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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 ☐	
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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	53
Q.2	—
Q.3	—
Q.4	31
Section-B	
Q.5	36
Q.6	50
Q.7	40
Q.8	
Total Marks Obtained	210

Signature of Evaluator: Sheryab

Cross Checked by: ....

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accuracy is good Keep it up

IMPORTANT INSTRUCTIONS

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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

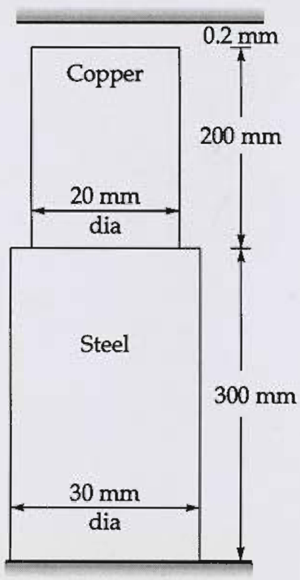
1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough 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/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]

for no stress:

$$(\Delta l)_{cu} + (\Delta l)_s = 0.2\,mm$$

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

$$\boxed{\Delta T = 28.17^\circ C} \text{ Ans.}$$

1.5

for stresses @ $\Delta T = 40^\circ C$

$$(\Delta l)_{cu} + (\Delta l)_s = \frac{PL_c}{A_c E_c} + \frac{PL_s}{A_s E_s}$$

$P \rightarrow$ compressive load.

$$(200 \times 17.5 \times 10^{-6} + 300 \times 12 \times 10^{-6}) \times 40 = \phi$$

$$0.284 = P\left[\frac{200}{\frac{\pi}{4} 20^2 \times 1.2 \times 10^5} + \frac{300}{\frac{\pi}{4} 30^2 \times 2 \times 10^5}\right]$$

$$P = 38237.67\,N$$

$\rightarrow \sigma_c = \frac{P}{A_c} = \frac{38237.67}{\frac{\pi}{4} \times 20^2} = 121.71 \text{ MPa}$ (comp) / Ans

$\rightarrow \sigma_s = \frac{P}{A_s} = \frac{38237.67}{\frac{\pi}{4} \times 30^2} = 54.09 \text{ MPa}$ (comp) / Ans

avoid silly mistakes and calculation errors

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 volu~~

$\Rightarrow (FM)_f = 2.9$

$(FM)_c = 7.8$

$x \to$ wt of FA $/m^3$

$$(FM)_{mix} = \frac{2.9 \times x + 1538 \times 7.8}{(1538 + x)}$$

$6.5(1538 + x) = 2.9x + 1538(7.8)$

$\Rightarrow \boxed{x = 555.38 \text{ kg}}$ Ans

⇒ FM determination

~~→ The cumulative percentage of aggregate retained in the series of IS sieves is added~~

① Aggregates are sieved in IS sieves.

② percentage retained on each sieve is measured

③ Cumulative percentage of aggregates retained above each sieve is determined

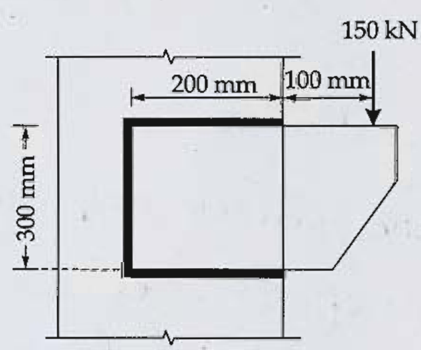
④ sum of $\frac{\text{cumulative percentage}}{100}$ gives FM.

Say FM = 2.6 ⇒ It tells the aggregates avg size in b/w sieve 2 & 3 from bottom

FM is more ⇒ agg are coarser
FM is low ⇒ agg are finer

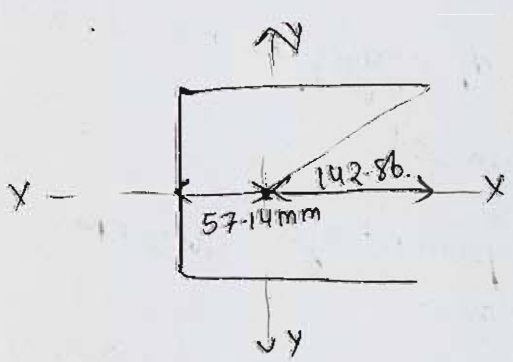
12

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]

Let thickness of throat = t_t



$$I_{xx} = \frac{200 t_t^3}{12} \times 2 + (200 t_t \times 150^2) \times 2 + \frac{300^3 t_t}{12}$$

$$I_{xx} = 112.5 \times 10^5 \text{ mm}^4 (t_t)$$

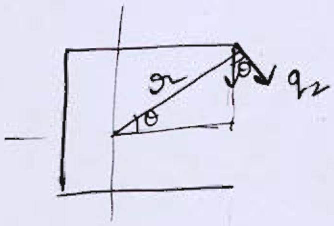
$$I_{yy} = (300 t_t) 57.14^2 + 2\left[\frac{t_t 200^3}{12} + 200 t_t (100 - 57.14)^2\right]$$

$$I_{yy} = 30.47 \times 10^5 \text{ mm}^4 \times t_t$$

$I_{zz} = 142.97 \times 10^5 (t_t)\ mm^4$
$(I_{xx} + I_{yy})$

$P_u = 150 kN$; $T_u = P_u(e)$
$T_u = P_u(100 + 142.86)$
$T_u = 36.43 kN\text{-}m$

direct stress due to load $\Rightarrow q_1 = \frac{150 \times 10^3}{700 t_t} = \frac{214.28}{t_t}$



$\theta = \tan^{-1}\left(\frac{150}{142.86}\right) = 46.39°$

$r = 207.144 mm$

$q_2 = \frac{(T) r}{I_{zz}} = \frac{36.43 \times 10^6 \times 207.144}{(142.97 \times 10^5) t_t}$

$= \frac{527.82}{t_t}$.

$q_R = \sqrt{q_1^2 + q_2^2 + 2q_1q_2\cos\theta} = \frac{693.20}{t_t}$

$f_{dgw} = \frac{f_u}{\sqrt{3} \times 1.25} = \frac{410}{\sqrt{3} \times 1.25} = 189.37$

shop weld

(12)

$q_R \leq f_{dgw}$

$t_t \geq \frac{693.2}{189.37}$

$t_t \geq 3.66 mm$

$S \geq \frac{3.66}{0.7} = 5.23 mm$

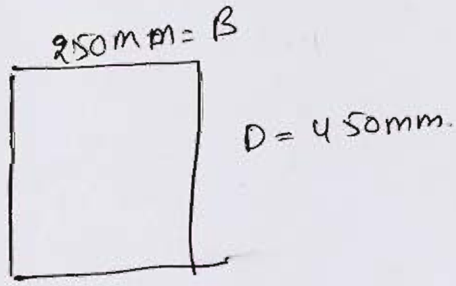
let us take $S = 6mm$

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 mm² each, which are initially prestressed to 1500 N/mm². 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/m³. Modulus of elasticity for concrete is 40 kN/mm².

