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Course Description

Session 2: Economic Considerations
February 6, 2017

Lesson 2 focuses on roof and bay optimization. Design considerations for roof trusses are discussed. Connection considerations, permanent, and erection bracing for roof trusses are presented. Economic issues pertaining to: span-to-depth ratios, location of splice points, use of tee chords, the advantages of LRFD, use of high strength steels, web arrangements, and the value of repetition of member sizes are all discussed. Design considerations for: Block Shear and Shear Rupture, Orientation of Wide Flange Chords, Slip Critical Joints, Seat Connections, and Splices are discussed. Additional information not covered in Lesson 1 on optimum member selection, and details for the support of hanging loads and roof top units are provided. An interactive Spreadsheet tool is demonstrated for selecting optimum bay layout. Roof diaphragm details and design requirements are also discussed.

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Learning Objectives

- List design considerations for roof trusses.
- List bracing considerations for roof trusses for both permanent and erection bracing.
- Describe economically advantageous considerations for truss design.
- Describe details for supporting hanging loads and roof top units.

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Design of Industrial Buildings
Lesson 2: Economic Considerations
February 6, 2017

Presented by
James M. Fisher, PE, PhD
Emeritus Vice President, Computerized Structural Design

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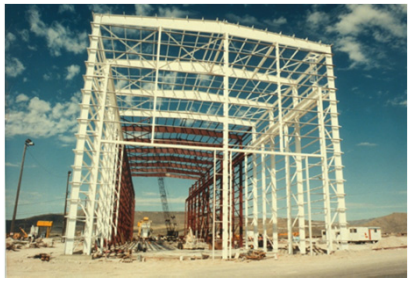
Design of Industrial Buildings
Lesson 2



Presenter:
Jim Fisher

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Buildings w/o Overhead Cranes

- **Lesson 2**
  - Roof Trusses
  - Framing Considerations
  - Bay Analysis
  - Miscellaneous Topics
    - Underhung Cranes
    - Hanging Loads and RTUs
  - Roof Diaphragms and Details

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Roof Trusses

- Economic Considerations
- Connection Considerations
- Truss Bracing
- Erection Bracing
- Other Considerations

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Roof Trusses

Economic Considerations:

- Span-to-depth ratio
- Splice points
- Tee chords
- LRFD
- High strength steels
- Repetition
- Web arrangements

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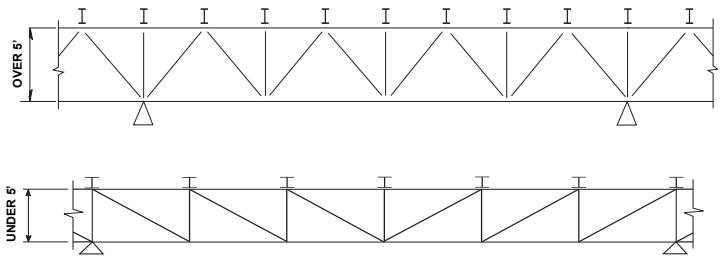
Roof Trusses

- **Span-to-depth ratios**: Ratios of 15 to 20 generally prove to be economical; however, shipping depth limitations should be considered so that shop fabrication can be maximized. The maximum depth for shipping is conservatively 14 feet. Greater depths will require the web members to be field bolted or welded, which will increase erection costs.
- **Splice points:** The length between splice points is limited by shipping lengths. Shippable lengths vary according to the destination of the trusses, but lengths of 80 feet are generally shippable and 100 feet is possible. Since maximum available mill length is 70 feet, the distance between splice points is normally set at a maximum of 70 feet. Greater distances between splice points will require truss chords to be shop spliced.

Roof Trusses

- **Tee chords:** If possible, select truss depths so that tees can be used for the chords rather than wide flange shapes. Tees can eliminate (or reduce) the need for gusset plates.
- **LRFD:** Designs using the LRFD load combinations will often lead to truss savings when heavy long span trusses are required. This is due to the higher DL to LL ratios for these trusses.
- **High strength steels:** Higher strength steels (F_y > 50 ksi) usually results in more efficient truss members.
- **Repetition:** Repetition is beneficial and economical. Use as few different truss depths as possible. It is cheaper to vary the chord size as compared to the truss depth.

