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ESE 2024 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-4 : Design of Concrete and Masonry Structures [All Topics]
Strength of Materials - 1+ Highway Engineering - 2
+ Surveying and Geology-2 [Part Syllabus]

Name :

Roll No

Test Centres			Student's Signature
Delhi ☑	Bhopal ☐	Jaipur ☐	
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Instructions for Candidates

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

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	58
Q.2	52
Q.3	
Q.4	48
Section-B	
Q.5	34
Q.6	
Q.7	46
Q.8	
Total Marks Obtained	238

Signature of Evaluator: Ujjawal

Cross Checked by: .....

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

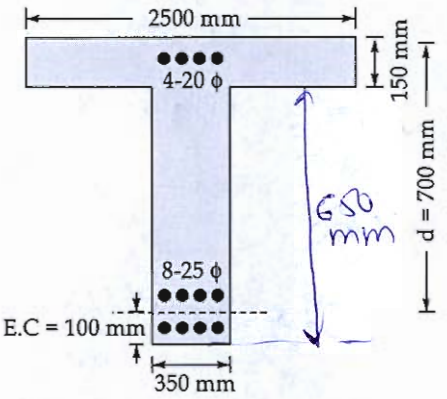
1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough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

Remarks

- Practice more & more questions.
- Presentation is good.
- All the best.

Section A : Design of Concrete and Masonry Structures

Q.1 (a) A simply supported *T*-beam is as shown in figure below.



Clear span of *T*-beam = 10 m.
Live load on beam = 52 kN/m
Width of support = 500 mm
Grade of concrete and steel are M30 and Fe415 respectively.
Design the shear reinforcement of the beam using the table given below:

p_t%	1.25	1.50	1.75	2.00	2.25	2.5
τ_c(MPa)	0.71	0.76	0.80	0.84	0.88	0.91

Use LSM.

[12 marks]

(1) $W_{live} = 52\ kN/m$

$W_{dead} = [2.5 \times 0.15 + 0.650 \times 0.35] \times 25$

$= 15.06\ kN/m.$

$W_{total} = 52 + 15.06 = 67.06\ kN/m.$

$V_u = 1.5 . W_{tot.} \times \frac{l_{effective}}{2}$

$= 1.5 \times \frac{10}{2} \times 67.06 =$

$= 502.96 \simeq 503\ kN.$

(2) $\tau_v = \frac{V_u}{b_w d} = \frac{503 \times 10^3}{350 \times 700} = 2.053\ N/mm^2$

$\tau_{cmax} = 3.5\ N/mm^2$

so $\tau_v < \tau_{cmax}$ Ok

(3) $p(t)\% = \frac{8 \times \frac{\pi}{4} \times 25^2}{350 \times 700} \times 100 = 1.603\%$

By interpolation:-

$$\frac{1.75-1.603}{1.75-1.5} = \frac{0.80-\tau_c}{0.80-0.76}$$

$$\tau_c = 0.776 \text{ N/mm}^2$$

(3) $V_s = (\tau_v - \tau_c) \times bd$

$$= (2.053-0.776) \times 350 \times \frac{700}{1000} \text{ kN}$$

$$= 312.75 \text{ kN}.$$

(4) Lets ~~up~~ us provide - 4 legged 8mm stirrups:-

then

$$\text{spacing } S_v = \frac{0.87 f_y A_{sv} d}{V_s}$$

$$= \frac{0.87 \times 415 \times 4 \times \frac{\pi}{4} \times 8^2 \times 700}{312.75 \times 10^3}$$

$$= 162.47 \text{ mm}.$$

also $S_v \le \frac{0.87 f_y A_{sv}}{0.4 b_w} = 518.52 \text{ mm}$

$\le 300 \text{ mm}$

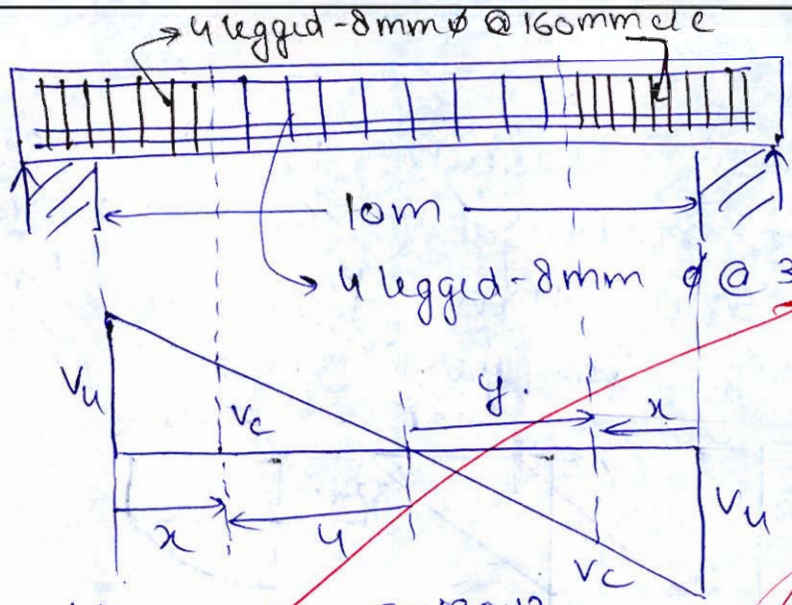
$\le 0.75d = 525 \text{ mm}$

} As per IS-456

⇒ So provide 4 legged - 8mm stirrups at 160mm c/c near the supports and at 300mm at the centre.

$$V_c = \tau_c b_w d = \frac{0.776 \times 350 \times 700}{1000}$$

$$= 190.12 \text{ kN}.$$



$$\frac{y}{V_c} = \frac{L/2}{V_u} \Rightarrow y = \frac{5 \times 190.12}{503}$$

$$= 1.889.$$

$$x = 5 - y = 3.11 \simeq 3.2\,m.$$

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.1 (b) What are the assumptions made in limit state method as per IS : 456 – 2000? Also, show that limiting depth of neutral axis is 0.48 times of effective depth of the beam if Fe415 steel is used. **[12 marks]**

Assumption of LSM:—

(1) Maxm strain in the concrete will go upto 0.0035.

(2) Maxm strain in the steel will go upto $\left[0.002 + \frac{0.87 f_y}{E_s}\right]$

(3) The strain diagram will be linear in the depth.

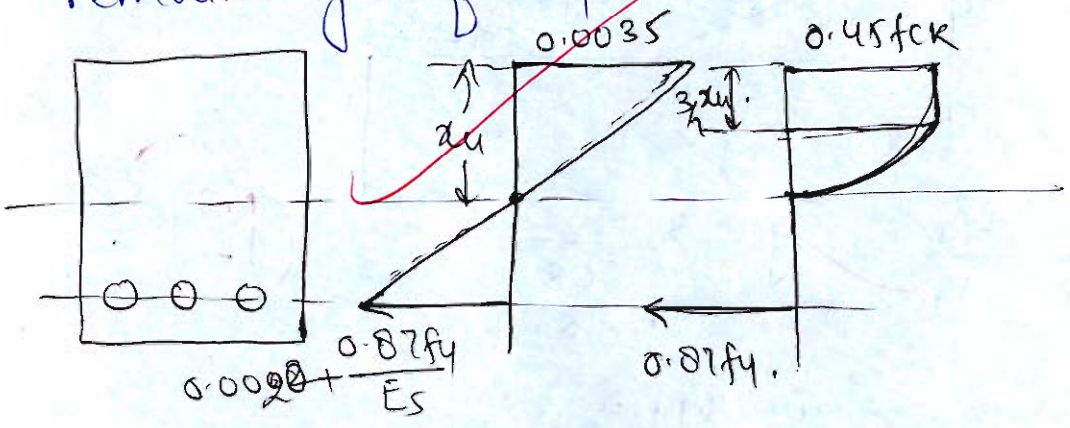
(4) The plane section will be plane before & after bending.

(5) Maxm stress in the concrete can go upto $0.45 f_{ck}$.

(6) Maxm stress in the steel can go

up 0.87fy.

(7) The stress diagram for the concrete will be rectangular for 3/7 x_u on the top and then parabolic for the remaining portion.



⇒ for balanced section:-

$C = T$.

$0.36f_{ck} B x_{u\,lim} = 0.87f_y A_{st}$.

here $x_{u\,lim} = kd$.

where $k = \frac{700}{1100 + 0.87f_y}$ [As per IS 456]

for fe415 steel:-

$k = \frac{700}{1100 + 0.87 \times 415}$ (12)

$= 0.479$

$\simeq 0.48$.

so $x_{u\,lim} = kd = 0.48\,d$.

.1 (c) Find the working moment of resistance of a beam section 300 mm × 600 mm (overall depth) reinforced with 800 mm^2 compression steel and 2160 mm^2 tension steel. Use M25 grade of concrete and Fe415 grade of steel.

Assume stress in compression steel as 350 N/mm^2 and take effective cover as 50 mm in both tension and compression.

[12 marks]

$B = 300m \quad D = 600m$

$d = 600 - 50 = 550m.$

$A_{sc} = 800 mm^2 \quad A_{st} = 2160 mm^2$

Assuming section to be URS :—

$x_{u,lim} = kd = 0.48 \times 550 = 264 mm.$

Actual x_u :—

$C = T$

$0.36 f_{ck} B x_u + (f_{sc} - 0.45 f_{ck}) A_{sc} = 0.87 f_y A_{st}$

$0.36 \times 25 \times 300 \times x_u + (350 - 0.45 \times 25) \times 800 = 0.87 \times 415 \times 2160$

$x_u = 188.46 \ mm.$

so $x_u < x_{u\,lim}$

so section is Under reinforced.

so assumption made is correct.

Now

$$MOR = M_u = 0.36 f_{ck} B x_u (d - 0.42 x_u) + (f_{sc} - 0.45 f_{ck}) A_{sc} (d - d_c)$$

$$M_u = 0.36 \times 25 \times 300 \times 188.46 (550 - 0.42 \times 188.46) + (350 - 0.45 \times 25) \times 800 \times (550 - 50)$$

$$= 375.086 \text{ kN-m.}$$

Assuming FOS = 1.5

$$M_{working} = \frac{M_u}{FOS}$$

$$= \frac{375.086}{1.5}$$

$$= 250.05 \text{ kN-m.}$$ Ans

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.1 (d) Briefly, explain the systems of prestressing.

[12 marks]

⇒ Prestressing can be done in two-way.

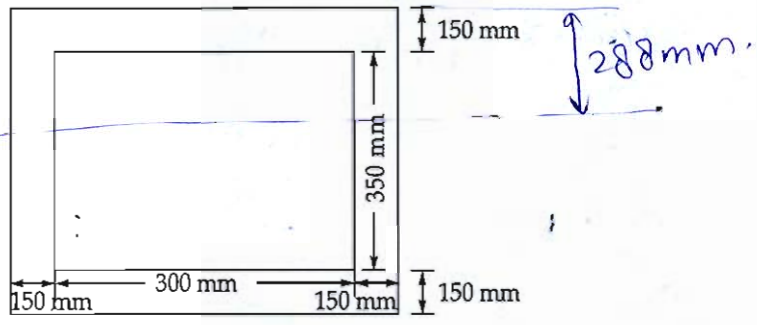
1. Pretensioning PSC:- In this system, the wires or tendons are stressed first and then casting is done. After the formwork removes the clips are removed from the tendons. There is bond formation between the wire & the concrete in this system.

2.- Post tensioning PSC:- In this system, the concrete beam is casted first with a duct in it so that wire can be inserted into it. After it dried and ready

to install then the wires are ~~inte~~ inserted into it ~~thro~~ and then tensioning of the wire is done. Tensioning can be done with different arrangements ~~lif~~ like Griffold's, wedge etc. Here there is no bond b/w the wire & the concrete. There is two extra loss in this system which are loss due to friction & anchorage or slip loss.

12

Q.1 (e) A box section is as shown in figure below.



Design the beam as shown in figure for a working bending moment of 285 kN-m using M25 concrete and Fe415 steel and using limit state method. Consider effective cover for all reinforcement as 50 mm.

[12 marks]

(1) $D = 350 + 150 + 150 = 650$ mm.

$d = 650 - 50 = 600$ m.

$x_{u\,lim} = 0.48d$ {for Fe415}

$= 0.48 \times 600$

$= 288$ mm

(2) BM = 285 kN·m.

$M_u = 1.5 \times BM = 1.5 \times 285 = 427.5$ kN·m.

$M_{u\,lim} = Q B d^2$

$= 0.36 f_{ck} k \cdot j \cdot B \cdot d^2$

$k = 0.48$, $j = 0.798$.

$M_{u\,lim} = (0.138 \times 25 \times 600 \times 600^2) \frac{1}{10^6}$ kN·m

$= 744.63$ kN·m.

$M_u < M_{u\,lim}$

so design URS – singly reinforced.

(3) Since $D_f < x_{u\,lim}$

(150)

$3/7\, x_{u\,lim} = 123.43$ mm.

$D_f > 3/7\, x_{u\,lim}$.

then

$y_f = 0.15 x_{u\,lim} + 0.65 d_f$ ~~0.15 x_u +~~

$= 0.15 \times 280 + 0.65 \times 150$

$= 140.7$ mm.

Now

MOR = $M_u = 0.36 f_{ck} b_w x_{u\,lim} (d - 0.42 x_{u\,lim}) + 0.45 f_{ck} (B - b_w)$

③ Assuming $D_f > x_u$

then

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

$427.5 \times 10^6 = 0.36 \times 25 \times 600\, x_u (600 - 0.42 x_u)$

$x_u = 147.08$ mm.

so $D_f = 150$ mm $> x_u$

so assumption is correct.

so $x_u = 147.08$ mm.

④ $C = T$.

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

$A_{st} = \dfrac{0.36 f_{ck} B x_u}{0.87 f_y}$ (10)

$= \dfrac{0.36 \times 25 \times 600 \times 147.08}{0.87 \times 415}$

$= 2199.78$ mm^2

Provide = 4 No. of 28 mm ϕ.

near the bottom at EC = 50mm.

show detailing

.2 (a) (i) Design a circular column with helical reinforcement for an axial load of 3600 kN under service condition. The unsupported length of column is 5 m and the column is held in position and restrained against rotation at both the ends. Use LSM. (Use M30 concrete and Fe415 grade of steel)

(ii) What are the differences between working stress method and limit state method of design?

[15 + 5 = 20 marks]

i):- $P = 3600$ kN.

$P_u = 3600 \times 1.5 = 5400$ kN.

$l_0 = 5$ m.

$l_{eff} = 0.65 \times 5$ m (As per end cond^n)

$= 3.25$ m.

$SR = \frac{l_{eff}}{D}$

Taking $D = 600$ mm (diameter of column)

(1) $SR = \frac{3250}{600} = 5.4167 < 12$ (short column)

② P_u = 5400 kN (axial)

③ $e_{min} = \left\{ \frac{l_o}{500} + \frac{D}{30}, 20 \right\}_{max}$

$= 30\,mm$

$0.05D = 30\,mm.$

$e_{min} \le 0.05D$

All the cond^n ~~statt~~ satisfies for the formula:-

④ $P_u = 1.05[0.40 f_{ck} A_c + 0.67 f_y A_s]$ {39.3 in IS-456}

$5400 \times 10^3 = 1.05\left[0.40 \times 30 \times \left[\frac{\pi}{4} \times 600^2 - A_s\right] + 0.67 \times 415 \times A_s\right]$

$\Rightarrow A_s = 6577.47\ mm^2$

provide steel of 28 mm ϕ

$n = \frac{6577.47}{\frac{\pi}{4} \times 28^2} = 10.68 \simeq 11$

so provide 11 no. of 28 mm ϕ steel.

⑤ Design of transverse steel:-

$\phi_h = \begin{cases} \frac{\phi_{main}}{4} = \frac{28}{4} = 7\,mm \\ 6 \quad [\text{as per IS 456}] \\ 8 \quad [\text{as per ductile detailing}] \end{cases}$

so provide helical steel of 8 mm ϕ

so $\phi_h = 8\,mm.$

Now:-

$$A_g = \frac{\pi}{4} D^2$$

$$= 282743.33 \text{ mm}^2$$

$$A_c = \frac{\pi}{4} D_c^2$$

$$D_c = D - \text{NC} \times 2$$

$$= 600 - 2 \times 50 \quad \text{[Assume clear cover = 50mm]}$$

$$= 500 \text{ mm}$$

$$A_c = 196349.54 \text{ mm}^2$$

$$V_c = A_c \times 1000$$

$$V_h = \frac{1000}{p} \times \pi D_h \times \pi \phi^2$$

$$D_h = D_c + \phi_h = 500 + 8 = 508 \text{ mm}$$

$$V_h = \frac{1000 \times 508 \times \pi \times \pi \times 8^2}{p}$$

$$= \frac{320880578.3}{p}$$

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Now as per IS-456:-

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

$$\frac{0.36 \times 30}{415} \left[\frac{600^2}{500^2} - 1\right] \leq \frac{320880578.3}{p \times 196349540} = \frac{1.63}{p}$$

$$p \leq 142.27 \text{ mm}.$$

As per code:-

$p \not> 75$mm

$\not< 25$mm

$\not> D_c/3 = 166.67$ mm

$\not< 3\phi_h = 24$ mm

so provide pitch of 70 mm
, base on all above criteria.

iii):- Difference b/w WSM & LSM:-

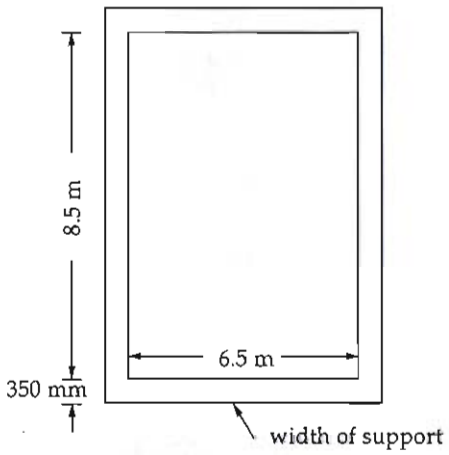
① In WSM, FOS is applied on ~~stress~~ permissible stress only where as ~~on~~ in LSM FOS is applied on both, permissible stress as well as loads.

② In LSM complete use of stress is done.

③ There is 2 failure in LSM which are collapsability & serviceability.

(2)4

Q.2 (b) A simply supported slab is provided as shown in figure. The edges and corners are not prevented from lifting. Design the slab using I.S. code method.



Live load = 6 kN/m^2.

Flooring thickness = 80 mm.

Unit weight of flooring = 24 kN/m^3.

Grade of concrete and steel are M30 and Fe500 respectively.

