



**Night School 26:  
Developing an Eye for  
Connection Design**

Thank you for joining our live  
webinar. We will begin shortly.  
Please standby.

**AISC  
Night School**



**Session 3 – Load Paths & Force Distribution**  
July 27, 2021 | Larry Muir



**Smarter.  
Stronger.  
Steel.**

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## AISC Live Webinars

### Course Description

#### Load Paths & Force Distribution July 27, 2021

This session will review Lower and Upper Bound Theorems and look at it from a practical approach: satisfying equilibrium, not exceeding any limit states, and taking measures to ensure ductility. The session will discuss strength/stiffness considerations, present Uniform Force Methods and address shear lag.



## AISC Live Webinars

### Learning Objectives

1. List common assumptions in design of connections.
2. List the three key items of the lower bound theorem to ensure a safe, practical connection.
3. Define ductility and its role in safe, connection design.
4. Explain the role of judgement in connection design.



## Night School 26: Developing an Eye for Connection Design

### Session 3: Load Paths & Force Distribution July 27, 2021

Larry Muir, PE, Consultant



## Load Paths & Force Distribution



## Load Paths & Force Distribution

Things I am going to talk about:

- Why there are decisions to be made and how judgement is involved in determining force distributions.
- What makes sense and what does not relative to force distributions.
- Economic impacts of assumptions about force distributions.



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### Lower Bound Theorem

**We do not know the distribution of forces in the structures we design**



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### Lower Bound Theorem

## Common Assumptions

- Isotropic
- Homogenous
- Elastic
- Perfectly Plastic
- Pinned
- Fixed
- Laterally Supported
- Torsionally Restrained
- And Many More



### Lower Bound Theorem

a redundant structure is so sensitive in the elastic range to the small imperfections and variations inevitable in practice that it is impossible to make a close estimate of the elastic stresses present

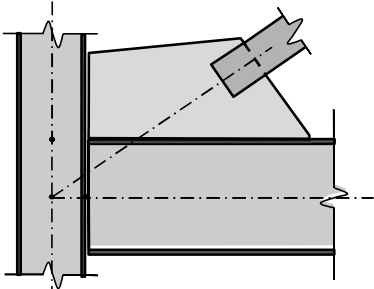

~ The Steel Skeleton



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**Lower Bound Theorem**

A vertical brace connection is an indeterminate system

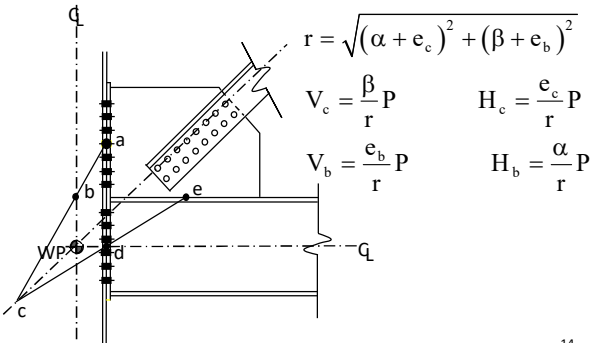



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**Lower Bound Theorem**


The Uniform Force Method

- Standardized procedure
- Consistent with the boundary conditions
- Satisfies equilibrium.



$$r = \sqrt{(\alpha + e_c)^2 + (\beta + e_b)^2}$$

$$V_c = \frac{\beta}{r} P \quad H_c = \frac{e_c}{r} P$$

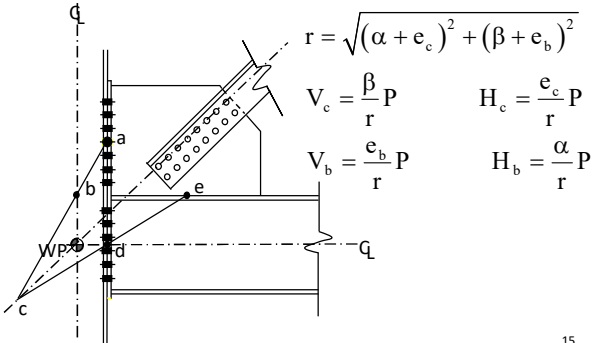
$$V_b = \frac{e_b}{r} P \quad H_b = \frac{\alpha}{r} P$$


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**Lower Bound Theorem**


The Uniform Force Method

It's Statics  
 Not Magic



$$r = \sqrt{(\alpha + e_c)^2 + (\beta + e_b)^2}$$

$$V_c = \frac{\beta}{r} P \quad H_c = \frac{e_c}{r} P$$

$$V_b = \frac{e_b}{r} P \quad H_b = \frac{\alpha}{r} P$$



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**Lower Bound Theorem**

The Uniform Force Method

Want more on the Uniform Force Method:

- AISC Design Guide 29 (a free download for members from [www.aisc.org/dg](http://www.aisc.org/dg)). Derivation in Appendix A.
- AISC Education Archives: Night School 6, Session 2: The Uniform Force Method



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Lower Bound  
Theorem

How do we know these are the forces that will exist in the connection?



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Lower Bound  
Theorem

How do we know these are the forces that will exist in the connection?

We don't. But it doesn't matter



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Lower Bound  
Theorem

How do we know these are the forces that will exist in the connection?

We don't. But it doesn't matter... too much.



