AISC Live Webinars

Thank you for joining our live webinar today.
We will begin shortly. Please standby.

Steel-Framed Stairway Design
Part 1 – Overview & Gravity Loading

May 14, 2020

AISC Live Webinars

Today's live webinar will begin shortly. Please stand by.

Today's audio will be broadcast through the internet. Please be sure to turn up the volume on your speakers.

Please type any questions or comments in the Q&A window.

AISC Live Webinars

AIA Credit

AISC is a Registered Provider with The American Institute of Architects Continuing Education Systems (AIA/CES). Credit(s) earned on completion of this program will be reported to AIA/CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This program is registered with AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Smarter. Stronger. Steel.

AISC Live Webinars

Copyright Materials

This presentation is protected by US and International Copyright laws. Reproduction, distribution, display and use of the presentation without written permission of AISC is prohibited.

The information presented herein is based on recognized engineering principles and is for general information only. While it is believed to be accurate, this information should not be applied to any specific application without competent professional examination and verification by a licensed professional engineer. Anyone making use of this information assumes all liability arising from such use.

Smarter. Stronger. Steel.

AISC Live Webinars

Course Description

Steel-Framed Stairway Design – Part 1 – Overview & Gravity Loading
May 14, 2020

This webinar provides guidance for the design and layout of steel elements for steel-framed stairways, guards, handrail and related components. Information regarding stairways, code requirements for gravity loading and serviceability criteria, design methods, and design examples will be presented.

Smarter. Stronger. Steel.

AISC Live Webinars

Learning Objectives

- Name the various components of steel-framed stairs.
- List the types of stair classes and their characteristics.
- Identify the critical code provisions for creating a stair layout.
- Explain the structural code requirements for gravity load design of stairs for both strength and serviceability.

Smarter. Stronger. Steel.

Steel Framed Stairway Design

Adam Friedman
Senior Associate
CSD Structural Engineers
Milwaukee, Wisconsin

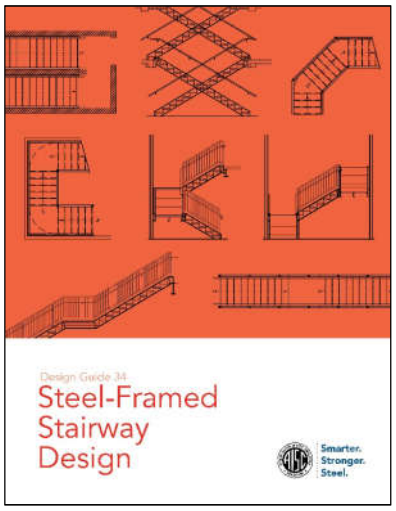
CSD STRUCTURAL ENGINEERS
EXPERTISE · INNOVATION · EXCELLENCE

Smarter. Stronger. Steel.

Introduction

AISC Design Guide 34: Steel Framed Stairway Design

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



8

Outline – Part 1

Step 1 – Purpose & Design Philosophy

Step 2 – Stairway Overview

Step 3 – Code Requirements - Gravity

Step 4 – Stairway Design

Step 5 – Members & Connx

Step 6 – Examples

9

Outline – Part 2

Step 7 – Code Requirements – Seismic Loading

Step 8 – Seismic Serviceability

Step 9 – Stairway Design

Step 10 – Examples

Step 11 – Delegated Design

Step 12 – Other Topics

10

Outline – Part 1

Step 1 – Purpose & Design Philosophy

Step 2 – Stairway Overview

Step 3 – Code Requirements - Gravity

Step 4 – Stairway Design

Step 5 – Members & Connx

Step 6 – Examples

11

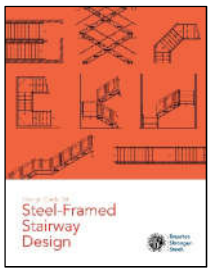
Purpose for Design Guide

- Improve communication & coordination
- Resolve common issues:
  - Misunderstanding code requirements
  - Inadequate or incorrect stairway dimensions
  - Unclear code criteria for project
  - Insufficient information in design documents
  - Coordination of support locations
  - Contractual concerns / delegated design

12

Design Philosophy

- IBC/ASCE7 Requirements
- NAAMM *Stair Manual* & *Railing Manual*
  - General Stair & Rail Layout
  - Design Criteria may be out of date
- AISC Design Guide 34
  - Specific layout and detail information
  - Design methods
  - Design recommendations



13

Design Philosophy

- AISC *Code of Standard Practice (COSP)* defines stairs and handrail as "other items", therefore these items are outside the scope of the COSP since it is not structural steel.
- But, for steel stairway design, use AISC documents as "reference standards" instead:
  - AISC 2016 *Code of Standard Practice (COSP)*
  - AISC *Steel Construction Manual, 15th Ed. (Manual)*
  - AISC 2016 *Specification for Structural Steel Buildings (Specification)*

14

Design Philosophy

- Use AISC documents in conjunction with design documents for steel stair design but confirm acceptance with:
  - Architect of Record (AOR)
  - Structural Engineer of Record (SER)
  - Authority Having Jurisdiction (AHJ)
  - General Contractor (GC)
- Make this a project specific requirement or include as part of your contract

15

Outline – Part 1

Step 1 – Purpose & Design Philosophy

Step 2 – Stairway Overview

Step 3 – Code Requirements - Gravity

Step 4 – Stairway Design

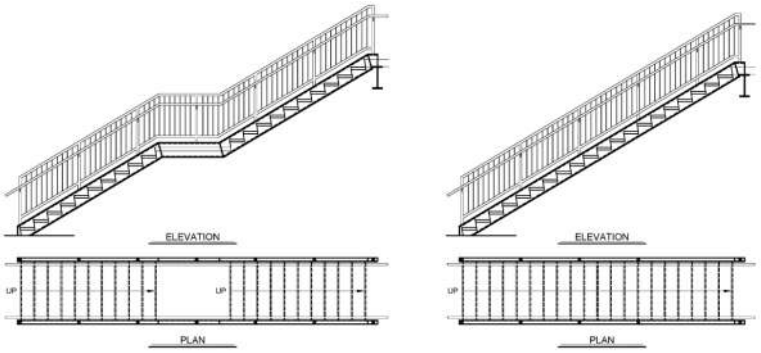
Step 5 – Members & Connx

Step 6 – Examples

16

Stair Types (NAAMM)

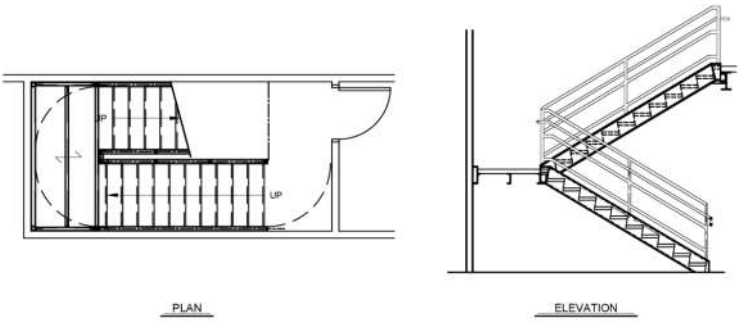
- Straight
  - Straight
  - Parallel (Switchback)
  - Angled
  - Scissor



17

Stair Types

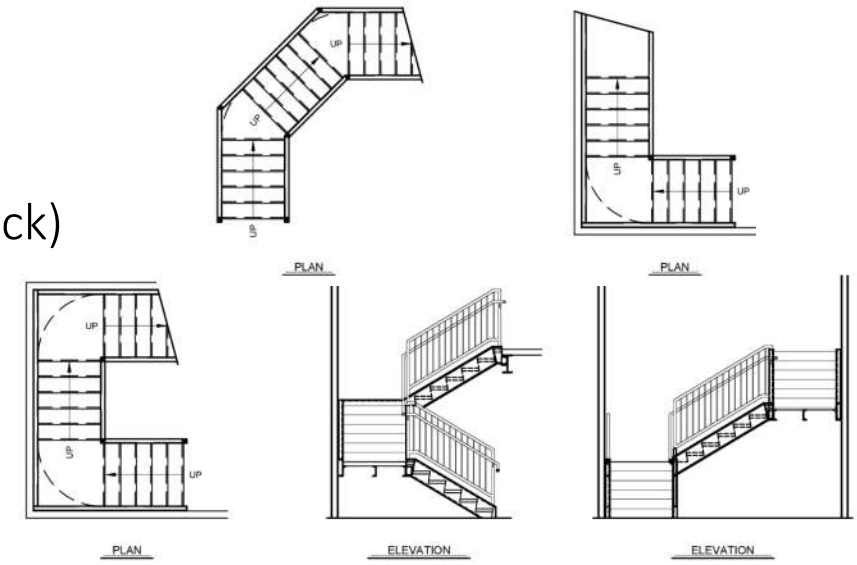
- Straight
  - Straight
  - Parallel (Switchback)
  - Angled
  - Scissor



18

Stair Types

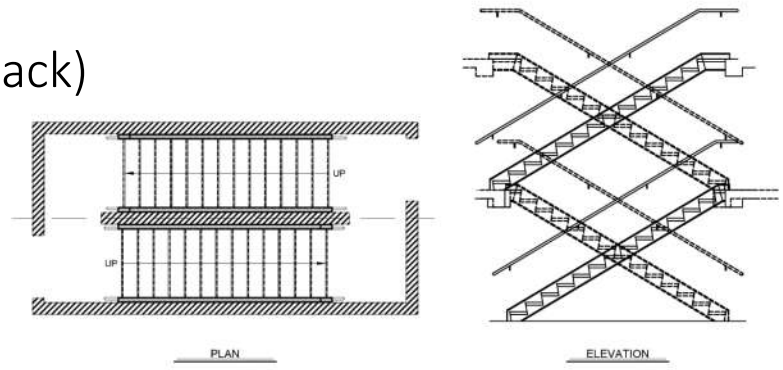
- Straight
  - Straight
  - Parallel (Switchback)
  - Angled
  - Scissor



19

Stair Types

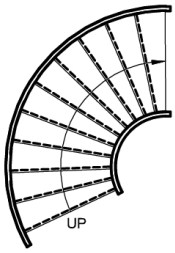
- Straight
  - Straight
  - Parallel (Switchback)
  - Angled
  - Scissor



20

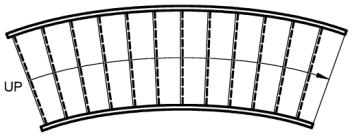
Stair Types

- Circular



PLAN

- Curved

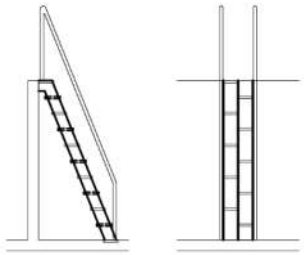


PLAN

21

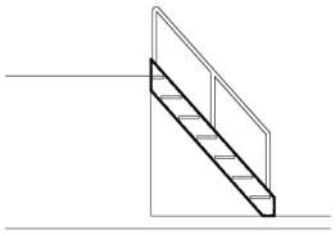
Stair Types

- Alternating Tread Device



SIDE VEIW ELEVATION

- Ships Ladder

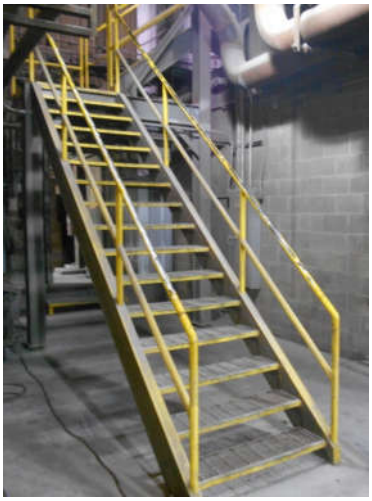


ELEVATION

22

Stair Class (NAAMM)

- Industrial
  - functional
  - economical
  - industrial setting
- Service
- Commercial
- Architectural

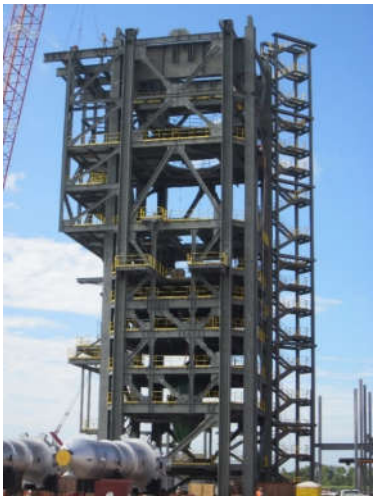


Type: Straight
Class: Industrial

23

Stair Class - Industrial

Type: Parallel



Type: Parallel

24

Stair Class - Industrial

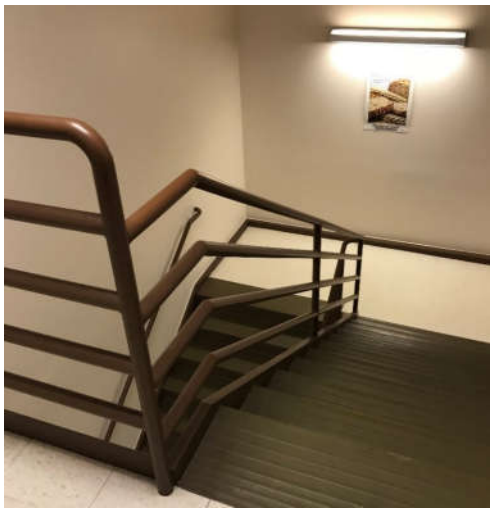
25

Stair Class - Industrial

26

Stair Class

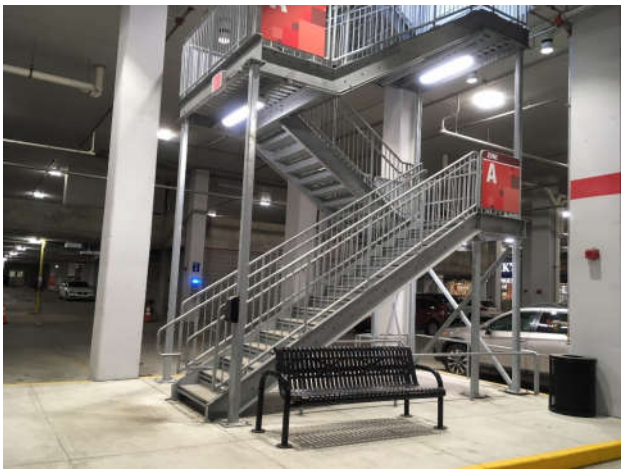
- Industrial
- Service
  - functional
  - "back of house"
  - common egress stair
- Commercial
- Architectural



Type: Parallel
Class: Service

27

Stair Class - Service



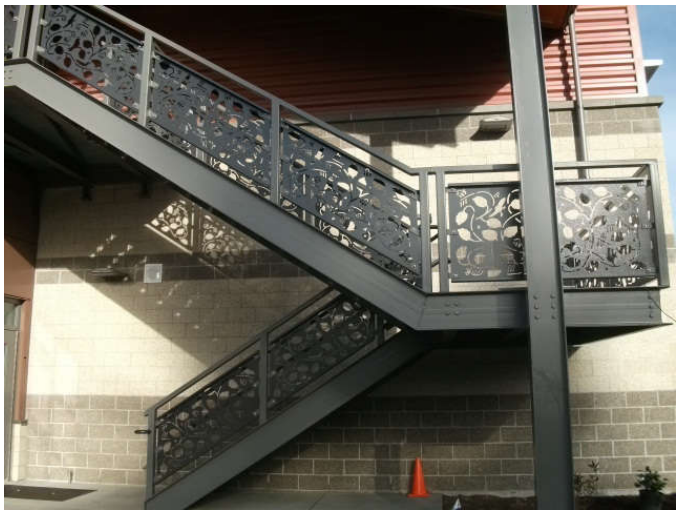
Type: Parallel

Type: Parallel

28

Stair Class

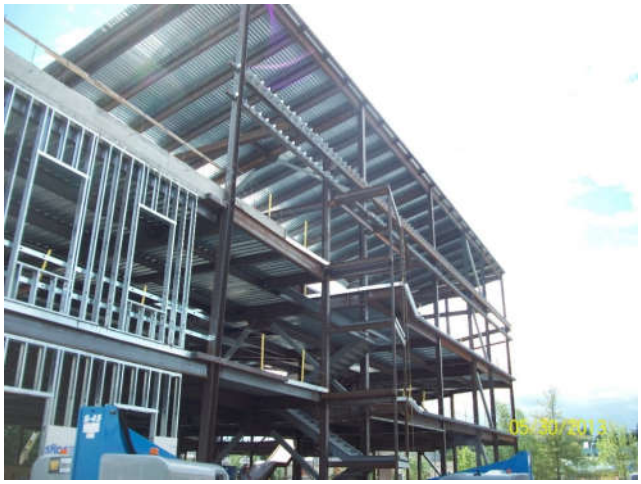
- Industrial
- Service
- Commercial
  - public use
  - more attractive
- Architectural



Type: Parallel
Class: Commercial

29

Stair Class - Commercial



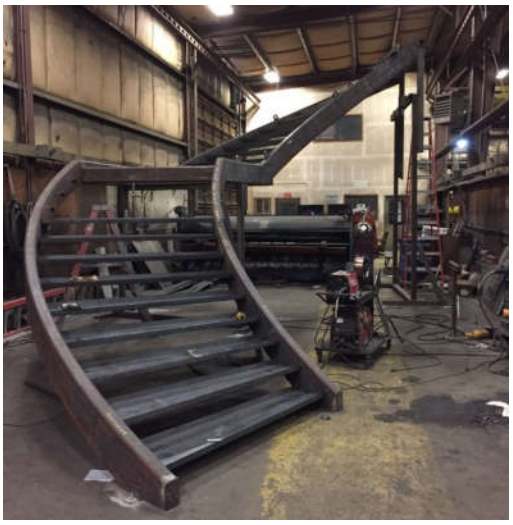
Type: Parallel

Type: Parallel

30

Stair Class

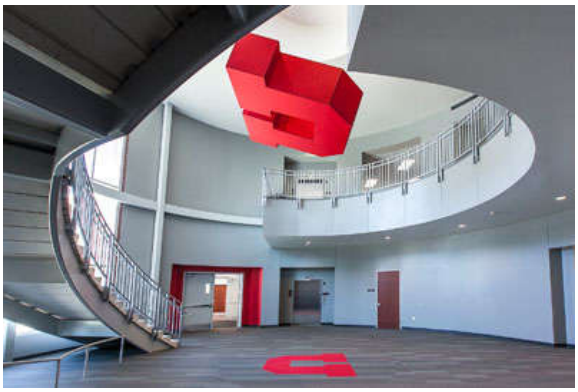
- Industrial
- Service
- Commercial
- Architectural
  - elaborate
  - custom
  - most expensive



