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

CEX6332 - Structural Design

FINAL EXAMINATION – 2016/2017

Time Allowed: **Four (04) Hours**

Date: 2017 - 12 - 09 (Saturday) 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. The beam shown in Fig. 1.1 is fully restrained along its length and has stiff bearing of 50 mm at the supports and 75 mm under the point load. For the loading shown design the beam in Grade 43 steel. The Loading arrangement is shown in Fig. 1.2

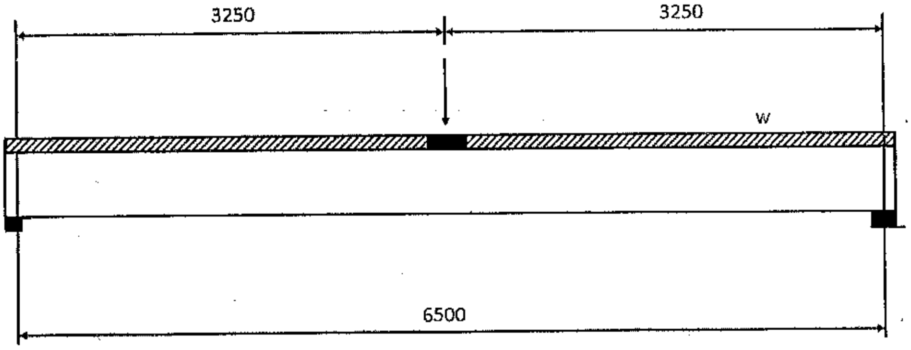


Fig. 1.1

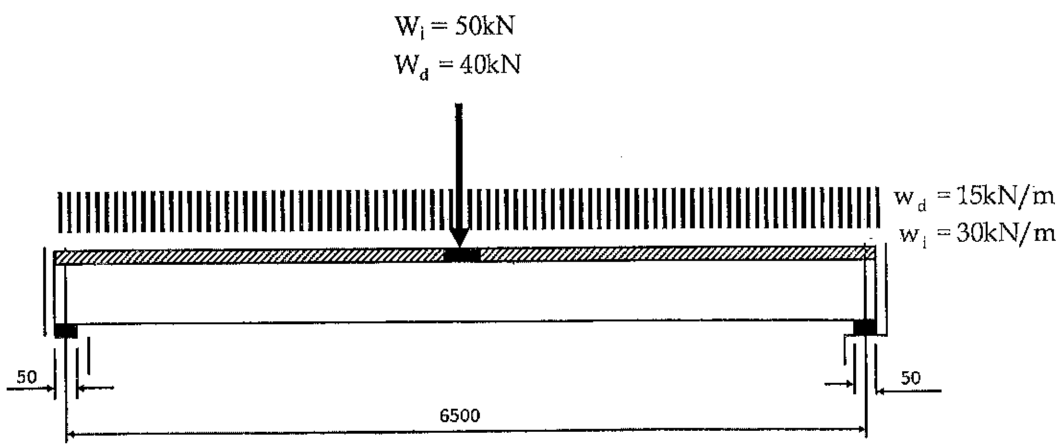


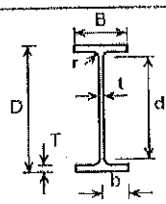
Fig. 1.2

$$w(UDL) = w_{d(Dead Load)} + w_{i(Imposed)}$$
$$W(Point\ Load) = W_{d(Dead\ Load)} + W_{i(Imposed)}$$

1.1 Determine the ultimate design loads for UDL and point load cases separately
$\gamma_d = 1.4, \gamma_i = 1.6$ (Marks 03)

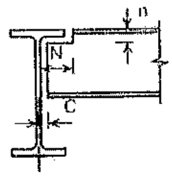
1.2 Draw the bending moment and shear force diagram using Ultimate design load
(Hint: You may assume simply supported condition at both ends) (Marks 04)

1.3 Do the section classification according to BS 5950 for the selected section. You may use the properties given in Table 1.1. (Marks 05)



