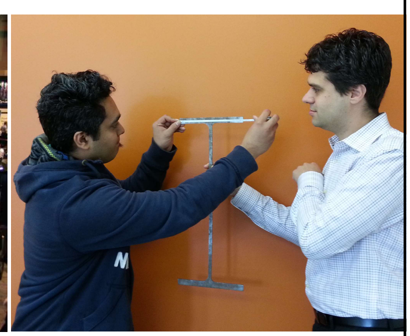
Hands-on Demonstrations (and other visual aids)

Low or no budget ways to help your students to understand behavior

Judy Liu, Ron Ziemian

1

First … collect steel “bits” from the NASCC Exhibit Hall



Slices of W-shapes, angles, channels …
… bolts (including TC bolts, DTIs), etc.
These don’t demonstrate behavior, but they are always good pass-arounds!

2

Some demos

- Foam 'beams'* / buckling models*
- Effective net area
- Block shear, connections
- Paper columns*
- Buildings in earthquakes
- Built-up compression members
- Stress-strain
- Residual stresses
- Shear lag
- Leaning columns, P-delta
- Live Loads

**Instructions can be found on the AISC Educator Forum.*

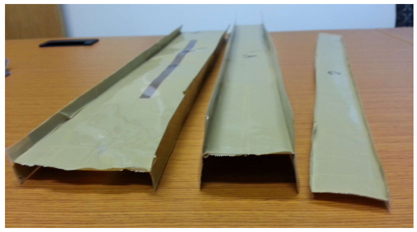
3

Foam Beams / Columns

Instructions include dimensions for a channel, angle, and "W-shape". The "W-shape" can be used to demonstrate lateral torsional buckling.

4

Beam Buckling Models



Instructions provide dimensions for beams that demonstrate local or lateral torsional buckling. Materials: overhead transparency film and packing tape.

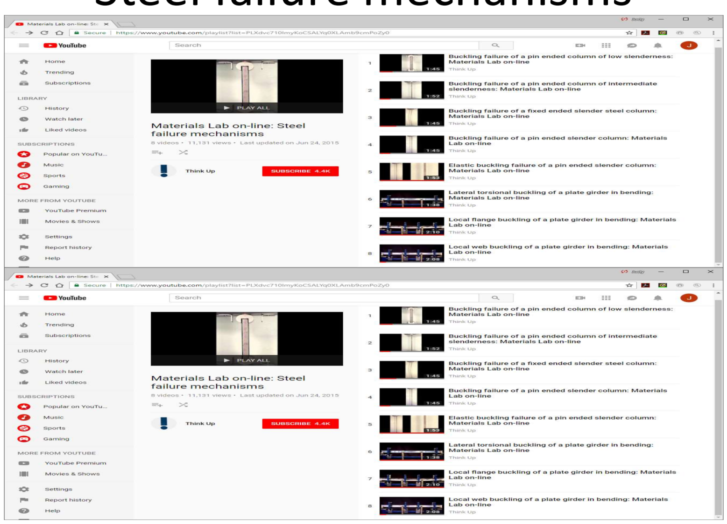
FLB

WLB

LTB

5

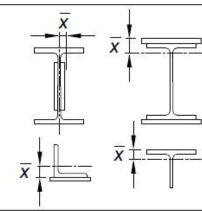
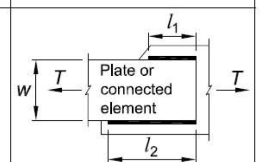
Materials Lab on-line: Steel failure mechanisms



https://www.youtube.com/playlist?list=PLXdvc710ImyKoCSALYq0XLAmb9cmPoZy0

6

TABLE D3.1
Shear Lag Factors for Connections to Tension Members

Case	Description of Element	Shear Lag Factor, U	Example
1	All tension members where the tension load is transmitted directly to each of the cross-sectional elements by fasteners or welds (except as in Cases 4, 5 and 6).	$U = 1.0$	–
2	All tension members, except HSS, where the tension load is transmitted to some but not all of the cross-sectional elements by fasteners or by longitudinal welds in combination with transverse welds. Alternatively, Case 7 is permitted for W, M, S and HP shapes. (For angles, Case 8 is permitted to be used.)	$U = 1 - \frac{\bar{x}}{l}$	
3	All tension members where the tension load is transmitted only by transverse welds to some but not all of the cross-sectional elements.	$U = 1.0$ and A_n = area of the directly connected elements	–
4[a]	Plates, angles, channels with welds at heels, tees, and W-shapes with connected elements, where the tension load is transmitted by longitudinal welds only. See Case 2 for definition of $\bar{x}$.	$U = \frac{3l^2}{3l^2 + w^2}\left(1 - \frac{\bar{x}}{l}\right)$	

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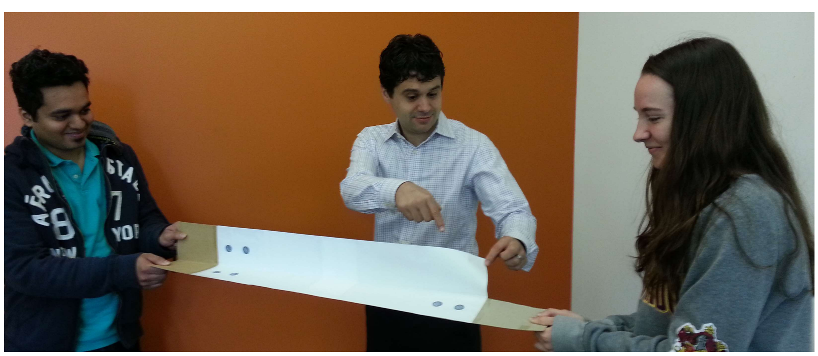
Effective Net Area

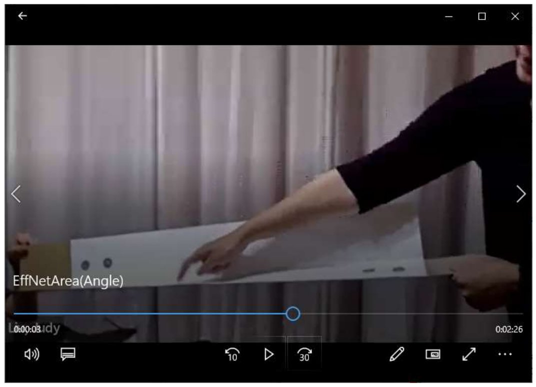
Case 2



Supplies: paper, cardboard, scotch tape, scissors, marker (optional)

8

Effective Net Area
Case 2



Supplies: paper, cardboard, scotch tape, scissors, marker (optional)
https://youtube.com/playlist?list=PL76luzqU9URxM_cCE6BGLckcUzp3GCBxD

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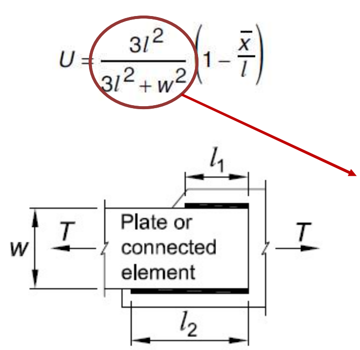
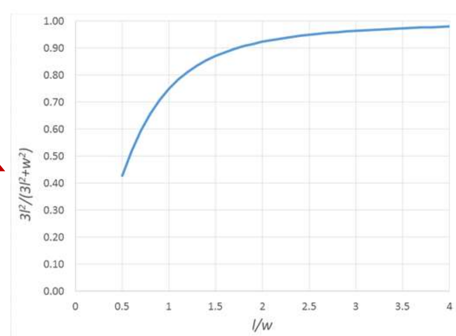
Effective Net Area
Case 4





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Effective Net Area
Case 4

Supplies: patchwork quilting fabric (or similar)

11

Effective Net Area
Case 4

Supplies: patchwork quilting fabric or similar, mixing spoon
https://youtube.com/playlist?list=PL76luzqU9URxM_cCE6BGLckcUzp3GCBxD

