



MADE EASY
Leading Institute for ESE, GATE & PSUs

ESE 2026 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test-6 : Section A : Structural Analysis + CPM Pert (All Topics)

Section B : Flow of fluids, hydraulic machines and hydro power-1 +

Design of Concrete and Masonry Structures-2 [Part syllabus]

Name :

Roll No :

Test Centres	Student's Signature
Delhi <input checked="" type="checkbox"/> Bhopal <input type="checkbox"/> Jaipur <input type="checkbox"/> Pune <input type="checkbox"/> Hyderabad <input type="checkbox"/>	

- ### 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	45
Q.2	41
Q.3	50
Q.4	—
Section-B	
Q.5	48
Q.6	—
Q.7	56
Q.8	—
Total Marks Obtained	240

Signature of Evaluator

Cross Checked by

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Good Keep it up

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

Section A : Structural Analysis + CPM Pert

Q.1 (a) Explain the concept of Resource Levelling in Construction Project Management. How is it different from Resource Loading?

[12 marks]

→ Resource Levelling in construction PM refers to equalizing resources based on Resource constraint rather than Time constrain.

→ Say there is need of 20 labourers on a day but we only have availability of 10, so for available float we extend the time of activity so that we do less work with less labourers each day & increase allowable duration.

→ Also the duration of project may or may not change.

Resource Loading

→ Unlimited resources
→ Time is a constrain
→ We put more resources in an activity so variation is less, more reliable and consistent work.

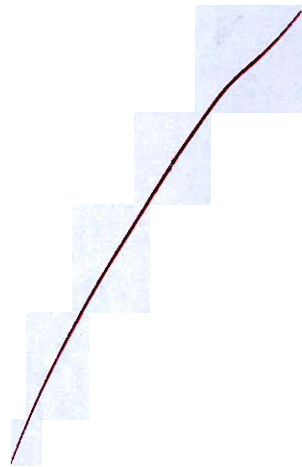
→ Float may be utilised but critical path won't change.

Resource levelling

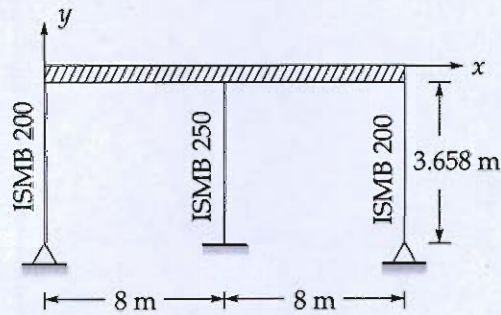
→ Limited resources
→ NO constrain on time
→ We don't have enough resources

→ Critical path may change

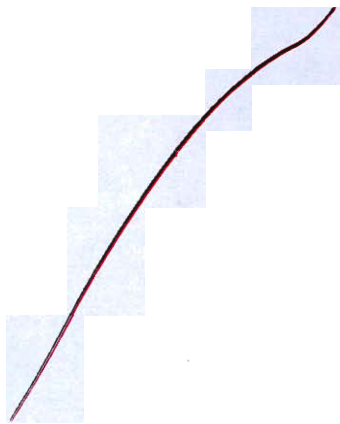
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- Q.1 (b) In an industrial facility located in Chennai, a heavy machinery platform is supported by a rigid horizontal floor system with a total weight of 222,411.08 N. The supporting structure consists of three ISMB columns, each having a clear height of 3.658 m. The two outer columns are ISMB 200 sections with pinned base connections, while the central column is an ISMB 250 section with a fixed base connection. The modulus of elasticity of steel is $E = 210 \text{ GPa}$ and acceleration due to gravity is $g = 9.81 \text{ m/s}^2$. Neglecting the mass of the columns, determine the natural frequency of horizontal vibration of the platform. Take, for ISMB 200, $I = 2235 \text{ cm}^4$, for ISMB 250, $I = 5131.6 \text{ cm}^4$

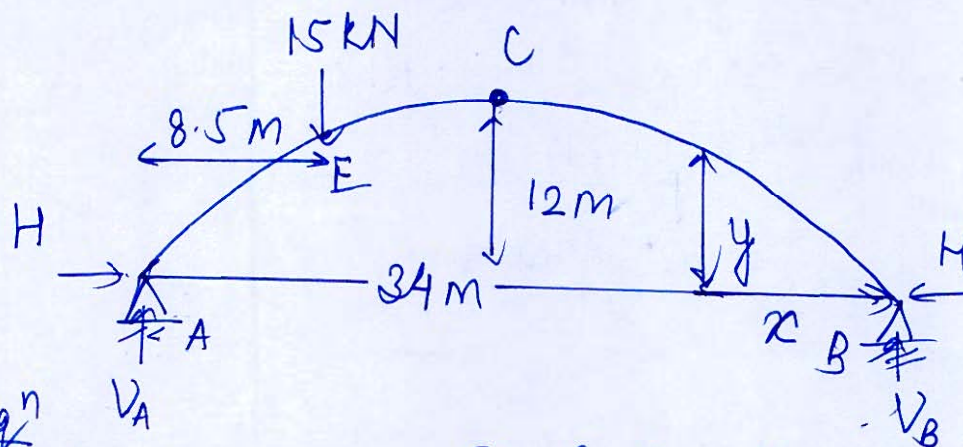


[12 marks]



- Q.1(c) A three-hinged parabolic arch has a span of 34 m and a rise of 12 m. It carries a point load of 15 kN at the quarter-span position, which is located 8.5 m from the left support. Calculate the vertical and horizontal reactions at the supports, also calculate the values of the maximum positive bending moment occurring in the arch.

[12 marks]



$$\Rightarrow V_A + V_B = 15 \rightarrow \textcircled{1} \quad (\Sigma F_x = 0)$$

$$\Rightarrow BM_C = 0$$

$$\Rightarrow V_B \times 17 = 12H$$

$$\Rightarrow \Sigma M_A = 0 \Rightarrow 15 \times 8.5 = V_B \times 34$$

$$\Rightarrow V_B = 3.75 \text{ kN} (\uparrow)$$

$$\Rightarrow V_A = 11.25 \text{ kN} (\uparrow)$$

$$\Rightarrow H = \frac{3.75 \times 17}{12} = 5.3125 \text{ kN} (\leftarrow)$$

BM in Three hinged arch,

$$\Rightarrow \text{For right of C} = 3.75x - 5.3125y$$

$$y = \frac{4h}{l^2}(lx - x^2)$$

$$= \frac{4 \times 12}{34^2}(34x - x^2) = \frac{48}{34^2}(34x - x^2)$$

$$= 0.0415(34x - x^2)$$

$$\Rightarrow BM_C = 3.75x - 5.3125 \times 0.0415(34x - x^2)$$

$$= 3.75x - 0.22(34x - x^2) \quad \boxed{x = 8.477}$$

$$\frac{dB.M}{dx} = 3.75 - 0.22 \times 34 + 0.44x = 0$$

$$BM = -18.5829 \text{ kN-M}$$

For left of E,

$$BM_x = 11.25x - 0.22(34x - x^2)$$

$$= 11.25 - 0.22 \times 34 + 0.44x$$

$$BM_{\text{point load}} = \boxed{47.94 \text{ kN-M}}$$

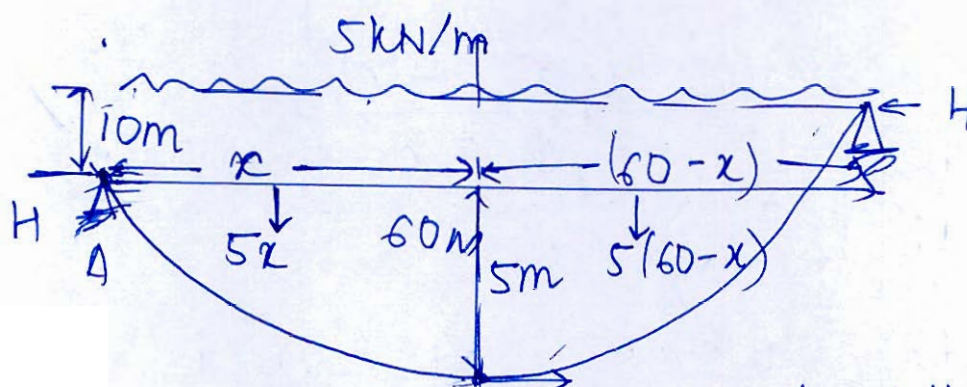
(x = 8.5 m)

↓
Max^m positive
BM

(12)

- Q.1(d) A cable is suspended between two supports A and B, which are at different levels. Support A is at the origin (0, 0) and support B is located at a horizontal distance of 60 m and a vertical height of 10 m above A. The cable carries a uniformly distributed load of 5 kN/m along the horizontal span. The lowest point of the cable (the vertex) is known to be at a vertical distance of 5 m below support A. Determine the horizontal and vertical reactions at both supports and calculate the maximum and minimum tension in the cable.

[12 marks]



* From lowest point, towards left side

$$\Rightarrow \boxed{BM_A = 0} \quad \& \quad H = \frac{x^2}{2}$$

$$\Rightarrow 5H = \frac{5x^2}{2}$$

(ii) $BM_B = 0$ (seeing from right)

$$\Rightarrow \frac{5(60-x)^2}{2} = 15H \quad (\text{From B, lowest point is 15m})$$

$$\Rightarrow \left| \frac{(60-x)^2}{6} = H \right|$$

* Equating both H:

$$\frac{(60-x)^2}{6} = \frac{x^2}{2}$$

$$\Rightarrow x = 21.96 \text{ m}$$

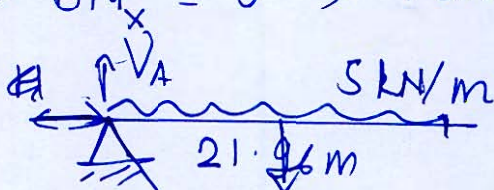
so from ~~right~~ left support lowest pt is at $x = 21.96 \text{ m}$

$$\Rightarrow H = \frac{21.96^2}{2} = 241.1208 \text{ kN}$$

$$* V_A + V_B = 5 \times 60 = 300 \text{ kN}$$

$\Rightarrow BM_x = 0 \Rightarrow$ Towards left side

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$$* \frac{V_A * 21.96}{2} = 5 * \frac{21.96^2}{2}$$

$$- * \frac{241.1208 * 5}{2}$$

$$H \quad V_A = 109.8 \text{ kN}$$

$$\Rightarrow V_B = 190.2 \text{ kN}$$

$$V_A = 5x = 5 * 21.96$$

$$V_A = 109.8$$

$$* V_B = 190.2$$

$$* V_A * x - \frac{5x^2}{2} = 5H$$

$$\Rightarrow V_A = 5x$$

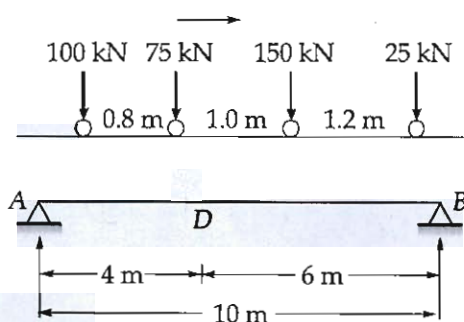
$$\Rightarrow \frac{5x^2}{2} = 5H \Rightarrow H =$$

$$* \text{Min}^n \text{ tension} = 241.1208 \text{ kN}$$

* Max^m tension in cable

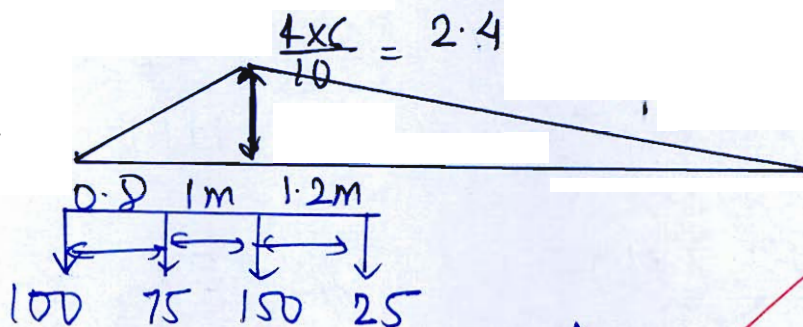
$$= \sqrt{V_B^2 + H^2} = \sqrt{190.2^2 + 241.1208^2} = 307.108 \text{ kN}$$

Q.1 (e) The train of wheel loads as shown in figure roll over from left to right along a girder of span 10 meters. Find out the maximum bending moment which can occur at section 4 m from the left end of the girder.