UNIVERSAL BEAMS

Dimensions and properties



Section Designation	Mass per Metre	Depth of Section D	Width of Section B	Thickness		Root Radius r	Depth between Fillets d	Dimensions for detailing			Surface Area		Area of Section A
				Web t	Flange T			End Clearance C	Notch N	Notch n	Per Metre	Per Tonne	
	kg/m	mm	mm	mm	mm	mm	mm	mm	mm	mm	m^2	m^2	cm^2
533x210x122	122.0	544.5	211.9	12.7	21.3	12.7	476.5	8	110	34	1.89	15.5	155
533x210x109	109.0	539.5	210.8	11.6	18.8	12.7	476.5	8	110	32	1.88	17.2	139
533x210x101	101.0	536.7	210.0	10.8	17.4	12.7	476.5	7	110	32	1.87	18.5	129
533x210x92	92.4	533.1	209.3	10.1	15.6	12.7	476.5	7	110	30	1.86	20.2	117
533x210x82	82.2	528.3	208.8	9.6	13.2	12.7	476.5	7	110	26	1.85	22.5	105

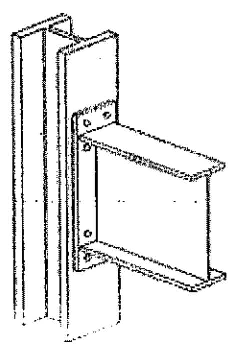
Table 1.1

1.4 Determine the moment capacity for selected section and check with the required moment. If not satisfied, suggest the new section. (Mark 04)

1.5 Determine the shear capacity of the section and check with the required shear. If not satisfied, suggest the new section. (Mark 04)

1.6 Suppose that the above design universal beam (under 1.4 and 1.5) connected to column flange at both ends by bolted connection as shown in Figure 1.3. Design the bolted connection assuming that the column and beam sizes are equal. Clear sketch should be provided with Nos of bolts, diameter size and clear distance between bolts etc.
Hint: Consider as the simply supported loading condition. (Mark 05)

Fig. 1.3



Q2.

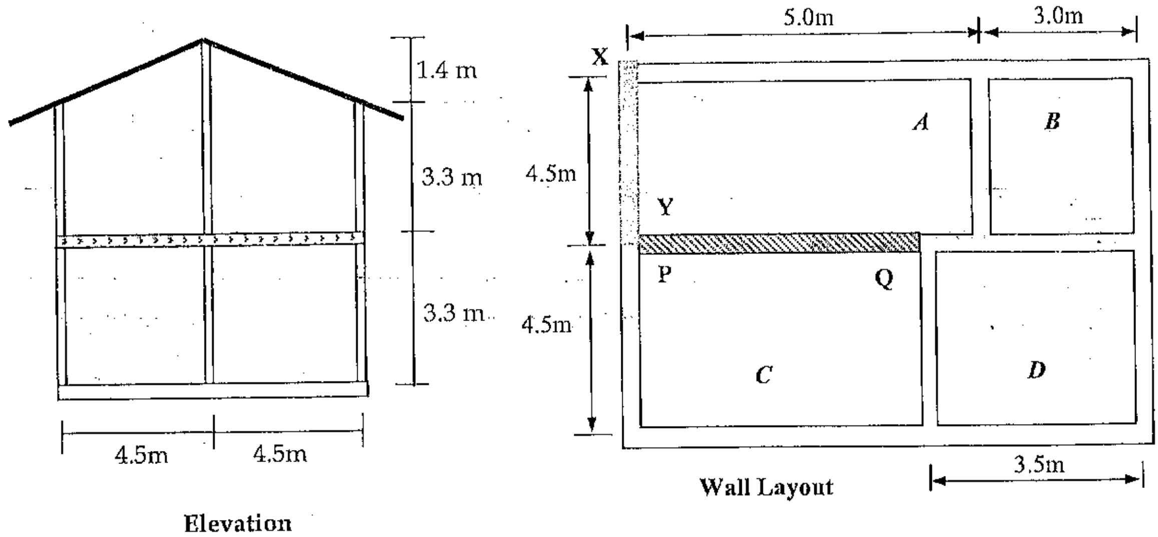


Figure 2: Proposed masonry building

A two-storied community building has been proposed in a certain place in Polonnaruwa district It is a load bearing masonry wall construction. The plan of and elevation of the building is shown in Figure 2. **A** and **B** are community gathering rooms. D and B are office room and wash room, respectively.

