Building Partnerships between Academia and Industry

Some Personal Reflections on Research in Steel Structures

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Steel Structures, Teaching and Research in Science and Technology
Brasilia
October 5, 2012

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Outline

- Personal reflections on my career as a steel researcher
- Future directions of steel research

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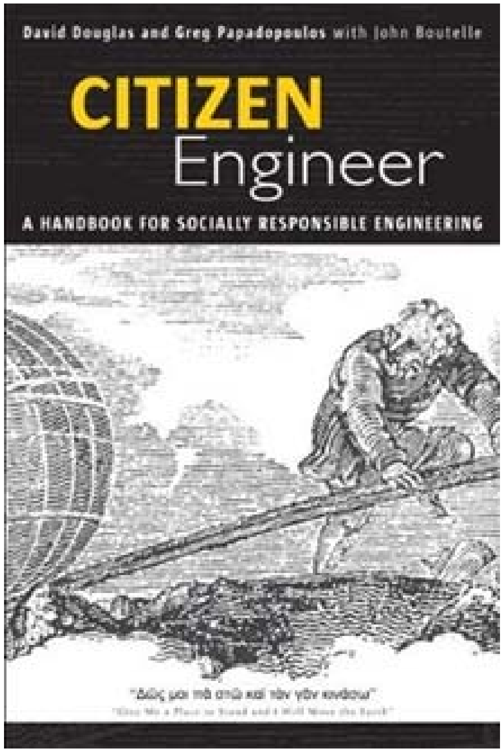
Citizen Engineers

"Citizen Engineers are techno-responsible, environmentally responsible, economically responsible, socially responsible participants in the engineering community"



"An engineer is a constructive artist. The art of engineering is based on science and mathematics, where the tools and materials are technological. It's a constructive art because engineers build and optimize things"

http://citizenengineer.org

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Innovation In Design of Steel Structures: Research Needs for Global Competitiveness

ASCE/SEI Workshop March 28, 2012

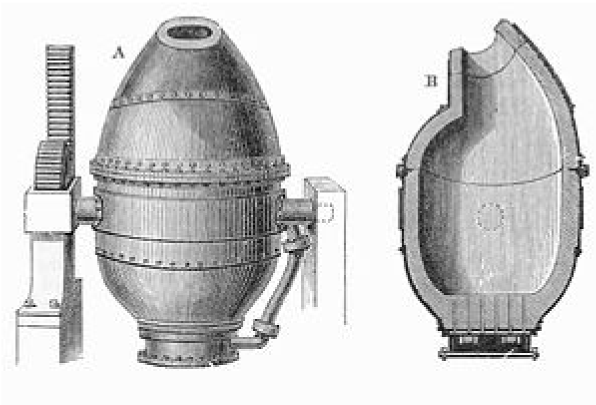
Andrea Surovek
South Dakota School of Mines & Technology

Judy Liu
Purdue University

http://www.aisc.org/uploadedcontent/2012NASCCSessions/N32/

The Steel Industry

- Driver of the industrial revolution
- Mature technology
- Little R&D investment
- Fair sustainability



Bessemer Converter (1857)

Home Insurance Building (1885)

USSteel – Bethlehem (PA)

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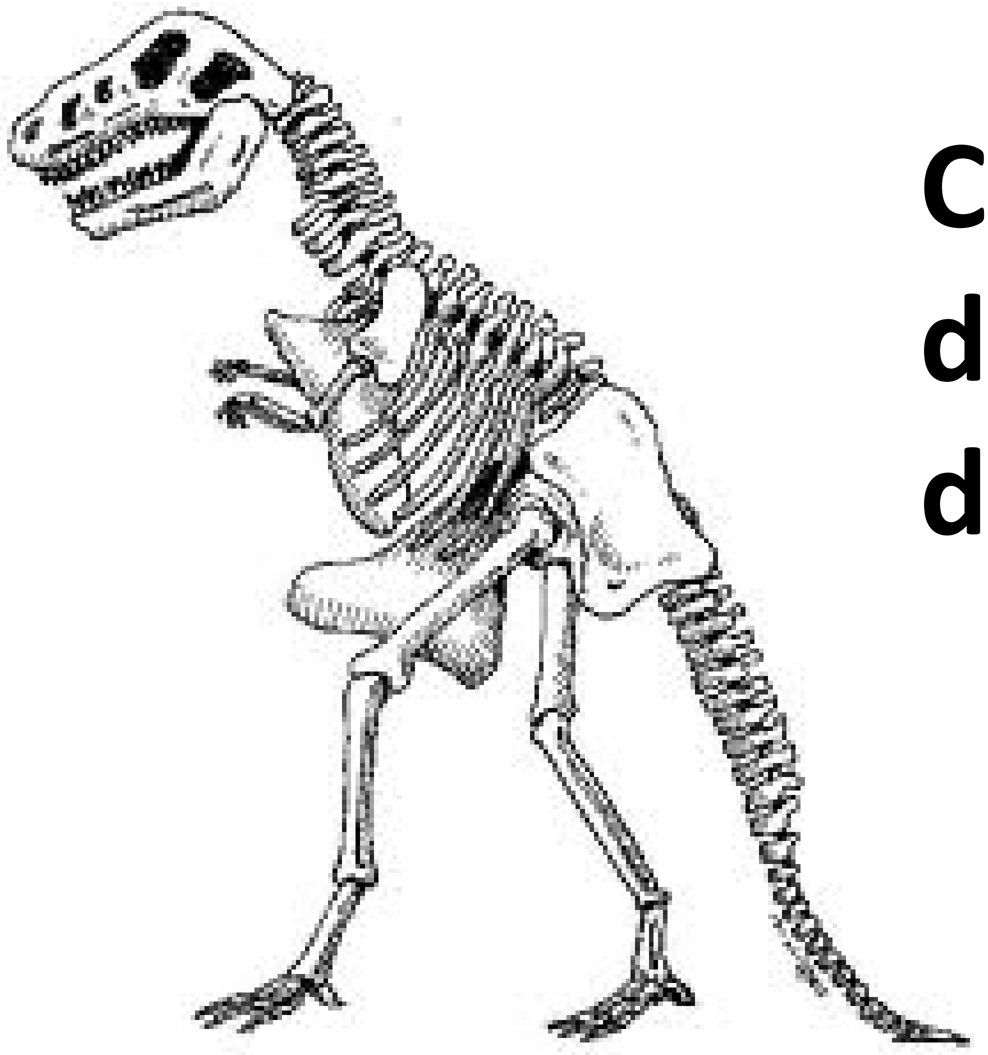
The Economist

In an age of disruptive innovation, big industries struggle to stay on top.



Can dinosaurs dance?

Innovation

Stimulating economic growth

innovation.economist.com

March 28, 2012, Berkeley, CA

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My Perspective on Brazil's Steel Industry

- Natural resources and need are there (supply and demand)
- Numerous fiscal and administrative obstacles (the "Brazilian" cost – also from *The Economist*)
- Private sector a key to solving this issue = alliance between producers, designers and educators
- Not a simple or easy task → a lot of heavy lifting ahead for you, good luck !!!

