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

00121

CEX6332 – Structural Design

FINAL EXAMINATION – 2011/2012

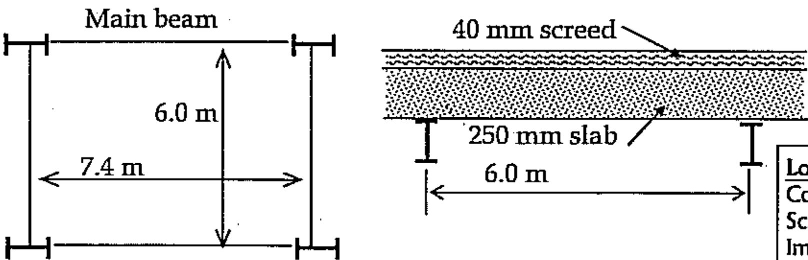
Time Allowed: Four (04) Hours

Date: 2012 - 03 - 21 (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.

a.) A steel beam supporting concrete floor slab is shown in the Fig. 1(a) below. It is suggested to use a universal beam 533X92UB of grade 275 steel for the main beam.



Loading:	
Concrete	= 23.7 kN/m³
Screed (40 mm)	= 0.9 kN/m²
Imposed load	= 5.0 kN/m²

Fig. 1(a)

i. Calculate the dead load (including self weight) and imposed load acting on the main beam.
ii. Calculate the ultimate (factored) load acting on the main beam.
iii. Determine the maximum ultimate bending moment and shear force acting on the beam.
iv. Check the shear capacity of the above suggested beam section
v. Check for the moment capacity of the above beam section. You may assume that the concrete slab provides full restraint to the compression flange of the beam and therefore you need not consider lateral torsional buckling.
vi. Check whether the maximum deflection of the beam is within the allowable limits

(12 marks)

b.) A braced column 4.5 m long is subjected to the factored end loads and moments about the X-X axis, as shown in the Fig. 1(b) below. The X-X axis as, shown in the figure below. The column is held in position but only partially restrained in direction at the ends. Carry out the local capacity check and the over all buckling check to confirm that a universal column section of 203X203 UC52 of Grade 275 steel is adequate to withstand the applied loads.

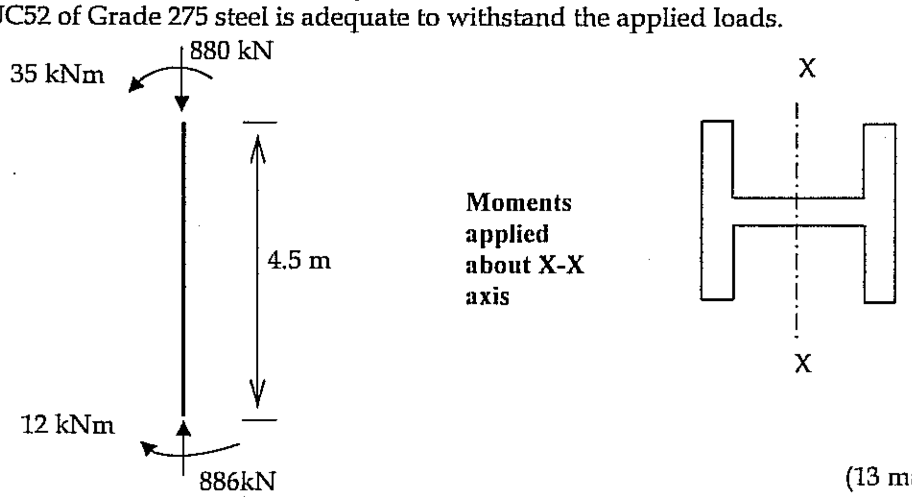


Fig. 1(b)

(13 marks)

Q2.

