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Leading Institute for ESE, GATE & PSUs

ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-4 : Section A : Design of Concrete and Masonry Structures (All Topics)
Section B : Strength of Materials-1 + Highway Engineering-2 + Surveying and Geology-2 [Part syllabus]

Name : ....

Roll No :

Test Centres

Delhi ☑ Bhopal ☐ Jaipur ☐

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Student's Signature

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	44
Q.2	47
Q.3	55
Q.4	—
Section-B	
Q.5	31
Q.6	—
Q.7	50
Q.8	—
Total Marks Obtained	227

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

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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 : Design of Concrete and Masonry Structures (All Topics)

Q.1 (a) Explain the reasons for the following:

(i) Ordinary mild steel cannot be used for prestressed wires.

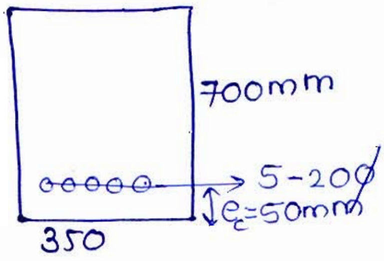
(ii) Loss due to elastic shortening in post-tensioned beam is less than that in pretensioned beam.

(iii) Deflection of prestressed beams with tendons provided as a parabolic profile compensates part of dead load deflections.

[12 marks]

Q.1 (b) A simply supported rectangular reinforced concrete (γ_c = 25 kN/m) beam of size 350 mm × 700 mm (overall depth) and has a effective span of 9 m. It is reinforced with 5 bars of 20 mm diameter at bottom with an effective cover of 50 mm. Determine the safe uniformly distributed live load Use: Limit state method that the beam can carry. Take M20 grade of concrete and Fe 415 grade of steel.

[12 marks]



$l_{eff} = 9\,m$

$\gamma_c = 25\ kN/m^3$

$A_{st} = 5 \times \frac{\pi}{4} \times 20^2 = 1570.796\ mm^2$

$d = 700 - 50 = 650\ mm$

M20 / Fe415

In LSM,

$C = T$

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

$x_u = \frac{0.87 \times 415 \times 1570.796}{0.36 \times 20 \times 350}$

$= 225\ mm$

$(x_u)_{lim} = Kd$
$= 0.48 \times 650$
$= 312 \text{ mm}$

$\left\{ K = \frac{700}{1100 + 0.87 f_y} \right.$
@ $f_y = 415$

$x_u < (x_u)_{lim} \longrightarrow$ URS section

$\therefore MOR = 0.87 \times f_y \times A_{st} \times (d - 0.42 x_u)$
$= 0.87 \times 415 \times 1570.796 (650 - 0.42 \times 225)$
$= \underline{315.044 \text{ kNm}}.$

$M_{working} = \frac{MOR}{1.5} = 210.03 \text{ kNm}$

$M_{working} = \frac{w_{working} \times l_{eff}^2}{8} = 210.03$

$w_{working} = 20.7436 = w_l + w_d.$

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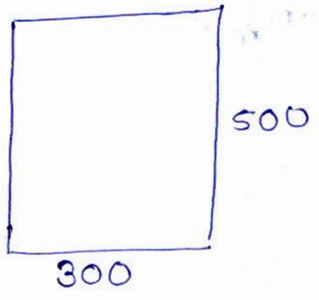
$w_d = 25 \times 0.35 \times 0.7 = 6.125 \text{ kN/m}$

$\therefore w_l = 20.7436 - w_d = 14.618 \text{ kN/m}.$

$\therefore$ Safe udl for live load $= 14.618 \text{ kN/m}.$

Q.1 (c) A simply supported rectangular prestressed concrete beam has a cross-section of 300 mm × 500 mm. It carries a superimposed service load of 8.5 kN/m over an effective span of 12.0 m. The beam is prestressed by a cable with a parabolic profile, having an eccentricity of 100 mm at the mid-span and zero eccentricity at the supports. The initial prestressing force is 650 kN. Assuming the unit weight of concrete is 24 kN/m³ and the total loss of prestress is 15%, determine the stresses in beam at transfer and service stages at mid span of beam.

[12 marks]



$w_\ell = 8.5 \text{ kN/m}$

$\ell_{eff} = 12 \text{ m}$

$e_{midspan} = 100 \text{ mm}$

$e_{end} = 0.$

$P_o = 650 \text{ kN}$

$\gamma_c = 24 \text{ kN/m}^3$

$P_f = (1-k) P_o = 0.85 \times 650$

$P_f = 552.5 \text{ kN}$

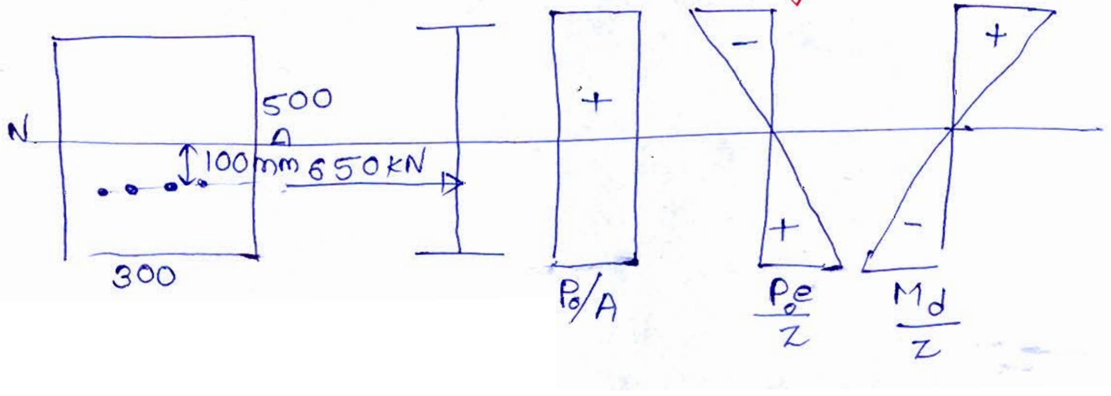
$w_d = 25 \times 0.3 \times 0.5 = 3.75 \text{ kN/m}.$; $M_{transfer} = \frac{w_d \ell_{eff}^2}{8}$

$= 67.5 \text{ kNm}$

$w_T = 8.5 + 3.75 = 12.25 \text{ kN/m}$

$(BM)_{midspan} = M_{service} = \frac{w_T \ell_{ef}^2}{8} = 220.5 \text{ kNm}$

(a) <u>At transfer stage</u>

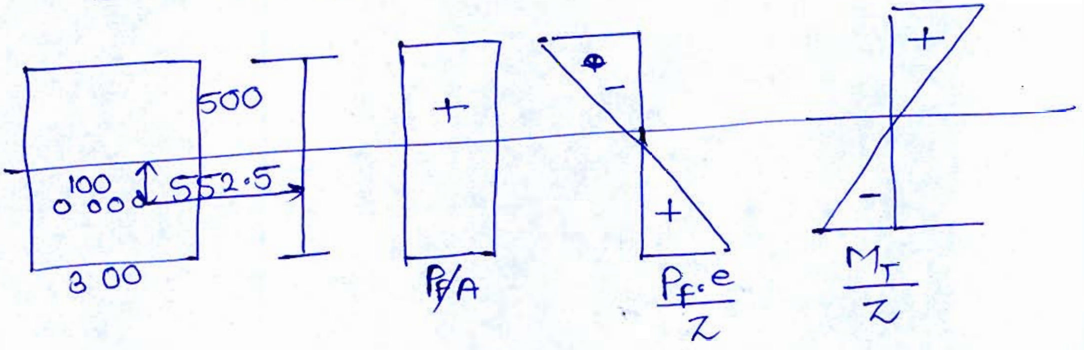


$$\sigma_{top} = P/A - \frac{Pe}{Z} + \frac{M_d}{Z} = \frac{650\times10^3}{300\times500} - \frac{650\times10^3\times100}{300\times500^2}\times6 + \frac{67.5\times10^6\times6}{300\times500^2}$$

$$= 4.533 \text{ MPa}$$

$$\sigma_{bottom} = P/A + \frac{Pe}{Z} - \frac{M_d}{Z} = 4.133 \text{ MPa}$$

(b) At service stage



$$\sigma_{top} = \frac{P_f}{A} - \frac{P_f \cdot e}{Z} + \frac{M_T}{Z}$$

$$= \frac{552.5\times10^3}{300\times500} - \frac{552.5\times10^3\times100\times6}{300\times500^2} + \frac{220.5\times10^6\times6}{300\times500^2}$$

$$= 16.903 \text{ N/mm}^2$$

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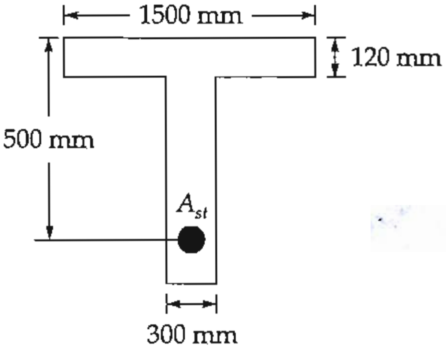
$$\sigma_{bottom} = \frac{P_f}{A} + \frac{P_f \cdot e}{Z} - \frac{M_T}{Z}$$

$$= -9.536 \text{ N/mm}^2$$

Q.1 (d) Determine the limiting moment of resistance for a T-beam as shown in figure below using the Limit State Method.

Grade of concrete: M-15

Grade of steel: Fe-415



[12 marks]

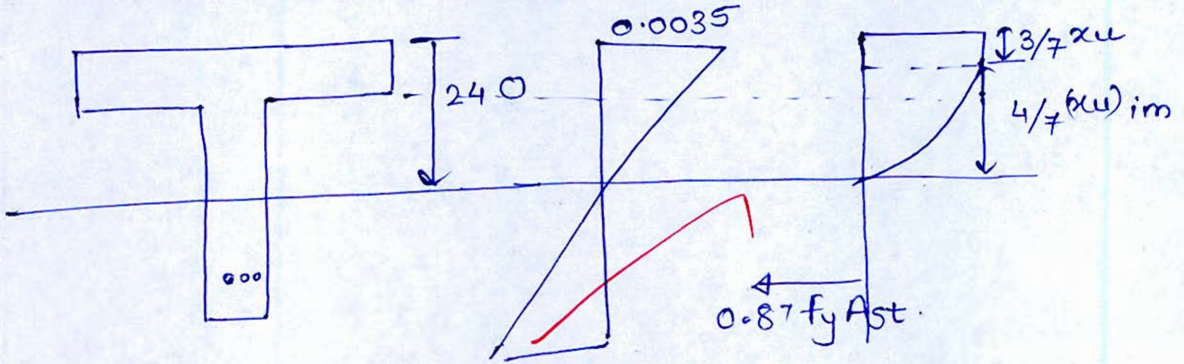
→ $(x_u)_{lim} = Kd$, $K = \frac{700}{1100 + 0.87 f_y}$

@ $f_y = 415$

$(x_u)_{lim} = 0.48 \times 500 = 240mm$

$(x_u)_{lim} > d_f$ & $\left(\frac{3 (x_u)_{lim}}{7} = 102.85 \right) < d_f$

∴ ~~te~~. The NA is within the web.



let, $y_f = 0.15 (x_u)_{lim} + 0.65\, d_f$

$$= 0.15 \times 240 + 0.65 \times 120$$

$$= 114 \text{ mm}.$$

$$\therefore \underline{MOR} = 0.36 f_{ck} b_w (x_u)_{lim} \times \left(d - 0.42 (x_u)_{lim}\right) + (B_f - b_w) y_f \times 0.45 f_{ck} * \left(d - y_f/2\right)$$

$$= 0.36 \times 15 \times 300 \times 240 \times (500 - 0.42 \times 240) +$$
$$(1500 - 300) \times 114 \times 0.45 \times 15 \times \left(500 - \frac{114}{2}\right) / 10^6$$

$$= 155.209 + 409.0662$$

$$= \underline{564.275 \text{ kNm}}$$

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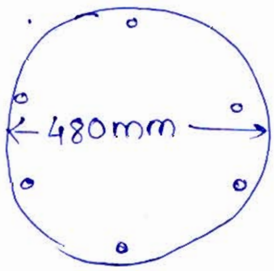
$$\therefore (M_u)_{lim} = \underline{564.275 \text{ kNm}}$$

Q.1 (e) A reinforced concrete short column of 480 mm diameter is reinforced with 6 numbers of 20 mm diameter bars of steel of grade Fe 415 and 8 mm diameter helical reinforcement with a pitch of 75 mm. Compute the maximum load-carrying capacity of the column if the concrete used is of grade M25. Assume a nominal cover of 40 mm to the helical reinforcement.

