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	54
Q.2	36
Q.3	38
Q.4	—
Section-B	
Q.5	44
Q.6	—
Q.7	—
Q.8	45
Total Marks Obtained	217

Signature of Evaluator: Sheryab .... Cross Checked by ....

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.

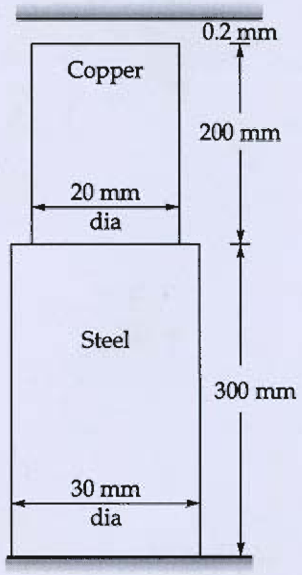
Do not write in this margin

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/mm²; $\alpha_s = 12 \times 10^{-6}$/°C;

$E_c = 1.2 \times 10^5$ N/mm²; $\alpha_c = 17.5 \times 10^{-6}$/°C



[12 marks]

Sol:- Temp. Rise will not Produce ~~Rise in Temp.~~ Stress in Bar

$$\therefore (\alpha \Delta T L)_{steel} + (\alpha \Delta T L)_{copper} = 0.2$$

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

$$\boxed{\Delta T = 28.169\,°C}$$

for $\boxed{\Delta T = 40\,°C}$

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

$$\frac{-P \times 300}{\pi/4 \times 30^2 \times 2\times10^5} + (12\times10^{-6} \times 40 \times 300) - \frac{P \times 200}{\pi/4 \times 20^2 \times 1.2\times10^5} + (17.5\times10^{-6} \times 40 \times 200) = 0.2$$

$$\therefore P = 11309.733\text{ N} = 11.309\text{ kN}.$$

Stress in Steel = $\frac{P}{A_s} = \frac{11.309 \times 10^3}{\pi/4 \times 30^2} = 15.998$ MPa

Stress in Copper = $\frac{P}{A_c} = \frac{11.309 \times 10^3}{\pi/4 \times 20^2} = 35.997$ MPa

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]

Ans: Let x Part of F.A Mixed with (1−x) Part of CA

$$\therefore 6.5 = \frac{x \times 2.9 + (1-x)\times 7.8}{1}$$

$\therefore$ $\boxed{x = 0.2653}$ = 26.53% FA (12)

Mixed with 73.47% of CA.

$\therefore$ Mass of fine Aggregate (kg/m^3) = $\frac{26.53}{73.47} \times 1538$

= 555.371 kg/m^3.

~~fine~~ fineness Modulus is determined with the help of Sieve Analysis ⇒ % Retained on Each Sieve is calculated.

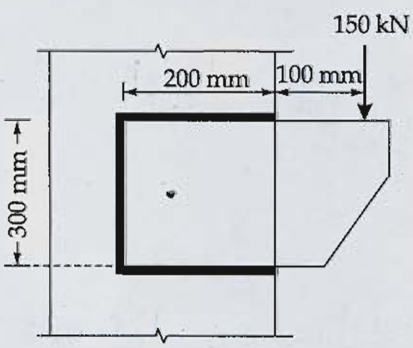
$$\therefore F.M = \frac{\Sigma \text{ Cummulative \% Wt. Retained}}{100}$$

F.M is Important to Control because it Affect the Workability & Strength of Concrete

If F.M ↑ ⇒ Result in Harsh Concrete Mix.

F.M ↓ ⇒ Result in Smooth Concrete Mix.

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.

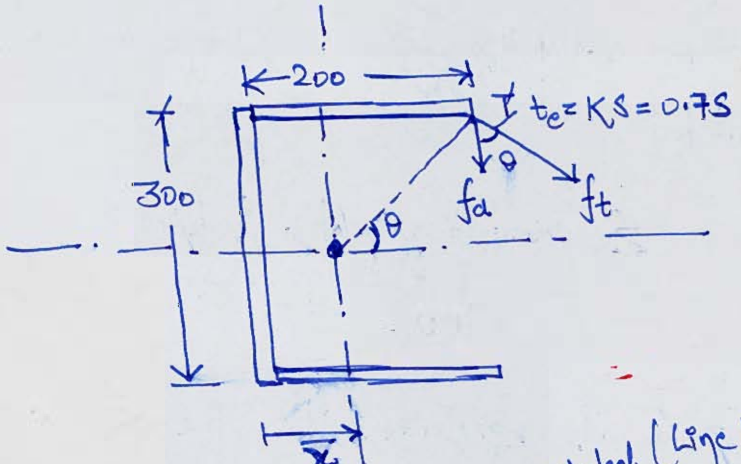


= factored Load.

$e = 100 + 200 - \bar{x}$

$= 242.858$ mm

[12 marks]



∵ e =

neglected (Line Load)

$$\bar{x} = \frac{(300 \times t_e) \times t_e/2 + [200 \times t_e \times 2] \times (200/2)}{(300 \times t_e) + (200 \times t_e) \times 2}$$

$= 57.142$ mm

$$\bar{x} = 57.142\text{ mm}$$

$$\tan\theta = \frac{300/2}{200-\bar{x}} = \frac{150}{200-57.142} \Rightarrow \theta = 46.397^\circ$$

$$q = f_d = \frac{P}{A_{weld}} = \frac{150\times10^3}{(300\times t_e) + 2(200\times t_e)} = \frac{214.285}{t_e} \quad (1)$$

08

$$f_t = \frac{(Pe)r_i}{\Sigma r_i^2} = \frac{My}{I}$$

~~$I = (300\times t_e)\times 57.142^2 + 2[(200\times t_e)+$~~

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

$$= 11.25\times10^6\, t_e\ \text{mm}^4$$

$$\therefore f_t = \frac{(Pe)\times 150\text{ mm}}{11.25\times10^6} = \frac{150\times10^3\times 242.858\times 150}{11.25\times10^6\, t_e}$$

$J = I_{xx} + I_{yy}$?

$$= \frac{485.716}{t_e}\ \text{N/mm}^2 \quad (2)$$

$\because$

$$f_R = \sqrt{f_d^2 + f_t^2 + 2f_d f_t\cos\theta} \le \frac{f_u}{\sqrt{3}\,\gamma_{mw}}$$

$$\sqrt{\left(\frac{214.285}{t_e}\right)^2 + \left(\frac{485.716}{t_e}\right)^2 + 2\left(\frac{214.285}{t_e}\right)\left(\frac{485.716}{t_e}\right)\cos 46.397^\circ}$$

$$\le \frac{f_u = 410}{\sqrt{3}\times 1.25}$$

$t_e \ge 3.444$ mm → Shop weld

$0.7 s \ge 3.444$

$s \ge 4.92$ mm

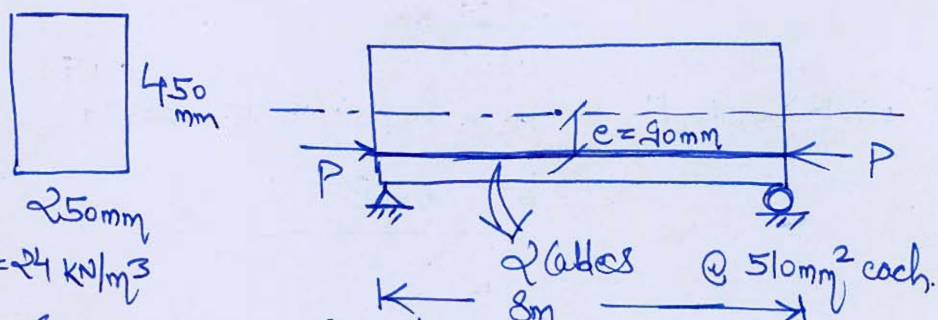
Provide [5 mm weld size]

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]

Sol^n:



$\gamma_{con.} = 24\ kN/m^3$

① δ due to its own wt:

Dead Load $= 0.25 \times 0.45 \times 24 = 2.7\ kN/m$

$\therefore\ M_d = \frac{wl^2}{8} = \frac{2.7 \times 8^2}{8} = 21.6\ kNm$

$\therefore\ \delta_{self\,wt.} = \frac{5}{384}\frac{wl^4}{EI}$

$E = 40\ kN/mm^2$, $I = \frac{250 \times 450^3}{12} = 1898.43 \times 10^6\ mm^4$.

