OCD030

UNIVERSITY OF BOLTON

WESTERN INTERNATIONAL COLLEGE FZE

BEng (HONS) CIVIL ENGINEERING

SEMESTER ONE EXAMINATION 2018/2019

ADVANCED STRUCTURAL ANALYSIS AND DESIGN

MODULE NO: CIE6001

Date: Tuesday 8th January 2019 **Time: 10.00am to 1.00pm**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions on this paper.

Answer ALL questions.

All questions carry equal marks.

Marks for parts of questions are shown in the brackets.

This examination paper carries a total of 100 marks.

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

Extracts from EC3 for use in Question 1 are attached on Pages 11-12 of this paper.

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Question 1

The roadway signboard structure shown in **Figure Q1(a) below** has a SHS 200X200 steelwork post with a square baseplate bolted with six holding down bolts as shown in **Figure Q1(d) on page 4**. The signboard whose dimensions are shown in **Figure Q1(b) on page 3** has a self-weight of 15kN(factored) acting downwards and a factored wind load of 8kN acting perpendicular (line of action acting towards the centre) to the sign board as shown in the plan view **Figure Q1(c) on page 3**.

The SHS steel section has the following properties:

Wall thickness	15mm
Depth of section	200mm
Width of section	200mm

i) Calculate the in plane and out of plane moments acting on the holding down bolts of the bolt group. Also state the direct shear acting on the bolt group. (4 marks)

ii) What are the tension and the shear forces in the bolt carrying the greatest tensile force? Provide Figures to support the solution. (16 marks)

