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Course Description

Practical Implementation of Composite Floor Designs
February 18, 2016

This lecture will move out of the classroom and into the field! Common design and detailing issues will be discussed such as the effect of openings, penetrations, and slab depressions on composite beam designs. Recommendations on best practices and tips for more constructible composite designs will also be presented on topics varying from deck attachment to contraction joints.

Learning Objectives

- Gain an understanding of some common design and detailing challenges associated with composite design.
- Become familiar with detailing and design considerations for openings, penetrations, and slab depressions in composite beams.
- Gain a thorough understanding of the strength and serviceability limits associated with composite beam strengthening including techniques to properly address them.
- Become familiar with practical tips for more constructible composite designs from deck attachment details to contraction joint layouts.

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Practical Implementation of Composite Floor Designs

February 18, 2016

Presented by
William P. Jacobs V, P.E., S.E.
Principal
Stanley D. Lindsey & Associates, Ltd.
Atlanta, Georgia

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Outline

Practical Implementation of Composite Floor Designs

- Part 1: Conduit, Penetrations, and Openings
- Part 2: Composite Beam Strengthening
- Part 3: Best Practices / Tips for Composite Floor Designs

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Outline

Part 1: Conduit, Penetrations, and Openings

- Conduit
- Penetrations and Openings
- Impact on Effective Width
- Special Cases

There's always a solution in Steel 10

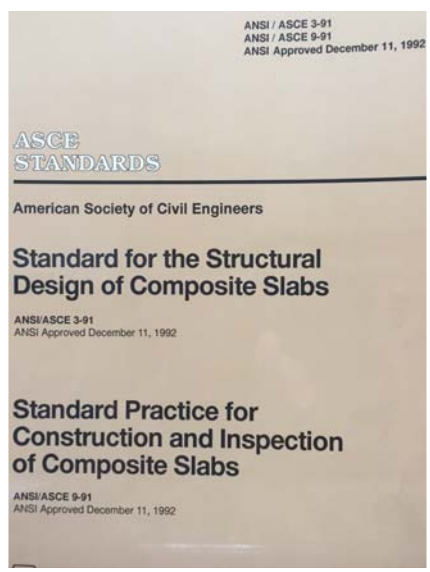
Part 1: Conduit

There's always a solution in Steel 11

Part 1: Conduit

Code Guidance

- ASCE 3-91



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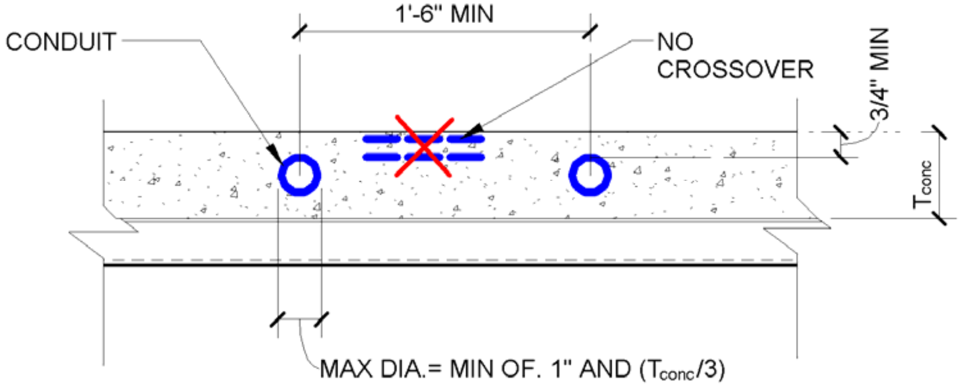
Part 1: Conduit

Code Guidance

❖ Review Fire Ratings

- ASCE 3-91



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Part 1: Conduit

Code Guidance

- Steel Deck Institute

Sputo, T. (2014), *Floor Deck Design Manual*, 1st Ed., Steel Deck Institute, Glenshaw, PA.

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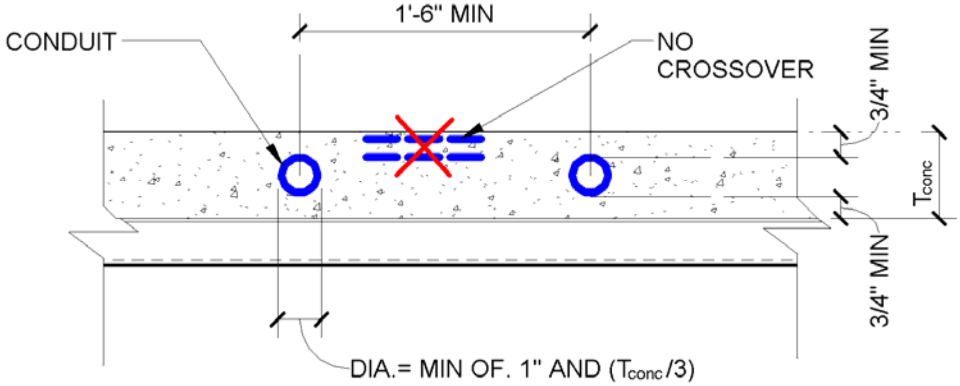
Part 1: Conduit

Code Guidance

- Steel Deck Institute



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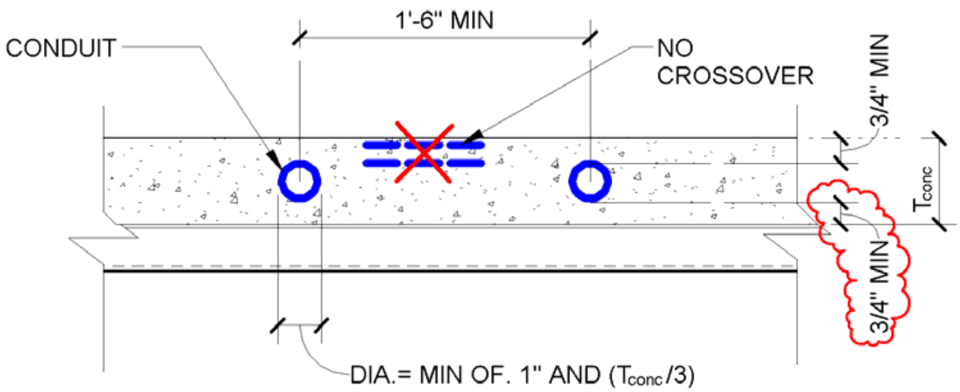
Part 1: Conduit

Code Guidance

- Steel Deck Institute

❖ Review Fire Ratings
❖ No Uncoated Aluminum
❖ No Conduit Within Ribs



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Part 1: Conduit

Code Guidance

- ACI 318-11 (Section 6.3)
- Applicable to Structural Slabs Meeting ACI 318
- Conduits Should Not Displace More than 4% of Concrete

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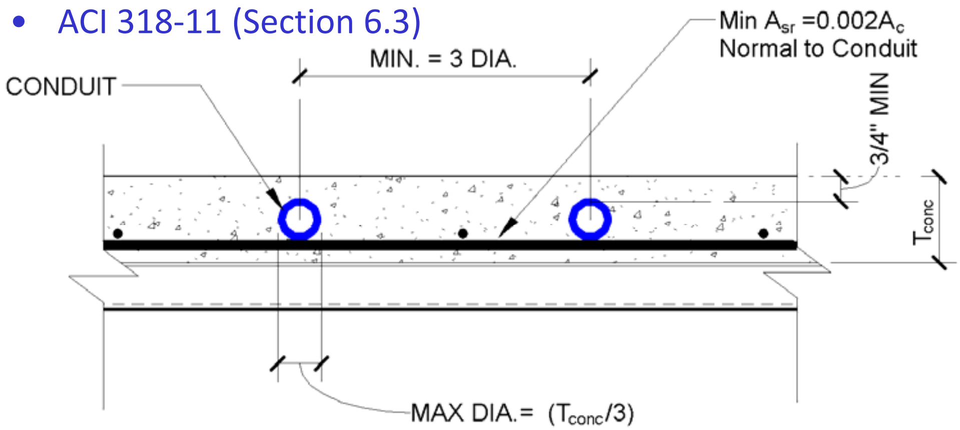
Part 1: Conduit

Code Guidance

- ACI 318-11 (Section 6.3)



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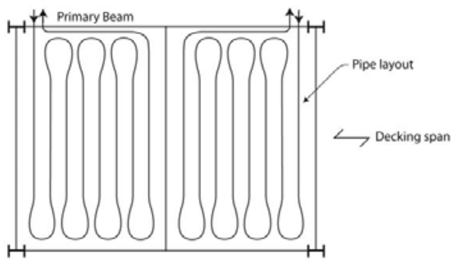
Part 1: Conduit

Radiant Heating Pipes?

- SDI: Install in Non-Structural Topping Slab
- Steel Construction Institute's (SCI) New Steel Construction (NSC) AD Note 350



REF: *http://www.newsteelconstruction.com/wp/ad-350-heating-pipes-in-composite-floors-effects-on-slab-beam-design/*

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Part 1: Conduit

Radiant Heating Pipes?

- Place Pipes Min. 1 in. Above Top of Metal Deck Surface
- Avoid Longitudinal Pipes within 8 in. Each Side of Beam
- Place Transverse Pipes in Outer Thirds of Span
- Ignore Concrete Displaced by Pipes for Strength Calculations
- Consider Studs where Conduit is within 1.75 x Stud Ht. as Ineffective (Typically Approx. 8 in. Radius Circle)

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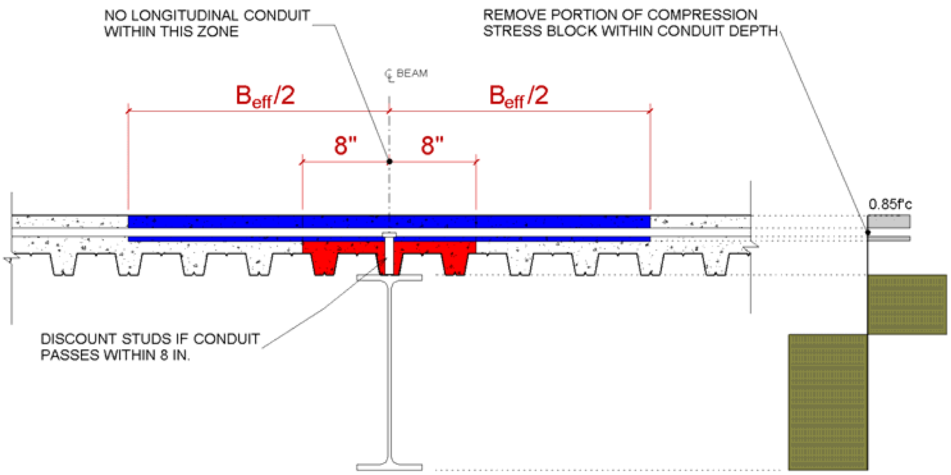
Part 1: Conduit

Radiant Heating Pipes?



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Part 1: Conduit

Summary Advice for Conduits

- Place SDI Requirements On Drawings in General Notes or Typical Details
- If Denser Conduit is Required at Specific Locations:
  - Place Transverse Conduit in Outer Third of Beam Spans
  - Design Beams with Multiple Transverse Conduits as Noncomposite
  - Design Junction Locations as Openings
- If Denser Conduit AND Composite Strength Required
  - Reinforce Slab in Accordance with ACI 318-11 Section 6.3
  - Discount Studs with Conduit within 8 in.
  - Remove Transverse Conduit from Compression Block

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Outline

Part 1: Penetrations, Openings, and Conduit

- Conduit
- Penetrations and Openings
- Impact on Effective Width
- Special Cases

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Part 1: Penetrations

There's always a solution in Steel 24

Part 1: Penetrations

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Part 1: Penetrations

Code Guidance

- OSHA Regulation 29 CFR Section 1926.754(e)(2)(2003)
- SDI "Floor Deck Design Manual" - Section 2.10
- SDI "Deck Damage and Penetrations" White Paper
  Ref: Heagler, Richard B. (1987), *Deck Damage and Penetrations*, Rev. 2000, Steel Deck Institute, Glenshaw, PA

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Part 1: Penetrations

Code Guidance

- OSHA Regulation 29 CFR Section 1926.754(e)(2)(2003)
  - "Roof and floor holes and openings shall be decked over."
  - "Metal decking holes and openings shall not be cut until immediately prior to being permanently filled with the equipment or structure needed or intended to fulfill it specific use"

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Part 1: Penetrations

Code Guidance

- SDI "Floor Deck Design Manual" - Section 2.10

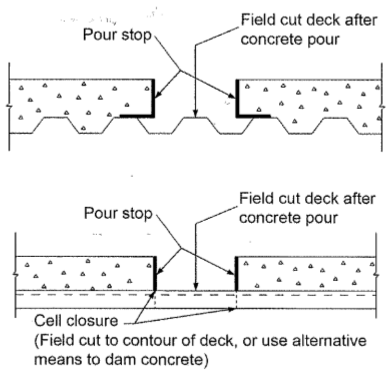

Figure 2.10 Decked Over Opening

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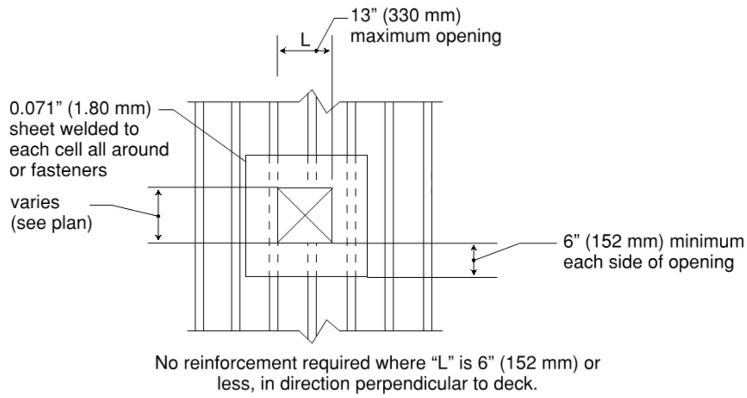
Part 1: Penetrations

Code Guidance

- SDI Deck Design and Damage White Paper



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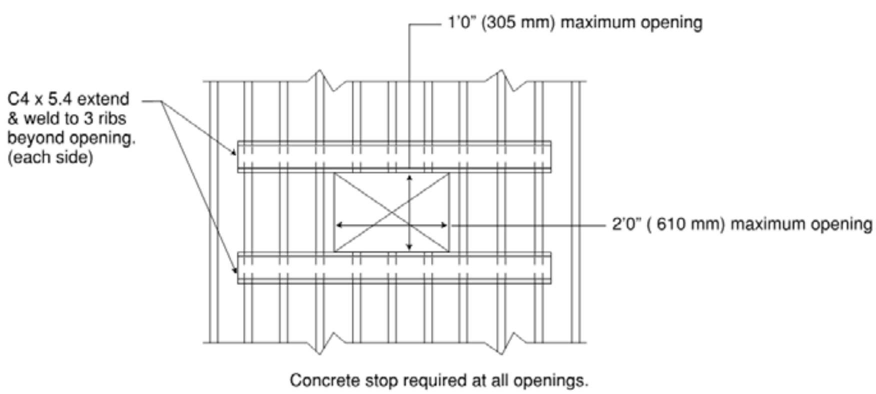
Part 1: Penetrations

Code Guidance

- SDI Deck Design and Damage White Paper



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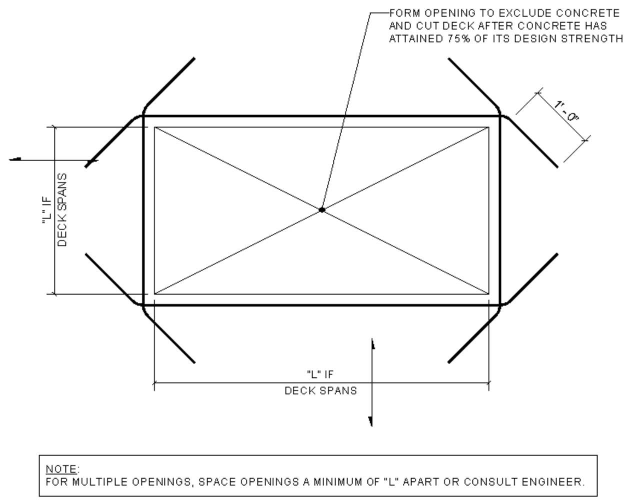
Part 1: Penetrations

Slab Reinforcement Option



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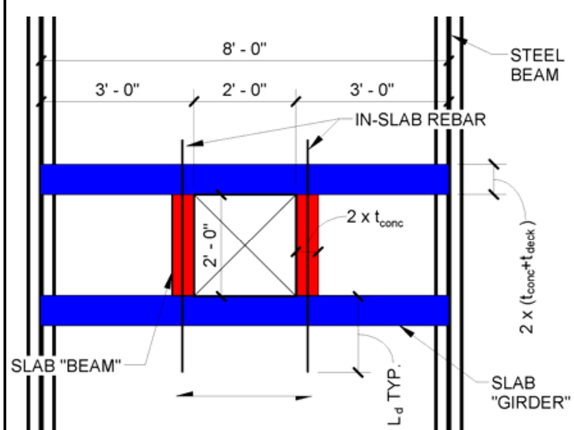
Part 1: Penetrations

Reinf. Example (SDI 2014)



2 in. 20 Ga. deck + 3.5 in. NW conc. (3 ksi)

DL = 50 psf   LL= 50 psf

$w_u = 1.2(50) + 1.6(50) = 140 \text{ psf}$

"beam" width = $2(t_{conc} = 3.5 \text{ in.}) = 7 \text{ in.}$

"beam" trib. load = $\dfrac{(3 \text{ ft})}{2}(140 \text{ psf}) = 210 \text{ plf}$

"beam" $M_u = \dfrac{(210 \text{ plf})(2 \text{ ft})^2}{8(1{,}000 \text{ lb/kip})} = 0.105 \text{ kip-ft}$

