00062

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

CEX6332 - Structural Design

FINAL EXAMINATION – 2010/2011

Time Allowed: Four (04) Hours

Date: 2011 - 03 - 30 (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 corner column of a three-storey building is shown in the figure below. The dead loads and imposed loads indicated on each beam are the end reactions from the beams. (consider them as unfactored loads) Beams are connected to the columns with eccentric pin joints.

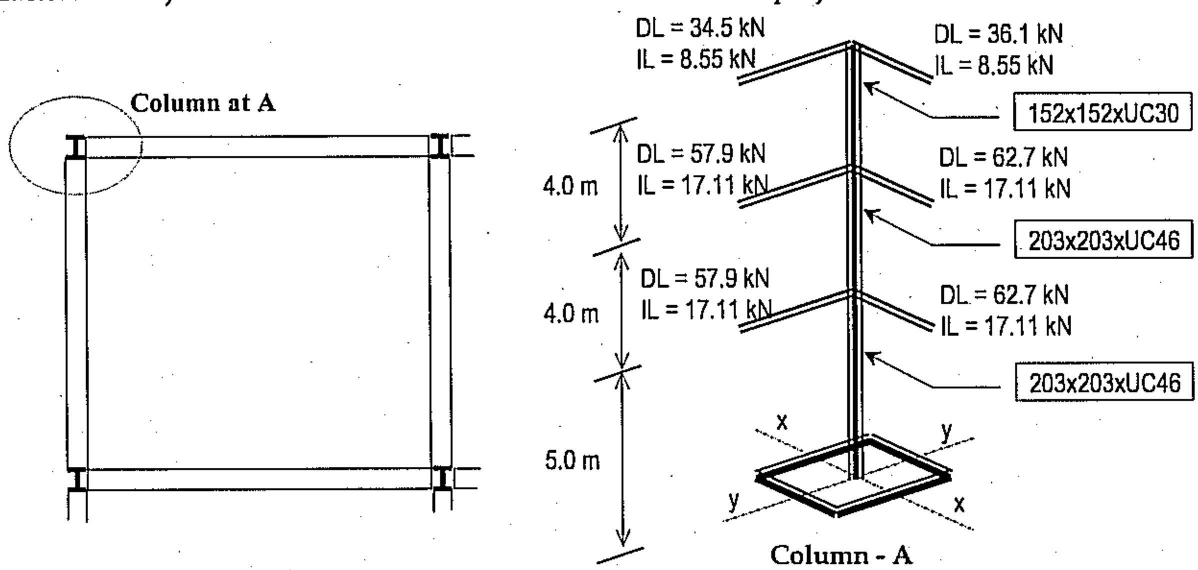


Fig. 1 - Plan & Isometric View of Corner Column

It is suggested to use Universal Column section of 152 x 152 x UC30 of S 275 steel for the portion from third floor to second floor and a Universal Column section of 203 x 203 x UC46 of S 275 steel for the portion from second floor to the base.

