00169

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

CVX7640/CVX6832 – Structural Design

FINAL EXAMINATION – 2021/2022

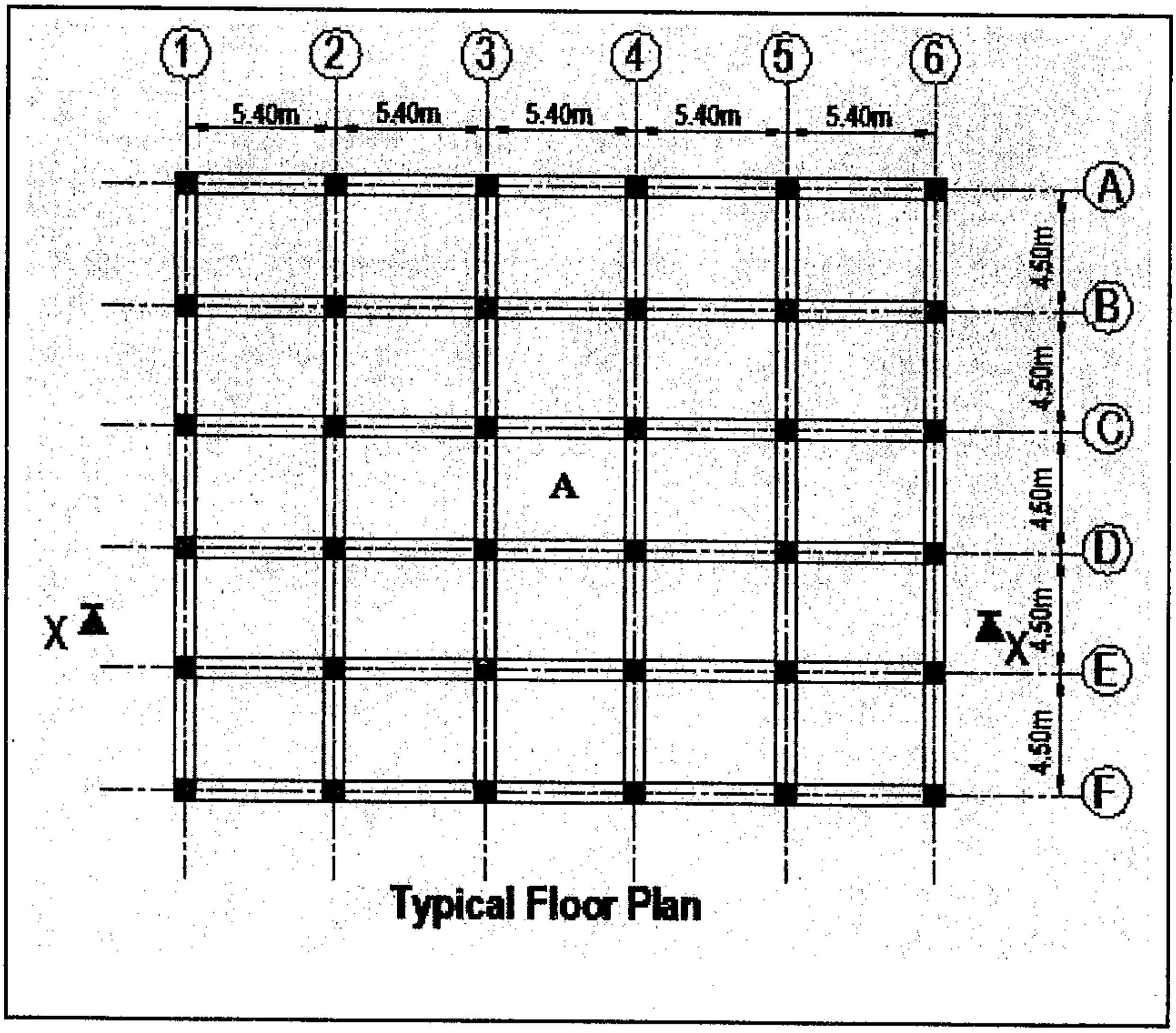
Time Allowed: Four (04) Hours

Date: 2023-02-06 (Monday) 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, which also contain concrete design charts & steel sectional properties
You may assume and state reasonable values for any factors not provided.

Q1.

A typical floor plan and a sectional view of a three-storied commercial building are shown in Figure Q1. The beams along the gridlines as shown are cast monolithically with the floor slab.



