[ENG21]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) CIVIL ENGINEERING

SEMESTER TWO EXAMINATION 2021/2022

STRUCTURAL ANALYSIS & CONCEPTUAL DESIGN

MODULE NO: CIE4023

Date: Friday 20th May 2022 **Time: 10:00 – 13:00**

INSTRUCTIONS TO CANDIDATES:

There are FOUR Questions.

Answer ALL questions.

Marks for each question are shown.

Sketches should be drawn neatly.

Answer books are provided.

All answers are to be written in the answer book or on the additional paper provided. Pre-prepared material will not be accepted.

Candidates should bring unmarked tables of steel design, extract from EC3, and concrete design to the examination.

Total 100 marks for the paper.

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Question 1: Steel Beam Design
Figure Q1 shows a fully restrained cantilever steel beam AB.
The size of the steel beam and loading data are shown in Figure Q1.
The size of the beam is **UB 610x229x140** with steel grade **S275**.

a. What is the classification of the beam section in bending? (5 marks)

b. Check the steel beam for the following design criteria:

(i) Bending strength (5 marks)

(ii) Shear strength (5 marks)

(iii) Web shear buckling (3 marks)

c. Calculate the deflection of the beam at point B under total <u>UNFACTORED</u> load.
Is the deflection satisfactory?
Assume admissible deflection to be **L**/250. (7 marks)

The deflection of the beam at point B is given by:

$$\delta_B = \frac{FL^4}{8EI_y} \qquad E = 210kN/mm^2$$

F = Unfactored total load in (kN/m)

I_y = Second moment of area of the beam section about y-y axis.

Design bending moment is given by: $M_{Ed} = \frac{wL^2}{2}$

Design Shear forces is given by: $V_{Ed} = wL$

L is the span of the beam
w is the total factored design load (kN/m):

$$w = 1.35G_k + 1.5Q_k$$

UB 610x229x140

h = 617.2 mm
b = 230.2 mm
t_w = 13.1 mm
t_f = 22.1 mm
I_y = 112000 cm^4

Unfactored load
Gk = 500 kN/m and Gk= 500 kN/m

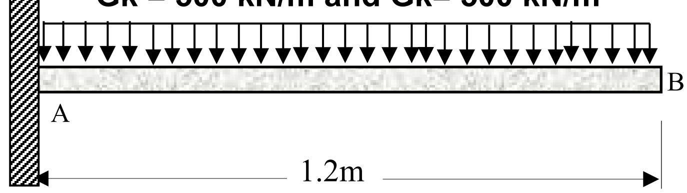

Figure Q1

Total 25 marks

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Question 2 (a) Concrete One-way Slab Design

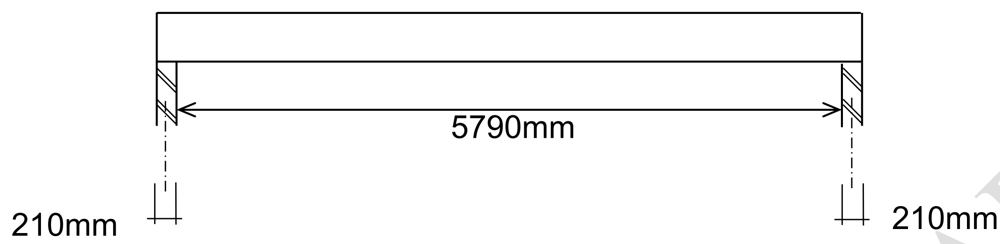

Figure Q2 (a)

Figure Q2 (a) shows a one-way spanning in-situ reinforced concrete slab, in an office building, with a clear span of 5790mm. The slab is supported on walls 210 mm thick, and is to be in C30/37 concrete with 30mm cover to all bars. The overall thickness of the slab is 250mm. Use the density of concrete as 25 kN/m^3

<u>Further information:</u>

Unfactored variable action	5.0 kN/m^2
Unfactored permanent action	Self-weight of the slab plus 3.0 kN/m^2 allowance for fixed partition walls, ceiling and services
Main bars	H16
f_{yk}	500N/mm^2

i) Show how the ultimate load on the slab amounts to 19.99 kN/m^2? (4 marks)
ii) Calculate the bending reinforcement required at mid-span and find the spacing of the steel bars. (11 marks)
iii) State the minimum and maximum reinforcement required. (3 marks)
iv) Draw a neat sketch of the slab cross-section showing the reinforcement distribution and relevant dimensions. (3 marks)

Question 2 continues over the page….

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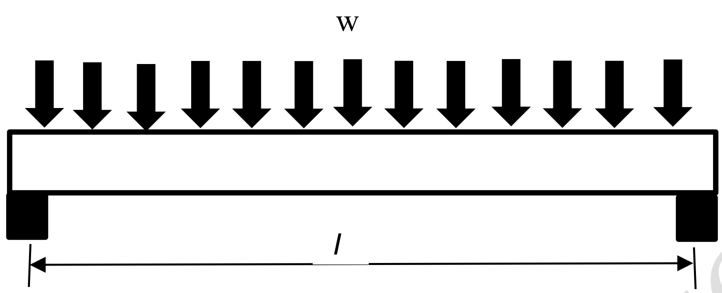
Question 2 continued…

Question 2 (b)

Figure Q2 (b) Shows a simply supported concrete beam with a span of ***l*** that loaded with a uniformly distributed load of ***w***. Draw a sketch to show the shape and locations of shear cracks in the beam (i.e. shear failure mode). Briefly comment on how the shear failure is prevented in concrete beams.



