Training Course on Civil/Structural Codes and Inspection

U.S.NRC

UNITED STATES NUCLEAR REGULATORY COMMISSION

BMA Engineering, Inc.

Overall Outline

1000. Introduction
2000. Federal Regulations, Guides, and Reports
3000. Site Investigation
4000. Loads, Load Factors, and Load Combinations
5000. Concrete Structures and Construction
6000. **Steel Structures and Construction**
7000. General Construction Methods
8000. Exams and Course Evaluation
9000. References and Sources

6000. STEEL

- Objective and Scope
  - Provide an intermediate level review and practical application of structural analysis and design to steel buildings and nuclear power plant steel structures
  - Present and discuss
    - Structural Steel Design Data, Principles and Tools
    - Materials
    - Design and Behavior
    - Fabrication and Construction
    - Construction Testing and Examination

6000. STEEL

6100 & 6200
- 6130 - Design Data, Principles and Tools
- 6140 - Codes and Standards
- 6200 - Material

6300
- 6310 - Members and Components
- 6320 - Connections, Joints and Details
- 6330 - Frames and Assembles

6400
- 6410 - AISC Specifications for Structural Joints
- 6420 - AISC 303 Code of Standard Practice
- 6430 - AWS D1.1 Structural Welding Code

6500
- 6510 - Nondestructive Testing Methods
- 6520 - AWS D1.1 Structural Welding Code Tests

6600
- 6610 - Steel Construction
- 6620/6630 - NUREG-0800 / RG 1.94

6000. STEEL

- Applicable Codes and Specifications, and applicable NRC Publications
  - AISC N690 Specification for the Design, Fabrication and Erection of Steel Safety-Related Structures for Nuclear Facilities (which uses the 2005 AISC Specification for Structural Steel Buildings as the baseline document and modifies the specific portions of the specification for nuclear facilities)
  - Specifications for Structural Joints Using ASTM A325 or A490 Bolts
  - AISC 303 Code of Standard Practice for Steel Buildings and Bridges

6000. STEEL

- Applicable Codes and Specifications, and applicable NRC Publications
  - AWS D1.1 Structural Welding Code
  - ASTM Applicable Sections
  - NUREG-0800 Standard Review Plan (SRP) for the Review of Safety Analysis Reports for Nuclear Power Plants
  - RG 1.94 Quality Assurance Requirements for Installation, Inspection, and Testing of Structural Concrete and Structural Steel During the Construction Phase of Nuclear Power Plants

6000. STEEL

6100 & 6200
- 6130 - Design Data, Principles and Tools
- 6140 - Codes and Standards
- 6200 - Material

6300
- 6310 - Members and Components
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6100. Introduction - Structural Steel Design Data, Principles, and Tools

- Structural Steel Types, Mechanical and Physical Properties, and Steel Sections
- Selecting Design Principles for Steel Structures
- Selecting Computational Methods For Steel Structure Design
- Primary Design Considerations in the Design of Steel Structures

6200. Materials

- ASTM Related Sections

History of Structural Steel

Iron

- Chief component of steel
- Wrought iron first used for tools around 4000 BC
- Produced by heating ore in a charcoal fire
- Cast and wrought iron used in the late 18C and early 19C
- in bridges

History of Structural Steel

Structural Steel

- Steel is an alloy of primarily iron, carbon (1 to 2%) and small amount of other components (manganese, nickel, …)
- Fewer impurities and less carbon than cast iron
- Carbon contributes to strength but reduces ductility.
- Began to replace iron in construction in the mid 1800s
- First steel railroad bridge in 1874
- First steel framed building in 1884

Grades of Steel

Numerous grades of steel are available in the marketplace. The choice is dependent on

- Application
- Yield strength
- Composition

Applicable ASTM Specifications/ Shapes

**Table 2-1.
Applicable ASTM Specifications
for Various Structural Shapes**

Steel Type	ASTM Designation		F_y Min. Yield Stress (ksi)	F_u Tensile Stress[a] (ksi)	Applicable Shape Series									
					W	M	S	HP	C	MC	L	HSS Rect.	HSS Round	Steel 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		36	58								░	░	
	A529[c]	Gr. 50	50	65–100	░	░	░	░	░	░	░			
		Gr. 55	55	70–100	░	░	░	░	░	░	░			
High-Strength Low-Alloy	A572	Gr. 42	42	60	░	░	░	░	░	░	░			
		Gr. 50	50	65[d]	░	░	░	░	░	░	░			
		Gr. 55	55	70	░	░	░	░	░	░	░			
		Gr. 60[e]	60	75	░	░	░	░	░	░	░			
		Gr. 65[e]	65	80	░	░	░	░	░	░	░			
	A618[f]	Gr. I & II	50[g]	70[g]								░	░	
		Gr. III	50	65								░	░	
	A913	50	50[h]	60[h]	░	░	░	░	░	░	░			
		60	60	75	░	░	░	░	░	░	░			
		65	65	80	░	░	░	░	░	░	░			
		70	70	90	░	░	░	░	░	░	░			
	A992		50–65[i]	65[i]	■									
Corrosion Resistant High-Strength Low-Alloy	A242		42[j]	63[j]	░									
			46[k]	67[k]	░			░				░		
			50[l]	70[l]	░	░	░	░	░	░	░	░		
	A588		50	70	░	░	░	░	░	░	░	░		
	A847[f]		50	70								░	░	

■ = Preferred material specification.

░ = Other applicable material specification, the availability of which should be confirmed prior to specification.

(blank) = Material specification does not apply.

Applicable ASTM Specifications/ Fasteners

Table 2–5
Applicable ASTM Specifications for Various Types of Structural Fasteners

ASTM Designation		F_y Min. Yield Stress (ksi)	F_u Tensile Stress[a] (ksi)	Diameter Range (in.)	High-Strength Bolts: Conventional	High-Strength Bolts: Twist-Off-Type Tension-Control[d]	Common Bolts	Nuts	Washers	Direct-Tension-Indicator Washers	Threaded Rods	Shear Stud Connectors	Anchor Rods: Hooked	Anchor Rods: Headed	Anchor Rods: Threaded & Nutted
A108		—	65	0.375 to 0.75, incl.								■			
A325[d]		—	105	over 1 to 1.5 incl.	■										
		—	120	0.5 to 1, incl.	■										
A490		—	150	0.5 to 1.5	■										
F1852		—	105	1.125		■									
		—	120	0.5 to 1, incl.		■									
A194 Gr. 2H		—	—	0.25 to 4				▒							
A563		—	—	0.25 to 4				■							
F436[b]		—	—	0.25 to 4					■						
F959		—	—	0.5 to 1.5						■					
A36		36	58-80	to 10							■		▒		▒
A193 Gr. B7[e]		—	100	over 4 to 7							▒		▒		▒
		—	115	over 2.5 to 4							▒		▒		▒
		—	125	2.5 and under							▒		▒		▒
A307	Gr. A	—	60	0.25 to 4			■							▒	
	Gr. C	—	58-80	0.25 to 4							▒		▒		▒
A354 Gr. BD		—	140	2.5 to 4 incl.							▒		▒	▒	▒
		—	150	0.25 to 2.5, incl.							▒		▒	▒	▒
A449		—	90	1.75 to 3 incl.	c						▒		▒	▒	▒
		—	105	1.125 to 1.5, incl.	c						▒		▒	▒	▒
		—	120	0.25 to 1, incl.	c						▒		▒	▒	▒
A572	Gr. 42	42	60	to 6							▒		▒		▒
	Gr. 50	50	65	to 4							▒		▒		▒
	Gr. 55	55	70	to 2							▒		▒		▒
	Gr. 60	60	75	to 1.25							▒		▒		▒
	Gr. 65	65	80	to 1.25							▒		▒		▒
A588		42	63	Over 5 to 8, incl.							▒		▒		▒
		46	67	Over 4 to 5, incl.							▒		▒		▒
		50	70	4 and under							▒		▒		▒
A687		105	150 max.	0.625 to 3							▒		▒		▒
F1554	Gr. 36	36	58-80	0.25 to 4									■	■	■
	Gr. 55	55	75-95	0.25 to 4									▒	▒	▒
	Gr. 105	105	125-150	0.25 to 3									▒	▒	▒

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

Types of Steel

- Ordinary grades
- High-strength
- Special purpose

Ordinary Grades of Steel

Availability of Shapes, Plates and Bars According to ASTM Structure Steel Specifications

Ordinary Grade Steel	Steel Type	ASTM Des-igna-tion	F_y Mini-Mum Yield Stress (ksi)	F_u Ten-sile Stress[a] (ksi)	Shapes: Group per ASTM A6 [b]1	2	3	4	5	Plates and Bars: To 1/2" Incl.	Over 1/2" To 3/4" Incl.	Over 3/4" To 1 1/4" Incl.	Over 1 1/4" To 1 1/2" Incl.	Over 1 1/2" To 2" Incl.	Over 2" To 2 1/2" Incl.	Over 2 1/2" To 4" Incl.	Over 4" To 5" Incl.	Over 5" To 6" Incl.	Over 6" To 8" Incl.	Over 8"
	Carbon	A36	32	58-80																■
			36	58-80[c]	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
		A529	42	60-85	■					■										

[a] Minimum unless a range is shown.
[b] Includes bar-size shapes.
[c] For shapes over 426 lbs./ft, minimum of 58 ksi only applies.

