

AISC Live Webinars

Basic Steel Design

Session R1: Introduction to Basic Steel Design

Originally Recorded: January 28, 2020



Smarter.
Stronger.
Steel.

AISC Live Webinars

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This recorded webinar is available to you upon registration for the AISC webinar series, *Basic Steel Design*.

Note that some slides in this handout have been updated to match the details of this webinar series. These details will not match those presented in the recorded presentation, which was originally presented as part of a past Night School course. However, the technical content of the presentation is unchanged.



Smarter.
Stronger.
Steel.



AISC Live Webinars

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Course Description

Introduction to Basic Steel Design

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

Lesson R1 Introduction



Basic Steel Design

- 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

Basic Steel Design - Lessons

R1. Introduction	Recorded
L1. Tension Members	2/25/2021
L2. Compression Members	3/4/2021
L3. Bending Members	3/11/2021
L4. Compression plus Bending	3/18/2021



1.10



Lesson R1 - 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

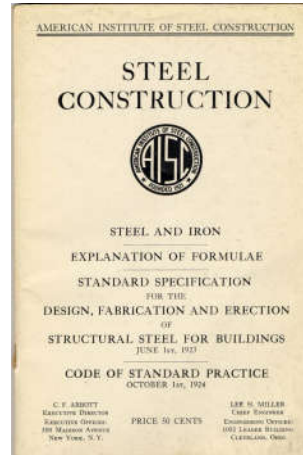
The city's oldest surviving
department store building



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



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

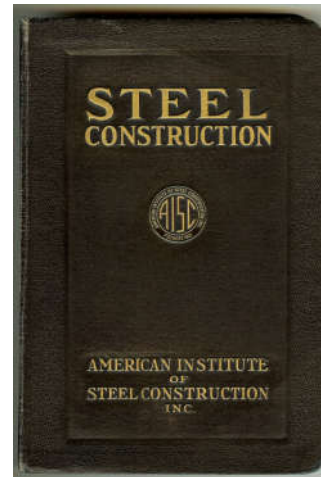
October 8, 1924



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

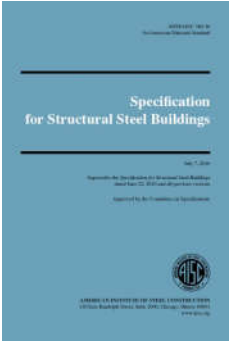
Specification For Structural Steel Buildings

July 7, 2016

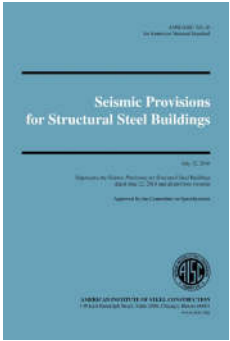


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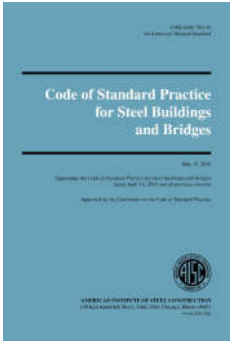
2016 AISC Specification




Basic Requirements



Seismic Requirements



Contractual Provisions

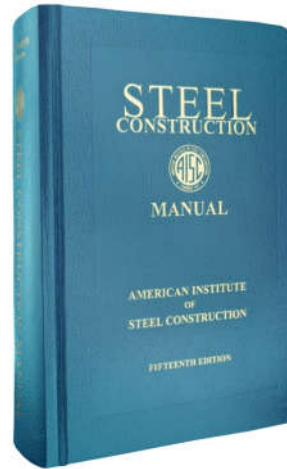


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2016 AISC Specification

Steel Construction Manual,
15th Edition



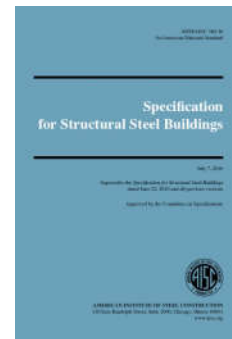
1.25

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

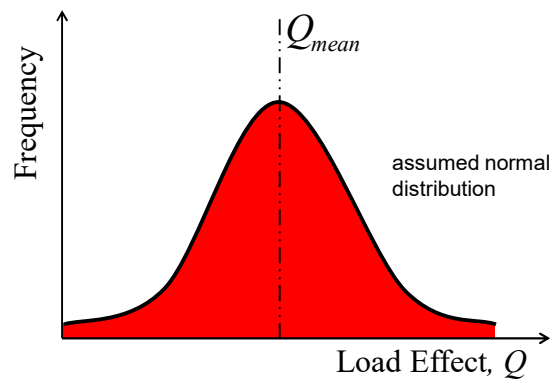
- The way we measure what the load does to our structures, M , V , P , etc.
 - Addressed in Chapter C of AISC *Specification*
- Factors influencing Load Effect
 - Type of load; live, dead, wind, etc.
 - Variability for specific load type
 - Calculation of load effect, $M = wl^2/8$, etc.
 - Likelihood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

