Basic Steel Design

Louis F. Geschwindner

Smarter.
Stronger.
Steel.

AISC Night School

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AISC Night School

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Session Description

22.1 Introduction to Basic Steel Design
January 28, 2020

This lecture will begin with a brief overview of the 8-session course. Next a brief history of the Specification and Manual will be provided as well as an overview of the organization of the current Specification and Manual. The lecture will then discuss the elements of structural safety with an emphasis on the principles of LRFD, variability of load effect and variability of strength. Resistance factors for LRFD and safety factors for ASD will be discussed as well as calibrating ASD to LRFD. The session will discuss steel as a material, various steel shapes, and introduces 1st and 2nd order structural analysis.

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Learning Objectives:

- List the historically significant steel framed structures.
- Describe the relationship between the resistance factors and safety factors used for LRFD and ASD design of steel buildings.
- Describe the safety that goes into the design of steel buildings.
- List the material properties for common structural shapes that are available for structural steel design.

Basic Steel Design: A review of the principles of steel design according to ANSI/AISC 360-16

Night School 22

Lesson 1

Introduction

Smarter.
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Steel.

Night School 22

- Introduction and review of basic principles of structural steel design
- Well suited for those who have not designed in structural steel for some time
- Useful for those who feel a basic review will improve their overall capabilities

1.9

Night School 22 - Lessons

1.	Introduction	1/28/2020
2.	Tension Members	2/4/2020
3.	Compression Members	2/11/2020
4.	Bending Members	2/25/2020
5.	Compression plus Bending	3/3/2020
6.	Stability Analysis and Design I	3/10/2020
7.	Stability Analysis and Design II	3/24/2020
8.	Composite Members	3/31/2020

1.10

Lesson 1 - Introduction

- AISC Specifications and Manuals
- Structural Safety
- Design Basis
- Shapes of Structural Steel
- Materials for Structural Steel
- Structural Analysis

1.11

AISC Specifications

In the early days of steel construction, architects were generally trained as structural engineers

- No standardized specifications
- City specific approaches
- Privately published specifications
- Standards were published by producers

1.12

Home Insurance Building

- 1884
- 135 S. LaSalle St.
- William LeBaron Jenney

First "Skyscraper"

Steel beams substituted during construction

Originally 10 stories

Added to later

Torn down 1929

1.13

Rookery

- 1885-1888
- 209 S. LaSalle St.
- Burnham & Root

Masonry bearing walls with skeletal frame

Oldest standing high-rise in Chicago

1.14

Tacoma Building

- 1887-1889
- 1 North LaSalle
- Holabird & Roche

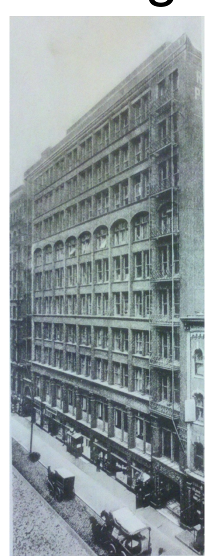
Second skyscraper
Cast iron columns/steel beams
First use of all riveted connections
Brickwork a true screen
  Erection begun simultaneously at different levels

1.15

Rand-McNally Building

- 1888-1890
- 165 West Adams
- Burnham and Root

First all steel skyscraper
10 stories



1.16

Reliance

- Base 1890, upper stories 1894-95
- 32 N. State Street
- Burnham and Root

Glass covered exterior
“Chicago” style windows

1.17

Leiter Building No. 2

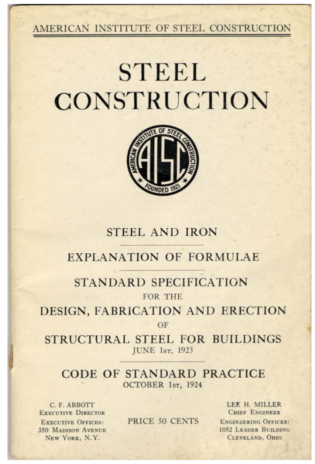
- 1891
- 403 S. State St.
- William Le Baron Jenney

The city's oldest surviving department store building

1.18

AISC Specifications

- AISC formed in 1921
- Institute's first priorities
  - Industry Standard Shape data
  - Standard Design Specification
  - Standard of Practice
- 1923 First approved specification


AMERICAN INSTITUTE OF STEEL CONSTRUCTION

STEEL CONSTRUCTION

STEEL AND IRON

EXPLANATION OF FORMULAE

STANDARD SPECIFICATION FOR THE DESIGN, FABRICATION AND ERECTION OF STRUCTURAL STEEL FOR BUILDINGS
JUNE 1ST, 1923

CODE OF STANDARD PRACTICE
OCTOBER 1ST, 1924

C. F. ABBOTT
Executive Director
Executive Offices:
350 Madison Avenue
New York, N.Y.

PRICE 50 CENTS

LEE H. MILLER
Chief Engineer
Engineering Offices:
1052 Leader Building
Cleveland, Ohio

1.19

AISC Specifications

Original Objective:

To Promote Uniform Practice

By 1924 (after just one year) the first AISC Specification had been adopted by 25 cities.

1.20

AISC Specifications

"It gives me pleasure to congratulate you and the members of the American Institute of Steel Construction on your splendid progress in simplification and standardization of your products and practices."

Herbert Hoover,

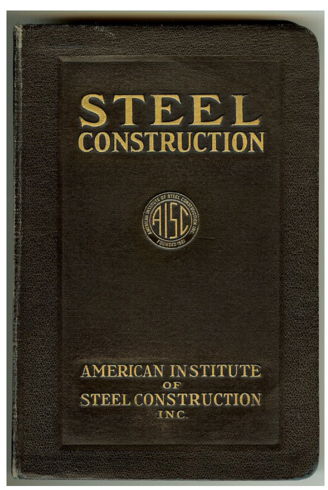
Secretary, Department of Commerce

October 8, 1924

1.21

AISC Specifications

- 1927 First AISC Steel Construction Manual



1.22

2016 AISC Specification

AISC is committed to one steel building design specification

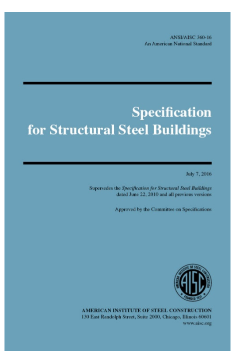
ANSI/AISC 360-16

Specification For Structural Steel Buildings

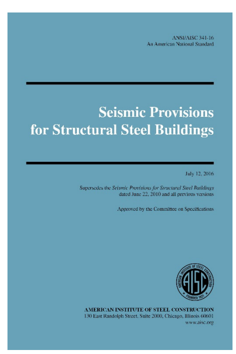
July 7, 2016

1.23

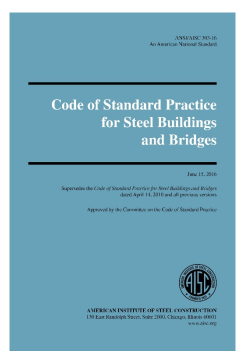
2016 AISC Specification



Basic Requirements



Seismic Requirements

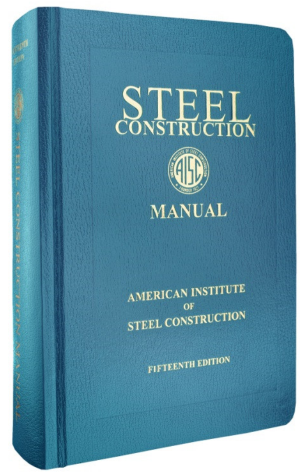


Contractual Provisions

1.24

2016 AISC Specification

Steel Construction Manual,
15th Edition



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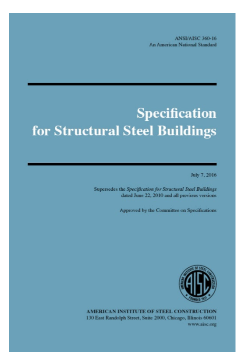
2016 AISC Specification

