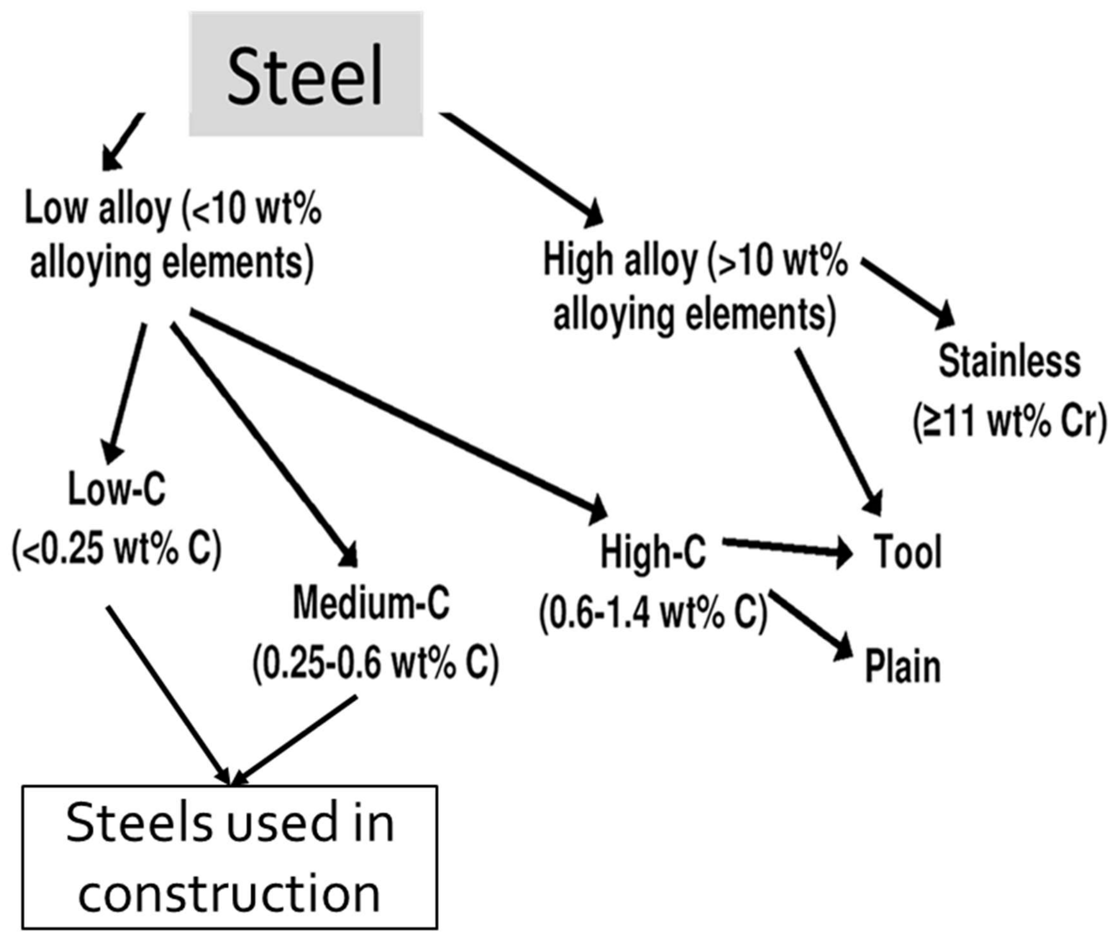
Structural Steel Buildings

Chapter 4

Structural Steel

Structural steel is construction material fabricated with a specific shape and chemical composition to suit a project's applicable specifications.



Structural Steel

Due to the widespread use of steel in many applications, there are a wide variety of systems for identifying or designating steel, based on grade, type and class. Virtually every country with an industrial capacity has specifications for steel.

The principal types of structural steel in the US identified and specified by ASTM

Steel Type	ASTM Designation		F_y[1] (ksi)	F_u[1] (ksi)	Minimum Elongation[2] (%)	Typical Chemical Composition[3] (%) C	Cu[5]	Mn	P	S	Ni	Cr	Si	Mo	V
Carbon	A36		36	58–80	23	0.26	0.2	0.8–1.2[6]	0.04	0.05					
	A53 Gr. B		35	60		0.25	0.4	0.95	0.05	0.045	0.4	0.4		0.15	0.08
	A500	Gr. B	42	58	23	0.3	0.18		0.045	0..045					
			46	58											
		Gr. C	46	62	21	0.27	0.18	1.4	0.045	0.045					
			50	62											
	A501		36	58	23	0.3	0.18		0.045	0.045					
	A529	Gr.50	50	65–100	19	0.27	0.2	1.35	0.04	0.05					
		Gr.55	55	70–100											
High-strength Low-alloy	A572	Gr. 42	42	60	24	0.21	-	1.35	0.04	0.05			0.15–0.4		
		Gr. 50	50	65	21	0.23	-	1.35	0.04	0.05			0.15–0.4		
		Gr. 55	55	70		0.25	-	1.35	0.04	0.05			0.15–0.5		
		Gr. 60	60	75	18	0.26	-	1.35	0.04	0.05			0.4		
		Gr. 65	65	80	17	0.23	-	1.65	0.04	0.05			0.4		
	A618	Gr. I&II	50	70	22	0.2	0.2	1.35	0.04	0.05					
		Gr. III	46	67	22	0.23	-	1.35	0.04	0.05			0.3		
	A913	50	50	65	21	0.12	0.45	1.6	0.04	0.03	0.25	0.25	0.4	0.07	0.06
		65	65	80	17	0.16	0.35	1.6	0.03	0.03	0.25	0.25	0.4	0.07	0.06
	A992[4]		50–65	65	18	0.23	0.6	0.5–1.5	0.04	0.05			0.4	0.15	0.11
Corrosion resistant High-strength low-alloy	A242	50	50	70	21	0.15	0.2	1	0.15	0.05					
	A588		50	70	21	0.19	0.25–0.4	0.8–1.25	0.04	0.05	0.4	0.4–0.65		0.02–0.1	

[1]Minimum values unless range or other control noted
[2]Two inch gauge length
[3]Maximum values unless range or other control noted
[4]A maximium yield to tensile strength ratio of 0.85 and carbon equivalent formula are included as mandatory in ASTM A992
[5]Several steel specifications can include a minimum copper content to provide weather resistance
[6]Range for plate given in table, bar range 0.6–0.9

Structural Steel

Structural steel grades – European standards

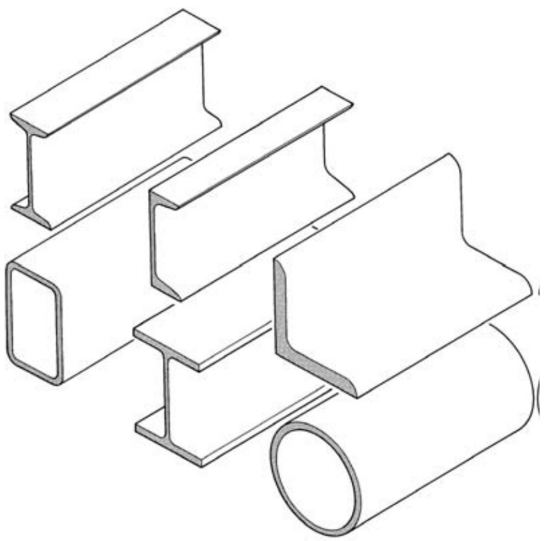
Designation: According EN 10027-1 and CR 10260	Designation: According EN 10027-2	Method of deoxi-dation [b]	C in % max. for nominal product thickness in mm: ≤ 16	> 16 ≤ 40	> 40[c]	Si % max.	Mn % max.	P % max. [d]	S % max. [d e]	N % max. [f]	Cu % max. [g]	Other % max. [h]
S235JR	1.0038	FN	0,17	0,17	0,20	-	1,40	0,035	0,035	0,012	0,55	-
S235J0	1.0114	FN	0,17	0,17	0,17	-	1,40	0,030	0,030	0,012	0,55	-
S235J2	1.0117	FF	0,17	0,17	0,17	-	1,40	0,025	0,025	-	0,55	-
S275JR	1.0044	FN	0,21	0,21	0,22	-	1,50	0,035	0,035	0,012	0,55	-
S275J0	1.0143	FN	0,18	0,18	0,18[i]	-	1,50	0,030	0,030	0,012	0,55	-
S275J2	1.0145	FF	0,18	0,18	0,18[i]	-	1,50	0,025	0,025	-	0,55	-
S355JR	1.0045	FN	0,24	0,24	0,24	0,55	1,60	0,035	0,035	0,012	0,55	-
S355J0	1.0553	FN	0,20[j]	0,20[k]	0,22	0,55	1,60	0,030	0,030	0,012	0,55	-
S355J2	1.0577	FF	0,20[j]	0,20[k]	0,22	0,55	1,60	0,025	0,025	-	0,55	-
S355K2	1.0596	FF	0,20[j]	0,20[k]	0,22	0,55	1,60	0,025	0,025	-	0,55	-
S450J0[l]	1.0590	FF	0,20	0,20[k]	0,22	0,55	1,70	0,030	0,030	0,025	0,55	[m]

Steel grades and qualities	Minimum yield strength R_{eH} (MPa), Nominal thickness (mm): ≤ 16	>16 ≤ 40	>40 ≤ 63	>63 ≤ 80	Tensile strength R_m (MPa), Nominal thickness (mm): < 3	≥3 ≤ 100	Minimum percentage elongation after fracture $L_o = 5.65\sqrt{S_0}$, Nominal thickness (mm): ≥3 ≤ 40	>40 ≤ 63	>63 ≤ 100
S235JR	235	225	215	215	360 to 510	360 to 510	26	25	24
S235J0	235	225	215	215	360 to 510	360 to 510			
S235J2	235	225	215	215	360 to 510	360 to 510	24	23	22
S275JR	275	265	255	245	430 to 580	410 to 560	23	22	21
S275J0	275	265	255	245	430 to 580	410 to 560			
S275J2	275	265	255	245	430 to 580	410 to 560	21	20	19
S355JR	355	345	335	325	510 to 680	470 to 630	22	21	20
S355J0	355	345	335	325	510 to 680	470 to 630			
S355J2	355	345	335	325	510 to 680	470 to 630			
S355K2	335	345	335	325	510 to 680	470 to 630	20	19	18
S450J0	450	430	410	390	-	550 to 720	17	17	17

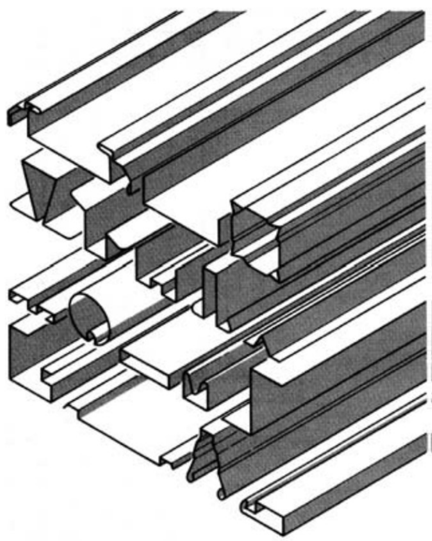
Typical grades are described as 'S275J2' or 'S355K2W'. In these examples, 'S' denotes structural; 275 or 355 denotes the yield strength in newton's per square millimeter; J2 or K2 denotes the materials toughness; and the 'W' denotes weathering steel.

Structural Steel sections

- Depending on each project's applicable specifications, the steel sections might have various shapes, sizes and gauges made by hot or cold rolling, others are made by casting or welding together flat or bent plates.



Hot-rolled steel elements



Cold-formed sections

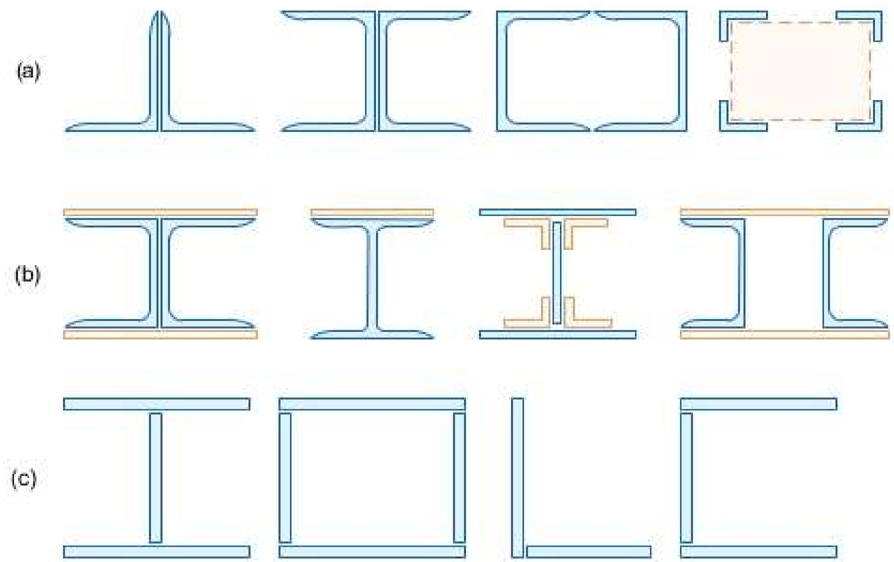
Fabrication by casting

Hot-Rolled Shapes

- Hot-rolling is a primary shaping process in which massive red-hot billets of steel are rolled between several sets of profiled rollers.
- I- and H-shapes of cross-section are common for the large elements that form the beams and columns of structural frameworks. Theses shapes have a high second moment of area in relation to the total area.
- Channel and angle shapes are suitable for smaller elements such as secondary cladding supports and sub-elements in triangulated frameworks
- Square, circular and rectangular hollow sections (HSS) are efficient forms for members subjected to multi-axes loading as the cross-sectional axes are symmetrical and thus exhibit uniform strength features. They also have good torsional resistance.
- Details of the dimensions and geometric properties of the sections are available from manufacturers.

Built Up Sections

Alternatively to standard sections it is possible to form welded sections with various cross section configurations using standard sections and plates or from welding different plates together.



