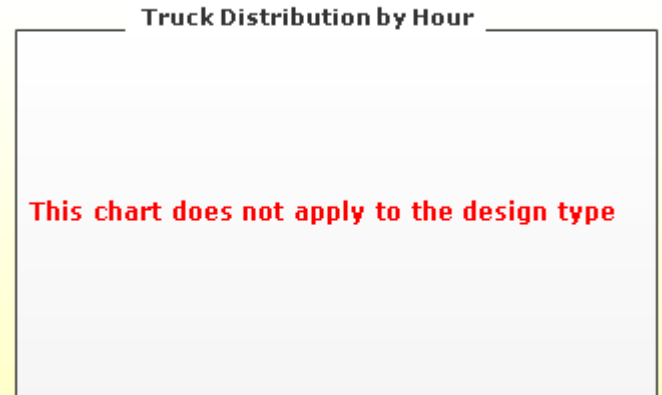
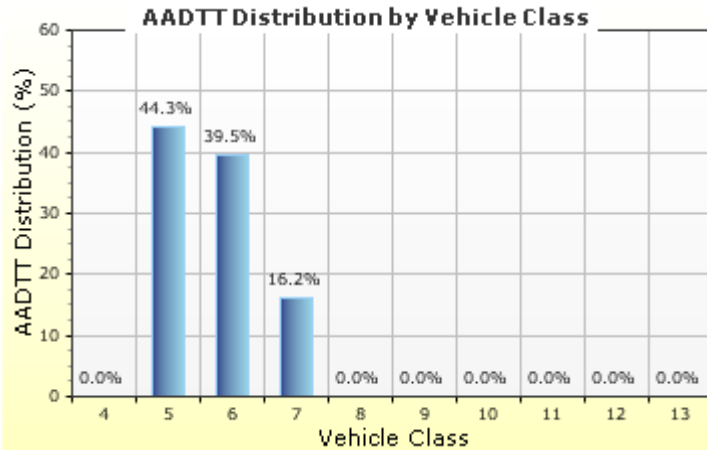


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

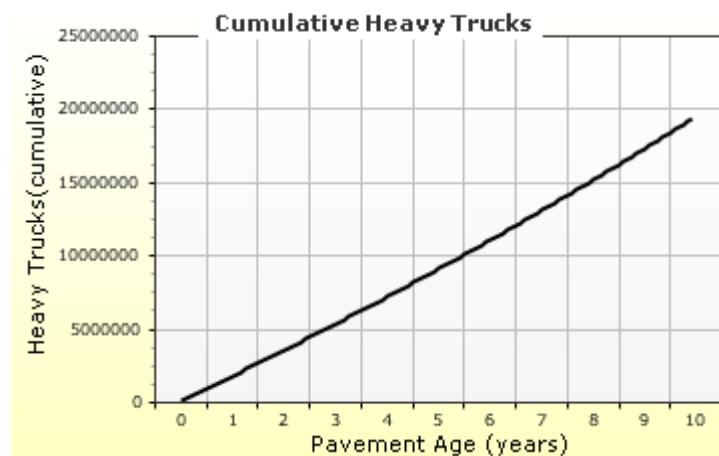
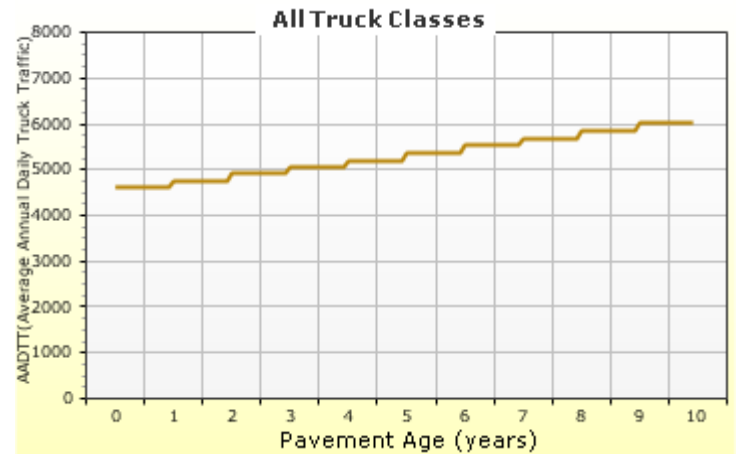
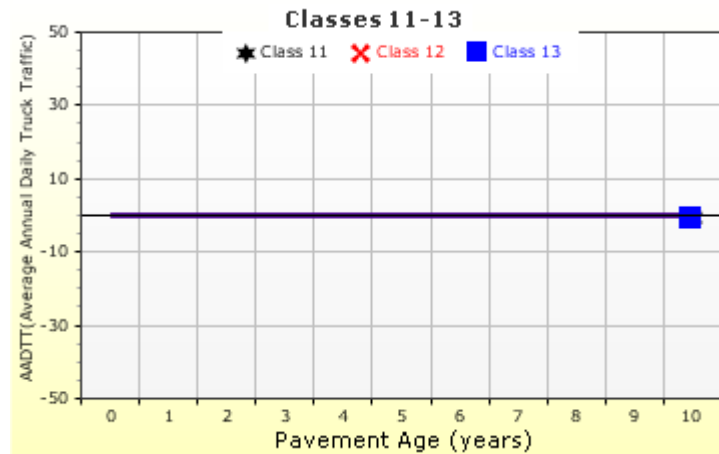
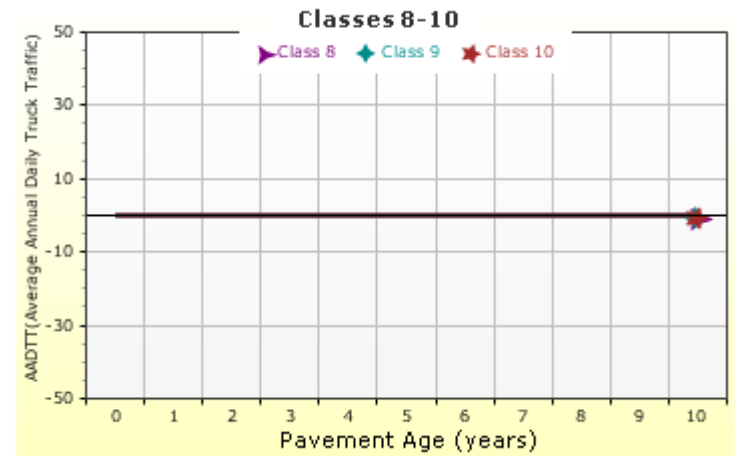
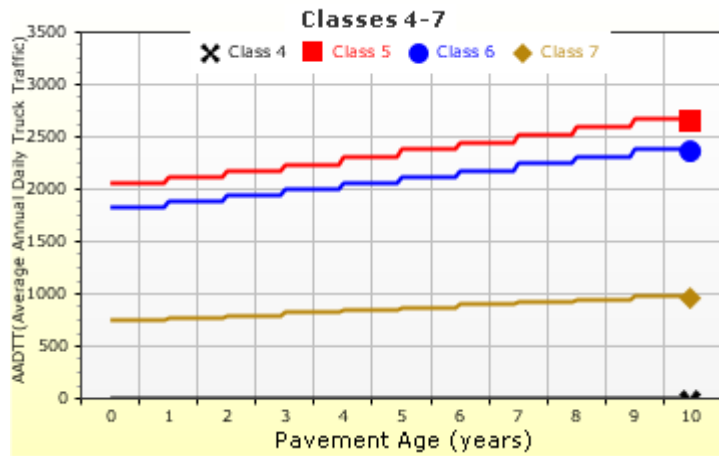
Wheelbase does not apply

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



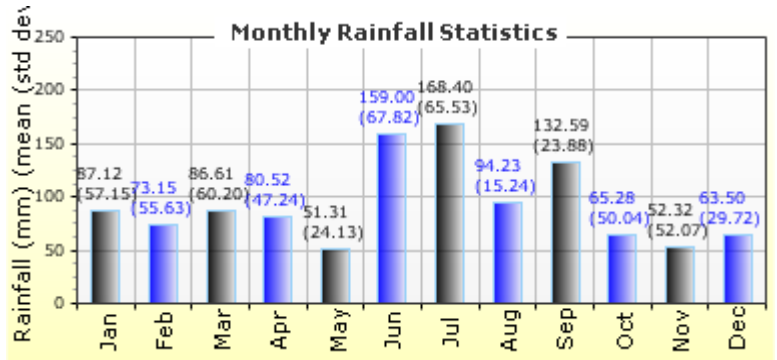
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

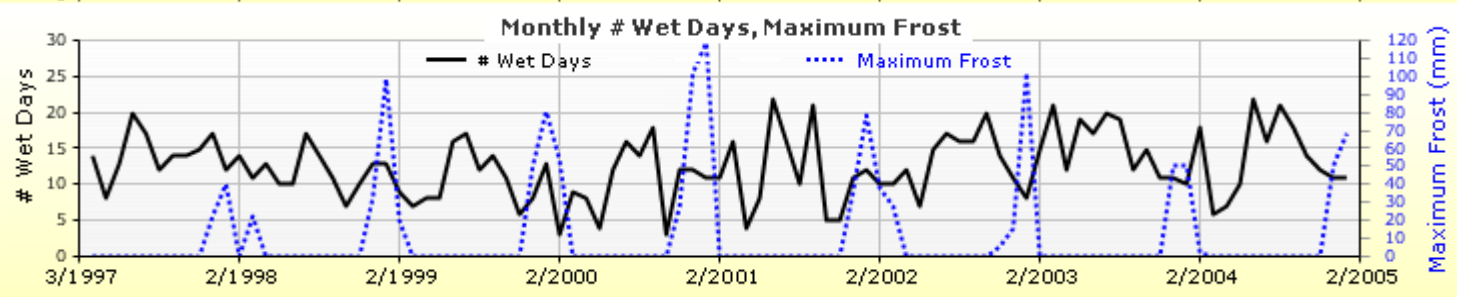
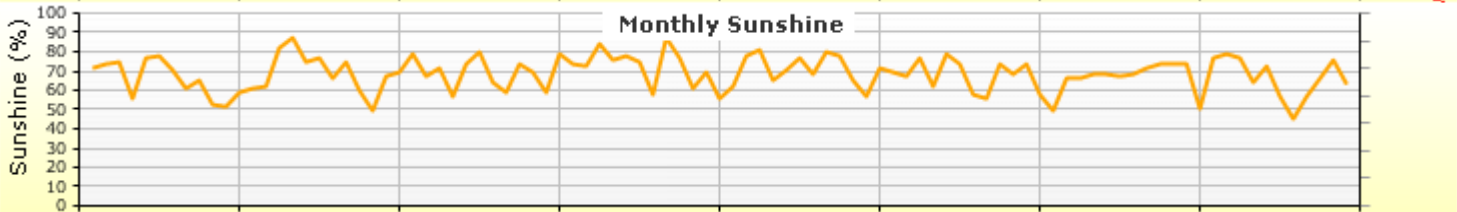
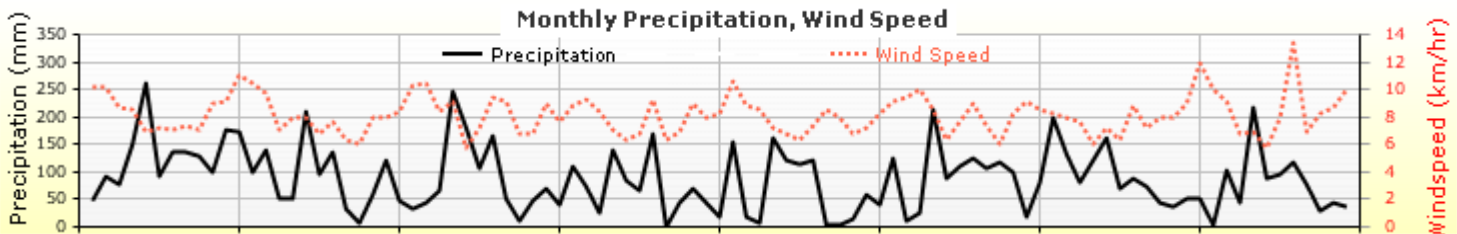
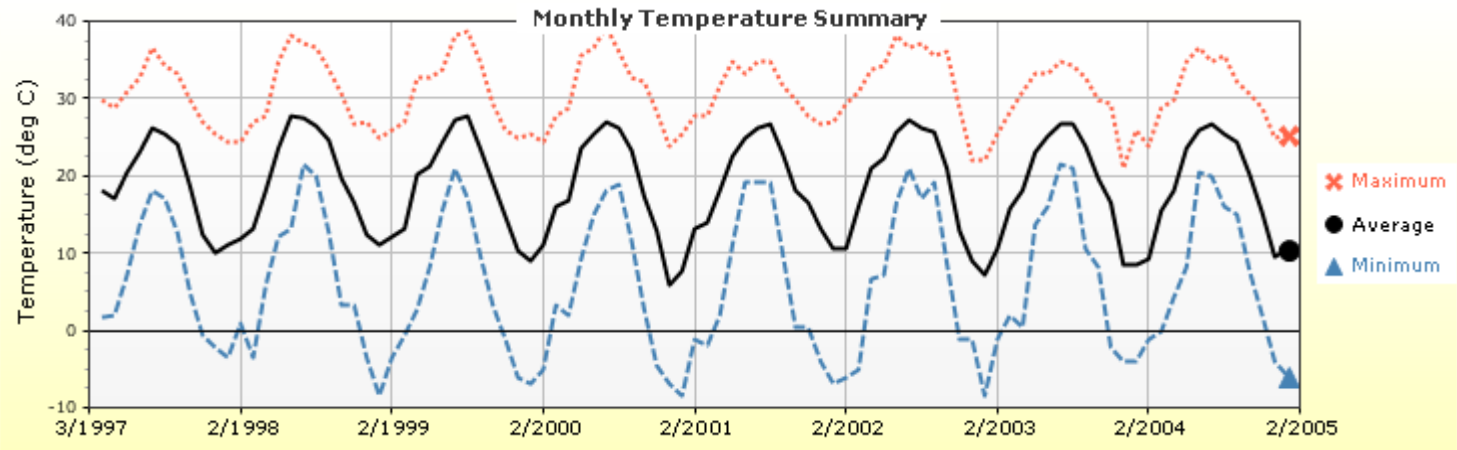
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

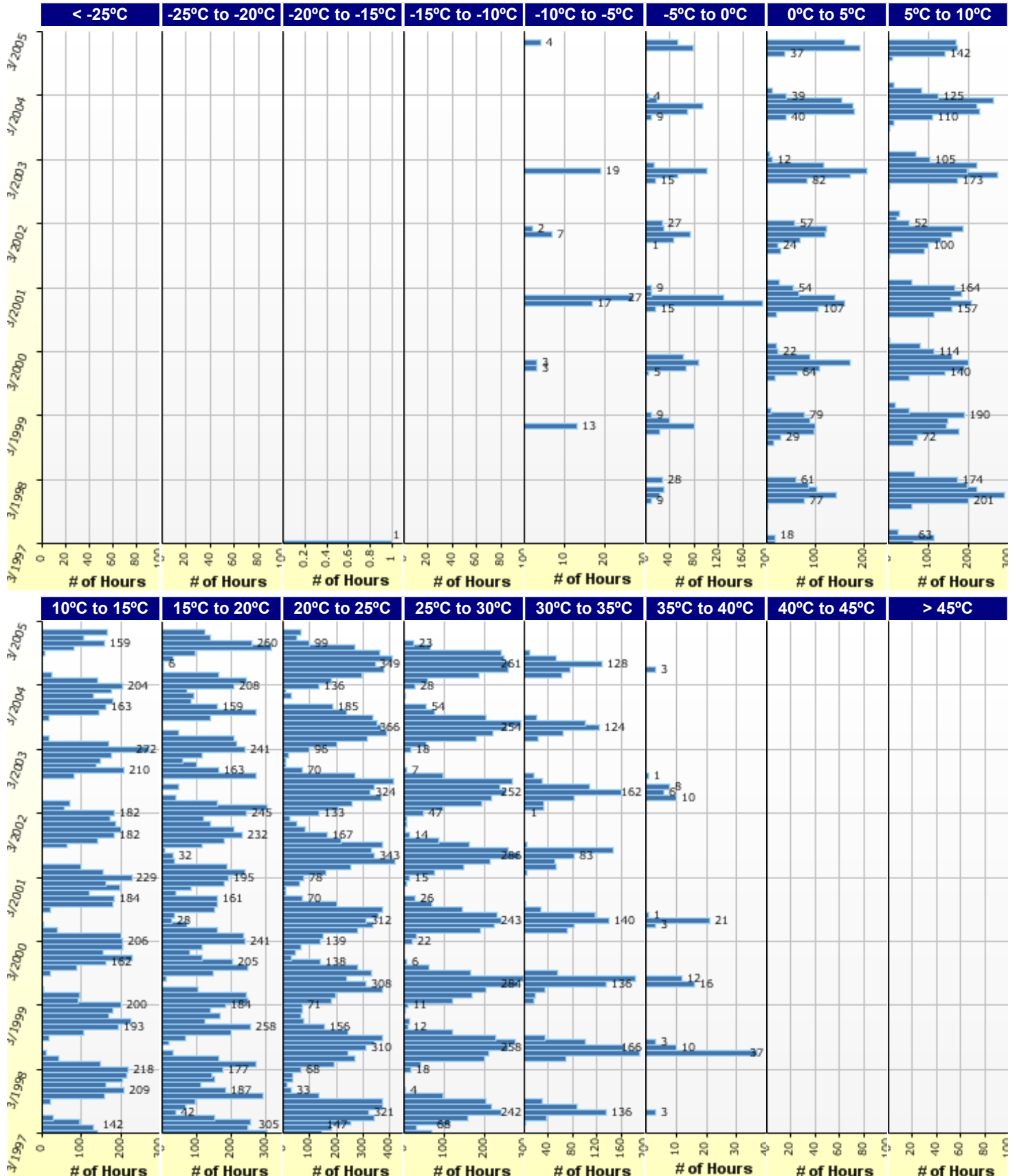


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF3_ALT4

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF3_ALT4.dgpx



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

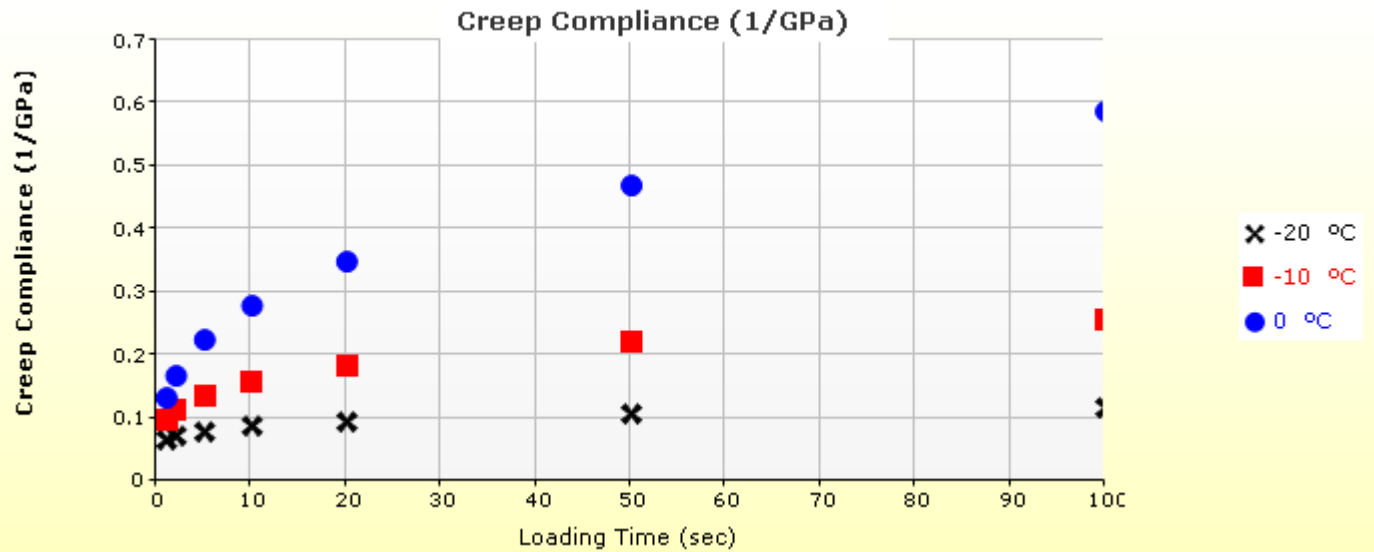
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Chemically Stabilized : Cement stabilized	Chemically Stabilized (2)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

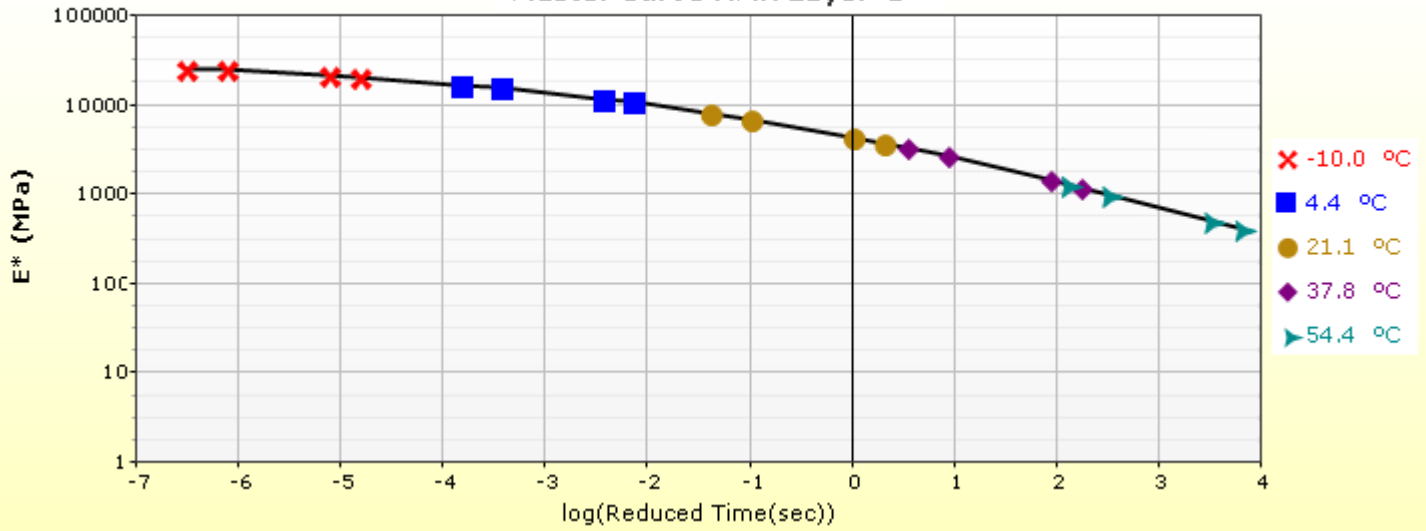
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

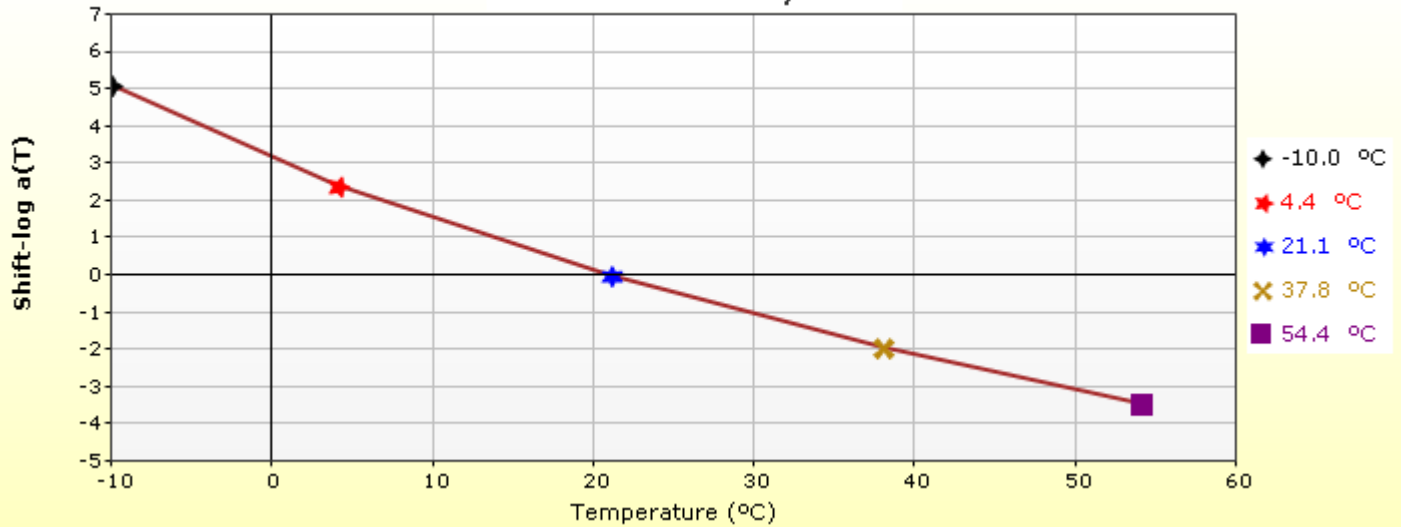


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

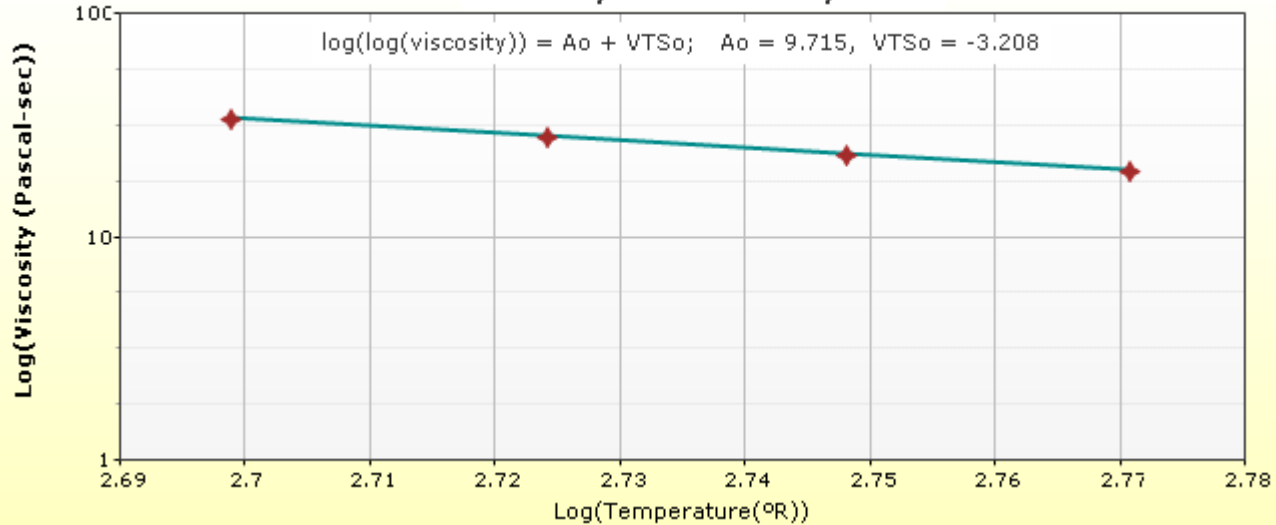
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

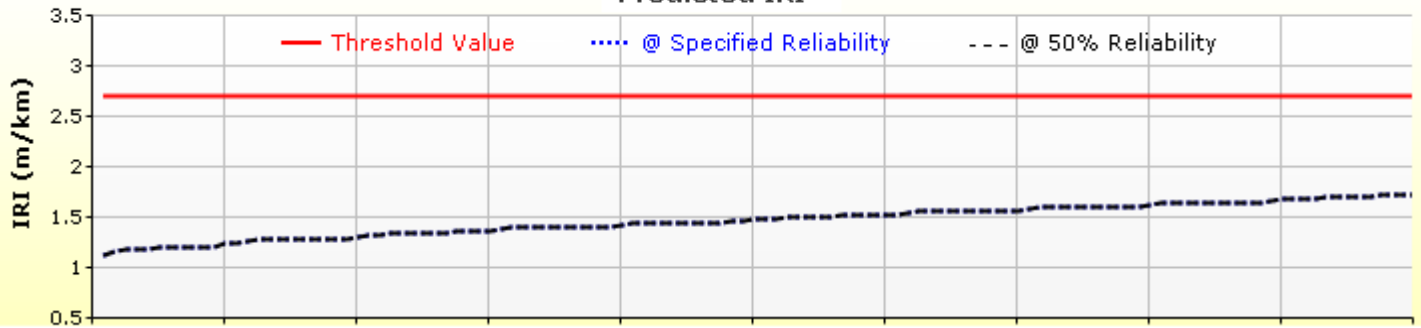


Viscosity Curve HMA Layer 1

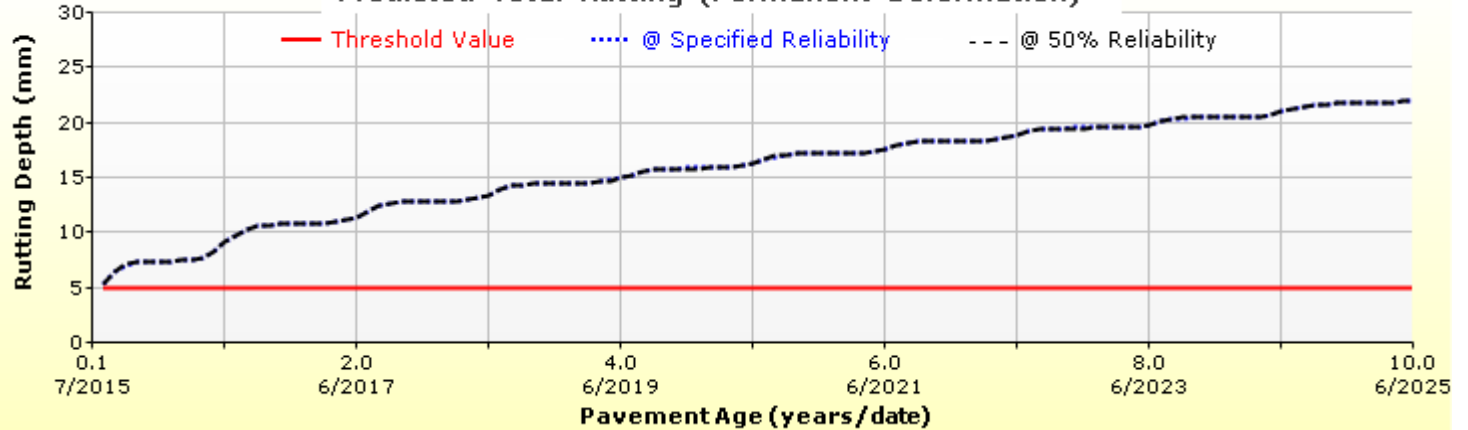


Analysis Output Charts

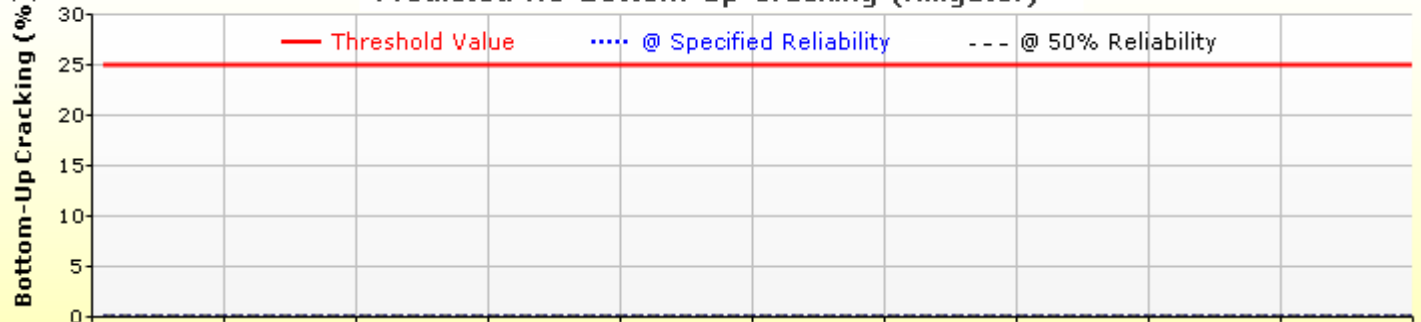
Predicted IRI



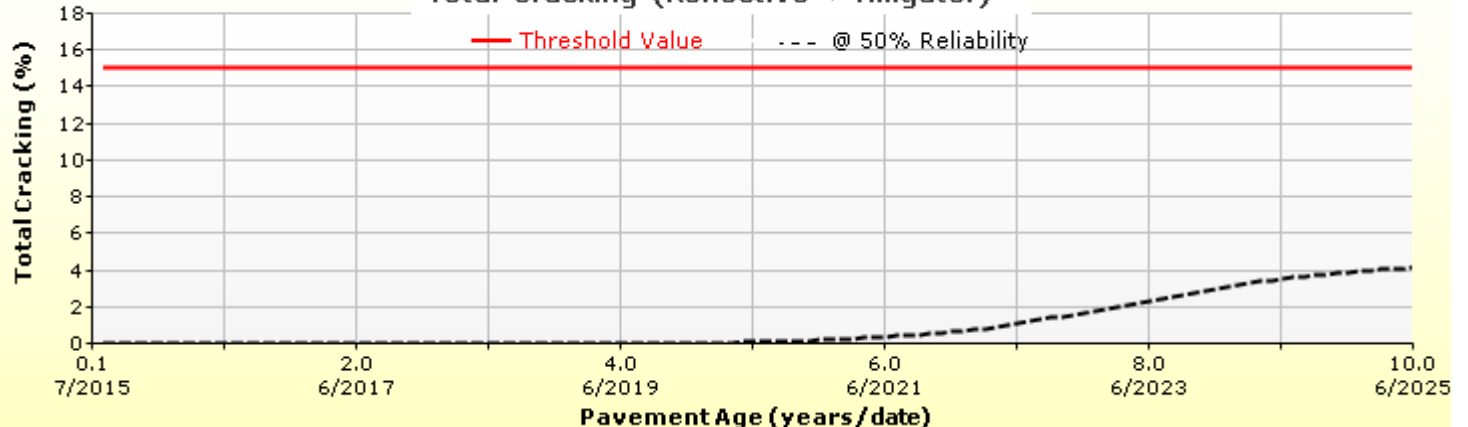
Predicted Total Rutting (Permanent Deformation)



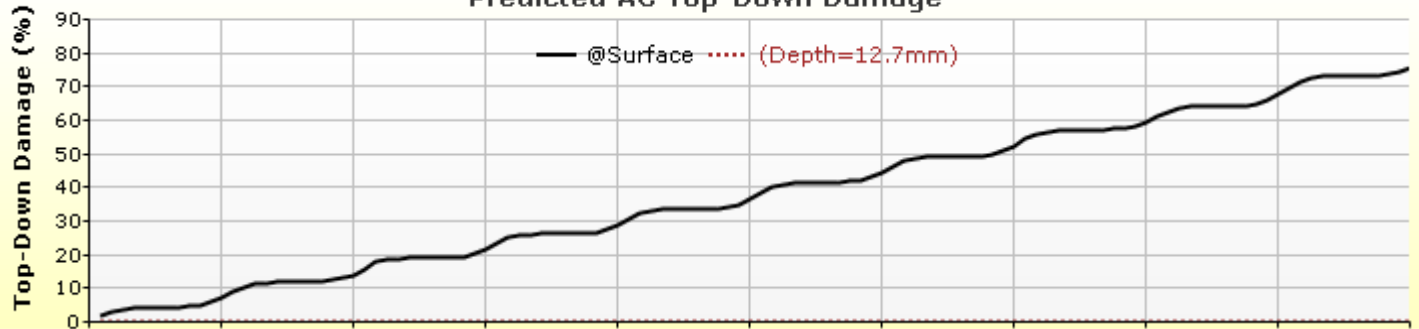
Predicted AC Bottom-Up Cracking (Alligator)



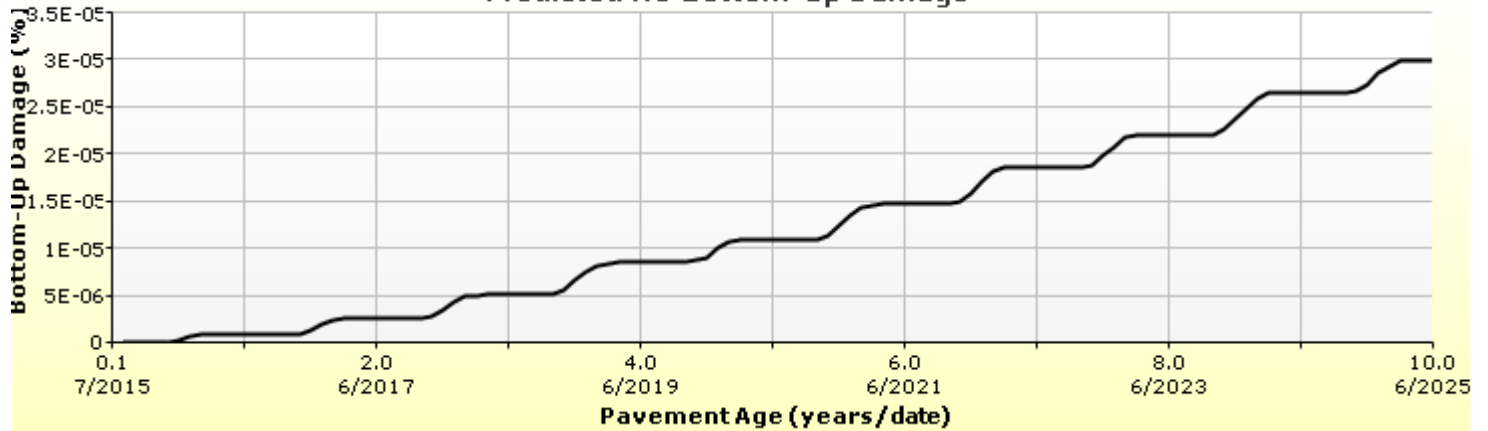
Total Cracking (Reflective + Alligator)



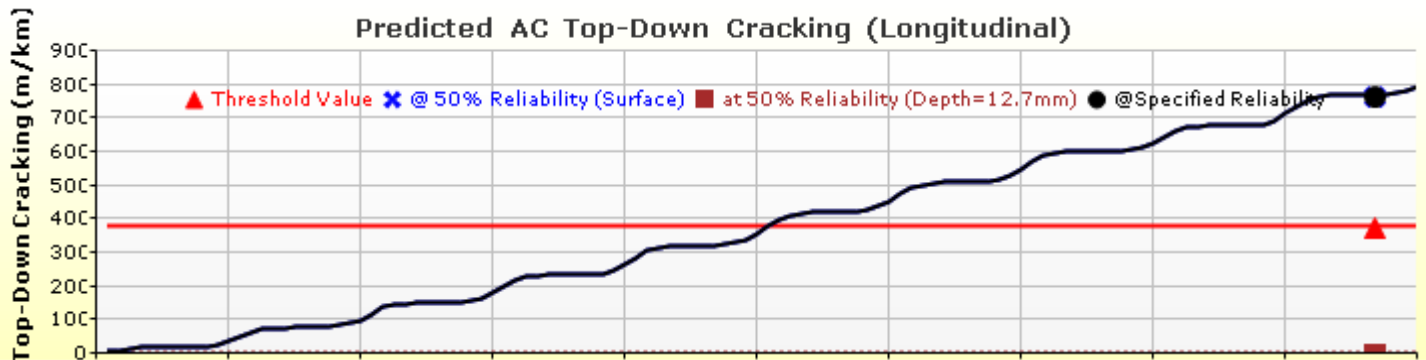
Predicted AC Top-Down Damage



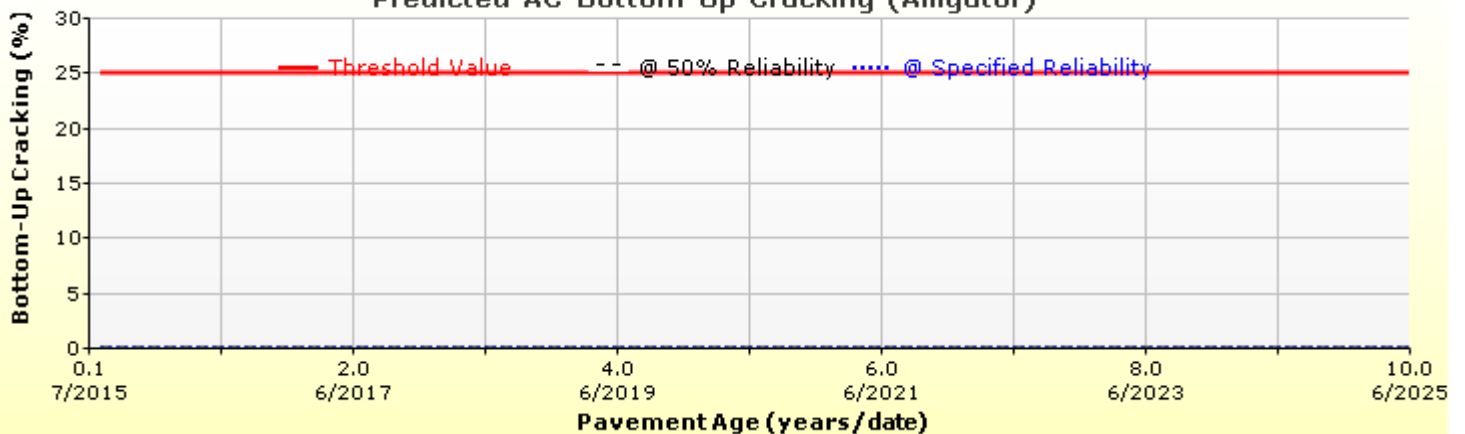
Predicted AC Bottom-Up Damage



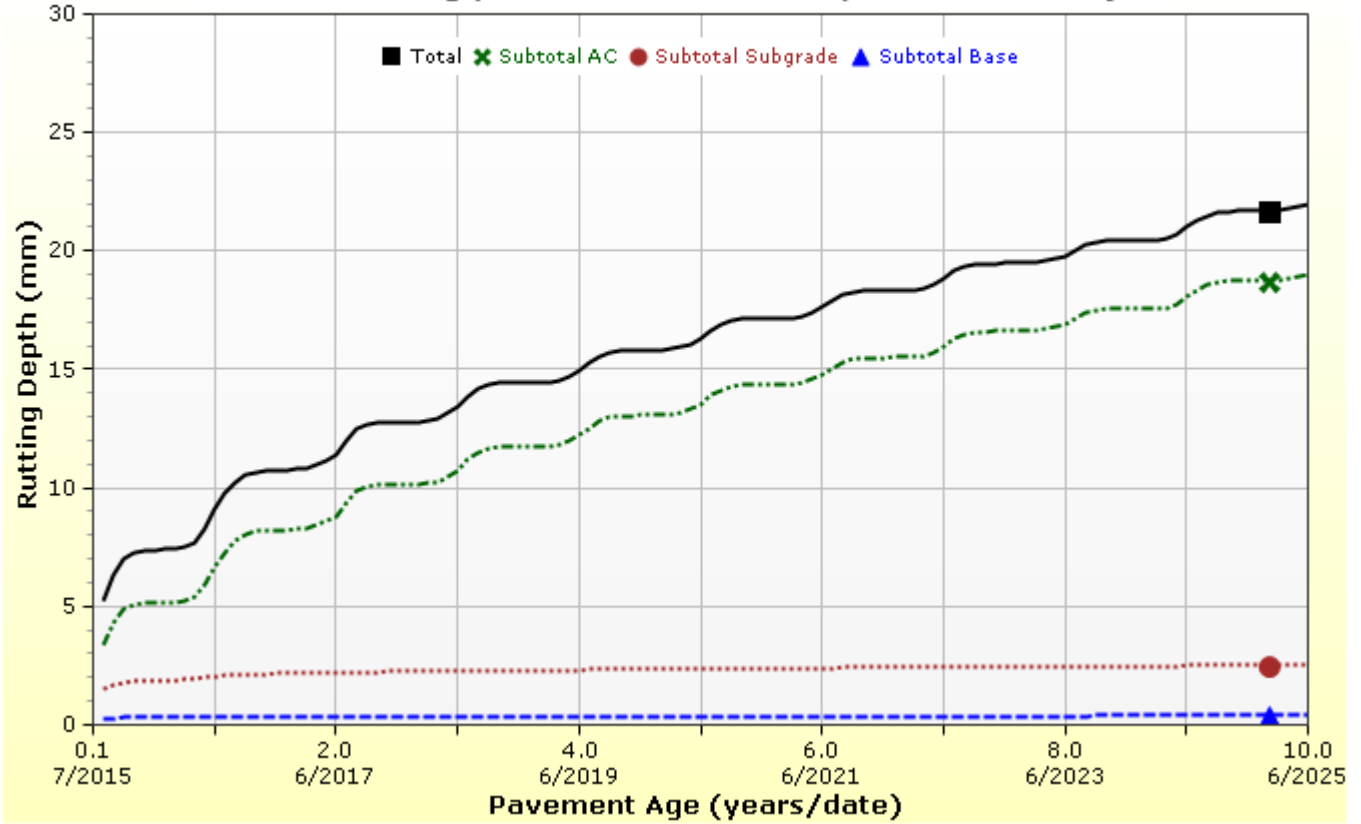
Predicted AC Top-Down Cracking (Longitudinal)



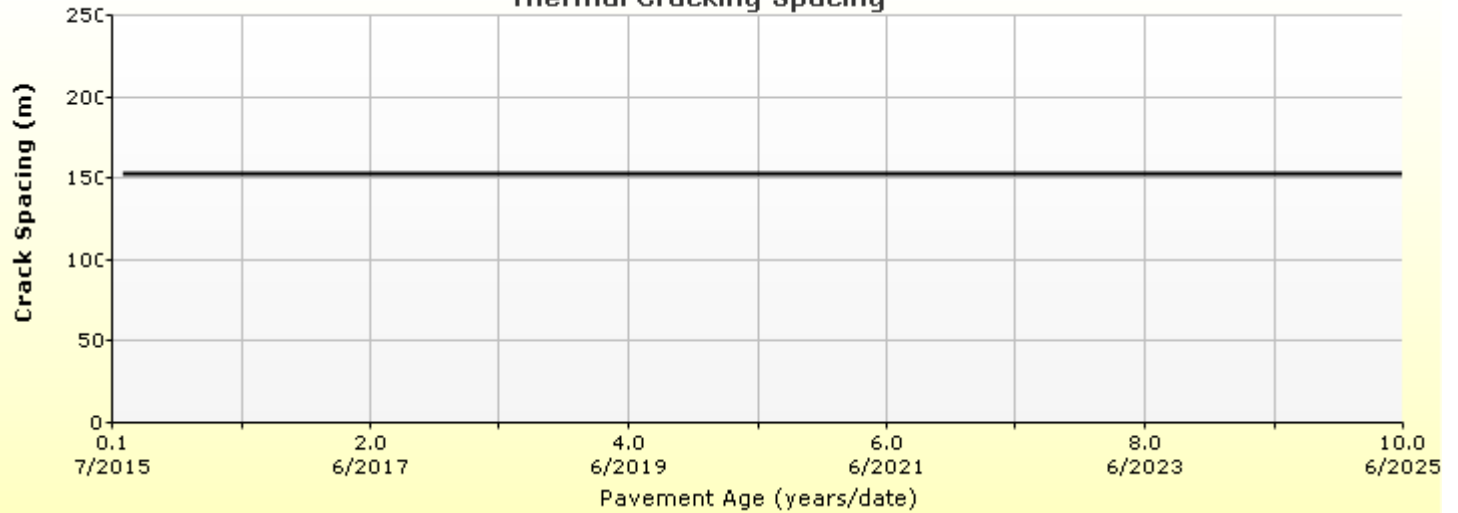
Predicted AC Bottom-Up Cracking (Alligator)



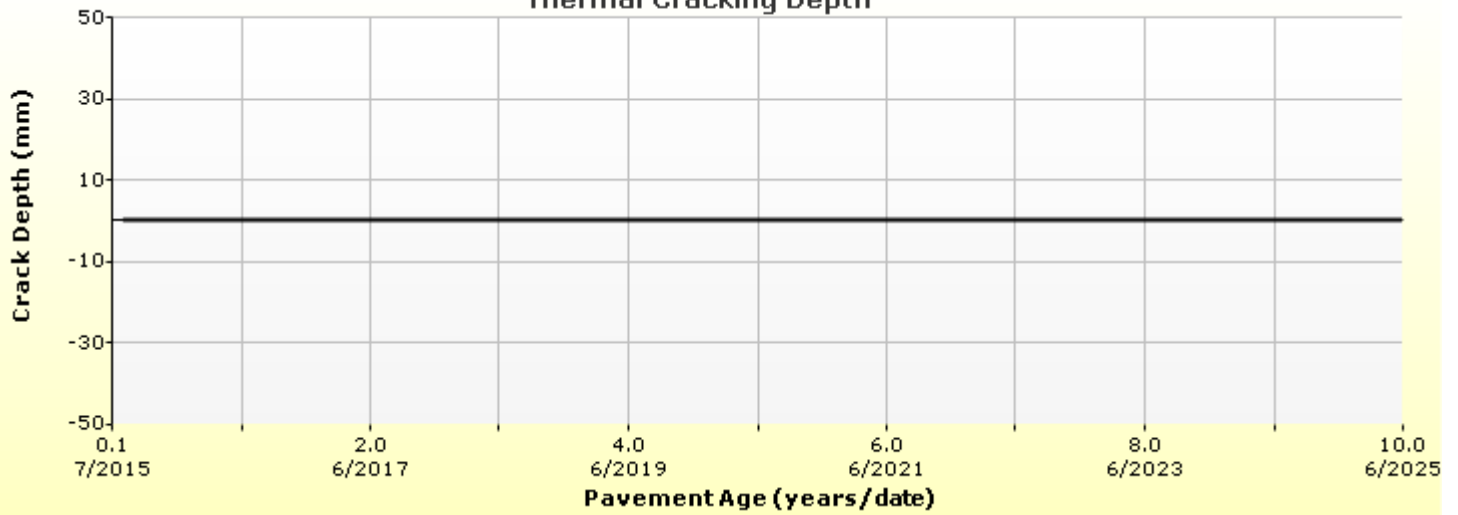
Predicted Rutting (Permanent Deformation) at 50% Reliability

