THE OPEN UNIVERSITY OF SRI LANKA
Department of Civil Engineering
Bachelor of Technology (Civil) - Level 6

CVX6832/CEX6332 – Structural Design

FINAL EXAMINATION – 2019/2020

Time Allowed: Four (04) Hours

Date: 2020 - 10 - 14 (Wednesday) 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 part structural plan of a typical floor in a multi-storied office building constructed using structural steel is shown in Figure Q1, indicating the general arrangement of beams and columns. The floor consist of precast concrete units which are supported only on the secondary beams (B2). The dead weight of the floor slab including finishes is 4.0 kN/m^2 and the imposed load is 3.0 kN/m^2. Both the secondary (B2) and main beams (B1) may be assumed as laterally restrained and have simple end connections. The height of each storey of the building is 3.8 m. Conduct the following steps using Grade S-275 structural steel in accordance with BS5950-1:2000. Modulus of elasticity of steel = 205 x 10^3 N/mm^2.

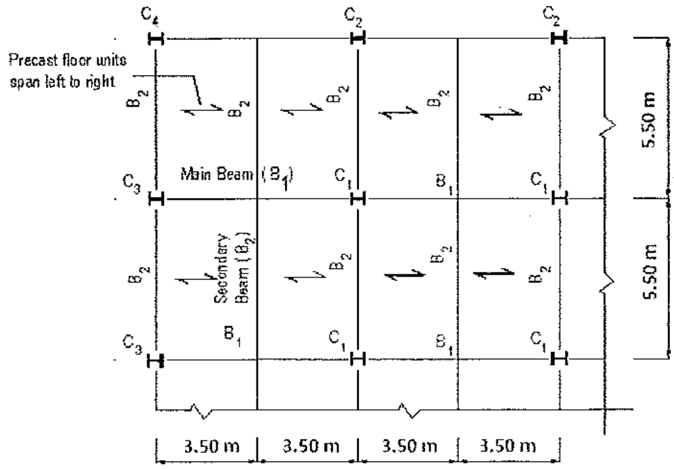

Figure Q1 – General arrangement of floor beams and columns

i.) Evaluate the service and ultimate loads acting on an interior secondary beam B2. (02 Marks)

ii.) Determine the most economical size of the Universal Beam that can be used as interior secondary beams satisfying all code requirements. (08 Marks)

iii.) Evaluate the service and ultimate loads acting on an interior main beam B1. (02 Marks)

iv.) Determine the most economical size of the Universal Beam that can be used as main interior beams satisfying all code requirements. (08 Marks)

v.) Evaluate the maximum axial load that can be carried by a Universal Column 305x305x198 provided for column C1. Assume the column to be held in position at both ends with no restraint in direction at either end. (05 Marks)

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Q2.

