MADE EASY

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	**Student's Signature**
Delhi ☑ Bhopal ☐ Jaipur ☐ Pune ☐ Hyderabad ☐	

Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	58
Q.2	41
Q.3	—
Q.4	—
Section-B	
Q.5	44
Q.6	45
Q.7	
Q.8	45
Total Marks Obtained	233

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

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.

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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.(i) Ordinary mild steel has a maximum load capacity or yield capacity as 250N/mm². For prestressing purposes a very high capacity tendom of order say 1500 N/mm². So at such high capacities mild steel will easily crack.

⇒ The capacity of mild steel is already equal to losses that occur in prestress, so it is not at all ~~viab~~ viable to use mild steel.

⇒ The ductility of mild steel is too high. There can be huge deflection of structure and serviceability can be compromised.

(ii) In pre-tensioned beam concrete is casted over stretched wires, so when wire are cut after concrete hardens whole force is transferred to concrete suddenly using bond action over transmission length. Due to this new high force concrete compresses and this leads to very high elastic shortening losses as steel looses its tensile force due to connection with concrete

Whereas in post-tensioned beams after concrete is hardened the wires are stressed. So even if due to shortening wires compress concrete, hydraulic jack instantly covers up that loss by extending the pre-stressed wires a bit more completely eliminating elastic shortening loss.

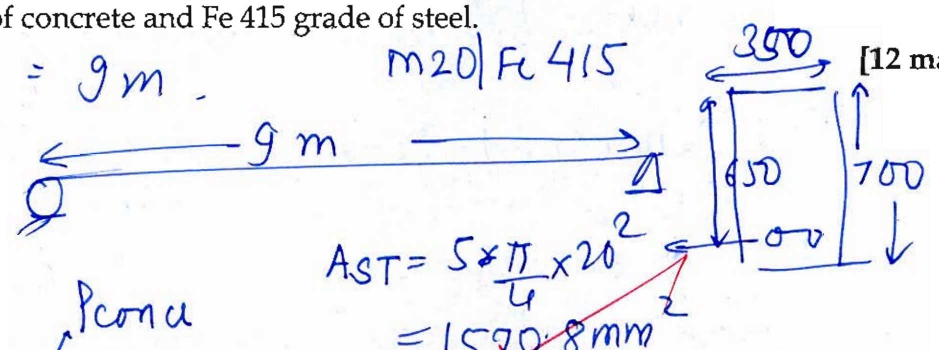
(iii) Parabolic profiles of tendons match the bending moment induced by dead loads. so the cancelling of these two moments is what enables parabolic profiles to cancel the effect of stress loss due to dead load. As dead load ~~releases~~ creates tension in parabolic ~~pat~~ sense as 0 at corners and max at centre same way parabolic wires releases the stress lost due to it. Thus (concordant) profile is formed.

10

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]

* $L_{eff} = 9\,m$.   M20 | Fe 415



$A_{ST} = 5 \times \frac{\pi}{4} \times 20^2$

$= 1570.8\,mm^2$

* $DL = 25 \times 0.35 \times 0.7 = 6.125\ kN/m$

⇒ We find capacity of concrete first we check if section is under or over reinforced.

⇒ $x_{u,bal} = 0.48 \times 650 = 312\,mm$.

⇒ From figure, $x_u = \frac{0.87 \times f_y \times A_{ST}}{0.36\, f_{ck}\, B} = 225.05\,mm$

So we have a UR - beam,

moment of resistance $= 0.87 f_y A_{ST} (d - 0.42 x_u)$

$= 0.87 * 415 * 1570.8 (650 - 0.42 * 225.05)$

factored $= 315.032$ kN-m

$\Rightarrow$ Max^m, B.M due to dead & Live load occurs at midspan as $= \frac{W_u l^2}{8}$

$\Rightarrow \frac{W_u * 9^2}{8} = 315.032$

$W_u = 31.11$ kN/m

$\Rightarrow W_{working} = 20.74$ kN/m

12

$\Rightarrow W_{DL} = 6.125$ kN/m

$\Rightarrow W_{LL} = W_W - W_{DL} = \boxed{14.618 \frac{kN}{m}}$

safe LL beam can carry

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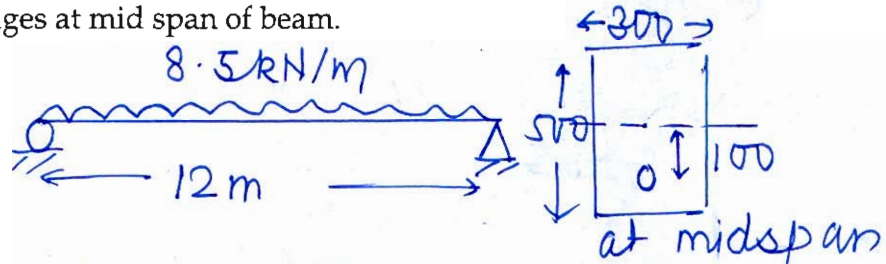
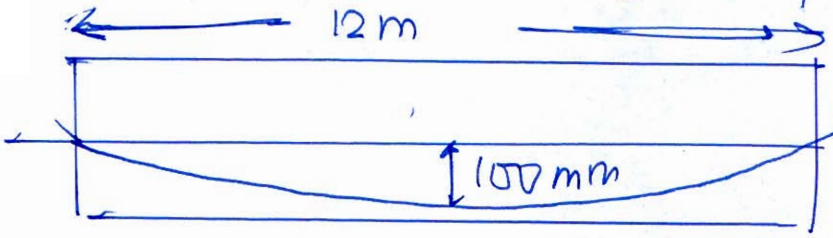
Q.1 (c) A simply supported rectangular prestressed concrete beam has a cross-section of 300 mm × 500 mm. It carries a superimposed service load of 8.5 kN/m over an effective span of 12.0 m. The beam is prestressed by a cable with a parabolic profile, having an eccentricity of 100 mm at the mid-span and zero eccentricity at the supports. The initial prestressing force is 650 kN. Assuming the unit weight of concrete is 24 kN/m^3 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]





$\rightarrow P_0 = 650$ kN

$P_f = (1-0.15)650$

$= \boxed{552.5 \text{ kN}}$ (as 15% loss)

* Dead Load $= 24 \times 0.3 \times 0.5$

$= 3.6$ kN/m.

$\therefore W_T = LL + DL = 12.1 \frac{kN}{m}$

$\Rightarrow$ for parabolic profile we take equivalent load both at transfer & service $\Rightarrow$

Total eccentricity

1) Transfer $= \frac{8Ph}{l^2} = \frac{8 \times 650 \times 0.1}{12^2}$

$= 3.611 \frac{kN}{m}$

2) Service $= \frac{8 \times 552.5 \times 0.1}{12^2}$

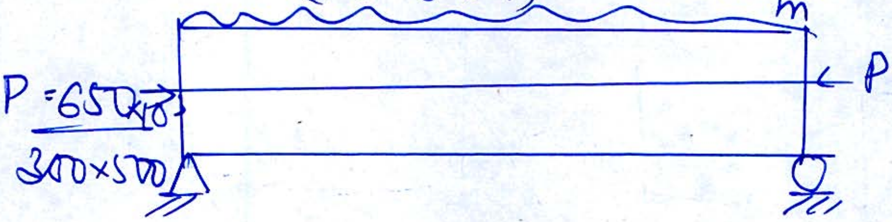
$= 3.069 \frac{kN}{m}$

After ~~these~~ these loads are applied we will assume wire having same eccentricity as at supports, i.e 0.

* Transfer stage: (Only DL acts)

19

$(3.6 - 3.611) = -0.011 \frac{kN}{m}$



⇒ stresses:

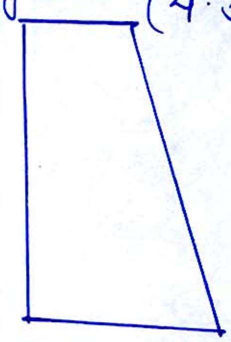
* due to compression $= \frac{650\times10^3}{500\times300} = \underline{4.33 \text{ MPa}}$

* due to bending (at midspan) ⇒ at top (tension) $= \frac{\frac{w_u l^2}{8}}{Z}$

$$= \frac{-\frac{0.011 * 12^2}{8} * 10^6}{\frac{300 * 500^2}{6}} = \boxed{-0.01584}$$

Stress diagram

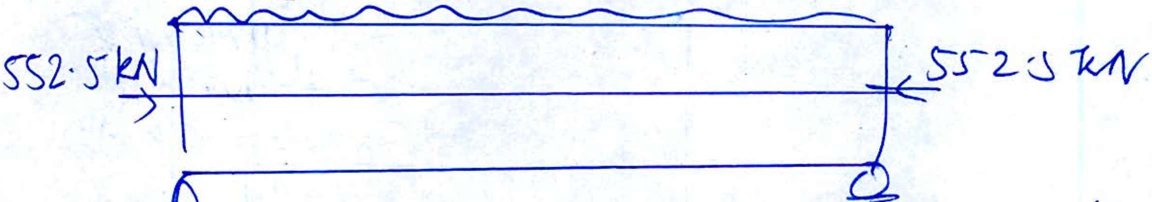
$(4.33 - 0.01584) = 4.31416$



$4.33 + 0.01584 = 4.34584$

At service: (Both DL & LL)