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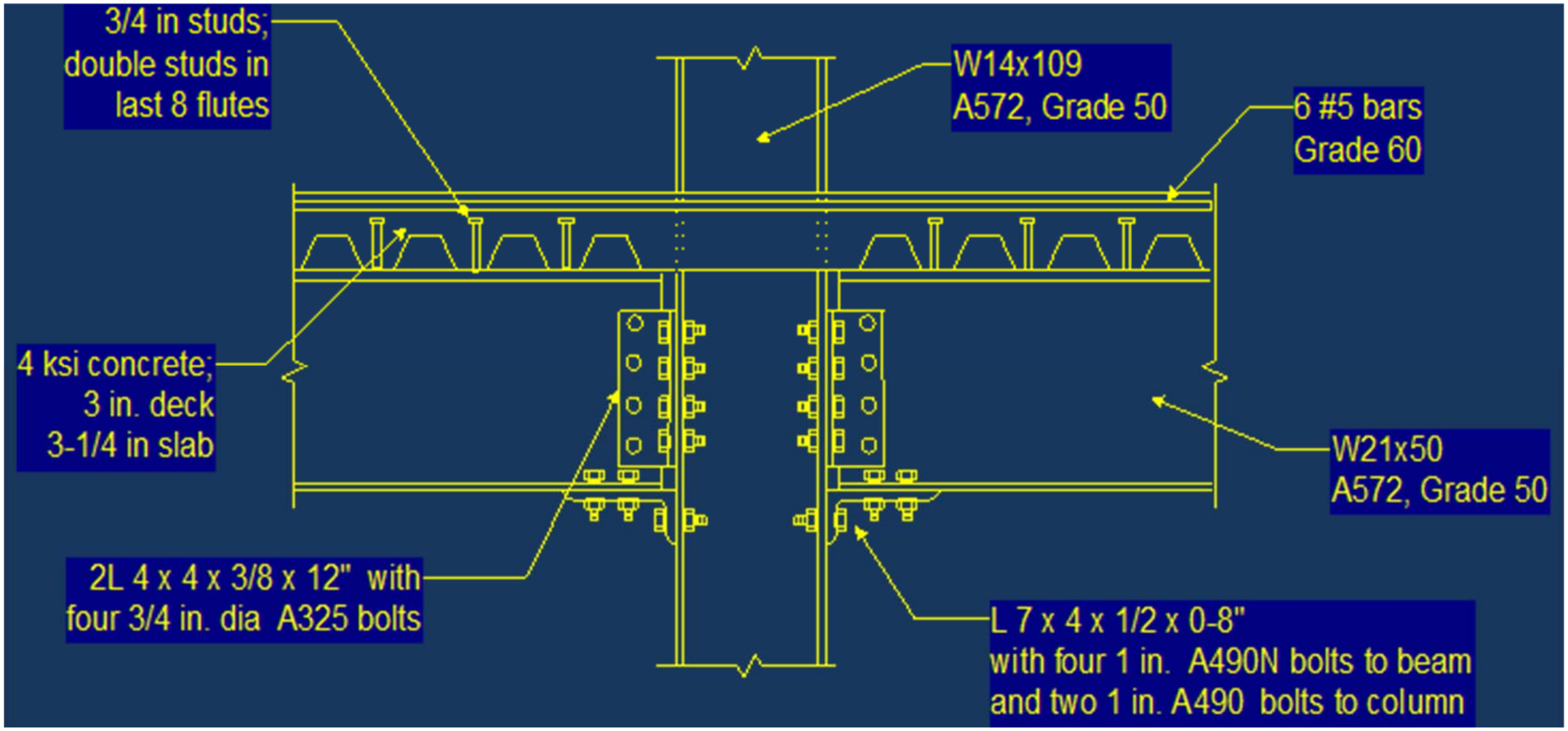
My Experience - AISC



AISC – Small grants for testing PR connections -1984

Nurture the young!!!!!

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My Experience

- Key to my career development – opened new avenues for me as a researcher
- Amount of money is not important; what is important is the backing of the institution
- Mentoring is a huge issue
- Support for research from within industry varies with time
- Basic vs. applied research in academia

T. Galambos

G. Haaijer

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My Experience – AISC Committees

- Technical committees in support of codes
- Membership about ⅓ fabricators, ⅓ designers, and ⅓ public (professors) – ANSI requirement
- Group of up of 120 people meets three times a year (AISC pays travel for most public reps.; most people work pro bono but universities encourage participation)
- Research ideas come from this discussion
- ***IT IS ABOUT PEOPLE*** – you get to meet and become friends with people from other areas, understand their points of view, and learn from them.

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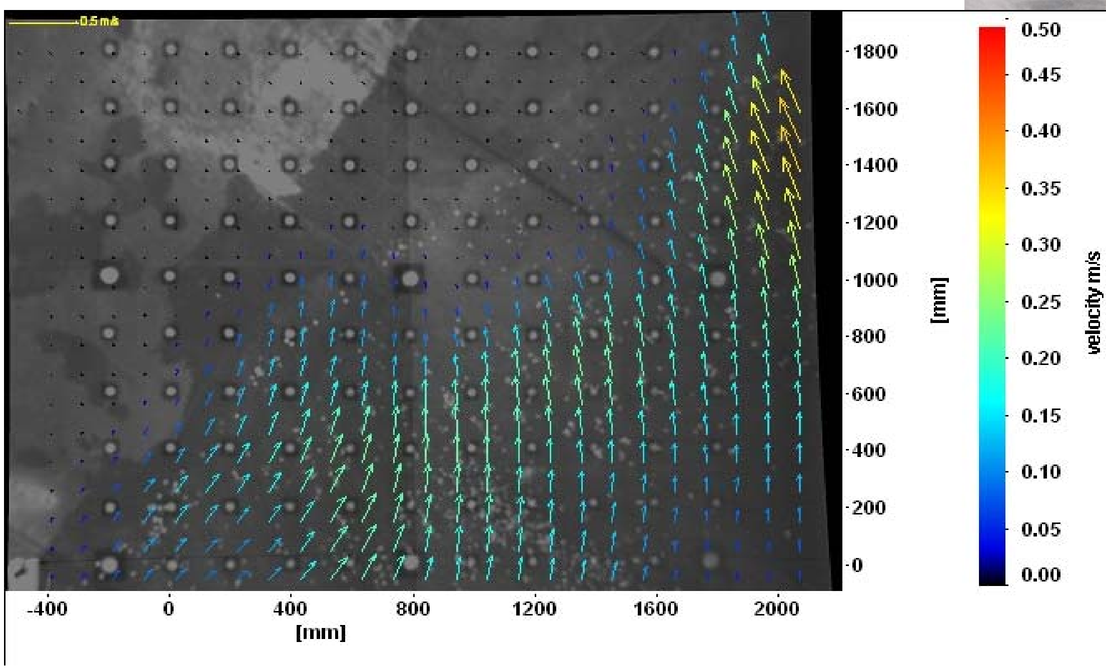
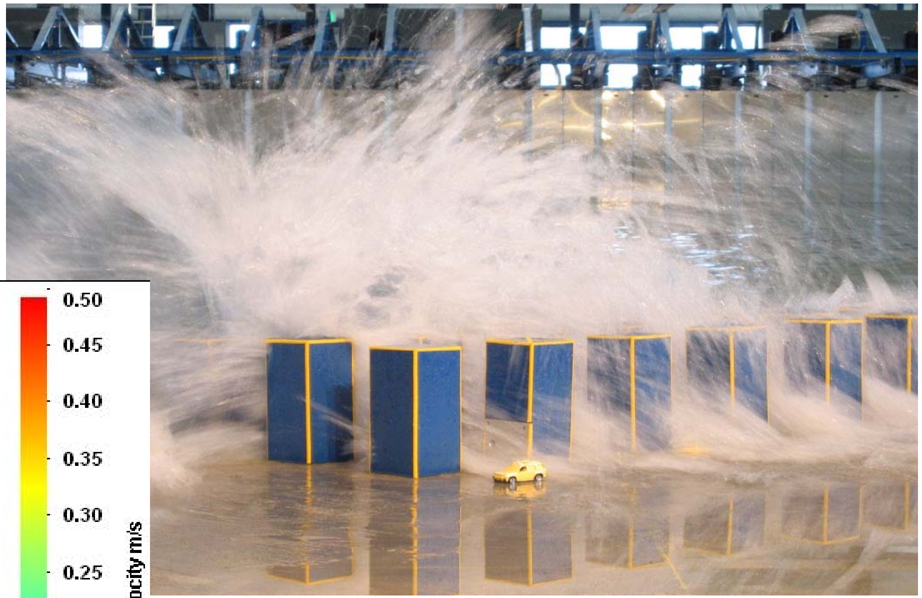
My Experience - NEES

The mission of the Network for Earthquake Engineering simulation (NEES) is to enable collaboration and transformative research to reduce seismic risk by providing world class community infrastructure = 15 national laboratories financed centrally and with free access by researchers from any institutions.

