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ESE 2023 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-4

Design of Concrete and Masonry Structures [All Topics]

Geo-technical & Foundation Engineering-1 [Part Syllabus]

+ Highway Engineering-2 + Surveying and Geology-2 [Part Syllabus]

Name : ....

Roll No :

Test Centres	**Student's Signature**
Delhi ☑ Bhopal ☐ Jaipur ☐ Pune ☐ Kolkata ☐ Bhubaneswar ☐ 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	48
Q.2	32
Q.3	—
Q.4	—
Section-B	
Q.5	35
Q.6	49
Q.7	40
Q.8	—
Total Marks Obtained	204

Signature of Evaluator: Akumar

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.

* excellent work in section-B
* keep practising
* keep it up

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Section A : Design of Concrete and Masonry Structure

Q.1 (a) What are the assumptions for the design of a reinforced concrete section for limit state of collapse in bending? Calculate the limiting percentage of tensile reinforcement in a flexural RC member for M30 grade concrete and Fe500 grade steel.

[12 marks]

(a) Assumptions of limit state of collapse

(i) Plane section before bending remains plane after bending.

(ii) In case of bending max^m bending compression strain in outermost compressed fibre is 0.0035

(iii) The stree - strain distribution may be rectangular or trapezoidal or parabolic

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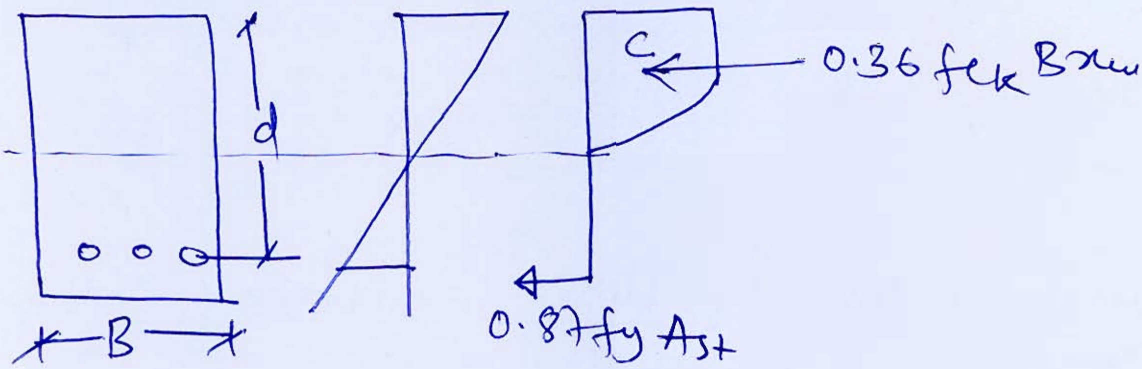
(iv) The compressive strength of concrete is 0.67 f_{ck} because of shape factor which is further reduced to 0.45 f_{ck} by partial safety factor

(v) The partial safety factor for steel is 1.15.

(vi) The max^m tensile strain at the time of failure should not be less than

$\left(0.002 + \frac{0.87 f_y}{E_s}\right)$



$x_{ulim} = \left(\frac{700}{1100 + 0.87 f_y}\right) d$

for Fe 500

$x_{ulim} = 0.46\,d$

6

$C = T$

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

$A_{st\,lim} = \frac{0.36 f_{ck} B \times 0.46 d}{0.87 f_y}$

$\frac{A_{st\,lim}}{B d} = \frac{0.36 \times 30 \times 0.46}{0.87 \times 500} \times 100$

$P_{t\,lim}\% = 1.144\%$

Ans

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Q.1 (b) A doubly reinforced beam is 200 mm wide and 350 mm deep to centre of the tensile reinforcement. The areas of the compression and tensile steel are 1245 mm² and 1600 mm² respectively. The effective cover to the compression reinforcement is 50 mm. Find the ultimate moment of resistance of the beam section. Use M20 concrete and Fe250 steel.

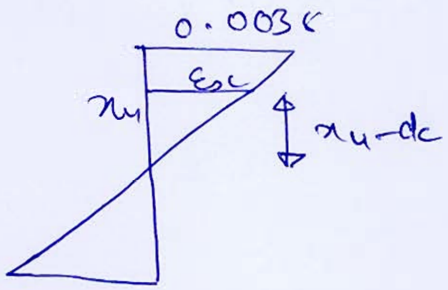
[12 marks]

$A_{st} = 1600 mm^2$

$A_{sc} = 1245 mm^2$

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

$1440 x_u = 359205 - 1245 f_{sc}$ — (I)



$$\frac{0.0035}{x_u} = \frac{\varepsilon_{sc}}{x_u - 50}$$

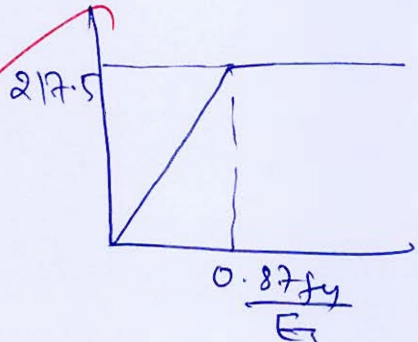
$$\varepsilon_{sc} = \left(\frac{x_u - 50}{x_u}\right) 0.0035$$ — (II)

As we know

below $\frac{0.87 f_y}{E_s}$

Strain f_{sc} is

$f_{sc} = E_s \times \varepsilon_{sc}$



Let us assume than ε_{sc} is less than $\frac{0.87 f_y}{E_s}$

$$f_{sc} = 2 \times 10^5 \times 0.0035 \left(\frac{x_u - 50}{x_u}\right)$$

$$f_{sc} = 700 \left(\frac{x_u - 50}{x_u}\right)$$ — (III)

put this in eqn (I) find x_u

$$1440 x_u = 359205 - 1245 \times 700 \left(\frac{x_u - 50}{x_u}\right)$$

$$\boxed{x_u = 70.92 \text{ mm}}$$

$$f_{sc} = 700\left(\frac{70.92 - 50}{70.92}\right)$$

$$\boxed{f_{sc} = 206.486\ N/mm^2}$$

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

$$= \frac{0.36 \times 20 \times 200 \times 70.92(350 - 0.42 \times 70.92) + 1245(206.486 - 0.45 \times 20)(350 - 50)}{10^6}$$

$$\boxed{M_R = 106.46\ kNm}$$

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Q.1 (c) **(i)** Discuss the importance of diagonal tension in RCC beams.

(ii) Explain advantages of limit state method of design as compared to working stress method, for reinforced concrete flexural members.

[6 + 6 marks]

(ii)

Limit state method	working stress method
(a) It is more economical section	(a) It is less economical section
(b) The concrete used is less	(b) concrete used is more
(c) section are of good size	(c) sections are of very big size
(d) this method is more safe method of design	(d) This method is less safe method of design
(e) FOS is applied to both load & stresses	(e) No FOS is applied to load & stress

3

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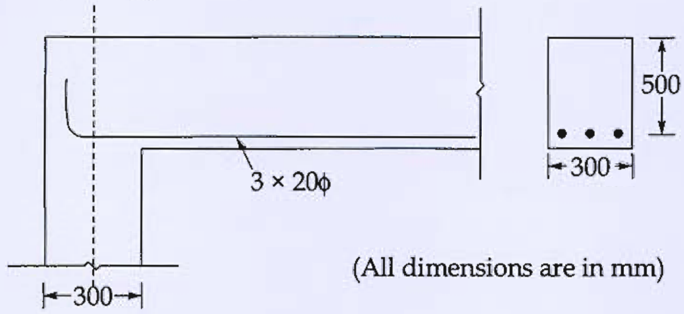
Q.1 (d) Determine the anchorage length of bars at the simply supported end of a reinforced concrete beam as shown below, if it is subjected to an ultimate shear force of 300 kN at the centre of support. Assume M20 grade concrete and steel of grade as Fe415.
[Take τ_{bd} = 1.92 N/mm^2]



(All dimensions are in mm)

[12 marks]