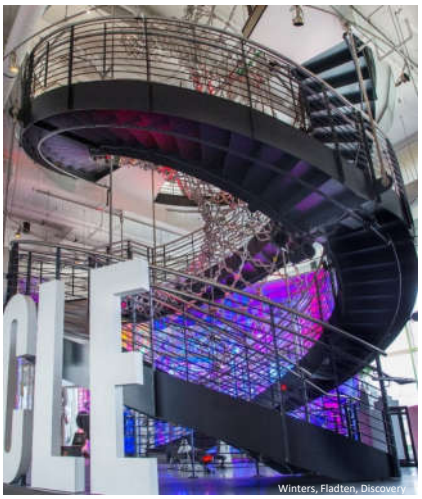
Type: Curved
Class: Architectural

31

Stair Class - Architectural



Type: Curved
Class: Architectural

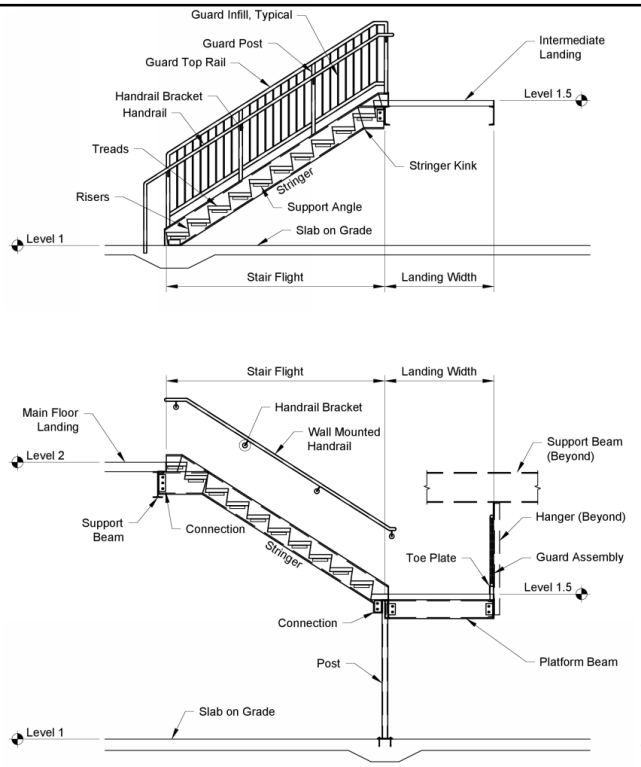


Type: Circular
Class: Architectural

32

Stairway Elements

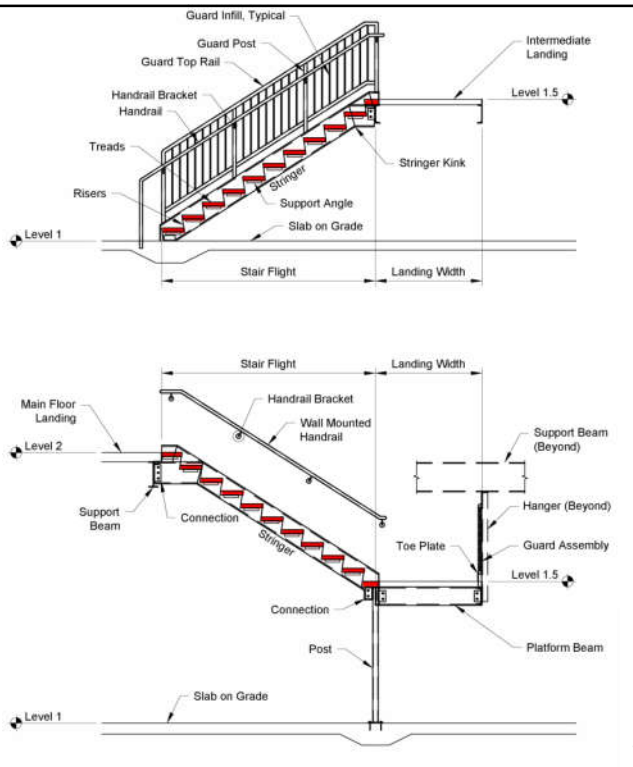
- Tread
- Riser
- Stringer
- Landing
- Handrail
- Guard
- Supports
- Connections



33

Stairway Elements

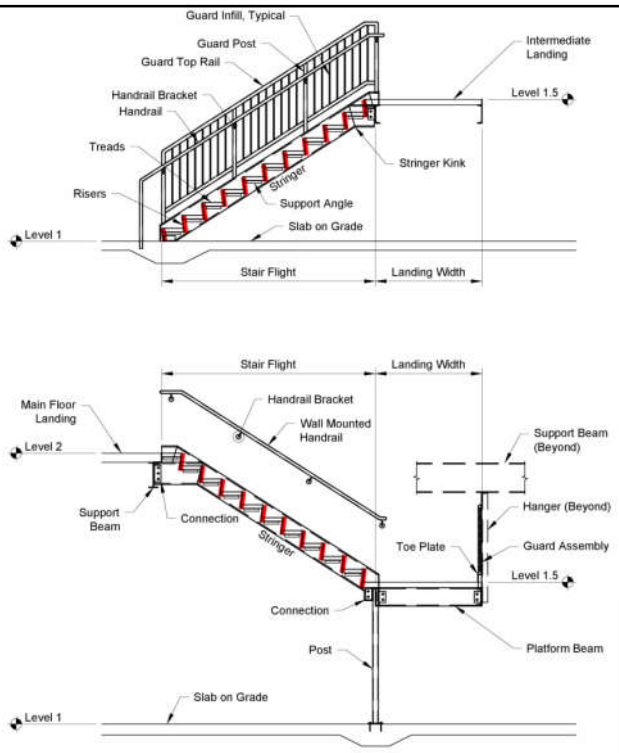
- Tread
- Riser
- Stringer
- Landing
- Handrail
- Guard
- Supports
- Connections



34

Stairway Elements

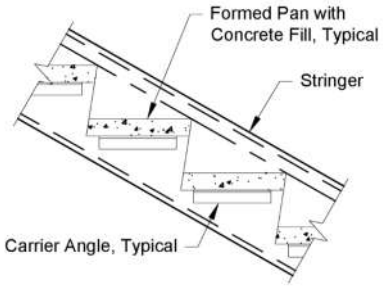
- Tread
- Riser
- Stringer
- Landing
- Handrail
- Guard
- Supports
- Connections



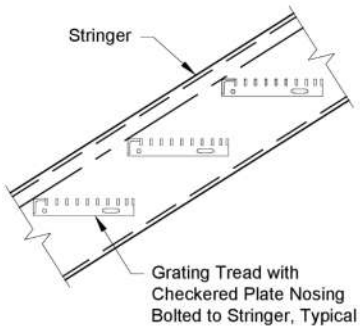
35

Stairway Elements

- Typical Tread / Riser Assembly



"IBC" / Commercial

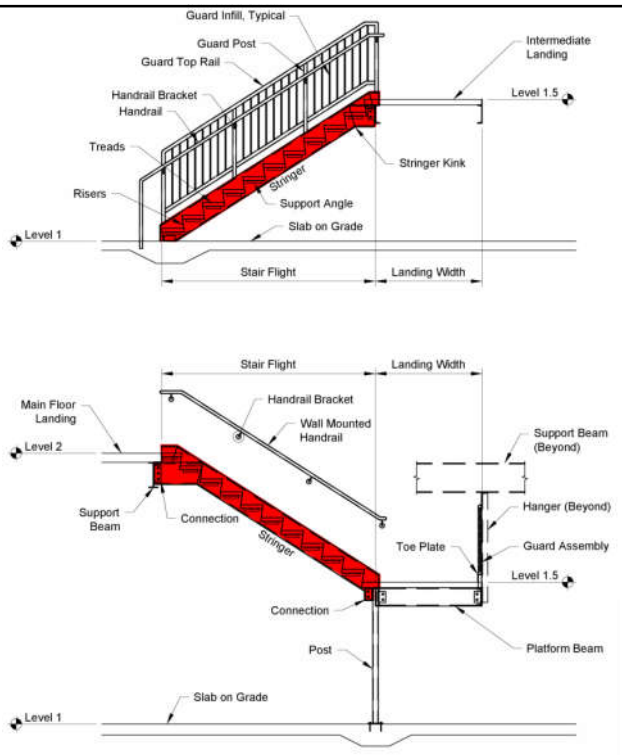


"OSHA" / Industrial

36

Stairway Elements

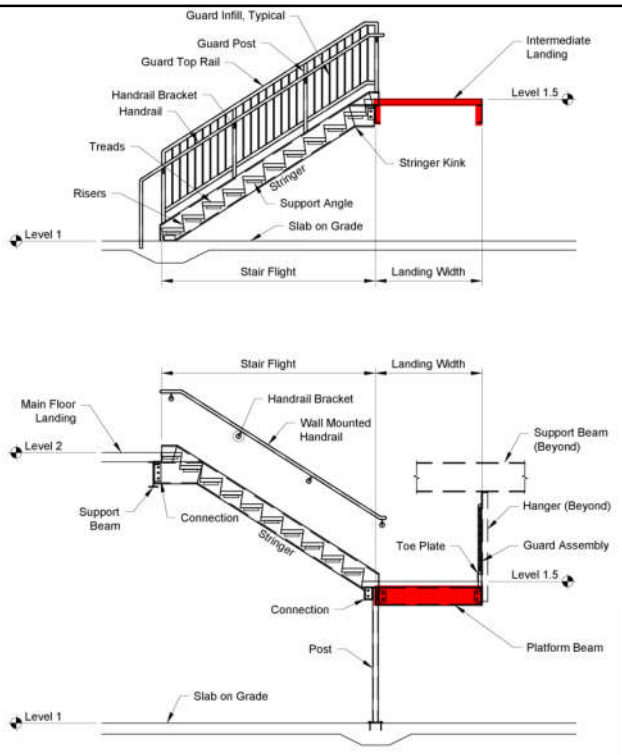
- Tread
- Riser
- Stringer
- Landing
- Handrail
- Guard
- Supports
- Connections



37

Stairway Elements

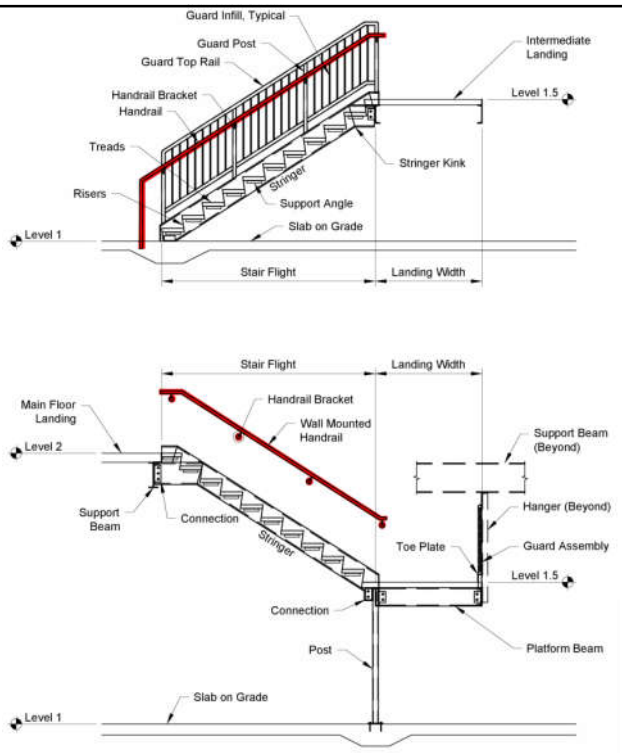
- Tread
- Riser
- Stringer
- Landing
- Handrail
- Guard
- Supports
- Connections



38

Stairway Elements

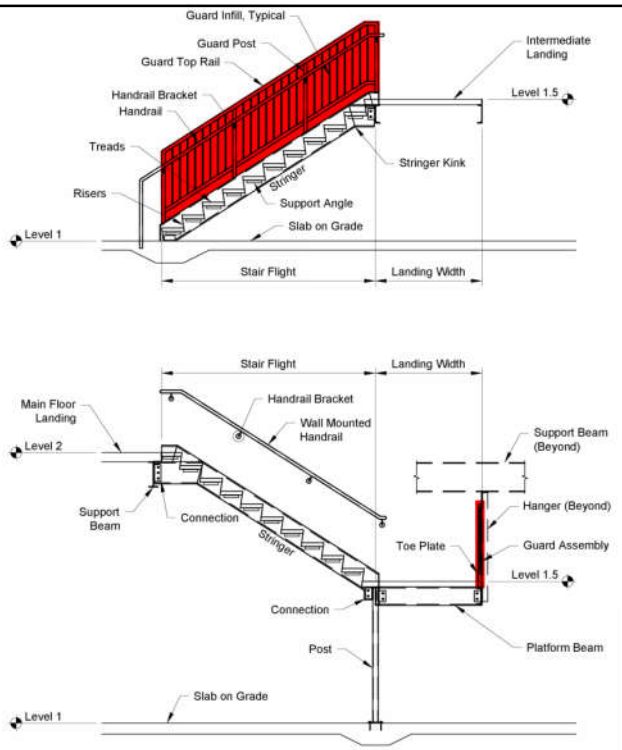
- Tread
- Riser
- Stringer
- Landing
- Handrail
- Guard
- Supports
- Connections



39

Stairway Elements

- Tread
- Riser
- Stringer
- Landing
- Handrail
- Guard / “Stair Rail System”
- Supports
- Connections

