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Course Description

Steel Framed Stairway Design

Part 1: Overview & Gravity Loading

May 30, 2018

This session 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.

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.

There's always a solution in steel.

Steel Framed Stairway Design

Presented by
Adam Friedman
CSD Structural Engineers
Milwaukee, WI

CSD STRUCTURAL ENGINEERS
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structural STEEL

Introduction

AISC Design Guide 34: Steel Framed Stairway Design

to be published late summer / fall

will be available at
www.aisc.org/designguides
free download for members or
available for purchase
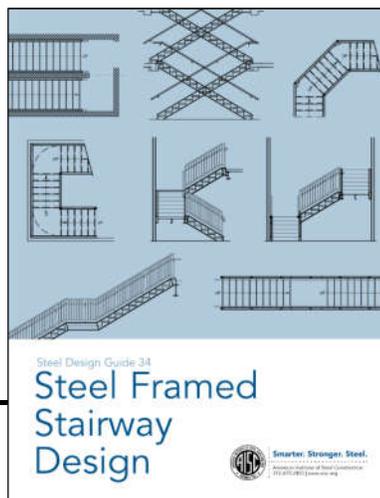
Steel Design Guide 34
Steel Framed Stairway Design

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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

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Outline – Part 2

Step 7 – Code Requirements – Seismic Loading

Step 8 – Seismic Serviceability

Step 9 – Stairway Design

Step 10 – Examples

Step 11 –   Delegated Design

Step 12 – Other Topics

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Outline – Part 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

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Purpose for Design Guide

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

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Design Philosophy

- Follow code & NAAMM *Stair Manual* & *Railing Manual*:
  - General Stair & Rail Layout
  - Construction Details (various materials)
  - Design Criteria may be out of date
- For steel stairs, the new Design Guide provides specific layout, details, design methods, and recommendations related to stairways, handrails, and guards fabricated from steel.
  - Provides the most up-to-date guidance for steel stair design

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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 considered 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)*

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Design Philosophy

- Use AISC documents in conjunction with design documents for steel stair design but confirm with:
  - Architect of Record (AOR)
  - Structural Engineer of Record (SER)
  - Authority Having Jurisdiction (AHJ)
  - General Contractor (GC)

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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

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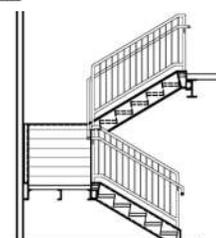# Stair Types (NAAMM)

- Straight
  - **Straight**
  - Parallel (Switchback)
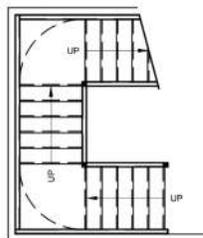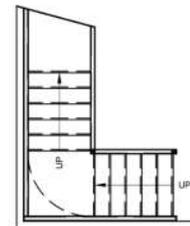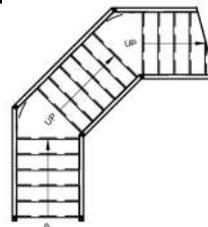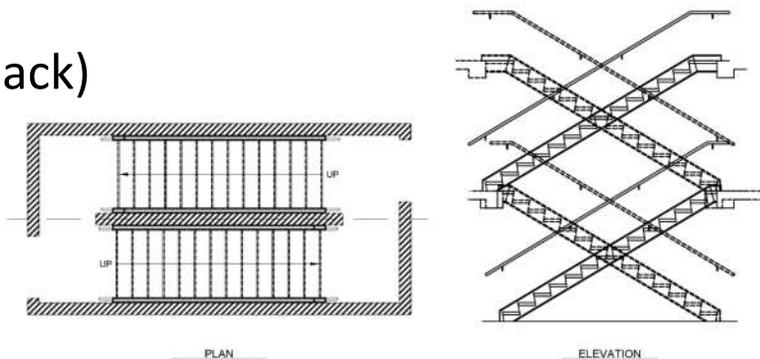 - Angled
  - Scissor
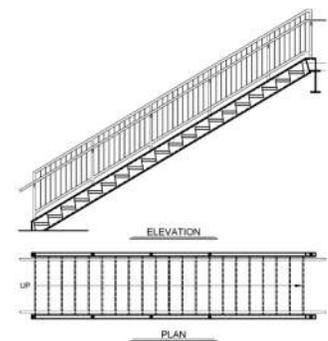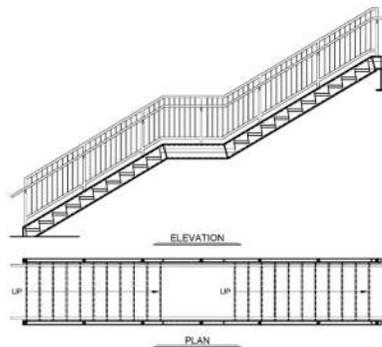
18

Stair Types

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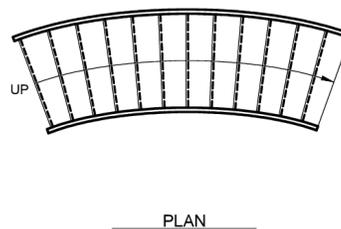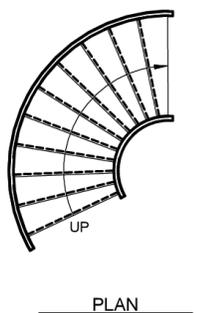 - **Parallel (Switchback)**
  - Angled
  - Scissor

PLAN

ELEVATION

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Stair Types

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

PLAN

PLAN

PLAN

ELEVATION

ELEVATION

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Stair Types

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

PLAN   ELEVATION
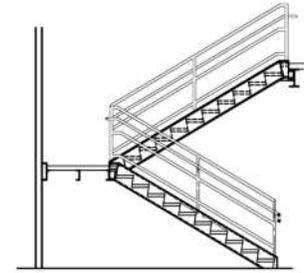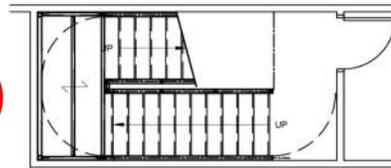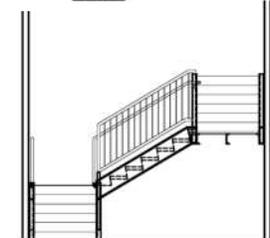
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Stair Types

- Circular

UP

PLAN

- Curved

UP

PLAN

22

Stair Types

- Alternating Tread Device

SIDE VEIW   ELEVATION

- Ships Ladder

ELEVATION

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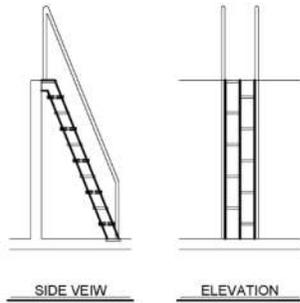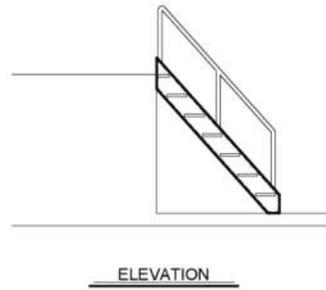
Stair Class (NAAMM)

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

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Stair Class - Industrial
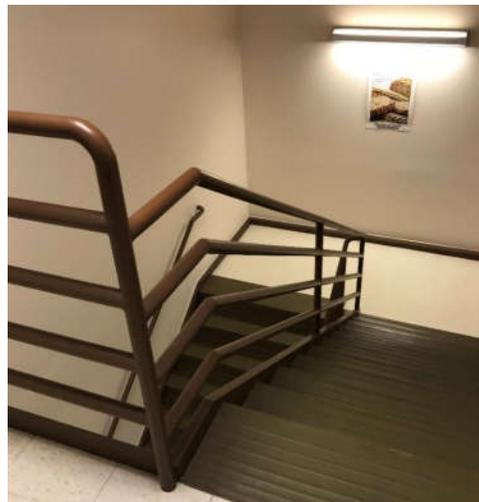

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Stair Class - Industrial
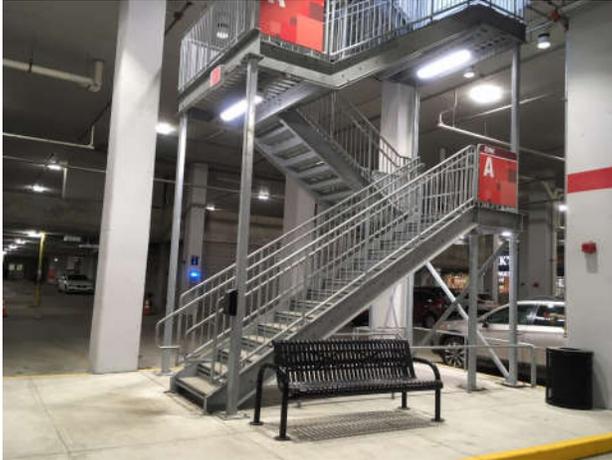

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Stair Class - Industrial

Stair Class

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

Stair Class - Service

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Stair Class

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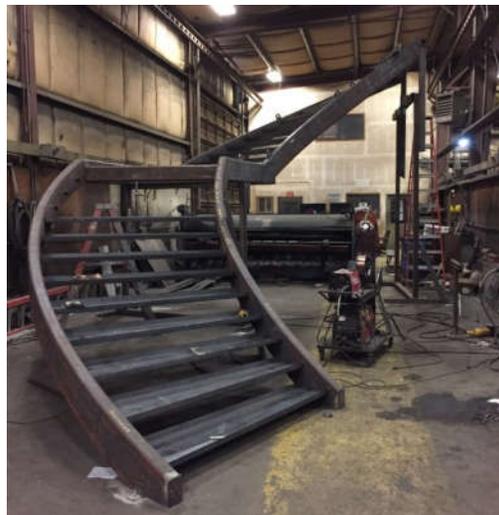 - more attractive
- Architectural