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

$A_{st} = 3 \times \frac{\pi}{4} \times 20^2 = 942.36 mm^2$

$x_u = \frac{0.87 \times 415 \times 942.36}{0.36 \times 20 \times 300}$

$x_u = 157.51 mm$

~~$M_u = 0$:~~ $x_{ulim} = 0.48d = 0.48 \times 500$
$= 240 mm$

$x_u < x_{ulim}$ underreinforced

$M_u = 0.87 f_y A_{st} (d - 0.42 x_u)$

$= \frac{0.87 \times 415 \times 942.36 (500 - 0.42 \times 157.51)}{10^6}$

$M_u = 147.6112$ kNm

$V_u = 300$ kN

Development length $L_d = \frac{0.87 f_y \phi}{4 \tau_{bd}}$

$$L_d = \frac{0.87 \times 415 \times 20}{4 \times 1.6 \times 1.92}$$

$L_d = 587.64$ mm

6

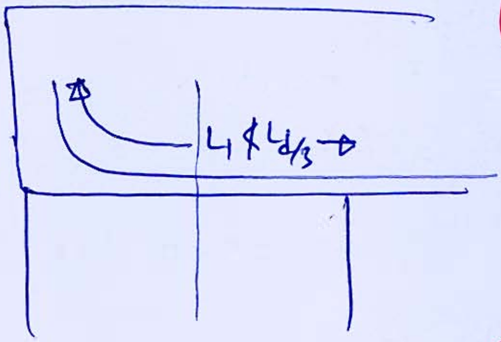
$$\frac{M_u}{V_u} + L_o \geq L_d$$

$$\frac{147.6112 \times 10^3}{300} + L_o = 587.64$$

$492.037 + L_o = 587.64.$

$L_o = 587.64 - 492.037$

$L_o = 95.602$ mm



$L_1 \nless L_d/3$

$587.64/3$

$\nless 195.88$ m

$L_o + 150 \geq 195.88$

$L_o > 45.88$ mm

$L_o = 95.602$ mm

Ans

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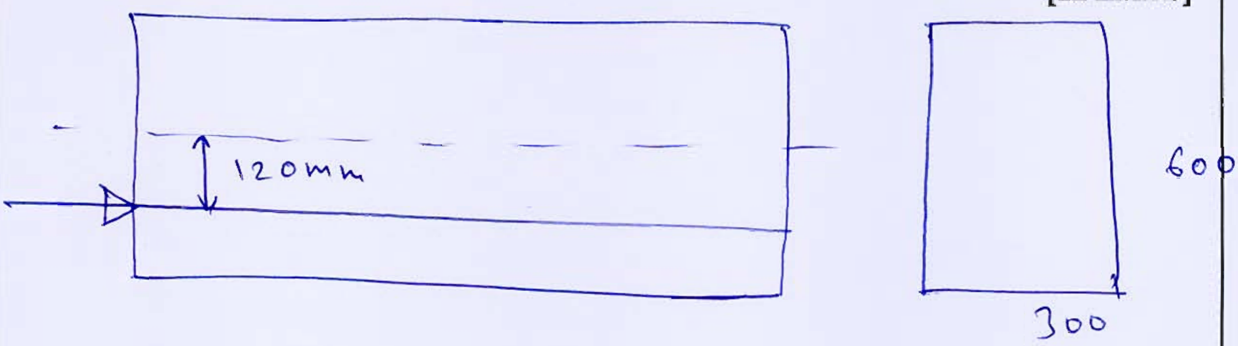
Q.1 (e) A simply supported prestressed concrete beam of rectangular section 300 mm wide and 600 mm deep has a span of 12 m. The effective prestressing force is 980 kN at an eccentricity of 120 mm. The dead load of the beam is 4.50 kN/m and the beam has to carry a live load of 7.50 kN/m. Determine the extremes stresses.

(i) at the end section.

(ii) at the midsection without the action of live load.

(iii) at the midsection considering the action of live load.

[12 marks]



$P = 980 kN$

$P/A = \frac{980 \times 10^3}{300 \times 600} = 5.44 N/mm^2$

$\frac{Pe}{Z} = \frac{980 \times 10^3 \times 120}{300 \times 600^2/6} = 6.53 N/mm^2$

(i) At end section

$Top = P/A - \frac{Pe}{Z} = 5.44 - 6.53 = -1.09 N/mm^2$

$Bottom = P/A + \frac{Pe}{Z} = 5.44 + 6.53 = 11.97 N/mm^2$

(ii) $W_D = 4.50$ & $W_L = 7.50$

$M_d = \frac{4.50 \times 12^2}{8}$ $\qquad M_l = \frac{7.50 \times 12^2}{8}$

$M_d = 81 kNm$ $\qquad M_l = 135 kNm$

$\frac{M_d}{Z} = \frac{81 \times 10^6}{Z}$ $\qquad \frac{M_l}{Z} = \frac{135 \times 10^6}{Z}$

$\frac{M_d}{Z} = 4.5 N/mm^2$ $\qquad \frac{M_l}{Z} = 7.5 N/mm^2$

At mid section without action of live load

$$Top = \frac{P}{A} - \frac{Pe}{Z} + \frac{M_d}{Z}$$

$= 5.44 - 6.53 + 4.5 = 3.41$ N/mm²

$$Bottom = \frac{P}{A} + \frac{Pe}{Z} - \frac{M_d}{Z}$$

$= 5.44 + 6.53 - 4.5 = 7.47$ N/mm²

(iii) At Mid section with considering live load

$$Top = \frac{P}{A} - \frac{Pe}{Z} + \frac{M_d + M_l}{Z}$$

$= 5.44 - 6.53 + 4.5 + 7.5$

$= 10.91$ N/mm²

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$$Botton = \frac{P}{A} + \frac{Pe}{Z} - \left(\frac{M_d + M_l}{Z}\right)$$

$= 5.44 + 6.53 - (4.5 + 7.5)$

$= -0.03$ N/mm

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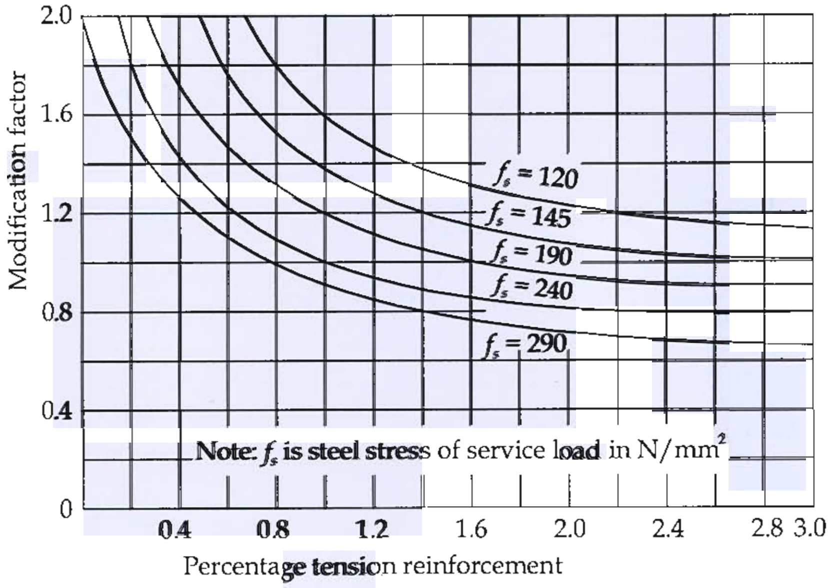
Q.2 (a) Design a 5.0 m × 7.5 m (clear spans) interior panel of a slab for flexure using the following data, by limit state method.

Width of supports = 400 mm
Live load over slab = 8 kN/m^2
Finishing load = 1.5 kN/m^2

Use M25 grade concrete and Fe415 steel. Check the slab for shear and deflection. Also sketch the reinforcement details.

Interior panels	Short span coefficients α_x (values of l_y/l_x)								Long span coefficient α_y
	1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0	
Negative moment at continous edge	0.032	0.037	0.043	0.047	0.051	0.053	0.060	0.065	0.032
Positive moment at mid span	0.024	0.028	0.032	0.036	0.039	0.041	0.045	0.049	0.024



$$f_s = 0.58 f_y \frac{\text{Area of cross-section of steel required}}{\text{Area of cross-section of steel provided}}$$

[20 marks]

Step 1) $d = \frac{\text{Span}}{A \times MF_t}$ Let $MF_t = 1.2$

$d = \frac{5000}{20 \times 1.2} = 208.33$

$d = 220$ mm $D = 220 + 30$ ~~= 240 mm~~ = 250 mm

$L_{eff} = \min \begin{cases} 5 + 0.22 = 5.22 \\ 5 + 0.4 \end{cases}$

$L_{eff} = 5.22$ m

$d = \frac{5220}{20 \times 1.2} = 218 < 220\,m$

ok

Step 2) Load calculation

$w_D = 1 \times 1 \times 0.25 \times 25 = 6.25\,kN/m^2$

$w_L = $ ______ $= 8\,kN/m^2$

$w_f = $ ______ $= 1.5\,kN/m^2$

$w = 15.75\,kN/m$

$w_u = 1.5 \times 15.75$

$= 23.625\,kN/m$

$L_{eff\,x} = 5.22\,m$

$L_{ey} = 7.72\,m$

$r = \frac{L_{ey}}{L_{ex}} = \frac{7.72}{5.22} = 1.47 < 2$

Two way slab

Step 3! Bending moment

$\alpha_{x+} = 0.040 \qquad \alpha_{y+} = 0.032$

$\alpha_{x-} = 0.052 \qquad \alpha_{y-} = 0.024$

$M_{ux+} = \alpha_{x+} w_u L_x^2 = 0.040 \times 23.625 \times 5.22^2$

$= 25.75$ KNm

$M_{uy-} = 0.052 \times 23.625 \times 5.22^2$

$= 33.47$ KNm

$M_{uy+} =$ ~~44.05 KNm~~ 20.60 KNm

$M_{uy-} = 15.45$ KNm

$A_{st x+} = \frac{0.5 f_{ck}}{f_y} \left[1 - \sqrt{1 - \frac{4.6\, B M_{ux}}{f_{ck} B d^2}} \right] B d$

$= 332.69$ mm²

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$A_{st x-} = 435.92$ mm²

$A_{st y+} = 291.17$ mm²

$A_{st y-} =$

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Q.2 (b) Design a cylindrical water tank of capacity 6.5 lakh litre. The diameter of the tank is 12 m and the wall is fixed with the base. Following parameters may be used for the design.

