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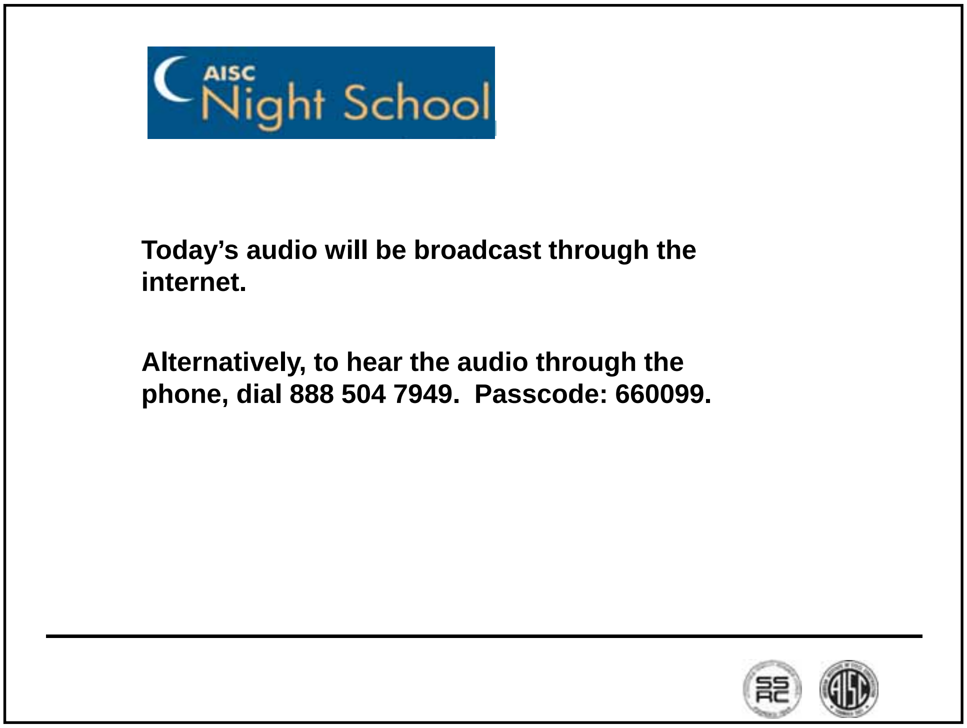

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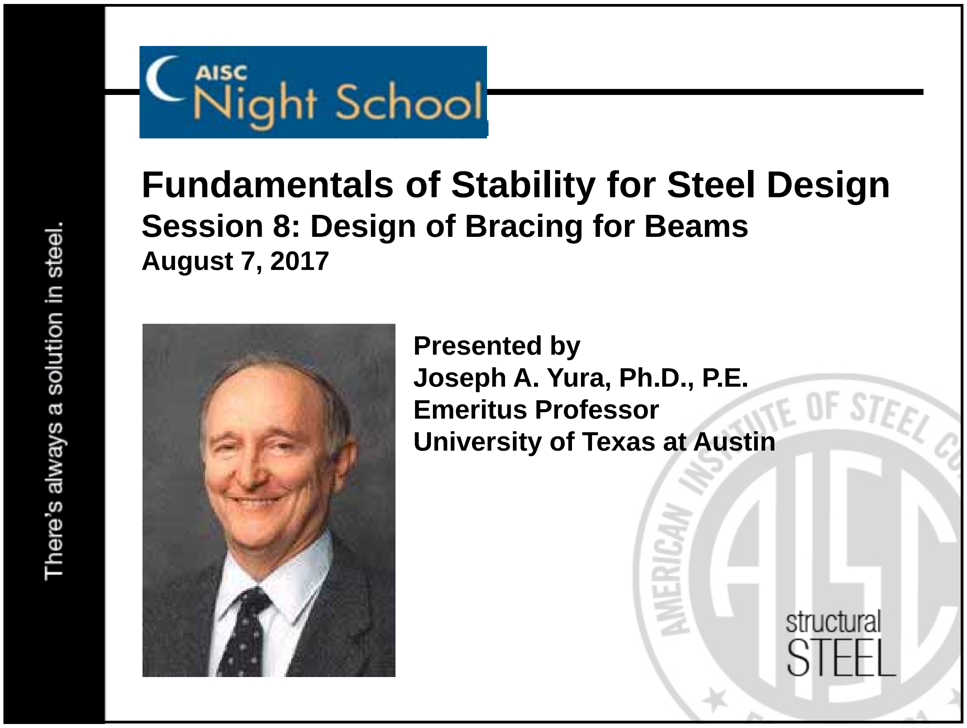
Course Description

August 7, 2017– Design of Bracing for Beams

This lecture will emphasize the design requirements for bracing of beam systems. Several design examples will demonstrate the effective use of the AISC Specification Appendix 6 provisions. These examples will include relative, nodal, and lean-on applications. The uses of the provisions covered in the Specification Appendix as well as modifications covered in the Specification Commentary will be addressed. The importance of brace connection details is emphasized.

Learning Objectives

- Learn and understand the design requirements related to bracing beams.
- Gain an understanding of AISC Specification Appendix 6 requirements.
- Become familiar with designing for relative, nodal, and lean-on bracing applications.
- Understand bracing design through the use of design examples.



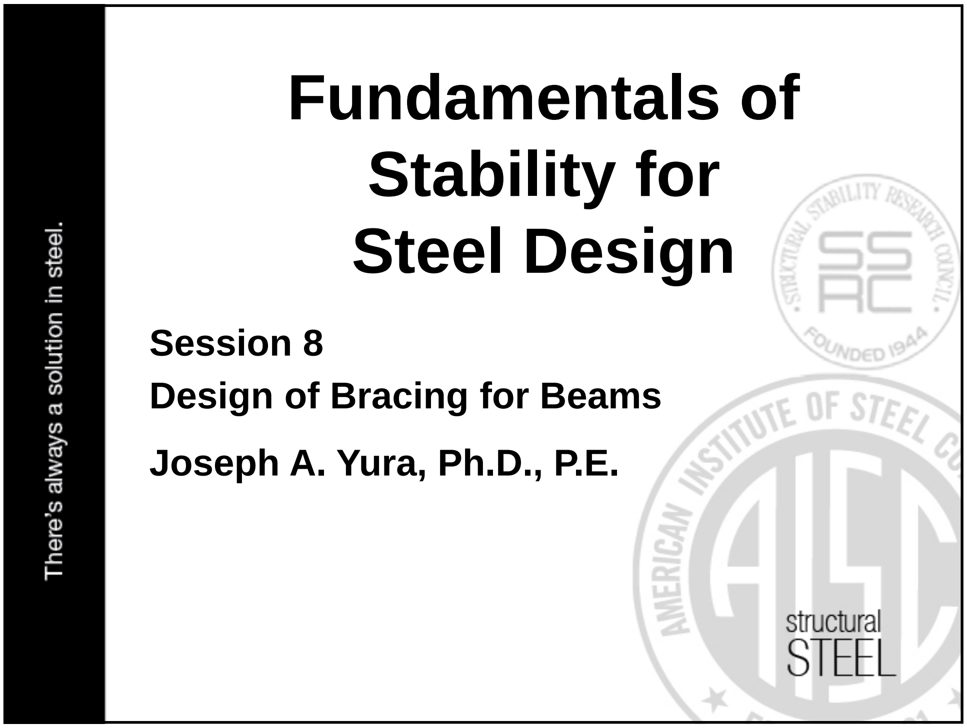
There's always a solution in steel.

Fundamentals of Stability for Steel Design

Session 8: Design of Bracing for Beams

August 7, 2017

Presented by
Joseph A. Yura, Ph.D., P.E.
Emeritus Professor
University of Texas at Austin



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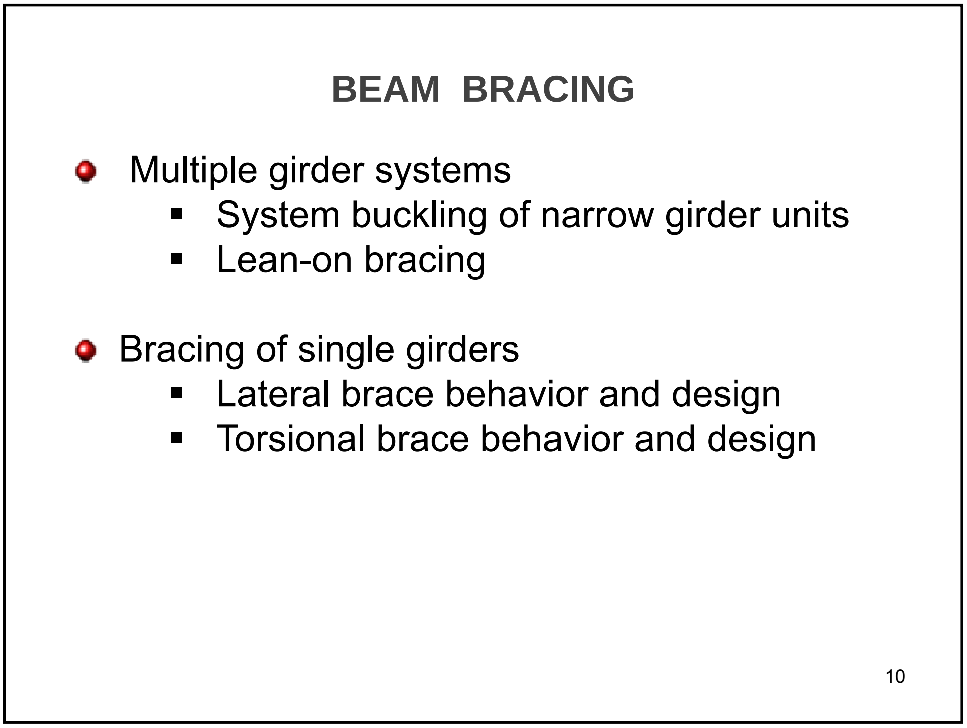
Fundamentals of Stability for Steel Design

Session 8

Design of Bracing for Beams

Joseph A. Yura, Ph.D., P.E.

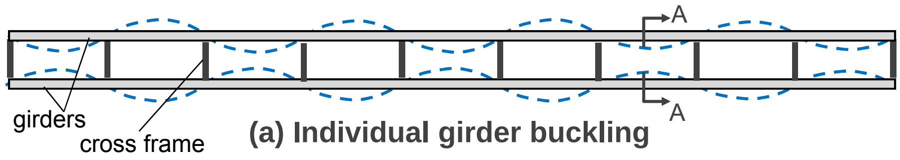


BEAM BRACING

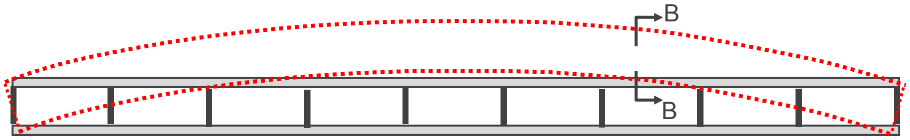
- Multiple girder systems
  - System buckling of narrow girder units
  - Lean-on bracing
- Bracing of single girders
  - Lateral brace behavior and design
  - Torsional brace behavior and design

- Multiple girder systems
  - **System buckling of narrow girder units**

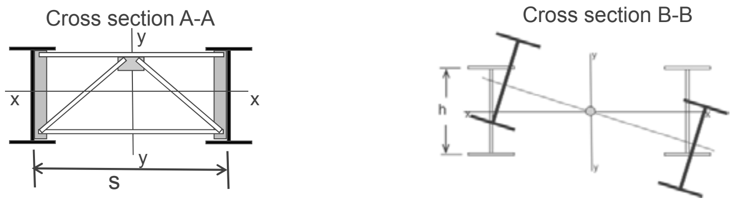
TWIN GIRDER SYSTEMS - Plan View



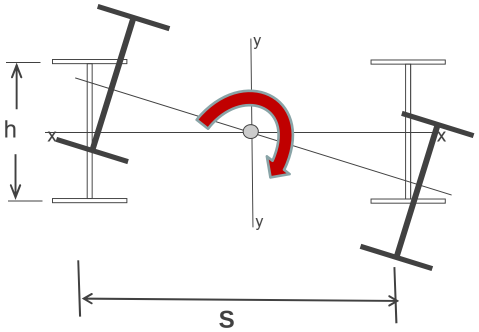
(a) Individual girder buckling



(b) Global system buckling : closely-spaced beams, long span



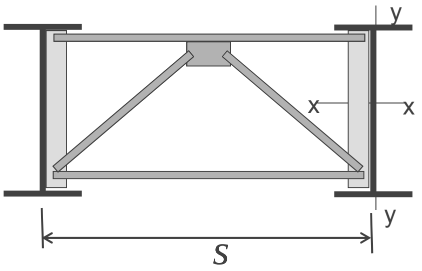
SYSTEM TWIST



Total warping rigidity $= 2E\left(\frac{h^2}{4}I_y + \boxed{\frac{s^2}{4}I_x}\right)$

Use with beam buckling formulas in Lectures 3 and 4

TWIN GIRDER SYSTEM BUCKLING

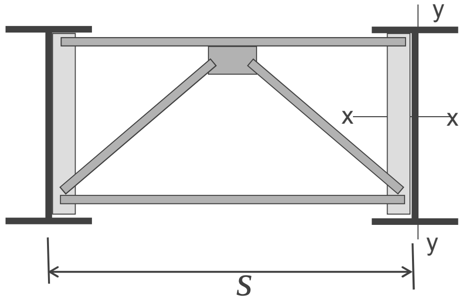


$$M_{crs} = \frac{2\pi}{L}\sqrt{EI_yGJ + \frac{\pi^2E^2I_y\left(I_yh^2 + \boxed{I_xs^2}\right)}{4L^2}}$$ (exact)

All section properties are for a single girder

Σ Girder Maximum Moments ≤ M_{crs}

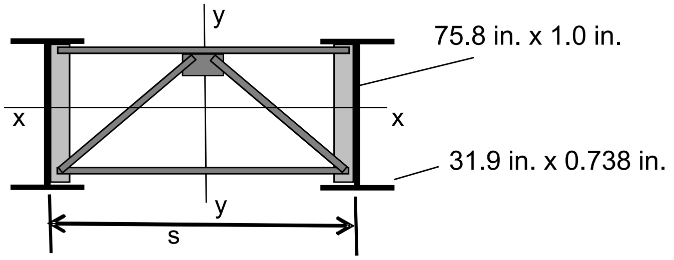
TWIN GIRDER SYSTEM BUCKLING



$$M_{crs} = \frac{2\pi}{L}\sqrt{\cancel{EI_y GJ} + \frac{\pi^2 E^2 I_y\left(\cancel{I_y h}^2 + I_x s^2\right)}{4L^2}} \quad \text{(exact)}$$

$$M_{crs} = \frac{\pi^2 sE}{L^2}\sqrt{I_y I_x} \quad \text{(simple)}$$

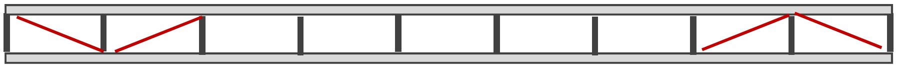
TWIN GIRDER EXAMPLE



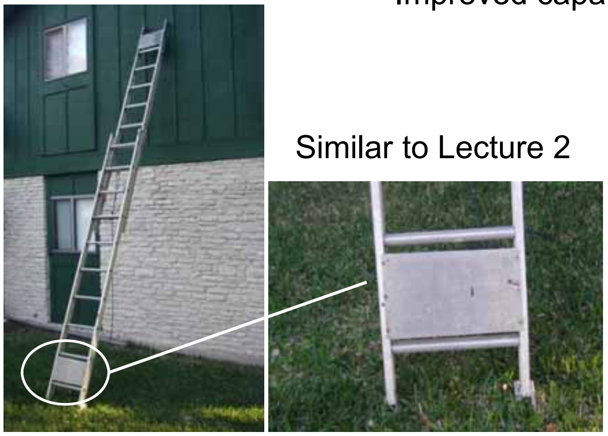
L = 170 ft

System Buckling Stress (ksi)			
	Girder Spacing S (in.)		
Analysis Type	**80**	**109**	**150**
FEA	**21.31**	**28.56**	**38.68**
Exact	**21.40**	**28.73**	**39.21**
Simple	**20.70**	**28.22**	**38.83**

