INTERNATIONAL UNIVERSITY OF AFRICA

CIVIL ENGINEERING DEPARTMENT

ANALYSIS AND DESIGN OF STEEL WORKS

Connections part 1

8TH SEMESTER

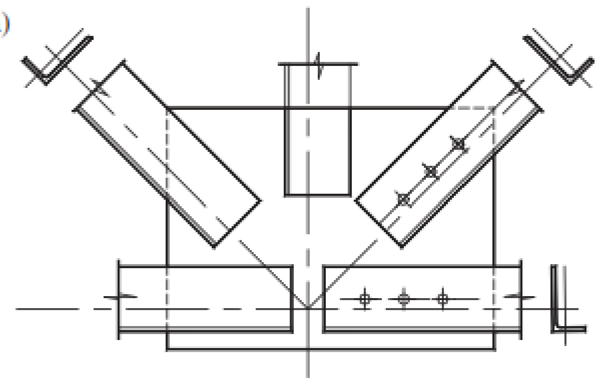
Connections

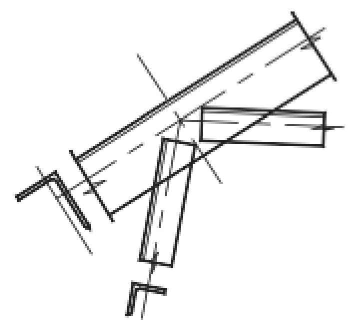
Types of connections

Connections are needed to join:

(a) members together in trusses and lattice girders;

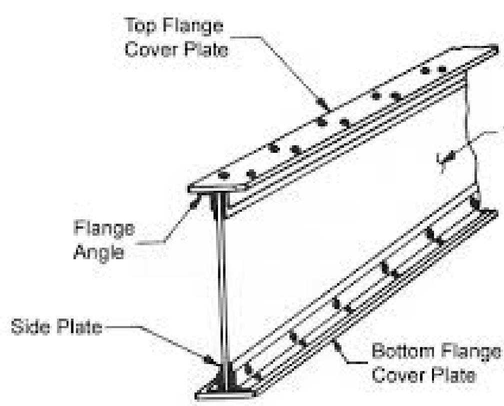
(a)

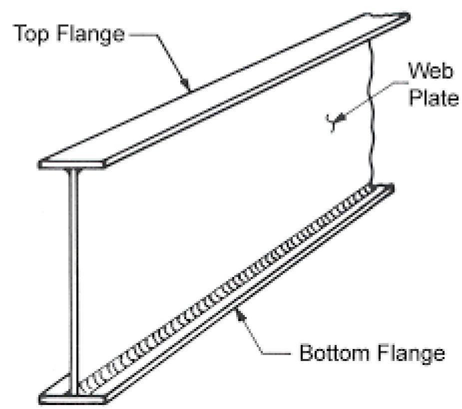


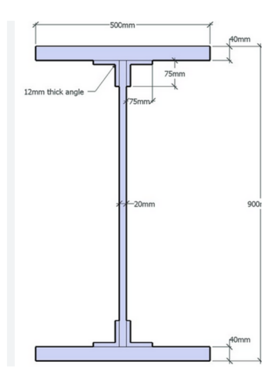


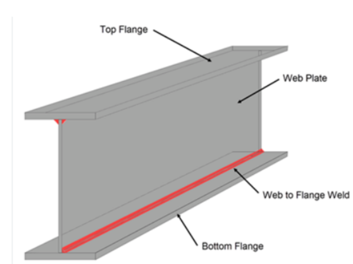
Internal truss joints

(b) plates together to form built-up members;



