Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2023/2024

COURSE NAME	:	STRUCTURAL STEEL DESIGN
COURSE CODE	:	BFC 44903
PROGRAMME CODE	:	BFF
EXAMINATION DATE	:	JANUARY/FEBRUARY 2024
DURATION	:	3 HOURS
INSTRUCTIONS	:	1. ANSWER ALL QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA ☒ Open book ☐ Closed book 3. STUDENTS ARE **ONLY ALLOWED** TO CONSULT THEIR OWN CODE OF PRACTICE BS EN 1993 AND TABLE OF SECTION PROPERTIES.

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

Q1 **Figure Q1.1** shows a floor layout plan. The floor is built from precast concrete slab which bonding between the slab and the steel beam does not provide restraint between the two structural elements. Secondary beam B/2-3 is providing restraint at point B for Beam 2/A-C (see **Figure Q1.2**). The characteristic loadings on the floor are as follows:

Self-weight of slab	=	3.5 kN/m^2
Floor finishing	=	1.0 kN/m^2
Imposed load	=	3.0 kN/m^2
Self-weight of the beam	=	0.7 kN/m

Refer to **Appendix A** and **Appendix B** for further information to solve this question.

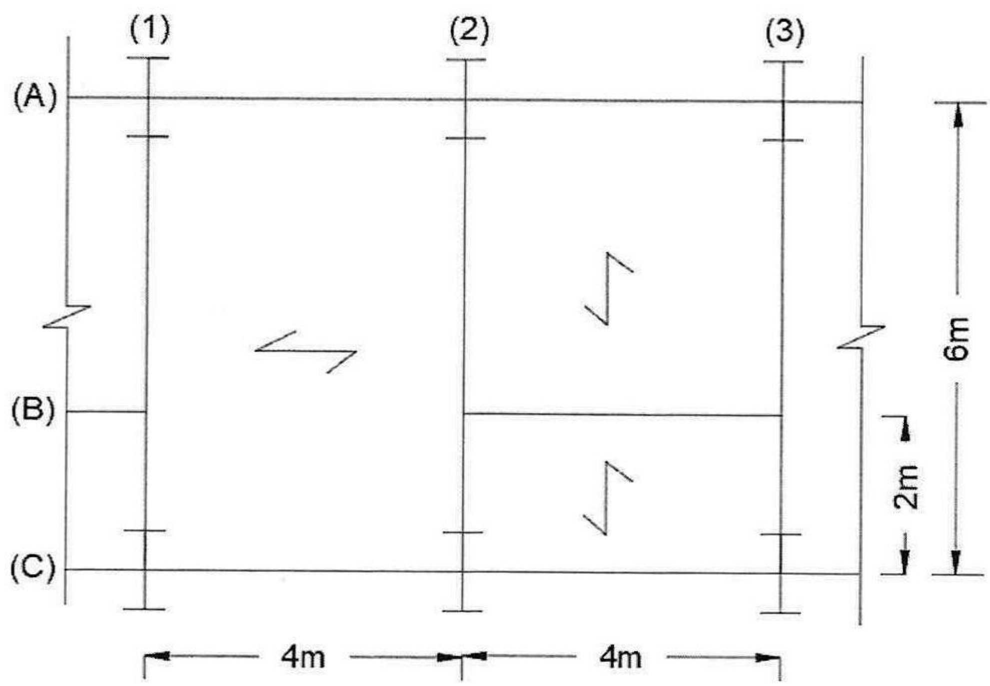


Figure Q1.1 – Floor layout plan

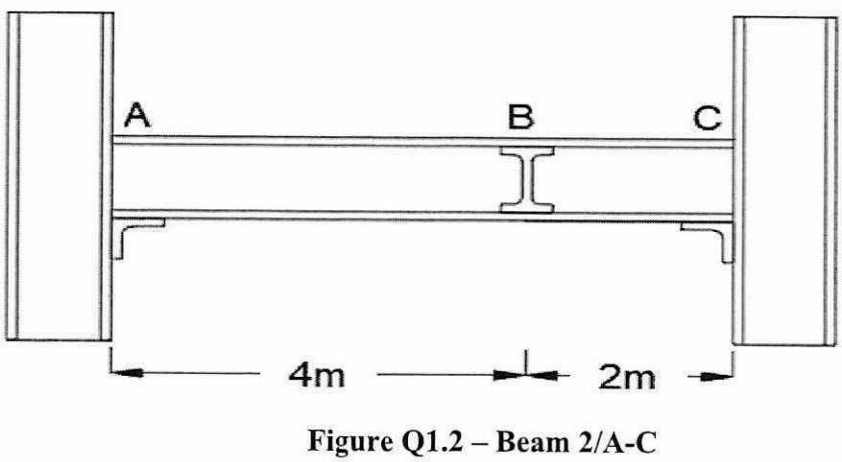


Figure Q1.2 – Beam 2/A-C

Consider Beam 2/A-C using 406 x 178 x 74 UB grade S275 steel where the elevation is given in **Figure Q1.2**. Determine the following:

(a) Bending moment (in kNm) and shear force (in kN) diagrams (5 marks)

(b) Classify the section. (4 marks)

(c) Shear capacity (in kN) and perform shear buckling check (5 marks)

(d) Check deflection under serviceability limit state (5 marks)

(e) Buckling resistance moment in kNm for the most critical segment. (11 marks)

Q2 This question assesses your competency in column design.

(a) List the **TWO (2)** phenomenon that can cause secondary bending effects in structural elements subjected to compression force. (4 marks)

(b) Draw the overall buckling shape for **ONE (1)** of the columns (from Ground to Roof Level) in **Figure Q2.1** and for typical compression members in the truss structure of **Figure Q2.2**. (4 marks)

