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

CVX6832/CEX6332 – Structural Design

FINAL EXAMINATION – 2017/2018

Time Allowed: Four (04) Hours

Date: 2019 - 02 - 16 (Saturday) 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.

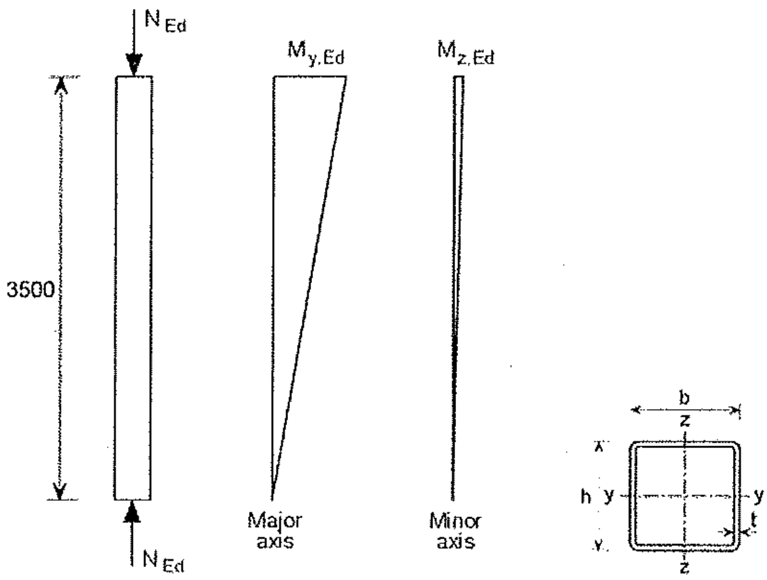


Figure Q1

All dimension are in mm unless or otherwise mentioned
Design compression force N_{Ed} = 600 kN
Design Moment about the y-y axis (major axis) $M_{y,Ed}$ = 20 kNm
Design Moment about the z-z axis (minor axis) $M_{z,Ed}$ = 5 kNm

<u>Sectional properties 150 x 150 x 6.3 SHS (S355)</u>

Depth of section h = 150 mm
Width of section b = 150 mm
Wall thickness t = 6.3 mm
Second moment of area I = 1223 cm^4
Radius of gyration i = 5.85 cm
Elastic modulus W_{el} = 163 cm^3
Plastic modulus W_{pl} = 192 cm^3
Area A = 35.8 cm^2
Modulus of elasticity E = 210000 N/mm^2

Verify the adequacy of a square hollow section (SHS) steel to resist the compression and bending about both axes shown in Figure Q1

I. Do the section classification according BS 5950
II. Calculate the cross-sectional resistance to combined compression and bi-axial bending
III. Check the buckling resistance for the compression and bi-axial bending using the verification given in the codal provision
IV. Explain the different between pre-engineered and prefabricated design in steel using advantages and disadvantages

Q2.

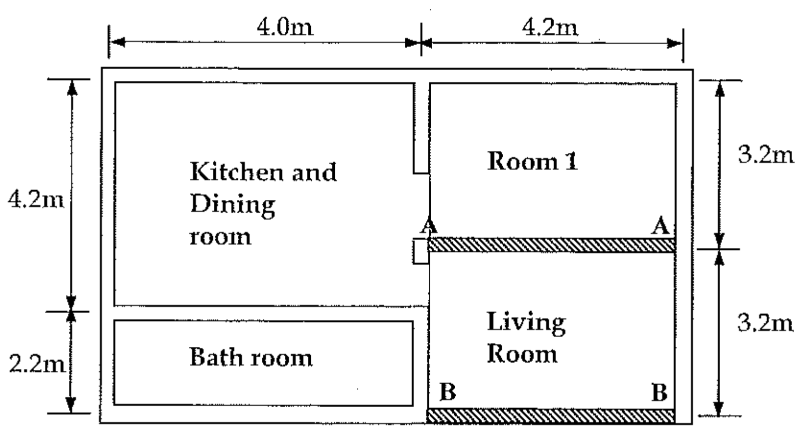
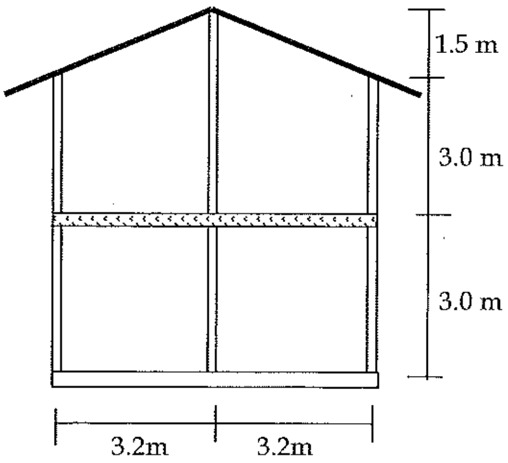


Figure Q2: Proposed masonry building



Elevation

A two-story masonry building construction is shown in Figure Q2. The plan of one living unit and elevation of the building is shown in the Figure.

