00158

THE OPEN UNIVERSITY OF SRI LANKA
Department of Civil Engineering
Bachelor of Technology (Civil) - Level 7

CVX7640/CVX6832 - Structural Design

FINAL EXAMINATION – 2020/2021

Time Allowed: Four (04) Hours

Date: 2022 - 02 - 03 (Thursday) Time: 0930 - 1330 hrs.

Paper consists of five (05) questions. Answer any four (04) questions.
You may use the booklet named "Extracts From Relevant Standards" provided to you with the course material as Block 3, which also contain concrete design charts & steel sectional properties
You may assume and state reasonable values for any factors not provided.

Q1.
A primary beam AB of a four storey steel office building needs to be designed according to BS5950-1:2000. The loads on the beam (including self-weight) are shown in **Figure Q1(a)**. The beam is laterally restrained and consider it is simply supported at both ends. The dead and live loads from the secondary beams are acting as point loads on the primary beam at points C and D. UB 457×191×67 steel sections are used for the primary beams. Take P_y = 275 N/mm². (You have to mention the relevant clauses and tables of BS5950-1:2000 near your calculations.) Sectional properties of UB 457×191×67 steel sections are given in **Table Q1**.

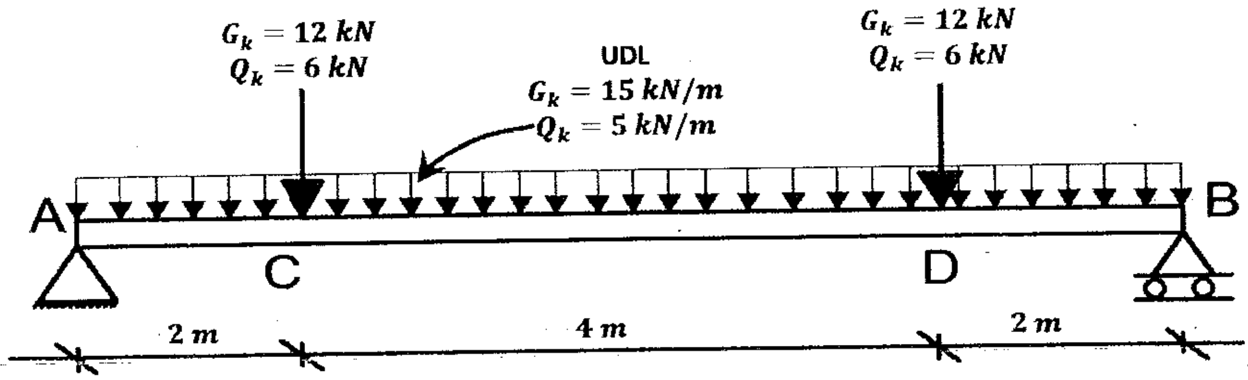


Figure Q1(a)

i) Calculate the design loads on the beam AB and draw the bending moment and shear force diagrams of the beam AB. **[05 Marks]**

ii) Calculate the section classification and identify the class of the steel section which is being used for Beam AB. **[04 Marks]**

iii) Check the adequacy of the given steel section for shear capacity and for moment capacity. **[04 Marks]**

iv) Check the adequacy of the given steel section for deflection (See **Annex Q1** for deflection calculation formulae) and web bearing (Take: b_1 = 150 mm, b_e = 25 mm and $n = 2+0.6[b_e]/k$, where: $k = T+r$ for rolled I sections) **[04 Marks]**

v) Check the adequacy of the given steel section for web buckling (Take a_e =125 mm). **[04 Marks]**

vi) A 200 mm wide steel plate shown in **Figure Q1(b)** is subjected to tension and it is connected to another steel plate using 12 mm diameter bolts. Determine the effective net area (A_e) of the steel plate. The steel plate thickness (t) is 16 mm and consider, s_1 = 55 mm, s_2 = 70 mm, g_1 = 40 mm, g_2 = 60 mm. **[04 Marks]**