"beam" $V_u = \dfrac{(210 \text{ plf})(2 \text{ ft})}{2(1{,}000 \text{ lb/kip})} = 0.210 \text{ kips}$

(note $V_s = 0.150$ kips for later checks)

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Part 1: Penetrations

Reinf. Example (SDI 2014)

$$\phi M_n = \phi 5 \lambda S_m \sqrt{f'_c} \quad (\text{ACI 318-11 Eq.22-2})$$

$$= (0.60)(5)(1.0)\frac{(7\text{ in.})(3.5\text{ in.})^2}{6}\frac{\sqrt{3{,}000\text{ psi}}}{1{,}000\text{ lb/kip}}\left(\frac{1}{12\text{ in./ft}}\right)$$

$$= 0.196\text{ kip-ft}$$

$$\phi M_n > M_u = 0.105\text{ kip-ft} \quad \textbf{o.k.}$$

$$\phi V_n = \phi 1.33 \lambda b_w h \sqrt{f'_c} \quad (\text{ACI 318-11 Eq.22-8})$$

$$= (0.60)(1.33)(1.0)(7\text{ in.})(3.5\text{ in.})\frac{\sqrt{3{,}000\text{ psi}}}{1{,}000\text{ lb/kip}}$$

$$= 1.07\text{ kips}$$

$$\phi V_n > V_u = 0.210\text{ kips} \quad \textbf{o.k.}$$

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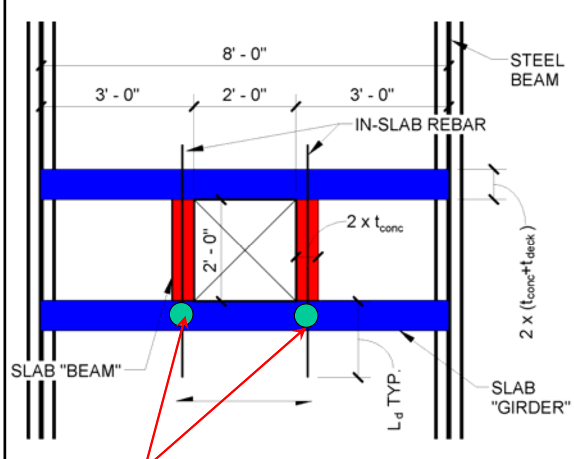
Part 1: Penetrations

Reinf. Example (SDI 2014)



P_s = reactions from slab beams

M_s "girder" from 2 point loads and uniform load:

"girder" width = $2(t_{deck} + t_{conc}) = 11\text{ in.} \rightarrow$ *say* 1 ft

$$M_s = \frac{w_{super} l^2_{girder}}{8} + P_s a$$

$$= \frac{(50\text{ plf})(8\text{ ft})^2}{8} + (150\text{ lbs})(3\text{ ft})$$

$$= 850\text{ lb-ft}$$

$$w_{s-equiv} = \frac{8M_s}{l^2_{girder}} = 107\text{ plf}$$

for 1ft width = 107 psf $\rightarrow$ check deck

Mnfr Literature $\rightarrow$ Allowable = 217 psf **o.k.**

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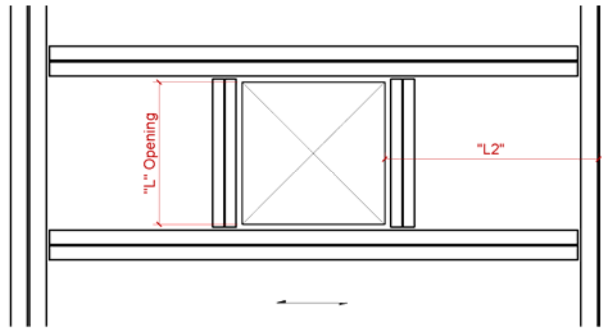
Part 1: Penetrations

Support Frames



- Generally Required for "L" Opening > 2'-6" or for Heavy Loadings
- Can Omit Side Beam if Slab Length "L2" is Checked for Cantilevered Condition (Both Pre and Post Concrete Placement)
- Can Be Post-Installed If Required for Unforeseen Openings

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Part 1: Penetrations

Summary Advice for Penetrations/Openings

- Specify Deck Openings Not Cut Until Slab Reaches 75% Strength
- Most Economical to Provide In-Slab Reinforcement
- Create Reinf. Details for Typical Slab Types and Loadings
- Specify Minimum Spacing Between Penetrations
- Add Support Frames as Required
- GO TO THE FIELD
- Pay Attention to Effect on Composite Beams…

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Outline

Part 1: Penetrations, Openings, and Conduit

- Conduit
- Penetrations and Openings
- Impact on Effective Width
- Special Cases

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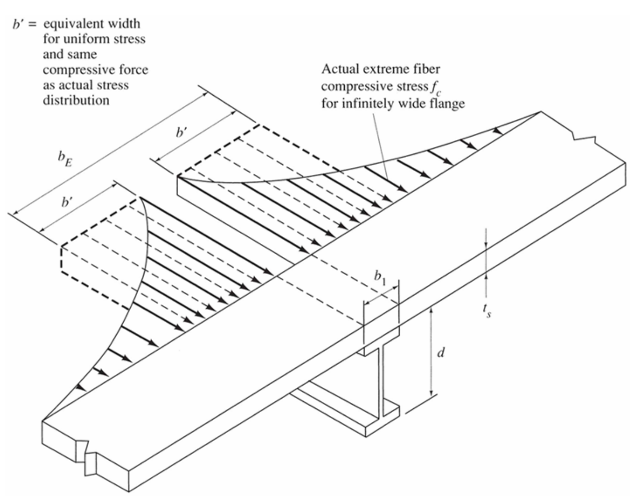
Part 1: Beff

Effective Slab Width



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Part 1: Beff

Effective Slab Width

- Least Theoretical Impact Near Supports Midway Between Beams
- Penetrations Up to 12 in. Generally Not Significant
- Wiesner, K.B., "Composite Beams with Slab Openings", Modern Steel Construction, March, 1996, pp26-30
  - Openings Located at End of Beam Less Than 1/8 Distance to Maximum Moment May Be Neglected
  - For Uniformly Loaded Beam = L/16
  - Openings Shall be Greater than L/80 or 6 in. Away from Beam

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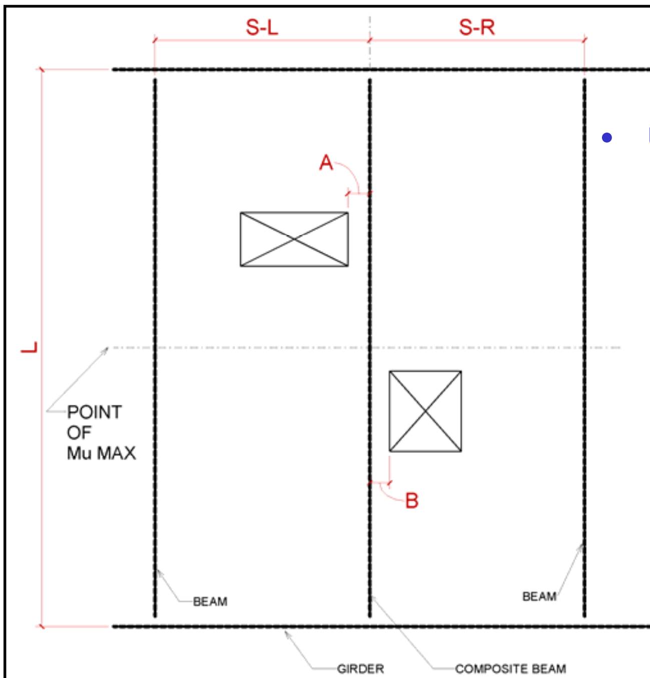
Part 1: Beff



- Uniformly Loaded Simple Span Beam

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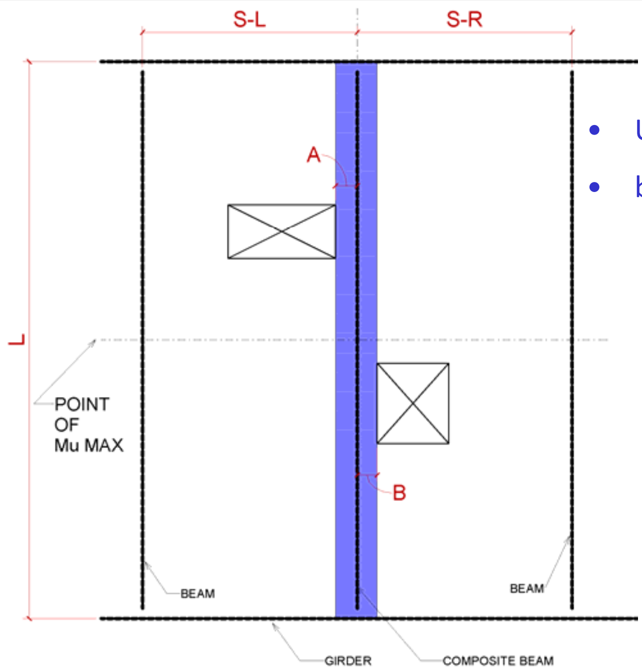
Part 1: Beff



- Uniformly Loaded Simple Span Beam
- b_{eff} = A+B

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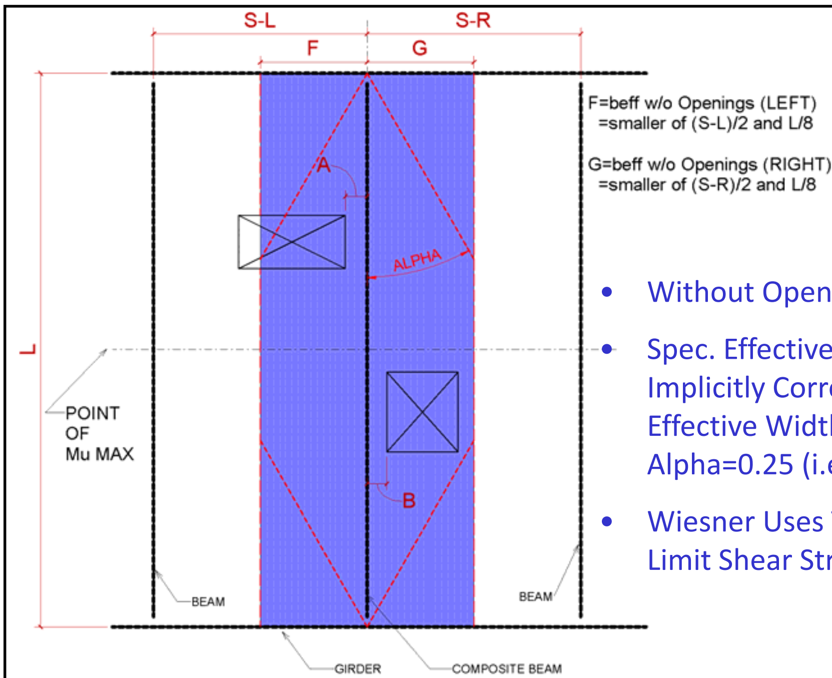
Part 1: Beff



- Without Openings: b_{eff} = F+G
- Spec. Effective Width Requirements Implicitly Correspond to Activated Effective Width Based on Tangent of Alpha=0.25 (i.e. Alpha = 14 deg)
- Wiesner Uses This Same Angle to Limit Shear Stress in Slab

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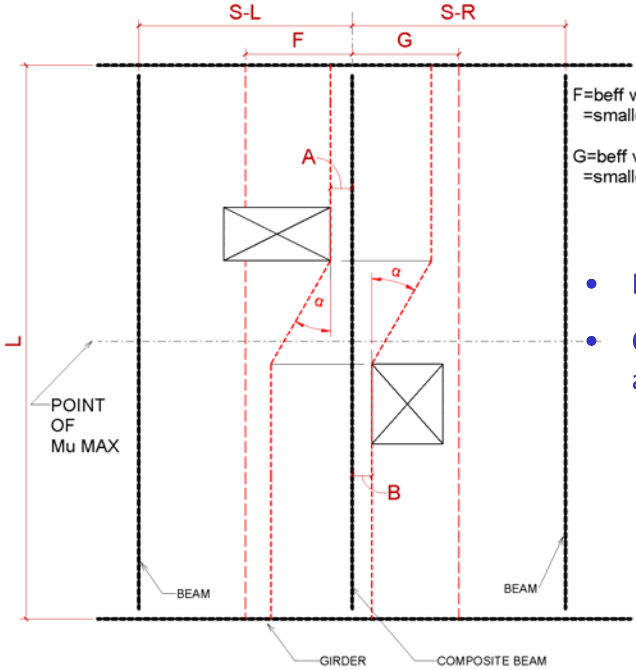
Part 1: Beff



F=beff w/o Openings (LEFT)
=smaller of (S-L)/2 and L/8

G=beff w/o Openings (RIGHT)
=smaller of (S-R)/2 and L/8

- Draw Effective Width Diagram
- Come off Openings at Alpha = 14 deg. away from beam

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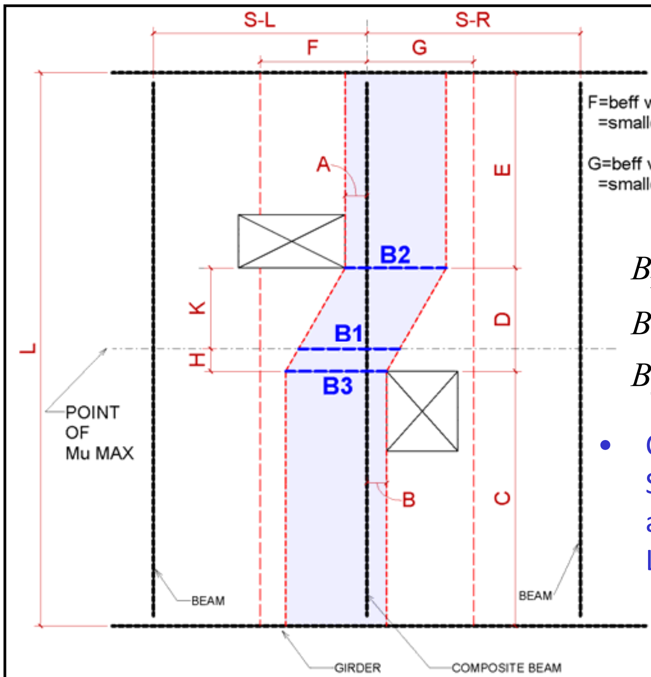
Part 1: Beff



F=beff w/o Openings (LEFT)
=smaller of (S-L)/2 and L/8

G=beff w/o Openings (RIGHT)
=smaller of (S-R)/2 and L/8

$$B_1 = A + B + 0.25(H + K) \le F + G$$

$$B_2 = A + B + 0.25(H + K) \le A + G$$

$$B_3 = A + B + 0.25(H + K) \le B + F$$

- Check Capacity vs. Demand at Each Section Using Effective Widths Above and $\sum Q_n$ From End of Beam to That Location

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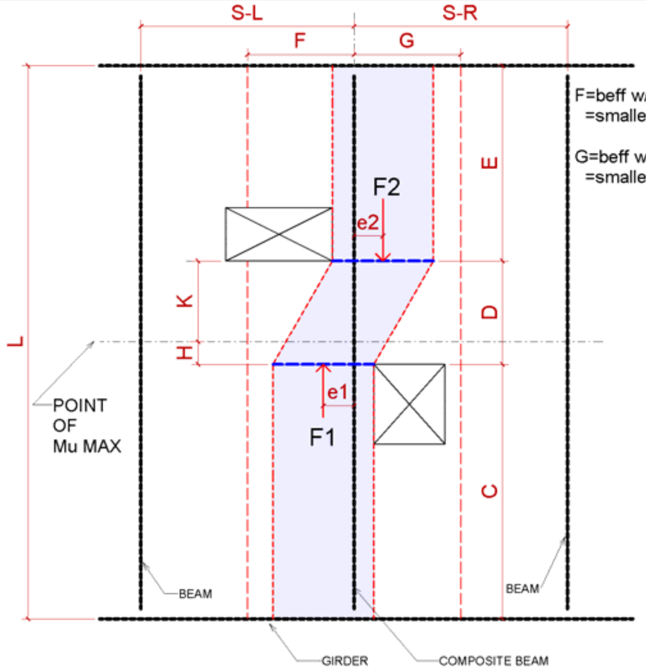
Part 1: Beff



$$F_1 = \sum Q_{n1}$$
$$F_2 = \sum Q_{n2}$$
$$M_1 = F_1 e_1$$
$$M_2 = F_2 e_2$$
$$M = \max(M_1, M_2)$$

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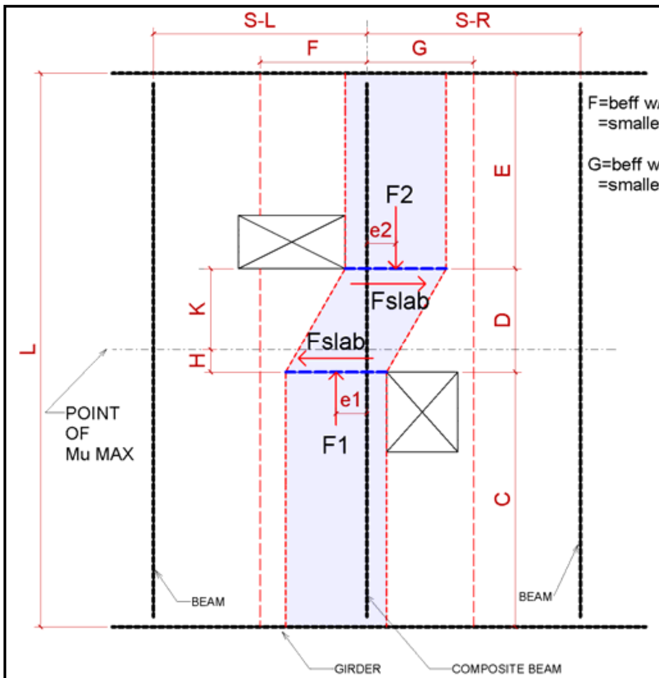
Part 1: Beff



$$F_1 = \sum Q_{n1}$$
$$F_2 = \sum Q_{n2}$$
$$M_1 = F_1 e_1$$
$$M_2 = F_2 e_2$$
$$M = \max(M_1, M_2)$$
$$F_{slab} = \frac{M}{d}$$
$$T_{slab} = 0.5 F_{slab}$$

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Outline

Part 1: Penetrations, Openings, and Conduit

- Conduit
- Penetrations and Openings
- Impact on Effective Width
- Special Cases

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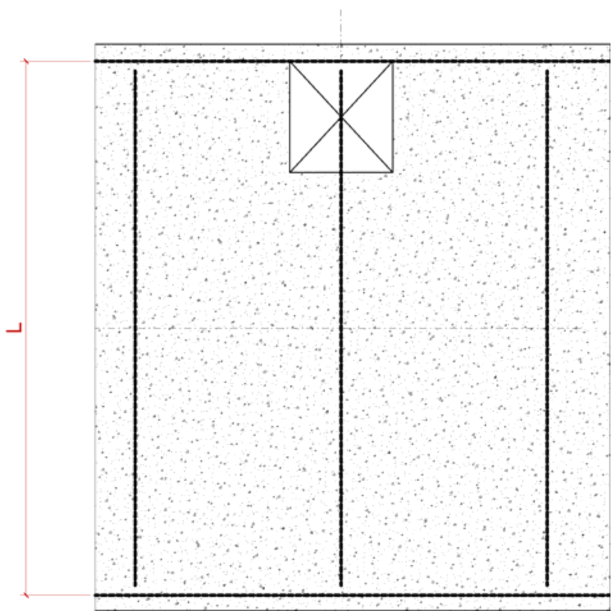
Part 1: Special Cases



- What About Opening at End?