[12 marks]

* For D, TLD for BM,



let's cross 25 to right of C,

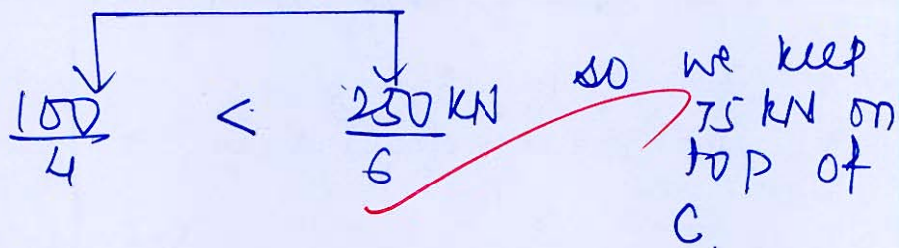
$$\frac{325}{4} = 81.25 > \frac{25}{6} = 4.167$$

Avg load

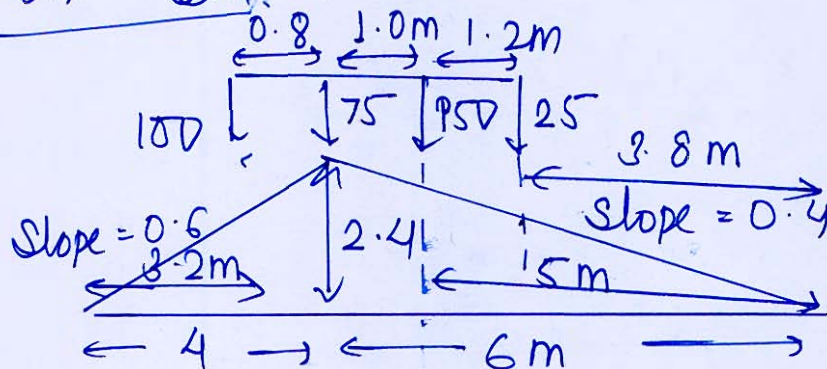
SO NO max^m BM; let's take 150 right of C,

$$\frac{175}{4} = 43.75 > \frac{175}{6} = 29.16$$

we shift loads again, now 75 kN crosses



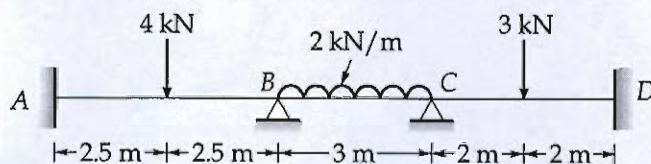
* Max^m BM



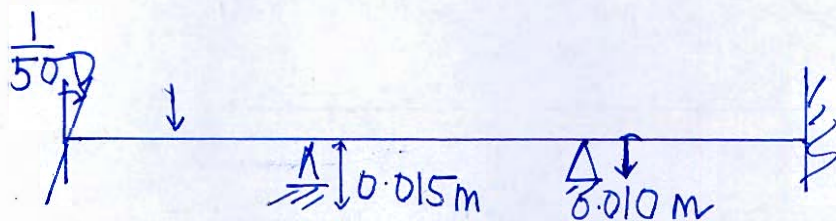
$$\begin{aligned}
 * \text{ Max BM} &= 75 * 2.4 + 3.2 * 0.6 * 150 \\
 &\quad + 150 * 0.4 * 5 + 25 * 3.8 * 0.4 \\
 &= \boxed{710 \text{ kN-m}}
 \end{aligned}$$

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- Q.2(a) A continuous beam ABCD having a total span length of 12 m is subjected to loading as shown in the figure. The beam is to be analysed using the slope deflection method considering that certain support movements occur simultaneously. Support A undergoes a rotation of $\frac{1}{500}$ Radians in the clockwise direction. Support B experiences a vertical settlement of 15 mm downward, and support C undergoes a vertical settlement of 10 mm downward. Draw the bending moment diagram. (Take $EI = 764 \text{ kN-m}^2$)



[20 marks]



* Fixed End Moments

$$\Rightarrow -M_{FAB} = M_{FBA} = \frac{PL}{8} = \frac{4 \times 2.5}{8} = 1.25 \text{ kN-m}$$

$$\Rightarrow -M_{FBC} = M_{FCB} = \frac{wL^2}{12} = \frac{2 \times 3^2}{12} = 1.5 \text{ kN-m}$$

$$\Rightarrow M_{FCD} = \frac{PL}{8} = \frac{3 \times 4}{8} = 1.5 \text{ kN-m} = M_{FDC}$$

Equations \Rightarrow

$$M_{AB} = M_{FBA} + \frac{2EI}{5} (2\theta_A + \theta_B - \frac{3\delta}{L})$$

$$M_{AB} = -2.5 + \frac{2 \times EI}{5} \left(\frac{2}{500} + \theta_B - 3 \times \frac{0.015}{5} \right)$$

— (1)

$$\Rightarrow M_{BA} = 2.5 + \frac{2EI}{5} \left(2\theta_B + \frac{1}{500} - 3 \times \frac{0.015}{5} \right)$$

— (2)

$$M_{be} = -1.5 + \frac{2EI}{3} (2\theta_b + \theta_c + 3 * \frac{0.005}{3})$$

$$M_{eb} = 1.5 + \frac{2EI}{3} (2\theta_c + \theta_b + 3 * \frac{0.005}{3})$$

$$\Rightarrow M_{cd} = -1.5 + \frac{2EI}{4} (2\theta_c + \theta_b + 3 * \frac{0.01}{4})$$

$$M_{dc} = 1.5 + \frac{2EI}{4} (\theta_c + 3 * \frac{0.01}{4})$$

* Also we know ;

$$M_{BA} + M_{BC} = 0$$

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$$\Rightarrow -1.5 + \frac{4EI\theta_b}{3} + \frac{2EI\theta_c}{3} + \frac{2}{3} * 764 * 0.005$$

$$+ 2.5 + \frac{4EI\theta_b}{3} + \frac{2 * 764}{2500}$$

$$- \frac{3 * 0.015 * 2 * 764}{25}$$

$$1.4074$$

$$= 0$$

$$\Rightarrow \cancel{5.824} + 2.133(\theta_b EI) + 0.67(\theta_c EI) = 0 \quad \text{--- (1)}$$

$$* M_{CB} + M_{CD} = 0$$

$$\Rightarrow \frac{4EI\theta_c}{4} + \frac{3}{8} * 0.01 * 764 + \frac{4EI\theta_c}{3}$$

$$+ \frac{2EI\theta_b}{3} + 0 + \frac{2 * 764 * 0.005}{3}$$

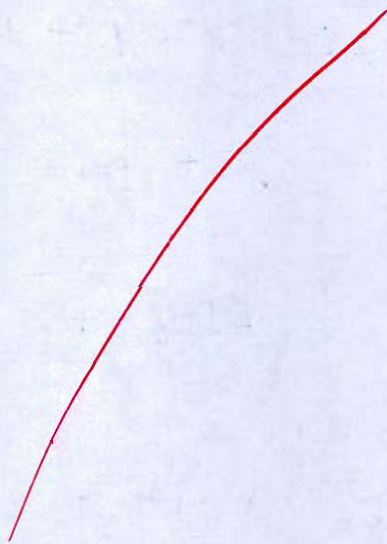
$$\Rightarrow 2.33(EI\theta_c) + 0.67(EI\theta_b) + \frac{5.41167}{\cancel{9.23}} = 0 \quad \text{--- (2)}$$

Solving (1) & (2)

$$\left. \begin{aligned} EI\theta_b &= \cancel{+944} \\ EI\theta_c &= \cancel{+764} \\ &= -2.344 \end{aligned} \right\}$$

$$* \theta_b = \frac{0.0766}{764} \quad \checkmark$$

$$\theta_c = \frac{-2.344}{764} \quad \checkmark$$



Q.2(b) Write short notes on the following terms related to the tendering and contract process:

1. Notice Inviting Tender (NIT)
2. Earnest Money Deposit (EMD)
3. Bid Security
4. Performance Guarantee
5. Letter of Acceptance (LOA)
6. Mobilization Advance
7. Variation Order
8. Defect Liability Period (DLP)
9. Liquidated Damages (LD)
10. Escalation Clause

1. Notice inviting tender is the advertisement ^[20 marks] published on media giving information regarding only release of tender, it doesn't contain any information of content of tender & is an indication for serious contractors to buy the tender and see the details.

2. Earnest Money Deposit: when a contractor submits his bid a money deposit of ~~10-15%~~ 5% is paid along with tender of total cost to show that contractor is serious. This deposit is later settled in security deposit if contractor wins the bid & returned back to other parties.

3. Bid Security: when a bid is made a security deposit of 10-15% in advance is made by contractor which is then stored in a bank & only returned after project completely, or if bid is later rejected. It is like a guarantee advance, so that contractor doesn't run away.

4. Performance Guarantee: Included in security deposit is performance guarantee which is only returned after few months.

of commissioning of project, otherwise if project is not upto mark it is taken as penalty.

5. Letter of Acceptance: When a contractor wins a tender a letter of acceptance is sent by tendered on acceptance of that is the contract finally accepted and a deal is made. If contractor doesn't sign this document bid is cancelled.

7. Variation Order: When order quantities change over certain time period & is not constant throughout the period of project it is known as variation order. Also it refers to changes that have to be made in project details for which an order is passed.

8. Defect Liability Period: After completion of project for a certain time period quality of project is assessed. Like for a road it is till first rain. If performance is upto mark then performance guarantee is returned otherwise penalty is imposed. This period of checking is known as defect liability period.

9) Liquidated Damages: So when there is a defect in project, or it is not completed in time, a penalty is imposed on contractor for reversing those damages this is known as liquidated damages.

10. Escalation

Clause: If an issue arises, the method of resolution is stated in Escalation clause. Like who will be the arbitrator, legal procedures that would be followed, whose liable for what, etc.

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- Q.2 (c) (i) Write the Fulkerson's numbering rules of nod-numbering in context of network diagram.
- (ii) A small project consists of certain activities with the following details:

Preceding event node number	Succeeding event node number	Optimistic time (in weeks)	Most likely time (in weeks)	Pressimistic time (in weeks)
1	2	10	12	20
1	4	5	15	19
2	3	10	15	26
2	7	15	20	25
3	6	5	10	15
4	5	4	8	12
5	6	5	10	15
6	8	2	4	6
7	6	2	4	6

- (a) Draw the network, find critical path, the expected completion time of project.
- (b) What project duration will have 95% confidence of completion. The values of Z and corresponding probability are given in the following table.

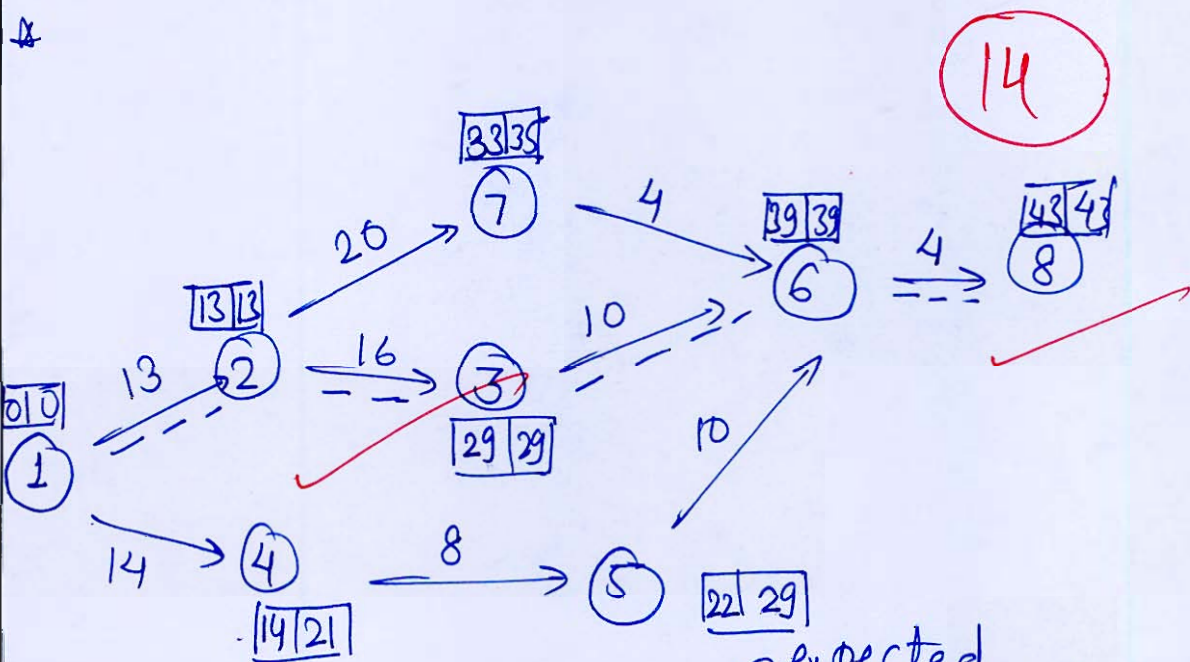
Z	1.0	1.1	1.2	1.5	2.0	3.0
Probability%	84.13	86.43	88.9	93.92	97.92	99.87

- (1) Fulkerson's numbering rule is as follows:— [5 + 15 marks]
- (i) First node should be single and numbered as 1.
- (ii) Subsequent node should be seen with following observations—
- ⇒ ~~The~~ The activity preceding it has been numbered. ~~It~~
- ⇒ The node with earliest time should be numbered first if many alternatives exist.
- ⇒ The node from which maximum no. of activities release should be given a smaller number.

4

$$\left(\frac{t_o + 4t_m + t_p}{6} \right)$$

Activity	t_o	t_m	t_p	t_{mean}	$\frac{(t_p - t_o)}{6}$
1 → 2	10	12	20	13 ✓	10/6 ✓
1 → 4	4 5	15	18 19	14 ✓	9/6 ✓ 14/6
2 → 3	2 10	15	18 26	16 ✓	16/6 ✓
2 → 7	7 15	20	24 25	20 ✓	10/6 ✓
3 → 6	5	10	15	10 ✓	10/6 ✓
4 → 5	4	8	12	8 ✓	8/6 ✓
5 → 6	5	10	15	10 ✓	10/6 ✓
6 → 8	2	4	6	4 ✓	4/6 ✓
7 → 6	2	4	6	4 ✓	4/6 ✓



* Total duration = 43 days / expected completion time
 Critical path ⇒ 1 → 2 → 3 → 6 → 8

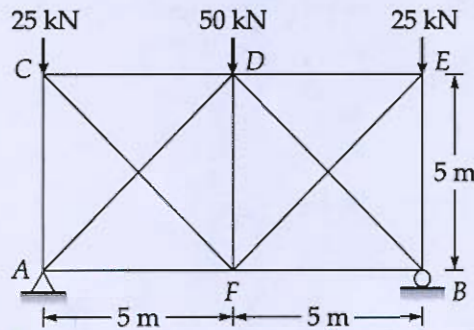
$$\sigma_{along\ CP} = \sqrt{\frac{10^2}{6^2} + \frac{16^2}{6^2} + \left(\frac{10}{6}\right)^2 + \left(\frac{4}{6}\right)^2} = 3.62$$

For 95% ⇒ $Z = 1.5 + \frac{(0.5) * (95 - 93.92)}{(97.92 - 93.92)}$
 $= 1.635$

$$\times 43 \Rightarrow \frac{t - 43}{3.62} = 1.635$$

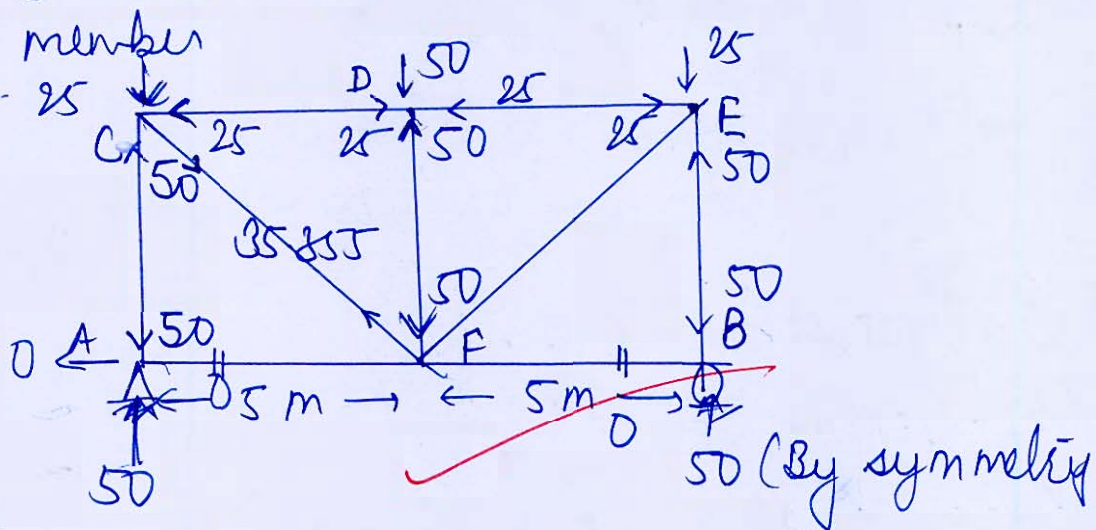
$$\Rightarrow t = 48.9187 \text{ days for } 95\% \text{ confidence}$$

Q.3(a) Determine the member forces in the pin jointed truss shown below in the figure. Take the area of each member as A and the modulus of elasticity as E . Make use of symmetry.



