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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	43
Q.2	44
Q.3	33
Q.4	—
Section-B	
Q.5	35
Q.6	39
Q.7	—
Q.8	—
Total Marks Obtained	194

Signature of Evaluator: Akuma

Cross Checked by ....

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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 RCC and other section
* Good presentation
* Improve Accuracy ; 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]

try ⇒ 1) (a) Assumptions for design of a Reinforced concrete section for limit state ~~are~~ of collapse in bending are-

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

(ii) The relationship between compressive stress in concrete and strain in concrete may be assume ~~of~~ rectangle, parabolic or any other shape. For design purpose compressive stress in concrete is taken as 0.67 fck where fck is ~~compressive~~ ct characteristic compressive strength of concrete. In addition to this the partial factor of safety of 1.5 is applied.

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(iii) The maximum compressive strain in outer most compression fibre in concrete is taken as 0.0035.

(iv) Tensile strength of concrete ~~is~~ ignored.

(v) The stress in steel can be taken from stress-strain curve of type of ~~steel~~ to be used. The partial factor of safety of 1.15 is applied in addition ~~to~~ this.

(vi) The maximum strain in steel shall not be less than

$$\epsilon_{st} > 0.002 + \frac{0.87 f_y}{E_s}$$

For limiting percent of tensile reinforcement

$$P_t(lim)\% = \frac{A_{st,lim}}{Bd} \times 100$$

⇒ compressive force = Tensile force

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

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$\Rightarrow \frac{A_{st,lim}}{B d} = \left(\frac{0.36}{0.87}\right) \times \left(\frac{f_{ck}}{f_y}\right) \times \left(\frac{x_{u,lim}}{d}\right)$

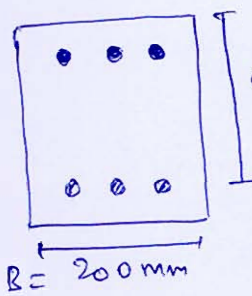
$P_{t(lim)}\% = \left(\frac{0.36}{0.87}\right) \times \left(\frac{30}{500}\right) \times \left(\frac{0.46 d}{d}\right) \times 100$

$\boxed{P_{t,lim}\% = 1.142\%}$

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]

Q1) (b)



Given,
$B = 200$ mm
$d = 350$ mm
$A_{sc} = 1245$ mm²
$A_{st} = 1600$ mm²
$d_c = 50$ mm M20 Fe 250

To find ultimate moment of Resistance of the beam

Step-1) To find x_u

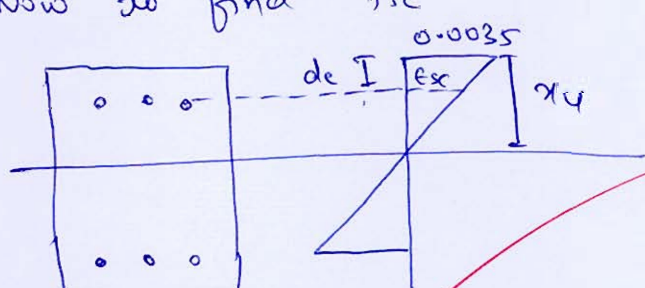
$\Rightarrow 0.36 f_{ck} B x_u + (f_{sc} - 0.45 f_{ck}) A_{sc} = 0.87 f_y A_{st}$

$\Rightarrow 0.36 \times 20 \times 200\, x_u + (f_{sc} - 0.45 \times 20) \times 1245 = 0.87 \times 250 \times 1600$

$\Rightarrow 1440\, x_u + 1245 f_{sc} - 11205 = 348000$

$\Rightarrow 1440\, x_u + 1245 f_{sc} = 359205$ —(1)

Now to find f_{sc}



From similar triangle

$$\Rightarrow \frac{\epsilon_{sc}}{0.0035} = \frac{x_u - d_c}{x_u}$$

$$\Rightarrow \epsilon_{sc} = \left(1 - \frac{d_c}{x_u}\right) \times 0.0035$$

$\Rightarrow f_{sc}$ — Assuming $E_s = 2 \times 10^5$ MPa

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

$f_{sc} = \left(1 - \frac{d_c}{x_u}\right) \times 0.0035 \times 2 \times 10^5$

$f_{sc} = \left(1 - \frac{50}{x_u}\right) 700$

putting value of f_{sc} in eq^n (1)

$\Rightarrow \quad 1440 x_u + 1245 \left(1 - \frac{50}{x_u}\right) \times 700 = 359205$

$\Rightarrow \quad x_u = 70.92 \text{ mm}$

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MOR

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

$f_{sc} = \left(1 - \frac{50}{70.92}\right) \times 700 = 206.48 \frac{N}{mm^2}$

$MOR = 0.36 \times 20 \times 200 \times 70.92 (350 - 0.42 \times 70.92) + (206.48 - 0.45 \times 20) \times 1245 \times (350 - 50)$

$MOR = 106.46 \text{ kNm}$

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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]

Ans ⇒ 1) (c)(i)

(ii) ~~In LSM smaller si~~

<u>Advantages of LSM</u>

(a) In LSM smaller size of members are required as compared to WSM.

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(b) In LSM structure are designed considering ultimate load unlike WSM considering working loads.

(c) LSM ~~co~~ design method consider both limit state of collapse & limit state of serviceability.

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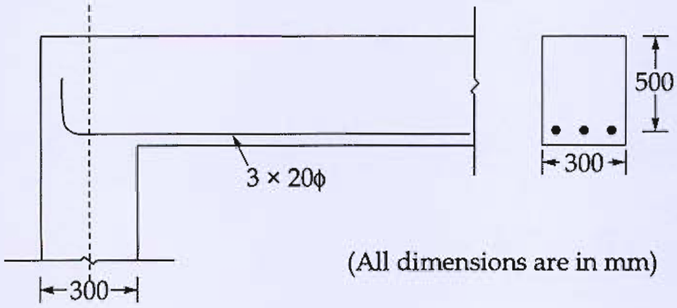
Q.1 (d) Determine the anchorage length of bars at the simply supported end of a reinforced concrete beam as shown below, if it is subjected to an ultimate shear force of 300 kN at the centre of support. Assume M20 grade concrete and steel of grade as Fe415. [Take τ_{bd} = 1.92 N/mm^2]



(All dimensions are in mm)

[12 marks]

Try ⇒ 1 (d) Given, $V_u = 300$ kN

M20 Fe 415 $\tau_{bd} = 1.92$ N/mm2

B = 300 mm d = 500 mm.

width of support, a = 300 mm

Ast = 3 – 20 ϕ

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

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

$L_d = 587.646$ mm

⇒ $L_d \le 1.3 \frac{M_u}{V_u} + L_0$.

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

calculation of x_u

$x_u = \frac{0.87 \times f_y A_{st}}{0.36 f_{ck} B} = \frac{0.87 \times 415 \times 3 \times \frac{\pi}{4} \times 20^2}{0.36 \times 20 \times 300}$

$x_u = 157.53$ mm

$M_u = 147.62$ kN m

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$\Rightarrow \quad L_d = \frac{M_u}{V_u} + L_0$

$\Rightarrow \quad 587.646 = \frac{147.62 \times 10^6}{300 \times 10^3} + L_0$

$L_0 = 587.64 - 492.06$

$L_0 = 95.57 \text{ mm}$

Hence minimum anchorage length required is 95.57 mm

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.

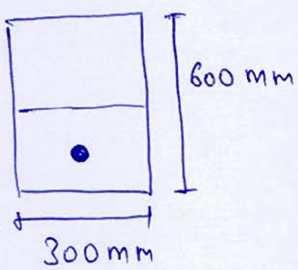
(i) at the end section.