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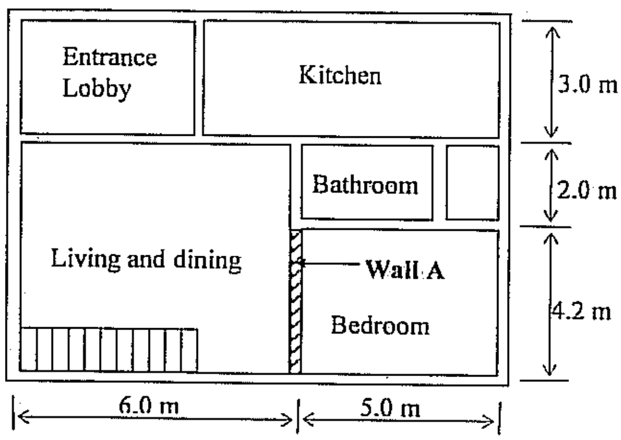
Proposed ground floor plan for a domestic dwelling of <u>two</u> stories is shown in the figure. The Structural Engineer who designed the layout of the building wishes to know whether brick walls made out of locally available bricks are suitable as load bearing walls. With the loadings on the wall as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

Material Properties:
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.

Loading:

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

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)

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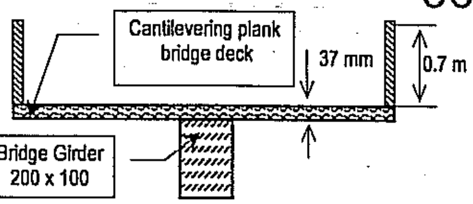
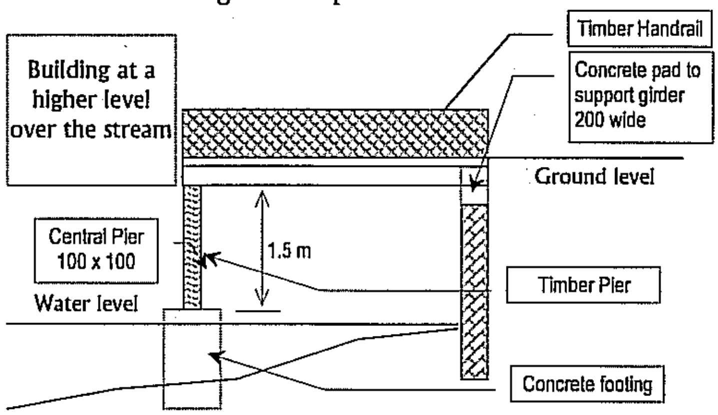
Q3.

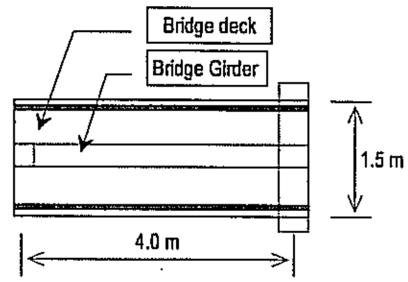
A timber bridge is to be constructed over a stream to gain access to an elevated building. Simply supported timber bridge girder is to be supported on a concrete pad at the bank side of the stream and on the end of a timber pier at the building side. Cantilevering plank deck is screwed on to the central 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)

Q4. 00121

Fig. 4 depicts a typical upper floor plan of a three storied commercial building intended to house small retail stores. Reinforced concrete framed structural system is to be adopted with infill walls out of 100 mm thick block masonry to seperate stores. Beam grid is to be supported on columns at intersections except the 1500 mm cantilevering beam extension supporting the corridor.

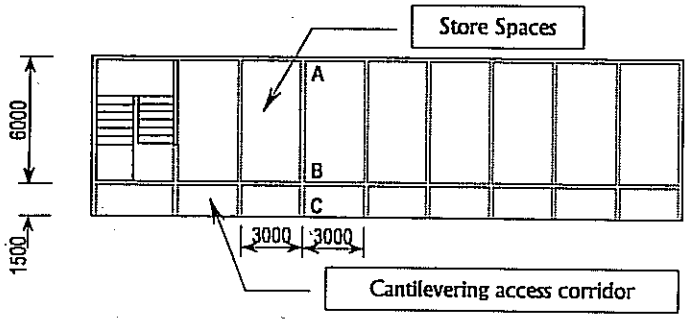


Fig. 4 - Upper Floor Plan of the proposed building

Loads on the structure;

Dead load of the Roof	= 1.5 kN/m²
Imposed load on the roof	= neglect
Imposed load on floors	= 3.0 kN/m²

** 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/m³
Unit weight of Masonry	= 18.0 kN/m³

Strength of materials;