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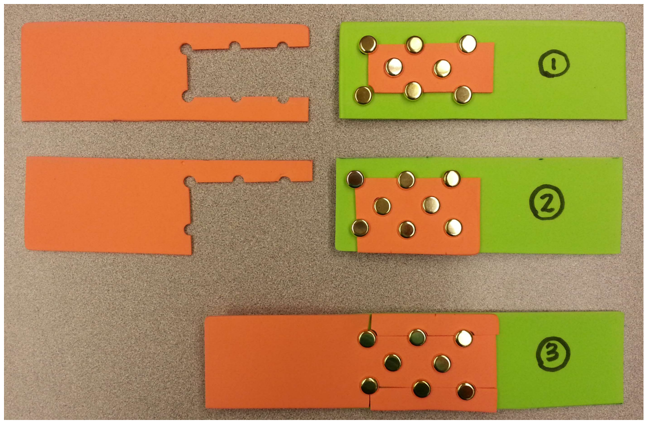
Block Shear



Supplies: craft foam sheets, paper fasteners, scissors, hole punch, marker (optional)

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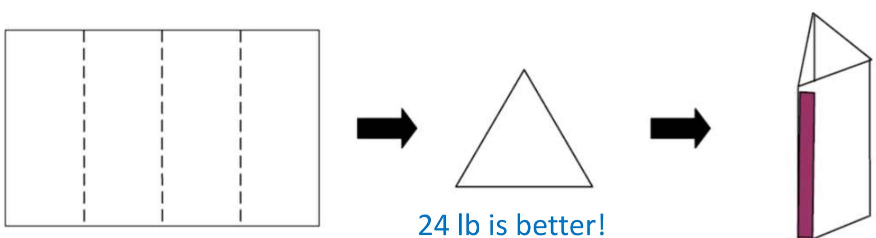
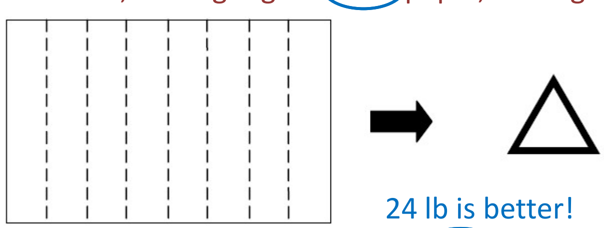
Paper Columns



24 lb is better!

Make 2 columns, 1 using regular 20 lb paper, 1 using cardstock.



24 lb is better!

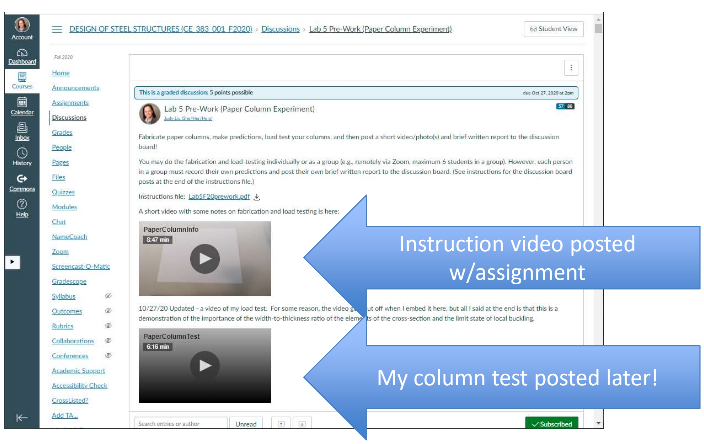
Make 1 column using regular 20 lb paper.

14

Paper Columns

15

Paper Columns



https://youtube.com/playlist?list=PL76luzqU9URxM_cCE6BGLckcUzp3GCBxD

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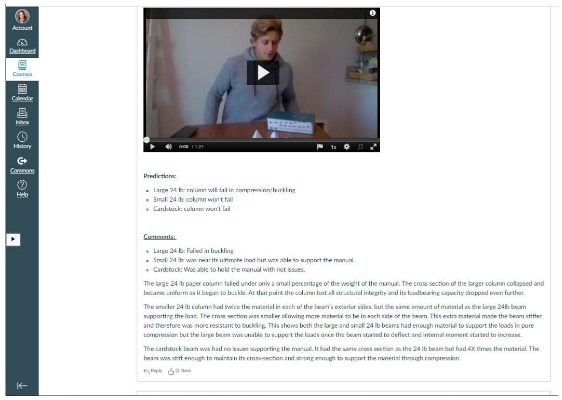
Paper Columns



Each student posted their prediction and load test photo(s)/short video to a discussion board. The one with the most “likes” from other students was shared and discussed in class.

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Building Fundamental Period “Demo” (on a tabletop – shake table or volunteer)

Building on the right is similar to our case study building.

Note responses of these 2 buildings to different frequencies of “ground motions” and with different mass.
(e.g., higher mode response for tall building?)

What changes when we add mass to each building?

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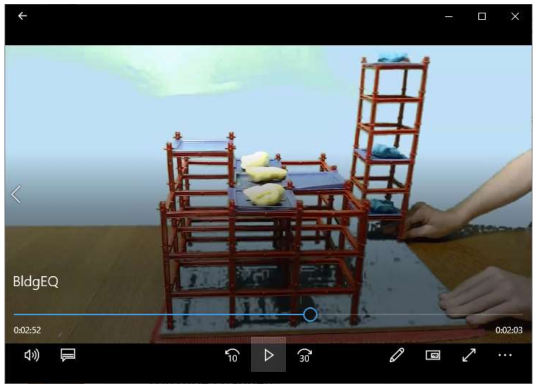
Building Fundamental Period "Demo"
(on a tabletop – shake table or volunteer)



https://youtube.com/playlist?list=PL76luzqU9URxM_cCE6BGLckcUzp3GCBxD

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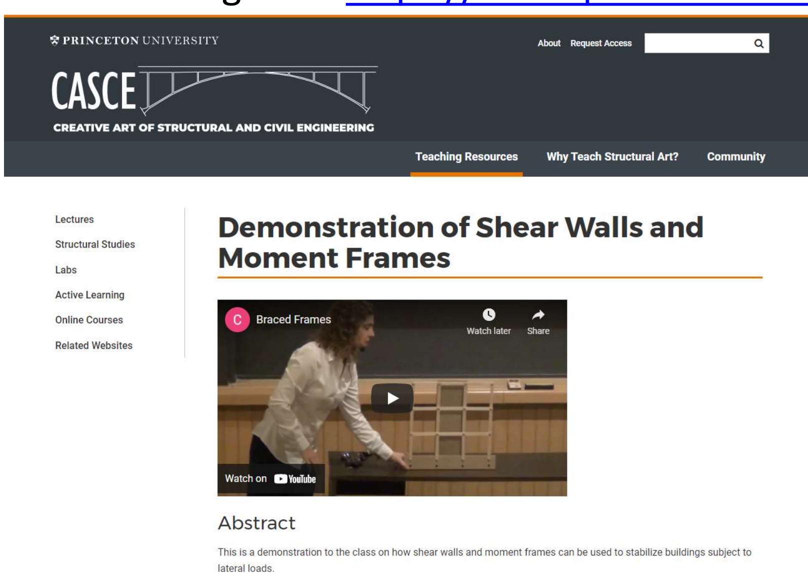
Active Learning from https://casce.princeton.edu/



