4
CHAPTER

Tension Members

Q.1 The permissible stress in tension in steel structures is worked out after applying a factor of safety of
(a) 1.15 (b) 1.5
(c) 1.65 (d) 2

Q.2 A member subjected to both axial tension and bending should be proportioned so that which of the following relationship is satisfied?

(a) $\frac{\sigma_{at,cal}}{0.6f_y}+\frac{\sigma_{bt,cal}}{0.66f_y}+\frac{\sigma_{by,cal}}{0.66fy}\le 1.4$

(b) $\frac{\sigma_{at,cal}}{0.6f_y}+\frac{\sigma_{bt,cal}}{0.66f_y}+\frac{\sigma_{by,cal}}{0.66fy}\le 1$

(c) $\frac{\sigma_{at,cal}}{0.66f_y}+\frac{\sigma_{bt,cal}}{0.6f_y}+\frac{\sigma_{by,cal}}{0.6fy}\le 1.4$

(d) $\frac{\sigma_{at,cal}}{0.66f_y}+\frac{\sigma_{bt,cal}}{0.6f_y}+\frac{\sigma_{by,cal}}{0.6fy}\le 1$

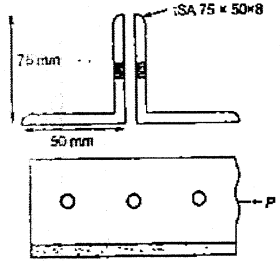
Q.3 The top edge of the gusset plate in stiffened if it becomes more than
(a) 12 times the thickness of the plate.
(b) 40 times the thickness of the plate.
(c) 60 times the thickness of the plate.
(d) 90 times the thickness of the plate.

Q.4 The minimum thickness of gusset plate is
(a) 9 mm (b) 12 mm
(c) 15 mm (d) 16 mm

Q.5 Lug angles are designed
(a) to develop a strength not less than 20% in excess of the force in the outstanding leg of an angle.
(b) the attachment of the leg angle to the angle member should be capable of developing 20% in excess of that force.
(c) both (a) and (b)
(d) Neither (a) nor (b)

Q.6 Splice covers and its connections in a tension member should be designed
(a) to develop net tensile strength of main member
(b) to carry 50% load of main member
(c) to carry 75% load of main member
(d) in tension member splices are not recommended

Q.7 A double angle tension member 75 × 50 × 8 mm is connected to gusset plate as shown in figure, with one line of 16 mm diameter bolts through long leg. The effective net area of section will be

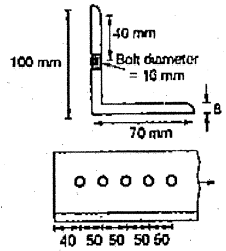


(a) 424 mm² (b) 368 mm²
(c) 792 mm² (d) 1109 mm²

Q.8 A single-angle tie of a welded steel truss in an industrial shed is required to be designed for an axial tension of 100 kN. If ultimate strength of material is 410 MPa, then the most suitable section satisfying IS 800 : 2007 codal requirements will be
(a) ISA 75 × 50 × 6
(b) ISA 60 × 40 × 5
(c) ISA 50 × 30 × 4
(d) ISA 45 × 30 × 5

Section	$A_1(mm^2)$	$A_2(mm^2)$	$A_{ne}(mm^2)$
ISA 75×50×6	432	282	570.4
ISA 60×40×5	287.5	187.5	380
ISA 50×30×4	192	112	243.2
ISA 45×30×5	212.5	137.5	280

Q.9 A single angle section ISA 100 × 70 × 8 mm with long leg connected to gusset plate gets failed due to net section rupture.



The value for 'β' is
(a) 0.700 (b) 1.153
(c) 1.443 (d) 1.531

Q.10 In the above question, the design strength of the angle section will be
(a) 270.52 kN (b) 303.18 kN
(c) 322.56 kN (d) 348.52 kN

Q.11 In case of single angle in tension connected by one leg only, the net effective area as per IS 800 : 1984 is
(a) gross area – area of holes
(b) $a+\frac{b}{1+0.33(b/a)}$
(c) $a+\frac{b}{1+0.2(b/a)}$
(d) $a+\frac{b}{1+0.35(a/b)}$

Q.12 A structural member subjected to a tensile force in the direction parallel to its longitudinal axis, is generally known as
(a) a tie (b) a tie member
(c) a tension member (d) all of the above

