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ESE 2020 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Civil Engineering

Test 10

Full Syllabus (Paper-I)

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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. Answer must be written in English only.
3. Use only black/blue pen.
4. 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.
5. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
6. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	

Signature of Evaluator   Cross Checked by

Section-A

Q.1 (a) Write a short note on artificial stones and also mention advantages of artificial stones. [12 marks]

Artificial stones are the building stones on external / internal walls. They are provided with light weight aggregates in order to have little weight compared to natural stones.

The lower weight and cost and variety are advantages which increased their popularity.

They are placed on vertical walls using special glues. Due to their light weight, they adhere very good to the walls.

The front of the artificial stones is generally smooth while the back of the stones is uneven to provide best bond with the walls.

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Advantages of artificial stones

(i) Are light weight and thus easy to handle.

(ii) They can be manufactured in small thicknesses. (2-4 cm thick)

(iii) Transportation cost is highly reduced.

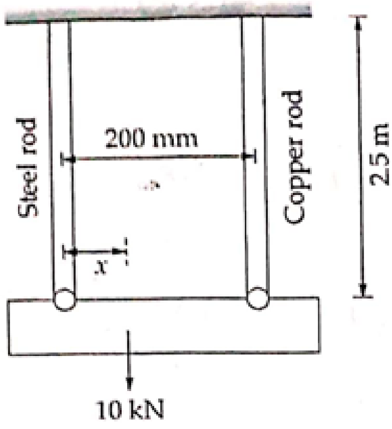
(iv) Can be manufactured in a variety of colors and designs as per the requirements.

(v) Quick installation → Makes them preferable over natural rocks.

Some examples of ~~natur~~ artificial stones are:

(i) Ransom stone
(ii) Victoria stone
(iii) Garlic stone
(iv) Imperial stone.
(v) Bituminous stone.

Q.1 (b) Two vertical rods one of steel and other of copper are rigidly fastened at their upper end at a horizontal distance of 200 mm as shown in figure. The lower ends support a rigid horizontal bar, which carries a load of 10 kN. Both the rods are 2.5 m long and have a cross-sectional area of 12.5 mm². Where should the load of 10 kN be placed on the bar, so that it remains horizontal after loading? Also find the stresses in each rod. Take $E_s = 200$ GPa and $E_c = 110$ GPa. Neglect bending of the cross-bar.



[12 marks]

For bar to be horizontal elongations in steel and copper rod have to be equal.

So, Let force in steel be F_1 and in copper rod be F_2.

So, using moment balance,

$$F_1 \times 200 = 10 \times (200 - x) \quad \text{--- (i)}$$

and, $\delta_1 = \delta_2$

$$\frac{F_1 \times 2500}{12.5 \times 2 \times 10^5} = \frac{F_2 \times 2500}{12.5 \times 110 \times 10^3} \quad \text{--- (ii)}$$

and $F_1 + F_2 = 10000$ --- (iii)

Thus, solving (ii) and (iii)

$F_1 = 1.81 F_2$

$F_1 = 6.44$ kN

$F_2 = 3.56$ kN

Using (i), we have,

$6.44 \times 200 = 10(200 - x)$

$x = 71.2 mm$

Thus, load should be placed @ 71.2 mm from steel rod.

Stress in steel rod $= \frac{6440}{12.5} = 515.2 MPa$

Stress in copper rod $= \frac{3560}{12.5} = 284.8 MPa$

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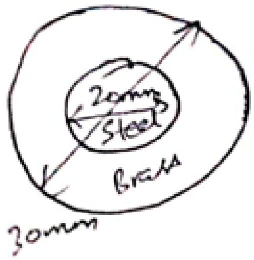
Q.1 (c) A vertical tie fixed rigidly at the top, consists of a steel rod 2.5 m long and 20 mm diameter encased throughout in a brass tube 20 mm internal diameter and 30 mm external diameter. The rod and casing are fixed together at both ends. The compound rod is suddenly loaded in tension by a weight of 10 kN falling through 3 mm before being arrested by the tie. Calculate the maximum stress in steel and brass. Take E_S = 200 GPa and E_B = 100 GPa.

[12 marks]



Length = 2.5m

Weight = 10kN

falling through 3mm.

$E_S = 200\times10^3$ MPa, $E_B = 10^5$ MPa.

Elongations have to be equal for both

Let stress in steel be σ_{st} and in brass be σ_b.

$$\frac{\sigma_{st}}{E_{st}} = \frac{\sigma_b}{E_b} \Rightarrow \boxed{\sigma_{st} = 2\sigma_b}$$

$$\therefore \frac{P_{st}}{\frac{\pi}{4}\times 20^2} = \frac{2P_b}{\frac{\pi}{4}(30^2-20^2)} \Rightarrow \boxed{P_{st} = 1.6P_b} \text{ --- (i)}$$

$$\delta_{static} = \frac{P_{st}\times 2500}{314\times 2\times10^5} = 3.98\times10^{-5} P_{st}$$

$$\text{or } \frac{P_b\times 2500}{392.7\times10^5} = 6.36\times10^{-5} P_b$$

~~Impact factor~~ = $P_{st} + P_b = 10000$ N --- (ii)

Thus, P_{st} = 6.15 kN, P_b = 3.85 kN.

δ_{static} = 0.244 mm

$$\text{Impact factor} = 1 + \sqrt{1 + \frac{2\times3}{0.244}} = 6.05$$

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Thus, max. stress in steel rod

$$= \frac{6.05 \times 6.15 \times 10^3}{314} = \boxed{118.495 \text{ MPa}}$$

Max stress in brass rod

$$\frac{6.05 \times 3.85 \times 10^3}{\frac{\pi}{4}(500)} = \boxed{59.31 \text{ MPa}}$$

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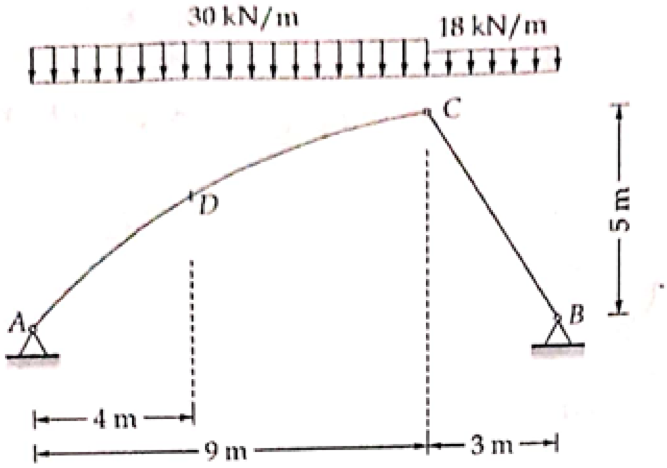
Q.1 (d) In the three-pinned arch ACB as shown in figure, the portion AC has the shape of a parabola with its origin at C, while CB is a straight line. The portion AC carries a uniformly distributed load of intensity 30 kN/m, while the portion CB carries a uniformly distributed load of intensity 18 kN/m. Calculate the normal force, shear force and bending moment at the point D.