Web Arrangements



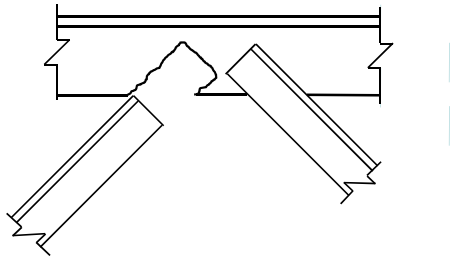
Roof Trusses

Connection Considerations

- Block Shear and Shear Rupture
- Orientation of Wide Flange Chords
- Slip Critical Joints
- Seat Connections

Block Shear Strength

Block Shear



Block Shear Strength

AISC Specification Section J4.3 Block Shear Strength

The *available strength* for the *limit state* of *block shear rupture* along a shear failure path or paths and a perpendicular tension failure path shall be taken as:

$$R_n = 0.60F_uA_{nv} + U_{bs}F_uA_{nt} \le 0.60F_yA_{gv} + U_{bs}F_uA_{nt} \quad \text{(J4-5)}$$

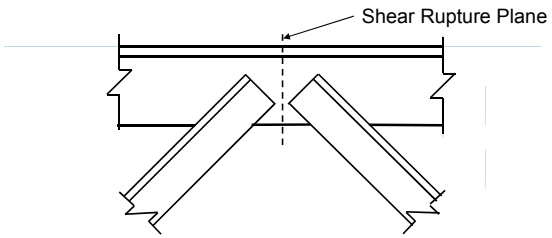
$$\phi = 0.75 \text{ (LRFD)} \quad \Omega = 2.00 \text{ (ASD)}$$

where

A_{nt} = *net area* subject to tension, in.^{2} (mm)^2

When the tension *stress* is uniform, U_{bs} = 1; when the tension stress in nonunifom, U_{bs} = = 0.5

Shear Yielding and Rupture



Shear Yielding and Rupture

AISC Specification Section J4.2 Strength of Elements in Shear

The available shear strength affected and connecting elements in shear shall be the lower value obtained according to the *limit states* of *shear yielding* and *shear rupture*:

(a) For shear yielding of the element:

$$R_n = 0.60F_yA_{gv}$$

$$\phi = 1.00 \text{ (LRFD)} \quad \Omega = 1.5 \text{ (ASD)} \quad \text{(J4-3)}$$

where

A_{gv} = gross area subject to shear, in.^{2} (mm^2)

(b) For shear rupture of the element:

$$R_n = 0.60F_uA_{nv} \quad \text{(J4-4)}$$

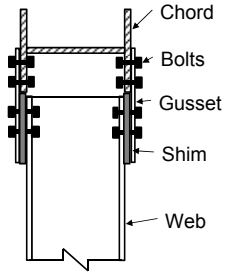
$$\phi = 0.75 \text{ (LRFD)} \quad \Omega = 2.0 \text{ (ASD)}$$

where

A_{nv} = net area subject to shear, in.^{2} (mm^2)

Connection Considerations

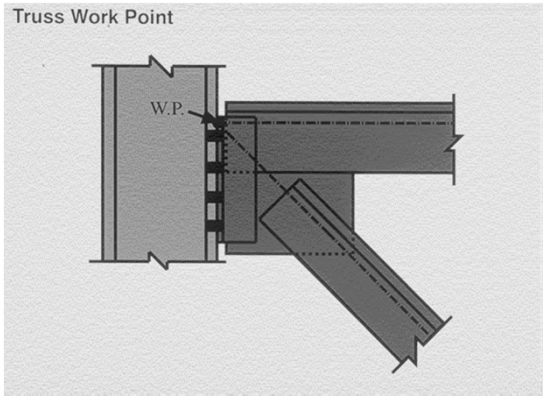
- **Orientation of Wide Flange Chords:** If wide flange chords are used with wide flange web members, orient the chords with their webs horizontal. Gusset plates for the web members can then be either bolted or welded to the chord flanges. The use of comparable depth wide flange diagonals should be considered.



Connection Considerations

- **Slip Critical Joints:** When trusses require field bolted joints, the use of slip-critical bolts in conjunction with oversize holes will allow for erection alignment. Also if standard holes are used with slip-critical bolts and field "fit-up" problems occur, holes can be reamed without significantly reducing the allowable bolt shears.
- **Seat Connections:** For the end connection of trusses, top chord seat type connections should also be considered. Seat connections allow more flexibility in correcting column-truss alignment during erection. Seats also provide for efficient erection and are more stable during erection than "bottom bearing" trusses. When seats are used, a simple bottom chord connection is recommended to prevent the truss from rolling during erection.

