Some thoughts on "Design"

Ron Ziemian

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Day 1: Z tries to explain his madness!

Address common philosophical questions, including

- Why does the professor take this material so seriously? "My Shakespearean Literature and Operations Management courses are so much more fun."
- Why is there so much emphasis on understanding behavior ("theory")? "Wait, maybe designing steel structures can be fun!"
- Is this course only an academic exercise, especially when commercial software such as RAM, RISA, and Fastrek have steel design modules?
- Others…

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On taking this course seriously…

Fact: Students in this class will design steel structures that members of society will occupy.

Question: Given that you, your loved ones, someone you know, children or anyone may be these occupants, wouldn't you prefer to make sure that these students are well prepared?

Result: Faculty are obligated to deliver a course that ensures future designers of steel structures will be successful in ensuring public safety.

Please be reminded that there is no partial credit for a structure that fails to meet its desired function.

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On emphasizing behavior…academic exercise

A specification containing a set of rules is intended to ensure safety; however, the designer must understand the behavior for which the rule applies, otherwise an absurd, a grossly conservative, and sometimes unsafe design may result. The authors contend that it is virtually impossible to write rules that fully apply to every situation. **Behavioral understanding must come first; application of rules then follows**. No matter what set of rules is applicable, the designer has the ultimate responsibility for a safe structure.

Steel Structures: Design and Behavior
Salmon, Johnson, and Malhas, 2009

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On emphasizing behavior…academic exercise

If the process of designing steel structures is reduced to plugging the correct number into the correct equation (or using the correct table in the manual), then that "engineering" firm really only needs computer software and a data entry person (or other software package).

On the other hand, computer design software provides awesome opportunities for structural engineers to be structural engineers; experienced professionals who understand the behavior of structures and have the opportunity to design them to withstand the forces of nature.

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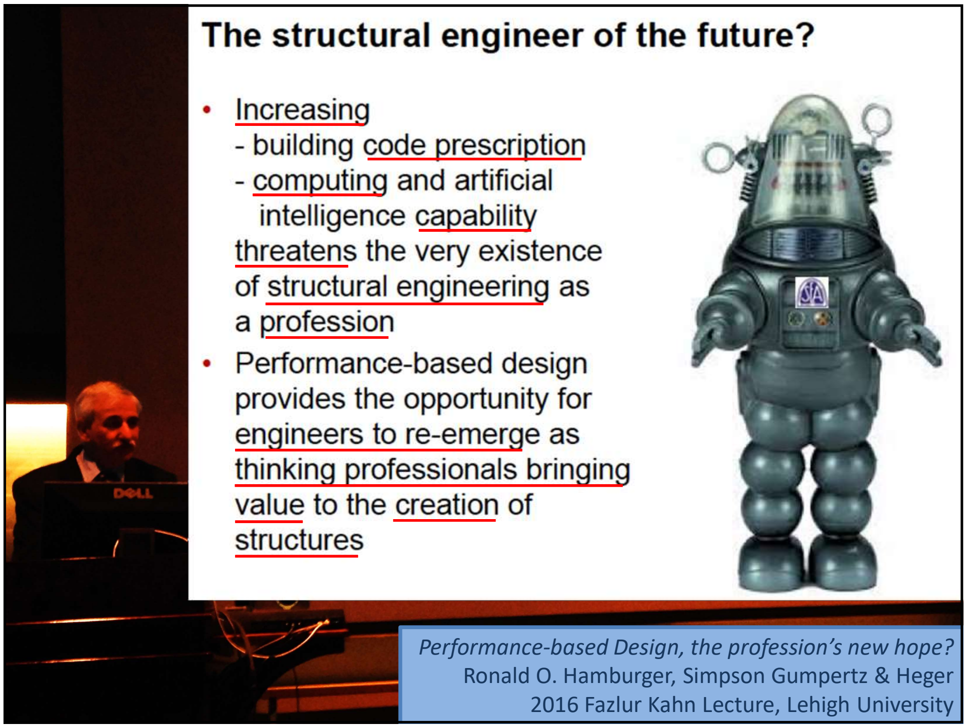
The structural engineer of the future?
• Increasing
- building code prescription
- computing and artificial intelligence capability
threatens the very existence of structural engineering as a profession
• Performance-based design provides the opportunity for engineers to re-emerge as thinking professionals bringing value to the creation of structures
DELL
Performance-based Design, the profession's new hope?
Ronald O. Hamburger, Simpson Gumpertz & Heger
2016 Fazlur Kahn Lecture, Lehigh University