Mission Statement of

AISC Committee on Specifications:

Develop the practice-oriented specification for structural steel buildings that provides for

- Life safety
- Economical building systems
- Predictable behavior and response
- Efficient use



1.26

2016 AISC Specification

Contents

- Symbols
- Glossary
- Abbreviations
- A. General Provisions
- B. Design Requirements
- C. Design for Stability

1.27

2016 AISC Specification

- D. Design of Members for Tension
- E. Design of Members for Compression
- F. Design of Members for Flexure
- G. Design of Members for Shear
- H. Design of Members for Combined Forces and Torsion
- I. Design of Composite Members
- …

1.28

2016 AISC Specification

- J. Design of Connections
- K. Additional Requirements for HSS and Box-section Connections
- L. Design for Serviceability
- M. Fabrication and Erection
- N. Quality Control and Quality Assurance
- …

1.29

2016 AISC Specification

- Appendices
  - 1. Design by Advanced Analysis
  - 2. Design for Ponding
  - 3. Fatigue
  - 4. Structural Design for Fire Conditions
  - 5. Evaluation of Existing Structures
  - …

1.30

2016 AISC Specification

– 6. Member Stability Bracing
– 7. Alternative Methods of Design for Stability
– 8. Approximate Second-Order Analysis

The appendices are an integral part of the Specification and are mandatory.

1.31

Steel Construction Manual
15th Edition

1. Dimensions and Properties
2. General Design Considerations
3. Design of Flexural Members
4. Design of Compression Members
5. Design of Tension Members
6. Design of Members Subject to Combined Forces
7. Design Considerations for Bolts

1.32

Steel Construction Manual
15th Edition

8. Design Considerations for Welds
9. Design of Connecting Elements
10. Design of Simple Shear Connections
11. Design of Partially Restrained Moment Connections
12. Design of Fully Restrained Moment Connections
13. Design of Bracing Connections and Truss Connections

1.33

Steel Construction Manual
15th Edition

14. Design of Beam Bearing Plates, Column Base Plates, Anchor Rods and Column Splices
15. Design of Hanger Connections, Bracket Plates and Crane-Rail Connections
16. Specifications and Codes
17. Miscellaneous Data and Mathematical Information

1.34

Structural Safety

- Basic Equation for Design:
  Required Strength $\leq$ Available Strength
- Required Strength
  - Determined through an analysis
  - Also called "Load Effect"
- Available Strength
  - Determined through *Specification*
  - Based on "Limit States"
  - Also called "Resistance"

1.35

Structural Safety

$$\sum_{i=1}^{n} \gamma_i Q_i \leq \phi R_n$$

Load Effect $\leq$ Resistance

1.36

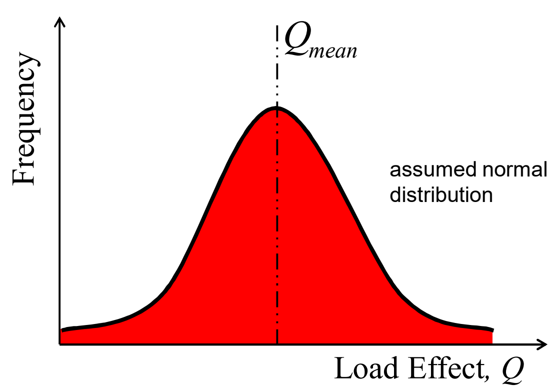
Load Effect

- The way we measure what the load does to our structures, M, V, P, etc.
  - Addressed in Chapter C of AISC *Specification*
- Factors influencing Load Effect
  - Type of load; live, dead, wind, etc.
  - Variability for specific load type
  - Calculation of load effect, $M = wl^2/8$, etc.
  - Likelihood of loads in combination

1.37

Variability of Load Effect

Frequency Distribution Curve
(Probability Density Function)



1.38

Resistance

- The way we measure the ability of a structure to carry load considering the influence of each limit state.
- When a structure or structural element becomes unfit for its intended purpose it has reached or exceeded a limit state.

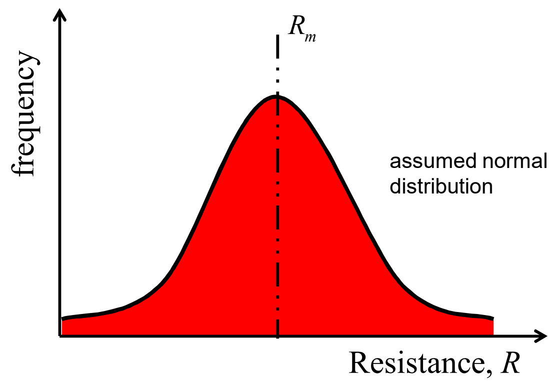
1.39

Factors Influencing Resistance

- Variability of member strength due to
  - variability of material properties
  - variability of dimensions
  - model error
  - increased risk due to a non-warning type failure
  - importance of member within system
  - designer's familiarity with method

1.40

Variability of Resistance



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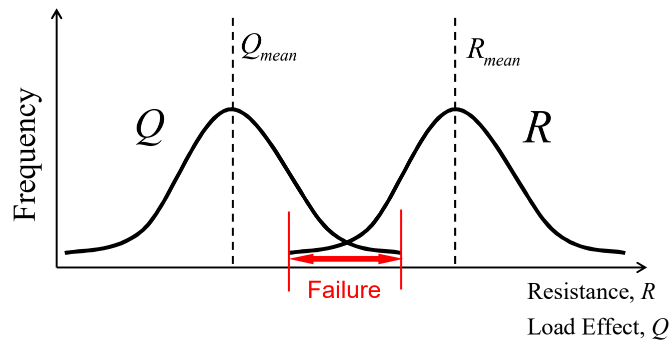
Definition of Failure

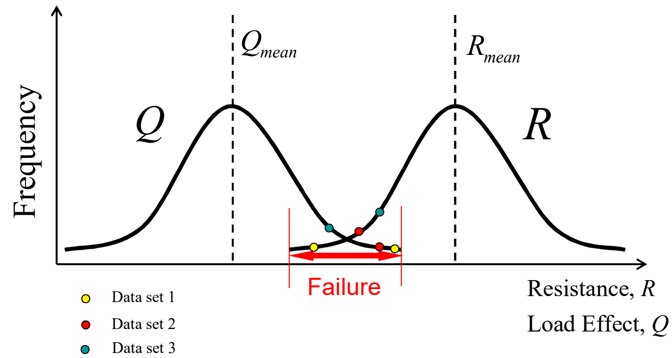
- Distribution of Resistance and Load Effect