$r=\frac{l_y}{l_x}$	1.2	1.30	1.40
α_x	0.084	0.093	0.099
α_y	0.059	0.055	0.051

Also, check the slab for shear. [Given $\tau_{c(min)}$ = 0.29 MPa for M30 concrete]

[25 marks]

(1) $L_x = 6.5\,m$

$L_y = 8.5\,m$

$\frac{L_y}{L_x} = \frac{8.5}{6.5} = 1.307 < 2$

$\simeq 1.30$

so it is supported from all 4 sides

so it is a two-way slab.

(2) :- Let $d <$ (width of support = 350mm)

By $L_{ex} = (6500 + d)$

By deflection criteria :—

$d = \frac{L_{ex}}{A \times m_{ft}}$

Let $m_{ft} = 1.5$

$A = 20$

$$d = \frac{6500 + d}{20 \times 1.5}$$

$d = 224.13$ mm.

take $d = 250$ mm

$EC = 40$ mm

$D = 250 + 40 = 290$ mm.

$l_{ex} = 6500 + 250 = 6750$ mm.

③ Calculation of loads:-

$W_{live} = 6\ kN/m^2$

$W_{dead} = (0.290 \times 1 \times 1) \times 25 = 6.75\ kN/m^2$

$W_{flooring} = 0.080 \times 1 \times 1 \times 24 = 1.92\ kN/m^2$

total $W = 6 + 6.75 + 1.92 = 14.67\ kN/m^2$

Taking 1m strip along lex direction.

$d_x = 250$.

$$r = \frac{l_y}{l_x} = 1.3$$

$\alpha_x = 0.093$

$\alpha_y = 0.055$.

$$M_{u,x\oplus} = \alpha_x \frac{W l_{ex}^2}{8} = \frac{0.093 \times 14.67 \times 6.75^2}{8} \times 1.5$$

$= 11.586\ kN \cdot m$

$$M_{uy\oplus} = \alpha_y \frac{W l_{ex}^2}{8} = 4.568\ kN \cdot m.$$

$= 6.852\ kN \cdot m$

④ check for the collapse:-

$$d_{req} = \sqrt{\frac{M_u}{Qb}}$$

$$= \sqrt{\frac{110.38 \times 10^6}{0.138 \times 30 \times 1000}} = 52.09 \text{ mm}$$

$d_{provide} = 230\text{mm} > d_{req}$.

Ok

⑤

$$A_{st_x} = \frac{0.5 f_{ck} b d_x}{f_y}\left[1 - \sqrt{1 - \frac{4.6 M_{ux}}{f_{ck} b d_x^2}}\right]$$

$$= \frac{0.5 \times 30 \times 1000 \times 230}{415}\left[1 - \sqrt{1 - \frac{4.6 \times 110.38 \times 10^6}{30 \times 1000 \times 230^2}}\right]$$

$$= 140.78 \text{ mm}^2$$

$$A_{st_y} = \frac{0.5 f_{ck} b d_y}{f_y}\left[1 - \sqrt{1 - \frac{4.6 M_{uy}}{f_{ck} b d_y^2}}\right]$$

let main bar is ϕ 8mm

$d_y = 230 - 8 = 292\text{mm}$

$A_{st_y} = 85.98 \text{ mm}^2$

$$A_{st\,min} = \frac{0.12}{BD} \times \frac{\phi 12}{100} \times BD$$

$$= \frac{0.12}{100} \times 1000 \times 290$$

$$= 348 \text{ mm}^2$$

So provide $A_{st_x} = A_{st_y} = 348 \text{ mm}^2$

⑥ Spacing:-

for main bar of 8mm dia.

Spacing in x direction

$$S_x = \frac{1000}{348} \times \frac{\pi}{4} \times 8^2$$

$$= 144.14$$

$$\simeq 140 \text{ mm}$$

so 8mm dia at 140mm c/c in x and y direction.

⑦ check for shear:-

$$V_u = \frac{1.5 w l_x}{2}$$

$$= \frac{1.5 \times 14.67 \times 6.5}{2}$$

$$= 71.516 \text{ kN.}$$

$$\tau_v = \frac{V_u}{bd} = \frac{71.516 \times 10^3}{1000 \times 250}$$

$$= 0.286 < \tau_{c\min}$$

ok

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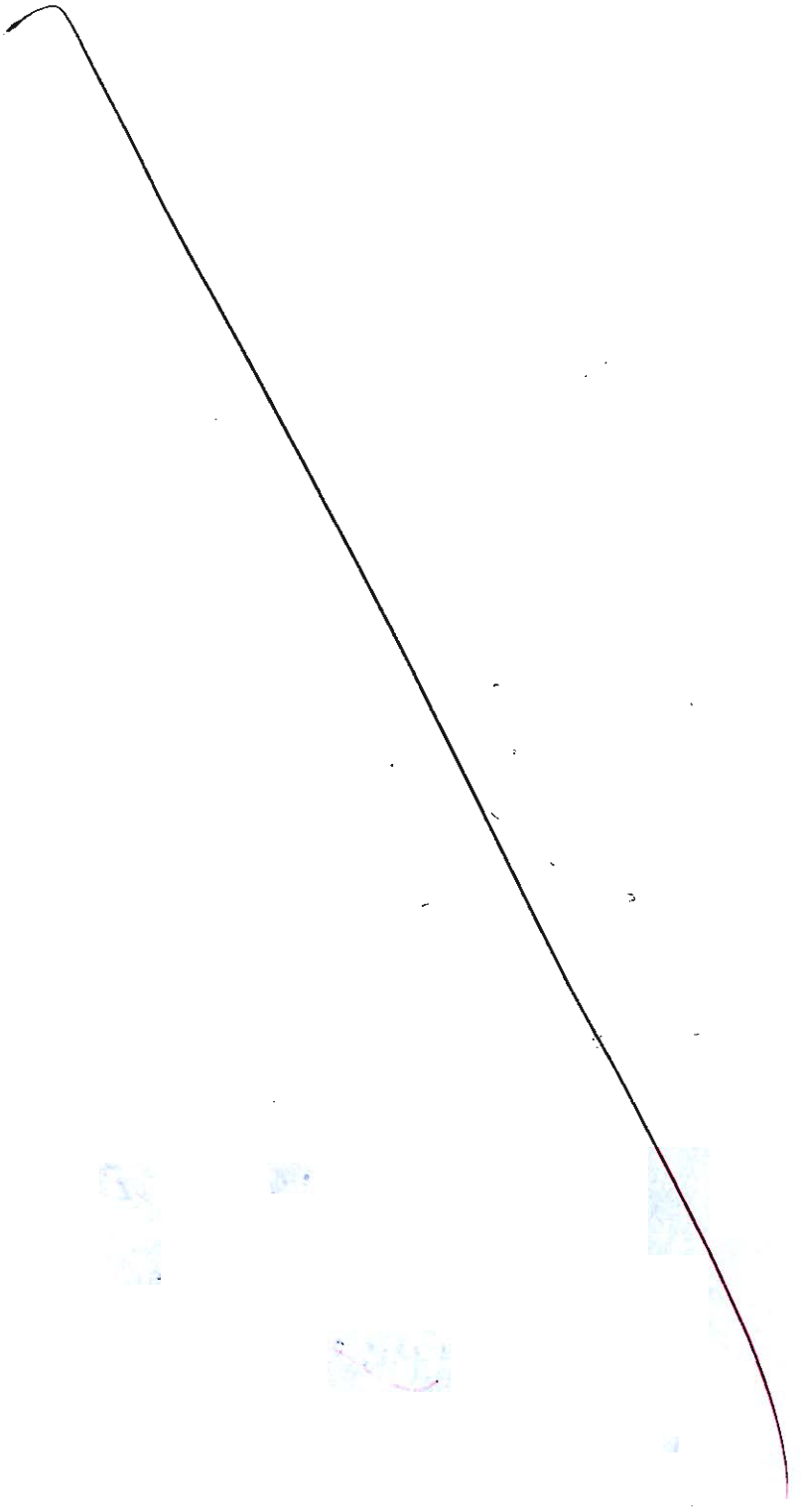
detailing



Q.2 (c) A continuous *T*-beam is used for an effective span of 15 m. Given below are its properties.

- Flange width = 2000 mm
- Flange thickness = 150 mm
- Overall depth = 1000 mm
- Effective cover = 100 mm
- Width of web = 500 mm
- 10 bars of 32 mm diameter are provided as tension reforcement
- M25 concrete and Fe500 steel used.

Calculate the ultimate moment of resistance of the *T*-beam section using LSM. **[15 marks]**

① $B_f = \frac{l_0}{6} + b_w + 6d_f$ {for continuous T-beam}

$= \frac{0.7 \times 15000}{6} + 500 + 6 \times 150$

$= 3150$ mm $\not> 2000$ mm.

so take $B_f = 2000$ mm.

② $x_{u\,lim} = kd$

$= 0.456 \times 900$

$= 410.4$ mm.

③ Assume $d_f > x_u$.

then.

$C = T$.

$0.36 f_{ck} B_f x_u = 0.87 f_y A_{st}$.

$x_u = \frac{0.87 f_y \times 10 \times \frac{\pi}{4} \times 32^2}{0.36 \times 25 \times 2000}$

$= 194.35$ mm.

$x_u = 194.35 > d_f = 150$.

assumption is wrong:-

then take

$x_u > d_f$ but $d_f < 3/7 x_u$.

$0.36 f_{ck} b_w x_u + 0.45 f_{ck} (B_f - b_w) D_f = 0.87 f_y A_{st}$.

$x_u = 214.9$ mm.

$3/7 x_u = 92.116$ mm.

$x_u > d_f$ and $d_f > 3/7 x_u$.

Assumption failed.

Case-3:-

$y_f = 0.15 x_u + 0.65 d_f$

$= 0.15 x_u + 97.5$.

$0.36 f_{ck} b_w x_u + 0.45 f_{ck} (B_f - b_w) y_f = 0.87 f_y A_{st}$.

$0.36 \times 25 \times 300 x_u + 0.45 \times 25 \times 1500 \times (0.15 x_u + 97.5) = 0.87 \times 500 \times 10 \times \frac{\pi}{4} \times 32^2$

$x_u = 263.56$ mm.

$3/7 x_u = 112.95$ mm.

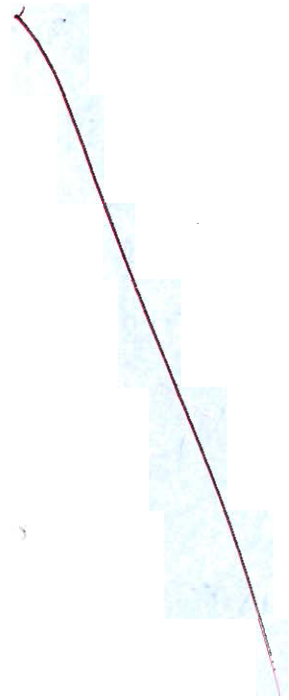
$x_u > d_f$ and $d_f > 3/7 x_u$. Ok

$y_f = 137.03$ mm.

(4) MOR

$M_u = 0.36 f_{ck} b_w x_u (d - 0.42 x_u) + 0.45 f_{ck} (B_f - b_w) y_f \times [d - y_f/2]$

$= 2858.84$ kN·m. Ans

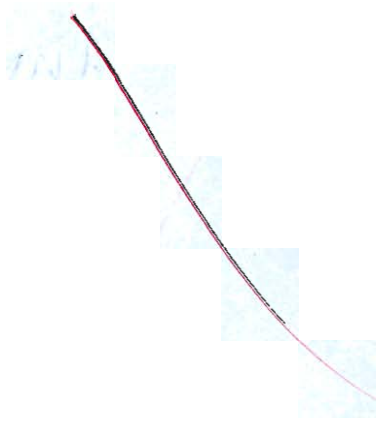


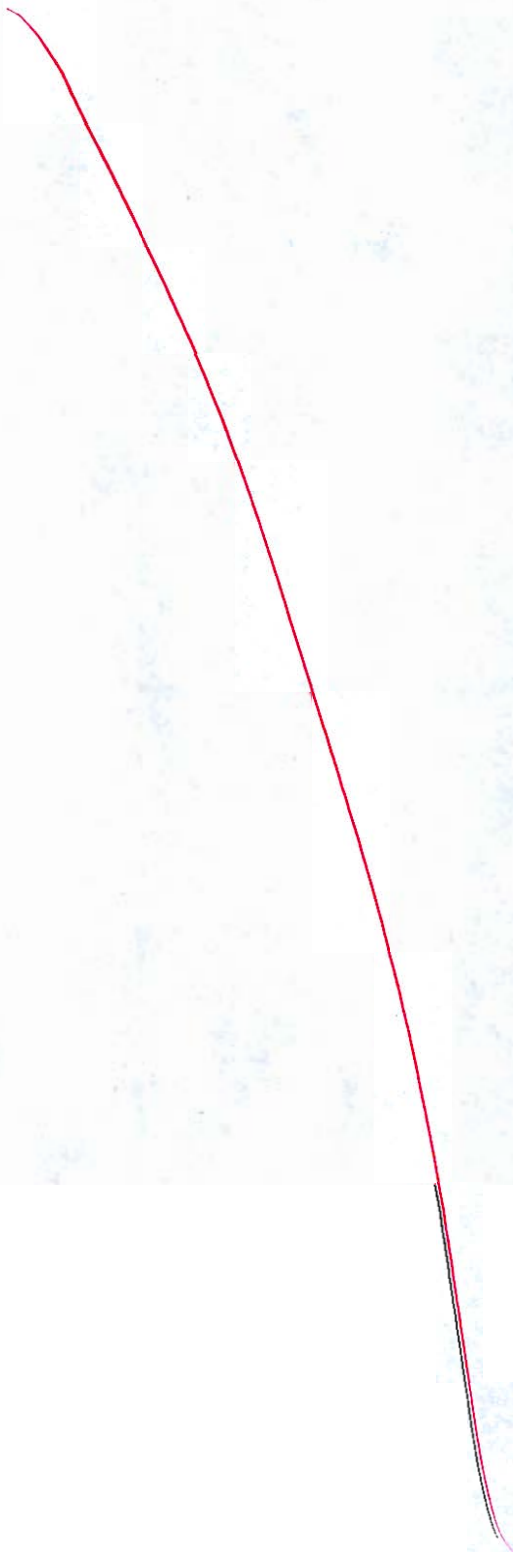
Q.3 (a) An unsymmetrical I-section is required to support an imposed load of 2 kN/m over a span of 8 m. Top flange is 300 mm wide and 50 mm thick, bottom flange is 100 mm wide and 50 mm thick, web thickness is 80 mm with overall depth of I-section as 450 mm. An effective prestressing force of 200 kN is applied at 40 mm from soffit of beam at mid-span. What are the stresses at the centre of span for

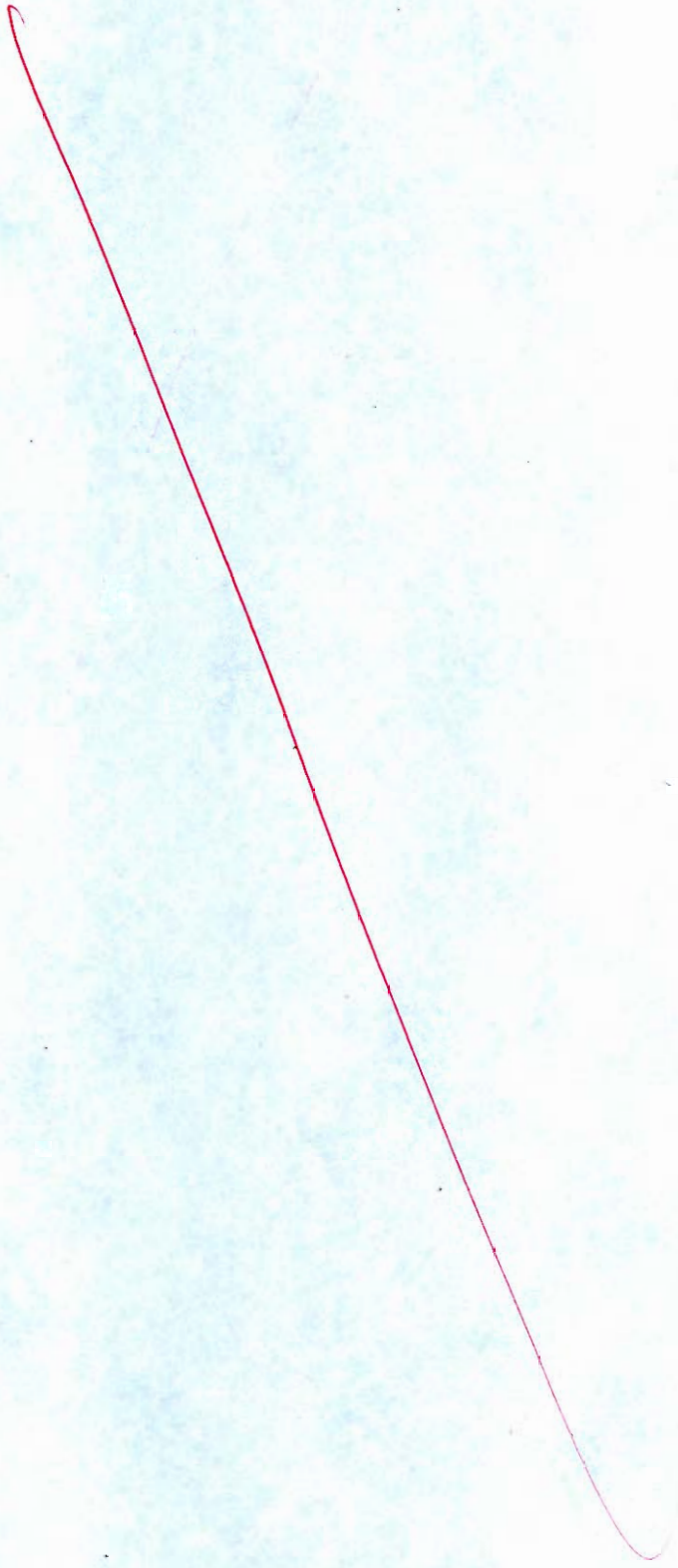
(i) prestress + self weight?

