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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	30
Q.2	56
Q.3	—
Q.4	—
Section-B	
Q.5	56
Q.6	45
Q.7	—
Q.8	40
Total Marks Obtained	229/300

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.

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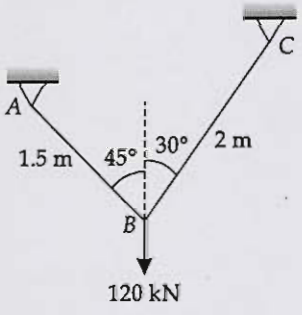
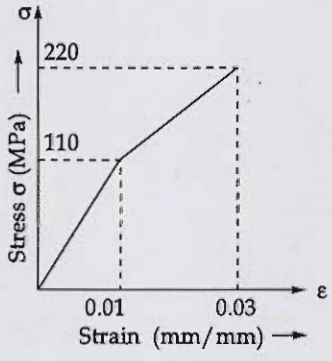
Section - A

.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]

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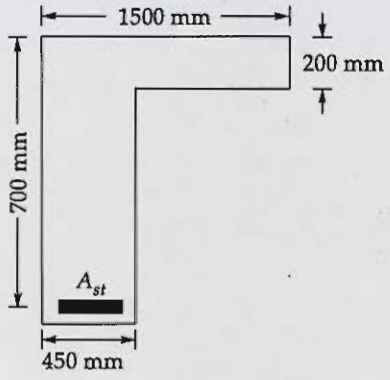
.1 (b) A simply supported beam is resting over an effective span of 14 m. If effective width of flange is 1500 mm. Calculate area of steel required for balanced a factored bending moment of 1000 kN-m. Use M30 grade of concrete and Fe415 grade of steel. (Use LSM).



[12 marks]

(b) Given,

Effective span, $l_{eff} = 14$ m $d = 700$ mm $b_w = 450$ mm

Effective width of flange, $b_f = 1500$ mm

M30 Fe 415 $BM_u = 1000$ kN-m

Let us assume ~~flange~~ ~~lies~~ ~~in~~ Neutral axis in the flange only.

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

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

On solving, we get $x_u = 93.42$ mm < 200 mm

Hence our assumption was correct.

Also,

$$x_{u,lim} = 0.48 \times d = 0.48 \times 700$$

$$= 336 \text{ mm}$$

$x_u < x_{u,lim}$ under Reinforced section.

So Area of steel required.

$$MOR = BM_u = 0.87 f_y A_{st} (d - 0.42 x_u)$$

$$A_{st} = \frac{1000 \times 10^6}{0.87 \times 415 \times [700 - 0.42 \times 93.42]}$$

12

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$A_{st} = 4191.66\ mm^2$

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

[12 marks]

TM⇒1) (c) Ceramic Material

properties

① They are brittle in natural.

② They have weak tensile strength.

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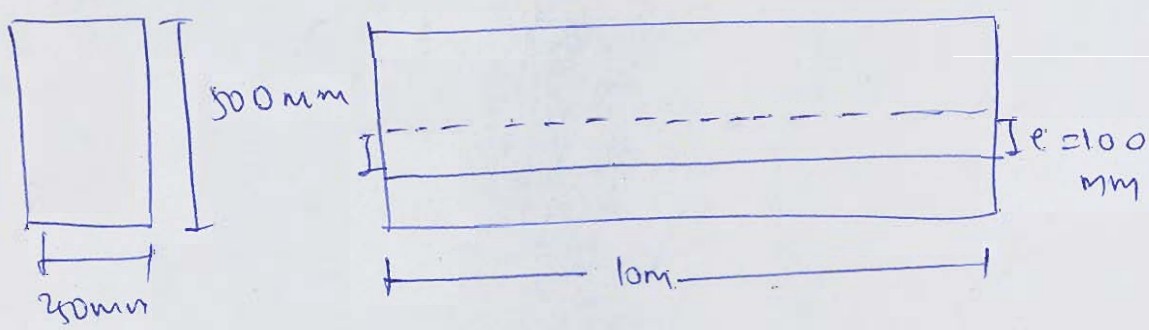
Q.1 (d) A prestressed concrete beam with a rectangular cross-section of 250 mm width and 500 mm depth spans 10 m. It carries a live load of 10 kN/m in addition to its self-weight. The beam is prestressed using a straight cable with a cross-sectional area 1800 mm^2, stressed to 750 N/mm^2. The cable is 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 ⇒ 1) (d)



$w_{dl} = 10\ KN/m$ $\quad w_{dl} = 25 \times 0.25 \times 0.50$

$= 3.125\ KN/m$

$w_T = 13.125\ \frac{KN}{m}$

$\sigma_0 = 750 \frac{N}{mm^2}$ $\quad A_c = 1800\ mm^2$

$P = \sigma_0 A = 1350\ KN$

At $x = 0$

$BM = 0$ $\quad \bar{x} = \frac{M}{P} = 0$

At $x = 1m$

$BM = 65.625 \times 1 - 13.125 \times 1 \times \frac{1}{2} = 59.06\ kNm$

$\bar{x} = \frac{59.06 \times 10^6}{1350 \times 10^3} = 43.75\ mm$

At $x = 2m$

$BM = 65.625 \times 2 - 13.125 \times 2 \times \frac{2}{2} = 105\ kNm$

$\bar{x} = \frac{105 \times 10^6}{1350 \times 10^3} = 77.78\ mm$

At $x = 3m$

$BM = 137.81\ kNm$

$\bar{x} = \frac{137.81 \times 10^6}{1350 \times 10^3} = 102.081\ mm$

check.

At $x = 4m$

$BM = 157.5\ kNm$

$\bar{x} = 116.67\ mm$

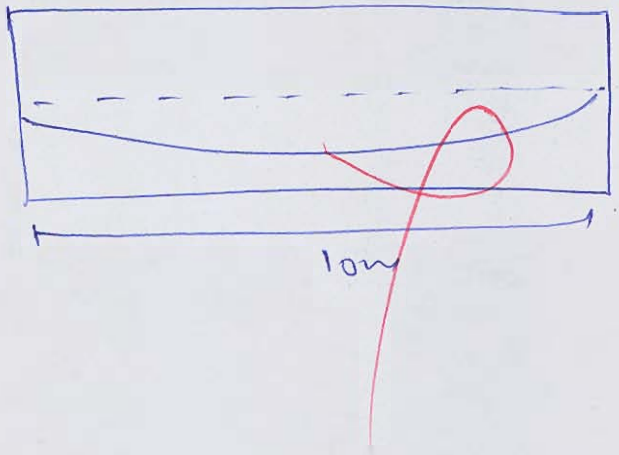
incomplete

(7)

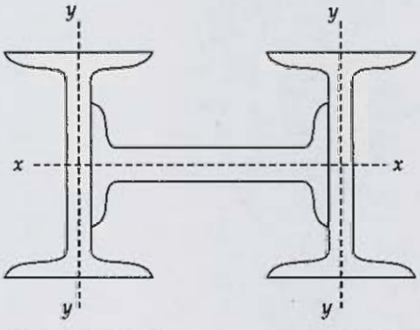
At $x = 5m$

$BM = 164.06\ kNm$

$\bar{x} = 121.525\ mm$



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.



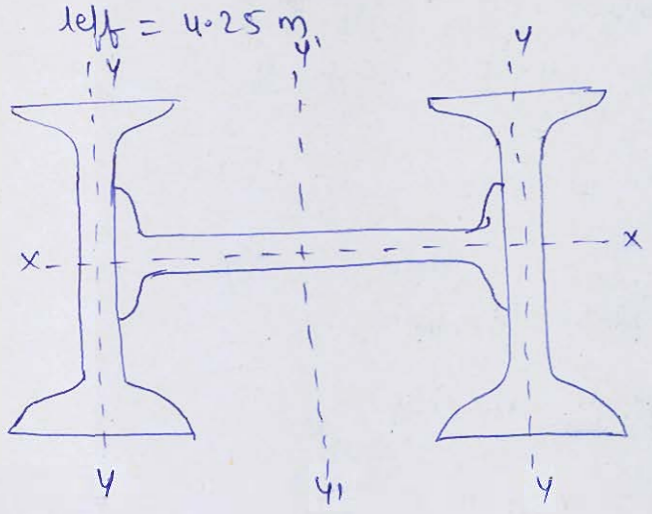
Properties of ISWB 450 @ 0.794 kg/m are as follows:

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]

~~y⇒1~~ (e) Given, $l_{eff} = 4.25\ m$



~~Area~~ $= 10111.5\ mm^2$

Area $= 10115\ mm^2$ $I_{xx} = 35057.6 \times 10^4\ mm^4$

$I_{44} = 1706.7 \times 10^4\ mm^4$ $t_w = 9.2mm$ $f_y = 250\ MPa$

MoI of Built up column about x-x axis

$$I_{xx} = 2 \times \left[35057.6 \times 10^4\right] + 1706.7 \times 10^4$$

$$= 71821.9 \times 10^4\ mm^4$$

MoI of Built up column about 4-4 axis

$$I_{44'} = 2 \times \left[1706.7 \times 10^4 \times 10115 \times \left(\frac{450}{2}\right)^2\right] + 35057.6 \times 10^4$$

$$= 14088.53 \times 10^5\ mm^4$$

~~I~~ $I_{min} = I_{xx}$

$$\therefore r_{min} = \sqrt{\frac{I_{xx}}{A}} = \sqrt{\frac{71821.9 \times 10^4}{3 \times 10115}}$$

$$r_{min} = 153.84\ mm$$

Slenderness Ratio

$$\left(\frac{KL}{r_{min}}\right) = \frac{4250}{153.84} = 27.625$$

$$f_{cd} = 223 + (204-223) \times \frac{(27.625-20)}{(30-20)}$$

$$f_{cd} = 208.51 \text{ N/mm}^2$$

Load carrying capacity

$$P_u = f_{cd} \times A_g$$

$$P_u = 208.51 \times 3 \times 10115$$

$$P_u = 6327.31 \text{ kN}$$

Safe load carrying capacity

$$P_{safe} = 4218.2 \text{ kN}$$

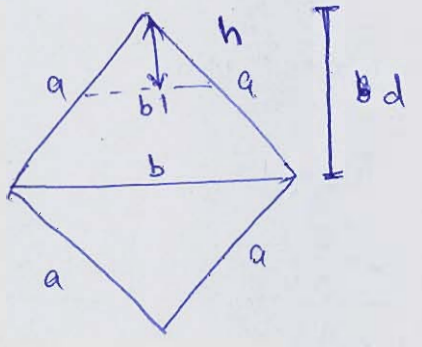
12

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]

Ans ⇒ 2> (a)



a = 2cm

V = 16000N

To find shear stress at a distance 'h' from top.

We know

Shear stress is given by

$$q = \frac{V A\bar{y}}{I b}$$

where I = MOI of entire section.

~~I =~~

~~web~~ we have $\boxed{b = \sqrt{2}\,a}$ $\boxed{d = \frac{a}{\sqrt{2}}}$

$$I = 2 \times \left[\frac{b d^3}{12}\right] = 2 \times \left[\frac{\sqrt{2}a \times (a/\sqrt{2})^3}{12}\right]$$

$$I = 2 \times \frac{\sqrt{2}a}{12} \times \frac{a^3}{2\sqrt{2}} = \frac{a^4}{12}$$

$$\boxed{I = \frac{a^4}{12}}$$

$$\frac{b'}{b} = \frac{h}{d} \Rightarrow \boxed{b' = \frac{bh}{d}}$$

$$\Rightarrow A = \frac{1}{2} b' \times h = \frac{1}{2} \times \frac{bh}{d} \times h = \frac{bh^2}{2d}$$

$$\bar{y} = \left(d - h + \frac{1}{3}h\right) = \left(d - \frac{2h}{3}\right)$$

∴ Shear stress

$$q = \frac{V \times \frac{bh^2}{2d} \times \left(d - \frac{2h}{3}\right)}{\frac{a^4}{12} \times \frac{bh}{d}}$$

$$q = \frac{V \times \left(d - \frac{2h}{3}\right) \times h}{\frac{a^4}{12} \times \times \times 2}$$

Substituting the value

$$q = \frac{V\left(d - \frac{2h}{3}\right) \times h}{\frac{a^4}{6}} \Rightarrow \boxed{q = \frac{6V\left(d - \frac{2h}{3}\right)h}{a^4}}$$

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Formula for shear stress

$$q = \frac{6V\left(d - \frac{2h}{3}\right)h}{a^4}$$

At NA

$$d = h = \frac{a}{\sqrt{2}}$$

$$q = \frac{6 \times 16000\left[\frac{a}{\sqrt{2}} - \frac{2}{\sqrt{2}}\times\frac{a}{3}\right]\times\frac{a}{\sqrt{2}}}{(\sqrt{2})^4}$$

$$q = 5490.33 \ \frac{N}{cm^2} = 16000 \ \frac{N}{cm^2}$$

$$q = 54.90 \ \frac{N}{mm^2}$$

$$q = 160 \ \frac{N}{mm^2}$$

For maximum shear stress

$$q = \frac{6V\left[\frac{a}{\sqrt{2}} - \frac{2}{3}\times\frac{a}{\sqrt{2}}\right]\times\frac{a}{\sqrt{2}}}{a^4}$$

$$q = \frac{6V\left[\frac{a^2}{2} - \frac{a^2}{3}\right]}{a^4}$$

$$\frac{dq}{dh} = 0 \Rightarrow \frac{6V}{a^4}\left[d - \frac{4h}{3}\right]$$

At $h = \frac{3}{4}d$

Max^m shear stress will occur at depth $\frac{3}{4}d$ from the top.