1.42

Definition of Failure

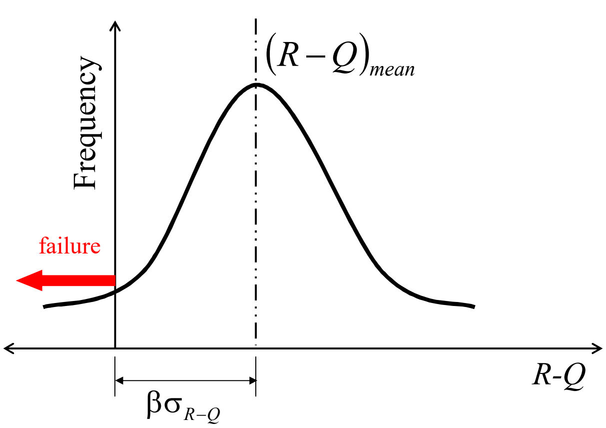
- Distribution of Resistance and Load Effect



1.43

Definition of Failure

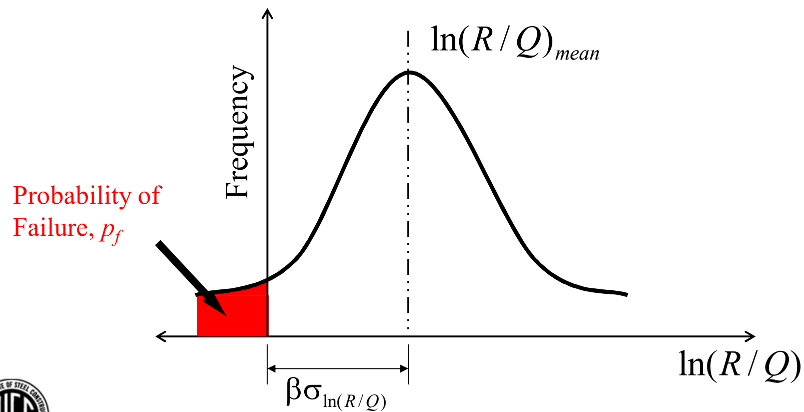
- Distribution of (Resistance - Load Effect)



1.44

Definition of Failure

- Distribution of $\ln(R/Q)$



1.45

Definition of Failure

- Reliability Index, β
  - This is how we measure safety
  - The number of standard deviations that the mean value is offset from zero
  - 68% of all values fall within the mean ± one standard deviation
  - 95 % fall with mean ± two standard deviations

1.46

Definition of Failure

- Probability of Failure, p_f
  - A number that represents the likelihood that a failure will occur.
  - Area under the curve in the region less than zero divided by the total area under the curve.

$\beta = 3$ yields $p_f = 1.4 \times 10^{-3}$

1.47

Structural Safety

$$\sum_{i=1}^{n} \gamma_i Q_i \leq \phi R_n$$

Load Effect $\leq$ Resistance

1.48

Resistance

- Strength Limit States
  the majority of what the AISC *Specification* addresses.

- Serviceability Limit States
  what usually controls our structural design in steel.

1.49

Resistance

Strength Limit States

1. Yielding
2. Buckling
3. Rupture
4. Others

Addressed in Chapters D through K of AISC *Specification*

1.50

Resistance

Serviceability Limit States

1. Deflections
2. Drift
3. Vibration
4. Wind-induced Motion
5. Thermal Expansion and Contraction
6. Connection Slip

Addressed in Chapter L of AISC *Specification*

1.51

Resistance

- Available resistance is the product of the nominal resistance and the resistance factor.

$$\phi R_n$$

- The nominal resistance is determined through an equation developed to predict the strength for a particular limit state.

$$R_n = A_g F_y$$

- The resistance factor is established through a statistical analysis of the variability in modeling, material and fabrication.

$$\phi$$

1.52

Resistance

- Variability

$$R = R_n(PMF)$$

$$P = \text{modeling} = \frac{\text{test}}{\text{prediction}} = \frac{M_{\text{test}}}{ZF_y}$$

$$M = \text{material} = \frac{F_y}{\text{code } F_y}$$

$$F = \text{fabrication} = \frac{Z}{Z_{\text{Manual}}}$$

1.53

Resistance

- Typical Resistance Factors, ϕ
  - Yielding, ϕ = 0.90
  - Rupture, ϕ = 0.75
  - Connection Slip (long slotted holes), ϕ = 0.70
  - Composite Component Shear Stud, ϕ = 0.65
- Safety Factors, Ω
  - So where do safety factors come from? We will get to this in a bit.

1.54

Load Effect

$$Q = E\left(c_D AD + c_L BL\right)$$

- D and L are the dead and live loads
- A and B are uncertainties in transforming loads to load effect
- c_D and c_L influence coefficients
- E represents uncertainties in structural analysis

1.55

Load Effect

- Example ASCE 7-16 specified loads
  - L = Live Load
  - L_r = Roof Live Load
  - W = Wind
  - D = Dead
  - S = Snow
  - E = Earthquake
- Analysis of variability of loads leads to ASCE 7-16 load combinations

1.56

Load Effect

- Example Basic ASD Load Combinations

  D

  D + L

  D + (L_r or S or R)

  D + 0.75L + 0.75(L_r or S or R)

  D + (0.6W)

  D + 0.75L + 0.75(0.6W) + 0.75(L_r or S or R)

  0.6D + 0.6 W

1.57

Load Effect

- Example Basic LRFD Load Combinations

  1.4D

  1.2D + 1.6L + 0.5(L_r or S or R)

  1.2D + 1.6 (L_r or S or R) + (L or 0.5W)

  1.2D + 1.0W + L + 0.5(L_r or S or R)

  0.9D + 1.0W

1.58

Load Factors

- 1986 LRFD was calibrated to ASD at

$$L / D = 3.0$$

- For the LRFD load combination

$$1.2D + 1.6L$$

we should get the same design as for the ASD load combination

$$D + L$$

1.59

Load Factors

- Since with ASD, the same load factor is applied to both D and L, we can write the equivalent LRFD combination as

$$1.2D + 1.6L = \gamma(D + L)$$

which yields, for $L/D = 3$, an effective load factor

$$\gamma = 1.5$$

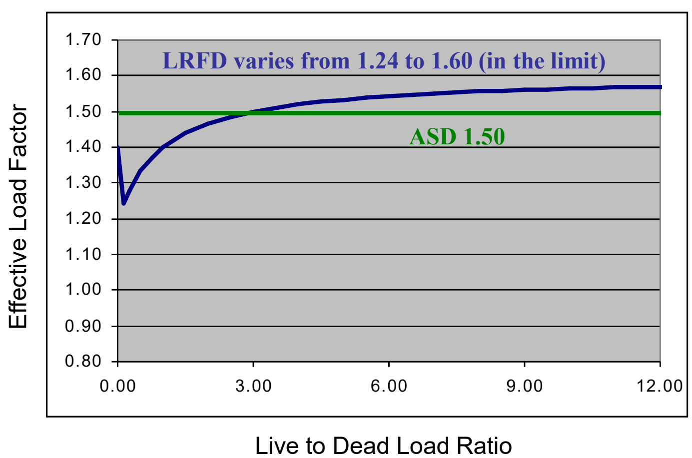
1.60

Load Factors

- This means that for design according to ASD we are effectively using a load factor of 1.5 on both D and L even though we don't actually see it.
- Thus, if we vary the live load to dead load ratio and plot the ASD and LRFD effective load factor we get:

1.61

Effective Load Factors



1.62

Safety Factors

With LRFD and ASD equal at L/D = 3, we can determine a relationship between resistance factors and safety factors. Remembering that

for LRFD $1.2D + 1.6L \leq \phi R_n$

and for ASD $D + L \leq \dfrac{R_n}{\Omega}$

1.63

Safety Factors

Solving for the nominal resistance

for LRFD

$$\frac{1.2D + 1.6L}{\phi} \leq R_n$$

and for ASD

$$\Omega(D + L) \leq R_n$$

1.64

Safety Factors

However, for LRFD, at $L/D = 3$

$$\frac{1.2D + 1.6L}{\phi} = \frac{1.5\left(D + L\right)}{\phi} \leq R_n$$

Setting R_n from LRFD = R_n from ASD

$$\frac{1.5(D + L)}{\phi} = \Omega(D + L)$$

1.65

Safety Factors

- Solving for Ω yields

$$\Omega = \frac{1.5}{\phi}$$

This relationship is used throughout the AISC *Specification* and means that the available LRFD strength is 1.5 times the ASD strength

1.66

Safety

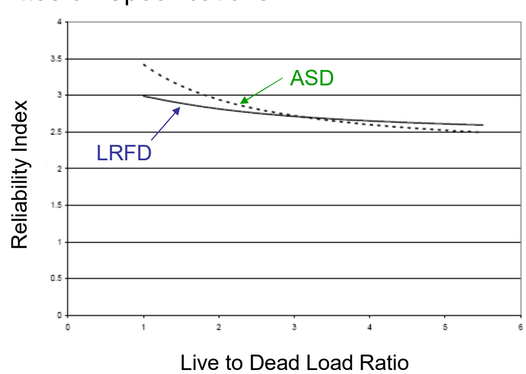
- ASD
  - Safety is established through the Safety Factors and the ASD load combinations
- LRFD
  - Safety is established through resistance factors and LRFD load combinations

There is a consistent relationship between safety factors and resistance factors in AISC 360 but not between ASD and LRFD load combinations in ASCE 7, thus reliability varies.

1.67

Reliability

- ASD and LRFD designs may yield different member sizes.
- Level of reliability may be different but that is deemed acceptable by the Committee on Specifications.

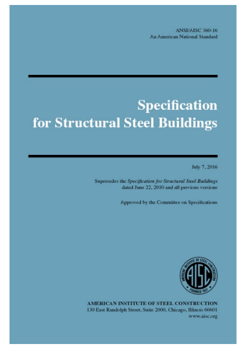


Compact, laterally supported beam

1.68

Design Basis

- Important definitions
  - Required Strength; R_r
    - ASD, R_a
    - LRFD, R_u
  - Nominal Strength, R_n
  - Available Strength; R_c
    - Allowable Strength, R_n/Ω
    - Design Strength, ϕR_n



1.69

Design Basis

B3.1. For LRFD, design shall be performed in accordance with:

Required Strength $\leq$ Available Strength

$$R_u \leq \phi R_n \qquad \text{(B3-1)}$$

where

R_u = required strength (LRFD) defined in Chapter C
R_n = nominal strength specified in Chapters D through K
ϕ = resistance factor specified in Chapters D through K
ϕR_n= design strength = resistance factor (nominal strength)

1.70

Design Basis

B3.2. For ASD, design shall be performed in accordance with:

Required Strength $\leq$ Available Strength

$$R_a \leq R_n / \Omega \qquad \text{(B3-2)}$$

where

R_a = required strength (ASD) defined in Chapter C

R_n = nominal strength specified in Chapters D through K

Ω = safety factor specified in Chapters D through K

R_n/Ω = allowable strength = $\frac{\text{nominal strength}}{\text{safety factor}}$

1.71

Design Basis

- Tensile Strength for Limit State of Yielding

$$P_n = F_y A_g \qquad \text{(D2-1)}$$

$\phi_t = 0.90$ (LRFD) $\Omega_t = 1.67$ (ASD)

1.72

Application of Design Basis

LRFD

Required Strength ≤ Design Strength

$$P_u \le \phi_t P_n = \phi_t F_y A_g$$

1.73

Application of Design Basis

- ASD

Required Strength ≤ Allowable Strength

$$P_a \le \frac{P_n}{\Omega_t} = \frac{F_y A_g}{\Omega_t}$$

1.74

Limit States Design Process

1. Determine required strength (ASD or LRFD)
2. Determine applicable limit states (modes of failure)
3. Determine the nominal strength for each limit state
4. Determine available strength for each limit state
5. Confirm acceptability

Levels of safety and reliability are established by the AISC *Specification*

1.75

Structural Steel Shapes

- Defined by ASTM A6-14
  - W-shapes, S-shapes, HP-shapes, M-shapes, C-shapes, MC-shapes, and L-shapes
  - Bars and plates

Designation: A6/A6M – 14

Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling[1]

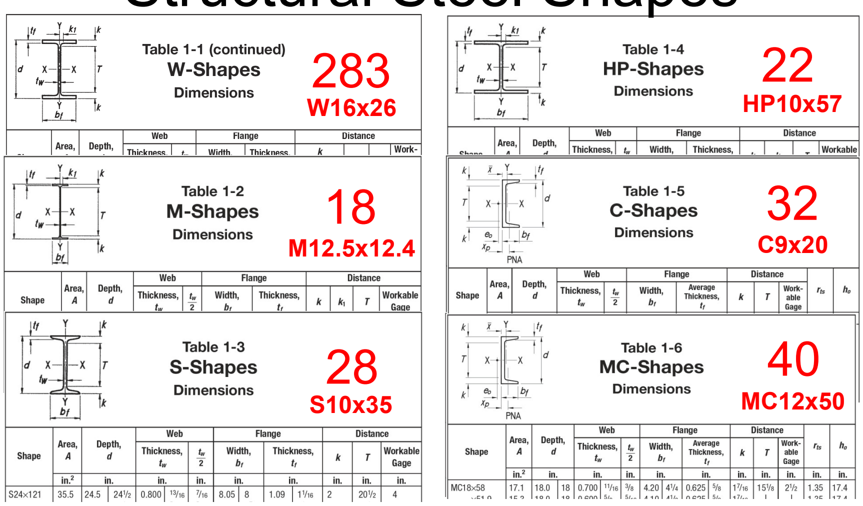
1.76

Structural Steel Shapes

- Other shapes
  - Hollow Shapes: HSS
    - Defined by several ASTM Standards
      - ASTM A53, A500, A501, A618, A847, A1065, A1085
      - These standards include requirements for material and shapes.
      - They address
        - » Round Tubing
        - » Square and Rectangular Tubing
        - » Steel Pipes

