CE 415:Design of Steel Structures

Course Teacher: Sinha Lamia Sultana

Recommended Text Book

- ❑ Steel Structures, Design and Behaviour, Fifth Edition, 2009. Authors: Salmon, Johnshon and Malhas.

Supporting materials

- ❑ Manual for Steel Construction, 14th Edition, 2011. Author: American Institute of Steel Construction (AISC).
- ❑ Design of Steel Structures, 3rd Ed., 1991, Authors: Gaylord, Gaylord and Stallmeyer, Publisher: McGraw-Hill

Steel Structures: Bridges

The Hardinge Bridge
Completed: 1912, Commissioned: 1915

Photo: Collected from Lecture Slides of Professor Dr. Khan Mahmud Amanat, BUET

Steel Structures: Bridges

শেওলা সেতু, সিলেট

Photo: Collected from Lecture Slides of Professor Dr. Khan Mahmud Amanat, BUET

Steel Structures: Lattice Towers

132kV 3-Phase Double Circuit Transmission Line
Rural Electrification Board, Sylhet

Photo: Collected from Lecture Slides of Professor Dr. Khan Mahmud Amanat, BUET

Limit States:

- Strength Limit State- Flexure, Shear, Settlement, Bearing
- Servicibility Limit States – Cracking, Excessive Deflection, Buckling, Stability
- Special Limit States- Collapse due to Earthquake effect, Structural effect of Fire, Explosion or Vehicular Collision

Design Philosophy

A general statement assuming safety in engineering design is:
Strength/Resistance/Capacity ≥ Effect of Applied Loads

Two Methods

❑ Load and Resistance Factor Design (LRFD)

Nominal Strength or Resistance: Rn
Resistance factor : Φ < 1
Design Strength : ΦRn
Factored Load (also called ultimate load): Ru (1.2 DL + 1.6 LL)
LRFD safety requirement: ΦRn >= Ru

❑ Allowable Strength Design (ASD)

Nominal strength or Resistance: Rn
Safety factor : Ω >1
Design strength : Rn/Ω
Required strength (also called allowable strength) : Ra (DL + LL)
ASD safety requirement: Rn/Ω ≥ Ra

Load Combinations

Load combination actually means combination of similar load effects.

Load Effect Combinations for LRFD:

1. $1.4D$
2. $1.2D + 1.6L + 0.5(L_r \text{ or } R)$
3. $1.2D + 1.6(L_r \text{ or } R) + (1.0L \text{ or } 0.8W)$
4. $1.2D + 1.6W + 0.5L + 0.5(L_r \text{ or } R)$
5. $1.2D + 1.0E + 0.5L$
6. $0.9D + (1.6W \text{ or } 1.0E)$

Load Effect Combinations for ASD:

1. D
2. $D + L$
3. $D + L + (L_r \text{ or } S \text{ or } R)$
4. $D + (W \text{ or } 0.7E) + L + (L_r \text{ or } R)$
5. $0.6D + W$
6. $0.6D + 0.7E$

Advantages & Disadvantages of Steel

❑ Advantages

1) High strength to weight ratio
2) Properties are uniform and homogeneous
3) High ductility, providing adequate warning before collapse
4) Can be easily recycled
5) Easy to fabricate & erect
6) Easy to inspect, repair or retrofit
7) Easy to make additions to existing structures because of relative ease of connections
8) Erection not affected by weather