■ Available

□ Not Available

For details, see AISC Steel Construction Manual 13th Ed. Table 2-4, page 2-40

Size Groupings

Structural Shape Size Groupings for Tensile Property Classification

Structural Shapes	Group 1	Group 2	Group 3	Group 4	Group 5
W Shapes	W 24 x 55, 62 W 21 x 44 to 57 incl. W 18 x 35 to 71 incl. W 16 x 26 to 57 incl. W 14 x 22 to 53 incl. W 12 x 14 to 58 incl. W 8 x 10 to 48 incl. W 0 x 9 to 25 incl. W 5 x 16, 19 W 4 x 13	W 44 x 244 W 40 x 49 to 268 incl. W 36 x 135 to 210 incl. W 33 x118 to 152 incl. W 30 x 90 to 211 incl. W 27 x 84 to 178 incl. W 24 x 68 to 162 incl. W 21 x 62 to 117 incl. W 18 x 78 to 143 incl. W 16 x 67 to 100 incl. W 14 x 61 to 132 incl. W 12 x 65 to 106 incl. W 10 x 49 to 112 incl. W 8 x 58, 67	W 44 x 248, 285 W 40 x 227 to 328 incl. W 36 x 230 to 300 incl. W 33 x 201 to 291 incl. W 30 x 235 to 261 incl. W 27 x 194 to 258 incl. W 24 x 176 to 229 incl. W 21 x 166 to 223 incl. W 18 x 158 to 192 incl. W 14 x 145 to 211 incl. W 12 x 120 to 190 incl.	W 40 x 362 to 655 incl. W 36 x 328 to 798 incl. W 33 x 318 to 619 incl. W 30 x 292 to 581 incl. W 27 x 281 to 539 incl. W 24 X 250 to 492 incl. W 21 x 248 to 402 incl. W 18 x 211 to 311 incl. W 12 x 210 to 336 incl.	W 36 x 848 W 14 x 6O5 to 730 incl.
M Shapes	to 37.7 lb/ft incl.				
S Shapes	to 35 lb/ft incl.				
HP Shapes		to 102 lb/ft incl.	over 102 lb/ft		
American Standards Channels (C)	to 20.7 lb/ft incl.	over 20.7 lb/ft			
Miscellaneous Channels (MC)	to 28.5 lb/ft incl.	over 28.5 lb/ft			
Angles (L) Structural Bar-size	to 1/2 in incl.	over 1/2 to 3/4 in. incl.	over 3/4 in.		

Notes: Structural tees from W, M, and S shapes fall into same group as the structural shape from which they are cut.
Group 4 and Group 5 shapes are generally contemplated as columns or compression components. When used in other applications (e.g., trusses) and when thermal cutting or welding is required, special material specification and fabrication procedures apply to minimize the possibility of cracking

High-Strength Steels

Availability of Shapes, Plates and Bars According to ASTM Structural Steel Specifications

Steel	Steel Type	ASTM Designation	F_y Minimum Yield Stress (ksi)	F_u Tensile Stress[a] (ksi)	Shapes: Group per ASTM A6 1[b]	2	3	4	5	Plates and Bars: To 1/2" Incl.	Over 1/2" to 3/4" Incl.	Over 3/4" to 1 1/4" Incl.	Over 1 1/4" to 1 1/2" Incl.	Over 1 1/2" to 2" Incl.	Over 2" to 2 1/2" Incl.	Over 2 1/2" to 4" Incl.	Over 4" to 5" Incl.	Over 5" to 6" Incl.	Over 6" to 8" Incl.	Over 8"
High-Strength Steel	High-Strength Low-alloy	A441	40	60													●	●	●	
			42	63				●	●					●	●	●				
			46	67			●					●	●							
			50	70	●	●				●	●									
		A572 Grade 42	42	60	●	●	●	●	●	●	●	●	●	●	●	●	●	●		
		A572 Grade 50	50	65	●	●	●	●	●	●	●	●	●	●	●	●	●			
		A572 Grade 60	60	75	●	●				●	●	●								
		A572 Grade 65	65	80	●					●	●	●								
		A242	42	63				●	●					●	●	●				
			46	67			●					●	●							
			50	70	●	●				●	●									
		A588	42	63														●	●	
			46	67													●			
			50	70	●	●	●	●	●	●	●	●	●	●	●	●				

[a] Minimum unless a range is shown.
[b] Includes bar-size shapes.
[c] For shapes over 426 lbs./ft, minimum of 58 ksi only applies.

● (yellow) Available

(blue) Not Available

For details, see AISC Steel Construction Manual 13th Ed. Table 2-4, page 2-40

Special Purpose Steels

Availability of Shapes, Plates and Bars According to ASTM Structural Steel Specifications

Steel	Steel Type	ASTM Designation	F_y Minimum Yield Stress (ksi)	F_u Tensile Stress[a] (ksi)	Shapes: Group per ASTM A6 1[b]	2	3	4	5	Plates and Bars: To 1/2" Incl.	Over 1/2" To 3/4" Incl.	Over 3/4" To 1 1/4" Incl.	Over 1 1/4" To 1 1/2" Incl.	Over 1 1/2" To 2" Incl.	Over 2" To 2 1/2" Incl.	Over 2 1/2" To 4" Incl.	Over 4" To 5" Incl.	Over 5" To 6" Incl.	Over 6" To 8" Incl.	Over 8"
Special Purpose Steel	Quenched & Tempered Low-alloy	A852[d]	70	90 - 110	●	●	●	●	●	●	●	●	●	●	●					
	Quenched & Tempered Low-alloy	A514[d]	90	100 - 130											●	●	●	●		
			100	100 - 130	●	●	●	●	●	●	●	●	●	●						

[a] Minimum unless a range is shown.
[b] Includes bar-size shapes.
[d] Plates only

(cyan) Available

(blue) Not Available

For details, see AISC Steel Construction Manual 13th Ed. Table 2-4, page 2-40

Factors Affecting Choice

CHECKLIST FOR USE OF HIGH-STRENGTH STEEL

In structural steel design, A36 is generally the most versatile and economical of the construction steels. However, there are occasions where the judicious use of high-strength steels can result in overall cost and weight savings, such as:

Tension Members
High-strength steels can usually be used to advantage in tension members except when the members are relatively small in section or when holes (i.e., for bolts or rivets) substantially reduce the net section of the member.

Beams
a. When steel dead load is a major portion of design load.
b. When deflection limitations are not a major factor in determining section.
c. When deflections can be reduced through design features such as continuity or composite design.
d. When weight is important.
e. When fabricating costs can be reduced.
f. When architectural considerations limit the beam dimensions.

Columns and Compression Members
a. When steel dead load is a major portion of design load.
b. When the slenderness ratio (L/r) of the member is small.
c. When weight is important.
d. When fabricating costs can be reduced.
e. When architectural considerations limit the column dimensions.