(4 marks)

Figure Q2 (b)

Total 25 marks

Question 3

(a) State three factors that affect the thickness of column base plates. (2 marks)

(b) **Figure Q3** shows a column base plate supporting an internal steel column with a size of:

254 × 254 × 73 UKC in **S275** steel.

The design value of axial compressive load is N_{Ed} = 1253 kN.

Design of compressive strength of foundation concrete is f_{cd} = 16 N/mm^2.
Assume the column base plate is with steel grade S275.

<u>Column details</u>
Height of section h= 254.1 mm
Breadth of section b = 254.6 mm
Thickness of flange t_f = 14.2 mm
Thickness of web t_w = 8.6 mm
Cross sectional Area A = 93.1 cm^2
Section perimeter = 1490 mm

Figure Q3

Question 3b continues over the page….
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Question 3b continued..

(i) Use the effective area method to calculate the minimum thickness of the column base plate to resist the design axial compressive load. (15 marks)
(ii) What is the minimum size (*WidthxDepth*) of the column base plate? (3 marks)
(iii) Draw to a suitable scale, the cross-section of the base plate showing part of the column and the holding down bolts. (5 marks)

Total 25 marks

***Effective Area Method*:**

Effective area ≈ 4c² + (Column section perimeter) × c + Column section area
Where c is the cantilever outstand of the effective area, as shown in Figure Q3.

Effective area = N_{Ed}/f_{cd}

$(Ac^2 + Bc + C = 0$ *) where A =4, B = Column perimeter,*
C = (Column section area – Effective area)

The value of *c* can be obtained by solving the above quadratic equation:

$$c = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$ With no overlap: $h - 2t_f - 2c > 0$

The minimum thickness of base plate (t_p) is given by: $$t_p \geq \frac{c}{\sqrt{f_{yp}/3f_{cd}}}$$

f_{cd} is the design compressive strength of concrete
f_{yp} is the yield strength of the base plate

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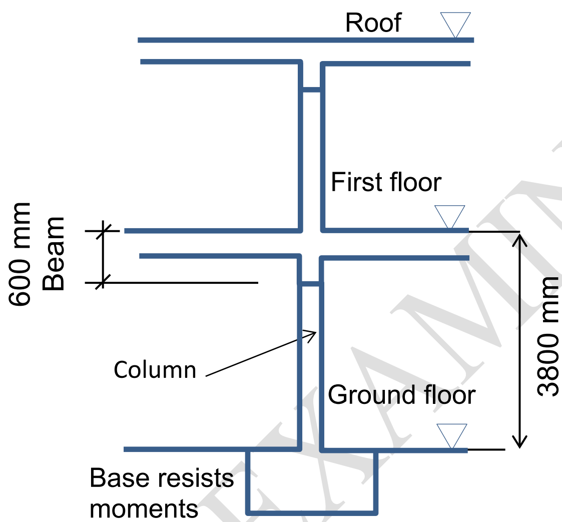
Question 4: Concrete Column Design

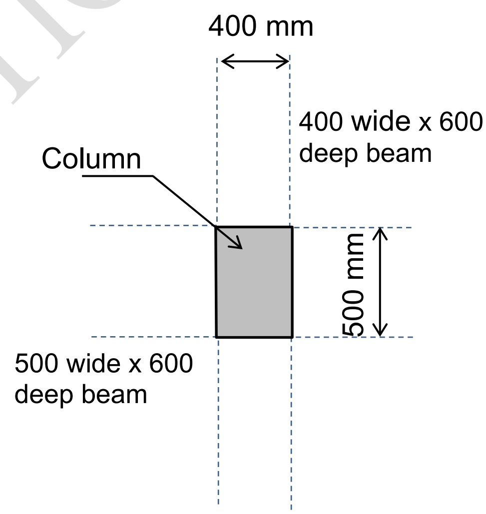
Figures Q4(a) and **Q4(b)** show a reinforced concrete column in ground floor supporting the first floor and roof of an office building. The column is supported on a base that is designed to resist moments. The plan dimensions of the column are 400mm x 500mm, and it is to be in C30/37 concrete with 35mm cover to all bars. Both of the beams framing into the column are 600mm deep. Floor to floor height is 3800mm. f_{yk} is 500 N/mm^2.

In your calculations, assume that longitudinal bars are H25 and ties are H8. In your final design, you may use different bars. It is necessary to design the column for bending and axial loads.

At ultimate limit state (ULS), the column supports an axial load of 1800 kN and framing action applies a bending moment of 350 kNm in the direction of the 500mm dimension (Column's strong axis).



Q4(a) Sectional Elevation



Q4(b) Plan view of the column

Figure Q4

Question 4 continues over the page ….

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Question 4 continued….

Answer the following questions:

(a) Determine whether the column is short (not slender) and calculate the design bending moment applied to the column.

(7 marks)

(b) State which column design chart should be used to design the reinforcement in the column and justify your choice.

(5 marks)

(c) Calculate the amount of longitudinal reinforcement and ties required for the column to support its design loads. Check with the minimum and maximum amount of reinforcement.

(8 marks)

(d) Draw an annotated transverse section through the column at around mid-height showing details of longitudinal reinforcement and ties.

(5 marks)

Total 25 marks

END OF QUESTIONS