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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 ☐	
Pune ☐	Kolkata ☐	Hyderabad ☐	

Instructions for Candidates

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

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	54
Q.2	55
Q.3	—
Q.4	—
Section-B	
Q.5	45
Q.6	—
Q.7	56
Q.8	43
Total Marks Obtained	253

Signature of Evaluator .... 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.

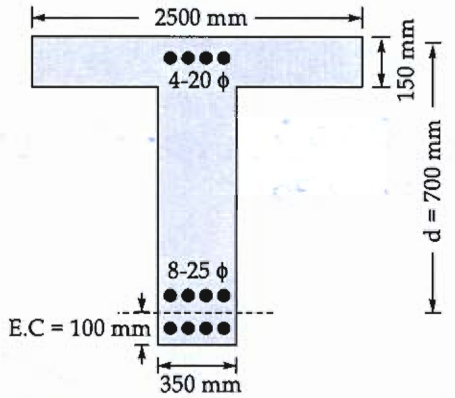
Good, keep it up.

(1) Avoid calculation error.
(2) Accuracy is good.
(3) Revise & practice more & more question.
(4) Improve answer presentat skills.

Do not write in this margin

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]

ol^{n}: Given, $b_w = 350mm$

$A_{st} = 8 \times \frac{\pi}{4} \times 25^2 = 3927 \, mm^2$

$A_{sc} = 4 \times \frac{\pi}{4} \times 20^2 = 1257 \, mm^2$

for shear R/f:

i) $V_u = \frac{w_u l_e}{2}$

LL on beam = 52 kN/m

DL of beam = $(2.5 \times 0.15 \times 1 \times 25) + 0.35 \times \left(\frac{800-150}{1000}\right) \times 1 \times 25$

$= 15.0625 \, kN/m$

Total load, $w = 67.0625$

$w_u = 1.5 \times 67.0625 = 100.59 \, kN/m$

$V_u = \frac{100.59 \times 10}{2} = 502.95 \, kN$

ii $\tau_v = \frac{V_u}{bwd} = \frac{502.95 \times 1000}{350 \times 700} = 2.052$ OK $\not> \tau_{c\,max}$ $(3.5\,N/mm^2)$

iii) $pt\% = \frac{Ast}{bwd} = \frac{3927}{350 \times 700} \times 100 = 1.6\%$

1.50	1.75
0.76	0.80

$\tau_c = 0.76 + \frac{0.8 - 0.76}{1.75 - 1.50}(1.6 - 1.5)$

$\tau_c = 0.776\ N/mm^2$

iv) $V_c = \tau_c bd = 0.776 \times 350 \times \frac{700}{1000} = 190.12$ KN

v) $V_s = V_u - V_c = 502.95 - 190.12 = 312.83$ KN

Assuming vertical shear R/f
2L - 10mm ϕ

$S_v = \frac{0.87 f_y A_{sv} d}{V_s} = \frac{0.87 \times 415 \times 2 \times \frac{\pi}{4} \times 10^2 \times 700}{312.83 \times 1000}$

$= 126.9mm$

~~Both~~

vi) Min^m Shear R/f

$S_v = \frac{0.87 f_y A_{sv}}{0.4 B} = 405.09mm$

vii Max^m spacing i) $0.75d = 0.75 \times 700 = 525mm$

ii) 300mm

[Provide 2L - 10mm @ 120mm cc] As

10

Q.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]

06

Assumption in LSM as per IS 456

a) for flexure :

i) The max^m compressive strain in bending in Concrete is 0.0035

ii) Plane section remain plane before & after bending

iii) Stress diagram for concrete is parabolic upto 0.002 strain & straight upto strain = 0.0035

iv) Tensile strength of concrete is ignored

v) Design stress in concrete = 0.45 fck (FOS = 1.5) & in steel = 0.87 fy (FOS = 1.15)

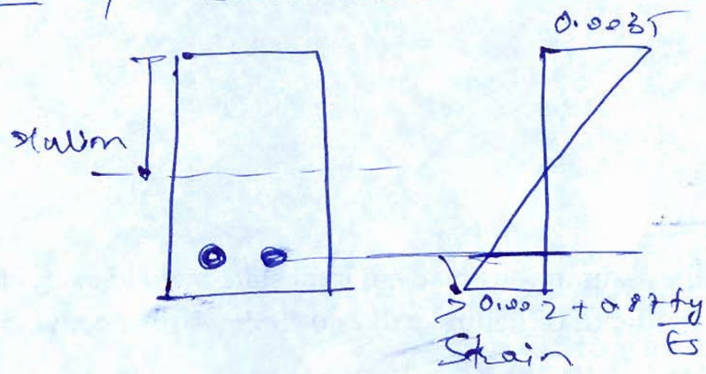
The max^m strain at failure (in steel) should not less than $0.002 + \frac{0.87 f_y}{E_s}$

b) Compression:

i) The max^m compressive strain in axial compression $= 0.002$

ii) The max^m compressive strain in axial comp and bending and no tension $= 0.0035 - 0.75\, \epsilon_{Lcf}$

Limiting depth of neutral axis



$$\frac{0.0035}{x_{ulim}} = \frac{0.002 + \frac{0.87 f_y}{E_s}}{d - x_{ulim}}$$

$$\frac{d - x_{ulim}}{x_{ulim}} = \frac{0.002 + \frac{0.87 f_y}{E_s}}{0.0035}$$

$$\frac{d}{x_{ulim}} - 1 = \frac{0.002 + \frac{0.87 f_y}{E_s}}{0.0035}$$

$$\frac{d}{x_{ulim}} = \frac{0.002 + \frac{0.87 \times 415}{2\times 10^5}}{0.0035} + 1$$

$E_s = 2\times 10^5$
$f_y = 415\ N/mm^2$

$x_{ulim} = 0.48d$

$\therefore$ x_{ulim} is $0.48d$ if Fe415 is used

Q.1 (c) Find the working moment of resistance of a beam section 300 mm × 600 mm (overall depth) reinforced with 800 mm² compression steel and 2160 mm² tension steel. Use M25 grade of concrete and Fe415 grade of steel.

Assume stress in compression steel as 350 N/mm² and take effective cover as 50 mm in both tension and compression.

[12 marks]

ns:

Given

$B = 300mm$

$D = 600mm$

$EC = 50\ mm$

$d = 550mm \quad d_c = 50mm$

$A_{sc} = 800mm^2$

$A_{st} = 2160\ mm^2$

$f_{sc} = 350\ N/mm^2$

Using LSM:

Let $C_1 + C_2 = T$

$0.36 f_{ck} B x_u + (f_{sc} - 0.45 f_{ck}) A_{sc}$

$= 0.87 f_y A_{st}$

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

$= 0.87 \times 415 \times 2160$

$x_u = \underline{188.47 mm}$

$x_{ulim} = Kd$

$= 0.48 \times 550 = \underline{264 mm}$

$x_u < x_{ulim}$ → OK

$\therefore (MOR)_u = C_1 LA_1 + C_2 LA_2$

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

$0.36 \times 25 \times 300 \times 188.47 \times (550 - 0.42 \times 188.47)$

$+ (350 - 0.45 \times 25) \times 800 \times (550 - 50) / 10^6$

$(MOR)_u = \underline{375.1}$ KN-m

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$(MR)_w = \frac{M_u}{\gamma_f}$ Assuming $\gamma_f = 1.5$