Mechanical Properties

- Tensile and compressive strength
- Yield strength
- Shear strength
- Elongation
- Ductility
- Hardness
- Chemical composition

Tensile and compressive strength

Tensile strength

- Resistance to a force acting to pull the material apart
- Determined by testing a specimen

Compressive Strength:

- Point at material under load experience crush failure
- For normal design practice, it is assumed to be equal to tensile strength

Stress and Strain Formulas

Normal Stress

$$\sigma = \frac{P}{A}$$

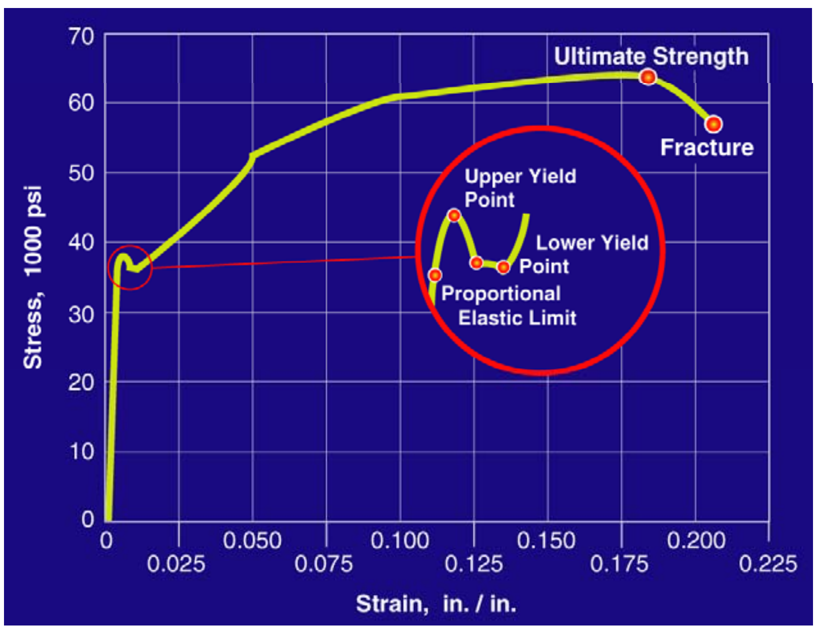
Where: σ = Stress
P = Applied load
A = Area

Strain

$$\varepsilon = \frac{\Delta L}{L_o}$$

ε = Strain
ΔL = Beam deflection
L_o = Starting length

Stress Strain Relationship



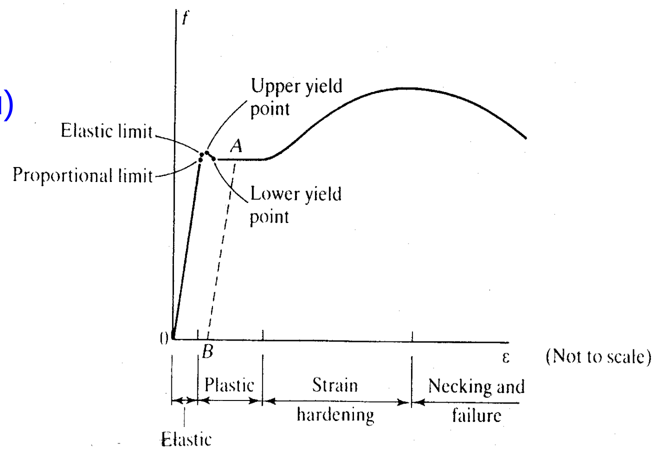
Steel Properties

- The important characteristics of steel for design purposes are:
  - yield stress (F_y)
  - ultimate stress (F_u)
  - modulus of elasticity (E)
  - percent elongation (ε)
  - coefficient of thermal expansion (α)

The Tension Test

4 Ranges of responses:

- Elastic
- Plastic (yield plateau)
- Strain hardening
- Necking and failure (strain softening)



Yield Strength

- Yield point is the point beyond which the material stretches briefly without an increase in load
- The stress at the yield point is the material's tensile yields strength

Shear Strength

The resistance to tearing or ripping of the material. The formula for computing shear stress is:

$$\tau = \frac{V}{A}$$

[which is an approximation of τ = VQ/ (It)]

where : τ = Shear stress
V = Applied shear force
A = Cross-sectional area

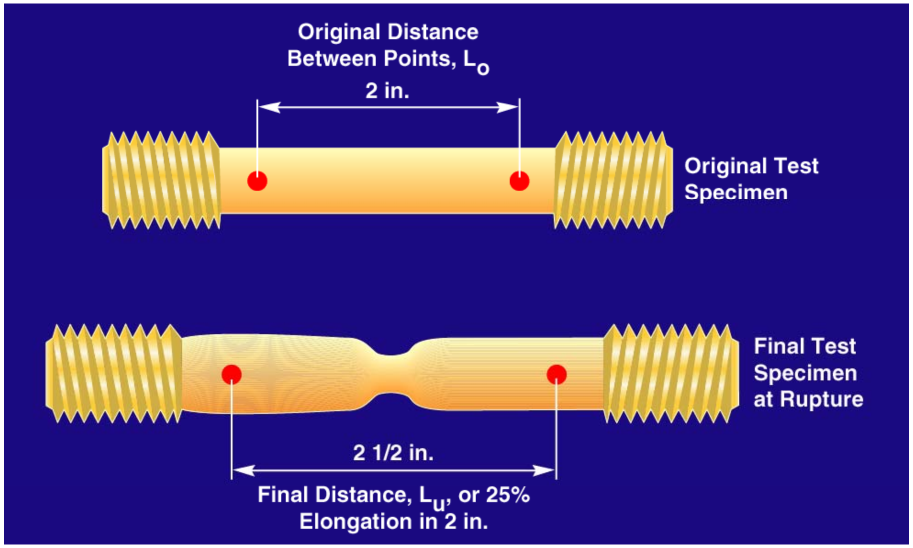
Elongation

The formula for computing elongation is:

$$e_u = 100 \frac{L_u - L_o}{L_o}$$

Where:
e_u = Elongation in percent
L_u = Length after elongation
L_o = Starting length

Elongation

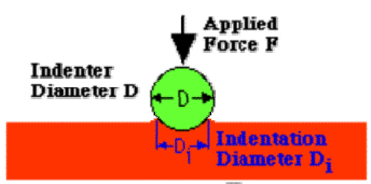


Ductility

- Ductility is the ability of a material to stretch and become permanently deformed without breaking or cracking.

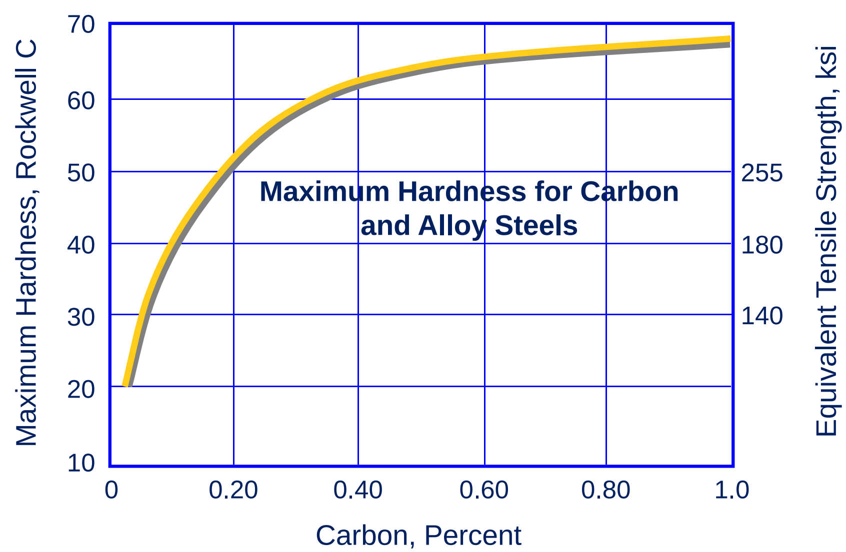
Hardness

Hardness is the ability of a material to resist indentation or penetration as measured by a hardness tester.



$$BHN = \frac{F}{\frac{\pi}{2}D \cdot (D - \sqrt{D^2 - D_i^2})}$$

Chemical Composition



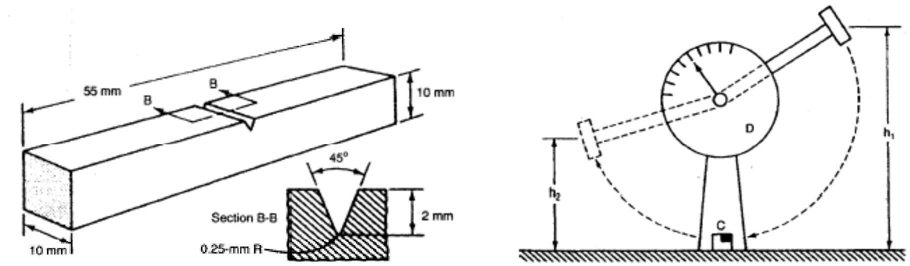
Material Toughness

- Charpy V-notch test was introduced
- Result of the test is a value for notch toughness (CVN) given by xx ft-lb at yy F. This is a characterization of the energy absorbed by the notched specimen

  (See AISC Manual pp 2-50 thru 2-53)