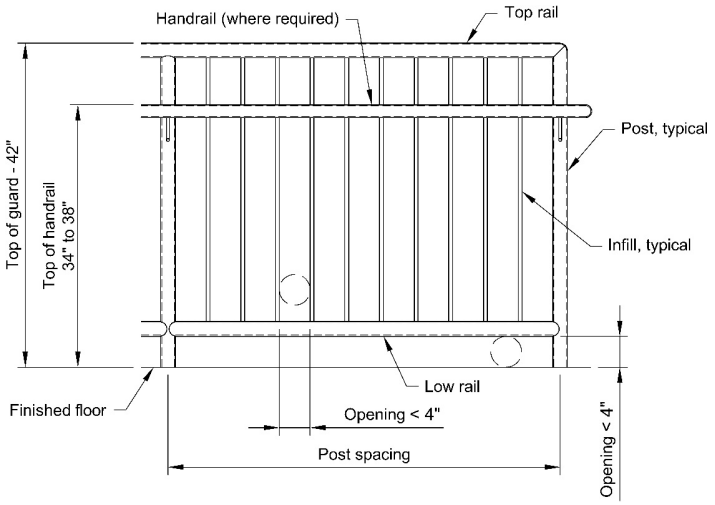


40

Stairway Elements

Guard

- Post
- Top Rail
- Low Rail
- Infill
- Toe Kick / Toeboard

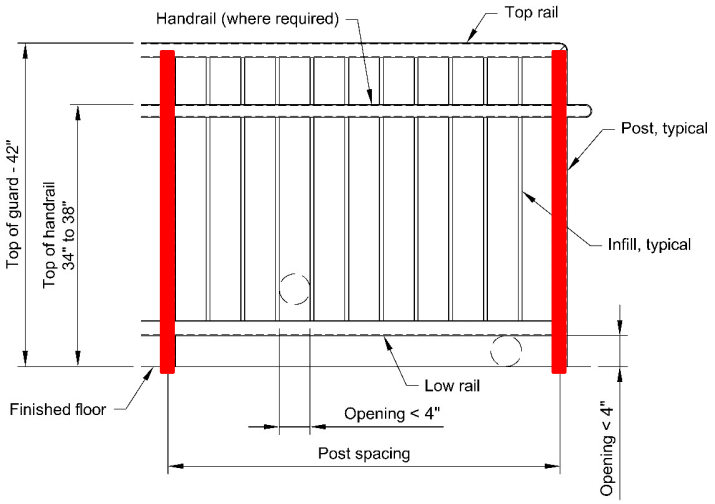


41

Stairway Elements

Guard

- Post
- Top Rail
- Low Rail
- Infill
- Toe Kick / Toeboard

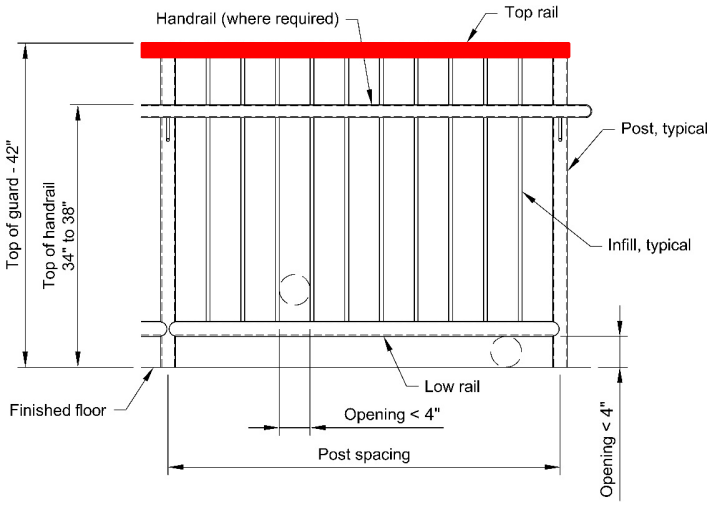


42

Stairway Elements

Guard

- Post
- Top Rail
- Low Rail
- Infill
- Toe Kick / Toeboard

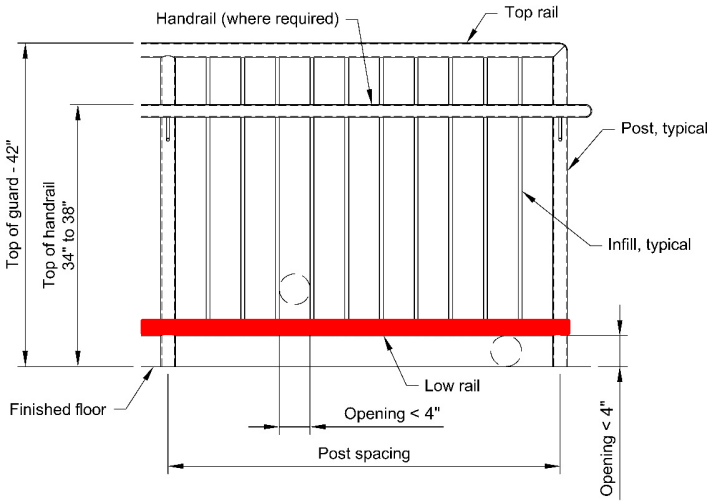


43

Stairway Elements

Guard

- Post
- Top Rail
- Low Rail
- Infill
- Toe Kick / Toeboard

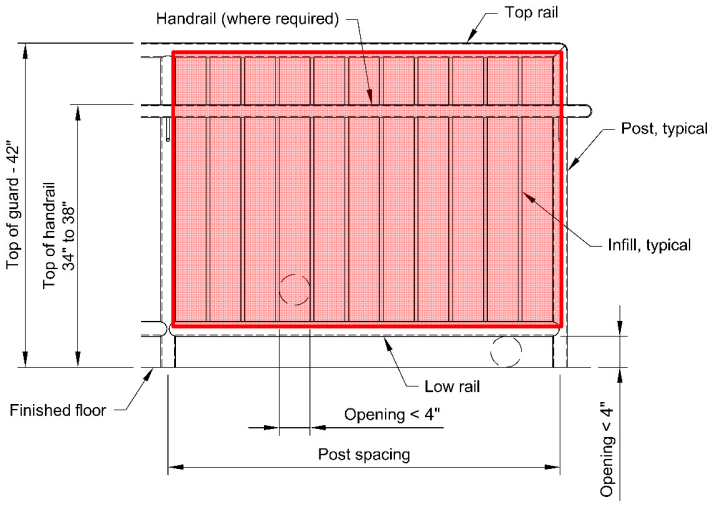


44

Stairway Elements

Guard

- Post
- Top Rail
- Low Rail
- Infill
- Toe Kick / Toeboard

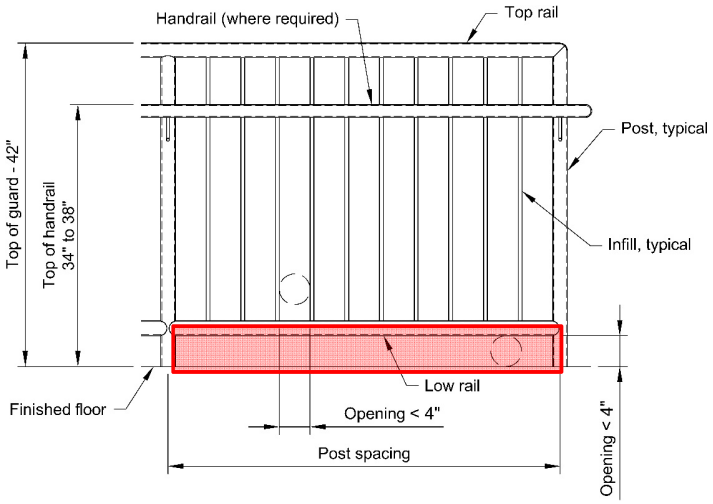


45

Stairway Elements

Guard

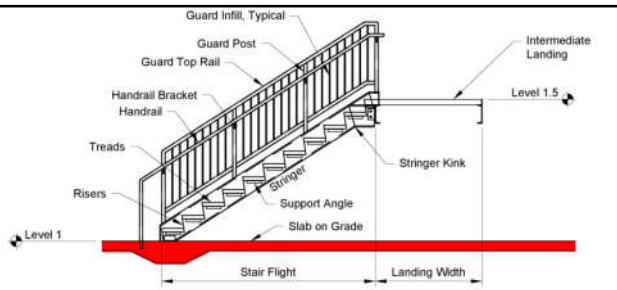
- Post
- Top Rail
- Low Rail
- Infill
- Toe Kick / Toeboard

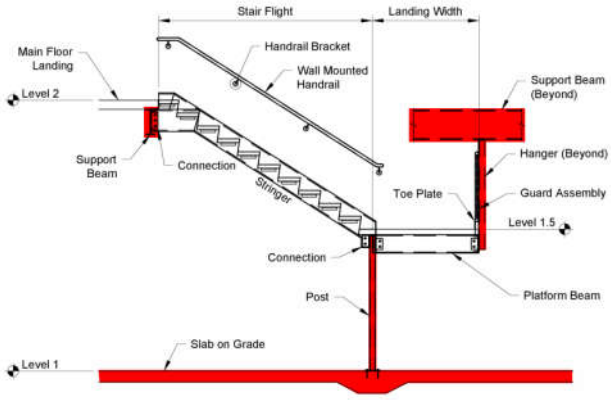


46

Stairway Elements

- Tread
- Riser
- Stringer
- Landing
- Handrail
- Guard
- Supports
- Connections

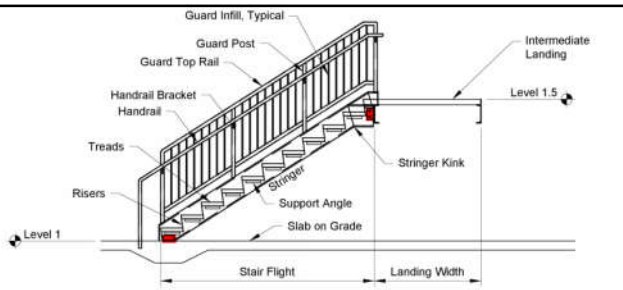


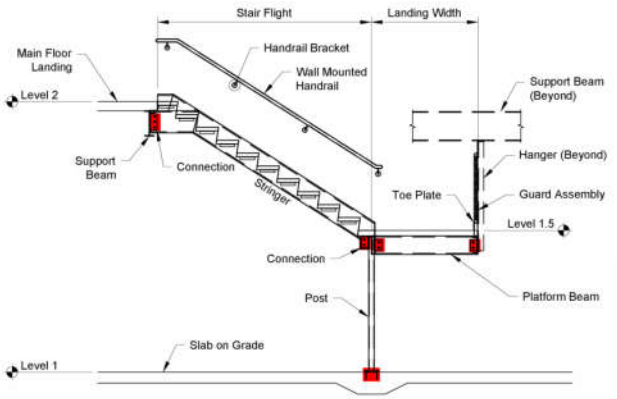


47

Stairway Elements

- Tread
- Riser
- Stringer
- Landing
- Handrail
- Guard
- Supports
- Connections





48

Stairway Layout – IBC or OSHA?

- Per International Code Council
  - All stairs should follow IBC unless AHJ approves
  - All stairs are egress stairs (even if area served is "unoccupied" or seldom used)
  - Certain exceptions for equipment per International Mechanical Code

49

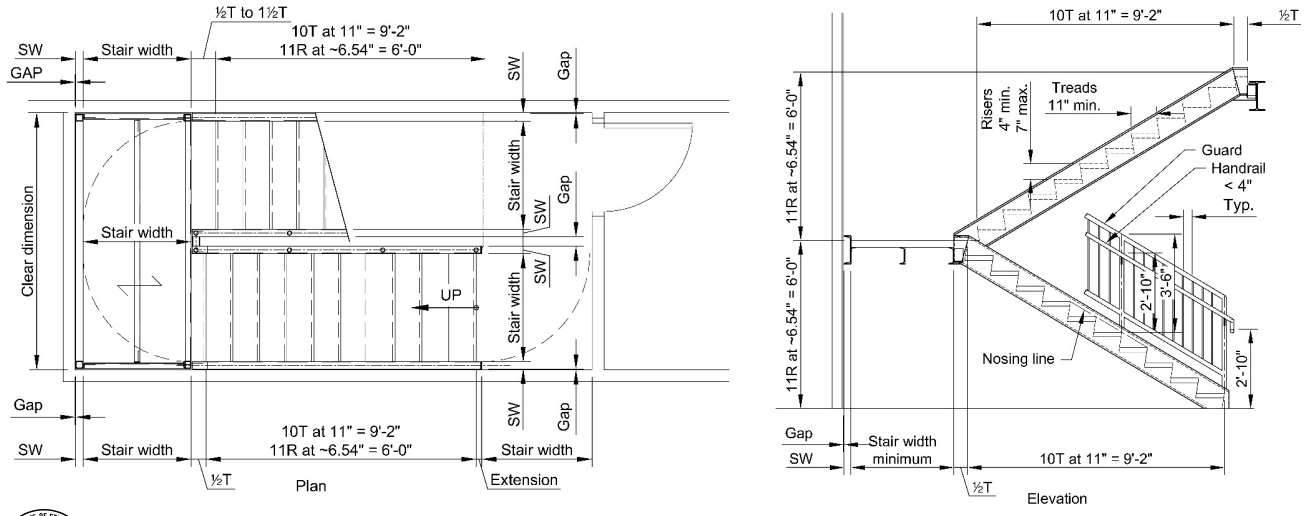
Stairway Layout – IBC or OSHA?

IBC stair is OSHA compliant** but…
OSHA stair may not be IBC compliant

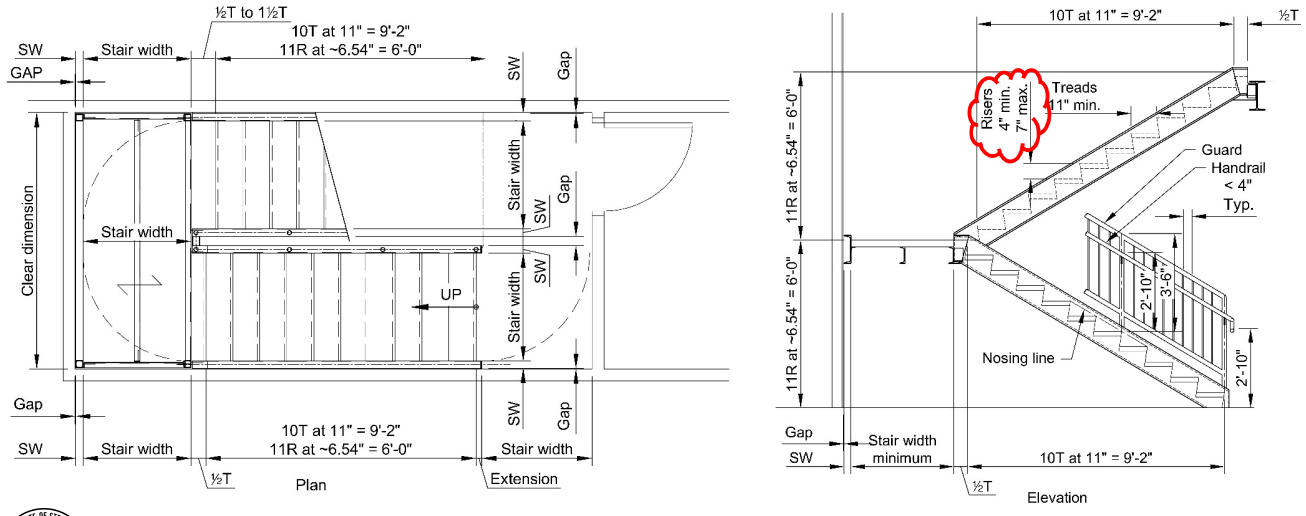
**OSHA 1910.29(f)(2) indicates a handrail finger clearance requirement of 2 ¼" while IBC requires 1 ½" minimum. *Waiting on response from OSHA to clarify…*

50

Stairway Layout - IBC

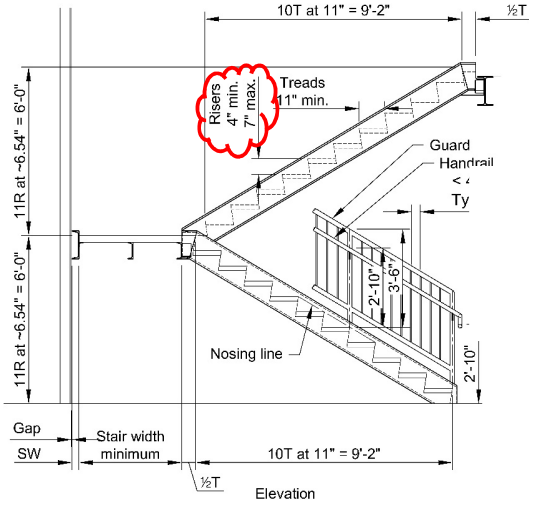


Stairway Layout – IBC: Riser Height



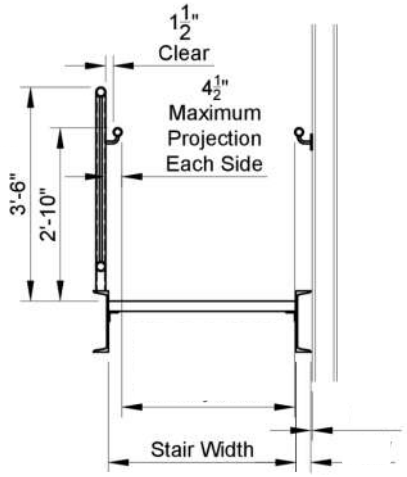
Stairway Layout – IBC: Riser Height

- 7” max riser height cannot be violated.
- Don’t let tolerances or mis-fits create problems.
  - IBC Section 1011.5.4 - 3/8” tolerance between max/min riser
  - Maybe consider 6 5/8” max riser height, when possible

