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Leading Institute for ESE, GATE & PSUs

ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-9

Full Syllabus Test (Paper-I)

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	50
Q.2	
Q.3	99
Q.4	—
Section-B	
Q.5	52
Q.6	—
Q.7	39
Q.8	44
Total Marks Obtained	232/300

Signature of Evaluator ..... Cross Checked by .....

IMPORTANT INSTRUCTIONS

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

DONT'S

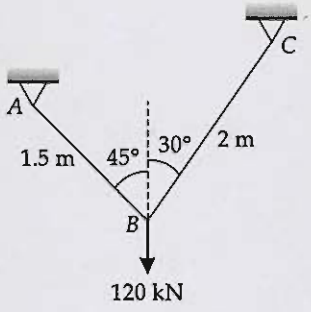
1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify 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.

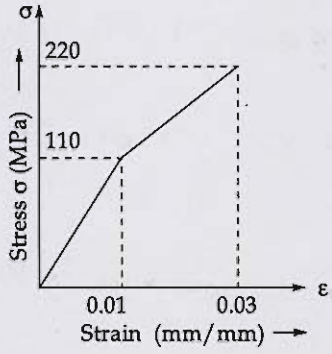
DO'S

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

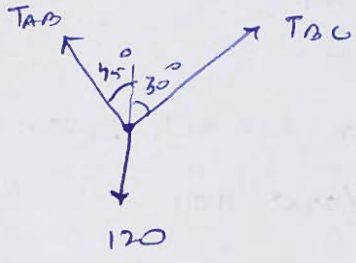
Q.1 (a) Two wires *AB* and *BC* have original length 1.5 m and 2 m and diameter of 20 mm and 35 mm respectively. These wires are made of a material with the stress strain behavior as shown in figure.





Determine the elongation of wires *AB* and *BC* after 120 kN load is applied.

[12 marks]



Apply sine rule. $\frac{120}{\sin 75^\circ} = \frac{T_{BC}}{\sin 135^\circ} = \frac{T_{AB}}{\sin 150}$

$T_{BC} \Rightarrow 87.85$ KN

$T_{AB} = 62.12$ KN

stresses in wire $\sigma_{BC} = \frac{87.85 \times 10^3}{\frac{\pi}{4} \times 35^2} \Rightarrow 91.31$ MPa

$\sigma_{AB} = \frac{62.12 \times 10^3}{\frac{\pi}{4} \times 20^2} \Rightarrow 197.73$ MPa

using the given stress-strain diagram

for BC member

$\sigma_{BC} = 91.31$ MPa

$\epsilon_{BC} = \frac{0.01 \times 91.31}{110} = 8.3 \times 10^{-3}$

$\Delta L_{BC} = 8.3 \times 10^{-3} \times 2000 = 16.6$ mm

elongation

for AB member

$\sigma_{AB} = 197.73$ MPa

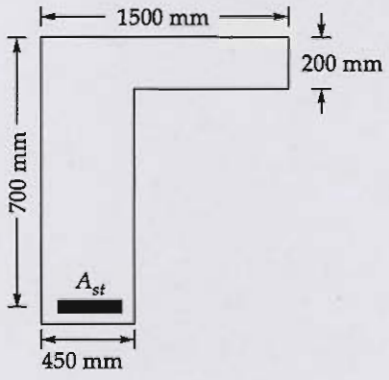
$\epsilon_{AB} = 0.01 + \frac{(0.03 - 0.01)}{(220 - 110)} \times (197.73 - 110)$

$= 0.02594$

$\Delta L_{AB} = 0.02594 \times 1500 = 38.93$ mm

elongation

.1 (b) A simply supported beam is resting over an effective span of 14 m. If effective width of flange is 1500 mm. Calculate area of steel required for balanced a factored bending moment of 1000 kN-m. Use M30 grade of concrete and Fe415 grade of steel. (Use LSM).



[12 marks]

$l_{eff} = 14\ m$, $M_u = 1000\ kN\text{-}m$

$b_f = 1500\ mm$ $f_{ck} = 30\ N/mm^2$, $f_y = 415\ N/mm^2$

Assume NA is in flange.

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

~~$0.36 \times 30 \times 1500 \times x_u = 0.87$~~

$MOR = 0.36 f_{ck} b x_u (d - 0.42 x_u)$

$1000 \times 10^6 = 0.36 \times 30 \times 1500 \times x_u (700 - 0.42 \times x_u)$

$1000 \times 10^6 = 16200\ x_u \times (700 - 0.42 x_u)$

$x_u = 93.42\ mm$

$\Rightarrow$ our assumption is correct

$x_u < D_f$ (OK)

C=T

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

$0.36 \times 30 \times 1500 \times 93.42 = 0.87 \times 415 \times A_{st}$

$A_{st} = 4191.67\ mm^2$

Area of steel required $\Rightarrow$ 4191.67 mm^2

.1 (c) What are ceramic materials? List some of their properties.

[12 marks]

Ceramic materials are hard & brittle materials used in construction industries.

⇒ These material are heterogenous in nature.

properties:

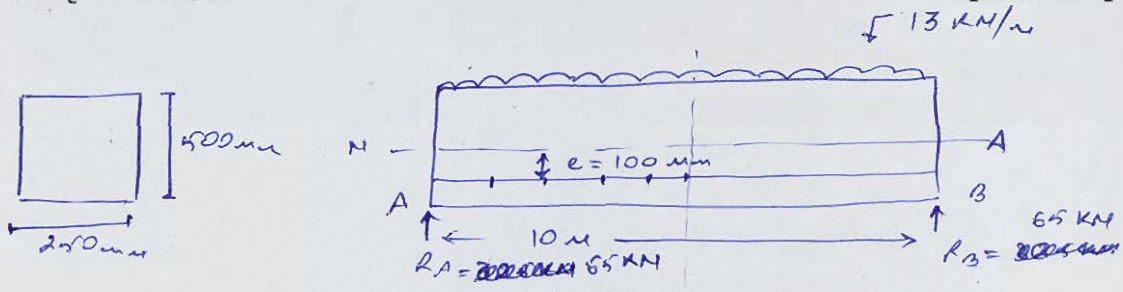
(1) Hard material
(2) brittle in nature
(3) high temperature susceptible
(4) low thermal conductivity.
(5) low toughness.
(6) weight to volume ratio is high
(7) insulating material.
(8) heterogenous in nature.

6

Q.1 (d) A prestressed concrete beam with a rectangular cross-section of 250 mm width and 500 mm depth spans 10 m. It carries a live load of 10 kN/m in addition to its self-weight. The beam is prestressed using a straight cable with a cross-sectional area 1800 mm^2, stressed to 750 N/mm^2. The cable is positioned 150 mm above the soffit (bottom surface) of the beam. Determine the shift of the pressure line from the centroidal axis at various distance from the support, providing values specifically at 0 m, 1 m, 2 m, 3 m, 4 m and 5 m from the support.

Assume $\gamma_c = 24$ kN/m^3. **[12 marks]**

Ans:



$w_D = 0.25 \times 0.5 \times 24 = 3$ KN/m

$w_L = 10$ KN/m

$\Rightarrow w_T = 13$ KN/m

Prestressing force, $P = 750 \times 1800 \times 10^{-3} = 1350$ KN

Moment value at intervals from left support,

$M @ 1m \Rightarrow R_A \times 1 - w \times 1 \times \frac{1}{2} \Rightarrow 65 \times 1 - 13 \times 1 \times \frac{1}{2}$

$\Rightarrow$ [illegible]

$= 58.5$ KN-m

Moment @ 2-m ⇒ $65 \times 2 - 13 \times 2 \times \frac{2}{2}$ = 104 KN-m

⇒ ~~624 KN-m~~

Moment @ 3-m ⇒ $65 \times 3 - 13 \times 3 \times \frac{3}{2}$ ⇒ 136.5 KN-m

= ~~936.5 KN-m~~

Moment @ 4-m ⇒ $65 \times 4 - 13 \times 4 \times \frac{4}{2}$ = 156 KN-m

⇒ ~~1248 KN-m~~

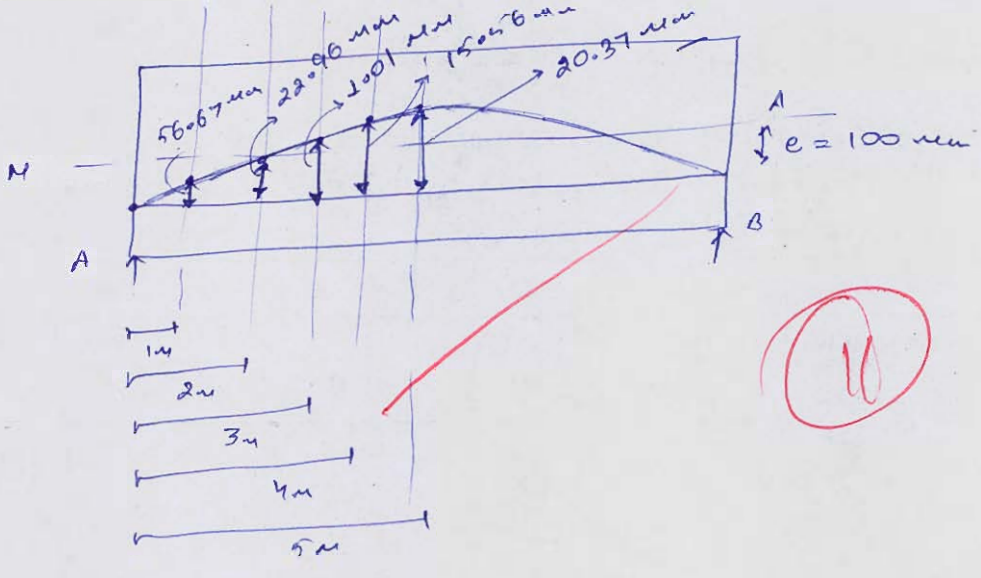
Moment @ 5-m ⇒ $65 \times 5 - 13 \times 5 \times \frac{5}{2}$ = 162.5 KN-m

⇒ ~~1462.5 KN-m~~

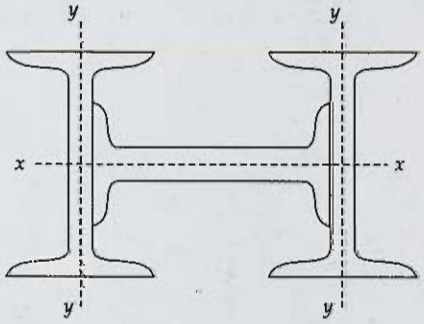
$\bar{x} = \frac{M}{P}$

$\bar{x}$ values at intervals.

at 1 m	M_1/P	$= \frac{58.5}{1350} \times 1000$ = ~~2340.93 mm~~	43.33 mm
at 2 m	M_2/P	$= \frac{104}{1350} \times 1000$ = ~~4622.22 mm~~	77.04 mm
at 3 m	M_3/P	$= \frac{136.5}{1350} \times 1000$ =	101.11 mm
at 4 m	M_4/P	$= \frac{156}{1350} \times 1000$ =	115.56 mm
at 5 m	M_5/P	$= \frac{162.5}{1350} \times 1000$ =	120.37 mm



Q.1 (e) A built-up column consists of three ISWB 450 @ 0.794 kN/m connected effectively as shown in figure to act as one column. Determine the safe load carrying capacity of built-up section if the effective length of column is 4.25 m.



Properties of ISWB 450 @ 0.794 kg/m are as follows:

Area = 101.15 cm^2; I_{xx} = 35057.6 cm^4; I_{yy} = 1706.7 cm^4; t_w = thickness of web = 9.2 mm; f_y = 250 MPa

Slenderness Ratio	10	20	30	40	50	60	70
Permissible stress in axial compression in MPa, (f_y = 250 MPa)	227	223	204	185	167	150	133

[12 marks]

I_{xx} of the section $\Rightarrow 2 \times 35057.6 + 1706.7$

$\Rightarrow 71821.9 \text{ cm}^4$

I_{yy} of section $\Rightarrow 35057.6 + 2 \times \left[1706.7 + 101.15 \times 229.6^2 \right]$

$\Rightarrow 107029450.17 \text{ cm}^4$

$I_{xx} < I_{yy}$

$I_{min} = I_{xx}$

$l_{eff} = 4.25 \text{ m}$

$\lambda = \frac{KL}{r}$

$\Rightarrow 71821.9 = A \times r_{xx}^2$

$71821.9 = 3 \times 101.15 \times r_{xx}^2$

$r_{xx} = 15.384 \text{ cm}$

$\lambda = \frac{4.25 \times 100}{15.384} \Rightarrow 27.63$

From table, for $\lambda = 27.63$, f_{cd}.