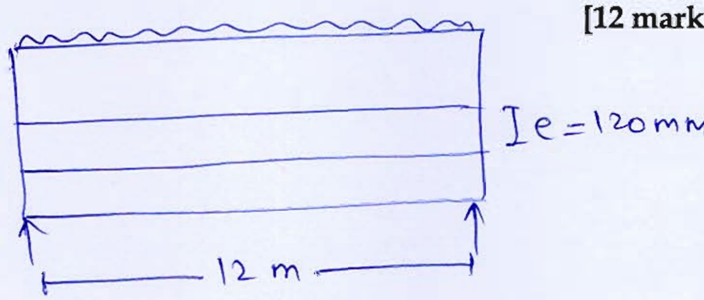
(ii) at the midsection without the action of live load.

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

[12 marks]

try⇒1 (e)





$P = 980$ kN $e = 120$ mm $w_D = 4.5$ kN/m
$w_L = 7.5$ kN/m

(i) $M_D = \frac{w_D l_{eff}^2}{8} = \frac{4.5 \times 12^2}{8} = 81$ kNm → At mid span

$M_L = \frac{w_L l_{eff}^2}{8} = \frac{7.5 \times 12^2}{8} = 135$ kNm → At mid span

$I = \frac{BD^3}{12} = \frac{300 \times 600^3}{12} = 54 \times 10^8$ mm^4

$\sigma_{Top} = \frac{P}{A} - \frac{Pe}{I} y_T + \frac{M_D + M_L}{I} y_T$

$\sigma_{Top} = \frac{980 \times 10^3}{300 \times 600} - \frac{980 \times 10^3 \times 120 \times 300}{54 \times 10^8} + 0$

$\sigma_{Top} = 5.444 - 6.533$

$\sigma_{Top} = -1.089 \frac{N}{mm^2}$

$\sigma_{Bottom} = \frac{P}{A} + \frac{Pe\, y_B}{I} - \frac{M_D + M_L}{I} y_B$

$\sigma_B = 5.444 + 6.533$

$\sigma_B = 11.98 \frac{N}{mm^2}$

(ii) $\sigma_T = \frac{P}{A} - \frac{Pe\,y_T}{I} + \frac{M_D}{I} y_T$

$\sigma_T = \frac{980\times10^3}{300\times600} - \frac{980\times10^3\times120\times300}{54\times10^8} + \frac{81\times10^6\times300}{54\times108}$

$\sigma_T = 5.444 - 6.533 + 4.5$

$\sigma_T = 3.411 \ \frac{N}{mm^2}$

$\sigma_B = 5.444 + 6.533 - 4.5$

$\sigma_B = 7.47 \ \frac{N}{mm^2}$

(iii) $\sigma_T = \frac{P}{A} - \frac{Pe\,y_T}{I} + \frac{M_D + M_L}{I} y_T$

$\sigma_T = 5.444 - 6.533 + \frac{(81+135)\times10^6\times300}{54\times108}$

$\sigma_T = 5.444 - 6.533 + 12$

$\sigma_T = 10.91 \ \frac{N}{mm^2}$

$\sigma_B = 5.444 + 6.533 - 12$

$\sigma_B = -0.023 \ \frac{N}{mm^2}$

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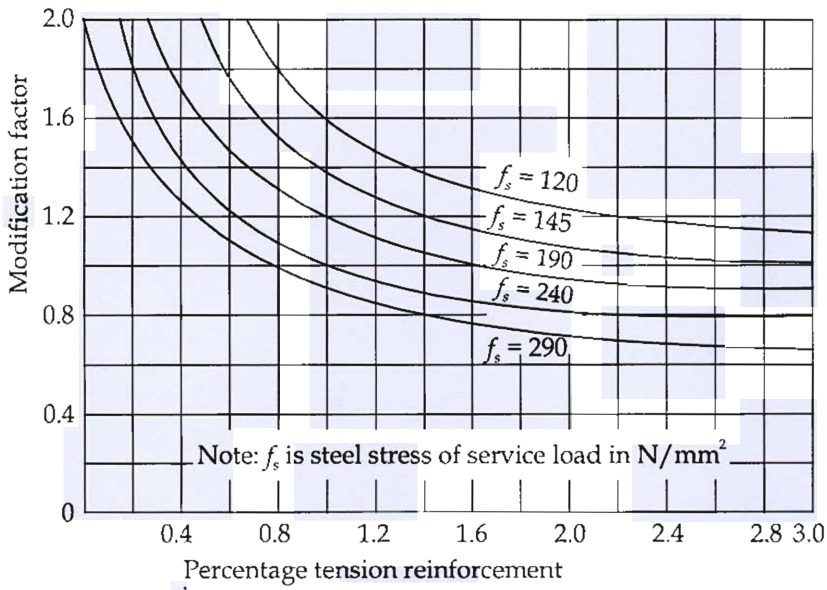
Q.2 (a) Design a 5.0 m × 7.5 m (clear spans) interior panel of a slab for flexure using the following data, by limit state method.

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]

Ans 2 (a) Given,

$l_{x_0} = 5\text{m}$ $l_{y_0} = 7.5\text{ m}$ $a = 400\text{ mm}$

$w_L = 8\text{ kN/m}^2$ FL, $w_F = 1.5\text{ kN/m}^2$ M25 Fe415

Check $\frac{l_{y_0}}{l_{x_0}} = \frac{7.5}{5} = 1.5 < 2$ Two way slab

Assume D ~~deff~~ $\geq \frac{l_{eff}}{28}$ As per IS 456-2000

$D \geq \frac{5000}{28}$

$D \geq 178.57$ mm

let us take D = overall depth = 230 mm

$d' = 30$ mm

$d = D - d' = 230 - 30 = 200\ mm$

$d = 200\ mm$

① Effective span.

$l_{eff\,x} = \min \begin{cases} l_{x0} + a \\ l_{x0} + d \end{cases} = \min \begin{cases} 5 + 0.4 \\ 5 + 0.2 \end{cases}$

$= 5.2\ m$

$l_{eff\,y} = \min \begin{cases} l_{y0} + a \\ l_{y0} + d \end{cases} = \min \begin{cases} 7.5 + 0.4 \\ 7.5 + 0.2 \end{cases}$

$= 7.7\ m$

Check $\frac{l_{eff\,y}}{l_{eff\,x}} = \frac{7.7}{5.2} = 1.48 < 2$ Two way slab

② Load calculation [All calculation is for 1m width slab]

$w_L = 8\ kN/m^2$

$w_F = 1.5\ kN/m^2$

$w_D = 25 \times 1 \times 0.23 = 5.75\ kN/m^2$

$w_T = w_L + w_F + w_D = 15.25\ kN/m$

Factored load,

$w_u = 1.5 \times 15.25 = 22.875\ kN/m$

③ BM calculation

for $\frac{l_y}{l_x} = 1.48$

$(\alpha_x)_+ = 0.039 + (0.041 - 0.039) \times \frac{1.48 - 1.4}{1.5 - 1.4}$

$= 0.0406$

$(\alpha_x)_- = 0.051 + (0.053 - 0.051) \times \frac{1.48 - 1.4}{1.5 - 1.4}$

$= 0.0526$

$(\alpha_y)_+ = 0.024$

$(\alpha_y)_- = 0.032$

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Moment	coefficient	BM values	A_{st} (mm²)	Spacing (mm)
$Mu_{x(+)}$	0.0406	25.11	360	140
$Mu_{x(-)}$	0.0526	32.53	502.65	~~140~~ 100
$Mu_{y(+)}$	0.024	14.85	209.44	240
$Mu_{y(-)}$	0.032	19.79	295.68	170