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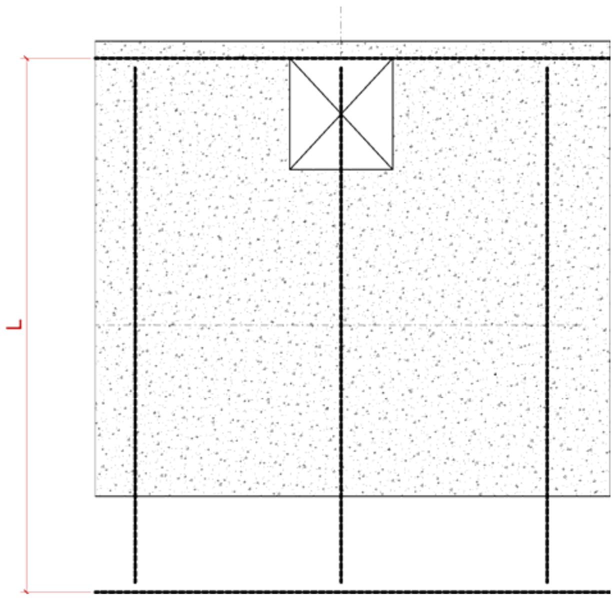
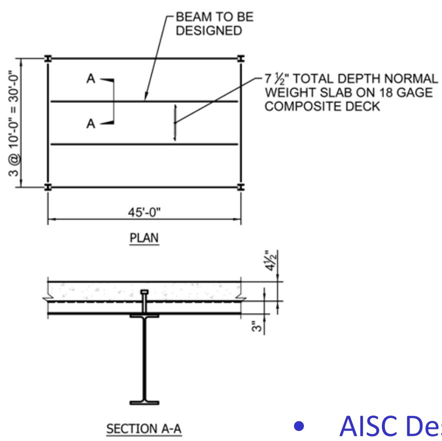
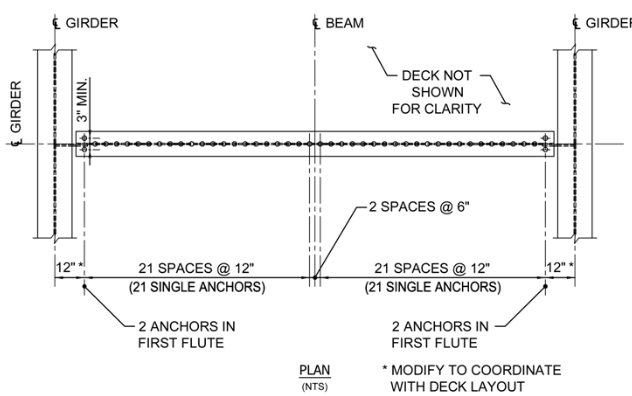
Part 1: Special Cases



- What About Opening at End?
- Or Beams Extend Beyond Slab Edge?

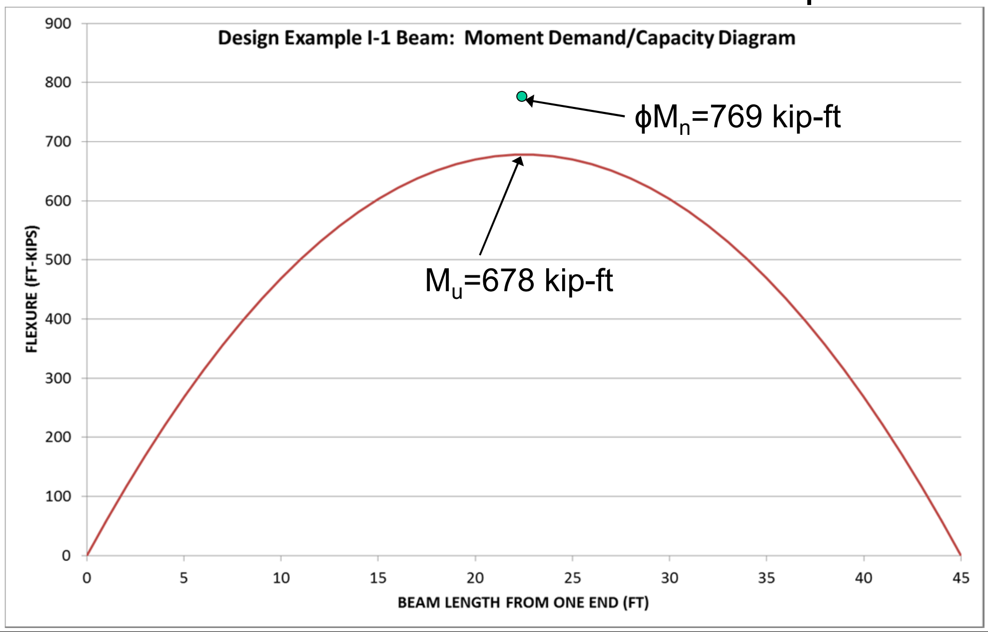
Part 1: Special Cases





- AISC Design Examples I-1
- W21x50 - Uniformly Loaded Beam, 45 ft Long
- M_u=678 kip-ft compared to ϕM_n=769 kip-ft

Part 1: Special Cases



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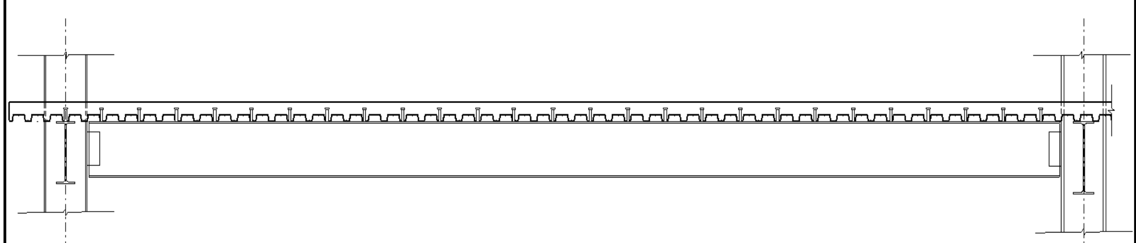
Part 1: Special Cases

Section Capacity



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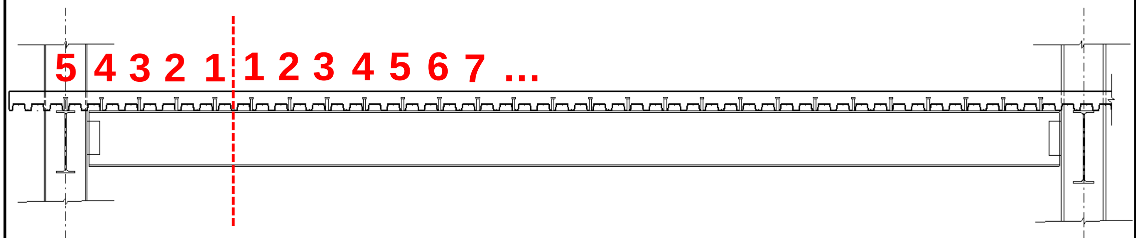
Part 1: Special Cases

Section Capacity



- $\sum Q_n$ at Each Section Based on Min. Number Studs to Each Side of that Section
- Can Calculate Available Flexural Strength at Each Section By Looking Available Shear Transfer At that Section

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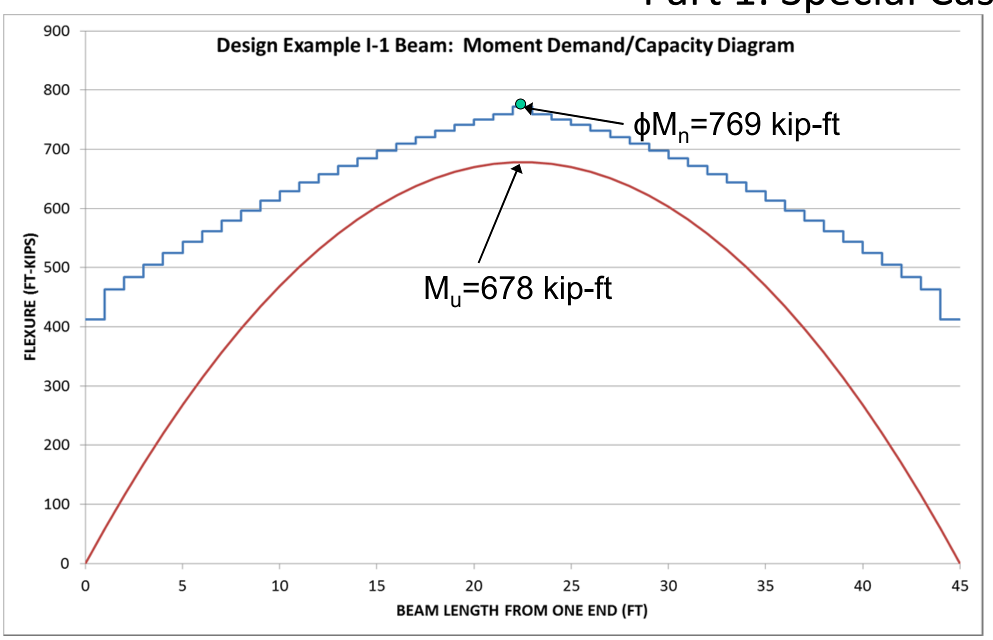
Part 1: Special Cases



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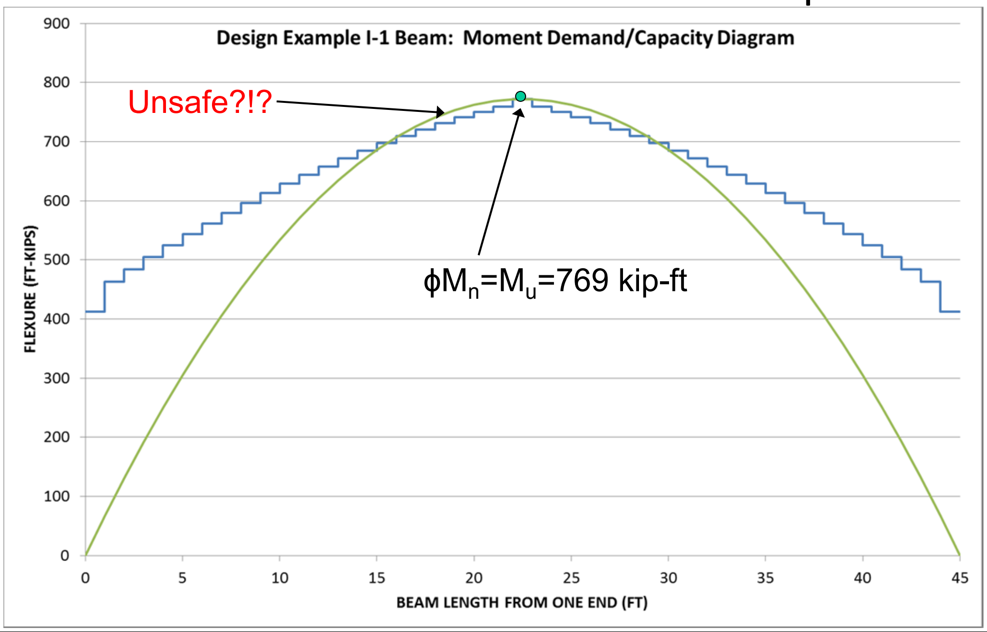
Part 1: Special Cases



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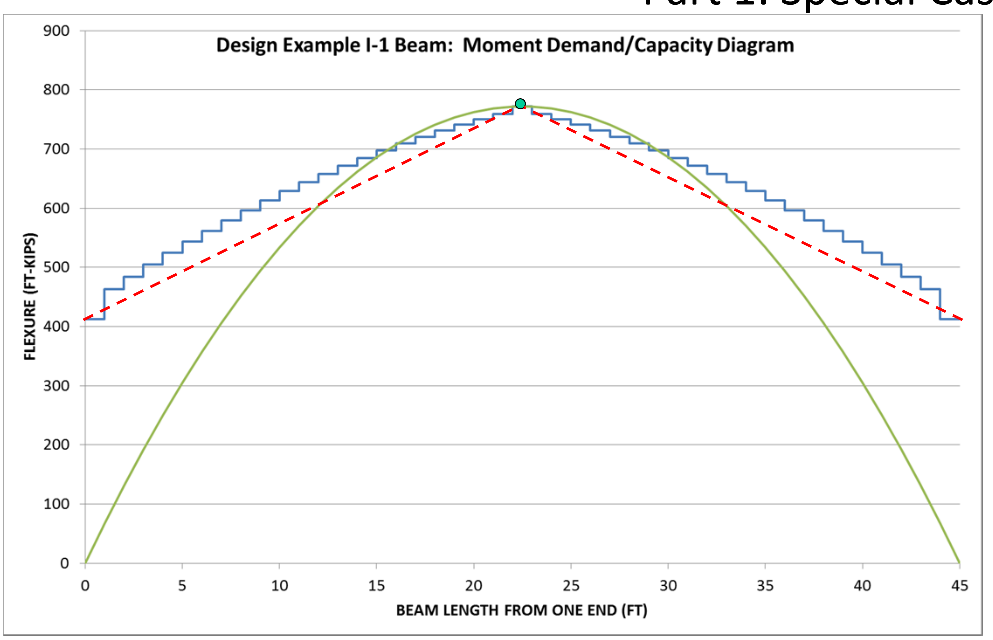
Part 1: Special Cases



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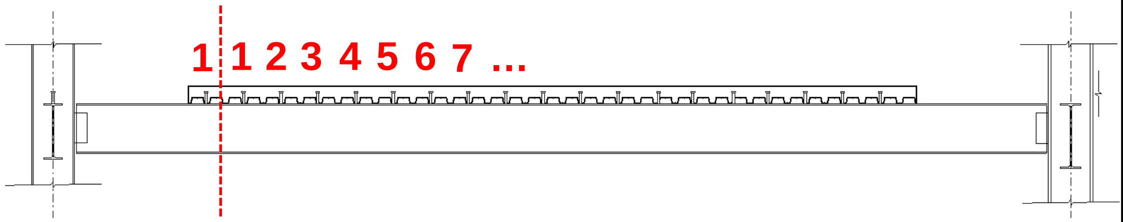
Part 1: Special Cases

Section Capacity



- $\sum Q_n$ at Each Section Based on Min. Number Studs to Each Side of that Section
- Can Calculate Available Flexural Strength at Each Section By Looking Available Shear Transfer At that Section

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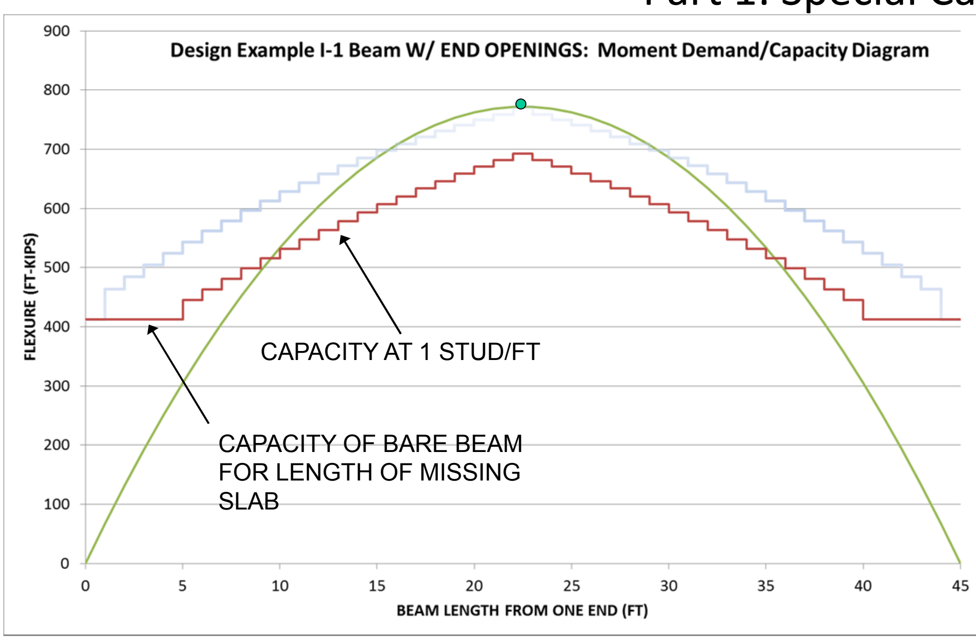
Part 1: Special Cases