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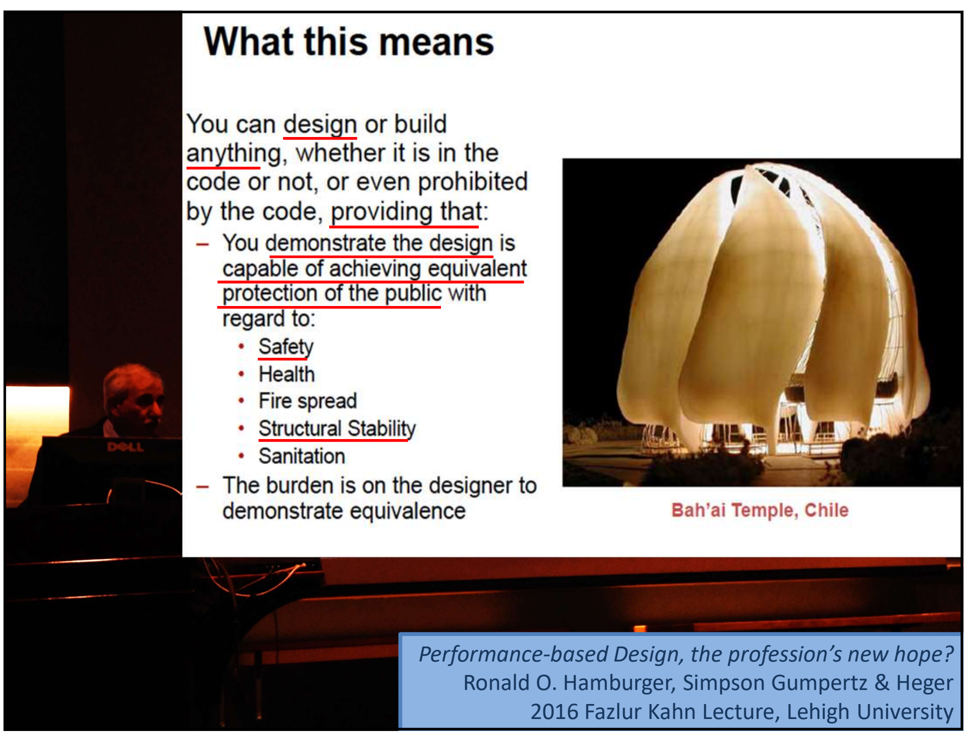
What this means
You can design or build anything, whether it is in the code or not, or even prohibited by the code, providing that:
– You demonstrate the design is capable of achieving equivalent protection of the public with regard to:
• Safety
• Health
• Fire spread
• Structural Stability
• Sanitation
– The burden is on the designer to demonstrate equivalence
Bah'ai Temple, Chile
DELL
Performance-based Design, the profession's new hope?
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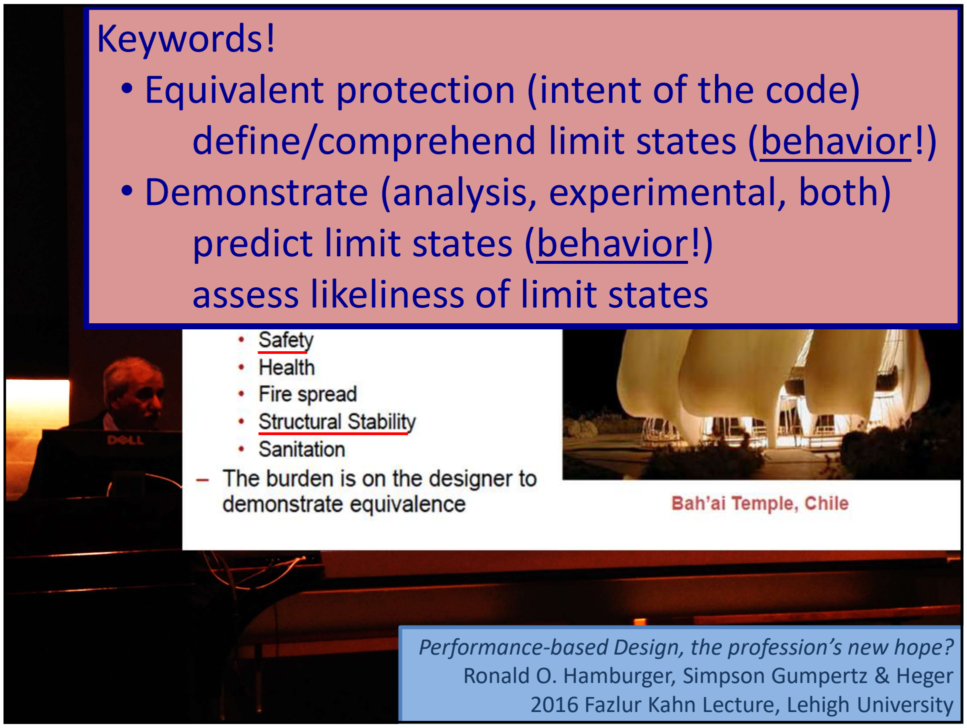
Keywords!
• Equivalent protection (intent of the code)
define/comprehend limit states (behavior!)