Experimentation + Modeling

= Simulation





OSU – Tsunami Facility

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Research Transformation

The journey from…

- Individual or small specialized groups to truly interdisciplinary teams
- Focused technical problems to societal impact and implementation
- Weakly linked experimental and analytical studies to simulation
- Creating technical knowledge to human capital and enabling technologies
- National to global relevance

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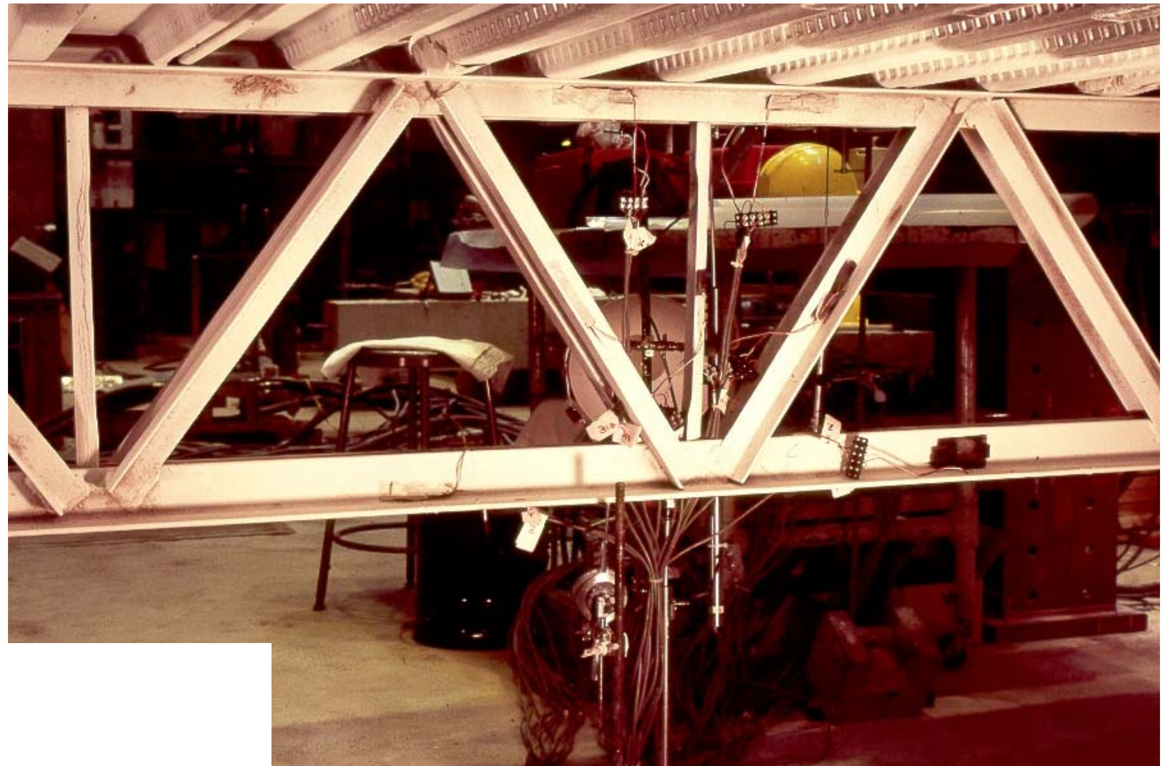
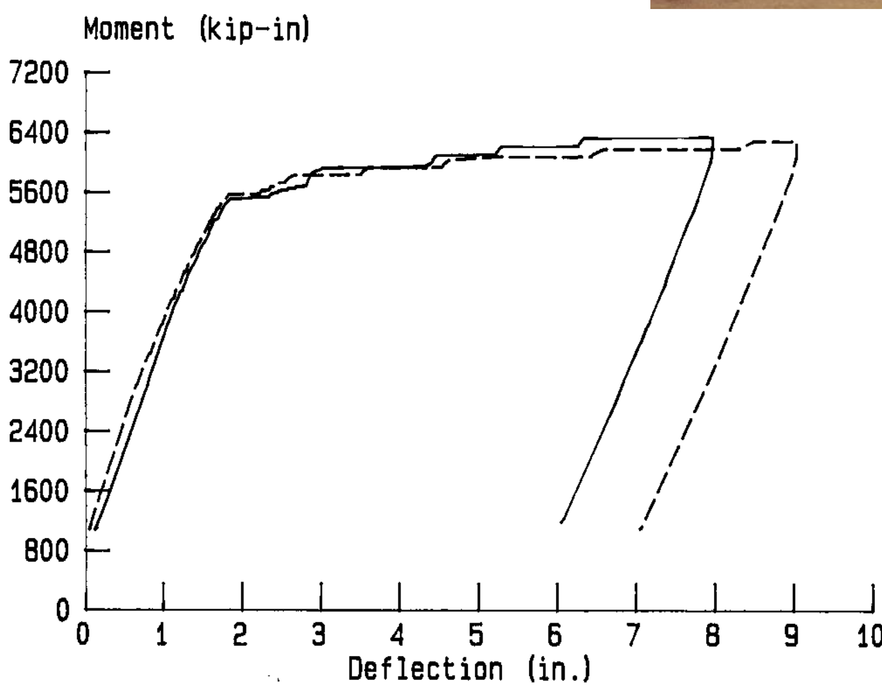
My Experience (Industry)

NUCOR – Composite Joists





Composite Construction Mentors

Larry Griffis

Ivan Viest

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Experience with Industry

- Leon & Galambos
- Easterling et al.
- Samuelson & NUCOR

- Took al most 15 years for product to become popular as joists (composite trusses existed)

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Experience with Industry - SAC

Welded Connection
(1994 Northridge Earthquake)

- Problem-driven research
- Strong industry participation
- Designer-academic panels leading
- Intimately linked to AISC TC9 (Seismic)

Transformational model

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AISC Professor’s Network

Steel Educators' Tip Sheet

April - May 2012

Click here to view the Tip Sheet with a web browser.

Scholarships and Students Connecting with Industry Sessions

This month, students have the opportunity to meet with and learn from industry leaders in special sessions at the NASCC. AISC 2012-13 scholarship applications are due May 1, 2012.

Students Connecting with Industry Sessions (SCIS) at the NASCC will be on Thursday, April 19, 2012 from 10AM - 2:30PM. In the morning session, Larry Griffis, P.E. of Walter P. Moore and Ted Zoli, P.E. of HNTB will speak on "Introduction to Life In the Workplace." In the afternoon, students will have one-on-one opportunities with industry experts at the "Direct Connect" session. The students will also receive lunch and an exhibit hall tour. Students who attend the **entire** SCIS will receive a complimentary ticket to the Thursday conference dinner, up to $100 in expense reimbursement, and a chance to win a new iPad! We will conduct

Try these teaching aids ...

SLIDE SETS: *Teaching Aids for Structural Steel Design Courses*
This series of slide sets can be used for instruction on beams, compression members, tension members, and combined forces. Pick and choose slides to incorporate into your lectures. Note that slides are divided in the "theory" and "manual"

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Strengths, Weaknesses, Opportunities, Threats (SWOT)

Aesthetics; availability; BIM and related electronic data; construction; design benefits or demands; education, training, professional knowledge and talent; design and architectural flexibility; frame properties; fire protection; life cycle costs, reliability and durability; sustainability; market issues; material properties; fabricator and erector processes; quality; speed; team relations; technology transfer

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Strengths, Weaknesses, Opportunities, **Threats** (SWOT)

Aesthetics; availability; BIM and related electronic data; construction; design bears on demands; education, training, professional knowledge and talent; design and architectural flexibility; frame properties; fire protection; life cycle costs, reliability and durability; sustainability; market issues; material properties; fabricator and erector processes; quality; speed; team relations; technology transfer

Potential Areas for Innovation

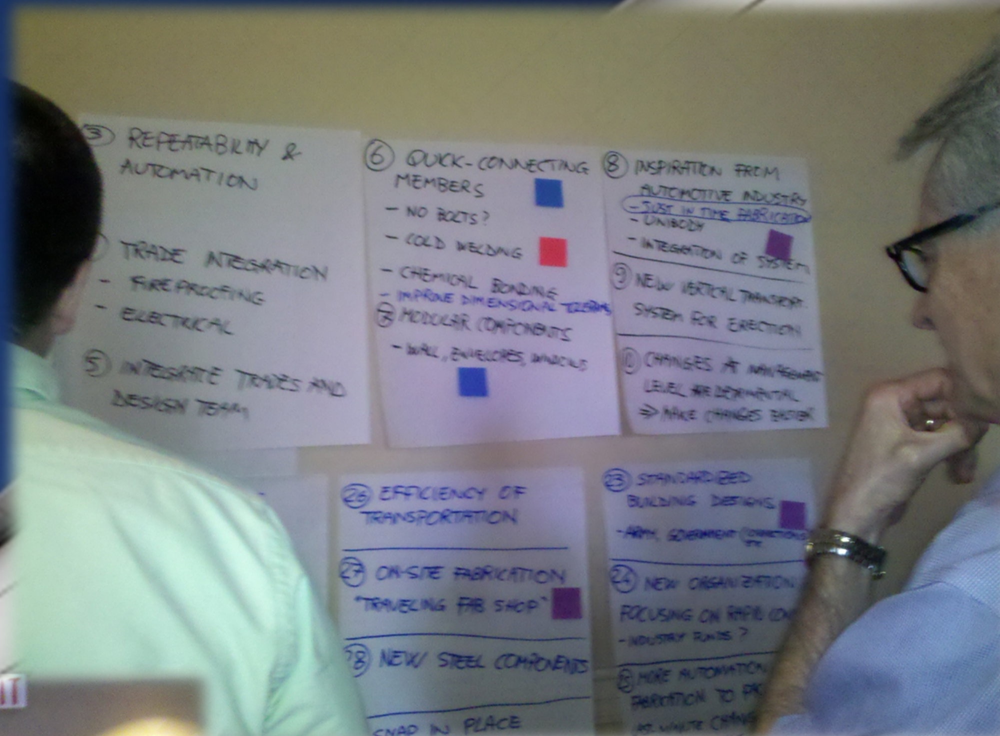
- Design, connections, shapes
- Integration, communication, team relations
- Fire (new materials?)
- Sustainability
- Process, modular construction
- Education