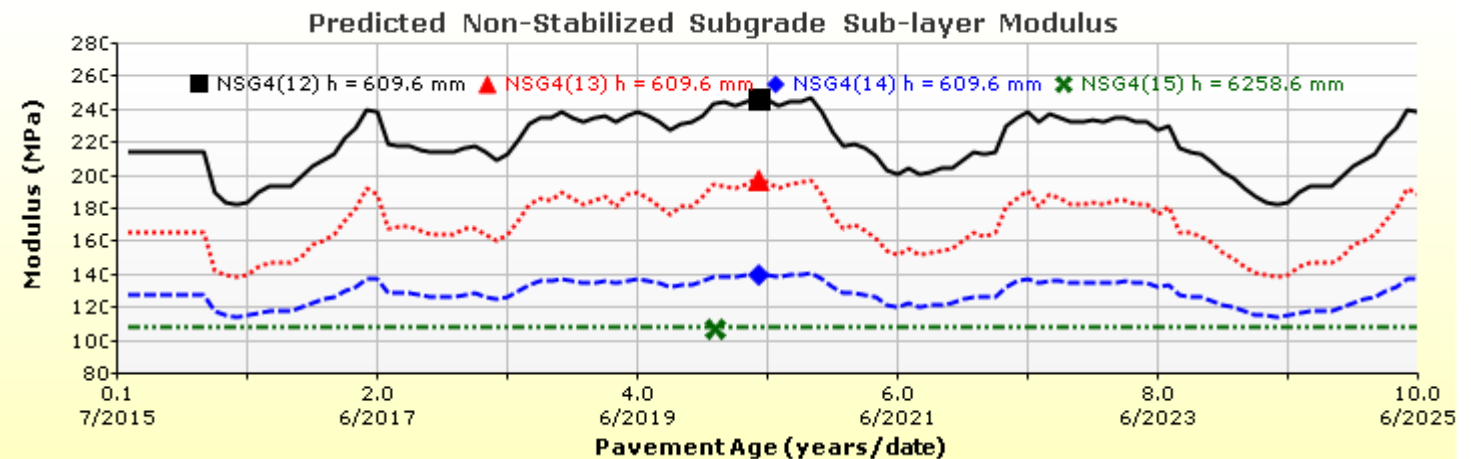
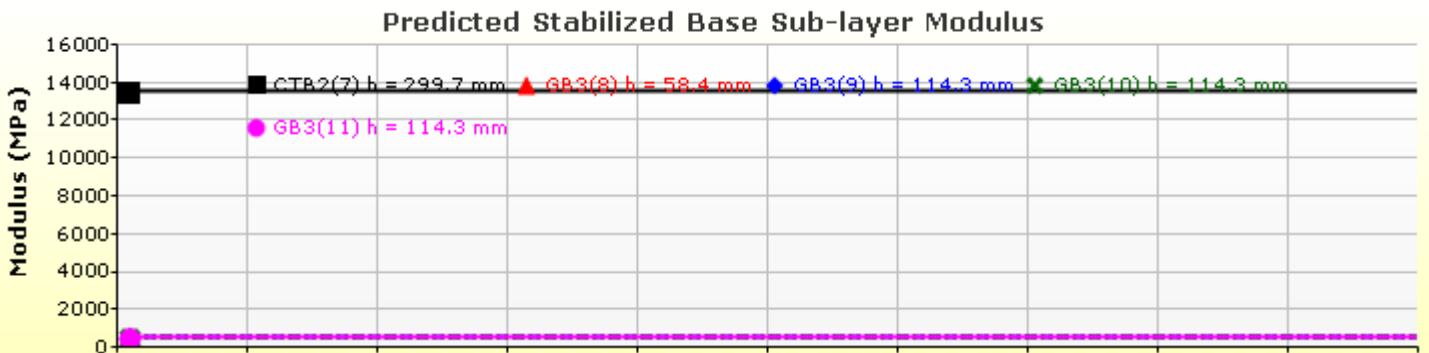
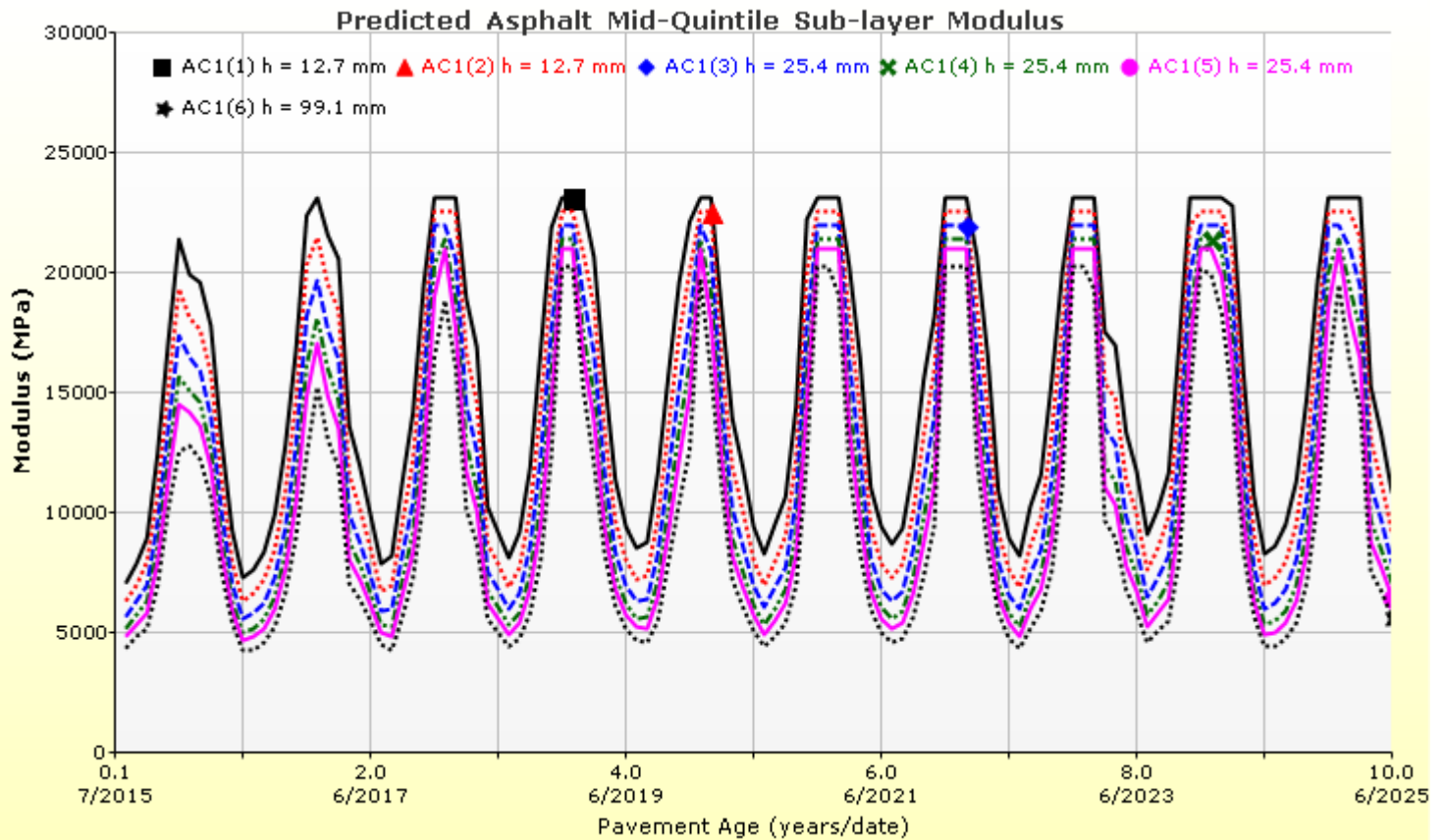


Thermal Cracking Spacing

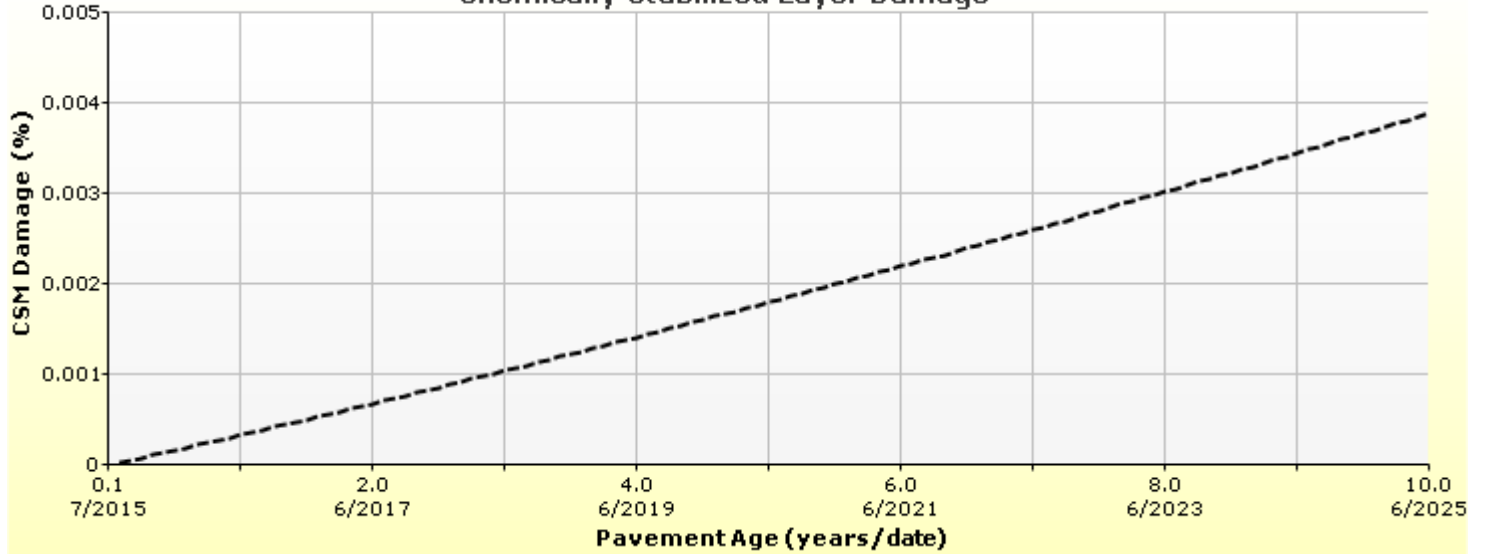


Thermal Cracking Depth

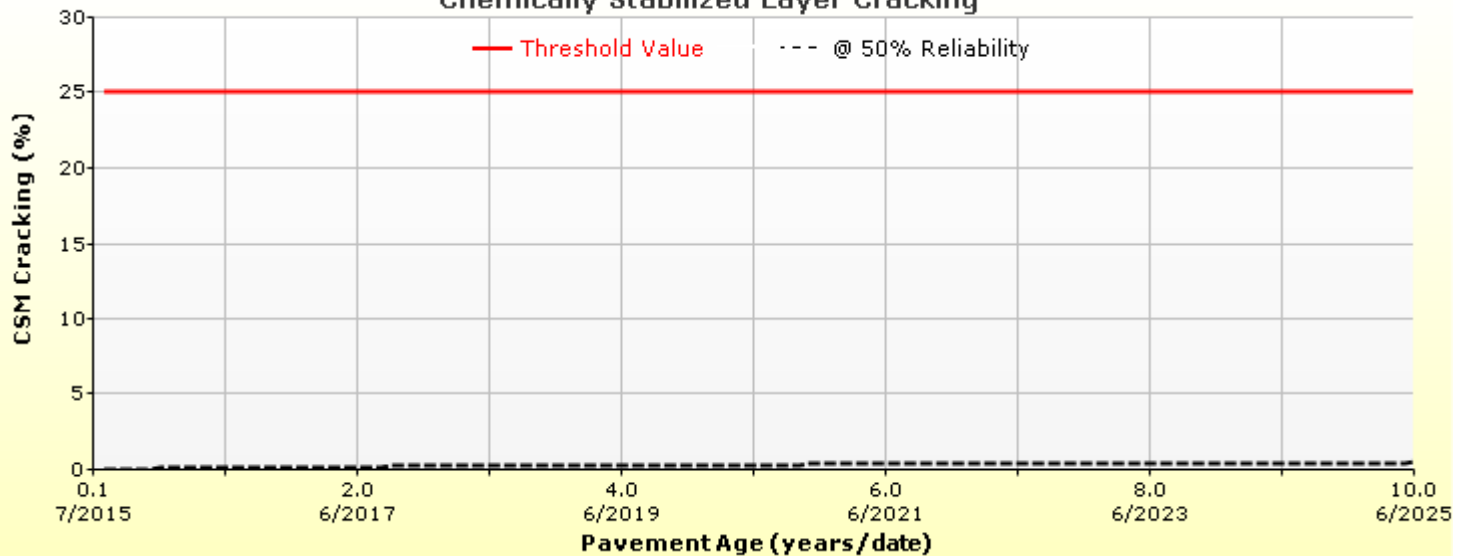




Chemically Stabilized Layer Damage



Chemically Stabilized Layer Cracking



Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 Chemically Stabilized : Cement stabilized

Chemically Stabilized

Layer thickness (mm)	300
Poisson's ratio	0.2
Unit weight (kgf/m^3)	2400

Strength

Elastic/resilient modulus (MPa)	13790

Thermal

Heat capacity (joule/kg-kelvin)	1172.3
Thermal conductivity (watt/meter-kelvin)	2.16

Identifiers

Field	Value
Display name/identifier	Cement stabilized
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 3 Non-stabilized Base : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T^{k_2 \beta_{r2}} N^{k_3 \beta_{r3}}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015



Project1 - Novo ALF4_ALT4

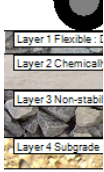
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Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data 32.119, -81.202
Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm):	Volumetric at Construction:	
Flexible	Default asphalt concrete	200.0	Effective binder content (%)	11.6
Cement_Base	Cement stabilized	300.0	Air voids (%)	7.0
NonStabilized	Crushed stone	400.0		
Subgrade	A-1-a	Semi-infinite		

Traffic

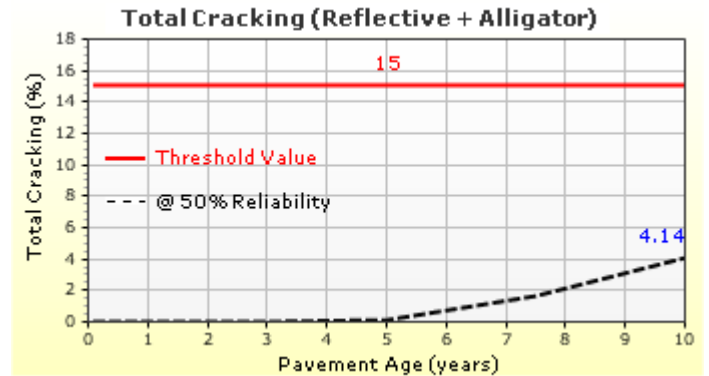
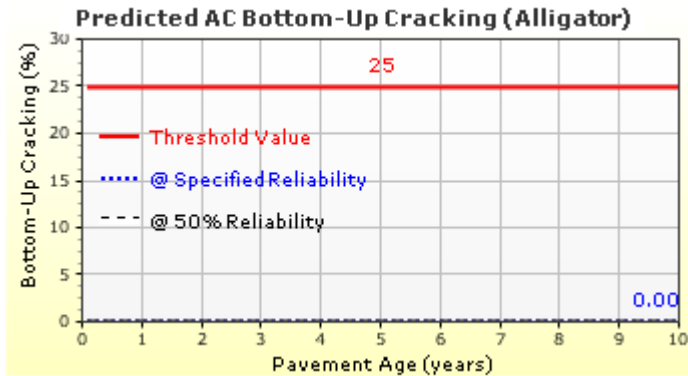
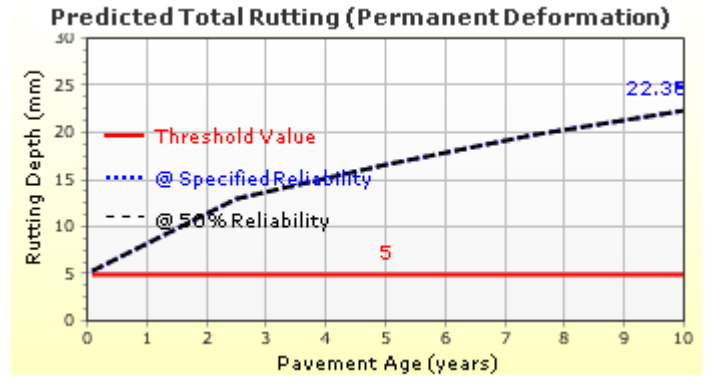
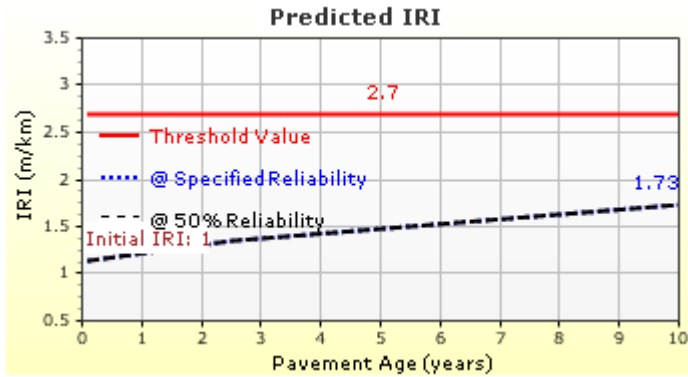
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	9,639
2020 (5 years)	8,971,960
2025 (10 years)	19,372,900

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.73	50.00	97.70	Pass
Permanent deformation - total pavement (mm)	5.00	22.36	50.00	0.03	Fail
AC bottom-up fatigue cracking (percent)	25.00	0.00	50.00	100.00	Pass
Total Cracking (Reflective + Alligator) (percent)	15	4.14	-	-	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	831.44	50.00	15.92	Fail
Permanent deformation - AC only (mm)	5.00	19.41	50.00	0.18	Fail
Chemically stabilized layer - fatigue fracture (percent)	25.00	0.53	-	-	-

Distress Charts

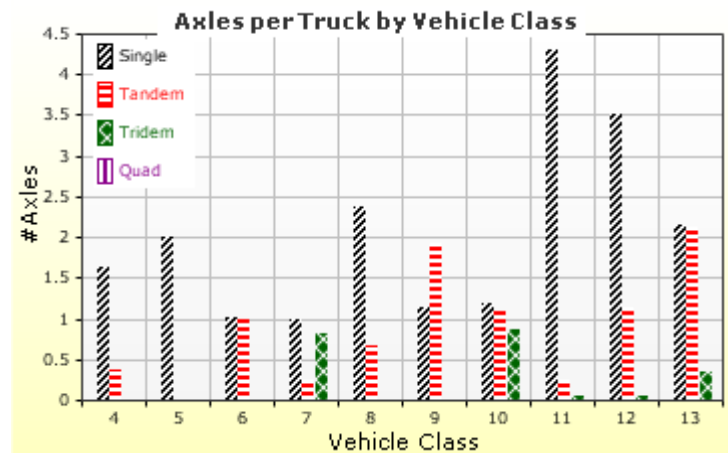
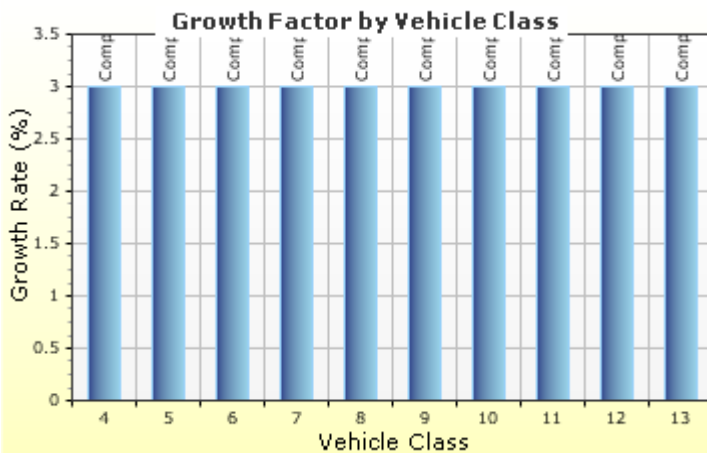
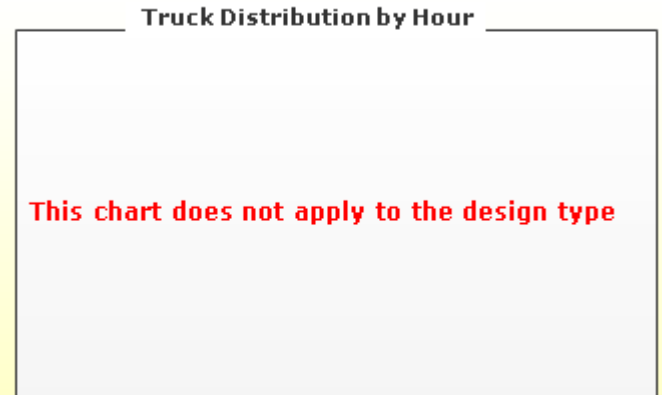
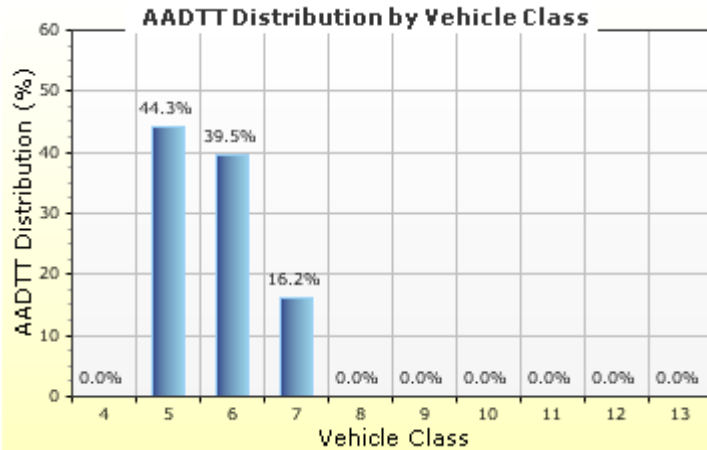


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 9,639
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

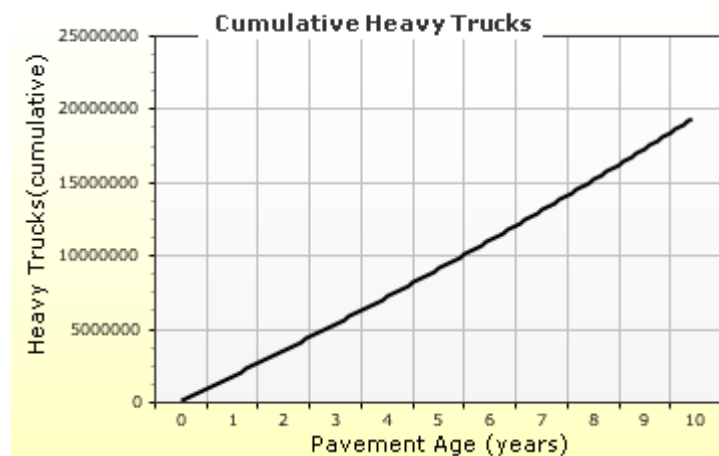
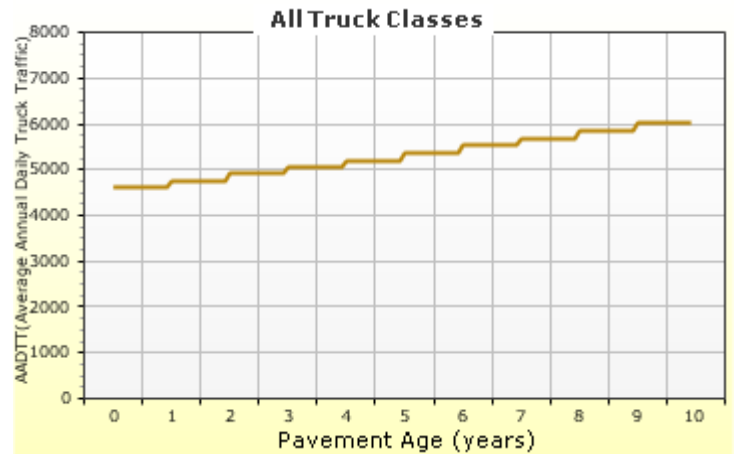
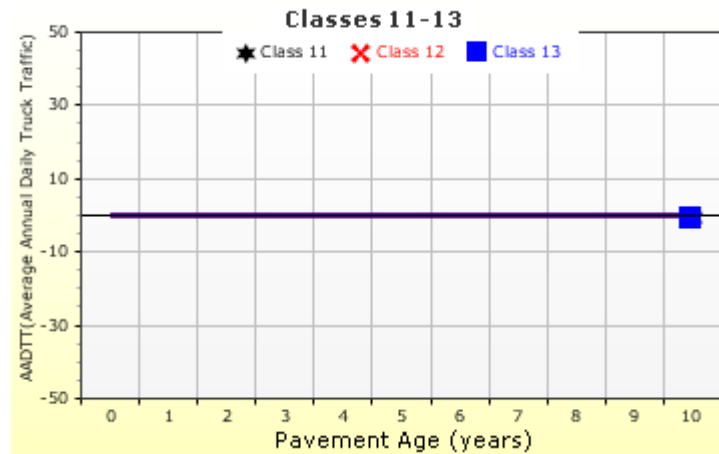
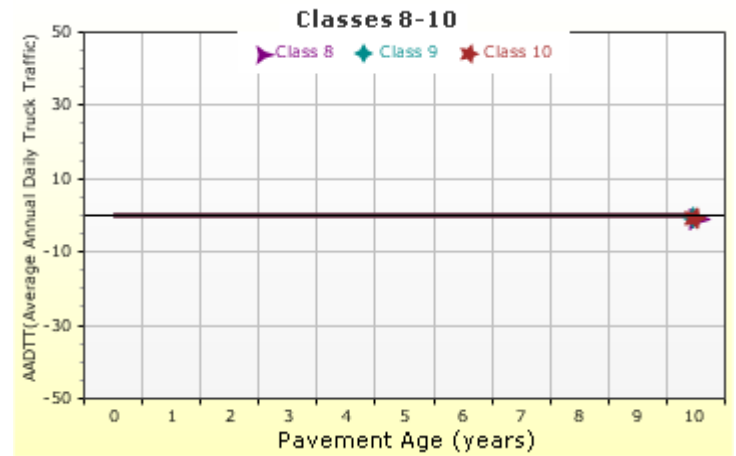
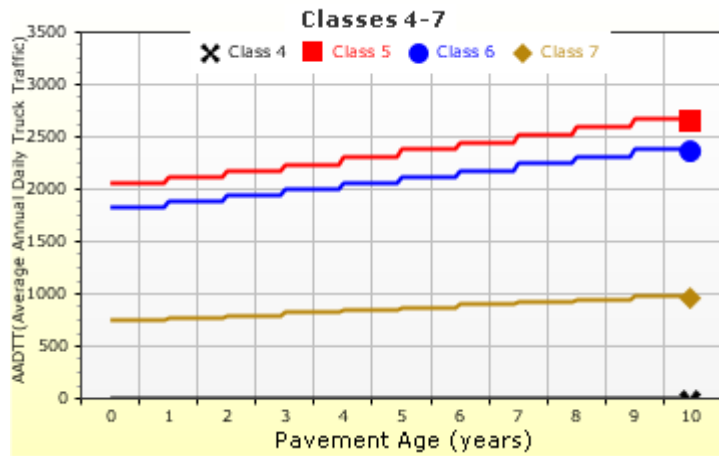
Wheelbase does not apply

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



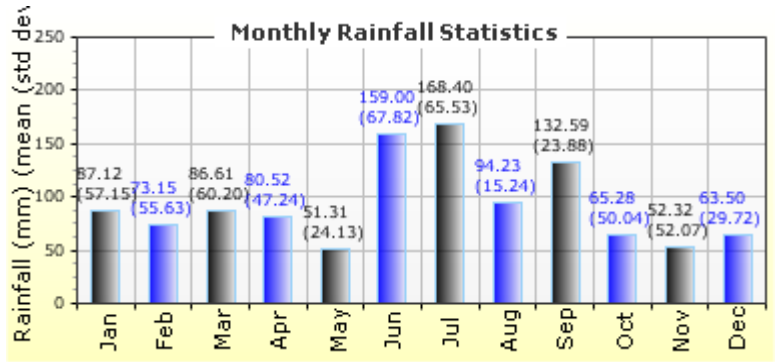
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

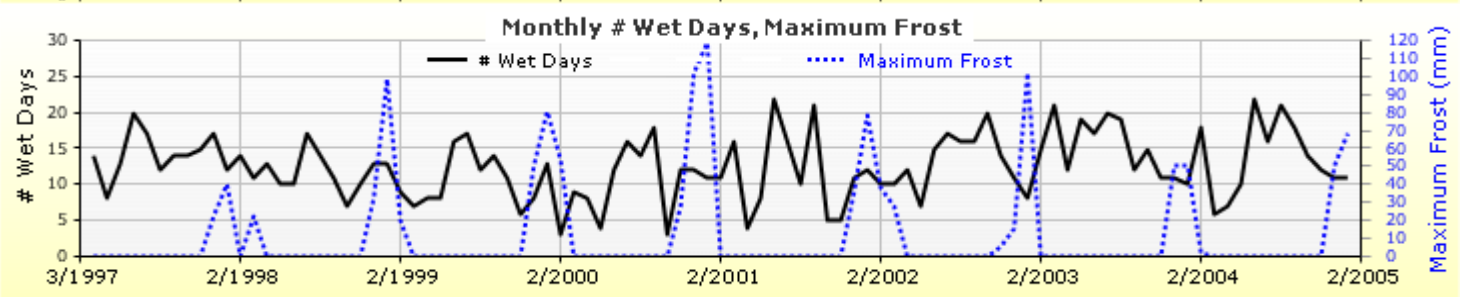
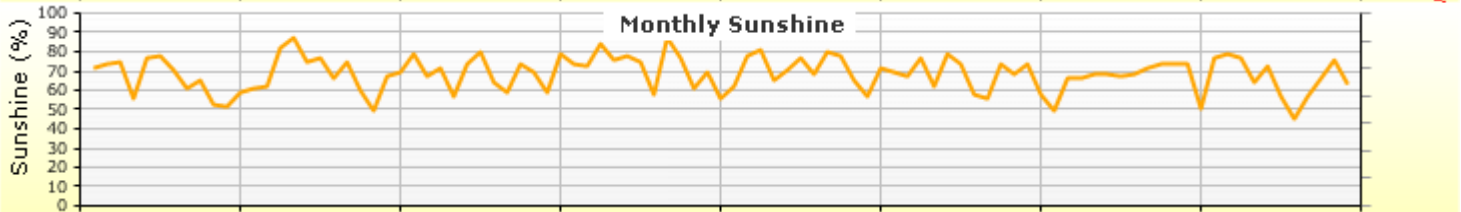
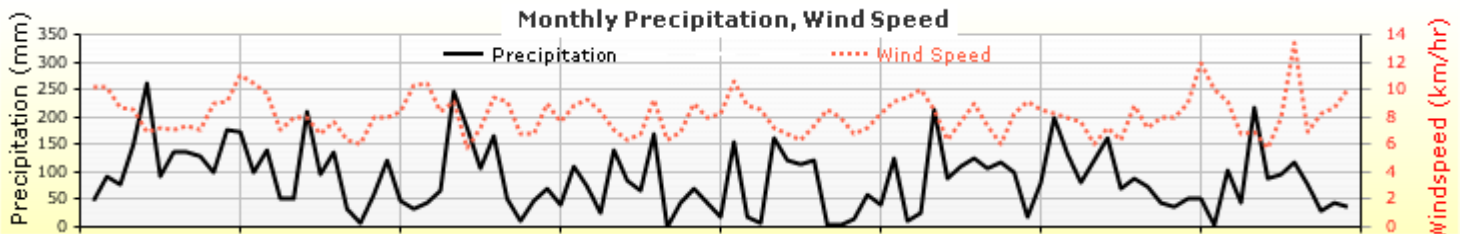
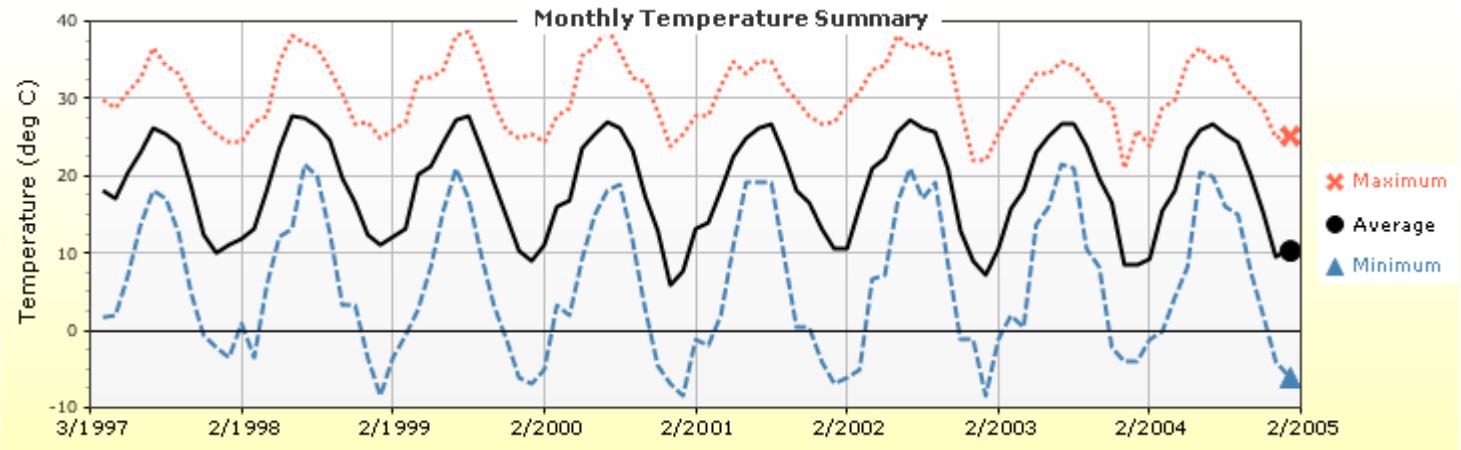
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

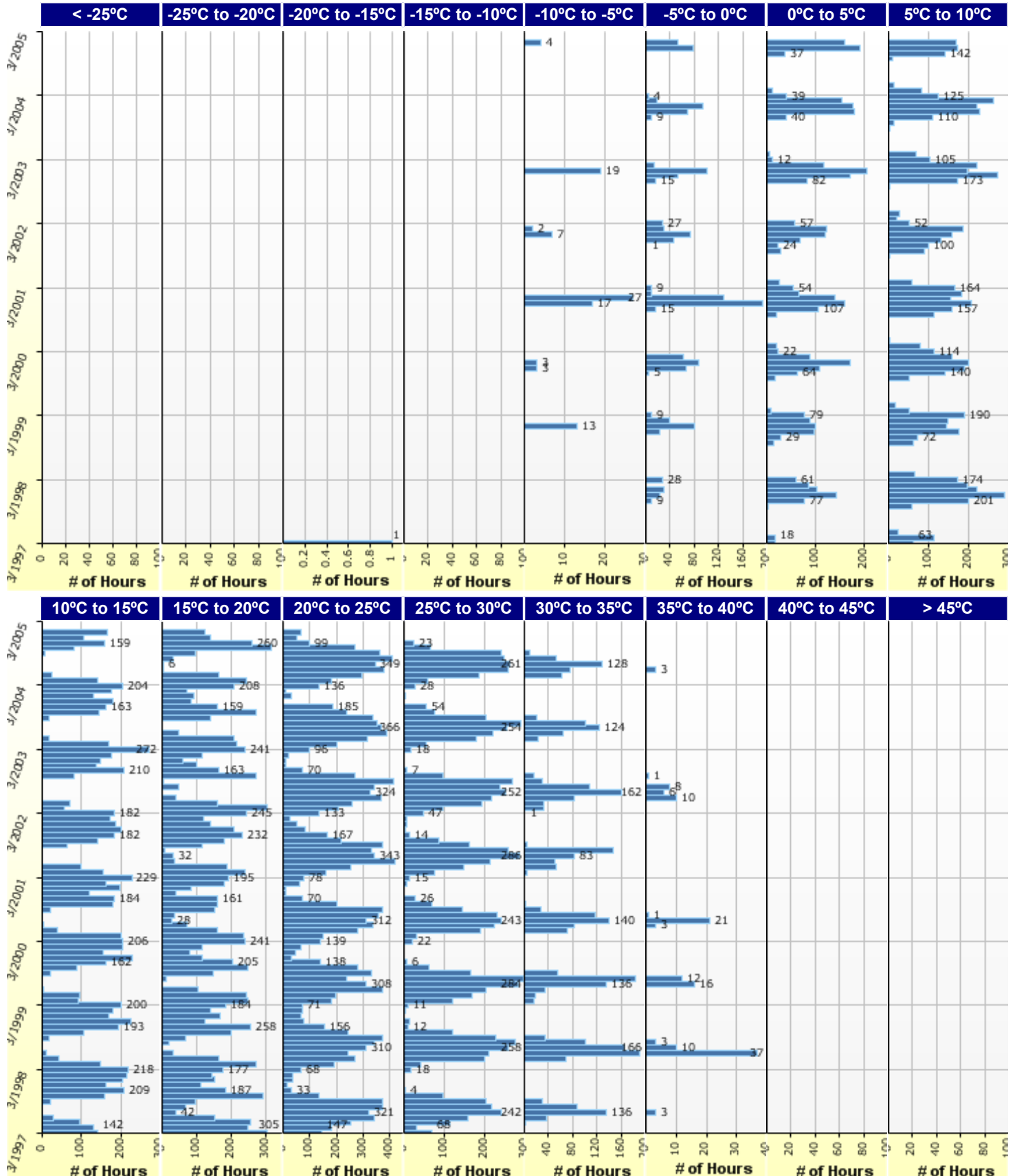


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF4_ALT4

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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

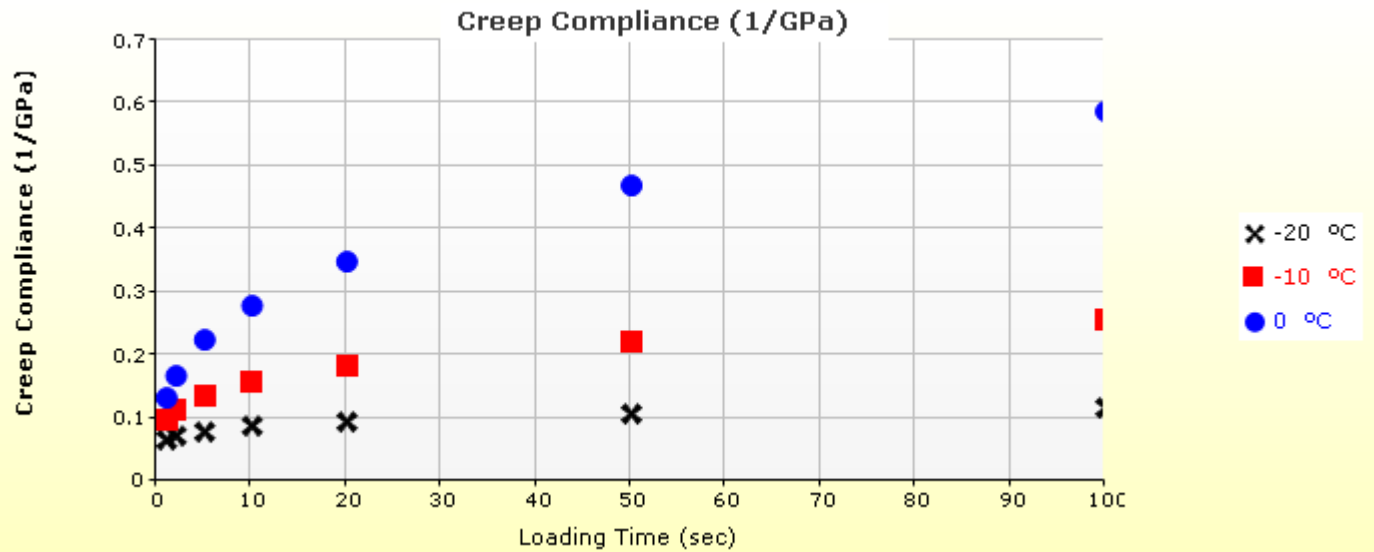
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Chemically Stabilized : Cement stabilized	Chemically Stabilized (2)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-1-a	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

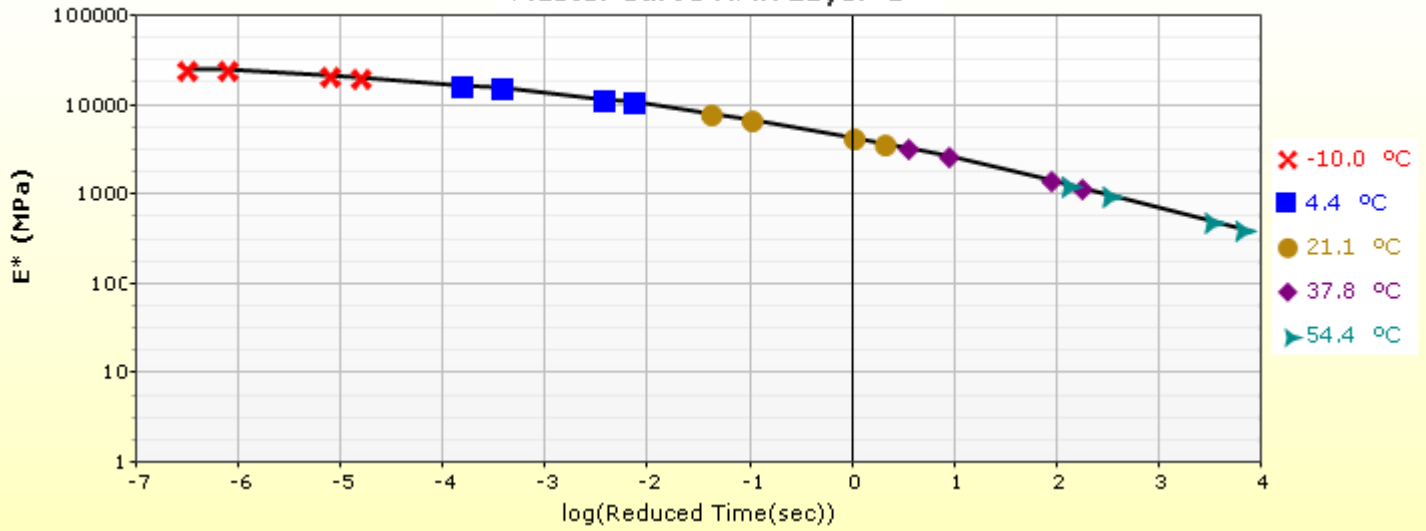
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

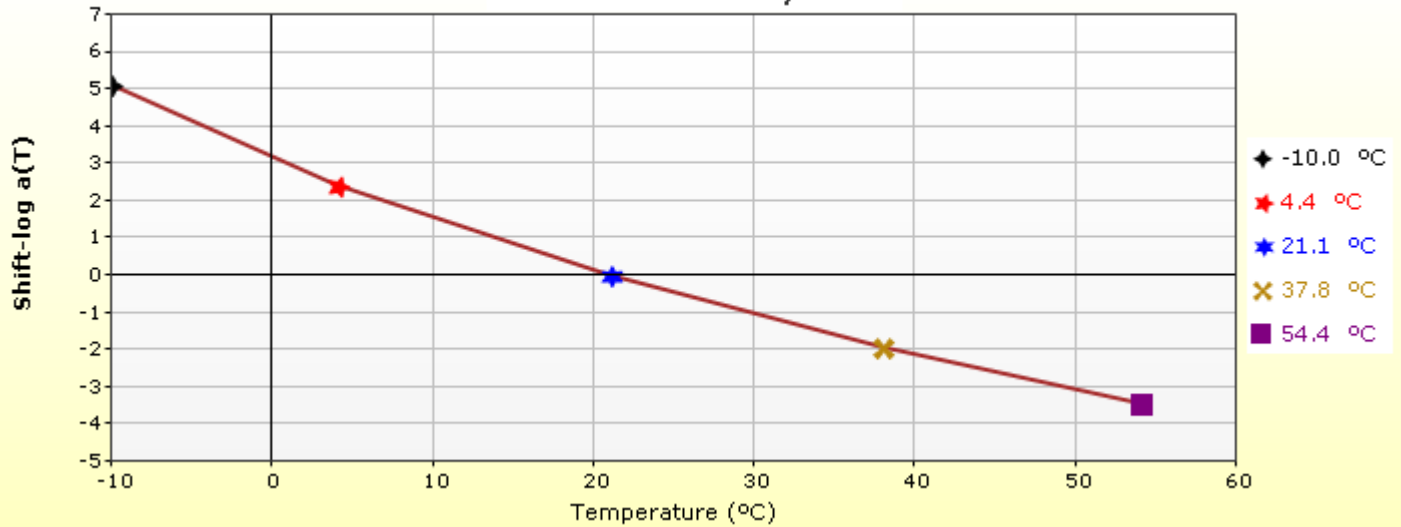


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

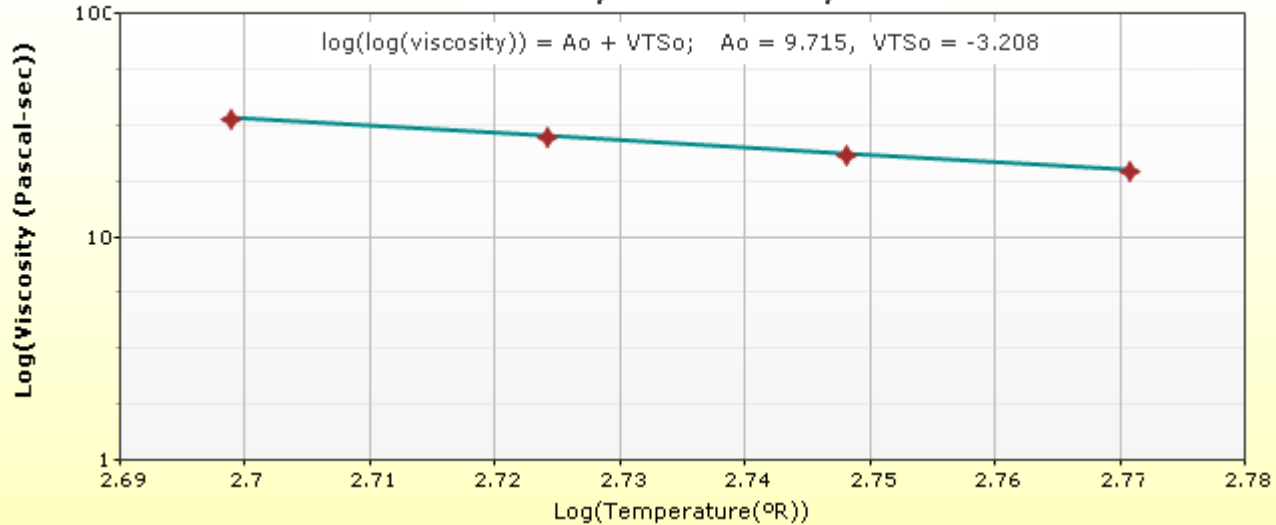
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