• Demonstrate (analysis, experimental, both)
predict limit states (behavior!)
assess likeliness of limit states
• Safety
• Health
• Fire spread
• Structural Stability
• Sanitation
– The burden is on the designer to demonstrate equivalence
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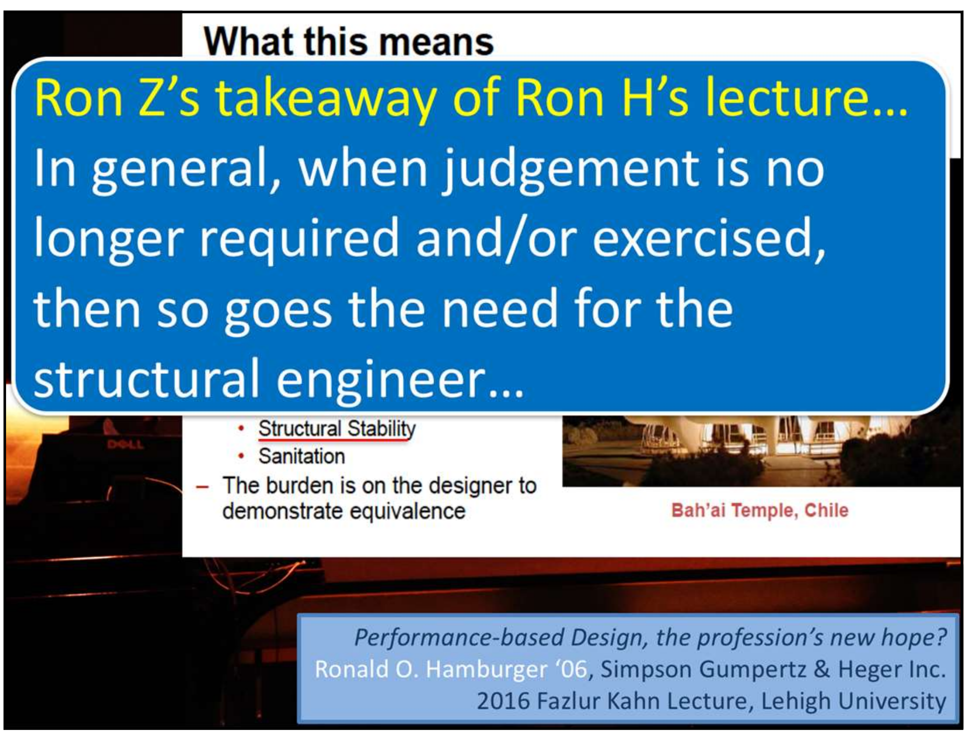
What this means
Ron Z's takeaway of Ron H's lecture…
In general, when judgement is no longer required and/or exercised, then so goes the need for the structural engineer…
• Structural Stability
• Sanitation
– The burden is on the designer to demonstrate equivalence
Bah'ai Temple, Chile
Performance-based Design, the profession's new hope?
Ronald O. Hamburger '06, Simpson Gumpertz & Heger Inc.
2016 Fazlur Kahn Lecture, Lehigh University

