OCD021

UNIVERSITY OF BOLTON

OFF CAMPUS DIVISION

WESTERN INTERNATIONAL COLLEGE FZE

BENG(HONS) CIVIL ENGINEERING

TRIMESTER TWO EXAMINATION 2021/2022

ADVANCED STRUCTURAL ANALYSIS AND DESIGN

MODULE NO. CIE6001

Date: Tuesday 26th April 2022 **Time: 10:00am – 1:00pm**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions on this paper.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

This examination paper carries a total of 100 marks.

Formula sheet / supplementary information is provided at the end of question paper.

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

University of Bolton
Western International College FZE
BEng (Hons) Civil Engineering
Trimester 2 Examination 2021/2022
Advanced Structural Analysis and Design
Module No. CIE6001

Q1

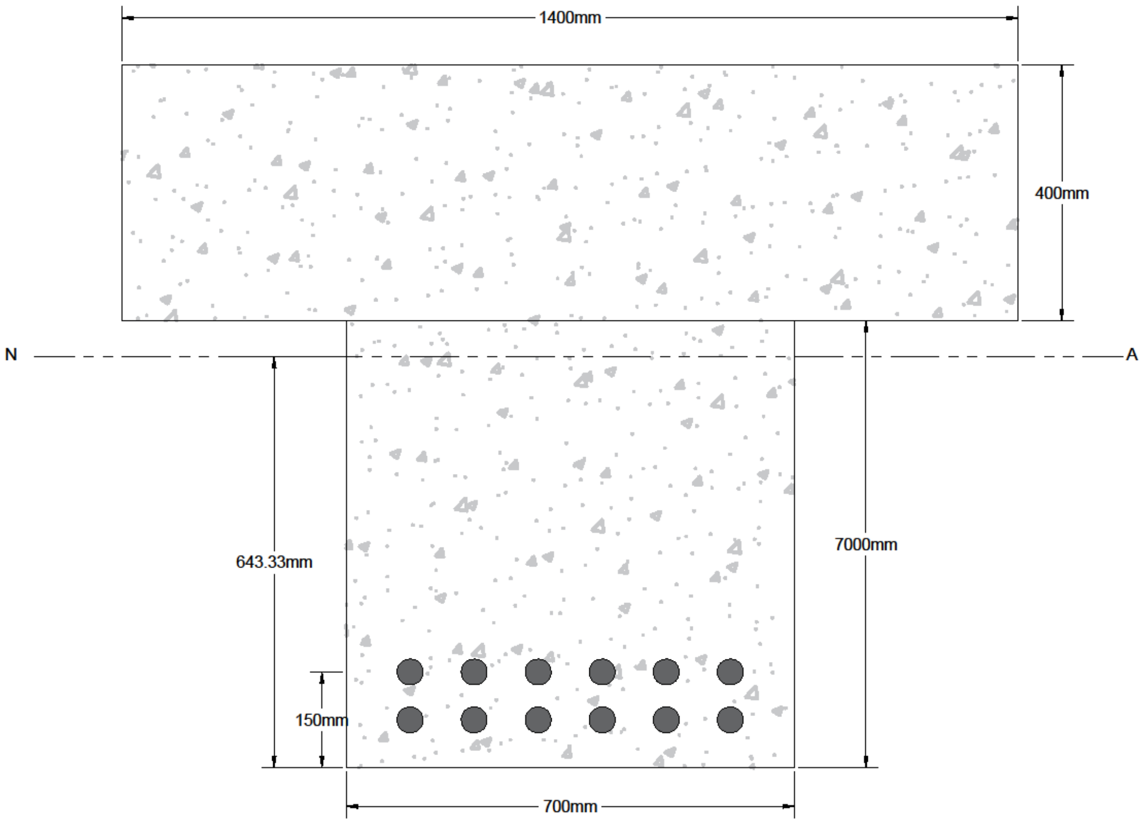


Figure Q1

Figure Q1 shows a T-shaped pre-stressed concrete beam section. The beam contains **twelve** pre-stressing strands (12.7mm diameter) at an average height of 150mm from the bottom of the beam.