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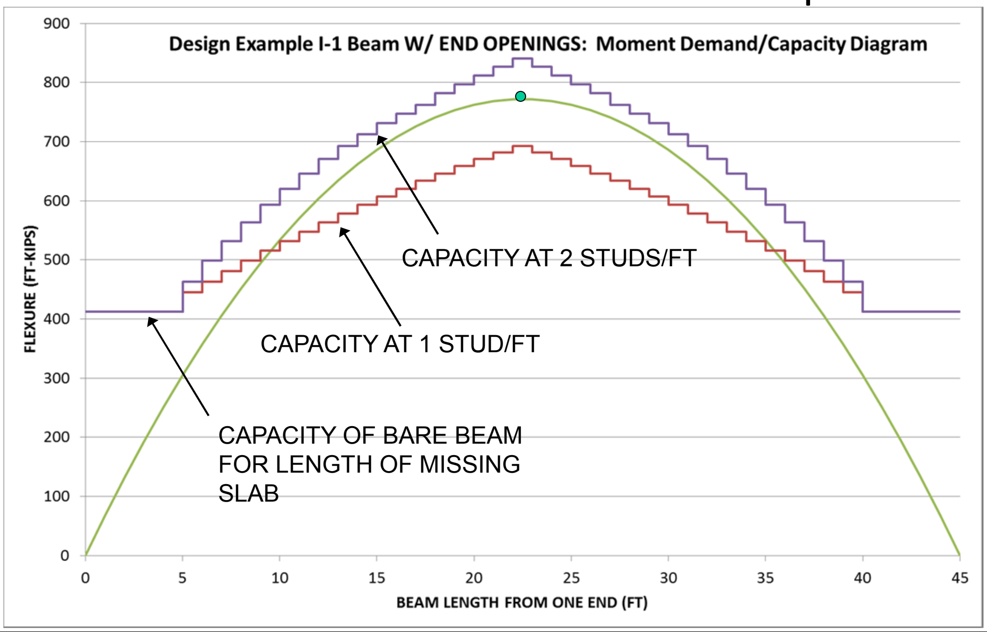
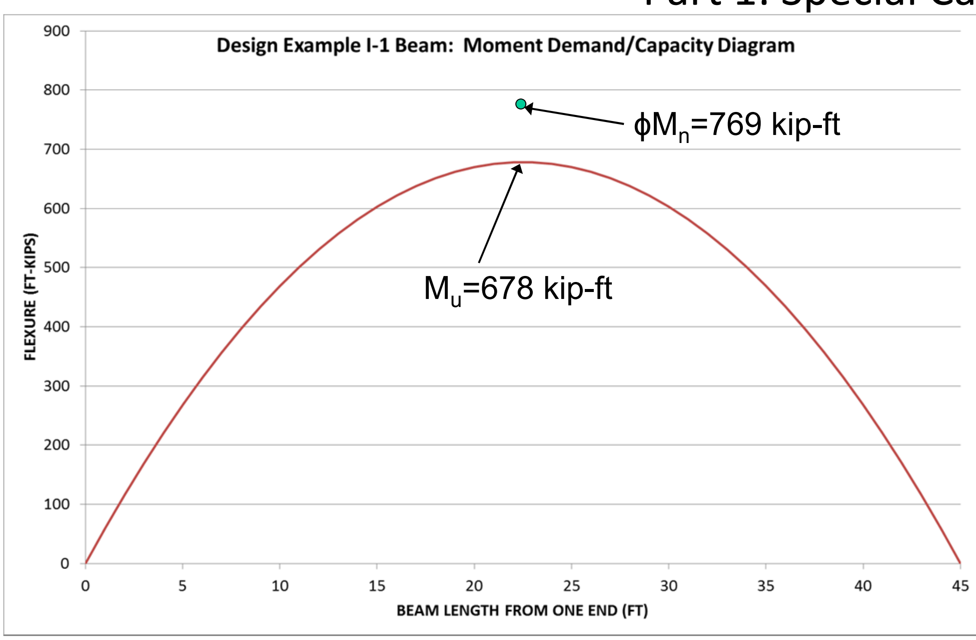
Part 1: Special Cases



There's always a solution in Steel

59

Part 1: Special Cases

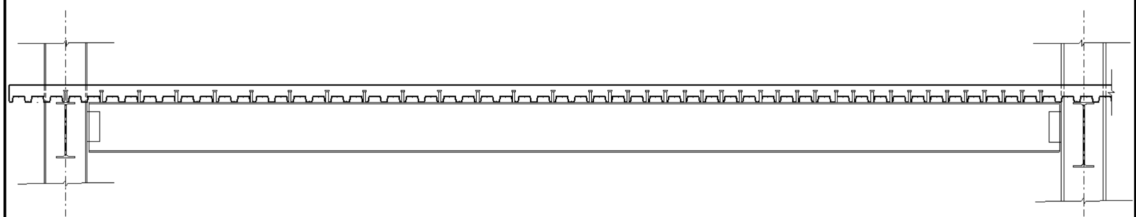


There's always a solution in Steel

60

Part 1: Special Cases

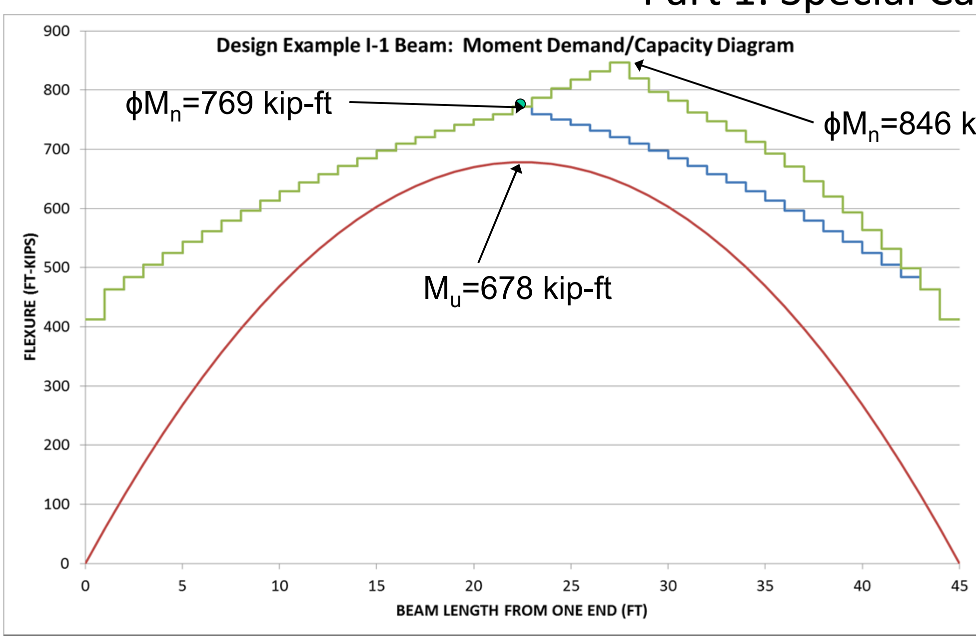
Uneven Stud Distribution



- What About Uneven Stud Distributions?
- Same Problem, But Double Studs on Right Half

There's always a solution in Steel **61**

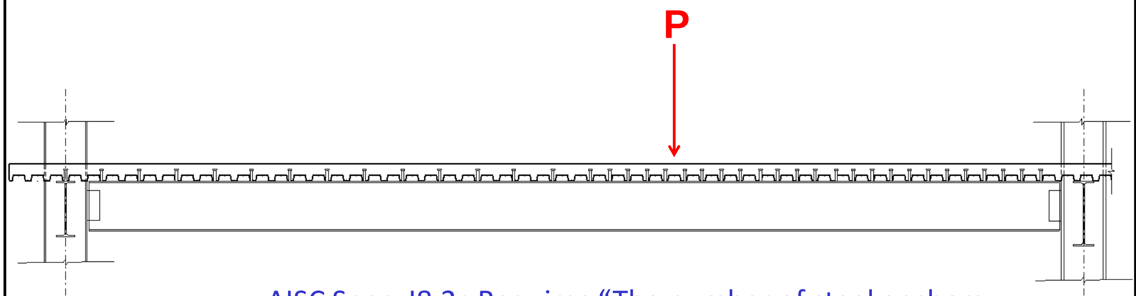
Part 1: Special Cases



There's always a solution in Steel **62**

Part 1: Special Cases

Uneven Stud Distribution



- AISC Spec. I8.2c Requires "The number of steel anchors required between any concentrated load and the nearest point of zero moment shall be sufficient to develop the maximum moment required at the concentrate load point."

There's always a solution in Steel 63

Outline

Practical Implementation of Composite Floor Designs

- Part 1: Conduit, Penetrations, and Openings
- Part 2: Composite Beam Strengthening
- Part 3: Best Practices / Tips for Composite Floor Designs

There's always a solution in Steel 64

Outline

Part 2: Composite Beam Strengthening

- General Issues
  - Why may strengthening be required?
  - Resources available to the designer
  - Reinforcing Options
- Strength
  - Effect of Load History (Is Unloading Required?)
  - Mixing Steel Grades
  - Welding Effects
  - Attachment of Reinforcement

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Outline

Part 2: Composite Beam Strengthening

- Strength Cont.
  - Minimum Composite Percentage
  - Flexural Strength Calculation
- Serviceability
  - Effect of Load Sequence
  - Non-Prismatic / Partial Length Deflections

There's always a solution in Steel

66

Part 2: General

Why Strengthen?

- Change of Use (Live Loading)
- Additional Loading (Dead Loading)
- More Stringent Deflection Requirements
- Vibration Criteria
- Changes in Load Path Not Feasible

There's always a solution in Steel **67**

Part 2: General

Resources for Composite Beam Strengthening

- Dowswell, B. (Nov. 15, 2013), Design of Reinforcement for Steel Members: Part I [Webinar], *AISC Live Webinar Series*, Retrieved From: www.aisc.org/webinars
- Dowswell, B. (Feb. 13, 2014), Design of Reinforcement for Steel Members: Part II [Webinar], *AISC Live Webinar Series*, Retrieved From: www.aisc.org/webinars
- Miller, J.P. (1996), "Strengthening of Existing Composite Beams Using LRFD Procedures," *Engineering Journal*, AISC, Second Quarter
  - Wanant, S. (1997), Critique, Fourth Quarter
  - Kocsis, P. (1997), Discussion, Third Quarter
  - Miller, J. (2003), Errata, Second Quarter
- Ricker, D.T. (1988), "Field Welding to Existing Steel Structures," *Engineering Journal*, AISC, First Quarter
- AISC Design Guide 15 (Rehabilitation and Retrofit Guide) / AISC Spec. Appendix 5

There's always a solution in Steel **68**

Part 2: General

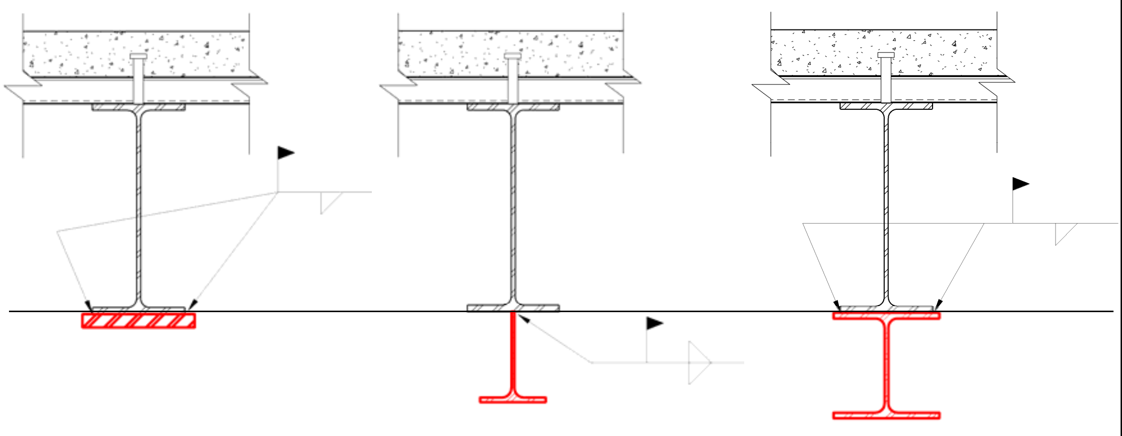
Reinforcing Options

- Add Plates / WTs / …other?

There's always a solution in Steel 69

Part 2: General

Reinforcing Options



There's always a solution in Steel 70

Part 2: General

Reinforcing Options

- Consider Site and Member Access
- Consider Constructability
- Consider Fit-Up
- Review Existing Connection Strength

There's always a solution in Steel

71

Part 2: General

Reinforcing Options

- Add Plates / WTs / …other?
- Additional Shear Transfer

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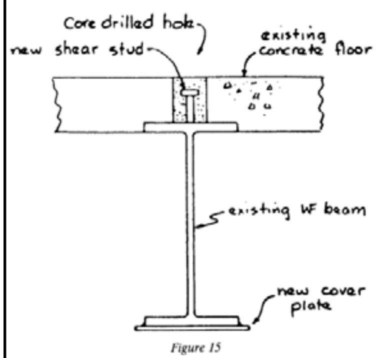
72

Part 2: General

Reinforcing Options



Ricker (1988)

Image Courtesy of Hilti

There's always a solution in Steel

73

Part 2: General

Reinforcing Options

- Best for Creating Composite Action in Noncomposite Beams
- Acceptable for Top Access Only Applications
- Utilize Non-Shrink Grout
- Difficult to Test Studs
- Messy (Water/Fire)
- Alternatives to Studs are Available

There's always a solution in Steel

74

Part 2: General

Reinforcing Options

- Kwon, G. et al. (2007), "Strengthening Existing Non-Composite Steel Bridge Girders Using Post-Installed Shear Connectors", Report FHWA/TX-07/0-4124-1, TDOT, Austin, TX.
- Kwon, G. et al. (2009), "Implementation Project: Strengthening of a Bridge near Hondo, Texas using Post-Installed Shear Connectors", Report FHWA/TX-09/5-4124-01-1, TDOT, Austin, TX.
- Hilti X-HVB Connectors

There's always a solution in Steel 75

Part 2: General

Reinforcing Options

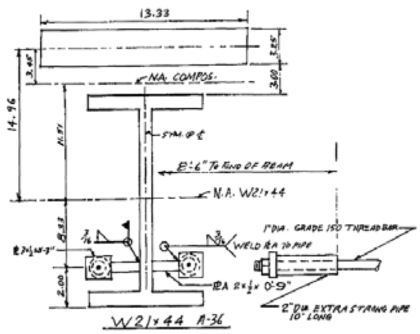
- Add Plates / WTs / …other?
- Additional Shear Transfer
- External Post-Tensioning

There's always a solution in Steel 76

Part 2: General

Reinforcing Options

- See Kocsis, P. (1997), "Discussion: Strengthening of Existing Composite Beams Using LRFD Procedures," *Engineering Journal*, AISC, Third Quarter



Kocsis (1997)

Image Courtesy of DYWIDAG-Systems International

There's always a solution in Steel

77

Outline

Part 2: Composite Beam Strengthening

- General Issues
  - Why may strengthening be required?
  - Resources available to the designer
  - Reinforcing Options
- Strength
  - Effect of Load History (Is Unloading Required?)
  - Mixing Steel Grades
  - Welding Effects
  - Attachment of Reinforcement

There's always a solution in Steel

78

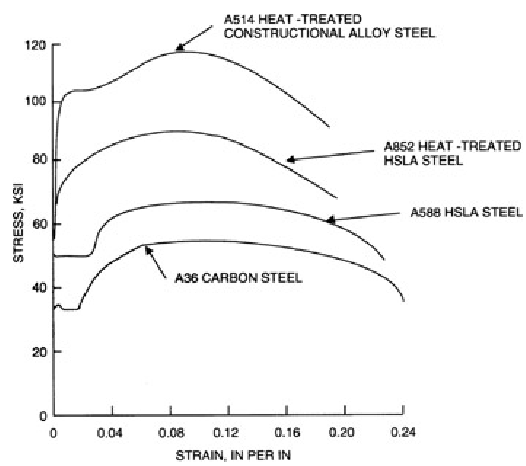
Part 2: Strength

Effect of Load History (On Strength)

- Composite Beams: Top Flange Laterally Braced by Default
- Composite Design: Typically Plastic Cross Section
  (All Rolled W-Shapes Meet Criteria for Plastic Stress Distribution)
- For Plastic Stress Distribution, Load History has NO EFFECT on available flexural strength of composite member

Part 2: Strength

Effect of Load History (On Strength)



- Recall Strain at Yield :

$$\varepsilon_y = F_y / E_s$$
$$= 36 \text{ ksi} / 29{,}000 \text{ ksi}$$
$$= 0.0012$$

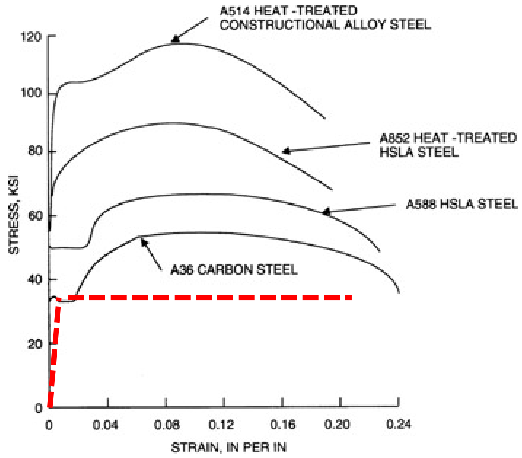
- Strain at End of Yield Plateau

$$\text{A36:} \quad \varepsilon_{sh} = 0.014$$

Approx. 12 Times Yield Strain!