$= \frac{M_u}{1.5} = \frac{375.1}{1.5}$ KN-m Ans

$= \underline{250.1 \text{ KN-m}}$ Ans

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

[12 marks]

Ans: The system of prestressing are :

i) Pretensioning

ii) Post tensioning

a) Pretensioning : This ~~system~~ system for prestressing is used for repititive type of construction

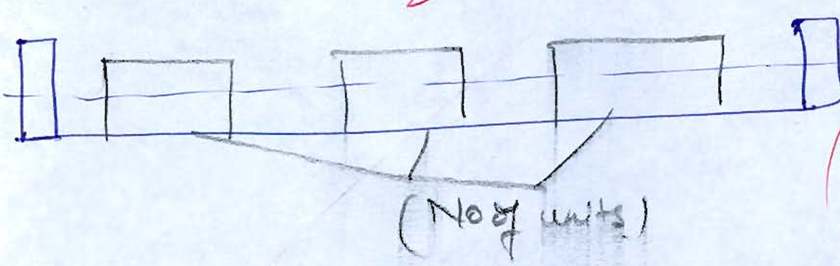
For: Railway sleepers. For pretensioning the most common methods used are

Honner / Long line method

In Pretensioning:

Process: Tensioning → Concrete → Stress application

In this process the steel is tensioned first between two ends and the steel is tied. The concreting is done and after successful gain of strength of concrete the wire are cut and stress is applied due to bond of tendons & concrete



PRETENSIONING

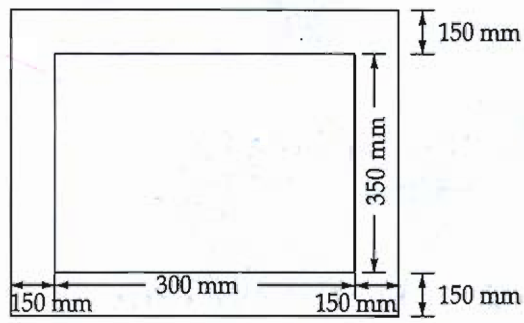
b) Post tensioning:

In this system the concrete is casted first with hollow ducts to accomodate tendons. The tendons are tensioned and anchored simultaneously and stress is transferred by bearing stress b/w concrete & steel

Process: Concreting — Tensioning — Anchoring

The various methods of anchoring are
i) Freessinet ii) Magnel Blatton iii) Gifford Udall
iv) Lee Mccall v) PSC Monowire

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]

Ans: Given:

BM = 285 KN/m

BMu = 1.5 × 285 = 427.5 KN-m

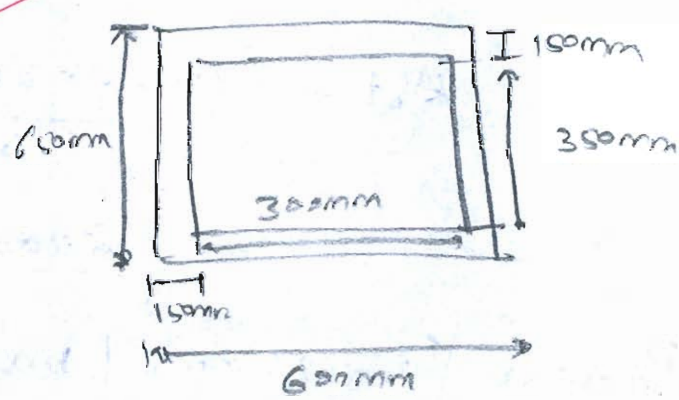
D = 650 mm

B_f = 600 mm

bw = 300 mm

EC = 50 mm

d = 600 mm



Assuming the NA is in flange: $x_u \le D_f$

$BM_u = 0.36 f_{ck} B_f x_u (d - 0.42 x_u)$

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

$\frac{427.5 \times 10^6}{0.36 \times 25 \times 600} = 600 x_u - 0.42 x_u^2$

$0.42 x_u^2 - 600 x_u + 79166.67$

$x_u = 147.08 mm$

Check: $x_u < D_f$

∴ NA is in flange

$x_{ulim} = 0.48 \times d = 288 mm$

∴ $x_u < x_{ulim}$ → and x_u is in flange

∴ Ast calculation:

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

$$A_{st} = \frac{0.36 \times 25 \times 600 \times 147.08}{0.87 \times 415}$$

$= 2200 mm^2$

Provide 5 - 25mm bars.

10

Reinforcement Detailing ?

Q.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]

s: Given $P = 3600$ KN

$P_u = 3600 \times 1.5 = 5400$ KN

$L_o = 5m$

$l_{eff} = 0.65 \times 5 = 3.25m$

Conditions:

i) Short column: ~~~~

) Axially loaded

) $e_{min} < 0.05D$

Let $e_{min} = 20mm$

$0.05D = 20$

$D = 400mm$

Let Diameter of column = 400mm

$SR = \frac{3210}{400} = 8.125 < 12$

for a helical column

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

$5400 \times 10^3 = 1.05 [0.4 \times 30 \times (\frac{\pi}{4} \times 400^2 - A_{sc}) + 0.67 \times 415 \times A_{sc})$

$A_{sc} = 1366.44 \ mm^2$

Let diameter of column is 600mm

$e_{min} = (\frac{5000}{500} + \frac{600}{30}]$ or 20mm

$= 30mm$

i) $e_{min} \leq 0.05D$

ii) Short column $\Rightarrow SR = \frac{3250}{600} = 5.41 < 12$

iii) Axially loaded

$\therefore \frac{P_u}{1.05} = 0.4 f_{ck} A_c + 0.67 f_y A_{sc}$

$\frac{5400 \times 10^3}{1.05} = 0.4 \times 30 \times (\frac{\pi}{4} \times 600^2 - A_{sc}) + 0.67 \times 415 \times A_{sc}$

$= 6577.47$ → units ??

$$Psc\% = \frac{65777}{\frac{\pi}{4} \times 600^2} = 2.32\% \; > 0.8\% \; < 4\%$$

[OK]

Provide = 10 – 32 mm bars

Design of helical R/f :

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

Let EC = 40 + 16 = 56 mm

D_g = 600 mm

D_c = 600 − 2×56 = 488 mm

D_h = 488 − 10 = 478 mm

ϕ_h = 10 mm

$$0.36 \times \frac{30}{415}\left(\frac{\frac{\pi}{4}\times 600^2}{\frac{\pi}{4}\times 488^2} - 1\right)$$

$$\le \frac{\frac{1000}{p} \times \frac{\pi}{4} \times 10^2 \times \pi \times 478}{\frac{\pi}{4} \times 488^2 \times 1000}$$

p = 47.38 mm

Let pitch = 45 mm

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pitch ≯ 75 mm — OK

pitch ≯ $\frac{D_c}{6} = \frac{488}{6} = 81$ — ok

pitch ≮ 25 mm — ok

pitch ≮ $3\phi_h$ = 30 mm — OK

∴ provide 10 mm bars @ 45 mm pitch

Ans: Difference b/w WSM & LSM :

a) In WSM :

i) The FOS for concrete is taken as 03 and for steel is taken as 1.8

ii) WSM stresses the concrete to a less level as LSM stresses the concrete

iii) Strain & stress diagram are linear

iv) Stress controlled approach

v) No FOS is taken to load values. ie services loads are taken

vi) WSM is more conservative approach

b) In LSM :