Connection Considerations



Roof Trusses

Permanent Bracing

- Standard Bracing Theory
- Stiffness: 4P/L
- Strength: .004P

Number of "Out of Straight Trusses"

- $\sqrt{n}$

Chen,S. and Tong,G. (1994), "*Design for Stability: Correct Use of Braces,* " Steel Structures, J. Singapore, Struct. Steel Soc., Vol 5, No. 1.

Roof Trusses

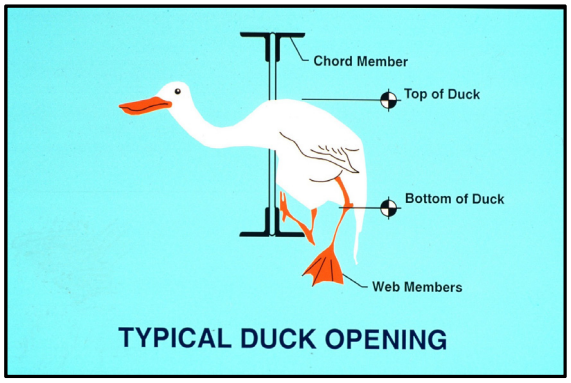
Erection Bracing

- Consider Erection Sequence
- Combine Erection and Permanent Bracing
- Sway Frames and Struts
- Seat Connections

Framing Considerations

- Bay Size
- Bay Proportions
  - Direction of main members vs. secondary members
- Member Types
  - W Shapes, Joists, Joist Girders, or Trusses
- Joist Spacing and Depths
  - Optimum depth for Joist Girders is depth equal to length in inches.
- Short Spans
  - HSS, Channels

Openings



Framing Considerations

As Bay Sizes Increase -

Horizontal framing weight increases

Square Bays -

Generally more economical

Framing Considerations

- Span the joist the long direction.
- K series joists are typically more economical than LH series.
- Use rolled sections for suspended loads.

Joist and Joist Girder Building

Bay Analysis

- SJI Roof Bay Analysis Tool
  - Free download from the Steel Joist Institute, www.steeljoist.org.
- SJI Floor Bay Analysis Tool
  - Free download from the Steel Joist Institute, www.steeljoist.org.
- AISC Bay Analysis Tool
  - Free download from www.steeltools.org.

Demonstration of Roof Bay Analysis Tool

- Comparisons:
- 40 ft. x 40 ft. bay ASD and LRFD

Column Selection

- Wide Flange Sections
- HSS

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Underhung Cranes

Source unknown

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CMAA Service Classifications

- Class A (Standby Service)
- Class B (Light Service)
- Class C (Moderate Service)

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Underhung Cranes

- Support underhung cranes every 15 to 20 feet
- Show locations and details on your plans

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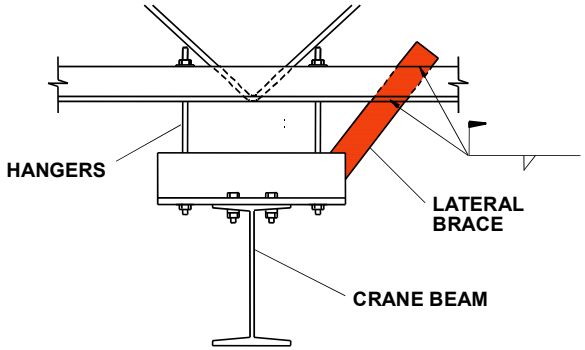
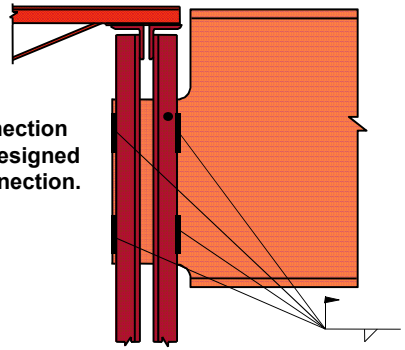
Crane Runway Hanger

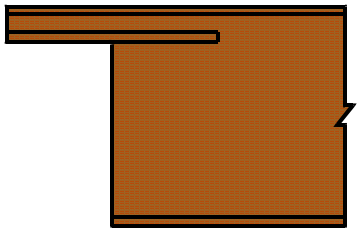


Beam to Girder Connection

Note: This connection could also be designed as a bolted connection.



