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

092

CEX6332 – Structural Design

FINAL EXAMINATION - 2009

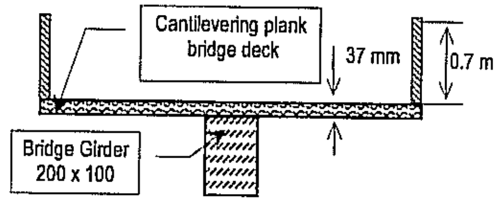
Time Allowed: Four (04) Hours

Date: 2010 - 03 - 31 (Wednesday) Time: 0930 - 1330 hrs.

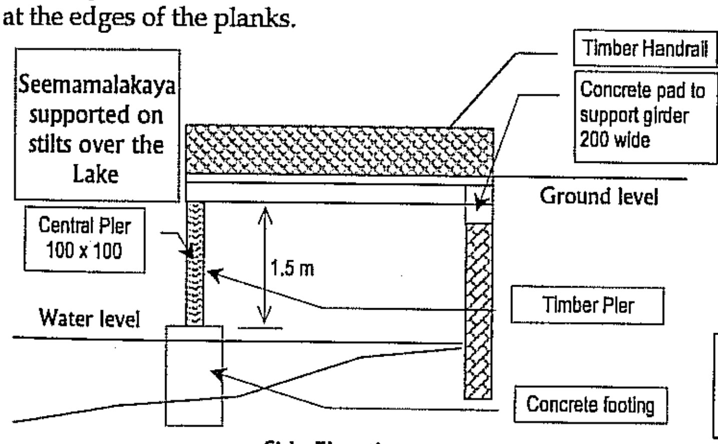
Paper consists of five (05) questions. Answer any four (04) questions.
You may use the booklet named "Extracts From Relevant Standards" provided to you with the course material, which also contain concrete design charts & steel sectional properties
You may assume and state reasonable values for any factors not provided.

Q1. Timber Design

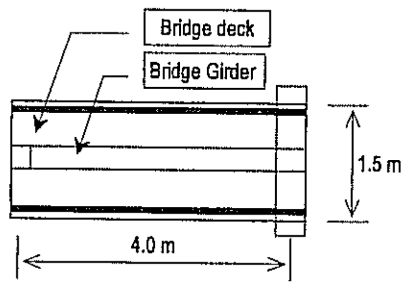
Access to a "Seemamalakaya" constructed in the Bolgoda Lake is to be provided by a timber bridge for aesthetic reasons. Simply supported timber bridge girder is to be supported on a concrete pad at the bank side of the lake and on the end of a timber pier at the Seemamalakaya side. Cantilevering plank deck is screwed on to the central girder and timber latticed handrails are fixed at the edges of the planks.



Cross section of the Bridge



Side Elevation



Plan of the Walk-way Bridge

Loads
Imposed load on the deck = 3.0 kN/m^2
Weight of a hand-rail = 0.2 kN/m

Assuming that the Strength Class of available timber is D50, environmental conditions to be **wet exposure** and **medium term loading**, check the design of the bridge girder and the central pier according to BS 5268.

Section A Use following steps in checking adequacy of the bridge girder.

i.) Evaluate the loading on the beam due to **dead and live** loads and check against **lateral stability** criteria.

(03 marks)

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

(03 marks)

iii.) Check whether the **maximum allowable deflection** is within the permissible limit (0.003L).

(03 marks)

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

(03 marks)

v.) Check whether applied **bearing stress** is within the permissible limit.

(03 marks)

Section B Use following steps in checking the adequacy of the pier.

i.) Evaluate the loading on the pier due to **dead & live** loads.

(03 marks)

ii.) Compute the applied maximum **compressive** stress in the pier and check whether this is within the permissible limit.

(03 marks)

iii.) Check the pier for combined flexural and compressive stresses.