Some typical built-up shapes and sections (a) made from standard shapes, (b) made from standard shapes and plates, (c)made from plates

Hot-Rolled Shapes - American

Dimensions and Section Properties - W Sections

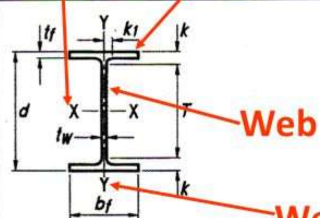


Table 1–1
W Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k k_{des}	Distance k k_{det}	Distance k_1	Distance T	Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W44×335^c	98.5	44.0	44	1.03	1	1/2	15.9	16	1.77	1 3/4	2.56	2 5/8	1 5/16	38 3/4	5 1/2
×290^c	85.4	43.6	43 5/8	0.865	7/8	7/16	15.8	15 7/8	1.58	1 9/16	2.36	2 7/16	1 1/4	↓	↓
×262^c	76.9	43.3	43 1/4	0.785	13/16	7/16	15.8	15 3/4	1.42	1 7/16	2.20	2 1/4	1 3/16		
×230^{c,v}	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

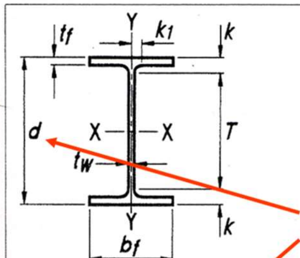


Table 1-1.
W-Shapes
Dimensions

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		

Cross-sectional area

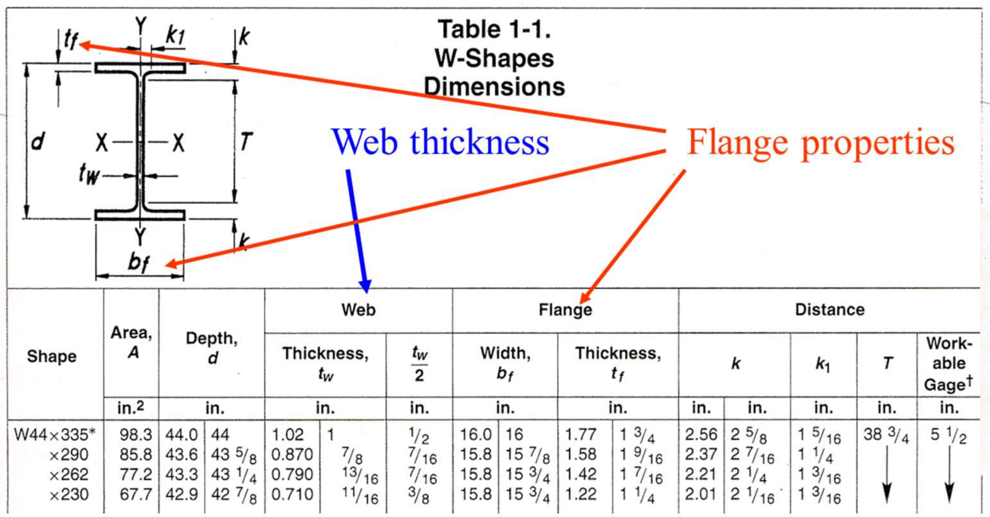
Section designation

W 24 x 55 ← Weight in pounds/per foot

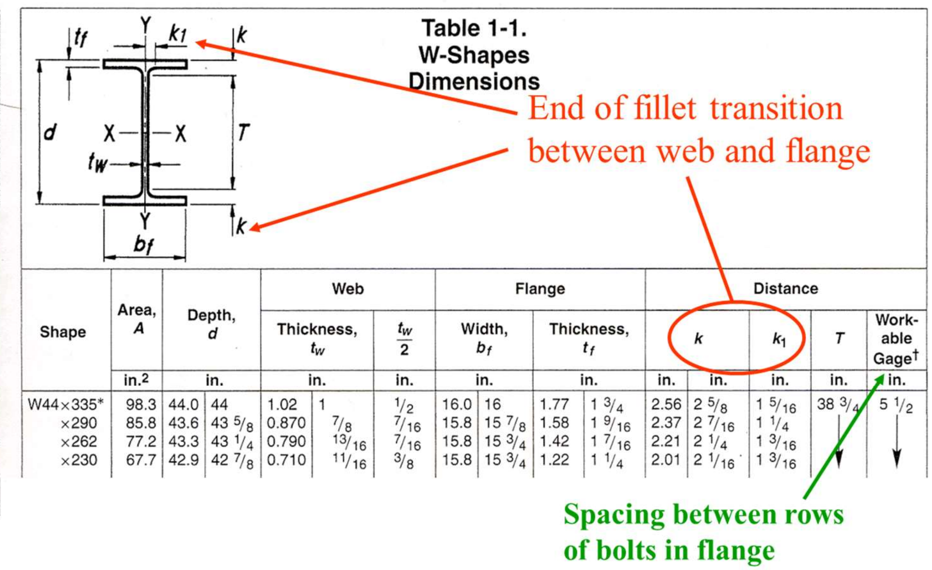
Nominal depth in full inches

Hot-Rolled Shapes - American

Dimensions and Section Properties - W Sections



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		



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		

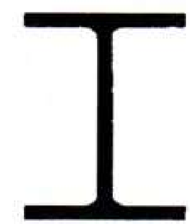
Hot-Rolled Shapes - American

Dimensions and Section Properties - W Sections

Moment of Inertia (*I*), elastic section modulus (*S*), radius of gyration (*r*), plastic section modulus (Z) for strong and weak axes

Weight per foot

Table 1–1 (continued)
W Shapes
Properties



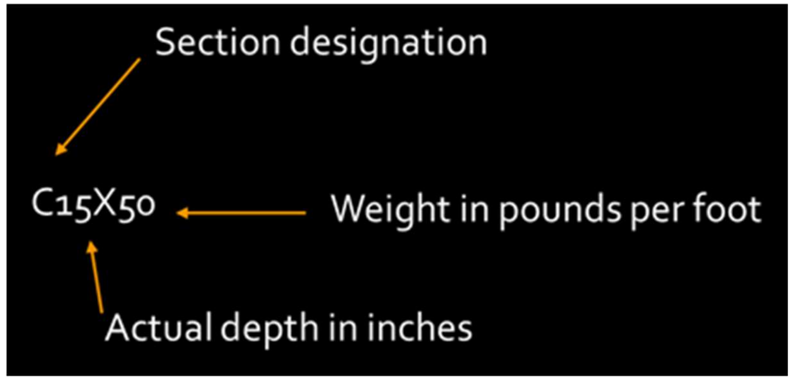
W44 – W40

Nom-inal 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}
335	4.50	38.0	31100	1410	17.8	1620	1200	150	3.49	236	4.24	42.3	74.7	535000
290	5.02	45.0	27000	1240	17.8	1410	1040	132	3.49	205	4.21	42.0	50.9	461000
262	5.57	49.6	24100	1110	17.7	1270	923	117	3.47	182	4.17	41.9	37.3	405000
230	6.45	54.8	20800	971	17.5	1100	796	101	3.43	157	4.13	41.7	24.9	346000

Flange and web stability parameters

Hot-Rolled Shapes - American

Dimensions and Section Properties - Channels Sections



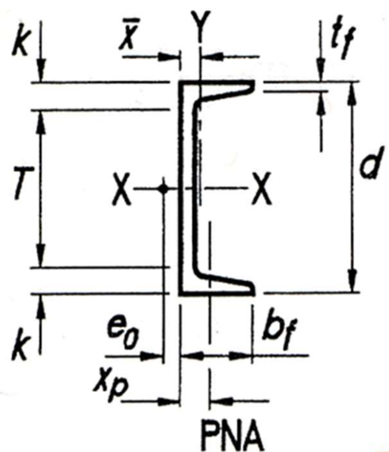


Table 1-5.
C-Shapes
(American Standard Channels)
Dimensions

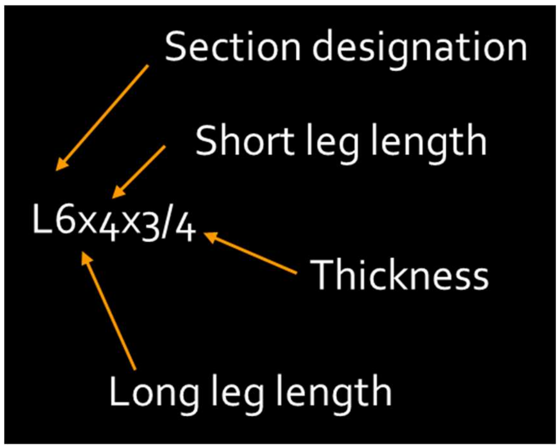
Actual depth

Property for design

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

Hot-Rolled Shapes - American

Dimensions and Section Properties – Angles Sections



Location of elastic centroid

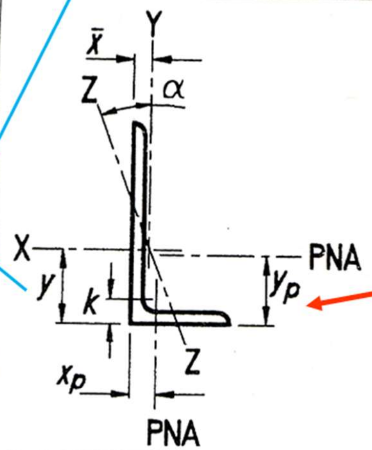


Table 1-7. Angles (L-Shapes) Properties

Location of plastic centroid

X-axis properties

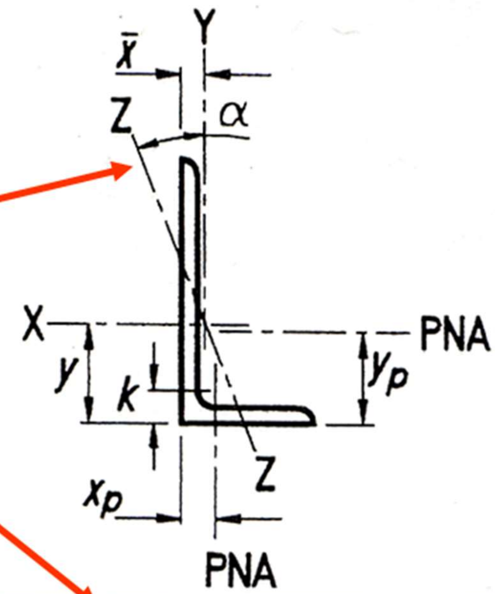
Shape	k	Wt.	Area, A	Axis X-X					
				I	S	r	$\bar{y}$	Z	y_p
	in.	lb/ft	in.^{2}	in.^{4}	in.^{3}	in.	in.	in.^{3}	in.
L8×8×1 1/8	1 3/4	57.2	16.8	98.1	17.5	2.41	2.40	31.6	1.05
×1	1 5/8	51.3	15.1	89.1	15.8	2.43	2.36	28.5	0.943
×7/8	1 1/2	45.3	13.3	79.7	14.0	2.45	2.31	25.3	0.832
×3/4	1 3/8	39.2	11.5	69.9	12.2	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

Hot-Rolled Shapes - American

Dimensions and Section Properties – Angles Sections

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



Minor (weak) axis **Z**

Y axis properties

Shape	Axis Y-Y						Axis Z-Z		Q_s^*
	I	S	r	$\bar{x}$	Z	x_p	r	Tan	$F_y = 36$
	in.^{4}	in.^{3}	in.	in.	in.^{3}	in.	in.	α	ksi
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

Hot-Rolled Shapes - American

Dimensions and Section Properties - Double Angles

- **X**-axis properties of double angles may be obtained from x-axis properties of a single angle
- Y-axis properties depend on separation between backs of angles and whether LLBB (Long Legs Back to Back) or SLBB (Short Legs Back to Back)

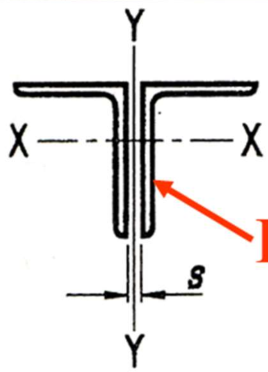
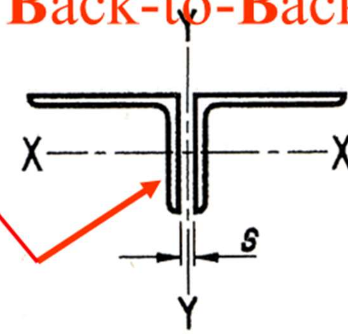


Table 1-14. Double Angles (2L-Shapes) Properties

Long Legs Back-to-Back

Short Legs Back-to-Back



Shape	Axis Y-Y Radii of Gyration						Q_s*			
	LLBB Separation *s*, in.			SLBB Separation *s*, in.			LLBB		SLBB	
	0	3/8	3/4	0	3/8	3/4	Angles in Contact	Angles Separated	Angles in Contact	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

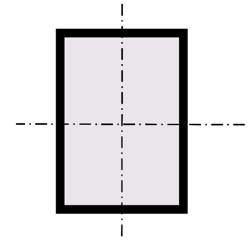
Hot-Rolled Shapes - American

Dimensions and Section Properties - HSS (Hollow Structural Shape)

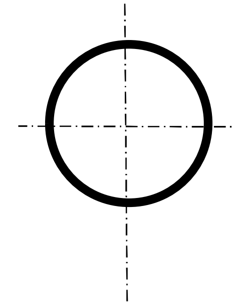
**Table 1-11.
Rectangular (and Square) HSS
Dimensions and Properties**

Shape	Wall Thickness, *t*		Nom-inal Wt.	Area, *A*	$\frac{b}{t}$	$\frac{h}{t}$	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

Rectangular



Round



Nominal versus
design wall thickness

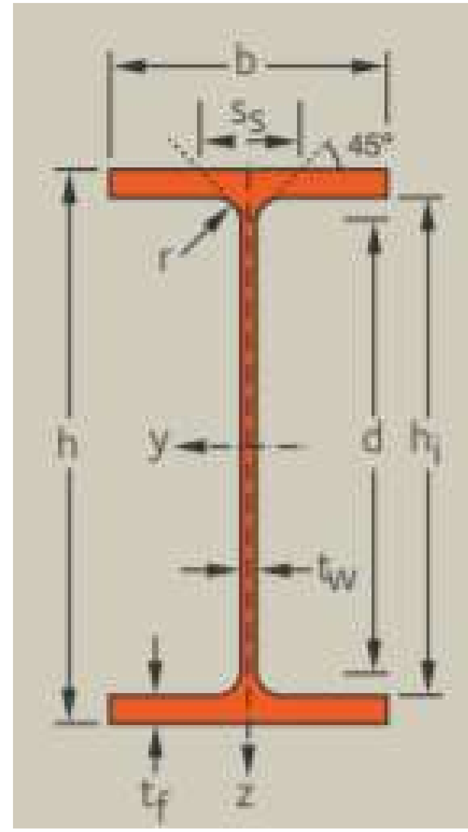
Diameter over design thickness

**Table 1-12.
Round HSS
Dimensions and Properties**

Shape	Wall Thickness, *t*		Nom-inal Wt.	Area, *A*	$\frac{D}{t}$	*I*	*S*	*r*	*Z*	Torsion		Surf. Area Per Ft
	nominal	design								*J*	*C*	
	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

Hot-Rolled Shapes - European standards

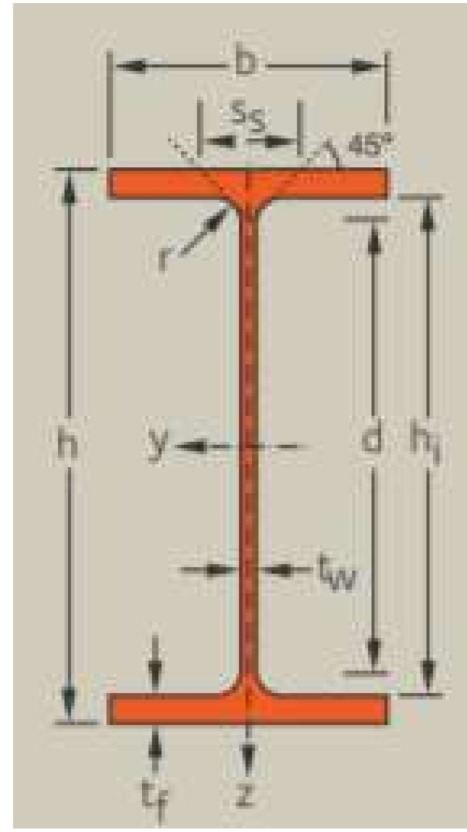
Désignation Designation Bezeichnung		Dimensions Abmessungen								Surface Oberfläche		
		G kg/m	h mm	b mm	t_w mm	t_f mm	r mm	h_i mm	d mm	A cm^2	A_L m^2/m	A_G m^2/t
IPE O 360	40	66,0	364,0	172,0	9,2	14,7	18	334,6	298,6	84,1	1,367	20,69
IPE 360		57,1	360,0	170,0	8,0	12,7	18	334,6	298,6	72,7	1,353	23,70
IPE A 360		50,2	357,6	170,0	6,6	11,5	18	334,6	298,6	64,0	1,351	26,91
IPE AA 360		47,0	356,4	170,0	6,0	10,9	18	334,6	298,6	59,9	1,350	28,70
IPE O 330	40	57,0	334,0	162,0	8,5	13,5	18	307,0	271,0	72,6	1,268	22,24
IPE 330		49,1	330,0	160,0	7,5	11,5	18	307,0	271,0	62,6	1,254	25,52
IPE A 330		43,0	327,0	160,0	6,5	10,0	18	307,0	271,0	54,7	1,250	29,09
IPE O 300	40	49,3	304,0	152,0	8,0	12,7	15	278,6	248,6	62,8	1,174	23,81
IPE 300		42,2	300,0	150,0	7,1	10,7	15	278,6	248,6	53,8	1,160	27,46
IPE A 300		36,5	297,0	150,0	6,1	9,2	15	278,6	248,6	46,5	1,156	31,65
IPE O 270	40	42,3	274,0	136,0	7,5	12,2	15	249,6	219,6	53,8	1,051	24,88
IPE 270		36,1	270,0	135,0	6,6	10,2	15	249,6	219,6	45,9	1,041	28,86
IPE A 270		30,7	267,0	135,0	5,5	8,7	15	249,6	219,6	39,2	1,037	33,75



Parallel Flange I Section (IPE)