[12 marks]



$A_{sc} = 6\times\frac{\pi}{4}\times20^2$

M25/Fe415 ; D_c = dia of core $= 480 - 2\times40$ $= 400$mm

&

$$P_u = 1.05\left[0.4 f_{ck} A_c + 0.67 f_y A_{sc}\right]$$

$$= 1.05\left[0.4\times25\left(\frac{\pi}{4}\times480^2 - 6\times\frac{\pi}{4}\times20^2\right) + 0.67\times415\times6\times\frac{\pi}{4}\times20^2\right] / 10^3$$

$P_u = 2430.56$ kN

check,

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

$$\frac{0.36\times25}{415}\left[\frac{\pi/4\times480^2}{\frac{\pi}{4}\times400^2}-1\right] \leq \frac{\left(\frac{1000}{75}\right)\times\pi\times(400-8)\times\frac{\pi}{4}\times8^2}{\frac{\pi}{4}\times400^2\times1000}$$

$9.542\times10^{-3} \not\leq 6.568\times10^{-3} \longrightarrow$ pitch needs to be changed.

$$\frac{0.36\times25}{415}\left[\frac{\pi/4\times480^2}{\pi/4\times400^2}-1\right] \leq \frac{\left(1000/p\right)\times\pi\times(400-8)\times\frac{\pi}{4}\times8^2}{\frac{\pi}{4}\times400^2\times1000}$$

$$p \leq 51.62$$

Provide $\underline{\underline{p = 50\,mm}}$

$\not< 25\,mm$

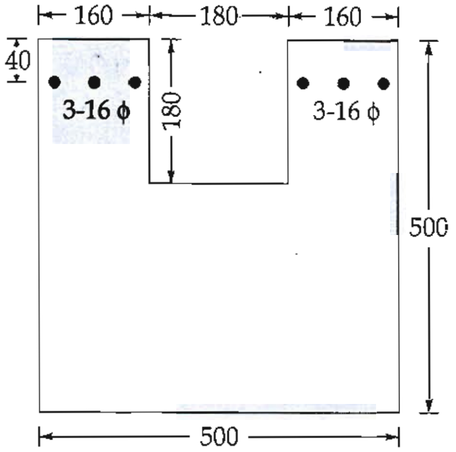
$\not< 3\phi_n = 24\,mm$

$\not> 75\,mm$

$\not> \frac{D_c}{6} = \frac{400}{6} = 66.67\,mm$

⑧

Q.2 (a) **(i)** A cantilever beam of effective length 2.5 m is constructed using the cross-section shown in the figure. The beam is reinforced with 6 bars of 16 mm diameter placed at an effective cover of 40 mm from the face. Using the Limit State Method, determine the maximum factored uniformly distributed load inclusive of self weight, that the beam can carry safely. Take: grade of concrete: M20, grade of steel: Fe415. Check in limit state of flexure only.



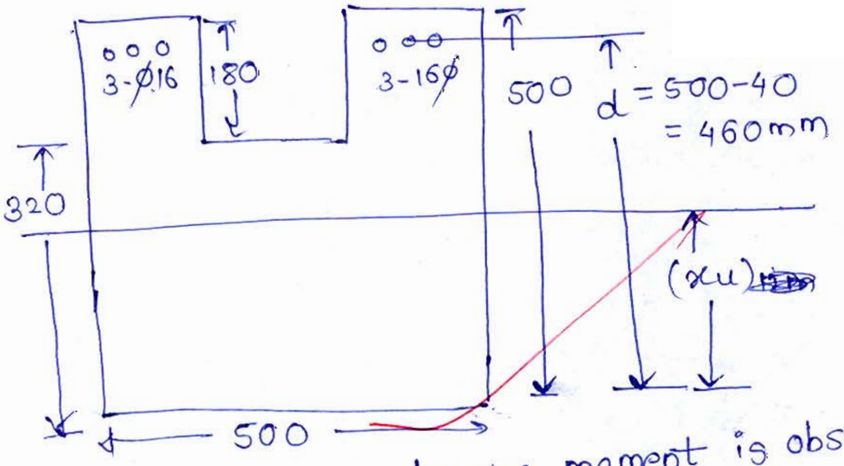
(All dimensions are in mm)

(ii) Explain the following with proper reasoning based on limit state design principles of reinforced concrete:

1. Why under-reinforced sections are preferred over over-reinforced sections in flexural members.
2. Why minimum reinforcement is pronded in beams and slabs even when bending moment is very small.
3. Why maximum reinforcement is limited in beams as per codal provisions.
4. Why shear reinforcement is required even when concrete has some shear strength.

[12 + 8 = 20 marks]

(i)



$d = 500 - 40$
$= 460\,mm$

M20/Fe415

$l_{eff} = 2.5\,m$

$M_u = \frac{w_u l_{eff}^2}{2}$

In cantilever hogging moment is observed & In cracked section concrete on tension side is ignored

Assumming $x_u < 320$ mm.

~~0.36 B xu~~

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

$0.36 \times 20 \times 500 \times x_u = 0.87 \times 415 \times \left(6 \times \frac{\pi}{4} \times 16^2\right)$

$x_u = 120.99 < 320$ mm

$x_u < (x_u)_{lim} \rightarrow \underline{URS}$ $\left\{ x_{u\,lim} = 0.48 \times 460 = 220.8 \text{ mm} \right.$

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

$= 0.87 \times 415 \times \left(6 \times \frac{\pi}{4} \times 16^2\right) \times (460 - 0.42 \times 120.99)$

$= 178.224$ kNm.

∴ Maxm allowable factored load inclusive of self weight ⟹ w_u

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$\frac{w_u l^2}{8} = MOR$

$\boxed{w_u = 57.0318 \text{ kNm}}$

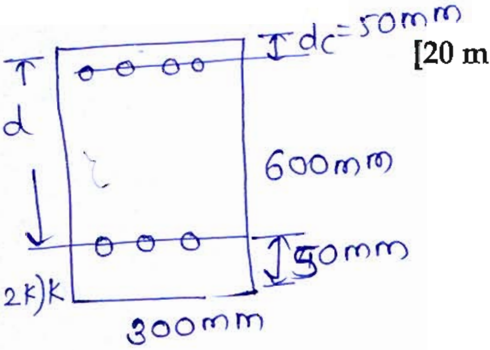
Q. 11

Q.2 (b) Design a rectangular reinforced concrete beam to resist a factored bending moment of 414 kNm. The beam has a width of 300 mm and an overall depth of 600 mm. An effective cover of 50 mm is provided to both the tension and compression reinforcement. The beam is constructed using M20 grade of concrete and Fe 415 grade of steel. Use Limit state method.

Design stress – Strain table For Fe-415

Design stress	**0.80 f_{yd}**	**0.85 f_{yd}**	**0.90 f_{yd}**	**0.95 f_{yd}**	**0.975 f_{yd}**	**1.00 f_{yd}**
Strain	0.00144	0.00163	0.00192	0.00241	0.00276	0.00380

[20 marks]



(i) $M_u = 414$ KNm

$M20/Fe415$, $d = 550$ mm

$$(M_u)_{lim} = Q B d^2$$

For Fe 415 ⟶ $Q = 0.36 f_{ck} \times (1-0.42k)k$

& $k = \dfrac{700}{1100 + 0.87 f_y}$

$\therefore\ Q = 0.138 \times f_{ck} B$

$$(M_u)_{lim} = 0.138 \times 20 \times 300 \times 550^2 / 10^6$$

$= 250$ kNm

$M_u > (M_u)_{lim} \longrightarrow$ over-reinforced section.

In LSM ORS are designed as doubly r/f section.

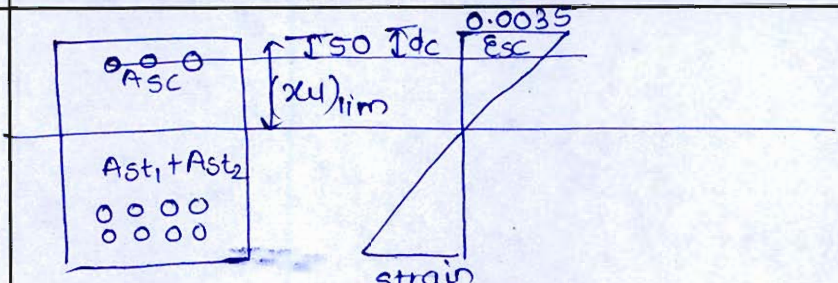
$$(x_u)_{lim} = kd = 0.48 \times 550 = \underline{264 \text{ mm}}$$

$$A_{st_1} = \frac{(M_u)_{lim}}{0.87 f_y (d - 0.42 (x_u)_{lim}} = \frac{250 \times 10^6}{0.87 \times 415 \times (550 - 0.42 \times 264)}$$

$$A_{st_1} = 1576.846 \text{ mm}^2.$$

$$A_{st_2} = \frac{(M_u - (M_u)_{lim})}{0.87 \times f_y (d - d_c)} = \frac{(414 - 250) \times 10^6}{0.87 \times 415 \times (550 - 50)}$$

$$A_{st_2} = 908.4614 \text{ mm}^2$$



strain diagram

$$\frac{0.0035}{(x_u)_{lim}} = \frac{\varepsilon_{sc}}{(x_{u\,lim} - d_c)} \Rightarrow \frac{0.0035}{264} = \frac{\varepsilon_{sc}}{(264-50)}$$

1B

$$\varepsilon_{sc} = 0.00283$$

for strain $\varepsilon_{sc} = 0.00283$

$$f_{sc} = 0.975 f_{yd} + \frac{(1 f_{yd} - 0.975 f_{yd})}{0.0038 - 0.00276} \times (0.00283 - 0.00276)$$

$$= 0.9768 f_{yd}.$$

$$f_{yd} = 0.87 f_y \longrightarrow f_{sc} = 0.9768 \times 0.87 \times \cancel{f_y}\ 415$$

$$f_{sc} = 352.693\ N/mm^2.$$

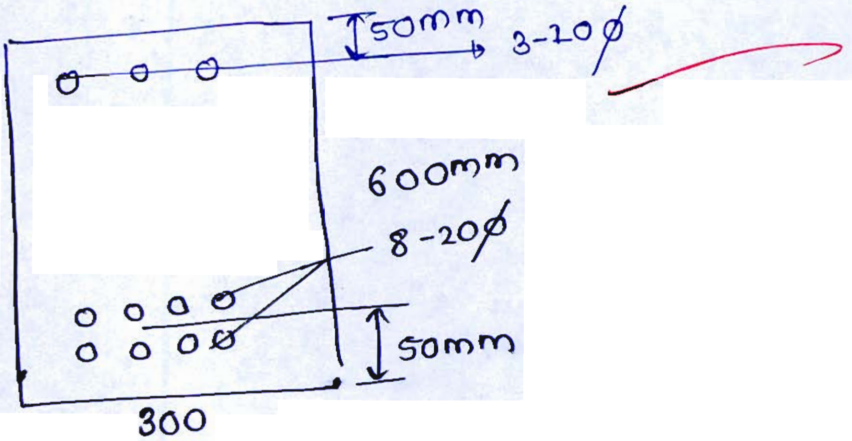
$$\therefore A_{sc} = \frac{M_u - (M_u)_{lim}}{f_{sc} \times (d - d_c)} = \frac{(414-250) \times 10^6}{352.693 \times (550-50)}$$

$$A_{sc} = 929.98\ mm^2 \longrightarrow \text{provide } 3\text{-}20\phi \text{ bars}$$

$$A_{st_{total}} = A_{st_1} + A_{st_2} = 1576.846 + 908.461\ mm^2$$

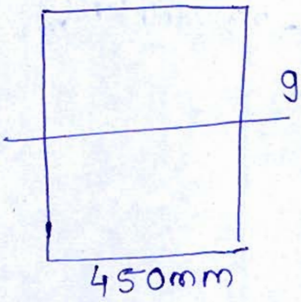
$$= 2485.307\ mm^2$$

↳ provide → 8-20∅ bars.



