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**Fundamentals of Connection Design**

Session 1: Fundamental Concepts, Part 1

October 23, 2019

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**Course Description**

Fundamental Concepts, Part I
October 23, 2019

This session will provide an overview of basic connection types including tension, compression, framing, and moment connections. How to classify beam-to-column connections will be discussed, followed by a review of limit states in the load path. Bolt-related limit states and detailing will be reviewed, including discussions on different types of bolts, bolt installation, bolt shear strength, and combined shear plus tension strength. Fillet weld-related limit states will also be discussed.

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## AISC Live Webinars

**Learning Objectives**

- Describe basic structural steel connection types.
- Explain limit states in the load path of a tension connection.
- Identify limit states related to bolts.
- Identify limit states related to welded connections.

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## Fundamentals of Connection Design

Session 1: Fundamental Concepts, Part I
October 23, 2019

Brad Davis, PhD, SE
Associate Professor, University of Kentucky
Owner, Davis Structural Engineering

Smarter. Stronger. Steel.

## Schedule

- October 23, 2019 — Fundamental Concepts Part I
- October 30, 2019 — Fundamental Concepts Part II
- November 6, 2019 — Shear Connections Part I
- November 13, 2019 — Shear Connections Part II

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# FUNDAMENTAL CONCEPTS PART I

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## Today's Topics

- Reference Documents
- Nomenclature
- Steel Properties
- Connection Types
- Classification of Beam-to-Column Connections
- Limit States in the Load Path
- Bolt Related Limit States and Detailing
- Fillet Weld Related Limit States and Detailing

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## REFERENCE DOCUMENTS
## NOMENCLATURE
## STEEL PROPERTIES

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## Reference Documents

AISC/ANSI 360-16 *Specification for Structural Steel Buildings*, 2016

- Chapter B Design Requirements
- Chapter D Design of Members for Tension
- Chapter J Design of Connections

AISC *Steel Construction Manual*, 15th Ed., 2017

Research Council on Structural Connections (RCSC)
*Specification for Structural Joints Using High Strength Bolts*, 2014

AWS D1.1 *Structural Welding Code - Steel*, 2015

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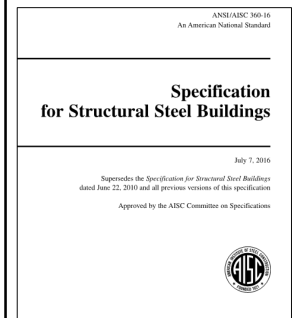
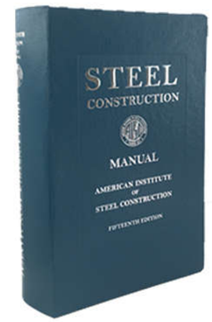
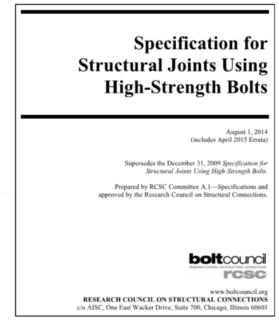
## Reference Documents




*"Specification"* or *"Spec."* *"Manual"* *"RCSC Spec."*

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## Nomenclature

Load and Resistance Factor Design (LRFD)

$$R_u \le \phi R_n$$

where $R_u$ = Required Strength using LRFD Load Combinations
$\phi$ = Resistance Factor
$R_n$ = Nominal Strength
$\phi R_n$ = Design Strength

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## Nomenclature

Allowable Strength Design (ASD)

$$R_a \le R_n / \Omega$$

where $R_a$ = Required Strength using ASD Load Combinations
$R_n$ = Nominal Strength
$\Omega$ = Safety Factor
$R_n / \Omega$ = Allowable Strength

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## Nomenclature

- Generic

  Required Strength ≤ Available Strength

- Specific for LRFD

  $$R_u \leq \phi R_n$$

- Specific for ASD

  $$R_a \leq R_n/\Omega$$

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## Nomenclature

LRFD Resistance Factors

Ductile Limit States: $\phi = 0.9$

Example: Tension Yielding

Non-Ductile Limit States: $\phi = 0.75$

Example: Tension Rupture

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## Steel Properties

Plates: A36 Steel

$F_y = 36$ ksi (Tensile Yield Stress)

$F_u = 58$ ksi (Tensile Rupture Strength)

Angles: A529, Gr. 50 Steel

$F_y = 50$ ksi $F_u = 65$ ksi

Beams and Columns: A992 Steel

$F_y = 50$ ksi $F_u = 65$ ksi

Note:

Shear Yield Stress = 0.6 $F_y$

Shear Rupture Stress = 0.6 $F_u$

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## CONNECTION TYPES

- Tension Connections
- Compression Connections
- Shear Connections
- Moment Connections

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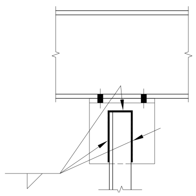
## Tension Connections



Tee Hanger

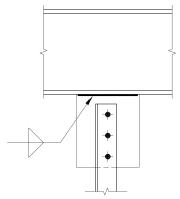
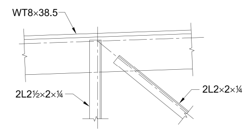
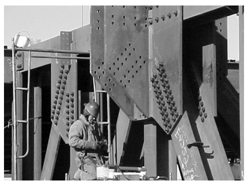


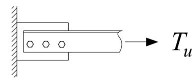
Plate Hanger




Truss



Bracing




Directly Loaded

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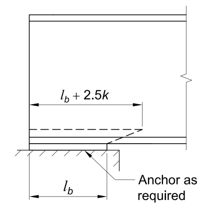
## Compression Connections

Column Splice




Beam Bearing

Column Base Plate

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## Simple Shear Connections

- Types in the *Manual*
  - Double-Angle
  - Single-Angle
  - Single-Plate (Shear Tab)
  - Shear End-Plate
  - Seated Connections
  - Tee Connections