$f_{cd} \Rightarrow 223 - \frac{(223-204)}{(30-20)} \times (27.63 - 20)$

$\Rightarrow 208.503 \text{ MPa}$

$P_u \Rightarrow f_{cd} \times A_g = 208.503 \times 3 \times 101.15 \times 100 \times 10^{-3}$

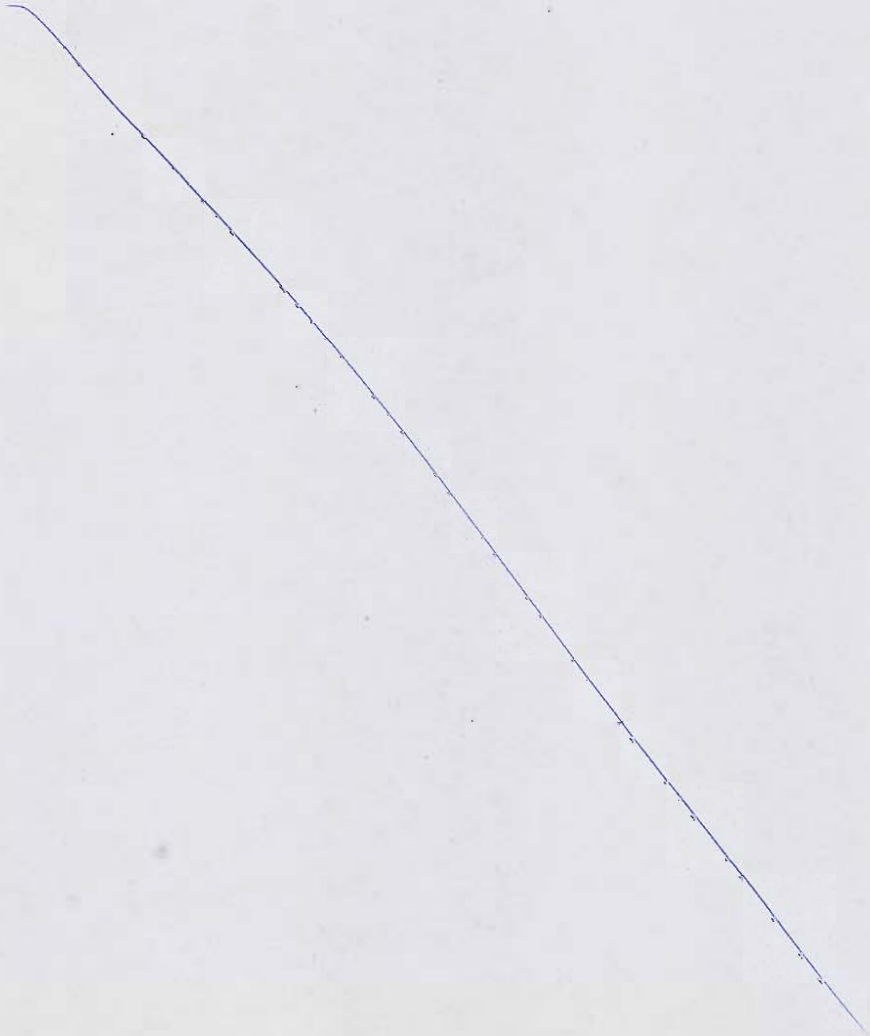
$= 6327.024 \text{ KN}$

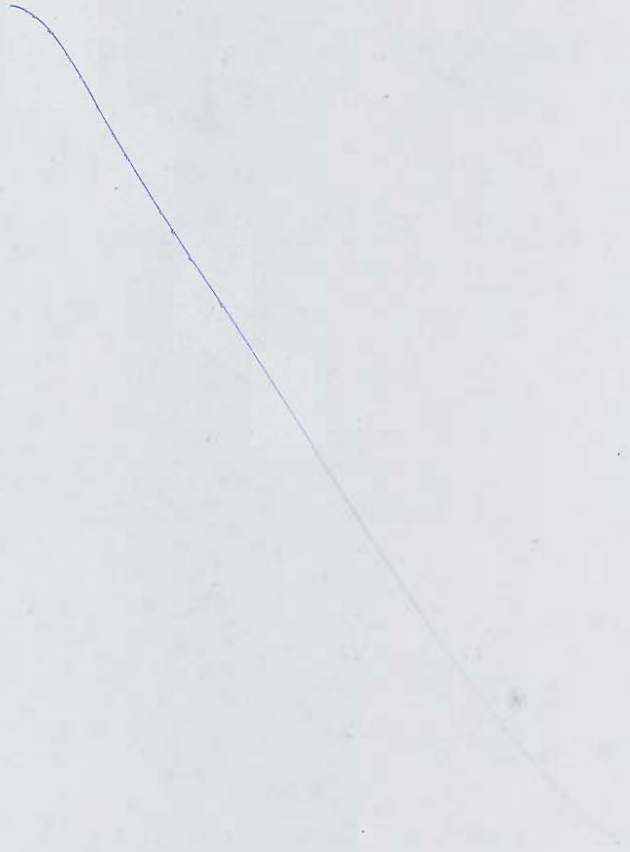
$P_{safe} = \frac{P_u}{1.5} \Rightarrow \frac{6327.024}{1.5} = 4218.02 \text{ KN}$

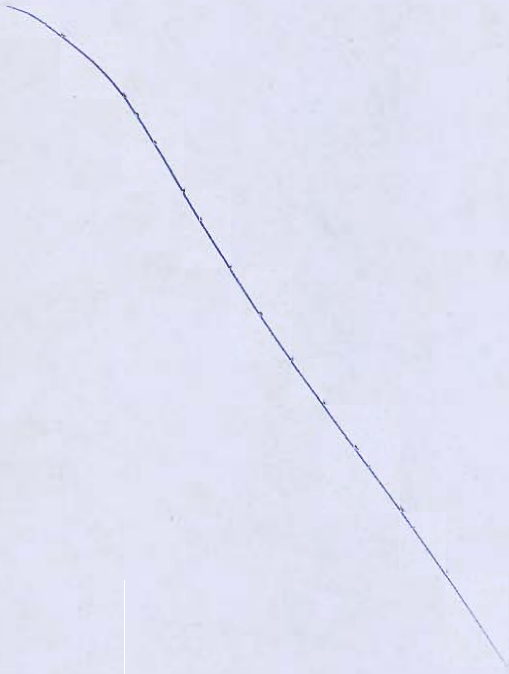
Q.2 (a) (i) A bar of square section is used as a beam so that the plane of bending is parallel to the diagonal. The side of square is 2 cm. The shearing force at a section is 16,000 N. Determine the formula for shear stress at a distance '*h*' from the top. Calculate the value of shear stress at neutral axis and magnitude and position of maximum shear stress.

(ii) A vertical steel bar 15 mm diameter, 1.4 m long is provided with a collar at lower end. Find the maximum weight W that can be dropped through a height of 95 mm over the collar, if maximum permissible tensile stress is 150 MPa. Use E = 200 GPa.

[14 + 6 = 20 marks]







.2 (b) (i) Explain the general principle of pre-stressing in concrete members using a rectangular beam as an example.

(ii) Design a circular column with a diameter of 400 mm, reinforced with helical reinforcement, to safely carry a working load of 1200 kN. Use M20 grade concrete and Fe415 grade steel. The column has an unsupported length of 3 m and is effectively held in position at both ends but is not restrained against rotation.

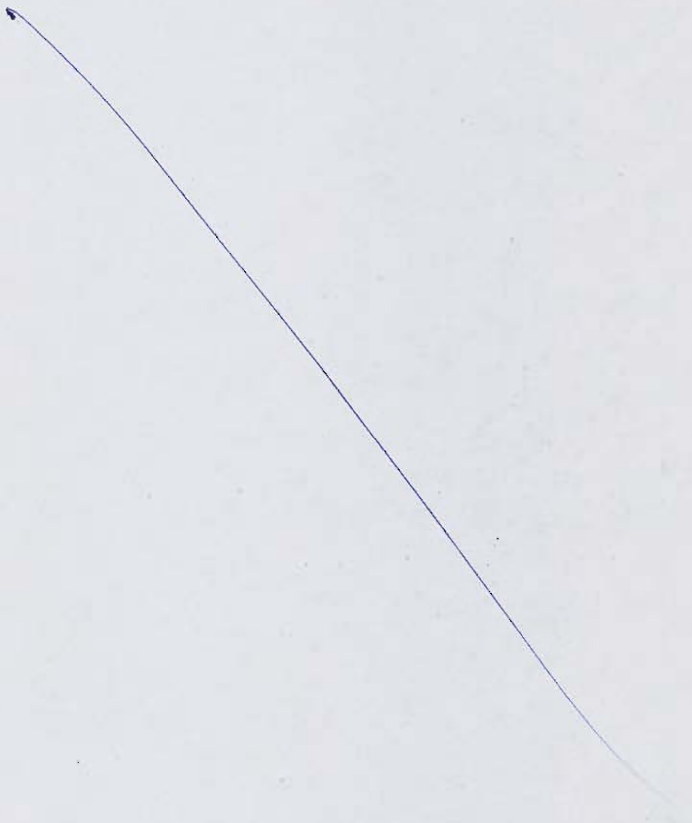
Provide the necessary design calculations, including gross area, check for short column criteria, minimum eccentricity, and reinforcement detailing as per the limit state method.

[6 + 14 = 20 marks]

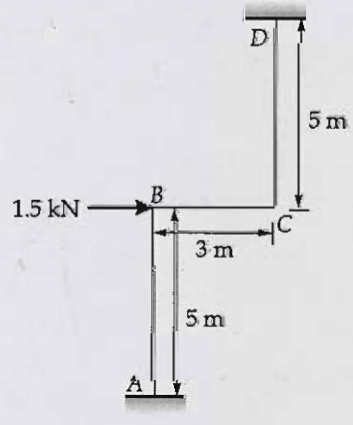
.2 (c) (i) Show the operations involved in the manufacturing of clay bricks using a flow chart. Describe the various steps involved in the preparation of brick earth.

(ii) What are the factors that affect the selection of construction equipment? Describe briefly each of them.

[10 + 10 = 20 marks]

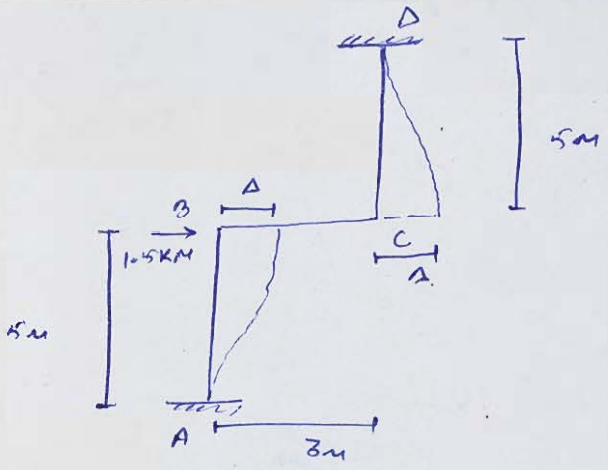


.3 (a) Analyse the portal frame as shown in figure by slope deflection method. Assume all members possess identical flexural rigidity *EI*.



[20 marks]

Ans 3



All fixed moments are zero

↓

No external load

$$M_{AB} = M^{\circ}_{FAB} + \frac{2EI}{5}\left(2\theta^{\circ}_{A} + \theta_B - \frac{3\Delta}{L}\right)$$

$$M_{AB} = \frac{2EI}{5}\left(\theta_B - \frac{3\Delta}{5}\right)$$

$$M_{BA} \Rightarrow \frac{2EI}{5}\left(2\theta_B + \theta^{\circ}_{A} - \frac{3\Delta}{5}\right) \Rightarrow \frac{2EI}{5}\left(2\theta_B - \frac{3\Delta}{5}\right)$$

$$M_{BC} \Rightarrow \frac{2EI}{3}\left(2\theta_B + \theta_C\right)$$

$$M_{CB} = \frac{2EI}{3}\left(2\theta_C + \theta_B\right)$$

$$M_{CD} = M^{\circ}_{FCD} + \frac{2EI}{5}\left(2\theta_C + \theta^{\circ}_{D} + \frac{3\Delta}{5}\right)$$

$$M_{CD} = \frac{2EI}{5}\left(2\theta_C + \frac{3\Delta}{5}\right)$$

$$M_{DC} \Rightarrow \frac{2EI}{5}\left(2\theta^{\circ}_{D} + \theta_C + \frac{3\Delta}{5}\right) \Rightarrow \frac{2EI}{5}\left(\theta_C + \frac{3\Delta}{5}\right)$$

Joint equilibrium eq,

$M_{BA} + M_{BC} = 0$ | $M_{CB} + M_{CD} = 0$

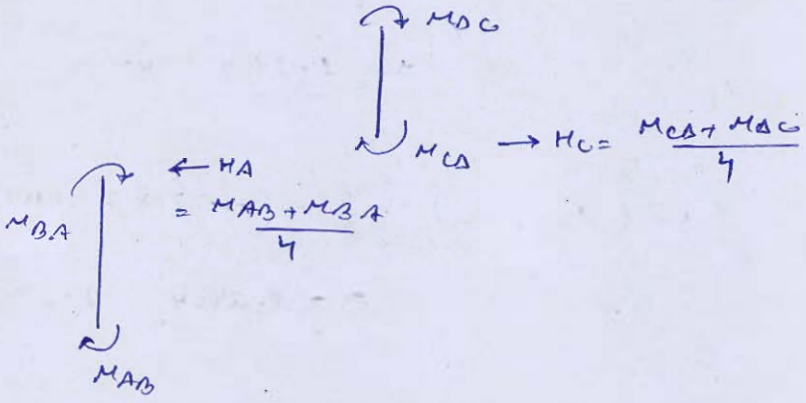
$$\frac{2EI}{5}\left(2\theta_B - \frac{3\Delta}{5}\right) + \frac{2EI}{3}\left(2\theta_B + \theta_C\right) = 0$$

$$\frac{32EI}{15}\theta_B + \frac{2EI\theta_C}{3} - \frac{6EI\Delta}{25} = 0 \longrightarrow (1)$$

