# UNIVERSITI TUN HUSSEIN ONN MALAYSIA

## FINAL EXAMINATION
## SEMESTER II
## SESSION 2023/2024

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

THIS QUESTION PAPER CONSISTS OF **TEN (10)** PAGES

**Q1** This question has two separate parts:

(a) Explain **FOUR (4)** classifications of cross-sections based on their ability to form a plastic hinge, develop plastic moment resistance, reach yield strength, and the occurrence of local buckling.

(2 marks)

(b) A simply supported beam with a clear span of 8 m is subjected to a uniformly distributed design load of 90 kN/m throughout the entire span (inclusive of beam self-weight). The beam's depth should not exceed 500 mm. Design the beam with the assumption that the compression flange is laterally supported by the floor construction. Determine the beam's section class and the beam's ratio of design bending moment to resistance bending moment. Use steel grade S275.

(10 marks)

**Q2** This question assesses your competency in beam design.

(a) List **TWO (2)** types of slab system that make the supporting beam considered as an unrestrained beam.

(2 marks)

(b) A beam-slab system was tested in the laboratory. Experimentally, it was found that the slab does not effectively hold the compression flange of the UB beam. Write the bending moment formula that should be used to design such beam.

(2 marks)

(c) Consider a simply supported beam 457 × 191 × 82 UB S275 with a clear span of 8 m that does not carry any floor is subjected to a uniformly distributed design load of 90 kN/m throughout the entire span (inclusive of beam self-weight). Calculate the elastic critical moment, $M_{cr}$ in kNm and determine $\chi_{LT}$ using Figure 6.4 in BS EN 1993-1-1.

(8 marks)

**Q3** **Figure Q3.1** shows the elevation of a truss connected to a column at node A and J. The truss is spaced 5 m centre-to-centre with purlins positioned at each node of the top chord. The truss is built from 40 × 40 × 3 SHS members and welded all around at all nodes. Characteristic load carried by purlin and truss are given as follows:

Roof cladding and purlins (on-slope) = 0.30 kN/m$^2$

Imposed load (on-plan) = 0.75 kN/m$^2$

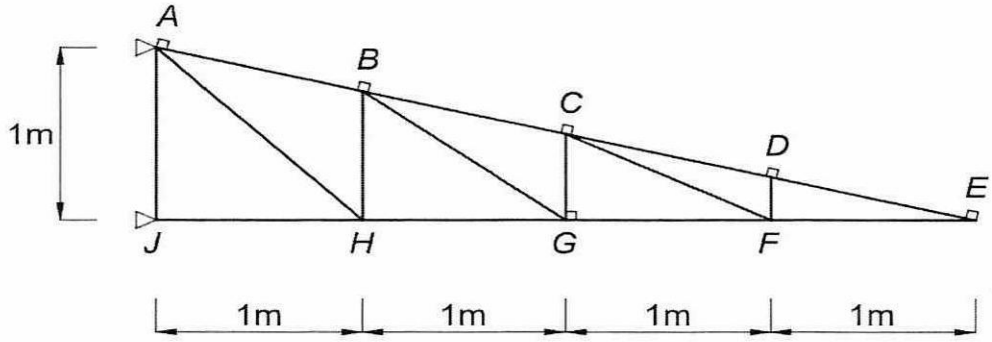


**Figure Q3.1 – Elevation of truss**

(a) Determine un-factored design load (working load) in kN for the purlin.

(4 marks)

(b) Propose a purlin size using angle section based on provisions from Table 27 BS5950. Sag rod is not used in the purlin construction.

(5 marks)

(c) Sketch the truss with the applied load from purlins.

(3 marks)

**Q4** Referring to the same truss given in **Q3** built from 40 × 40 × 3 SHS members, the internal forces in tension member DE and compression member EF are 19.8 kN and 19.2 kN, respectively. Answer the following:

(a) Design tension member DE.

(5 marks)

(b) Design compression member EF.