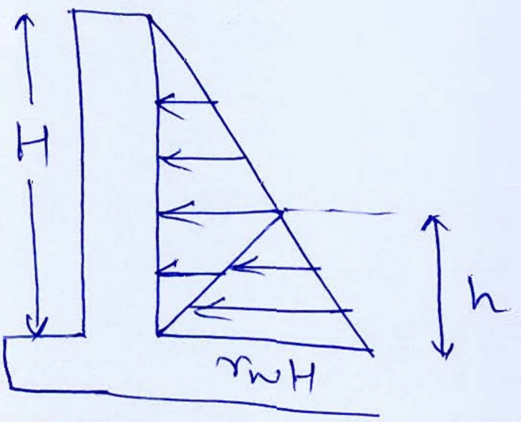
1. $\sigma_{cbc} = 11.5$ N/mm^2
2. $\sigma_{cbt} = 2.21$ N/mm^2
3. $\sigma_{ct} = 1.6$ N/mm^2
4. $\sigma_{st} = 130$ N/mm^2
5. $\gamma_w = 10$ N/mm^3
6. $m = 8.11$

[20 marks]

$$\text{volume} = 6.5 \times 10^5 \, l$$

$$\frac{\pi}{4}(12)^2 \times H = \frac{6.5 \times 10^5}{10^3}$$

$$H = 5.74 \text{ m} \simeq 5.75 \text{ m}$$



$$\frac{H^2}{DT} = \frac{5.75^2}{12 \times 0.25} = 11.020$$

$$6 < \frac{H^2}{DT} < 12$$

Approx

$$T = 30H + 50$$
$$= 30 \times 5.75 + 50$$
$$T = 222.5 \simeq 250 \text{ mm}$$

$$h = \max \begin{cases} H/3 = \frac{5.75}{3} \\ 1 \text{ m} \end{cases}$$

$$\boxed{h = 1.92 \text{ m}}$$

(a) For Hoop Tension

$$T_H = \frac{\gamma_w (H-h) D}{2} = \frac{10(5.75 - 1.92) \times 12}{2}$$

$$T_H = 229.8 \text{ kN}$$

$$T_H = f_{ct} A_c + f_{st} A_{st}$$

For design of steel consider as crack sec^n

$A_{st} = \frac{T_H}{f_{st}} = \frac{229.8 \times 10^3}{130} = 1767.69 \, mm^2$

Take 20mm φ

No. of bars $= \frac{1000}{\frac{\pi}{4}(20)^2} = 5.62 \simeq 6$ nos

spacing $= \frac{1000}{1767.69} \times \frac{\pi}{4}(20)^2 = 177.7$ mm

provide 20 mm φ @ 170mm c/c

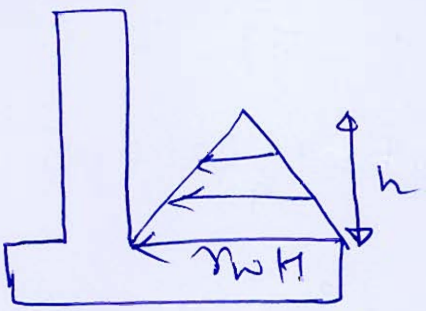
$f_{ct} = \frac{T_H}{1000T + (m-1)A_{st}}$

$= \frac{229.8 \times 1000}{1000 \times 250 + (8.11-1) \times 1767.69}$

$f_{ct} = 0.875 \, N/mm^2 < 1.6 \, N/mm^2$

safe OK

(b) For cantilever moment



$BM = \frac{1}{2} \gamma_w H \cdot h \cdot \frac{h}{3}$

$= \frac{\gamma_w H h^2}{6}$

$= \frac{10 \times 5.75 \times 1.92^2}{6}$

$BM = 35.328$ kNm

$\frac{BM}{Z} < \sigma_{cbt} \Rightarrow \frac{35.328}{2.21} = \frac{1000T^2}{6}$

$T = 309.69$ mm

$K = \frac{mc}{t+mc} = 0.4177$

$j = 1 - K/3 = 0.86$

Take $T = 320$ mm

$d = 320 - (50 + 10)$
$d = 260$ mm

$A_{st} = \frac{BM}{\sigma_{st}\, j\, d} = \frac{35.328 \times 10^6}{130 \times 0.86 \times 260}$

$A_{st} = 1215.35$ mm² $A_{stp} = 1256.40$

ϕ Spacing $= \frac{1000}{1215.35} \times \frac{\pi}{4}(16)^2$

$= 165.41$

provide 16mm ϕ @ 160 mm c/c

$\bar{y}_{uc} = \frac{1000 \times \frac{320^2}{2} + (8.11-1) \times 1256.40 \times 260}{1000 \times 320 + 7.11 \times 1256.40}$

$\bar{y} = 162.71$ mm

$I_{uc} = \frac{1000 \times t^3}{12} + 1000T\left(\frac{T}{2} - \bar{y}\right)^2 + (m-1)\left(n \times \frac{\pi}{64}\phi^4 + \frac{\pi}{4}\phi^2(d-\bar{y})^2\right)$

$= \frac{1000 \times 320^3}{12} + 1000 \times 320\left(\frac{320}{2} - 162.71\right)^2 + 7.11\left(\frac{1000}{160} \times \frac{\pi}{64} \times 16^4 + 1256.40(260 - 162.71)^2\right)$

$= 27.33 \times 10^8 + 0.847 \times 10^8$
$= 28.18 \times 10^8$ mm⁴

$f_{cbt} = \frac{BM}{I_{uc}} \times (T - \bar{y})$

$= \frac{35.328 \times 10^6}{28.18 \times 10^8} (320 - 162.71)$

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~~$f_{cbt} = 0.971$ N/mm² $< \sigma_{cbt}$ =~~

$f_{cbt} = 1.9718 \frac{N}{mm^2} < \sigma_{cbt} = 2.21$ N/mm²

Hence Safe

Q.2 (c) Design the torsional reinforcement in a rectangular beam section, 350 mm wide and 750 mm deep, subjected to an ultimate twisting moment of 140 kN-m combined with an ultimate (hogging) bending moment of 200 kN-m and an ultimate shear force of 110 kN. Assume M25 concrete and Fe415 steel. Consider an effective cover of 50 mm.

[20 marks]

$T_u = 140$ kN m

$M_u = 200$ kN (Hogging)

$V_u = 110$ kN &

M25/Fe415 ec = 50 mm

$d = 750 - 50 = 700$ mm

$B = 350$ mm

(1) ~~Check for shear~~

$V_{ue} = V_u + \frac{1.6 T_u}{B}$

$= 110 + \frac{1.6 \times 140}{0.35}$

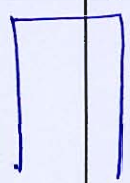
$V_{ue} = 750$ kN

$\tau_{ve} = \frac{750 \times 10^3}{350 \times 700} = 3.061 < \tau_{cmax}$ ~~[illegible]~~ NO

$$M_{TU} = \frac{T_u}{1.7}\left(1 + \frac{D}{B}\right) = \frac{140}{1.7}\left(1 + \frac{780}{380}\right)$$

$$M_{TU} = 258.82 \text{ kNm}$$

$$M_{ue_1} = M_u + M_{TU} = 200 + 258.82$$
$$= 458.82 \text{ kNm} \quad (\text{hogging})$$



$$M_{ue_2} = 258.82 - 200$$
$$= 58.82 \text{ kNm} \quad (\text{sagging})$$

$$A_{st_1} = \frac{0.5 f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6\, B M}{f_{ck} B d^2}}\right] B d$$

$$= \frac{0.5 \times 25}{415}\left[1 - \sqrt{1 - \frac{4.6 \times 458.82 \times 10^6}{25 \times 350 \times 700^2}}\right] 350 \times 700$$