$\delta_{self\,wt} = \frac{5 \times (2.7) \times (8000)^4}{384 \times 40 \times 10^3 \frac{N}{mm^2} \times 1898.43 \times 10^6\ mm^4}$

$= 1.8963\ mm$

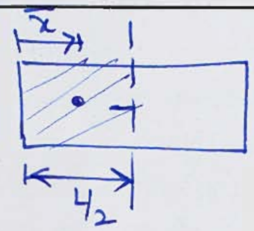
② Due to imposed + D.L + Prestressing:

$\delta_{self_{DL}} = 1.8963\ mm\ (\downarrow)$

$\delta_{I.L} = \frac{5 \times 15 \times 8000^4}{384 \times 40 \times 10^3 \times 1898.43 \times 10^6} = 10.535\ mm\ (\downarrow)$

Do not write in this margin

Due to Prestressing $= A\bar{x}$ $= \frac{Pe}{EI} \times \frac{L}{2} \times \frac{L}{4}$



$= -\frac{PeL^2}{8EI}$

$= -\frac{0.8 \times (1500 \times 2 \times 510) \times 90 \times (8000)^2}{8 \times 40 \times 10^3 \times 1898.43 \times 10^6}$

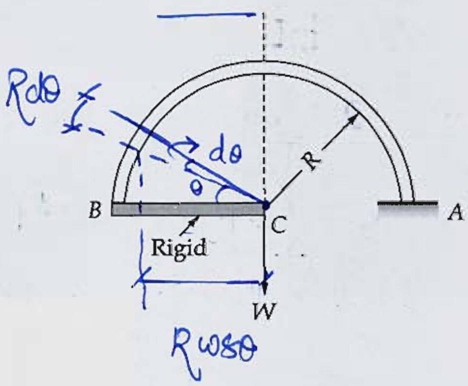
$= -11.605$ mm

(10)

$\therefore$ Net Deflect^n $= 1.8963 + 10.535 - 11.605$

$= 0.8263$ mm

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 $\frac{\pi WR^3}{2EI}$, where *EI* is flexural rigidity of the bracket.



[12 marks]

$\therefore M_x = W \times R\cos\theta$

$\therefore \frac{dM_x}{dW} = R\cos\theta$

$\therefore \delta = \frac{d}{dW} \int \frac{M_x^2\,dx}{EI}$

$\therefore \delta = \int \frac{M_x \cdot \left(\frac{dM_x}{dW}\right) \cdot ds}{EI}$

$$\delta_v = \int \frac{(WR\cos\theta) \times (R\cos\theta) \cdot R \cdot d\theta}{EI} \quad \because ds = R\,d\theta$$

$$\delta_v = \frac{WR^3}{EI} \int_0^{\pi} \cos^2\theta \cdot d\theta .$$

$$\boxed{\delta_v = \frac{\pi}{2} \frac{WR^3}{EI}}$$

12

Do not write in this margin

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]

factors Affecting rheological Property:

- Water/Cement Ratio:—
  As w/c Ratio Increase workability increase But Strength decrease
- Size of Agg: Size of Aggregate ↑ ∝ Workability increase
- Surface Texture of Agg.
  ↳ Smooth Surface Texture Increase Workability
- Temp. ⟶ Higher Temp Leads to greater water loss from Concrete.

- Humidity
-

6+8

(ii) Pozzolanic Actⁿ:

When Pozzolanic Material like fly Ash Mix with Cement in Concrete it acts as filler Material & React with $Ca(OH)_2$ to produce C-S-H Gel. which increase durability & strength of concrete.

Various Pozzolanic Material:

- fly Ash
- Silica fumes.
- GGBS

Implicatⁿ Seen:

- Decrease Permeability
- Increase durability
- Rate of Hydratⁿ of Heat Reduces.
- Provide Strength @ Later Stage.
- Provide filler Material to Concrete
- Economical Concrete will Prepare.

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 ϕ bars and nominal cover = 25 mm]

Also provide 10 mm ϕ bars for bottom 1 m height of wall.

Detailing not required.

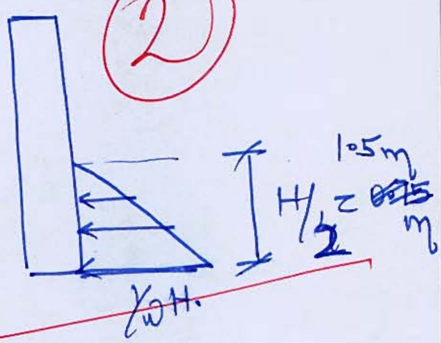
[20 marks]

$T = \frac{PD}{2t} = \frac{\gamma_w \times 1.5 \times 3}{2 \times 150} =$ ~~73.575~~ $0.147\ \text{kN}$ for Approximate Method

Hoop Tension

(2)

Assume $t = 150\text{mm}$



$\therefore A_{st\,req.} = \frac{0.147 \times 10^3}{115}$

$= 1.278\ \text{mm}^2$

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

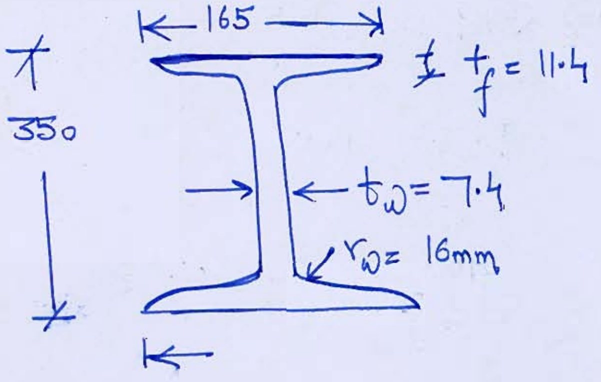
No need to check for deflection

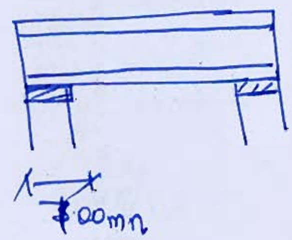
For buckling curve, (*c*)

k/r	70	80	90	100
f_{cd} (N/mm²)	152	136	121	107

[20 marks]

Soln:





Assume factored is Given:

∴ factored B.M =

M_u = 150 KNm

V_u = 210 KN.

$\because \frac{b_f}{t_f} = \frac{(165/2)}{11.4} = 7.2368 < 9.4\varepsilon_e$
Plastic Sectⁿ

$\therefore \frac{d}{t_w} = \frac{350}{7.4} = 47.297 < 84\varepsilon_e$
Plastic web.

∴ Hence Given Sectⁿ is Plastic

$\because V_d = \frac{f_y}{\sqrt{3}\gamma_{m_0}}(D t_w) = \frac{250}{\sqrt{3} \times 1.10} \times 350 \times 7.4$
$= 339.849$ KN. > 210 KN [OK]

$\because 0.6 V_d = 203.9094$ KN

$V_u > 0.6 V_d \Rightarrow$ High Shear Case.

$\therefore M_{dv} = M_d - \beta [M_d - M_{fd}]$

$M_d = \beta Z_p \frac{f_y}{\gamma_{m_0}} = 1 \times 851.11 \times 10^3 \times \frac{250}{1.10}$
(β = 1 for Plastic sectⁿ)
$= 193.434$ KNm

$\beta = \left[\frac{2V_u}{V_d} - 1\right]^2 = \left[\frac{2 \times 210}{339.85} - 1\right]^2 = 0.0556.$

$M_{fd} = M_d - \frac{f_y}{\gamma_{m_0}}\left[\frac{D t_w^2}{4}\right] = 193.434 \times 10^6 - \frac{250}{1.10} \times \frac{350 \times 7.4^2}{4}$

$\boxed{M_{fd} = 192.345 \text{ KNm}}$

$\therefore M_{dv} = 193.434 - 0.0556 \times [193.434 - 192.345]$

$= 193.373$ KNm > 150 KNm [OK].