Walls are constructed with locally made high quality bricks and their dimensions are 200mm x 100mm x 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, the finished external and internal wall thicknesses are 350 mm and 240mm, respectively.

Loads
Dead load of the roof (Plan area) = 0.5 kN/m^2
Imposed load on the roof = 0.25 kN/m^2
Imposed load on the floor = 1.5 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 = 18.0 kN/m^3
Mortar Designation IV

Compressive Strength of Brick = 5.0 N/mm^2
γ_m = 3.5
Water absorption >12%

Part A: Internal wall design

I. Evaluate characteristic dead and live loads acting on the internal wall **A-A** in the first floor slab level. (05 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. Check whether the internal wall is able to carry the design compressive load considering vertical load resistance of the wall. (02 Marks)

Part B: External wall design

V. Draw a figure showing boundary conditions for the external wall in 1st floor level to the roof, wall panel area (With wall **B-B**) (02 Marks)

VI. Determine the moments parallel and perpendicular to the bed joint if it is subjected a lateral load of 4.0 kN/m^2. (05 Marks)

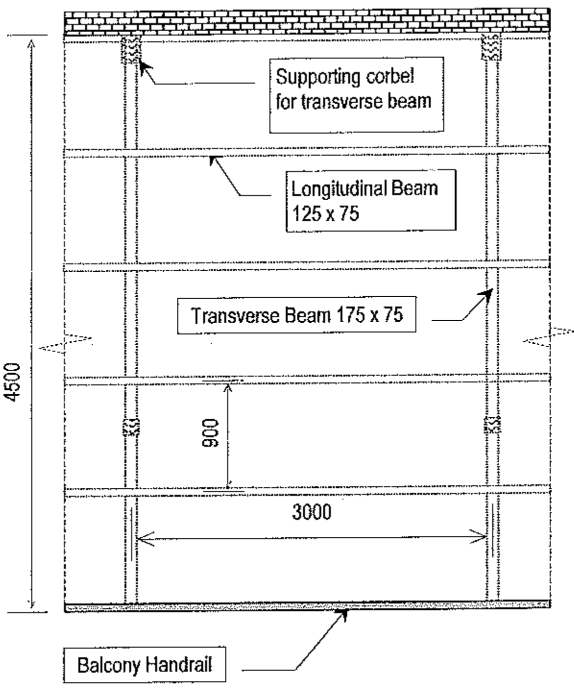
VII. Check the safety of the external wall panel under the given lateral load considering shear and flexural resistances. (05 Marks)

Indicate whatever your assumptions used clearly.

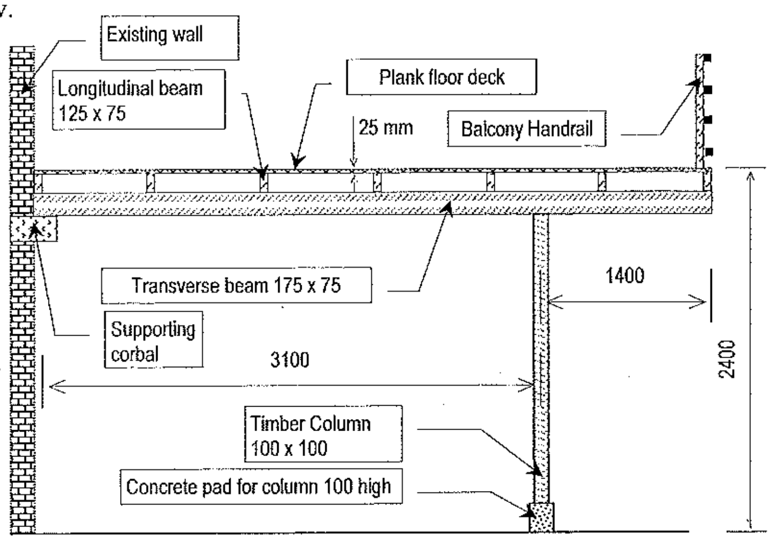
Q3.