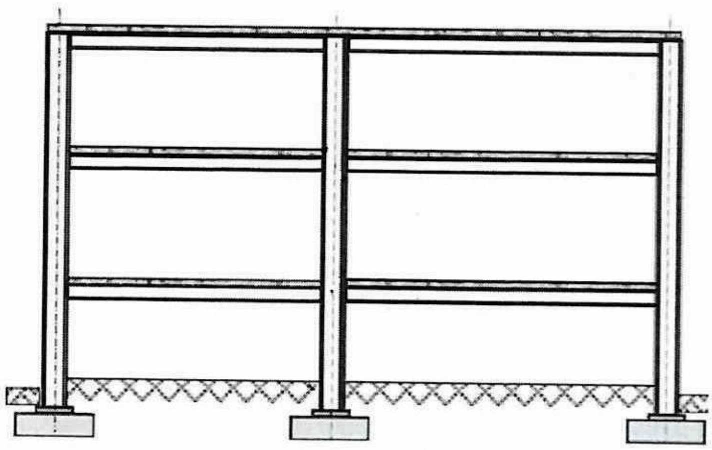


Figure Q2.1 – Building elevation

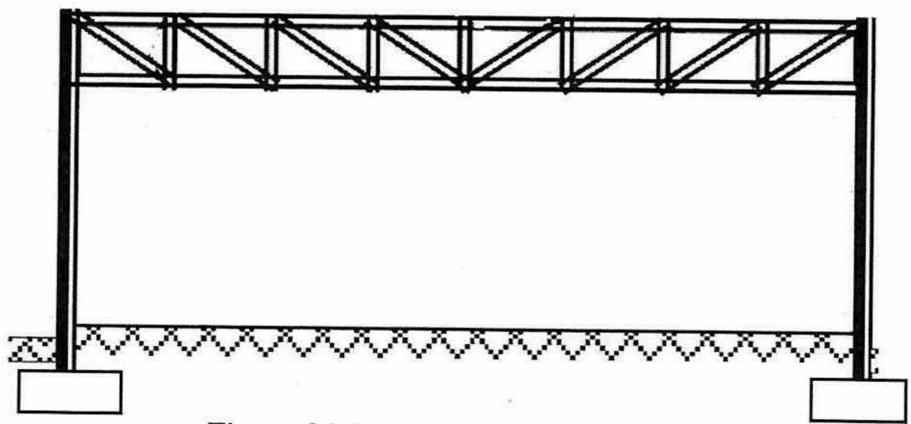


Figure Q2.2 – Truss frame elevation

(c) Consider a five-story steel building with columns of I-shape section. The effective height of the column is 5.5 meters. An interior column on the ground floor level is subjected to axial loads resulting from upper floor columns and steel beams. These axial load are permanent action of 1860 kN and variable action of 530 kN. Carry out design calculation to determine the size of this interior column. The size estimation must be based on the concept of cross section capacity together with a reasonable increment to overcome buckling effects. Perform section classification on the proposed size and buckling verifications for this column. You do not need to repeat the process if your verifications do not pass. All loads given are characteristic values.

(25 marks)

(d) For the same building in **Q2(c)**, now consider a ground floor column at the corner of the building. The size of this column is 254 x 254 x 89 UC grade S275, subjected to axial loads of 1000 kN permanent action and 400 kN variable action. In addition to this axial load, there are two in-coming beams perpendicular to each other connected to this corner column (see **Figure Q2.3**). The load details from beams transferred to the column are as follows: 250 kN permanent action and 130 kN variable action for Beam A, and 200 kN permanent action and 140 kN variable action for Beam B. Calculate the nominal design moments in kNm caused by the beams onto the column. All loads given are characteristic values.

(7 marks)

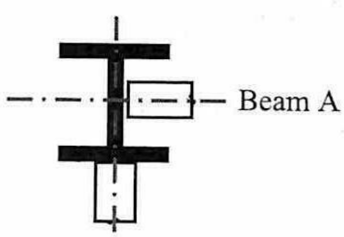


Figure Q2.3 – Corner column with incoming beams

Q3 This question is comprised of three sub-questions that are not inter-related.

(a) **Figure Q3.1** shows a futsal court shelter built from truss frame. The frame spans 24 m and has 4 bays with total length of 40 m. The roofing system is lightweight metal deck and lipped channel purlins spaced at 1 m c/c. First, propose a possible estimate of the truss depth (in mm). Second, propose a suitable truss to column connection based on good engineering practice. This suitable truss to column connection proposal must be supported by clear conceptual description of the design calculation processes and verifications that includes how demand and resistance forces are to be computed for bolts and weld type. Write the important formulas with their references that should be used. Demonstrate the number of bolts and weld type determined from the load demand. Clear and well labelled relevant layout and detailing sketches are required to support your answers. Use **Appendix C**, hence you do not need to provide comprehensive design calculations for the connection if you use the given relevant design tables.

(20 marks)