∵ Web Buckling @ Support:

$A_e = (b + \frac{D}{2}) t_w$

∵ $f_{cd} A_e \geq P$

20

∵ $\frac{Kl}{r} = \frac{l_{eff}}{r_{min}} = \frac{6000}{\sqrt{\frac{I_z}{A}}} = \frac{6000}{\sqrt{\frac{13158.3 \times 10^4}{6183.28}}} = 41.13$

Not in Table

$r_{min} = \sqrt{\frac{I}{A}}$ $I = Ar^2$

$A = (165 \times 11.4) \times 2 + [350 - 2(t_f)] t_w$

$= 6183.28$ mm²

∵ $Z_p = f_y$ Assume $K/r = 70$

$\therefore f_{cd} = 152$ MPa

∴ $152 \times (100 + \frac{350}{2}) \times 7.4 = 309.32$ KN > 210 KN [OK]

∵ Web Bearing:

$f_y/\gamma_{m0} [b + 2.5(t_f + r)] t_w \geq P$

$\frac{250}{1.10} [100 + 2.5(11.4 + 16)] \times 7.4 \geq 210$ KN

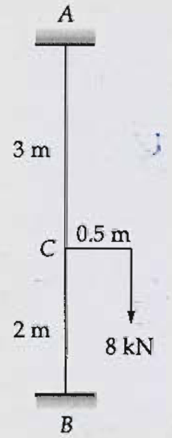
283.386 KN > 210 KN [OK]

∴ Sectⁿ is Adequate.

Do not write in this margin

Do not write in this margin

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



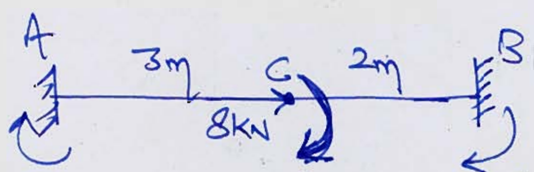
≅

Using slope-deflection method,

(i) Plot the bending moment diagram.

(ii) Plot the deflected shape of the column.

[20 marks]



$= \frac{M \times 2(3\times3-5)}{5^2}$ $\qquad$ $\frac{M \times 3(3\times2-5)}{5^2}$

$= 1.28\,KNm$ $\qquad$ $= 0.48\,KNm$

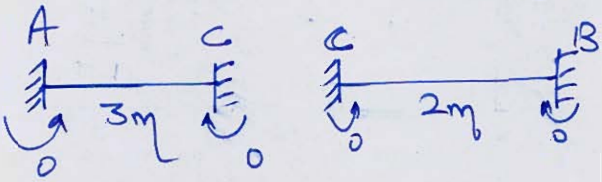
$\because$ $M_{CA} + M_{CB} = +4\,KN$ ①

$V_A + V_B = 0$ — ②

$\therefore$ ~~$M_{AC} = M_{F_{AC}} + \frac{2EI}{3}\left[2\theta_A + \theta_C - \frac{3\delta}{3}\right]$~~

~~$= +1.28 + \frac{2EI}{3}\left[\theta_C - \frac{3\delta}{3}\right]$~~ ③

~~$M_{CA} =$~~



$\because$

$$M_{AC} = 0 + \frac{2EI}{3}\left[2\theta_A^{\,0} + \theta_C - \frac{3\delta}{L}\right]$$

$$= \frac{2EI}{3}\left[\theta_C - \frac{3\delta}{3}\right] \quad \text{—(3)}$$

$$M_{CA} = 0 + \frac{2EI}{3}\left[2\theta_C + 0 - \frac{3\delta}{L}\right]$$

$$= \frac{2EI}{3}\left[2\theta_C - \frac{3\delta}{3}\right] \quad \text{—(4)}$$

$$M_{CB} = 0 + \frac{2EI}{2}\left[2\theta_C + \theta_B^{\,0} - \frac{3\delta}{2}\right]$$

$$= EI\left[2\theta_C - \frac{3\delta}{2}\right] \quad \text{—(5)}$$

$$M_{BC} = 0 + \frac{2EI}{2}\left[2\theta_B^{\,0} + \theta_C - \frac{3\delta}{L}\right]$$

$$= EI\left[\theta_C - \frac{3\delta}{2}\right] \quad \text{—(6)}$$

from eq (1)

$$\frac{2EI}{3}\left[\theta_C - \frac{3\delta}{3}\right] + EI\left[2\theta_C - \frac{3\delta}{2}\right] = 4$$

$$\frac{2}{3}\left(\theta_C - \frac{3\delta}{3}\right) + 1\left[2\theta_C - \frac{3\delta}{2}\right] = \frac{4}{EI}$$

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

$$\boxed{\frac{8}{3}\theta_C - \frac{13}{6}\delta = \frac{4}{EI}} \quad \text{—(I)}$$

$$V_A = \frac{M_{AC}+M_{CA}}{3}$$

$$V_B = \frac{M_{CB}+M_{BC}}{2}$$

Avoid silly mistakes and calculation Errors

$$\because \frac{M_{AC}+M_{CA}}{3} + \frac{M_{CB}+M_{BC}}{2} = 0$$

$$\frac{\frac{2EI}{3}\left[\theta_c - \frac{3\delta}{3}\right] + \frac{2EI}{3}\left[2\theta_B - \frac{3\delta}{3}\right]}{3} + \frac{EI\left[2\theta_c - \frac{3\delta}{2}\right] + EI\left[\theta_c - \frac{3\delta}{2}\right]}{2} = 0$$

$$\frac{\frac{2}{3}\theta_c - \frac{2}{3}\delta + \frac{4}{3}\theta_B - \frac{2}{3}\delta}{3} + \frac{2\theta_c - \frac{3\delta}{2} + \theta_c - \frac{3\delta}{2}}{2} = 0$$

$$\frac{2\theta_c - \frac{4}{3}\delta}{3} + \frac{3\theta_c - 3\delta}{2} = 0$$

$$2\left[2\theta_c - \frac{4}{3}\delta\right] + 3\left[3\theta_c - 3\delta\right] = 0$$