$A_{st_1} = 2121.18 \text{ mm}^2$

provide 7 - 20mm ϕ

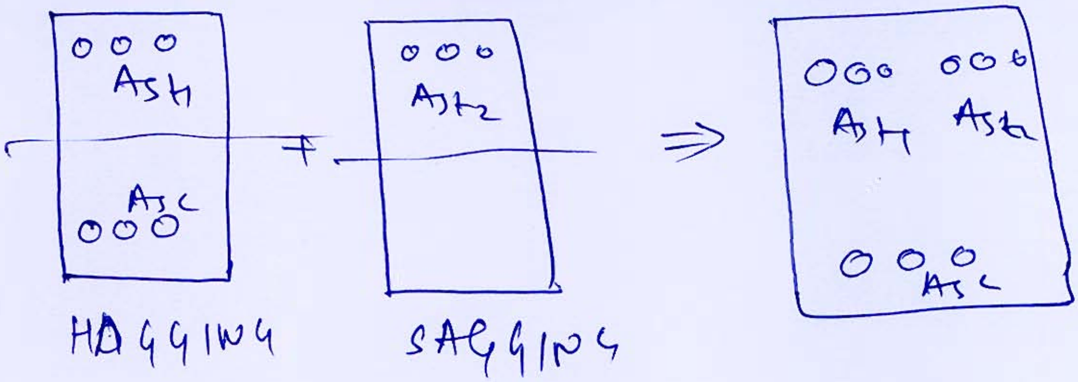
8

~~Spacing =~~

$$A_{st_2} = \frac{B\, M_{ue_2}}{0.87 f_y (d - d_c)}$$

$$= \frac{58.82 \times 10^6}{0.87 \times 415 (700 - 50)} = 250.63 \text{ mm}^2$$

provide 3 - 12mm ϕ



~~Check f~~

(b) for shear reinf

$V_u = 750$ kN

$\tau_{ve} = 3.061 \leq \tau_{cmax}$

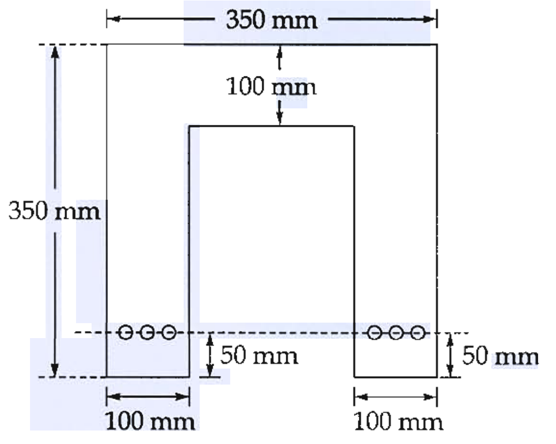
Ok

$\% P_t =$

Q.3 (a) A rectangular column 600 mm × 400 mm carry an axial load of 800 **kN**. Design a rectangular footing of width 2 m to support the column. The safe bearing capacity of the soil is 200 kN/m^2. Use M20 grade concrete and Fe415 grade steel. Consider self weight of footing as 10% of column load and neglect the weight of soil above the footing.

[20 marks]

Q.3 (b) The section of a precast slab unit is shown in the figure. Each slab unit is supported on a span of 8 m. The section is pretensioned by 6 wires of 5 mm diameter, with three wires in each rib. The wires are provided at a distance of 50 mm from the bottom of the ribs. The wires are subjected to an initial stress of 1250 N/mm^2, the total loss of prestress is 15% of the initial stress. The permissible stress in concrete are 14 N/mm^2 in compression and 0.75 N/mm^2 in tension. Determine the safe uniformly distributed load on the slab unit.



[20 marks]

Q.3 (c) A reinforced concrete column of unsupported length 6 m is 340 mm × 500 mm in section and is reinforced with 10 bars of 20 mm diameter, consisting of 3 bars along each short edge and the remaining 4 bars equally distributed along the long faces with 2 bars per face as shown in figure. The column is held in position and restrained against rotation at both the ends. The column is subjected to an ultimate load of 1490 kN whose eccentricities are 80 mm about x-x axis and 60 mm about the y-y axis. M20 grade concrete and Fe415 grade steel are used. Check the adequacy of this column under the above loading conditions.

Chart - 44, SP : 16

Compression with bending. Reinforcement distributed equally on four sides.

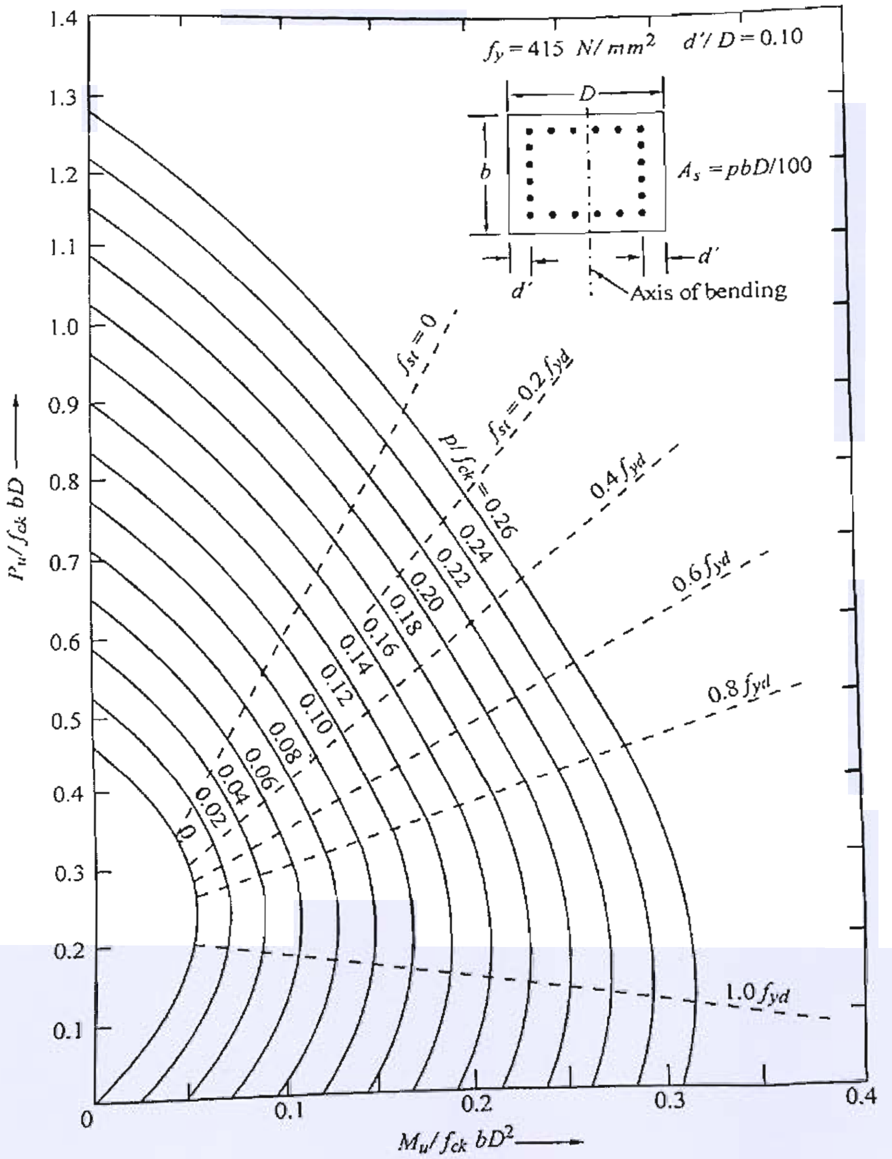
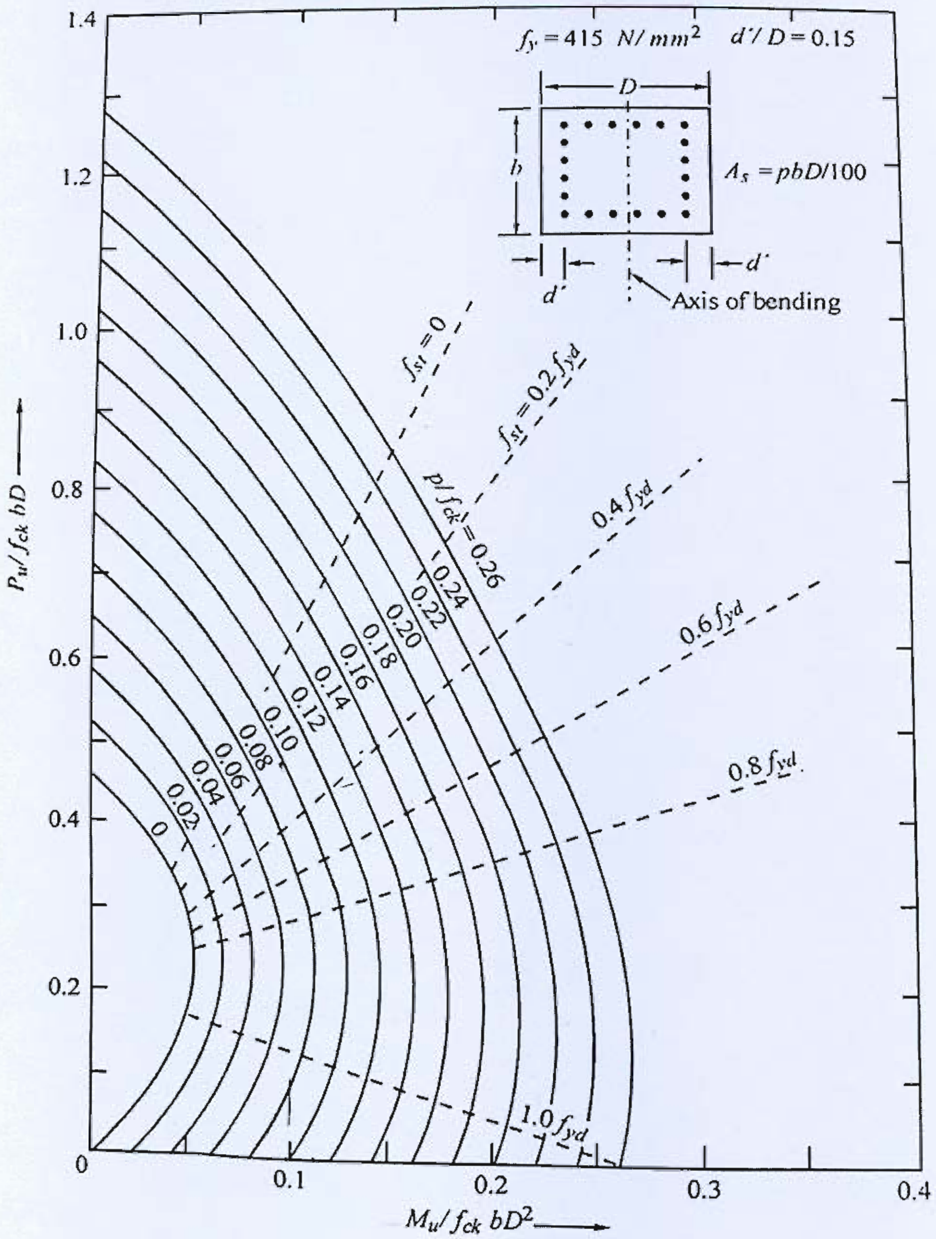
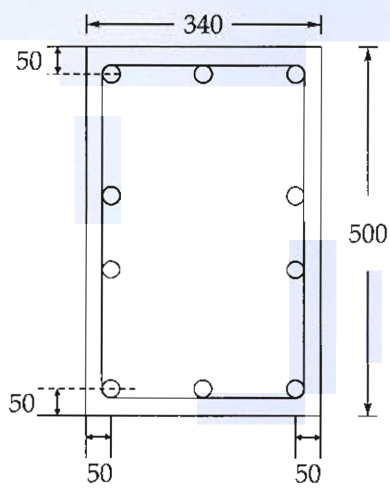