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Lower Bound  
Theorem

## The Lower Bound Theorem

The applied external forces in equilibrium with the internal force field are less than or, at most, equal to the applied external force that would cause failure, provided that all the limit states are satisfied and sufficient ductility exists to allow redistribution of the forces.


~~~Paraphrased From Baker, Neal, etc.



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**Lower Bound Theorem** A Practical Approach

1. Choose a force distribution that satisfies equilibrium – statically admissible.
2. Do not exceed any limit states.
3. Take reasonable measures to ensure ductility.




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**Lower Bound Theorem** A Practical Approach

1. Choose a force distribution that satisfies equilibrium
2. Do not exceed any limit states.
3. Take reasonable measures to ensure ductility.


Requires some judgement and faith. <sup>22</sup>



**Lower Bound Theorem** A Practical Approach

1. Choose a force distribution that satisfies equilibrium
2. Do not exceed any limit states.
3. Take reasonable measures to ensure ductility.


Could there be a relationship between these?



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**Lower Bound Theorem** The Lower Bound Theorem

Why does this work?





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**Lower Bound Theorem** **The Popeye Effect**

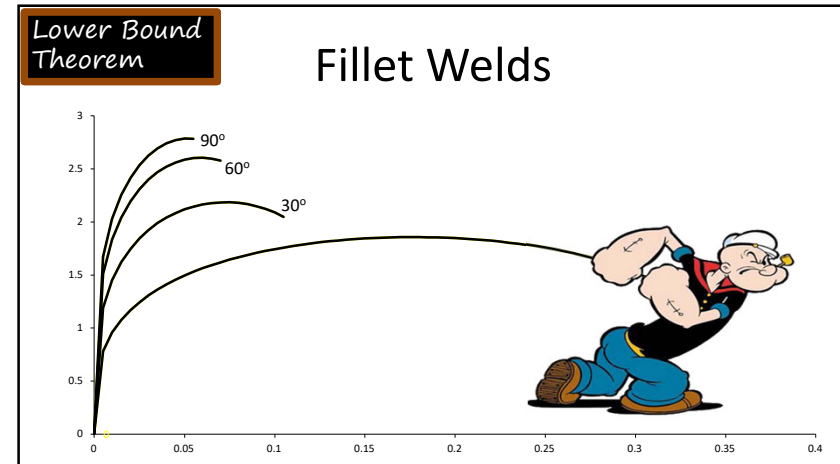
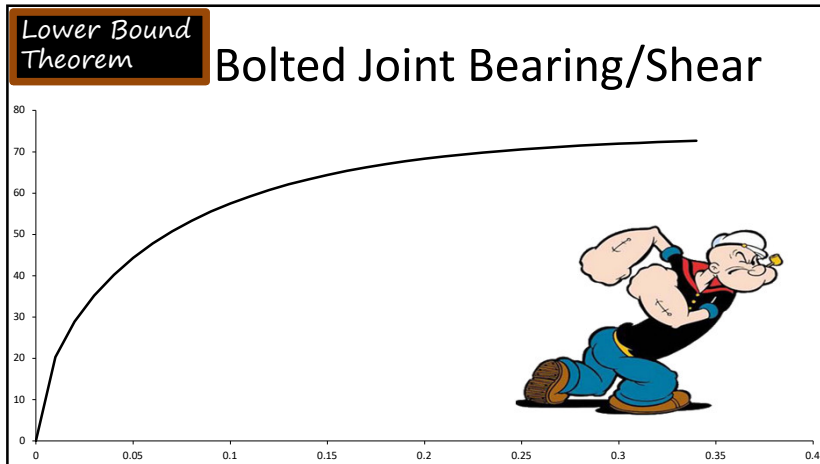
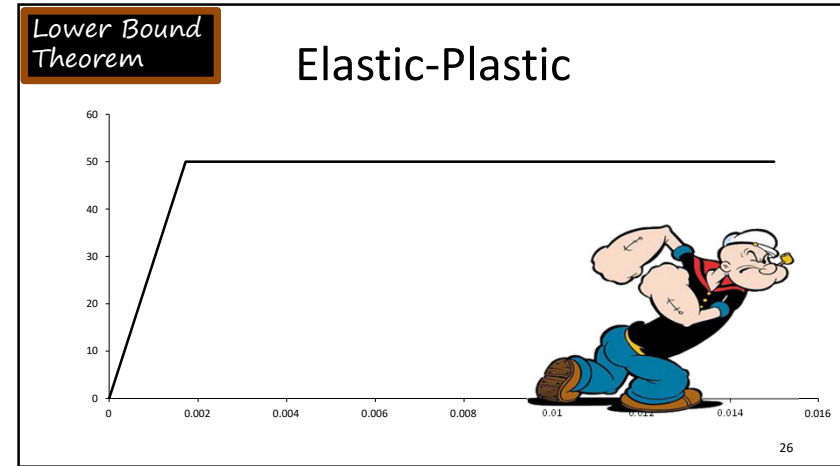
At some point every material stands all it can stand and it can't stand no more.

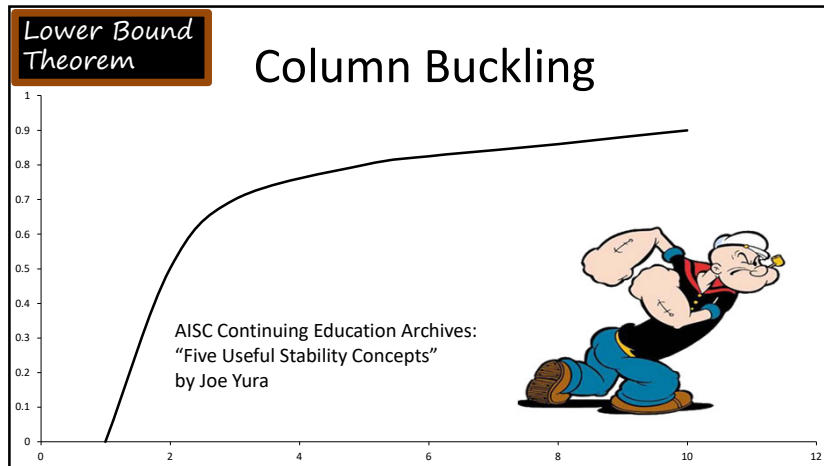
Brittle materials break

Ductile materials, like steel, yield.




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**Ductility**

## Ductility???



What is ductility?


- Duane Miller will say ductility is something like, "the degree to which a material can sustain plastic deformation under tensile stress before failure."
- He will probably stress that it is a material property.
- He is *probably* right.



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**Ductility**

## Ductility???




Duane Miller will also tell there are three rules to problem solving:

Rule #1: Get all the facts.

Rule #2: You'll never get all the facts.

Rule #3: Some facts aren't... facts.



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**Ductility**

## Ductility???

"All models are wrong, but some are useful"  
~~~ George E.P. Box

Engineers don't need the right model and should never assume they have the right answer.

Engineers need useful models in order to produce safe and useful designs.



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**Ductility**


## Ductility – Wrong but Useful

What is ductility?

Useful definition: The ability of a structural system to lose stiffness and redistribute load without stuff breaking (too much).

“Like a tree / Out in the backyard/ That never has been broken by the wind... strong enough to bend.”

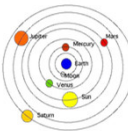
~~~ Don Schlitz & Beth Nielson Chapman



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**Ductility**

## Wrong but Useful Models



The geocentric model of the solar system was used to:

- Accurately determined the Earth's radius.
- Accurately determine the distance between the Earth and the Moon
- Develop navigation by compass and mariner's astrolabe
- Embed in our minds the image of the sun setting and rising. Who says, “Oh what a beautiful moving of the Earth relative to the Sun.”





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**Ductility**

## A Nod to Duane

**Ductile Design of Steel Structures**




**Preface**

“Many practicing engineers have wrongly believed for years that **the ductile nature of the structural steel material directly translates into inherently ductile structures.**”

**Ductile Design of Steel Structures**  
~~~ Bruneau, Uang, Whittaker

**Correct view: the ductile nature of steel does not directly translate into a ductile structure.**


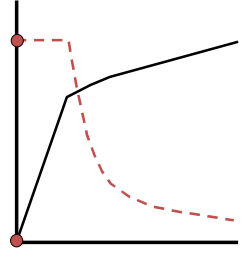


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**Stiffness**

## Strength and Stiffness

- The solid black line represents stress versus strain.
- The red dashed line represents the stiffness versus strain.
- As the material yields, the stiffness decreases and additional loads go elsewhere.