$M_{BA} + M_{CD} = 0$

$$\frac{2EI}{3}(2\theta_C + \theta_B) + \frac{2EI}{5}\left(2\theta_C + \frac{3\Delta}{5}\right) = 0$$

$$\frac{2EI\theta_B}{3} + \frac{32}{15}EI\theta_C + \frac{6EI\Delta}{25} = 0 \longrightarrow (2)$$



$\Sigma H = 0 \Rightarrow -H_A + 10.5 + H_C = 0$

$$H_A - H_C = 10.5$$

$$(M_{AB}+M_{BA}) - (M_{CD}+M_{DC}) = 60$$

$$\Rightarrow \left[\frac{2EI}{5}\left(\theta_B - \frac{3\Delta}{5}\right) + \frac{2EI}{5}\left(2\theta_B - \frac{3\Delta}{5}\right)\right] - \left[\left(\frac{2EI}{5}\left(2\theta_C + \frac{3\Delta}{5}\right)\right) + \frac{2EI}{5}\left(\theta_C + \frac{3\Delta}{5}\right)\right] = 6$$

$$\frac{6EI\theta_B}{5} + \frac{6}{5}EI\theta_C - \frac{12}{25}EI\Delta - \left(\frac{6}{25} + \frac{6}{25}\right)EI\Delta = 6$$

$$\frac{6}{5}EI\theta_B - \frac{6}{5}EI\theta_C - \frac{24}{25}EI\Delta = 6 \longrightarrow (3)$$

On solving eq. (1), (2) & (3)

Check

$EI\theta_B = -1.731$

$EI\theta_C = 1.731$

$EI\Delta = -10.577$

Ok

$$M_{AB} = \frac{2}{5}\left(EI\theta_B - \frac{3EI\Delta}{5}\right) \Rightarrow \frac{2}{5}\left(-1.0731 - \frac{3}{5}\times(-10.577)\right)$$

$$M_{AB} \Rightarrow 1.846 \quad \text{KN-m}$$

$$M_{BA} = \frac{2}{5}\left(2EI\theta_B - \frac{3EI\Delta}{5}\right) = \frac{2}{5}\left(-1.0731\times 2 - \frac{3}{5}\times(-10.577)\right)$$

$$\Rightarrow 1.154 \quad \text{KN-m}$$

$$M_{BC} = \frac{2}{3}EI\left(2\theta_B + \theta_C\right) \Rightarrow \frac{2}{3}\times\left(-1.0731\times 2 + 1.731\right)$$

$$\Rightarrow -1.154 \quad \text{KN-m}$$

$$M_{CB} = \frac{2EI}{3}\left(2\theta_C + \theta_B\right) = \frac{2}{3}\left(2\times 1.731 - 1.731\right)$$

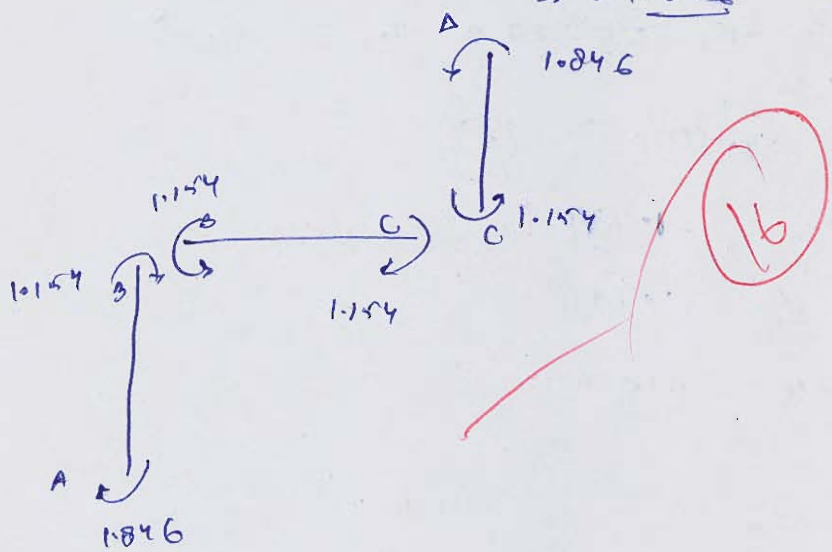
$$\Rightarrow +1.154 \quad \text{KN-m}$$

$$M_{CD} = \frac{2EI}{5}\left(2\theta_C + \frac{3\Delta}{5}\right) \Rightarrow \frac{2}{5}\left[2\times 1.731 + \frac{3}{5}\times(-10.577)\right)$$

$$\Rightarrow -1.154 \quad \text{KN-m}$$

$$M_{DC} \Rightarrow \frac{2EI}{5}\left(\theta_C + \frac{3\Delta}{5}\right) = \frac{2}{5}\left[1.731 + \frac{3}{5}\times(-10.577)\right)$$

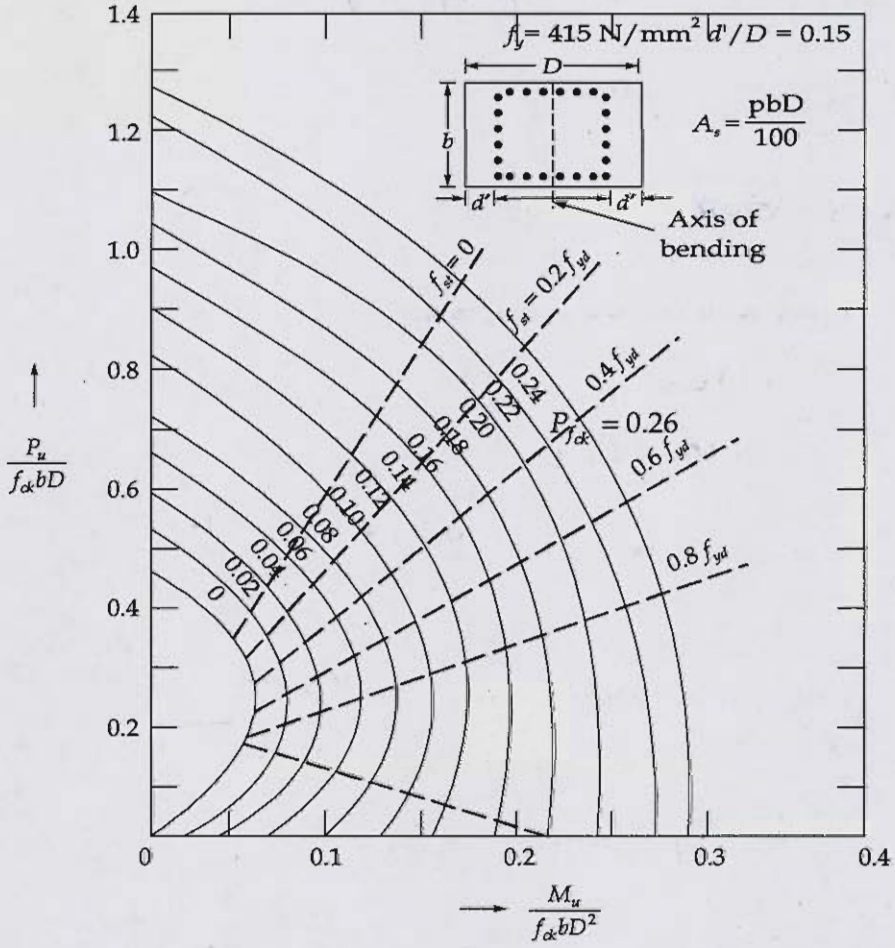
$$\Rightarrow -1.846 \quad \text{KN-m}$$



(b)

.3 (b) (i) Explain Non-Destructive Testing (NDT) in concrete. Describe the working principle and procedure of the Rebound Hammer Test. Also mention its suitability and limitations.

(ii) Find the reinforcement for an *RCC* column for the following particulars:
Size of the column : 450 mm × 450 mm
Concrete mix: M25
Grade of steel: Fe415
Factored load: 2500 kN
Factored moment: 180 kNm
Arrangement of reinforcement bars: On four sides
Diameter of bars used: 35 mm
Nominal cover: 50 mm
Use the chart given below.
Compression with bending, reinforcement distributed equally on four sides.



[10 + 10 = 20 marks]

(ii) Ans (b)

Size = 450 mm × 450 mm , P_u = 2500 KN

f_{ck} = 25 M/a , M_u = 180 KN

$$\frac{P_u}{f_{ck} B D} \Rightarrow \frac{2500 \times 1000}{25 \times 450 \times 450} \Rightarrow 0.494 \simeq 0.5$$

$$\frac{M_u}{f_{ck} B D^2} \Rightarrow \frac{180 \times 1000 \times 1000}{25 \times 450 \times 450^2} \Rightarrow 0.08$$

from the graph given

for above values,

$\frac{P_t}{f_{ck}} \Rightarrow$ 0.07 ⇒ approx

$A_{st} \Rightarrow$ ~~0.08 × 450 × 450 × 25~~

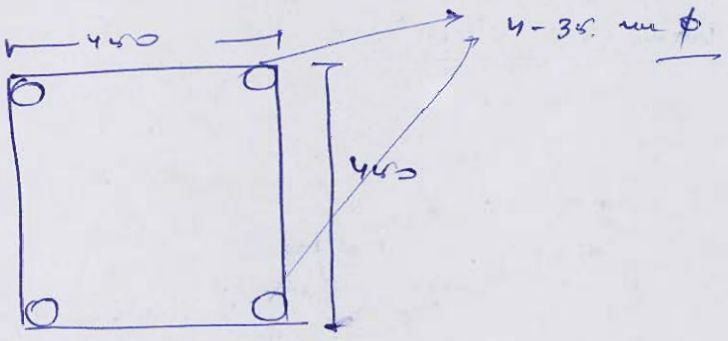
$\Rightarrow$

$$\frac{P_t}{f_{ck}} = 0.07 \Rightarrow P_t \Rightarrow 0.07 \times 25 = 1.75\ \%$$

$$A_{st} \Rightarrow \frac{1.75}{100} \times 450 \times 450 \Rightarrow 3543.75\ mm^2$$

provide 25 mm ϕ bars.

$$n = \frac{3543.75}{\frac{\pi}{4} \times 25^2} \Rightarrow 3.60 \simeq (4)\ \text{bars}$$



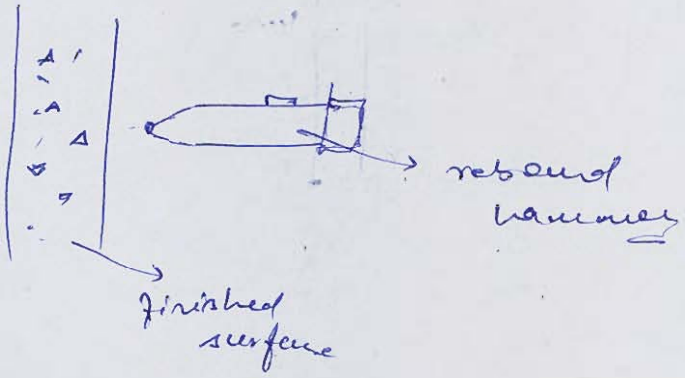
Non-Destructive Testing is done / performed over the finished concrete structure.

* It is done after the ~~~~ construction of concrete members.
* As there is no sample required prior to construction for testing in this process.
* There are 2 types of NDT test generally used :

① Rebound hammer Test

② Ultrasonic Pulse velocity Test.
↳ depends upon modulus of elasticity of concrete.
& density of concrete.

Rebound hammer Test:



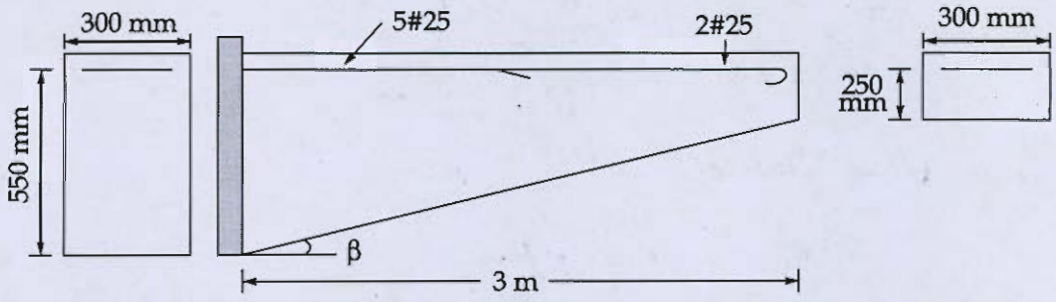
→ Properties:

1) The angle should be vertical to the wall surface.
   → inclination of hammer give incorrect reading.
2) There is no air void, at the place of impact of hammer.
3) Steel reinforcement does not come in direct contact with the hammer
4) A calibration scale is attached over the assembly.

7

.3 (c) (i) Explain briefly the concept of shear lag effect in beams. As per IS 800:2007, under which conditions can shear lag effect in flanges be neglected? Also, mention the factors that influence the shear lag effect.

(ii) Design the shear reinforcement in a tapered cantilever beam of span 3 m, having a section of 250 mm effective depth and 300 mm width at the free end and 550 mm effective depth and 300 mm width at the support as shown in figure below. The beam has to support a factored uniform load of 80 kN/m, including its self weight. Assume an effective cover of 50 mm, M25 concrete and Fe415 steel.