More Info on Global Buckling



Improved capacity

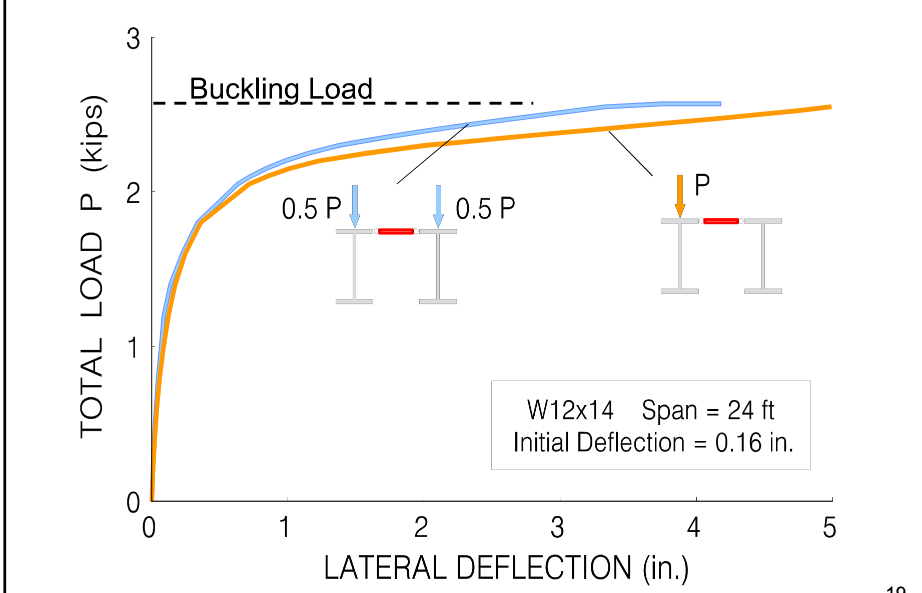


Similar to Lecture 2

Yura et al,(2008) "Global Lateral Buckling of I-Shaped Girder Systems", *J. Struct. Engrg*., ASCE, Vol. 134, No. 9, pp. 1487-1494

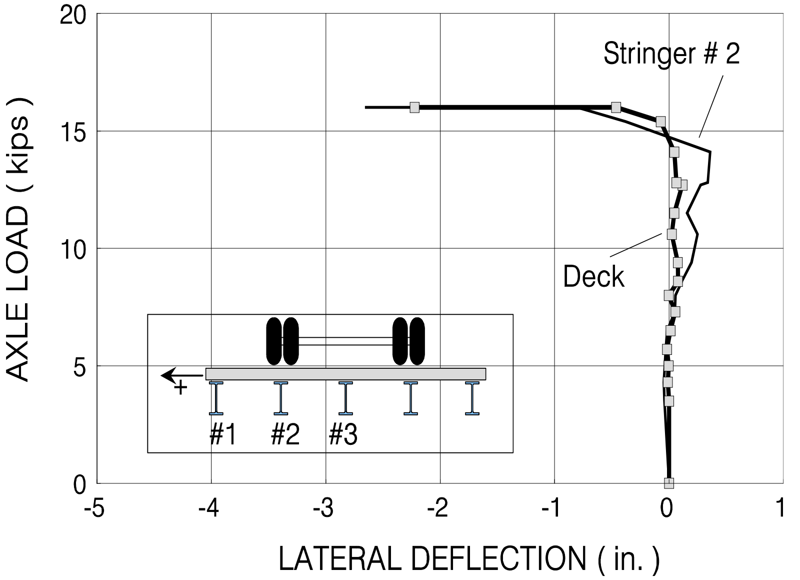
- Multiple girder systems
    - **Lean-on bracing**

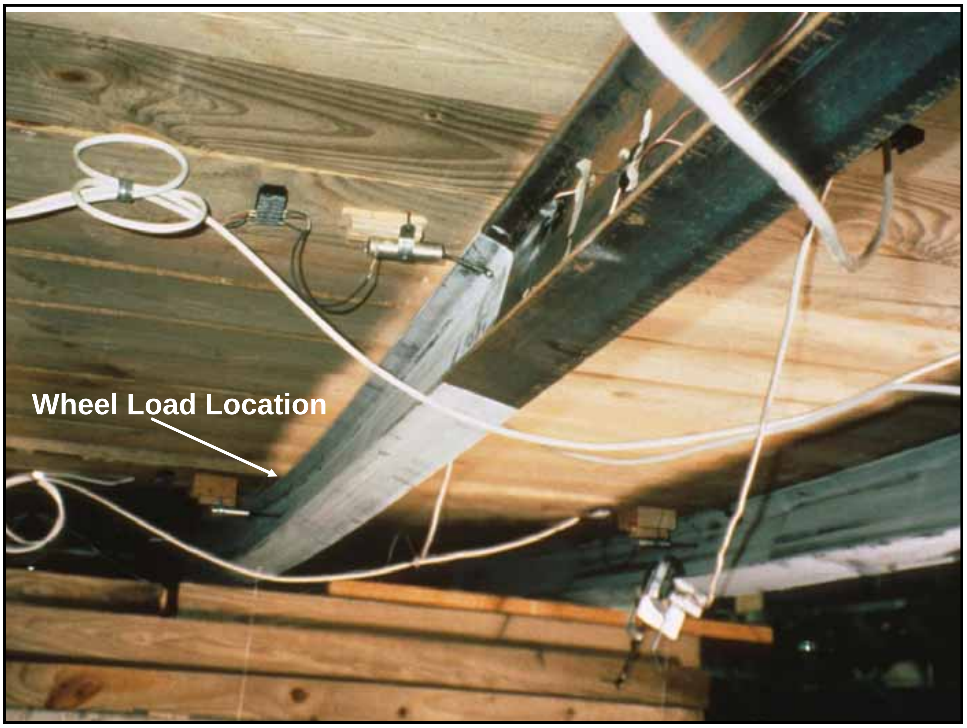
LEAN-ON LATERAL BRACING



W12x14 Span = 24 ft
Initial Deflection = 0.16 in.

wood deck – not attached to the beams





LEAN-ON BEAM SYSTEMS

- Beams that are interconnected by members without torsional restraint lateral-torsional buckle as a system :

$$\Sigma M_r \leq \Sigma M_{cr}$$

M_r = maximum moment in an individual beam
M_{cr} = lateral-torsional buckling capacity of an individual beam assuming that the interconnection points are not brace points

- Check individual beams for buckling between the intersection points treated as brace points

- Bracing of single girders
  - Lateral brace behavior and design
  - Torsional brace behavior and design

BEAM BRACING

A successful bracing system prevents twist of the cross section

LATERAL BRACING of the compression flange will prevent twist since the tension flange would prefer to remain straight for simply-supported beams. For beams with inflection points both flanges must be laterally braced to prevent twist.

TORSIONAL BRACING prevents twist of the cross section at the brace location. The brace does not need to prevent lateral movement of the cross section to be successful.

An inflection point is not a brace point. Twist of the cross section is not prevented at the inflection point.

Bracing must have sufficient stiffness and strength

TYPES OF BEAM BRACING

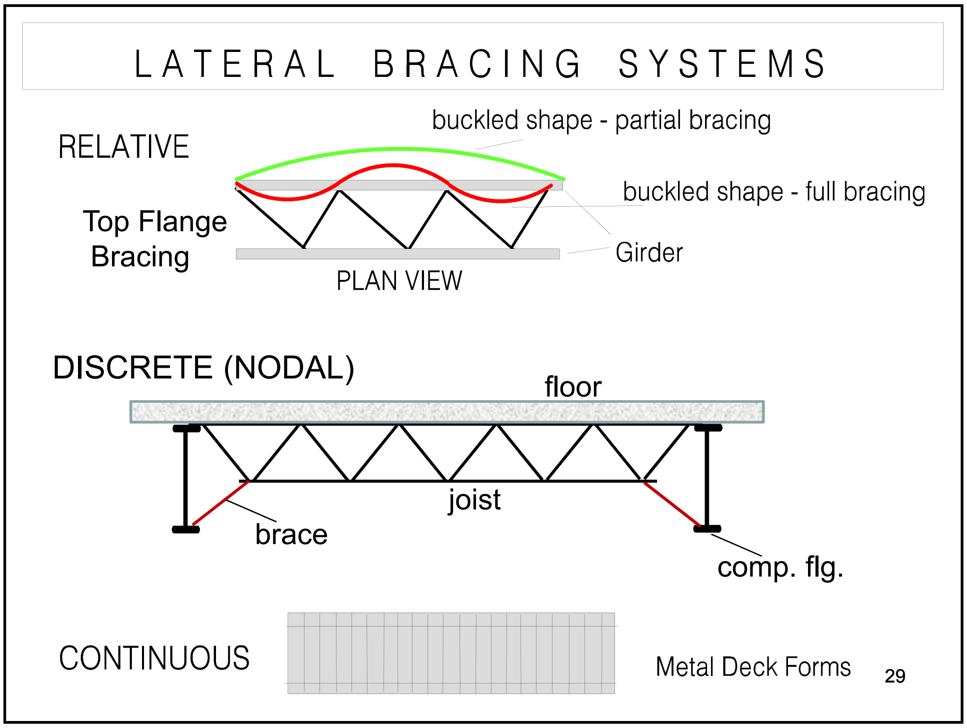
LATERAL BRACING

- *RELATIVE*
- *DISCRETE* ***(NODAL)***
- ~~*CONTINUOUS*~~
- *LEAN - ON*

TORSIONAL BRACING

- *DISCRETE* ***(NODAL)***
- *CONTINUOUS*

- Bracing of single girders
  - **Lateral brace behavior and design**



LATERAL BRACING SYSTEMS

RELATIVE

Top Flange Bracing

buckled shape - partial bracing

buckled shape - full bracing

Girder

PLAN VIEW

DISCRETE (NODAL)

floor

joist

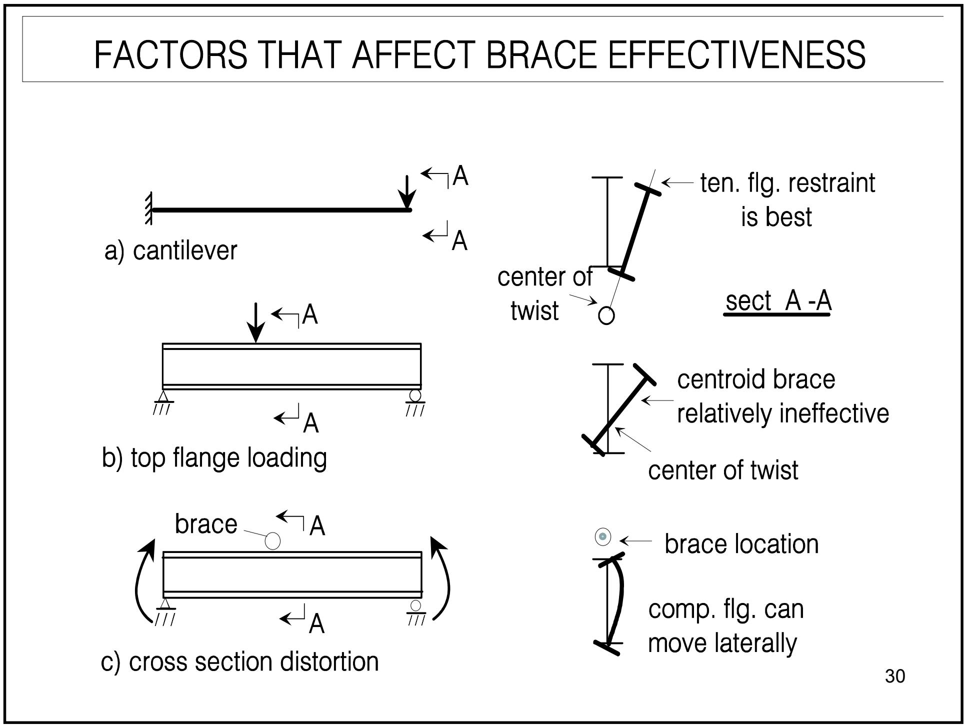
brace

comp. flg.