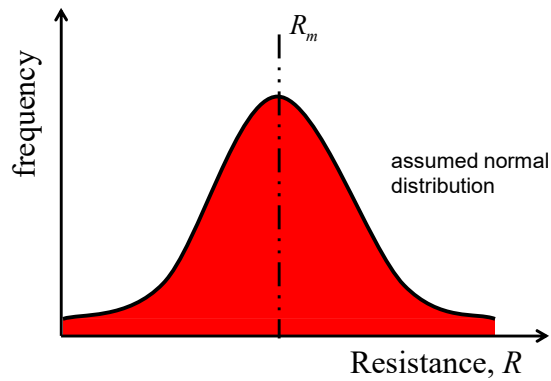
- Variability of member strength due to
 - variability of material properties
 - variability of dimensions
 - model error
 - increased risk due to a non-warning type failure
 - importance of member within system
 - designer's familiarity with method



1.40



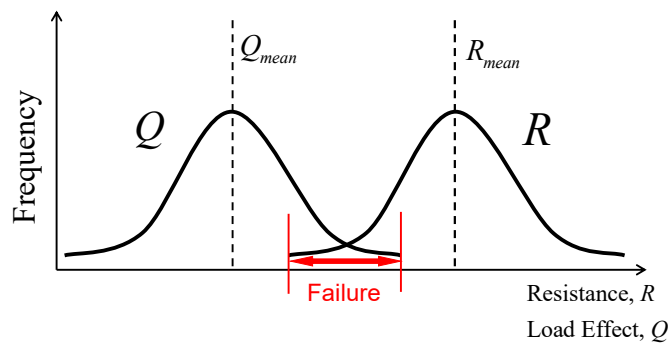
Variability of Resistance



1.41

Definition of Failure

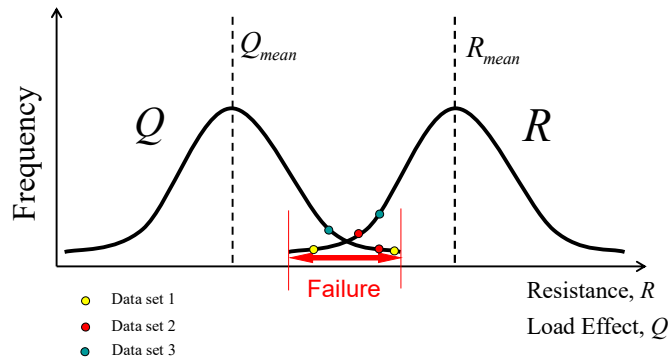
- Distribution of Resistance and Load Effect



1.42

Definition of Failure

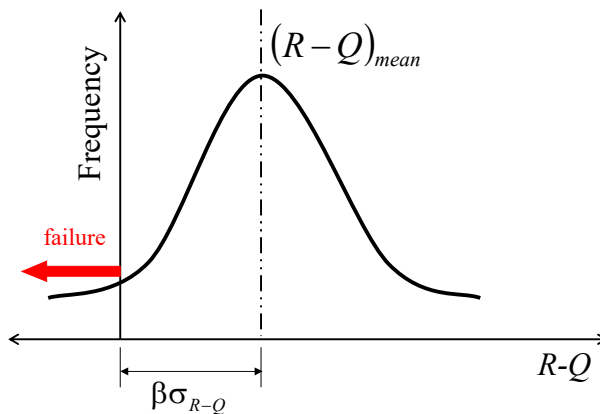
- Distribution of Resistance and Load Effect



1.43

Definition of Failure

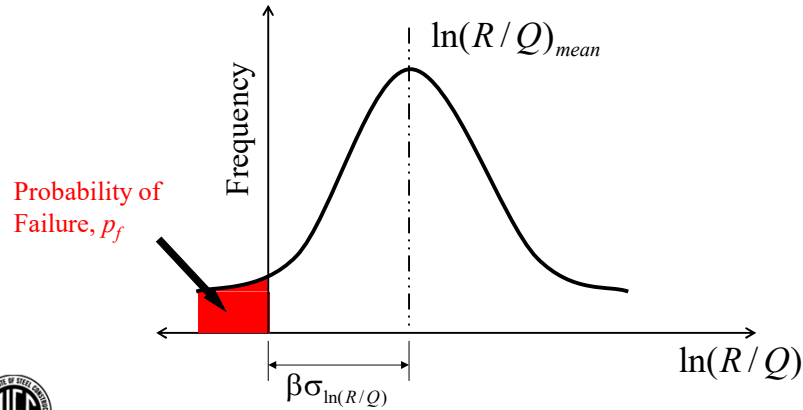
- Distribution of (Resistance - Load Effect)



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 \pm one standard deviation
 - 95 % fall with mean \pm 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.