1.77

Structural Steel Shapes



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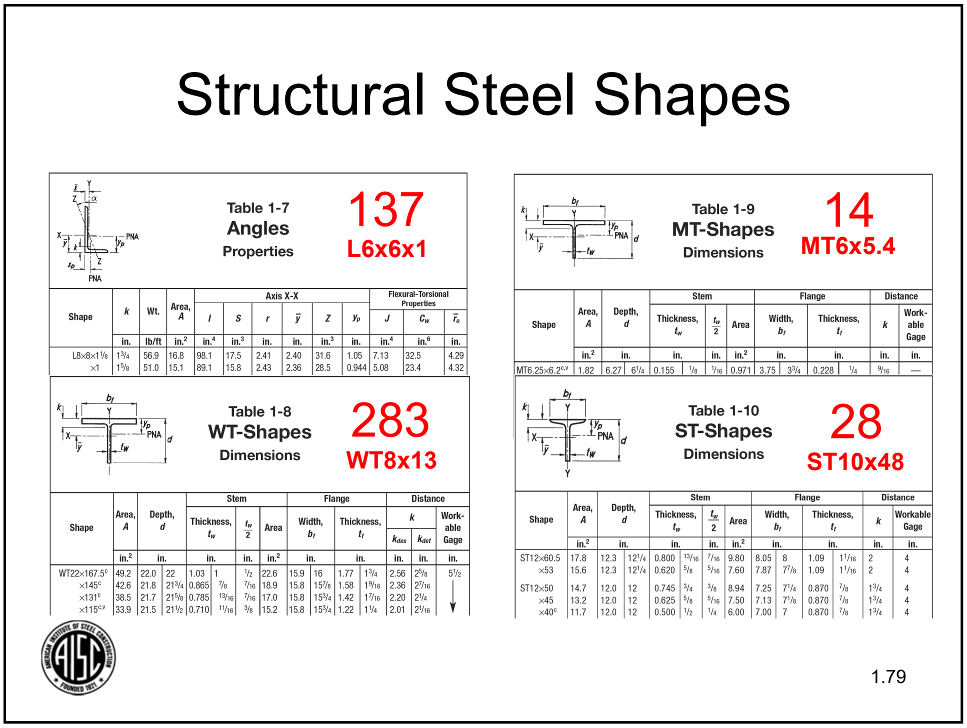
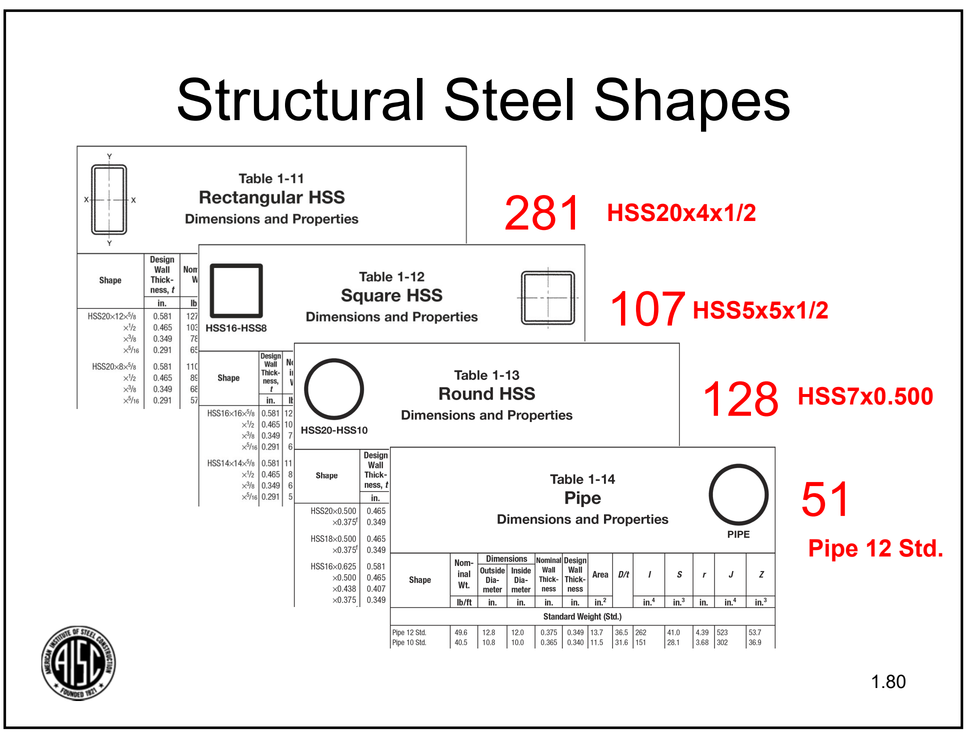

Structural Steel Shapes
Table 1-7
Angles
Properties
137
L6x6x1
Table 1-9
MT-Shapes
Dimensions
14
MT6x5.4
Table 1-8
WT-Shapes
Dimensions
283
WT8x13
Table 1-10
ST-Shapes
Dimensions
28
ST10x48
1.79


Structural Steel Shapes
Table 1-11
Rectangular HSS
Dimensions and Properties
281
HSS20x4x1/2
Table 1-12
Square HSS
Dimensions and Properties
HSS16-HSS8
107
HSS5x5x1/2
Table 1-13
Round HSS
Dimensions and Properties
HSS20-HSS10
128
HSS7x0.500
Table 1-14
Pipe
Dimensions and Properties
PIPE
51
Pipe 12 Std.
1.80

Structural Steel Shapes

- A total of 1452 shapes + combined shapes
- Maximum weight 925 lb/ft (W36x925)
- Least weight 0.850 lb/ft   (Pipe ½ std.)
- Steel weight, 490 lb/ft^3
- An infinite number of built-up shapes

1.81

Steel as a Material

- AISC Specification A3.1a identifies 21 different approved material designations.
  - Hot-rolled structural shapes – 8
  - Hollow structural sections (HSS) – 7
  - Plates – 10
  - Bars – 4
  - Sheets – 2

Table 2-4
Applicable ASTM Specifications for Various Structural Shapes

Steel Type	ASTM Designation		F_y Yield Stress[a] (ksi)	F_u Tensile Stress[a] (ksi)	Applicable Shape Series: W	M	S	HP	C	MC	L	HSS: Rect.	HSS: Round	Pipe
Carbon	A36		36	58–80[b]	▒	■	■	▒	■	■	■			
	A53 Gr. B		35	60										■
	A500	Gr. B	42	58									▒	
			46	58								▒		
		Gr. C	46	62									■	
			50	62								■		
	A501	Gr. A	36	58								▒	▒	
		Gr. B	50	70								▒	▒	
	A529[c]	Gr. 50	50	65–100	▒	▒	▒	▒	▒	▒	▒			
		Gr. 55	55	70–100	▒	▒	▒	▒	▒	▒	▒			
	A709	36	36	58–80[b]	▒	▒	▒	▒	▒	▒	▒			
	A1043[d,k]	36	36–52	58	▒									
		50	50–65	65	▒									
	A1085	Gr. A	50	65								▒	▒	
High-Strength Low-Alloy	A572	Gr. 42	42	60	▒	▒	▒	▒	▒	▒	▒			
		Gr. 50	50	65	▒	▒	▒	■	▒	▒	▒			
		Gr. 55	55	70	▒	▒	▒	▒	▒	▒	▒			
		Gr. 60[e]	60	75	▒	▒	▒	▒	▒	▒	▒			
		Gr. 65[e]	65	80	▒	▒	▒	▒	▒	▒	▒			
	A618[f]	Gr. Ia[k], Ib & II	50[g]	70[g]								▒	▒	
		Gr. III	50	65								▒	▒	
	A709	50	50	65	▒	▒	▒	▒	▒	▒	▒			
		50S	50–65	65	▒	▒	▒	▒	▒	▒	▒			
		50W	50	70	▒	▒	▒	▒	▒	▒	▒			
	A913	50	50[h]	65[h]	▒	▒	▒	▒	▒	▒	▒			
		60	60	75	▒	▒	▒	▒	▒	▒	▒			
		65	65	80	▒	▒	▒	▒	▒	▒	▒			
		70	70	90	▒	▒	▒	▒	▒	▒	▒			
	A992		50[i]	65[i]	■	▒	▒	▒	▒	▒	▒			
	A1065[k]	Gr. 50[j]	50	60								▒		

■ = Preferred material specification.
▒ = Other applicable material specification, the availability of which should be confirmed prior to specification.
□ = Material specification does not apply.