Calculation for Mu_{x+}

$$Mu_{x(+)} = \alpha_x w_u d_{eff x}^2 = 0.0406 \times 22.875 \times 5.2^2$$

$$= 25.11 \text{ KNm}$$

Check for d req for maximum moment

$$d = \sqrt{\frac{BMu}{QB}} = \sqrt{\frac{32.53 \times 10^6}{0.138 \times 25 \times 10^3}}$$

$$d = 97.10 \text{ mm}$$

∴ $d_{req} < d_{provided}$ Hence safe

~~spacing of~~

(4) Calculation of steel

$$A_{st x(+)} = 0.5 \frac{f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 Mu_{x+}}{f_{ck} B d^2}}\right] Bd$$

$$= 0.5 \times \frac{25}{415}\left[1 - \sqrt{1 - \frac{25.11 \times 10^6 \times 4.6}{25 \times 10^3 \times 200^2}}\right] \times 10^3 \times 200$$

$$= 358.58 \text{ mm}^2$$

spacing of 8 mm bar

$$= \frac{1000}{358.58} \times \frac{\pi}{4} \times 8^2 = 140.17 \text{ mm}$$

provide 8 mm dia bar @ 140 mm c/c spacing

~~to~~ All values for other moment are shown in table

A_{st} req = 358.58 mm^2

A_{st} prov = $\frac{1000}{140} \times \frac{\pi}{4} \times 8^2$ = 359.039 mm^2 ~~say 359 mm^2~~

(8) Check for deflection

maximum ~~moment~~, positive moment

M_{ux} = 25.11 kN m

$f_s = 0.58 f_y \times \frac{A_{st}(Req)}{A_{st}(pro)} = 0.58 \times 415 \times \frac{358.58}{359.039}$

$f_s = 240.39 \frac{N}{mm^2}$

$\% p_t = \frac{A_{st}}{Bd} \times 100 = \frac{359.039}{10^3 \times 200} \times 100 = 0.18\%$

$MF_t = 1.7$

$d_{req} = \frac{l_{eff}}{A \times MF_t} = \frac{5200}{1.7 \times 20}$

d_{req} = 152.94 < 200 mm

∴ $d_{req} < d_{prov}$ Hence safe.

(6) Check for shear.

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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]

Ans ⇒ 2 (b) ∵ Given, Volume $= 6.5 \times 10^5\ l$

$= 6.5 \times 10^2\ m^3$

$= 650\ m^3$

$D = 12\ m$

$\Rightarrow \frac{\pi}{4} \times D^2 H = 650$

$H = 5.747\ m$ say $H = 5.8\ m$

Ⓐ Design for Hoop Tension (Design for 1 m width)

① Hoop Tension

$T_H = \frac{pD}{2} = \frac{\gamma_w (H-h) D}{2}$

$h = \max \begin{cases} \frac{H}{3} \\ \text{or} \\ 1\ m \end{cases} = \max \begin{cases} \frac{5.8}{3} \\ 1 \end{cases}$

$h = 1.94\ m$

$T_H = \frac{10 \times (5.8 - 1.94) \times 12}{2} = 231.6\ kN$

② Calculation of steel

$T_H = f_{st} \times A_{st}$

$A_{st_1} = \frac{T_H}{f_{st}} = \frac{231.6 \times 10^3}{130} = 1781.53$

say $A_{st_1} = 1782\ mm^2$

provide all steel in one face.

spacing of 16 mm ϕ bar $= \frac{1000}{1782} \times \frac{\pi}{4} \times 16^2 = 112.82\ mm$

provide 16 mm ϕ bar @ 110 mm c/c spacing.

Approximate formula to calculate thickness

$T = 30H + 50 = 30 \times 5.8 + 50$

$T = 224$ mm

let $T = 300$ mm $d' = 60$ mm $d = 240$ mm

③ ~~Calculate~~ check for stress in concrete

$$f_{ct(dev)} = \frac{T_H}{1000T + (m-1)A_{st}} = \frac{231.6 \times 10^3}{1000 \times 300 + (8.11-1)1782}$$

$f_{ct(dev)} = 0.74 \frac{N}{mm^2}$

Design for Bending moment

① $BM = \frac{1}{2} \times \gamma_w H \times h \times \frac{h}{3} = \frac{1}{6} \gamma_w H h^2$

$BM = \frac{1}{6} \times 10 \times 5.8 \times 1.94^2$

$BM = 36.38$ KNm

let us modify thickness $T = 350$ mm $d' = 60$ mm

$d = 290$ mm

∴ Thickness value is increased above condition need not to be check because it is safe.

② Steel calculation

$$A_{st2} = \frac{BM}{\sigma_{st}\, j\, d}$$

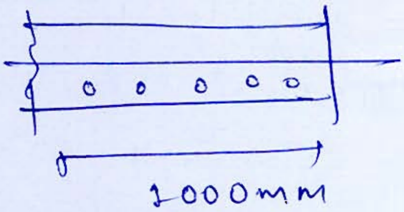
$k = \frac{280/3}{280/3 + \sigma_{st}} = 0.4179$ $j = 1 - \frac{k}{3} = 0.86$

$$A_{st2} = \frac{36.38 \times 10^6}{130 \times 0.86 \times 290} = 1122.07 \text{ mm}^2$$

spacing of 16 mm dia bar $= \frac{1000}{1122.07} \times \frac{\pi}{4} \times 16^2 = 179.18$

provide 16 mm ϕ bar @ 170 mm c/c spacing.

(3) stress in concrete.



~~y_{NA} =~~

(a) $y_{NA} = \dfrac{1000 \times \frac{350^2}{2} + (8.11-1) \times 1122.07 \times 290}{1000 \times 350 + (8.11-1) \times 1122.07}$

$y_{NA} = 177.56$

(b) $I_{NA} = 1000 \times \frac{350^3}{12} + 1000 \times 350 (177.56 \times 175)^2$

$+ (8.11-1) \times \left[\frac{1000}{170} \times \frac{\pi}{64} \times 16^4 + \frac{\pi}{4} \times 16^2 \times (290 - 177.56)^2 \times \frac{1000}{170} \right]$

$I_{NA} = 3.6762 \times 10^9 \ mm^4$

(c) $f_{cbt}(dev) = \dfrac{BM}{(I_{NA})_{uc}} \times (D - y_{NA})$

$= \dfrac{36.38 \times 10^6}{3.6762 \times 10^9} (350 - 177.56)$

$= 1.706 \ \frac{N}{mm^2}$

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Check

$\dfrac{f_{ct}(dev)}{f_{ct}(per)} + \dfrac{f_{cbt}(dev)}{f_{cbt}(per)} \le 1$

$= \dfrac{0.74}{1.6} + \dfrac{1.706}{2.21}$

$\Rightarrow 1.234 > 1$

Hence It is not safe.

So we must increase thickness & have to do all calculation by taking higher Thickness.

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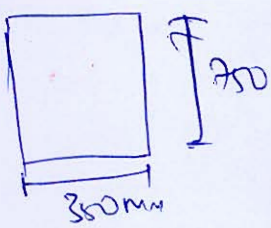
Q.2 (c) Design the torsional reinforcement in a rectangular beam section, 350 mm wide and 750 mm deep, subjected to an ultimate twisting moment of 140 kN-m combined with an ultimate (hogging) bending moment of 200 kN-m and an ultimate shear force of 110 kN. Assume M25 concrete and Fe415 steel. Consider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

[20 marks]

Ans ⇒ 2 (c)



B = 350 mm   D = 750 mm

considering ultimate value as factored value.

