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Course Description

Session 1: Design Criteria
January 30, 2017

In Lesson 1, loads as required by IBC 2015 and ASCE 7-10 are discussed as well as owner established design criteria. Advantages and disadvantages of various roof and wall systems are presented. Serviceability issues and other design considerations are discussed in detail for roof and wall types. Expansion joint requirements and details for expansion joints for both buildings without overhead cranes and those with overhead cranes are presented. Member selection guidelines for optimum design are discussed.

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Learning Objectives

- Establish design criteria and loads for building design based on IBC 2015, ASCE 7-10 and owner requirements.
- List advantages and disadvantages of various roof and wall systems.
- Describe expansion joint requirements and explain appropriate expansion joint details based on the type of building being designed.
- Describe the guidelines for the optimum member design.

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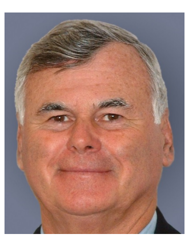
Design of Industrial Buildings
Lesson 1: Design Criteria
January 30, 2017



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

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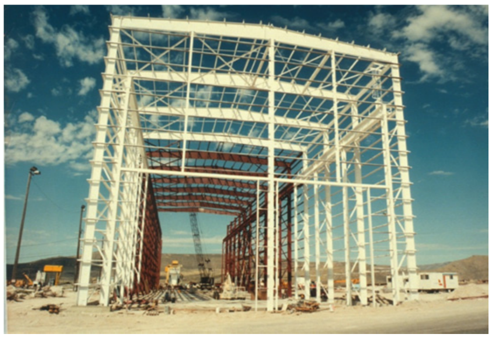
structural STEEL

AISC Night School 13

Design of Industrial Buildings
Lesson 1



Presenter:
Jim Fisher

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Night School- 13

- In this Night School a complete design of an industrial building with a 50 ton overhead crane will be presented along with a discussion of the critical design issues. Prior to that discussion we will discuss design issues that pertain to buildings, both with and without, overhead cranes.
- Calculations will be presented in a manner that serve as a teaching tool for engineers.

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Night School- 13

There are eight 1.5 hours of discussion.

Lessons include:

Lesson 1: Loads, Roofs, Walls, Serviceability, and Expansion Joints

Lesson 2: Roof Trusses, Framing Considerations, Bay Analysis, Hanging Loads, RTUs, Roof Diaphragms, and Details

Lesson 3: Lateral Load Systems and Examples

Lesson 4: Project Description (50 ton crane building): Design Criteria and Preliminary Design

Lesson 5: Crane Runway Design, Building Loads and Analysis

Lesson 6: Column Design, Connections, Specification of Components and Anchor Rod Design

Lesson 7: Longitudinal and Endwall Bracing

Lesson 8: Roof, Wall and Stability Bracing

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Buildings w/o Overhead Cranes

- **Lesson 1**
  - Loading Conditions and Load Combinations
  - Owner Established Criteria
  - Roof Systems
  - Wall Systems
  - Serviceability Considerations
  - Expansion Joints

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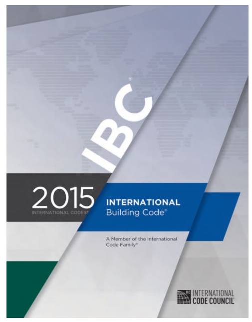
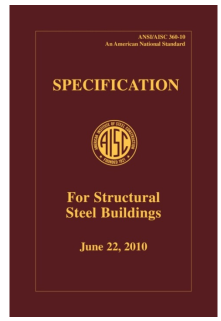
Codes, Loads and Other Design Criteria





Also ASCE 7-10 and the AISC Seismic Provisions

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Loads and Combinations

- Loads from ***IBC*** and ***ASCE 7***
  - Dead Loads
  - Live Loads
  - Snow Loads
  - Wind Loads
  - Seismic Loads
  - Other Loads
- Load Combinations

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Required Design Loads

Code specified loads are specified in locally adopted governing codes, i.e., the International Building Code, in most jurisdictions.

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Dead Load – Roofs & Floors

- Steel Systems
  - Roof deck, joists and Joist Girders
  - Floor deck, concrete slabs, wide flange beams, joists, Joist Girders
  - Columns

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Dead Load - Roof

• Roofing – Ballast and Membrane	10 - 18 psf
• Insulation	2 - 4 psf
• Deck	2 - 4 psf
• Framing – Joists, and infill beams	3 - 5 psf
• Framing – Girders	1 - 2 psf
• Ceiling	1 - 4 psf
• M - E - P	3 - 10 psf

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Dead Loads - Walls

- Exterior walls

– Glass and aluminum curtain walls	8 - 16 psf
– Brick and block	70 - 100 psf
– Brick and steel studs	45 - 55 psf
– Brick and wood studs	45 - 55 psf
– Exterior insulation systems	10 - 15 psf

- Interior walls

– Studs and drywall or plaster	5 - 20 psf
– Concrete block	30 - 60 psf

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Live Loads – IBC 1607

- 1607.3 Uniform live loads
- "The live loads used in the design of buildings and other structures shall be the maximum loads expected in the intended use or occupancy but in no case shall be less than the minimum uniformly distributed unit loads required by Table 1607.1."

