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

CEX6332 – Structural Design

FINAL EXAMINATION - 2008

Time Allowed: Four (04) Hours

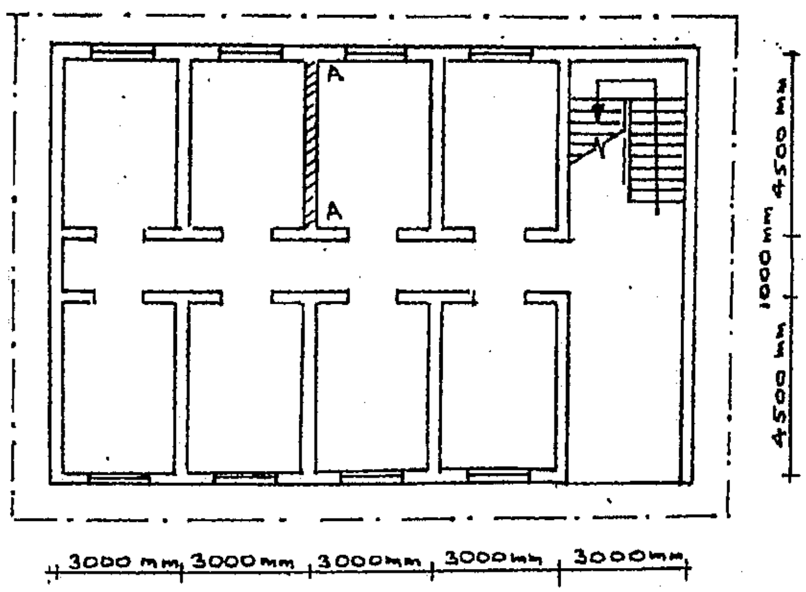
Date: 2009 - 04 - 07 (Tuesday) Time: 0930 - 1330 hrs.

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.

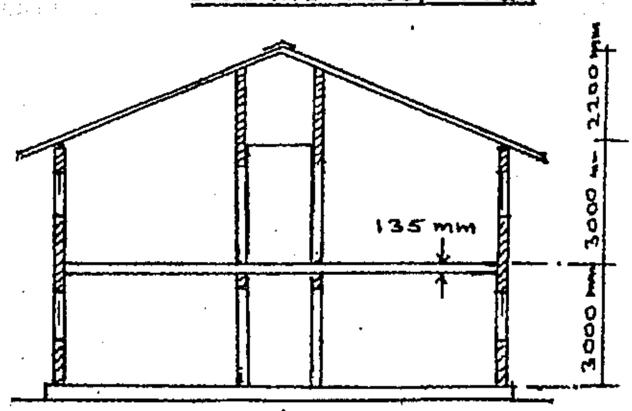
Q1. Masonry Design

a.) Sketch three types of wall arrangements that can be used in load bearing masonry structures. (05 marks)

b.) The past students association of your school wishes to donate a two storied class room building for your school. The architectural design which was done by one of the past students is shown in Figure 1. You and one of your colleagues were asked to study the possibility of utilizing a load bearing brick masonry structure for the proposed building. Your colleague had already determined the loads acting on wall AA and you have been asked to design the walls.



Ground Floor Plan



Section

<u>Loads acting on ground floor wall AA</u>

Dead load from roof	= 2.0 kN/m
Imposed load from roof	= 1.5 kN/m
Dead load from first floor wall	= 21.5 kN/m
Dead load from the right hand side slab	= 4.5 kN/m
Imposed load from the right hand side slab	= 3.0 kN/m
Dead load from the left hand side slab	= 4.5 kN/m
Imposed load from the left hand side slab	= 3.0 kN/m
Self weight of ground floor wall AA	= 14.0 kN/m

You may also use the following data

- Dimension of locally available bricks = 215 mm x 102.5mm x 65 mm
- Mortar joint size = 10 mm
- Structural thickness of the walls = 215 mm
- Maximum water absorption =28%
- Normal manufacturing and Construction controls are applicable.
- Assume that the forces due to wind are negligible.

b1.) Determine the ultimate design loads and relevant eccentricities for different load combinations for wall AA.

(07 marks)

b2.) Identity the critical case and recommended a suitable brick and mortar designation to build the ground floor wall AA.

