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

093

FINAL EXAMINATION - 2008

Time Allowed: Three (03) Hours

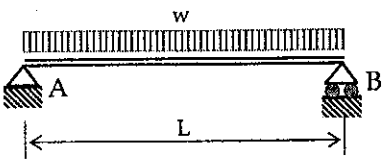
Date: 2009 - 03 - 25 (Wednesday) Time: 1400 - 1700 hrs.

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

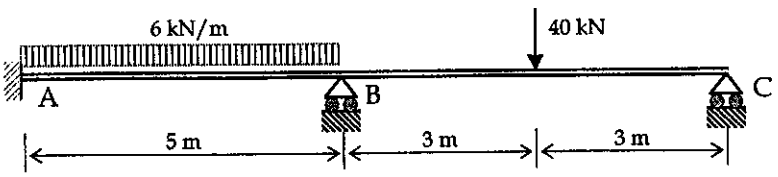
Section A - Structural Analysis

Q1.

a.) Using Moment Area Method, show that the maximum deflection in the simply supported beam shown in the diagram below is $5wL^4/384EI$. (06 marks)



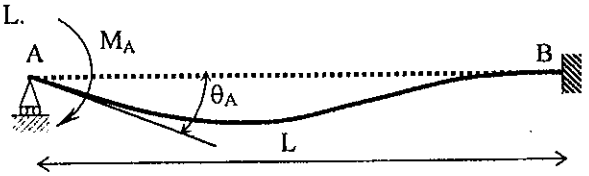
b.) Analyse the continuous beam shown in figure below using Three Moments Theorem Method and draw Bending Moment diagram. ($E = 200{,}000\ N/mm^2$, $I_{AB} = 9x10^6\ mm^4$, $I_{BC} = 12x10^6\ mm^4$)



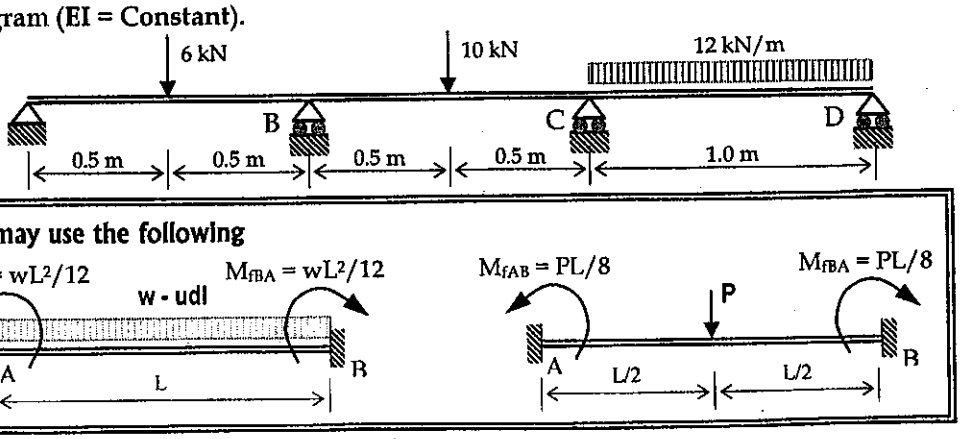
(14 marks)

Q2.

a.) Show that when moment M is applied at A for the beam shown in the diagram below, the moment induced at support B will be M/2. Also show that if the rotation at A is θ_A then bending moment at A, $M_A = 4EI\theta_A/L$. (08 marks)



b.) Analyse the frame shown below using **Slope Deflection Method** and sketch the Bending Moment diagram **(EI = Constant)**.

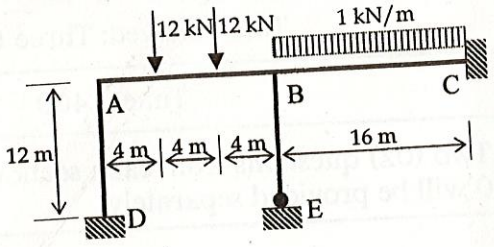


(15 marks)

Q3.

a.) When a moment M_A is applied at A for the beam shown below, if the rotation at A is θ_A, show that $M_A = 3EI\theta_A/L$. (05 marks)

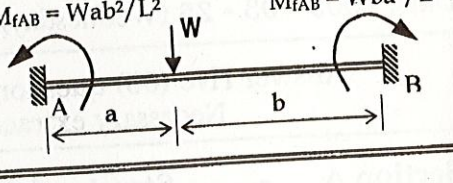
b.) Analyse the frame shown below using Moment Distribution Method and draw the bending moment diagram (EI = Constant).