$$4\theta_c - \frac{8}{3}\delta + 9\theta_c - 9\delta = 0$$

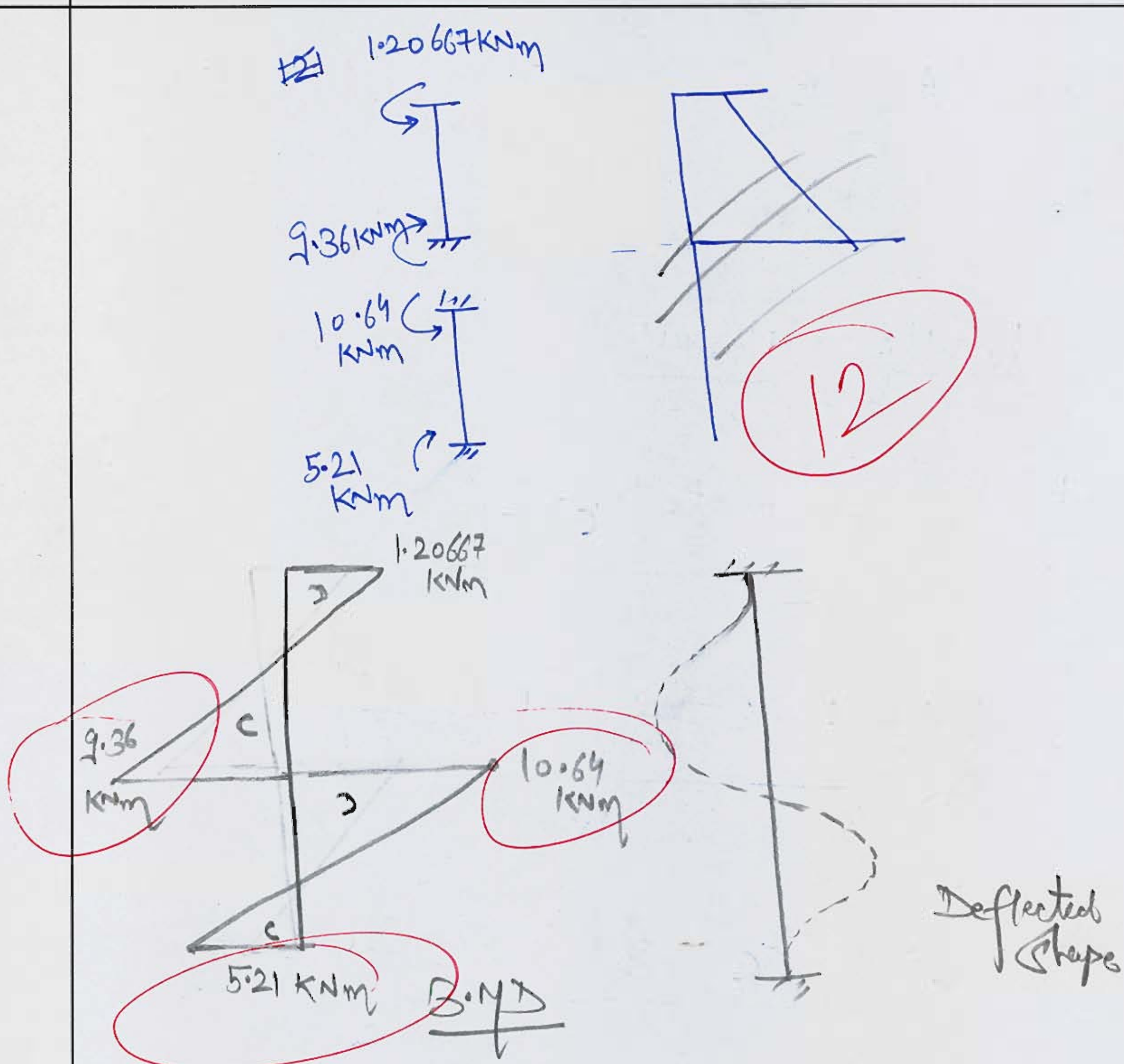
~~$13\theta_c - \frac{8\delta}{3}$~~ $= 0$ $\boxed{13\theta_c - \frac{35}{3}\delta = 0}$ — (II)

from eq (I) & (II)

$$\theta_c = \frac{15.85}{EI} \qquad \delta = \frac{17.66}{EI}$$

$\therefore$ from Above eqn

$M_{AC} = -1.20667$ kNm | $M_{CA} = 9.36$ kNm | $M_{BC} = -10.64$ kNm | $M_{CB} = 5.21$ kNm



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]

Scrap Value: Value @ the end of the life span of the Component

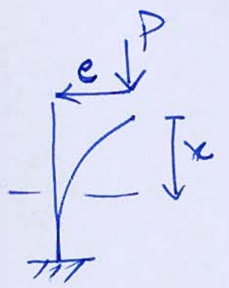
Salvage Value: ⇒ Value @ which the items can be return ~~After~~ its useful time.

Book Value: ⇒ Cost @ which the Particular item Booked

Capitalized Value ⇒ When life is too long

Capitalized Value = A/i

4+2



$M_x = Pe$

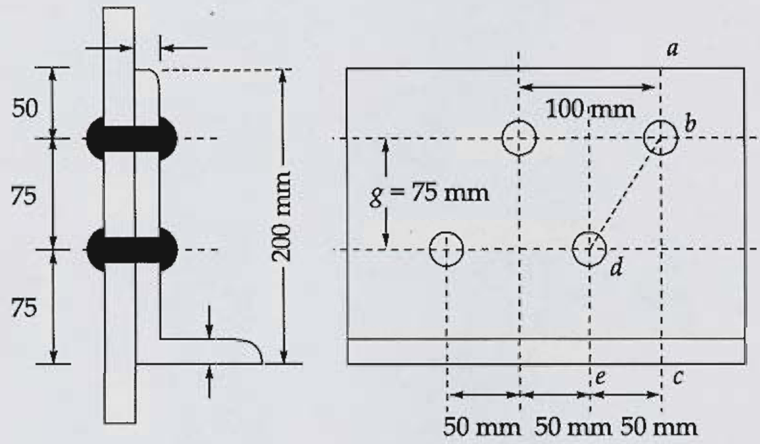
$$\frac{d^2y}{dx} = \frac{Pe}{EI}$$

On ~~diff~~ solving differential eqⁿ

: We Get.

$$P_{cr} = \frac{\pi^2 EI}{(2l)^2} = \boxed{\frac{\pi^2 EI}{4l^2} = P_{cr} = P.}$$

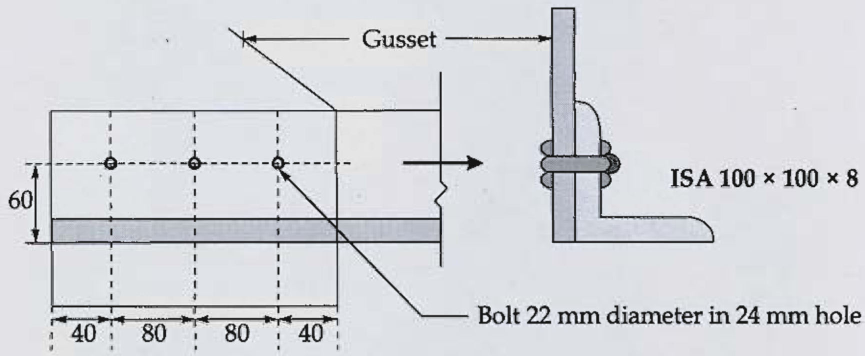
Q.3 (c) (i) The long leg of ISA 200 × 100 is connected to gusset plate by 22 mm diameter rivets in two rows, with gauge space of 75 mm and staggered pitch of 50 mm, as shown in figure. Determine suitable thickness of the angle to transmit a pull of 350 kN. Take σ_{at} = 180 N/mm^2.



(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]

(c) (i)

$\sigma_{at} = 180\ N/mm^2$ $\quad d_h = 22 + 1.5 = 23.5\,mm$

$A_{net} = A_1 = \left[200 - 2\times 23.5 + \frac{50^2}{4\times 75} - t/2\right] t.$ (Connected)

$= \sout{161.33t}\ mm^2$

$= (161.33 - t/2)t\ mm^2$ — (1)

$A_2 = (100 - t/2)t =$ — (2)

$K = \frac{3A_1}{3A_1 + A_2} = \frac{3\left(161.33 - \frac{t}{2}\right)t}{3\left[161.33 - \frac{t}{2}\right]t + \left(100 - \frac{t}{2}\right)t}$

$\because\ A_{net} = A_1 + KA_2$

$\because\ \sigma A_{net} = 350\,kN$

$180 \times \left[\left(161.33 - \frac{t}{2}\right)t + \frac{3\left(161.33 - \frac{t}{2}\right)t}{3\left[161.33 - \frac{t}{2}\right]t + \left(100 - t/2\right)t} \times \left(100 - \frac{t}{2}\right)t\right]$

$= 350\times 10^3$

10

$\boxed{t \geq 8.2071\,mm}$ (A)

(c) (ii)

(i) Gross Sect^n Yielding

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

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

$$T_{dg} = \frac{250}{1.10} \times 1536 = 349.09 \text{ kN}$$

10

(ii) Net Sect^n Rupture

$$\because T_{dn} = \frac{0.9 f_u A_{nc}}{\gamma_{m1}} + \beta \frac{f_y}{\gamma_{m0}} A_g$$

