THE OPEN UNIVERSITY OF SRI LANKA
Department of Civil Engineering
Diploma in Technology (Civil)/Bachelor of Technology (Civil) - Level 4

CEX 4231 - Structural Analysis and Design II

FINAL EXAMINATION - 2007

Time Allowed: Three (03) Hours

Date: 2008 - 05 - 03 (Saturday) Time: 0930 - 1230 hrs.

Answer Five (05) questions with at least Two (02) questions from each section.
Necessary extracts from BS 8110 will be provided separately.

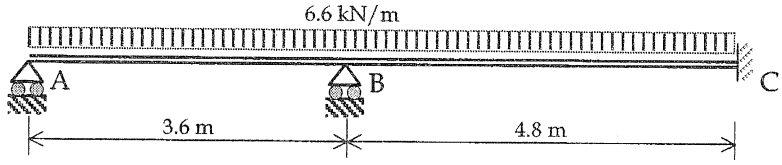
Section A - Structural Analysis

Q1.

a.) Draw a small sketch and explain what the First Theorem of Moment Area Method States.

(04 marks)

b.) Analyse the continuous beam shown in figure below using Theorem of Three Moments and draw the Bending Moment diagram. (Support B sinks by 6.35 mm below the level of A & C, 'EI' is constant, E = 20 kN/mm², I = 33,200 cm⁴).



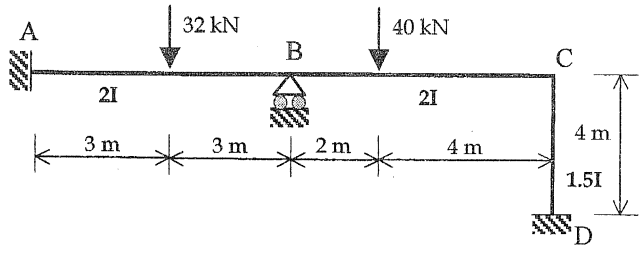
(16 marks)

Q2.

a.) Describe briefly how you would use Slope Deflection Method to analyse an unbraced statically indeterminate frame that is subjected to sway displacements.

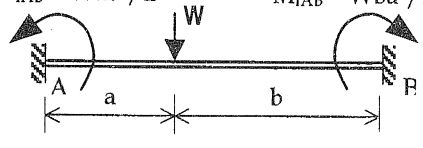
(05 marks)

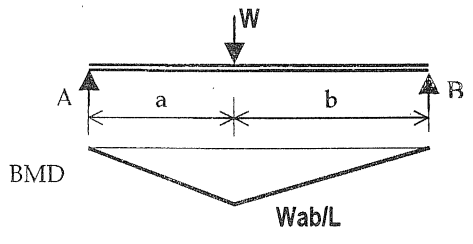
b.) Analyse the frame shown below using Slope Deflection Method and sketch the Bending Moment diagram (I values are indicated near the members).



You may use the following

$M_{fAB} = Wab^2/L^2$ $M_{fAB} = Wba^2/L^2$





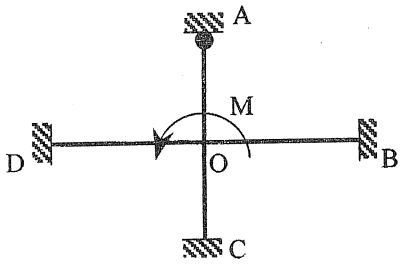
(15 marks)

Q3.

a.) Members OA, OB, OC & OD are rigidly connected at O. Ends B, C, & D are fixed. End A is hinged as shown in the figure. A moment M is applied at joint O. Show that the moment induced in member OA is given by;

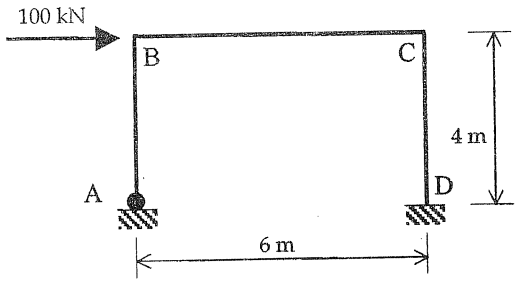
$M_{OA} = \frac{3}{4}K_{OA}\, M/(\frac{3}{4}K_{OA}+K_{OB}+K_{OC}+K_{OD})$

where, K_{OA}, K_{OB}, K_{OC} & K_{OD} are stiffnesses of OA, OB, OC & OD, respectively.