You may use the following

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

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



(15 marks)

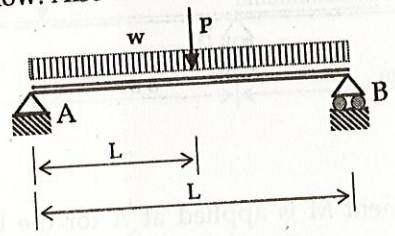
Q4.

a.) State the Principle of Superposition. (02 marks)

b.) State Betti's theorem. (02 marks)

c.) State Castigliano's two theorems on strain energy. (04 marks)

d.) Using Castigliano's theorems, determine the maximum vertical displacement of the simply supported beam shown below. Also determine the rotation at support B.



(12 marks)

Section B - Design of Structures

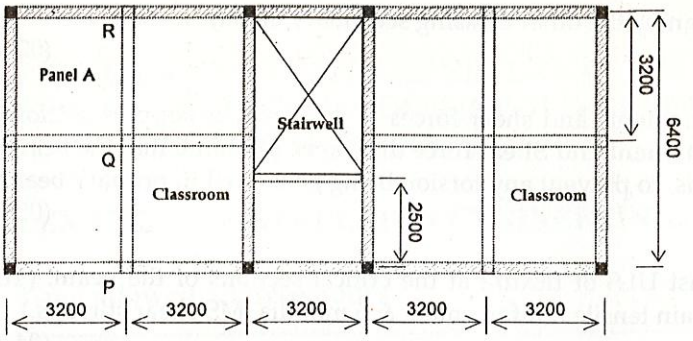
All designs are to be done according to the recommendations of the Standard BS 8110. (Handout provided)
For questions Q5 Q6 & Q7 use the data and parameters pertaining to the following structure.

The plan and elevation of the structure shown in the next page relate to a proposed structural layo of a eight classroom four storied building for urban schools, where ground bearing capacity conditions a favourable. The Design Engineer in charge has decided on a reinforced concrete framed structural layout the building. The roof is to be a timber structure clad by tera-cota roofing tiles.

Following material properties and parameters are to be applicable to the structure;

Material Properties:		
Concrete grade		- C30
Grade of Steel fy	HT steel	- 460 N/mm²
	MS	- 250 N/mm²
Allowable bearing capacity of soil		- 250 kN/m²

Loads & Structural Parameters:	
Unit weight of concrete	- 24 kN/m³
Unit weight of block walls	- 16 kN/m³
Dead load by floor finishes	- 0.5 kN/m²
Dead load by the roof	- 1.5 kN/m²
Imposed load on floors	- 2.5 kN/m²
Nominal cover for reinforcement- 20 mm	



Plan of an upper floor

Front elevation of School Building

Notes:

* All walls are to be of 150 mm thick hollow block masonry.
* Founding depth to be 900 mm.
* Upper floor slabs are to be 112 mm thick.
* Beams monolithic with the upper floor slab are to be cast over all walls.
* Hatched beams on the plan indicate walls constructed over them.
* All Primary beams are to be 500 x 225 section.
* Secondary beam PQR is to be 450 x 225 section.
* Column positions are as indicated by dark squares on the plan.
* Columns are to be 225 mm square.
* Since walls are constructed over each other for lower and upper floors, wall loads may be assumed to be transferred directly down without going through the concrete frame structure
* All footings are to be square individual footings 300 mm depth, capable of resisting moments from columns.

All Dimensions are in 'mm'

Q5.

Design the **'Panel A'** of the upper floor slab, assuming all loads as uniformly distributed. Follow the steps below, for the design.

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

(02 marks)

ii.) Identify the <u>spanning condition,</u> <u>end conditions</u> 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, <u>only propose</u> suitable modifications.

(04 marks)

v.) <u>Sketch</u> 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 secondary beam **PQR** (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 <u>linear</u> loads. (Assume that loads on the beam are uniformly distributed & <u>neglect</u>

the point load created at mid span by the other crossing secondary beam) (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 beam PQR is simply supported at the two ends, to prevent any torsion being generated in primary beams.) (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 <u>two or four</u> legged 6 mm MS shear stirrups.) (05 marks)

v.) Check against SLS of deflection of the beam based on conditions at the mid span. <u>Only</u> propose modifications if this check fails. (04 marks)

Q7.

Using data pertaining to the structure given above, design the **Column segment** from <u>foundation</u> to <u>first floor</u> at **corner column of the 'Panel A'**, 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 may assume that no moments are transferred to the column segment by primary beams connected to it). However, 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 <u>main reinforcement</u> against ULSs of **compression** & **flexure** and the <u>requirement</u> 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 section You should adopt the standard method of detailing. (04 marks)