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

$$A_g = (100 - 8/2) \times 8 = 768 \text{ mm}^2$$

$$\therefore \beta = 1.4 - 0.076 \left(\frac{w}{t}\right)\left(\frac{b_s}{L_c}\right)\left(\frac{f_y}{f_u}\right) \quad \geq 0.7, \quad \leq 1.299 = \frac{0.9 f_u / \gamma_{m1}}{f_y / \gamma_{m0}}$$

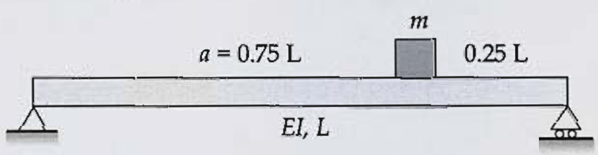
$$= 1.4 - 0.076 \left[\frac{100}{8}\right]\left[\frac{100+60-}{160}\right]\left[\frac{250}{410}\right]$$

$$= 0.8207$$

$$\therefore T_{dn} = \frac{0.9 \times 410 \times 576}{1.25} + 0.8207 \times \frac{250}{1.10} \times 768$$

$$= \boxed{313.284 \text{ kN}}$$

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

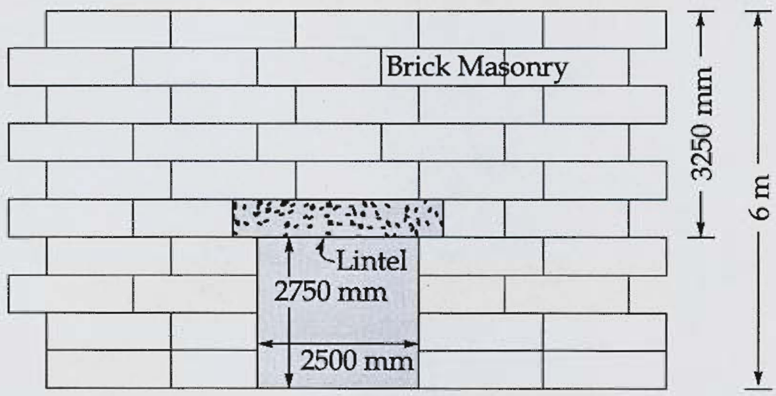
[10 + 10 = 20 marks]

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]

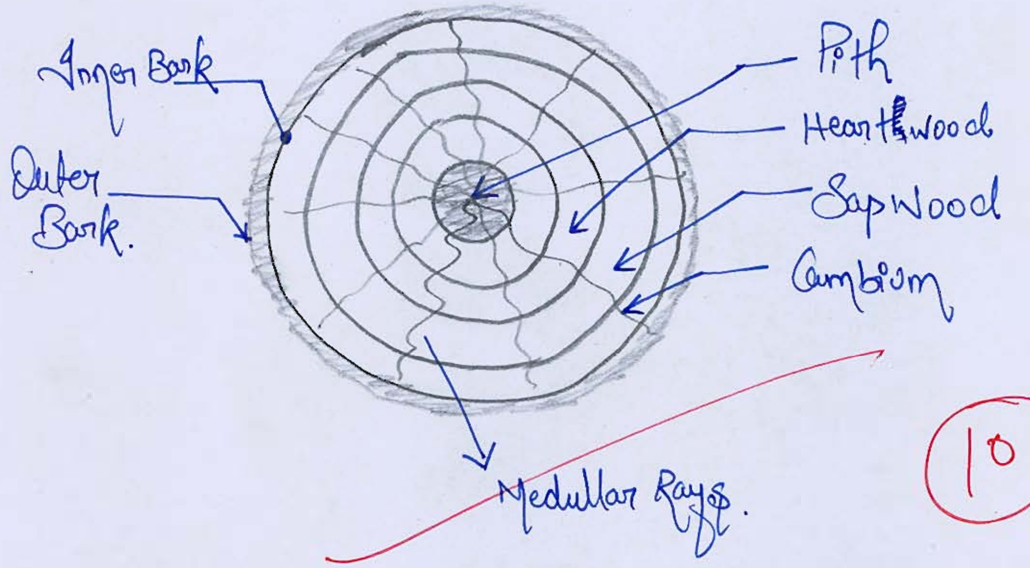
Do not write in this margin

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]

Sol^n



10

Pith → Oldest Part of the Tree, dark in Colour.
→ Helps in initial Growth

Heartwood: → Wood Part Recently formed from the Sap wood.
→ Provide flexural Strength to Timber

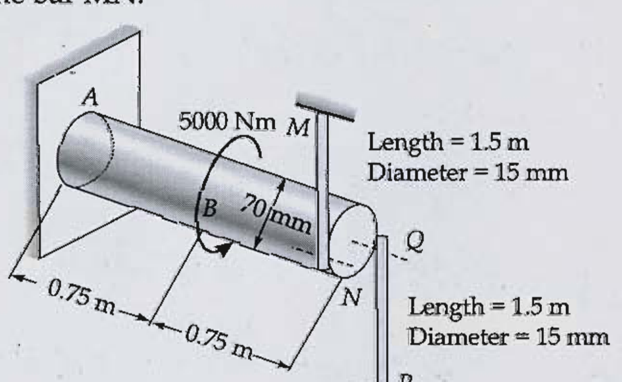
Sap wood: Not Converted to Wood it is in stage of conversion
→ Helps in Transverse Growth of Timber

Cambium → Initial Stage of Sapwood

Inner Bark → Protect Inner Part of timber

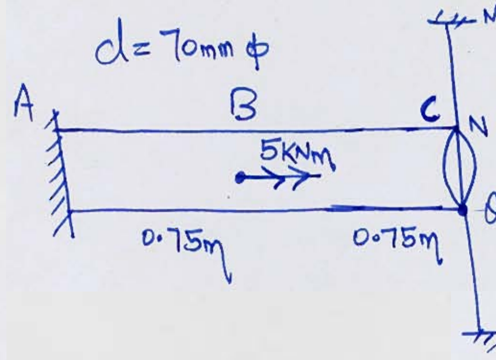
Outer Bark → Protect Timber from External factors like Temp, Humidity, Insects etc.

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]

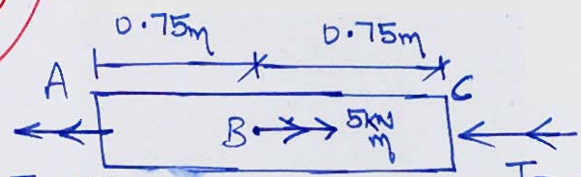
$d = 70\,mm\ \phi$



$L = 1.5m$
Dia = 15mm

$L = 1.5m$
D = 15mm

(3)



$T = \frac{5 \times 0.75}{1.5} = 2.5\,KNm$ $\qquad T = \frac{5 \times 0.75}{1.5} = 2.5\,KNm$

Do work on the concept of torsion

∴ Peak Shearing Stress in Bar ABC

$$= \frac{16T}{\pi D^3} = \frac{16 \times 2.5 \times 10^6}{\pi \times 70^3} = 3.712\ MPa$$

N 

∴ Tensile Stress in Bar MN $= \frac{P}{A_{Bar}}$

$\because \tau_{max} = \frac{4}{3} \tau_{avg.} \Rightarrow \tau_{max} = \frac{4}{3} \tau_{avg}$