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Live Loads – IBC 1607

- 1607.4 Concentrated loads
- "Floors and other similar surfaces shall be designed for uniformly distributed live loads prescribed in Section 1607.3 or the concentrated live loads, given in Table 1607.1, whichever produces the greater load effects."
- Distribute over area 2.5- feet by 2.5- feet. Locate to produce maximum effects.

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Live Loads – IBC 1607

- 1607.9 Impact loads
- "The live loads specified in Sections 1607.3 through 1607.8 include allowance for impact conditions. Provisions shall be made in the structural design for uses and loads that involve unusual vibration and impact forces."

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Live Loads – IBC 1607

- 1607.9.2 Machinery
- Weight of machinery and moving loads to be increased by
  - 20% - light, shaft- or motor driven
  - 50% - reciprocation or power driven
- Percentages shall be increased where specified by the manufacturer.

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Snow Loads – IBC 1608

- Ground Snow Load, p_g
- Flat Roof Snow Load, p_f
  - Exposure Factor
  - Thermal Factor
  - Importance Factor
- Sloped Roof Snow Load, p_s
  - Surface
  - Temperature

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Snow Loads – IBC 1608

- Drifts on Lower Roofs, Behind Parapets and at Projections
  - Roof length (source of snow)
  - Height of roof offset, etc.
- Sliding snow
  - Extent of upper roof
  - Surface of upper roof
  - Slope
  - Snow Guards

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Snow Loads – IBC 1608

- Rain-on-Snow
  - Where p_g ≤ 20 psf, add 5 psf surcharge to balanced case only.

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Rain Loads – IBC 1611

- 1611.1 Design Rain Loads
- "Each portion of a roof shall be designed to sustain the load of rainwater that will accumulate on it if the primary drainage system for that portion is blocked, plus the uniform load caused by water that rises above the inlet of the secondary drainage at its design flow."

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Rain Loads – IBC 1611

- $R = 5.2 (d_s + d_h)$ (Eq. 16-36)
  - Where
    - d_s = height to secondary inlet
    - d_h = hydraulic head above secondary inlet

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Rain Loads- Ponding

- AISC Specification and Appendix 2
- AISC Design Guide 3, "Serviceability Design Considerations for Steel Buildings" (Second Edition)
- SJI Technical Digest 3, "Structural Design of Steel Joist Roofs to Resist Ponding Loads"

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Rain Loads

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Rain Loads

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Rain Loads

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Rain Loads

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Rain Loads

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Wind Loads – IBC 1609

- Basic Wind Speed
- Topography
- Importance Factor
- Exposure Category
- Enclosure Classification
- Gust
- Building Geometry

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Wind Loads – IBC 1609

- Main Wind-Force Resisting Systems
- Components and Cladding
  - Effective Area
- Reference ASCE 7 – 10, "Minimum Design Loads for Buildings and Other Structures"
- Another reference is the ATC Windspeed web site:windspeed.atcouncil.org

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Wind Loads – ASCE 7-10

Main Wind-Force Resisting System (MWFRS)

- Method 1- Directional Procedure
- Method 2- Envelope Procedure
- Method 3- Directional Procedure for Building Appurtenances (roof top equipment, free standing walls etc.)
- Method 4- Wind Tunnel Procedure

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Earthquake Loads- ASCE 7-10

- Seismic Design Category A
  - $F_x = 0.01w_x$

  where

  F_x = the design lateral force applied at story *x*

  w_x = the proportion of the total dead load of the structure, D, located or assigned to level *x*
- R values are not used

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Earthquake Loads- ASCE 7-10

- Seismic Design Categories B and C
- R = 3 permitted and should be used
- ANSI/AISC 360-10 *Specification for Structural Steel Buildings* is applicable (Seismic Provisions not required)

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Earthquake Loads- ASCE 7-10

- Design Categories D, E, and F
- Use R values per ASCE 7-10 Table 12.2-1
- ANSI/AISC 341-10 *Seismic Provisions for Structural Steel Buildings*, is required

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Seismic Design Criteria– ASCE 7 Chapter 12

- Structural System Selection – basic lateral and vertical seismic force-resisting system per Table 12.2-1 or Combinations per Sections 12.2.2, .3 or .4
  - Seismic design category (SDC)
  - Height limitations

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Seismic Loads

- The 2015 IBC references ASCE 7-10 for seismic design requirements. Spectral accelerations (S_s and S_1) are provided in maps contained in this standard. However, these values can also be obtained from the US Geological Survey (USGS) website:
- http://earthquake.usgs.gov/hazards/designmaps/.