CONTINUOUS

Metal Deck Forms

29



FACTORS THAT AFFECT BRACE EFFECTIVENESS

a) cantilever

b) top flange loading

brace

c) cross section distortion

ten. flg. restraint is best

center of twist

sect A -A

centroid brace relatively ineffective

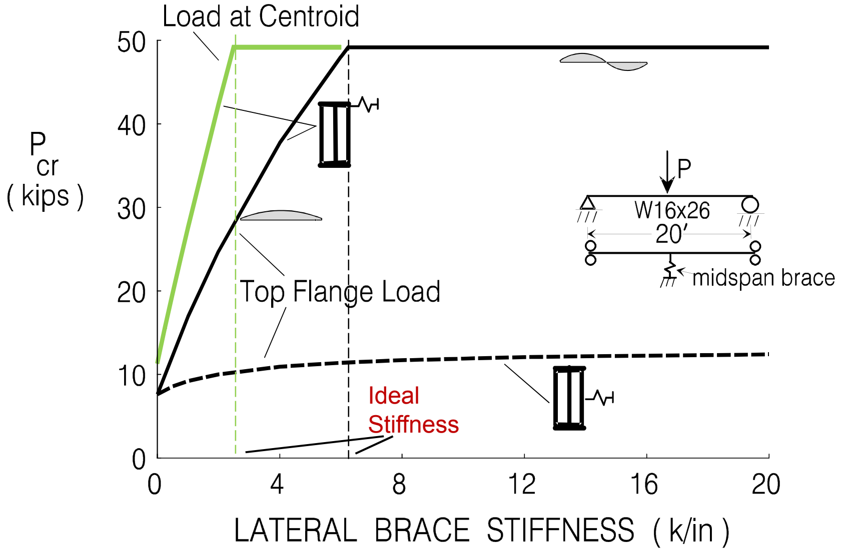
center of twist

brace location

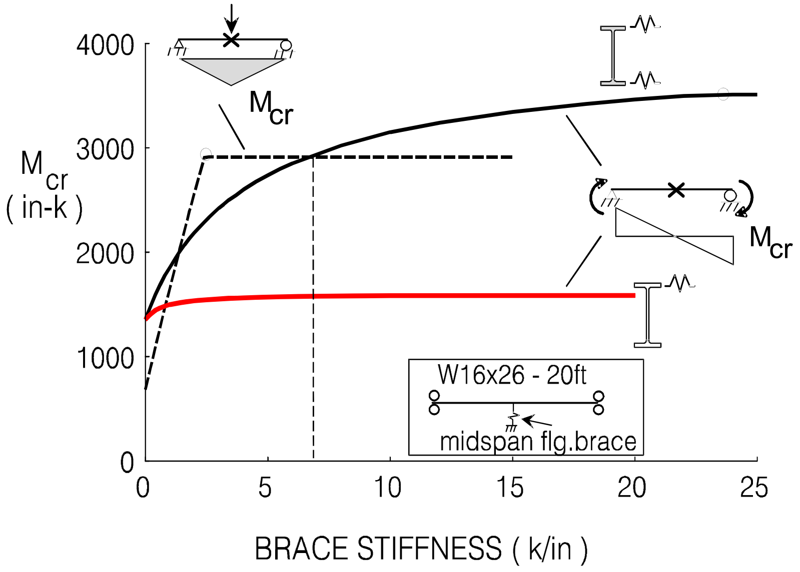
comp. flg. can move laterally

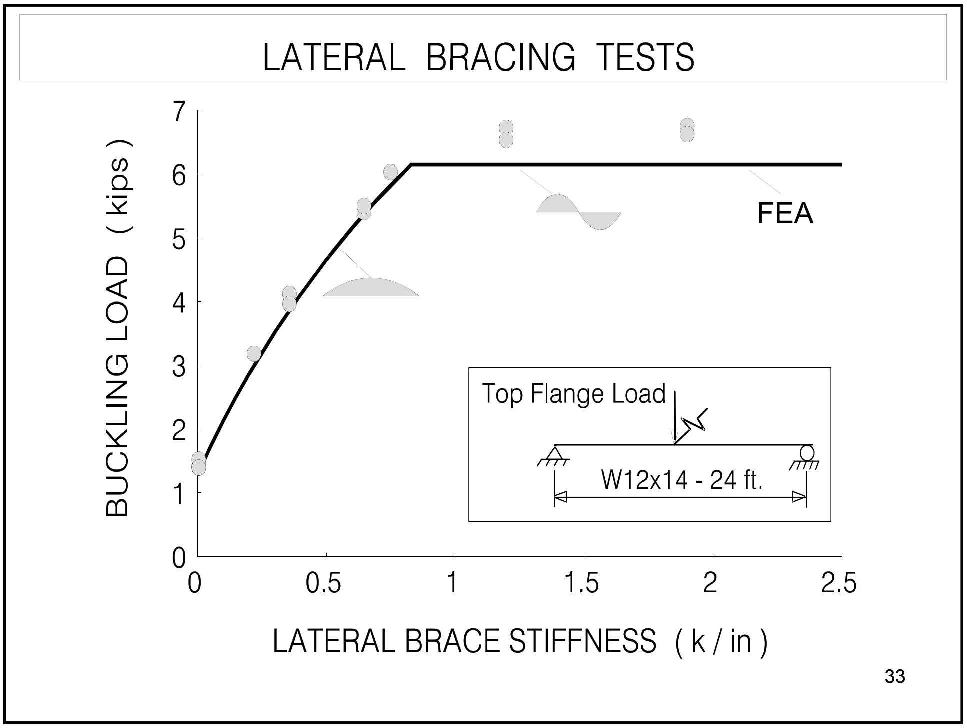
30

EFFECT OF LOAD AND BRACE POSITION



BEAMS WITH INFLECTION POINTS





LATERAL BRACING TESTS

LATERAL BRACING DESIGN FACTORS

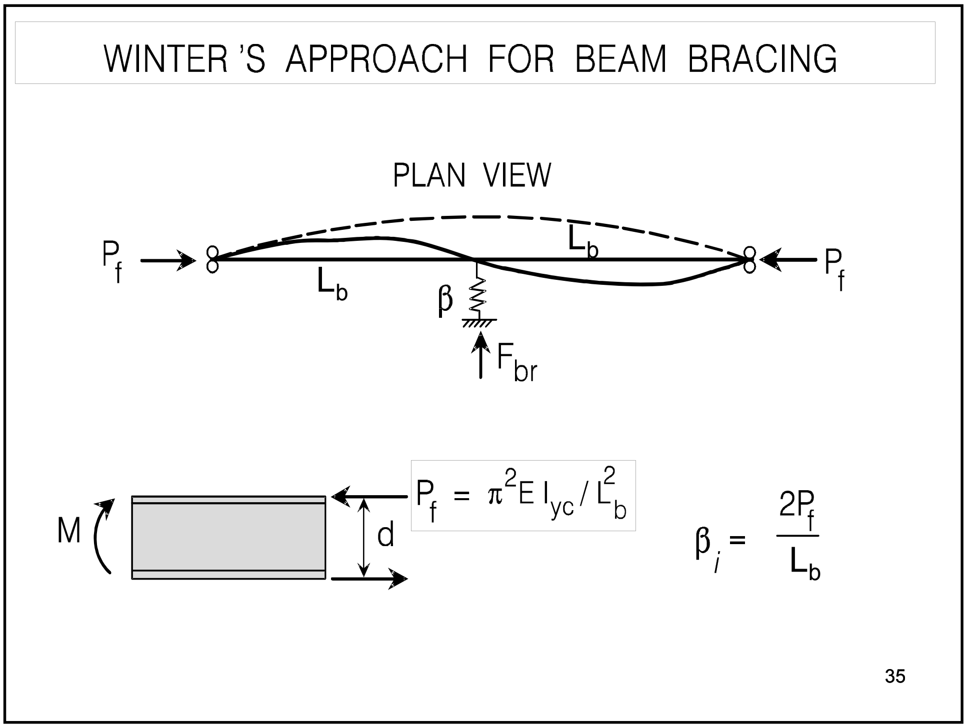
- NUMBER OF BRACES
- BRACE POSITION

  Place at or near the flange

  Top and bottom braces needed
  for compression on both flanges
- LOAD POSITION

  Top flange loading is the worst
- MOMENT DIAGRAM

  Consider the C_b modification factor

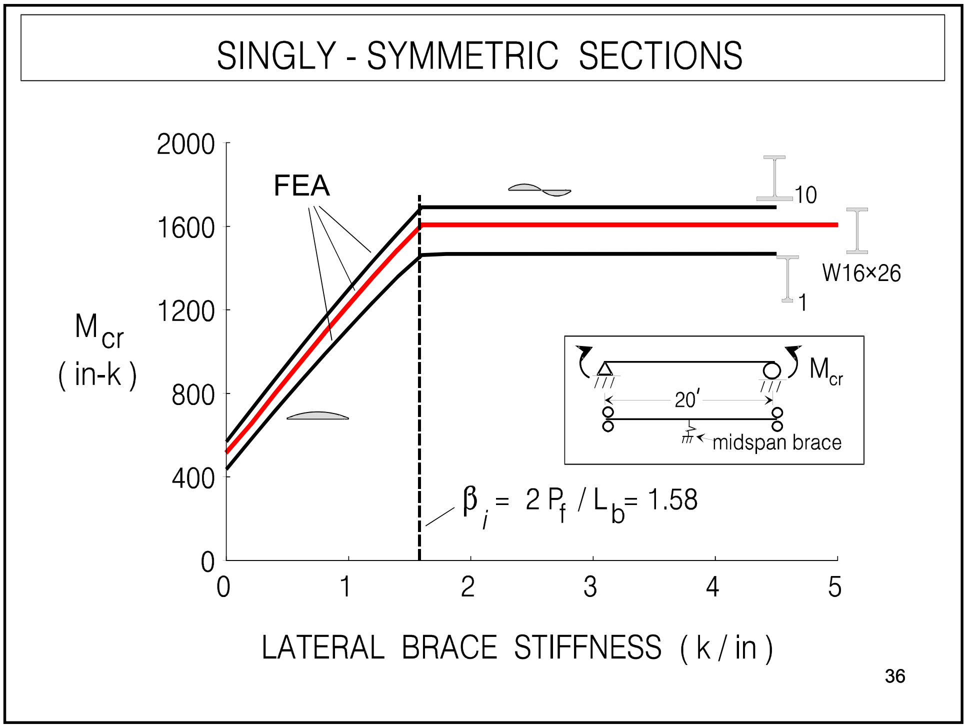


WINTER 'S APPROACH FOR BEAM BRACING

$$P_f = \pi^2 E\, I_{yc} / L_b^2$$

$$\beta_i = \frac{2P_f}{L_b}$$

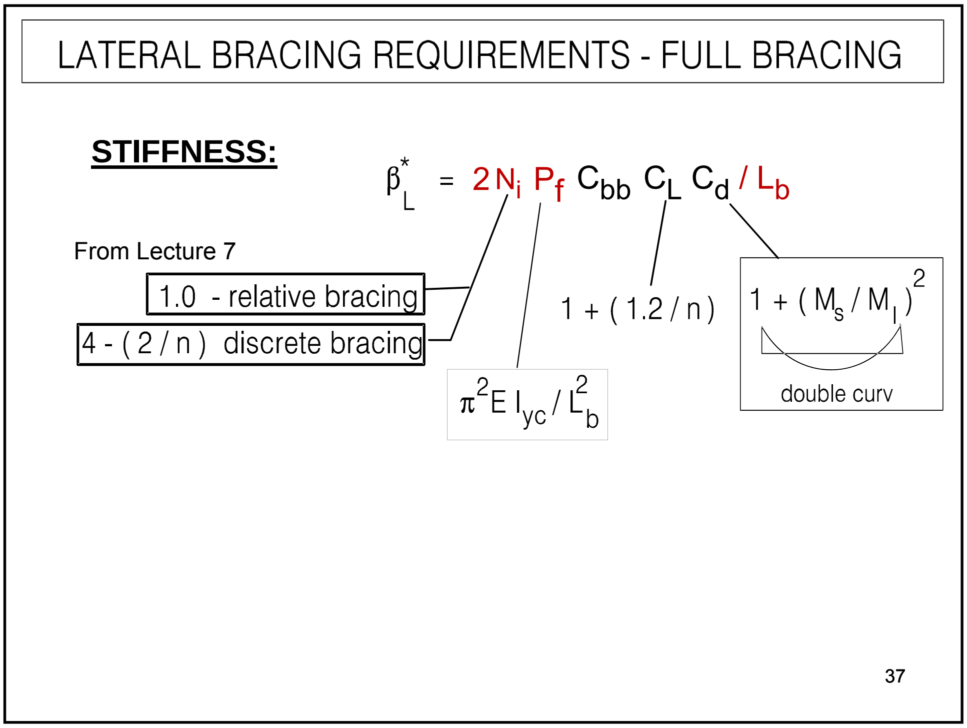
35



SINGLY - SYMMETRIC SECTIONS

$\beta_i = 2\, P_f / L_b = 1.58$

36



LATERAL BRACING REQUIREMENTS - FULL BRACING

STIFFNESS:

$$\beta^*_L = 2 N_i P_f C_{bb} C_L C_d / L_b$$

From Lecture 7

1.0 - relative bracing

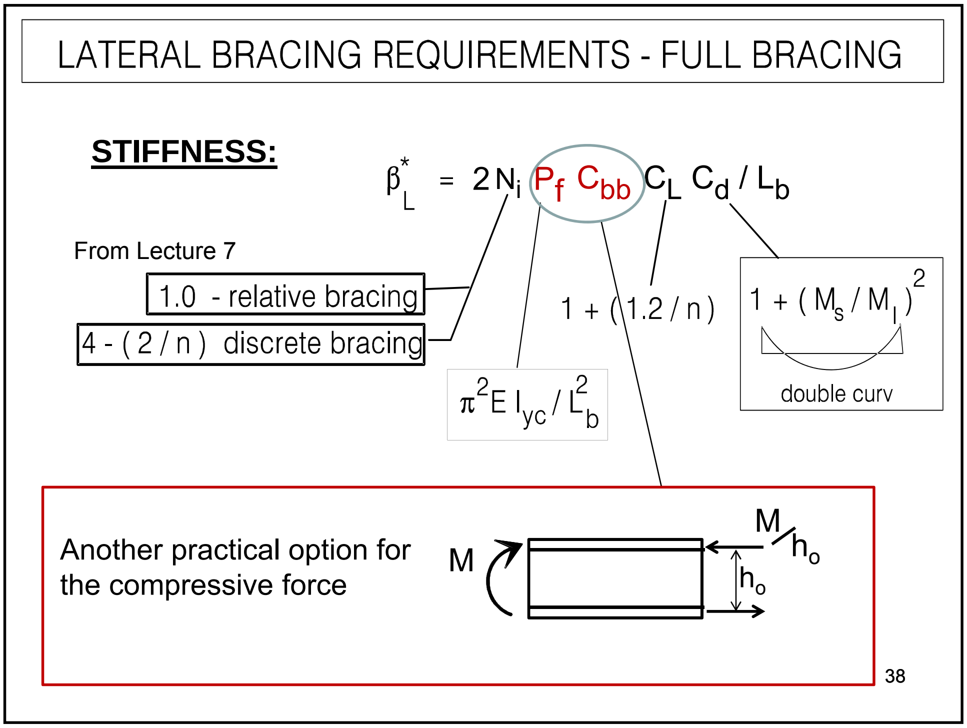
4 - (2 / n) discrete bracing

$\pi^2 E I_{yc} / L_b^2$

$1 + (1.2 / n)$

$1 + (M_S / M_L)^2$

double curv



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$\pi^2 E I_{yc} / L_b^2$

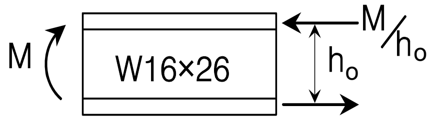
$1 + (1.2 / n)$

$1 + (M_S / M_L)^2$

double curv

Another practical option for the compressive force

APPROXIMATE COMPRESSIVE FLANGE FORCE



L_b ft	M_{cr} k-in	$P_f = \pi^2 E I_{yc} / L_b^2$ kips	M / h_o kips	$\frac{M / h_o}{P_f}$
5	6035	381	393	1.03
10	1640	95.3	107	1.12
15	817	42.4	53.3	1.26

SIMPLIFIED BRACING REQUIREMENTS

STIFFNESS : $$\beta^*_L = 2\underbrace{N_i}_{4-(2/n)\ \text{discrete bracing}} \overbrace{P_f}^{M/h_o} C_{bb} \underbrace{C_L}_{1+(1.2/n)\ \text{top flg loading}} C_d / L_b$$

n	1	2	3	4	5	6
$2 N_i C_L$	8.8	9.6	9.3	9.1	8.9	8.8

say 10

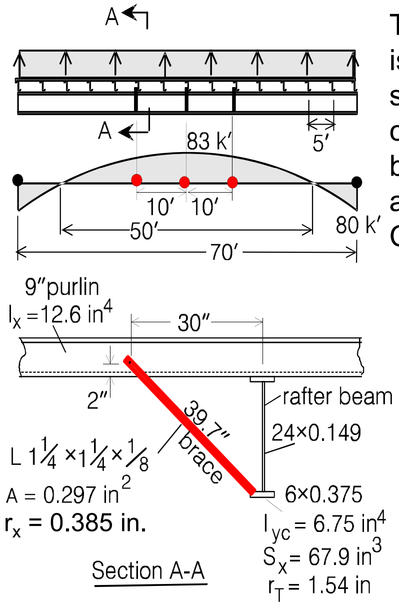
LATERAL BRACING – LRFD RECOMMENDATIONS

	Relative	Nodal
Stiffness $\phi = 0.75$	A6-6 $\beta_L = 4M_r C_d / \phi L_b h_o$	A6-8 $\beta_L = 10M_r C_d / \phi L_b h_o$
		max. moment
	$\Delta_o = 0.002 L_b$	
Strength	A6-5 $F_{br} = 0.008M_r C_d / h_o$	A6-7 $F_{br} = 0.02 M_r C_d / h_o$

1.0 – single curvature
2.0 – double curvature

Note: The required bracing spacing, L_q, can be substituted for the actual spacing, L_b.