The proposal to introduce a balcony at the rear end of the Auditorium of the OUSL at Nawala, discussed at the Design Class #1 for this course in 2017/18 has to be modified to reduce the obstruction to view by supporting columns. Therefore, the supporting columns spaced at 2400 mm originally, were made 3000 mm apart and taken backwards by 900 mm to result in the layout given below. Due to practical reasons and to minimize damages to the internal finishes of the Auditorium during the fabrication, the balcony structure is to be constructed in timber. The balcony floor is to be a wodden plank decking supported by a timber beam framework.

Transverse beams support the longitudinal beams topped by the decking. Transverse beams are supported on corbels extending from the rear wall and on timber columns in the front with a cantilevering portion as shown in the dimensioned sketch below.



Part Plan of the Timber floor



Cross section of the Balcony

Loads
Imposed load on Balcony = 1.0 kN/m²
[You may assume the loads transferred to a Tranverse beam by the longitudinal beams as uniformly distributed load(udl)]
Dead load by handrail could be neglected
Assumptions
Exposure condition is Dry

Assuming Strength Class D70 Red Balau timber, check the design adequacy of a transverse **beam** according to BS 5268-1996, using following steps;

i.) Evaluate the loading on a Transverse Beam due to **live and dead** loads and sketch Bending Moment and Shear Force diagrams. (03 Marks)

ii.) Check the proposed flexural member 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 flexural member. (03 Marks)

iv.) Check whether the **maximum allowable deflection** is within the permissible limit which is generally equal to 0.003L. (03 Marks)

(You may use; Deflection at midspan = 5wL⁴ / (384EI) — Simply supported section loaded with a udl
Deflection at tip = wL⁴ / (8EI) — Catilever section loaded with a udl)

v.) Check whether the flexural member is safe against failure due to **shear.** (02 Marks)

vi.) Evaluate the minimum corbal **protrusion length** required to support a transverse beam. (02 Marks)

vii.) Comment on the selection of <u>timber Class</u> and <u>section size</u> of the transverse beam. (03 Marks)

Assuming Strength Class D70 Red Balau timber, check the design adequacy of a structural timber **column** according to BS 5268-1996, using following steps;

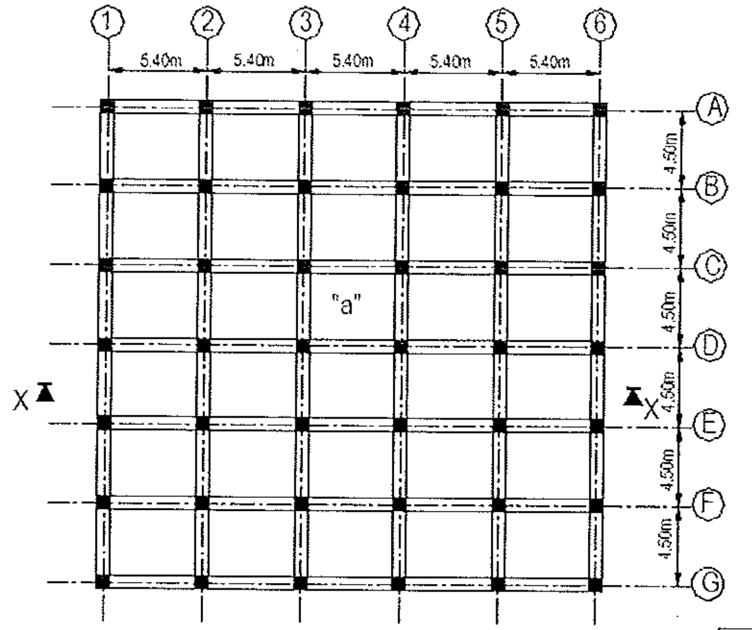
viii.) Evaluate the loading (including moment due to nominal eccentricity) on the column due to **live and dead** loads and check for slenderness limits. (02 Marks)

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

x.) Check the column for combined flexural (due to nominal eccentricity) and compressive stresses. (03 Marks)

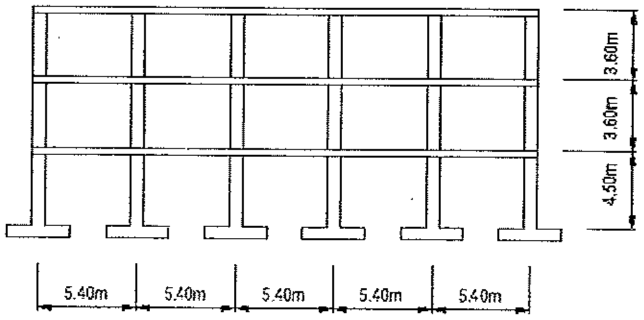
00130

Q4. A typical floor plan and a sectional view of a three storied commercial building is shown in Figure 4. The beams are cast monolithically with the floor slab.