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Load Combinations– IBC 1605

- 1605.2 Load combinations using strength design or load and resistance factor design
- 1605.3 Load combinations using allowable stress design
  - 1605.3.1 Basic load combinations
  - 1605.3.2 Alternate basic load combinations

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Load Combinations - LRFD

- *BASIC COMBINATIONS – IBC 1605.2*

$1.4D$
$1.2D + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
$1.2D + 1.6(L_r \text{ or } S \text{ or } R) + (f_1L \text{ or } 0.5W)$
$1.2D + 0.6W + 0.5(L_r \text{ or } S \text{ or } R)$
$1.2D + 1.0E + f_1L + f_2S$
$0.9D + 1.0W$
$0.9D + 1.0E$

Relative to one story industrial buildings: f_1 = 0.5 for live loads, f_2 = 0.7 for roofs that do not shed snow and 0.2 for other roof configurations

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Load Combinations - ASD

- *BASIC COMBINATIONS – IBC 1605.3*

D
$D + L$
$D + (L_r \text{ or } S \text{ or } R)$
$D + (0.6W \text{ or } 0.7E)$
$D + 0.75L + 0.75(0.6W \text{ or } 0.7E) + 0.75(L_r \text{ or } S \text{ or } R)$
$0.6D + 0.6W$
$0.6D + 0.7E$

Note: Flood and Lateral Pressure Loads not shown

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AISC Specification

- B2 Loads and Load Combinations
- "The loads and load combinations shall be as stipulated by the *applicable building code*. In the absence of a building code, the loads and load combinations shall be those stipulated in SEI / ASCE 7. For design purposes, the *nominal loads* shall be taken as the *loads* stipulated by the applicable building code."

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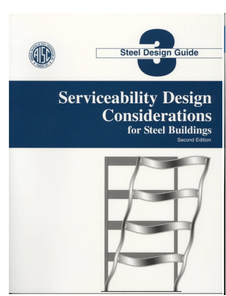
Other Design Criteria

- Drift Criteria
- Loss Prevention (FM Global or other insurance requirements)
- Roof Drainage
- OSHA rules



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Drift Criteria

- Code Requirements
  - See ASCE 7- 10, Section 12.12 and Table 12.12-1 for allowable story drift for seismic loads.

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Loss Prevention (FM Global)

- Wind Forces on Buildings
- Roof Deck Securement
- Metal Roof Systems
- Perimeter Roof Flashing
- Roof Loads for New Construction

For additional information
Go to :http://www.fmglobal.com

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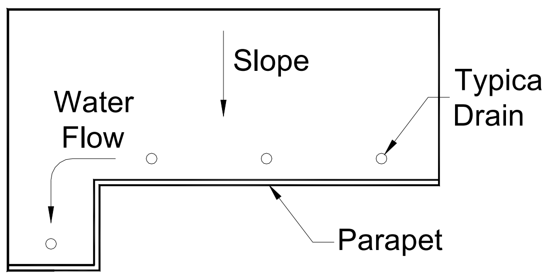
Drainage

- Drainage and Slopes
  - Built-up and membrane roofs
  - Metal roofs



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OSHA Rules

- Code of Federal Code Regulations 29, Part 1926, Subpart R regulates the work of steel erection.
- These rules apply to steel erectors and their employees.
- These rules prescriptively describe features of the structure that should be incorporated in the construction documents and shop drawings.

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Owner Established Criteria

- Slab-on-Grade Design
- Jib Cranes
- Type of Usage
- Future Expansion

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Slabs on Grade

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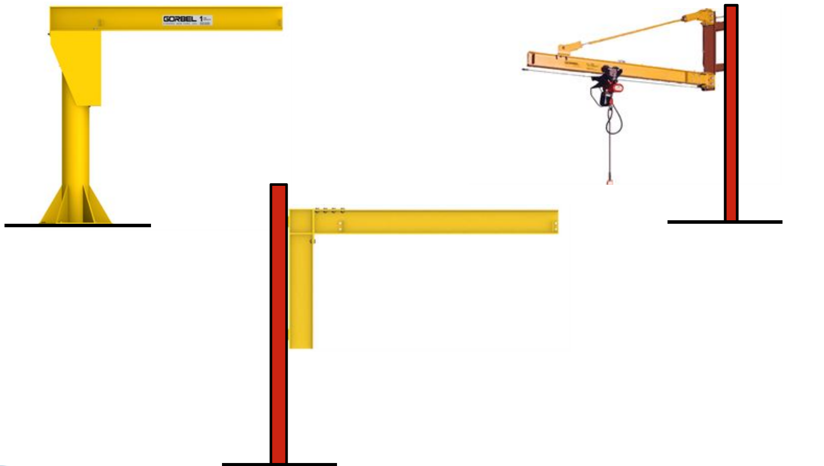
Jib Cranes



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Type of Usage:

Forklift trucks require special attention:

- Type of Walls
- Column Protection
- Use of Guard Rails

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Future Expansion

- Direction of primary and secondary framing
- Roof Slopes
- Location of X bracing