Footnotes on facing page.

1.82

Steel as a Material

- Preferred hot rolled material specifications
  - A992 for W-shapes,

    $F_y = 50$ ksi, $F_u = 65$ ksi
  - A36 for M, S, C, MC, L-shapes

    $F_y = 36$ ksi, $F_u = 58 - 80$ ksi
  - A572 Gr. 50 for HP-shapes

    $F_y = 50$ ksi, $F_u = 65$ ksi

1.83

Steel as a Material

- Preferred HSS material specifications
  - A500 Gr. C for
    - Rectangular Tube $F_y = 50$ ksi, $F_u = 62$ ksi
    - Round Tube $F_y = 46$ ksi, $F_u = 62$ ksi
  - A53 Gr. B for Pipe

    $F_y = 35$ ksi, $F_u = 60$ ksi

1.84

Steel as a Material

- Chemical Components for A992 Steel

TABLE 1 Chemical Requirements (Heat Analysis)

Element	Composition, %
Carbon, max	0.23
Manganese,	0.50 to 1.60[A]
Silicon, max	0.40
Vanadium, max	0.15[B]
Columbium, max	0.05[B]
Phosphorus, max	0.035
Sulfur, max	0.045
Copper, max	0.60
Nickel, max	0.45
Chromium, max	0.35
Molybdenum, max	0.15

[A] Provided that the ratio of manganese to sulfur is not less than 20 to 1, the minimum limit for manganese for shapes with flange or leg thickness not exceeding 1 in. [25 mm] shall be 0.30 %.
[B] The sum of columbium and vanadium shall not exceed 0.15 %.

1.85

Steel as a Material

- Carbon:
  - Most common after Iron, increases strength and decreases ductility.
- Manganese:
  - Similar impact on strength as carbon, improves notch toughness, negative impact on weldability.
- Silicon:
  - Removes oxygen from hot steel.
- Vanadium:
  - Increases strength but does not negatively impact weldability.

1.86

Steel as a Material

- Columbium:
  - Increases strength but has significant negative impact on notch toughness.
- Phosphorus:
  - Increases strength while decreasing ductility but improves resistance to atmospheric corrosion. Negative impact on weldability.
- Sulfur:
  - Permitted in very limited quantities. Has same negative impact as phosphorus. Negative impact on weldability.

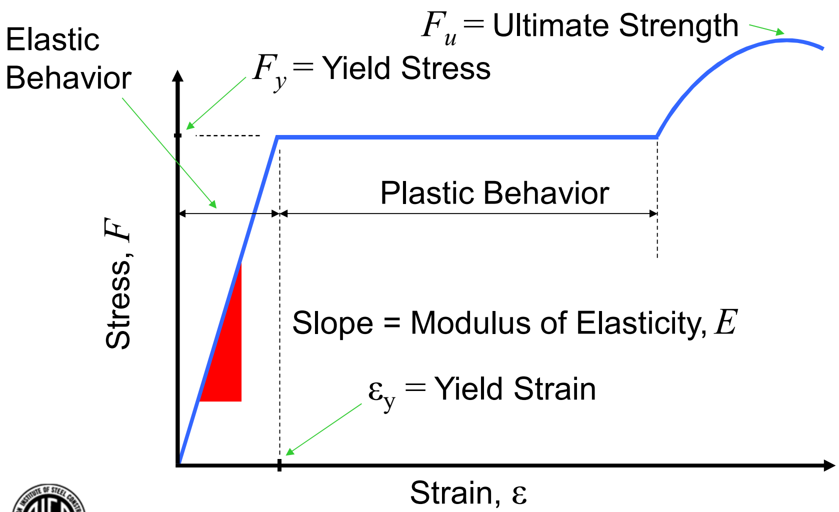
1.87

Steel as a Material

- Copper:
  - Increases strength with only limited negative impact on weldability. Most significant contributor to corrosion resistant steel.
- Nickel:
  - Moderate strength increase and improvement in notch toughness.
- Chromium:
  - In combination with copper to improve corrosion resistance. Integral to stainless steel.
- Molybdenum:
  - Increases strength and slight increase notch toughness.

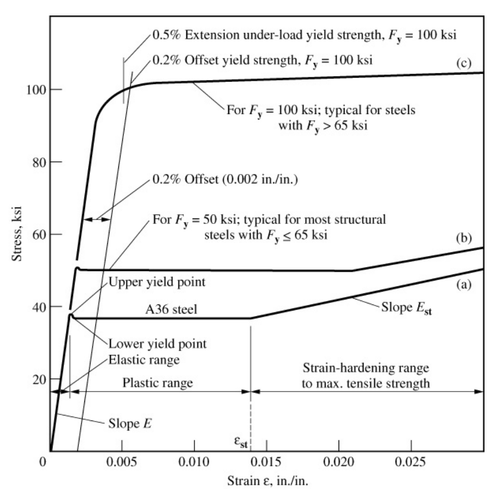
1.88

Steel as a Material



1.89

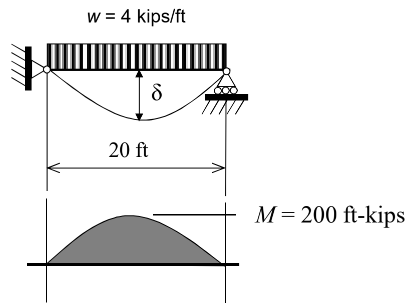
Steel as a Material



1.90

Structural Analysis

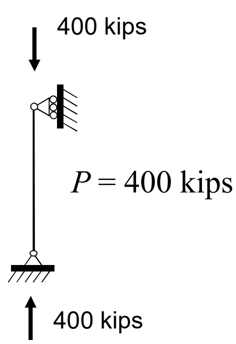
- The load effect is obtained through a structural analysis. It could be as simple as determining the moment on a simple beam



1.91

Structural Analysis

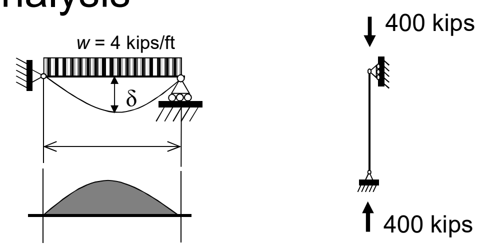
- or the compression in a column



1.92

Structural Analysis

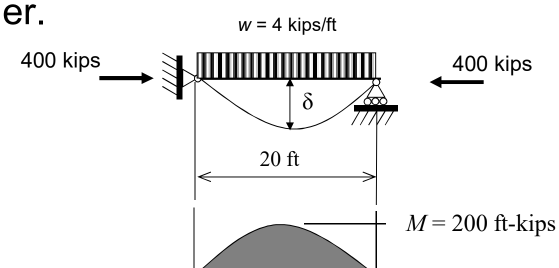
- In both situations, any deflection that occurs has no influence on the resulting forces or moments. This is called a first-order analysis



1.93

Structural Analysis

- But what happens if we put the two loadings together.



- Now the axial force combined with the deflection caused by the uniform load will increase the moment all along the span.