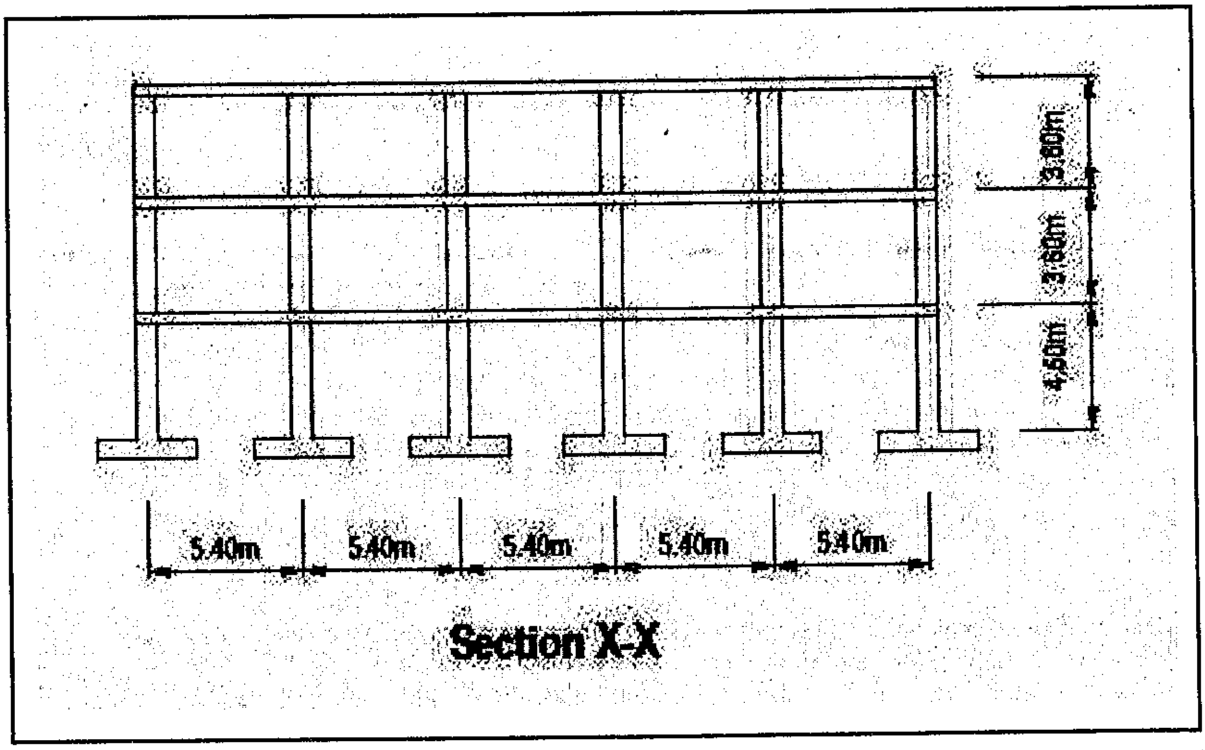


Figure Q1

Loads on the structure;	
Imposed load on the roof	= 1.0 kN/m^2
Dead load by finishes on floors & roof	= 1.0 kN/m^2
Imposed load on floors	= 3.0 kN/m^2
** You may neglect the effects of Wind	
Thickness of floor & roof slabs	= 140 mm
Weights of materials	
Unit weight of RC	= 24.0 kN/m^3
Unit weight of Masonry	= 20.0 kN/m^3

Strength of materials;	
Grade of concrete	= 25
Characteristic strength of steel	
Main r/f	= 460 N/mm^2
Shear r/f	= 250 N/mm^2
Nominal cover for reinforcement	= 20 mm
Order of floors – Ground, 1st, 2nd, Roof	
Note: 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 slab panel "A" using the bending moment coefficients from the code. (04Marks)

ii.) Design reinforcements for this panel to satisfy code requirements and draw a typical plan showing the reinforcement detail for slab panel "A" only. Indicate curtailment of reinforcements without dimensions. (06 Marks)

iii.) Explain what is meant by a "flanged beam". If you are required to design reinforcements at mid spans/ interior supports of a continuous beam explain where flanged beam action can be considered giving reasons. (05 Marks)

iv.) Assuming the column at the point of intersection of grids 4 and C (250 x 250 mm) is unbraced and no bending moments are transferred from beams framing into the column, evaluate the design ultimate axial load on the column at ground floor level and the slenderness condition of the column segment between ground and first floor. (04 Marks)

v.) Provided the allowable bearing capacity of soil is 150 kN/m^2, determine the required size of the pad footing and design the reinforcements required for the pad footing to satisfy all code requirements. (06 Marks)

Q2.

