MADE EASY

# MADE EASY

Leading Institute for ESE, GATE & PSUs

# ESE 2025 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

## Civil Engineering

### Test-7 : 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 | 52 |
| Q.2 | — |
| Q.3 | 43 |
| Q.4 | — |
| Section-B | |
| Q.5 | 30 |
| Q.6 | |
| Q.7 | 52 |
| Q.8 | 54 |
| **Total Marks Obtained** | 231 |

Signature of Evaluator: Sheryab

Cross Checked by: ..........

Corp. office : 44 - A/1, Kalu Sarai, New Delhi-110016 | Ph: 9021300500 | Web: www.madeeasy.in

accuracy is good Keep it up

# IMPORTANT INSTRUCTIONS

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

## DONT'S

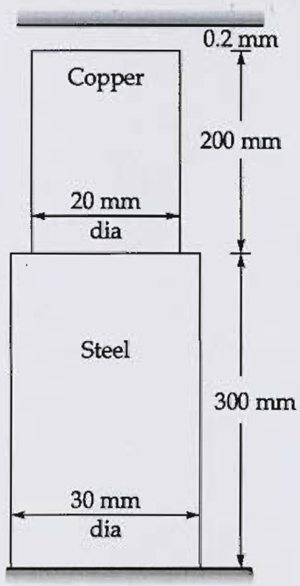
1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify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

## DO'S

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

## Section - A

**Q.1 (a)** The composite bar as shown in figure is 0.2 mm short of distance between the rigid supports at room temperature. What is the maximum temperature rise which will not produce any stresses in the bar? Find the stresses induced when the temperature rise is 40 °C.
Assume $E_s = 2 \times 10^5$ N/mm$^2$; $\alpha_s = 12 \times 10^{-6}$/°C;
$E_c = 1.2 \times 10^5$ N/mm$^2$; $\alpha_c = 17.5 \times 10^{-6}$/°C




**[12 marks]**

$(L\alpha\Delta T)_s + (L\alpha\Delta T)_{cu} = 0.2$

$300 \times 12 \times 10^{-6} \times \Delta T + 200 \times 17.5 \times 10^{-6} \times \Delta T = 0.2$

$\boxed{\Delta T = 28.169°C}$

$\left(L\alpha\Delta T - \frac{PL}{AE}\right)_s + \left(L\alpha\Delta T - \frac{PL}{AE}\right)_{cu} = 0.2$

$\left(300 \times 12 \times 10^{-6} \times 40 - \frac{P \times 300}{\frac{\pi}{4} \times 30^2 \times 2 \times 10^5}\right)$

$+\left(200 \times 17.5 \times 10^{-6} \times 40 - \frac{P \times 200}{\frac{\pi}{4} \times 20^2 \times 1.2 \times 10^5}\right) = 0.2$

$P = 11.309$ kN

$\nearrow$ Steel

$\sigma_s = \dfrac{P}{\frac{\pi}{4}\times 30^2} = \underline{\underline{4\ MPa}}$ (c)

$\sigma_{cu} = \dfrac{P}{\frac{\pi}{4}\times 21^2} = \underline{\underline{36\ MPa}}$ (c)

$\downarrow$

copper

12

**Q.1 (b)** It is needed to blend fine and coarse aggregates to achieve a target fineness modulus (FM) of 6.5 for an optimized concrete mix.

1. The fine aggregate available has FM of 2.9.
2. The coarse aggregate, with FM = 7.8, has a stockpile mass of 1538 kg/m$^3$

If 355 kg/m$^3$ of cement is used in the mix, calculate the required mass (in kg/m$^3$) of fine aggregate to achieve the desired FM of the combined aggregate mix.

Also, briefly explain how fineness modulus of an aggregate is determined and why its control is important in concrete mix design?

**[12 marks]**

let, $x$ % of fine agg used

$\rightarrow$ $6.5 = x \times 2.6 + (1-x)7.8$

$x = 0.25$

$(1-x) = 0.75$

4

mass of fine agg. used $= \frac{1538}{0.75} \times 0.25$

$= 512.67$ kg/m$^3$

→ Fineness modulus represent gradation of aggregates present in the concrete matrix.

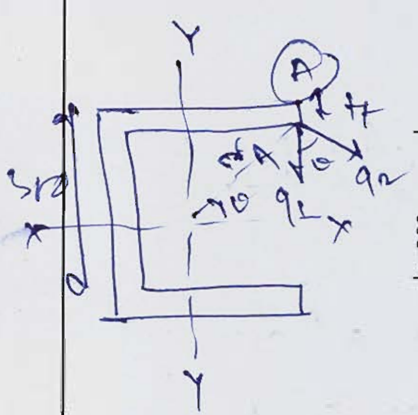
$$FM = \frac{\Sigma \text{ cumulative \% retain on sieves}}{100}.$$

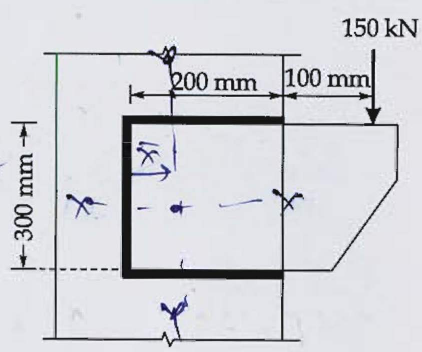
→ A lower FM, represents high proportation of fine aggregates, which in strength, uniformity of concrete.

→ it also prevents from segregation and bleeding.

→ So, it is important to control FM in concrete mix design.

Q.1 (c) Determine the size of weld required to resist a factored load of 150 kN. Assume Fe-410 grade of steel and shop weld.






[12 marks]

$$\bar{x} = \frac{300 t_t \times 0 + 200 \times t_t \times 2 \times 100}{300 t_t + 200 \times t_t \times 2}$$

$\bar{x} = 57.14$ mm

$$I_{xx} = \frac{t_t \times 300^3}{12} + 2 \times \left[ \frac{200 \times t_t^3}{12} + 200 \times t_t \times 150^2 \right]$$

$I_{xx} = 11.25 \times 10^6 \, t_t$ mm$^4$

$I_{yy} = \frac{300\, t_f^{3}}{12} + 300\, t_f \times 57.14^2$

$+ 2\left[\frac{t_f \times 200^3}{12} + 200\, t_f \times 42.86^2\right]$

$I_{yy} = 3.05 \times 10^6\, t_f\ mm^4$

12

$I_{zz} = (I_{xx} + I_{yy}) = 14.3 \times 10^6\, t_f$

(i) Direct stress $= q_1 = \frac{150 \times 10^3}{(200 \times 2 + 300)\, t_f}$

$q_1 = \frac{214.286}{t_f}$

(ii) Torsional stress $= q_2 = \frac{Pe}{I_{zz}} \times r_A$

$= \frac{150 \times 10^3 \times 242.86}{14.3 \times 10^6 \times t_f} \times \sqrt{150^2 + 142.86^2}$

$= \frac{527.7}{t_f}$

$\cos\theta = \tan^{-1}\frac{150}{142.86} = 46.39°$

(iii) $\sqrt{q_1^2 + q_2^2 + 2 q_1 q_2 \cos\theta} \le \frac{f_u\ 410}{\sqrt{3} \times 1.25}$

$\frac{693.09}{t_f} \le \frac{410}{\sqrt{3} \times 1.25}$

$t_f \le 3.658\ mm$

$\phi_{f} 0.75$

$S \geq 5.22$ mm

provide $\boxed{S = 6\,mm}$ Ans

**Q.1 (d)** A post tensioned concrete beam of rectangular section is 250 mm wide and 450 mm deep. The beam is prestressed by two cables of area 510 mm$^2$ each, which are initially prestressed to 1500 N/mm$^2$. The eccentricity of the cables is 90 mm throughout the length of the beam, the span of the beam being 8 m. Ignoring all losses find the deflection at the centre when the beam supports its own weight.

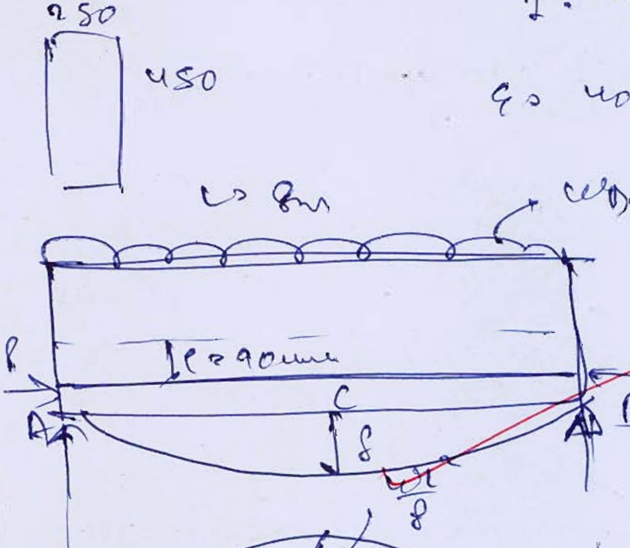
What would be the deflection at the centre when the beam has an imposed load of 15 kN/m and there is a 20% loss in prestress. Concrete weighs 24 kN/m$^3$. Modulus of elasticity for concrete is 40 kN/mm$^2$.

**[12 marks]**

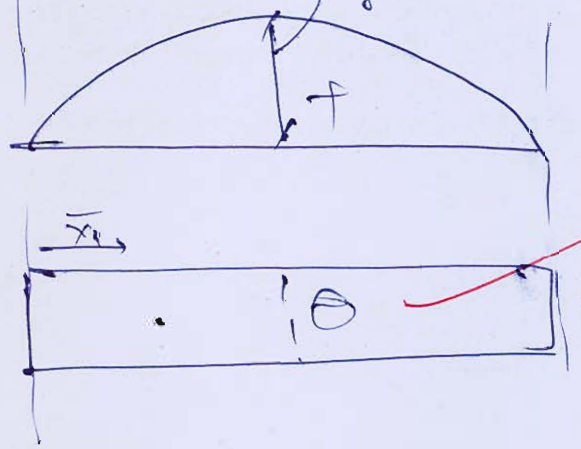
$I = \frac{250 \times 450^3}{12} = 1.9 \times 10^9 \text{ mm}^4$

$E = 40 \times 10^3 = 4 \times 10^4$ MPa

$w_D = .25 \times .45 \times 24 = 2.7$ kN/m



$P = 510 \times 1500 \times 2 \times 10^{-3}$
$= 1530$ kN.