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Magnitude

$$q_{max} = \frac{6V}{a^4}\left[\frac{3}{4}\times d^2 - \frac{2}{3}\times\left(\frac{3}{4}d\right)^2\right]$$

$$q_{max} = \frac{6\times 16000}{(\sqrt{2})^4}\left[\frac{3}{4}\times\left(\frac{a}{\sqrt{2}}\right)^2 - \frac{2}{3}\times\left(\frac{3}{4}\times\sqrt{2}\right)^2\right]$$

$$q_{max} = 18000\ \frac{N}{cm^2}$$

12

$$\boxed{q_{max} = 180\ \frac{N}{mm^2}}$$

Ans⇒2⟩(a) (ii) $d = 15mm$ $L = 1.4m$ $h_{max} = 95\ mm$

$W = ?$ $\sigma_{max} = 150\ MPa$ $E = 200$

$$W\left[\delta_{max} + h\right] = \frac{1}{2}\frac{\sigma^2}{2E}\times A\times L$$

$$\Rightarrow W\left[\frac{\sigma L}{E} + h\right] = \frac{1}{2}\times\frac{\sigma^2}{2E}\times A\times L$$

$$\Rightarrow W\left[\frac{150\times 1.4}{200\times 10^3} + 0.095\right] = \frac{1}{2}\times\frac{(150)^2}{200\times 10^3}\times\frac{\pi}{4}\times 15^2\times 1400$$

$$\Rightarrow W\times 0.096 = 13.916$$

$$\boxed{W = 144.96\ N}$$

8

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

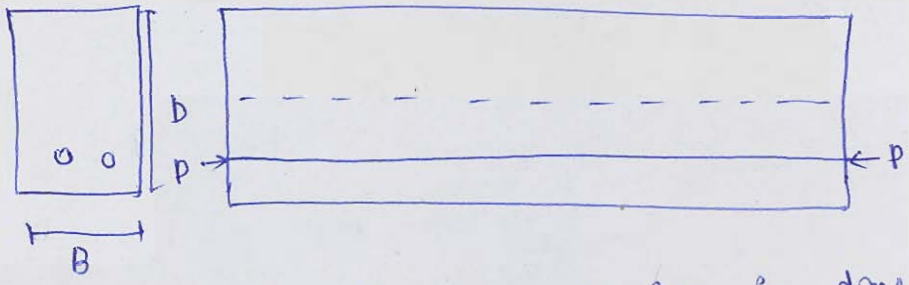
(ii) Design a circular column with a diameter of 400 mm, reinforced with helical reinforcement, to safely carry a working load of 1200 kN. Use M20 grade concrete and Fe415 grade steel. The column has an unsupported length of 3 m and is effectively held in position at both ends but is not restrained against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

Ans⇒2> (b) (i) Prestressing is done in RCC members so as so introduce compressive force at the bottom position of the concrete.

* These compressive force by prestress compensate the tensile force develop by dead load & live load of the RCC member. So No cracking or cracking upto certain limit which permissible is formed.



* In the above figure prestressing is done at bottom portion to neutralise the tensile stresses.
* Tendons can be straight cable or parabolic cable.
* There are generally 2 methods of prestressing
  1) Pre-tensioning. 2) post tensioning.
* In Pre-tensioning method, tendons are first stressed and then concrete is casted. Tendons & concrete are in direct contact with each other. After some time when the ~~tendons~~ concrete harden, tendons are cut & prestressing force is transferred to concrete Also called as Hoyer line method.
* In post tensioning method - Duct are provided & concrete is casted. then tendons are provided in the duct & they are threaded at the end.
* Jacking is done either from one end or both end & in this way prestress is transfer.

* Various method of post tensioning are.
a) Freyssinet
b) magnel Blaton
c) Gifford udal
d) Lemcall method.

(6)

Q.2 (b) (ii) Diameter, D = 400 mm P = 1200 kN

M 20 Fe 415 $P_u = 1.5 \times 1200$

$= 1800$ kN

$l_{eff} = 3$ m

check

$\frac{l_{eff}}{D} = \frac{3000}{400} = 7.5 < 12$ short column

load carrying capacity of circular column.

$$1800 \times 10^3 = 1.05 \left[0.4 f_{ck} A_g + A_{sc} (0.67 f_y - 0.4 f_{ck}) \right]$$

$$\Rightarrow 1800 \times 10^3 = 1.05 \left[0.4 \times 20 \times \frac{\pi}{4} \times 400^2 + (0.67 \times 415 - 0.4 \times 20) \times A_{sc} \right]$$

$$\Rightarrow A_{sc} = \frac{\frac{1800 \times 10^3}{1.05} - 1005.3 \times 10^3}{0.67 \times 415 - 0.4 \times 20}$$

$$A_{sc} = 2625.38 \text{ mm}^2$$

use 24 mm ϕ of 6 nos.

check for eccentricity

$$e_{x-x} = \max \left\{ \frac{l_0}{500} + \frac{D}{30} = 19.33 \text{ mm} \right.$$

$$\left. \text{or} \quad 20 = 20 \text{ mm} \right.$$

$= 20$ mm

$e_{min} \leq 0.05\,D$

$20 \leq 0.05\,D$

$D \geq 400\,mm$ Hence OK

Design for R/f

$$0.36\,\frac{f_{ck}}{f_y}\left[\frac{A_g}{A_c} - 1\right] \leq \frac{V_h}{V_c}$$

$D = 400\,mm$ let $EC = 40\,mm$. $D_c = 320\,mm$.

$$0.36 \times \frac{20}{415}\left[\frac{400^2}{320^2} - 1\right] \leq \frac{1000}{p} \times \frac{\pi \times D_h \times \frac{\pi}{4} \times \phi_h^2}{\frac{\pi}{4} \times 320^2 \times 1000}$$

let $\phi_h = 8\,mm$ & $D_h = 320 + 8 = 328\,mm$

$$\Rightarrow 9.75 \times 10^{-3} \leq \frac{1000}{p} \times \frac{\pi \times 328 \times \pi \times 8^2}{\pi \times 320^2}$$

$$\boxed{p \leq 66.05\,mm}$$

Check

$p \geq 3 \times \phi_h \geq 24\,mm$

$\geq 25\,mm$

& $p \leq 75\,mm$

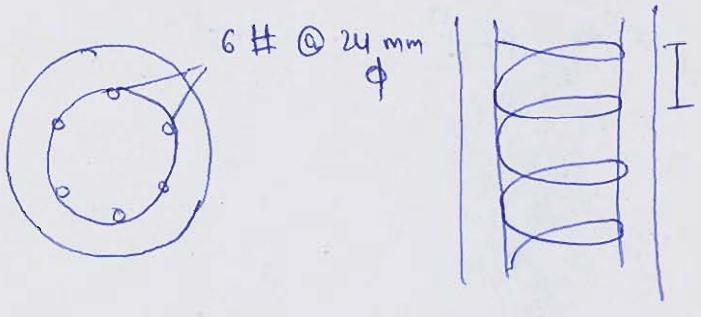
$p \leq \frac{D_c}{6} \leq 53.33\,mm$

$$\phi_h = \max\left\{\frac{\phi_{main}}{4} = \frac{24}{4} = 6\,mm,\ 6\,mm\right\}$$

~~let~~ we have use

$\boxed{\phi_h = 8\,mm}$ OK

Hence provide pitch @ 50 mm c/c spacing.



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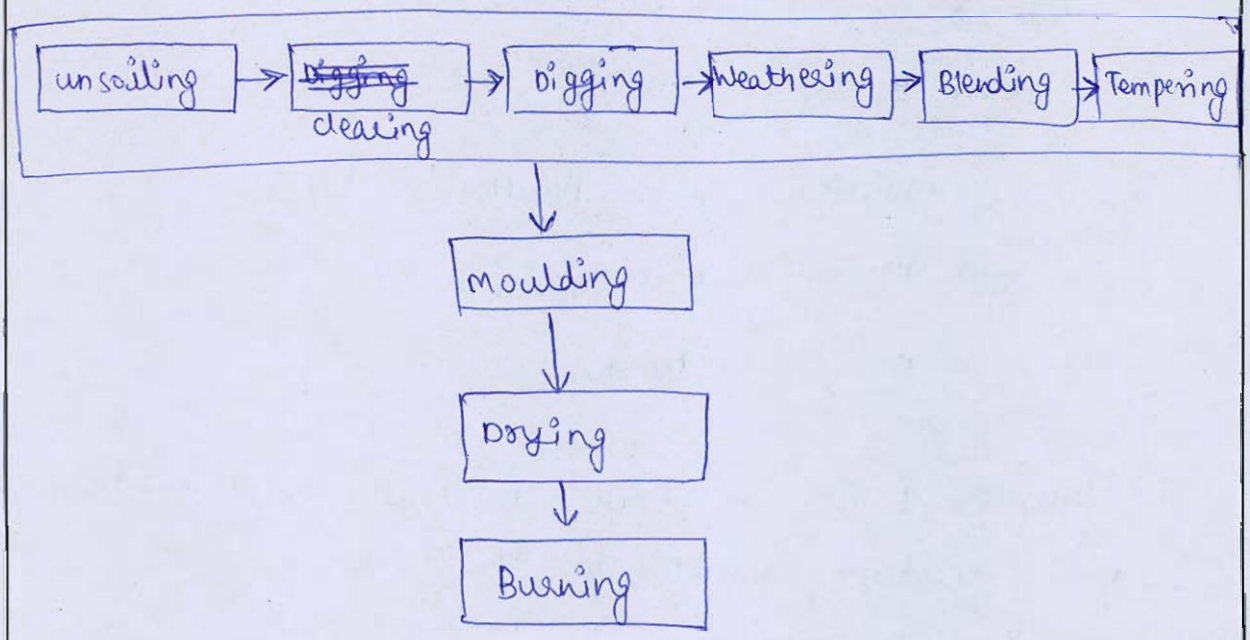
Q.2 (c) (i) Show the operations involved in the manufacturing of clay bricks using a flow chart. Describe the various steps involved in the preparation of brick earth.

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

[10 + 10 = 20 marks]

Ans=>2> (c) (i) Various operations involved in the manufacturing of brick are



(A) • Unsoiling – Top 200 mm soil layer is removed ~~and~~ to obtain good soil material.

• Clearing – clearing of top layer of the soil to remove grit, gravel and pebbles.

• Digging – The ~~soil~~ soil sample is dig out & sprinkled on the surface on the levelled ground.

• Weathering – The soil is exposed to atmosphere for oxidation & removal of moisture.

• Blending – Blending of soil is done to make soil loose.

• Tempering – Tempering is done in pug mill.

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(B) Moulding - The clay after tempering is moulded to obtain definite shape.

* Moulding can be done in 2 ways.
  1) Hand Moulding 2) Machine Moulding

* Hand moulding can be further 2 types
  - Ground moulding.
  - Table moulding

* Machine moulding can be further 2 types
  - Plastic clay brick
  - Dry clay brick.

(C) Drying - Drying is brick is done to lower down the moisture content of the brick.

* Drying can be done by proper stacking or in Hot flow Tunnel.