(7 marks)

**Q5** Study **Figure Q5.1** and **Figure Q5.2** carefully. **Figure Q5.1** shows a plan view of Column C1 intersection with three roof beams RB1, RB2, and RB3. RB3 is a new extension roof beam. The load values indicated to each beam are factored load values. **Figure Q5.2** presents the 3-dimensional expression of the Column C1. The size of Column C1 is 152 × 152 × 37 UC. Following are some design parameters:

| | | |
|---|---|---|
| Section Classification | = | Flange and web are to be Class 1 |
| Ultimate strength, $f_u$ | = | 430 N/mm$^2$ |
| Yield strength, $f_y$ | = | 275 N/mm$^2$ |

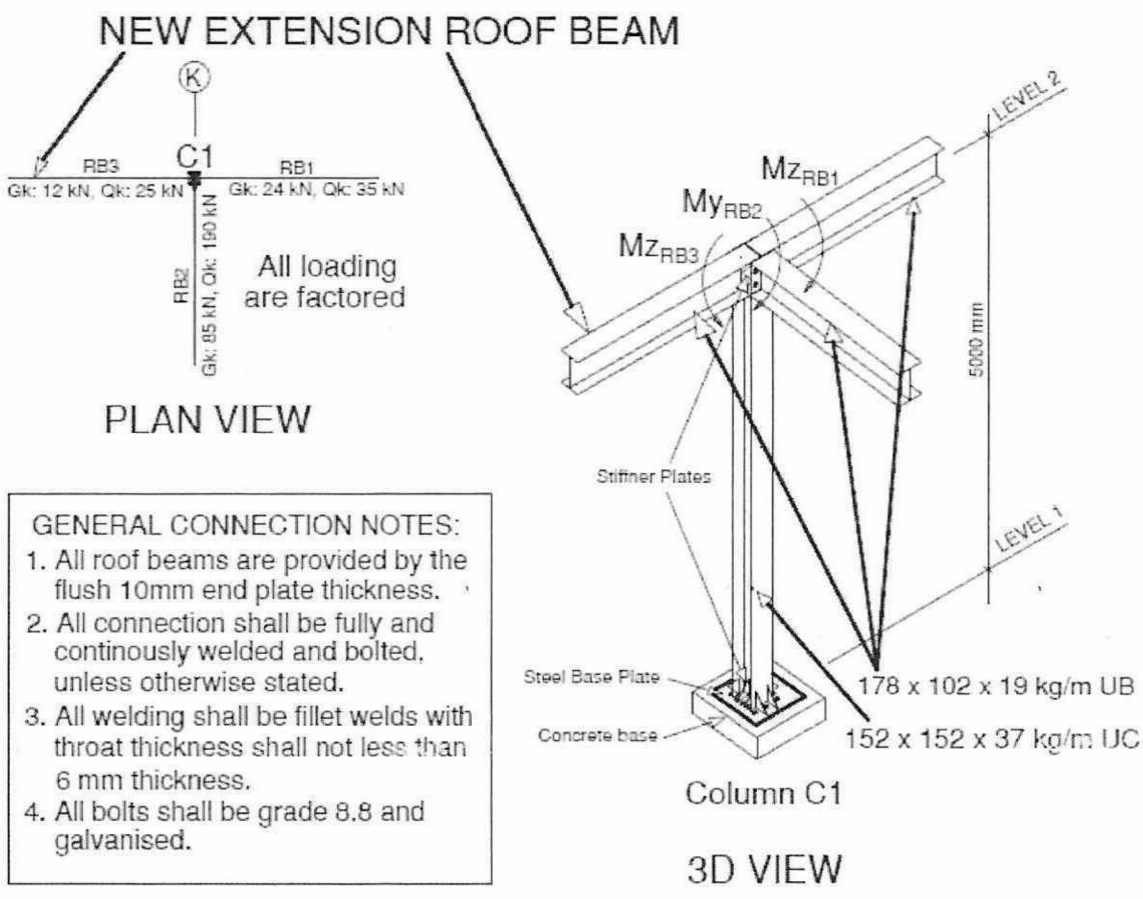


**Figure Q5.1 – Plan View** **Figure Q5.2 – 3D View**

(a) Calculate the design compression demand, $N_{Ed}$ and compression resistance, $N_{CRd}$ of Column C1 in kN. Do not consider the height effect and moment effect.