Material Toughness

Charpy V-notch test



Physical Properties

- Density (490 lb/ft^3)

$$\text{Density} = \frac{\text{Mass (M)}}{\text{Volume (V)}}$$

- Elastic Modulus or Young's Modulus (29,000 Ksi)
- Thermal expansion (.00065 /100^{o}F)
  - Example: 40' long medium steel, find the change of length from 60 ^{o}F to 90 ^{o}F
    Change in length=$\alpha\Delta T l$ = (.00065/100) x 30 x 40 = .0078 ft

Thermal Expansion

Formal for thermal expansion are:

Strain = $\alpha\,\Delta T$

e = $\alpha\,\Delta T L$

Where: α = Coefficient of thermal expansion

ΔT = Change in temperature

e = Change in length

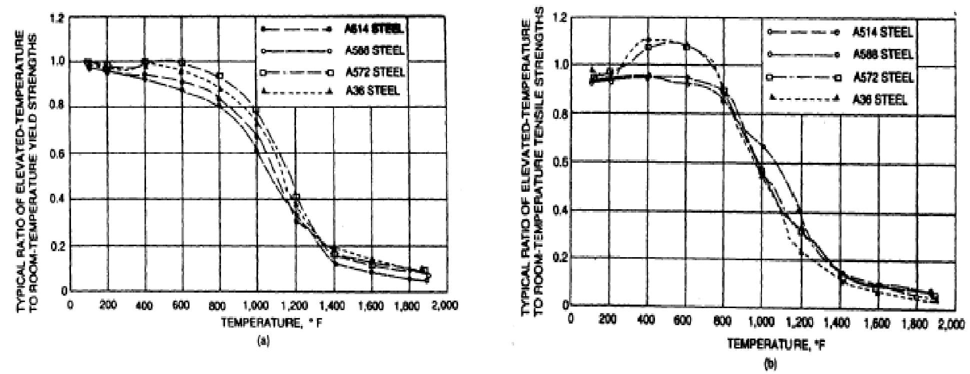
L = Original length

Effect of Temperature on the Properties of Steel

- Elevated temperatures generally degrade the properties of structural steel. Threshold temperatures vary as a function of mechanical property under consideration.
- Temperatures below room temperature do not have an adverse effect on F_y but can have a significant effect on ductility.
- Behavior will transform from ductile to brittle at a threshold temperature rang e known as the Ductile-to- Brittle Transition Temperature (DBTT) range.

Effect of Temperature on the Properties of Steel

- For sample information on the effect of temperature on yield stress, tensile strength, and Young's modulus



Properties Section

- Area of the section
- Moment of inertia
- Section modulus
- Radius of gyration

Area of Section

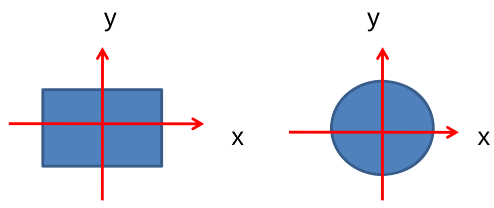
Area of cross-section (A) is applied to computations off:

- Simple tension
- Compression
- Shear

Moment of Inertia & Section Modules

Moment of inertia (I) of the cross section measures the resistance to rotation offered by the section:

- Geometry
- Size

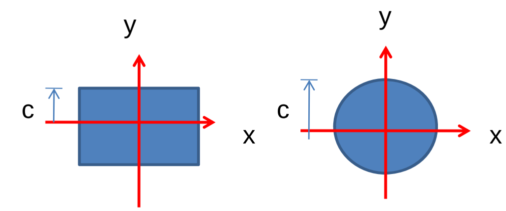


$I_{yy} > I_{xx}$ $\quad$ $I_{yy} = I_{xx}$

Section Modules

The formula for section modulus (S) is:

$$S = \frac{I}{C}$$



Radius of Gyration

The formula for radius of gyration (r) is:

$$r = \sqrt{\frac{I}{A}}$$

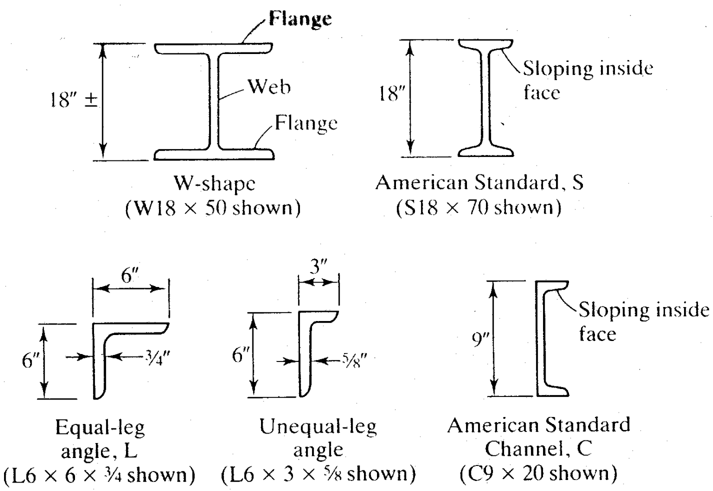
Steel Shapes

Hot-rolled shapes are produced from molten steel in a furnace that is poured into a continuous casting where the steel solidifies but does not cool completely. The partially cooled steel is then passed through rollers to achieve the desired shape.

(On the other hand, cold-formed steel (CFS) is from steel sheet, strip, plate, or flat bar in roll forming machines or by press brake or bending operations. The material thicknesses for such thin-walled steel members usually range from 0.0147 to about ¼”. (gage 6 = .2031”; gage 29 = .0141”))

Standard Cross-Sectional Shapes

W4 - W44
M3 – M12.5
S3 – S24
H8 – H14
C3 – C15
MC3 – MC18
L2½xL1½ - L8x8
WT2 – WT22
MT2 – MT6.25
ST1.5 – ST12

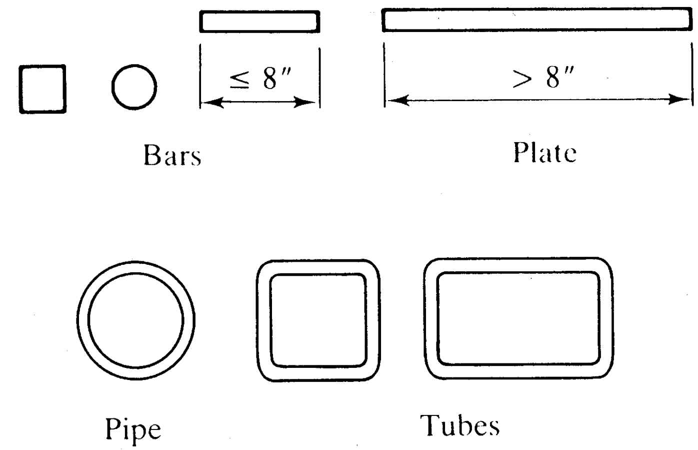


Standard Cross-Sectional Shapes

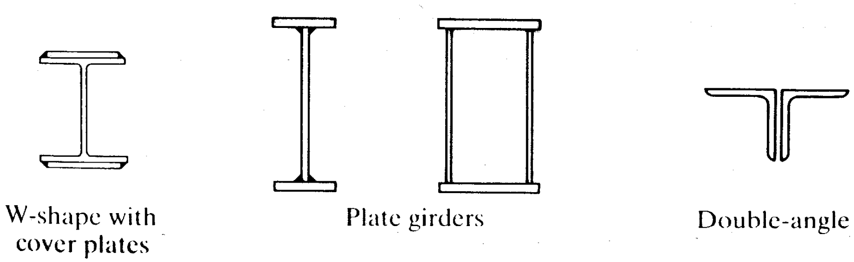
HSS2x1 – 20x12

HSS1.660 – 20.000

Pipe ½ Std. – 12 Std.
(x-Strong, xx-Strong)