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



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



1.54

Load Effect

$$Q = E(c_D AD + c_L BL)$$

- 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

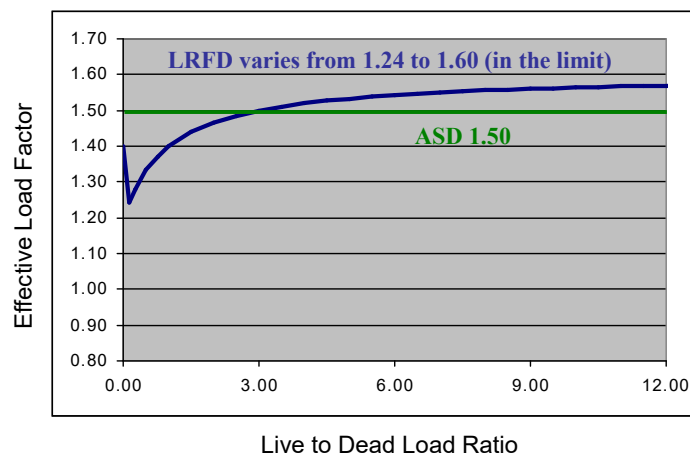
Load Factors

- 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

$$\text{for LRFD} \quad 1.2D + 1.6L \leq \phi R_n$$

$$\text{and for ASD} \quad D + L \leq \frac{R_n}{\Omega}$$



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 $L/D = 3$

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

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

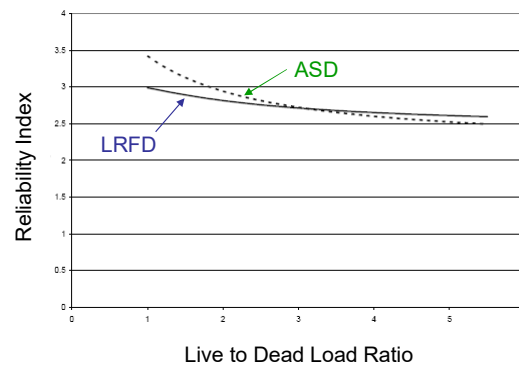
There is a consistent relationship between safety factors and resistance factors in AISC 360 but not between ASD and LRFD load combinations in ASCE 7, thus reliability varies.



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.



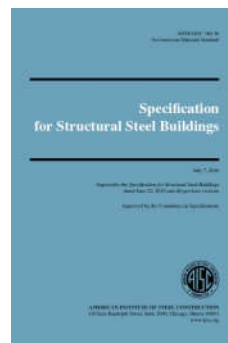
Compact,
laterally
supported beam



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

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

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

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

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

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

$$\phi_t = 0.90 \text{ (LRFD)} \quad \Omega_t = 1.67 \text{ (ASD)}$$



1.72

Application of Design Basis

LRFD

Required Strength \leq Design Strength

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



1.73

Application of Design Basis

• ASD

Required Strength \leq Allowable Strength

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



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 Piling¹



1.76

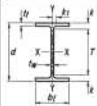
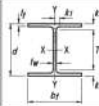
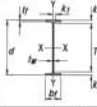
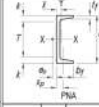
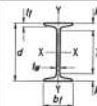
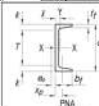
Structural Steel Shapes

- 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

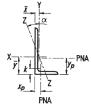
 <p>Table 1-1 (continued) W-Shapes Dimensions</p> <p>283 W16x26</p> <table border="1"> <thead> <tr> <th rowspan="2">Shape</th> <th rowspan="2">Area, A</th> <th rowspan="2">Depth, d</th> <th colspan="2">Web</th> <th colspan="2">Flange</th> <th colspan="2">Distance</th> <th rowspan="2">Workable Gage</th> </tr> <tr> <th>Thickness, t_w</th> <th>t_w/2</th> <th>Width, b_f</th> <th>Thickness, t_f</th> <th>k</th> <th>T</th> </tr> </thead> <tbody> <tr> <td>W16x26</td> <td>35.5</td> <td>24.5</td> <td>0.800</td> <td>1/16</td> <td>1/16</td> <td>8.05</td> <td>11</td> <td>2</td> <td>20 1/2</td> <td>4</td> </tr> </tbody> </table>	Shape	Area, A	Depth, d	Web		Flange		Distance		Workable Gage	Thickness, t _w	t _w /2	Width, b _f	Thickness, t _f	k	T	W16x26	35.5	24.5	0.800	1/16	1/16	8.05	11	2	20 1/2	4	 <p>Table 1-4 HP-Shapes Dimensions</p> <p>22 HP10x57</p> <table border="1"> <thead> <tr> <th rowspan="2">Shape</th> <th rowspan="2">Area, A</th> <th rowspan="2">Depth, d</th> <th colspan="2">Web</th> <th colspan="2">Flange</th> <th colspan="2">Distance</th> <th rowspan="2">Workable Gage</th> </tr> <tr> <th>Thickness, t_w</th> <th>t_w/2</th> <th>Width, b_f</th> <th>Average Thickness, t_f</th> <th>k</th> <th>T</th> </tr> </thead> <tbody> <tr> <td>HP10x57</td> <td>17.1</td> <td>18.0</td> <td>0.700</td> <td>1/16</td> <td>1/16</td> <td>4.20</td> <td>4 1/2</td> <td>0.625</td> <td>1 1/2</td> <td>17 1/2</td> <td>15 1/2</td> <td>2 1/2</td> <td>1.35</td> <td>17.4</td> </tr> </tbody> </table>	Shape	Area, A	Depth, d	Web		Flange		Distance		Workable Gage	Thickness, t _w	t _w /2	Width, b _f	Average Thickness, t _f	k	T	HP10x57	17.1	18.0	0.700	1/16	1/16	4.20	4 1/2	0.625	1 1/2	17 1/2	15 1/2	2 1/2	1.35	17.4				
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 <p>Table 1-3 S-Shapes Dimensions</p> <p>28 S10x35</p> <table border="1"> <thead> <tr> <th rowspan="2">Shape</th> <th rowspan="2">Area, A</th> <th rowspan="2">Depth, d</th> <th colspan="2">Web</th> <th colspan="2">Flange</th> <th colspan="2">Distance</th> <th rowspan="2">Workable Gage</th> </tr> <tr> <th>Thickness, t_w</th> <th>t_w/2</th> <th>Width, b_f</th> <th>Thickness, t_f</th> <th>k</th> <th>T</th> </tr> </thead> <tbody> <tr> <td>S10x35</td> <td>35.5</td> <td>24.5</td> <td>0.800</td> <td>1/16</td> <td>1/16</td> <td>8.05</td> <td>11</td> <td>2</td> <td>20 1/2</td> <td>4</td> </tr> </tbody> </table>	Shape	Area, A	Depth, d	Web		Flange		Distance		Workable Gage	Thickness, t _w	t _w /2	Width, b _f	Thickness, t _f	k	T	S10x35	35.5	24.5	0.800	1/16	1/16	8.05	11	2	20 1/2	4	 <p>Table 1-6 MC-Shapes Dimensions</p> <p>40 MC12x50</p> <table border="1"> <thead> <tr> <th rowspan="2">Shape</th> <th rowspan="2">Area, A</th> <th rowspan="2">Depth, d</th> <th colspan="2">Web</th> <th colspan="2">Flange</th> <th colspan="2">Distance</th> <th rowspan="2">Workable Gage</th> </tr> <tr> <th>Thickness, t_w</th> <th>t_w/2</th> <th>Width, b_f</th> <th>Average Thickness, t_f</th> <th>k</th> <th>T</th> </tr> </thead> <tbody> <tr> <td>MC12x50</td> <td>17.1</td> <td>18.0</td> <td>0.700</td> <td>1/16</td> <td>1/16</td> <td>4.20</td> <td>4 1/2</td> <td>0.625</td> <td>1 1/2</td> <td>17 1/2</td> <td>15 1/2</td> <td>2 1/2</td> <td>1.35</td> <td>17.4</td> </tr> </tbody> </table>	Shape	Area, A	Depth, d	Web		Flange		Distance		Workable Gage	Thickness, t _w	t _w /2	Width, b _f	Average Thickness, t _f	k	T	MC12x50	17.1	18.0	0.700	1/16	1/16	4.20	4 1/2	0.625	1 1/2	17 1/2	15 1/2	2 1/2	1.35	17.4				
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1.78