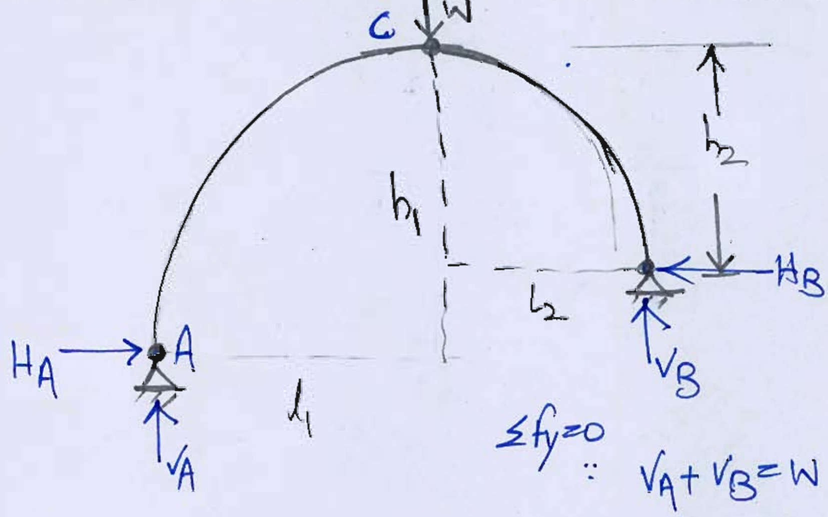
$$3.712 = \frac{4}{3} \times \frac{P}{\frac{\pi}{4} \times 70^2} \Rightarrow \boxed{P = 10.714\ KN}$$

$$\therefore \quad \sigma_{Bar_{MN}} = \frac{10.714 \times 10^3}{\frac{\pi}{4} \times 15^2} = 60.628\ MPa$$

0

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]



$\Sigma f_y = 0$ ∴ $V_A + V_B = W$ — (1)

∴ $H_A = H_B$ — (2)

∵ $B.M_{@A} = 0$

$+ V_B \times (L_1 + L_2) + H_B(h_1 - h_2) - W \times L_1 = 0$

$V_B(L) + H_B(h_1 - h_2) = WL_1$

∵ $B.M_{@C} = 0 \Rightarrow V_B \times L_2 - H_B \times h_2 = 0$

∴ $V_B L_2 = H_B h_2 \Rightarrow \boxed{V_B = \dfrac{H_B h_2}{L_2} = H_B\left(\dfrac{h_2}{L_2}\right)}$

Putting in Above eqⁿ

$\dfrac{H_B}{1}\left(\dfrac{h_2}{L_2}\right)(L) + H_B(h_1 - h_2) = WL_1$

$H_B\left[\dfrac{h_2 L}{L_2} + h_1 - h_2\right] = WL_1$

from Geometry

$$\boxed{H_B = \dfrac{WL_1}{\left[\dfrac{h_2 L}{L_2} + h_1 - h_2\right]}}$$

∵ $\dfrac{l_1}{l_2} = \sqrt{\dfrac{h_1}{h_2}}$

By Rearranging We Get

$$H = \frac{WL}{8\left[\sqrt{h_1}+\sqrt{h_2}\right]^2}$$

12

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]

Methods

- Critical Path Method ⇒] for Plannings
- PERT, GERT etc =]

for Management:

- functional ~~Matrix~~/ Organizatⁿ Arrangement
- * Work Breakdown
- * Matrix Arrangement.

for Control Over Various Activities We Use

- Critical Path Method Approach
- PERT
- GERT [Graphical Evaluatⁿ & Review Technique]
- Line of Balance Technique
- Software like Microsoft Planner, Orcale Software for planning.

07

Scheduling is done by Two Approach

Resource Smoothing
→ Resources are Unlimited
→ No change in Critical

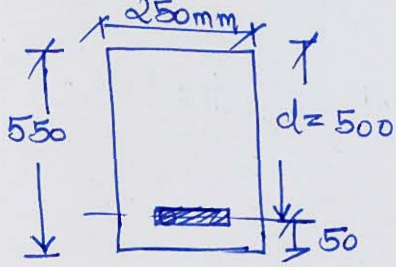
Resource Levelling
→ Resource are Limited
→ Change in Critical Path

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]

Solⁿ:



$M_u = 225$ kNm

$\therefore M_{ulim} = 0.138 f_{ck} b d^2$

$= 0.138 \times 20 \times 250 \times 500^2$

$= 172.5$ kNm

$\because M_u > M_{ulim} \Rightarrow$ Doubly Reinforced Sectⁿ

C = T

$\therefore 0.36 f_{ck} b x_u + [f_{sc} - 0.45 f_{ck}] A_{sc} = 0.87 f_y A_{st}$

$\because A_{st_1} \Rightarrow$ Corresponds to M_{ulim}.

$\therefore A_{st_1} = \frac{0.5 f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 M_{u,lim}}{f_{ck} b d^2}}\right] bd$

$= \frac{0.5 \times 20}{415}\left[1 - \sqrt{1 - \frac{4.6 \times 172.5 \times 10^6}{20 \times 250 \times 500^2}}\right] \times 250 \times 500$

$= 1191.813$ mm²

Assume $d' = 50$mm

$\therefore A_{st_2} \longrightarrow$ Corresponds to $M_u - M_{ulim}$.

$0.87 f_y A_{st_2} (d - d') = (225 - 172.5) \times 10^6$

$0.87 \times 415 \times A_{st_2} [500 - 50] = (225 - 172.5) \times 10^6$

$\boxed{A_{st_2} = 323.131 \text{ mm}^2}$

$\therefore A_{st} = A_{st_1} + A_{st_2} = 1514.944$ mm²

Provide 4 # 25 φ.

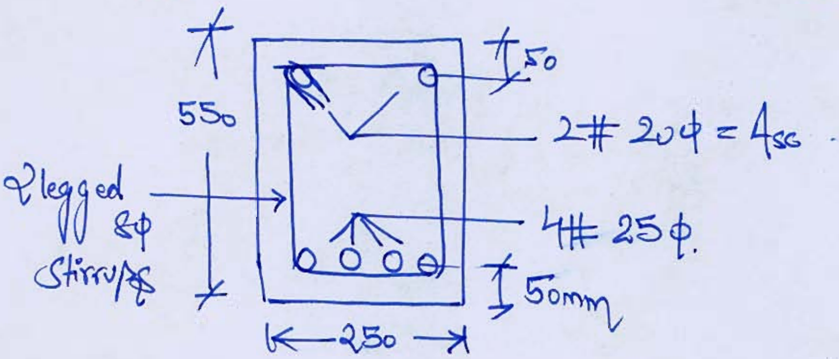
$\therefore \left(f_{sc} - 0.45 f_{ck}\right) A_{sc} = 0.87 f_y A_{st_2}$

$\Rightarrow \left[351.93 - 0.45 \times 20\right] A_{sc} = 0.87 \times 415 \times 323.13$

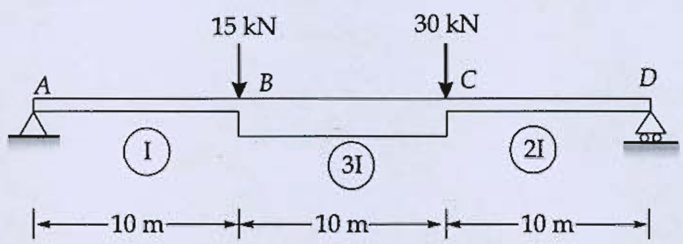
$\therefore \boxed{A_{sc} = 340.203 \text{ mm}^2}$

Provide = 2# 20φ.

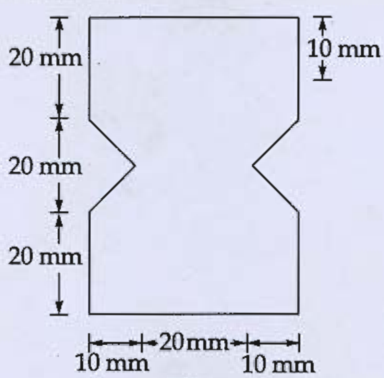
12



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 = 2×10^5 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
τ_c N/mm^2	0.29	0.49	0.64	0.70	0.74

[10 + 10 = 20 marks]

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.