$Pe = 1530 \times .09 = 137.7$

$\delta_N = \delta_{DL} + \delta_{Pforce}$

$\delta_{DL} = +\frac{5}{384}\frac{wL^4}{EI} = +1.89$ mm

$\delta_{Pforce} = -\delta_{A/C} = -\frac{A_1 \bar{x}_1}{EI} = -\frac{137.7 \times 4 \times 2}{EI}$ kN-m$^2$ / N-mm$^2$

$\delta_{Pforce} = -14.50$ mm

$\boxed{\delta_{net} = -12.62\,mm}$ ↑ (upward)

(ii) $\delta_{net} = \delta_{DL+LL} + \delta_{Pforce}$

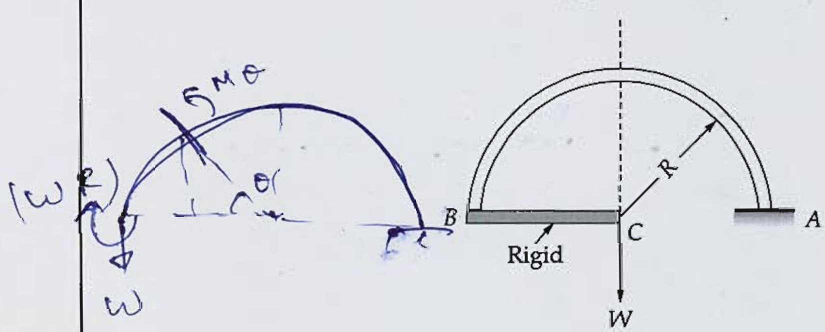
$\delta_{DL+LL} = 12.43\,mm$

$\delta_{Pforce} = -0.8 \times 14.5 = -11.6\,mm$

$\boxed{\delta_{net} = 0.83\,mm}$ ↓ (downward)

12

**Q.1 (e)** A thin semicircular bracket *AB* of radius *R* is encastered at *A* and has at *B* a rigid arm *BC* of length *R*. The bracket carries a vertical load *W* at *C* as shown in figure. Show that the vertical deflection at the load is $\frac{\pi W R^3}{2EI}$, where *EI* is flexural rigidity of the bracket.




**[12 marks]**

$$\delta = \int \frac{M_x \frac{\partial M_x}{\partial W}\, dx}{EI}$$

$M_x = WR - W(R - R\cos\theta)$

$M_x = +WR\cos\theta$

$\frac{\partial M_x}{\partial W} = R\cos\theta$

$$\delta = \int_0^{\pi} \frac{(wR\cos\theta)(R - R\cos\theta)(R\,d\theta)}{GI}$$

$$\boxed{\delta = \frac{\pi w R^3}{2GI}\ (\downarrow)}$$

12

Do work on the presentation part

**Q.2 (a)** **(i)** Enumerate the factors affecting rheological properties of fresh concrete.

**(ii)** What is pozzolanic action? Classify pozzolanic materials. Discuss various implications seen on application of pozzolana in cement concrete.

**[10 + 10 = 20 marks]**

Q.2 (b) An open square water tank 5 m × 5 m × 3 m deep rests on firm ground. Design the side walls of the tank using approximate design method. Use M20 concrete and mild steel reinforcement. The permissible stresses are as follows:

$\sigma_{cbc} = 7\ \text{N/mm}^2$

$\sigma_{st} = 115\ \text{N/mm}^2$ (near water face)

$\sigma_{st} = 125\ \text{N/mm}^2$ (away from water face)

[Use 18 mm $\phi$ bars and nominal cover = 25 mm]

Also provide 10 mm $\phi$ bars for bottom 1 m height of wall.

Detailing not required.

**[20 marks]**

Q.2 (c) Check the suitability of laterally supported beam ISLB 350 @ 495 N/m of effective span 6 m for the following data:

Grade of steel: Fe410

Maximum bending moment: $M = 150$ kNm

Maximum shear force: $V = 210$ kN

Check the beam for:

- Shear capacity
- Bending capacity
- Web buckling at support
- Web bearing

Properties of ISLB 350 @ 495 N/m are as follows:

Depth of section, $h = 350$ mm

Width of flange, $b_f = 165$ mm

Thickness of flange, $t_f = 11.4$ mm

Thickness of web, $t_w = 7.4$ mm

Radius of root, $R = 16$ mm

Moment of inertia, $I_z = 13158.3 \times 10^4$ mm$^4$

Plastic section modulus, $Z_{pz} = 851.11 \times 10^3$ mm$^3$

Elastic section modulus, $Z_{ez} = 751.9 \times 10^3$ mm$^3$

Stiff bearing length, $b = 100$ mm

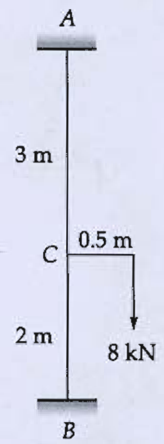
No need to check for deflection

For buckling curve, ($c$)

| $k/r$ | 70 | 80 | 90 | 100 |
|---|---|---|---|---|
| $f_{cd}\,(\text{N/mm}^2)$ | 152 | 136 | 121 | 107 |

**[20 marks]**

Q.3 (a) A column *AB* fixed at the ends carries a load of 8 kN on the bracket as shown in figure below.

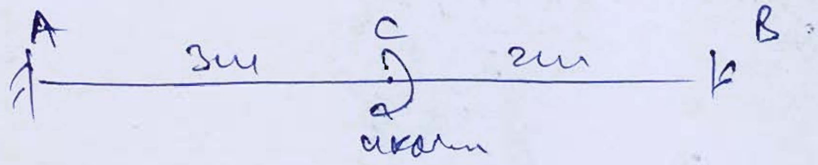



Using slope-deflection method,

(i) Plot the bending moment diagram.

(ii) Plot the deflected shape of the column.

**[20 marks]**




① $D_K = \theta_c, \delta_c$

② $\bar{M}_{AC} = \bar{M}_{CA} = \bar{M}_{CB} = \bar{M}_{BC} = 0.$

③ $M_{AC} = \cancel{\bar{M}_{AC}}^{0} + \frac{2EI}{\cancel{L}\,3}\left(2\cancel{\theta_A}^{0} + \theta_c - \frac{3\delta}{\cancel{L}\,3}\right)$

$M_{AC} = \left(\frac{2}{3}EI\theta_c - \frac{2}{3}EI\delta\right)$

$M_{CA} = \left(\frac{4}{3}EI\theta_c - \frac{2}{3}EI\delta\right)$

$M_{CB} = \frac{\cancel{2}EI}{\cancel{2}}\left(2\theta_c + \cancel{\theta_B}^{0} + \frac{3\delta}{2}\right)$

$M_{CB} = 2EI\theta_c + 1.5EI\delta$

$M_{BC} = EI\theta_C + 1.5EI\delta$

$M_{CA} + M_{CB} = 4$

$\frac{10}{3}EI\theta_C + \frac{5}{6}EI\delta = 4$ — (1).

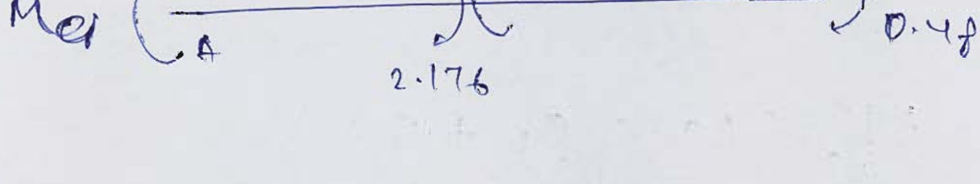

$\frac{M_{AC}+M_{CA}}{3} = \frac{M_{CB}+M_{BC}}{2}$

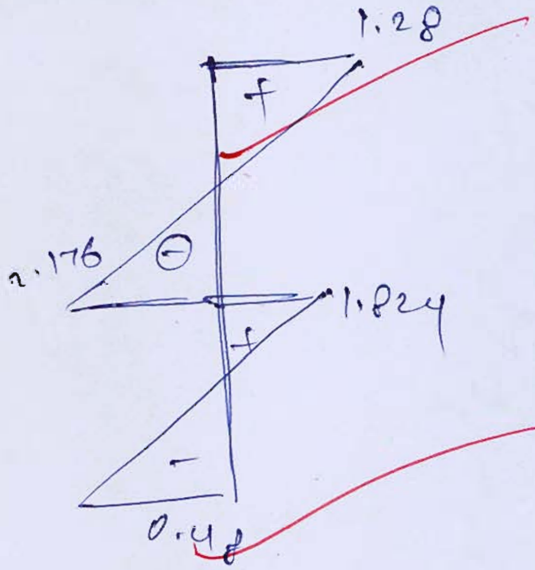
$\frac{2EI\theta_C - \frac{4}{3}EI\delta}{3} = \frac{3EI\theta_C + 3EI\delta}{2}$

$+5EI\theta_C + \frac{35}{3}EI\delta = 0$ — (2)

(1) & (2)  $EI\theta_C = 1.344$

$EI\delta = -0.576$



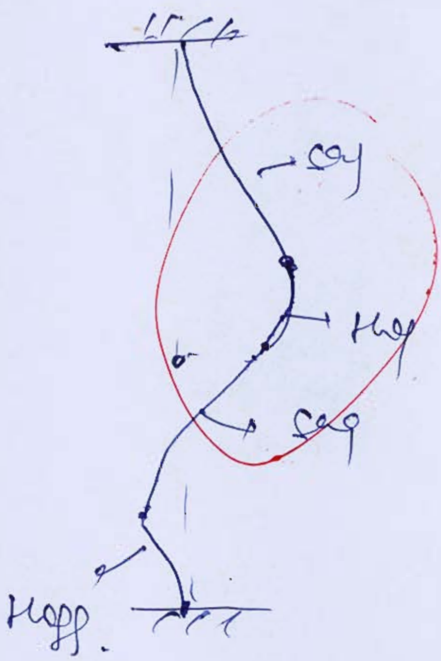



BMD

⊕ → sag

⊖ → Hogg.

20



**Q.3 (b)** **(i)** Briefly discuss the following terms:

1. Scrap value
2. Salvage value
3. Book value
4. Annuity
5. Capitalised value

**(ii)** A slender column is of length $L$ and is built-in at its lower end and free at its upper end. Find the first critical value of the compressive load $P$.

**[10 + 10 = 20 marks]**

(1) Scrape value:
it is the value of an ~~asset~~ asset after it's ~~value~~ useful life is over & its utility is also over.

