MADE EASY

Leading Institute for ESE, GATE & PSUs

ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-3

Section A : Design of Concrete and Masonry Structure [All topics]

Section B : Design of Steel Structures [All topics]

Name : ....

Roll No :

Test Centres			Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐	
Pune ☐	Kolkata ☐	Hyderabad ☐	

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	58
Q.2	58
Q.3	50
Q.4	
Section-B	
Q.5	57
Q.6	
Q.7	60
Q.8	
Total Marks Obtained	283

Signature of Evaluator: Sheryab

Cross Checked by ....

good performance Keep it up

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Section A : Design of Concrete and Masonry Structure

Q.1 (a) **(i)** Write the comparison of ultimate load method and elastic theory method.

(ii) A singly reinforced concrete beam of rectangular section is of breadth equal to half of its effective depth. Determine the area of tension steel required to resist a bending moment of 6 tm.
(Take: σ_{cbc} = 50 kg/cm^2, σ_{st} = 1400 kg/cm^2, m = 18).

[6 + 6 = 12 marks]

i) Ans:

Ultimate load method	Elastic theory method
1) In case of ultimate load method, stresses in steel & concrete are utilised upto its ultimate limit	1) In case of elastic theory method, stresses are utilized upto yield limit
2) The size of section required in this method is comparatively less than elastic theory method.	2) The size of section required is comparatively more.
3) The area of steel required is more.	3) The area of steel required is less.
4) As the ultimate stress concept, it is closer to the realistic approach.	4) It is found to be uneconomical, as the stresses are not fully utilized.

Do not write in this margin

ii) Ans:

$B = d/2$ → Given

BM ⇒ 6 tm ⇒ 6000 kg-m ⇒ 6×10^5 kg-cm

~~Location of neutral~~

Assume the section to be limiting section

$BM = B\, n_a \frac{c_a}{2}\left(d - \frac{n_a}{3}\right)$; $n_a = kd$

$k = \frac{mc}{mc+t} \Rightarrow \frac{18 \times 50}{18\times 50 + 1400}$

$\Rightarrow 0.391$

$6\times10^5 = \frac{d}{2} \times 0.391 \times d \times \frac{50}{2}\left(d - \frac{0.391\times d}{3}\right)$

$141160.002 = d^3$

$d = 52.07$ cm ≈ 55 cm

effective depth ⇒ ~~d = 60 cm = 600 mm~~

$d = 55$ cm $= 550$ mm

$B = \frac{d}{2} = \frac{550}{2} = 275$ mm

$n_a = 0.391 \times 550 = 215.05$ mm

Area of steel:

~~$280 \times 215.05 \times \left(\frac{50}{100}\right) \times \frac{1}{2} = (18 \times Ast \times (550 - 215.05))$~~

$B \times n_a \times \frac{n_a}{2} = m\, Ast\,(d - n_a)$

$275 \times 215.05 \times \frac{215.05}{2} = 18 \times Ast \times (550 - 215.05)$

$Ast \Rightarrow 1054.7\ mm^2$

use 16 mm dia bars ⇒ $n = \frac{1054.7}{\frac{\pi}{4} \times 16^2} = 5.25 \approx 6$

12

$B = 275$ mm

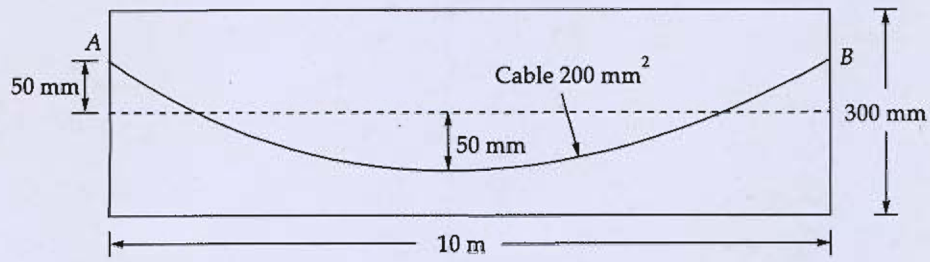
$d = 550$ mm

$D = 550 + \frac{16}{2} + 30 = 588$ mm ≈ 590 mm

Ast ⇒ 6 - 16 mm φ bars.

Do not write in this margin

Q.1 (b) A concrete beam of 10 m span, 100 mm wide and 300 mm deep is prestressed by a cable with cross-sectional area of 200 mm². The cable profile is parabolic with an eccentricity of 50 mm above the centroid of the section at the supports and 50 mm below at mid-span. If the cable is tensioned from one end only, estimate the percentage loss of prestress in the cable due to effect of friction. Assume $\mu = 0.35$ and $k = 0.0015$ per metre.



[12 marks]

prestress loss due to friction, $P_L = P_0(kx + \mu\alpha)$

$k = 0.0015$

$x = L = 10\ m$

$\mu = 0.35$

$\alpha = 2\theta$

$\alpha = 2 \times \frac{4 \times 100}{10 \times 1000}$

$\Rightarrow 0.08$

for parabolic cable

$y \Rightarrow \frac{4hx(l-x)}{l^2}$

$\frac{dy}{dx} \Rightarrow \frac{4h}{l^2}(l-2x)$

~~$\tan\theta = \frac{4 \times 100}{(10 \times 10^3)^2} \times (10 \times 1000 - 2 \times 5000)$~~

$P_L = P_0(0.0015 \times 10 + 0.35 \times 0.08)$

$\Rightarrow 0.043 P_0$

(12)

percentage loss $\Rightarrow \frac{0.043 P_0}{P_0} \times 100\ \%$

$\Rightarrow 4.3\ \%$

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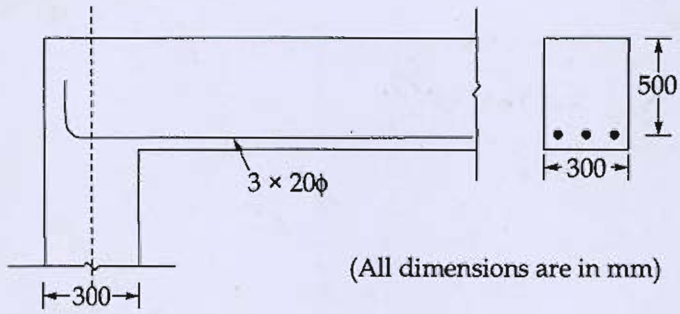
Q.1 (c) Determine the anchorage length of bars at the simply supported end of reinforced concrete beam as shown below, if it is subjected to an ultimate shear force of 300 kN at the centre of support. Assume M20 grade concrete and steel of grade Fe415.
[Take τ_{bd} = 1.92 N/mm^2]



(All dimensions are in mm)

[12 marks]

Location of Neutral axis:

$0.36 f_{ck} B x_u = 0.87 f_y A_{st}$

$0.36 \times 20 \times 300 \times x_u = 0.87 \times 415 \times 3 \times \frac{\pi}{4} \times 20^2$

$x_u = 157.54$ mm

$x_{u,lim} \Rightarrow 0.48 \times d \Rightarrow 0.48 \times 500 = 240$ mm

$x_u < x_{u,lim} \Rightarrow$ under reinforced section

$MOR_u \Rightarrow 0.36 f_{ck} B x_u (d - 0.42 x_u)$

$\Rightarrow 0.36 \times 20 \times 300 \times 157.54 \times (500 - 0.42 \times 157.54)$

$\Rightarrow 147.63 \times 10^6$ N-mm

$\Rightarrow 147.63$ kN-m

development length, $L_d = \frac{\phi \sigma_s}{4 \tau_{bd}} \Rightarrow \frac{20 \times 0.87 \times 415}{4 \times 1.92}$

$\Rightarrow 940.23$ mm

$1.3 \frac{M_{u1}}{V_{u1}} \Rightarrow \frac{1.3 \times 147.63}{300} \Rightarrow 0.6397$ m $\Rightarrow 639.73$ mm

$1.3 \frac{M_{u1}}{V_1} + L_0 \geq L_d$

$639.73 + L_0 \geq 940.23$

$L_0 \geq 300.5$ mm

12

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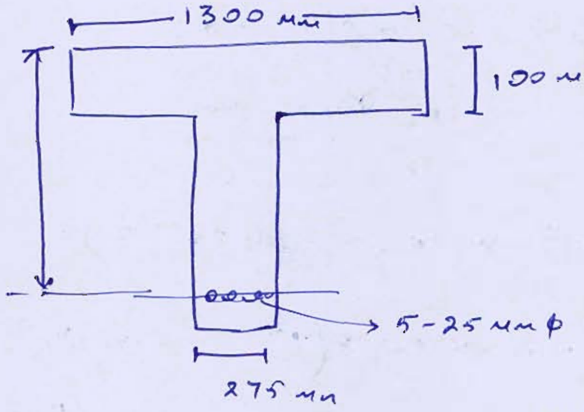
Q.1 (d) A T-beam of effective flange width 1300 mm, flange thickness 100 mm, rib width 275 mm has an effective depth of 550 mm. The beam is reinforced with 5 bars of 25 mm diameter. Find the ultimate moment of resistance by the limit-state method. Use M15 grade of concrete and Fe415 steel.