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 8m and carries the following loads:

Permanent load (including beam self-weight)	35 kN/m
Variable load	50 kN/m
Characteristic breaking load of one strand	184 kN

Q1 continued over the page

PLEASE TURN THE PAGE…

Q1 continued

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 $_{ck}$ in compression;	3.80 N/mm^2 in tension

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

(i) At transfer;

(9 marks)

(ii) In service under quasi-permanent loads

(6 marks)

b) Draw the distribution of stress over the height of the beam

(i) At transfer;

(2.5 marks)

(ii) In service under quasi-permanent loads

(2.5 marks)

c) Compare the calculated values of stress in the concrete with the limiting values of stress in the concrete:

(i) at transfer; (ii) in service under quasi-permanent loads.

Comment on the adequacy of the beam.

(5 marks)

Total 25 marks

University of Bolton
Western International College FZE
BEng (Hons) Civil Engineering
Trimester 2 Examination 2021/2022
Advanced Structural Analysis and Design
Module No. CIE6001

PLEASE TURN THE PAGE…..

Q2

a) **Figure Q2(a**) shows the section of an internal steel column UKC 254x254x132 to be used in a multi story building. The column has pinned boundary conditions at each end; and the inter storey height is 5m.

By using the EC3 method, assess the suitability of the section to resist an ultimate design axial compressive load of 2800Kn.

(18 marks)

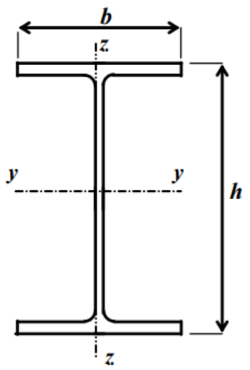


Figure Q2(a)

h	=	276.3mm
b	=	261.3mm
t_w	=	15.3mm
t_f	=	25.3mm
A	=	168cm^2
I_y	=	22529cm^4
I_z	=	7531cm^4
i_y	=	11.6cm
i_z	=	6.69cm
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.

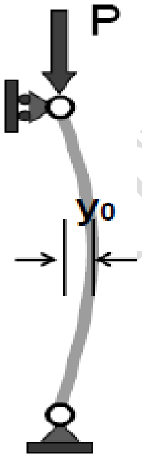
Q2 continued over the page

PLEASE TURN THE PAGE…..

Q 2 continued

b)

Figure Q2(b) shows a pin ended real strut made of steel strip 30mm x 4mm having a length equal to 150 mm. The strut has a small initial curvature causing a departure of y_0 = 0.6 mm at its mid length. If an axial load of 5.5 KN is applied to the strut compute the average stress in the strut.



E = 200KN/mm^2
fy = 275 N/mm^2

Figure Q2(b)

(7 marks)

Total 25 marks

PLEASE TURN THE PAGE …

University of Bolton
Western International College FZE
BEng (Hons) Civil Engineering
Trimester 2 Examination 2021/2022
Advanced Structural Analysis and Design
Module No. CIE6001

Q3

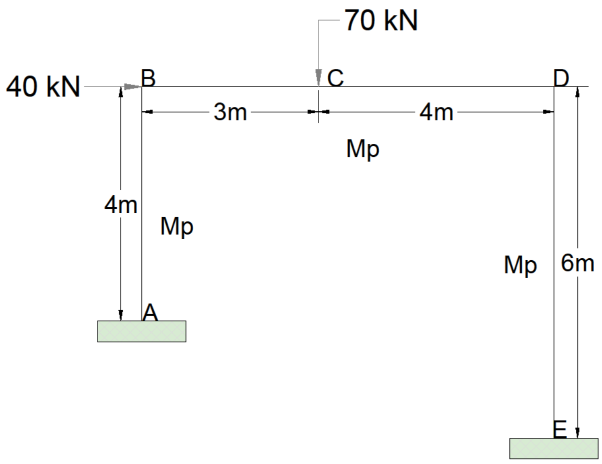


Figure Q3

Figure Q3 shows a rigid-jointed frame ABCDE consists of the beam BD of span 7m and columns of height 4m (Column AB) and 6m (Column DE). The columns are fixed at the base. The frame carries a vertical point load 70 kN, 3m away from B and a horizontal point load at B as depicted in **Figure Q3.**

a) Find the values of plastic moment which correspond to the following collapse mechanisms:

(i) Plastic hinges at B, C and D

(6 marks)

(ii) Plastic hinges at A, D and E

(6 marks)

(iii) Plastic hinges at A, B,D and E

(6 marks)

b) Draw the bending moment diagram for the most critical of the collapse mechanisms in part (a), showing values at A, B, C, D and E.

