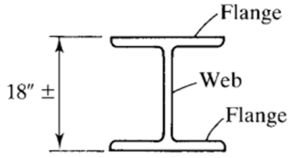
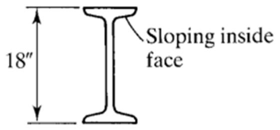
STANDARD CROSS-SECTIONAL SHAPES

In the design process, one of the objectives is the selection of the appropriate cross sections for the individual members of the structure being designed. Most often, this selection will entail choosing a standard cross-sectional shape that is widely available rather than requiring the fabrication of a shape with unique dimensions and properties.

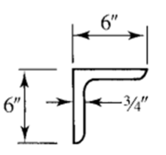
Cross sections of some of the more commonly used **STANDARD CROSS-SECTIONAL SHAPES** are shown in the figure



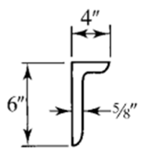
W-shape
(W18 × 50 shown)



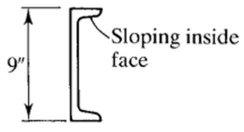
American Standard, S
(S18 × 70 shown)



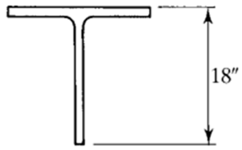
Equal-leg angle, L
(L6 × 6 × 3/4 shown)



Unequal-leg angle
(L6 × 4 × 5/8 shown)



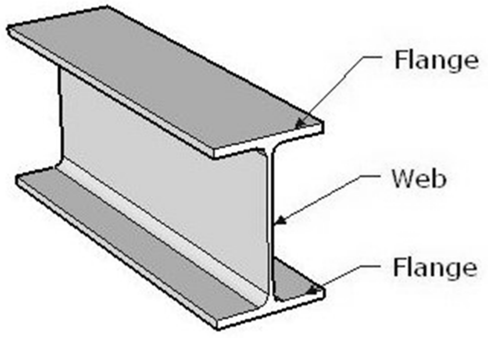
American Standard Channel, C
(C9 × 20 shown)

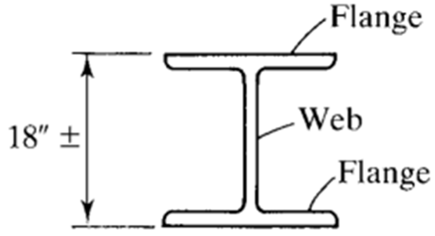


Structural Tee: WT, ST, or MT
(WT18 × 105 shown)

W-shape,* also called a *wide-flange shape

A typical designation would be ***W18x50***, where ***W*** indicates the type of shape, **18** is the nominal depth parallel to the web, and **50** is the weight in pounds per foot of length.





W-shape
(W18 × 50 shown)

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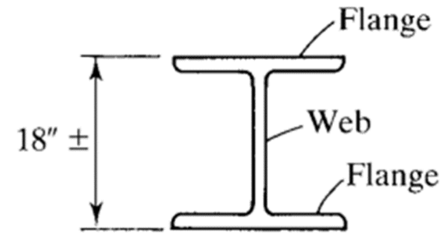
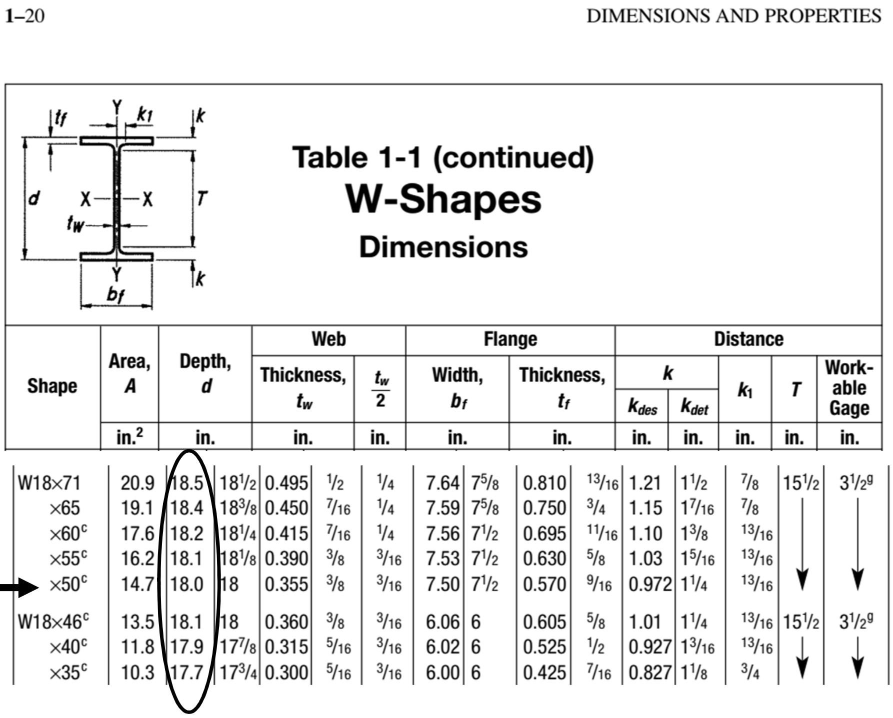


W-shape
(W18 × 50 shown)