Total 20 marks

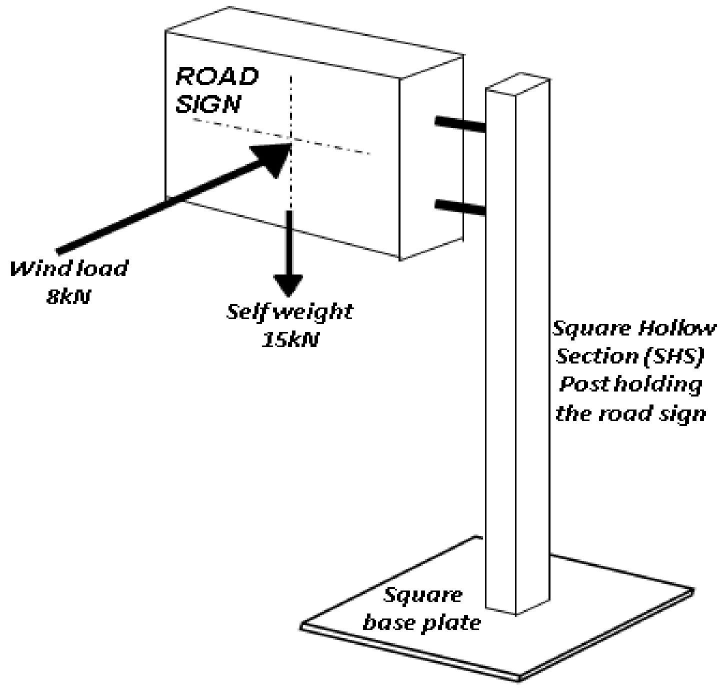

Figure Q1(a): Elevation of a roadway signboard

Question 1 continued over the page

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Question 1 continued

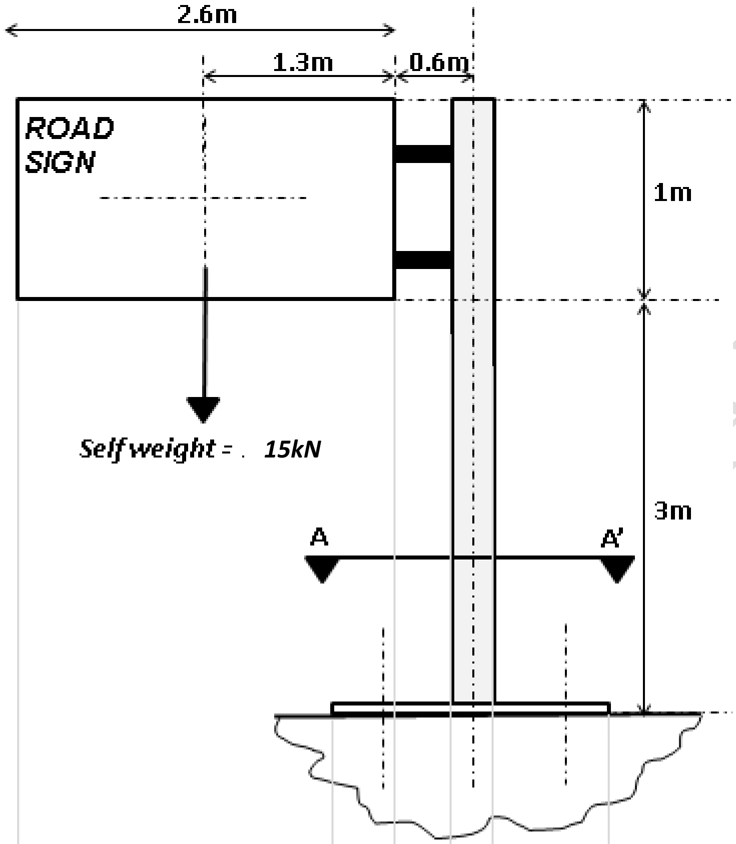

Figure Q1(b): Front elevation view of the steel structure holding the road sign

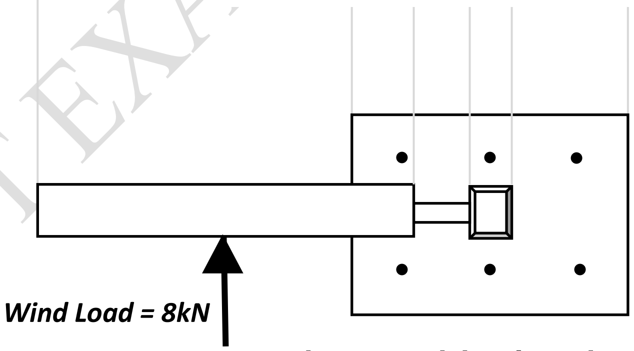

Figure Q1(c): Plan view of the road sign showing the direction of the wind load

Question 1 continued over the page
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Question 1 continued

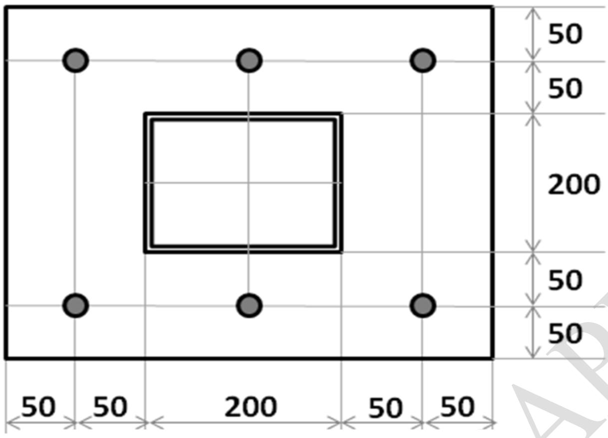

Figure Q1(d): Section A-A'
Plan view of base plate
All dimensions are in mm

Question 2

A multi-storey building requires an internal steel column which will carry an ultimate design axial compressive load of 1700 kN. The column has pinned boundary conditions at each end, and the inter-storey height is 6 m.