The plan and elevation in Figure 2, show a masonry structure to be designed in a hostel facility of a certain university. First and second floors are reinforced concrete slabs of 125mm thick. 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 of the ground and the first floors are 355 mm and 240 mm, respectively. The staircases are externally fixed and do not contribute to loadings of the building.

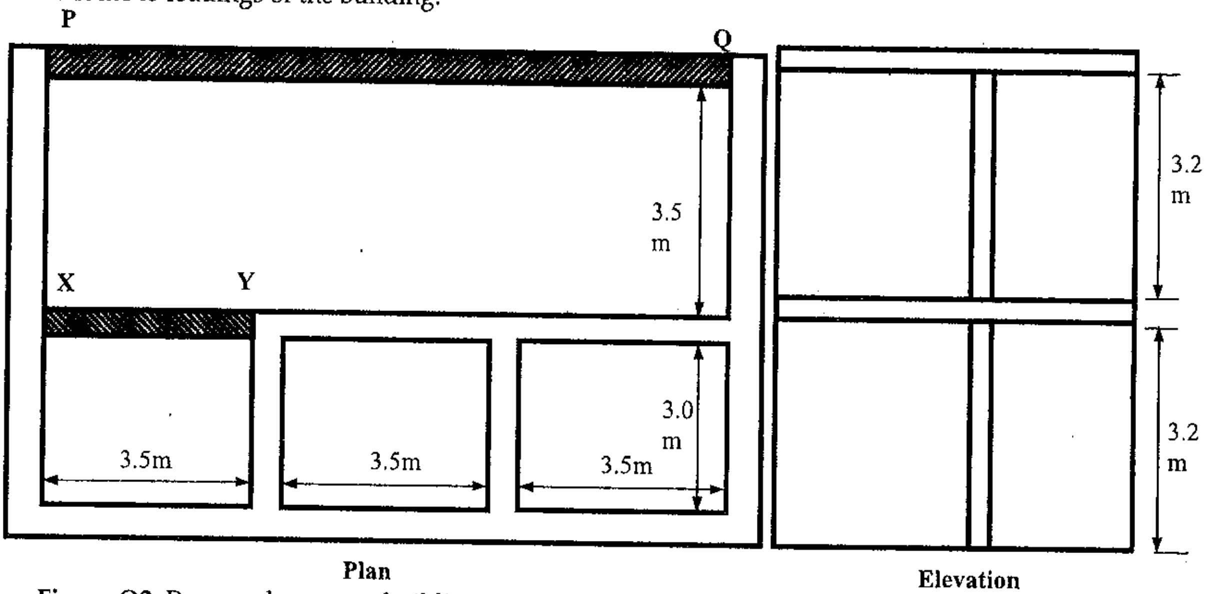


Figure Q2: Proposed masonry building

Loads	
Imposed load on the 1st floor slab	- 3.0 kN/m²
Imposed load on the 2nd floor slab	- 2.0 kN/m²
Dead load due to finishes on slab	- 0.5 kN/m²
Geometry	
Thickness of floor slabs	- 150mm
Floor to floor clear height	- 3.2m

Material Properties	
Unit weight of RC	- 24.0 kN/m³
Unit weight of masonry	- 18.0 kN/m³
Mortar Designation	- III
Compressive Strength of Brick	- 5.0 N/mm²
Partial Safety Factors for Masonry;	
Compression & Flexure	γ_m - 3.5
Shear	γ_m - 2.5
Water absorption	- 7.0 - 12 %

Part I

(i) Evaluate **characteristic dead and imposed loads** acting on the internal wall **X-Y** (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 to first floor level) and compare with its permissible value. (02 Marks)

(iv) Check whether the internal wall (ground floor level to first 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 **P-Q** in 1st floor level to 2nd floor level. (01 Mark)

(ii) Check the limiting dimensions of the wall panel **P-Q**. (01 Mark)

(iii) Determine the **bending moments parallel and perpendicular to the bed joint** if it is subjected a lateral load of 3.5 kN/m² 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)

Q3. Figure Q3. shows a timber observation platform to be erected between two trees at a national park. At the selected site, **Tree 1** has two branches going up in Y shape, so that the two corners A & B of the platform could be supported. As shown in the elevation, a branch stub of **Tree 2** can support the corner C of the platform while the corner D is on a timber prop mounted on a lower branch stub. The platform consist of 2 longitudinal beams connected by 5 cross beams topped by timber plank deck.