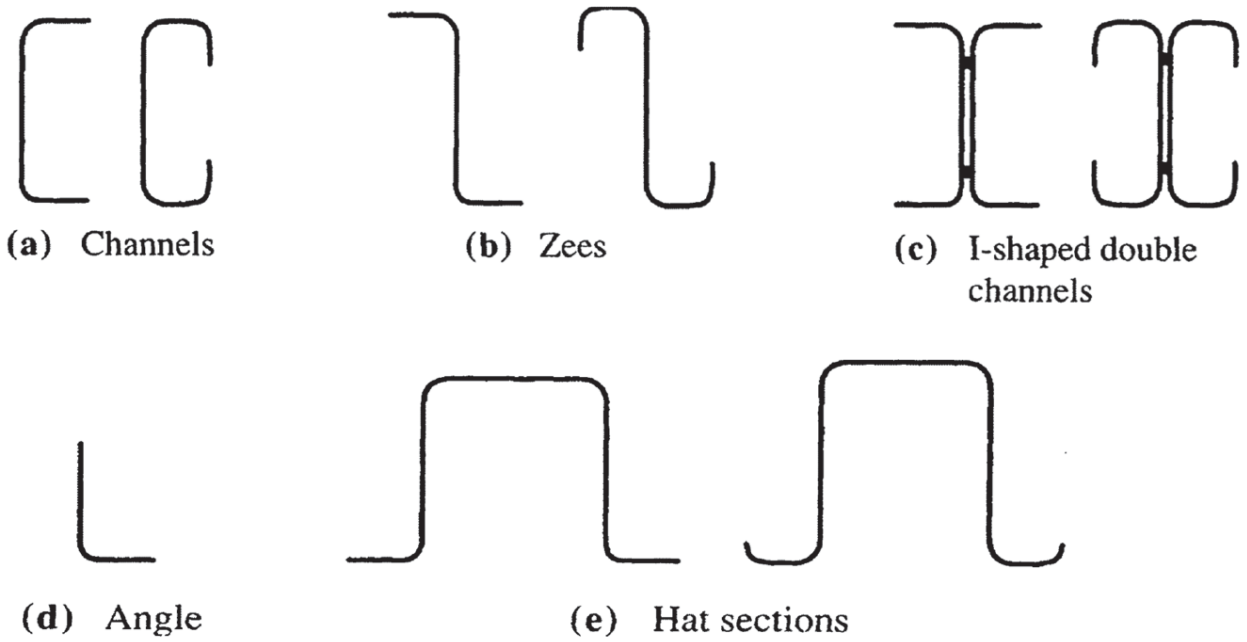
❑ Disadvantages

1) Corrosion
2) Susceptibility to temperature
3) Susceptibility to buckling

Steel Shapes

❑ Cold formed shapes

Cold formed shapes are manufactured by bending or folding or cold rolling mild steel sheets of thickness 3 mm or less to the desired shape