[12 marks]

Ans:



$f_{ck} = 15$

$f_y = 415$

$A_{st} = 5 \times \frac{\pi}{4} \times 25^2$

$\Rightarrow 2454.37 \text{ mm}^2$

12

i) Assume Neutral axis lies in flange.

$0.36 \times f_{ck} \times B_f \cdot x_u = 0.87 f_y A_{st}$

$0.36 \times 15 \times 1300 \times x_u = 0.87 \times 415 \times 2454.37$

$x_u = 126.23 \text{ mm} > D_f$

$\Rightarrow$ Our assumption is wrong.

ii) Assume: $x_u > D_f$; $D_f > \frac{3}{7} x_u$

$y_f = 0.15 x_u + 0.65 D_f \Rightarrow 0.15 x_u + 0.65 \times 100$

$y_f \Rightarrow 0.15 x_u + 65$

$0.36 f_{ck} b_w x_u + 0.45 f_{ck} (B_f - b_w) y_f = 0.87 f_y A_{st}$

$0.36 \times 15 \times 275 \times x_u + 0.45 \times 15 \times (1300 - 275) \times (0.15 x_u + 65)$

$= 0.87 \times 415 \times 2454.37$

$1485 x_u + 6918.75 (0.15 x_u + 65) = 886150.289$

$x_u = 172.99 \approx 173 \text{ mm}$

$\frac{3}{7} x_u \Rightarrow \frac{3}{7} \times 173 \Rightarrow 74.14 < 100 \text{ mm} \Rightarrow D_f$

$\Rightarrow$ Assumption is correct

Do not write in this margin

$M_u = 0.36 f_{ck} B_w \cdot x_u (d - 0.42 x_u) + 0.45 f_{ck} (B_f - b_w) \times y_f \times \left(d - \frac{y_f}{2}\right)$

$y_f = 0.15 x_u + 65 \Rightarrow 0.15 \times 173 + 65$

$\Rightarrow 90.95$ mm

$M_u = 0.36 \times 15 \times 275 \times 173 \times (550 - 0.42 \times 173) + 0.45 \times 15 \times (1300 - 275) \times 90.95 \times \left(550 - \frac{90.95}{2}\right)$

$\Rightarrow 122631032.7 + 317477559.2$

$\Rightarrow 440.11 \times 10^6$ N-mm

$M_u = 440.11$ kN-m

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Q.1 (e) (i) Describe light weight concrete or foam concrete.

(ii) Briefly explain how underwater concreting is done?

[7 + 5 = 12 marks]

Ans: Light weight concrete:

⇒ In case of light weight concrete, we use fibre reinforced polymers, generally made up of carbon.

⇒ These polymers act as a reinforcement in the concrete.

⇒ By the use of polymers, the weight of concrete is reduced.

⇒ A net is formed which bounds the aggregate & cement solids.

⇒ A mesh of polymers are used in both direction to confine the concrete & provide sufficient strength.

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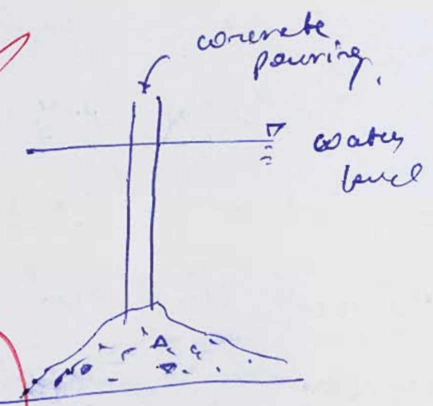
ii) Ans:

Under water concreting can be done with the help of Tremie method.

→ In this method, a hollow pipe is inserted in the water body & rest over the hard bottom strata.

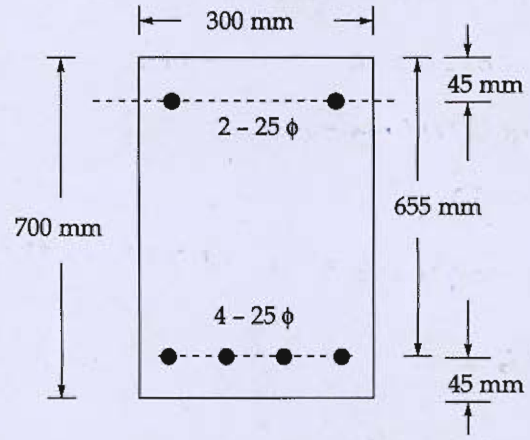
→ Admixtures are used by which, it hardens (concrete) very rapidly after reaching the surface of bed.

→ concrete is applied under sufficient pressure conditions.



6+4

Q.2 (a) Determine the ultimate moment of resistance of the doubly reinforced section as shown in figure below. Assume M20 concrete and Fe415 steel.



Strain, ϵ_{sc}	0.00000	0.00144	0.00163	0.00192	0.00241	0.00276	≥ 0.00380
Stress, f_{sc} (MPa)	0.0	288.7	306.7	324.8	342.8	351.8	360.9

[20 marks]

$A_{sc} \Rightarrow 2 \times \frac{\pi}{4} \times 25^2 = 981.75 \text{ mm}^2$

$A_{st} \Rightarrow 4 \times \frac{\pi}{4} \times 25^2 \Rightarrow 1963.5 \text{ mm}^2$

Location of Neutral axis :-

$0.36 f_{ck} b x_u + (f_{sc} - 0.45 f_{ck}) A_{sc} = 0.87 f_y A_{st}$

$0.36 \times 20 \times 300 x_u + (f_{sc} - 0.45 \times 20) \times 981.75 = 0.87 \times 415 \times 1963.5$

$2160 x_u + (f_{sc} - 9) \times 981.75 = 708921.675$

$2160 x_u + 981.75 f_{sc} = 717757.425 \longrightarrow (1)$

$\frac{0.0035}{x_u} \Rightarrow \frac{\epsilon_{sc}}{x_u - 45}$

Assume $x_u = 150$ mm

$\frac{0.0035}{150} = \frac{\epsilon_{sc}}{150 - 45} \Rightarrow \epsilon_{sc} = 2.45 \times 10^{-3}$

As per table, for $\varepsilon_{sc} = 0.00245$

$$f_{sc} \Rightarrow 342.8 + \frac{(351.8 - 342.8)}{(0.00276 - 0.00241)} \times (0.00245 - 0.00241)$$

$\Rightarrow 343.83 \ N/mm^2$

put f_{sc} in eq ①

$2160\, x_u + 981.75 \times 343.83 = 717757.425$

$x_u \Rightarrow 176\ mm$

Assume $x_u \Rightarrow 160\ mm$

$$\frac{0.0035}{160} = \frac{\varepsilon_{sc}}{160-45}$$

$\varepsilon_{sc} \Rightarrow 0.00252$

$$f_{sc} \Rightarrow 342.8 + \frac{(351.8 - 342.8)}{(0.00276 - 0.00241)} \times (0.00252 - 0.00241)$$

$\Rightarrow 345.63\ N/mm^2$

$2160\, x_u + 981.75 \times 345.63 = 717757.425$

$x_u = 175\ mm$

$\Rightarrow$ use $x_u \Rightarrow \frac{175+160}{2} \Rightarrow 167.5\ mm$

$$M_u \rightarrow 0.36\, f_{ck} \times B\, x_u \times (d - 0.42\, x_u) + (f_{sc} - 0.45 f_{ck}) A_{sc} \times (d - d_c)$$

$$\Rightarrow 0.36 \times 20 \times 300 \times 167.5 \times (655 - 0.42 \times 167.5) + (f_{sc} - 0.45 \times 20) \times 981.75 \times (655 - 45)$$

$$f_{sc} \Rightarrow \frac{0.0035}{167.5} = \frac{\varepsilon_{sc}}{167.5 - 45} \Rightarrow \varepsilon_{sc} = 0.00256$$

$f_{sc} \Rightarrow 346.66\ N/mm^2$

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$M_u \Rightarrow 211526370 + (346.66 - 0.45 \times 20) \times 981.75 \times 610$

$\Rightarrow 211526370 + 215473508.3$

$\Rightarrow 426.99$ kN-m

$M_u \approx 427$ kN-m

20

Q.2 (b) (i) State the assumptions made while analyzing the reinforced concrete beam using Limit State Method as per **IS 456:2000 Code**.

(ii) A short RCC column 400 mm × 400 mm is provided with 8 bars of 16 mm diameter. If the effective length of the column is 2.25 m, find the ultimate load for the column. Use M20 concrete and Fe415 steel.

[10 + 10 = 20 marks]

Ans: Assumption in LSM as IS-456 are!

① Plane section remains plane before and after bending → strain diagram is linear.

② Maximum compressive strain at the outermost extreme fibre is 0.0035.

③ The partial factor of safety in concrete & steel are 1.5 & 1.15.

(4) The strain at the location of steel should not be less than $0.002 + 0.87 \frac{f_y}{E_s}$.

$\epsilon_{sc} \nless 0.002 + 0.87 \frac{f_y}{E_s}$.

(5) The beam is considered to be a cracked section.