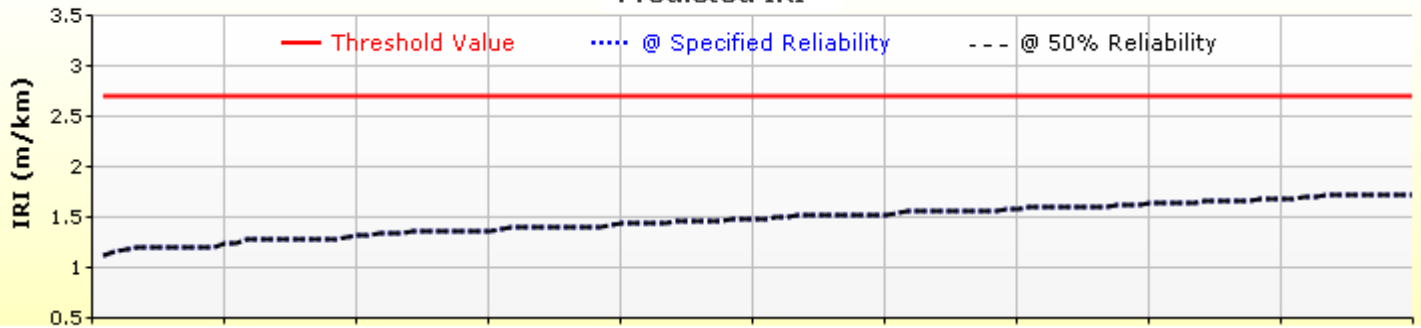


Viscosity Curve HMA Layer 1

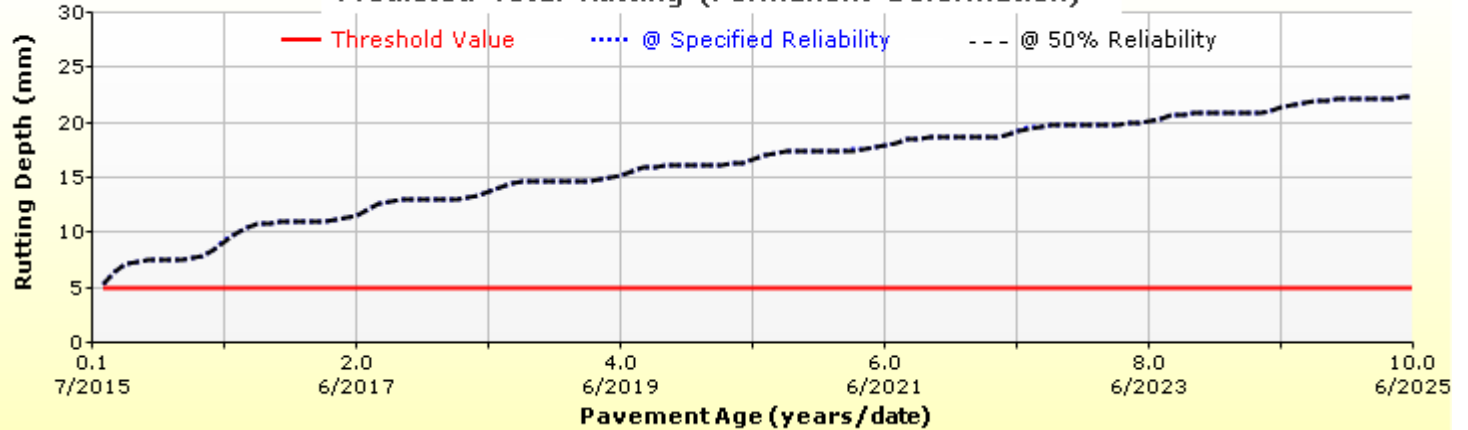


Analysis Output Charts

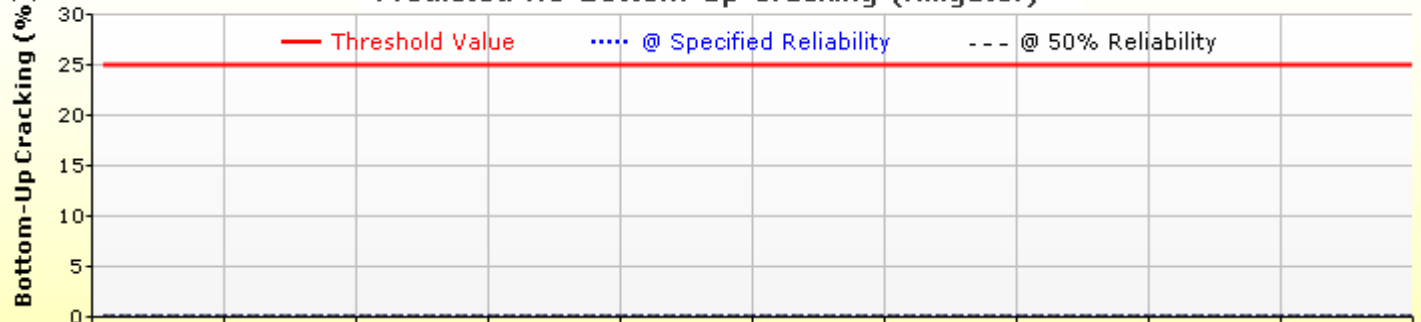
Predicted IRI



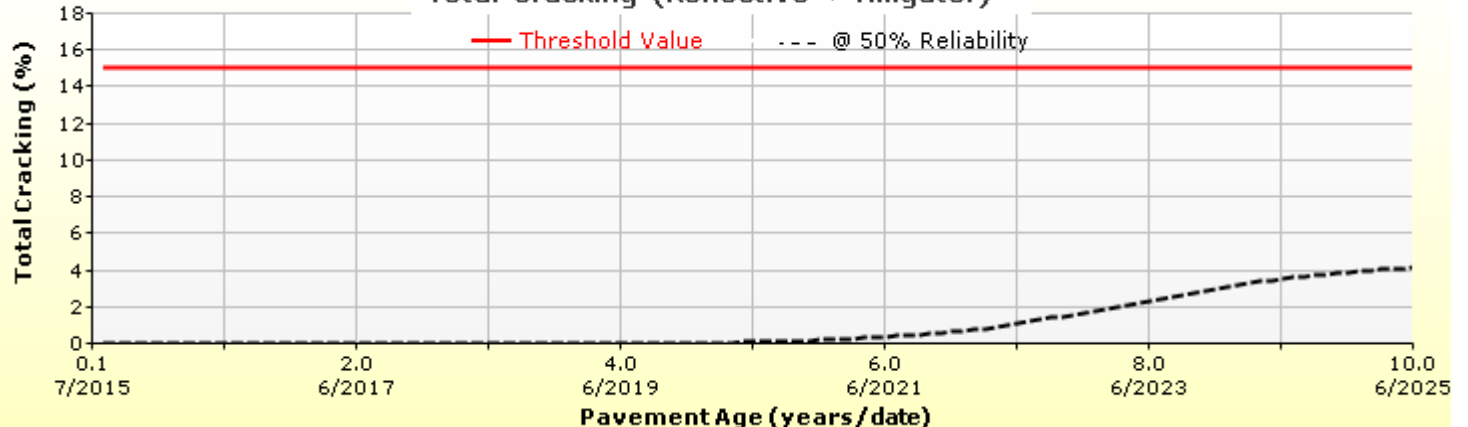
Predicted Total Rutting (Permanent Deformation)

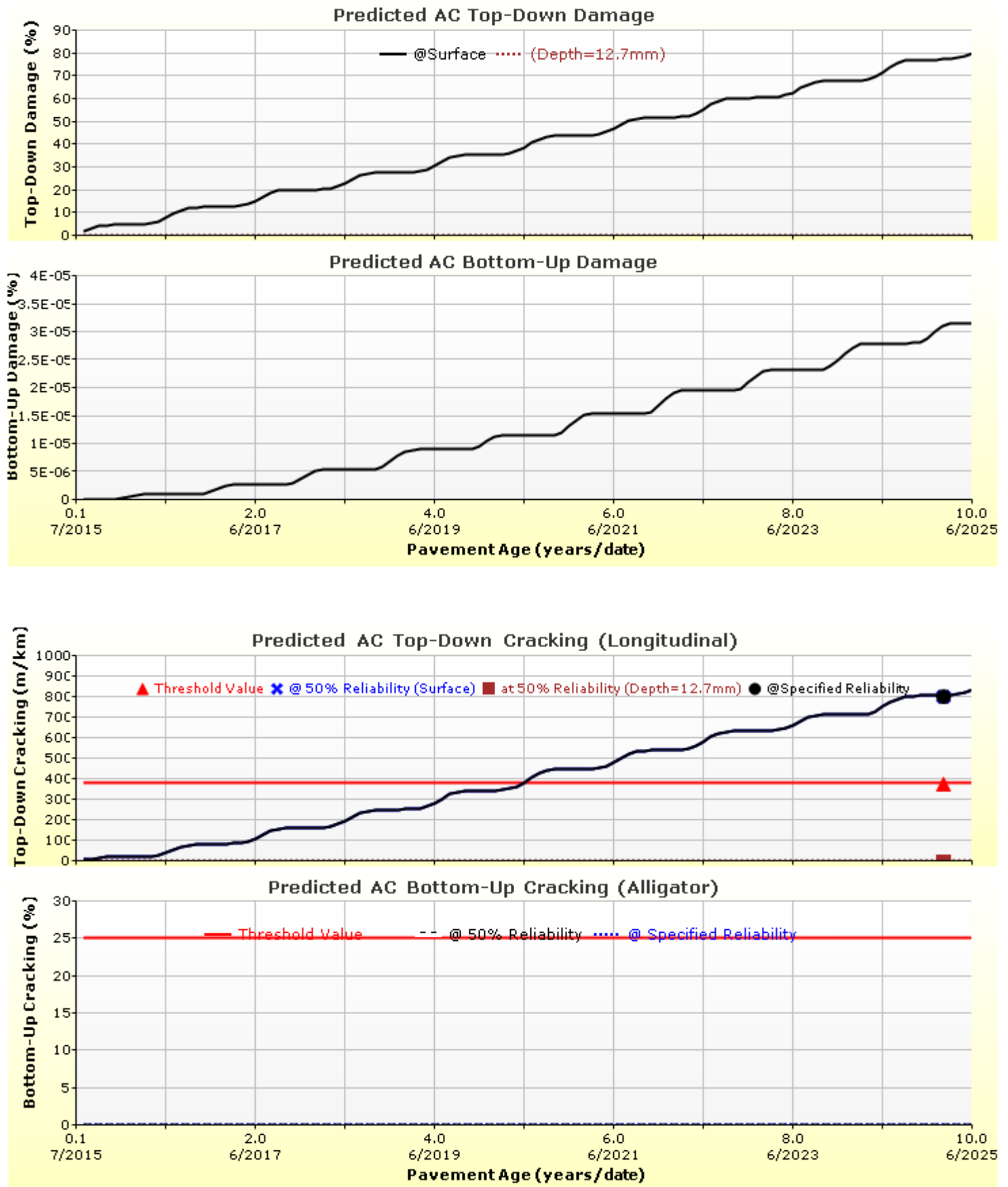


Predicted AC Bottom-Up Cracking (Alligator)

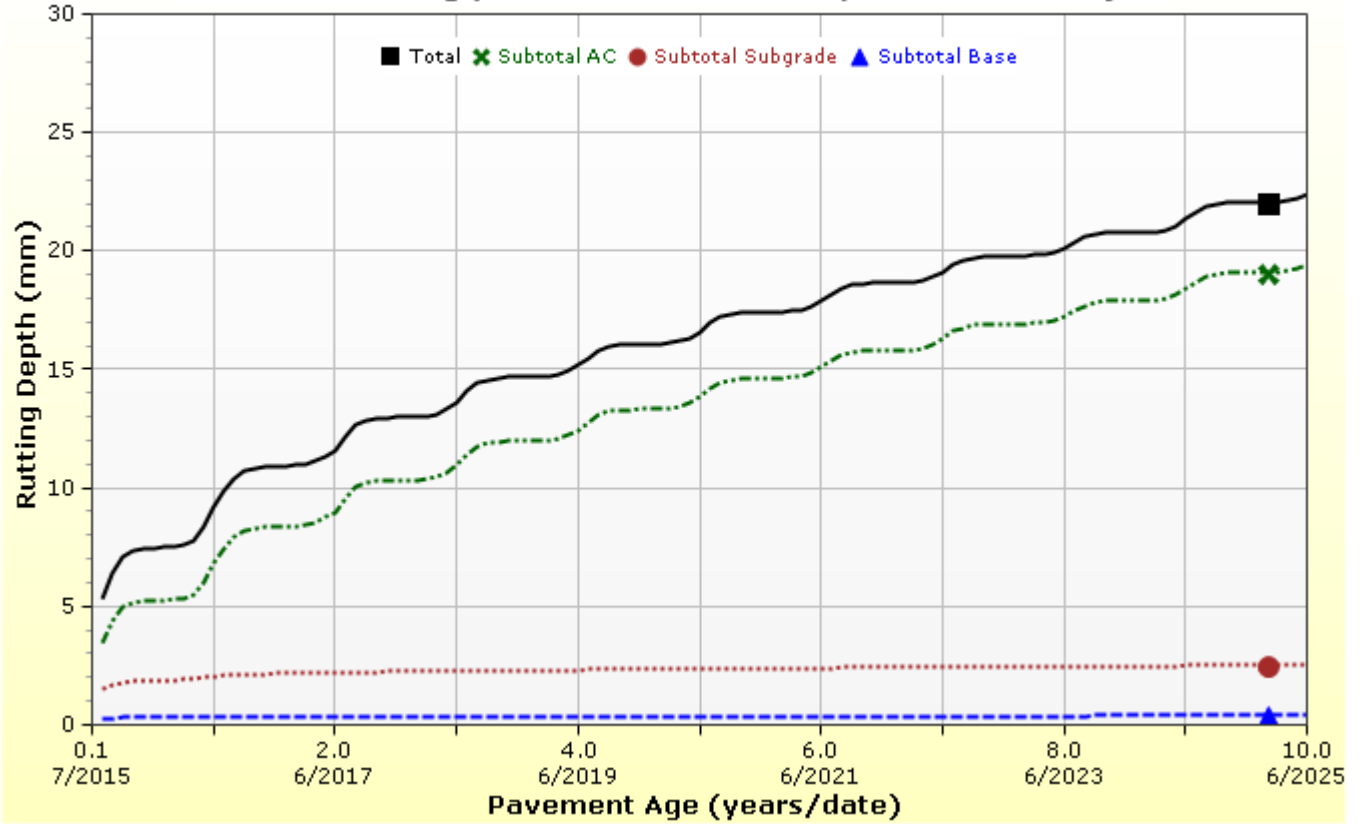


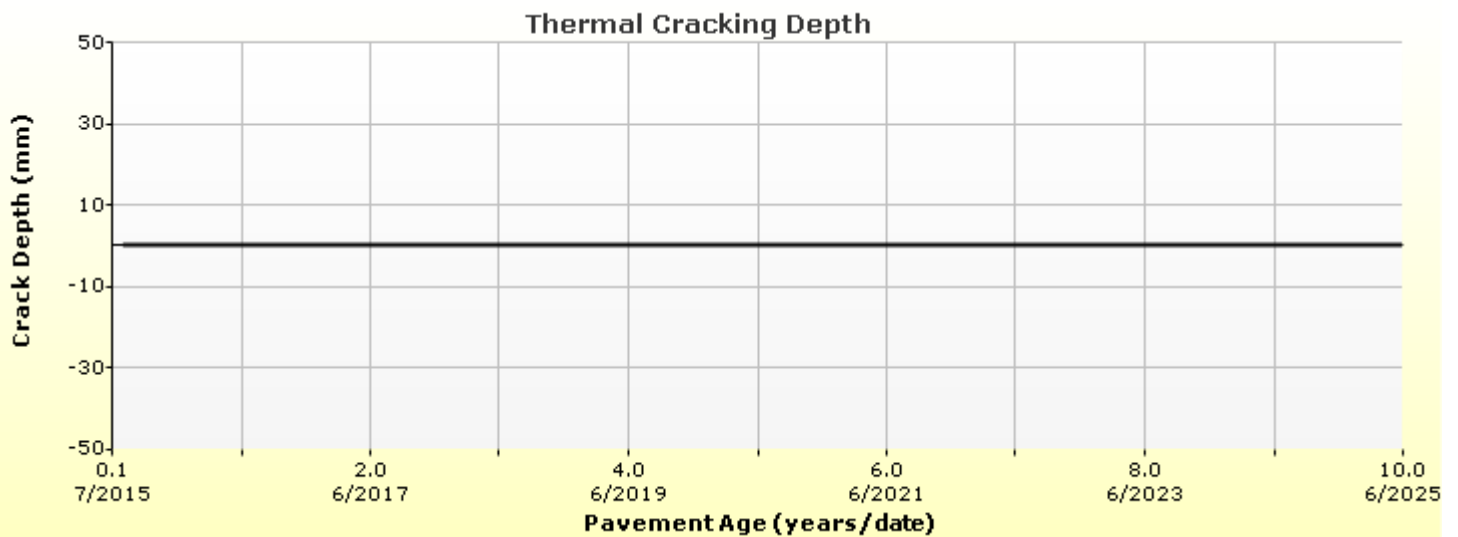
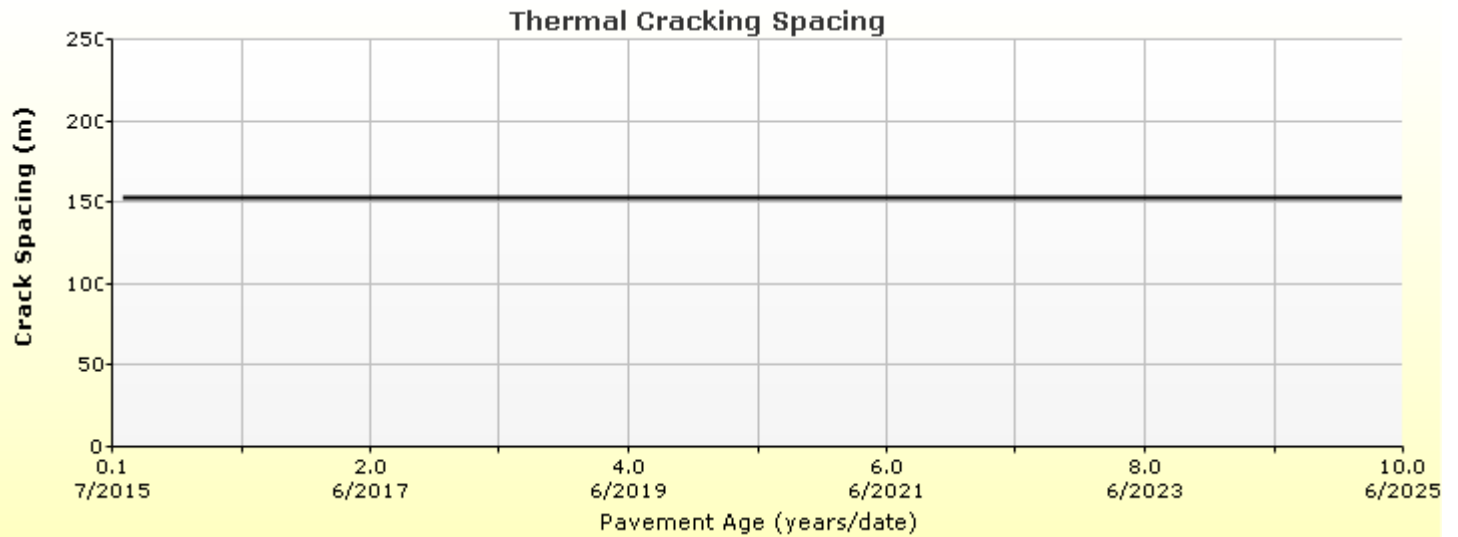
Total Cracking (Reflective + Alligator)

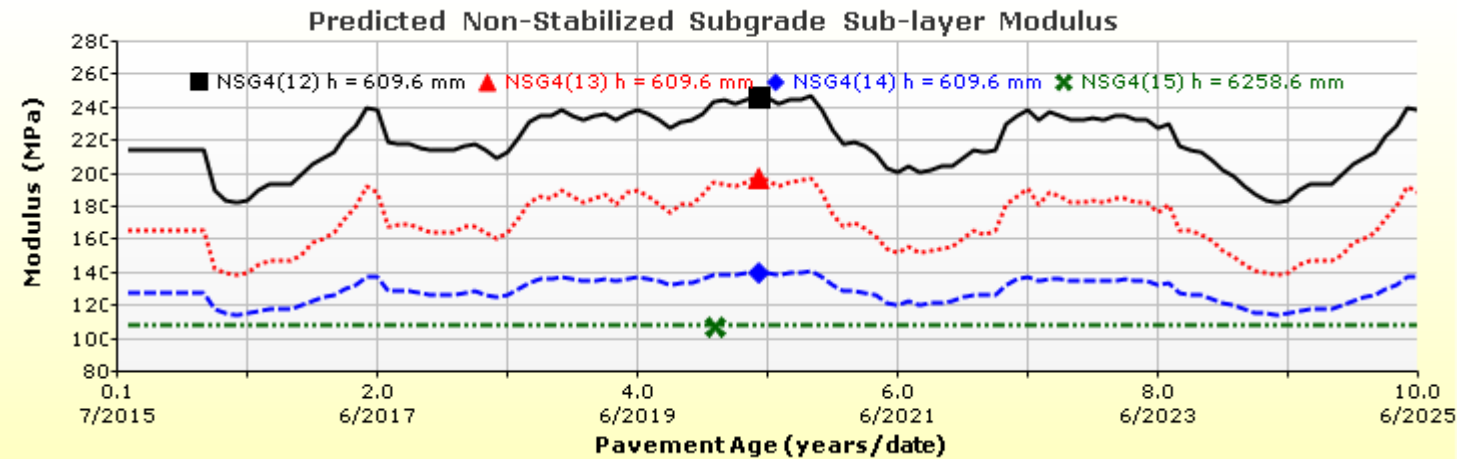
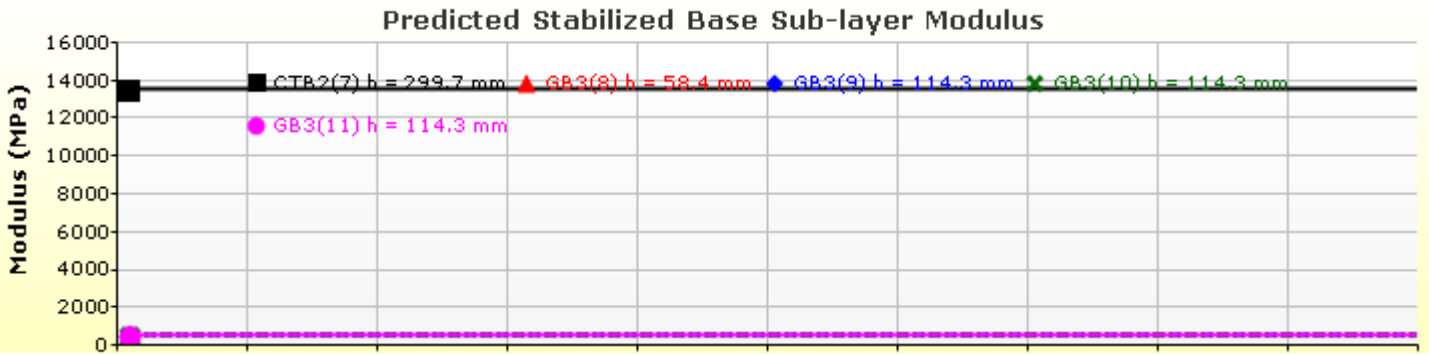
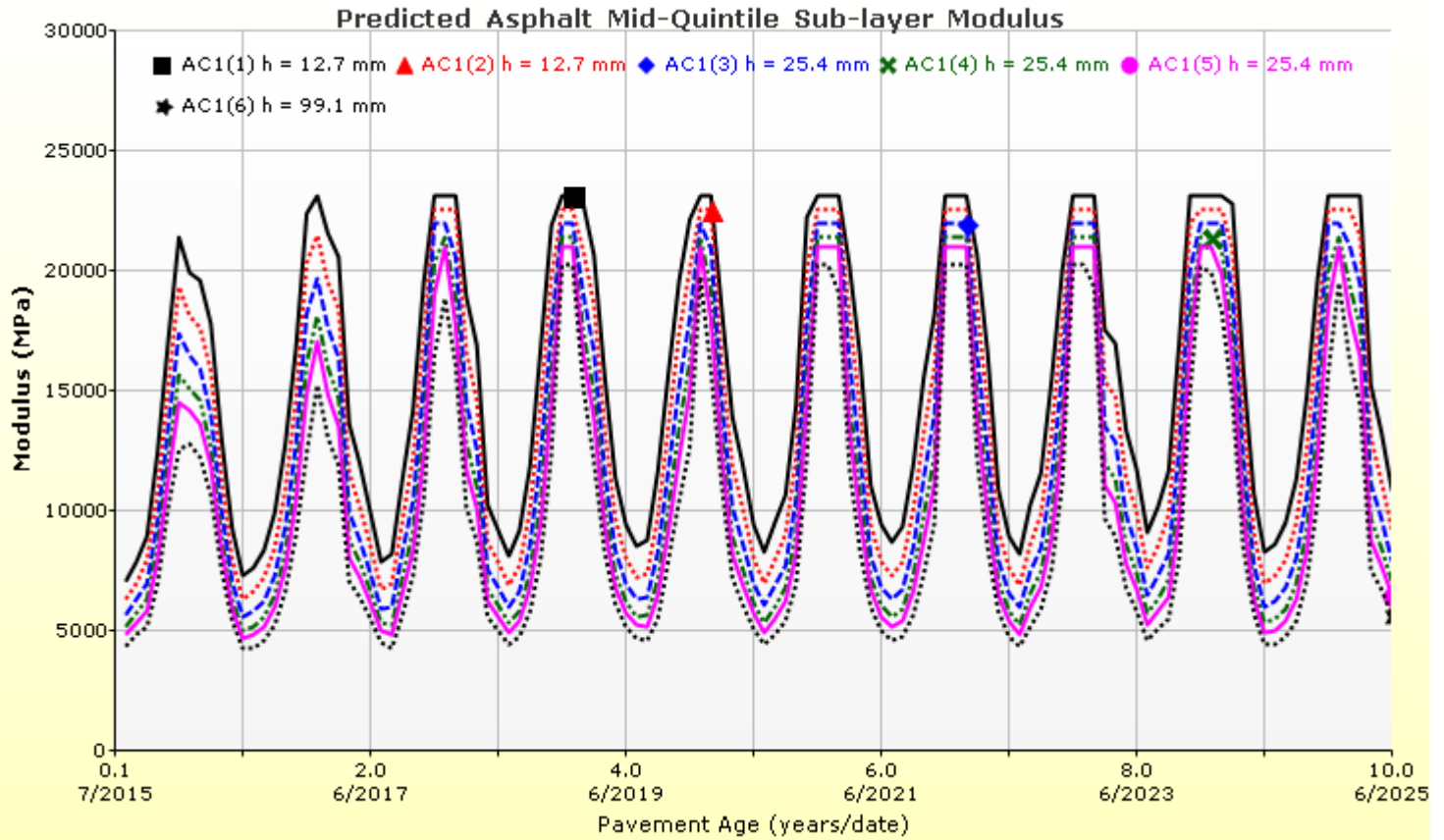




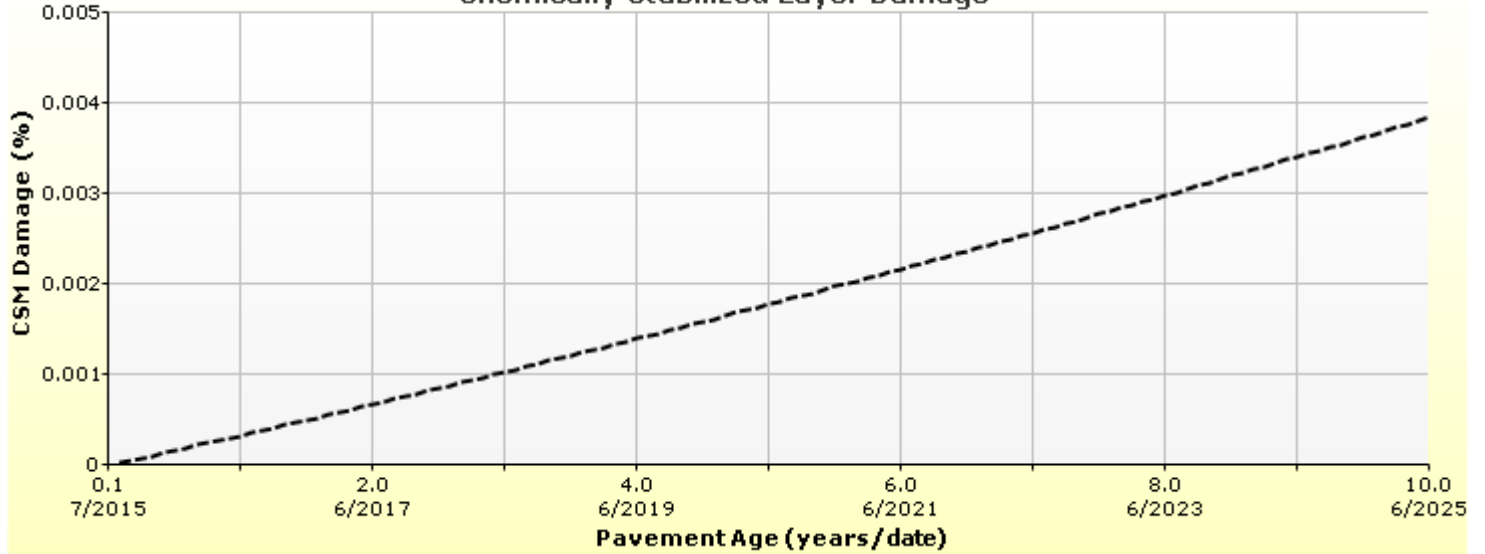
Predicted Rutting (Permanent Deformation) at 50% Reliability



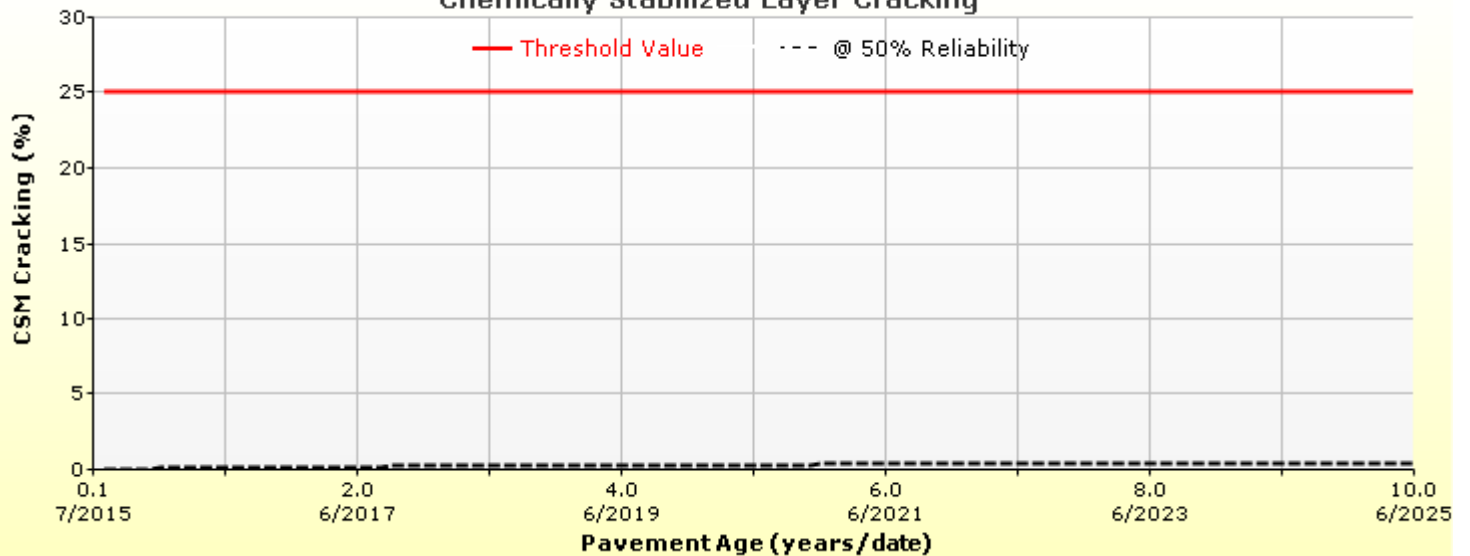




Chemically Stabilized Layer Damage



Chemically Stabilized Layer Cracking



Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	200.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 Chemically Stabilized : Cement stabilized

Chemically Stabilized

Layer thickness (mm)	300
Poisson's ratio	0.2
Unit weight (kgf/m ³)	2400

Strength

Elastic/resilient modulus (MPa)	13790

Thermal

Heat capacity (joule/kg-kelvin)	1172.3
Thermal conductivity (watt/meter-kelvin)	2.16

Identifiers

Field	Value
Display name/identifier	Cement stabilized
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 3 Non-stabilized Base : Crushed stone

Unbound

Layer thickness (mm)	400.0
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 (MPa)

Resilient Modulus (MPa)

500.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-1-a

Unbound

Layer thickness (mm)	Semi-infinite
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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	A-1-a
Description of object	Default Material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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

Calibration Coefficients

AC Fatigue

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = total\ AC\ thickness(in)$	$\varepsilon_p = plastic\ strain(in/in)$ $\varepsilon_r = resilient\ strain(in/in)$ $T = layer\ temperature(^{\circ}F)$ $N = number\ of\ load\ repetitions$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma} \right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = observed\ amount\ of\ thermal\ cracking(ft/500ft)$ $k = regression\ coefficient\ determined\ through\ field\ calibration$ $N() = standard\ normal\ distribution\ evaluated\ at()$ $\sigma = standard\ deviation\ of\ the\ log\ of\ the\ depth\ of\ cracks\ in\ the\ pavments$ $C = crack\ depth(in)$ $h_{ac} = thickness\ of\ asphalt\ layer(in)$ $\Delta C = Change\ in\ the\ crack\ depth\ due\ to\ a\ cooling\ cycle$ $\Delta K = Change\ in\ the\ stress\ intensity\ factor\ due\ to\ a\ cooling\ cycle$ $A, n = Fracture\ parameters\ for\ the\ asphalt\ mixture$ $E = mixture\ stiffness$ $\sigma_m = Undamaged\ mixture\ tensile\ strength$ $\beta_t = Calibration\ parameter$
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

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

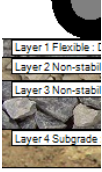
C3: 0.008

C4: 0.015

Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data: 32.119, -81.202
 Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
 Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

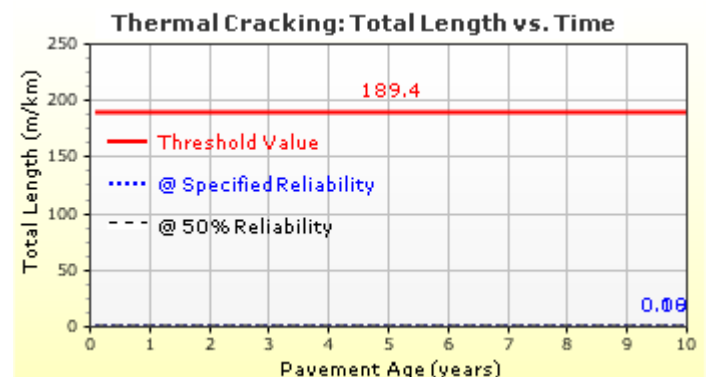
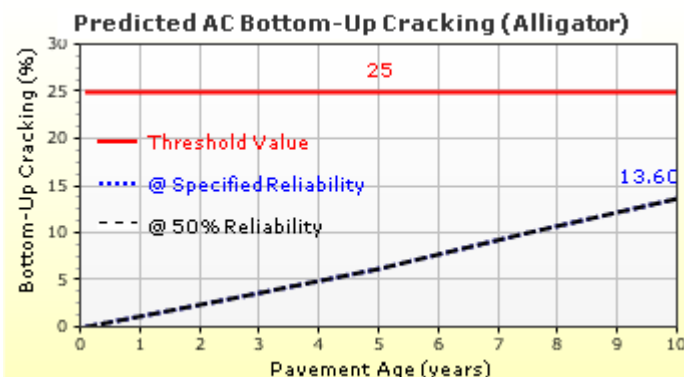
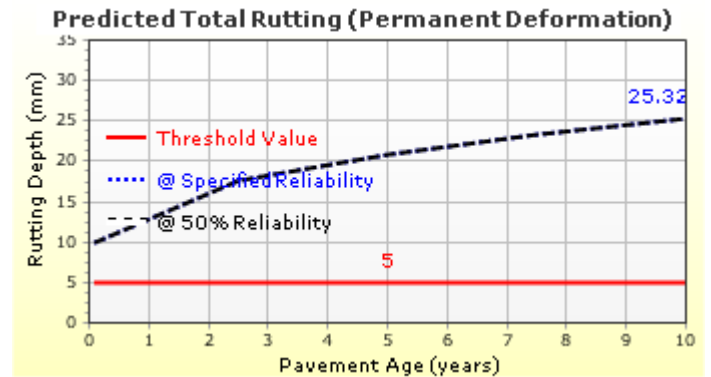
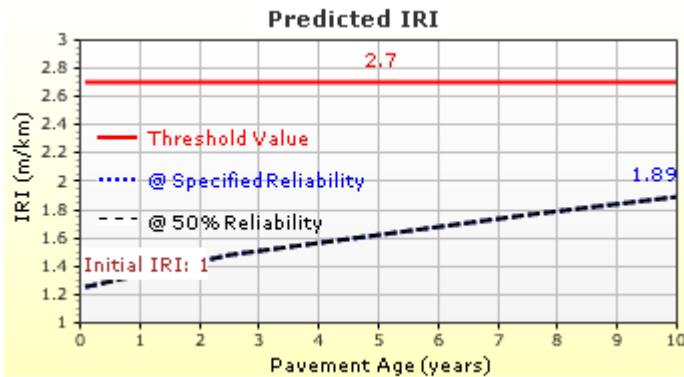
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	4,820
2020 (5 years)	4,486,440
2025 (10 years)	9,687,460

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	1.89	50.00	94.13	Pass
Permanent deformation - total pavement (mm)	5.00	25.33	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	13.60	50.00	79.01	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	285.98	50.00	58.58	Pass
Permanent deformation - AC only (mm)	5.00	10.41	50.00	3.60	Fail

Distress Charts

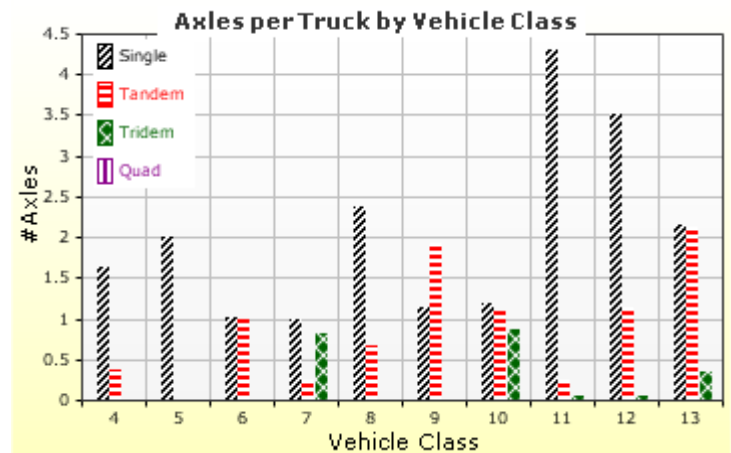
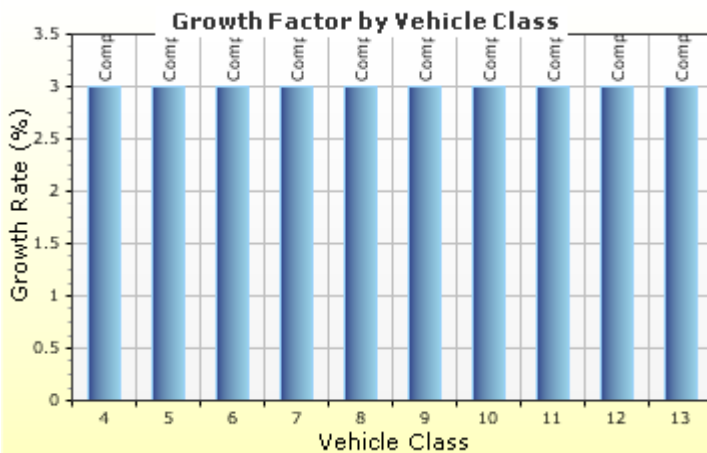
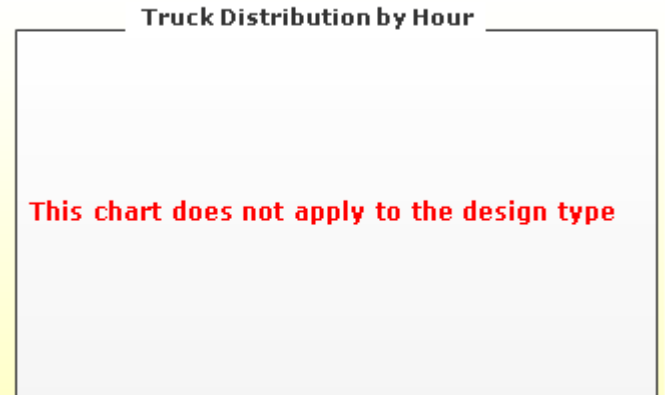
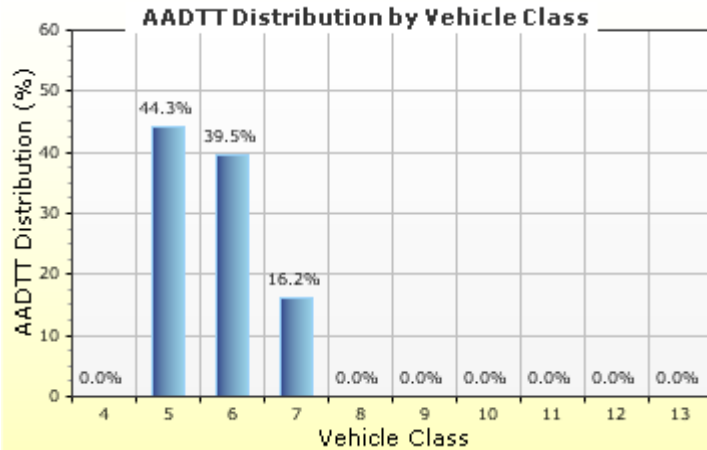


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 4,820
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

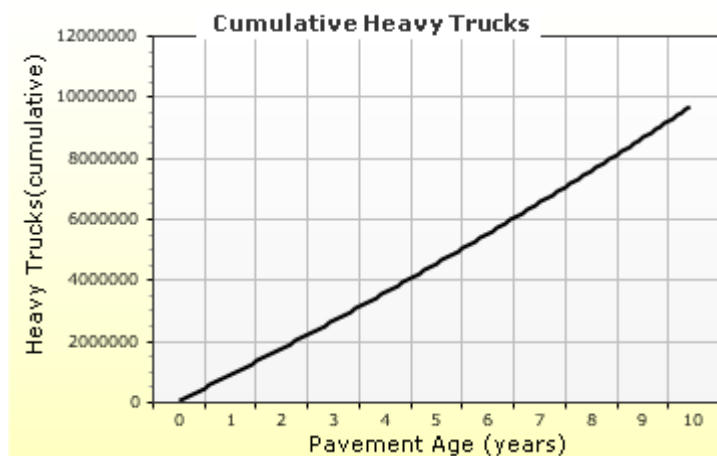
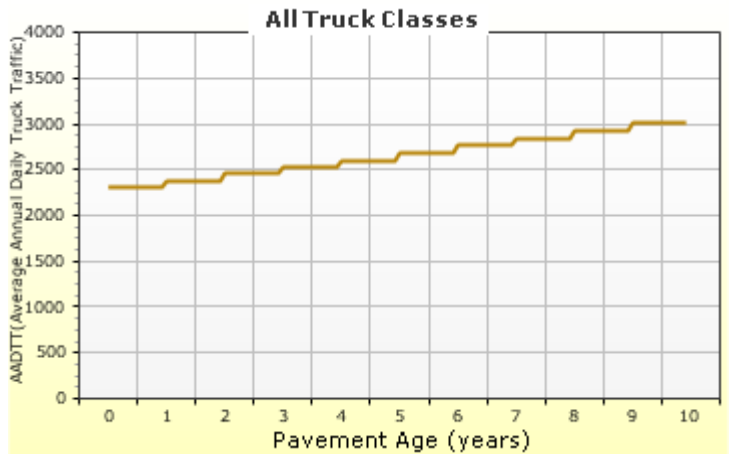
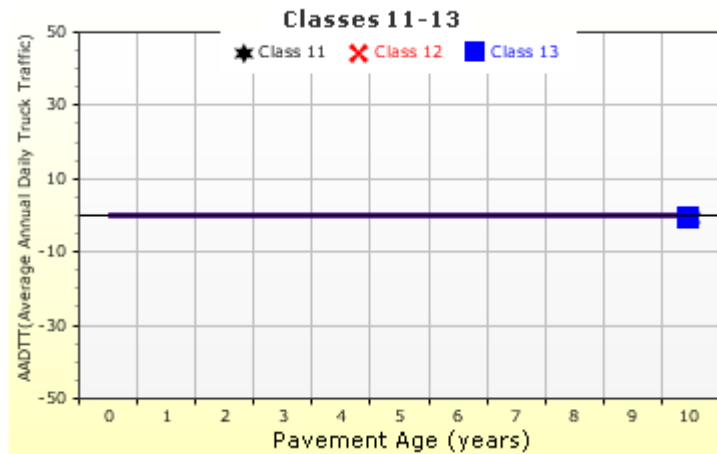
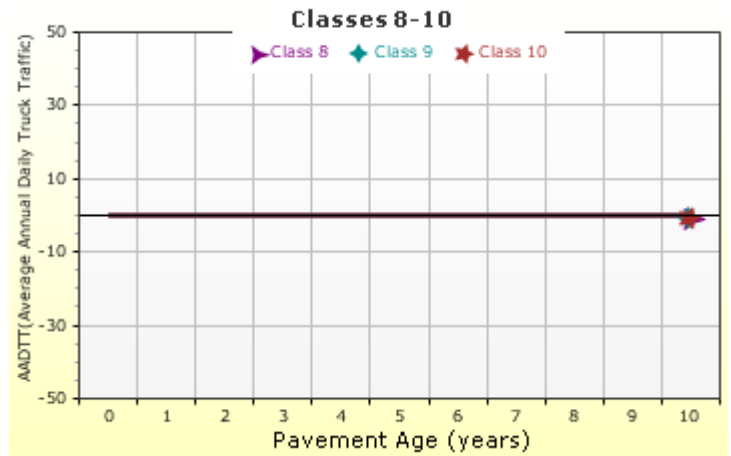
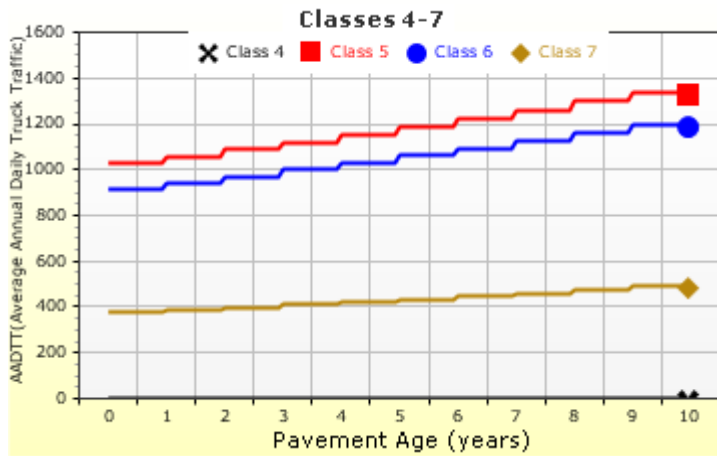
Wheelbase does not apply

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



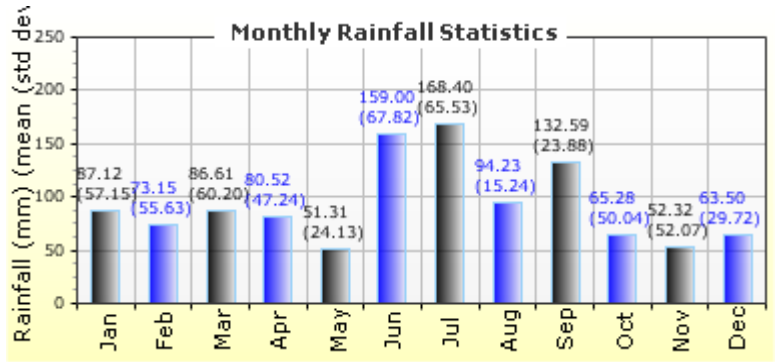
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

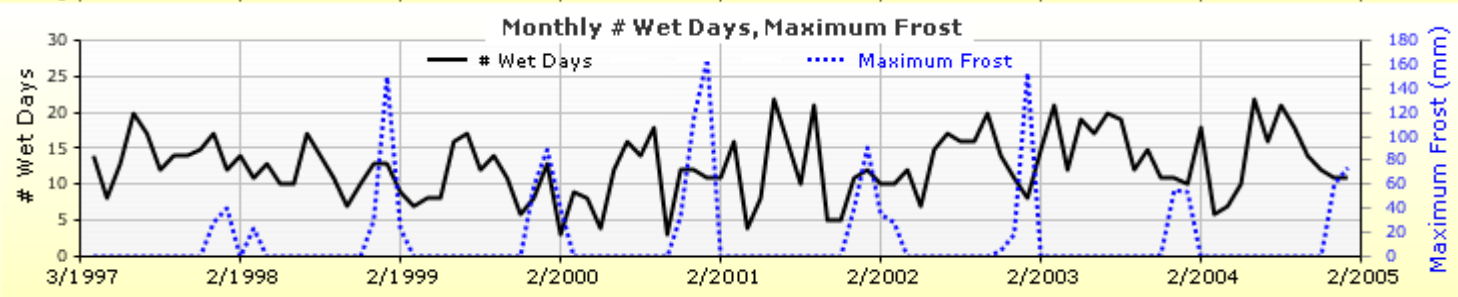
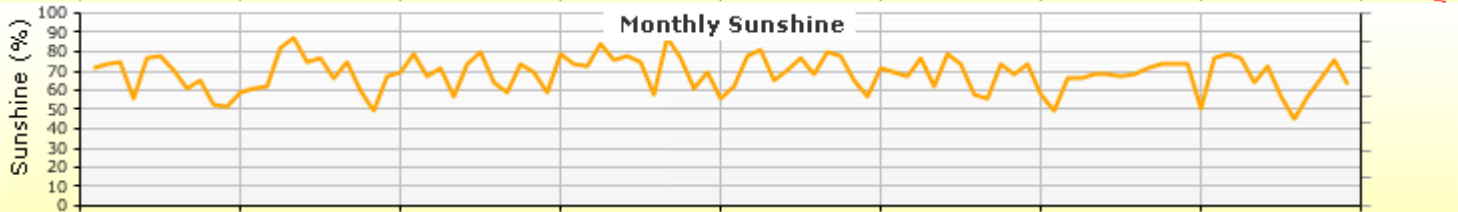
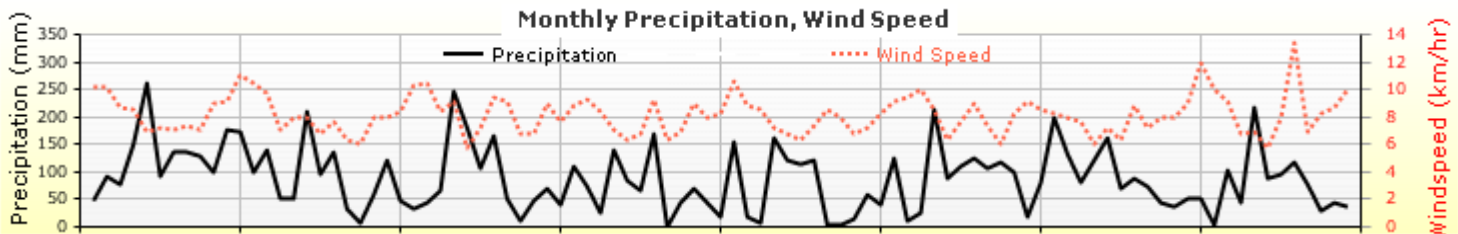
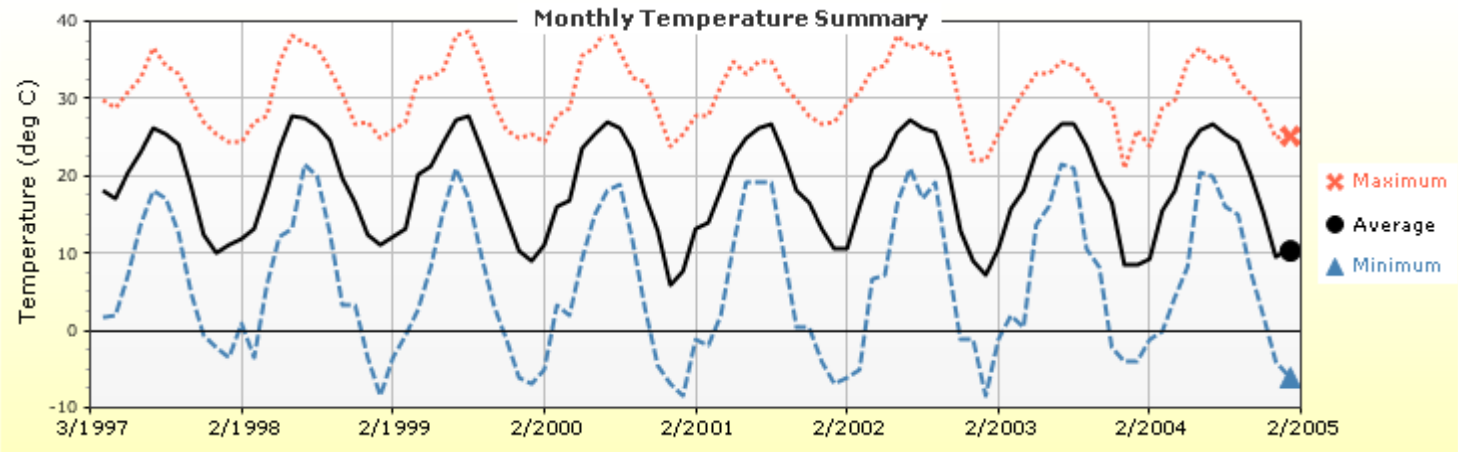
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