(04 marks)

b.) Analyse the frame shown below using Moment Distribution Method and sketch the bending moment diagram (EI = Constant).



(16 marks)

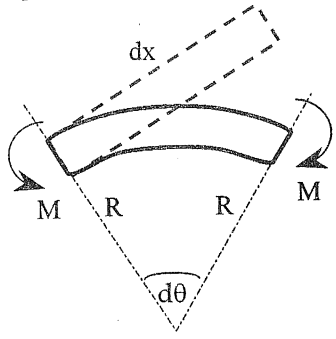
Q4.

a.) State Castigliano's two theorems on strain energy.

(04 marks)

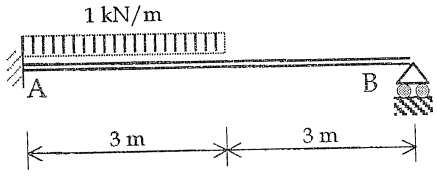
b.) A small element of a bar, length dx, is subjected to a constant bending moment M causing it to bend into an arc of radius R subtending an angle dθ at the centre. Show that the strain energy resulting from bending is given by;

$\delta U_B = M^2 dx/(2EI)$



(04 marks)

c.) A propped cantilever beam AB is loaded as shown below. Using Castigliano's Theorem, determine the reaction at support B and bending moment at A. (EI = Constant).



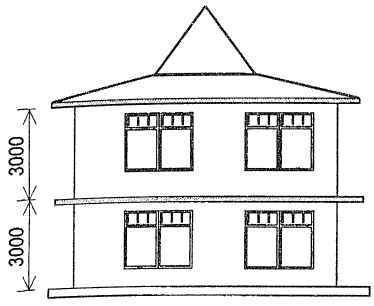
(12 marks)

Section B - Design of Structures

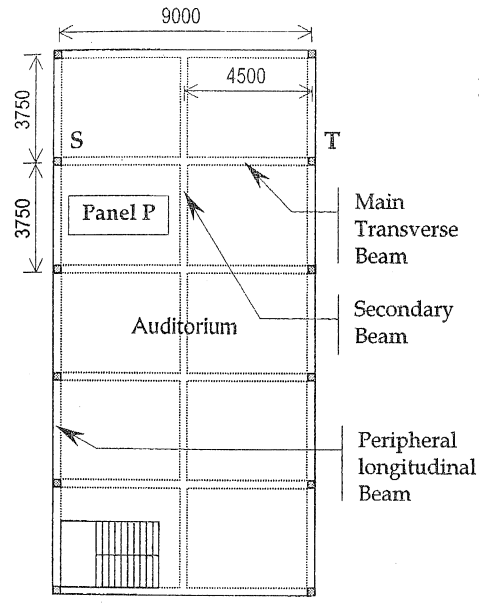
All designs are to be done according to the recommendations of the Standard BS 8110. (Handout provided)
For questions Q5 Q6 & Q7 use the data and parameters pertaining to the following structure.

A temple in Mahanuwara area requires an Auditorium building for the conduct of Sermons and 'Dayaka Sabha' meetings. The Designs Engineer in charge of this project has decided on two storied layout for the building as given in the diagram below, in consultation with the Chief Priest of the temple.

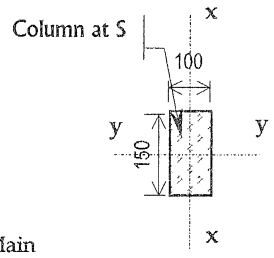
The Designs Engineer further decided that for durability and structural integrity, the building should be a reinforced concrete framed structure. The outside walls are to be made with masonry block work. To maintain a clear line of sight form all locations inside the upper and lower floor Auditoriums, no internal columns were placed in the halls. Under this condition, to reduce spans of the slab panels, secondary beams were provided between primary beams.