30

Stair Class - Commercial

Stair Class

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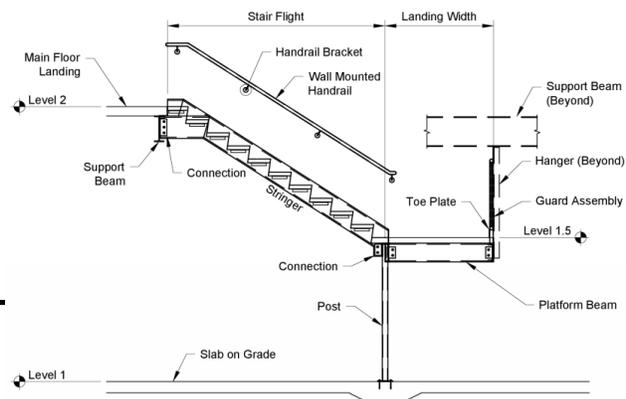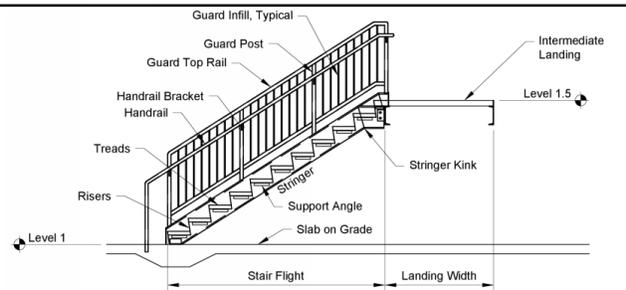   - elaborate
    - custom
    - most expensive

Stair Class - Architectural

Winters, Fladten, Discovery

33

Stairway Elements

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

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Stairway Elements

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

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Stairway Elements

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

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Stairway Elements

- Typical Tread / Riser Ass

"IBC" / Commercial

"OSHA" / Industrial

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Stairway Elements

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

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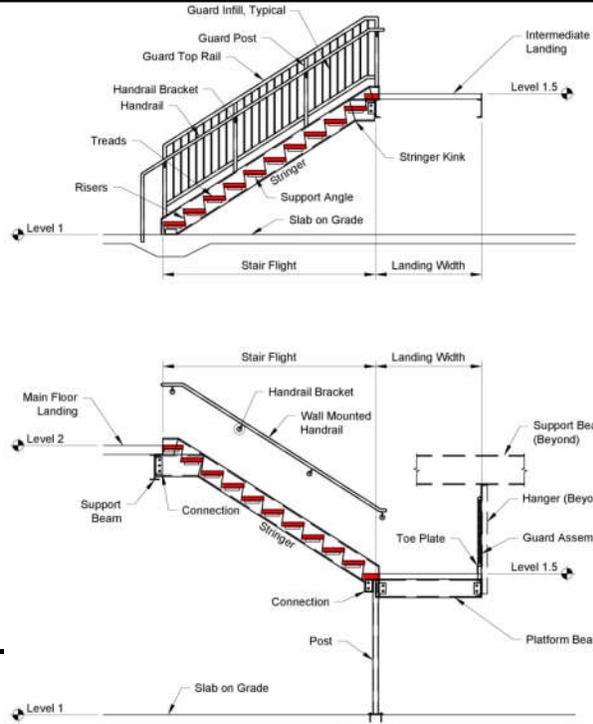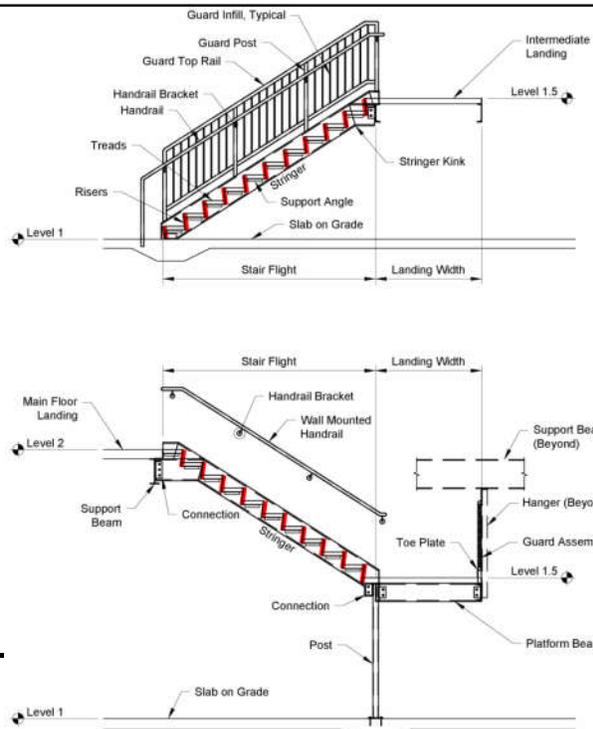American Institute of Steel Construction

Stairway Elements

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

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Stairway Elements

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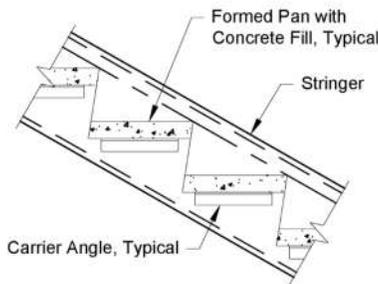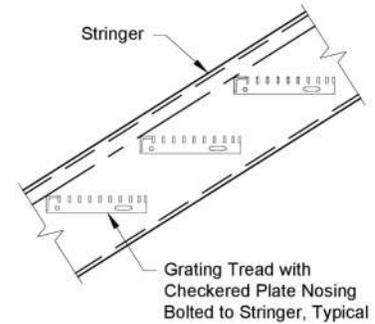- Guard
- Supports
- Connections

40

Stairway Elements

- Tread
- Riser
- Stringer
- Landing
- Handrail
- **Guard / "Stair Rail System"**
- Supports
- Connections

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Stairway Elements

Guard

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

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Stairway Elements

Guard

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

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Stairway Elements

Guard

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

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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

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Stairway Elements

Guard
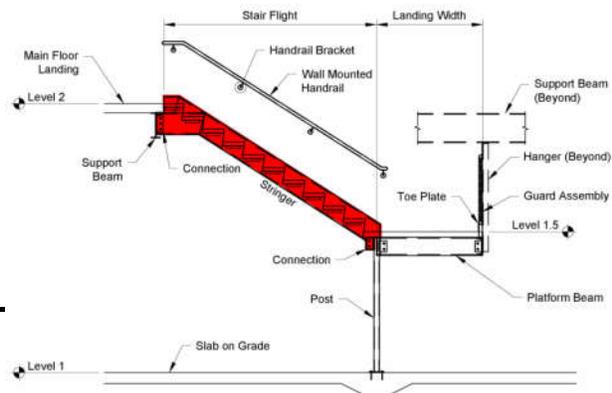
- Post
- Top Rail
- Low Rail
- Infill
- Toe Kick / Toeboard
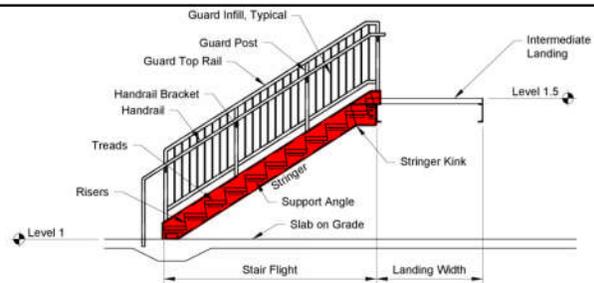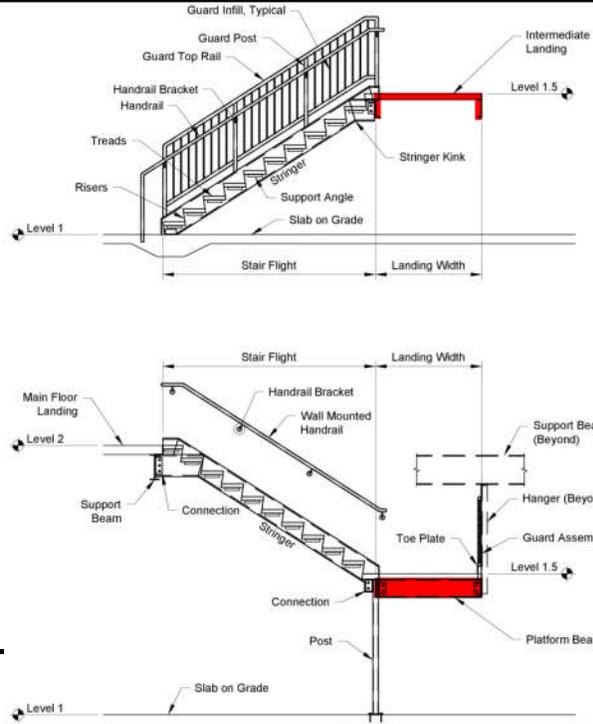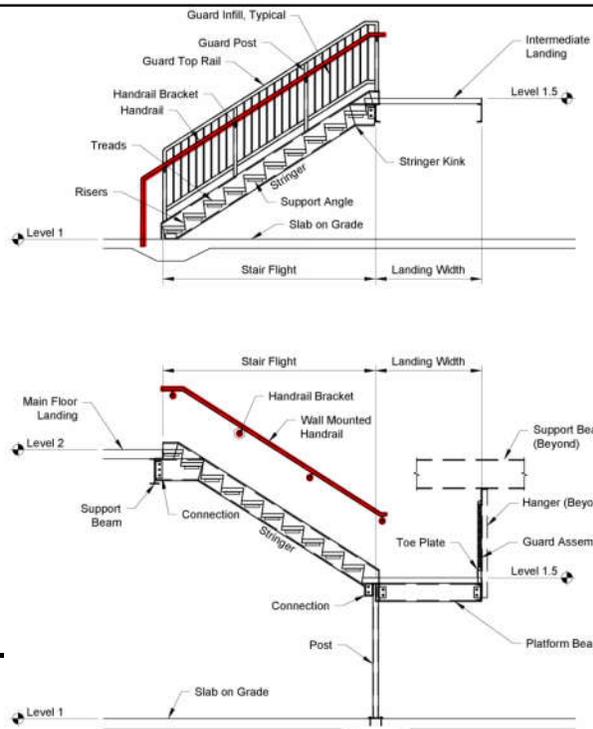
47

Stairway Elements

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

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Stairway Elements

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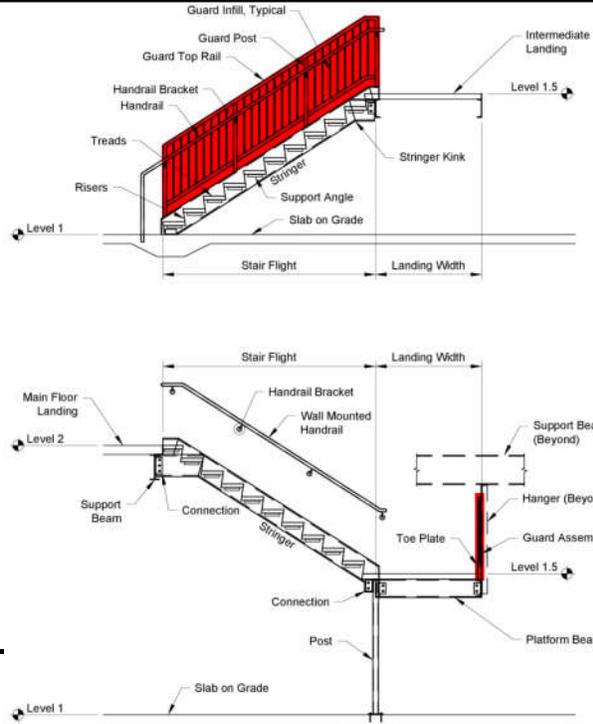- Landing
- Handrail
- Guard
- Supports
- **Connections**