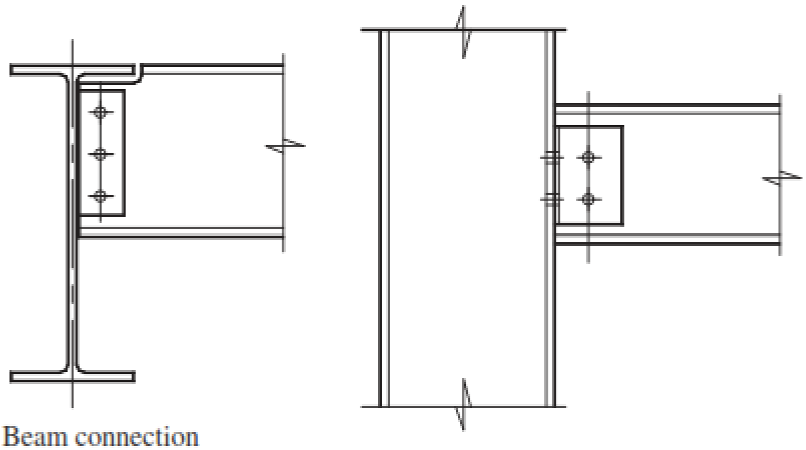






(c) beams to beams, beams, trusses, bracing, etc. to columns in structural frames,

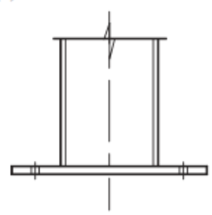
(c)



Beam connection

(d) columns to foundations.

(d)



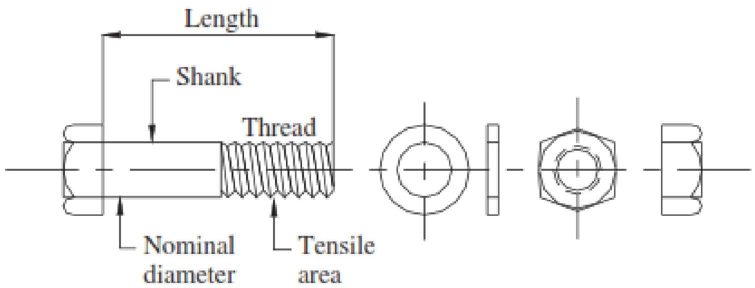
Column base

Connections may be made by:

- bolting
  - non-preloaded bolts in standard clearance or oversize holes;
  - preloaded or friction-grip bolt;
- welding – fillet and butt welds.

1. BOLTS

❖ *Non-preloaded bolts*



Hexagon head bolt, nut and washer

The ISO metric 'black' hexagon head ordinary non-preloaded bolt with nut and washer is the most commonly used structural fastener in the industry. The bolts, in the three common strength grades given below,

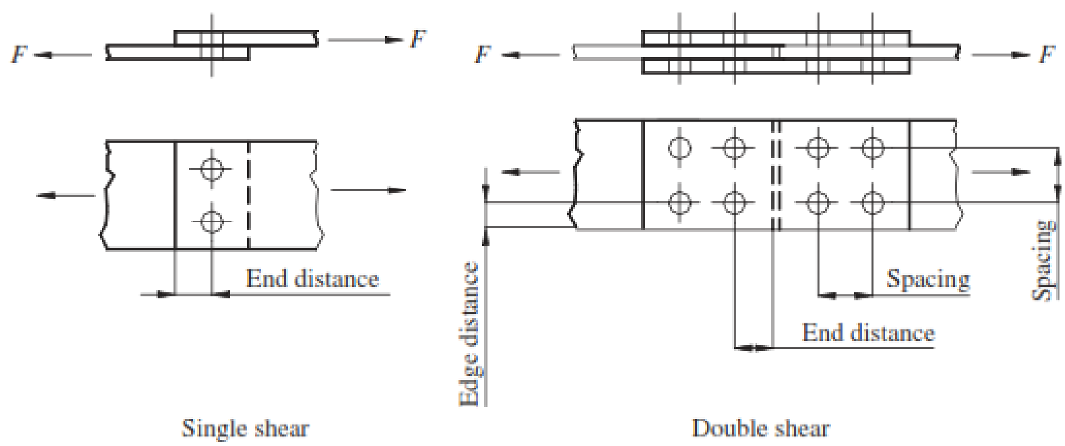
Strength grade	*Yield stress* (N/mm^2)	*Tensile stress* (N/mm^2)
4.6	240	400
8.8	640	800
10.9	900	1000

Two grades of bolt are commonly used.