(D) Burning - Burning is done to get hardened brick & to get desired strength.
3 steps in burning are.
(a) Dehydration (450° - 600°C)
(b) Oxidation (600 - 900°C)
(c) Vitrification (900 - 1150°C)

10

Any=>2 (c) (ii) Factors affecting the selection of construction equipment are -

(1) Condition of equipment - If repairing cost of old equipment is less than depreciation cost of new equipment, then it is desirable to use old

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equipment.

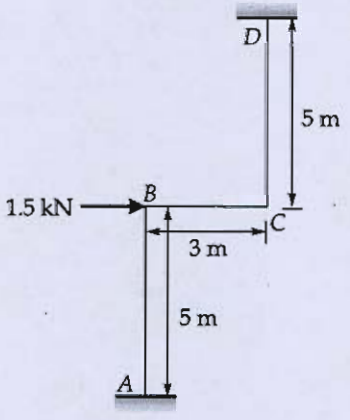
(2) Life of equipment - The equipment selected must have good service life. ~~before its scrap~~ valu

(3) ~~The const~~ Less maintenance - The equipment should have less maintenance cost & should have good scrap value.

(4) Capacity to work - The equipment should be chosen to carry out desired work in respective location.

(5) Efficiency - The equipment should have high efficiency.

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



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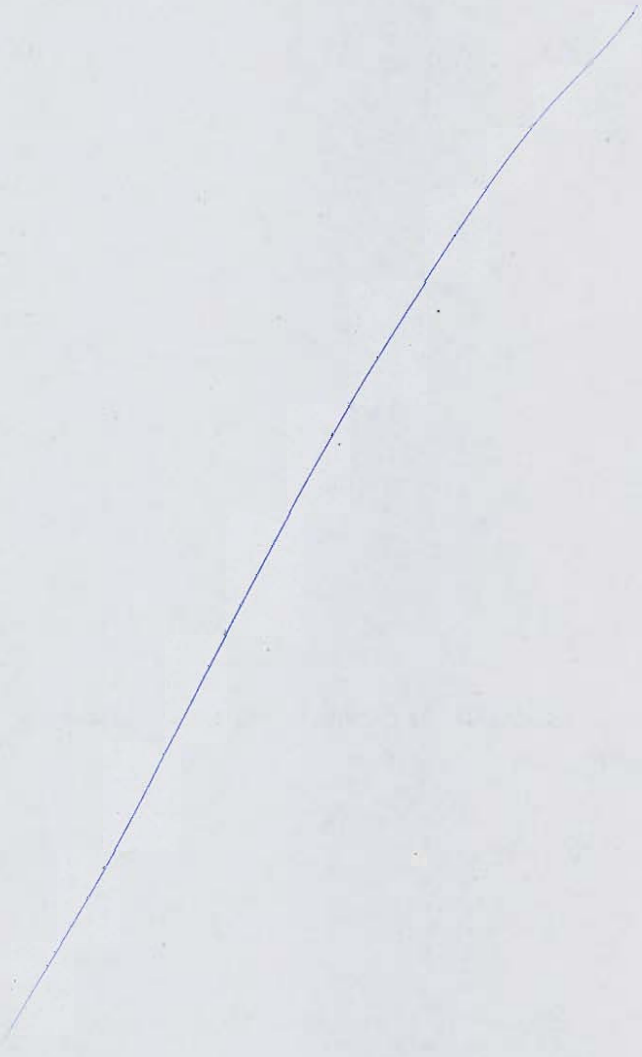

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Q.3 (b) (i) Explain Non-Destructive Testing (NDT) in concrete. Describe the working principle and procedure of the Rebound Hammer Test. Also mention its suitability and limitations.

(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

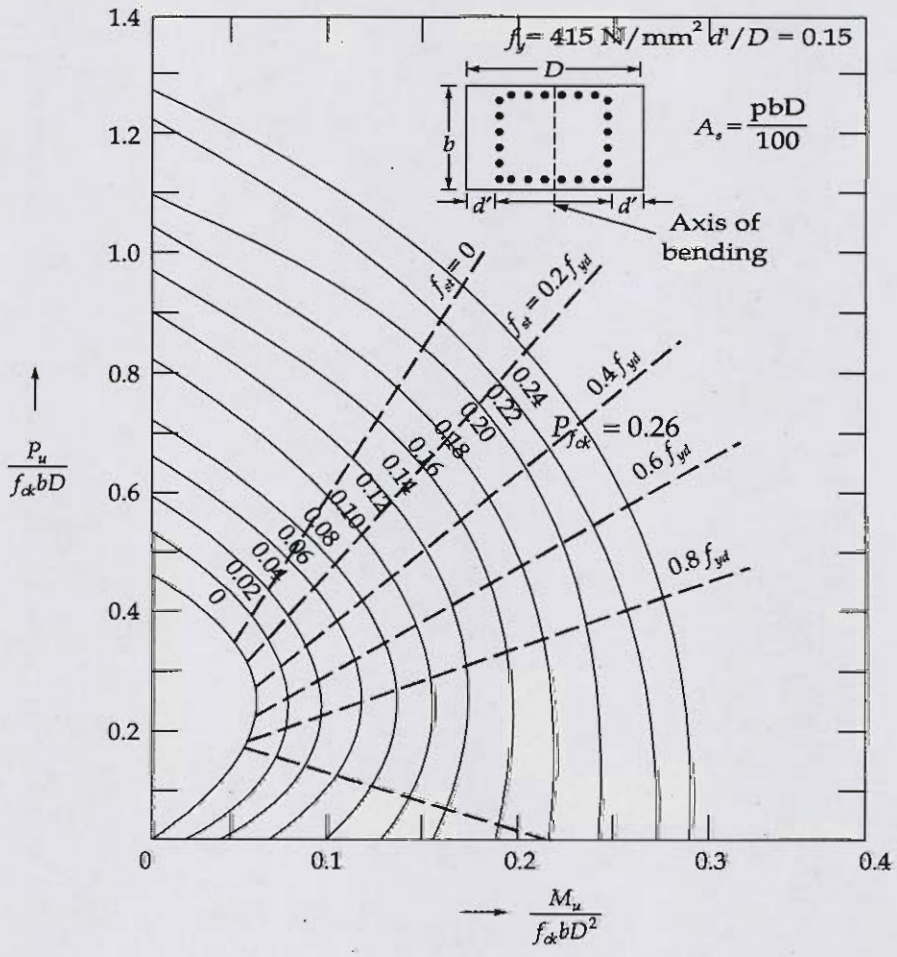
Arrangement of reinforcement bars: On four sides

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]

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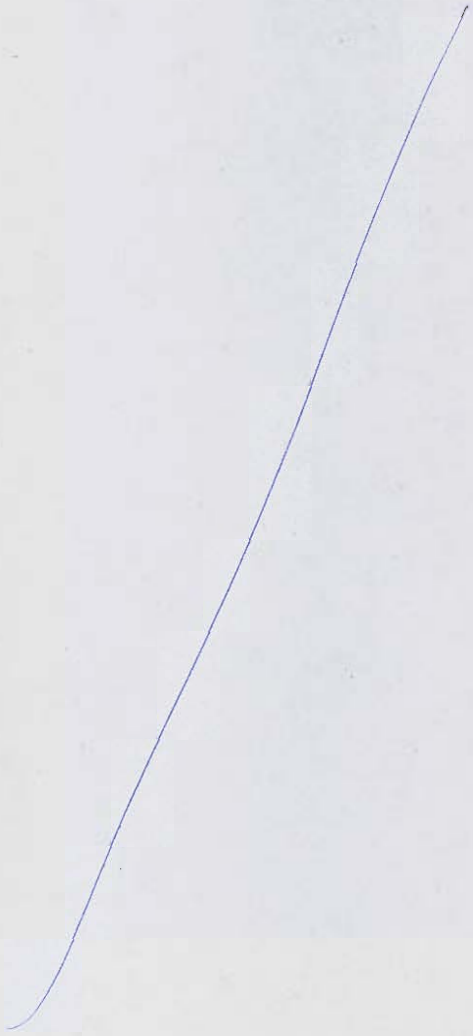

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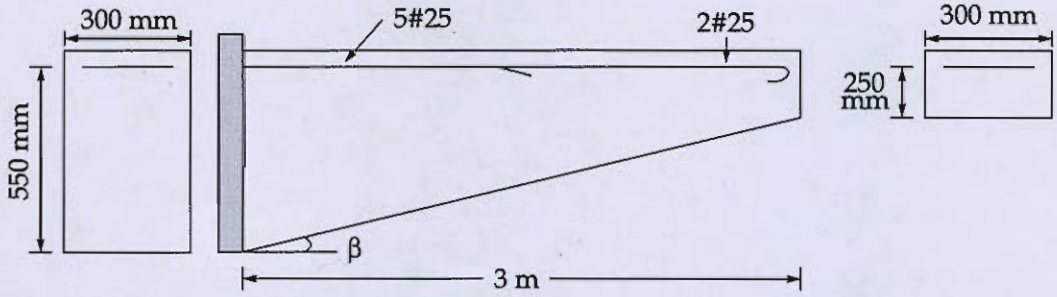
Q.3 (c) (i) Explain briefly the concept of shear lag effect in beams. As per IS 800:2007, under which conditions can shear lag effect in flanges be neglected? Also, mention the factors that influence the shear lag effect.

(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]

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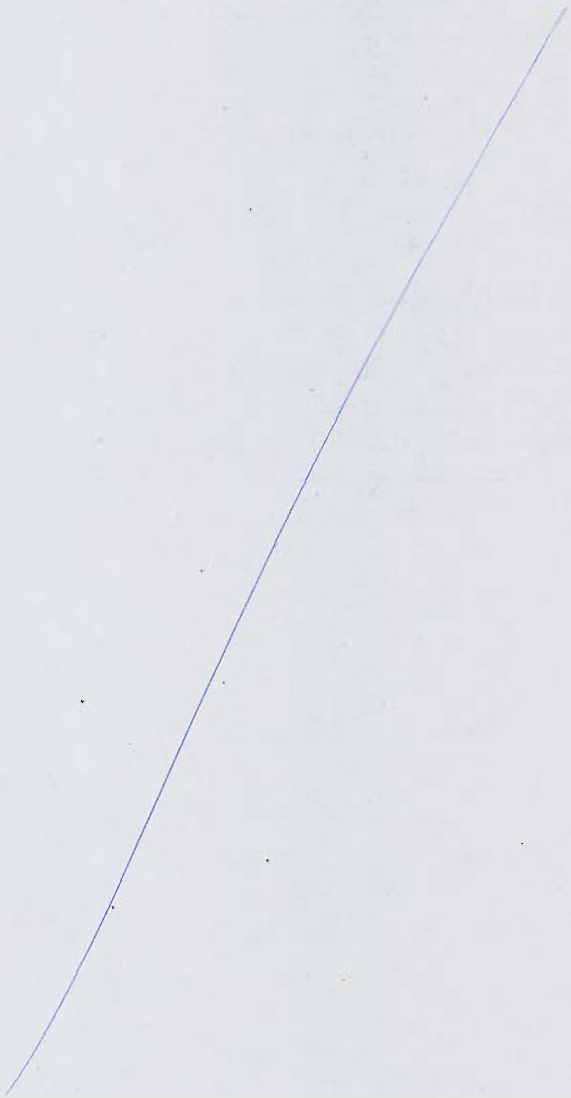

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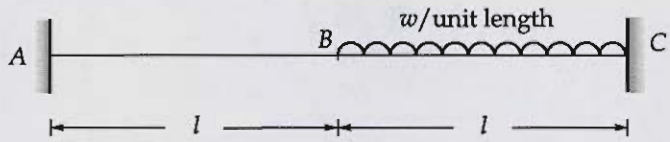
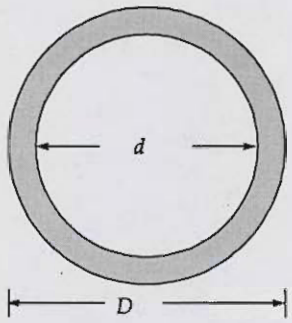
Q.4 (a) (i) A beam fixed at both the ends is subjected to a uniformly distributed load w per unit length on its right half portion as shown below. Determine the collapse load if the beam is of uniform cross-section.