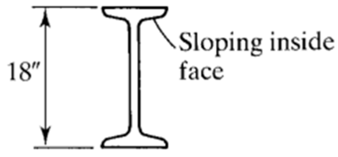


1–20 DIMENSIONS AND PROPERTIES

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_{des}	k: k_{det}	k_1	T	Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W18×71	20.9	18.5	$18\frac{1}{2}$	0.495	$\frac{1}{2}$	$\frac{1}{4}$	7.64	$7\frac{5}{8}$	0.810	$\frac{13}{16}$	1.21	$1\frac{1}{2}$	$\frac{7}{8}$	$15\frac{1}{2}$	$3\frac{1}{2}^g$
×65	19.1	18.4	$18\frac{3}{8}$	0.450	$\frac{7}{16}$	$\frac{1}{4}$	7.59	$7\frac{5}{8}$	0.750	$\frac{3}{4}$	1.15	$1\frac{7}{16}$	$\frac{7}{8}$		
×60^c	17.6	18.2	$18\frac{1}{4}$	0.415	$\frac{7}{16}$	$\frac{1}{4}$	7.56	$7\frac{1}{2}$	0.695	$\frac{11}{16}$	1.10	$1\frac{3}{8}$	$\frac{13}{16}$		
×55^c	16.2	18.1	$18\frac{1}{8}$	0.390	$\frac{3}{8}$	$\frac{3}{16}$	7.53	$7\frac{1}{2}$	0.630	$\frac{5}{8}$	1.03	$1\frac{5}{16}$	$\frac{13}{16}$		
×50^c	14.7	18.0	18	0.355	$\frac{3}{8}$	$\frac{3}{16}$	7.50	$7\frac{1}{2}$	0.570	$\frac{9}{16}$	0.972	$1\frac{1}{4}$	$\frac{13}{16}$	↓	↓
W18×46^c	13.5	18.1	18	0.360	$\frac{3}{8}$	$\frac{3}{16}$	6.06	6	0.605	$\frac{5}{8}$	1.01	$1\frac{1}{4}$	$\frac{13}{16}$	$15\frac{1}{2}$	$3\frac{1}{2}^g$
×40^c	11.8	17.9	$17\frac{7}{8}$	0.315	$\frac{5}{16}$	$\frac{3}{16}$	6.02	6	0.525	$\frac{1}{2}$	0.927	$1\frac{3}{16}$	$\frac{13}{16}$		
×35^c	10.3	17.7	$17\frac{3}{4}$	0.300	$\frac{5}{16}$	$\frac{3}{16}$	6.00	6	0.425	$\frac{7}{16}$	0.827	$1\frac{1}{8}$	$\frac{3}{4}$	↓	↓

The *American Standard,* or *S-shape,* is similar to the W-shape. The difference is the flanges of the *W* are wider in relation to the web than are the flanges of the *S.* An example of the designation of an S-shape is “S18 × 70,” with the S indicating the type of shape, and the two numbers giving the depth in inches and the weight in pounds per foot. This shape was formerly called an *I-beam*.



American Standard, S
(S18 × 70 shown)

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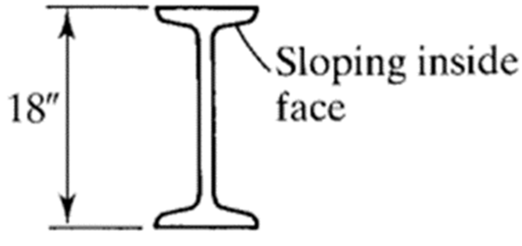
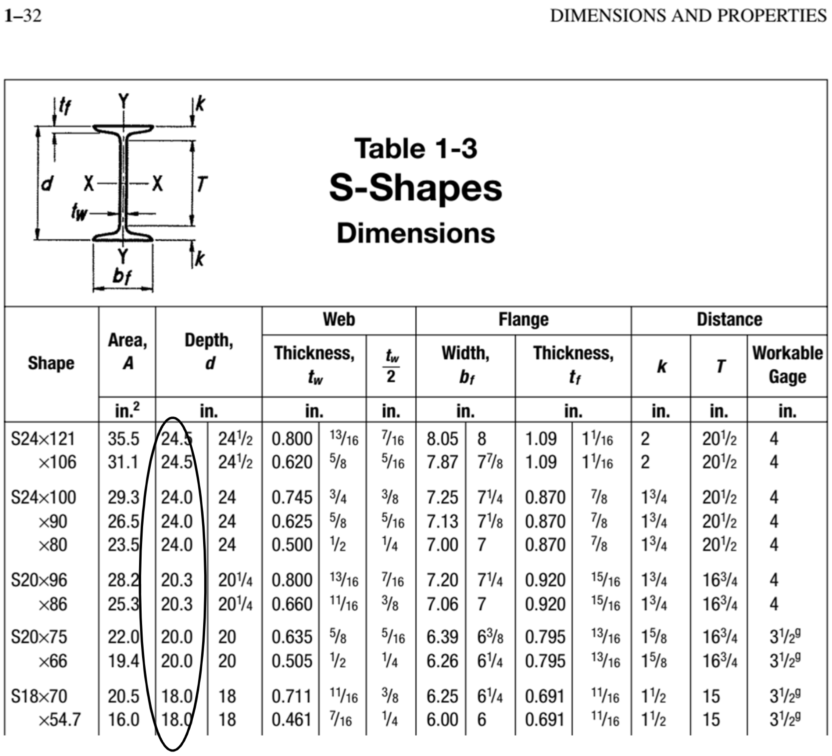