(2) Salvage value
it is the value of an asset after its useful life is over, But it's utility is there.

07

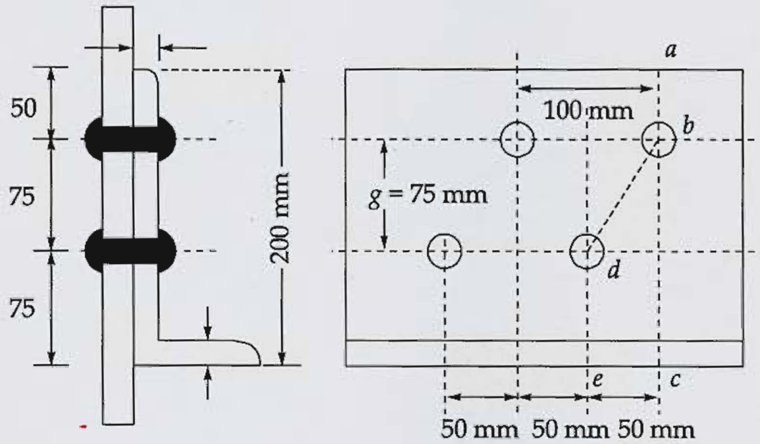
(3). Book value
Value of an asset after deducting depreciation.

(4). Annuity
→ An Amount given after every particular period for entire life.

(5). Capitalised value
→ value of asset after capitalising.

**Q.3 (c)** **(i)** The long leg of ISA 200 × 100 is connected to gusset plate by 22 mm diameter rivets in two rows, with gauge space of 75 mm and staggered pitch of 50 mm, as shown in figure. Determine suitable thickness of the angle to transmit a pull of 350 kN.

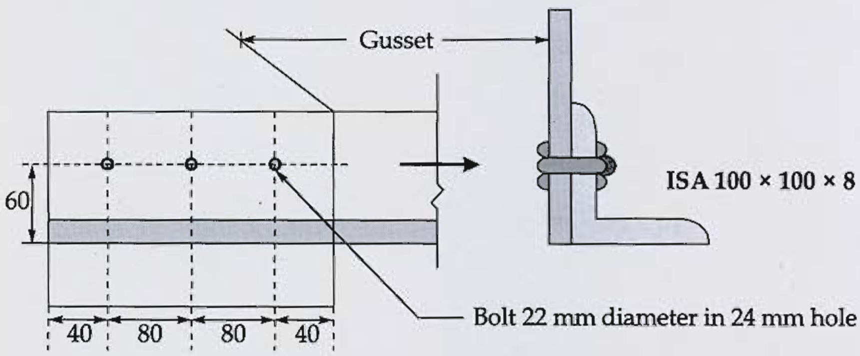
Take $\sigma_{at} = 180\ \text{N/mm}^2$.




**(ii)** A single angle ISA 100 mm × 100 mm × 8 mm is connected to gusset by means of three bolts of 22 mm diameter at pitch of 80 mm c/c in one line as shown in figure. Find the tension carrying capacity of the angle section for the following cases,

1. Gross section yielding
2. Net section rupture

Take $f_u = 410$ MPa [Use LSM]

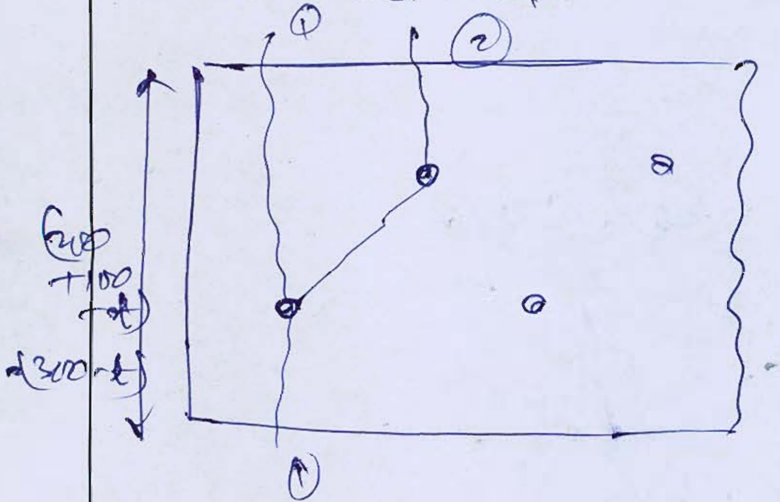



*[All dimensions are in mm]*

**[10 + 10 = 20 marks]**

(i) $d_o = 23.5\,mm$

$P = \sigma_{ACt} A_{net}$




6

1 - 1 . $A_{net} = \cancel{(300-\phi)x}$

$= (300 - t - 23.5) \times t$

$= (276.5 - t)\,t$

1 - 2 = $A_{net} = \left(300 - t - 2\times 23.5 + \frac{50^2}{4\times 75}\right) t$

$A_{net} = (261.33 - t) \times t$

$\rightarrow\ 350\times10^3 = 180 \times (261.33 - t)\,t$

$t = 7.66\,m$

provide $t = 10\,mm$

ISA 200×100×10

(ii)

① Gross area yielding

$T_{dg} = A_g \cdot \frac{f_y}{1.1}$ 250.

$A_g = (100 + 100 - 8) \times 8 = 1536 \text{ mm}^2$

$\boxed{T_{dg} = 349.09 \text{ kN}}$

② Net section rupture

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

10

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

$\beta = 1.4 - 0.076 \times \frac{250}{410} \times \left(\frac{100}{8}\right)\left(\frac{152}{160}\right)$

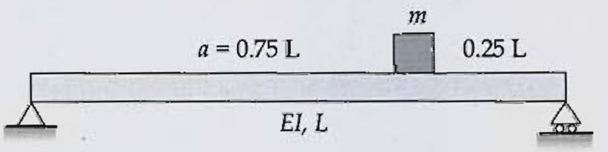
$\beta = 0.85$ $\quad \beta \in (0.7 - 1.3)$ OK

$A_{nc} = (100 - 4 - 24) \times 8 = 576 \text{ mm}^2$

$A_{go} = (100 - 4) \times 8 = 768 \text{ mm}^2$

$\boxed{T_{dn} = 318.398 \text{ kN}}$

**Q.4 (a)** (i) Evaluate the natural period of vibration for the structural system as shown in figure below, when $L$ =4.0 m, $E$ = 22000 MPa, $I = 1.2 \times 10^{-4}$ m$^4$, $K$ = 40 kN/m, $m$ = 20 kN.




(ii) What assumptions are made in simple theory of bending?

**[15 + 5 = 20 marks]**

**Q.4 (b)** **(i)** What are the essential rules to be followed while drawing a network diagram in project management? Explain with the help of neat sketches the common types of errors that can occur in a network diagram.

**(ii)** Write short notes on the following:

1. Soundness of aggregates
2. Alkali-aggregate reaction

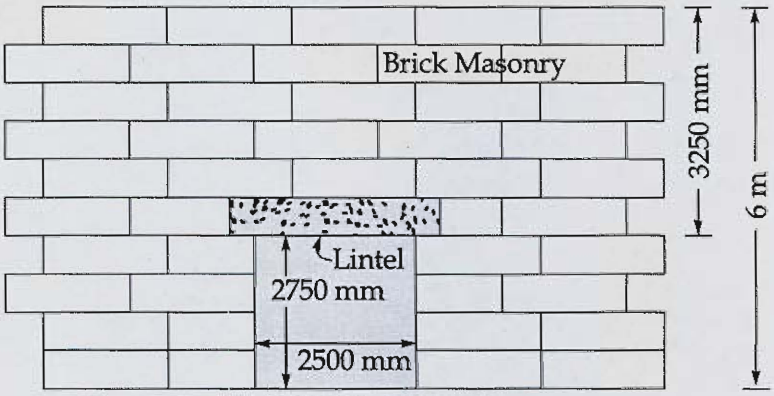
**[10 + 10 = 20 marks]**

**Q.4 (c)** **(i)** A 20 storey R.C. framed building has plan dimensions 15 m × 30 m. Height of the building is 70 m. Estimate its fundamental period of vibration if the building is

1. unbraced i.e., without any masonry infill
2. braced with infilled brick masonry wall

**(ii)** Design a lintel over a 2.5 m wide opening in an industrial shed wall as shown in figure below. The thickness of wall is 40 cm, height of opening is 2.75 m and eaves level is 6 m above the floor level. Use M20 mix and Fe415 steel. Unit weight of masonry is 19 $kN/m^3$. Check for shear and development length at support are not required and detailing also not required.

[Take base angle of imaginary triangle = 60°, unit weight of RCC = 25 $kN/m^3$]




**Lintel over door opening**

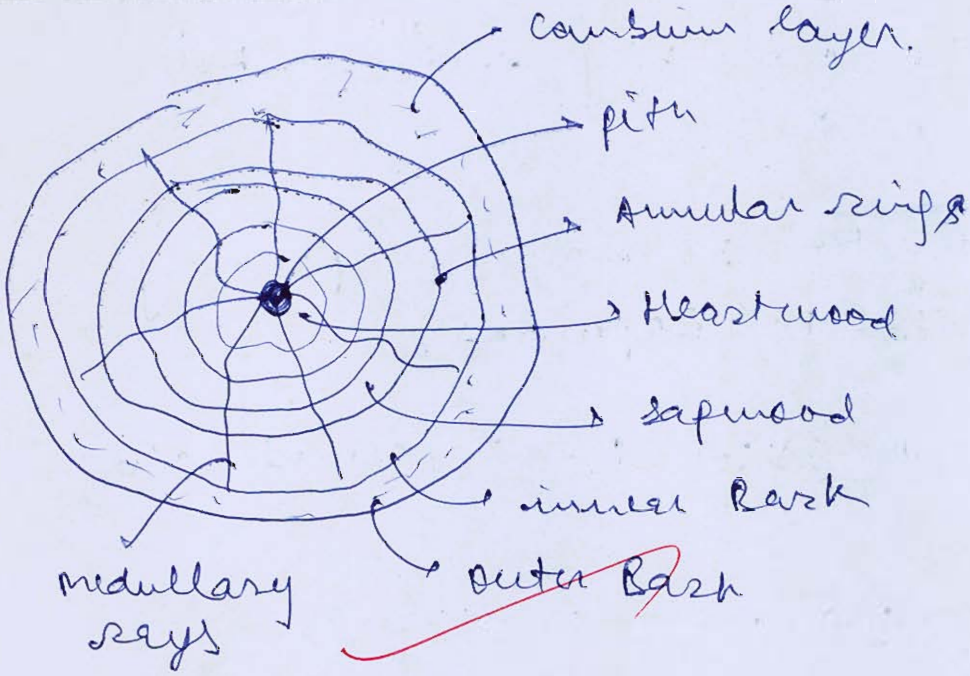
**[6 + 14 = 20 marks]**

Do not write in this margin

## Section - B

**Q.5 (a)** With the help of a neat and well-labeled sketch, explain the macrostructure of a tree trunk as seen in cross-section. Discuss the significance and function of its various anatomical components.