[12 marks]

for portion AC

$y = \frac{4hx}{l^2}(l-x)$ $h = 5m$

$y = \frac{4\times5}{(9\times2)^2}(18-x) \times x = 0.0617x(18-x)$

~~$y = 0.55(18-x)$~~

Thus @ $x = 4m$, $y = 3.455m$

Now, $\Sigma F_V = 0$

$R_A + R_B = 30\times9 + 18\times3$

and $R_A \times 12 - 30\times9\times7.5 - \frac{18\times3^2}{2} = 0$

$R_A = 175.5$ kN

$R_B = 148.5$ kN

$\Sigma M_C = 0$

Now, $R_A\times9 - H\times5 - \frac{30\times9^2}{2} = 0$

$H = 72.9$ kN

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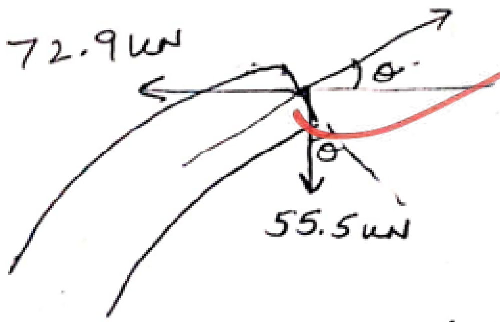
@ D

Shear force = 175.5 − 30×4 = 55.5 kN (↓)

Bending moment = 175.5×4 − 72.9×3.455 − $\frac{30\times4^2}{2}$

= 210.1305 kNm



$\frac{dy}{dx}$ = 0.617 @ x = 4m = tanθ

cosθ = 0.85, sinθ = 0.525

Normal force = 55.5 × 0.525 + 72.9 × 0.85

= 91.1025 kN

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Q.1 (e) What is meant by the term "refractories"? Mention the desired properties of refractories and also explain their classification.

[12 marks]

Refractories are defined as the substances which can resist a good amount of heat and temperature without getting deterior- ated or spalled.

Refractories generally contain a good amount of alumina.

Refractories are classified as

On basis of Chemical Composition

(i) Acid refractories → used in the lining of walls and ceilings exposed to acidic attack
E.g.; Silicon Carbide, Zircon cristobalite

(ii) Basic Refractories – Used against basic slag
E.g., Dolomite, Magnesite

(iii) Neutral Refractories – Exposed to both the type of slags. Used in copper reverberatory furnace.
Chromite, Forsterite etc.

On basis of thermal conductivity

(i) Heat Resistant Temp ≤ 1100°C

(ii) Refractory Temp ≤ 1400°C

(iii) High refractory Temp ≤ 1700°C

(iv) Ultra high refractory Temp ≤ 2000°C

On basis of fusion temperature

(i) Normal refractories - fusion temperature of around 1600°C.

(ii) High refractories - Fusion temperature of around 2000°C.

(iii) Super refractories - fusion temperature of > 2000°C.

Properties of good refractories are

(i) These must resist the stresses developed @ high temperature

(ii) Must preserve their rigidity at high temperature

(iii) Must not fuse with slage

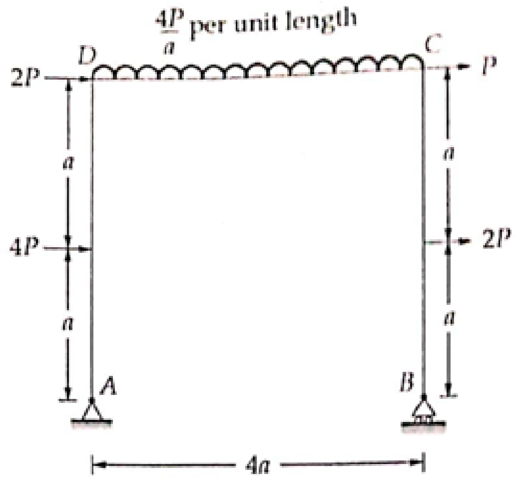
(iv) Must not react with furnace gases

(v) Must resist the tendency to crack and split off fragments

(vi) Must not absorb water more than 6% by weight

(vii) Irreversible volume change should not occur as it may lead to opening of joints.

Q.3 (a) Draw shear force and bending moment diagrams for the frame shown in figure below.



$\rightarrow \Delta$

[20 marks]

Fixed end moments

$M_{FAD} = -\frac{4P \times 2a}{8} = -Pa$

$M_{FDA} = Pa$, $M_{FDC} = -\frac{4P}{a} \times \frac{(4a)^2}{12} = -5.33Pa$

$M_{FCD} = 5.33Pa$

$M_{FCB} = \frac{2P \times 2a}{8} = \frac{Pa}{2}$, $M_{FBC} = -\frac{Pa}{2}$

~~$M_{AD} = -Pa$~~

$M_{DA} = Pa + \frac{Pa}{2} + \frac{3EI}{2a}\left(\theta_D - \frac{\Delta}{2a}\right)$ [Using modified slope deflection]

$M_{DA} = \frac{3Pa}{2} + \frac{3EI\theta_D}{2a} - \frac{3EI\Delta}{4a^2}$

$M_{DC} = -5.33Pa + \frac{2EI}{4a}(2\theta_D + \theta_C)$

$M_{CD} = 5.33Pa + \frac{2EI}{4a}(2\theta_C + \theta_D)$

$M_{CB} = \frac{3Pa}{4} + \frac{3EI}{2a}\left(\theta_C - \frac{\Delta}{2a}\right)$

Now eqn joint equilibrium

$M_{DA} + M_{DC} = 0 \qquad M_{CD} + M_{CB} = 0$

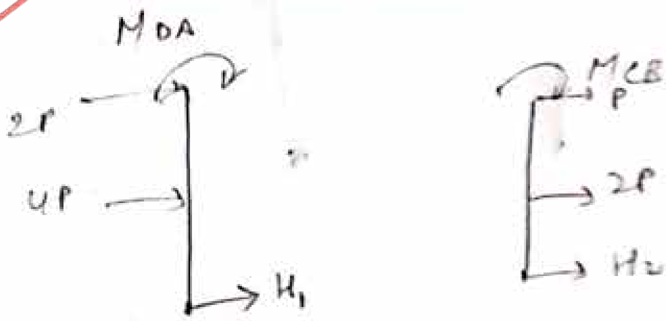
$5.33Pa + \frac{EI\theta_C}{a} + \frac{EI\theta_D}{2a} + \frac{3Pa}{4} + \frac{3EI\theta_C}{2a} - \frac{3EI\Delta}{4a^2} = 0$

$$\boxed{\frac{5EI\theta_C}{2a} + \frac{EI\theta_D}{2a} - \frac{3EI\Delta}{4a^2} = -6.08Pa} \quad (i)$$

$\frac{3Pa}{2} - 5.33Pa + 1.5EI\theta_D - \frac{3EI\Delta}{4a^2} + EI\theta_D + \frac{EI\theta_C}{2a} = 0$

$$\boxed{\frac{EI\theta_C}{2a} + 2.5EI\theta_D - \frac{3EI\Delta}{4a^2} = 3.83Pa} \quad (ii)$$