Hot-Rolled Shapes - European standards

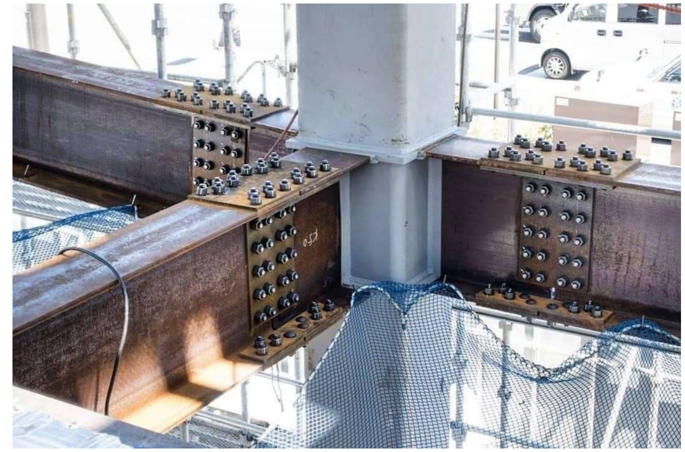
Désignation / Designation / Bezeichnung	Valeurs statiques / Section properties / Statische Kennwerte												
		axe fort y-y / strong axis y-y / starke Achse y-y					axe faible z-z / weak axis y-y / schwache Achse y-y						
	G	I_y	$W_{el.y}$	$W_{pl.y}$	i_y	A_{vz}	I_z	$W_{el.z}$	$W_{pl.z}$	i_z	s_s	I_t	I_w
	kg/m	cm^4	cm^3	cm^3	cm	cm^2	cm^4	cm^3	cm^3	cm	cm	cm^4	cm^6 x10^3
IPE O 360	66,0	19050	1047	1186	15,1	40,20	1251	146,0	227,0	3,9	6,0	55,74	380,0
IPE 360	57,1	16270	904,0	1019	15,0	35,10	1043	123,0	191,0	3,8	5,5	37,44	314,0
IPE A 360	50,2	14520	812,0	907,0	15,1	29,80	944,0	111,0	172,0	3,8	5,1	27,37	282,0
IPE AA 360	47,0	13680	767,6	853,6	15,1	27,44	894,8	105,30	162,5	3,9	4,9	23,37	266,4
IPE O 330	57,0	13910	833,0	943,0	13,8	34,90	960,0	119,0	185,0	3,6	5,7	42,20	246,0
IPE 330	49,1	11770	713,0	804,0	13,7	30,80	788,0	98,50	154,0	3,6	5,2	28,06	199,0
IPE A 330	43,0	10230	626,0	702,0	13,7	27,00	685,0	85,60	133,0	3,5	4,8	19,64	172,0
IPE O 300	49,3	9994	658,0	744,0	12,6	29,10	746,0	98,10	153,0	3,5	5,1	30,98	158,0
IPE 300	42,2	8356	557,0	628,0	12,5	25,70	604,0	80,50	125,0	3,4	4,6	19,92	126,0
IPE A 300	36,5	7173	483,0	542,0	12,4	22,30	519,0	69,20	107,0	3,3	4,2	13,35	107,0
IPE O 270	42,3	6947	507,0	575,0	11,4	25,20	514,0	75,50	118,0	3,1	5,0	24,99	87,60
IPE 270	36,1	5790	429,0	484,0	11,2	22,10	420,0	62,20	97,00	3,0	4,5	15,90	70,60
IPE A 270	30,7	4917	368,0	413,0	11,2	18,80	358,0	53,00	82,30	3,0	4,1	10,41	59,50
IPE O 240	34,3	4369	361,0	410,0	10,0	21,40	329,0	53,90	84,40	2,7	4,6	17,09	43,70
IPE 240	30,7	3892	324,0	367,0	10,0	19,10	284,0	47,30	73,90	2,7	4,3	12,95	37,40
IPE A 240	26,2	3290	278,0	312,0	9,9	16,30	240,0	40,00	62,40	2,7	3,9	8,503	31,30
IPE AA 240	24,9	3154	267,0	298,0	10,0	15,30	231,0	38,60	60,00	2,7	3,8	7,608	30,10



Parallel Flange I Section (IPE)

Connecting Structural Steel

- Proper connection of steel members is crucial for the structure's strength and stability.
- The primary connection methods for structural steel are bolting and welding.
- Connections made in a fabrication shop are called shop connections, while connections made in the field by the steel erector are called field connections.
- Bolting and welding may be used for shop and field connections. However, field connections are typically bolted, and shop connections are typically welded.



Bolted connection

Welded connection

Steel Buildings

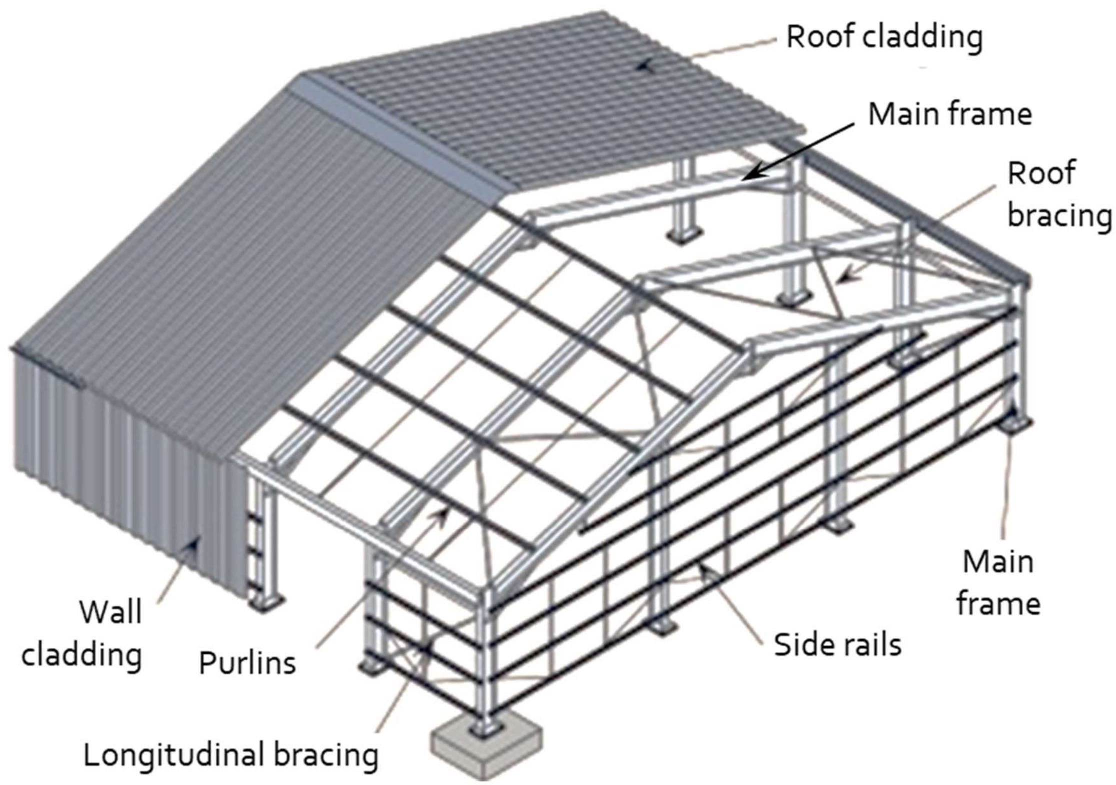
- A steel building is a metal structure that is made of structural steel components connected to carry loads and provide rigidity.
- Steel buildings are categorized as
  - Single-story/ industrial buildings
  - Multi-story buildings – moment resisting (Rigid) or braced frames.

Single-story building

Multi-story building

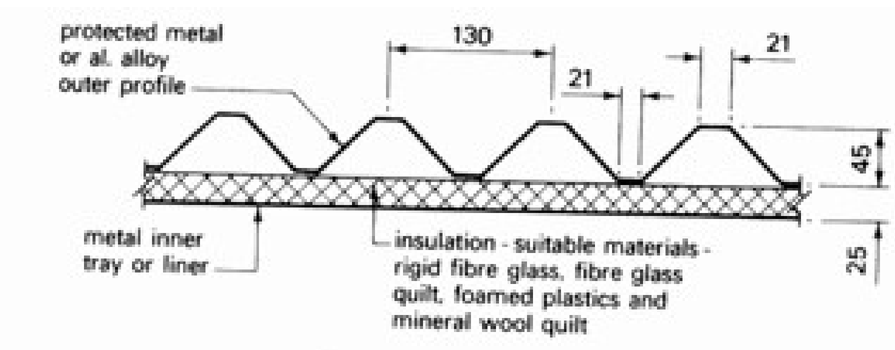
Single Story Buildings

- The skeleton of a typical single-story building consists of three major elements:
  - Cladding for both roof and walls.
  - Secondary elements to support the cladding (purlins; rails).
  - Main frame of the structure, including all necessary bracing.

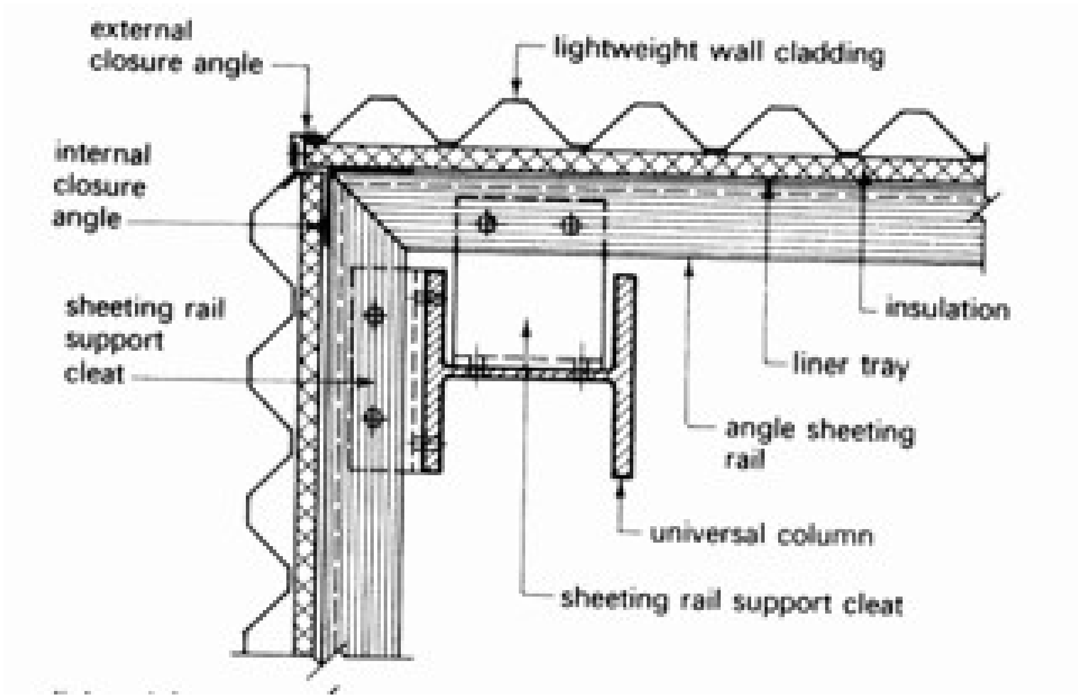


Single Story Buildings

- **Cladding.** Cladding is the outer skin of the building to provide, Weather protection; Daylight/ Ventilation, and Aesthetic value. They are made from Fiber cement; Coated steel sheets and Aluminum alloy sheets.

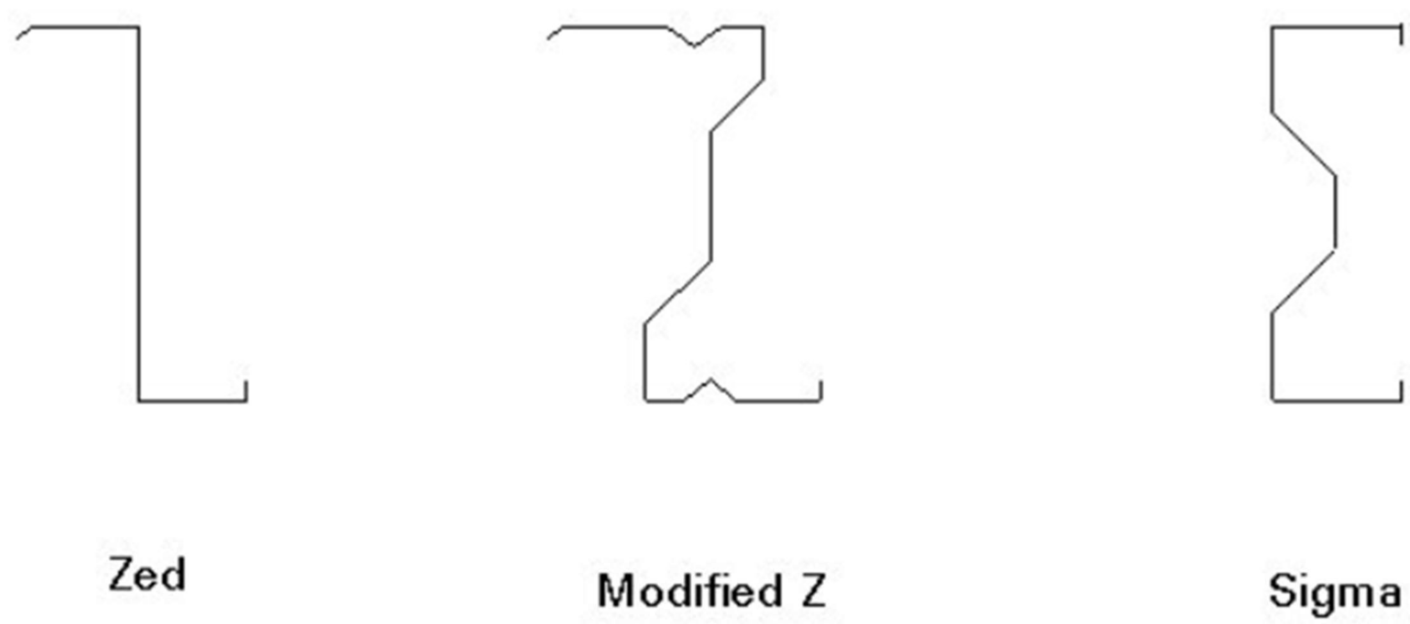


Typical cladding profile



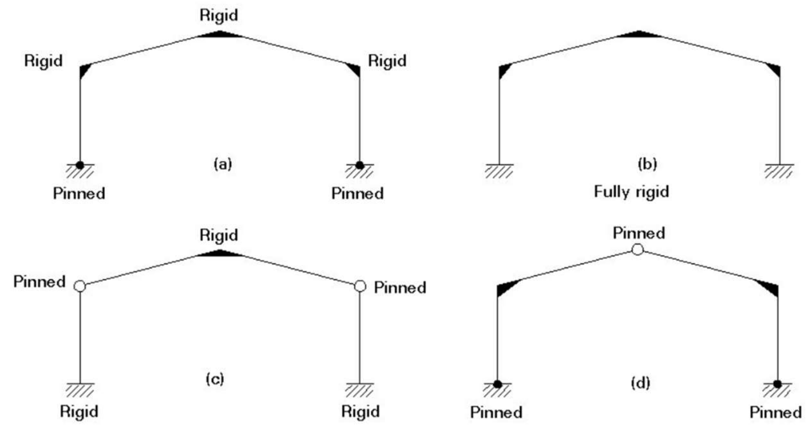
Single Story Buildings

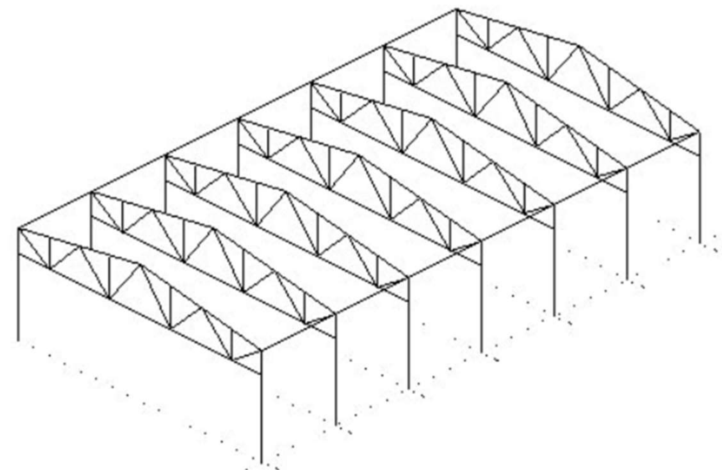
- **Secondary Elements.** In the normal single-story building the cladding is supported on secondary members, which transmit the loads back to main structural steel frames. There are three main types of these members namely, Zed, Modified Zed and Sigma



Single Story Buildings

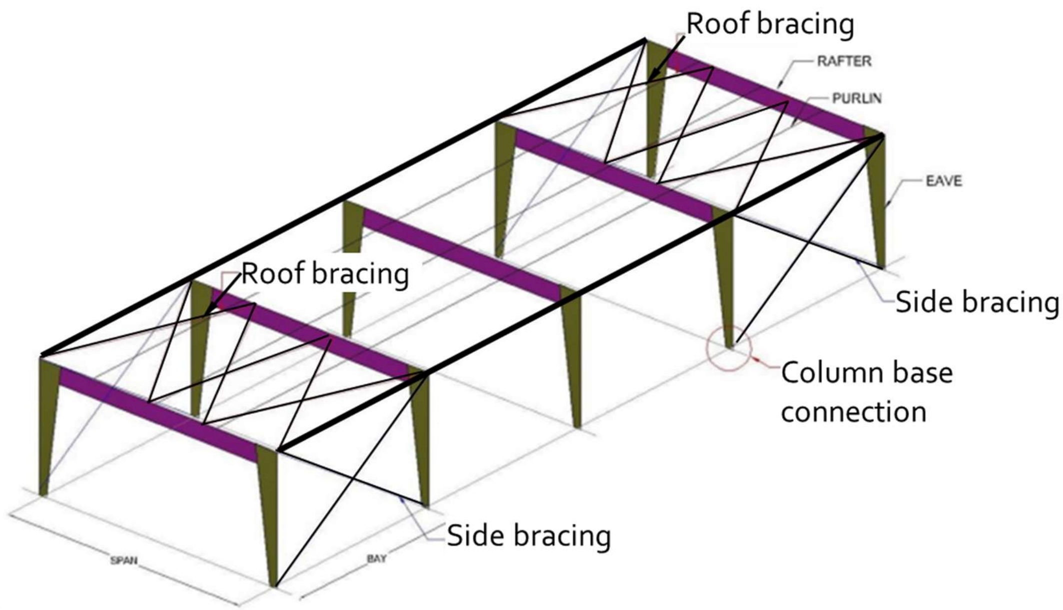
- **The Main Frame of the Structure.** The building frame can be portal frame eighter Pre-Engineered or Conventional Steel frame. Additionally, trusses are widely used in this type of construction.
- A pre-engineered steel building is a modern technology where the complete design is done at the factory using customized built-up sections. An efficiently designed pre-engineered frame can be lighter than the conventional frame by up to 30%.