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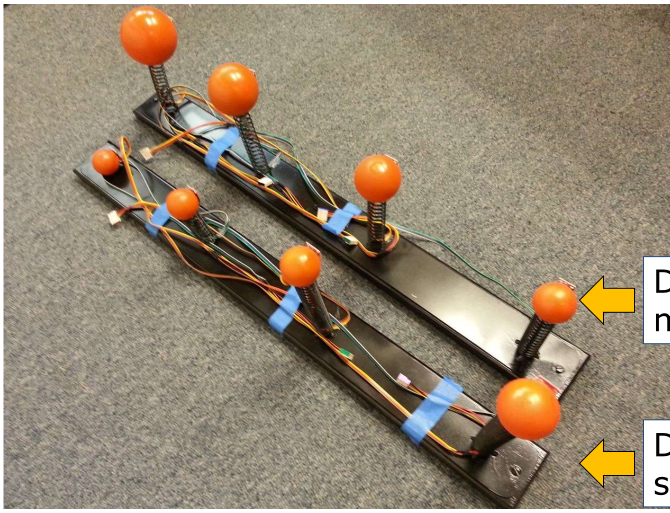
Another tabletop shake table demo



Different mass

Different stiffness

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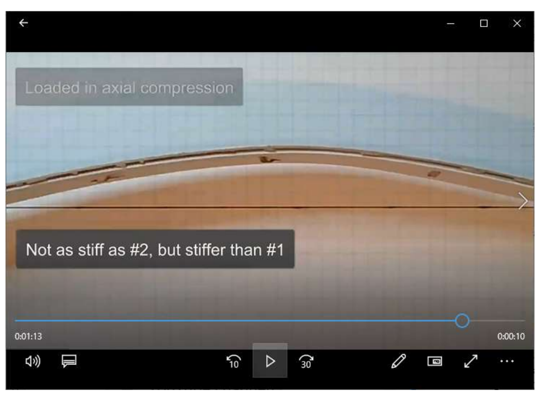
Built-Up Compression Member Demo



https://youtube.com/playlist?list=PL76luzqU9URxM_cCE6BGLckcUzp3GCBxD

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The fundamentals…stabilty

- Force follows stiffness (wet spaghetti test!)
- Basis for every structural analysis
  - Equilibrium (“forces” must be in agreement!)
  - Compatibility (“displacements” must be in agreement)
  - Constitutive Relationship (“forces” -to- “displacements”)
- Superposition – always so tempting!
  - Linear response (geometric and material)
  - Serviceability (yeah!) vs. ultimate strength (instability?!)
- Behavior of steel structures
  - Material level
  - Cross-section, Member, System level

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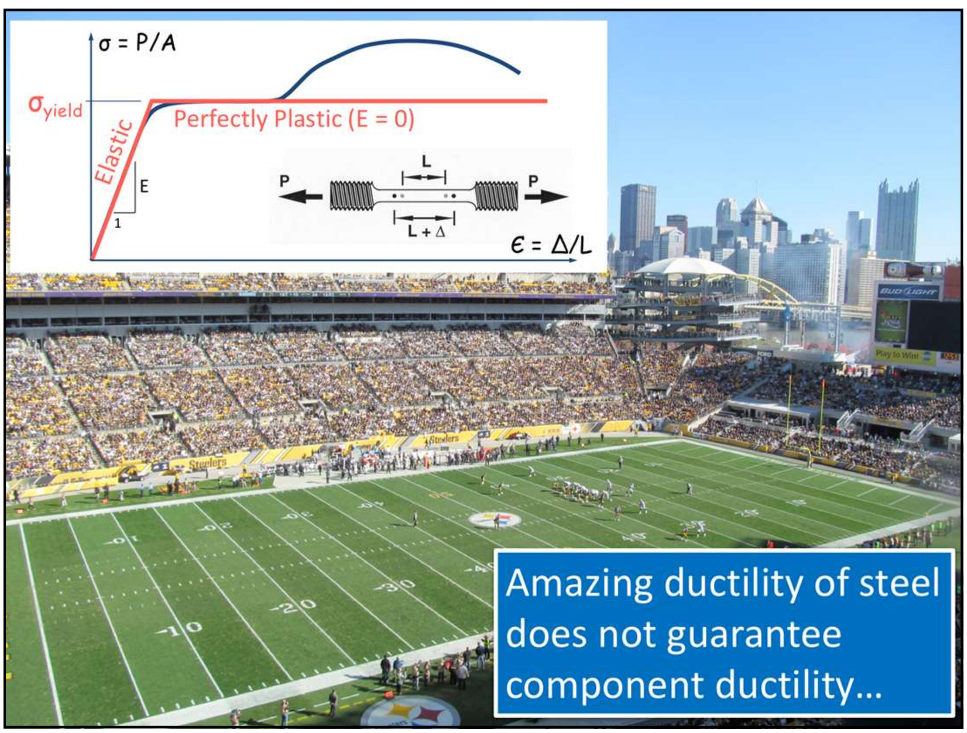
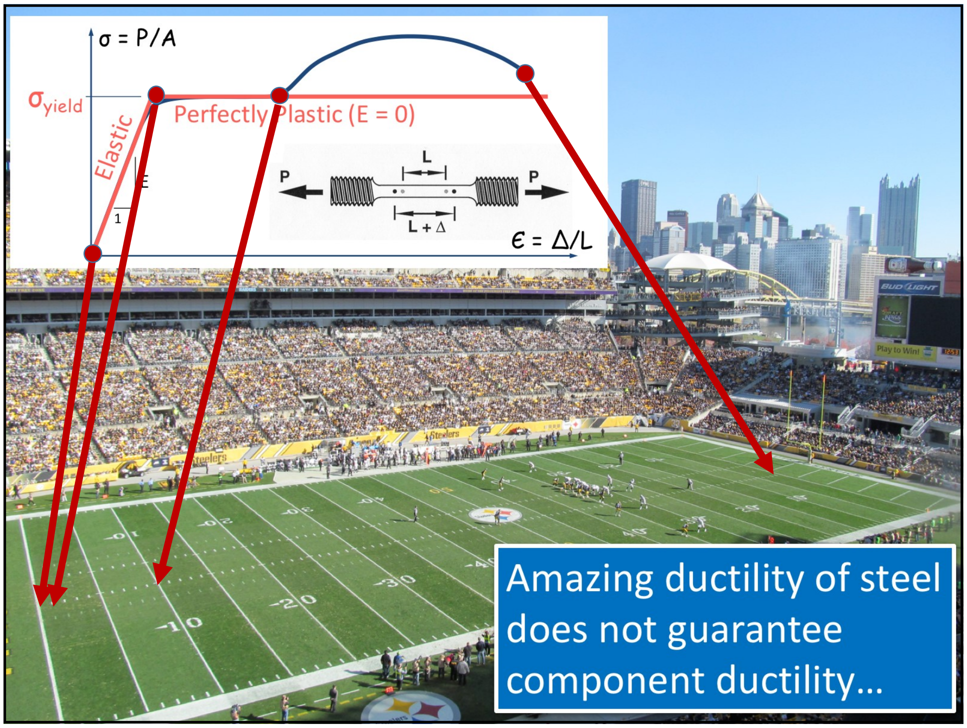


24


σ = P/A
σyield
Elastic
E
1
Perfectly Plastic (E = 0)
P
L
P
L + Δ
ϵ = Δ/L
Amazing ductility of steel does not guarantee component ductility…

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There is a reason that this person is smiling!
Well proportioned steel connection = ductility!

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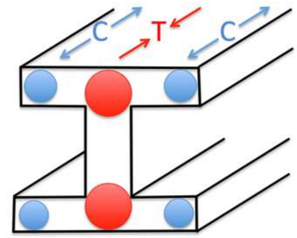
Residual Stresses



1. Entire section hot and starts to cool…lengthwise contraction with $E_o << E$
2. Flange tips (surface area!) cool relatively faster than flange-web intersection (smaller surface) area, $E_{fl} \approx E$
3. Flange-web intersection (smaller surface area) now cools and wants to contract, but flange tips are already set and do not want to contract.
4. Result – locations to cool last end up in tension and equilibrium requires locations that cooled first to end up in compression.