Shear equation



$H_1 \times 2a + 4Pa = M_{DA}$

$H_1 = \frac{M_{DA} - 4Pa}{2a}$

$H_2 \times 2a + 2Pa = M_{CB}$

$H_2 = \frac{M_{CB} - 2Pa}{2a}$

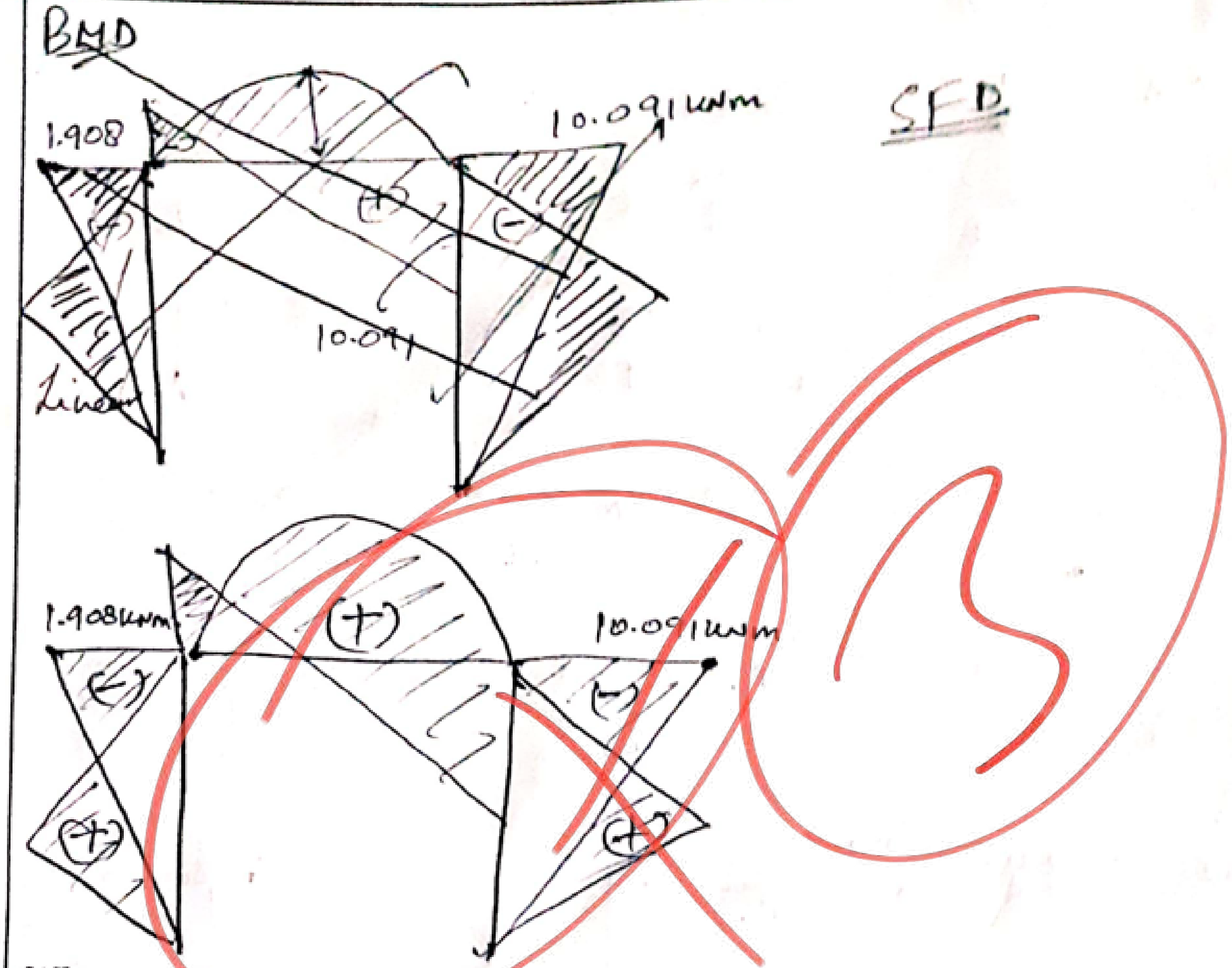
$H_1 + H_2 + 9P = 0$

$$\boxed{H_1 + H_2 = -9P}$$

$1.5Pa + \frac{1.5EI\theta_D}{a} - \frac{3}{4}\frac{EI\Delta}{a^2} - 4Pa + 0.75Pa + \frac{1.5EI\theta_C}{a} - \frac{3EI\Delta}{4a^2} - 2Pa = -18Pa$

$$\boxed{\frac{1.5EI\theta_C}{a} + \frac{1.5EI\theta_D}{a} - \frac{3EI\Delta}{2a^2} = -14.25Pa}$$

$\theta_C = \frac{1.5275}{EI}, \quad \theta_D = \frac{6.4775}{EI}, \quad \Delta = \frac{17.8}{EI}$



Q.3 (b) What are the objects of preservation of timber? State the requirements of a good preservative. Also describe the preservatives which are commonly used in the process of preservation of timber?

[20 marks]

Objectives of preservation of timber

(i) To prevent it from the attack of termites, fungi, marine borers etc.

(ii) To prevent the attack of extensive heat of sun

(iii) To reduce the amount of freeze and thaw cycle.

(iv) To make it durable and strong

(v) To make it look good in aesthetics.

Requirements of a good preservative

(i) It should be durable and non-toxic to humans
(ii) It should spread easily
(iii) It should not be flammable
(iv) Must be toxic to fungi, white ants etc
(v) Must be cheap and economical
(vi) Must penetrate deeply inside the timber core.
(vii) Must not leach out when in contact with water
(viii) Must not give out any unpleasant odour when applied
(ix) Must not get evaporated easily / must not be volatile.
(x) Should not be very gross to work with - handling should be easy and clean.

Commonly used preservatives are

Coal tar Liquide (Creosote Oil) is used for the coating of the timber. It is a fraction of coal tar distillate with a BP above 200°C.

Petroleum oil by 50% wt. in mixture and ensure protection against evaporation and leaching.

Advantages of Creosote - Non-toxic, make service life longer, imparts non-corrosiveness.

Organic solvent preservatives - May be used alone or in combination.

Advantage - Clean to handle, permanent, can be polished or waxed.

Disadvantage - Some organic solvents are inflammable, therefore should be applied in cold.

Water soluble preservatives

(i) Leachable type - Their concentration gets reduced with passage of time as they get leached out. Generally, these are odourless, less chances of fire hazard, can be waxed.

(ii) Non-leachable type - Consists of a base generally $K_2Cr_2O_7$ so it becomes difficult to leach them.

AsCu Treatment

1:3:4 by parts of ~~$CuSO_4 \cdot 5H_2O$~~ $As_2O_5 \cdot 2H_2O$, $CuSO_4 \cdot 5H_2O$ and $K_2Cr_2O_7$ when mixed in the ratio of 6 parts in 100 parts of water gives a good preservation against white ants.

— Solution is odourless

— Can be sprayed on timber.

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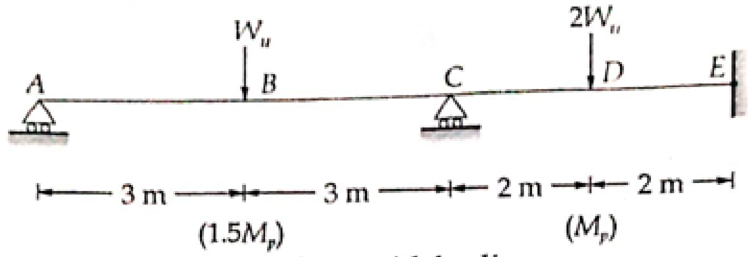
Section-B

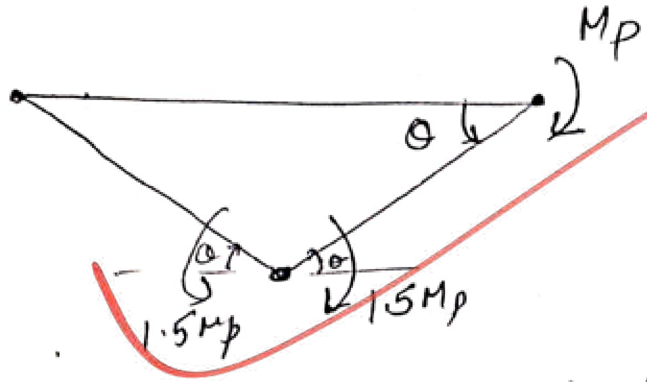
Q.5 (a) Determine collapse load W_u for continuous beam *ABCDE* loaded and supported as shown in figure. For span *AC* plastic moment of resistance is 50% more than that of *CE*.