(6) The tensile strength of concrete is ignored

ii) Ans:

Size of column = 400 × 400 mm

$A_{st} = 8 \times \frac{\pi}{4} \times 16^2 = 1608.50 \text{ mm}^2$

$f_{ck} = 20 \text{ N/mm}^2$

$f_y = 415 \text{ N/mm}^2$

$e_{min} \Rightarrow \frac{L}{500} + \frac{D}{30} \Rightarrow \frac{2250}{500} + \frac{400}{30} = 17.83 \text{ mm}$ } max

or

20 mm

$e_{min} \Rightarrow 20 \text{ mm} \leq 0.05 B$

$20 \text{ mm} \leq 0.05 \times 400 = 20 \text{ mm}$

use, $P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$

$P_u = 0.4 \times 20 \times [400 \times 400 - 1608.50] + 0.67 \times 415 \times 1608.50$

$\Rightarrow 1267132 + 447243.425$

$\Rightarrow 1714.375$ KN

18

$P_u = 1714.375$ KN

provide lateral ties!

dia $\Rightarrow \frac{\phi}{4} \Rightarrow \frac{16}{4} \Rightarrow 4$ } 6 mm

6 mm $\Rightarrow$ 6 m

spacing of lateral ties!

(a) 400 mm $\Rightarrow$ 400 m
16×16 mm $\Rightarrow$ 256 mm } min $\Rightarrow$ 256 mm
300 mm $\Rightarrow$ 300 m

provide 6 mm ϕ lateral ties @ 250 mm

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Q.2 (c) Design the reinforcement in a column of size 450 mm × 600 mm, subjected to an axial load of 2000 kN under service dead and live loads. The column has an unsupported length of 3.0 m and is braced against side sway in both directions. Use M20 and Fe415.

[20 marks]

Ans:

size ⇒ 450 × 600 mm

$P_{working}$ = 2000 kN

$P_u = 1.5 \times 2000 \Rightarrow 3000$ kN

$L_0 \Rightarrow 3$ m.

$e_{min_{xx}} \Rightarrow \frac{3000}{500} + \frac{450}{30} \Rightarrow 21$ mm $< 0.05 \times 450$
< 22.5 mm

$e_{min_{yy}} \Rightarrow \frac{3000}{500} + \frac{600}{30} \Rightarrow 26$ mm $< 0.05 \times 600$
< 30 mm

$f_{ck} = 20$ N/mm², $f_y = 415$ N/mm²

provide ~~vertical reinforcement~~

$P_u = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$

$\Rightarrow 3000 \times 10^3 = 0.4 \times 20 \times [450 \times 600 - A_{sc}] + 0.67 \times 415 A_{sc}$

$\Rightarrow 3000 \times 10^3 = 2160000 - 8 A_{sc} + 278.05 A_{sc}$

$270.05 A_{sc} \Rightarrow 840 \times 10^3$

$A_{sc} \Rightarrow 3110.54$ mm² ⇒ OK

$A_{st_{min}} \Rightarrow \frac{0.8}{100} \times 450 \times 600 \Rightarrow 2160$ mm²

$A_{st_{max}} \Rightarrow \frac{6}{100} \times 450 \times 600 \Rightarrow 16200$ mm² provide 25 mm ϕ bars,

$$n \Rightarrow \frac{3110.54}{\frac{\pi}{4} \times 25^2} \Rightarrow 6.4 \approx \boxed{8}$$

provide 8-25 mm ϕ bars.

lateral ties:

1) diameter ⇒ max $\begin{cases} \phi/4 \\ 6\text{ mm} \end{cases}$ ⇒ max $\begin{cases} \frac{25}{4} \Rightarrow 6.25 \\ 6 \end{cases}$

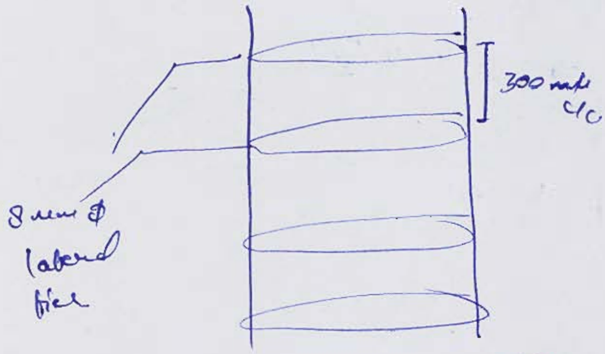
provide ⇒ 8 mm ϕ lateral ties.

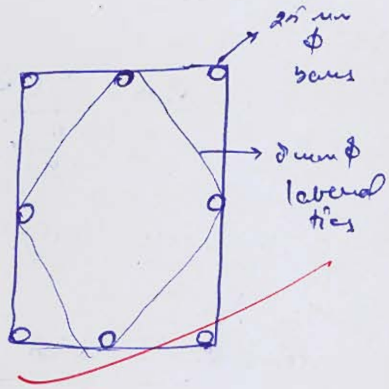
2) spacing:

min $\begin{cases} ① \text{ least lateral dimension} \\ ② \ 16\phi \\ ③ \ 300\text{ mm} \end{cases}$

min ⇒ $\begin{cases} 450\text{ mm} \\ 16 \times 25 = 400\text{ mm} \\ 300 = 300\text{ mm} \end{cases}$ ⇒ 300 mm

provide 8 mm dia lateral ties @ 300 mm c/c spacing.





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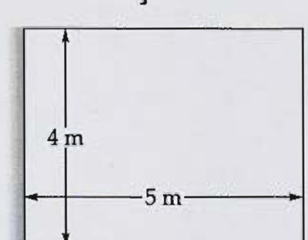
Q.3 (a) Design a two way slab of 4 m × 5 m size. Slab is subjected to a superimposed load of 8 kN/m^2. Self weight should be included as per depth and weight of finishes. Depth should satisfy the deflection criteria as mentioned in **IS 456:2000**. For the given end condition as shown in figure, values of α_x and α_y for positive and negative moments as per **IS 456:2000** are as follows:

	α_x	α_y
+ve moment at mid span	0.047	0.035
–ve moment at ends	0.062	0.047

Calculate the reinforcement required at mid span for positive B.M. in both the directions. Use M20 concrete and Fe415 steel. [Assume modification factor (k_t) for tension reinforcement = 1.6, as per IS 456:2000].



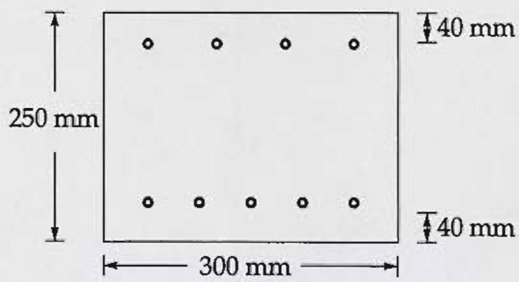
[20 marks]

Q.3 (b) The size of a *RC* column is 400 mm × 600 mm. The column has to support a dervice load of 1500 kN. Find out the effective depth of foundation for this column if safe bearing capacity of the soil is 160 kN/m^2. Use M25 grade concrete and Fe500 steel. The width of the footing in one of the direction can not exceed 2.5 m and the value of design shear strength of concrete corresponding to minimum tensile reinforcement for M25 is 0.29 N/mm^2. Use Limit State Method. For an effective cover of 60 mm, what is the total depth of foundation?

[20 marks]

Q.3 (c) **(i)** Enumerate the situations in which doubly reinforced concrete beams become necessary. What is the role of compression steel?

(ii) A prestressed concrete sleeper produced by pretensioning method has a rectangular cross-section of 300 mm × 250 mm depth. It is prestressed with 9 numbers of straight 7 mm diameter wires at 0.8 times the ultimate strength of 1570 N/mm^2. Cut of 9 wires, four are placed at top at a distance of 40 mm from top and balance five wires are located at bottom at a distance of 40 mm from bottom of beam. Estimate the percentage loss of stress due to elastic shortening of concrete. [Take m = 6].



[8 + 12 =20 marks]

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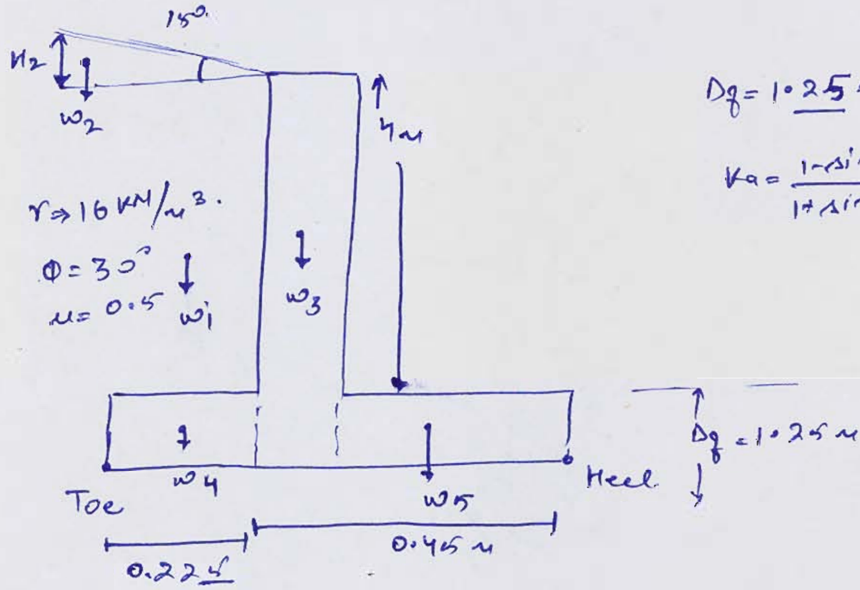
Q.4 (a) Determine suitable dimensions of a cantilever retaining wall, which is required to support a 4.0 m high bank of earth above the ground level on the toe side of the wall. Consider the backfill surface to be inclined at an angle of 15° with the horizontal. Assume good soil for foundation at a depth of 1.25 m below the ground level with a safe bearing capacity of 160 kN/m². Further assume the backfill to comprise granular soil with a unit weight of 16 kN/m³ and an angle of shearing resistance of 30°. Assume the coefficient of friction between soil and concrete to be 0.5.