$M_u = 200$ kNm $T_u = 140$ kNm $V_u = 110$ kN

M25   Fe 415 $d' = 50$ mm $d = 700$ mm

① Equivalent shear force

$$V_{ueq} = V_u + \frac{1.6 T_u}{B} = 110 + \frac{1.6 \times 140}{.350}$$

$$= 750 \text{ kN}$$

Check

$$\tau_{veq} = \frac{V_{ueq}}{Bd} = \frac{750 \times 10^3}{350 \times 700} = 3.06 \ \frac{N}{mm^2}$$

For M25 $\tau_{c\,max} = 3.1$ N/mm²

$\therefore$ $\tau_{veq} < \tau_{c,max}$ (3.06)   Hence ok

② Equivalent BM

$BM_{ue1} = M_u + M_t = M_u + \frac{T_u}{1.7}\left(1 + \frac{D}{B}\right)$

$= 200 + \frac{140}{1.7}\left(1 + \frac{750}{350}\right) = 200 + 258.82$

$= 458.82$ kNm

$\because M_t > M_u$

So we need to provide additional reinforcement on compression side to cater for moment M_{ue2}

$\Rightarrow M_{ue2} = M_t - M_u = 258.82 - 200 = 58.82$ kNm

③ $M_{u,lim} = 0.138 f_{ck} Bd^2$

$= 0.138 \times 25 \times 350 \times 700^2$

$= 591.675$ kNm

$\because BM_{ue1} < M_{u,lim}$ so under reinforced singly reinforced section

③ Calculation of steel

$A_{st1} = \frac{M_{ue1}}{0.87 f_y (d - 0.42 x_u)}$

$M_{ue1} = 0.36 f_{ck} B x_u (d - 0.42 x_u)$

$\Rightarrow 458.82 \times 10^6 = 0.36 \times 25 \times 350 \times x_u (700 - 0.42 x_u)$

$x_u = 243.72$ mm

$A_{st1} = \frac{458.82 \times 10^6}{0.87 \times 415 (700 - 0.42 \times 243.72)}$

$A_{st1} = 2126.36$ mm^2

~~Spacin~~

No. of bars $= \frac{2126.36}{\frac{\pi}{4} \times 25^2} = 4.33 \approx 5$

provide 5-25 mm dia bar. Tension side.

$$A_{st_2} = \frac{M_{ue_2}}{0.87 f_y (d-d_c)} = \frac{58.82\times10^6}{0.87\times415(700-50)}$$

$$A_{t_2} = 250.636 \text{ mm}^2$$

$$\text{No. of bar} = \frac{250.636}{\frac{\pi}{4}\times16^2} = 1.24 \simeq 2 \text{ bars}$$

provide 2-16 mm bar on compression side

(4) Check for Ast min

$$A_{st}\text{min} = \frac{0.12}{100}\times BD$$

$$= \frac{0.12}{100}\times 350\times750$$

$$= 315 \text{ mm}^2$$

10

Ast (prov) > Ast (min) Hence OK.

(5) Provide side Reinforcement

$$A_{st_{side}} = \frac{0.05}{100}\times BD = \frac{0.05}{100}\times 350\times750$$

$$= 131.25 \text{ mm}^2$$

$$\text{No. of Bar} = \frac{131.25}{\frac{\pi}{4}\times12^2} = 1.16 \simeq 2$$

provide 2-12 mm Φ bar on each side

as side reinforment.

Shear = ?

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/m². 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]

Ans⇒3 (a) column = 600×400

Axial load, P = 800 kN

Width B = 2 m

SBC = 200 kN/m²

M20 Fe 415

① Assuming 10% of column load

Total load, $P_T = 1.1 \times 800 = 880$ kN

Area of footing $= \frac{P_T}{SBC} = \frac{880}{200}$

$= 4.4\ m^2$

$L \times B = 4.4$

$L = \frac{4.4}{2} = 2.2$ m

So dimension of footing

L = 2.2 m B = 2 m

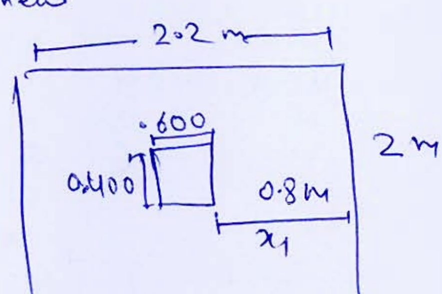
② Net soil pressure $= \frac{800}{L \times B} = \frac{800}{2.2 \times 2} = 181.81\ kN/m^2$

Factored soil pressure, $w_u = 1.5 \times 181.81$

$= 272.72\ kN/m^2$

③ ~~Desi~~ check for Bending moment

For BM critical section is at the face of support



$BM = w_u \times 1 \times \frac{x_1^2}{2}$

$= 272.72 \times \frac{0.8^2}{2}$

$= 87.27$ kN m/m

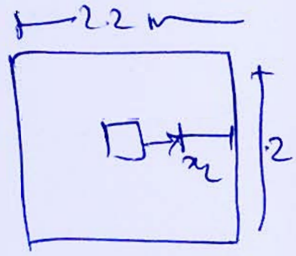
[All design is done considering 1m width of slab]

$$d_{req} = \sqrt{\frac{BM_u}{QB}} = \sqrt{\frac{87.27 \times 10^6}{0.138 \times 10^3 \times 20}}$$

$$d_{req} = 177.82 \text{ mm}$$

④ Check for one way shear.

For one way shear critical section is at d distance from face of column



$$x_2 = 0.8 - d$$

$$\Rightarrow \tau_{v_1} < K \tau_{c(min)}$$

where $K = 1.3 - (D - 150) \times 0.002$

For safety taking $K = 1$

$$\Rightarrow \tau_{v_1} = \frac{V_u}{Bd} = \frac{w_u \times 1 \times (0.8 - d)}{B \times d}$$

$$\therefore \Rightarrow \frac{w_u \times 1 \times (0.8 - d)}{1 \times d} < 0.29 \frac{N}{mm^2}$$

$$\Rightarrow \frac{272.72 \times (0.8 - d)}{d} < 290 \frac{kN}{m^2}$$

$$d > 387.7 \text{ mm}$$

$$d = 387.7 \text{ mm}$$

⑤ Check for Two way shear

For Two way shear critical section is at $\frac{d}{2}$ distance from face of column.

$$\Rightarrow \tau_{v_2} < K_\beta \times \tau_{vp(per)}$$

$$K_\beta = 0.5 + \frac{b}{a}$$

b = short side of column

a = long side of column

$\beta = 0.5 + \frac{0.4}{0.6} = 1.16 \not> 1$

$\beta = 1$

$\tau_{vp}(per) = 0.25\sqrt{f_{ck}} = 0.25\sqrt{20} = 1.118\ N/mm^2$
$= 1180\ KN/m^2$

$\tau_{v_2} = \frac{P_{net}}{Area}$

$P_{net} = 1.5P - w_u[a+d][b+d]$.

$\Rightarrow \tau_{v_2} < \tau_{vp}(per)$

$\Rightarrow \frac{1.5 \times 800 - 272.72[0.6+d][0.4+d]}{[(0.6+d)d + (0.4+d)d] \times 2} = 1180$

$d = 0.281\ m$

$d = 281.09\ mm$

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Hence let us adopt maximum of the above value $d = 400\ mm$

$d' = 60\ mm$ $D = 460\ mm$

(6) Calculation of steel.

$A_{st} = 0.5 \times \frac{f_{ck}}{f_y}\left[1 - \sqrt{1 - \frac{4.6 \times BM}{f_{ck} B d^2}}\right] \times Bd$

$= 0.5 \times \frac{20}{415}\left[1 - \sqrt{1 - \frac{4.6 \times 87.27 \times 10^6}{20 \times 10^3 \times 400^2}}\right] \times 10^3 \times 400$

$= 624.83\ mm^2$

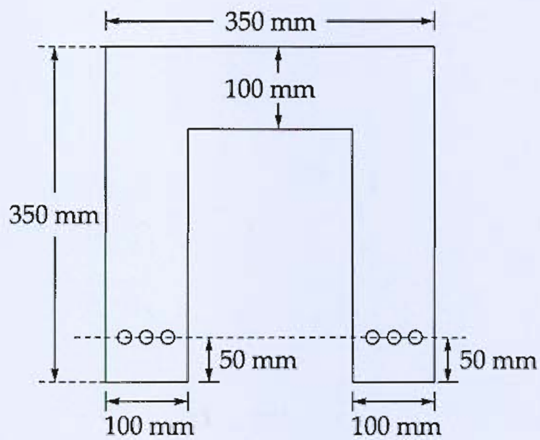
spacing of 10 mm ϕ bar $= \frac{1000}{624.83} \times \frac{\pi}{4} \times 10^2 = 125.69\ mm$

So provide 10 mm dia bar @ 120 mm c/c spacing.