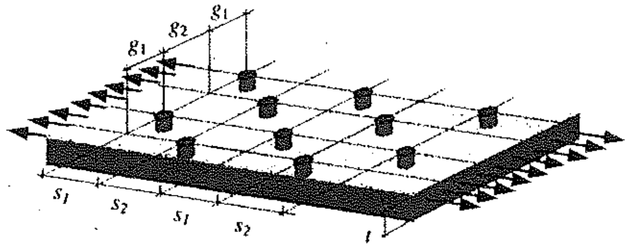
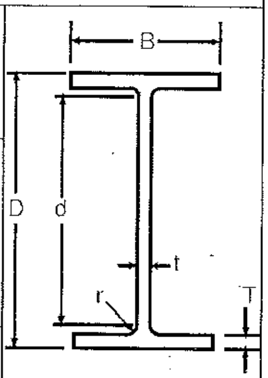


Figure Q1(b)

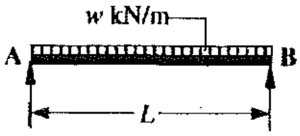
Table 1 – Sectional Properties of UB 457 × 191 × 67 steel section

Section Designation	Mass per meter [kg/m]	Depth of section (D) [mm]	Width of section (B) [mm]	Thickness of web (t) [mm]	Thickness of Flange (T) [mm]	Root radius (r) mm]	Depth between fillets (d) [mm]	Ratios for local buckling		Second moment of area		Radius of gyration	
								Flange (B/2T)	Web (d/t)	Axis x-x [cm^4]	Axis y-y [cm^4]	Axis x-x [cm]	Axis y-y [cm]
457x191x67	67.1	453.4	189.9	8.5	12.7	10.2	407.6	7.48	48	29380	1452	18.5	4.12

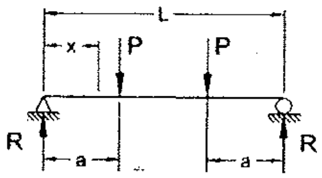
Section Designation	Elastic modulus		Plastic modulus		Buckling parameter (u)	Torsional index (x)	Warping constant (H) [dm^6]	Torsional constant (J) [cm^4]	Area of section [cm^2]	Indicative values for Advance275	
	Axis x-x [cm^3]	Axis y-y [cm^3]	Axis x-x [cm^3]	Axis y-y [cm^3]						M_{cx} [kNm]	P_{cy} for L_e=3.5 [kN]
457x191x67	1296	153	1471	237	0.872	37.9	0.705	37.1	85.5	405	1460



Annex for Q1



Deflection at midspan $= \dfrac{5wL^4}{384EI}$



Deflection at midspan $= \dfrac{Pa}{24EI(3L^2 - 4a^2)}$

Deflections at midspan due to different loadings

Q2.

Under the rural development programme of the government of Sri Lanka, a SEVA PIYASA building has been proposed to be built in a certain village of Kandy district. This building hosts four government officers assigned for various village development programs. The building is a masonry wall construction with the reinforced concrete first and second floors as shown in Figure Q2.