[20 marks]

Ans:



$D_f = 1.25$ m

$K_a = \frac{1-\sin\phi}{1+\sin\phi} \Rightarrow \frac{1}{3}$

⇒ width of Heel slab ⇒ $K_a\sqrt{\frac{H+1.25}{3}}$

$\Rightarrow \frac{1}{3} \times \sqrt{\frac{4}{3}} \Rightarrow 0.45$ m.

Total width of base slab ⇒ 1.5×0.45

$\Rightarrow 0.675$ m

Assume thickness of base slab ⇒ $\frac{H}{8} = \frac{4000}{8}$

⇒ 500 mm

⇒ thickness of vertical stem ⇒ 500 mm

⇒ for inclined backfill ⇒ $\tan 15° = \frac{H_2}{0.225}$

$H_2 \Rightarrow 0.06$ m

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load	x from toe		moment
$w_1 \Rightarrow 16 \times 0.225 \times 4 = 14.4$	$0.225/2$	$\Rightarrow$	1.62 kN-m
$w_2 = 0.5 \times 0.06 \times 0.225 \times 16 \Rightarrow 0.108$	$0.225/3$	=	0.0081
$w_3 \Rightarrow 0.5 \times (4.5) \times 25 \Rightarrow 56.25$	0.475	=	26.72
$w_4 = 0.225 \times 0.5 \times 25 \Rightarrow 2.8125$	$\frac{0.225}{2}$	=	0.3164
$w_5 \Rightarrow 0.40 \times 0.5 \times 25 = 5$	0.925	=	4.625

$w_T = 78.5705$ kN

12

$FOS = \frac{\Sigma M_R - \Sigma M_O}{\Sigma W} > 1.4 \Rightarrow$ against overturning.

FOS against sliding = $\frac{\mu \Sigma V}{\Sigma H} > 1.4$

$\Rightarrow$

$P_H \Rightarrow \frac{1}{2} \times \frac{1}{3} \times 16 \times (4.5)^2 \times 8 = 54$ kN

$\Rightarrow$

$\Sigma M_O \Rightarrow 54 \times \frac{4.5}{3} \Rightarrow 81$ kN

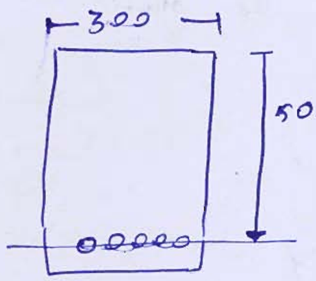
Q.4 (b) A rectangular beam section of 300 mm width and 500 mm effective depth is reinforced with 5 bars of 20 mm φ, out of which 2 bars have been bent at 45°. Determine the shear resistance of the bent up bars and additional shear reinforcement required if it is subjected to ultimate shear force of 300 kN. Also show the reinforcement details. (Use M20 grade of concrete and Fe415 steel)

Design shear strength for M20 grade concrete:

$\frac{100A_{st}}{bd}$	0.50	0.75	1.00	1.25
$\tau_c (N/mm^2)$	0.48	0.56	0.62	0.67

[20 marks]

Ans:



$f_{ck} = 20$
$f_y = 415$

Shear strength of bent up bars ⇒ $0.87 f_y A_{st} \times \sin\alpha$

$\Rightarrow 0.87 \times 415 \times 2 \times \frac{\pi}{4} \times 20^2 \times \sin 45^\circ$

$\Rightarrow 160.41$ kN

Shear force, $V_u \Rightarrow 300$ kN

$\tau_v \Rightarrow \frac{V_u}{B \times d} \Rightarrow \frac{300 \times 1000}{300 \times 500} \Rightarrow 2\ N/mm^2$

$\tau_{cmax} = 0.625\sqrt{f_{ck}} \Rightarrow 0.625 \times \sqrt{20} \Rightarrow 2.8\ N/mm^2$

$\tau_v < \tau_{cmax} \Rightarrow$ OK

$p_t \Rightarrow \frac{100 A_{st}}{Bd} \Rightarrow \frac{100 \times 3 \times \frac{\pi}{4} \times 20^2}{300 \times 500} \Rightarrow 0.63\%$

for $p_t = 0.63\% \Rightarrow \tau_c \rightarrow$ from table.

$p_t \rightarrow 0.50 \Rightarrow \tau_c = 0.48$ MPa

$p_t \rightarrow 0.75 \Rightarrow \tau_c = 0.56$ MPa

$\tau_c \Rightarrow 0.48 + \frac{(0.56-0.48)}{(0.75-0.50)} \times (0.63-0.50)$

$\Rightarrow 0.5216$ M/q

$V_c = \tau_c \cdot B \times d \Rightarrow 0.5216 \times 300 \times 500$

$= 78.24$ KN

$V_{us} \Rightarrow 300 - 78.24 = 221.76$ KN

shear reinforcement is required to be designed

for ! $V_{us} = 221.76$ KN

$\Rightarrow$ As 2 No. of bent up bars provided,

shear strength provided by bent up bars,

$\Rightarrow \frac{V_{sb}}{2}$

$\Rightarrow$ shear reinforcement to be designed for $\Rightarrow \left[\begin{matrix} V_{us} - V_{sb} \\ \frac{V_{sb}}{2} \end{matrix} \right\}$ max

$\Rightarrow \left[\begin{matrix} 221.76 - 160.4 \\ \frac{160.4}{2} \end{matrix} \right.$

$\Rightarrow \begin{matrix} 61.36 \\ 80.2 \end{matrix} \Big\}$ max

$V_s \Rightarrow 80.2$ KN.

provide 2- legged 8 mm ϕ vertical stirrups

$80.2 \times 1000 = 0.87 f_y \frac{A_{sv} \times d}{S_v}$

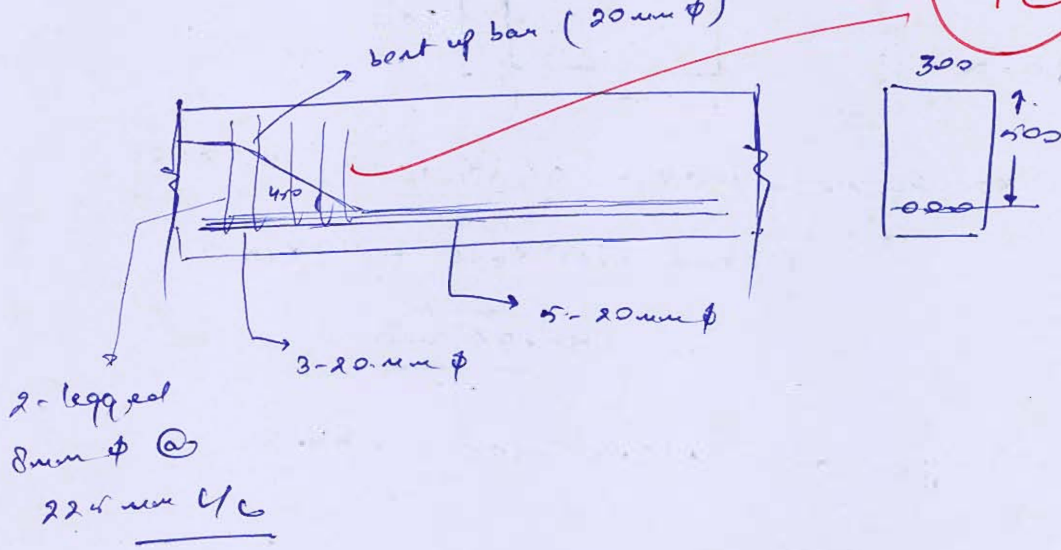
$80.2 \times 1000 = 0.87 \times 415 \times \frac{2 \times \frac{\pi}{4} \times 8^2 \times 500}{S_v}$

$S_v \Rightarrow 226.28$ mm

spacing ≯ 226.28 mm
300 mm } min
d = 500 mm

provide 2-legged 8 mm dia vertical stirrup @ 225 mm c/c spacing.