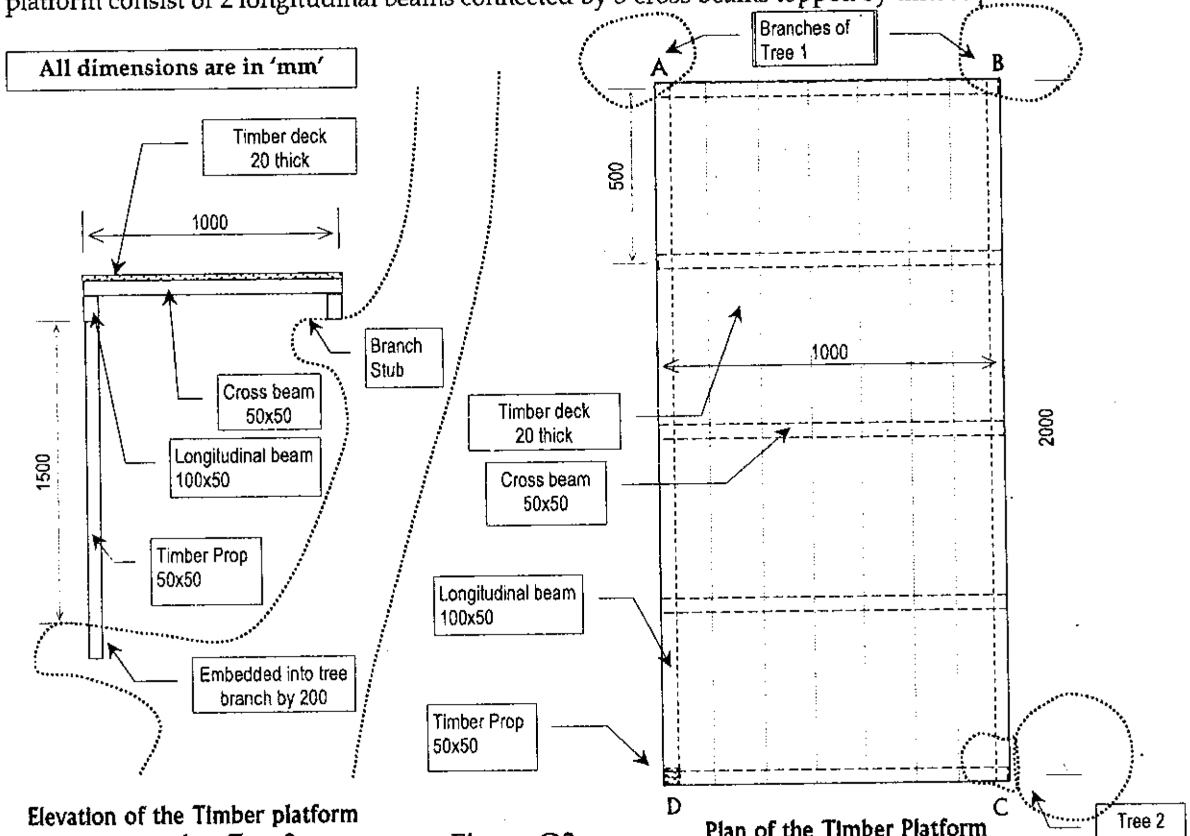


Figure Q3

Taking that the platoform decking planks are by C24 "Ginisapu" timber and other beams and the Prop (column) are by D30 "Palu" timber, and Service Class 3 (wet exposure), **check the design** of a critical Cross beam and the Prop supporting the corner D of the platform according to BS 5268-1996. Also assume that imposed load is an uniformly distributed area load of 1.2 kN/m^2, **wane** is permitted and all connections are made by wire nailing, if not mentioned otherwise.