$(12.1 - 3.069) = 9.031$ kN/m

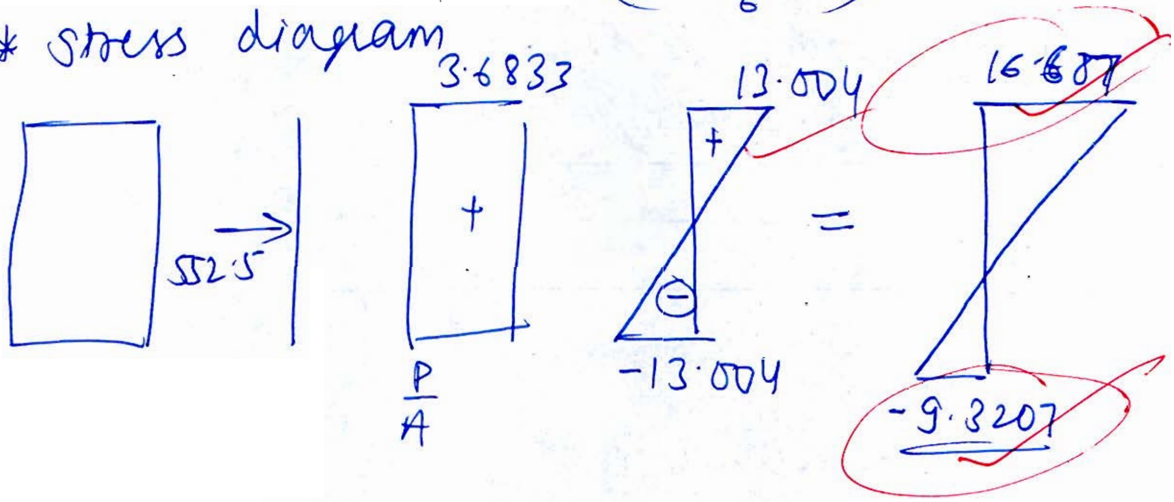


Stresses: 1) Due to compression $= \frac{552.5\times10^3}{300\times500}$ $= 3.6833$ MPa

2) Due to BM of loads applied $= \left(\frac{W_u l^2}{8} / Z\right)$

$\Rightarrow$ & σ_{bottom} (tension) $= \dfrac{\dfrac{9.031 * 12^2 \times 10^6}{8}}{\left(\dfrac{300 \times 500^2}{6}\right)} = 13.004$

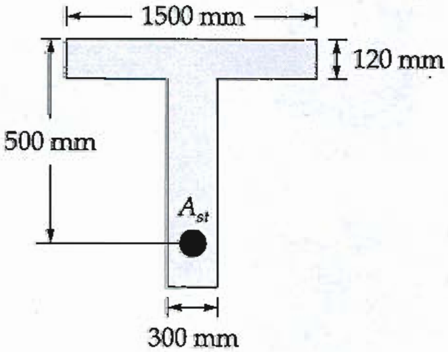
* stress diagram



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

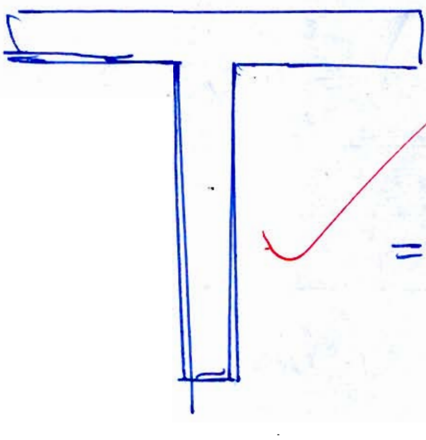
Grade of concrete: M-15

Grade of steel: Fe-415



[12 marks]

$x_{u,bal} = 0.48 * d = 240\,mm$
(for Fe415) $\Rightarrow \frac{3}{7} x_u = 102.857\,mm$



So we have to use ~~$y_f = 0.15 x_u + 0.65 D_f$~~

$\Rightarrow$ Equivalent depth ~~thickness~~ of flange

$=$ ~~$0.15 * 240 + 0.65 * 120$~~

$=$ ~~$\boxed{114\,mm}$~~

$y_f = \cancel{0.65 x_u + 0.15 D_f}$ $0.65 D_f + 0.15 x_u$

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

* SO NOW $MOR = 0.36 f_{ck} B_w x_u (d - 0.42 x_u) + 0.45 f_{ck} (B_f - B_w) y_f (d - 0.5 y_f)$

$= 0.36 * 15 * 300 * 240 * (500 - 0.42 \times 240) + 0.45 * 15 * (1200) * \cancel{174}\ 114\ (500 - 0.5 \times 174)$

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

12

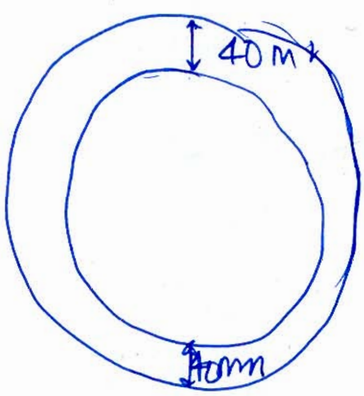
Q.1 (e) A reinforced concrete short column of 480 mm diameter is reinforced with 6 numbers of 20 mm diameter bars of steel of grade Fe 415 and 8 mm diameter helical reinforcement with a pitch of 75 mm. Compute the maximum load-carrying capacity of the column if the concrete used is of grade M25. Assume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

[12 marks]

* Pu (for helical beams) $= 1.05\,(0.4 f_{ck} A_c + 0.67 f_y A_{sc})$ ⇒

⇒ First let's check if pitch is ok otherwise 5% increase won't be applied.

$$\Rightarrow 0.36\,\frac{f_{ck}}{f_y}\left(\frac{A_g}{A_c} - 1\right) \le \frac{V_h}{V_c}$$



$\Rightarrow D_c = 480 - 80$
$= 400$ mm

$\Rightarrow D_h = 400 - 8$ m
$= 392$ mm

* $V_h = \frac{1000}{P} * \pi D_h * \frac{\pi}{4} * \phi_h^2$

$= \frac{1000}{}$

$$\frac{V_h}{V_c} = \frac{\frac{1000}{P} * \pi D_h * \frac{\pi}{4} * 8^2}{1000 * \frac{\pi D_c^2}{4}}$$

$$\frac{V_h}{V_c} = 6.5680 \times 10^{-3}$$

$$\Rightarrow 0.36 \frac{f_{ck}}{f_y}\left(\frac{A_g}{A_c} - 1\right)$$

$$= 0.36 * \frac{25}{415}\left(\frac{\frac{\pi}{4} * 480^2}{\pi \times 400^2} - 1\right)$$

12

$$= 9.5421 \times 10^{-3}$$

As LHS ≥ RHS, so no increase of 5% in capacity, so Load carrying Capacity ⇒ as just short column assuming
- SR < 12
- No extra moment
- min eccentricity < 0.05D (Least Lateral dimension)

$$\Rightarrow P_u = 0.4 * 25 \times \left(\frac{\pi}{4} \times 480^2 - 6 * \frac{\pi}{4} \times 20^2\right) + 0.67 * 415 * \frac{\pi}{4} \times 20^2 \times 6$$

$$= \boxed{2314.82 \text{ kN}}$$

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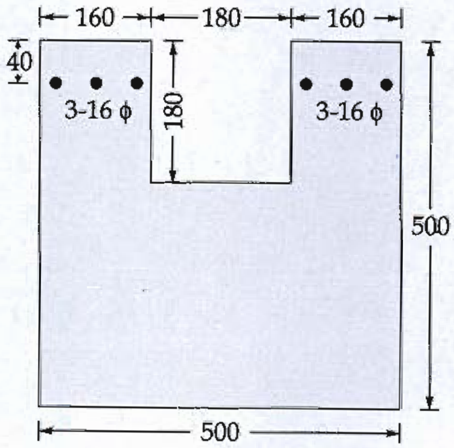
Q.2 (a) (i) A cantilever beam of effective length 2.5 m is constructed using the cross-section shown in the figure. The beam is reinforced with 6 bars of 16 mm diameter placed at an effective cover of 40 mm from the face. Using the Limit State Method, determine the maximum factored uniformly distributed 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:

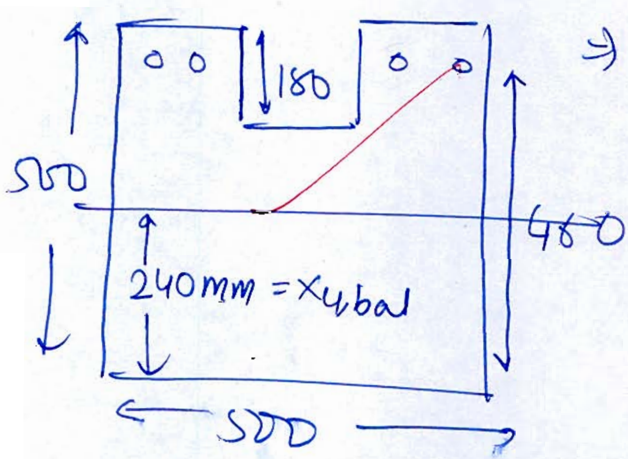
1. Why under-reinforced sections are preferred over over-reinforced sections in flexural members.
2. Why minimum reinforcement is pronded in beams and slabs even when bending moment is very small.
3. Why maximum reinforcement is limited in beams as per codal provisions.
4. Why shear reinforcement is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

[12 + 8 = 20 marks]

M20 | Fe 415

* For beam: $x_{u,bal} = 0.48 * 500$

$= 240$ mm



⇒ So we just ignore the cut out part as we check capacity by x_{u_bal}.

* We check for x_u :- $A_{ST} = 1206.37$.

$$\Rightarrow x_u = \frac{\cancel{0.36 * 20 *}\ 0.87 * 415 * 6 * \frac{\pi}{4} \times 16^2}{0.36 * 20 * 500}$$

$$= 120.988 \approx \boxed{121\,mm}$$

so for this x_u we find beam to be under reinforced & then for MOR:

$$MOR = 0.87 \times 415 \times 1206.37 (460 - 0.42 \times 121)$$

$$= \boxed{178.22\,kN\text{-}m}$$

9

→ So factored load that can be applied $\Rightarrow \frac{W_u l_{eff}^2}{8} = 178.22 \cancel{\times 10^6}$

$\frac{W_u l^2}{2}$

Max^m BM at midspan

$$\Rightarrow \frac{W_u * 2.5^2}{8} = 178.22$$

For simply supported beam.