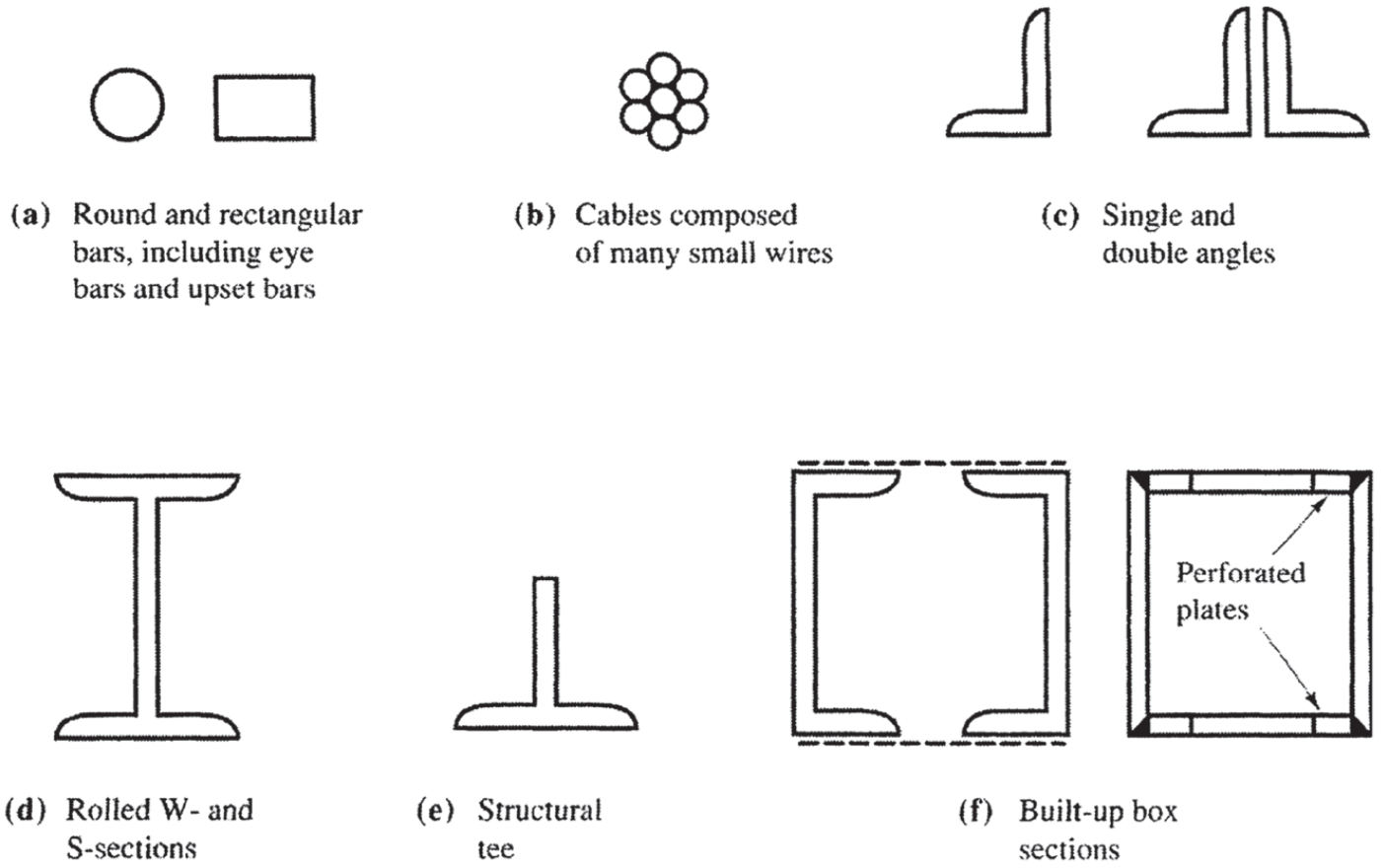


(a) Channels (b) Zees (c) I-shaped double channels

(d) Angle (e) Hat sections

❑ Hot rolled shapes

Hot rolled shapes are formed by heating steel billets to softer state and then passing the billets through carefully shaped and aligned rollers to force the billet to achieve the desired shape.



