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

CEX6332 – Structural Design

FINAL EXAMINATION - 2007

Time Allowed: Four (04) Hours

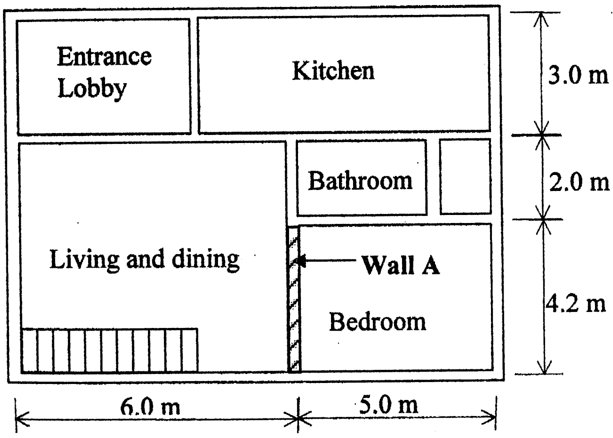
Date: 2008 - 05 - 03 (Saturday) Time: 0930 - 1330 hrs.

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. Masonry Design

Proposed ground floor plan for a domestic dwelling of two stories is shown in the figure. The Structural Engineer who designed the layout of the building wishes to know whether brick walls made out of locally available bricks are suitable as load bearing walls. With the loadings on the wall as given by the Sturctural Engineer, design the 3.0 m high Wall A on the ground floor.

dead load by roof structure	= 3.3 kN/m
dead load by ceiling structure	= 1.1 kN/m
dead load by upper floor slab	= 15.0 kN/m
imposed load by roof structure	= 1.5 kN/m
imposed load by ceiling structure	= 0.2 kN/m
imposed load by upper floor slab	= 12.0 kN/m



Compressive strength of local bricks:
Grade I - 4.5 N/mm²
Grade II - 2.5 N/mm²
Grade III - 1.8 N/mm²
maximum water absorption = 28%

You may also use the following data;

- Normal Manufacturing and Construction controls are applicable
- Assume that the forces due to wind are negligible.
- The wall to be plastered on both sides with 15mm thick plaster (weight = 0.3 kN/m²)
- Both floor heights are 3.0 m each
- Dimensions of locally available bricks: 215 mm x 102.5 mm x 65 mm and with the 10mm mortar joint size changes to 225 mm 112.5 mm x75 mm, structural thickness of the wall is 225 mm.

i.) Determine the usability of locally available bricks to construct the Wall A assuming a suitable mortar designation.

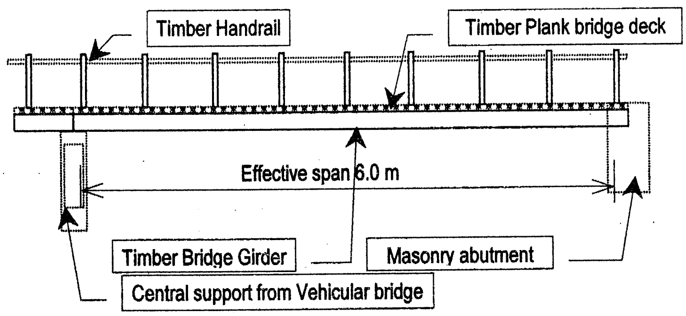
(20 Marks)

ii.) Compute the magnitude of shear resistance of Wall A in the longitudinal direction.

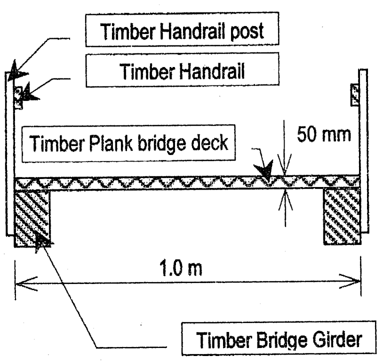
(05 Marks)

Q2. Timber Design

Q2 - Part A



Elevation of the Bridge



Cross section of the Bridge

To fulfill the long felt need for a pedestrian bridge between Central Campus and CRC of the OUSL, one proposal was a structural Timber alternative. Since 12.0 m space over the canal is difficult to be bridged by a single span of timber bridge, centrally supported two span bridge had been proposed. The central support is to be provided in the form of a cantilevering frame from the existing vehicular bridge. Structurally, each span of the bridge is to consist of two simply supported timber girders overlain with timber planks to make the deck as shown in the figures.