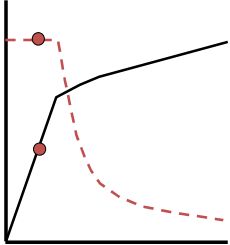



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**Stiffness**

### Strength and Stiffness

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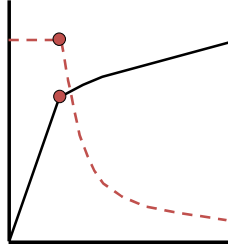



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**Stiffness**

### Strength and Stiffness

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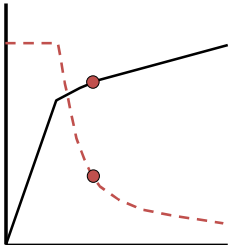



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**Stiffness**

### Strength and Stiffness

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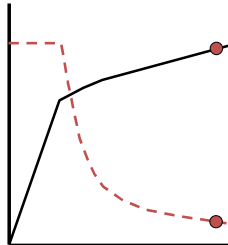



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**Stiffness**

### Strength and Stiffness

- The solid black line represents stress versus strain.
- The red dashed line represents the stiffness versus strain.
- As the material yields, the stiffness decreases and additional loads go elsewhere.




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**Stiffness**

## Strength and Stiffness

- Force is attracted to stiffness.
- When a member yields, it becomes less stiff and sheds loads to other elements.
- If there is somewhere for the load to go, it will go there.
- Steel is inherently ductile.




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**Lower Bound Theorem**

## The Lower Bound Theorem Corollary

The admissible internal force field that maximizes the capacity is closest to the collapse solution.



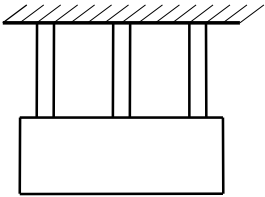

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**Lower Bound Theorem**

## An Example

As an example

- Assume a simple system of three identical tension members supporting a load.
- This is an indeterminate structure, though intuitively we know each bar supports an equal load.
- However, if we assume the center bar supports a percentage of the load,  $x$ , and the results are plotted, we have a very simple example of the Lower Bound Theorem.

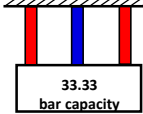
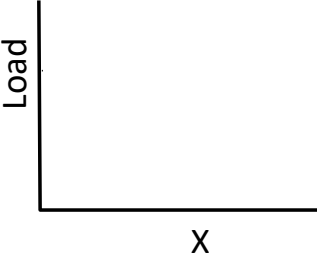



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**Lower Bound Theorem**

## An Example

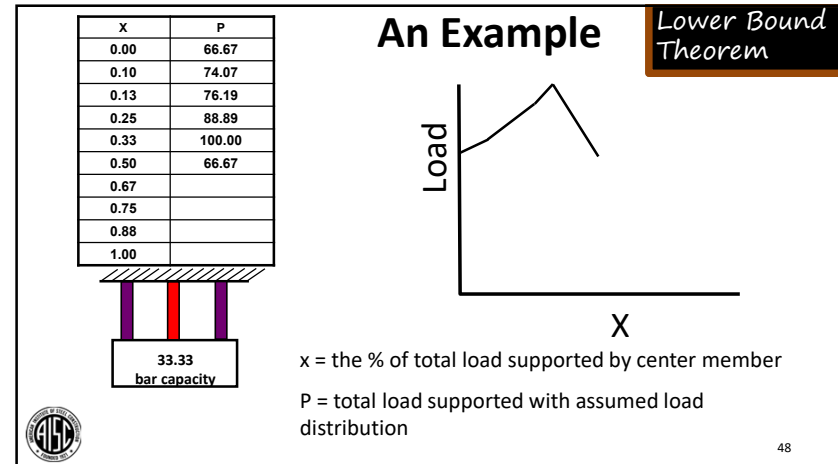
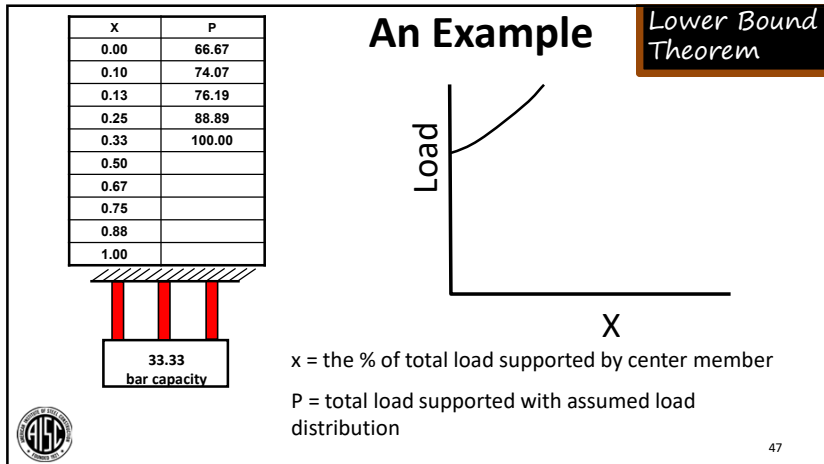
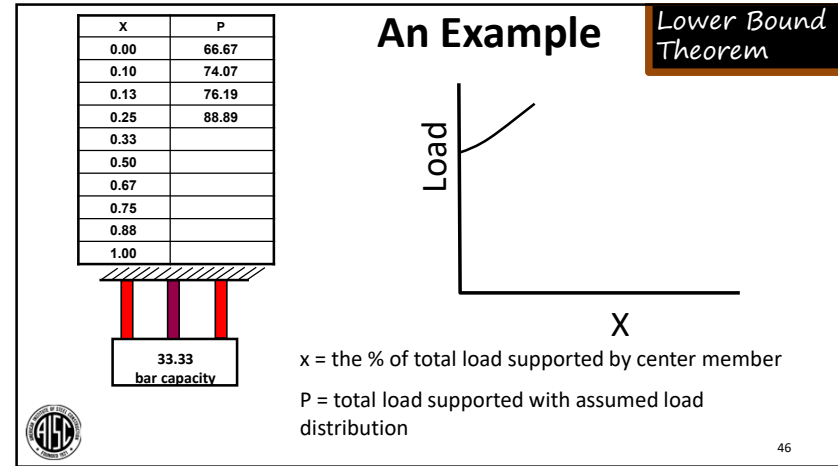
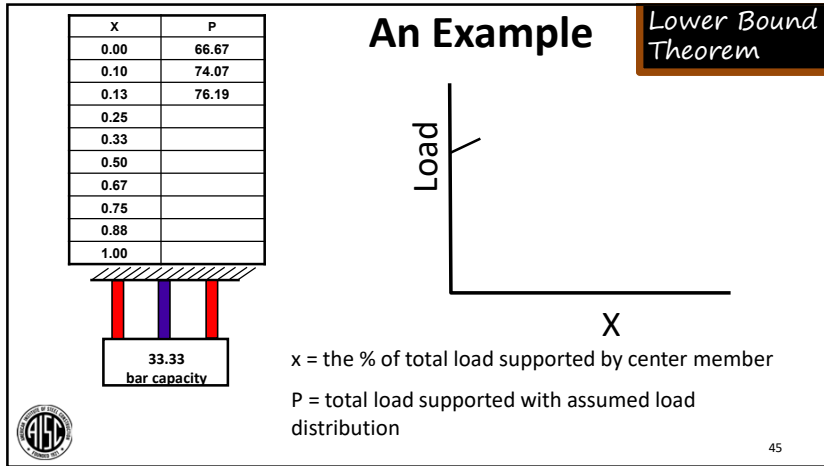
| X    | P     |
|------|-------|
| 0.00 | 66.67 |
| 0.10 |       |
| 0.13 |       |
| 0.25 |       |
| 0.33 |       |
| 0.50 |       |
| 0.67 |       |
| 0.75 |       |
| 0.88 |       |
| 1.00 |       |