(1B)



4 (c) A post-tensioned prestressed concrete beam spans 20 m and carries a uniformly distributed live load of 12 kN/m covering the entire span besides its own weight. The cross-section of beam at mid span is as follows:

Top flange : 500 mm × 150 mm

Web : 150 mm × 650 mm

Bottom flange : 300 mm × 200 mm

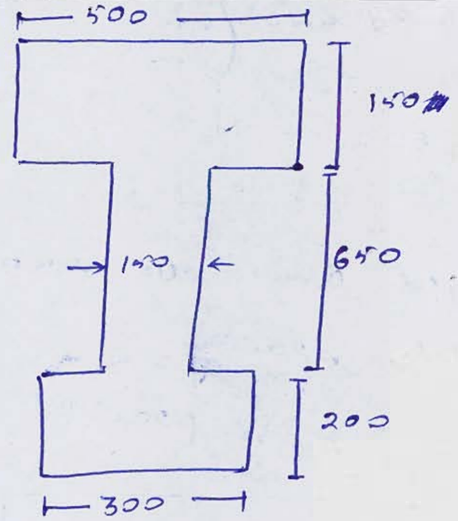
The prestressing force is applied by cables of total area 1385.44 mm^2 stretched initially to 1100 N/mm^2 and located at 100 mm from the bottom edge of the beam. Determine the stresses in the beam at transfer and at final stage of loading at mid span. Assume 15% loss of prestress in final stage. (Take density of concrete as 24 kN/m^3)

[20 marks]

Ans:

$L = 20\,m$.

$w_L = 12\,KN/m$



Area

$\Rightarrow 500\times150 + 150\times650 + 200\times300$

$\Rightarrow 232500\ mm^2$

NA from bottom:

$$\bar{y}_b \Rightarrow \frac{300\times200\times100 + 150\times650\times525 + 500\times150\times925}{300\times200 + 150\times650 + 500\times150}$$

$\Rightarrow 544.35\ mm$

$e \Rightarrow \bar{y}_b - 100 \Rightarrow 544.35 - 100 = 444.35\ mm$

$$I_{NA} \Rightarrow \frac{300\times200^3}{12} + 300\times200\times(544.35-100)^2 + \frac{150\times650^3}{12} + 150\times650\times(544.35-525)^2 + \frac{500\times150^3}{12} + 500\times150\times(925-544.35)^2$$

$\Rightarrow 2.652\times10^{10}\ mm^4$

dead load, $w_D \Rightarrow [0.5\times0.15 + 0.15\times0.65 + 0.3\times0.2]\times24$

$\Rightarrow 5.58\ KN/m$

Prestressing force, $P \Rightarrow 1385.44\times1100 \Rightarrow 1523.984\ KN$

stresses at Transfer;

$f_T \Rightarrow \frac{P}{A} - \frac{Pe\times y_T}{I} + \frac{M_d\times y_T}{I}$

$y_T = 1000 - 544.35$

$\Rightarrow 455.65\ mm$

$M_d \Rightarrow \frac{5.58 \times 20^2}{8} \Rightarrow 279$ kN-m

$f_T = \frac{1523.984 \times 1000}{232500} - \frac{1523.984 \times 10^3 \times 444.35 \times 455.65}{2.652 \times 10^{10}} + \frac{279 \times 10^6 \times 455.65}{2.652 \times 10^{10}}$

$\Rightarrow 6.5547 - 11.635 + 4.794$

$\Rightarrow -0.286$ N/mm²

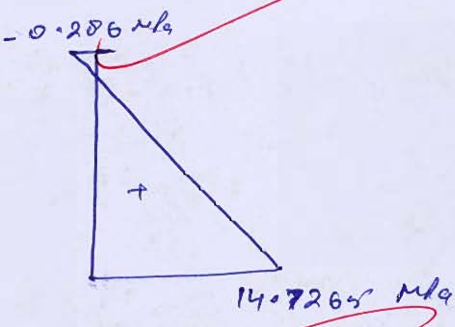
$f_b \Rightarrow \frac{P}{A} + \frac{Pe \times y_b}{I} - \frac{M_d \times y_b}{I}$

$\Rightarrow 6.5547 + \frac{11.635}{455.65} \times 544.35 - \frac{4.794 \times 544.35}{455.65}$

$= 6.5547 + 13.899 - 5.7272$

$\Rightarrow 14.7265$ N/mm²

At transfer:



Stresses at Final stage:

$M_2 \Rightarrow M_d + M_L \Rightarrow (5.58 + 12) \times \frac{20 \times 20}{8} \Rightarrow 879$ kN-m

$K \Rightarrow 1 - 0.15 \Rightarrow 0.85$

$f_T \Rightarrow \frac{KP}{A} - \frac{KP.e \times y_T}{I} + \frac{(M_d + M_L) \times y_T}{I}$

$f_b \Rightarrow \frac{KP}{A} + \frac{KPe.y_T}{I} - \frac{(M_d + M_L) \times y_T}{I}$

$f_T = 0.85 \times 6.5547 - 0.85 \times 11.635 + \frac{879 \times 10^6 \times 455.65}{2.652 \times 10^{10}}$

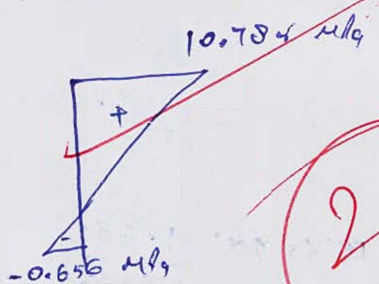
$= 5.5715 - 9.889 + 15.1024 \Rightarrow 10.785 \ N/mm^2$

$f_b \Rightarrow 0.85 \times 6.5547 + 0.85 \times 13.899 - \frac{879 \times 10^6 \times 544.35}{2.652 \times 10^{10}}$

$= 5.5715 + 11.8141 - 18.042$

$\Rightarrow -0.6564 \ N/mm^2$

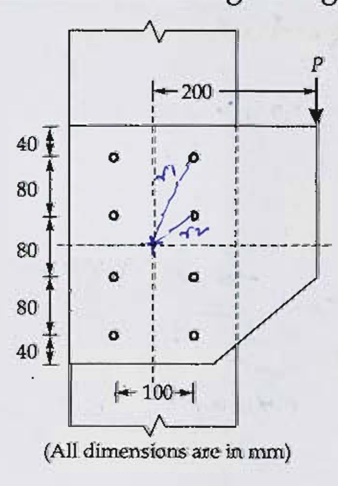
At final stage:



Section B : Design of Steel Structures

Q.5 (a) In the bracket connection as shown in the figure, the bracket plate of 10 mm thickness is connected to column whose flange thickness is 9.1 mm. The bolts used are 20 mm diameter of grade 4.6. Calculate the safe load P that can be carried by the bracket connection. (Use grade of steel Fe410).

[Assume k_b = 0.606 in calculation of bearing strength of bolt]



(All dimensions are in mm)

[12 marks]

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Shear strength of bolt ⇒ $0.78 \times \frac{\pi}{4} \times 20^2 \times \frac{400}{1.25\sqrt{3}}$

⇒ 45.27 KN

Bearing strength of bolt ⇒ $2.5\, K_b \times d \times t_{min} \times \frac{f_{up}}{1.25}$

⇒ $2.5 \times 0.606 \times 20 \times 9.1 \times \frac{410}{1.25}$

⇒ 90.44 KN

Strength of bolt = min (Shear strength, bearing strength)

⇒ min (45.27 , 90.44)

⇒ 45.27 KN

stress developed in bolt :

$f_1 \Rightarrow \frac{P}{8} \Rightarrow 0.125\,P$ KN → due to direct shear.

$f_2 = \frac{T \cdot r_1}{\Sigma r_i^2}$ ⇒ due to torsional shear.

$r_1 \Rightarrow \sqrt{50^2 + 120^2} \Rightarrow 130$ mm

$r_2 \Rightarrow \sqrt{50^2 + 40^2} \Rightarrow 64.03$ mm

$\Sigma r^2 \Rightarrow 4 \times [r_1^2 + r_2^2] \Rightarrow 4 \times [130^2 + 64.03^2]$

⇒ 83999.364

Torque, T = P × 200 = KN-mm

$f_2 \Rightarrow \frac{200 \times P \times 130}{83999.364} \Rightarrow$ ~~0.30954P~~

= 0.3095 P

$f_R \Rightarrow \sqrt{f_1^2 + f_2^2 + 2 f_1 \cdot f_2 \cdot \cos\theta}$

$\Rightarrow$

$\cos\theta \Rightarrow \frac{50}{130}$

$f_R = \sqrt{(0.125P)^2 + (0.3095P)^2 + 2 \times 0.125P \times 0.3095P \times \frac{50}{130}}$

$\Rightarrow 0.3757P$

$f_R \leq$ Bolt strength

$0.3757P = 45.27$

$P = 120.5$ KN

Safe load, $P_{safe} = \frac{120.5}{1.5}$

$\Rightarrow 80.33$ KN

12

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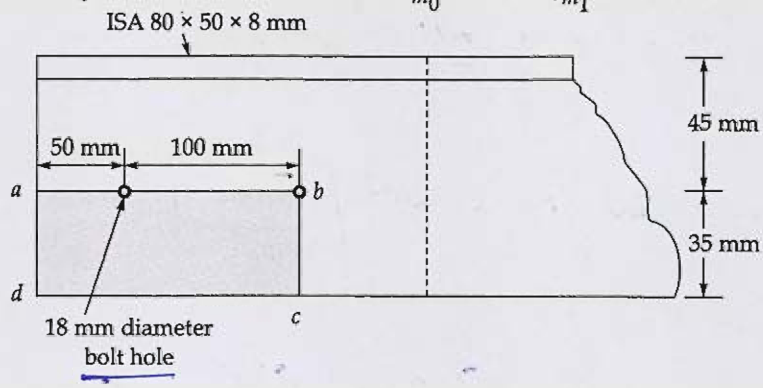
Q.5 (b) Determine the block shear strength of the tension member as shown below. The steel is of grade Fe 410.