Q.2 (c) A rectangular prestressed concrete beam of size 450 mm × 900 mm is simply supported over a span of 15 m. The beam is prestressed using a parabolic cable having an eccentricity of 150 mm at the supports and 350 mm at mid-span. The initial prestressing force applied is 2200 kN. The beam carries a live load of intensity 15 kN/m. The modulus of elasticity of concrete is 36 kN/mm^2 and the unit weight of concrete is 25 kN/m^3. Estimate the initial mid-span deflection due to prestressing force and dead load and also determine the final deflection assuming 15% loss of prestress. Also derive the deflection formula due to prestressing force.

[20 marks]



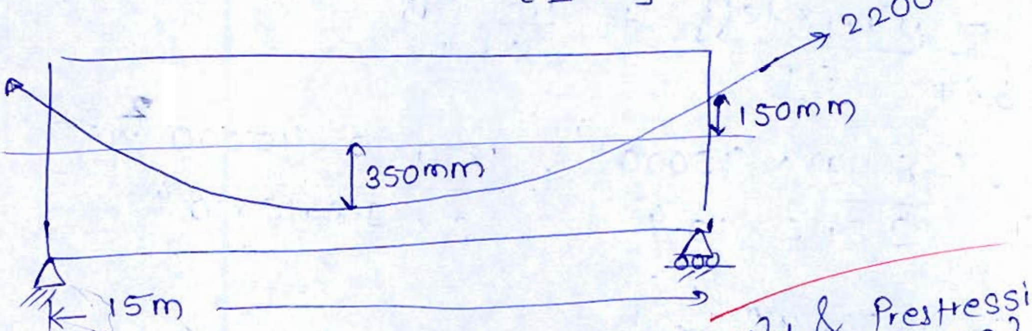
$\omega_l = 15\ kN/m$

$E = 36\ kN/mm^2 = 36{,}000\ N/mm^2$

$\gamma_c = 25\ kN/m^3$

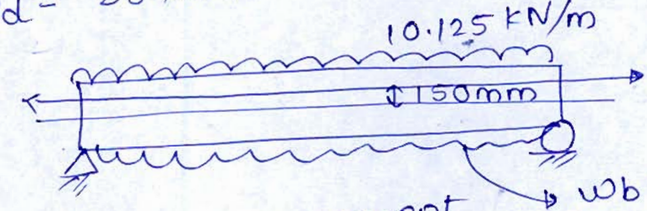
$I = \frac{450\times900^3}{12} = 2.73375\times10^{10}$

$EI = 9.8415\times10^{14}\ Nmm^2$



(i) Initial midspan deflection {δ due to ωd & Prestressing force}

$\omega_d = 25\times0.45\times0.9 = 10.125\ kN/m$



$\omega_b = 39.11\ kN/m.$

By load balancing concept

$$P\times h = \frac{\omega_b\, l_{eff}^2}{8}$$

$$\frac{2200\times(150+350)}{1000} = \frac{\omega_b\times15^2}{8}$$

$\omega_b = 39.11\ kN/m$

$\therefore\ \omega_{net} = 10.125 - 39.11 = \cancel{6.214}\ -28.986\ kN/m.$

$$\delta_{midspan} = \frac{5}{384}\frac{\omega_{net}\times l_{eff}^4}{EI} + \frac{\cancel{(Pe)}\, l_{eff}^2}{8\,EI}.$$

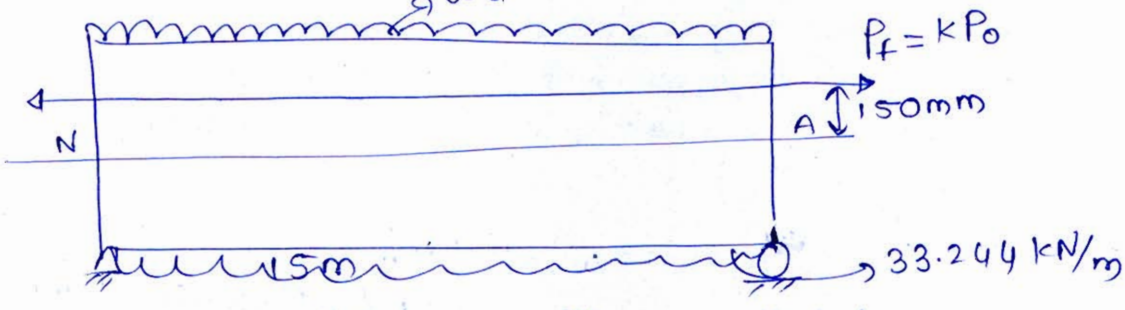
$$= -\frac{5\times\cancel{6.214}\,28.986\times(15{,}000)^4}{384\times36000\times2.73375\times10^{10}} + \frac{2200\times(15000)^2\times10^3\times150}{8\times36{,}000\times2.73375\times10^{10}}$$

$\delta_{midspan} =$ ~~5.105 mm.~~ ~~923.65 mm~~

$= -9.984\,mm\,(\uparrow)$

(ii) Final deflection $\longrightarrow P_f = 0.85 \times 2200 = 1870\,kN$

$w_d + w_l = 15 + 10.125 = 25.125$



$$w_b = \frac{P_f \times h \times 8}{l^2} = 33.244\,kN/m$$

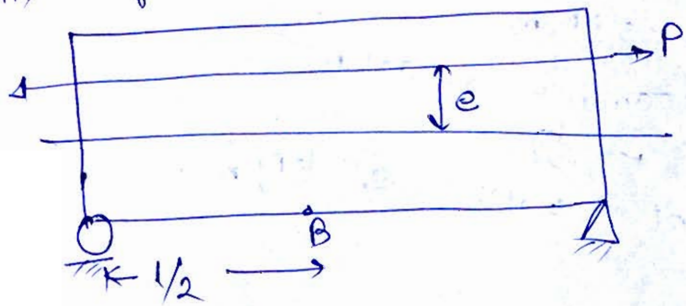
$$w_{net} = 25.125 - 33.244 = -8.119\,kN/m.$$

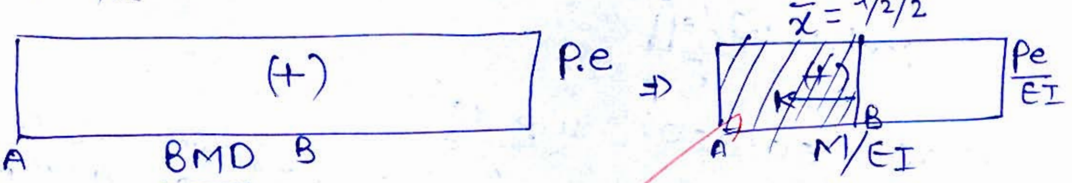
$$\delta_{net} = \frac{5}{384}\frac{w_{net} \times l_{eff}^4}{EI} + \left(\frac{P_f e \times l_{eff}^2}{8EI}\right.$$

$$= \frac{5}{384} \times \frac{(-8.119) \times (15000)^4}{9.8415 \times 10^{14}} + \frac{1870 \times 10^3 \times (15000)^2 \times 150}{8 \times 9.8415 \times 10^{14}}$$

$$= 2.578\,mm\,(\downarrow)$$

(iii) Deflection due to prestress with eccentricity e.





$\delta_B = \delta_A + \theta_A(AB) + \delta_{B/A}$

& $\theta_B - \theta_A =$ Area of $\frac{M}{EI}$ betn A & B

& $\theta_B = 0 \longrightarrow$ maxm(δ)

$\therefore \theta_A = - \frac{pe}{EI} \times \frac{l}{2} = \left(-\frac{Pel}{2EI}\right)$

$$\delta_B = \cancel{\delta_A}^{\,0} + \left(\frac{-Pel}{2EI}\right) \times \frac{l}{2} + A \times \bar{x}$$

$\left\{ \bar{x} = \right.$ dist^n ~~Area~~ of CG of area from B

$$\delta_B = -\frac{Pel^2}{4EI} + \left(\frac{Pel}{2EI}\right) * \left(\frac{l}{4}\right)$$