Effective span of a timber girder is to be 6.0 m and the two girders have to share the loading on the bridge. 'Balau' timber beam of section 150 mm x 100 mm is to be considered for the bridge girders. Girders are simply supported on masonry abutment on one end and on a central support bracket at the other end with 150 mm of bearing length each, as shown in the figures.

Design a bridge girder along the steps given below, assuming the following;

- The critical live loading comes from 1.25 kN/m^2 uniformly distributed load on the deck.
- Deck planks are rigidly fixed on to the beams.
- All timber is to be 'Balau', with density 9.9 kN/m^3
- The bridge to be subject to wet exposure conditions
- Loads are medium term loads.
- Maximum allowable deflection for a girder is 50 mm at mid span.

i.) Evaluate the loading on a timber girder due to **live and dead** loads.

(02 marks)

ii.) Check the proposed girder against **lateral stability** criteria.

(02 marks)

iii.) Compute the applied **bending stress** at the critical section of the girder and check whether this is within the permissible limit.

(02 marks)

iv.) Check whether the **maximum allowable deflection** is within the permissible limit.
You may use the following deflection values at mid span of a simply supported beam loaded with an udl;
Deflection due to Bending = $5wL^4/(384EI)$
Deflection due to Shear = $3wL^2/(20GA)$ ... ($G = E/16$)

(03 marks)

v.) Check whether the beam is safe against failure due to **shear.**

(03 marks)

vi.) Check whether applied **bearing stress** is within the permissible limit. Assume that wane is not permitted at bearing area.

(03 marks)

Q2 - Part B

The table given below shows the description of two elements of the above bridge supporting bracket (in the form of a truss), AB and BE, which will only deflect in its own plane.

Element	Length (m)	Magnitude of force (kN)	Magnitude of Moment (kNm)
AB	2.5	22 (tensile)	3.0
BE	2.8	28 (compressive)	4.0

Timber members of strength class 8 (SC 8) with cross sectional dimensions of 150 mm x 75 mm are proposed for both elements. The frame is subject to wet exposure conditions. All loads acting on the frame are of medium term duration.

i.) Determine the adequacy of member AB to carry the combined force and moment.

(05 marks)

ii.) Determine the adequacy of member BE to carry the combined force and moment.

(05 marks)

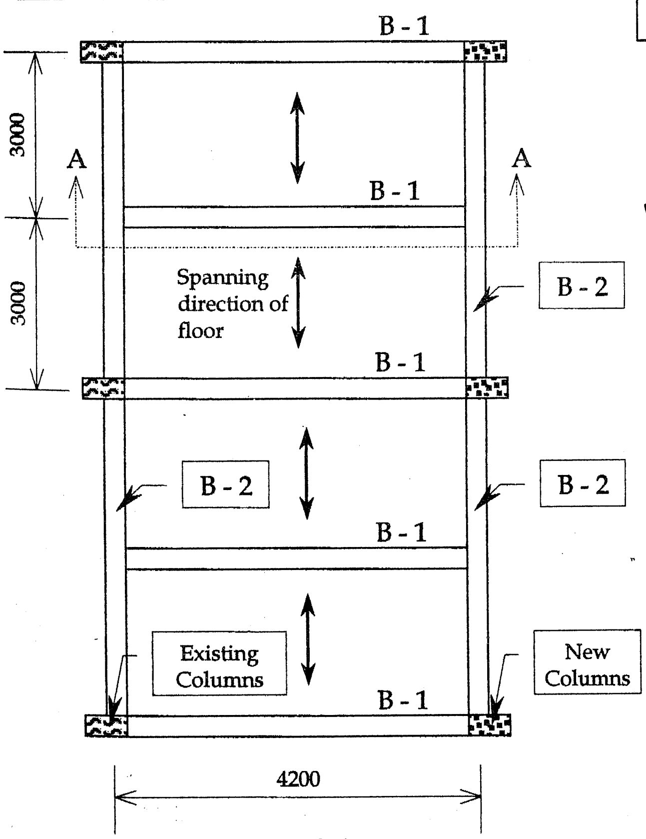
Q3. Steel Design

The layout plan of the proposed mezzanine floor for the Civil Engineering lab in Block 1 is shown in the figure below.with cross section A-A.