Take partial safety factors for materials : $\gamma_{m_0} = 1.1$; $\gamma_{m_1} = 1.25$



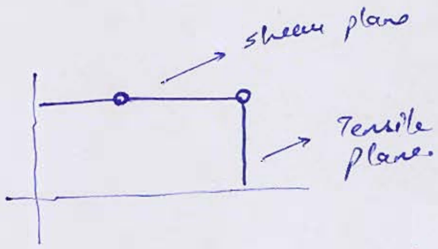
[12 marks]

Ans:

Block shear strength :

$$T_{db_1} \Rightarrow \frac{A_{vg} \times f_y}{1.1\sqrt{3}} + \frac{0.9 \times A_{TN} \times f_u}{1.25} \rightarrow (1)$$

$$T_{db_2} \Rightarrow \frac{0.9 \times A_{VN} \times f_u}{1.25\sqrt{3}} + \frac{A_{Tg} \times f_y}{1.1} \rightarrow (2)$$



$A_{vg} \Rightarrow 150 \times 8$

$\Rightarrow 1200\ mm^2$

$A_{VN} = (150 - 1.5 \times 18) \times 8$

$\Rightarrow 984\ mm^2$

$A_{Tg} \Rightarrow 35 \times 8 = 280\ mm^2$

$A_{TN} \Rightarrow (35 - 0.5 \times 18) \times 8$

$\Rightarrow 208\ mm^2$

First criteria :

$$T_{db_1} \Rightarrow \frac{1200 \times 250}{1.1\sqrt{3}} + \frac{0.9 \times 208 \times 410}{1.25}$$

$\Rightarrow 218.86$ kN

$$T_{db_2} = \frac{0.9 \times 984 \times 410}{1.25\sqrt{3}} + \frac{280 \times 250}{1.1}$$

$$\Rightarrow 231.34 \text{ KN}$$

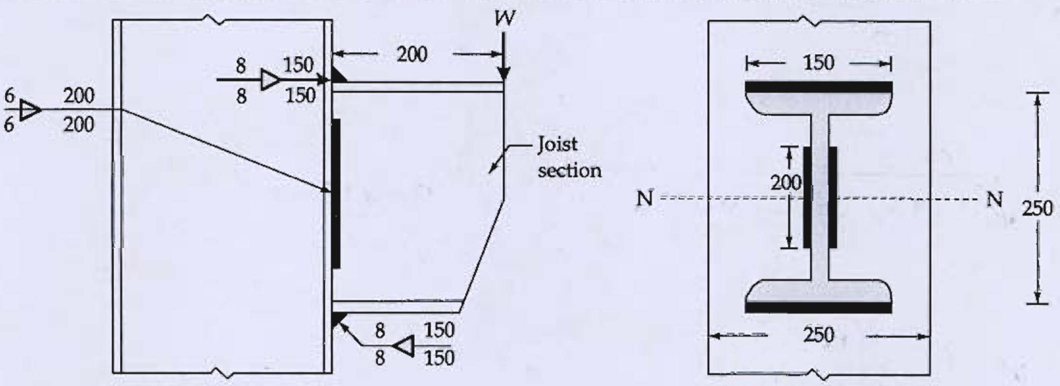
Block shear strength $\Rightarrow \min \begin{bmatrix} T_{db_1} \\ T_{db_2} \end{bmatrix}$

$$\Rightarrow \min \begin{bmatrix} 218.86 \\ 231.34 \end{bmatrix}$$

$$T_{db} \Rightarrow 218.86 \text{ KN}$$

12

Q.5 (c) The bracket connection as shown in below figures (a) and (b) consists of a joist cutting welded to the flange of a column by shop fillet welds 8 mm in size on the flanges and 6 mm on the web. Determine the safe service load *W*, the bracket can support at a distance of 200 mm from the face of the column if structural steel used is of grade Fe410.



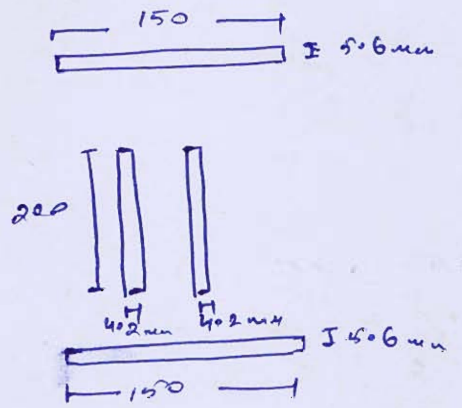
(a) Side view

(b) Front view (weldlines)

$\gamma_{mw} = 1.25$ for shop weld

(All dimensions are in mm)

[12 marks]



$$\Rightarrow f_1 \Rightarrow \frac{W}{150 \times 5.6 \times 2 + 200 \times 4.2 \times 2}$$

$$f_1 \Rightarrow \frac{W}{3360} \ \frac{kN}{mm^2}$$

$f_2 \rightarrow$ due to bending moment.

$$f_2 = \frac{M}{I} \times y \Rightarrow$$

$$I_{xx} \Rightarrow \left[\frac{150 \times 5.6^3}{12} + 150 \times 5.6 \times \left(125 + \frac{5.6}{2}\right)^2 + \frac{4.2 \times 200^3}{12} \right] \times 2$$

$$\Rightarrow 3304.356 \times 10^4 \ mm^4$$

$f_2 \Rightarrow \frac{w \times 1000 \times 200}{3304.356 \times 10^4} \times \frac{250}{2} \Rightarrow 0.7566\,w$ N/mm²

$f_1 = \frac{w \times 1000}{3360} \Rightarrow 0.2976\,w$ N/mm²

$f_R \Rightarrow \sqrt{(0.7566\,w)^2 + 3(0.2976\,w)^2} \Rightarrow 0.913\,w$

$f_R \leq \frac{410}{1.25\sqrt{3}}$

$0.913\,w \leq \frac{410}{1.25\sqrt{3}}$

$w \leq 232.93$ kN 200

10

$w_{safe} \Rightarrow \frac{232.93}{1.5} = 155.28$ kN

200

133.

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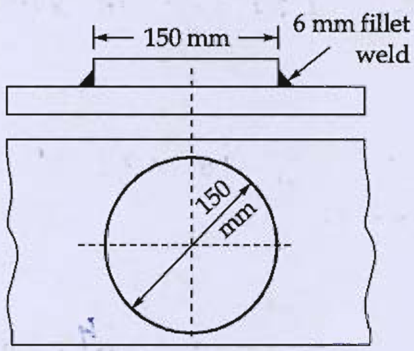
Q.5 (d) (i) What are the various limit states of design for a steel structure as per IS : 800-2007?

(ii) A circular plate, 150 mm in diameter is welded to another plate by means of 6 mm fillet weld as shown in figure. Calculate the ultimate twisting moment that can be resisted by the weld use steel of grade Fe410 and shop welding.



[6 + 6 = 12 marks]

Ans:

The various states of design for steel as per IS 800-2007:

1) Limit state of collapse:

a) Tension

b) Compression

c) Torsion

d) Flexure.

2) Limit state of serviceability:

a) vibration

b) Deflection

c) cracking

d) corrosion

ii) Ans:

$\frac{T}{J} = \frac{\tau}{r}$

$t \Rightarrow 6 \times 0.7 \Rightarrow 4.2\ mm$

$J = 2\pi r^3 t \Rightarrow$

$J = 2\pi \times 75^3 \times 4.2 \Rightarrow 1113.3018 \times 10^4\ mm^4$

$\tau \Rightarrow \frac{84}{1.25\sqrt{3}} \Rightarrow \frac{410}{1.25\sqrt{3}} \Rightarrow 189.37\ N/mm^2$

$\frac{T}{J} = \frac{\tau}{r} \Rightarrow T \Rightarrow \frac{1113.3018 \times 10^4 \times 189.37}{150/2} \times 10^{-6}$

$T = 28.11\ kN-m$

5+6

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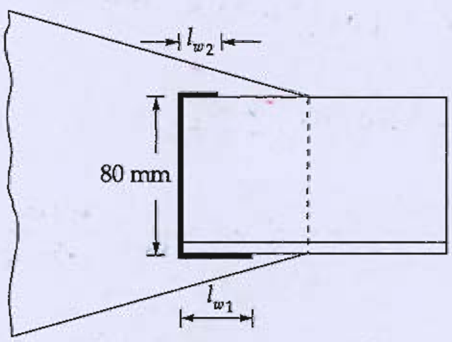
Q.5 (e) Design the fillet weld for the angle secion, if the welding is to be done on its three sides as shown in figure. Take design strength of tie member is 222.27 kN and size of weld is 6 mm. Use grade of steel Fe410.

