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	: 2023/24
Date	: 23rd February 2025
Time	: 13:30-16:30 hrs
Duration	: **3 hours**

General Instructions

1. Read all the instructions carefully before answering the questions.

2. This question paper consists of **SEVEN (7)** questions on **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. This is a **Closed Book Examination**.

6. Answer for each question should commence from a **new page**.

7. **Clearly mention any assumptions** made for calculations.

8. 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 E* joints. Flexural rigidity of **AB is 2*EI*** and that of **BC, CD, and CE is *EI***. (***You may use the details given in ANNEX.***) **[20 *Marks*]**

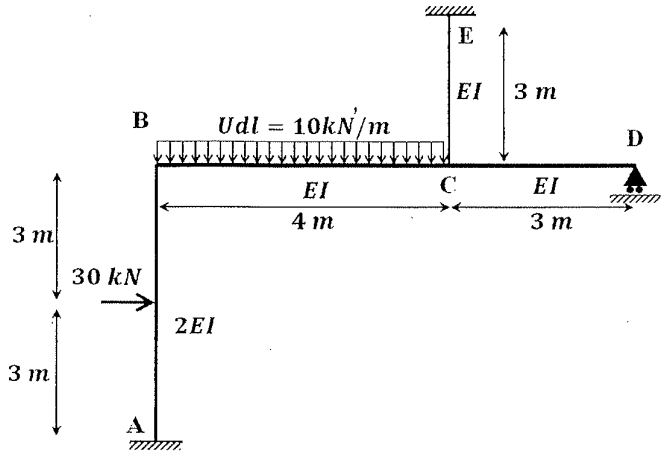


Figure Q1

[Q2]

(i) As shown in **Figure Q2a**, Beam AB is subjected to point loads (P) applied at C and D. Flexural rigidity of the beam is EI. Using **Mohr's 1st and 2nd theorems**,

a) Determine the **rotation (angle) at point A from the horizontal.** **[4 Marks]**

b) Determine the **deflection at beam's mid-point E.** **[6 Marks]**

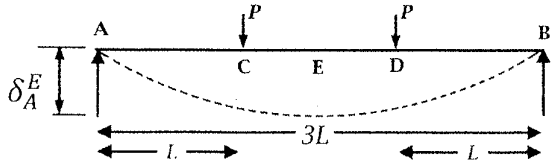


Figure Q2a

(ii) 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]**

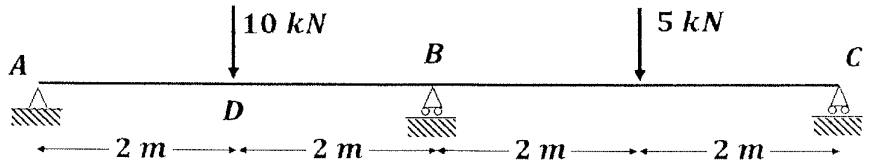


Figure Q2b

[Q3]

(i) Find the degree of statical indeterminacy of the frame shown in **Figure Q3a**. **[5 Marks]**

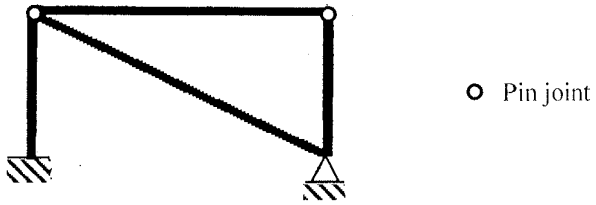


Figure Q3a

(ii) **Figure Q3b** shows the loading arrangement in ABC frame. Point *A* and Point *C* of the frame are fixed.

a) Using the **slope deflection method**, find the moments at all joints in the frame. **(Flexural rigidity of AB is 2EI and that of BC is EI.)** **[10 Marks]**

b) Draw the **bending moment diagram** for the frame. **[5 Marks]**

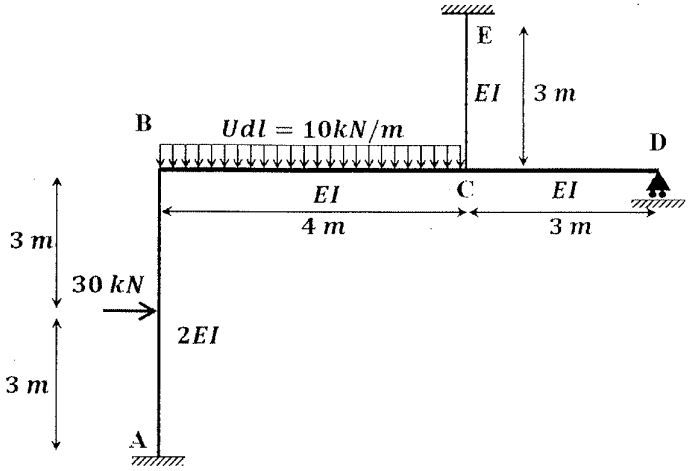


Figure Q3b

[Q4]