Part 2: Strength

Effect of Load History (On Strength)



- Recall Strain at Yield :

$$\varepsilon_y = F_y / E_s$$
$$= 36 \text{ ksi} / 29{,}000 \text{ ksi}$$
$$= 0.0012$$

- Min. ASTM Elongation:

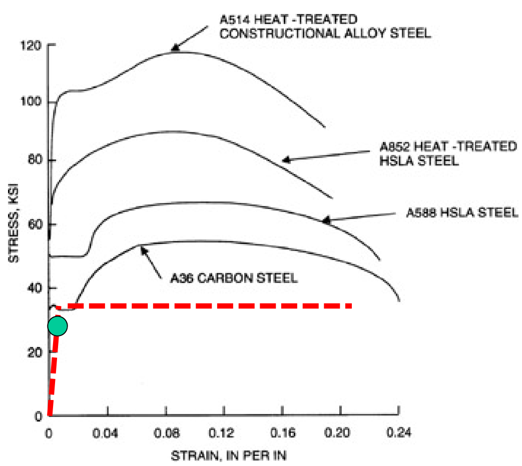
A36: $\varepsilon_{ult} = 0.20$

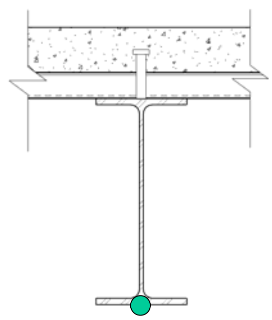
A992: $\varepsilon_{ult} = 0.18$

There's always a solution in Steel **81**

Part 2: Strength

Effect of Load History (On Strength)

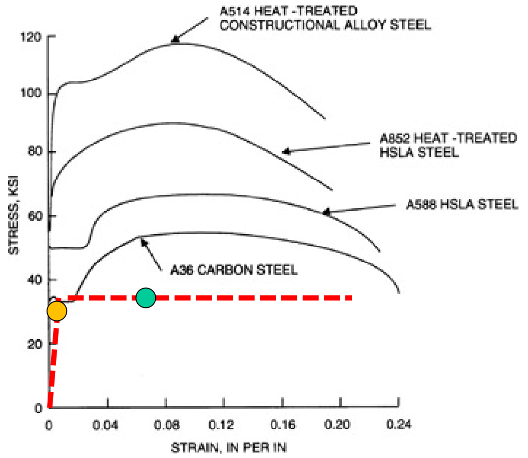


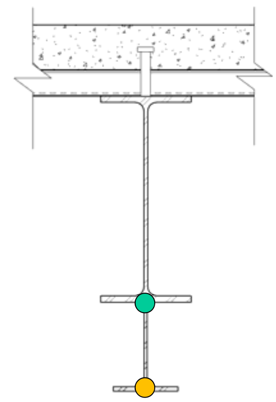


There's always a solution in Steel **82**

Part 2: Strength

Effect of Load History (On Strength)

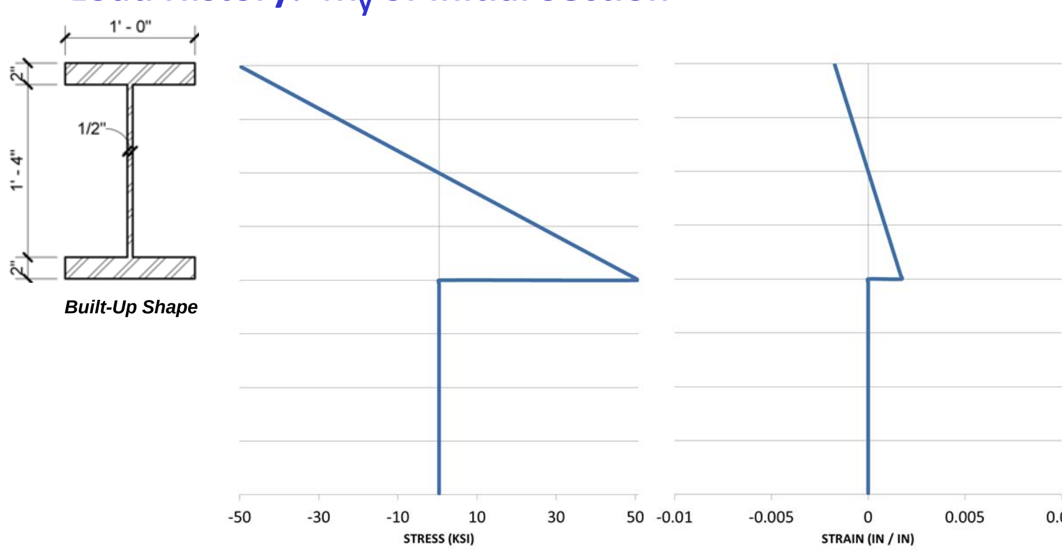




There's always a solution in Steel **83**

Part 2: Strength

Load History: M_y of Initial Section

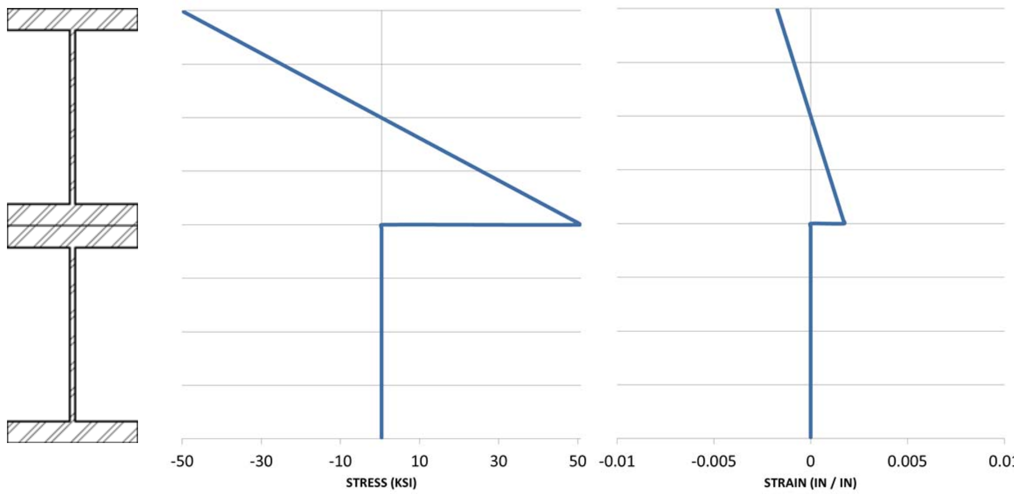


- M_u =1,700 kip-ft (36% M_p)
- Neutral Axis = 30 in. from Datum
- Max Tensile Strain =0.0017 (1% Rupture)

There's always a solution in Steel **84**

Load History: "Composite" Member

Part 2: Strength



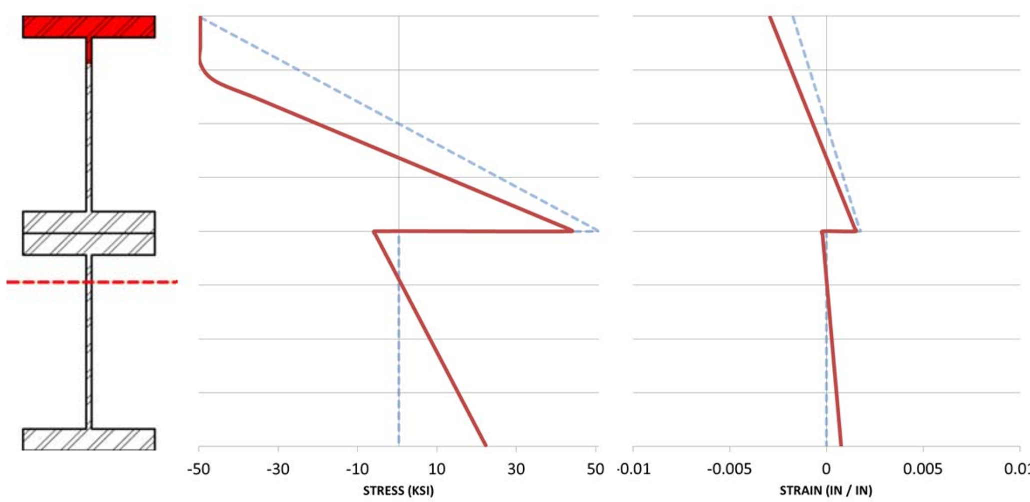
- FULLY Connected Member (100% "Composite")
- Compact Shapes (more on this later…)

There's always a solution in Steel

85

Load History: 50% to Bot. Flange Yield

Part 2: Strength



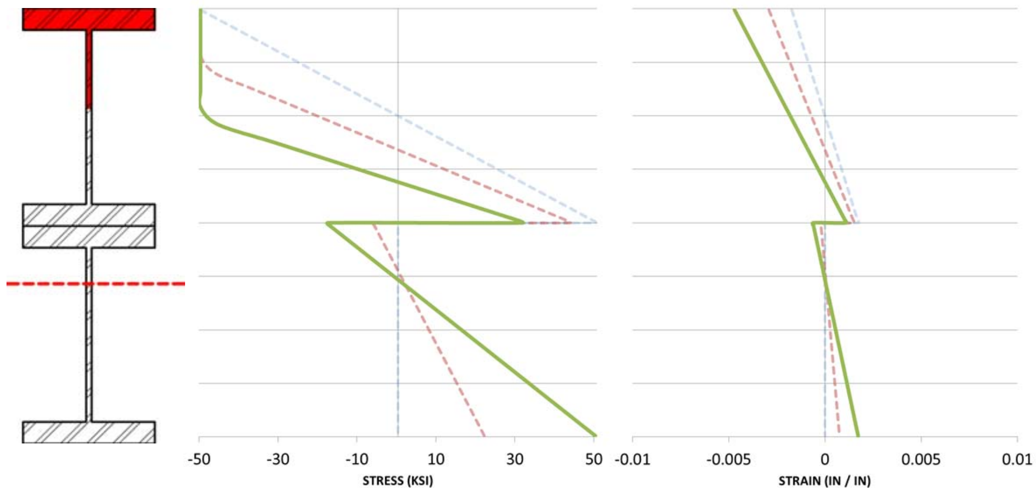
- M_u =2,880 kip-ft (62% M_p)
- Max Tensile Strain =0.0015 (1% Rupture)
- Neutral Axis = 15.5 in. from Datum

There's always a solution in Steel

86

Load History: First Yield of Bot. Flange

Part 2: Strength



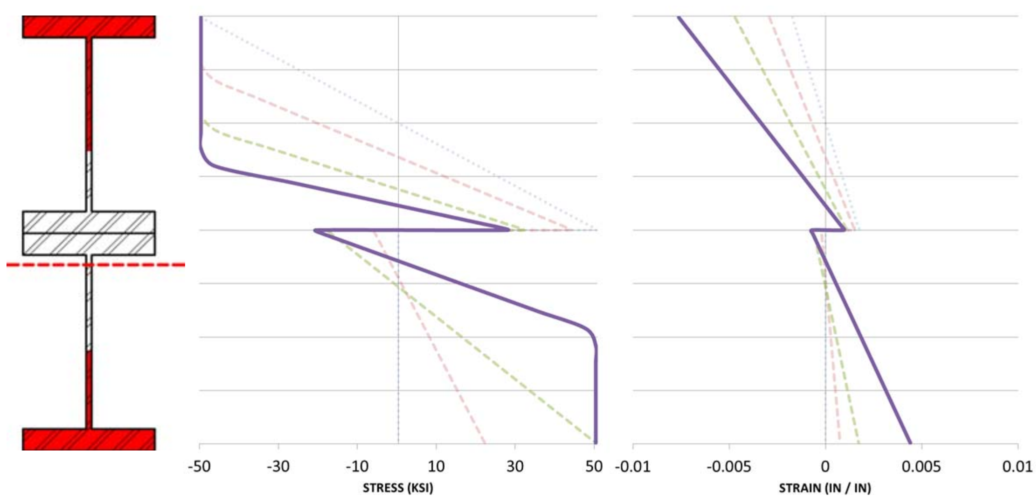
- M_u =4,060 kip-ft (87% M_p)
- Max Tensile Strain =0.0017 (1% Rupture)
- Neutral Axis = 14.7 in. from Datum

There's always a solution in Steel

87

Load History: 50% from Fl. Yield to Mp

Part 2: Strength



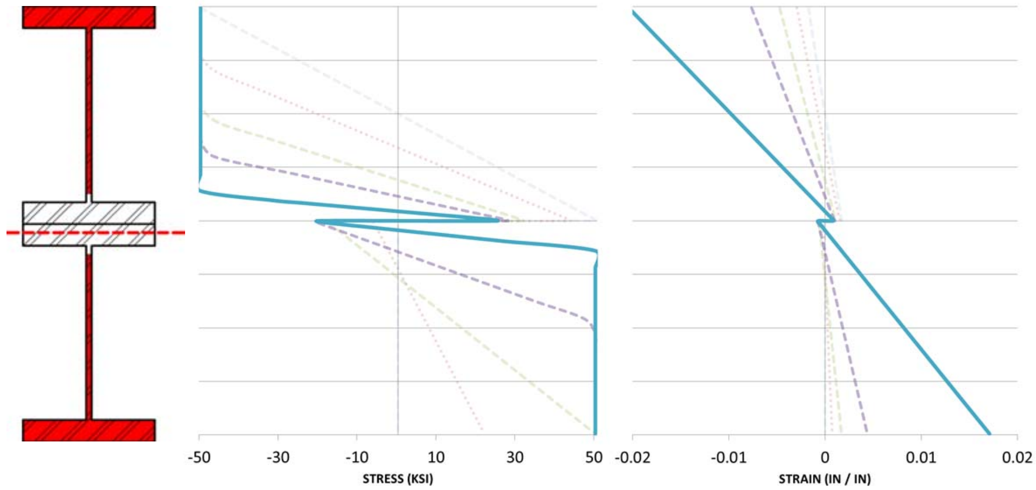
- M_u =4,362 kip-ft (93% M_p)
- Max Tensile Strain =0.0044 (2% Rupture)
- Neutral Axis = 17.1 in. from Datum

There's always a solution in Steel

88

Load History: End of Yield Plateau

Part 2: Strength



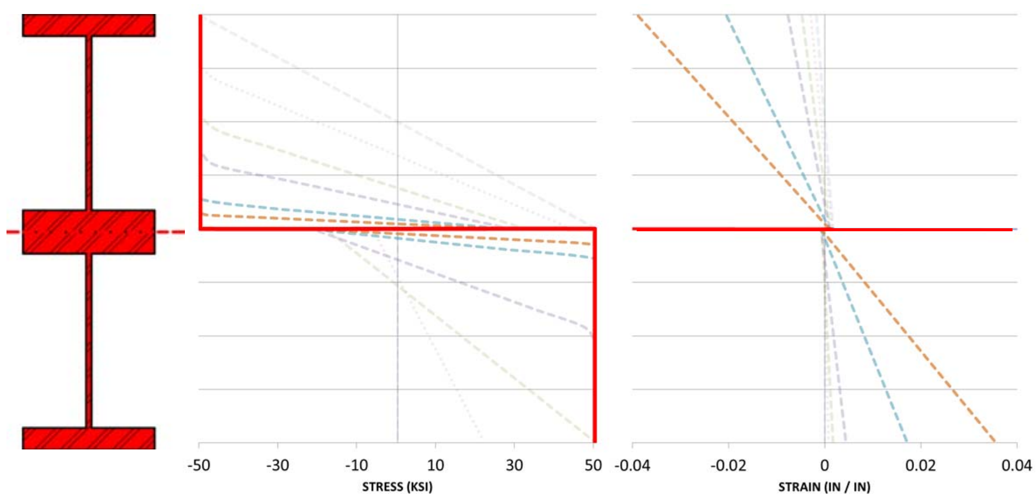
- M_u =4,518 kip-ft (97% M_p)
- Max Tensile Strain =0.017 (10% Rupture)
- Neutral Axis = 19.2 in. from Datum

There's always a solution in Steel

89

Load History: M_p

Part 2: Strength



- M_u =4,667 kip-ft (100% M_p)
- Max Tensile Strain = Infinite
- Neutral Axis = 20 in. from Datum

There's always a solution in Steel

90

Part 2: Strength

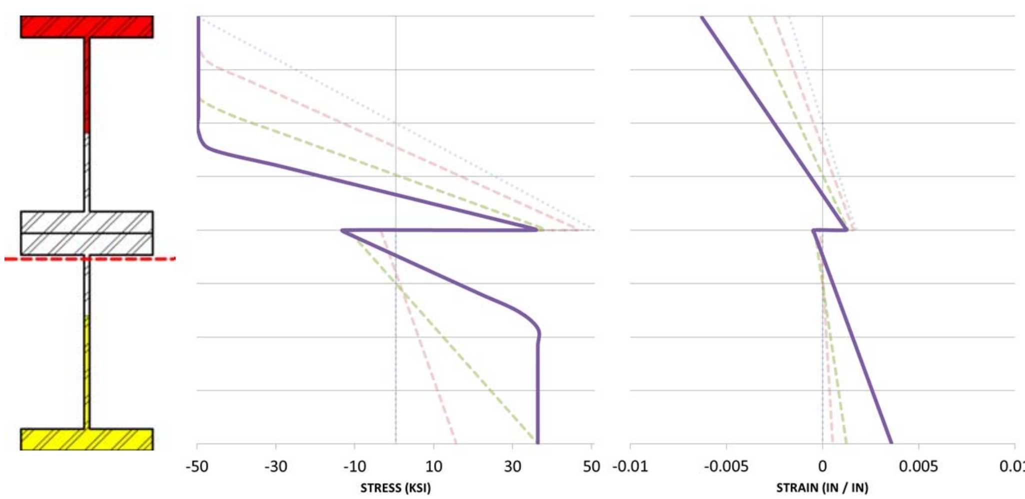
Mixing Steel Grades

- Can Grade 50 Material Reinforce Grade 36 Material and Vice Versa?
- If Plastic Stress Distribution: YES
- For Same Reason that Load History is Unimportant for Strength – Steel Has Enough Ductility To Allow Mixed Materials to Both Yield
- Review the Same "Double Stacked W-Shape" as Before, with Same Pre-Load, but A36 Lower Member

There's always a solution in Steel **91**

Load History: 36 KSI BASE – Intermed.

