

The Open University of Sri Lanka
Faculty of Engineering Technology
Department of Civil Engineering



Study Programme	: Bachelor of Science Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	: CVX 4545 Structural Analysis and Design II
Academic Year	: 2022/23
Date	: 18 th February 2024
Time	: 13:30-16:30 hrs
Duration	: 3 hours

General Instructions

1. Read all instructions carefully before answering the questions.
2. This question paper consists of **SEVEN (7)** questions in **SEVEN (7)** pages.
3. Answer **ANY FIVE (05)** questions with **at least Two (2)** questions from each section (from Section A and Section B). Each question carries **20 Marks**.
4. **Relevant Charts** or “**Extract from BS8110**” are provided. See **ANNEX** for additional information.
5. Answer for each question should commence from a **new page**.
6. **Clearly mention any assumptions** made for calculations.
7. This is a **Closed Book Examination**.
8. Answers should be in clear hand writing.
9. Do not use Red colour pen.
10. An electronic non-programmable calculator may be used.

Section A – Structural Analysis

[Q1]

- (i) Analyze the frame shown in **Figure Q1** using the **Moment Distribution method** and find the moments at A, B, C , and D joints. Flexural rigidity of AB is $2EI$ and that of BC and CD is EI . [12 Marks]
- (ii) Draw the **bending moment diagram** for the frame. [8 Marks]

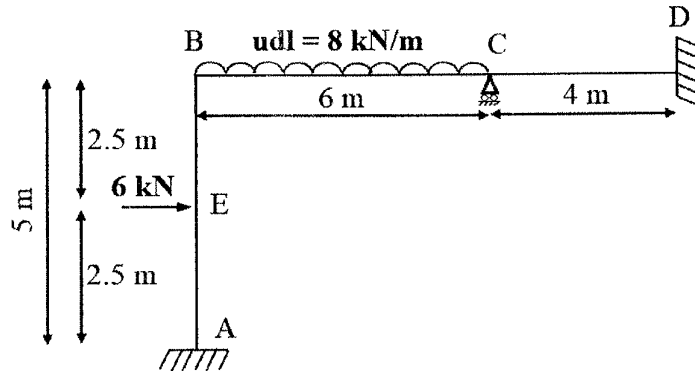


Figure Q1

[Q2]

- (i) State **Mohr's 1st Theorem**. Use a neat sketch for your answer. [4 Marks]
- (ii) As shown in **Figure Q2a**, Beam AB is subjected to a uniformly distributed load (w) along the beam. Flexural rigidity of the beam is EI . Using **Mohr's 1st and 2nd theorems**,
- Determine the **rotation (angle)** at point A from the horizontal. [3 Marks]
 - Determine the **deflection** at beam's mid-point C . [3 Marks]

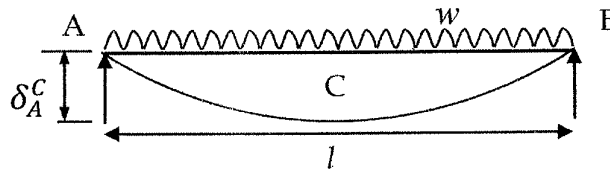


Figure Q2a

- (iii) Using the **Theorem of Three Moments**, analyse the continuous beam shown in **Figure Q2b** and draw the bending moment diagram. (EI is constant) [10 Marks]

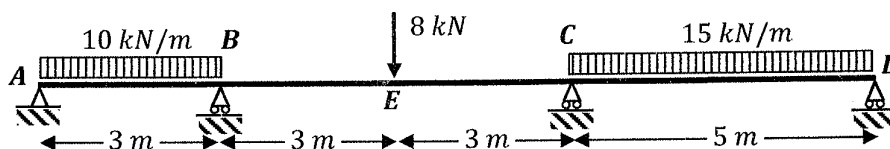


Figure Q2b

[Q3]

- (i) Briefly describe 'degree of statical indeterminacy' of a frame. [2 Marks]
- (ii) Find the degree of statical indeterminacy of the frame shown in **Figure Q3a**. [3 Marks]

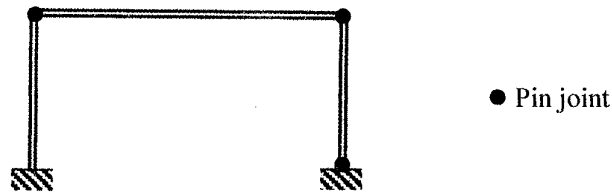


Figure Q3a

- (iii) **Figure Q3b** shows the loading arrangement in ABCD frame. Point A and Point C of the frame are fixed and Beam BD is a cantilever.
 - a) Using the slope deflection method, find the moments at all joints in the frame (EI is constant for all members) [8 Marks]
 - b) Draw the bending moment diagram for the frame. [7 Marks]