49
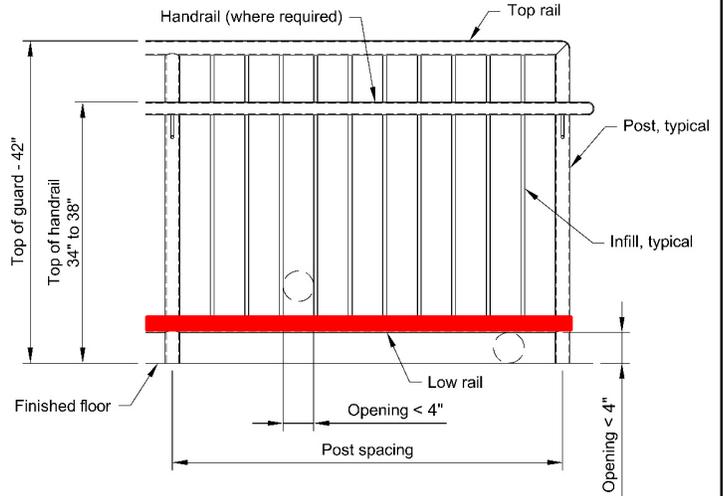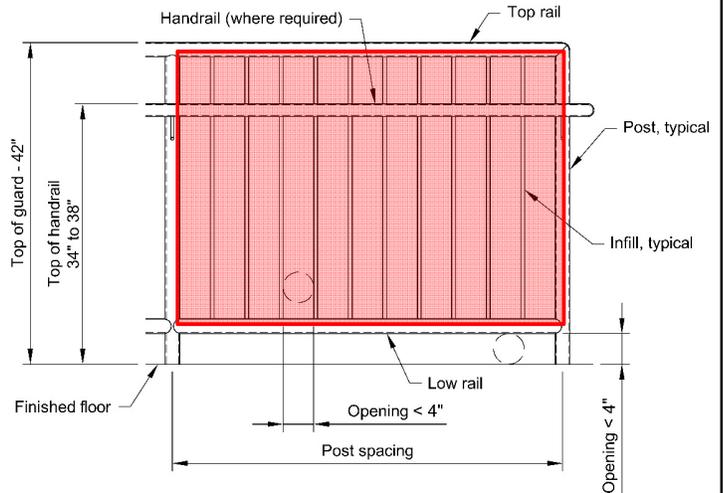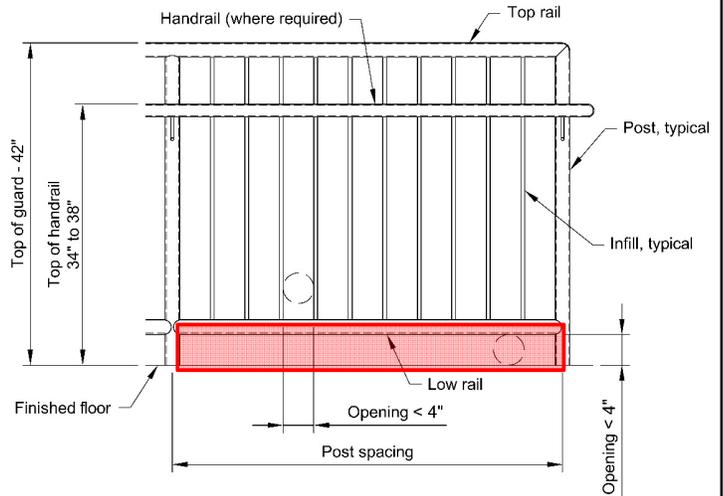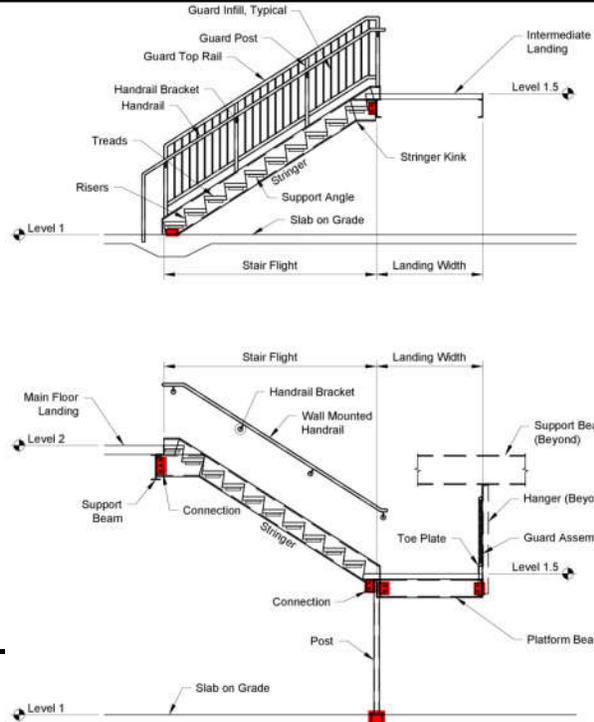
Stairway Layout – IBC or OSHA?

- 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

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Stairway Layout – IBC or OSHA?

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

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Stairway Layout - IBC

Plan

Elevation

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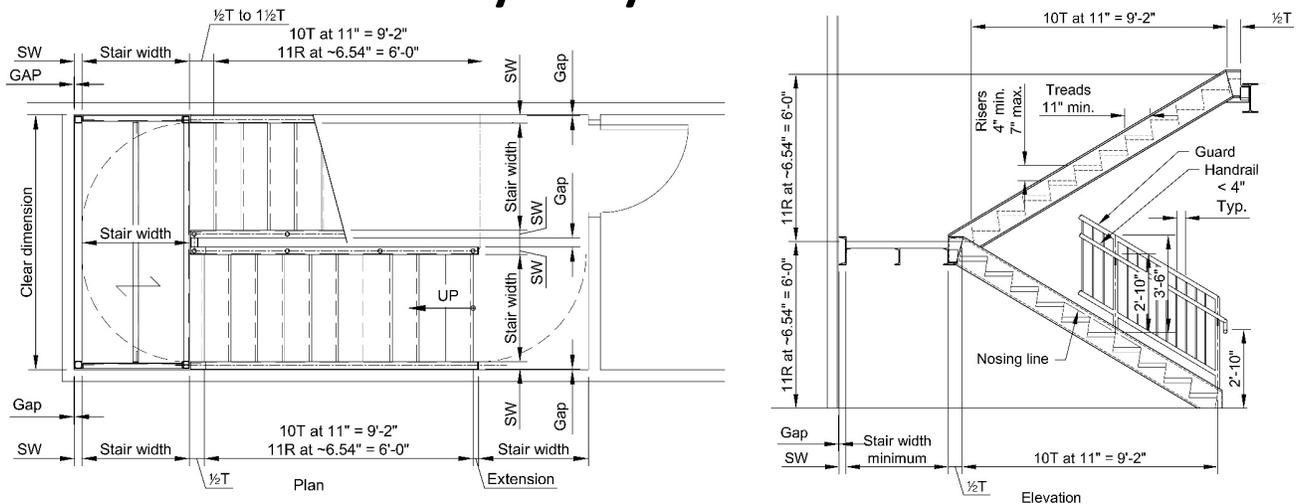
Stairway Layout – IBC: Riser Height

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Stairway Layout – IBC: Egress Width

Section at Stairway

Section at Landing

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Stairway Layout – IBC: Egress Width