Beam Seat

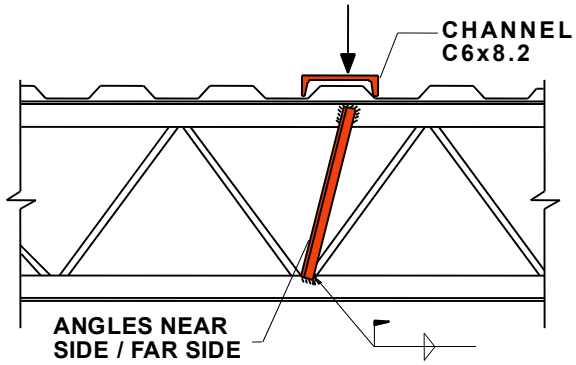


Beam Seat

Hanging Loads

- The SJI allows a 100 pound load to be placed anywhere along the top or bottom chords of joists so long as the load has been accounted for in the total load on the joist

Joist Reinforcement

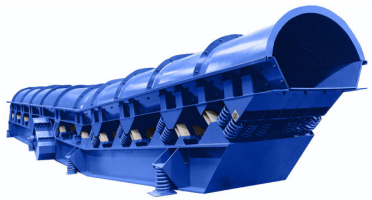


Hanging Loads: Conveyors

- Continuous Belt Conveyors (Thrusts are usually self contained)
- Trolley Conveyers (Chain Driven)
- Vibratory Conveyors

Hanging Loads: Conveyors

It is not recommended that vibratory conveyors be hung from joist systems.



Supports for Roof Top Units

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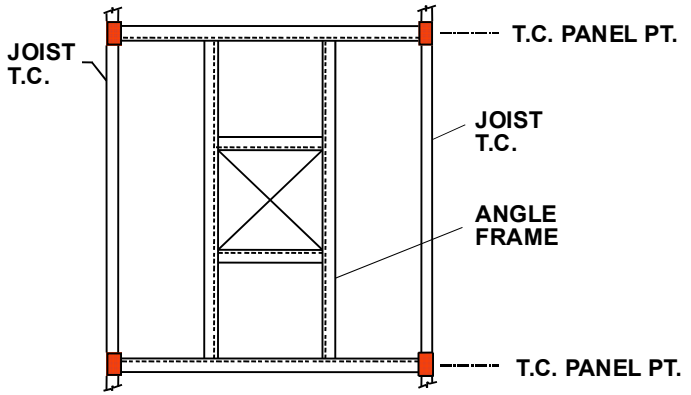
Double Frame



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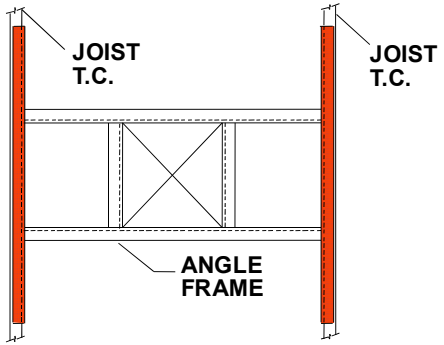
Double Frame



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Roof Top Units (RTUs)

- Do Not Have Uniform Density
- Weight of Curb and Support Frame

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Support for RTUs

- Special Joists
- KCS Series Joists
- Zoning

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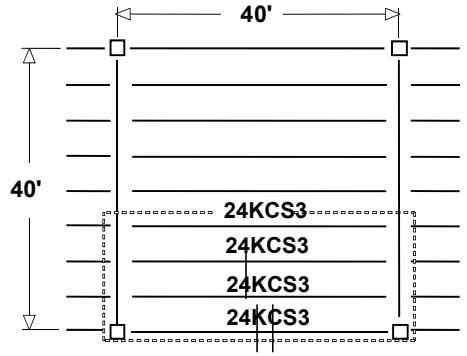
Roof Top Zone



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Joist Girder at Roof Top Zone

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Vibration Considerations

Supporting Joists or beams should have a natural frequency 50% > or < 50% of the Operating Frequency of the Unit

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Lateral Load Systems

- Diaphragms
- Covered in Lesson 3:
  - Horizontal Bracing
  - Braced Frames
  - Rigid Frames
  - Selection of the System
  - Examples

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Diaphragms

- Types
- Fastening Means
- Load Tables
- Design Procedure
- Diaphragm Connections