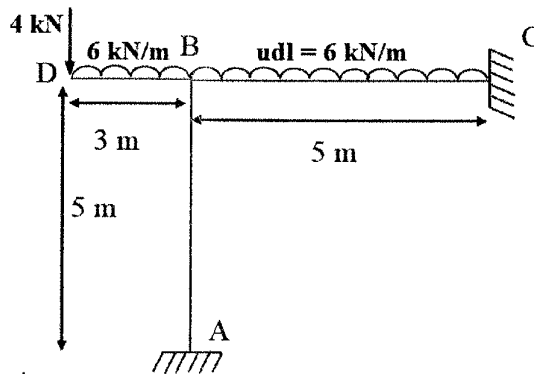


Figure Q3b

[Q4]

- (i) State two Castigliano's Theorems. [6 Marks]
- (ii) As shown in **Figure Q4**, a cantilever beam is loaded with a distributed load (w) and a point load (P) at its free end. Using Castigliano's first theorem,
 - a) Determine the rotation (angle) from the horizontal at **Point B**. [7 Marks]
 - b) Determine the vertical deflection at **Point B**. [7 Marks]

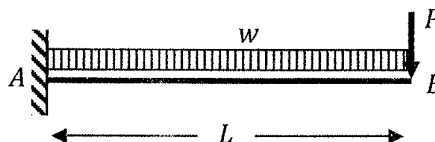
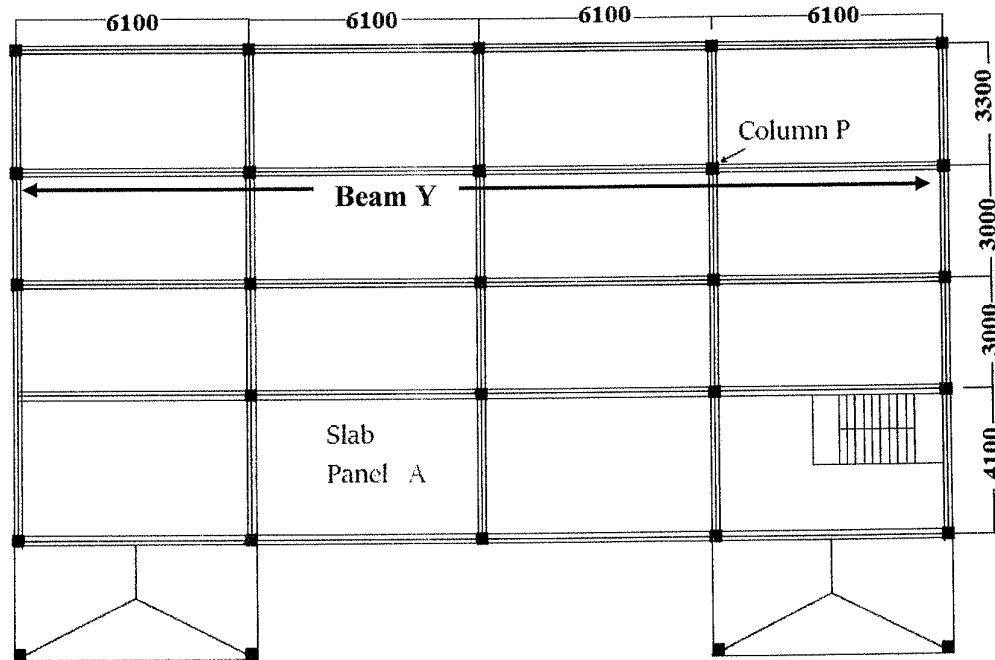


Figure Q4

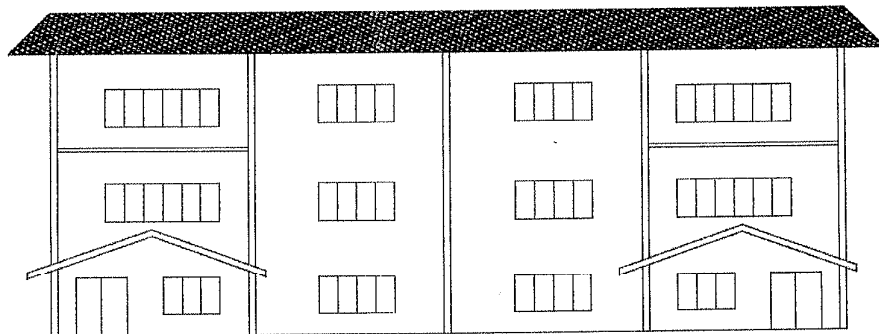
Section B – Design of Structures

All designs shall be carried out as per recommendations of BS 8110. You are allowed to use Design extracts provided at the examination hall. **Any assumptions that you will be making (if any) shall be clearly stated.**

Question 5, 6 and 7 shall be based on the building project details described below.