Q.13 In a tension member if one or more than one rivet holes are off the line, the failure of the member depends on
(a) pitch
(b) gauge
(c) diameter of the rivet holes
(d) all of the above

Q.14 For double angles carrying tension placed back to back and connected to either side of the gusset plate, the sectional area of the section, is equal to gross sectional area of the
(a) section
(b) section plus area of rivet holes
(c) section minus area of rivet holes
(d) section multiplied by the area of the rivet hole

Q.15 A tension member, if subjected to possible reversal of stress due to wind or earthquake, the slenderness ratio of the member should not exceed
(a) 180 (b) 300
(c) 250 (d) 350

Q.16 For a single section used as a tension member, the gross area is assumed
(a) 20% to 30% in excess of the net area
(b) 30% to 40% in excess of the net area
(c) 40% to 50% in excess of the net area
(d) 50% to 60% in excess of the net area

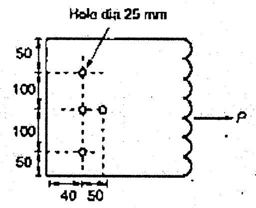
Q.17 Lug angle is
(a) used with single angle member
(b) not used with double angle member
(c) used with channel member
(d) All of the above

Q.18 Tacking rivets in tension members, are provided at a pitch in line not exceeding
(a) 25 cm (b) 50 cm
(c) 60 cm (d) 100 cm

Q.19 A single angle tie in a welded steel roof truss of an industrial building is subjected to an axial tensile force of 60 kN. If the yield stress of the material is 250 MPa, then the section that would best satisfy the requirement of IS 800 : 1984 is
(a) ISA 50 × 50 × 5 (b) ISA 50 × 50 × 6
(c) ISA 55 × 55 × 5 (d) ISA 55 × 55 × 6

Q.20 An equal angle of area A has been welded on one side of a gusset plate and carries tension along the axis. What is the effective area of the angle?
(a) 0.5 A (b) 0.75 A
(c) 0.875 A (d) A

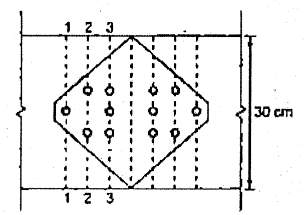
Q.21 What is the effective net width of plate as shown in figure for carrying tension?



(All dimensions are in mm)

(a) 212.5 mm (b) 237.5 mm
(c) 250 mm (d) 275 mm

Q.22 Two steel plates each of 12 mm thickness are connected by a double cover butt joint by rivets as shown in the figure. If the rivet diameter is 22 mm with rivet value of 53150 N and permissible stress in tension of plate is 142 N/mm², which one of the following section is the most critical section?



(a) Section 1 - 1
(b) Section 2 - 2
(c) Section 3 - 3
(d) Both section 1 - 1 and section 2 - 2

Q.23 The capacity of a single ISA 100 × 100 × 10 mm as tension member connected by one leg only using 6 rivets of 20 mm diameter is
(a) 333 kN (b) 253 kN
(c) 238 kN (d) 210 kN
The allowable stress in tension is 150 N/mm²

Q.24 Failure of tension member is considered when either of following statement is true
1. Excessive elongation in member.
2. Rupture of critical section.
3. Buckling of member.
4. Block shear failure of end connection.
(a) 1, 2 and 3
(b) 2, 3 and 4
(c) 1, 3 and 4
(d) 1, 2 and 4

Q.25 When two angle sections subjected to a tensile force are connected to same side of the gusset plate (back to back) then effective area is (as per IS 800 : 1984)
(a) A_{gross} – deduction for rivet holes
(b) $A_1 + kA_2,\ k = \dfrac{5A_1}{(5A_1 + A_2)}$
(c) $A_1 + kA_2,\ k = \dfrac{3A_1}{(3A_1 + A_2)}$
(d) None of these

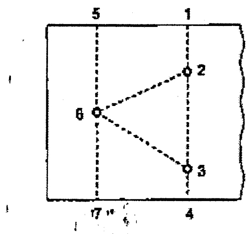
Q.26 Match List-I (Type of stress) with List-II (Allowable value of stress) and select the correct answer using the codes given below the lists:
(f_y = minimum yield stress of steel)

List-I		List-II	
A.	Axial tension	1.	$0.75\ f_y$
B.	Bending tension	2.	$0.66\ f_y$
C.	Maximum shear stress	3.	$0.60\ f_y$
D.	Bearing stress	4.	$0.45\ f_y$

Codes:

	A	B	C	D
(a)	2	3	1	4
(b)	3	2	4	1
(c)	2	3	4	1
(d)	3	2	1	4

Q.27 The net area of the flat, as shown in figure to be considered in design will be along the section

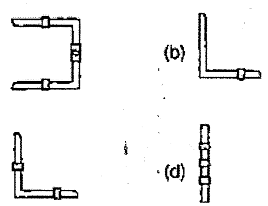


(a) 1 – 2 – 3 – 4 (b) 1 – 2 – 6 – 3 – 4
(c) 5 – 6 – 7 (d) 1 – 2 – 6 – 7

Q.28 The design tensile strength of a member due to yielding of gross section T_{dg} is given by
(a) $\dfrac{A_g f_u}{\gamma_{m_1}}$ (b) $\dfrac{A_g f_y}{\gamma_{m_1}}$
(c) $\dfrac{A_g f_u}{\gamma_{m_0}}$ (d) $\dfrac{A_g f_y}{\gamma_{m_0}}$

Q.29 For block shear failure of tension member, the failure occurs along a path through connection involving
(a) tension on two perpendicular planes.
(b) shear on two perpendicular planes.
(c) tension on one plane and shear on the other perpendicular plane.
(d) tension on one plane and compression on the other perpendicular plane.

Q.30 Which of the following member will be affected by shear lag?



Q.31 A plate used for connecting two or more structural members intersecting each other is termed as
(a) Template (b) Base plate
(c) Gusset plate (d) Shoe plate

Q.32 Which one of the following stress is independent of yield stress as a permissible stress for steel members?
(a) Axial tensile stress
(b) Maximum shear stress
(c) Bearing stress
(d) Stress in slab base

Q.33 The effective length of an angle member in a riveted truss is equal to which one of the following?
(a) l (b) $0.85l$
(c) $0.65l$ (d) $0.5l$
where l is the centre to centre distance between the joints.

Q.34 Steel of yield strength 400 MPa has been used in a structure. What is the value of the maximum allowable tensile strength?
(a) 240 MPa (b) 200 MPa
(c) 120 MPa (d) 96 MPa

Q.35 Consider the following statements:
Lug angles are used to
1. increase the lengths of the end connections of angle section.
2. decrease the lengths of the end connections of angle section.
3. increase the lengths of the end connections of channel section.
4. decrease the lengths of the end connections of channel section.
Which of the above statements are correct?
(a) 1 and 2 (b) 2 and 4
(c) 1, 3 and 4 (d) 1, 2 and 3

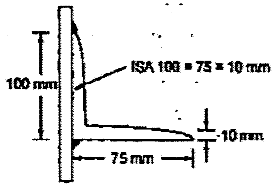
Q.36 Bending compressive and tensile stresses respectively are calculated based on
(a) net area and gross area
(b) gross area and net area
(c) net area in both cases
(d) gross area in both cases

Q.37 As per IS 800 : 1984, the ultimate load carrying capacity of a tension member is
(a) $0.6\ f_y A_s$ (b) $0.67\ f_y A_s$
(c) $0.75\ f_y A_s$ (d) $0.85\ f_y A_s$

Q.38 If the yield stress of a structural member made of steel is $f_y = 230\ N/mm^2$, then which of the following are correctly matched?
(a) Permissible tensile stress in axial tension — $150\ N/mm^2$
(b) Permissible bending stress in tension — $160\ N/mm^2$
(c) Permissible shear stress — $92\ N/mm^2$
(d) None of the above

Q.39 A steel rod 16 mm diameter has been used as a tie member in roof bracing system, but may be subjected to possible reversal of stresses due to wind. What is the maximum permissible length of member?
(a) 1600 mm (b) 1440 mm
(c) 1400 mm (d) 2800 mm

Q.40 The angles are connected as shown in figure below. The steel is of grade Fe410. The effective net area of the section is



(a) $1650\ mm^2$ (b) $990\ mm^2$
(c) $1155\ mm^2$ (d) $1320\ mm^2$

Q.41 An angle section ISA 150 × 115 × 8 mm of Fe410 grade of steel connected with the gusset plate. The tensile strength of section assuming gross-section yielding:
($\gamma_{m0} = 1.1$, $\gamma_{m1} = 1.25$, $A_g = 2058\ mm^2$, $f_y = 250$ MPa, $f_u = 410$ MPa)
(a) 342.3 kN (b) 467.7 kN
(c) 402.3 kN (d) 523.2 kN