Walls are constructed with locally made high quality bricks and their dimensions are 200mm*100mm*50mm, length, breath, height, respectively. Half brick wall construction is 100mm, one brick wall construction is 210 mm, one and half brick wall construction is 320mm. Further, external and internal wall thicknesses are proposed to be 350 mm and 240mm, respectively.

Loads	
Dead load of the roof (Plan area)	= 0.5 kN/m^2
Imposed load on the roof	=0.25 kN/m^2
Imposed load on the floor	= 3.5 kN/m^2
Dead load by 125mm slab	= 3.0 kN/m^2
Dead load due to finishes on slab	= 0.5 kN/m^2
Geometry	
Thickness of floor slab	= 125mm
Floor to floor clear height	= 3.2m
Eave of the roof	= 1.0m

Weights of Materials	
Unit weight of RC	= 24.0 kN/m^3
Unit weight of masonry	= 18.0 kN/m^3
Mortar Designation IV	
Compressive Strength of Brick	= 5.0 N/mm^2
γ_m	= 3.5
Water absorption	≥12%

I. Evaluate characteristic dead and live loads acting on the internal wall **P-Q** in the first floor level. (05 Marks)

II. Find different load combinations and corresponding design loads and eccentricities. (05 Marks)

III. Determine the slenderness ratio of the wall and compare with its permissible value. (02 Marks)

IV. Check whether the internal wall can carry the design compressive load considering vertical load resistance of the wall. (03 Marks)

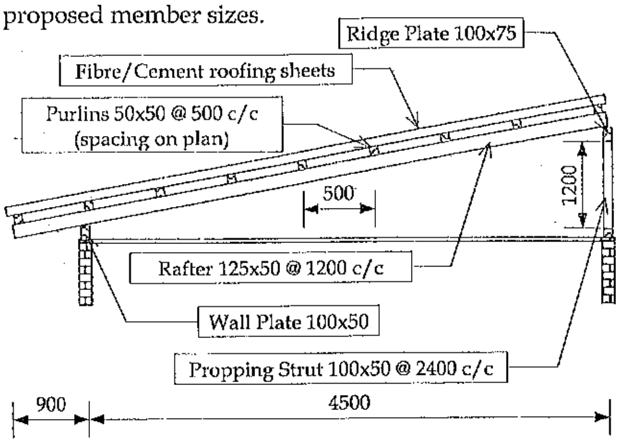
V. Draw a figure showing boundary conditions for the external wall panel **X-Y** (1st floor to roof office area). (02 Marks)

VI. Determine the moments parallel and perpendicular to the bed joint if it is subjected a a lateral load of 4.0 kN/m^2. (04 Marks)

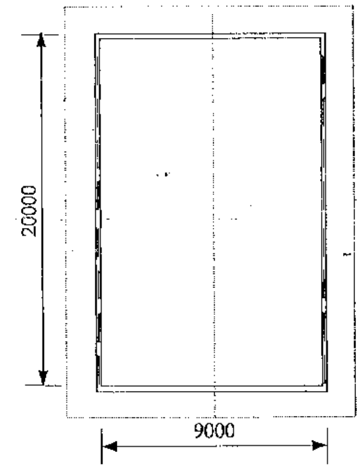
VII. Check the safety of the external wall panel under the given lateral load (04 Marks)

Q3.

For a single storey examination hall intended to be used for an interim period before a permanent building is constructed at the Gampaha Study Centre of the OUSL a timber roof structure is proposed. The diagrams below show the general layout of the building and half cross section of the roof structure, with proposed member sizes.



Half Cross Section of Roof



General Layout of the Building

Timber Strength Class	- TR26
Unit weight of Timber	- 4.4 kN/m³
Weight of Roofing sheets	- 0.2 kN/m² (on plan)
All dimensions are in 'mm'	

Assume:
* Exposure condition is could be wet.
* Rafters uniformly loaded by the purlins
* Sloping span is approximated to span in plan
* Wane is permitted.
* Maximum allowable deflection for the rafter is 0.003L at mid span. (L=span)

Using the above data check the design of a rafter and a propping struct according to **BS 5268** -1996 (you may neglect the wind loading).