DISCRETE BEAM BRACING - Gravity plus Uplift Wind



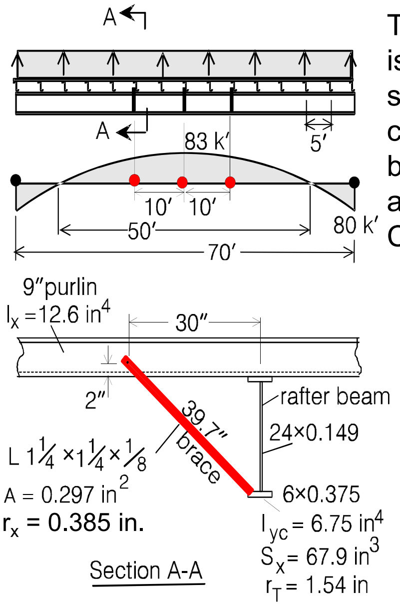
The rafter of an industrial building frame is braced along the top flange by purlins spaced at 5 ft interval. The uplift load condition produces compression on the bottom flange and three angle braces are proposed to stabilize the rafter. Check the detail shown. F_y = 50 ksi.

From F5-4 for LTB of the rafter at 83 k' with C_b = 1.0.

$$83x12 = 0.9(67.9)(1.0)\frac{\pi^2(29000)(1.54)^2}{L_q^2}$$

L_q = 17.0'

DISCRETE BEAM BRACING - Gravity plus Uplift Wind



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L_q = 17.0′

A6-8 and A6-7

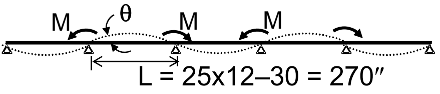
β_L = 10(83)/(0.75(17.0)24.38) $\underline{= 2.67 \text{ k/in}}$

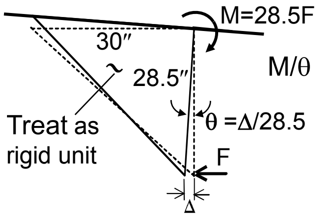
F_{br} = 0.02 (83×12)1.0 / 24.38 $\underline{= 0.82 \text{ k}}$

Brace Stiffness

The angle braces are supported by the continuous purlins that span 25′ between rafters. The effect of the purlin stiffness must be considered when evaluating the stiffness of the brace system

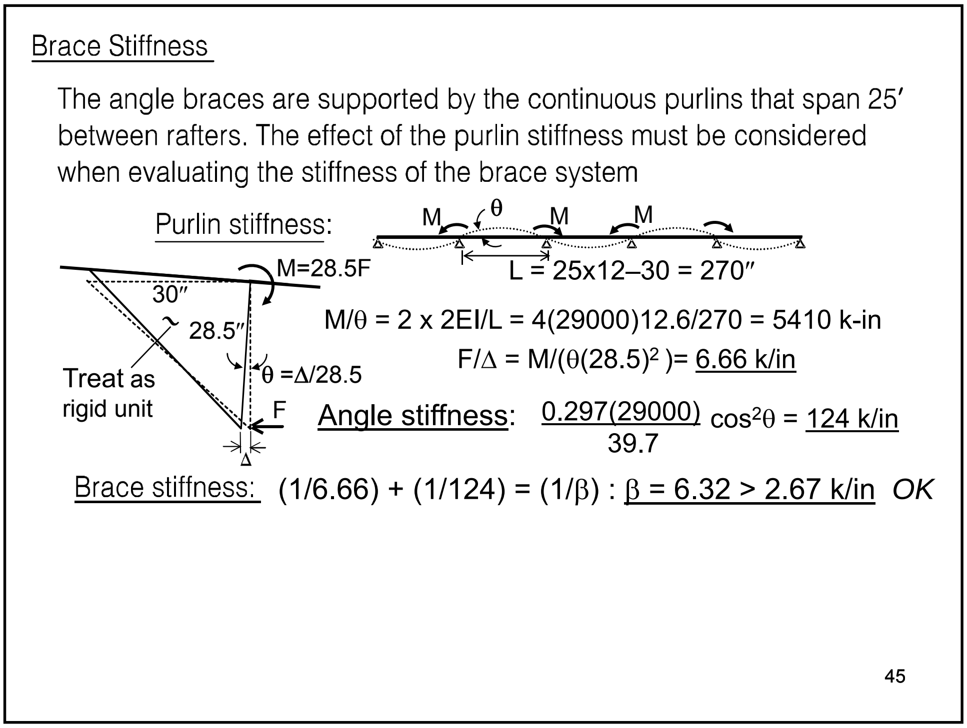
Purlin stiffness:





M/θ = 2 x 2EI/L = 4(29000)12.6/270 = 5410 k-in

F/Δ = M/(θ(28.5)^2)= $\underline{6.66 \text{ k/in}}$



Brace Stiffness

The angle braces are supported by the continuous purlins that span 25′ between rafters. The effect of the purlin stiffness must be considered when evaluating the stiffness of the brace system

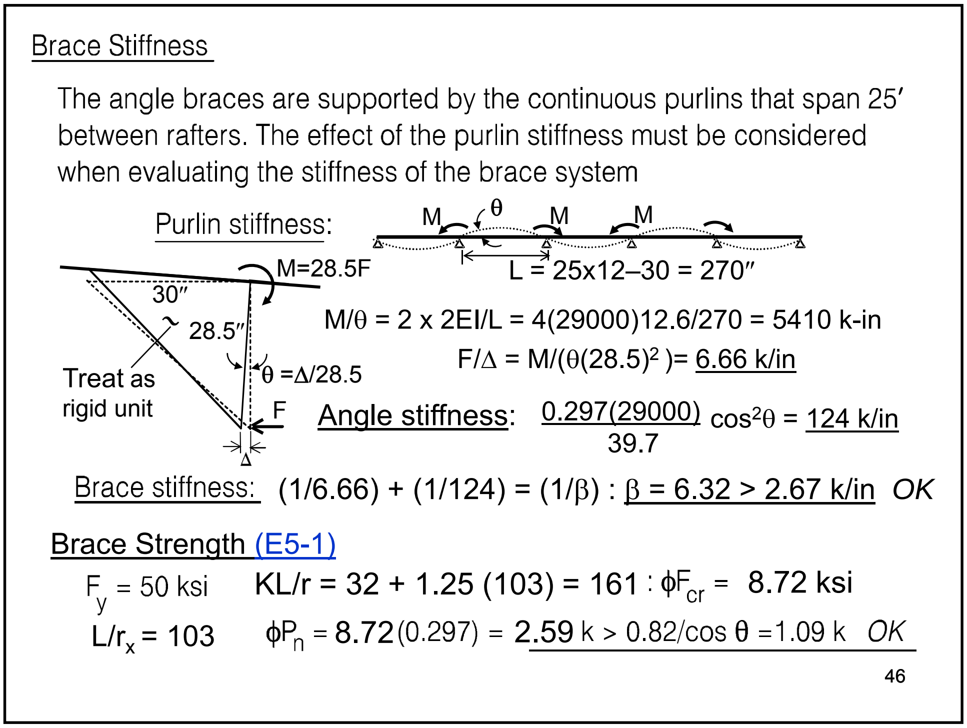
Purlin stiffness:

$M/\theta = 2 \times 2EI/L = 4(29000)12.6/270 = 5410$ k-in

$F/\Delta = M/(\theta(28.5)^2) = \underline{6.66 \text{ k/in}}$

Angle stiffness: $\frac{0.297(29000)}{39.7}\cos^2\theta = \underline{124 \text{ k/in}}$

Brace stiffness: $(1/6.66) + (1/124) = (1/\beta)$: $\underline{\beta = 6.32 > 2.67 \text{ k/in}}$ *OK*



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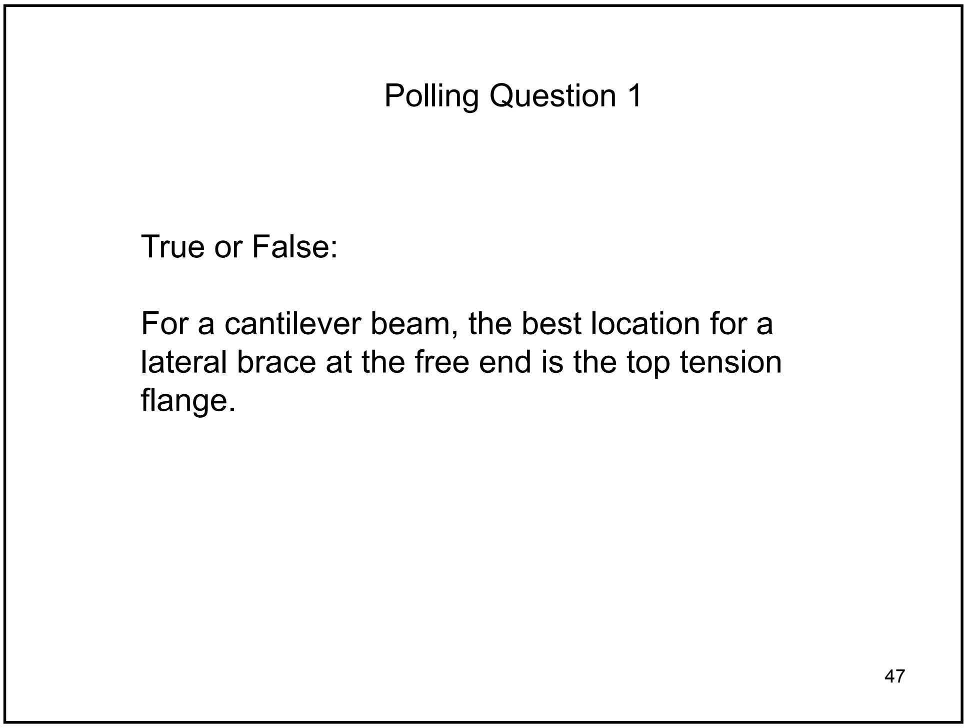
Brace stiffness: $(1/6.66) + (1/124) = (1/\beta)$: $\underline{\beta = 6.32 > 2.67 \text{ k/in}}$ *OK*

Brace Strength (E5-1)

$F_y = 50$ ksi $KL/r = 32 + 1.25\,(103) = 161$: $\phi F_{cr} = 8.72$ ksi

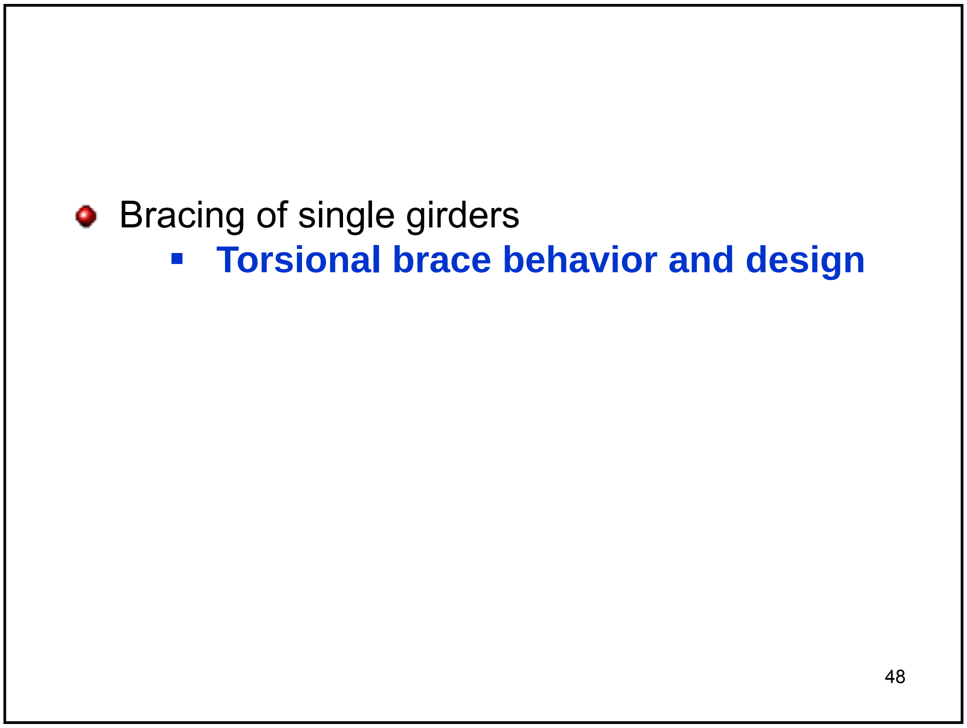
$L/r_x = 103$ $\phi P_n = 8.72(0.297) = \underline{2.59 \text{ k} > 0.82/\cos\theta = 1.09 \text{ k}}$ *OK*



Polling Question 1

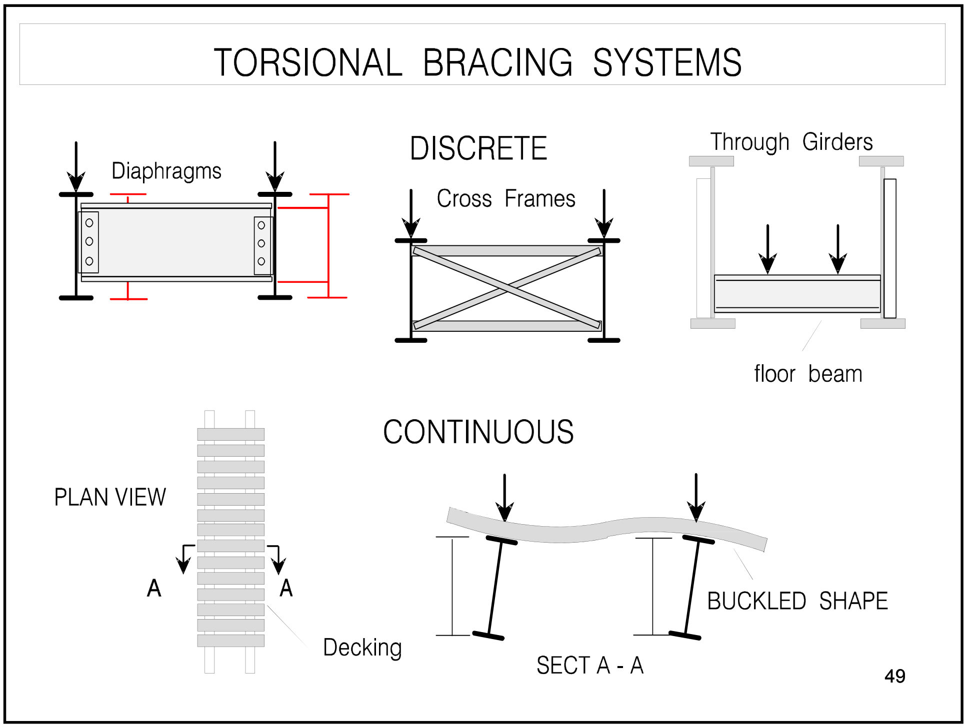
True or False:

For a cantilever beam, the best location for a lateral brace at the free end is the top tension flange.