PLAN



FRONT ELEVATION

Above Figures show a new three storey building proposed for a new regional center of OUSL. This building will be designed and constructed as a framed reinforced concrete building. Layout of all floors are same except two entrance lobbies in the Ground floor. Floor loadings of 1st and 2nd floors are identical and design load are described below. **Exterior masonry walls shall be capable of resisting lateral loads of the building.**

Material properties and load parameters

Concrete grade	- Grade 30
Grade of steel	HS steel - 460 N/mm ²
MS	- 250 N/mm ²
Unit weight of concrete	- 24 kN/m ³
unit weight of masonry walls	- 18 kN/m ³
Dead load on floors due to finishes and partitions	- 1.5 kN/m ²
Dead load by roof	- 1.0 kN/m ²
Imposed load on floors	- 3.5 kN/m ²
Neglect the imposed load on the roof	
Exposure condition of slabs/ beams/columns	- Mild
Exposure condition for foundation	- Very severe
Fire protection required	- 1 hr

Notes:

- All perimeter walls shall be brick masonry walls having thickness of 225 *mm*
- Thickness of slabs shall be 125 *mm*
- All beams parallel to longer direction of the building shall be 225 *mm* × 500 *mm* and beams parallel to shorter direction shall be 225 *mm* × 400 *mm*
- All beams and slabs shall be cast together ensuring monolithic connection
- All columns shall be 275*mm* × 275*mm*

Floor to floor height of each floor (height from top of floor slab to top level next floor slab) is 3.2 *m*. The height from top of 2nd floor slab to ceiling level of roof is also 3.2 *m*.

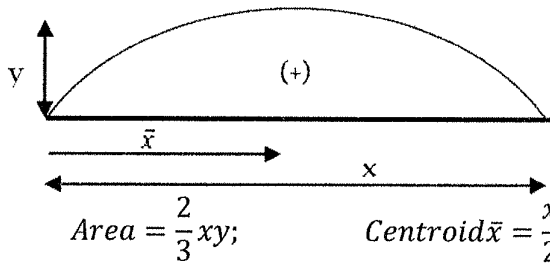
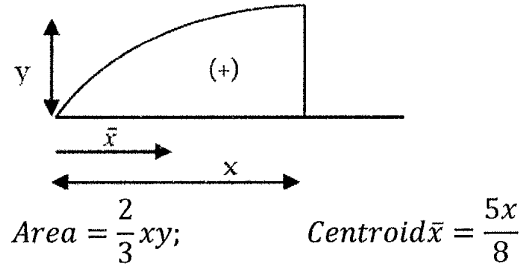
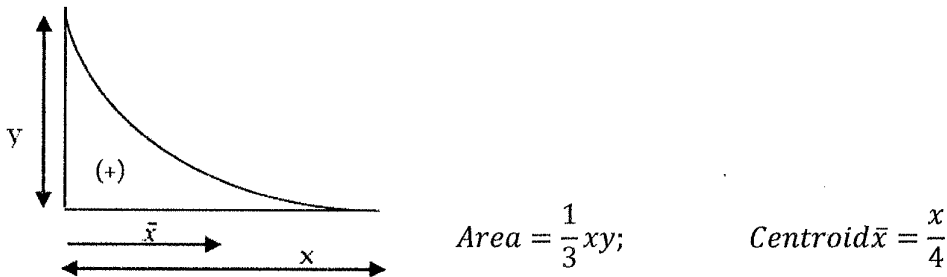
[Q5] It is required to carry out design of slab **Panel A** of the first-floor slab of the given building.

- (i) Decide the nominal cover for the slab considering durability and fire resistance requirements under SLS condition. Also, calculate the ultimate design load for the slab panel as uniformly distributed area load. **[3 Marks]**
- (ii) Based on the span condition and end conditions of the slab **Panel A**, calculate mid span moment and moments over continuous supports under ULS conditions. You may use the relevant chart of the provided design extracts. **[4 Marks]**
- (iii) Calculate reinforcement requirements to resist ULS flexural moments at all critical locations calculated in **Part (ii)**. You may use 10 *mm* HYS as reinforcements. **[4 Marks]**
- (iv) Check the SLS deflection control requirement of slab **Panel A** and if necessary, propose suitable modification to comply with the deflection control requirement. **[5 Marks]**
- (v) Sketch the reinforcement arrangement on plan of the slab panel using the standard method of detailing. (**Not necessary to indicate curtailment lengths**) **[4 Marks]**