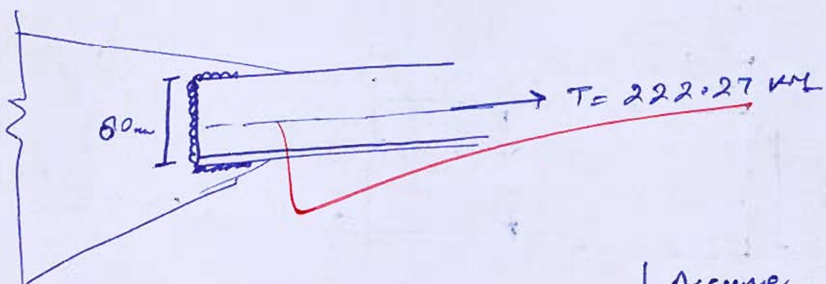


[12 marks]

Sol:

size of weld, $s = 6$ mm

$t_t = Ks = 0.7 \times 6 = 4.2$ mm



Assume shop welded

$\gamma = 1.25$

Total length of fillet weld.

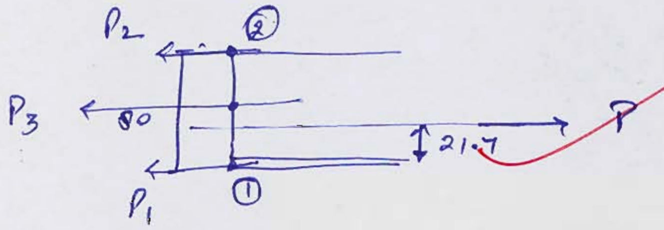
$T \Rightarrow ks \times l_{eff} \times \frac{f_{up}}{1.25\sqrt{3}}$

$222.27 \times 10^3 = 0.7 \times 6 \times l_{eff} \times \frac{410}{1.25\sqrt{3}}$

$l_{eff} \Rightarrow 279.46 \simeq 280$ mm

In question the size of angle is not given,

Assume $\Rightarrow C_{yy} \Rightarrow 21.7$ mm



Take moment about ②

$\Rightarrow P \times (80 - 21.7) = P_3 \times \frac{80}{2} + P_1 \times 80$

$P_3 \Rightarrow 0.7 \times 6 \times 80 \times \frac{410}{1.25\sqrt{3}} = 63.63$ KN.

$\Rightarrow 222.27 \times (80 - 21.7) = 63.63 \times 40 + P_1 \times 80$

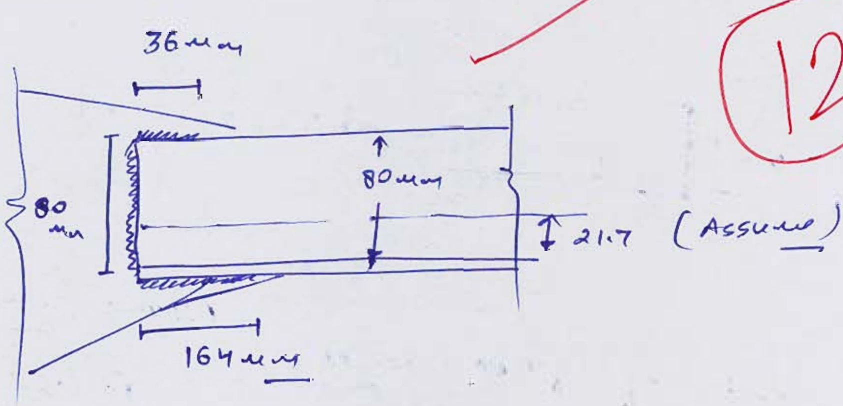
$P_1 = 130.16$ KN

Lw1 =

$130.16 \times 10^3 = 0.7 \times 6 \times l_{eff} \times \frac{410}{1.25\sqrt{3}}$

$l_{eff_1} \Rightarrow 163.65 \simeq 164$ mm

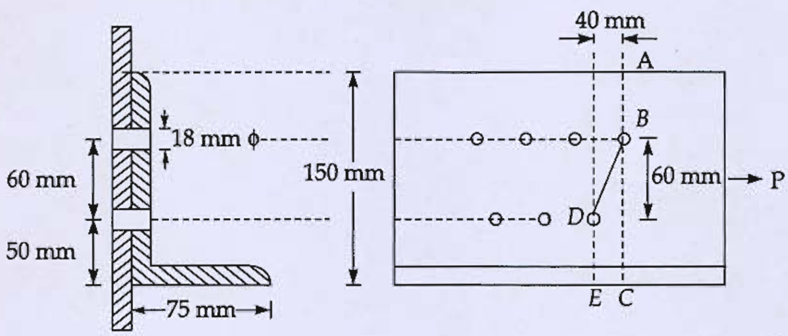
$l_{eff_2} \Rightarrow 280 - 80 - 164 \Rightarrow 36$ mm



12

Q.6 (a) **(i)** Explain the upper bound and lower bound theorems as applied to plastic analysis taking an example of a fixed beam under UDL.

(ii) An ISA 150 × 75 × 12 angle riveted on one side of gusset plate by two rows of 18 mm rivets through the 150 mm leg as shown in the figure. Calculate the allowable load in tension if allowable stress is 150 MPa.



[10 + 10 = 20 marks]

Q.6 (b) A welded plate girder of span 25 m is laterally restrained throughout its length. It has to carry a load of 80 kN/m over the whole span besides its weight. The girder is without intermediate transverse stiffeners. The steel used is of grade E250 (Fe 410). Design the cross-section and the welded connections. Draw a neat sketch of the designed section. (Plate girder is fabricated in the workshop).

Take, $E = 2 \times 10^5$ N/mm², $\mu = 0.3$

Partially safety factor, $\gamma_{mw} = 1.25$

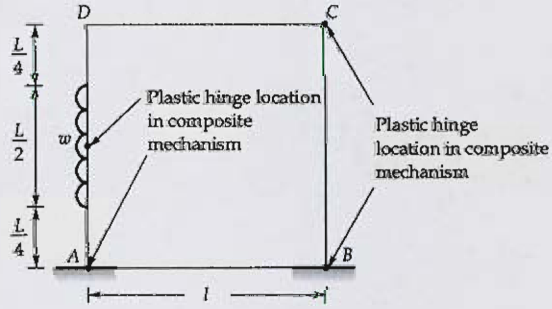
Self weight of the plate girder = $\frac{WL}{400}$

Where, W is superimposed load acting on the girder.

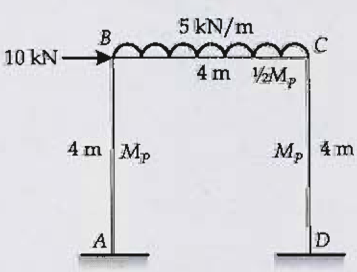
Use limit state method of design.

[20 marks]

Q.6 (c) (i) Given is a rectangular frame of uniform section whose plastic moment capacity is M_p. What is the ultimate load in composite mechanism as shown. Sketch BM distribution at collapse.

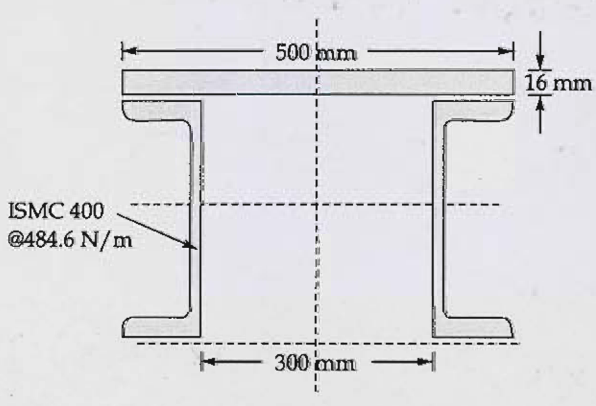


(ii) For the service load system shown, final minimum M_p required to prevent failure, if $(M_p)_{beam} = \frac{1}{2}(M_P)_{column}$. Assume load factor = 2.



[10 + 10 = 20 marks]

Q.7 (a) Determine the allowable compressive load which the built-up member can carry as shown in figure, if the member is of 5.5 m effective length. Assume $f_y = 250\ N/mm^2$.



[For ISMC 400@484.6 N/m, $A = 6293\ mm^2$, $b_f = 100\ mm$, $t_f = 15.3\ mm$, $t_w = 8.6\ mm$, $r_{xx} = 154.8\ mm$, $I_{xx} = 15082.8 \times 10^4\ mm^4$, $I_{yy} = 504.8 \times 10^4\ mm^4$, $C_{yy} = 24.2\ mm$] [Use WSM]

For $f_y = 250\ N/mm^2$	
$\lambda = l / r$	$\sigma_{ac}\ (N/mm^2)$
30	145
40	139
50	132

[20 marks]

Ans :-

$l_{eff} = 5.5\ m$

$$\bar{y}_T \Rightarrow \frac{500 \times 16 \times 8 + 2 \times 6293 \times (16 + 200)}{500 \times 16 + 2 \times 6293}$$

$$\Rightarrow 135.17\ mm$$

$$I_{xx} \Rightarrow \frac{500 \times 16^3}{12} + 500 \times 16 \times (135.17 - 8)^2 + 2 \times \left[1508.2.8 \times 10^4 + 6293 \times (216 - 135.17)^2\right]$$

$$\Rightarrow 129548337.9 + 383886491.3$$

$$\Rightarrow 51343.483 \times 10^4\ mm^4$$

$$I_{yy} \Rightarrow \frac{16 \times 500^3}{12} + 2\left[504.8 \times 10^4 + 6293 \times (150 + 24.2)^2\right]$$

$$\Rightarrow 55869.289 \times 10^4\ mm^4$$

$I_{xx} < I_{yy}$. $\Rightarrow$ $I_{min} = I_{xx}$

$$I_{xx} = A \times r_{xx}^2$$

$$51343.48 \times 10^4 = (500 \times 16 + 2 \times 6293)\ r_{xx}^2$$

$$r_{xx} = 157.927\ mm$$

$$\lambda_{xx} = \frac{KL}{r_{xx}} \Rightarrow \frac{5.5 \times 1000}{157.927} \Rightarrow 34.83$$

from given table :