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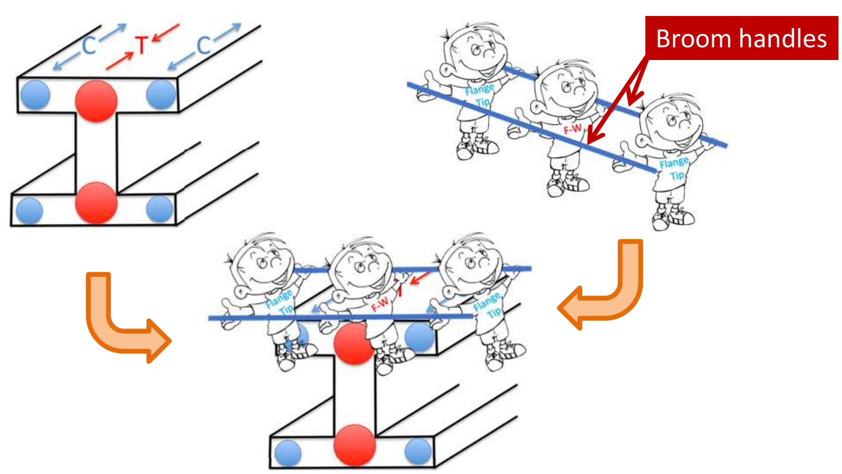
To demonstrate this, we will need to 3 students and 2 broom handles (or equivalent)



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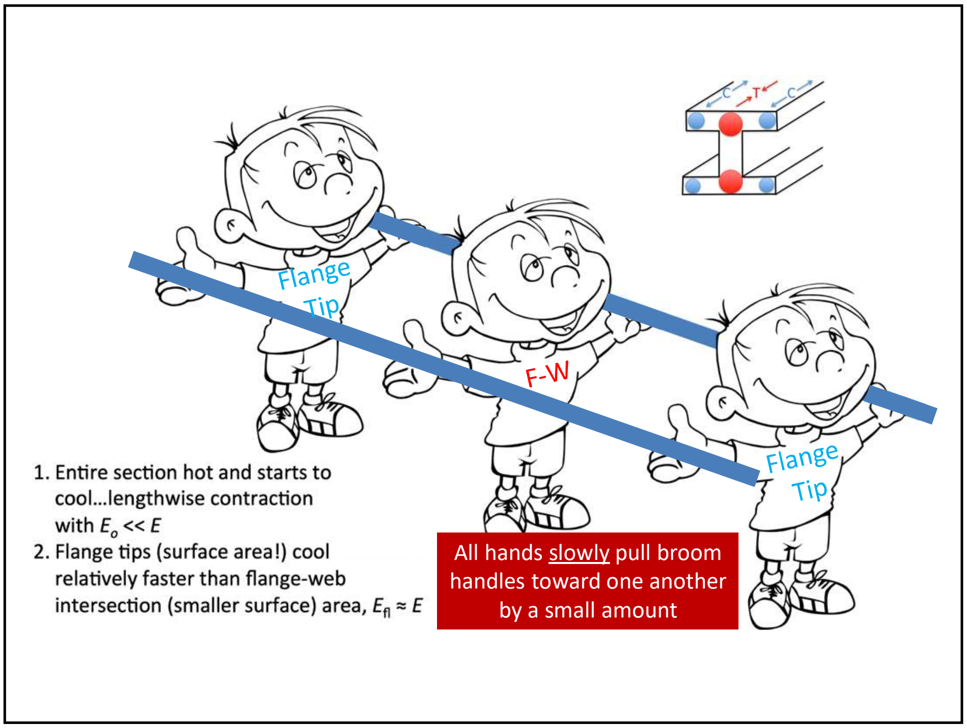
C
T
C
Flange Tip
F-W
Flange Tip
1. Entire section hot and starts to cool…lengthwise contraction with $E_o << E$
2. Flange tips (surface area!) cool relatively faster than flange-web intersection (smaller surface) area, $E_{fl} \approx E$
All hands slowly pull broom handles toward one another by a small amount

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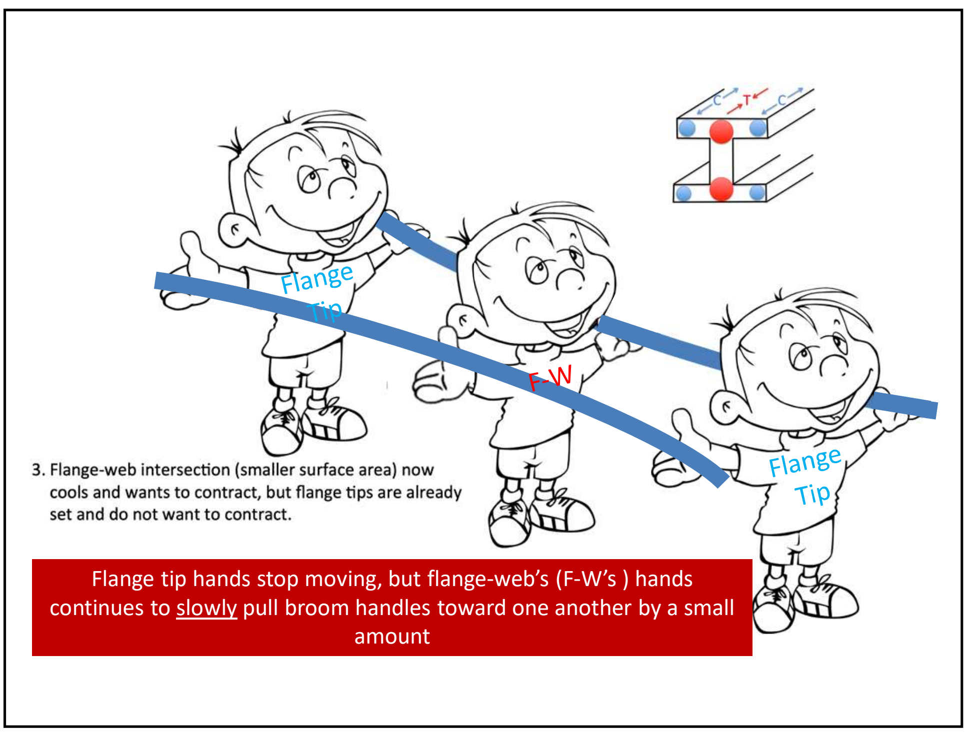
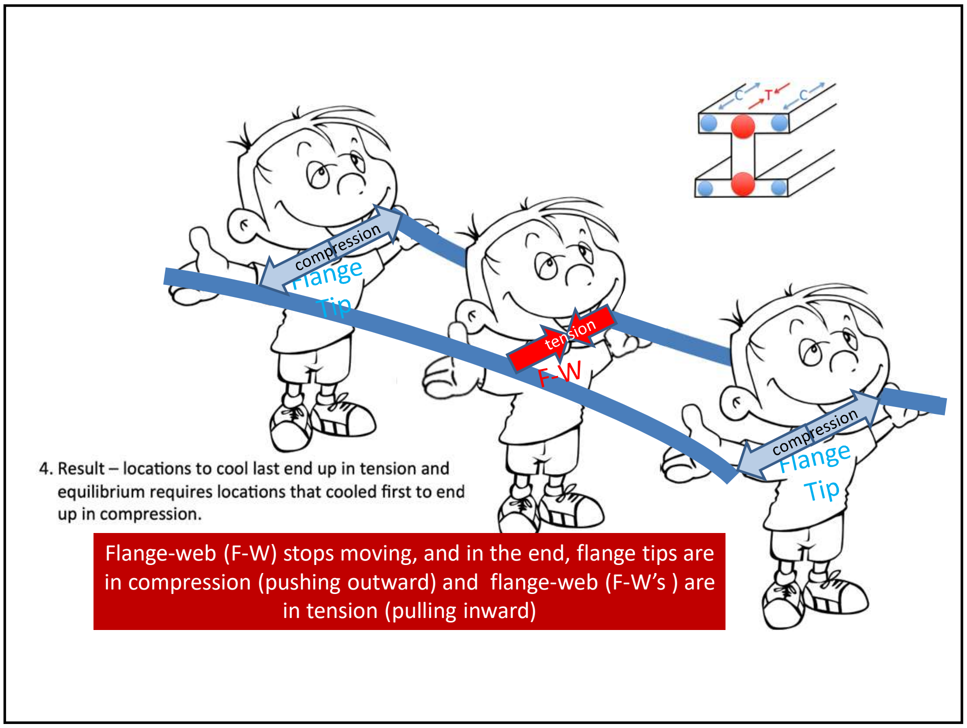