(7 marks)

Total 25 marks

PLEASE TURN THE PAGE…

Q4

The L shaped bracket shown in **Figure Q4(a)** and **Q4(b)** 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 70 kN is applied at the location shown in the plan view of the bracket.

(i) What is the out of plane moment in the bolt group?

(2.5 marks)

(ii) What is the in plane moment in the bolt group?

(2.5 marks)

(iii) What are the tension and the shear in the four bolts in bolt rows b1 and b3?

(15 marks)

(iv) Comment on the adequacy of the specified bolts.

(5 marks)

Total 25 marks

Q 4 continued over the page

University of Bolton
Western International College FZE
BEng (Hons) Civil Engineering
Trimester 2 Examination 2021/2022
Advanced Structural Analysis and Design
Module No. CIE6001

PLEASE TURN THE PAGE…

Q4 continued

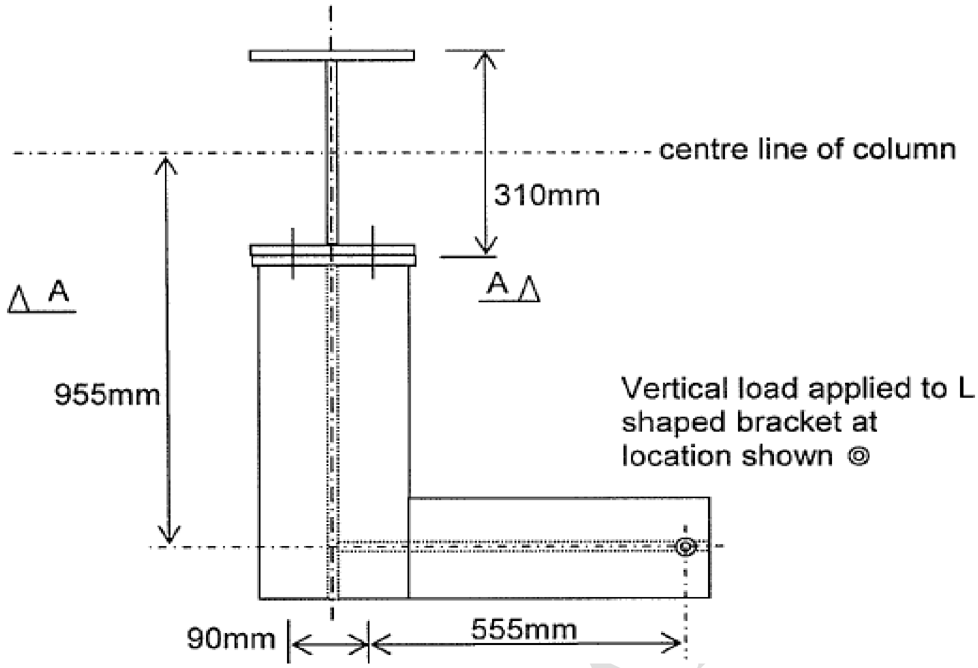


Figure Q4 (a)
PLAN VIEW ON BRACKET

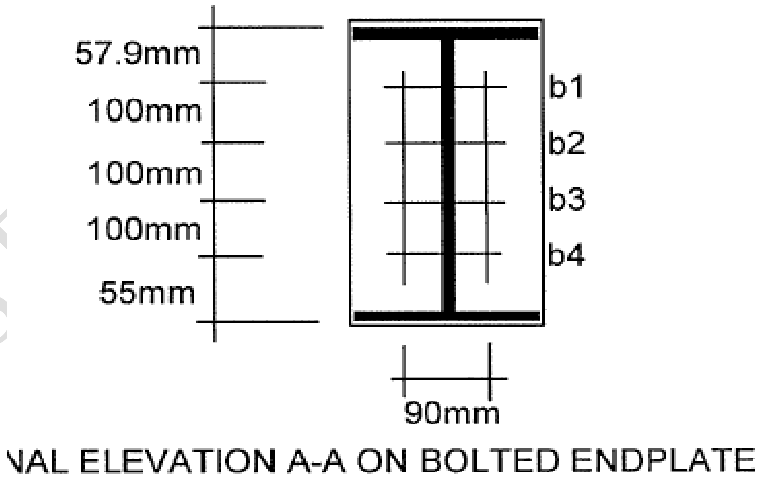


Figure Q4 (b)
SECTIONAL ELEVATION A-A ON BOLTED ENDPLATE
SHOWING SETTING OUT OF BOLTS

PLEASE TURN THE PAGE…

University of Bolton
Western International College FZE
BEng (Hons) Civil Engineering
Trimester 2 Examination 2021/2022
Advanced Structural Analysis and Design
Module No. CIE6001

Q5

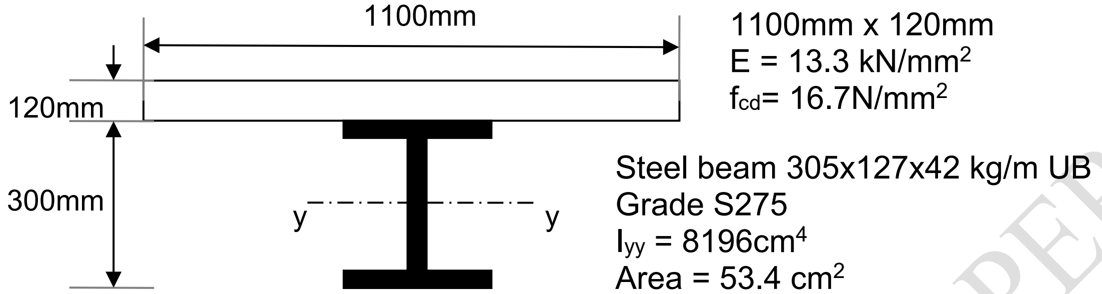


Figure Q5

Figure Q5 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 simple supported over a span of 5.5m 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

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

(5 marks)