$A_{st\,min} = \frac{0.12}{100} \times 10^3 \times 460$

$= 552\ mm^2$

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/mm², the total loss of prestress is 15% of the initial stress. The permissible stress in concrete are 14 N/mm² in compression and 0.75 N/mm² in tension. Determine the safe uniformly distributed load on the slab unit.



[20 marks]

Ans => 3 (b) Given, $l_{eff} = 8$ m

$A_c = 6 \times \frac{\pi}{4} \times 5^2 = 117.81$ mm²

$e = 50$ mm $p_o = 1250$ N/mm² $e = 147.05$

$K = 0.85$

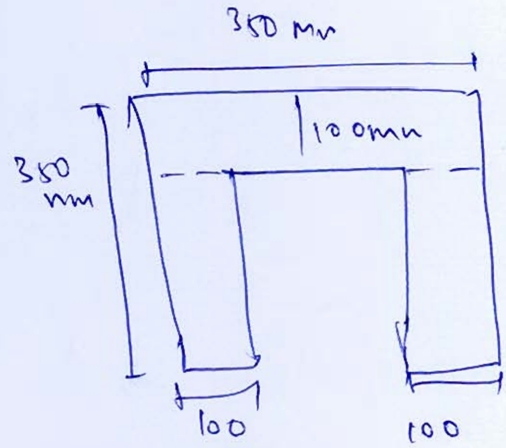
loss = 15%

$(\sigma_c)_{per} = 14 \frac{N}{mm^2}$ $(\sigma_T)_{per} = 0.75 \frac{N}{mm^2}$

① To calculate $\bar{y}$

(Neglecting wire area)

From bottom



$$\bar{y} = \frac{100 \times 250 \times \frac{250}{2} \times 2 + 350 \times 100 \times 300}{100 \times 250 \times 2 + 350 \times 100}$$

$\bar{y} = 197.05$ mm

(2) $I_{NA} = 2 \times \left[\frac{100 \times 250^3}{12} + 100 \times 250 \times (197.05 - 125)^2 \right]$

$+ \frac{350 \times 100^3}{12} + 350 \times 100 (300 - 197.05)^2$

$I_{NA} = 9.2 \times 10^8 \text{ mm}^4$

(3) $\sigma_{Top} = \frac{KP}{A} - \frac{KPe \times y_T}{I} + \frac{M_{Total} \times y_T}{I} = 14$

$A = 2 \times 100 \times 250 + 350 \times 100$

$A = 85000 \text{ mm}^2$

$P = p_0 \times A_c = 147.26 \text{ kN}$

$\Rightarrow \frac{0.85 \times 147.26 \times 10^3}{85000} - \frac{0.85 \times 147.26 \times 10^3 \times 152.95 \times 147.05}{9.2 \times 10^8} + \frac{M_T \times 152.95}{9.2 \times 10^8}$

$= 14 \text{ N/mm}^2$

$= 1.4726 - 3.06 + \frac{M_T \times 152.95}{9.2 \times 10^8} = 14$

$M_T = 93.758 \text{ kNm}$

$\frac{w_T l^2}{8} = 93.758$

$w_T = 11.71 \text{ kN/m}$

~~$w_D =$~~

$\sigma_{Bottom} = \frac{KP}{A} + \frac{KPe \times y_B}{I} - \frac{M_T \times y_B}{I} = 0.75$

$= 1.4726 + 3.942 - \frac{M_T \times 197.05}{9.2 \times 10^8} = -0.75$

$M_T = 21.778 \text{ kNm}$

$\frac{w_{Teff}\, l^2}{8} = 21.778 \text{ kNm}$

~~$W_T = 2.722 \frac{kN}{m}$~~

$M_T = 28.78$ kNm

$W_T = 3.597 \frac{kN}{m}$

So safe distribution load $= 3.597 \frac{kN}{m}$

deduct dead load :

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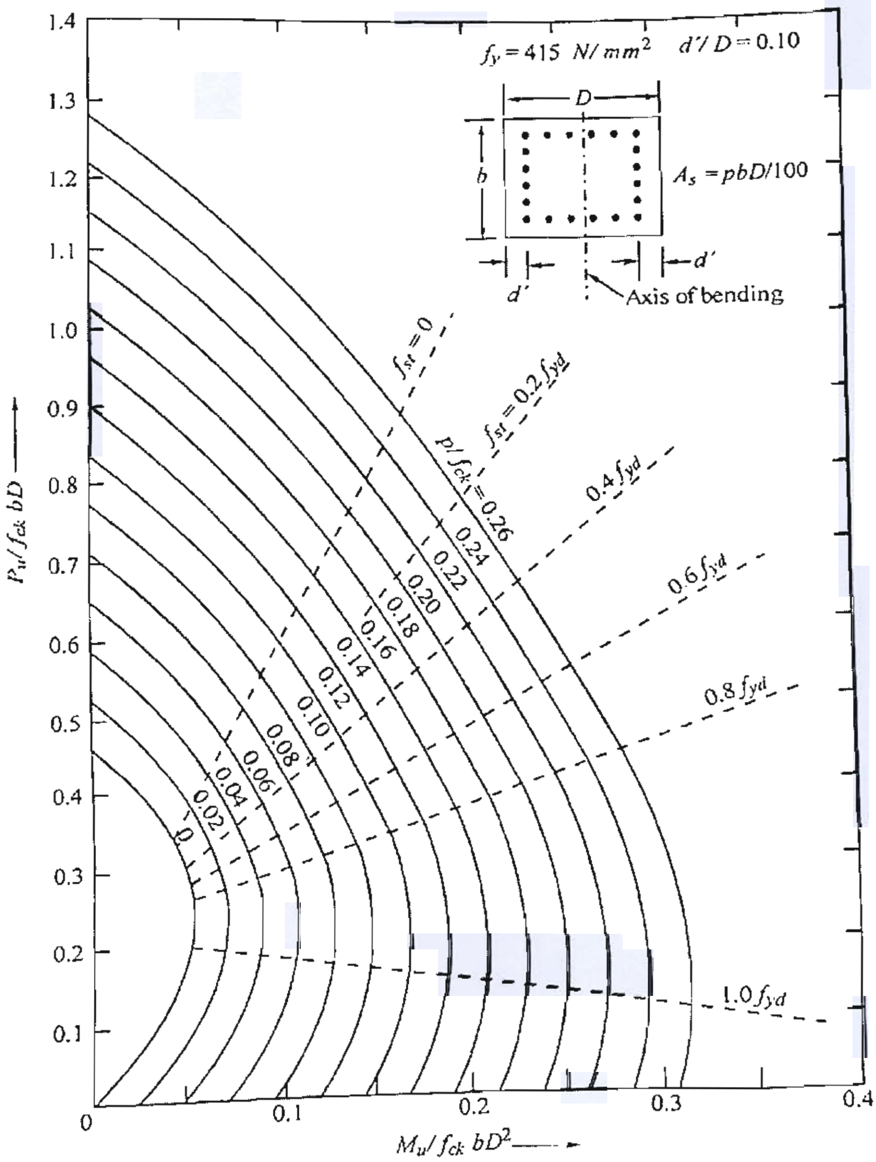
Q.3 (c) A reinforced concrete column of unsupported length 6 m is 340 mm × 500 mm in section and is reinforced with 10 bars of 20 mm diameter, consisting of 3 bars along each short edge and the remaining 4 bars equally distributed along the long faces with 2 bars per face as shown in figure. The column 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