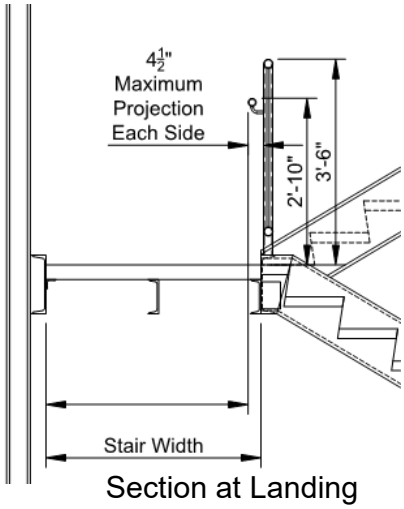


53

Stairway Layout – IBC: Egress Width



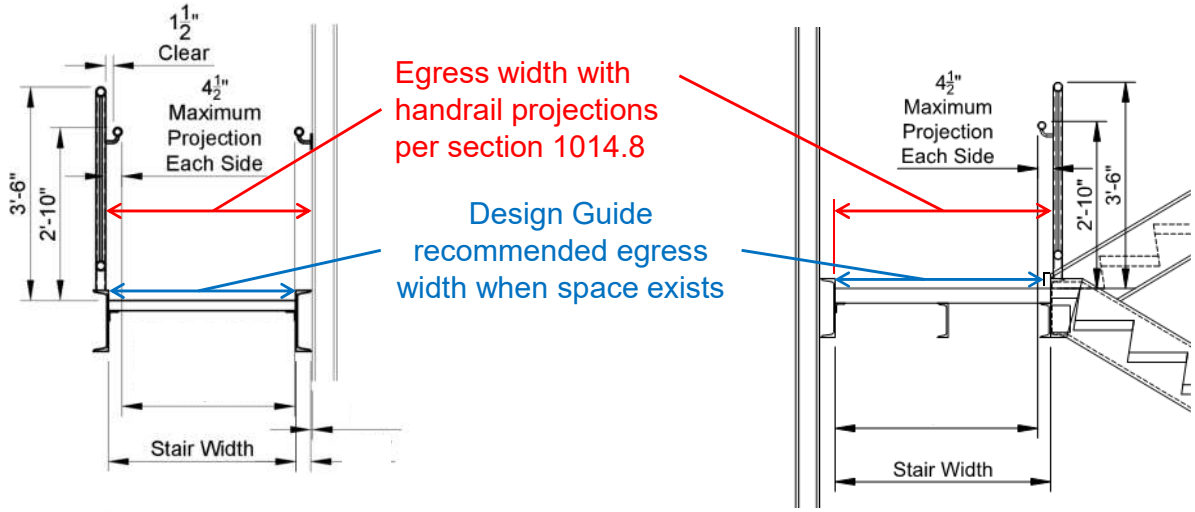
Section at Stairway



Section at Landing

54

Stairway Layout – IBC: Egress Width

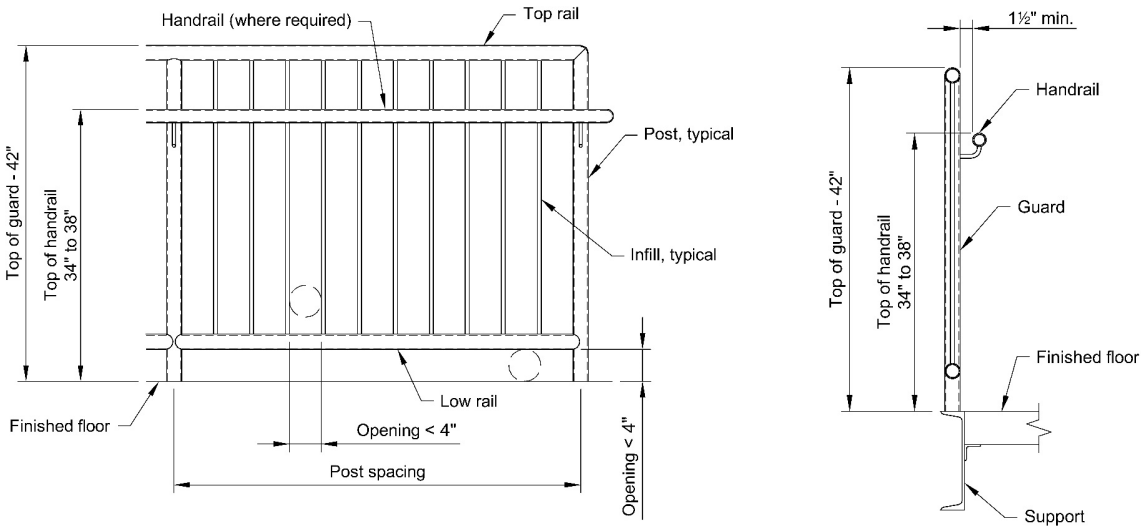


Section at Stairway

Section at Landing

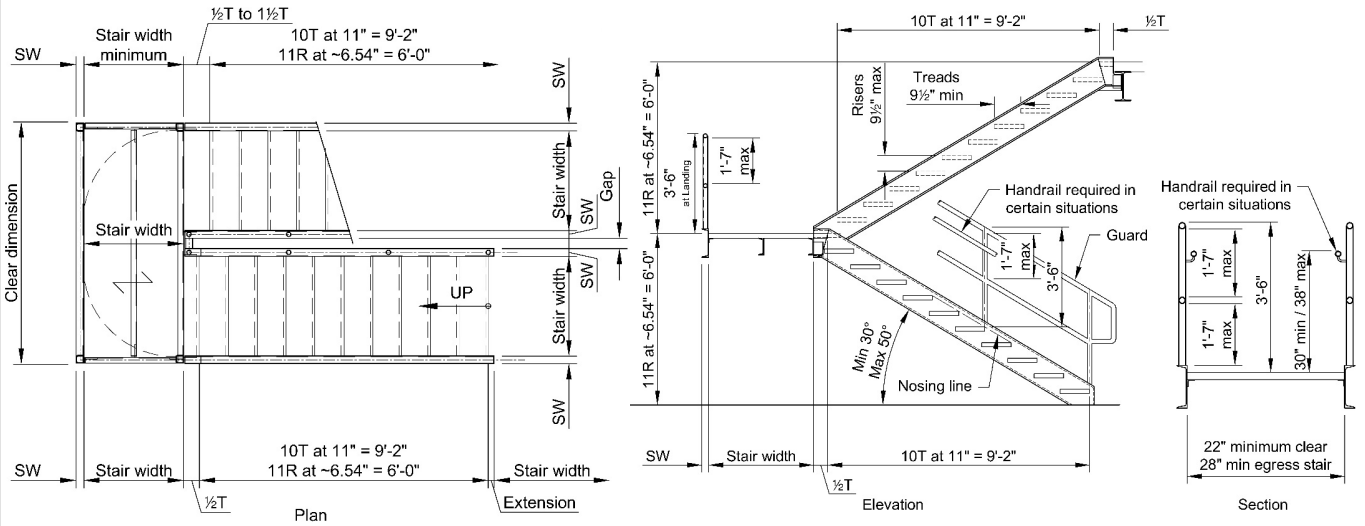
55

Stairway Layout – IBC: Guard



56

Stairway Layout – OSHA



Stairway Layout – OSHA: Updates

- OSHA revised standard 1910 Subpart D as of 1/17/2017
- Renumbered and reorganized:
  - 1910.25 – Stairways
  - 1910.28 – Duty to have fall protection & falling object protection
  - 1910.29 – Fall protection systems and falling object protection-criteria and practices
- Changed riser/tread limits
- Changed vertical clearance
- Revised guard height and handrail requirements

Stairway Layout – OSHA: Updates

- Revised guard height and handrail requirements

https://www.osha.gov/laws-regs/standardinterpretations/2019-09-23

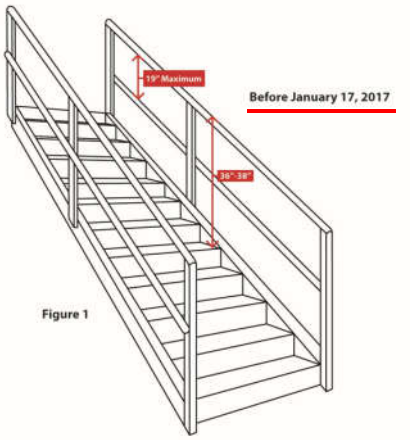


Figure 1

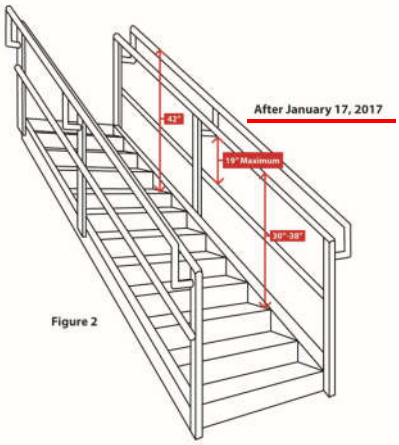
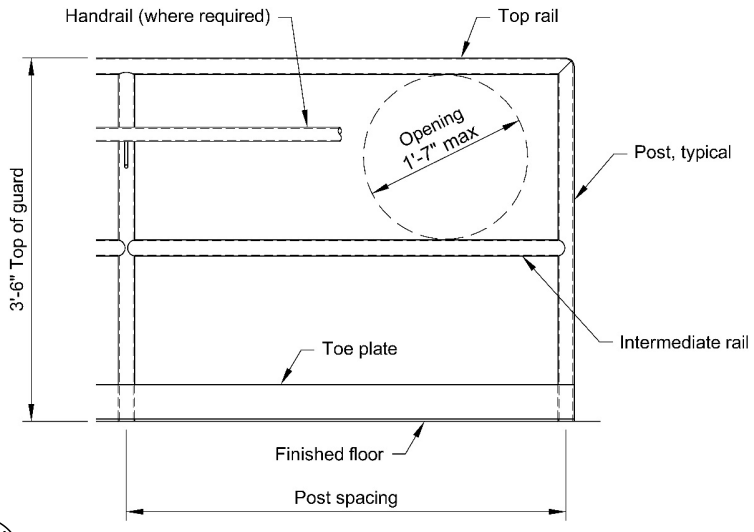
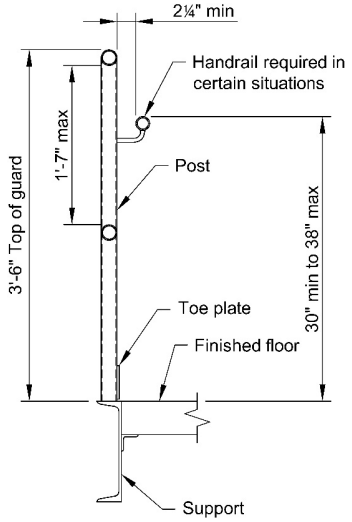


Figure 2

59

Stairway Layout – OSHA: Guard

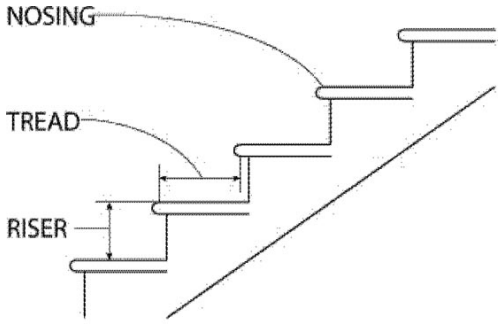




60

Stairway Layout – OSHA: Width

- 1910.25(c)(4)
  - Minimum width = 22” between *vertical barriers*
- 1910.25 Figure D-8
  - Minimum *tread* width = 22”
- 1910.36(g)(2)
  - Minimum width = 28” at *all points* for exit routes



MINIMUM TREAD WIDTH 22 IN (56 CM)
MINIMUM TREAD DEPTH 9.5 IN (24 CM)
MAXIMUM RISER HEIGHT 9.5 IN (24 CM)

OSHA Figure D-8

61

Stairway Layout – OSHA: Width

- 1910.28(b)(11)(ii) & Table D-2

1910.28(b)(11)(ii)

Each flight of stairs having at least 3 treads and at least 4 risers is equipped with stair rail systems and handrails as follows:

Table D-2 -- Stairway Handrail Requirements

Stair width	Enclosed	One open side	Two open sides	With earth built up on both sides
Less than 44 inches (1.1 m).	At least one handrail	One stair rail system with handrail on open side.	One stair rail system each open side.	
44 inches (1.1 m) to 88 inches (2.2 m).	One handrail on each enclosed side	One Stair rail system with handrail on open side and one handrail on enclosed side.	One stair rail system with handrail on each open side.	
Greater than 88 inches (2.2 m).	One handrail on each enclosed side and one intermediate handrail located in the middle of the stair	One stair rail system with handrail on open side, one handrail on enclosed side, and one intermediate handrail located in the middle of the stair.	One stair rail system with handrail on each open side and one intermediate handrail located in the middle of the stair.	
Exterior stairs less than 44 inches (1.1 m).				One handrail on least one side.

Note to table: The width of the stair must be clear of all obstructions except handrails.

62

Stairway Layout – OSHA: Width

- 1910.28(b)(11)(ii) & Table D-2

1910.28(b)(11)(ii)

Each flight of stairs having at least 3 treads and at least 4 risers is equipped with stair rail systems and handrails as follows:

Table D-2 -- Stairway Handrail Requirements

Stair width	Enclosed	One open side	Two open sides	With earth built up on both sides
Less than 44 inches	At least one handrail	One stair rail system with handrail on open side.	One stair rail system each open side.	
m).				
Greater than 88 inches (2.2 m).	One handrail on each enclosed side and one intermediate handrail located in the middle of the stair	One stair rail system with handrail on open side, one handrail on enclosed side, and one intermediate handrail located in the middle of the stair.	One stair rail system with handrail on each open side and one intermediate handrail located in the middle of the stair.	
Exterior stairs less than 44 inches (1.1 m).				One handrail on least one side.

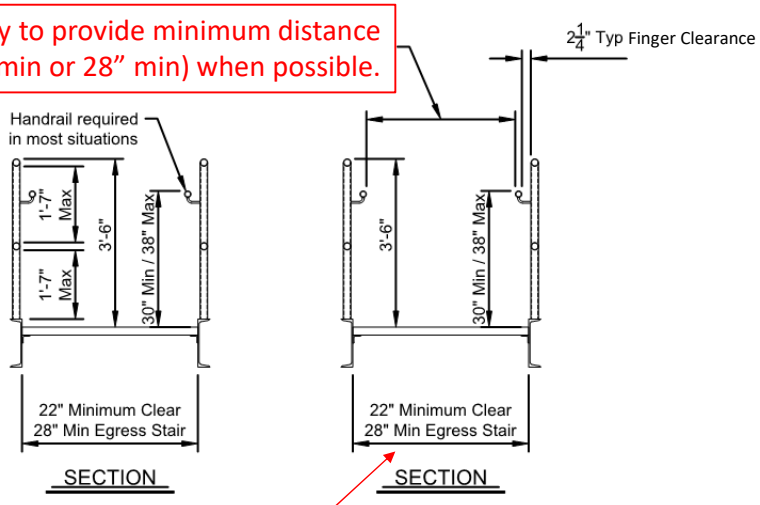
Note to table: The width of the stair must be clear of all obstructions except handrails.

Note to table: The width of the stair must be clear of all obstructions except handrails.

63

Stairway Layout – OSHA: Width

Try to provide minimum distance (22” min or 28” min) when possible.

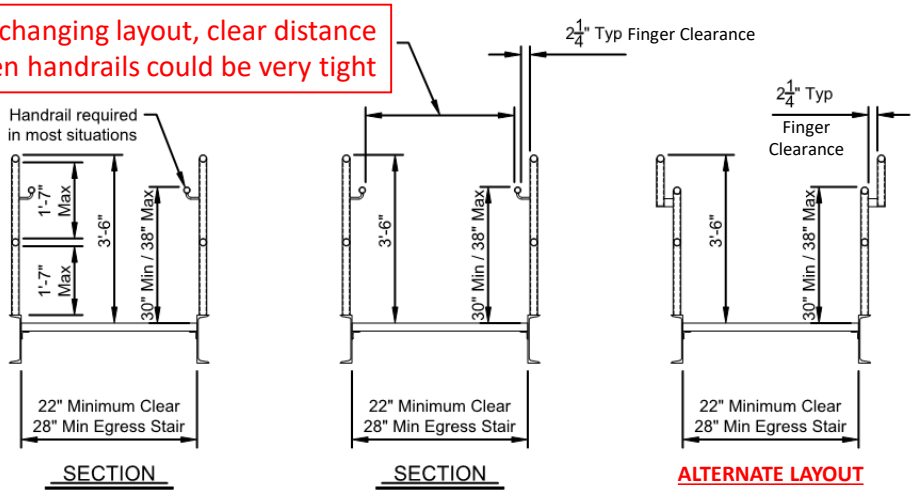


Actual egress width requirement

64

Stairway Layout – OSHA: Width

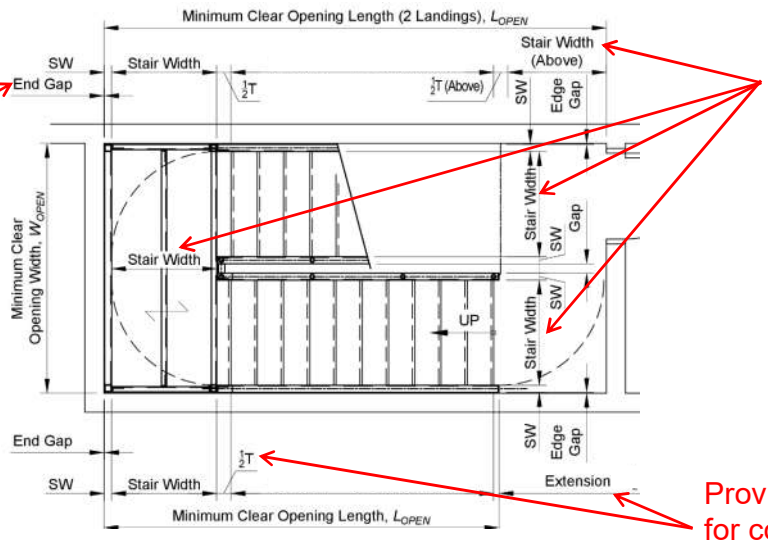
Without changing layout, clear distance between handrails could be very tight



65

Stairway Opening Size

¼" minimum, ½" preferred

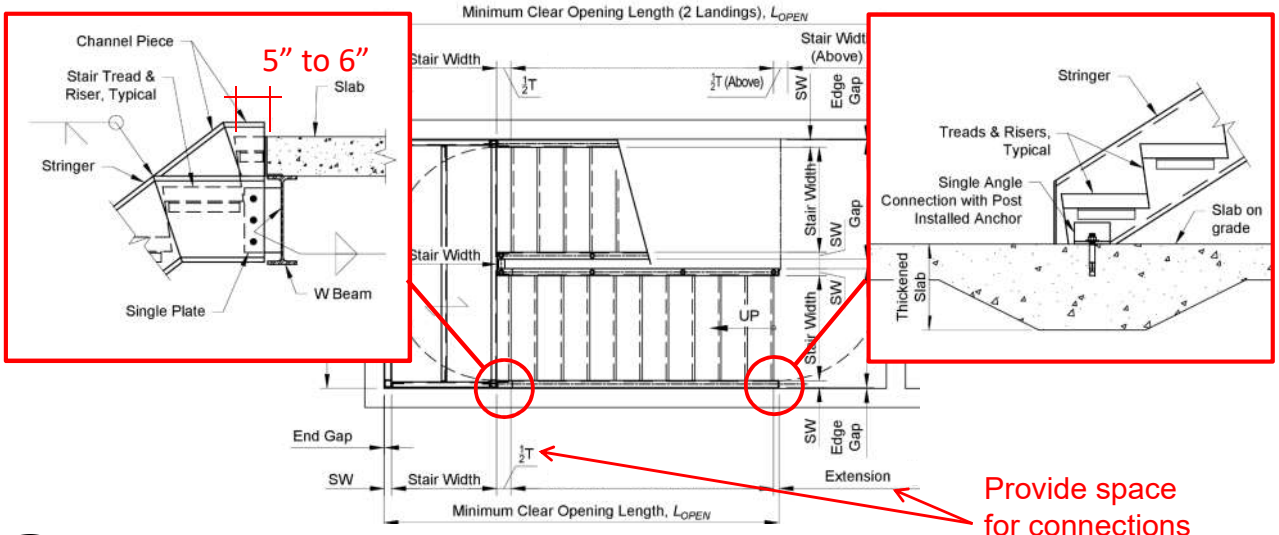


44" minimum, or per code

Provide space for connections

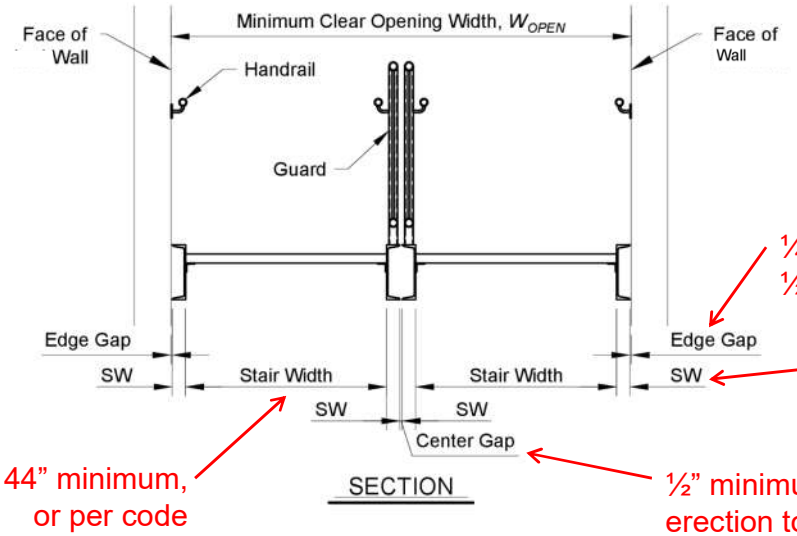
66

Stairway Opening Size



Provide space for connections

Stairway Opening Size



Allow for additional space for connections!

¼" minimum,
½" preferred

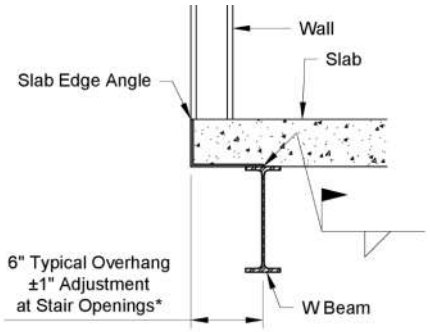
2" minimum,
3" recommended or
actual member width

44" minimum,
or per code

½" minimum but consider
erection tolerances & access

Stairway Opening Size

- Field installed slab edge angle
  - Allows for adjustment in field to help with fit-up



* - Coordinate final opening dimensions with Architect & SER during detailing.