(ii) 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)

Q5 continued over the page

PLEASE TURN THE PAGE…

Q5 continued

(iii) 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

(5 marks)

(iv) 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: $\delta = \dfrac{5wL^4}{384EI}$

END OF QUESTIONS

PLEASE TURN THE PAGE FOR 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:

$$\frac{N_{Ed}}{N_{b,Rd}} \leq 1,0 \tag{6.46}$$

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:

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

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

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:

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

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

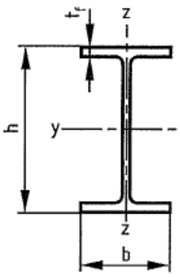
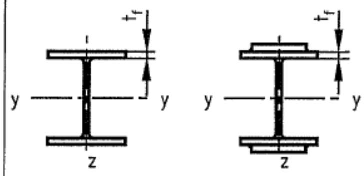
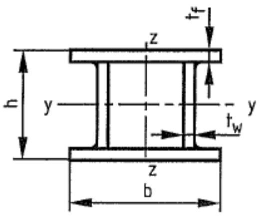
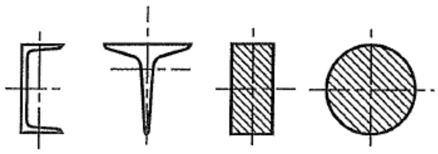
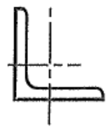
(3) Values of the reduction factor χ for the appropriate non-dimensional slenderness $\bar{\lambda}$ may be obtained from Figure 6.4.

(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.

PLEASE TURN THE PAGE…

University of Bolton
Western International College FZE
BEng (Hons) Civil Engineering
Trimester 2 Examination 2021/2022
Advanced Structural Analysis and Design
Module No. CIE6001

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 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

END OF SUPPLEMENTARY INFORMATION
END OF PAPER