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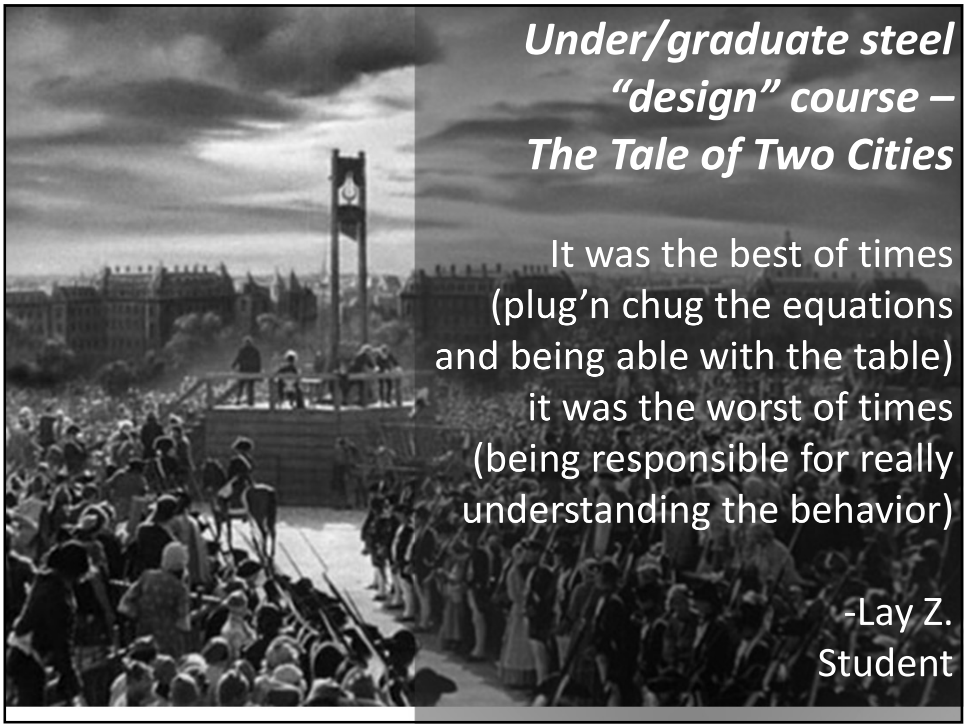