Two alternatives are proposed:

i) A hot formed circular hollow section with a diameter 200 mm and wall thickness of 10 mm with Class 2 section, as shown in **Figure Q2(a).**

ii) Hot rolled UKC 254x146x43 section in steel grade S275 and Class 1 section, as shown in **Figure Q2(b).**

a) By using the EC3 method, assess the suitability of both alternatives to resist the ultimate design axial compressive load. (17 marks)

b) What conclusion do you draw from the results in part (a)? Which section shape do you recommend and why? (3 marks)

Total 20 marks

Question 2 continued over the page
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Question 2 continued...

d	=	200mm
t	=	10mm
A	=	$74.9cm^2$
$I_y = I_z$	=	$4470cm^4$
Class 2 section		
Steel grade S355		
Modulus of Elasticity E = $210kN/mm^2$		
Yield Strength fy = $275N/mm^2$		

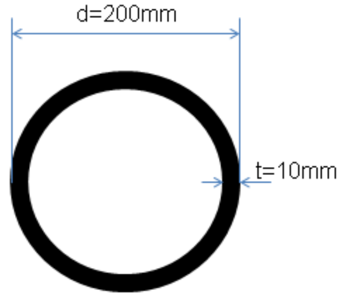

Figure Q2(a): Circular Hollow Section (CHS)

h	=	259.6
b	=	147.3mm
t_w	=	7.2mm
t_f	=	12.7mm
A	=	$54.8cm^2$
I_y	=	$6540cm^4$
I_z	=	$677cm^4$
i_y	=	10.9cm
i_z	=	3.52cm
Class 1 section		
Steel grade S275		
Modulus of Elasticity E = $210kN/mm^2$		
Yield Strength fy = $275 N/mm^2$		

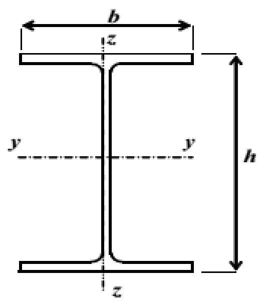

Figure Q2(b): UKC254x146x43

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 11 and Page 12.

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Question 3

A composite floor construction consists of a concrete floor slab supported on a steel beam as shown in **Figure Q3(a)**. The steel beam is propped during casting of the concrete, so that, when the concrete has hardened, the props are removed and all loading is carried by composite beam action.

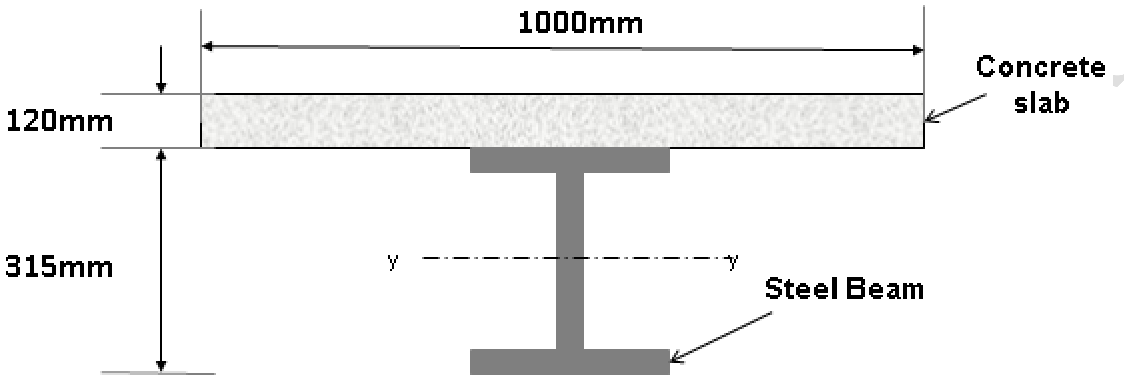

Figure Q3(a)

Steel beam 305x102x33 kg/m UB
Grade S275
I_{yy} = 6500cm^4
Area = 41.6cm^2
E = 205 kN/mm^2

Concrete slab 1000mm x 120mm
E = 13.3 kN/mm^2
f_{cd}= 16.7N/mm^2

The beam is simple supported over a span of 8.0m and carries the following factored uniformly distributed loads:

During construction (steel section alone carries loads):
7kN/m Dead Load + 15kN/m Imposed Load