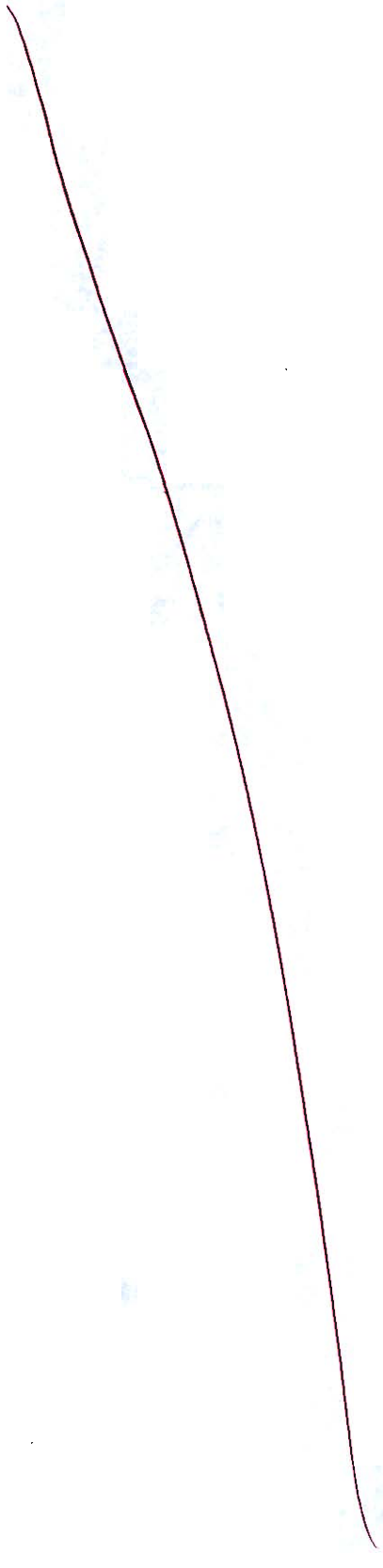
(ii) prestress + self weight + imposed load?

[20 marks]

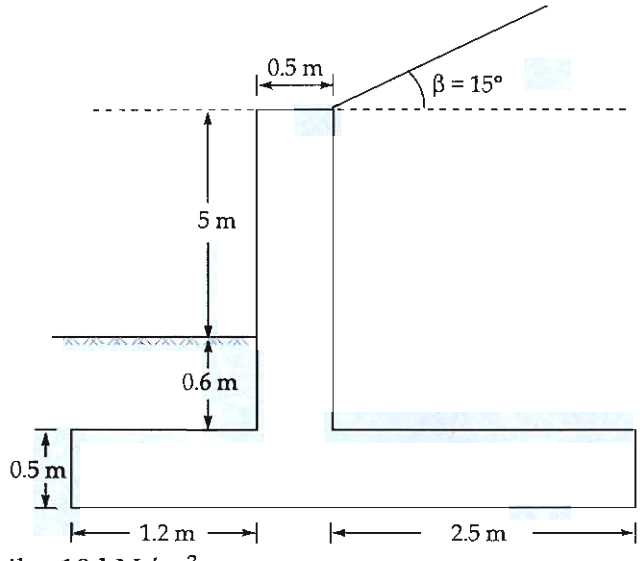








Q.3 (b) A retaining wall is as shown in figure.



Unit weight of soil = 19 kN/m^3.

Angle of repose, $\phi = 32°$

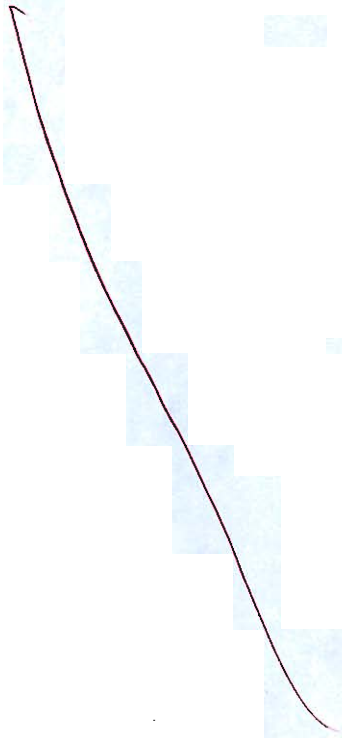
Coefficient of friction between concrete and soil = 0.6

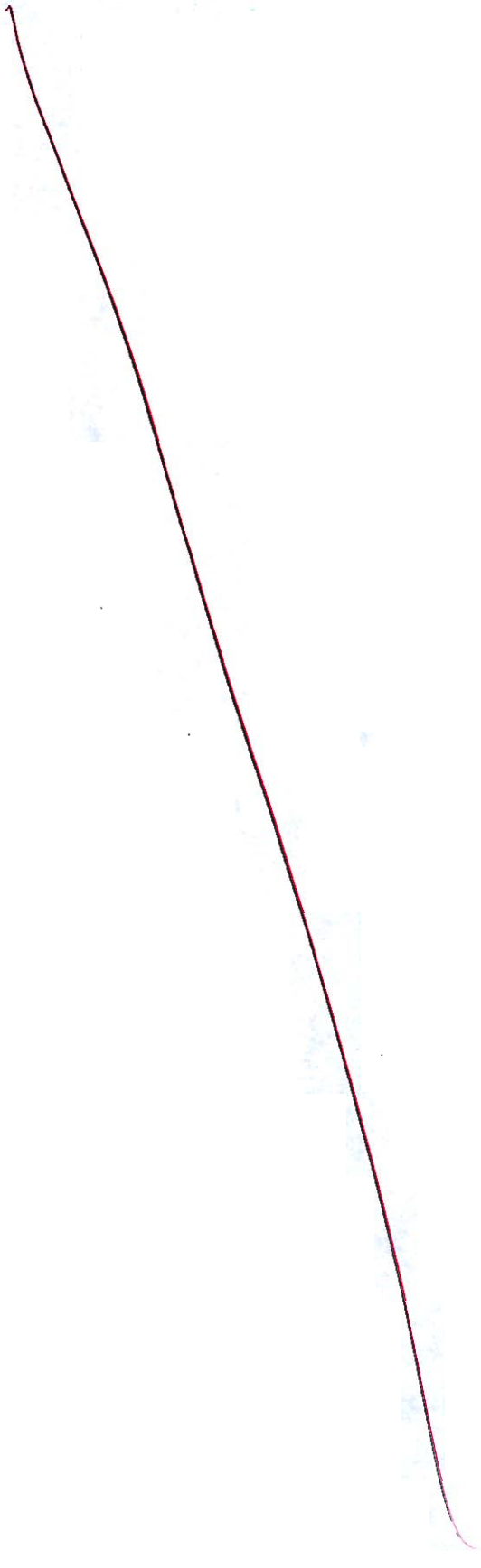
Safe bearing capacity of soil = 300 kN/m^2.

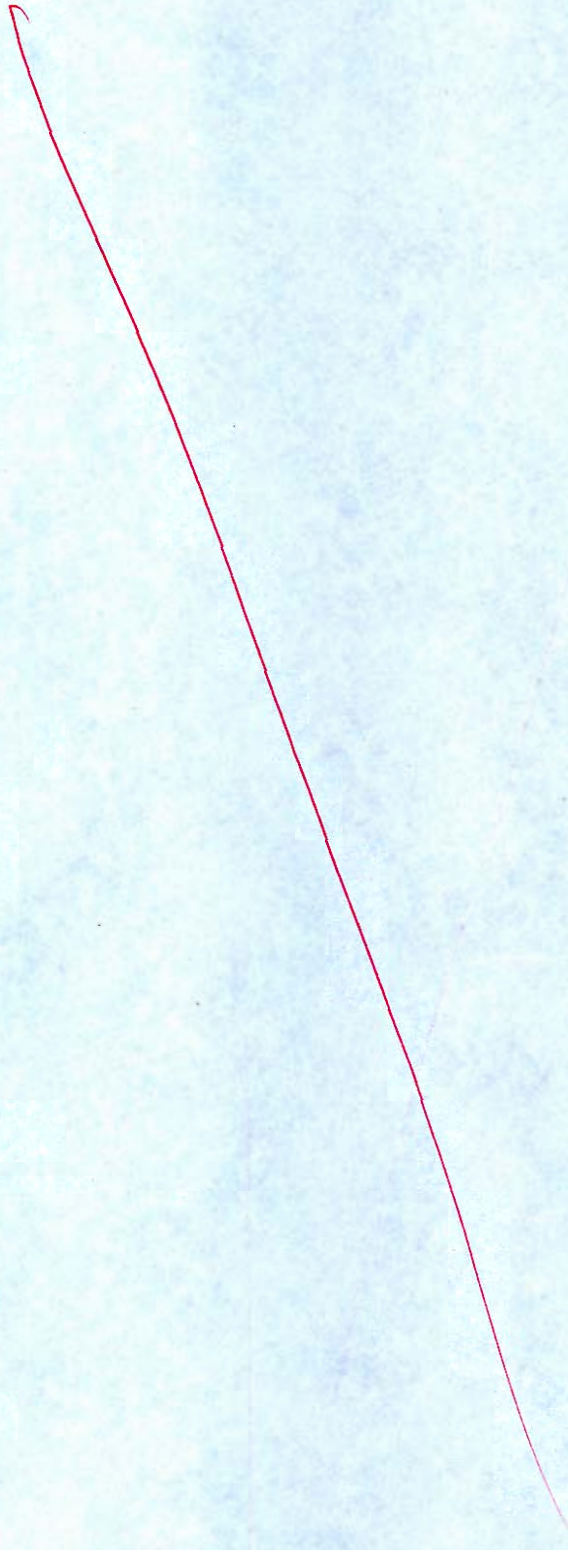
Use M30 concrete and Fe500 steel.

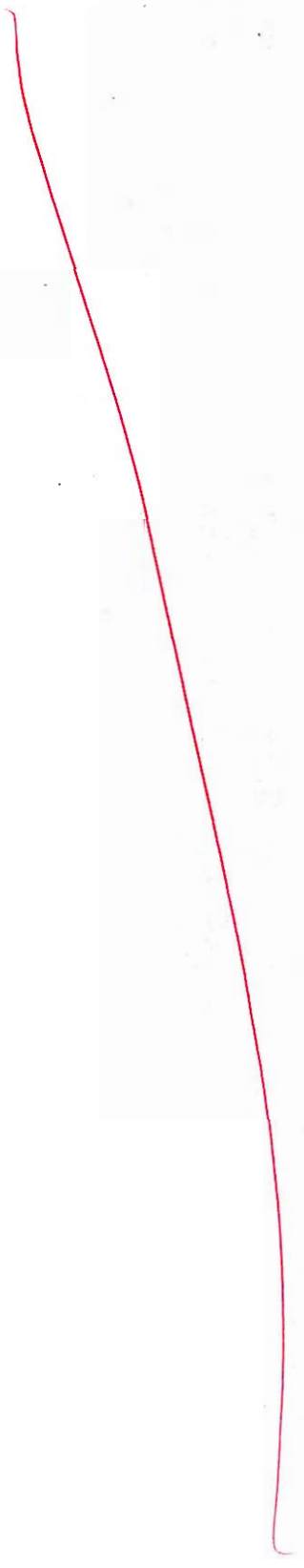
Check the stability of retaining wall and determine the minimum and maximum pressure at base of retaining wall.

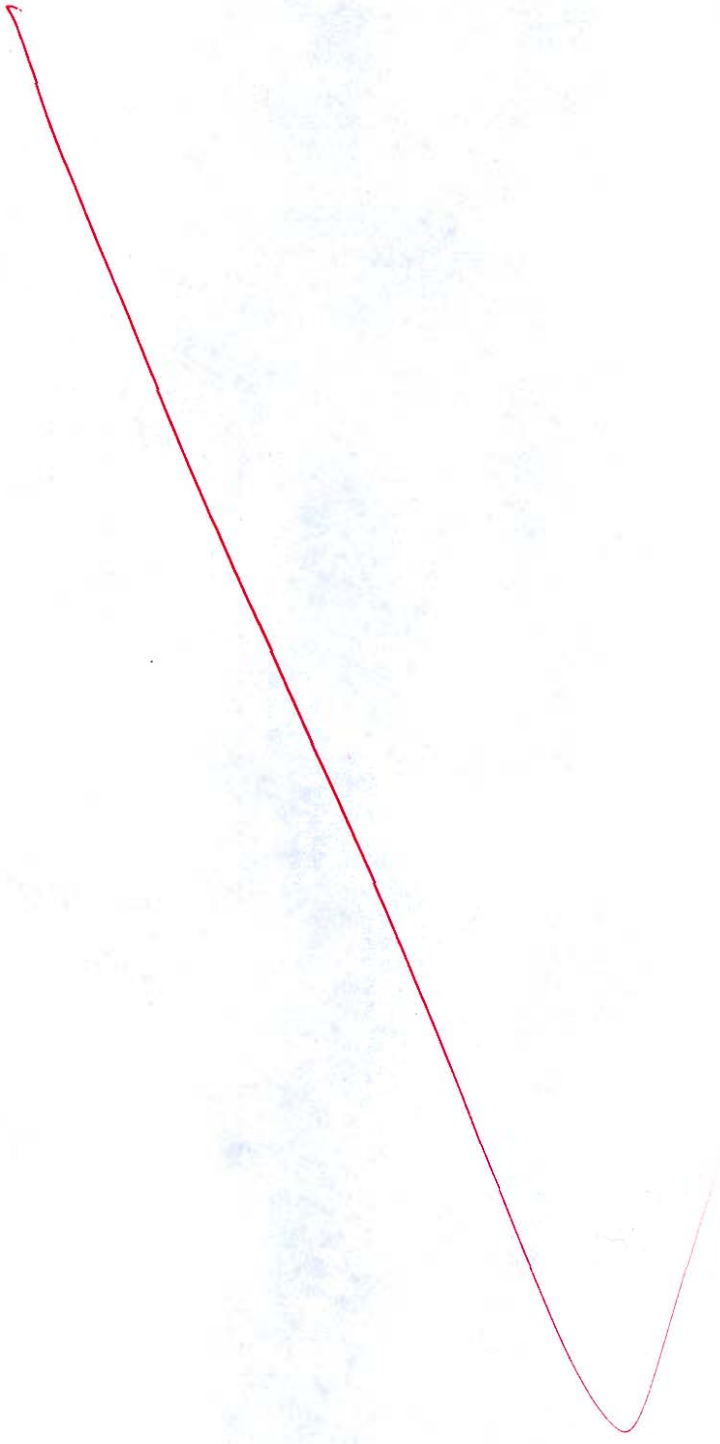
[30 marks]

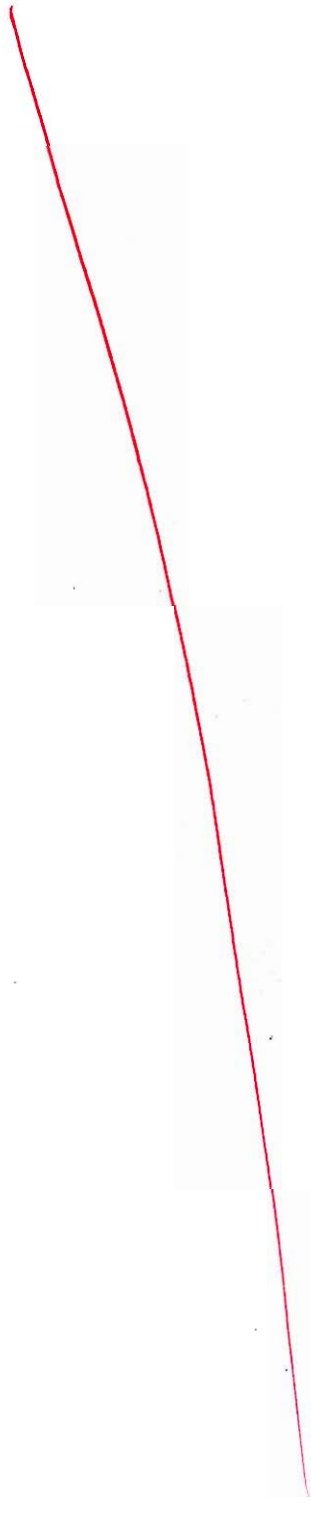












Q.3 (c) Explain the reasons for essentially using high tensile steel and high grade concrete in PSC structures.

[10 marks]

2.4 (a) Design one of the flights of staircase of a school building spanning between landing beams to suit the following data:
Type of staircase: Waist slab type.
Number of steps in flight = 12
Tread, T = 300 mm
Riser, R = 150 mm
Width of landing beams = 400 mm
Finished load = 0.6 kN/m
Live load = 4 kN/m
Materials: M20 grade concrete and Fe415 HYSD bars.

[20 marks]

① $L_f = 12 \times \sqrt{R^2 + T^2}$

$= 12 \times \sqrt{300^2 + 150^2}$

$= 4024.92$ mm.

$L_c = 12 \times T = 3600$ mm

Let $d = 250$ mm $D = 300$ mm.

$L_{eff} = 3850$ mm.

② $W_{dead} = 0.25 \times 1 \times 25 = 6.25$ kN/m.

$W_{live} = 4$ kN/m.

$W_{FL} = 0.6$ kN/m.

total w = 6.25 + 4 + 0.6

= 10.85 kN/m.

$M_u = \frac{1.5 w l_f^2}{8} = 32.876$ kNm.

① check for collapse.

$d_{req.} = \sqrt{\frac{M_u}{Qb}}$

$= \sqrt{\frac{32.876 \times 10^6}{0.138 \times 20 \times 1000}}$

= 109.14 mm.

$d_{provide} = 250 > d_{req.}$ safe

② check for shear:-

$V_u = \frac{1.5 w l_f}{2} = 32.713$ kN.

$\tau_v = \frac{V_u}{bd} = 0.1308$ mPa $< \tau_{min}$

so safe

③ $A_{st} = \frac{0.5 f_{ck} bd}{f_y}\left[1 - \sqrt{1 - \frac{4.6 M_u}{f_{ck} bd^2}}\right]$

$= 367.709 \text{ mm}^2$

$A_{st\,min} = \frac{0.12}{100} \times bd$

$= \frac{0.12}{100} \times 1000 \times 250 = 300 \text{ mm}^2$

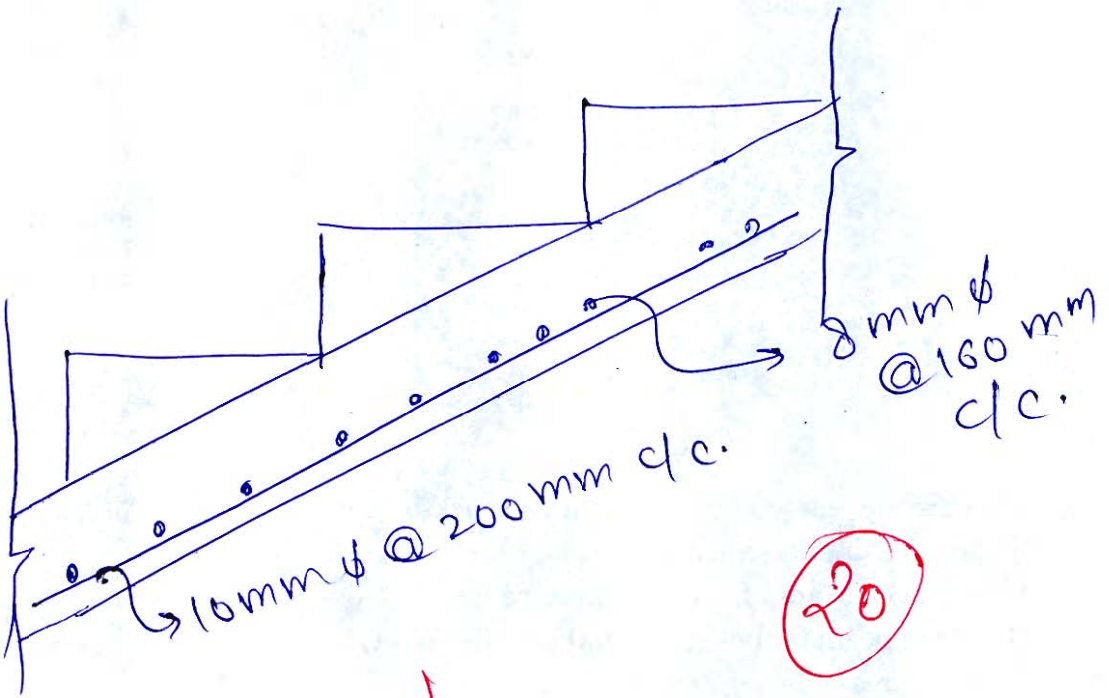
providing 10 mm bar in main

$s_v = \frac{1000}{367.709} \times \frac{\pi}{4} \times 10^2 = 213.592 \geq 200$ mm

providing
Amin as distributed as 8mm dia
then

$$s = \frac{1000}{300} \times \pi/4\, 8^2 = 167.55.$$

$\simeq$ 160mm c/c.