69

Outline – Part 1

Step 1 – Purpose & Design Philosophy

Step 2 – Stairway Overview

Step 3 – Code Requirements - Gravity

Step 4 – Stairway Design

Step 5 – Members & Connx

Step 6 – Examples

70

Applicable Codes

- International Building Code (IBC)
  - Chapter 10 "Means of Egress"
  - Chapter 16 "Structural Design" – Loads, Combos, & Serviceability
- ASCE/SEI 7-16 Minimum Design Loads for Buildings & Other Structures
  - Loading & Load Combinations
- Occupational Safety & Health Administration (OSHA)
  - 1910 Subpart D
    - 1910.25 Stairways
    - 1910.28 Duty to have fall protection and falling object protection
    - 1910.29 Fall protection systems and falling object protection
    - 1910.36 Design and construction requirements for exit routes

71

Load Combinations

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

LRFD

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

ASD

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

72

Loading

- Dead Loads
  - Self weight (steel members, concrete fill, etc.)
  - MEP Allowances
  - Architectural finishes (flooring, walls, soffits, etc.)
  - Typical material weights found in
    - ASCE 7-16 commentary Chapter C3 "Dead Loads"
    - AISC Tables 17-12 & 17-13

73

Loading – IBC 2015 / ASCE 7-16

- Live Loads

Component	Loading
Stair Tread	300 lb concentrated load on 4 in^2 or 100 psf uniform load
Stair Landing	100 psf uniform load
Guard – Top Rail	200 lb force in any direction or 50 lb/foot in any direction
Guard – Infill & Other Rails	50 lb over 1 square foot
Handrail	200 lb force in any direction or 50 lb/foot in any direction

74

Loading – OSHA

Component	Loading
Stair Tread / Landing	Five times "normal live load" or 1,000 lb concentrated load
Guard/Stair Rail System – Top Rail	200 lb force in downward or outward direction
Guard/Stair Rail System – Infill	150 lb force in downward or outward direction
Handrail	200 lb force in downward or outward direction
Toeboard / Toeplate	50 lb force in downward or outward direction

75

Loading – OSHA

- What is "normal live load"?
  - Based on actual usage of the stair
  - Divide total weight of users over stair plan area
    - 300 lbs / 20 ft^2 = 15 psf
  - Multiply above value by five
    - 15 psf × 5 = 75 psf → "normal live load"
- Recommend using 60 psf minimum design value based on ASCE 7 Table 4-1 for "walkways and elevated platforms"
- 1,000 lb concentrated force may govern

76

Loading – OSHA

- Standard interpretation

https://www.osha.gov/laws-regs/standardinterpretations/2000-05-08-0

  - Design of stairs and components based on ultimate strength (yield stress, Fy or ultimate stress Fu) and not on allowable stresses per AISC.
  - Place loads in such a way that maximum stress is experienced
  - "normal live load" distributed over whole stair
  - Concentered force is a point load on any element

77

Serviceability – IBC 2015, Table 1604.3

Deflection

Component	L	D+L
Floor members (stringers/landings)	Span/360	Span/240
Supporting tile/brittle floor finish	*Span/600*	Span/240
Cantilever Guard Post*	Height/60	
Guard, Handrail, Infill**	Span/120	

* - Matches deflection limit for interior partitions with flexible finishes and twice the height for cantilever members

** - Matches deflection limit for interior partitions with flexible finishes

78

Outline – Part 1

Step 1 – Purpose & Design Philosophy

Step 2 – Stairway Overview

Step 3 – Code Requirements - Gravity

Step 4 – Stairway Design

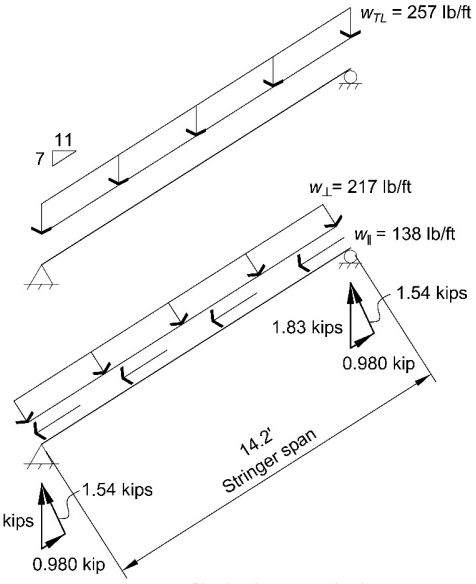
Step 5 – Members & Connx

Step 6 – Examples

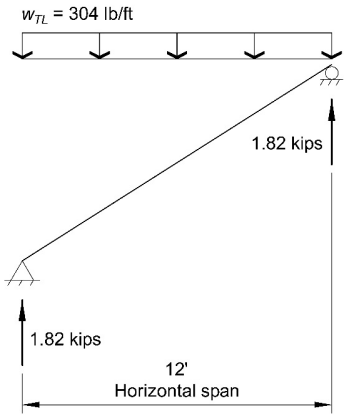
79

Stairway Design

Sloping Beam versus Horizontal Plane Method



Sloping beam method



Horizontal plane method

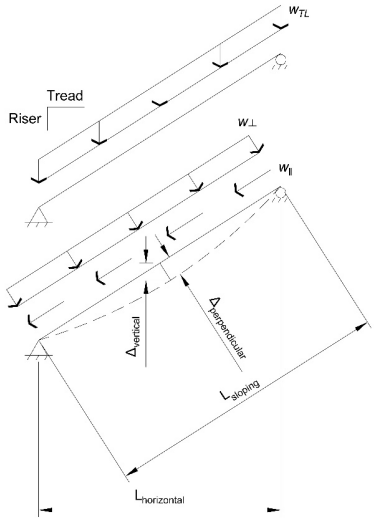
80

Stairway Design

Sloping Beam versus Horizontal Plane Method

Vertical Deflection

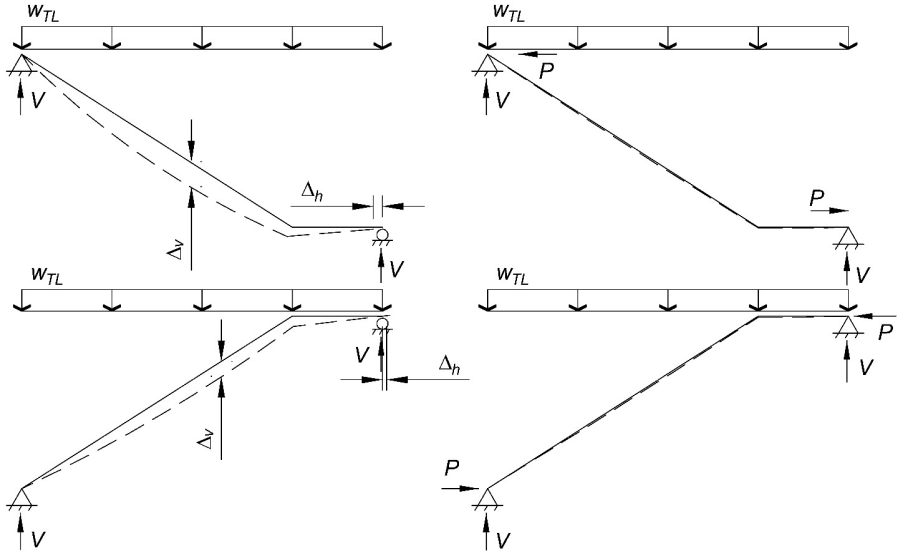
- Additional length of a sloping member will result in larger vertical deflections
- Deflections should be calculated using
  - sloping beam method
  - horizontal plane method with adjustment factor



81

Stairway Design

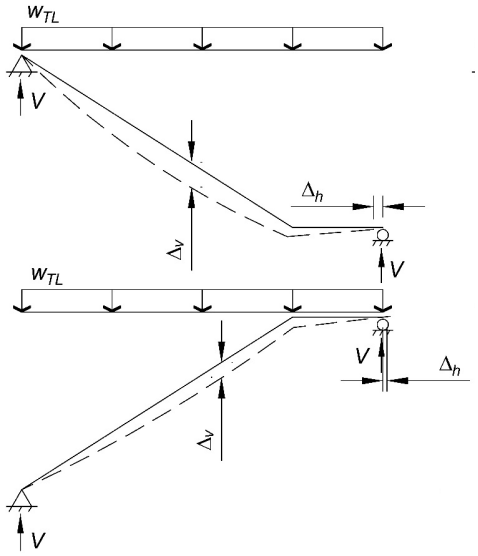
Simple Span versus Frame Analysis



82

Stairway Design

- Simple Span



Simple span beam analysis

- Roller support allows for some lateral movement. This is a relatively small value for Δ_h on most stairs.
- Designers can ensure simple span behavior with simple shear connections, flexible supports, and drift details.

$$R = V = \frac{wl}{2}$$

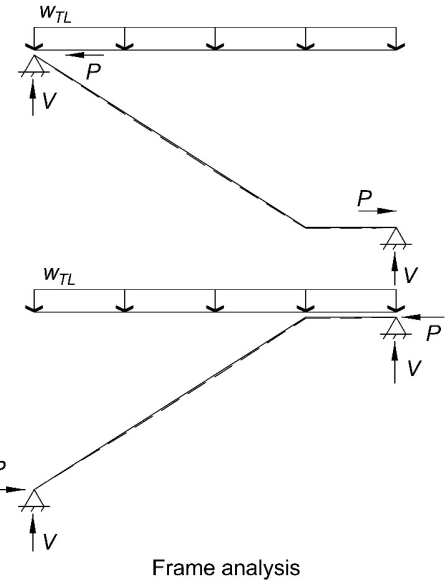
$$M_{\max} = \frac{wl^2}{8}$$

$$\Delta_{\max} = \frac{5wl^4}{384EI}$$

83

Stairway Design

- Frame Analysis



Frame analysis

- Pin supports at each end restrain lateral deflection. Results in very small vertical deflection and large axial reactions due to catenary action or arching action.
- Designers must design connections for large axial reactions.
- Designer should ensure supporting structure can accommodate the end connection forces.

84

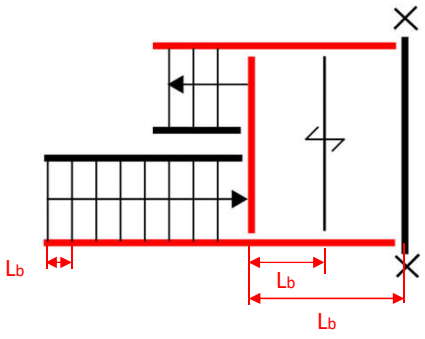
Stairway Design – Unbraced Length

- Refer to AISC *Specification* Appendix Section 6.3
  - Determine if tread/riser has adequate stiffness and strength to brace stringer
- Likely fully braced using:
  - Welded tread/riser "Z shape" pans (concrete filled)
  - Welded checker plate
- Needs more research:
  - Bolted grating treads
  - Flat pans (tread only, no riser)
  - Precast, fiberglass, or other manufactured products

85

Stairway Design – Unbraced Length

- Consider unbraced length at integrated landings
  - Infill members & connections
  - Slab type
    - Cast in place concrete over deck/pans
    - Grating
    - Precast



- Compare flexural capacity based on Lb to moment at that location *(don't be too conservative)*

86

Stairway Design – Serviceability

- Deflection Limits
  - IBC Limits versus Project Specifications
    - 1/4" maximum on Live Load or Total Load?
    - Span/360 on Live Load or Total Load?
  - Floor/wall finishes
- Vibration Concerns

87

Outline – Part 1

Step 1 – Purpose & Design Philosophy

Step 2 – Stairway Overview

Step 3 – Code Requirements - Gravity

Step 4 – Stairway Design

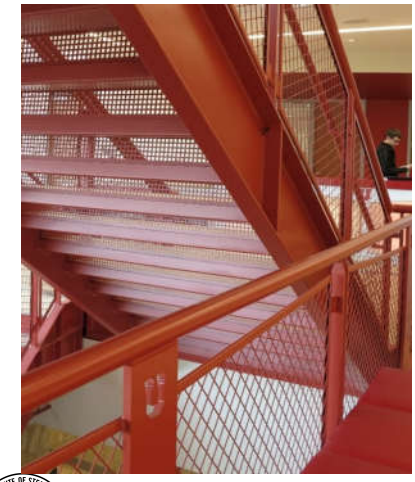
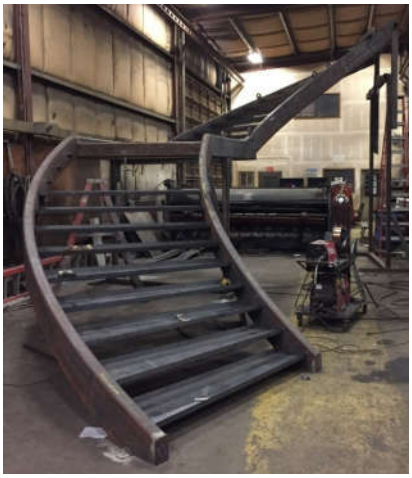
Step 5 – Members & Connx

Step 6 – Examples

88

Member Selection

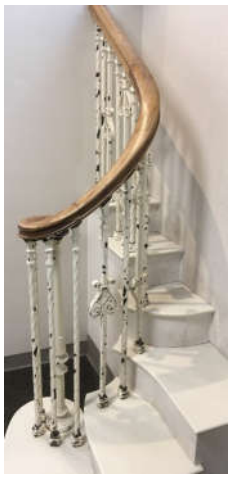
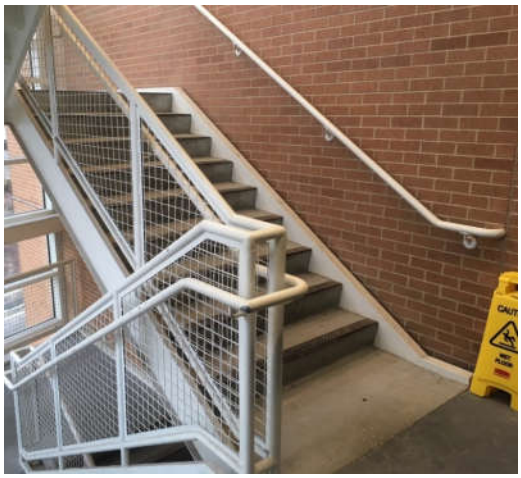
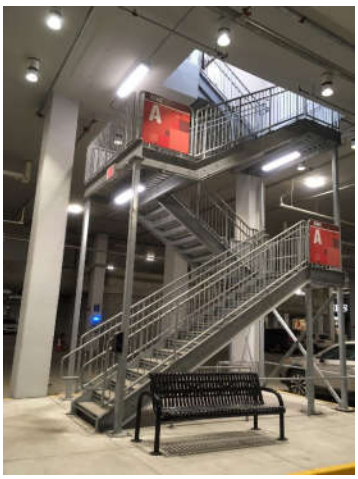
Stringers – Channel, Plate, Rectangular HSS, WF


89

Member Selection

Guards/Rails – Pipe, HSS, Bar, Rounds, Custom

90

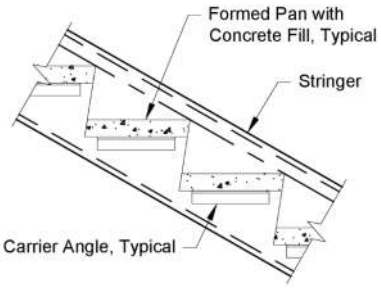
Member Selection

Guards/Rails – Pipe, HSS, Bar, Rounds, Custom

91

Treads/Risers

- Integral Pan Tread & Riser with Concrete Fill
  - Directly welded
  - Carrier bar or angle for support
  - Refer to AISI code for design of light gauge material
    - Use effective section properties
    - Consider which portion of profile provides strength and stiffness (partially effective



92

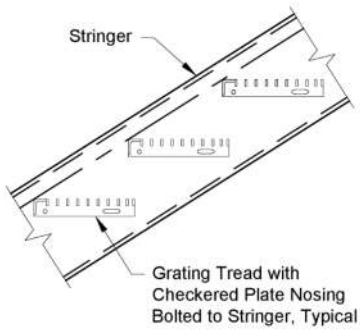
Treads/Risers

- Steel Plate
  - Checkered Plate or Diamond Plate
    - AISC Manual Table 3-18a provides recommended maximum uniform load based on span for a deflection limit of L/100
    - AISC Manual Table 3-18b provides recommended maximum uniform load based on span and stress limit of 24 ksi in LRFD and 16 ksi in ASD.
      - Based on ASTM A786 Standard Specification for Steel Floor Plates typically used for checkered/diamond plate applications.
    - Verify section properties and material properties with supplier.
  - Flat plate or stiffened plate

93

Treads/Risers

- Steel Grating
  - Good for wet environments, outdoors, industrial
  - Typically a purchased "buy out" item
    - Confirm with manufacturer for strength & serviceability
  - Verify if ADA requirements must be met (opening sizes in grating)
- Non-steel Options
  - Precast concrete, glass, plastic, wood, fiberglass.
  - Consider if special deflection criteria should be used



94

Stringer

Stringer Type	Advantages	Disadvantages
Channel (C or MC)	• Variety of sizes, weights, and depths that are widely available • Flange can be used to support guard posts • End connections can use typical bolted simple shear connections	• Wider than plate and some HSS members
Plate	• Readily available • Narrower than other alternatives • End connections can use typical bolted simple shear connections	• Lower flexural strength than other options compared to member weight • Lower member strength for lateral loading
Rectangular HSS	• Variety of sizes, weights, and depths that are widely available • Flange can be used to support guardrail posts	• Additional fabrication required at joints and connections • More difficult end connections than other options • Typically heavier weight per foot than other options

95

Landings

- Cast-in-place concrete over metal deck
- Cast-in-place concrete over metal plate or stiffened metal plate
- Checkered plate flooring
- Steel grating
- Precast concrete