i) FOS for concrete is 1.5 & steel = 1.15

ii) LSM stresses the concrete to a higher level

iii) Strain diagram is linear while stress diagram is parabolic & straight

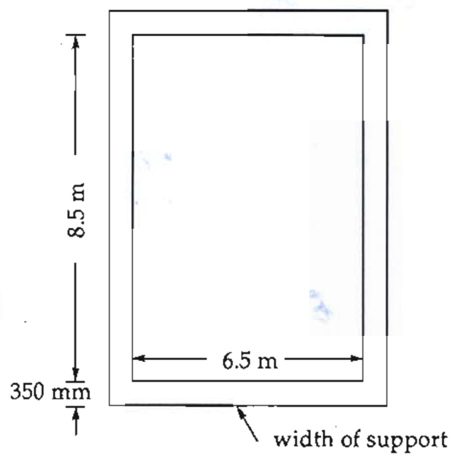
iv) Strain controlled approach

v) FOS is applied to load as per limit state of collapsibility or limit state of serviceability

vi) LSM is less conservative than WSM

04

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]

s: Given

$L_x = 6.5\,m$ $L_y = 8.5\,m$

$w = 350\,mm$

i) Effective depth, $d = \frac{6500 + d}{20 \times MF_t}$ (Assuming $d < w$)

$MF_t = 1.0$

$d = 342.10\,mm$

Let $d = 345\,mm$

$D = 375\,mm$

ii) Leff

$(L_{eff})_x = L_u + d = 6500 + 345$
$= 6.845 m$

$(L_e)_y = (L_u)_y + d = 8.845 mm$

$r = \frac{(L_e)_y}{(L_e)_x} = \frac{8.845}{6.845} = 1.29 \simeq 1.30$

$\therefore \alpha_x = 0.093$
$\alpha_y = 0.055$

iii) Load calculation (1m x 1m)

DL = 0.375 x 1 x 1 x 25 = 9.375
LL = 6 x 1 x 1 = 6
flooring = 0.08 x 1 x 1 x 24 = 1.92
w = 17.295

$w_u = 25.9$

Let $w_u = 26$ kN/m

iv) Moments:

$M_{ux} = \alpha_x w_u l_{ex}^2 = 0.093 \times 26 \times 6.845^2$
$= 113.29$ kN-m

$M_{uy} = \alpha_y w_u l_{ey}^2 = 67$ kN-m

v) Effective depth

$$d = \sqrt{\frac{BM_{max}}{Q B}} = \sqrt{\frac{113.29 \times 10^6}{0.133 \times 30 \times 1000}}$$

$$= \underline{168.5\ mm} < \underline{d_{provided}}$$

$\therefore d_x = 345 mm$

~~dy~~

vi) $$Ast_x = 0.5 \frac{f_{ck}}{f_y} \left(1 - \sqrt{1 - \frac{4.6\ BM_y}{f_{ck} B d_x^2}}\right) B \cdot d_x$$

$$= 0.5 \times \frac{30}{500} \left(1 - \sqrt{1 - \frac{4.6 \times 113.29 \times 10^6}{30 \times 1000 \times 345^2}}\right) 1000 \times 345$$

$$= \underline{785.038\ mm}$$

$Ast_x \Rightarrow$ 10 mm bars @ <u>100 mm c/c</u>

$d_y = d_x - \phi_x = 345 - 10 = 335 mm$

$$Ast_y = 0.5 \times \frac{30}{500} \left(1 - \sqrt{1 - \frac{4.6 \times 67 \times 10^6}{30 \times 1000 \times 335^2}}\right) 1000 \times 335$$

$$= \underline{471.038\ mm}$$

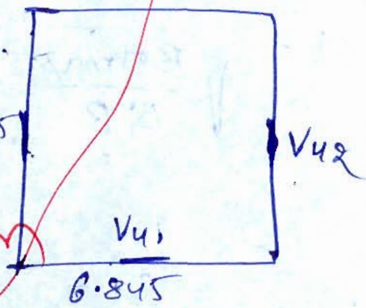
$Ast_{min} = 0.12 \times 1000 \times 375 = \underline{450 mm^2}$

Ast_y = <u>10 mm @ 160 mm c/c</u>

Since corners are not prevented from lifting $\therefore$ <u>no torsion R/f</u>

Check for shear:

shorter span or longer span ?? mention it



i) $V_{u1} = \frac{w_u l_x}{3}$

$= \frac{26 \times 6.845}{3}$

$= 59.32$ kN

$\tau_{v1} = \frac{V_{u1}}{B d_y} = \frac{59.32 \times 1000}{1000 \times 325} = 0.177 < \tau_{c\,min}$ (0.29)

$\therefore \tau_{v1} < \tau_{c\,min} \rightarrow$ Safe

ii) $V_{u2} = w_u l_x \left(\frac{r}{2+r}\right)$

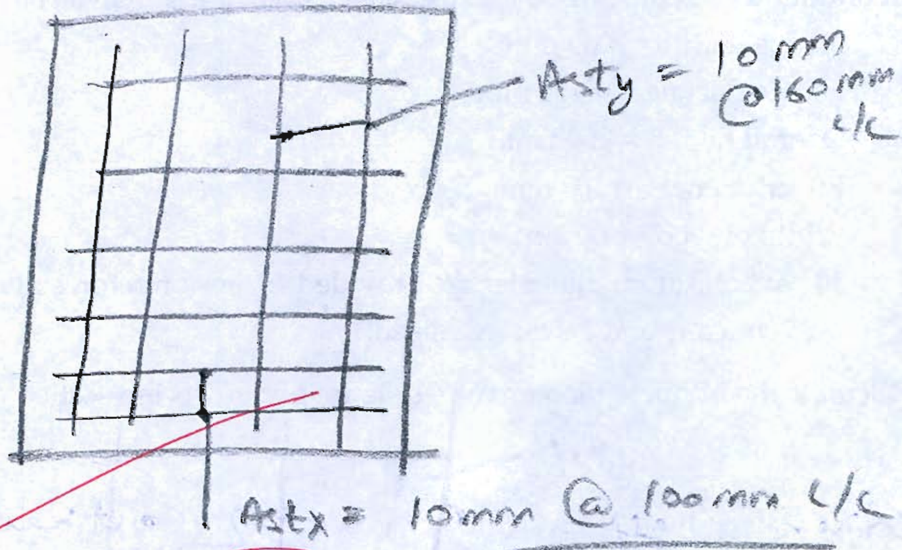
$= 26 \times 6.845 \times \left(\frac{1.3}{2+1.3}\right)$

$= 70.1$ kN

$\tau_{v2} = \frac{V_{u2}}{B d_x} = \frac{70.1 \times 1000}{1000 \times 345} = 0.2 < 0.29$

$\tau_{v2} < \tau_{c\,min} \rightarrow$ Safe

The slab is safe in shear


Asty = 10 mm @160 mm c/c
Astx = 10 mm @ 100 mm c/c

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]