These are grade 4.6 and 8.8. The first digit relates to the ultimate strength of the material, whilst the second is the ratio of yield stress to ultimate strength. Thus grade 4.6 bolts have an ultimate material strength of 400N/mm2 and the yield (or proof) stress is 60% of the ultimate strength. Similarly grade 8.8 bolts have an ultimate strength of 800 N/mm2 and a ratio of yield/proof stress to ultimate strength of 80%. Simple grade 4.6 bolts without corrosion protection are commonly called 'black 'bolts'

1.1 Direct shear joints

Bolts may be arranged to act in single or double shear, as shown in Figure



Bolts in single and double shear

Provisions governing spacing, edge and end distances are set out in Section 6.2 of BS 5950: Part 1.

<u>The principal provisions in normal conditions are:</u> assume bolt 20mm and thickness t=10mm

(1) The minimum spacing is 2.5 times the bolt diameter; =2.5x20 =50 mm

(2) The maximum spacing in unstiffened plates in the direction of stress is 14t where *t* is the thickness of the thinner plate connected; =14x10x=140

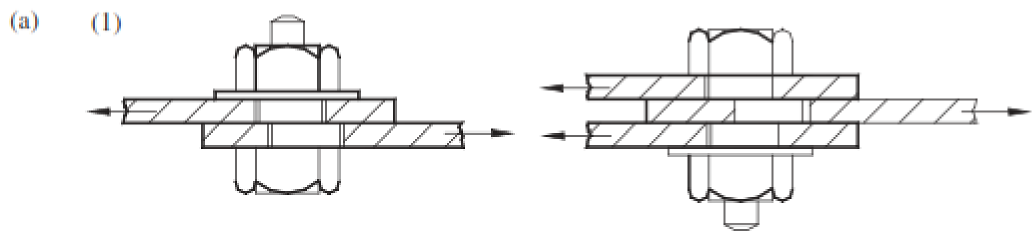
(3) The minimum edge and end distance as shown in Figure from a rolled, <u>machine-flame cut</u> or plane edge is 1.25D, where D is the hole diameter <u>For a sheared, hand flame cut edge or any end is</u> 1.40D.

=1.25x20= 250 mm or =1.4x20 =28 mm

(4) The maximum edge distance is $11t\epsilon$, where $\epsilon = (275/p)$ =11x10 =110 mm assume p =275N.mm2

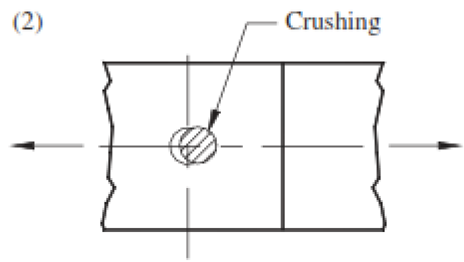
A shear joint can fail in the following four ways:

(1) by shear on the bolt shank;



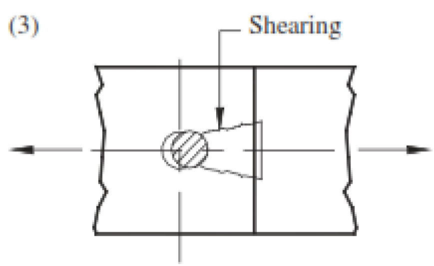
Single shear Double shear

(2) by bearing on the member or bolt;



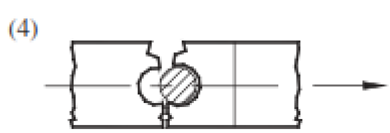
Bearing on plate and bolt

(3) by shear at the end of the member; and



End shear failure

(4) by tension in the member.