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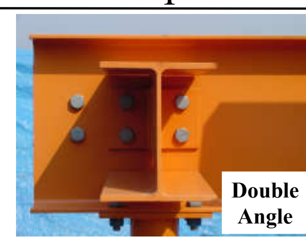
## Simple Shear Connections







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## Simple Shear Connections





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## Moment Connections

- Flange Welded Moment Connection
- Flange Plate Welded or Bolted Moment Connection
- Tee-Stub Moment Connection
- Flange Angle Moment Connection
- Moment End-Plate Connection

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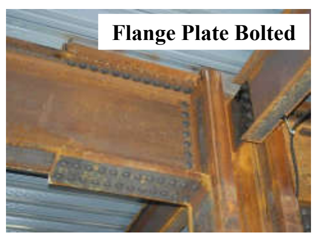
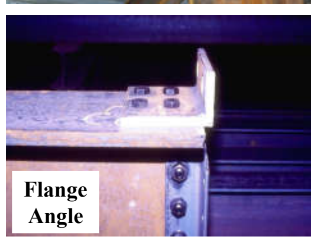
## Moment Connections



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## Moment Connections


Flush Moment End-Plate


Extended Moment End-Plate

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# CLASSIFICATION OF CONNECTIONS

- Fully Restrained (FR) Moment Connections
- Partially Restrained (PR) Moment Connections
- Simple Shear Connections

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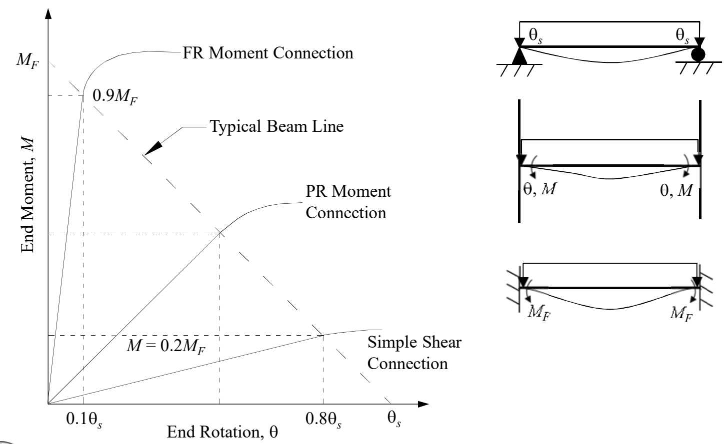
## Classification of Connections

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## Classification of Connections

- Fully Restrained – FR
  - Flange Welded
  - Flange Plate Welded or Bolted
  - Tee-Stub
  - Moment End-Plate

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## Classification of Connections

- Partially Restrained – PR
  - Flush End-Plate
  - Flange Angles
  - Double Angles

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## Classification of Connections

- Simple Shear Connections
  - Double-Angle
  - Single-Angle
  - Single-Plate
  - Shear End-Plate
  - Seated Connections
  - Tee Framing Connection

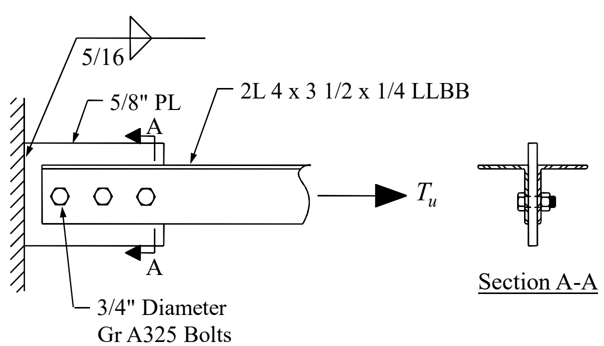


## LIMIT STATES IN THE LOAD PATH



## Load Paths / Limit States

Example: Directly Loaded Tension Connection






## Load Paths / Limit States

1. Angle Yielding
2. Angle Rupture
3. Angle Block Shear
4. Shear Transfer
5. Plate Rupture
6. Plate Yielding
7. Weld Rupture

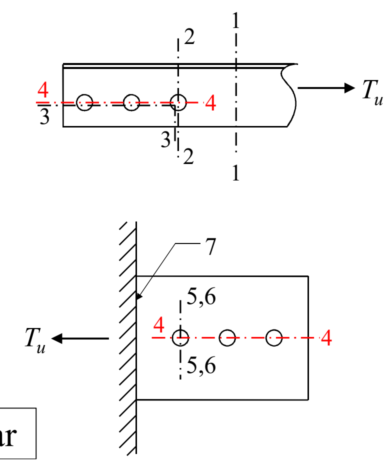



Plate Block Shear

# BASIC BOLT RELATED LIMIT STATES AND DETAILING

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## Bolt Types

A307 Machine Bolts – $F_u$ = 60 ksi

Group A – High Strength Bolts – $F_u$ = 120-125 ksi

- ASTM F3125 Grades A325, F1852
- ASTM A354 Grade BC*

Group B – High Strength Bolts – $F_u$ = 150 ksi

- ASTM F3125 Grades A490, F2280 (new in the *Manual*)
- ASTM A354 Grade BD*

Group C – High Strength Bolts – $F_u$ = 200 ksi**

- ASTM F3043 and F3111

*Lower $F_u$ for large diameters

**Currently not readily available (Fall of 2019)

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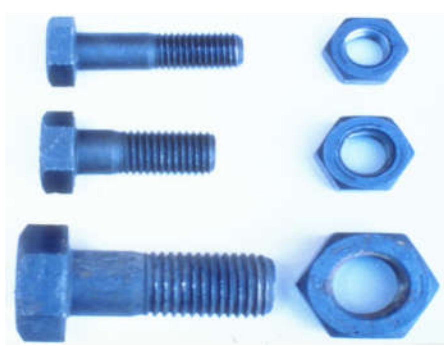
## Grade A325 and A490 Bolts

3/4 in. Diameter

7/8 in. Diameter

1-1/4 in. Diameter



Note:

Thread length is a function of bolt diameter, not the bolt length.