(i) State two Castigliano's Theorems. **[6 Marks]**

(ii) As shown in **Figure Q4**, AB beam is loaded with a udl (*w*). **Using Castigliano's theorems,**

a) Determine the rotation (angle) from the horizontal at **Point *B***. **[7 Marks]**

b) Determine the vertical deflection at midspan. **[7 Marks]**

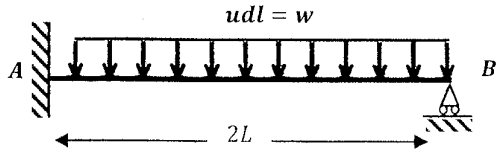
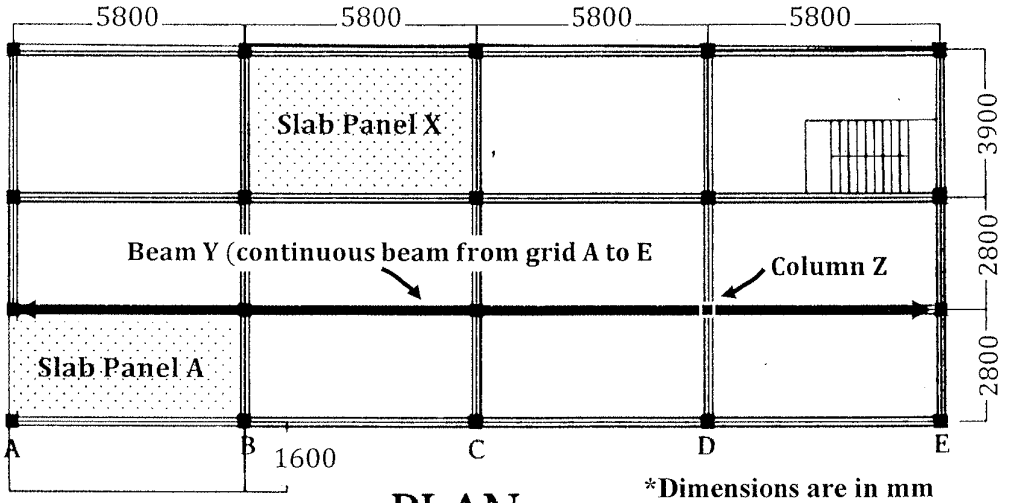


Figure Q4

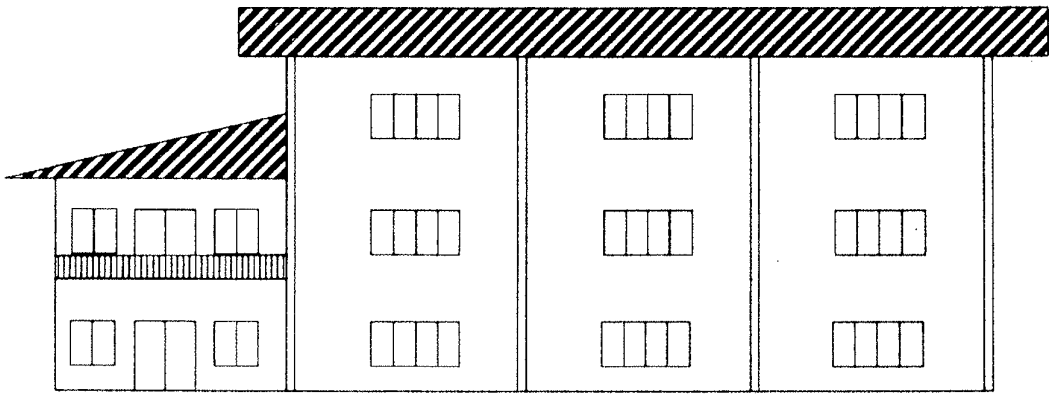
Section B – Design of Structures

All designs shall be carried out as per recommendations of BS 8110. You are allowed to use **Design Extract** 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 building proposed for an office. This building will be designed and constructed as a framed reinforced concrete building. Layout of ground floor and 1st floor are same. But the part of the building between grid A and grid B does not have a 2nd floor (see front elevation). The remaining part of the building has a 3rd floor as well and which is identical to the lower floors of that part of the building.

Material properties and load parameters

Concrete grade	- Grade 25
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 roof	- 0.5 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 the longer direction of the building shall be 225 $mm \times 450$ mm and beams parallel to shorter direction shall be 225 $mm \times 400$ mm. Beam heights include the thickness of slab as well.
- All beams and slabs shall be cast together ensuring monolithic connection
- All columns shall be 250 $mm \times 250$ mm

Floor to floor height of each floor (height from top of floor slab to top level next floor slab) is 3.1 m. The height from top of 2nd floor slab to ceiling level of roof is also 3.1m.