Beam with loading

[12 marks]

<u>For span AC</u>



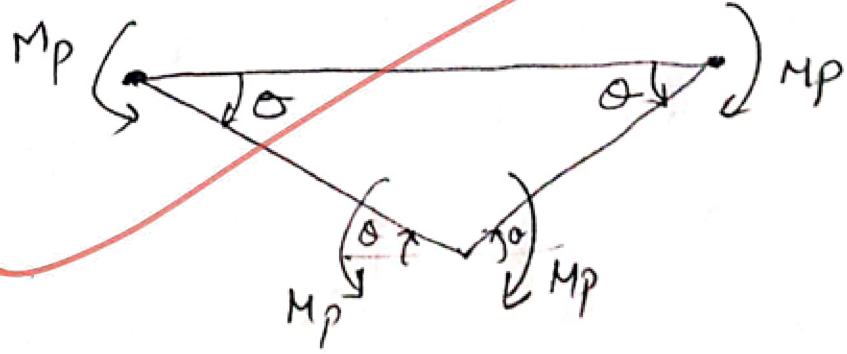
Using principle of virtual work,

$$W_u \times 3\theta = 1.5M_p\theta + 1.5M_p\theta + M_p\theta$$

$$3W_u\theta = 4M_p\theta$$

$$\boxed{W_u = \frac{4M_p}{3}}$$

<u>For span CE</u>



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Using principle of virtual work,

$$M_p\theta + M_p(2\theta) + M_p\theta = 2W_u \times 2\theta$$

$$4M_p\theta = 4W_u\theta$$

$$\boxed{W_u = M_p}$$

Thus collapse load for the continuous beam ABCDE is $\boxed{M_p}$

12

Q.5 (b) (i) What are the assumptions in earthquake resistant designing of structures?
(ii) State any four applications of prestressed concrete.
[6 + 6 = 12 marks]

Assumptions in Earthquake resistant designing

(i) The plastic strength of the structures is not taken into account

(ii) Only 1 degree of freedom is taken

(iii) Underdamped vibrations are used in calculations.

(iv) Lateral stiffness is assumed to be constant though it reduces with the damage.

(3)

Applications of Prestressed Concrete

(i) Prestressed concrete is used in the manufacture of railway sleepers through Hoyer System.
Generally a concrete grade of M55 to M60 is used as it gives better elasticity and strength to railway sleepers

(ii) They are also used in water pipelines which carry water free from sulphates as they are susceptible to sulphate attack.

(6)

They can withstand compressive pressure from the backfill and also negative collapsive pressure, thus an advantage over steel pipes.

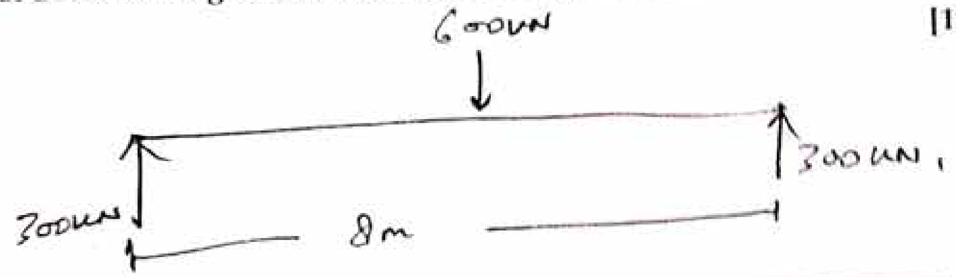
(iii) Used in manufacture of long span bridges as the dead load is much lesser and strength is more, thus proves to be economical.

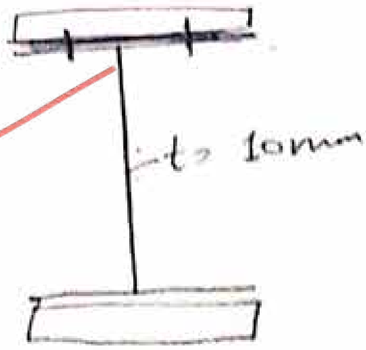
(iv) Used for manufacturing slabs in halls and big structures owing to its large strength and reduced cross-sectional size, thus providing good spacious room.

Q.5 (c) A simply supported beam of span 8 m is subjected to a concentrated load $W = 600$ kN at its mid-span. The beam section consists of ISMB 400 together with steel plates of size 200 mm × 10 mm provided with each flange of the beam. For ISMB 400, $I_{xx} = 20458$ cm^4, thickness of web = 10 mm, width of flange = 200 mm.

Calculate from first principle, the design shear force in the rivets provided for each flange at a pitch of 200 mm. Neglect the effect of self-weight of beam.

[12 marks]





Moment of inertia of combined assembly

$$= 20458\times10^4 + \frac{2\times200\times10^3}{12}$$

$$+ 2\times 200\times10\times(200+5)^2$$

$$= \boxed{372.71\times10^6\ mm^4}$$

Shear flow (q) = $\frac{VA\bar{y}}{I}$ $V = \frac{600}{2} = 300$ kN.

$$q = \frac{300\times10^3 [200\times10]\times 205}{372.71\times10^6} = 330.01 \text{ N/mm}$$

Thus, for a pitch of 200 mm, assuming 2 rivets in each pitch length,

force on 2 rivets = $330.01 \times 200 = 66$ kN

Thus design force on each rivet

$= \frac{66}{2} = 33$ kN.

(9)

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Q.5 (d) The ring beam of a water tank has a diameter of 12.5 m and it is subjected to an outward radial force of 25 kN/m. Design the section of ring beam using M25 and Fe415. Assume m = 11 and allowable stress in concrete in tension as 1.2 N/mm². (σ_s = 150 N/mm²).

[12 marks]

Outward radial force to which ring beam is subjected = 25000 N/m

Permissible tensile stress = 150 MPa

Area of steel reqd. = $\frac{25000}{150} = 166.67 \text{ mm}^2$

Using 8 mm bars
number of rings reqd. = $\frac{166.67}{\frac{\pi}{4}\times 8^2} = 3.32 \simeq 4$

Thus, providing 4 rings of 8 mm ϕ bars

Actual area of steel provided = $4\times 50 = 200 \text{ mm}^2$

Equivalent area of c/s

$= A + (m-1)\times 200$

$= A + (11-1)\times 200 = (A + 2000) \text{ mm}^2$

Allowable tensile stress in concrete
= 1.2 MPa

$\frac{25000}{A + 2000} = 1.2$

$A = 18833.33 \text{ mm}^2$

Thus provide ring of size 170 mm × 120 mm

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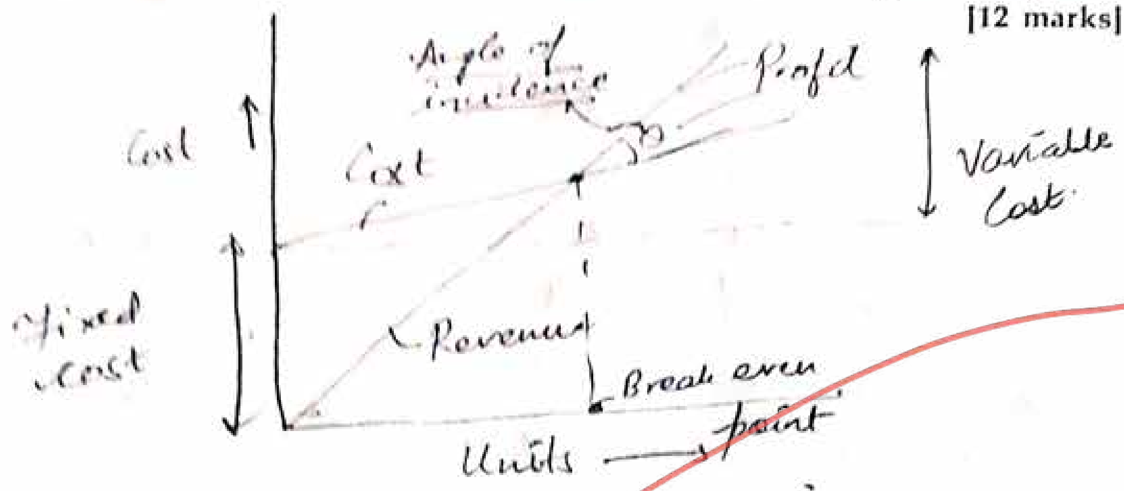
Q.5(e) Explain the functions and limitations of Break even analysis along with diagram. [12 marks]



Functions of break even analysis

(i) Used to determine the no. of units to be sold to start generating revenue

(ii) Used to determine the profit / loss incurred using angle of incidence. More is the angle of incidence, more is the profit.