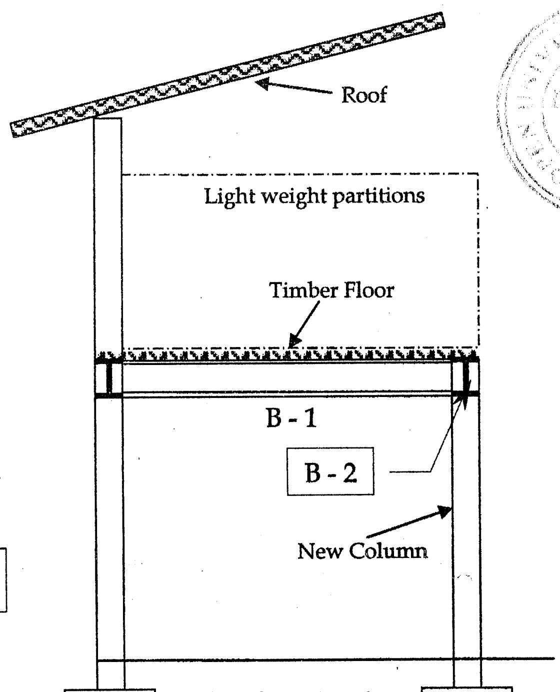
Show that 203 x 133 x 30 kg Universal beams (I beams) of Grade S 275 steel can be used as secondary beam B-1, as per BS 5950.

Note:
The timber flooring is not considered to be suitable for a top flange restraint to the beams, which should be considered as 'unrestrained'.

Loading	
Dead Load (floor + light weight partitions)	- 1.0 kN/m^2
Live loading (floor))	- 2.5 kN/m^2



Plan of the Mezzanine Floor

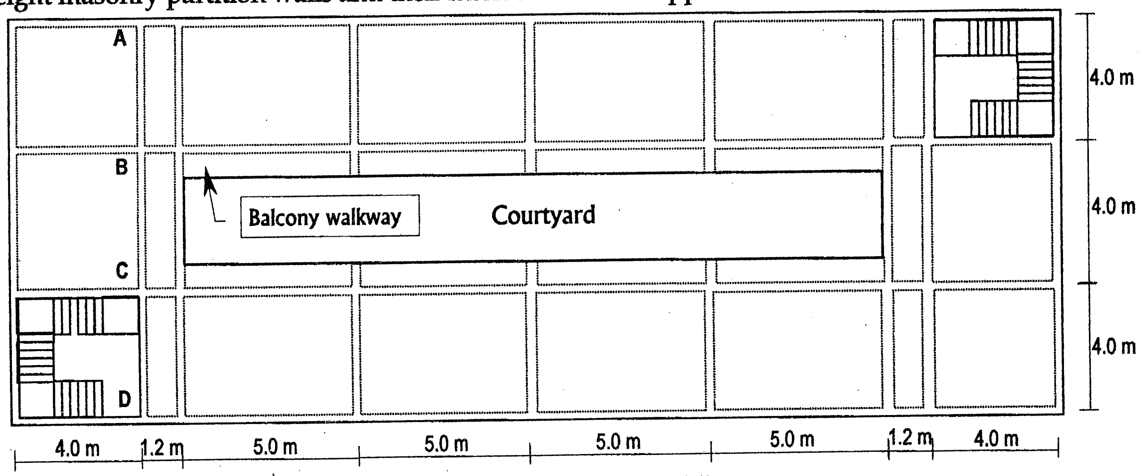


Section A - A

(25 marks)

Q4. Reinforced Concrete Design

The design team for a dormitory decided on a structure in the form of a four storied building. Plan of the proposed building is given in the figure below. All grid beams support 200 mm thick full height masonry partition walls and their intersections are supported on columns.