(5 marks)

(b) Perform an analysis to compute the nominal moment demand, $M_{Ed}$ and moment resistance, $M_{Rd}$ in kNm for major and minor axes of Column C1.

(7 marks)

**Q6** Consider a 5 m height column pinned at both ends built from 254 × 254 × 73 UC S355 stiffened with 12 mm thick stiffener plate at every 1 m height interval on both sides. This stiffener plate increases the elastic critical buckling load about minor axis by 60%. Determine the buckling resistance of the column in kN.

(12 marks)

**Q7** **Figure Q7.1** shows a typical portal frame engineering drawing and the analysis result. A series of manual calculations have been carried out to check the size of the proposed column size. However, the position of the first torsional restraint has not been decided. Therefore, further calculations should be performed.

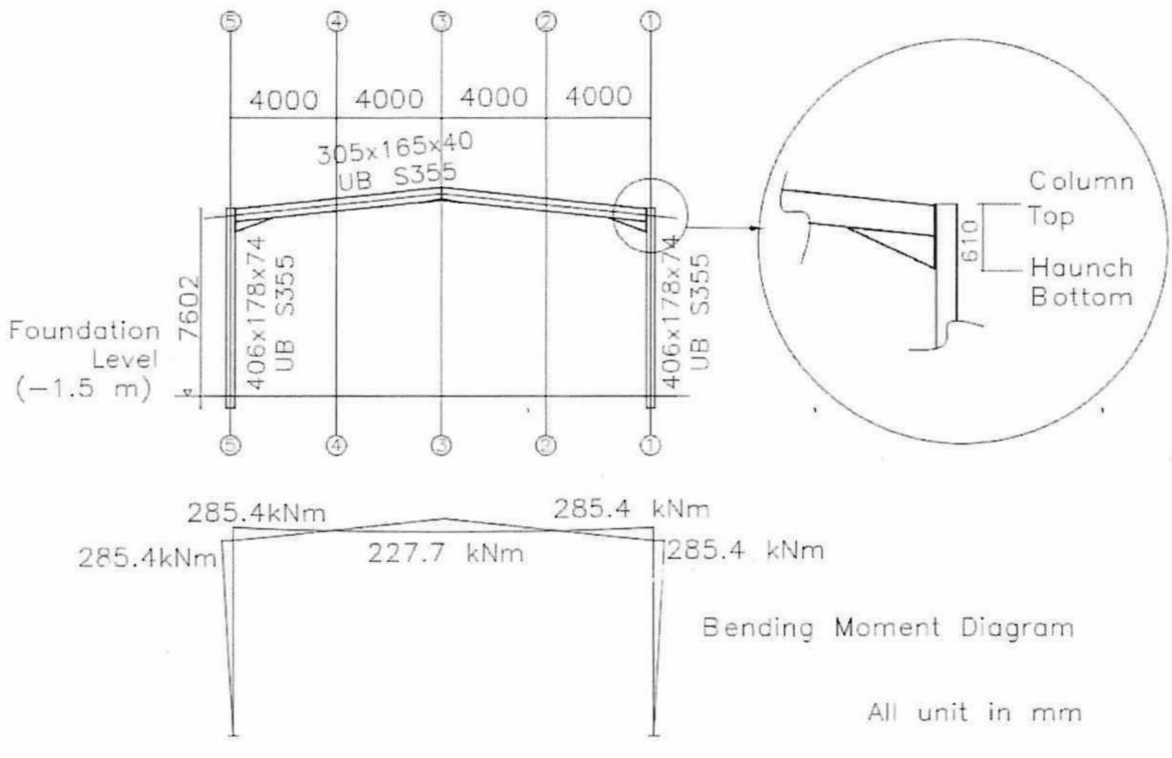


**Figure Q7.1 – Portal Frame**

(a) Calculate the maximum moment at the underside of the haunch.

(2 marks)

(b) Calculate the bending moment at the first torsional restraint if the proposed position is 3 m from the underside of the haunch.

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(2 marks)

(c) Check the position of the first torsional restraint position in **Q7(b)**. Assume no reduction in plastic moment due to axial force. Given: $a = 306$ mm; $L_k = 2967.4$ mm; $N_{ED} = 146.3$ kN; $N_{crE} = 3569$ kN; $N_{crT} = 4228$ kN.