Tension failure of plate

These failures modes can be prevented by taking the following MEASURES:

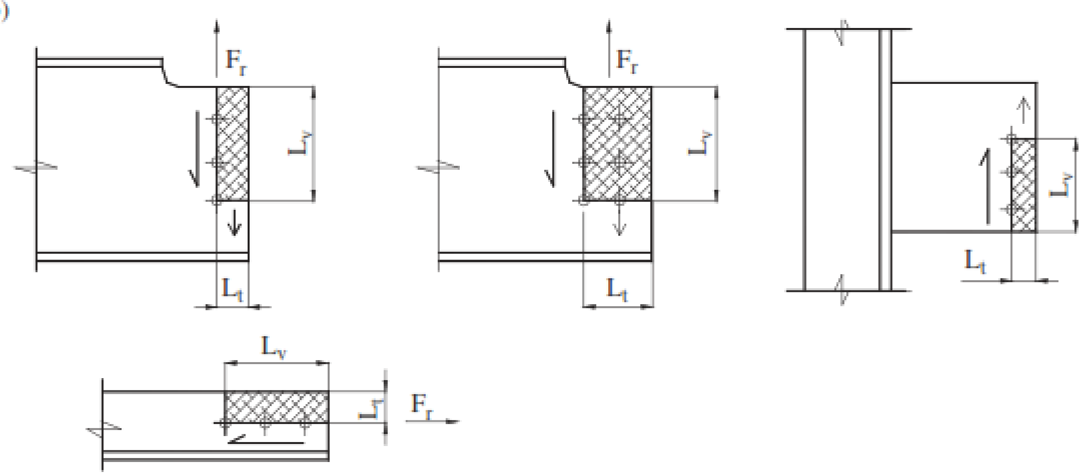
(1) For modes 1 and 2, provide sufficient bolts of suitable diameter.

(2) For mode 3. Provide sufficient end distance

(3) For mode 4, design tension members for effective area

In addition, a new failure mode, block shear, has been observed in a shear joint involving a group of bolts as shown in Figure b below, and a check of the effective shear area against this failure mode is now required in the revised code.

(b)



Block shear-effective shear area

Revit showing failure by bearing of plates Mode 1

Mode 2 failure of Revit (bolt)

BOLTS IN SHEAR AND BEARING

The design of bolted shear joints is set out in Section 6.3 of BS 5950: Part 1.

The basic provisions are:

1 Shear capacity *Ps* of a bolt:

$$P_s = p_s A_s$$

where P_s is shear strength given in Table 30 of the revised code and A_s is the nominal area $= \pi d^2/4$

(see Table 10.1).

Table 10.1 Non-preloaded bolts in standard clearance holes (shear and bearing strengths of bolts and connected parts in N/mm²)

Strength of bolts	*Bolt grade*					
	4.6	8.8	10.9	S275[a]	S355[a]	S460[a]
Shear strength p_s	160	375	400	–	–	–
Bearing strength p_{bb}	460	1000	1300	–	–	–
Bearing strength p_{bs}	–	–	–	460[b]	550[b]	670[b]

[a] Steel grade.
[b] Connected parts.

2 Block shear:

Block shear failure through a group of bolt holes at a free edge, see Figure 22, (consisting of failure in shear at the row of bolt holes along the shear face of the hole group, accompanied by tensile rupture along the line of bolt holes on the tension face of the hole group, see Figure 22) should be prevented by checking that the reaction F_r. does not exceed the block shear capacity P_r determined from:

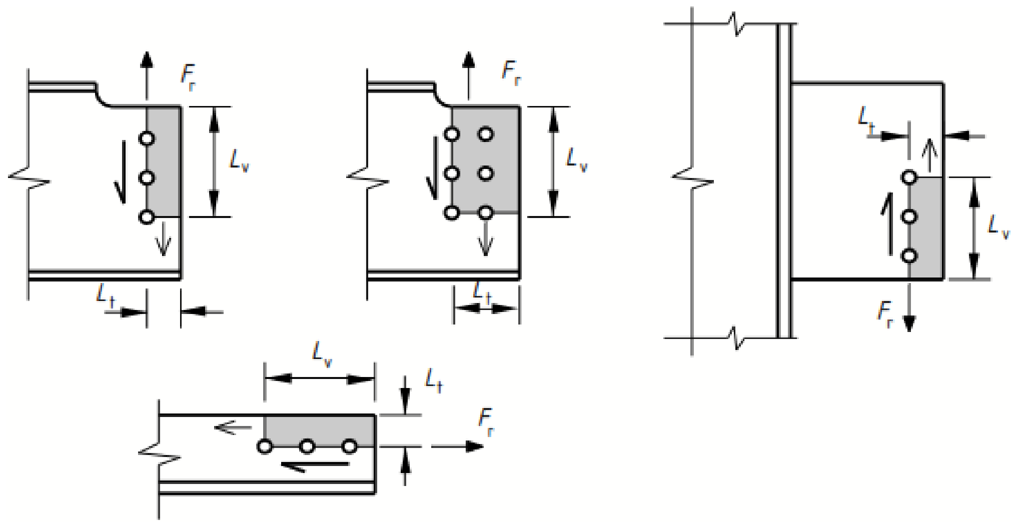


Figure 22 — Block shear — Effective shear area

$$P_r = 0.6 p_y t [L_v + K_e (L_t - k D_t)]$$

where

- D_t is the hole size for the tension face, generally the hole diameter, but for slotted holes the dimension perpendicular to the direction of load transfer should be used;
- k is a coefficient with values as follows:
  - — for a single line of bolts: $k = 0.5$;
  - — for two lines of bolts: $k = 2.5$;
- L_t is the length of the tension face, see Figure 22;
- L_v is the length of the shear face, see Figure 22;
- t is the thickness.

— for grade S 275: $K_e = 1.2$

— for grade S 355: $K_e = 1.1$

— for grade S 460: $K_e = 1.0$

3 Bearing capacity

should be taken *as lesser* of:

$$\text{Capacity of the bolt, } P_{bb} = d t_p p_{bb}$$

where d is the nominal diameter of bolt, t_p the thickness of connected part and p_{bb} the bearing strength of bolt given in Table 31 of the code (see Table 10.1).

Bearing capacity of connected part

$$P_{bs} = k_{bs} d t_p p_{bs} \quad \text{but} \quad P_{bs} \leq 0.5 k_{bs} e t_p p_{bs}$$

=1.0 standad size hole
=0.7over size holles
= 0.5 oval holes

if u make e=2d then equation will be safe

e is the end distance,

p_{bs} is the bearing strength of the connected part, see Table 32.

where p_{bs} is the bearing strength of the connected parts given in Table 32 of the code (see Table 10.1), e the end distance and k_{bs} the coefficient depending on the type of hole: 1.0 for standard clearance hole, 0.7 for oversize, short or long slotted hole, and 0.5 for kidney-shaped slotted hole.

Table 32 — Bearing strength p_{bs} of connected parts

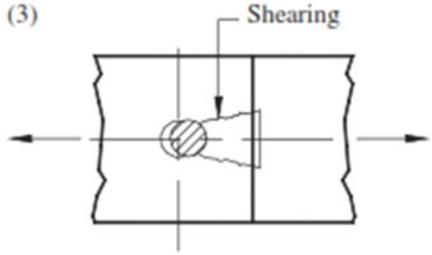
Steel grade	S 275	S 355	S 460	Other grades
Bearing strength p_{bs} (N/mm²)	460	550	670	$0.67(U_s + Y_s)$

NOTE 1 U_s is the specified minimum tensile strength of the steel.

NOTE 2 Y_s is the specified minimum yield strength of the steel.

The second part of the bearing check ensures that the plate does not fail by end shear as shown in mode 3.