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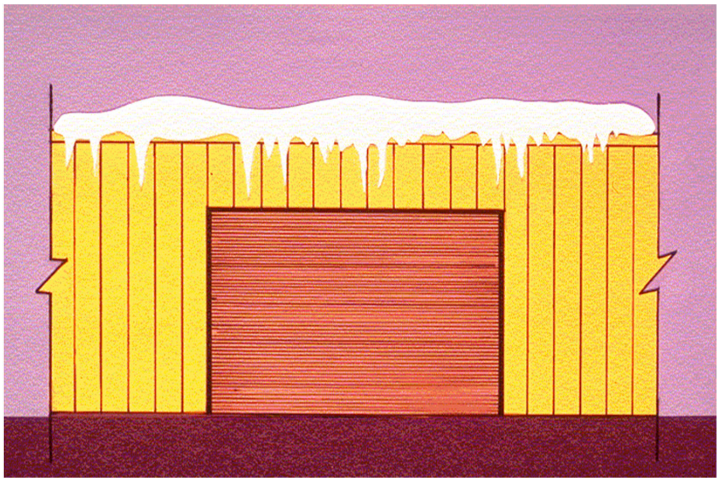
Exterior Gutters



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Roof Systems

Expensive Portion of Building:
Therefore:

- Do not over design
- Note mechanical loads on drawings

Member Selection Guidelines

- Deck
- Open Web Steel Joists and Beams
- Columns

Structural Roof Systems

- Through Fastened Roofs (TFR)
  - 100 to 200 feet between joints, if supported by cold formed Zees or Cees
- Standing Seam Roofs
  - 150 to 200 feet between joints

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Deck Selection Guidelines

- SDI Recommended Spans
- FM Global and other Insurance Requirements

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SDI Maximum Deck Spans

	3.5' LWC Above Flutes	Deck Gage						
2-Hr. Fire Rating	Deck Depth	22	21	20	19	18	17	16
	2	8'-5"	9'-0"	9'-6"	10'-6"	11'-4"	12'-1"	12'-8"
	3	9'-1"	10'-9"	11'-7"	12'-10'	13'-8"	14'-7"	15'-3"
	4.5' NWC Above Flutes	Deck Gage						
	Deck Depth	22	21	20	19	18	17	16
	2	6'-2"	7'-6"	8'-1"	8'-11"	9'-8"	10'-3"	10'-9"
	3	6'-6"	7'-9"	8'-10'	10'-10'	11'-7"	12'-4"	13'-0"
1-Hr. Fire Rating	2.75' LWC Above Flutes	Deck Gage						
	Deck Depth	22	21	20	19	18	17	16
	2	8'-10'	9'-6"	10'-1"	11'-2"	12'-0"	12'-10'	13'-5"
	3	10'-1"	11'-7"	12'-3"	13'-6"	14'-5"	15'-4"	16'-1"
	3.5' NWC Above Flutes	Deck Gage						
	Deck Depth	22	21	20	19	18	17	16
	2	7'-2"	8'-2"	8'-8"	9'-7"	10'-4"	11'-0"	11'-7"
	3	7'-5"	8'-10'	10'-1"	11'-7"	12'-5"	13'-3"	13'-11"

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FM Global Data for Roof Deck

Vulcraft Division – Nucor Corp 2100 Rexford Rd Charlotte NC 28211

Trade Name:	Type 1.5A
Type:	Type A Narrow Rib
Thickness:	18, 20 or 22 ga. (0.0474, 0.0358, 0.0295 in. [1.2, 0.91, 0.75 mm])
Depth:	1.5 in. (38 mm)
Max Spans:	4 ft 10 in. (1.5 m) for 22 ga. (0.0295 in. [0.75 mm]) 5 ft 3 in. (1.6 m) for 20 ga. (0.0358 in. [0.91 mm]) 6 ft 0 in. (1.8 m) for 18 ga. (0.0474 in. [1.20 mm])
Trade Name:	Type 1.5F
Type:	Type F Intermediate Rib
Thickness:	18, 20 or 22 ga. (0.0474, 0.0358, 0.0295 in. [1.2, 0.91, 0.75 mm])
Depth:	1.5 in. (38 mm)
Max Spans:	4 ft 11 in. (1.5 m) for 22 ga. (0.0295 in. [0.75 mm]) 5 ft 5 in. (1.7 m) for 20 ga. (0.0358 in. [0.91 mm]) 6 ft 3 in. (2.0 m) for 18 ga. (0.0474 in. [1.20 mm])
Trade Name:	Type 1.5B, 1.5BI
Type:	Type B Wide Rib
Thickness:	18, 20 or 22 ga. (0.0474, 0.0358, 0.0295 in. [1.2, 0.91, 0.75 mm])
Depth:	1.5 in. (38 mm)
Max Spans:	6 ft 0 in. (1.8 m) for 22 ga. (0.0295 in. [0.75 mm]) 6 ft 6 in. (2.0 m) for 20 ga. (0.0358 in. [0.91 mm]) 7 ft 5 in. (2.3 m) for 18 ga. (0.0474 in. [1.20 mm])

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Secondary Roof Members

- Cold formed members
- Open Web Steel Joists
- HSS

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C and Z Purlins

Designed as Continuous Members

- Z's can be nested
- Z's can be loaded through shear center, C's cannot
- Z's may have principal axis vertical

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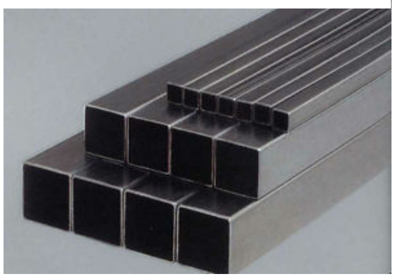
Open Web Steel Joists