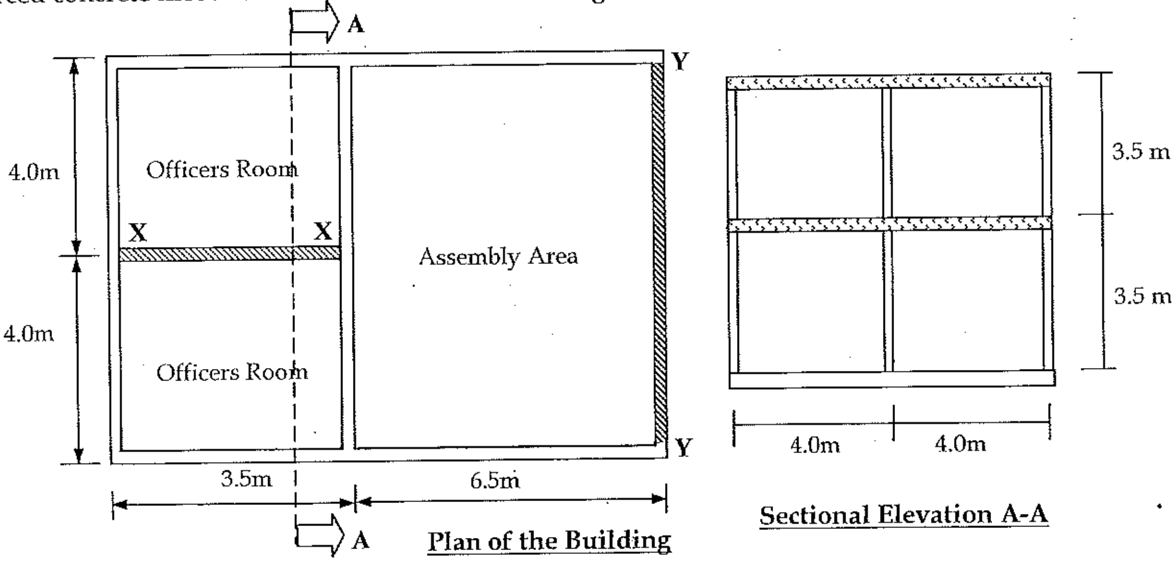


Figure Q2: Proposed masonry building

It has identical floor allocation in the ground and the 1st floor levels. 2nd floor is a reinforced concrete roof slab. Walls are constructed with locally made high quality bricks and their dimensions are 210mm*105mm*50mm, length, breath, height, respectively. Half brick wall construction is 105 mm, one brick wall construction is 220 mm, one & half brick wall construction is 335 mm. Further, wall thickness for the ground and the first floors are 355 mm and 240 mm, respectively. The stair cases are externally fixed and do not contribute to loadings of the building.

Loads
Imposed load on the floor = 3.0 kN/m^2
Dead load due to finishes on slab = 0.5 kN/m^2
Geometry
Thickness of floor slabs = 125mm
Floor to floor height = 3.5 m

Material Properties

Unit weight of RC	= 24.0 kN/m^3
Unit weight of masonry	= 20.0 kN/m^3
Mortar Designation	- III
Compressive Strength of Brick	= 5.0 N/mm^2
γ_m for compression and flexure	= 3.5
γ_m for shear	= 2.5
Water absorption – between	- 7%- 12%

Part I

(i) Evaluate **characteristic dead and imposed loads** acting on the internal wall **X-X** (in the 1st floor level). (04 Marks)

(ii) Find different load combinations and corresponding **design loads and eccentricities** at the first floor level. (04 Marks)

(iii) Determine the **slenderness ratio** of the wall (ground floor level) and compare with its permissible value. (02 Marks)

(iv) Check whether the internal wall (ground floor level) is able to carry the design compressive load considering vertical load resistance of the wall. (02 Marks)

Part II

(i) Draw a figure showing boundary conditions for the external wall **Y-Y** in 1st floor level to 2nd floor level. (01 Marks)

(ii) Check the limiting dimensions of the wall panel **Y-Y**. (01 Marks)

(iii) Determine the **bending moments parallel and perpendicular to the bed joint** if it is subjected to a lateral load of 4 kN/m^2 from the 1st floor level to the 2nd floor level. (04 Marks)

(iv) Determine the **design shear force** applied due to above lateral load at the 1st floor level. (03 Marks)

(v) Check the safety of the external wall panel under the given wind loads considering moment and shear failures. (04 Marks)

You can assume any logical value for any parameter if it is not given.

Q3. An under-hung timber truss bridge is to be constructed over a rock gorge for pedestrian traffic at an rock temple in Anuradhapura area. Side elevation and plan of the bridge spanning 6.0 m are depicted in Figure Q3. Two identical under-hung trusses are used to support 25 mm thick deck planks of the 1.2 m wide walk path. Matured 'Ginisapu' timber (Class C24) is to be used for deck planks while 'Milla' timber (Class D35) is intended for the trusses.

