OCD011

UNIVERSITY OF BOLTON

OFF CAMPUS DIVISION

WESTERN INTERNATIONAL COLLEGE

BENG (HONS) CIVIL ENGINEERING

SEMESTER TWO EXAMINATION 2023/2024

ADVANCE STRUCTURAL ANALYSIS AND DESIGN

MODULE NO: CIE6018

Date: 18th May 2024 **Time:10:00am – 1:00pm**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions on this paper.

Answer Any FOUR questions.

Marks for parts of questions are shown in brackets.

This examination carries a total of 100 marks.

Supplementary Information is provided on pages 10-11.

All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.

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QUESTION 1

a) Figure Q1(A) shows the section of an internal steel column UKC 254x254x107 to be used in a multi-story building. The column has pinned boundary conditions at each end, and the inter-storey height is 4.5m. By using the EC3 method, assess the suitability of the section to resist an ultimate design axial compressive load of 2875kN.

(18 marks)

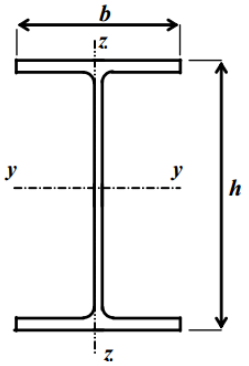

Figure Q1(A)

h = 266.7mm
b = 258.8mm
t_w = 12.8mm
t_f = 20.5mm
A = 136cm^2
I_y = 17510cm^4
I_z = 5928cm^4
i_y = 11.3cm
i_z = 6.59cm
Class 1 section
Steel grade S275
Modulus of Elasticity E = 210 kN/mm^2
Yield Strength fy = 275 N/mm^2

Additional information:

Euler Critical load $$N_{cr} = \frac{\pi^2 EI}{l_{cr}^2}$$

Design method and data sheet for buckling of columns to EC3 are attached at the end of this paper on Page 10 and Page 11.

b) Compare the structural behaviour between stocky and slender columns and analyse the imperfections that affect the buckling behaviour of slender columns.

(7 marks)

Total 25 marks

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QUESTION 2

a) A connection comprises of 6 bolts, arranged in pairs as shown in **Figure Q2 (A)**

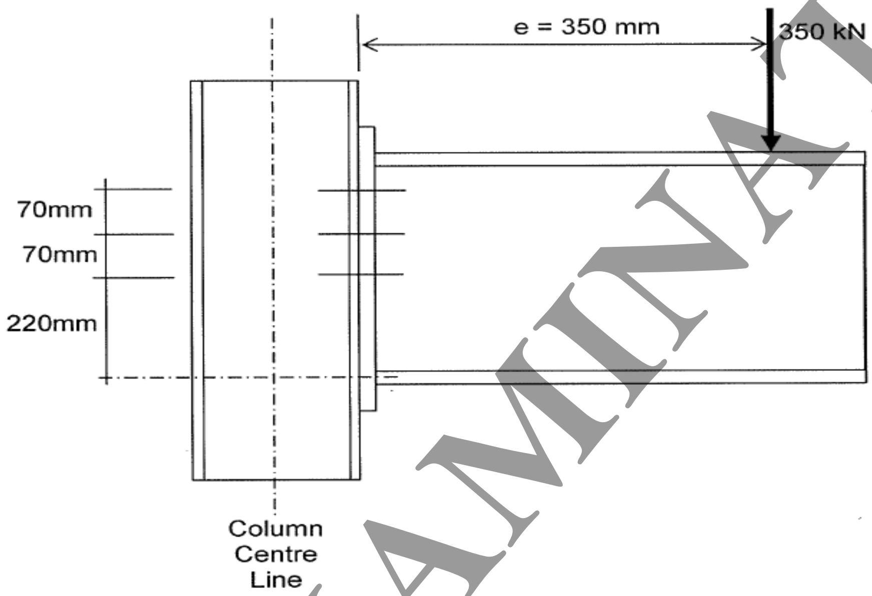

Figure Q2 (A)

Note: Engineers Bending Equation is $\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$

i) Which bolt should be checked for tension?

(3 marks)

ii) What are the maximum shear and tension loads in the bolts?