[12 marks]



$A_{st} = 2 \times 510\ mm^2$

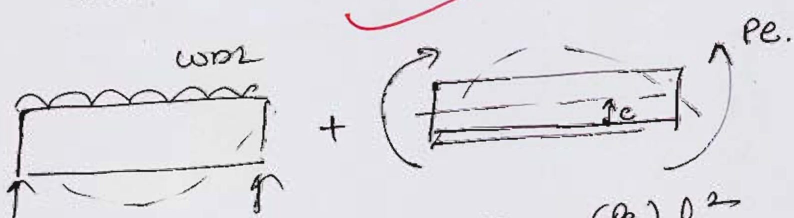
$f_o = 1500\ MPa$

$e = 90mm$

$l = 8m.$

(i) $P_o = 1500 \times 2 \times 510 = 1530\ kN.$

$w_{DL} = 0.25 \times 0.45 \times 24\ kN/m = 2.7\ kN/m$



$\delta_1 = \frac{5}{384}\frac{wl^4}{EI}$ $\delta_2 = \frac{(Pe)\,l^2}{8EI}$

$\delta = \delta_1 - \delta_2$; $I = \frac{250 \times 450^3}{12} = 1898.43 \times 10^6\ mm^4$

$\delta_1 = \frac{5}{384} \times \frac{2.7 \times (8000)^4 \times 10^{-3}}{40\ \frac{kN}{mm^2} \times 1898.43 \times 10^6\ mm^4} = 1.896\ mm$

$\delta_2 = \frac{(1530\ kN) \times 90 \times (8000)^2}{8 \times 40\ \frac{kN}{mm^2} \times (1898.43 \times 10^6)\ mm^4} = 14.50\ mm$

$\delta = \delta_1 - \delta_2 = -12.610mm$ (upward)

Ans.

(ii) ~~Case~~ $w = w_{DL} + w_{LL} = 17.7 \text{ kN/m}$

$$\delta_1 = \frac{5}{384}\frac{wl^4}{8EI} = 12.43 \text{ mm}$$

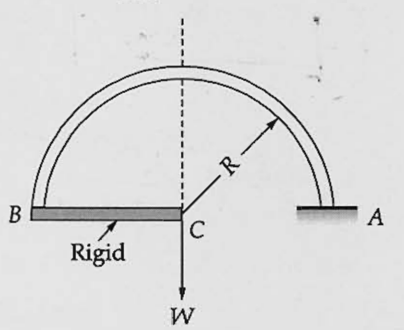
$$\delta_2 = \frac{(0.8Pe)\,l^2}{8EI} = 11.6 \text{ mm}$$

$$\delta = \delta_1 - \delta_2 = 0.83 \text{ mm (downwards)}$$

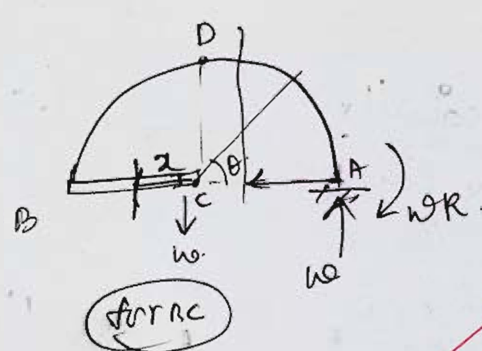
Ans.

12

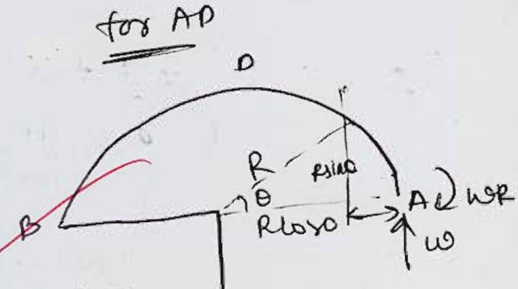
Q.1 (e) A thin semicircular bracket *AB* of radius *R* is encastered at *A* and has at *B* a rigid arm *BC* of length *R*. The bracket carries a vertical load *W* at *C* as shown in figure. Show that the vertical deflection at the load is $\frac{\pi W R^3}{2EI}$, where *EI* is flexural rigidity of the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



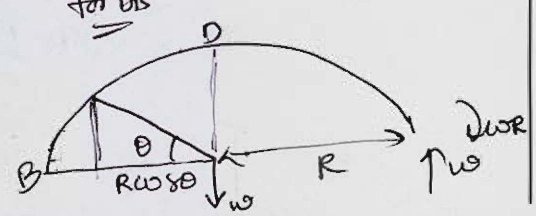
[12 marks]



for AD



for DB



member	moment	range	flexural
AD	$wR(1-\cos\theta) - wR = -wR\cos\theta$	0 - 90°	EI
DB	$wR(1+\cos\theta) - wR = wR\cos\theta$	0 - 90°	EI
BC	wx	0 - R	∞

$$U_{AD} = \int_{\theta=0}^{\pi/2} \frac{(-wR\cos\theta)^2}{2EI} R\,d\theta$$

$$U_{DB} = \int_{\theta=0}^{\pi/2} \frac{(wR\cos\theta)^2 R\,d\theta}{2EI}$$

$$U_{BC} = \int_0^R \frac{(wx)^2\,dx}{2E_R I_R} = 0$$

$$U = U_{AD} + U_{DB} + U_{BC} = \left(\int_{\theta=0}^{\pi/2} \frac{w^2R^3\cos^2\theta}{2EI}\right) \times 2$$

$$= \left[\frac{w^2R^3}{2EI}\left(\frac{\pi}{4}\right)\right] \times 2$$

$$= \left(\frac{w^2R^3\pi}{8EI}\right) \times 2 = \frac{w^2R^3\pi}{4EI}$$

$$\frac{\partial U}{\partial w_i} = \left(\frac{2wR^3\pi}{4EI}\right)$$

$$\boxed{\frac{\partial U}{\partial w_i} = \frac{\pi w R^3}{2EI}}$$

Ans

12

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]

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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:

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

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

$\sigma_{st} = 125\ N/mm^2$ (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]

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

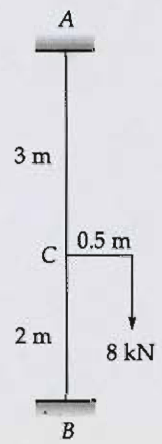
No need to check for deflection

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]

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]

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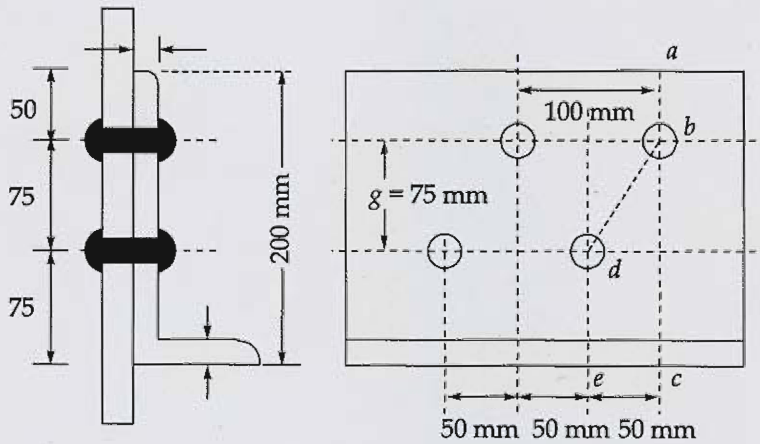
Q.3 (c) (i) The long leg of ISA 200 × 100 is connected to gusset plate by 22 mm diameter rivets in two rows, with gauge space of 75 mm and staggered pitch of 50 mm, as shown in figure. Determine suitable thickness of the angle to transmit a pull of 350 kN.

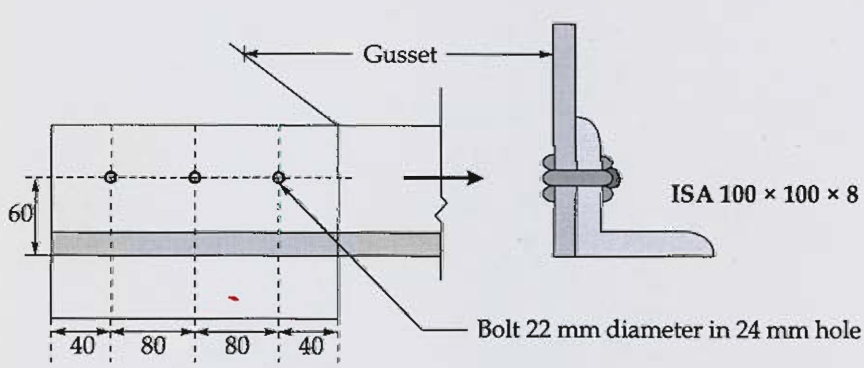
Take $\sigma_{at} = 180\ N/mm^2$.