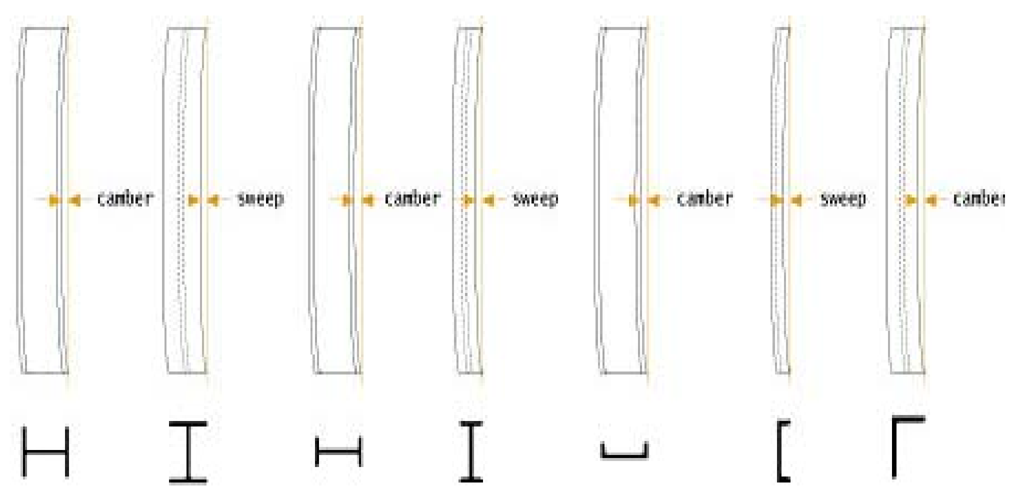
Standard Cross-Sectional Shapes



2L (LLBB or SLBB): 2L2x2 – 2L8x8

2C: 2C3 – 2C15
2MC: 2MC3 – 2MC18

Camber and Sweep



Standard Mill Practices

Variations are limited by the dimensional and profile tolerances summarized in:

- Hot-rolled Structural Shapes – ASTM A6 Section 13 & AISC Tables 1-22 through 1-26
- Hollow Structural Sections (HSS) – ASTM A500 Section 10, A501 Section 11, A618 Section 8 or A847 Section 10 & AISC Tables 1-27 & 1-28
- Pipe – ASTM A53 Section 12 & AISC Table 1-28
- Plate Products – ASTM Section 13 & AISC Table 1-29

Tolerances

- Mill Tolerances (above)
- Fabrication Tolerances – AISC Specification Section M2 & Code of Standard Practices Section 6.4
- Erection Tolerances - AISC Specification Section M4 & Code of Standard Practices Section 7.13
- Building Façade Tolerances - Code of Standard Practices Section 7.13.1.3

Accumulation of the mill tolerances and fabrication tolerances shall not cause the erection tolerances to be exceeded per Code of Standard Practices Section 7.12

Wide-flange (W) Shapes

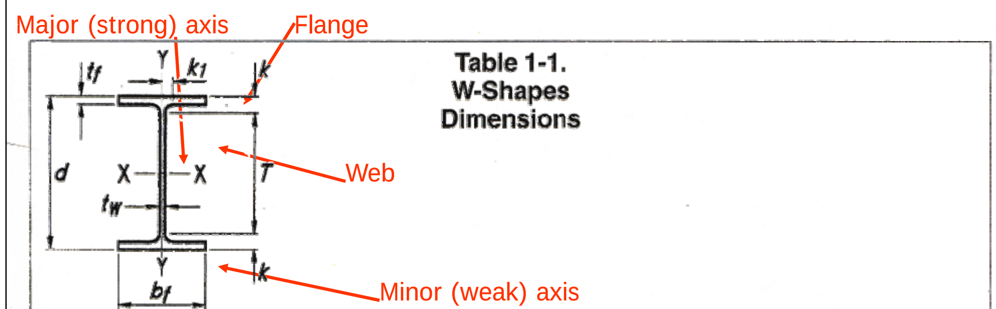
- Most widely used section
- Two flanges held apart by a web
- Essentially parallel inner and outer flange surfaces

Section designation

W24x55 ← Weight per foot

Nominal depth

Wide-flange (W) Shapes

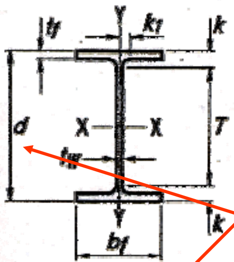


Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k		Distance k_1	Distance T	Distance Workable Gage†
	in.²	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W44×335*	98.3	44.0	44	1.02	1	1/2	16.0	16	1.77	1 3/4	2.56	2 5/8	1 5/16	38 3/4	5 1/2
×290	85.8	43.6	43 5/8	0.870	7/8	7/16	15.8	15 7/8	1.58	1 9/16	2.37	2 7/16	1 1/4	↓	↓
×262	77.2	43.3	43 1/4	0.790	13/16	7/16	15.8	15 3/4	1.42	1 7/16	2.21	2 1/4	1 3/16		
×230	67.7	42.9	42 7/8	0.710	11/16	3/8	15.8	15 3/4	1.22	1 1/4	2.01	2 1/16	1 3/16		

Designation

Wide-flange (W) Shapes

Table 1-1.
W-Shapes
Dimensions



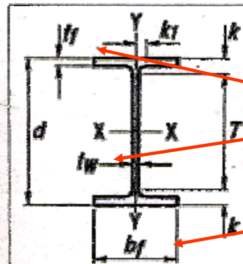
Cross-sectional area

Actual depth

Shape	Area, A	Depth, d		Web: Thickness, t_w		Web: $\frac{t_w}{2}$	Flange: Width, b_f		Flange: Thickness, t_f		Distance: k		Distance: k_1	Distance: T	Workable Gage†
	in.²	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W44×335*	98.3	44.0	44	1.02	1	1/2	16.0	16	1.77	1 3/4	2.56	2 5/8	1 5/16	38 3/4	5 1/2
×290	85.8	43.6	43 5/8	0.870	7/8	7/16	15.8	15 7/8	1.58	1 9/16	2.37	2 7/16	1 1/4	↓	↓
×262	77.2	43.3	43 1/4	0.790	13/16	7/16	15.8	15 3/4	1.42	1 7/16	2.21	2 1/4	1 3/16		
×230	67.7	42.9	42 7/8	0.710	11/16	3/8	15.8	15 3/4	1.22	1 1/4	2.01	2 1/16	1 3/16		

Wide-flange (W) Shapes

Table 1-1.
W-Shapes
Dimensions



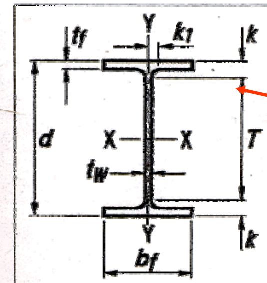
Web thickness

Flange properties

Shape	Area, A	Depth, d		Web: Thickness, t_w		Web: $\frac{t_w}{2}$	Flange: Width, b_f		Flange: Thickness, t_f		Distance: k		Distance: k_1	Distance: T	Workable Gage†
	in.²	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W44×335*	98.3	44.0	44	1.02	1	1/2	16.0	16	1.77	1 3/4	2.56	2 5/8	1 5/16	38 3/4	5 1/2
×290	85.8	43.6	43 5/8	0.870	7/8	7/16	15.8	15 7/8	1.58	1 9/16	2.37	2 7/16	1 1/4	↓	↓
×262	77.2	43.3	43 1/4	0.790	13/16	7/16	15.8	15 3/4	1.42	1 7/16	2.21	2 1/4	1 3/16		
×230	67.7	42.9	42 7/8	0.710	11/16	3/8	15.8	15 3/4	1.22	1 1/4	2.01	2 1/16	1 3/16		

Wide-flange (W) Shapes

Table 1-1.
W-Shapes
Dimensions



End of fillet transition between web and flange

Flat portion of web

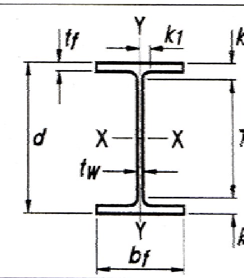
Shape	Area, A	Depth, d		Web: Thickness, t_w		Web: $\frac{t_w}{2}$	Flange: Width, b_f		Flange: Thickness, t_f		Distance: k		Distance: k_1	Distance: T	Workable Gage†
	in.²	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W44×335*	98.3	44.0	44	1.02	1	1/2	16.0	16	1.77	1 3/4	2.56	2 5/8	1 5/16	38 3/4	5 1/2
×290	85.8	43.6	43 5/8	0.870	7/8	7/16	15.8	15 7/8	1.58	1 9/16	2.37	2 7/16	1 1/4	↓	↓
×262	77.2	43.3	43 1/4	0.790	13/16	7/16	15.8	15 3/4	1.42	1 7/16	2.21	2 1/4	1 3/16		
×230	67.7	42.9	42 7/8	0.710	11/16	3/8	15.8	15 3/4	1.22	1 1/4	2.01	2 1/16	1 3/16		

Spacing between rows of bolts in flange

Wide-flange (W) Shapes

Second moment, elastic section modulus, radius of gyration, plastic section modulus for strong and weak axes