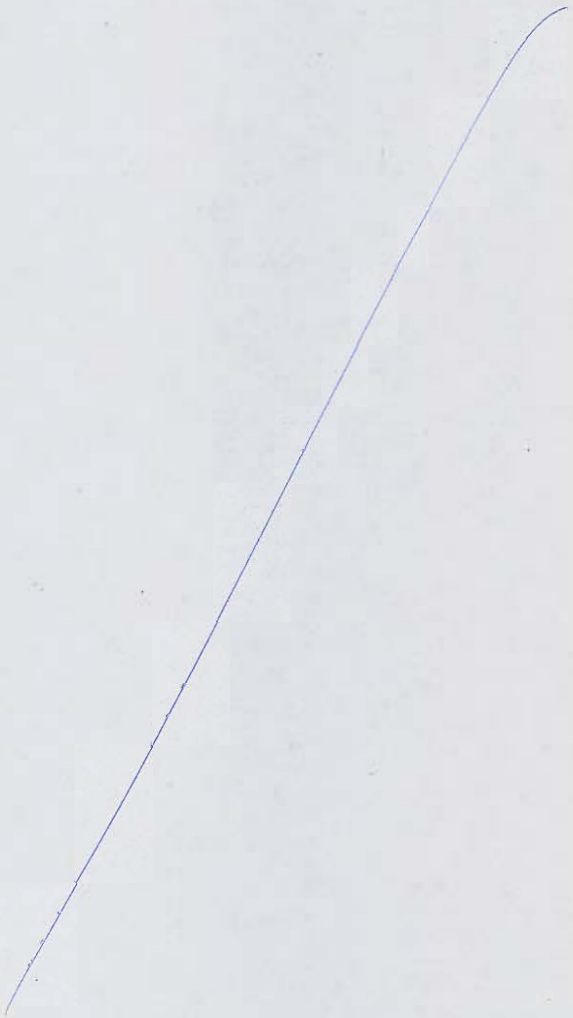
Take: Plastic moment capacity = M_p



(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]



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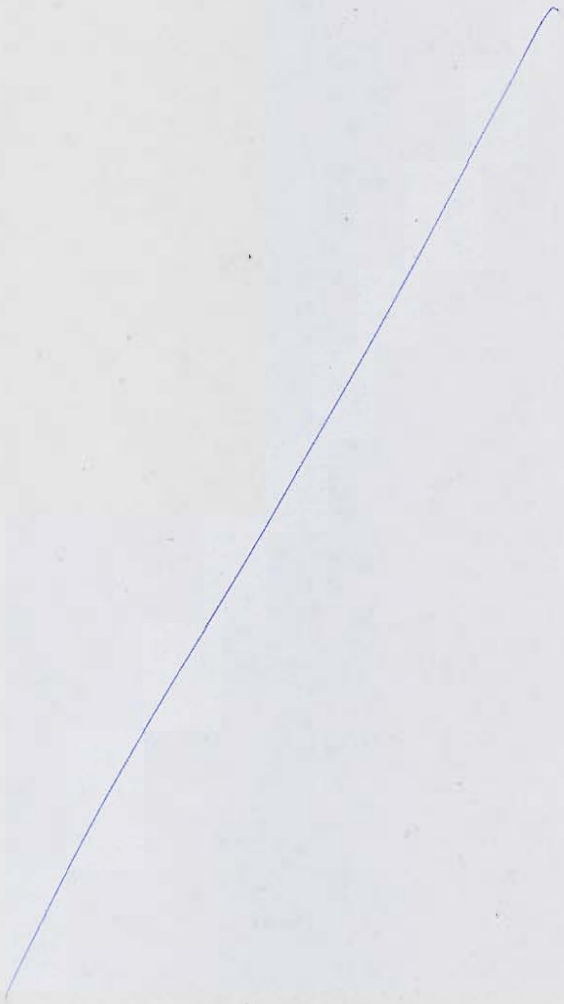

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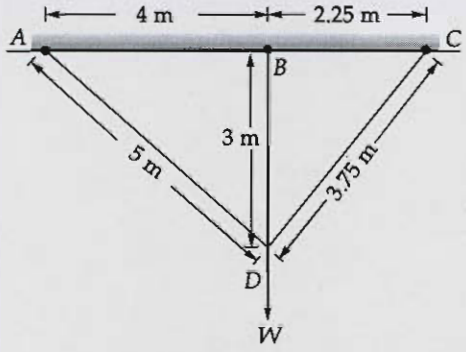
Q.4 (b) Three wires *AD*, *BD* and *CD* having the same cross-sectional area and of the same material support a load *W* as shown in figure. Determine the tension in the three wires. Show also that the horizontal movement of *D* equals one-seventh of the extension of *BD*.



[20 marks]

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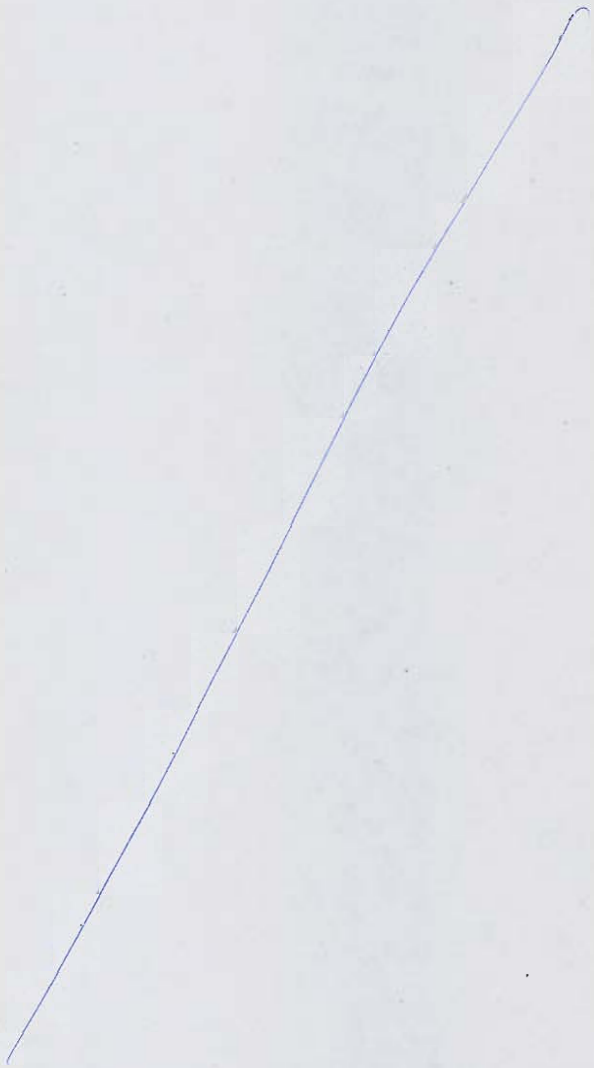

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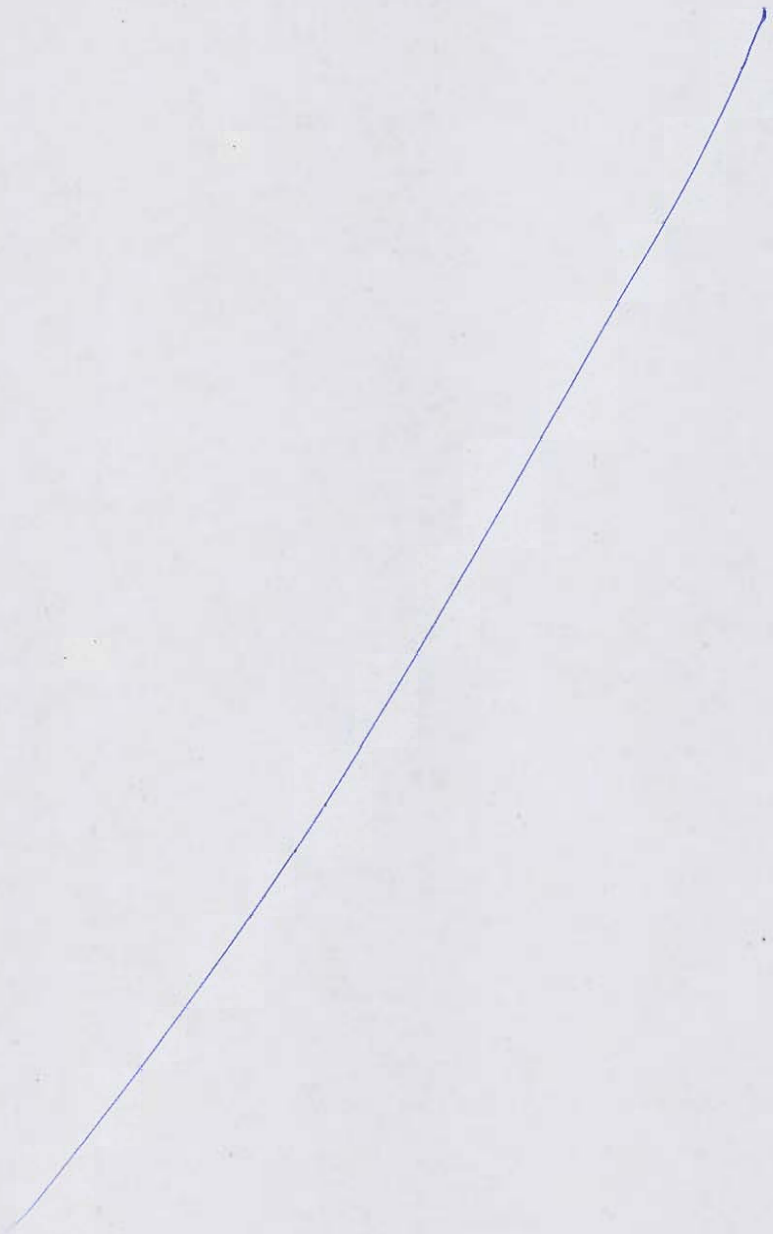

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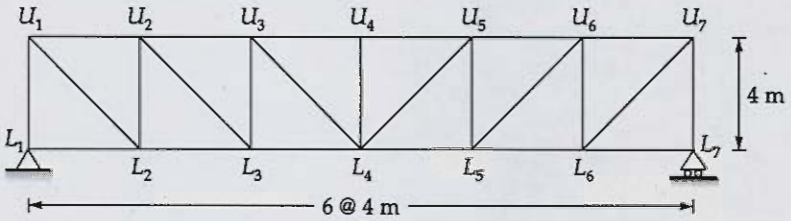
Q.4 (c) Draw the influence line diagram for forces in the members U_3L_4, U_3U_4 and U_3L_3 of the frame as shown in figure and find the maximum forces developed, when uniformly distributed load of intensity 40 kN/m, longer than the span moves from left to right on bottom chord (Neglect the self weight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



[20 marks]

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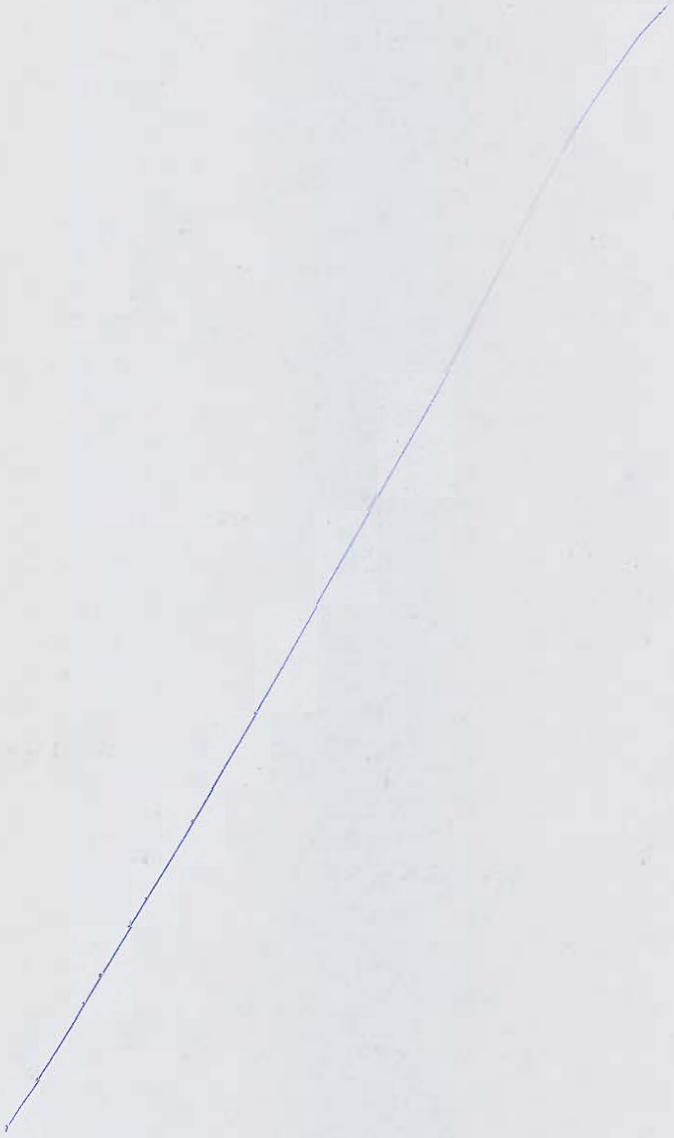

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Section - B

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]

M-25) (a) Slump Test for workability

- ★ In this test concrete is prepared.
- ★ Frustum of cone having top dia 100 mm & bottom dia 200 mm & height 300 mm is used.
- ★ The frustum is placed on the impervious flat surface on the levelled ground & the concrete is powed into it.
- ★ The concrete is compacted in 3 to 4 layer with tamping bar.
- ★ Top surface is levelled & excess of concrete is screed off from the surface.
- ★ Now the cone is lifted up.

