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Course Description

Steel Framed Stairway Design

Part 2: Seismic Loads & Delegated Design

June 6, 2018

This session provides information regarding code requirements for seismic loading and serviceability criteria, guard/handrail design, design examples, considerations related to construction tolerances, additional design considerations, and delegated design.

Learning Objectives

- Describe how seismic loads are combined with gravity loads in steel stair design.
- Select details that might be used to allow for stair movement during seismic events.
- Identify the items to be included in design documents when delegating the structural design of steel stairs.
- List tolerances to be accounted for at the interface between steel stairs and concrete or masonry elements.

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Steel Framed Stairway Design

Presented by
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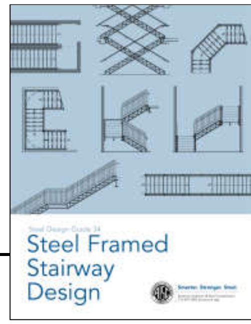
Introduction

AISC Design Guide 34: Steel Framed Stairway Design

to be published late summer / fall

will be available at
www.aisc.org/designguides
free download for members or
available for purchase



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Outline – Part 1 Recap

Step 1 – Purpose & Design Philosophy
Step 2 – Stairway Overview
Step 3 – Code Requirements - Gravity
Step 4 – Stairway Design
Step 5 – Members & Connx
Step 6 – Examples

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Outline – Part 2

Step 7 – Code Requirements – Seismic Loading
Step 8 – Seismic Serviceability
Step 9 – Stairway Design
Step 10 – Examples
Step 11 – Delegated Design
Step 12 – Other Topics

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Outline – Part 2

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Step 12 – Other Topics

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Applicable Codes

- International Building Code (IBC)
  - Chapter 16 "Structural Design" – Loads, Combos, & Serviceability
- ASCE/SEI 7-16 Minimum Design Loads for Buildings & Other Structures
  - Chapter 2 Combinations of Loads
  - Chapter 11 Seismic Design Criteria
  - Chapter 12 Seismic Design Criteria for Building Structures
  - Chapter 13 Seismic Design Criteria for Nonstructural Components

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Load Combinations

- Refer to ASCE7-16 Chapter 2 for LRFD & ASD Load Combinations

LRFD

1. 1.4D
2. 1.2D+1.6L+0.5(Lr or S or R)
3. 1.2D+1.6(Lr or S or R)+1.0(L or 0.5W)
4. 1.2D+1.0W+1.0L+0.5(Lr or S or R)
5. 0.9D+1.0W
6. 1.2D+1.0Ev+1.0Eh+1.0L+0.2S
7. 0.9D-1.0Ev+1.0Eh

ASD

1. D
2. D+L
3. D+(Lr or S or R)
4. D+0.75L+0.75(Lr or S or R)
5. D+0.6W
6. D+0.75L+0.75(0.6W)+0.75(Lr or S or R)
7. 0.6D+0.6W
8. D+0.7Ev+0.7Eh
9. D+0.525Ev+0.525Eh+0.75L+0.75S
10. 0.6D-0.7Ev+0.7Eh

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Loading – ASCE 7-16

- General Structural Integrity, Section 1.4.2 (SDC = A)
  - $F_x = 0.01 W_x$ (1.4-1)
- Seismic Loads (SDC = B, C, D, E, F)
  - Seismic Design Criteria (i.e. S_{DS}) per Chapter 11 or from SER General Notes drawing
    - S_{DS} = spectral acceleration, short period
  - Stairs to be designed per Chapter 13 for Nonstructural Components

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Loading – ASCE 7-16

- Horizontal Seismic Design Force, Eq. 13.3-1

$$F_P = \frac{0.4 a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)}\left(1 + 2\frac{z}{h}\right)$$

F_p = horizontal seismic design force at component center of gravity
- I_p = component importance factor per Section 13.1.3

Refer to Table 13.5-1
- a_p = component amplification factor
- R_p = component response modification factor

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Loading – ASCE 7-16, Table 13.5-1

TABLE 13.5-1 Coefficients for Architectural Components

Architectural Component	a_p[a]	R_p[b]	Ω_0[c]
Egress stairways not part of the building ~~structure~~ seismic force-resisting system	1	2 ½	~~2 ½~~ 2
Egress stairs and ramp fasteners and attachments	2 ½	2 ½	2 ½

Previously (ASCE 7-10): $a_p = 1$, $R_p = 2½$, $\Omega_0 = 2½$

a_p = component amplification factor
R_p = component response modification factor
Ω_0 = overstrength factor for anchorage to concrete & masonry

Loading – ASCE 7-16, Table 13.5-1

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a_p = component amplification factor
R_p = component response modification factor
Ω_0 = overstrength factor for anchorage to concrete & masonry

Loading – ASCE 7-16, Table 13.5-1

- Multiple design criteria

1. Design of members and connection material:
   – a_p=1.0, R_p=2.5
2. Design of fasteners/attachment (bolts/welds):
   – a_p=2.5, R_p=2.5 *(250% increase in forces from 2010)*

Loading – ASCE 7-16, Table 13.5-1

3. Design of fasteners/attachment (anchors, embeds) in concrete/masonry:
   – Ω_0 = 2.5 *(250% increase in forces from 2010 due to a_p = 2.5)*
   – Or ductile yielding of support/component
4. Design of concrete/masonry member:
   – Ω_0 = 2.0 *(20% reduction in forces from 2010)*
   – Or ductile yielding of support/component

Loading – ASCE 7-16

- Horizontal Seismic Design Force, Eq. 13.3-1

$$F_P = \frac{0.4 a_p S_{DS} W_p}{\left(\frac{R_p}{I_p}\right)}\left(1+2\frac{z}{h}\right)$$