$$\left(\delta_B = \frac{Pel^2}{8EI} \downarrow\right)$$

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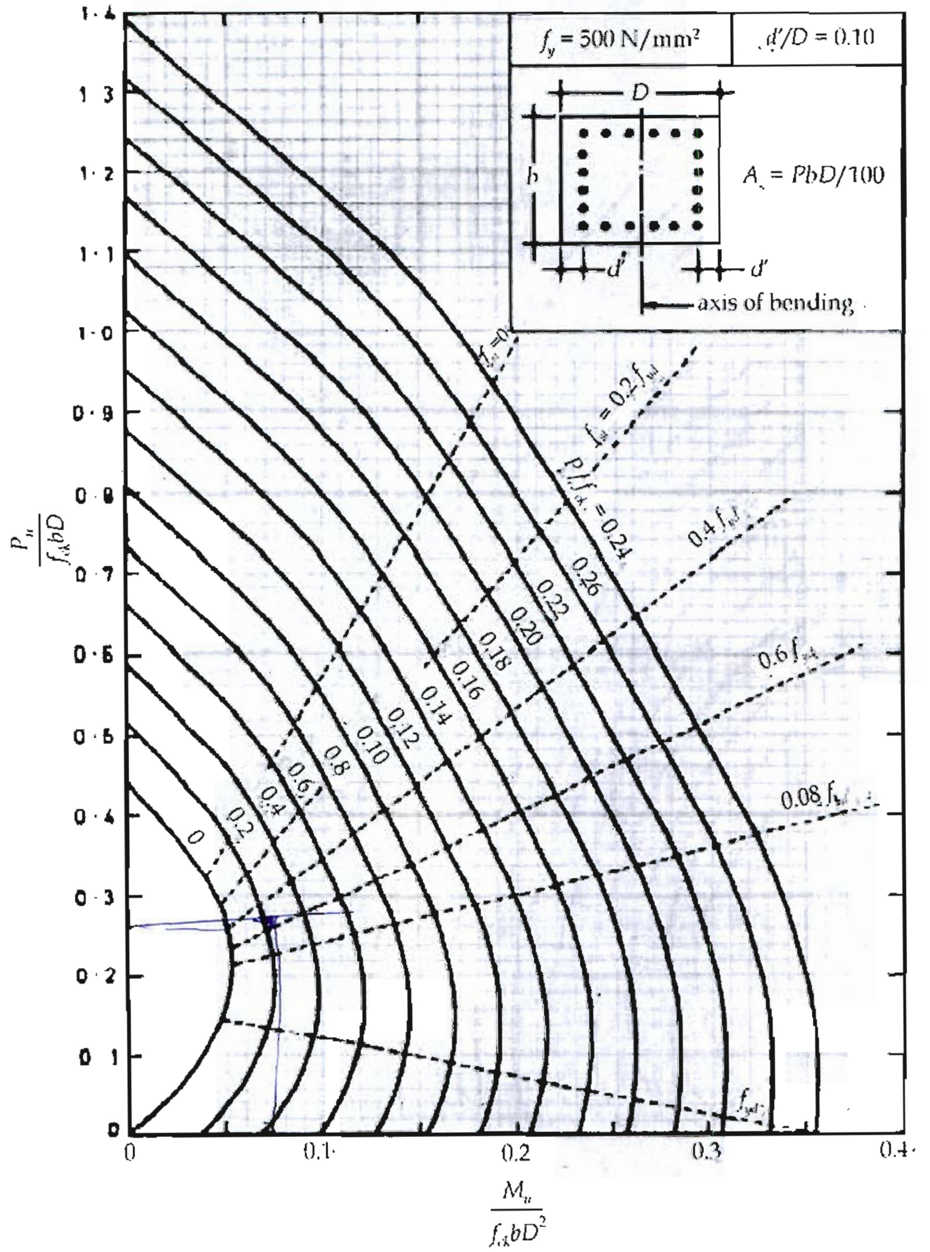
Q.3 (a) Design a short rectangular reinforced concrete column of size 400 mm × 600 mm to resist a factored axial load P_u = 1600 kN and a factored uniaxial bending moment M_u = 250 KN-m acting about the major axis. The reinforcement is to be distributed equally on all four sides of the column. The unsupported length of the column is 3000 mm. Use the following material properties: take M25 mix, Fe500 steel and effective cover as 60 mm. Relevant chart from *SP* 16 is enclosed.

Chart 48 COMPRESSION WITH BENDING - Rectangular Section-Reinforcement Distributed Equally on Four Sides



[20 marks]

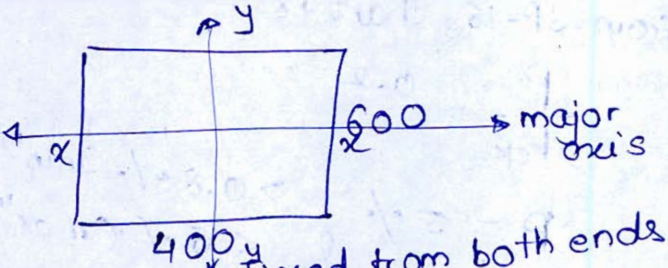
$P_u = 1600\,kN.$

$M_{u\bar{x}} = 250\,kN.$

$l_o = 3000\,mm.$

M25/Fe500.

$d' = 60\,mm.$



(i) Assuming the given column is ~~fixed~~ ~~pinned~~ Fixed from both ends.

$$l_{eff} = l_o \times 0.65$$
$$= 0.65 * 3000$$
$$= 1950\,mm$$

(ii) slenderness ratio.

$$\lambda x = \frac{l_{eff}}{D} \quad , \quad \lambda y = \frac{l_{eff}}{B}$$

$$\lambda x = \frac{1950}{600} \qquad \lambda y = \frac{1950}{400}$$

$$\lambda x = 3.25 < 12 \qquad \lambda y = 4.875 < 12$$

(Short column)

(iii) Minimum moment about xx

$$e_x = \left[\left\{\frac{1950}{500} + \frac{600}{30}\right\} \text{ or } 20\,mm\right]_{max^m}$$
$$= 23.9$$

$$(M_{ux})_{min} = P_u \times e_x = 1600 \times 23.9 \times 10^{-3}$$
$$= 38.24 \quad < 250\,kN.$$

∴ Design load $P_u = 1600\,kN$

design moment $M_u = 250\,kN$

$$\frac{d'}{D} = \frac{60}{600} = 0.1$$

$$\therefore \frac{P_u}{f_{ck} BD} = \frac{1600 \times 10^3}{25 \times 400 \times 600} = 0.266$$

$$\frac{M_u}{f_{ck} BD^2} = \frac{250 \times 10^6}{25 \times 400 \times 600^2} = 0.0694$$

from SP-16, chart 48

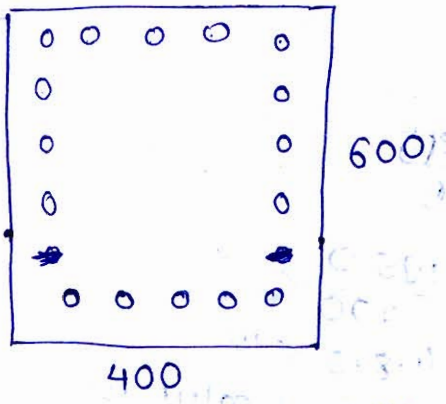
$$\frac{P}{f_{ck}} = 0.2$$

$p = 5\%$ $> 0.8\%$ (min^m) & $< 6\%$ (max^m)

$$\therefore A_s = \frac{5}{100} \times 400 \times 600 = 12{,}000\ mm^2$$

↳ provide 20 - 28ϕ

↳ 5 on each face



17

Design of lateral ties.

$$\phi = max^m \begin{cases} \frac{\phi_{main}}{4} = \frac{28}{4} = 7m \\ 6mm \end{cases}$$

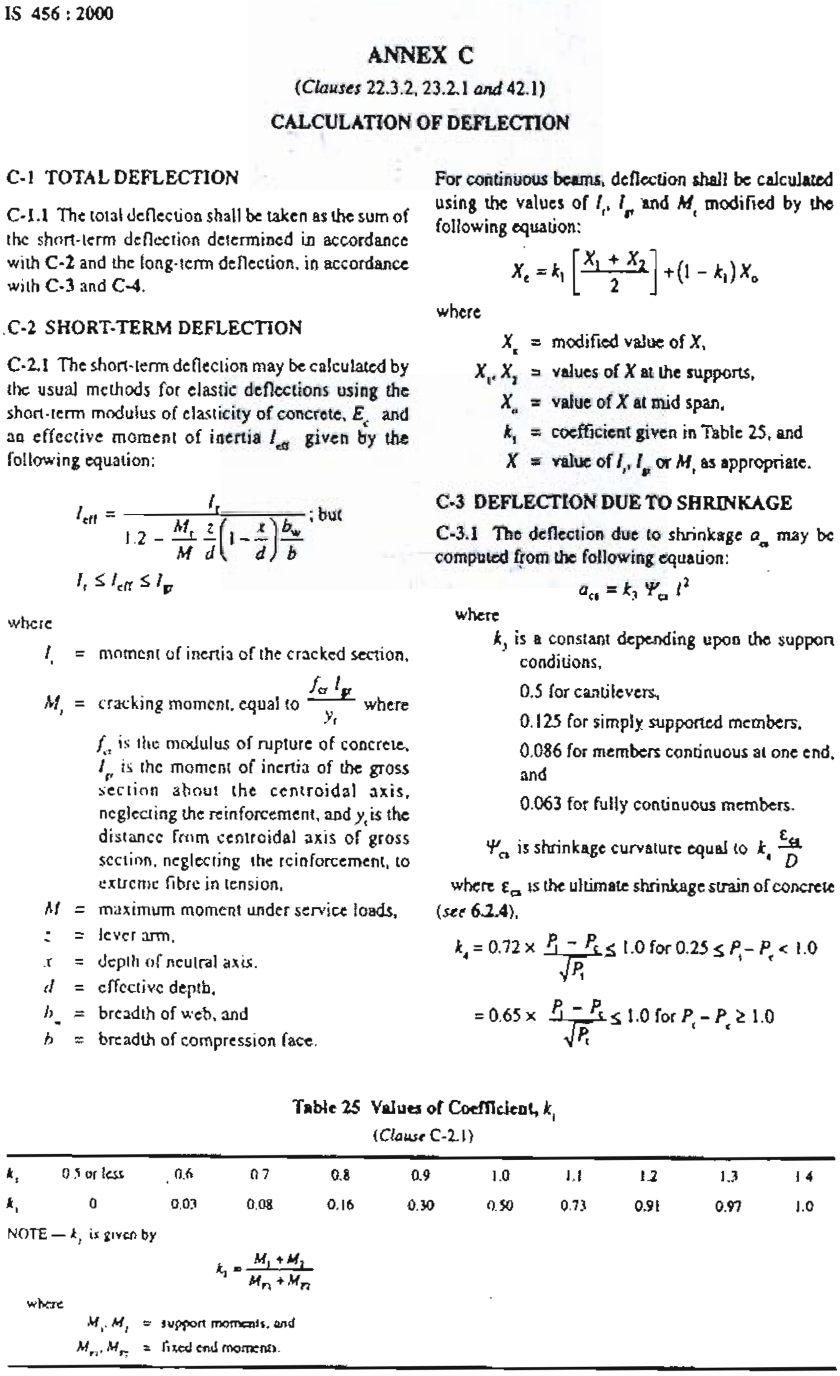
↳ provide 8 mmϕ ties

$$S = \begin{cases} 16\phi_{main} = 448 \\ LLD = 400 \\ 300 \end{cases} = 300mm$$

min^m

Provide 8 mmϕ lateral tie with 300mm c/c spacing.

Q.3 (b) A simply supported reinforced concrete T-beam is required to span 6 m. The beam has a effective flange width of 1500 mm, a flange thickness of 150 mm, and a web width of 600 mm. The overall depth of the section is 600 mm with an effective depth of 550 mm. The beam is reinforced with 4 bars of 25 mm diameter in the tension zone. No compression reinforcement is provided. The materials used are M25 grade concrete and Fe500 grade steel. The beam is subjected to a total sustained (Including self weight) service load of 40 kN/m. The total long-term deflection, accounting for Immediate short-term deflection and additional deflection due to creep using a creep coefficient of 1.6. Ignore deflection due to shrinkage. Finally, verify if the total deflection is within the permissible limit of Span/250 keep the. Over there the given total service load includes the self weight. Take elastic modulus of steel $E_s = 200$ GPa.



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ANNEX C

(Clauses 22.3.2, 23.2.1 *and* 42.1)

CALCULATION OF DEFLECTION

C-1 TOTAL DEFLECTION

C-1.1 The total deflection shall be taken as the sum of the short-term deflection determined in accordance with C-2 and the long-term deflection, in accordance with C-3 and C-4.

C-2 SHORT-TERM DEFLECTION

C-2.1 The short-term deflection may be calculated by the usual methods for elastic deflections using the short-term modulus of elasticity of concrete, E_c and an effective moment of inertia I_{eff} given by the following equation:

$$I_{eff} = \frac{I_r}{1.2 - \frac{M_r}{M}\frac{z}{d}\left(1 - \frac{x}{d}\right)\frac{b_w}{b}}; \text{ but}$$

$$I_r \le I_{eff} \le I_{gr}$$

where

I_r = moment of inertia of the cracked section,

M_r = cracking moment, equal to $\frac{f_{cr} I_{gr}}{y_t}$ where f_{cr} is the modulus of rupture of concrete, I_{gr} is the moment of inertia of the gross section about the centroidal axis, neglecting the reinforcement, and y_t is the distance from centroidal axis of gross section, neglecting the reinforcement, to extreme fibre in tension,

M = maximum moment under service loads,

z = lever arm,

x = depth of neutral axis,

d = effective depth,

b_w = breadth of web, and

b = breadth of compression face.