Design shear strength for M25 grade concrete.

$\frac{100A_{st}}{bd}$	1.00	1.25	1.50	1.75
$\tau_c\left(\text{N/mm}^2\right)$	0.64	0.70	0.74	0.78

[8 + 12 = 20 marks]

$\tau_{ve} = \dfrac{V_u \pm \frac{M_u}{d}\tan\beta}{B \cdot d}$

for given loading condition, Moment & depth both are increasing towards fixed end.

$\tau_{ve} = \dfrac{V_u - \frac{M_u}{d}\tan\beta}{Bd}$ ⇒

$\tan\beta \Rightarrow \frac{550-250}{3000}$

$\tan\beta = \frac{300}{3000} = \frac{1}{10}$

$V_u \Rightarrow 80 \times 3 \Rightarrow 240\ \text{KN}$

$M_u = \frac{wl^2}{2} \Rightarrow \frac{80 \times 3 \times 3}{2} \Rightarrow 360\ \text{KN-m}$

$$\tau_{ve} = \frac{240\times10^3 - \frac{360\times10^6}{550}\times\left(\frac{1}{10}\right)}{300\times550}$$

$\tau_{ve} = 1.006 \ N/mm^2$

$\tau_{c,max} \Rightarrow 0.62\sqrt{25} \Rightarrow 3.125 \ N/mm^2$

$\tau_{ve} < \tau_{c,max} \Rightarrow$ OK

$p_t \Rightarrow \frac{5\times\frac{\pi}{4}\times25^2\times100}{550\times300} \Rightarrow 1.049\% \simeq 1.50\%$

$\tau_c \Rightarrow$ from table

$\tau_c = 0.74 \ N/mm^2$

$V_{us} \Rightarrow (\tau_{ve} - \tau_c)\times b\times d$

$\Rightarrow (1.06 - 0.74)\times300\times550$

$\Rightarrow 52.8 \ KN$

provide 2-legged 8mm ϕ vertical stirrups

$V_{us} = \frac{0.87 f_y \times A_{sv}\times d}{S_v}$

$52.8\times1000 = \frac{0.87\times415\times2\times\frac{\pi}{4}\times8^2\times550}{S_v}$

$S_v = 378.01 \ mm$

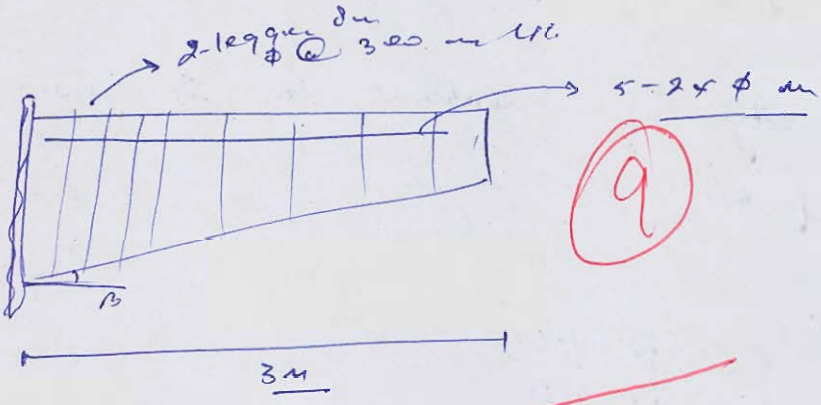
spacing $=$ min $\begin{cases} 378.01 \\ 300 \ mm \\ 300 \ mm \end{cases} \Rightarrow 300 \ mm$

$\frac{A_{sv}}{bS_v} = \frac{0.32}{0.87f_y} \Rightarrow \frac{2\times\frac{\pi}{4}\times8\times8}{300\times S_v} \Rightarrow \frac{0.32}{0.87\times415}$

$S_v = 378.01 \ mm$

provide 2-legged 8 mm ϕ vertical stirrups

@ 300 mm c/c



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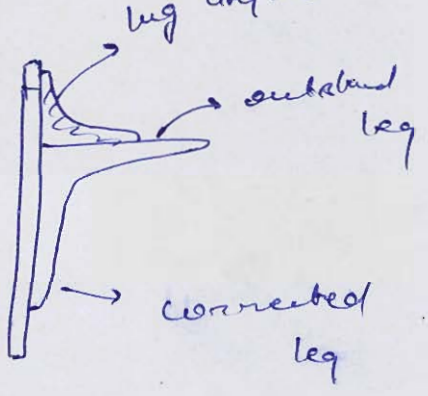


* The outstand leg of the member does not impart in carrying load upto its full capacity.

* Shear lugs can be avoided!

1) length of connection should not be very large.

2) use of lug angle.

2½

⇒ use of leg angle increase the load carrying capacity of member.

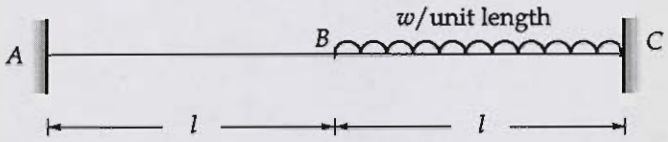
⇒ the capacity of outstand leg is governed by a factor β.

$$0.7 \leq \beta \leq 0.9 \frac{f_u}{f_y} \times \frac{1.1}{1.2\gamma}$$

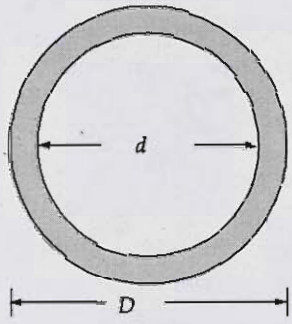
$$\left(\beta = 1.4 - 0.076 \times \frac{w}{t} \times \frac{b_s}{L_c} \times \frac{f_y}{f_u}\right)$$

.4 (a) (i) A beam fixed at both the ends is subjected to a uniformly distributed load w per unit length on its right half portion as shown below. Determine the collapse load if the beam is of uniform cross-section.

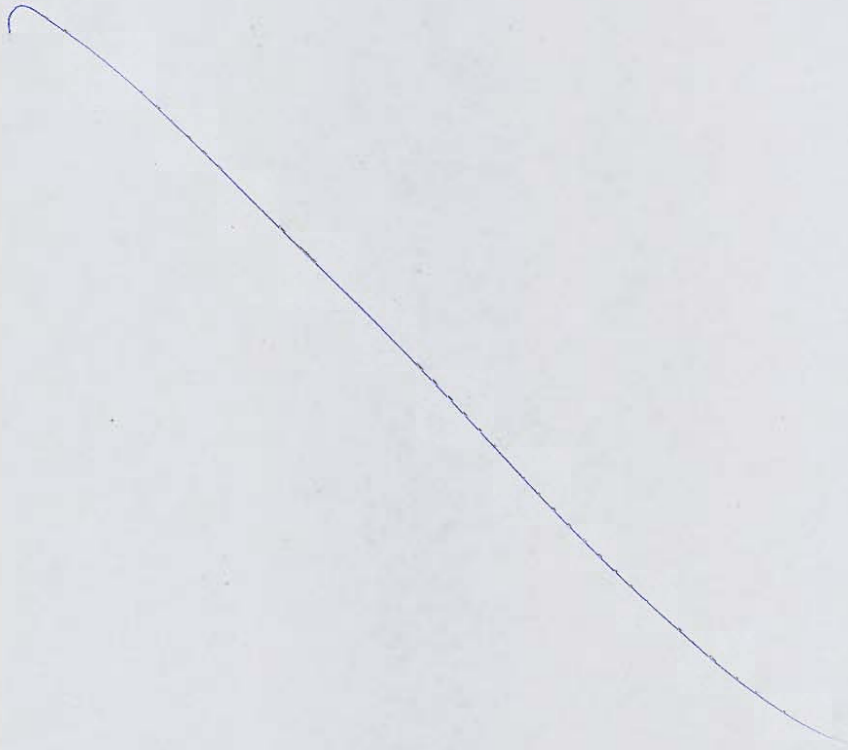
Take: Plastic moment capacity = M_p



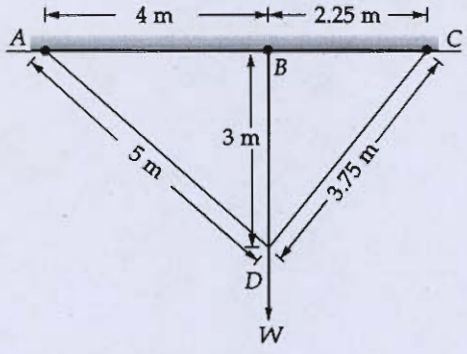
(ii) Show that the shape factor for the hollow circular section as shown in figure will be $\frac{1.7(1-k^3)}{(1-k^4)}$ where, $k = \frac{d}{D}$.



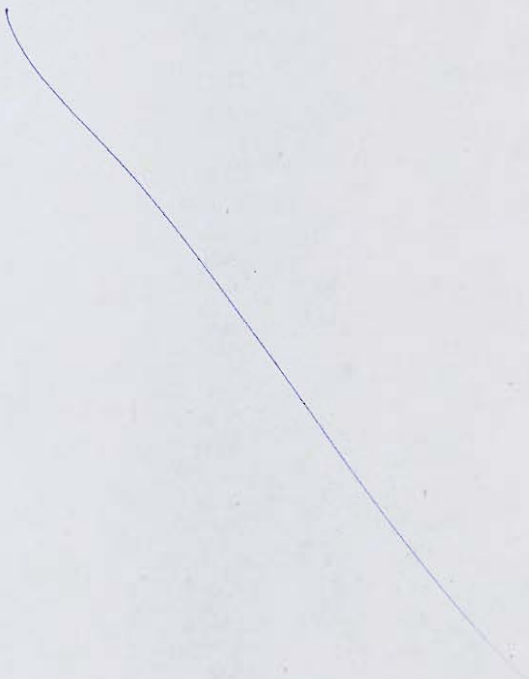
[12 + 8 = 20 marks]

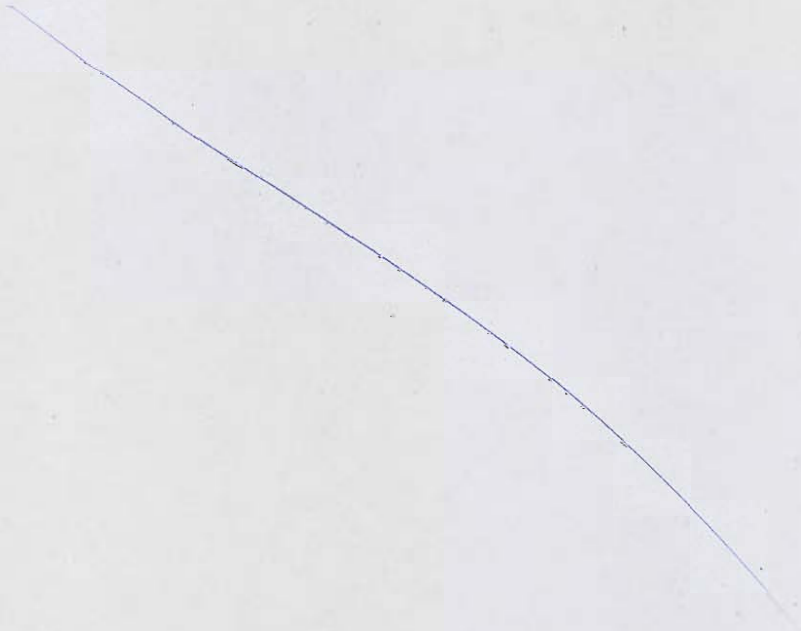


Q.4 (b) Three wires *AD*, *BD* and *CD* having the same cross-sectional area and of the same material support a load *W* as shown in figure. Determine the tension in the three wires. Show also that the horizontal movement of *D* equals one-seventh of the extension of *BD*.