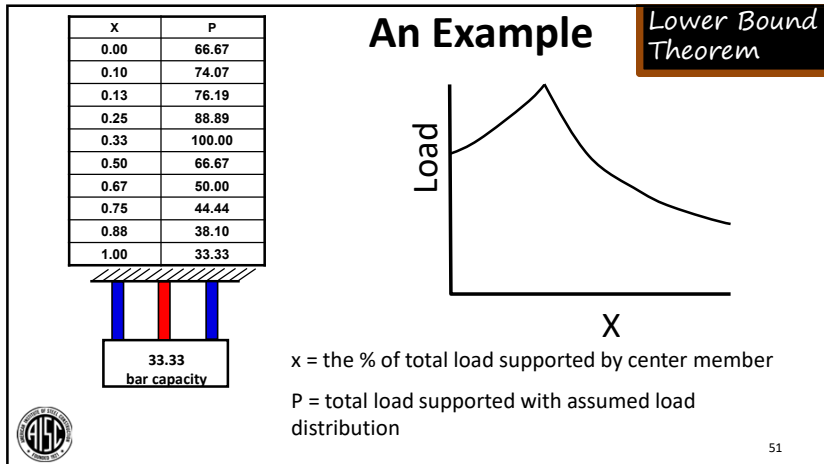
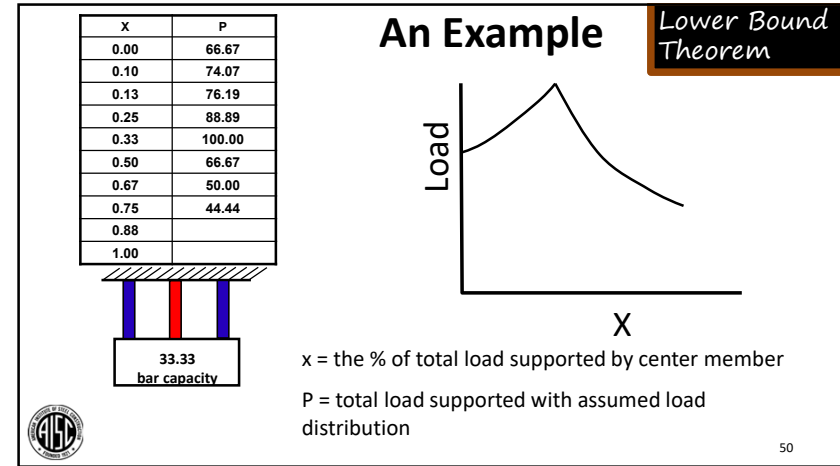
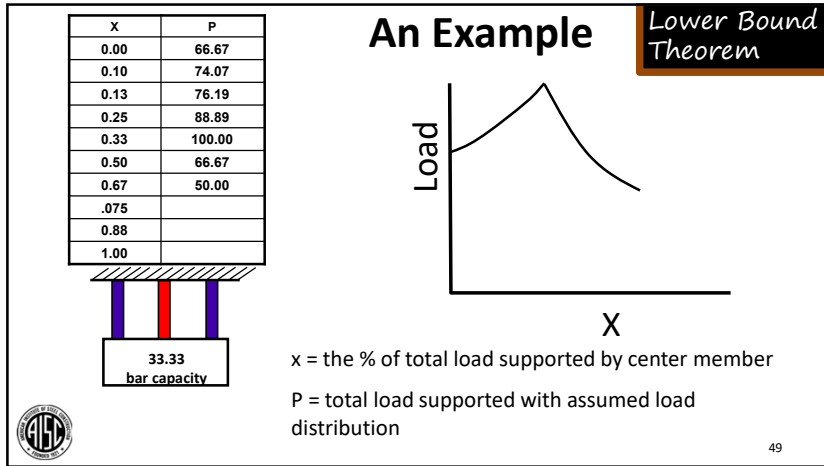



$x$  = the % of total load supported by center member  
 $P$  = total load supported with assumed load distribution



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**Judgement** Requires some judgement and faith

Lesson #1 from Duane Miller's "Important Lessons I've Learned During The Past 40 Years" (2018 NASCC):

"Provide a Path for the Force to Enter Into a Parallel Member or Section"

~Omer Blodgett


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**Lower Bound Theorem**

## A Practical Approach

1. Choose a force distribution that satisfies equilibrium
2. Do not exceed any limit states.
3. Take reasonable measures to ensure ductility.

Requires some judgement and faith. 53



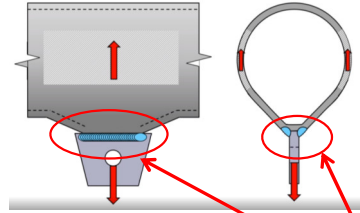

**Judgement**

## Requires some judgement and faith


“Provide a Path for the Force to Enter Into a Parallel Member or Section”

- The face of the HSS is in bending and is flexible.
- The sides of the HSS are in tension and are stiff.

This stuff must be ductile enough to...

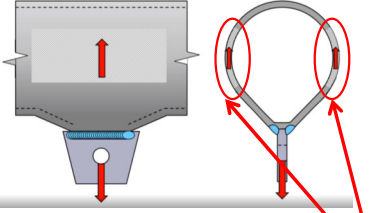
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**Judgement**

## Requires some judgement and faith

...get the load here.



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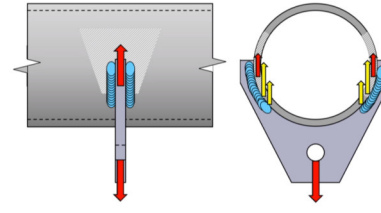
**Judgement**

## Requires some judgement and faith


This requires less deformation than the previous alternative.

This is easier to design.



This should be a more efficient design.