(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

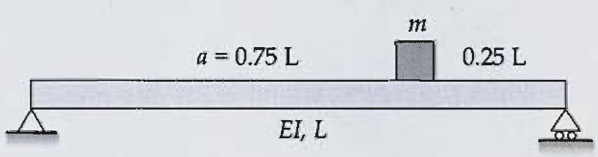
Take f_u = 410 MPa [Use LSM]



[All dimensions are in mm]

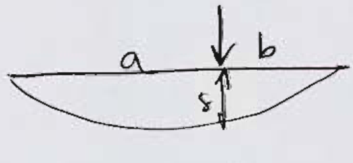
[10 + 10 = 20 marks]

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]



$$\delta = \frac{P a^2 b^2}{3EIL}$$

$$\underbrace{\left(\frac{3EIL}{a^2 b^2}\right)}_{K} \delta = P$$

$$K = \frac{3 \times \left\{22000 \times 10^6 \times 10^{-3} \frac{kN}{m^2}\right\}\left(\times 1.2 \times 10^{-4}\right) \times L}{(0.75L)^2 (0.25L)^2}$$

$$k = 3520 \text{ kN/m}$$

$\frac{kN}{m^2} \times m^4 \times m / m^4$

$$\omega = \sqrt{K/m} = \sqrt{\frac{3520 \times 10^3}{\left(\frac{20 \times 10^3}{9.81}\right)}} = 41.55 \text{ rad/sec}$$

$$T = 2\pi/\omega = \underline{0.151 \text{ sec}}$$

(ii) → Plane section remains plane before & after Bending

[⇒ shear deformations Ignored]

→ Strain is linear

15+2

→ Hookes law is valid

→ ~~Material is~~ Stresses are within elastic range.

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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.

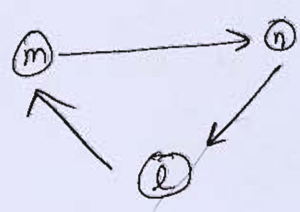
(ii) Write short notes on the following:

1. Soundness of aggregates
2. Alkali-aggregate reaction

[10 + 10 = 20 marks]

(i) →


(n > m)

→


Looping shouldn't be there.

(X)

→ dummy activity shouldn't be used unnecessary

→ There shouldn't be more than one end/~~start~~ event.

(ii) 2. Alkali Aggregate Reaction

→ if aggregates contains active silica; they will react with alkalis present in cement & the (Na_2O, K_2O) end product will have more volume hence induce stress & cracks.

→ The transistion zone b/w aggregate & matrix will become poor.

→ alkali present should be less than ~~0~~.5% in cement.

→ Hence aggregates to be tested for their reactiveness before used in concrete.

1. Soundness of Aggregates:

→ Resistance of aggregates due to ~~alternate w~~ environmetal cond^ns

→ understood by alternate wetting & drying the aggregates in sodium (or) Magnesium salts.

→ Gives Indication of ~~their~~ durability.

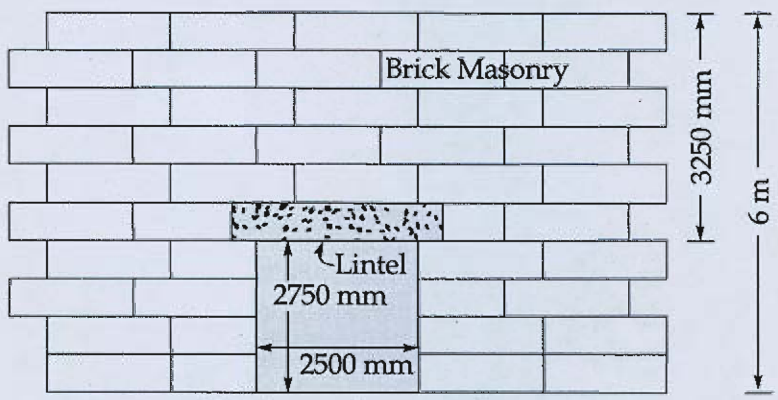
2×6

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.

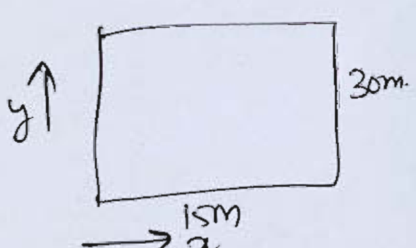
[Take base angle of imaginary triangle = 60°, unit weight of RCC = 25 kN/m^3]



Lintel over door opening

[6 + 14 = 20 marks]

(i)



$H = 70\,m$

1. $T = 0.075\,H^{0.75}$ (for unbraced without brickinfill)

$= 0.075 \times 70^{0.75}$

$= 1.815$ sec

2. $T = \frac{0.09\,H}{\sqrt{d}} = \frac{0.09 \times 70}{\sqrt{15}} = 0.05$ sec (along x)

$T = \frac{0.09\,H}{30} = 0.025$ sec (along y)

2.

$$T_{(\text{al}_y X)} = \frac{0.09H}{\sqrt{d_x}} = \frac{0.09 \times 70}{\sqrt{15}} = 1.626 \text{ sec}$$

$$T_{(\text{al}_y y)} = \frac{0.09H}{\sqrt{d_y}} = \frac{0.09 \times 70}{\sqrt{30}} = 1.15 \text{ sec}$$

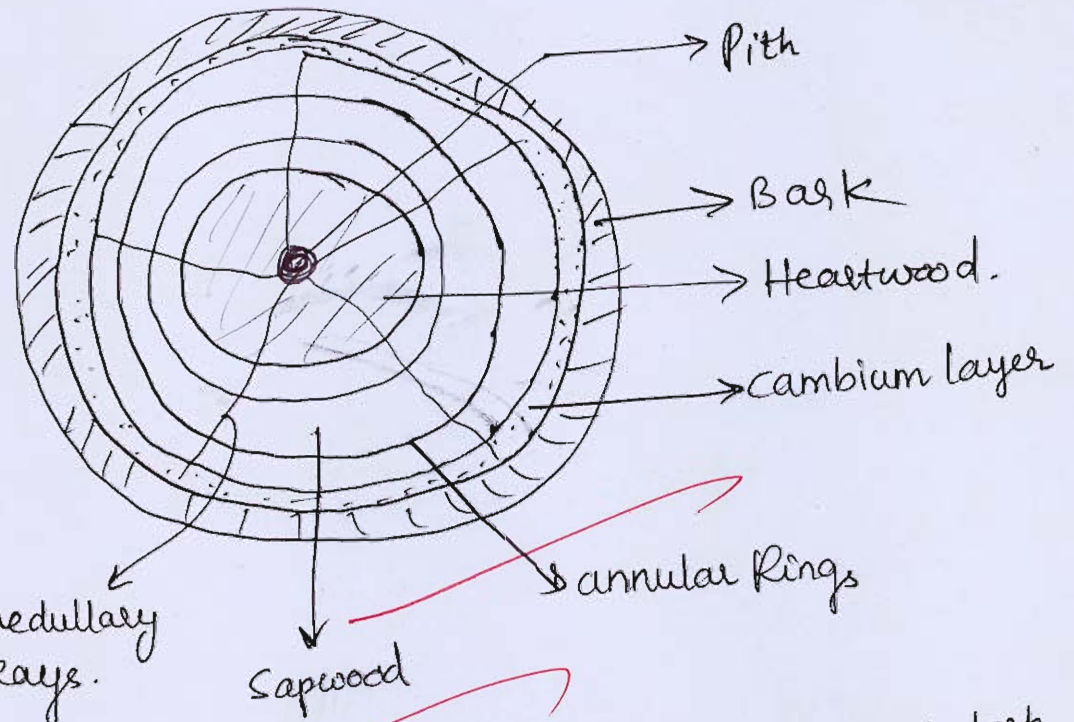
6

(b)

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: core portion of tree & it is the oldest portion & dark in colour

Heartwood: Next portion after pith & the strongest part

Sapwood: it carries nutrients along trunk; after sometime it will become heartwood.

