TED (15) 6013

(Revision-2015)

A20-00120

Reg.No............................

Signature.........................

DIPLOMA EXAMINATION IN ENGINEERING/TECHNOLOGY/
MANAGEMENT/COMMERCIAL PRACTICE, APRIL-2020

STRUCTURAL DESIGN-II

[Maximum marks: 75] (Time: 2.15 Hours)

PART – A

(Answer any ***three*** questions in one or two sentences. Each question carries 2 marks)

I. (1). List any four types of rolled steel section used in steel structures.

(2). Define slenderness ratio of column.

(3). Identify the effective throat thickness of fillet weld.

(4). List the types of loads to be considered in the design of steel roof truss.

(5). Define plastic hinge. (3 x 2 = 6)

PART – B

(Answer any ***four*** of the following questions. Each question carries 6 marks)

II. (1). Write any six advantages of steel structures over R.C,C structures.

(2). Explain different types of welded connections with sketches.

(3). Define (i). Gross area, (ii). Net area and (iii). Net effective area of tension members.

(4). Sketch a column with

(i). Single laced system. (ii). Double laced system. (iii). Battened system.

(5). Explain the plastic moment carrying capacity of a section.

(6). Distinguish between (i). Laterally supported beam and (ii). Laterally unsupported beam.

(7). Write shot notes on: (i). Stress reduction factor. (ii). Area reduction factor. (4 x 6= 24)

PART – C

(Answer ***any of the three units*** from the following. Each question carries 15 marks)

UNIT –I

III. (a). Explain types of failures in bolted joint. (7)

(b). Two plates of grade 410, 12mm thick are connected by lap joint using M16 bolts of grade 4.6. The plates transmit a factored load of 120 kN. Find the number of bolts required for the connection. Take e=30mm and pitch = 40mm (8)

OR

IV. (a). Write the physical and mechanical properties of structural steel. (6)

(b). A tie member of a truss consisting of an angle section ISA 65 x 65 x 6mm of Fe-410 grade is welded to an 8mm gusset plate. Design a weld to transmit a load equal to the full strength of the member. Assume shop welding. (9)

UNIT-II

V. (a). Which are the different shapes of compression member commonly used. (5)

(b). Design a single angle strut connected to the gusset plate to carry the load of 150 kN. The length of strut between centre to centre of connection is 3m. (10)

OR

VI. (a). Write short notes on Lug angles. (5)

(b). Design a double angle tension member to carry a load of 600 kN, Use fillet weld. (10)

UNIT-III

VII. (a). Identify the classification of a cross section of beams. (6)

(b). Design a suitable I-section for simply supported beam having effective span 6m carrying a uniformly distributed load of 19 kN/m in its entire span. Check the section for shear. (9)

OR

VIII. (a). Draw the cross section of a plate girder and state the functions of

(i). Flange, (ii). Web. (iii). Stiffner. (8)

(b). An ISMB 400 @ 616 N/m is used as a simply supported beam. Calculate the design bending strength and shear strength of beam. The grade of steel is Fe 250. (7)

UNIT-IV

IX. (a). Sketch the following types of roof truss.

(i). King post truss. (ii). Fink truss. (iii). North light truss. (8)

(b). Calculate the design wind pressure for a shed of 40 x 20 x 12 m size if basic wind speed is 47 m/s, K1 = 1, K2 = 0.904, K3 = 1. (7)

OR

X. (a). Write short notes on:

(i). Effective height. (ii). Effective length (iii). Slenderness ratio of masonry wall. (6)

(b). A masonry wall 200mm thick carrying an axial load of 80 KN/m is of 3.5m effective length. It is not braced by cross walls. The effective height of the wall is 2.4m. Design masonry wall. . (9)

TED(15) - 6013
(REVISION - 2015)

19 Pages

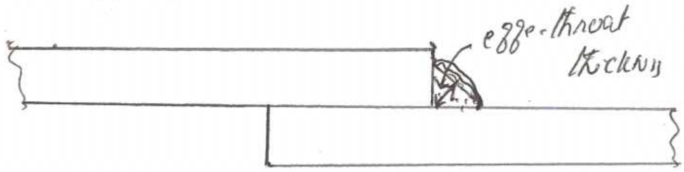
DIPLOMA EXAMINATION IN ENGINEERING

STRUCTURAL DESIGN - II

I 1. I-section, Angle, channel, T, flat plate, structural steel tubes etc

2. Slenderness ratio of column is the ratio of effective length of column to the least radius of gyration of the cross section. (2 marks)

3. Effective throat thickness of fillet weld is the length of perpendicular from the right angle corner of the hypotenuse.