Egress width with handrail projections per section 1014.8

Design Guide recommended egress width when space exists

Section at Stairway

Section at Landing

55
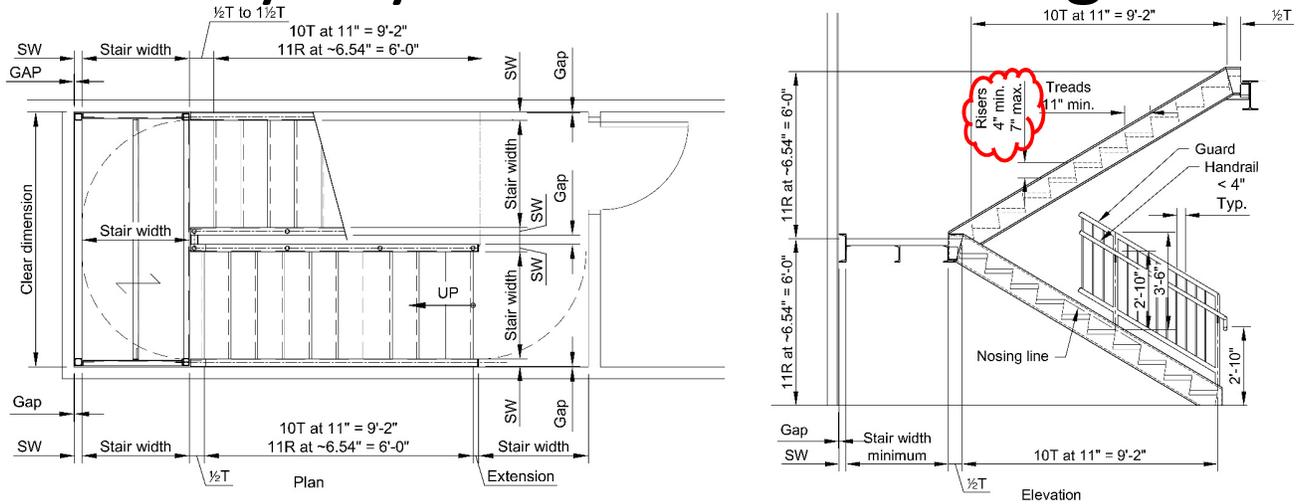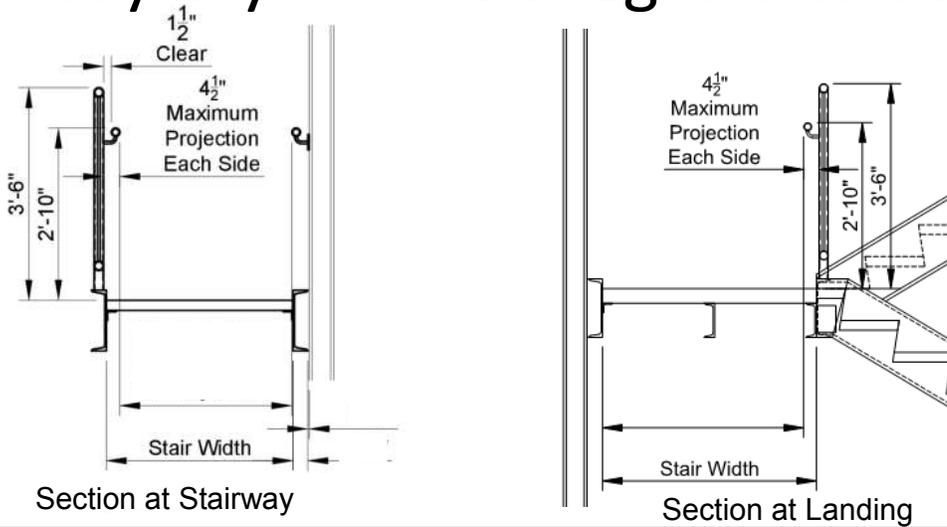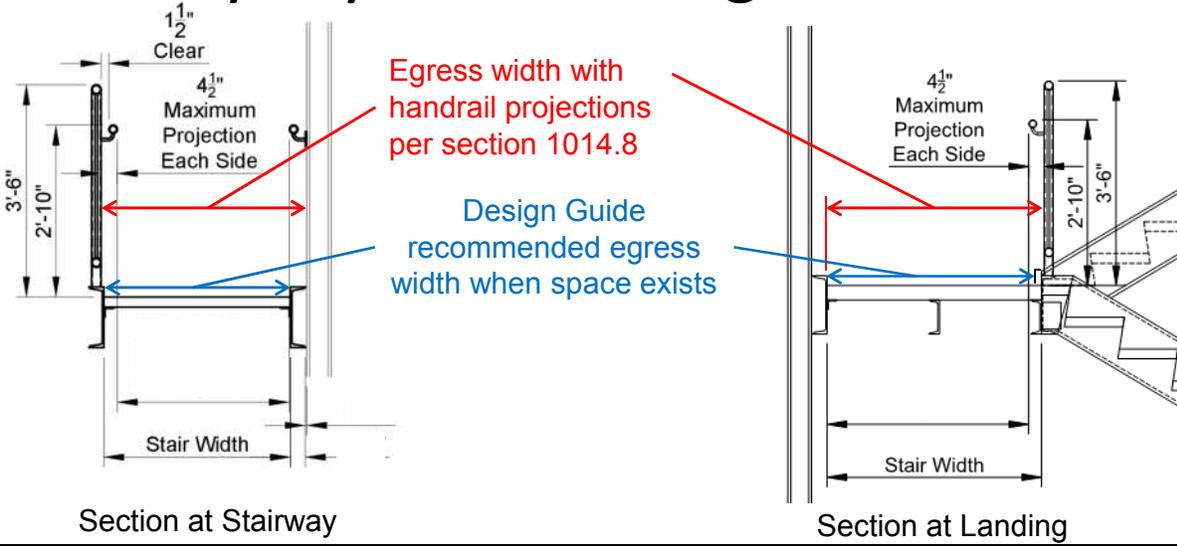
Stairway Layout – IBC: Guard

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Stairway Layout – OSHA

57
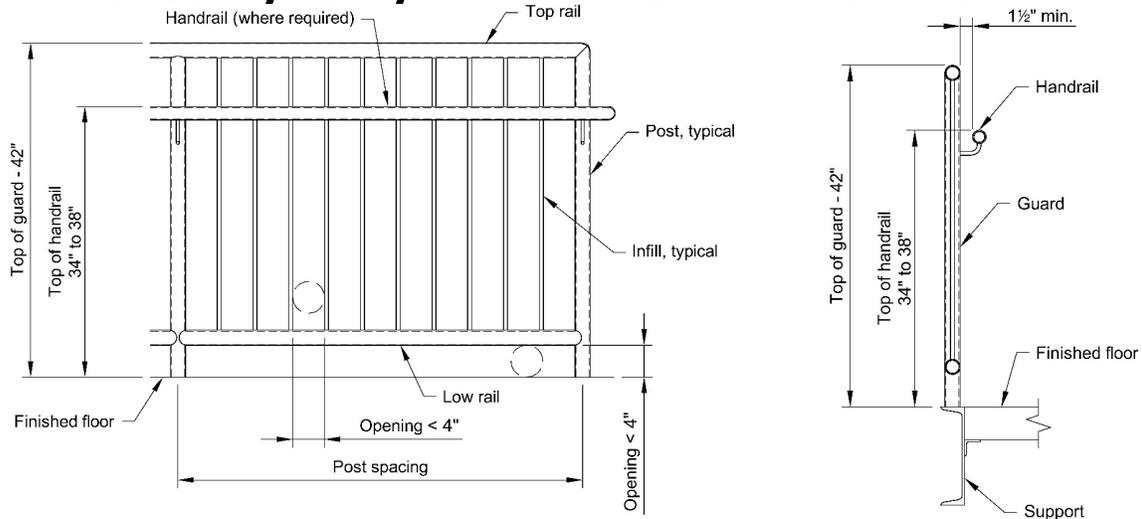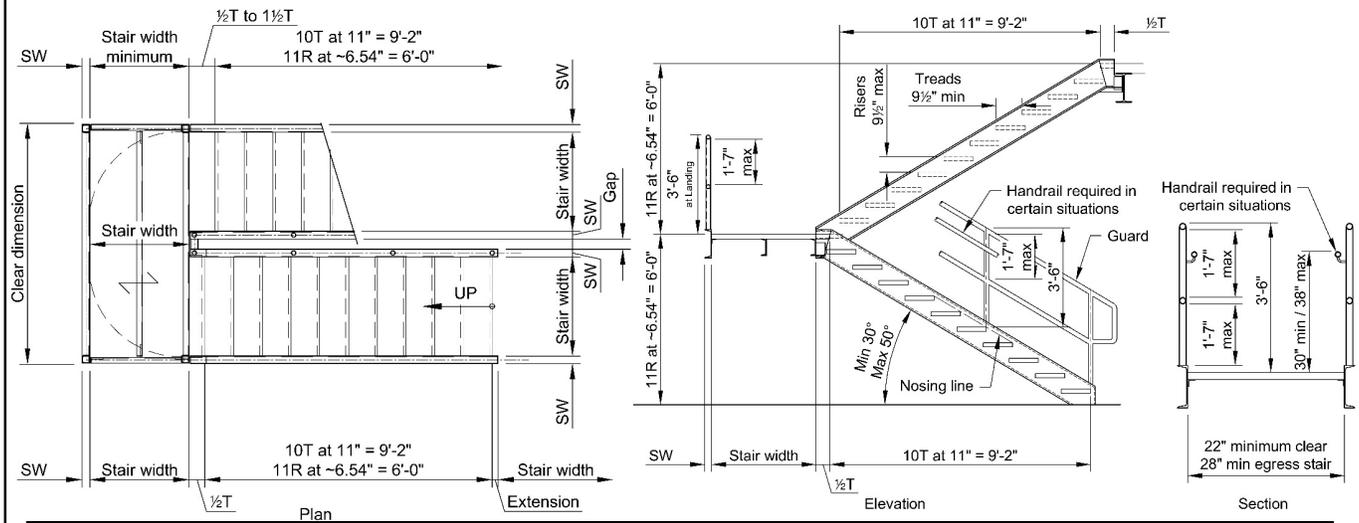
Stairway Layout – OSHA: Updates

- 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**

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Stairway Layout – OSHA: Guard

59
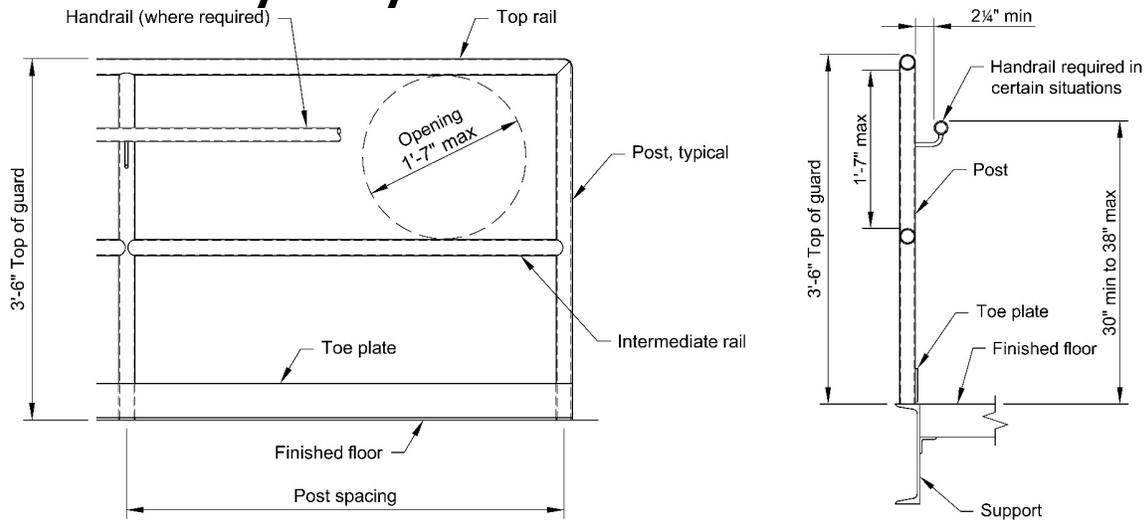
Stairway Layout – OSHA: Width

- 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

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Stairway Layout – OSHA: Width

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

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

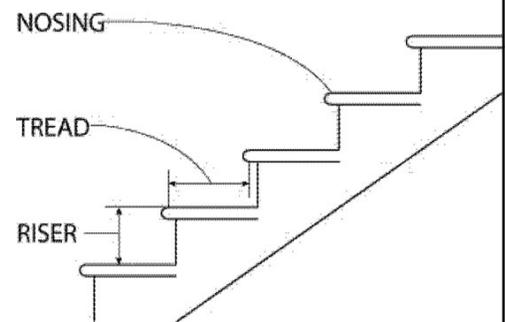| Stair width	Enclosed	One open side	Two open sides	With earth built up on both sides
Less than 44 inches (1.1 m).	At least one handrail	One stair rail system with handrail on open side.	One stair rail system each open side.	
44 inches (1.1 m) to 88 inches (2.2 m).	One handrail on each enclosed side	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.

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Stairway Layout – OSHA: Width

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

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.	

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

to 88 inches (2.2 m).		handrail on enclosed side.	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.