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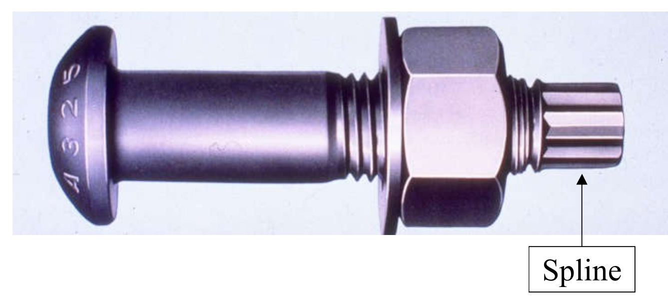
## Grade F1852 and F2280 Twist-Off Bolt




Note: Requires a special tightening tool.

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## Bolts: Connection Types

Types of Connections (Not Types of Bolts)

(a) Bearing Type

N - threads included in shear plane

X - threads excluded from shear plane

(b) Slip Critical

SC - slip critical (friction)

Example Designations: 3/4 in. Gr A325 – N

1 in. Gr A490 – SC

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## Bolts: Tightening

-N or -X Bearing Type Connections

Snug Tight per *RCSC Spec.* "The snug tightened condition is the tightness that is attained with a few impacts of an impact wrench or the full effort of an ironworker using an ordinary spud wrench to bring the plies into firm contact."



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## Bolts: Tightening

-SC Slip Critical Type Connections

- Requires clean mill scale (Class A) or faying surface preparation (Class B) and field inspection.
- Pretensioning: - Turn of Nut Method
  - Calibrated Wrench
  - Direct Tension Indicator (DTI)
  - Twist-Off Bolt

Pretensioned Bolt Connections

- Pretensioning: same as for -SC connections
- No surface preparation or inspection required.

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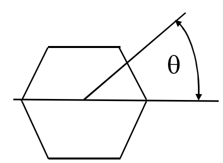
## Bolts: Pretensioned Installation

Turn-of-Nut Tightening



θ from *RCSC Spec.* Table 8.2

Example: Bolt Length ≤ 4*d*, θ = 1/3 Turn

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## Bolts: Pretensioned Installation

<u>Calibrated Wrench Tightening</u>

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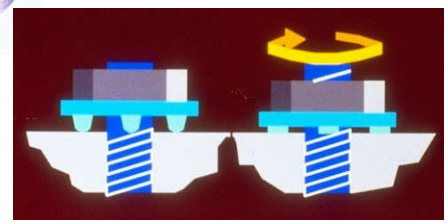
## Bolts: Pretensioned Installation

<u>Direct Tension Indicator (DTI) Tightening</u>

ASTM F959



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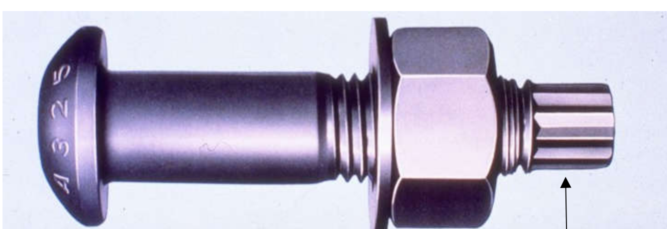
## Bolts: Pretensioned Installation

<u>Twist Off Bolt Tightening</u>




Spline

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## Bolt Holes

<u>Hole Types and Dimensions (*Spec.* Table J3.3)</u>

- Standard (STD) If $d \leq 7/8$ in. then $d + 1/16$ in.
  If $d > 7/8$ in. then $d + 1/8$ in. (new)
- Oversized (OVS) $d$ + (1/8 in. to 5/16 in.)
- Short Slots (SS) STD by (OVS + 1/16 in.)
- Long Slots (LS) STD by up to $2.5d$

(Standard Hole, STD, is Default for Course.)

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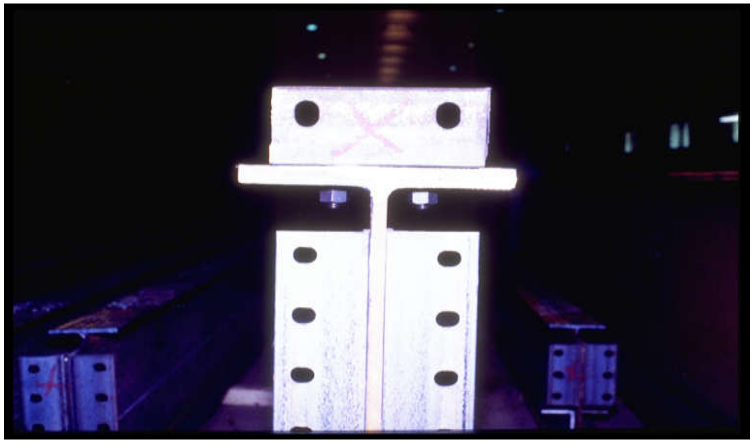
## Example Use of Slotted Holes



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## Bolt Tensile Strength

Design Tensile Strength of One Bolt, $\phi r_n$

(*Specification* J3.6)

Note: Using LRFD for the course. ASD nominal strengths are the same.