Q.42 The design strength criteria of a tension member is given by which of the following factors:
(i) Yielding of gross-area.
(ii) Rupture at critical section.
(iii) Block shear of end region.
(a) (i) and (ii) only (b) (i) and (iii) only
(c) (ii) and (iii) only (d) All of the above

Q.43 Prying forces can be reduced by which of the following parameters.
(i) Increasing the end distance.
(ii) Decreasing the end distance.
(iii) Increasing the distance of the bolt from half the root radius for a rolled section.
(a) Only (i) is correct
(b) Only (iii) is correct
(c) (i) and (iii) are correct
(d) (ii) and (iii) are correct

Q.44 A tie member of roof truss consists of 2ISA 100 × 75 × 8 mm. The angles are connected to either side of 10 mm gusset plates and subjected to factored load of 450 kN. Assuming 6 mm size of weld (normal), the total length of weld required is:
(a) 183 mm (b) 243 mm
(c) 283 mm (d) 143 mm

Q.45 A hanger joint along with on end plate is designed to carry a downward load of 330 kN. Using end plate size 240 mm × 160 mm and 2 no.s M 25 G_r 8.8 HSFG bolts (f_u = 565 MPa, f_y = 236), size of weld = 10 mm thickness of hanger = 20 mm. The minimum thickness required is:
(a) 15 mm (b) 20 mm
(c) 30 mm (d) 25 mm

■■■■

Answers : Tension Members

1. (c)	2. (b)	3. (c)	4. (b)	5. (a)	6. (a)	7. (d)	8. (b)	9. (b)	10. (c)
11. (b)	12. (d)	13. (d)	14. (c)	15. (d)	16. (a)	17. (d)	18. (d)	19. (a)	20. (c)
21. (b)	22. (a)	23. (d)	24. (d)	25. (b)	26. (b)	27. (b)	28. (d)	29. (c)	30. (b)
31. (c)	32. (d)	33. (b)	34. (a)	35. (b)	36. (b)	37. (d)	38. (c)	39. (c)	40. (d)
41. (b)	42. (d)	43. (a)	44. (c)	45. (d)					

Explanations : Tension Members

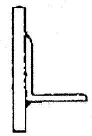
1. (c)
Permissible stress in axial tension,
$$\sigma_{at} = \frac{f_y}{1.65} = 0.6\, f_y$$

4. (b)
Design specification give a little guidance to decide thickness of gusset plates but in any case it should not be less than 12 mm.

5. (a)
The attachment of the leg angle to the angle member should be capable of developing 40% in excess of the force in the outstanding leg of the angle.

7. (d)
Hole dia = Bolt dia. + 2 mm = 18 mm
Effective area of connected leg
$$A_1 = \left(75 - 18 - \frac{8}{2}\right) \times 8 = 424\ mm^2$$
Effective area of outstanding lag,
$$A_2 = \left(50 - \frac{8}{2}\right) \times 8 = 368\ mm^2$$
Net Area, $A_n = (A_1 + A_2)$
$= 424 + 368 = 792\ mm^2$
Effective net area,
$A_{ne} = 2\alpha A_n$
For 3 bolts, $\alpha = 0.7$
Thus, $A_{ne} = 2 \times 0.7 \times 792$
$= 1108.8\ mm^2$

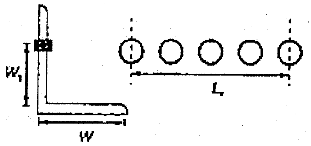
8. (b)



Considering failure by net section rupture
Stress on net sectional area < ultimate stress
$$\frac{\text{Pull (Axial tension)}}{\text{Net sectional area}} < f_u$$
Design strength $T_{dn} = \dfrac{0.9 f_u A_n}{\gamma_{m_1}}$
$$100 \times 10^3 = \frac{0.9 \times 410 \times A_n}{1.25}$$
$A_n = 338.75\ mm^2$
For an angle of size ISA $a \times b \times t$
Area of connected leg with dimension 'a'
$$A_1 = \left(a - \frac{t}{2}\right)t$$
Net area,
$A_n = A_1 + A_2$
Effective net area,
$A_{ne} = \alpha A_n$
where, α = 0.8 for welds
i.e., $A_{ne} = 0.8\left[\left(a - \frac{t}{2}\right)t + \left(b - \frac{t}{2}\right)t\right]$
Thus ISA 60 × 40 × 5 is most suitable with net area 380 mm^2, which is more than the required area of 338.75 mm^2.