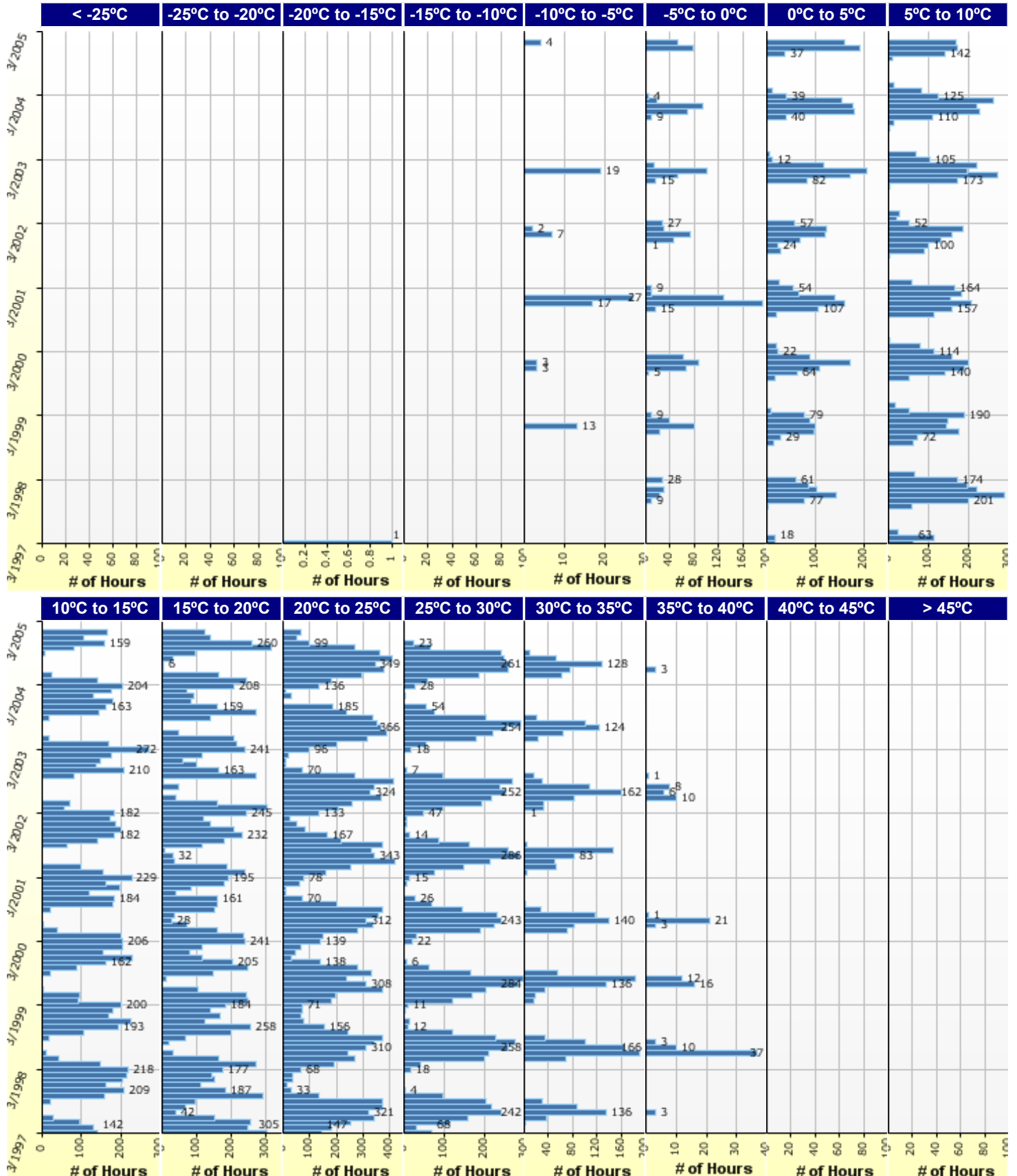


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF1_50%

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF1_50%.dgp



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

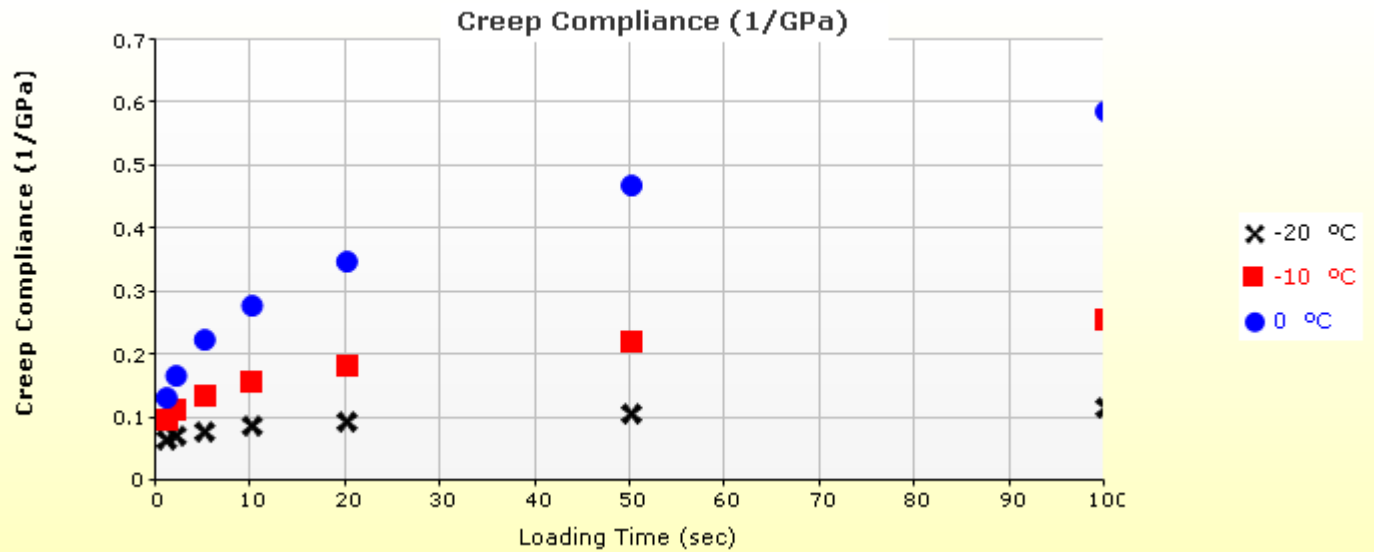
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

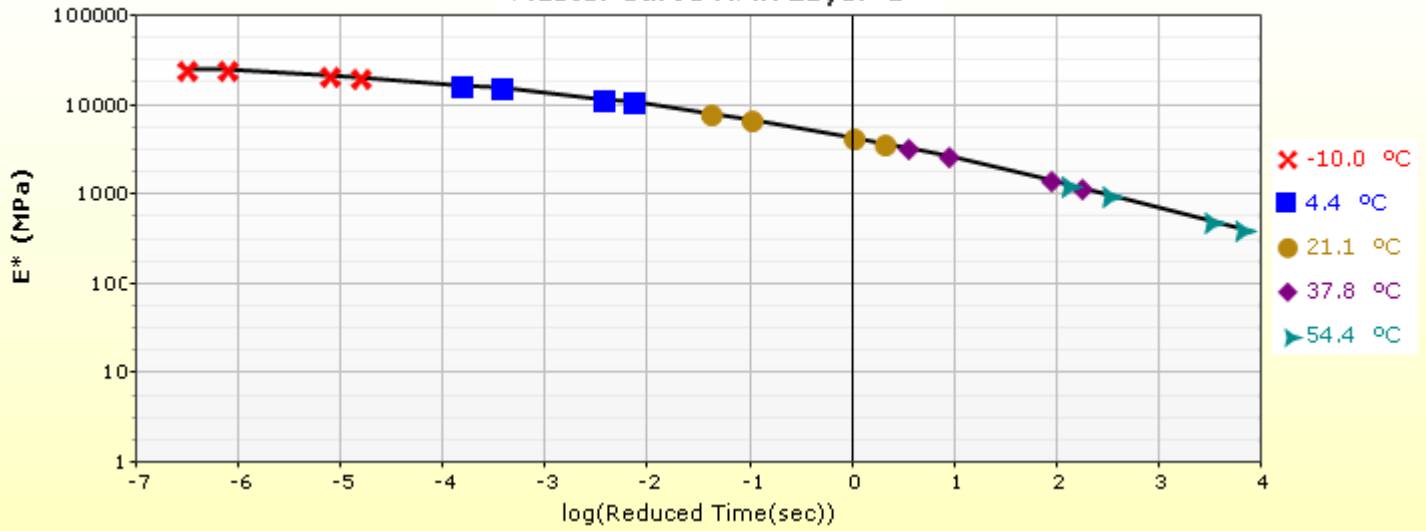
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

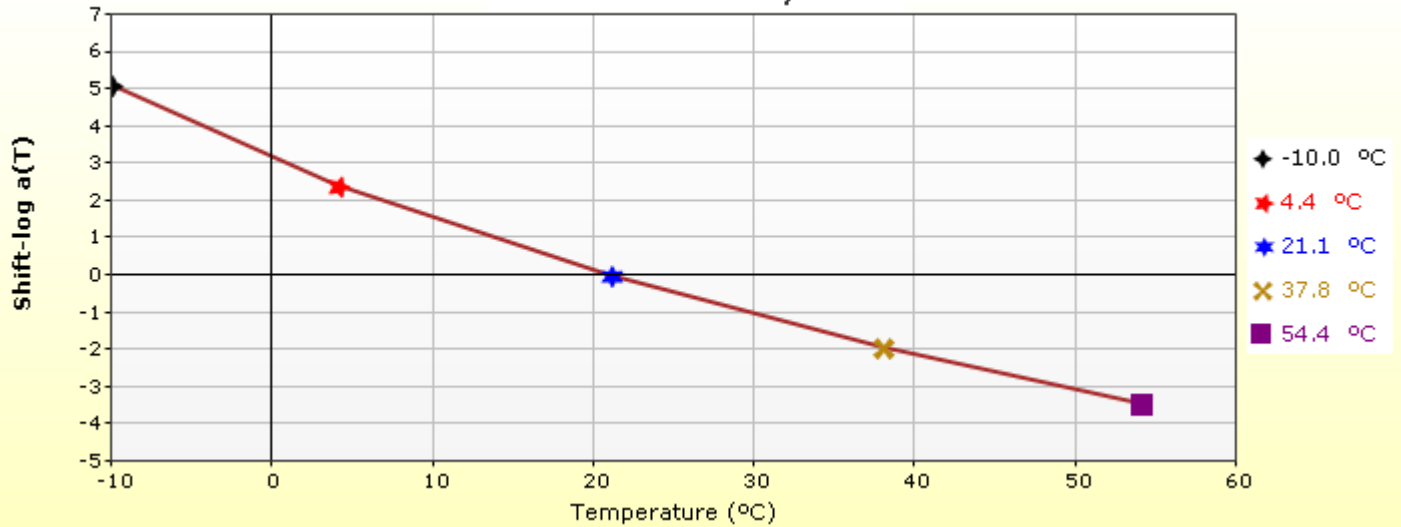


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

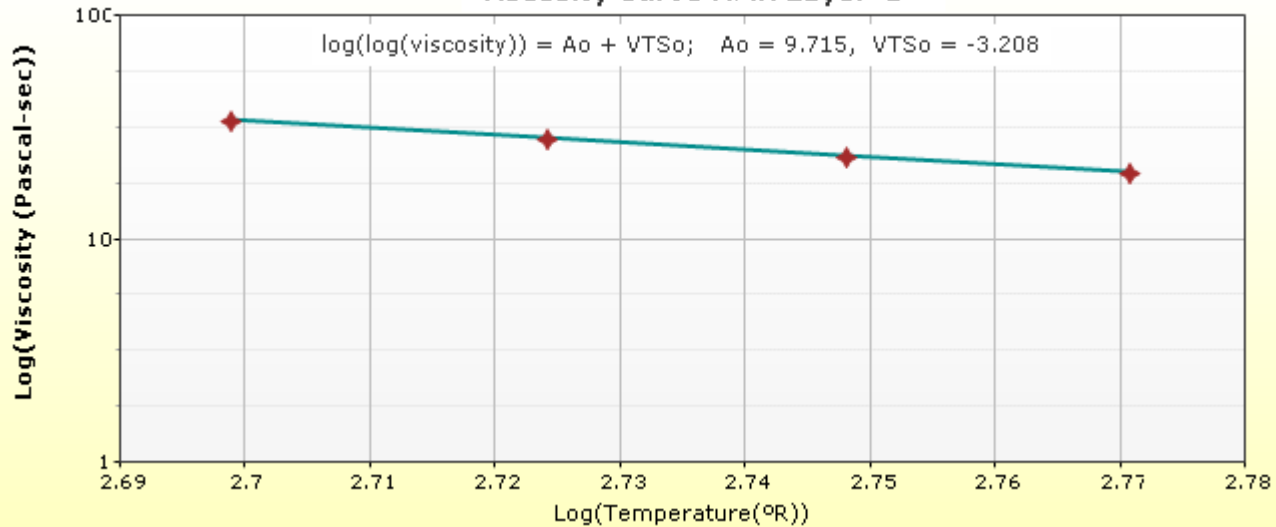
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

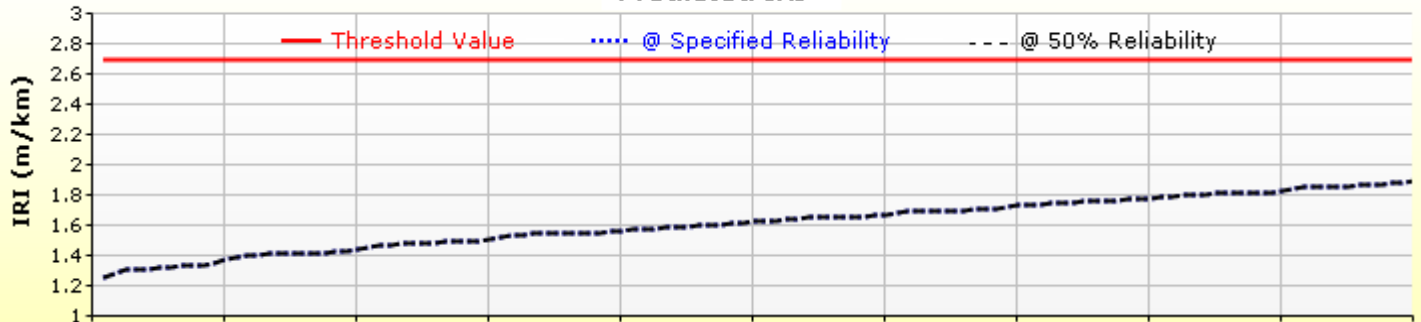


Viscosity Curve HMA Layer 1

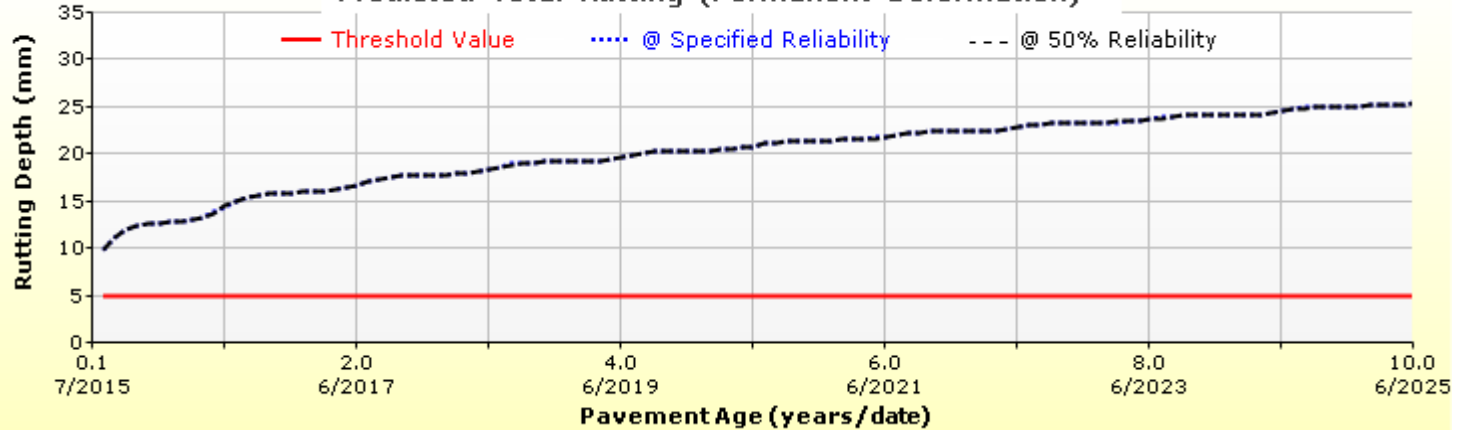


Analysis Output Charts

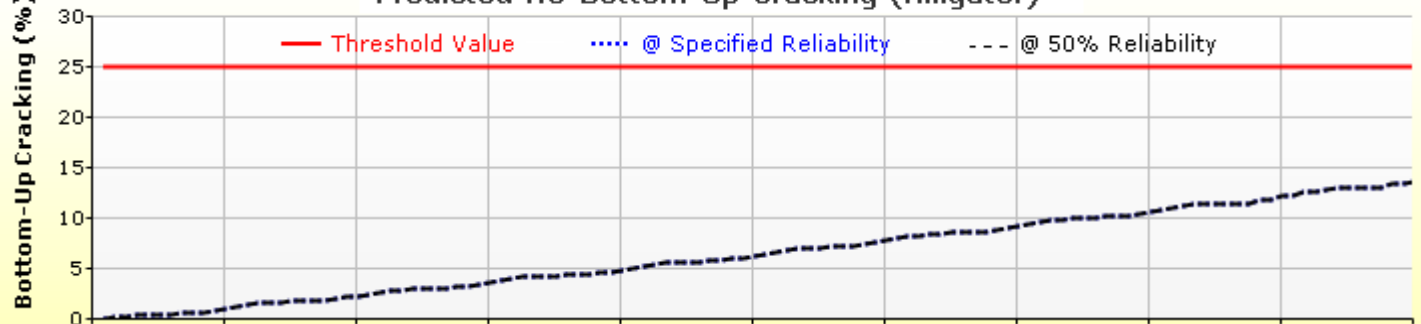
Predicted IRI



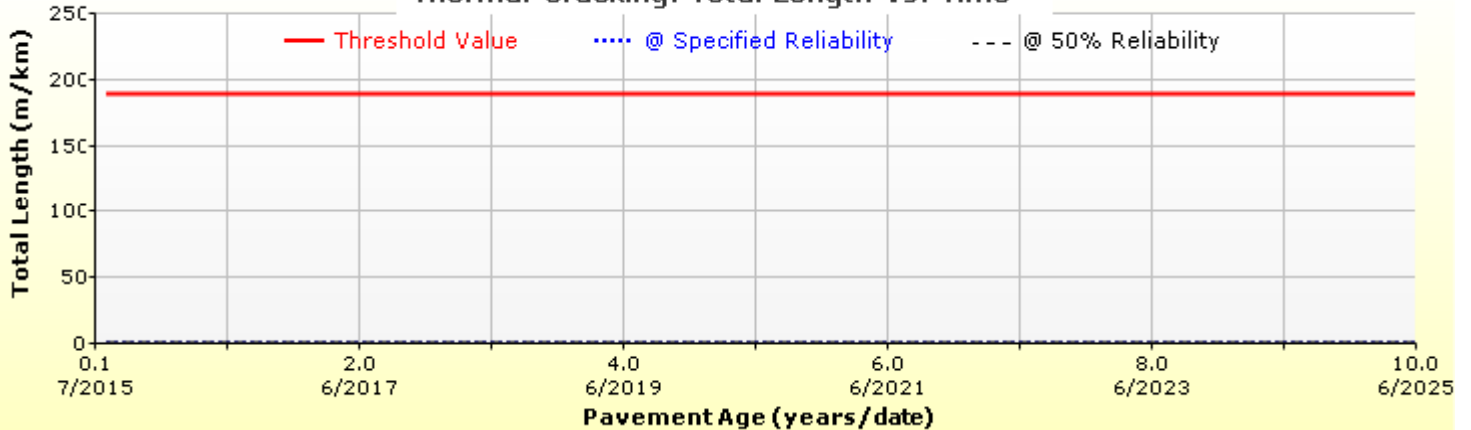
Predicted Total Rutting (Permanent Deformation)



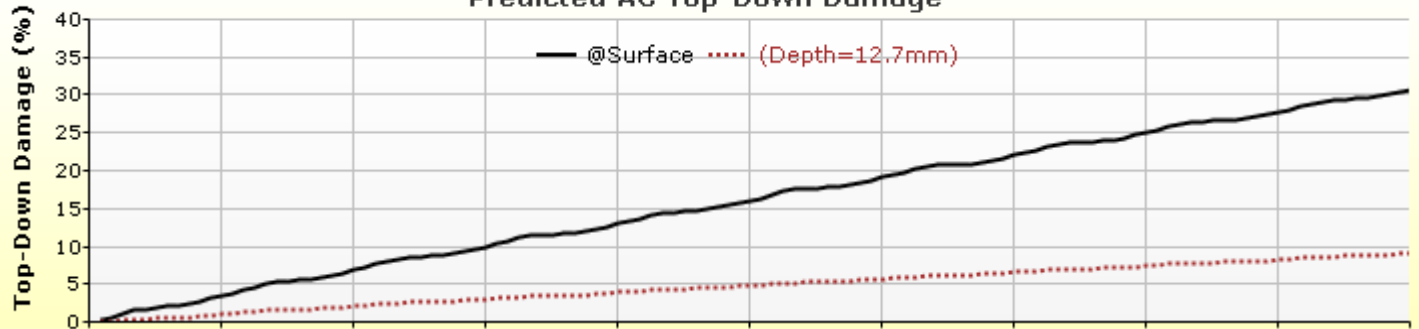
Predicted AC Bottom-Up Cracking (Alligator)



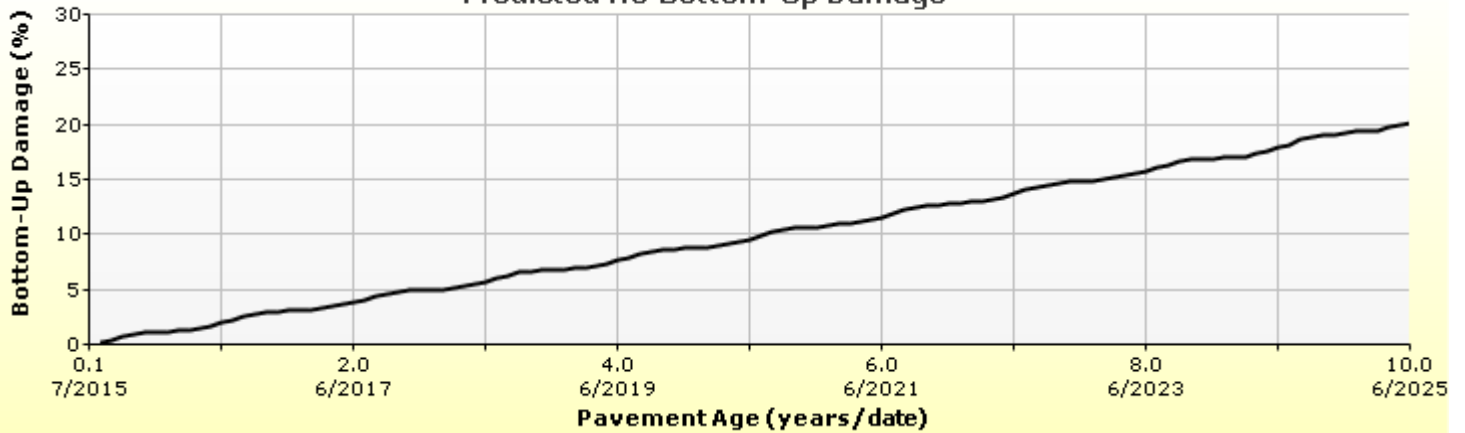
Thermal Cracking: Total Length vs. Time



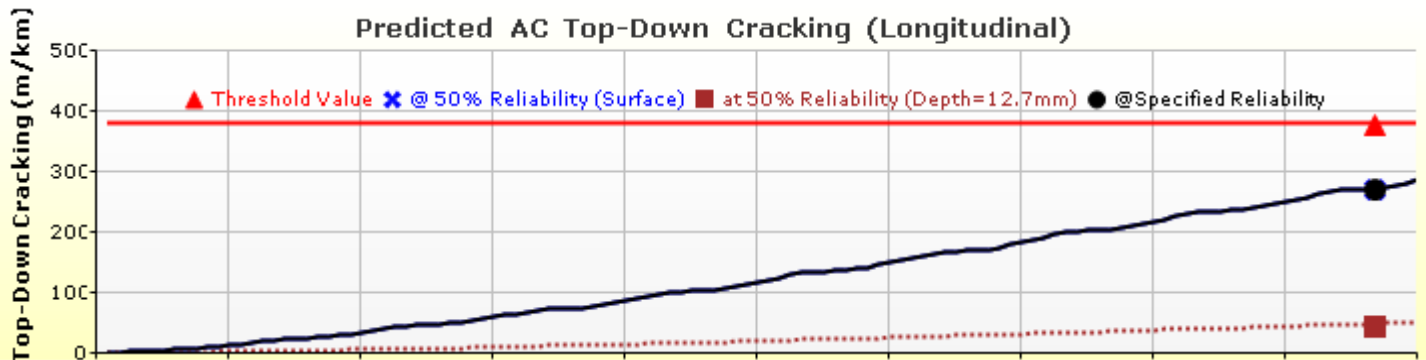
Predicted AC Top-Down Damage



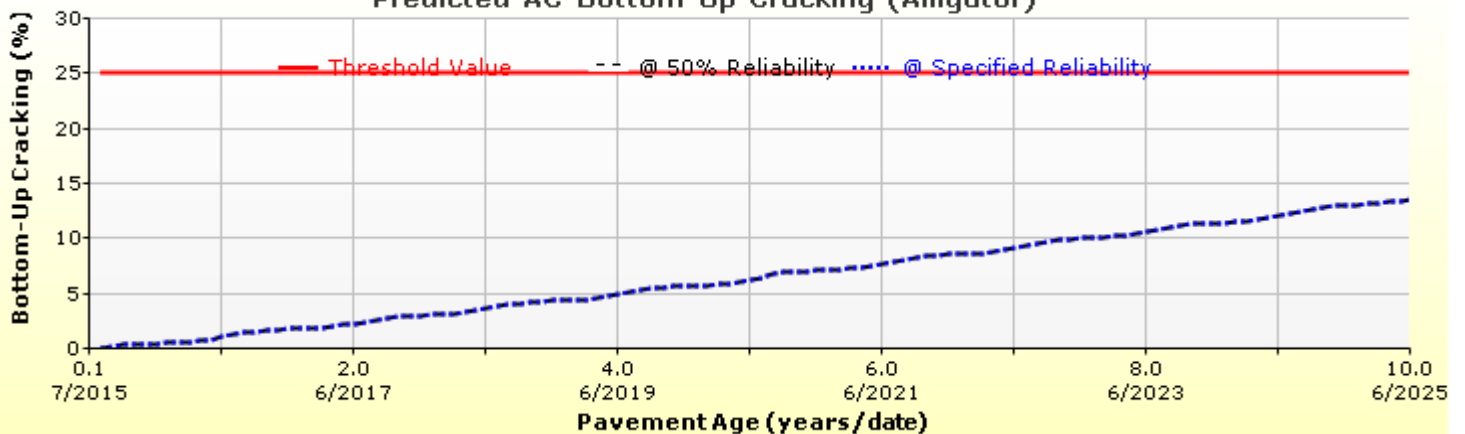
Predicted AC Bottom-Up Damage



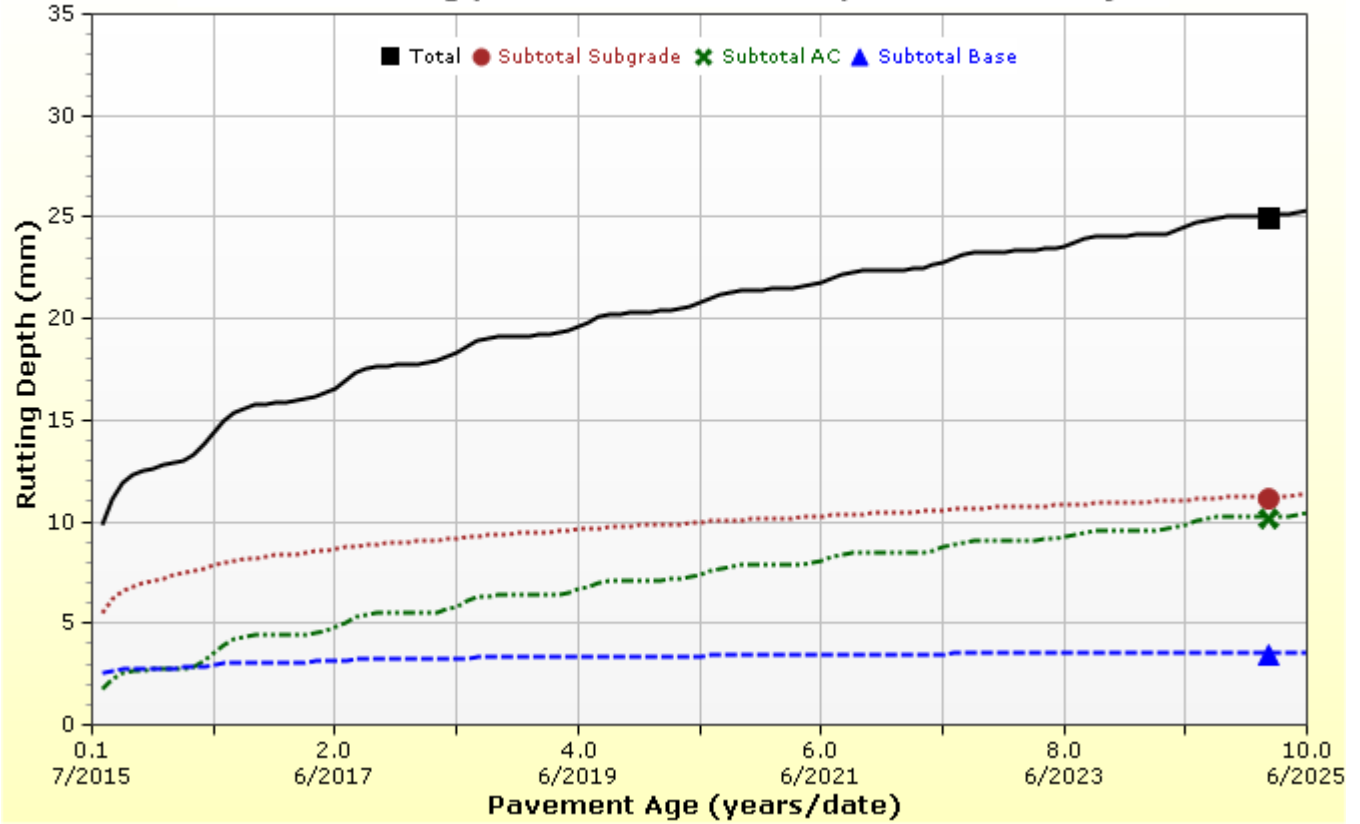
Predicted AC Top-Down Cracking (Longitudinal)

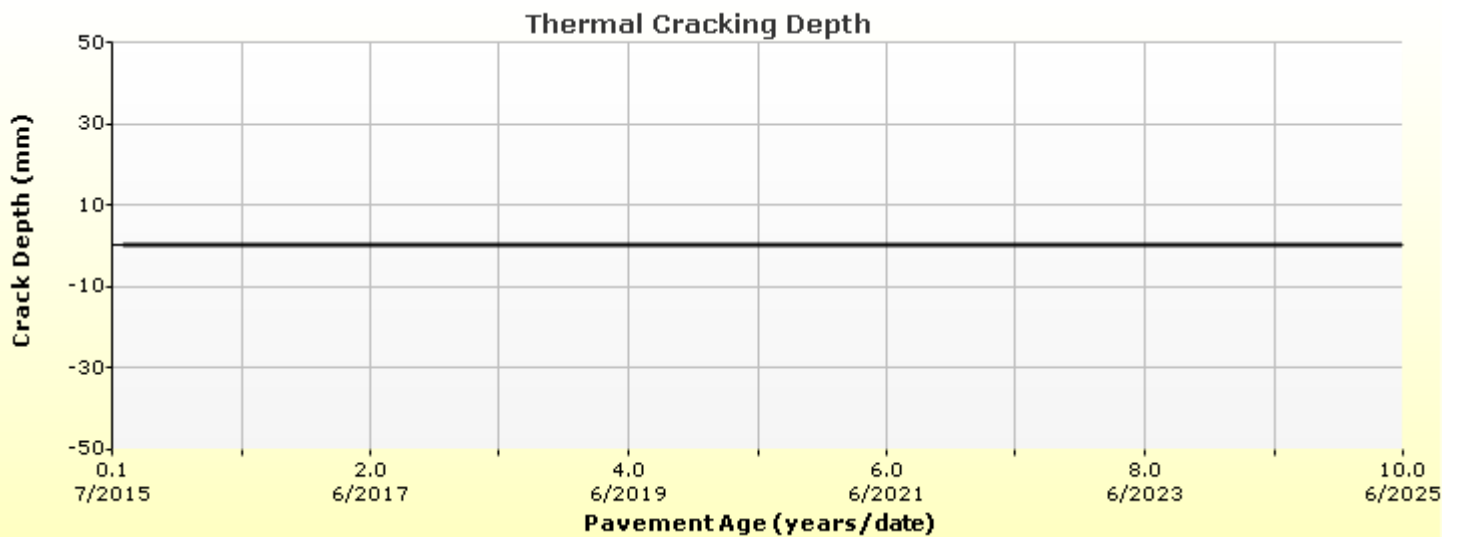
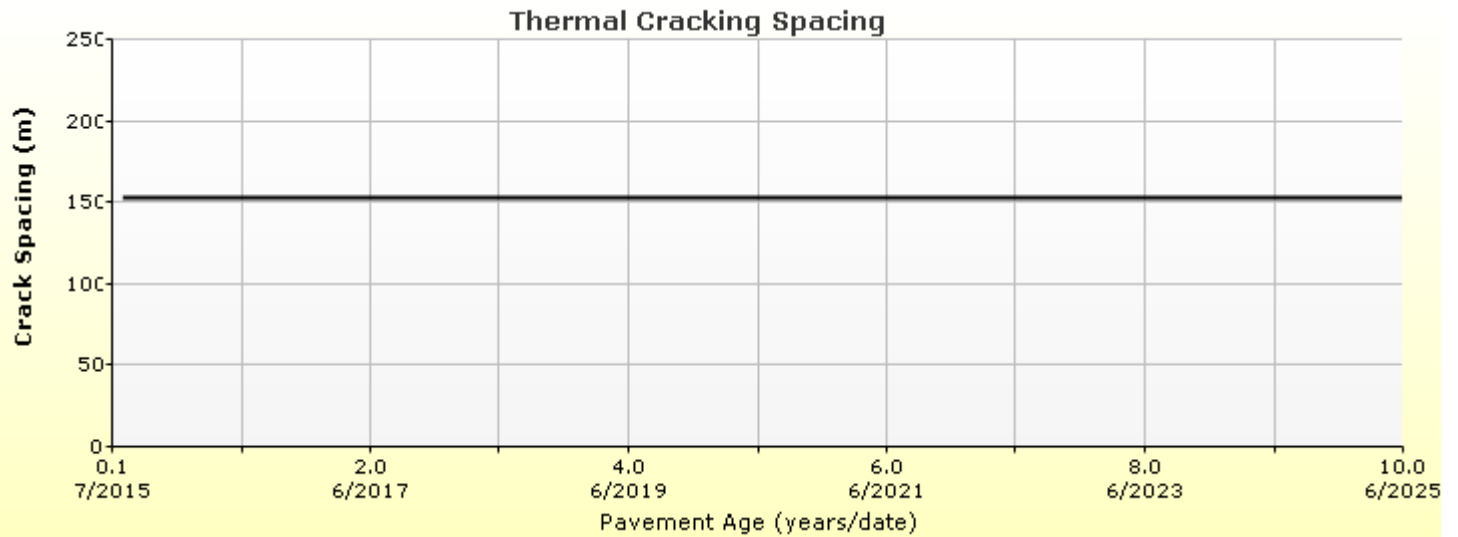


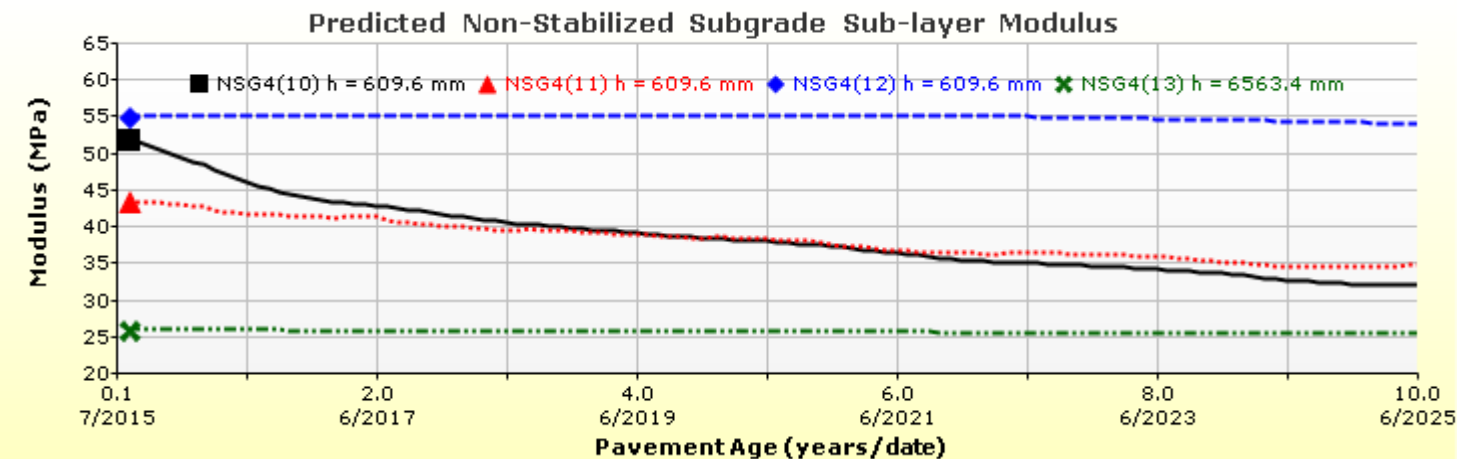
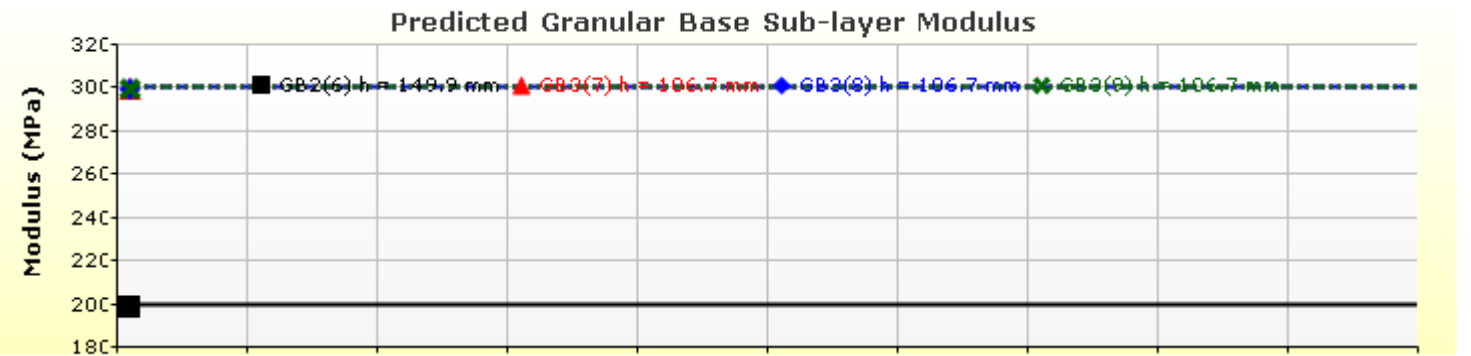
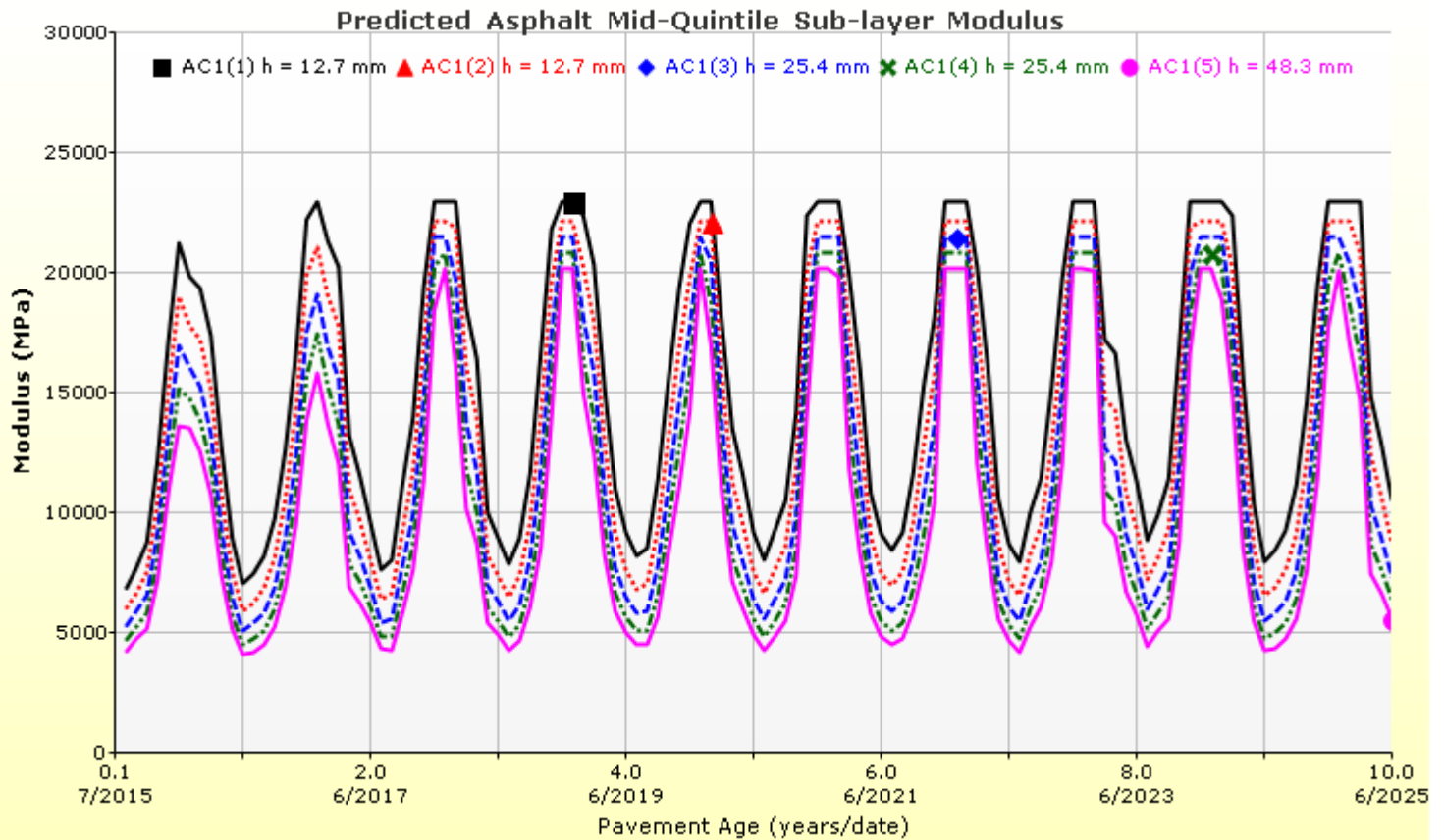
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: $H_{ac} = \text{total AC thickness(in)}$	$\varepsilon_p = \text{plastic strain(in/in)}$ $\varepsilon_r = \text{resilient strain(in/in)}$ $T = \text{layer temperature(}^\circ\text{F)}$ $N = \text{number of load repetitions}$
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

$C_f = 400 * N \left(\frac{\log C / h_{ac}}{\sigma}\right)$ $\Delta C = (k * \beta_t)^{n+1} * A * \Delta K^n$ $A = 10^{(4.389 - 2.52 * \log(E * \sigma_m * n))}$	$C_f = \text{observed amount of thermal cracking(ft/500ft)}$ $k = \text{refression coefficient determined through field calibration}$ $N() = \text{standard normal distribution evaluated at()}$ $\sigma = \text{standard deviation of the log of the depth of cracks in the pavments}$ $C = \text{crack depth(in)}$ $h_{ac} = \text{thickness of asphalt layer(in)}$ $\Delta C = \text{Change in the crack depth due to a cooling cycle}$ $\Delta K = \text{Change in the stress intensity factor due to a cooling cycle}$ $A, n = \text{Fracture parameters for the asphalt mixture}$ $E = \text{mixture stiffness}$ $\sigma_m = \text{Undamaged mixture tensile strength}$ $\beta_t = \text{Calibration parameter}$
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

$N_f = 10^{\left(\frac{k_1 \beta_{c1} \left(\frac{\sigma_s}{M_r}\right)}{k_2 \beta_{c2}}\right)}$	$N_f = \text{number of repetitions to fatigue cracking}$ $\sigma_s = \text{Tensile stress(psi)}$ $M_r = \text{modulus of rupture(psi)}$
k1: 1	k2: 1 Bc1: 1 Bc2:1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

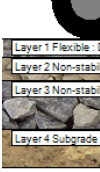
C3: 0.008

C4: 0.015

Design Inputs

Design Life: 10 years Base construction: March, 2015 Climate Data: 32.119, -81.202
 Design Type: Flexible Pavement Pavement construction: June, 2015 Sources (Lat/Lon)
 Traffic opening: July, 2015

Design Structure



Layer type	Material Type	Thickness(mm)	Volumetric at Construction:	
Flexible	Default asphalt concrete	125.0	Effective binder content (%)	11.6
NonStabilized	Crushed stone	150.0	Air voids (%)	7.0
NonStabilized	Crushed stone	320.0		
Subgrade	A-5	Semi-infinite		