$\phi = 0.75$

$r_n = F_{nt} A_b$

$F_{nt}$ = nominal strength from *Spec.* Table J3.2

$A_b$ = nominal bolt area

$\phi r_n = \phi F_{nt} A_b$ = Design Tensile Strength

Note: net tensile area at the threads is accounted for in $F_{nt}$

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## Bolt Shear Strength

Design Shear Strength of One Bolt, $\phi r_n$

(*Specification* J3.6)

$\phi = 0.75$

$r_n = F_{nv} A_b$

$F_{nv}$ = nominal strength from *Spec.* Table J3.2

$A_b$ = nominal bolt area

$\phi r_n = \phi F_{nv} A_b$ = Design Shear Strength

Note: net shear area at the threads is accounted for in $F_{nv}$

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## Bolt Nominal Strengths

**TABLE J3.2**
**Nominal Strength of Fasteners and Threaded Parts, ksi (MPa)**

| Description of Fasteners | Nominal Tensile Strength, $F_{nt}$, ksi (MPa)[a] | Nominal Shear Strength in Bearing-Type Connections, $F_{nv}$, ksi (MPa)[b] |
|---|---|---|
| A307 bolts | 45 (310) | 27 (188)[c][d] |
| Group A (e.g., A325) bolts, when threads are not excluded from shear planes -N | 90 (620) | 54 (372) |
| Group A (e.g., A325) bolts, when threads are excluded from shear planes -X | 90 (620) | 68 (457) |
| Group B (e.g., A490) bolts, when threads are not excluded from shear planes -N | 113 (780) | 68 (457) |
| Group B (e.g., A490) bolts, when threads are excluded from shear planes -X | 113 (780) | 84 (579) |

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# Bolt Nominal Strengths

Table J3.2 Continued

Anchor Rods

| | | |
|---|---|---|
| Group C (e.g., F3043) bolt assemblies, when threads and transition area of shank are excluded from the shear plane | 150 (1040) | 113 (779) |
| Threaded parts meeting the requirements of Section A3.4, when threads are not excluded from shear planes | $0.75F_u$ | $0.450F_u$ |
| Threaded parts meeting the requirements of Section A3.4, when threads are excluded from shear planes | $0.75F_u$ | $0.563F_u$ |

[a] For high-strength bolts subject to tensile fatigue loading, see Appendix 3.
[b] For end loaded connections with a fastener pattern length greater than 38 in. (950 mm), $F_{nv}$ shall be reduced to 83.3% of the tabulated values. Fastener pattern length is the maximum distance parallel to the line of force between the centerline of the bolts connecting two parts with one faying surface.
[c] For A307 bolts, the tabulated values shall be reduced by 1% for each 1/16 in. (2 mm) over five diameters of length in the grip.
[d] Threads permitted in shear planes.

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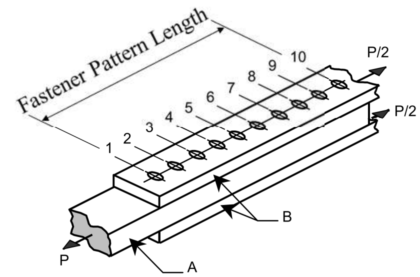
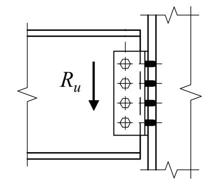
# Bolts: Connection Length Effect

*Specification* Table J3.2 Footnote [b]

[b] For end loaded connections with a fastener pattern length greater than 38 in. (965 mm), $F_{nv}$ shall be reduced to 83.3% of the tabulated values. Fastener pattern length is the maximum distance parallel to the line of force between the centerline of the bolts connecting two parts with one faying surface.



Design Guide 17 Figure 5.2



Not End Loaded

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# Connection Slip (-SC Connections)

*Specification* J3.8. *High-Strength Bolts in Slip-Critical Connections*

$$r_n = \mu D_u h_f T_b n_s \qquad (Spec.\ \text{J3-4})$$

$\phi$ = 1.00 for STD and SSLT (Transverse)
= 0.85 for OVS and SSLP (Parallel)
= 0.70 for LSL (Long Slots T or P)

Design Strength:

$$\phi r_n = \phi \mu D_u h_f T_b n_s$$

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# Connection Slip (-SC Connections)

*Specification* J3.8. *High-Strength Bolts in Slip-Critical Connections*

$$r_n = \mu D_u h_f T_b n_s \qquad (Spec.\ \text{J3-4})$$

$\mu$ = mean slip coefficient depending on faying surface:
Class A – 0.30 Class B – 0.50

$T_b$ = minimum bolt pretension, Table J3.1

$D_u$ = 1.13 = avg pretension / min. pretension

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## Connection Slip (-SC Connections)

**TABLE J3.1**
**Minimum Bolt Pretension, kips[a]**

| Bolt Size, in. | Group A[a] (e.g., A325 Bolts) | Group B[a] ( e.g., A490 Bolts) | Group C, Grade 2[b] (e.g., F3043 Gr. 2 bolts) |
|---|---|---|---|
| 1/2 | 12 | 15 | – |
| 5/8 | 19 | 24 | – |
| 3/4 | 28 | 35 | – |
| 7/8 | 39 | 49 | – |
| 1 | 51 | 64 | 90 |
| 1 1/8 | 64 | 80 | 113 |
| 1 1/4 | 81 | 102 | 143 |
| 1 3/8 | 97 | 121 | – |
| 1 1/2 | 118 | 148 | – |

[a] Equal to 0.70 times the minimum tensile strength of bolts as specified in ASTM F3125/F3125M for Grade A325 and Grade A490 bolts with UNC threads, rounded off to nearest kip.
[b] Equal to 0.70 times the minimum tensile strength of bolts, rounded off to nearest kip, for ASTM F3043 Grade 2 and ASTM F3111 Grade 2.

Increased in the 2016 *Specification*

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## Connection Slip (-SC Connections)

*Specification* J3.8. *High-Strength Bolts in Slip-Critical Connections*

$$r_n = \mu D_u h_f T_b n_s \qquad (Spec.\ \text{J3-4})$$

$h_f$ = factor for fillers
= 1.0 for no fillers or one filler
= 0.85 for two or more fillers
$n_s$ = number of slip planes

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## Connection Slip (-SC Connections)

IMPORTANT

- Slip Critical Connections
  - Expensive because of surface preparation, tightening, and inspection requirements.
  - Not needed for typical shear connections and most moment connections.
  - May be needed for dynamic or vibration loads.
  - May be used to control drift in frames.
  - Are required in some moment connections (especially for seismic applications).