Q. Let AD & DB be redundant member

[20 marks]



\Rightarrow At C: $F_{CF} \sin 45^\circ = 50 - 25$
 $F_{CF} = 35.355$

* So $F_{CD} = 35.355 \cos 45^\circ$

* Forces in members :-

$F_{CA} = F_{EB} = -50 \text{ kN}$ (compressive \Rightarrow -ve
 tensile \Rightarrow +ve)

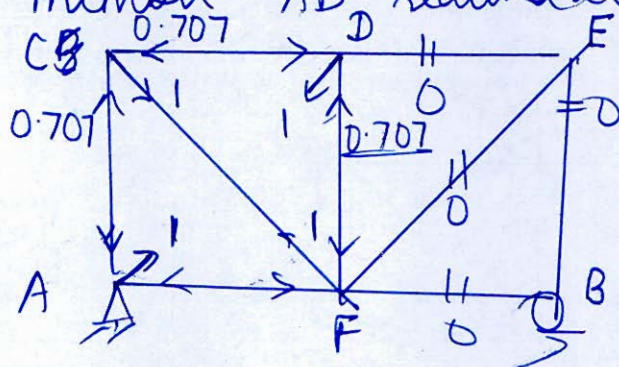
* $F_{CD} = F_{DE} = -25 \text{ kN}$

* $F_{DF} = -50 \text{ kN}$

$F_{CF} = F_{FE} = 35.355 \text{ kN}$

$F_{AF} = F_{FB} = 0$

* For member AD, redundant,



$$\Rightarrow K_{xAC} = -0.707 = K_{xCD} = K_{xDF} = K_{xAF}$$

$$\rightarrow K_{xCF} = 1 \Rightarrow K_{xDA} = 1$$

$$\Rightarrow K_{xDE/EB/BF/FD/EF} = 0$$

* For redundant member DB, similarly

$$K_{yAC/CD/DF/AF/CF} = 0$$

$$\rightarrow K_{yDE, yEB, yBF, yFD} = -0.707$$

$$\Rightarrow K_{yEF} = K_{yBD} = 1$$

* We know,

$$\sum (F + K_x X + K_y Y)^2 = U$$

$$\frac{\partial U}{\partial X} = \sum \frac{2AE}{AE} (F + K_x X + K_y Y) K_x + \frac{X l_0}{AE} = 0$$

$$\frac{\partial U}{\partial Y} = \sum \frac{2AE}{AE} (F + K_x X + K_y Y) K_y + \frac{Y l_0}{AE} = 0$$

$$\Rightarrow \sum \frac{F K_x l}{AE} + X \left(\sum \frac{K_x^2 l}{AE} + \frac{l_0}{AE} \right) + \sum \frac{K_y K_x l Y}{AE} = 0$$

$$\rightarrow \sum \frac{F K_y l}{AE} + Y \left(\sum \frac{K_y^2 l}{AE} + \frac{l_0}{AE} \right) + \sum \frac{K_x K_y l}{AE} = 0$$

\(\Rightarrow\) So subtracting two eqⁿs

$$* \boxed{X = Y}$$

$$\sum \frac{Fkl}{AE} + x \left(\sum \frac{l k^2}{AE} + \frac{l_0}{AE} \right) + \frac{(0.707)^2 * (x)}{AE} = 0$$

Mem	F	k	l	$\frac{Fkl}{AE}$	$k^2 l$	Force
AC	-50	-0.707	5	176.75 35.35	2.5	Only for DF Force Forces ($F + k_x x + k_y y$) $\Rightarrow AC, EB = \underline{\underline{-35.86}}$ $CD, DE = \underline{\underline{-10.86}}$ $DF = \underline{\underline{-78.28}}$ $CF, EF = \underline{\underline{15.355}}$ $AD, DB = 20$ $AF, FB = \underline{\underline{14.14}}$
CD	-25	-0.707	5	88.375	2.5	
DF	-50	-0.707	5	176.75 35.35	2.5	
AF	0	-0.707	5	0	2.5	
CF	35.35	1	$5\sqrt{2}$	250	7.07	
DA	0	1	$5\sqrt{2}$	0	7.07	

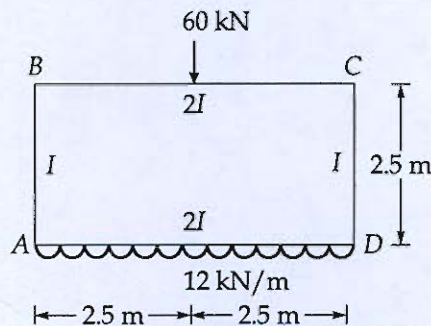
$\sum 532.875 \quad 24.14$

Do work on the concept

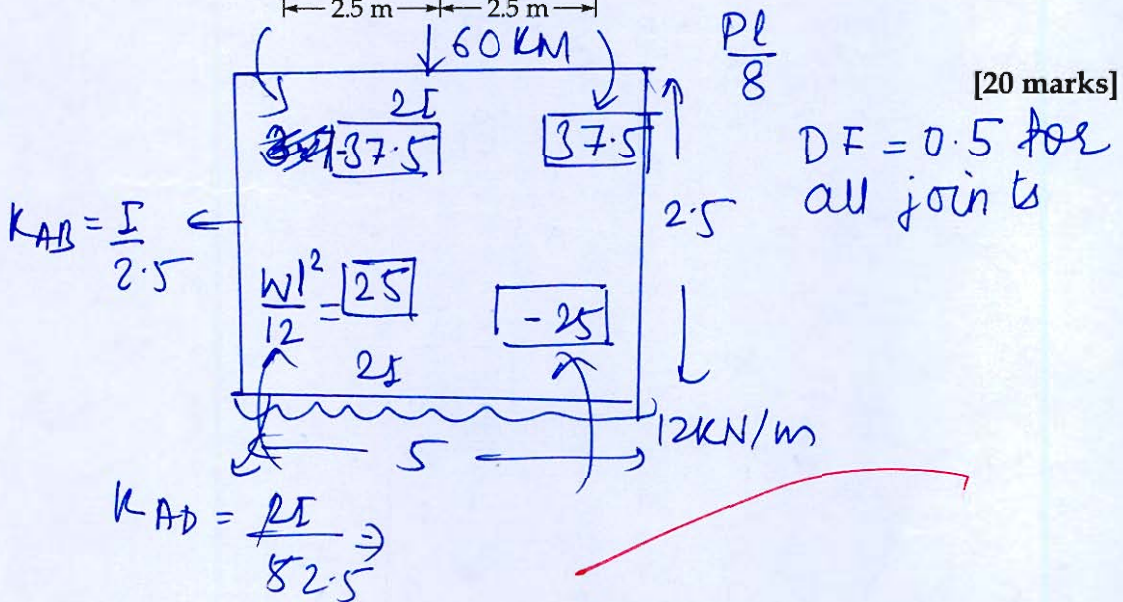
$$x = \frac{-532.875}{24.14 + (0.707)^2 * 5} = \underline{\underline{20 \text{ kN}}}$$

$$y = \underline{\underline{-20 \text{ kN}}}$$

Q.3(b) Analyse the plane box frame (by moment distribution method) shown in the figure. Also draw the bending moment diagram.

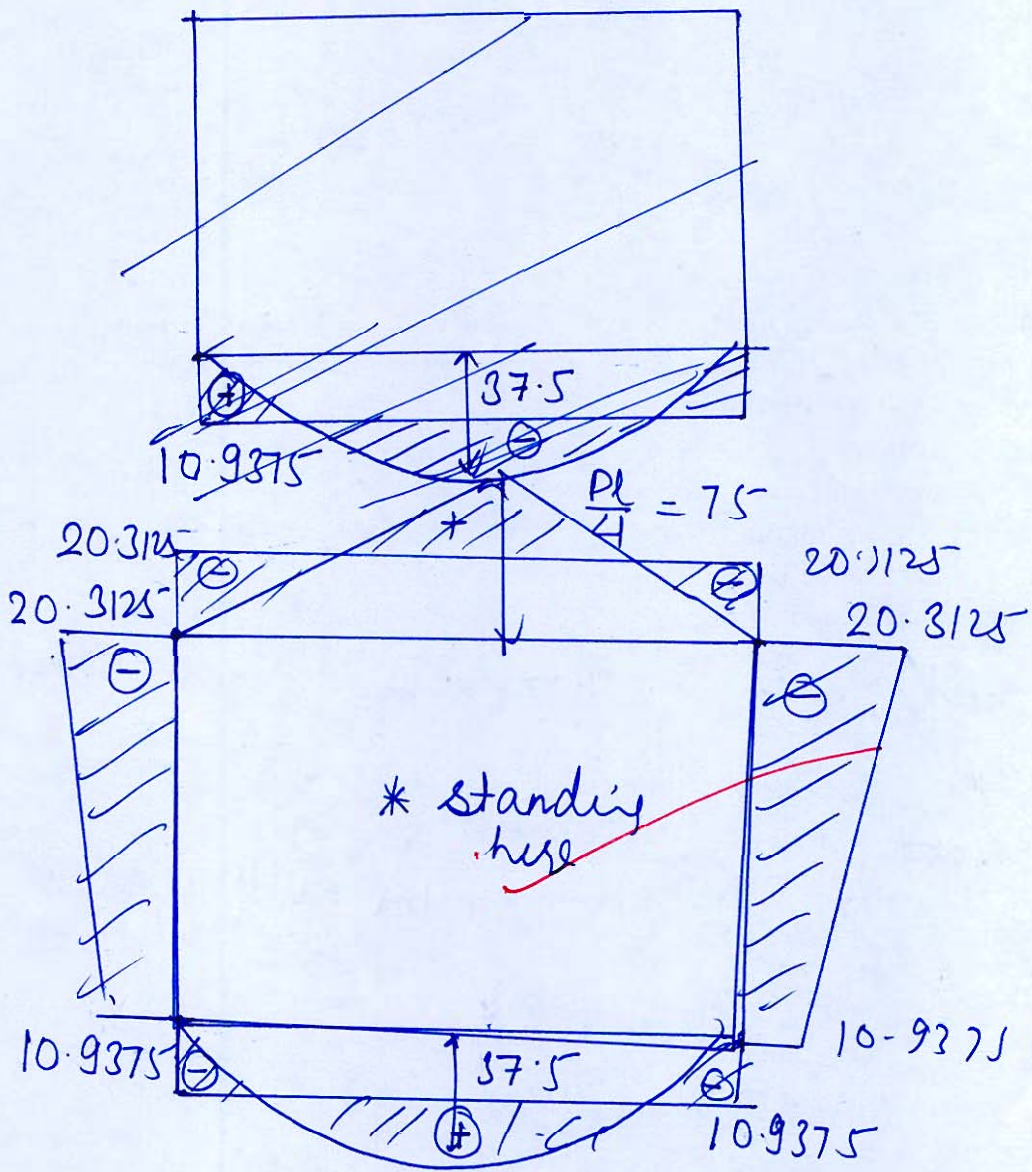
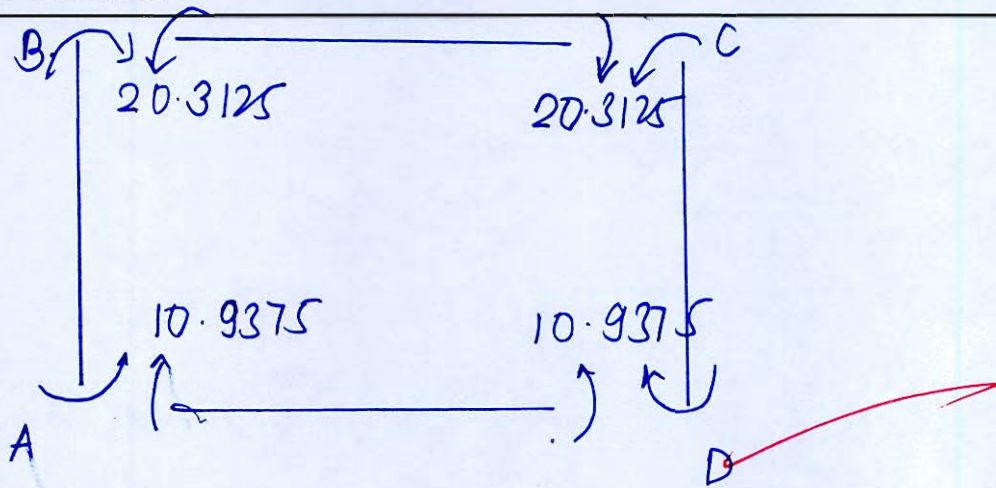