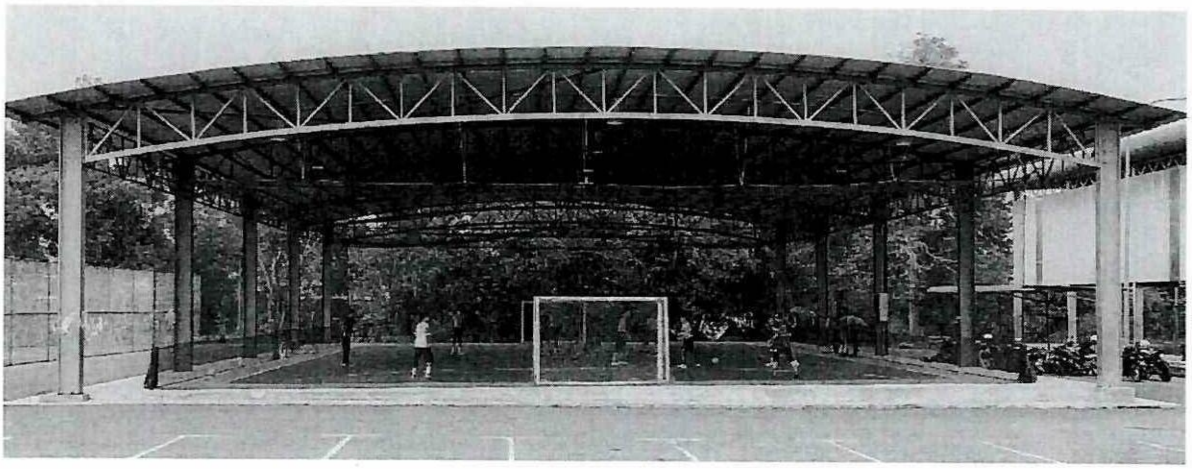


Figure Q3.1 – Futsal court

(b) **Figure Q3.2** shows a car parking shelter constructed out of structural steel. The detail enlargement of the circled section is given on the right of **Figure Q3.3**. Explain the purpose of the steel element pointed by the three white arrows shown in the detail enlargement.

(4 marks)

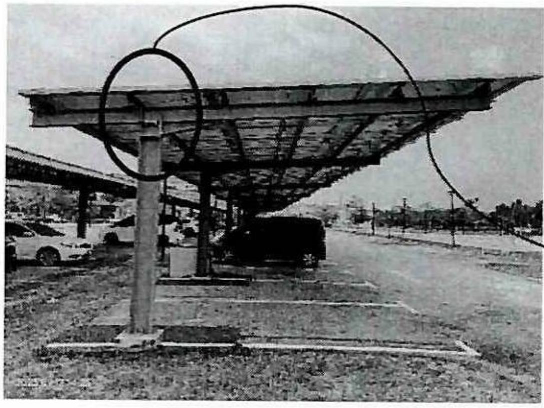


Figure Q3.2 – Car park shelter

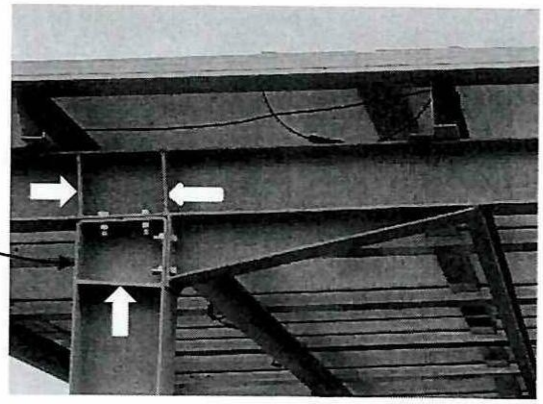


Figure Q3.3 – Detail enlargement

(c) **Figure Q3.4** shows another car parking shelter. Describe the purpose of the structural member pointed by the black arrow. Next, explain how this structural member should be designed (this includes size determination and design verifications).

(6 marks)