1.94

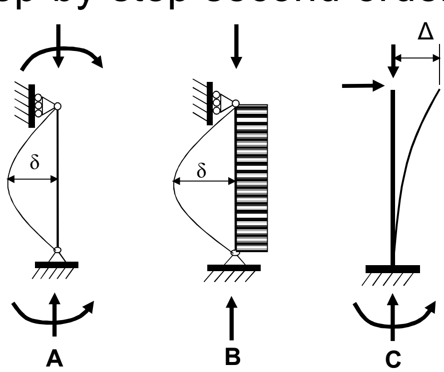
Structural Analysis

- We account for this increase with what is called a second-order analysis.
- The AISC *Specification,* Chapter C*,* requires that we design for these second-order effects.
- We can determine these second-order effects through approximate or rigorous methods.

1.95

Structural Analysis

- Look at 3 examples to illustrate an approximate step-by-step second-order analysis

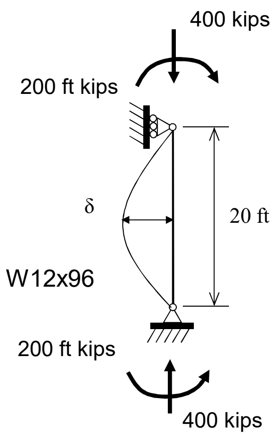


1.96

Structural Analysis

A

First Iteration on member effect



$$\delta_{1st} = \frac{Ml^2}{8EI} = \frac{200(20)^2(1728)}{8(29000)(833)} = 0.715 \text{ in.}$$

$$M_{2nd} = \frac{(400(0.715))}{12} = 23.8 \text{ ft-kips}$$

$$M_r = 200 + 23.8 = 224 \text{ ft-kips}$$

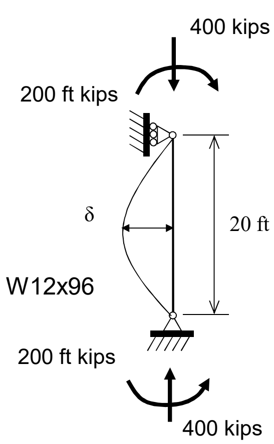
$$\text{Amplification Factor} = \frac{(224)}{200} = 1.12$$

1.97

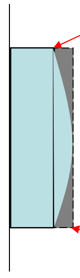
Structural Analysis

A

First Iteration on member effect



First-order moment = 200 ft-kips



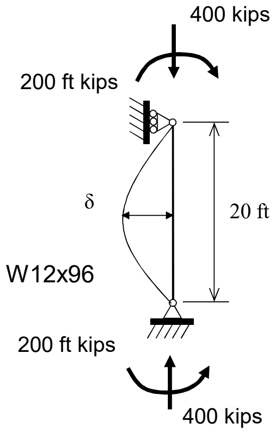
Using the rectangular moment diagram will yield more deflection than will actually occur.

First cycle second-order moment = 224 ft-kips

1.98

Structural Analysis

A



Second Iteration on member effect (Approximation)

$$\delta_{1st} = \frac{Ml^2}{8EI} = \frac{23.8(20)^2(1728)}{8(29000)(833)} = 0.0851 \text{ in.}$$

$$M_{2nd} = \frac{(400(0.0851))}{12} = 2.84 \text{ ft-kips}$$

$$M_r = 200 + 23.8 + 2.84 = 227 \text{ ft-kips}$$

$$\text{Amplification Factor } = \frac{(227)}{200} = 1.14$$

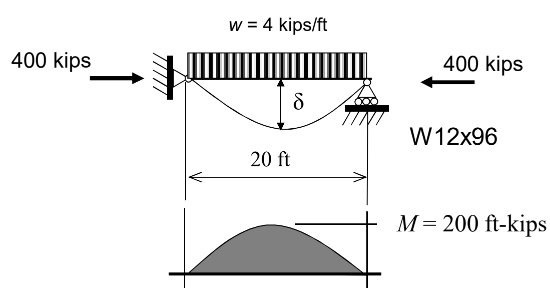
This might be expected to over estimate the amplification

1.99

Structural Analysis

B

Beam with axial force

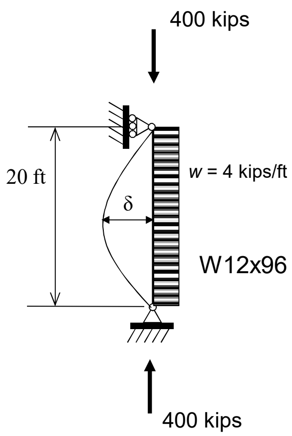


1.100

Structural Analysis

B

First Iteration on member effect



$$\delta_{1st} = \frac{5wl^4}{384EI} = \frac{5(4.0)(20)^4(1728)}{384(29000)(833)} = 0.596 \text{ in.}$$

$$M_{2nd} = \frac{(400(0.596))}{12} = 19.9 \text{ ft-kips}$$

$$M_r = 200 + 19.9 = 220 \text{ ft-kips}$$

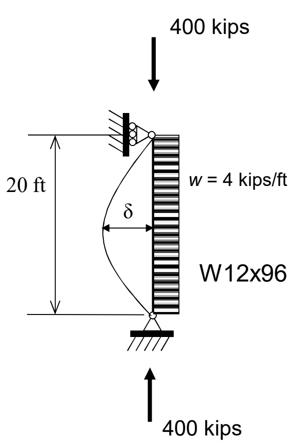
$$\text{Amplification Factor } = \frac{(220)}{200} = 1.10$$

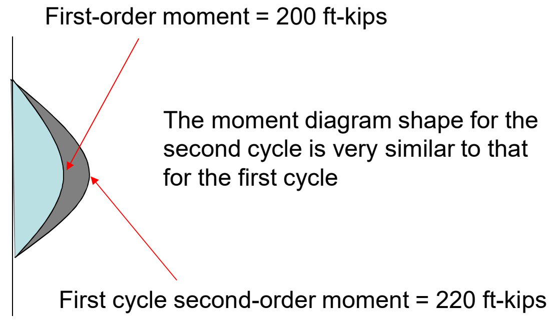
1.101

Structural Analysis

B

First Iteration on member effect



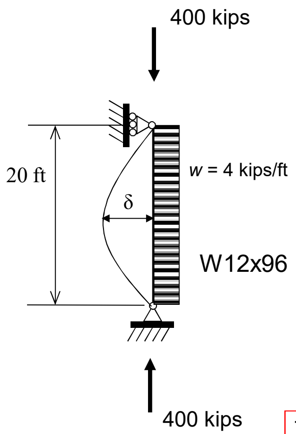


1.102

Structural Analysis

B

Second Iteration on member effect (Approximation)



$$\delta_{1st} = \frac{5Ml^2}{48EI} = \frac{5(19.9)(20)^2(1728)}{48(29000)(833)} = 0.0593 \text{ in.}$$

$$M_{2nd} = \frac{(400(0.0593))}{12} = 1.98 \text{ ft-kips}$$

$$M_r = 200 + 19.9 + 1.98 = 222 \text{ ft-kips}$$

$$\text{Amplification Factor} = \frac{(222)}{200} = 1.11$$

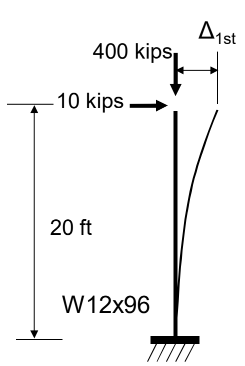
This can be expected to accurately estimate the amplification