American Standard, S
(S18 × 70 shown)



1–32 DIMENSIONS AND PROPERTIES

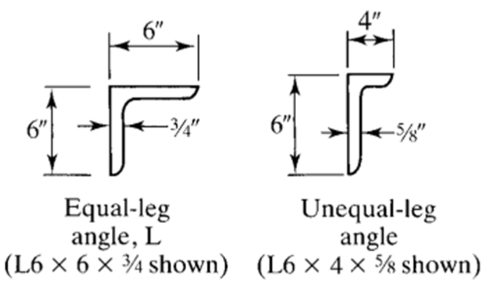
Table 1-3

S-Shapes

Dimensions

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.
S24×121	35.5	24.5	$24\frac{1}{2}$	0.800	$\frac{13}{16}$	$\frac{7}{16}$	8.05	8	1.09	$1\frac{1}{16}$	2	$20\frac{1}{2}$	4
×106	31.1	24.5	$24\frac{1}{2}$	0.620	$\frac{5}{8}$	$\frac{5}{16}$	7.87	$7\frac{7}{8}$	1.09	$1\frac{1}{16}$	2	$20\frac{1}{2}$	4
S24×100	29.3	24.0	24	0.745	$\frac{3}{4}$	$\frac{3}{8}$	7.25	$7\frac{1}{4}$	0.870	$\frac{7}{8}$	$1\frac{3}{4}$	$20\frac{1}{2}$	4
×90	26.5	24.0	24	0.625	$\frac{5}{8}$	$\frac{5}{16}$	7.13	$7\frac{1}{8}$	0.870	$\frac{7}{8}$	$1\frac{3}{4}$	$20\frac{1}{2}$	4
×80	23.5	24.0	24	0.500	$\frac{1}{2}$	$\frac{1}{4}$	7.00	7	0.870	$\frac{7}{8}$	$1\frac{3}{4}$	$20\frac{1}{2}$	4
S20×96	28.2	20.3	$20\frac{1}{4}$	0.800	$\frac{13}{16}$	$\frac{7}{16}$	7.20	$7\frac{1}{4}$	0.920	$\frac{15}{16}$	$1\frac{3}{4}$	$16\frac{3}{4}$	4
×86	25.3	20.3	$20\frac{1}{4}$	0.660	$\frac{11}{16}$	$\frac{3}{8}$	7.06	7	0.920	$\frac{15}{16}$	$1\frac{3}{4}$	$16\frac{3}{4}$	4
S20×75	22.0	20.0	20	0.635	$\frac{5}{8}$	$\frac{5}{16}$	6.39	$6\frac{3}{8}$	0.795	$\frac{13}{16}$	$1\frac{5}{8}$	$16\frac{3}{4}$	$3\frac{1}{2}^{g}$
×66	19.4	20.0	20	0.505	$\frac{1}{2}$	$\frac{1}{4}$	6.26	$6\frac{1}{4}$	0.795	$\frac{13}{16}$	$1\frac{5}{8}$	$16\frac{3}{4}$	$3\frac{1}{2}^{g}$
S18×70	20.5	18.0	18	0.711	$\frac{11}{16}$	$\frac{3}{8}$	6.25	$6\frac{1}{4}$	0.691	$\frac{11}{16}$	$1\frac{1}{2}$	15	$3\frac{1}{2}^{g}$
×54.7	16.0	18.0	18	0.461	$\frac{7}{16}$	$\frac{1}{4}$	6.00	6	0.691	$\frac{11}{16}$	$1\frac{1}{2}$	15	$3\frac{1}{2}^{g}$

The angle shapes are available in either equal-leg or unequal-leg versions. A typical designation would be “L6 × 6 × 3⁄4” or “L6 × 4 × 5⁄8.” The three numbers are the lengths of each of the two legs and the thickness, which is the same for both legs. In the case of the unequal-leg angle, the longer leg dimension is always given first.



Equal-leg angle, L (L6 × 6 × ¾ shown)

Unequal-leg angle (L6 × 4 × ⅝ shown)