(2 marks)

4. (i) Dead load
(ii) Live load
(iii) Wind load
(iv) Snow load
(v) Erection load

any 4 × ½
(2 marks)

5. When the entire beam cross section becomes plastic, it resists any further rotation under a constant moment. At this stage, the beam is said to have formed a plastic hinge. (2 marks)

PART - B

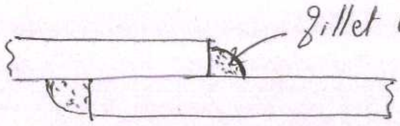
II 1. Advantages of steel structures

(i) High strength per unit weight
(ii) High ductility
(iii) Uniformity
(iv) Environment - friendly
(v) Versatility
(vi) Prefabrication
(vii) Performance
(viii) Additions to existing structures
(ix) Least disturbance to the community
(x) Fracture toughness
(xi) Elasticity

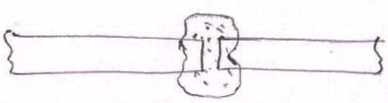
any 6 points
(1 × 6 = 6 marks)

2. Types of welded connections

(i) Fillet weld is a weld of approximately triangular cross section joining two surfaces approximately right angles to each other in a lap joint, tee joint or corner joint

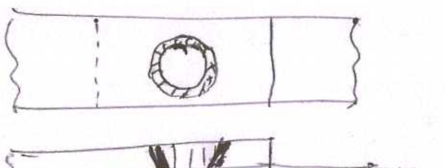


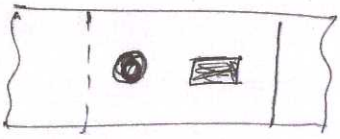
(ii) Butt weld



(iv) Plug weld

(iii) Slot weld





(1½ × 4 = 6 marks)

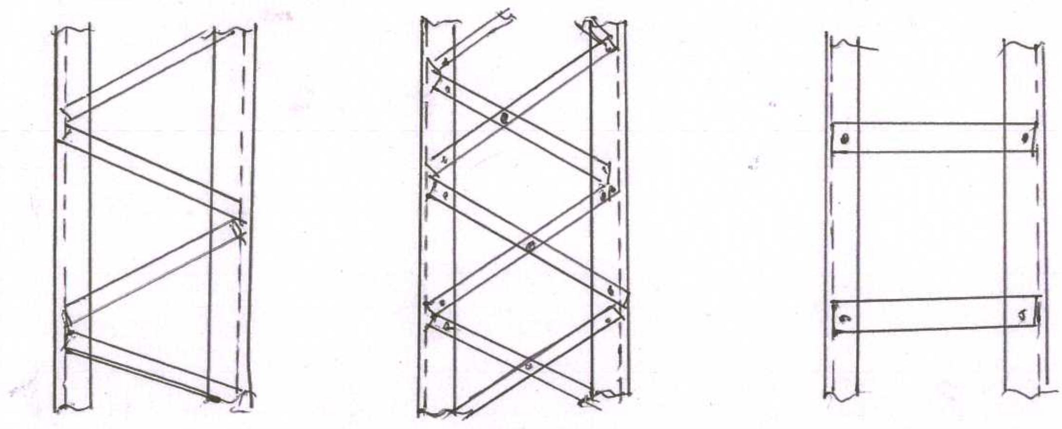
3. <u>Gross area</u> – The total area of cross section of the member without deducting the area of bolt holes.

<u>Net area</u> – The area of cross section of the members after deducting the area of bolt holes.

<u>Net effective area</u> – The equivalent area of an imaginary axially loaded member of equal load carrying capacity.