Traffic

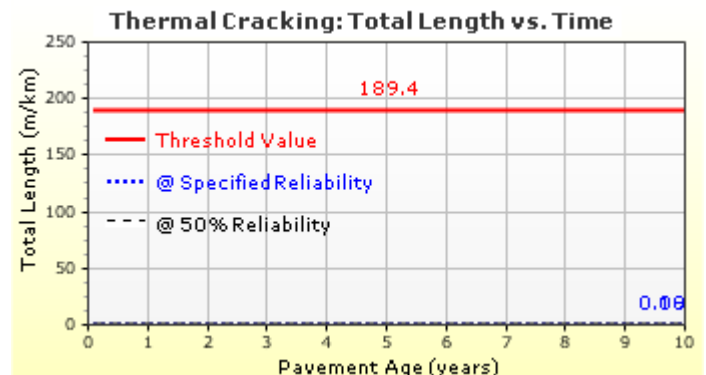
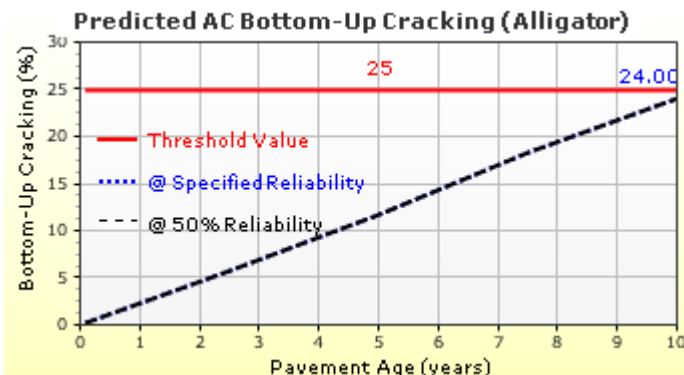
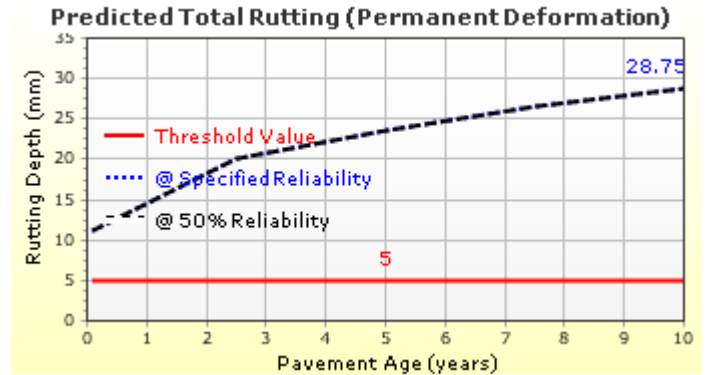
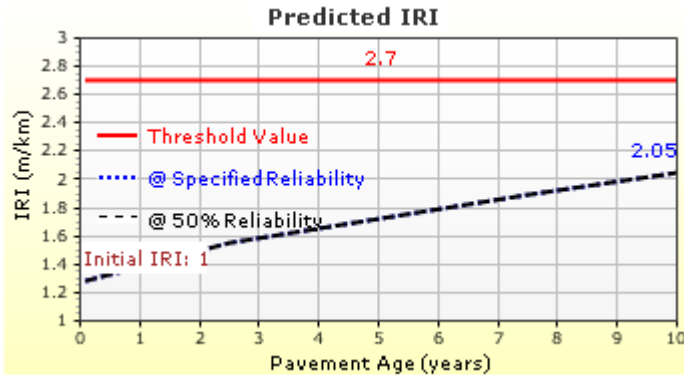
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	4,820
2020 (5 years)	4,486,440
2025 (10 years)	9,687,460

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.05	50.00	88.19	Pass
Permanent deformation - total pavement (mm)	5.00	28.75	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	24.00	50.00	52.82	Pass
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	465.91	50.00	42.17	Fail
Permanent deformation - AC only (mm)	5.00	12.21	50.00	1.74	Fail

Distress Charts

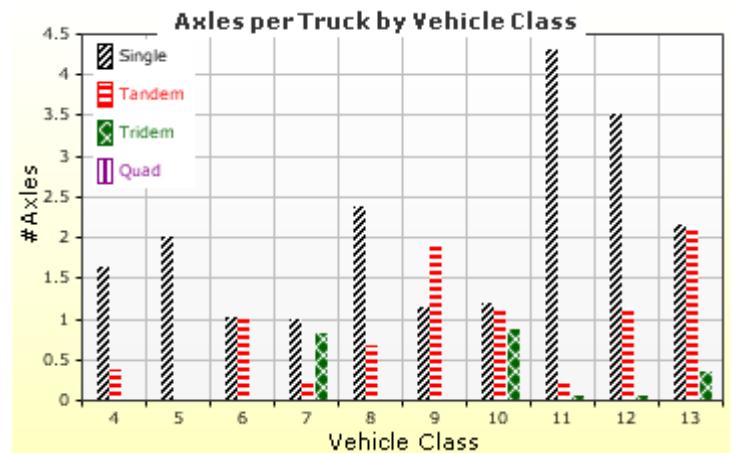
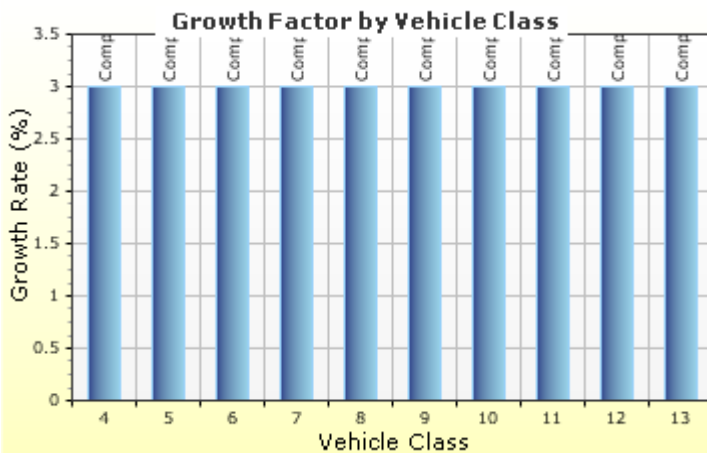
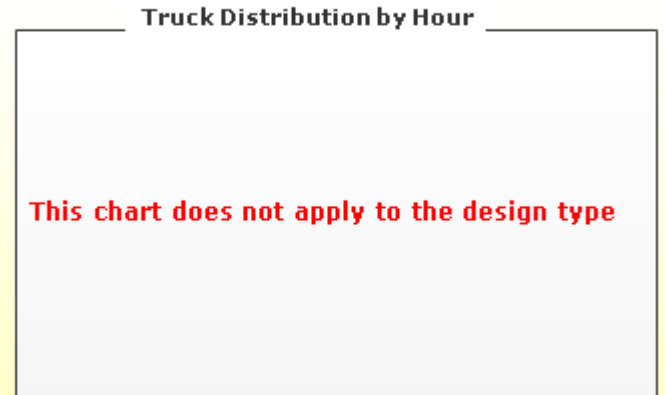
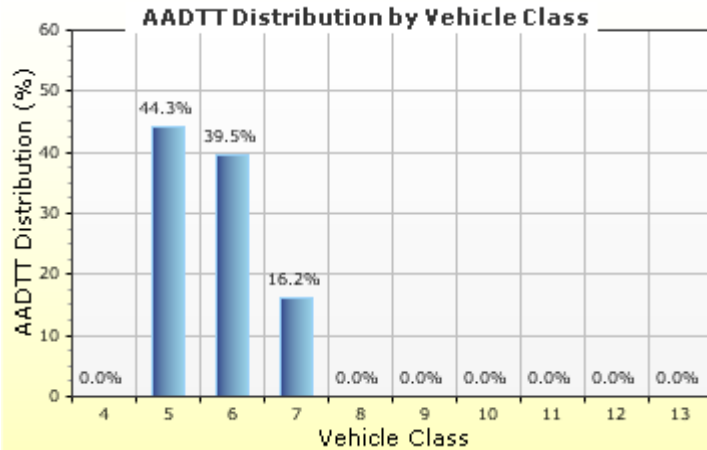


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 4,820
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

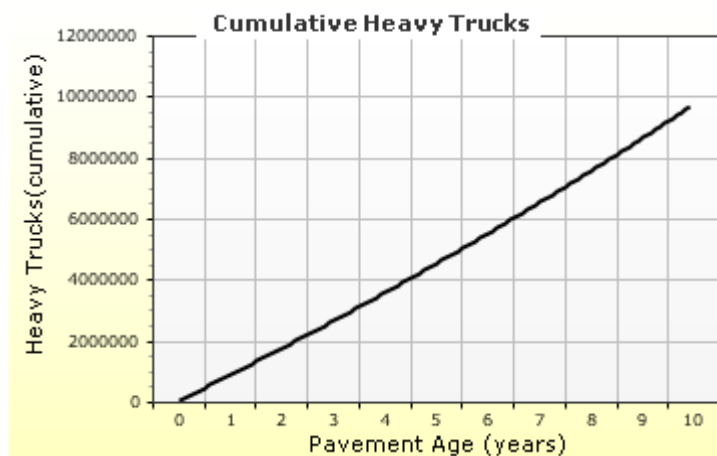
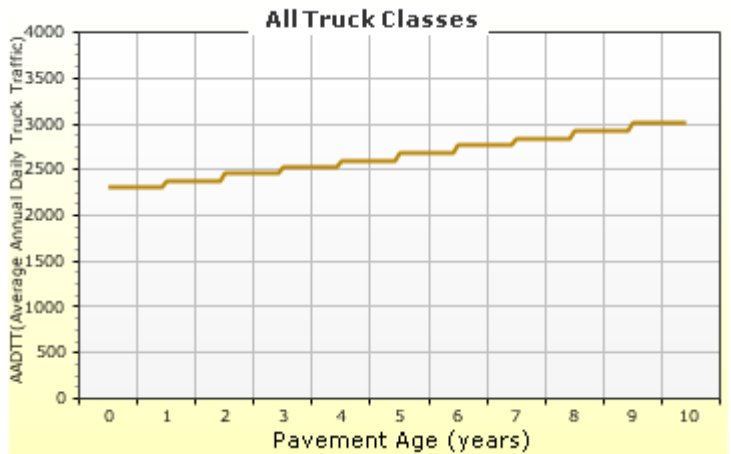
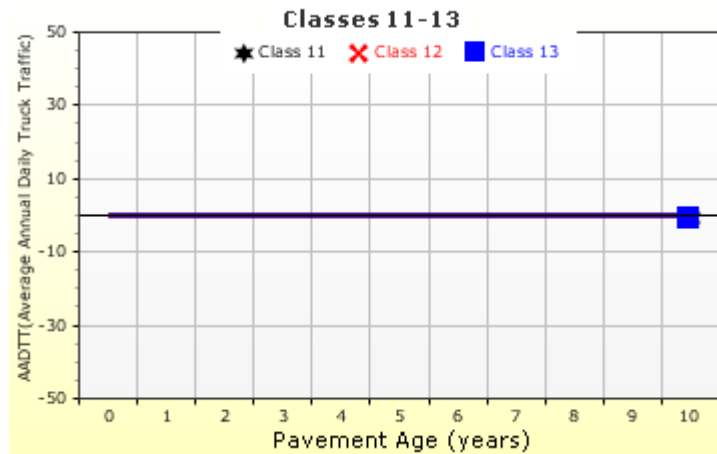
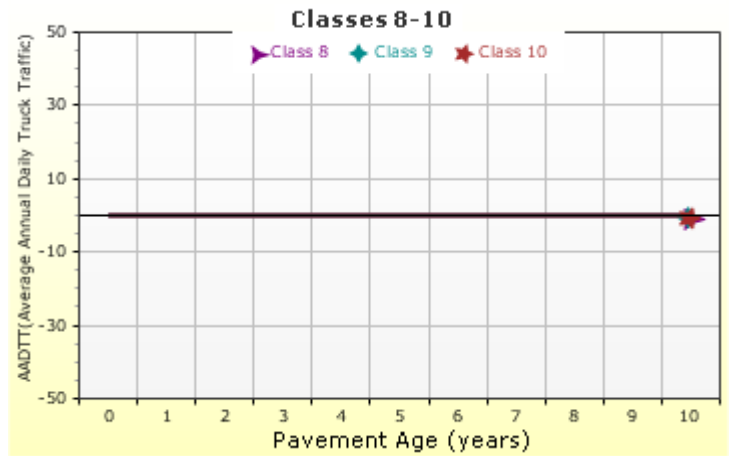
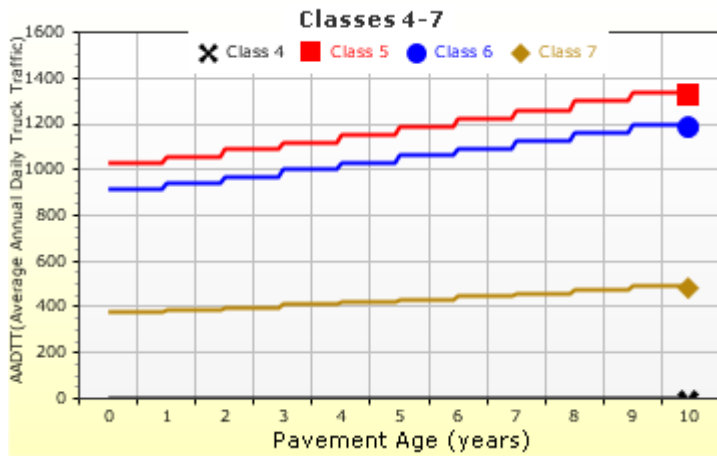
Wheelbase does not apply

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



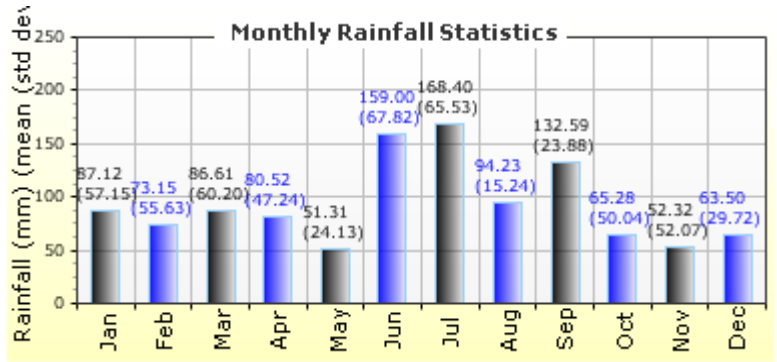
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

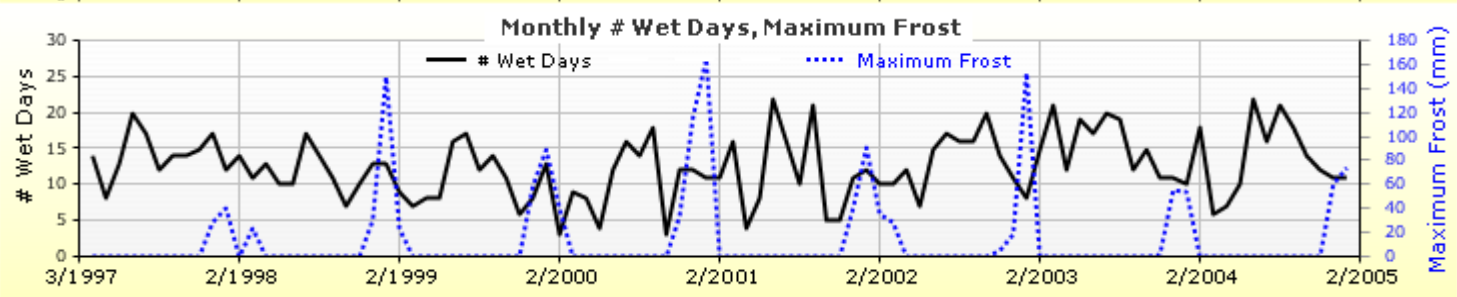
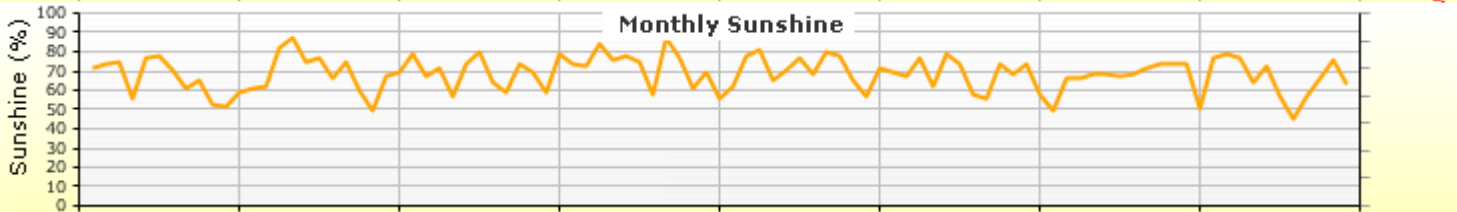
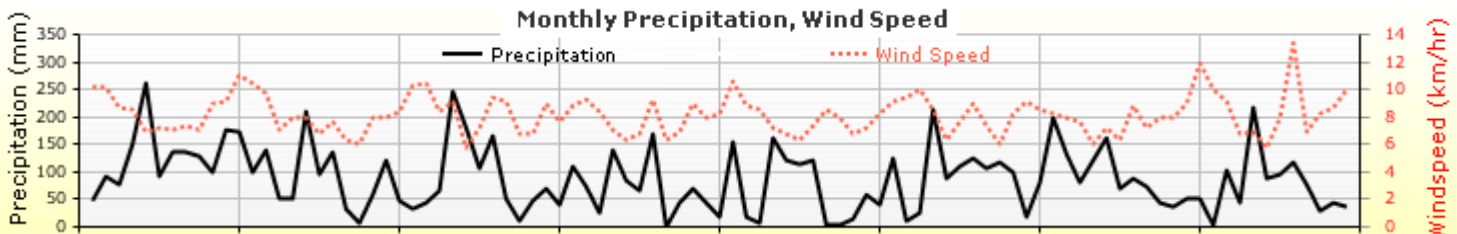
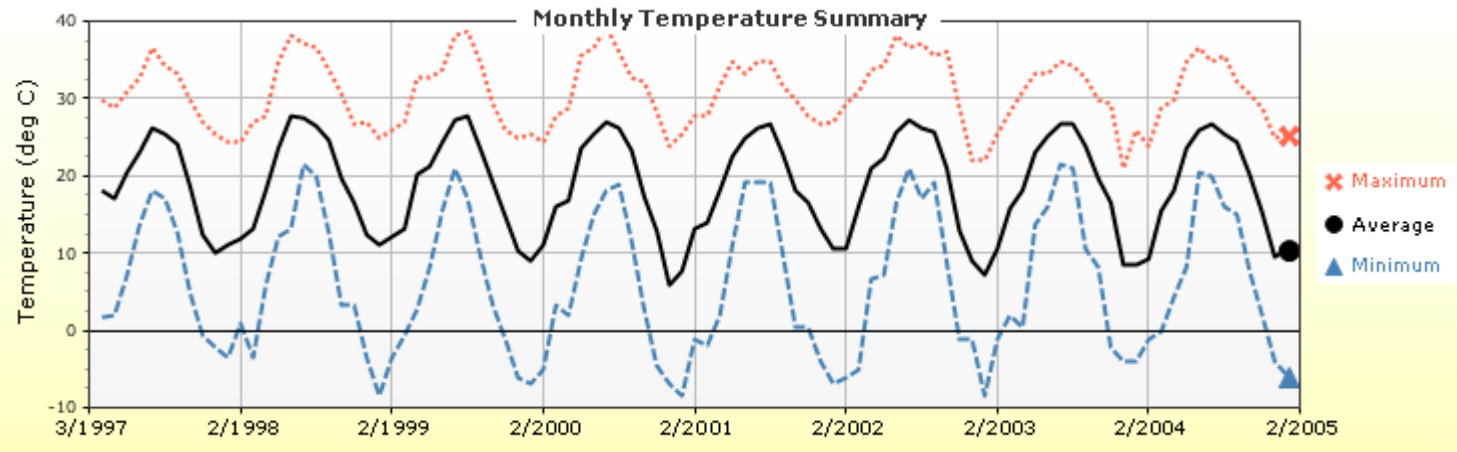
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

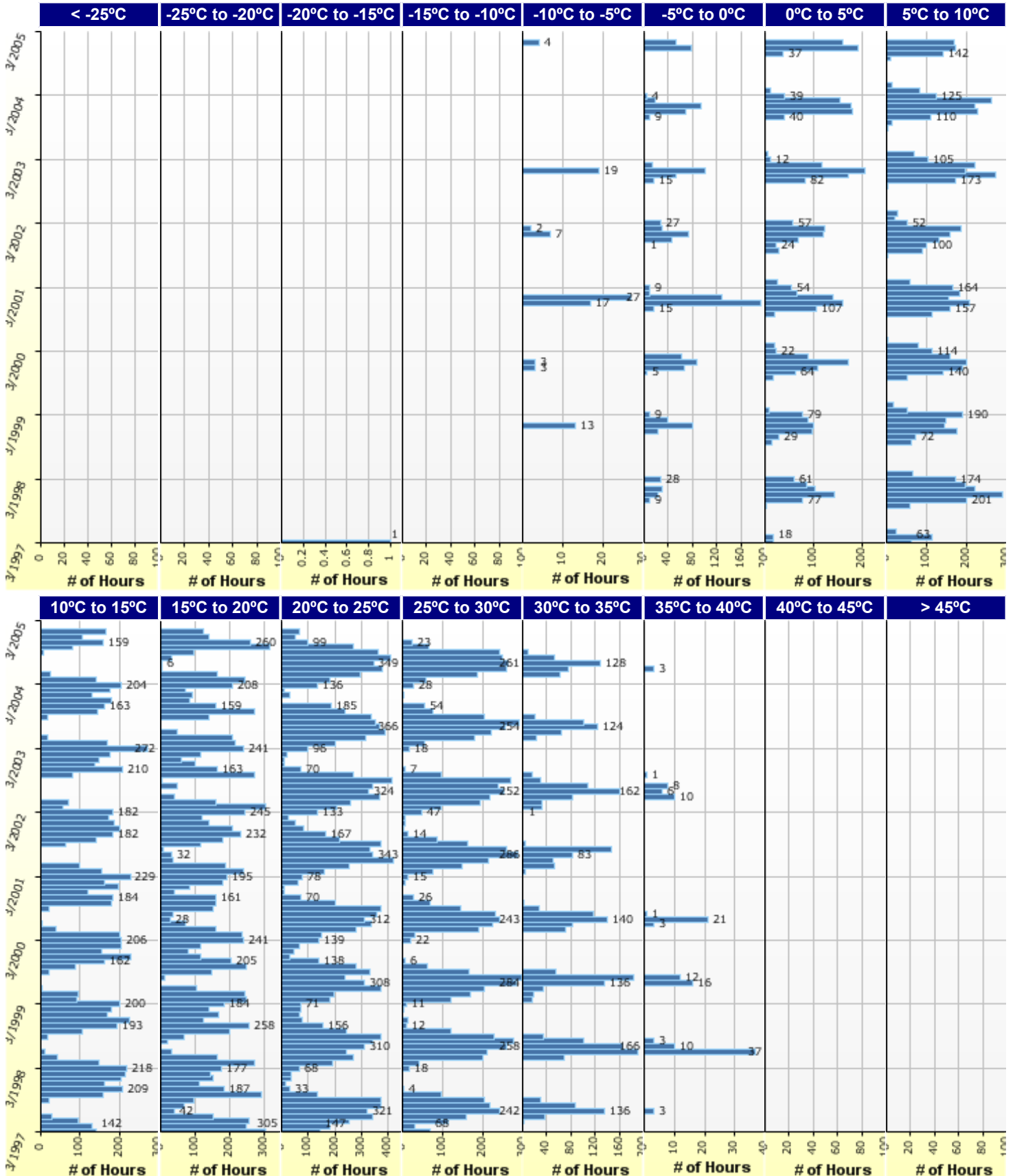


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF2_50%

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF2_50%.dgp



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

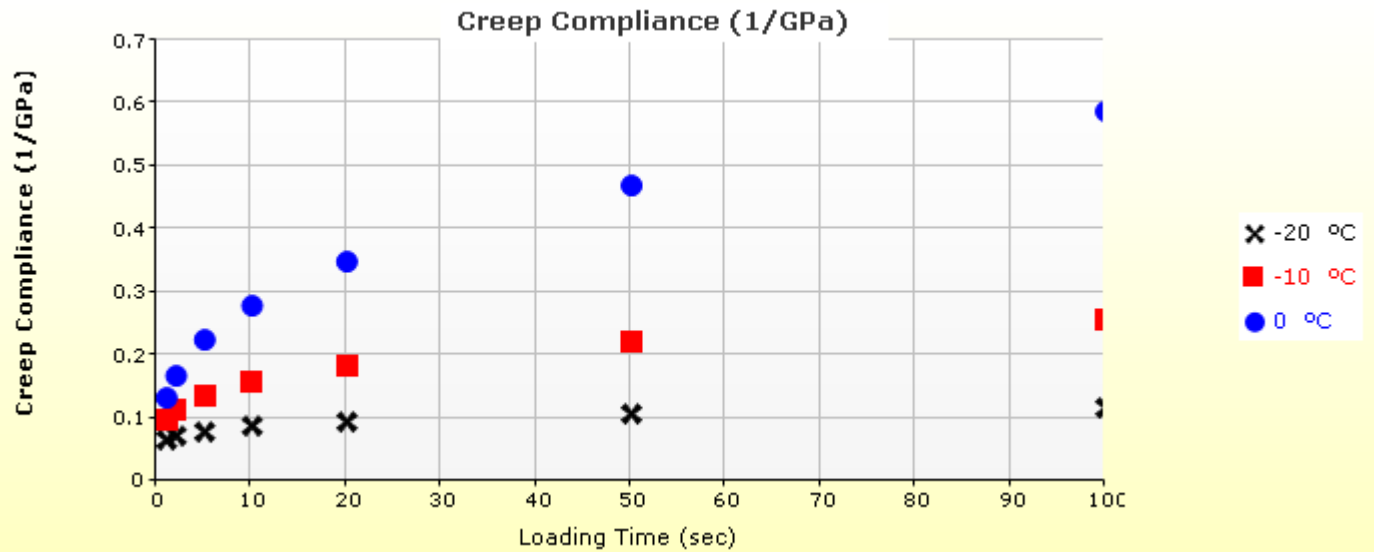
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

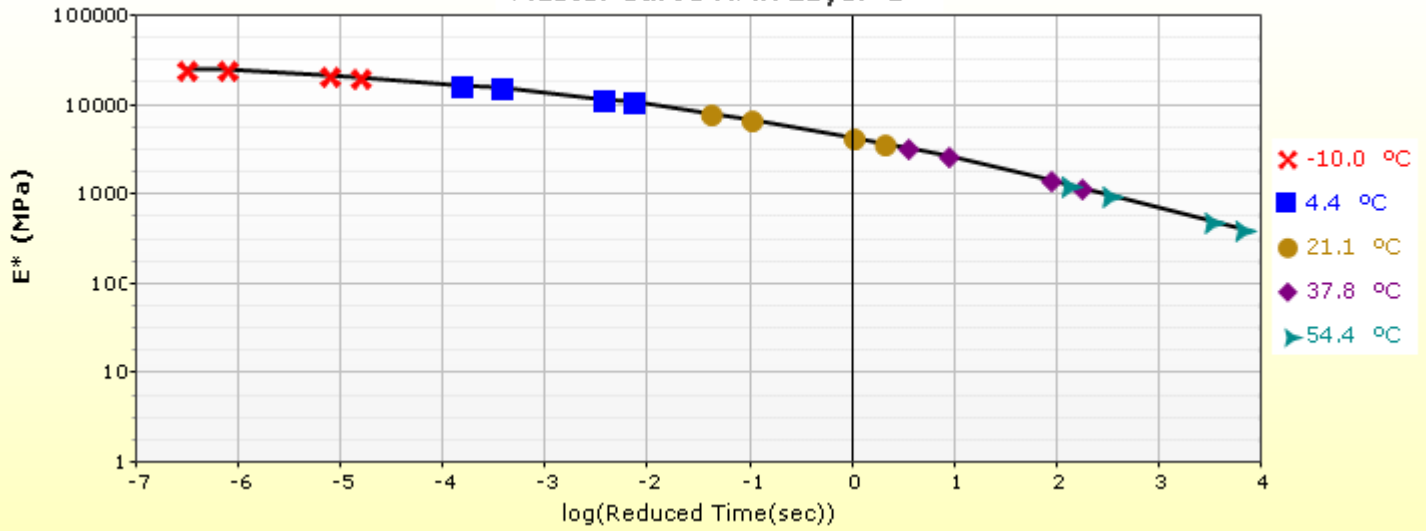
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

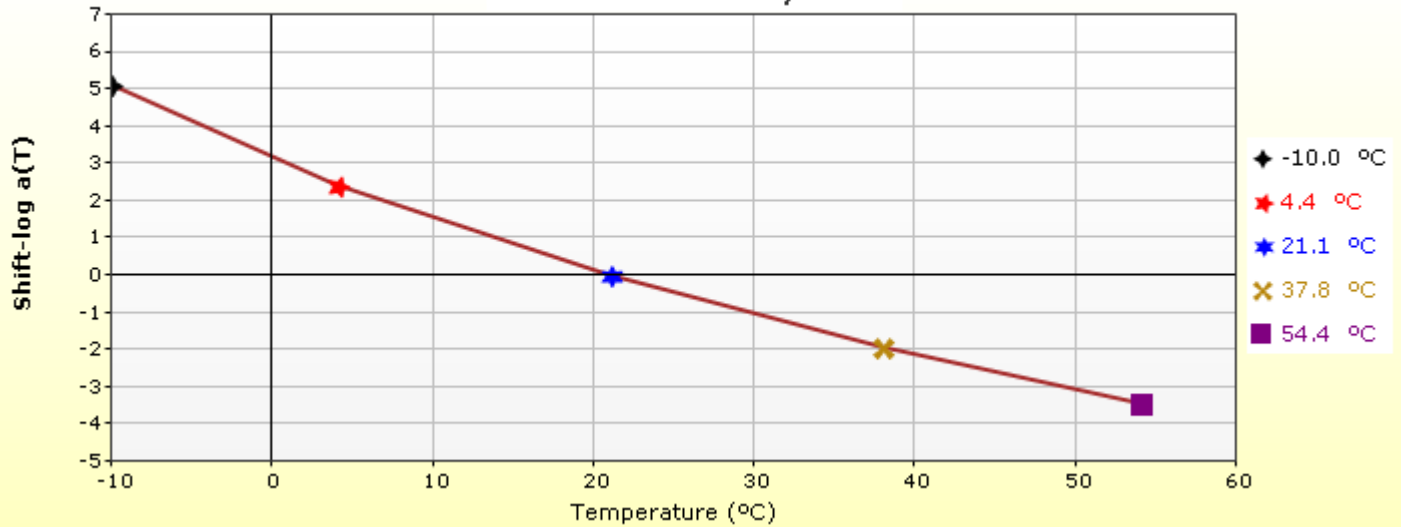


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

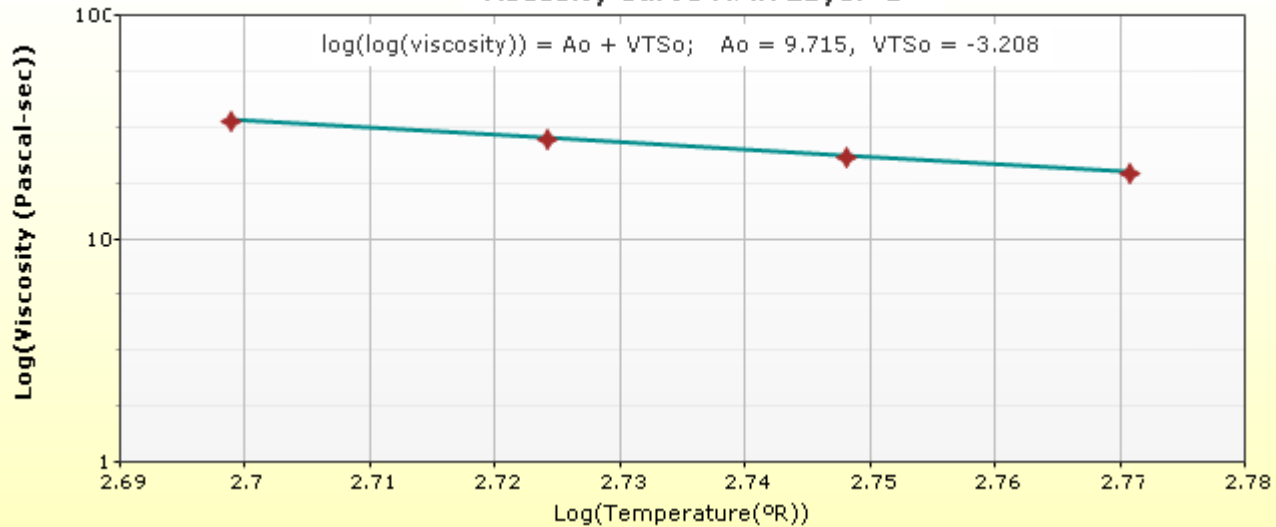
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

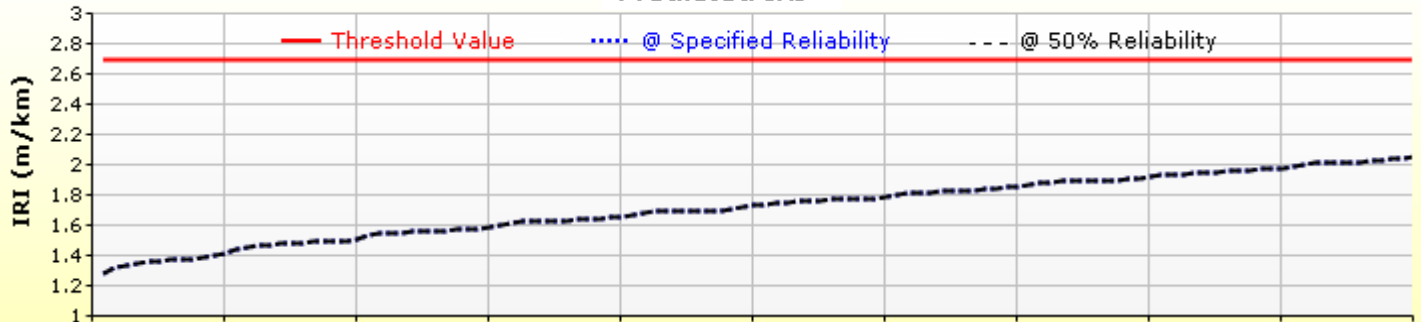


Viscosity Curve HMA Layer 1

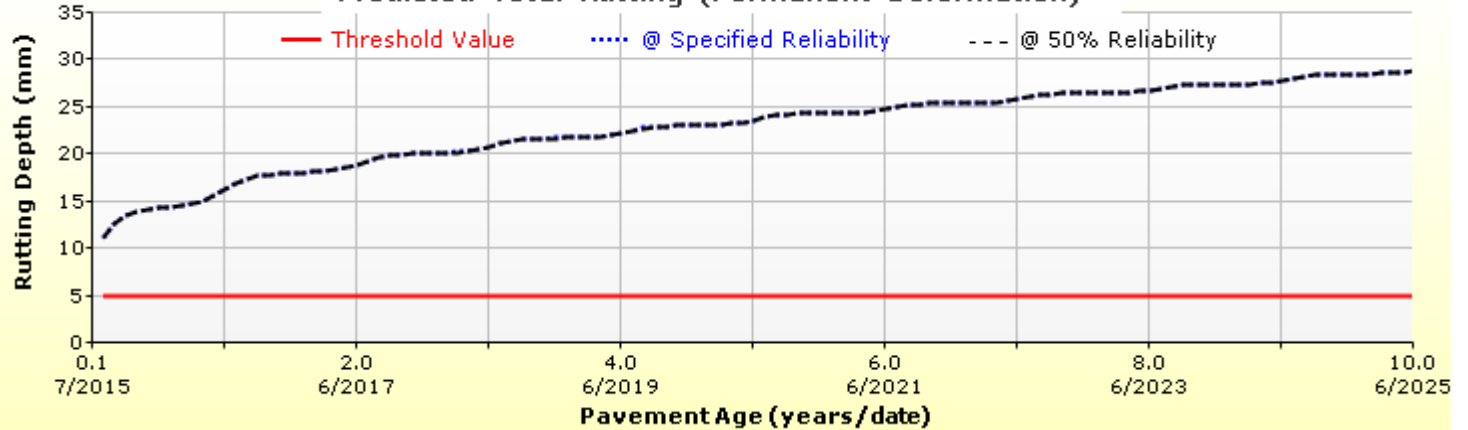


Analysis Output Charts

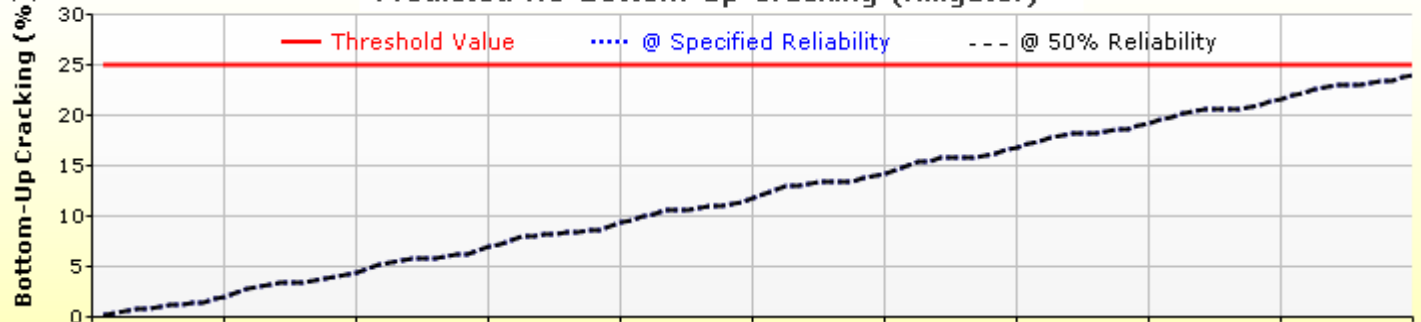
Predicted IRI



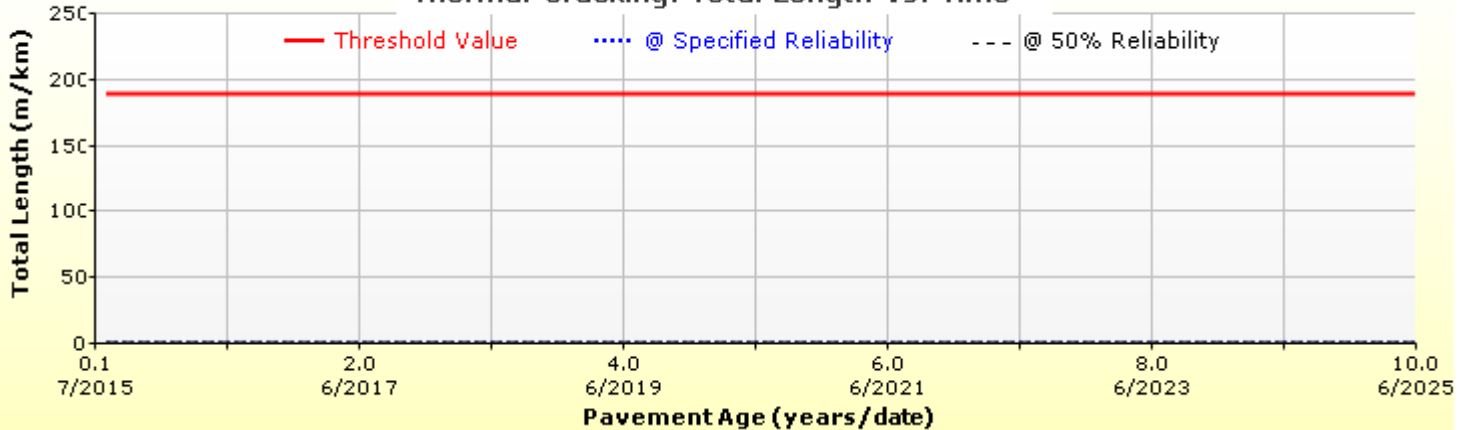
Predicted Total Rutting (Permanent Deformation)



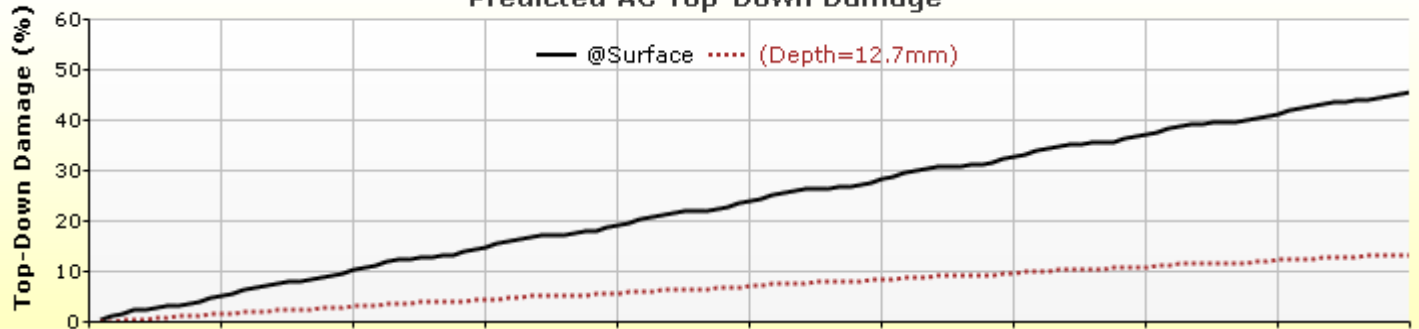
Predicted AC Bottom-Up Cracking (Alligator)



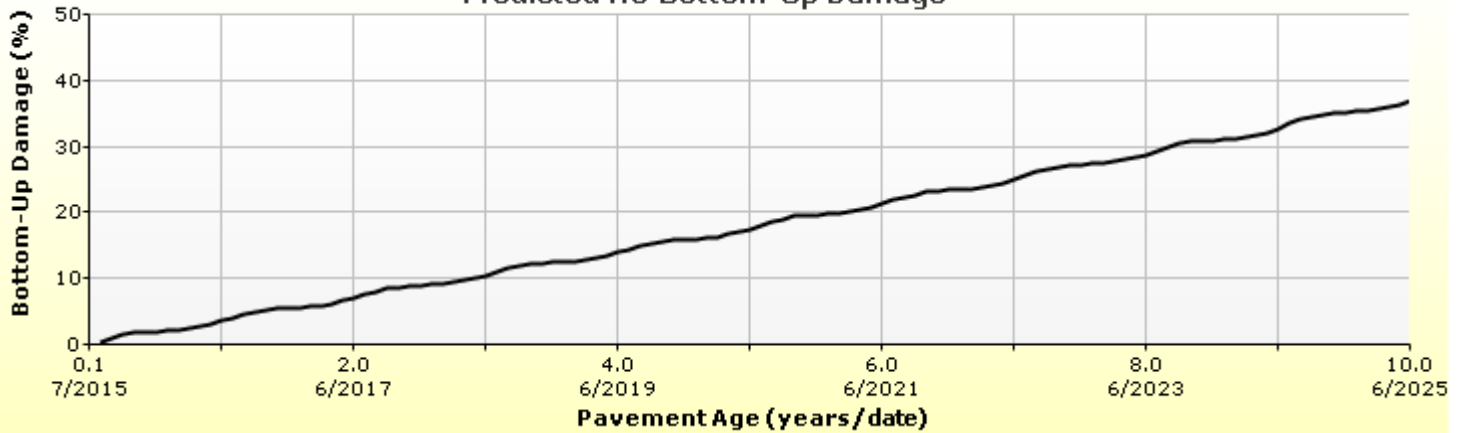
Thermal Cracking: Total Length vs. Time



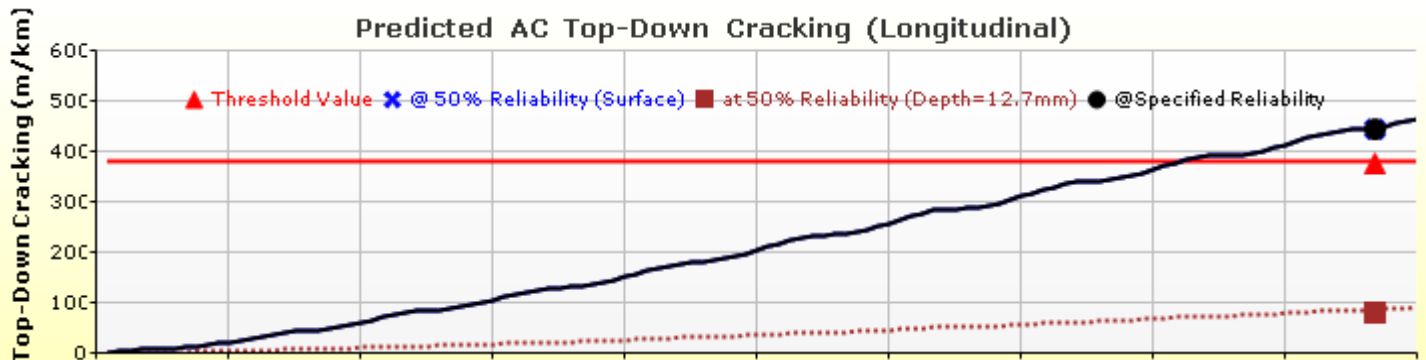
Predicted AC Top-Down Damage



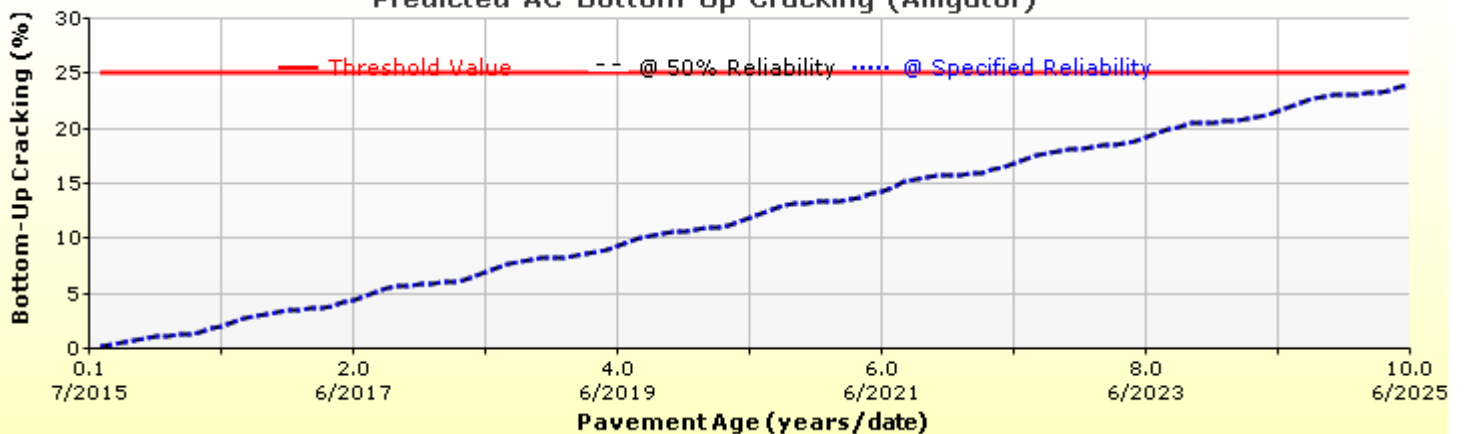
Predicted AC Bottom-Up Damage



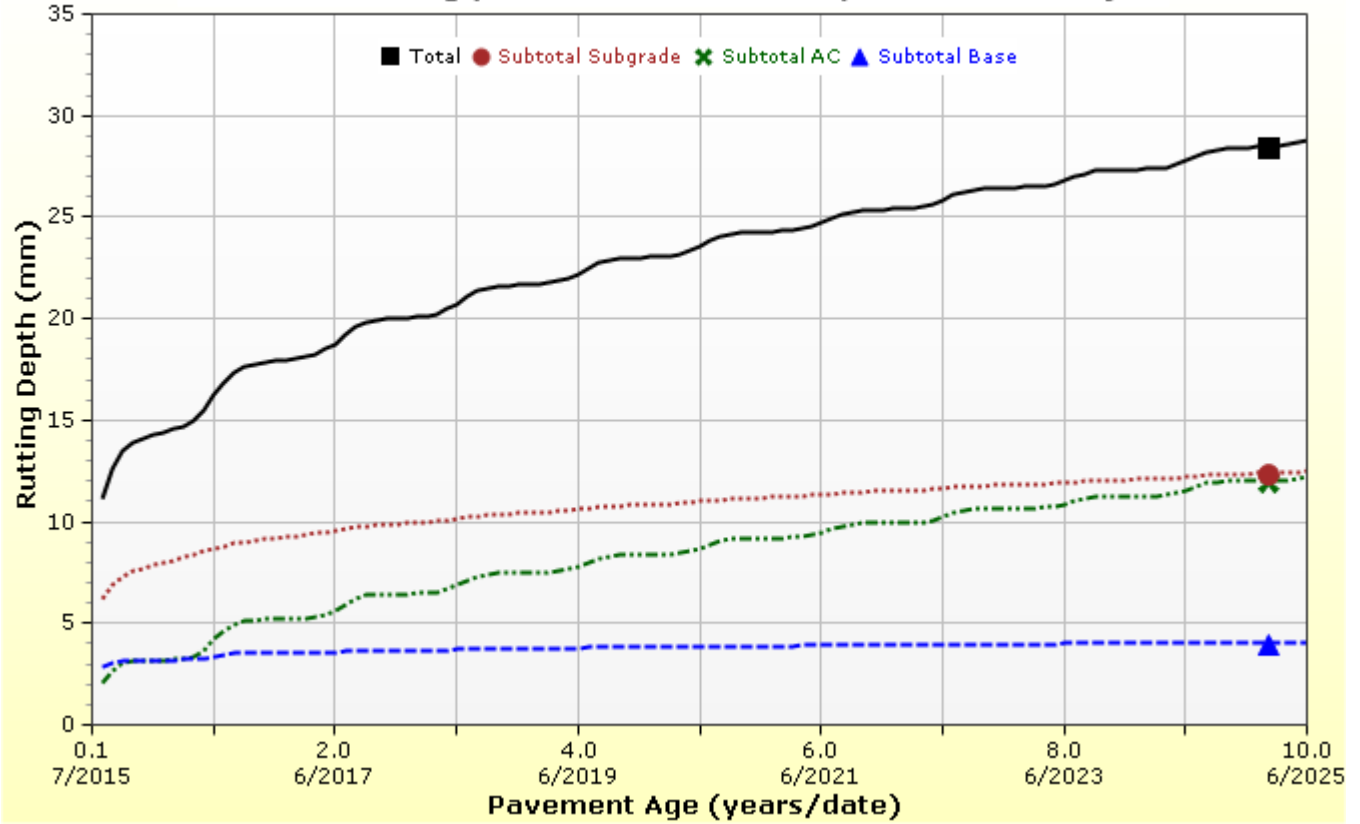
Predicted AC Top-Down Cracking (Longitudinal)