(b)



J+	A	B	C	D
Mum	AD	BA	CB	DC
DF	0.5	0.5	0.5	0.5
FEM	0	-37.5	37.5	0
Bar	-12.5	18.75	-18.75	12.5
COM	9.375	-9.375	9.375	-9.375
Bar	-7.8125	7.8125	-7.8125	7.8125
COM	3.90625	-3.90625	3.90625	-3.90625
	-3.90625	3.90625	-3.90625	3.90625
	10.9375	20.3125	20.3125	10.9375
	-10.9375	-20.3125	-20.3125	-10.9375

20



- Q.3(c) The initial cost of an equipment is Rs. 2200, the salvage value is Rs. 200, and the useful life is 4 years. The rate of interest is 10%. Calculate the yearly depreciation and book value at the end of each year by

(Solve in table format)

- (i) Straight-line method
- (ii) Declining balance method
- (iii) Sum of years digits method
- (iv) Sinking fund method

[20 marks]

(i) Method	Yr	Book value	Depreciation
1. Straight			
(1) Straight line method :-			
			$\Rightarrow D = \frac{2200 - 200}{4} = 500$ (for all 4 years depreciation)
Book Value	At end of 1 yr	$B_1 = 2200 - 500 = 1700$ ✓	
		$B_2 = 1700 - 500 = 1200$ ✓	
		$B_3 = 1200 - 500 = 700$ ✓	
		$B_4 = 700 - 500 = 200$ ✓	

(ii) Declining balance:-

$$\Rightarrow C_s = C_0 (1 - P)^n \text{ 1. decrease}$$

$$\Rightarrow \left(\frac{C_s}{C_0}\right)^{1/n} + 1 = P \Rightarrow \underline{1 - P = 0.549} \Rightarrow (1 - P) = 0.451$$

$$\Rightarrow B_1 = 2200 (0.451) = 992.2 \quad \checkmark$$

$$B_2 = 2200 (0.451)^2 = 447.48 \quad \checkmark$$

$$B_3 = 2200 (0.451)^3 = 201.81 \quad \checkmark$$

$$B_4 = 2200 (0.451)^4 = 92.00 \quad \checkmark$$

$$D_1 = B_0 - B_1 = 992.2$$

$$D_2 = B_1 - B_2 = 544.72$$

$$D_3 = B_2 - B_3 = 299.04$$

$$D_4 = B_3 - B_4 = 164.032$$

(iii) Sum of years diged \Rightarrow

$$\frac{n(n+1)}{2} = \frac{4 \times 5}{2} = 10$$

$$\Rightarrow (n - m + 1) = (5 - m)$$

$$* D_m = (C_0 - C_s) * \frac{(n - m + 1)}{\frac{n(n+1)}{2}}$$

$$\Rightarrow D_1 = 2000 * \frac{4}{10} = 800 \quad ; \quad B_1 = 1400 \quad \checkmark$$

$$\Rightarrow D_2 = 600 \quad ; \quad B_2 = 800 \quad \checkmark$$

$$\Rightarrow D_3 = 400 \quad ; \quad B_3 = 400 \quad \checkmark$$

$$\Rightarrow D_4 = 200 \quad ; \quad B_4 = 200 \quad \checkmark$$

(iv) Sinking Fund:

$$\star D_0 = 2000 \left(\frac{0.1}{(1.1)^4 - 1} \right)$$

$$= \underline{430.94}$$

(D \Rightarrow depreciation
B \Rightarrow Book value)

$$\Rightarrow D_1 = 430.94 \times 1.1$$

$$\Rightarrow B_1 = 1769.06$$

$$\Rightarrow D_2 = 430.94 \times 1.1^2 = 474.034$$

$$B_2 = 1295.026$$

$$D_3 = 521.4374$$

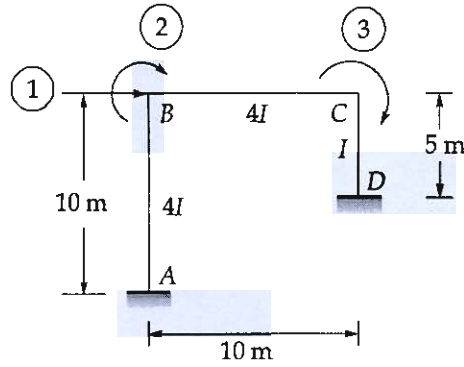
$$B_3 = 773.588$$

$$D_4 = 573.58$$

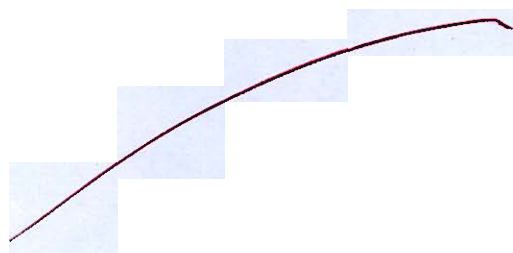
$$B_4 = \boxed{200}$$

20

Q.4(a) Develop the stiffness matrix for portal frame ABCD with reference to the coordinates shown in figure.



[20 marks]

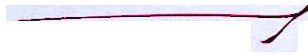




- Q.4(b) The cost and benefit details for two alternative schemes *A* and *B* are given. Scheme *A* requires an initial investment of 15 lacs, has an annual running cost of 2 lacs, and provides an annual benefit of 4.5 lacs starting after 1 year for a total life of 6 years. Scheme *B* requires an initial investment of 25 lacs, has an annual running cost of 2.5 lacs, and provides an annual benefit of 6.2 lacs starting after 2 years for a total life of 12 years. Taking the rate of interest as 12%, determine the most economical proposal using the present worth method.

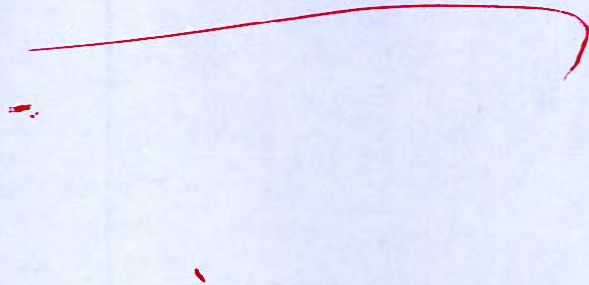
[20 marks]

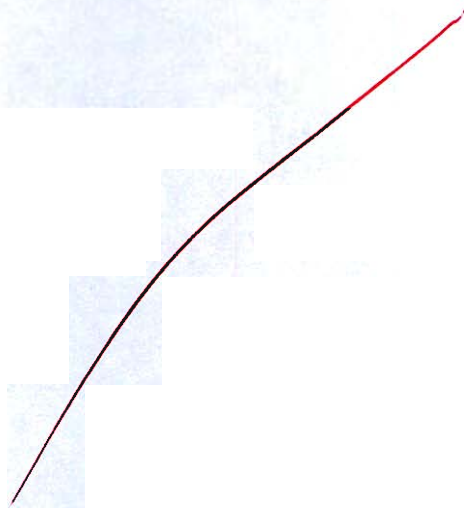




- Q.4 (c) (i) A vibrating system consists of a mass $m = 5$ kg and a spring with stiffness $k = 4500$ N/m. The system is viscously damped such that the ratio of two consecutive amplitudes of vibration is 1.00 to 0.85. Determine the natural frequency of the undamped system, the logarithmic decrement, the damping ratio, the damping coefficient, and the damped natural frequency.
- (ii) Briefly describe the various factor affecting the output of power shovel to excavate the earth.

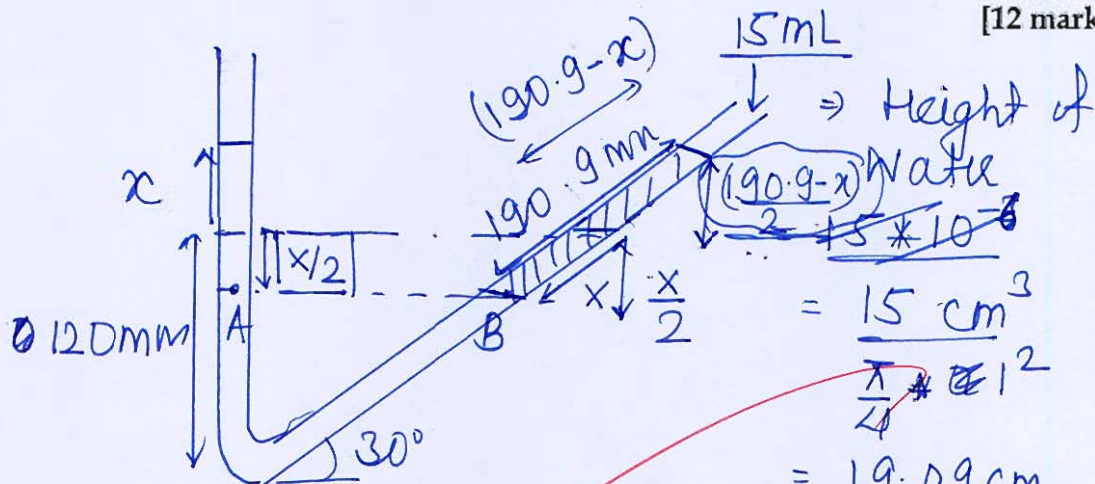
[12 + 8 = 20 marks]





Section B : Flow of fluids, hydraulic machines and hydro power-1
+ Design of Concrete and Masonry Structures-2

Q.5(a) A U-tube has a constant internal diameter of 10 mm. The left leg is vertical, while the right leg is inclined at an angle of 30° to the horizontal. Initially, the tube contains mercury (SG = 13.6) such that the vertical height of mercury in both legs is 120 mm. If 15.0 mL of water is poured into the inclined right-hand leg, determine the vertical height of the mercury levels in both legs. [12 marks]



$$\begin{aligned} & \Rightarrow \text{Height of Water} \\ & = \frac{15 \text{ cm}^3}{\frac{\pi}{4} \cdot 10^2} \\ & = 19.09 \text{ cm} \\ & = \underline{190.9 \text{ mm}} \end{aligned}$$

$$P_A = P_B$$

$$\Rightarrow 13.6 \cdot \frac{3x}{2} = \frac{190.9}{2}$$

$$x = 4.678 \text{ mm}$$

Height of Hg in left leg

$$= 120 + 4.678$$

$$= \underline{124.678 \text{ mm}}$$

* Height of Hg in right leg

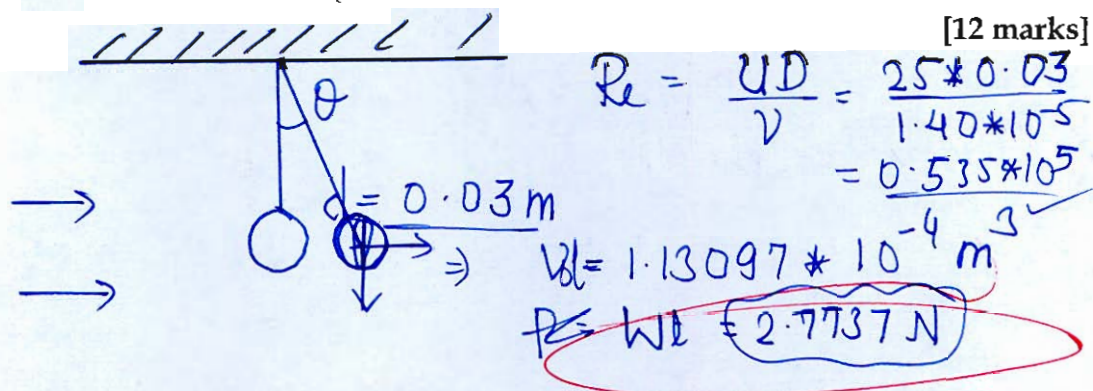
$$= 120 - \frac{4.678}{2} = \underline{117.661 \text{ mm}}$$

12

- Q.5(b) A sphere 3 cm in diameter and of relative density 2.5 is attached to a string and is suspended from the roof of a wind tunnel. If an air stream of 25 m/s flows past the sphere then determine the inclination of the string to horizontal and the tension in the string. (Neglect the weight and drag of the string).

[Take : Mass density of air, $\rho_{\text{air}} = 1.25 \text{ kg/m}^3$, kinematic viscosity of air, $\nu_{\text{air}} = 1.40 \times 10^{-5} \text{ m}^2/\text{s}$.]