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Diaphragm Types

- Steel Deck
- Steel Decks with Insulating Fills
- Concrete Slabs on Steel Form Deck
- Composite Steel Deck with Lightweight Concrete
- Composite Steel Decks with Normal Weight Concrete
- Wood Diaphragms

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Strength and Stiffness

Determined by:

- Deck Thickness
- Type of Fastening to the Structure
- Frequency of Fastening to the Structure
- Type and Spacing of Side Lap Fastening

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Means of Fastening

- Welding
- Power Driven Fasteners
- Self Driven Screws
- Button Punching

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Advantages of Screws and Power Driven Fasteners

- Easy to Install with Unskilled Labor
- Clean Neat Appearance
- Dependable

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Disadvantages of Screws and Power Driven Fasteners

- Capacity
- Cost

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Diaphragm Design Procedure

- Determination of Forces
- Selection of Deck Type and Fastening
  - Steel Deck Institute (SDI)
  - ICC-ES Reports
- Evaluation of Deflections
- Analysis of Chord Forces
- Force Transfer Details

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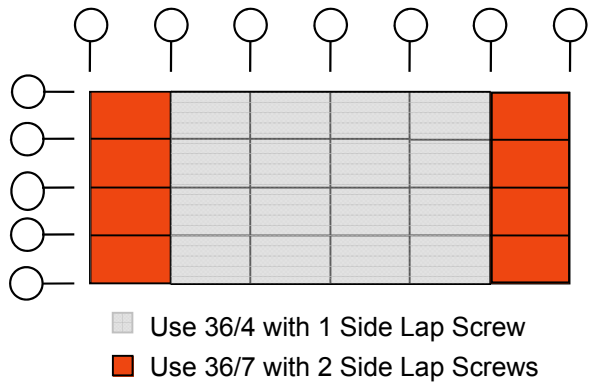
Roof Diaphragm Key Plan



Connections

- Chord Forces
- Shear Transfer

Chord Forces

The Engineer of Record Must Indicate the Chord Force Requirements on the Contract Documents

Chord Forces

- The specifying professional shall provide the nominal loads and load combinations as stipulated by the applicable code under which the structure is designed and shall provide the design basis, ASD or LRFD.
- The specifying professional shall calculate and provide the magnitude and location of ALL JOIST and JOIST GIRDER LOADS. This includes all special loads (drift loads, mechanical units, net uplift, axial loads, moments, structural bracing loads, or other applied loads) which are to be incorporated into the joist or Joist Girder design…
- Type and magnitude of end moments and/or axial forces at the joist and Joist Girder end supports shall be shown on the structural drawings...

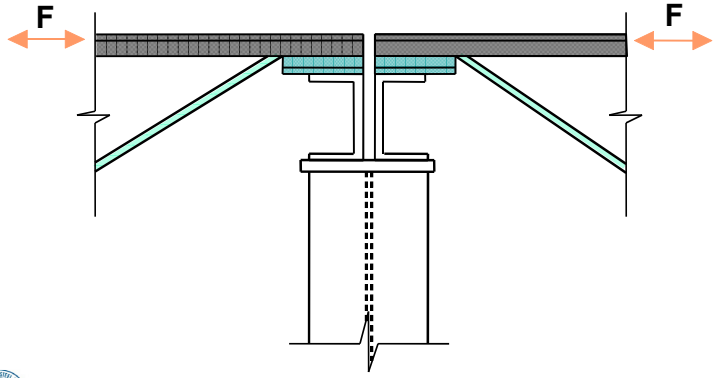
From: SJI Code of Standard Practice 6.1(a)

Chord Forces

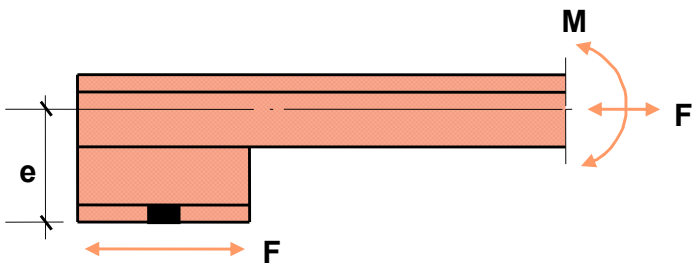
- Chord Forces are carried as additional axial loads by the top chords of joists and/or Joist Girders.
- Chord Forces may vary from one end of the chord to the other. The additional axial load for each joist and/or Joist Girder must be indicated.
- When applicable, a load factor for the axial loads must be indicated.
- Avoid resolving joist or Joist Girder end moments and axial forces through the bearing seat connection.
- The top and bottom chord moment connection details shall be designed by the specifying professional. The joist designer shall furnish the specifying professional with the joist detail information if requested.