Ans: Given $L_{eff} = 15m \Rightarrow$ continuous

$\therefore L_o = 0.7 L_{eff} = 0.7 \times 15 = 10.5m$

Effective flange width, B_f

$$B_f = \frac{l_o}{\frac{l_o}{B} + 4} + b_w$$

$$= \frac{10500}{\frac{10500}{2000} + 4} + 500 = 1635.13 < 2000mm$$

Let $B_f = 1636 mm$

$D = 1000 mm$ $EC = 100 mm$

$d = 900 mm$

$A_{st} = 10 \times \frac{\pi}{4} \times 32^2 = 8042.48 mm$

i) Let $x_u \leq D_f$

$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} B_f} = \frac{0.87 \times 500 \times 8041}{0.36 \times 25 \times 1636}$$

$= 237.56 mm$

$x_u \nleq D_f$

Let $x_u > D_f$ & $\frac{3}{7}x_u < D_f \rightarrow y_f$ case

$y_f = 0.15x_u + 0.65D_f$

$= 0.15x_u + 0.65 \times 150$

$= 0.15x_u + 97.5$ mm

$\therefore C_1 + C_2 = T$

$0.36 f_{ck} b_w x_u + 0.45 f_{ck} (b_f - b_w) \cdot y_f = 0.87 f_y A_{st}$

$0.36 \times 25 \times 500\, x_u + 0.45 \times 25 \times (1636 - 500) \times [0.15x_u + 97.5] = 0.87 \times 500 \times 8041$

$x_u = 350.9$ mm

$x_u > D_f$ but $\frac{3}{7}x_u \not< D_f$. $\therefore$ assumption wrong

) Let $x_u > D_f$ $\frac{3}{7}x_u > D_f$.

$0.36 \times 25 \times 500 \times x_u + 0.45 \times 25 \times (1636 - 500) \times 150 = 0.87 \times 500 \times 8041$

$x_u = 351.2967$

$x_u > D_f$ ✓ OK

$\frac{3}{7}x_u > D_f$ ✓ OK

$\therefore MOR = C_1 LA_1 + C_2 LA_2$

$0.36 f_{ck} B_w x_u (d - 0.42x_u) + 0.45 f_{ck} \times (B_f - b_w) D_f \times (d - \frac{d_f}{2})$

$= 0.36 \times 25 \times 500 \times 351.29 \times (900 - 0.42 \times 351.29)$

$+ 0.45 \times 25 \times (1636 - 500) \times 150 \; (900 - \frac{150}{2}) \Big/ 10^6$

MOR = 2771 KN-m

Ultimate MOR of T-Beam = 2771 KN-m

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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]

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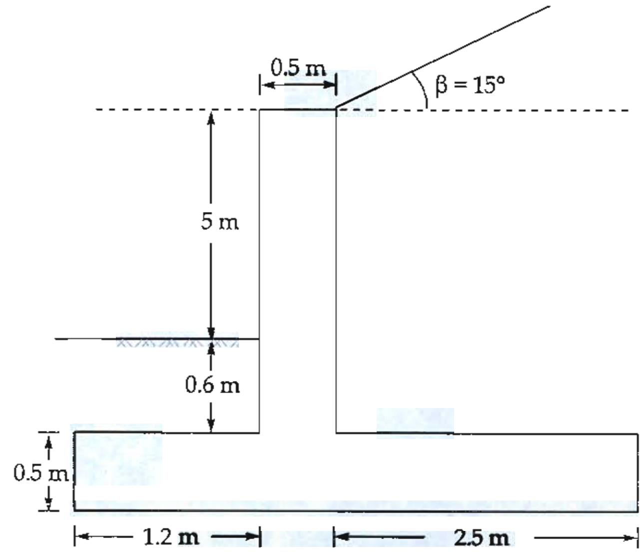
Q.3 (b) A retaining wall is as shown in figure.



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

Angle of repose, ϕ = 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]

Q.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]

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]

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]

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

Q.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]

ns: Given LDF = 0.5

$n = 15$ $\quad x = 1.5$

for Bus → N design 1

for Truck → N design-2

N design = Ndesign 1 + Ndesign 2

$(VDF)_{Bus} = \left(\frac{16000}{8160}\right)^4 = 14.78$

$(VDF)_{Truck} = 4.67$

$P_1 = 250 \qquad P_2 = 1200$

$A_1 = P_1\left(1+\frac{r_1}{100}\right)^n = 250 \times \left(1+\frac{5}{100}\right)^{1.5}$

$= 268.98$

$A_2 = 1200\left(1+\frac{8}{100}\right)^{1.5} = \underline{1346.84}$

$N_{design\,1} = \frac{365 A_1\left((1+r_1)^n - 1\right)}{r_1 \times 10^6} \times LDF \times VDF_1$

$= \frac{365 \times 268.98\left[(1+0.05)^{15} - 1\right]}{0.05 \times 10^6} \times 0.5 \times 14.78$

$= \underline{15.654}$ msa

$N_{design\,2} = \frac{365 \times 1346.84 \times \left((1+0.08)^{15} - 1\right)}{0.08 \times 10^6} \times 0.5 \times 4.67$

$= \underline{31.167}$ msa

$N_{design} = N_{design\,1} + N_{design\,2}$

$= \boxed{46.82 \text{ msa}}$

Let $\underline{47 \text{ msa}}$

∴ BC wearing course = 40mm

DBM = 115 mm

WMM = 200 mm

GSB subbase = 200 mm

12

Improve Answer presentation Skills

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

Ans: The Engineering Geology is one of most important branch of ~~civil~~ civil engineering field when any project is planned for eg:- Construction of dam, the first thing to be done is geological investigation.

∴ to get proper information about rocks the geological investigation is important.

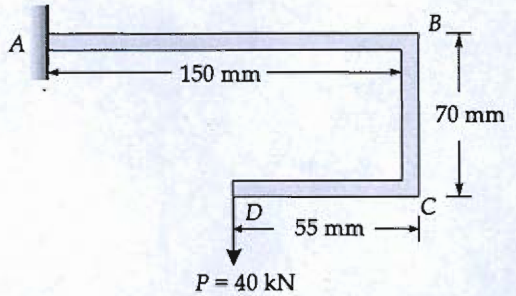
To start any mega project, geological investigation is must. This tells us about the rock (i.e) the foundation properties of the structure to be built

The various geological hazards are:

i) The various geological hazards includes the foundation failure due to faults and strikes in the foundation rock.

03

Q.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]

Ans: $P = 40$ KN

Bending stress = 30 MPa

for CD:

$BM_C = 40 \times \frac{55}{1000} = 2.2$ KN-m

$BM_B = 40 \times \frac{55}{1000} = 2.2$ KN-m

at B:

40 KN, 2.2 KN-m, 150mm

$BM_A = 40 \times \frac{150}{1000} - 2.2$

$= 3.8$ KN-m

∴ $\frac{\sigma_b}{\frac{D}{2}} = \frac{M_{max}}{I_{NA}}$

$\frac{30}{\left(\frac{D}{2}\right)} = \frac{3.8 \times 10^6}{\frac{\pi}{64} \times D^4} \Rightarrow D^3 = \frac{3.8 \times 10^6}{\frac{\pi}{64} \times 30 \times 2}$

Diameter, $D = 1186.87$ mm $\Rightarrow$ 1.135m

Avoid this type of mistake

calculation error

08

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

[12 marks]

Ans: Different type of rocks:

i) On the basis of formation:

a) Igneous rocks: These rocks are formed inside the earth by cooling of magma. Or volcanic eruptions. These are of following types:

Plutonic: formed at considerable depth
Eg: Granite

Hypabassal: formed at shallow depth
Eg: Dolerite

Volcanic: by volcanic eruption
Eg: Basalt

b) Sedimentary rocks : These rocks are formed by action of physical agencies of nature such as water, air etc.
The sedimentary rocks are of stratified nature
Eg: Limestone, chalk etc

c) Metamorphic rocks: These rocks are formed by action of heat & pressure on igneous & sedimentary rocks.
Eg: Marble etc

ii) On the basis of stratification

i) Non-stratified rocks: These rocks do not have proper formation layers and cannot cut in layers Eg: Igneous rocks

ii) Stratified rocks: These rocks have proper stratification & are formed in layers
Eg: Sedimentary rocks

iii) Foliated rocks: These rocks are neither stratified properly nor non-stratified
Eg: Metamorphic rocks

Do not write in this margin

c) On basis of components:

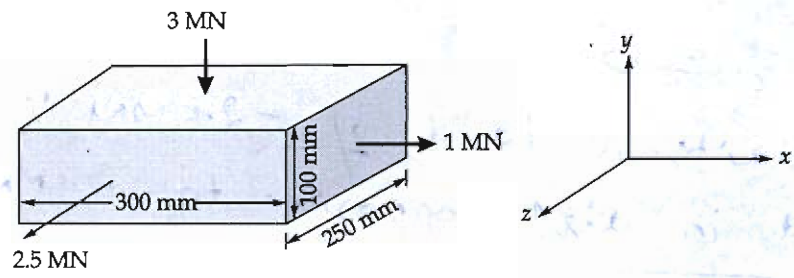
i) Argillaceous: In these rocks clay is of major proportion.

ii) Siliceous: Silica is one of the main components in these rocks

iii) Calcareous: These are lime containing rocks

10

Q.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/mm² and $\mu = 0.25$.



[12 marks]

Ans.

$P_x = +1 \text{ MN}$

$P_y = -3 \text{ MN}$

$P_z = +2.5 \text{ MN}$

$\sigma_x = \frac{+1 \times 10^6 \text{ N}}{250 \times 100} = +40 \text{ N/mm}^2$

$\sigma_y = -\frac{3 \times 10^6}{300 \times 250} = -40$

$\sigma_z = +\frac{2.5 \times 10^6}{300 \times 100} = +83.33$

We know

$\epsilon_x = \frac{\sigma_x}{E} - \frac{\mu \sigma_y}{E} - \frac{\mu \sigma_z}{E}$ — (i)

$\epsilon_y = \frac{\sigma_y}{E} - \frac{\mu \sigma_z}{E} - \frac{\mu \sigma_x}{E}$ — (ii)

$\epsilon_z = \frac{\sigma_z}{E} - \frac{\mu \sigma_x}{E} - \frac{\mu \sigma_y}{E}$ — (iii)

Volumetric strain

$\epsilon_v = \epsilon_x + \epsilon_y + \epsilon_z$ (from eq n (i) (ii) + (iii))

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

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

$\epsilon_v = \frac{\Delta V}{V} = 2.08 \times 10^{-4}$

$\Delta V = 1562.4375 \text{ mm}^3$

for $\epsilon_v = 0$

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

$40 - 40 + \sigma_z = 0$

$\sigma_z = 0$

∴ The additional load of −2.5 MN is applied in dirⁿ opposite to 2.5 MN we get $\boxed{\epsilon_v = 0}$

Q.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:

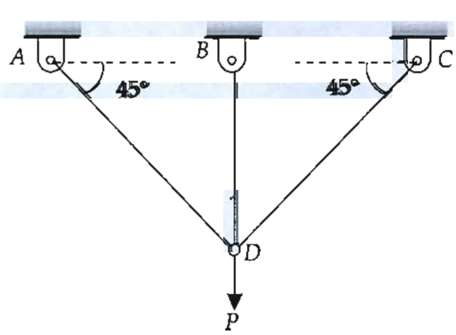
(i) the average delay to vehicles arriving between 0 - 120 sec.

(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]

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]

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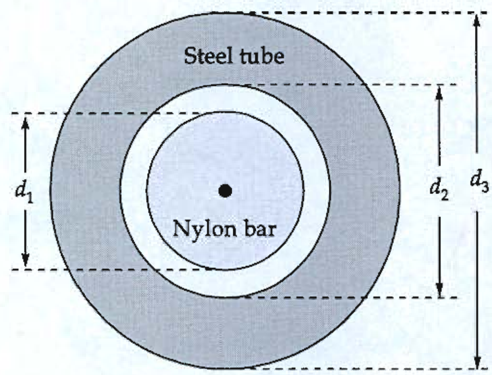
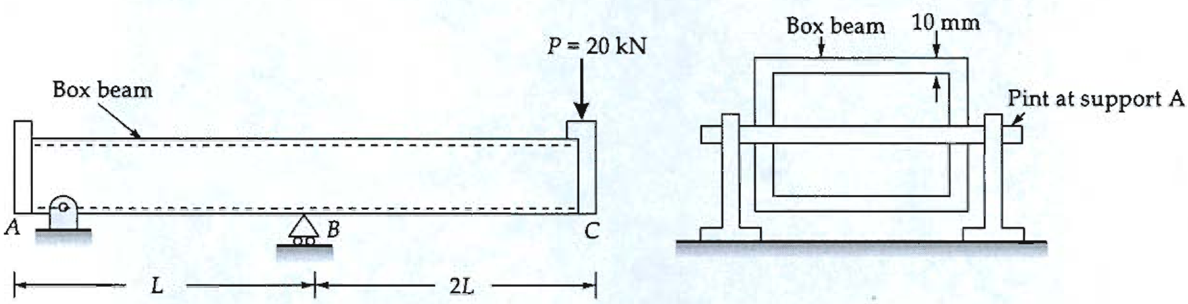
Q.6 (c) (i) A nylon bar having diameter d_1 = 8.8 cm is placed inside a steel tube having inner diameter d_2 = 8.85 cm and outer diameter d_3 = 9.1 cm as shown in the figure. The nylon bar is then compressed by an axial force P. For what value of P, space between the nylon bar and steel tube will be 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]

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Q.7 (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]

Q:

Given Area = 750 km²

Scale = 1 : 10000

= 1 cm = 100 m   S = 100

l = 250 mm = 25 cm

b = 250 mm = 25 cm

pl = 65%   ps = 35%

$$\therefore N = \frac{A}{[ls(1-pl)] \times [bs(1-pb)]}$$

$$= \frac{750 \times 10^6 \; m^2}{(25 \times 100 \times [1-0.65]) \times [25 \times 100 [1-0.35]]}$$

N = 527.47

∴ no. of photograph, N = 528 Ans

10

Ans: ii) Laws of weights'

a) If x have weight w_x
y have weight w_y

i) $x+y$ have weight $= \frac{1}{\frac{1}{w_x}+\frac{1}{w_y}}$

ii) Kx have weight $= \frac{w_x}{K^2}$

iii) $\frac{x}{K}$ have weight $= w_x \times K^2$

iv) $x+K$, $x-K$, $y+K$, $x-K$ etc have weight equal to x & y respectively

---

b) Different types of errors:

a) Compensating errors: These type of errors are of compensating nature. These errors do not have any fixed direction & magnitude. Therefore these errors are called accident or random errors. These errors will either increase the error or decrease the error we cannot say anything. The compensating errors are due ~~to~~ weather conditions etc

b) Systematic errors:

These errors are of fixed magnitude & direction. These are always accumulated in one dirⁿ. ∴ The result is either too positive or too negative. These are also called comprehensive errors.