Bracing

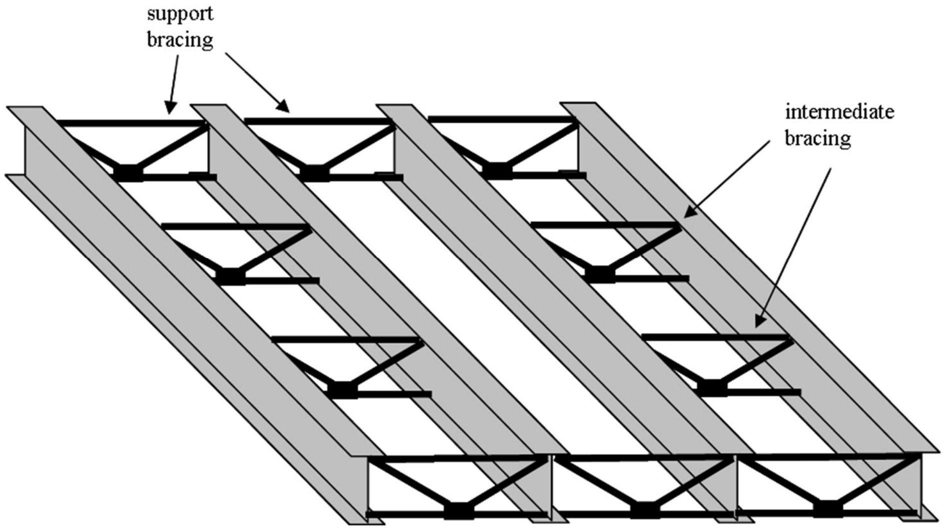
- The longitudinal structural rigidity of portal steel frame structure is relatively weak in the length direction, so it is necessary to set up bracings along the longitudinal direction to ensure its longitudinal rigidity and longitudinal stability.

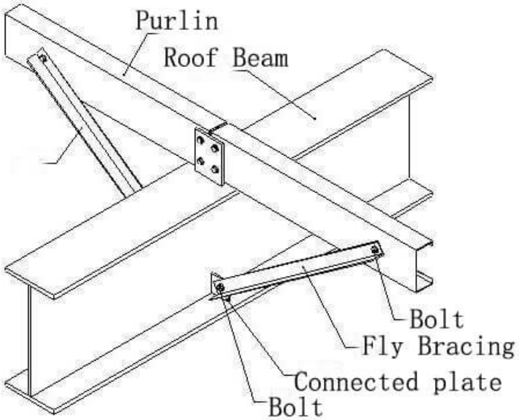


- The bracing system of light portal steel frame structure includes roof horizontal bracing and inter-column bracing.

Bracing

- Lateral buckling can be induced in a steel beam by compressive stresses acting on a slender portion insufficiently rigid in the lateral direction. Accordingly lateral support as shown shall be provided.

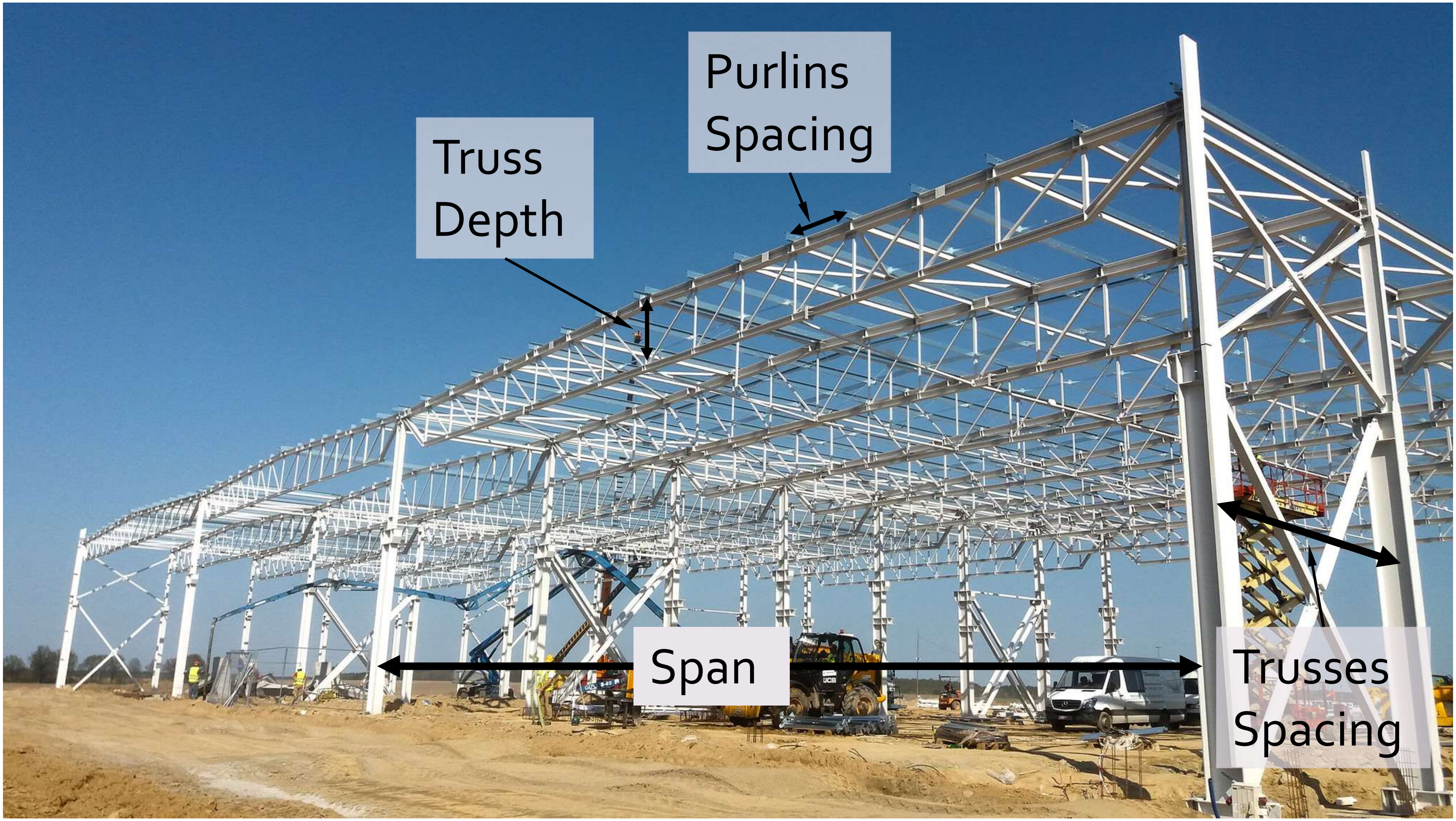




Steel Trusses

- A truss is an assemblage of straight members connected at their ends by pin connections to form a rigid configuration either in space (space truss) or plane (2D truss).
- The main characteristic of trusses is that they are composed of axially loaded members. The internal forces are either purely tensile or purely compressive. Bending is not present, nor can it be developed, as long as external loads are applied at nodal points.

Important Dimensional Variables



Designers aim to minimize the lengths of Compression members.

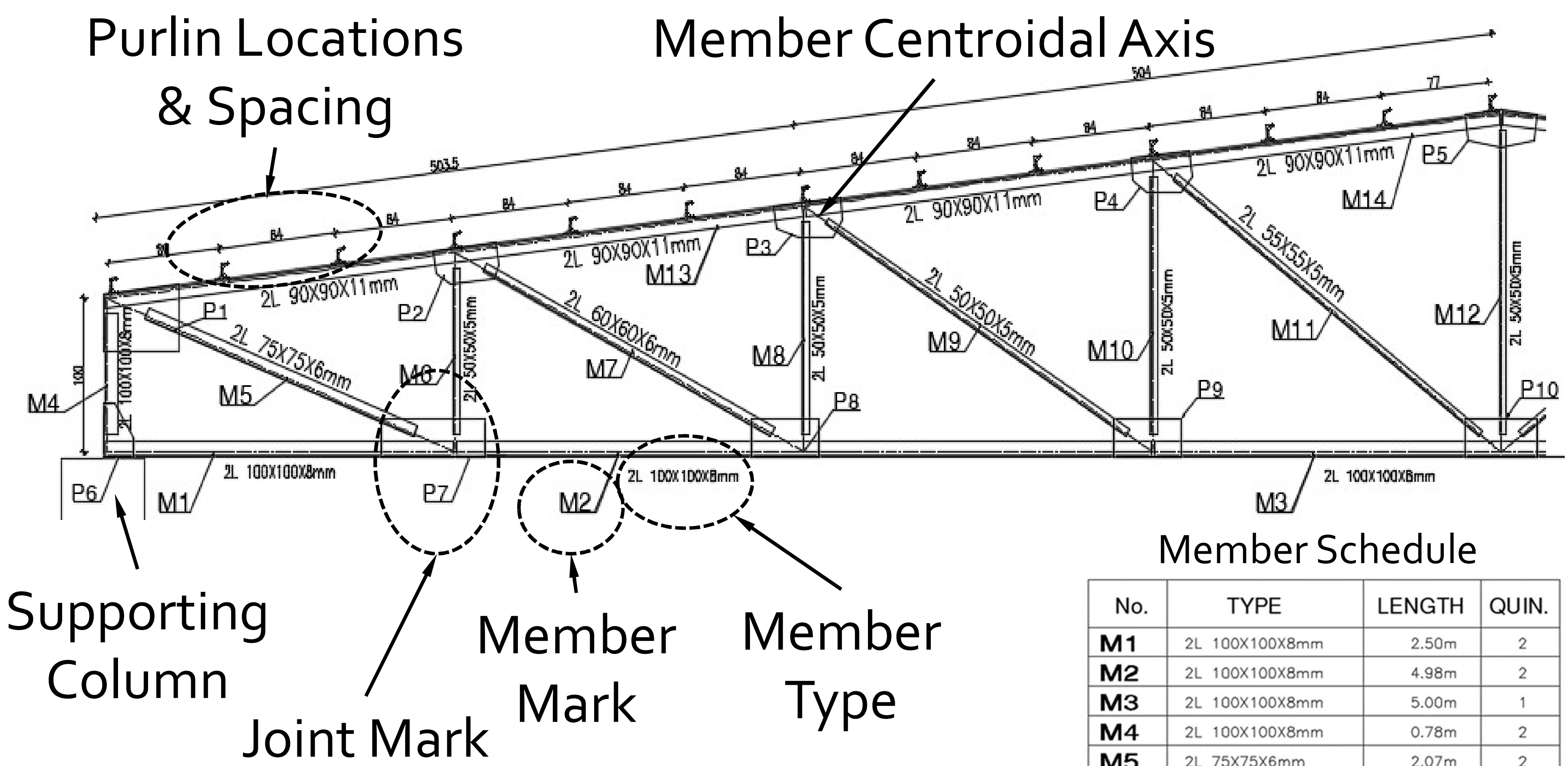
Steel Trusses

Trusses are very efficient structures for single-story buildings. However, for long spans, the required depth of the truss significantly increases.

Table 1 Approximate depths and span ranges for trusses of hot-rolled sections in single-storey steel frames

	Depth of main frame (mm)		
Span (m)	*Solid web*	*Plane truss*	*Space truss*
10	450	1000	1000
15	600	1200	1200
20	700	1400	1400
30	900	1800	1600
40	1200	2500	2200
50	–	3000	2800
60	–	4000	3800
70	–	5000	4800
80	–	6000	5500
100	–	8000	6000

Trusses Details - Elevation



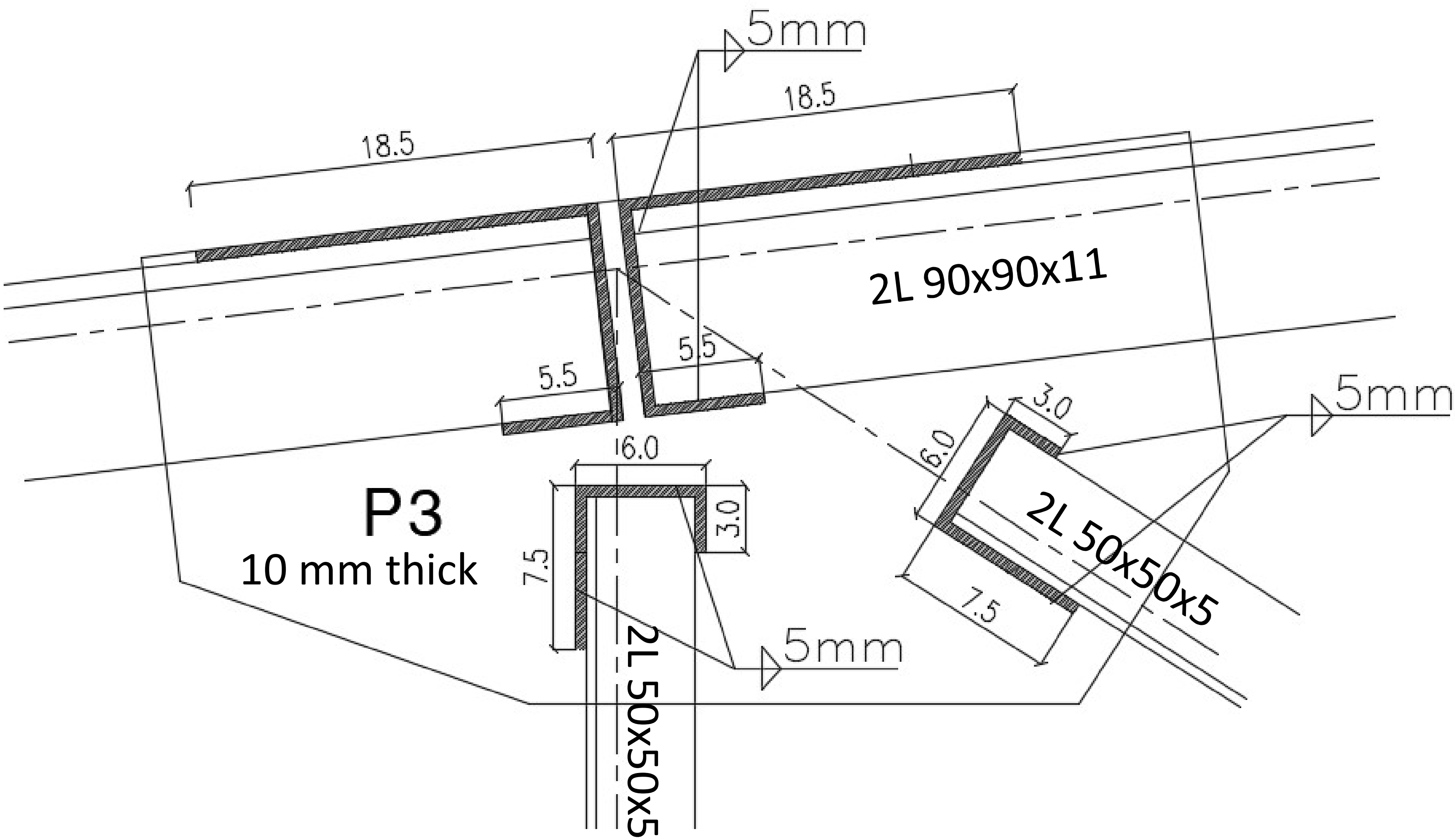
Member Schedule

No.	TYPE	LENGTH	QUIN.
M1	2L 100X100X8mm	2.50m	2
M2	2L 100X100X8mm	4.98m	2
M3	2L 100X100X8mm	5.00m	1
M4	2L 100X100X8mm	0.78m	2
M5	2L 75X75X6mm	2.07m	2
M6	2L 50X50X5mm	1.08m	2
M7	2L 60X60X6mm	2.33m	2
M8	2L 50X50X5mm	1.38m	2
M9	2L 50X50X5mm	2.56m	2
M10	2L 50X50X5mm	1.68m	2
M11	2L 55X55X5mm	2.75m	2
M12	2L 50X50X5mm	1.98m	2
M13	2L 90X90X11mm	5.04m	2
M14	2L 90X90X11mm	5.04m	2