(2 x 3 = 6 marks)

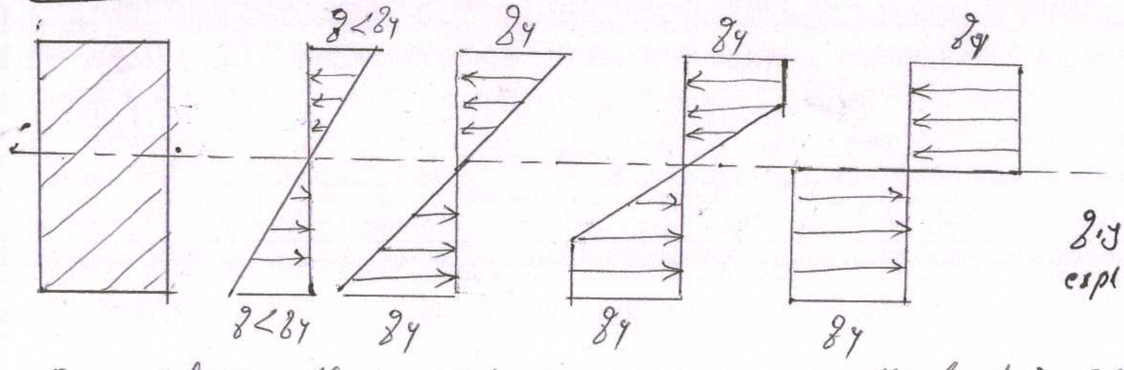
4.



Single laced system — Double laced system — Battened system

(2 x 3 = 6 marks)

5. <u>Plastic moment carrying capacity of a section</u>



f.y – 3
expl. – 3
6 marks

Fig. shows the yielding of fibres as the load is gradually increased. The moment capacity at which all fibres at a section yield (formation of plastic hinge) is called plastic moment carrying capacity

4

6. (i) Laterally supported beam

In steel structures, especially in buildings, beams are restrained laterally by the floor decks, which are placed on top of them. During construction stage, before the floor decks are in place, if the beams are not adequately supported laterally, they may be susceptible to lateral buckling. If adequate lateral restraints are not provided to beams in the plane of their compression flanges, the beams would buckle laterally resulting in a reduction of their maximum moment capacity. Lateral buckling can be prevented, if adequate restraints are provided to the beam in the plane of compression flange; such beams are called laterally restrained/supported beams. This type of beams mainly subjected to bending and shear

(ii) Laterally unsupported beams

A beam in which the compression flange of beam is not laterally supported is known as laterally unsupported unsupported beam. It is mainly subjected to bending, shear, web buckling and web bearing.

(3+3 = 6 marks)

7. Stress reduction factor

The value of stress reduction factor depends on the slenderness ratio and eccentricity of loading divided by the thickness of the member. The values of stress reduction factor for slenderness ratio varying from 6 to 27 and eccentricity of loading divided by the thickness of the member varying from 0 to 1/3 (given in Table (9) of IS : 1905 - 1987)

Area reduction factor

This factor takes into consideration smallness of the sectional area of the element and is applicable when cross sectional area of the element is less than $0.2 m^2$. As per IS ~~2~~1905 - 1987 the area reduction factor is given by, $K_a = 0.7 + 1.5A$, where A is the area of the section in m^2.

PART - C

(3+3 = 6 marks)

III (a) Types of failures in bolted joint

i. Shear failure of bolts

Shear stresses are generated when the plates slip due to applied forces. The maximum factored shear force in the bolt may exceed the nominal shear capacity of the bolt. Shear failure of the bolt takes place at the bolt shear plane (interface). The bolt may fail in single shear or double shear.

2. Bearing failure of bolt

The bolt is crushed around half circumference. The plate may be strong in bearing and the heaviest stressed plate may press the bolt shank. Bearing failure of bolts generally does not occur in practice except when plates are made of high strength steel and the bolts are of very low grade steel.

3. Bearing failure of plates

When an ordinary bolt is subjected to shear forces, the slip takes place and bolt comes in contact with the plates. The plate may get crushed, if the plate material is weaker than the bolt material. The bearing problem can be complicated by the presence of a near by bolt or the proximity of an edge in the direction of load. The bolt spacing and end-distance will influence the bearing strength. A possible failure mode of resulting from excessive bearing is shear tear-out at the end of connected member.

4. Tension failure of bolt

Bolts subjected to tension may fail at the stress area. In case if any of the connecting plates is sufficiently flexible additional prying forces induced in the bolts must also be considered.

5. Tension or Tearing failure of plates

Tearing failure occurs when the bolts are stronger than the plates. Tension on both the gross area (yielding) and net effective area (rupture) must be considered.