Chart - 45, SP : 16

Compression with bending. Reinforcement distributed equally on four sides.





(All dimensions in mm)

[20 marks]

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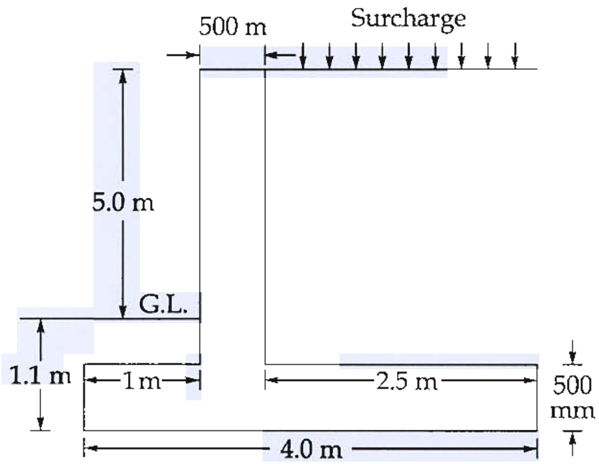
Q.4 (a) An RCC retaining wall is used to retain a level earth-fill 5.0 m above the ground level. Due to construction of a building, there is a surcharge of 30 kN/m^2 on the earth-fill. A good soil for foundation is existing at a depth of 1.1 m below the ground level with a safe bearing capacity of 280 kN/m^2. The unit weight and the angle of repose of the soil are 19 kN/m^3 and 30° respectively. Assume the coefficient of friction between soil and concrete to be 0.50. The initial proportioning of the retaining wall is shown in the figure below:



$\frac{100 A_s}{bd}$	τ_c for M - 30 N/mm^2
0.25	0.37
0.50	0.50
0.75	0.59
1.00	0.66

(i) Check the safety of retaining wall against overturning.

(ii) Check whether shear key is required.

(iii) Design the stem of the retaining wall.

Use M30 grade concrete and Fe-415 grade steel.

[20 marks]

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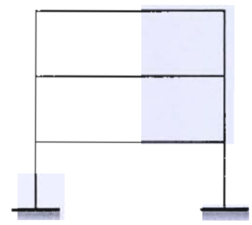
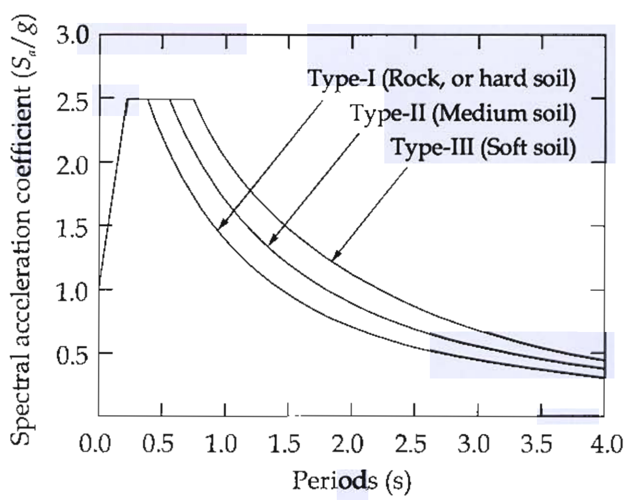
Q.4 (b) A three storeyed symmetrical RC school building is situated at Bhuj (zone V) and the following details are available:



Plan dimension	=	7 m
Storey height	=	3.5 m
Total weight of beams in a storey	=	130 kN
Total weight of slab in a storey	=	250 kN
Total weight of columns in a storey	=	50 kN
Total weight of walls in a storey	=	530 kN
Live load on each floor	=	130 kN
Live load on terrace	=	0 kN
Weight of terrace floor	=	655 kN

The structure is resting on hard rock and infill panels are provided. Determine the total base shear and lateral loads at each floor levels for 5% damping using seismic coefficient method. Also draw shear force diagram due to lateral forces only.



Response spectra for rock and soil sites for 5% damping.

[20 marks]

Do not write in this margin

Q.4 (c) **(i)** Show that development length of a steel bar of diameter ϕ embedded in concrete is given by $L_d = \dfrac{0.87 f_y \phi}{4\tau_{bd}}$.

Also draw the variation of bond stress along the length of the bar.

(ii) Name five types of staircases based on geometrical configurations along with suitable sketch of each. Also draw a typical stair case flight and show:

1. tread
2. nosing
3. riser
4. waist
5. going

[8 + 12 marks]

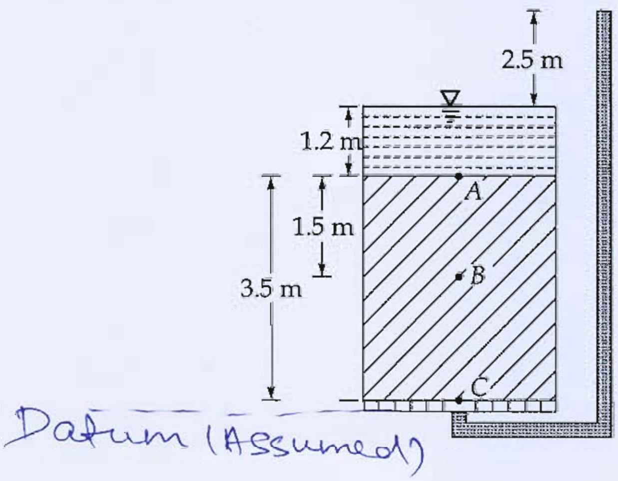
Do not write in this margin

Section B : Geo-technical & Foundation Engineering-1 + Highway Engineering-2 + Surveying and Geology-2

Q.5 (a) An upward flow of water is occurring through a layer of sand as shown in the figure below. Sand is having a specific gravity of 2.72 and void ratio of 0.61.

(i) Calculate the total stress, pore water pressure and effective stress at points A, B and C.

(ii) What is the upward seepage force per unit volume of soil?



[12 marks]

	(C) Entry	(A) Exit	B
Datum Head	0	3.5	2
Pressure Head	7.2	1.2	3.771
Total Head	7.2	4.7	5.771

$$\text{Hydraulic gradient} = \frac{7.2 - 4.7}{3.5} = 0.7142$$

$$\text{TH at } B = (TH)_c - iz$$

$$= 7.2 - 0.7142 \times 2$$

$$= 5.771 \text{ m}$$

$$\text{PH at } B = 5.771 - 2 = 3.771 \text{ m}$$

$$\gamma_{sat} = \left(\frac{G + Se}{1+e}\right)\gamma_w = \left(\frac{2.72 + 1\times 0.61}{1+0.61}\right)9.81$$

$\gamma_{sat} = 20.29$ kN/m³

Point	σ_0	u	$\bar{\sigma} = \sigma_0 - u$ (kN/m²)
A	$1.2\times 9.81 = 11.77$	$1.2\times 9.81 = 11.77$	0
B	$1.2\times 9.81 + 1.5\times 20.29 = 42.207$	~~2.7×9.81 = 26.48~~ $3.77\times 9.81 = 36.98$	5.227
C	$1.2\times 9.81 + 3.5\times 20.29 = 82.78$	$7.2\times 9.81 = 70.632$	12.148