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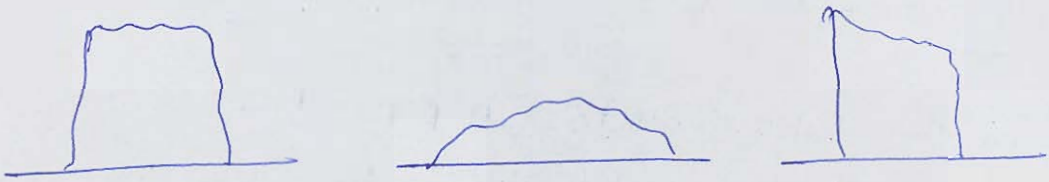
* The height difference between the top of frustum & top of subside cone is given as slump value. various types of slump formed are as follows -

1) True slump indicate concrete of desired workability.

2) Collapse slump indicate concrete of very high workability.

3) Shear slump indicate concrete of dry workability.



True slump | Collapse slump | Shear slump

various Range of slump required are

1. For Road - 25-50 mm
2. mass concrete - 20-40 mm
3. concrete to be vibrated - 10-15 mm
4. Normal RCC work - 100-150 mm
5. Canal lining - 70-80 mm

12

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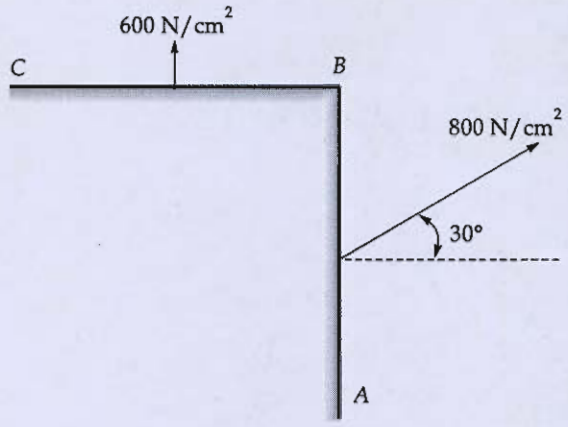
Q.5 (b) The intensity of resultant stress on a plane *AB* as shown in figure at a point in a material under stress is 800 N/cm^2 and it is inclined at 30° to the normal to that plane. The normal component of stress on another plane *BC* at right angles to plane *AB* is 600 N/cm^2.



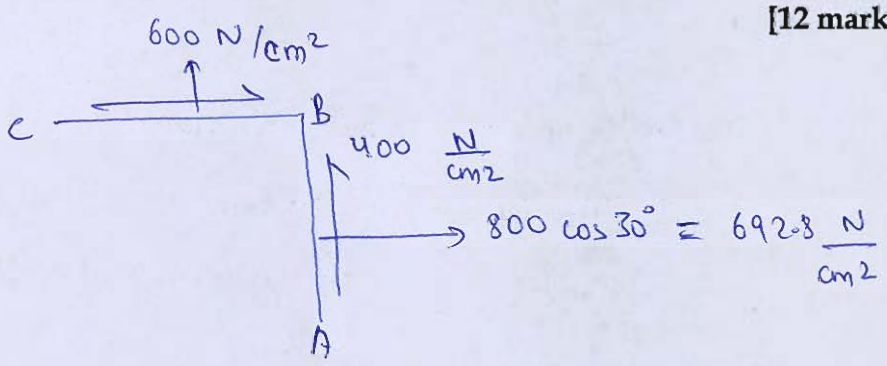
Determine the following:

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

(ii) the principal stresses and their directions.

[12 marks]

my ⇒ 5) (b)



(i) Resultant stress on the plane BC

$$(\sigma_R)_{BC} = \sqrt{600^2 + 400^2}$$

$$= 721.11 \ \frac{N}{cm^2}$$

(ii) Principal stresses and their directions

$$\sigma_x = 692.8 \ \frac{N}{cm^2} \qquad \sigma_y = 600 \ \frac{N}{cm^2} \qquad \tau_{xy} = 400 \ \frac{N}{cm^2}$$

$$\sigma_{1/2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \left(\frac{692.8 + 600}{2}\right) \pm \sqrt{\left(\frac{692.8 - 600}{2}\right)^2 + 400^2}$$

$= 646 \pm 402.68$

$\sigma_1 = 1049.08 \frac{N}{cm^2}$ $\quad \sigma_2 = 243.72 \frac{N}{cm^2}$

Inclination on principal stresses

$$\tan 2\theta_{p1} = \left(\frac{2\tau_{xy}}{\sigma_x - \sigma_y}\right)$$

$$= \left(\frac{2 \times 400}{692.8 - 600}\right)$$

$\theta_{p1} = 41.69°$ $\quad \theta_{p2} = 131.69°$

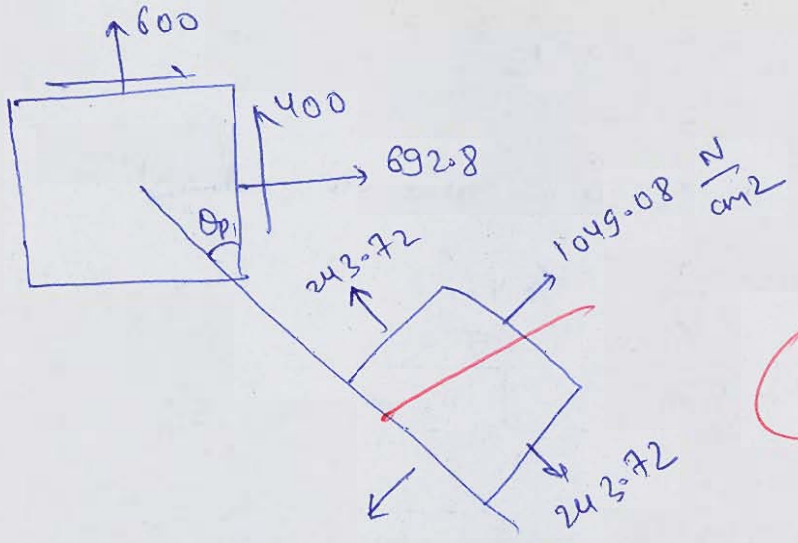
Check

$$\sigma_{x'} = \sigma_x \cos^2\theta + \sigma_y \sin^2\theta + 2\tau_{xy} \sin\theta \cos\theta$$

$$= 692.8 \times \cos^2(41.69) + 600 \sin^2(41.69) + 2 \times 400 \times \sin(41.69) \cos(41.69)$$

$\sigma_{x'} = 1049.08 \frac{N}{cm^2}$

So $\theta_{p1} = 41.69°$ is major principal plane



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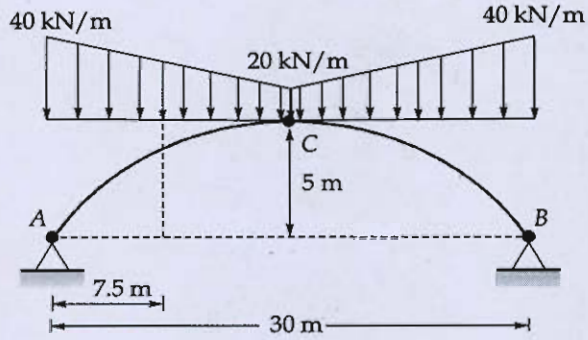
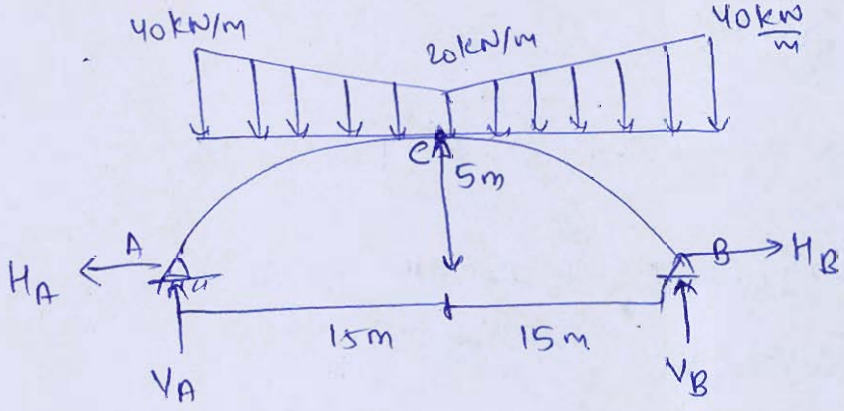
Q.5 (c) A three-hinged parabolic arch of span 30 m and rise 5 m carries a load whose intensity uniformly varies from 20 kN/m at the crown to 40 kN/m at the ends. Find the bending moment, normal thrust and radial shear at a section passing through arch vertically at a distance of 7.5 m from the left end.



[12 marks]

Ans⇒5 (c)



$\Sigma F_y = 0$

$\Rightarrow V_A + V_B = 2 \times \left[\frac{1}{2} \times (40+20) \times 15\right] = 900\ kN$

$\Sigma M_B = 0$

$\Rightarrow V_A \times 30 - 20 \times 30 \times \frac{30}{2} - \frac{1}{2} \times 15 \times 20 \times \left(\frac{15}{3}\right)$

$- \frac{1}{2} \times 15 \times 20 \times \left[15 + \frac{2}{3} \times 15\right] = 0$

$\Rightarrow \boxed{V_A = 450\ kN}$ $\boxed{V_B = 450\ kN}$

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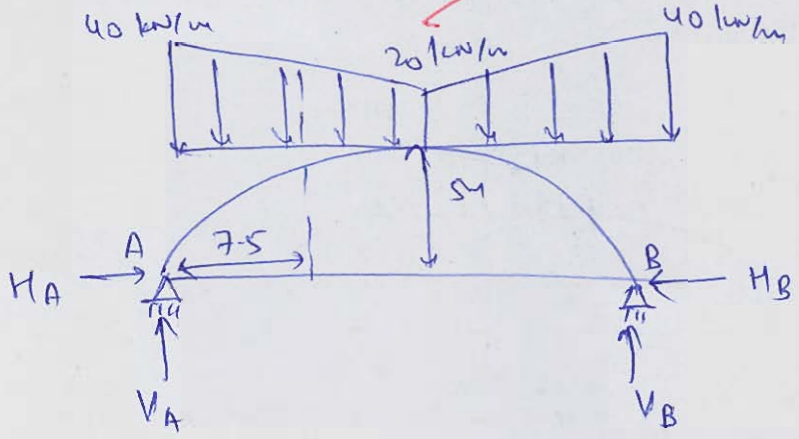
$\Sigma m_C = 0$

$\Rightarrow V_A \times 15 - 20 \times \frac{15 \times 15}{2} - \frac{1}{2} \times 15 \times 20 \times \left(\frac{2}{3} \times 20\right) + H_A \times 5 = 0$

$\Rightarrow 450 \times 15 - 20 \times \frac{15^2}{2} - \frac{15}{2} \times 20 \left(\frac{2}{3} \times 20\right) + H_A \times 5 = 0$

$H_A = -500$ KN

$H_B = -500$ kN



$y = \frac{4h}{L^2}(Lx - x^2)$

$\frac{dy}{dx} = \frac{4h}{L^2}(L - 2x) \Rightarrow \frac{4 \times 5}{30^2}(30 - 2 \times 7.5)$