C
T
C
Flange Tip
F-W
Flange Tip
3. Flange-web intersection (smaller surface area) now cools and wants to contract, but flange tips are already set and do not want to contract.
Flange tip hands stop moving, but flange-web's (F-W's) hands continues to slowly pull broom handles toward one another by a small amount

30


compression
Flange Tip
tension
F-W
compression
Flange Tip
4. Result – locations to cool last end up in tension and equilibrium requires locations that cooled first to end up in compression.
Flange-web (F-W) stops moving, and in the end, flange tips are in compression (pushing outward) and flange-web (F-W's) are in tension (pulling inward)

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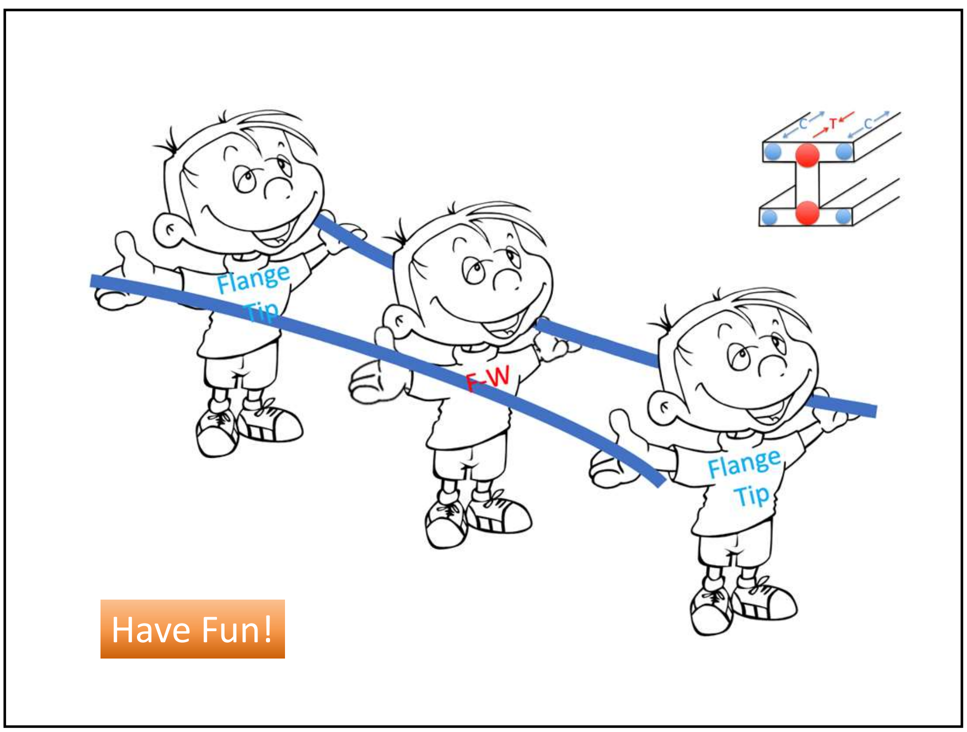
Flange Tip
F-W
Flange Tip
Have Fun!

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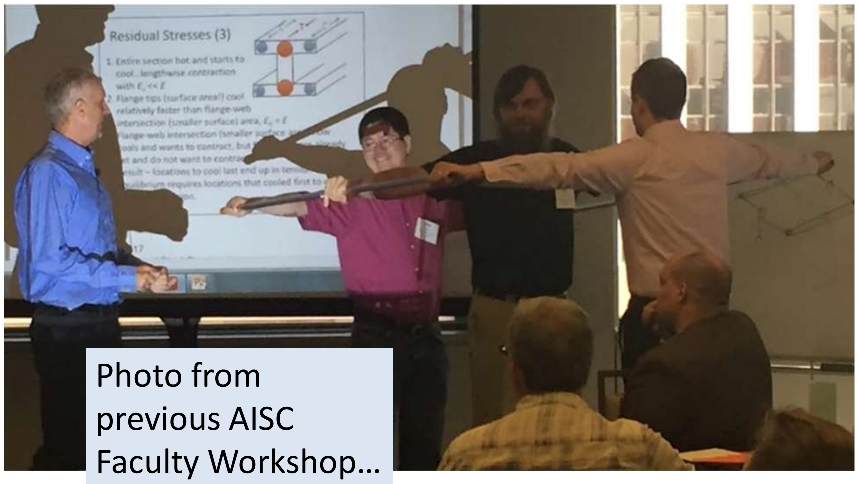

Photo from previous AISC Faculty Workshop…

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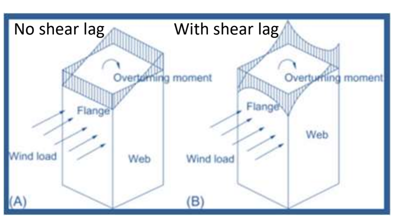
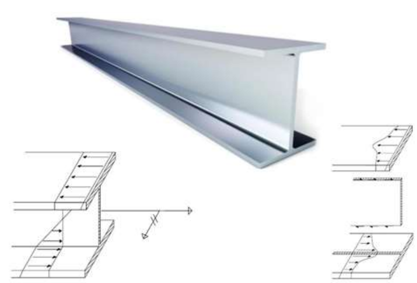
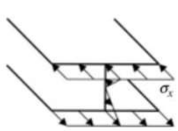
Shear lag – normal stresses are not uniformly distributed over the width of an element (e.g. flange) due to the shear flexibility of that element



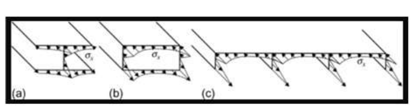


No shear lag

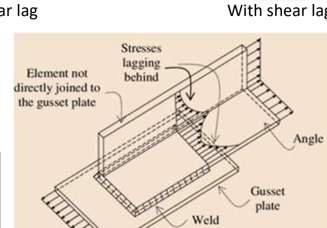
With shear lag



No shear lag



With shear lag



With shear lag

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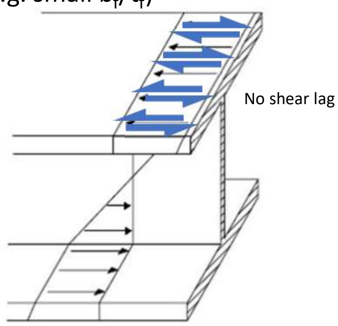
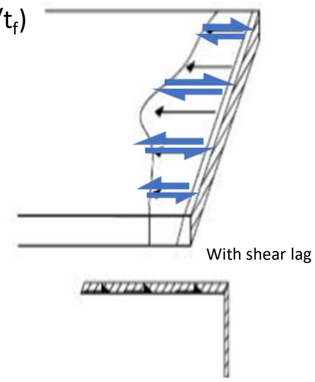
To demonstrate this within the flange of an I-shape, we will need <u>6</u> students

<u>Case #1</u>
Little to no shear
flexibility of the flange
(e.g. small b_f/t_f)



<u>Case #2</u>
Significant shear
flexibility of the flange
(e.g. large b_f/t_f)



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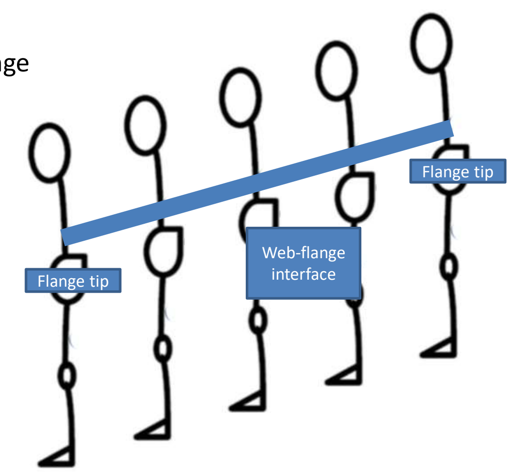
<u>Case #1</u>
Little to no shear
flexibility of the flange
(e.g. small b_f/t_f)



