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
Outline

• Personal reflections on my career as a steel researcher

• Future directions of steel research
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
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)
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
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 !!!
My Experience - AISC

AISC – Small grants for testing PR connections -1984

Nurture the young!!!!!!
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

Virginia Tech
Invent the Future
My Experience – AISC Committees

• Technical committees in support of codes
• Membership about \( \frac{1}{3} \) fabricators, \( \frac{1}{3} \) designers, and \( \frac{1}{3} \) 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.
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
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
My Experience
(Industry)

NUCOR – Composite Joists

Composite Construction Mentors
Larry Griffis
Ivan Viest
Experience with Industry

• Took almost 15 years for product to become popular as joists (composite trusses existed)

• Leon & Galambos
• Easterling et al.
• Samuelson & NUCOR
Experience with Industry - SAC

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

**Transformational model**

Welded Connection
(1994 Northridge Earthquake)
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"
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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Potential Areas for Innovation

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

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Brainstorming

About 250 ideas generated

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

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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

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Steel as a Material

Processing
• Forging, casting, rolling
• Melt spinning
• Pulsed laser ablation
• ... talk to your materials expert

Characterization
• Mechanical testing
• SEM
• X-ray diffraction
• ... what is important?

Properties
• Strength
• Stiffness
• Toughness
• Fatigue
• .... Can we improve them?

Theory
• Continuum mechanics
• Quantum mechanics
• Thermodynamics
• Crystallography
• Multiphysics modeling
• .... How far do we go?
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))
The Materials Genome Project

![Graph showing Young's modulus at 300K (GPa) vs Atomic number for different elements. Key elements labeled: Carbon (C), Chromium (Cr), Silicon (Si), Ruthenium (Ru), Osmium (Os), Silver (Ag), Potassium (K), Rubidium (Rb), Cesium (Cs), Francium (Fr).]
**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?
Composite Materials: Metallic Foams

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).
Steel Devices

Pin Fuse Joint
© SOM/Sarkisian

Robust Hybrid Brace
© Yang, Leon and DesRoches
Prefabrication of Steel Products

(a) CONXTECH

(b) KAISER

(c) Cast Connex
Steel Products

(a) Older technologies with new material combinations

(b) Newer geometries and ideas with new material combinations
Theories

From theories to codes?

C. Moen, Virginia Tech
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
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
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
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)

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
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
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

© Andrea Surovek
2. Kinetic Structures

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

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http://www.uauim.ro
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

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4. Temporary / transportable structures

- Shipping containers – dual purpose / reuse
- Deployable structures
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http://www.treehugger.com/modular-design/port-a-bach-shipping-container-holiday-home.html

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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

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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
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
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)
Eliminating problems

Looking at the whole picture

Can dinosaurs dance?

Yes! Brazil can!!!!

www.storytimecrafts.org