1.103

Structural Analysis

C

First Iteration on sidesway effect



$$\Delta_{1st} = \frac{Hl^3}{3EI} = \frac{10(20)^3(1728)}{3(29000)(833)} = 1.91 \text{ in.}$$

$$M_{2nd} = \frac{1.91 \text{ in. } (400 \text{ kips})}{12} = 63.7 \text{ ft-kips}$$

$$M_r = 10(20) + 63.7 = 264 \text{ ft-kips}$$

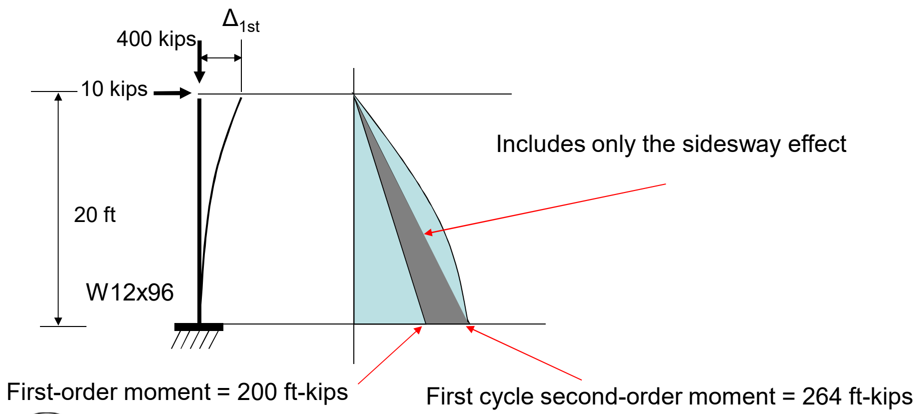
$$\text{Amplification Factor} = \frac{(264)}{200} = 1.32$$

1.104

Structural Analysis

C

First Iteration on sidesway effect

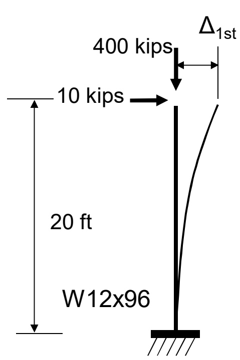


1.105

Structural Analysis

C

Second Iteration on sidesway effect (Approximation)



$$H_2 = \frac{63.7}{20} = 3.19 \text{ kips}$$

$$\Delta_{1st} = \frac{Hl^3}{3EI} = \frac{3.19(20)^3(1728)}{3(29000)(833)} = 0.608 \text{ in.}$$

$$M_{2nd} = \frac{0.608 \text{ in. } (400 \text{ kips})}{12} = 20.3 \text{ ft-kips}$$

$$M_r = 200 + 63.7 + 20.3 = 284 \text{ ft-kips}$$

$$\text{Amplification Factor } = \frac{(284)}{200} = 1.42$$

This might be expected to under estimate the amplification

1.106

Structural Analysis

- This has illustrated that the moments, when considering second-order effects, are larger than those when only first-order effects are considered.
- This can be very significant when comparing required strength and available strength.

1.107

Summary

- Looked at AISC as the basis for structural steel design
- Considered safety and a model for developing a specification
- Identified the shapes of structural steel members that are available to the designer
- Reviewed steel as a material
- Discussed structural analysis

1.108

Lesson 2

- The next lesson will look at the principles of design for tension members.
- We will look primarily at the material in Chapter D of the *Specification*
- We will also look at Part 5 of the *Manual*

1.109

Thank You

American Institute of Steel Construction
130 East Randolph St., Suite 2000
Chicago, IL 60601

1.110

Individual Session Registrants

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!

Individual Session Registrants

PDH Certificates

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

8-Session Registrants

PDH Certificates

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

8-Session Registrants

Access to the quiz

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

Quiz and attendance records

Posted Thursday mornings. www.aisc.org/nightschool -- Click on Current Course Details.

Reasons for quiz

- EEU – You must take all quizzes and the final exam to receive EEU.
- PDHs – If you watch a recorded session, you must pass quiz for PDHs.
- REINFORCEMENT – Reinforce what you learn tonight. Get more out of the course.

Note: If you attend the live presentation, you do not have to take the quizzes to receive PDHs

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Access to the recording

Information for accessing the recording will be emailed to you by Thursday. The recording will be available for four weeks. (For 8-session registrants only.)
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PDHs via recording

If you watch a recorded session, you must take *and pass* the quiz for PDHs.

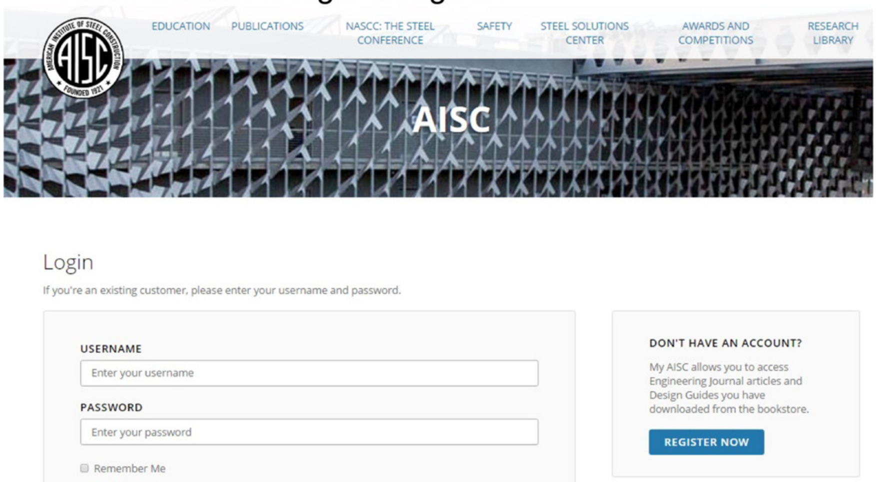
8-Session Registrants

Night School Resources

Find all your handouts, quizzes and quiz scores, recording access, and attendance information all in one place!

Night School Resources for 8-session package Registrants

Go to www.aisc.org and sign in.



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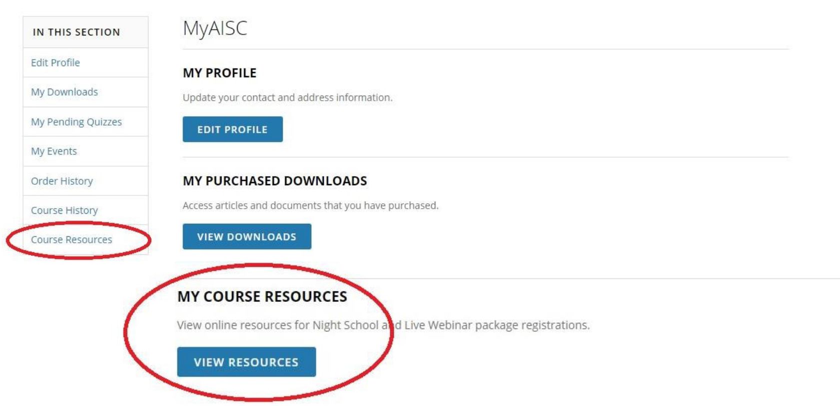

Please fill out our brief survey at the conclusion of the webinar. We greatly appreciate your feedback.

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Smarter.
Stronger.
Steel.