**[12 marks]**




pith :→ central portion of tree.
→ Dead & Dark in Nature
→ provides rigidity to tree

Heartwood :→ Hard in Nature
→ Dead in Nature
→ provides strength to timber.

Sapwood :→ Contains sap
→ Structurally weak
→ Help to supply water & Nutrient from Roots to leaves.

Cambium layer :→ layer which contains sap
→ Helps in circumference growth of tree

Inner Back :→ layer separating sapwood & cambium layer

Outter Back :→ outter surface layer

→ Help in preventing environmental impact on tree.

Medullary Ray :→ rays propogating from pitch to sapwood.

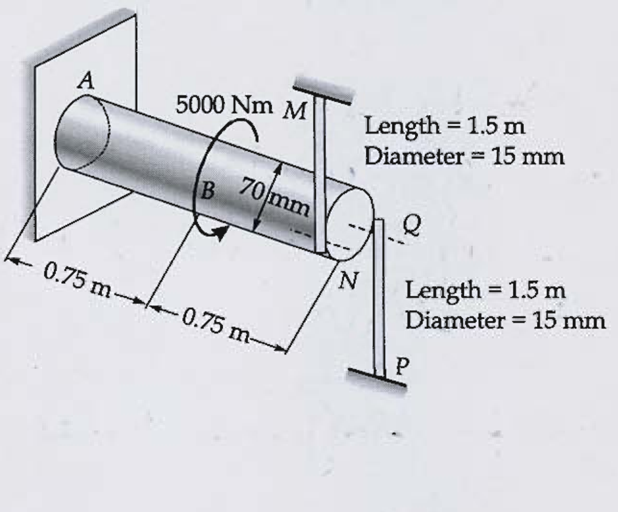
10

Annular rings :→ Rings formed along pith.

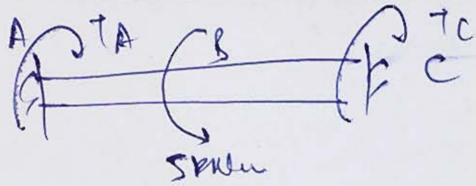
→ every year, one new rings is formed.

→ provides transverse strength.

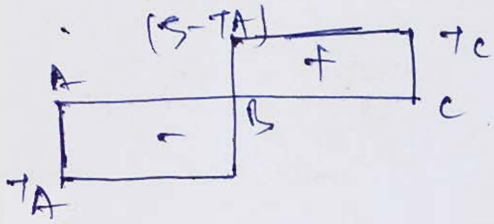
**Q.5 (b)** A steel shaft ABC, of constant circular cross-section and of diameter 70 mm, is clamped at the left end A, loaded by a twisting moment of 5000 Nm at its midpoint B, and elastically restrained against twisting at the right end C as shown in the figure. At end C the bar ABC is attached to vertical steel bars each of 15 mm diameter. The upper bar MN is attached to the end N shaft of *ABC* of diameter 70 mm and the lower bar PQ is attached to the other end Q of this same horizontal diameter as shown in the figure. For all materials E = 200 GPa and G = 80 GPa. Determine the peak shearing stress in bar ABC as well as the tensile stress in the bar MN.




**[12 marks]**



$T_A + T_C = 5 kN$ — ①



Do work on the concept of torsion

$\theta_{C/A} = 0 = \left(\frac{TL}{GJ}\right)_{BC} + \left(\frac{TL}{GJ}\right)_{BA}$

$0 = -\frac{T_A (0.75)}{GJ} + \frac{(5 - T_A) \times 0.75}{GJ}$

3

$T_A = 5 - T_A$

$T_A = 2.5$ kNm

$T_C = 2.5$ kNm

$\tau_{max\,CABC} = \frac{16\,T_{max}}{\pi D^3} = \frac{16 \times 2.5 \times 10^6}{\pi \times 70^3}$

$\boxed{\tau_{max} = 37.12 \text{ MPa}}$

Force induced in MN $= \frac{T}{R}$

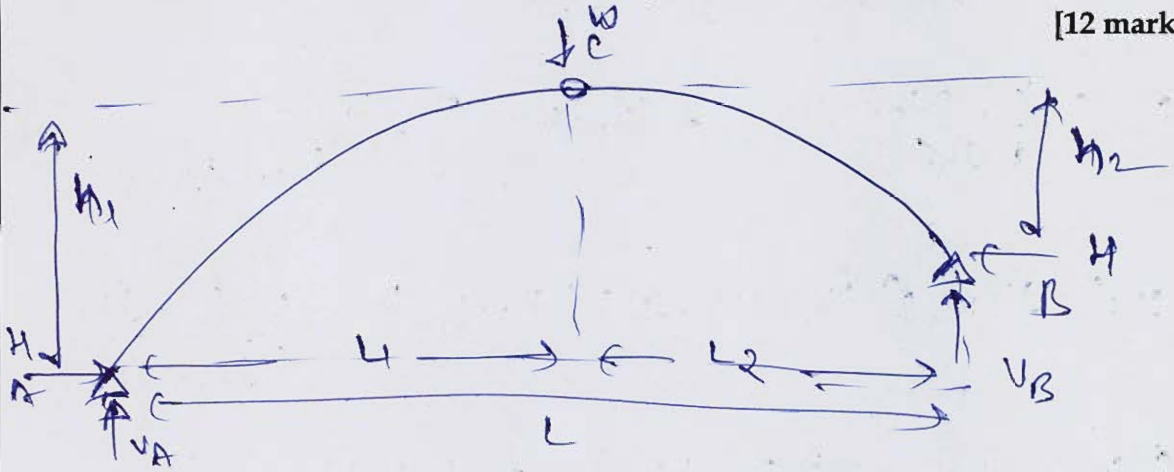
$= \frac{2.5 \times 10^6}{35}$

$= 71.428$ kN

$\boxed{\sigma_{max\,CMN} = \frac{71.428}{\frac{\pi}{4} \times 15^2} = 404.20 \text{ MPa}}$

**Q.5 (c)** Derive an expression for the horizontal thrust developed at the supports of a three-hinged parabolic arch of span $l$, when the abutments are located at depth $h_1$ and $h_2$ below the crown. A concentrated vertical load $W$ is acting at the crown of the arch.

**[12 marks]**




$\frac{L_1}{L_2} = \sqrt{\frac{H_1}{H_2}}$ $\quad L_1 = L_2\sqrt{\frac{H_1}{H_2}}$

05

$L = (L_1 + L_2)$

$L = L_2 + L_2\sqrt{\frac{H_1}{H_2}}$

$L = L_2\left(\frac{\sqrt{h_2}+\sqrt{h_1}}{\sqrt{h_2}}\right)$

$L_2 = L\left(\frac{\sqrt{h_2}}{\sqrt{h_1}+\sqrt{h_2}}\right)$

$L_1 = L\left(\frac{\sqrt{h_1}}{\sqrt{h_2}+\sqrt{h_1}}\right)$

$\Sigma M_C = 0$ (right)

$V_B L_2 = H \times h_2$

$V_B = \left(H \times \frac{h_2}{L_2}\right)$

$\Sigma M_A = 0.$

$V_B \times L + H(h_1 - h_2) = \omega 4$

$H \cdot \frac{h_2}{L_2} + H(h_1 - h_2) = \omega 4$ $\quad H = \frac{\omega l}{(\sqrt{h_1}+\sqrt{h_2})^2}$

$H\left[\frac{\sqrt{h_2}(\sqrt{h_1}+\sqrt{h_2})}{L\sqrt{h_2}} + (h_1 - h_2)\right] = \frac{\omega \times \sqrt{h_1}}{(\sqrt{h_1}+\sqrt{h_2})}$

$H\left(\sqrt{h_2}(\sqrt{h_1}+\sqrt{h_2}) + L(h_1 - h_2)\right) = \frac{\omega L \sqrt{h_1}}{(\sqrt{h_1}+\sqrt{h_2})}$

$H\left(h_2 + \sqrt{h_1 h_2} + L h_1 - L h_2\right) = \frac{\omega L \sqrt{h_1}}{(\sqrt{h_1}+\sqrt{h_2})}$

$$\boxed{H = \frac{\omega L \sqrt{h_1}}{(\sqrt{h_1}+\sqrt{h_2})(h_2 + \sqrt{h_1 h_2} + L h_1 - L h_2)}}$$

**Q.5 (d)** Enlist the methods of management of a large construction project in civil engineering. How do we have control over various activities from monthly and daily point of view? How is the schedule updated?

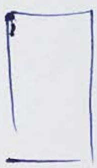
**[12 marks]**

Do not write in this margin

**Q.5 (e)** A reinforced concrete beam of rectangular section of size 250 mm × 550 mm overall depth is to be designed for a factored moment of 225 kNm. Compute the reinforcement required if the effective cover is 50 mm. The concrete mix to be used is M20 and the grade of steel is Fe415. Take $f_{sc}$ = 351.93 MPa.

**[12 marks]**

B = 250mm



D = 550mm

d = 500mm

EC = 50mm

BMu = 225kNm

(1) $x_{ulim} = kd = 0.48 \times 500 = 240mm$

(2) Assume under rlf beam

$BMu = 0.36 f_{ck} B x_u (d - 0.42 x_u)$

$x_u = 357.14$ mm

$x_u > x_{ulim} \rightarrow$ over rlf section.