(07 marks)

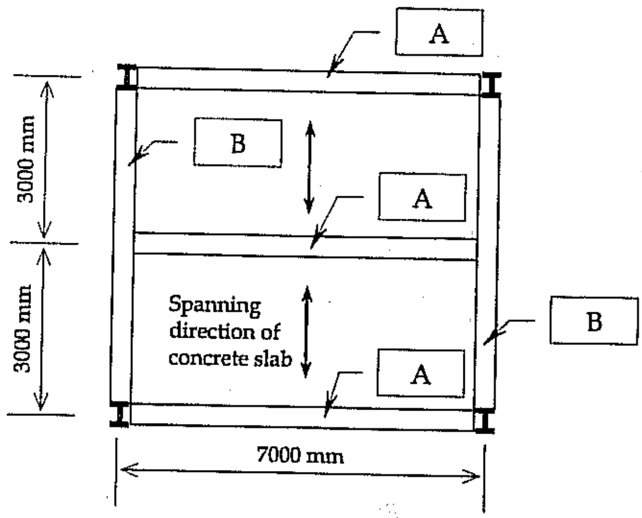
b3.) Compute the magnitude of shear resistance of wall AA in the longitudinal direction.

(06 marks)

Q2. Steel Design

The part plan of the floor steel for a laboratory building is shown in the figure below.

Characteristic Loading
Dead Load (g_k) including concrete slab and steelwork - 4.8 kN/m^2
Imposed loading (q_k) including allowance for vibration - 10.0 kN/m^2



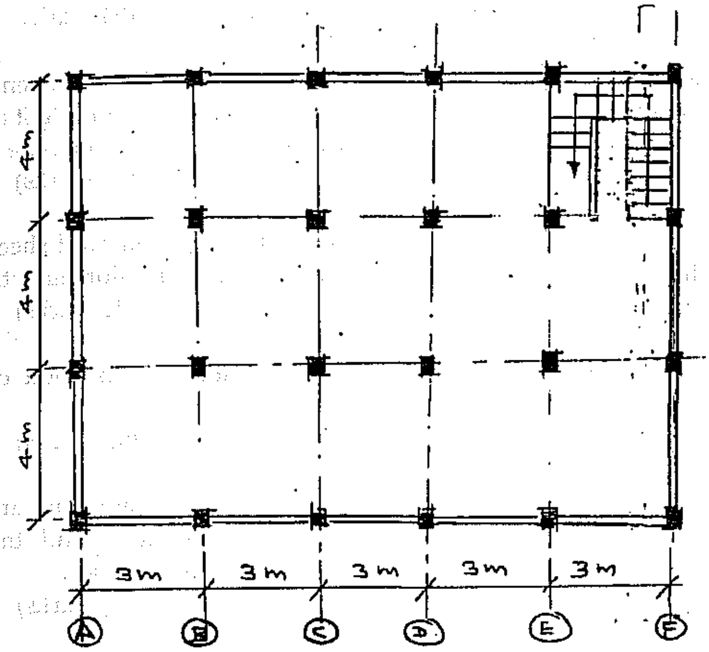
Design the universal steel beam 'A', using grade S275 steel, assuming that the top flanges are fully restrained by the concrete slab. In the process consider the most critically loaded beam and follow following steps;

i.) Calculate design load.
ii.) Calculate maximum bending moment & shear force acting on the beam.
iii.) Calculate the minimum required plastic modulus of the section.
iv.) Select a suitable beam section.
v.) Identify the class of the beam section.
vi.) Carryout the shear check for the beam section.
vii.) Carryout the check for bending moment.
viii.) Carryout the deflection check assuming that the deflection limit of the beam is 'span/500'. (maximum deflection of a simply supported beam under uniformly distributed load is given by '$5wL^4/384EI$').

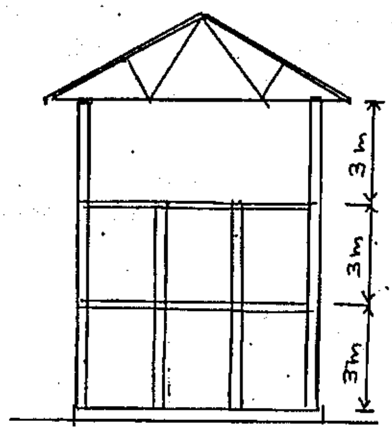
(25 marks)

Q3. Reinforced Concrete Design

Typical upper floor plan of a 3 storied office building is shown in the figure.



PLAN



SECTION

There is a 200 mm thick masonry wall along the perimeter. All internal partitioning is done using light weight materials.