- Load tables for uniformly loaded simple span members
- For other end conditions and other loading conditions see the SJI Catalog

HSS

- Used primarily for columns and lintels



Wall Systems

- Field Assembled Metal Panels
- Factory Assembled Metal Panels
- Precast Concrete Panels
- Masonry Walls

Wall Systems- Considerations

Cost Interior Surface Characteristics
Appearance Acoustical Considerations
Insulating Properties Fire Consideration
Dust Control Ease of Erection
Maintenance Considerations
Ease of Future Expansion
Speed of Erection

Field Assembled Panels

- Rapid Erection
- Good Cost Competition
- Easily Replaced
- Openings Easily Created
- Panels Are Lightweight
- Easy Acoustic Treatment

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Factory Assembled Panels

- Light Weight
- Hard Interior Liner
- "Clean" Appearance

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Factory Assembled Panels

- Color matching for expansion may be a problem
- Inside - Outside temperature gradient may cause bowing between girts
- Openings may be difficult
- Attention to details and tolerances is important

Precast Wall Panels

Hollow Core Slabs
Double - T Sections
Site Cast Tilt - Up Panels
Factory Cast Panels

Precast Wall Panels

- Hard Surface
- Excellent Fire Resistance
- Less Maintenance
- Girts Not Required
- Excellent Sound Barrier

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Precast Wall Panels

- Color matching may be difficult
- Possible condensation problems
- Adding wall openings difficult
- Require heavier foundations
- Require heavier eave struts
- Heavy cranes required for erection
- Future expansion may be difficult

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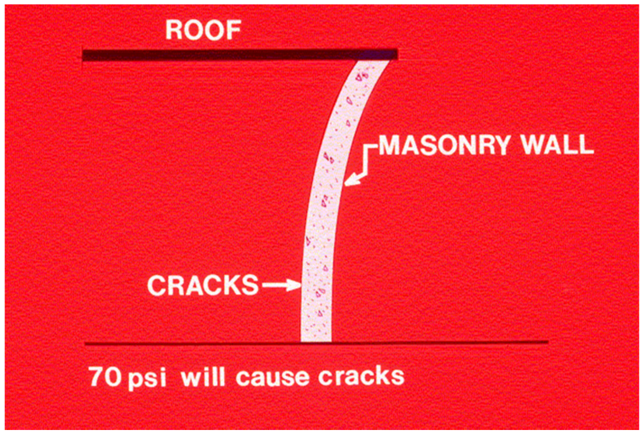
Masonry Walls

- Many colors, textures and finishes available
- Economical
- Special reinforcement is easy
- Can be utilized as shear walls
- Easy maintenance

Masonry Walls

- Low bending resistance
- May require heavy foundation
- Special considerations required for masonry ties

Masonry Wall Cracks



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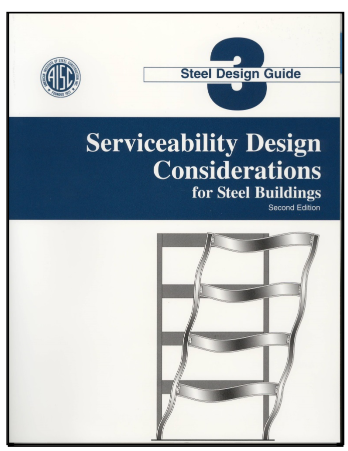
Checks for Masonry Walls



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Girts

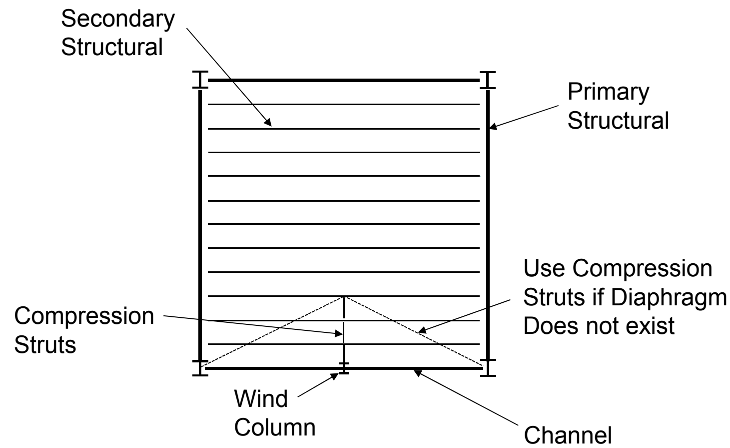
Required for metal panels and some precast and masonry panels.

C and Z, hot or cold rolled sections most commonly used.