(a) Round and rectangular bars, including eye bars and upset bars

(b) Cables composed of many small wires

(c) Single and double angles

(d) Rolled W- and S-sections

(e) Structural tee

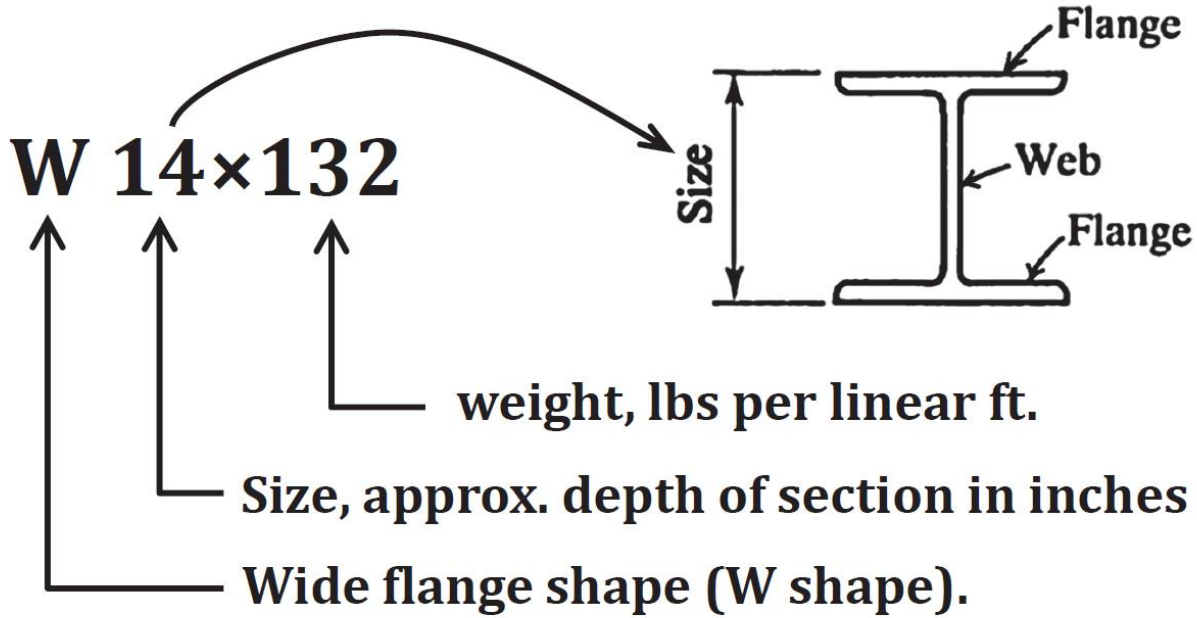
(f) Built-up box sections

Different Types of Structural Steel

ASTM† designation	F_y Minimum yield stress ksi (MPa)‡	F_u Tensile strength ksi (MPa)‡	Maximum thickness for plates in. (mm)	ASTM A6 groups* for shapes
A36	32 (220)	58–80 (400–550)	Over 8 (200)	—
	36 (250)	58–80 (400–550)	To 8 (200)	All
A572 Grade 42	42 (290)	60 (415)	To 6 (150)	All
Grade 50	50 (345)	65 (450)	To 4 (100)	All
Grade 60	60 (415)	75 (520)	To $1\frac{1}{4}$ (32)	1, 2, 3
Grade 65	65 (450)	80 (550)	To $1\frac{1}{4}$ (32)	1, 2, 3
A913 Grade 50	50 (345)	60 (415)		
Grade 60	60 (415)	75 (520)		All
Grade 65	65 (450)	80 (550)		
Grade 70	70 (485)	90 (620)		
A992	50 (345)	65 (450)		All

Unit weight: **490 lb/ft^3**
Young's Modulus: **29000 ksi**

AISC STEEL SHAPES



AISC Steel Construction Manual, 13th Ed.

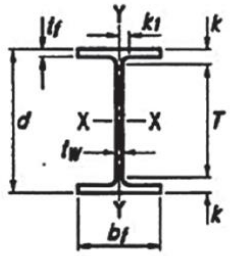


Table 1–1 (continued)
W Shapes
Dimensions

Shape	Area, A	Depth, d		Web			Flange				Distance				
				Thickness, t_w		$\frac{t_w}{2}$	Width, b_f		Thickness, t_f		k		k_1	T	Work-able Gage
											k_{des}	k_{det}			
	in.²	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W14×132	38.8	14.7	14 5/8	0.645	5/8	5/16	14.7	14 3/4	1.03	1	1.63	2 5/16	1 9/16	10	5 1/2
×120	35.3	14.5	14 1/2	0.590	9/16	5/16	14.7	14 5/8	0.940	15/16	1.54	2 1/4	1 1/2		
×109	32.0	14.3	14 3/8	0.525	1/2	1/4	14.6	14 5/8	0.860	7/8	1.46	2 3/16	1 1/2		
×99[f]	29.1	14.2	14 1/8	0.485	1/2	1/4	14.6	14 5/8	0.780	3/4	1.38	2 1/16	1 7/16		
×90[f]	26.5	14.0	14	0.440	7/16	1/4	14.5	14 1/2	0.710	11/16	1.31	2	1 7/16		