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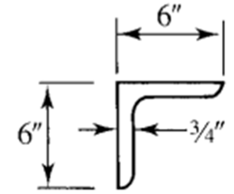
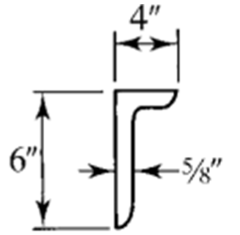
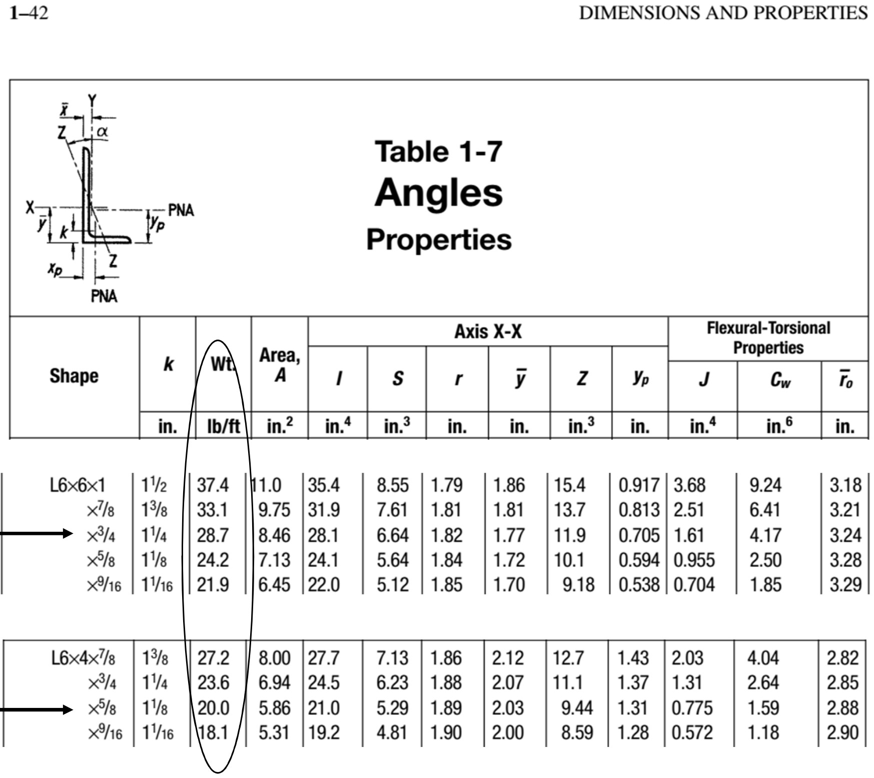


Equal-leg angle, L (L6 × 6 × ¾ shown)



Unequal-leg angle (L6 × 4 × ⅝ shown)

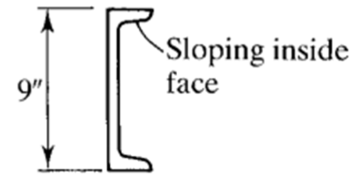


1–42 DIMENSIONS AND PROPERTIES

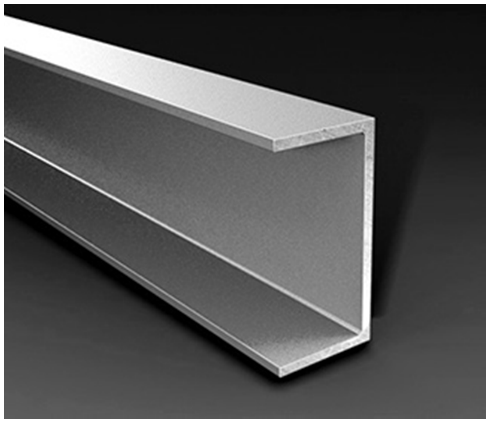
Table 1-7
Angles
Properties

Shape	k	Wt.	Area, A	Axis X-X						Flexural-Torsional Properties		
				I	S	r	$\bar{y}$	Z	y_p	J	C_w	$\bar{r}_o$
	in.	lb/ft	in.^{2}	in.^{4}	in.^{3}	in.	in.	in.^{3}	in.	in.^{4}	in.^{6}	in.
L6×6×1	$1\frac{1}{2}$	37.4	11.0	35.4	8.55	1.79	1.86	15.4	0.917	3.68	9.24	3.18
×$\frac{7}{8}$	$1\frac{3}{8}$	33.1	9.75	31.9	7.61	1.81	1.81	13.7	0.813	2.51	6.41	3.21
×$\frac{3}{4}$	$1\frac{1}{4}$	28.7	8.46	28.1	6.64	1.82	1.77	11.9	0.705	1.61	4.17	3.24
×$\frac{5}{8}$	$1\frac{1}{8}$	24.2	7.13	24.1	5.64	1.84	1.72	10.1	0.594	0.955	2.50	3.28
×$\frac{9}{16}$	$1\frac{1}{16}$	21.9	6.45	22.0	5.12	1.85	1.70	9.18	0.538	0.704	1.85	3.29
L6×4×$\frac{7}{8}$	$1\frac{3}{8}$	27.2	8.00	27.7	7.13	1.86	2.12	12.7	1.43	2.03	4.04	2.82
×$\frac{3}{4}$	$1\frac{1}{4}$	23.6	6.94	24.5	6.23	1.88	2.07	11.1	1.37	1.31	2.64	2.85
×$\frac{5}{8}$	$1\frac{1}{8}$	20.0	5.86	21.0	5.29	1.89	2.03	9.44	1.31	0.775	1.59	2.88
×$\frac{9}{16}$	$1\frac{1}{16}$	18.1	5.31	19.2	4.81	1.90	2.00	8.59	1.28	0.572	1.18	2.90

The *American Standard Channel,* or *C-shape,* has two flanges and a web. It carries a designation such as “*C9 × 20*.” The first number giving the total depth in inches and the second number the weight in pounds per linear foot. For the channel, however, the depth is exact rather than nominal.