SJI Code of Standard Practice 6.1(a)

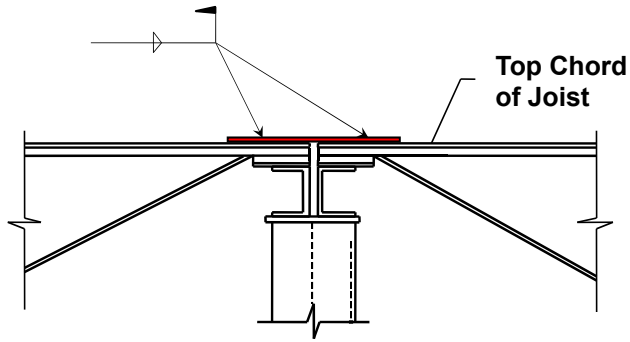
Diaphragm Chord



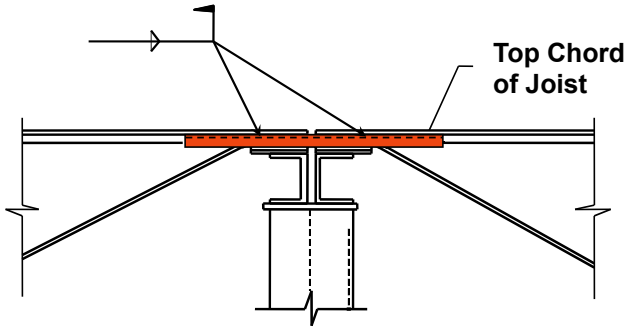
Joist Chord Bending



Joist Tie Plate



Joist Tie Angles



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Shear Transfer Methods

- Deck Support Angles
- Joist Seat Rollover
- Shear Collectors
- Transfer to Shear Walls
- Across Expansion Joists
- Attachment to Vertical Bracing with Joist Girder

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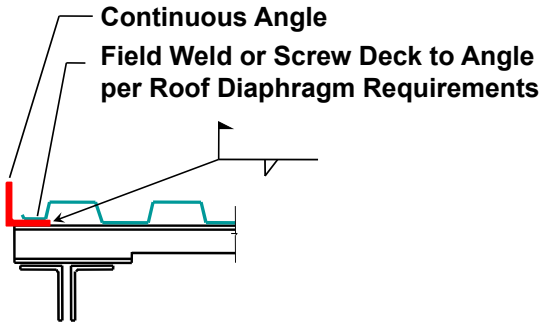
Deck Support Angle



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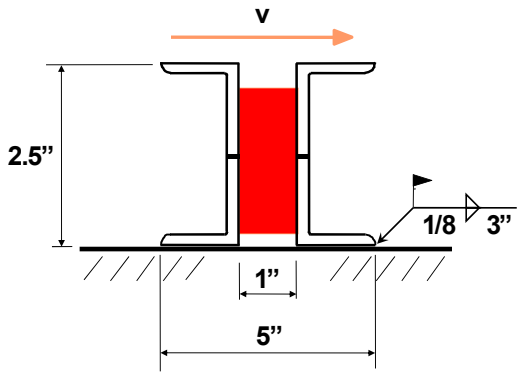
Joist Seat Rollover



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Deck Support Angle and Joist Seat Rollover

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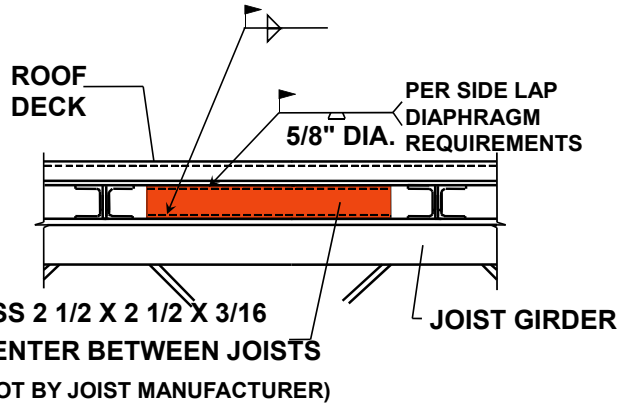
Shear Collector K-Series Joist