FOR EACH TRUSS (No. OF TRUSSES = 5)

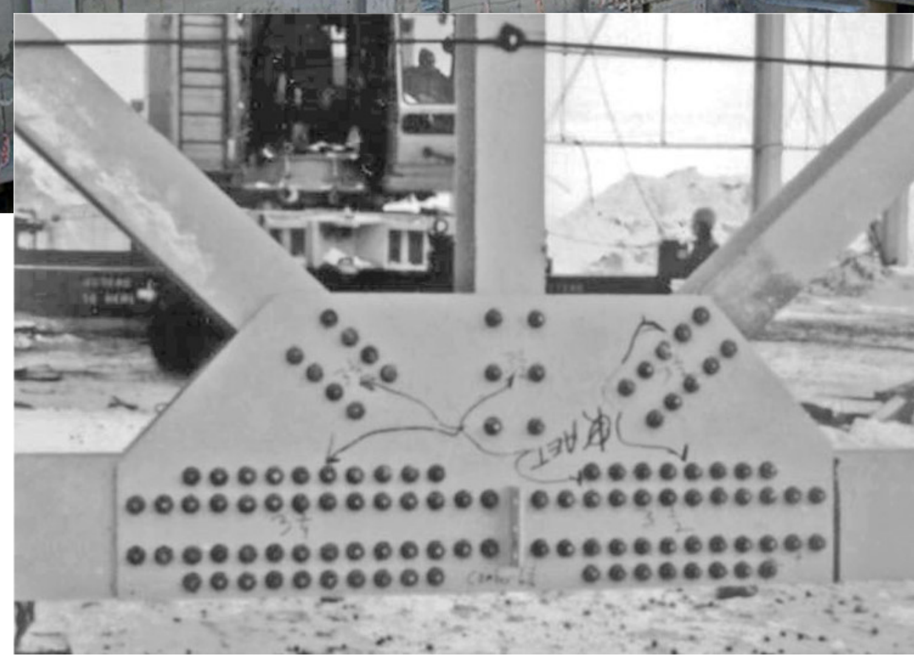
- Note that the centroidal axis of all members meeting at the same joint should intersect in the joint center.

Truss Joint Detail



- Note that the centroidal axis of each member coincides with the line connecting the centers of the adjacent joints.

Truss – Joints & Supports

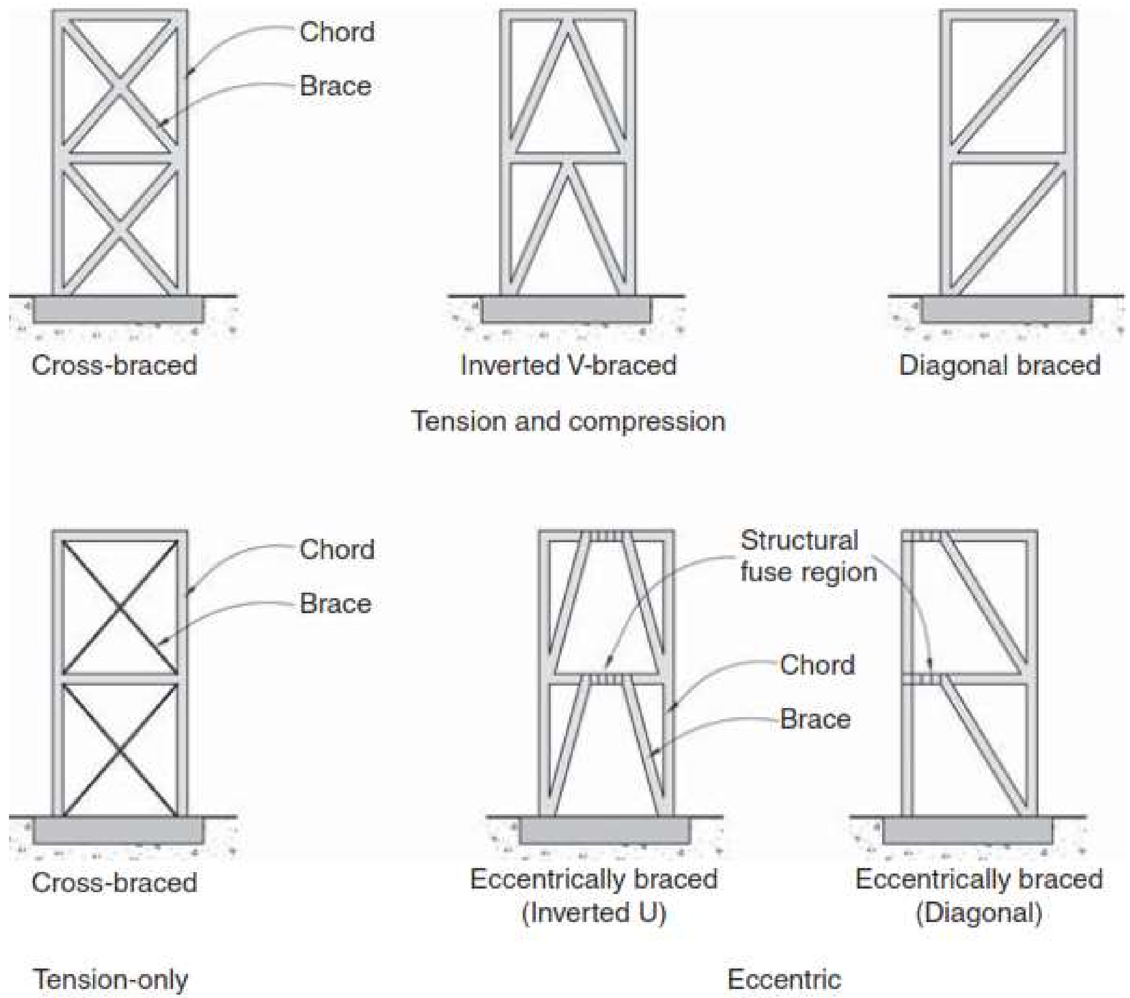


Braced Frames

- Braced frames are essentially pin-jointed structures (a pin connections are used to make beam-column joints & connection).
- Braced frames are effective structural solution for resisting lateral loads due to wind and earthquakes.
- Most of their horizontal load-carrying capability is achieved by their members working in either pure compression or tension. They can be visualized as vertical trusses.
- Braced frames are popular in industrial countries where steel is affordable.

Types of Braced Frames

- There are two general types of braced frames: conventional concentric and eccentric.
- In the concentric frame, the center lines of the bracing members meet the horizontal beam at a single point.



- In the eccentric-braced frame, the braces are deliberately designed to meet the beam some distance apart from one another.

Flooring systems of Steel structures

- Typical floor slab systems for steel frameworks include:

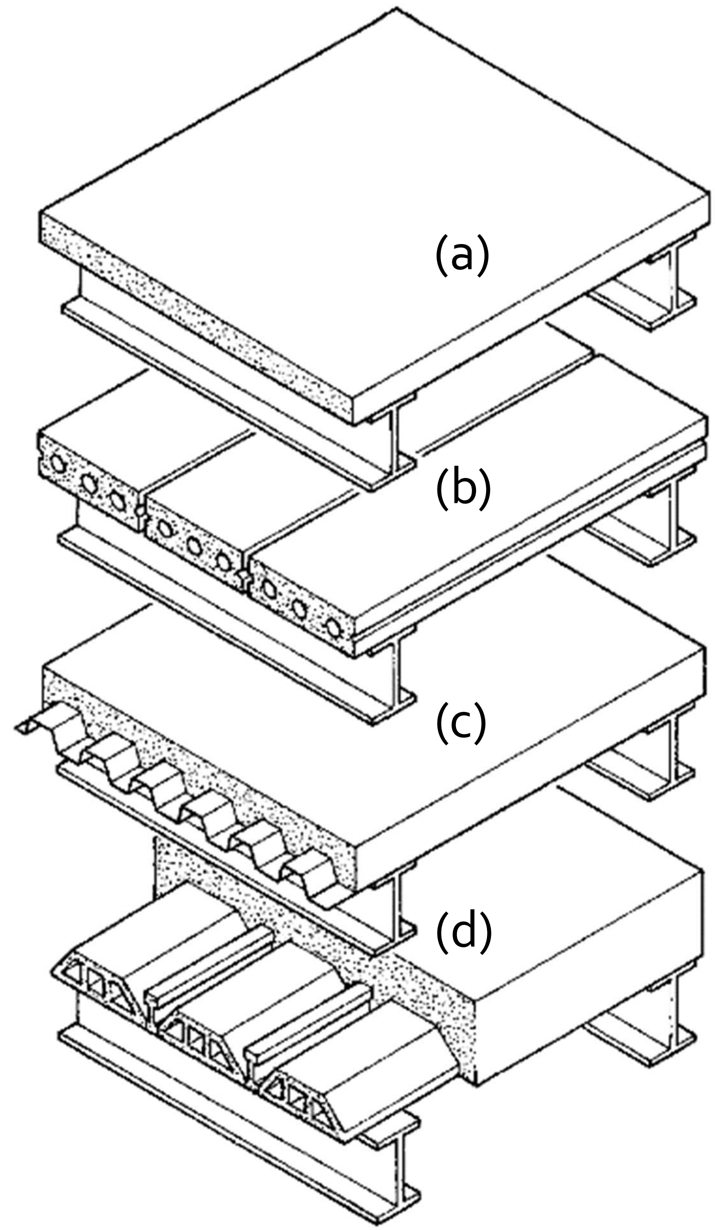
a) In - situ reinforced concrete flat slab.

b) Precast concrete floor units.

c) In situ concrete on profiled steel permanent formwork.

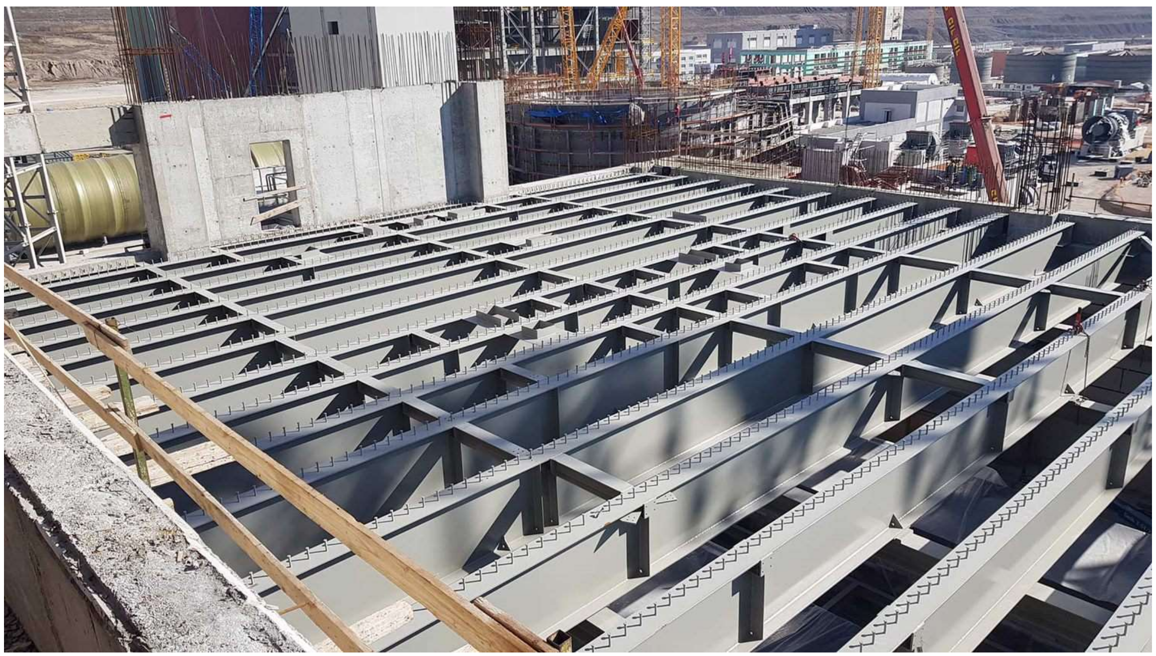
d) Composite precast and in situ concrete.

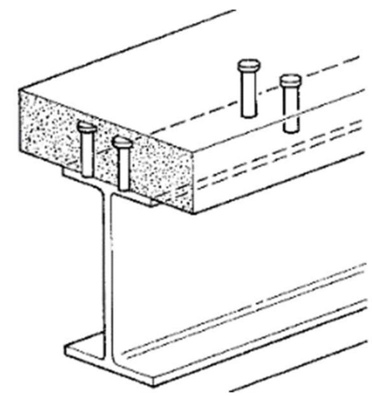
- All of these systems are normally one-way-spanning and require to be supported on a parallel arrangement of steel beams. However, system (a) can be a two-way-spanning structure.

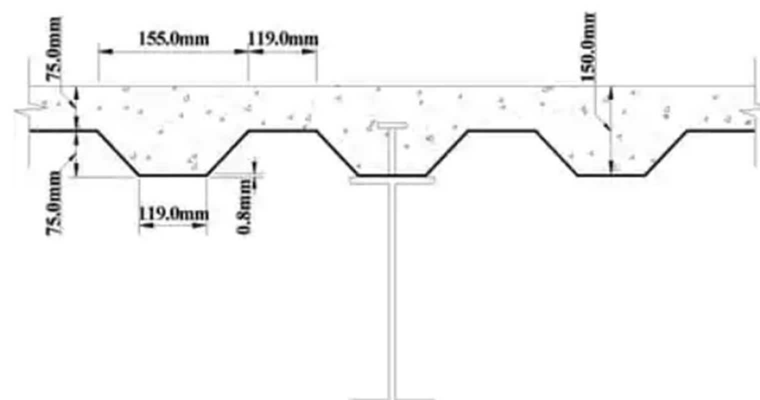


Flooring systems of Steel structures

- To increase efficiency and therefore reduce the size of the beams, shear studs are usually welded to the floor beams which allow composite action to be developed between the beams and the floor slabs.