96

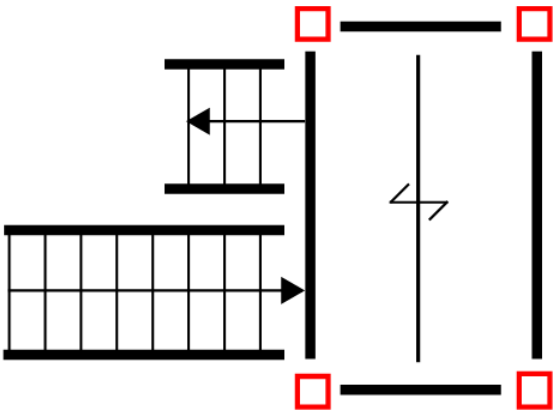
Landings

- Support Conditions
  - Building Supports
  - Post Supported Landing
  - Hanger Supported Landing
  - Integrated Landing
  - Separate Stair Flights

97

Landings

- Support Conditions
  - Building Supports
  - Post Supported Landing
  - Hanger Supported Landing
  - Integrated Landing
  - Separate Stair Flights



98

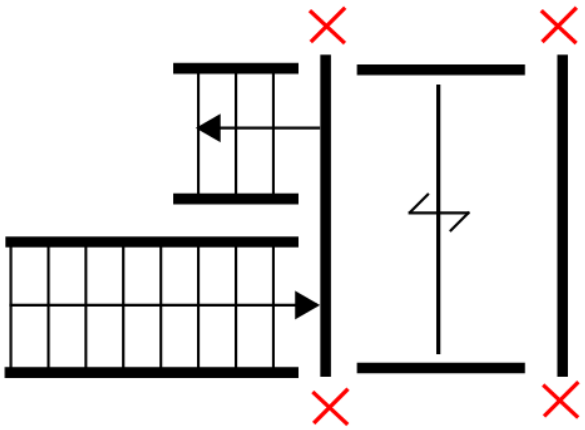
Landings

- Support Conditions
  - Building Supports
  - Post Supported Landing
  - Hanger Supported Landing
  - Integrated Landing
  - Separate Stair Flights

99

Landings

- Support Conditions
  - Building Supports
  - Post Supported Landing
  - Hanger Supported Landing
  - Integrated Landing
  - Separate Stair Flights



100

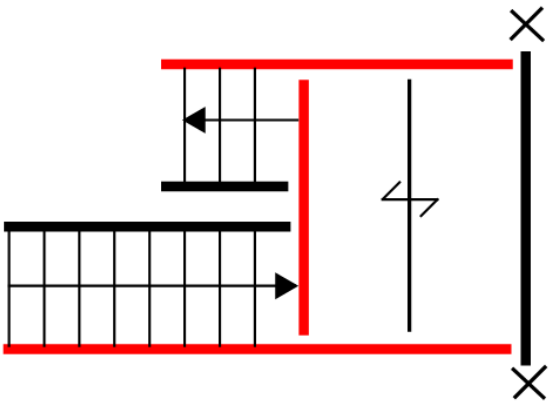
Landings

- Support Conditions
  - Building Supports
  - Post Supported Landing
  - Hanger Supported Landing
  - Integrated Landing
  - Separate Stair Flights

101

Landings

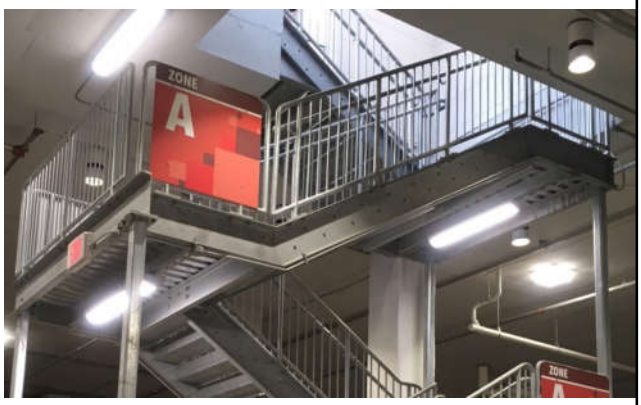
- Support Conditions
  - Building Supports
  - Post Supported Landing
  - Hanger Supported Landing
  - Integrated Landing
  - Separate Stair Flights



102

Landings

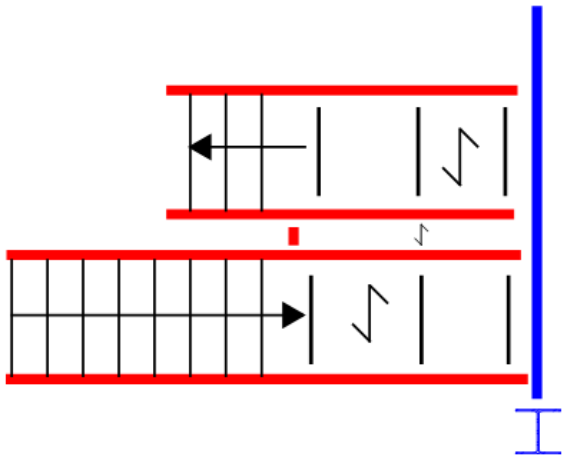
- Support Conditions
  - Building Supports
  - Post Supported Landing
  - Hanger Supported Landing
  - Integrated Landing
  - Separate Stair Flights



103

Landings

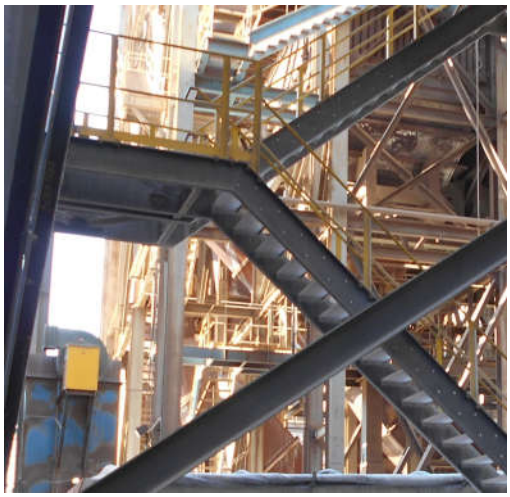
- Support Conditions
  - Building Supports
  - Post Supported Landing
  - Hanger Supported Landing
  - Integrated Landing
  - Separate Stair Flights



104

Landings

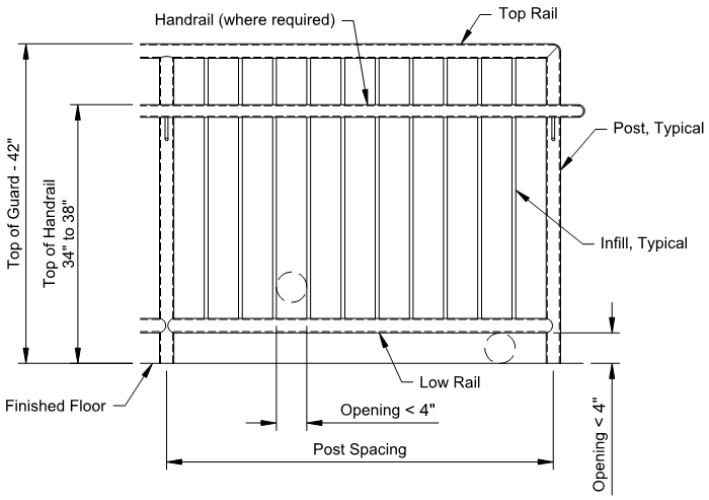
- Support Conditions
  - Building Supports
  - Post Supported Landing
  - Hanger Supported Landing
  - Integrated Landing
  - Separate Stair Flights



105

Guard & Handrail

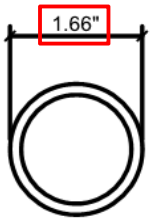
- Member Types
  - Pipe
  - HSS Round
  - Rectangular HSS
  - Angle
  - Plate, Bar, & Rod



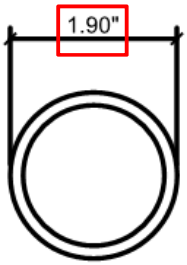
106

Guard & Handrail

- Member Types
  - Pipe A53 Gr. B
  - HSS Round
  - Rectangular HSS
  - Angle
  - Plate, Bar, & Rod



ASTM A53 GR B
PIPE 1 1/4“



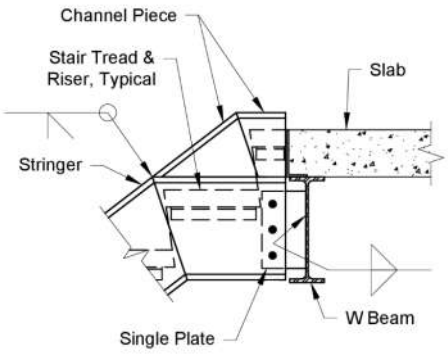
ASTM A53 GR B
PIPE 1 1/2“

- Consider using HSS Round A500 Gr B/Gr C
  - Discuss cost and availability with fabricator

107

Connections

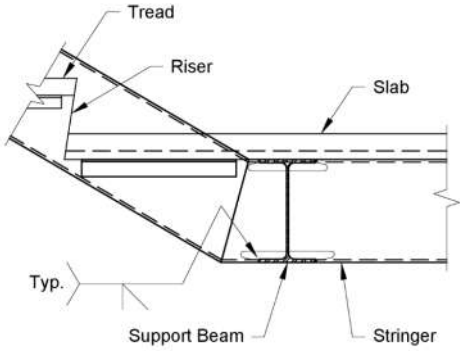
- General
  - AISC *Manual* Part 7 Bolts
  - AISC *Manual* Part 8 Welds
  - AISC *Manual* Part 9 Connecting Elements
  - AISC *Specification*
  - AISC *Design Examples (available at aisc.org)*
  - DG24 – Hollow Structural Section Connections
- Shear
  - AISC *Manual* Part 10



108

Connections

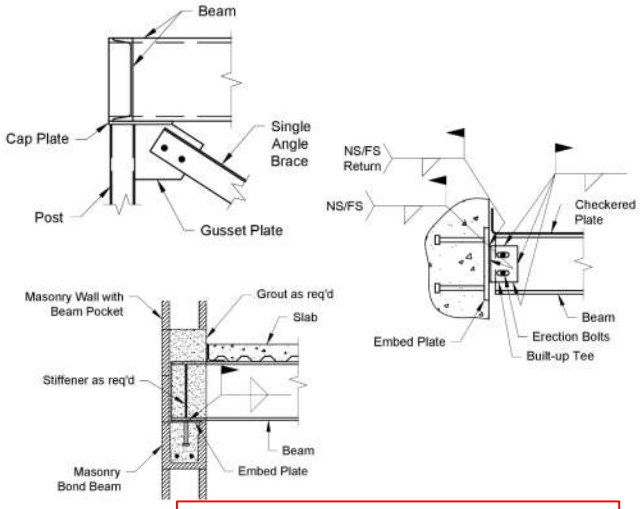
- Shear & Axial
  - Follow AISC *Specification* & *Design Examples* *(available at aisc.org)*
- Moment
  - AISC *Manual* Part 11
  - AISC *Manual* Part 12
  - DG4 – Extended End-Plate Moment Connections
  - DG16 – Flush & Extended Multiple-Row Moment End-Plate Connx



109

Connections

- Bracing
  - AISC *Manual* Part 13
  - DG29 – Vertical Bracing Connections-Analysis and Design
- Embedded Plates
- Post Installed Anchors
- Beam Pockets

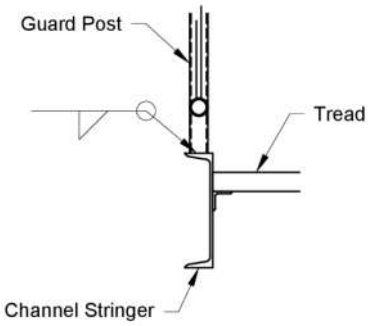


Consider tolerances when connecting to concrete/masonry

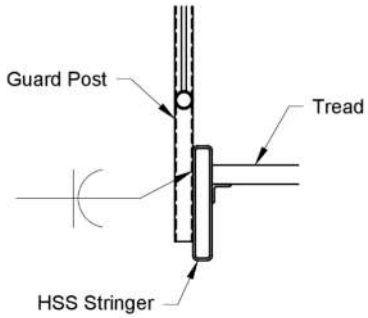
110

Guard Post Connx

- Imparts torsion, shear, axial loads on stringer



Channel Stringer



HSS Stringer

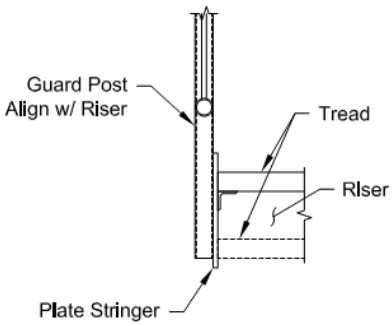
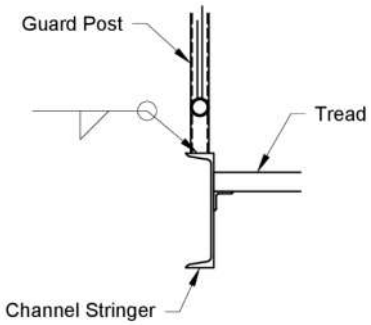


Plate Stringer

111

Guard Post Connx

- Consider fit-up of post to stringer



Channel Stringer

Engineering doesn't work…
Doesn't look great…

112

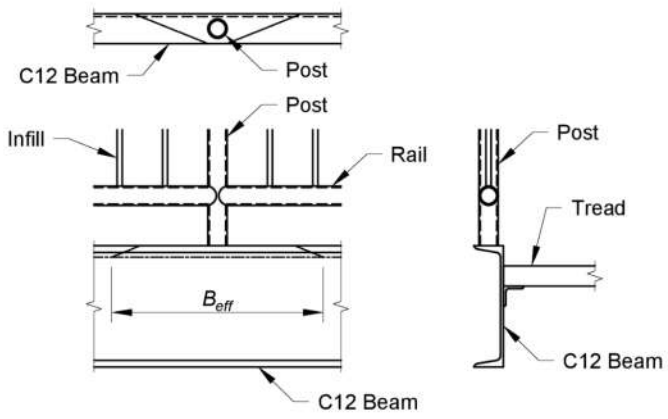
Guard Post Connx

- Channel Stringer
  - Determine strength of channel flange

$$B_{eff} = N + 2(2.5)\left[\left(k - \frac{t_f}{2}\right) + b_f\right]$$

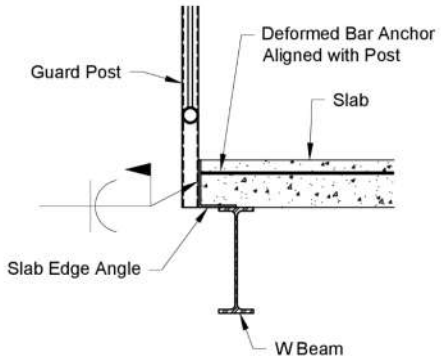
where
k = beam fillet dimension
t_f = flange thickness
b_f = flange width
N = guard post diameter

$$Z = \frac{B_{eff} t_w^2}{4} \qquad S = \frac{B_{eff} t_w^2}{6}$$

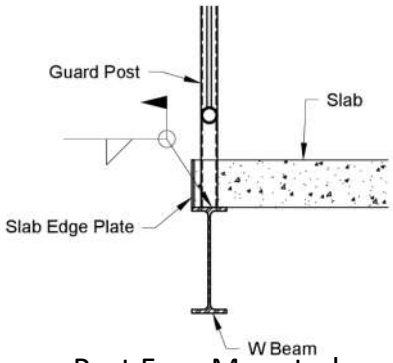


Guard Post Connx

- Imparts torsion, shear, axial loads on support member



Post Face Mounted to Pour Stop



Post Face Mounted to Beam Flange

Outline – Part 1

Step 1 – Purpose & Design Philosophy

Step 2 – Stairway Overview

Step 3 – Code Requirements - Gravity

Step 4 – Stairway Design

Step 5 – Members & Connx

Step 6 – Examples

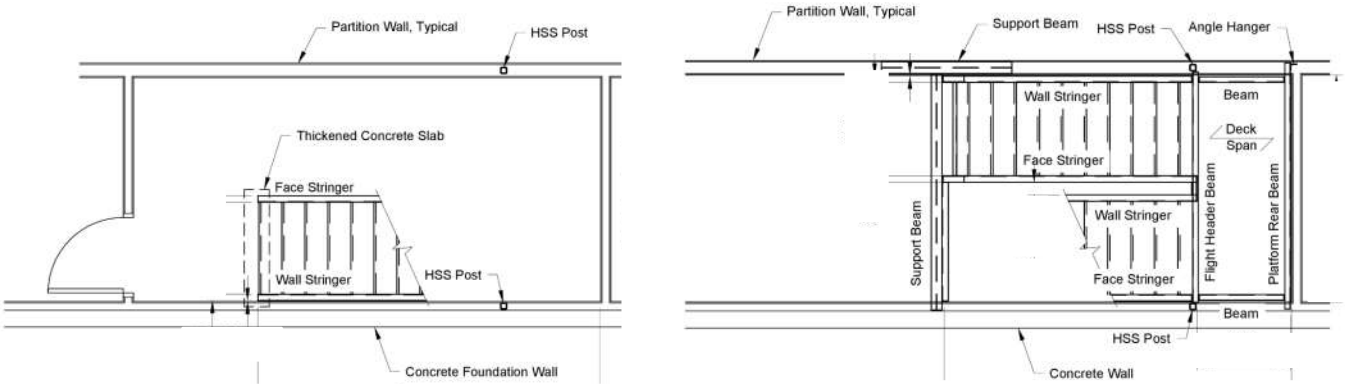
115

Example 1: Opening Size

- Project requires:
  - Egress Stair for Office Building
  - Masonry Core Walls
  - Channel Stringers
  - Provide 6” clear gap between stringers