Cambium layer: → It is the growing portion; it forms sapwood & moves radially outward as sapwood is getting formed

→ Carries Nutrients

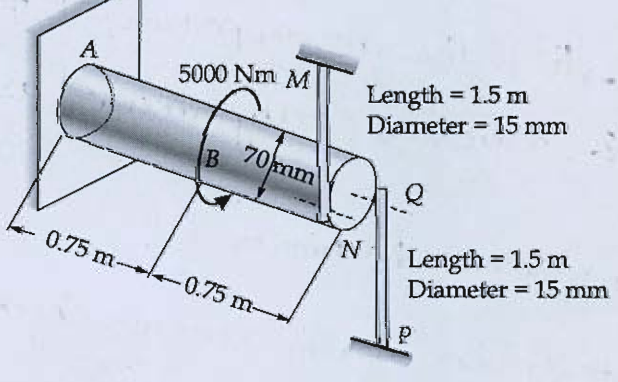
Bark: It protects tree from external Environment.

Annular rings: Tree grow outward, & ~~space b/w each to~~ distinction b/w each layer is annular ring.

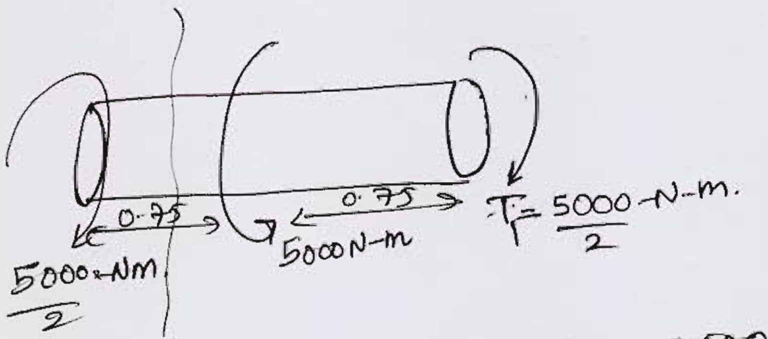
Medullary rays: They are in radial direction & act like holding of different portions of tree.

10

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]



(2)

max torque in ABC is 2500 N-m.

→ $\tau_{max} = \frac{Tr}{J} = \frac{2500 \times \left(\frac{70}{2}\right) \times 10^3}{\frac{\pi}{32}(70)^4}$

$\tau_{max} = 37.12$ MPa Ans

→ @ C let tensile force in MN = P

& in OP = P. {as end 'C' is restrained against twist}

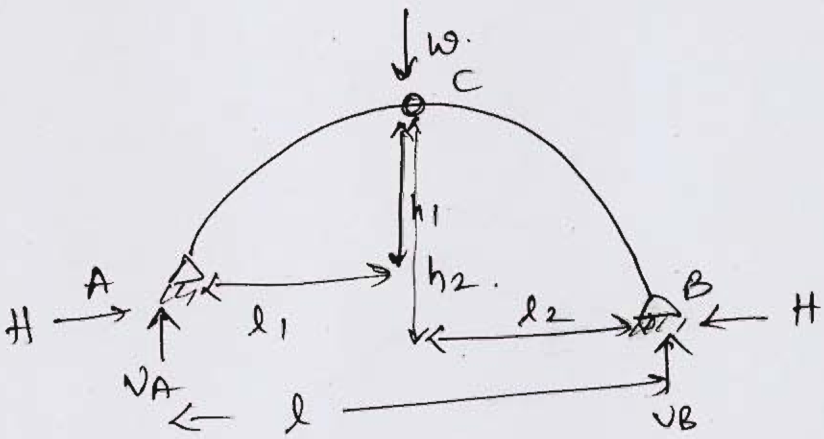
P(70) = 2500 N-m.

P = 35.714 kN Ans.

Do work on the concept of torsion

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.

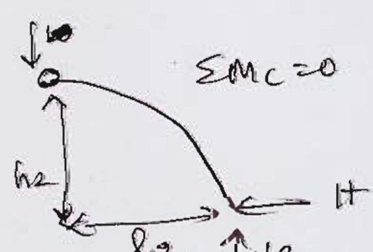
[12 marks]



$$l_1 = \frac{l\sqrt{h_1}}{\sqrt{h_1}+\sqrt{h_2}} \; ; \quad l_2 = \frac{l\sqrt{h_2}}{\sqrt{h_1}+\sqrt{h_2}}$$ (from property of parabola)

$\Sigma F_V = 0 \Rightarrow V_A + V_B = W \longrightarrow (1)$

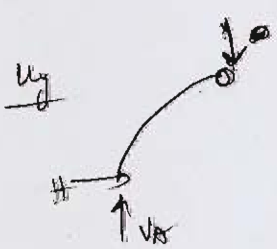
~~$\Sigma M_A = 0 \Rightarrow W(l_1) - V_B(l) + H(h_2 - h_1) = 0$~~



$\Sigma M_C = 0 \Rightarrow V_B(l_2) = H h_2$.

$$H = \frac{V_B}{h_2}\,\frac{l\sqrt{h_2}}{\sqrt{h_1}+\sqrt{h_2}}$$

$$H = \frac{V_B\, l}{\sqrt{h_2}(\sqrt{h_1}+\sqrt{h_2})} \longrightarrow (2)$$



$\Sigma M_C = 0 \Rightarrow V_A(l_1) = H h_1$

$$\frac{V_A\, l\sqrt{h_1}}{\sqrt{h_1}+\sqrt{h_2}} = H h_1 \longrightarrow (3)$$

Put eq 2, 3 in (1)

$$\frac{H\sqrt{h_1}(\sqrt{h_1}+\sqrt{h_2})}{l} + \frac{H\sqrt{h_2}(\sqrt{h_1}+\sqrt{h_2})}{l} = W$$

Do not write in this margin

$$H = \frac{w \theta l}{(\sqrt{n_1} + \sqrt{n_2})^2}$$ Ans

12

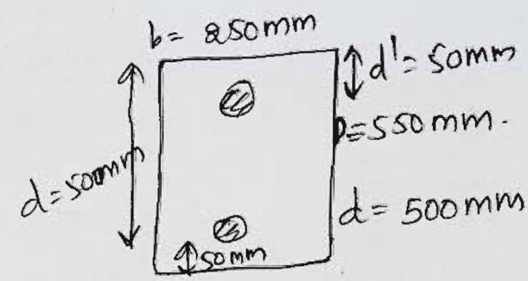
Q.5 (d) Enlist the methods of management of a large construction project in civil engineering. How do we have control over various activities from monthly and daily point of view? How is the schedule updated?

[12 marks]

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]



Mu = 225 kNm

M20, Fe415

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

$= 172.5$ kN-m $(> 225$ kN-m$)$

Hence design Doubly Reinforced secn

→ $M_{u1} = 172.5$ kN-m $= 0.87 f_y A_{st1} (d - 0.42 x_u)$

$(x_u = 0.48d = 240$ mm$)$

$A_{st1} = 1196.82$ mm²

$M_u - M_{u1} = M_{u2} \Rightarrow M_{u2} = 52.5$ kN-m.