$\boxed{W_u = 228.121 \frac{kN}{m}}$ ⇒ Max^m factored distributed load

$\boxed{W_{working} = 152.08 \frac{kN}{m}}$

1. Over reinforced sections are based on idea that concrete ~~ce~~ fails first, or there is primary compression failure. This failure is sudden, without warning as there is no strain plateau in concrete or strain yielding capability. Also a chunk of steel strength is wasted as steel doesn't even fully yield. On the other hand in Under-reinforced section there is primary tension failure which means steel fails ~~first~~. Its advantage are:-

⇒ No sudden failure so better design for safety

⇒ Steel is not wasted as complete strength is utilised.

⇒ more economical.

That's why URS are preffered over Over reinforced sections.

2. Minimum reinforcement is provided for following reasons:-

⇒ Even without presence of heavy loads, concrete undergoes shrinkage deflections which induce moments and can cause failure. This could be due to chemical reactions or temperature changes and get more and more intense as size of beam increases. So minimum reinforcement prevent these forces from acting on beam by providing both strength and anchorage to bear the load concrete itself can't. That is why provision of

$\frac{A_{st}}{Bd} \geq \frac{0.85}{f_y}$ & 0.12% (HYSD) & 0.15% (Fe250) of Gross area of slab

are provided without fail

3. Too much reinforcement causes the beam to be overscrowded & prevents concrete from being properly placed.
→ Also proper bond b/w concrete and steel can't be formed along with stuck aggregates.
→ This alarmingly decreases strength of concrete.

6

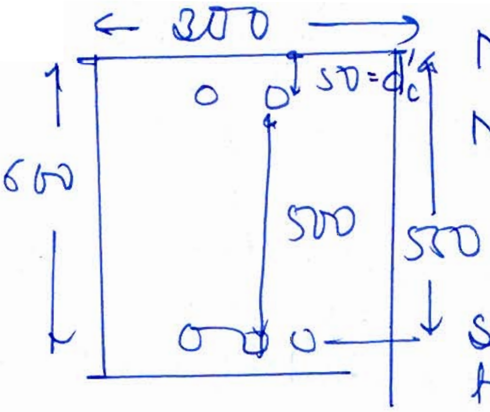
4. Shear reinforcement is provided even when concrete can bear the forces to prevent shear failure due to shrinkage and temperature and creep effects Sometimes concrete's own strength and aggregate interlocking can be overestimated so to be on safe side and to prevent sudden failure we provide ductile steel members

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]



M20 | Fe415

$M = 414$ kN-m

$M_{u,bal} = 0.138 * 20 * 300 \times 550^2$

$= \cancel{250\,kN}$

$= 250.47$ kN-m

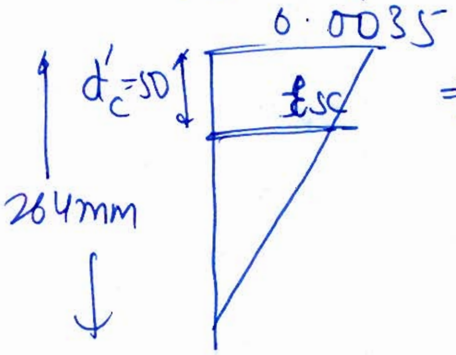
So we provide steel in two ways, first A_{ST_1} for balanced section & A_{ST_2} for extra moment. So

$M_e = 414 - 250.47 = 163.53$ MPa

⇒ So we know Asc (compression steel)

$\Rightarrow f_{sc} * A_{sc} * (d - d_c') = 163.53$ MPa

For fsc we use strain compatibility as our assumed $x_u = 0.48 * 550 = 264$ mm



$\Rightarrow \dfrac{\varepsilon_{sc}}{214} = \dfrac{0.0035}{264}$

$\varepsilon_{sc} = 2.837 \times 10^{-3}$

$f_{sc} \Rightarrow$ interpolating given table

$f_{sc} = 0.975 f_y + \dfrac{(2.837 - 2.76)(0.025 f_y)}{(3.80 - 2.76)}$

$= 0.9768 f_y = 405.39$ MPa

$$A_{sc} = \frac{163.53\times10^6}{405.39 * (550-50)} = 806.778\ mm^2$$

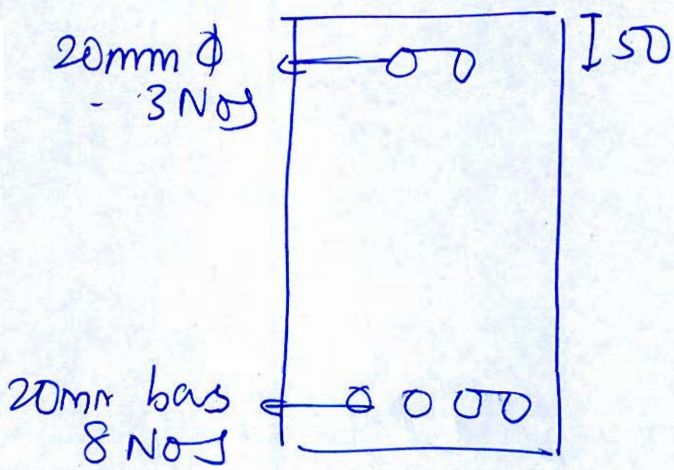
$$A_{ST_2} = \frac{163.53\times10^6}{0.87 * 415(500)} = 905.857\ mm^2$$

$$A_{ST_1} = \frac{250.47\times10^6}{0.87\times415(550-0.42*264)}$$
$$= 1579.811$$

14

$A_{ST_{TOTAL}} = 2485.66\ mm$ → Taking 20mm bars = 8 bars

$A_{sc} = 806.778\ mm$ → Taking 20mm bars = 3 bars

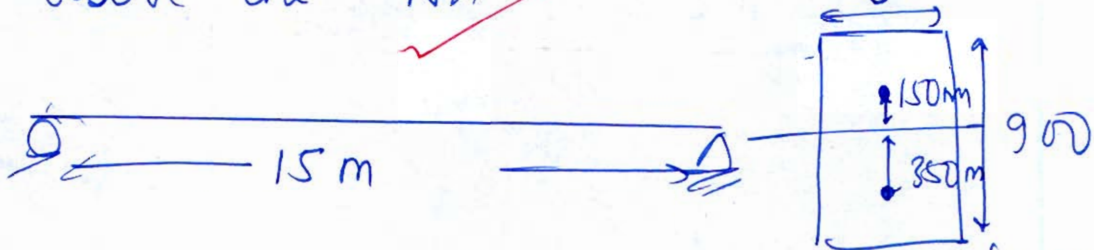


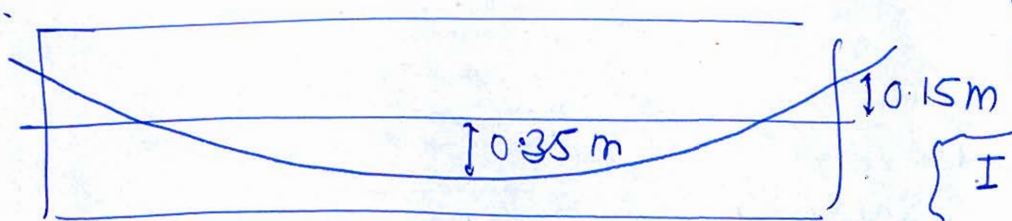
$$\boxed{f_{yd} = 0.87 f_y}$$

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]

⇒ Sol^n: Assuming support eccentricity is above the NA





$E = 36 \frac{kN}{mm^2}$

$I = \frac{450 \times 900^3}{12}$

⇒ $P_0 = 2200$ kN. ⇒ For initial deflection

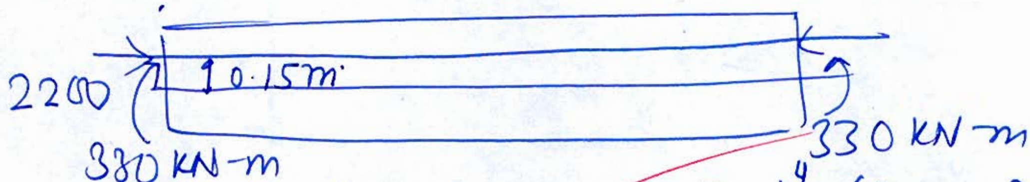
* We assume equivalent load due to ~~concrete~~ parabolic cable $= \frac{8 * 2200 * 0.5}{15^2}$

$= 39.11$ kN/m (↑)

⇒ DL $= 25 * 0.45 \times 0.9 = 10.125$ kN/m (↓)

Total UDL $= 28.985 \frac{kN}{m}$ (↑)

Now wire is like



⇒ Total deflection due to dead load & pre-stressing force $= \frac{5wL^4}{384EI}$ (↑) $- \frac{Ml^2}{8EI}$ (↓)

$$\delta_{DL+PS}(\uparrow) = \frac{5 * 28.985 * 15^4 * 10^9}{384 * 36 * \frac{450 * 900^3}{12}} - \frac{380 * 10^3 * 15^2 \times 10^9}{8 * 36 * \left(\frac{450 \times 900^3}{12}\right)}$$

$$= \boxed{9.98\ mm}$$

⇒ Also for final deflection ⇒

$P_f = 2200\,(1 - 0.15)$

$= 1870\ kN.$

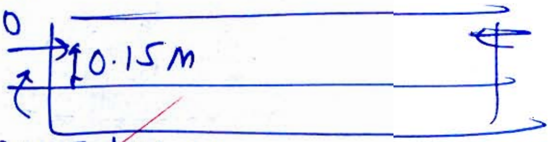
$$W_{eq} = \frac{1870 \times 8 \times 0.5}{15^2} = 33.244\ \frac{kN}{m}$$