For stair members:
- I_p = 1.5

Refer to Table 13.5-1
- a_p = 1.0
- R_p = 2.5

Loading – ASCE 7-16

- Horizontal Seismic Design Force, Eq. 13.3-1

$$F_{p,\text{ stairs}} = 0.24 S_{DS} W_p \left(1+2\frac{z}{h}\right)$$

S_{DS} = short period spectral acceleration
W_p = component weight (dead load only)
z = component height from grade at point of attachment
h = average roof height
(z/h) may conservatively be taken as 1.0

Loading – ASCE 7-16

- Horizontal Seismic Design Force
  - Minimum per Eq. 13.3-3

$$F_{p,\text{ min}} = 0.3 S_{DS} I_p W_p$$

  - Maximum per Eq 13.3-2

$$F_{p,\text{ max}} = 1.6 S_{DS} I_p W_p$$

Loading – ASCE 7-16

- Horizontal Seismic Design Force for Stairs
  - If I_p=1.5 and (z/h)=1.0

$$F_{p,\text{ stairs, min}} = 0.45 S_{DS} W_p$$

$$F_{p,\text{ stairs}} = 0.72 S_{DS} W_p$$

$$F_{p,\text{ stairs, max}} = 2.4 S_{DS} W_p$$

Loading – ASCE 7-16

- Vertical Seismic Design Force per Section 13.3.1.2

$$F_{pv} = \pm 0.2 S_{DS} W_p$$

Seismic Load Combos

Refer to Sections 2.3.6 LRFD, 2.4.5 ASD, & 12.4.2.1/12.4.2.2 for combinations with F_{pv}

LRFD

6. $1.2D+0.2S_{DS}D+Q_E+L+0.2S$
7. $0.9-0.2S_{DS}D+Q_E$

ASD

8. $1.0D+0.7(0.2S_{DS})D+0.7Q_E$
9. $1.0D+0.525(0.2S_{DS})D+0.75L+0.525Q_E+0.75S$
10. $0.6D-0.7(0.2S_{DS})D+0.7Q_E$

Apply to dead load only

Seismic Load Combos - Anchorage

- Refer to Sections 2.3.6 LRFD, 2.4.5 ASD, & 12.4.3/12.4.3.1 for combinations with overstrength factor Ω_0
- Use for design of anchors at concrete/masonry
- Ω_0 = 2.0 to 2.5 (SDC = B*, C, D, E, F) *Ω_0 = 1.0 for SDC B for concrete per ACI 318-14 section 17.2.3.1

LRFD

6. $1.2D+0.2S_{DS}D+\Omega_0 Q_E+L+0.2S$
7. $0.9D-0.2S_{DS}D+\Omega_0 Q_E$

ASD

8. $1.0D+0.7(0.2S_{DS})D+0.7\Omega_0 Q_E$
9. $1.0D+0.525(0.2S_{DS})D+0.75L+0.525\Omega_0 Q_E+0.75S$
10. $0.6D-0.7(0.2S_{DS})D+0.7\Omega_0 Q_E$

Apply Ω_0 to seismic portion of load only

Outline – Part 2

Step 7 – Code Requirements – Seismic Loading

Step 8 – Seismic Serviceability

Step 9 – Stairway Design

Step 10 – Examples

Step 11 – Delegated Design

Step 12 – Other Topics

Seismic Serviceability – ASCE 7-16

- Section 13.5.10 Egress Stairs & Ramps
  - Shall accommodate seismic displacement, D_{pI}
    - Occur in any horizontal direction
    - Positive attachment
    - Direct structural supports or mechanical connections
  - **Not** part of seismic force-resisting system of structure

Seismic Serviceability – ASCE 7-16

- Accommodate seismic displacement, D_{pl}
  - Direct structural supports or mechanical connections with following requirements:
    - A. Sliding connx with holes, keepers, or stops
      - D_{pl} or ½" minimum
      - Without loss of vertical support
      - Without inducing compression

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Seismic Serviceability – ASCE 7-16

B. Bearing style details
- $1.5D_{pl}$ or 1" minimum
- Without loss of vertical support

C. Metal supports with rotation capacity
- $1.5D_{pl}$ or 1" minimum
- Without loss of vertical support
- No brittle failure modes

D. Fasteners and attachments
- Design for R_p, a_p, Ω_0 per table 13.5-1

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Seismic Serviceability – ASCE 7-16

EXCEPTION:

- If sliding or ductile connections <u>not</u> provided then stair must be designed in the building structural model and designed for Ω_0 of structure, but minimum 2.5.

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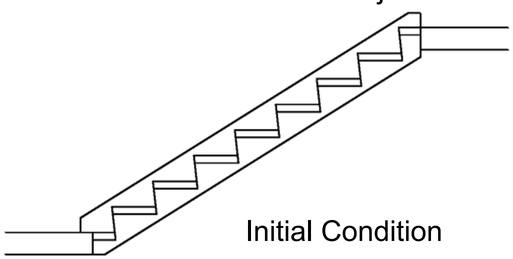
Serviceability – ASCE7-16 Section 13.3.2

- Seismic Displacement = Differential lateral movements between adjacent floors



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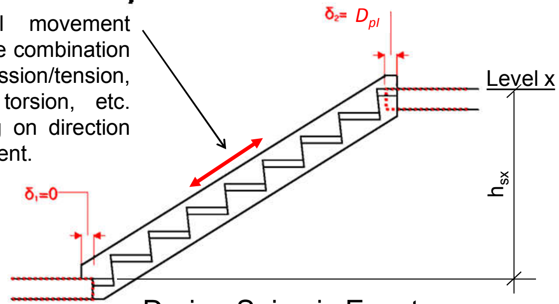
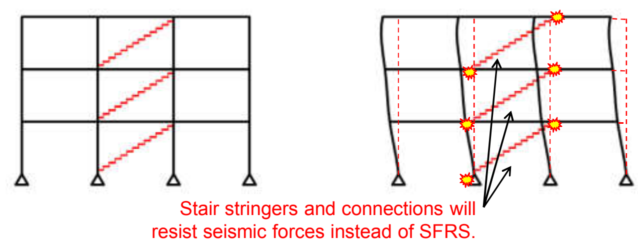
Seismic Displacement – ASCE 7-16

Differential movement may cause combination of compression/tension, bending, torsion, etc. depending on direction of movement.