Under/graduate steel "design" course – The Tale of Two Cities

It was the best of times
(plug'n chug the equations
and being able with the table)
it was the worst of times
(being responsible for really
understanding the behavior)

-Lay Z.
Student

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Engineering Design Process

- 1. Identify the problem
- 2. Define the criteria/goals
- 3. Research and gather data
- 4. Brainstorm/generate creative ideas
- 5. Analyze potential solutions
- 6. Develop and test models
- 7. Make the decision
- 8. Communicate and specify
- 9. Implement and commercialize
- 10. Perform post-implementation assessment

Perhaps provided in 1st-year engineering course

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Engineering

Apply math, science, and judgment

Utilize the materials and forces of nature

To create a benefit to society

Civil Engineering
Architectural Engineering

Structural Engineering

Codes, Standards, Specifications,…

Design of Steel Structures

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Design of Steel Structures

Structural design may be defined as a mixture of art and science, combining the experienced engineer's intuitive feeling for the behavior of a structure with a sound knowledge of the principles of statics, dynamics, mechanics of materials, and structural analysis, to produce a safe economical structure that will serve its intended purpose.

Steel Structures: Design and Behavior
Salmon, Johnson, and Malhas, 2008

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Design of Steel Structures

Selection of system(s) for gravity loads, lateral loads, or both

Definition of loads

Analysis to determine behavior

Proportion system and components

Specifications: AISC 360, 341, 690
AISI, AASHTO, CISC, Eurocode, AS4100,…

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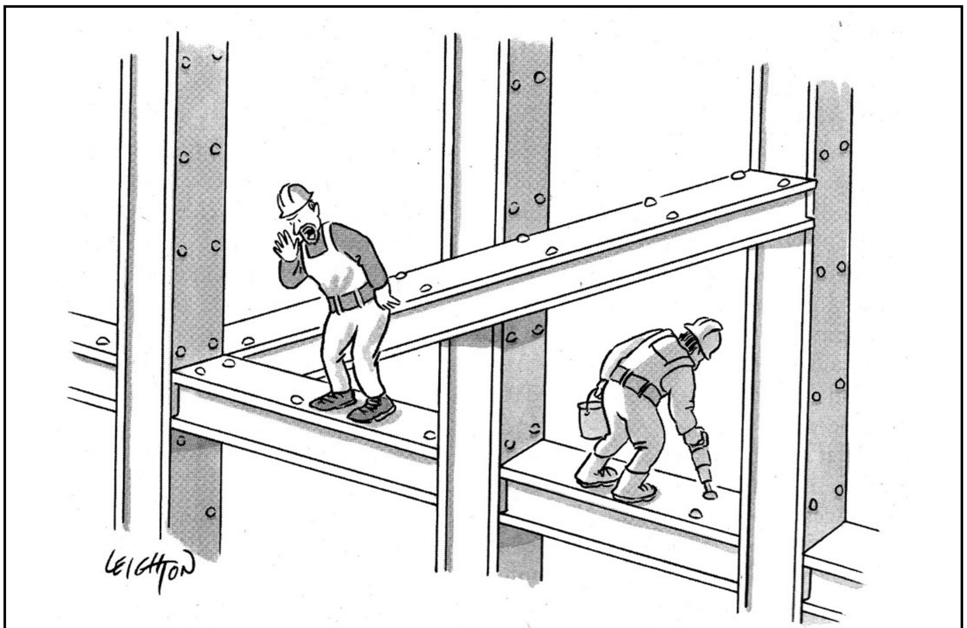

"Escher! Get your ass up here."

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Specification for Structural Steel Buildings (AISC 360)

Designing for stability…

Rules for proportioning components are a function of the destabilizing effects included in the structural analysis

Include:
- system sway imperfections?
- reduction for inelasticity?
- member out-of-straightness?
- inelastic force redistribution?

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New to Glossary of AISC Specification, 2016

Design. The process of establishing the physical and other properties of a structure for the purpose of achieving the desired strength, serviceability, durability, constructability, economy and other desired characteristics. Design f… s used in this Spec…, includes analysis t… red strength and proportioning to have adequate available strength.

Predict what is needed…

Provide what is needed…

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Coming into your course:

Analysis

Proportioning

During your course:

Design

System selection

Definition of loads

Analysis

Proportioning components

And more…

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Engineering

Apply math & science → Hypothesizing what "should" happen (limits state behavior = demands + response)
- ✓ Theoretical studies
- ✓ Computational studies
- ✓ Experimental studies

Include judgment → Meeting "Standard of Care" expectations
- ✓ You and your colleagues' experience
- ✓ The profession's experience
  - Codes and Specifications

Utilize materials and forces of nature → Taking "best" advantage of
- ✓ Materials – strength, stiffness, ductility
- ✓ Forces of nature – fabrication and assembly

To create a benefit to society → Contributing to the success of the endeavor by
- ✓ Proportioning steel structure and its components
- ✓ Providing drawings and specifications based on well-documented calculations
- ✓ Assisting to ensure safe and adequate construction

CEEG405: ~~Design of~~ Engineering Steel Structures

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On Using a Consistent Format to Deliver Steel Design Topics –

or better yet, hoping for
"Gestalt Psychology"…

Ron Ziemian

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Typical undergraduate course – Designing Steel Structures

1. Steel as a Structural Material
2. Design Principles / Design Philosophies
3. Design of Tension Members
4. Design of Compression Members
5. Design of Flexural Members
6. Design for Combined Actions
   a. Tension plus Flexure
   b. Compression plus Flexure
7. Design of Connections
8. Design of Structural Systems – Strength and Serviceability

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Consistent Lecture Sequence

(tension members, …, flexural members, …, connections, …)