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Stairway Layout – OSHA: Width

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

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Stairway Layout – OSHA: Width

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Stairway Opening Size

¼" minimum,
½" preferred

44" minimum,
or per code

Provide space
for connections

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Stairway Opening Size

5"-6"

Provide space
for connections

66

Stairway Opening Size

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Stairway Opening Size

- Field installed slab edge angle
  - Allows for adjustment in field to help with fit-up
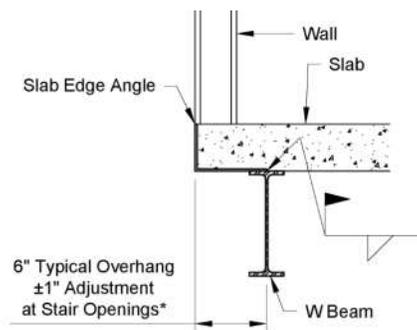
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Outline – Part 1

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

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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

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Load Combinations

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

LRFD

1. $1.4D$
2. $1.2D+1.6L+0.5(L_r$ 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. $0.6D-0.7E_v+0.7E_h$

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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

72

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

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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

74

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 $\times$ 5 = 75 psf $\rightarrow$ "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

75

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

76

Outline – Part 1

Step 1 – Purpose & Design Philosophy

Step 2 – Stairway Overview

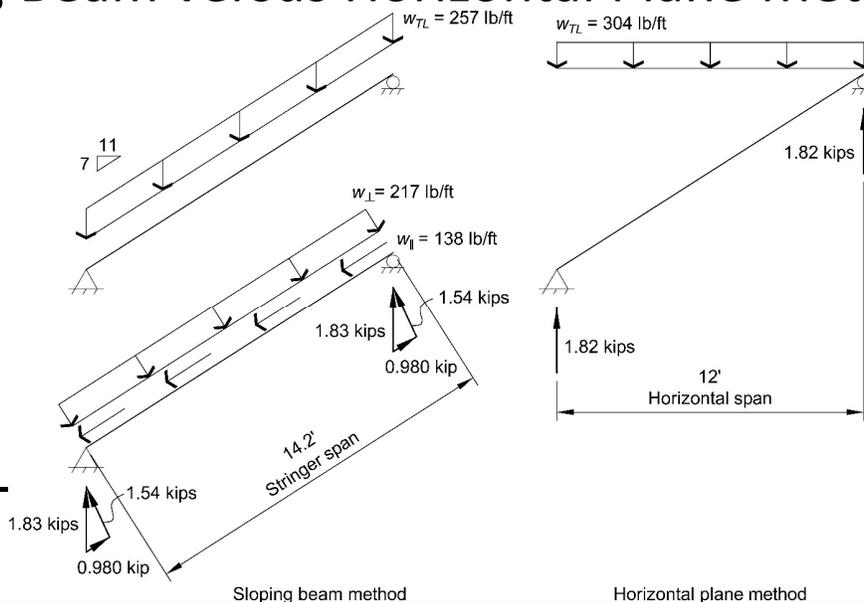Step 3 – Code Requirements - Gravity

Step 4 – Stairway Design

Step 5 – Members & Connx

Step 6 – Examples

77

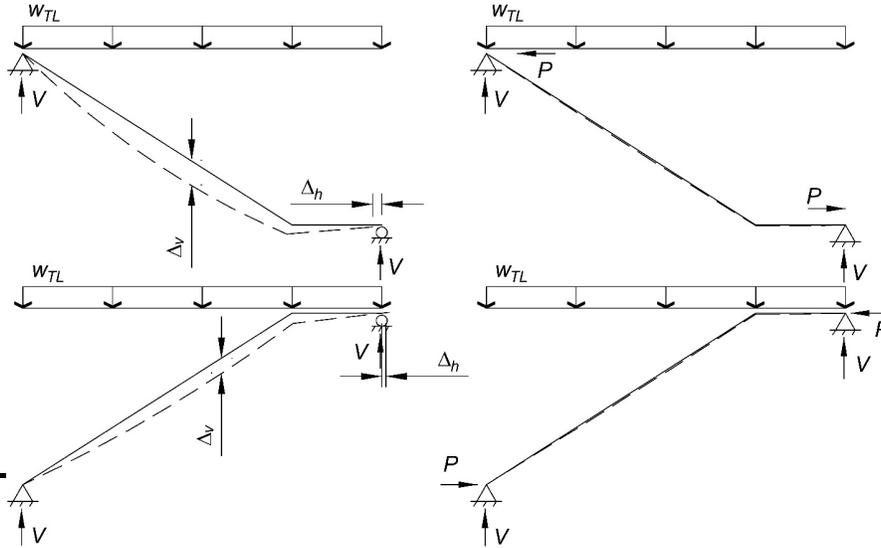# Stairway Design

- Sloping Beam versus Horizontal Plane Method

78

39

Stairway Design

- Simple Span versus Frame Analysis

Simple span beam analysis   Frame analysis

79

Stairway Design

- Simple Span

Simple span beam analysis
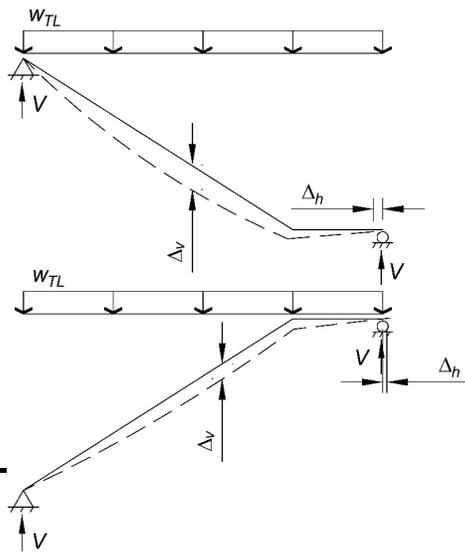
- Roller support allows for some lateral movement. This is a relatively small value for Δ_h on most stairs.
- Designers can accommodate with connections, flexible supports, drift detail.

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

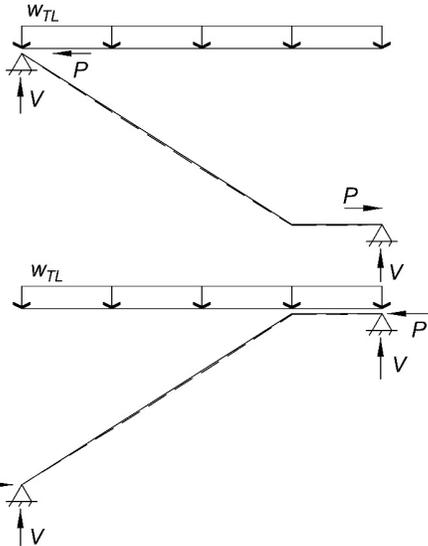$$M_{max} = \frac{wl^2}{8}$$

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

80

Stairway Design

- ## 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.

Frame analysis

81

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

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Stairway Design – Serviceability

- Deflection Limits
  - IBC Limits
  - 1/4" maximum?
  - Floor/wall finishes
- Vibration Concerns

83

Outline – Part 1

Step 1 – Purpose & Design Philosophy

Step 2 – Stairway Overview

Step 3 – Code Requirements - Gravity

Step 4 – Stairway Design

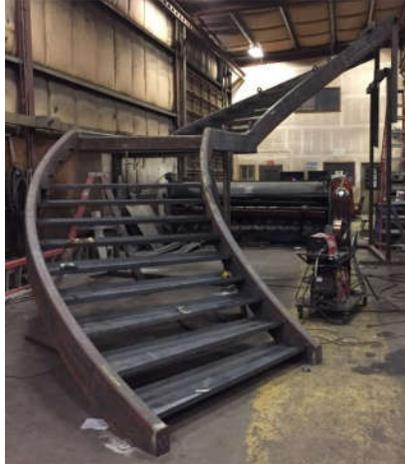Step 5 – Members & Connx

Step 6 – Examples

84

Member Selection

- Stringers – Channel, Plate, Rectangular HSS, WF

85

Member Selection

- Guards/Rails – Pipe, HSS, Bar, Rounds, Custom
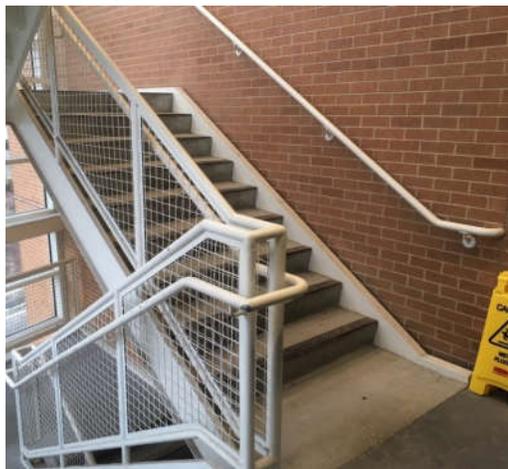
86

Member Selection

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

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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)

88

Treads/Risers
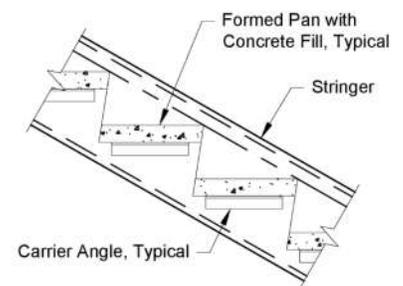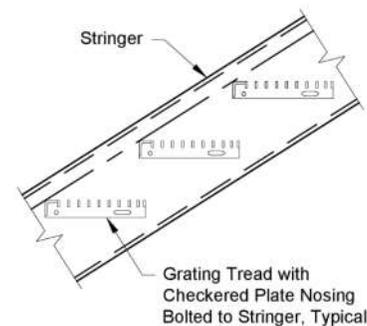
- Steel Plate
  - Checkered Plate or Diamond Plate
    - AISC Manual Table 3-18a provides recommended maximum uniform load based on span for a deflection limit of L/100
    - AISC Manual Table 3-18b provides recommended maximum uniform load based on span and stress limit of 24 ksi in LRFD and 16 ksi 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

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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

Stringer

Grating Tread with
Checkered Plate Nosing
Bolted to Stringer, Typical

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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

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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

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Landings

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

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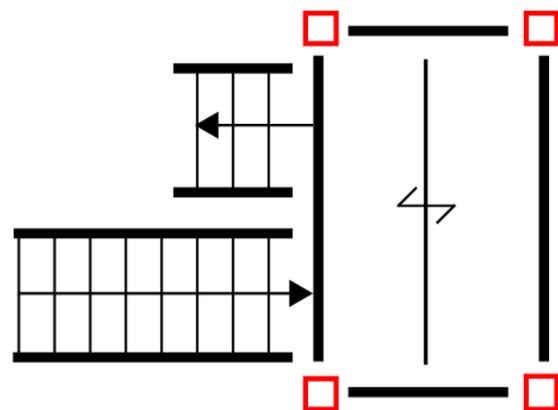# Landings