Side Elevation



Plan of the upper floor slab



Material Specifications:

Concrete grade	- 30
Grade of Steel fy HYS	- 460 N/mm²
MS	- 250 N/mm²
Unit weight of concrete	- 24 kN/m³
Unit weight of block Masonry	- 18 kN/m³
Dead load by roof (incl. ceiling)	- 1.8 kN/m²
Imposed load on roof	- 0.6 kN/m²
Weight of finishes on slab	- 1.0 kN/m²
Imposed load on slab	- 2.5 kN/m²
Nominal cover for reinforcement	- 20 mm

* Use only necessary values *

General Notes:

* Dotted lines indicate beams cast integral with slabs.
* Grids are spaces equally.
* Marked intersection points of beams are supported on 150 x 100 mm RC columns
* Transverse beams (ex. ST) are of 500 x 300 mm & peripheral longitudinal beams and secondary beams are 300 x 200 mm cross-section
* Internal beams do not carry any walls on top
* Slabs are to be 125 mm thick
* Roof is entirely supported by the 12 columns.
* Block work peripheral walls are 100 mm thick

Q5.

Using the given data, design the **'Panel P'** of the upper floor slab, assuming all loads to be uniformly distributed. Follow the steps below for the design.

i.) Calculate the **Characteristic** (dead load & imposed load due to normal loading) and the **Design** load on the panel as area loads.

(02 marks)

ii.) Identify the spanning condition, end conditions of the slab and evaluate appropriate mid span and over the support moments. (You may use the factors from table in the handout)

(05 marks)

iii.) Design reinforcement against ULS of flexure to resist bending at mid spans and over supports for the slab panel. (Assume 10 mm HYS for main reinforcement)

(05 marks)

iv.) Check against the SLS of deflection for the slab panel and if necessary, only propose suitable modifications.

(04 marks)

v.) Sketch the reinforcement on a plan and one cross section of the slab panel using the **Standard Method of Detailing** (not necessary to indicate curtailment lengths)

(04 marks)

Q6.

Using data pertaining to the structure given above, design the beam ST (there are no walls on the beam), along following steps (assume that the effective beam section is rectangular);

i.) Evaluate the characteristic **dead and imposed** loads transferred on to the beam and the maximum design load as linear loads. (Assume that loads on the beam are uniformly distributed & neglect the point load created at mid span by secondary beams)

(02 marks)

ii.) Calculate the design bending moments and shear forces at mid span & support sections of the beam and sketch the **Bending moment** and **Shear force** diagrams. (**Assume** that the fixity moment at the ends of the beam ST due to connection to columns is $wl^2/24$, where 'w' is the design udl on the beam.)

(05 marks)

iii.) Design the reinforcement against ULS of flexure at the critical sections of the beam. (You may assume 20 mm dia. HYS steel main tensile reinforcement & 6 mm dia. MS shear stirrups.)

(04 marks)

iv.) Check for ULS of shear at critical sections of the beam and provide shear reinforcement if necessary. (You may assume two or four legged 6 mm MS shear stirrups.)

(05 marks)

v.) Check against SLS of deflection of the beam based on conditions at the mid span. Only propose modifications if this check fails.

(04 marks)

Q7. Using data pertaining to the structure given above, design the Column segment from upper floor to roof at location S, along the following steps.

i.) Determine the **type** of the column segment (braced/unbraced), about its two principle axes of bending and state reasons for your conclusions.

(03 marks)

ii.) Evaluate the **effective heights**, and **slenderness ratios** of the column segment and determine the slenderness condition (slender/short), about both principle axes. Clearly state reasons for your answers.

(04 marks)

iii.) Evaluate the **characteristic loads** and calculate **design axial load** and **design bending moments** (if any) acting on the column segment. You should pay due consideration to the moments created by eccentricity of loading and possibility of slenderness buckling in evaluating these values.

(05 marks)

iv.) Design the column main reinforcement against ULSs of **compression & flexure** and the tie requirement against SLS of cracking, assuming a symmetrical arrangement of reinforcement. (Assume 12 mm HYS for main steel & 6 mm MS for ties)

(04 marks)

v.) Produce a detailed reinforcement **sketch** with column in elevation and required cross sections. You should adopt the standard method of detailing.

(04 marks)