For continuous beams, deflection shall be calculated using the values of I_r, I_{gr} and M_r modified by the following equation:

$$X_e = k_1\left[\frac{X_1 + X_2}{2}\right] + (1 - k_1)X_o$$

where

X_e = modified value of X,

X_1, X_2 = values of X at the supports,

X_o = value of X at mid span,

k_1 = coefficient given in Table 25, and

X = value of I_r, I_{gr} or M_r as appropriate.

C-3 DEFLECTION DUE TO SHRINKAGE

C-3.1 The deflection due to shrinkage a_{cs} may be computed from the following equation:

$$a_{cs} = k_3 \psi_{cs} l^2$$

where

k_3 is a constant depending upon the support conditions,

0.5 for cantilevers,

0.125 for simply supported members,

0.086 for members continuous at one end, and

0.063 for fully continuous members.

ψ_{cs} is shrinkage curvature equal to $k_4 \frac{\varepsilon_{cs}}{D}$

where ε_{cs} is the ultimate shrinkage strain of concrete (*see* 6.2.4).

$$k_4 = 0.72 \times \frac{P_t - P_c}{\sqrt{P_t}} \le 1.0 \text{ for } 0.25 \le P_t - P_c < 1.0$$

$$= 0.65 \times \frac{P_t - P_c}{\sqrt{P_t}} \le 1.0 \text{ for } P_t - P_c \ge 1.0$$

Table 25 Values of Coefficient, k_1

(*Clause* C-2.1)

k_2	0.5 or less	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4
k_1	0	0.03	0.08	0.16	0.30	0.50	0.73	0.91	0.97	1.0

NOTE — k_2 is given by

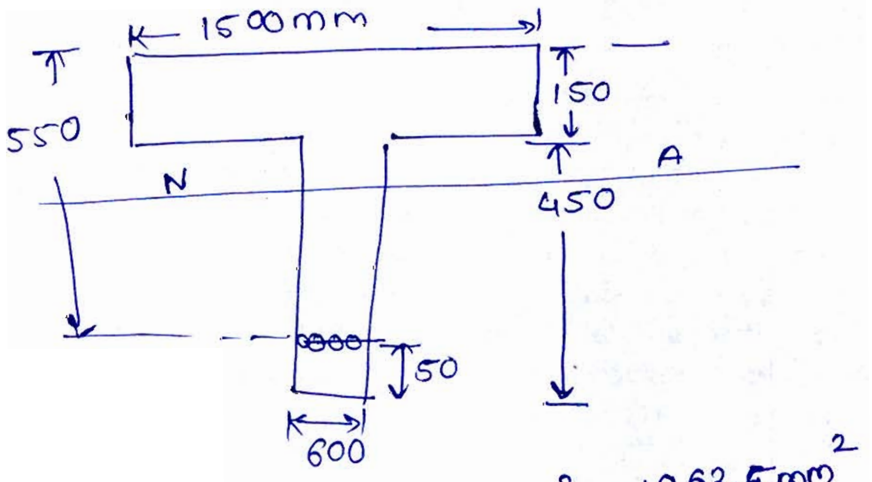
$$k_2 = \frac{M_1 + M_2}{M_{F1} + M_{F2}}$$

where

M_1, M_2 = support moments, and

M_{F1}, M_{F2} = fixed end moments.

[20 marks]



$A_{st} = 4 \times \frac{\pi}{4} \times 25^2 = 1963.5 \, mm^2$

M25/Fe 500

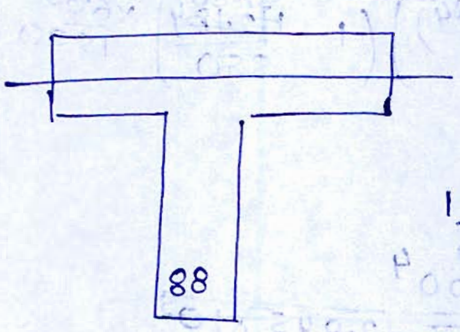
$\omega = 40\ kN/m$

$m = \frac{\cancel{280}}{\cancel{3\sigma_{cbc}}} \frac{E_s}{5000\sqrt{f_{ck}}}$; $\sigma_{cbc} = 8.5$

$= \cancel{10.98}\ 8$

$M_a = \frac{w l_e^2}{8} = \frac{40 \times 6^2}{8} = \overline{\underline{180\ kNm}}$

Icracked



Let, NA is within the flange

$$\frac{B \times x_a^2}{2} = m A_{st} (d - x_a)$$

$$\frac{1500 \times x_a^2}{2} = \cancel{10.98}\ 8 \times 1963.5 \times (550 - x_a)$$

$$x_a = \cancel{112.184}\ 97.3652 < 150\ mm.$$

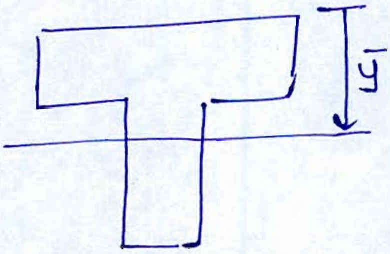
$$\therefore I_{cracked} = \frac{B \times x_a^3}{3} + m \left[n \times \frac{\pi}{64} \times \phi^4 + A_{st}(d - x_a)^2 \right]$$

$$= \frac{1500 \times 112.184^3}{3} + \cancel{10.98}\ 8 \left[4 \times \frac{\pi}{64} \times 25^4 + 1963.5(550 - 112.184)^2 \right]$$

$$= \cancel{4.8393}\ 3.6803 \times 10^9\ mm^4.$$

$$M_{cr} = \cancel{7 \times I_g}\ \frac{0.7\sqrt{f_{ck}} \times I}{y} \quad \{no\ steel)$$

13



$$\bar{y} = \frac{1500 \times 150 \times 75 + 600 \times 450 \times \left(150 + \frac{450}{2}\right)}{1500 \times 150 + 600 \times 450}$$

$$\bar{y} = 238.636\ mm$$

$$I = \frac{1500 \times 150^3}{12} + 1500 \times 150 \times (238.636 - 75)^2.$$

$$+ \frac{600 \times 450^3}{12} + 600 \times 450 \left(\left(150 + \frac{450}{2}\right) - 238.636 \right)^2$$

$$= 1.6023 \times 10^{10}$$

$$M_{cr} = \frac{0.7\sqrt{25} \times 1.6023 \times 10^{10}}{(600 - 238.636)}$$

$$M_{cr} = 155.196\ kNm.$$

$$I_{eff} = \frac{I_{crac}}{1.2 - \frac{M_{cr}}{M} \times \frac{zA}{d}\left(1 - \frac{x_a}{d}\right) \times \frac{b_w}{b}}$$

$$= \frac{\overset{3.6803}{\cancel{4.833}3} \times 10^{9}}{1.2 - \frac{155.196}{180} \times \left(\frac{550 - \frac{\overset{97.36}{\cancel{112.184}}}{3}}{550}\right)\left(1 - \frac{\overset{97.36}{\cancel{112.184}}}{550}\right) \times \frac{600}{1500}}$$

$$I_{eff} = \underset{3.945}{\cancel{3.1256}} \times 10^{9}\ mm^4$$

$$\therefore \delta = \frac{5}{384}\frac{w l_{eff}^4}{EI} = \frac{5}{384} \times \frac{40 \times 6000^4}{5000\sqrt{25} \times 3.945 \times 10^{9}}$$

$$\delta = 6.844\ mm$$

& δ due to creep $= \theta \times \delta = 1.6 \times 6.8444$

$$= 10.95\ mm$$

$$\delta_{total} = 17.795\ mm$$

Check,

$$(\delta)_{perm} = \frac{span}{250} = \frac{6000}{250} = 24\ mm$$

$\delta_{total} < \delta_{per}$ (OK)

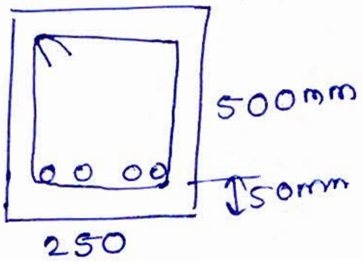
Q.3 (c) (i) A reinforced concrete beam of rectangular cross-section 250 mm × 500 mm has a clear cover to reinforcement of 25 mm. At the support, the tension reinforcement consists of 4 numbers of 20 mm diameter Fe 415 steel bars. The support transfers a factored shear force of 150 KN to the beam. Design the spacing of two-legged 8 mm stirrups. Concrete grade is M20. Use the given τ_c values.

$\frac{100A_{st}}{bd}$	0.75	1.00	1.25
$\tau_c\,(MPa)$	0.56	0.62	0.67

(ii) A rectangular reinforced concrete beam has a width of 300 mm and a total depth of 600 mm. The tension reinforcement consists of 4 bars of 25 mm diameter at an effective depth of 550 mm. The section is composed of M20 grade concrete and Fe415 grade steel. Given the permissible compressive stress in bending σ_{cbc} is 7.0 MPa, determine the maximum stresses developed in the concrete and the steel reinforcement when the section is subjected to an applied bending moment of 45 kNm.

[10 + 10 = 20 marks]

ⓘ



effective cover $= 25 + 8 + \frac{20}{2}$

$= 43 \simeq 50mm$

$d = 450mm.$, M20/Fe415

$V_u = 150KN$

$A_{st} = 4 \times \frac{\pi}{4} \times 20^2 = 1256.63 \, mm^2$

$$\tau_v = \frac{V_u}{bd} = \frac{150 \times 10^3}{250 \times 450} = 1.33 < (2.8 \, MPa = \tau_{cmax})$$

$$\% P_t = \frac{100 \times 1256.63}{250 \times 450} = 1.117$$

τ_c @ 1.117

$$\tau_c = 0.62 + \frac{0.67 - 0.62}{1.25 - 1} \times (1.117 - 1)$$

$= 0.6434$

$$V_S = (\tau_v - \tau_c)bd = (1.33 - 0.6434) \times 250 \times 450 / 10^3$$

$= 77.2425 \, KN$

for 2legged 8mmϕ stirrup

$$S = \frac{0.87 f_y \left(2 \times \frac{\pi}{4} \times 8^2\right) \times 450}{V_S \rightarrow 77.2425 \times 10^3} = 211.457 \simeq 210mm$$

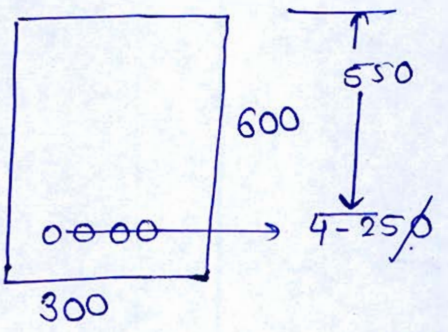
$$S \ngtr \begin{cases} 0.75d = 0.75 \times 450 = 337.5mm \\ 300 \end{cases}$$

$$S_{min} = \frac{0.87\times415\times\left(2\times\frac{\pi}{4}\times8^2\right)}{0.4\times250} = 362.96$$

$\therefore$ provide ~~8L~~ 2L-8ϕ stirrup with spacing of 210 mm c/c.