Use following steps in checking adequacy of a critical the deck supporting cross beam;

i.) Evaluate the **udl** on a critical cross beam due to **live and dead** loads. (03 Marks)

ii.) Check the critical cross beam against **lateral stability** criteria. (01 Marks)

iii.) Compute the highest applied **bending stress** in the critical cross beam and check whether this is within the permissible limit. (03 Marks)

iv.) Check whether the **maximum deflection** of the critical cross beam is within the permissible limit (0.003L). (You may use - *Deflection due to Bending* = $5wL^4 / (384EI)$) (03 Marks)

v.) Check whether the critical cross beam is safe against failure due to **shear.** (03 Marks)

vi.) Check whether applied **bearing stresses** at supports are within the permissible limit for the longitudinal beam resting on the Prop at D. (03 Marks)

For checking adequacy of the prop at the corner D, use following steps;

vii.) Evaluate the loading on the prop at D due to **live and dead** loads. (03 Marks)

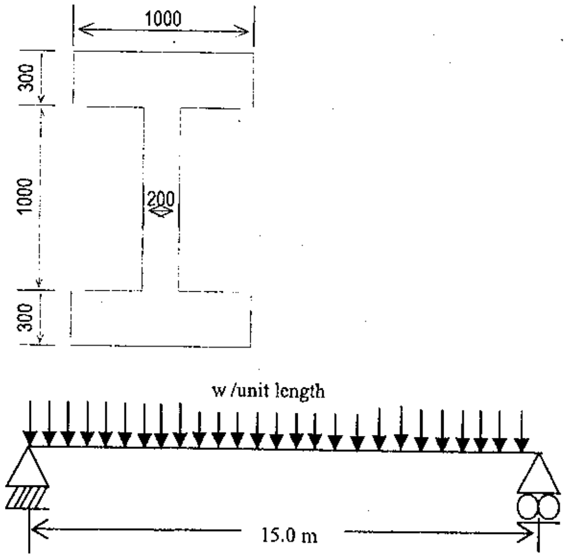
viii.) Compute the applied maximum **compressive stress** in the prop and check whether this is within the permissible limit. (03 Marks)

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

Q4.

The post tensioned beam shown in Figure Q4 is used for a bridge with medium span. The body diagram of the beam as shown in Figure Q4. The beam carries only its own weight at transfer. The beam can be considered as type 2 beam.

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



Strengths

f_{cu} at 28 days = 35 N/mm²

f_{ci} at 7 days (transfer) = 28 N/mm²

Transfer is 7 day after casting

f_{pu} Super strand 25.0 mm dia. Tendons = 1050 N/mm²

Loads

Unit weight of concrete = 24 kN/m³

Dead load other than self weight = 30.0 kN/m

Imposed load = 20.0 kN/m

(Assuming loads to be distributed evenly.)

Loss of prestress

at transfer = 10 %

at service = 20 %

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

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

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

$P_i \geq (Z_t f'_{min} - M_i) \;/\; \alpha(Z_t/A_c - e)$ $\quad$ $e \leq (M_i - Z_t f'_{min}) \;/\; \alpha P_i \; + Z_t/A_c$

$P_i \leq (Z_b f'_{max} + M_i) \;/\; \alpha(Z_b/A_c + e)$ $\quad$ $e \leq (M_i + Z_b f'_{max}) \;/\; \alpha P_i - Z_b/A_c$

$P_i \leq (Z_t f_{max} - M_s) \;/\; \beta\,(Z_t/A_c - e)$ $\quad$ $e \geq (M_s - Z_t f_{max}) \;/\; \beta P_i \; + Z_t/A_c$

$P_i \geq (Z_b f_{min} + M_s) \;/\; \beta\,(Z_b/A_c + e)$ $\quad$ $e \geq (M_s + Z_b f_{min}) \;/\; \beta P_i \; - Z_b/A_c$

Figure Q4

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

i). Discuss the merits and demerits of the selection of;
a). Prestress concrete over other alternative materials
b.) Post-tension beam over pretension beam for the application given above. (03 Marks)

ii). Find the required sectional properties of the given section (03 Marks)

iii). Evaluate the dead and imposed loads on the beam at transfer and in service and calculate the critical bending moments at the two instances for critical sagging moment. (04 Marks)

iv). Check the adequacy of the section in carrying the stresses at **transfer** and in **service** for the range of spans. (02 Marks)

v). Find the suitable range for Pre-Stress force by assuming suitable eccentricity (04 Marks)

vi). By considering all the appropriate conditions select a value for Prestress force and propose a suitable tendon arrangement for the mid span. (Assume $f_{pi} = 0.7\, f_{pu}$). (03 Marks)

vii.) Check whether the proposed tendon arrangement is suitable for a support of the beam. If mid span arrangement is not suitable for the supports, state the solution for this issue. (02 Marks)

viii). Check the suitability of the section respect to Ultimate Moment capacity and state whether additional reinforcement is required. Find the number of additional reinforcement bars if necessary. (04 Marks)

Q5.