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**Judgement** Requires some judgement and faith





This  makes more sense than this .


This  can be designed safely, but it takes more judgement than this .



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**Judgement** Confused???

This  makes more sense than this , but this  is directly and explicitly addressed in the Specification while this  is not.



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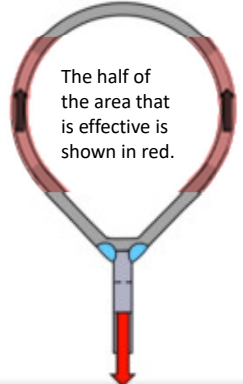

**Judgement** Breadcrumbs

Specification Section G5 in effect states:

The nominal shear strength,  $V_n$ , of round HSS, according to the limit states of shear yielding... shall be determined as:

$$V_n = 0.6F_yA_g/2$$

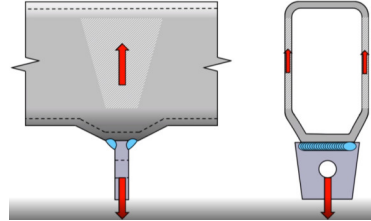

The half of the area that is effective is shown in red.

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**Judgement** Requires some judgement and faith

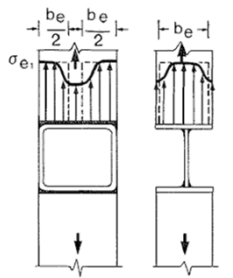
A similar situation exists for rectangular HSS...

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**Judgement**

### Requires some judgement and faith



A similar situation exists for rectangular HSS... and for wide flange members.

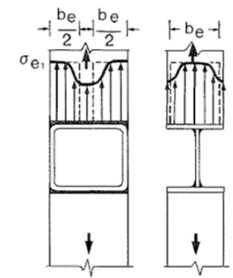
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**Judgement**

### Breadcrumbs

#### Flange Local Bending

Commentary to Section J10.1: "In the original tests, the strength given by Equation J10-1 was intended to provide a lower bound to the force required for weld fracture, which was aggravated by the uneven stress and strain demand on the weld caused by the flange deformation (Graham et al., 1959)."



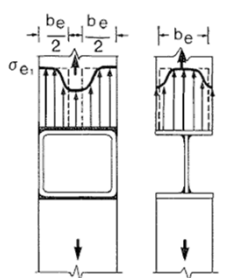
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**Judgement**

### Breadcrumbs

For the wide flange section, it is common to address a deficiency with stiffeners.

This is not commonly done for HSS.



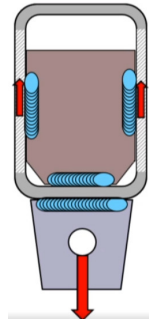
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**Judgement**

### Breadcrumbs

For the wide flange section, it is common to address a deficiency with stiffeners.

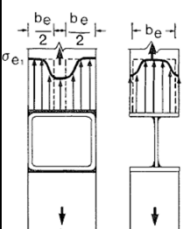
This is not commonly done for HSS because it is often difficult and very expensive to place the stiffener. Instead, we calculate an effective width.



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**Judgement**

## Requires some judgement and faith



Essentially the same considerations – strength & ductility.

Two different approaches.









Do what makes sense for a given situation.

Do not simply do what you have always done.

“Do not do unto others as you would that they should do unto you. Their tastes may not be the same.”  
~ George Bernard Shaw

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**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 uniformly distributed along the entire length of the connection (see Fig. D3.1.1)   | $U = 1.0$                          |  |
| 2    | All tension members, except HSS, where the tension load is transmitted to one end of the cross-sectional elements by fasteners or by endplate welds in connection with transverse welds (see Fig. D3.1.2)   | $U = 1 - \frac{e}{l}$              |  |
| 3    | All tension members where the tension load is transmitted along the entire length of the member by fasteners or by endplate welds in connection with transverse welds only (see Case 2 for definition of U) | $U = 1.0$                          |  |
| 4    | Flat, square, circular and rectangular HSS, and all other HSS with fasteners or endplate welds in connection with transverse welds only (see Case 2 for definition of U)                                    | $U = \frac{1.25}{1 + \frac{e}{l}}$ |  |
| 5    | Round rods with a single concentric gusset plate through hole in the HSS.   | $U = 1.30, U = 1.0$                |  |
| 6    | Rectangular rods, with a single concentric gusset plate   | $U = 1.30, U = 1.0$                |  |
| 7    | W, M, S or HP with flange connected with fasteners or endplate welds in connection with transverse welds in the direction of loading (see Case 2 for definition of U)                                       | $U = 0.85$                         |  |
| 8    | W, M, S or HP with flange connected with fasteners or endplate welds in connection with transverse welds in the direction of loading (see Case 2 for definition of U)                                       | $U = 0.85$                         |  |

**Shear Lag**

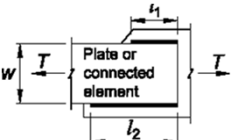
Specification Table D3.1 addresses A LOT of conditions.

It does not provide “specific criteria for infrequently encountered problems, which occur in the full range of structural design”.

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**Judgement**

## Shear Lag



From the Steel Interchange:

- 1/2019: “When checking the wider plate, some judgement must be exercised. A local yielding check based on the Whitmore section is typically used, as is indicated in the User Note to Section J4.1.”
- 9/2016: “... non-uniform stress can occur in elements subjected to both tension and compression... In extreme cases... the strength of a compression member could be affected by shear lag... Hopefully, this will provide enough information for you to use your own judgement...”

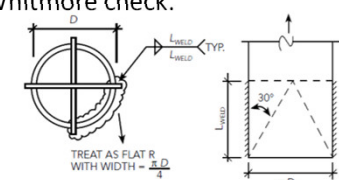
67

**Judgement**

## Shear Lag

From the Interchange:

3/2014: “Table D3.1 does not address this condition, so you will have to rely on your own engineering judgement... you might consider an approach similar to the Whitmore check.”



68

**Judgement**

### Double Angles with Axial Loads

Both force distributions shown are statically admissible and both can result in a safe design.

**B=T**

**B=T+Q**

Prying force  $Q$

69

**Judgement**

### Double Angles with Axial Loads

- All three force distributions shown are statically admissible and all can result in a safe design – if there is enough ductility.
- Only one makes sense and requires little ductility.

70

### Requires some judgement and faith

To get the load out to the flanges, a local failure of either the stem or the support – or some combination of both - must occur.

Either or both must squash without cracking.

Is this really what you want?  
 Does it make sense?

71

**Judgement**

### Requires some judgement and faith

What if this was a column base plate?

Then it is generally reasonable to assume the support will deform and the stress will distribute. Note Design Guide 1 discusses two different distributions – uniform and triangular.

Anchor Bolt Force

Bearing Stress

72

### Judgement

## Requires some judgement and faith

The examples just presented represent only a few specific conditions and are provided to illustrate more general ideas.