- Bracing of single girders
    - **Torsional brace behavior and design**

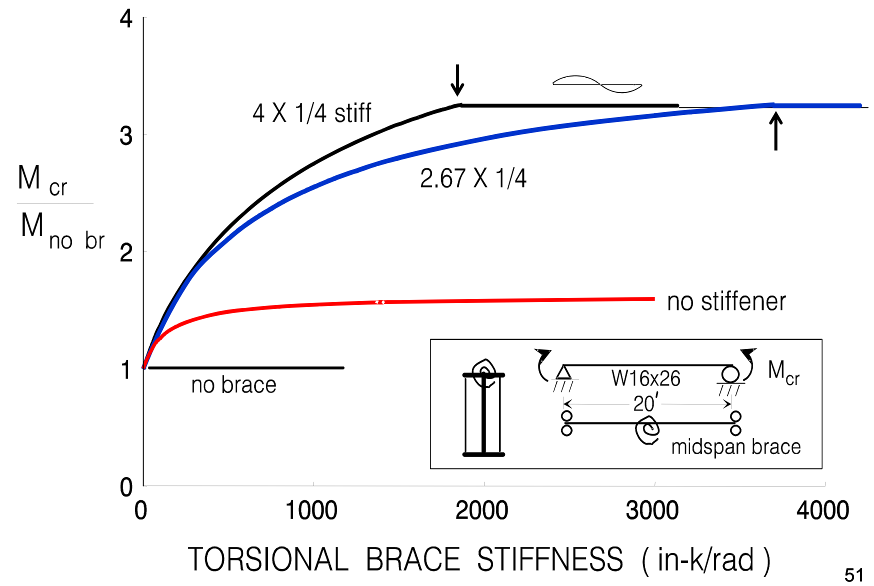
TORSIONAL BRACING SYSTEMS



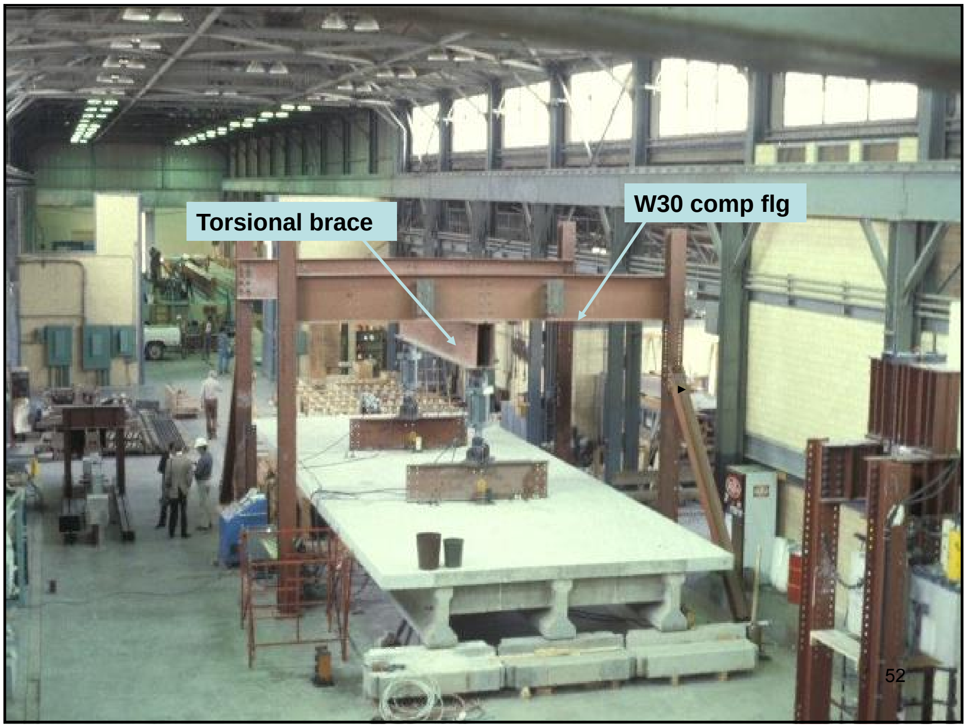
SECTION IS FULLY BRACED AT A LOCATION

IF TWIST IS PREVENTED

TORSIONAL BRACING - EFFECT OF STIFFENER



51



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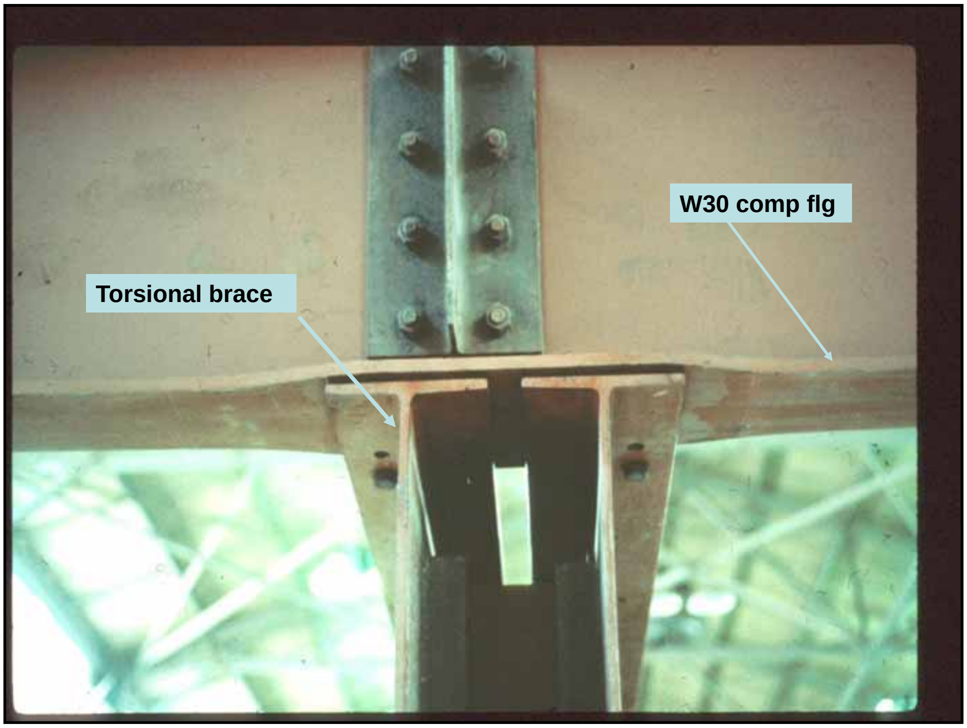
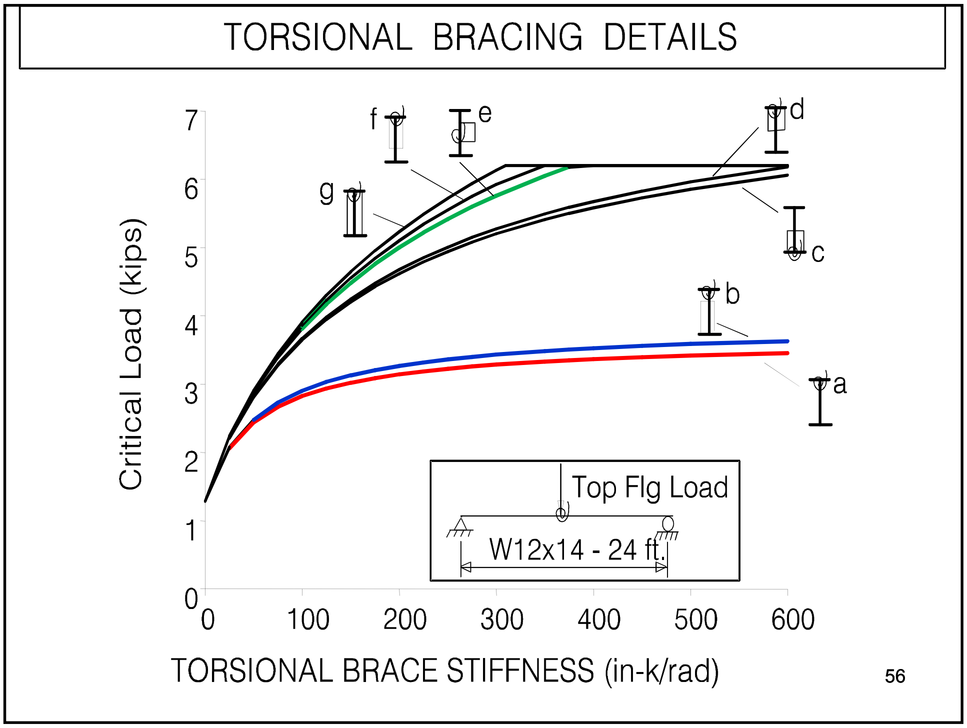
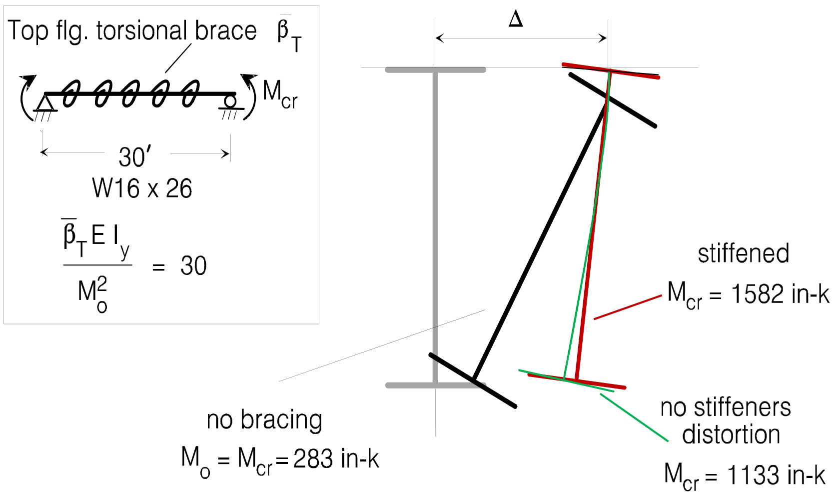

W30 comp flg
Torsional brace



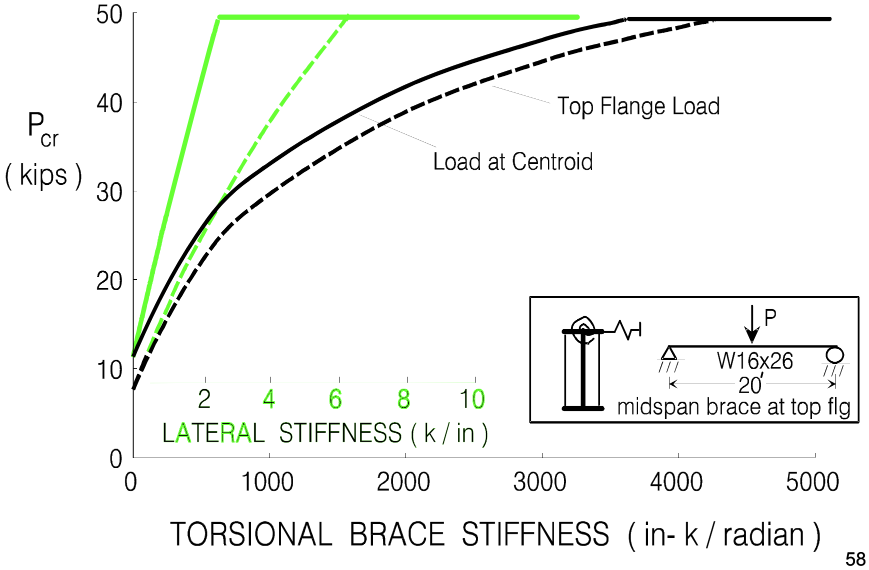
TORSIONAL BRACING DETAILS

56

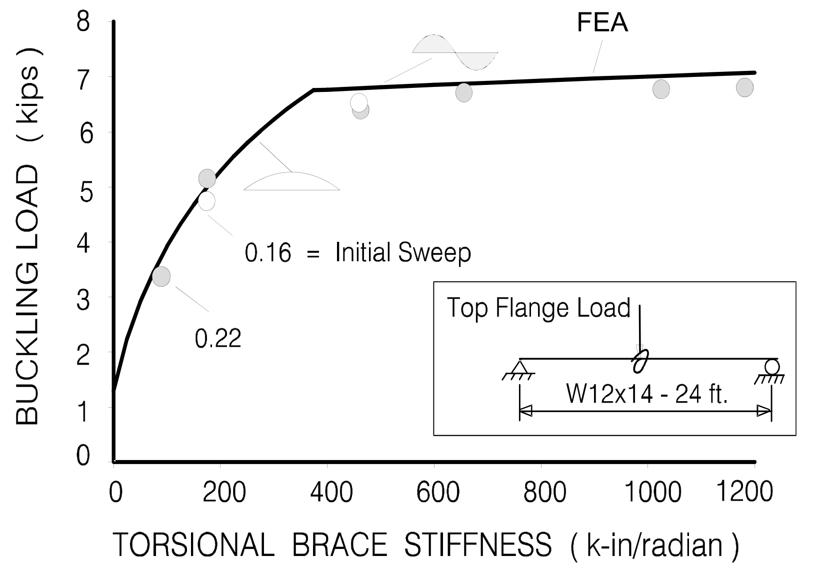
BUCKLED SHAPES AT MIDSPAN



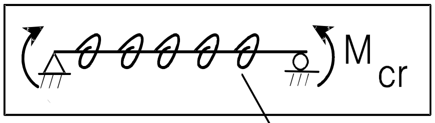
EFFECT OF LOAD POSITION



TORSIONAL BRACING TESTS



TORSIONALLY BRACED BEAMS -Taylor and Ojalvo



$$M_{cr} = \sqrt{M_o^2 + E I_y \overline{\beta}_T}$$

Unbraced Beam Buckling Strength

TORSIONALLY BRACED BEAMS

$$M_{cr} = \sqrt{C_{bu}^2 M_o^2 + \frac{C_{bb}^2 E I_y \overline{\beta}_T}{C_T}} \leq M_p \text{ or } M_s$$

unbraced capacity

top flange loading = 1.2

$$\overline{\beta}_T = \frac{\beta_T \text{ x n braces}}{\text{span length}}$$

cross section distortion

$$\frac{1}{\beta_T} = \frac{1}{\beta_{Tb}} + \frac{1}{\beta_{sec}}$$

$$\frac{1}{\beta_T} = \frac{1}{\beta_{Tb}} + \frac{1}{\beta_{sec}}$$

(C-A-6-12)

β_T = System Stiffness

β_{Tb} = X-frame or Diaphragm Stiffness

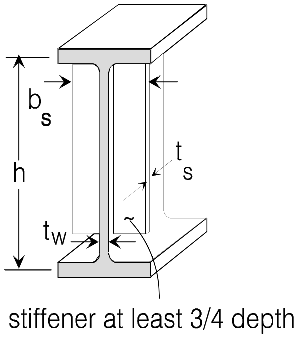
β_{sec} = Web Distortional Stiffness

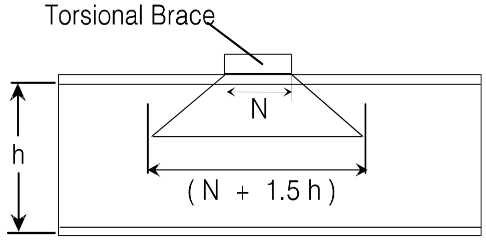
$$\beta_{Tb} = \frac{\beta_T}{1 - \frac{\beta_T}{\beta_{sec}}}$$

(A-6-10)

NOTE: The system stiffness is less than or at best equal to the smaller of the brace or web stiffness.