(iii) Fixed cost could be varied to check the profit generated

(iv) For a short term analysis, it is a good tool for business strategy making

(v) The sooner the break even is achieved the better is the model.

Limitations of Break-even analysis

(i) It is a short term model i.e. long term strategies could not be formed.

(ii) It is a static model, i.e, does not change with the dynamics of business.

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(iii) If the company manufactures many items then the break even chart could not be used.

(iv) Revenue generation line may not be a straight line.

(v) There might not be a continuous demand of units in the market

(vi) May sometimes give a false picture of the model, incurring a huge loss to the company.

Q.6 (a) A laterally supported simply supported beam of span 4 m is subjected to factored column load of 400 kN. Load is transferred through base plate of 200 mm length. Section available is ISMB 400. Properties of ISMB 400.

Depth, h = 400
Width of flange, b_f = 140 mm
Thickness of flange, t_f = 16 mm
Thickness of web, t_w = 8.9 mm
Radius at root, R_1 = 14 mm
Stiff bearing length, b = 150 mm
I_{xx} = 20458.4×10^4 mm⁴
Z_p = 1176.18×10^3 mm³

The design compressive stresses for slenderness ratio for curve 'C'

Slenderness ratio (kL/r)	70	80	90	100	110	120
Design compressive stres (f_{cd}) in N/mm²	152	136	121	107	94.6	83.7

Assume Fe410 grade steel.

Check the following limit states:

(i) Bending capacity
(ii) Shear capacity
(iii) Web buckling
(iv) Web crippling
(v) Deflection

[25 marks]

Given, Span = 4m

Factored column load = 400 kN

Factored Bending moment = $\frac{400 \times 4}{4} = 400$ kNm

(Assuming concentrated load)

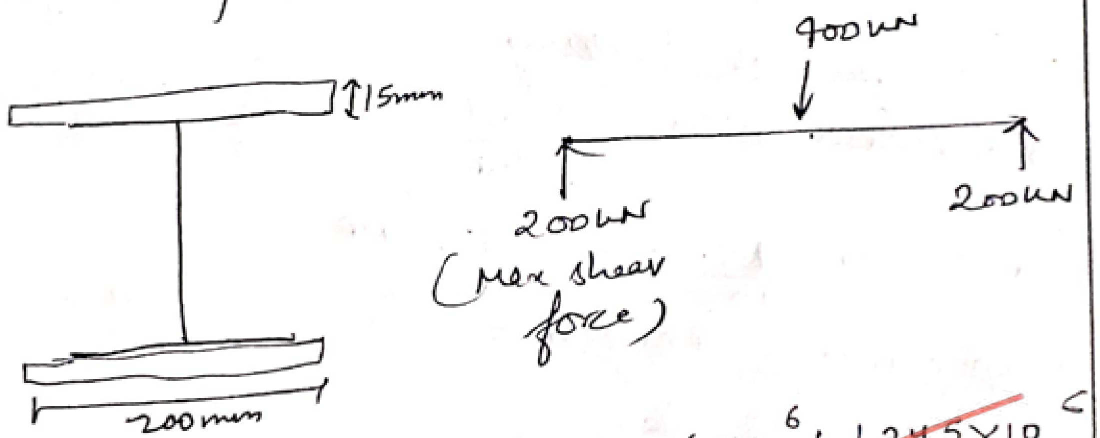
Z_p reqd = $\frac{400 \times 10^6 \times 1.1}{250} = 1.76 \times 10^6 \, mm^3$

But Z_p of beam = $1.176 \times 10^6 \, mm^3$

Hence, we need to provide plates.

∴ Extra $Z_p = 1.76 - 1.176 = 0.584 \times 10^6 \, mm^3$

Provide plates of size 200mm × 15mm



Thus, Z_p of assembly = $1.176 \times 10^6 + 1.245 \times 10^6$
$= 2.421 \times 10^6 \, mm^3$

Design shear capacity

$V_{ds} = \frac{250}{1.1\sqrt{3}} \times 400 \times 8.9 = 467.12$ kN

$0.6 V_d = 280.277 \ngtr 200$ kN, hence it's a low shear case.

Design moment capacity

$M_d = \frac{2.421 \times 10^6 \times 250}{1.1} = 550.22$ kNm > 400

hence safe in bending

Check for ~~web~~ section

$\frac{d_1}{t_w} = \frac{400 - 2\times14 - 2\times16}{8.9} = 38.2 < 84\varepsilon$

$\frac{b}{t_f} = \frac{70}{16} = 4.375 < 9.4\varepsilon$

hence section is plastic

$(\beta = 1)$

Check for web buckling

Slenderness ratio $= \frac{2.5 d_1}{t_w} = \frac{2.5 \times (340)}{8.9} = 95.5$

$f_{cd} = 121 - \frac{14}{10} \times 5.5 = 113.3$ MPa

Compressive strength = 113.3 × Area of resistance

Assuming 45° flow

B = 150 + 200 = 350 mm

∴ Strength = 113.3 × 350 × 8.9 = 352.929 kN > 200 kN

Safe in web buckling

Check for web crippling

b = 150 + 2.5 (16 + 14) = 225 mm

Thus, $\frac{200 \times 10^3}{225 \times 8.9} = 99.875 < \frac{250}{1.1}$

Hence safe in web crippling

Check for deflection

Working load = $400/1.5 = 266.67$ kN

$$\text{Deflection} = \frac{266.67\times10^3\times4000^3}{48\times2\times10^5\, I_{xx}}$$

$$I_{xx} = 20458.4\times10^4 + \frac{200\times15^3}{12}\times2 + [200\times15\times(207.5)^2\times2]$$

$$= 463.034\times10^6\ \text{mm}^4$$

$$\therefore\ \delta = \frac{266.67\times10^3\times4000^3}{48\times2\times10^5\times463.034\times10^6} = 3.839\text{mm}$$

Limiting deflection $= \frac{\text{Span}}{300} = 13.33$ mm

hence, beam is safe in deflection

20

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Q.6 (b) (i) What are the similarities and basic differences between PERT and CPM?

(ii) A product development project consists of the following activities, with their timing and precedents:

Activity	Activity designation	Immediate precedents	Time in Weeks
Design	A		21
Build prototype	B	A	5
Evaluate equipment	C	A	7
Test prototype	D	B	2
Write equipment report	E	C, D	5
Write method report	F	C, D	8
Write final report and release for manufacture	G	E, F	2

Represent the project as a network diagram in the CPM format.

Identify the critical path and project completion time. Calculate the earliest and latest starting and completion time of activity 'E'.