$\theta = 0.333$ rad

$\theta = 19.09°$

At $x = 7.5$ m

$y = 3.75$ m

BM at $x = 7.5$

$BM = 450 \times 7.5 - 500 \times 3.75 - \frac{1}{2} \times 7.5 \times 30 \times \frac{7.5}{2}$

$- \frac{1}{2} \times 7.5 \times 10 \times \frac{2}{3} \times 7.5$

$BM = 468.75$ kN m

1D

Normal Thrust

$T = H_A \cos\theta - V_A \sin\theta$

$= 500 \times \cos(19.09) - 450 \sin(19.09)$

$= 325.33$ kN

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Radial shear

$Q = H_A \sin\theta + V_A \cos\theta$

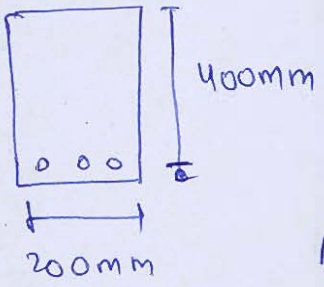
$Q = 500 \sin(19.09) + 450 \cos(19.09)$

$\boxed{Q = 588.78 \text{ kN}}$

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]

Y⇒S> (d)



$B = 200$ mm

$d = 400$ mm

Fe 415 M 20

$A_{st} = 3 \times \frac{\pi}{4} \times 16^2 = 603.18 \text{ mm}^2$

$l_{eff} = 5$ m

$MOR = 0.87 \times f_y \times A_{st} (d - 0.42 x_u)$

For NA

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

$\Rightarrow 0.36 \times 20 \times 200 \, x_u = 0.87 \times 415 \times 603.18$

$x_u = 157.23$ mm

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

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

$MOR = 0.87 \times 415 \times 603.18 (400 - 0.42 \times 157.23)$

$MOR = 73.27$ KNm

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For ultimate load

$$MOR = BM_{max}$$

for simply supported Beam

$$MOR = \frac{w_u \, d_{eff}^2}{8}$$

$$73.27 = \frac{w_u \times 5^2}{8}$$

$$\boxed{w_u = 23.45 \ \frac{KN}{m}}$$

∴ ultimate load per unit length = $23.45 \frac{KN}{m}$

For point load

$$MOR = \frac{W_u L}{4}$$

$$73.27 = \frac{W_u \times 5}{4}$$

$$\boxed{W_u = 58.616 \ KN}$$

(12)

ultimate load = 58.616 KN

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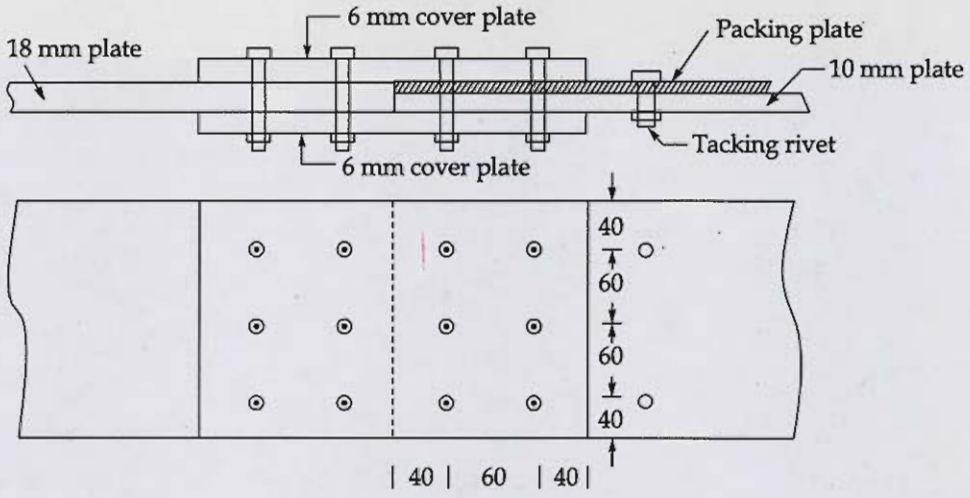
Q.5 (e) Two cover plates, 10 mm and 18 mm thick are connected by a double cover butt joint using 6 mm cover plates as shown in figure. Find the strength of the joint. Given M20 bolts of grade 4.6 and Fe 415 plates are used.

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]

(e) Given, M20 Bolt $f_{ub} = 400$ MPa

$f_{yb} = 240$ MPa Fe 415 plates

(a) Strength of Bolt in shear.

$$V_{dsb} = \frac{f_{ub}}{\sqrt{3}\,\gamma_{mb}} \times [n \times A_{nb} + n \times A_{sb}]$$

$$= \frac{400}{\sqrt{3} \times 1.25}\left[1 \times 0.78 \times \frac{\pi}{4} \times 20^2 + 1 \times \frac{\pi}{4} \times 20^2\right]$$

$$= 103.31 \text{ KN}$$

(b) Strength of bolt in bearing.

$$V_{dpb} = 2.5\,K\,d\,t\,\frac{f_u}{\gamma_{mw}}$$

$$K = \min\left\{\frac{e}{3d_0},\ \frac{p}{3d_0} - 0.25,\ \frac{f_{ub}}{f_u},\ 1\right\}$$

$e = 40\,mm \quad d_0 = 22\,mm \quad p = 60\,mm$

$$k_b = \min \begin{cases} \frac{40}{3\times 22} & = 0.606 \\ \frac{60}{3\times 22} - 0.25 & = 0.659 \\ \frac{400}{410} & = 0.97 \\ 1 & = 1 \end{cases}$$

$k_b = 0.606$

$$V_{dpb} = 2.5 \times 0.606 \times 20 \times 10 \times \frac{400}{1.25}$$

$$= 96.96\ kN$$

(c) Strength of plate in rupture

$$T_{dn} = \frac{0.9 f_u \times A_n}{1.25}$$

$$A_n = (200 - 3\times 22)\times 10 = 1340\ mm^2$$

$$T_{dn} = \frac{0.9\times 400 \times 1340}{1.25} = 385.92\ kN$$

(d) Strength of solid plate

$$T_{dg} = \frac{(200\times 10)\times 250}{1.1} = 454.54\ kN$$

10

Efficiency of Joint

$$\eta = \frac{\text{strength of Joint}}{\text{strength of solid plate}} \times 100$$

strength of Joint $= \min\{3\times 103.31, 3\times 96.96, 385.92\}$

$= 290.88\ kN$

$$\eta = \frac{290.88}{454.54} \times 100 = 63.99\,\% \simeq \boxed{64\,\%}$$

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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]

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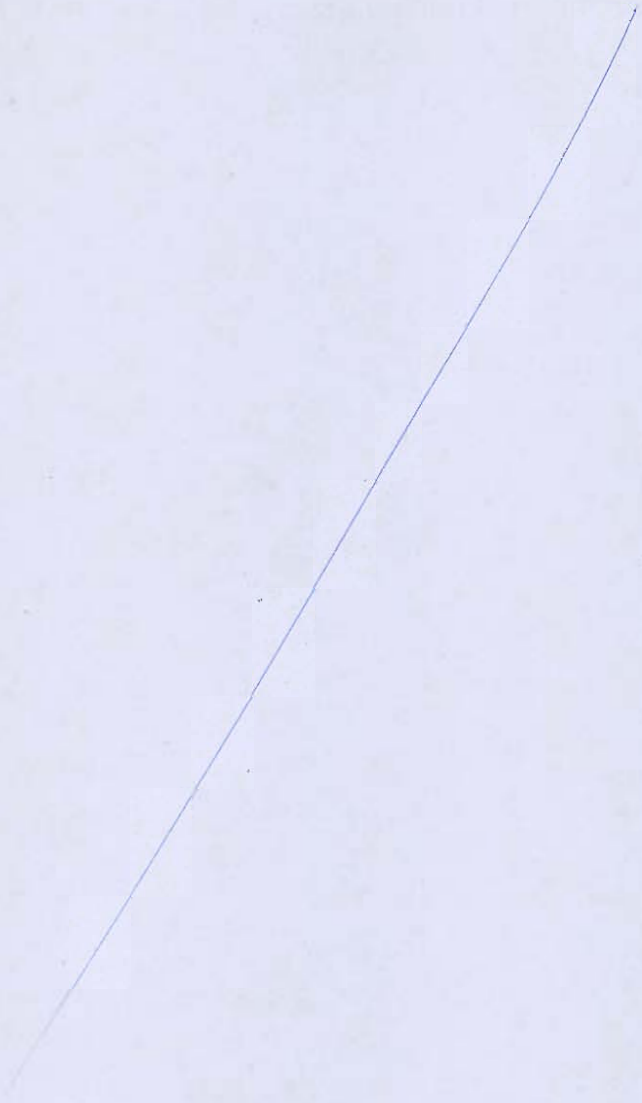

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Q.6 (b) (i) Describe the following tests performed on building stones:

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]

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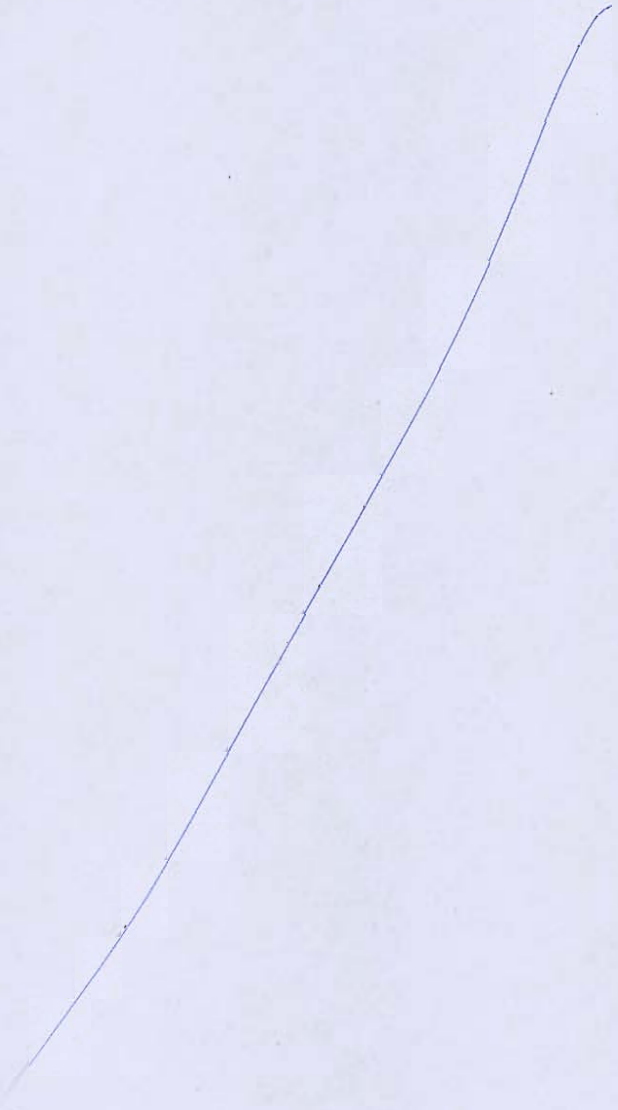

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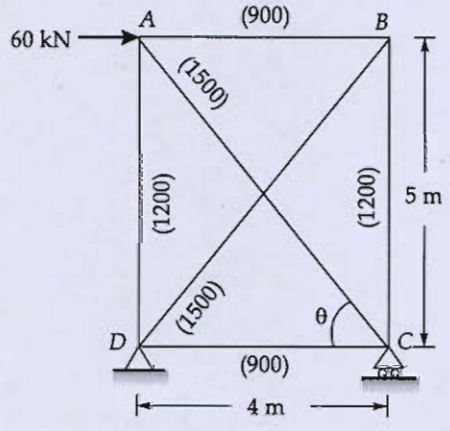
Q.6 (c) Determine the force in the members of the frame as shown in figure. The sectional areas of the members in square millimetre of each member are indicated in brackets.