TORSIONAL BRACING - CROSS SECTION DISTORTION



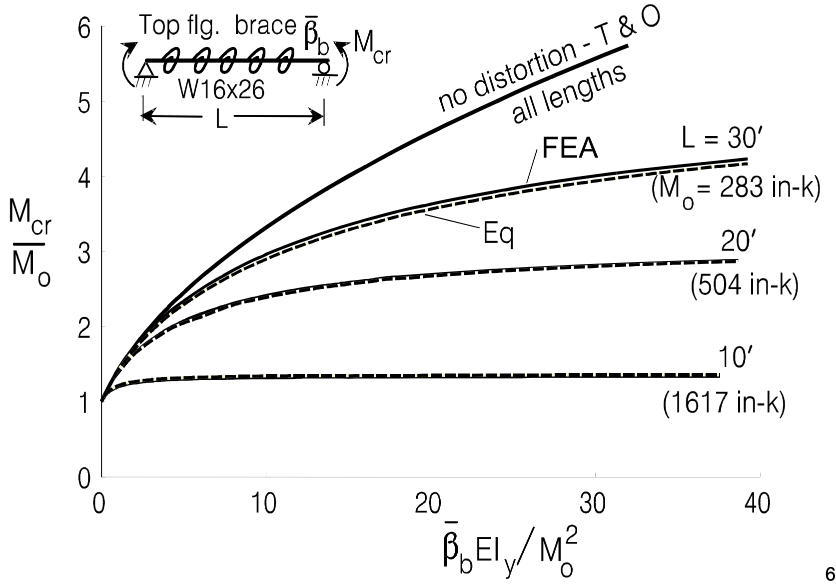


Effective Web Width for Distortion

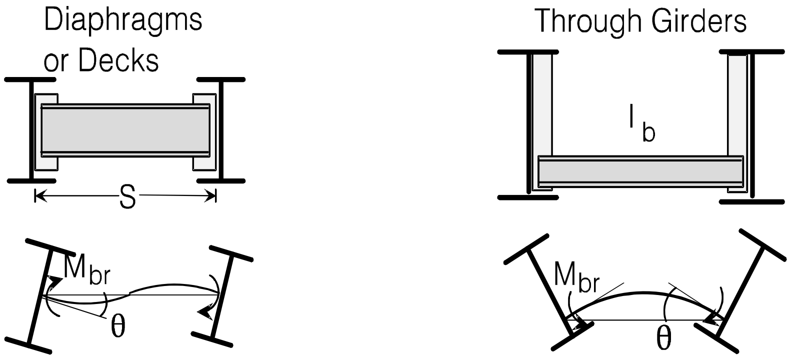
$$\beta_{sec} = \frac{3.3\,E}{h}\left(\frac{t_w^3}{12}\underbrace{(N + 1.5\,h)}_{\uparrow} + \frac{t_s\,b_s^3}{12}\right)$$

use 1 in. for continuous bracing

APPROXIMATE BUCKLING FORMULA



DIAPHRAGM BRACE STIFFNESS

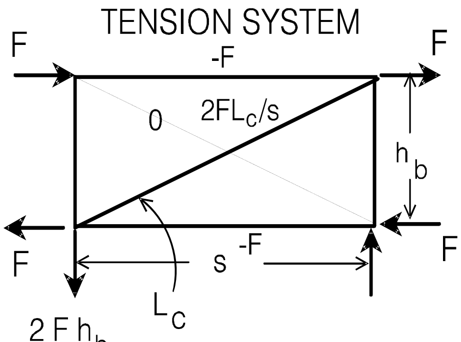


$$\beta_b = \frac{6\,E\,I_b}{S}$$

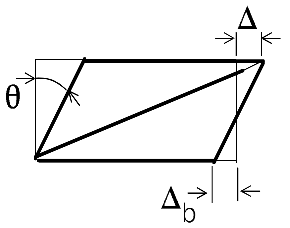
$$\beta_b = \frac{2\,E\,I_b}{S}$$

Use if diaphragm is at midheight or closer to the compression flange

CROSS FRAME STIFFNESS



$$\frac{2\,F\,h_b}{s}$$



$$\theta = \frac{\Delta + \Delta_b}{h_b} \qquad M = F\,h_b$$

$$\boxed{\beta_b = M/\theta = \frac{E\,s^2 h_b^2}{\dfrac{2\,L_c^3}{A_c} + \dfrac{s^3}{A_h}}}$$

Other Geometries
in Reference

Recent Tests: Cross Frame Specimens

Battistini et al(2016), J. of Bridge Engrg.,ASCE, Vol 21, No.6

Single Angle X-Frame

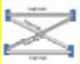
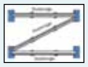
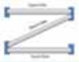
Single Angle K-Frame

Double Angle Z-Frame
(Single Angle Struts)

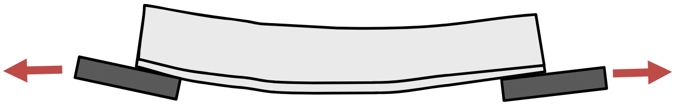
Double Angle Z-Frame
(Double Angle Struts)

Square Tube Z-Frame

Stiffness: Test vs. Analytical vs. FEA

Type of Cross Frames		Test Results	Analytic Solution	Error %	Line Element Solution	Error %
Single Angle X Frame		872,000	1,579,000	82%	1,572,000	81%
Single Angle K Frame		760,000	1,189,000	56%	1,180,000	55%
Unequal Leg Angle X Frame		1,054,000	1,609,000	53%	1,614,000	53%
Double Angle Z (Single Struts)		597,000	907,000	52%	905,000	52%
Double Angle Z (Double Struts)		1,182,000	1,152,000	-2.5%	1,152,000	-2.5%
Square Tube Z-frame		658,000	649,000	-1%	647,000	-2%

ECCENTRIC CONNECTION



The reduction in the stiffness is due to the bending caused by the eccentric connection

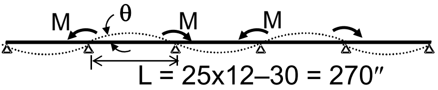
Reduce stiffness 50 % for eccentric connections

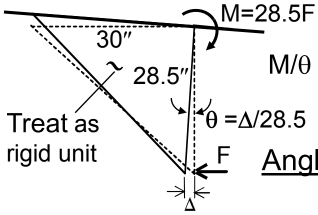
What about the angle brace in the earlier lateral brace example?

Brace Stiffness

The angle braces are supported by the continuous purlins that span 25′ between rafters. The effect of the purlin stiffness must be considered when evaluating the stiffness of the brace system

Purlin stiffness:





$M/\theta = 2 \times 2EI/L = 4(29000)12.6/270 = 5410$ k-in

$F/\Delta = M/(\theta(28.5)^2) = \underline{6.66 \text{ k/in}}$

Angle stiffness: $\dfrac{0.297(29000)}{39.7}\cos^2\theta = \underline{\overset{62}{\cancel{124}} \text{ k/in}}$

Brace stiffness: $(1/6.66) + (1/\underset{62}{\cancel{124}}) = (1/\beta) : \underline{\beta = \underset{6.01}{\cancel{6.32}} > 2.67 \text{ k/in}}$ *OK*

Brace Strength (E5-1)

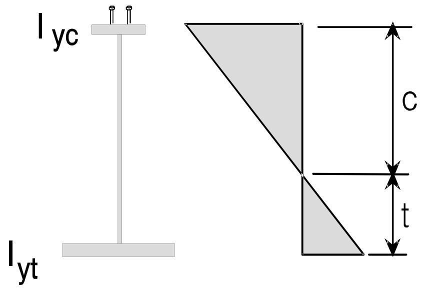
$F_y = 50$ ksi $\quad KL/r = 32 + 1.25\,(103) = 161 : \phi F_{cr} = 8.72$ ksi

$L/r_x = 103 \quad \phi P_n = 8.72(0.297) = \underline{2.59 \text{ k} > 0.82/\cos\theta = 1.09 \text{ k}}$ *OK*

SINGLY - SYMMETRIC GIRDERS

$$M_{cr} = \sqrt{C_{bu}^2 M_o^2 + \frac{C_{bb}^2 E I_y \overline{\beta}_T}{C_T}} \leq M_p \text{ or } M_s$$

$$I_{eff} = I_{yc} + \frac{t}{c} I_{yt}$$



DEVELOPMENT OF DESIGN RECOMMENDATIONS

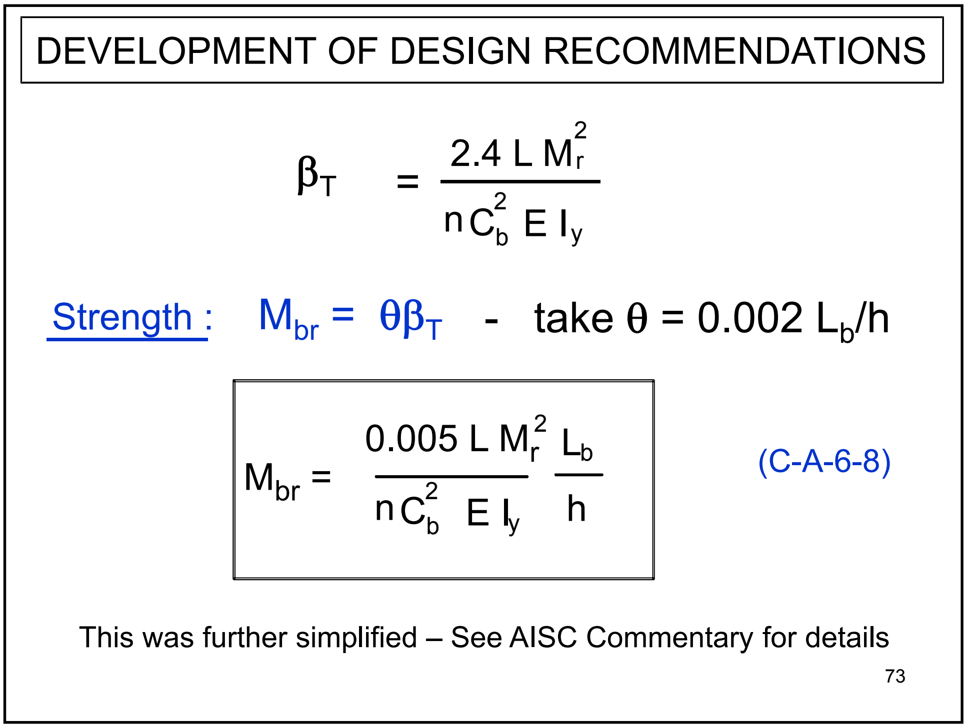
$$M_{cr} = \sqrt{\cancel{(C_{bu} M_o)^2} + \frac{C_{bb}^2 E I_{eff} \overline{\beta}_T}{2 C_T}}$$

Maximum Moment, M_r

1.2

Stiffness :

$$\overline{\beta}_T = \frac{2.4 M_r^2}{C_{bb}^2 E I_{eff}} = \frac{\beta_T n}{L}$$



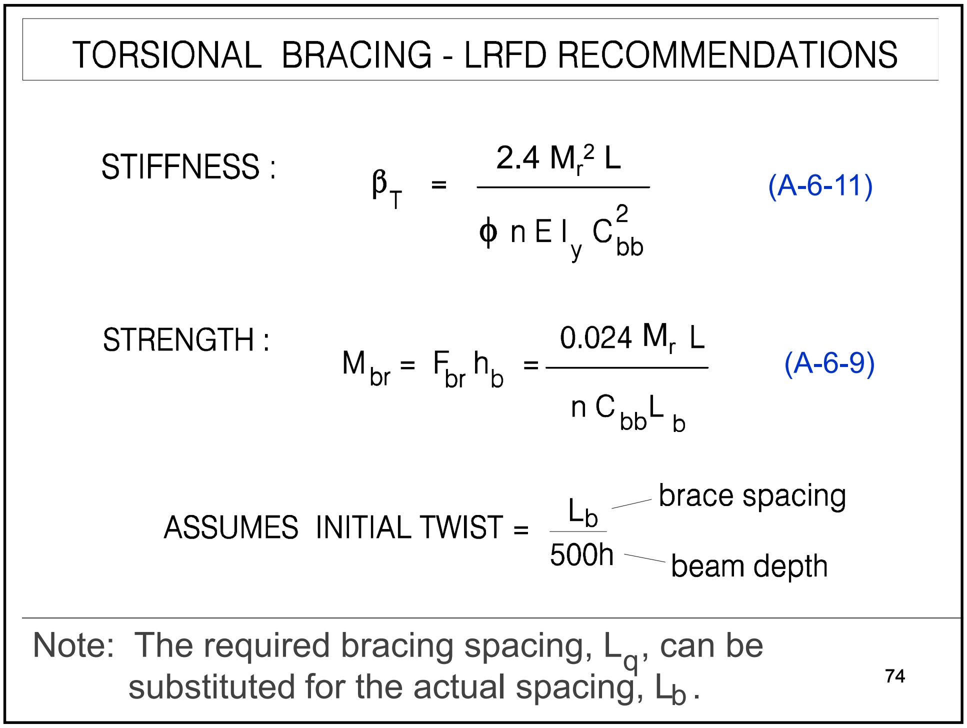
DEVELOPMENT OF DESIGN RECOMMENDATIONS

$$\beta_T = \frac{2.4\, L\, M_r^2}{n\, C_b^2\, E\, I_y}$$

Strength : $M_{br} = \theta\beta_T$ - take $\theta = 0.002\, L_b/h$

$$\boxed{M_{br} = \frac{0.005\, L\, M_r^2}{n\, C_b^2\, E\, I_y} \frac{L_b}{h}} \qquad \text{(C-A-6-8)}$$

This was further simplified – See AISC Commentary for details



TORSIONAL BRACING - LRFD RECOMMENDATIONS

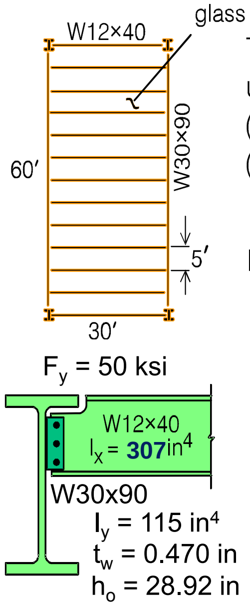
STIFFNESS : $\beta_T = \dfrac{2.4\, M_r^2\, L}{\phi\, n\, E\, I_y\, C_{bb}^2}$ (A-6-11)

STRENGTH : $M_{br} = F_{br}\, h_b = \dfrac{0.024\, M_r\, L}{n\, C_{bb} L_b}$ (A-6-9)

ASSUMES INITIAL TWIST = $\dfrac{L_b}{500h}$ L_b — brace spacing, h — beam depth

Note: The required bracing spacing, L_q, can be substituted for the actual spacing, L_b.