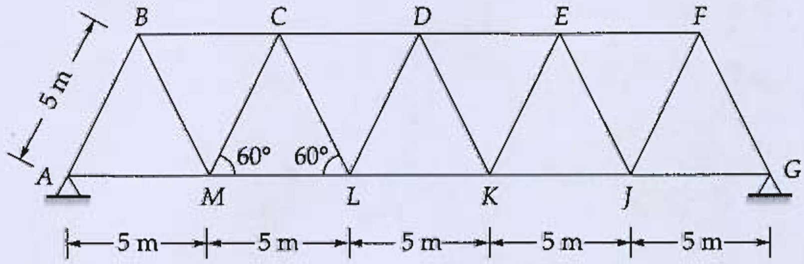
Activity	Time duration (in days)		
	Optimistic (t_o)	Most likely (t_m)	Pessimistic (t_p)
1 - 2	3	4	5
1 - 3	2	3	4
2 - 3	6	7	8
2 - 4	5	9	13
3 - 5	8	9	16
4 - 5	2	7	12

Standard normal distribution table:

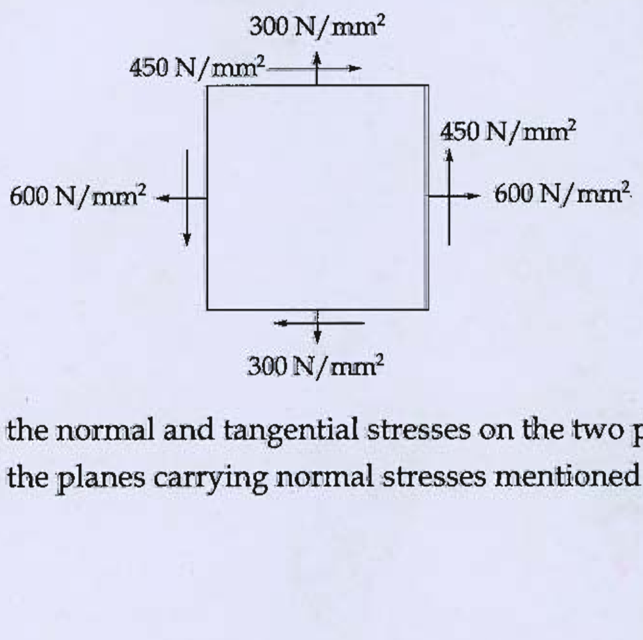
Z	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8
Probability	97.72	98.21	98.61	98.93	99.18	99.38	99.53	99.65	99.74

[20 marks]

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.



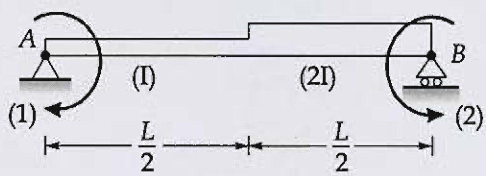
Determine the normal and tangential stresses on the two planes which are equally inclined to the planes carrying normal stresses mentioned above.

[12 + 8 = 20 marks]

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.

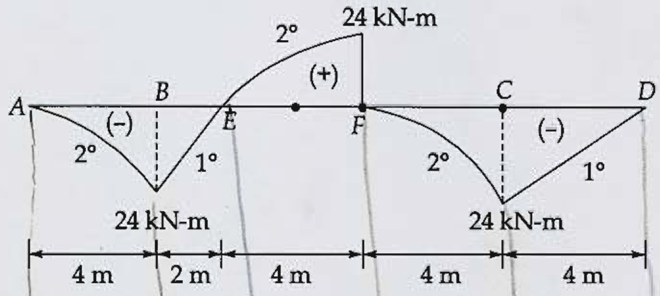
[20 marks]

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

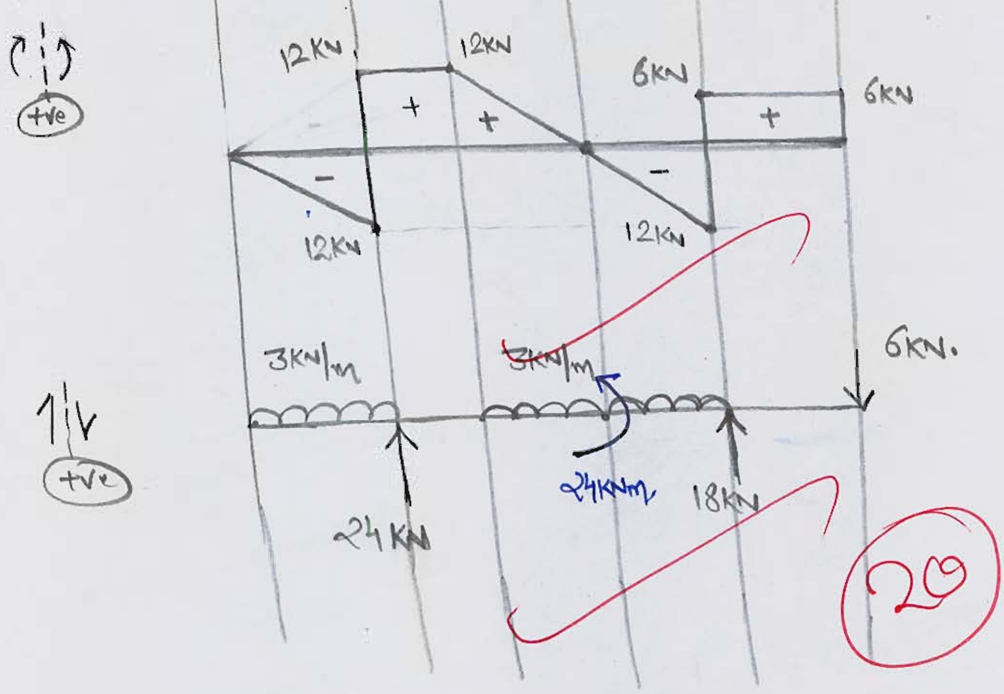


[20 marks]

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]



Concept

$\because \frac{dM_x}{dx} = V_x$ & $\frac{dV_x}{dx} = w_x$

SFD Calculatⁿ:

$\because$ Span AB (-ve) & Increasing Slope.

$\because \frac{1}{2} \times V_x \times 4 = 24$

$V_x = 12 \text{ KN}$

Span BE $\frac{0-(-24)}{2} = +12 \text{ KN}.$

Span EF +ve & Decreasing Slope

$\therefore \frac{1}{2} \times V_x \times 4 = 24 \Rightarrow$ $12 \text{ KN} = V_x$

Span FC (-ve) & Increasing Slope

$\therefore \frac{1}{2} \times V_x \times 4 = 24$

$V_x = 12 KN.$

Span CD Constant Slope

$\therefore \frac{0-(-24)}{4} = +6 KN.$

Loading Calculatⁿ.

Span AB $\frac{-12-0}{4} = -3 KN/m$ (↓)

Span BE $\frac{12-(-12)}{~~2~~} = 24 KN.$
@ B.

Span EF $\frac{0-12}{4} = -3 KN/m$ ↓

Span FC $\frac{-12-0}{4} = -3 KN/m$ ↓

Span CD ~~6=0~~ 6 KN

$\therefore$ (-ve) $\Sigma M_B = 0$

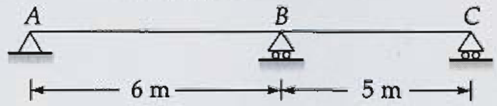
$\therefore -3\times4\times2 - 18\times10 + 6\times14 + 3\times8\times6 = 0$

$+24 KNm \neq 0$

$\therefore$ for Bal. $-24 KNm$ @ Junctⁿ F is to be Applied

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.

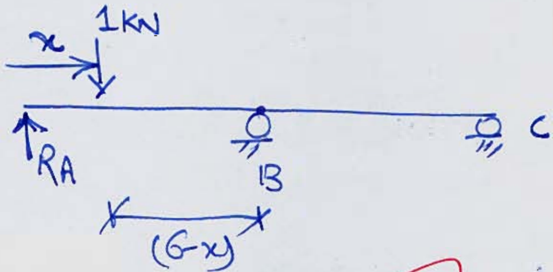


[20 marks]

$D_s = 2 + 1 + 1 - 2$
$= 4 - 2 = 2$

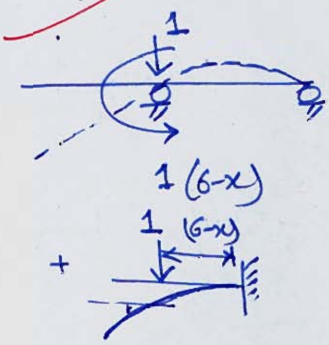
Indeterminate Structure

∵ Taking React^n @ A as Redundant



∴ Deflect^n @ A = 0

Due to 1KN Load.