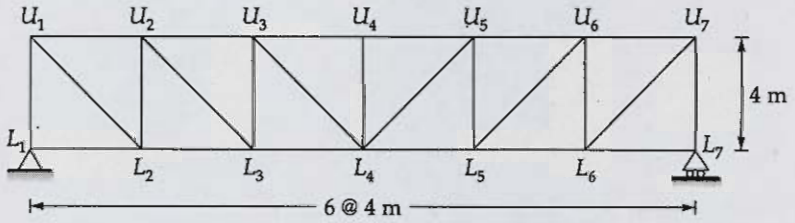


[20 marks]

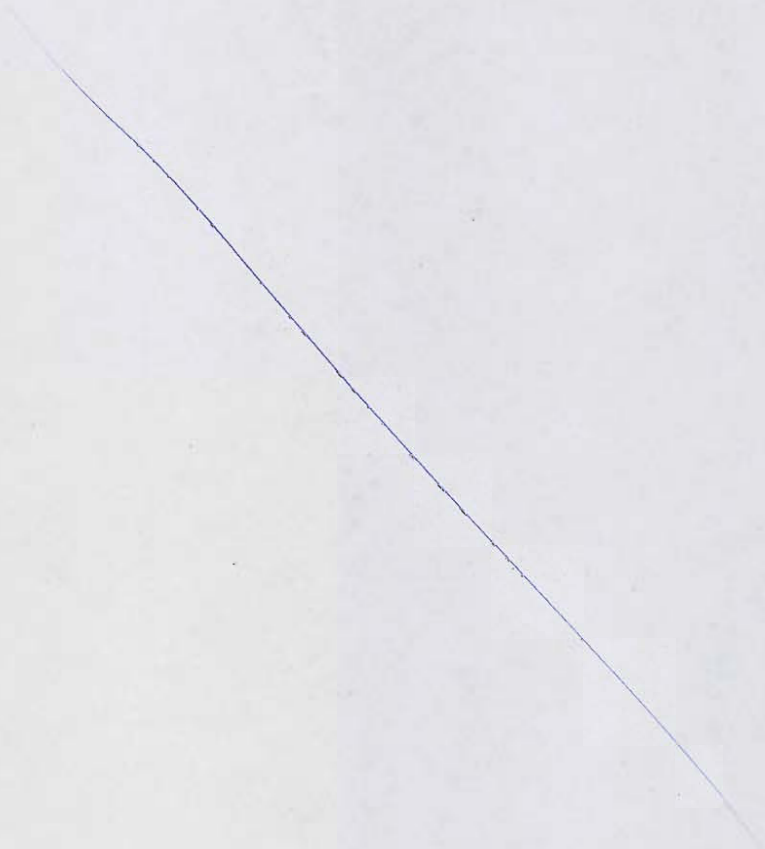


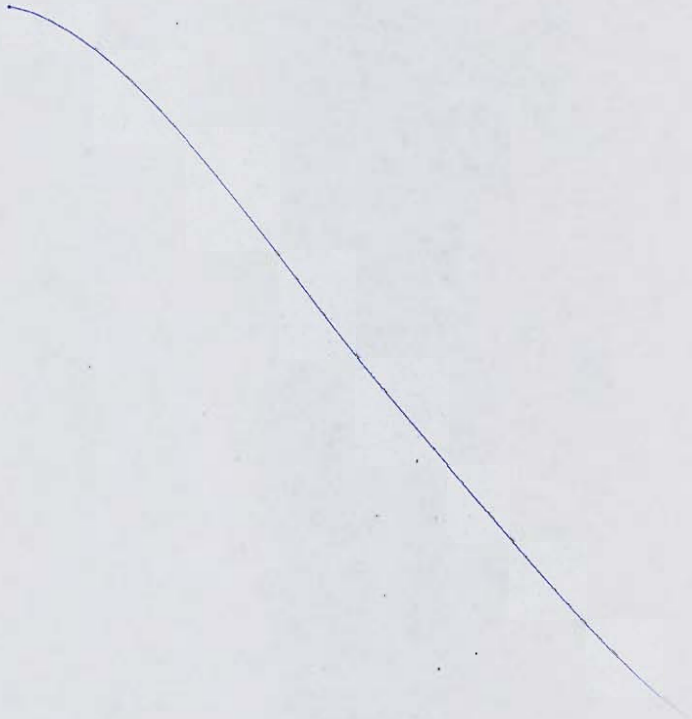


Q.4 (c) Draw the influence line diagram for forces in the members U_3L_4, U_3U_4 and U_3L_3 of the frame as shown in figure and find the maximum forces developed, when uniformly distributed load of intensity 40 kN/m, longer than the span moves from left to right on bottom chord (Neglect the self weight of truss).



[20 marks]

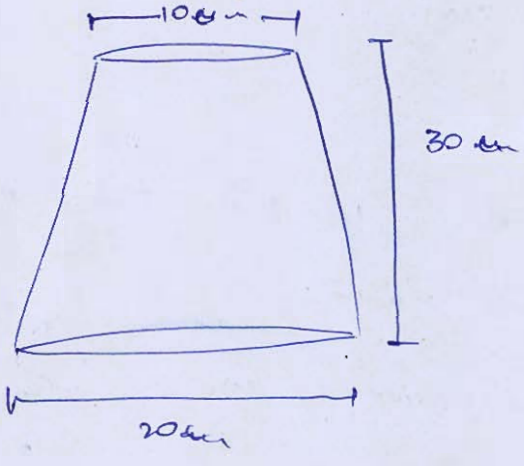




Section - B

Q.5 (a) Describe the Slump Test for measuring the workability of concrete. Explain the test procedure and write the interpretation of results.

[12 marks]

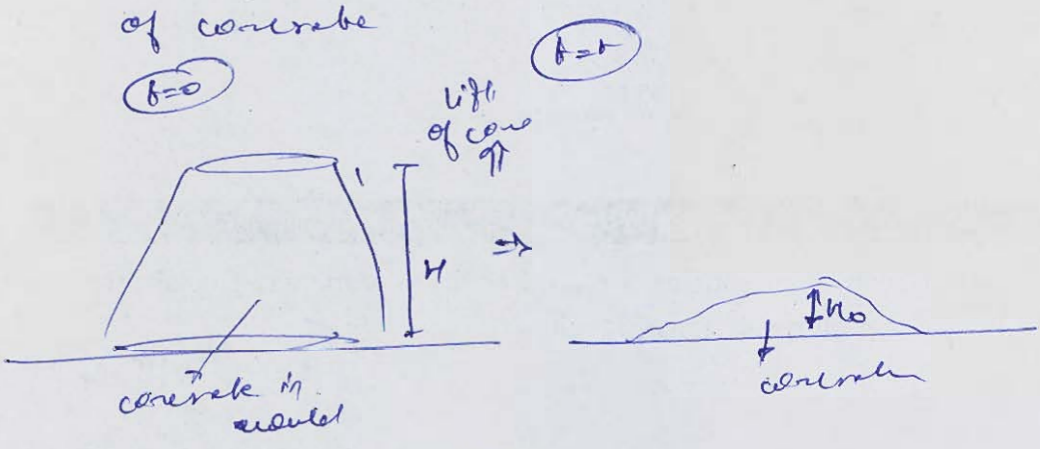


⇒ Slump cone is used to check the workability of concrete.

⇒ This test is performed, when the workability lies between medium to low workability of concrete.

Procedure:

1) Fill the concrete inside the mould
2) Lift the cone.
3) Allow the concrete to subside
4) check the height after the subsidence of concrete



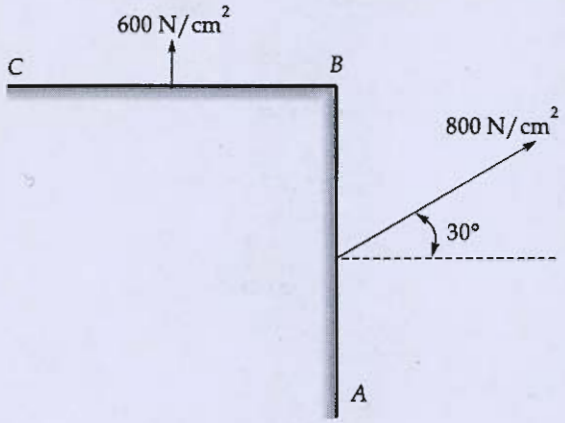
Slump value $= \frac{Ho}{H} \times 100$

⇒ Calibration is done to find the workability with the slump value.

⇒ Slump values are like = 40mm, 60mm
beam, column

9

Q.5 (b) The intensity of resultant stress on a plane *AB* as shown in figure at a point in a material under stress is 800 N/cm^2 and it is inclined at 30° to the normal to that plane. The normal component of stress on another plane *BC* at right angles to plane *AB* is 600 N/cm^2.

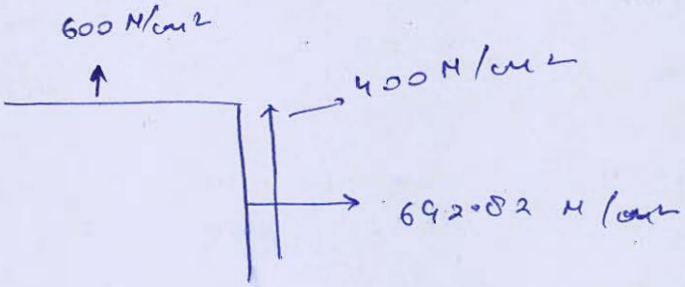


Determine the following:

(i) the resultant stress on the plane *BC*,

(ii) the principal stresses and their directions.

[12 marks]



on plane BC.

$\sigma_R = \sqrt{\sigma_n^2 + \tau^2} = \sqrt{600^2 + 400^2}$

$\Rightarrow 721.11$ N/cm2

principal stress:

$\sigma_{p1}/\sigma_{p2} = \frac{\sigma_n + \sigma_y}{2} \pm \frac{1}{2}\sqrt{(\sigma_y - \sigma_n)^2 + 4\tau^2}$

$\sigma_{p1} \Rightarrow \frac{692.82 + 600}{2} + \frac{1}{2}\sqrt{(600 - 692.82)^2 + 4 \times 400^2}$

$= 646.41 + 402.68$

$\sigma_{p1} = 1049.09$ N/cm2

$\sigma_{p_2} = 646.41 - 402.68$

$\sigma_{p_2} \Rightarrow 243.73 \ N/cm^2$

$\tan 2\theta_1 \Rightarrow \frac{2\tau_{xy}}{\sigma_x - \sigma_y} = \frac{2 \times 400}{692.82 - 600}$

$= 8.6188$

$\theta_{p_1} \Rightarrow 41.69°$

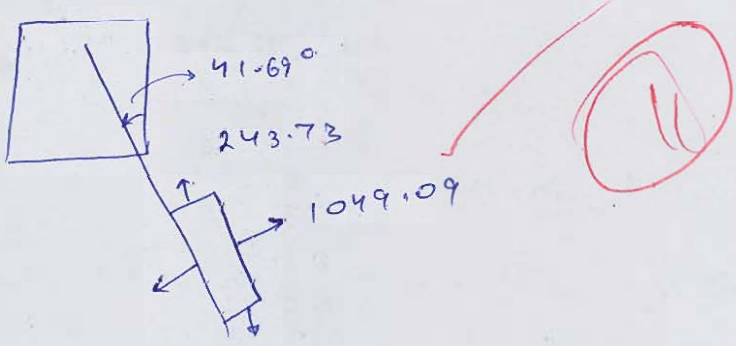
$\sigma_N = \sigma_x \cos^2\theta + \sigma_y \sin^2\theta + 2\tau_{xy} \sin\theta \cos\theta$

$\sigma_N = 692.82 \cos^2(41.69°) + 600 \sin^2(41.69°) + 2 \times 400 \times \sin(41.69) \times \cos(41.69)$

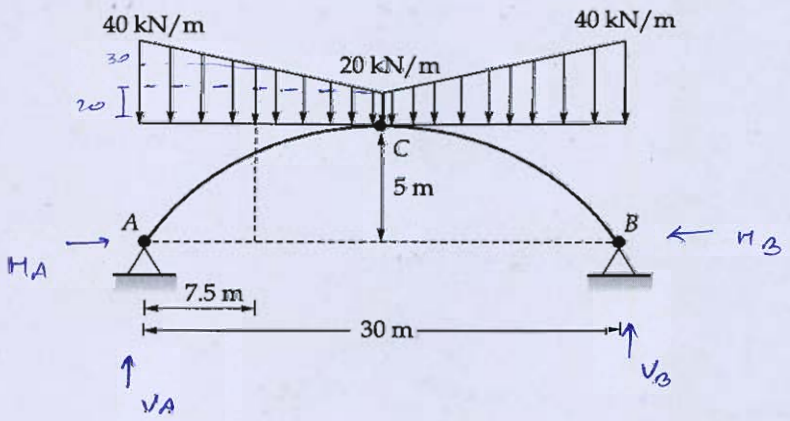
$\sigma_N = 1049.09 \ N/cm^2 \Rightarrow$ (Check OK)

$\Rightarrow \theta_{p_1} = 41.69°$ from major principal plane

$\sigma_{p_1} = 1049.09 \ N/cm^2$



Q.5 (c) A three-hinged parabolic arch of span 30 m and rise 5 m carries a load whose intensity uniformly varies from 20 kN/m at the crown to 40 kN/m at the ends. Find the bending moment, normal thrust and radial shear at a section passing through arch vertically at a distance of 7.5 m from the left end.



[12 marks]

$V_A = V_B = \frac{1}{2} \times (40+20) \times 15 = 450$ KN

$\Sigma M_C \Rightarrow 450 \times 15 - H_A \times 5 - 20 \times 15 \times \frac{15}{2} - \frac{1}{2} \times 20 \times 15 \times \frac{2}{3} \times 15$

$450 \times 15 - 3750 = 5 H_A$

$H_A = 600$ KN

eq. from parabola eq.