Grade of concrete		= 30
Characteristic strength of steel	Main r/f	= 460 N/mm²
	Shear r/f	= 250 N/mm²

Other parameters;

Condition of exposure = Mild
Center to center 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
All Dimensions are in 'mm'

Follow the steps given below;

i.) Identify the different slab panels in the upper floor slab (except in the stairwell area) and check the adequacy of 125 mm thickness for each of these panels based on the criterion for SLS deflection only. You <u>need not</u> 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.) Identify the most critical slab panel for a upper floor slab and design it using the approach given in BS8110. In the design process you should check for satisfying the **Ultimate Limit State** of Flexure and **Serviceability Limit States** of Durability, Fire resistance, Cracking and Deflection.
(05 marks)

iii.) Evaluate the Characteristic and Design loads and tabulate Design **Bending moments** and Shear forces at **Critical sections** of the reinforced concrete transverse beam ABC (450 x 300 mm). (You may assume that beam is simply supported at A & B with a cantilevered end at C and the loads transferred to the beam are uniformly distributed along its span.
(05 marks)

iv.) Design reinforcement for the two spans of the above beam at critical sections to satisfy ULS flexure and ULS shear. (Assume 20 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.
(05 marks)

v.) Assuming the column at B (250 x 250), is **unbraced** and <u>no</u> bending moments are transferred from beams framing in to the column, evaluate the slenderness condition, the **Design axial load** and generated **Bending moments** (if any), and design reinforcement against **ULS compression** & **flexure** for the column segment between **1st floor** and **2nd floor**. Sketch elevation and required cross sections using the standard method of detailing.
(05 marks)

Q5. 00121

As an alteranative to concrete T girders for overpasses in expressway construction in Sri Lanka prestresses concrete box girders are both economical and light weight. Since concrete extrusion technology allows casting of such box girders using high strength concretes with very good workability and flow characteristics coupled with quick setting properties, this type of girders could be cast at prestressing yards and transported to required locations.

Typically required span for such box girders would be 20.0 m. You are required to design a bridge box girder loaded with an equivalent udl against the serviceability limit state of cracking, with given specifications along the indicated steps. The cross section would be 900 x 900 mm (external) square hollow with 75 mm wall thickness. It has to be Pretensioned, Class 2, beam with a simply supported span of 20.0 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;

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 = 1860 MPa
(Super Strand 12.9 mm dia. Tendons A_s = 100 mm^2)

Allowable concrete stresses for Class 2 members
at transfer;
f'_{max} = $0.50\, f_{ci}$
f'_{min} = $0.45\, \sqrt{f_{ci}}$
at service;
f_{max} = $0.33\, f_{cu}$
f_{min} = $0.45\, \sqrt{f_{cu}}$

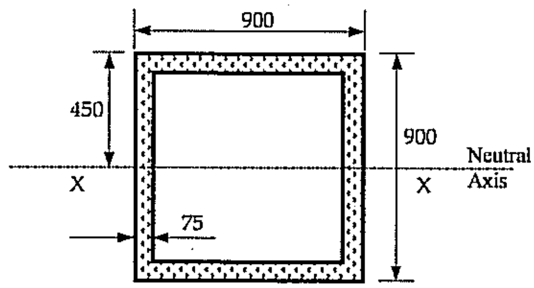


Fig. 5 - Cross section of the Prestressed Beam

Following inequalities based on limiting concrete stresses (in standard notation) could be used for calculations

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

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

Loads
Unit weight of concrete = 24 kN/m^3
Imposed load on beam = 4.0 kN/m
(Uniformly distributed)

Loss of prestress
at transfer = 10 %
at service = 25 %

Using above data, design 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. Assume that the beam is kept in the same orientation at casting and in service. [05 marks]

ii.) Check the adequacy of the section in carrying the stresses at transfer and in service. [05 marks]

iii.) Determine the range of prestress force required at the mid span of the beam. [05 marks]

iv.) Suggest the minimum possible number of tendons (and corresponding initial prestress force) and sketch a suitable physical arrangement for them (Assume $f_{pi} = 0.7\, f_{pu}$). [05 marks]

v.) 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 debonding). If debonding has to be carried out, evaluate how many tendons should be debonded at the supports so that straight tendons could be used. [05 marks]