Wind Columns

- Bay spacing greater than 30 feet
- End Walls
- Suction and Uplift may be important
- Roof must take top reaction

Wind Columns



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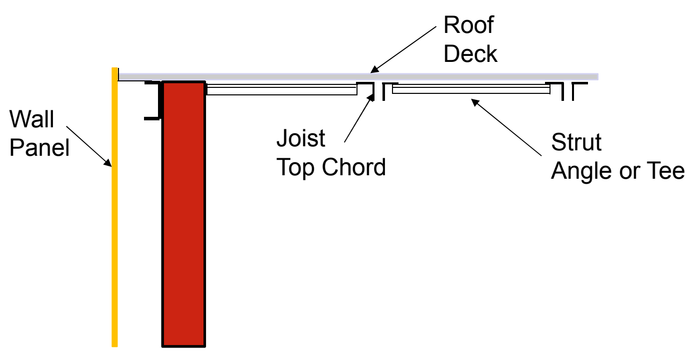
Wind Columns



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Serviceability Limit States

- Expansion and Contraction
- Deflection

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Strength vs. Serviceability

- Strength limit states control the safety of the structure and must be met.
- Serviceability limit states define the functional performance of the structure and should be met.
- Consider different loading requirements.

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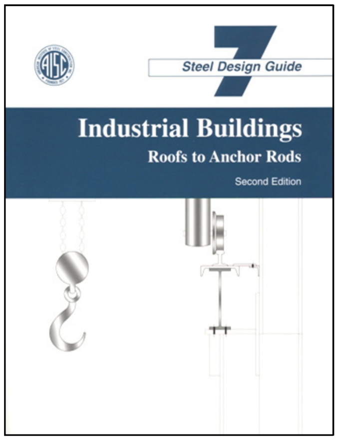
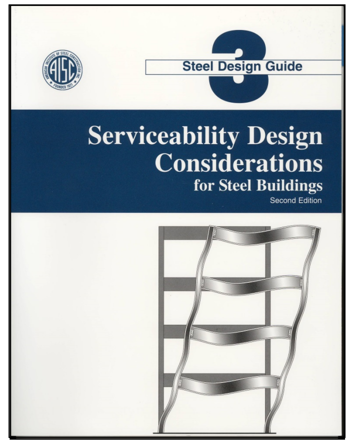
AISC Design Guides





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Serviceability Requirements

- Live Load Deflection Limit for Roof Members
  - Joists and Joist Girders: Span/240
  - SSR: Span/180
- Deflection Limit for Walls
  - Wind Columns: Span/120- 10 year wind
  - Girts: Span/120- 10 year wind
  - Panels: Span/120- 10 year wind

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Serviceability- SSR

Structural Element	Deformation	Recommended	Loading
Expansion Joints	Horizontal Movement	150 ft. to 200 ft. Maximum	Thermal
Roof	Slope	1 / 4 in. per ft. Minimum	Drainage
Purlin	Vertical Deflection	L / 150 Maximum	Snow Load
Purlin	Vertical Deflection	Positive Drainage	DL+ 0.5 x Snow DL+ 5 psf (min)

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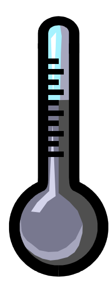
Expansion Joints

VARIABLES

Mean temperature during construction



Expected service temperature range

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Expansion Joints

This lesson will focus on the basic requirements used to determine if an expansion joint is required at a given location, or locations, within a structure.

Area dividers as provided in roof membranes to control the effects of thermal loads for roofing are not discussed, as they are relief joints in the membrane and do not require a joint in the roof structure below.

Control joints for materials other than structural steel are also eliminated from this discussion.

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Expansion Joints

- AISC 360, Section L.7, "The effects of thermal expansion and contraction of a building shall be considered."
- ASCE 7-10, Appendix C: "Dimensional changes in a structure and its elements due to variations in temperature, relative humidity, or other effects shall not impair the serviceability of the structure."

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General Requirements

From the National Roofing Contractors Association, structural expansion joints shall be used:

- Where steel framing, structural steel, or decking change direction.
- Where separate wings of L, U, T or similar configurations exist.
- Where the type of decking changes, for example, where a precast concrete deck and a steel deck abut.
- Where additions are connected to existing buildings.
- At junctions where interior heating conditions change, such as a heated office abutting unheated warehouse, canopies, etc.
- Where movement between vertical walls and the roof deck may occur.

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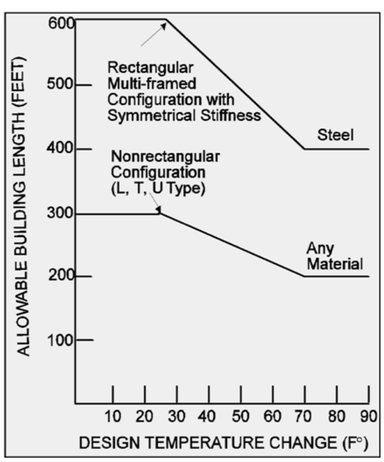
Length Between Expansion Joints vs. Design Temperature Change



Federal Construction Council, 1974

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Use of the Curves

The curves are directly applicable to buildings of beam and column construction, hinged at the base, and with heated interiors. When other conditions prevail, the following rules are applicable:

1. If the building will be heated only and will have hinged-column bases, use the allowable length as specified;
2. If the building will be air conditioned as well as heated, increase the allowable length by 15 percent (provided the environmental control system will run continuously);
3. If the building will be unheated, decrease the allowable length by 33 percent;
4. If the building will have fixed column bases, decrease the allowable length by 15 percent;
5. If the building will have substantially greater stiffness against lateral displacement at one end of the plan dimension, decrease the allowable length by 25 percent.