12

$$\Rightarrow \text{Load} = (10.125 + 15) - 33.244$$

$$= 8.119\ \frac{kN}{m}\ (\uparrow)$$

⇒ moment by prestress eccentricity = 1870



280.5 kN-m

\# Final deflection :

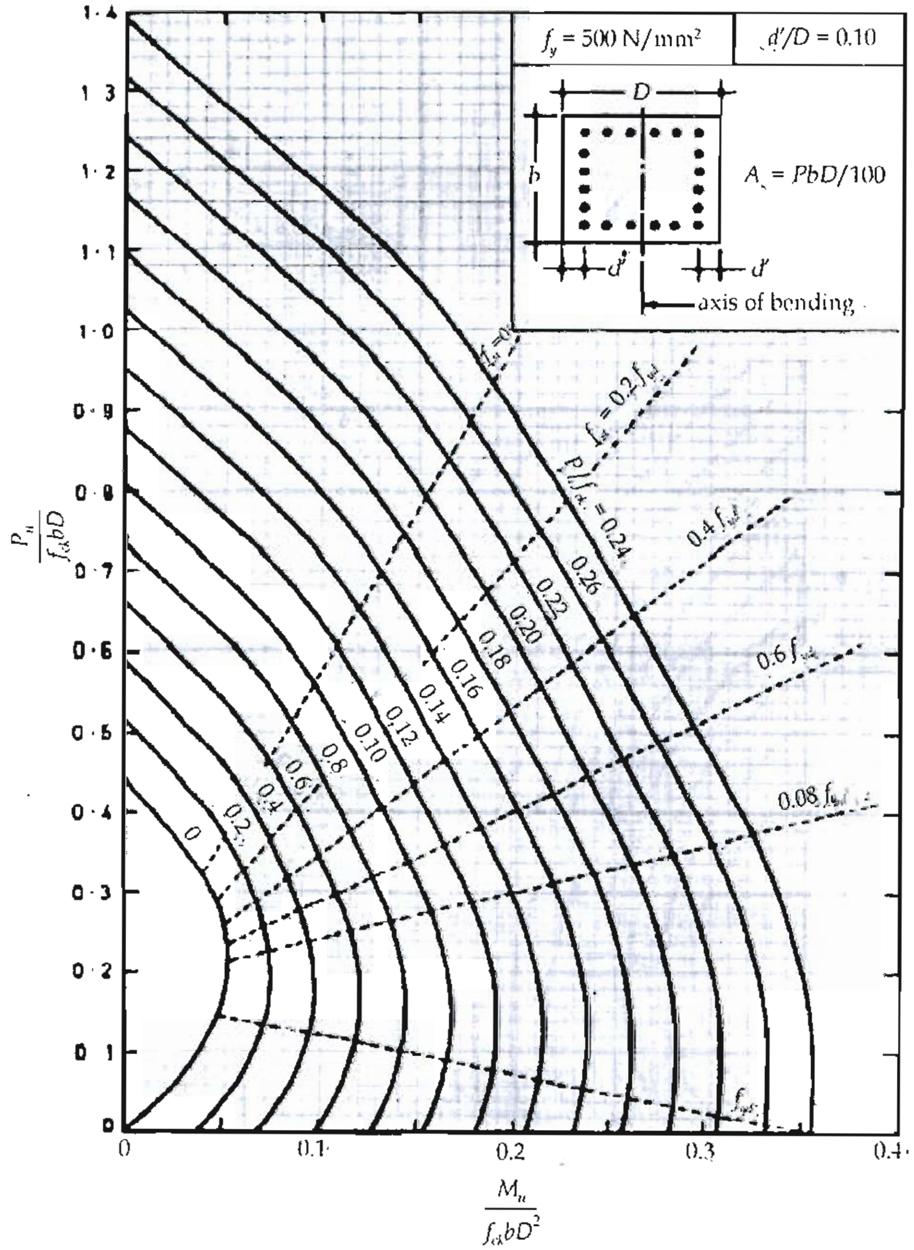
$$\delta(\uparrow) = \frac{5 W_u l^4}{384 EI} - \frac{280.5 * 15^2}{8 E_c I_c}$$

$$= (-2.578\ mm)$$

downward deflection

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]

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.

IS 456 : 2000

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]

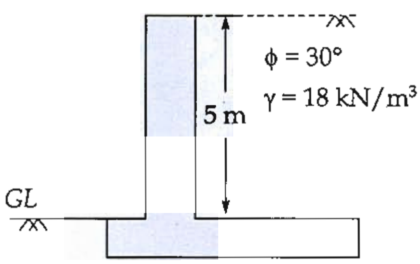
Q.3 (c) (i) A reinforced concrete beam of rectangular cross-section 250 mm × 500 mm has a clear cover to reinforcement of 25 mm. At the support, the tension reinforcement consists of 4 numbers of 20 mm diameter Fe 415 steel bars. The support transfers a factored shear force of 150 KN to the beam. Design 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]

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.

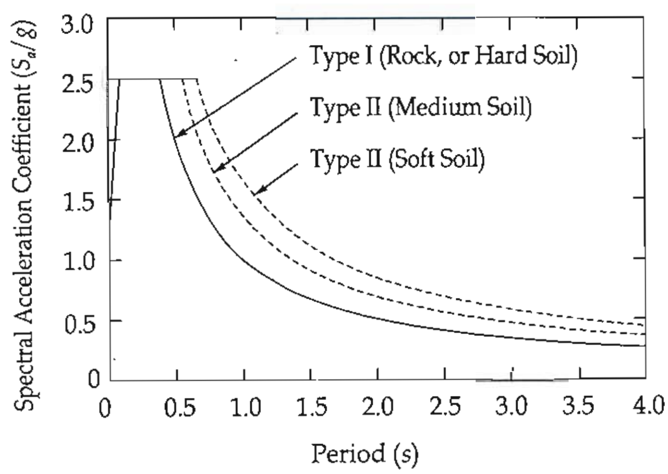
[20 marks]

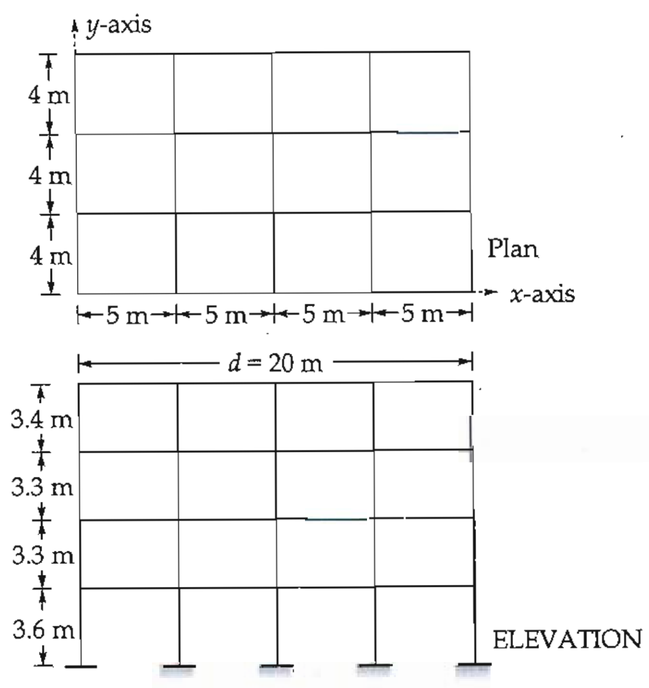
Q.4 (c) A four-storey reinforced concrete (*RC*) office building located in seismic zone VI is shown in the figure. The *RC* frames are infilled with brick masonry. The lumped weights due to dead loads are 12 kN/m^2 on the floors and 10 kN/m^2 on the roof. The floors must cater to a live load of 3 kN/m^2 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]

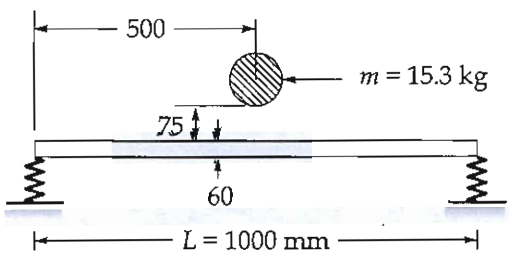
Section B : Strength of Materials-1 + Highway Engineering-2 + Surveying and Geology-2

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

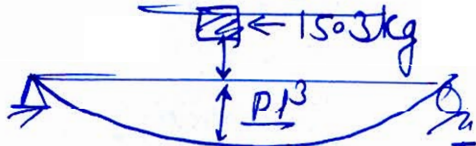


[12 marks]

1. For rigid supports :-

$h = 75\,mm$

$W = 15.3 \times 9.81\ N = 150.913\ N$



$\delta_{\substack{deflection\\static}} = \dfrac{Pl^3}{48EI_c}$ $\qquad I = \dfrac{0.06 * 0.06^3}{12}$

$$= \frac{150.913 * 1^3}{48 * 200 * 10^9 * \frac{0.06 * 0.06^3}{12}}$$

$$= 0.0145\ mm.$$

$$\Rightarrow \delta_{max} = \underbrace{\delta_{static}}_{0.0145\,mm}\left(1 + \sqrt{1 + \frac{2 * 75}{0.0145}}\right)$$

$$= \boxed{1.489\ mm}$$ instantaneous deflection.