Table 1-1 (cont.).
W-Shapes
Properties



Flange and web stability parameters

Weight per foot

Nominal Wt.	Compact Section Criteria: $\frac{b_f}{2t_f}$	Compact Section Criteria: $\frac{h}{t_w}$	Compact Section Criteria: F_y'''	X_1	$X_2 \times 10^6$	Axis X-X: I	Axis X-X: S	Axis X-X: r	Axis X-X: Z	Axis Y-Y: I	Axis Y-Y: S	Axis Y-Y: r	Axis Y-Y: Z
lb/ft			ksi	ksi	(1/ksi)²	in.⁴	in.³	in.	in.³	in.⁴	in.³	in.	in.³
335	4.51	38.1	44.3	2430	5110	31100	1410	17.8	1620	1200	151	3.50	236
290	5.01	44.7	32.2	2150	8170	27100	1240	17.8	1420	1050	132	3.49	206
262	5.55	49.2	26.6	1930	12300	24200	1120	17.7	1270	927	118	3.46	183
230	6.45	54.8	21.5	1690	21100	20800	971	17.5	1100	796	101	3.43	157

Used for beam strength calculations

Wide-flange (W) Shapes

$$\frac{VQ}{Ib}$$

Table 1-25. W-Shapes Torsional Properties

Shape	Torsional Constant, J	Warping Constant, C_w	$\sqrt{\frac{EC_w}{GJ}}$	Normalized Warping Constant, W_{no}	Warping Statical Moment, S_w	Statical Moment Q_f	Statical Moment Q_w
	in.^{4}	in.^{6}	in.	in.^{2}	in.^{4}	in.^{3}	in.^{3}
W44×335*	74.4	536000	137	168	1190	279	805
×290	51.5	464000	153	166	1040	248	704
×262	37.7	407000	167	165	922	222	630
×230	24.9	346000	190	164	789	191	546

M Shapes

- Not classified in ASTM 6 as W-, S- or HP- shapes
- Same properties (A, d, t_w, b_f, etc) as W- shapes

HP-Shapes

- Also known as bearing piles
- Similar to W-shapes, except their webs and flanges are of equal thickness and the depth and flange width are nominally equal for a given designation

M Shapes

- 16-2/3% slope on inner flange surface

Section designation

S24x121 ← Weight per foot

Nominal depth

- Relatively narrow flange when compared to W shapes

M Shapes

Narrow flange

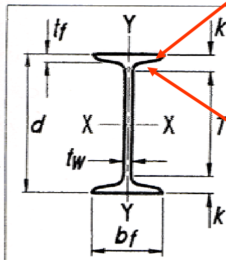


Table 1-3. S-Shapes (American Standard Beams) Dimensions

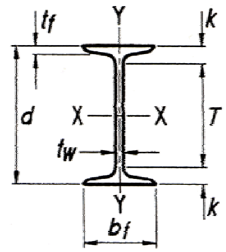
Note slope on inside of flange

Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k	Distance T	Distance Workable Gage†
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.
S24×121	35.5	24.5	24 1/2	0.800	13/16	7/16	8.05	8	1.09	1 1/16	2	20 1/2	4
×106	31.1	24.5	24 1/2	0.620	5/8	5/16	7.87	7 7/8	1.09	1 1/16	2	20 1/2	4

M Shapes

Same properties as for W shapes

Table 1-3 (cont.).
S-Shapes
(American Standard Beams)
Properties



Nom-inal Wt.	Compact Section Criteria			X_1	$X_2 \times 10^6$	Axis X-X				Axis Y-Y			
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	F_y'''			I	S	r	Z	I	S	r	Z
lb/ft			ksi	ksi	$(1/\text{ksi})^2$	in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}
121	3.69	25.9	–	3310	1770	3160	258	9.43	306	83.0	20.6	1.53	36.3
106	3.61	33.4	57.8	2960	2470	2940	240	9.71	279	76.8	19.5	1.57	33.4

Channels

- 16-2/3% slope on inner flange surface

Section designation

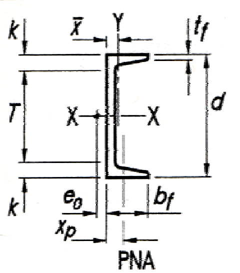
C15x50 ← Weight per foot

Actual depth

MC – Miscellaneous channel – 2 on 12 slope on inner flange

Channels

Table 1-5.
C-Shapes
(American Standard Channels)
Dimensions



Property for design

Actual depth

Property for detailing

Shape	Area, A	Depth, d		Web			Flange				Distance		
				Thickness, t_w		$\frac{t_w}{2}$	Width, b_f		Thickness, t_f		k	T	Workable Gage†
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.
C15×50	14.7	15.0	15	0.716	11/16	3/8	3.72	3 3/4	0.650	5/8	1 7/16	12 1/8	2 1/4
×40	11.8	↓	↓	0.520	1/2	1/4	3.52	3 1/2	↓	↓	↓	↓	2
×33.9	9.95			0.400	3/8	3/16	3.40	3 3/8					2

Angles

Section designation

Short leg length

L6x4x3/4 ← Thickness

Long leg length

- Major axes do not correspond to X and Y axes

Angles

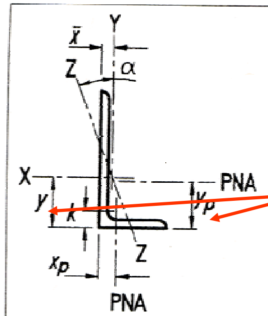


Table 1-7.
Angles
(L-Shapes)
Properties

Location of plastic centroid

Location of elastic centroid

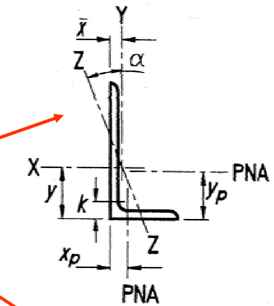
X axis properties

Shape	k	Wt.	Area, A	Axis X-X: I	S	r	$\bar{y}$	Z	y_p
	in.	lb/ft	in.^{2}	in.^{4}	in.^{3}	in.	in.	in.^{3}	in.
L8×8×1 1/8	1 3/4	57.2	16.8	98.1	17.5	2.41	2.40	31.6	1.05
×1	1 5/8	51.3	15.1	89.1	15.8	2.43	2.36	28.5	0.943
×7/8	1 1/2	45.3	13.3	79.7	14.0	2.45	2.31	25.3	0.832
×3/4	1 3/8	39.2	11.5	69.9	12.2	2.46	2.26	22.0	0.720
×5/8	1 1/4	33.0	9.69	59.6	10.3	2.48	2.21	18.6	0.606
×9/16	1 3/16	29.8	8.77	54.2	9.33	2.49	2.19	16.8	0.548
×1/2	1 1/8	26.7	7.84	48.8	8.36	2.49	2.17	15.1	0.490

Designation

Angles

Table 1-7 (cont.).
Angles
(L-Shapes)
Properties



Minor (weak) axis

Y axis properties

Shape	Axis Y-Y: I	S	r	$\bar{x}$	Z	x_p	Axis Z-Z: r	Tan α	Q_s^* $F_y = 36$ ksi
	in.^{4}	in.^{3}	in.	in.	in.^{3}	in.	in.		
L8×8×1 1/8	98.1	17.5	2.41	2.40	31.6	1.05	1.56	1.00	–
×1	89.1	15.8	2.43	2.36	28.5	0.943	1.56	1.00	–
×7/8	79.7	14.0	2.45	2.31	25.3	0.832	1.57	1.00	–
×3/4	69.9	12.2	2.46	2.26	22.0	0.720	1.57	1.00	–
×5/8	59.6	10.3	2.48	2.21	18.6	0.606	1.58	1.00	0.997
×9/16	54.2	9.33	2.49	2.19	16.8	0.548	1.58	1.00	0.959
×1/2	48.8	8.36	2.49	2.17	15.1	0.490	1.59	1.00	0.912

Tees

- WT – cut from W shape

  WT22x131 is cut from W44x262

- ST – cut from S shape

- MT – cut from M shape

Tees

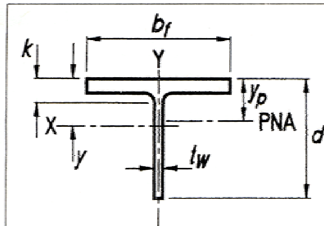


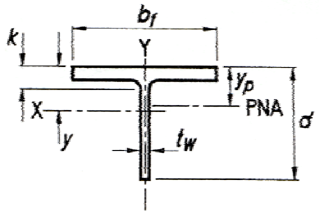
Table 1-8.
WT-Shapes
(Structural Tees Split from W-Shapes)
Dimensions