(12 marks)

Question 2 continues over the page

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Question 2 Continued

b) Determine the tension and shear in the hardest working bolt for the connection shown in **Figure Q2 (B)**

(10 Marks)

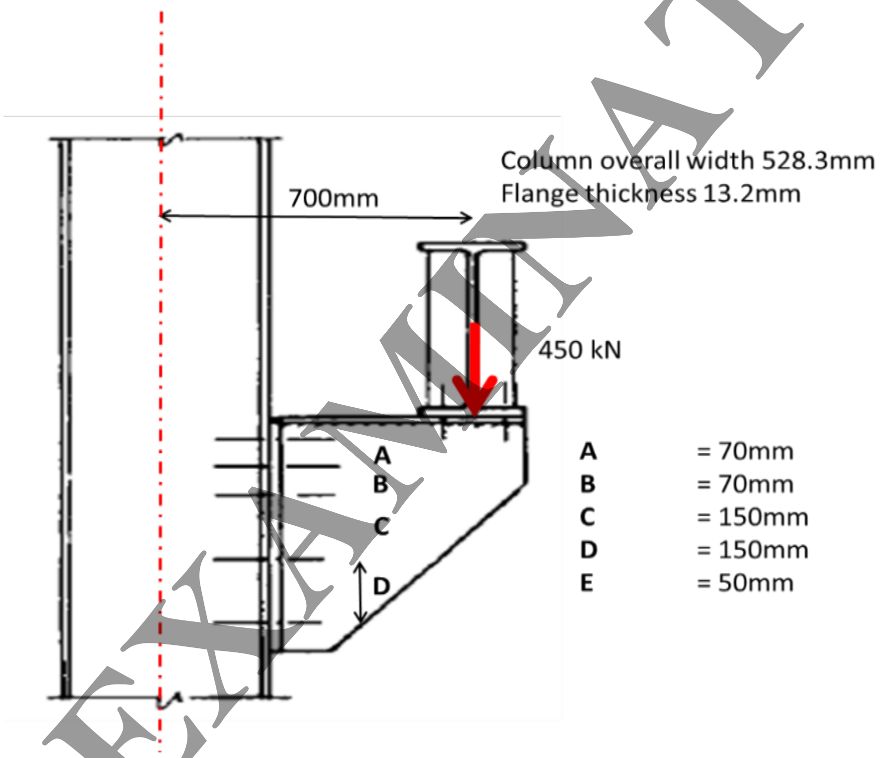

Figure Q2 (B)

Total 25 marks

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QUESTION 3

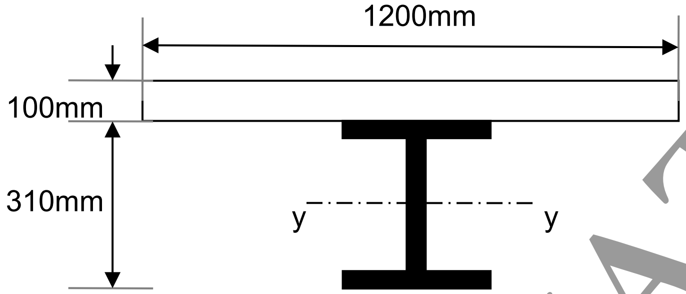

Figure Q3 (A)

Figure Q3 (A) shows the section of a composite steel/concrete beam. The E value of the steel is 205 kN/mm^2 and the E value of the concrete is 13.3 KN/mm^2.

The beam is simply supported over a span of 5.0m and carries the following factored uniformly distributed loads:

During construction (steel section alone carries loads)
10kN/m Dead Load + 15kN/m Imposed Load

In service (Loads are carried by the composite action)
15kN/m Dead Load + 18kN/m Imposed Load

a) Find the maximum working stress and maximum deflection of the beam during construction.

(4 marks)

Question 3 continues over the page

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Question 3 continued

b) Transform the composite section to an equivalent steel beam. Find the position of the neutral axis, the value of the moment of inertia, $I_{y,comp}$, and the values of elastic section modulus, $W_{el,y,comp}$, for the transformed beam.

(12 marks)

c) For the in-service condition, find the maximum stress in the steel, the maximum stress in the concrete and the maximum deflection of the composite beam. **(6 marks)**

d) Check whether the stresses in steel and concrete are within the allowable limits.

(3 marks)

Total 25 marks

DATA

The central deflection of a simply supported beam carrying a uniformly distributed load w per unit length is given by: $\delta = \frac{5wL^4}{384EI}$

QUESTION 4

a) Using the data given below, evaluate the stresses at top and bottom at transfer of a rectangular shaped beam which supports a bridge.