Coefficient of drag $C_D = \begin{cases} 0.5 \text{ for } 10^4 < R_e < 3 \times 10^5 \\ 0.2 \text{ for } R_e \geq 3 \times 10^5 \end{cases}$



As $Re < 3 \times 10^5$

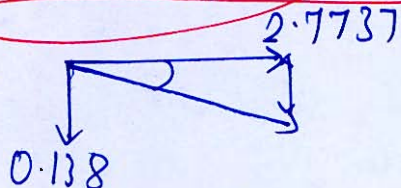
$$\Rightarrow \text{Drag} = \frac{1}{2} C_D \rho A V^2$$

$$= \frac{1}{2} \times 0.5 \times 1.25 \times \frac{\pi}{4} \times 0.03^2$$

$$= 0.1389 \text{ N}$$

4

$$\Rightarrow \text{Tension in string} = \sqrt{2.7737^2 + 0.138^2}$$
$$= \boxed{2.777 \text{ N}}$$

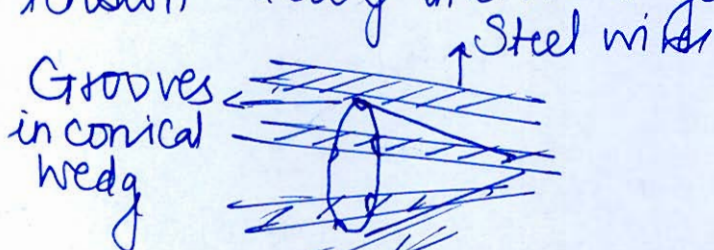
$$\neq \text{Angle of inclination} =$$


$$\tan^{-1}\left(\frac{0.138}{2.7737}\right) = \underline{2.84}$$

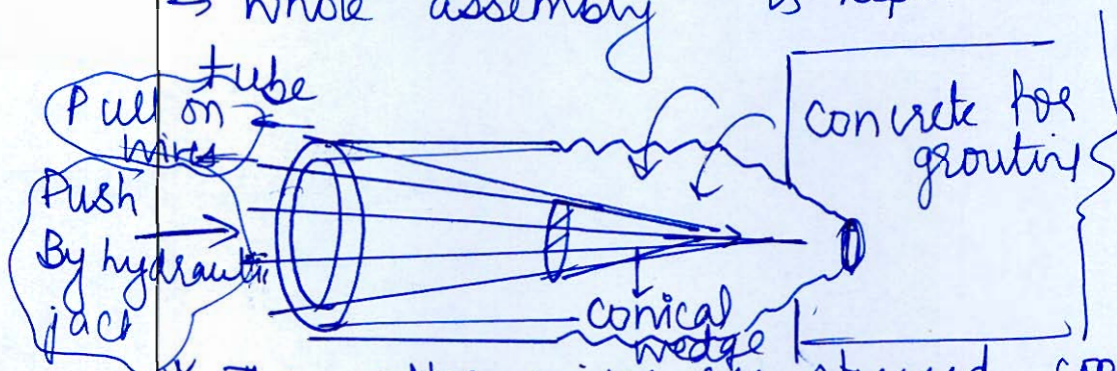
$$\neq \text{Angle of inclination from horizontal} = \underline{90 - 2.84}$$
$$= \boxed{87.151^\circ}$$

Q.5 (c) Explain with neat sketches about Freyssinet prestressing system. Also discuss its advantages and disadvantages.

* Freyssinet prestressing system is based on the thrusting of conical wedge with wires placed on its indentation & hydraulic tension acting in two ways:- [12 marks]



⇒ Hydraulic jack performs two functions:-
 → One it pushes the conical wedge in
 & second it pulls the wire out.
 → whole assembly is kept in a cylindrical



* Then after wires are stressed, concrete is poured in to lock & seal the joint.

Advantages

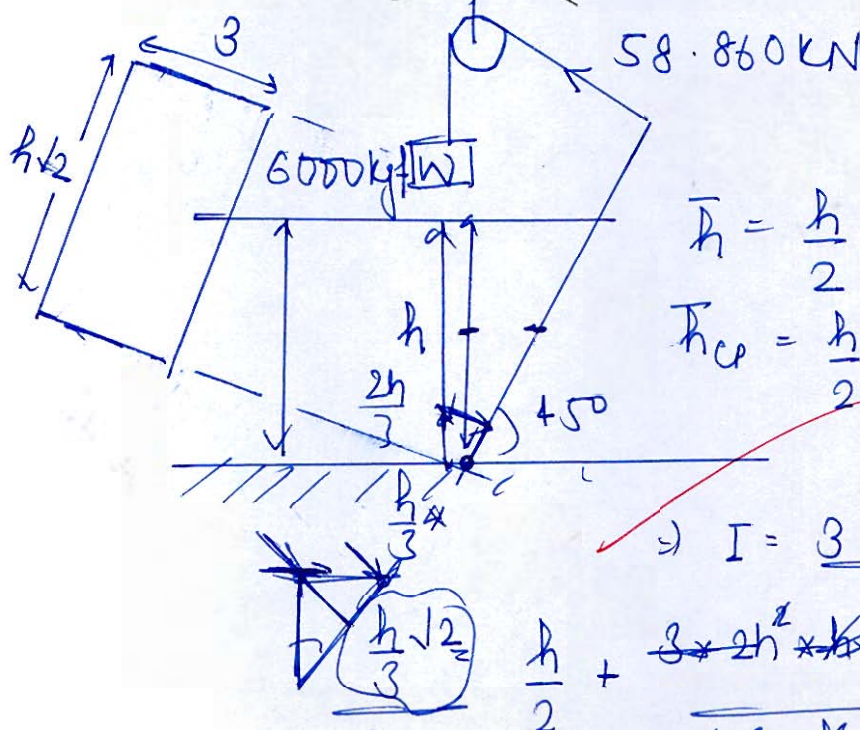
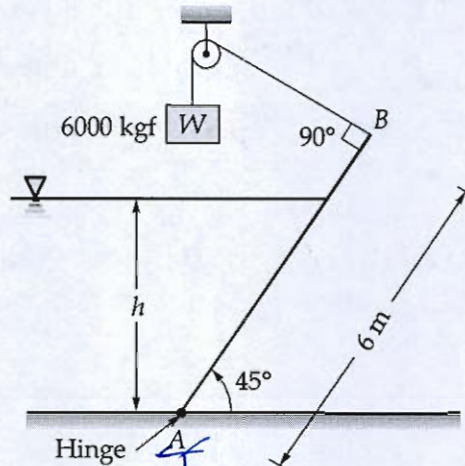
- ⇒ Fast & effective prestressing method.
- ⇒ All wires are pulled at once so elastic shortening is not present.
- ⇒ The opening is tightly sealed by conical wedge.
- ⇒ Can be used for very large to small structures.
- ⇒ Economical method.

- Disadvantages: → # Friction losses are high
- Conical wedge is made of concrete & it can shatter
 - If a wire is broken during stressing it can't be known as all wires are stressed at once
 - Hydraulic Jack requires lot of energy

10

Q.5(d)

A rectangular gate of dimensions 6 m × 3 m is hinged at its base and inclined at an angle of 45° to the horizontal. To maintain the gate's stability, a counterweight of 6000 kgf is attached to the top edge of the gate through a cable and pulley system. Determine the depth of water h at which the gate is just on the verge of falling. Neglect the self-weight of the gate and friction in the system.



[12 marks]

$$\bar{h} = \frac{h}{2}$$

$$\bar{h}_{cp} = \frac{h}{2} + \frac{I \sin^2 45}{\frac{h}{2} * 3 * h/2}$$

$$\Rightarrow I = \frac{3 * 2h^2 * h/2}{2}$$

$$\frac{h}{2} + \frac{3 * 2h^2 * h/2 * \frac{1}{2}}{1/2 * h * 3 * h/2} = \frac{h}{2} + \frac{h}{2} = \frac{2h}{3}$$

Force = $\rho g h A \cdot \bar{h}$
 Moment abt hinge

$$\Rightarrow 58.860 * 6 = 9.81 * h^3$$

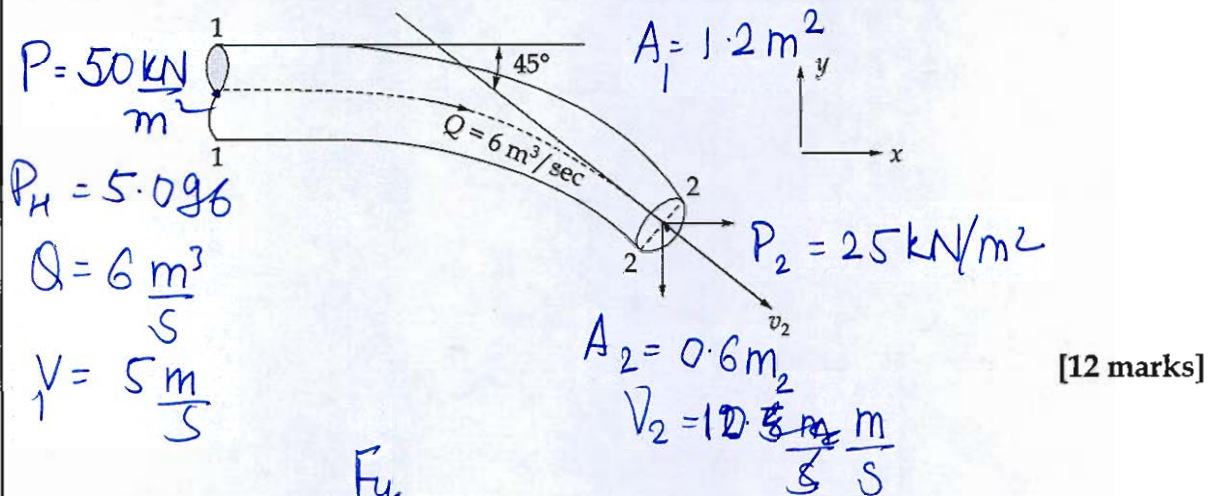
$$\Rightarrow h^3 = \frac{58.860 * 6}{9.81} \Rightarrow h = 3.3m$$

12

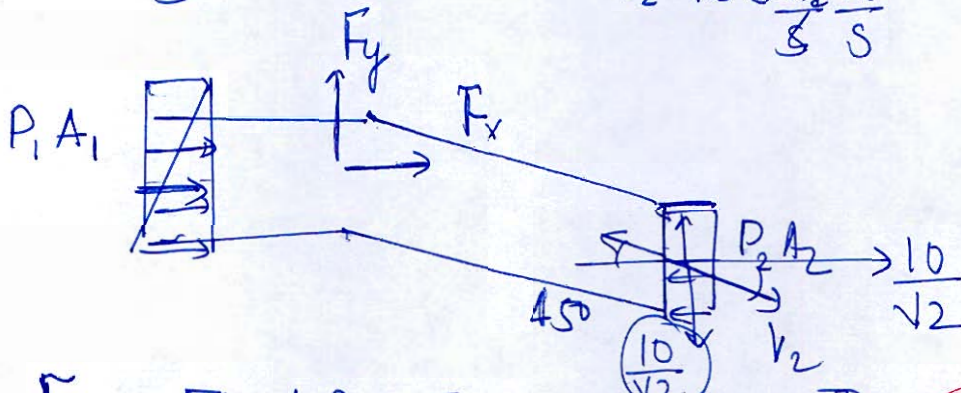


Q.5(e)

A pipeline carrying water has a 45° reducing bend in a horizontal plane. The cross-sectional area at the inlet of the bend is 1.2 m^2 and at the outlet is 0.6 m^2 . The pressure at the inlet is 50 kN/m^2 , while at the outlet it is 25 kN/m^2 . The discharge through the pipe is $6 \text{ m}^3/\text{s}$. Taking the density of water as 1000 kg/m^3 , determine the magnitude and direction of the force required to hold the bend in position.



[12 marks]



$$F_x + 50 \times 1.2 - 25 \times 0.6 \times \sin 45^\circ$$

$$= \rho Q \left(\frac{10}{\sqrt{2}} - 5 \right)$$

$$\Rightarrow F_x = \boxed{36.966} \text{ kN (By pipe)}$$

$$\Rightarrow F_y + 25 \times 0.6 \times \sin 45^\circ$$

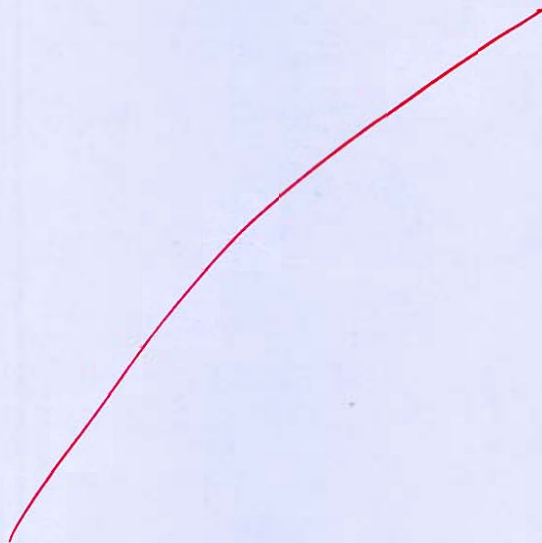
$$= \rho Q \left(\frac{10}{\sqrt{2}} - 0 \right)$$

as velocity change is in downward dirⁿ.

$$\Rightarrow \boxed{F_y = -53.033 \text{ kN}}$$

$$F_R = \sqrt{F_x^2 + F_y^2}$$

direction . $\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$ from x-axis



Q.6(a) The difference in water surface levels in two tanks connected by three pipes in series of lengths 300 m, 170 m, and 210 m with diameters 300 mm, 200 mm, and 400 mm respectively is 12 m. The coefficients of friction for the three pipes are 0.005, 0.0052, and 0.0048 respectively. Determine the rate of flow of water considering-

- (i) Minor losses
- (ii) Neglecting minor losses.

Also calculate the percentage error in discharge estimation.