$y = \frac{4hx(l-x)}{l^2}$; $\frac{dy}{dx} = \tan\theta = \frac{4h(l-2x)}{l^2}$

$y = \frac{4 \times 5 \times 7.5 \times (30-7.5)}{30 \times 30}$

$y = 3.75$ m

$\tan\theta = \frac{4 \times 5 \times (30 - 2 \times 7.5)}{30 \times 30}$

$\tan\theta = 1/3$

$\cos\theta = 0.949$

$\sin\theta = 0.316$

$$\text{Moment}@_{7.5m} = VA \times 7.5 - HA \times 3.75 - 30 \times 7.5 \times \frac{7.5}{2} - \frac{1}{2} \times 10 \times 7.5 \times \frac{2 \times 7.5}{3}$$

$$\Rightarrow 450 \times 7.5 - 600 \times 3.75 - 1031.25$$

$$\Rightarrow 93.75 \text{ KN-m}$$

Normal thrust $\Rightarrow V \sin\theta + N \cos\theta$

$$= \left(450 - (30 \times 7.5 + 0.5 \times 10 \times 7.5)\right) \times 0.316$$

$$+ 600 \times 0.949$$

$$\Rightarrow 628.65 \text{ KN}$$

Radial shear $\Rightarrow V \cos\theta - N \sin\theta$

$$\Rightarrow (450 - 262.5) \times 0.949$$

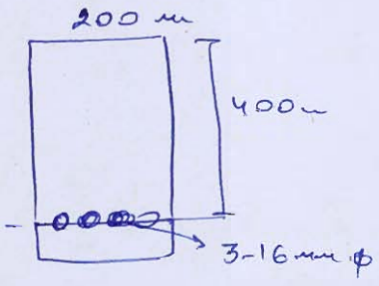
$$- 600 \times 0.316$$

$$\Rightarrow -11.6625 \text{ KN}$$

Negative rep reverse (left) ←

Q.5 (d) An R.C.C. beam, 200 mm × 400 mm (effective depth), is reinforced with 3-16 mm diameter bars of Fe 415 steel. Determine the ultimate load inclusive of its self-weight which the beam can carry safely over a span of 5 m. (Take M20 grade of concrete)

[12 marks]



$A_{st} \Rightarrow 3 \times \frac{\pi}{4} \times 16^2 = 603.186 \text{ mm}^2$

$L_{eff} \Rightarrow 5 \text{ m}$

$f_{ck} = 20 \text{ MPa}$

$f_y = 415 \text{ MPa}$

⇒ location of NA.

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

$0.36 \times 20 \times 200 \times x_u = 0.87 \times 415 \times 603.186$

$x_u = 151.24 \text{ mm}$

$x_{u,lim} \Rightarrow 0.48 \times d = 0.48 \times 400 = 192 \text{ mm}$

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

$M_{DL} = 0.36 f_{ck} b x_u (d - 0.42 x_u)$

$\Rightarrow 0.36 \times 20 \times 200 \times 151.24 \times (400 - 0.42 \times 151.24)$

$\Rightarrow 73.28 \times 10^6 \text{ N-m}$

$\Rightarrow 73.28 \text{ KN-m}$

$$M_u = \frac{w_T \cdot L^2}{8}$$

$$73.28 = \frac{w_T \times 4 \times 4}{8}$$

$$w_{T_u} \Rightarrow 23.45 \text{ KN/m}$$

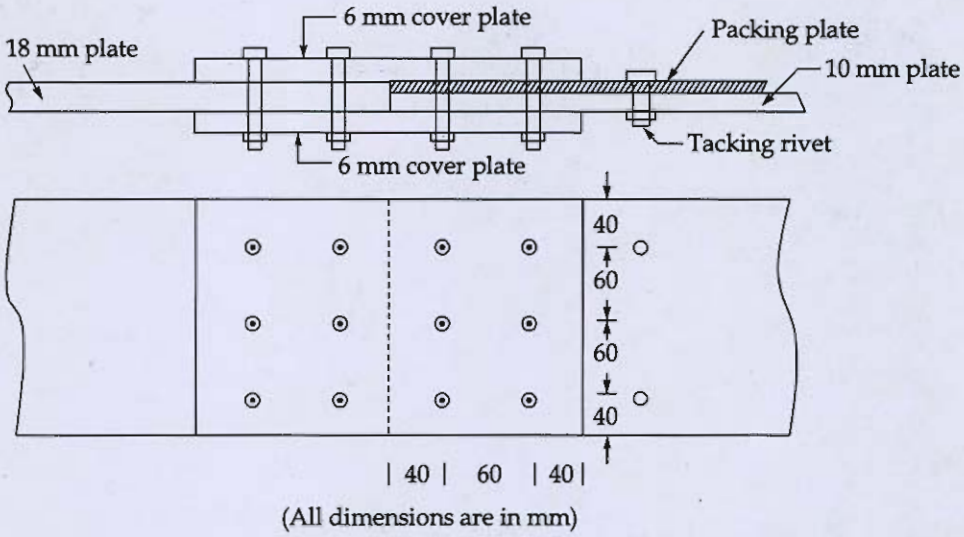
ultimate load, $w_{Tu} = 23.45$ KN/m

12

Q.5 (e) Two cover plates, 10 mm and 18 mm thick are connected by a double cover butt joint using 6 mm cover plates as shown in figure. Find the strength of the joint. Given M20 bolts of grade 4.6 and Fe 415 plates are used.

Consider first shear plane passing through shank area of bolt and second shear plane passing through threaded portion of bolt.

(Strength of tacking bolts are not to be considered in the design.)



(All dimensions are in mm)

[12 marks]

Shear strength of bolt $\Rightarrow \beta \times 1.78 \times \frac{\pi}{4} \times 20^2 \times \frac{400}{1.25\sqrt{3}}$

$\beta = 1 - 0.0125 \times 8 \Rightarrow 0.9$ $\Rightarrow$ for packing plate.

S.S. of bolt $= 0.9 \times 1.78 \times \frac{\pi}{4} \times 20^2 \times \frac{400}{1.25\sqrt{3}}$

$\Rightarrow 92.98$ KN

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

$K_b = \frac{e}{3d_0} \Rightarrow \frac{40}{3\times22} \Rightarrow 0.606$

$\frac{p}{3d_0} - 0.25 \Rightarrow \frac{60}{3\times22} - 0.25 \Rightarrow 0.6479$ min

$\frac{f_{ub}}{f_{up}} = \frac{400}{410} \Rightarrow 0.976$

$1 \quad \geq 1 \quad = 1$

$K_b \Rightarrow 0.606$

B.S. of bolt $\Rightarrow \frac{2.5 \times 0.606 \times 20 \times 10 \times 410}{1.25}$

$\Rightarrow$ 99.384 KN

Bolt strength $\Rightarrow$ min (S.S., B.S) $\Rightarrow$ 92.98 KN

Gross strength of plate $\Rightarrow \frac{A_g \times f_y}{1.1} \Rightarrow \frac{200 \times 10 \times 250}{1000 \times 1.1} =$ 454.54 KN

Net rupture strength of plate $\Rightarrow \frac{0.9 \times (200 - 3 \times 22) \times 10 \times 410}{1.25 \times 1000}$

$\Rightarrow$ 395.568 KN

Strength of joint = min { $8 \times 92.98 = 557.88$ KN, 454.54 KN, 395.568 KN }

$\Rightarrow$ 395.568 KN

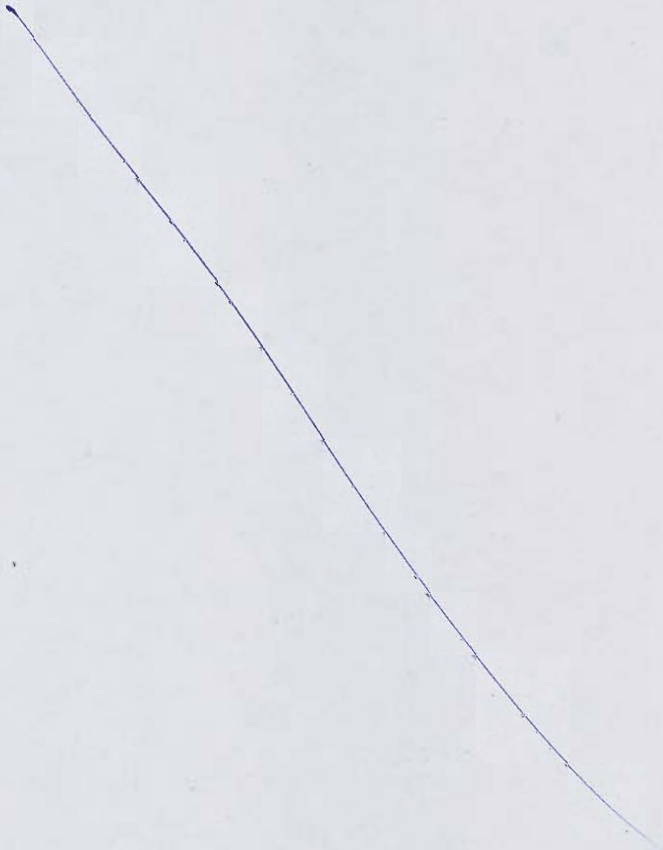
10

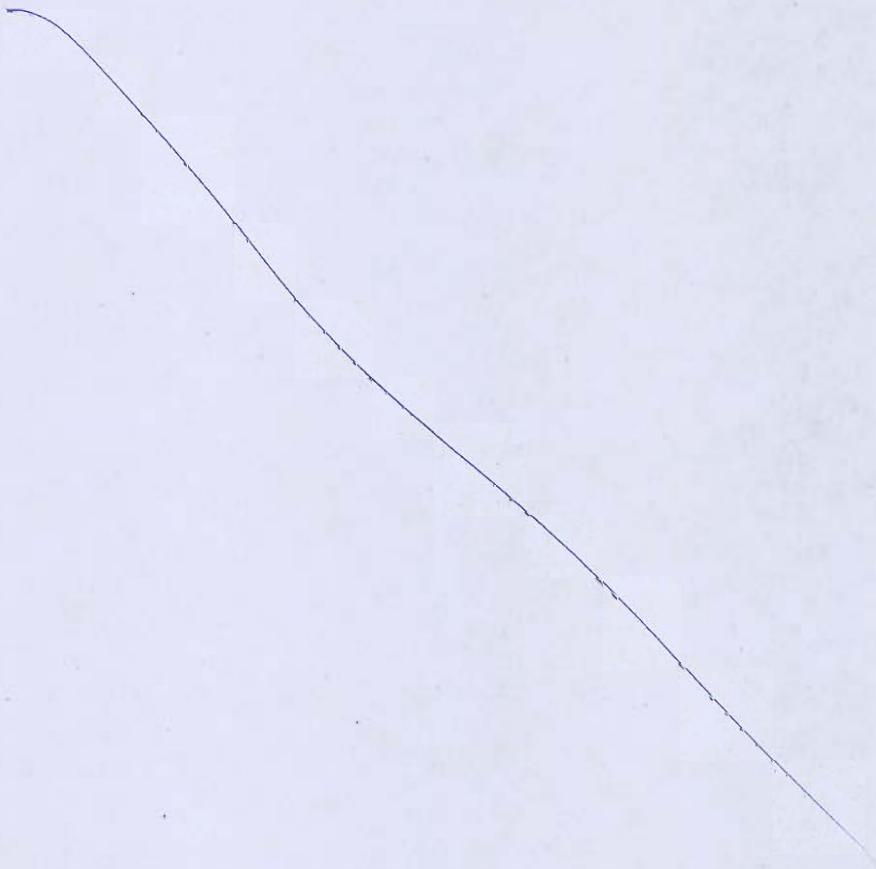
Q.6 (a) Table below provides cost and time estimates of seven activities of a project:

Activity	Time estimates (weeks)		Direct cost estimates (Rs. in thousands)	
(*i-j*)	Normal	Crash	Normal	Crash
1 - 2	2	1	10	15
1 - 3	8	5	15	21
2 - 4	4	3	20	24
3 - 4	1	1	7	7
3 - 5	2	1	8	15
4 - 6	5	3	10	16
5 - 6	6	2	12	36

1. Draw the project network corresponding to normal time.
2. Determine the critical path and the normal duration and normal cost of the project.
3. Crash the activities so that the project completion time reaches to 9 weeks, with minimum additional cost. (Indirect cost (in thousands) = Rs 5/week).

[20 marks]



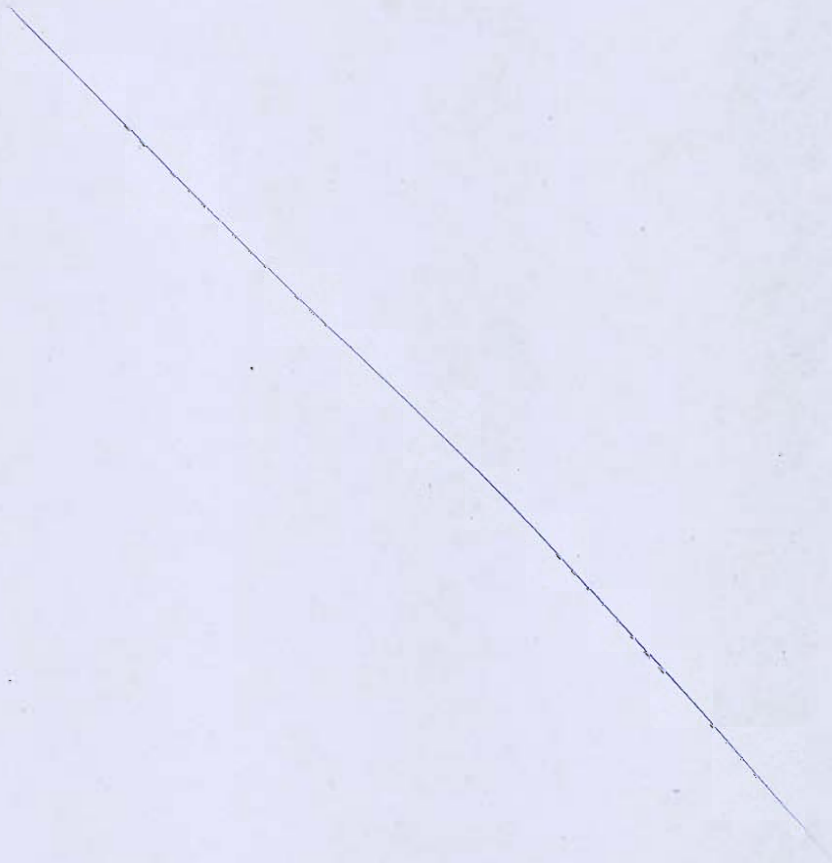


Q.6 (b) (i) Describe the following tests performed on building stones:

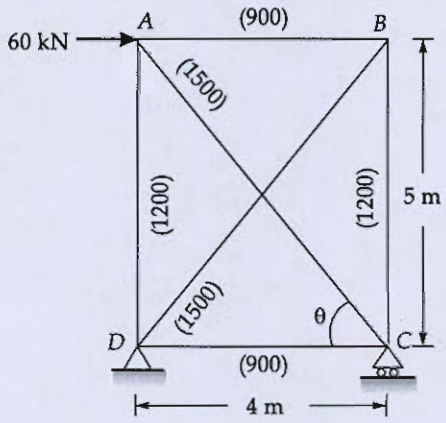
1. Hardness test
2. Water absorption test.
3. Acid test

(ii) Briefly discuss the use of lime in building construction. Describe the various field test for lime.