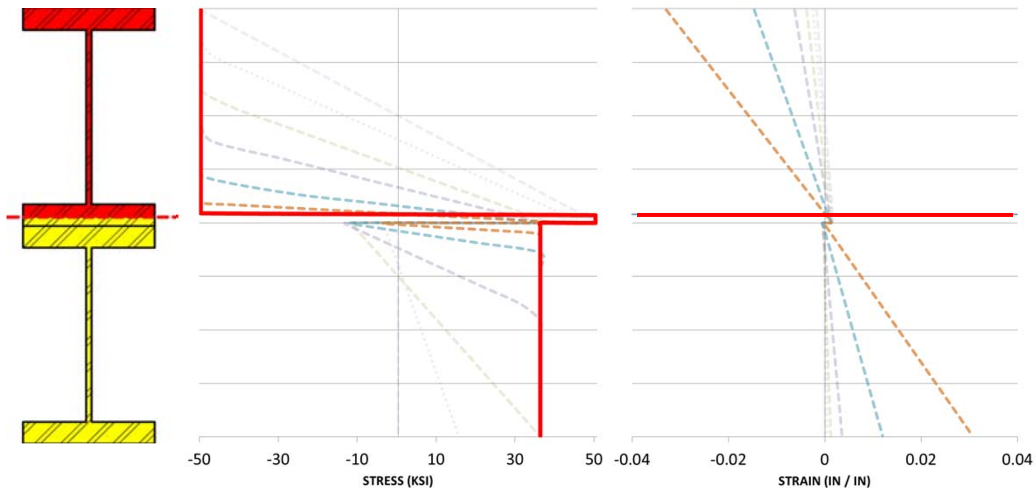
Part 2: Strength



There's always a solution in Steel **92**

Part 2: Strength

Load History: 36 KSI BASE - M_p

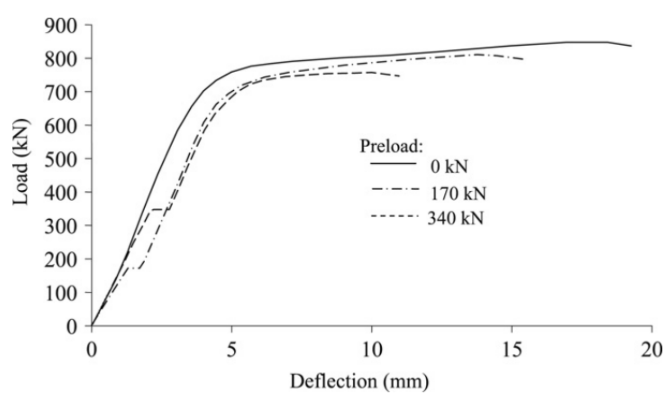


- M_u =3,993 kip-ft (86% gr50 M_p)
- Neutral Axis = 20.82 in. from Datum
- Max Tensile Strain = Infinite (at 0.99M_p =17% of Rupture Strain

There's always a solution in Steel **93**

Part 2: Strength

Experimental Evidence



Liu, Y., and Gannon, L. (2009a), "Experimental behavior and strength of steel beams strengthened while under load", *Journal of Constructional Steel Research*, Vol. 65, pp 1346-1354.

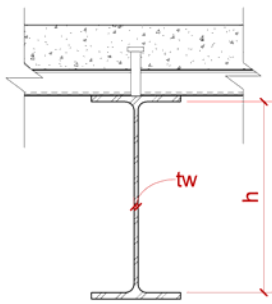
There's always a solution in Steel **94**

Part 2: Strength

Effect of Load History (On Strength)

- Composite Design = Plastic Cross Section (Ref: I3.2a)

$$h / t_w \leq 3.76\sqrt{E/F_y} \rightarrow \text{Plastic Stress Distribution O.K.}$$



- Where did this come from?
- How does it apply to reinforced composite members?

There's always a solution in Steel

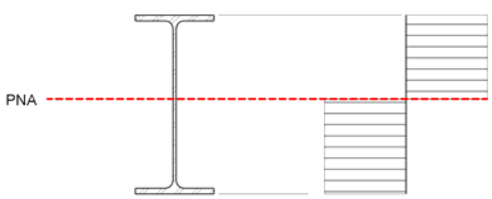
95

Part 2: Strength

Effect of Load History (On Strength)

- Composite Design = Plastic Cross Section (Ref: I3.2a)

$$h / t_w \leq 3.76\sqrt{E/F_y} \rightarrow \text{Plastic Stress Distribution O.K.}$$



- This is simply Table B4.1b for web compactness criteria of Typical Shapes (Non-Composite)
- Based on Stress Gradient in Web (Top Half of Web in Compression / Bottom Half in Tension)

There's always a solution in Steel

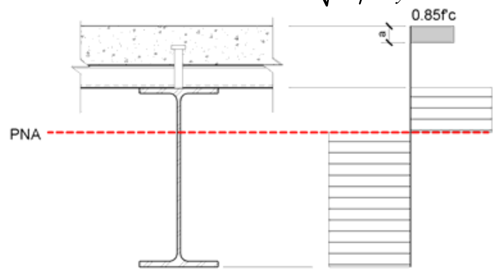
96

Part 2: Strength

Effect of Load History (On Strength)

- Composite Design = Plastic Cross Section (Ref: I3.2a)

$h/t_w \leq 3.76\sqrt{E/F_y}$ → Plastic Stress Distribution O.K.



- Typically Conservative for Composite Members (Less Web in Compression)
- Note for Standard Composite Members Could Use Table B4.1b Case 16 (Webs of Singly-Symmetric I-shaped Sections) vs. Transformed Section to Increase Limit

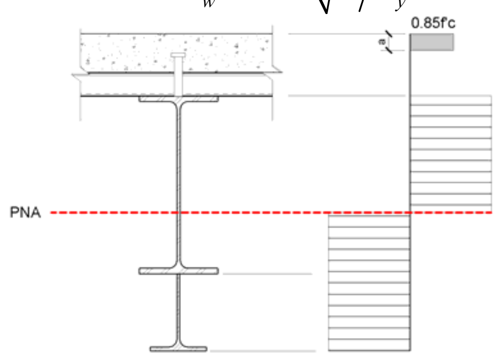
There's always a solution in Steel 97

Part 2: Strength

Effect of Load History (On Strength)

- Composite Design = Plastic Cross Section (Ref: I3.2a)

$h/t_w \leq 3.76\sqrt{E/F_y}$ → Plastic Stress Distribution O.K.



- Could be Unconservative for Upper Member Web if PNA below Mid-Depth – Check with Table B4.1B Case 16
- Typically No Lower Buckling Issues in Lower Member as it is in Tension
- At Worse Case, Upper Member Web Fully Yielded in Compression– Similar to Column Limits: $h/t_w \leq 1.49\sqrt{E/F_y}$

There's always a solution in Steel 98

Part 2: Strength

Effect of Load History (On Strength)

- What About Flange Local Buckling?
  - Not Addressed in Current Specification
  - Assumed Not to Control Due to Adjacent Concrete and Shear Connection (Salmon and Johnson)
  - 9th Edition AISC (Green Book) Section I2:

  "…the steel section is exempt from compact flange criteria and there is no limit on unsupported length of composite flange"

There's always a solution in Steel 99

Part 2: Strength

Welding Effects

- High Temperature Reduces Steel Properties (E / F_y / F_u)
- Welding Produces High Temperatures

**TABLE A-4.2.1
Properties of Steel at Elevated Temperatures**

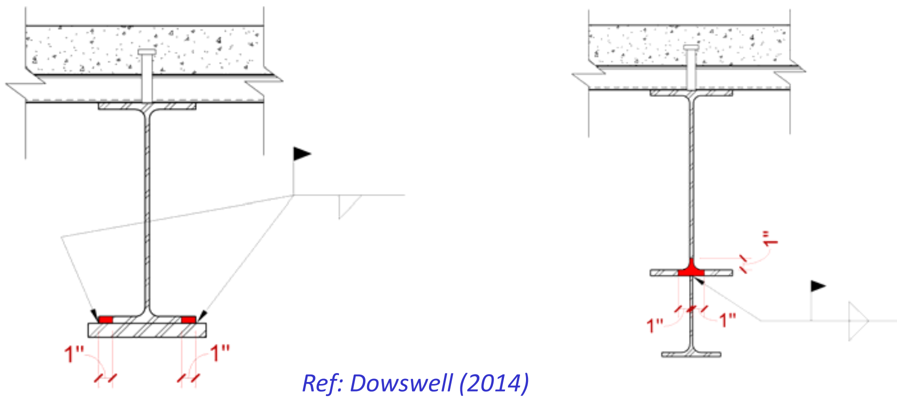
Steel Temperature, °F (°C)	$k_E = E(T)/E = G(T)/G$	$k_p = F_p(T)/F_y$	$k_y = F_y(T)/F_y$	$k_u = F_u(T)/F_y$
68 (20)	1.00	1.00	1.00	1.00
200 (93)	1.00	1.00	1.00	1.00
400 (204)	0.90	0.80	1.00	1.00
600 (316)	0.78	0.58	1.00	1.00
750 (399)	0.70	0.42	1.00	1.00
800 (427)	0.67	0.40	0.94	0.94
1000 (538)	0.49	0.29	0.66	0.66
1200 (649)	0.22	0.13	0.35	0.35

There's always a solution in Steel 100

Part 2: Strength

Welding Effects

- Reduced Sections for Stick Welding Along the Flange



Ref: Dowswell (2014)

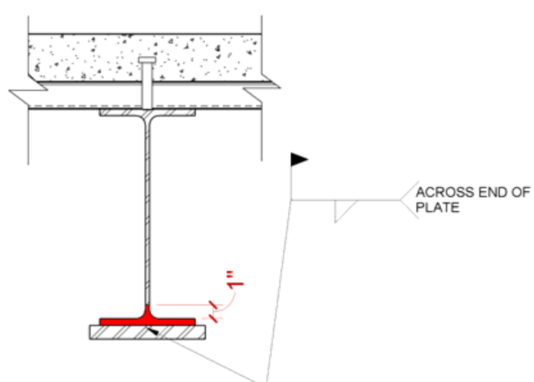
There's always a solution in Steel

101

Part 2: Strength

Welding Effects

- Reduced Sections for Stick Welding Across the Flange



There's always a solution in Steel

102

Part 2: Strength

Attachment of Reinforcement (General)

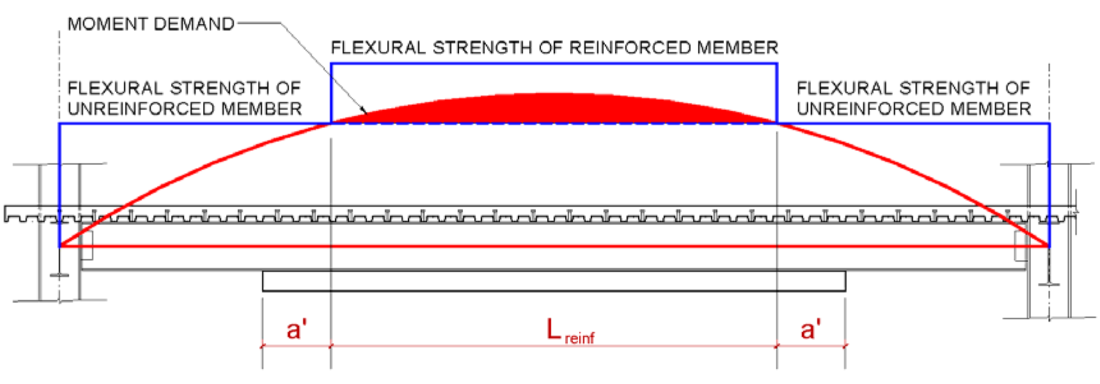
- AISC F13.3 - Cover Plates
  - "[Connections] shall be proportioned to resist the total horizontal shear resulting from the bending forces…the longitudinal distribution…shall be in proportion to the intensity of the shear"
  - "Partial-length cover plates shall be extended beyond the theoretical cutoff point and the extended portion shall be attached to the beam…"
  - "The attachment shall be adequate…to develop the cover plate's portion of the flexural strength in the beam or girder at the theoretical cutoff point."

There's always a solution in Steel

103

Part 2: Strength

Attachment of Reinforcement (General)



There's always a solution in Steel

104

Part 2: Strength

Attachment of Reinforcement (Anchorage Force)

- Commentary AISC F13.3 – Elastic Cutoff Strength
  - Given as MQ/I
  - ONLY Applicable If Composite Section Remains Elastic:

$$M_u \leq \phi F_y S_x$$

There's always a solution in Steel

105

Part 2: Strength

Attachment of Reinforcement (Anchorage Force)

- Commentary AISC F13.3 – Elastic Cutoff Strength
  - Given as MQ/I
  - ONLY Applicable If Composite Section Remains Elastic:

$$M_u \leq \phi F_y S_x$$

  - **NOT COMMON** for Composite

$$f_s = \left(\frac{Mc}{I}\right)$$

$$F_{pl} = f_s A_{pl}$$

$$F_{pl} = \left(\frac{Mc}{I}\right) A_{pl}$$

$$Q_{pl} = A_{pl} c$$

$$\boxed{F_{pl} = \frac{MQ}{I}}$$

There's always a solution in Steel

106

Part 2: Strength

Attachment of Reinforcement (Anchorage Force)

- Commentary AISC F13.3 – Plastic Cutoff Strength
  - Typical for Composite Beam Reinforcement
  - Develop Available Tension Strength of Section Past Theoretical Cutoff Point

$$\phi_t P_n = 0.9 F_y A_g$$

  - Could Also Perform an "Elastic-Plastic Analysis of the Cross Section"

There's always a solution in Steel 107

Part 2: Strength

Attachment of Reinforcement (Anchorage Length)

- AISC F13.3 - Cover Plates

IF NO End Weld:

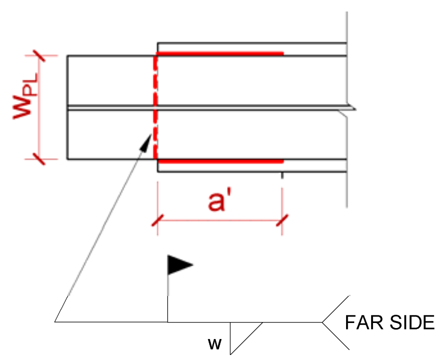
$$a'_{\min} = 2w_{pl} \qquad Eq.\ \text{F13-7}$$

IF END WELD $w < 0.75t_{pl}$:

$$a'_{\min} = 1.5w_{pl} \qquad Eq.\ \text{F13-6}$$

IF END WELD $w \geq 0.75t_{pl}$:

$$a'_{\min} = w_{pl} \qquad Eq.\ \text{F13-5}$$



There's always a solution in Steel 108

Part 2: Strength

Attachment of Reinforcement (General)

- AISC F13.3 - Cover Plates
  - "[Connections] shall be proportioned to resist the total horizontal shear resulting from the bending forces...the longitudinal distribution...shall be in proportion to the intensity of the shear"
  - "Partial-length cover plates shall be extended beyond the theoretical cutoff point and the extended portion shall be attached to the beam..."
  - "The attachment shall be adequate...to develop the cover plate's portion of the flexural strength in the beam or girder at the theoretical cutoff point."

There's always a solution in Steel **109**

Part 2: Strength

Attachment of Reinforcement (Intermittent)

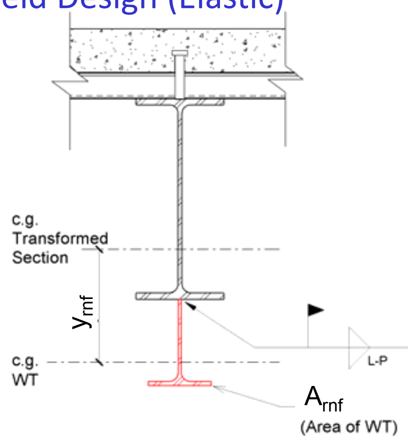
- Horizontal Shear Flow for Weld Design (Elastic)

$$f = \frac{VQ}{It}$$

$$v = \frac{VQ}{I}$$

$$Q = A_{rnf}\, y_{rnf}$$

$$f_{weld} = \frac{V_{cutoff} A_{rnf}\, y_{rnf}}{2I_{tr}}$$

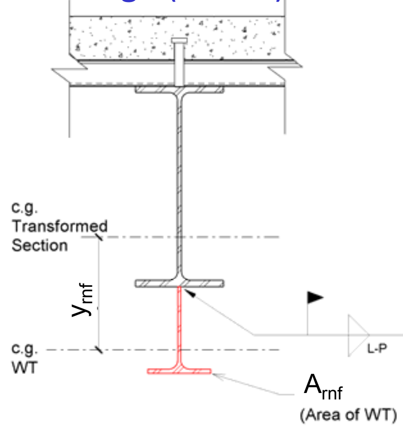


There's always a solution in Steel **110**

Part 2: Strength

Attachment of Reinforcement (Intermittent)

- Horizontal Shear Flow for Weld Design (Plastic)
- Typically Ends are Welded for Full Yield
- Minimum Intermittent Welds Used Between
- Prudent to Provide Intermittent Welds for VQ/I



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111

Part 2: Strength

Attachment of Reinforcement (Intermittent)

- Maximum Spacing Between Connectors (AISC *Spec*. D4 and J3.5):

$$s_{\text{max}} = 24t \leq 12 \text{ in.}$$

t = thickness of thinnest part joined (in.)