Loads on the structure

Dead load of the roof	= 1.5 kN/m^2
Imposed load on the roof	= 0.75 kN/m^2
Dead loads on floors due to portioning	=1.0 kN/m^2
Imposed load on floors	= 3 kN/m^2
Thickness of the floor slabs	= 125 mm
Storey height (floor to floor)	= 3.0 m

Weight of Materials

Unit weight of RC	= 24 kN/m^3
Unit weight of masonry	= 18 kN/m^3

Strength of materials

Grade of concrete		= 30
Characteristic strength of steel	Main r/f	= 460 N/ mm^2
	Shear r/f	= 460 N/ mm^2

Other parameters

Condition of exposure = Mild

Centre to centre dimensions are given for the grid

Order of floors – Ground, 1st, 2nd

Service Stress = Design Stress / 1.5 (for footing design)

Required design charts are provided

i.) Identify the critical slab panel in the 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 modification. (You may assume that to slabs are continuous with the supporting beams and a suitable value for M/bd^2 for the expected loading).

(03 marks)

ii.) Identify the most critical slab panel for a upper flour slab and design it using the approach given in BS 8110. In the design process you should check for satisfying the Ultimate Limit State of Flexure and Serviceability Limit state of Durability, Fire resistance, Cracking, and Deflection.

(04 marks)

iii.) Evaluate the characteristic and Design Loads and tabulate the Design Bending Moments and Shear Forces at Critical sections of the RC beam (300mm x 350 mm) along grid C, assuming it to be continuous over the spans. (You may use the table with simplified factors given in the code.)

(03 marks)

iv.) Design reinforced for the above beam at critical sections to resist bending moment and sheer forces. (Assume 16 mm bars for main reinforcement and 6mm MS bars for shear reinforcement.)

(04 marks)

v.) Sketch elevation and necessary cross sections in compliance with the standard method of detailing.

(03 marks)

vi.) Assuming the column at C2 (300mm x 300mm) 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 the ground floor and the first floor.

(04 marks)

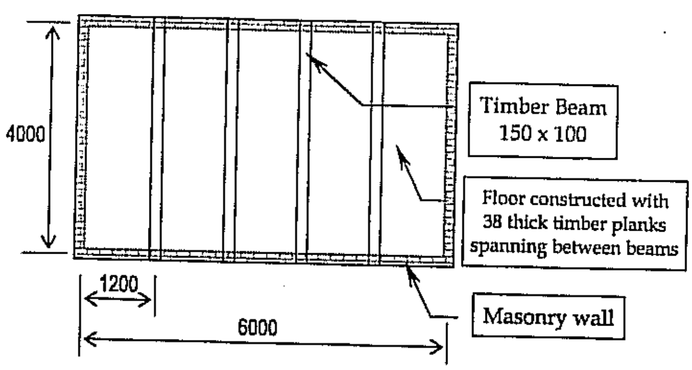
vii.) Evaluate the Design axial load and generated Bending Moments (if any) and design reinforced for the column segment in section (vi). Sketch elevation and required cross sections using the standard method of detailing.

(04 marks)

Q4. Timber Design

Q4 - Part A

An upper floor is to be constructed over an existing rectangular room. The room had been constructed with 225 thick masonry walls, as shown in the figure. The upper floor deck is to be constructed in timber.



Plan of the proposed timber floor

Timber	- Balau
Strength Class	- D70/SC8
Dead loads on the floor:	
Weight of finishes	- 0.3 kN/m^2
Unit weight of planks	- 8.0 kN/m^3
Unit weight of Balau	- 10.8 kN/m^3
Imposed loads on the floor:	
under normal service	- 1.5 kN/m^2

Assume:
* Exposure condition is wet.
* lateral support at the ends of the beams due to embedment in the masonry walls.
* Loads are medium term.
* Maximum allowable deflection for the beam is 25 mm at mid span.

All dimensions are in 'mm'

The floor layout consists of timber planks supported by timber beams which are simply supported on existing masonry walls as shown .Effective span of a timber beam is 4.0 m and they are spaced at 1.2 m.

i.) Evaluate the loading on the beam due to live and dead loads.

(02 marks)

ii.) Check the proposed beam against lateral stability criteria.

(02 marks)

iii.) Compute the applied **bending stress** at the critical section 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 $= 3wL^2 / (20GA)$

(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 permitted at bearing area.