20

Q.4 (b) **(i)** What are the reasons due to which the cracks in concrete occurs? Also, explain the factors affecting the crack width.

(ii) A cantilever beam of span 6.5 m is having of cross-sections 250 mm × 550 mm. Check the beam for deflection and lateral stability.
[Use effective cover as 50 mm]

[10 + 10 = 20 marks]

ii):- $l_0 = 6.5\ m. = 6500\ mm.$

$b = 250\ mm.$

$d = 550 - 50 = 500\ mm.$

for cantilever:-

$l_0 \neq 25b = 25 \times 250 = 6250\ mm.$

$\frac{100b^2}{d} = 12500\ mm$

$l_0 = 6500 > 25b\ (6250)$

so lateraly not stable. Ans.

for deflection:-

$d \geq \frac{l_0}{A}$

$A = 7$ for cantilevr.

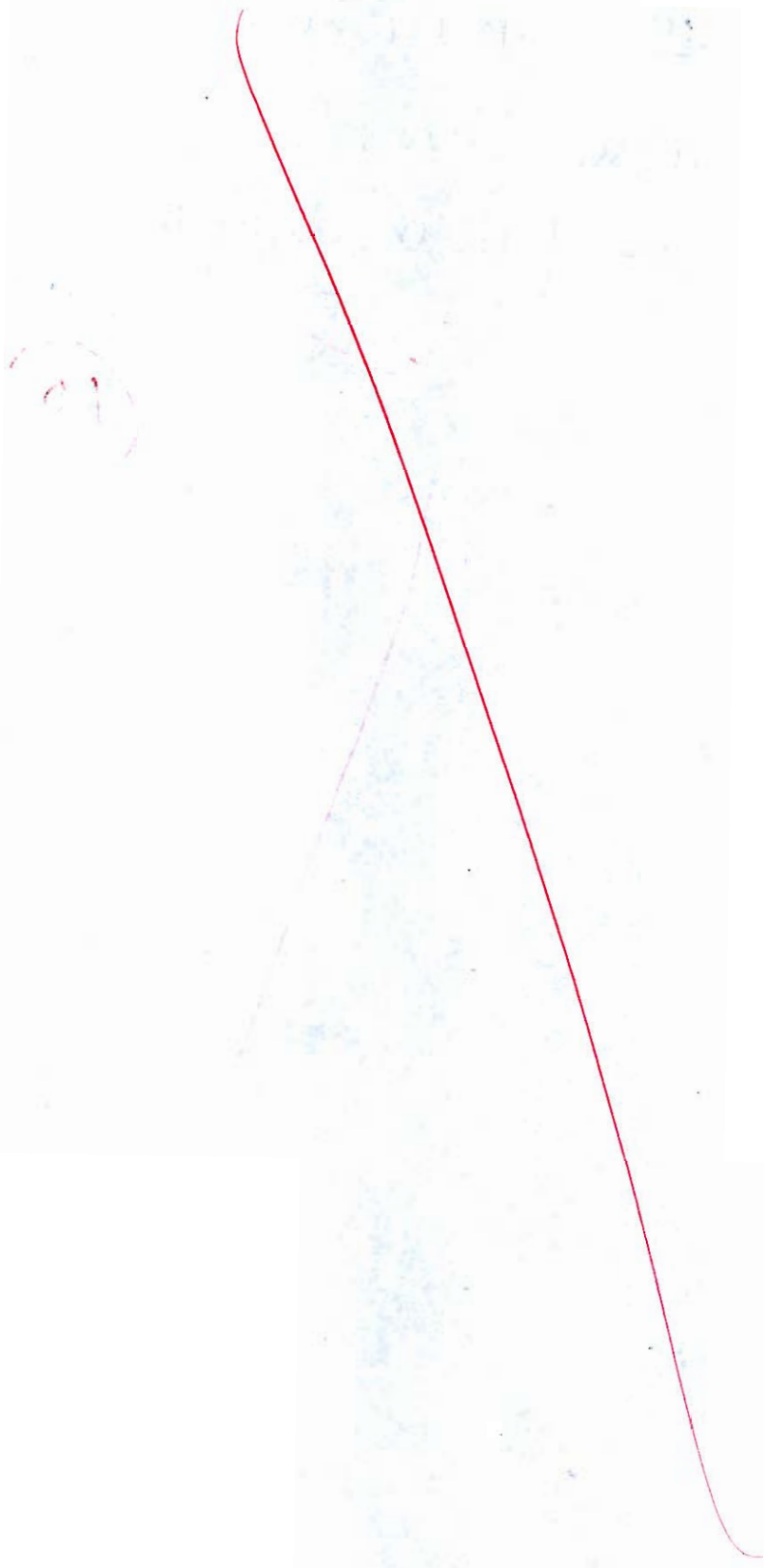
$d \geq \frac{5500}{7} = 928.57$ mm.

$d = 550 < 928.57$

so fail in dfletion as well.

Ans

10



Q.4 (c) A simply supported lintel beam is to be designed for a clear span of 2.60 m.
Width of support on both sides is 300 mm.
Height of brick wall above lintel is 1.5 m and brick work is 250 mm wide.
Slab of 150 mm thickness is resting on top of brick work and is transferring a line load of 30 kN/m on the wall.
Consider 50 mm effective cover.
Design the lintel using M30 concrete and Fe500 steel.
Check the lintel for shear also and use LSM.
Take $\gamma_{brick} = 20\ kN/m^3$ and $\gamma_{RCC} = 25\ kN/m^3$

Design shear strength of M30 concrete	
p_t	τ_c (MPa)
0.75	0.59
1.0	0.66
1.25	0.71
1.5	0.76

[20 marks]

① Let depth of lintel

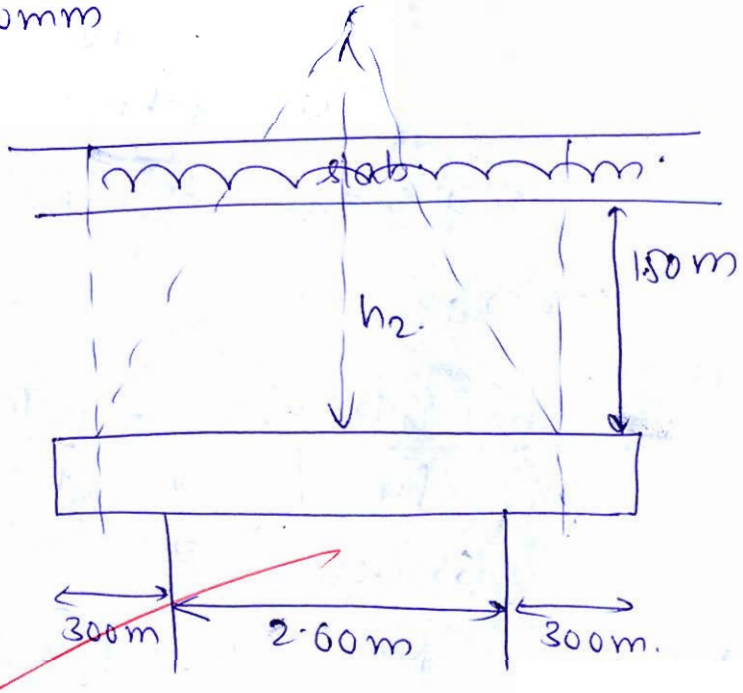
$d = l/10 \approx 250mm$

$D = 300mm.$

$l_{eff} = \begin{cases} l+d \\ l+w \end{cases}$ min

$= 2.6 + 0.25$

$= 2.85\ m.$



$h_2 = l_{eff} \times \frac{\sqrt{3}}{2}$

$= 2.85 \times \frac{\sqrt{3}}{2}$

$2.468 > h_1 = 1.50m.$

rectangular loading will be taken.

② Loads :-

$W_1 = 30\ kN/m$ from slab.

$W_2 = 0.25 \times 1.50 \times 1 \times 20 = 7.5\ kN/m$ (bricks)

$W_{dead} = 0.3 \times 1 \times 0.25 \times 25 = 1.875\ kN/m.$

$W_{total} = 30 + 7.5 + 1.875$

$= 39.375 \text{ kN/m}.$

$M_{umax} = \frac{1.5 W \times l_{eff}^2}{8}$

$= \frac{1.5 \times 39.375 \times 2.85^2}{8}$

$= 59.96$

$\approx 60 \text{ kN.m}.$

③

$M_{ulim} = Q b d^2$

$= \frac{0.133 \times 30 \times 250 \times 250^2}{10^6}$

$= 62.34 \text{ kN.m}.$

$M_u < M_{ulim} \rightarrow$ URS.

④ :-

$A_{st} = \frac{0.5 f_{ck} b d}{f_y} \left[1 - \sqrt{1 - \frac{4.5 M_u}{f_{ck} b d^2}}\right]$

$= 654.08 \text{ mm}^2.$

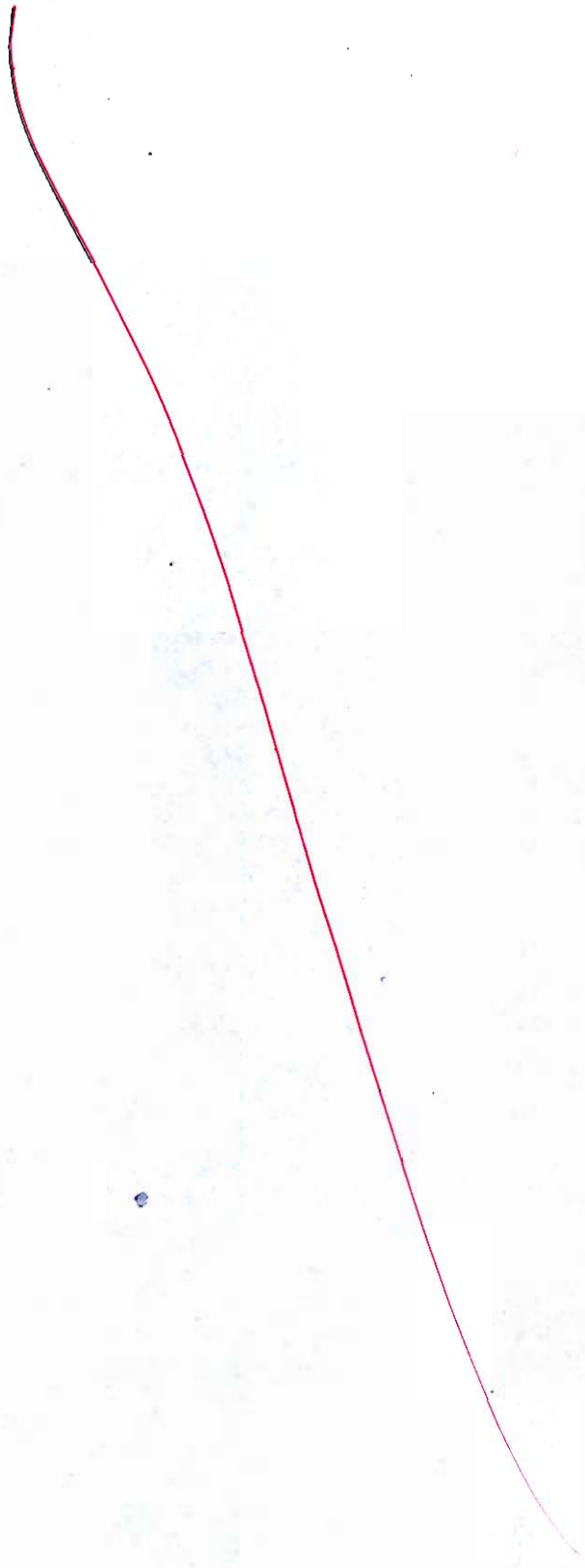
provide 6 No. of 12 mm ϕ bar :-

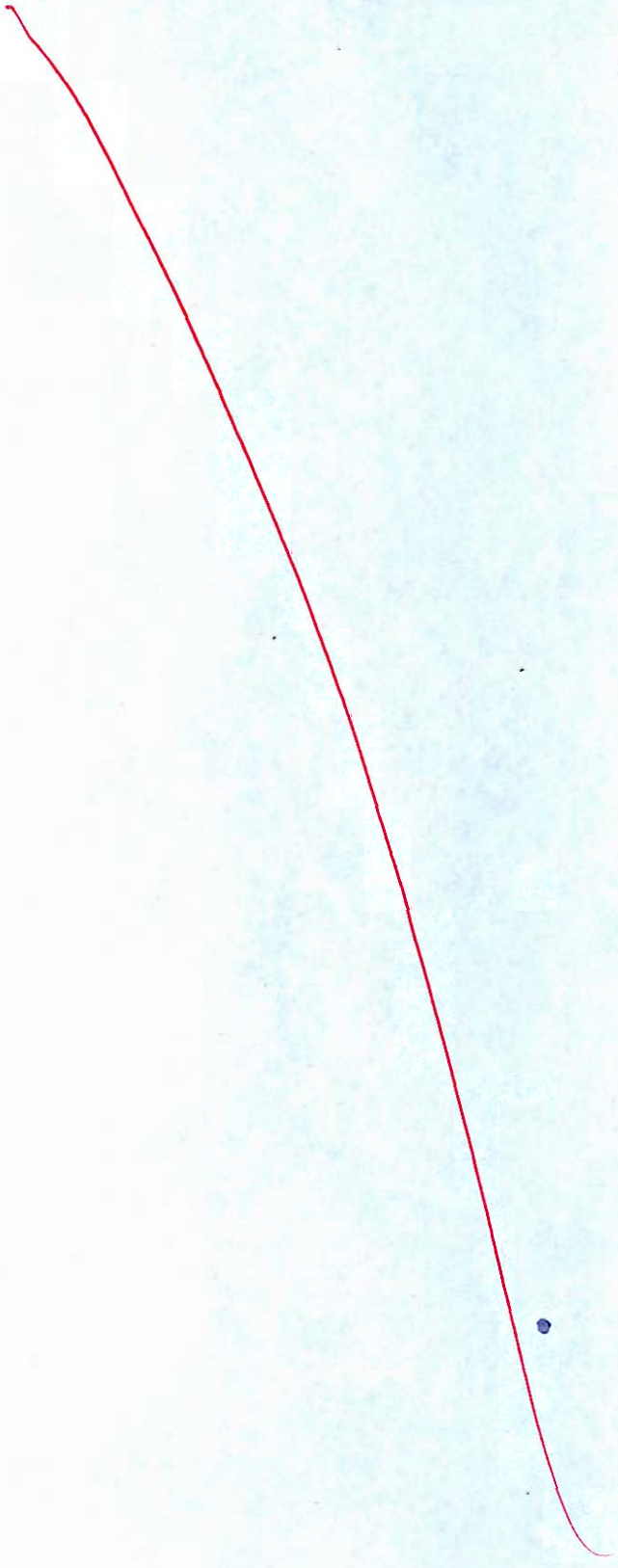
⑤ $V_u = \frac{1.5 W l_c}{2} = \frac{1.5 \times 39.375 \times 2.6}{2}$

$= 76.78 \text{ kN}.$

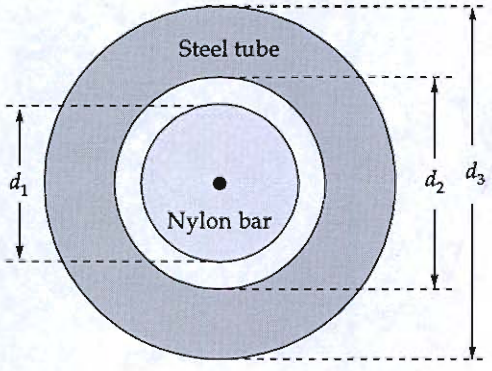
$\tau_v = \frac{V_u}{bd} = 1.2285 < \tau_{max} = 3.5 \text{ Mpa}$

$p\% = \frac{6 \times \frac{\pi}{4} \times 12^2}{250 \times 250} \times 100 = 1.08\%$



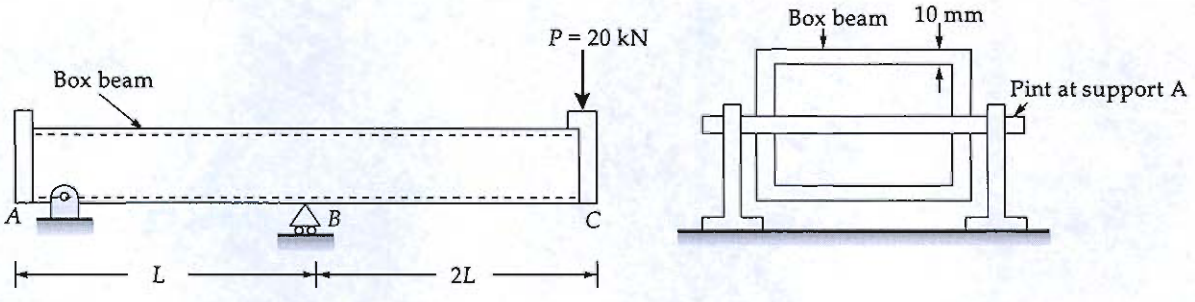


Q.6 (c) (i) A nylon bar having diameter d_1 = 8.8 cm is placed inside a steel tube having inner diameter d_2 = 8.85 cm and outer diameter d_3 = 9.1 cm as shown in the figure. The nylon bar is then compressed by an axial force P. For what value of P, space between the nylon bar and steel tube will be closed so that no stress is developed in steel tube?