American Standard
Channel, C
(C9 × 20 shown)



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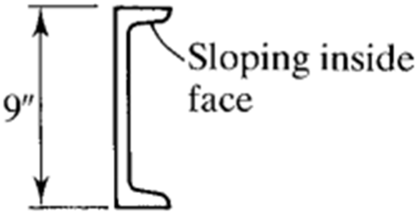
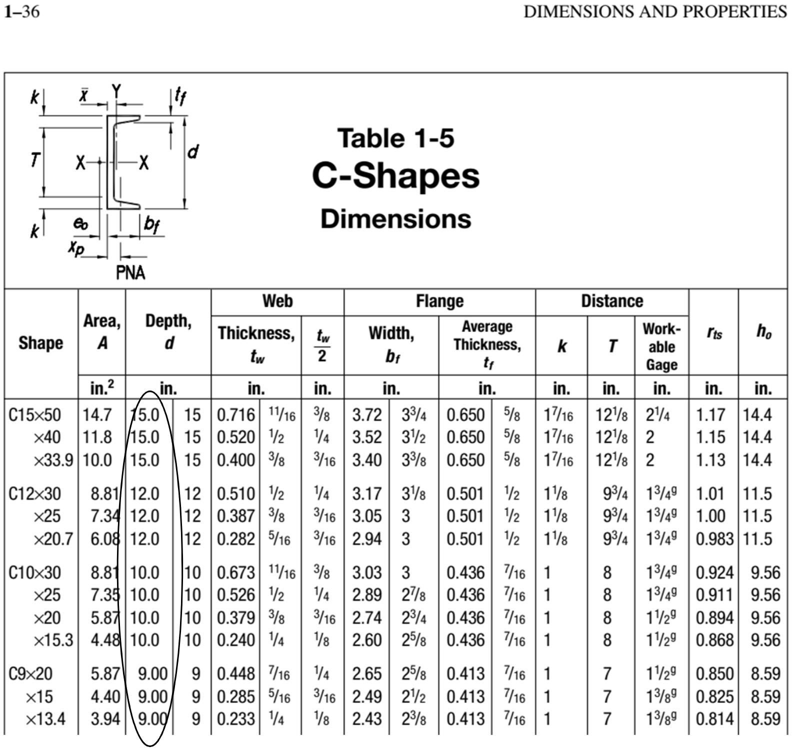


American Standard
Channel, C
(C9 × 20 shown)



1–36 DIMENSIONS AND PROPERTIES

Table 1-5
C-Shapes
Dimensions

Shape	Area, A	Depth, d		Web			Flange				Distance			r_{ts}	h_o
				Thickness, t_w		$\frac{t_w}{2}$	Width, b_f		Average Thickness, t_f		k	T	Workable Gage		
	in.^{2}	in.		in.		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	1.17	14.4
×40	11.8	15.0	15	0.520	1/2	1/4	3.52	3 1/2	0.650	5/8	1 7/16	12 1/8	2	1.15	14.4
×33.9	10.0	15.0	15	0.400	3/8	3/16	3.40	3 3/8	0.650	5/8	1 7/16	12 1/8	2	1.13	14.4
C12×30	8.81	12.0	12	0.510	1/2	1/4	3.17	3 1/8	0.501	1/2	1 1/8	9 3/4	1 3/4[g]	1.01	11.5
×25	7.34	12.0	12	0.387	3/8	3/16	3.05	3	0.501	1/2	1 1/8	9 3/4	1 3/4[g]	1.00	11.5
×20.7	6.08	12.0	12	0.282	5/16	3/16	2.94	3	0.501	1/2	1 1/8	9 3/4	1 3/4[g]	0.983	11.5
C10×30	8.81	10.0	10	0.673	11/16	3/8	3.03	3	0.436	7/16	1	8	1 3/4[g]	0.924	9.56
×25	7.35	10.0	10	0.526	1/2	1/4	2.89	2 7/8	0.436	7/16	1	8	1 3/4[g]	0.911	9.56
×20	5.87	10.0	10	0.379	3/8	3/16	2.74	2 3/4	0.436	7/16	1	8	1 1/2[g]	0.894	9.56
×15.3	4.48	10.0	10	0.240	1/4	1/8	2.60	2 5/8	0.436	7/16	1	8	1 1/2[g]	0.868	9.56
C9×20	5.87	9.00	9	0.448	7/16	1/4	2.65	2 5/8	0.413	7/16	1	7	1 1/2[g]	0.850	8.59
×15	4.40	9.00	9	0.285	5/16	3/16	2.49	2 1/2	0.413	7/16	1	7	1 3/8[g]	0.825	8.59
×13.4	3.94	9.00	9	0.233	1/4	1/8	2.43	2 3/8	0.413	7/16	1	7	1 3/8[g]	0.814	8.59

The *Structural Tee* is produced by splitting an I-shaped member at middepth. This shape is sometimes referred to as a *split-tee*. The prefix of the designation is either *WT, or ST*, depending on which shape is the “parent.”

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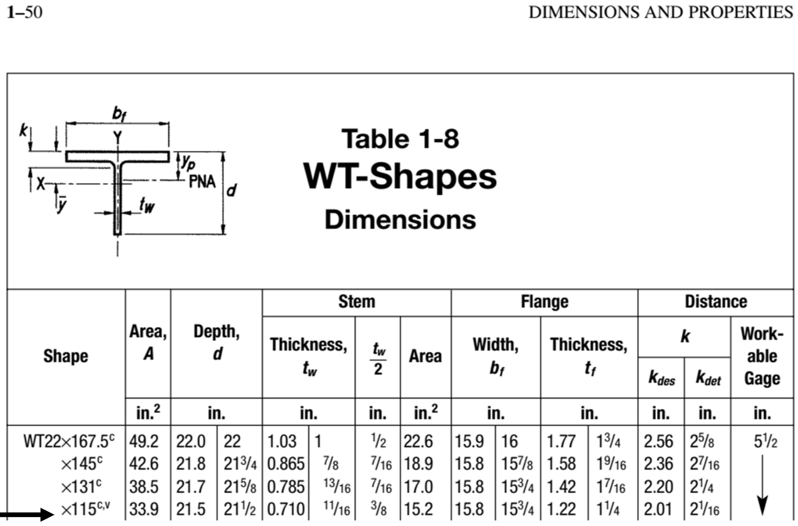
For example, a *WT 22×115* has a nominal depth of *22 inches* and a weight of 115 *pounds per foot*, and is cut from a *W 44x230*.