⑩

(ii)



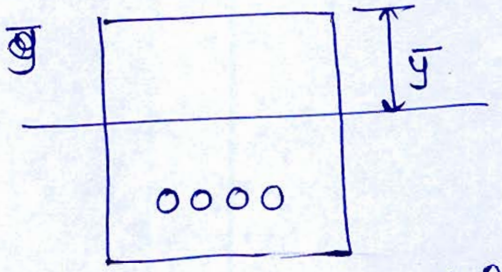
d = 550 mm
M20/Fe415
$\sigma_{cbc} = 7$.
BM = 45 kNm.

$$M_{cracking} = 0.7\times\sqrt{f_{ck}}\times\frac{B\times D^2}{6}$$

$$= 0.7\frac{\sqrt{20}\times300\times600^2}{6} = 56.349 \text{ kNm}$$

BM < Mcracking

$\therefore$ Uncracked section.



$$m = \frac{280}{3\sigma_{cbc}} = \frac{280}{3\times7}$$

$m = 13.33$.

$$A_{st} = 4\times\frac{\pi}{4}\times25^2 = 1963.49 \text{ mm}^2$$

$$\bar{y} = \frac{B\times D\times\frac{D}{2} + (m-1)A_{st}\times d}{BD + (m-1)A_{st}}$$

$$\bar{y} = \frac{300\times600\times300 + (13.33-1)\times1963.49\times550}{300\times600 + 12.33\times1963.49}$$

$\bar{y} = 329.733$ mm

$$I_{uncracked} = \frac{BD^3}{12} + BD\times\left(\bar{y}-\frac{D}{2}\right)^2 + (m-1)\left[n\times\frac{\pi}{64}\times\phi^4 + A_{st}(d-\bar{y})^2\right]$$

$$= \frac{300\times600^3}{12} + 300\times600(329.733-300)^2 + 12.33\left[4\times\frac{\pi}{64}\times25^4 + 1963.49(550-329.733)^2\right]$$

$I_{uncracked} = 6734.676 \times 10^6 \ mm^4.$

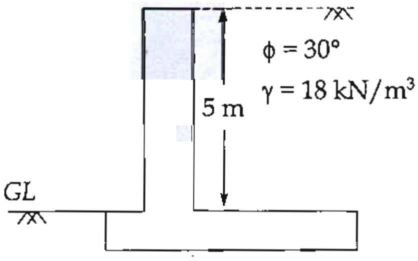
$$\therefore \sigma_{top} = \frac{My}{I} = \frac{45\times10^6 \times 329.733}{6734.676\times10^6} = 2.203 \ N/mm^2 = Ca$$

$$\sigma_{\cancel{Stee}\ \cancel{concrte}\ Steel} = ta = \overset{13.33}{\cancel{m}} \times \frac{45\times10^6 \times (550-329.733)}{6734.676\times10^6}$$

$$ta = \sigma_{steel} = \underline{19.619 \ N/mm^2.}$$

10

Q.4 (a) Design the vertical and horizontal reinforcement for the stem of a cantilever retaining wall to retain a level earth bank. The stem has a constant width and a height of 5.0 m above ground level. Sketch the reinforcement details showing the arrangement of the bars. Take M-25 grade of concrete and Fe 415 grade of steel. Also check in shear. Assume wall is safe is stability.



Unit weight of back fill soil (γ): 18 kN/m^3

Angle of internal friction (ϕ): 30°

Effective depth (d): 450 mm

Clear cover: 50 mm

Main reinforcement: 16 mm diameter bars

Secondary reinforcement: 12 mm diameter bars

(Design Shear Strength of Concrete, τ_c, N/mm^2)

$100\frac{A_{st}}{bd}$	Concrete Grade					
	M 15	M 20	M 25	M 30	M 35	M 40 and above
(1)	(2)	(3)	(4)	(5)	(6)	(7)
≤ 0.15	0.28	0.28	0.29	0.29	0.29	0.30
0.25	0.35	0.36	0.36	0.37	0.37	0.38
0.50	0.46	0.48	0.49	0.50	0.50	0.51
0.75	0.54	0.56	0.57	0.59	0.59	0.60
1.00	0.60	0.62	0.64	0.66	0.67	0.68
1.25	0.64	0.67	0.70	0.71	0.73	0.74
1.50	0.68	0.72	0.74	0.76	0.78	0.79
1.75	0.71	0.75	0.78	0.80	0.82	0.84
2.00	0.71	0.79	0.82	0.84	0.86	0.88
2.25	0.71	0.81	0.85	0.88	0.90	0.92
2.50	0.71	0.82	0.88	0.91	0.93	0.95
2.75	0.71	0.82	0.90	0.94	0.96	0.98
≥ 3.00	0.71	0.82	0.92	0.96	0.99	1.01

[20 marks]

Q.4 (b) Design a square footing for a column load of 1500 kN at service from a 400 mm square column containing 8 bars of 20 mm diameter. The bearing capacity of soil is 120 kN/m^2. Use M25 grade concrete and Fe 415 grade steel, load factor = 1.5. Shear strength of concrete = 0.35 MPa. Design for bending and shear only. Development length check is not required. Show the reinforcement detail. Assume diameter of main bar = 16 mm.

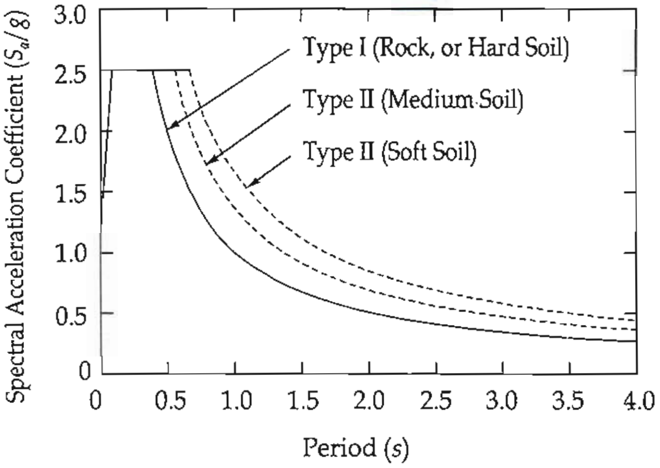
[20 marks]

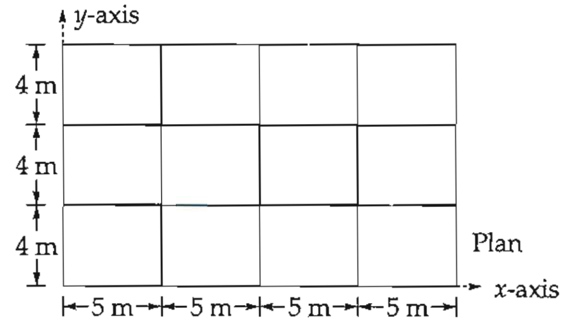
Q.4 (c) A four-storey reinforced concrete (*RC*) office building located in seismic zone VI is shown in the figure. The *RC* frames are infilled with brick masonry. The lumped weights due to dead loads are 12 kN/m^2 on the floors and 10 kN/m^2 on the roof. The floors must cater to a live load of 3 kN/m^2 on the floors and 1.0 kN/m^2 on roof. Calculate the design seismic load on the structure at different storeys using Linear Static (Equivalent Static) analysis, along *y*-axis. Assume the foundation of the office is laid on the fresh rock.

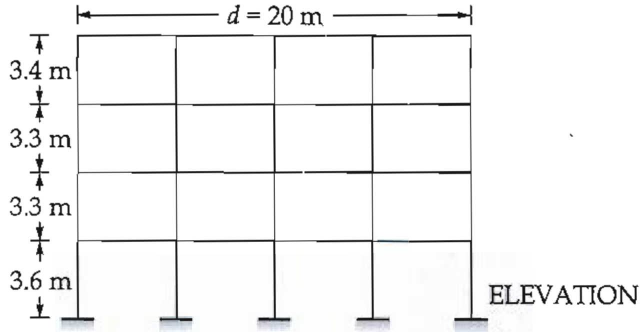
Zone factor $Z = 0.24$

Importance factor $I = 1.2$

Response Reduction Factor $R = 5$







[20 marks]

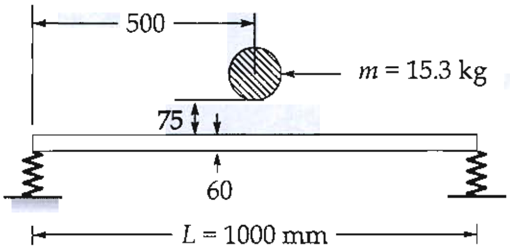
Section B : Strength of Materials-1 + Highway Engineering-2 + Surveying and Geology-2

Q.5 (a) A steel beam of cross-section 60 × 60 mm and span 1000 mm is subjected to impact loading as shown in the figure. A mass of 15.3 kg falls freely from a height of 75 mm above the beam at midspan.

Determine the maximum instantaneous deflection and the maximum bending stress in the beam for the following cases:

1. When the beam is supported on rigid supports
2. When the beam is supported at both ends by springs, each having a stiffness of $k = 200\text{N/mm}$

Take the modulus of elasticity $E = 200$ GPa



[12 marks]

(i) rigid supports

②

$$P_g = P \times I.F$$

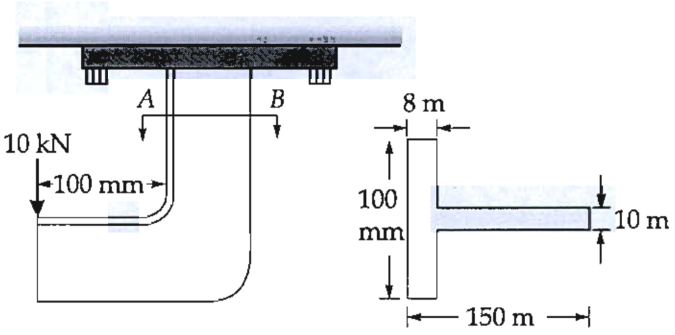
$$= 15.3 \times 9.81\,(N) \times \left[1 + \sqrt{1 + \frac{2h}{\Delta g}}\right]$$

$$P = \underline{150.093\,N}$$

Work done = strain energy stored.

$$P \times (0.075 + \delta) =$$

Q.5 (b) A load of 10 kN acts on a cast iron bracket as shown in figure below. Determine the stresses at extreme fibre of section *AB*.

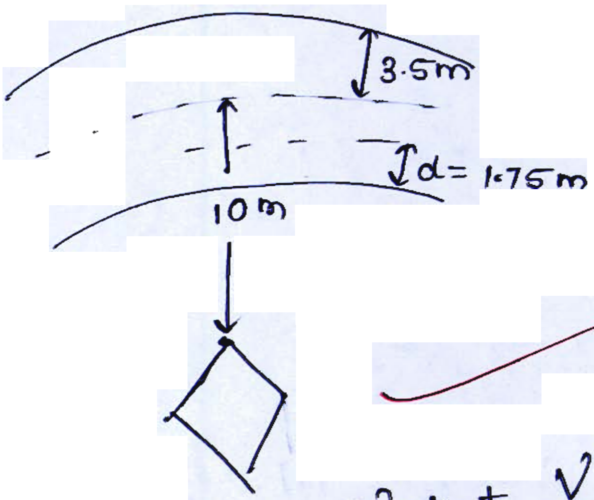


Section at *AB*

[12 marks]

Q.5 (c) The corner of an existing building is 10 m from centre line on a curved portion of two-lane highway. Considering the stopping sight distance, what is safe operating speed if the radius of curve measured from centerline of road is 160 m? Lane width is 3.5 m. Assume reaction time of driver as 2.5 sec, longitudinal friction coefficient as 0.40 and length of curve is greater than stopping sight distance.