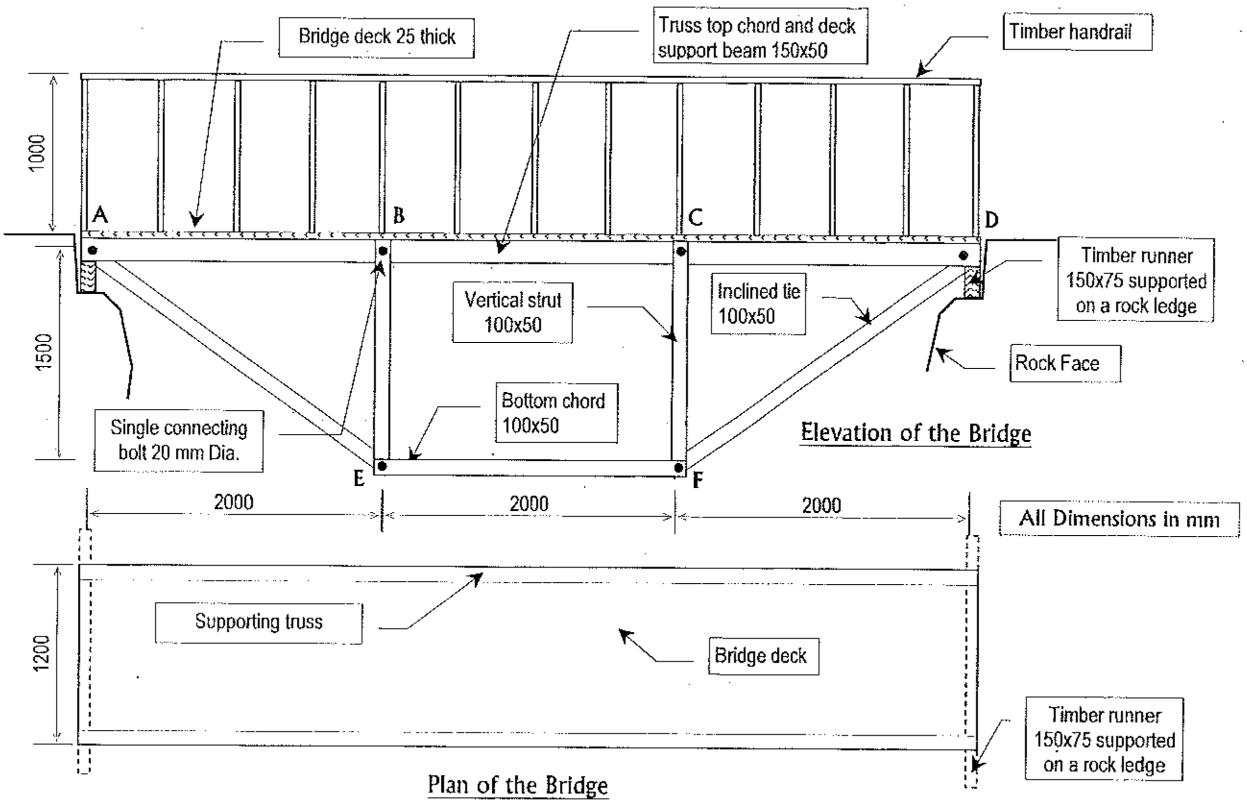


Figure Q3

Assuming that the imposed load by pedestrians is a uniformly distributed load of 2.0 kN/m² (on plan area), weight of a handrail is a uniform line load of 0.1 kN/m and the exposure condition is Service Class 3 (wet exposure), **check the design** of top chord and deck supporting segment AB according to BS 5268-1996. Also assume that for analysis of the truss, loads are applied at nodes A, B, C & D as concentrated loads including self-weights of truss members. All connections are through 20 mm diameter single bolts at each end and planks are wire-nailed to supporting beams.

Use following steps in analysing a truss;

i.) Evaluate the uniformly distributed loading on the top chord ABCD of a truss due to weight of bridge deck and pedestrians and add total self-weight of the truss as a uniformly distributed load (UDL) over the total span of 6000 mm to obtain the equivalent UDL on the truss. (03 Marks)

ii.) Find equivalent nodal forces on the truss by assuming AB, BC & CD segment transfer point loads at A, B, C & D, and analyse the axial forces produced in the truss members. (02 Marks)

Use following steps in checking adequacy of top chord and deck supporting segment AB;

iii.) Using the equivalent udl from i.) evaluate the maximum bending moment in the segment AB assuming it to be simply supported. (01 Marks)

iv.) Check the segment AB against **lateral stability** criteria. (01 Marks)

v.) Compute the applied **flexural stress** at the critical section of the segment AB and check whether this is within the permissible limit (03 Marks)

vi.) Check whether the **maximum allowable deflection** is within the permissible limit (0.003L) for the segment AB. (You may use - *Deflection due to Bending under udl* = $5wL^4/(384EI)$) (03 Marks) vii.) Check whether the segment AB is safe against failure due to **shear**. (03 Marks)

viii.) Compute the applied maximum **compressive stress** in the segment AB due to axial loading and check whether this is within the permissible limit. (03 Marks)

ix.) Check the segment AB for combined flexural and compressive stresses. (03 Marks)

x.) Check whether the critical **bearing stress** produceds between end A of segment AB and the timber runner supported on the rock ledge is within the permissible limit (assume that wane is permitted for the timber members). (03 Marks)

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Q4.