(ii) Upward seepage force per unit volm

Seepage pressure $= h\gamma_w$

$= iz\gamma_w$ ~~$\times A / A$~~

12

Seepage Force $= iz\gamma_w A$

Seepage force per unit vol^n $= \frac{i\gamma_w zA}{Az}$

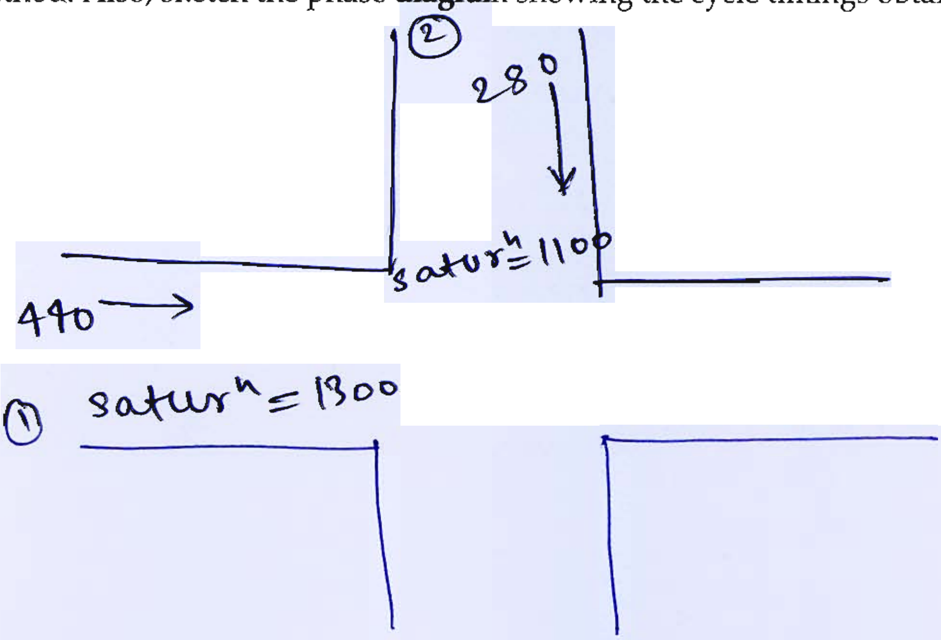
$= i\gamma_w$

$= 0.7142\times 9.81$

$= 7$ kN/m³

Q.5 (b) The average normal flow of traffic on cross roads 1 and 2 during design period are 440 and 280 PCU per hour, the saturation flow values on these roads are estimated as 1300 and 1100 PCU per hour respectively. The all-red time required for pedestrian crossing is 12 sec. Design two phase traffic signal with pedestrian crossing by Webster's method. Also, sketch the phase diagram showing the cycle timings obtained.

[12 marks]



All Red time = 12 secs

critical Flow ratio for Road 1

$$y_1 = \frac{440}{1300} = \frac{22}{65}$$

critical flow ratio for Road ②

$$y_2 = \frac{280}{1100} = \frac{14}{55}$$

Y = sum of critical flow ratio

$$= \frac{22}{65} + \frac{14}{55} = \frac{424}{715}$$

~~Green tii~~ cycle length $= \frac{1.5L + 5}{1 - Y}$

$L = 2n + R = 2 \times 2 + 12 = 16$ sec

(Assume loss time = 2 sec)

$$C_0 = \frac{1.5 \times 16 + 5}{1 - 424/715} = 71.25 \text{ secs}$$

$$G_1 = \left(\frac{C_0 - L}{Y}\right) y_1 = \left(\frac{71.25 - 16}{424/715}\right) \times \frac{22}{65}$$

$G_1 = 31.53$ secs

$$G_2 = \left(\frac{71.25 - 16}{424/715}\right) \times \frac{14}{55} = 23.71 \text{ secs}$$

$G_2 = 23.71$ secs

12

PHASE DIAGRAM

$G_1 = 31.53$	A = 2	AR = 6	$R_1 = 31.72$
$R_2 = 39.54$ secs	$G_2 = 23.71$	A 2	AR 6

A → Amber time = 2 secs

AR → All Red time per phase = 6 secs

Q.5 (c) (i) A mass of soil coated with a thin layer of paraffin weighs 5.23×10^{-3} kN. When immersed in water, it displaces 3.7×10^{-4} m^3 of water. The paraffin is peeled off and found to weigh 1.71×10^{-4} kN. The specific gravity of the soil particles is 2.72 and that of paraffin is 0.9. Determine the void ratio of the soil if its water content is 11%.

(ii) Write a short note on 'Quick sand condition'.

[8 + 4 marks]

Volume of paraffin $V_p = \dfrac{1.71 \times 10^{-4}}{0.9 \times 9.81}$

$V_p = 1.9367 \times 10^{-5}$ m^3

$G = 2.72$

Weight of soil $= 5.23 \times 10^{-3} - 1.71 \times 10^{-4}$

$W_T = 5.059 \times 10^{-3}$ kN

Vol^m of soil $= 3.7 \times 10^{-4} - 1.9367 \times 10^{-5}$

$V_T = 3.506 \times 10^{-4}$ m^3

Bulk Density $= \dfrac{W_T}{V_T} = \dfrac{5.059 \times 10^{-3}}{3.506 \times 10^{-4}}$

$= 14.429$ kN/m³

8

Dry density $\gamma_d = \dfrac{\gamma_b}{1+w}$

$\gamma_d = \dfrac{14.429}{1+0.11} = 12.99$ kN/m³

$12.99 = \dfrac{G\gamma_w}{1+e}$

Void ratio $e = 1.052$

(ii) Quick sand condition

- The condition arrives in sand soil
- soil looses it all shear strength
- flows like a mud with water

Process

→ when there is upward seepage flow then the effective stress of soil reduces

→ A stage comes when the submerged weight of soil is equal to seepage pressure

→ At that the point soil looses all its shear strength & flows with water

$$\gamma_{sub} Z = i Z \gamma_w$$

$$\boxed{i_{cr} = \frac{\gamma_{sub}}{\gamma_w}}$$

3

Do not write in this margin

Q.5 (d) **(i)** Find the shortest distance between two places A and B, given that the latitudes of A and B are 15° N and 16°10′ N and their longitudes are 70°30′ E and 75° E, respectively. Take radius of earth as 6400 km.

(ii) Write a short note on signal propagation errors.

[8 + 4 marks]

Q.5 (e) Briefly discuss about the suitability of igneous rocks for building and foundation works.

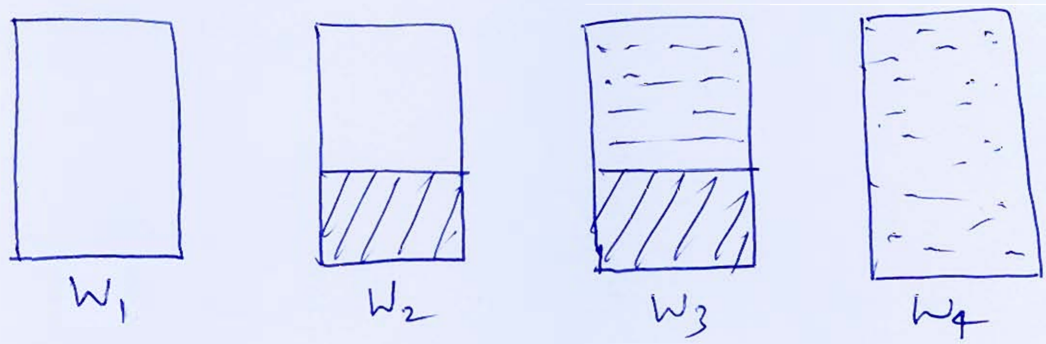
[12 marks]

Q.6 (a) **(i)** Derive an expression for determination of water content in soil by pycnometer method.

(ii) A clay layer 5 m thick has double drainage. It was consolidated under a load of 127.5 kN/m². The load is increased to 197.5 kN/m². The coefficient of volume compressibility is 5.79×10^{-4} m²/kN and value of permeability is 1.6×10^{-8} m/min. Find ultimate settlement and settlement at 50% consolidation. Also, determine probable period of time required for clay stratum to undergo 90% of ultimate settlement under the given increment of load.

[10 + 10 marks]

(i)



W_1 = wt of Empty pycnometer
W_2 = wt of soil + pycnometer
W_3 = wt of soil + water + pycnometer
W_4 = wt of water + pycnometer

As we know

$$W_4 = W_3 - W_s + V_s \gamma_w$$

$$W_4 = W_3 - W_s + \frac{W_s}{G\gamma_w}\gamma_w$$

$$W_4 - W_3 = -W_s\left(\frac{G-1}{G}\right)$$

$$W_s = -\left(\frac{W_4 - W_3}{\left(\frac{G-1}{G}\right)}\right)$$

$$\text{water content} = \frac{W_w}{W_s} \times 100$$

$$= \frac{W_2 - W_1 - W_s}{W_s} \times 100$$

$$= \left(\frac{W_2 - W_1}{W_s} - 1 \right) 100$$

10

$$= \left(\frac{W_2 - W_1}{\left(\frac{W_4 - W_3}{\frac{G-1}{G}} \right)} - 1 \right) \times 100$$

$$w = \left(\frac{W_2 - W_1}{W_3 - W_4} \times \left(\frac{G-1}{G} \right) - 1 \right) \times 100$$