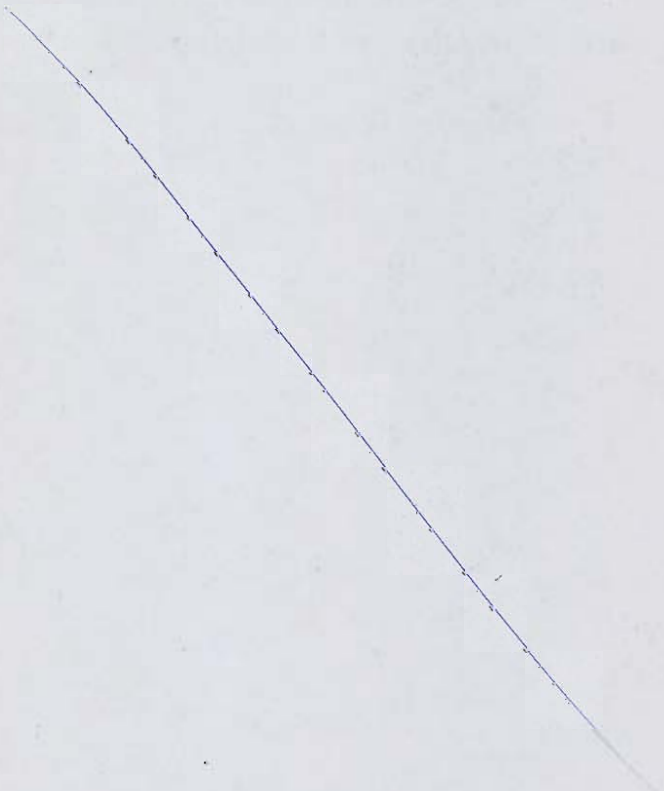
[10 + 10 = 20 marks]

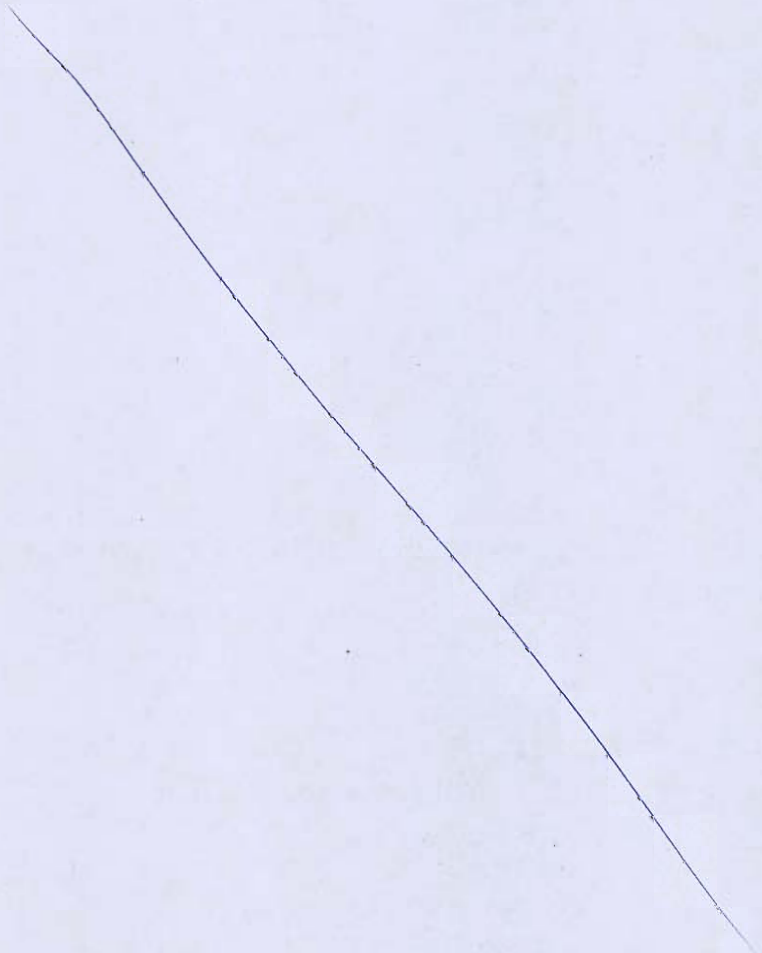


6 (c) Determine the force in the members of the frame as shown in figure. The sectional areas of the members in square millimetre of each member are indicated in brackets.

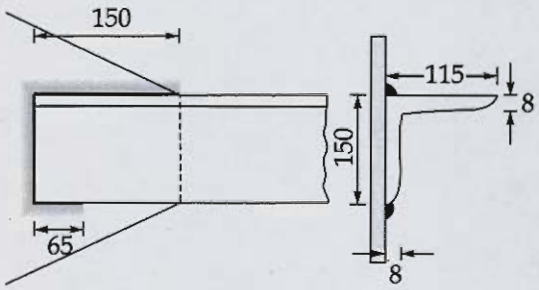


[20 marks]





Q.7 (a) Determine the tensile strength of an angle section ISA 150 × 115 × 8 which is connected to gusset plate for the following cases:



(All dimensions are in mm)

(i) Yielding of gross-section

(ii) Rupture strength of critical section

Use Fe410. For ISA 150 × 115 × 8, $A_g = 2058\ mm^2$.

[20 marks]

Ans

i) Gross yielding of section

$\Rightarrow T_{dg} = \frac{A_g \times f_y}{1.1} = \frac{2058 \times 250}{1.1}$

$\Rightarrow 467.73\ KN$

ii) rupture strength

$$T_{dN} = \frac{0.9 \times A_{NC} \times f_u}{1.25} + \beta \times \frac{A_{go} \times f_y}{1.1}$$

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

$$\Rightarrow 1.4 - 0.076 \times \frac{115}{8} \times \frac{115}{365} \times \frac{250}{410}$$

$$\Rightarrow 1.019$$

$A_{NC} \Rightarrow (150 - 4) \times 8 = 1168 \text{ mm}^2$

$A_{go} \Rightarrow (115 - 4) \times 8 = 888 \text{ mm}^2$

$$T_{dN} \Rightarrow 0.9 \times \frac{1168 \times 410}{1.25} + 1.019 \times \frac{888 \times 250}{1.1}$$

$$\Rightarrow 484.96 \text{ KN}$$

(15)

Tensile strength of Angle section

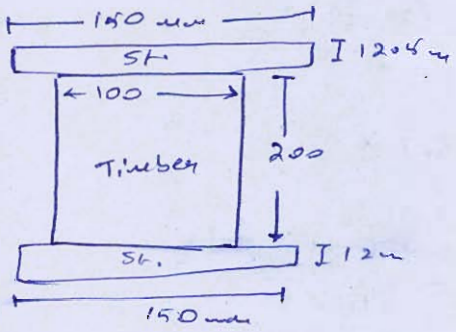
$\Rightarrow \min(467.73, 484.96)$

$T_d \Rightarrow 467.73 \text{ KN}$

7 (b) A timber beam 100 mm wide and 200 mm deep is to be reinforced by bolting two steel flitches each 150 mm by 12.5 mm in section. Calculate the moment of resistance in the following cases: (i) flitches attached symmetrically at the top and bottom; (ii) flitches attached symmetrically at the sides. Allowable stress in timber is 6 N/mm^2. What is the maximum stress in the steel in each case? Take $E_s = 2 \times 10^5$ N/mm^2 and $E_t = 1 \times 10^4$ N/mm^2.

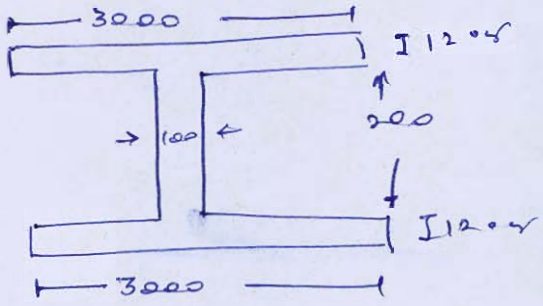
[20 marks]

i) Steel flitches @ top.



$$M = \frac{2 \times 10^5}{1 \times 10^4} = 20$$

equivalent timber beam



$$I_{NA} = \frac{3000 \times 225^3}{12} - \frac{2400 \times 200^3}{12}$$

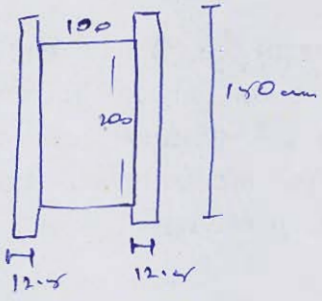
$$\Rightarrow 914.323 \times 10^6 \text{ mm}^4$$

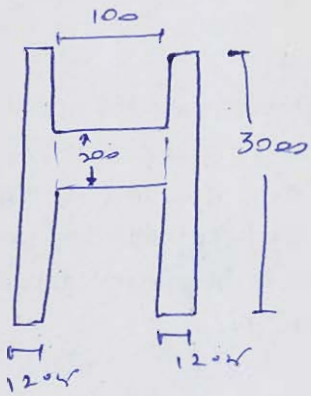
(6)

$$\frac{M}{I} = \frac{\sigma}{y}$$

$$M \Rightarrow \frac{6 \times 914.323 \times 10^6 \times 10^{-6}}{112.5} \Rightarrow 48.764 \text{ KN-M}$$

ii) steel flitches at sides.





equivalent Timber beam.

$$\Rightarrow I_{NA} \Rightarrow \frac{100 \times 200^3}{12} + \frac{12.5 \times 3000^3}{12} \times 2$$

$$\Rightarrow 56316.67 \times 10^6 \text{ mm}^4$$

$$\frac{M}{I} = \frac{\sigma}{y} \Rightarrow M \Rightarrow \frac{6 \times 56316.67 \times 10^6 \times 10^{-6}}{150}$$

$$M = 225.267 \text{ KN-M}$$

Q.7 (c) (i) Write short notes on the following artificial pozzolanas used in concrete:

(a) Silica fume

(b) Rice husk ash

(ii) What is analysis of rates? Explain its purpose and also describe the factors affecting the rate analysis:

[10 + 10 = 20 marks]

Ans: (i)

Silica fume:

⇒ Silica fume is a type of pozzolanic materials.

⇒ It is used in manufacturing of of cement.

⇒ It is obtained from the thermal power plants.

→ The concentration of silica is very in RHA.

→ Silica imparts strength → control the setting time.

b) Rice husk:

→ It is produced from the agricultural field of rice.

→ After the harvesting of rice, the waste products is utilised in the manufacturing of cement as a pozzolanic material.

→ It also contain silica in it. (6)

Rate Analysis:

→ Cost rate analysis is done on the basis of item & their quantities.

→ Schedule of rates is used to calculate the rate of quantities of a material

The various factors are:

1) Transportation cost

2) Availability of raw / local material.

3) Presence of natural resources like / stones, rock.

4) Living standards of labour

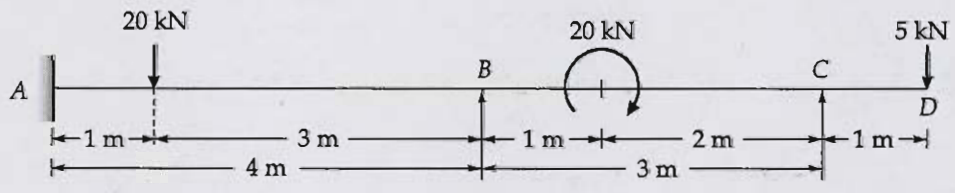
5) Labour cost.

Total cost $\Rightarrow$ (cost of one item $\times$ quantity of an item)

7

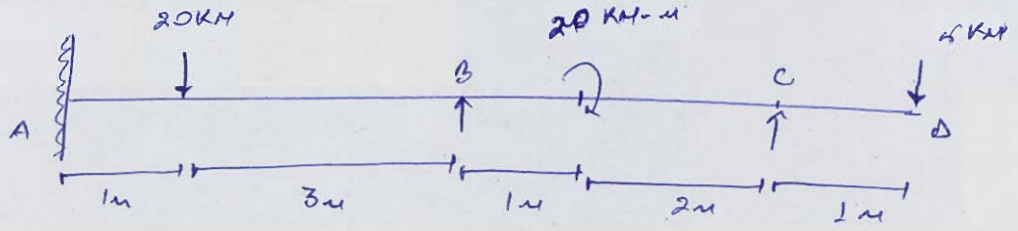
(a) Find the support moments, reactions and draw BMD for the continuous beam as shown in figure by moment distribution method.