Typical Floor Plan

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	
* Required design charts are provided *	



Section X-X

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

Figure 4

i.) Identify the most critical slab panel (name the gridline numbers on the four edges) 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 slab panel "a" using the bending moment coefficients from the code. Design reinforcements only for this panel to satisfy code requirements and draw a typical plan showing the reinforcement detail for slab panel "a". Indicate curtailment of reinforcements without dimensions. (06 Marks)

iii.) Evaluate the design ultimate load acting on the beam on grid 4, 350x300 mm (you may assume that a 225mm thick masonry wall is supported on top of the beam and the loads transferred to the beam are uniformly distributed along its span) 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 4 using the bending moments computed above. Design the required reinforcements for the beam to resist bending at critical locations and indicate how you would curtail reinforcements in the bending moment diagram. (05 Marks)

v.) Assuming the column at the point of intersection of grids 4 and C (250 x 250) 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. (05 Marks)

Q5.

Figure Q5-a shows a view of pretension PC beam which is proposed to support the RC slab of a pavilion of sport complex.

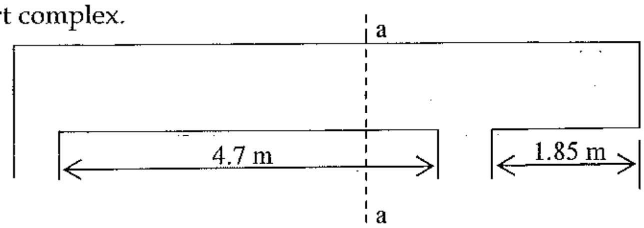


Figure Q5-a – PC Beam

Figure Q5 – b shows the cross section of the beam on section a-a.

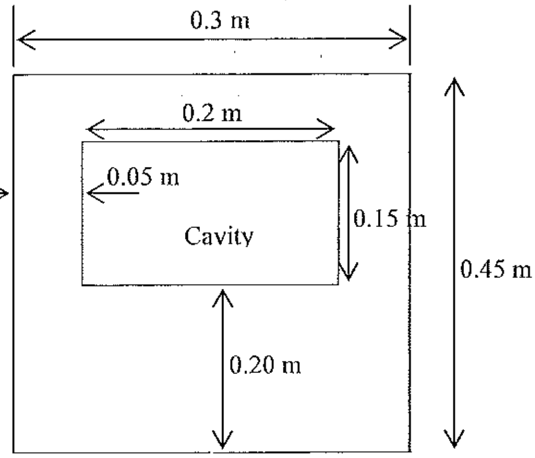


Figure Q5 – b – Cross section on aa

The cross section of the beam is rectangular and with a rectangular cavity. The main purposes of the cavity is reducing the self-weight and install the service ducts.

Carry out following design steps using given data below.

RC Slab Thickness – 150 mm

Column Size – 0.3 m x 0.3 m

Spacing of the beam 3m (Centre to Centre)

Service Class of the member – Class 2

Loads

Unit weight of concrete = 24 kN/m³

Dead load other than self weight = 1.0 kN/m²

Imposed load = 2.5 kN/m²

(Assuming loads to be distributed evenly.)

Strengths

f_{cu} at 28 days = 40 N/mm²

f_{ci} at 7 days (transfer) = 32 N/mm²

Transfer is 7 day after casting

Super strand 5.0 mm dia. tendons

f_{pu} = 1500 N/mm²

(Assume the Mechanical loss – 30 %)

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

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

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

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

i.) Find out Cross Sectional Area and Distance to the center of gravity of given section (02 Marks)

ii.) Show that Second Moment of area I is 0.00212525 m⁴ hence calculate the sectional modulus. (03 Marks)

iii.) Evaluate the dead and imposed loads on the beam at transfer and in-service stages and calculate the critical sagging bending moments at the two instances. (By drawing the BM diagram or any other method.) (04 Marks)

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

v.) Assuming the eccentricity as 0.15 m find a range for Pre-stress force using analytical method. (04 Marks)

vi.) Discuss the advantages and disadvantages of Magnel Diagram method is used to find Pre-stress force range with respect to the method used in answering question v.) (02 Marks)

vii.) Propose suitable tendon arrangement for the section considering the minimum spacing of the tendons as 20 mm. (Maximum Aggregate size. (02 Marks)

viii.)Check the designed tendon arrangement can be used for the supports of the beam. If not suggest the method to improve the tendons. (03 Marks)

ix.) Check the suitability of the section respect to Ultimate Moment capacity. (03 Marks)