[20marks]

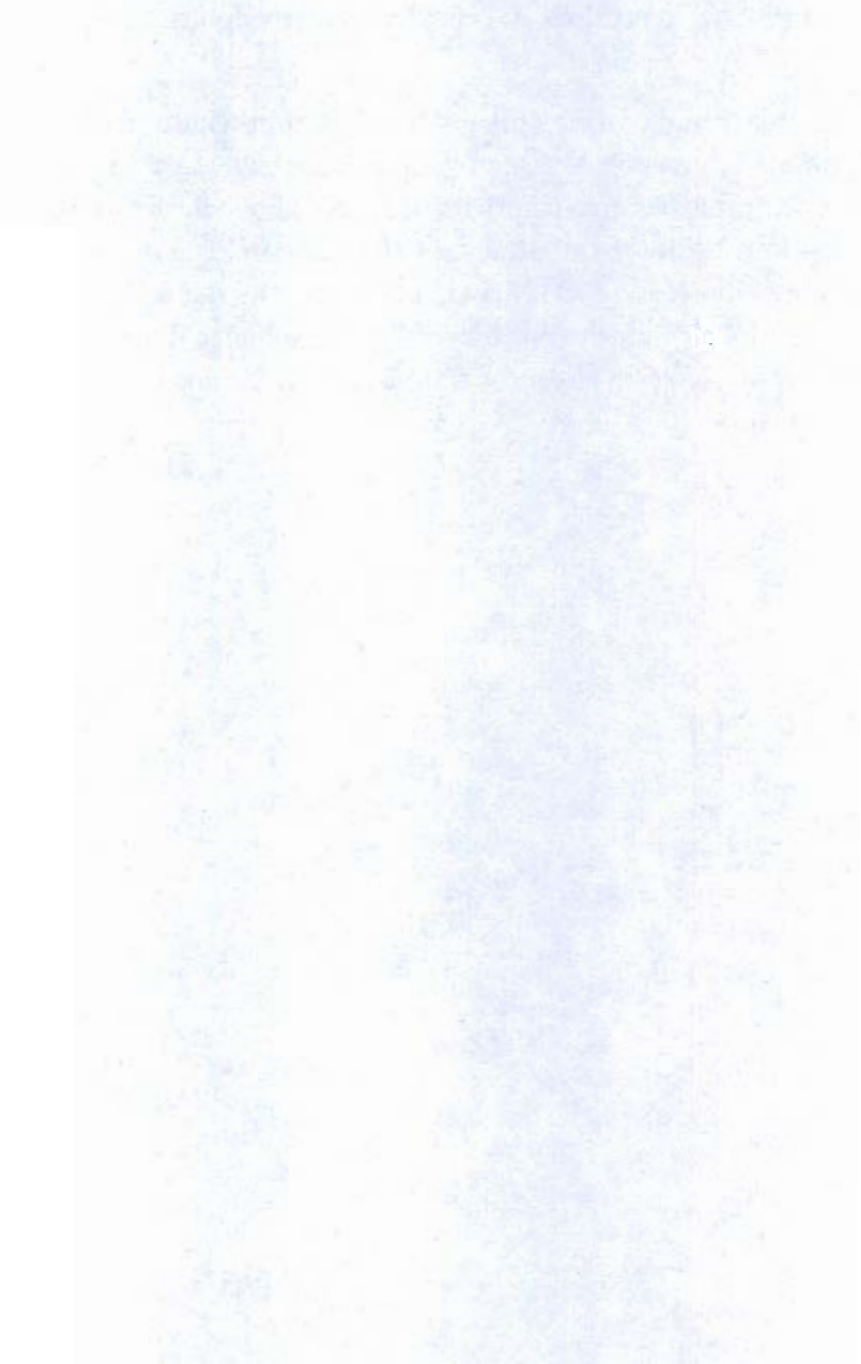




- Q.6 (b) (i) What is thrust line (C-line) in prestressed beam? Explain its significance with respect to kern.
- (ii) A prestressed concrete beam of rectangular section 300 mm wide and 600 mm deep spans over 10 m. The beam is prestressed by a parabolic cable carrying an effective force of 1000 kN. The cable has an eccentricity of 50 mm above the neutral axis at the supports and 150 mm below the neutral axis at mid-span. The beam supports a uniformly distributed live load of 10 kN/m in addition to its self-weight (density of concrete is 24 kN/m³). Calculate the position of the thrust line (C-line) relative to the cable profile at intervals of 2.5 m along the span. Based on the position of C-line also draw the locus of C-line.

[5 + 15 = 20 marks]

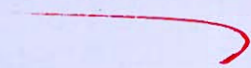


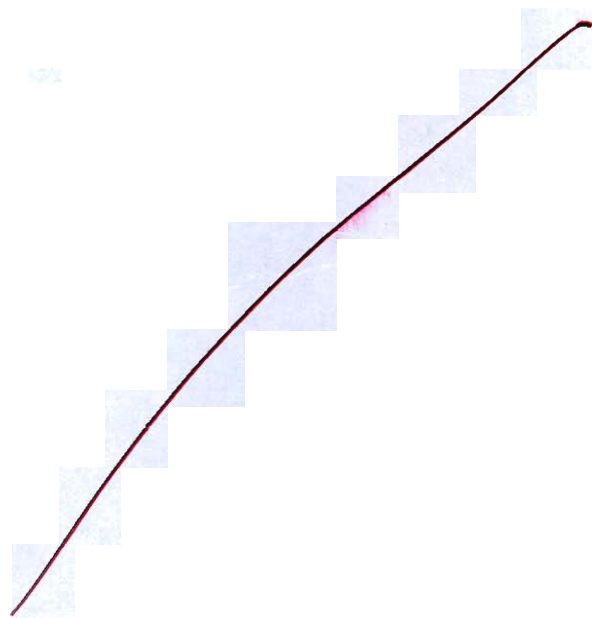




- Q.6 (c) (i) Derive the equation of pressure in vortex motion. Prove that the isobars in forced vortex motion are parabolic in nature and also prove that the volume of paraboloid formed is half the volume of circumscribing cylinder.
- (ii) A 15 cm diameter vertical cylinder rotates concentrically inside another cylinder of diameter 15.10 cm. Both cylinders are 25 cm high. The space between the cylinder is filled with a liquid whose viscosity is unknown. If a torque of 12 Nm is required to rotate the inner cylinder at 100 rpm, then determine the viscosity of the fluid. Assume linear velocity profile within the thin oil film.

[10 + 10 = 20 marks]





- Q.7 (a) (i) A head of water of 6 m is maintained over an orifice of 150 mm diameter. The water issuing from the orifice is collected in a circular measuring tank of 2.5 m diameter, where the rise of water level is observed to be 0.5 m in 25 sec. The coordinates of a point on the jet measured from the vena contracta are 120 cm horizontally and 6.5 cm vertically. Determine the hydraulic coefficients of the orifice, namely the coefficient of discharge, coefficient of velocity, and coefficient of contraction.
- (ii) Consider a laminar boundary layer where the velocity profile is approximated by the expression

$$\frac{u}{u_{\infty}} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$$

Here, u represents the velocity in the x -direction at a distance y from the boundary, δ denotes the boundary layer thickness, and u_{∞} is the free stream velocity. Determine the ratio of the displacement thickness to the boundary layer thickness for this specific parabolic profile. Also work out the momentum thickness.

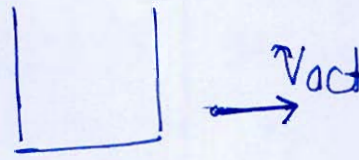
[10 + 10 = 20 marks]

$$Q.7(a) Q_{act} = \frac{0.5 \times \frac{\pi}{4} \times 2.5^2}{25} = \boxed{0.09817 \frac{m^3}{s}}$$

$$\begin{aligned} Q_{theor} &= \frac{\pi}{4} \times 0.15^2 \times \sqrt{2g(6)} \\ &= 0.1917 \frac{m^3}{s} \end{aligned}$$

10

$$\Rightarrow C_d = \frac{Q_{actu}}{Q_{theor}} = \frac{0.09817}{0.1917} = \boxed{0.5121}$$

\Rightarrow  $\Rightarrow x = V_{act} t$
 $\Rightarrow t = \frac{x}{V_{act}}$ Equating time
 $\Rightarrow y = \frac{1}{2} g t^2 \Rightarrow t = \left(\frac{2y}{g}\right)^{1/2}$
 $\Rightarrow \sqrt{\frac{2y}{g}} = \frac{x}{V_{act}} \Rightarrow V_{act} = \frac{x \sqrt{g}}{\sqrt{2y}} = \frac{1.2 \sqrt{9.81}}{\sqrt{2 \times 0.065}} = 10.424 \text{ m/s}$

$$V_{theor} = \sqrt{2gh} = \sqrt{10.8498}$$

$$C_v = \frac{V_{act}}{V_{theor}} = \boxed{0.9607}$$

$$C_c \times C_v = C_d$$

$$C_c = \frac{C_d}{C_v} = \boxed{0.533}$$

$$\delta^* (\text{displacement thickness}) = \int_0^{\delta} \left(1 - \frac{u}{u_{\infty}}\right) dy$$

$$\Rightarrow \frac{u}{u_{\infty}} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2 \Rightarrow \eta = \frac{y}{\delta}$$

$$\Rightarrow \delta d\eta = dy$$

$$= 2\eta - \eta^2$$

$$\Rightarrow \delta^* = \delta \int_0^1 (1 - 2\eta + \eta^2) d\eta$$

$$\frac{\delta^*}{\delta} = 0.33$$

Boundary Layer thickness

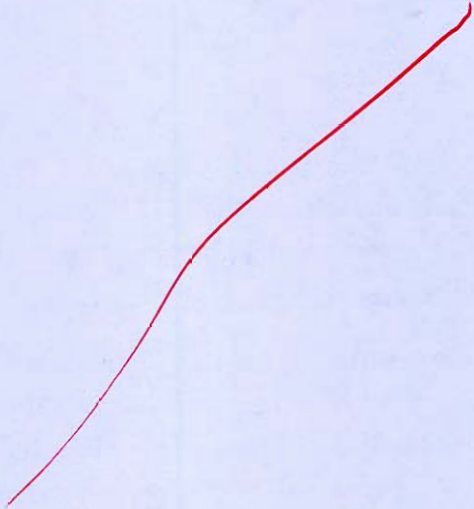
10

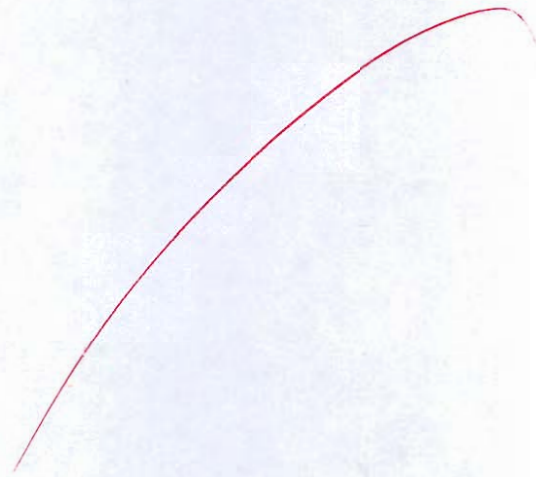
$$\theta = \int_0^{\delta} \frac{u}{u_{\infty}} \left(1 - \frac{u}{u_{\infty}}\right) dy$$

$$\Rightarrow \text{Momentum thickness} = \theta = \delta \int_0^1 (2\eta - \eta^2) (1 - 2\eta + \eta^2) d\eta$$

$$= \delta \int_0^1 (2\eta - \eta^2) (1 - 2\eta + \eta^2) d\eta$$

$$= 0.1333\delta$$





- Q.7 (b) (i) A solid wooden cylinder of diameter 400 mm and length 600 mm has a specific gravity of 0.6. The cylinder is placed vertically in water so that its longitudinal axis remains vertical while floating. Determine the metacentric height of the cylinder and state whether the equilibrium is stable or unstable.
- (ii) A simply supported post-tensioned concrete beam of 10 m span, 230 mm wide and 400 mm deep is prestressed with a straight cable having a cross-sectional area of 385 mm² located at 60 mm from the soffit of the beam. The cable is subjected to an initial stress of 1200 N/mm² at the one jacking end. Estimate the total percentage loss of prestress.

Use the following data:

Modulus of Elasticity of steel (E_s) = 2.1×10^5 N/mm²

Grade of concrete = M50 ($E_c = 5000 \sqrt{f_{ck}}$)

Relaxation of stress in steel = 4.5%

Shrinkage strain of concrete = 0.0003

Creep coefficient of concrete (ϕ) = 1.6

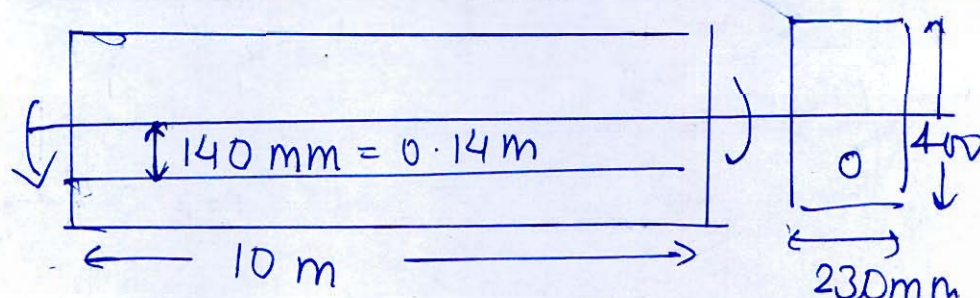
Friction coefficient for wave effect (k) = 0.0025 per metre

Slip at anchorage = 2 mm

[8 + 12 = 20 marks]

(11)

64.68



$$\Rightarrow \text{Force in wire} = 1250 \times 385 = 462 \text{ kN}$$

Moment due to wire eccentricity
 $= 462 \times 0.14 = 64.68 \text{ kN-m}$

$$\Rightarrow \text{Stress in concrete at support at wire}$$

$$= \frac{P}{A} = \frac{462 \times 10^3}{400 \times 230} \left[1 + \frac{Pe}{I} \right]$$

$$= \frac{462 \times 10^3}{400 \times 230} + \frac{64.68 \times 10^6 \times 140}{400^3 \times 230 \times 12}$$

$$= 5.021 + 7.38$$

$$= 12.403 \text{ MPa}$$

at centre, due to dead load stress will be added :- $DL = 25 \times 0.4 \times 0.23 = 2.3 \text{ kN/m}$

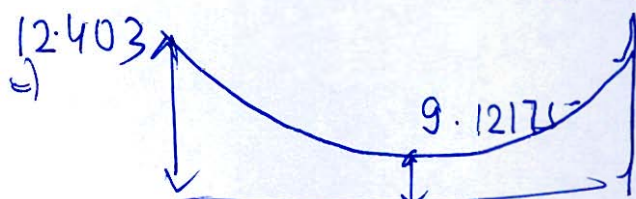
assume $f_{\text{cone}} = 25$

BM_{max} at centre

$$= \frac{2.3 \times 10^2}{8} = 28.75$$

$$\Rightarrow \text{Stress extra at level of wire (negative)} = \frac{28.75 \times 10^6 \times 140}{400^3 \times 230 \times 12}$$

$$= 3.28 \text{ MPa}$$



$$\Rightarrow f_{\text{avg}} = 9.122 + (12.403 - 9.122)$$

$$= 10.215 \text{ MPa}$$

$$\begin{aligned}
 \text{Loss due to creep} &= \phi m f_{avg} \\
 &= \cancel{1.6} \times \cancel{2.1} \\
 &= 1.6 \times 5.94 \times 10.215 \\
 &= \boxed{97.083 \text{ MPa}}
 \end{aligned}$$

$$\begin{aligned}
 m &= \frac{2.1 \times 10^5}{5000 \sqrt{50}} \\
 &= 5.939 \\
 &= \boxed{5.94}
 \end{aligned}$$

$$\begin{aligned}
 \text{Loss due to relaxation} \\
 \text{of steel} &= 0.045 \times 1200 \\
 &= \boxed{54 \text{ MPa}}
 \end{aligned}$$

$$\begin{aligned}
 \rightarrow \text{Loss due to slip} \\
 &= \frac{2 \times 10^{-3}}{10} \times E_s \\
 &= \boxed{42 \text{ MPa}}
 \end{aligned}$$

$$\begin{aligned}
 * \text{ Loss due to shrinkage} \\
 &= 0.0003 \times 2 \times 10^5 \\
 &= \boxed{63 \text{ MPa}}
 \end{aligned}$$