116

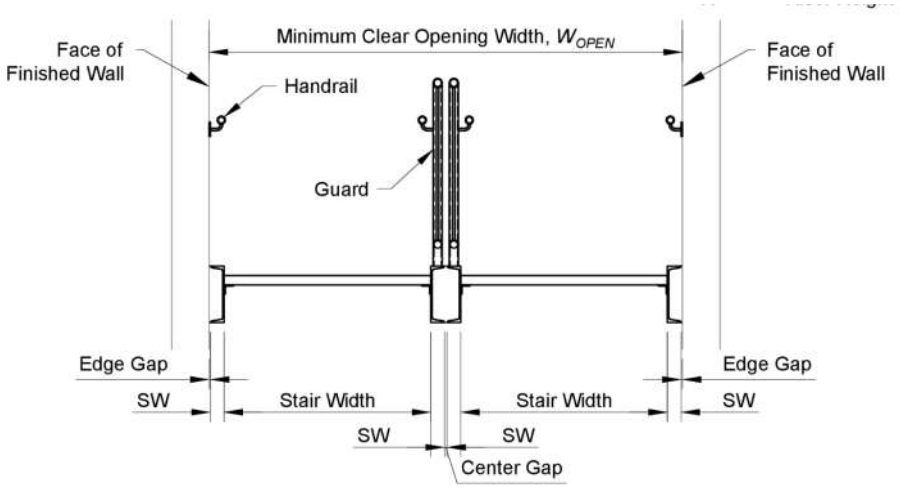
Example 1: Opening Size



Example Stair Layout

117

Example 1: Opening Size - Width



118

Example 1: Opening Size - Width

W_{open} = 2(Edge Gap) + 4(Stringer Width) + 2(Egress Width) + 1(Center Gap)

- Edge Gap = 1/2“
- Stringer Width = 3” (C12x20.7)
- Egress Width = 44”
- Center Gap = 6”

119

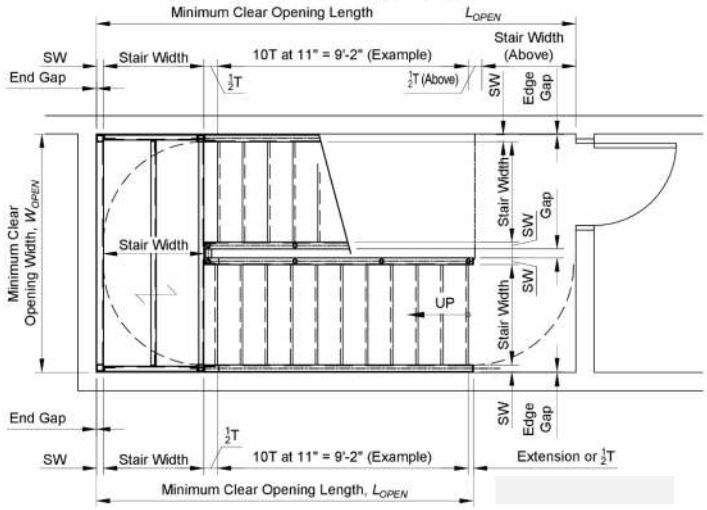
Example 1: Opening Size - Width

W_{open} = 2(1/2”) + 4(3”) + 2(44”) + 1(6”)

W_{open} = 107” = **8’-11”** clear dimension

120

Example 1: Opening Size - Length

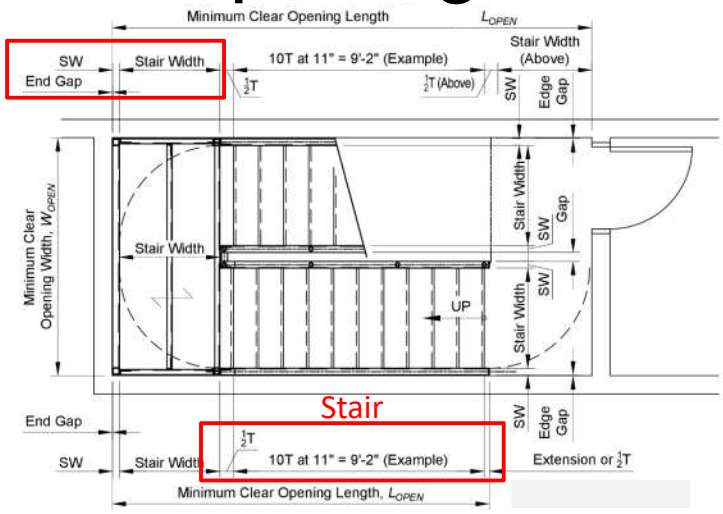


Generic Layout

121

Example 1: Opening Size - Length

Landing



Generic Layout

122

Example 1: Opening Size - Length

$L_{open} = L_{stair} + L_{landing}$

$L_{stair} = N_{tread}$(Tread Length) + (Connection Allowance)

$L_{landing} = N_{landing}$[(Stringer Width) + (Egress Width) + (End Gap)]

123

Example 1: Opening Size - Length

$L_{stair} = N_{tread}$(Tread Length) + (Connection Allowance)

N = 10

Tread Length = 11”

Allowance = 6”

124

Example 1: Opening Size - Length

$L_{landing} = N_{landing}[(\text{Stringer Width}) + (\text{Egress Width}) + (\text{End Gap})]$

N = 1 landing

Stringer Width = 3”

Egress Width = 44”

End Gap = 1/2"

125

Example 1: Opening Size - Length

$L_{open} = L_{stair} + L_{landing}$

$L_{stair} = 10(11”) + (6”) = 116”$

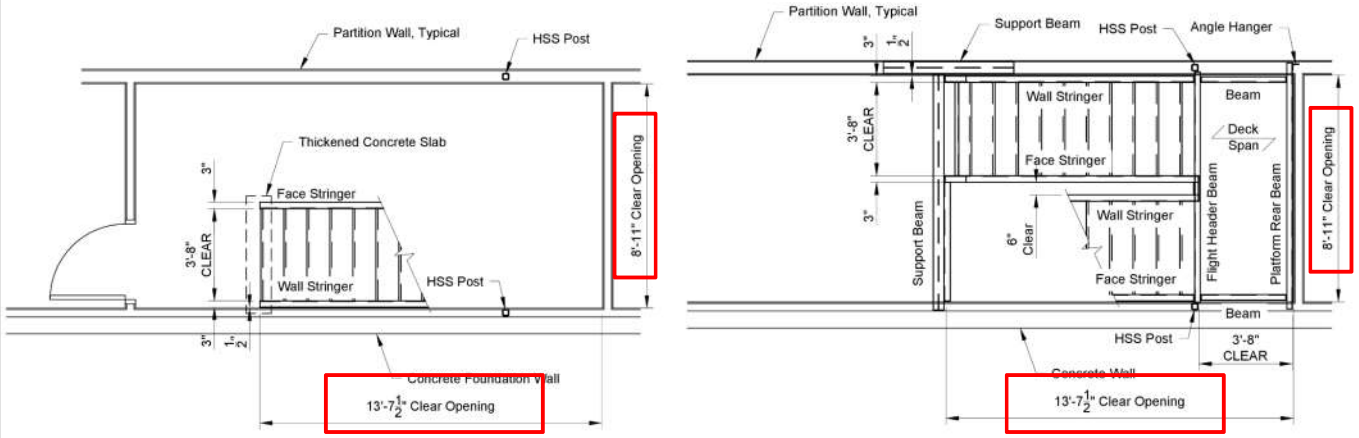
$L_{landing} = 1[(3”) + (44”) + (1/2”)] = 47.5”$

$L_{open} = L_{stair} + L_{landing} = 116” + 47.5” = 163.5” = \mathbf{13’\text{-}7\ ½”}$

126

Example 1: Opening Size

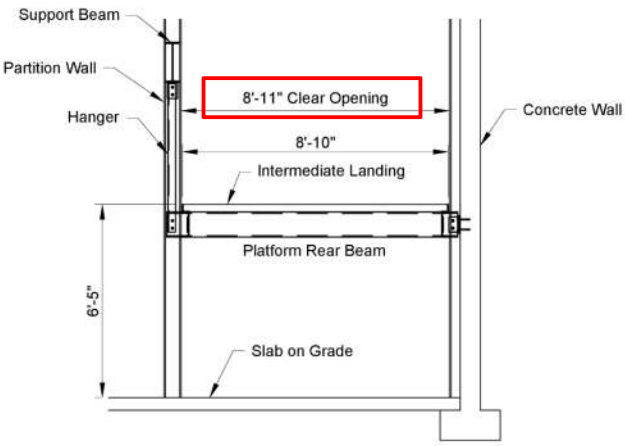
Provide 8’-11” x 13’-7 ½” Opening



127

Example 1: Opening Size

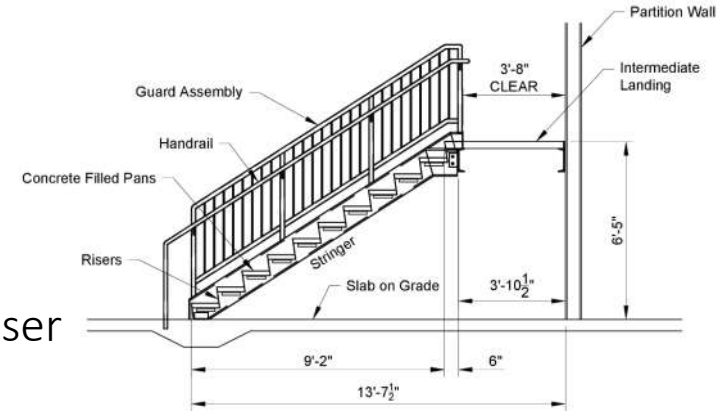
Provide 8’-11” x 13’-7 ½” Opening



128

Example 2: Stringer Design

- Design low stringer
- 44” Wide Stair
- Span = 9’-8”
- Try C12x20.7
  - Fully braced by tread/riser
- LC = D+L or 1.2D+1.6L



Example 2: Stringer Design

- Imposed Loading

Dead Load:

Stringer Self weight			
Guard Self weight			
12 ga treads/risers with 2” concrete fill	=	30	psf
Superimposed MEP loads	=	5	psf
Total	=	35	psf

Live Load:

Live load	=	100	psf
Total	=	100	psf

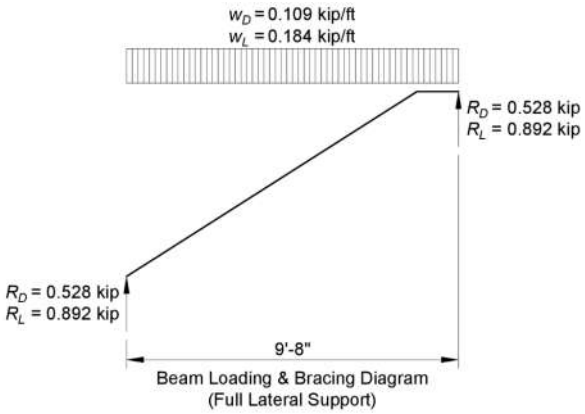
Example 2: Stringer Design

- Stringer Loads

Dead Load:				
Stringer Self weight (20.7 lb/ft X 1.185 slope factor)		=	24.5	lb/ft
Guard Self weight (20 lb/ft)		=	20	lb/ft
12 ga treads/risers with 2" concrete fill	= 30 psf X 1.84'	=	55.2	lb/ft
Superimposed MEP loads	= 5 psf X 1.84'	=	9.2	lb/ft
Total		=	109	lb/ft
Live Load:				
Live load	= 100 psf X 1.84'	=	184	lb/ft
Total		=	184	lb/ft

131

Example 2: Stringer Design



Beam Loading & Bracing Diagram
(Full Lateral Support)

$$R = V = \frac{wl}{2}$$

$$M_{max} = \frac{wl^2}{8}$$

	ASD	LRFD
w	0.293 k/ft	0.425 k/ft
R	1.42 k	2.05 k
M	3.43 k-ft	4.97 k-ft

132

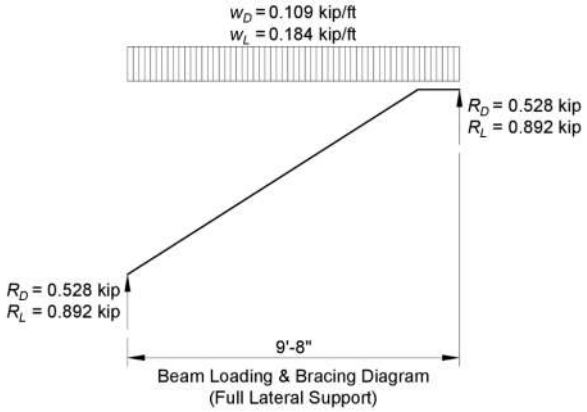
Example 2: Stringer Design

	ASD	LRFD
w	0.293 k/ft	0.425 k/ft
R	1.42 k	2.05 k
M	3.43 k-ft	4.97 k-ft

Refer to Manual Table 3-8
For C12x20.7, $L_b < L_p$
ASD
V_n/Ω_v = 43.8 k > 1.42 k OK
M_p/Ω_b = 46.0 k-ft > 3.43 k-ft OK
LRFD
$\Phi_v V_n$ = 65.8 k > 2.05 k OK
$\Phi_b M_p$ = 69.1 k-ft > 4.97 k-ft OK

C12x20.7 is adequate for imposed loads

Example 2: Stringer Design



Beam Loading & Bracing Diagram
(Full Lateral Support)

Check Deflection:

$$\Delta = \frac{5\,w\ \text{kip/in.}(L\ \text{in.})^4}{384(29{,}000\ \text{ksi})(I\ \text{in.}^4)} = \frac{w\ \text{kip/ft}(L\ \text{ft})^4}{1{,}290(I\ \text{in.}^4)}$$

Live Load:

$$\Delta_{LL\ allowable} = \frac{(9.67\ \text{ft})\left(\frac{12\ \text{in.}}{1\ \text{ft}}\right)}{360} = 0.322\ \text{in.}$$

$$\Delta_{LL} = \frac{0.184\ \text{kip/ft}(9.67\ \text{ft})^4}{1{,}290(129\ \text{in.}^4)} = 0.010\ \text{in.}$$

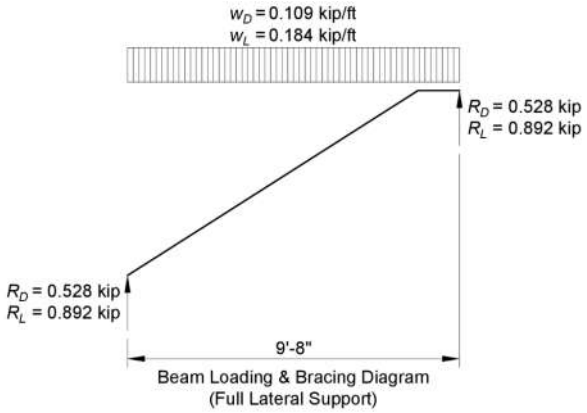
Adjustment factor for sloping length:

$$F_\Delta = \left(\frac{\sqrt{(7\ \text{in.})^2 + (11\ \text{in.})^2}}{11\ \text{in.}}\right)^4 \times \left[\cos\left(\tan^{-1}\left(\frac{7\ \text{in.}}{11\ \text{in.}}\right)\right)\right]^2 = 1.40$$

Adjusted Live Load Deflection:

$$\begin{aligned}\Delta_{LL} &= F_\Delta \Delta \\ &= 1.4(0.0010\ \text{in.}) \\ &= 0.014\ \text{in.} < 0.322\ \text{in.}\end{aligned}$$ OK

Example 2: Stringer Design



Check Deflection:

$$\Delta = \frac{5\,w\ \text{kip/in.}(L\ \text{in.})^4}{384(29{,}000\ \text{ksi})(I\ \text{in.}^4)} = \frac{w\ \text{kip/ft}(L\ \text{ft})^4}{1{,}290(I\ \text{in.}^4)}$$

Total Load:

$$\Delta_{TL\ allowable} = \frac{(9.67\ \text{ft})\left(\frac{12\ \text{in.}}{1\ \text{ft}}\right)}{240} = 0.484\ \text{in.}$$

$$\Delta_{TL} = \frac{0.293\ \text{kip/ft}(9.67\ \text{ft})^4}{1{,}290(129\ \text{in.}^4)} = 0.015\ \text{in.}$$

Adjustment factor for sloping length:

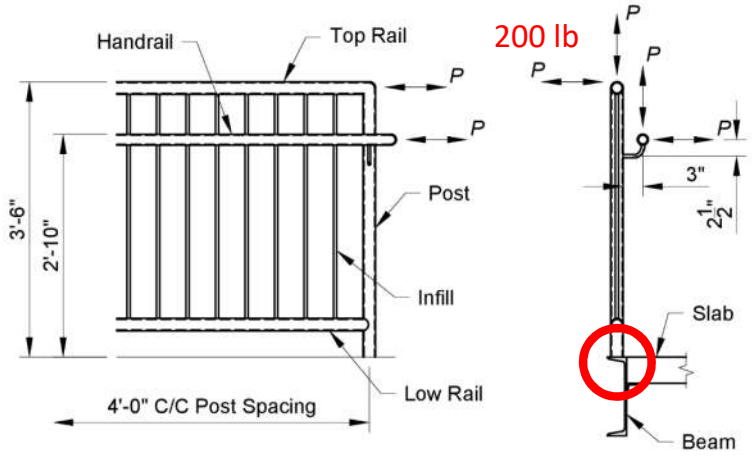
$$F_\Delta = \left(\frac{\sqrt{(7\ \text{in.})^2 + (11\ \text{in.})^2}}{11\ \text{in.}}\right)^4 \times \left[\cos\left(\tan^{-1}\left(\frac{7\ \text{in.}}{11\ \text{in.}}\right)\right)\right]^2 = 1.40$$

Adjusted Total Load Deflection:

$$\begin{aligned}\Delta_{TL} &= F_\Delta \Delta \\ &= 1.4(0.015\ \text{in.}) \\ &= 0.021\ \text{in.} < 0.484\ \text{in.}\end{aligned}$$ OK