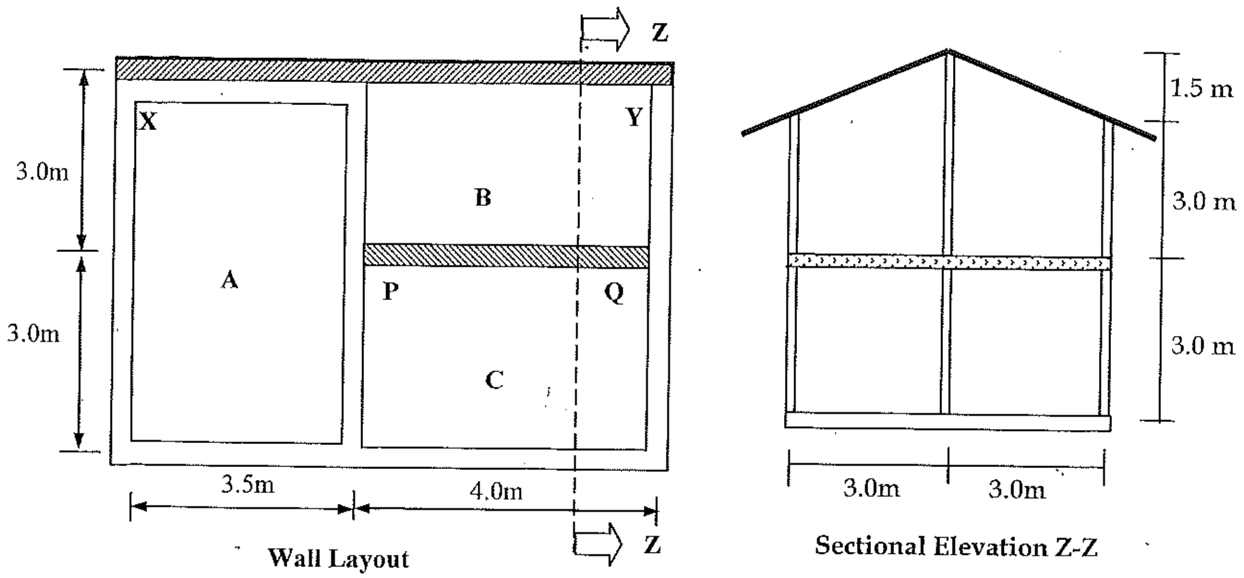

Figure Q2: Proposed masonry building

A two storied building has been proposed to be constructed under a community development project. The structure is to be of load bearing masonry wall construction. The plan of and elevation of the building is shown in Figure Q2. There are three rooms in ground and upper floors, respectively. Walls are to be constructed with locally made high quality bricks and their dimensions are 200mm*100mm*50mm, length, breath, height, respectively. Half brick wall construction is 100mm, one brick wall construction is 210 mm, one and half brick wall construction is 320mm. Further, external and internal wall thicknesses are 350 mm and 240mm, respectively considering the addition of 15mm plaster layer on either side of wall.

Loads	
Dead load of the roof (Plan area)	- 0.5 kN/m^2
Imposed load on the roof	- 0.5 kN/m^2
Imposed load on the floor	- 3.5 kN/m^2
Dead load by 125mm slab	- 3.0 kN/m^2
Dead load due to finishes on slab	- 0.5 kN/m^2
Geometry	
Thickness of floor slab	- 125mm
Floor to floor clear height	- 3.0m
Eave of the roof	- 1.0m

Weights of Materials	
Unit weight of RC	- 24.0 kN/m^3
Unit weight of masonry	- 20.0 kN/m^3
Mortar Designation	- IV
Compressive Strength of Brick	- 5.0 N/mm^2
Partial Safety Factor for Masonry γ_m	- 3.5
Water absorption	>12%

Stating any assumptions made, conduct the following steps of design;

i. Evaluate characteristic dead and imposed loads acting on the internal wall **P-Q** in the first-floor level. (04 Marks)

ii. Find different load combinations and corresponding design loads and eccentricities. (04 Marks)

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

iv. Determine the vertical load resistance of the internal wall **P-Q**. (02 Marks)

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

vi. Draw a figure showing boundary conditions for the external wall panel **X-Y** (1st floor to roof office area). (01 Marks)

vii. Determine the moments parallel and perpendicular to the bed joint if it is subjected a wind load of 4.0 kN/m^2. (04 Marks)

viii. Check the safety of the external wall panel under the given wind load by considering moment failures. (04 Marks)

ix. If either or both checks in sections v. and viii. are failed, what kind of structural suggestions would you propose to carry the design loads. (02 Marks)