[12 marks]



$R = 160 m$

$d = \frac{3.5}{2} m = 1.75 m$

$t = 2.5$

$f = 0.4.$

(i) $SSD = 0.278 \times V \times t_r + \frac{V^2}{254 \times f}$ — ①

$= ~~0.278\times~~$

(2) for $\underline{L > SSD}$

$m = R - (R-d)\cos\frac{\alpha}{2}$

$10 = 160 - (160 - 1.75)\cos\frac{\alpha}{2}$

⑫

$\left\{ \frac{\alpha}{2} = \frac{180 S}{2\pi(R-d)} \right.$

$\frac{\alpha}{2} = 18.58^\circ = \frac{180 \times S}{2\pi(R-d)}$

$(~~R-d~~) =$ $S = 102.64 m.$

∴ from eqⁿ ①

$$S = 102.64 = V \times 0.278 \times 2.5 + \frac{V^2}{254 \times 0.4}$$

$$V_{kmph} = 72.747 \text{ kmph}$$

Q.5 (d) A new 4-lane divided highway is planned for a high-traffic corridor. A commercial vehicle survey conducted this year indicates an Average Daily Traffic (ADT) of 2,500 commercial vehicles per day (CVPD) in both directions combined. The construction of the pavement is expected to take 2 years, during which the traffic is projected to grow at a rate of 7.5% per annum. The highway is designed for a service life of 15 years post-construction. Due to shifting economic conditions, the traffic growth rate is expected to remain at 7.5% per annum for the first 10 years of operation, then increase to 9% per annum for the final 5 years. An axle load survey reveals a mixed vehicle composition: 40% of the commercial vehicles have a Vehicle Damage Factor (VDF) of 3.5, while the remaining 60% have a VDF of 5.5. For the design of each carriageway, use a Lane Distribution Factor (LDF) of 0.75. Calculate the total design traffic in Million Standard Axles (msa). Assume any other detail as per latest IRC code.

[12 marks]

$$\rightarrow \text{msa} = \frac{365((1+r)^n-1)}{r \times 10^6} \times A \times D \times F \times LSF$$

$D = 0.75$, A → CVPD after the constructⁿ

$$= \frac{365 * D * LSF}{10^6}\left[A \times F(1+r)^n - 1\right]$$

5

~~A=~~ For 1st 10 years

$$AF = A_1F_1 + A_2F_2$$

$$= 0.4 \times 2500\left(1 + \frac{7.5}{100}\right)^2 + 0.6 \times 2500\left(1+\frac{7.5}{100}\right)^2$$

$$= 1155.625 + 1733.4375$$

$$= 2889.062$$

{D = 0.75}

∴ msa for n = 10 years

$$= \frac{365\left[1+\left(\frac{7.5}{100}\right)^{10}-1\right]}{\left(\frac{7.5}{100}\right) \times 10^6} \times [2889.062] \times 0.75$$

{LSF = 1.

$$= 11.188 \text{ msa}$$

for n = 10 to n = 15 years → n = 5

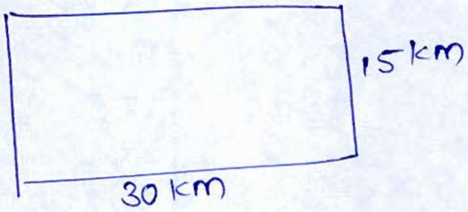
$$\text{msa} = \frac{365\left[\left(1+\frac{9}{100}\right)^5-1\right]}{\left(\frac{9}{100}\right) \times 10^6}\left[2889.062 \times 0.75 \times (1+0.075)^{10}\right]$$

$= ~~4.733~~$ 9.755 msa

∴ $(\text{Msa})_{\text{total}}$ = 20.943 msa.

Q.5 (e) An aerial survey is to be conducted over a rectangular area of 30 km × 15 km. The scale of the photographs is 1: 15,000, and the size of each photograph is 23 cm × 23 cm. The flight is planned with a longitudinal overlap of 60% and a side overlap of 30%. Determine the total number of photographs required to cover the entire area.

[12 marks]



$\frac{1}{15{,}000} = \frac{1}{S}$

(23cm×23cm).

$P_o = 60\%$.

$P_s = 30\%$.

No. of photographs in a row $= \frac{30\times10^3 (m)}{lS(1-P_o)} + 1$

$= \frac{30\times10^3 \times 100\text{ cm}}{23\times15000\times(1-0.6)\text{ cm}} + 1$

$= 21.739 + 1$

$= 22 + 1$

$= 23.$

12

No. of rows $= \frac{B}{dbS(1-P_s)} + 1$

$= \frac{15\times10^5\text{ cm}}{23\times15{,}000(1-0.3)} + 1$

$= 6.211 + 1$

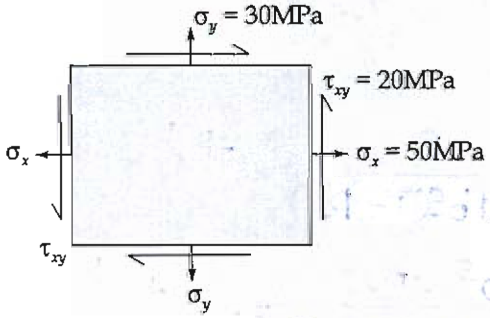
$= 7 + 1$

$= 8.$

∴ Total no. of photographs $= 23\times8$

$= \underline{184}.$

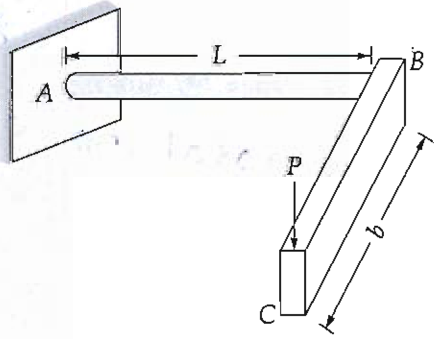
Q.6 (a) (i) At a point in a material, the stresses forming a two-dimensional system are shown below:



Using Mohr's circle of stress, determine the magnitude and direction of the principal stresses. Also, determine the value of maximum shearing stress.

(ii) A circular steel rod *AB* of diameter d_1, length *L* and modulus of rigidity *G*, is loaded as shown is figure. A rigid bar *BC* of length *b* is rigidly fixed to *AB* at *B* such that *BC* is perpendicular to *AB* and lies in the horizontal plane. Find the deflection of point *C* due to

1. Bending of AB
2. Torsion of AB
3. Combined bending and torsion



[10 + 10 = 20 marks]

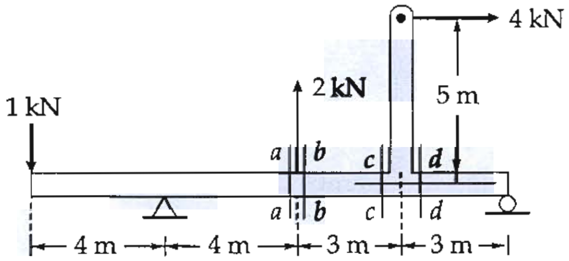
Q.6 (b) **(i)** Two tangents intersect at a chainage of 1250 m. The angle of intersection is 150°. Calculate all the necessary data for setting out a curve of 250 m radius by deflection angle method. The peg intervals may be taken as 20 m.

(ii) Explain the field procedure for setting out curve by the radial offset method.

[14 + 6 = 20 marks]

Q.6 (c) (i) Describe the relationship between traffic speed and density as per Green shield model. What will be the maximum capacity of the flow and when do that occurs? Sketch the relevant curves.

(ii) For the planar structures shown in the figures, find the reactions and determine the axial forces *P*, the shears *V*, and the bending moments *M* caused by the applied loads at sections *a–a*, *b–b*, etc., as specified. Magnitude and sense of calculated quantities should be shown on separate free-body diagrams. When sections such as *a–a* and *b–b* are shown close together, one section is just to the left of a given dimension, and the other is just to the right.



[10 + 10 = 20 marks]

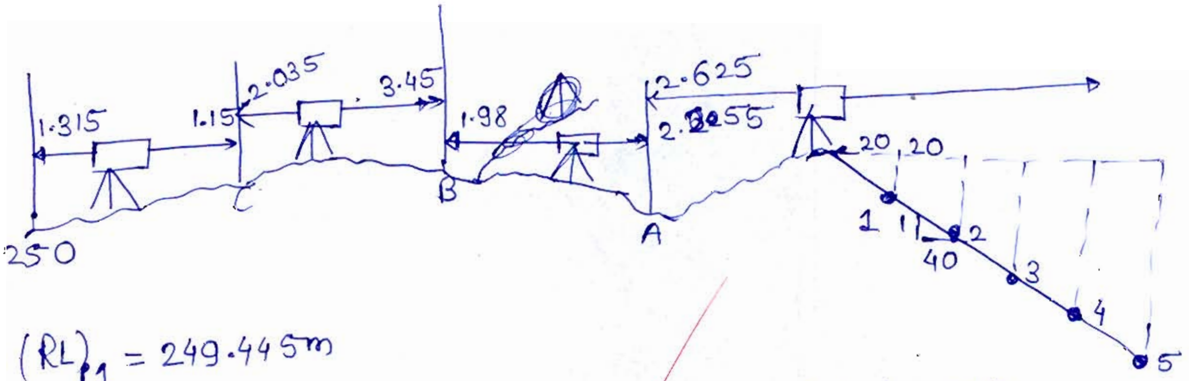
Q.7 (a) **(i)** In running fly levels from a BM of RL 250.00 m, the following readings (in m) were obtained:

B.S.	1.315	2.035	1.980	2.625
F.S.	1.150	3.450	2.255	

From the last position of the instrument, five pegs at 20 m interval are to be set out on a uniform decreasing gradient of 1 in 40. The first peg is to have a RL of 249.445 m. Work out the staff readings for setting the tops of the pegs on the given gradient. Show complete calculations.

(ii) Explain the procedure for the two point problem in plane table surveying.

[12 + 8 = 20 marks]



$(RL)_{P_1} = 249.445 m$

$(RL)_{instrument} = (RL)_{P_1} + 5 \times 20 = 249.445 + \frac{1}{40} \times 20$

$(RL)_{instrument} = 249.945.$

$(RL)_A = (RL)_{inst}$

$(RL)_2 = (RL)_1 - 20\times\frac{1}{40} = 248.945$ m

$(RL)_3 = (RL)_2 - \frac{20}{40} = 248.445$ m

$(RL)_4 = (RL)_3 - \frac{20}{40} = 247.945$ m

$(RL)_5 = (RL)_4 - \frac{20}{40} = 247.445$ m

R.L of Pegs.

12

pt	BS	IS	FS	Height of instrument	R.L	Remark
BM	1.315	–	–	251.315	250	BM
C	2.035	–	1.15	252.2	250.165	C.P
B	1.98	–	3.45	250.73	248.75	C.P
A	2.625	–	2.255	251.1	248.475	C.P.
Peg 1		1.655		251.1	249.445	Peg-1
Peg 2		2.155		251.1	248.945	Peg-2
Peg-3		2.655		251.1	248.445	Peg-3
Peg 4		3.155		251.1	247.945	Peg-4
Peg-5			3.655	251.1	247.445	Peg-5

Q.7 (b) **(i)** A bituminous mix specimen for a highway project was prepared in a laboratory. The constituent proportions and their respective specific gravities are detailed in the table below. The laboratory compacted the specimen to a final weight of 1150g with a measured volume of 490cc. Assuming that the absorption of bitumen into the aggregate is negligible, perform a complete volumetric analysis.