6. Block Shear failure

Bolts may have been placed at a lesser end-distance than required causing the plates to shear out which, however, can be checked by observing the specifications for end-distance. The failure of connections in block shear may occur when a block of material within the bolted area breaks away from the remainder area. The possibility of this increases when high strength bolts are used; fewer bolts will be used for making connection.

(7 marks)

III (b) $d = 16mm$, $d_0 = 16+2 = 18mm$, $e = 30mm$, $p = 40mm$

Bolts are in single shear

Shear capacity of bolt in single shear

$$= \frac{f_u}{\sqrt{3}\,\gamma_{mb}}\left[n_n \cdot A_{nb} + n_s \cdot A_{sb}\right]$$

$n_n = 1$ and $n_s = 0$

$$A_{nb} = 0.78 \times \frac{\pi}{4} \times d^2 = 0.78 \times \frac{\pi}{4} \times 16^2 = 156.75\,mm^2$$

$$\text{shear capacity} = \frac{400}{\sqrt{3} \times 1.25}\left[1 \times 156.75\right] = \underline{28.96\ kN}$$

(2 marks)

Bearing strength = $2.5 \cdot k_b \cdot d \cdot t \cdot f_u / \gamma_{mb}$

k_b is the least of (i) $\frac{e}{3d_o} = \frac{30}{3 \times 18} = 0.56$

(ii) $\frac{p}{3d_o} - 0.25 = \frac{40}{3 \times 18} - 0.25 = 0.49$

(iii) $\frac{f_{ub}}{f_u} = \frac{400}{410} = 0.98$ (2 marks)

(iv) 1.0

$\therefore k_b = 0.49$

Bearing strength $= 2.5 \times 0.49 \times 16 \times 12 \times 410 / 1.25 = 77.14\ kN$ (2 marks)

Bolt value = 28.96 kN

Number of bolts required $= \frac{120}{28.96} = 4.14$ (2 marks)

(8 marks)

$\therefore$ Provide 5 bolts

IV (a) Physical Properties

1. Durability and corrosion of steel
2. Fire resistance
3. Hardness of steel
4. Resilience of steel
5. Toughness

Mechanical properties

1. Modulus of Elasticity
2. Shear modulus of Elasticity
3. Bulk modulus of Elasticity
4. Poisson ratio
5. Tensile strength
6. Fatigue strength
7. Impact strength
8. Ductility
9. Malleability

(6 marks)

IV (b) ISA 65 × 65 × 6 mm

Gross area, $A_g = 744\ mm^2$

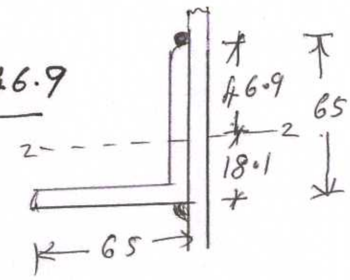
$C_z = 18.1\ mm$

Tensile capacity of the member $= \frac{A_g \cdot f_y}{\gamma_{mo}}$

$= \frac{744 \times 250}{1.1} = \underline{169.091\ kN}$

Force resisted by the weld at the lower side of the angle }, $P_1 = \frac{169.091 \times 46.9}{65}$

$= \underline{122.01\ kN}$



Force resisted by the upper side of the angle }, $P_2 = \frac{169.091 \times 18.1}{65} = \underline{47.09\ kN}$

Assume 4 mm size weld

Effective throat thickness of the weld $= 0.7s = 0.7 \times 4$

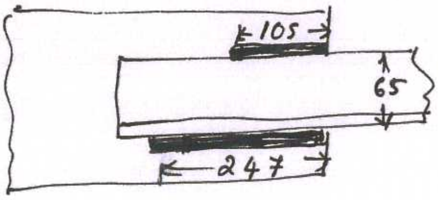
$= 2.8\ mm$

Strength of the weld $= \frac{2.8 \times 410}{\sqrt{3} \times 1.25} = 530.24\ N/mm$

$L_{w_1} = \frac{122.01 \times 10^3}{530} = 230.1\ mm$

Provide $230.1 + (2 \times 4) 2 = 246.1$

Say 247 mm length at bottom



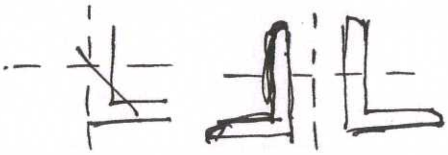
$L_{w_2} = \frac{47.09 \times 10^3}{530} = 88.8\ mm$

$88.8 + (2 \times 4) 2 = 104.8\ mm$

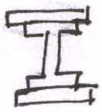
Provide 105 mm length at top

9

V (a) Angle 

Double angle 

I - Section. 