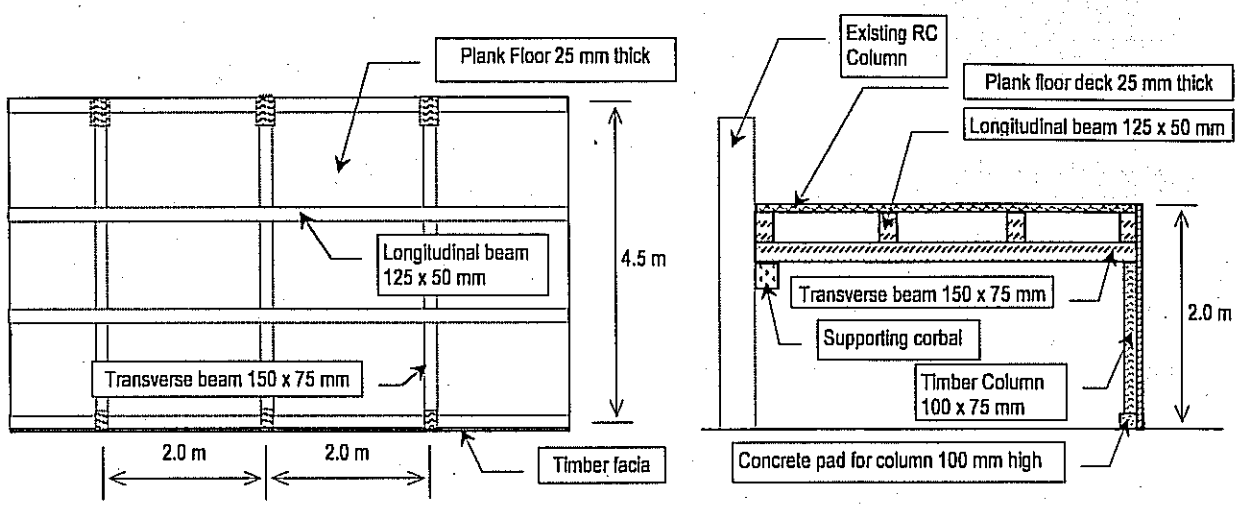
1.) Determine the total dead load, total imposed load, reduced imposed load, bending moments in the column with respect to major axis x-x and minor axis y-y, for the following positions of the column. Assume that the self weight of the column including fire protection is 1.5 kN/m.
a.) just below the 3rd floor lelvel
b.) just above the 2nd floor level
c.) just below the 2nd floor lelvel
e.) just above the 1st floor lelvel
f.) just below the 1st floor lelvel [09 marks]

2.) Check whether the suggested section 152x152 UC30 is adequate to withstand the loading applied on the column from 3rd floor to second floor. [08 marks]

3.) Check whether the suggested section 203x203 UC46 is adequate to withstand the loading applied on the column from 2nd floor to the base. [08 marks]

Q2.

The stage constructed at the far end of the second floor of the Exam Hall no. 03, consistes of a floor in wodden plank decking supported by a timber beam framework as shown in Fig. 2, below. Simply supported transverse timber beams support the longitudinal timber beams connected to the decking. Transverse beams are then supported at front end of the stage by timber columns and in the rear by corbels attached to structural concrete columns. Structural dimensions and sectional sizes are given in the figures. The stage was designed for an imposed load of 1.5 kN/m².



Part Plan of the Timber floor

Cross section of the Stage

Fig. 2 – Plan & a Cross Section of the Stage

Strength Class D40 Teak timber had been used for the fabrication. Dry exposure condtion with medium term loading had been assumed in the original design calculations. You are required to check the design of a critical longitudinal beam and a structural timber column according to BS 5268-1996.

<u>Section A</u> Use the following steps in checking adequacy of a longitudinal beam. You may aasume that longitudinal beams are simply supported.

i.) Evaluate the loading on the beam due to **live and dead** loads. [03 marks]

ii.) Check the proposed beam 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. [03 marks]

iv.) Check whether the **maximum allowable deflection** is within the permissible limit (0.003L). [03 marks]

v.) Check whether the beam is safe against failure due to **shear.** [03 marks]

vi.) Check whether applied **bearing** stresses at supports are within the permissible limit. [03 marks]

<u>Section B</u> For checking a supporting column design, use the following steps.

i.) Evaluate the loading on the column due to **live and dead** loads as a <u>total axial load</u> and a <u>bending moment</u>. (You may neglect the load by the facia.) [04 marks]