(04 marks)

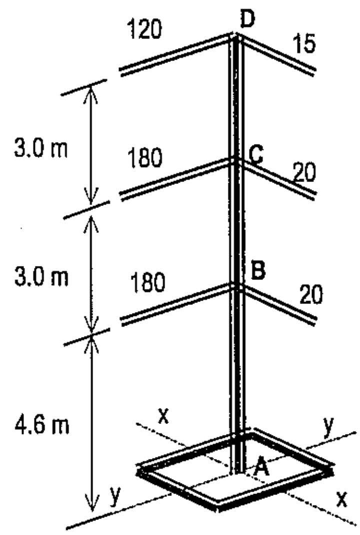
Q2. Steel Design

A corner column of a three-storey building is shown in the figure below. The design loads indicated in kN on each beam are the end reactions from beams. Beams are connected to the column with eccentric pin-joints. Assuming a grade 43 steel Universal Column (UC) section (H – section) 203 x 203 of adequate weight, determine the bending moments in the column with respect to major axis x-x and minor axis y-y, just above and just below the first floor level (connection B).

(10 marks)

Using simplified approach check whether the assumed column section AB can withstand the applied loads. If not, design a suitable section. (Section properties for standard sizes of H sections are provided at the end of the paper)

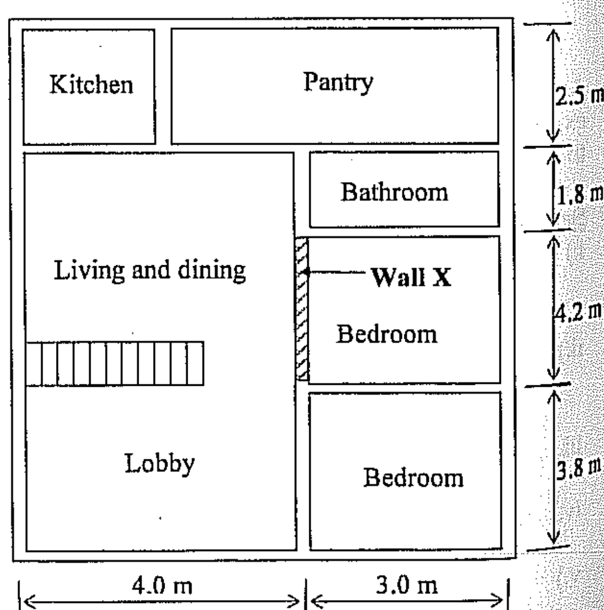
(15 marks)



Q3. Masonry Design

A typical floor plan for a circuit bungalow is shown in the figure below. The building is to be two stories. The Chief Structural Engineer wishes to look into the possibility of utilizing a load bearing brick masonry structure for the proposed building. He particularly wants to know whether brick walls made out of locally available bricks could stand the given loading.

As a member of the design team you have been entrusted with the design the wall X on the ground floor which is 3.0 m high. Another team mate had analysed the structural loads and had provided you with the list below;



Typical Floor Plan

dead load due to roof	= 3.50 kN/m
imposed load due to roof	= 1.75 kN/m
dead load due to ceiling	= 0.90 kN/m
imposed load due to ceiling	= 0.80 kN/m
dead load due to slab	= 14.0 kN/m
imposed load due to slab	= 10.5 kN/m

The standard size locally available bricks will be used with 10mm motor joints
Density of brickwork is 2300 kg/m^3
The weight of the 15mm thick plaster is 0.3 kN/m^2

- The wall should be plastered on both sides
- Manufacturing and Construction controls are normal
- The effects due to wind are negligible
- 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
- Compression strength of locally available bricks units:
  - Grade I 4.8 N/m^2
  - Grade II 2.8 N/m^2
  - Grade III 2.0 N/m^2
- For all grades maximum water absorption is 28%

i.) Determine whether locally available bricks could be used to construct the wall assuming a suitable mortar designation.