- Often multiple possible load paths exist.
- Multiple possible load paths can produce safe designs.
- Some load paths are more reasonable than others.
- Consider the basics from Statics and Strength of Materials.
- Judgement and communication are important.

73

### Avoiding Problems

## Circling Back to Communication

- Boundary conditions are assumed when the members are designed.
- The connections should be designed based on the same (or at least very similar) boundary conditions.
- How???



74

### Avoiding Problems

## Circling Back to Communication

The Connection Engineer tries to design connections “consistent with the intended behavior of the framing system and the assumptions made in the structural analysis” by:

- designing consistent with work-points shown in the drawings.
- abiding by “any restrictions on the types of connections”
- considering the loads provided
- judgement and experience
- exercising psychic abilities



### Avoiding Problems

## Circling Back to Communication

The Connection Engineer reveals his or her “predictions” through the substantiating connection information.

The substantiating connection information indicates how the Connection Engineer interpreted the:

- work-points shown in the drawings.
- “any restrictions on the types of connections”
- the loads provided



## Avoiding Problems Circling Back to Communication

The Engineer of Record provides feedback about the "predictions" through:

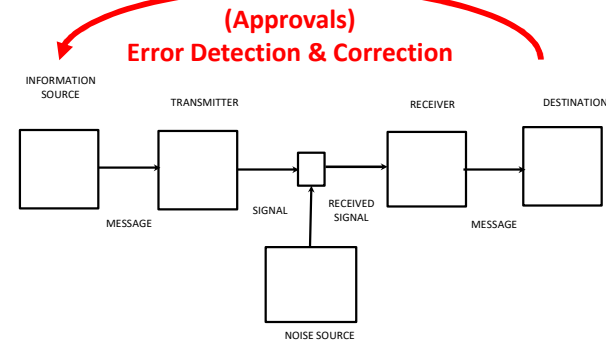
- Confirmation "in writing in a timely manner that these representative samples are consistent with the requirements"

OR

- Advising "what modifications are required to bring the representative samples into compliance with the requirements in the contract documents".



## Avoiding Problems Circling Back to Communication



78

## Load Paths Have Consequences




79



A \$2 Million savings compared to the original estimate was attributed to the connection design on these two projects.




80

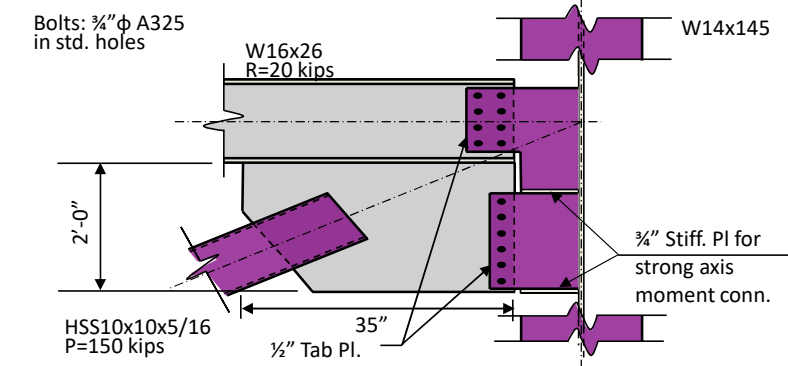


The Uniform Force Method (Statics) was used extensively in novel ways to optimize the connections.

Fine Print: Other factors such as the extensive use of "X-bolts" and welding instead of bolting to heavy columns were also employed to reduce costs.



81



Bolts:  $\frac{3}{4}$ "  $\phi$  A325 in std. holes

W16x26  
R=20 kips

W14x145


2'-0"

HSS10x10x5/16  
P=150 kips

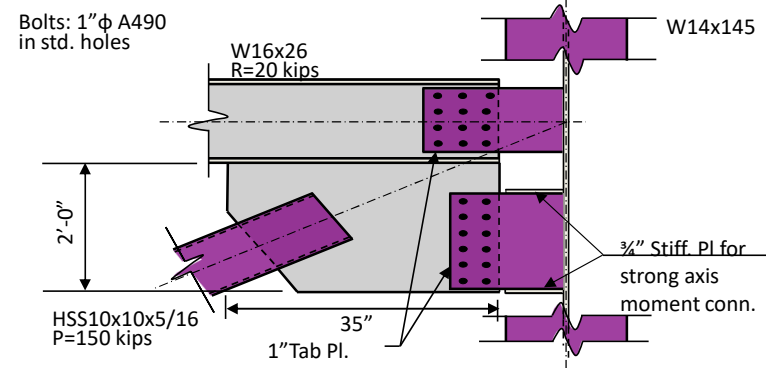
35"  
 $\frac{1}{2}$ " Tab Pl.

$\frac{3}{4}$ " Stiff. Pl for strong axis moment conn.

Vertical Bracing w/ Ext. Tab Optimum Load Path



82



Bolts: 1"  $\phi$  A490 in std. holes

W16x26  
R=20 kips

W14x145


2'-0"

HSS10x10x5/16  
P=150 kips

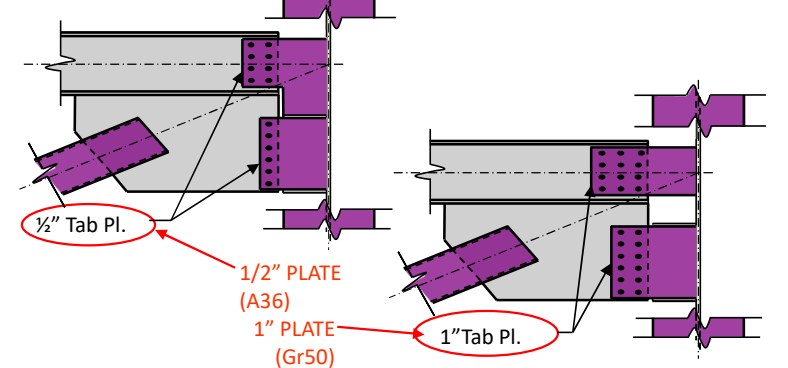
35"  
1" Tab Pl.

$\frac{3}{4}$ " Stiff. Pl for strong axis moment conn.

Vertical Bracing w/ Ext. Tab Standard Load Path



83




$\frac{1}{2}$ " Tab Pl.

1/2" PLATE (A36)

1" PLATE (Gr50)

1" Tab Pl.