[20 marks]

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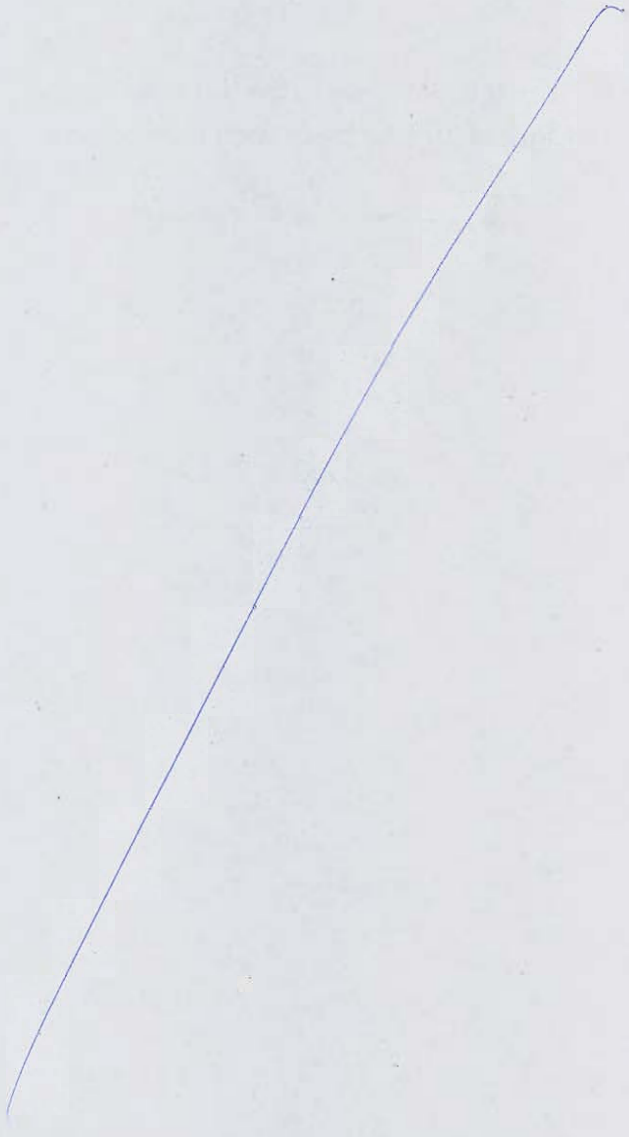

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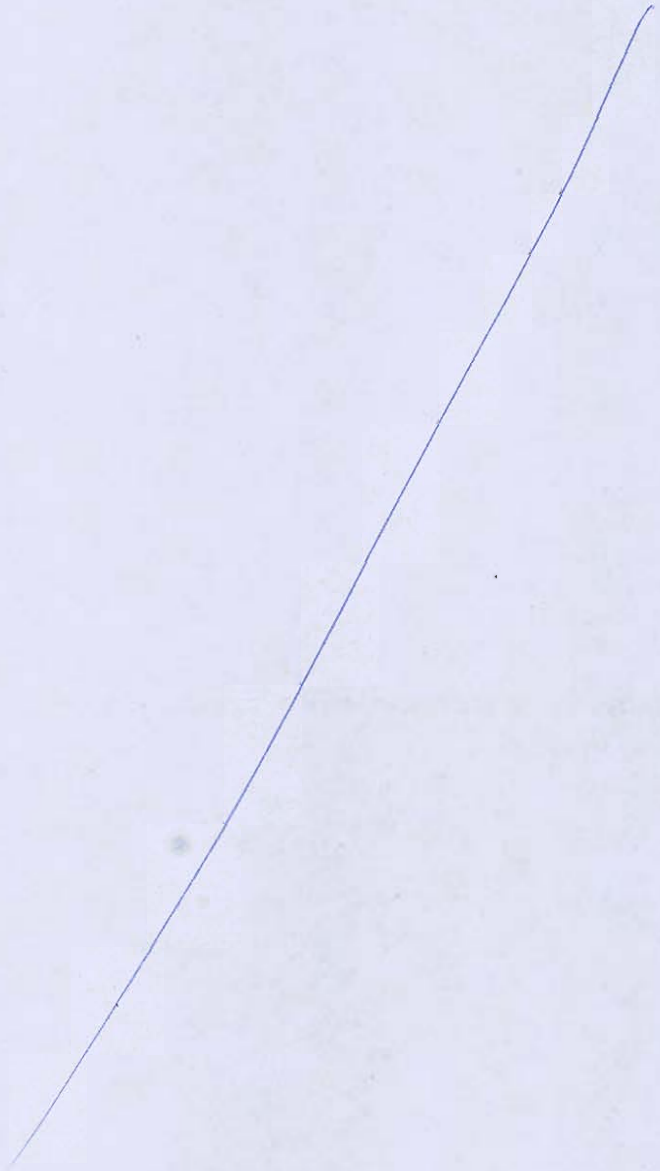

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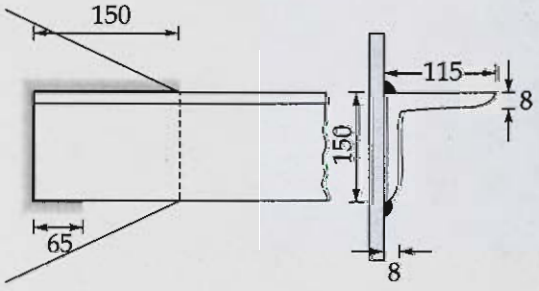
Q.7 (a) Determine the tensile strength of an angle section ISA 150 × 115 × 8 which is connected to gusset plate for the following cases:



(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 ⇒ 7(a)

(i) Based on gross-section

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

$$= \frac{250 \times 2058}{1.1} = 467.72 \text{ kN}$$

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(ii) Based on Rupture strength

$$T_{dn} = \frac{0.9 f_u A_{nc}}{1.25} + \frac{\beta f_y A_{go}}{1.1}$$

$$A_{nc} = \left(150 - \frac{8}{2}\right) \times 8 = 1168 \text{ mm}^2$$

$$A_{go} = \left(115 - \frac{8}{2}\right) \times 8 = 888 \text{ mm}^2$$

$$\beta = 1.4 - 0.076 \left(\frac{w}{t}\right)\left(\frac{b_s}{L_c}\right)\left(\frac{f_y}{f_u}\right) \leq \frac{0.9 f_u \gamma_{m0}}{f_y \gamma_{m1}}$$

$w = 115$ mm $b_s = 115$ mm $t = 8$ mm

$L_c = 150 + 65 = 215$ mm

$f_y = 250$ mpa $f_u = 410$ mpa

$$\beta = 1.4 - 0.076 \times \left(\frac{115}{8}\right)\left(\frac{115}{215}\right)\left(\frac{250}{410}\right)$$

$$= 1.043 \leq \frac{0.9 \times 410 \times 1.1}{250 \times 1.25}$$

$0.7 \leq 1.043 \leq 1.298$ ok

$$T_{dn} = \frac{0.9 \times 410 \times 1168}{1.25} + \frac{1.043 \times 250 \times 888}{1.1}$$

$$T_{dn} = 344.79 + 210.496$$

$$\boxed{T_{dn} = 555.286 \text{ kN}}$$

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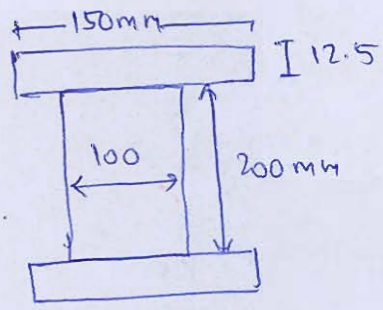
Q.7 (b) A timber beam 100 mm wide and 200 mm deep is to be reinforced by bolting two steel flitches each 150 mm by 12.5 mm in section. Calculate the moment of resistance in the following cases: (i) flitches attached symmetrically at the top and bottom; (ii) flitches attached symmetrically at the sides. 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]

Ans=> (b) (i)



Given

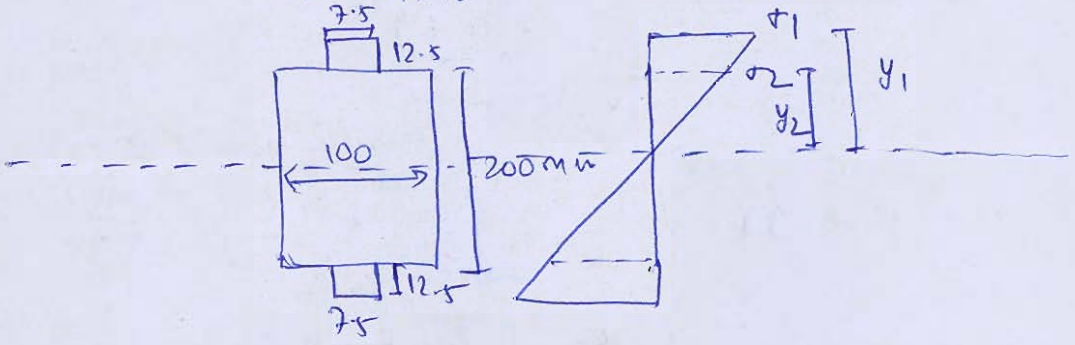
$E_s = 2 \times 10^5$ N/mm^2

$E_t = 1 \times 10^4$ N/mm^2

To find MOR

Converting into equivalent steel

$$m = \frac{E_s}{E_t} = \frac{2 \times 10^5}{1 \times 10^4} = 20$$



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$(\sigma_{allow})_t = \frac{6N}{mm^2}$ we have $\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$

$$\Rightarrow \frac{(\sigma_{allow})_t}{E_t} = \frac{(\sigma_{allow})_{steel}}{E_{st}}$$

$$\Rightarrow (\sigma_{allow})_{st} = \frac{2\times10^5}{1\times10^4} \times 6 = 120 \frac{N}{mm^2}$$

$\therefore \sigma_2 = 120 \frac{N}{mm^2}$

Also, $\frac{\sigma_1}{y_1} = \frac{\sigma_2}{y_2}$

$$\Rightarrow \sigma_1 = \frac{(100+12.5)}{100} \times 120 = 135\ N/mm^2$$

Hence

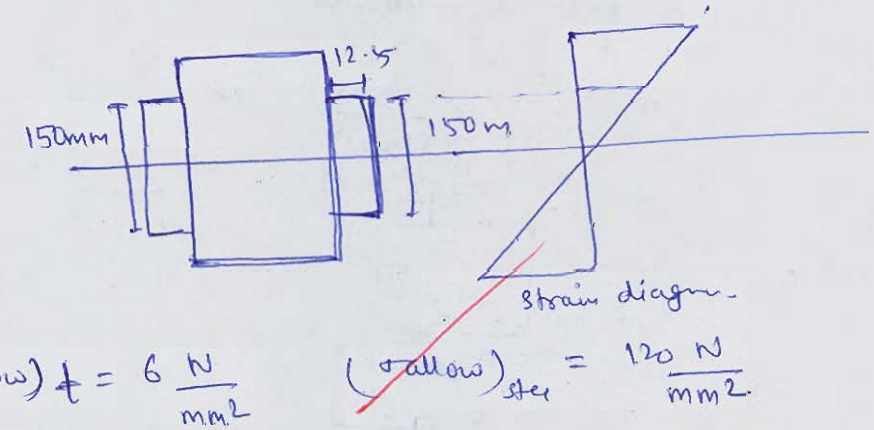
$$MOR = \sigma_1 \frac{b_1 d_1^2}{6} + \sigma_2 \frac{b_2 d_2^2}{6}$$

$$= 135 \left[\frac{\frac{7.5\times12.5^3}{12} + 7.5\times12.5\times106.25^2}{112.5} \right] \times 2 + 120 \times \frac{100\times200^2}{6}$$

$$= 2.54\ KNm + 80\ KNm$$

$$\boxed{MOR = 82.54\ KNm}$$

(ii)



$(\sigma_{allow})_t = 6 \frac{N}{mm^2}$ $(\sigma_{allow})_{steel} = 120 \frac{N}{mm^2}$

$$MOR = (\sigma_t) \times \frac{b_t d_t^2}{6} \times 2 + \sigma_s \frac{b_s d_s^2}{6}$$

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$$MoR = 6 \times \frac{12.5 \times 150^2}{6} * 2 + 120 \times \frac{100 \times 200^2}{6}$$

$MoR = 80.5625$ KNm

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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=>7) (C) (i) Artificial Pozzolana - Pozzalana are the siliceous material which on themselves do not posses any cementing values but when they combine by $Ca(OH)_2$ obtained during Hydration process, they posses cementing properties. This is called as pozzolonic action.

(a) Silica Fume - Silica Feme is an artificial Pozzalonas used in concrete that is obtained from silicon industry.

It posses following properties in the concrete -

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(i) It reduces the rate of hydration & heat of hydration, and hence suitable for mass concreting.

(ii) It increases workability of concrete.