Plan of the proposed building

Loads on the structure;	
Dead load of the Roof	= 1.5 kN/m^2
Imposed load on the roof	= 0.8 kN/m^2
Imposed load on floors	= 3.5 kN/m^2
** You may neglect the effects of Wind	
Thickness of floor slab	= 125 mm
Storey height (floor to floor)	= 3.0 m
Weights of materials	
Unit weight of RC	= 24.0 kN/m^3
Unit weight of Masonry	= 18.0 kN/m^3

Strength of materials;	
Grade of concrete	= 30
Characteristic strength of steel	
Main r/f	= 460 N/mm^2
Shear r/f	= 250 N/mm^2
Condition of exposure	= Mild
Center to center dimensions are given for the grid	
Order of floors – Ground, 1st, 2nd, 3rd	
Service stress = Design Stress / 1.5	
* Required design charts are provided *	

Using the above data, design the selected elements of the structure along following steps;

i.) Identify the critical slab panels for a upper floor slab and check whether a thickness of 125 mm is **adequate** for these panels based on **deflection criterion** only. You need not do any modifications. (You may assume that the slabs are continuous with the supporting beams & a suitable value for M/bd^2 for the expected loading).

(05 marks)

ii.) Evaluate the Characteristic and Design loads and tabulate Design **Bending moments** and **Shear forces** at **Critical** sections of the RC beam ABC (350 x 300 mm), assuming it to be continuous over the spans. (You may assume that the loads transferred to the beam are uniformly distributed along its span. Also, you may use the table with simplified factors given in the code. Neglect the effect of non symmetrical loading due to staircase.)

(05 marks)

iii.) Design reinforcement for the two spans of the above beam at critical sections to resist bending and shear forces. (Assume 16 mm bars for main reinforcement and 6 mm MS bars for shear reinforcement.) Curtail the beam reinforcement using simplified rules and sketch elevation and necessary cross sections in compliance with the standard method of detailing.

(06 marks)

iv.) Assuming the column at B (250 x 250), is **unbraced** and no bending moments are transferred from beams framing in to the column, evaluate **Critical Axial Load**, and the slenderness condition of the column segment between 2nd floor and 3rd floor.

(04 marks)

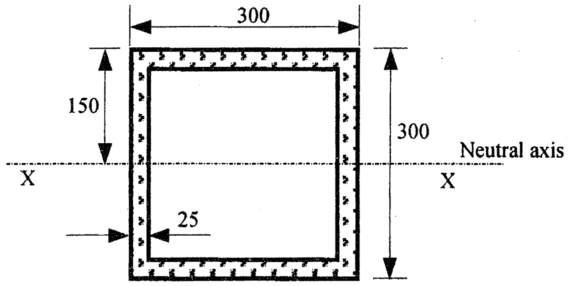
v.) Evaluate the **Design axial load** and generated **Bending moments** (if any), and design reinforcement for the column segment in section v.). Sketch elevation and required cross sections using the standard method of detailing.

(05 marks)

Q5. Prestressed Concrete Design

The cross section of a square hollow extruded prestressed box girder of a section 300 x 300 mm (external) with 25 mm wall thickness (using chip concrete) is shown in the diagram. It is a Pretensioned, Class 2, simply supported beam with a span of 10.0 m. In order to prevent damages or failure of girders due to mis-orienting, the prestressing tendons have to be symmetrically distributed about both orthogonal axes (In other words, eccentricity for prestressing should be zero). Material properties and the loading on the beam are as follows;

All dimensions are in 'mm'



Strengths

f_{cu} at 28 days	= 50 MPa
f_{ci} at 7 days (transfer)	= 35 MPa
Transfer is 7 day after casting	
f_{pu} steel (5 mm dia. tendons)	= 1860 MPa

Allowable concrete stresses for class 2 members

at transfer;	
f'_{max}	= 17.5 MPa
f'_{min}	= - 2.7 MPa
at service;	
f_{max}	= 16.7 MPa
f_{min}	= - 3.2 MPa

Loads

Unit weight of concrete	= 24 kN/m³
Imposed load on the girder (Uniformly distributed)	= 2.0 kN/m

Loss of prestress

at transfer	= 07 %
at service	= 22 %

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, conduct design checks on 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.

(05 marks)

ii.) Evaluate sectional properties and check the adequacy of the section in carrying the stresses at transfer and in service.

(04 marks)

iii.) Determine the range of prestressing force required at the mid span of the beam, assuming that the tendons are symmetrically distributed about both horizontal and vertical axes of the girder.

(08 marks)

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

(04 marks)

v.) Comment on the possible requirement of de bonding of tendons in this girder.

(04 marks)