9. (b)

As $\beta = 1.4 - 0.076 \times \frac{w}{t} \times \frac{f_y}{f_u} \times \frac{b_s}{L_c}$



Shear leg width $b_s = w + w_1 - t$

$= 70 + (100 - 40) - 8$

$= 122$ mm

L_c = distance between first and last bolt

$= 4 \times 50 = 200$ mm

Thus, $\beta = 1.4 - 0.076 \times \frac{70}{8} \times \frac{250}{410} \times \frac{122}{200}$

$= 1.153$

Since, $\beta \le \frac{\gamma_{m_0}}{\gamma_{m_1}} \times \frac{f_u}{f_y}$

$\le \frac{1.10}{1.25} \times \frac{410}{250} = 1.4432$ (OK)

$\therefore \quad \beta = 1.153$

10. (c)

Design strength

$$T_{dn} = \frac{0.9 A_{nc} f_u}{\gamma_{m_1}} + \frac{\beta A_{go} f_y}{\gamma_{m_0}}$$

Net area of connected leg

$$A_{nc} = \left(100 - 18 - \frac{8}{2}\right) \times 8 = 624 \text{ mm}^2$$

Gross area of outstanding leg

$$A_{go} = \left(70 - \frac{8}{2}\right) \times 8 = 528 \text{ mm}^2$$

Thus,

$$T_{dn} = \left(\frac{0.9 \times 624 \times 410}{1.25}\right) + \left(\frac{1.153 \times 528 \times 250}{1.10}\right)$$

$= 322.56$ kN

17. (d)

Lug angles are used to reduce the length of the connections, however their main purpose is to accommodate more number of rivets so that size of the gusset plate may be reduced.

20. (c)

In case of single angle connected through one leg, the net effective sectional area shall be taken as

$A_{net} = A_1 + KA_2$

where

A_1 = area of connected

leg $= \frac{A}{2}$ also, $A_2 = \frac{A}{2}$

$$\therefore \quad K = \frac{3A_1}{3A_1 + A_2} = \frac{3\frac{A}{2}}{3\frac{A}{2} + \frac{A}{2}} = \frac{3}{2}$$

$\Rightarrow A_{net} = \frac{A}{2} + \frac{3A}{4 \times 2}$

$\Rightarrow A_{net} = 0.875 A$

21. (b)

Effective net width of plate

$$= 300 - \left[3d - \frac{s_1^2}{4g_1} - \frac{s_2^2}{4g_2}\right]$$

$s_1 = s_2 = 50$ mm

$g_1 = g_2 = 100$ mm; $d = 25$ mm

$$\therefore \text{Net width} = 300 - \left[3 \times 25 - \frac{2 \times 50^2}{4 \times 100}\right]$$

$= 237.5$ mm

22. (a)

Gross dia of hole

$= 22 + 1.5 = 23.5$ mm

Strength of main plate of section 1-1

$= \sigma_{at} (B - d) \times t$

$= 142 \times (300 - 23.5) \times 12$

$= 471.156$ kN

At section 2-2, strength of plate

$= \sigma_{at} (B - 2d) \times t + R_v$

$= 142 (300 - 2 \times 23.5) \times 12 + 53150$

$= 484.262$ kN

At section 3-3, strength of plate

$= \sigma_{at} (B - 3d) \times t + 3R_v$

$= 142 (300 - 3 \times 23.5) \times 12 + 3 \times 53150$

$= 550.518$ kN

So section 1-1 is the most critical section

23. (d)

The net area of the tension member is given by

$A_{net} = A_1 + kA_2$

$$A_1 = \left(100 - 21.5 - \frac{10}{2}\right) 10 = 735 \text{ mm}^2$$

$$A_2 = \left(100 - \frac{10}{2}\right) \times 10 = 950 \text{ mm}^2$$

The angle section is connected by one leg only.

$$\therefore \; k = \frac{3A_1}{3A_1 + A_2} = \frac{3 \times 735}{3 \times 735 + 950} = 0.7$$

$\therefore \quad A_{net} = 735 + 0.7 \times 950 = 1400 \text{ mm}^2$

$\therefore \quad P_{safe} = \sigma_{at} \times A_{net}$

$= 150 \times 1400 \times 10^{-3} = 210$ kN

24. (d)

The three criterion for failure has been considered in new code. Buckling takes place in compression members and not in tension members.

27. (b)

Net area will be taken along the section having the minimum width.

