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

Study Programme	: Bachelor of Technology Honours in Engineering
Name of the Examination	: Final Examination
Course Code and Title	**: CVX 4545 Structural Analysis and Design II**
Academic Year	: 2021/22
Date	: 19th February 2023
Time	: 13:30-16:30hrs
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 $A, B, and\ C$ joints. (Flexural rigidity of **AB is $2EI$** and that of **BC and BD is EI.**) Hint: There is no moment transferred to the cantilever ($DF_{BD} = 0$). **[10 *Marks*]**

(ii) Draw the **bending moment diagram** of the frame. **[5 *Marks*]**

(iii) Draw the **shear force diagram** of the frame. **[5 *Marks*]**

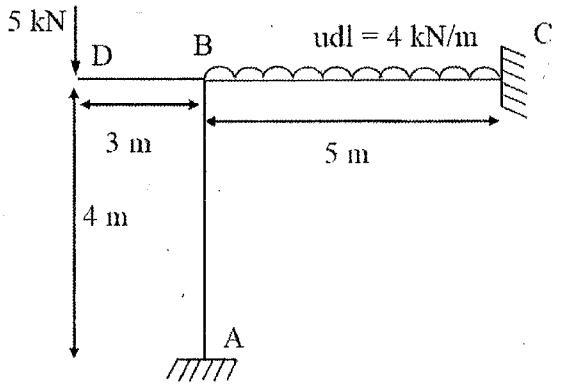


Figure Q1

[Q2]

(i) State **Mohr's 1st Theorem.** Use neat sketches for your answer. **[4 Marks]**

(ii) As shown in **Figure Q2a**, Beam AB is subjected to a uniformly distributed load (w) along the beam and a point load (P) at the mid-span ($at\ C$). Using **Mohr's 1st and 2nd theorems,** determine the **rotation at point A from the horizontal** (4 Marks) and the **deflection at point C** (4 Marks). Flexural rigidity of the beam is EI. **[Total 8 Marks]**

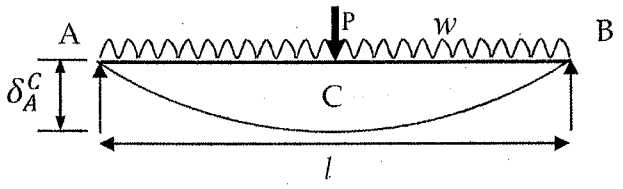


Figure Q2a

(iii) Using the **Theorem of Three Moments**, analyse the continuous beam shown in **Figure Q2b** and draw the bending moment diagram. (EI is constant) **[8 Marks]**

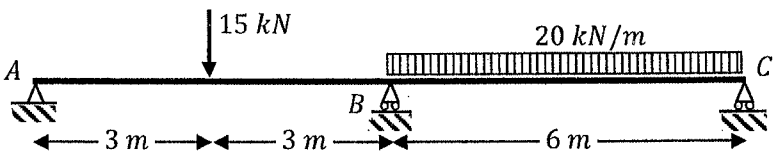


Figure Q2b

[Q3]

(i) Beam AB is **simply supported at A** and **fixed at B (see Figure Q3a)**. If a moment $\boldsymbol{M}$ is applied at Point A (i.e. $M_A = M$), show that $\boldsymbol{M_B = M/2}$ (M_B is the moment carried over to the fixed support B). Flexural rigidity of the beam is EI. **[5 Marks]**

Hint: You may use the Slope Deflection Equation.

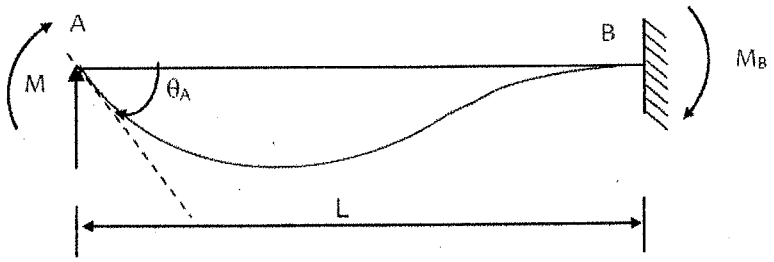


Figure Q3a

(ii) Analyze the ABCD continuous beam shown in **Figure Q3b** using the **slope deflection method** (7 Marks) and draw the **bending moment diagram** (4 Marks) and the **shear force diagram** (4 Marks). (EI is constant) **[Total 15 Marks]**