[Q5] It is required to carry out design of slab **Panel *X*** 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 limit state (ULS) 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 X, calculate mid span moments and moments over continuous supports under ULS conditions. You may use the relevant chart provided in the design extract. **4 Marks]**

(iii) Calculate reinforcement requirements to resist ULS flexural moments at all critical locations calculated in part Q5 (ii). You may use 10 mm HS as reinforcements. **[4 Marks]**

(iv) Check the serviceability limit state (SLS) deflection control requirement of the slab panel X and if necessary, propose suitable modification to comply with the deflection control requirement. **[5 Marks]**

(v) If you are asked to design slab panel A too, discuss the fundamental difference between design approaches of slab panel X and Slab panel A with any necessary calculations. **[4 Marks]**

[Q6] It is required to carry out the design of the **Beam *Y***. There is no brick wall along this beam. Carry out the steps below for the purpose of designing this beam. You may use 6 mm or 10 mm MS stirrups as shear links and appropriate HS rebars as the main reinforcements.

(i) (a) Calculate ULS design loading on the Beam Y as a uniformly distributed load. **[3 Marks]**

(b) Recalculate ULS design loading on Beam Y if the effective widths of relevant bay are changed to 3900 mm instead of 2800 mm. **[3 Marks]**

(ii) Calculate the design bending moments and shear force values at mid spans and over the supports using the relevant table of provided design extract and present it in a table using the loading calculated in **Q6 (i) (a)**. **[4 Marks]**

(iii) Calculate the required amount of at reinforcements for ULS flexure at critical locations based on the bending moment calculated in **Q6 (ii)** (at midspans and over the supports). **[6 Marks]**

(iv) Carry out the ULS shear checks **considering the maximum shear force reported in beam Y** as a conservative approach and propose a shear link spacing for the beam. **[4 Marks]**

[Q7] It is required to design **Column Z** and foundation of Column Z. It has been decided to place column footing at a depth of 900 mm from the formation level of the ground floor level. The allowable bearing pressure of the soil at that level is 125 kN/m^2. Carry out the specified steps below relevant to the design of **Column Z** and **foundation of column Z**. From the initial design checks, it has been found that Column Z can be designed as a short-braced column.

(i) 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 Column **Z** using a standard design approach of a short-braced column (No need prove it as short-braced column). **[3 Marks]**

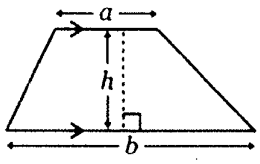
(iii) Calculate suitable size for a square shape symmetrical individual footing for the **Column Z (no need to consider any eccentric moment for the calculation).** **[3 Marks]**

(iv) Assume that due to a site restriction, it had to shift the column by 100mm along one of the center lines of the square footing selected in section **Q7 (iii)** from the center of the footing. Recalculate the footing size under this condition to control pressure below the footing within specified allowable bearing pressure. **[4 Marks]**

(v) Carry out **necessary shear checks** for the selected footing under condition discussed in section **Q7 (iii)**, if the selected footing thickness is 300 mm and proposed reinforcement requirement under flexure is T12/175cc both ways. **(No need to perform flexural design for the footing)** **[6 Marks]**

ANNEX

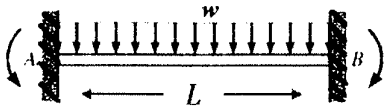
Area:



$$Area = \frac{1}{2}(a+b)h$$

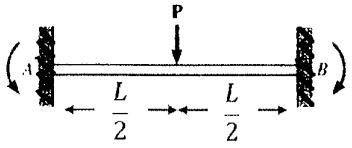
Fixed End Moments (FEM):

$$(FEM)_{AB} = \frac{wL^2}{12}$$



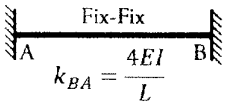
$$(FEM)_{BA} = \frac{wL^2}{12}$$

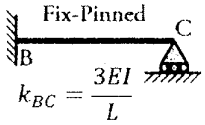
$$(FEM)_{AB} = \frac{PL}{8}$$



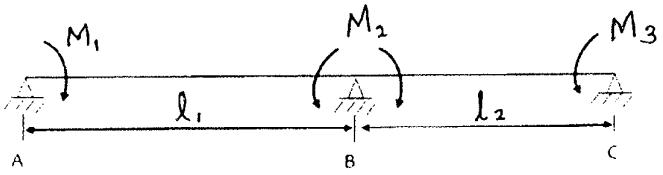
$$(FEM)_{BA} = \frac{PL}{8}$$

Member Stiffness:





Three moments theorem:



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

*All parameters have their respective meanings.

– End of Paper –