TORSIONAL BEAM BRACING



The grillage supports glass roof panels subjected to uniform load. The maximum beam moments are:

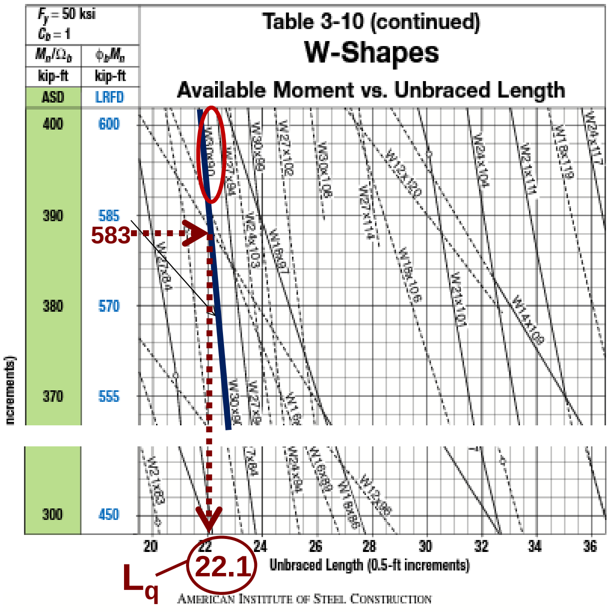
(W12×40) M_r =45 k′ < ϕM_n =**97** k′ (L_b= 30′,C_b=1.14)

(W30×90) M_r = 583 k′ > ϕM_n= **144** k′ (L_b= 60′,C_b=1.14)

∴ the W30×90 needs bracing from the W12×40

From p.**3-123**, AISC Manual, L_q=**22.1**′ for ϕM_n = 583 k′

PLOTS OF AVAILABLE FLEXURAL STRENGTH VS. UNBRACED LENGTH 3–123



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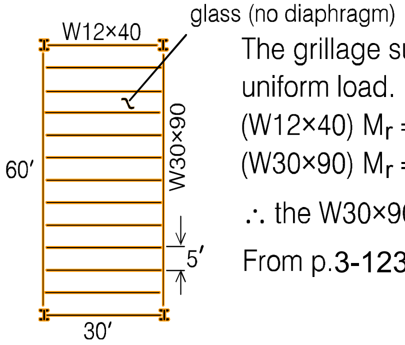
TORSIONAL BEAM BRACING



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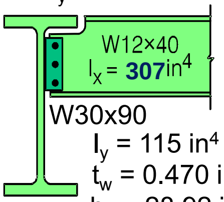
∴ the W30×90 needs bracing from the W12×40

From p.**3-123**, AISC Manual, L_q=**22.1**′ for ϕM_n = 583 k′

F_y = 50 ksi



W30x90

I_y = 115 in^4

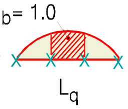
t_w = 0.470 in

h_o = 28.92 in

Brace Requirements

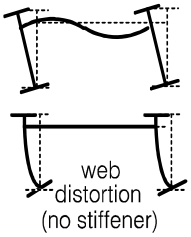
(A6-11) $$\beta_T = \frac{2.4(60\times12)(583\times12)^2}{0.75(11)(29000)(115)(1.0)^2} = \underline{3074 \text{ in-k/rad}}$$

(A6-9) Use L_q= **22.1**′ instead of L_b= 5′



$$M_{br} = \frac{0.024(583)60}{11(1.0)\,22.1} = \underline{3.45\text{ k}'}$$

Try W12×40 as bracing - assume that the shear tab connection can act as a moment connection for the small M_{br}

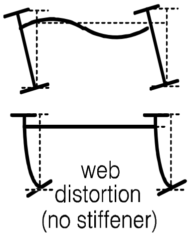


$$\beta_{Tb} = 6EI/L = 6(29000)\mathbf{307}/(30\times12) = \boxed{\mathbf{148{,}400}\text{ in-k/radian}}$$

(A6-12) $$\beta_{sec} = \frac{3.3(29000)}{28.92}\left(\frac{1.5(28.92)(0.47)^3}{12} + 0\right)$$

= **1242** < 3074 in-k/rad ∴ need web stiffeners (or thicker web)

Try W12×40 as bracing - assume that the shear tab connection can act as a moment connection for the small M_{br}



$$\beta_{Tb} = 6EI/L = 6(29000)307/(30\times12) = \boxed{148{,}400 \text{ in-k/radian}}$$

(A6-12) $$\beta_{sec} = \frac{3.3(29000)}{28.92}\left(\frac{1.5(28.92)(0.47)^3}{12} + 0\right)$$

$= \underline{1242 < 3074 \text{ in-k/rad}}$ ∴ need web stiffeners (or thicker web)

(C-A-6-12) $$\frac{1}{3074} = \frac{1}{148{,}400} + \frac{1}{\beta_{sec}}$$: required $\beta_{sec} = 3140$ in-k/rad

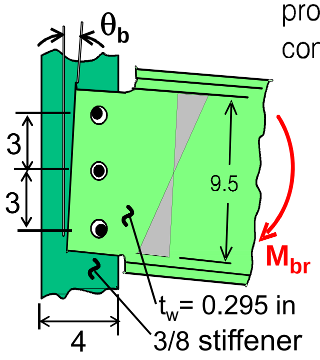
Assume 3/8 thick stiffener -

$$3140 = \frac{3.3(29000)}{28.92}\left(\frac{1.5(28.92)(0.47)^3}{12} + \frac{0.375(b_s)^3}{12}\right) \;;\; b_s = 2.63 \text{ in}$$

- use 4×3/8 full-depth one-sided stiffener for connection

Brace strength:

The bolted connection to the coped W12×40 can provide moment capacity as the bolts come in contact with the web when the beam tries to rotate.



$\phi M_n = 0.9\, S\, F_y$ where S is the section modulus of the web in the connection zone

$$\phi M_n = 0.9(50)(9.5)^2(0.295)/6(12) = 16.6 \text{ k-ft}$$

$\phi M_n > M_{br} = 3.45$ k-ft *OK*

Because of hole clearance, some rotation, θ_b, may occur before flexural resistance can be developed. Check **increase** in brace force.

Say $\theta_b = (2/16'') \div 6'' = 0.0208$ $\quad \theta_o = 0.002(22.1\times12)/28.92 = 0.0183$

$$M_{br} = 3.45\left(\frac{0.0208 + 0.0183}{0.0183}\right) = 7.37 < 16.6 \text{ k-ft, still } OK$$

Minimum Web Thickness to Eliminate the Web Stiffeners

(C-A-6-12) $\frac{1}{3074} = \frac{1}{148{,}400} + \frac{1}{\beta_{sec}}$: required β_{sec} = <u>3139 in-k/rad</u>

(A6-12) $3139 = 3.3(29000)(1.5\,t_w^3)/12$ ∴ approx. min t_w = <u>0.640 in</u>

W30x148 (t_w = 0.650 in)

Minimum Web Thickness to Eliminate the Web Stiffeners

(C-A-6-12) $\frac{1}{3074} = \frac{1}{148{,}400} + \frac{1}{\beta_{sec}}$: required β_{sec} = <u>3139 in-k/rad</u>

(A6-12) $3139 = 3.3(29000)(1.5\,t_w^3)/12$ ∴ approx. min t_w = <u>0.640 in</u>

W30x148 (t_w = 0.650 in)

<u>Try W30x124</u>, t_w = 0.585 in, ϕM_n unbraced = 284 k′ (M_r = 583 k′)

Account for unbraced buckling strength :

Replace M_r^2 with $(M_r^2 - (\phi M_n)^2)$ (AISC C-A-6-7)

$\beta_T = 3074\,(583^2 - 284^2)/\,583^2 =$ <u>2344 in-k/rad</u>

(C-A-6-12) $\frac{1}{2344} = \frac{1}{148{,}400} + \frac{1}{\beta_{sec}}$: required β_{sec} = <u>2381 in-k/rad</u>

(A6-12) $2381 = 3.3(29000)(1.5\,t_w^3)/12$ ∴ min t_w = <u>0.583 < 0.585 in</u>

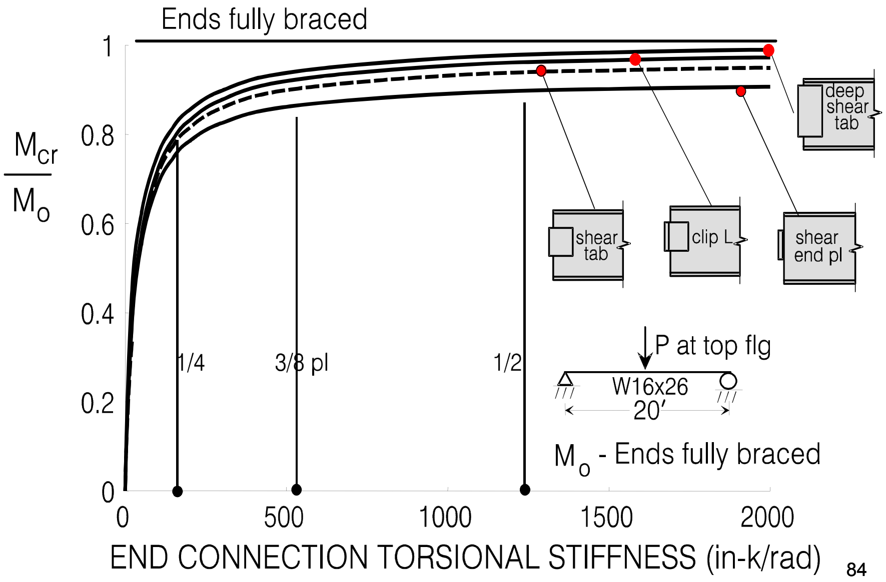
OK

Polling Question

To be effective, a torsional brace system must

a. be attached near the compression flange
b. prevent lateral movement and twist
c. have a web stiffener
d. limit distortion
e. all of the above

END CONNECTION TORSIONAL RESTRAINT



SUMMARY

- Closely-spaced long-span beams can buckle as a unit
- Beam braces can be designed to either prevent movement of the compression flange(s) or twist of the cross section
- Braces must have adequate stiffness in addition to strength
- Distortion of the cross section must be controlled for effective torsional bracing

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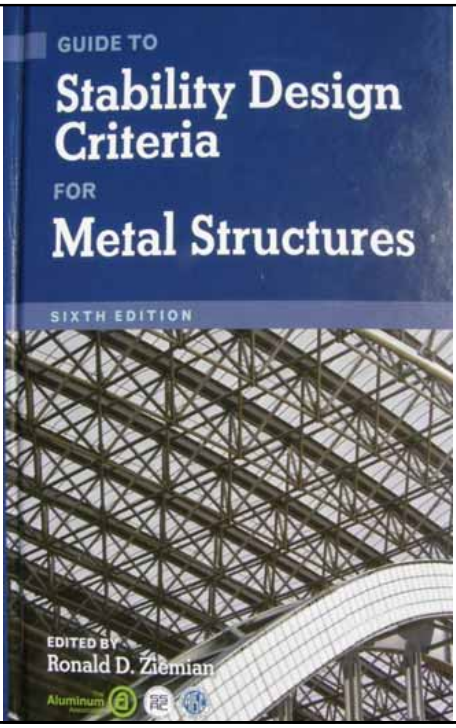
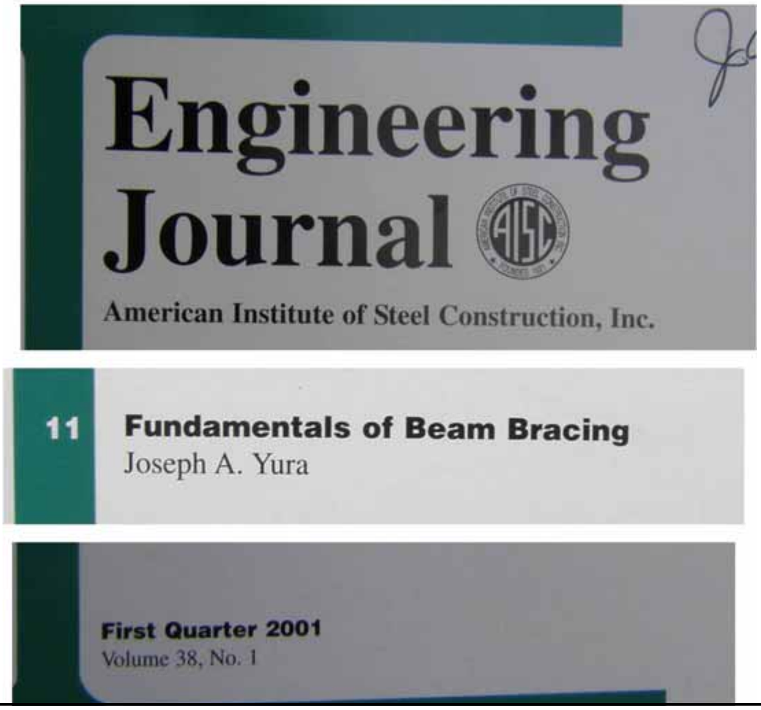
CHAPTER 12

BRACING





Engineering Journal

American Institute of Steel Construction, Inc.

11 **Fundamentals of Beam Bracing**
Joseph A. Yura

First Quarter 2001
Volume 38, No. 1

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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!
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Individual Webinar Registrants

CEU/PDH Certificates

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- New reporting site (URL will be provided in the forthcoming email).
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8-Session Registrants

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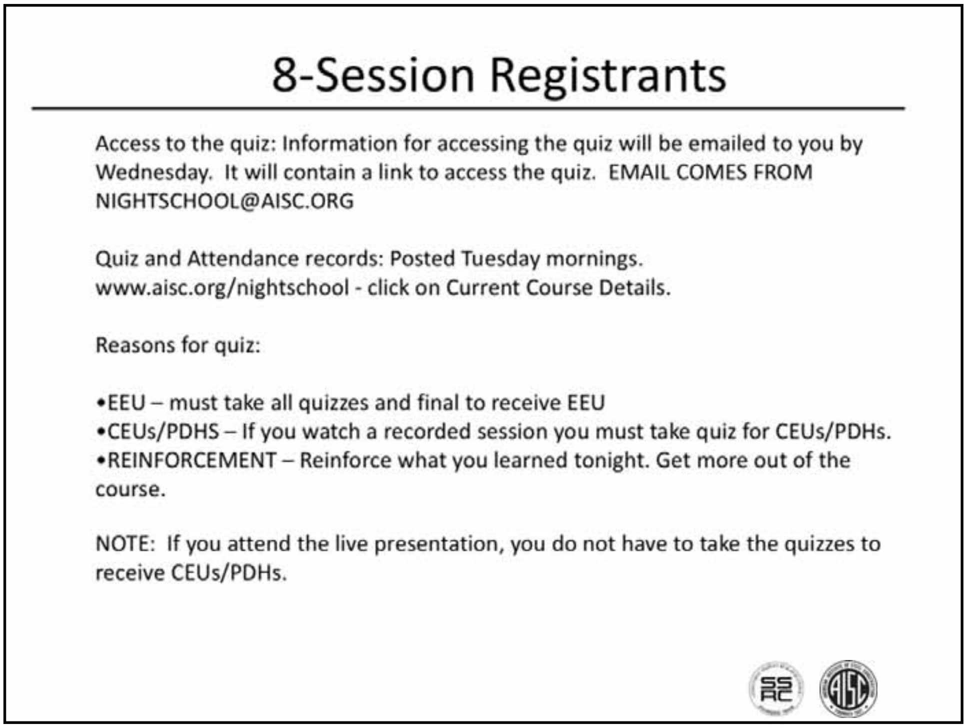
One certificate will be issued at the conclusion of all 8 sessions.