I section with plates 

T Section 

(1×5 = 5 marks)

V (b) Single angle strut

Design strength, $P_d = A_e \cdot f_{cd}$

$\therefore A_e = \frac{P_d}{f_{cd}} = \frac{225 \times 10^3}{90} = 2500\ mm^2$

Design load = 150×1.5 = 225 kN

$f_{cd} = 90\ N/mm^2$ (Angle section)

Select a section of area $= 2500 + \left(\frac{2500 \times 20}{100}\right) = 3000\ mm^2$

Select ISA 110×110×15mm having area $3081\ mm^2$

(Another sections can also be selected)

Angle section → Class C

Assume the strut is connected to the gusset plate using two bolts.

$\therefore$ Effective length, $KL = 0.85 L = 0.85 \times 3000 = 2550\ mm$

$r_{xx} = r_{yy} = 33.1\ mm$ $r_{min} = 33.1$ & class C

$\frac{KL}{r} = \frac{2550}{33.1} = 77.03$ $f_{cd} = 140.75\ N/mm^2$ 6

Load carrying capacity of the section, $P_d = A_e \cdot f_{cd}$

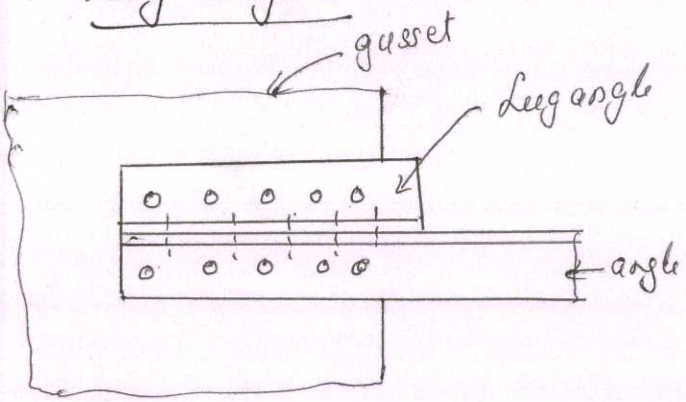
$P_d = 3081 \times 140.75 = 433.56\ kN > 225\ kN$

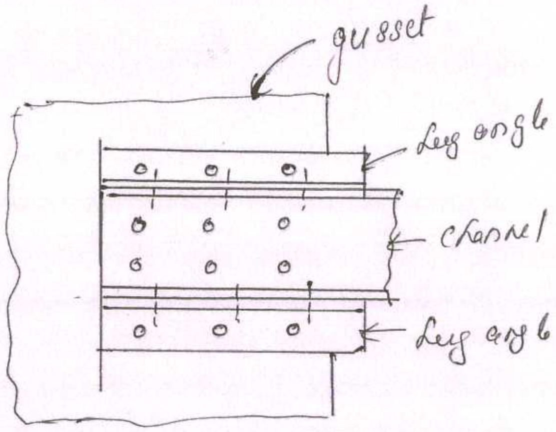
Hence OK (10 marks)

10.

1.

VI (a) Lug angles





A piece of angle used to reduce the length of the bolted end connection of a single angle or a channel type tension member with gusset is known as Lug angle. In the case of channel type tension member, lug angles are provided on either side of the flange. The provision of lug angles make the stress distribution in single angle or channel type tension members uniform and the shear-lag effect is nullified.

fig - 2
Expl - 3
5 marks

VI (b) Design of Double angle Tension member

Factored load $= 1.5 \times 600 = 900\,kN = 900 \times 10^3\,N$

Factored load on each angle $= \frac{900 \times 10^3}{2} = 450 \times 10^3\,N$

Cross sectional area required $= \frac{\text{Factored load}}{\text{stress}} = \frac{450 \times 10^3}{(250/1.1)} = 1980\,mm^2$

Increase 30%

Ag required $= (1980 \times \frac{30}{100}) + 1980 = 2574\,mm^2$

select ISA $150 \times 115 \times 8\,mm$ having $Ag = 2058\,mm^2$

(Another section can also be selected)

Assume that the long leg is connected to the gusset plate having thickness 10mm.