→ $M_{u2} = 0.87 f_y A_{st2} (d - d')$

$A_{st2} = 323.13$ mm²

→ $0.87 f_y A_{st2} = (f_{sc} - 0.45 f_{ck}) A_{sc}$

$A_{sc} = \dfrac{0.87 \times 415 \times 323.13}{(351.93 - 0.45 \times 20)} = 340.2$ mm²

$A_{sc} = 340.2$ mm² **Ans** → 2 bars of 16mm ϕ

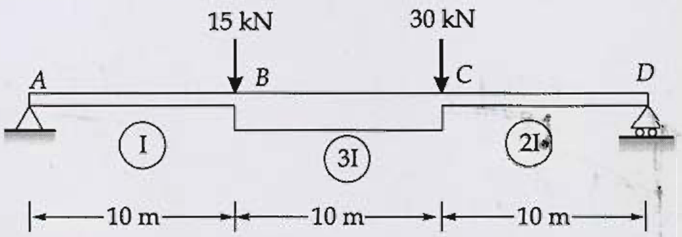
$A_{st} = A_{st1} + A_{st2}$

$A_{st} = 1519.95$ mm² **Ans** → use 5 bars of dia 20 mm

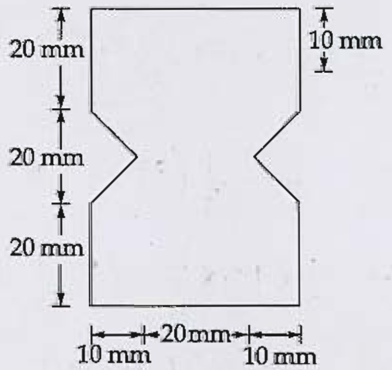
12

Ast max = 0.4 %, (bD)
= 5500 mm^2
(⇒ ok)

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.)



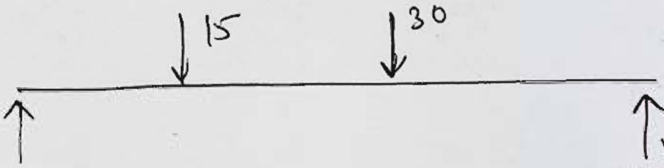
(ii) A rollel steel 60 mm × 40 mm section is shown in figure and a transverse shear force of 50 kN is acting on this section. Plot the shear stress distribution across the depth of the section and mention the value of shear stress at distance 10 mm, 20 mm from top fibre and maximum value of shear stress.



Cross-section of beam

[10 + 10 = 20 marks]

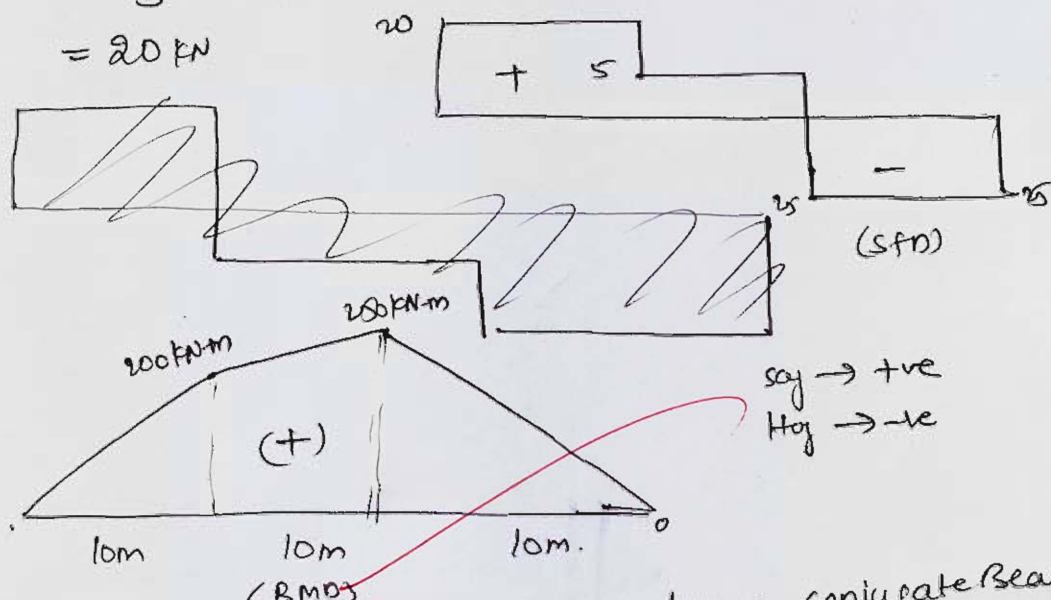
(a)



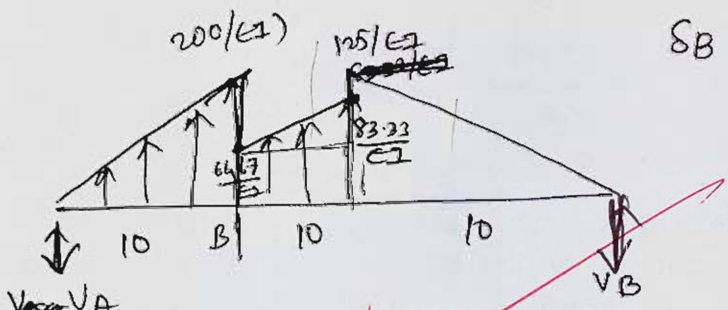
$V_A = 15 \times \frac{2}{3} + 30 \times \frac{1}{3}$

$= 20 \text{ kN}$

$V_D = 15 \times \frac{1}{3} + 30 \times \frac{2}{3} = 25 \text{ kN}$



In Conjugate Beam method loading on conjugate Beam is M/EI



$\delta_B = (BM)@B$

$V_A + V_B = \frac{2375}{EI}$

$\Sigma M_B = 0$

$EI(V_A(30)) = \frac{1}{2}(125) \times 10 \times \frac{20}{3} + (66.67 \times 10)(10+5)$

$+ \frac{1}{2}(83.33 - 66.67) \times 10 \times (10 + 10/3)$

$+ \frac{1}{2} \times 10 \times 200 (20 + \frac{10}{3})$

$EI(V_A)30 = 37611.567$

$$V_A = \frac{1253.72}{EI}$$

$$BM_B = -V_A \times 10 + \frac{1}{2} \times 10 \times \frac{200}{EI} \times \frac{10}{3}$$

$$= \frac{-1253.72 \times 10}{EI} + \frac{3333.33}{EI}$$

$$= -9203.87/EI$$

10

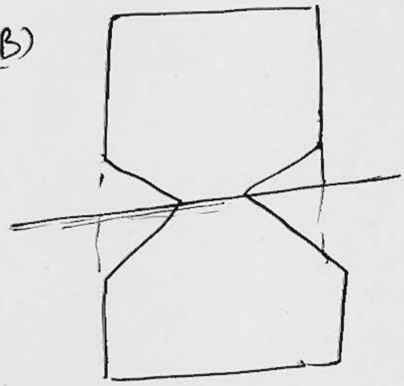
$$\Rightarrow \delta_B = \frac{-9203.87 \times 10^6 \times 10^6}{2 \times 10^5 \times 2 \times 10^{10}} = -2.3\,mm$$ (downwards)

$$SF_B = -V_A + \frac{1}{2} \times 10 \times \frac{200}{EI}$$

$$= \frac{-1253.72}{EI} + \frac{1020}{EI} = \frac{-253.72}{EI} = -6.34 \times 10^{-5}$$ (radian)

(acw)

(B)



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

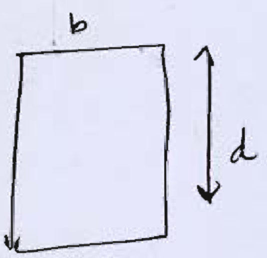
Characteristic elasticity of steel = 2×10^5 MPa

(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.