A typical floor plan and a sectional view of a three-storied commercial building are shown in Figure Q4 (a) and (b) respectively. The beams along the gridlines as shown are cast monolithically with the floor slab.

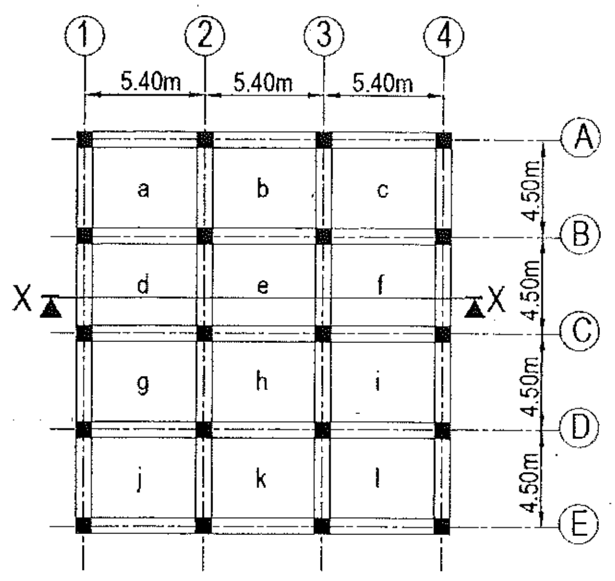

Figure Q1 (a) - Typical Floor Plan

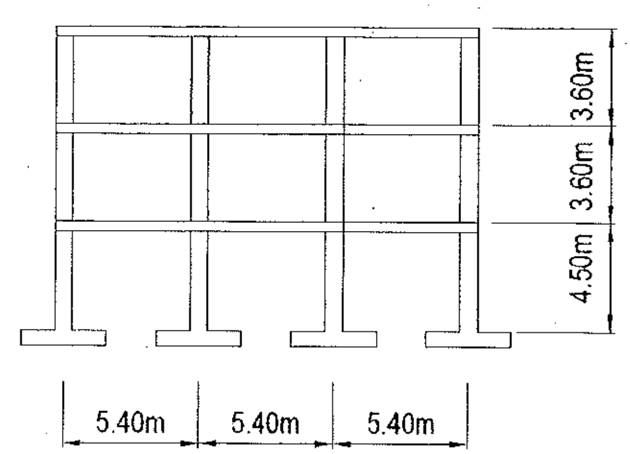

Figure Q1 (b) – Section XX

Loads on the structure;	
Imposed load on the roof	= 1.0 kN/m²
Dead load by finishes on floors & roof	= 1.0 kN/m²
Imposed load on floors	= 3.0 kN/m²
** You may neglect the effects of Wind	
Thickness of floor & roof slabs	= 130 mm
Weights of materials	
Unit weight of RC	= 24.0 kN/m³
Unit weight of Masonry	= 20.0 kN/m³

Strength of materials;	
Grade of concrete	= 25
Characteristic strength of steel	
Main r/f	= 460 N/mm²
Shear r/f	= 250 N/mm²
Nominal cover for reinforcement	= 20 mm
Order of floors – Ground, 1st, 2nd, Roof	
* Required design charts are provided *	

i.) Evaluate the design ultimate load acting on the 1st floor slab and compute the mid span and support bending moments acting on the short direction only of slab panel "e" using the bending moment coefficients from the code. Design reinforcements only for the short direction of this panel to satisfy code requirements and draw a typical plan showing the reinforcement detail for slab panel "e". Indicate curtailment of reinforcements without dimensions. (08 Marks)

ii.) Evaluate the design ultimate load acting on the beam on grid 3, 300mm wide and 350mm deep, (instead of the exact load carried by the beam you may assume a uniformly distributed strip load along its span to simplify the analysis) and calculate the ultimate bending moments at critical locations when all spans are loaded with the ultimate load using the design formula given in BS8110-1:1997 for uniformly loaded continuous beams. (05 Marks)

iii.) Draw the bending moment diagram for the beam on grid 3 using the bending moments computed above. Design the required reinforcements for the span BC to resist bending at critical locations and indicate how you would curtail reinforcements (without dimensions) within span BC in the bending moment diagram. (08 Marks)

iv.) Determine whether the 250mm square column segment, from ground to 1st floor, at the intersection of grids 3 and B is short or slender. Assume that the column is unbraced in both X and Y directions. (04 Marks)