5 students stand in line and barely separated such that arms can interlock well with neighbor

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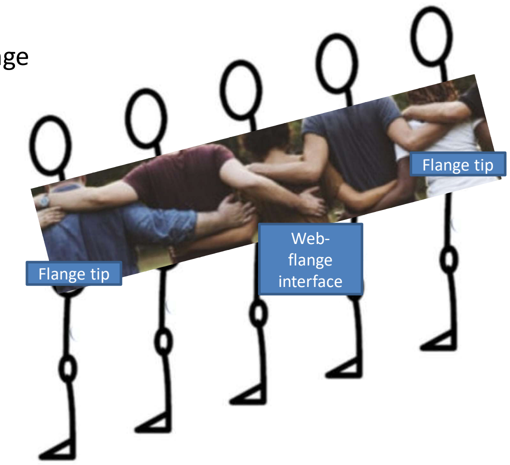
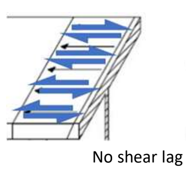
<u>Case #1</u>
Little to no shear flexibility of the flange
(e.g. small b_f/t_f)

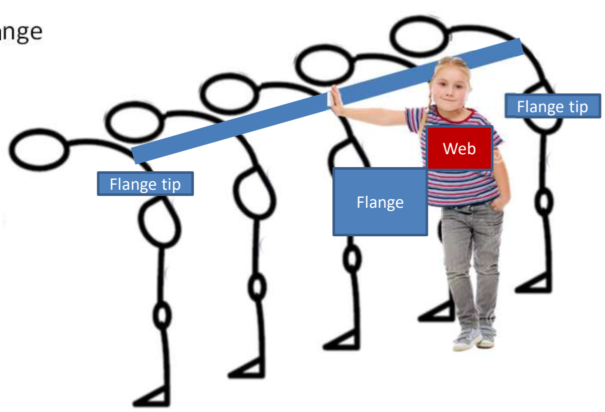


5 students stand in line and barely separated such that arms can interlock well with neighbor

37

<u>Case #1</u>
Little to no shear flexibility of the flange
(e.g. small b_f/t_f)





6th student (web) transfers force into flange, and because hand/arm interlock has little to no shear flexibility, the flange-tip students resist an equal portion of this force.

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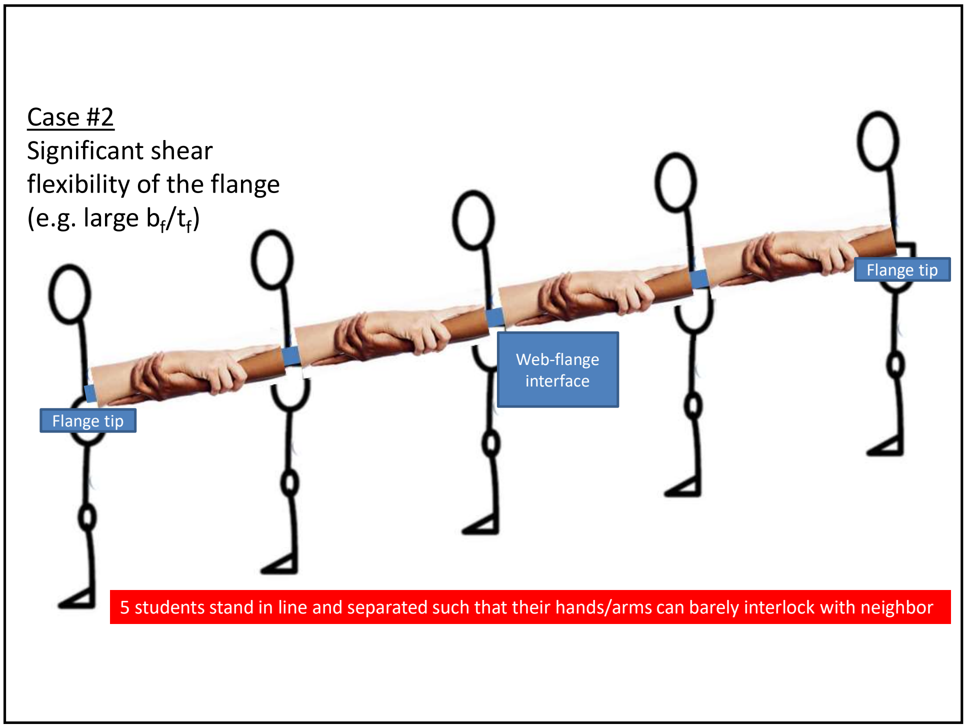
Case #2
Significant shear
flexibility of the flange
(e.g. large b_f/t_f)
Flange tip
Web-flange interface
Flange tip
5 students stand in line and separated such that their hands/arms can barely interlock with neighbor

39

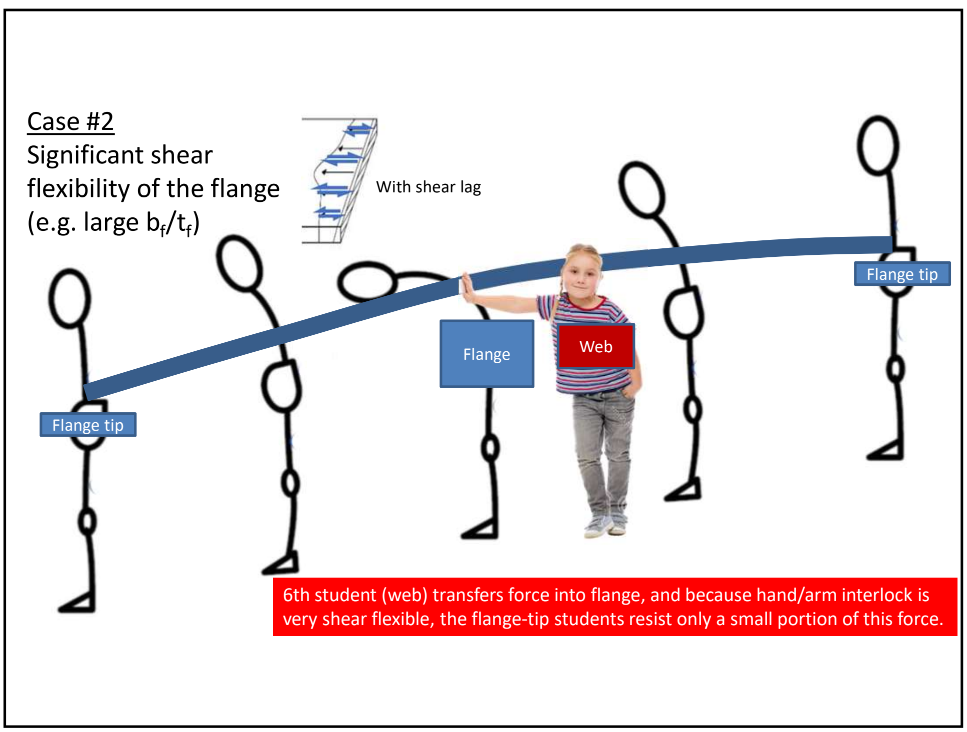
Case #2
Significant shear
flexibility of the flange
(e.g. large b_f/t_f)
With shear lag
Flange tip
Flange
Web
Flange tip
6th student (web) transfers force into flange, and because hand/arm interlock is very shear flexible, the flange-tip students resist only a small portion of this force.