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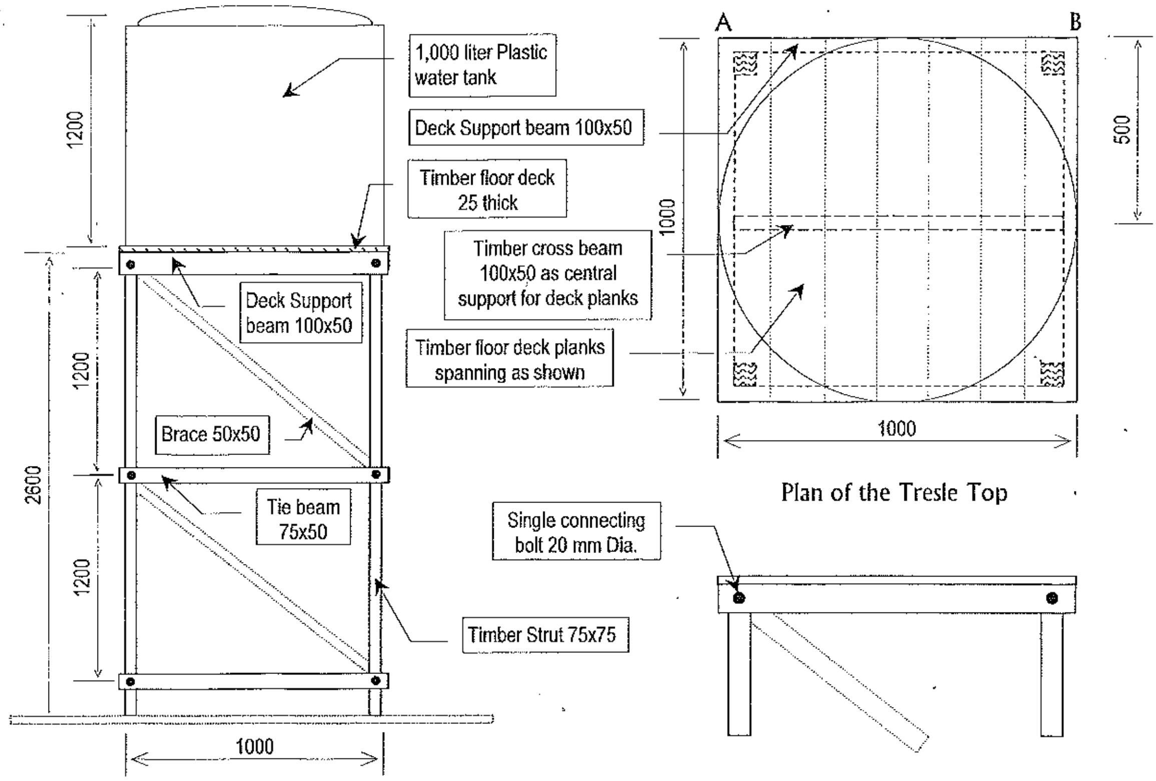
Q3. Side elevation and plan of a tresle fabricated with timber to support a plastic water tank of 1,000 liter capacity is depicted in Figure Q3. The top of the tresle is made as a platform to support the water tank by spanning 25 mm thick timber planks as shown in the plan. The tresle is 2600 m high and is to be made with Class D30 timber. The deck planks are to be with Class C24 timber.



Elevation of the Timber Tresle supporting the water tank — **Figure Q3** — Elevation of the Tresle Top

Assuming that the weight of the empty plastic water tank is 25 kg, the load imparted by the full water tank on the platform is uniform and the exposure condition is Service Class 3 (wet exposure), **check the design of** deck supporting beam AB and a leg struct of the tresle according to BS 5268-1996. Also assume that all connections are through 20 mm diameter single bolts at each end and planks are wire-nailed to supporting beams.

Use following steps in checking adequacy of the deck supporting beam AB;

i.) Evaluate the loading on the beam AB due to **live and dead** loads. (03 Marks)

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

iii.) Compute the applied **bending stress** at the critical section and check whether this is within the permissible limit for the beam AB. (03 Marks)

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

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

vi.) Check whether applied **bearing stresses** at supports are within the permissible limit for the single bolted connection of the beam AB. (03 Marks)

For checking adequacy of a leg strut, use following steps (You may neglect the self weights of the tresle members below deck level);

vii.) Evaluate the loading on a lower strut segment of the legs due to live and dead loads. (03 Marks)

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

ix.) Check the column for combined flexural and compressive stresses. (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.