Potential Areas for Innovation

- Design, **connections**, shapes
- **Integration**, communication, team relations
- Fire (new **materials**?)
- Sustainability
- Process, **modular construction**
- **Education**

Brainstorming

About 250 ideas generated



http://www.ideo.com/work/shopping-cart-concept

ASCE Workshop: Main Themes

Integration

- of disciplines
- of systems (e.g structural & mechanical)
- of design / construction
- of education and industry
- of material properties and function

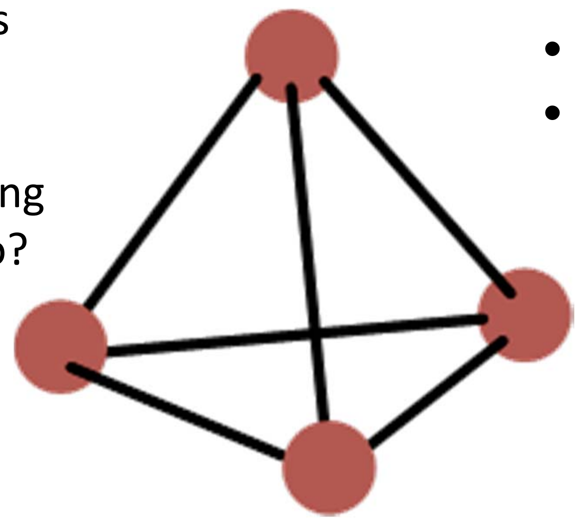
Steel as a Material

Processing

- Forging, casting, rolling
- Melt spinning
- Pulsed laser ablation
- … talk to your materials expert

Theory

- Continuum mechanics
- Quantum mechanics
- Thermodynamics
- Cristallography
- Multiphysics modeling
- …. How far do we go?



Characterization

- Mechanical testing
- SEM
- X-ray diffraction
- … what is important?

Properties

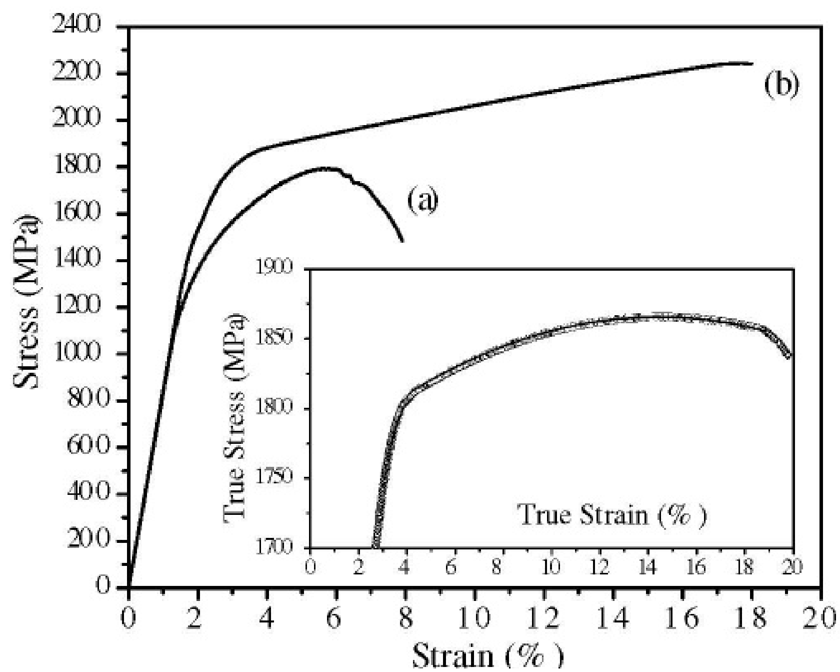
- Strength
- Stiffness
- Toughness
- Fatigue
- …. Can we improve them?

Materials Tetragon
by G. Thomas

New Materials: Future

Glass metals – amorphous (very rapid cooling)

By adding just the right amounts of aluminum atoms to a copper-based alloy, J. Eckert (TU Darmstadt) and W. H. Wang (CAS – Beijing) have produced the first amorphous material that gets harder under stress. … it's stronger than conventional steel and has a higher resistance to scratching and corrosion (*Phys. Rev. Focus* ***15****, 20 (2005)*)



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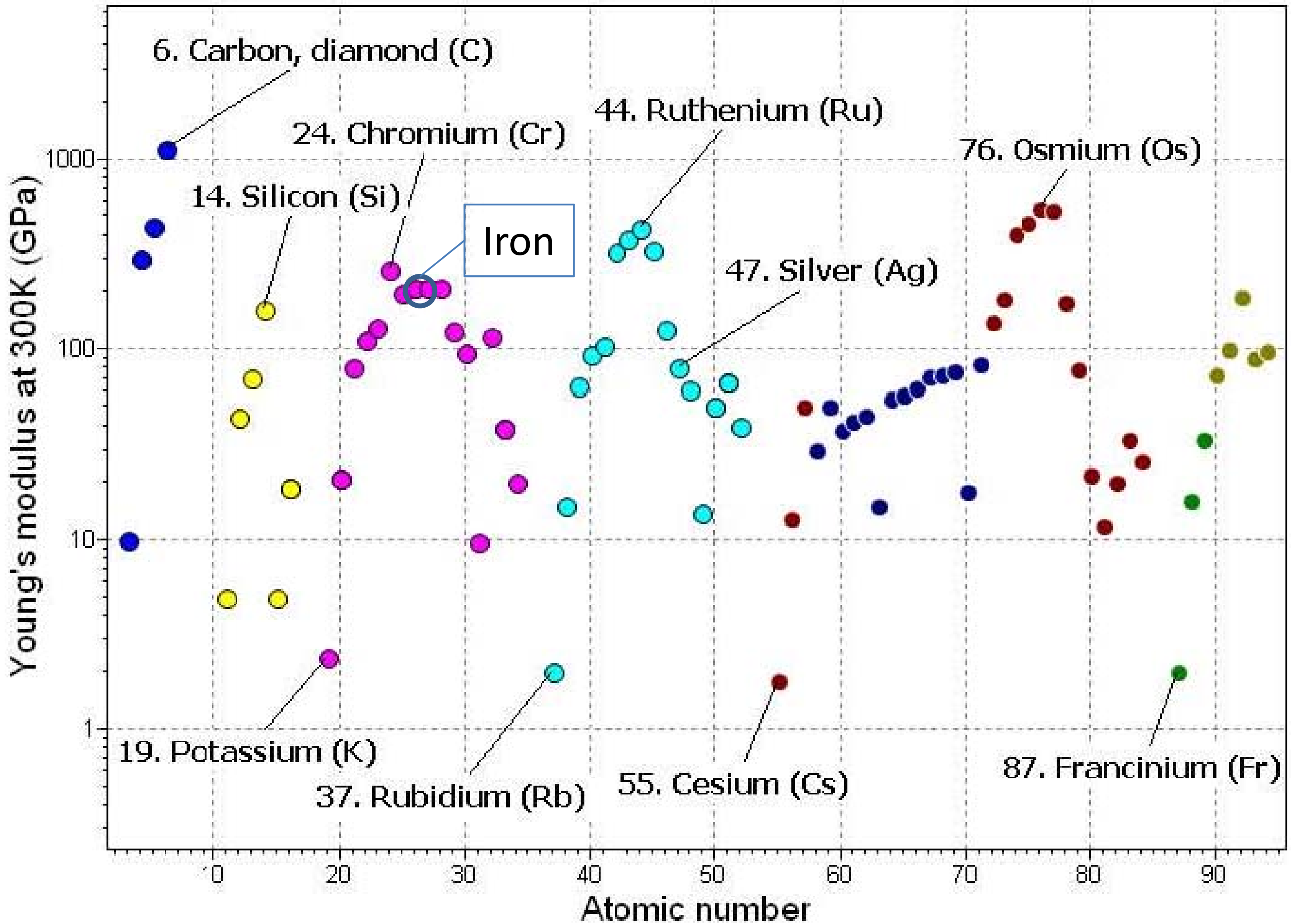
The Materials Genome Project