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Photo from previous AISC Faculty Workshop…

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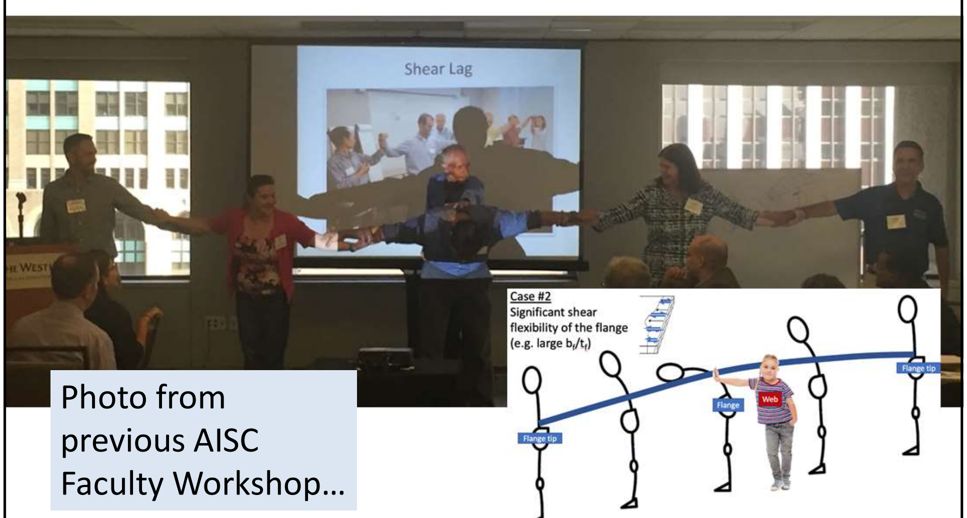

Photo from previous AISC Faculty Workshop…

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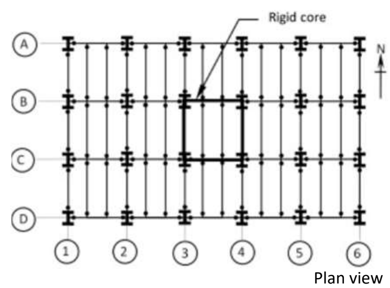
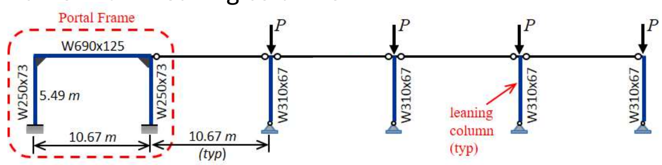
Leaning columns and the P-Δ effect

With exception of 4 columns within rigid core, the 20 gravity-only columns remain stable by "leaning" on the rigid core…of course, floor diaphragm plays an important role in this behavior.



Simplified version of this concept – portal frame with 4 leaning columns



Let's demonstrate that the P-Δ effect from the leaning columns produces lateral load on the portal frame

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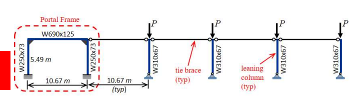
Time for class participation…we need 4 students and a bathroom scale

Record value on scale with one leaning student (column!)

Very important – only standing on one foot



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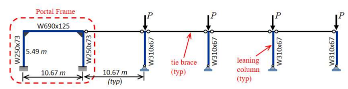
Record value on scale with two leaning students (columns!)

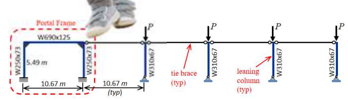
Very important – all only standing on one foot



45

Record value on scale with three leaning students (columns!)

Very important – all only standing on one foot



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Record value on scale with four leaning students (columns!)

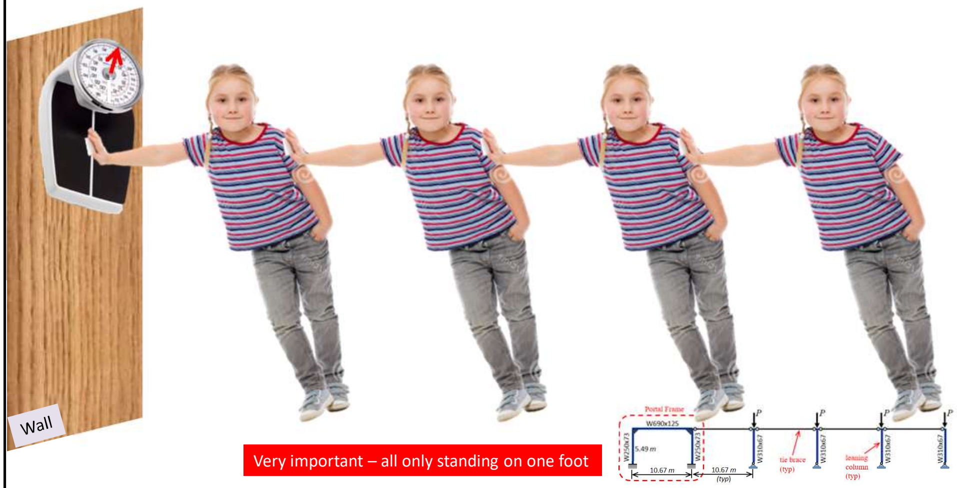

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Photo from previous AISC Faculty Workshop… yes, beers can add to the destabilizing P-Δ effect!

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Simple demonstration of loss of stability due to the P-Δ effect

Without backpack (P=0), the backpacker can resist lateral load

With backpack (P>>0), the backpacker will struggle to resist lateral load

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Live Loads

SIMPSON GUMPERTZ & HEGER

Engineering of Structures and Building Enclosures

SGH LIVE LOAD EVALUATION

Photo 1

28.82 pounds per square foot.

12 people in 64 sq ft.

5.33 sq ft per person.

Photo 2

44.56 pounds per square foot (approximate design load; design live load = 50 psf).

17 people in 64 sq ft.

3.76 sq ft per person.

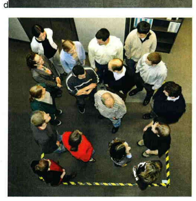

Photo 3

59.85 pounds per square foot (approximate design load; design live load = 50 psf).

23 people in 64 sq ft.

2.78 sq ft per person.

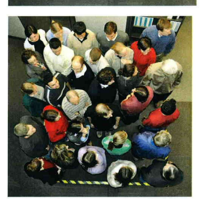

Photo 4

76.10 pounds per square foot.

30 people in 64 sq ft.

2.13 sq ft per person.

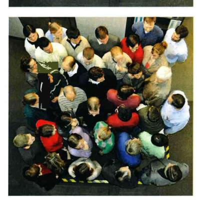

Photo 5

93.13 pounds per square foot.

36 people in 64 sq ft.

1.64 sq ft per person.

SGH Project Live Load Test / February 201

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Questions?

Note: on the following slides are visual aids/demonstrations suggested by 2018 Educator Workshop participants!

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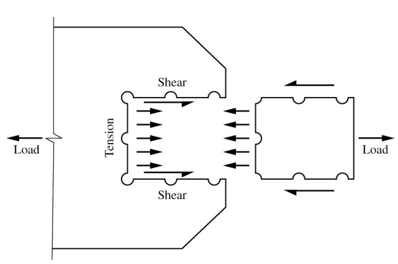
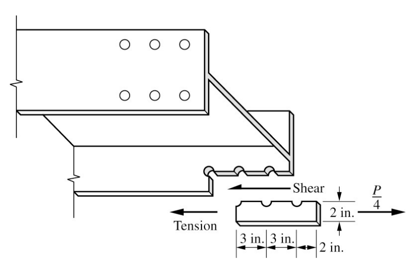
Block Shear

Block shear failure is difficult to explain using plan (2D) drawings.