(3) ~~0.36 fck B xu d~~

(3) Provide doubly rlf section

(4) $M_{ulim} = Qbd^2 = 0.138 \times 20 \times 250 \times 500^2$

$M_{ulim} = 172.5$ kNm

(5). $A_{st_1} = \dfrac{M_{ulim}}{0.87 f_y (d - 0.42 x_{ulim})}$

$A_{st_1} = 1196.82 mm^2$

$A_{st_2} = \dfrac{BMu - M_{ulim}}{0.87 f_y (d - d_c)}$  $d_c = 50mm$

$= 323.13 mm^2$

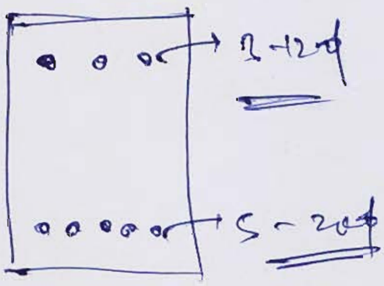
Do not write in this margin

$$A_{sc} = \frac{BMW - M_{u\lim}}{(f_{sc} - 0.45 f_{ck})(d - d_c)}$$

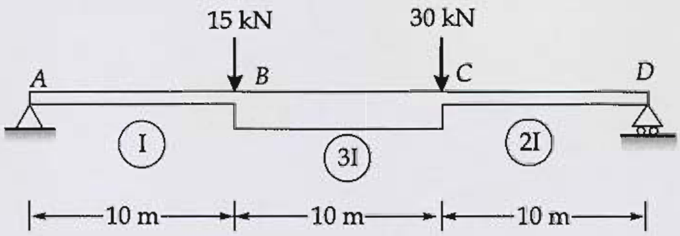
$A_{sc} = 340.205\ mm^2$ → provide 3-12 mm φ

$A_{st}$ total = 1519.95 mm² → provide 5-20 mm φ

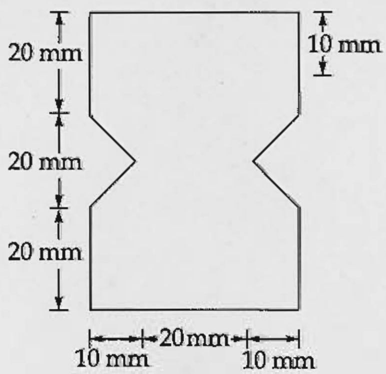
12




**Q.6 (a)** **(i)** For the simply supported beam as shown in figure, determine the deflection and slope at point B.
(Take $I = 2 \times 10^{10}$ mm$^4$, $E = 2 \times 10^5$ MPa.)




**(ii)** A rollel steel 60 mm × 40 mm section is shown in figure and a transverse shear force of 50 kN is acting on this section. Plot the shear stress distribution across the depth of the section and mention the value of shear stress at distance 10 mm, 20 mm from top fibre and maximum value of shear stress.




Cross-section of beam

[10 + 10 = 20 marks]

**Q.6 (b)** **(i)** Derive the following relations for the limit state design of a balanced rectangular RCC beam:

1. Depth of the neutral axis, $x_u = 0.479\,d$
2. Limiting BM, $M_c = 0.138 f_{ck}\, bd^2$
3. Steel area, $A_s = 4.78 \times 10^{-4} f_{ck}$ bd.

Where,

Width of beam = $b$

Effective depth of beam= $d$

Characteristic strength of concrete = $f_{ck}$ MPa

Characteristic strength of steel = 415 MPa

Characteristic elasticity of steel = $2 \times 10^5$ MPa

**(ii)** A RC beam has an effective depth of 500 mm and a breadth of 350 mm. It contains 4-25 mm bars in tension zone. If $f_{ck}$ = 25 N/mm$^2$ and $f_y$ = 415 N/mm$^2$, calculate the shear reinforcement needed for a factored shear force of 350 kN.

| $\frac{100A_s}{bd}$ | 0.15 | 0.5 | 1.0 | 1.25 | 1.5 |
|---|---|---|---|---|---|
| $\tau_c$ N/mm$^2$ | 0.29 | 0.49 | 0.64 | 0.70 | 0.74 |

**[10 + 10 = 20 marks]**

Do not write in this margin

**Q.6 (c)** For the given project in the following table, determine:

1. Critical path and standard deviation.
2. Probability of completion of project in 24 days.
3. Time duration that will provide 98.8% probability of its completion with in time.

| Activity | Time duration (in days) | | |
|---|---|---|---|
| | Optimistic ($t_o$) | Most likely ($t_m$) | Pessimistic ($t_p$) |
| 1 - 2 | 3 | 4 | 5 |
| 1 - 3 | 2 | 3 | 4 |
| 2 - 3 | 6 | 7 | 8 |
| 2 - 4 | 5 | 9 | 13 |
| 3 - 5 | 8 | 9 | 16 |
| 4 - 5 | 2 | 7 | 12 |

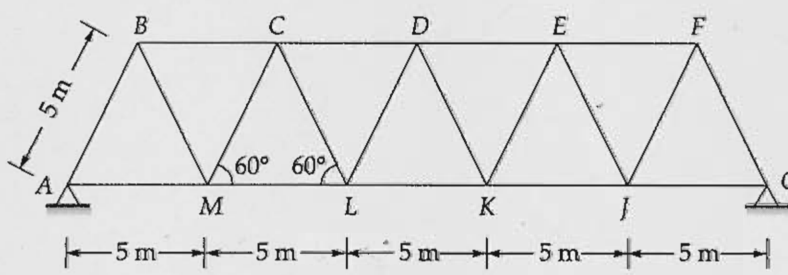
Standard normal distribution table:

| Z | 2.0 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.7 | 2.8 |
|---|---|---|---|---|---|---|---|---|---|
| Probability | 97.72 | 98.21 | 98.61 | 98.93 | 99.18 | 99.38 | 99.53 | 99.65 | 99.74 |

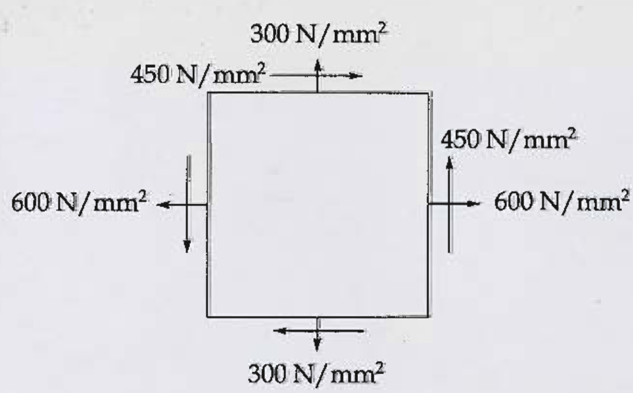
**[20 marks]**

Do not write in this margin

**Q.7 (a)** (i) Draw the influence line for the bottom chord member ML (the member in the second panel from the left).



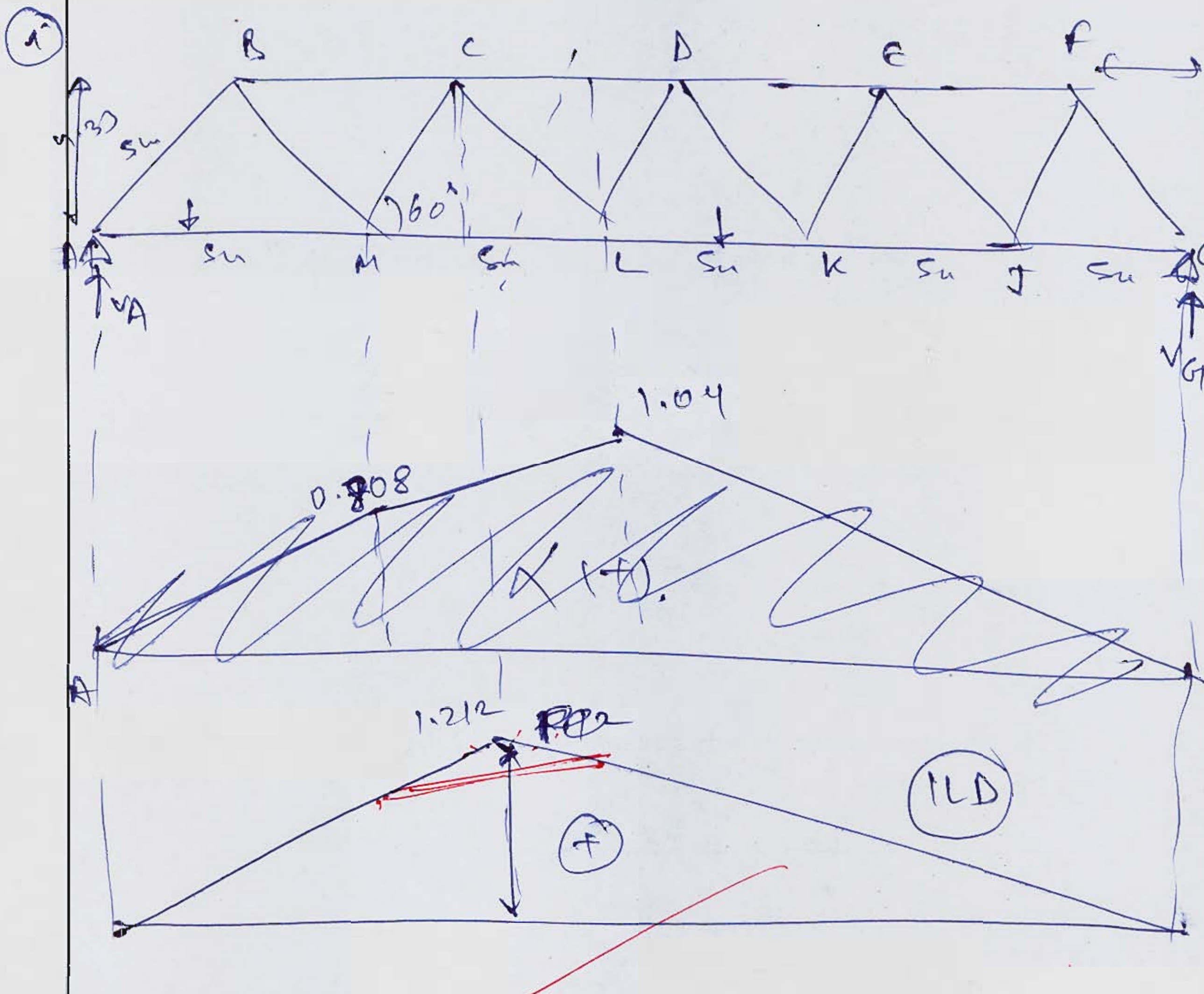

(ii) In two mutually perpendicular directions, the normal stresses are 600 $N/mm^2$ and 300 $N/mm^2$, both tensile. The corresponding complementary shear stresses acting in these directions have an intensity of 450 $N/mm^2$, as illustrated in the figure.




Determine the normal and tangential stresses on the two planes which are equally inclined to the planes carrying normal stresses mentioned above.