Seismic Displacement – ASCE 7-16

- Stairs may provide inadvertent load path which braces building structure instead of seismic force resisting system (SFRS)



Seismic Displacement – ASCE 7-16

- *Some* damage is acceptable, as long as other performance goals are not jeopardized (i.e. life safety for egress stairs). Refer to ASCE 7-16 commentary.

Seismic Displacement – ASCE 7-16

- Refer to Section 13.3.2 Seismic Relative Displacements & Displacements within Structures 13.3.2.1

  $D_{pI} = D_p I_e$ (Eq 13.3-6)

  I_e = importance factor in Section 11.5.1 & Table 1.5-2

  $D_p = \delta_{xA} - \delta_{yA}$ (Eq 13.3-7)

  δ = deflection in building at x or y level

- **For delegated design, request SER provide accurate drift values for each floor level at each stairway**

Seismic Displacement – ASCE 7-16

- Alternatively, ASCE 7 equation 13.3-8 & Table 12.12-1

$$D_{p,\max} = \frac{(h_x - h_y)\Delta_{aA}}{h_{sx}} = \frac{(h_x - h_y)(x h_{sx})}{h_{sx}} = (h_x - h_y)(x)$$

  - h_x = height of level x
  - h_y = height of level y
  - h_{sx} = story height

Δ_{aA} = allowable story drift
$\Delta_{aA} = x h_{sx}$ (Table 12.12-1)
x = constant per Structure & Risk Category

- $D_{p,max}$ will result in large values that may be very difficult and costly to accommodate
- Designers can also use a linear dynamic procedure to determine D_p per Section 12.9.

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Seismic Displacement – ASCE 7-16

- How to accommodate seismic displacement?
  - Drift Details
  - Expansion joint or expansion gap
  - Connections / supports with rotation capacity
  - Design for imparted forces

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Seismic Displacement – ASCE 7-16

- Drift Details
  - Provide end connections allowing movement or drift at one end of stairway flight.
  - Other end connections must provide load path to resist lateral forces.
  - Use bearing for vertical loads.
  - Follow section 13.10.5 criteria A or B

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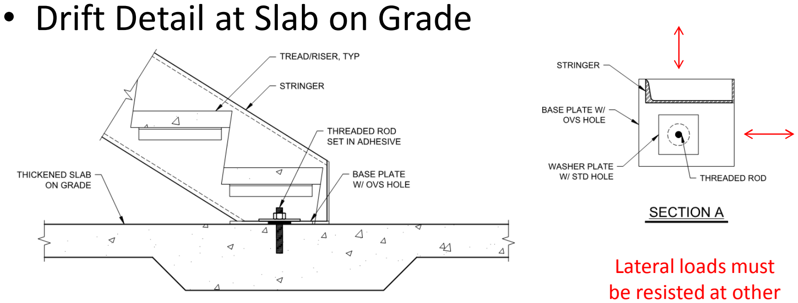
Seismic Displacement – ASCE 7-16

- Drift Detail at Slab on Grade



Lateral loads must be resisted at other end of stair flight.

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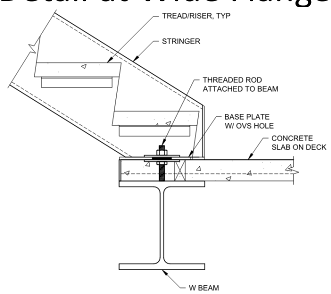
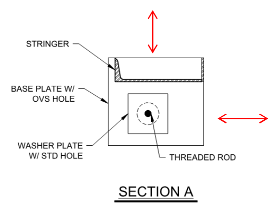
Seismic Displacement – ASCE 7-16

- Drift Detail at Wide Flange Beam





Lateral loads must be resisted at other end of stair flight.

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Seismic Displacement – ASCE 7-16

- Expansion joint or expansion cover
  - Likely requires input/approval from Architect
  - Provide gap allowing movement at one end of stairway flight.
  - Other end connections must provide load path to resist lateral forces.
  - Use bearing for vertical loads.
  - Follow section 13.10.5 criteria A or B

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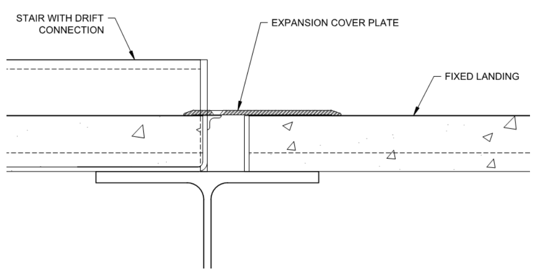
Seismic Displacement – ASCE 7-16

- Expansion joint or expansion cover



Lateral loads must be resisted at other end of stair flight.

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Seismic Displacement – ASCE 7-16

- Connections / supports with rotation capacity
  - Moment frame designed for imparted seismic displacement
  - Connections (that are part of a system) allowing for lateral displacement through the use of slotted/oversized holes or ductile elements
  - Requires careful detailing and analysis to ensure intended performance for seismic event

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Seismic Displacement – ASCE 7-16

- Design for imparted forces…
  …but remember:

$$\delta = \frac{PL}{AE} \quad \therefore \quad P = \frac{\delta AE}{L}$$

…likely results in very large forces.