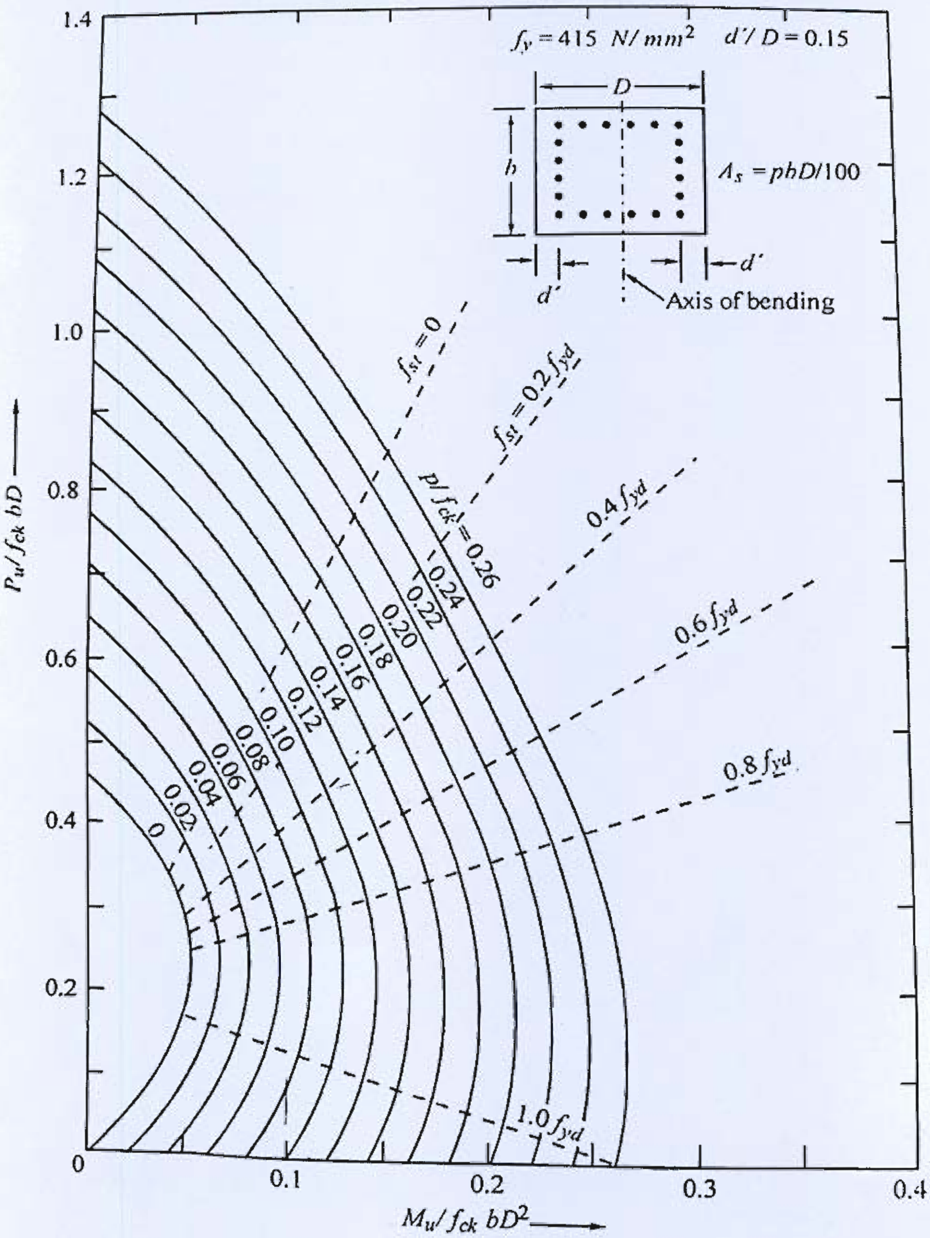
Compression with bending. Reinforcement distributed equally on four sides.

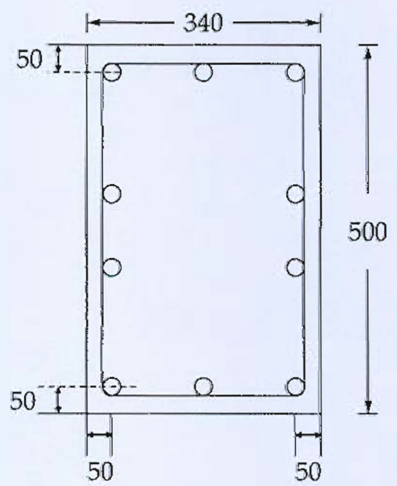


Ans-23>(c)

Chart - 45, SP : 16

Compression with bending. Reinforcement distributed equally on four sides.





(All dimensions in mm)

[20 marks]

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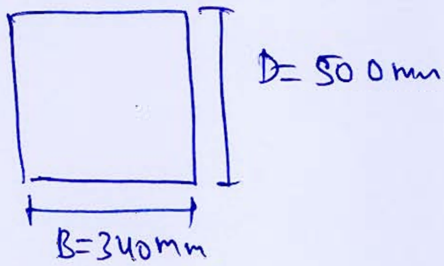
try ⇒ 37(c) $l_0 = 6\,m$



$A_{sc} = 10 - 20\ mm\ \phi$

$= 10 \times \frac{\pi}{4} \times 20^2 = 3142\ mm^2$

Effective length $= 0.65\,l_0 = 0.65 \times 6 = 3.9\,m$

$P_u = 1490\ kN$ $e_{xx} = 80\ mm$ $e_{yy} = 60\ mm$

M20 Fe415

1

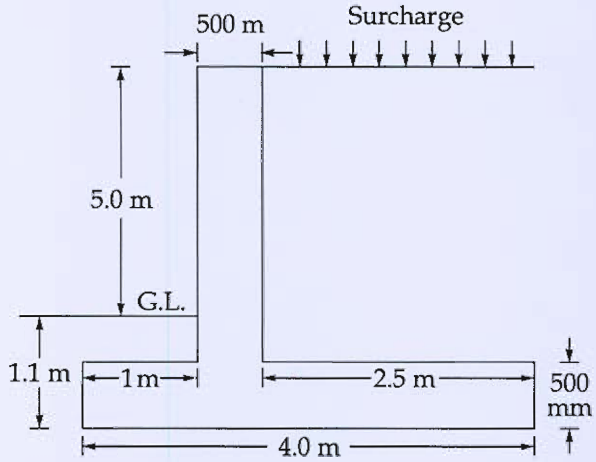
① Check type of column

ⓐ $SR = \frac{l_{eff}}{D} = \frac{3.9}{0.34} = 11.47 < 12$

short column.

ⓑ ~~emin x-x~~ = max{

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.

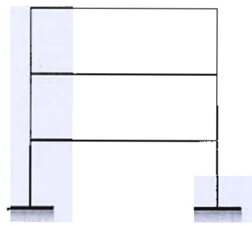
(iii) Design the stem of the retaining wall.

Use M30 grade concrete and Fe-415 grade steel.