Stem, not web

Shape	Area, A	Depth of Tee, d		Stem: Thickness, t_w		$\frac{t_w}{2}$	Area	Flange: Width, b_f		Thickness, t_f		Distance: k		Workable Gage†
	in.^{2}	in.		in.		in.	in.^{2}	in.		in.		in.	in.	in.
WT22×167.5*	49.1	22.0	22	1.02	1	1/2	22.5	16.0	16	1.77	1 3/4	2.56	2 5/8	5 1/2
×145	42.9	21.8	21 3/4	0.870	7/8	7/16	19.0	15.8	15 7/8	1.58	1 9/16	2.37	2 7/16	↓
×131	38.6	21.7	21 5/8	0.790	13/16	7/16	17.1	15.8	15 3/4	1.42	1 7/16	2.21	2 1/4	↓
×115	33.8	21.5	21 1/2	0.710	11/16	3/8	15.2	15.8	15 3/4	1.22	1 1/4	2.01	2 1/16	↓

Tees

Table 1-8 (cont.). WT-Shapes (Structural Tees Split from W-Shapes) Properties



Nominal Wt.	h/t_w	Axis X-X						Axis Y-Y				Q_s**
		I	S	r	$\bar{y}$	Z	y_p	I	S	r	Z	F_y = 50 ksi
lb/ft		in.^{4}	in.^{3}	in.	in.	in.^{3}	in.	in.^{4}	in.^{3}	in.	in.^{3}	
167.5	19.1	2160	131	6.63	5.51	233	1.54	600	75.3	3.50	118	0.817
145	22.3	1840	111	6.55	5.27	197	1.35	523	66.1	3.49	103	0.636
131	24.6	1650	100	6.53	5.20	177	1.23	463	58.8	3.46	91.3	0.532
115	27.4	1440	88.6	6.53	5.17	157	1.07	398	50.5	3.43	78.3	0.438

Reduction factor for slender stiffened compression elements

Hollow Structural Shapes (HSS)

- Rectangular (or square)
- Round

Steel Pipe

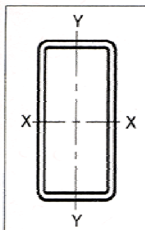
- Pipe diameter (Std., X-Strong, XX-Strong)

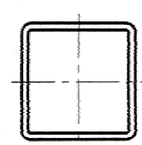
For example, Pipe 5 Std.

(steel pipe is dimensioned and classed differently than HSS)

Hollow Structural Shapes (HSS)

Table 1-11. Rectangular (and Square) HSS Dimensions and Properties

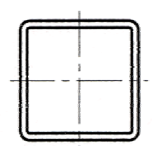


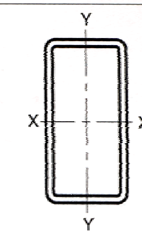


Shape	Wall Thickness, t		Nominal Wt.	Area, A	b/t	h/t	Axis X-X			
	nominal	design					I	S	r	Z
	in.	in.	lb/ft	in.^{2}			in.^{4}	in.^{3}	in.	in.^{3}
HSS20×12	5/8	0.581	127	35.0	17.7	31.4	1880	188	7.33	230
	1/2	0.465	103	28.3	22.8	40.0	1550	155	7.39	188
	3/8	0.349	78.4	21.5	31.4	54.3	1200	120	7.45	144
	5/16	0.291	65.8	18.1	38.2	65.7	1010	101	7.48	122

Hollow Structural Shapes (HSS)

Table 1-11 (cont.). Rectangular (and Square) HSS Dimensions and Properties





Torsion and warping constants

Shape	Wall Thickness, t		Axis Y-Y				Torsion		Surface Area Per Foot
	nominal	design	I	S	r	Z	J	C	
	in.	in.	in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	ft^2
HSS20×12	5/8	0.581	851	142	4.93	162	1890	257	5.17
	1/2	0.465	705	117	4.99	132	1540	209	5.20
	3/8	0.349	547	91.1	5.04	102	1180	160	5.23
	5/16	0.291	464	77.3	5.07	85.8	997	134	5.25

Hollow Structural Shapes (HSS)

Diameter over design thickness

Nominal versus design thickness

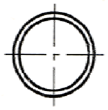


Table 1-12. Round HSS Dimensions and Properties

Shape	Wall Thickness, t nominal	Wall Thickness, t design	Nominal Wt.	Area, A	D/t	I	S	r	Z	Torsion J	Torsion C	Surf. Area Per Ft
	in.	in.	lb/ft	in.^{2}		in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	ft^2
HSS20.000	0.500	0.465	104	28.5	43.0	1360	136	6.91	177	2720	272	5.24
	0.375	0.349	78.7	21.5	57.3	1040	104	6.95	135	2080	208	5.24

Double Angles

2L6x4x3/4

- Major axes are now x and y
- X axis properties may be obtained from x axis properties of single angle
- Y axis properties depend on separation between backs angles and whether LLBB or SLBB

Double Angles

Long legs back-to-back

Short legs back-to-back

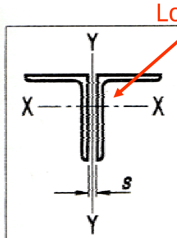
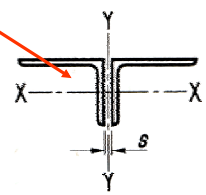


Table 1-14. Double Angles (2L-Shapes) Properties



Shape	Axis Y-Y Radii of Gyration, LLBB, Separation s, in. 0	LLBB 3/8	LLBB 3/4	SLBB, Separation s, in. 0	SLBB 3/8	SLBB 3/4	Q_s* LLBB Angles in Contact	Q_s* LLBB Angles Separated	Q_s* SLBB Angles in Contact	Q_s* SLBB Angles Separated
2L8×8×1 1/8	3.41	3.54	3.68	3.41	3.54	3.68	–	–	–	–
×1	3.39	3.52	3.66	3.39	3.52	3.66	–	–	–	–
×7/8	3.36	3.50	3.63	3.36	3.50	3.63	–	–	–	–
×3/4	3.34	3.47	3.61	3.34	3.47	3.61	–	–	–	–
×5/8	3.32	3.45	3.58	3.32	3.45	3.58	–	0.997	–	0.997
×9/16	3.31	3.44	3.57	3.31	3.44	3.57	–	0.959	–	0.959
×1/2	3.30	3.43	3.56	3.30	3.43	3.56	0.998	0.912	0.998	0.912

Double Angles

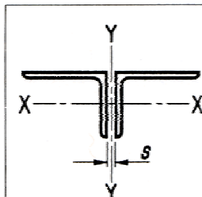
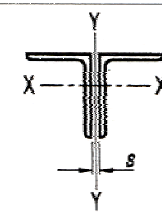


Table 1-14 (cont.). Double Angles (2L-Shapes) Properties



Shape	Axis Y-Y Radii of Gyration, LLBB, Separation s, in. 0	LLBB 3/8	LLBB 3/4	SLBB, Separation s, in. 0	SLBB 3/8	SLBB 3/4	Q_s* LLBB Angles in Contact	Q_s* LLBB Angles Separated	Q_s* SLBB Angles in Contact	Q_s* SLBB Angles Separated
2L5×3 1/2×3/4	1.39	1.53	1.68	2.33	2.47	2.62	–	–	–	–
×5/8	1.37	1.50	1.65	2.30	2.45	2.59	–	–	–	–
×1/2	1.35	1.48	1.62	2.28	2.42	2.57	–	–	–	–
×3/8	1.33	1.46	1.59	2.26	2.39	2.54	–	0.983	–	0.983
×5/16	1.32	1.44	1.58	2.25	2.38	2.52	–	0.912	0.998	0.912
×1/4	1.31	1.43	1.57	2.23	2.37	2.51	–	0.804	0.894	0.804

Double Channels

- Designated as 2C or 2MC

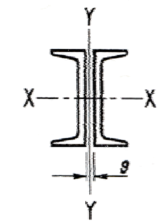
  2C15x50

- Y axis properties depend on back-to-back separation
- X axis properties can be obtained from x axis properties of single channel