3D isometrics may help





Mohamed Zeidan

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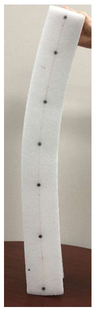
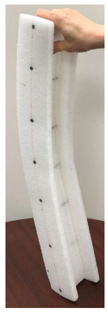
Use of Models to Explain Steel Member Design

Simple Styrofoam models can be used to explain compression buckling modes. Many of the following design concepts can be presented:

- Directionality of buckling and the plane of buckling
- Local (element) buckling and member buckling
- Demonstration of buckling about X-axis and Y-axis
- Relevant properties governing the directionality: L_{cx}, I_x, r_x and L_{cy}, I_y, r_y
- Lateral braces, their effects on member buckling and ideal brace spacing

Weak Axis (Member) Buckling

Strong Axis (Member) Buckling

Flange Local Buckling
(Table B4.1a)

The University of Akron

Steel1: Anil Patnaik Patnaik@uakron.edu

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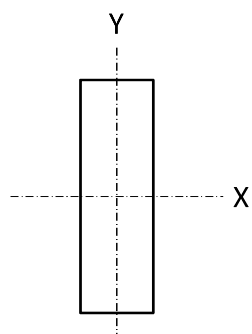
Physical Aids – Euler Buckling Demonstration Using 3^{ft} Carpenter Ruler

Strong axis before buckling

Weak axis before buckling

Weak axis after buckling



$r_y << r_x$

$L_c/r_y >> L_c/r_x$

$F_{ey} << F_{ex}$

Yongwook Kim, PhD, PE, Manhattan College

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LTB Demo Using Flex Beam

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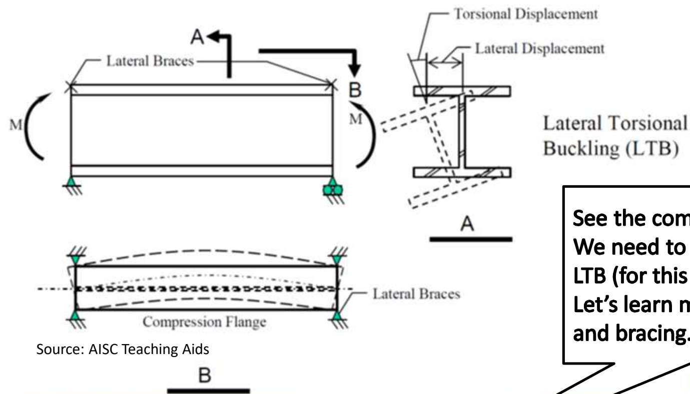
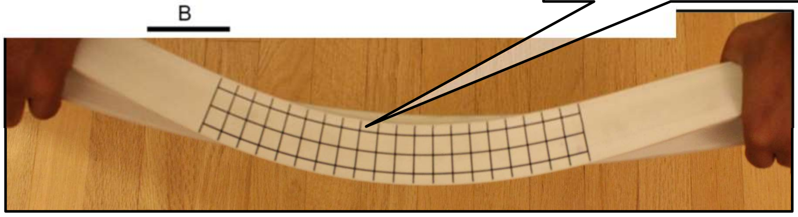


Source: AISC Teaching Aids

See the compression flange? We need to brace it to avoid LTB (for this case).
Let's learn more about LTB and bracing…



Strong-Axis Bending: Top View

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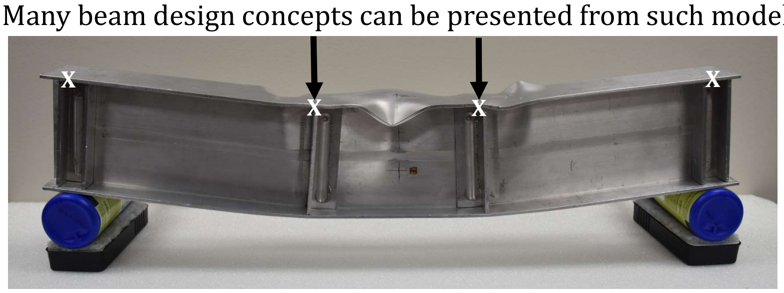
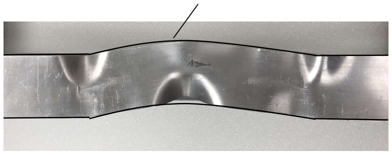
Use of Models to Explain Steel Member Design

A failed test specimen is useful to explain different beam failure modes.
Many beam design concepts can be presented from such models.

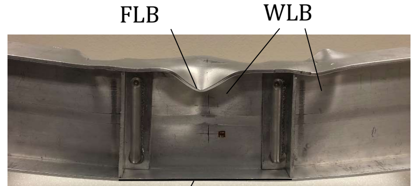


Effect of LTB



Top View of Compression Flange

FLB WLB



Tension Flange Yielding

The University of Akron

Steel1: Anil Patnaik Patnaik@uakron.edu

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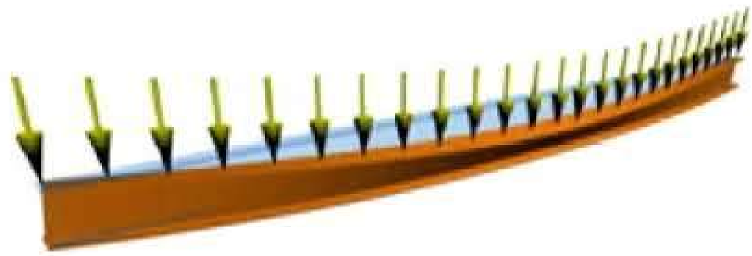
Visual Aids – Lateral Torsional Buckling Demonstration Using YouTube Video Developed by Others



AISC Teaching Aid: https://www.aisc.org/education/university-programs/ta-web-enhanced-teaching/
AISC Educator Forum: https://sites.google.com/a/aisc.org/educator_forum/videos/
YouTube: https://www.youtube.com/watch?v=dBP2VFHvun4

Yongwook Kim, PhD, PE, Manhattan College

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Shear Lag Demo Using Paper Angles

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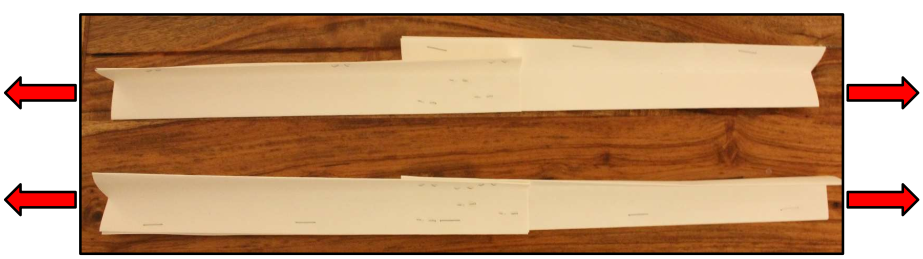
Let's make paper angles: (show how)
Now, let's try to pull the first paper angle
How did it fail? Remember what it felt like when it broke.
Now, try to pull the second paper angle
Do you feel a difference in the force you applied?
Which one was easier to break?
Let's learn what happened at the connection and the stress distribution in both cases…



Paper Angles (copy paper bent 3 times lengthwise and stapled)
Top: only one leg connected, Bottom: both legs connected

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Tension Connection Testing

- Specimens designed by instructor and fabricated by campus technicians to fail in variety of modes
- Small groups of students assigned to calculate all failure modes for one specimen
- Specimens broken during class to determine peak strength and ductility
- Differences between nominal and design strength are highlighted and differences in phi-factors are reviewed
- Groups submit hand calculations and a summary memo for a project grade

Kerry Hall

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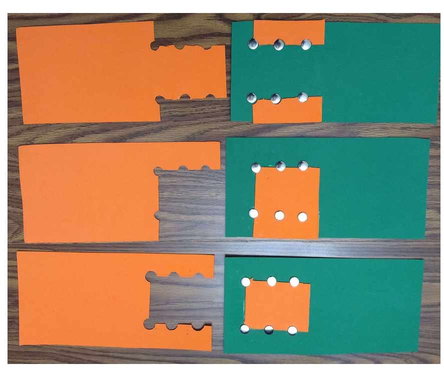
Block Shear

Using physical objects to show different possible mode of failure is the most efficient



Mohamed Zeidan

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