1. Subject
2. Background reading (textbook, Specification, Commentary)
3. Photos of subject
4. Identify/discuss limits states
    a. Strength (primary)
    b. Serviceability (as needed)
5. For each limit state (that will be addressed in detail)
    a. overview of behavior (photos, animations, demonstrations)
    b. theory to model behavior (chalk 'n talk, learning modules)
    c. design equations (AISC Specification)
    d. worked examples (textbook, AISC Manual, in-class)
6. Summary
    a. closing thoughts
    b. homework and quiz/exam problems

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Example

1. Subject: Compression Members
2. Background reading
    a. Geschwindner, Chapter 5
    b. AISC Specification
        Ch. B pages 16.1-14 to 16.1-16
        Ch. E pages 16.1-31 to 16.1-33, 16.1-40 to 16.1-43
    c. AISC Commentary
        Ch. B pages 16.1-268 to 16.1-270
        Ch. E pages 16.1-290 to 16.1-294, 16.1-298 to 16.1-301
3. Photos of subject
    <next slide and many more>

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Example (cont.)

3. Photos of Compression Members

Pop quiz! Find as many types of compression members as you can in 60 sec.

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Example (cont.)

1. Subject: Compression Members
2. Background reading (textbook, Specification, Commentary)
3. Photos of subject
4. Identify/discuss limits states
   a. Strength (primary)
   b. Serviceability (as needed)
5. For each limit state (that will be addressed in detail)
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   c. design equations (AISC Specification)
   d. worked examples (textbook, AISC Manual, in-class)
6. Summary
   a. closing thoughts
   b. homework and quiz/exam problems

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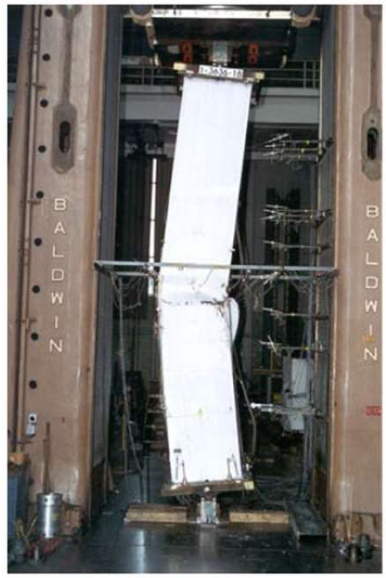
FLEXURAL BUCKLING
DOUBLY-SYMMETRIC MEMBERS



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https://ceprofs.civil.tamu.edu/llowery/cven446/

Local Buckling

- Flange
- Web

Pop quiz! What’s strange about the flange buckling mode?

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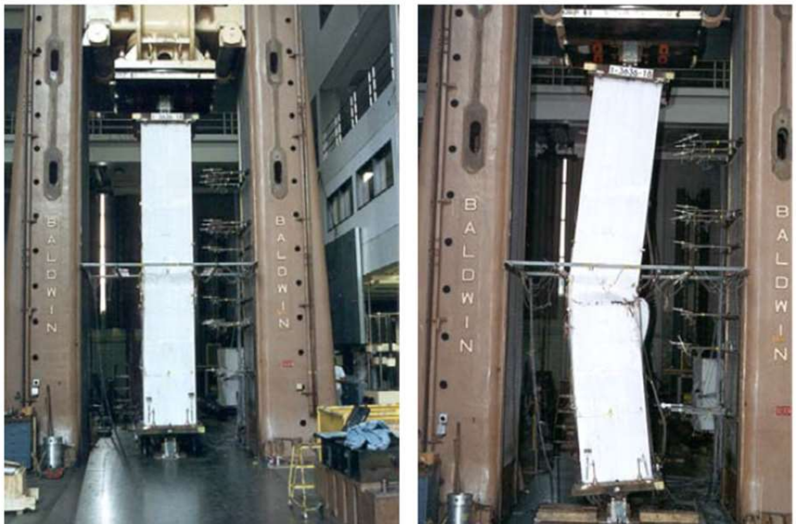
FLEXURAL BUCKLING
DOUBLY-SYMMETRIC MEMBERS



Wait! Which came first, local buckling or flexural buckling?

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Example (cont.)