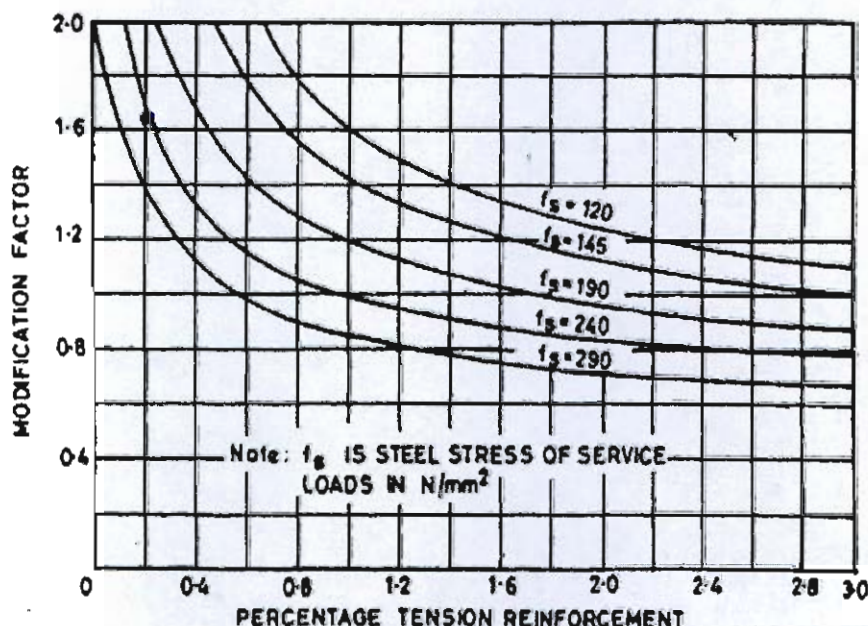
$$\begin{aligned}
 * \text{ Loss due to friction} \\
 &= P_o (k\alpha) = P_o (0.0025 \times 10) \\
 &= \boxed{80 \text{ MPa}}
 \end{aligned}$$

$$\begin{aligned}
 \text{Total loss} &= \frac{286.083 \text{ MPa}}{1200} \quad (\text{including creep}) \\
 &= \boxed{23.841}
 \end{aligned}$$

$$\begin{aligned}
 \rightarrow \text{Loss without} \\
 \text{considering} \\
 \text{creep} &= \frac{189 \text{ MPa}}{1200} = \boxed{15.75\%}
 \end{aligned}$$

Q.7(c) Design a simply supported reinforced concrete slab for a clear room dimension of 4.0 m × 10.0 m. The slab is supported on masonry walls 350 mm thick. The slab is subjected to a live load of 3 kN/m² and a floor finish load of 0.75 kN/m². Use M-25 grade concrete and Fe-415 grade steel. Perform all necessary design checks, including shear and deflection, to ensure structural safety and serviceability. Assume any other data suitably. Relevant chart from IS 456 is enclosed here.

$\frac{100 A_{st}}{bd}$	0.25	0.5	0.75	1.0	1.25	1.50	1.75
τ_c (MPa)	0.36	0.49	0.57	0.64	0.70	0.74	0.78



Let $L_{xe} = 4.35$ (Taking $d < 0.85m$) [20 marks]
 $L_{ye} = 10.35$

$\Rightarrow r = \frac{L_{ye}}{L_{xe}} = 2.379 > 2$ so one way slab, we design for short length $L_{xe} = 4.35$

* $d_{eff} = \frac{4.35}{20 * 1.1} \approx 200mm$

let $d_{eff} = 200mm$

& $d_{total} = 230mm$

Loads : ① Dead Load = $25 * 0.23 = 5.75 kN/m$

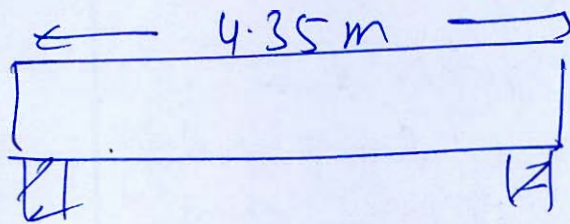
② Live load = $3 kN/m^2$

③ flooring load = $0.75 \frac{kN}{m}$

for one m in long dir.

$$\text{Total load} = 9.5 \frac{\text{kN}}{\text{m}}$$

$$\text{Factored load} = 14.25$$



$$\rightarrow \text{BM}_{u, \max} = \frac{14.25 \times 4.35^2}{8}$$

$$= 33.7057 \text{ kN-m}$$

* We design for URS

$$A_{ST} = 0.5 \times \frac{25}{415} \left(1 - \sqrt{1 - \frac{4.6 \times 33.7057 \times 10^6}{25 \times 10000 \times 200^2}} \right)$$

$$\times 1000 \times 200$$

$$= 486.66 \text{ mm}^2 \Rightarrow \text{Main bars (Take 10mm bars)}$$

$$A_{ST, \min} = \frac{0.12 \times 1000 \times 230}{100}$$

$$= 276 \text{ mm}^2 \Rightarrow \text{distribution bars}$$

Spacing \Rightarrow

$$\Rightarrow \text{Main Bars} = \frac{10000 \times \pi \times 10^2}{486.66 \times 4} = 160 \text{ mm spacing}$$

(10mm ϕ bar)

$$A_{ST \text{ provided}} = 49087.$$

\Rightarrow Distribution

$$\text{Bars} = \frac{10000 \times \pi \times 8^2}{276 \times 4} = 180 \text{ mm spacing}$$

(8mm ϕ bar)

17

\Rightarrow Check for shear

$$= \frac{W L \times d}{2} = \frac{14.25 \times 4}{2} = 28.5 \text{ kN}$$

$$\text{* Shear stress } \tau = \tau_v = \frac{28.5 \times 10^3}{1000 \times 200} = 0.1425 < \tau_{v, \min} = 0.29$$

\rightarrow SO OK in shear

⇒ Deflection check:

$$d_{eff} = \frac{LH}{20 * MF_t}$$

$$MF_t \Rightarrow f^n = 0.58 f_y \frac{A_{ST \text{ provd req}}}{A_{ST \text{ provd}}}$$

$$= 0.58 * 415 * \frac{486.66}{490.87}$$

$$= \boxed{238.63}$$

$$\% Pt = \frac{490.87}{1000 * 217} * 100 = \boxed{22.174}$$

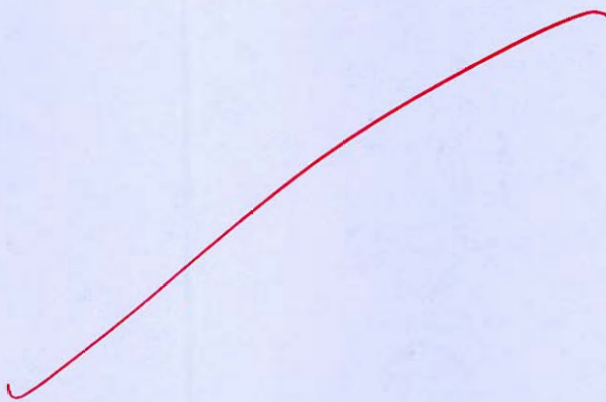
$$= \underline{0.245}$$

$$* K_t = \boxed{1.6}$$

→ so safe in deflection

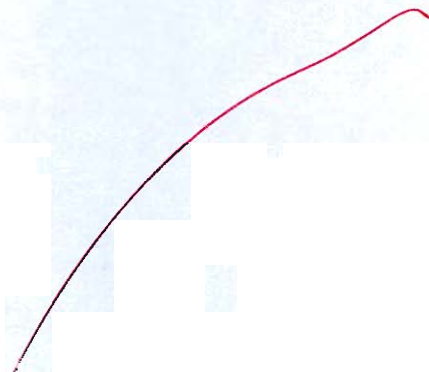
$$\rightarrow d_{eff} = \frac{4.35}{1.6 * 20} = 135.93 < d_{prov} \quad \checkmark \underline{OK}$$

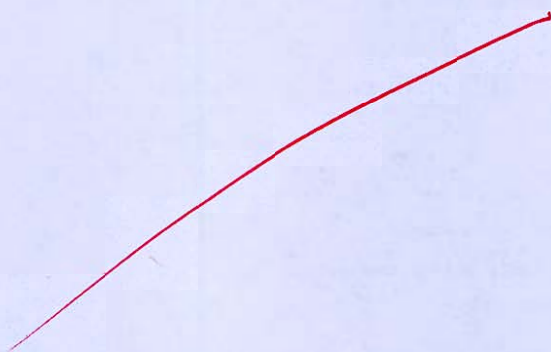
Show Diagram also



- Q.8(a) A Vertical cylindrical tank of 2 m diameter initially contains water up to a height of 1 m. Water enters the tank at a constant rate of $0.15 \text{ m}^3/\text{s}$ through an inlet pipe, while it simultaneously discharges through a sharp-edged orifice of 150 mm diameter provided at the base. The coefficient of discharge of the orifice is 0.62. Determine the time required for the water level to rise from 1 m to 3 m.

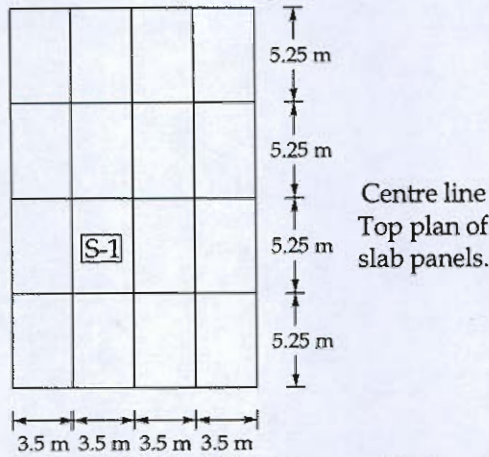
[20 marks]





Q.8 (b)

A solid interior RCC slab panel S-1 with effective spans $L_x = 3.5$ m and $L_y = 5.25$ m forms part of a floor system as shown in the figure below.



The slab carries a total design load of 25 kN/m². Using the Limit State Method as per IS 456: 2000, determine the spacing of all main reinforcements using 10 mm diameter HYSD bars throughout. The effective depth of slab may be assumed as 150 mm. Concrete grade is M25 and steel grade is Fe 415. Check spacing limits and specify the vertical placement of reinforcement. Shear check is not required.

IS 456 : 2000

Table 26 Bending Moment Coefficients for Rectangular Panels Supported on Four Sides with Provision for Torsion at Corners
(Clauses D-1.1 and 24.4.1)

Case No.	Type of Panel and Moments Considered	Short Span Coefficients α_x (Values of l_y/l_x)								Long Span Coefficients α_y for All Values of l_y/l_x
		1.0	1.1	1.2	1.3	1.4	1.5	1.75	2.0	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	<i>Interior Panels:</i>									
	Negative moment at continuous edge	0.032	0.037	0.043	0.047	0.051	0.053	0.060	0.065	0.072
	Positive moment at mid-span	0.024	0.028	0.032	0.036	0.039	0.041	0.045	0.049	0.024
2	<i>One Short Edge Continuous:</i>									
	Negative moment at continuous edge	0.037	0.043	0.048	0.051	0.055	0.057	0.064	0.068	0.037
	Positive moment at mid-span	0.028	0.032	0.036	0.039	0.041	0.044	0.048	0.052	0.028
3	<i>One Long Edge Discontinuous:</i>									
	Negative moment at continuous edge	0.037	0.044	0.052	0.057	0.063	0.067	0.077	0.085	0.037
	Positive moment at mid-span	0.028	0.033	0.039	0.044	0.047	0.051	0.059	0.065	0.028
4	<i>Two Adjacent Edges Discontinuous:</i>									
	Negative moment at continuous edge	0.047	0.053	0.060	0.065	0.071	0.075	0.084	0.091	0.047
	Positive moment at mid-span	0.035	0.040	0.045	0.049	0.051	0.056	0.063	0.069	0.035
5	<i>Two Short Edges Discontinuous:</i>									
	Negative moment at continuous edge	0.045	0.049	0.052	0.056	0.059	0.060	0.065	0.069	—
	Positive moment at mid-span	0.035	0.037	0.040	0.043	0.046	0.049	0.052	0.052	0.035
6	<i>Two Long Edges Discontinuous:</i>									
	Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.045
	Positive moment at mid-span	0.035	0.043	0.051	0.057	0.063	0.068	0.080	0.088	0.035
7	<i>Three Edges Discontinuous (One Long Edge Continuous):</i>									
	Negative moment at continuous edge	0.057	0.064	0.071	0.076	0.080	0.084	0.091	0.097	—
	Positive moment at mid-span	0.043	0.048	0.054	0.057	0.060	0.064	0.069	0.073	0.043
8	<i>Three Edges Discontinuous (One Short Edge Continuous):</i>									
	Negative moment at continuous edge	—	—	—	—	—	—	—	—	0.057
	Positive moment at mid-span	0.043	0.051	0.059	0.065	0.071	0.076	0.087	0.096	0.043
9	<i>Four Edges Discontinuous:</i>									
	Positive moment at mid-span	0.056	0.064	0.072	0.079	0.085	0.089	0.100	0.107	0.056