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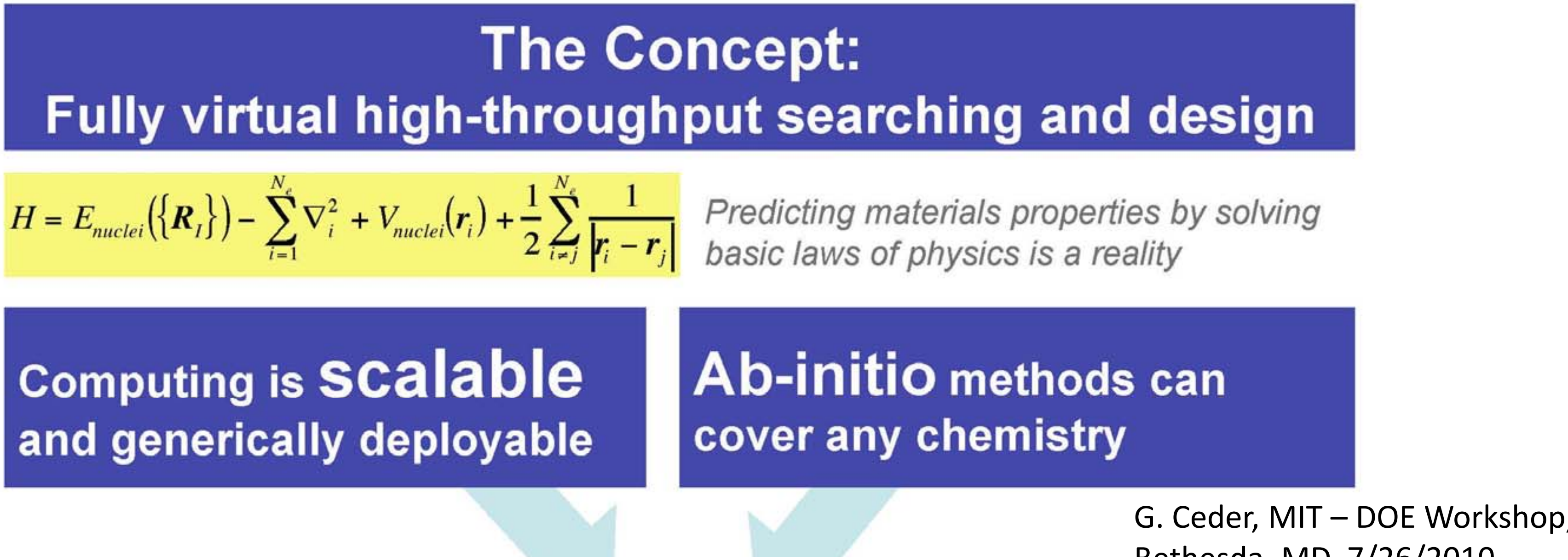

***Ab initio* quantum chemistry methods** are computational chemistry methods based on *quantum chemistry*… Almost always the *basis set* (which is usually built from the *LCAO ansatz*) used to solve the *Schrödinger* equation is not complete, and does not span the *Hilbert space* associated with ionization and scattering processes (see continuous spectrum for more details). In the *Hartree–Fock* method and the configuration interaction method, this approximation allows one to treat the Schrödinger equation as a "simple" eigenvalue equation of the *electronic molecular Hamiltonian*, with a discrete set of solutions.

Wikipedia

New Materials: Present

- HS/HM carbon epoxy composites with 4 to 6 times strength and stiffness of steel are being used in the aerospace industry
- Steel:
  - High and low strengths (130 to 700 MPa)
  - Higher modulus (not too successful)
  - Corrosion resistance (improving)
  - Toughness (good to excellent)
  - Ductility (very good to excellent)
  - Fire resistance (many new products + NIST)

What can / should we improve?

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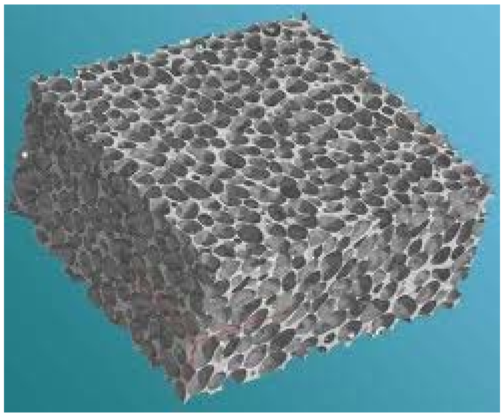
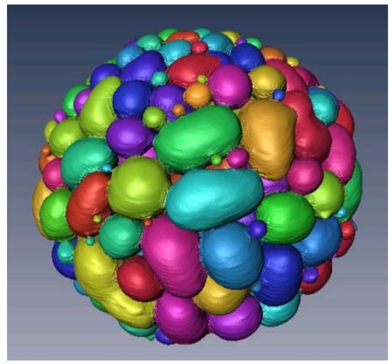
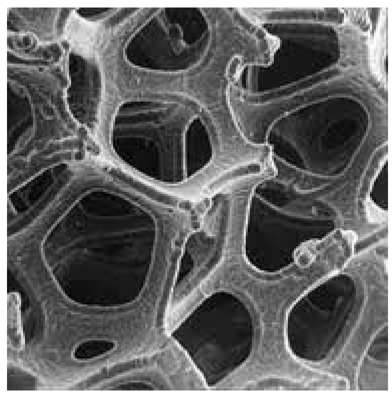
Composite Materials: Metallic Foams



metalfoam.net

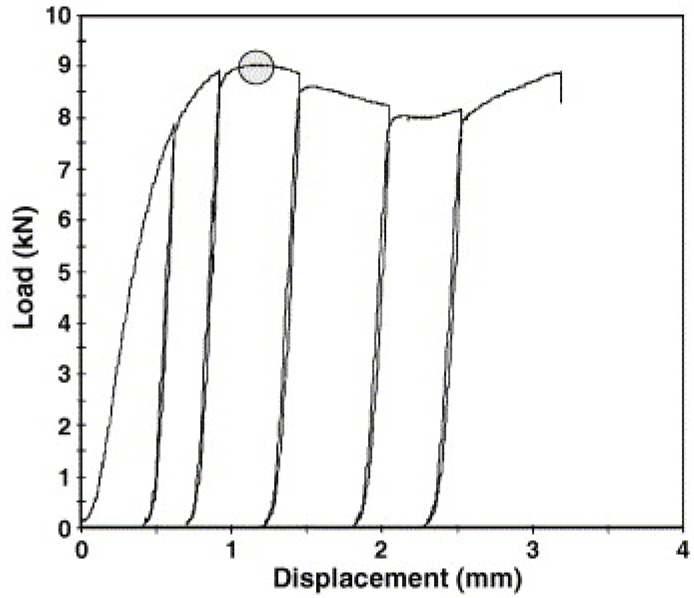


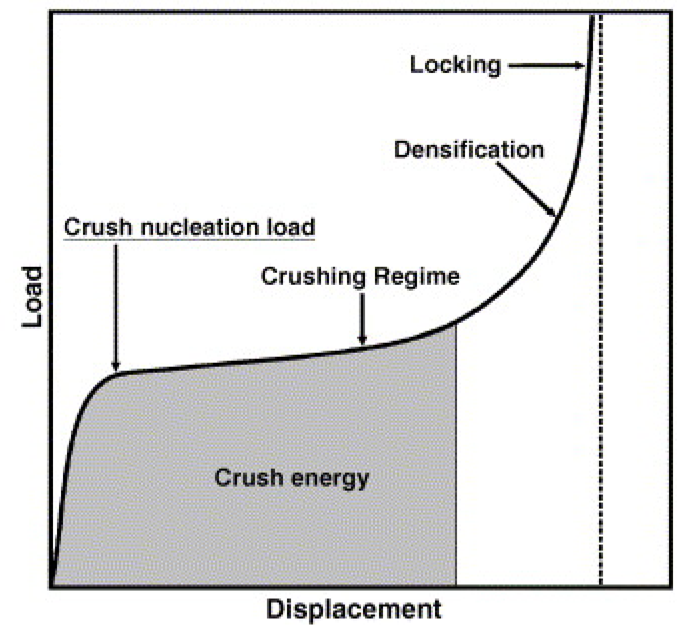
metalfoam.net



recemat.com

Cellular structure consisting of a solid metal, frequently aluminum, containing a large volume fraction of gas-filled pores. The pores can be sealed (closed-cell foam), or they can form an interconnected network (open-cell foam).