Section 1 - 2 - 3 - 4, $B_{e1} = B - 2d$

Section 1 - 2 - 6 - 3 - 4, $B_{e2} = B - 3d + \frac{2P^2}{4g}$

Section 1 - 2 - 6 - 7, $B_{e3} = B - 2d + \frac{P^2}{4g}$

Section 5 - 6 - 7, $B_{e4} = B - d$

Out of all options, there is uncertainty about minimum value of B_{e1} and B_{e2}.

Be_2 will be taken as minimum as section 1 - 2 - 6 - 3 - 4 considers critical combination of bolts.

30. (b)

Shear lag phenomenon is prominent in the section in which all the various elements forming the section are not connected.

31. (c)

Base plates are provided to distribute the load of a column on greater area.

32. (d)

Permissible values

Axial tensile stress = 0.6 f_y

Bearing stress = 0.75 f_y

Maximum shear stress = 0.45 f_y

Stress in slab base = 185 MPa for all type of steels.

34. (a)

Maximum allowable tensile strength

$$= \frac{f_y}{1.67} = \frac{400}{1.67} = 239.52 \text{ MPa}$$

35. (b)

Lug angles are sometimes used to reduce the length of the connections. However their main purpose is to accommodate more number of rivets so that size of the gusset plate may be reduced.

38. (c)

- Permissible tensile stress in axial tension $= 0.6 f_y = 138$ N/mm².
- Permissible bending stress in tension $= 0.66 f_y = 151.8$ N/mm².
- Permissible shear stress $= 0.4 f_y = 92$ N/mm².

39. (c)

Slenderness ratio,

$$\lambda = \frac{L}{r_{min}} = 350$$

where, min. radius of gyration,

$$r_{min} = \sqrt{\frac{I}{A}}$$

$$= \sqrt{\frac{\pi d^4/64}{\pi d^2/4}} = \frac{d}{4}$$

or, $\frac{L}{\left(\frac{d}{4}\right)} = 350$

$\Rightarrow \quad L = 350 \times \frac{16}{4} = 1400$ mm.

40. (d)

Net area of connected leg

$$= \left(100 - \frac{10}{2}\right) = 950 \text{ mm}^2$$

Net area of outstanding leg

$$= \left(75-\frac{10}{2}\right) = 700 \text{ mm}^2$$

Total net area = 950 + 700 = 1650 mm^2

Since only one leg of angle is connected, the net area will be reduce by factor 0.8 (for welded connection)

Effective area,

$$A_n = 0.8 \times 1650 = 1320 \text{ mm}^2$$

41. (b)

Tensile strength due to gross-section yielding.

$$T_{dg} = \frac{A_g f_y}{\gamma_{m0}}$$

$$= \frac{2058 \times 250}{1.1} \times 10^{-3} = 467.7 \text{ kN}$$

(As per limit 800 : 2007)

42. (d)

The design strength of tension member is determined by yielding of gross-area, rupture at critical section and block shear of end region.

43. (a)

Prying forces are the additional tensile forces due to the flexibility of connected parts leading to deformations. It can be reduced by increasing the end distance.

44. (c)

Each angle carry a factored load

$$= \frac{450}{2} = 225 \text{ kN}$$

Let L_w = Length of weld required

For normal weld,

$$t = 0.75 = 0.7 \times 6 = 4.2 \text{ mm}$$

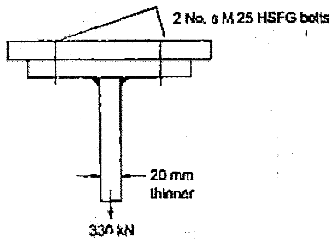
Design strength of weld

$$= L_w t \times \frac{f_u}{\sqrt{3}} \times \frac{1}{1.25}$$

$$= L_w \times 0.7 \times 6 \times \frac{410}{\sqrt{3}} \times \frac{1}{1.25}$$

$\therefore \quad L_w = 283 \text{ mm}$

45. (d)



Distance from centreline of bolt to toe of fillet weld,

$$l_v = 60 \text{ mm}$$

For minimum thickness design,

$$M = \frac{T l_v}{2} = \frac{165 \times 60}{2}$$

$$= 4950 \text{ Nm}$$

$$t_{min} = \sqrt{\frac{4 M_p \gamma_{m0}}{\gamma_y \times w}}$$

$$= \sqrt{\frac{4 \times 1.15 \times 4950 \times 10^3}{236 \times 160}}$$

$$= 24.56 \approx 25 \text{ mm}$$

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