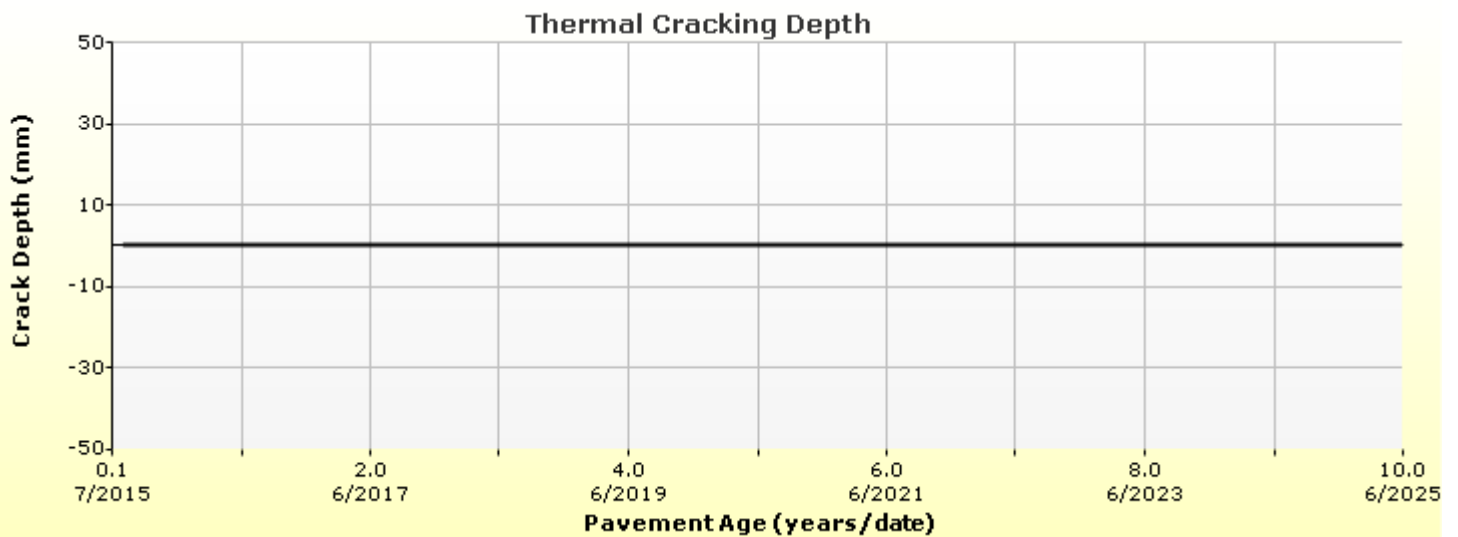
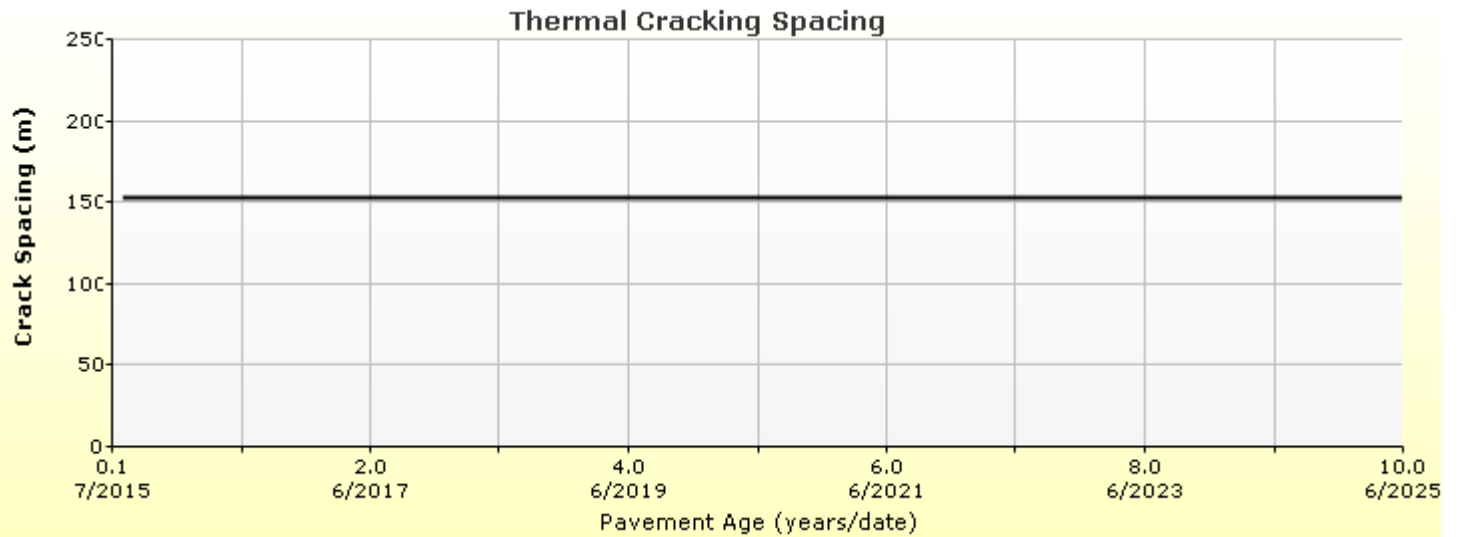


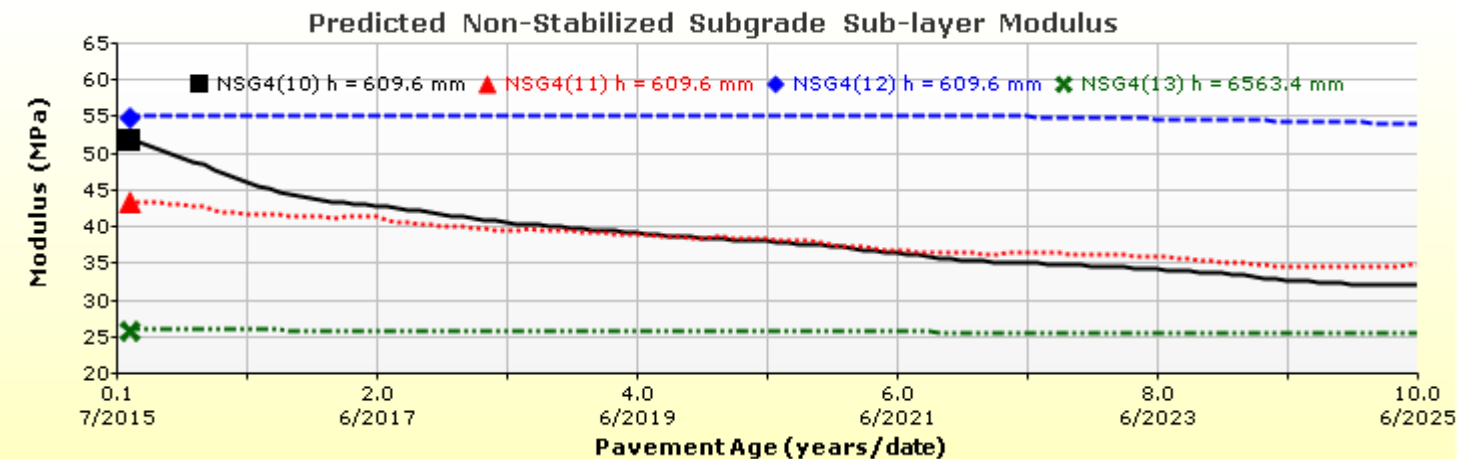
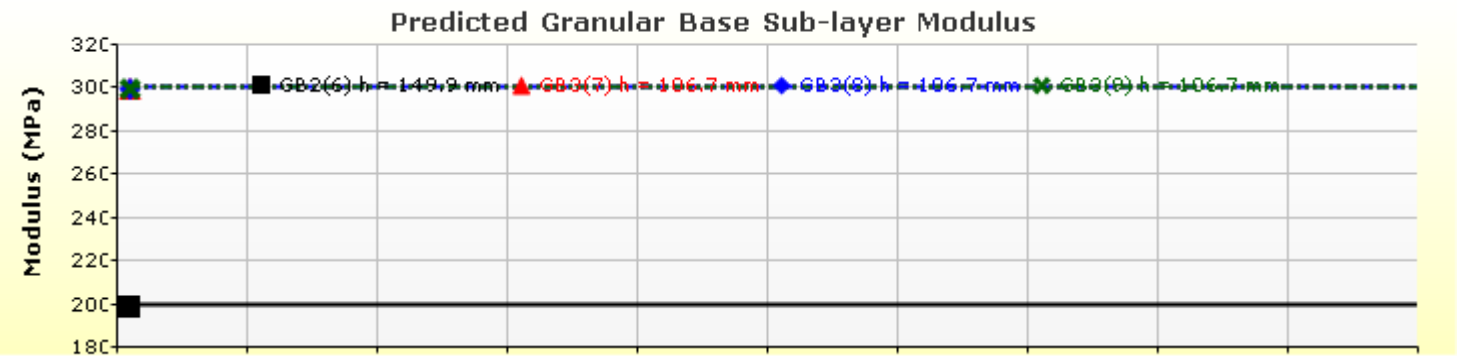
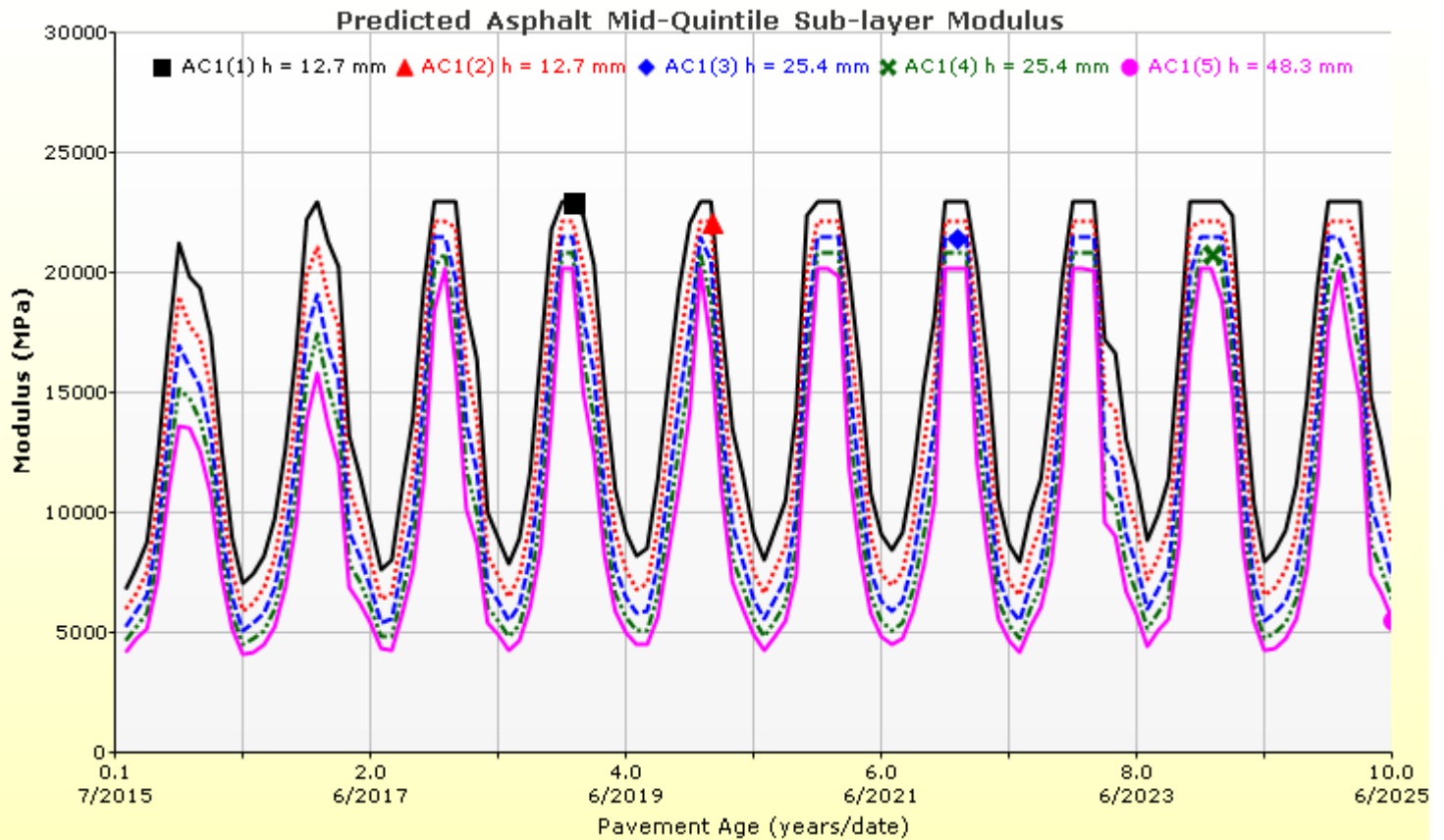
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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 = regression coefficient determined through field calibration $N()$ = standard normal distribution evaluated at() σ = standard deviation of the log of the depth of cracks in the pavements C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_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 $		δ_a = permanent deformation for the layer N = number of repetitions ε_v = average vertical strain(in/in) $\varepsilon_0, \beta, \rho$ = material properties ε_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		AC Bottom Up Cracking	
$FC_{top} = \left(\frac{C_4}{1 + e^{(C_1 - C_2 * \log_{10}(Damage))}} \right) * 10.56$		$FC = \left(\frac{6000}{1 + e^{(C_1 * C'_1 + C_2 * C'_2 * \log_{10}(D * 100))}} \right) * \left(\frac{1}{60} \right)$ $C'_2 = -2.40874 - 39.748 * (1 + h_{ac})^{-2.856}$ $C'_1 = -2 * C'_2$	
c1: 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 Cracking Bottom Standard Deviation 1.13+13/(1+exp(7.57-15.5*LOG10(BOTTOM+0.0001)))	

CSM Cracking		IRI Flexible Pavements	
$FC_{ctb} = C_1 + \frac{C_2}{1 + e^{C_3 - C_4(Damage)}}$		C1 - Rutting C3 - Transverse Crack C2 - Fatigue Crack C4 - Site Factors	
C1: 1	C2: 1	C3: 0	C4: 1000
CSM Standard Deviation CTB*1		C1: 40	C2: 0.4
		C3: 0.008	C4: 0.015

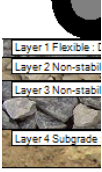
Design Inputs

Design Life: 10 years
Design Type: Flexible Pavement

Base construction: March, 2015
Pavement construction: June, 2015
Traffic opening: July, 2015

Climate Data 32.119, -81.202
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

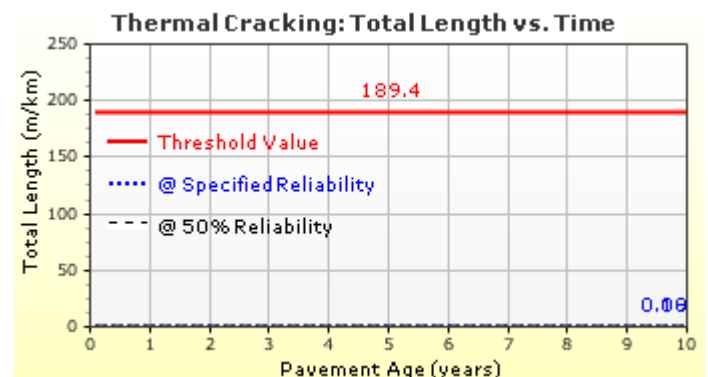
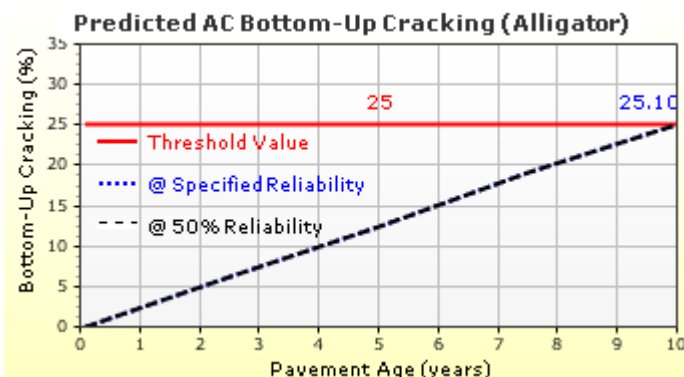
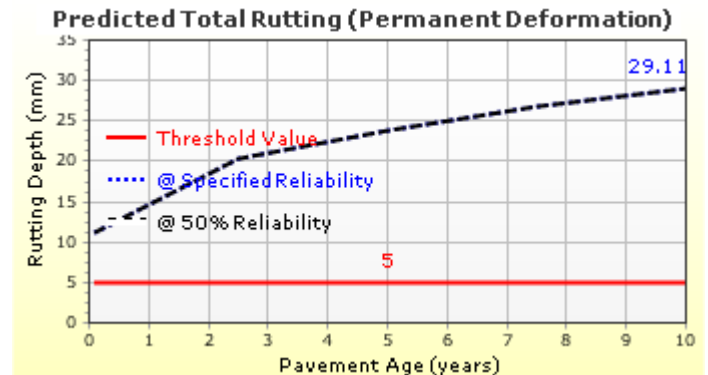
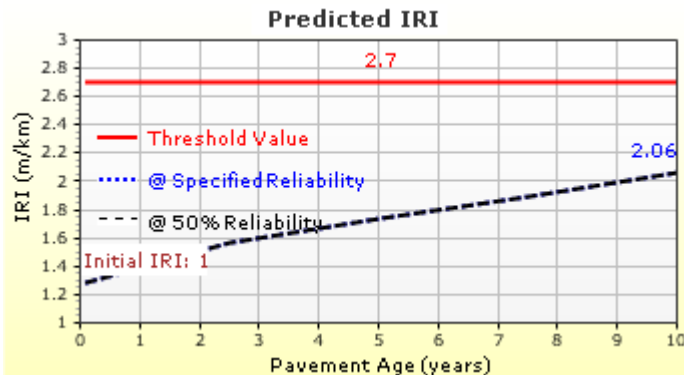
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	4,820
2020 (5 years)	4,486,440
2025 (10 years)	9,687,460

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.06	50.00	87.54	Pass
Permanent deformation - total pavement (mm)	5.00	29.11	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	25.10	50.00	49.72	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	446.97	50.00	43.84	Fail
Permanent deformation - AC only (mm)	5.00	11.86	50.00	1.98	Fail

Distress Charts

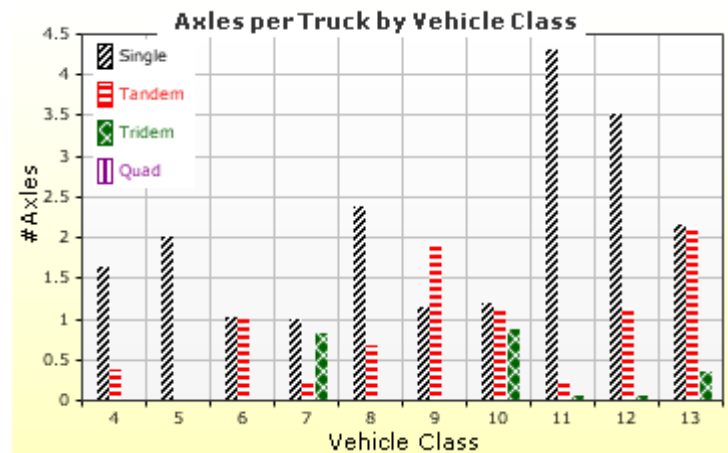
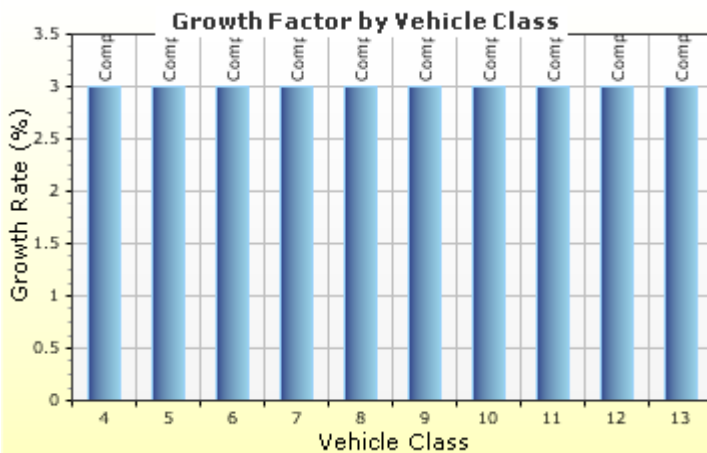
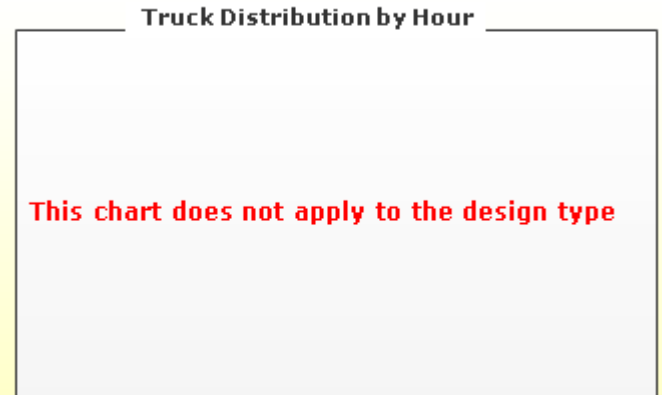
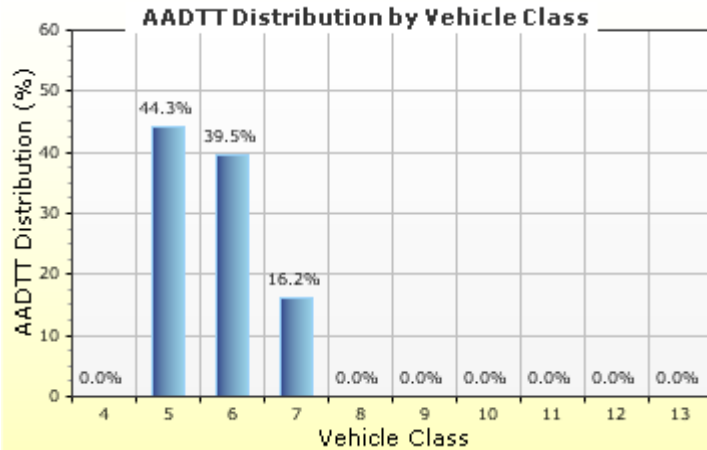


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 4,820
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

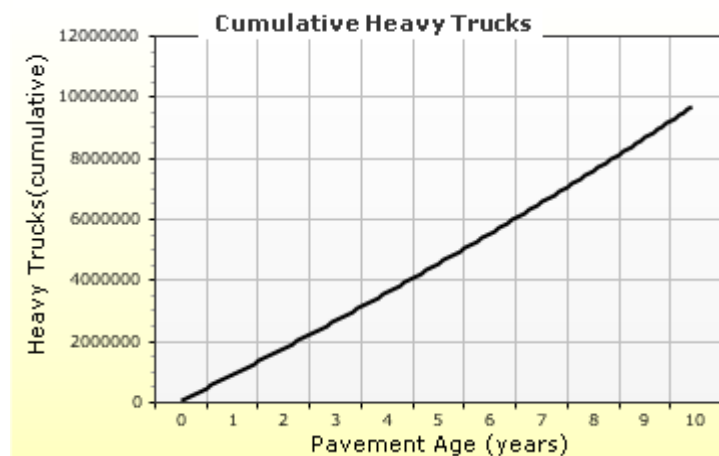
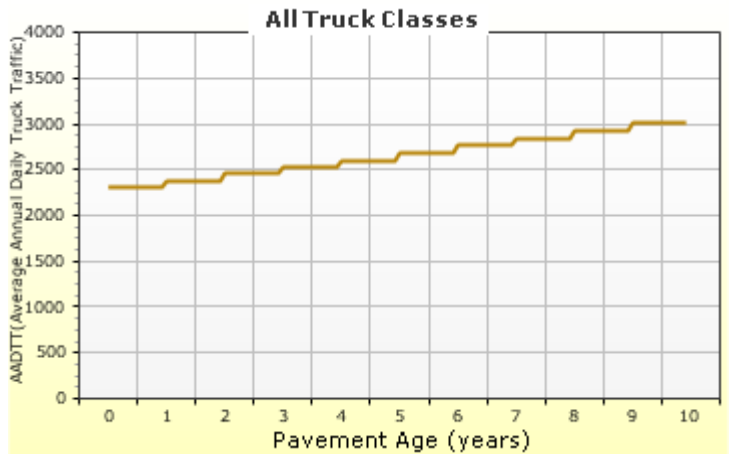
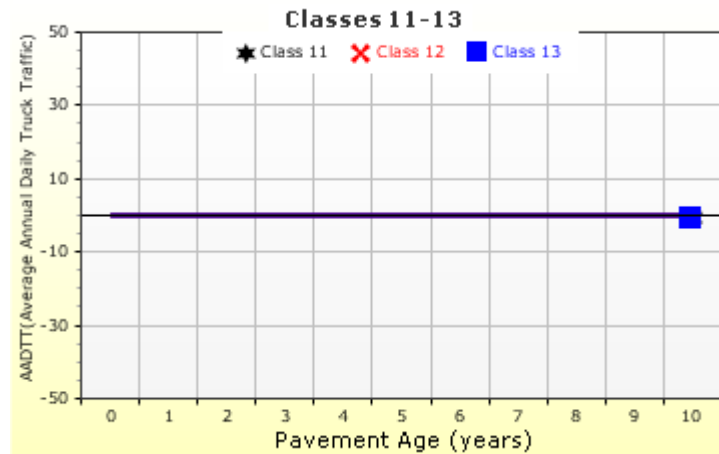
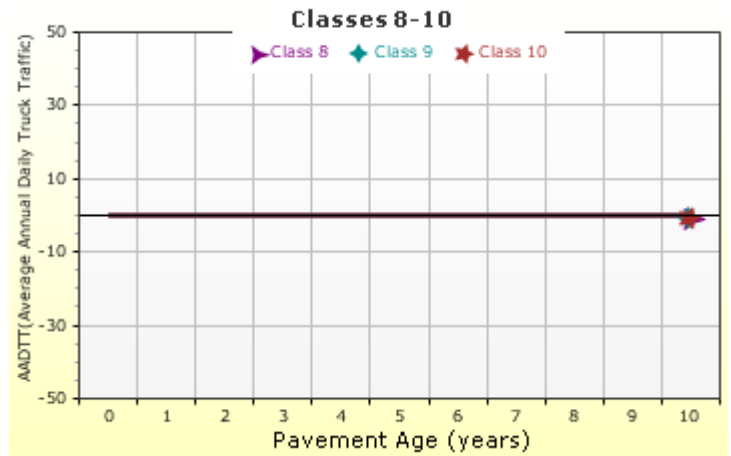
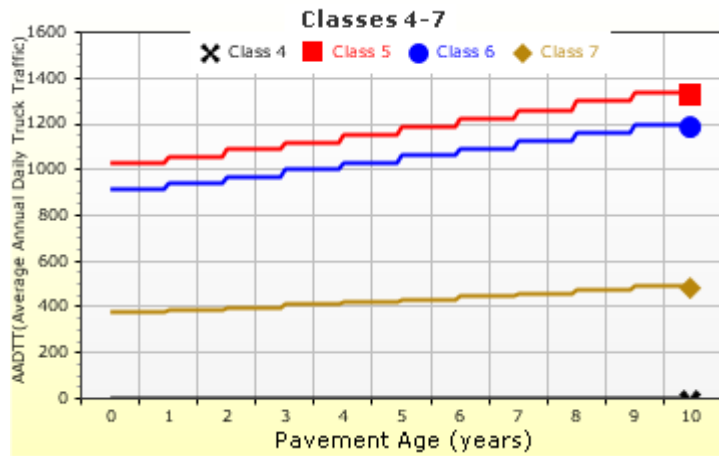
Wheelbase does not apply

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



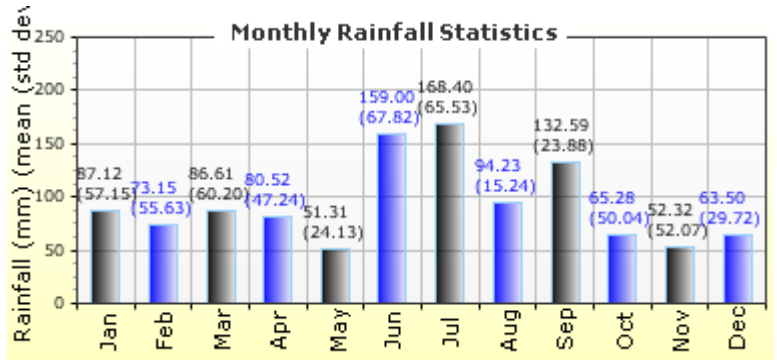
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

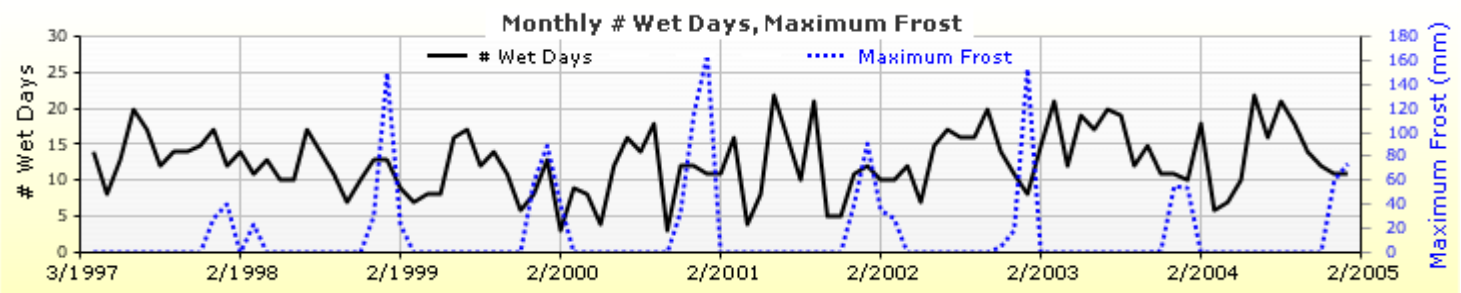
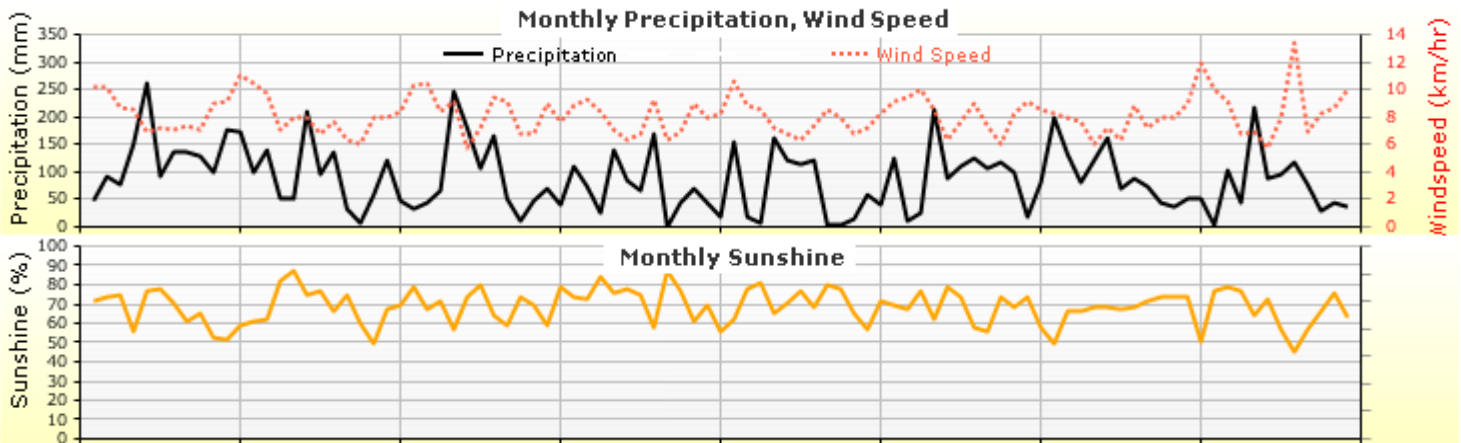
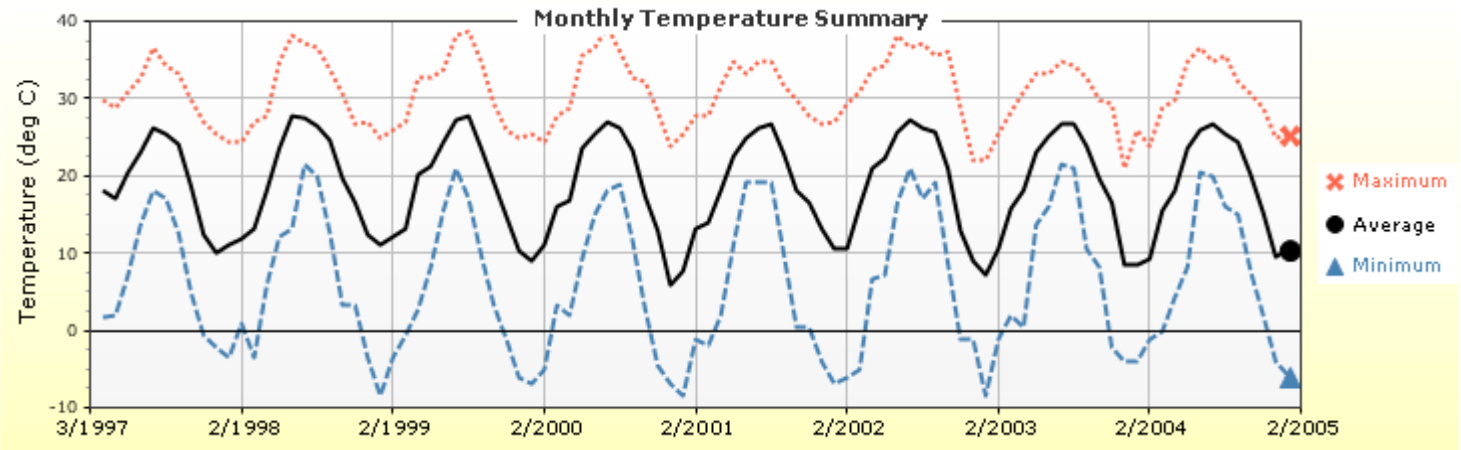
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

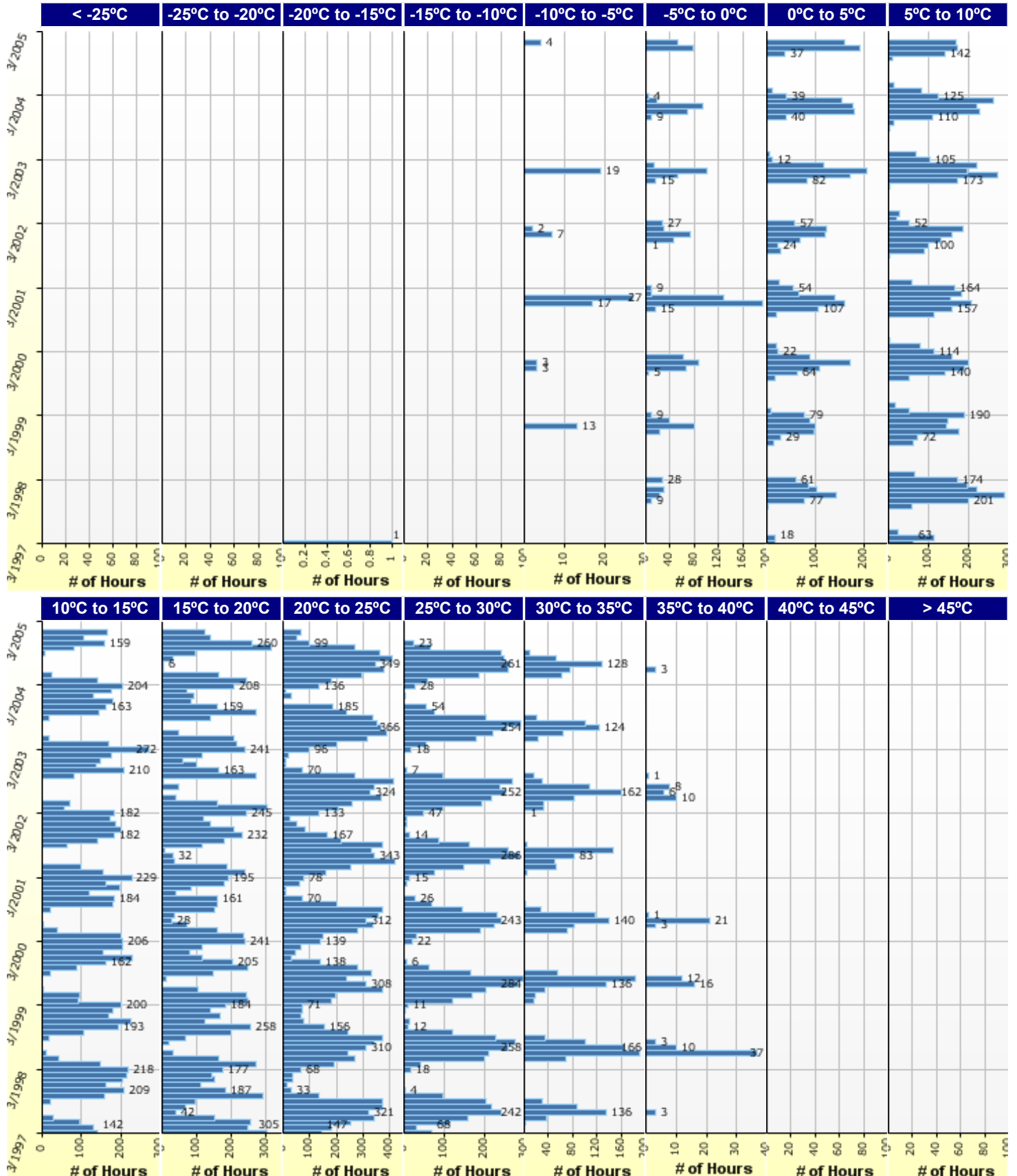


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF3_50%

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF3_50%.dgp



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

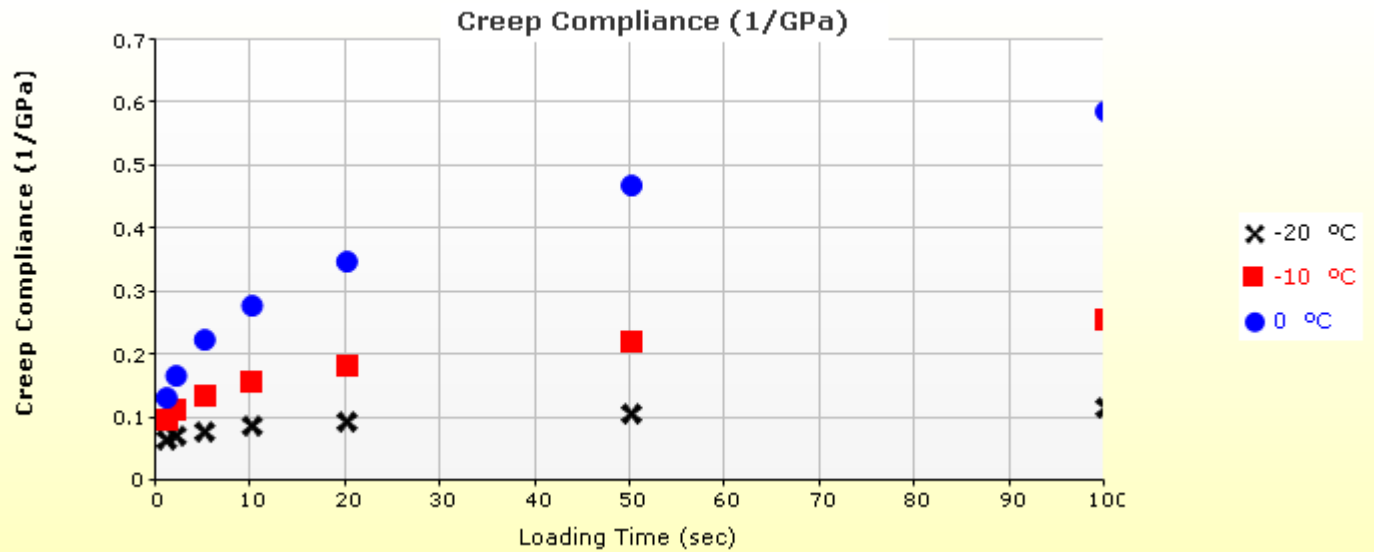
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

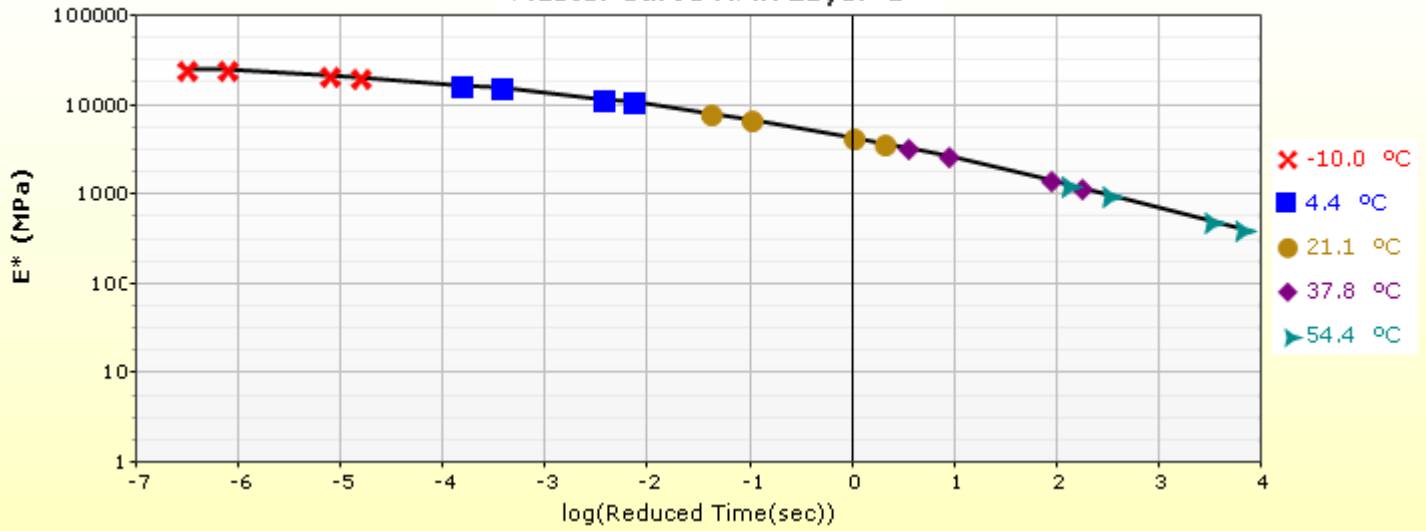
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

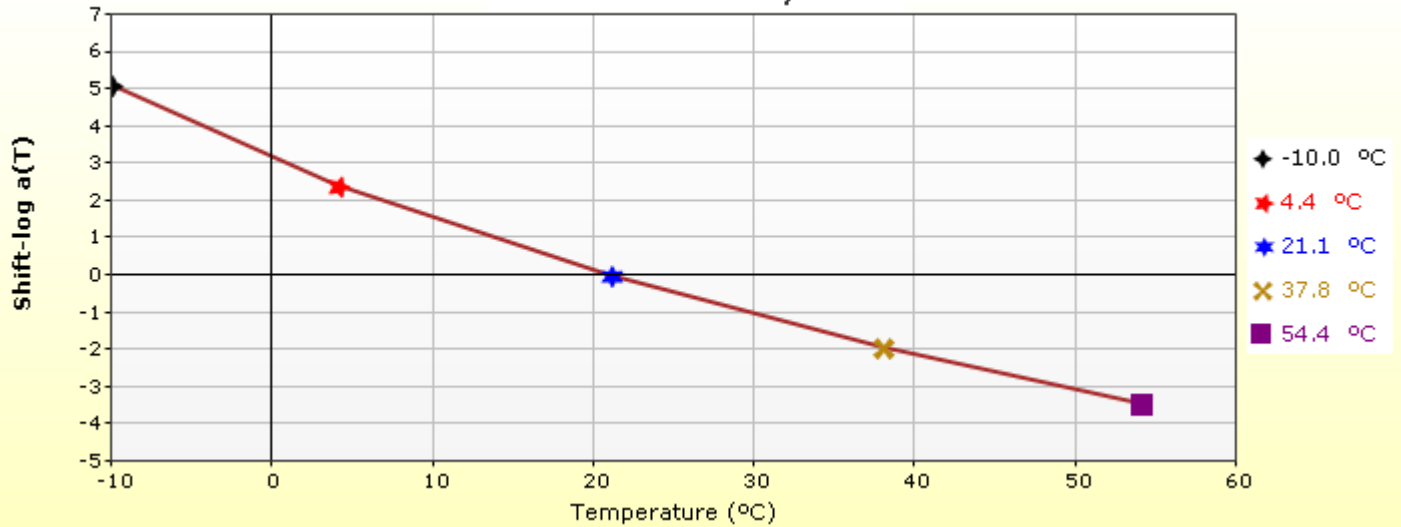


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

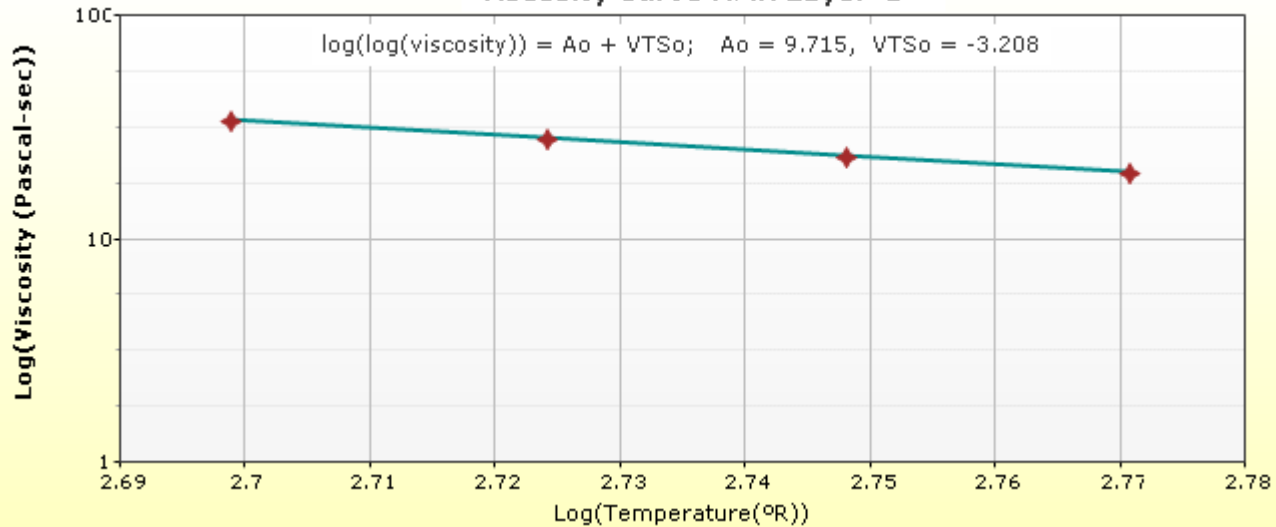
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