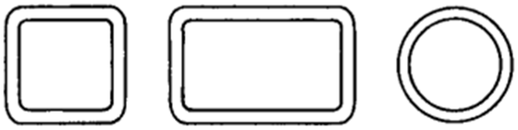


1–50 DIMENSIONS AND PROPERTIES

Table 1-8
WT-Shapes
Dimensions

Shape	Area, A	Depth, d		Stem				Flange				Distance		
				Thickness, t_w		$\frac{t_w}{2}$	Area	Width, b_f		Thickness, t_f		k		Workable Gage
												k_{des}	k_{det}	
	in.^{2}	in.		in.		in.	in.^{2}	in.		in.		in.	in.	in.
WT22×167.5^c	49.2	22.0	22	1.03	1	1/2	22.6	15.9	16	1.77	1 3/4	2.56	2 5/8	5 1/2
×145^c	42.6	21.8	21 3/4	0.865	7/8	7/16	18.9	15.8	15 7/8	1.58	1 9/16	2.36	2 7/16	↓
×131^c	38.5	21.7	21 5/8	0.785	13/16	7/16	17.0	15.8	15 3/4	1.42	1 7/16	2.20	2 1/4	
×115^{c,v}	33.9	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	

Other frequently used cross-sectional shapes are shown in the figure. The shapes are categorized as *round HSS*, and square and rectangular *HSS*. The designation *HSS* is for "*Hollow Structural Sections*".



Hollow Structural Sections

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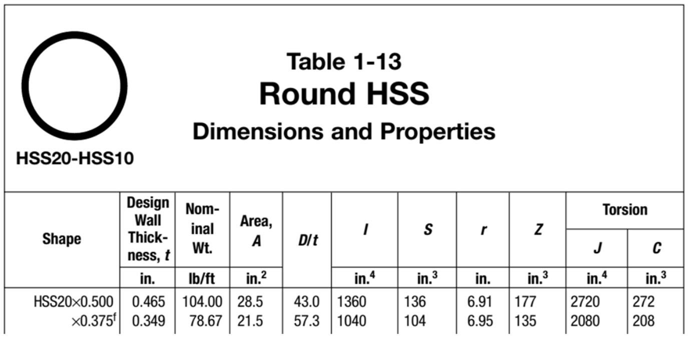


Table 1-13
Round HSS
Dimensions and Properties

HSS20-HSS10

Shape	Design Wall Thickness, t	Nominal Wt.	Area, A	D/t	I	S	r	Z	Torsion	
									J	C
	in.	lb/ft	in.^{2}		in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}
HSS20×0.500	0.465	104.00	28.5	43.0	1360	136	6.91	177	2720	272
×0.375$^{\text{f}}$	0.349	78.67	21.5	57.3	1040	104	6.95	135	2080	208

Round HSS are designated by outer diameter and wall thickness, expressed to three decimal places; for example, HSS 8.625 × 0.250. *Square and rectangular HSS are designated by nominal outside dimensions and wall thickness, expressed in rational numbers; for example, HSS 7 × 5 × 3⁄8.*

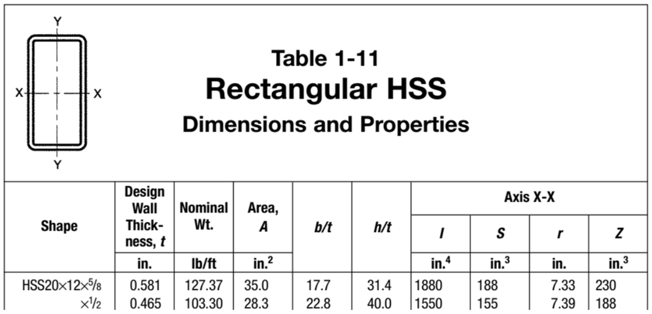


Table 1-11
Rectangular HSS
Dimensions and Properties

Shape	Design Wall Thickness, t	Nominal Wt.	Area, A	b/t	h/t	Axis X-X			
						I	S	r	Z
	in.	lb/ft	in.^{2}			in.^{4}	in.^{3}	in.	in.^{3}
HSS20×12×$^5/_8$	0.581	127.37	35.0	17.7	31.4	1880	188	7.33	230
×$^1/_2$	0.465	103.30	28.3	22.8	40.0	1550	155	7.39	188