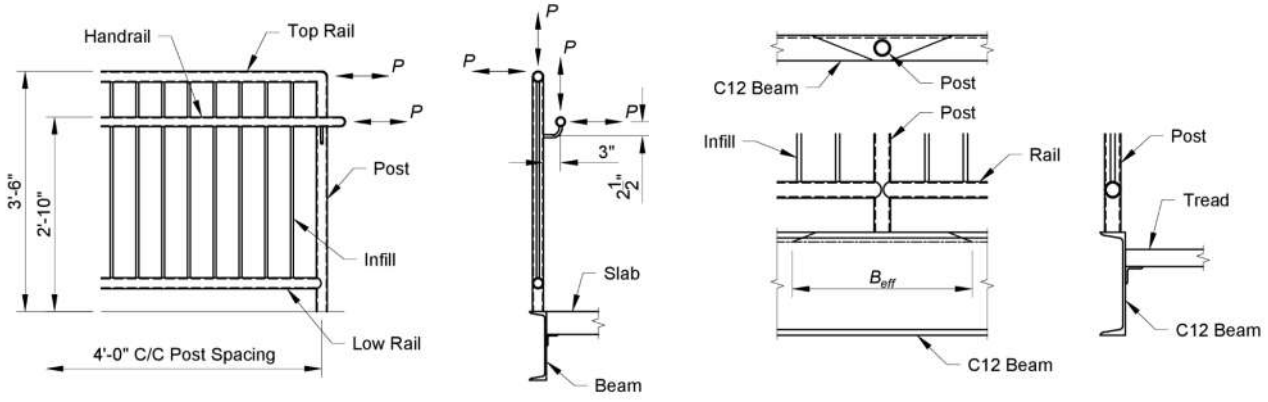
135

Example 3: Guard Post Connx



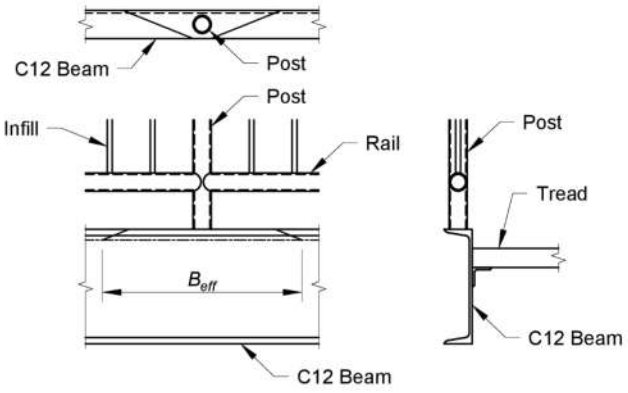
136

Example 3: Guard Post Connx



137

Example 3: Guard Post Connx

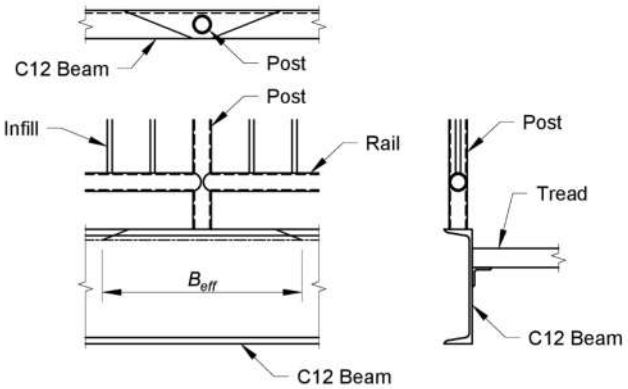


Guard Post
ASTM A500 Gr. C Round
F_y = 46 ksi
F_u = 62 ksi

Channel
ASTM A36
F_y = 36 ksi
F_u = 58 ksi

138

Example 3: Guard Post Connx

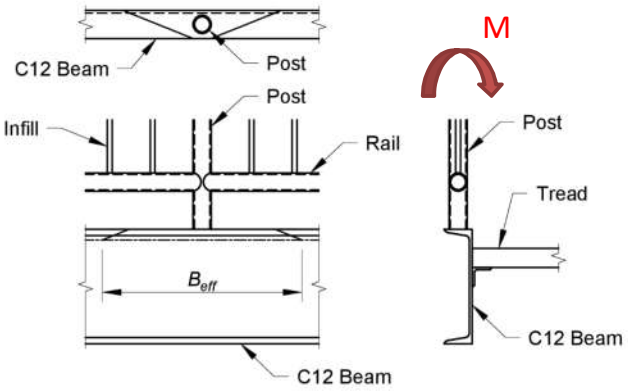


From AISC *Manual* Table 1-13, the geometric properties are as follows:
ASTM A500 Gr. C HSS1.90x0.145
Outside diameter = 1.90 in.

From AISC *Manual* Table 1-5, the geometric properties are as follows:
ASTM A36 C12×20.7
k = 1.125 in.
t_f = 0.501 in.
b_f = 2.94 in.
t_w = 0.282 in.

139

Example 3: Guard Post Connx



$$M_{max} = PL$$

	ASD	LRFD
P	0.200 k	0.320 k
L	42”	
M	8.4 k-in	13.4 k-in

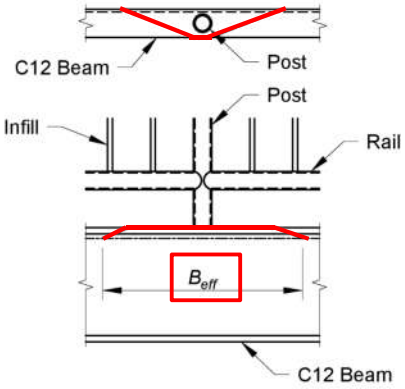
140

Example 3: Guard Post Connx

Determine effective width of channel top flange:

$$B_{eff} = N + 2(2.5)\left[\left(k - \frac{t_f}{2}\right) + b_f\right]$$

$$B_{eff} = 1.90 \text{ in.} + 2(2.5)\left[\left(1.125 \text{ in.} - \frac{0.501 \text{ in.}}{2}\right) + 2.94 \text{ in.}\right] = 20.97 \text{ in.}$$



Determine section modulus of effective web:

$$Z = \frac{B_{eff} t_w^2}{4} = \frac{20.97 \text{ in.}(0.282 \text{ in.})^2}{4} = 0.417 \text{ in.}^3$$

$$S = \frac{B_{eff} t_w^2}{6} = \frac{20.97 \text{ in.}(0.282 \text{ in.})^2}{6} = 0.278 \text{ in.}^3$$

Example 3: Guard Post Connx

Determine nominal flexural strength of C12 web:

$$\begin{aligned} M_p &= F_y Z \le 1.6 M_y \\ &= F_y Z \le 1.6 F_y S \\ &= 36 \text{ ksi}\left(0.417 \text{ in.}^3\right) \le 1.6(36 \text{ ksi})\left(0.278 \text{ in.}^3\right) \\ &= 15.0 \text{ kip-in.} \le 16.0 \text{ kip-in.} \\ &= 15.0 \text{ kip-in.} \end{aligned}$$

ASD
M_p/Ω_b = 15.0 k-in / 1.67
M_p/Ω_b = 8.98 k-in > 8.4 k-in OK

LRFD
$\Phi_b M_p$ = 0.9(15.0 k-in)
$\Phi_b M_p$ = 13.5 k-in > 13.4 k-in OK

Thank you!

Part 2 will be presented on May 21st

AISC | Questions?

Smarter. Stronger. Steel.

Group Registration

PDH Certificates

- 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!

Smarter. Stronger. Steel.

Group Registration

PDH Certificates

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

Smarter. Stronger. Steel.

Individual Registration

PDH Certificates

One certificate will be issued at the conclusion of the course.

Smarter. Stronger. Steel.

Individual Registration

Attendance and PDH Certificates

- You have two options to receive credit for each session.
    - Option 1: Watch the live session.
    - Option 2: Watch the recording and pass the associated quiz.

Video and Recording Access

- Access is provided within two business days after the live air date.
- Video recordings and quizzes for both sessions are available until 8:00 a.m. ET on June 18 (4 weeks after the completion of the course).

Distribution of Certificates

- All certificates will be issued after the course is completed.
- Only the registrant will receive a certificate for the course.

Smarter. Stronger. Steel.

Individual Registration

Course Resources

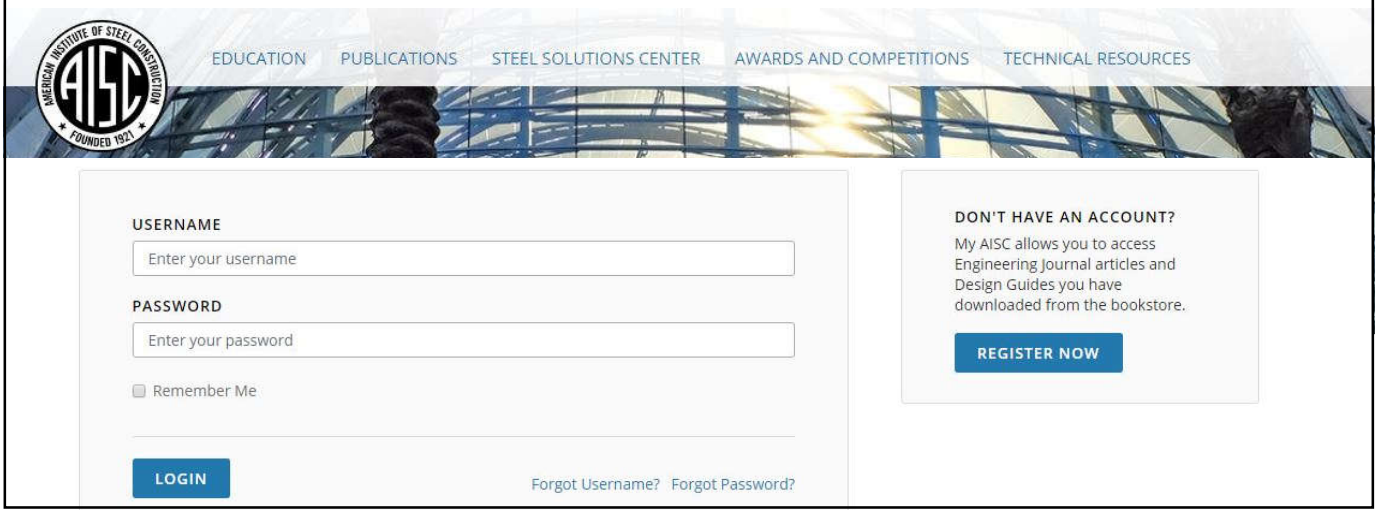
Access to video recordings and quizzes can be found on your AISC account.

Smarter. Stronger. Steel.

Individual Registration

Course Resources

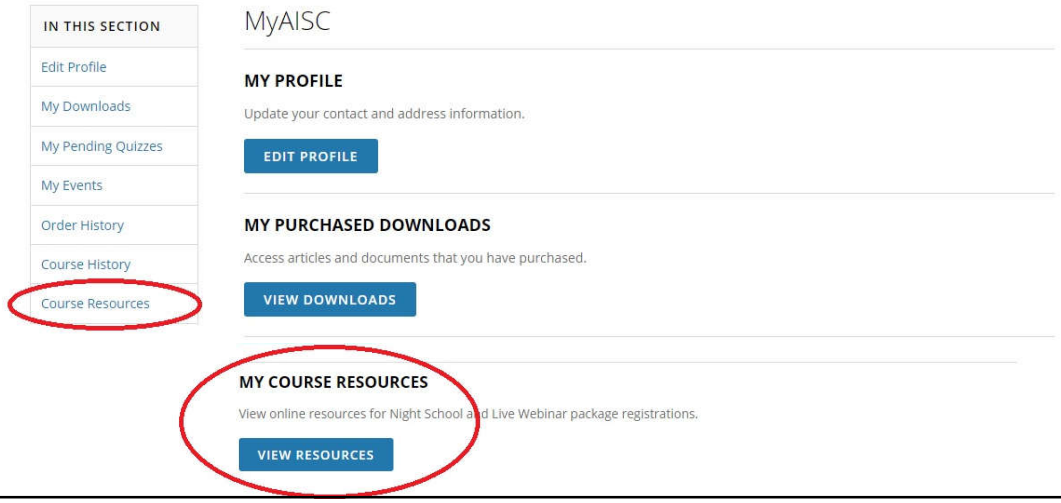
Go to www.aisc.org and sign in.



Individual Registration

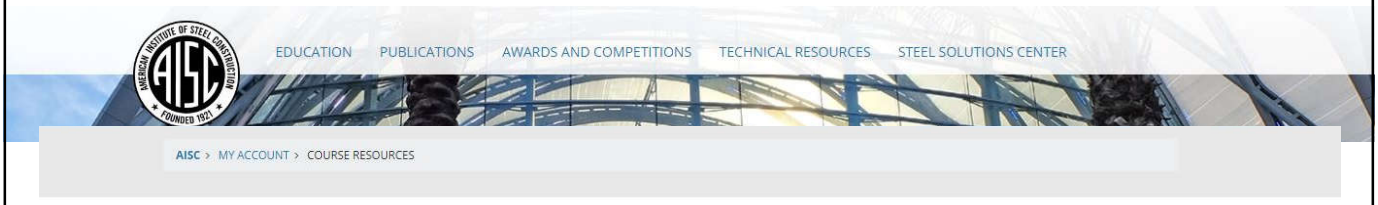
Course Resources

Go to www.aisc.org and sign in.



Individual Registration

Course Resources

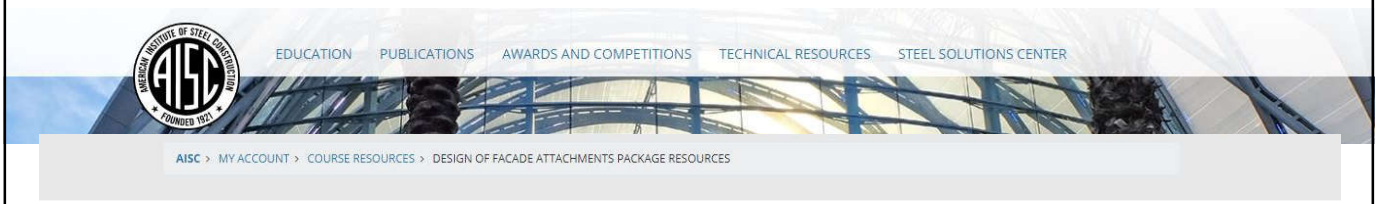


Course Resources

Event	Start Date
Seismic Design in Steel	1/1/1900 12:00:00 AM
4-Session Package-Design of Façade Attachments	5/9/2019 1:30:00 PM
NS 15 8-Session Package-Night School 15 - Fundamentals of Connection Design	10/3/2017 7:00:00 PM
NS 16 8-Session Package-Night School 16 - Seismic Design in Steel	2/5/2018 7:00:00 PM
NS 17 4-Session Package-Night School 17: Design of Façade Attachments	7/16/2018 7:00:00 PM
NS 18 8-Session Package-Night School 18: Steel Construction: Mill To Topping Out	10/15/2018 7:00:00 PM
NS 19 8-Session Package-Night School 19: Connection Design	2/4/2019 7:00:00 PM
NS 20 8-Session Package-Night School 20: Classical Methods of Structural Analysis	6/3/2019 7:00:00 PM
8-Session Package-Seismic Design in Steel - Concepts & Examples	7/16/2018 1:30:00 PM

Individual Registration

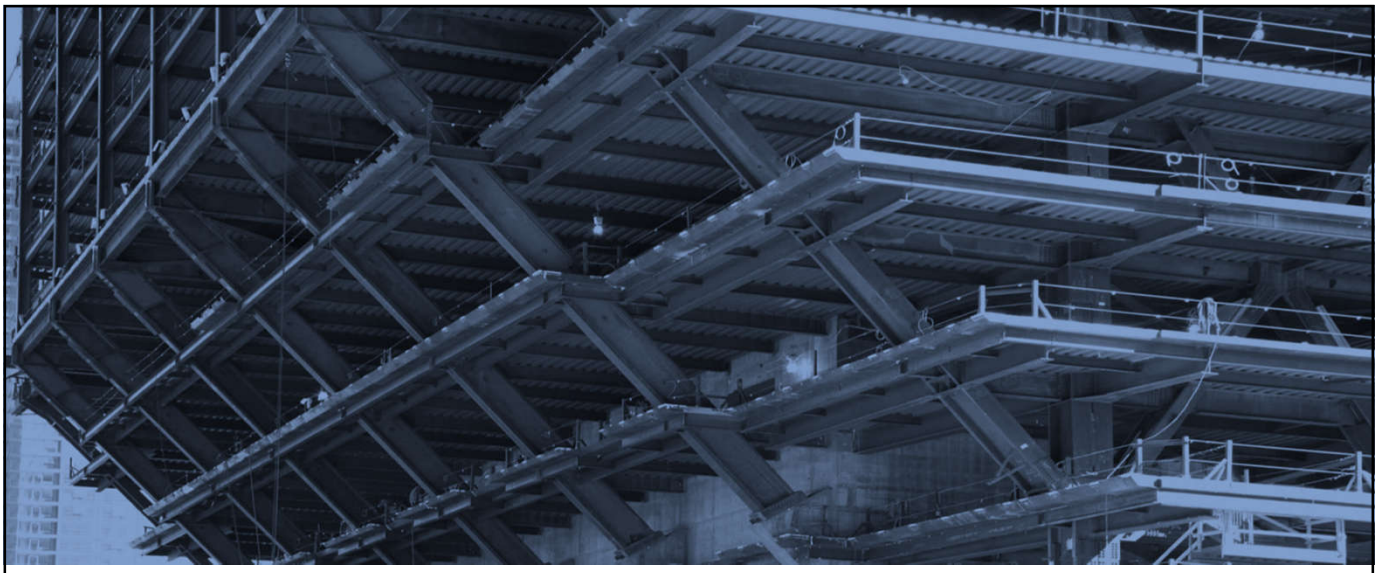
Course Resources



Design of Facade Attachments

4-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
R1: Facade Fundamentals	N/A	Handouts	View Passcode: AZNS175	Pass Score: 100	N/A
L1: Façade Attachments Part 1	May 9 2019 1:30PM EDT	Handouts	Available 05/11/2019 5:00PM EDT	Available 05/11/2019 5:00 PM EDT	Pending
L2: Façade Attachments Part 2	May 16 2019 1:30PM EDT	Handouts	Available 05/18/2019 5:00PM EDT	Available 05/18/2019 5:00 PM EDT	Pending
L3: Façade Attachments - Building Lateral Drifts	May 23 2019 1:30PM EDT	Handouts	Available 05/25/2019 5:00PM EDT	Available 05/25/2019 5:00 PM EDT	Pending
Final Exam	N/A			Available 5/27/2019 5:00 PM EDT	



AISC | Thank you

Smarter.
Stronger.
Steel.