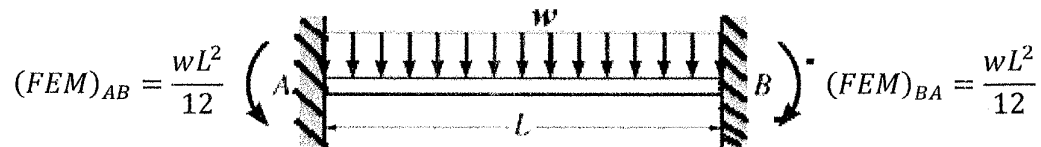
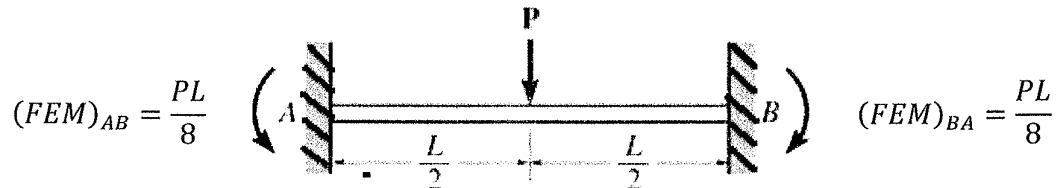
- [Q6] It is required to carry out design of **Beam Y (continuous beam)**. There is no brick wall along this beam. Carry out below steps for the purpose of designing this beam. You may use 6 mm or 10 mm MS stirrups as shear links and appropriate HYS bars as main reinforcements.
- (i) Calculate ULS characteristics design loading that transfer to the beam as a uniformly distributed load. [3 Marks]
 - (ii) Draw the most simplified sub frame (beam) arrangement that can be considered for the analysis and design of this beam [2 Marks]
 - (iii) Calculate the design Bending Moments and Shear Force values at mid-spans and over the supports using the relevant table of provided design extracts and present it in a table. [3 Marks]
 - (iv) Calculate the required amount of reinforcements for ULS flexure at critical locations (at Mid spans and over the supports). [5 Marks]
 - (v) Carry out ULS shear checks **considering maximum shear forced reported in beam Y** as a conservative approach and propose a shear link spacing for the beam. [4 Marks]
 - (vi) Carry out deflection check for the **first span of the beam** and propose any modification of reinforcements (if required) to satisfy the deflection control requirement of that span. [3 Marks]
- [Q7] It is required to design **Column P** and foundation of the **Column P**. It has been decided to place column footing at a depth of 900 mm from the formation level of the ground floor level. Allowable bearing pressure of the soil at that level is 175 kN/m^2 . Carry out the specified steps below relevant to design of **Column P** and **footing of P**.
- (i) From the initial design checks, it has been found that **Column P** can be designed as a short-braced column (**no need to prove it**). Calculate the ULS axial load that has to be considered when designing the column exists from the foundation level to first floor level. [4 Marks]
 - (ii) Calculate the amount of reinforcement required for the **Column P** using a standard design approach of a short-braced column. [4 Marks]
 - (iii) Calculate suitable size for a square shape symmetrical individual footing for the **Column P (no need to consider any eccentric moment for the calculation)**. [4 Marks]
 - (iv) Carry out flexural design and necessary shear checks of the footing of **Column P** by selecting an appropriate thickness for the footing. [5 Marks]
 - (v) Sketch a cross-section and a plan consisting of column and footing relevant to **Column P**. It shall show provided reinforcements for the column and footing based on standard method of detailing. [3 Marks]

ANNEX

Area and centroid for some common shapes



Fixed End Moments (FEM)



Three moments theorem

A diagram of a continuous beam over three supports, A, B, and C. The beam is divided into two segments, l_1 and l_2 . The moments at the supports are M_1 , M_2 , and M_3 respectively. The theorem states:

$$\frac{M_1 l_1}{E_1 I_1} + 2M_2 \left[\frac{l_1}{E_1 I_1} + \frac{l_2}{E_2 I_2} \right] + \frac{M_3 l_2}{E_2 I_2} = -6 \left[\frac{A_1 a_1}{E_1 I_1 l_1} + \frac{A_2 a_2}{E_2 I_2 l_2} \right] + 6 \left[\frac{\Delta_B - \Delta_A}{l_1} + \frac{\Delta_B - \Delta_C}{l_2} \right]$$

*All parameters have their respective meanings.

– End of Paper –