Constituent	**Weight in Mix Batch (*g*)**	**Specific Gravity (*G*)**
Coarse Aggregate	1250	2.66
Fine Aggregate	950	2.58
Mineral Filler	200	2.72
Bitumen	120	1.03

Calculate the following parameters:

1. Theoretical Maximum Specific Gravity (G_t).
2. Bulk Specific Gravity (G_m) of the compacted specimen.
3. Percent Air Voids (V_v).
4. Percent Volume of Bitumen (V_b).
5. Voids in Mineral Aggregate (*VMA*).
6. Voids Filled with Bitumen (*VFB*).

(ii) Also draw the typical curves of stability value, Flow value, *VMA* and air voids against binder content.

[12 + 8 = 20 marks]

(i) (1) $$G_t = \frac{W_t}{\frac{W_{CA}}{G_{CA}} + \frac{W_{FA}}{G_{FA}} + \frac{W_{MF}}{G_{MF}} + \frac{W_B}{G_B}}$$

$$= \frac{1250 + 950 + 200 + 120}{\frac{1250}{2.66} + \frac{950}{2.58} + \frac{200}{2.72} + \frac{120}{1.03}}$$

$$G_t = 2.45094 \simeq 2.451.$$

(2) $$G_B = \frac{W}{V} = \frac{1150}{490} = 2.3469$$

(3) % air voids $= \frac{G_t - G_m}{G_t} \times 100$

$= \left(\frac{2.451 - 2.347}{2.451}\right) \times 100$

$= 4.243\%$

(4) % Volume of bitumen $= \% \frac{W_b}{W_T} \frac{G_m}{G_b}$

$= \frac{120}{2520} \times \frac{2.347}{1.03} \times 100$

$= 10.8506\%$

(5) voids in minneral aggregate

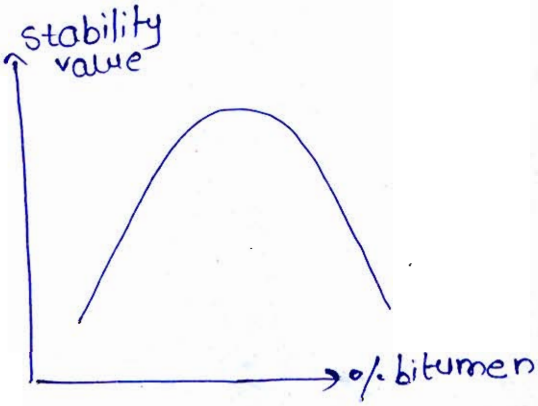
$= V_a + V_b \%$

$= 10.8506 + 4.243$

$= 15.093\%$

(6) $VFB = \frac{V_b}{V_a + V_b} = \frac{10.8506}{15.093} \times 100 = 71.88\%$

(ii)



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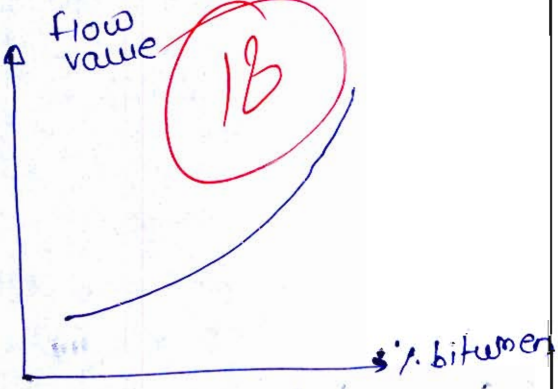
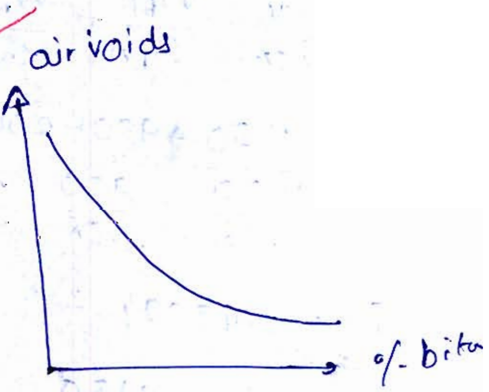
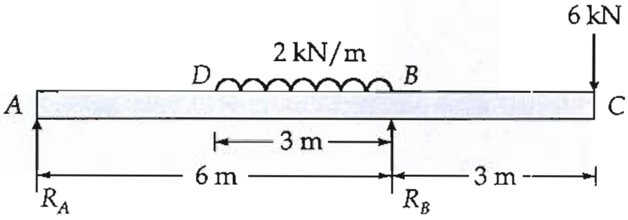
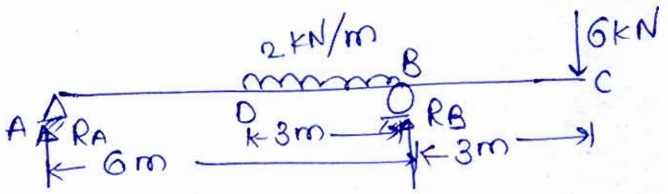




Q.7 (c) A beam *ABC* of length 9 m has one support at the left end and the other support at a distance of 6 m from the left end. The beam carries a point load of 6 KN at the right end and also carries a uniformly distributed load of 2 kN/m over a length of 3 m as shown in Figure. Determine the slope and deflection at point C and D.
Use Macaulay's method.
Take $E = 2 \times 10^5$ N/mm^2 and $I = 5 \times 10^8$ mm^4.



[20 marks]

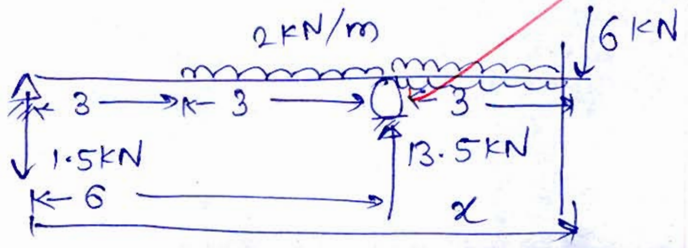


$R_A + R_B = 2\times3 + 6 = 12$ kN

$M_A = 0 \rightarrow \quad 6\times9 + 2\times3\times(3+3/2) = R_B\times6$

$R_B = 13.5$ kN

$\therefore \quad R_A = -1.5$ kN



$$M_x = -1.5\times x - 2\times\frac{(x-3)\times(x-3)}{2} + 13.5(x-6) + \frac{2\times(x-6)^2}{2}$$

$$-1.5x - (x-3)^2 + 13.5(x-6) + (x-6)^2$$

$$\frac{M_x}{EI} = \frac{d^2y}{dx^2} = \frac{-1.5x - (x-3)^2 + 13.5(x-6) + (x-6)^2}{EI}$$

$$\frac{dy}{dx} = \frac{-1.5x^2/2 - \frac{(x-3)^3}{3} + \frac{13.5}{2}(x-6)^2 + \frac{(x-6)^3}{3} + C_1}{EI}$$

$$EI\times y = -\frac{1.5x^3}{6} - \frac{(x-3)^4}{12} + \frac{13.5}{6}(x-6)^3 + \frac{(x-6)^4}{12} + C_1x + \overset{0}{\cancel{C_2}}$$

20

at $x = 0 \rightarrow y = 0$

$\therefore\ C_2 = 0$

at $x = 6m \rightarrow y = 0$

$$0 = -\frac{1.5}{6}\times 6^3 - \frac{(6-3)^4}{12} + 0 + C_1\times 6$$

$C_1 = \cancel{80.78}\ 10.125$

$$EIy = \left(\frac{-1.5x^3}{6}\right) - \frac{(x-3)^4}{12} + \frac{13.5}{6}(x-6)^3 + \frac{(x-6)^4}{12} + 10.125\times x$$

$$EI\frac{dy}{dx} = \left(\frac{-1.5x^2}{2}\right) - \frac{(x-3)^3}{3} + \frac{13.5}{2}(x-6)^2 + \frac{(x-6)^3}{3} + 10.125$$

$\theta_C, \delta_C \Rightarrow \rightarrow x = 9m$

$$\delta_C = \frac{-131.625}{EI}$$

$$\theta_C = \frac{-52.875}{EI}$$ ↳ clockwise

$\theta_D, \delta_D \rightarrow x = 3m.$

$$\delta_D = \frac{\cancel{6.75}\ 23.625}{EI}, \quad EI = 2\times10^5\times\frac{5\times10^8}{10^3}\ kNmm^2$$

$$EI = 10^{11}\ kNmm^2 = 10^5\ kNm^2$$

$$\theta_D = \frac{3.375}{EI} \rightarrow \text{anticlockwise}$$

$\therefore\ \theta_C = -5.2875\times10^{-4}$ (↻)

$\theta_D = 3.375\times10^{-5}$ anti(clock) (↺)

$\delta_C = -1.3162$ mm (↓).

$\delta_D = 0.23625$ mm (↑)

Q.8 (a) **(i)** A pair of overlapping vertical aerial photographs were taken with a camera having a focal length (*f*) of 150 mm. The flying height (*h*) was 2,500 m above sea level, and the air base (*B*) was 900 m. The photo coordinates (in mm) measured for two points, *A* and *B*, on the left (*L*) and right (*R*) photographs are given below. The *x*-axis is parallel to the flight line.

Point	x_L (mm)	y_L (mm)	x_R (mm)
A	45.20	52.60	–38.40
B	22.50	–40.10	–52.30

Determine:

1. The elevations of points *A* and *B*.
2. The horizontal ground distance between *A* and *B*.
3. The gradient (percentage slope) of the line connecting *A* and *B*.

(ii) State the difference between map and photo.

[15 + 5 = 20 marks]

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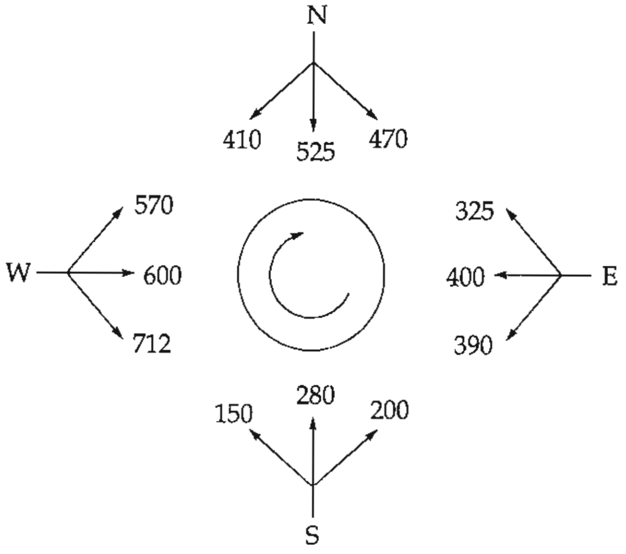
Q.8 (b) The width of a carriage way approaching an intersection is given as 16 m. The entry and exit width at the rotary is 10 m. The traffic approaching the intersection from the four sides is shown below. Calculate the capacity of rotary using the given data. (Assume suitable assumptions as per IRC guidelines)



[20 marks]

Q.8 (c) Two rectangular plates, one made of steel and the other of aluminium, each of size 50 mm wide and 12 mm deep, are placed together to form a composite beam of total depth 24 mm and width 50 mm. The beam is simply supported over a span of 1.2 m, with the aluminium plate placed on top of the steel plate. Determine the maximum central load that can be applied if:

(i) The two plates are not connected and hence bend independently.

(ii) The two plates are firmly secured throughout their length and act as a composite beam.

Maximum allowable stress in steel = 120 N/mm^2

Maximum allowable stress in aluminium = 80 N/mm^2

Modulus of elasticity of steel, $E_s = 2 \times 10^5$ N/mm^2

Modulus of elasticity of aluminium, $E_a = 7 \times 10^4$ N/mm^2

[20 marks]

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OOOO

Space for Rough Work

Space for Rough Work

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