(10 marks)

**Q8** **Figure Q8.1** shows a picture of an advertisement billboard supported on two steel columns. The following questions relate to the structural system of this advertisement billboard.

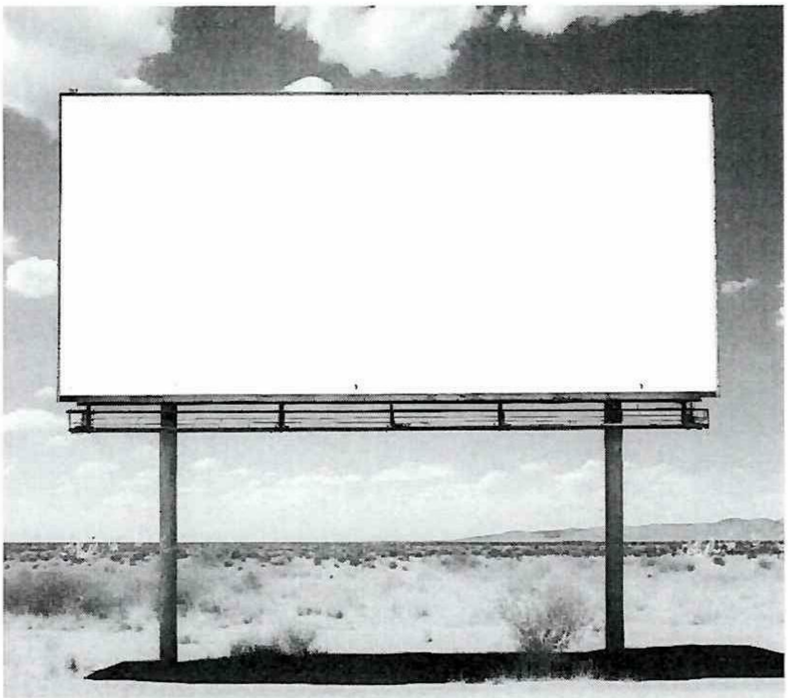


**Figure Q8.1 – Advertisement Billboard**

(a) **Figure Q8.2** and **Figure Q8.3** are the structural drawings that present the front and side elevations of the system that supports the advertisement billboard, respectively. Given the characteristic wind action on the billboard is 2 kN/m$^2$, calculate the design horizontal force demand, $F_{Hed}$ in kN and the overturning moment demand, $M_{ed}$ in kNm at the foot of the column.

(6 marks)