Detailing of Steel Buildings

Steel structural drawings have different levels of details including:

A. General drawings such as general notes and foundation plans.

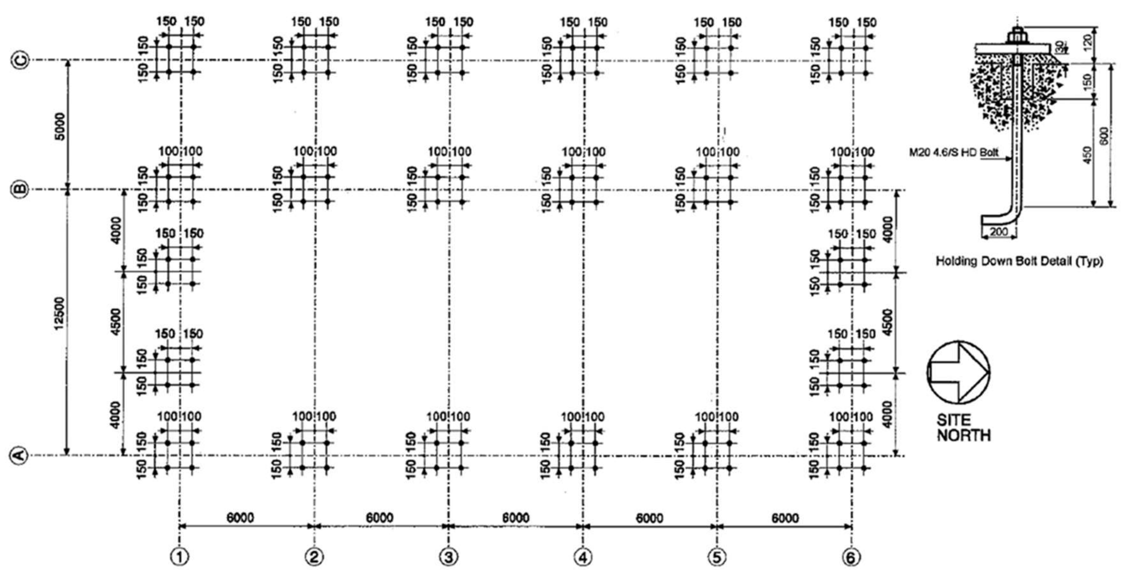
B. layout of the whole structures (floor plans) for which the steel works are to form. Usually consists of plans and elevations when needed.

C. Layout of the steelworks (e.g. a truss, columns, girders, …) usually represented by plans, elevations and sections.

D. Details of connections of the steelworks represented by plans, elevations and sections, even sometimes by isometric views.

Foundation plan

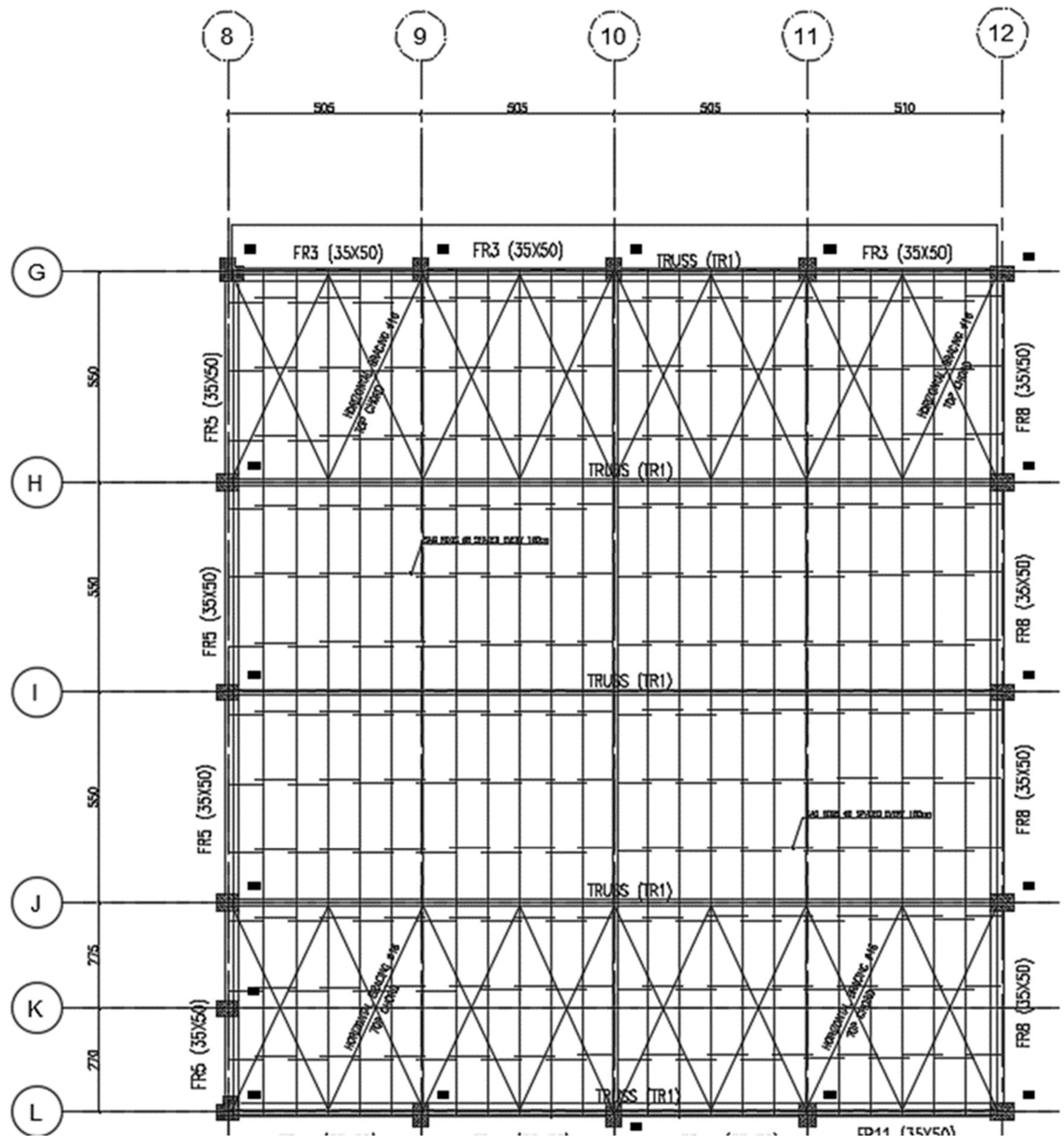
- Steel buildings usually have concrete foundations designed and details as explained for the concrete buildings. After constructing the foundations, steel structure is fixed using the anchor bolts installed in the footings
- The foundation plan and grid line plan of a steel structure is similar to that of concrete buildings. However the plans usually shows the anchorage bolts locations on the concrete footing.



General layout (Floor) plan

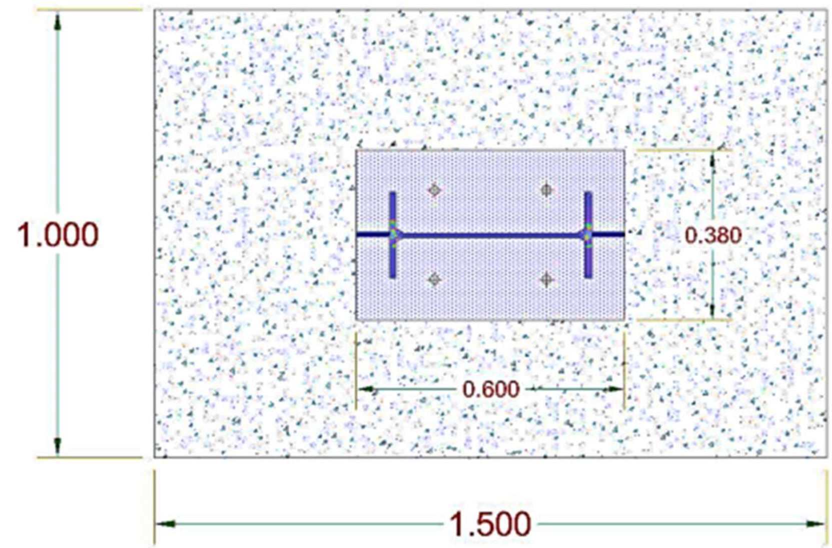
<u>The plans show</u>

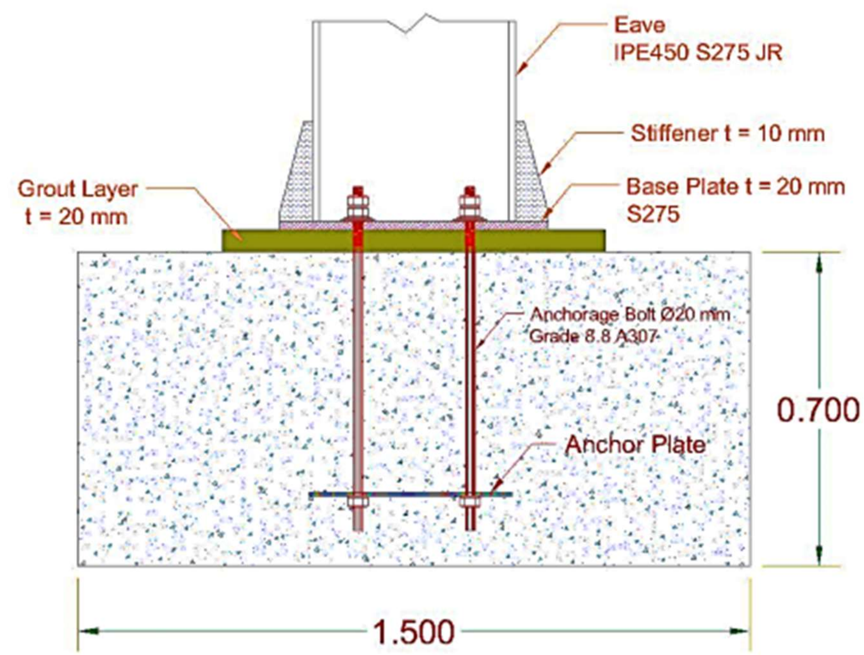
1. The general dimensions of the steelworks
2. The nominal size of the members
3. The center lines (or line of centroid) of members forming the framework.
4. The arrangements of connection (referred to enlarged details where necessary)



Column Base Plate

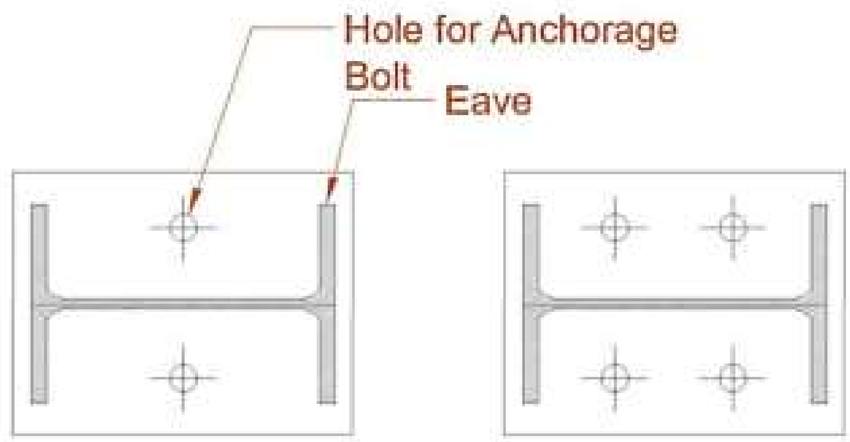
- Typical column bases consist of a single plate fillet welded to the end of the column and attached to the foundation with holding down bolts. A layer of grout is used for leveling of the plate and setting it at the specified elevation.
- The plate is designed to transfer the column loads (axial, shear and moment) to the foundation through the anchor bolts.



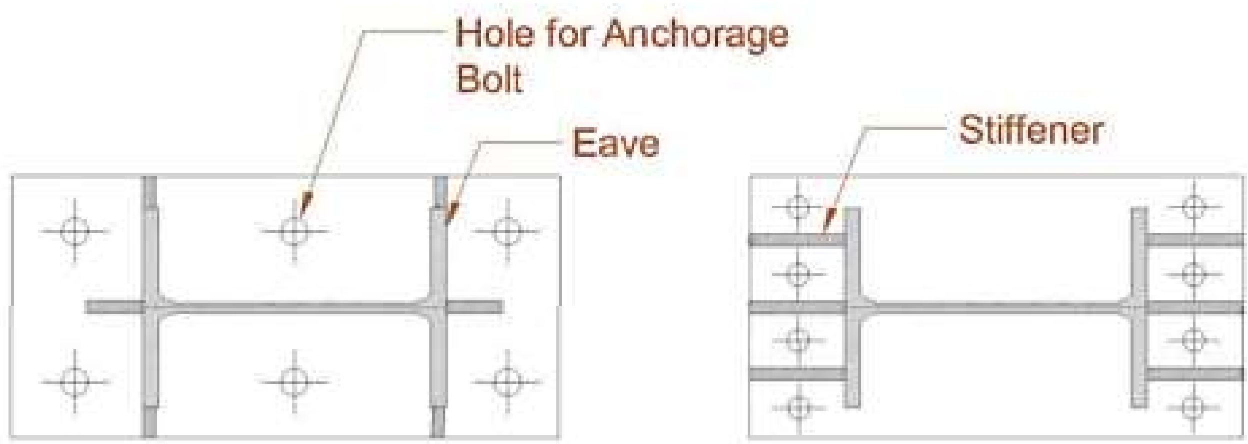


Column Base Plate

The distribution of the anchor bolts determine the transferred loads or type of the connection (pin or fixed).



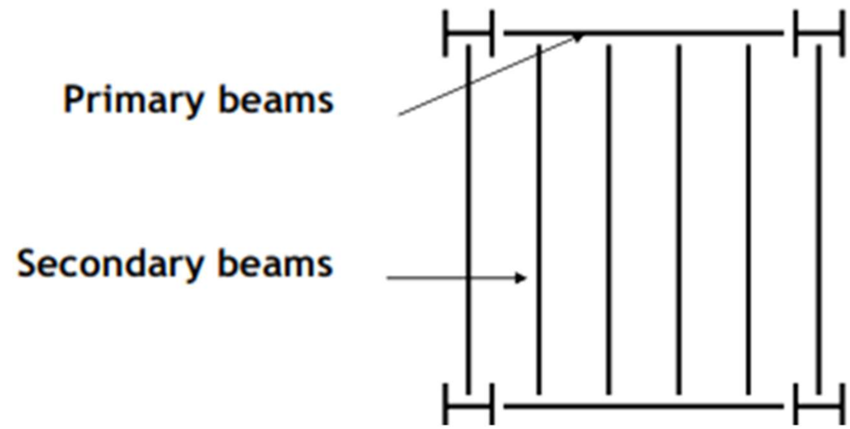
Pinned Connection



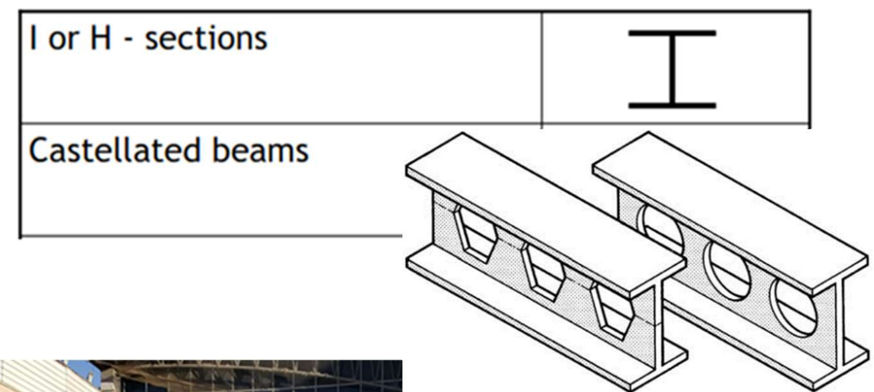
Fixed Connection

Beams & Beam Connections

- Structural steel floors are laid on repetitive grid which establishes a standard structural bay. The most efficient floor plan is rectangular, in which 'main' or 'primary' beams span the shorter distance between columns and closely-spaced 'secondary' beams span the longer distance between primary beams.