[5 + 10 = 15 marks]

Similarities

i) Both are used to determine the time of completion of project

~~(ii) Both PERT as a whol~~

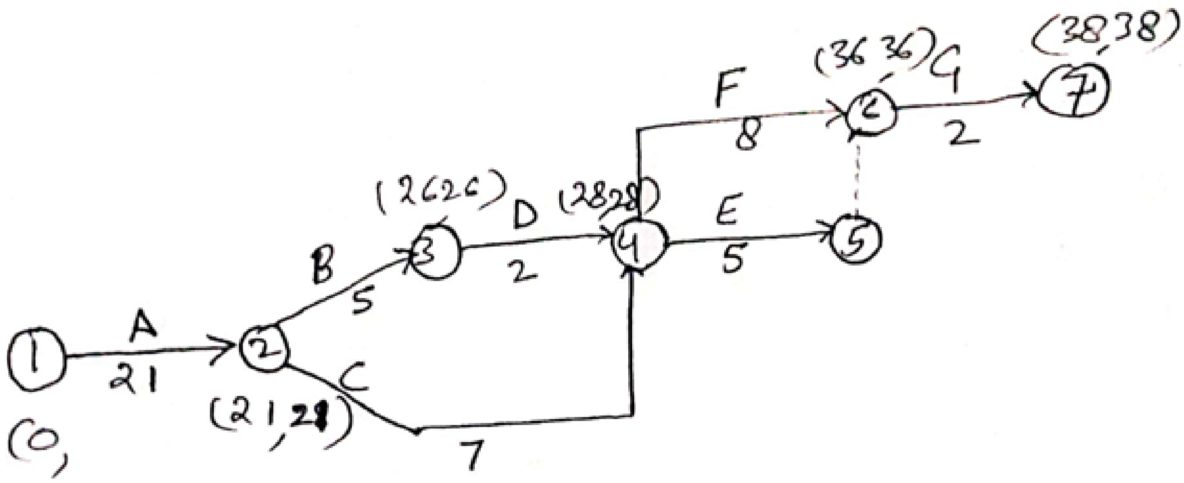
(ii) PERT has slack associated with event while CPM has float associated with activity. Both are analogous to each other.

(iii) Both use forward pass and backward pass.

Differences

PERT	CPM
(i) Event oriented	(i) Activity oriented
(ii) 3 time estimates	(ii) Single time estimate
(iii) Probabilistic approach	(iii) Deterministic approach
(iv) Used for R&D projects	(iv) Used for projects done earlier
(v) Slack is used	(v) Float is used.

2



Critical path is A-B-D-F-G

A-C-F-G

For activity E

Earliest start time EST = 28 weeks

Latest start time LST = 31 weeks (36-5)

Project Completion time = 38 weeks.

Completion time of E, EFT = 33 weeks (28+5)

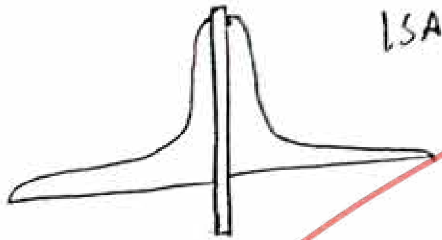
10

Q.6 (c) Design a tie member of roof truss subjected to working loads of 80 kN (DL) and 120 kN (LL). Use double angle section connected back-to-back on either side of gusset plate of 8 mm thickness with 16 mm dia. bolts of grade 4.6. Section is Fe410 grade steel. Use angle section 75 × 50 × 6 mm, A_g = 716 mm². (Given e = 40 mm, p = 50 mm) **[20 marks]**

Given, working loads = 80 kN + 120 kN

Total factored load = 200×1.5 = 300 kN

Fe410 steel, M16 4.6 grade.



ISA 75×50×6

A_g = 716 mm²

e = 40 mm

p = 50 mm.

Hence, for single angle

Load = 300/2 = 150 kN.

Bolt value

$$V_{sb} = \frac{410}{\sqrt{3}\times 1.25}\left(0.78\times\frac{\pi}{4}\times 16^2\right) = 29.7\text{ kN}$$

Bearing strength

$$k_b = \min\left\{\frac{40}{3\times 18}, \frac{50}{3\times 18} - 0.25, \frac{400}{410}, 1\right\}$$

$$k_b = \min\{0.74, 0.676, 0.975, 1\}$$

$$k_b = 0.676$$

$$V_{dpb} = \frac{2.5\times 0.676\times 16\times 6\times 410}{1.25} = 53.214\text{ kN}$$

Thus bolt value = 29.7 kN.

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No. of bolts required $= \frac{150}{29.7} = 5.05 \approx 6$ bolts

Thus, provide 6 bolts.

Now,

Tensile Capacity

Gross yield capacity $= \frac{716 \times 250}{1.1} = \boxed{162.727 kN}$

Net rupture strength

$T_{dn} = \frac{0.9 A_{nc} f_u}{\gamma_{m1}} + \frac{\beta A_{go} f_y}{\gamma_{m0}}$

$\beta = 1.4 - 0.076 \frac{b_s}{l_c} \cdot \frac{w}{t} \cdot \frac{f_y}{f_u}$

$0.7 < \beta < \frac{0.9 f_u/\gamma_{m1}}{f_y/\gamma_{m0}}$

$b_s = 50 + 30 - 6 = 74$ mm (Taking $g = 30$ mm)

$l_c = 5 \times 50 = 250$ mm

$w = 50$ mm

$t = 6$ mm

$\beta = 1.285 < 1.2988$ hence o.k.

thus, ~~T_{dn}~~ =

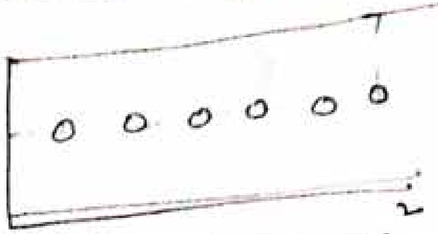
$A_{nc} = \left(75 - \frac{6}{2} - 18\right) \times 6 = 324$ mm^2

$A_{go} = (50 - 3) \times 6 = 282$ mm^2

$T_{dn} = \frac{0.9 \times 324 \times 410}{1.25} + \frac{1.285 \times 282 \times 250}{1.1}$

$\boxed{T_{dn} = 178 \text{ kN}}$

Block shear strength



$A_{vg} = 290 \times 6 = 1740\ mm^2$

$A_{vn} = 191 \times 6 = 1146\ mm^2$

$A_{tg} = 40 \times 6 = 240\ mm^2$

$A_{tn} = 31 \times 6 = 186\ mm^2$

$$T_{db} = \min \begin{cases} \dfrac{1740 \times 250}{\sqrt{3} \times 1.1} + \dfrac{0.9 \times 186 \times 410}{1.25} = 283.22\ kN \\ \dfrac{0.9 \times 1146 \times 410}{\sqrt{3} \times 1.1} + \dfrac{240 \times 250}{1.1} = 276.49\ kN \end{cases}$$

Hence, block shear strength $= 276.49\ kN$

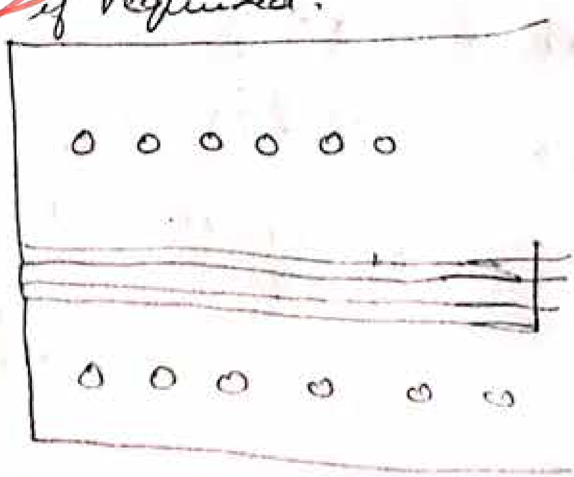
Thus the tensile capacity is governed by gross-section yielding

Hence capacity of both the sections

$= 162.727 \times 2 = 325.454\ kN > 300\ kN$

Provide 6 bolts

Provide tack bolts if required.