1. Subject: Compression Members
2. Background reading (textbook, Specification, Commentary)
3. Photos of subject
4. Identify/discuss limits states
   a. Strength (primary)
   b. Serviceability (as needed)
5. For each limit state (that will be addressed in detail)
   a. overview of behavior (photos, animations, demonstrations)
   b. theory to model behavior (chalk 'n talk, learning modules)
   c. design equations (AISC Specification)
   d. worked examples (textbook, AISC Manual, in-class)
6. Summary
   a. closing thoughts
   b. homework and quiz/exam problems

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Background: Summers 2013, 2017, and 2020, AISC contracted with members of the Structural Stability Research Council to provide a Night School Course (8 lectures) titled "Fundamentals of Stability for Steel Design"

I was responsible for three of these lectures and was forced to put my "interactive" lectures and board work into Powerpoint lectures…

Behavior of Compression Members

Behavior of Flexural Members

Behavior of Structural Systems / Beam-Columns

The course notes have been provided to you…

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Example (cont.)

5. For each limit state (that will be addressed in detail)
   a. overview of behavior (photos, animations, demonstrations)
   b. theory to model behavior (chalk 'n talk, learning modules)
   c. design equations (AISC Specification)
   d. worked examples (textbook, AISC Manual, in-class)

Feel free to cruise my AISC Night School lecture notes to see what content would be presented in the interactive lectures related to the flexural buckling of compression members…

and have some fun along the way!

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Some thoughts…compression members

- Work towards "deriving" AISC's column curve presented in Ch. E of Specification
- The key is to start with Euler's assumptions and math, and then work backwards to "undo" the assumptions and return to reality!
- Yes, we setup and solve the governing diff. eq., but you may choose not to…or use wolframalpha.com
- Several of the stability learning modules (to be discussed tomorrow morning) are used to create a virtual lab experience
- Alignment charts relate to system stability, and are not presented at this time in the course

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Example (cont.)

5. For each limit state (that will be addressed in detail)
   a. overview of behavior (photos, animations, demonstrations)
   b. theory to model behavior (chalk 'n talk, learning modules)
   c. design equations (AISC Specification)
   d. worked examples (textbook, AISC Manual, in-class)
6. Summary
   a. closing thoughts
   b. Homework, learning modules, and quiz/exam problems

Some more thoughts:
- No numerical examples are worked in class. Textbooks and AISC manual are simply awesome!
- Sometimes have them re-solve textbook example or Manual problem with different shape size, member length, etc.
- Before any AISC Manual tables may be used, students must confirm their accuracy; which is typically a homework problem

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Fun with Euler…

$$\sigma_E = \pi^2 E/(L/r)^2$$

$$\varepsilon_E = \pi^2/(L/r)^2 = \Delta L_E/L$$

$$\Delta L_E = \pi^2 r^2/L$$

So, why is that interesting?

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Typical undergraduate course – Desig

So, what's this "Gestalt Psychology" all about?

1. Steel
2. Desig
3. Design of Tension Mem
4. Design of Compression Members
5. Design of Flexural Members
6. Design for Combined Actions
   a. Tension plus Flexure
   b. Compression plus Flexure
7. Design of Connections
8. Design of Structural Systems – Strength and Stability!

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The central principle of *gestalt psychology* maintains that the human mind considers objects in their entirety before, or in parallel with, perception of their individual parts; suggesting *the whole is other than the sum of its parts*.

When it comes to designing a steel structure, the engineer must consider the entire system before, or in parallel with, perception of the beams, columns, braces, connections, …

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The engineer perceives a steel building…

And, should design accordingly…

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Consistent Lecture Sequence

1. Subject – **Steel Structure**
2. Background reading (textbook, Specification, Commentary)
3. Photos of subject
4. Identify/discuss limits states
   a. Strength (primary)
   b. Serviceability (as needed)
5. For each limit state (that will be addressed in detail)
   a. overview of behavior (photos, animations, demonstrations)
   b. theory to model behavior (chalk 'n talk, learning modules)
   c. design methods (AISC Specification, ELM or DM)
   d. worked examples (textbook, AISC Manual, in-class)
6. Summary
   a. closing thoughts
   b. homework and quiz/exam problems

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Course Title?

Design of Steel Structures

versus

Proportioning of Structural Components Fabricated from Steel

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