**[12 + 8 = 20 marks]**

(a)




Load b/w AM

$\Sigma M_C = 0$

$V_G \times 17.5 = F_{ML} \times 4.33$

$F_{ML} = 4.04\, V_G$ (T)

Load b/w LG

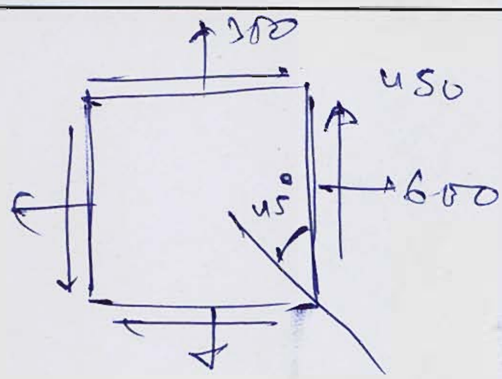
$\Sigma M_L = 0$

$V_A \times 7.5 = F_{ML} \times 4.33$

$F_{ML} = 1.732\, V_A$ (T)

Do not write in this margin

(iii)




$\theta = 45°$

$\sigma_x = 600$

$\sigma_y = 300$

$\tau_{xy} = 450$

5+7

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

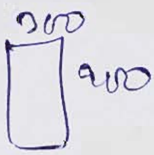
$\boxed{\sigma_{x'} = 900 \text{ MPa}} \rightarrow$ Normal stress

$\tau_{x'y'} = (\sigma_y - \sigma_x) \cos\theta \sin\theta + \tau_{xy}(\cos^2\theta - \sin^2\theta)$

$\boxed{\tau_{x'y'} = -150 \text{ MPa}} \rightarrow$ Tangential stresses

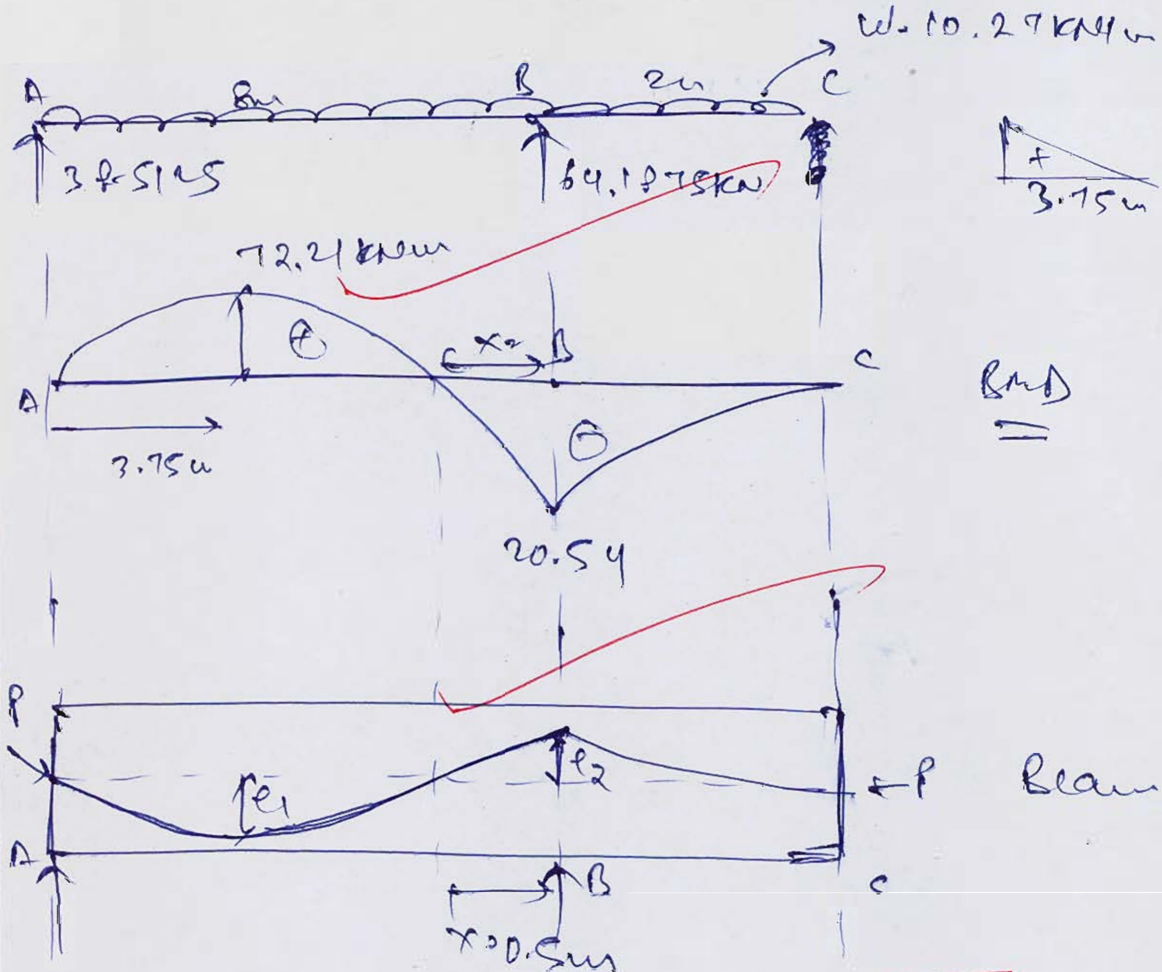
**Q.7 (b)** A concrete beam with a single overhang is simply supported at A and B over a span of 8 m and the overhang BC is 2 m. The beam is of rectangular section 300 mm wide by 900 mm deep and supports is uniformly distributed live load of 3.52 kN/m over the entire length in addition to its self-weight. Determine the profile of the prestressing cable with an effective force of 500 kN which can balance the dead and live loads on the beam. Sketch the profile of the cable along the length of the beam.

**[20 marks]**




$w_L = 3.52$ kN/m

$w_D = .3 \times .9 \times 25 = 6.75$ kN/m




Cable profile provided to the beam should coincide by the BMD of the beam

$(e_1) \Rightarrow \quad M_x = Pe_1$

$72.21 \times 10^3 = 500\, e_1$

$\boxed{e_1 = 144.21\,mm}$

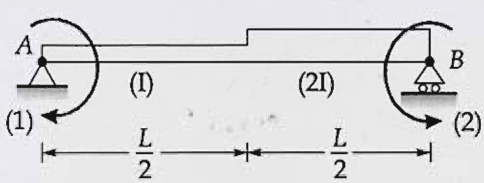
$(e_2) \Rightarrow \quad M_x = Pe_2$

$20.54 \times 10^3 = 500\, e_1$

$\boxed{e_2 = 41.08\,mm}$

20

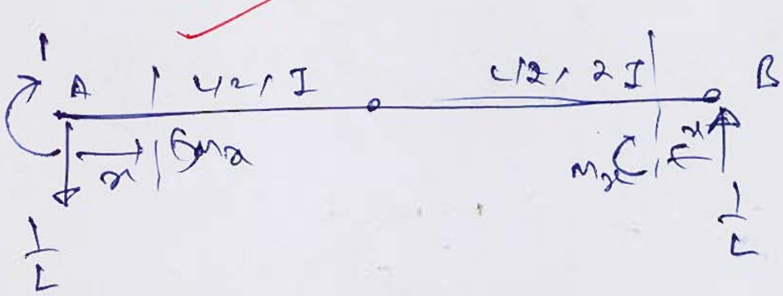
**Q.7 (c)** Compute the flexibility matrix with reference to the indicated coordinates




**[20 marks]**

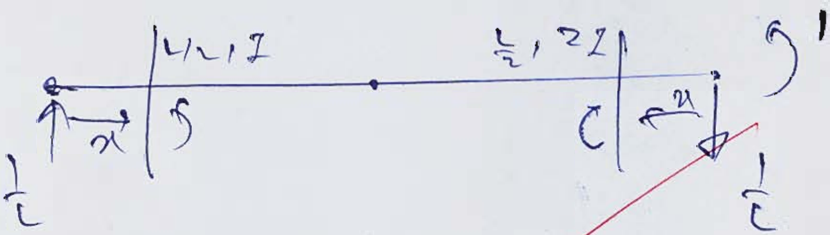
① $\delta = \begin{bmatrix} \delta_{11} & \delta_{12} \\ \delta_{21} & \delta_{22} \end{bmatrix}$

② ~~colum~~.  (m1)



| | $m_1$ | $m_2$ |
|---|---|---|
| (1) AB $(0 - L/2)$ | $\left(1 - \frac{x}{L}\right)$ | $\frac{x}{L}$ |
| (2) BC $\left(0 - \frac{L}{2}\right)$ | $\frac{x}{L}$ | $\left(1 - \frac{x}{L}\right)$ |

$m_2$




$$\delta_{11} = \int_{AB} \frac{m_1 m_1\, dx}{EI} + \int_{BC} \frac{m_1 m_1\, dx}{EI}$$

$$= \int_0^{L/2} \frac{\left(1 - \frac{x}{L}\right)^2 dx}{EI} + \int_0^{L/2} \frac{\left(\frac{x}{L}\right)^2}{2EI}\, dx$$

$$\delta_{11} = \frac{7}{24} \cdot \frac{L}{EI} + \frac{1}{48} \cdot \frac{L}{EI}$$

$$\delta_{11} = \frac{5}{16} \frac{L}{EI}$$

$$\delta_{12} = \int_{AB} \frac{m_1 m_1\, dx}{EI} + \int_{BC} \frac{m_1 m_2\, dx}{EI}$$

$$= \int_0^{L/2} \frac{\left(1 - \frac{x}{L}\right)\left(\frac{x}{L}\right)}{EI}\, dx + \int_0^{L/2} \frac{\left(\frac{x}{L}\right)\left(1 - \frac{x}{L}\right) dx}{2EI}$$

$$\delta_{12} = \delta_{21} = \frac{1}{8} \cdot \frac{L}{EI}$$

$$\delta_{21} = \int_{AB} \frac{m_2 m_2 \, dx}{EI} + \int_{BC} \frac{m_2 m_2 \, dx}{EI}$$