$$* \quad \frac{P_{max} l^3}{48EI_c} = 1.489\ mm = 1.489 \times 10^{-3}\ m$$

$$\Rightarrow P_{max} = \frac{1.489 \times 10^{-3} \times 48 \times 200 \times 10^9 * \frac{0.06^4}{12}}{}$$

$$= 15437.952\ N$$

$$= 15.437\ kN$$

BM at centre $= \dfrac{PL}{4} = \dfrac{15.437}{4} = 3.85925\ kN\text{-}m$

max^m Bending stress $= \dfrac{M}{Z} = \boxed{0.10722\ MPa}$

12

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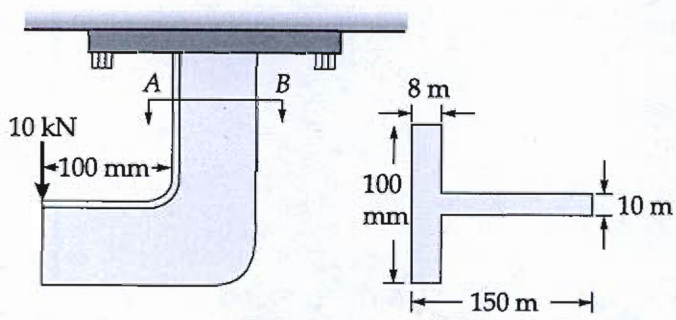
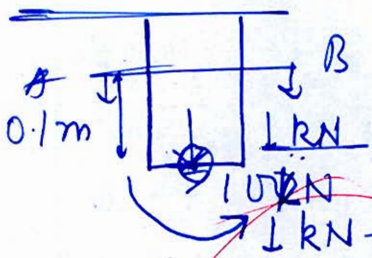
Q.5 (b) A load of 10 kN acts on a cast iron bracket as shown in figure below. Determine the stresses at extreme fibre of section *AB*.

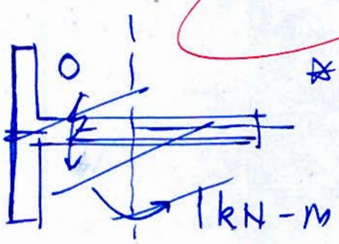


Section at *AB*

[12 marks]

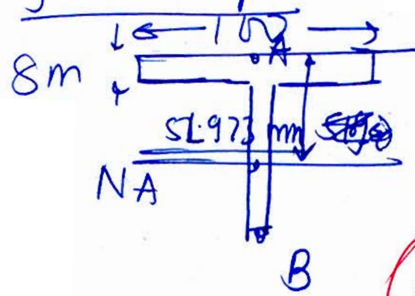


As distance of AB is not given; we assume it ~~to be~~ at 0.1 m from curve of beam



* so forces due to bending & tensile stress.

Bending analysis.



$x_{NA} = \dfrac{100 \times 8 \times 4 + 142 * 10 * \left(8 + \frac{142}{2}\right)}{100 \times 8 + 142 \times 10}$

5

$= 51.973\,mm$

$I_{NA} = \dfrac{100 * 8^3}{12} + 100 * 8 * (51.973 - 4)^2 + \dfrac{142^3 * 10}{12} + 142 * 10 * (51.973 - 79)^2$

$= \underline{5268718.378\ mm^4}$

* Stress due BM:-

(i) at A (tensile) $= \dfrac{10^6}{5268718.378} * (51.973 + 100) = 9.8644\ MPa$

(ii) at B (compressive) $= \dfrac{10^6}{I} * (150 - 51.973) = 18.605\,MPa$

* stress due to tension $= \dfrac{10 \times 10^3}{100 \times 8 + 142 \times 10}$

$= 4.504\,MPa$

=> Stresses at extreme fibres:-

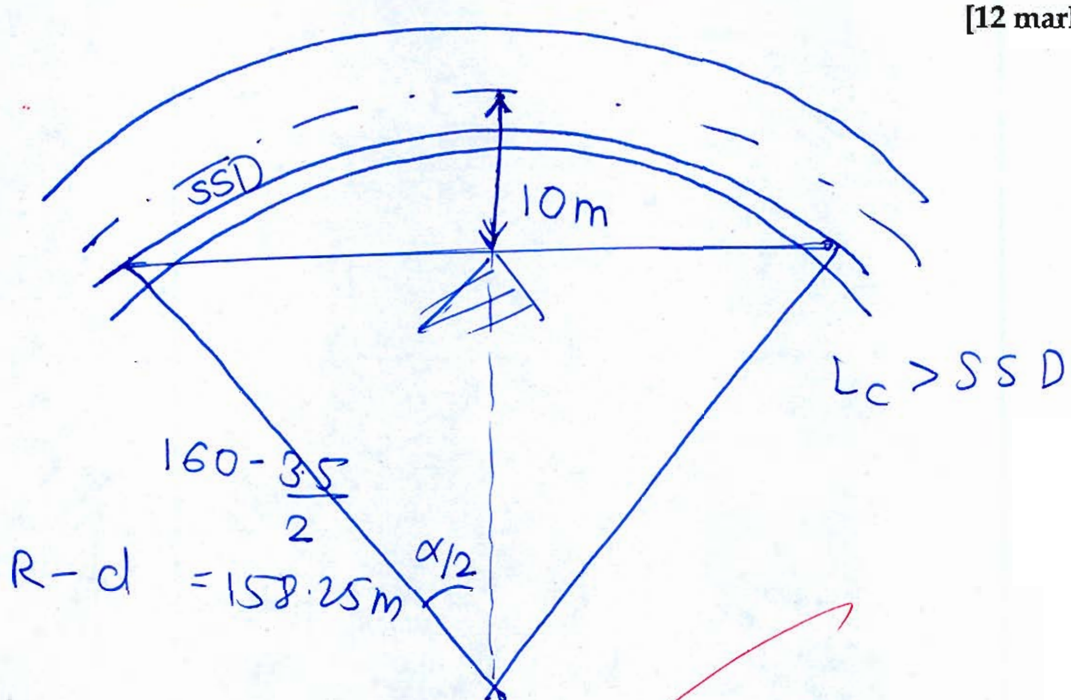
at A $= 9.8644 + 4.504$ (tensile) $= 14.3684\ MPa$

at B $= 18.605 - 4.504$ (compressive)

$= 14.101\ MPa$

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]



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

$\Rightarrow 10 = 160 - 158.25\cos\left(\frac{\alpha}{2}\right)$

$\cos\frac{\alpha}{2} = 0.9478 \Rightarrow \boxed{\frac{\alpha}{2} = 18.594^{\circ}}$

$\Rightarrow (R-d) * \frac{\alpha}{180} * \pi = SSD = \boxed{102.712\ m} = \boxed{SSD}$

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* $102.712 m = 0.278 * V * 2.5 + \frac{V^2}{254(0.4)}$

* Solving for V :

$V = 72.778$ kmph

12

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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]

5(d) Let's find traffic at end of construction considering (ADT = AADT) → Annual Average daily traffic

$\Rightarrow 2500 * (1+0.075)^2 = 2889.0625$ CPVD

* We solve problem in two segments:
(1) For first ten years then next 5 years

$r = 7.5\%$ $r = 9\%$

⇒ First we find VDF combined

$= 0.4 * 3.5 + 0.6 * 5.5$

$= \boxed{4.7}$

* $\boxed{LDF = 0.75}$

* So after 10 years, traffic will be

$\Rightarrow 2889.06 * (1.075)^{10} = 5954.433$

We first add vehicles for ten yrs

$= 2889.06 * \left(\frac{1.075^{10}-1}{0.075}\right) * \cancel{595}$

Then for next ~~4~~5 years

$= 5954.433 \times \left(\frac{\cancel{10}\ 1.09^5 - 1}{0.09}\right)$

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$$\text{Total} = \frac{365 * 4.7 \times 0.75}{10^6}\left(\frac{2889.06(1.075^{10}-1)}{0.075} + \frac{5954.433 \times (1.09^{5}-1)}{0.09}\right)$$

$$= \boxed{98.4362 \text{ msa}}$$

$\downarrow$

Total design traffic.

12

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]

(e) ~~Area~~ Length ~~Scale~~ of photograph in longitudnal dist^n on ground $= \text{Scale} * 23\text{cm}(1-\underbrace{0.6}_{\text{Longitudal overlap factor}})$

$= 15000 * 0.23(1-0.6)\text{m}$

3

⇒ Similarly for width $= 15000 * 0.23\ (1-\underbrace{0.4}_{\text{lateral overlap}})$

Area of one photo $= (S^2 * 0.23^2 (1-0.6)(1-0.4))$

Total area $= 30 \times 15\ \text{km}^2$

$= 450\ \text{km}^2 = 450 \times 10^6\ \text{m}^2$

No. of photos $= \dfrac{\text{Total area}}{\text{Area covered by one photo}}$

$= \dfrac{450 \times 10^6}{15000^2 * 0.23^2 (1-0.6)(1-0.4)}$

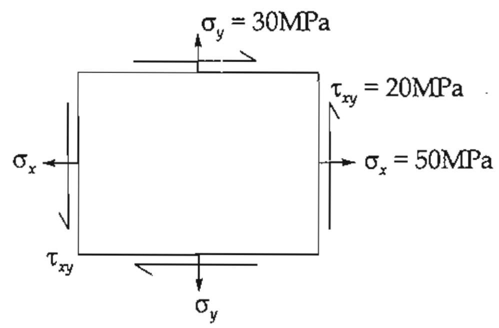
$\simeq 157.53$ photos $\simeq \boxed{158 \text{ photos}}$

when dimensions of area is given.