$\lambda_{xx} = 30 \rightarrow \sigma_{ac} = 145$

$\lambda_{xx} = 40 \rightarrow \sigma_{ac} = 139.$

for $\lambda_{xx} = 34.83$

$\sigma_{ac} \Rightarrow 145 - \frac{(145-139)}{40-30} \times (34.83-30)$

$\Rightarrow 142.102 \ N/mm^2$

$P \Rightarrow \sigma_{ac} \times A$

$\Rightarrow 142.102 \times (500 \times 16 + 2 \times 6293)$

$\Rightarrow 2925.31 \times 10^3 \ N$

Load, $P = 2925.31$ kN $\Rightarrow$ allowable compressive load

20

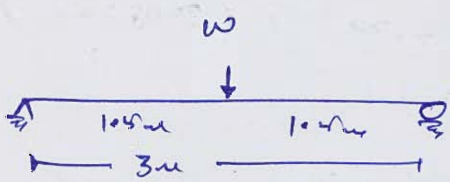
Q.7 (b) A simply supported rectangular beam 3 cm × 4 cm carries a concentrated load *W*, at mid point of span 3 m. Take yield stres, σ_y = 250 MPa.

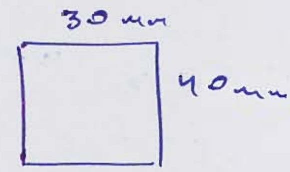
(i) Determine load *W* and draw the shape of the plastic zone when strain at the extreme fiber is 4 $\in_y$ (4 times yield strain)

(ii) Determine the plastic hinge length at mid span of beam.

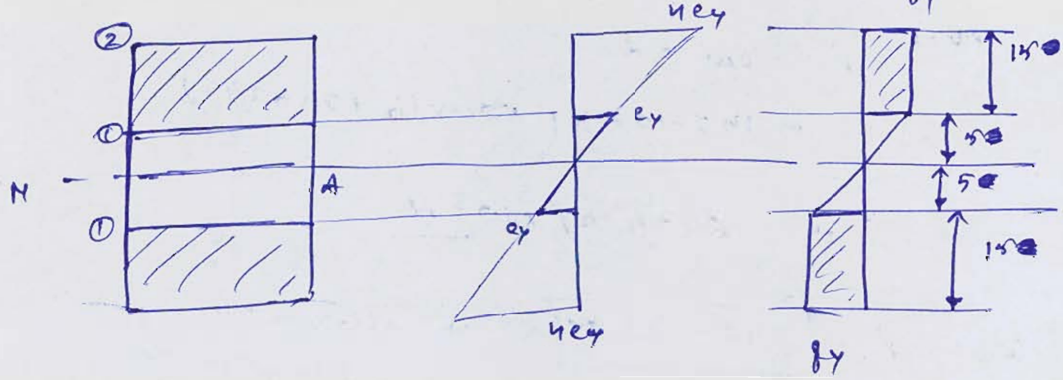
[20 marks]

Ans:





$\sigma_y = 250$ MPa



$\Rightarrow Z_{11} \Rightarrow \frac{bd^2}{6} \Rightarrow \frac{30\times 10^2}{6} = 500 \text{ mm}^3$

$Z_{12} \Rightarrow 2\times\left[30\times 15\times\left(5+\frac{15}{2}\right)\right]$

$\Rightarrow 11250 \text{ mm}^3$

$\text{Moment} \Rightarrow (500+11250)\times 250$

$\Rightarrow 2.9375\times 10^6 \text{ N-mm}$

$\Rightarrow 2.9375 \text{ kN-m}$

$$\text{moment} = \frac{wL}{4}$$

$$2.4375 = w \times \frac{3}{4}$$

$$w = 3.917 \text{ kN/m}$$

iii) length of plastic hinge ⇒ $l_p = l\left(1 - \frac{1}{SF}\right)$

$$\Rightarrow l_p = 3 \times \left(1 - \frac{1}{1.5}\right)$$

$$l_p \Rightarrow 1 \text{ m}$$

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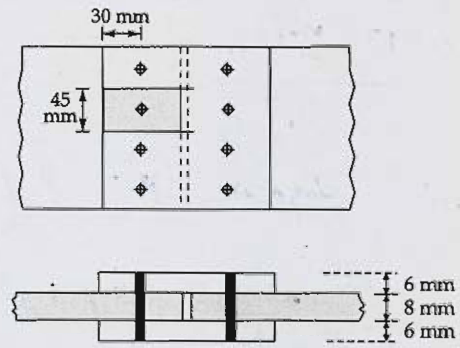
Do not write in this margin

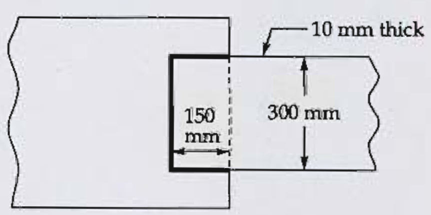
Q.7 (c) **(i)** A double cover butt joint is used to connect two plates which are 8 mm thick. Assume 16 mm diameter bolts of grade 4.6 and cover plates to be 6 mm thick. Arrangement of bolts is as shown in figure. Steel used is of grade Fe410.



Calculate:

1. Strength of joint per pitch length
2. Efficiency of the joint per pitch length

(ii) Determine the block shear strength of the welded tension member as shown in figure. Steel is of grade Fe410.



Given: $T_{db_1} = \dfrac{A_{vg} f_y}{\sqrt{3}\gamma_{m_0}} + \dfrac{0.9 A_{tn} f_y}{\gamma_{m_1}}$ and $T_{db_2} = \dfrac{0.9 A_{vn} f_u}{\sqrt{3}\gamma_{m_1}} + \dfrac{A_{tg} f_y}{\gamma_{m_0}}$

[10 + 10 = 20 marks]

i) Ans:

shear strength of bolt ⇒ $2 \times 0.78 \times \frac{\pi}{4} \times 16^2 \times \frac{400}{1.25\sqrt{3}}$

+ (assume both shear plane passes through shank area)

⇒ 57.95 kN

Bearing strength of bolt ⇒ $2.5\, k_b \times d \times t_{min} \times \frac{f_{up}}{1.25}$

k_b ⇒ $\frac{e}{3d_0}$ → $\frac{30}{3\times18} = 0.56$

$\frac{p}{3d_0} - 0.25$ ⇒ $\frac{45}{3\times18} - 0.25 = 0.583$

f_{ub}/f_{up} ⇒ 400/410

1 ⇒ 1

} min

$k_b = 0.56$

B.S. of bolt = $2.5 \times 0.56 \times 16 \times 8 \times \frac{410}{1.25} \Rightarrow 58.78$ kN

T_{dg} = Gross tensile strength of plate per pitch. $\Rightarrow \frac{45 \times 8 \times 250}{1.1} = 81.82$ kN

T_{dN} = Net rupture strength of plate per pitch. $\Rightarrow \frac{(45-18) \times 410 \times 8 \times 0.9}{1.25}$

$\Rightarrow 63.76$ kN

Strength of joint per pitch length $\Rightarrow$ min $\begin{bmatrix} S.S. \text{ of bolt} \\ B.S. \text{ of bolt} \\ T_{dg} \\ T_{dN} \end{bmatrix}$

$\Rightarrow 57.95$ kN

efficiency of joint = $\frac{57.95}{81.82} \times 100$

$\Rightarrow 70.83\ \%$

Ans:

Block shear strength:

$A_{vg} \Rightarrow 2 \times 150 \times 10 \Rightarrow 3000 \text{ mm}^2$

$A_{vN} = 2 \times 150 \times 10 = 3000 \text{ mm}^2$

$A_{Tg} = 300 \times 10 = 3000 \text{ mm}^2$

$A_{TN} = 300 \times 10 = 3000 \text{ mm}^2$

$T_{db_1} \Rightarrow \frac{A_{vg} \times f_y}{1.1\sqrt{3}} + \frac{0.9 \times A_{TN} \times f_u}{1.25}$

$\Rightarrow \frac{3000 \times 250}{1.1\sqrt{3}} + \frac{0.9 \times 3000 \times 410}{1.25}$

$\Rightarrow 1279.25$ kN

$$T_{db_2} = \frac{0.9 \times A_{vn} \times f_u}{1.25\sqrt{3}} + \frac{A_{vg} \times f_y}{1.1}$$

$$\Rightarrow \frac{0.9 \times 3000 \times 410}{1.25\sqrt{3}} + \frac{3000 \times 250}{1.1}$$

$$\Rightarrow 1193.12 \text{ kN}$$

Block shear strength = min $\begin{pmatrix} 1279.25 \\ 1193.12 \end{pmatrix}$

$$\Rightarrow 1193.12 \text{ kN}$$

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