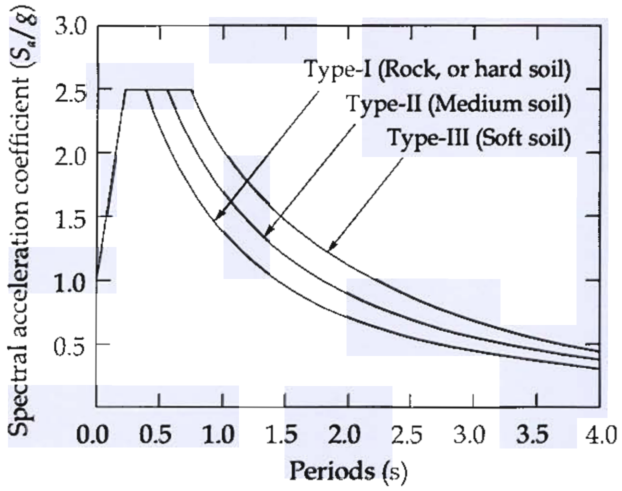
[20 marks]

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]

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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

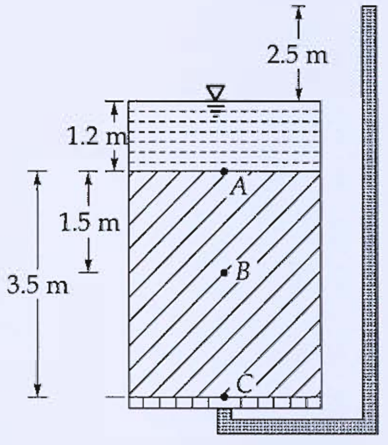
[8 + 12 marks]

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]

Ans⇒5> (a) Given, $G = 2.72$ $e = 0.61$

	TH	PH	DA
A	~~1.2~~ 4.7	1.2	3.5
B	~~…~~ 5.77	3.77	2
C	~~…~~ 7.2	7.2	0

considering C as datum.

At A $(TH)_A = (PH)_A + (DA)_A$

⇒ ~~1.2~~ = ~~(PH)~~$_A$ ~~+ 3.5~~

$(TH)_A = 1.2 + 3.5 =$

At B

$(TH)_B = (PH)_B + (DH)_B$

$(TH)_B = 7.2$

Do not write in this margin

$(TH)_C = (TH)_B - iz$

$= 7.2 - \frac{2.5}{3.5} \times 2 = 5.77$

	Total	Pore	Effective
A	11.772	11.772	0
B	42.207	36.98	5.227
C	82.787	70.632	12.155

$\gamma_{sat} = \left(\frac{G + eS}{1 + e}\right) \gamma_w = 20.29$

12

(ii) Seepage force $= i \gamma_w$

$= \frac{2.5}{3.5} \times 9.81$

$= 7 \ \frac{kN}{m^3}$

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]

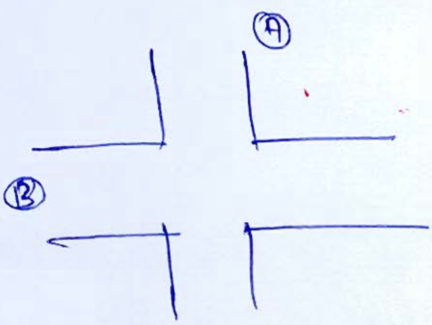
Ans→5> (b) $n_A = 440$ PCU / hour

$n_B = 280$ PCU / hour.

$S_A = 1300$ PCU / hour.

$S_B = 1100$ PCU / hour.

$R = 12$ sec.



As per webster method cycle time is given by

$$C_o = \frac{1.5\,L + 5}{1 - Y}$$

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

Y = critical flow ratio = $Y_A + Y_B$

$$Y_A = \frac{\text{normal flow on road A}}{\text{saturation flow on road A}} = \frac{440}{1300} = 0.33846$$

$$Y_B = \frac{280}{1100} = 0.2545$$

$y_{Total} = y_A + y_B = 0.5929$

$C = \frac{1.5 \times 16 + 5}{1 - 0.5929} = 71.23$ sec

$C = 71.23$ sec

Effective Green time

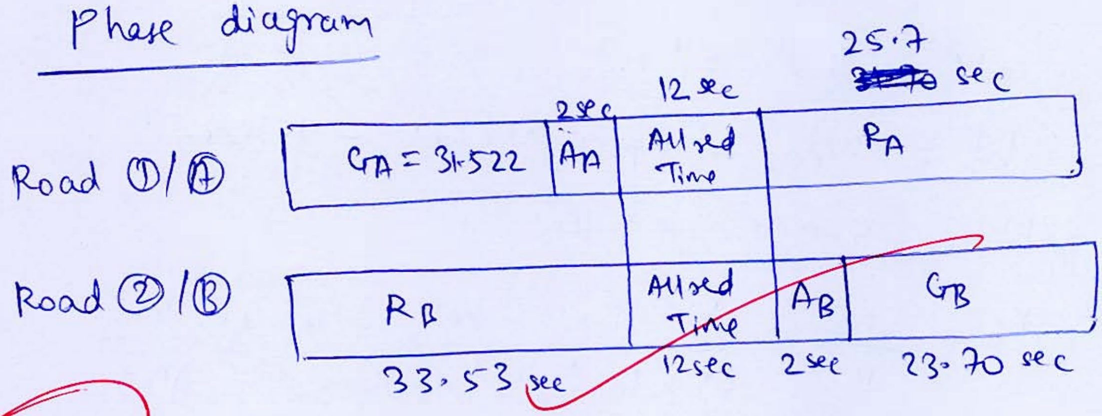
G_A, Road ① / Ⓐ $= \frac{y_A}{y_{Total}} [C_o - L] = \frac{0.3384}{0.5929} [71.23 - 16]$

$= 31.522$ sec

G_B, Road B/② $= \frac{y_B}{y_{Total}} \times [C_o - L] = \frac{0.2545}{0.5929} [71.23 - 16]$

$= 23.70$ sec

Phase diagram



12

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]

Ans⇒5(c) (i)

W_{pcs} = weight of paraffin coated soil

$= 5.23 \times 10^{-3}$ kN

$V_{pcs} = 3.7 \times 10^{-4}$ m^3

$W_p = 1.71 \times 10^{-4}$ kN

$G_s = 2.72$ $G_p = 0.9$ $w = 11\%$

$V_{soil} = V_{pcs} - V_p$

$V_{soil} = 3.7 \times 10^{-4} - \frac{1.71 \times 10^{-4}}{0.9 \times 9.81}$

$V = 3.5 \times 10^{-4}$ m^3

$W = W_{pcs} - W_p = 5.23 \times 10^{-3} - 1.71 \times 10^{-4}$

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

$\gamma_b = \frac{W}{V} = \frac{5.059 \times 10^{-3} \text{ kN}}{3.5 \times 10^{-4} \text{ m}^3} = 14.45 \frac{\text{kN}}{\text{m}^3}$

$\gamma_d = \frac{\gamma_b}{1+w} = \frac{14.45}{1+0.11} = 13.01$ kN/m³

8

$\gamma_d = \frac{G\gamma_w}{1+e}$

$e = \frac{2.72 \times 9.81}{13.01} - 1$

$e = 1.051$

(ii) Quick sand condition - In upward flow condition seepage also acts in upward direction. When submerged weight of the

the soil becomes equal to seepage pressure, then ~~so~~ effective stress reduces to zero. In cohesionless soil losses all its shear strength and have tendency to flow along with liquid. This is known as quick sand condition.

Condition for quick sand

$$i_{cr} = \frac{G-1}{1+e}$$

i_{cr} = critical hydraulic gradient.

3

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]

Do not write in this margin

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/m^2. The load is increased to 197.5 kN/m^2. The coefficient of volume compressibility is 5.79×10^{-4} m^2/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]

Ans⇒6> (a) (i)

(ii)

$H = 5\,m \qquad d = \frac{H}{2}$.

$\bar{\sigma}_1 = 127.5\ \frac{kN}{m^2} \qquad \bar{\sigma}_2 = 197.5\ \frac{kN}{m^2}$

$m_v = 5.79 \times 10^{-4}\ \frac{m^2}{kN} \qquad k = 1.6 \times 10^{-8}\ m/min$.