Minimum length of weld = length of connected leg.

11

Provide length of weld = 150mm

Check for strength of selected section

(i) strength due to yielding of gross section

$$T_{dg} = \frac{A_g \cdot f_y}{\gamma_{mo}} = \frac{2058 \times 250}{1.1} = 467.73 \text{ kN}.$$

$T_{dg} > 450$ kN $\therefore$ safe against yielding

(ii) strength against rupture of net section

$$T_{dn} = \frac{0.9 A_{nc} \cdot f_u}{\gamma_{m1}} + \frac{\beta \cdot A_{go} \cdot f_y}{\gamma_{mo}}$$

$w = 115$ mm
$L_c = 150$ mm
$t = 8$ mm
$f_y = 250 \text{ N/mm}^2$
$f_u = 410 \text{ N/mm}^2$
$b_s = w = 115$ mm
$A_{nc} = (150 - \frac{8}{2})8 = 1168 \text{ mm}^2$
$A_{go} = (115 - \frac{8}{2})8 = 888 \text{ mm}^2$

$$\beta = 1.4 - 0.076 \left[\frac{w}{t}\right]\left[\frac{f_y}{f_u}\right]\left[\frac{b_s}{L_c}\right]$$

$$\beta = 1.4 - 0.076 \left[\frac{115}{8}\right]\left[\frac{250}{410}\right]\left[\frac{115}{150}\right] = 0.889$$

$$\frac{f_u \cdot \gamma_{mo}}{f_y \cdot \gamma_{m1}} = \frac{410 \times 1.1}{250 \times 1.25} = 1.44$$

$0.889 < 1.44$
$0.889 > 0.7$

$$T_{dn} = \frac{0.9 \times 1168 \times 410}{1.25} + \frac{0.889 \times 888 \times 250}{1.1} = 524.21 \text{ kN}$$

$T_{dn} > 450$ kN $\therefore$ safe against rupture

Provide ISA 150 × 115 × 8mm for Tension members.

(10 marks)

VII (a) Classification of cross section of beams

(i) Class 1 (Plastic) Cross section :- These sections can develop plastic hinges and have the rotation capacity required for failure of the structure by formation of plastic mechanism. The sections having width to thickness ratio of plate elements shall be less than that specified under Class 1 as shown in Table 2 in IS 800 belong to this class.

(ii) Class 2 (Compact) cross section :- Such sections can develop plastic moment of resistance, but have inadequate plastic hinge rotation capacity for formation of plastic mechanism, due to local buckling. The section having width to thickness ratio of plate elements between those specified for class 2 and class 1 (Table 2 in IS 800) belong to this class of sections.

(iii) Class 3 Cross sections (Semi Compact) :- These are the sections in which the extreme fibre in compression can reach yield stress, but cannot develop the plastic moment of resistance, due to local buckling. The sections having width to thickness ratio in the range b/w class 2 and class 3 belong to this class.

(iv) Class 4 Cross section (Slender) :- The cross sections the elements of which buckle locally even before reaching yield stress belong to this category. They are having width to thickness ratio more than those specified for class 3. (1½ × 4 = 6 marks)

VII (b) Effe. span = 6m

udl = 19 kN/m

Factored load = 19 × 1.5 = 28.5 kN/m

Factored BM = $\frac{wl^2}{8} = \frac{28.5 \times 6^2}{8}$ = 128.25 kNm

$= 128.25 \times 10^6$ Nmm

Factored shear force = $\frac{wl}{2} = \frac{28.5 \times 6}{2}$ = 85.5 kN

$= 85.5 \times 10^3$ N

Zp required = $\frac{M \gamma_{mo}}{f_y} = \frac{128.25 \times 10^6 \times 1.1}{250} = 564300\ mm^3$

30% extra for laterally unsupported.