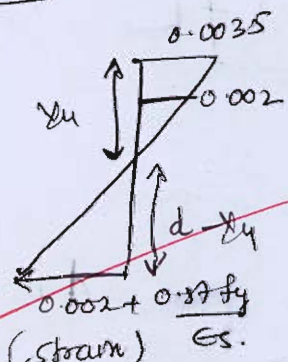
$\frac{100A_s}{bd}$	0.15	0.5	1.0	1.25	1.5
τ_c N/mm^2	0.29	0.49	0.64	0.70	0.74

[10 + 10 = 20 marks]

(i)



(1) @ limit



$$\frac{0.0035}{x_u} = \frac{0.002 + 0.87 f_y / E_s}{d - x_u}$$

$$0.0035 \left[\frac{d}{x_u} - 1\right] = 3.80525 \times 10^{-3}$$

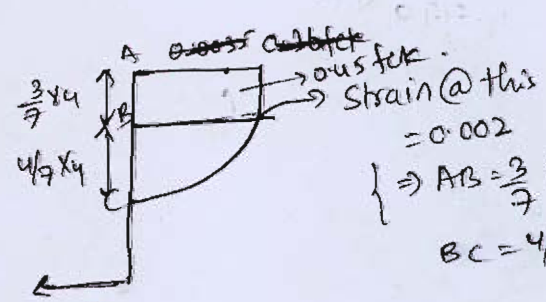
$$\frac{d}{x_u} - 1 = 1.0872$$

$$d/x_u = 2.0872$$

$$x_u = 0.479\, d$$

Ans

(2)



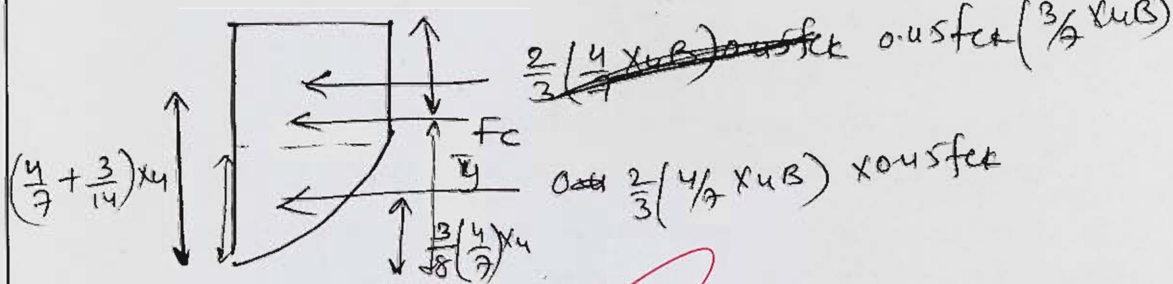
→ Strain @ this = 0.002

$\{ \Rightarrow AB = \frac{3}{7} x_u$

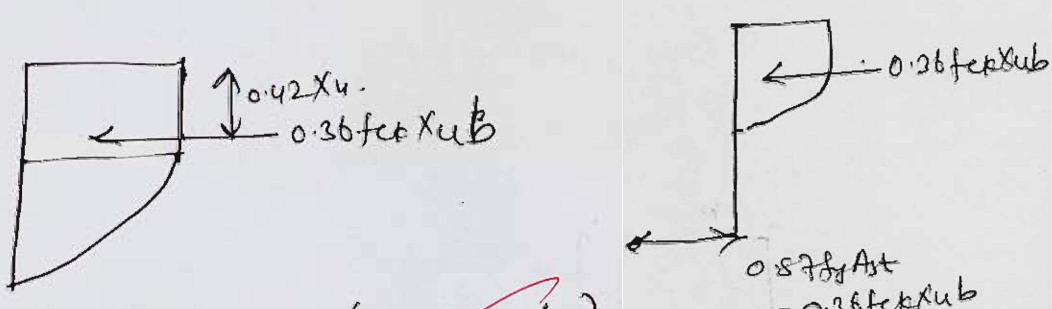
$BC = 4/7\, x_u \}$.

$$\text{compressive force} = \frac{2}{3}\left(\frac{4}{7}X_u B\right) \times 0.45 f_{ck} + 0.45 f_{ck}\left(\frac{3}{7}X_u B\right)$$

$$F_c = 0.36 f_{ck} X_u B$$



$$\Rightarrow \bar{y} = 0.58 X_u \Rightarrow X_u - \bar{y} = 0.42 X_u$$



$$M = 0.36 f_{ck} X_u b (d - 0.42 X_u)$$

$$\boxed{M = 0.138 f_{ck} b d^2} \quad (\because x_u = 0.479d)$$

Ans.

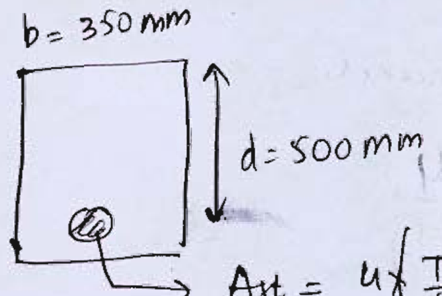
(3) $0.87 f_y A_{st} = 0.36 f_{ck} X_u b$

$$A_{st} = \frac{0.36 \times 0.479 d b}{0.87 \times 415} f_{ck}$$

$$\boxed{A_{st} = 4.776 \times 10^{-4} f_{ck} bd}$$

Ans

(ii)



M25 | Fe415

$A_{st} = 4 \times \left(\frac{\pi}{4} \times 25^2 \right) mm^2$

$= 1963.49\ mm^2$

$V_u = 350 kN$.

$P_t\% = \frac{1963.49}{350 \times 500} \times 100 = 1.122\%$

10 + 8 + 2

~~$\tau_c = 0.70 + \frac{0.74 - 0.7}{1.5 - 1.25}$~~

$\tau_c = 0.64 + \frac{0.7 - 0.64}{1.25 - 1} \times (1.122 - 1)$

$\boxed{\tau_c = 0.67 MPa}$

$V_{uc} = \tau_c bd = 0.67 \times 350 \times 500 = 117.25 kN$.

(shear resisted by concrete)

$V_{us} = (350 - 117.25) kN = 232.75$

→ let us use ~~2~~ legged 10mm ϕ bars of grade Fe415 (vertical)

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

$S_v = \frac{0.87 \times 415 \left[2 \times \pi/4 \times 10^2 \right] \times 500}{232.75 \times 10^3}$ mm

$S_v = 121.833 mm$

→ ~~S_v for min shear reinforce~~

Sv for min shear Reinforcement:

$$\frac{A_{sv}}{b s_v} = \frac{0.4}{0.87 f_y}$$

$$\frac{2 \times \pi/4 \times 10^2}{350 \times S_v} = \frac{0.4}{0.87 \times 415} \Rightarrow S_v = 405.1 \text{ mm}$$

$$S_{v\,max} \leq \begin{cases} 0.75d = 375 \text{ mm} \\ 300 \end{cases}$$

⇒ provide 2 legged 10mmϕ vertical shear reinforcement vertically @ 120mm c/c spacing

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

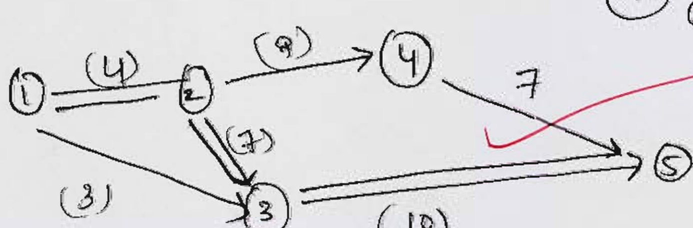
Standard normal distribution table:

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]

$\sigma = \left(\frac{t_p - t_o}{6}\right)^2$

Activit	$t_e = \left(\frac{t_o + 4t_m + t_p}{6}\right)$	
1–2	4	$\left(\frac{5-3}{6}\right)^2$
1–3	3.	
2–3	7	$\left(\frac{8-6}{6}\right)^2$
2–4	9	
3–5	10	$\left(\frac{16-8}{6}\right)^2$
4–5	7	