M. Doyoyo and D. Mohr, *Mechanics of Materials* (38/4), 2006

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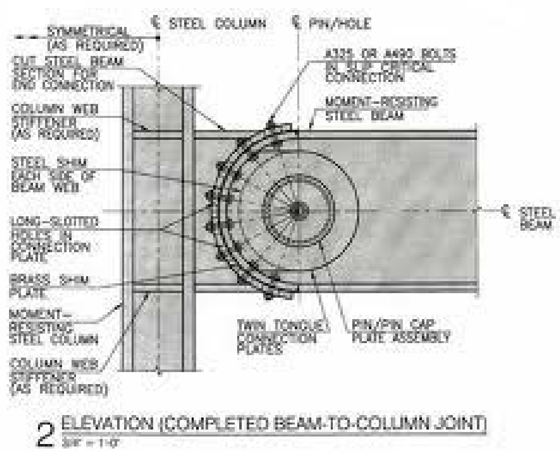
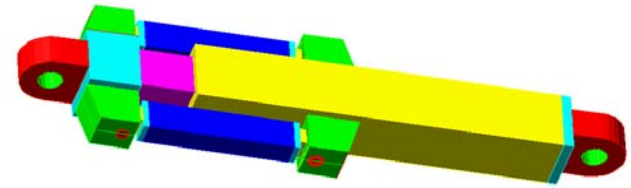
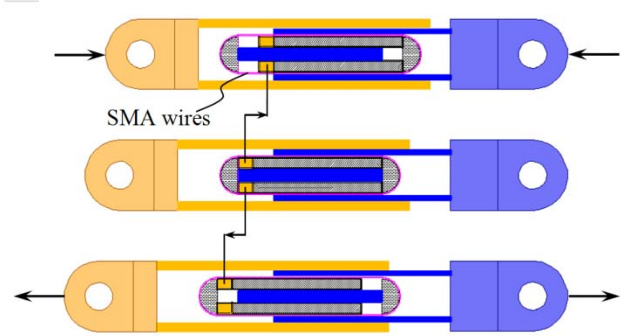
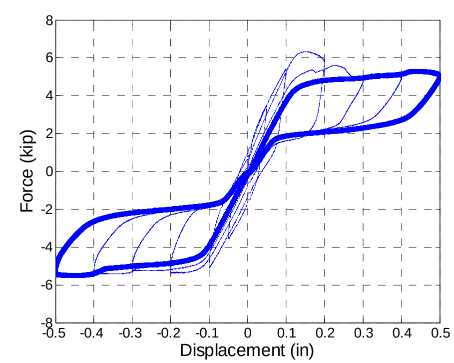
Steel Devices



Pin Fuse Joint
© SOM/Sarkisian







Robust Hybrid Brace
© Yang, Leon and DesRoches

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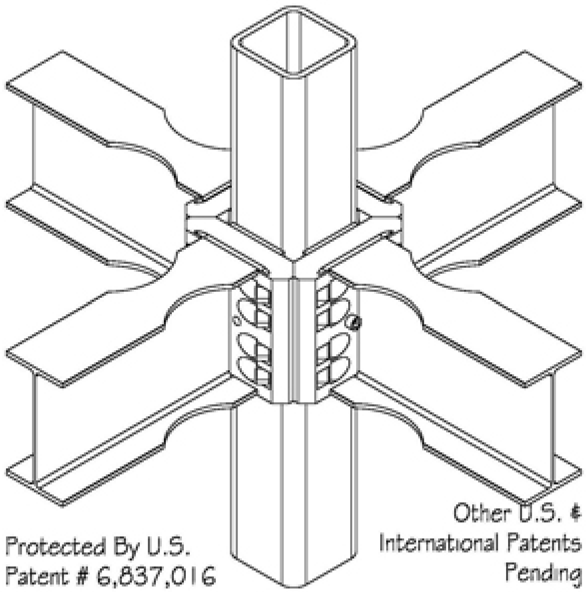
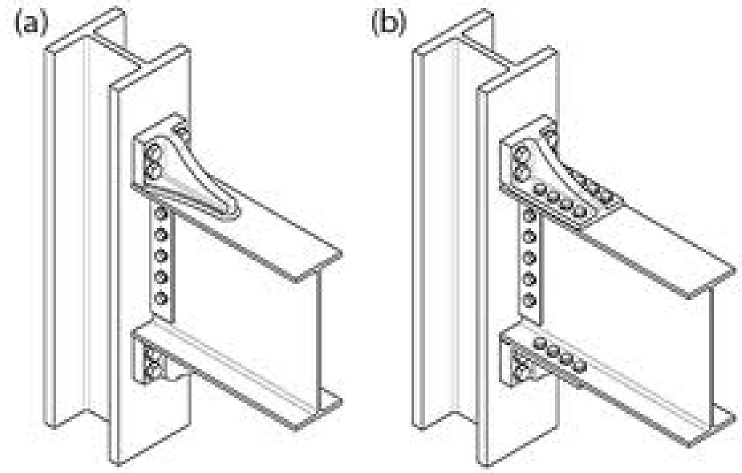
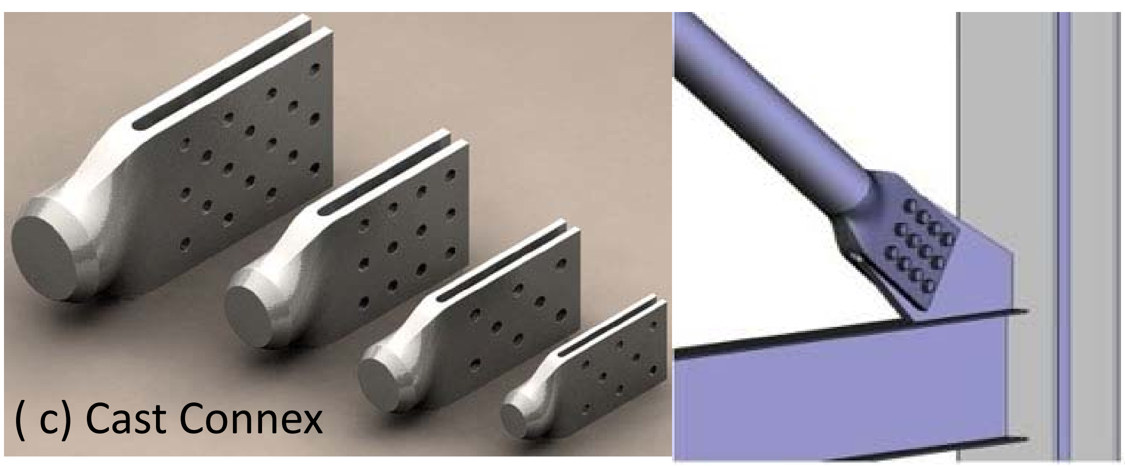
Prefabrication of Steel Products



(a) CONXTECH



(b) KAISER



(c) Cast Connex

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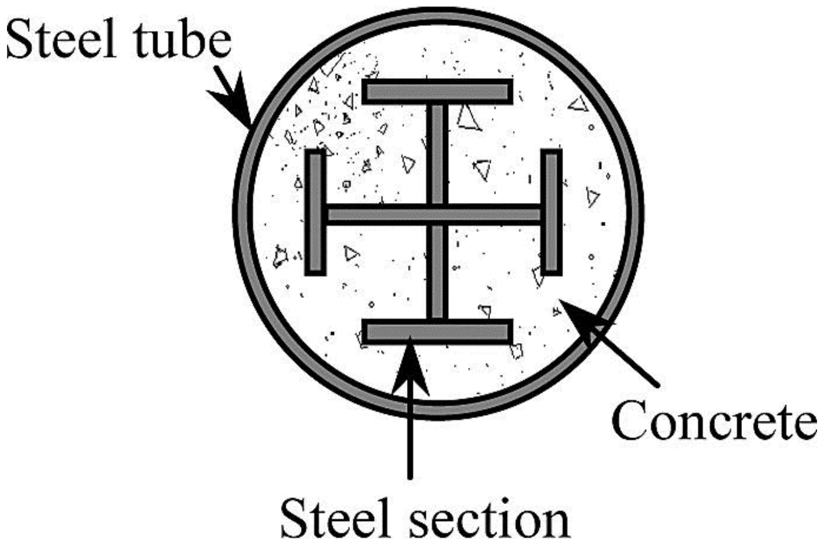
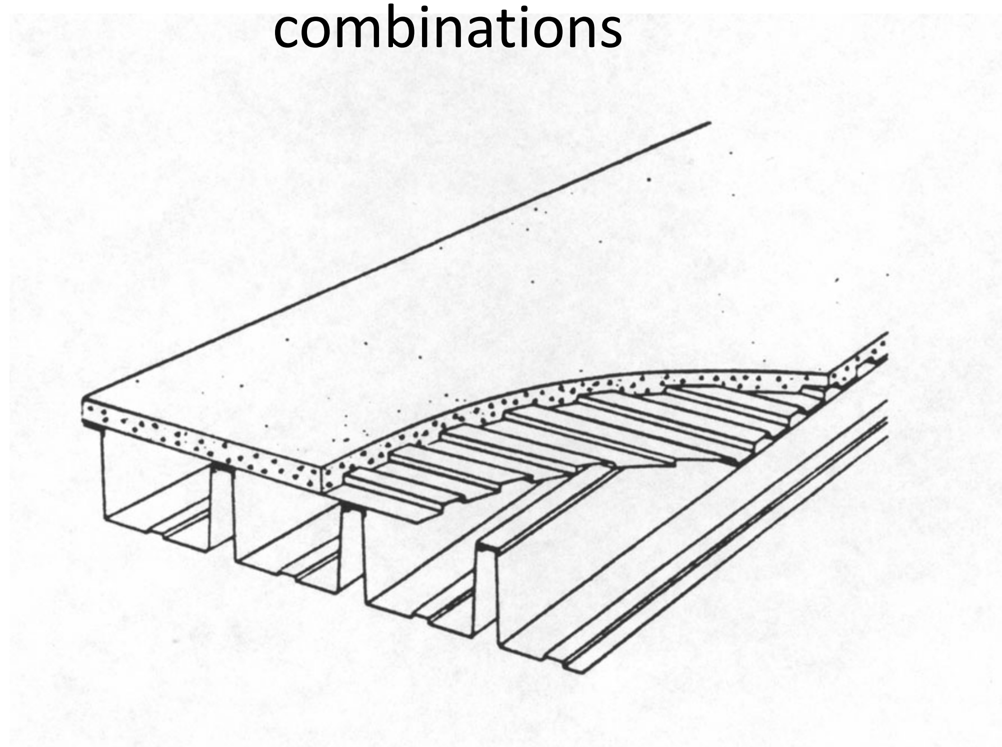
Steel Products