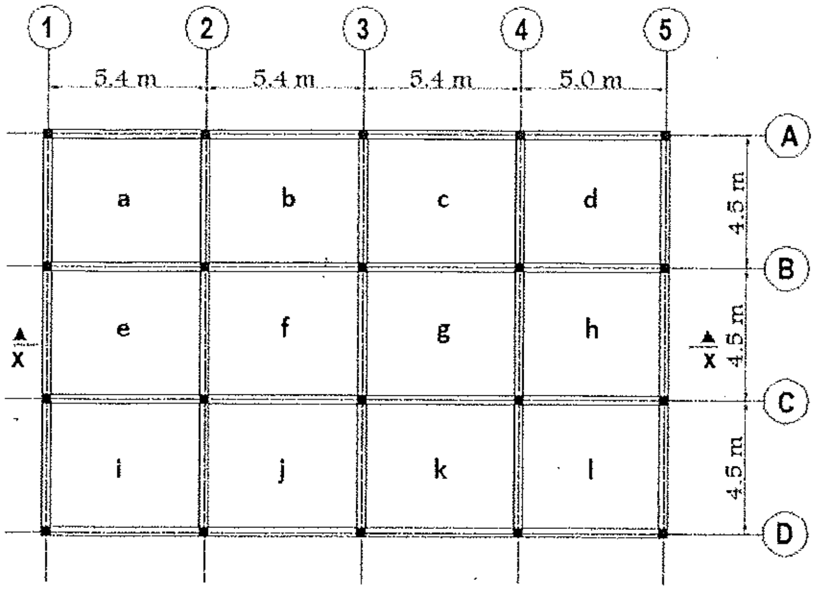


Figure Q4 (a) - Typical Floor Plan

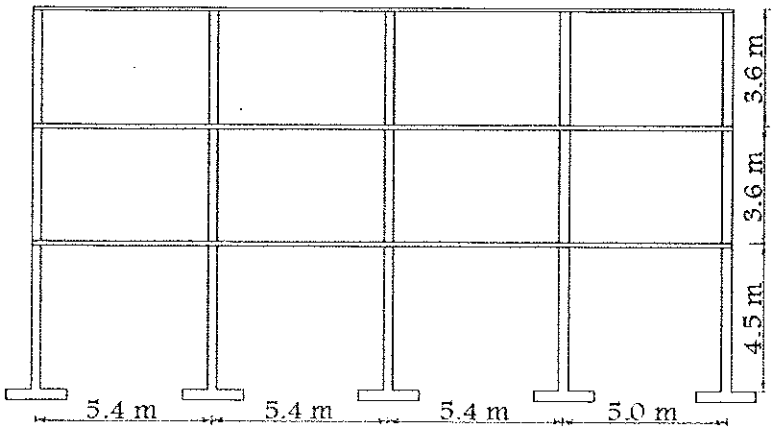


Figure Q4 (b) – Section XX

Figure Q4

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	= 125 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	= 30
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	
* Get Required design charts from Code Extracts Book*	

i.) Identify the most critical slab panel giving reasons for your choice. (04 Marks)

ii.) Evaluate the design ultimate load acting on the 1st floor slab and compute the bending moments acting on the short direction of slab panel "f"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 "f". Indicate curtailment of reinforcements without dimensions. (06 Marks)

iii.) Evaluate the design ultimate load acting on the beam on grid 2, 350x300 mm (you may assume that a 225mm thick masonry wall is supported on top of the beam and take a uniformly distributed 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)