- Needs to be part of building model for this analysis!

Outline – Part 2

Step 7 – Code Requirements – Seismic Loading
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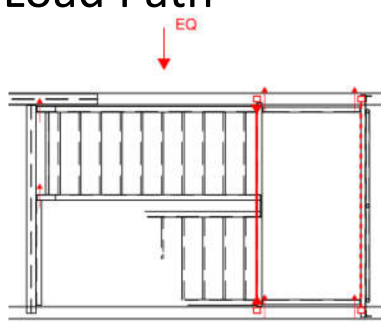
Horizontal Load Path

- How do we analyze stair flight?
- How are forces transferred through landings?

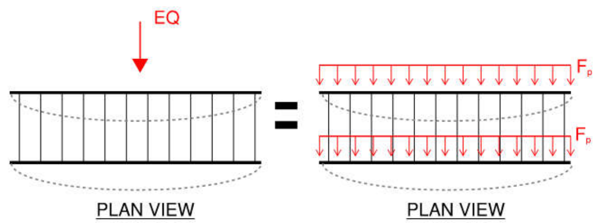


Stair Flight Assembly

- Load path for seismic forces on stair flight?
  - Option 1 – Individual Simple Span Members
  - Option 2 – Built-up Horizontal Beam
  - Option 3 – Cantilever Built-up Horizontal Beam
- Alternative options using engineering judgment

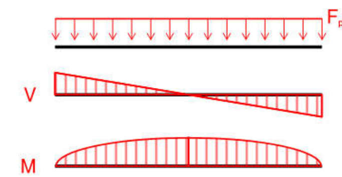
Stair Flight Assembly

- Option 1 – Individual Simple Span Members



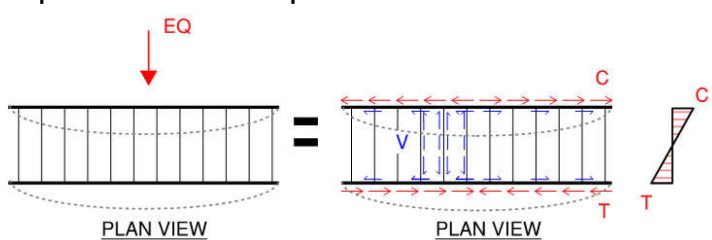
Stair Flight Assembly

- Option 1 – Individual Simple Span Members
  - Assumes ductile connx or rotation capacity at supports
  - Treat as a simple span beam with uniformly distributed load
  - Design per AISC Spec



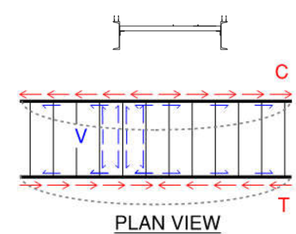
Stair Flight Assembly

- Option 2 – Built-up Horizontal Beam



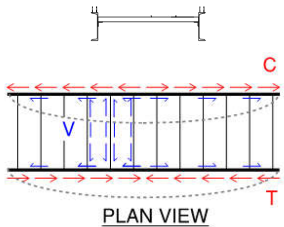
Stair Flight Assembly

- Option 2 – Built-up Horizontal Beam
  - Assumes ductile connx or rotation capacity at supports
  - Built-up beam may not satisfy local buckling criteria at treads/risers in many cases (AISC, AISI)
  - Difficult to quantify capacity of tread/riser elements



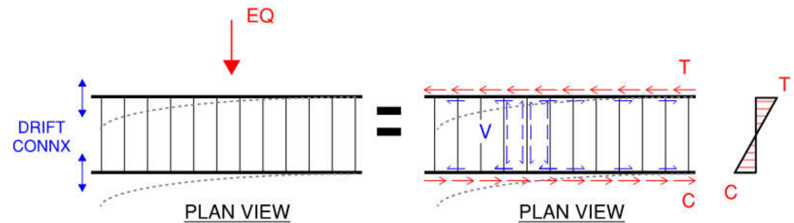
Stair Flight Assembly

- Option 2 – Built-up Horizontal Beam



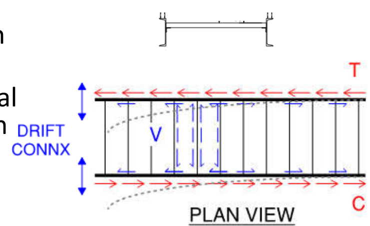
Stair Flight Assembly

- Option 3 – Cantilever Built-up Horizontal Beam



Stair Flight Assembly

- Option 3 – Cantilever Built-up Horizontal Beam
  - Assumes drift connx at one end
  - Force couple at opposite end with axial and weak axis connx forces
  - Built-up beam may not satisfy local buckling criteria at treads/risers in many cases (AISC, AISI)
  - Difficult to quantify capacity of tread/riser elements

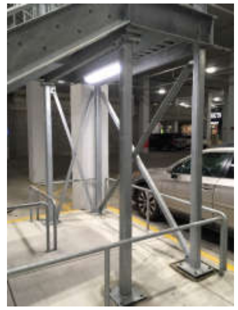


Landing Diaphragm

- Load path is more similar to conventional floor framing
  - Cast-in-place concrete over metal deck
    - Deck capacity / concrete capacity
  - Cast-in-place concrete over stiffened plate
  - Steel plate diaphragm

Vertical Load Path

- Best systems for stairs?
- Least impact on
  - Aesthetics
  - Space constraints
  - Cost



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Vertical Lateral Load Resisting Systems