Figure Q5 (a) shows the arrangement of beams and columns in a two storey office building. S275 steel sections are used for all beams and columns in the building. A UC 203x203x52 section is proposed for **Column A** and the loads applied at the top beam-column joint of Column A is shown in **Figure Q5 (b)**. Consider the following when the designing.

- Clear height of the **Column A** is 4 m.
- Loads shown in **Figure Q5 (b)** are not design loads.
- **Column A** is effectively held in position at both ends but only restrained in direction at bottom.
- Neglect the self-weight of the column.
- The impose load form the first floor need **NOT** to be reduced by 10%.
- Consider the bending moments applied about **both axes** (X-axis and Y-axis) due to a minimum eccentricity of 100 mm from the face of the column section.
- Sectional Properties of UC 203x203x52 steel section are given in the **Annex Table Q5 (a)**.

(You have to mention the relevant clauses and tables of BS5950-1:2000 near your calculation steps.)

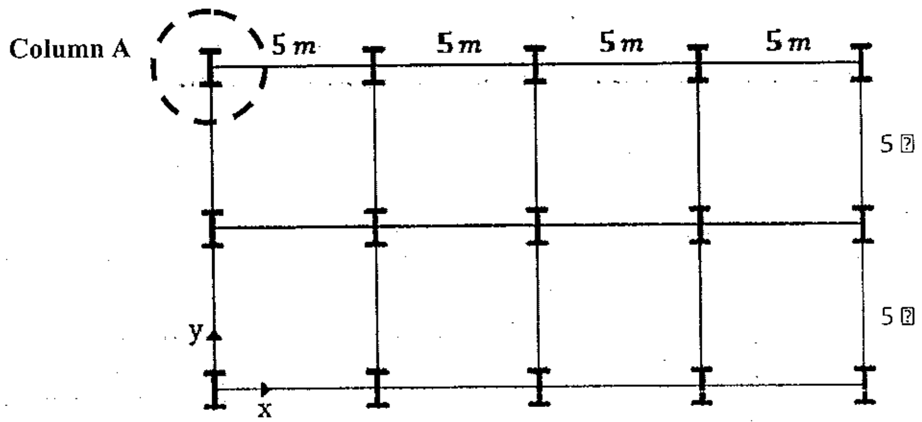


Figure Q5 (a) Arrangement of beams and columns in a two storey office building

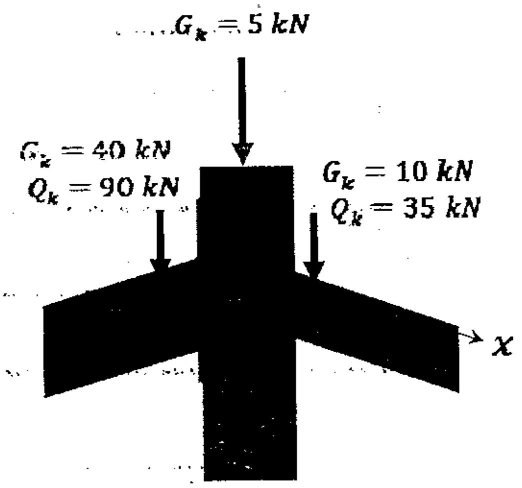


Figure Q5 (b) Loads applied at the top beam-column joint of Column A (not design loads)

i) Briefly explain what is meant by 'local buckling' and 'overall buckling' in structural steel sections? [05 Marks]

ii) Calculate the design axial load and bending moments (due to eccentricities) applied on the Column A. [04 Marks]

iii) Do the section classification and identify the class of the steel section which is being used for Column A. [04 Marks]

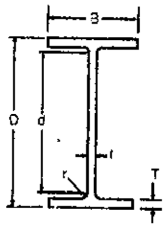
iv) Calculate the slenderness λ of both x – axis and y – axis of Column A. [04 Marks]

v) Check the adequacy of the UC 203x203x52 section for Column A. [08 Marks]

Annex

Table Q5 (a) – Sectional Properties of UC 203 × 203 × 52 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]
203x203x52	52.0	206.2	204.3	7.9	12.5	10.2	160.8	8.17	20.4	5259	1778	8.91	5.18

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]	
203x203x52	510	174	567	264	0.848	15.8	0.167	31.8	66.3	156	1230	