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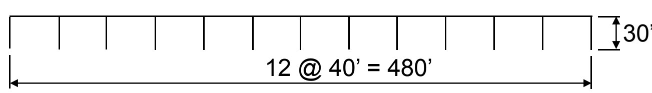
Analytical Calculation-Moment Frame



All columns: W12X90 All beams: W24X52

Δ_T = 50^0 F

Fixed base M = 74.4 kip-ft., Δ = 0.87 in. *f* = 6.2 ksi

Pinned base M = 36.5 kip-ft., Δ = 0.92 in. *f* = 3.1 ksi

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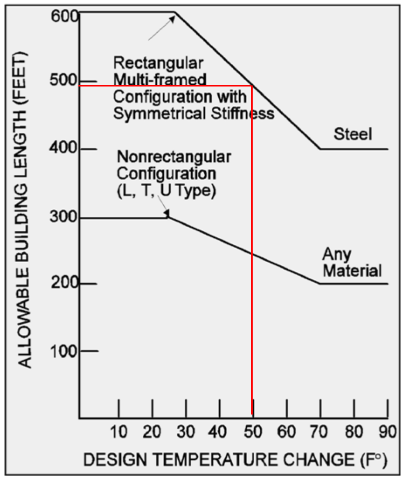
Federal Construction Council



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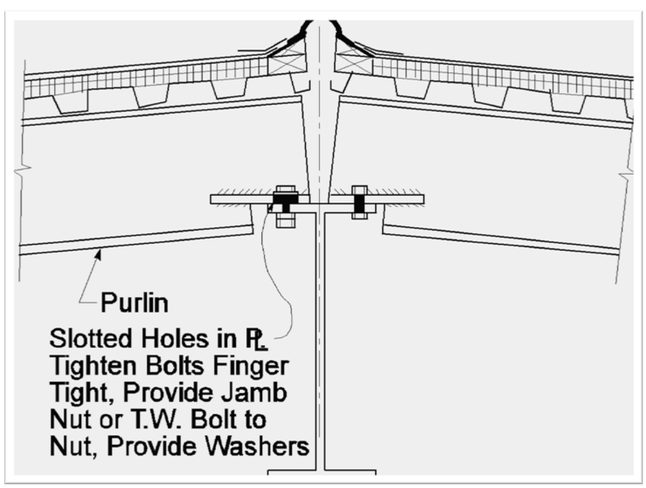
Beam Expansion Joint



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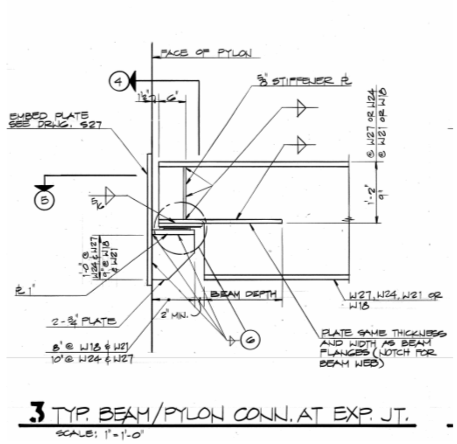
Beam Expansion Joint



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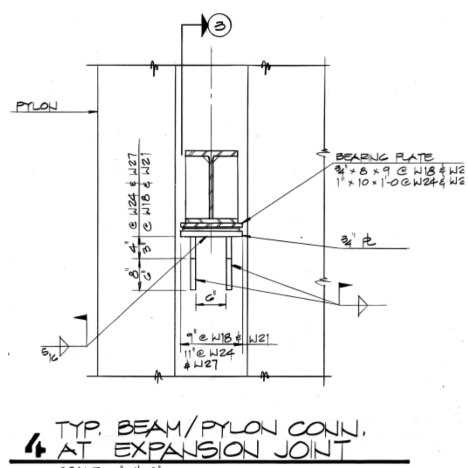
Beam Expansion Joint



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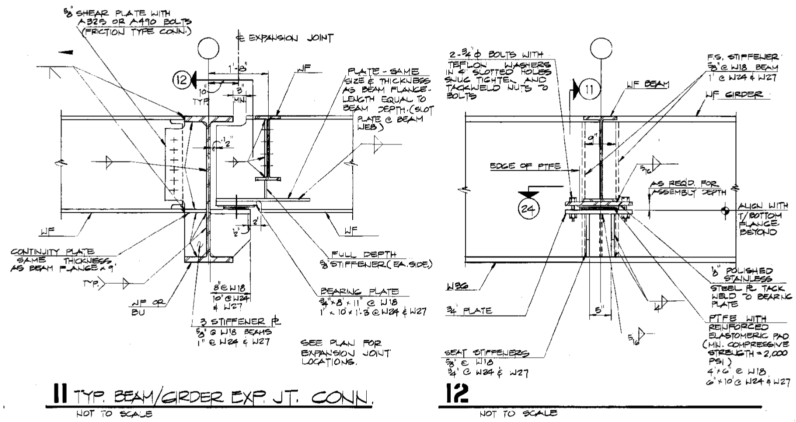
Beam Expansion Joint