(1) Critical path

(1) → (2) → (3) → (5)

$= 4 + 7 + 10$

$= 21$ days (Ans)

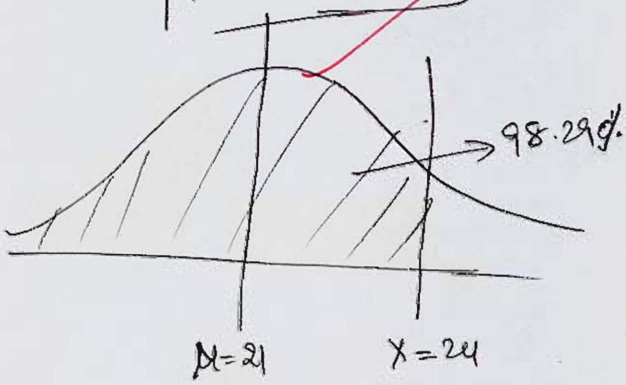
$\sigma = \sqrt{\left(\frac{1}{3}\right)^2 + \left(\frac{1}{3}\right)^2 + \left(\frac{4}{3}\right)^2}$

$\sigma = \sqrt{2} = 1.414$ Ans

2. $z = \frac{X - \mu}{\sigma} = \frac{24 - 21}{1.414} = 2.12$

$\text{probability} = 98.21 + \frac{98.61 - 98.21}{0.1} \times (2.12 - 2.1)$

$\boxed{P = 98.29}$ Ans



20

3. $z = \frac{X_1 - \mu}{\sigma}$

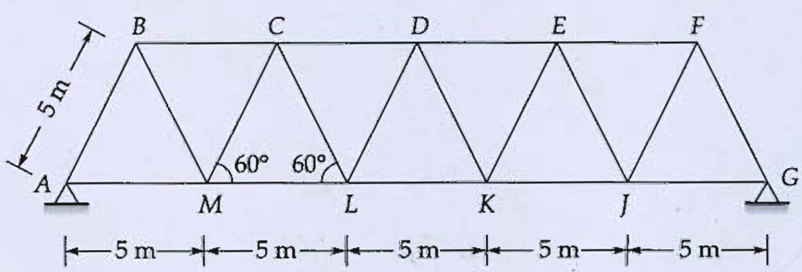
for 98.8% $\quad z = 2.2 + \frac{0.1}{98.93 - 98.61} \times (98.8 - 98.61)$

$z = 2.259$

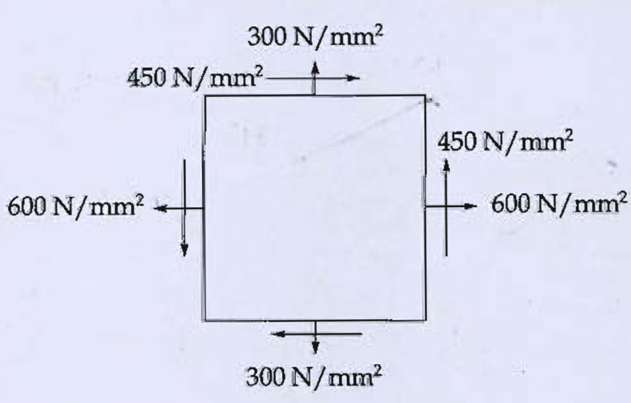
$z = 2.259 = \frac{X_1 - \mu}{\sigma} \Rightarrow \boxed{X_1 = 24.19 \text{ days}}$

Ans

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]

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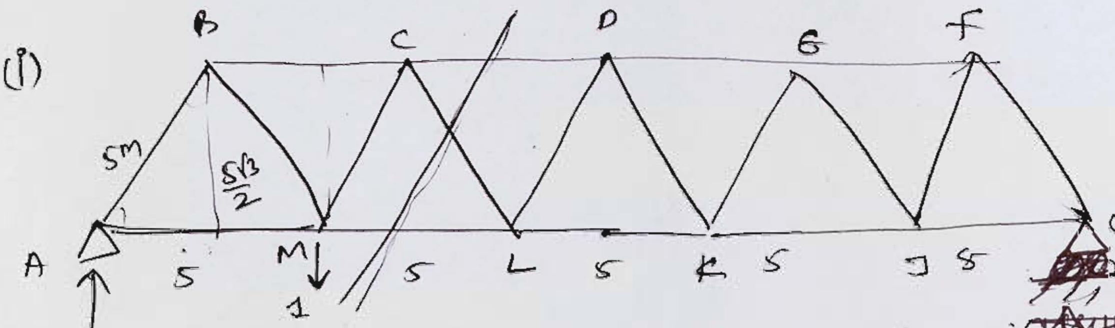
(i)

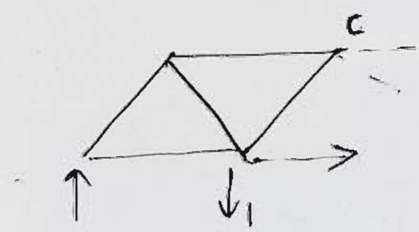


$V_B = \frac{1}{5}$ (assuming Roller)

$V_A = \frac{4}{5}$

Load @ M

F_{MJ}



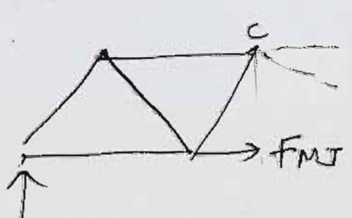
$\Sigma M_C = 0$

$F_{ML}\left(\frac{5\sqrt{3}}{2}\right) + 1\left(\frac{5}{2}\right) = \left(5+\frac{5}{2}\right)\frac{4}{5}$

$F_{ML} = 0.808$

(12)

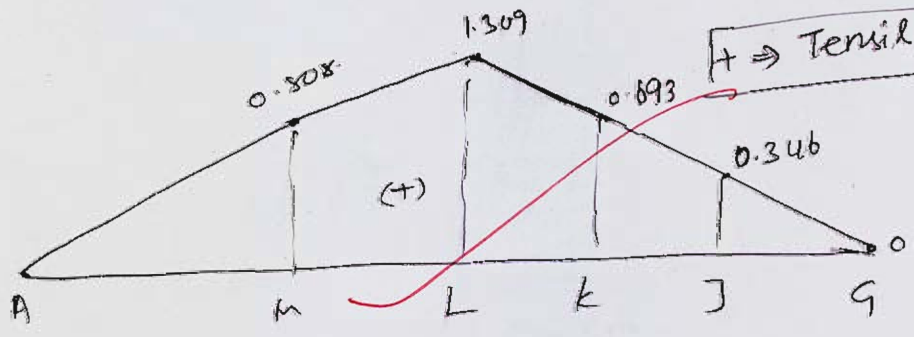
Load @ L



$\Sigma M_C = 0$

$F_{MJ}\left(\frac{5\sqrt{3}}{2}\right) = \frac{3}{5}\left(5+\frac{5}{2}\right)$

$F_{MJ} = \frac{3\sqrt{3}}{5} = 1.039$



+ ⇒ Tensile

Ans

(not to scale)

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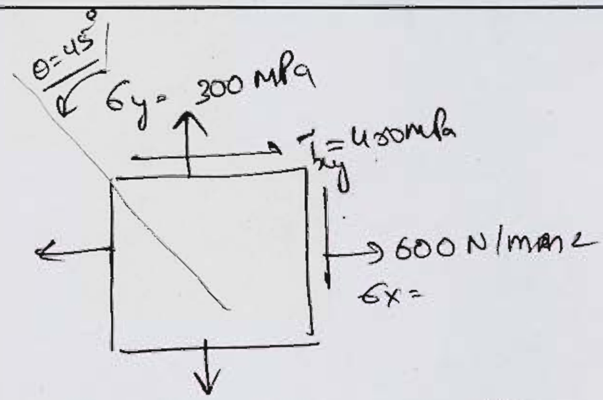
(ii)