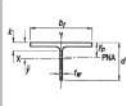
Structural Steel Shapes



**Table 1-7
Angles
Properties**

**137
L6x6x1**

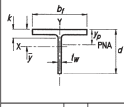
Shape	k	WT	Area, A		Axis X-X							Flexural-Torsional Properties		
			in.	lb/ft	in. ²	in. ⁴	in. ³	in.	in. ²	in.	in. ⁴	in. ⁴	in. ⁶	in.
L8x8x1 1/4	1 1/4	56.9	16.8	98.1	17.5	2.41	2.40	31.6	1.05	7.13	32.5	4.29		
			15.1	89.1	15.8	2.43	2.36	28.5	0.944	5.06	23.4	4.32		



**Table 1-9
MT-Shapes
Dimensions**

**14
MT6x5.4**

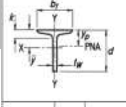
Shape	Area, A	Depth, d	Stem		Flange		Distance						
			Thickness, t _w	L _w /2	Width, b _f	Thickness, t _f	k	Workable Gage					
MT6.25-6.75	1.82	6.27	6 5/16	0.195	3/4	3/4	0.971	3.75	3 3/4	0.228	1/4	3/8	—



**Table 1-8
WT-Shapes
Dimensions**

**283
WT8x13**

Shape	Area, A	Depth, d	Stem		Flange		Distance		Workable Gage				
			Thickness, t _w	L _w /2	Width, b _f	Thickness, t _f	k	K _{ext}					
WT22-167.5F	49.2	22.0	22	1.03	1	22.6	15.9	16	1.77	1 3/4	2.56	2 1/8	5 1/2
x145F	42.6	21.8	21 1/4	0.965	7/8	17.0	15.8	15 1/4	1.42	1 3/8	2.20	2 1/4	4
x131F	38.5	21.7	21 1/4	0.765	1 1/8	15.2	15.8	15 1/4	1.22	1 1/4	2.01	2 1/4	4
x115F	33.9	21.5	21 1/4	0.710	1 1/8	15.2	15.8	15 1/4	1.22	1 1/4	2.01	2 1/4	4



**Table 1-10
ST-Shapes
Dimensions**

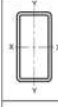
**28
ST10x48**

Shape	Area, A	Depth, d	Stem		Flange		Distance					
			Thickness, t _w	L _w /2	Width, b _f	Thickness, t _f	k	Workable Gage				
ST12-60.5	17.8	12.3	12 1/4	0.800	7/16	9.50	8.05	8	1.09	1 1/8	2	4
x53	15.6	12.3	12 1/4	0.620	9/16	8.94	7.25	7 1/4	0.870	7/8	1 1/2	4
ST12-50	14.7	12.0	12	0.743	5/8	8.94	7.25	7 1/4	0.870	7/8	1 1/2	4
x45	13.2	12.0	12	0.625	7/8	8.94	7.25	7 1/4	0.870	7/8	1 1/2	4
x40F	11.7	12.0	12	0.500	1 1/4	8.00	7.00	7	0.870	1 1/4	1 1/4	4