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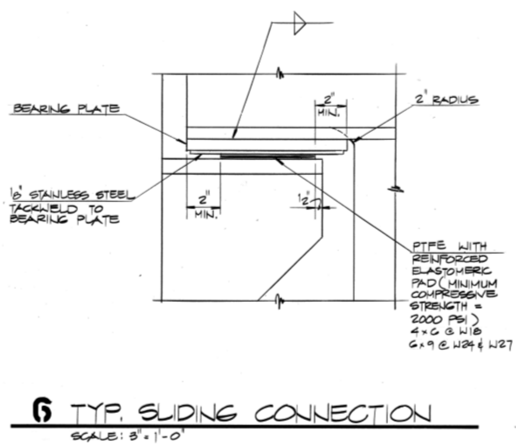
Beam Expansion Joint



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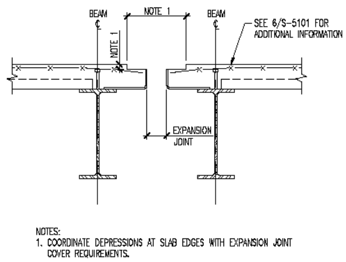
Deck Expansion Joint



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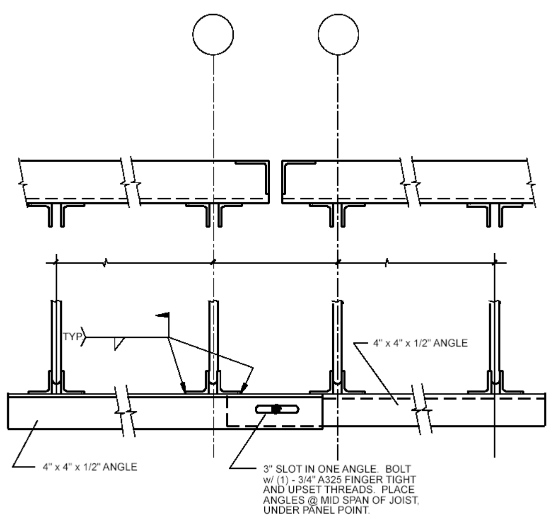
Special Details



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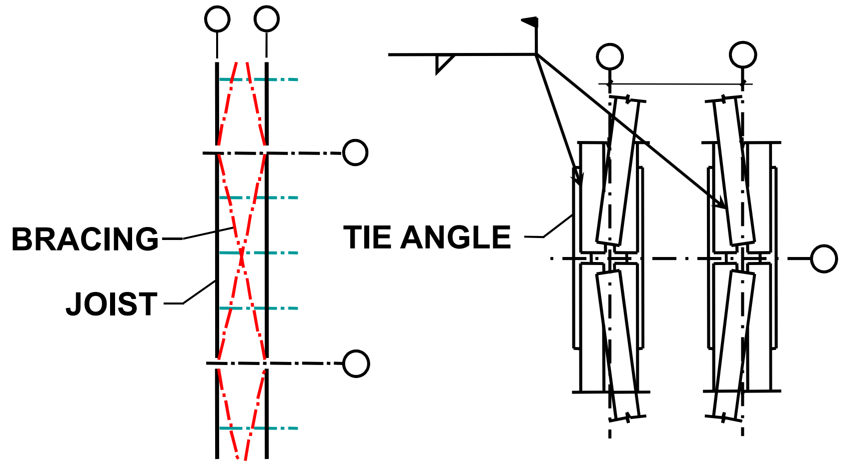
Expansion Joint Shear Transfer



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1.1#

Overhead Crane Buildings- Crane Runway Beams

Only as a last resort should expansion joints are provided for runway beams:

- By providing oversize holes at the beam ends expansion and contraction can be allowed in each beam segment, so that an expansion joint is not necessary.
- If an expansion joint is provided in the runway system, careful consideration must be given as to how the lateral crane forces are transferred across the joint.
- Special details are required to prevent high shears in the crane rail, and large forces in the rail clamps.

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Overhead Crane Buildings-Crane Rails

Expansion joints should never be provided in the crane rails:

- Such joints often lead to rail cracking. In lieu of such joints, the rail should be allowed to expand toward the stops.
- Adequate space must be allowed between the end of the rail and the face of the crane stops.
- In addition, a rail clamping system which allows longitudinal expansion and contraction of the rail must be provided, particularly in runway systems which exceed 400 ft. in length.

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Large Clear Span Structures

- Long span structures and components often require special expansion joint hardware.

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End of Lesson 1

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PDH Certificates
Within 2 business days…

- You will receive an email on how to report attendance from: registration@aisc.org.
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- 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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8-Session Registrants

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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 Thursday. 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 - click on Current Course Details.

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 Thursday. 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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Thank You

Please give us your feedback!
Survey at conclusion of webinar.

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