Type	Advantages	Disadvantages
Tension Only Bracing	• Smaller member sizes • Can be concealed in walls • Can fit under landings	• Will require more members and more connections
Tension-Compression Bracing	• Less members • Less connections • Can be concealed in walls • Can fit under landings	• Members may be heavier and larger • Splices at member intersections are needed
Moment Frames	• Members do not cross path of travel (if required) • Can be concealed in walls • Beam member can also act as landing support member	• More lateral drift than other options • Connections typically more complex and more expensive

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Outline – Part 2

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Example 1: Load Determination

Given:

- OSHA Style Industrial Stair
- Location: Southern California
- Seismic Design Category = D
- Spectral Response, S_{DS} = 0.660g

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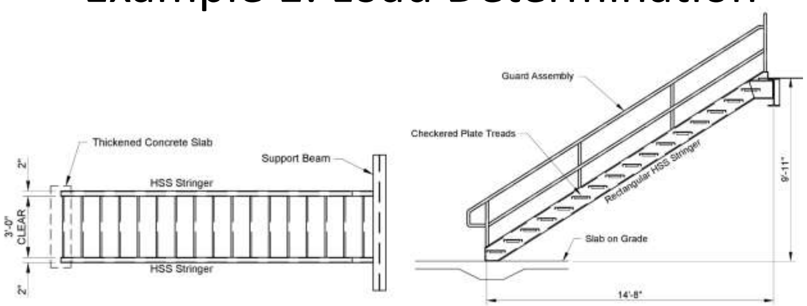
Example 1: Load Determination



PLAN SECTION

Example 1: Load Determination

- Load Combinations, ASCE7-16, 2.3.1 & 2.4.1

	LRFD	ASD	
2	1.2D + 1.6L	D+L	2

Example 1: Load Determination

- Load Combinations, ASCE7-16, 2.3.6 & 2.4.5

	LRFD	ASD	
6	$1.2D+E_v+E_h+L+0.2S$ $=1.2D+0.2S_{DS}D+\rho Q_E+L$ $=1.2D+0.2(0.660)D+1.0Q_E+L$ $=1.33D+1.0Q_E+L$	$1.0D+0.7E_v+0.7E_h$ $=1.0D+0.7(0.2S_{DS})D+0.7\rho Q_E$ $=1.0D+0.7(0.2(0.660))D+0.7(1.0)Q_E$ $=1.09D+0.7Q_E$	8
7	$0.9D-E_v+E_h$ $=0.9D-0.2S_{DS}D+\rho Q_E$ $=0.9D-0.2(0.660)D+1.0Q_E$ $=0.768D+1.0Q_E$	$1.0D+0.525E_v+0.525E_h+0.75L+0.75S$ $=1.0D+0.525(0.2S_{DS})D+0.525\rho Q_E+0.75L$ $=1.0D+0.525((0.2)(0.660))D+0.525(1.0)Q_E+0.75L$ $=1.07D+0.525Q_E+0.75L$	9
		$0.6D-0.7E_v+0.7E_h$ $=0.6D-0.7(0.2S_{DS})D+0.7\rho Q_E$ $=0.6D-0.7((0.2)(0.660))D+0.7(1.0)Q_E$ $=0.508D+0.7Q_E$	10

Example 1: Load Determination

- Horizontal Seismic Force, *Fp*

$$F_p=\frac{0.4a_pS_{DS}w_p}{\left(\frac{R_p}{I_p}\right)}\left(1+2\frac{z}{h}\right)$$

where

I_p = component importance factor from ASCE/SEI 7, Section 13.1.3	= 1.5
R_p = component response modification factor from ASCE/SEI 7, Table 13.5-1	= 2.5
S_{DS} = spectral acceleration, short period, determined from ASCE/SEI 7, Section 11.4.5	= 0.660g
a_p = component amplification factor from ASCE/SEI 7, Table 13.5-1	= 1.0
h = average roof height of structure with respect to base	= 19.8 ft
z= height in structure of point of attachment of component with respect to base	= 9.92 ft

Example 1: Load Determination

- Horizontal Seismic Force, *Fp*

$$F_p = \frac{0.4(1.0)(0.660)W_p}{\left(\frac{2.5}{1.5}\right)}\left[1+2\left(\frac{9.92\text{ ft}}{19.8\text{ ft}}\right)\right]$$
$$= 0.317W_p$$

Example 1: Load Determination

- Maximum Horizontal Seismic Force, *Fp max*

$$F_p \max = 1.6S_{DS}I_pW_p$$
$$= 1.6(0.660)(1.5)W_p$$
$$= 1.58W_p$$

- Minimum Horizontal Seismic Force, *Fp min*

$$F_p \min = 0.3S_{DS}I_pW_p$$
$$= 0.3(0.660)(1.5)W_p$$
$$= 0.297W_p$$

Example 1: Load Determination

- Vertical Seismic Force, *Fpv*

$$F_{pv} = \pm 0.2S_{DS}W_p$$
$$= \pm 0.2(0.660)W_p$$
$$= \pm 0.132W_p$$

Example 1: Load Determination

- Summary
  - Horizontal
    $F_p = 0.317W_p$
  - Vertical
    $F_{pv} = \pm 0.132W_p$

Remember, this is built into load combinations

Example 2: Stringer Design

Given:

- OSHA Style Industrial Stair
- Location: Southern California
- Seismic Design Category = D
- Spectral Response, S_{DS} = 0.660g
- Provide HSS A500 Gr. C Stringer

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Example 2: Stringer Design

Given:

- Supports with rotation capacity to accommodate seismic displacement using ductile connections
- Checkered plate tread/risers
  - Stringer fully braced
  - For seismic lateral loads, design as individual members