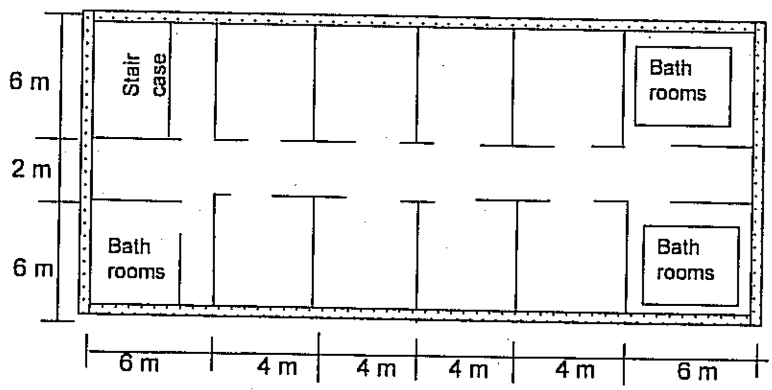
ii.) Compute the applied maximum **compressive** stress in the column and check whether this is within the permissible limit. [03 marks]

iii.) Check the column for combined flexural and compressive stresses. [03 marks]

00062

Q3.
The following structural details are obtained from a three storey hostel in a school. Each floor has eight rooms.

Wall construction
The wall construction is made with bricks of length 200 mm, width 100 mm and height 50 mm. Half brick wall construction is 100 mm, one brick wall is 210 mm and one and half brick wall is 320 mm in size. The wall thickness for the first and second floor with plaster is 0.24 m. The wall thickness for ground floor level with plaster is 0.35 mm.



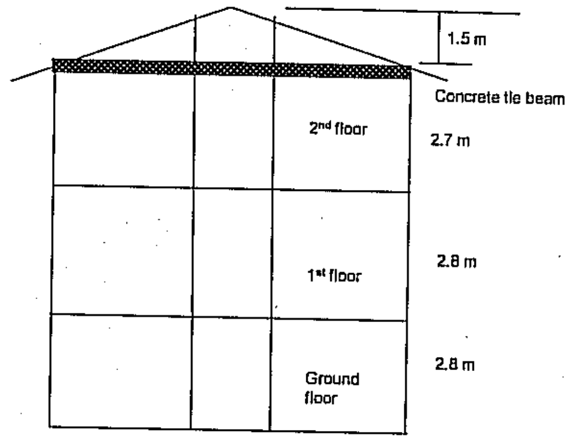


Figure 3 - Plan and the elevation of the building

Loads on the structure;	
Dead load of the Roof	= 0.5 kN/m²
Imposed load on the roof	= 0.25 kN/m²
Imposed load on floors	= 2.0 kN/m²
Dead load on the slab by finishes	= 1.5 kN/m²
** You may neglect the effects of Wind	
Thickness of floor slab	= 150 mm
Storey height (floor to floor)	= 2.7m
Weights of materials	
Unit weight of RC	= 24.0 kN/m³
Unit weight of Masonry	= 18.0 kN/m³
Mortar designation IV	

Building geometry and material conditions;	
Floor to floor clear height	= 2.7 m
Overall length of the building	= 28 m
Width of the building	= 13.5 m
Compressive strength of Brick	=5.0 N/mm2
γ_m	= 3.5
Water absorption ratio	> 12%

i) Evaluate the design load for a typical internal cross wall in the 1st floor. [03 marks]

ii) Determine the maximum eccentricity for the wall at 1st floor level and slenderness ratio. [02 marks]

iii) Hence check whether the typical internal cross wall is satisfactory for compressive load. [06 marks]