Section A - Use following steps in checking the adequacy of a rafter.

i.) Evaluate loading by roof structure on the rafter due to **dead** loads and identify the critical load combination on the rafter as a uniformly distributed load (udl).
(03 marks)

ii.) Check the proposed rafter against **lateral stability** criteria.
(01 marks)

iii.) Compute the applied **bending stress** at the critical section of the rafter for the critical load and check whether this is within the permissible limit.
(03 marks)

iv.) Check whether the **maximum allowable deflection** is within the permissible limit. (you may assume deflection due to bending at midspan of a udl loaded beam to be = $5wL^4 / (384EI)$ *in standard notations)*
(03 marks)

v.) Check whether the rafter is safe against failure due to **shear**. (you may assume that no notches are made on the rafter for fixing purposes)
(03 marks)

Section B - Use the following steps in checking the adequacy of a propping timber strut.

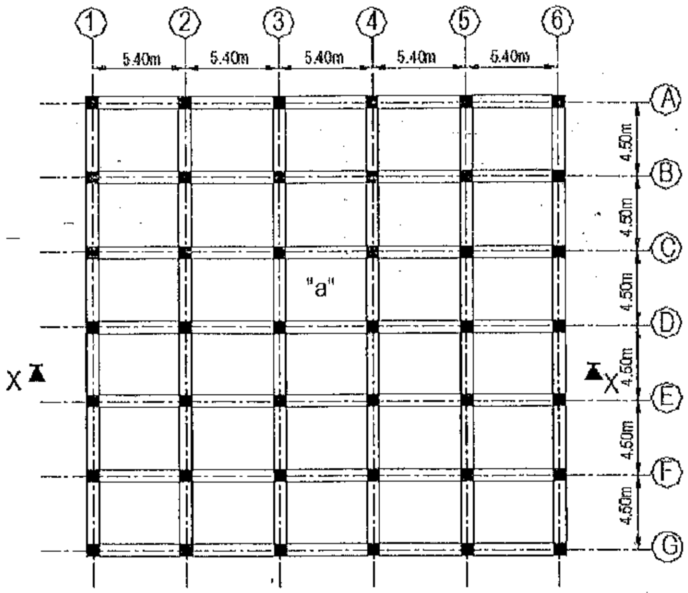
i.) Evaluate the total axial load on the strut due to **Long term** loads (in kN).
(03 marks)

ii.) Evaluate the **Slenderness Ratio** of the strut and whether this is within the admissible limit.
(03 marks)

iii.) Compute the applied maximum **compressive stress** in the strut and check whether this is within the admissible limit.
(03 marks)

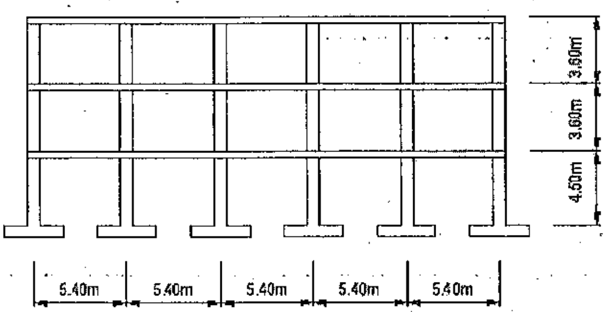
iv.) Check the strut for combined flexural and compressive stresses.
(03 marks)

Q4. A typical floor plan and a sectional view of a three storied commercial building is shown in Figure 4. The beams are cast monolithically with the floor slab. A 200mm thick blind wall constructed on grid D seperates the building to two units.