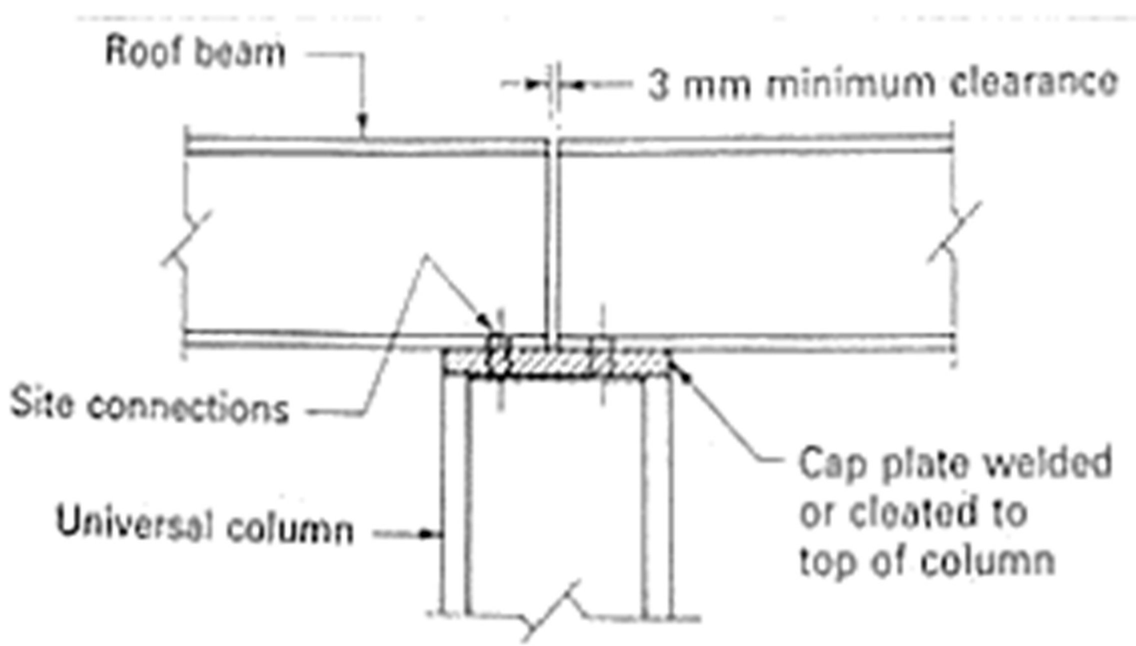


- Typical beams cross sections are I, H or castellated beams to improve the structural efficiency .



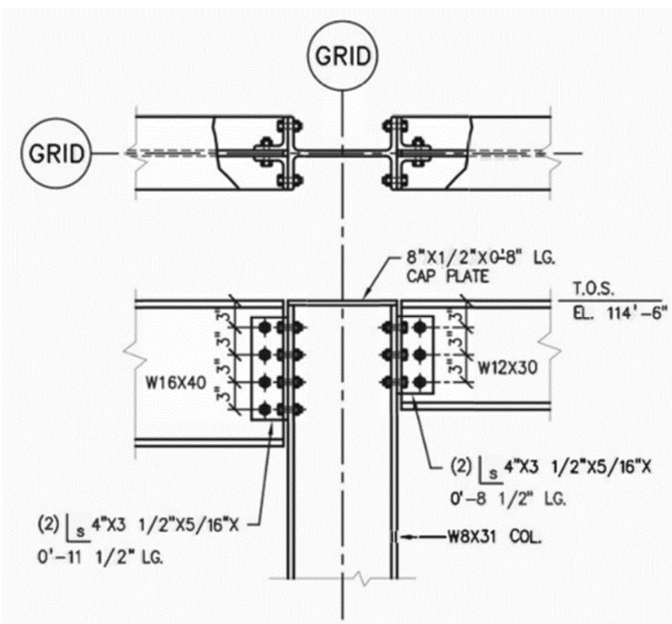
Beam-to-Column Connections

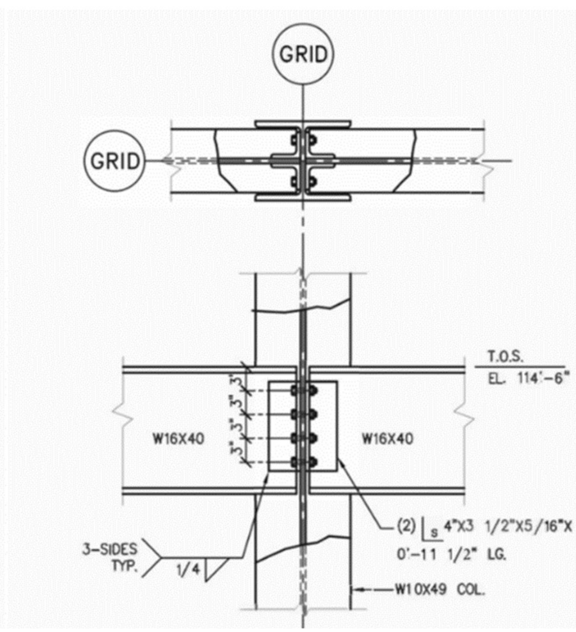
- **Cap Plate Connection.** One of the most common types of beam-to-column connections in commercial and industrial buildings. A cap plate connection calls for a steel plate, commonly called a cap plate, to be welded to the top end of a W-shape, pipe, or HSS column at the fabricating shop. The beam will be attached to the plate at the site, as shown.

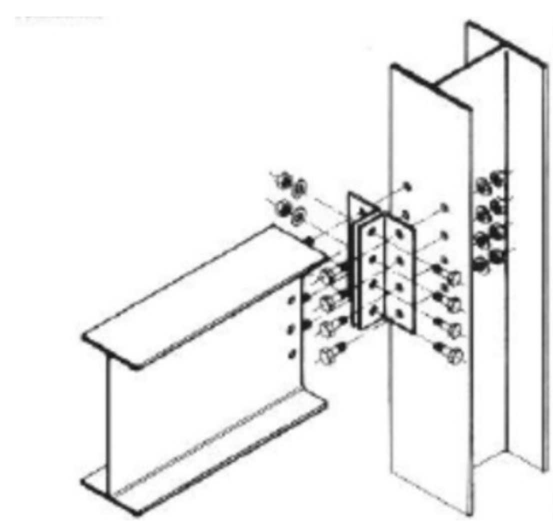


Beam-to-Column Connections

Standard Framed Beam-to Column Connection. Beams are fastened to columns by means of framing angles. This usually consists of two structural steel angles, one on either side of the beam, which are either welded or bolted to the beam web in the fabricator’s shop and then fastened to a column at the job site with high strength bolts. This type of connections is assumed to transfer end reaction only where only the Web of the beam is connected with no connection for the flanges

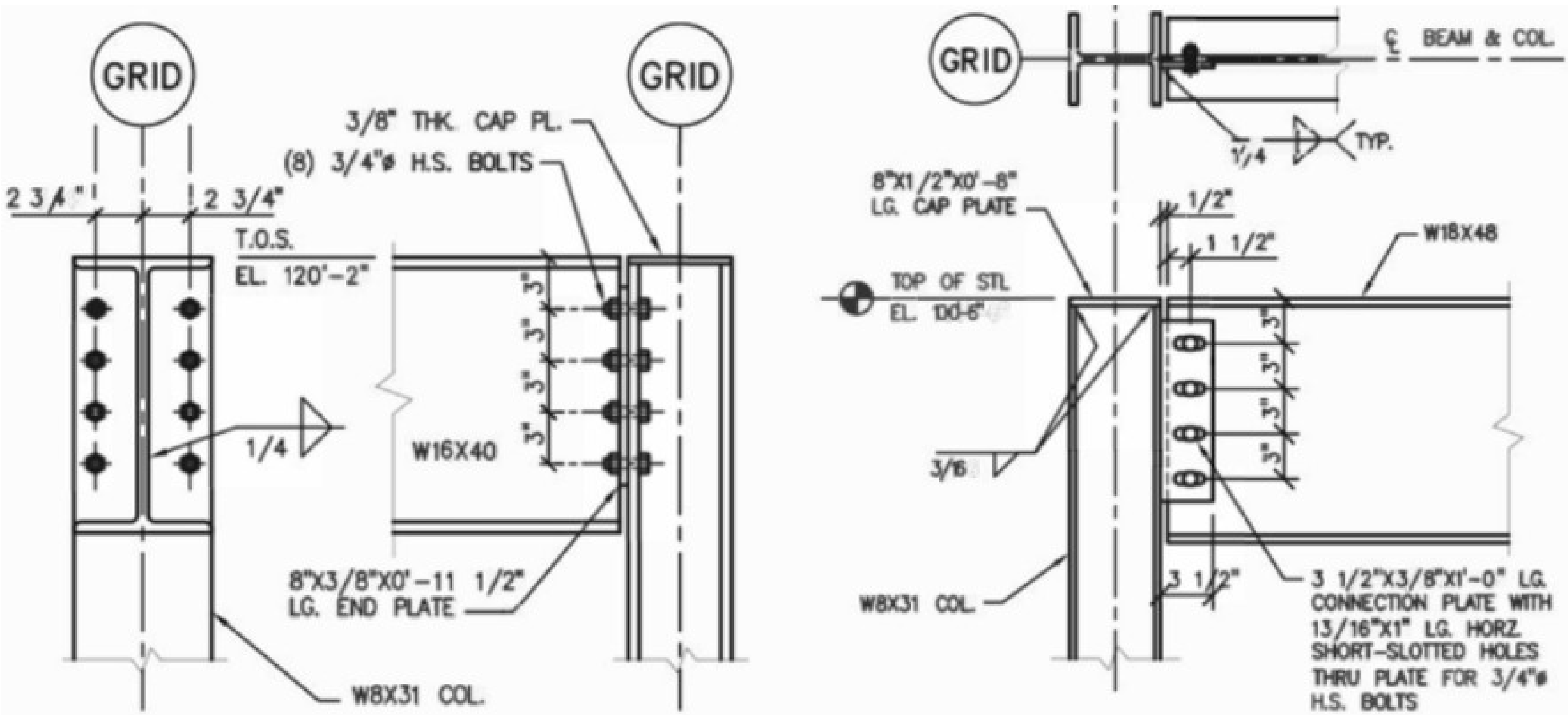






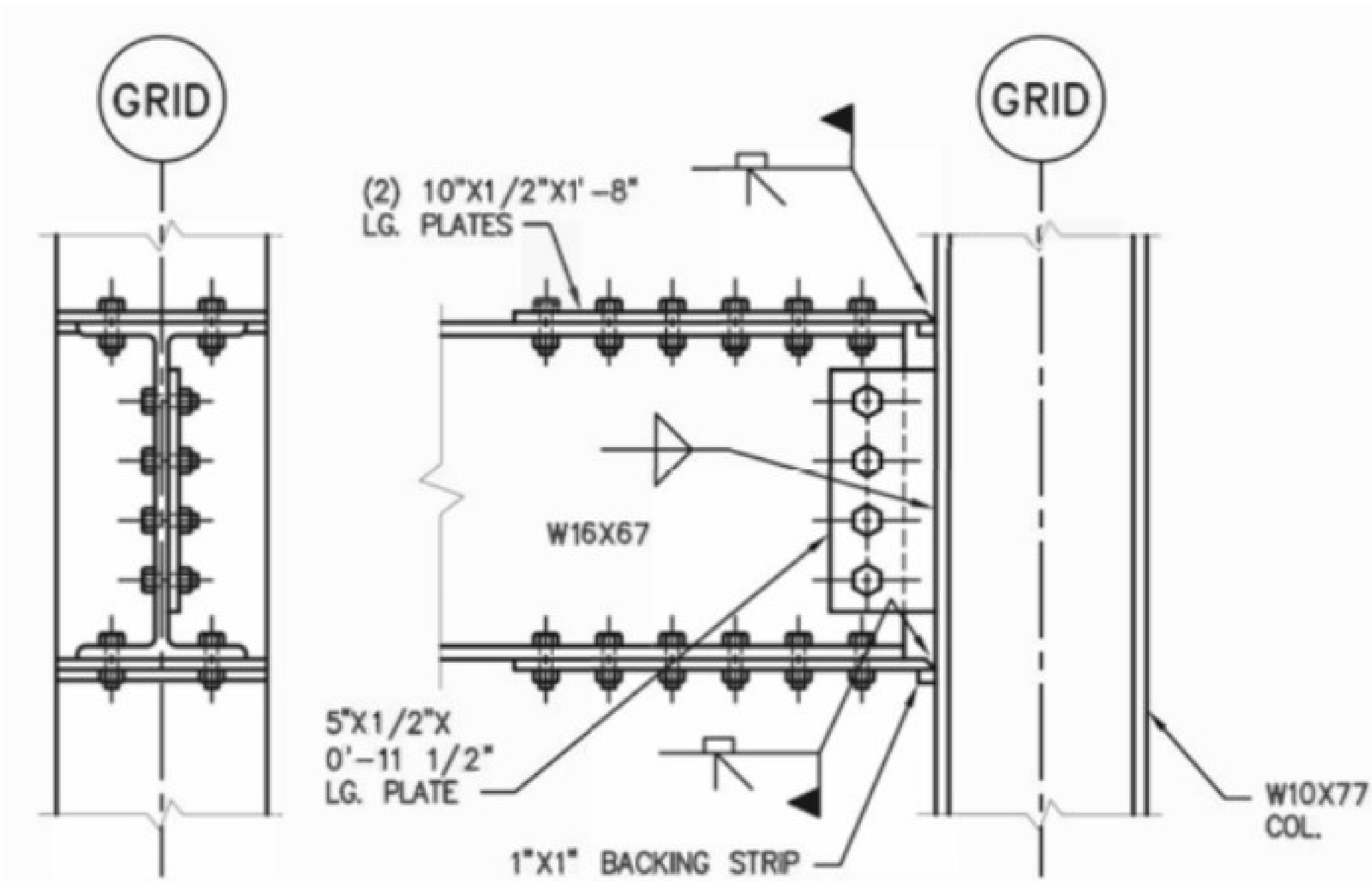
Beam-to-Column Connections

- **Standard Framed Beam-to Column Connection**: other types of these connections include the end plate sheer connection (left) and the single plate shear connection (right).



Beam-to-Column Connections

Beam to Column Rigid Joints: this is a connection that designed to transfer moment from beam to columns, here web as well as flange of the beam shall be connected to the column as shown below.

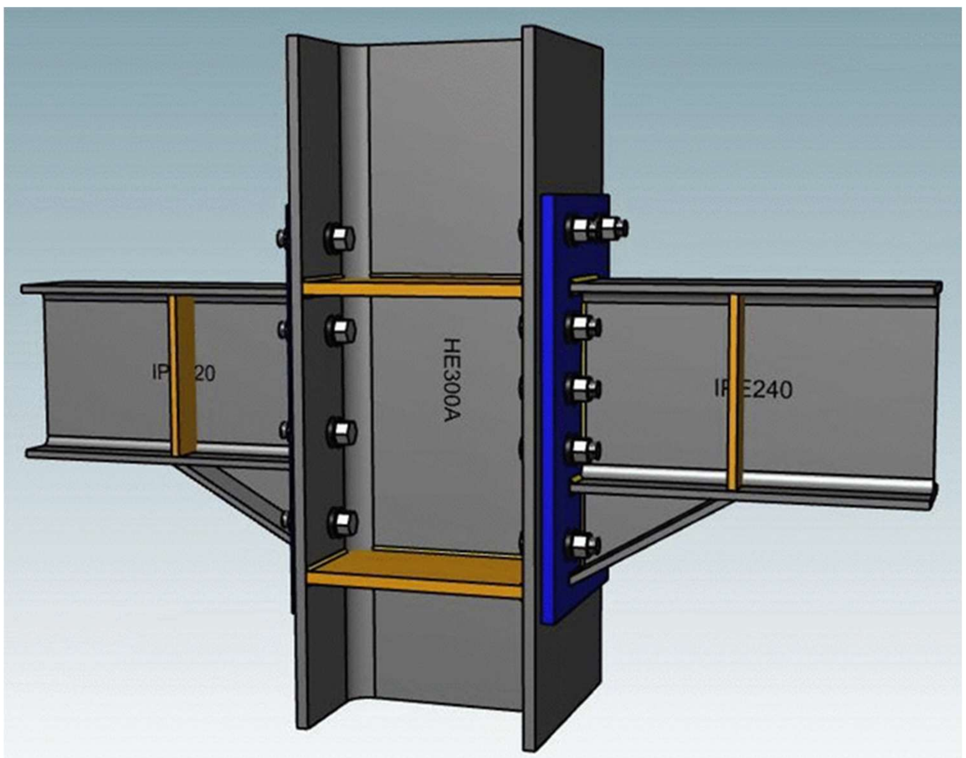


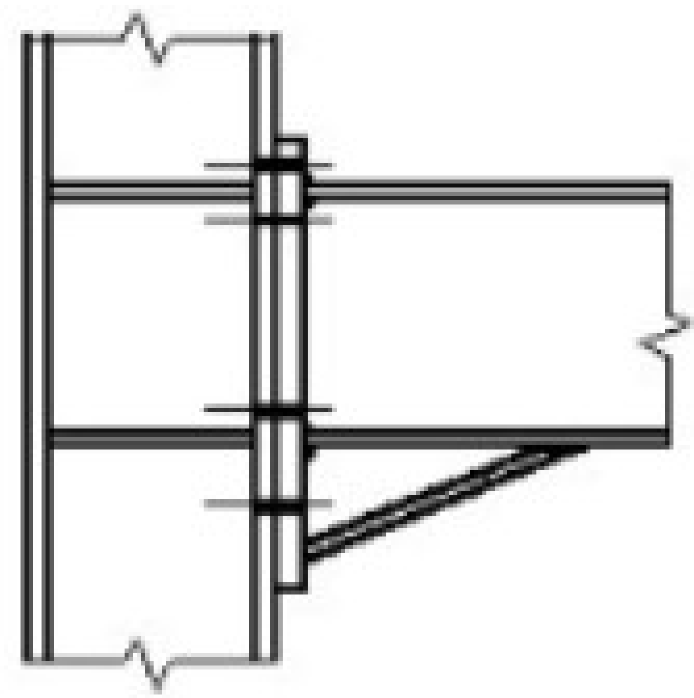
Beam-to-column moment-resisting connection detail

Beam-to-Column Connections

Beam to Column Rigid Joints

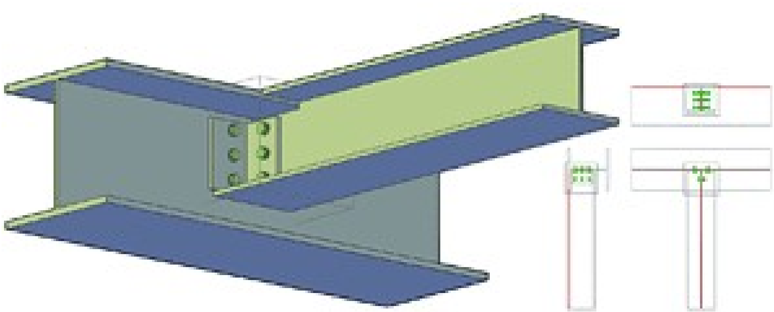
- Some times Stiffener plates are used to 'shore up' the column flanges against the forces transmitted by the beam flanges. The stiffeners may be full length or may extend only part of the column web depth.