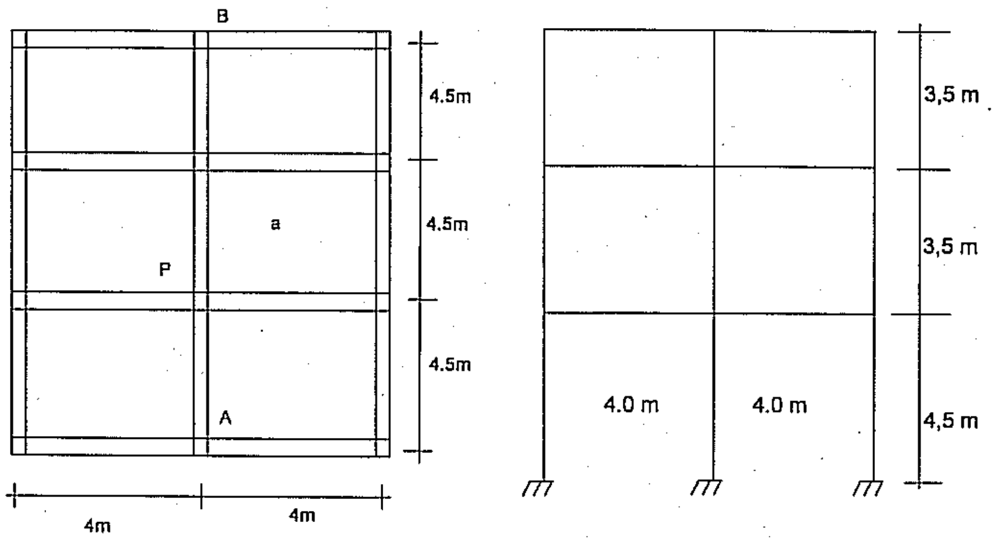
iv) Draw a figure showing the boundary conditions for a 2nd floor external wall. [04 marks]

v) Assuming that the wind pressure is 0.40 kN/m², determine the moment perpendicular to bed joint. [04 marks]

vi) Hence check whether the wall is safe under this wind pressure. Indicate all your assumption very clearly. [06 marks]

Q4.

The upper floor plan of a three storey commercial building is given in Fig. 4. Assume that the beams are to be cast monolithic with the floor slab.



Plan View

Sectional view

Fig. 4 – Plan and a cross section of the three storey building

Loads on the structure;	
Dead load of the Roof	= 1.0 kN/m²
Imposed load on the roof	= 0.8 kN/m²
Imposed load on floors	= 2.0 kN/m²
Dead load on the slab by finishes	= 1.5 kN/m²
** You may neglect the effects of Wind	
Thickness of floor slab	= 160 mm
Storey height (floor to floor)	= 3.5m
Storey height (ground floor to 1st floor)	= 4.5 m
Weights of materials	
Unit weight of RC	= 24.0 kN/m³
Unit weight of Masonry	= 18.0 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
Condition of exposure	= Mild
Center to center dimensions are given for the grid	
Order of floors – Ground, 1st, 2nd, 3rd	
Size of beams 350 x 300 mm	
Size of column 250 x 250 mm	
Nominal cover for reinforcement 20 mm	

a) Considering the following steps, design the slab panel 'a'
   - i) Evaluate the design load on the slab panel a.
   - ii) Evaluate the bending moment on the slab.
   - iii) Find the design steel to the short way mid span of the slab using the BS 8110.

[10 marks]

b) Considering the following steps, design the beam 'AB'
   - i) Evaluate the design load on beam segment AB
   - ii) Using the method provided in BS 8110, determine the bending moment and shear force at location 'P'. Assume the design load is all over the beam.
   - iii) Design the beam when the imposed load is acting all over the beam.

[10 marks]

c) Considering the following steps, design the column at 'P'.
   - i) Evaluate the design load on column P at ground floor level
   - i) Assuming that the column is braced, determine whether the column is slender or short.
   - ii) Hence design the column at ground floor level assuming the moment at top 22 kNm and bottom 10 kNm.

[05 marks]

Q5. 00062

As a general solution for precast floor construction, pretensioned prestressed beam with the cross section shown below has been proposed. Since the beams are to be used inside buildings, mild exposure condition could be adopted in the design. The 'T' shaped beam is to be designed as **simply supported, Class 1, pretensioned with 15.0 m span.** Such beams could be placed side by side with a floor screed to form the floor.