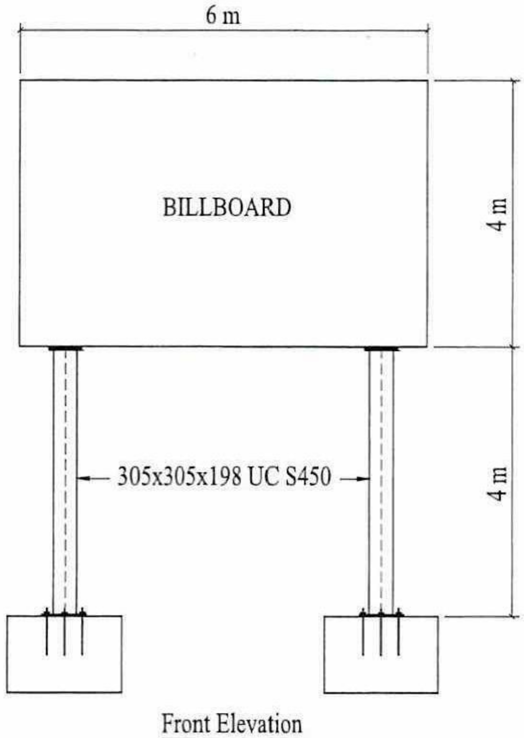



**Figure Q8.2 – Front Elevation**

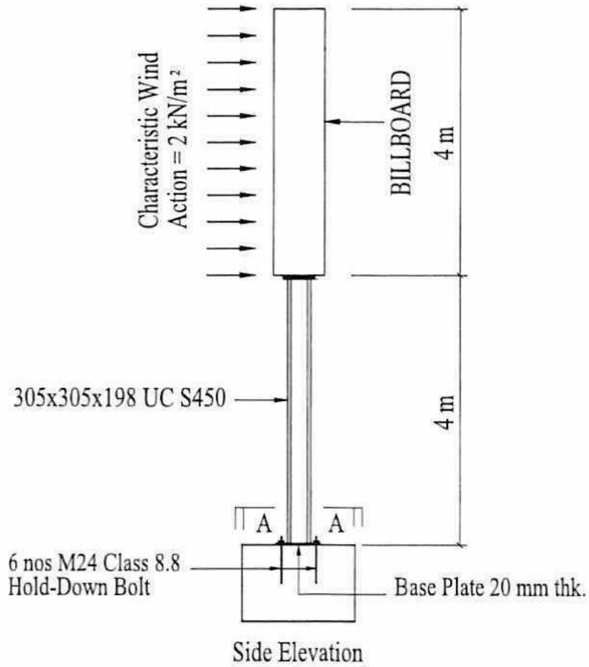



**Figure Q8.3 – Side Elevation**

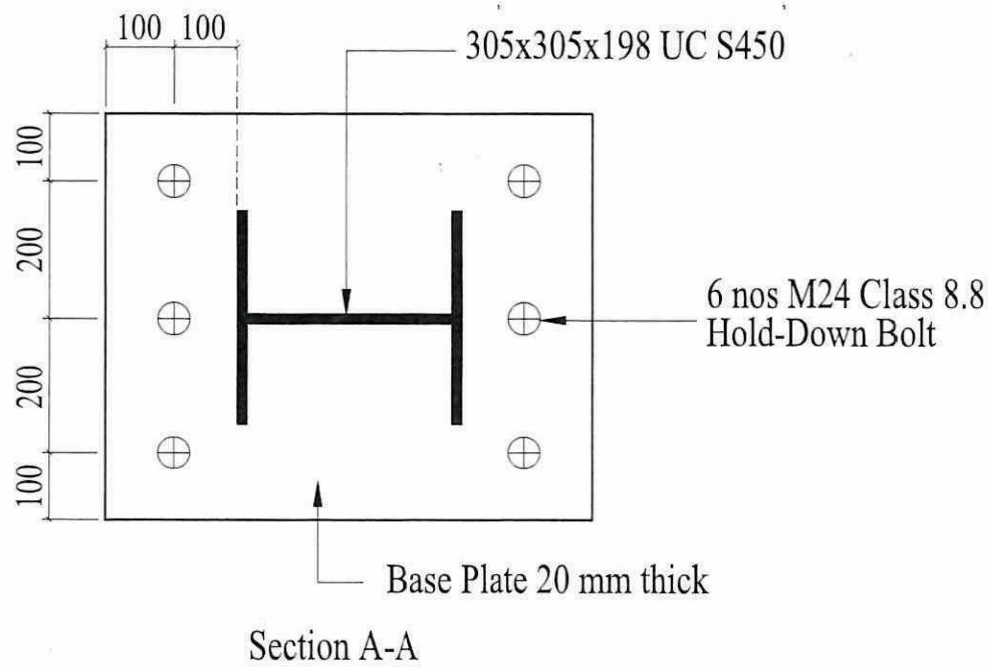



**Figure Q8.4 – Column to base connection**

(b) **Figure Q8.4** shows the column to base connection of the advertisement billboard. Study the detailing carefully. Calculate the pull-out tensile force demand, $F_{Ted}$ in kN due to the overturning moment demand, $M_{ed}$ solved in **Q8(a)**. Next, determine whether the proposed hold-down bolts M24 Class 8.8 S355 are adequate to withstand the tension demand due to the wind action pushing on the advertisement billboard.