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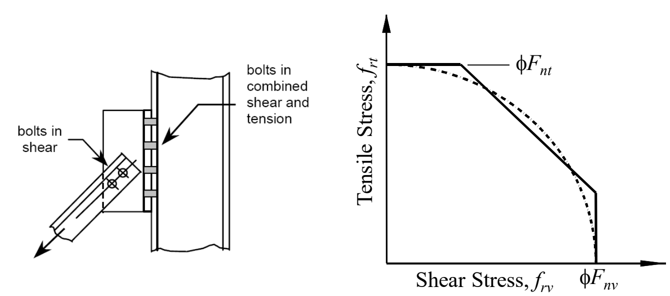
## Bearing Bolts: Combined Shear and Tension Strength




Bearing Bolt Interaction Diagram
(*Specification* Equation J3-3)

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## Bolts: Combined Tension and Shear Strength in Bearing Conn. (*Spec.* J3.7)

$r_{ut} \le \phi F'_{nt} A_b$

$r_{uv} \le \phi F_{nv} A_b$ or in terms of stress: $f_{rv} \le \phi F_{nv}$

where

$r_{ut}$, $r_{uv}$ = required tension and shear per bolt

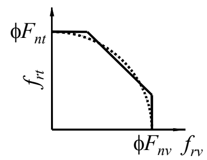
$\phi = 0.75$

$$F'_{nt} = 1.3F_{nt} - \frac{F_{nt}}{\phi F_{nv}} f_{rv} \le F_{nt}$$

$F_{nt}$ = nominal tensile stress

$F_{nv}$ = nominal shear stress

$f_{rv}$ = required shear stress = $r_{uv} / A_b$

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## Diameters Used in Calculations

- *Specification* Section B4.3b, for all hole related limit states except tearout, use the effective hole diameter (or "dimension" for slots).

$$d'_h = d_h + 1/16 \text{ in.}$$

The additional 1/16 in. accounts for damage from punching and drilling.

- For tearout, the nominal hole diameter, $d_h$, is used.
- For bearing, the bolt diameter, $d$, is used.

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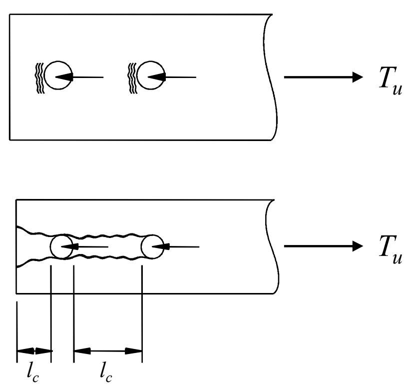
## Bolt Holes: Bearing and Tearout

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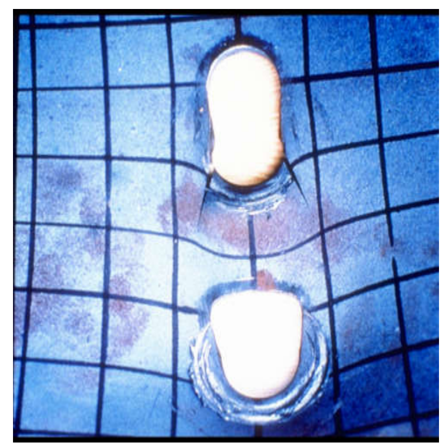
## Bolt Holes: Bearing and Tearout

Tearout

Bearing



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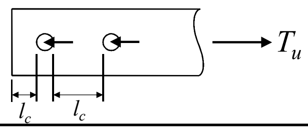
## Bolt Holes: Bearing and Tearout

*Specification* J3.10 *Bearing and Tearout Strength at Bolt Holes*

For standard, oversized, and short-slotted holes where deformation at a bolt hole is a consideration:

Bearing Strength: $r_n = 2.4\, d\, t\, F_u$ (*Spec.* J3-6a)
Tearout Strength: $r_n = 1.2\, l_c\, t\, F_u$ (*Spec.* J3-6c)

$l_c$ = clear distance to edge or between holes, in direction of the force

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## Shear Transfer for Bearing Connections

Clarified Method for Bolt Shear Rupture, Bearing, and Tearout. User Note in *Spec.* J3.6.

- Effective Strength of Individual Fastener, $r_n$

$$r_n = \min \left| \begin{array}{l} r_n \text{ for bolt shear rupture} \\ r_n \text{ for bearing (connected part 1)} \\ r_n \text{ for tearout (connected part 1)} \\ r_n \text{ for bearing (connected part 2)} \\ r_n \text{ for tearout (connected part 2)} \end{array} \right.$$

$$R_n = \Sigma r_n \qquad \phi = 0.75$$

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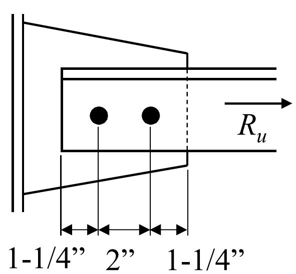
## Shear Transfer Example

Compute the design strength for shear transfer.

- PL5/8, A36
- 2L3-1/2x2-1/2x1/4, A529 Gr. 50
- 3/4 in. F3125 Gr. A325-N bolts
- Standard holes.