Using the loadings, section in Fig. 5 and material properties given below for this symmetrical prestressed beam, conduct the design checks as outlined below for the **SLS of cracking.**

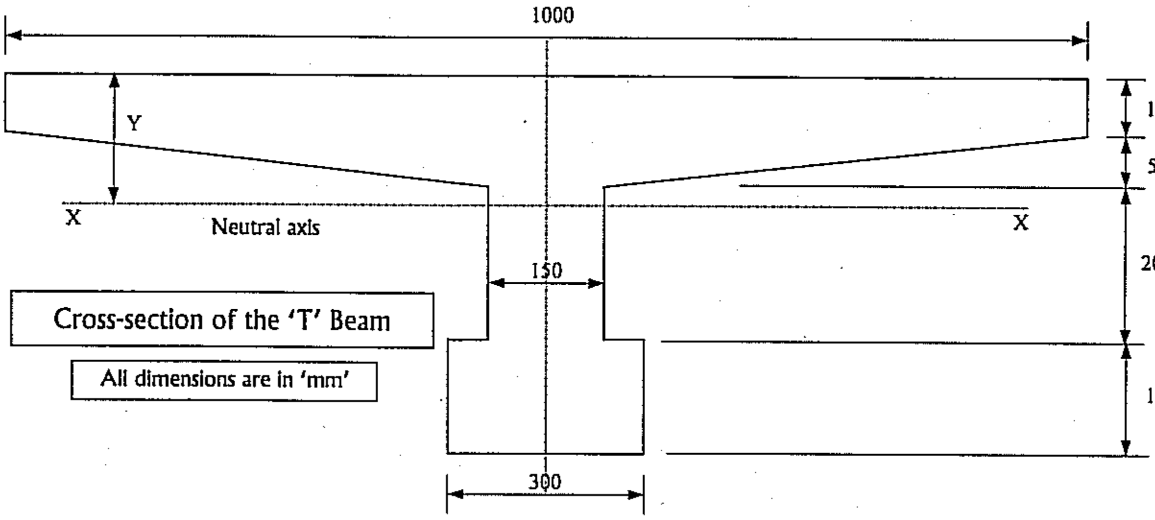


Fig. 5 – Cross section of the prestressed beam

<u>Strengths</u>

f_{cu} at 28 days	= 40 MPa
f_{ci} at 7 days (transfer)	= 25 MPa
Transfer is 7 day after casting	
f_{pu} steel	= 1860 MPa
use Sup. Stra. (11.3 mm) A_s = 75 mm² / tendon	
$f_{pi} = 0.7\, f_{pu}$	

<u>Allowable concrete stresses for class 1 members</u>

<u>at transfer;</u>

f'_{max}	$= 0.5 f_{ci}$
f'_{min}	= - 1.0 MPa

<u>at service;</u>

f_{max}	$= 0.33 f_{cu}$
f_{min}	= 0

<u>Loads</u>

Unit weight of concrete	= 24 kN/m³
Weight of surfacing	= 1.5 kN/m²
Imposed load on the floor	= 2.50 kN/m²

<u>Loss of prestress</u>

at transfer	= 9 %
at service	= 25 %

<u>Concrete section properties</u>

$A_c = 203.75 \times 10^3$ mm²
$I_{xx} = 4.9 \times 10^9$ mm⁴
Y = 172 mm

<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 this prestressed beam along the following steps;

i.) Evaluate the dead and imposed loads on the beam at transfer and in service and calculate the critical bending moments at the two instances. Assume that the beam is kept in the same orientation at casting and in service.

[05 marks]

ii.) Check the adequacy of the section in carrying the stresses at transfer and in service.

[05 marks]

iii.) Determine the range of prestress force required at the mid span of the beam (You may assume eccetricity e = 253 mm for iterations).

[05 marks]

iv.) Suggest the minimum possible number of tendons (and corresponding initial prestress force) and sketch a suitable physical arrangement for them (Assume $f_{pi} = 0.7\ f_{pu}$).

[05 marks]

v.) Check whether the prestress force calculated above allows for same location of tendon centroid at the supports of the beam (In other words check whether straight tendons could be used without debonding). If debonding has to be carried out, evaluate how many tendons should be debonded at the supports so that straight tendons could be used.

[05 marks]