Data:

- The beam is simply supported with a span of 6.0m
- Depth of beam 300 mm, Breadth of beam 150mm
- Section modulus of the beam is 2.25 x 10^6 mm^3
- Distance from neutral axis of beam from bottom is 150mm
- The beam contains **six pre-stressing strands** (10mm diameter) at an average height of 100mm from the bottom of the beam
- The ultimate tensile force of the beam is 659.735 kN

(10 marks)

b) Critically compare and contrast pre-tensioning and post-tensioning methods of prestressing, considering:

i) The stages involved in each method using neat sketches

(10 marks)

ii) The advantages and disadvantages of each of the methods.

(5 marks)

Total 25 marks

QUESTION 5

a) **Figure Q5** shows a T-shaped pre-stressed concrete beam section. The beam contains **eight** pre-stressing strands (10mm diameter) at an average height of 100mm from the bottom of the beam.

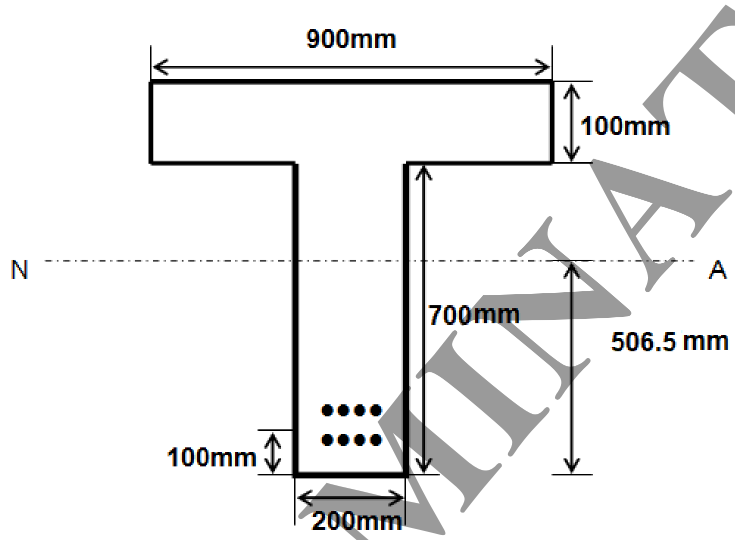

Figure Q5

The beam supports a parking area and so the proportion of the variable load to be considered in the quasi permanent loading condition is 0.6. In service, the beam is simply supported over a span of 12.0m and carries the following loads:

Permanent load (including beam self-weight)	9 kN/m	
Variable load	25 kN/m	
Characteristic breaking load of one strand	= 150.3 kN	
Initial pre-stress	= 70% of UTS	
Pre-stress losses	= 25% of initial pre-stress	
Concrete strength at transfer	fck	= 40 N/mm^2
Concrete strength in service	fck	= 55 N/mm^2

Limiting stresses in concrete:

At transfer	0.6 f_{ck} in compression;	1 N/mm^2 in tension
In service	0.45 f_{ck} in compression;	3.80 N/mm^2 in tension

Question 5 continues over the page
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Question 5 continued

i) Calculate the stresses in the concrete at the top and bottom of the beam:

- At transfer;

(5 marks)

- In service under quasi-permanent loads

(7 marks)

ii) Draw the distribution of stress over the height of the beam in service under quasi-permanent loads

(3 marks)

iii) Compare the calculated values of stress in the concrete with the limiting values of stress in the concrete and comment on the adequacy of the beam at transfer and service under quasi-permanent loads.

(5 marks)

b) Explain the concept of the pressure line in prestressed concrete beams. Use a neatly sketched diagram to illustrate the pressure line along the beam's cross-section due to prestressing, considering a simply supported beam prestressed by a force P at a constant eccentricity e with a uniformly distributed load throughout the beam.

(5 marks)

Total 25 marks

END OF QUESTIONS

Supplementary Information follows over the page

Supplementary Information

Extracts from Eurocode 3 : Design of Steel Structures

6.3 Buckling resistance of members

6.3.1 Uniform members in compression

6.3.1.1 Buckling resistance

(1) A compression member shall be verified against buckling as follows:

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1,0 \qquad (6.46)$$

where

N_{Ed} is the design value of the compression force
$N_{b,Rd}$ is the design buckling resistance of the compression member.