(iii) It reduces permeability, bleeding in concrete.

(iv) Due to pozzalonic action on $Ca(OH)_2$, leached out during hydration proces, it make concrete durable.

~~(v)~~ However it has some disadvantage

(i) Rate of strength gain reduces. Hence not suitable for early strength gaining.

(ii) Strength may be effected.

(b) Rice husk ash- It is also an artificial pozzolona used in concrete structures. It has also ability to increase workability of concrete.

* It is obtained by burning the agricultural waste.

Advantages of Rice husk ash

(i) Reduced bleeding, permeability and chances of segregation in concrete.

(ii) Good resistance against the chemical attack.

(iii) Improves the durability of concrete.

Disadvantages

(i) It lead to delayed setting of concrete.

10

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Ans ⇒ 7) (c) (ii) Analysis of Rates

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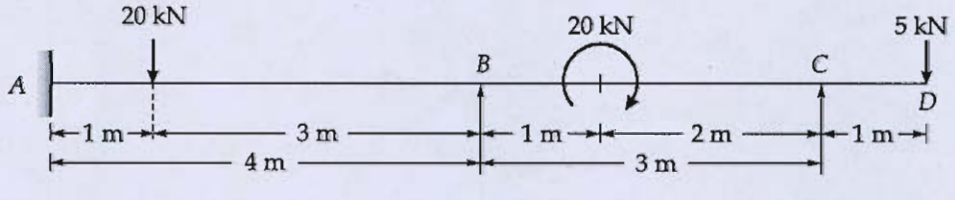
.8 (a) Find the support moments, reactions and draw BMD for the continuous beam as shown in figure by moment distribution method.

(Take EI = constant)



[20 marks]

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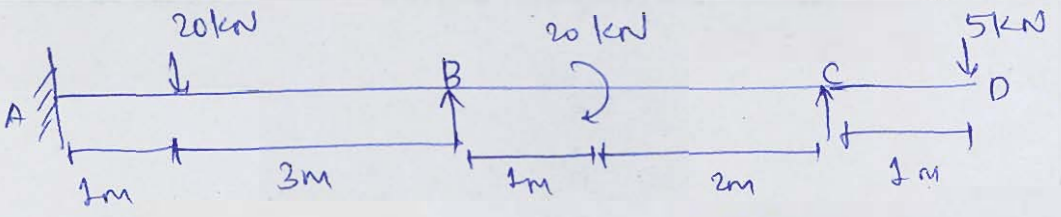
Ans ⇒ 8) (a)



① FEM

$$M_{FAB} = \frac{-20 \times 1 \times 3^2}{4^2} = -11.25 \text{ kNm}$$

$$M_{FBA} = +3.75 \text{ kNm}$$

$$M_{FBC} = \frac{-20 \times 2 (3 \times 1 - 3)}{3^2} = -7.2$$

$$M_{FCB} = \frac{+20 \times 1 (3 \times 2 - 3)}{3^2} = +2.8$$

$$M_{FCD} = -5 \text{ kNm}$$

② Distribution factors

Joint	member	stiffney	sum	DF
	BA	$\frac{4EI}{4}$		0.5
B			2EI	
	BC	$\frac{3EI}{3}$		0.5
	CB	$\frac{4EI}{3}$		1
C			$\frac{4EI}{3}$	1
	CD	0		0

③

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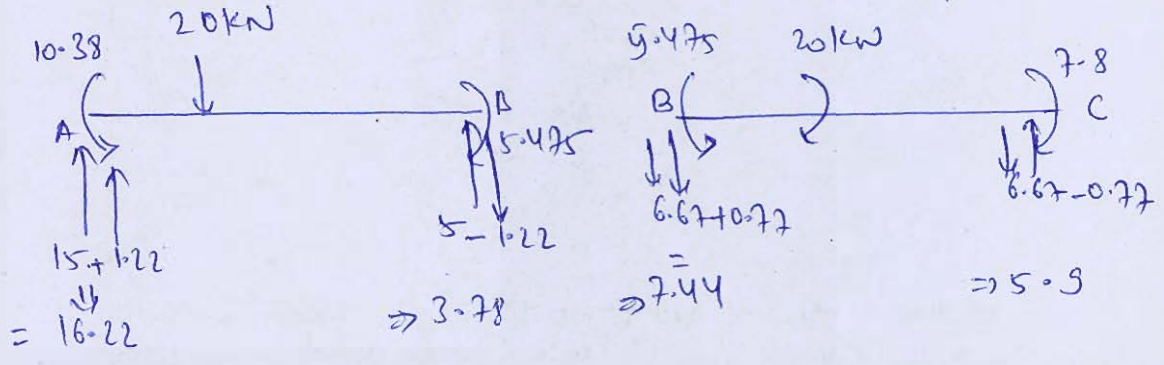
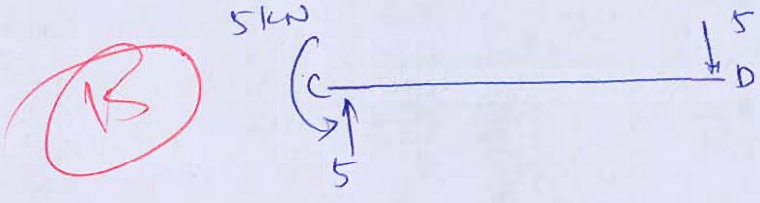
(3) Table

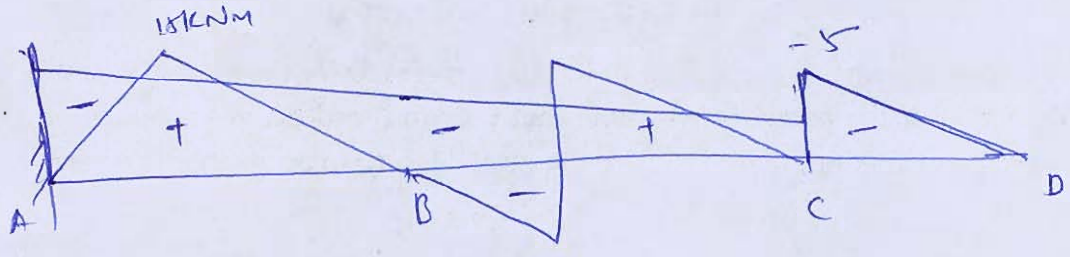
Joint	A	B		C	D
DF	0	0.5	0.5	1	0
FEM	-11.25	3.75	-7.2	+2.8	-5
CO				+5	
~~Bal~~					
Bal		1.725	1.725		
CO	0.8625				
REM	-10.38	5.475	-5.475	7.8	-5

check





BMD



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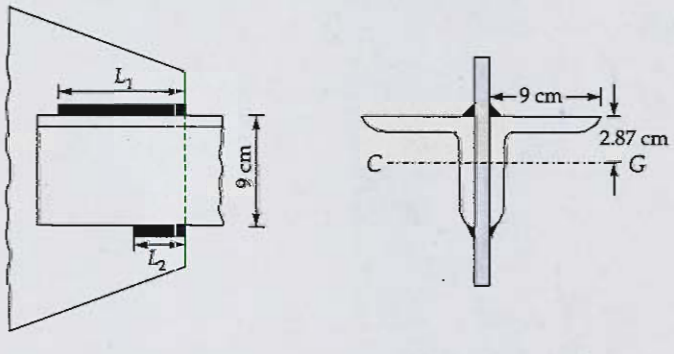
Q.8 (b) (i) Two angles 90 mm × 90 mm × 8 mm transmit a tensile force of 250 kN. The angles are connected to the gusset on either side by welding. Design the joint if size of the weld is 6 mm and allowable shear stress is 102.5 N/mm^2.



(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]

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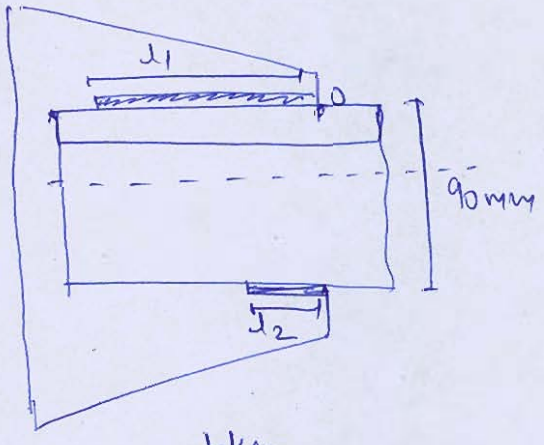
Ans⇒8) (b) (i) Tensile force = 250 kN

Force on each angle = $\frac{250}{2}$ = 125 kN.

size of weld, s = 6 mm $\quad \sigma_{allow} = 102.5 \frac{N}{mm^2}$



taken

~~let~~ load by upper position = P_1

load taken by downward portion = P_2

$P_1 + P_2 = \frac{250}{2}$ kN = 125 kN

⇒ ~~125 x 10~~ $P = (\sigma_{allow}) \times l_{eff} \times t_t$

⇒ $125 \times 10^3 = 102.5 \times l_{eff} \times (0.7 \times 6)$

$$\boxed{l_{eff} = 290.36 \text{ mm}}$$

~~let~~ us assume c.g of angle at c_{yy} = 21.6 mm.

then moment about point O.

$(l_2 \times 90 \text{ mm}) \times (0.7 \times 6) \times 102.5 = 125 \times 10^3 \times 21.5$

$l_2 = 69.363$ mm say 70 mm

7

$l_1 = 291 - 70$

$\boxed{l_1 = 221 \text{ mm}}$ $\quad \boxed{l_2 = 70 \text{ mm}}$

Any => 8) (b) (ii)

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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.

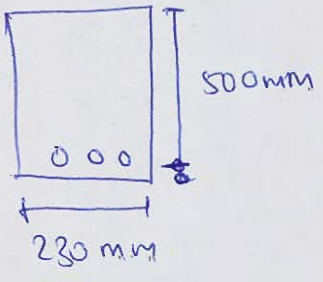
Take effective cover as 50 mm

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]

Any ⇒ 8) (c)



Given,

$BM_u = 200$ KNM

M20 Fe 415 EC = 50mm

$D = 500 + 50 = 550$ mm

Check for limiting moment

$M_{u,lim} = 0.138 \times f_{ck} b d^2$

$= 0.138 \times 20 \times 230 \times 500^2$

$= 158.7$ KN m < 200 KNm

Hence we need to design doubly reinforced section.

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$\frac{d'}{d} = \frac{50}{500} = 0.1$

For Fe 415 $f_y = 415 \frac{N}{mm^2}$ $\quad f_{sc} = 353 \frac{N}{mm^2}$

~~Depth / ϕ / %~~

⇒ a- Design for Reinforcement

$$A_{st_1} = \frac{M_{u,lim}}{0.87 f_y (d - 0.42 x_{u,lim})}$$

$$= \frac{158.7 \times 10^6}{0.87 \times 415 (500 - 0.42 \times 0.48 \times 500)}$$

$$A_{st_1} = 1101.08 \text{ mm}^2$$

$$A_{st_2} = \frac{M_u - M_{u,lim}}{0.87 f_y (d - d')}$$

$$= \frac{(200 - 158.7) \times 10^6}{0.87 \times 415 (500 - 50)}$$

$$A_{st_2} = 254.196 \text{ mm}^2$$

$$A_{sc} = \frac{M_u - M_{u,lim}}{(f_{sc} - 0.45 f_{ck})(d - d')}$$

$$= \frac{(200 - 158.7) \times 10^6}{(353 - 0.45 \times 20)(500 - 50)}$$

$$A_{sc} = 266.79 \text{ mm}^2$$

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For A_{st1}

$A_{st1} = 1101.08\ mm^2$

use 16mm dia bar.

$$\text{No. of Bar} = \frac{1101.08}{\frac{\pi}{4} \times 16^2} = 5.47 \simeq 6 \text{ bar}$$

For A_{st2}

$A_{st2} = 254.196\ mm^2$

use 12 mm dia bar

$$\text{No. of Bar} = \frac{254.19}{\frac{\pi}{4} \times 12^2} = 2.24 \simeq 3 \text{ bar}$$

For A_{st3}

$A_{st3} = 266.79\ mm^2$

use 12 mm dia bar

$$\text{No. of Bar} = \frac{266.79}{\frac{\pi}{4} \times 12^2} = 2.35 \simeq 3 \text{ bar}$$

20

■■■■

Space for Rough Work

Space for Rough Work

Space for Rough Work