Double Channels

Y axis properties depend on back-to-back distance between individual channels

Table 1-15.
2C-Shapes
(Double Channels)
Properties



Shape	Axis Y-Y											
	Separation s, in.											
	0				3/8				3/4			
	I	*S*	*r*	*Z*	*I*	*S*	*r*	*Z*	*I*	*S*	*r*	*Z*
	$in.^4$	$in.^3$	in.	$in.^3$	$in.^4$	$in.^3$	in.	$in.^3$	$in.^4$	$in.^3$	in.	$in.^3$
2C15×50	40.7	11.0	1.18	30.7	50.5	12.9	1.31	36.2	62.4	15.3	1.46	41.7
×40	32.6	9.25	1.18	22.9	40.2	10.9	1.31	27.3	49.6	12.7	1.45	31.7
×33.9	28.5	8.38	1.20	19.0	35.1	9.78	1.33	22.7	43.1	11.4	1.47	26.4

6200. Material - ASTM A6/A6M

- General Requirements for Rolled Steel Plates, Shapes, Sheet Piling and Bars for Structural Use
- Requirements are included for ordering, heat treatment, chemical analysis, metallurgical structure, quality, test methods, tension tests, identifications of material, permissible variations in dimensions or weight, inspection and testing, retests, rejection, retreatment, test reports, packaging, marking and loading for shipment

ASTM A36/A36M & A992/A992M

- Carbon steel shapes, plates, and bars of structural quality for use in riveted, bolted, or welded construction
- For general structural purposes
- Minimum yield point of 36 ksi and tensile strength of 58 to 80 ksi
- ASTM A992/A992M - The new 50 ksi steel for wide-flange shapes (only) that replaces ASTM A36, ASTM A572 grade 50 and the similar dual-certified products for wide-flange shapes (only).

ASTM A500 & A501

- ASTM A500 –
  - Cold-formed welded and seamless carbon steel structural tubing in rounds and squares
  - Both welded and seamless sizes with a maximum periphery of 64” and a maximum wall thickness of 0.625”. Grade D requires for heat treatment.
- ASTM A501 –
  - Hot-formed welded and seamless carbon steel structural tubing
  - Round tubing is furnished in NPS ½ to 24” incl. with nominal (average) wall thickness 0.109 to 1.000” depending on size.

ASTM A572/A572M

- 4 grades of high strength low-alloy structural steel shapes, plates, sheet piling, and bars.
  - Grades 42 and 50 are intended for riveted, bolted, or welded construction of bridges, buildings, and other structures
  - Grades 60 and 65 are intended for riveted or bolted construction of bridges or for riveted, bolted, or welded construction of other structures
  - The requirements of Grade 50 are equivalent to ASTM A709, Grade 50

ASTM A588/A588M

- High strength low-alloy “weathering” structural steel with 50 ksi minimum yield point to 4” thick.
  - "Weathering" means that due to their chemical compositions, these steels exhibit increased resistance to atmospheric corrosion compared to unalloyed steels.
  - This is because the steel forms a protective layer on its surface under the influence of the weather.
  - “Challenges” are requiring special welding techniques or material; not rustproof in itself needing provision for drainage; preventing stain needing better detailing

ASTM A618

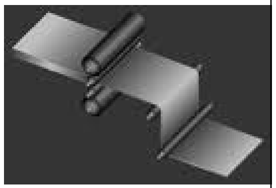
- Hot-formed welded and seamless high-strength low-alloy structural tubing
  - 3 grades of square, rectangular, round, or special shape for welded, riveted, or bolted construction of bridges and buildings and for general structural purposes
  - Grade II has atmospheric corrosion resistance equivalent to that of carbon steel wit copper (0.2 minimum Cu)
  - Grades Ia and Ib have atmospheric corrosion resistance substantially better than that of Grade II

ASTM A108

- Standard quality cold-finished carbon steel bars
- Suitable for heat treatment, for machining into components, or for use in the as-finished condition as shafting, or in constructional applications, or for other similar purposes
- Grades of steel are identified by grade numbers or by chemical composition

ASTM A109/A109M , A635/A635M

- ASTM A109/A109M - Cold rolled carbon steel strip in cut lengths or coils In sizes as follows:
  - Width – over ½ to 23 -15/16
  - Thickness – 0.2499 and under



- ASTM A635 / A635M - Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Alloy, Carbon, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability

ASTM A123 & A153

- ASTM A123 –
  - Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
  - For steel forging and iron castings incorporated into pieces fabricated before galvanizing or which are too large to be centrifuged
- ASTM A153 –
  - Zinc Coating (Hot-Dip) on Iron and Steel Hardware
  - Applicable to hardware items that are centrifuged or otherwise handled to remove excess galvanizing bath metal (free zinc)

Galvanization

- Galvanizing Steel (video)
  YouTube - Galvanizing Steel.mht
- Galvanizing Process (video)
  YouTube - Galvanizing Process.mht

ASTM A328/A328M

- For carbon steel sheet piling
- For use in the construction of dock walls, sea walls, cofferdams, excavations, and like applications
- Minimum yield point of 39 ksi and a minimum tensile strength of 70 ksi

ASTM A307, A325/A325M & A449

- ASTM A307 – Carbon Steel Bolts and Studs, 60,000 Psi Tensile Strength (Grade A: minimum strength 60 ksi; B: 60-100 ksi; C: nonheaded anchor bolts)
- ASTM A325/A325M – Structural Bolts, Steel, Heat Treated, 120/105 Ksi Minimum Tensile Strength (Type 1: medium carbon, carbon boron, or medium carbon alloy steel; 2: withdrawn; Type 3 – weathering steel)
- ASTM A449 – Quenched and Tempered Steel Bolts and Studs (Type 1: medium-carbon steel ¼ to 2" incl. in diameters)

ASTM A354 & A490/A490M

- ASTM 354 - Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners 4" and under (Grade BC and BD; up through 1 ½" in diameter are covered in ASTM A490; pver 1 ½" covered in Grade BD here)
- ASTM A490/A490M – Heat-Treated Steel Structural Bolts, 150 Minimum Tensile Strength (Type 1: alloy steel ½ to 1 ½" incl. in diameters; 2: low-carbon martensite steel, ½ to 1" incl.; 3: ½ to 1 ½" in diameters weathering)

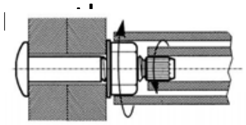
ASTM A563/A563M, F436/F436M & F606/F606M

- ASTM A563/A563M –
  - 8 grades of carbon and alloy steel nuts
  - Grades C3 and DH3 nuts for atmospheric corrosion resistance and weathering characteristics
- ASTM F436/F436M –
  - Hardened Steel Washers diameters of ¼ to 4", incl.
  - Type 1: Carbon steel; 3: weathering steel
- ASTM F606/F606M – Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

ASTM F959, F1852 & F2250

- ASTM F959 – Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners

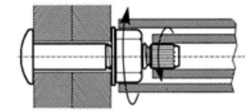
- ASTM F1852 & F2250 Standard Specification for "Twist Off" Type Tension Control Structural Bolt/Nut/Washer Assemblies, Steel, Heat Treated, 120/105 & 150 ksi Minimum Tensile St



Pretension Methods

Bolt Installation:

- Turn-of-nut method
- Direct tension indicator
- Calibrated wrench
- Alternative design bolt
  - Twist-off type tension-control bolt assemblies (F1852 & F2250)
  - Compressible washer-type direct tension indicator (ASTM F959/F959M)



6200. Material (N690) - ASTM A167, A217/A217M & A240/A240M

- A167 Standard Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
- A217/A217M Standard Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service
- A240/A240M Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

6200. Material (N690) - Stainless Steel and Material Enhancement

- Outokumpu's Stainless steel production process (Video)

YouTube - Outokumpu's Stainless steel production process.mht

- **Austenitization** means to heat the iron, iron-based metal, or steel to a temperature at which it changes crystal structure from ferrite to austenite
- The martensite is formed by rapid cooling (quenching) of austenite which traps carbon atoms that do not have time to diffuse out of the crystal structure
- **Annealing**, in metallurgy and materials science, is a heat treatment wherein a material is altered, causing changes in its properties such as strength and hardness
- A **quench** refers to a rapid cooling

6200. Material (N690) - ASTM A479/A479M, A515/A515M, A516/A516M & D3843

- A479/A479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels
- A515/A515M Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service
- A516/A516M Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
- D3843 Standard Practice for Quality Assurance for Protective Coatings Applied to Nuclear Facilities

6100. Introduction/6200. Material

- Objective and Scope Met
  - Structural Steel Types, Mechanical and Physical Properties, and Steel Sections
  - Selecting Design Principles for Steel Structures
  - Selecting Computational Methods For Steel Structure Design
  - Primary Design Considerations in the Design of Steel Structures
  - ASTM Steel Material