84



### Comparison of Design Results

| COMPARISON OF DESIGNS RESULTING FROM DIFFERENT LOAD PATHS |            |                    |                                |                                   |                 |              |                            |                               |                                  |                   |                                 |                                    |                     |                                   |                                 |
|---|------------|--------------------|--------------------------------|-----------------------------------|-----------------|--------------|----------------------------|-------------------------------|----------------------------------|-------------------|---------------------------------|------------------------------------|---------------------|-----------------------------------|---------------------------------|
|   | DRILLING   |                    |                                |                                   | WELDING         |              |                            |                               | MATERIAL                         |                   |                                 |                                    |                     |                                   |                                 |
|   | # of Holes | Plate Thick. (in.) | Area Holes (in. <sup>2</sup> ) | Vol. of Holes (in. <sup>3</sup> ) | Weld Size (in.) | Length (in.) | Volume (in. <sup>3</sup> ) | Length Single Pass Weld (in.) | Area of Tabs (in. <sup>2</sup> ) | Thick. Tabs (in.) | Volume Tabs (in. <sup>3</sup> ) | Area of Gusset (in. <sup>2</sup> ) | Thick. Gusset (in.) | Volume Gusset (in. <sup>3</sup> ) | Weight Connection Plates (lbs.) |
| Standard Load Path  | 24         | 1                  | 0.6                            | 14.4                              | 5/8             | 30.0         | 5.86                       | 180                           | 3.25                             | 0.083             | 0.27                            | 5.41                               | 0.417               | 0.226                             | 243                             |
| Optimum Load Path   | 14         | 0.5                | 0.44                           | 3.09                              | 5/16            | 52.3         | 2.55                       | 52.3                          | 3.00                             | 0.042             | 0.12                            | 5.41                               | 0.417               | 0.226                             | 172                             |
| Optimum Standard  |            |                    |                                | 21%                               |                 |              | 44%                        | 29%                           |                                  |                   |                                 |                                    |                     |                                   | 71%                             |

± 80% SAVINGS IN DRILLING TIME




89

### Comparison of Design Results

| COMPARISON OF DESIGNS RESULTING FROM DIFFERENT LOAD PATHS |            |                    |                                |                                   |                 |              |                            |                               |                                  |                   |                                 |                                    |                     |                                   |                                 |
|---|------------|--------------------|--------------------------------|-----------------------------------|-----------------|--------------|----------------------------|-------------------------------|----------------------------------|-------------------|---------------------------------|------------------------------------|---------------------|-----------------------------------|---------------------------------|
|   | DRILLING   |                    |                                |                                   | WELDING         |              |                            |                               | MATERIAL                         |                   |                                 |                                    |                     |                                   |                                 |
|   | # of Holes | Plate Thick. (in.) | Area Holes (in. <sup>2</sup> ) | Vol. of Holes (in. <sup>3</sup> ) | Weld Size (in.) | Length (in.) | Volume (in. <sup>3</sup> ) | Length Single Pass Weld (in.) | Area of Tabs (in. <sup>2</sup> ) | Thick. Tabs (in.) | Volume Tabs (in. <sup>3</sup> ) | Area of Gusset (in. <sup>2</sup> ) | Thick. Gusset (in.) | Volume Gusset (in. <sup>3</sup> ) | Weight Connection Plates (lbs.) |
| Standard Load Path  | 24         | 1                  | 0.6                            | 14.4                              | 5/8             | 30.0         | 5.86                       | 180                           | 3.25                             | 0.083             | 0.27                            | 5.41                               | 0.417               | 0.226                             | 243                             |
| Optimum Load Path   | 14         | 0.5                | 0.44                           | 3.09                              | 5/16            | 52.3         | 2.55                       | 52.3                          | 3.00                             | 0.042             | 0.12                            | 5.41                               | 0.417               | 0.226                             | 172                             |
| Optimum Standard  |            |                    |                                | 21%                               |                 |              | 44%                        | 29%                           |                                  |                   |                                 |                                    |                     |                                   | 71%                             |

± 50% SAVINGS IN WELD CONSUMABLES




90

### Comparison of Design Results

| COMPARISON OF DESIGNS RESULTING FROM DIFFERENT LOAD PATHS |            |                    |                                |                                   |                 |              |                            |                               |                                  |                   |                                 |                                    |                     |                                   |                                 |
|---|------------|--------------------|--------------------------------|-----------------------------------|-----------------|--------------|----------------------------|-------------------------------|----------------------------------|-------------------|---------------------------------|------------------------------------|---------------------|-----------------------------------|---------------------------------|
|   | DRILLING   |                    |                                |                                   | WELDING         |              |                            |                               | MATERIAL                         |                   |                                 |                                    |                     |                                   |                                 |
|   | # of Holes | Plate Thick. (in.) | Area Holes (in. <sup>2</sup> ) | Vol. of Holes (in. <sup>3</sup> ) | Weld Size (in.) | Length (in.) | Volume (in. <sup>3</sup> ) | Length Single Pass Weld (in.) | Area of Tabs (in. <sup>2</sup> ) | Thick. Tabs (in.) | Volume Tabs (in. <sup>3</sup> ) | Area of Gusset (in. <sup>2</sup> ) | Thick. Gusset (in.) | Volume Gusset (in. <sup>3</sup> ) | Weight Connection Plates (lbs.) |
| Standard Load Path  | 24         | 1                  | 0.6                            | 14.4                              | 5/8             | 30.0         | 5.86                       | 180                           | 3.25                             | 0.083             | 0.27                            | 5.41                               | 0.417               | 0.226                             | 243                             |
| Optimum Load Path   | 14         | 0.5                | 0.44                           | 3.09                              | 5/16            | 52.3         | 2.55                       | 52.3                          | 3.00                             | 0.042             | 0.12                            | 5.41                               | 0.417               | 0.226                             | 172                             |
| Optimum Standard  |            |                    |                                | 21%                               |                 |              | 44%                        | 29%                           |                                  |                   |                                 |                                    |                     |                                   | 71%                             |

± 60% SAVINGS IN WELDING LABOR




91

### Comparison of Design Results

| COMPARISON OF DESIGNS RESULTING FROM DIFFERENT LOAD PATHS |            |                    |                                |                                   |                 |              |                            |                               |                                  |                   |                                 |                                    |                     |                                   |                                 |
|---|------------|--------------------|--------------------------------|-----------------------------------|-----------------|--------------|----------------------------|-------------------------------|----------------------------------|-------------------|---------------------------------|------------------------------------|---------------------|-----------------------------------|---------------------------------|
|   | DRILLING   |                    |                                |                                   | WELDING         |              |                            |                               | MATERIAL                         |                   |                                 |                                    |                     |                                   |                                 |
|   | # of Holes | Plate Thick. (in.) | Area Holes (in. <sup>2</sup> ) | Vol. of Holes (in. <sup>3</sup> ) | Weld Size (in.) | Length (in.) | Volume (in. <sup>3</sup> ) | Length Single Pass Weld (in.) | Area of Tabs (in. <sup>2</sup> ) | Thick. Tabs (in.) | Volume Tabs (in. <sup>3</sup> ) | Area of Gusset (in. <sup>2</sup> ) | Thick. Gusset (in.) | Volume Gusset (in. <sup>3</sup> ) | Weight Connection Plates (lbs.) |
| Standard Load Path  | 24         | 1                  | 0.6                            | 14.4                              | 5/8             | 30.0         | 5.86                       | 180                           | 3.25                             | 0.083             | 0.27                            | 5.41                               | 0.417               | 0.226                             | 243                             |
| Optimum Load Path   | 14         | 0.5                | 0.44                           | 3.09                              | 5/16            | 52.3         | 2.55                       | 52.3                          | 3.00                             | 0.042             | 0.12                            | 5.41                               | 0.417               | 0.226                             | 172                             |
| Optimum Standard  |            |                    |                                | 21%                               |                 |              | 44%                        | 29%                           |                                  |                   |                                 |                                    |                     |                                   | 71%                             |

± 30% SAVINGS IN MATERIAL



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## OH NO!!! HOMEWORK!!!