1.79

Structural Steel Shapes



**Table 1-11
Rectangular HSS
Dimensions and Properties**

281 HSS20x4x1/2

Shape	Design Wall Thickness, t	Nominal Width, B	Nominal Depth, D	Area, A		Moment of Inertia, I _x	Moment of Inertia, I _y	Torsion Constant, J
				in. ²	in. ⁴			
HSS20x12x1/4	1/4	127	107	0.581	127	0.465	107	0.349
	3/8	78	65	0.349	78	0.291	65	0.291
	1/2	57	48	0.291	57	0.291	48	0.291
HSS20x8x1/4	1/4	110	88	0.581	110	0.465	88	0.349
	3/8	88	72	0.349	88	0.291	72	0.291
	1/2	65	53	0.291	65	0.291	53	0.291

281 HSS20x4x1/2




**Table 1-12
Square HSS
Dimensions and Properties**

107 HSS5x5x1/2

Shape	Design Wall Thickness, t	Nominal Width, B	Nominal Depth, D	Area, A		Moment of Inertia, I _x	Moment of Inertia, I _y	Torsion Constant, J
				in. ²	in. ⁴			
HSS16-HSS8	1/4	127	107	0.581	127	0.465	107	0.349
	3/8	78	65	0.349	78	0.291	65	0.291
	1/2	57	48	0.291	57	0.291	48	0.291

107 HSS5x5x1/2




**Table 1-13
Round HSS
Dimensions and Properties**

128 HSS7x0.500

Shape	Design Wall Thickness, t	Nominal Width, B	Nominal Depth, D	Area, A		Moment of Inertia, I _x	Moment of Inertia, I _y	Torsion Constant, J
				in. ²	in. ⁴			
HSS16-HSS10	1/4	127	107	0.581	127	0.465	107	0.349
	3/8	78	65	0.349	78	0.291	65	0.291
	1/2	57	48	0.291	57	0.291	48	0.291

128 HSS7x0.500



**Table 1-14
Pipe
Dimensions and Properties**

51 Pipe 12 Std.

Shape	Nominal WT	Dimensions		Nominal Outside Diameter	Nominal Wall Thickness	Area	D _o ²	I	S	r	J	Z
		in.	mm									
HSS20-0.500	0.483	20	508	20	0.483	301	40,000	1,100	110	10	1,100	300
		508	508	0.483	301	40,000	1,100	110	1,100	300		
HSS18-0.500	0.465	18	457	18	0.465	267	32,400	800	100	10	800	260
		457	457	0.465	267	32,400	800	100	800	260		
HSS16-0.625	0.581	16	406	16	0.625	201	25,600	600	90	10	600	200
		406	406	0.625	201	25,600	600	90	600	200		
HSS14-0.500	0.465	14	354	14	0.465	153	17,640	400	70	10	400	150
		354	354	0.465	153	17,640	400	70	400	150		
HSS12-0.500	0.465	12	305	12	0.465	106	12,960	300	60	10	300	100
		305	305	0.465	106	12,960	300	60	300	100		

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/ft³
- 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* (ksi)	F _t Tensile Stress* (ksi)	Applicable Shape Series													
				W	M	S	HP	C	MC	L	Round	HSS	Plate				
AISC SLS	A36	36	58-60														
	A572 Gr 50	50	65														
	A572 Gr 55	55	70														
	A572 Gr 60	60	75														
A307	A307 Gr A	36	58														
	A307 Gr B	50	70														
	A307 Gr 50	50	65-100														
	A307 Gr 55	55	70-100														
A309	A309 Gr 30	30	58-60														
	A309 Gr 35	35	58-60														
	A309 Gr 40	40	58-60														
	A309 Gr 50	50	65-100														
A312	A312 Gr 30	30	58-60														
	A312 Gr 35	35	58-60														
	A312 Gr 40	40	58-60														
	A312 Gr 50	50	65-100														
A313	A313 Gr 30	30	58-60														
	A313 Gr 35	35	58-60														
	A313 Gr 40	40	58-60														
	A313 Gr 50	50	65-100														
A314	A314 Gr 30	30	58-60														
	A314 Gr 35	35	58-60														
	A314 Gr 40	40	58-60														
	A314 Gr 50	50	65-100														
A315	A315 Gr 30	30	58-60														
	A315 Gr 35	35	58-60														
	A315 Gr 40	40	58-60														
	A315 Gr 50	50	65-100														
A318	A318 Gr 30	30	58-60														
	A318 Gr 35	35	58-60														
	A318 Gr 40	40	58-60														
	A318 Gr 50	50	65-100														
A319	A319 Gr 30	30	58-60														
	A319 Gr 35	35	58-60														
	A319 Gr 40	40	58-60														
	A319 Gr 50	50	65-100														
A320	A320 Gr 30	30	58-60														
	A320 Gr 35	35	58-60														
	A320 Gr 40	40	58-60														
	A320 Gr 50	50	65-100														
A321	A321 Gr 30	30	58-60														
	A321 Gr 35	35	58-60														
	A321 Gr 40	40	58-60														
	A321 Gr 50	50	65-100														
A322	A322 Gr 30	30	58-60														
	A322 Gr 35	35	58-60														
	A322 Gr 40	40	58-60														
	A322 Gr 50	50	65-100														
A323	A323 Gr 30	30	58-60														
	A323 Gr 35	35	58-60														
	A323 Gr 40	40	58-60														
	A323 Gr 50	50	65-100														

