INTERNATIONAL UNIVERSITY OF AFRICA

CIVIL ENGINEERING DEPARTMENT

ANALYSIS AND DESIGN OF STEEL WORKS

GRADE 4

7TH SEMESTER

Lecture No 6

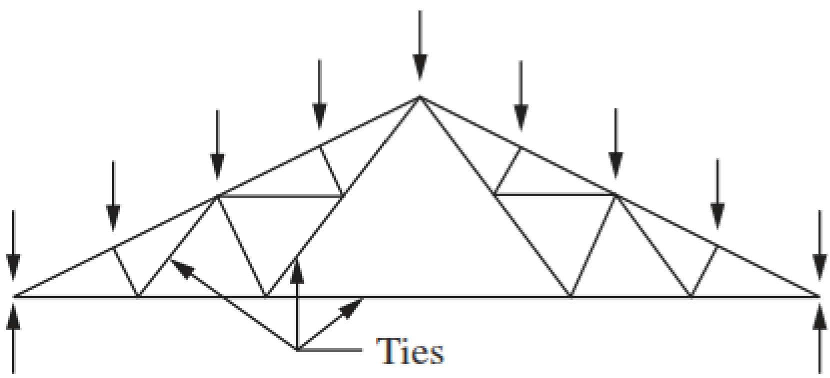
TENSION MEMBERS

USES, TYPES AND DESIGN CONSIDERATIONS

A tension member transmits a direct axial pull between two points in structural frame. A rope supporting a load or cables in a suspension bridge are obvious examples. In building frames, tension members occur as:

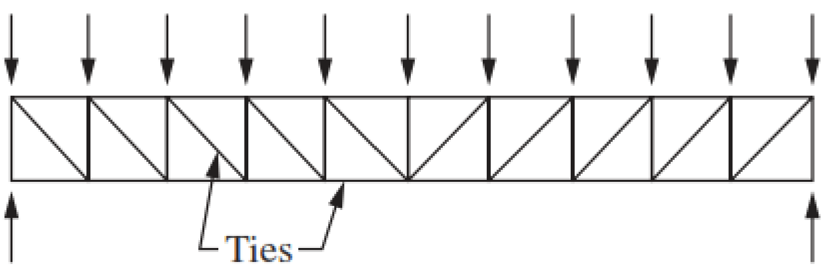
(1) tension chords and internal ties in trusses;
(2) tension bracing members;
(3) hangers supporting floor beams.

(a)



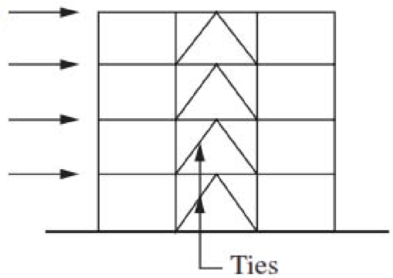
Roof truss

(b)



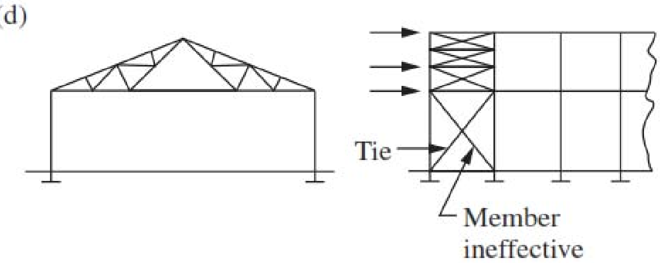
Lattice girder

(c)



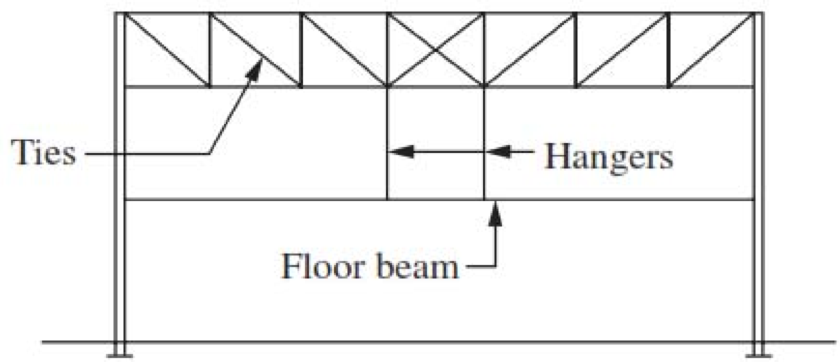
Multi-storey building

(d)