(ii) $H_0 = 5m$

$m_v = 5.79 \times 10^{-4}\ m^2/kN$

$k = 1.6 \times 10^{-8}\ m/min$

$\Delta\bar{\sigma} = 197.5 - 127.8 = 70\ kN/m^2$

$\Delta H = H_0 m_v \Delta\bar{\sigma}$

$= 5 \times 10^3 \times 5.79 \times 10^{-4} \times 70$

$\Delta H = 202.65\ mm$ ultimate settlement

At 50 % consolidation

$0.50 = \frac{\Delta h}{\Delta H} \Rightarrow \Delta h = 0.50 \times 202.65$

$\Delta h = 101.325\ mm$

For 90 % settlement % Degree of consolid^n $\Rightarrow U = \frac{0.9 \times \Delta H}{\Delta H} \times 100$

$U = 90\%$

$$C_v = \frac{k}{m_v \gamma_w} = \frac{1.6 \times 10^{-8}\ m/min \times 60\ \frac{min}{s}}{5.79 \times 10^{-4} \times 9.81}$$

$$C_v = 4.69484 \times 10^{-8}\ m^2/s$$

For $\%U = 90\%$

$$T_v = 1.782 - 0.933 \log(100 - U)$$

$$= 1.782 - 0.9331 \log(100 - 90)$$

$$T_v = 0.848$$

$$T_v = \frac{C_v t}{d^2} \Rightarrow ~~0.848 \times 1.69~~$$

$$0.848 = \frac{4.69~~484~~ \times 10^{-8} \times t}{(5/2)^2}$$

~~t = 8.7~~

t = 3.58 days

10

Q.6 (b) **(i)** Determine the total thickness of flexible pavement assuming single layer elastic theory and using the following data:

Design wheel load = 5100 kg,
Tyre pressure = 7.0 kg/cm^2,
Elastic modulus = 180 kg/cm^2,
Permissible deflection = 0.25 cm.

(ii) The spacing between the contraction joints of a CC pavement is 4.5 m. Determine the tensile stress developed in CC pavement due to contraction if the coefficient of friction between the bottom of the pavement and the supporting layer is 1.3 and the unit weight of CC is 2400 kg/m^3.

(iii) A rigid pavement of 15 cm thickness is supported over a subgrade having modulus of subgrade reaction as 7.5 kg/cm^3. If dowel bars are placed at every 30 cm, calculate the maximum load carried by a single dowel which is just below the wheel. Assume the wheel load as 4100 kg, participation of dowel bars in load distribution upto 1.8 times radius of relative stiffness and load to be transferred by the joint as 50%. Poissons' ratio and modulus of elasticity of cement concrete may be taken as 0.15 and 2.1 × 10^5 kg/cm^2 respectively.

[4 + 4 + 12 marks]

(i) Thicknes of Flexible pavement

$$t\,(cm) = \sqrt{\left(\frac{3P}{2\pi E_s \Delta}\right)^2 - a^2}$$

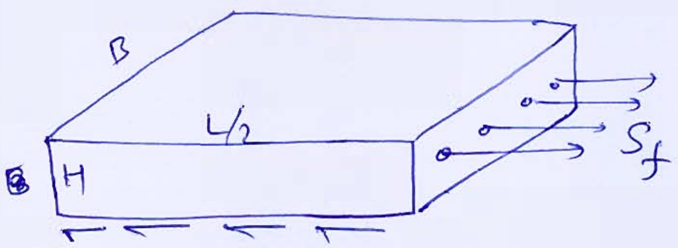
$$a = \sqrt{\frac{P}{\pi p}} = \sqrt{\frac{5100}{\pi \times 7}} = 15.22\ cm$$

$$t\,(cm) = \sqrt{\left(\frac{3 \times 5100}{2\pi \times 180 \times 0.25}\right)^2 - (15.22)^2}$$

$$\boxed{t\,(cm) = 51.92\ cm}$$

(4)

(ii)



$$S_f \times B \times H = f\left(\gamma \times \frac{L}{2} B H\right)$$

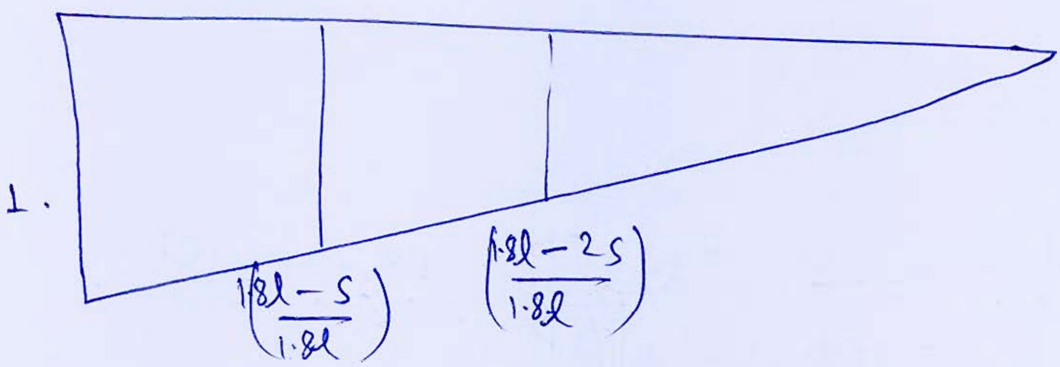
Tensile stress $\boxed{S_f = \frac{1}{2} \gamma f L}$

$$= \frac{1}{2} \times 2400 \times 1.3 \times 4.5$$

(4)

$$\boxed{S_f = 7020 \text{ kg/m}^2}$$

(iii) load distribution $= 1.8 l$



$$l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4} = \left[\frac{2.1 \times 10^5 \times (15)^3}{12 \times 7.5(1 - 0.15^2)}\right]^{1/4}$$

$$\boxed{l = 53.27 \text{ cm}}$$

spacing $s = 30$ cm

Actual load carrying capacity $= 1 + \frac{1.8l - s}{1.8l} + \frac{1.8l - 2s}{1.8l}$

~~$= 1 + \frac{1.8 \times 53.27 - 30}{53.27}$~~

~~$= 1.4369$~~

$$= 1 + \frac{1.8 \times 53.27 - 30}{1.8 \times 53.27} + \frac{1.8 \times 53.27 - 60}{1.8 \times 53.27} + \frac{1.8 \times 53.27 - 90}{1.8 \times 53.27}$$

$= 1 + 0.6871 + 0.3742 + 0.0613$

$= 2.1226$

Required load carrying capacity

$$= \frac{0.50P}{P_D}$$

P = wheel load

P_D = Max^m load carried by single dowel bar

12

$$= \frac{0.50 \times 4100}{P_D}$$

Reqd load carrying capacity = Actual load carrying capacity

$$\frac{0.50 \times 4100}{P_D} = 2.1226$$

$$\boxed{P_D = 965.80\ kg/cm^4}$$

Q.6 (c) (i) An area of 150 km × 100 km is to be surveyed using aerial photogrammetry. From the data given below:

Size of photograph = 25 cm × 25 cm
Average scale of photograph = 1 : 25000
Average elevation of terrain = 330 m
Longitudinal overlap = 60%
Side overlap = 40%
Ground speed of aircraft = 270 km/hr
Focal length of camera = 200 mm
Least count of intervalometer = 0.5 seconds

Determine:

1. Number of photographs required to cover the complete area.
2. Height of flight
3. Spacing of flight lines
4. Ground exposure distance and
5. Exposure interval.

[15 marks]

No. of photograph in a strip

(i) $N_1 = \frac{L}{(1-P_l)\,l\,S} = \frac{150 \times 10^3}{(1-0.6)0.25 \times 25000} + 1$

$N_1 = 61$

No. of total strips $N_2 = \frac{B}{(1-P_s)\,b\,S}$

$N_2 = \frac{100 \times 10^3}{(1-0.4) \times 0.25 \times 25000} + 1$

$N_2 = 27.66 \simeq 28$

Total Number of photographs $= N_1 \times N_2$

$= 61 \times 28 = \boxed{1708}$

(ii) $Scale = \frac{f}{H - h_{avg}}$

$\frac{1}{25000} = \frac{0.20}{H - 330}$

$\boxed{H = 5330 \text{ m}}$ Height of flight

(iii) Spacing of flight lines

$= (1 - P_s) \times b \times S$

$= (1 - 0.4) \times 0.25 \times 25000$

$= 3750 m$

(iv) Ground exposure distance

$= (1 - P_l) \times l \times S$

$= (1 - 0.6) \times 0.25 \times 25000$

$= 2500 m$

(v) Exposure Interval $= \frac{\text{Ground distance}}{\text{ground Speed of aircraft}}$

$= \frac{2500}{270 \times 5/18}$

$= 33.33$ secs

Incomplete

1

Q.6 (c) (ii) Define the following terms briefly:

1. Zenith and nadir
2. Azimuth
3. Prime vertical
4. Declination.

[5 marks]

1) Nadir :- Nadir is the point used in vertical photogrammetry.
It is the point along plumbline which is straight in the direction of gravity

2) Azimuth :- Azimuth is the ~~angle~~ ~~meo~~ Horizontal Angle

2

4) Declination :- It is ~~a~~ Horizontal Angle b/w True meridian and magnetic meridian

Q.7 (a) Pore pressure measurement were made during undrained triaxial tests on samples of compacted fill material from an earthen dam after saturating them in the laboratory. The results were as follows:

Property measured (kN/m^2)	Test-1	Test-2
Lateral pressure (σ_3)	150	450
Total vertical pressure (σ_1)	400	1000
Pore water pressure (u)	30	125

Determine the apparent cohesion and the angle of shearing resistance with respect to (i) total stress (ii) effective stress.