*Manual* Table 2-5
A529 Gr. 50
$F_y = 50$ ksi
$F_u = 65$ ksi

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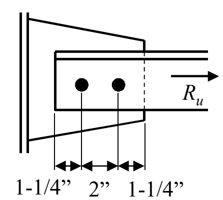
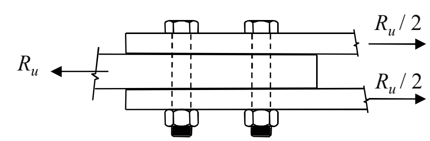
## Shear Transfer Example

Bolt Shear Rupture




$$\begin{aligned} r_n &= F_{nv} A_b \\ &= (54\text{ ksi})(0.442\text{ in.}^2 /\ \text{shear plane})(2\text{ shear planes}) \\ &= 47.7\text{ kips} \end{aligned}$$

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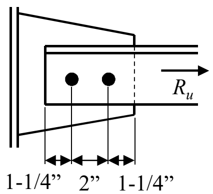
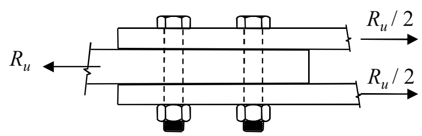
## Shear Transfer Example

Angle Bearing



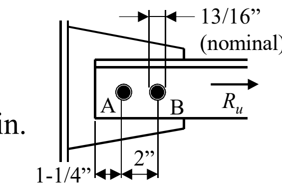




$$r_n = 2.4dtF_u$$
$$= (2.4)(3/4 \text{ in.})(1/4 \text{ in.})(65 \text{ ksi})(2 \text{ angles})$$
$$= 58.5 \text{ kips}$$



## Shear Transfer Example

Angle Tearout




- Bolt A

$$l_c = 1.25 \text{ in.} - 13/32 \text{ in.} = 0.844 \text{ in.}$$
$$r_n = 1.2 l_c t F_u$$
$$= (1.2)(0.844 \text{ in.})(1/4 \text{ in.})(65 \text{ ksi})(2 \text{ angles})$$
$$= 32.9 \text{ kips}$$

- Bolt B

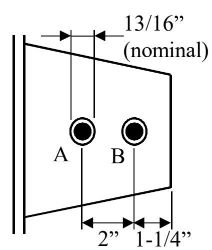
$$l_c = 2 \text{ in.} - 13/16 \text{ in.} = 1.19 \text{ in.}$$
$$r_n = 1.2 l_c t F_u$$
$$= (1.2)(1.19 \text{ in.})(1/4 \text{ in.})(65 \text{ ksi})(2 \text{ angles})$$
$$= 46.3 \text{ kips}$$



## Shear Transfer Example

Plate Bearing and Tearout

- Bearing
  - $r_n = 65.3$ kips
- Tearout at Bolt A
  - $r_n = 51.7$ kips
- Tearout at Bolt B
  - $r_n = 36.7$ kips






## Shear Transfer Example

Effective Strength at Bolt A

$$r_n = \min \left| \begin{array}{l} r_n \text{ for bolt shear rupture} = 47.7 \text{ kips} \\ r_n \text{ for bearing (angles)} = 58.5 \text{ kips} \\ r_n \text{ for tearout (angles)} = 32.9 \text{ kips} \\ r_n \text{ for bearing (plate)} = 65.3 \text{ kips} \\ r_n \text{ for tearout (plate)} = 51.7 \text{ kips} \end{array} \right.$$

Effective Strength at Bolt B

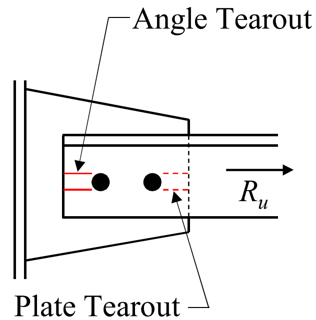
$$r_n = \min \left| \begin{array}{l} r_n \text{ for bolt shear rupture} = 47.7 \text{ kips} \\ r_n \text{ for bearing (angles)} = 58.5 \text{ kips} \\ r_n \text{ for tearout (angles)} = 46.3 \text{ kips} \\ r_n \text{ for bearing (plate)} = 65.3 \text{ kips} \\ r_n \text{ for tearout (plate)} = 36.7 \text{ kips} \end{array} \right.$$

## Shear Transfer Example

Total for the Connection

$$R_n = \sum r_n$$
$$= 32.9 \text{ kips} + 36.7 \text{ kips}$$
$$= 69.6 \text{ kips}$$

$$\phi R_n = (0.75)(69.6 \text{ kips})$$
$$= 52.2 \text{ kips}$$

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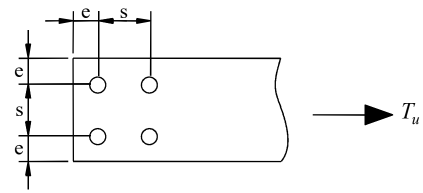
## Holes: Min. Spacing and Edge Distance




*Specification* J3.3 *Minimum Spacing*

- Standard, oversized, or slotted holes: $s \geq 2\text{-}2/3\ d$.
- User Note: $s \geq 3d$ is preferred.
- Clear distance between holes or slots $\geq d$

When $d \leq 1$ in. the typical spacing, $s$, is 3 in.

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## Holes: Min. Spacing and Edge Distance

**TABLE J3.4**
**Minimum Edge Distance[a] from Center of Standard Hole[b] to Edge of Connected Part, in.**

| Bolt Diameter, in. | Minimum Edge Distance |
|---|---|
| 1/2 | 3/4 |
| 5/8 | 7/8 |
| 3/4 | 1 |
| 7/8 | 1 1/8 |
| 1 | 1 1/4 |
| 1 1/8 | 1 1/2 |
| 1 1/4 | 1 5/8 |
| Over 1 1/4 | $1\frac{1}{4} \times d$ |

[a] If necessary, lesser edge distances are permitted provided the appropriate provisions from Sections J3.10 and J4 are satisfied, but edge distances less than one bolt diameter are not permitted without approval from the engineer of record.
[b] For oversized or slotted holes, see Table J3.5.