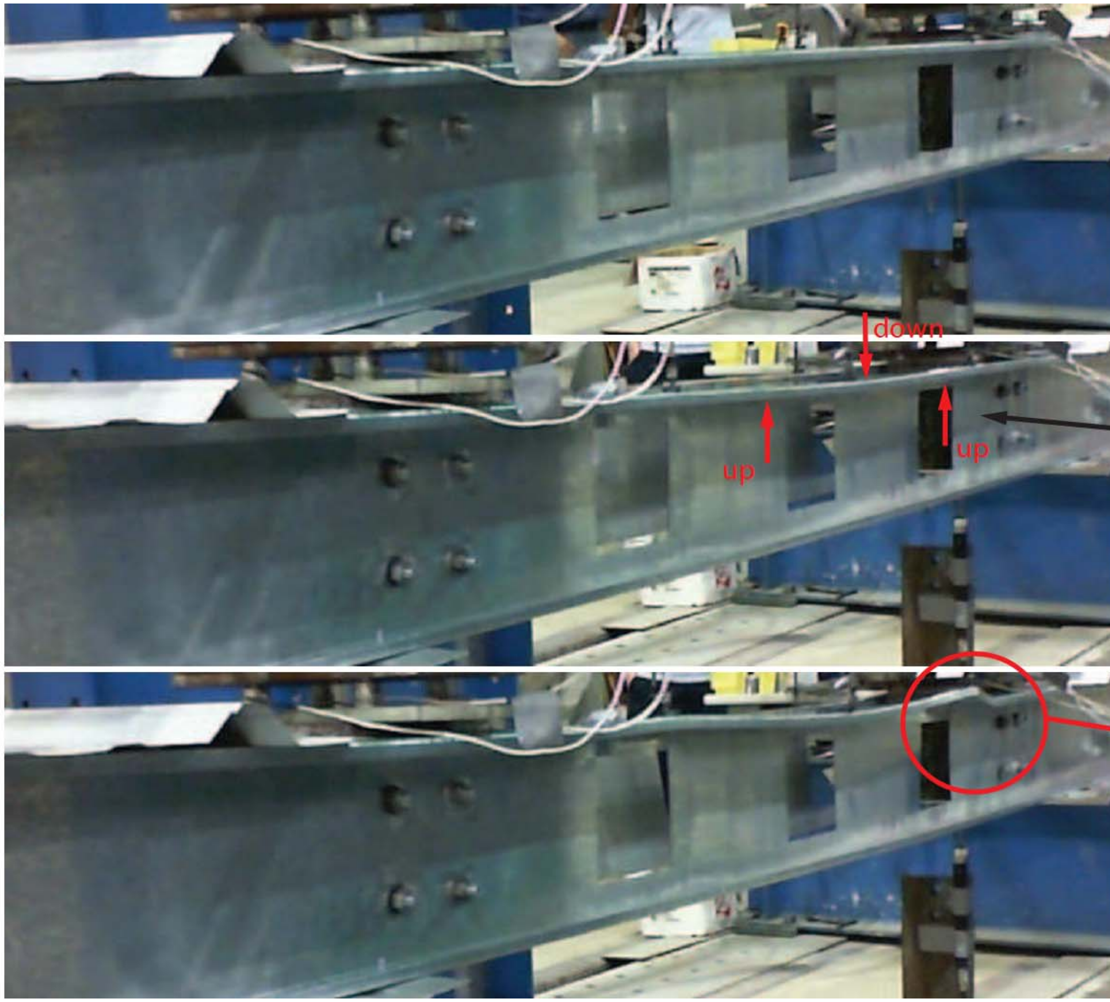
(a) Older technologies with new material combinations

(b) Newer geometries and ideas with new material combinations



Theories

From theories to codes?



Distortional buckling

C. Moen, Virginia Tech

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Sustainability

Timeframe:

- 5 yr.: Develop strategies for facilitating buy--in from professionals, owners, and regulators :
- 10 yr.: Link to: public health; popular culture; broad advertising/videos/apps
- 30 yr.: ***Culture Shift: Sustainable = beautiful/natural***

Issues:

- Sustainability data, metrics and cost-benefit frameworks
- New designs, new systems: Integrated, Multi--disciplinary, Multi--functional
- Integrate other disciplines within our research, design strategies and implementation
- Design for deconstruction, reuse and adaptability
- Education

Sustainability Research Examples

1. Multi--disciplinary collaboration (e.g. combined structural mechanical systems)
2. Material supply chains – where to focus
3. Bigger push for green energy/ Emission capturing and repurposing
4. Floor framing / sandwich – are concrete toppings really necessary?
5. How do we assess fireproofing sustainability?
6. Component Design & Assembly Design (moving away from stick buildings)
7. More pre--qualified systems/connection = less waste
8. Explicitly measure sustainability as a design criterion/ Sustainability performance goals

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Rapid Construction

Main Themes – 5 years

- Proprietary connections in electronic standards
- Modular wall panels combined with fireproofing
- Industry should educate members on team integration
- Standard for RFID – 3D identification of as--built

Main themes – 10 years out

- Chemical bonding, cold welding
- FRP applications
- Traveling fab shop
- BIM – Interoperability, standardization

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Rapid Construction

Main themes – 10 years out

- Increase academic involvement in industry partnership for mutual benefit
- Snap--on connections
- Research on better coatings, self--coated materials
- Tighter tolerances on steel members

Main themes – 30 years out

- Make steel on site
- New materials with “designer” properties

Extreme Events

1. **Performance Based Design for Fire**
   a. New materials
   b. Realistic fire tests
   c. Innovative connection designs
   d Risk management, probability of fire….
2. **Improved analysis and simulation techniques, multiphysics**
   a. Fracture at elevated temperatures / ultra low cycle fatigue
   b. Meso--scale and macro--scale material science collaboration
   c. Stochastic material models
   d. Load quantification (fire + blast)

e. 3. Multi--Hazard
   a. Accessible tools for sequences of extreme loads
   b. High fidelity simulation tools
   c. Testing methodologies for multiple hazards
   d. Robustness independent of loading

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Extreme Events

4. More rigorous progressive collapse requirements

a) Move away from column removal scenario
b) Real building demolition with column removal tests
c) Progressive collapse of bridges and other non building structures (industrial, infrastructure, etc.)
d) Benchmark tests
e) Create maximum connection capacity to quantify resilience and collapse
f) Developing secondary system to mitigate progressive collapse

5. Steel specific structural health monitoring

- Instrument real buildings in high probability of extreme load event
- New sensing technology for strains in steel/ redundant sensor networks
- Sensors embedded in steel during forming without degrading it or
- creating impurities

6. Innovative rehabilitation and reparability

- Better robotic instrumentation for evaluating damage and need for rehabilitation
- Structural fuses for different hazards

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Other ideas

2. Kinetic structures

- Telescoping members and systems
- Deployable, “openable”, adaptable

3. Bio--Inspired Structures

- High strength to weight ratios (e.g. spider webs)
- Unique forms and shapes: sea shells, beehives, tree roots
- Self--healing steel