8-Session Registrants

Final Exam

The final exam will be issued on August 14.

The final exam must be submitted by August 28 at 8:00 AM EDT.



8-Session Registrants

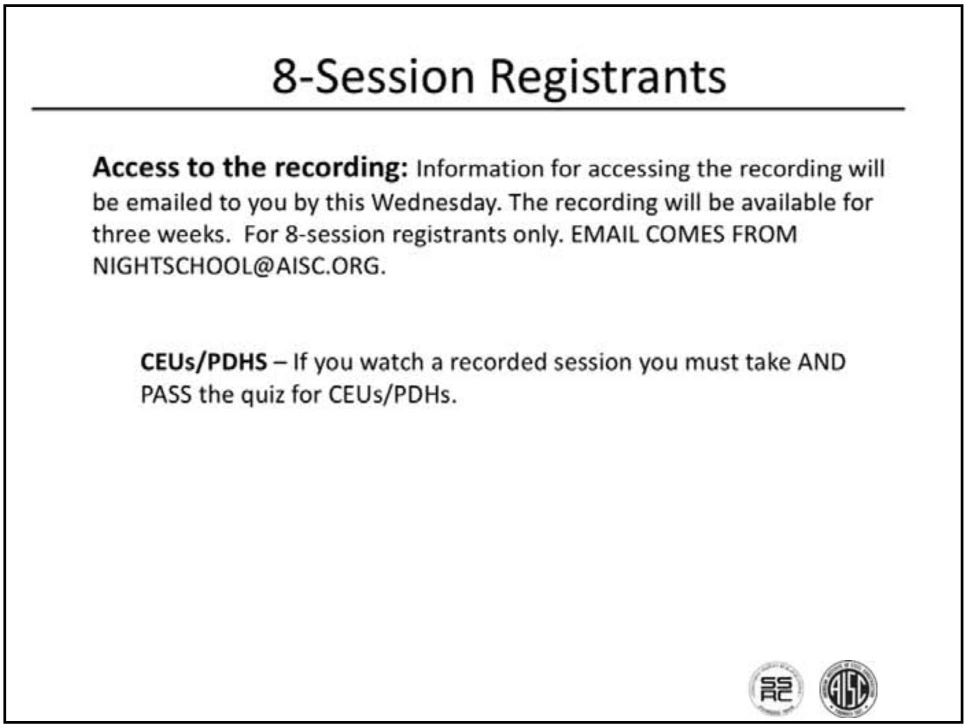
Access to the quiz: Information for accessing the quiz will be emailed to you by Wednesday. It will contain a link to access the quiz. EMAIL COMES FROM NIGHTSCHOOL@AISC.ORG

Quiz and Attendance records: Posted Tuesday mornings. www.aisc.org/nightschool - click on Current Course Details.

Reasons for quiz:

- EEU – must take all quizzes and final to receive EEU
- CEUs/PDHS – If you watch a recorded session you must take quiz for CEUs/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 CEUs/PDHs.



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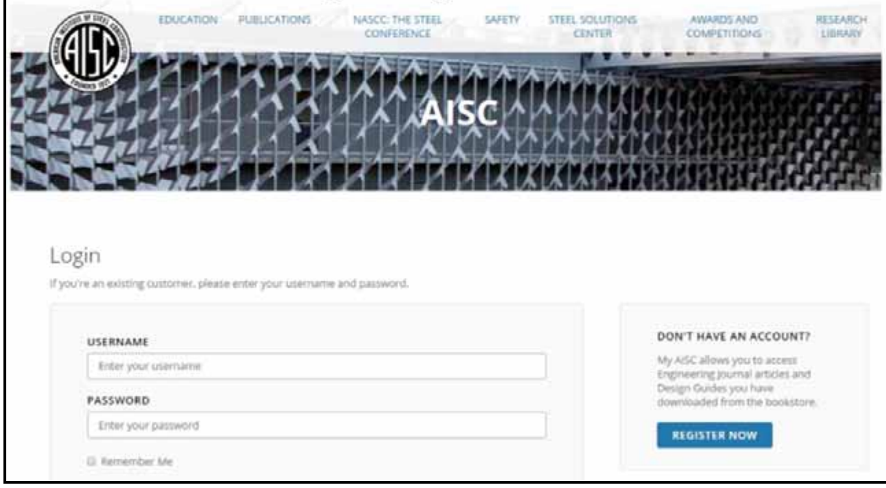

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Night School Resources for 8-session package Registrants

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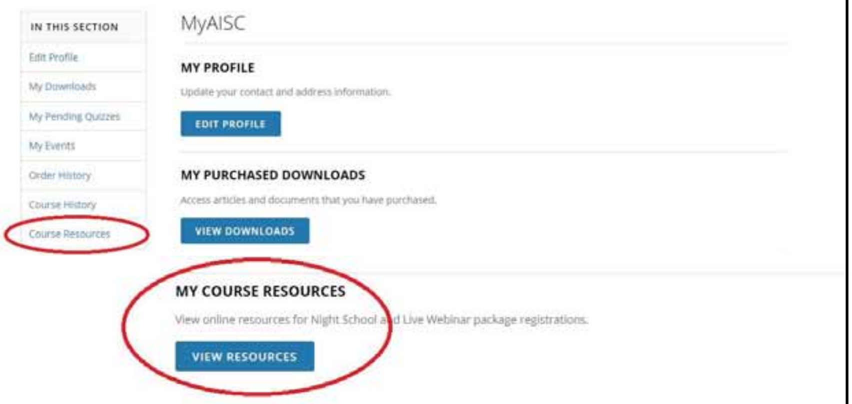


MyAISC

MY PROFILE

Update your contact and address information.

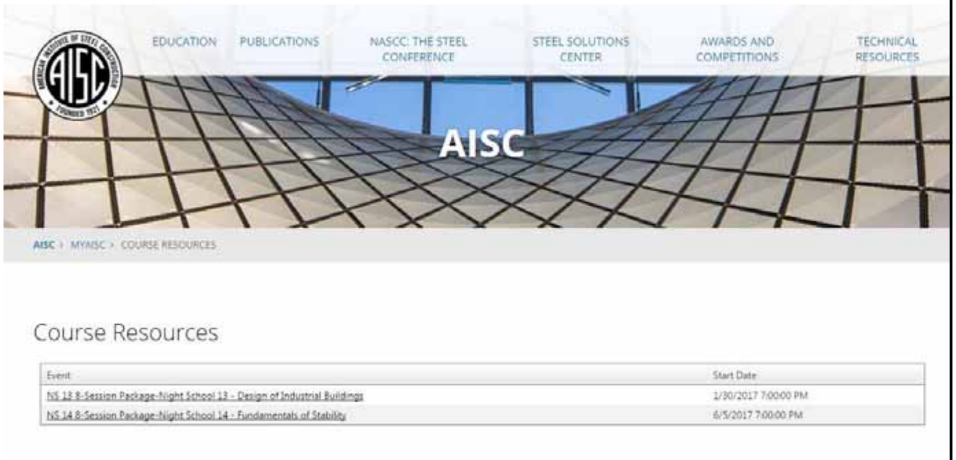
MY PURCHASED DOWNLOADS

Access articles and documents that you have purchased.

MY COURSE RESOURCES

View online resources for Night School and Live Webinar package registrations.

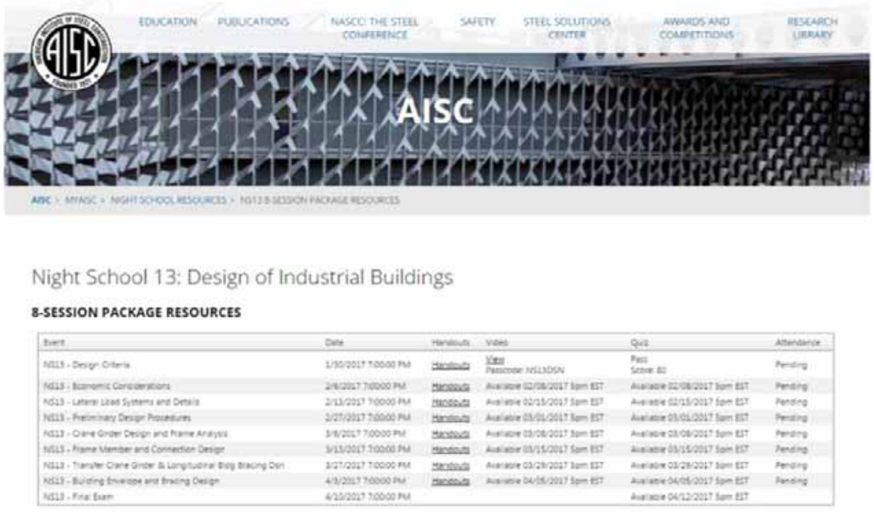
Night School Resources for 8-session package Registrants



Course Resources

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

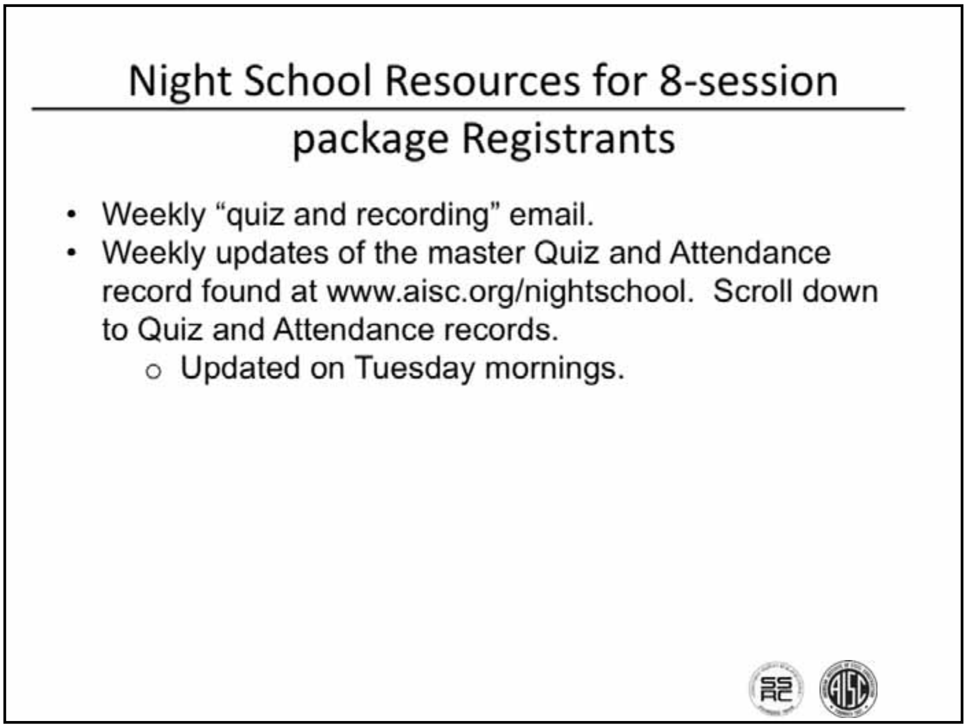
Night School Resources for 8-session package Registrants



Night School 13: Design of Industrial Buildings

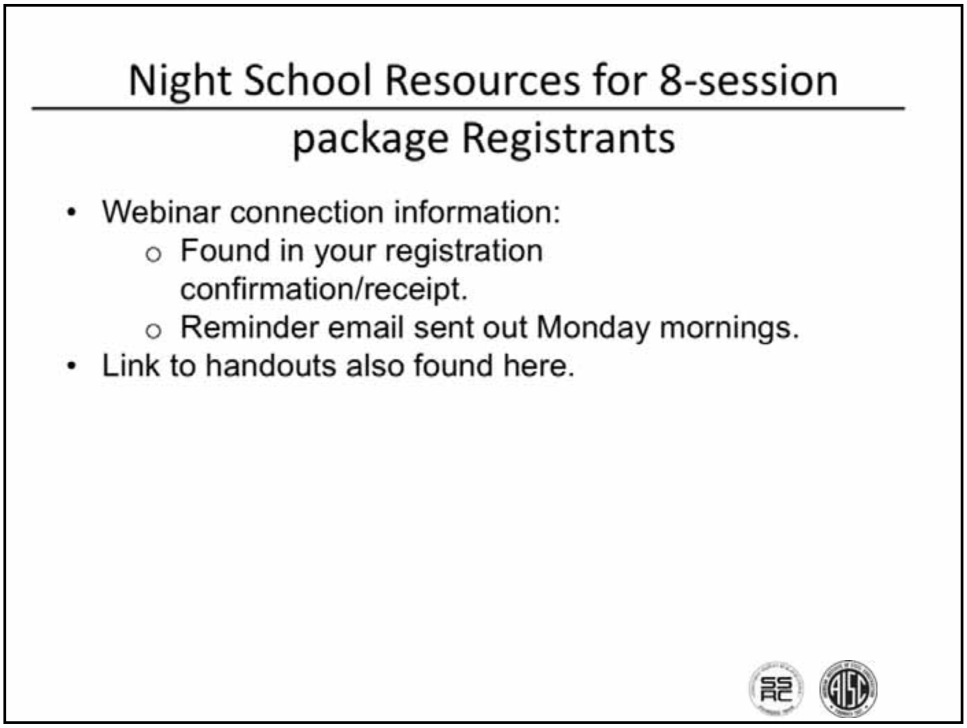
8-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
NS13 - Design Criteria	1/30/2017 7:00:00 PM	Handouts	View Passcode: NS13DSN	Pass Score: 80	Pending
NS13 - Economic Considerations	2/6/2017 7:00:00 PM	Handouts	Available 02/08/2017 5pm EST	Available 02/08/2017 5pm EST	Pending
NS13 - Lateral Load Systems and Details	2/13/2017 7:00:00 PM	Handouts	Available 02/15/2017 5pm EST	Available 02/15/2017 5pm EST	Pending
NS13 - Preliminary Design Procedures	2/27/2017 7:00:00 PM	Handouts	Available 03/01/2017 5pm EST	Available 03/01/2017 5pm EST	Pending
NS13 - Crane Girder Design and Frame Analysis	3/6/2017 7:00:00 PM	Handouts	Available 03/08/2017 5pm EST	Available 03/08/2017 5pm EST	Pending
NS13 - Frame Member and Connection Design	3/13/2017 7:00:00 PM	Handouts	Available 03/15/2017 5pm EST	Available 03/15/2017 5pm EST	Pending
NS13 - Transfer Crane Girder & Longitudinal Bldg Bracing Dsn	3/27/2017 7:00:00 PM	Handouts	Available 03/29/2017 5pm EST	Available 03/29/2017 5pm EST	Pending
NS13 - Building Envelope and Bracing Design	4/3/2017 7:00:00 PM	Handouts	Available 04/05/2017 5pm EST	Available 04/05/2017 5pm EST	Pending
NS13 - Final Exam	4/10/2017 7:00:00 PM			Available 04/12/2017 5pm EST	



Night School Resources for 8-session package Registrants

- Weekly “quiz and recording” email.
- Weekly updates of the master Quiz and Attendance record found at www.aisc.org/nightschool. Scroll down to Quiz and Attendance records.
  - Updated on Tuesday mornings.



Night School Resources for 8-session package Registrants

- Webinar connection information:
  - Found in your registration confirmation/receipt.
  - Reminder email sent out Monday mornings.
- Link to handouts also found here.

There's always a solution in steel.

Thank You

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

structural
STEEL