08

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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]

Ans: Given: $\epsilon_x = 460 \times 10^{-6}$

$\epsilon_y = 60 \times 10^{-6}$

$\gamma_{xy} = 400 \times 10^{-6}$

a) $\theta = 80^\circ$ (ACW) $\Rightarrow \therefore \theta = +80^\circ$

Normal strain

$\epsilon'_{80^\circ} = \epsilon_x \cos^2\theta + \epsilon_y \sin^2\theta + \gamma_{xy} \cos\theta \sin\theta$

$= (460 \times 10^{-6}) \cos^2 80 + 60 \times 10^{-6} \times \sin^2 80$
$+ (400 \times 10^{-6}) \times \cos 80 \times \sin 80$

$= 140.1 \times 10^{-6}$

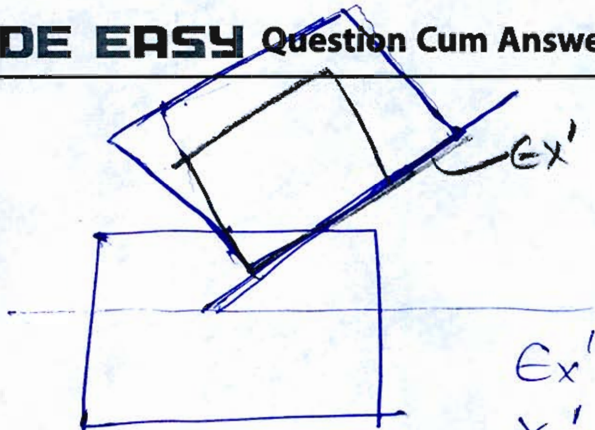
$\frac{\gamma'_{80^\circ}}{2} = (\epsilon_y - \epsilon_x) \cos 80 \sin 80 + \frac{\gamma_{xy}}{2} (\cos^2 80 - \sin^2 80)$

$= ((60 \times 10^{-6}) - 460 \times 10^{-6}) \cos 80 \sin 80 + \frac{400 \times 10^{-6}}{2} (\cos^2 80 - \sin^2 80)$

$\gamma'_{80^\circ} = -254.63 \times 10^{-6}$

$\because \gamma' = -ve$

$\theta = \frac{\pi}{2} - (-\gamma') = \theta > 90^\circ$



$\epsilon_{x'}$ = +ve (length increased)

$\gamma_{x'y'}$ = −ve ($\theta > 90°$)

) Principal strains

$$\epsilon_{p1} / \epsilon_{p2} = \frac{\epsilon_x + \epsilon_y}{2} \pm \frac{1}{2}\sqrt{(\epsilon_y - \epsilon_x)^2 + (\gamma_{xy})^2}$$

$$= \frac{60\times10^{-6} + 480\times10^{-6}}{2} \pm \frac{1}{2}\sqrt{(60\times10^{-6} - 450\times10^{-6})^2 + (400\times10^{-6})^2}$$

$\epsilon_{p1} = 534.33 \times 10^{-6}$

$\epsilon_{p2} = -240.329 \times 10^{-6}$

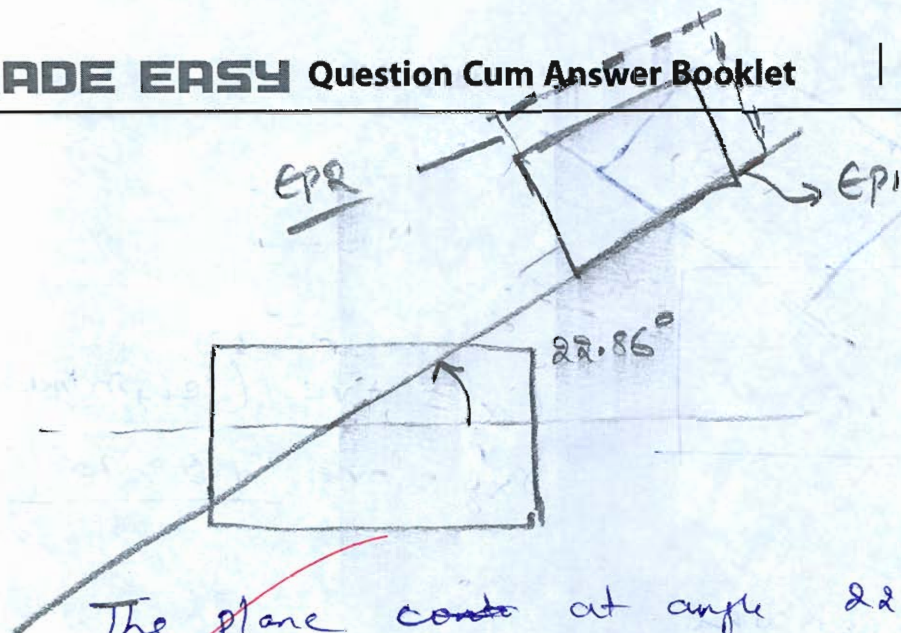
18

Location of principal strains

$$\tan(2\theta_{p1}) = \frac{\gamma_{xy}}{\epsilon_x - \epsilon_y}$$

$$= \frac{1}{2}\tan^{-1}\left(\frac{400\times10^{-6}}{480\times10^{-6} - 60\times10^{-6}}\right)$$

θ_{p1} = 22.86 ACW from Horizontal



Cross check: The plane ~~conta~~ at angle 22.86° contains ϵ_{P1} & (90° to 22.86°) contains ϵ_{P2}

$(\epsilon_{22.86} = 34.33 \times 10^{-6})$

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:

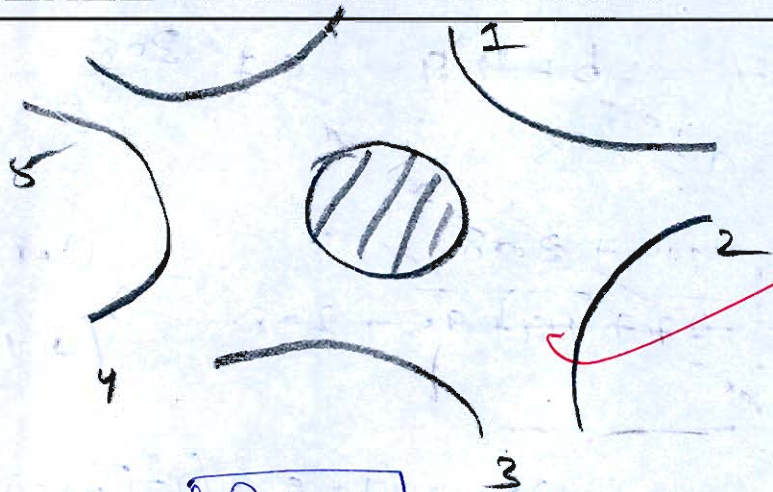
v_{12}	37	v_{31}	466	v_{41}	182	v_{51}	45
v_{13}	303	v_{32}	122	v_{42}	54	v_{52}	132
v_{14}	64	v_{34}	47	v_{43}	18	v_{53}	62
v_{15}	52	v_{35}	657	v_{45}	116	v_{54}	15

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]

Ans:



Rotary

~~Given w_1 & w_2 = 10m.~~

~~Let urban road ∴ $e_1 = 7.5m$~~

~~$e = \frac{e_1+e_2}{2} = 7.5m$~~

Given: $e_1 = 10m$ Let $e_2 = 10m$

$e = \frac{10+10}{2} = 10m$

$L = 50m$

Let $w = \frac{e_1+e_2}{2} + 3.5$

$= \underline{13.5m}$

$\frac{L}{w} \not> 4$

$= \frac{50}{13.5} = 3.7 \not> 4$ **OK**

For leg 1 - 2

$P_{12} = \frac{\text{weaving traffic}}{\text{Total traffic}}$

$= \frac{b+c}{a+b+c+d}$

$a = V_{12} = 37$

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

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

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

$\therefore a = 37 \quad b = 419 \quad c = 308$

$d = 95$

$$p = \frac{419+308}{37+419+95+308} = 0.846$$

(0.4-10) ok

$$\text{Practical capacity} = \frac{280w\left(1+\frac{e}{w}\right)\left(1-\frac{P_{max}}{3}\right)}{1+\frac{w}{L}}$$

$$= \frac{280\times 13.5\left(1+\frac{10}{13.5}\right)\left(1-\frac{0.843}{3}\right)}{1+\frac{13.5}{50}}$$

$= 3720.031$ Pcu/hr

16

Guidelines:

a) Rotary can take max^m of 3000 veh/hr & min of 500 veh/hr

b) Rotary is needed if:
Total intersecting traffic is > 50%
Right turning traffic is > 30%

c) Speed Urban = 30 Km/hr
Rural = 40 Km/hr

d) Radius at entry = $R_1 = \frac{V^2}{127f}$

$R_{cs} = \frac{4}{3}R_1 \quad R_{exit} = 1.5-2\,R_g$

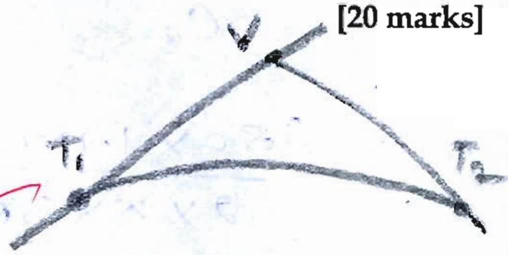
e) weaving angle $\nless 15^\circ$

f). Tangential rotary is not preferred
Circular & elliptical are preferred

04

Q.8 (a) 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]



Sol: Given: $\Delta = 48^\circ$

Tangent length $= VT_1$

$= R \tan \frac{\Delta}{2}$

$= 380 \tan \frac{48}{2} = 169.187$

Length of curve $= \frac{2\pi R \Delta}{360^\circ} = 2 \times \pi \times 380 \times \frac{48}{360}$

$= 318.348$ mm

Length of first chord:

Chainage at V $= 40 \times 30 + \frac{60}{100} \times 30$

$= 1218$ m

Ch at T_1 $= 1218 - 169.187 = 1048.813$ m

Ch at T_2 $= 1367.161$ m $(T_1 + L_c)$

$L_1 = \left(\begin{matrix}\text{Multiple of 30} \\ > \text{Ch at } T_1\end{matrix} - \text{Ch. at } T_1\right)$

$= 1050 - 1048.813 = 1.187$

$L_n = \text{Ch at } T_2 - \begin{matrix}\text{Multiple of 30} \\ < \text{Ch. at } T_2\end{matrix}$

$= 1367.161 - 1350 = 17.161$

No. of chords $= \left(\frac{L_c - L_1 - L_n}{30}\right) + 2$

$= 12$ chords

All other chords = 30 m

Using Rankine Method,

$C_1 = 1.187 \quad C_n = 17.161$

$C_2 \ldots C_{n-1} = 30m$

$\delta_1 = \left(\frac{180 \times 1.187}{2 \times \pi \times 380}\right) = 0.089°$

$\Delta_1 = \delta_1 = 0.089$

$\delta_2 = \delta_3 = \ldots \quad \delta_{n-1} = 2.261° \left(\frac{180 \times 30}{2 \times \pi \times 380}\right)$

$\delta_n = \frac{180 \times 17.161}{2 \times \pi \times 380} = 1.293°$

$\therefore \Delta_1 = \delta_1 = 0.089$

$\Delta_2 = \delta_2 + \Delta_1 = 0.089 + 2.261 = 2.35°$

$\Delta_3 = \Delta_2 + \delta_3 = 2.35 + 2.261 = 4.611$

$\Delta_4 = \Delta_3 + \delta_4 = 4.611 + 2.261 = 6.872$

$\Delta_5 = 9.133$

$\Delta_6 = 11.394$

$\Delta_7 = 13.655$

$\Delta_8 = 15.916$

$\Delta_9 = 18.177$

$\Delta_{10} = 20.438$

$\Delta_{11} = 22.699$

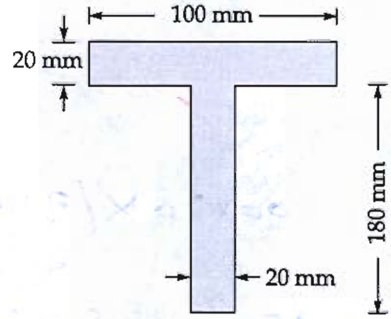
$\Delta_{12} = 22.699 + 1.293 = 23.99 \simeq 24$

$\therefore \Delta_{12} = \frac{1}{2}\Delta = 24°$

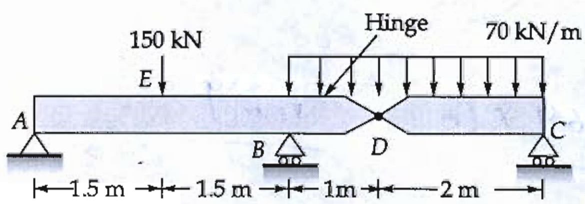
20

Checked OK

Q.8 (b) (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.

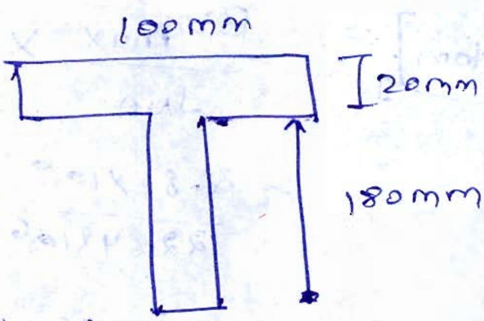


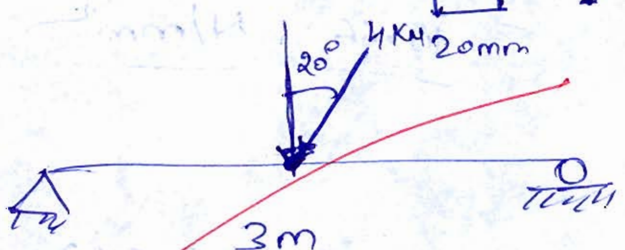
(ii) Draw the shear force diagram for the beam loading as shown in figure.