Zp required = 564300 × 1.3 = 733590 mm^3

From Anex H of IS 800-2007

Choose ISLB 350 @ 495 N/m

C.S. area = 6301 mm^2

Depth of section D = 350 mm

Width of flange = 165 mm

Thickness of flange = 11.4 mm

Thickness of web = 7.4 mm

r_z = 14.45 cm = 144.5 mm

r_y = 31.7 mm

$Z_{ez} = 751.9 \times 10^3\ mm^3$

$Z_{pz} = 851.11 \times 10^3\ mm^3$

Root radius = 16 mm } from steel table
toe radius = 8 mm }

Depth of web = 350 − 2 [11.4 + 16] = 295.2

Section classification $\varepsilon = \sqrt{\frac{250}{250}} = 1$

Outstanding element of compression flange

$$\frac{b}{t_f} = \frac{165/2}{11.4} = 7.236 < 9.4\varepsilon$$

∴ the section is plastic

$$\frac{d}{t_w} = \frac{295.2}{7.4} = 39.89 < 84\varepsilon$$

∴ plastic section

Hence safe

Check for shear

Shear capacity of the section, $V_d = \frac{A_v \cdot f_{yw}}{\sqrt{3}\,\gamma_{mo}}$

$$= \frac{295.2 \times 7.2 \times 250}{\sqrt{3} \times 1.1} = 278.9 \text{ kN}$$

$V_d > 85.5$ kN (factored shear force)

Hence safe

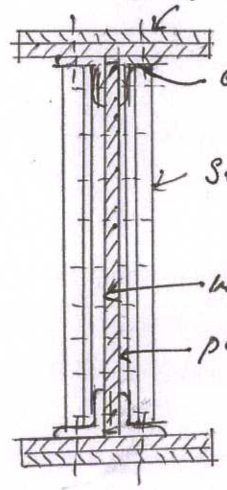
1 9 marks

VIII (a) (i) Flange

The flanges are provided to resist the bending moment.

(ii) Web

The web is designed for maximum shear. It should also satisfy the requirements of local buckling.



C.S. of plate girder

(iii) Stiffeners

The bearing stiffeners are provided to avoid local bending failure of the flange, local crippling or buckling and crushing of web.

fig – 3
expl. – 5
8 marks

VIII (b)

ISMB 400 @ 616 N/m

$I_x = 20458.4 \times 10^4 \, mm^4$

$Z_{ez} = 1022.9 \times 10^3 \, mm^3$

$Z_{pz} = 1176.18 \times 10^3 \, mm^3$

$\varepsilon = \sqrt{\frac{250}{250}} = 1$

$\frac{b}{t_f} = \frac{140/2}{16} = 4.4 < 9.4\varepsilon$

$\frac{d}{t_w} = \frac{(400 - 2 \times 16)}{8.9} = 41.3 < 84\varepsilon$

The section is plastic

$\beta_b = 1.0$

Bending strength

$M_d = \beta_b \cdot Z_{pz} \cdot f_y / \gamma_{mo}$

$= 1.0 \times 1176.18 \times 10^3 \times 250 / 1.1 = \underline{267.3\ kNm}$

This should ~~be~~ not be greater than $1.2\, Z_{ez} \cdot f_y / \gamma_{mo}$

$= 1.2 \times 1022.9 \times 10^3 \times 250 / 1.1 = 279\ kNm$

$\therefore$ Bending strength, $M_d = \underline{267.3\ kNm}$

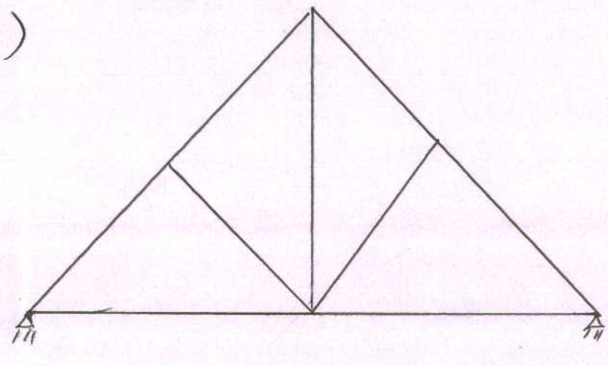
Shear strength

$V_d = \dfrac{A_v \cdot f_y}{\sqrt{3} \cdot \gamma_{mo}} = \dfrac{400 \times 8.9 \times 250}{\sqrt{3} \times 1.1} = 467.683\ kN$