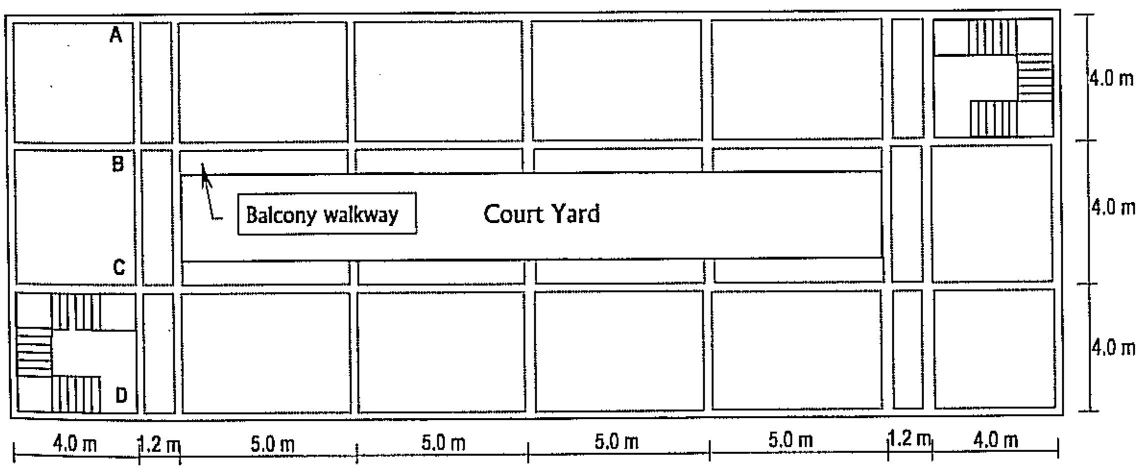
(20 Marks)

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

(05 Marks)

Q4. Reinforced Concrete Design

A dormitory building for the staff of the University of Ruhuna is proposed to be built. Consultancy for the building project was undertaken by the Department of Civil Engineering at the OUSL through CERC. The design team decided on an economical, functional and aesthetically pleasing 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 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).

(04 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.)

(04 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.)

(04 marks)

iv.) Curtail the beam reinforcement using simplified rules and sketch elevation and necessary cross sections in compliance with the standard method of detailing.

(02 marks)

v.) 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**.

(03 marks)

vi.) 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.

(04 marks)

vii.) **Square RC Pad Footings** have been decided to support columns. If the size of the square footing for the column at **B** is 1500 x 1500 x 300(thick) mm, estimate the required **Allowable Bearing Capacity** of the foundation soil. (Assume that the ground floor does not transfer any load to the footing.)

(04 marks)

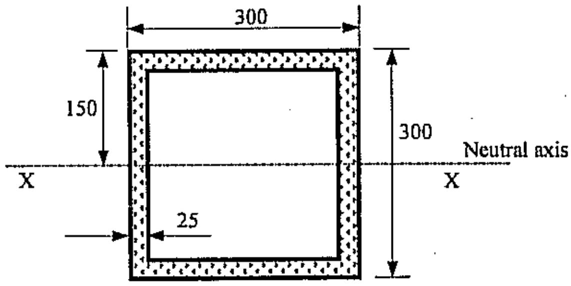
Q5. Prestressed Concrete Design

Advances in concrete extrusion technology and possibility of producing high strength concretes with very good workability and flow characteristics coupled with quick setting properties has made small dimension concrete box girders possible. This type of sections is especially useful for large span structures with relatively low imposed loads such as sign board structures erected over highways. Typically such structures are fabricated using steel. However, based on the above mentioned technology, Prestressed Concrete box girders can be used to substitute conventional steel girders with economy and durability.

Typically required span for use over highways in this country is 10.0 m and extruded prestressed box girders can be produced in prestressing yards. Design a box girder against the serviceability limit state of cracking, with given specifications along following steps.

The cross section would be 300 x 300 mm (external) square hollow with 25 mm wall thickness (using chip concrete). It has to be Pretensioned, Class 2, simply supported beam with a simply supported 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). Proposed section for the prestressed beam, 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

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

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

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

Using above data, 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)