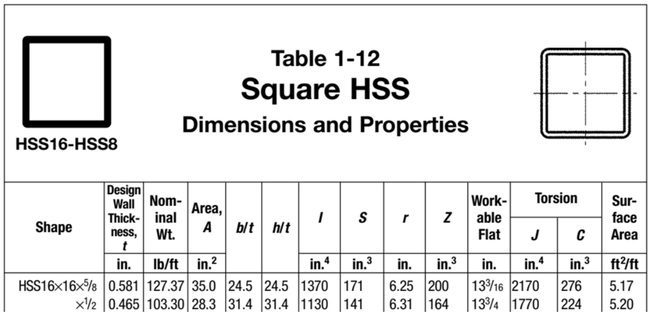


Table 1-12
Square HSS
Dimensions and Properties

HSS16-HSS8

Shape	Design Wall Thickness, t	Nominal Wt.	Area, A	b/t	h/t	I	S	r	Z	Workable Flat	Torsion		Surface Area
											J	C	
	in.	lb/ft	in.^{2}			in.^{4}	in.^{3}	in.	in.^{3}	in.	in.^{4}	in.^{3}	ft^2/ft
HSS16×16×$^5/_8$	0.581	127.37	35.0	24.5	24.5	1370	171	6.25	200	13$^3/_{16}$	2170	276	5.17
×$^1/_2$	0.465	103.30	28.3	31.4	31.4	1130	141	6.31	164	13$^3/_4$	1770	224	5.20

The *HP shape*, used for bearing piles, has parallel flange surfaces, approximately the same width and depth, and equal flange and web thicknesses. *HP*-shapes are designated in the same manner as the W-shape; for example, *HP18 × 204.*

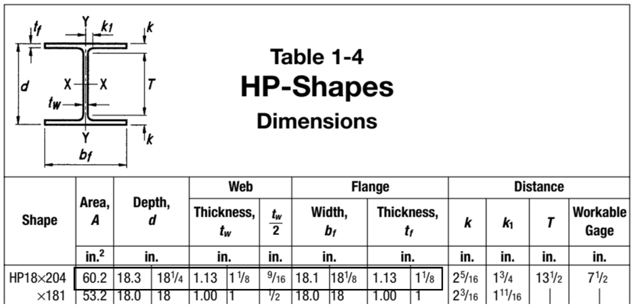


Table 1-4

HP-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	Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.
HP18×204	60.2	18.3	$18\frac{1}{4}$	1.13	$1\frac{1}{8}$	$\frac{9}{16}$	18.1	$18\frac{1}{8}$	1.13	$1\frac{1}{8}$	$2\frac{5}{16}$	$1\frac{3}{4}$	$13\frac{1}{2}$	$7\frac{1}{2}$
×181	53.2	18.0	18	1.00	1	$\frac{1}{2}$	18.0	18	1.00	1	$2\frac{3}{16}$	$1\frac{11}{16}$	│	│

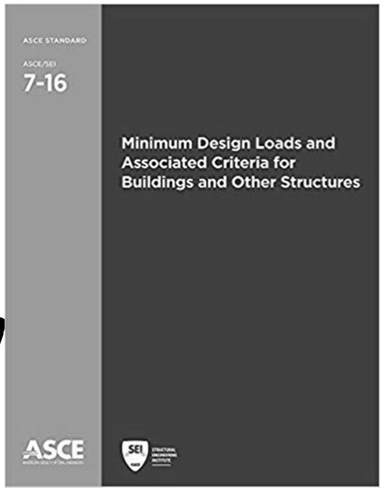
Specifications, Loads, and Methods of Design

The design of structures is controlled by building codes and design specifications. These codes and specifications, which are actually laws or ordinances, *specify minimum design loads, design stresses, construction types, material quality, and other factors.*

LOADS

Perhaps the most important and most difficult task faced by the structural engineer is the accurate estimation of the loads that may be applied to a structure during its life. In general, loads are classified according to *their character and duration of application*. As such, they are said to be *dead loads, live loads, and environmental loads.*

If there is an absence of a code, the design loads shall be those provided in a publication of the *American Society of Civil Engineers* entitled *Minimum Design Loads for Buildings and Other Structures*. This publication is commonly referred to as *ASCE* 7



ASCE STANDARD

ASCE/SEI

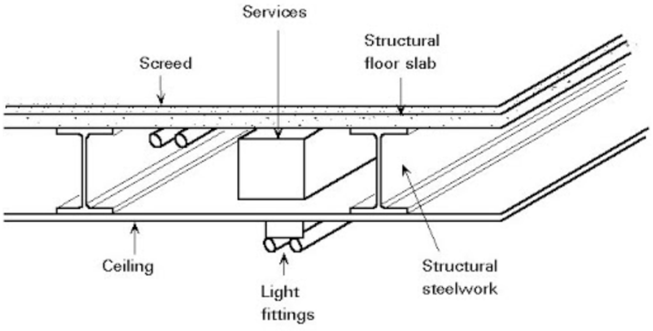
7-16

Minimum Design Loads and Associated Criteria for Buildings and Other Structures

ASCE

SEI

DEAD LOADS



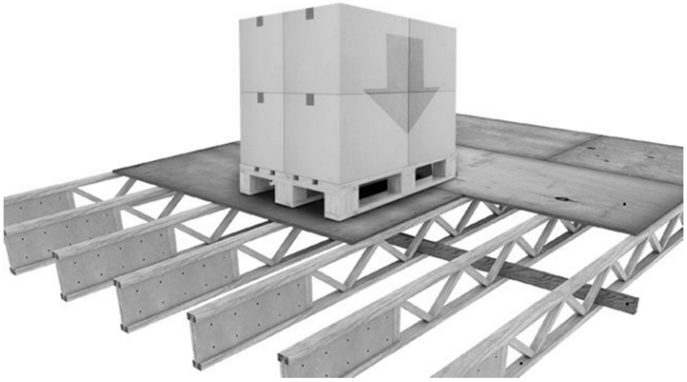
Typical dead loads

Dead loads are loads of constant magnitude that remain in one position. They consist of the structures own weight and other loads that are permanently attached to the structure.