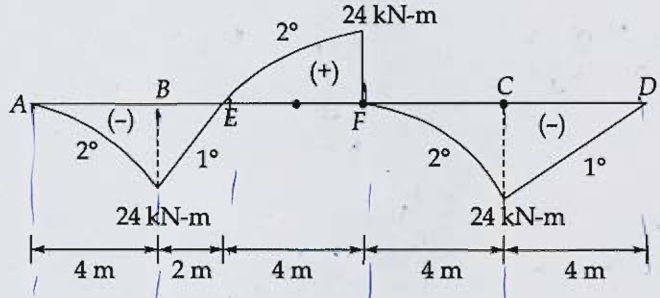
$$= \int_0^{L/2} \frac{(x/L)^2}{EI} dx + \int_L^{L/2} \frac{\left(1 - \frac{x}{L}\right)^2}{2EI} dx$$

$$= \frac{3}{16} \frac{L}{EI}$$

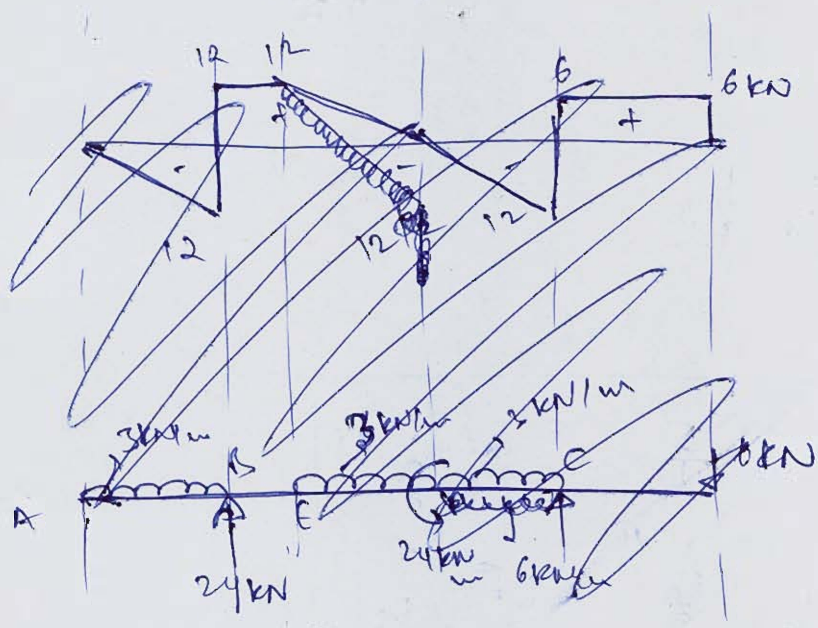
20

$$\boxed{\delta = \frac{L}{EI} \begin{bmatrix} \frac{5}{16} & \frac{1}{8} \\ \frac{1}{8} & \frac{3}{16} \end{bmatrix}}$$

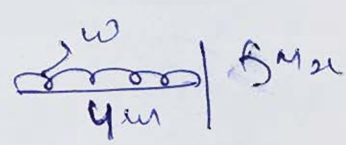
**Q.8 (a)** BMD for beam is given below. Draw loading diagram and shear force diagram. The beam is simply supported with overhangs on *B* and *C*.




**[20 marks]**



AB: $V = \frac{dM}{dx}$



$w \times 4 \times 2 = 24$

$w = 3$ kN/m

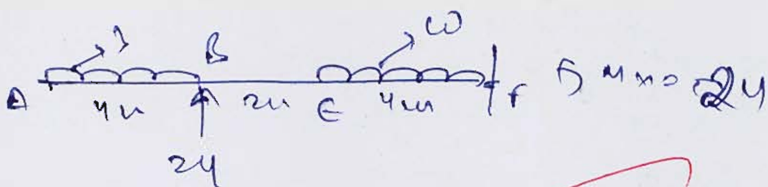
BE: $V = \frac{dM}{dx}$ : $V = \frac{M_E - M_B}{2m}$

$V = \frac{0 - (-24)}{2} = 12$ kN

CD: $V = \frac{dM}{dx} \Rightarrow V = \frac{M_D - M_C}{4}$

$V = \frac{0 - (-24)}{4} = 6$ kN

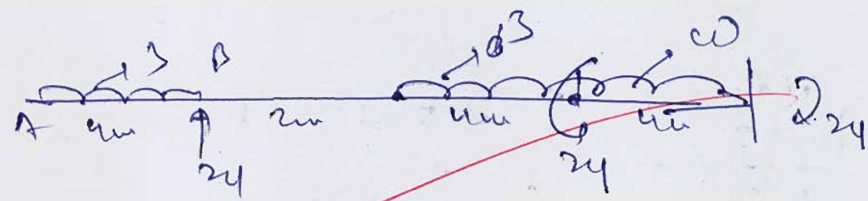
~~BC~~ AF =




$3\times4\times8 + w\times4\times2 = 24\times6$

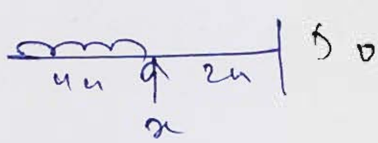
$w = \cancel{6}\,3$

AC:



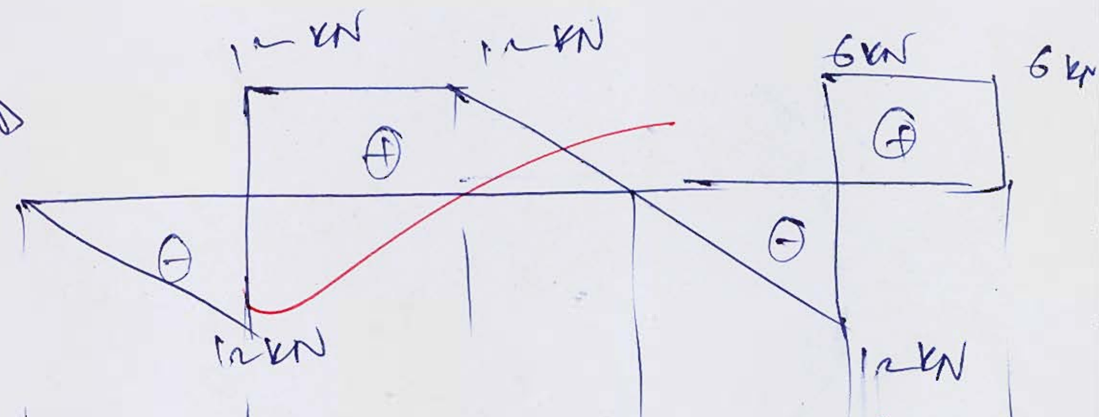

$3\times4\times12 - 24\times10 + 3\times4\times6 + 24$
$+ w\times4\times2 = 24$

$w = -6\ \text{kN/m}$

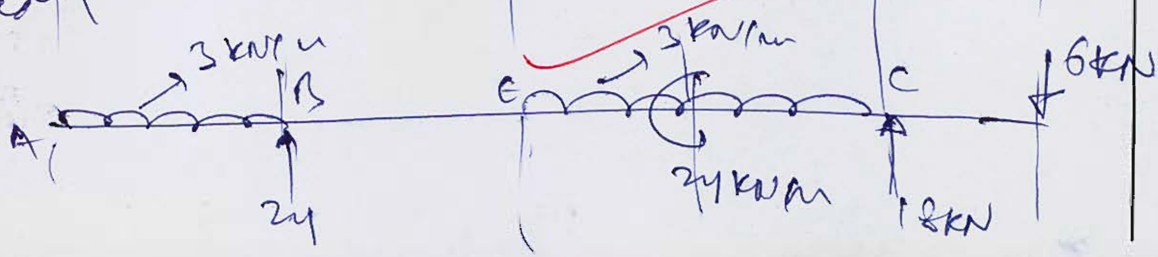



20

SFD

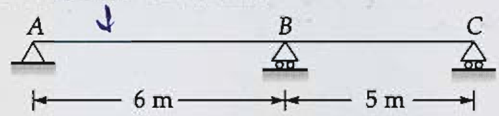



Loading

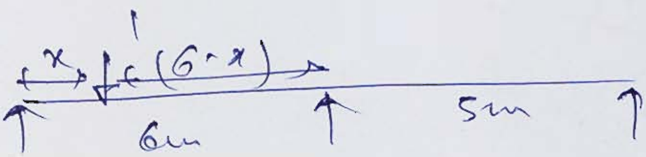


Do not write in this margin

**Q.8 (b)** For the beam as shown in figure, compute the ordinate of influence line for $R_A$ at 1 m interval. Assume EI of beam is constant.

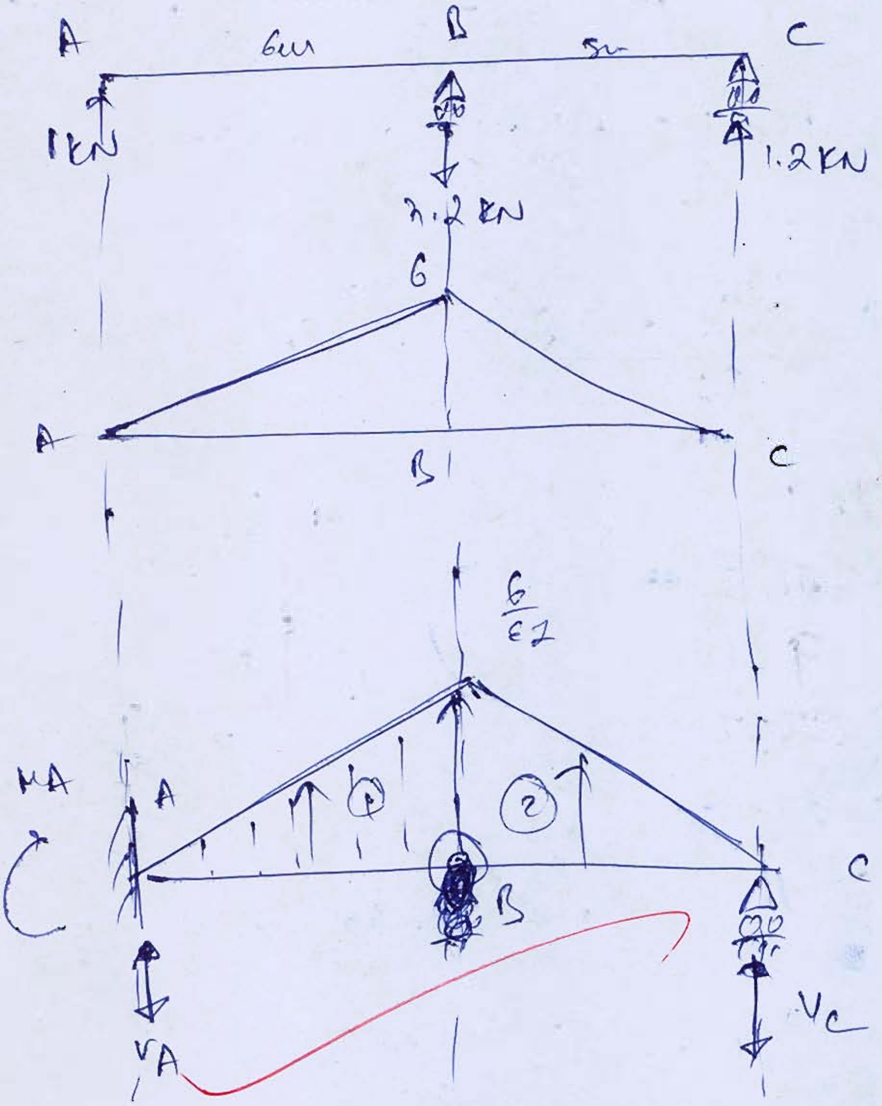



**[20 marks]**




| | | | |
|---|---|---|---|
| B | ~~BA~~ | $\frac{4EI}{6}$ | $\frac{5}{11} = 0.45$ |
| | BC | $\frac{4EI}{5}$ | $\frac{6}{11} = 0.55$ |