(03 marks)

Q1 - Part B

The table given below shows the description of two elements; AB and BE of a cantilevering Timber truss supporting an out-door canopy. The two elements can be assumed to only deflect in the plane of the truss.

Element	Length (m)	Magnitude of force (kN)	Magnitude of Moment (kNm)
AB	2.5	22 (tensile)	3.2
BE	2.8	28 (compressive)	3.8

Timber members of strength class 9 (SC 9) 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 tensile force and moment.

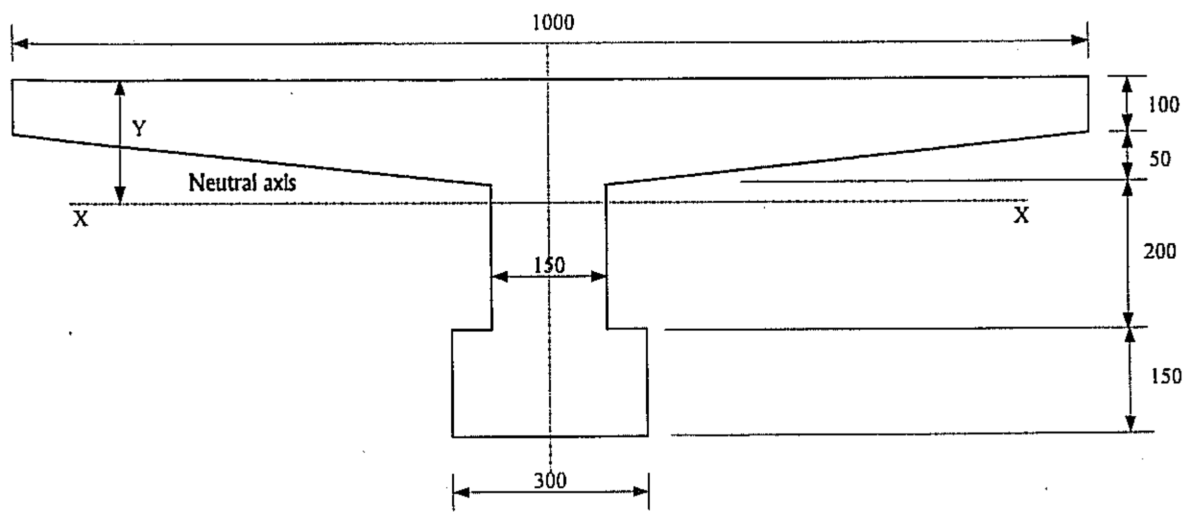
(05 marks)

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

(05 marks)

Q5. Prestressed Concrete Design

Wide top flanged beams are required for an auditorium floor with a large span. To satisfy the required span, the Design Engineer decided on a prestressed concrete beam. Cross section of the proposed beam is shown in the diagram below. The beam is to span 15.0 m under simply supported condition. Based on the structural and economic considerations the beam is to be a Class 2 Pretensioned beam.



Based on preliminary calculations the Design Engineer has selected the above cross section and the following, material properties and probable loading on the floor applicable to the proposed prestressed beam;

Strengths
f_{cu} at 28 days = 50 MPa
f_{ci} at 7 days (transfer) = 35 MPa
Transfer is 7 day after casting
f_{pu} Super strand 11.3 mm dia. tendons (Area 75 mm^2) = 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
Weight of concrete = 24 kN/m^3
Imposed load = 4.0 kN/m^2
(loads are distributed evenly.)

Loss of prestress
at transfer = 07 %
at service = 22 %

Concrete section properties
A_c = 204 x 10^3 mm^2
I_{xx} = 4.9 x 10^9 mm^4
y_{na} = 172 mm

You may use following inequalities (in standard notation)

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

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

Using above data, design the beam along the following steps;

i.) Evaluate the section properties (A, I, Z_t & Z_b) of the beam and check against the given values where applicable.

(03 marks)

ii.) 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.).

(03 marks)

iii.) Check the adequacy of the section in carrying the stresses at **Transfer** and in **Service**.

(03 marks)

iv.) Determine the range of prestress force required at the mid span of the beam, assuming that tendons are to be placed at an eccentricity of 217 mm below neutral axis.

(08 marks)

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

(03 marks)

vi.) 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 de-bonding). If de-bonding has to be carried out, evaluate how many tendons should be de-bonded at the supports of the slab segments so that straight tendons could be used.

(05 marks)