[20 marks]

(i) Total stress parameters

$\sigma_3 = 150$ $\quad\quad$ $\sigma_3 = 450$

$\sigma_1 = 400$ $\quad\quad$ $\sigma_1 = 1000$

$\sigma_1 = \sigma_3 \tan^2(45 + \phi/2) + 2c \tan(45 + \phi/2)$

$\sigma_1 = \sigma_3 N_\phi + 2c\sqrt{N_\phi}$

$400 = 150 N_\phi + 2c\sqrt{N_\phi}$ — (I) Test No. 1

$1000 = 450 N_\phi + 2c\sqrt{N_\phi}$ — (II) Test No. 2

From (I) & (II)

$N_\phi = 2$

$\tan^2(45 + \phi/2) = 2$

$\boxed{\phi = 19.471°}$

$\boxed{c = 35.355 \text{ kN/m}^2}$

} Total shear parameter

(ii) Effective shear parameter

$(\sigma_1 - u) = (\sigma_3 - u)\tan^2(45 + \phi/2) + 2c\tan(45 + \phi/2)$

$(\sigma_1 - u) = (\sigma_3 - u) N_\phi + 2c\sqrt{N_\phi}$

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Test No. 1

$400 - 30 = (150 - 30) N_\phi + 2c\sqrt{N_\phi}$

$370 = 120 N_\phi + 2c\sqrt{N_\phi}$ — (I)

Test No. 2

$1000 - 125 = (450 - 125) N_\phi + 2c\sqrt{N_\phi}$

$875 = 325 N_\phi + 2c\sqrt{N_\phi}$ — (II)

From (I) & (II)

$N_\phi = 2.4634$

$\phi' = 25°$

$c' = 23.699 \text{ kN/m}^2$

} Effective shear parameter

20

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Q.7 (b) The consolidated data collected from speed and delay studies by floating car method on a stretch of urban road of length 3.5 km, are given below. Determine the average values of (i) traffic volume, (ii) journey speed and (iii) running speed of the traffic stream along both the directions.

Trip no.	Direction of trip	Journey time, min-sec	Total stopped delay, min-sec	No. of vehicles overtaking	No. of vehicles overtaken	No. of vehicles from opposite direction
1	N - S	6 - 48	1 - 50	3	7	270
2	S - N	7 - 20	1 - 40	4	3	190
3	N - S	7 - 10	1 - 30	5	3	290
4	S - N	7 - 40	2 - 00	3	1	220
5	N - S	6 - 10	1 - 30	3	6	270
6	S - N	8 - 00	2 - 30	2	2	190
7	N - S	6 - 32	1 - 50	2	5	320
8	S - N	7 - 40	1 - 30	3	2	190

[20 marks]

	Direc	Journey time	Delay	No. of overtaking	No. of overtaken	No. of vehicle opp
1	N – S	6 min 40 sec	1 min 40 sec	3.25	5.25	287.5
2	S – N	7 min 40 sec	1 min 55 sec	3	2	197.5

(A) Along N – S

(i) Traffic volh $q_{NS} = \frac{n_a + n_y}{t_a + t_w}$

$q_{N-S} = \frac{197.5 + (3.25 - 5.25)}{6.67 + 7.67}$

$q_{N-S} = 13.63$ veh/min

~~Journey time~~

~~t_{NS}~~ $\bar{t} = t_w - \frac{n_y}{q} = 6.67 - \frac{(3.25 - 5.25)}{13.63}$

~~= 7.81 min~~ 6.81 min

~~$\bar{t}$ = 7.81 min~~ $\bar{t} = 6.81$ min

(ii) Journey Speed $= \frac{3500}{7.81 \times 60}$

$=$ ~~7.46 m/s~~ 8.56 m/s

(iii) Running time $= 7.81 - 1.67$

$= 5.14$ min

Running speed $= \frac{3500}{5.14 \times 60} =$ ~~9.5 m/s~~

$= 11.34$ m/s

(B) Along S-N

(i) Traffic volm =

$q_{S-N} = \frac{287.5 + (3-2)}{7.67 + 6.67}$

$q_{S-N} = 20.11$ veh/min

$\bar{t} = t_w - \frac{n_y}{q} = 7.67 - \frac{(3-2)}{20.11}$

$\bar{t} = 7.62$ min

(ii) Journey speed $= \frac{3500}{7.62 \times 60} = 7.655$ m/s

(iii) Running time $= 7.62 - 1.917$

$= 5.70$ min

Running Speed $= \frac{3500}{5.703 \times 60}$

$= 10.22$ m/s

20

Q.7 (c) (i) What do you mean by the term 'Metamorphism'? Describe the various agents associated with it.

[10 marks]

Q.7 (c) **(ii)** Briefly explain the igneous formations viz. dykes and sills. Also state the importance of dykes from civil engineering point of view.

[10 marks]

Q.8 (a) (i) Define the following terms:

1. Coefficient of compressibility
2. Coefficient of volume change
3. Compression index
4. Expansion index
5. Recompression index

[10 marks]

Q.8 (a) **(ii)** A wall with smooth vertical back 5 m high retains a mass of dry cohesionless sand that has a horizontal surface. The sand behind the wall is having specific gravity of 2.65, void ratio of 0.65 and angle of shearing resistance of 20°. The water level behind the wall is at an elevation of 1 m below the crest. The backfill carries a uniformly distributed load of 14.6 kN/m^2. If the deformation condition for active Rankine state is satisfied, then what is the total horizontal pressure on the back of the wall?

[10 marks]

Q.8 (b) **(i)** Briefly discuss about the angular methods commonly employed for curve setting.

(ii) Two straights *AB* and *BC* intersect at a chainage of 4274.0 m. The angle of intersection is 150°. It is required to set out a 3° simple circular curve to connect the straights. Calculate all the data necessary to set out the curve by the method of offsets from the chord produced with an interval of 30 m.

(iii) Discuss briefly about the terms 'Drift' and 'Crab'.

[6 + 10 + 4 marks]

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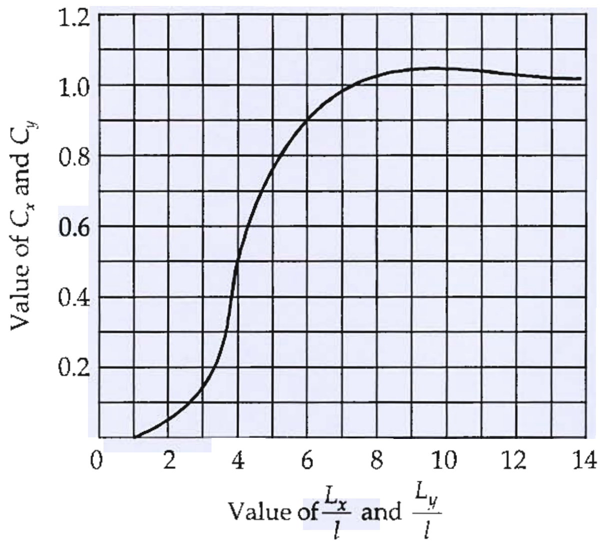
Q.8 (c) (i) Determine the warping stresses at interior, edge and corner of a 26 cm thick cement concrete pavement with transverse joints at 4.5 m interval and longitudinal joints at 3.5 m intervals. The modulus of subgrade reaction is 15 kg/cm^3 and radius of loaded area is 15 cm. Assume maximum temperature differential during day to be 0.6° C per cm slab thickness and maximum temperature differential of 0.4° C per cm slab thickness during the night. Additional data are given below:

$\alpha = 10 \times 10^{-6}$ per °C, $E = 3 \times 10^5$ kg/cm^2 , $\mu = 0.15$



Warping stress coefficient chart (by Bradbury)

[15 marks]

Q.8 (c) (ii) What is prime coat and what purpose does it serve in the construction of bituminous pavement?

[5 marks]

OOOO

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work

$W_4 = W_3 - W_s + V_s \gamma_w$

$= W_3 - W_s + \frac{W_s}{G \gamma_w} \gamma_w$

$W_4 = W_3 + W_s \left(1 - \frac{1}{G}\right)$

$W_s = \frac{W_4 - W_3}{\left(\frac{G-1}{G}\right)}$

$\frac{W_w}{W_s}$

$\frac{W_2 - W_1 - W_s}{W_s}$

$\frac{W_2 - W_1}{W}$

$\frac{0.36 f_{ck} B x_{ulim}}{0.87 f_y} = A_s$

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

$1440 x_u = \frac{359205 - 1245 f_{sc}}{1440}$

$\frac{0.0035}{x_u} = \frac{\varepsilon_{sc}}{x_u - 50}$

$f_{sc} = E_s \varepsilon_{sc}$

$\varepsilon_{sc} = \left(\frac{x_u - 50}{x_u}\right) 0.0035$

$f_{sc} = 700 \left(\frac{x_u - 50}{x_u}\right)$

$1440 x_u = 359205 - 1245 \times 700 \left(\frac{x_u - 50}{x_u}\right)$

$x_u = 70.92$

$\varepsilon_{sc} = 1.0324 \times 10^{-3}$