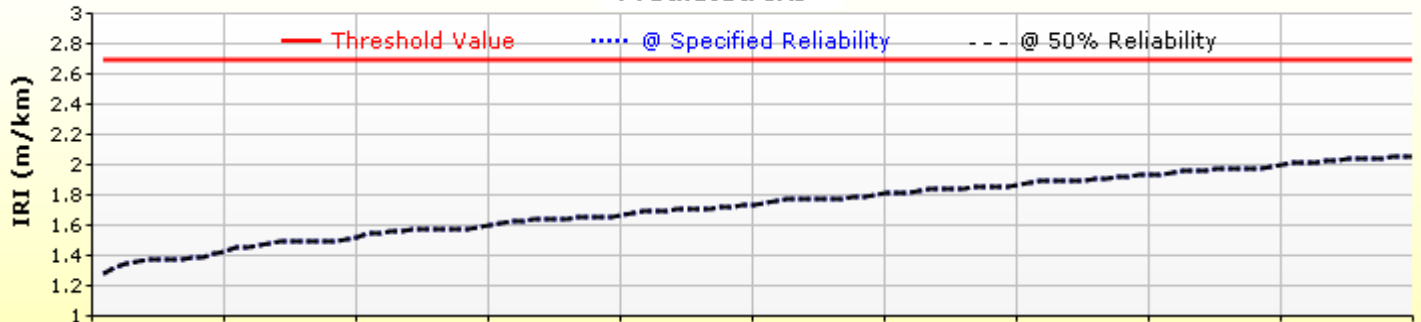


Viscosity Curve HMA Layer 1

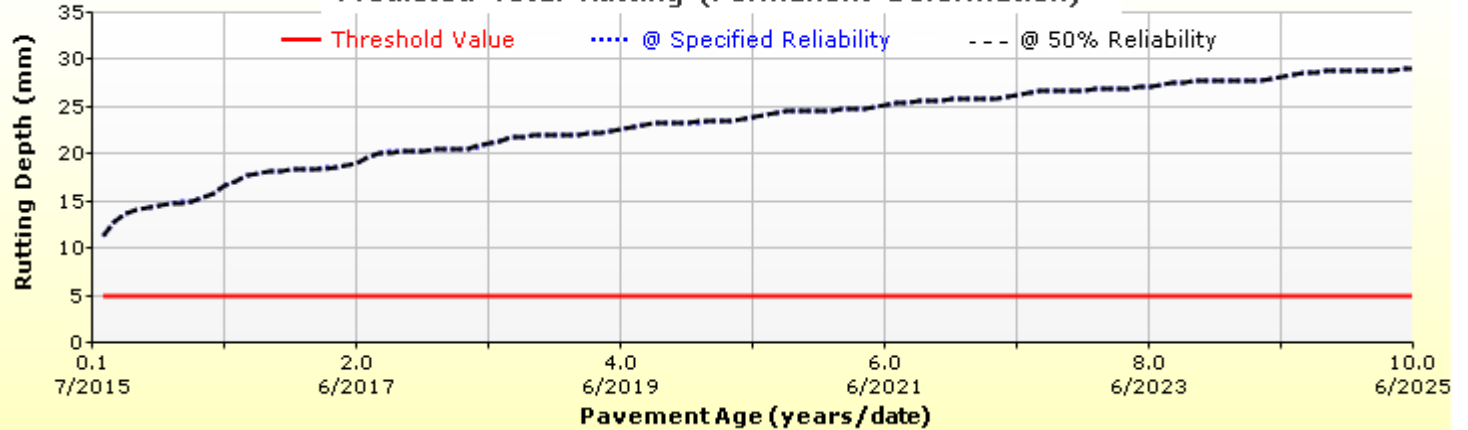


Analysis Output Charts

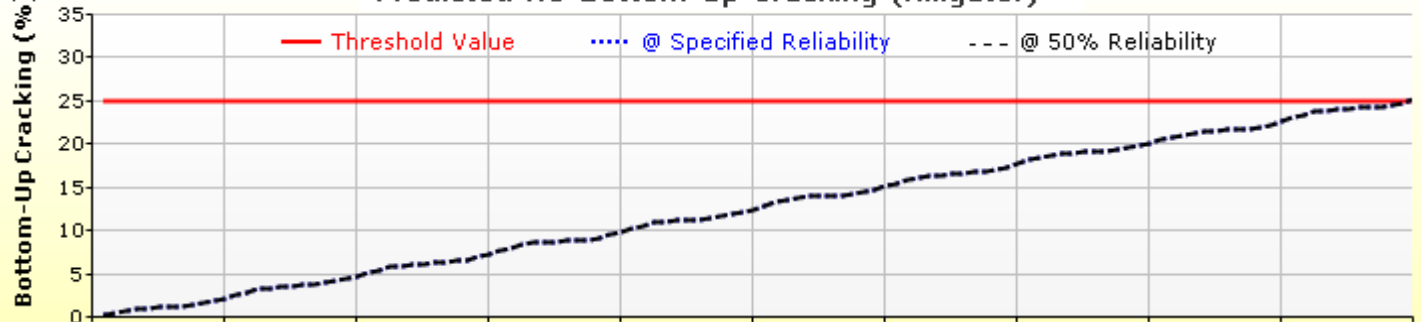
Predicted IRI



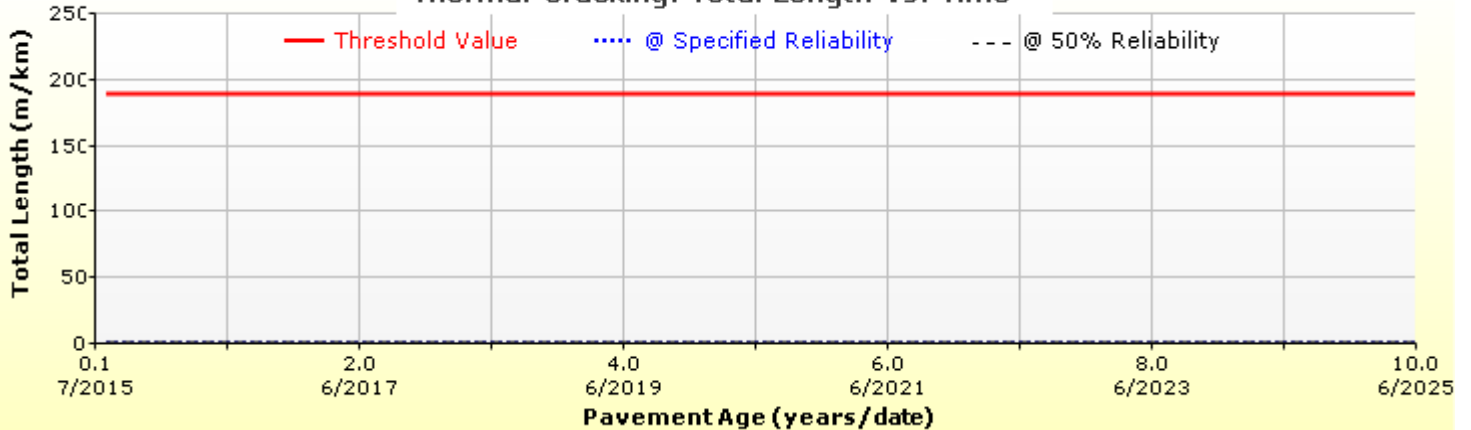
Predicted Total Rutting (Permanent Deformation)



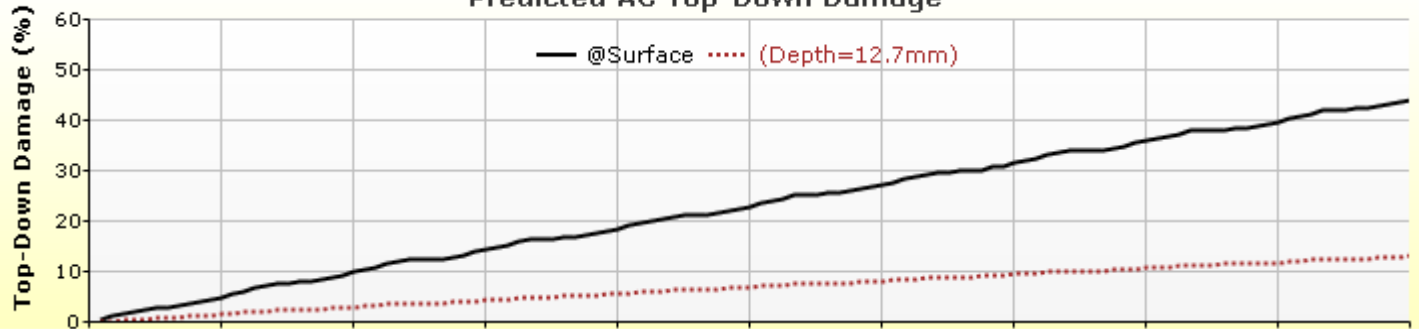
Predicted AC Bottom-Up Cracking (Alligator)



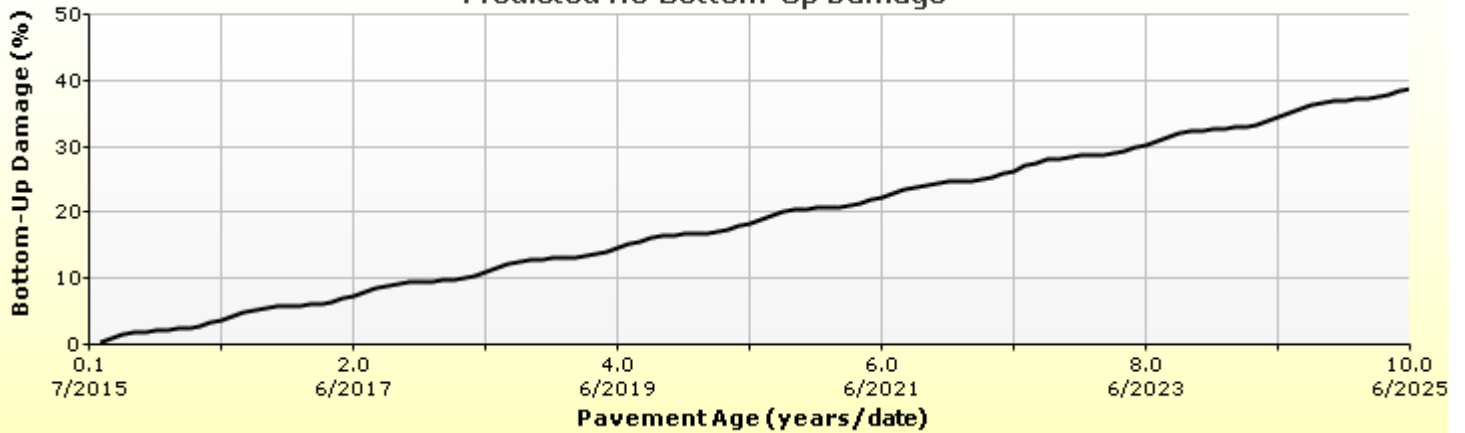
Thermal Cracking: Total Length vs. Time



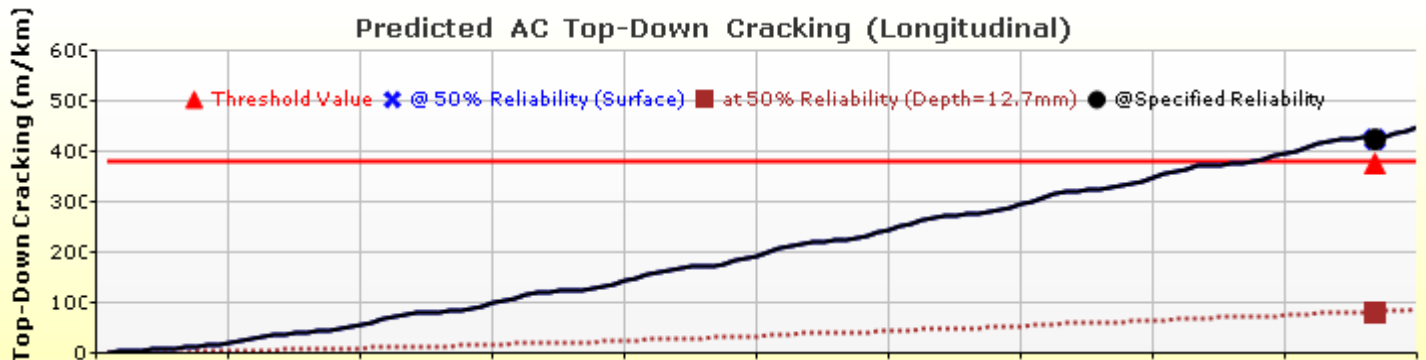
Predicted AC Top-Down Damage



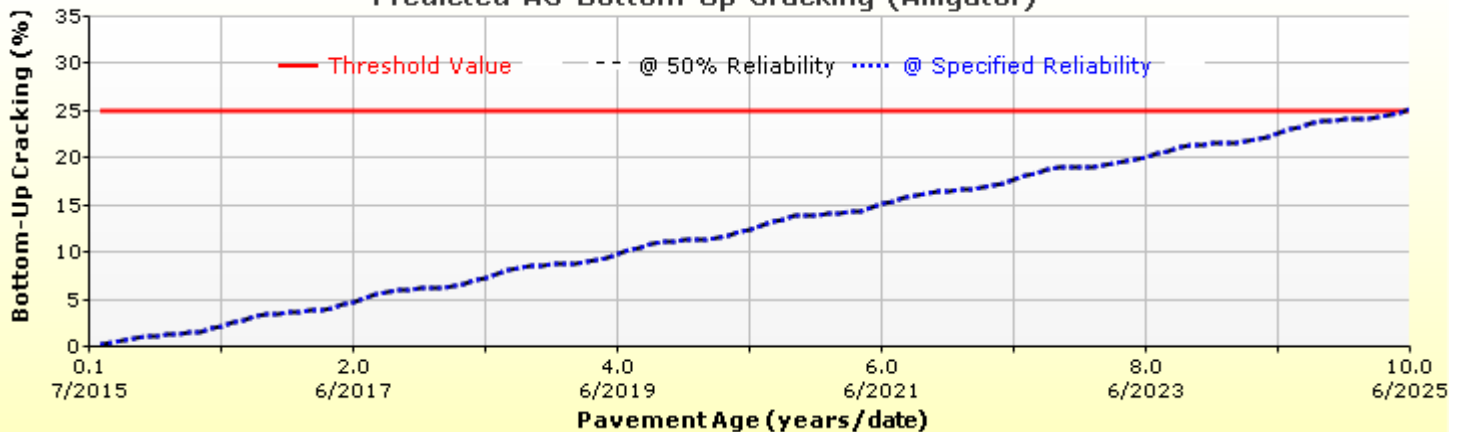
Predicted AC Bottom-Up Damage



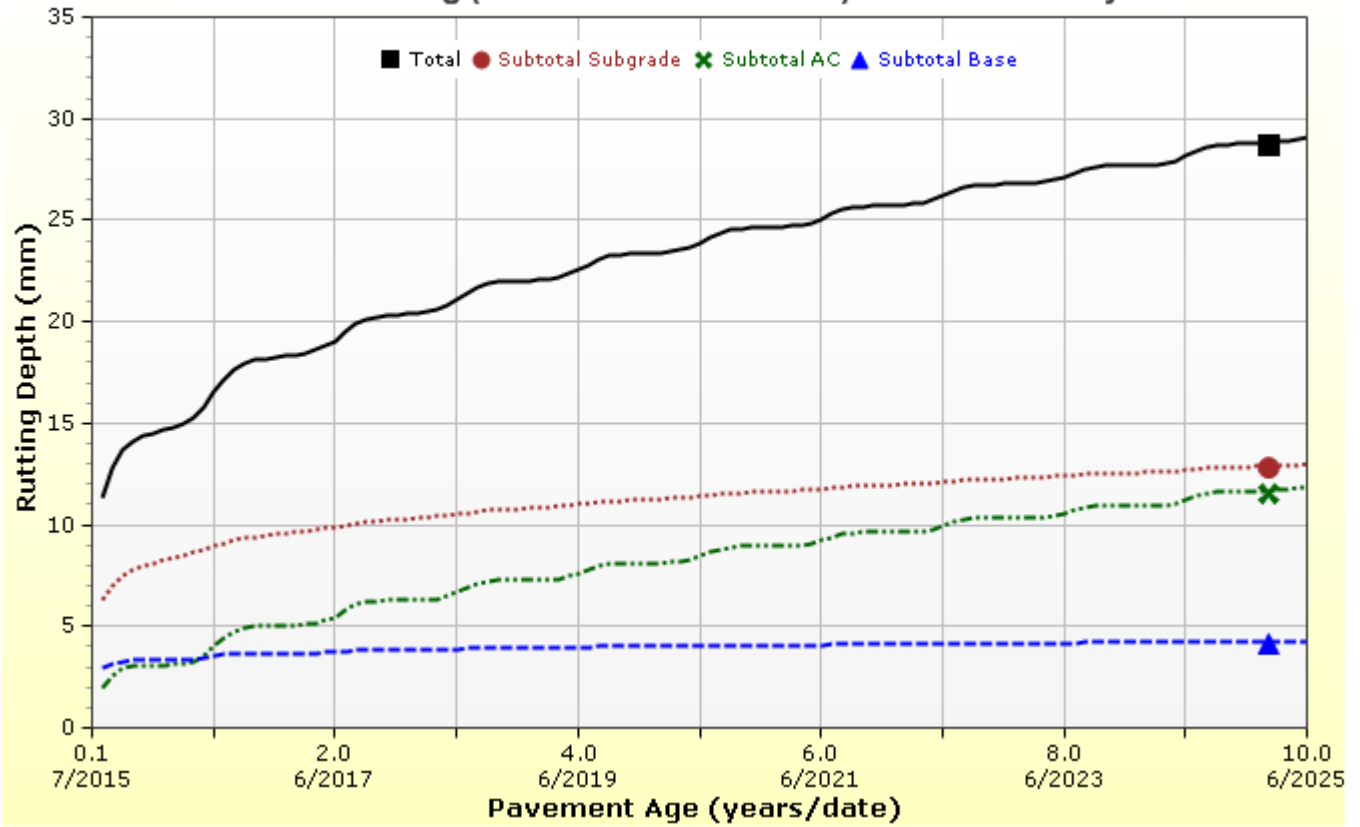
Predicted AC Top-Down Cracking (Longitudinal)

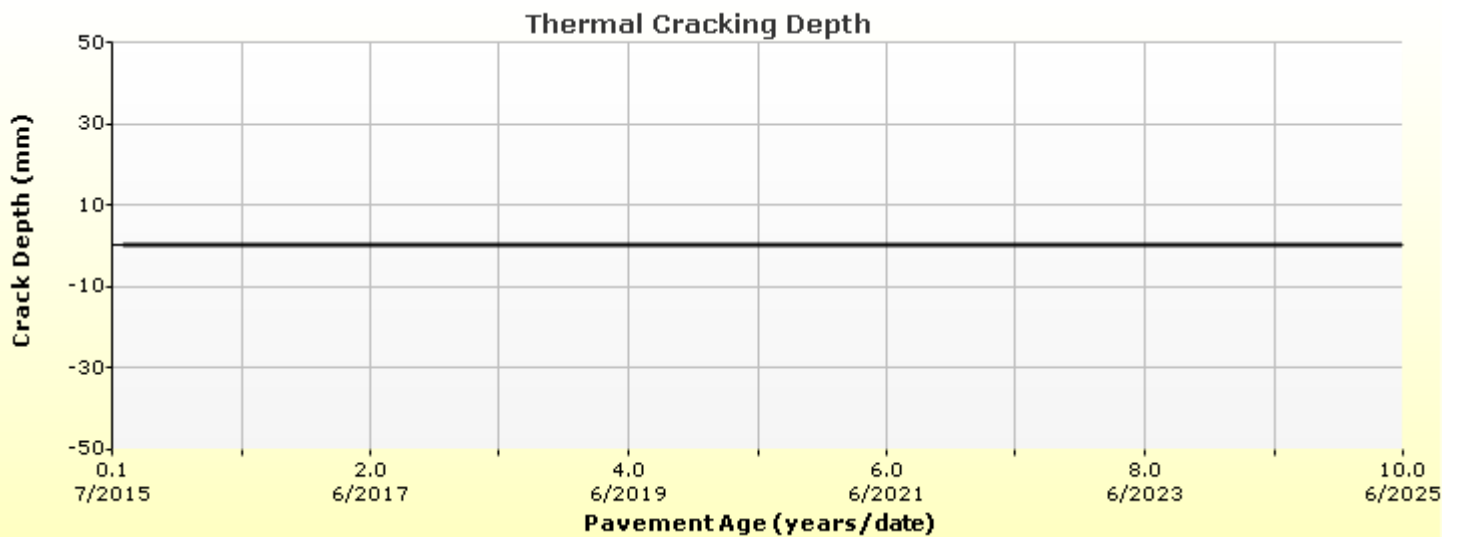
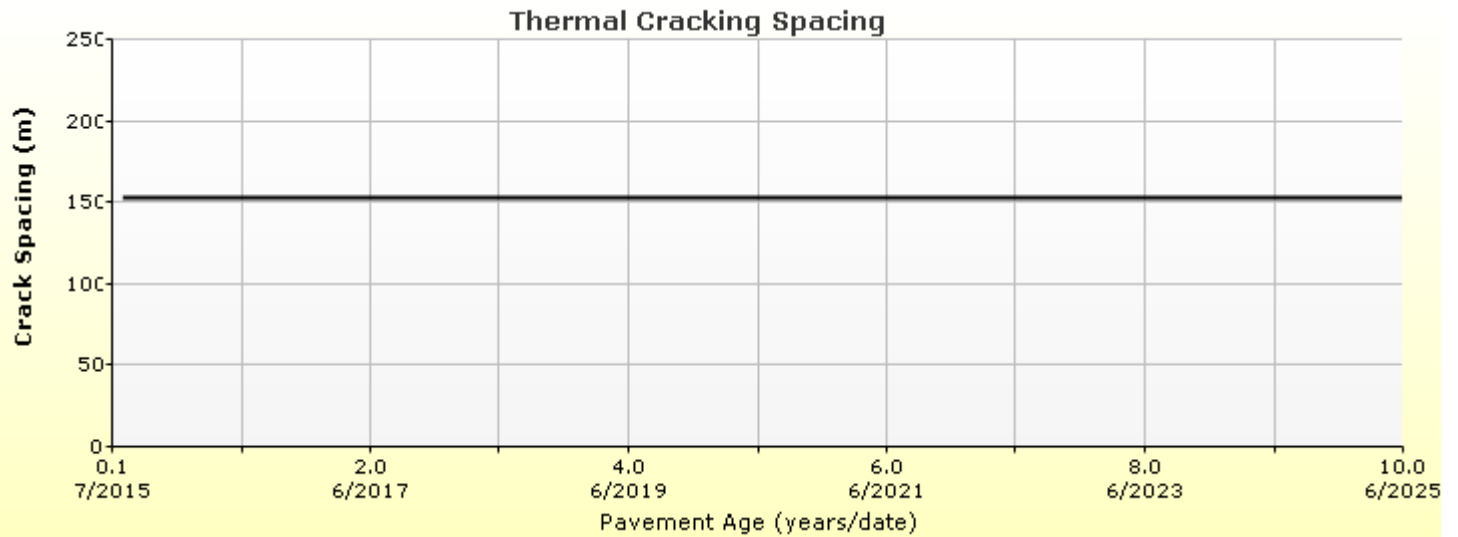


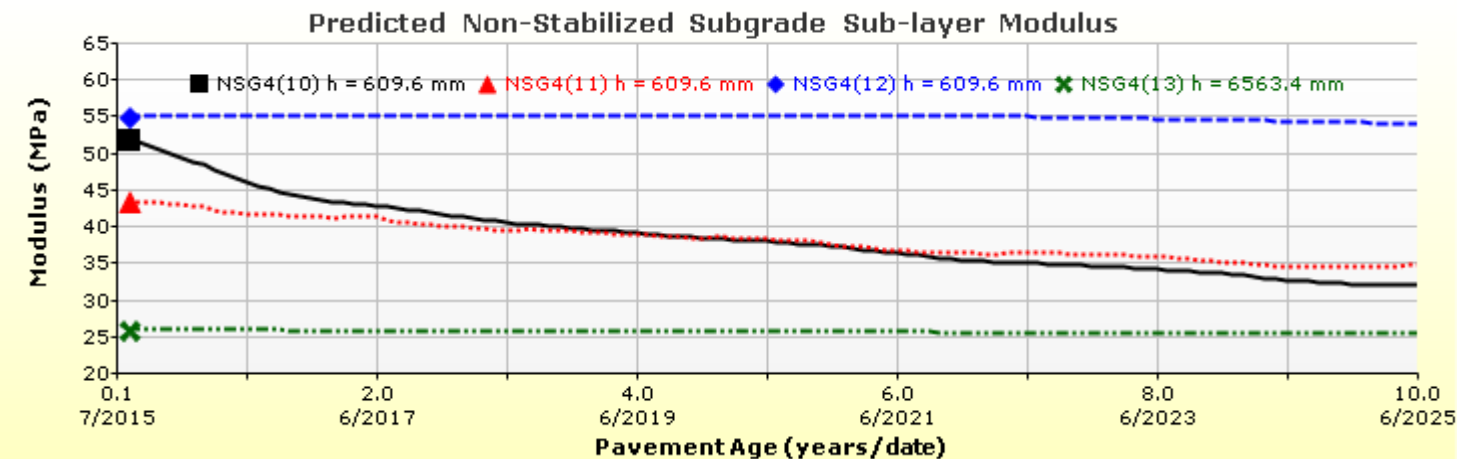
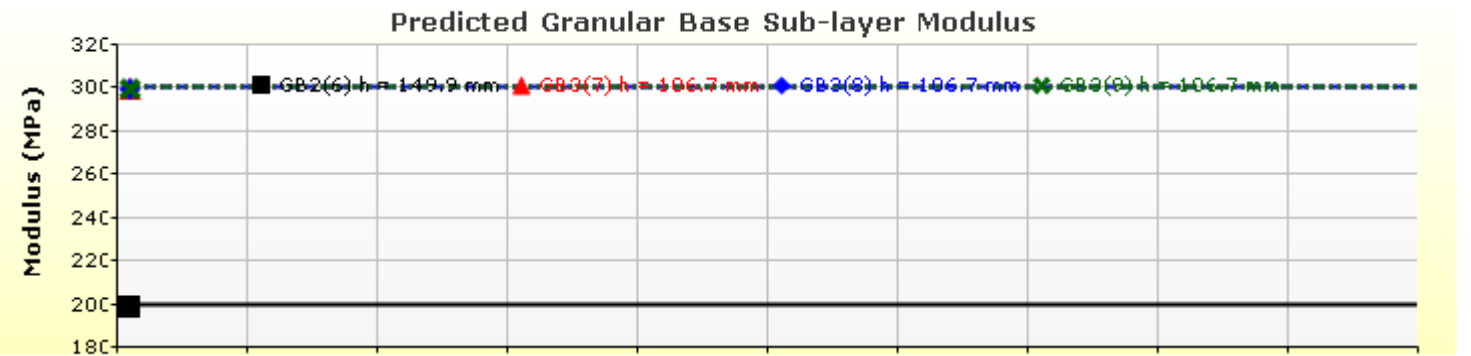
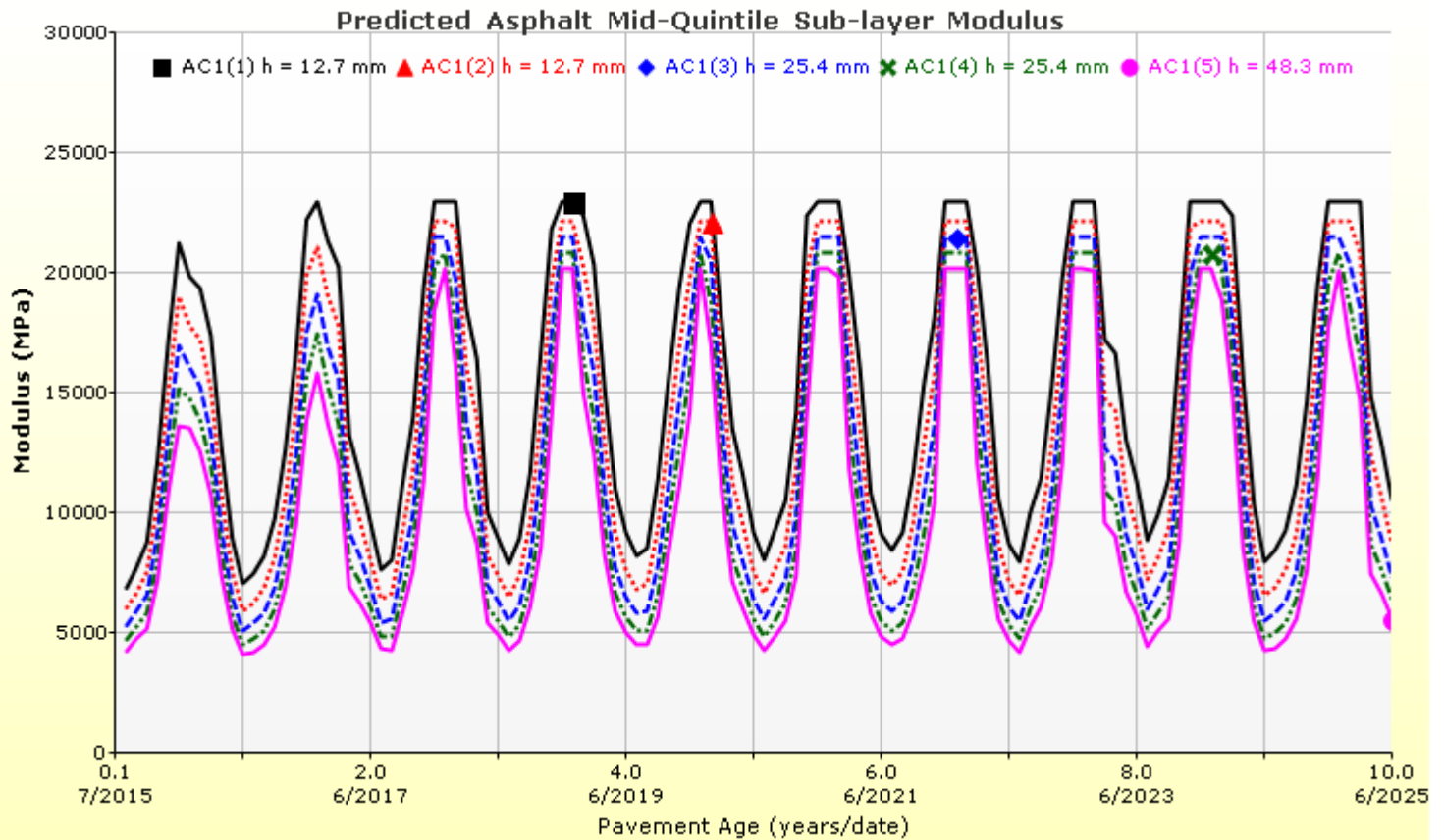
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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() σ = standard deviation of the log of the depth of cracks in the pavments C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_s = Tensile stress(psi) M_r = modulus of rupture(psi)
k1: 1	k2: 1
Bc1: 1	Bc2: 1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

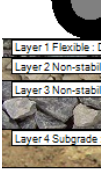
Design Inputs

Design Life: **10 years**
Design Type: **Flexible Pavement**

Base construction: **March, 2015**
Pavement construction: **June, 2015**
Traffic opening: **July, 2015**

Climate Data **32.119, -81.202**
Sources (Lat/Lon)

Design Structure



Layer type	Material Type	Thickness(mm)
Flexible	Default asphalt concrete	125.0
NonStabilized	Crushed stone	150.0
NonStabilized	Crushed stone	320.0
Subgrade	A-5	Semi-infinite

Volumetric at Construction:

Effective binder content (%)	11.6
Air voids (%)	7.0

Traffic

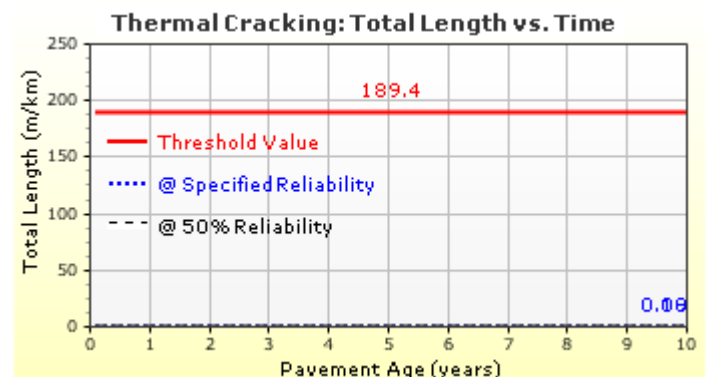
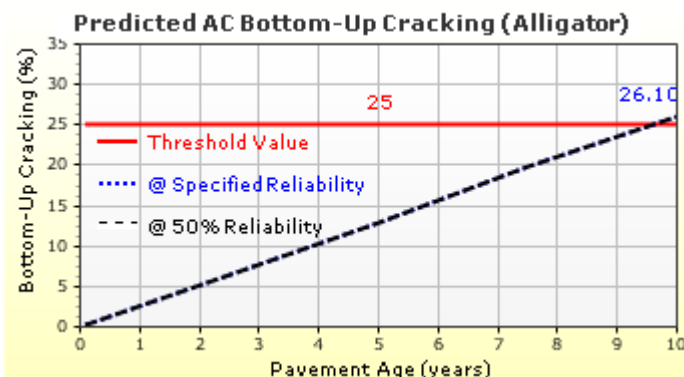
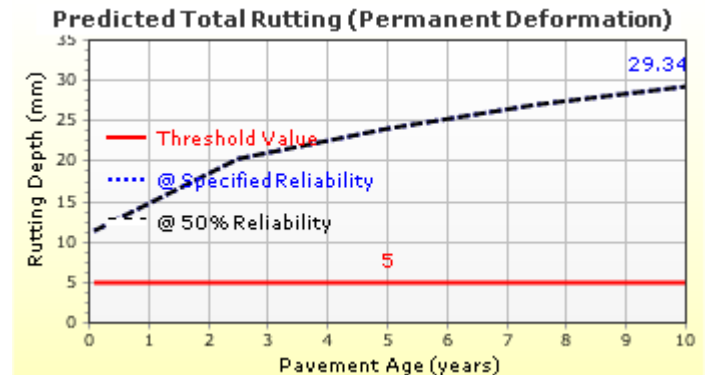
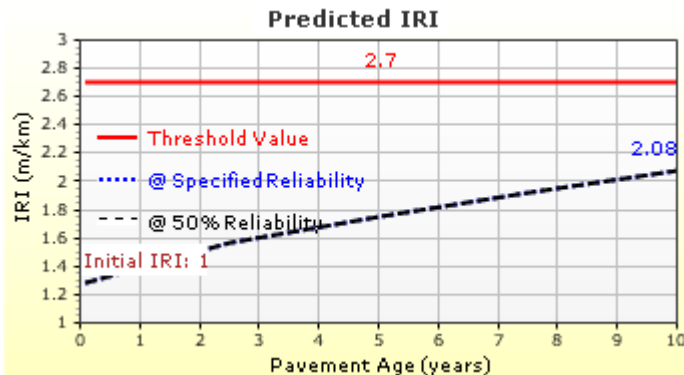
Age (year)	Heavy Trucks (cumulative)
2015 (initial)	4,820
2020 (5 years)	4,486,440
2025 (10 years)	9,687,460

Design Outputs

Distress Prediction Summary

Distress Type	Distress @ Specified Reliability		Reliability (%)		Criterion Satisfied?
	Target	Predicted	Target	Achieved	
Terminal IRI (m/km)	2.70	2.08	50.00	86.99	Pass
Permanent deformation - total pavement (mm)	5.00	29.34	50.00	0.00	Fail
AC bottom-up fatigue cracking (percent)	25.00	26.10	50.00	46.90	Fail
AC thermal cracking (m/km)	189.40	0.19	50.00	100.00	Pass
AC top-down fatigue cracking (m/km)	378.80	448.86	50.00	43.68	Fail
Permanent deformation - AC only (mm)	5.00	12.09	50.00	1.81	Fail

Distress Charts

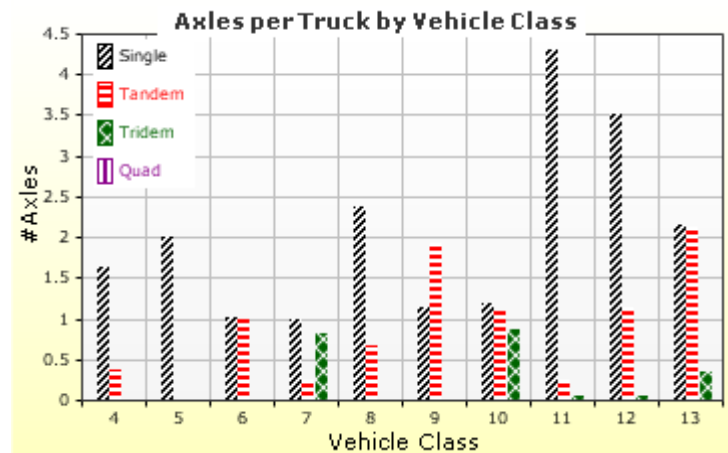
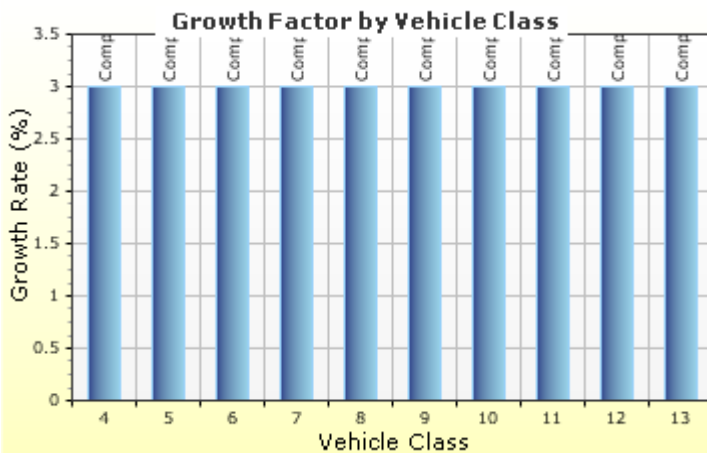
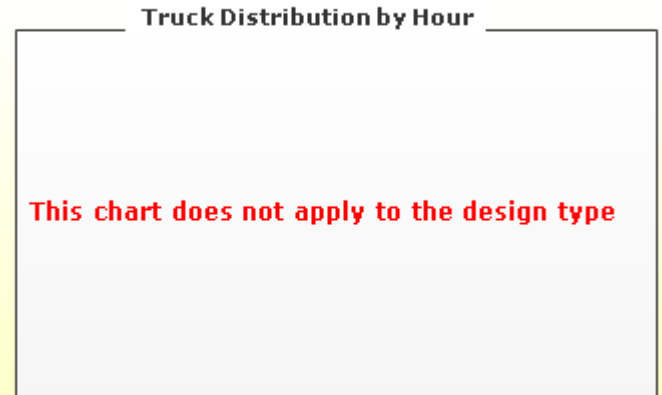
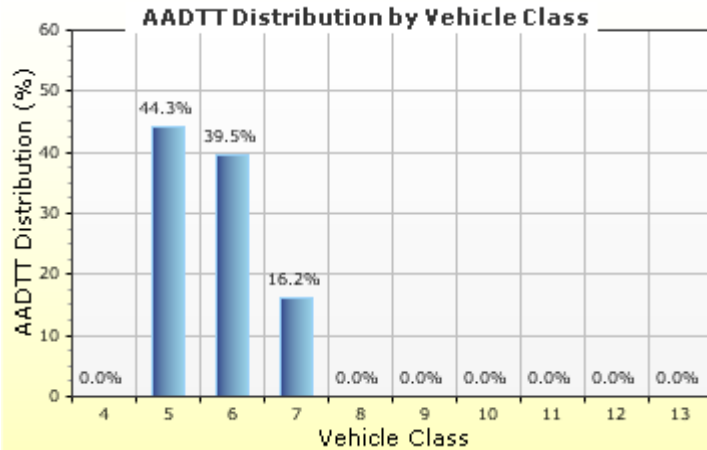


Traffic Inputs

Graphical Representation of Traffic Inputs

Initial two-way AADTT: 4,820
Number of lanes in design direction: 4

Percent of trucks in design direction (%): 50.0
Percent of trucks in design lane (%): 96.0
Operational speed (kph): 100.0



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	0%	3%	Compound
Class 5	44.3%	3%	Compound
Class 6	39.5%	3%	Compound
Class 7	16.2%	3%	Compound
Class 8	0%	3%	Compound
Class 9	0%	3%	Compound
Class 10	0%	3%	Compound
Class 11	0%	3%	Compound
Class 12	0%	3%	Compound
Class 13	0%	3%	Compound

Truck Distribution by Hour does not apply

Axle Configuration

Traffic Wander	
Mean wheel location (mm)	460
Traffic wander standard deviation (mm)	254
Design lane width (m)	3.7

Axle Configuration	
Average axle width (m)	2.59
Dual tire spacing (mm)	305
Tire pressure (kPa)	827.4

Average Axle Spacing	
Tandem axle spacing (m)	1.31
Tridem axle spacing (m)	1.25
Quad axle spacing (m)	1.25

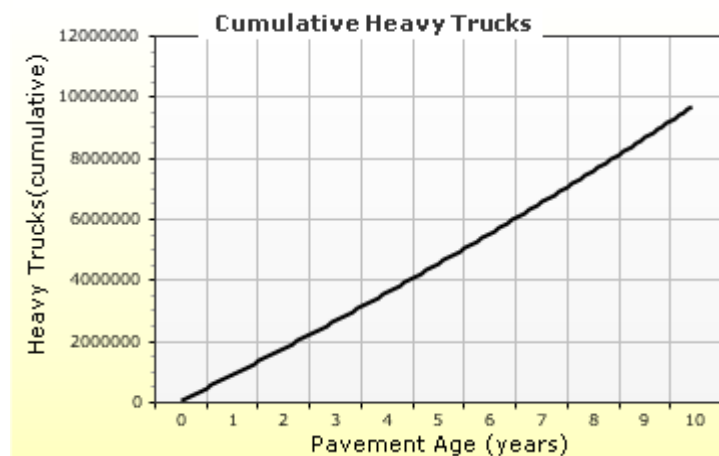
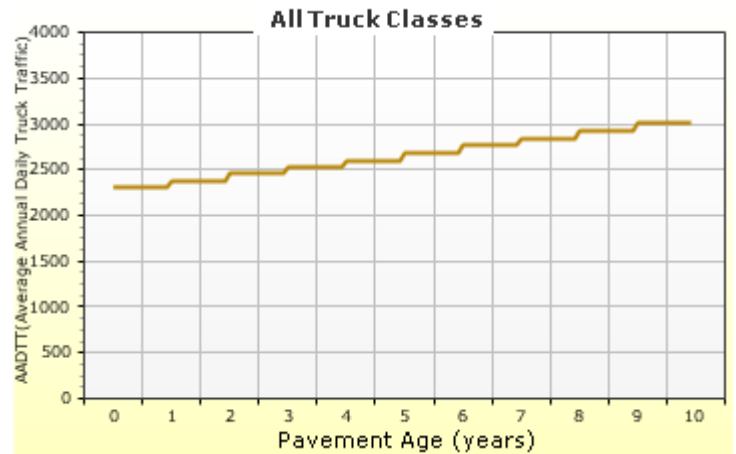
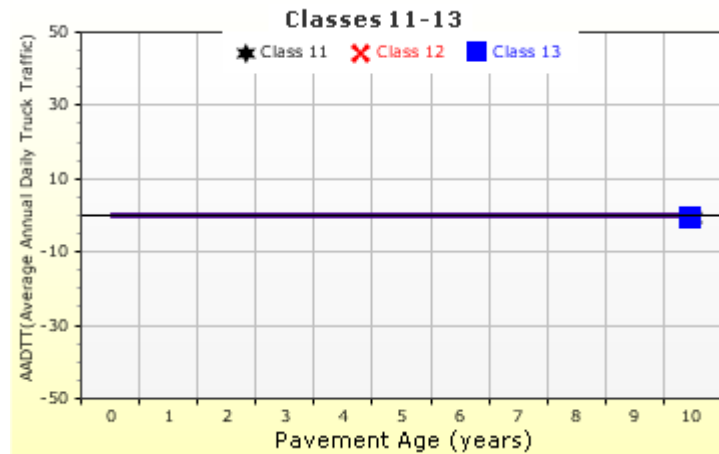
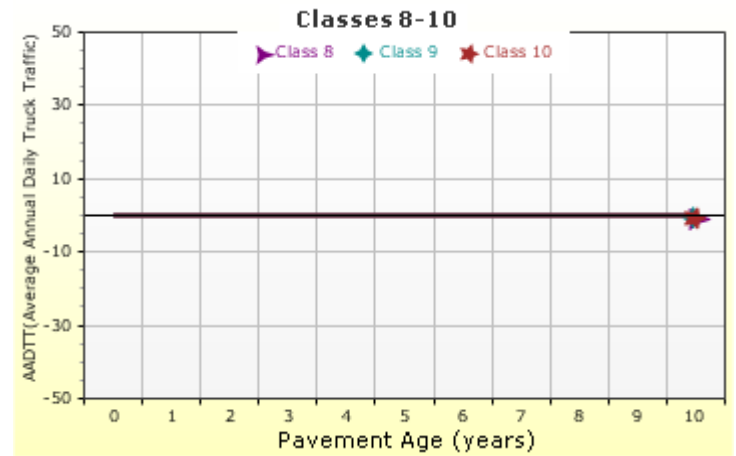
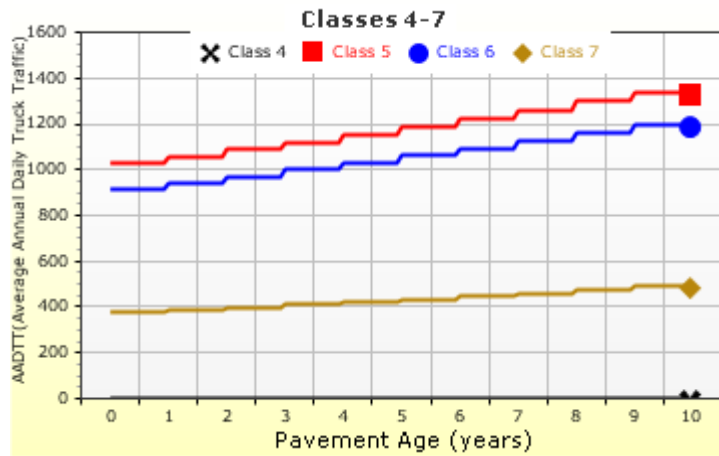
Wheelbase does not apply

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



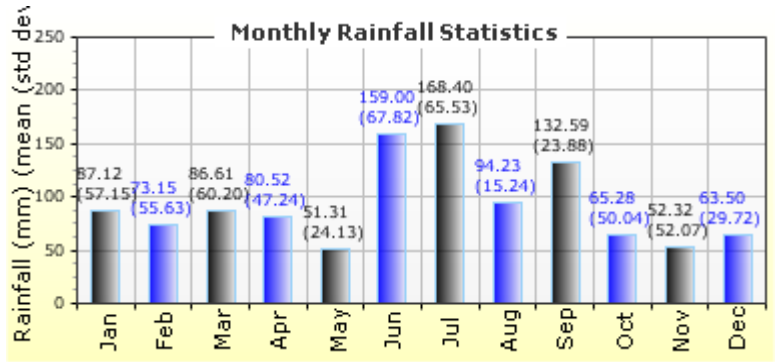
Climate Inputs

Climate Data Sources:

Climate Station Cities: Location (lat lon elevation(m))
SAVANNAH, GA **32.11900 -81.20200 8**

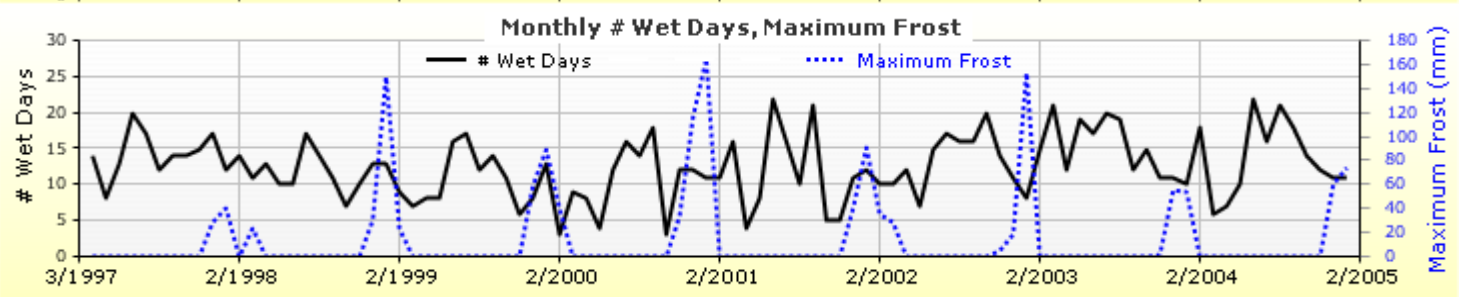
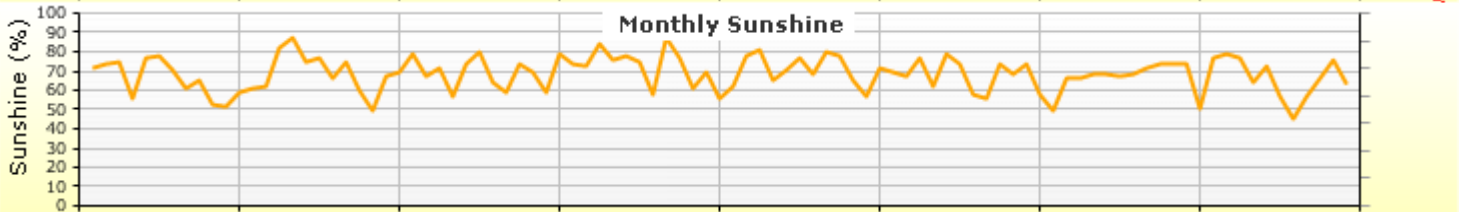
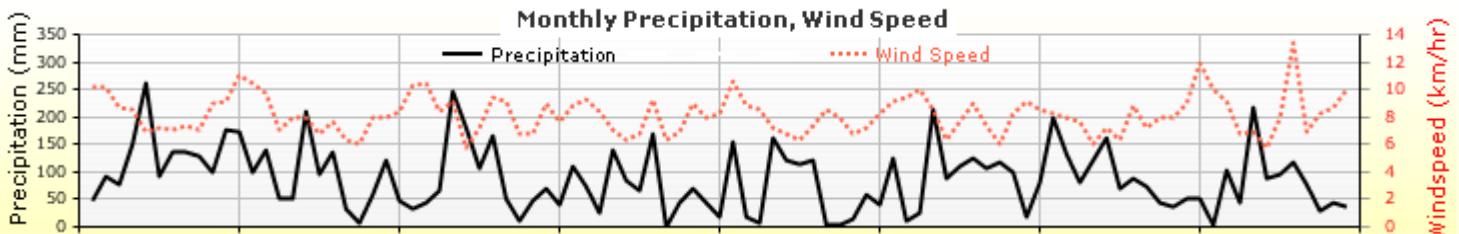
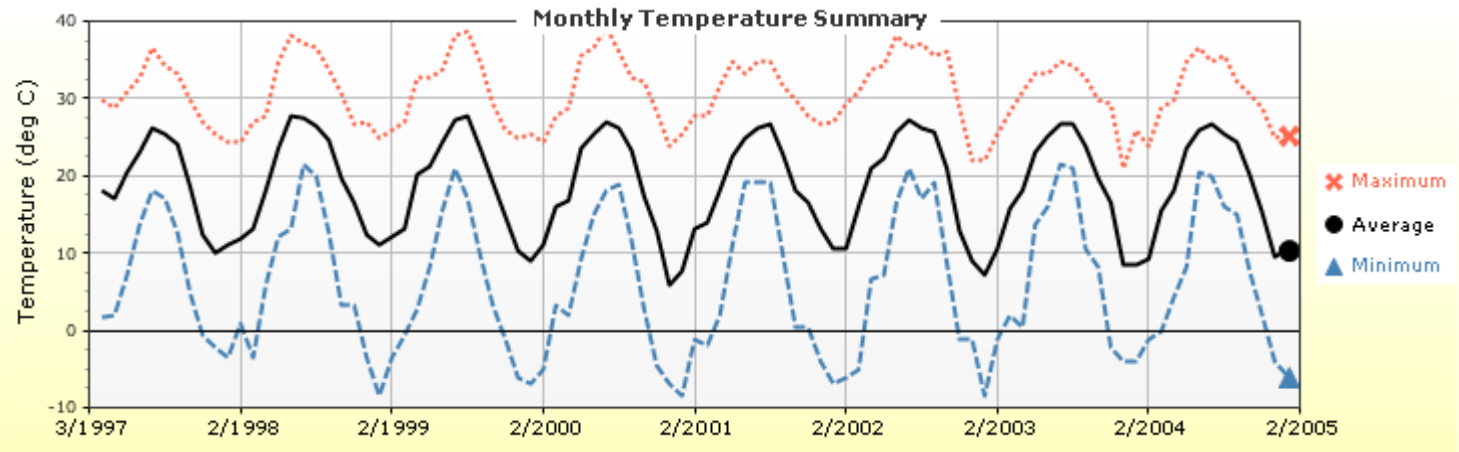
Annual Statistics:

Mean annual air temperature (°C) **18.89**
 Mean annual precipitation (mm) **1121.92**
 Freezing index (°C - days) **20.556**
 Average annual number of freeze/thaw cycles: **20.49**

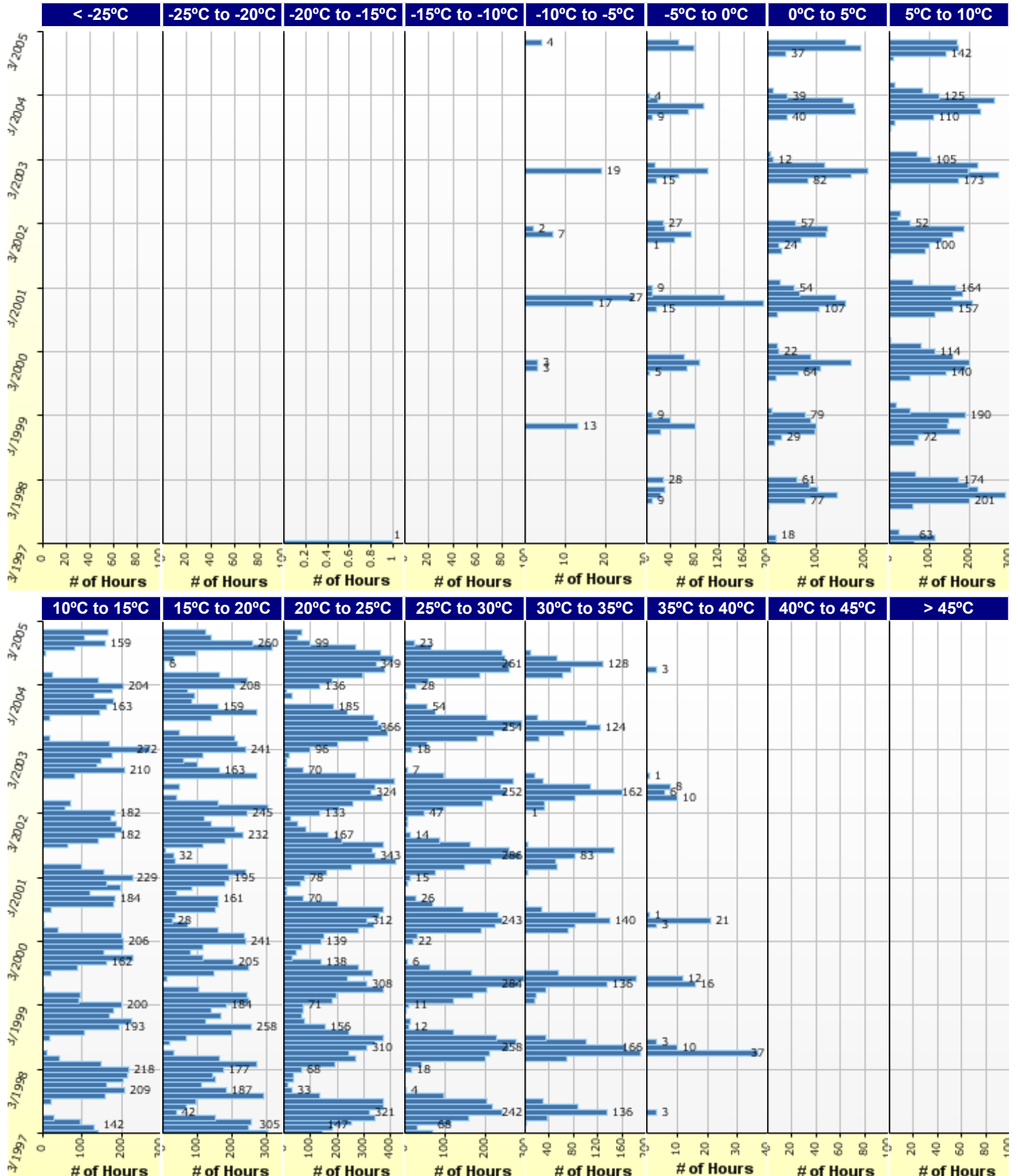


Water table depth (m) **3.05**

Monthly Climate Summary:



Hourly Air Temperature Distribution by Month:





Project1 - Novo ALF4_50%

File Name: C:\Users\Lelio Brito\My ME Design\Concepa\Project1 - Novo ALF4_50%.dgp



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

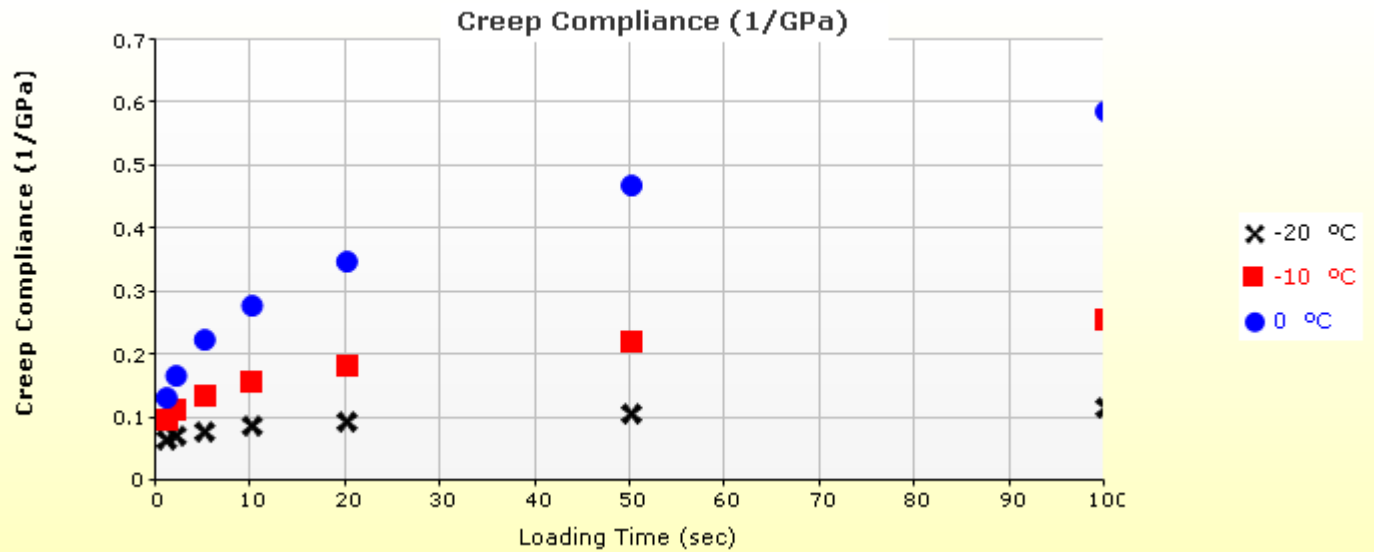
Structure - ICM Properties	
AC surface shortwave absorptivity	0.85

Layer Name	Layer Type	Interface Friction
Layer 1 Flexible : Default asphalt concrete	Flexible (1)	1.00
Layer 2 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 3 Non-stabilized Base : Crushed stone	Non-stabilized Base (4)	1.00
Layer 4 Subgrade : A-5	Subgrade (5)	-

Thermal Cracking (Input Level: 3)

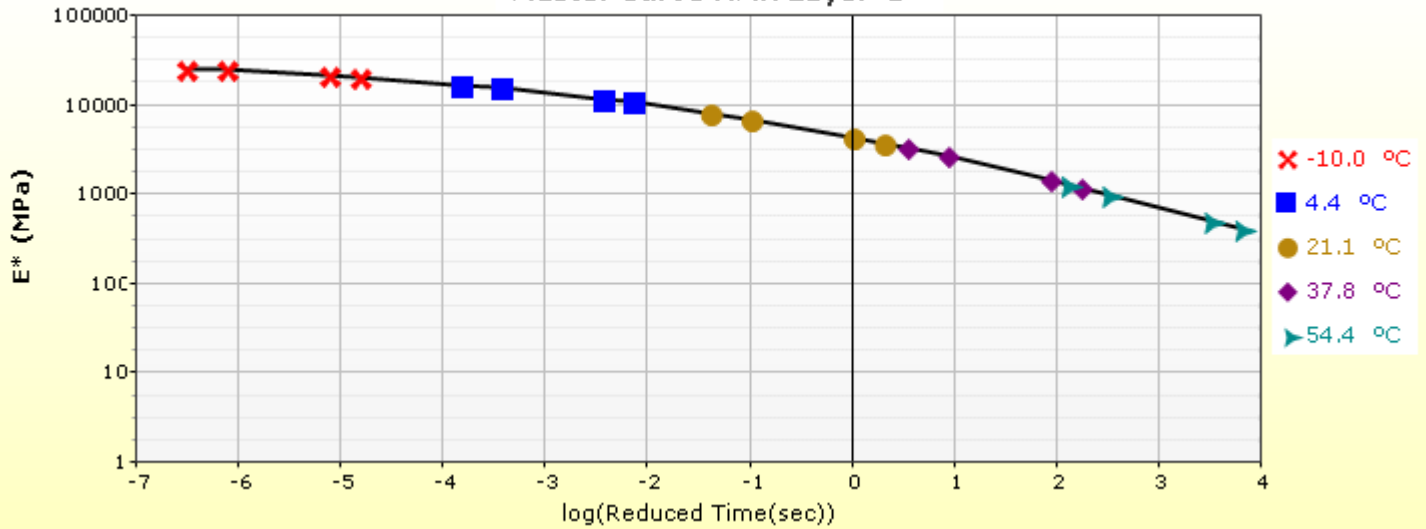
Indirect tensile strength at -10 °C (MPa)	2.68
Thermal Contraction	
Is thermal contraction calculated?	True
Mix coefficient of thermal contraction (mm/mm/°C)	-
Aggregate coefficient of thermal contraction (mm/mm/°C)	9.0e-006
Voids in Mineral Aggregate (%)	18.6

Loading time (sec)	Creep Compliance (1/GPa)		
	-20 °C	-10 °C	0 °C
1	6.79e-002	1.00e-001	1.35e-001
2	7.38e-002	1.16e-001	1.69e-001
5	8.24e-002	1.40e-001	2.26e-001
10	8.96e-002	1.61e-001	2.82e-001
20	9.73e-002	1.86e-001	3.52e-001
50	1.09e-001	2.24e-001	4.72e-001
100	1.18e-001	2.58e-001	5.89e-001

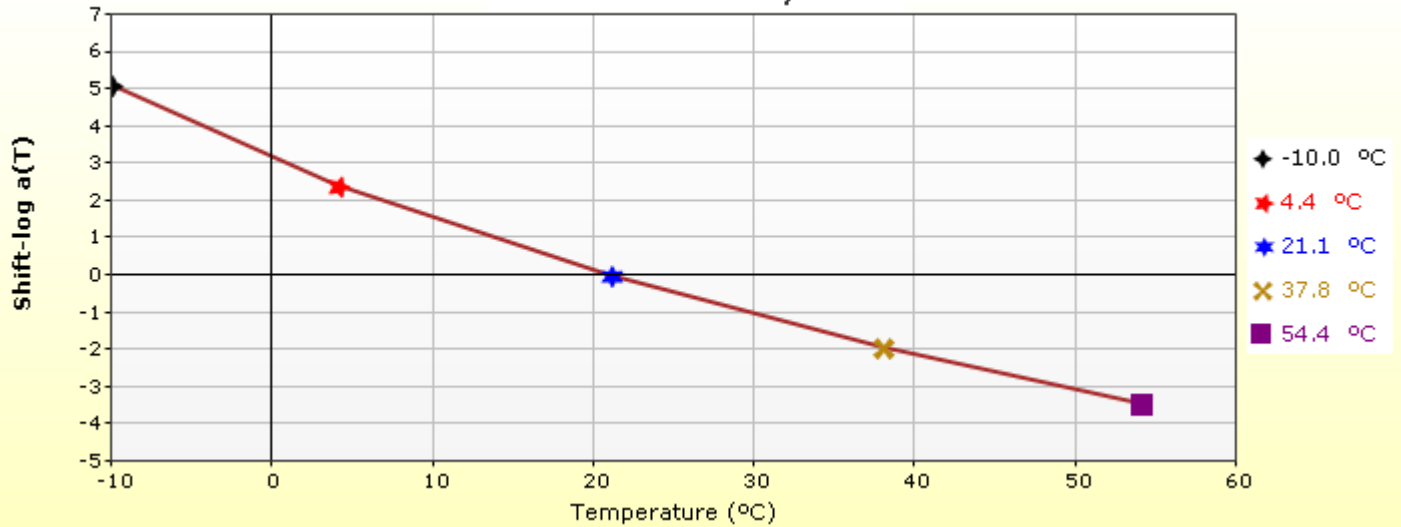


HMA Layer 1: Layer 1 Flexible : Default asphalt concrete

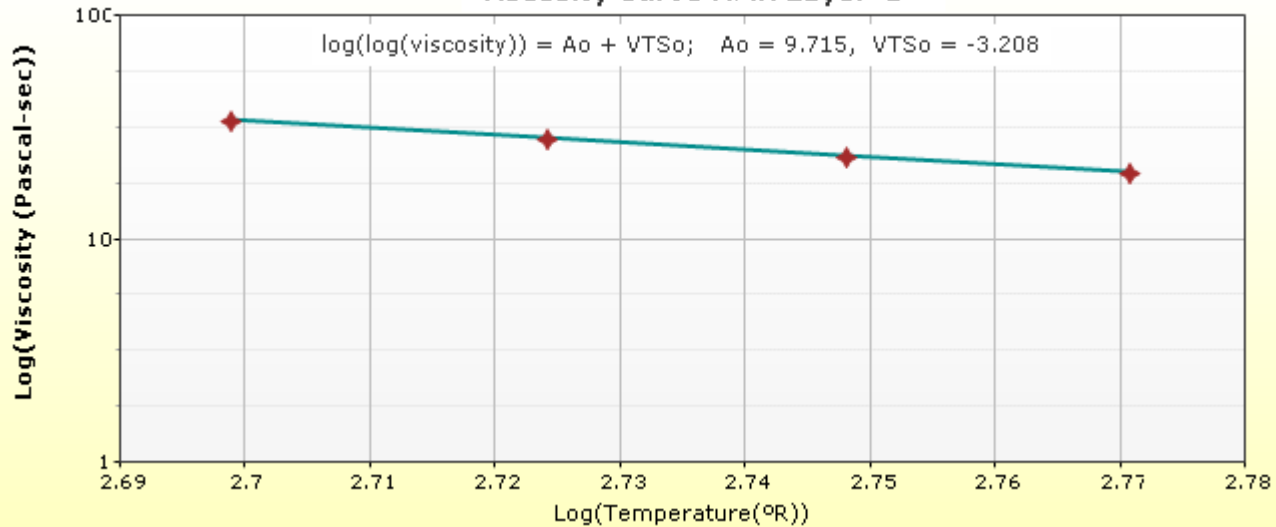
Master Curve HMA Layer 1



Shift Curve HMA Layer 1

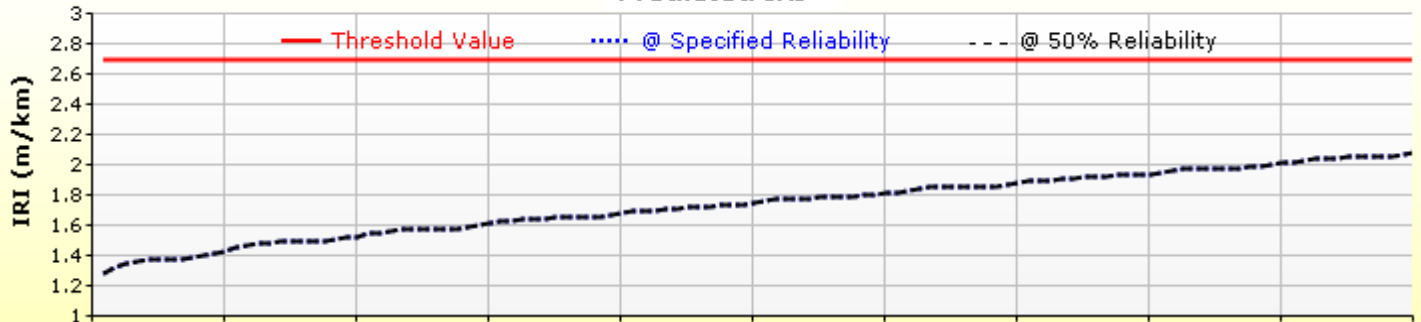


Viscosity Curve HMA Layer 1

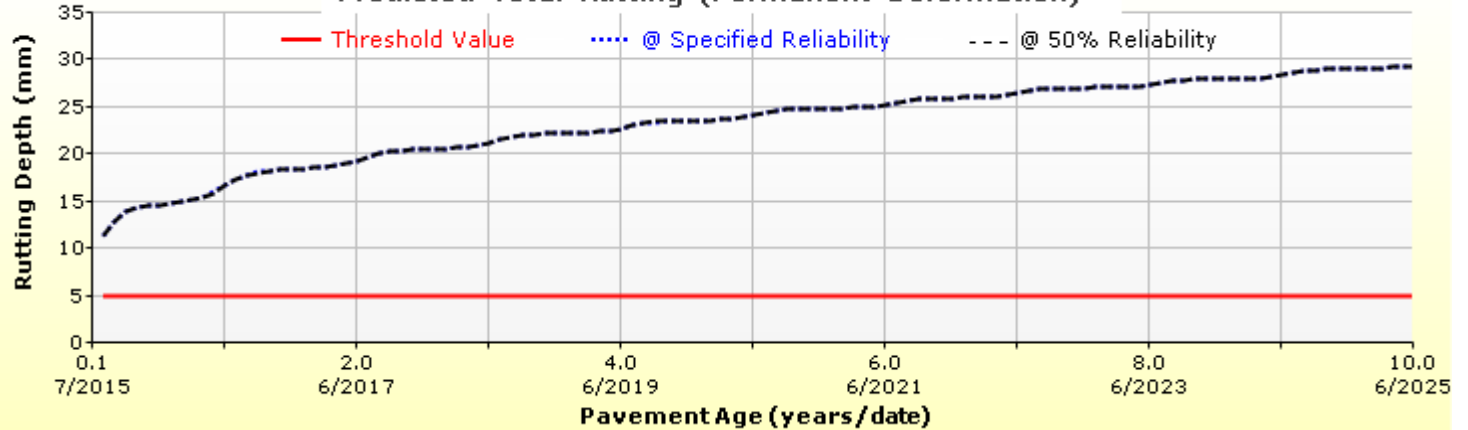


Analysis Output Charts

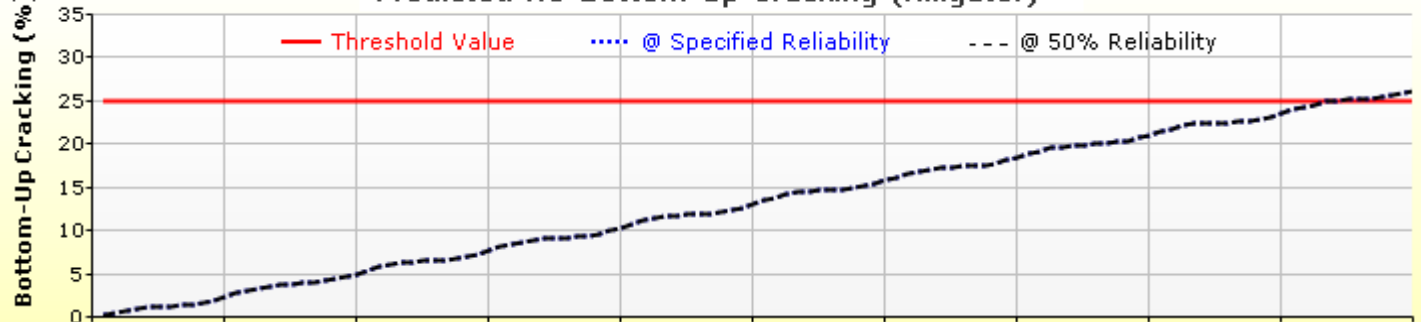
Predicted IRI



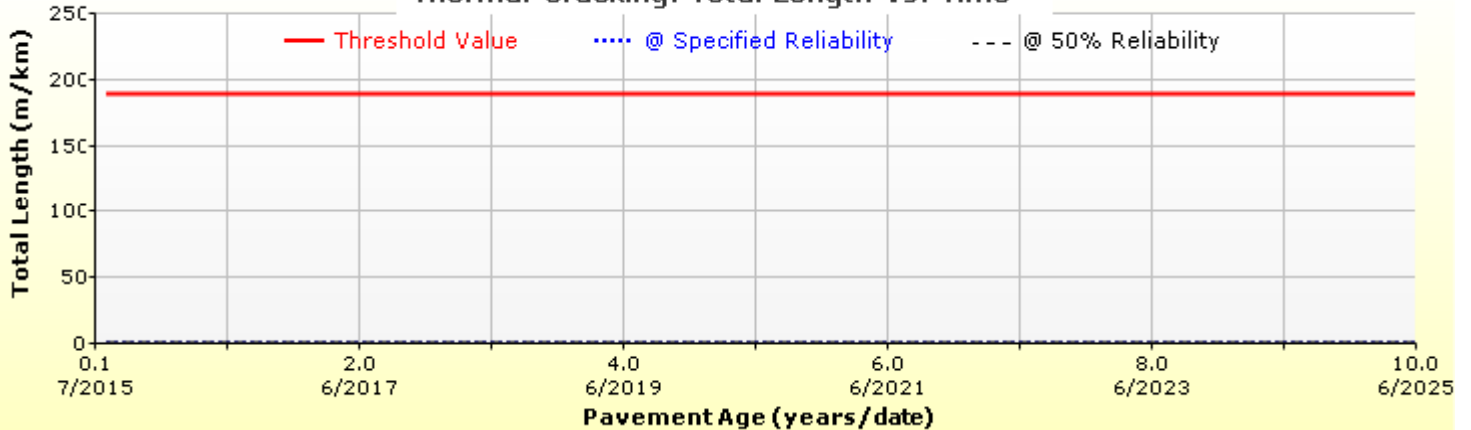
Predicted Total Rutting (Permanent Deformation)



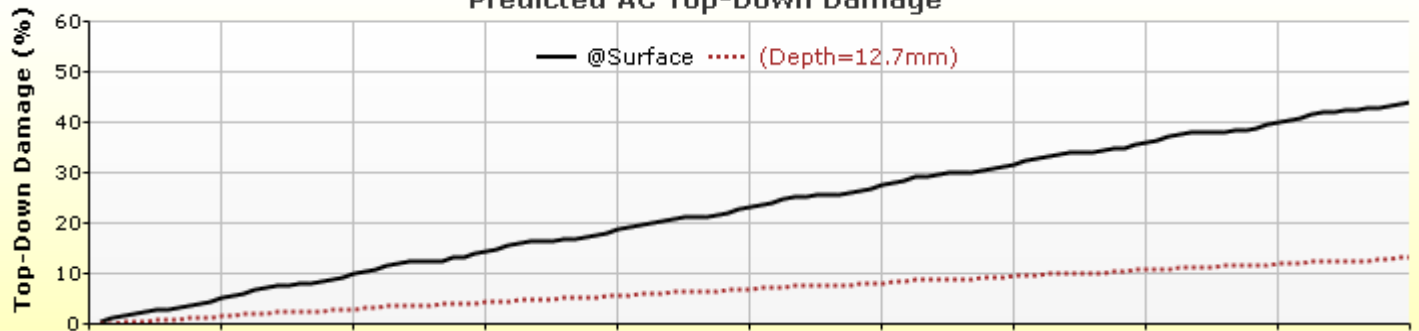
Predicted AC Bottom-Up Cracking (Alligator)



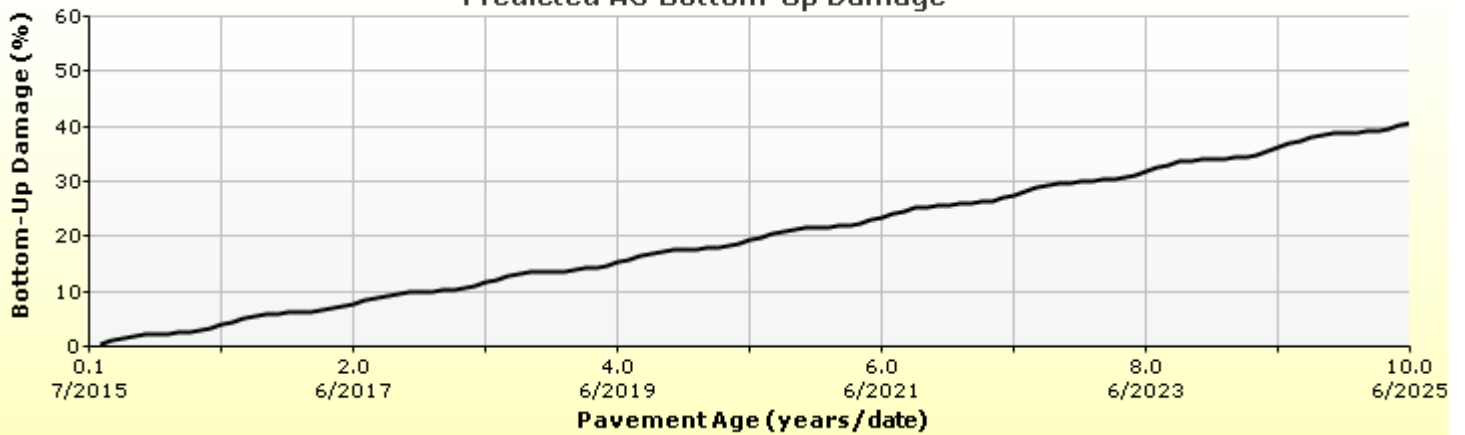
Thermal Cracking: Total Length vs. Time



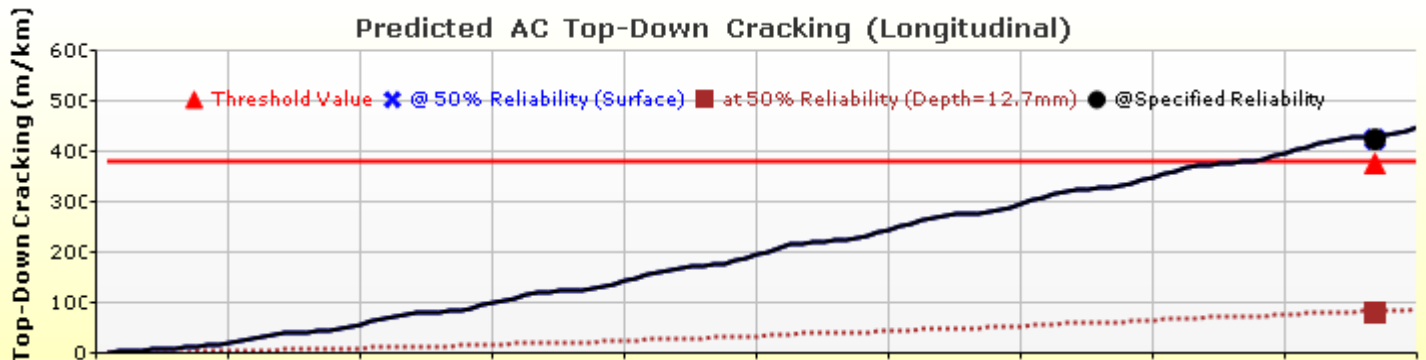
Predicted AC Top-Down Damage



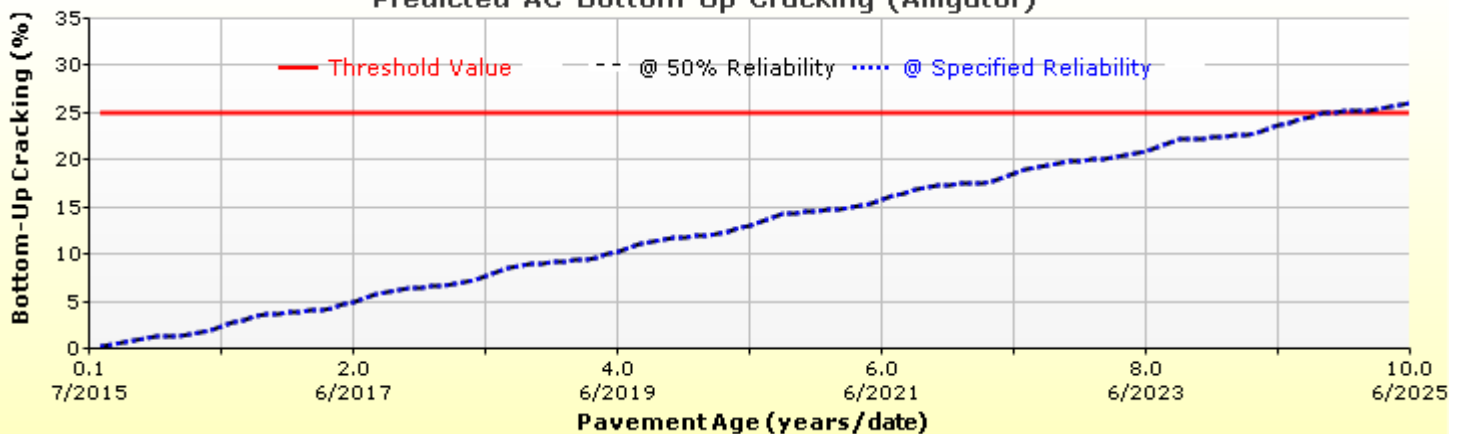
Predicted AC Bottom-Up Damage



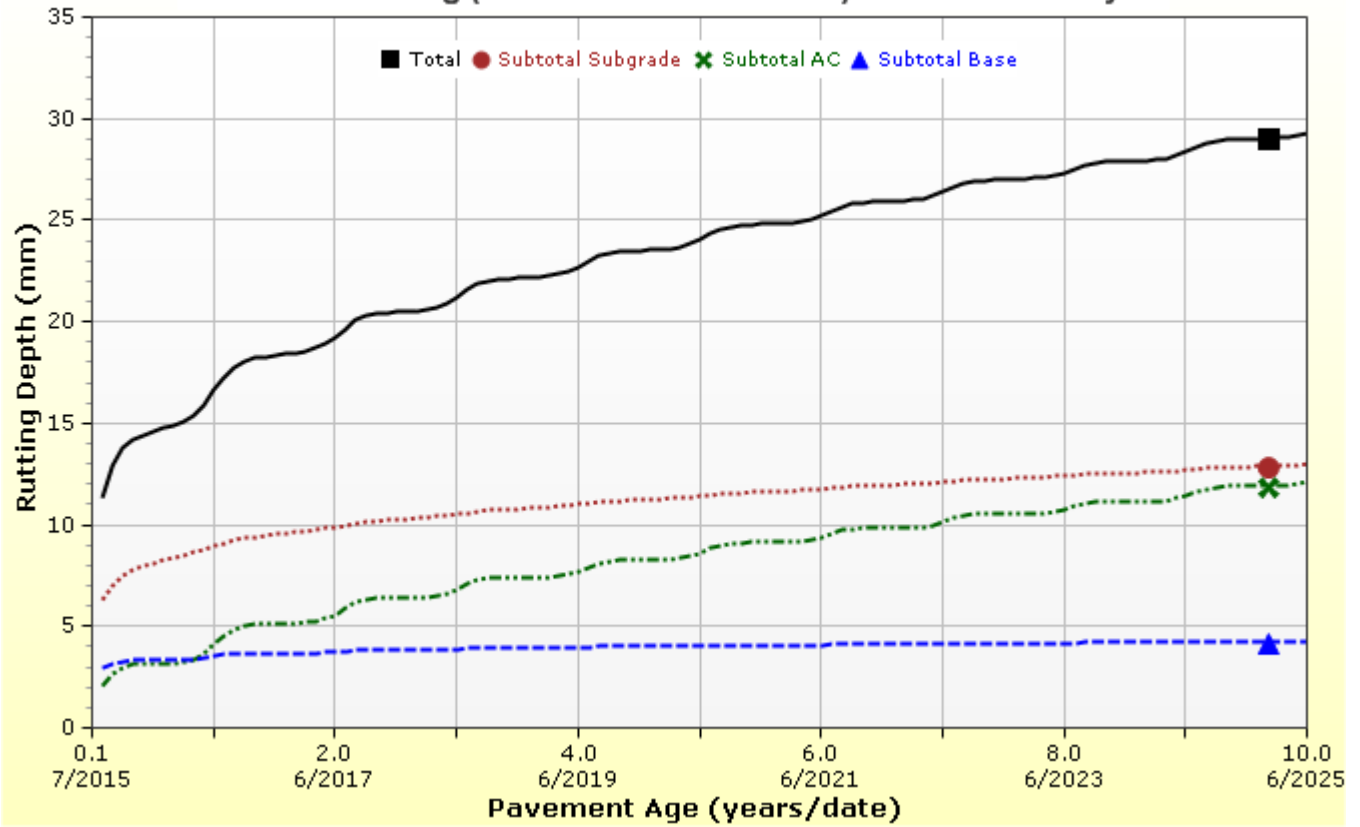
Predicted AC Top-Down Cracking (Longitudinal)

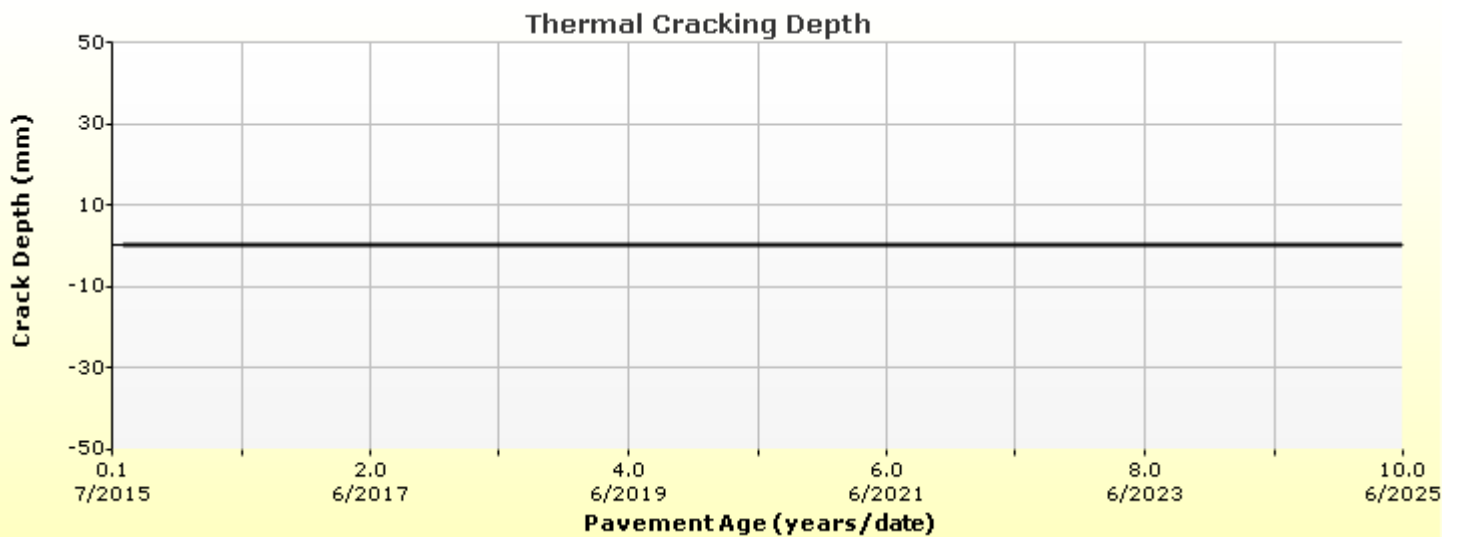
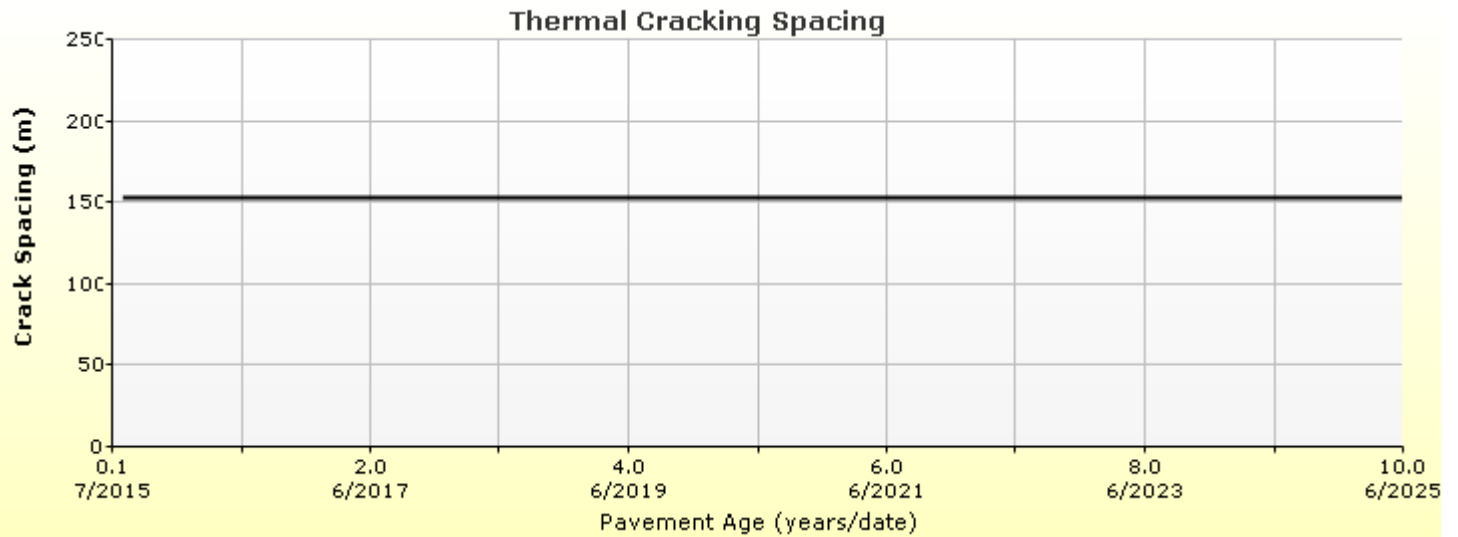


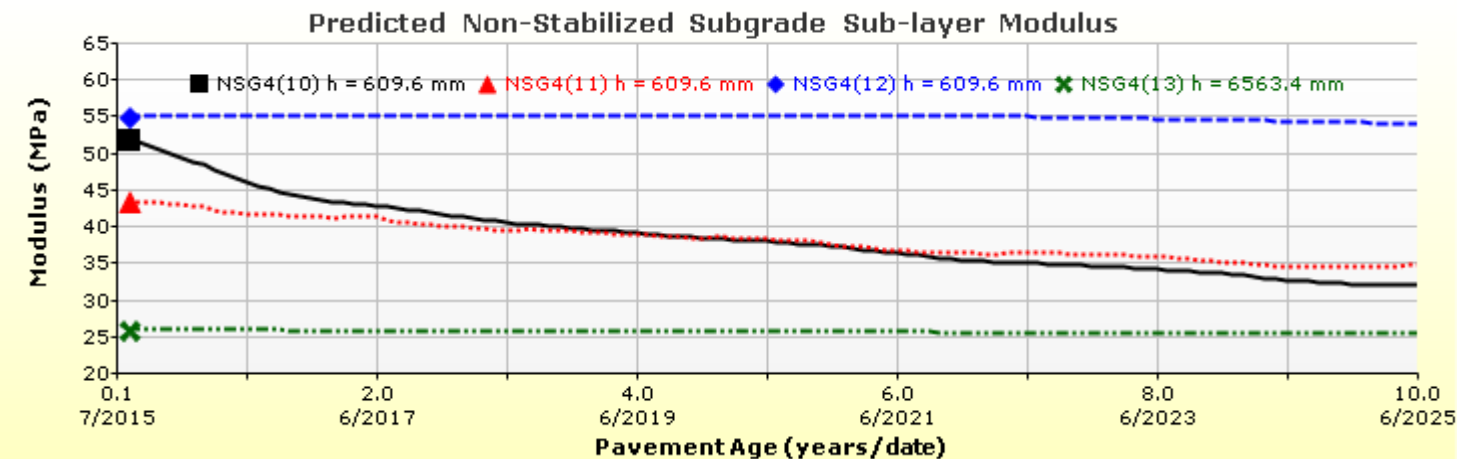
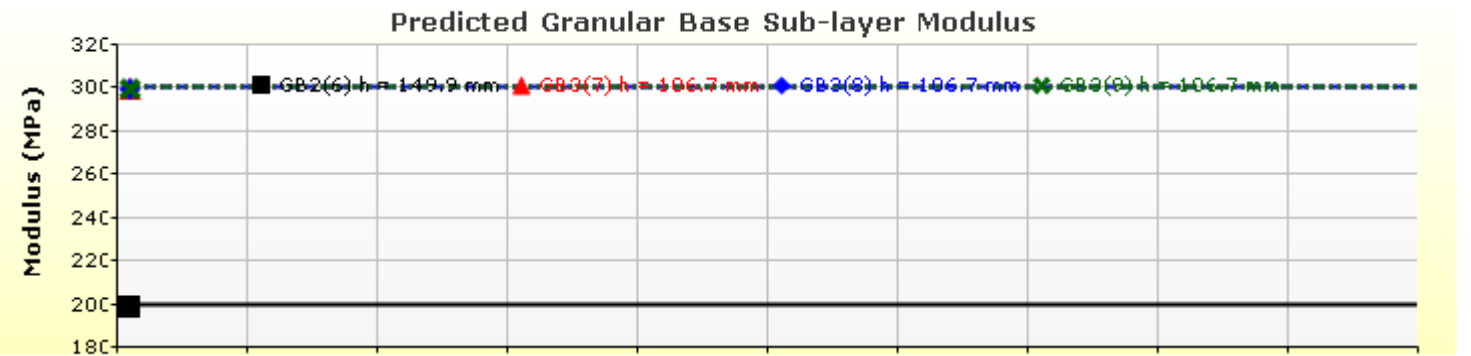
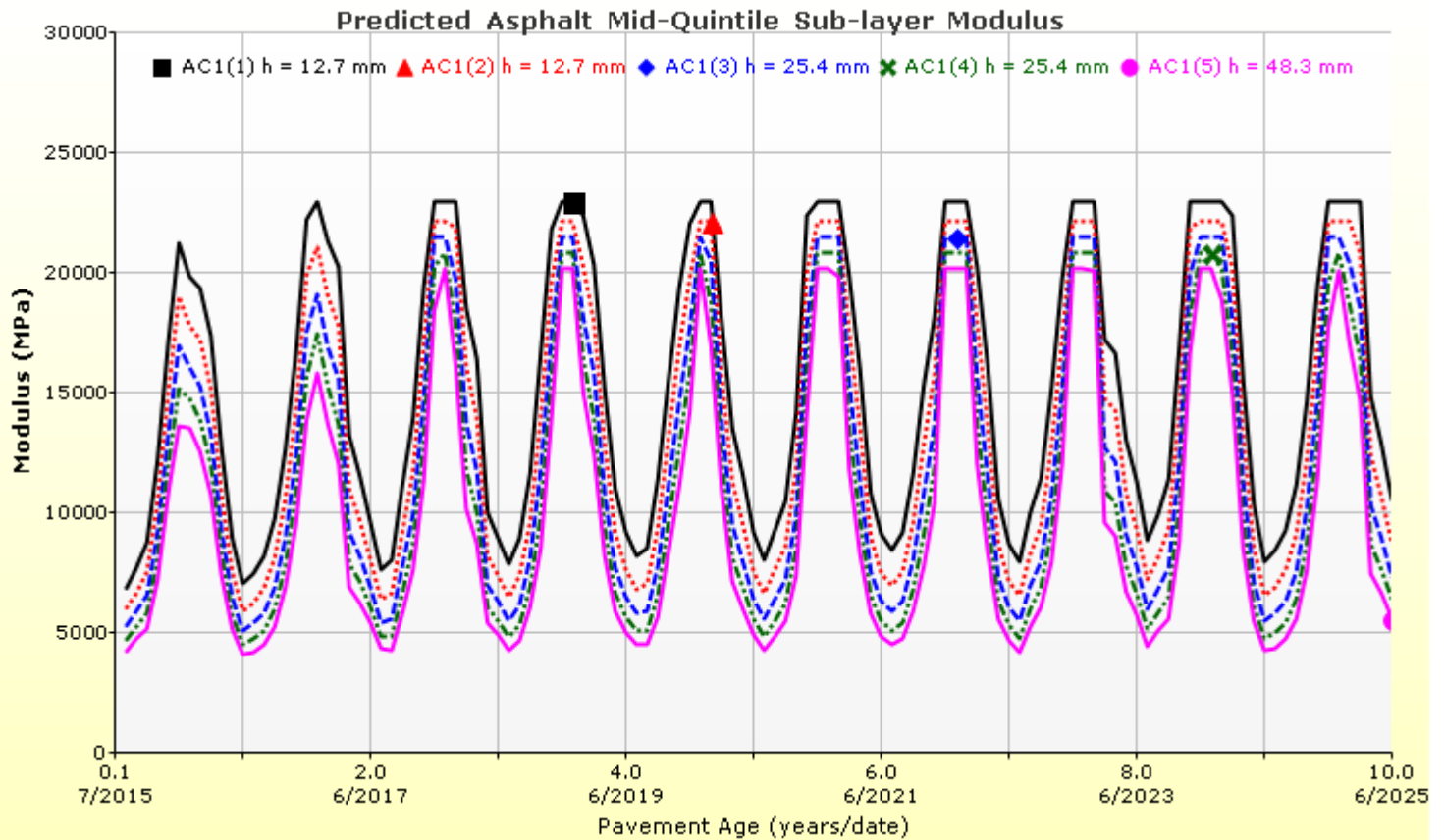
Predicted AC Bottom-Up Cracking (Alligator)



Predicted Rutting (Permanent Deformation) at 50% Reliability







Layer Information

Layer 1 Flexible : Default asphalt concrete

Asphalt		
Thickness (mm)	125.0	
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	76-22
A	9.715
VTS	-3.208

General Info

Name	Value
Reference temperature (°C)	21.1
Effective binder content (%)	11.6
Air voids (%)	7
Thermal conductivity (watt/meter-kelvin)	1.16
Heat capacity (joule/kg-kelvin)	963

Identifiers

Field	Value
Display name/identifier	Default asphalt concrete
Description of object	
Author	
Date Created	9/16/2010 12:00:00 AM
Approver	
Date approved	9/16/2010 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 : Crushed stone

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 (MPa)

Resilient Modulus (MPa)

200.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 : Crushed stone

Unbound

Layer thickness (mm)	320.0
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 (MPa)

Resilient Modulus (MPa)

300.0

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

Identifiers

Field	Value
Display name/identifier	Crushed stone
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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 4 Subgrade : A-5

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:	Modify input values by temperature/moisture
Method:	Resilient Modulus (MPa)

Resilient Modulus (MPa)

55.2

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

Identifiers

Field	Value
Display name/identifier	A-5
Description of object	Default material
Author	AASHTO
Date Created	1/1/2011 12:00:00 AM
Approver	
Date approved	1/1/2011 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?	True

	Is User Defined?	Value
Maximum dry unit weight (kgf/m ³)	False	1918.4
Saturated hydraulic conductivity (m/hr)	False	2.576e-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

$N_f = 0.00432 * C * \beta_{f1} k_1 \left(\frac{1}{\varepsilon_1}\right)^{k_2 \beta_{f2}} \left(\frac{1}{E}\right)^{k_3 \beta_{f3}}$	k1: 0.007566
$C = 10^M$	k2: 3.9492
$M = 4.84 \left(\frac{V_b}{V_a + V_b} - 0.69\right)$	k3: 1.281
	Bf1: 1
	Bf2: 1
	Bf3: 1

AC Rutting

$\frac{\varepsilon_p}{\varepsilon_r} = k_z \beta_{r1} 10^{k_1 T} k_2 \beta_{r2} N^{k_3 \beta_{r3}}$ $k_z = (C_1 + C_2 * depth) * 0.328196^{depth}$ $C_1 = -0.1039 * H_a^2 + 2.4868 * H_a - 17.342$ $C_2 = 0.0172 * H_a^2 - 1.7331 * H_a + 27.428$ Where: H_{ac} = total AC thickness(in)	ε_p = plastic strain(in/in) ε_r = resilient strain(in/in) T = layer temperature(°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 = regression coefficient determined through field calibration $N()$ = standard normal distribution evaluated at() σ = standard deviation of the log of the depth of cracks in the pavements C = crack depth(in) h_{ac} = thickness of asphalt layer(in) ΔC = Change in the crack depth due to a cooling cycle ΔK = Change in the stress intensity factor due to a cooling cycle A, n = Fracture parameters for the asphalt mixture E = mixture stiffness σ_m = Undamaged mixture tensile strength β_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 σ_s = Tensile stress(psi) M_r = modulus of rupture(psi)
k1: 1	k2: 1
Bc1: 1	Bc2: 1

Subgrade Rutting

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

δ_a = permanent deformation for the layer
 N = number of repetitions
 ε_v = average vertical strain(in/in)
 $\varepsilon_0, \beta, \rho$ = material properties
 ε_r = resilient strain(in/in)

Granular

k1: 2.03

Bs1: 1

Standard Deviation (BASERUT)

0.1477*Pow(BASERUT,0.6711)+0.001

Fine

k1: 1.35

Bs1: 1

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

C3 - Transverse Crack

C2 - Fatigue Crack

C4 - Site Factors

C1: 40

C2: 0.4

C3: 0.008

C4: 0.015