Q.7 (a) A built-up laced column of overall square cross-section, 300 mm size has been formed by placing four angles of ISA 50 × 50 × 6 mm at the corners of the square. If the effective height of column is 10 m, then calculate the load carrying capacity of the column. Also, check the lacing system for safety against:

(i) Local buckling of column angles.

(ii) Strength of lacing bars in tension and compression against shear load.

(iii) Strength of M20 bolts of grade 4.6, check safety of bolt.

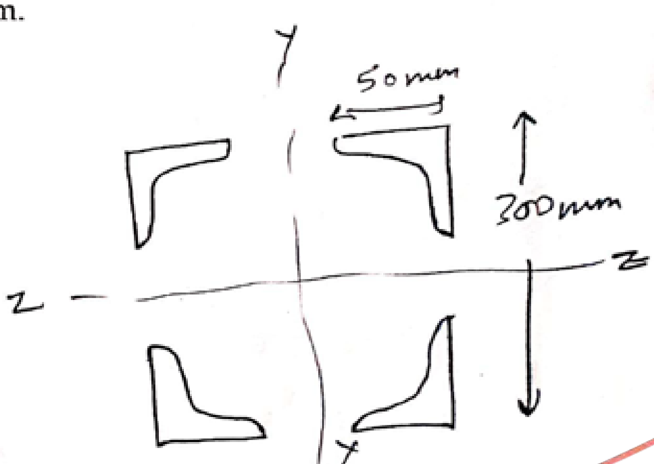
Lacing system consist of 60 × 10 mm flat bars arranged in a single laced system and inclined to the axis of the column at an angle of 45°

kL/r	40	50	60	70	80	90	100	145
f_{cd} (MPa)	164	153	135	125	111	98	86	50

For ISA 50 × 50 × 6 mm, area = 568 mm², $I_x = I_y = 12.9 \times 10^4$ mm⁴, $c_y = 14.5$ mm, $r_{min} = 15.1$ mm.

[20 marks]

Given,



Effective height, $l_{eff} = 10$ m.

Angle of inclination = 45°

Lacing flat size = 60 mm × 10 mm.

Now, for laced column,

slenderness ratio $\lambda = \frac{1.05 l_{eff}}{r_{min}}$

Now, $I_{yy} = I_{zz} =$ ~~568×~~

$I_{xx} = I_{yy} = [12.9 \times 10^4 + 568(150 - 14.5)^2] \times 4$

$= 10.55 \times 10^6 \text{ mm}^4 \times 4 = 42.23 \times 10^6 \text{ mm}^4$

Radius of gyration $r = \sqrt{\frac{10.55 \times 4 \times 10^6}{568 \times 4}}$

$r = 136.28$ mm

Thus, slenderness ratio = $\frac{1.05 \times 10000}{136.28} = 77.04$

from table, by interpolation

$f_{cd} = 125 - \frac{14}{10} \times 7.04 =$ ~~124.94 MPa~~ 115.144

hence load carrying capacity

$= 124.94 \times 563 \times 4 =$ ~~283.863~~ $\times 10^3$ N
261.607

= [261.607 kN] ~~[283.86 kN]~~ Ans

Check for lacing design

length of lacing feet = $(300 - 2 \times 14.5)\sqrt{2}$

$= 271\sqrt{2}$ mm

Thus, $C = 2 \times 271 = 542$ mm

So, $\frac{c}{r_{min}} \not> 50$

$\not> 0.7 \lambda_{whole} = 53.92$

∴ ~~$\frac{542}{136.28}$~~ $\frac{542}{15.1} = 35.89 < 50$ hence safe in local buckling of column angles

Transverse load

2.5% of axial load = 7.096 kN

Now, $\lambda_{lacing} = \frac{l}{t/\sqrt{12}}$ (assuming single line bolt)

$\lambda_{lacing} = \frac{271\sqrt{2} \times \sqrt{12}}{10} = 132.76 < 145$ O.K.

Thus, compressive strength,

$f_{cd} = 86 - \frac{36 \times 32.76}{45} = 59.792 \text{ MPa}$

Compressive strength $= 59.792 \times 60 \times 10$
$= 35.875 \text{ kN} > 7.096 \text{ kN}$

hence safe.

<u>Tensile capacity</u>

$\frac{0.9 \times (60-22) \times 10 \times 410}{1.25} = 112.176 \text{ kN}$
$> 7.096 \text{ kN}$,

hence, safe in tension

<u>Gross yielding check:</u>

$\frac{60 \times 10 \times 250}{1.1} = 136.363 \text{ kN} > 7.096 \text{ kN}$, O.K.

Now, assuming interconnected lacing flat,

force in bolt $= \frac{V}{2 \sin\theta} = 5.0176 \text{ kN}$

<u>Bolt value</u>

for single shear,

$V_{dsb} = \frac{400}{\sqrt{3} \times 1.25}\left(0.78 \times \frac{\pi}{4} \times 20^2\right) = 45.27 \text{ kN}$

<u>Bearing strength</u>

$V_{dpb} = \frac{2.5 k_b d t f_u}{1.25}$

$k_b = \min\left\{\frac{e}{3d_0}, \frac{p}{3d_0} - 0.25, \frac{f_{ub}}{f_u}, 1\right\}$

take $e = 1.5 d_o$ $p = 2.5 d$

$K_b = 0.5$

$$V_{dpb} = \frac{2.5 \times 0.5 \times 20 \times 10 \times 410}{1.25} = 82 \text{ kN}$$

Thus, bolt value = 45.27 kN

hence no. of bolts required = 1

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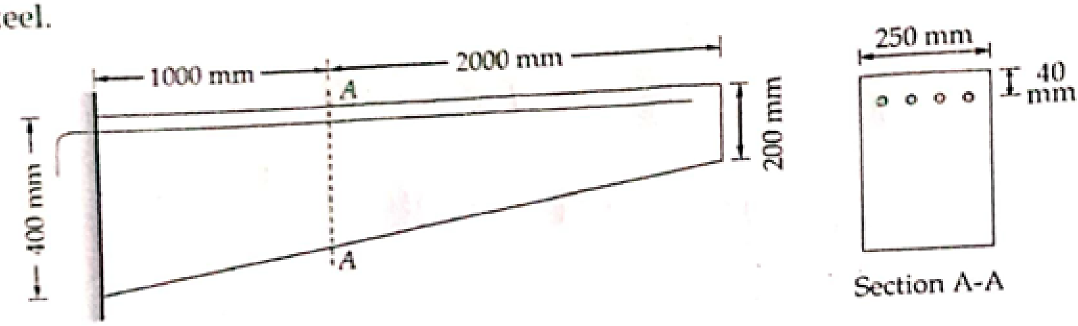
Q.7 (b) Design the shear reinforcement in a tapered cantilever beam of constant width 250 mm whose section at 1 m from the face of support is shown in the figure. It consists of 2-22 mm + 2-18 mm dia bars in tension zone. The shear force is 100 kN and bending moment is 150 kNm at this section at working loads. Assume M20 mix and Fe415 grade steel.