| | A | B | | C |
|---|---|---|---|---|
| | 0 | 0.45 | 0.55 | 0 |
| ~~FEM~~ FEM | | | | |




BMD

20

conjugate beam

$A_1 = \frac{18}{EI}$

$A_2 = \frac{15}{EI}$

$\Sigma M_B = 0$

$\rightarrow \frac{15}{EI} \times \frac{5}{3} = V_C \times 5$

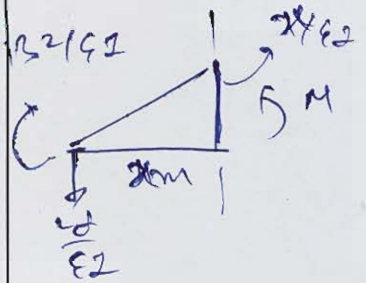
$\boxed{V_C = \frac{5}{EI}}$

$A_1 + A_2 = V_A + V_C$

$\boxed{V_A = \frac{28}{EI}}$

$M_A + \frac{18}{EI} \times \frac{6}{3} = \frac{28}{EI} \times 6$

$\boxed{M_A = 132/EI}$




$M = \cancel{132 - \frac{1}{2} \times 1 \times 1 \times \frac{1}{3} - 28 \times 1}$

$$M = \frac{132}{EI} + \frac{1}{2} \cdot x \cdot \frac{x}{EI} \cdot \frac{x}{3} - \frac{28}{EI} \cdot x$$

$$M = \frac{132 + x^3/6 - 28x}{EI} = \delta A$$

$\delta A_{1m} = 0.789$

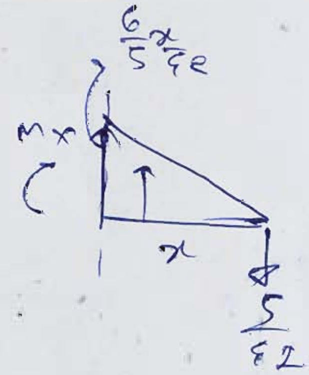
$\delta A_{2m} = 0.5885$

$\delta A_{3m} = 0.39$

$\delta A_{4m} = 0.2323$

$\delta A_{5m} = 0.097$

$\delta A_{6m} = 0$




$$M_x = \frac{1}{2} \cdot \frac{6x}{5EI} \cdot x \cdot \frac{x}{3} - \frac{5}{EI} x$$

$$M_x = \frac{x^3/5 - 5x}{EI}$$

$x = 0, \ \delta_A = 0$

$x = 1, \ \delta = -0.0363$

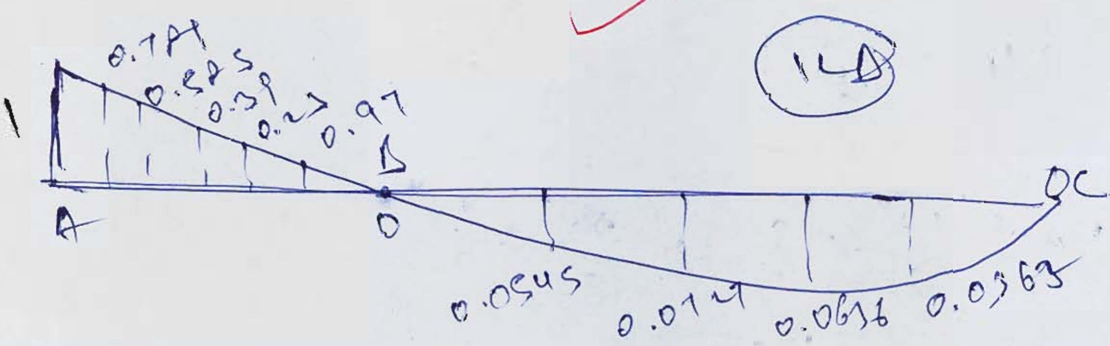
$x = 2, \ \delta = -0.0636$

$x = 3, \ \delta = -0.0727$

$x = 4, \ \delta = -0.0545$

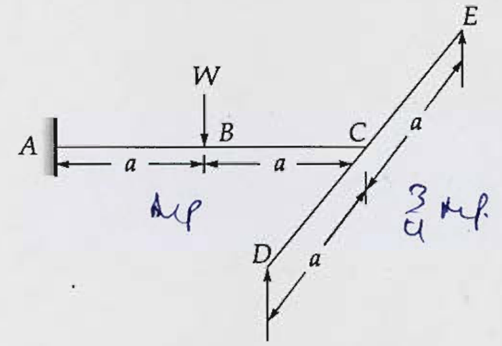
$x = 5, \ \delta = 0$

ILD



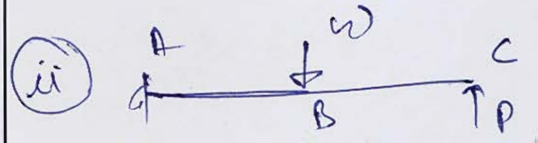
.8 (c) (i) Enumerate the advantages of high-strength friction grip (HSFG) bolts. Illustrate and explain the load transfer mechanism of HSFG bolts with the help of a neat and labeled sketch.

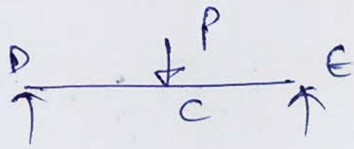
(ii) A load 'W' is supported by a propped cantilever resting on a simply supported beam as shown in the figure. Assuming that plastic moment of the simply supported beam is three-quarter of the cantilever beam, evaluate the collapse load.




**[8 + 12 = 20 marks]**

(ii)




Def$^n$:

$$\frac{Wa^3}{3EI} + \frac{Wa^2}{2EI} \times a = \frac{P(2a)^3}{3EI} + \frac{P(2a)^3}{48EI}$$

$$\frac{5}{6}\frac{Wa^3}{EI} = \frac{17}{48}\frac{P(2a)^3}{EI}$$

$$\frac{5}{6} W = \frac{17}{48} P \times 8$$

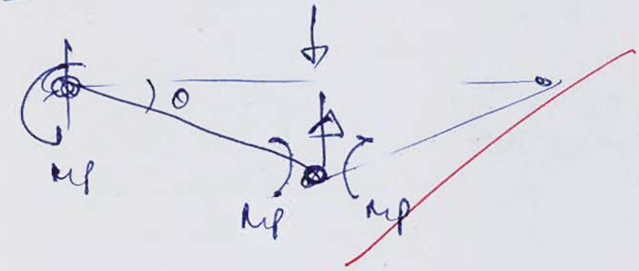
$$\boxed{P = \frac{5}{17} W}$$

$$(M_P)_{DE} = \frac{3}{4}(M_P)_{AC}.$$

$$M_P = (M_P)_{AC}$$

$$(M_P)_{DE} = \frac{3}{4} M_P$$

A C

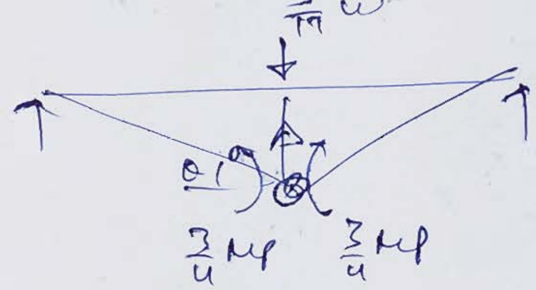



$3M_p\theta = w\Delta$

$3M_p \frac{\Delta}{a} = w\Delta$

$\boxed{w = \frac{3M_p}{a}}$

B E




$\frac{5}{17} w\Delta = \frac{3}{4} M_p \theta \times 2$

$\frac{5}{17} w\Delta = \frac{3}{4} \times M_p \times 2 \times \frac{\Delta}{a}$

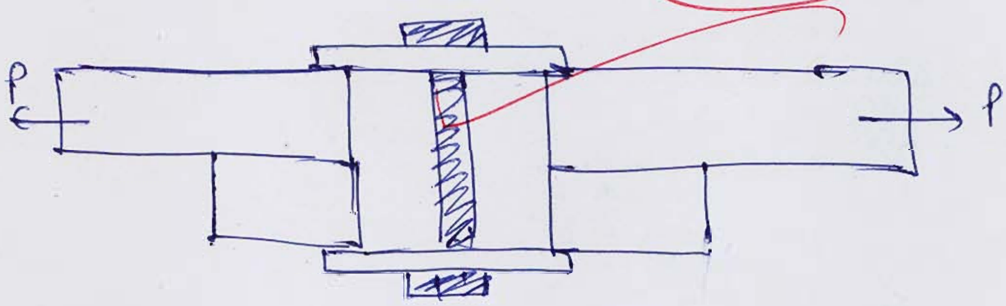
$\boxed{w = \frac{5.1\, M_p}{a}}$

$\Rightarrow$ collapse load $= \min \left\{ \frac{3M_p}{a}, \frac{5.1 M_p}{a} \right. = \frac{3M_p}{a}$

Advantages of HSFG Bolts

→ provides rigid connection
→ load transfer is through friction
→ Highly durable
→ more strength than normal Bolts.
→ Bearing failure is eliminated

4+10




Load transfer is through frictional force generated in Bolt.

■■■■

Space for Rough Work

Space for Rough Work

## Space for Rough Work