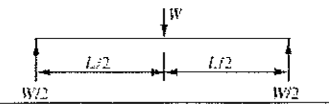
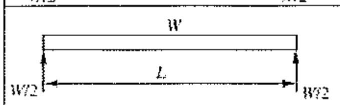
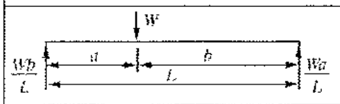
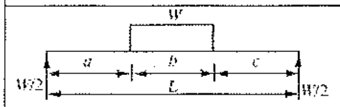
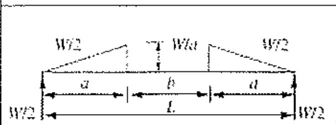
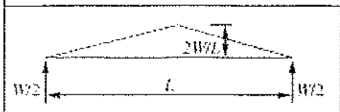
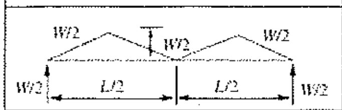
iv.) Draw the bending moment diagram for the beam on grid 2 using the bending moments computed above. Design the required reinforcements for the span BC to resist bending at critical locations and indicate how you would curtail reinforcements (without dimensions) within span BC in the bending moment diagram. (05 Marks)

v.) Explain with a neat sketch what is meant by "punching shear" failure of a pad footing. If your calculations indicated that the footing with the initially selected dimensions fails under punching shear what action you would take to remedy this situation. (05 Marks)

Supplementary Information

For question Q1.

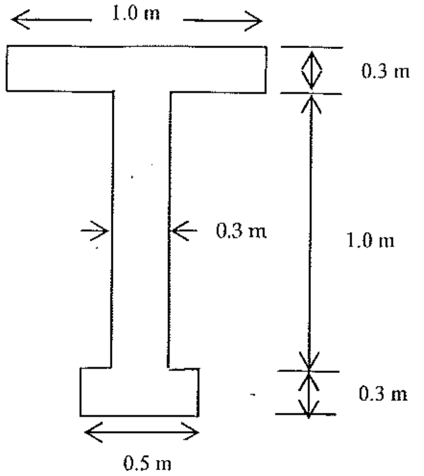
Simply supported beam maximum moments and deflections

Beam and load	Maximum moment	Deflection at centre
	$WL/4$	$\frac{WL^3}{48EI}$
	$WL/8$	$\frac{5WL^3}{384EI}$
	Wab/L	$\frac{WL^3}{48EI}\left[\frac{3a}{L}-4\left(\frac{a}{L}\right)^3\right]$
	$W(a/2+b/8)$	$\frac{W}{384EI}[8L^3-4Lb^2+b^3]$
	$Wa/3$	$\frac{Wa}{120EI}[16a^2-20ab+5b^2]$
	$WL/6$	$\frac{WL^3}{60EI}$
	$WL/8$	$\frac{WL^3}{73.14EI}$

Q5.

The post-tensioned beam shown in Figure Q5 is used for a bridge with medium span. The 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-2** beam.

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



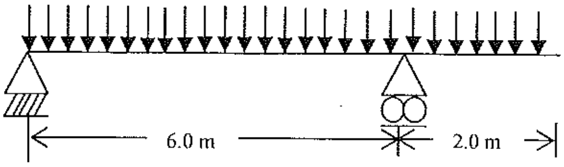


Figure Q5.

<u>Strengths</u>

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} Super strand 20.0 mm dia. Tendons = 1600 N/mm²

<u>Loss of prestress</u>
at transfer = 10 %
at service = 20 %

<u>Loads</u>

Unit weight of concrete	= 24.0 kN/m³
Dead load other than self weight	= 12.0 kN/m
Imposed load	= 10.0 kN/m

(Assuming loads to be distributed evenly.)

<u>You may use following inequalities (in standard notation) for your calculations</u>

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

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

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_b, Y_t
Second Moment of Area – I_{xx}, Section Moduli – Z_t, Z_b (04 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 (03 Marks)

iii.) Check the adequacy of the section in carrying the stresses at **transfer** and in **service** for the critical sagging moment at mid span. (02 Marks)

iv.) Find the suitable range for Pre-Stress force by assuming the eccentricity as 800 mm. (04 Marks)

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

vi.) Check whether the proposed tendon arrangement is suitable for the support B of the beam. If mid span arrangement is not suitable for the supports, state the solution for this issue. (no numerical answer is required). (02 Marks)

vii.) 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)

viii) Carry out the Ultimate Shear Design of the Beam. (03 Marks)