(3) The design buckling resistance of a compression member should be taken as:

$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}} \quad \text{for Class 1, 2 and 3 cross-sections} \qquad (6.47)$$

$$N_{b,Rd} = \frac{\chi A_{eff} f_y}{\gamma_{M1}} \quad \text{for Class 4 cross-sections} \qquad (6.48)$$

where χ is the reduction factor for the relevant buckling mode.

NOTE For determining the buckling resistance of members with tapered sections along the member or for non-uniform distribution of the compression force second-order analysis according to 5.3.4(2) may be performed. For out-of-plane buckling see also 6.3.4.

(4) In determining A and A_{eff} holes for fasteners at the column ends need not to be taken into account.

6.3.1.2 Buckling curves

(1) For axial compression in members the value of χ for the appropriate non-dimensional slenderness $\bar{\lambda}$ should be determined from the relevant buckling curve according to:

$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \quad \text{but } \chi \leq 1,0 \qquad (6.49)$$

where $\Phi = 0,5\left[1 + \alpha\left(\bar{\lambda} - 0,2\right) + \bar{\lambda}^2\right]$

$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}}$ for Class 1, 2 and 3 cross-sections

$\bar{\lambda} = \sqrt{\frac{A_{eff} f_y}{N_{cr}}}$ for Class 4 cross-sections

α is an imperfection factor
N_{cr} is the elastic critical force for the relevant buckling mode based on the gross cross sectional properties.

(2) The imperfection factor α corresponding to the appropriate buckling curve should be obtained from Table 6.1 and Table 6.2.

Table 6.1 — Imperfection factors for buckling curves

Buckling curve	a_0	a	b	c	d
Imperfection factor α	0,13	0,21	0,34	0,49	0,76

(3) Values of the reduction factor χ for the appropriate non-dimensional slenderness $\bar{\lambda}$ may be obtained from Figure 6.4.

(4) For slenderness $\bar{\lambda} \leq 0,2$ or for $\frac{N_{Ed}}{N_{cr}} \leq 0,04$ the buckling effects may be ignored and only cross-sectional checks apply.

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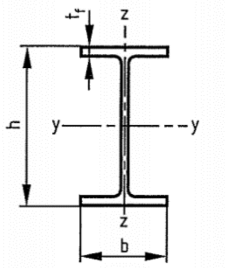
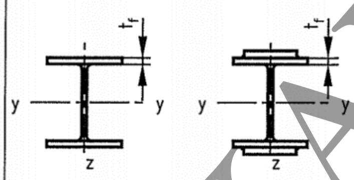
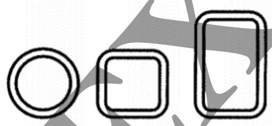
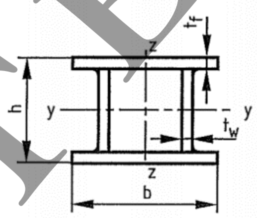
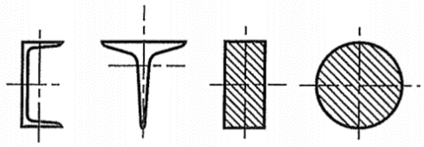
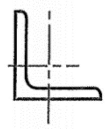
Supplementary Information continued

Guide to the Structural Eurocodes for students of structural design

Table 6.2 — Selection of buckling curve for a cross-section

Cross section		Limits		Buckling about axis	Buckling curve S 235, S 275, S 355, S 420	Buckling curve S 460
Rolled sections		$h/b > 1,2$	$t_f \le 40$ mm	y – y	a	a_0
				z – z	b	a_0
			$40 \text{ mm} < t_f \le 100$	y – y	b	a
				z – z	c	a
		$h/b \le 1,2$	$t_f \le 100$ mm	y – y	b	a
				z – z	c	a
			$t_f > 100$ mm	y – y	d	c
				z – z	d	c
Welded I sections		$t_f \le 40$ mm		y – y	b	b
				z – z	c	c
		$t_f > 40$ mm		y – y	c	c
				z – z	d	d
Hollow sections		hot finished		any	a	a_0
		cold formed		any	c	c
Welded box sections		generally (except as below)		any	b	b
		thick welds: $a > 0,5t_f$; $b/t_f < 30$; $h/t_w < 30$		any	c	c
U, T and solid sections				any	c	c
L sections				any	b	b

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