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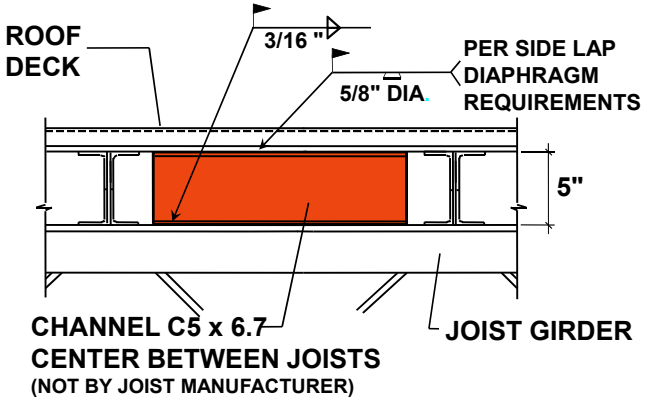
Shear Collector LH-Series Joist



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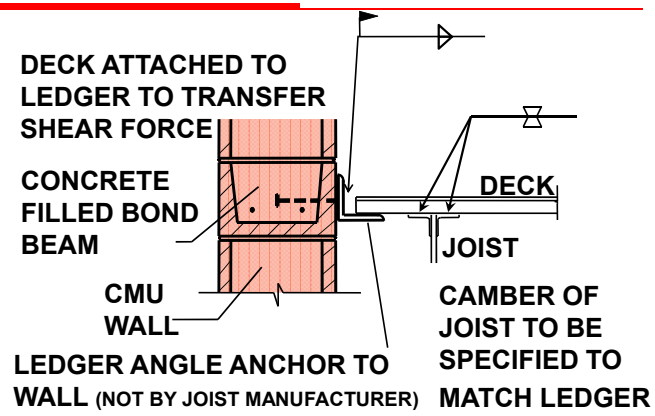
Shear Transfer to Masonry



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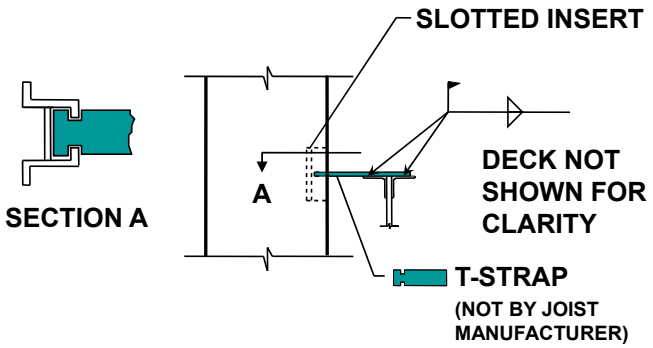
Precast Insert



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End of Lesson 2

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Individual Webinar Registrants

PDH Certificates

Within 2 business days…

- You will receive an email on how to report attendance from: 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!

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Individual Webinar Registrants

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Within 2 business days…

- New reporting site (URL will be provided in the forthcoming email).
- Username: Same as AISC website username.
- Password: Same as AISC website password.

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8-Session Registrants

PDH Certificates

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

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8-Session Registrants

QUIZZES

Access to the quiz: Information for accessing the quiz will be emailed to you by Wednesday. It will contain a link to access the quiz. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG

Quiz and Attendance records: Posted Tuesday mornings. www.aisc.org/nightschool - scroll down to Quiz and Attendance Records.

Reasons for quiz:

EEU – must take all quizzes and final to receive EEU
PDHS – If you watch a recorded session you must take quiz for PDHs.
REINFORCEMENT – Reinforce what you learned 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.

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8-Session Registrants

RECORDINGS

Access to the recording: Information for accessing the recording will be emailed to you by this Wednesday. The recording will be available for two weeks. For 8-session registrants only. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG.

PDHS – If you watch a recorded session you must take AND PASS the quiz for PDHs.

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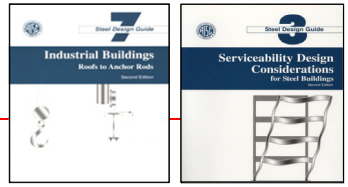

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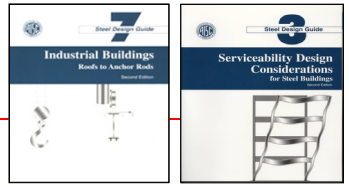

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Thank You

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Survey at conclusion of webinar.