- Minimum Length of Stitch Weld (AISC *Spec*. J2.2b):

$$l_{\text{min}} = 4w \geq 1.5 \text{ in.}$$

w = nominal leg size (in.)

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112

Part 2: Strength

Minimum Composite Percentage

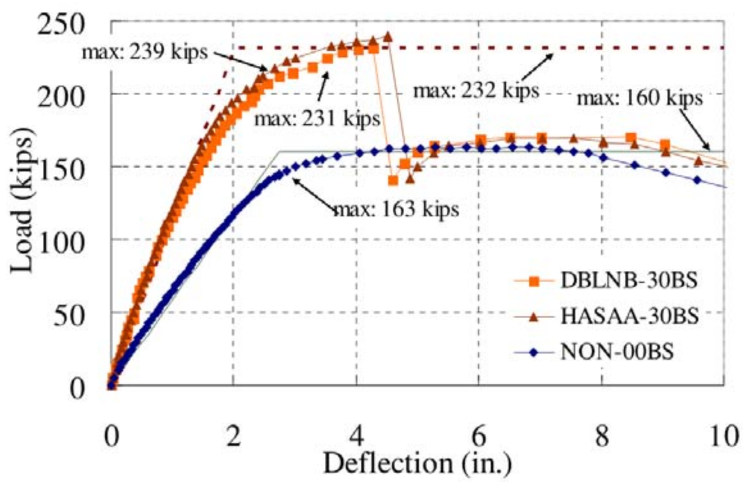
- De Facto Spec. Minimum of 25%

$$\%\ \text{Composite} = \frac{\sum Q_n}{MIN\begin{cases} A_s F_y & \leftarrow \text{Steel Yielding} \\ 0.85 f'_c A_c & \leftarrow \text{Concrete Crushing} \end{cases}}$$

- Be Careful! For Existing Comp. Beams with Low % Composite, It is Possible for Addition of Steel to Result in Violating this Limit
- Commentary Recommends 50% for New Construction

There's always a solution in Steel 113

Part 2: Strength



Kwon, G. et al. (2007), "Strengthening Existing Non-Composite Steel Bridge Girders Using Post-Installed Shear Connectors", Report FHWA/TX-07/0-4124-1, TDOT, Austin, TX.

There's always a solution in Steel 114

Part 2: Strength

Kwon, G. et al. (2007), "Strengthening Existing Non-Composite Steel Bridge Girders Using Post-Installed Shear Connectors", Report FHWA/TX-07/0-4124-1, TDOT, Austin, TX.

Part 2: Strength

Flexural Strength Calculation

- How to Determine Flexural Strength of Reinforced Section?
- Simple: Sum F_x, Sum M_x

Part 2: Strength

Flexural Strength Calculation

- Step 1: Determine Compressive Force in Concrete and Depth of Compression Block

$$C = MIN \begin{cases} \left(A_s F_{ys} + A_{rnf} F_{yrnf}\right) & \leftarrow \text{Steel Yielding} \\ 0.85 f'_c A_c & \leftarrow \text{Concrete Crushing} \\ \sum Q_n & \leftarrow \text{Stud Anchor Strength} \end{cases}$$

$$a = \frac{C}{0.85 f'_c b}$$

- Typically Stud Anchor Strength Will Control (Partially Composite)

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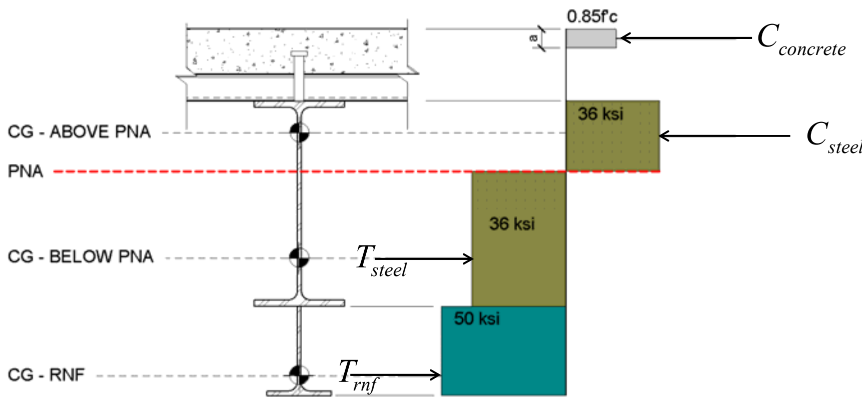
Part 2: Strength

Flexural Strength Calculation

- Step 2: Determine Location of Plastic Neutral Axis (ΣF_x)



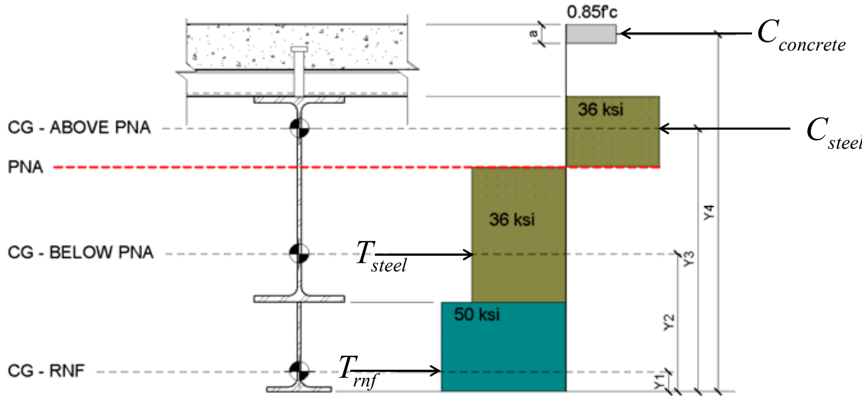
$$\sum F_{\text{above PNA}} = \sum F_{\text{below PNA}}$$

There's always a solution in Steel **118**

Part 2: Strength

Flexural Strength Calculation

- Step 3: Calculate Nominal Flexural Strength (ΣM)



$$M_n = \sum M = \left| T_{rnf} y_1 + T_{steel} y_2 - C_{steel} y_3 - C_{concrete} y_4 \right|$$

There's always a solution in Steel **119**

Outline

Part 2: Composite Beam Strengthening

- Strength Cont.
  - Minimum Composite Percentage
  - Flexural Strength Calculation
- Serviceability
  - Effect of Load Sequence
  - Non-Prismatic / Partial Length Deflections

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Part 2: Serviceability

Effect of Load History (On Serviceability)

- If Reinforcement is Applied Without Load Relief:
  - Welding on Member Must be Carefully Reviewed
  - Deflection that is Currently in Member is Maintained
  - Additional Deflection Based on Reinforced Properties

$$\delta_{total} = \delta_{current} + \delta_{future}$$

- Example: Uniform Load and Full Length Reinforcement:

$$\delta_{total} = \frac{5w_{current}L^4}{384EI_{exist}} + \frac{5w_{future}L^4}{384EI_{new}}$$

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121

Part 2: Serviceability

Effect of Load History (On Serviceability)

- If Reinforcement is Applied After Load is Relieved:
  - Deflection for Relieved Load and all Future Loading and is based on Reinforced Properties

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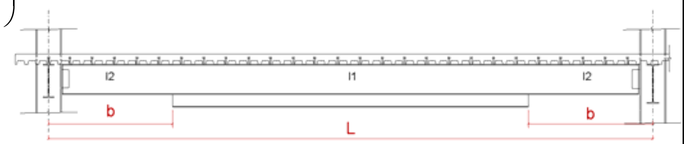
122

Part 2: Serviceability

What About Partial Reinforcement?

- Classical Methods (Wanant, 1997)

$$\delta_{\max} = \frac{5wL^4}{384EI_1} + \frac{\left(\frac{I_1}{I_2} - 1\right)w}{2EI_1}\left(\frac{Lb^3}{3} - \frac{b^4}{4}\right)$$



where:

L = Total Span

w = Unform Load Per Unit Length

I_1 = Reinforced Moment of Inertia

I_2 = Unreinforced Moment of Inertia

b = Distance from End to Start of Reinforcement (Must be Equal)

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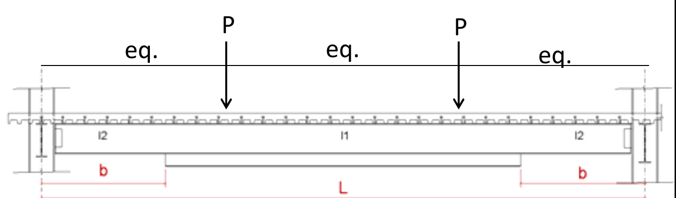
123

Part 2: Serviceability

What About Partial Reinforcement?

- Classical Methods (Wanant, 1997)

$$\delta_{\max} = \frac{23PL^3}{648EI_1} + \frac{\left(\frac{I_1}{I_2} - 1\right)Pb^3}{3EI_1}$$



where:

L = Total Span

P = Applied Load at Third Points of Total Span (L/3 > b)

I_1 = Reinforced Moment of Inertia

I_2 = Unreinforced Moment of Inertia

b =Distance from End to Start of Reinforcement (Must be Equal)

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124

Part 2: General

Design Example Resources

- Miller, J.P. (1996), "Strengthening of Existing Composite Beams Using LRFD Procedures," *Engineering Journal*, AISC, Second Quarter
- Dowswell, B. (Feb. 13, 2014), Design of Reinforcement for Steel Members: Part II [Webinar], *AISC Live Webinar Series*, Retrieved From: www.aisc.org/webinars
- Newman, A. (2001), "Structural Renovation of Buildings," McGraw-Hill.

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Outline

Practical Implementation of Composite Floor Designs

- Part 1: Conduit, Penetrations, and Openings
- Part 2: Composite Beam Strengthening
- Part 3: Best Practices / Tips for Composite Floor Designs

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Part 3: Tips

1. Fire Rating Requirements for Deck

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Part 3: Tips

Restrained Assembly Rating	Type of Protection	Concrete Thickness & Type (1)	U.L. Design No. (2,3,4)	Classified Deck Type		Unrestrained Beam Rating
				Fluted Deck	Cellular Deck (5)	
3/4 Hr.	Unprotected Deck	2 1/2" LW	D914 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1 Hr.
			D916 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
1 Hr.	Exposed Grid	2 1/2" NW	D216 +	1.5VL,1.5VLI,2VLI,3VLI	2VLP, 3VLP	2,3 Hr.
	Cementitious	2" NW&LW	D743 #	2VLI,3VLI	2VLP, 3VLP	1,1.5,2,3 Hr.
		2 1/2" NW&LW	D703 *	1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1.5 Hr.
			D712 *	3VLI	3VLP	2 Hr.
			D722 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2 Hr.
			D739 *	1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3,4 Hr.
			D759	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
	Sprayed Fiber	2" NW&LW	D859 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2,3 Hr.
		2 1/2" NW&LW	D832 *	1.5VLI,2VLI,3VLI	3VLP	1,1.5,2,3 Hr.
			D847 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,3 Hr.
			D858 *	2VLI,3VLI	2VLP, 3VLP	1,1.5,2,4 Hr.
			D871 *	2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
	Unprotected Deck	2 1/2" LW	D902 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
			D914 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1 Hr.
			D916 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
			D918 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
			D919 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
		3 1/2" NW	D902 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
			D916 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5,2,3 Hr.
			D918 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.
			D919 #	1.5VL,1.5VLI,2VLI,3VLI	1.5VLP, 2VLP, 3VLP	1,1.5 Hr.

http://database.ul.com/cgi-bin/XYV/template/LISEXT/1FRAME/index.html
Type U.L. Design No. Into “UL FILE NUMBER” Blank and Click Search

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Part 3: Tips

1. **Normal Weight or Lightweight Concrete** — Normal weight concrete carbonate or siliceous aggregate, 3500 psi compressive strength, vibrated. Lightweight concrete, expanded shale, or slate aggregate by rotary-kiln method, or expanded clay aggregate by rotary-kiln or sintered-grate method, 3000 psi compressive strength, vibrated, 4 to 7 percent entrained air.

Restrained Assembly Rating Hr	Concrete (Type)	Concrete Unit Weight pcf	Concrete Thkns In.
1	Normal Weight	147-153	3-1/2
1-1/2	Normal Weight	147-153	4
2	Normal Weight	147-153	4-1/2
3	Normal Weight	147-153	5-1/4
3/4 or 1 (See Item 6)	Lightweight	107-113	2-1/2
1	Lightweight	107-120	2-5/8
1-1/2	Lightweight	107-113	3
2	Lightweight	107-113	3-1/4
2	Lightweight	107-116	3-1/4*
2	Lightweight	114-120	3-1/2
3	Lightweight	107-113	4-3/16
3	Lightweight	114-120	4-7/16

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Part 3: Tips

1. Fire Rating Requirements for Deck
2. Studs Help Deck Too!

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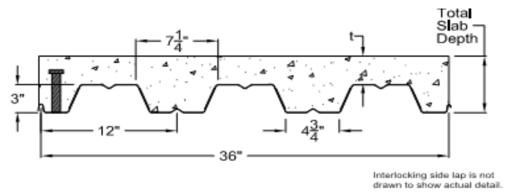
Part 3: Tips

3 VLI

Stud Spacing - 36in C-C

Maximum Sheet Length 42'-0"
Extra charge for lengths under 6'-0"
ICBO Approved (No. 3415)



(N=9.35) NORMAL WEIGHT CONCRETE (145 PCF)

Total Slab Depth	Deck Type	SDI Max. Unshored Clear Span			A_c in²/ft	ΦV_{nt} lb/ft	Superimposed Live Load (PSF) - Shear Studs at 36 in. c/c Clear Span (ft.-in.)														
		1 Span	2 Span	3 Span			7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0	10'-6	11'-0	11'-6	12'-0	12'-6	13'-0	13'-6	14'-0
5.50	3VLI22	8'-9	9'-8	10'-11	38.73	5745	329	318	308	300	259	231	207	186	168	152	138	125	114	104	95
	3VLI20	10'-1	12'-4	12'-9	38.73	7212	330	315	301	290	281	268	242	202	183	166	151	138	126	115	106
(t=2.50)	3VLI19	11'-4	13'-8	14'-2	38.73	7212	339	319	303	289	277	267	259	236	216	178	162	148	136	125	115
51 PSF	3VLI18	12'-5	14'-7	14'-7	38.73	7212	353	332	314	299	286	275	265	256	237	219	202	166	153	142	131
	3VLI16	12'-9	14'-11	15'-5	38.73	7212	382	357	336	318	303	290	268	245	225	208	193	179	145	134	124
6.00	3VLI22	8'-4	8'-10	10'-1	43.50	6189	343	330	320	294	286	262	235	211	190	172	156	142	129	118	108
	3VLI20	9'-8	11'-10	12'-3	43.50	7828	349	331	317	304	294	284	255	230	208	189	172	157	143	131	120
(t=3.00)	3VLI19	10'-10	13'-2	13'-7	43.50	8101	362	340	322	306	293	282	272	263	223	203	185	169	155	142	131
57 PSF	3VLI18	11'-10	14'-2	14'-2	43.50	8101	380	356	336	319	305	292	281	271	263	248	206	189	175	161	149
	3VLI16	12'-2	14'-4	14'-10	43.50	8101	400	384	361	341	324	309	296	277	255	236	218	178	164	152	141

255 psf

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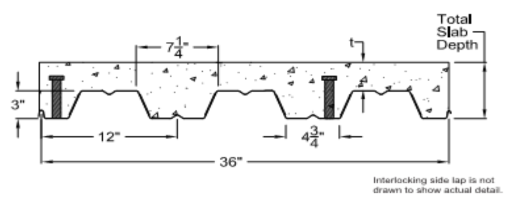
Part 3: Tips

3 VLI

Stud Spacing - 24in C-C

Maximum Sheet Length 42'-0"
Extra charge for lengths under 6'-0"
ICBO Approved (No. 3415)



(N=9.35) NORMAL WEIGHT CONCRETE (145 PCF)

Total Slab Depth	Deck Type	SDI Max. Unshored Clear Span			A_c in²/ft	ΦV_{nt} lb/ft	Superimposed Live Load (PSF) - Shear Studs at 24 in. c/c Clear Span (ft.-in.)														
		1 Span	2 Span	3 Span			7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0	10'-6	11'-0	11'-6	12'-0	12'-6	13'-0	13'-6	14'-0
5.50	3VLI22	8'-9	9'-8	10'-11	38.73	5745	370	365	361	358	320	284	253	227	204	184	167	151	137	125	113
	3VLI20	10'-1	12'-4	12'-9	38.73	7212	358	348	341	334	328	316	284	246	222	201	182	166	151	138	126
(t=2.50)	3VLI19	11'-4	13'-8	14'-2	38.73	7212	358	344	333	323	315	308	302	274	249	213	194	177	162	148	136
51 PSF	3VLI18	12'-5	14'-7	14'-7	38.73	7212	365	349	336	324	315	306	299	292	269	247	227	193	178	164	151
	3VLI16	12'-9	14'-11	15'-5	38.73	7212	386	367	352	338	327	317	292	266	243	223	205	189	159	146	135
6.00	3VLI22	8'-4	8'-10	10'-1	43.50	6189	376	371	366	356	352	323	289	259	233	210	190	172	156	142	129
	3VLI20	9'-8	11'-10	12'-3	43.50	7828	369	359	350	342	336	330	312	280	253	229	208	189	173	158	144
(t=3.00)	3VLI19	10'-10	13'-2	13'-7	43.50	8101	374	358	346	335	326	318	311	305	269	244	222	202	185	170	156
57 PSF	3VLI18	11'-10	14'-2	14'-2	43.50	8101	385	367	352	340	329	319	311	304	297	282	241	221	203	187	173
	3VLI16	12'-2	14'-4	14'-10	43.50	8101	400	388	370	355	343	332	322	302	276	253	233	197	181	166	153