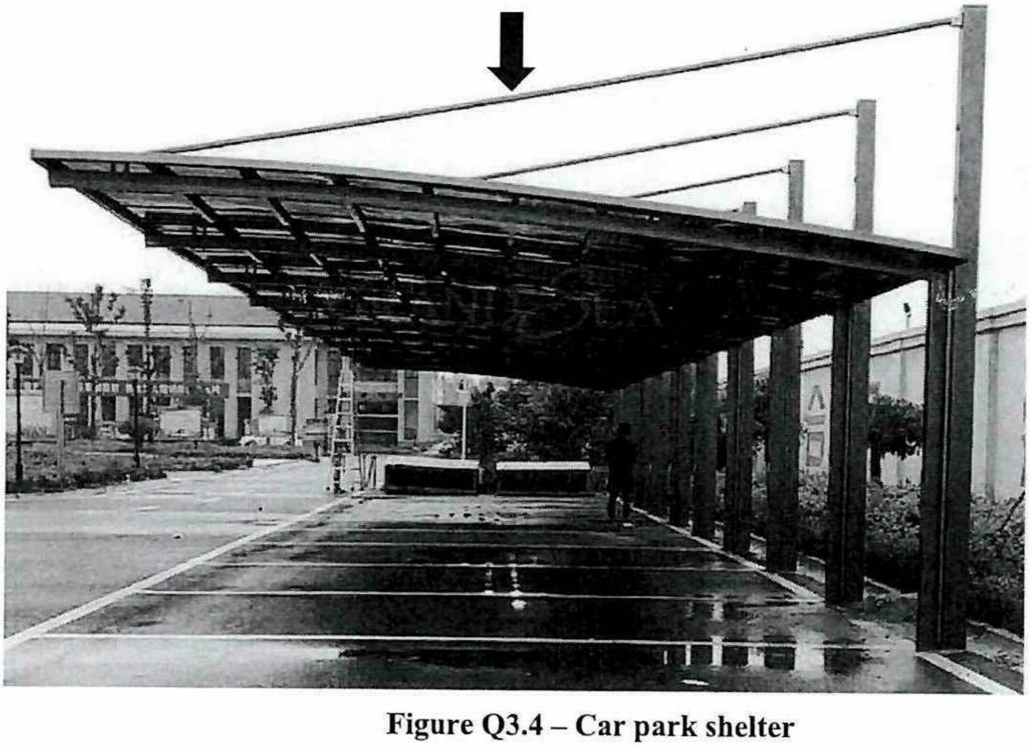


Figure Q3.4 – Car park shelter

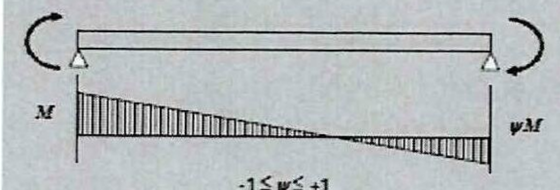
- END OF QUESTIONS -

APPENDIX A

Table APPENDIX A.1

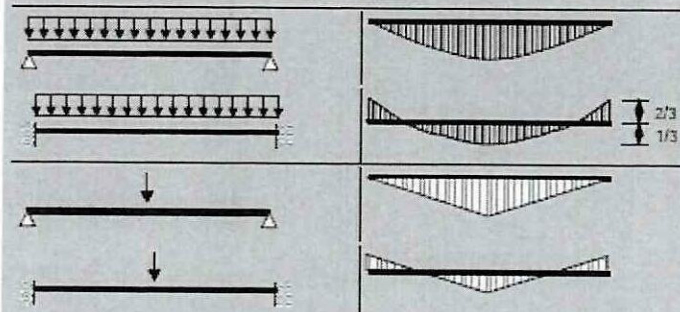
Table 6.4 *Values of* $\frac{1}{\sqrt{C_1}}$ *and* C_1 *for various moment conditions (load is not destabilising)*

End Moment Loading



ψ	$\frac{1}{\sqrt{C_1}}$	C_1
+1.00	1.00	1.00
+0.75	0.92	1.17
+0.50	0.86	1.36
+0.25	0.80	1.56
0.00	0.75	1.77
-0.25	0.71	2.00
-0.50	0.67	2.24
-0.75	0.63	2.49
-1.00	0.60	2.76