For M20 grade concrete τ_c values are tabulated:

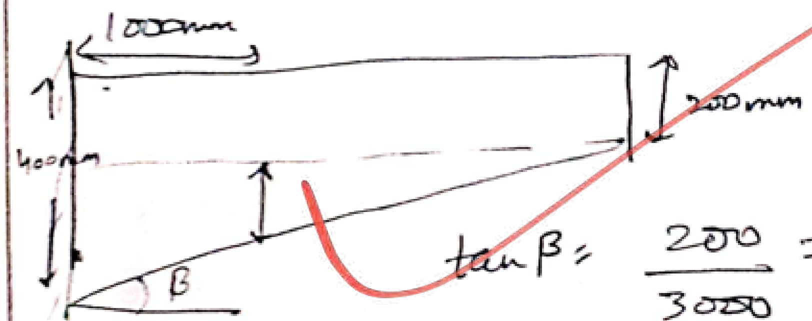
$\frac{100A_{st}}{bd}$	1.25	1.50	1.75	2.00
τ_c (MPa)	0.67	0.72	0.75	0.79

[20 marks]

Given, SF = 100 kN
BM = 150 kNm

Factored shear force = 100×1.5 = 150 kN

Factored Bending moment = 150×1.5 = 225 kNm



$\tan\beta = \frac{200}{3000} = \frac{1}{15}$

Given, tensile steel = 2-22φ + 2-18φ

$= 2\times\frac{\pi}{4}\times 22^2 + 2\times\frac{\pi}{4}\times 18^2$

$= 1269.2\ mm^2$

Effective depth @ the given section

= 333.33 − 40 = 293.33 mm

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Thus, $p_t = \frac{1269.2}{250 \times 293.33} \times 100 = 1.73\%$

from table, by interpolation,

$\tau_c = 0.72 + \frac{0.03}{0.25} \times 0.23 = 0.747$ MPa

Nominal shear stress @ section

$$\tau_v = \frac{150 \times 10^3 - \frac{225 \times 10^6}{293.33} \times \frac{1}{15}}{250 \times 293.33} = 1.348 \text{ MPa}$$

Let's adopt 2-legged 8mm dia vertical closed stirrups.

$$\frac{0.87 \times 415 \times 2 \times 50}{S_v} \geq (1.348 - 0.747) \times 250$$

$S_v \leq 240.3$ mm

As per IS code, spacing $\not>$ min $\begin{cases} 0.75 \times 293.33 = 220 \text{ mm} \\ 200 \text{ mm} \end{cases}$

~~Thus,~~ Check for spacing from minimum shear r/f

$$\frac{0.87 \times 415 \times 100}{S_v} \geq 0.4 \times 250$$

$S_v \leq 361.05$ mm

Thus, provide 2-legged 8mm dia vertical closed stirrups @ 210 mm c/c

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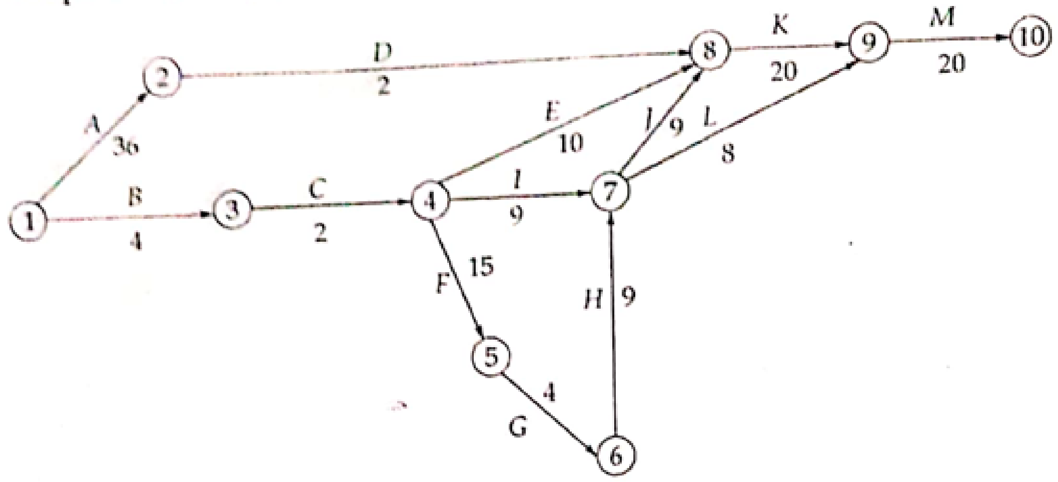
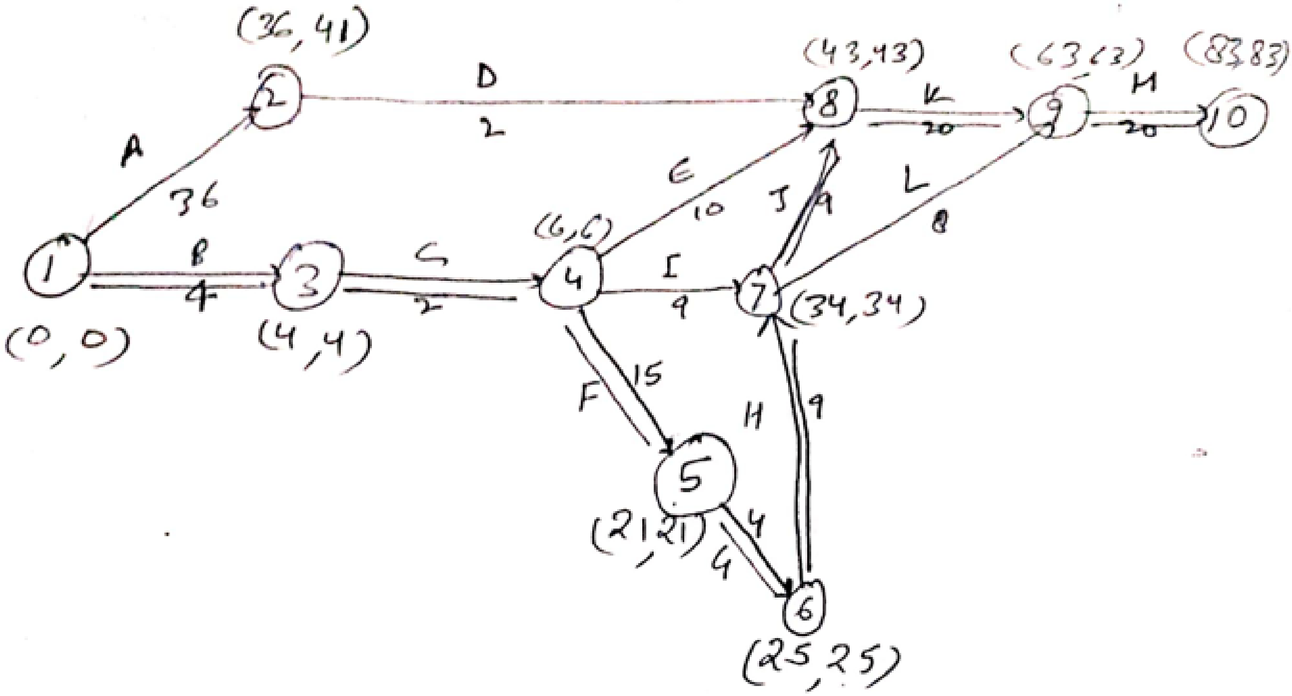
Q.7 (c) For a certain project, the network diagram is shown below along with the estimated time of completion (in days) of each activity marked.



(i) Compute the activity times and event times.
(ii) Determine total, free and independent float for each activity.
(iii) Locate the critical path on the network.

[20 marks]

Activity	Duration	EST	EFT	LST	LFT	F_T	F_F	F_I
A	36	0	36	5	41	5	0	0
B	4	0	4	0	4	0	0	0
C	2	4	6	4	6	0	0	0
D	2	36	38	41	43	5	5	0
E	10	6	16	33	43	17	17	17
F	15	6	21	6	21	0	0	0
G	4	21	25	21	25	0	0	0
H	9	25	34	25	34	0	0	0
I	9	6	15	25	34	19	19	19
J	9	34	43	34	43	0	0	0
K	20	43	63	43	63	0	0	0
L	8	34	42	55	63	21	21	21
M	20	63	83	63	83	0	0	0



Critical path is

B – C – F – G – H – J – K – M.

where.

F_T = total float

F_F = free float

F_I = Independent float

F_T = LFT – EFT / LST – EST

F_F = F_T – S_j S = slack in event.

F_I = F_F – S_i

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