In service (Loads are carried by the composite action) as shown in **Figure Q3(b)**

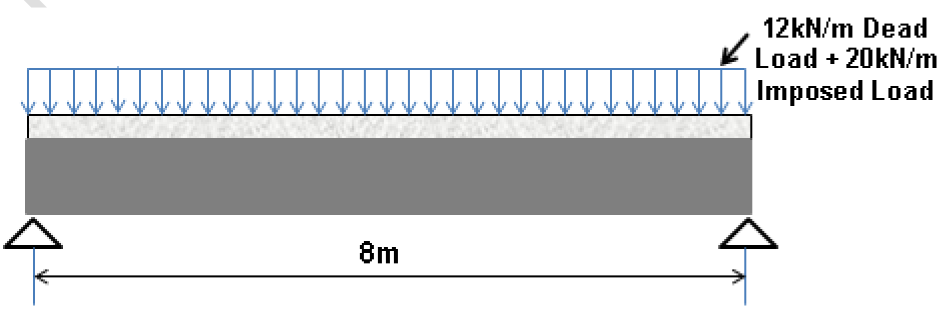

Figure Q3(b)

Question 3 continued over the page
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Question 3 continued

a. Find the maximum working stress and maximum deflection of the beam during construction. (3 marks)

b. Transform the composite section to an equivalent steel beam. Find the position of the neutral axis, the value of the moment of inertia, $\mathbf{I_{y,comp}}$, and the values of elastic section modulus, $\mathbf{W_{el,y,comp}}$, for the transformed beam. (10 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. (5 marks)

d. Check whether the stresses in steel and concrete are within the allowable limits. (2 marks)

DATA

The central deflection of a simply supported beam carrying a uniformly distributed load w per unit length is given by:

$$\delta = \frac{5wL^4}{384EI}$$

Total 20 marks

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Question 4

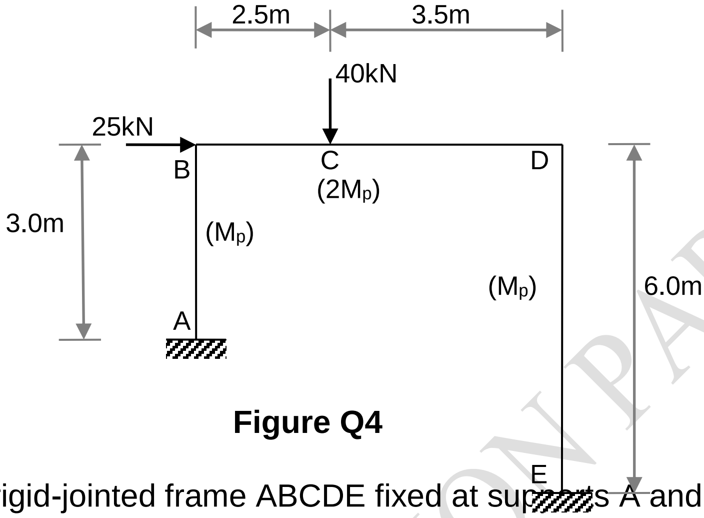

Figure Q4

Figure Q4 shows a rigid-jointed frame ABCDE fixed at supports A and E. The plastic moment is $2M_p$ for the beam BCD and M_p for columns AB and DE. The frame carries one horizontal load of 25kN at B and one vertical load of 40kN at C.