To prepare for Sessions 6 & 7 please be familiar with:

- Design Guide 29 – Example 5.11
- Design Guide 29 – Example A.1
- Manual Equations (9-2) & (9-3):
- Manual Design Examples – Example II.A-1B
- Manual Design Examples – Example II.A-19B
- The *Specification* Section J10.5 Web Compression Buckling



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## Foreshadowing

- Sessions 4 & 5 will cover bolts & welds for approximately 60 minutes. The remaining time will be devoted to questions & topics received from attendees.
- Session 6 will address issues related to Design Examples for approximately 60 minutes. The remaining time will be devoted to questions & topics received from attendees.
- Session 7 will be a continuation of Session 6 with concentration on a specific example.
- Session 8 will be devoted entirely to questions & topics received from attendees.



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## OH NO!!! MORE HOMEWORK!!!

- Submit Your Questions & Topics
- Feel free to submit any questions & topics you wish
- Priority will be given to:
  - Questions & topics shared by multiple attendees
  - Questions & topics related to material presented in this Night School
  - Questions & topics directly related to connection design
  - Questions & topics of interest to the presenter



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## OH NO!!! MORE HOMEWORK!!!

- Submit Your Questions & Topics
- Ultimately the success of this Night School depends on YOU.
- I want to address YOUR concerns.

I will make an attempt to address ALL questions submitted. I will TRY to address questions not included in the Night School through the Steel Solutions Center.



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Thank you!

AISC | Questions



## Individual Session Registrants

### PDH Certificates

- All WFH individuals associated with a group registration will be issued a certificate.
- All individuals attending at your connection; you will receive an email on how to report their attendance from: [registration@aisc.org](mailto:registration@aisc.org).
  - Be on the lookout: Check your spam filter! Check your junk folder!
  - Completely fill out online form. Don't forget to check the boxes next to each attendee's name!



## 8-Session Registrants

### PDH Certificates

One certificate will be issued at the conclusion of all 8 sessions.



## 8-Session Registrants

### Access to the quiz

Information for accessing the quiz will be emailed to you by Thursday. It will contain a link to access the quiz. EMAIL COMES FROM [NIGHTSCHOOL@AISC.ORG](mailto:NIGHTSCHOOL@AISC.ORG).

### Quiz and attendance records

Posted Thursday mornings. [www.aisc.org/night school](http://www.aisc.org/night school) -- Click on Current Course Details.

### Reasons for quiz

- EEU – You must take all quizzes and the final exam to receive EEU.
- PDHs – If you watch a recorded session, you must pass quiz for PDHs.
- REINFORCEMENT – Reinforce what you learn tonight. Get more out of the course.

*Note: If you attend the live presentation, you do not have to take the quizzes to receive PDHs*



## 8-Session Registrants

### Access to the recording

Information for accessing the recording will be emailed to you by Thursday. The recording will be available for four weeks. (For 8-session registrants only.) EMAIL COMES FROM [NIGHTSCHOOL@AISC.ORG](mailto:NIGHTSCHOOL@AISC.ORG).

### PDHs via recording

If you watch a recorded session, you must take *and pass* the quiz for PDHs.



## 8-Session Registrants

### Night School Resources

Find all your handouts, quizzes and quiz scores, recording access, and attendance information all in one place!



## 8-Session Registrants

### Night School Resources

Go to [www.aisc.org](http://www.aisc.org) and sign in.



#### Login

If you're an existing customer, please enter your username and password.

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Enter your username

##### PASSWORD

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### Night School Resources

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## 8-Session Registrants

### Night School Resources




Course Resources

| Event  | Start Date           |
|--|----------------------|
| NS 13 8-Session Package Night School 13 - Design of Industrial Buildings | 1/30/2017 7:00:00 PM |
| NS 14 8-Session Package Night School 14 - Fundamentals of Stability      | 6/5/2017 7:00:00 PM  |

## 8-Session Registrants

### Night School Resources



Night School 13: Design of Industrial Buildings


8-SESSION PACKAGE RESOURCES

| Event   | Date                 | Handouts | Video                        | Quiz                         | Attendance |
|---|----------------------|----------|------------------------------|------------------------------|------------|
| NS13 - Design Criteria                                      | 1/30/2017 7:00:00 PM | Handouts | Video                        | Pass Score 80                | Pending    |
| NS13 - Economic Considerations                              | 2/6/2017 7:00:00 PM  | Handouts | Available 02/08/2017 5pm EST | Available 02/08/2017 5pm EST | Pending    |
| NS13 - Lateral Load Systems and Details                     | 2/13/2017 7:00:00 PM | Handouts | Available 02/15/2017 5pm EST | Available 02/15/2017 5pm EST | Pending    |
| NS13 - Preliminary Design Procedures                        | 2/27/2017 7:00:00 PM | Handouts | Available 03/05/2017 5pm EST | Available 03/05/2017 5pm EST | Pending    |
| NS13 - Core Order Design and Frame Analysis                 | 3/6/2017 7:00:00 PM  | Handouts | Available 03/08/2017 5pm EST | Available 03/08/2017 5pm EST | Pending    |
| NS13 - Frame Member and Connection Design                   | 3/13/2017 7:00:00 PM | Handouts | Available 03/15/2017 5pm EST | Available 03/15/2017 5pm EST | Pending    |
| NS13 - Transfer Crane Girder & Longitudinal Bdy Bracing Dcn | 3/27/2017 7:00:00 PM | Handouts | Available 03/29/2017 5pm EST | Available 03/29/2017 5pm EST | Pending    |
| NS13 - Building Elevation and Bracing Design                | 4/3/2017 7:00:00 PM  | Handouts | Available 04/05/2017 5pm EST | Available 04/05/2017 5pm EST | Pending    |

## 8-Session Registrants

### Night School Resources

- Weekly “quiz and recording” email.
- Weekly updates of the master quiz and attendance record, found at [www.aisc.org/nightschool26](http://www.aisc.org/nightschool26). Scroll down to Quiz and Attendance records.
  - Updated on Friday mornings.



## 8-Session Registrants

### Night School Resources

- Webinar connection information
  - Reminder email sent out Tuesday mornings
- Links to handouts also found here