Industrial building

(e)

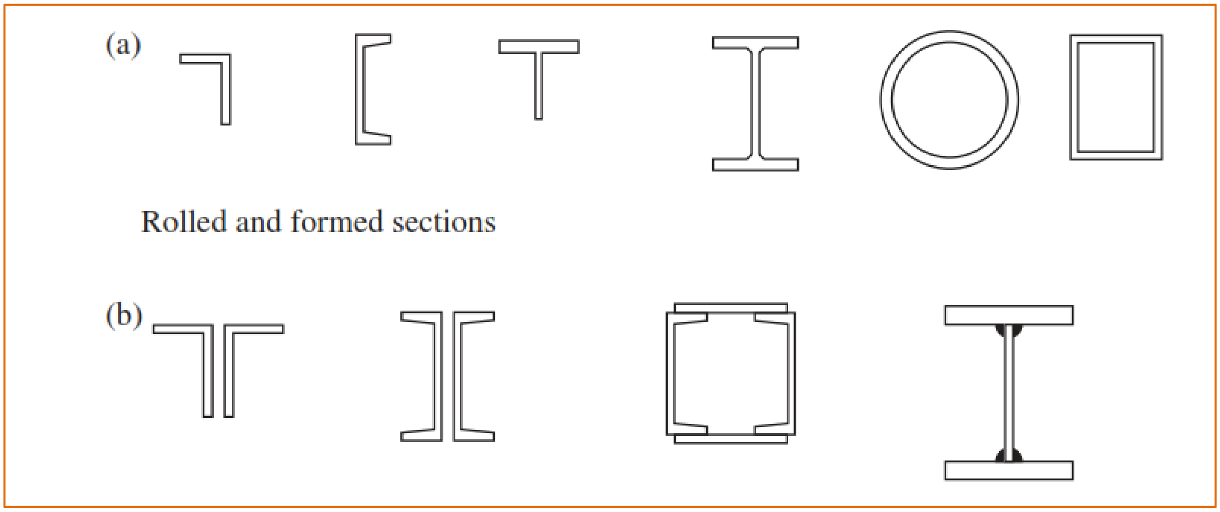


Hangers supporting floor beam

Examples of tension members from figure a to e

The main sections used for tension members are:

(1) open sections such as angles, channels, tees, joists, universal beams and columns;
(2) closed sections. Circular, square and rectangular hollow sections;
(3) compound and built-up sections. Double angles and double channels are. Common compound sections used in trusses. Built-up sections are used in bridge trusses.



Tension member sections

Design considerations

Theoretically, the tension member is the most efficient structural element, but its efficiency may be seriously affected by the following factors:

(1) The end connections. For example, bolt holes reduce the member section.

(2) The member may be subject to reversal of load, in which case it is liable to buckle because a tension member is slenderer than a compression member.

(3) Many tension members must also resist moment as well as axial load. The moment is due to eccentricity in the end connections or to lateral load on the member.

DESIGN OF TENSION MEMBERS

1 Axially loaded tension members

The tension capacity is given in Section 4.6.1 of BS 5950: Part 1. This is:

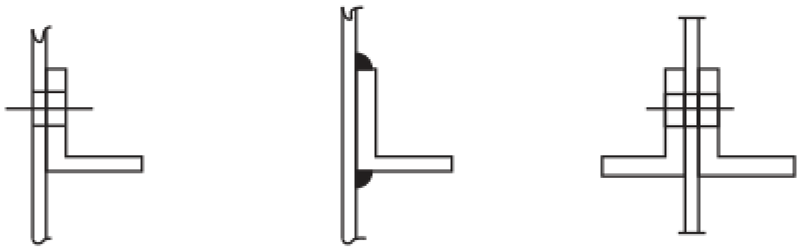
$$P_t = A_e p_y$$

where A_e is the effective area of the section defined in Sections 3.4.3, 4.6.2 and 4.6.3 of the code.

$A_e = K_e \times$ net area where holes occur $\leq$ gross area
$K_e = 1.2$ for Grade S275 and 1.1 for S355 steel
(Net area = gross area less holes.)