LIVE LOADS

Live loads are loads that may change in position and magnitude. They are caused when a structure is occupied, used, and maintained. Live loads that move under their own power, such as trucks, people, and cranes, are said to be moving loads. Those loads that may be moved are movable loads, such as furniture and warehouse materials.

1. Floor loads. The minimum gravity live loads to be used for building floors are clearly specified by the applicable building code



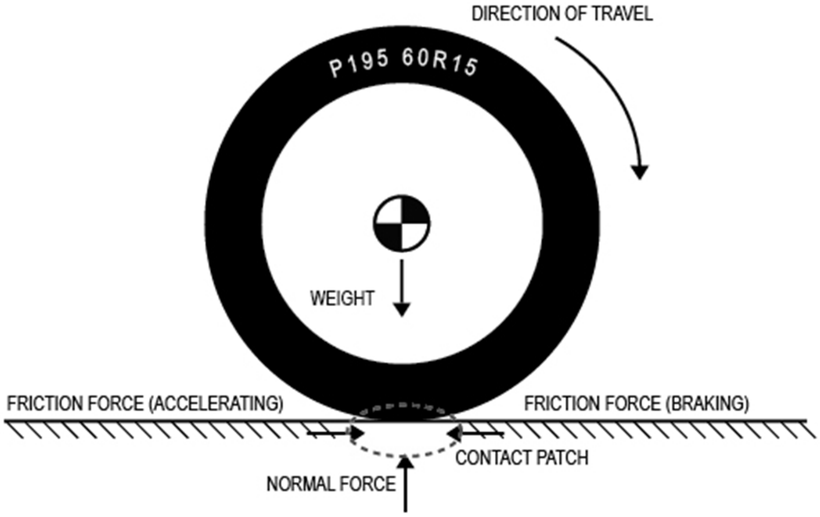
2. Traffic loads for bridges. Bridges are subjected to series of concentrated loads of varying magnitude caused by groups of truck or train wheels.

Overhead crane

3. Impact loads. Impact loads are caused by the *vibration* of moving or movable Loads. *Cranes* picking up loads and *elevators* starting and stopping are other examples of impact loads.

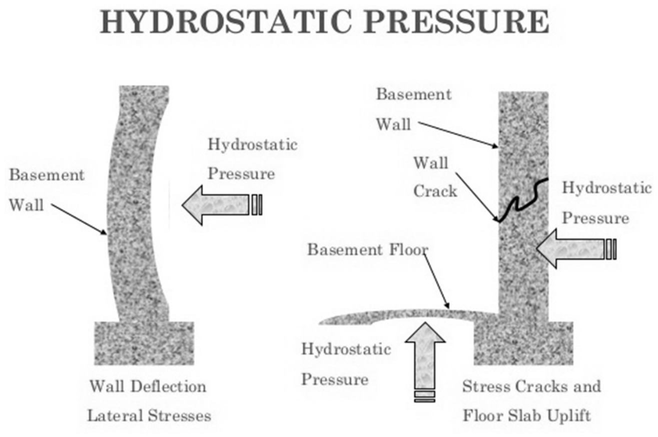
4. Longitudinal loads. Longitudinal loads are another type of load that needs to be considered in designing some structures. *Stopping* a train on a railroad bridge or a truck on a highway bridge causes *longitudinal forces* to be applied. There are other longitudinal load situations, such as the movement of *traveling cranes* that are supported by building frames.

Longitudinal loads



5. Other live loads

Among the other types of live loads with which the structural engineer will have to contend are *soil pressures*, *hydrostatic pressures*, *thermal forces* (due to changes in temperature, causing structural deformations and resulting structural forces); and *centrifugal forces* (such as those on curved bridges and caused by trucks and trains).



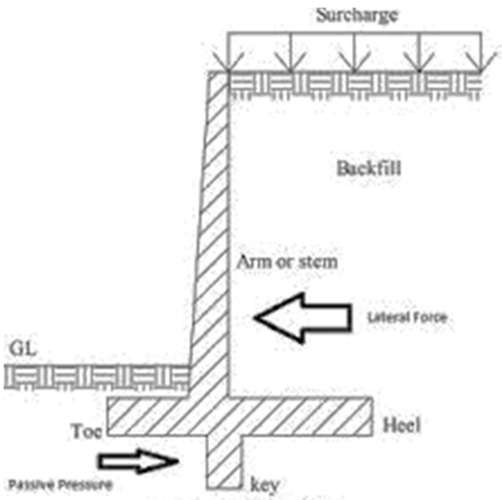
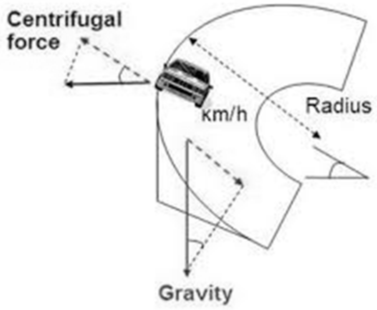


Figure 1: Retaining Wall



ENVIRONMENTAL LOADS

Environmental loads are caused by the environment in which a particular structure is located.

1. *Snow*
2. *Rain*
3. *Wind load*
4. *Earthquake Loads*.