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,

$$F_y = 50 \text{ ksi}, F_u = 65 \text{ ksi}$$

- A36 for M, S, C, MC, L-shapes

$$F_y = 36 \text{ ksi}, F_u = 58 - 80 \text{ ksi}$$

- A572 Gr. 50 for HP-shapes

$$F_y = 50 \text{ ksi}, F_u = 65 \text{ ksi}$$



1.83

Steel as a Material

- Preferred HSS material specifications

- A500 Gr. C for

- Rectangular Tube $F_y = 50 \text{ ksi}, F_u = 62 \text{ ksi}$

- Round Tube $F_y = 46 \text{ ksi}, F_u = 62 \text{ ksi}$

- A53 Gr. B for Pipe

$$F_y = 35 \text{ ksi}, F_u = 60 \text{ ksi}$$



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.



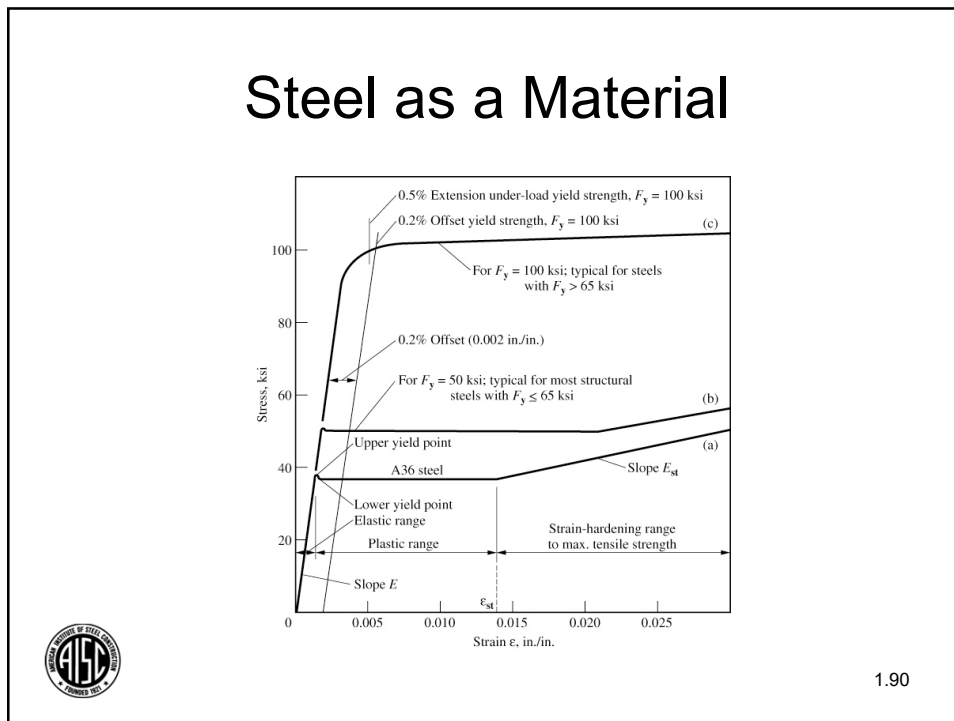
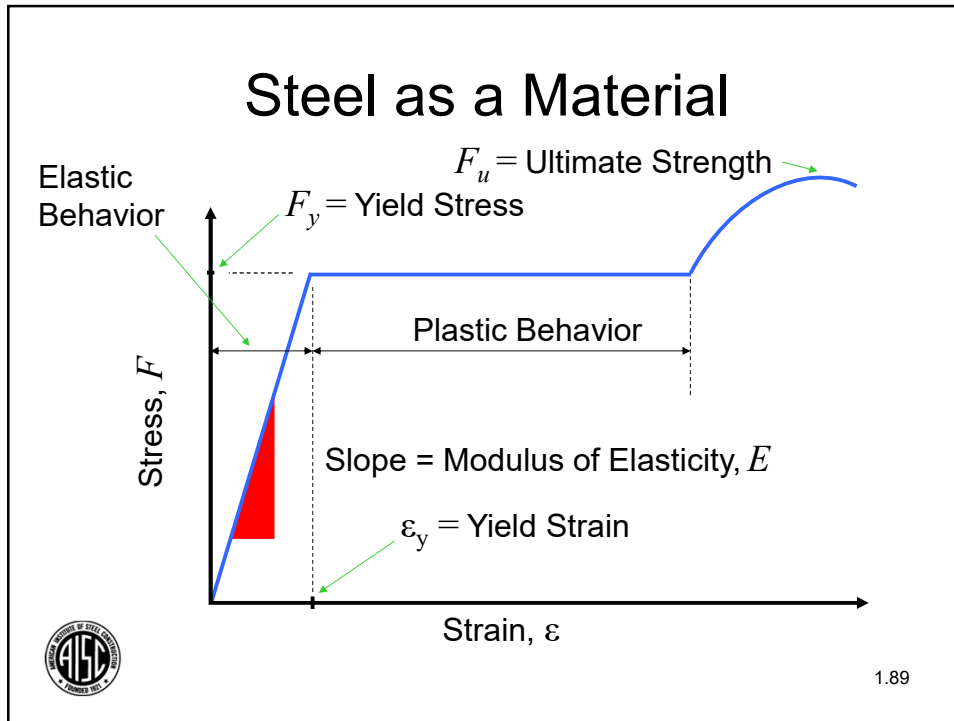
1.87

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.