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## BASIC FILLET WELD RELATED LIMIT STATES AND DETAILING

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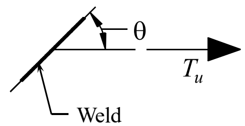
## Fillet Weld Rupture

*Specification* Section J2.4

Design Strength, $\phi R_n = \phi F_{nw} A_{we}$

$\phi = 0.75$

$F_{nw} = 0.60\ F_{EXX}(1.0 + 0.50 \sin^{1.5}\theta)$




where

$F_{EXX}$ = filler metal classification strength, ksi

$\theta$ = angle between the line of action of the required force and the weld longitudinal axis.

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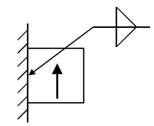
## Fillet Weld Rupture

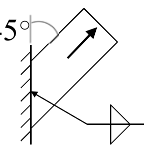
Equation J2-5:

$F_{nw} = 0.60\ F_{EXX}(1.0 + 0.50 \sin^{1.5}\theta)$

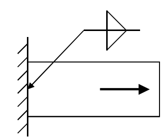
$\theta = 0° \rightarrow F_{nw} = 0.60 F_{EXX}(1.00)$



$\theta = 45° \rightarrow F_{nw} = 0.60 F_{EXX}(1.30)$




$\theta = 90° \rightarrow F_{nw} = 0.60 F_{EXX}(1.50)$



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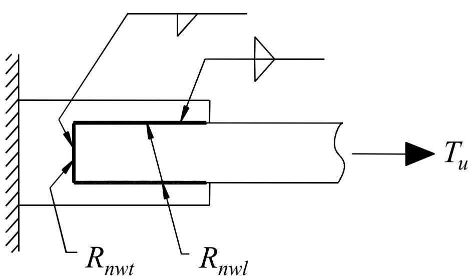
## Fillet Weld Rupture – Special Case

*Specification* J2.4(b)(2):




$$R_n = \max \left| \begin{array}{ll} R_{nwl} + R_{nwt} & (\textit{Spec.}\ \text{J2-6a}) \\ 0.85 R_{nwl} + 1.5 R_{nwt} & (\textit{Spec.}\ \text{J2-6b}) \end{array} \right.$$

$R_{nwl}$ and $R_{nwt}$ are the weld strengths with $\theta = 0°$.

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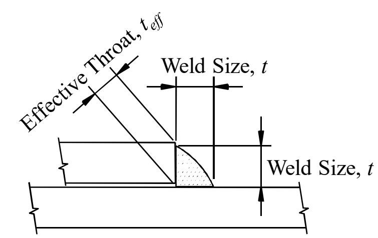
## Fillet Weld Rupture – Effective Area




Typical: $t_{eff} = 0.707\ t$

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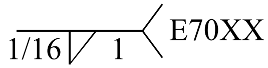
## Fillet Weld Rupture

Example: $\theta = 0^0$



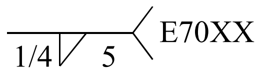

$\phi R_n = (0.75)(0.6)(70 \text{ ksi})(0.707)(1/16 \text{ in.})(1 \text{ in.})$

$= \underline{1.392 \text{ kips / 1/16 in. / in.}}$

1.392 will be used for the reminder of the course.

Example: $\theta = 90^0$

Let $D$ = no. of 1/16's




$\phi R_n = 1.392(1.0 + 0.50 \sin^{1.5}\theta) D\, L_{weld}$

$= 1.392 \times 1.5 \times 4 \times 5 = \underline{41.8 \text{ kips}}$

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## Minimum Fillet Weld Sizes

**TABLE J2.4**
**Minimum Size of Fillet Welds**

| Material Thickness of Thinner Part Joined, in. (mm) | Minimum Size of Fillet Weld,[a] in. (mm) |
|---|---|
| To 1/4 (6) inclusive | 1/8 (3) |
| Over 1/4 (6) to 1/2 (13) | 3/16 (5) |
| Over 1/2 (13) to 3/4 (19) | 1/4 (6) |
| Over 3/4 (19) | 5/16 (8) |

[a] Leg dimension of fillet welds. Single pass welds must be used.
Note: See Section J2.2b for maximum size of fillet welds.

Note: Thinner part controls minimum size of fillet weld.

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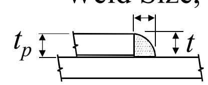
## Maximum Fillet Weld Sizes

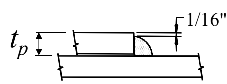
*Specification* J2.2b Maximum Fillet Weld Size

Weld Size, $t$

$t_p < 1/4$ in. $\quad t_{max} = t_p$

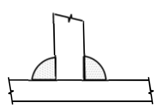



$t_p \geq 1/4$ in. $\quad t_{max} = t_p - 1/16$ in.




(To prevent under cutting of upper plate)

Limits apply only at edges, not:



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## Base Metal Strength at Fillet Welds

Table J2.5 and *Specification* J4.2 *Strength of Elements in Shear*

$$\phi R_n = \phi\, 0.6\, F_u\, A_{gv}$$

where

$\phi = 0.75$

$F_u$ = tensile strength of base metal

$A_{gv}$ = shear area of the element at the weld

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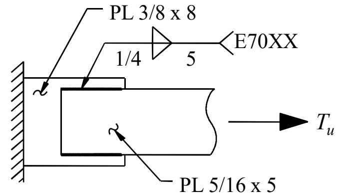
## Example: Fillet Weld Strength

Ex. Determine $\phi T_n$.
A36 Steel
$F_u = 58$ ksi




Weld Rupture:

$\phi T_n = (1.392)(4)(5 \text{ in.})(2 \text{ welds}) = 55.7$ kips

Base Metal:

$\phi T_n = \phi\, 0.6\, F_u A_{gv}$

$= (0.75)(0.6)(58)(5/16)(5 \text{ in.})(2) = 81.6$ kips

$\phi T_n = \underline{55.7 \text{ kips}}$

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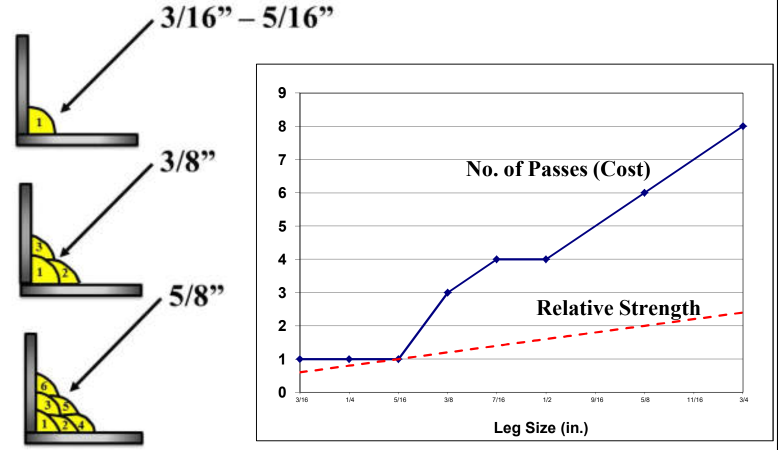
## Use Single Pass Welds When Possible

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## End of Session 1

Thank You for
Attending

Next Up

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## Next Session

- October 30, 2019 Fundamental Concepts Part II

Topics

- Eccentric Bolted and Welded Connections
- Direct Loaded Tension Connections
- Light Bracing Connection Example
- Beam Bearing Plate Design
- Column Base Plate Design

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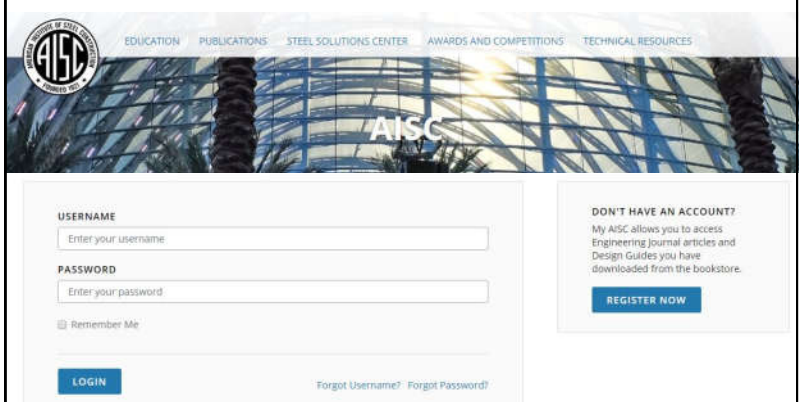


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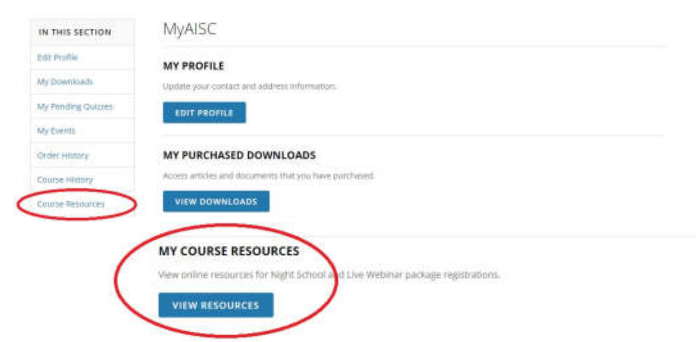

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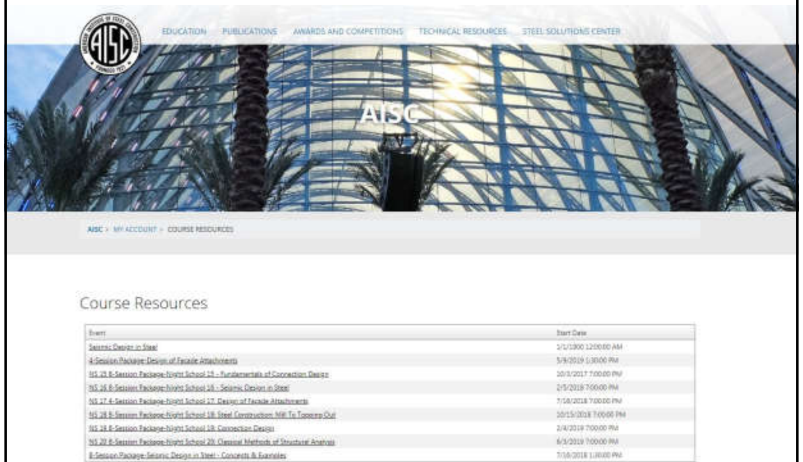


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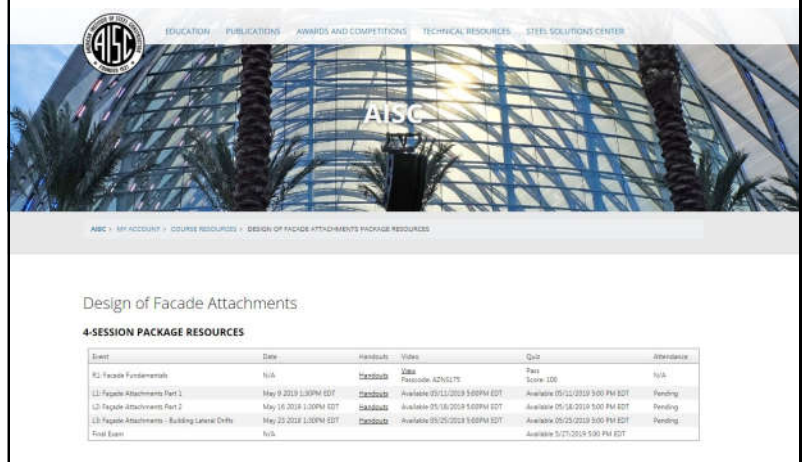


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