(Take EI = constant)



[20 marks]

Ans°



$M_{FAB} \Rightarrow \frac{-20 \times 1 \times 3 \times 3}{4 \times 4} \Rightarrow -11.25$ KN-m

$M_{FBA} = \frac{+20 \times 3 \times 1 \times 1}{4 \times 4} \Rightarrow +3.75$ KN-m

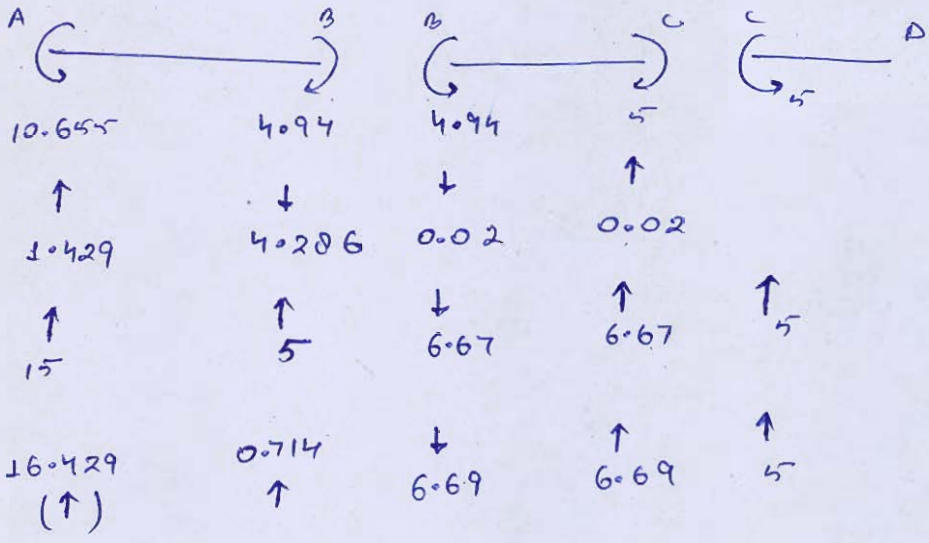
$M_{FBC} = -\frac{14.55}{2} = -7.275$

$M_{FCB} = +\frac{5.45}{2} \Rightarrow +2.725$

$M_{CD} \Rightarrow -5$

$K_{BA} \Rightarrow \frac{\frac{4EI}{4}}{\frac{4EI}{4} + \frac{3EI}{3}} \Rightarrow 0.5$, $K_{BC} = 0.5$

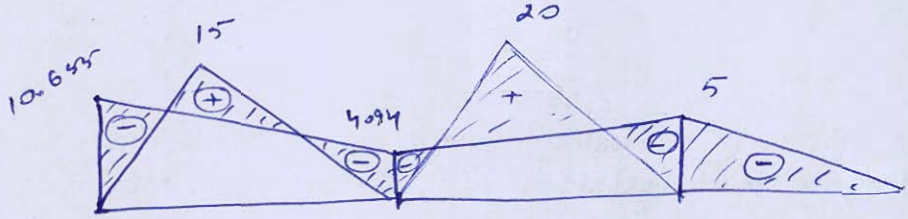
Joint	A		B		C	
Member	AB	BA	BC	CB	CD	
DF	-	0.5	0.5	1.0	-	
FEM	-11.25	+3.75	-7.275	+2.725	-5	
Bal.		+1.76	+1.76	+2.275		
COM	+0.88			0		
			1.1375			
Bal.		-0.57	-0.57			
COM	-0.285					
Final Moment	-10.655	+4.94	-4.94	+5	-5	



$R_A \Rightarrow 16.429$ KN (↑)

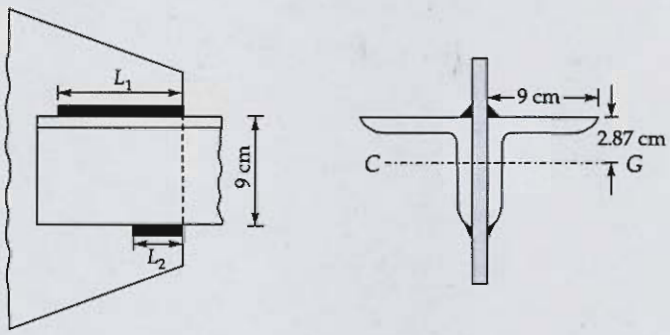
$R_B \Rightarrow 6.69 - 0.714 = 5.976$ KN (↓)

$R_C \Rightarrow 6.69 + 5 \Rightarrow 11.69$ KN (↑)



BMD for the beam

Q.8 (b) (i) Two angles 90 mm × 90 mm × 8 mm transmit a tensile force of 250 kN. The angles are connected to the gusset on either side by welding. Design the joint if size of the weld is 6 mm and allowable shear stress is 102.5 N/mm^2.



(ii) Write short notes on assessed value and sinking fund.

(iii) A building fetches a net income of Rs. 16000 per year for the next 60 years. What is the value of the property? Assume that the land lord desires a return of 8% on capital and sinking fund to replace the capital is also to be taken into consideration at 8%

[10 + 5 + 5 = 20 marks]

$P_T = 250$ KN

~~load sharing~~

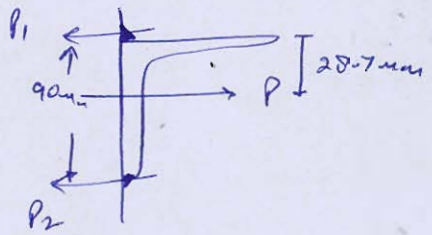
$P_T = V_s \, l_{eff} \times \frac{f_{up}}{1.25\sqrt{3}}$ $\longrightarrow 102.5$

$250 \times 1000 = 0.7 \times 6 \times l_{eff} \times 102.5 \times 2$

$l_{eff} \Rightarrow 290.36$ mm $\Rightarrow$ for one angle

~~Plate 250 × 287 + 2x~~

l_{eff} for one angle $\Rightarrow$ 290.36 mm ~~= [illegible]~~



$\Rightarrow \Sigma M_1 = 0$

$P \times 28.7 = P_2 \times 90$

$P_2 = \frac{28.7P}{90}$

$P_2 = \frac{28.7}{90} \times \frac{250}{2}$

$P_2 = 39.86$ KN

$P_2 = V_s \, l_{eff_2} \times 102.5$

$39.86 \times 1000 = 0.7 \times 6 \times l_2 \times 102.5$

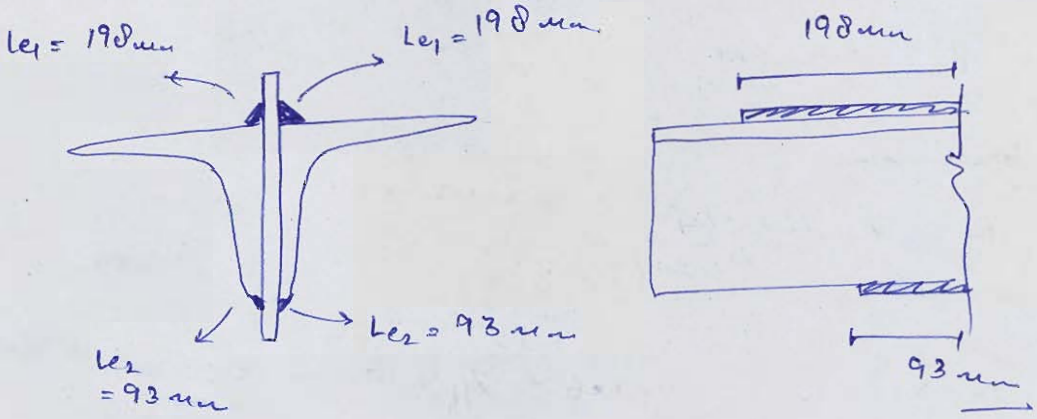
$l_{eff_2} \Rightarrow 92.59$

$l_{eff_1} \Rightarrow 290.36 - 92.59 \simeq 197.78$ mm

Provide

$L_1 \Rightarrow 198$ mm

$L_2 = 93$ mm } for one angle section



ii) Ans:- Sinking fund method is used to find depreciation value of a product

⇒ sinking fund factor ⇒ $\dfrac{(1+i)^n - 1}{i}$

⇒ Depreciable ⇒ $(L_i - L_s)\left[\dfrac{(1+i)^n - 1}{i}\right]$

(4)

⇒ if

iii) Ans:-

~~value ⇒ $\dfrac{16000}{(1+0.08)^{60}}$~~

value ⇒ $16000 \times (1+0.08)^{60}$

(2)

⇒ 1620113.019 Rs

Q.8 (c) An R.C.C. beam 230 mm × 500 mm effective depth is subjected to a factored moment of 200 kNm. Find the flexural reinforcement required. Use M 20 concrete and Fe 415 steel.

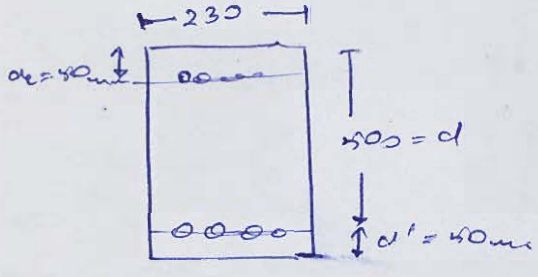
Take effective cover as 50 mm

Stress in compression steel (f_{sc}) N/mm²

Grade of Steel f_y (N/mm²)	d'/d			
	0.05	0.10	0.15	0.20
250	217	217	217	217
415	355	353	342	329
500	424	412	395	370
550	458	441	419	380

[20 marks]

Ans°



$BM_u = 200\ KN-m$

Assume balanced section

$x_u = 0.48 \times 500 = 240\ mm$

(MOR) for single reinforced section

$\Rightarrow 0.36 \times f_{ck} \times b \times x_u (d - 0.42 x_u)$

$\Rightarrow 0.36 \times 20 \times 230 \times 240 (500 - 0.42 \times 240)$

$= 156.66\ KN-m$

$M_u > MOR \Rightarrow$ Design doubly reinforced beam

$\Rightarrow A_{st1} \Rightarrow \dfrac{MOR}{0.87 f_y (d - 0.42 x_u)}$

$\Rightarrow \dfrac{156.66 \times 10^6}{0.87 \times 415 \times (500 - 0.42 \times 240)}$

$\Rightarrow 1086.93 \text{ mm}^2$

$\Rightarrow A_{st2} \Rightarrow \dfrac{M_u - MOR}{0.87 f_y (d - d')} \Rightarrow \dfrac{(200 - 156.66) \times 10^6}{0.87 \times 415 \times (500 - 50)}$

$\Rightarrow 266.75 \text{ mm}^2$

f_{sc} from table, $\dfrac{d'}{d} = \dfrac{50}{500} \Rightarrow 0.10$

for $f_y = 415$

$f_{sc} \Rightarrow 353 \text{ MPa}$

18

$A_{sc} \Rightarrow \dfrac{(200 - 156.66) \times 10^6}{(f_{sc} - 0.45 f_{ck}) \times (d - d')} \Rightarrow \dfrac{(200 - 156.66) \times 10^6}{(353 - 0.45 \times 20)(500 - 50)}$

$\Rightarrow 279.97 \text{ mm}^2$

Total $A_{st} \Rightarrow 1086.93 + 266.75$

$\Rightarrow 1353.68 \text{ mm}^2$

$A_{sc} \Rightarrow 279.97 \text{ mm}^2$

For longitudinal reinforcem

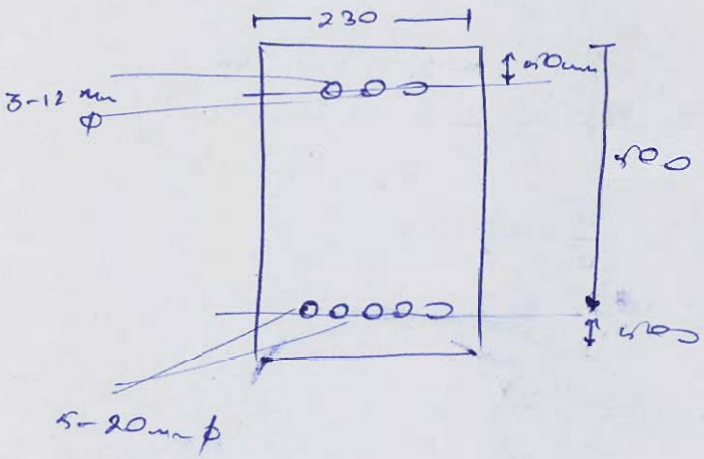
provide 20 mm dia bars

$$\Rightarrow n \Rightarrow \frac{1353.68}{\frac{\pi}{4}\times 20\times 20} \Rightarrow 4.3 \simeq (5)$$

For comp. reinforcement.

provide 12 mm ϕ bars

$$n \Rightarrow \frac{279.97}{\frac{\pi}{4}\times 12^2} \Rightarrow 2.4 \simeq (3)$$



Space for Rough Work

Space for Rough Work

Space for Rough Work