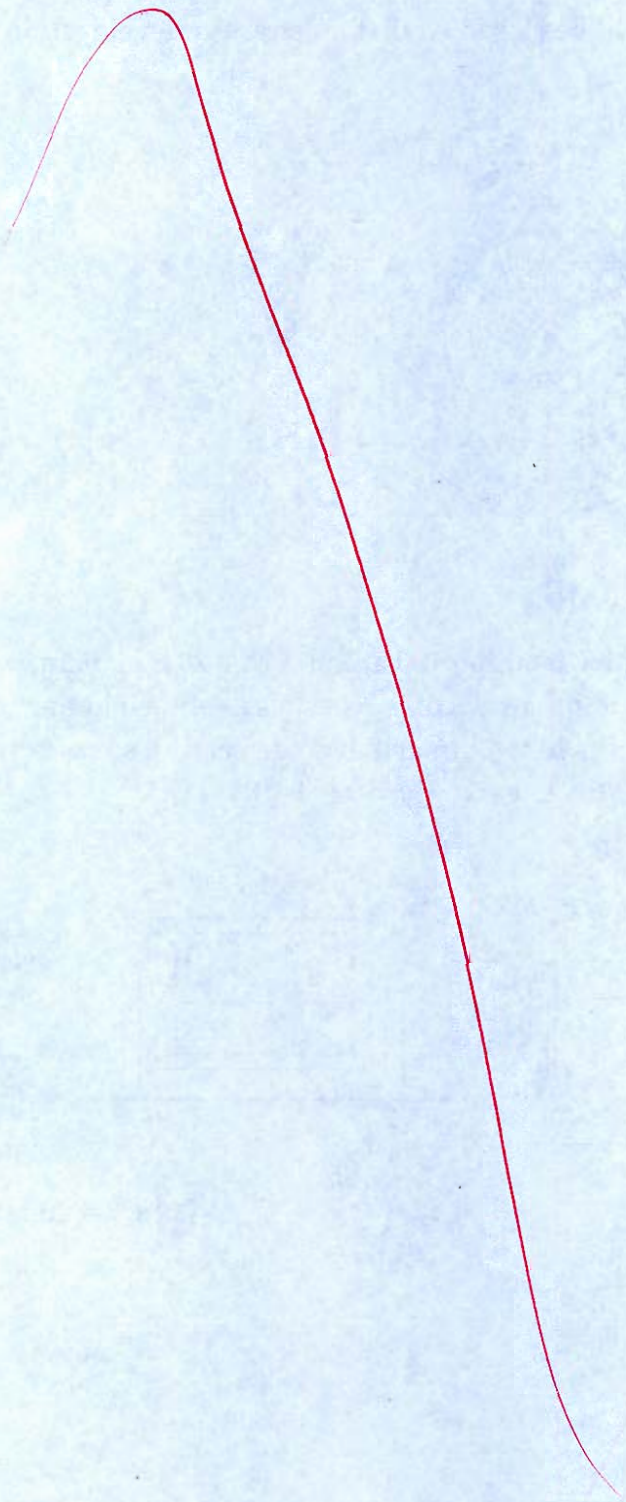


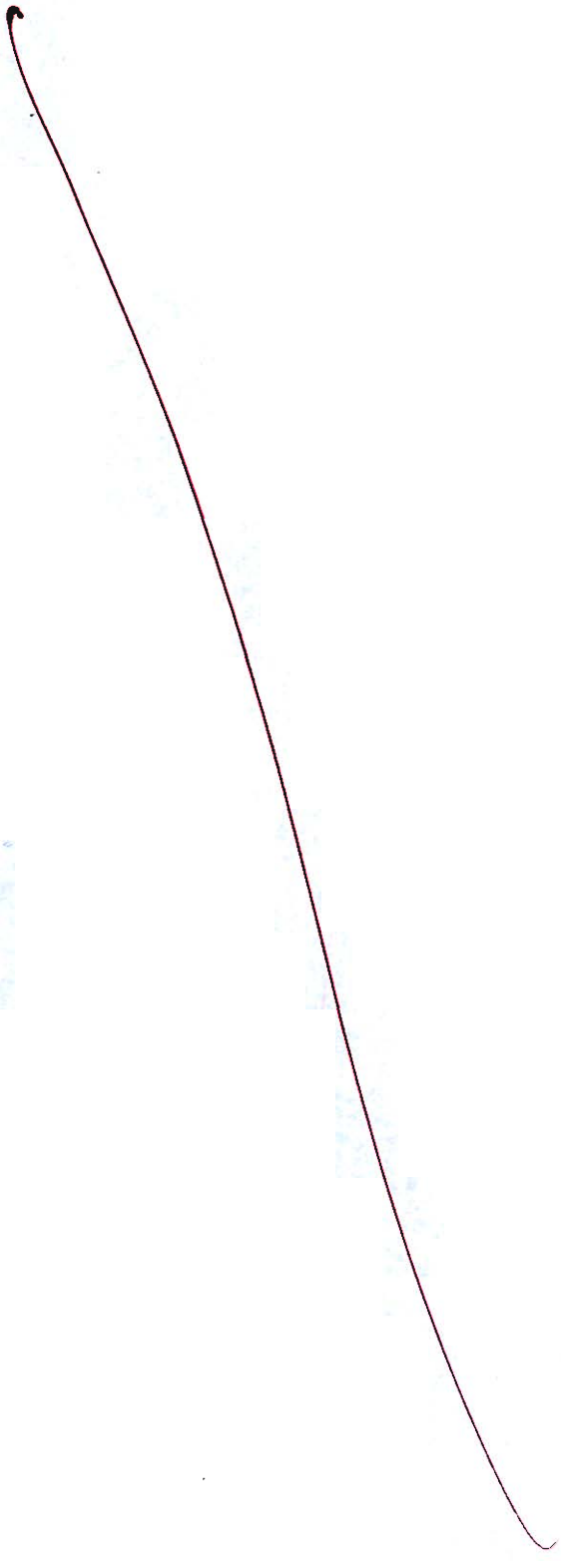
[For nylon, E = 2.7 GPa and μ = 0.4]

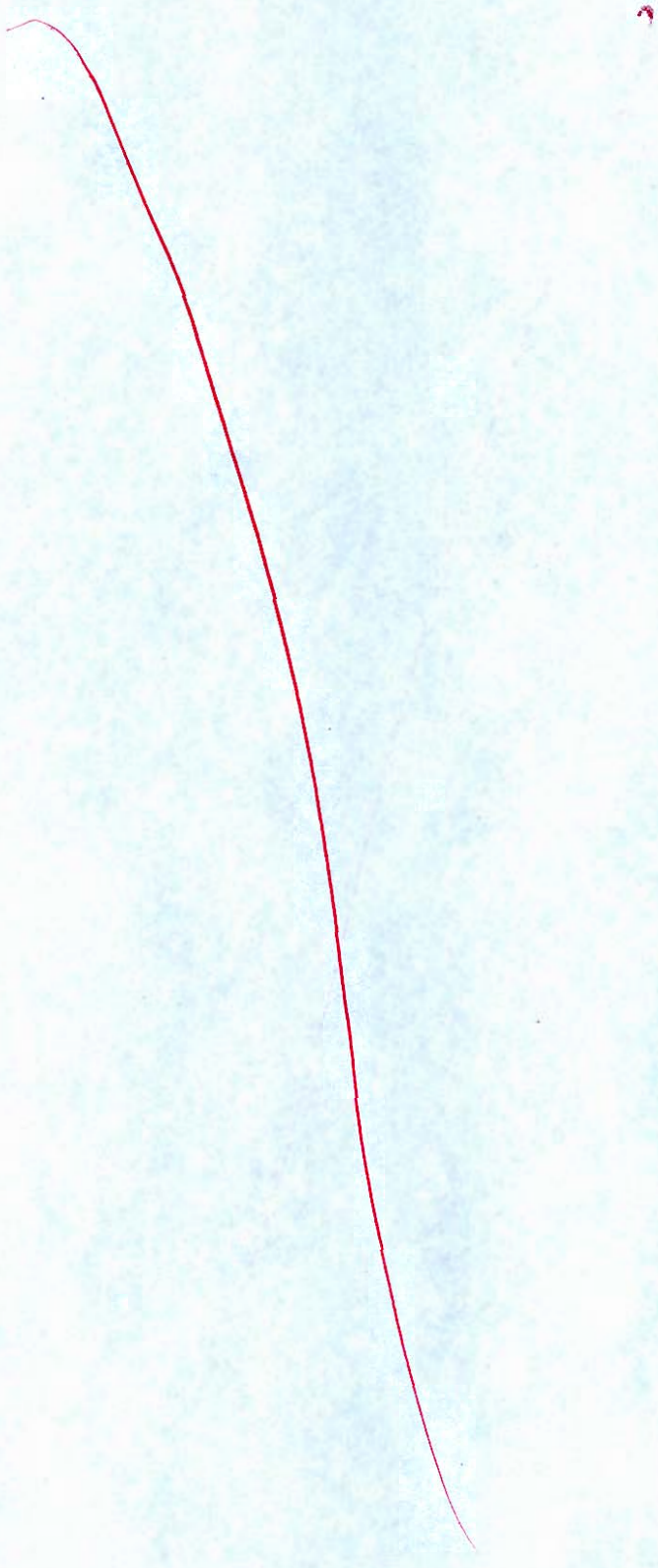
(ii) A hollow box beam *ABC* of length *L* is supported at end A by a 20 mm diameter pin that passes through the beam and its supporting pedestals as shown in the figure. Determine the average shear stress in the pin and average bearing stress between the pin and the box beam if wall thickness of the beam is 10 mm.



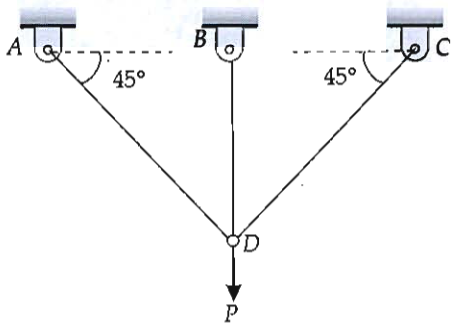
[12 + 8 = 20 marks]







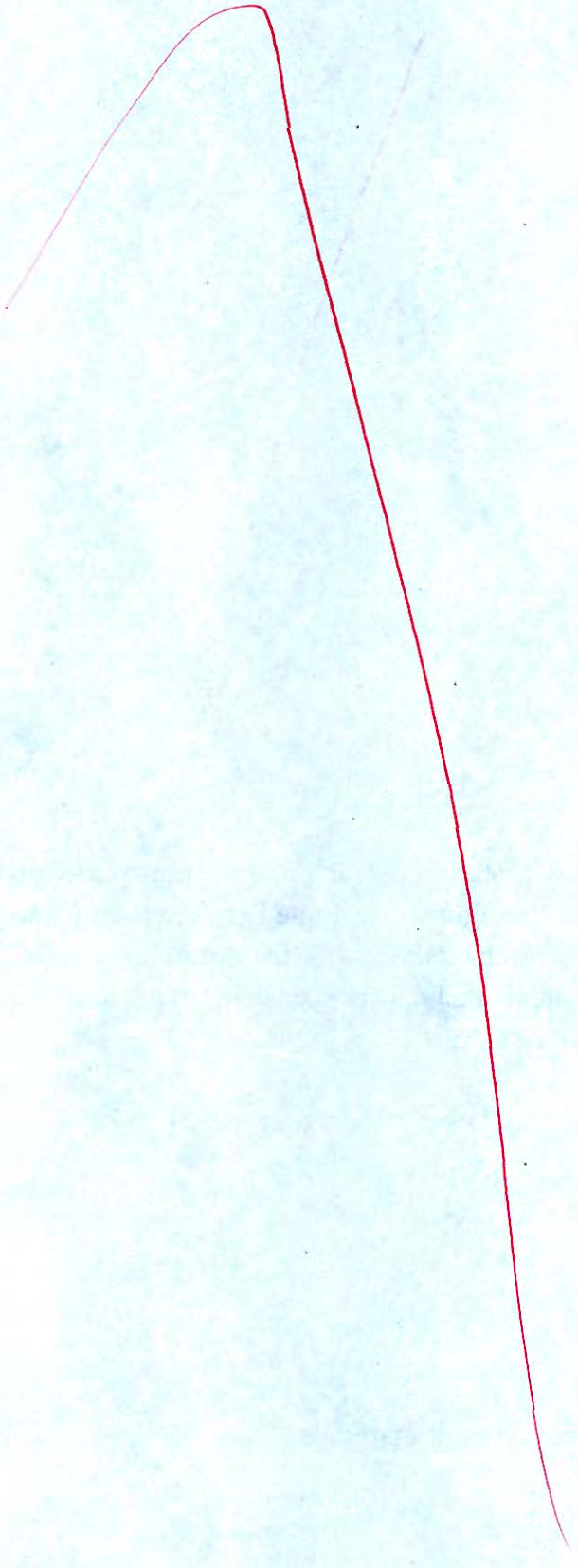
Q.6 (b) (i) A symmetrical framework system consisting of three pin-connected bars is loaded by a force P as shown in the figure. The angle between the inclined bars and the horizontal is 45°. The axial strain in the middle bar is measured as 0.0814. Determine the tensile stress in the outer bars if they are constructed of aluminium alloy having modulus of elasticity, E = 70 GPa.

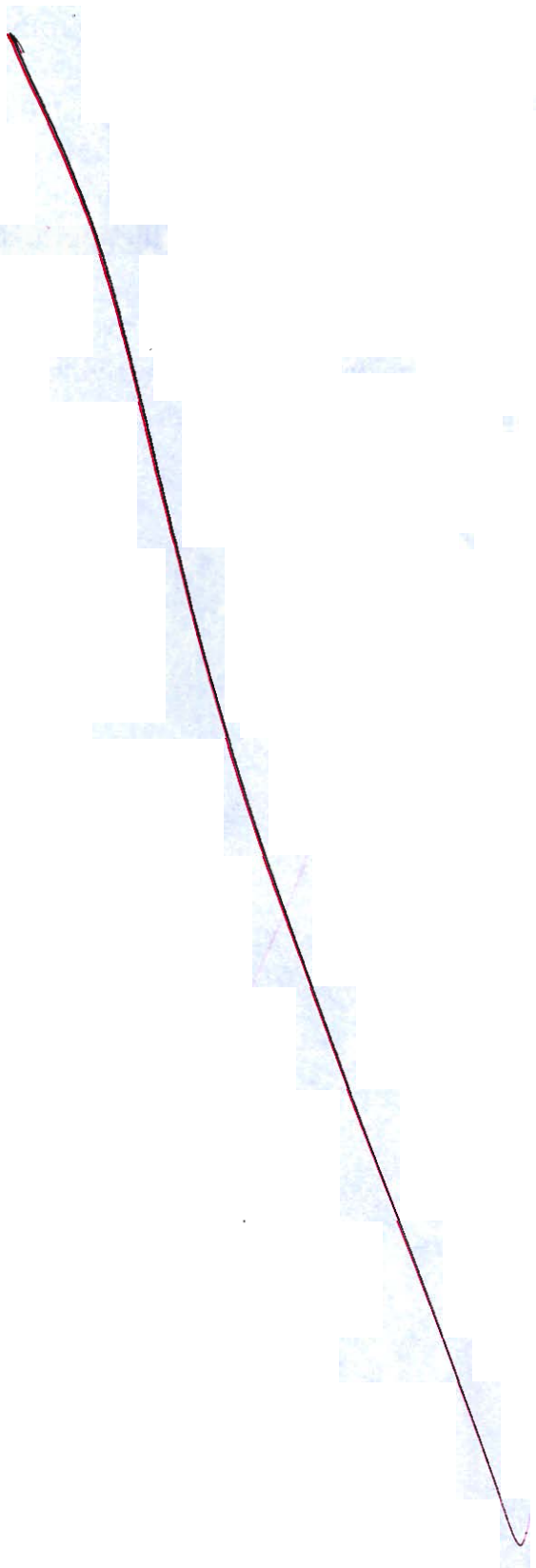


(ii) Explain the following properties of materials

1. Proof stress
2. Modulus of toughness

[14 + 6 = 20 marks]





6 (a) (i) What is forecasting of traffic and its importance. Enumerate the various factors that affect growth of traffic.

(ii) On an approach to a signalized intersection, the effective green time and the effective red time are 30 sec each. The arrival rate of vehicles on this approach is 360 vph between 0 to 120 sec, 1800 vph between 120 to 240 sec, and 0 vph between 240 to 420 sec. The saturation flow rate for this approach is 1440 vphgpl (Vehicles per hour of green per lane). The approach under consideration has one lane. Assume that at time, $t = 0$ sec the light for the approach has just turned red.

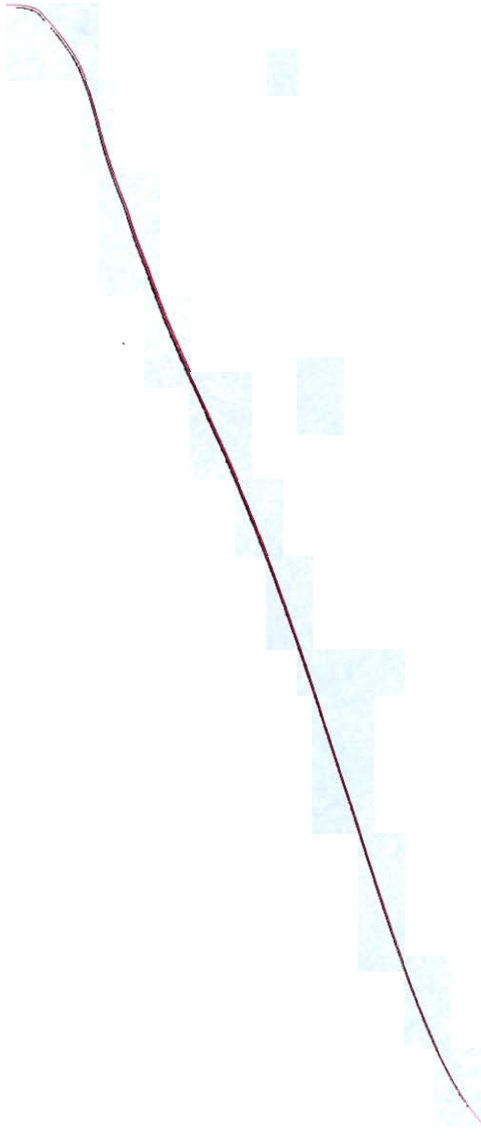
Determine:

(i) the average delay to vehicles arriving between 0 - 120 sec.

(ii) the average delay to vehicles arriving between 120 - 420 sec.

(iii) the average delay to vehicles arriving between 0 - 420 sec.