A-Simple tension members

- Single angles, channels or T-section members connected through one leg



Angle connections

These may be designed in accordance with Section 4.6.3 of the code as axially loaded members with an effective area

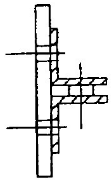
Ae=1.2 x net area S275
Ae =1.1 x net area S355

For bolted connection: $P_t = p_y(A_e - 0.5a_2)$
For welded connection: $P_t = p_y(A_g - 0.3a_2)$

a2 is an area

where a_2 equals $(A_g - a_1)$, where A_g is the gross cross-sectional area and a_1 the gross sectional area of the connected leg.

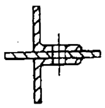
a1 is an area



DOUBLE ANGLE BACK-TO-BACK INTERCONNECTED; CONNECTED TO ONE SIDE OF A GUSSET PLATE

- Double angles, channels or T-section members connected through one side of a gusset

For bolted connection: $P_t = p_y(A_e - 0.25a_2)$,
For welded connection: $P_t = p_y(A_g - 0.15a_2)$.



DOUBLE ANGLE BACK-TO-BACK INTERCONNECTED; CONNECTED TO BOTH SIDES OF A CENTRAL GUSSET PLATE

- Double angles, channels or T-section members connected to both sides of gusset plates

If these members are connected together as specified in the code, they can be designed as axially loaded members using the net area specified in Section 3.3.2 of the code. This is the gross area minus the deduction for holes.

Tension members with moments

The code states that moments from eccentric end connections and other causes must be taken into account in design.

Design of tension members with moments is covered in CODE. This states that the member should be checked for capacity at points of greatest moment using the simplified interaction expression:

$$\frac{F}{A_e p_y} + \frac{M_x}{M_{cx}} + \frac{M_y}{M_{cy}} \leq 1$$

where F is the applied axial load, A_e the effective area, M_x the applied moment about the x–x axis, M_{cx} the moment capacity about the x–x axis in the absence of axial load, and M_y the applied moment about the y–y axis. M_{cy} the moment capacity about the y–y axis in the absence of axial load.

DESIGN EXAMPLES

Angle connected through one leg

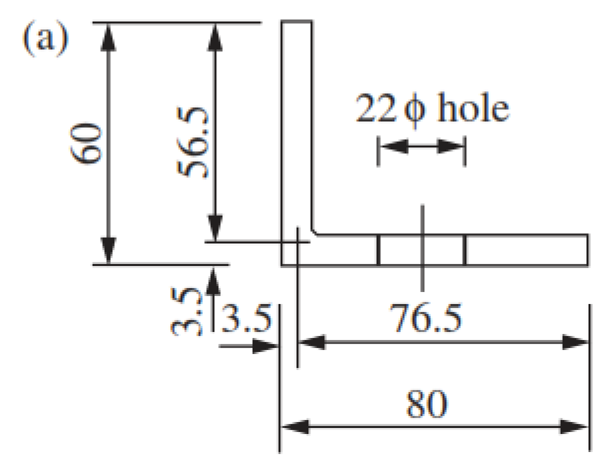
Design a single angle to carry a dead load of 70 kN and an imposed load of 35 kN The bolt hole is 22 mm diameter for 20 mm diameter bolts. = Design strength= py= 275 N/mm2

(1) Bolted connection

solution

Factored load = (1.4 × 70) + (1.6 × 35) = 154 kN.

Try 80 × 60× 7 angle connected through the long leg,



Bolted connection

$$a_1 = \text{net area of connected leg} = (76.5 - 22)7 = 381.5\,\text{mm}^2,$$

$$a_2 = \text{area of unconnected leg} = 56.5 \times 7 = 395.5\,\text{mm}^2,$$

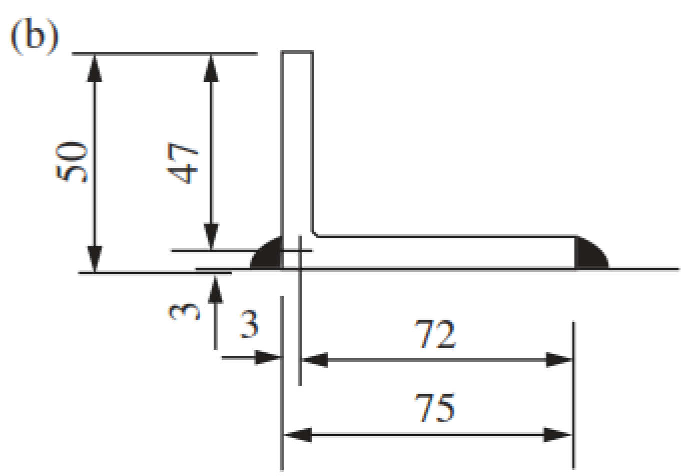
Effective area $A_e = a_1 + a_2 = 777\,\text{mm}^2$.