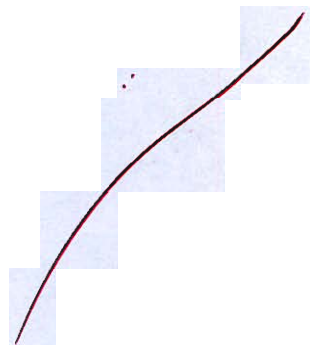
TABLE 3 FLEXURE — REINFORCEMENT PERCENTAGE, p_t FOR SINGLY REINFORCED SECTIONS

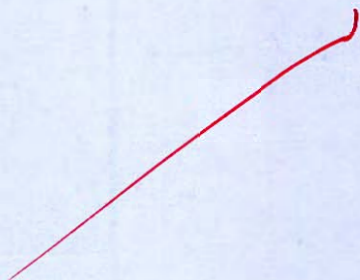
$f_{ck} = 25 \text{ N/mm}^2$

M_u/bd^2 , N/mm^2	f_y , N/mm^2					M_u/bd^2 , N/mm^2	f_y , N/mm^2				
	240	250	415	480	500		240	250	415	480	500
0.30	0.146	0.140	0.084	0.073	0.070	2.55	1.415	1.358	0.818	0.708	0.679
0.35	0.171	0.164	0.099	0.085	0.082	2.60	1.448	1.390	0.837	0.724	0.695
0.40	0.195	0.188	0.113	0.098	0.094	2.65	1.482	1.422	0.857	0.741	0.711
0.45	0.220	0.211	0.127	0.110	0.106	2.70	1.515	1.455	0.876	0.758	0.727
0.50	0.245	0.236	0.142	0.123	0.118	2.75	1.549	1.487	0.896	0.775	0.744
0.55	0.271	0.260	0.156	0.135	0.130	2.80	1.584	1.520	0.916	0.792	0.760
0.60	0.296	0.284	0.171	0.148	0.142	2.85	1.618	1.554	0.936	0.809	0.777
0.65	0.321	0.309	0.186	0.161	0.154	2.90	1.653	1.587	0.956	0.827	0.794
0.70	0.347	0.333	0.201	0.174	0.167	2.95	1.689	1.621	0.977	0.844	0.811
0.75	0.373	0.358	0.216	0.186	0.179	3.00	1.724	1.655	0.997	0.862	0.828
0.80	0.399	0.383	0.231	0.199	0.191	3.05	1.760	1.690	1.018	0.880	0.845
0.85	0.425	0.408	0.246	0.212	0.204	3.10	1.797	1.725	1.039	0.898	0.863
0.90	0.451	0.433	0.261	0.225	0.216	3.15	1.834	1.760	1.061	0.917	0.880
0.95	0.477	0.458	0.276	0.239	0.229	3.20	1.871	1.796	1.082	0.936	0.898
1.00	0.504	0.483	0.291	0.252	0.242	3.25	1.909	1.832	1.104	0.954	0.916
1.05	0.530	0.509	0.307	0.265	0.255	3.30	1.947	1.869	1.126	0.973	0.935
1.10	0.557	0.535	0.322	0.279	0.267	3.32	1.962	1.884	1.135	0.981	0.942
1.15	0.584	0.561	0.338	0.292	0.280	3.34	1.978	1.899	1.144	0.989	
1.20	0.611	0.587	0.353	0.306	0.293	3.36	1.993	1.914	1.153		
1.25	0.638	0.613	0.369	0.319	0.306	3.38	2.009	1.929	1.162		
1.30	0.666	0.639	0.385	0.333	0.320	3.40	2.025	1.944	1.171		
1.35	0.693	0.666	0.401	0.347	0.333	3.42	2.040	1.959	1.180		
1.40	0.721	0.692	0.417	0.360	0.346	3.44	2.056	1.974	1.189		
1.45	0.749	0.719	0.433	0.374	0.359	3.46	2.072	1.989			
1.50	0.777	0.746	0.449	0.388	0.373	3.48	2.088	2.005			
1.55	0.805	0.773	0.466	0.403	0.387	3.50	2.104	2.020			
1.60	0.834	0.800	0.482	0.417	0.400	3.52	2.120	2.036			
1.65	0.862	0.828	0.499	0.431	0.414	3.54	2.137	2.051			
1.70	0.891	0.856	0.515	0.446	0.428	3.56	2.153	2.067			
1.75	0.920	0.883	0.532	0.460	0.442	3.58	2.170	2.083			
1.80	0.949	0.911	0.549	0.475	0.456	3.60	2.186	2.099			
1.85	0.979	0.940	0.566	0.489	0.470	3.62	2.203	2.115			
1.90	1.009	0.968	0.583	0.504	0.484	3.64	2.219	2.131			
1.95	1.038	0.997	0.601	0.519	0.498	3.66	2.236	2.147			
2.00	1.068	1.026	0.618	0.534	0.513	3.68	2.253	2.163			
2.05	1.099	1.055	0.635	0.549	0.527	3.70	2.270	2.179			
2.10	1.129	1.084	0.653	0.565	0.542	3.72	2.287	2.196			
2.15	1.160	1.114	0.671	0.580	0.557	3.74	2.304				
2.20	1.191	1.143	0.689	0.596	0.572						
2.25	1.222	1.173	0.707	0.611	0.587						
2.30	1.254	1.204	0.725	0.627	0.602						
2.35	1.285	1.234	0.743	0.643	0.617						
2.40	1.317	1.265	0.762	0.659	0.632						
2.45	1.350	1.296	0.781	0.675	0.648						
2.50	1.382	1.327	0.799	0.691	0.663						

NOTE — Blanks indicate inadmissible reinforcement percentage (see Table E).

[20 marks]



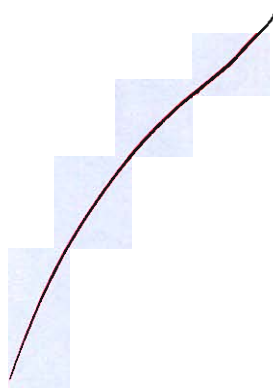


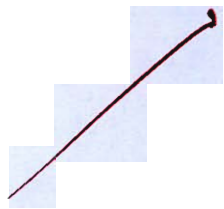


- Q.8(c) Air flows over a flat plate of 6 m length and 1.5 m width at a free-stream velocity of 6 m/s. The density of air is 1.205 kg/m^3 and the dynamic viscosity is $1.81 \times 10^{-5} \text{ Pa}\cdot\text{s}$. Assume The flow undergoes transition to turbulent flow at a critical Reynolds number of 5×10^5 . Determine the total drag force acting on one side of the plate. Assume the flow occurs along the length of the plate.

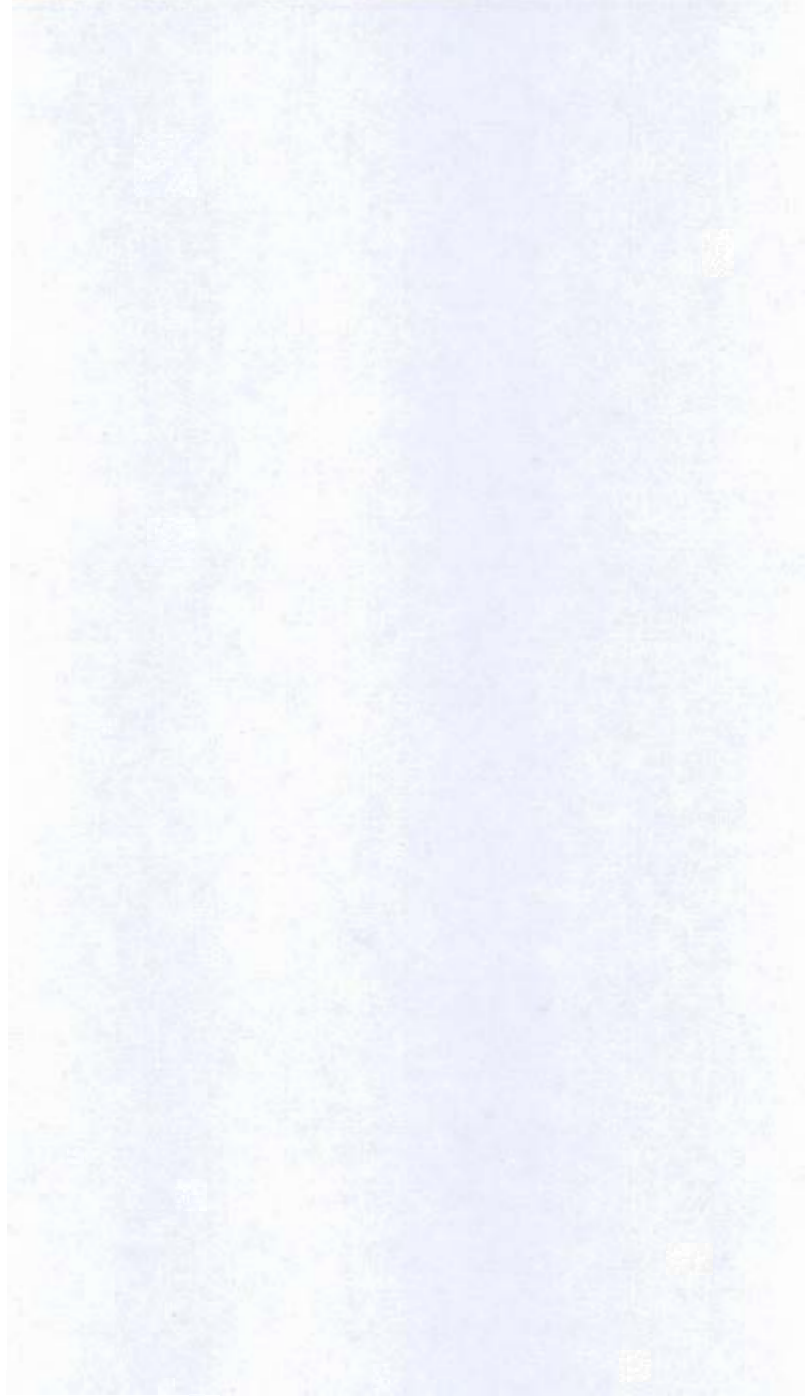
$$\text{Take, coefficient of drag, } C_D = \begin{cases} \frac{1.328}{(R_e)^{0.5}} & \text{(For laminar flow)} \\ \frac{0.074}{(R_e)^{0.2}} & \text{(For turbulent flow)} \end{cases}$$

[20 marks]





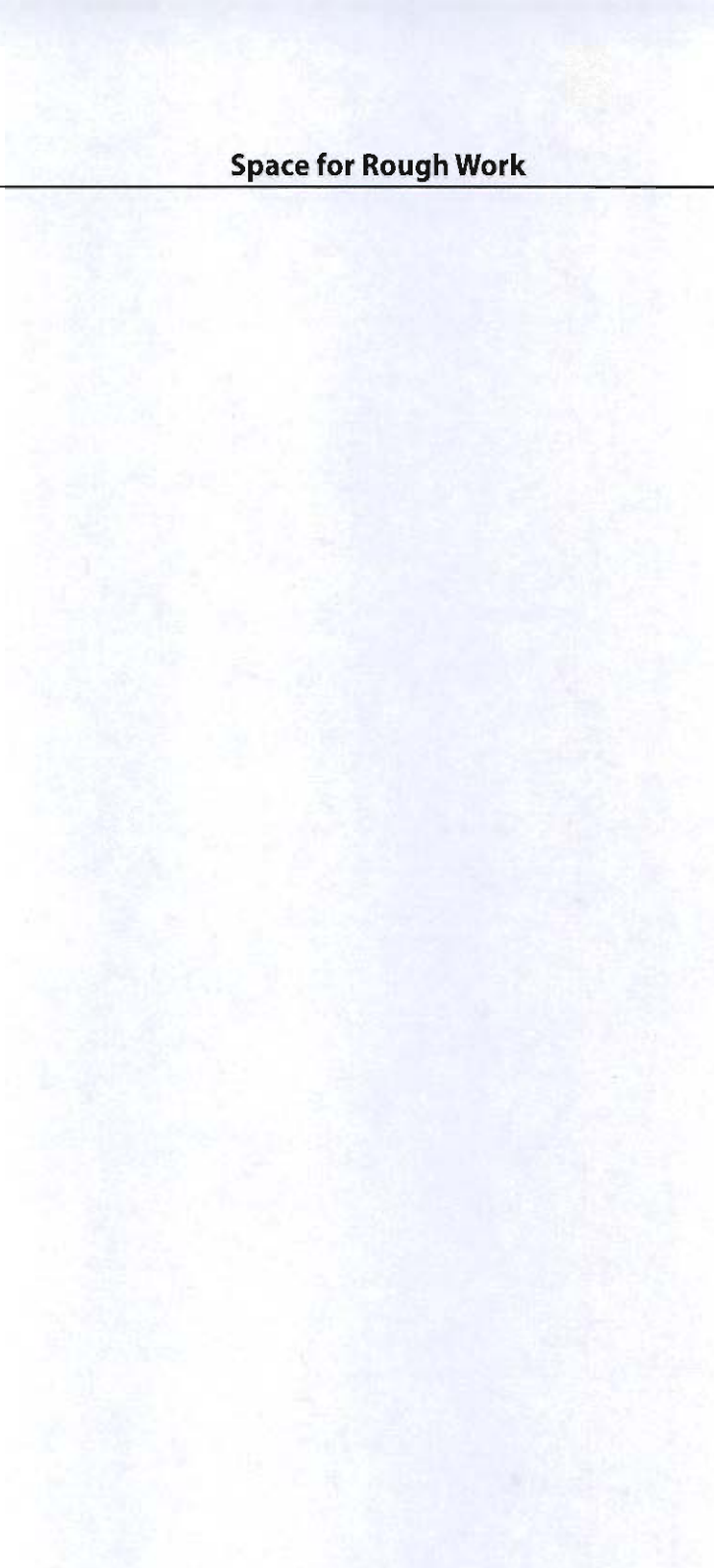
Space for Rough Work



Space for Rough Work



Space for Rough Work



Space for Rough Work

Space for Rough Work