[10 + 10 = 20 marks]

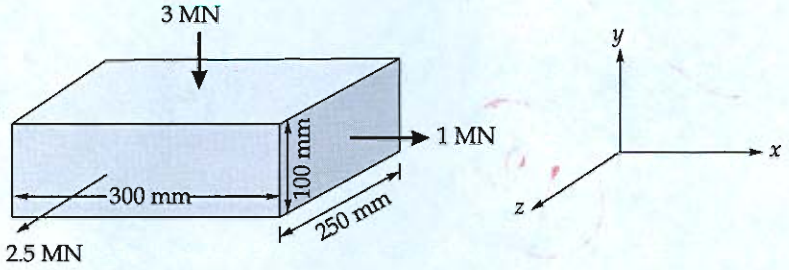


to make $\sigma_z = 0$

2.5 MN must be applied in z direction in -ve side. Ans

12

5 (e) A metallic cuboid of size 300 mm × 250 mm × 100 mm is subjected to the loading as shown in the figure. Determine the change in the volume of cuboid. What additional load should be applied in direction of 2.5 MN load so that no volume change takes place? Assume $E = 2 \times 10^5$ N/mm^2 and $\mu = 0.25$.



[12 marks]

$P_x = 1000$ kN.

$P_y = -3000$ kN.

$P_z = 2500$ kN.

$\sigma_x = \dfrac{1000 \times 10^3}{(250 \times 100)} = 40$ mPa.

$\sigma_y = -40$ mPa.

$\sigma_z = 83.33$ mPa.

$$\epsilon_v = \frac{\sigma_x + \sigma_y + \sigma_z}{E}(1 - 2\mu)$$

$$= \frac{(40 + (-40) + 83.33)}{2 \times 10^5}(1 - 2 \times 0.25)$$

$$= 2.08 \times 10^{-4}$$

$$\Delta V = \epsilon_v \times V$$

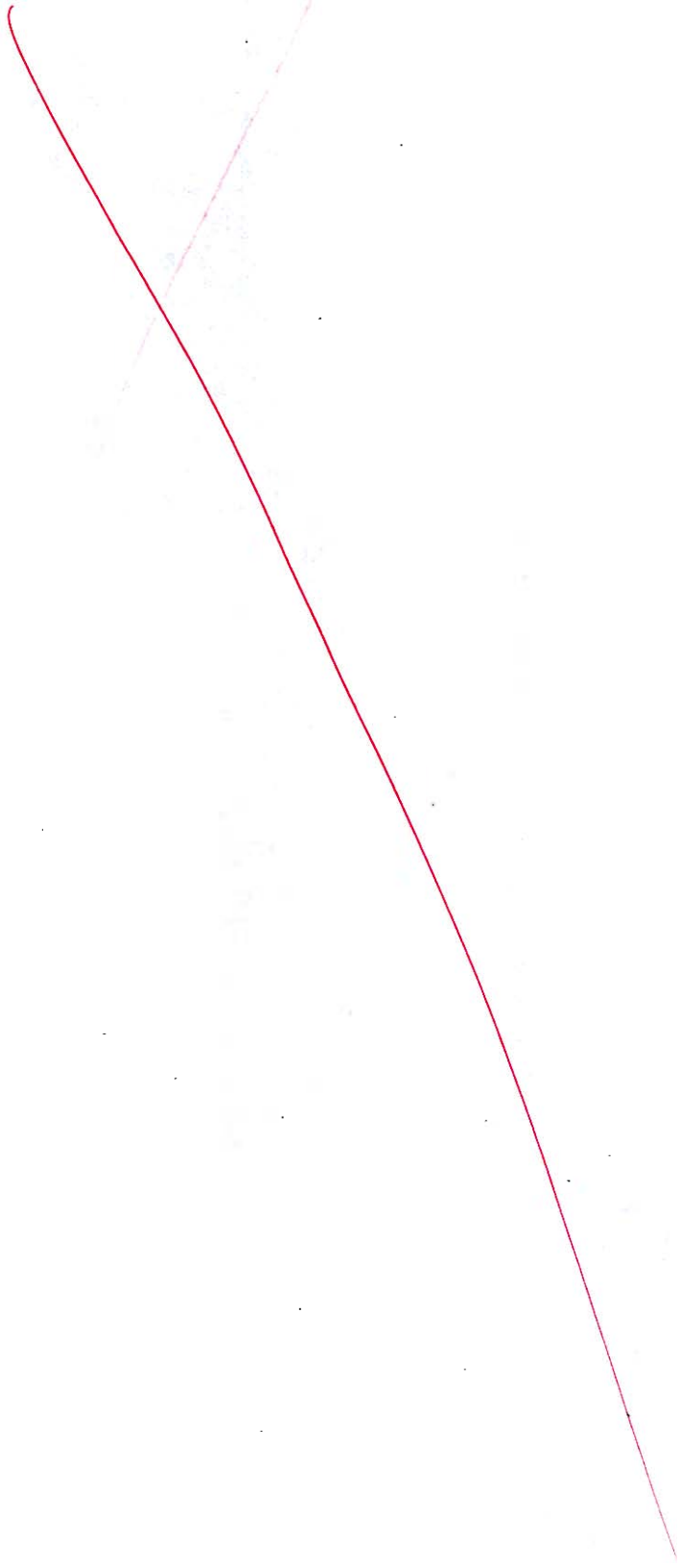
$$= 2.08 \times 10^{-4} \times (300 \times 250 \times 100)$$

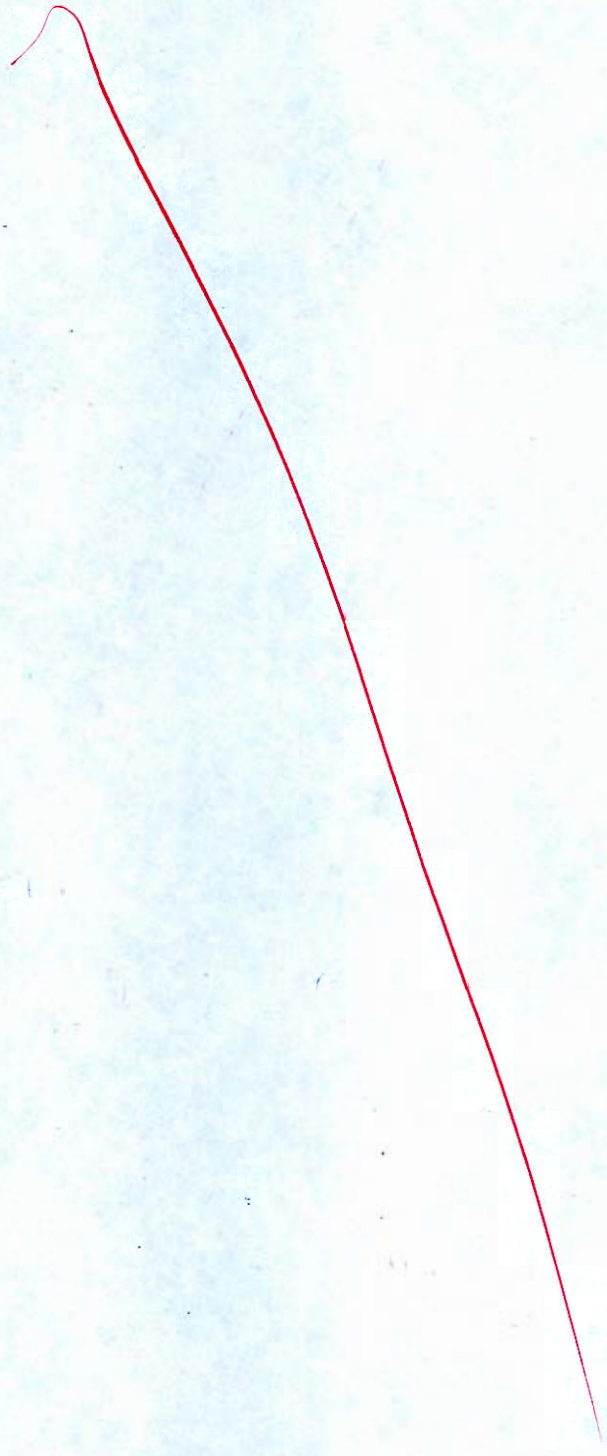
$= 1562.5$ mm^2 Ans

for $\epsilon_v = 0$

$\sigma_x + \sigma_y + \sigma_z = 0$

$40 - 40 + \sigma_z = 0 \Rightarrow \sigma_z = 0$





$$\frac{M}{I} = \frac{\sigma}{y}$$

$$\frac{3.8\times10^6}{\frac{\pi}{64} D^4} = \frac{30}{D/2}$$

$$D^3 = 108.86 \text{ mm}$$ Ans

12

Q.5 (d) What are different type of rocks? Explain briefly.

[12 marks]

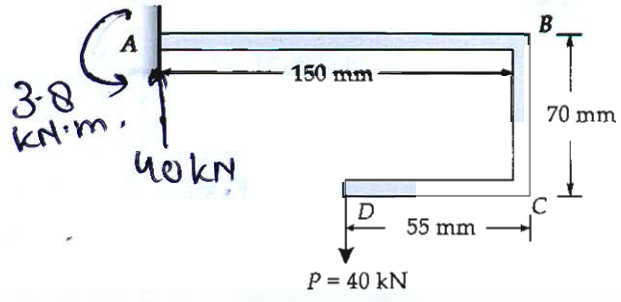
1:- Igneous Rock:- It forms due to explusion of magma from earth core at the same place. It is hard & homogenous.

2:- Sedimentary Rock:- It forms when a rock is weathered & transferred to the another place due to wind & water.

3:- Metamorphic Rock:-

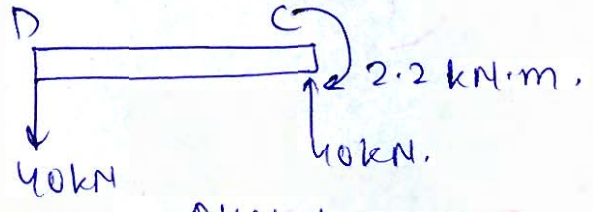
9 6

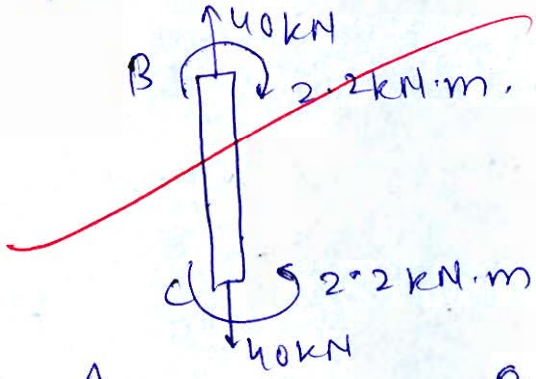
5 (c) A fiber glass bracket ABCD of solid circular cross-section is subjected to a vertical load $P = 40$ kN at its free end as shown in the figure. Determine the minimum permissible diameter of the bracket if the allowable bending stress in the material is 30 MPa.

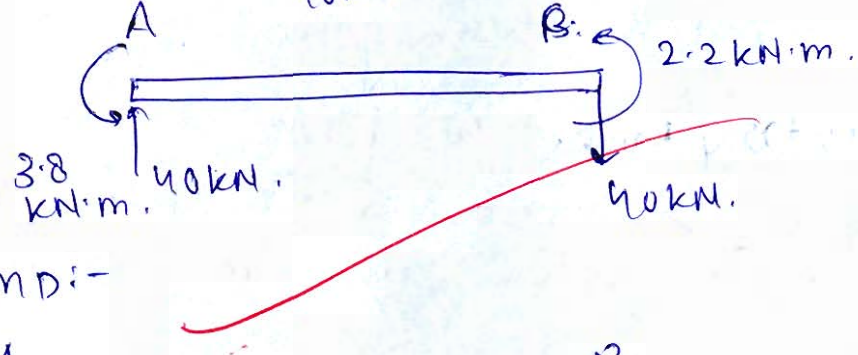


[12 marks]

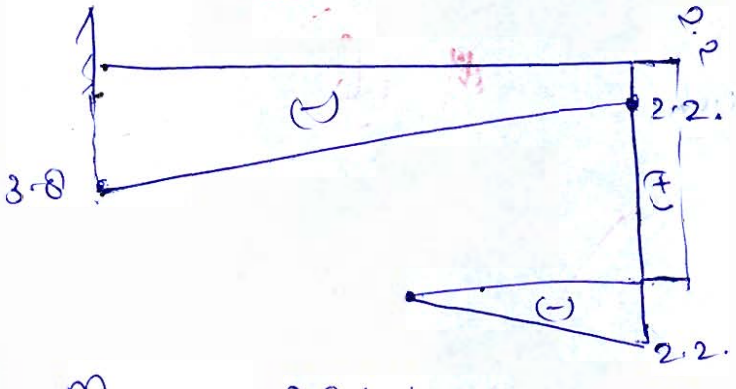
FBD of DC:-



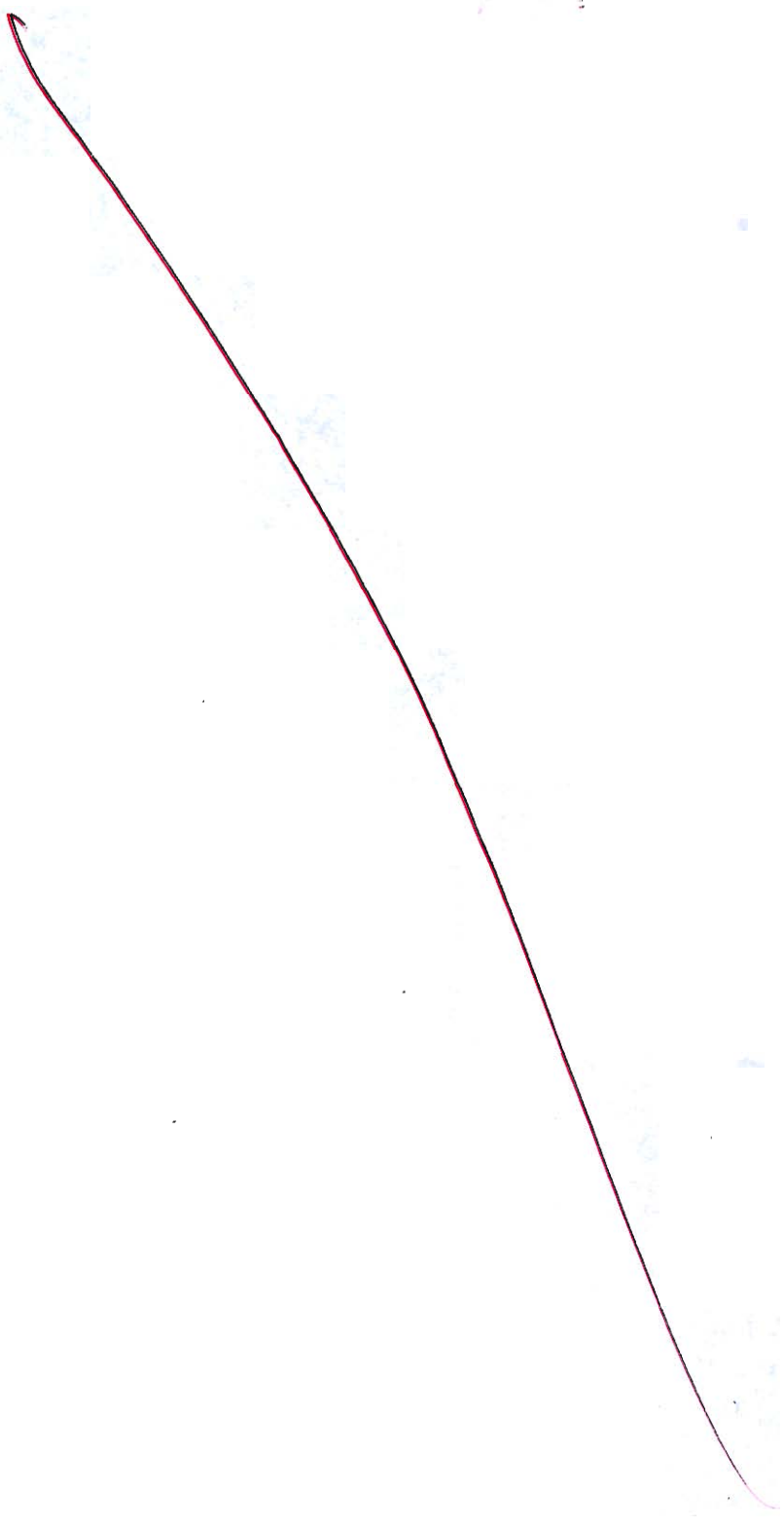




BMD:-



$M_{max} = 3.8$ kN·m.



Q.5 (b) Explain the importance of Engineering Geology and discuss various geological hazards.

[12 marks]

msa = 15.856 msa.

≈ 16 msa.

Now for 16 msa & CBR = 8%

(from table)

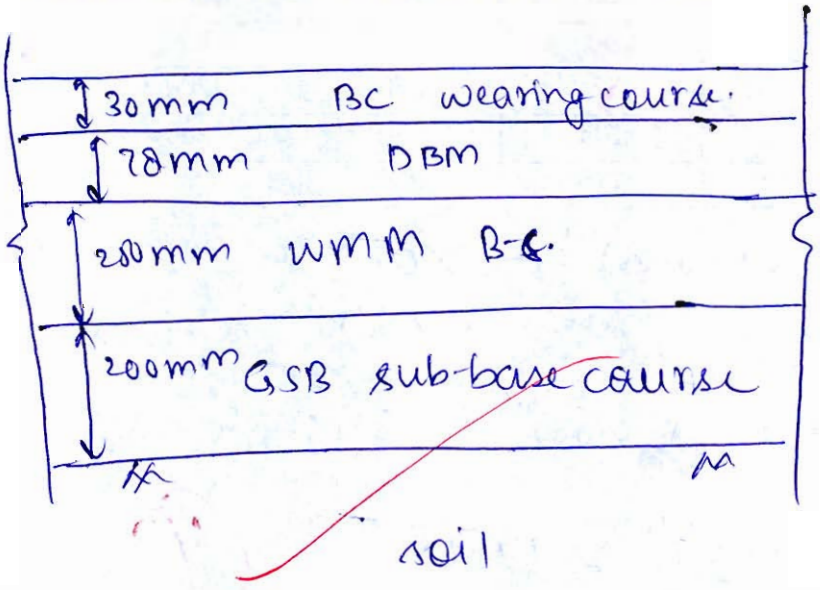
Thickness of BC wearing course = 30 mm

DBM binder course = $60 + \frac{(90-60)}{(20-10)}(16-10)$

= 78 mm.

WMM base course = 250 mm.

GSB sub-base course = 200 mm.



Section B : SOM - 1 + Highway Engineering - 2 + Surveying and Geology-2

.5 (a) Design a flexible pavement for a two-lane undivided carriage way using the following data:
Subgrade CBR value = 8%
Lane distribution factor = 0.5
Design life = 15 years
Planning and construction period = 1.5 years
Present commercial traffic is as under:

Vehicle type	Gross weight (kg)	No. of vehicles per day	Wheel configuration	Growth rate	Standard axle load
Bus	16000	250	Front axle-single rear axle -Dual	5%	8160 kg
Truck	22000	1200	Front axle-single rear axle-tendem	8%	14968 kg

As per IRC 37-2018 the following pavement composition is desired for CBR of 8% subgrade corresponding to different design traffic:

Design traffic (msa)	BC wearing course (mm)	DBM binder course (mm)	WMM base course (mm)	GSB sub-base course (mm)
5	30	50	250	150
10	30	60	250	200
20	30	90	250	200
30	40	95	250	200
40	40	105	250	200
50	40	115	250	200

[12 marks]

$A_{bus} = 250(1+0.05)^{1.5} = 268.98$

≈ 269 veh/day.