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

94

Landings

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

95

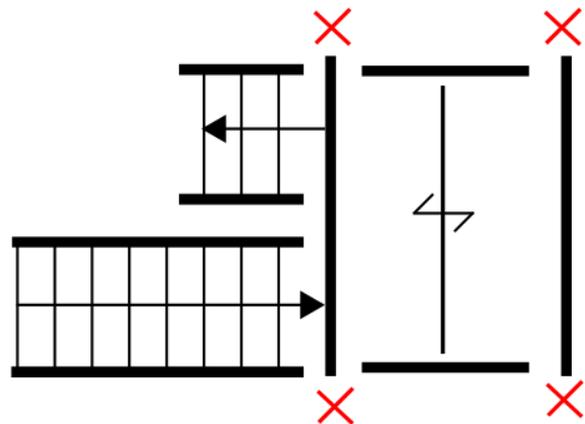# Landings

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

96

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Landings

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

Davis Parsons

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Landings

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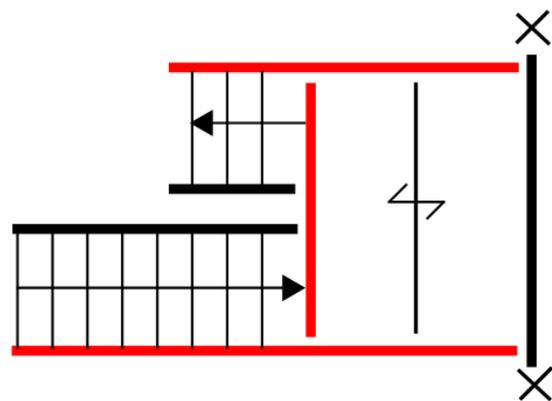 - Separate Stair Flights

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
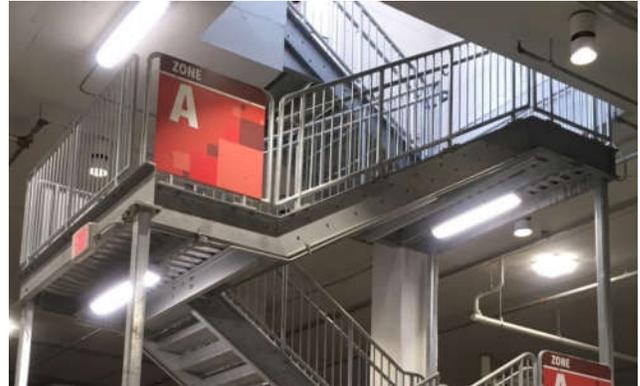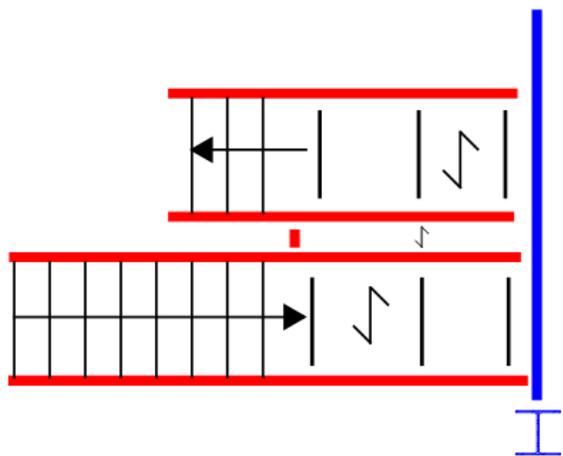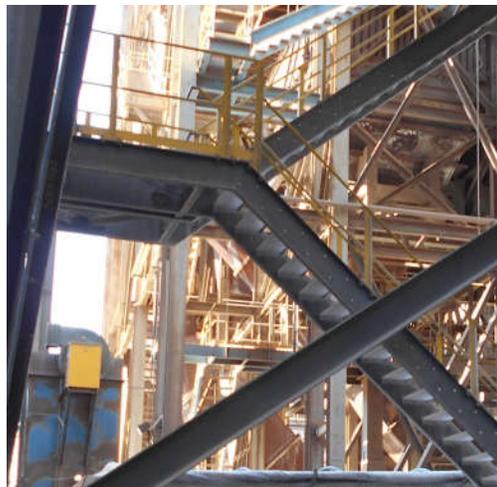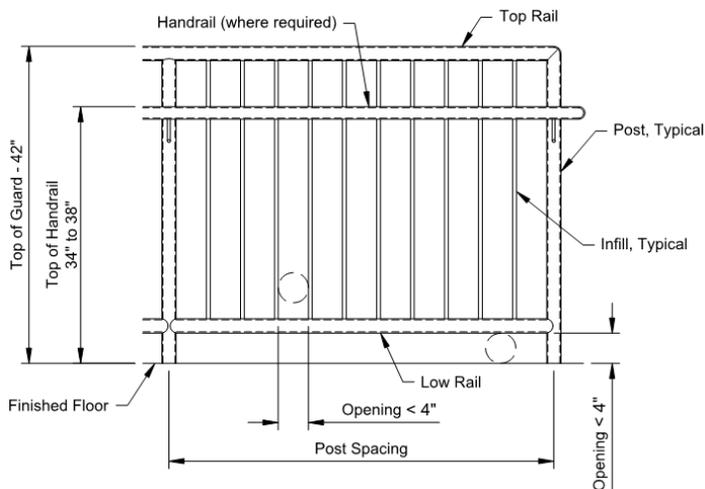 - Integrated Landing
  - Separate Stair Flights

101

Guard & Handrail

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

102

Guard & Handrail

- ## Member Types
  - **Pipe**
  - HSS Round
  - Rectangular HSS
  - Angle
  - Plate, Bar, & Rod
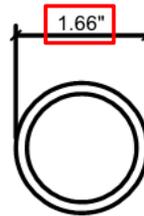
ASTM A53 GR B
PIPE 1 1/4"
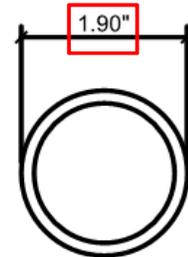
ASTM A53 GR B
PIPE 1 1/2"

103

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

104

Connections

- ## Shear & Axial
  - Follow AISC *Specification* & *Design Examples* (available at aisc.org)

- ## Moment
  - AISC *Manual* Part 11
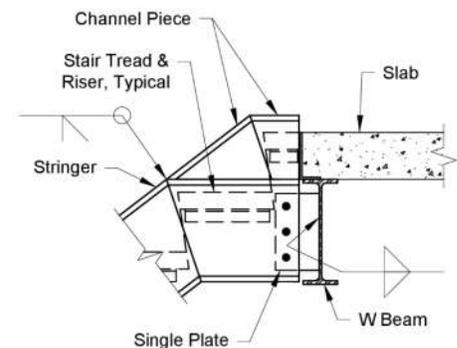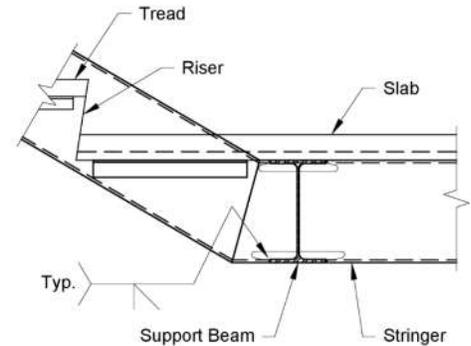 - AISC *Manual* Part 12
  - DG4 – Extended End-Plate Moment Connections
  - DG16 – Flush & Extended Multiple-Row Moment End-Plate Connx

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Connections

- ## Bracing
  - AISC *Manual* Part 13
  - DG29 – Vertical Bracing Connections-Analysis and Design

- ## Embedded Plates

- ## Post Installed Anchors

- ## Beam Pockets

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Guard Post Connx

- Imparts torsion, shear, axial loads on stringer

Channel Stringer | HSS Stringer | Plate Stringer

107
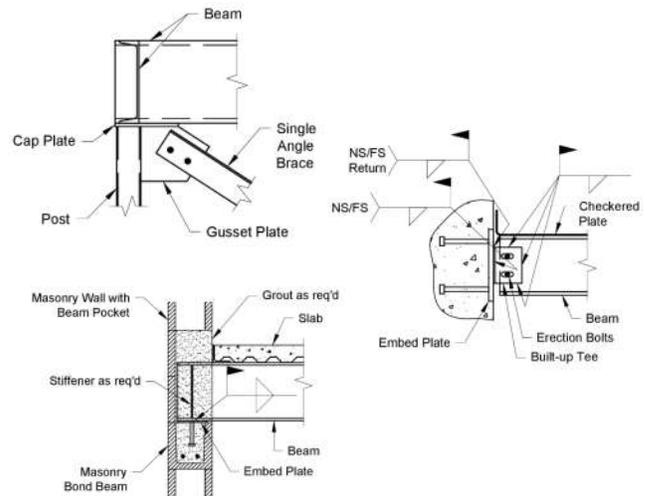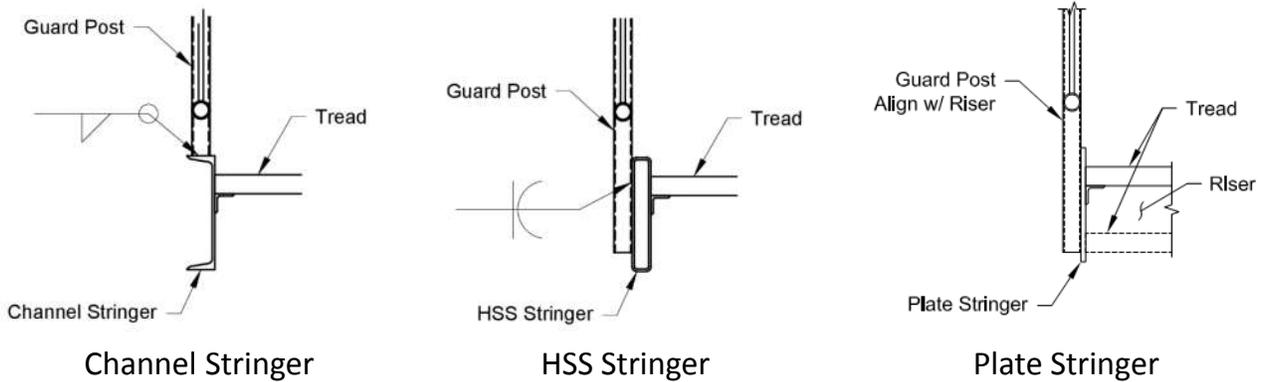
Guard Post Connx