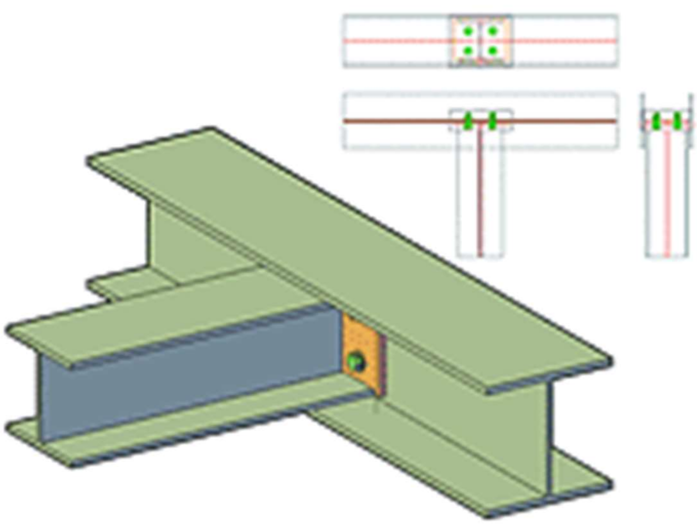


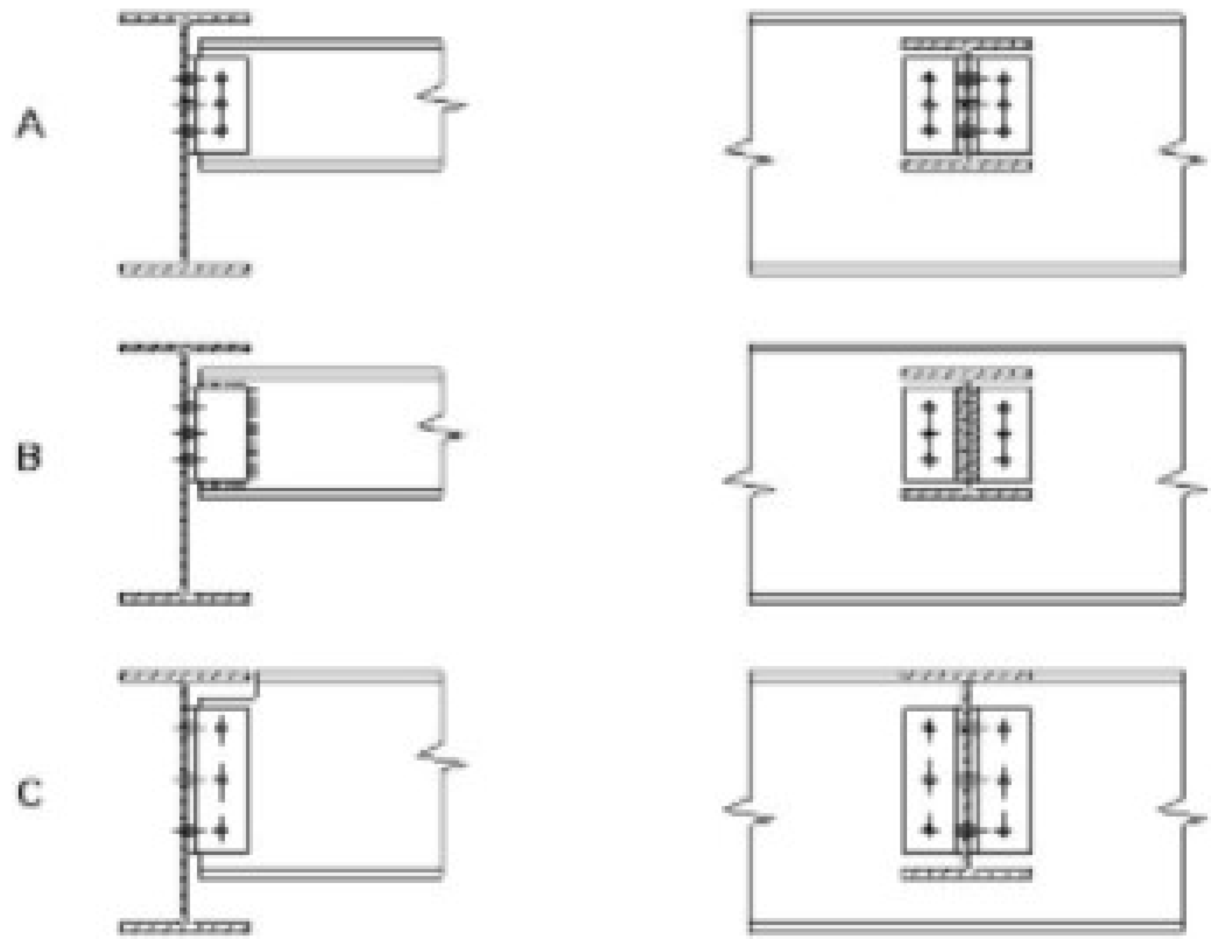


Beam-to-Beam Connections

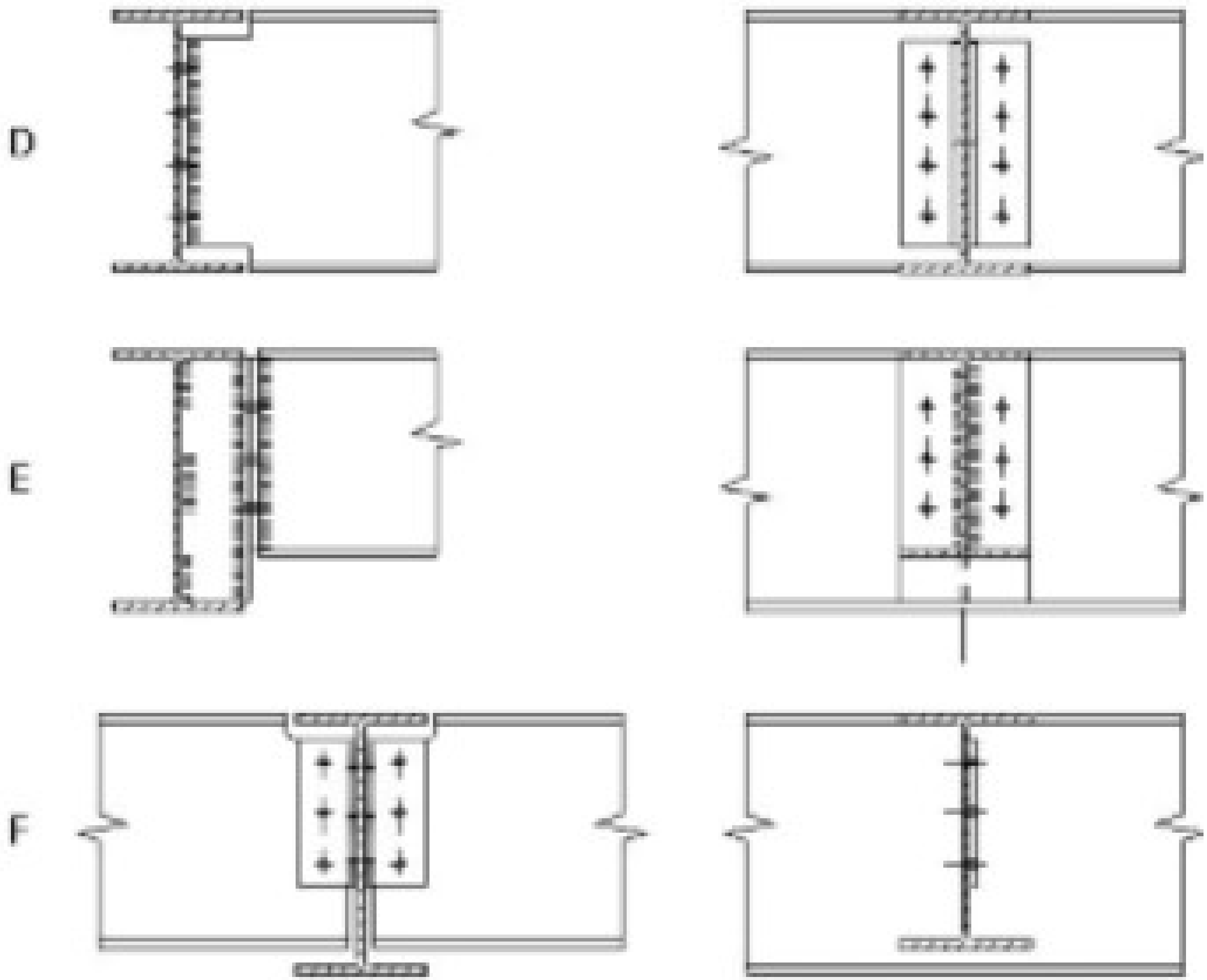
Those are simple connections that connect secondary beams to girders, they are usually designed to transfer shear only. They have several arrangement based on the level and sizes of the secondary beams relative to the girders.







Beam-to-Beam Connections



Steel Protection

- Two problems associated with steel are

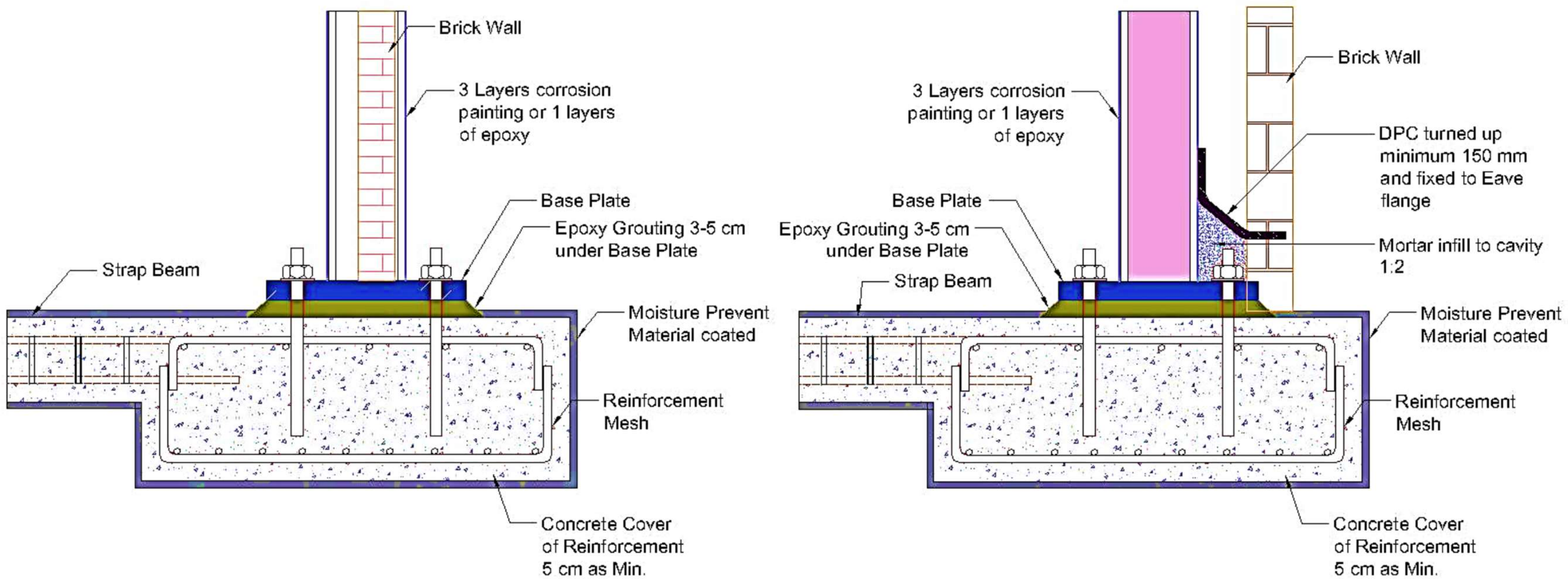
1. Its poor performance in fire, due to the loss of mechanical properties at relatively low temperatures.
2. Its high chemical instability, which makes it susceptible to corrosion.

- Both of these have been overcome to some extent by the development of fireproof and corrosion protection materials, especially paints, but the exposure of steel structures, either internally, where fire must be considered, or externally, where durability is an issue, is always problematic.

الحماية من التأكل – عزل الرطوبة

تتركز الحماية من التأكل على ما يلي

1. منع اختراق الرطوبة للمبنى بإجراءات الحماية المتعارف عليها في كل المباني.
2. حماية الأعضاء الإنشائية الملامسة للتربة مثل الأسس والأجزاء الإنشائية المرتبطة معها مثل صفيحة القاعدة.
3. تنظيم الرطوبة داخل المبنى لمنع تكثف البخار على العناصر المعدنية عن طريق التكييف.
4. دهان العناصر المعدنية بطلاء مقاوم للتأكل.



الحماية من الحريق

1. الطلاءات المنتفخة (Thin film intumescent coatings)

وهي مواد شبيهة بالطلاء تكون خاملة عند درجات حرارة منخفضة ولكنها توفر العزل نتيجة لتفاعل كيميائي معقد عند درجات حرارة تتراوح عادة بين 200 و 250 درجة مئوية. في درجات الحرارة هذه لن تتأثر خصائص الفولاذ. ونتيجة لهذا التفاعل فإنها تنتفخ وتوفر طبقة موسعة من الفحم منخفض التوصيل.

2. الألواح (Boards)

تستخدم الألواح على نطاق واسع للحماية من الحرائق الهيكلية في المملكة المتحدة. يغلف العنصر بطبقة من هذه الألواح والتي تختلف في وزنها وتركيبها وسماكتها وفقا للحماية المطلوبة وقرارات المصمم.

يعتبر التداخل بين الألواح والطلاءات الرقيقة المنتفخة أمرًا شائعًا جدًا

الحماية من الحريق

3. الرش بالمواد الأسمنتية العازلة (Spray protection)

تستخدم الحماية بالرش على نطاق واسع في الولايات المتحدة. تتميز بإمكانية استخدامها لتغطية الأشكال والتفاصيل المعقدة. يمكن أيضًا استخدام بعضها في التطبيقات الخارجية وتطبيقات الحرائق الهيدروكربونية.

4. أنظمة البطانيات المرنة (Flexible blanket systems)

تم تطوير هذه الأنظمة للحماية من الحرائق كاستجابة للحاجة إلى مادة حماية سهلة التطبيق يمكن استخدامها في الأشكال والتفاصيل المعقدة. خفيفة الوزن وسهلة التركيب وتمتلك مقاومة جيدة للحرارة تصل الى حماية مدتها 90 دقيقة للأنواع الجيدة منها ولكنها معيقة للجمالية وتثبيت التشطيبات.