[12 + 8 = 20 marks]

Ans : b) i)





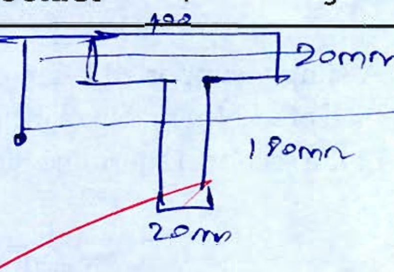
Vertical Load $= 4\cos 20° = 3.76$ KN

Horizontal load $= 4\sin 20° = 1.368$ KN

Vertical load Stress :

$$\text{Max}^m \text{ BM} = \frac{WL}{4} = \frac{3.76 \times 3}{4} = 2.82 \text{ KN-m}$$

for beam:



$$\bar{y} = \left(\frac{100 \times 20 \times 10 + 180 \times 20 \times 110}{100 \times 20 + 180 \times 20}\right)$$

$\bar{y} = 74.29$ mm

$$I_{NA_1} = \frac{100 \times 20^3}{12} + 100 \times 20 \times (74.29 - 10)^2 + \left(\frac{20 \times 180^3}{12} + (20 \times 180) \times [110 - 74.29]^2\right)$$

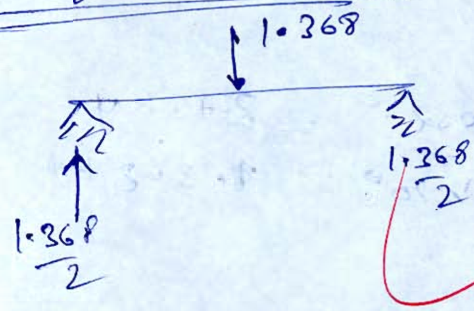
$= 22.64 \times 10^6$ mm^4

$$\left[(\sigma_{tensile}) \text{ at bottom}\right]_1 = \frac{BM_{max}}{I_{NA}} \times y_{bottom}$$

$$= \frac{2.82 \times 10^6}{22.64 \times 10^6} \times (200 - 74.29)$$

$= 15.66$ N/mm^2

Horizontal Load:



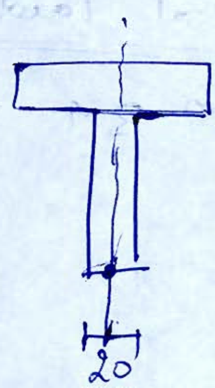
$BM_{max} = \frac{1.368 \times 3}{4}$

$= 1.026$ kN-m

~~$(\sigma_{tensile})_2 = \frac{1.026 \times 10^6}{...}$~~

$$(I_{NA})_2 = \frac{20 \times 100^3}{12} + \frac{180 \times 20^3}{12}$$

$= 1.78 \times 10^6$



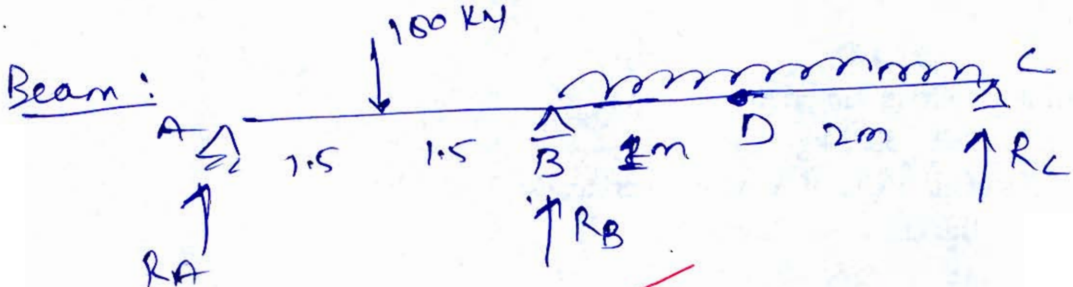
$$(\sigma_{tensile})_2 = \frac{1.026 \times 10^8}{1.78 \times 10^6} \times [10\,mm]$$

$$= 5.76\ N/mm^2$$

$$\text{Max}^m \text{ Tensile stress} = 15.66 + 5.76 = 21.42\ N/mm^2$$

12

Beam :



$$R_A + R_B + R_C = 150 + 70 \times 3 = 360\ KN$$

$\Sigma M_D = 0$ (from right)

$$R_C \times 2 = 70 \times 2 \times 1$$

$$R_C = 70\ KN$$

$$R_A + R_B = 290 \quad \text{(i)}$$

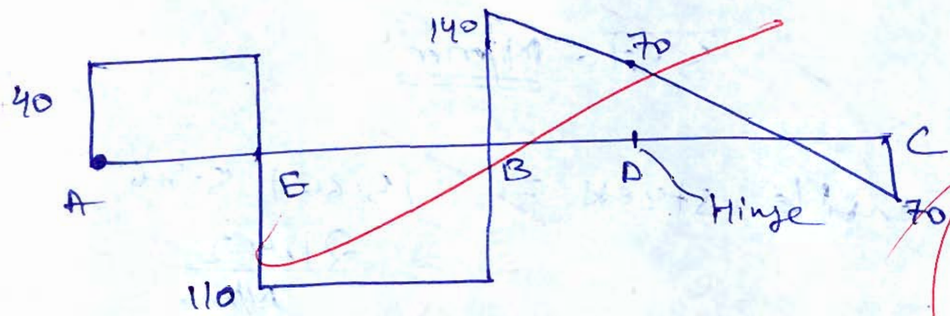
$\Sigma M_D = 0$ (from left)

$$R_A \times 4 - 150 \times 2.5 + R_B \times 1 - 70 \times 1 \times \tfrac{1}{2} = 0$$

$$4R_A + R_B = 410 \quad \text{(ii)}$$

Solving $R_A = 40$, $R_B = 250$

SFD :



SF equation :

for AE: $V_A = SF_1$

for EB ⇒ $SF_2 = V_A - 150 = -110$

for BC ⇒ $V_A - 150 + V_B - 70 \times x = SF_3$

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]

Ans: Radius of relative stiffness

$$l = \left(\frac{Eh^3}{12k(1-\mu^2)}\right)^{1/4}$$

$$= \left(\frac{3\times10^5 \times 20^3}{12\times6\times(1-0.15^2)}\right)^{1/4}$$

$= 76.417$ cm

Radius of ~~stiffener~~ section, b

$b = \sqrt{1.6a^2 + h^2} - 0.675h$ [$a < 1.724h$

$a = 15cm < 1.724 \times 20$

$b = \sqrt{1.6 \times 15^2 + 20^2} - 0.675 \times 15$

$= 17.44cm$

→ h = 20cm

03

Ans:- for WBM road:

i) Preparation of subgrade & subbase:

The subgrade & subbase is being prepared as per the guidelines of IRC-19 (WBM)

The subgrade should have LL ≯ 50%
I_p ≯ 25%

& it is compacted to 98% of MDD

The subbase should have LL ≯ 25%
I_p ≯ 6%

and compacted to 98% of MDD.

The subgrade can be prepared with moorum, soil etc

iii) Laying of stone aggregate:
The stone aggregate as per Grade of WBM
(ie) Grade -1 , Grade -2 and Grade - 3
are being laid out On the prepared subbase.
The water is sprinkled over the aggregates
The screenings to be added are added
to WBM road.

iv) Rolling: The rolling is being done
by smooth wheeled roller to the
aggregates such that voids are placed to
be minimum. The rolling of road
should start from centre to edges.

v) The rolling is done accompanied with
the sprinkling of water. In WBM water
act as binding material for aggregates
∴ the construction of WBM takes very
important steps to be taken in consideration

05

Space for Rough Work

Space for Rough Work

Space for Rough Work