$\Delta\bar{\sigma} = \bar{\sigma}_2 - \bar{\sigma}_1 = 197.5 - 127.5 = 70\ kN/m^2$

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

$\Delta H = 70\ \frac{kN}{m^2} \times 5\,m \times 5.79 \times 10^{-4}\ \frac{m^2}{kN}$

$\Delta H = 202.65\ mm$

10

$U_{50}\% = \frac{\Delta h}{\Delta H} \times 100$

$U_{50} = \frac{50}{100} = \frac{\Delta h}{202.65}$

$\Delta h = 101.325\ mm$

For 90% of the ultimate settlement

$T_v = 1.781 - 0.933 \log_{10}(100-90)$

$T_v = 0.848$

$T_v = \frac{C_v t}{d^2}$

$k = C_v\, m_v\, \gamma_w$

$\Rightarrow 1.6 \times 10^{-8}\ \frac{m}{min} = C_v \times 5.79 \times 10^{-4}\ \frac{m^2}{kN} \times 9.81\ \frac{kN}{m^3}$

$C_v = 2.817 \times 10^{-6}\ \frac{m^2}{min}$

$\Rightarrow 0.848 = \frac{2.817 \times 10^{-6}\ m^2/min \times t}{\left(\frac{5}{2}\right)^2 m^2}$

$t = 1881496.68$ min

$t = 3.579$ years

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]

y ⇒ 6) (b) (i)

$P = 5100$ kg
$p = 7$ kg/cm^2
$E = 180$ kg/cm^2
$\Delta = 0.25$ cm

using ~~B~~ single layer elastic theory.

$$T = \sqrt{\left(\frac{3P \times y}{2\pi \Delta E}\right)^2 - \frac{P}{p\pi}}$$

(4)

Here $x = y = 1$

$$T = \sqrt{\left(\frac{3 \times 5100}{2\pi \times 0.25 \times 180}\right)^2 - \frac{5100}{7 \times \pi}}$$

$T = 51.92$ cm

(ii) spacing = 4.5 m
$f = 1.3$ $\quad \gamma_c = 2400$ kg/m^3
~~Sf~~ ⇒ $S_f = ?$

⇒ Tensile stress in concrete = Friction between pavement & soil subgrade.

$= S_f \times B \times h = \gamma \times f \times \frac{L}{2} \times Bh$

$S_f = \frac{\gamma f \times L}{2}$

$S_f = \frac{2400 \text{ kg/m}^3 \times 1.3 \times 4.5}{2}$

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

or $S_f = 0.702 \text{ kg/cm}^2$

4

(iii) Given,

$h = 15 \text{ cm}$ $\quad k = 7.5 \text{ kg/cm}^3$

$S = 30 \text{ cm}$ $\quad P = 4100 \text{ kg}$

50% of wheel load transfer.

$\mu = 0.15$ $\quad E = 2.1 \times 10^5 \text{ kg/cm}^2$

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

$l = 53.27 \text{ cm}$

∴ participation of dowel bar is upto $1.8\,l$.

① Load capacity factor.

$$\text{Factor} = 1 + \frac{1.8l - S}{1.8l} + \frac{1.8l - 2S}{1.8l} + \cdots$$

$1.8\,l = 95.886$

$$\text{Factor} = 1 + \frac{95.886 - 30}{95.886} + \frac{95.886 - 60}{95.886} - \frac{95.886 - 90}{95.886}$$

$= 2.122$

(2) load capacity factor = max^m $\left\{ \frac{0.5P}{P_s}, \frac{0.5P}{P_b}, \frac{0.5P}{P_{br}} \right.$

~~let~~ load capacity factor $= \frac{0.5 \times P}{\text{load capacity}}$

load capacity $= \frac{0.5 \times P}{2.122}$

$= \frac{0.5 \times 4100}{2.122}$

$= 966.069$ kg

Hence maximum load carried by single dowel $= 966.069$ kg.

12

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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]

Ans ⇒ 6> (c) (i) Area = 150 km × 100 km

L = ~~100~~ 150 km   B = 100 km   S = ~~10~~ 25000

l = 25 cm   b = 25 cm

h_{avg} = 330 m

p_l = 60% p_s = 40%

V = 270 km/hr.

f = 200 mm

~~To~~ LC = 0.5

1. No. of photograph required.

$N_1 = \frac{L}{L_0} + 1$ $N_2 = \frac{B}{B_0} + 1$

$L_0 =$ ~~$p_l s$~~ ~~(1-~~ $l s (1-p_l)$

~~s =~~ f

$N_1 = \frac{150 \times 10^5 \text{ cm}}{25 \times 25000 (1-0.6)} + 1 = 61$

$N_2 = \frac{100 \times 10^5 \text{ cm}}{25 \times 25000 (1-0.4)} + 1 = 27.66$

= 27

No. of photograph = $N_1 \times N_2$

$= 61 \times 27 = 1647$ photos

2. Height of flight

$$\text{scale} = \frac{1}{25000} = \frac{f}{H - h_{avg}}$$

$$\Rightarrow \frac{1}{25000} = \frac{200\text{ mm}}{H - 330}$$

$$\Rightarrow H = 5000 + 330$$

$$H = 5330\text{ m}$$

6

3. Spacing of flight line $= \frac{100\text{ Km}}{27}$

$= 3.7$ km.

4. Ground exposure distance

$$L_0 = l s (1 - p_l)$$

$= 25 \times 25000 (1 - 0.6)$

$= 250000$ cm

$= 2500$ m

5. Exposure interval, $T = \frac{\text{Distance}}{\text{Ground speed}}$

$= \frac{2500\text{ m}}{0.278 \times 270}$

$T = 33.306$ sec

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

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

[5 marks]

Ans⇒ (c) (ii) (1) Zenith – Top most point on earth surface.

Nadir – Bottom most point where plumb Bob touches vertically on earth surface.

(2) Azimuth –

3

(3) Prime vertical – A large imaginary circle plane passing through earth surface.

(4) Declination – Declination is the horizontal angle made by the between the magnetic meridian and True 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]

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]

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

[10 marks]

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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]

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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.

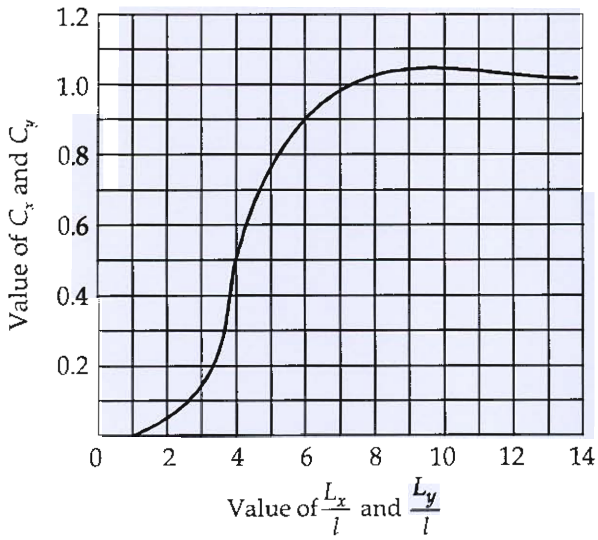
(ii) Two straights *AB* and *BC* intersect at a chainage of 4274.0 m. The angle of intersection is 150°. It is required to set out a 3° simple circular curve to connect the straights. Calculate all the data necessary to set out the curve by the method of offsets from the chord produced with an interval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

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

[6 + 10 + 4 marks]

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]

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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

$x_u = 0.8$

$Pt\% = 41.28 \left(\frac{f_{ck}}{f_y}\right) \frac{x_{u,lim}}{d}$

$\Rightarrow \quad x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} B d}$ $\quad Pt\% \Rightarrow \frac{A_{st}}{Bd} = \left(\frac{0.36 \times 100}{0.87}\right) \times \left(\frac{f_{ck}}{f_y}\right) x_u,$

$f = \frac{M}{Z}$

$1000 \times \frac{D^2}{6} = \frac{36.38 \times 10^6}{2.21}$