(8 marks)

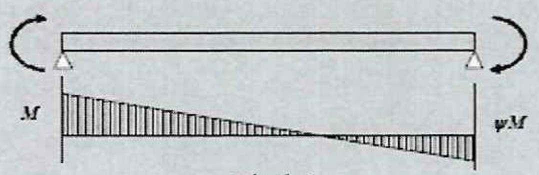
**- END OF QUESTIONS -**

## APPENDIX A

### Table APPENDIX A.1 Extract from SN003a: Values for C1 and C2 for transverse load

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

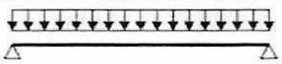
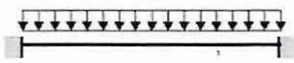
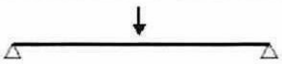
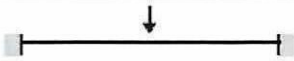
End Moment Loading




$-1 \le \psi \le +1$

| $\psi$ | $\frac{1}{\sqrt{C_1}}$ | $C_1$ |
|---|---|---|
| +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 |

*Table 3.2 Values of factors $C_1$ and $C_2$ for cases with transverse loading (for $k = 1$)*

| Loading and support conditions | Bending moment diagram | $C_1$ | $C_2$ |
|---|---|---|---|
|  |  | 1,127 | 0,454 |
|  |  | 2,578 | 1,554 |
|  |  | 1,348 | 0,630 |
|  |  | 1,683 | 1,645 |

Note : the critical moment $M_{cr}$ is calculated for the section with the maximal moment along the member

**Formula APPENDIX A.2**

$$M_{cr} = C_1 \frac{\pi^2 E I_z}{L^2} \sqrt{\frac{I_w}{I_z} + \frac{L^2 G I_t}{\pi^2 E I_z}}$$

**Formula APPENDIX A.3**

$$L_s = \sqrt{C_m} L_k \left[ \frac{M_{pl,y,Rk}}{M_{N,y,Rk} + a N_{ED}} \right]$$

## APPENDIX B

### Table APPENDIX B.1

### Extracted from Table 27 BS5950: Part 1: 2000

Table 27 — Empirical values for purlins

| Purlin section | $Z_p$ (cm³) | $Z_q$ (cm³) | | $D$ (mm) | $B$ (mm) |
|---|---|---|---|---|---|
| | | Wind load from BS 6399-2 | Wind load from CP3:Ch V:Part 2 | | |
| Angle | $W_pL/1\,800$ | $W_qL/2\,250$ | $W_qL/1\,800$ | $L/45$ | $L/60$ |
| CHS | $W_pL/2\,000$ | $W_qL/2\,500$ | $W_qL/2\,000$ | $L/65$ | — |
| RHS | $W_pL/1\,800$ | $W_qL/2\,250$ | $W_qL/1\,800$ | $L/70$ | $L/150$ |

NOTE 1 $W_p$ and $W_q$ are the total unfactored loads (in kN) on one span of the purlin, acting perpendicular to the plane of the cladding, due to (dead plus imposed) and (wind minus dead) loading respectively.

NOTE 2 $L$ is the span of the purlin (in mm) centre-to-centre of main vertical supports. However, if properly supported sag rods are used, $L$ may be taken as the sag rod spacing in determining $B$ only.

## APPENDIX C

### Table APPENDIX C.1

### Design of S355 Class 8.8 Hexagon Head Non-Preloaded Bolt Resistance

BS EN 1993-1-8:2005
BS EN ISO 4014
BS EN ISO 4017

# BOLT RESISTANCES

Non Preloaded bolts

Class 8.8 hexagon head bolts

| Diameter of Bolt | Tensile Stress Area | Tension Resistance | Shear Resistance | | Bolts in tension |
|---|---|---|---|---|---|
| | | | Single Shear | Double Shear | Min thickness for punching shear |
| d mm | $A_s$ mm² | $F_{t,Rd}$ kN | $F_{v,Rd}$ kN | 2 x $F_{v,Rd}$ kN | $t_{min}$ mm |
| 12 | 84.3 | 48.6 | 27.5 | 55.0 | 3.7 |
| 16 | 157 | 90.4 | 60.3 | 121 | 5.5 |
| 20 | 245 | 141 | 94.1 | 188 | 6.8 |
| 24 | 353 | 203 | 136 | 271 | 8.2 |
| 30 | 561 | 323 | 215 | 431 | 10.1 |