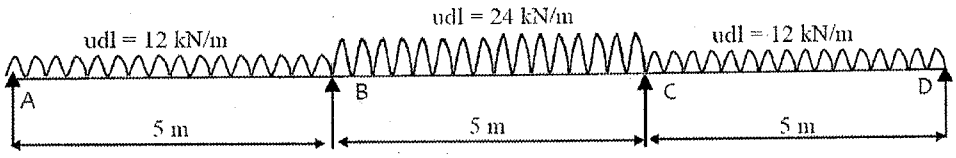


Figure Q3b

[Q4]

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

(ii) As shown in **Figure Q4**, a cantilever beam is loaded with a point load (P) at its free end and a distributed load (w). Determine the rotation from the horizontal (7 Marks) and vertical deflection (7 Marks) at **point $\boldsymbol{B}$** of the beam using **Castigliano's first theorem**.

[Total 14 Marks]

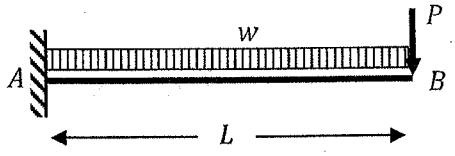
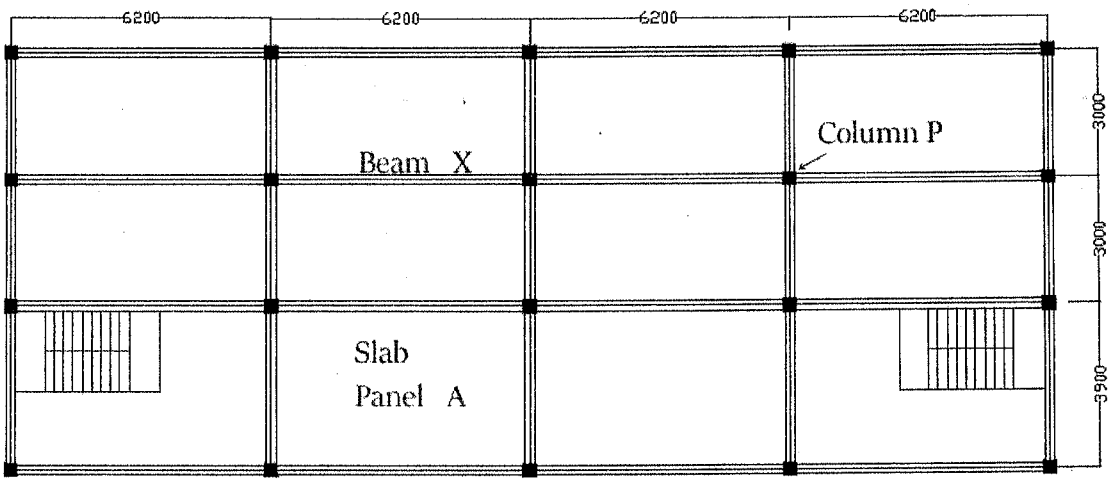


Figure Q4

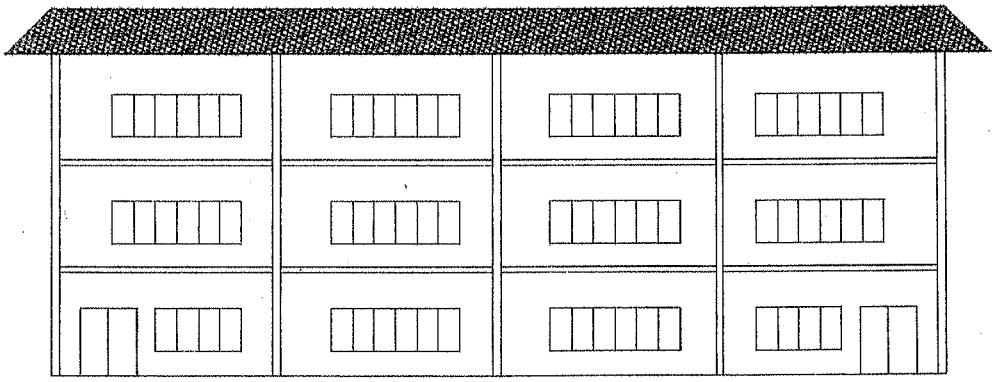
Section B – Design of Structures

All designs shall be carried out as per recommendations of BS 8110. You are allowed to use "**Extract from BS8110**" 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 describe below.