- Consider fit-up of post to stringer

Channel Stringer

108
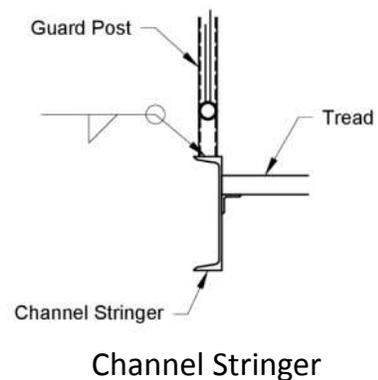
Guard Post Connx

- 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

$$Z = \frac{B_{eff}\,t_w^2}{4} \qquad S = \frac{B_{eff}\,t_w^2}{6}$$
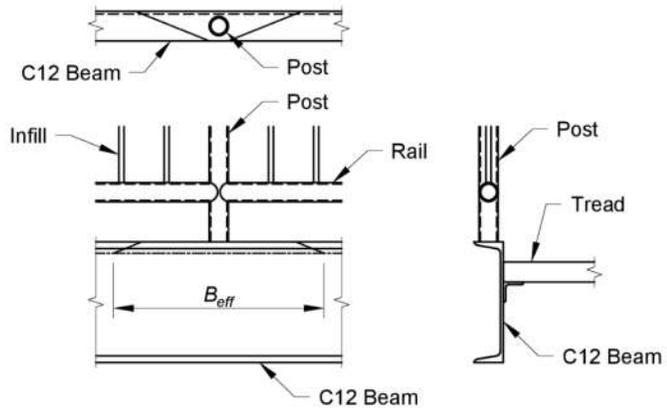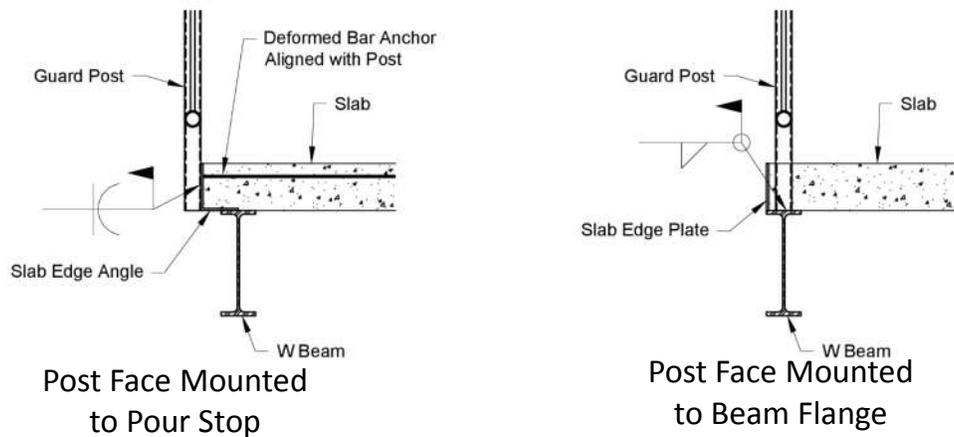
109

Guard Post Connx

- Imparts torsion, shear, axial loads on stringer

Post Face Mounted
to Pour Stop

Post Face Mounted
to Beam Flange

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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

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Example 1: Opening Size

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

112

Example 1: Opening Size
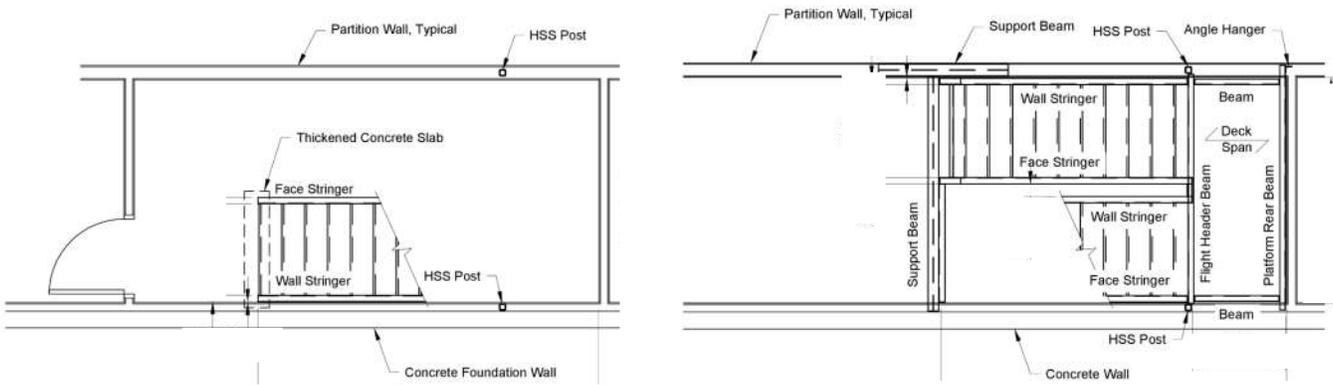
Example Stair Layout

113

Example 1: Opening Size - Width

114
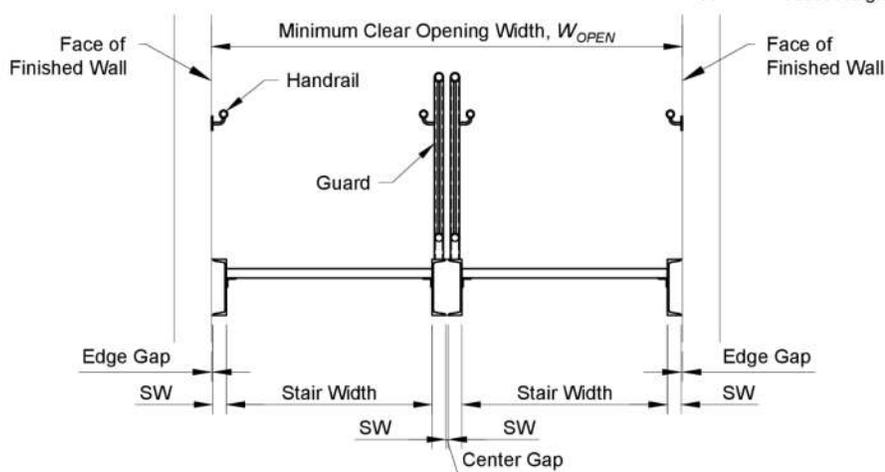
Example 1: Opening Size - Width

$W_{open} =$ 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"

115

Example 1: Opening Size - Width

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

$W_{open} = 107" = $ **8'-11"** clear dimension

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Example 1: Opening Size - Length

Generic Layout

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Example 1: Opening Size - Length

Landing

Stair

Generic Layout

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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)]

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Example 1: Opening Size - Length

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

N = 10

Tread Length = 11"

Allowance = 6"

120

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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"

121

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" = $ **13'-7 ½"**

122

Example 1: Opening Size
Provide 8'-11" x 13'-7 ½" Opening

123

Example 1: Opening Size
Provide 8'-11" x 13'-7 ½" Opening

124
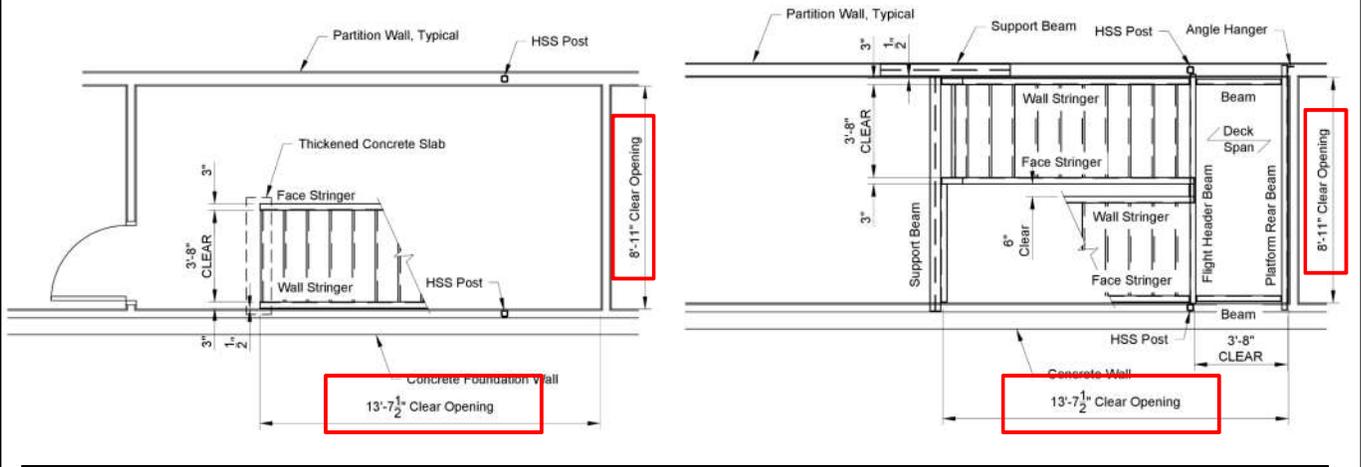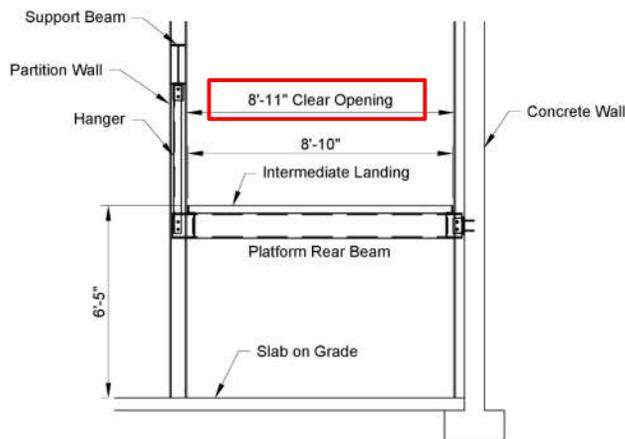
Example 2: Stringer Design