(3)



End shear failure

NOTE IF ABIDE TO THE RULE OF A THUMB AND MAKE END DISTANCE = 2D THE SECOND PART OF THE EQUATION WILL BE SAFE

لاحظ أنه إذا التزمت بقاعدة المسافات وجعلت المسافة النهائية = 2د، فسيكون الجزء الثاني من المعادلة آمنًا

BOLTS IN TENSION

Two methods are now permitted; either the simple or more exact method can be used. The simple method covers the prying action (see Figure 10.5(b)) by a reduced bolt strength , whereas the more exact method uses the full bolt tension capacity where prying is zero or allowed for in the applied load.

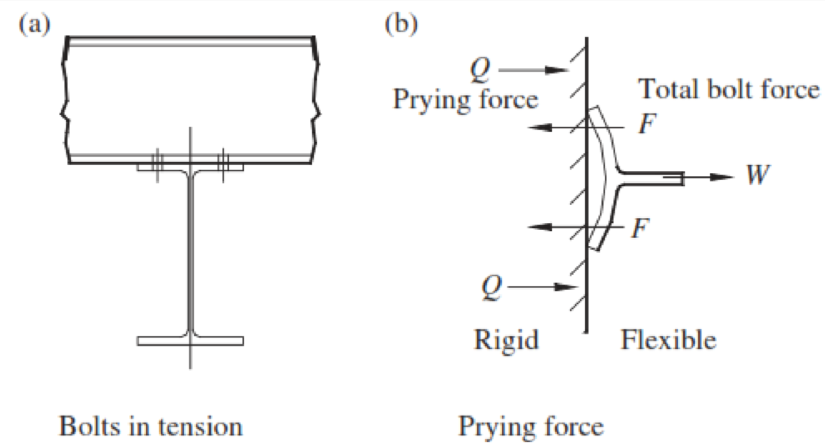
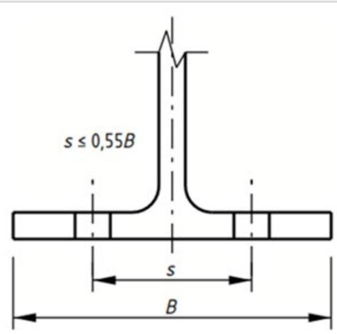


Figure 10.5 Bolts in tension

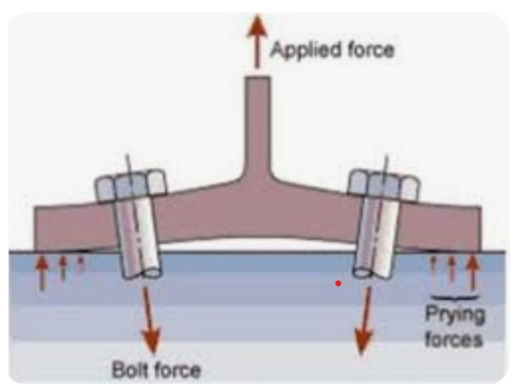
Simple method

The simple method may be used if the connection primarily satisfies the following:

The cross-center spacing of the bolt lines should not exceed 55 % of the flange width or end-plate width, see Figure below



— **Maximum cross-centres of bolt lines for the simple method**



CalcBook
Prying Action (AISC 360)

In the simple method the prying force need not be calculated. The tensile force per bolt F_t transmitted by the connection should not exceed the nominal tension capacity P_{nom} of the bolt, obtained from:

$$P_{nom} = 0.8 p_t A_t$$

where

A_t is the tensile stress area as specified in the appropriate bolt standard. For bolts where the tensile stress area is not defined, A_t should be taken as the area at the bottom of the threads;

p_t is the tension strength of the bolt obtained from Table 34.

Table 34 — Tension strength of bolts

Bolt grade	Tension strength p_t (N/mm²)
4.6	240
8.8	560
10.9	700

Tension capacity of bolts—more exact method

$$P_t = p_t A_t$$

The prying force Q adds directly to the tension in the bolt. Referring to the figure,

Total bolt tension, $F = W/2 + Q \leq P_t$

where W is the external tension on the joint.

In the more exact method, it is necessary to calculate the prying force. The