Table 1–1 (continued)
W Shapes
Properties

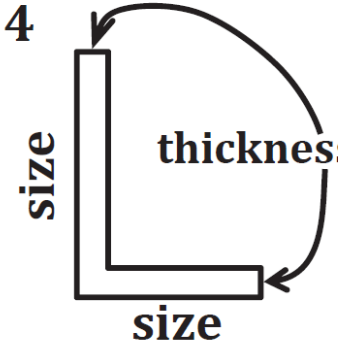
W14 – W12

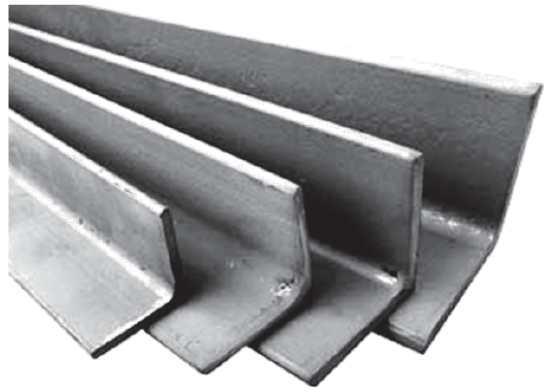
Nominal Wt.	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$\frac{b_f}{2t_f}$	$\frac{h}{t_w}$	I	S	r	Z	I	S	r	Z			J	C_w
lb/ft			in.⁴	in.³	in.	in.³	in.⁴	in.³	in.	in.³	in.	in.	in.⁴	in.⁶
132	7.15	17.7	1530	209	6.28	234	548	74.5	3.76	113	4.23	13.6	12.3	25500
120	7.80	19.3	1380	190	6.24	212	495	67.5	3.74	102	4.20	13.5	9.37	22700
109	8.49	21.7	1240	173	6.22	192	447	61.2	3.73	92.7	4.17	13.5	7.12	20200
99	9.34	23.5	1110	157	6.17	173	402	55.2	3.71	83.6	4.14	13.4	5.37	18000
90	10.2	25.9	999	143	6.14	157	362	49.9	3.70	75.6	4.11	13.3	4.06	16000

AISC STEEL SHAPES

$$L\ 8\times8\times{}^{3}/_{4}$$

Angle shape (L shape)
Size (width) of one leg, inch
Size (width) of other leg, inch
Thickness of legs, inch





AISC Steel Construction Manual, 13th Ed.

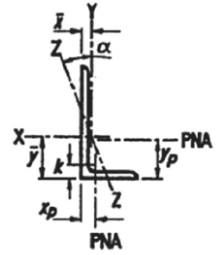


Table 1–7
Angles
Properties

Table 1–7 (continued)
Angles
Properties

L8-L6

Shape	k	Wt.	Area, A	Axis X-X						Flexural-Torsional Properties			Axis Y-Y						Axis Z-Z				Q_s
				I	S	r	$\bar{y}$	Z	y_p	J	C_w	$\bar{r}_o$	I	S	r	$\bar{x}$	Z	x_p	I	S	r	Tan α	F_y=36 ksi
	in.	lb/ft	in.²	in.⁴	in.³	in.	in.	in.³	in.	in.⁴	in.⁶	in.	in.⁴	in.³	in.	in.	in.³	in.	in.⁴	in.³	in.		
L8×8×1⅛	1¾	56.9	16.7	98.1	17.5	2.41	2.40	31.6	1.05	7.13	32.5	4.29	98.1	17.5	2.41	2.40	31.6	1.05	40.9	7.23	1.56	1.00	1.00
×1	1⅝	51.0	15.0	89.1	15.8	2.43	2.36	28.5	0.943	5.08	23.4	4.32	89.1	15.8	2.43	2.36	28.5	0.943	36.8	6.51	1.56	1.00	1.00
×⅞	1½	45.0	13.2	79.7	14.0	2.45	2.31	25.3	0.832	3.46	16.1	4.36	79.7	14.0	2.45	2.31	25.3	0.832	32.7	5.78	1.57	1.00	1.00
×¾	1⅜	38.9	11.4	69.9	12.2	2.46	2.26	22.0	0.720	2.21	10.4	4.39	69.9	12.2	2.46	2.26	22.0	0.720	28.5	5.04	1.57	1.00	1.00
×⅝	1¼	32.7	9.61	59.6	10.3	2.48	2.21	18.6	0.606	1.30	6.16	4.42	59.6	10.3	2.48	2.21	18.6	0.606	24.2	4.27	1.58	1.00	0.997
×9/16	1 3/16	29.6	8.68	54.2	9.33	2.49	2.19	16.8	0.548	0.961	4.55	4.43	54.2	9.33	2.49	2.19	16.8	0.548	22.0	3.88	1.58	1.00	0.959
×½	1⅛	26.4	7.75	48.8	8.36	2.49	2.17	15.1	0.490	0.683	3.23	4.45	48.8	8.36	2.49	2.17	15.1	0.490	19.7	3.49	1.59	1.00	0.912