4. Temporary/Transportable Structures

- Shipping containers – dual purpose / reuse
- Staging systems / storage racks
- Origami / self--assembling structures

5. Adaptable Plug--n--Play Connections

- Joining methods that minimize the effort / energy required for assembly

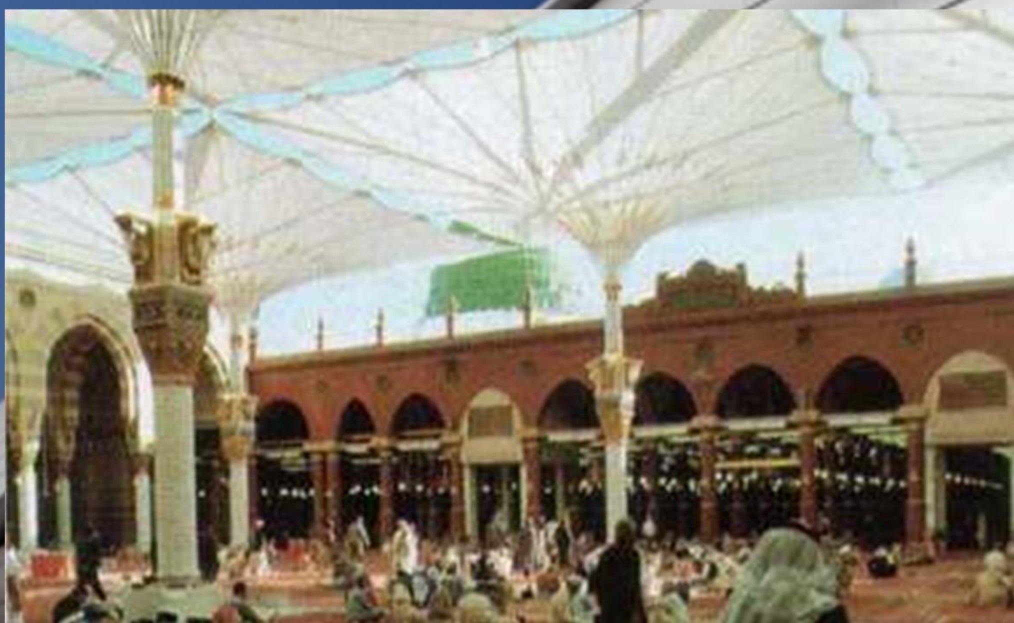
1. System Integration

- Modular building units
- Integration of struct / mech systems
- Adaptation of existing shapes (e.g. tubes)

Industrialized housing

2. Kinetic Structures

- Telescoping members and systems
- Pneumatic structures
- Deployable, “openable”, adaptable



3. Bio-inspired Structures

- High strength to weight ratios (e.g. spider webs)
- Adaptable
- Resilient
- Unique forms and shapes
  - Sea shells
  - Beehives
  - Tree root foundations
- Self-healing steel

http://flow.doorsofperception.com/content/th

4. Temporary / transportable structures

- Shipping containers – dual purpose / reuse
- Deployable structures
- Staging systems / storage racks
- Origami / self-assembling structures

http://www.treehugger.com/modular-design/port-a-bach-shipping-container-holiday-home.html

5. Adaptable / plug and play connections

Joining methods that minimize the effort / energy required for assembly

- Universal
- Standardized
- Ball & Socket – adjustable
- Snap together

http://gammasquad.uproxx.com/2012/03/free-universal-construction-kit-adapter-set-for-construction-toys

Short Term Technologies

- Better field QA/QC for welding
- Stronger and more ductile bolts ©
- Rethinking rivets for thin steel sections ©
- Unsymmetrical steel sections
- Built-up sections with LBW technologies ©
- Thin composite systems (not just concrete…) ©
- New materials (SMA,…)©
- Prefabricated systems (analogous to PS/PC)
- Low-rise cold formed systems (wood / AAC)
- New composite systems

© = my next proposals! Keep away

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Next Steps

1. Identify Partners
   a. Fabricators
   b. Erectors
   c. Government
2. Prototype Structures and Design competitions
3. Incentives for increased R&D
4. Optimize Materials and Labor
5. Write better standards so others adopt them

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Opportunities

- Attract venture capital
- Develop more aesthetically pleasing designs (w/ architects)
- Modeling and simulation of realistic boundary conditions, fracture, multi-axial plasticity, contact problems, and system effects
- BIM and associated technologies – input into the development of foundation classes (w/ CS)
- Innovation in fire design – both computationally and functionally (w/ fire engineers)
- Prefabrication/fast erection of structural systems with variable "skins"
- Development of reliable and useful life cycle cost tools and data (w/ construction sector and LEED)

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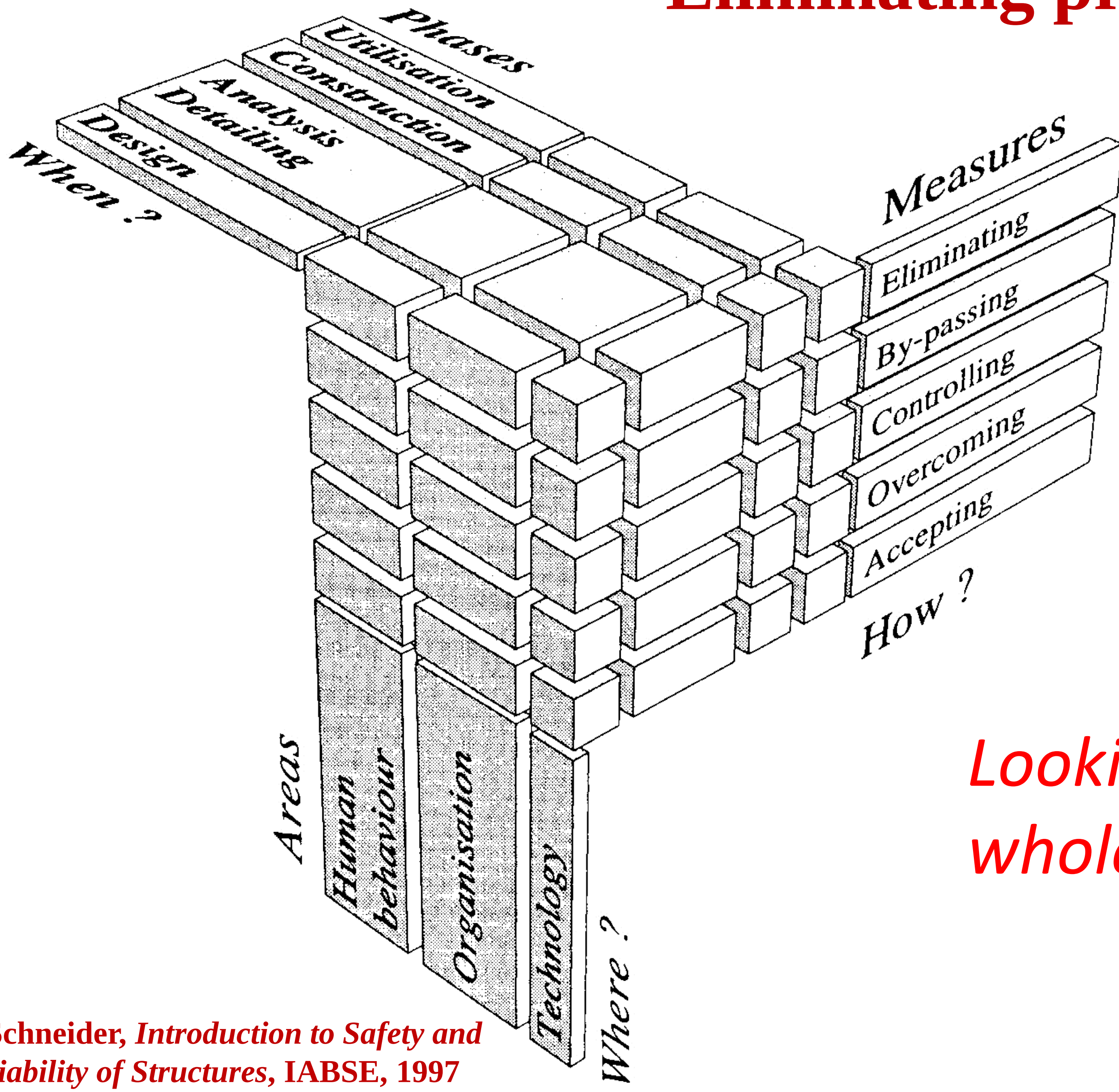
Eliminating problems



Looking at the whole picture

J. Schneider, *Introduction to Safety and Reliability of Structures*, IABSE, 1997

Can dinosaurs dance?

Yes ! Brazil can!!!!

www.storytimecrafts.org

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