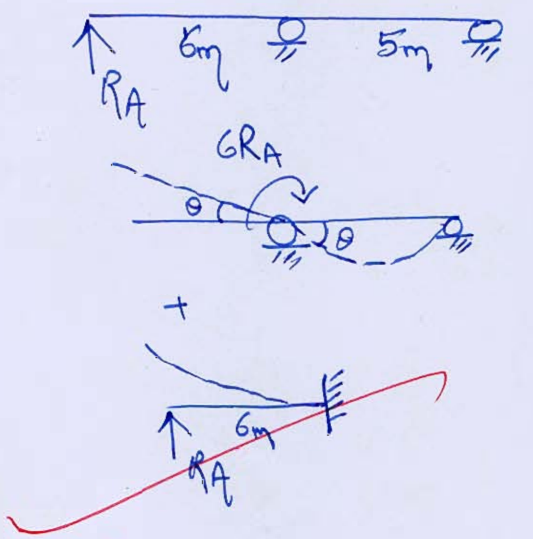


$$\therefore \delta_A' = \frac{ML_2}{3EI} \times 6 + \frac{P(6-x)^3}{3EI} + \frac{P(6-x)^2}{2EI} \times x$$

$$\delta_A' = \frac{(6-x)\times 5}{3EI} \times 6 + \frac{1(6-x)^3}{3EI} + \frac{(6-x)^2}{2EI}x$$

$$\delta_A' = \frac{(6-x)30}{3EI} + \frac{(6-x)^3}{3EI} + \frac{(6-x)^2}{2EI} \quad (1)$$

$\delta_A'' \rightarrow$ Due to R_A



15

$\therefore \quad \delta_A'' = \frac{M L_2}{3EI} \times 6 + \frac{R_A L_1^3}{3EI}$

$\delta_A'' = \frac{(6R_A) \times 5}{3EI} \times 6 + \frac{R_A \times 6^3}{3EI}$

$= \frac{180 R_A}{3EI} + \frac{6^3 R_A}{3EI} \quad -(2)$

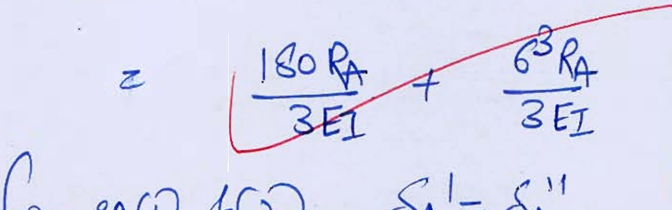
from eq (1) & (2) $\quad \delta_A' = \delta_A'' \quad [\because \delta_A = 0]$

$\therefore \quad \frac{180 R_A}{3EI} + \frac{216 R_A}{3EI} = \frac{30(6-x)}{3EI} + \frac{(6-x)^3}{3EI} + \frac{(6-x)^2}{3EI}$

$60 R_A + 72 R_A = 30(6-x) + (6-x)^3 + (6-x)^2$

$R_A = \frac{1}{132}\left[30(6-x) + (6-x)^3 + (6-x)^2\right]$

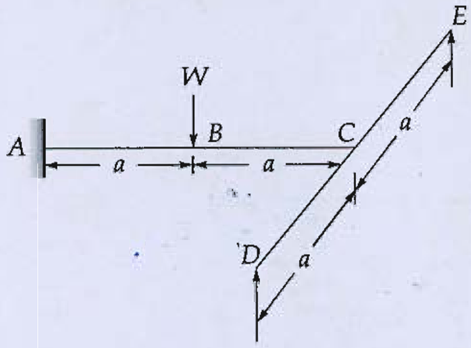
ordinate = ?



ILD for R_A

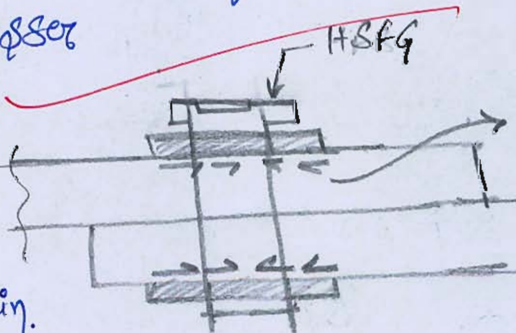
Q.8 (c) (i) Enumerate the advantages of high-strength friction grip (HSFG) bolts. Illustrate and explain the load transfer mechanism of HSFG bolts with the help of a neat and labeled sketch.

(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]

Advantage of HFSG Grip:
- No Bending Stress is there.
- Provide Greater Strength as compared to Ordinary Bolt.
- Req^d Lesser Area to Provide Same Strength.
- Easy to Maintain.

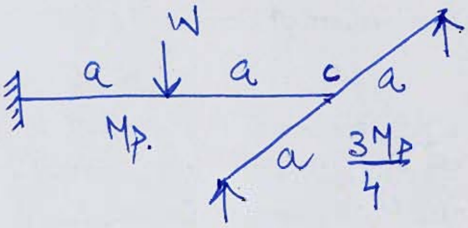


Provide Strength due to frict^n b/w the Surface.

Load Mechanism → Load is transfer through frict^n b/w the plate. Bolt is tighted upto the Proof Stress. & frict^n b/w Surface is so enough to Bearing Load.

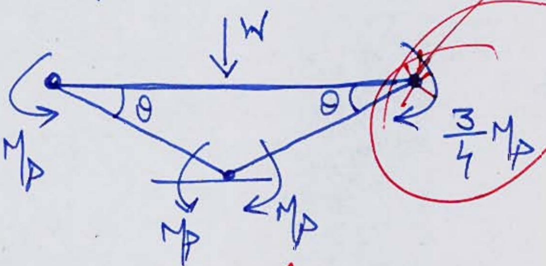
5

(ii)



for Collapse Mechanism

for Cantilever Beam



not PH

5

$$3M_p\theta + \frac{3}{4}M_p\theta = W \times a\theta$$

$$\frac{15}{4}M_p = Wa$$

$$W = \frac{15M_p}{4a}$$

$$\frac{3M_p}{a}$$

for Simply Supported Beam

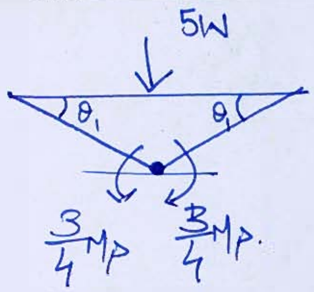
$$\delta_{c\ \text{canti.}} = \delta_{\text{simply}}$$

$$\frac{Wa^3}{3EI} + \frac{Wa^2}{2EI} \times a = \frac{PL^3}{48EI}$$

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

$$\frac{5}{6}Wa^3 = \frac{8Pa^3}{48} \Rightarrow P = 5W.$$

$\therefore$



$\Rightarrow 2 \times \frac{3}{4} M_p \theta = 5W \times a \theta$

$\frac{6M_p}{4} = 5Wa$

$W = \frac{6M_p}{5 \times 4a}$

$\boxed{W = \frac{0.3M_p}{a}}$

$\therefore$ Collapse Load to be Min^m

$= \text{Min}^m \left[\frac{0.3M_p}{a}, \frac{3.75M_p}{a} \right]$

$\therefore = \boxed{\frac{0.3M_p}{a}}$

■■■■

Space for Rough Work

Space for Rough Work

$$f_t = \frac{M\bar{y}}{I} = \frac{My}{I}$$

Space for Rough Work