Typical Floor Plan

Strength of materials;
Grade of concrete = 30
Characteristic strength of steel
Main r/f = 460 N/mm²
Shear r/f = 250 N/mm²
Nominal cover for reinforcement = 20 mm
Order of floors – Ground, 1st, 2nd, Roof
* Required design charts are provided *



Section X-X

Loads on the structure;	
Dead load by finishes on floors & roof	= 1.0 kN/m²
Imposed load on floors & roof	= 3.0 kN/m²
** You may neglect the effects of Wind	
Thickness of floor & roof slabs	= 125 mm
Weights of materials	
Unit weight of RC	= 24.0 kN/m³
Unit weight of Masonry	= 20.0 kN/m³

Figure 4

i.) Compute the design ultimate load acting on the 1st floor slab. Considering the slab panel "a", compute the bending moments acting at critical locations of the panel using the bending moment coefficients from the BS8110-1:1997 and design reinforcements for this panel to satisfy code requirements. Draw a typical plan showing the reinforcement detail of slab panel "a". Indicate curtailment of reinforcements without dimensions. (07 Marks)

ii.) Evaluate the design ultimate load acting on the beam (375 x 225 mm in size) on grid D. (you may assume that the loads transferred to the beam from the slab are uniformly distributed along its span) and calculate the ultimate bending moments at critical locations using the design formula given in BS8110-1:1997 for uniformly loaded continuous beams. (06 Marks)

iii.) Draw the bending moment diagram for the beam on grid D using the bending moments computed above. Design the required reinforcements only for the span 3-4 to resist bending at critical locations of the span and indicate how you would curtail reinforcements within span 3-4 in the bending moment diagram. (06 Marks)

iv.) Assuming the column at D-3 (225 x 225) is unbraced and no bending moments are transferred from beams framing into the column, evaluate the design ultimate axial load on the column at ground floor level and the slenderness condition of the column segment between ground and first floor. (06 Marks)

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Q5.

The post tensioned beam shown in figure 5 is used for a bridge with a medium span. The beam can be considered as simply supported beam with effective span of 12 m. The beam carries only its own weight at transfer and it is to be a type 2 prestressed member. Proposed section of the pre stressed beam, material properties and the loading on the beam are as follows;

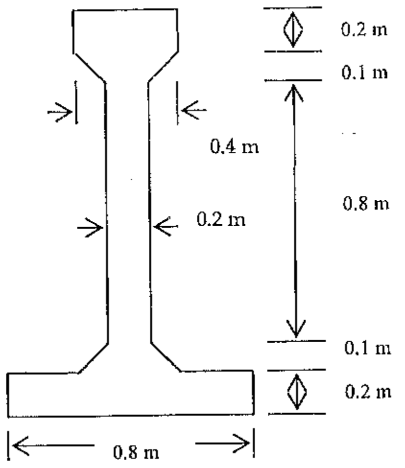

Figure 5

Sectional properties
$I = 0.085\ m^4$, $Y_B = 0.565\ m$

Loss of prestress

at transfer	= 10 %
at service	= 20 %

Loads

Unit weight of concrete	= 24 kN/m^3
Dead load other than self weight	= 10.0 kN/m
Imposed load	= 7.5 kN/m

(Assuming loads to be distributed evenly.)

Strengths

f_{cu} at 28 days	= 40 N/mm^2
f_{ci} at 7 days (transfer)	= 32 N/mm^2

Transfer is 7 day after casting

f_{pu} Super strand 15.0 mm dia. tendons = 1500 N/mm^2

You may use following inequalities (in standard notation) for your calculations

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

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

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

Using above data, design the beam according to the following steps;

i.) Show that cross sectional area of the given beam is 0.34 m^2 using given sectional properties of the beam find the Z_t and Z_b.
(02 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.
(03 Marks)

iii.) Check the adequacy of the section in carrying the stresses at **transfer** and in **service** for the given span.
(03 Marks)

iv.) Assuming the tendon eccentricity as 0.5 m find a range for prestress force. (04 Marks)

v). Explain how the Magnel diagram method can be used to find the suitable pre stress force and eccentricity for the given section and load condition. (no calculation is required)
(03 Marks)

vi). Propose suitable tendon arrangement for the section considering the minimum spacing of the tendons as the diameter of the tendons.
(02 Marks)

vii) Check whether the designed tendon arrangement can be used for the supports of the beam.
(03 Marks)

viii) Check the suitability of the section respect to Ultimate Moment capacity.
(05 Marks)