→ Since given planes are ⊥r ; Two planes equally Inclined ⇒ θ = 45°

$$\sigma_\theta = \left(\frac{\sigma_x+\sigma_y}{2}\right) + \left(\frac{\sigma_x-\sigma_y}{2}\right)\cos 2\theta + \tau_{xy}\sin 2\theta$$

~~$\sigma_{\theta+90} = $~~ $\boxed{\sigma_{\theta=45^\circ} = 900}$ Ans

(8)

$\boxed{\sigma_{\theta+90} = 0}$ Ans

$$\tau_\theta = -\left(\frac{\sigma_x-\sigma_y}{2}\right)\sin 2\theta + \tau_{xy}\cos 2\theta$$

$$= -\left(\frac{600-300}{2}\right)\sin 90 + 450\cos(90)$$

$\boxed{\tau_\theta = -150 \text{ MPa}}$ Ans

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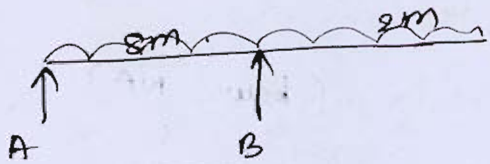
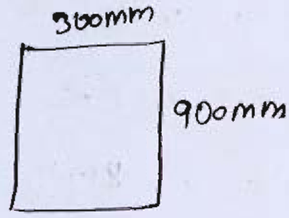
Q.7 (b) A concrete beam with a single overhang is simply supported at A and B over a span of 8 m and the overhang BC is 2 m. The beam is of rectangular section 300 mm wide by 900 mm deep and supports is uniformly distributed live load of 3.52 kN/m over the entire length in addition to its self-weight. 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]





$w_{LL} = 3.52$ kN/m.

$w_{DL} = 0.3 \times 0.9 \times 24 = 6.48$ kN/m

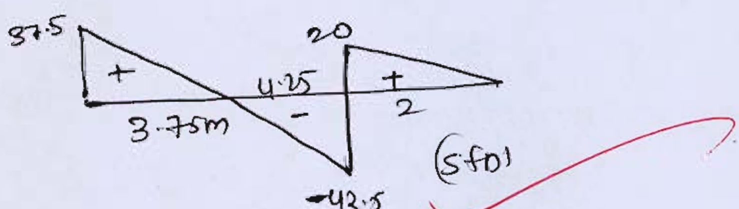
$P_e = 500$ kN.

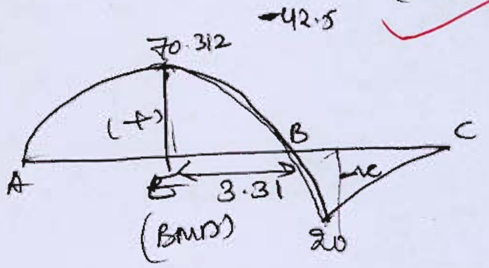
$w = w_{DL} + w_{LL} = 10$ kN/m

$R_A + R_B = 10 \times 10 = 100.$

$R_B(8) = 100 \times 5$

$\Rightarrow R_B = 62.5$ kN, $R_A = 37.5$ kN





position of Pushes In AB

$P(e) = M_x$

$e = \left(\dfrac{37.5x - 5x^2}{500}\right) \times 10^3$ (mm) x in m

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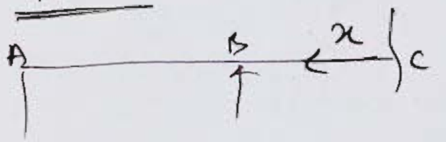
In BC



−ve ⇒ above NA

+ve ⇒ below NA

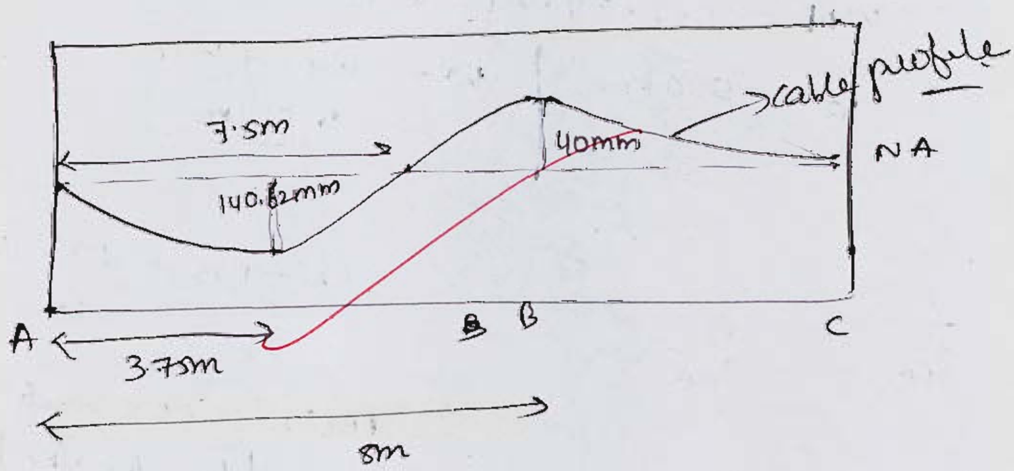
$P(e) = -5x^2 \Rightarrow e = \frac{5x^2}{500} \times 10^3$ mm

at $x = 0$ $e = 0$

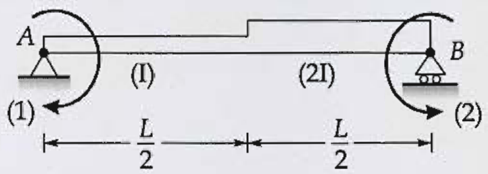
at $x = 3.75$ $e = 140.62$ mm (below NA)

at $x = 8$ m $e = -40$ mm (~~below NA~~) above NA

20



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



[20 marks]

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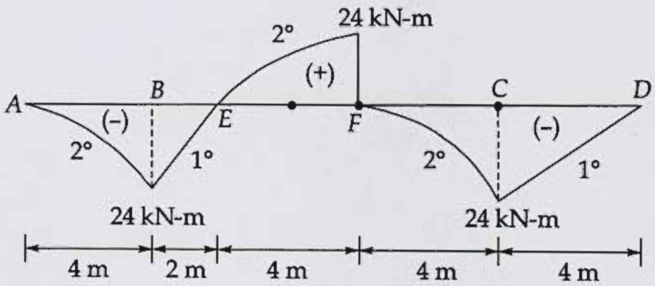
Q.8 (a) BMD for beam is given below. Draw loading diagram and shear force diagram. The beam is simply supported with overhangs on *B* and *C*.



[20 marks]

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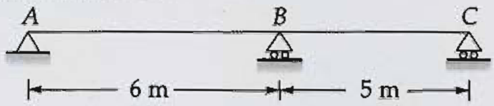
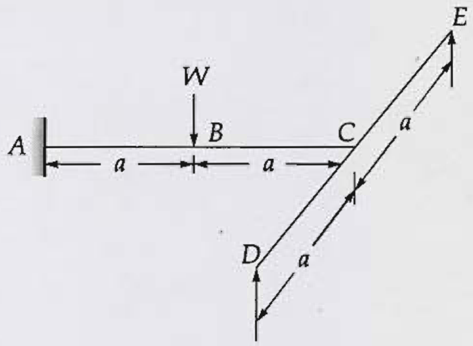
Q.8 (b) For the beam as shown in figure, compute the ordinate of influence line for R_A at 1 m interval. Assume EI of beam is constant.



[20 marks]

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]