312 psf

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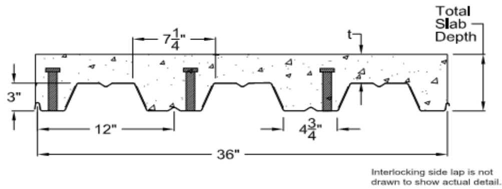
Part 3: Tips

3 VLI

Stud Spacing - 12in C-C

Maximum Sheet Length 42'-0"
Extra charge for lengths under 6'-0"
ICBO Approved (No. 3415)



(N=9.35) NORMAL WEIGHT CONCRETE (145 PCF)

Total Slab Depth	Deck Type	SDI Max. Unshored Clear Span			A_c in²/ft	ΦV_{nt} lb/ft	Superimposed Live Load (PSF) - Shear Studs at 12 in. c/c Clear Span (ft.-in.)														
		1 Span	2 Span	3 Span			7'-0	7'-6	8'-0	8'-6	9'-0	9'-6	10'-0	10'-6	11'-0	11'-6	12'-0	12'-6	13'-0	13'-6	14'-0
5.50 (t=2.50) 51 PSF	3VLI22	8'-9	9'-8	10'-11	38.73	5745	400	400	400	400	364	323	287	257	231	208	187	170	154	140	127
	3VLI20	10'-1	12'-4	12'-9	38.73	7212	400	400	400	400	400	389	347	311	280	253	229	208	189	173	158
	3VLI19	11'-4	13'-8	14'-2	38.73	7212	400	400	400	400	400	400	400	361	325	294	267	243	221	202	181
	3VLI18	12'-5	14'-7	14'-7	38.73	7212	400	400	400	400	400	400	400	400	365	330	300	267	238	212	190
	3VLI16	12'-9	14'-11	15'-5	38.73	7212	400	400	399	399	399	399	366	329	296	267	242	220	200	183	167
6.00 (t=3.00) 57 PSF	3VLI22	8'-4	8'-10	10'-1	43.50	6189	400	400	400	400	400	367	327	293	263	237	214	194	175	159	145
	3VLI20	9'-8	11'-10	12'-3	43.50	7828	400	400	400	400	400	400	397	356	321	289	262	238	217	198	181
	3VLI19	10'-10	13'-2	13'-7	43.50	8101	400	400	400	400	400	400	400	400	373	337	306	279	254	232	213
	3VLI18	11'-10	14'-2	14'-2	43.50	8101	400	400	400	400	400	400	400	400	400	380	345	315	288	263	242
	3VLI16	12'-2	14'-4	14'-10	43.50	8101	400	400	400	399	399	399	399	376	339	306	278	252	230	210	192

397 psf

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Part 3: Tips

1. Fire Rating Requirements for Deck
2. Studs Help Deck Too!
3. Composite Slabs and Contraction Joints Don't Mix

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Part 3: Tips

Contraction Joints in Elevated Slabs

Position Statement #23

ACI 318 "Building Code Requirements for Structural Concrete," ANSI/ASCE 3 "Standard for the Structural Design of Composite Slabs," and SDI #30 "Design

seems clear: let the cracks occur and control the crack width by using reinforcing steel. An article published in *Concrete Construction* (August 1999) called "Let it Crack," by J. Thomas Ryan,

ASCC POSITION STATEMENT 23 – "Contraction Joints in Elevated Slabs"

References "Let it Crack" by J. Thomas Ryan (Concrete Construction, August, 1999)

There's always a solution in Steel **135**

Part 3: Tips

1. Fire Rating Requirements for Deck
2. Studs Help Deck Too!
3. Composite Slabs and Contraction Joints Don't Mix
4. Pay Attention to Deck Placement/Orientation

There's always a solution in Steel **136**

Part 3: Tips

There's always a solution in Steel

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Part 3: Tips

There's always a solution in Steel

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Part 3: Tips

There's always a solution in Steel **139**

Part 3: Tips

Min Lat. Clear Distance to Side of Stud = 1" (AISC Spec. Section I8.2d)

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Part 3: Tips

1. Fire Rating Requirements for Deck
2. Studs Help Deck Too!
3. Composite Slabs and Contraction Joints Don't Mix
4. Pay Attention to Deck Placement/Orientation
5. Provide Min. Flange Widths at Edge Conditions

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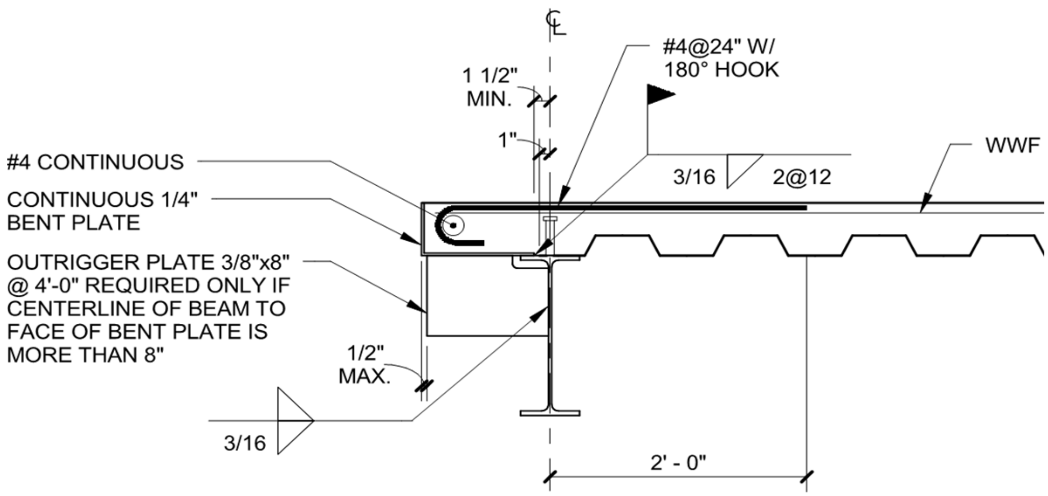
Part 3: Tips



5" Flange Width Minimum
e.g. W14x22, W12x26

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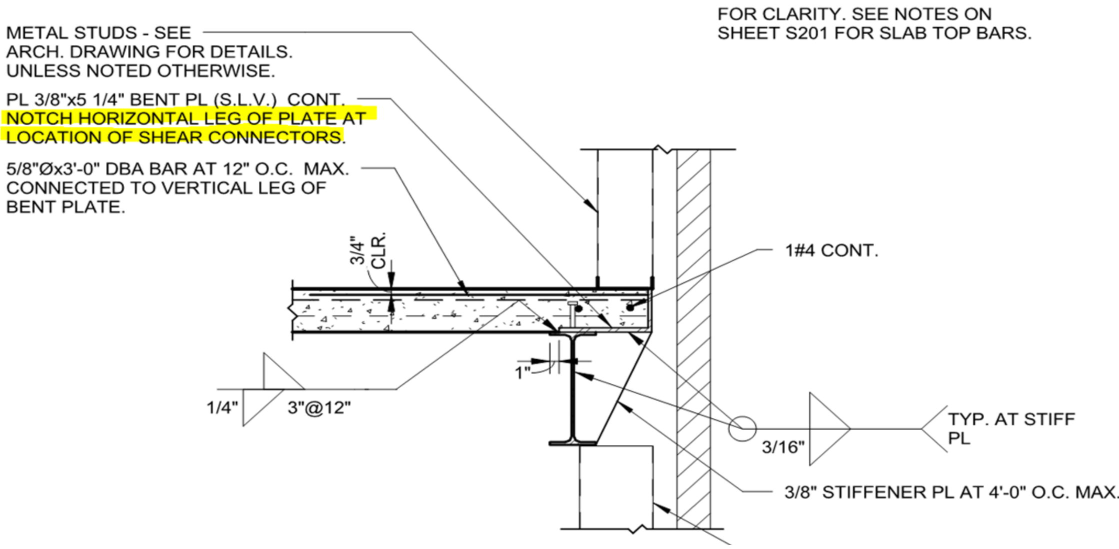
Part 3: Tips



There's always a solution in Steel

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Part 3: Tips

There's always a solution in Steel

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Part 3: Tips

1. Fire Rating Requirements for Deck
2. Studs Help Deck Too!
3. Composite Slabs and Contraction Joints Don’t Mix
4. Pay Attention to Deck Placement/Orientation
5. Provide Min. Flange Widths at Edge Conditions
6. Slab Depressions and Steps

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Part 3: Tips

Shallow Depressions (<1 in)

- Consider Fire Rating!
- If Typical Concrete Cover on Job Allows Reduction within Fire Rating, Locally Reduce Thickness
- If Reduction Would Violate Fire Rating Either:
  - Utilize Thinner Deck (i.e. 2 in. in lieu of 3 in. Deck)
  - Spray Fireproof Bays with Reduced Thickness
  - Coordinate Shorter Studs if Required

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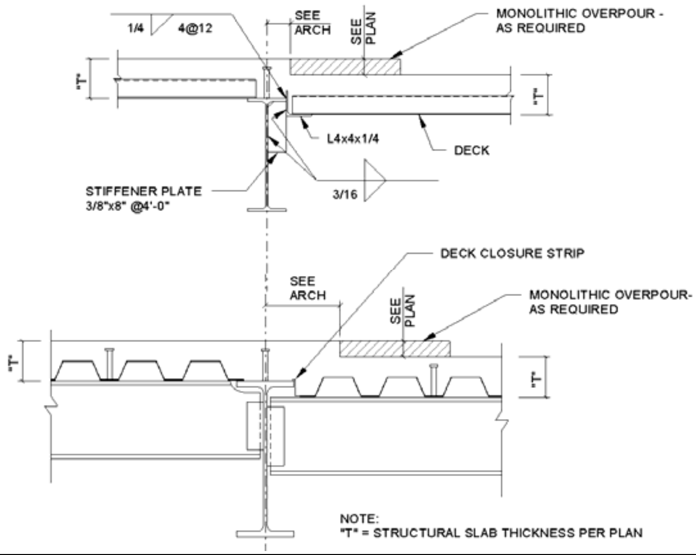
Part 3: Tips

Shallow Depressions (<3 in)



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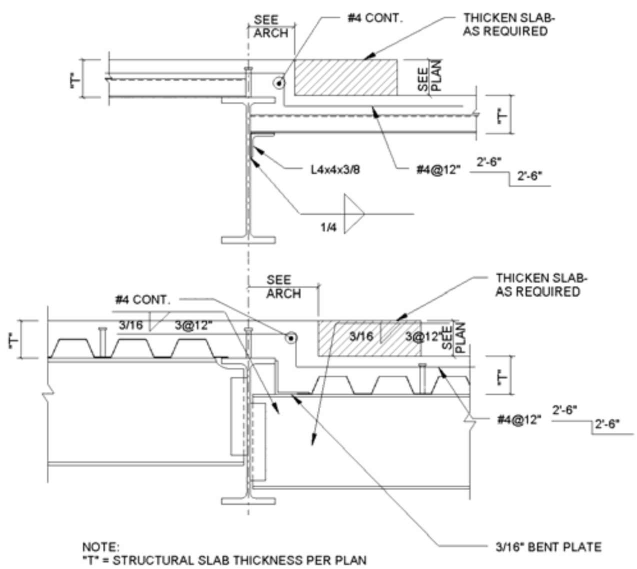
Part 3: Tips

Shallow Depressions (>3 in)



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Part 3: Tips

1. Fire Rating Requirements for Deck
2. Studs Help Deck Too!
3. Composite Slabs and Contraction Joints Don't Mix
4. Pay Attention to Deck Placement/Orientation
5. Provide Min. Flange Widths at Edge Conditions
6. Slab Depressions and Steps
7. Account for Ponding

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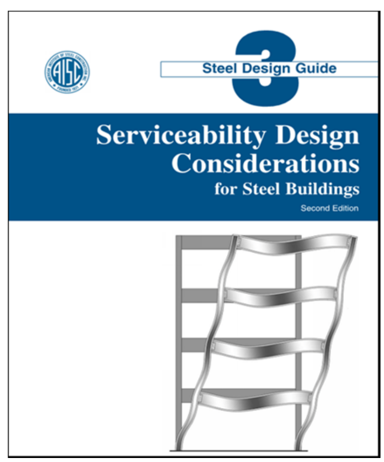
Part 3: Tips



AISC Design Guide 3 Recommends increasing slab weight by 10% (after Ruddy, Engineering Journal, 3Q, 1986)

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Part 3: Tips

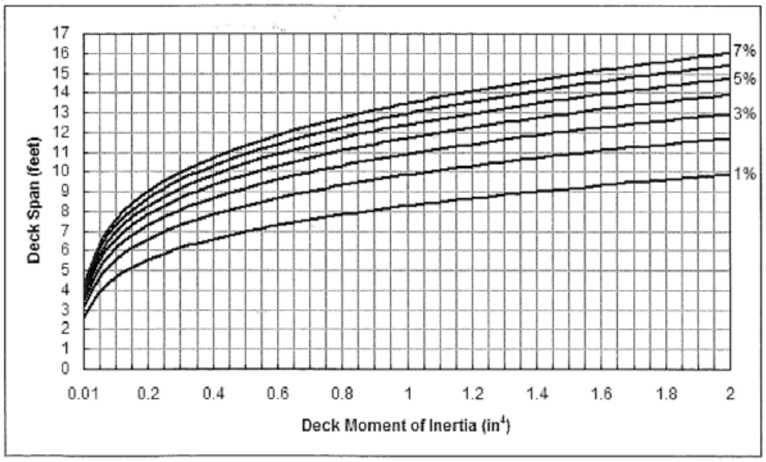

Figure 4.2 – Concrete Volume Increase (Normalweight Concrete)

- Addition from Deck Deflection is Minimal for Typical Conditions

REF: SDI Floor Deck Design Manual

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Part 3: Tips

X.X FLOOR SLABS ARE TO BE FINISHED LEVEL. THE WEIGHT OF THE WET CONCRETE WILL CAUSE DEFLECTIONS OF THE STEEL FRAMING, THUS, CONCRETE OVERRUNS ARE TO BE ANTICIPATED AND INCLUDED IN THE CONTRACTOR'S BASE BID.

- Consider Adding General Note to Account for Additional Concrete Due to Framing Deflections
- For LONG SPAN Systems Specify Constant Thickness Placements Instead of Placing to a Level

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Part 3: Tips

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8. Stud Burnoff

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Part 3: Tips

Steel Anchor Length

2010 Specification:

"Steel headed stud anchors, after installation, shall extend not less than 1 ½ in. above the top of the steel deck …

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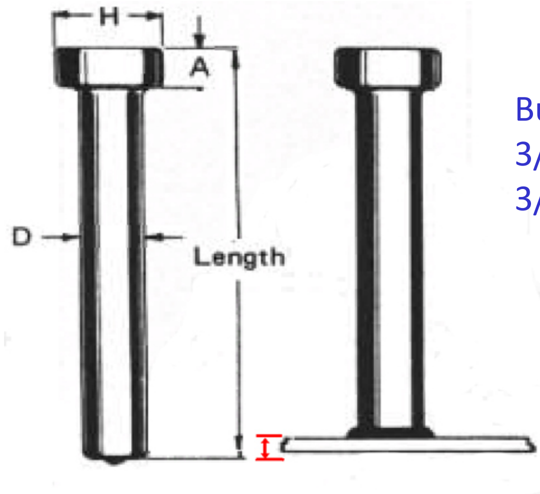
Part 3: Tips

Steel Anchor Length



Burn off Values:
3/16" to Bare Steel
3/8" through Deck

Reference: www.nelsonstud.com

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Part 3: Tips

Anchors and Galvanizing

- Generally NOT Recommended
- Hazardous Fumes + Weaker Weld
- AISC Design Guide 18 (Parking Deck): Recommends removal of coating or masking off of stud shooting areas at galvanizer
- AISC Sponsored Research Report: *http://www.aisc.org/uploadedFiles/Research/Research_Reports/Adonyi%20-%20Studs%20Thru%20Deck%20Welding.pdf*
- American Galvanizers Association: Recommends using one stud to burn off coating and then placing a second stud *http://www.galvanizeit.org/education-and-resources/resources/technical-faq-dr-galv/galvanized-steel-and-stud-welding*

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Part 3: Tips

1. Fire Rating Requirements for Deck
2. Studs Help Deck Too!
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5. Provide Min. Flange Widths at Edge Conditions
6. Slab Depressions and Steps
7. Account for Ponding
8. Stud Burnoff
9. The 80% Rule!

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Part 3: Tips

Steel Anchor Length

2010 Specification: "Steel headed stud anchors, after installation, shall extend not less than 1 ½ in. above the top of the steel deck and there shall be at least ½ in. of specified concrete cover above the top of the steel headed stud anchors."

Camber 80% of Pre-Composite Dead Load

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Part 3: Tips

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8. Stud Burnoff
9. The 80% Rule!
10. Consider Alternates to Deck Welding

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Part 3: Tips

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Part 3: Tips

Mechanical Pins/Screws

- Hilti / Pneutek / Simpson
- Pay Attention to Substrate Thickness
- Included in Addendums to SDI's Diaphragm Design Manual
- Well Suited for High Sloped Roofs
  - AWS limits puddle welding (arc spot welding) of deck on slope to 15 degrees (approx. 3/12) unless a Welding Procedure Specification provided for specific slop
  - SDI issued a position statement in 2012 reiterating this issue: *http://www.sdi.org/wp-content/uploads/2013/04/PPSLOPEDDECK.pdf*

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Outline

Practical Implementation of Composite Floor Designs

- Part 1: Conduit, Penetrations, and Openings
- Part 2: Composite Beam Strengthening
- Part 3: Best Practices / Tips for Composite Floor Designs

Thank you:

- Bo Dowswell, ARC International, LLC
- Don White, Georgia Tech

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CEU/PDH Certificates

Within 2 business days…

- You will receive an email on how to report attendance from: registration@aisc.org.
- Be on the lookout: Check your spam filter! Check your junk folder!
- Completely fill out online form. Don't forget to check the boxes next to each attendee's name!

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CEU/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.

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Thank You

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

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