UNIVERSITY OF GREATER MANCHESTER

OFF CAMPUS DIVISION

WESTERN INTERNATIONAL COLLEGE, RAS AL KHAIMAH

BENG (HONS) CIVIL ENGINEERING

SEMESTER TWO EXAMINATION 2024/2025

ADVANCED STRUCTURAL ANALYSIS AND DESIGN

MODULE NO: CIE6018

Date: Saturday, 17 May 2025 **Time: 1:00 pm – 4:00 pm**

INSTRUCTIONS TO CANDIDATES:

There are FIVE (5) questions on this paper.

Answer ANY FOUR (4) 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 1** shows the section of an internal steel column UKC 254x254x107 kg/m to be used in a multi-story building. The column has pinned boundary conditions at each end, and the inter-storey height is 4m. By using the EC3 method, assess the suitability of the section to resist an ultimate design axial compressive load of 2650kN.

(18 marks)

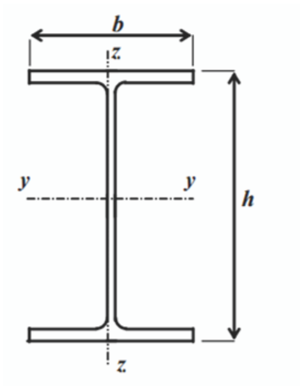

Figure 1

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) With reference to Euler's buckling theory, evaluate how column slenderness ratio influences failure modes. Discuss the role of geometric imperfections and loading eccentricities in reducing the load-carrying capacity of slender columns.

(7 marks)

[TOTAL 25 MARKS]

Please turn the page

QUESTION 2

The L shaped bracket shown in **Figure 2** and **Figure 3** is connected to a steel column 310mm deep with 8 Nos M20 grade 8.8 bolts. The bracket is formed from UB 409 x 178 x 74 kg/m steel section with the following properties:

Web thickness	9.7mm
Flange thickness	16mm
Depth of section	412.9mm
Width of section	179.7mm

A factored vertical load of 70 kN is applied at the location shown in the plan view of the bracket.

a) Calculate both the out-of-plane moment and the in-plane moment acting on the bolt group in the given connection.

(5 marks)

b) Compute the resulting tensile and shear forces in each of the four bolts located in bolt rows b1 and b3 **(Figure 3)** due to the applied loads.

(15 marks)

c) Assess whether the selected bolt size and grade are sufficient to resist the applied loads. Support your answer with calculations or reference to relevant design codes.

(5 marks)

[TOTAL 25 MARKS]

Question 2 continued over the page…

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Question 2 continued…

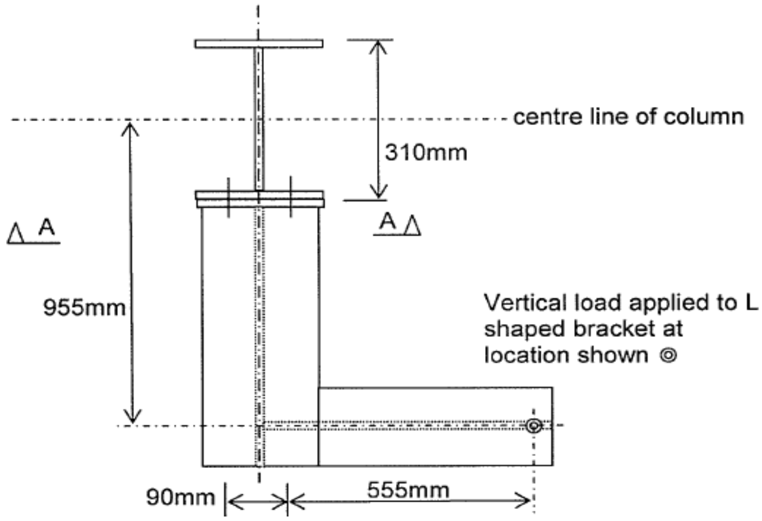

Figure 2

PLAN VIEW ON BRACKET

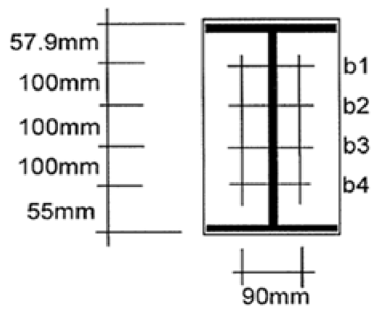

Figure 3

SECTIONAL ELEVATION A-A ON BOLTED ENDPLATE

SHOWING SETTING OUT OF BOLTS

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QUESTION 3

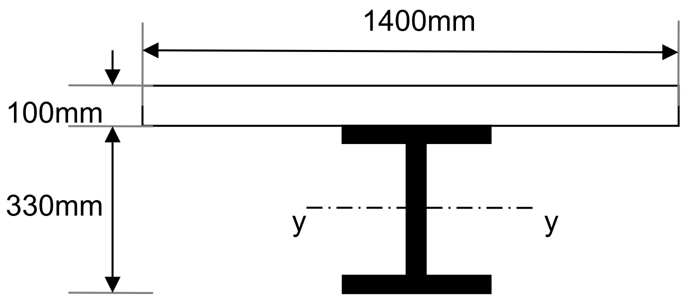

Figure 4

Figure 4 shows the section of a composite steel/concrete beam. The E value of the steel is 200 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 6.0m and carries the following factored uniformly distributed loads:

During construction (steel section alone carries loads)

12kN/m Dead Load + 17kN/m Imposed Load

In service (Loads are carried by the composite action)

17kN/m Dead Load + 20kN/m Imposed Load

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

(4 marks)

Question 3 continued over the page…

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 provided below, evaluate the stresses at the top and bottom fibres at transfer for a rectangular shaped pre-stressed beam used in an elevated roadway.

Data:

- The beam is simply supported with a span of 8.0m
- Depth of beam 400 mm, Breadth of beam 200 mm
- Section modulus of the beam is 5.33 x 10^6 mm^3
- Distance from neutral axis of beam from bottom is 200mm
- The beam contains **five pre-stressing strands** (12 mm diameter) at an average height of 75 mm from the bottom of the beam
- Initial prestress is 75% of ultimate tensile force
- Prestress loss is 25% of initial
- The ultimate tensile force of the beam is 791.68 kN

(12 marks)

b) Why is high tensile steel needed for prestressed concrete construction?

(6 marks)

c) List out the advantages of prestressed concrete.

(7 marks)

[TOTAL 25 MARKS]

Please turn the page

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QUESTION 5

a) **Figure 5** shows a T-shaped pre-stressed concrete beam section. The beam contains **twelve** pre-stressing strands (12mm diameter) at an average height of 150mm from the bottom of the beam.

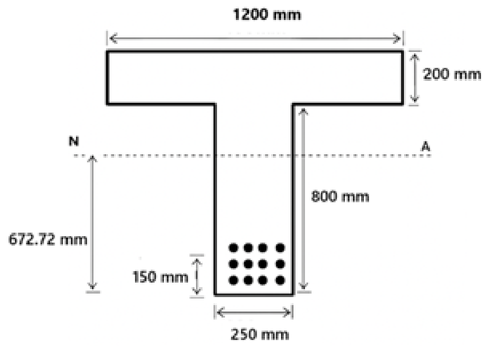

Figure 5

The beam supports residential roof slab and therefore 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 10.0m and carries the following loads:

Permanent load (including beam self-weight)		8 kN/m	
Variable load		27 kN/m	
Characteristic breaking load of one strand		158.67 kN	
Initial pre-stress		75% of UTS	
Pre-stress losses		25% of initial pre-stress	
Concrete strength at transfer		f_{ck}	40 N/mm^2
Concrete strength in service		f_{ck}	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 continued over the page…

Question 5 continued…

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

- At transfer;

(7 marks)

- In service under quasi-permanent loads

(5 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) List the different types of prestress losses in concrete. Briefly explain the loss due to friction and the loss due to anchorage slip.

(5 marks)

[TOTAL 25 MARKS]

END OF QUESTIONS
PLEASE TURN THE PAGE FOR SUPPLEMENTARY INFORMATION

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SUPPLEMENTARY INFORMATION

Extracts from Eurocode 3: Design of Steel Structures

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

$\bar{\lambda} = \sqrt{\frac{A f_y}{N_{cr}}}$ 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.

Supplementary Information continued over the page…

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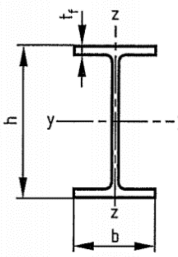
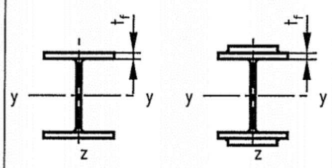
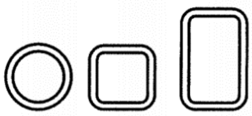
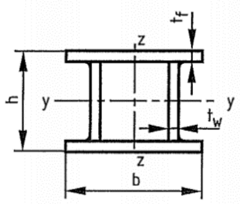
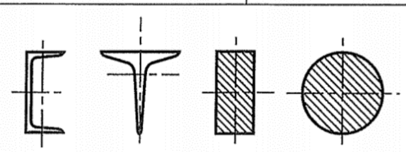
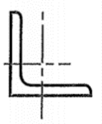
Supplementary Information continued…

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 z – z	a b	a_0 a_0
			$40 \text{ mm} < t_f \le 100$	y – y z – z	b c	a a
		$h/b \le 1,2$	$t_f \le 100$ mm	y – y z – z	b c	a a
			$t_f > 100$ mm	y – y z – z	d d	c c
Welded I sections		$t_f \le 40$ mm		y – y z – z	b c	b c
		$t_f > 40$ mm		y – y z – z	c d	c 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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