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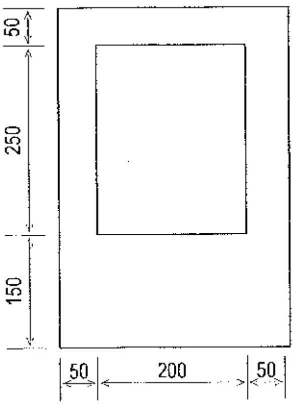
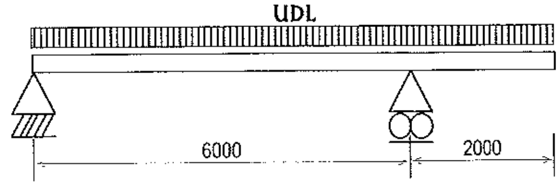
Q5.

The pre-tensioned beam shown in Figure Q5 is used to support a RC slab of a gymnasium. The free body diagram of the beam is shown in Figure Q5. The beam carries only its own weight at transfer. The beam can be considered as a **Type-1** beam.

Proposed section of the prestress beam, material properties and the loading on the beam are as follows;



Cross Section of the Beam



All Dimensions are in mm

Loss of prestress
at transfer = 10 %
at service = 25 %

Strengths
f_{cu} at 28 days = 40 N/mm²
f_{ci} at 7 days (transfer) = 30 N/mm²
Transfer is 7 day after casting
f_{pu} (5.0 mm dia. Wires) = 1600 N/mm²

Loads
Unit weight of concrete = 24.0 kN/m³
RC Slab thickness = 50 mm
Beam spacing (center to center) = 2500 mm

Dead due to finishes = 1.0 kN/m²
Imposed load = 2.0 kN/m²
(Assuming loads to be distributed evenly.)

Figure Q5.

You may use following inequalities (in standard notation) for your calculations

$Z_t \geq (\alpha M_s - \beta M_i) / (\alpha f_{max} - \beta f'_{min})$
$Z_b \geq (\alpha M_s - \beta M_i) / (\beta f'_{max} - \alpha f_{min})$

$P_i \geq (Z_t f'_{min} - M_i) \;/\; \alpha(Z_t/A_c - e)$ $\qquad e \leq (M_i - Z_t f'_{min}) / \alpha P_i + Z_t/A_c$
$P_i \leq (Z_b f'_{max} + M_i) \;/\; \alpha(Z_b/A_c + e)$ $\qquad e \leq (M_i + Z_b f'_{max}) / \alpha P_i - Z_b/A_c$
$P_i \leq (Z_t f_{max} - M_s) \;/\; \beta(Z_t/A_c - e)$ $\qquad e \geq (M_s - Z_t f_{max}) / \beta P_i + Z_t/A_c$
$P_i \geq (Z_b f_{min} + M_s) \;/\; \beta(Z_b/A_c + e)$ $\qquad e \geq (M_s + Z_b f_{min}) / \beta P_i - Z_b/A_c$

Using above data, design the beam according to the following steps;

i.) Find the following parameters of the given section
Cross Sectional Area – A, Distances to the Centroid - Y_t, Y_b
Second Moment of Area – I_{xx}, Section Moduli – Z_t, Z_b (05 Marks)

ii.) Evaluate the dead and imposed loads on the beam at transfer and in service and calculate the critical Bending Moments on the beam (04 Marks)

iii.) Check the adequacy of the section in carrying the stresses at **transfer** and in **service** for the sagging moment at critical section. (04 Marks)

iv.) Using an appropriate technique find the suitable range for Pre-Stress force and corresponding tendon eccentricity. (04 Marks)

v.) By considering all the appropriate conditions select a value for Prestress force and propose a suitable tendon arrangement for the critical sagging section. (Assume $f_{pi} = 0.7 f_{pu}$). (02 Marks)

vi.) Check whether the proposed tendon arrangement is suitable for the support with the critical hogging moment. If mid span tendon arrangement is not suitable for the support, state the solution for this issue. (no numerical answer is required). (02 Marks)

vii.) Check the suitability of the section with respect to Ultimate Moment capacity and state whether additional reinforcement is required. (No need to calculate the quantity of additional reinforcement). (04 Marks)