$n_1 = \left(\dfrac{L_{area}}{L_P} + 1\right), \quad n_2 = \left(\dfrac{W_{area}}{W_P} + 1\right)$

$\boxed{N = n_1 * N_2}$

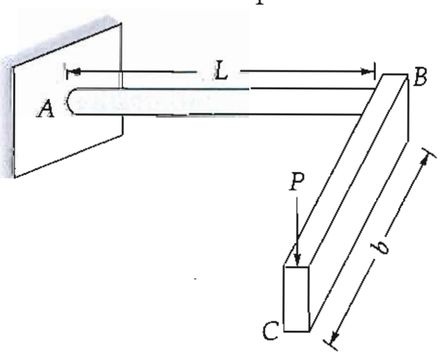
Q.6 (a) (i) At a point in a material, the stresses forming a two-dimensional system are shown below:



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

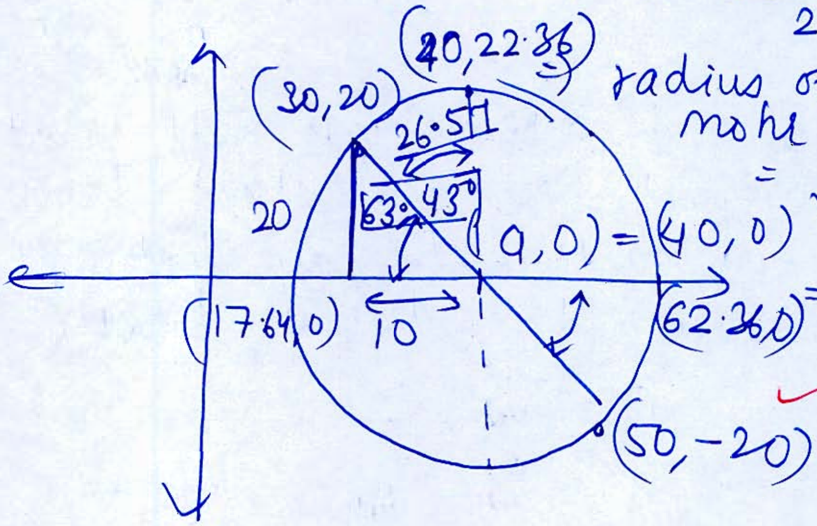
1. Bending of AB
2. Torsion of AB
3. Combined bending and torsion



[10 + 10 = 20 marks]

* We take clockwise rotating shear as +ve.
so points of diametrically opposite ends of mohr circle :-
⇒ points = (50, -20)
= (30, 20)

⇒ $O = \frac{30+50}{2} = 40$



radius of mohr circle $= \sqrt{(50-40)^2 + 20^2} = 22.36$

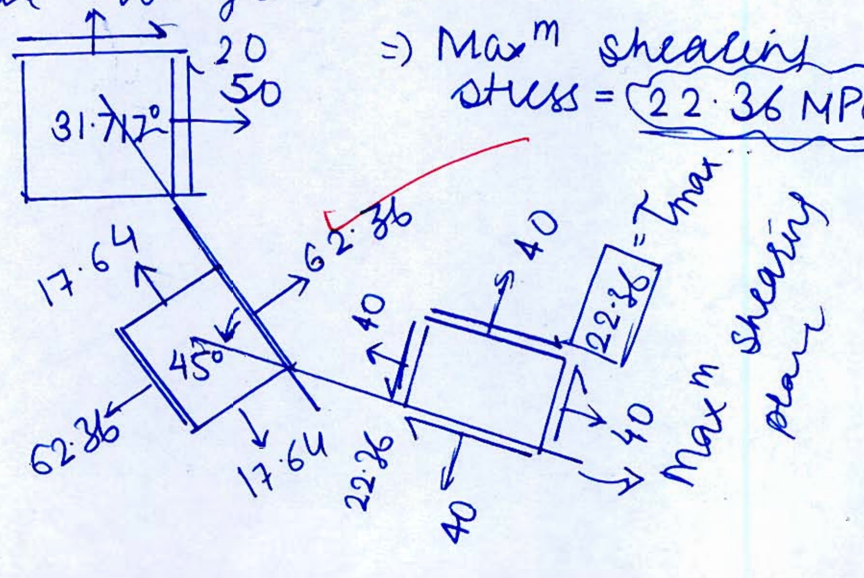
10

* Principal stresses : $\sigma_{P_1} = 40 + 22.36$
$= \boxed{62.36 \text{ MPa}}$

$\sigma_{P_2} = 40 - 22.36$
$= \boxed{17.64 \text{ MPa}}$

We know any angle on mohr circle is twice the angle on normal planes.
So if we rotate $\frac{63.43°}{2}$ anticlockwise from given vertical plane we get our max^m principal planes

⇒ Max^m shearing stress = $\boxed{22.36 \text{ MPa}}$



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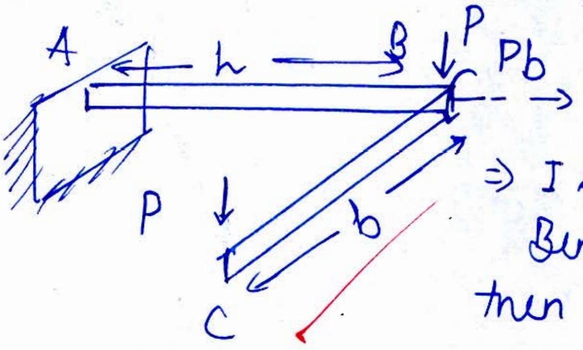


⇒ If we take only Bending of AB then $\delta_c = \frac{PL^3}{3E_{AB}I_{AB}} + \frac{Pb^3}{3E_{BC}I_{BC}}$

0

*| II) Because of torsion AB will twist and tangent BC will shift down, when it is multiplied by b it will give us δ. deflection of C due to torsion.

$$\Rightarrow \frac{G\theta}{L_{AB}} = \frac{T_{AB}}{J_{AB}} \Rightarrow \theta = \frac{T_{AB}}{J_{AB}} * \frac{L}{G_{AB}}$$

$$\theta = \frac{PbL}{J_{AB}G_{AB}}$$

8

$$* \ \theta * b = \delta_{c/torsion} = \frac{PbL * b}{J_{AB}G_{AB}} = \frac{Pb^2L}{J_{AB}G_{AB}}$$

* Total deflection = $\delta_{c/bending} + \delta_{c/torsion}$

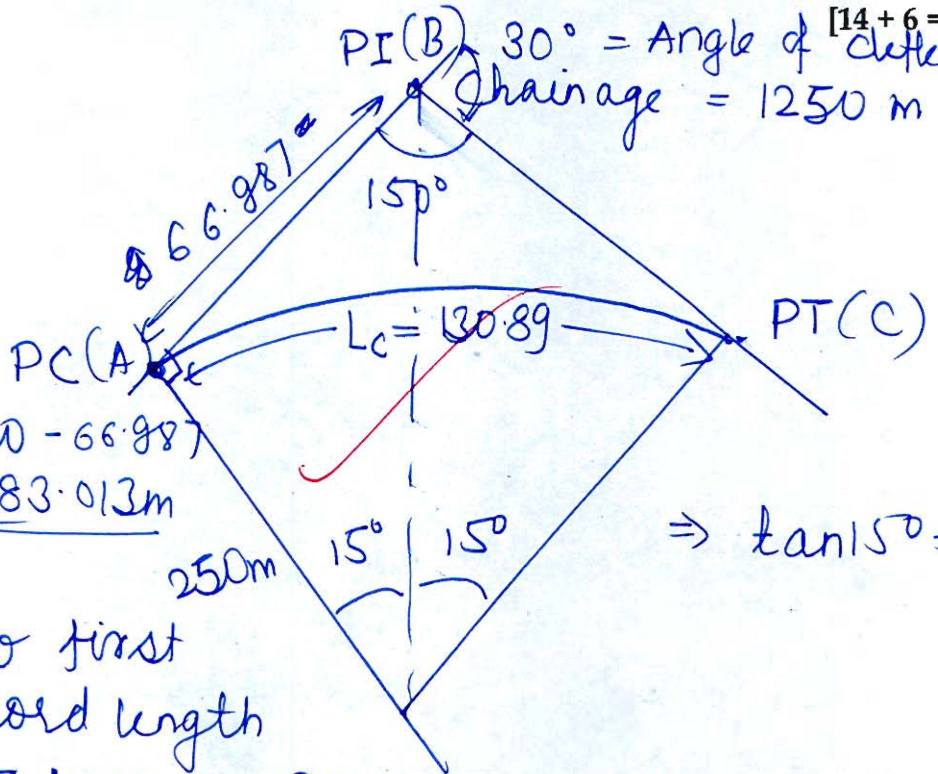
$$= \frac{PL^3}{3E_{AB}I_{AB}} + \frac{Pb^3}{3E_{BC}I_{BC}} + \frac{Pb^2L}{J_{AB}G_{AB}}$$

$\frac{\pi}{64}d^4$ 0 (∵ BC bar is rigid) $\frac{\pi}{64}d^4$

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]



Chainage = 1250 − 66.987
= 1183.013m

$\Rightarrow \tan 15^\circ = \frac{AB}{R}$

$\Rightarrow$ So first chord length
= 1200 − 1183.013
= 16.987 m

$\therefore$ We use deflection Angle method or Rankine's method so in that we find Δ cumulative & then tell the field help to place pegs respectively from previous peg to next while we see Δ from theodolite

$\Rightarrow$ Chainage of C = 1183.013 + 130.89
= $\boxed{1313.9126 m}$

So final chain length = 1300 + 1313.9126
= $\boxed{\cancel{6.0873} m}$ $\boxed{13.913 m}$

No. of chains = 120.89 − $\cancel{6.0873}$ 13.913 − 16.987
= $\frac{100 m}{20}$ = 5 chains.