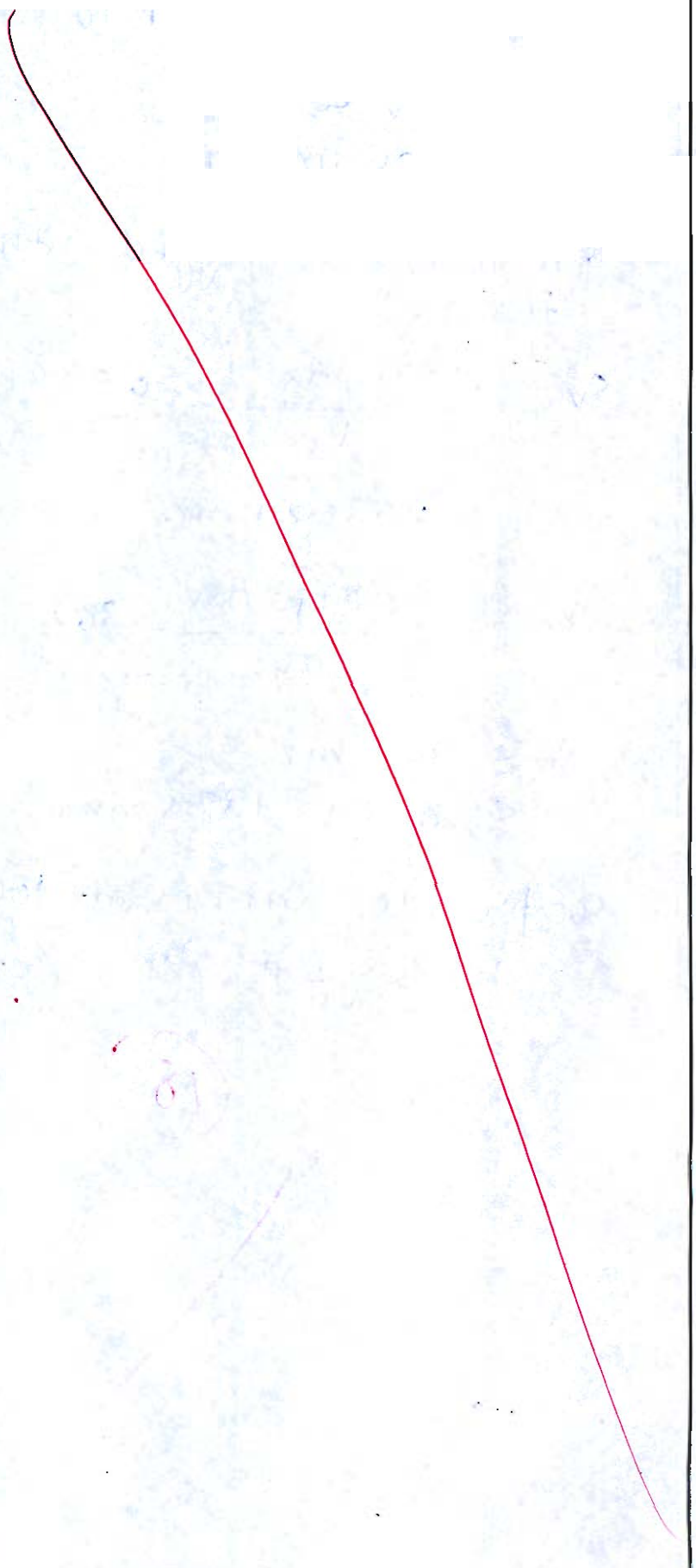
$A_{Truck} = 1200(1+0.08)^{1.5} = 1346.84$ veh/day

$V_{bus} = \left[\frac{16000}{8160}\right]^4 = 14.78$ (4)

$V_{truck} = \left[\frac{22000}{14968}\right]^4 = 4.669$

$$msa = \frac{365A[(1+r)^n - 1]VFD}{r \times 10^6}$$

$$= \frac{365 \times 269(1.05^{15}-1)}{0.05 \times 10^6} \times 14.78 \times 0.5 + \frac{365 \times 1346.84(1.08^{15}-1)}{0.08 \times 10^6} \times 4.669 \times 0.5$$



$$\frac{1.25-1.08}{1.25-1.0} = \frac{0.71-\tau_c}{0.71-0.66}$$

$$\tau_c = 0.677 \text{ MPa.}$$

$$V_s = (\tau_v - \tau_c) bd.$$

$$= 34.46 \text{ kN.}$$

providing 2 legged 8mm ϕ stirrups then

$$S_v = \frac{0.87 f_y A_{sv} d}{V_s} = \frac{0.87 \times 415 \times 2 \times \frac{\pi}{4} \times 8^2 \times 250}{34.46 \times 10^3}$$

$$= 263.32 \text{ mm.}$$

$$S_{v\,min} = \frac{0.87 f_y A_{sv}}{0.4 b} = 362.96$$

$$S_v \leq 300 \text{ mm}$$

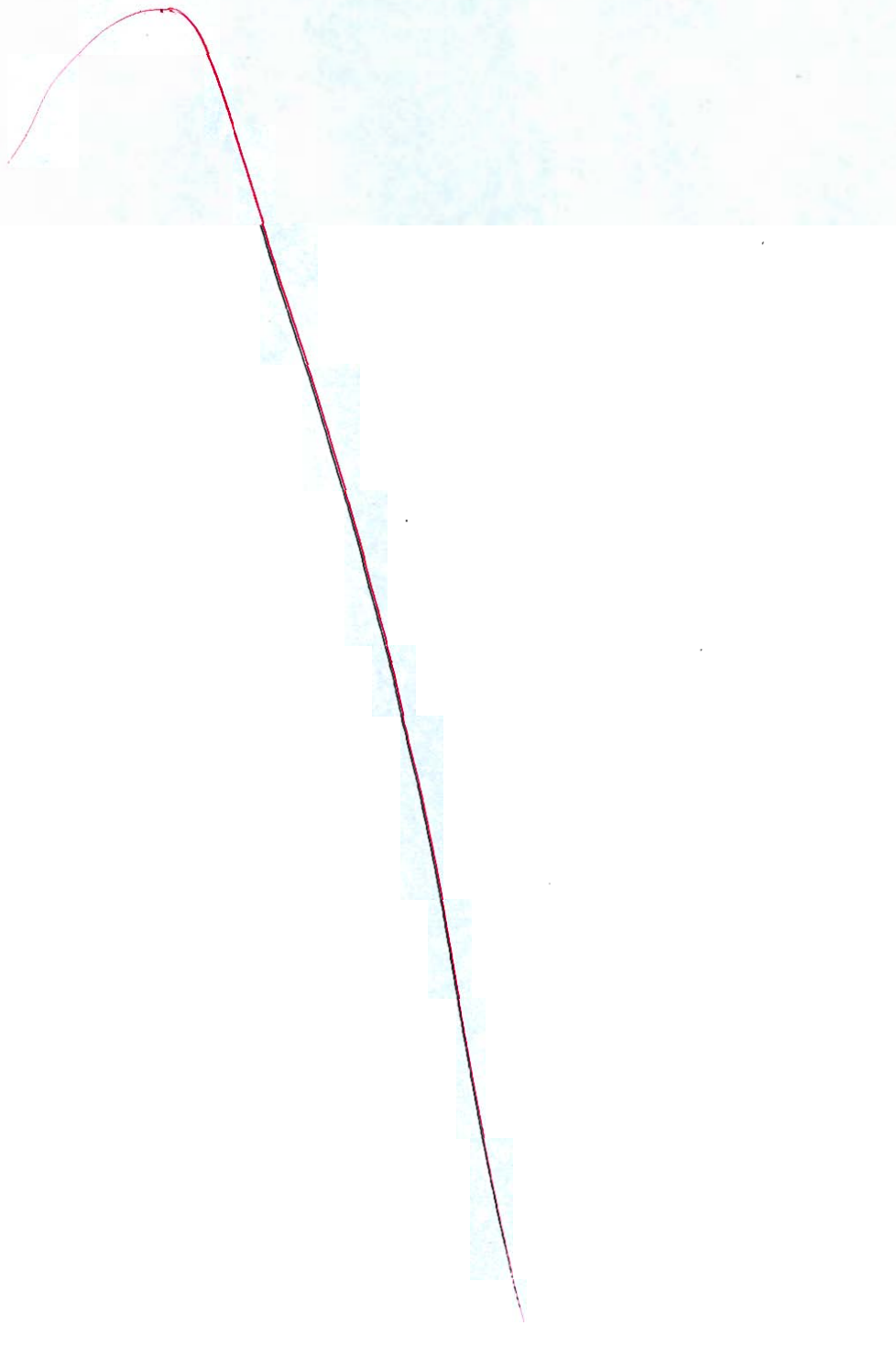
$$\leq 0.75d = 187.5 \text{ mm.}$$

so provide stirrups at 180 mm c/c of 2 legged 8mm ϕ.

18

Space for Rough Work

Space for Rough Work



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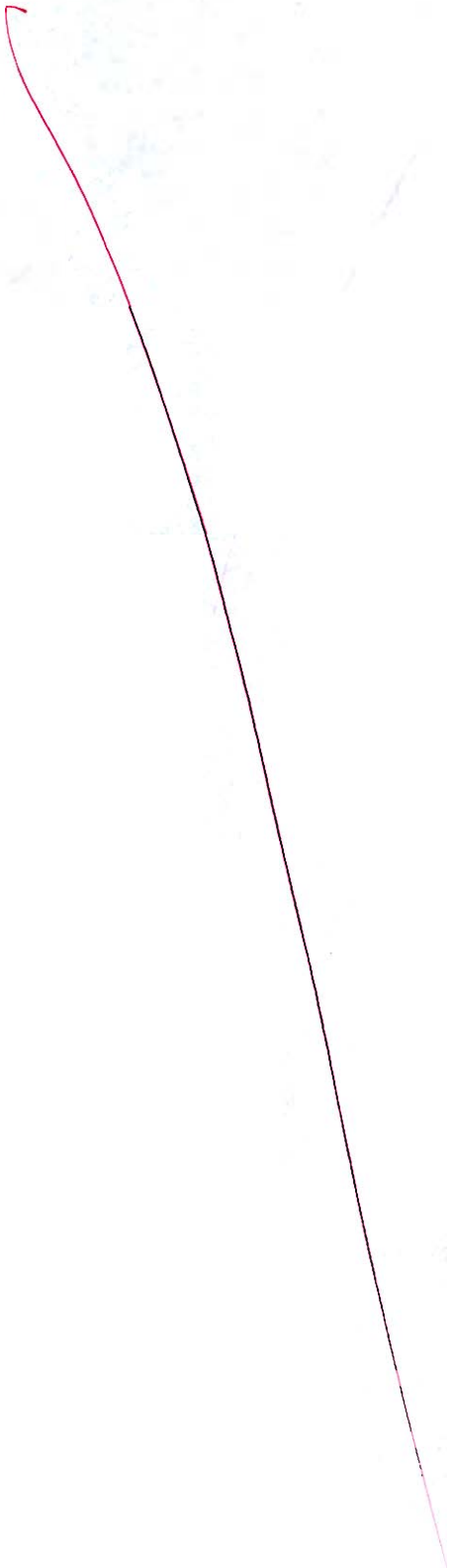
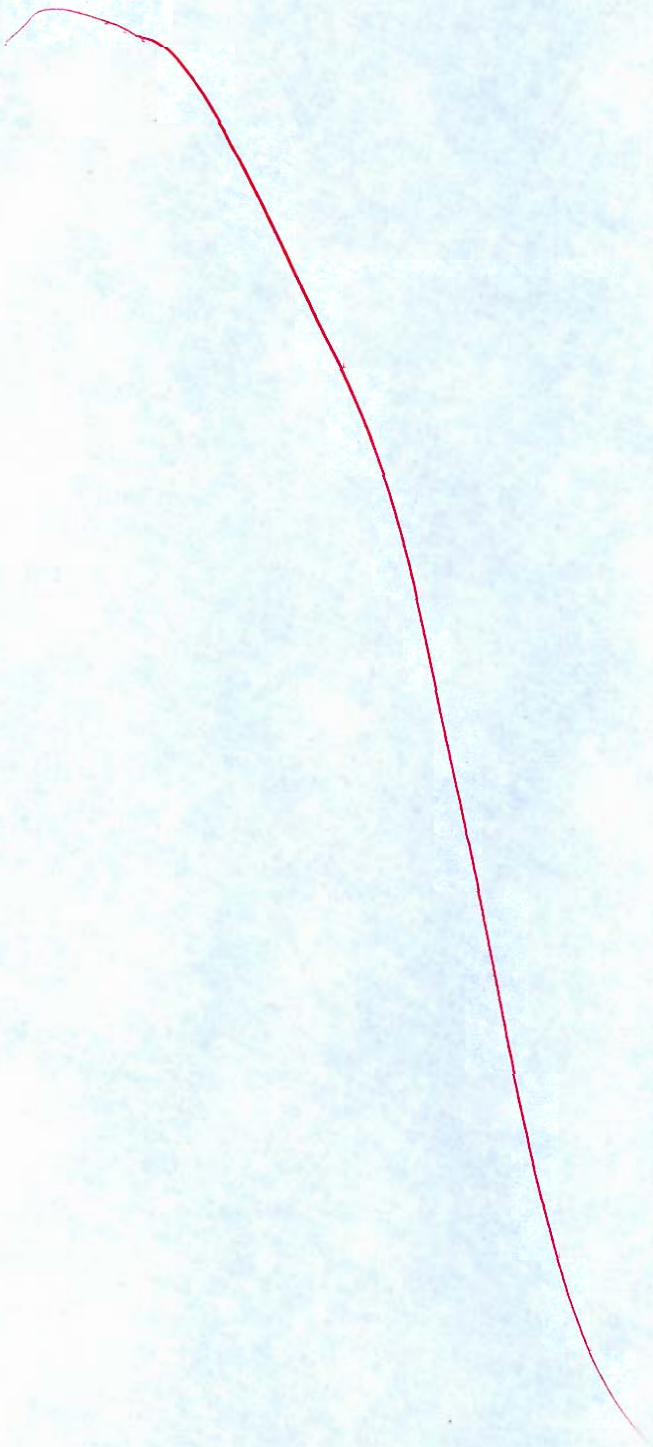




Q.8 (c) (i) Consider the following data:

Wheel load, $P = 5000$ kg

Modulus of elasticity of cement concrete, $E = 3 \times 10^5$ kg/cm^2.

Pavement thickness, $h = 20$ cm.

Poisson's ratio of concrete, $\mu = 0.15$.

Modulus of subgrade reaction, $k = 6.0$ kg/cm^3.

Radius of contact area, $a = 15$ cm.

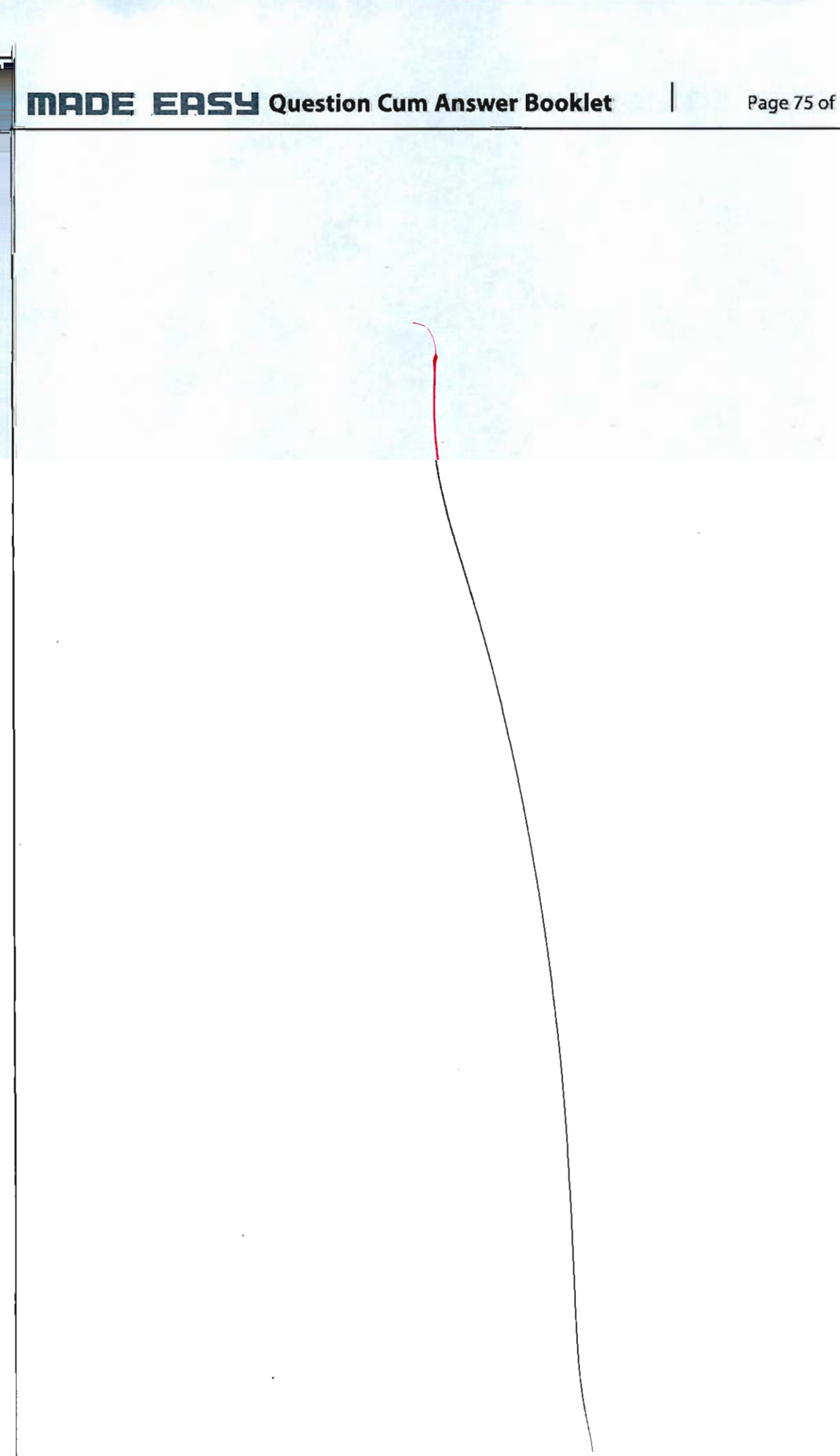
Calculate:

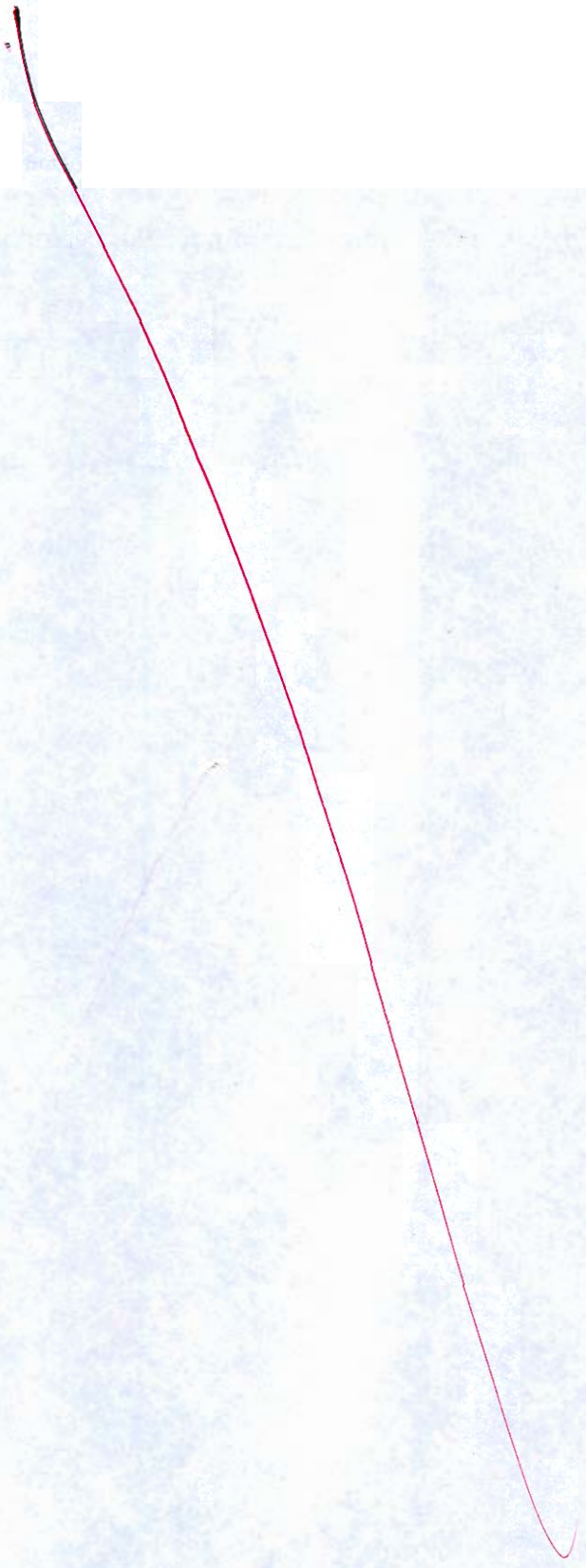
(a) The edge load stresses using modified equation of Teller and Sutherland.

(b) Corner load stress using modified equation of Kelley.

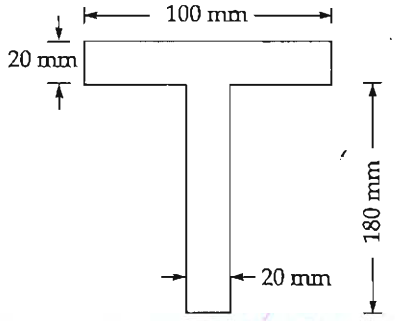
(ii) Write down the construction steps for water bound macadam road?

[12 + 8 = 20 marks]

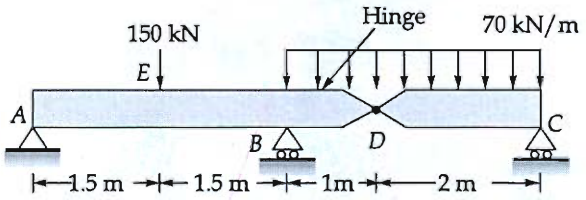




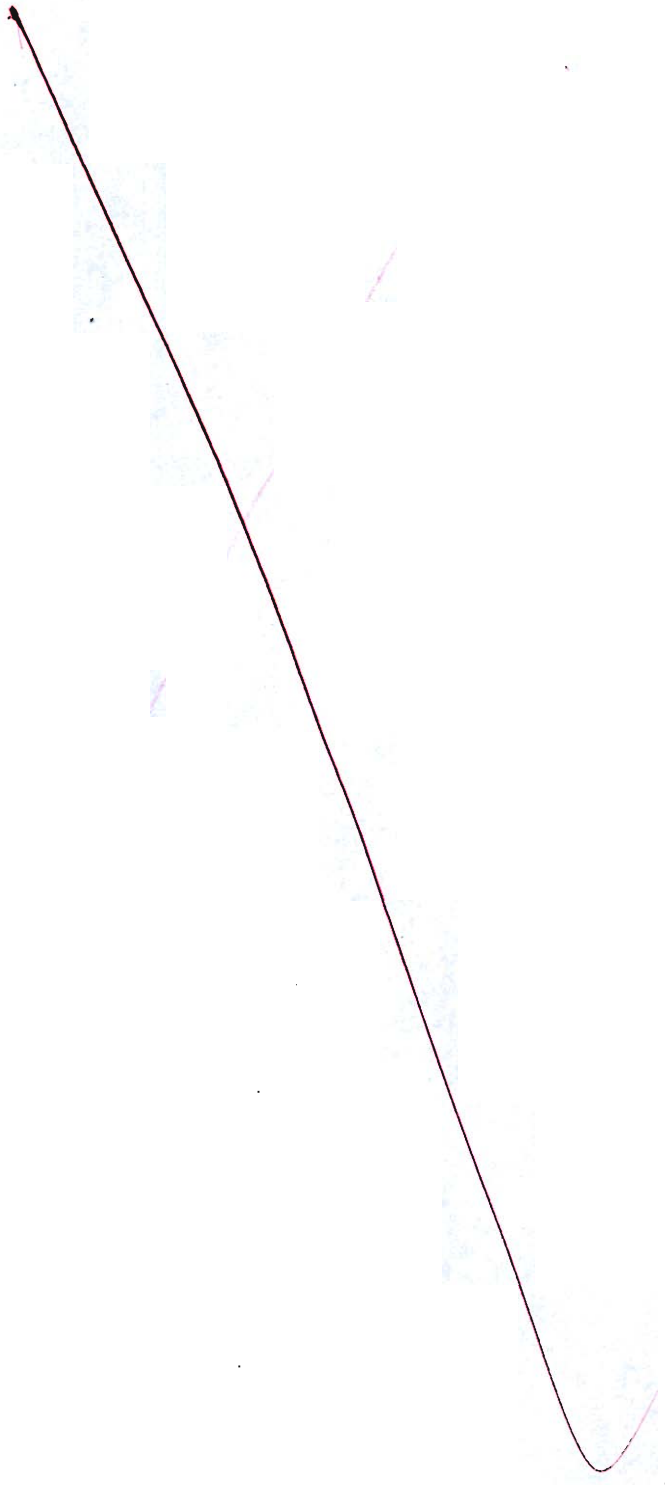
(i) A simply supported beam of T-section (as shown in figure) of span 3 m carries a load of 4 kN at midspan inclined at 20° to the vertical, passing through the centroid of the section. Determine the maximum tensile stress induced in the section.



(ii) Draw the shear force diagram for the beam loading as shown in figure.



[12 + 8 = 20 marks]



Two straight lines intersect at a chainage of 40 chains and 60 links with a deflection angle of 48°. Calculate the necessary data for setting out the curve of radius 380 m using Rankine's method. Use 30 m chain length with 100 links.

[20 marks]

iii):- General guidelines for rotaries:-

⇒ It should be designed when flow is b/w 500-3000 veh/hr.

⇒ Exit radius = 4/3 × Entry radius.

⇒ Island radius = 1.25 Rentry

⇒ W/L should be in range of 0.2-0.4

⇒ $W = \left[\frac{e_1+e_2}{2} + 3.5\right]$

e_1 = entry width

e_2 = exit width.

⇒ e_1 = 10 m for 14 m carriageway width

= 7 m for 10 m " "

3

For leg ① & ②:-

$a = V_{12} = 37$

$b = V_{13} + V_{14} + V_{15} = 303 + 64 + 52 = 419$

$c = V_{52} + V_{42} + V_{32} = 132 + 54 + 122 = 308$

$d = V_{53} + V_{54} + V_{43} = 62 + 15 + 18 = 95.$

$$p_{12} = \frac{b+c}{a+b+c+d} = \frac{419+308}{37+419+308+95}$$

$$= 0.846.$$

$e_1 = e_2 = 10m.$

$L = 50m.$

$$W = \frac{e_1+e_2}{2} + 3.5 = 10 + 3.5 = 13.5.$$

Now.

(a) Rotary capacity $= \dfrac{280\, W\left[1+\frac{e}{W}\right]\left[1-p/2\right]}{\left[1+W/L\right]}$

$$= \frac{280 \times 13.5\left[1+\frac{10}{13.5}\right] \times \left[1-\frac{0.846}{2}\right]}{\left[1+\frac{13.5}{50}\right]}$$

$= 3720.03$ veh/hr.

(16)

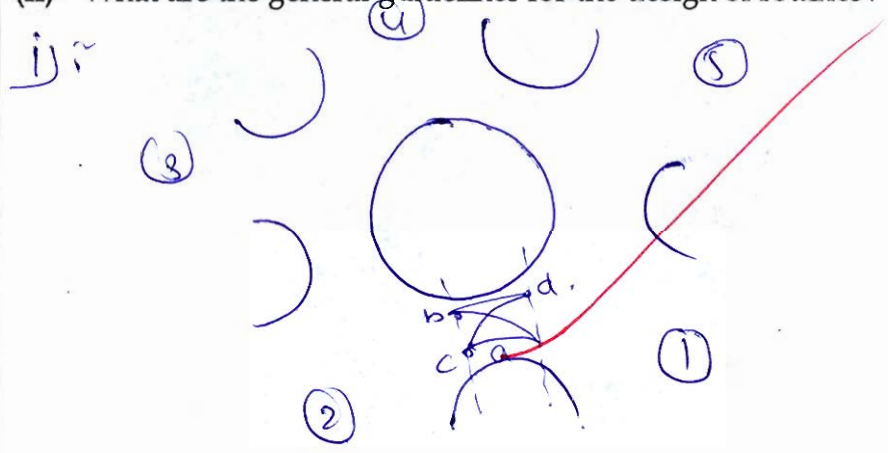
Q.7 (c) (i) A road intersection has five legs designated as 1, 2, 3, 4 and 5. Leg 1 is in N-S direction and others are marked clockwise. The traffic volumes in terms of PCU(V_{ij}) per hour during peak period are given below:

v_{12}	37	v_{31}	466	v_{41}	182	v_{51}	45
v_{13}	303	v_{32}	122	v_{42}	54	v_{52}	132
v_{14}	64	v_{34}	47	v_{43}	18	v_{53}	62
v_{15}	52	v_{35}	657	v_{45}	116	v_{54}	15

Width of carriage way at entry and exit is 10 m.
Weaving length is 50 m.
Find the weaving ratio between the legs 1 and 2, also calculate the practical capacity of rotary corresponding to this weaving ratio.

(ii) What are the general guidelines for the design of rotaries?

[16 + 4 = 20 marks]



Now for θ_p

$$\tan\theta_p = \left|\frac{\epsilon_y - \epsilon_x}{\gamma_{xy}}\right| = 0.975$$

$\theta_p = 44.27°$.

Check:- for $\theta_p = 44.27°$

$\epsilon_{x'} = \epsilon_x \cos^2\theta + \epsilon_y \sin^2\theta + \gamma_{xy} \sin\theta\cos\theta$

$=$

(12)

Q.7 (b) An element of material in plane strain is subjected to strains $\epsilon_x = 450 \times 10^{-6}$, $\epsilon_y = 60 \times 10^{-6}$ and $\gamma_{xy} = 400 \times 10^{-6}$.

Determine the following quantities:

(a) the strains for an element oriented at an angle of 80° anticlockwise from horizontal.

(b) the principal strains.

Also, show the strain element in each case.

[20 marks]

a):- $\theta = 80^0$.

$$\epsilon_{x'} = \epsilon_x \cos^2\theta + \epsilon_y \sin^2\theta + \gamma_{xy} \sin\theta\cos\theta$$

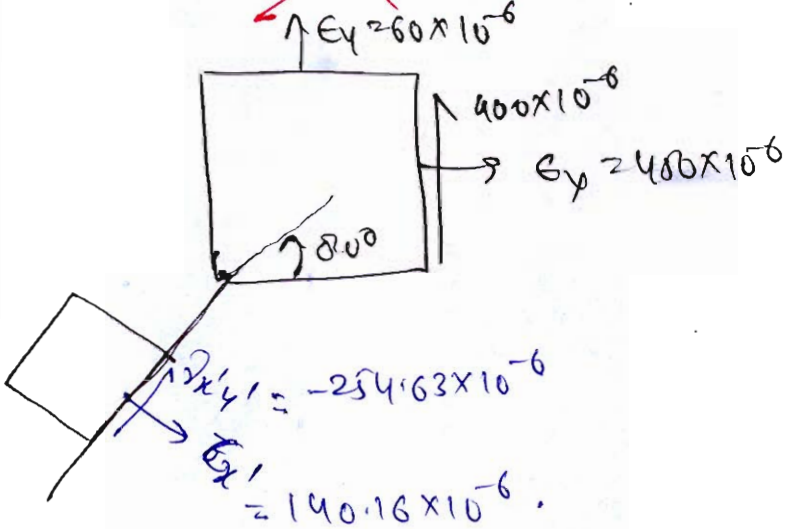
$$= 450\times10^{-6}\cos^2 80 + 60\times10^{-6}\times\sin^2 80 + 400\times10^{-6}\times \sin 80\times\cos 80$$

$$= 140.16\times10^{-6}$$

$$\gamma_{x'y'} = (\epsilon_y - \epsilon_x)\cos\theta\sin\theta + \frac{\gamma_{xy}}{2}(\cos^2\theta - \sin^2\theta)$$

$$= (60-450)\times10^{-6}\times\cos 80\sin 80 + \frac{400}{2}\times10^{-6}(\cos^2 80 - \sin^2 80)$$

$$= -254.63\times10^{-6}$$

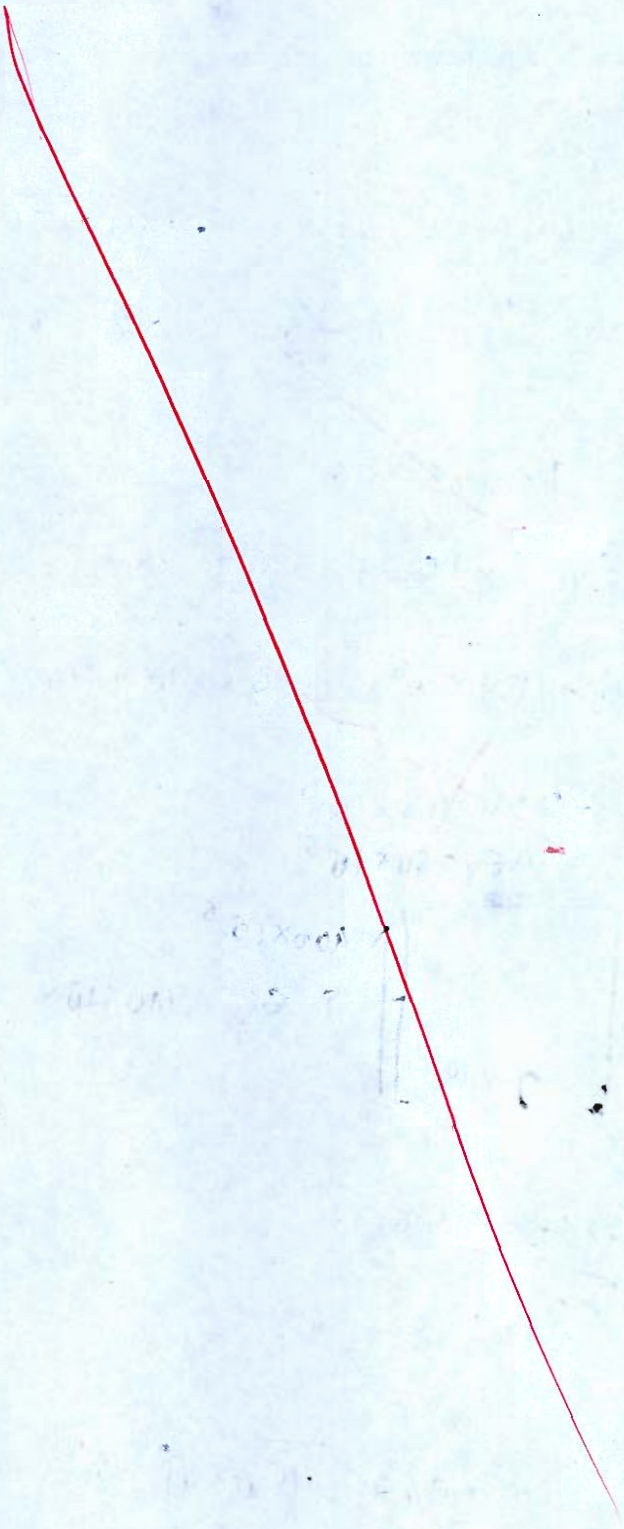


b):-

$$\epsilon_{p_1/p_2} = \frac{\epsilon_x + \epsilon_y}{2} \pm \sqrt{\left(\frac{\epsilon_x - \epsilon_y}{2}\right)^2 + \frac{\gamma_{xy}^2}{4}}$$

$$\epsilon_{p_1} = 534.32\times10^{-6}$$

$$\epsilon_{p_2} = -24.32\times10^{-6}$$



2:- Types of errors:-

i) Human error:- It occurs due to negligence of human.

(5)

ii) Instrumental error:- It occurs due to the defect in the instrument like collimation error.

iii):- Environmental error:- It occurs due to the surrounding like refraction error, or error due to earth curvature.

(a) (i) Determine the number of photographs required to cover an area of 750 sq. km. Given the scale of the photograph is 1 in 10,000 and the photograph format is 250 mm × 250 mm. Consider the longitudinal overlap and side overlap as 65% and 35% respectively.

(ii) 1. What are the various laws of weights?

2. Explain types of errors.

[10 + 10 = 20 marks]

i):- Area = 750 km^2

$b \times d = 250 \times 250\ mm^2$

No. of photographs

$$= \frac{750 \times 10^6 \times 10^6\ mm^2}{250 \times 250 \times (1-0.65) \times (1-0.35) \times (10000)^2}$$

$= 527.47$

$\simeq 528$ No. Ans

10

ii):- 1:- Various law of weight:-