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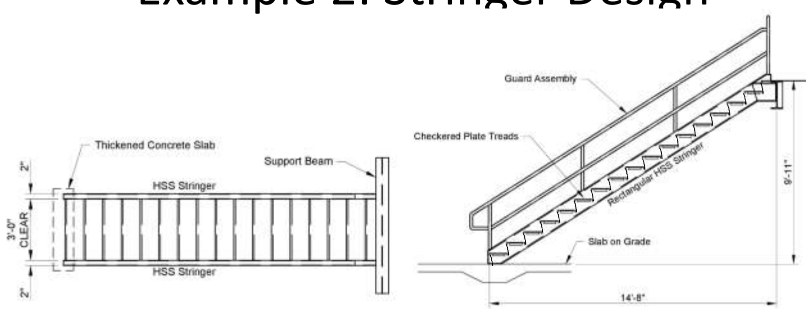
Example 2: Stringer Design



PLAN

SECTION

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Example 2: Stringer Design

- Imposed Gravity Loading

Dead Load:			
Stringer Self weight, HSS12x2x1/4			
Guard Self weight			
3/16" Checkered Plate	=	10	psf
Total	=	10	psf
Live Load:			
Live load – Case 1	=	60	psf
Or			
Live load – Case 2	=	1000	lbs

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Example 2: Stringer Design

- Stringer Gravity Uniform Loads

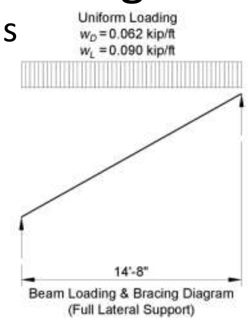
Dead Load:				
Stringer Self weight (22.42 lb/ft X 1.19 slope factor)		=	26.7	lb/ft
Guard Self weight (20 lb/ft)		=	20	lb/ft
3/16" Checkered Plate	= 10 psf X 1.5'	=	15	lb/ft
Total		=	61.7	lb/ft
Live Load:				
Live load	= 60 psf X 1.5'	=	90	lb/ft
Total		=	90	lb/ft

Example 2: Stringer Design

- Stringer Gravity Uniform Loads

$$w_D = \left(\frac{3\text{ ft}}{2}\right)\left(0.010\text{ kip/ft}^2\right) + \left(0.0267\text{ kip/ft} + 0.020\text{ kip/ft}\right)$$
$$= 0.0617\text{ kip/ft}$$

$$w_L = \left(\frac{3\text{ ft}}{2}\right)\left(0.060\text{ kip/ft}^2\right)$$
$$= 0.090\text{ kip/ft}$$



Example 2: Stringer Design

LRFD	ASD
Uniform loading	*Uniform loading*
$w_u = \left(\frac{3\text{ ft}}{2}\right)\left[1.2\left(0.010\text{ kip/ft}^2\right) + 1.6\left(0.060\text{ kip/ft}^2\right)\right]$ $+1.2\left(0.0267\text{ kip/ft} + 0.020\text{ kip/ft}\right)$ $= 0.218\text{ kip/ft}$	$w_a = \left(\frac{3\text{ ft}}{2}\right)\left[\left(0.010\text{ kip/ft}^2\right) + \left(0.060\text{ kip/ft}^2\right)\right]$ $+\left(0.0267\text{ kip/ft} + 0.020\text{ kip/ft}\right)$ $= 0.152\text{ kip/ft}$
$V_u = \frac{14.7\text{ ft}}{2}\left(0.218\text{ kip/ft}\right)$ $= 1.60\text{ kips}$	$V_a = \frac{14.7\text{ ft}}{2}\left(0.152\text{ kip/ft}\right)$ $= 1.12\text{ kips}$
$M_u = \frac{\left(0.218\text{ kip/ft}\right)\left(14.7\text{ ft}\right)^2}{8}$ $= 5.89\text{ kip-ft}$	$M_a = \frac{\left(0.152\text{ kip/ft}\right)\left(14.7\text{ ft}\right)^2}{8}$ $= 4.11\text{ kip-ft}$

Example 2: Stringer Design

- Stringer Point Load, 1000 lbs

Point loading	*Point loading*
$V_u = \frac{14.7\text{ ft}}{2}\left[1.2\left(0.0617\text{ kip/ft}\right)\right] + 1.6\left(1\text{ kip}\right)$ $= 2.14\text{ kips}$ GOVERNS	$V_a = \frac{14.7\text{ ft}}{2}\left(0.0617\text{ kip/ft}\right) + 1\text{ kip}$ $= 1.45\text{ kips}$ GOVERNS
$M_u = \frac{1.2\left(0.0617\text{ kip/ft}\right)\left(14.7\text{ ft}\right)^2}{8}$ $+\frac{1.6\left(1\text{ kip}\right)\left(14.7\text{ ft}\right)}{4}$ $= 7.88\text{ kip-ft}$ GOVERNS	$M_a = \frac{\left(0.0617\text{ kip/ft}\right)\left(14.7\text{ ft}\right)^2}{8} + \frac{\left(1\text{ kip}\right)\left(14.7\text{ ft}\right)}{4}$ $= 5.34\text{ kip-ft}$ GOVERNS

Example 2: Stringer Design

- Summary, Gravity Loads

	LRFD	ASD
w	0.218 k/ft	0.152 k/ft
V	2.14 k	1.45 k
M	7.88 k-ft	5.34 k-ft

Refer to *Specification* Section G1 & Manual Table 3-12
For HSS12x2x1/4 A500 Gr. C
LRFD
ΦvVn = 142 k > 2.14 k OK
ΦbMp = 75.4 k-ft > 7.88 k-ft OK
ASD
Vn/Ωv = 94.6 k > 1.45 k OK
Mp/Ωb = 50.1 k-ft > 5.34 k-ft OK