Total 7 deflections angles will be added

$\Delta_1 = \delta_1 = \frac{C_1}{2R} = \frac{16.987}{2 \times 250} * \frac{180°}{\pi} = 1.94650°$

$\Delta_2 = \delta_1 + \delta_2 = 1.9465 + \frac{20}{2*250} * \frac{180}{\pi} \rightarrow \underline{2.291}$

$= \underline{4.238}$

$\Delta_3 = \delta_1 + 2*\delta = 9.67065^\circ$ 14

$\delta \downarrow$ For equal chords

$\Delta_4 = \delta_1 + 3\delta = 8.8195^\circ$

$\Delta_5 = \delta_1 + 4\delta = 11.9105^\circ$

$\Delta_6 = \delta_1 + 5\delta = 13.4015^\circ$

$\underline{\Delta_7} = \Delta_6 + \delta_{c'} = 13.4015 + \frac{13.913}{2\times250} * \frac{180}{\pi}$

$= \boxed{15^\circ}$

(ii) Field procedure of radial offset method :-

* First from known pt of intersection the angle of ~~ditte~~ intersection is calculated by turning from Point of curve i.e point of tangent.

* Then tangent is calculated by finding deflection angle (π − intersection angle) & taking half the angle we go back the initial tangent by same length of tangent to get to point of curve at A.

⇒ Then from there we know offset distance for each offset. we move along tangent initially ~~to~~ crafted for a distance till first partial chain length (to get perfect multiple of 20 or 30, whichever chain is used)

* After that we ~~...~~ go perpendicular to tangent to length of offset & place a peg. Now ~~from~~ that peg we again ~~...~~ take a slight turn of angle $\delta_2 = \frac{C}{2R}$ (20m or 30m) as written in field book., again move a distance of C (chord length) and then at right angle move inwards by a distance of offset length & place a peg. Same procedure is repeated, till last chord whose length is different.

3

⇒ Now deflection angle & chord length to go forward both changes and we have to again go till that chord length, move inward using offset and place a peg

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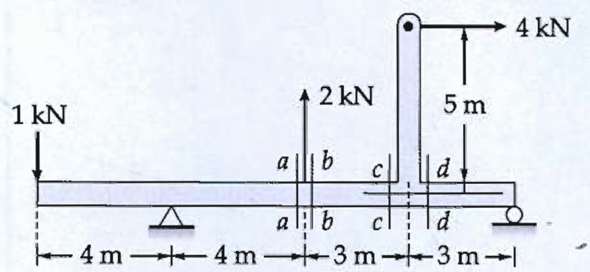
Q.6 (c) (i) Describe the relationship between traffic speed and density as per Green shield model. What will be the maximum capacity of the flow and when do that occurs? Sketch the relevant curves.

(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]

⇒ (i) In Green shield model we assume speed & density are related linearly.

$$\boxed{V = V_0 - \frac{K}{K_j} V_0} = V_0\left(1 - \frac{K}{K_j}\right)$$

V_0 → Max speed; K ⇒ traffic density for given V; K_j → Jam density.

Also Flow (in veh/hr) $= V * K$

Placing $\boxed{V}$ as represented above $= V_0\left(1 - \frac{K}{K_j}\right) * K$

$$= V_0\left(K - \frac{K^2}{K_j}\right)$$

* So for max^m density

$$\frac{dq}{dK} = 0 \Rightarrow V_0\left(1 - \frac{2K}{K_j}\right) = 0$$

$$\Rightarrow 1 = \frac{2K}{K_j} \Rightarrow \boxed{K = \frac{K_j}{2}}$$

$$V = V_0\left(1 - \frac{K_j}{2K_j}\right) = \boxed{\frac{V_0}{2}}$$

So max^m flow occurs at $K = \frac{K_j}{2}$ & $V = \frac{V_0}{2}$

& value of maximum flow $= VK = \frac{V_0 K_j}{4}$

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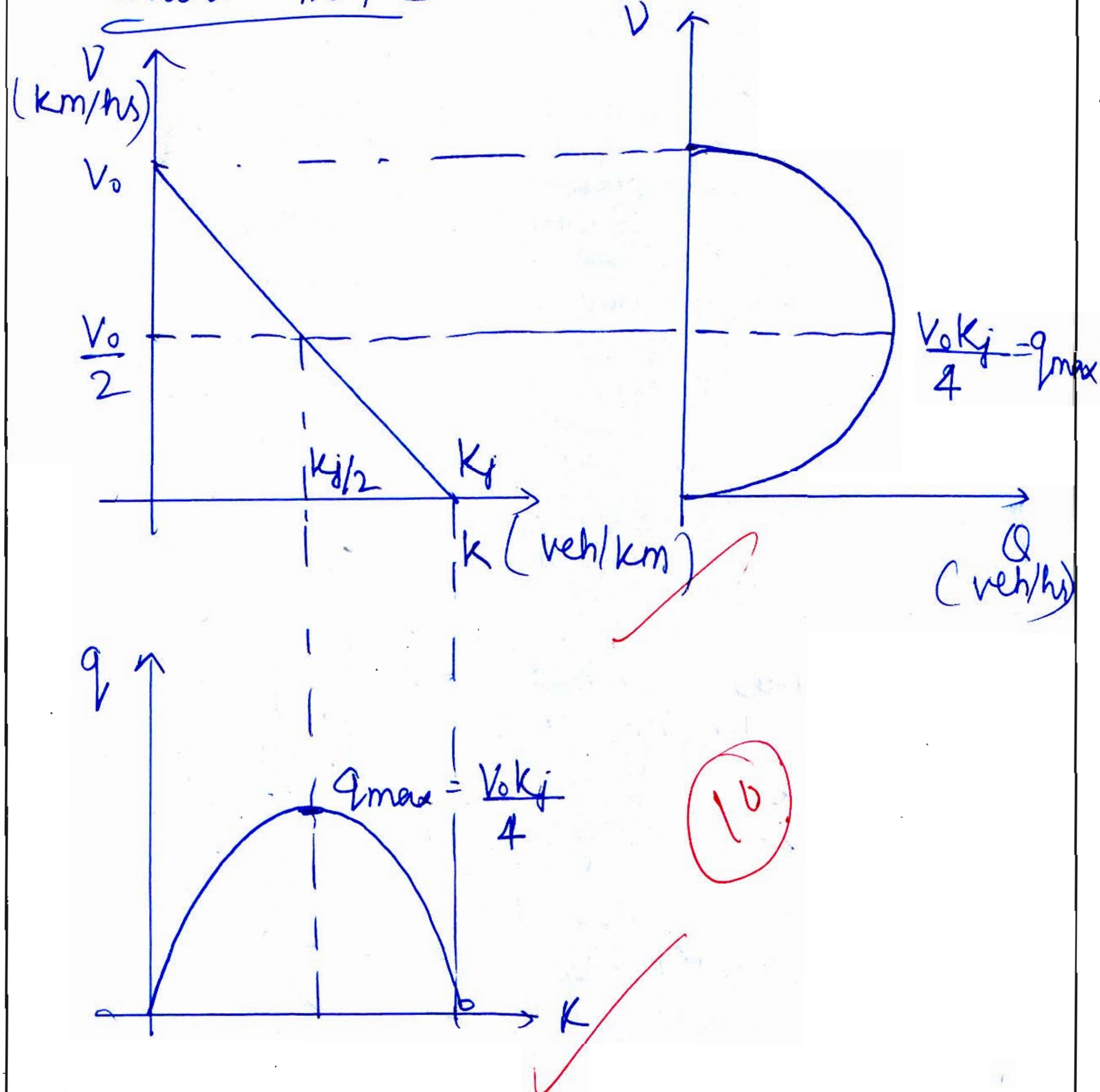
* Relevant Graphs



(ii)

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]

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

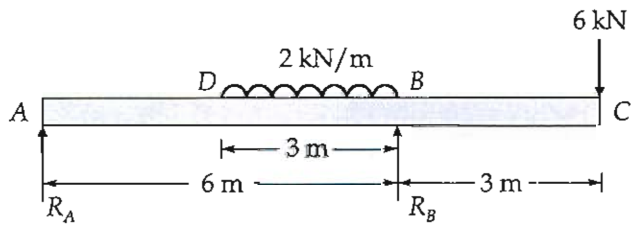
Calculate the following parameters:

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]

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]

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]

$\Rightarrow \frac{f}{H-h} = \cancel{\frac{(x_L+x_R)}{X_A}} = \frac{y_A}{Y_A} \qquad \frac{f}{H}$ $\Rightarrow$ lets take middle point of A = 3.4 mm towards left

$\Rightarrow \cancel{\frac{f}{H-h} = \frac{x_R = 38.4\,mm}{B = 900\,m}} \qquad \frac{f}{H-h} = \frac{45.20+38.4}{B}$

$\Rightarrow X_A = \frac{3.4 * 900}{83.6}\ m = 36.6\ m$

$Y_L = \frac{52.6 * 900}{83.6} = 566.26\ m$

Elevation $\Rightarrow 2500 - h = \frac{150 \times 900}{83.6} \Rightarrow \boxed{h = 885.167\,m}$

* For B, similarly :-

$\Rightarrow \frac{f}{H-h_b} = \frac{(x_L+x_R)}{B} \Rightarrow x_L + x_R = 74.8$

$\Rightarrow h_b = 2500 - \frac{fB}{(x_L+x_R)} = 2500 - \frac{150 \times 900}{74.8}$

$= \boxed{695.187\,m}$

~~Horizontal~~ lets take middle of x_L & x_R as position of B $\Rightarrow x_B = -14.9$ (towards right.