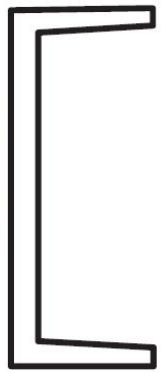
AISC STEEL SHAPES

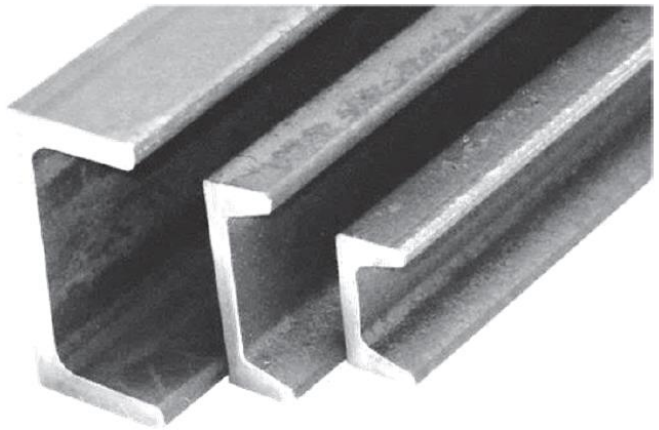
C 9×15

Channel shape (C shape)

Size (depth), inch

Weight , lbs per linear foot





AISC Steel Construction Manual, 13th Ed.

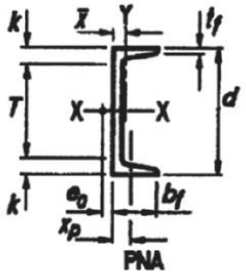


Table 1–5
C Shapes
Dimensions

Table 1–5 (continued)
C Shapes
Properties

C SHAPES

Shape	Area, A	Depth, d		Web Thickness, t_w		$\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		r_{ts}	h_o	Nominal Wt.	Shear Ctr, e_o	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 $\bar{x}$	Axis Y-Y Z	Axis Y-Y x_p	Torsional Properties J	Torsional Properties C_w	Torsional Properties $\bar{r}_o$	Torsional Properties H
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	lb/ft	in.	in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.	in.^{3}	in.	in.^{4}	in.^{6}	in.	
C9×20	5.87	9.00	9	0.448	7/16	1/4	2.65	2 5/8	0.413	7/16	0.848	8.59	20	0.515	60.9	13.5	3.22	16.9	2.41	1.17	0.640	0.583	2.46	0.326	0.427	39.4	3.46	0.899
×15	4.41	9.00	9	0.285	5/16	3/16	2.49	2 1/2	0.413	7/16	0.824	8.59	15	0.681	51.0	11.3	3.40	13.6	1.91	1.01	0.659	0.586	2.04	0.245	0.208	31.0	3.69	0.882
×13.4	3.94	9.00	9	0.233	1/4	1/8	2.43	2 3/8	0.413	7/16	0.813	8.59	13.4	0.742	47.8	10.6	3.49	12.6	1.75	0.954	0.666	0.601	1.94	0.219	0.168	28.2	3.79	0.875

References

The following references will be used to prepare the lecture slides for this course.

- Lecture Slides of the course CE 319 (Design of Steel Structures) of Professor Dr. Khan Mahmud Amanat, Department of Civil Engineering, BUET
- Lecture slides of Asifur Rahman (www.asifurrahman.net)
- Steel Structures, Design and Behaviour, Fifth Edition, 2009. Authors: Salmon, Johnshon and Malhas.
- Manual for Steel Construction, 14th Edition, 2011. Author: American Institute of Steel Construction (AISC).
- Steel Design, Fifth Edition. Authors: Willam T. Segui.