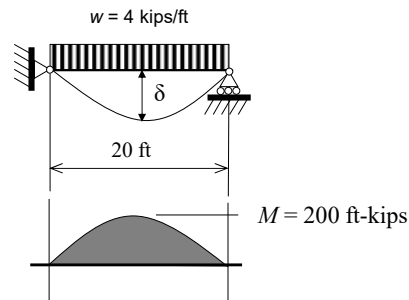


1.88



Structural Analysis

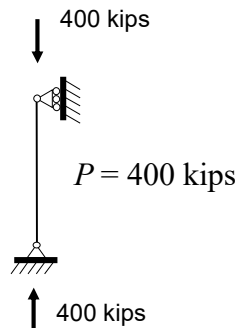
- The load effect is obtained through a structural analysis. It could be as simple as determining the moment on a simple beam



1.91

Structural Analysis

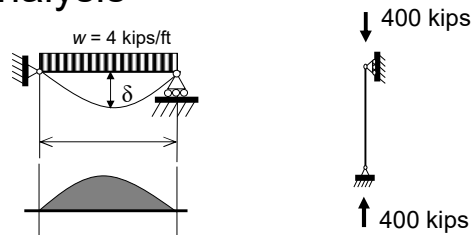
- or the compression in a column



1.92

Structural Analysis

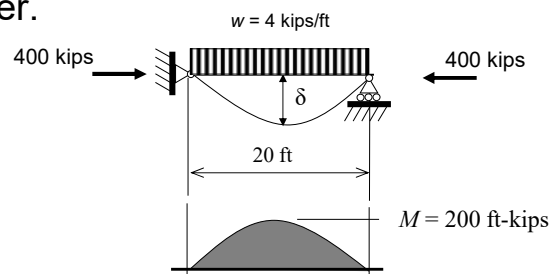
- In both situations, any deflection that occurs has no influence on the resulting forces or moments. This is called a first-order analysis



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

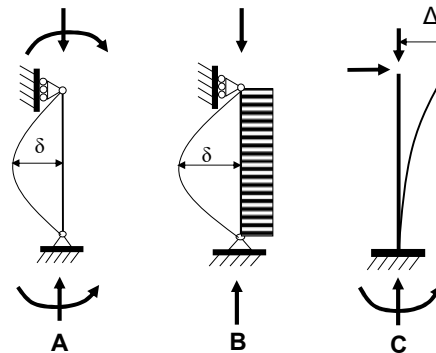
- We account for this increase with what is called a second-order analysis.
- The AISC *Specification*, Chapter C, requires that we design for these second-order effects.
- We can determine these second-order effects through approximate or rigorous methods.



1.95

Structural Analysis

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

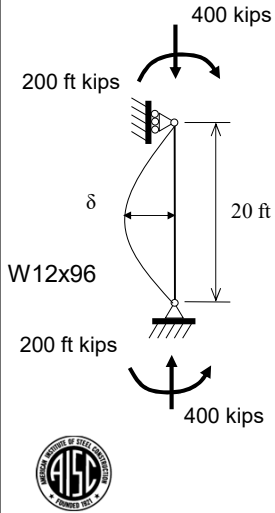


1.96

Structural Analysis

A

First Iteration on member effect



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

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

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

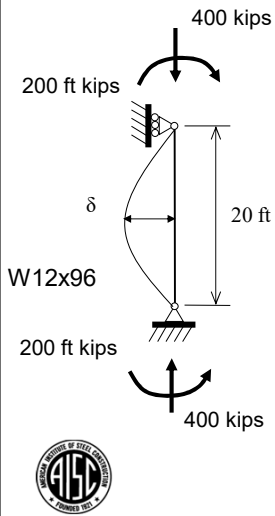
$$\text{Amplification Factor} = \frac{(224)}{200} = 1.12$$

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

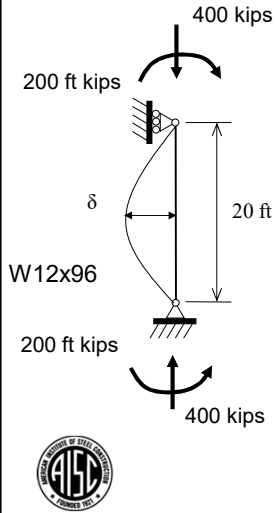
1.98



Structural Analysis

A

Second Iteration on member effect (Approximation)



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

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

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

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

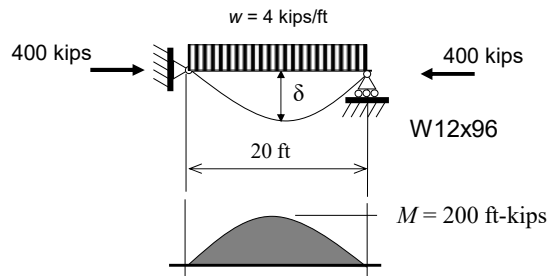
This might be expected to over estimate the amplification