Tension capacity: $P_t = p_y(A_e - 0.5a_2) = 275(777 - 0.5 \times 395.5)/10^3$
$= 159\,\text{kN}.$

(2) Welded connection

Try 75 × 50 × 6 L connected through the long leg (

$$a_1 = 72 \times 6 = 432\,\text{mm}^2,$$
$$a_2 = 47 \times 6 = 282\,\text{mm}^2,$$
$$A_g = a_1 + a_2 = 714\,\text{mm}^2.$$



Welded connection

Tension capacity:

$$P_t = p_y(A_g - 0.3a_2) = 275(714 - 0.3 \times 282)/10^3 = 173\,\text{kN}.$$

The angle is satisfactory.

Design examples

Angle connected through one leg

Design a single angle to carry a dead load of 70 kN and an imposed load of 35 kN.

(1) Bolted connection

Factored load $= (1.4 \times 70) + (1.6 \times 35) = 154$ kN.
Try $80 \times 60 \times 7$ angle connected through the long leg, as shown in Figure (a). The bolt hole is 22 mm diameter for 20 mm diameter bolts.
Design strength from Table 6 in the code $p_y = 275$ N/mm^2

$$a_1 = \text{net area of connected leg} = (76.5 - 22)7 = 381.5\ \text{mm}^2,$$

$$a_2 = \text{area of unconnected leg} = 56.5 \times 7 = 395.5\ \text{mm}^2,$$

$$\text{Effective area } A_e = a_1 + a_2 = 777\ \text{mm}^2.$$

$$\text{Tension capacity: } P_t = p_y(A_e - 0.5a_2) = 275(777 - 0.5 \times 395.5)/10^3 = 159\ \text{kN}.$$

The angle is satisfactory.
Note that the connection would require either 3 No. Grade 8.8 or 3 No. friction-grip 20 mm diameter bolts to support the load.

(2) Welded connection

Try $75 \times 50 \times 6$ L connected through the long leg (see Figure (b)):

$$a_1 = 72 \times 6 = 432\ \text{mm}^2,$$

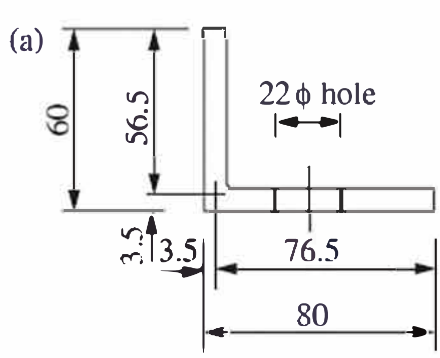
$$a_2 = 47 \times 6 = 282\ \text{mm}^2,$$

$$A_g = a_1 + a_2 = 714\ \text{mm}^2.$$

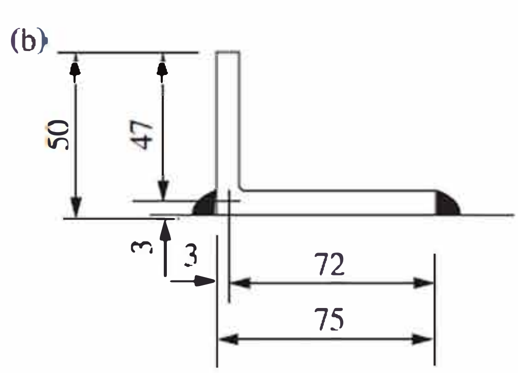
Tension capacity:

$$P_t = p_y(A_g - 0.3a_2) = 275(714 - 0.3 \times 282)/10^3 = 173\ \text{kN}.$$

The angle is satisfactory.



Bolted connection
Figure (a)



Welded connection
Figure (b)