(a) Find the values of M_p which correspond to the following collapse mechanisms:
- i) Plastic hinges at B, C and D.
- ii) Plastic hinges at A, B, D and E.
- iii) Plastic hinges at A, C, D and E. (15 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. (5 marks)

Total 20 marks

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Question 5

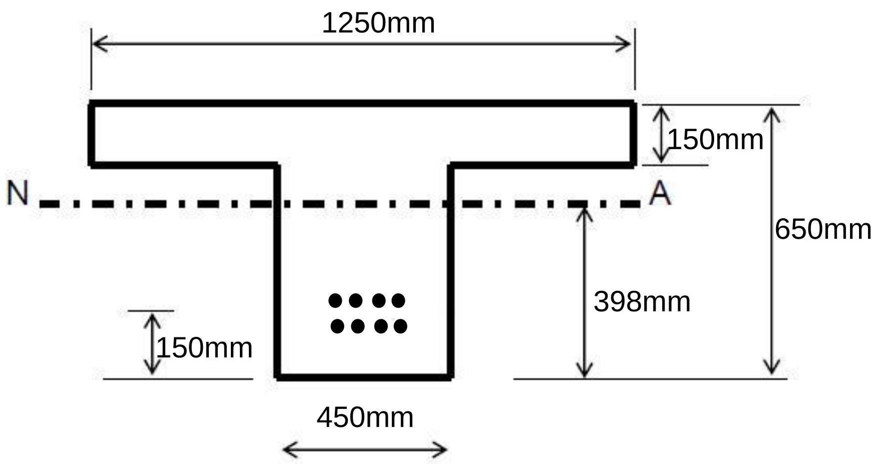

Figure Q5

Figure Q5 shows the cross section of a simply supported pre-stressed concrete beam of span 6.5m. The beam contains eight 12.9mm diameter (7 wire Super Strand) pre-stressing strands at a height of 150 mm from the bottom of the beam.

The beam supports offices and so the proportion of the variable load to be considered in the quasi permanent loading condition is 0.3. In service, the beam carries the following loads:
Permanent load (including beam self weight) 50kN/m
Variable load 40kN/m

Characteristic strength of one pre-stressing strand = $1860 N/mm^2$
Initial pre-stress = 70% of UTS
Pre-stress losses = 25% of initial pre-stress
Concrete strength at transfer f_{ck} = $35 N/mm^2$
Concrete strength in service f_{ck} = $45 N/mm^2$
For the whole concrete section Area = $412.5x 10^3 mm^2$
I_{NA} = $15.8 x 10^9 mm^4$

Limiting stresses in concrete:
At transfer $0.6f_{ck}$ in compression; $1N/mm^2$ in tension
In service $0.45f_{ck}$ in compression; $3.8N/mm^2$ in tension

Question 5 continued over the page

Please turn the page

Question 5 continued

(a) Calculate the stresses in the concrete at the top and bottom of the beam:
(i) at transfer and
(ii) In service under quasi-permanent loads

(13 marks)

(b) Draw the distribution of stress over the height of the beam:
(i) at transfer and
(ii) In service under quasi-permanent loads

(4 marks)

(c) Compare the calculated values of stress in the concrete with the limiting values of stress in the concrete:
(i) at transfer and
(ii) In service under quasi-permanent loads. Comment on the adequacy of the beam

(3 marks)

Total 20 marks

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:

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

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:

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

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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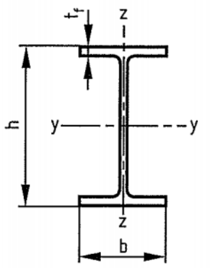
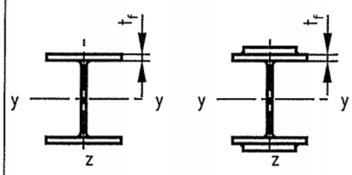
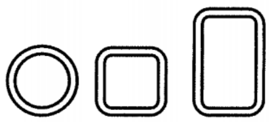
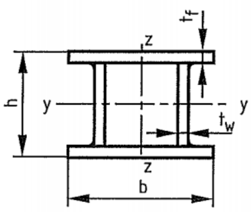
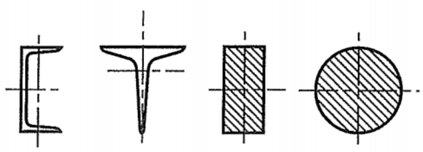
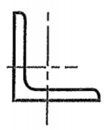
Guide to the Structural Eurocodes for students of structural design

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 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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