$$* \frac{14.9 * 900}{74.8} = -179.27\,m$$

$$* \; y_B = \frac{-40.10 \times 900}{74.8} = -482.48$$

=) Horizontal distance between

$$\cancel{A} \& B = \sqrt{(36.6+179.27)^2 + (482.48 + 566.26)^2}$$

$$= \boxed{1070.72\,m}$$

=) Gradient => ~~havg ab =~~

$$\Delta h = 885.167 - 695.187$$

$$= 186.98\,m$$

=) Gradient $= \frac{\Delta h}{L_{AB}} = \frac{186.98}{1070.72} = \boxed{0.1746}$

20

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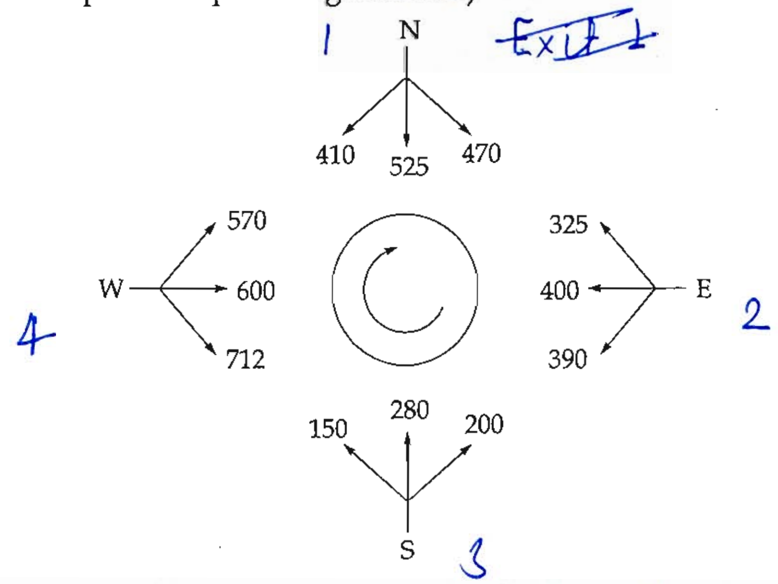
Q.8 (b) The width of a carriage way approaching an intersection is given as 16 m. The entry and exit width at the rotary is 10 m. The traffic approaching the intersection from the four sides is shown below. Calculate the capacity of rotary using the given data. (Assume suitable assumptions as per IRC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



[20 marks]

Capacity of rotary $= \dfrac{280w\left(1+\frac{e}{w}\right)\left(1-\frac{p_{max}}{3}\right)}{\left(1+\frac{w}{L}\right)}$

$\frac{w}{L}$ $L > 4w$ as per IRC

$e_1 = 10$; $e_2 = 10$ $\Rightarrow$ $w = \dfrac{e_1+e_2}{2} + 3.5$

$= 10 + 3.5 = 13.5$

$e = e_{avg} = 10$

For Pmax

$\Rightarrow P_{13} = 525$ $\quad P_{21} = 325$ $\quad P_{32} = 200$

$P_{12} = 470$ $\quad P_{24} = 400$ $\quad P_{31} = 280$

$P_{14} = 410$ $\quad P_{23} = 390$ $\quad P_{34} = 150$

$\Rightarrow P_{43} = 712$

$P_{41} = 570$

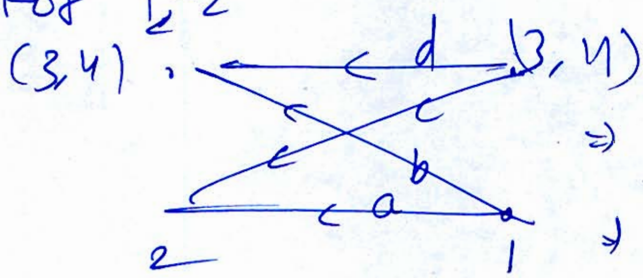
$P_{42} = 600$

Length of weaving section $= 4 * 13.5 = \boxed{54\ m}$

$\Rightarrow$ weaving ratio

15

$\Rightarrow$ For 1-2



$\Rightarrow P = \dfrac{b+c}{a+b+c+d}$

$\Rightarrow b = P_{13} + P_{14} = \boxed{935}$

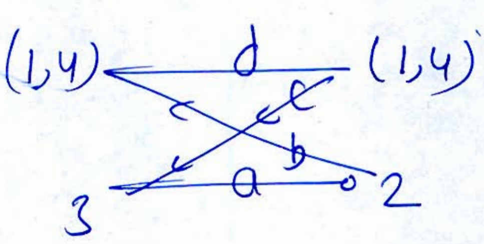
$\boxed{a = 470}$

$c = P_{32} + P_{42} = \boxed{800}$

$d = P_{43} = \boxed{712}$

$\Rightarrow P = \dfrac{1735}{2917} = 0.5940$

$\Rightarrow$ For 2-3



$\Rightarrow P = \dfrac{b+c}{a+b+c+d}$

$b = P_{21} + P_{24} = 725$

$c = P_{13} + P_{43} = 1237$

$d = P_{14} = 410$

$a = 390$

$\Rightarrow P = \dfrac{1962}{2762} = 0.710$

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⇒ Taking $p_{max} = \boxed{0.710}$

⇒ Capacity of rotary $= \dfrac{280 * 13.5 * \left(1+\frac{10}{13.5}\right)\left(\frac{1-0.710}{2}\right)}{\left(1+\frac{1\cancel{4}}{4}\right)}$

$= 4018$ as capacity > 3000

so rotary fails

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

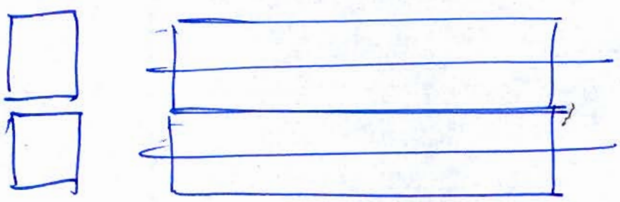
Maximum allowable stress in aluminium = 80 N/mm^2

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]

⇒(1) For beams not connected : Each will bend at its neutral axis & radius of curvature will be same so :-



* $\frac{E}{R} = \frac{M}{I} = \frac{\sigma}{y}$ $\cancel{\frac{1}{R} = \frac{M}{I}}$

& So say steel reaches its max stress = 120 N/mm

$\frac{E}{R} = \frac{120}{25\,mm} \Rightarrow \frac{1}{R} = \frac{120}{25 \times E_{st}} = \frac{\sigma_{max\,brass}}{25 \times E_{brass}}$

$\Rightarrow \sigma_{max\,brass} = 120 \times \frac{7}{20} = 42$ ✓ 80 OK.

we only stress steel till $\boxed{120\,MPa}$ & brass till $\boxed{42\,MPa}$

$MOR = \sigma_{st} * Z + \sigma_{Br} * Z$

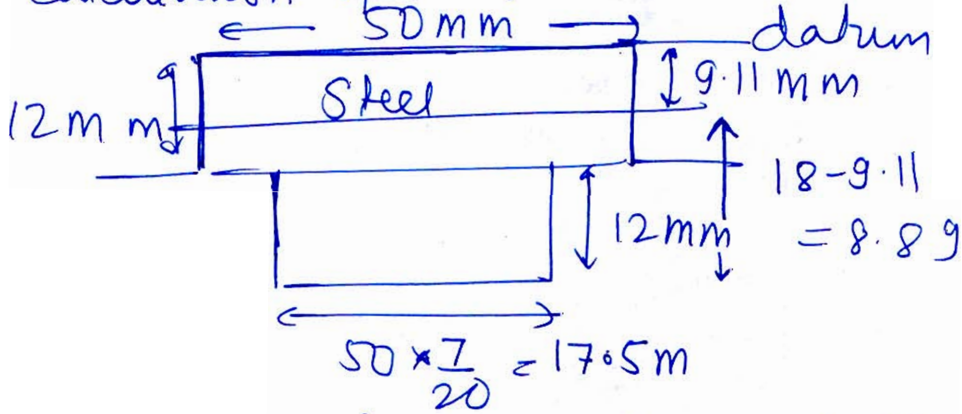
$= 162 * \frac{50*12^2}{6} = \cancel{2.3328\,kN\text{-}m}\ 0.1944$

* Max central Load = P_{max}

$\frac{P_{max} \times 1.2}{4} = \cancel{2.3328}\ 0.1944\,kN\text{-}m$

$\Rightarrow \boxed{P_{max} = \cancel{7.776}\ 0.648\,kN}$

(ii) For composite beam
calculation of NA ~~for~~ transformed section



$X_{NA} = \cancel{\frac{50\times12^3}{12}}\ \frac{50\times12\times6 + 17.5*12*18}{50\times12 + 17.5\times12}$

$= \boxed{9.11\,mm}$

$\Rightarrow I_{NA} = \frac{50\times12^3}{12} + 50\times12\,(9.11-6)^2 + \frac{17.5\times12^3}{12} + 17.5\times12\,(18-9.11)^2$

$= 32120.001$

So we check what yields first, say ~~brass at end~~ steel yields at 120 N/mm²

So, $\cancel{\frac{M}{32120}}\ \frac{120}{9.11} = \frac{\sigma_{st})_{trans}}{8.89} \Rightarrow \sigma_{st})_{transf} = 117.102\,MPa$

$\Rightarrow \sigma_{Brass} = 117.1 * \cancel{\frac{10}{9}} \frac{7}{20} = 40.98 < 80$

so we assumed right
steel yields first

$$so \quad \frac{M}{32120} = \frac{120}{9.11} \Rightarrow \boxed{0.42309 \text{ kN-m}} = M_{OR}$$

$\Rightarrow \frac{PL}{4} = 0.42309 \Rightarrow$ for max^m BM under point load

$\boxed{P = \cancel{1.4} \; 1.41 \; \cancel{MPa} \; kN}$

20

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Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work