HSS12x2x1/4 is adequate for imposed gravity loads

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Example 2: Stringer Design

- Seismic Loading
  - Consider equivalent uniform load for concentrated point load since it will govern design

$$P_L = 1\text{ kip}$$
$$M = \frac{PL}{4} = \frac{wL^2}{8}$$

therefore...

$$w_{Leq} = \frac{2P}{L} = \frac{2(1\text{ kip})}{14.7\text{ ft}} = 0.136\text{ kip/ft}$$
$$w_{Leq} = 0.136\text{ kip/ft} > w_L = 0.090\text{ kip/ft}$$

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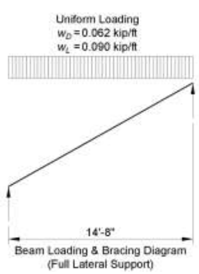
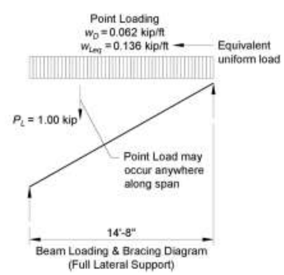
Example 2: Stringer Design





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Example 2: Stringer Design

- Stringer Vertical Loads, Seismic Load Combo

LRFD	ASD
$1.33D + 1.0Q_E + L$ (Controls for stringer design)	$1.07D + 0.525Q_E + 0.75L$ (Controls for stringer design)
$V_{u,v} = \left(\frac{14.7\text{ ft}}{2}\right)\begin{bmatrix}1.33(0.0617\text{ kip/ft})\\+1.0(0)\\+(0.136\text{ kip/ft})\end{bmatrix} = 1.60\text{ kips}$	$V_{a,v} = \left(\frac{14.7\text{ ft}}{2}\right)\begin{bmatrix}1.07(0.0617\text{ kip/ft})\\+0.525(0)\\+0.75(0.136\text{ kip/ft})\end{bmatrix} = 1.23\text{ kips}$
$M_{u,v} = \frac{(14.7\text{ ft})^2}{8}\begin{bmatrix}1.33(0.0617\text{ kip/ft})\\+1.0(0)\\+(0.136\text{ kip/ft})\end{bmatrix} = 5.89\text{ kip-ft}$	$M_{a,v} = \frac{(14.7\text{ ft})^2}{8}\begin{bmatrix}1.07(0.0617\text{ kip/ft})\\+0.525(0)\\+0.75(0.136\text{ kip/ft})\end{bmatrix} = 4.54\text{ kip-ft}$

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Example 2: Stringer Design

- Summary - Vertical Loads, Seismic Load Combo

	LRFD	ASD
w	0.218 k/ft	0.168 k/ft
V	1.60 k	1.23 k
M	5.89 k-ft	4.54 k-ft

Refer to *Specification* Section G1 &
Manual Table 3-12
For HSS12x2x1/4 A500 Gr. C
LRFD
ΦvVn = 142 k > 1.60 k OK
ΦbMp = 75.4 k-ft > 5.89 k-ft OK
ASD
Vn/Ωv = 94.6 k > 1.23 k OK
Mp/Ωb = 50.1 k-ft > 4.54 k-ft OK

HSS12x2x1/4 is adequate for imposed vertical loads

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Example 2: Stringer Design

- Horizontal Loading

$$F_{ph} = 0.317W_p$$
$$= 0.317(0.062 \text{ kip/ft})$$
$$= 0.020 \text{ kip/ft}$$

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Example 2: Stringer Design

- Horizontal Loads, Seismic Load Combo

LRFD	ASD
$1.33D + 1.0Q_E + L$ (Controls for stringer design)	$1.07D + 0.525Q_E + 0.75L$ (Controls for stringer design)
$V_{u,h} = \left(\frac{14.7 \text{ ft}}{2}\right)\left[1.33(0) + 1.0(0.020 \text{ kip/ft}) + 0\right] = 0.147 \text{ kip}$	$V_{a,h} = \left(\frac{14.7 \text{ ft}}{2}\right)\left[1.07(0) + 0.525(0.020 \text{ kip/ft}) + 0.75(0)\right] = 0.0772 \text{ kip}$
$M_{u,h} = \frac{(14.7 \text{ ft})^2}{8}\left[1.33(0) + 1.0(0.020 \text{ kip/ft}) + 0\right] = 0.540 \text{ kip-ft}$	$M_{a,h} = \frac{(14.7 \text{ ft})^2}{8}\left[1.07(0) + 0.525(0.020 \text{ kip/ft}) + 0.75(0)\right] = 0.284 \text{ kip-ft}$

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Example 2: Stringer Design

- Summary - Horizontal Loads, Seismic Load Combo

	LRFD	ASD
w	0.020 k/ft	0.0105 k/ft
V	0.147 k	0.077 k
M	0.540 k-ft	0.284 k-ft

Refer to *Specification* Section G1 &
Manual Table 3-12
For HSS12x2x1/4 A500 Gr. C
LRFD
ΦvVn = 16.4 k > 0.147 k OK
ΦbMp = 13.3 k-ft > 0.540 k-ft OK
ASD
Vn/Ωv = 10.9 k > 0.077 k OK
Mp/Ωb = 8.87 k-ft > 0.284 k-ft OK

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Example 2: Stringer Design

- Check Interaction
  - Because $P_r/P_c < 0.2$, use AISC *Specification* Equation H1-1b:

LRFD	ASD
$\frac{P_r}{2P_c} + \left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) \le 1.0$	$\frac{P_r}{2P_c} + \left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) \le 1.0$
$0 + \left(\frac{5.89\text{ kip-ft}}{75.4\text{ kip-ft}} + \frac{0.540\text{ kip-ft}}{13.3\text{ kip-ft}}\right) \le 1.0$	$0 + \left(\frac{4.54\text{ kip-ft}}{50.1\text{ kip-ft}} + \frac{0.284\text{ kip-ft}}{8.87\text{ kip-ft}}\right) \le 1.0$
$0.119 < 1.0$ **o.k.**	$0.123 < 1.0$ **o.k.**