- 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
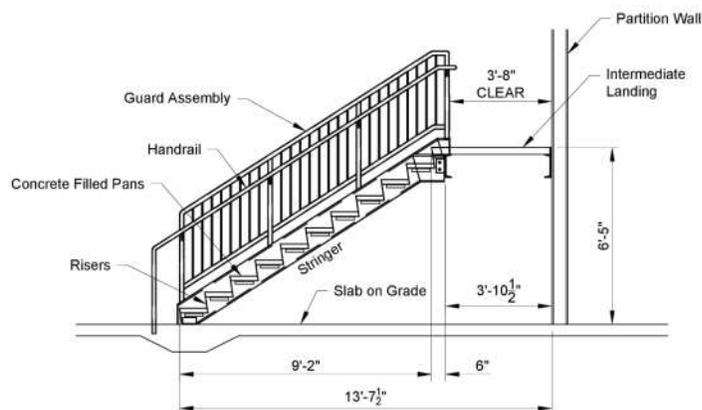
125

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

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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

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Example 2: Stringer Design

$w_D = 0.109$ kip/ft
$w_L = 0.184$ kip/ft

$R_D = 0.528$ kip
$R_L = 0.892$ kip

$R_D = 0.528$ kip
$R_L = 0.892$ kip

9'-8"

Beam Loading & Bracing Diagram
(Full Lateral Support)
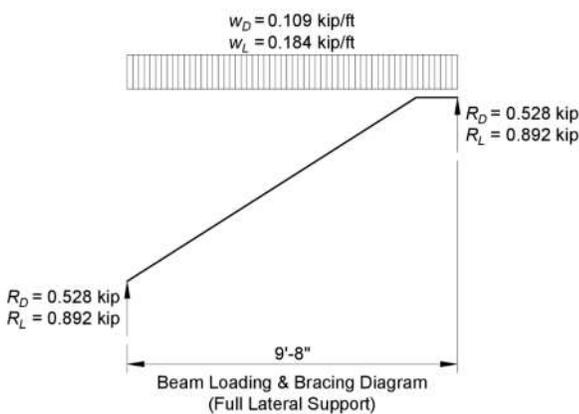
$$R = V = \frac{wl}{2}$$

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

	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

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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
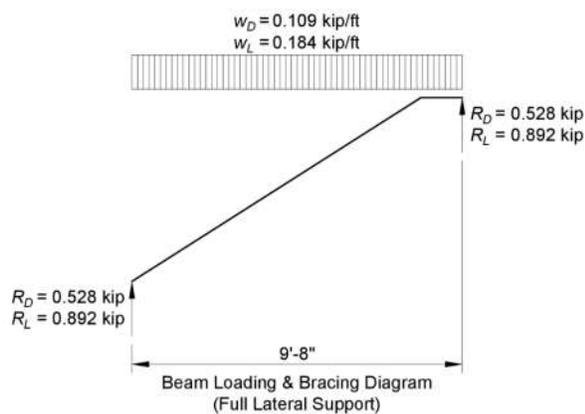M_p/Ω_b = 46.0 k-ft > 3.43 k-ft OK
LRFD
$\Phi_v V_n$ = 65.8 k > 2.05 k OK
$\Phi_b M_p$ = 69.1 k-ft > 4.97 k-ft OK

C12x20.7 is adequate for imposed loads

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Example 2: Stringer Design

$w_D = 0.109$ kip/ft
$w_L = 0.184$ kip/ft

$R_D = 0.528$ kip
$R_L = 0.892$ kip

$R_D = 0.528$ kip
$R_L = 0.892$ kip

9'-8"

Beam Loading & Bracing Diagram
(Full Lateral Support)

Check Deflection:

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

Live Load:

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

$$\Delta_{LL} = \frac{0.184\ \text{kip/ft}\left(9.67\ \text{ft}\right)^4}{1{,}290\left(129\ \text{in.}^4\right)} = 0.010\ \text{in.} < 0.322\ \text{in.}\quad \text{OK}$$
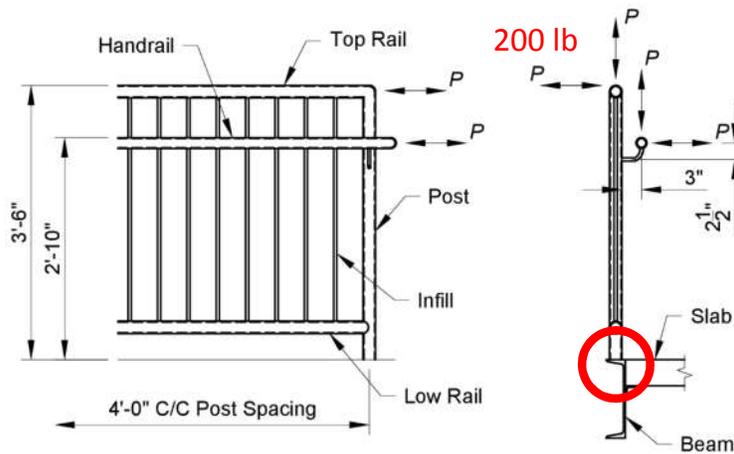
Total Load:

$$\Delta_{TL\ allowable} = \frac{\left(9.67\ \text{ft}\right)\left(\dfrac{12\ \text{in.}}{1\ \text{ft}}\right)}{240} = 0.484\ \text{in.}$$
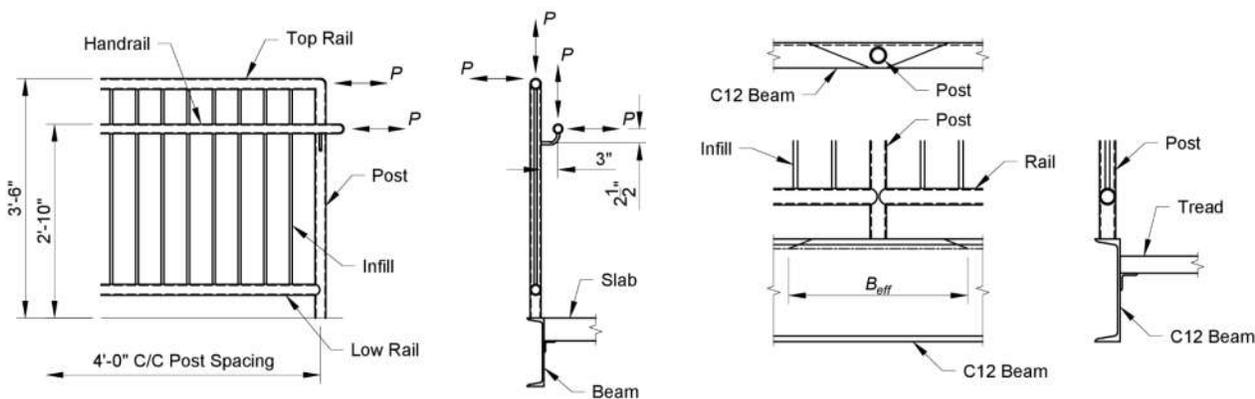
$$\Delta_{TL} = \frac{0.293\ \text{kip/ft}\left(9.67\ \text{ft}\right)^4}{1{,}290\left(129\ \text{in.}^4\right)} = 0.015\ \text{in.} < 0.484\ \text{in.}\quad \text{OK}$$

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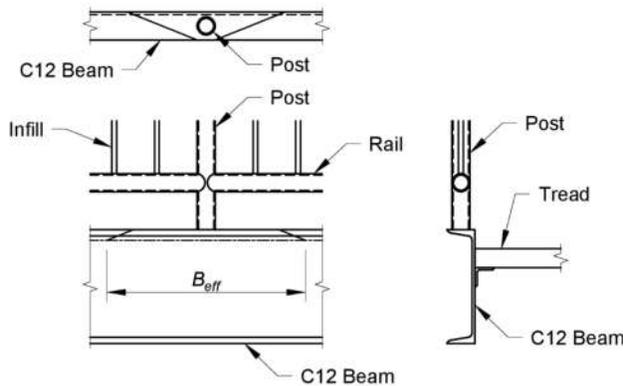American Institute of Steel Construction

Example 3: Guard Post Connx

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Example 3: Guard Post Connx
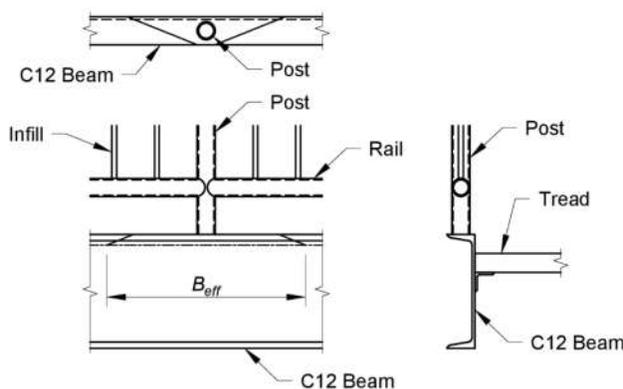

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Example 3: Guard Post Connx

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
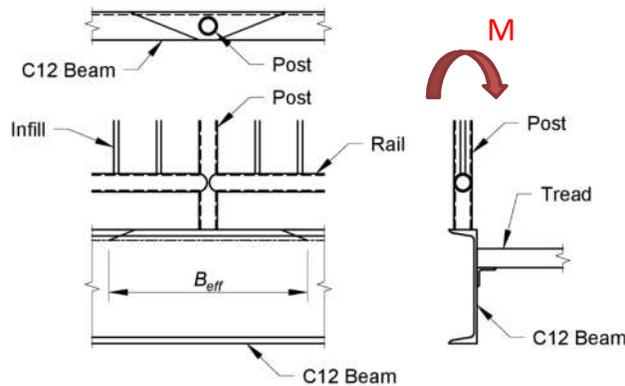
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Example 3: Guard Post Connx

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.

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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

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Example 3: Guard Post Connx
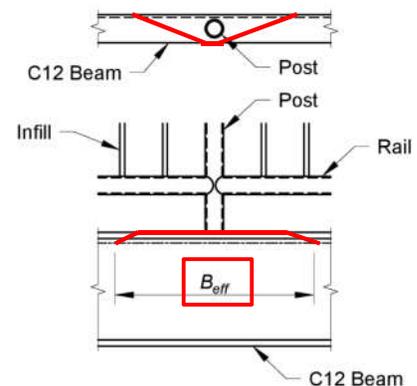
Determine effective width of channel top flange:

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

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

Determine section modulus of effective web:

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

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

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Example 3: Guard Post Connx

Determine nominal flexural strength of C12 web:

$$M_p = F_y Z \leq 1.6 M_y$$

$$= F_y Z \leq 1.6 F_y S$$

$$= 36 \text{ ksi} \left(0.417 \text{ in.}^3\right) \leq 1.6 \left(36 \text{ ksi}\right)\left(0.278 \text{ in.}^3\right)$$

$$= 15.0 \text{ kip-in.} \leq 16.0 \text{ kip-in.}$$

$$= 15.0 \text{ kip-in.}$$

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

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Questions?

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PDH Certificates

Within 2 business days…

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

PDH Certificates

Within 2 business days…

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

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