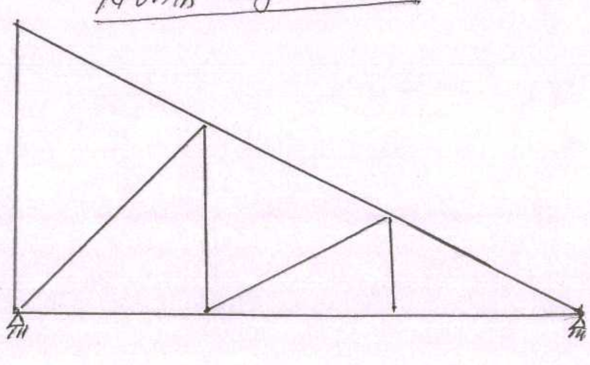
$V_d = \underline{467.683\ kN}$ (7 marks)

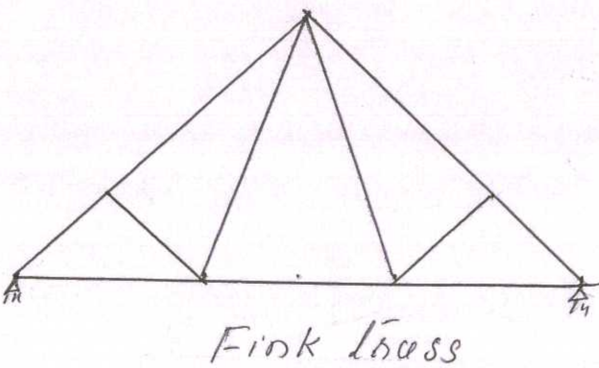
IX (a)

King Post Truss



North light Truss





Fink Truss

(8 marks)

IX (b) Design wind pressure

$V_b = 47$ m/sec

Design wind speed, $V_z = K_1 \cdot K_2 \cdot K_3 \cdot V_b$

$= 1 \times 0.904 \times 1 \times 47$ 1

$= 42.488$ m/sec

Design wind pressure, $P_z = 0.6\, V_z^2$

$= 0.6 \times (42.488)^2$

$= 1083.13\ N/m^2$

(7 marks)

X (a) i) Effective height of wall

The effective height of the wall (h) to be used for calculating the slenderness ratio, is the function of the actual height (H) of the wall and the condition of lateral support. The value of effe. height varies from 0.75H to 1.5H depending on the lateral support condition (Table(4) — IS: 1905 – 1987)

(ii) Effective length of wall

The effective length of wall (l) to be used in the calculation of slenderness ratio depends upon the length of wall from or b/w centre of cross wall, piers or buttresses (L) and the support condition. The effe. length varies from 0.8L to 2.0L depending upon support conditions. [Table (5) of IS: 1905]

(ii) Slenderness ratio of masonry wall

The slenderness ratio of a wall is the ratio of its effective height divided by the effective thickness or effective length divided by the effective thickness whichever is less.

(2 × 3 = 6 marks)

X (b) Design of masonry wall

Thickness of wall = 200 mm , Effe. length = 3.5 m
Effe. height = 2.4 m

Since effective height is less than the effe. length

$\therefore$ slenderness ratio $= \frac{2400}{200} = 12$

Assuming CM 1:5 (M_1 grade) and brick with compressive strength $5\,N/mm^2$

From Table (8) of IS 1905-1987 , $f_b = 0.5\,N/mm^2$

Area of the wall, $A = 3.5 \times 0.2 = 0.7\,m^2 > 0.2\,m^2$

$\therefore K_a = 1$

From T(9) → for slenderness ratio 14 and zero eccentricity

stress reduction factor, $K_a = 0.84$

Assuming height to width ratio of unit as 1.0,

Shape modification factor, $K_p = 1.2$ (T.(10) - 1905)

Permissible compressive stress, $f_c = K_a \cdot K_s \cdot K_p \cdot f_b$

$$f_c = 1.0 \times 0.84 \times 1.2 \times 0.5 = 0.504\,N/mm^2$$

Actual compressive stress, $f = \frac{P}{A} = \frac{80 \times 1000}{1000 \times 200} = 0.4\,N/mm^2$

Actual compressive stress is less than permissible comp. stress
Hence the wall is safe.

$\therefore$ Provide 200 mm thick brick wall with bricks of compressive strength $5\,N/mm^2$ and use M_1 grade mortar.