Intermediate Transverse Loading



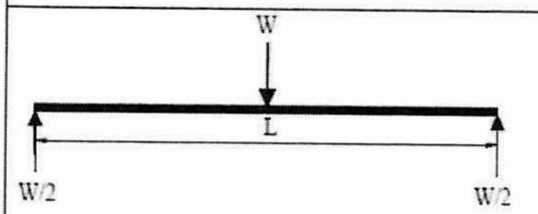
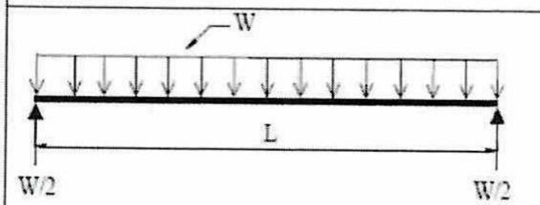
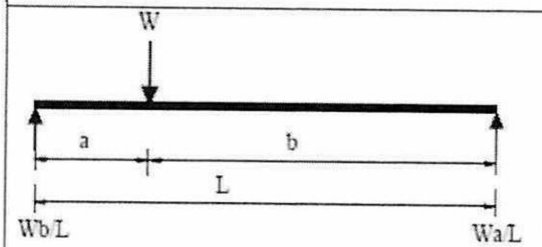
Loading (top to bottom in diagram)	$\frac{1}{\sqrt{C_1}}$	C_1
1	0.94	1.13
2	0.62	2.60
3	0.86	1.35
4	0.77	1.69

Formula APPENDIX A.2

$$M_{cr} = C_1 \frac{\pi^2 EI_z}{L^2} \sqrt{\frac{I_w}{I_z} + \frac{L^2 GI_t}{\pi^2 EI_z}}$$

APPENDIX B

Table APPENDIX B.1

Load where: W = total load in kN	Maximum Moment	Deflection at mid-span
	$\frac{WL}{4}$	$\frac{1}{48}\left(\frac{WL^3}{EI}\right)$
	$\frac{WL}{8}$	$\frac{5}{384}\left(\frac{WL^3}{EI}\right)$
	$\frac{Wab}{L}$	$\frac{1}{48}\left(\frac{WL^3}{EI}\right)\left(\frac{3a}{L}-4\left(\frac{a}{L}\right)^3\right)$

APPENDIX C

Table APPENDIX C.1

Design of S275 Class 4.6 Hexagon Head Non-Preloaded Bolt Resistance

Diameter of Bolt	Minimum				Bearing Resistance (kN)										
	Edge distance	End distance	Pitch	Gauge	Thickness in mm of ply, t										
d	e_2	e_1	p_1	p_2											
mm	mm	mm	mm	mm	5	6	7	8	9	10	12	15	20	25	30
12	20	25	35	40	25.9	31.0	36.2	41.4	46.6	51.7	62.1	77.6	103	129	155
16	25	35	50	50	34.0	40.8	47.7	54.5	61.3	68.1	81.7	102	136	170	204
20	30	40	60	60	42.1	50.5	58.9	67.4	75.8	84.2	101	126	168	211	253
24	35	50	70	70	50.1	60.1	70.2	80.2	90.2	100	120	150	200	251	301
30	45	60	85	90	63.2	75.8	88.4	101	114	126	152	189	253	316	379

Diameter of Bolt	Tensile Stress Area	Tension Resistance	Shear Resistance		Bolts in tension
			Single Shear	Double Shear	Min thickness for punching shear
d	A_s	$F_{t,Rd}$	$F_{v,Rd}$	$2 \times F_{v,Rd}$	t_{min}
mm	mm^2	kN	kN	kN	mm
12	84.3	24.3	13.8	27.5	2.1
16	157	45.2	30.1	60.3	3.2
20	245	70.6	47.0	94.1	3.9
24	353	102	67.8	136	4.7
30	561	162	108	215	5.8

Table APPENDIX C.2

Design of S275 Fillet Weld Resistance

Leg Length	Throat Thickness	Longitudinal resistance	Transverse resistance
s	a	$F_{w,L,Rd}$	$F_{w,T,Rd}$
mm	mm	kN/mm	kN/mm
3.0	2.1	0.47	0.57
4.0	2.8	0.62	0.76
5.0	3.5	0.78	0.96
6.0	4.2	0.94	1.15
8.0	5.6	1.25	1.53
10.0	7.0	1.56	1.91
12.0	8.4	1.87	2.29
15.0	10.5	2.34	2.87
18.0	12.6	2.81	3.44
20.0	14.0	3.12	3.82
22.0	15.4	3.43	4.20
25.0	17.5	3.90	4.78