HSS12x2x1/4 is adequate for seismic loads

Example 2: Stringer Design

- Not quite done…
  - Consider seismic loads parallel to stair flight resulting in axial forces (and vertical loads)
  - Connection design
    - Remember that anchorage to concrete or masonry requires the use of load combinations with overstrength factor, Ω_0

Outline – Part 2

Step 7 – Code Requirements – Seismic Loading
Step 8 – Seismic Serviceability
Step 9 – Stairway Design
Step 10 – Examples
Step 11 – Delegated Design
Step 12 – Other Topics

Delegated Design

- Design Team (architect/SER) request contractor or fabricator to complete an aspect of design. For stairs:
  - Option 1 – Delegate all aspects of design
    - Contractor makes all design decisions with code input from design documents
  - Option 2 – Delegate structural engineering *(most common)*
    - Use design documents for architectural & code
  - Option 3 – Design-build
    - Use design documents and coordination with Design Team to establish parameters

Delegated Design – Required Information

Design Drawings

- Plans, sections, & elevations of each stair
- Dimensions for clear distances at stairs/landings
- Guard layout with handrail position
- Preferred/required member types (C, HSS, Plate)
- Slab openings
- Conceptual layout of stair elements
- Conceptual connection details

Clearly indicate if details are suggestions or required

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Delegated Design – Required Information

Project Specification

- Performance requirements (loading / serviceability)
- Materials, member, & fasteners criteria
- Fabrication instructions
- Finishes

Carefully review for conflicts between drawings and specification

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Delegated Design – Code Compliance

- Stairways, guard, and handrail are critical components related to life safety.
- Architect/SER are the most knowledgeable about the specific project requirements (and code requirements)
- Architect & SER are responsible for providing code parameters and reviewing submittals for conformance.

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Delegated Design

- Delegated Design ≠ "Not my problem"

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Delegated Design – Shop Drawings

- Shop drawings should be created by Fabricator/Detailer based on information provided by the specialty structural engineer (SSE) and design documents
- Provide shop drawings to SSE for review and comment
- Do not request SSE to seal shop drawings if they are created by others
  - Not allowed in some jurisdictions
  - Insurance typically will not allow SSE to do this

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Delegated Design – Submittals

- Submittal to Design Team & AHJ:
  - Shop & Erection drawings from Fabricator/Detailer
    - Reviewed by SSE
  - Sealed structural engineering calculations from specialty structural engineer (SSE)
    - Should include any plans, sketches, and details as required

Be sure to clarify scope of work and expectations before submittals are made

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Outline – Part 2

Step 7 – Code Requirements – Seismic Loading
Step 8 – Seismic Serviceability
Step 9 – Stairway Design
Step 10 – Examples
Step 11 – Delegated Design
Step 12 – Other Topics

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Tolerances

- Steel
  - Mill Variations, ASTM A6 / AISC *COSP* Section 5.1
  - Fabrication Tolerances, AISC *COSP* Section 6.4
  - Erection Tolerances, AISC *COSP* Section 7.13
  - AESS, AISC *COSP* Sections 10.2-10.6

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Tolerances - Concrete

- Field verify dimensions based on actual construction!

Tolerances

- Concrete (ACI117 & *Handbook of Construction Tolerances*)
  - ± 1/4" over 10 feet from plumb for walls
  - ± 1/4" to 1/2" variation in distance between members
  - +3/8" to -1/4" for cross sections
  - +1" to -1/4" variation in floor openings
  - ± 1/2" member misplaced in plan
- Field verify dimensions based on actual construction!

Tolerances

- Masonry (ASTM C90 & *Handbook of Construction Tolerances*)
  - ± 1/8" for cross sections
  - ± 1/4" to ± 1/2" from plumb for walls
  - ± 1/2" alignment for bearing walls
- Field verify dimensions based on actual construction!

Galvanizing

- For exterior locations or environments that need additional corrosion protection
- Consider:
  - Avoid field welding
  - Provide bolted connections
  - Match fasteners & metals
  - Limit on size of piece/assembly
  - Potential distortion or warpage (ASTM A384)

Erectability

- Think about installation
  - Stringers adjacent to concrete/masonry walls may have limited access to install bolts
  - Will masonry supports be in place?
- Erector preferences
  - Bolting versus Welding

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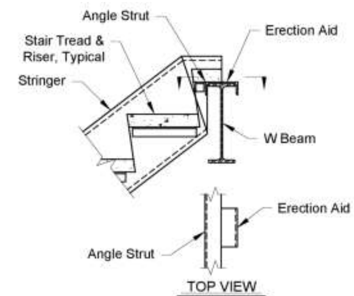
Erectability

- Maximize repetition in framing and connections
- Erection aids
- Adjustability and fit-up in connections



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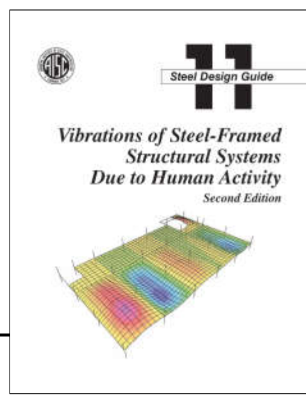
Vibration

- Refer to AISC Design Guide 11: Vibrations of Steel-Framed Structural Systems Due to Human Activity (Second Edition)
- Vibration is all about perception and comfort
- Discuss project goals as it relates to vibration



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Questions?

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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!

PDH Certificates

Within 2 business days…

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

There's always a solution in steel.

Thank You

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