1.99

Structural Analysis

B

Beam with axial force



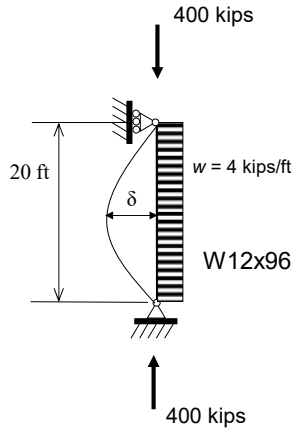
1.100



Structural Analysis

B

First Iteration on member effect



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

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

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

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

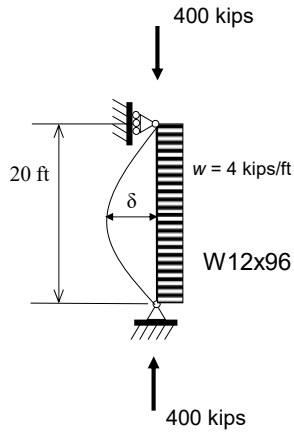


1.101

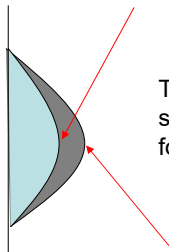
Structural Analysis

B

First Iteration on member effect



First-order moment = 200 ft-kips



The moment diagram shape for the second cycle is very similar to that for the first cycle

First cycle second-order moment = 220 ft-kips



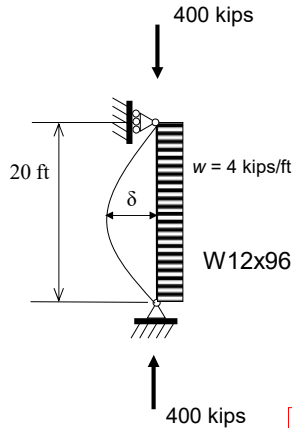
1.102



Structural Analysis

B

Second Iteration on member effect (Approximation)



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

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

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

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

This can be expected to accurately estimate the amplification

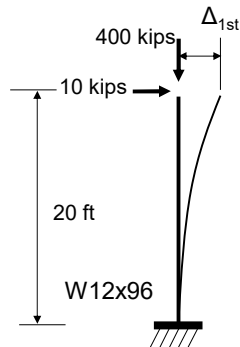


1.103

Structural Analysis

C

First Iteration on sidesway effect



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

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

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

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

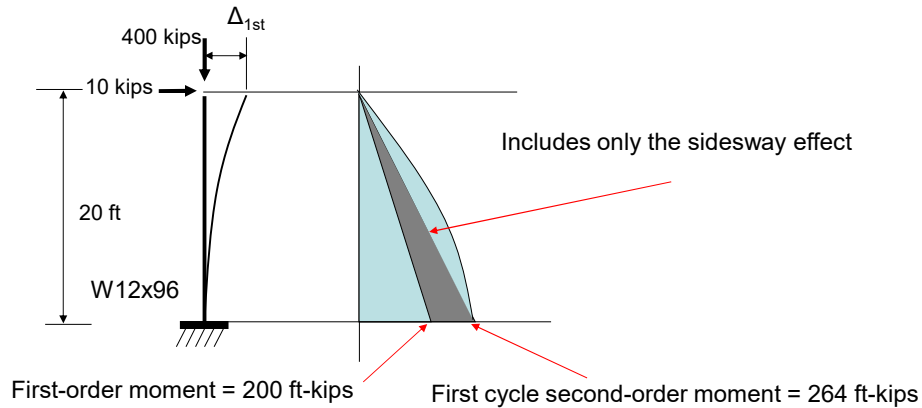


1.104

Structural Analysis

C

First Iteration on sidesway effect

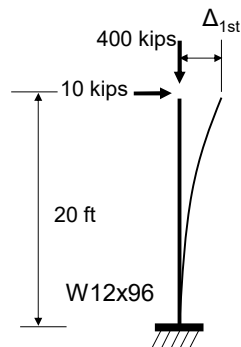


1.105

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 L1

- 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
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1.110



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8-Session Package-Design of Steel	1/2/1900 12:00:00 AM
8-Session Package-Design of Facade Attachments	5/9/2019 1:30:00 PM
05_15 8-Session Package-Night School 15 - Fundamentals of Connection Design	10/3/2017 7:00:00 PM
05_16 8-Session Package-Night School 16 - Seismic Design in Steel	2/5/2018 7:00:00 PM
05_17 8-Session Package-Night School 17 - Design of Facade Attachments	7/18/2018 7:00:00 PM
05_18 8-Session Package-Night School 18 - Steel Construction: Mill To Topping Out	10/15/2018 7:00:00 PM
05_19 8-Session Package-Night School 19 - Connection Design	2/4/2019 7:00:00 PM
05_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 - Concrete & Steeldeck	7/18/2018 1:30:00 PM



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Design of Facade Attachments

4-SESSION PACKAGE RESOURCES

Event	Date	Handouts	Video	Quiz	Attendance
R1: Facade Fundamentals	N/A	Handouts	Video Rescode AZN6175	Pass Score: 100	N/A
L1: Facade 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: Facade 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: Facade 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	



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