PLAN



FRONT ELEVATION

Above Figures show a new three storey building proposed for a regional center of OUSL. This building will be designed and constructed as a framed reinforced concrete building. The column spacing of first grid has been increased to accommodate testing laboratories and staircases of the building. **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	- 3.0 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 $mm \times 450$ mm and beams parallel to shorter direction shall be 225 $mm \times 375$ mm.
- All beams and slabs shall be cast together ensuring monolithic connection.
- All columns shall be 300 $mm \times 300mm$.

Floor-to-floor height of each floor (height from floor to ceiling level in top most floor) is 3.3 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 moments and moments over continues supports under ULS conditions. You may use the relevant chart of the provided in "Extract from BS8110". **[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 a suitable modification to comply with the deflection control requirement. **[5 Marks]**

(v) Sketch the reinforcement arrangement on plan and one cross section 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 *X***. 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. **[2 Marks]**

(ii) a) Draw the most simplified sub frame (beam) arrangement that can be considered for the analysis and design of this beam. **[1 Mark]**

b) Specify the reason that enables the simplification done in **part (ii) a)** for this structure. **[2 Marks]**

(iii) a) Calculate the design Bending Moments and Shear Force values at mid-spans and over the supports, respectively, using the relevant table in "**Extract from BS8110**" provided. **[3 Marks]**

b) Draw sketches of Bending Moment and Shear Forces envelopes for the beam using values calculated in **part (iii) a)**. **[2 Marks]**

(iv) Calculate the required amount of reinforcements for ULS flexure at critical locations (at mid-spans and over the supports). **[4 Marks]**

(v) Carry out ULS shear checks at critical locations and propose shear link spacings for the different spans of 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. **[2 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 750 mm from the formation level of the ground floor level. Allowable bearing pressure of the soil at that level is 125 kN/m^2. Carry out the specified steps below relevant to design of **Column *P*** and its footing.

(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. **[3 Marks]**

(ii) Calculate the amount of reinforcement required for the **Column *P*** using a standard design approach of a short-braced column. **[4 Marks]**

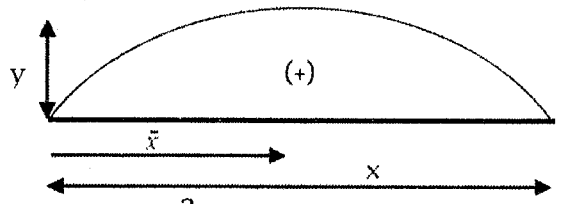
(iii) Calculate suitable size for a square shape symmetrical individual footing for the **Column *P*** (no need to consider any eccentric moment for the calculation). **[3 Marks]**

(iv) Carry out flexural designing and necessary shear checks of the footing of **Column *P*** by selecting an appropriate thickness for the footing. **[6 Marks]**

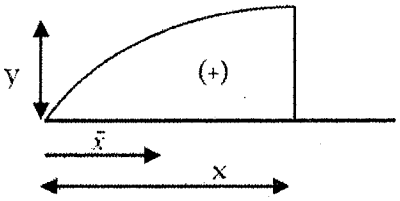
(v) Draw a sketch of a cross section and a plan consisting of column and footing relevant to **Column *P***. It shall show provided reinforcements for the column and footing based on standard method of detailing. **[4 Marks]**

ANNEX

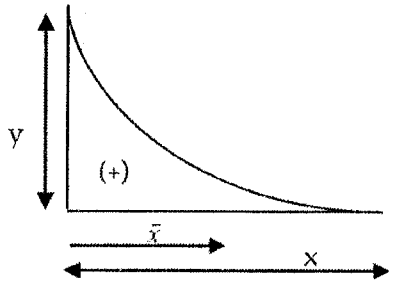
Area and centroid for some common shapes



$Area = \frac{2}{3}xy;$ $Centroid\bar{x} = \frac{x}{2}$



$Area = \frac{2}{3}xy;$ $Centroid\bar{x} = \frac{5x}{8}$



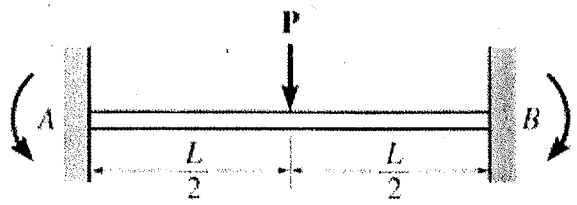
$Area = \frac{1}{3}xy;$ $Centroid\bar{x} = \frac{x}{4}$

Fixed End Moments (FEM)

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

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

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



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

– End of Paper –