Prime Consulting Engineers Pty. Ltd.

Design Report:

4m Round Cantilever Umbrella

For

EXTREME MARQUEES

Ref: R-22-174-3

Date: 20/01/2022

Amendment: -

Prepared by: KZ

Checked by: BG

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1 Introduction and Scope:

The report and certification are the sole property of Prime Consulting Engineers Pty. Ltd.

Prime Consulting Engineers have been engaged by Extreme Marquees Pty. Ltd. to carry out a structural analysis of three different sizes of Aluminium Cantilever Umbrellas for wind region A (non-cyclonic). It should be noted that the outcome of our analysis is limited to the selected items as outlined in this report.

This report shall be read in conjunction with the documents listed in the references (Section 1.2)

1.1 Project Description

The report examines the effect of 3s gust wind of **(refer to summary)** positioned for the worst effect on 4m round cantilever umbrella structure. The relevant Australian Standards AS1170.0:2002 General principles, AS1170.1:2002 Permanent, imposed and other actions and AS1170.2:2011 Wind actions are used. The design check is in accordance with AS1664.1 Aluminum Structures.

1.2 References

- The documents referred to in this report are as follows:
  - Report of results produced through SAP2000 V23 software & excel spreadsheets.
  - Detail drawing provided by manufacturer (YEEZE). Refer to appendix ‘A’.
- The basic standards used in this report are as follows:
  - AS 1170.0:2002 – Structural Design Actions (Part 0: General principles)
  - AS 1170.1:2002 – Structural Design Actions (Part 1: Permanent, imposed, and other actions)
  - AS 1170.2:2011 – Structural Design Actions (Part 2: Wind Actions)
  - AS1664.1 Aluminium Structures.
- Section Properties of Aluminium Section provided by the client. (Refer Appendix ‘A’.
- The program(s) used for this analysis are as follows:
  - SAP2000 V23
  - Microsoft Excel

1.3 Notation

AS/NZS	Australian Standard/New Zealand Standard
FEM/FEA	Finite Element Method/Finite Element Analysis
SLS	Serviceability Limit State
ULS	Ultimate Limit State

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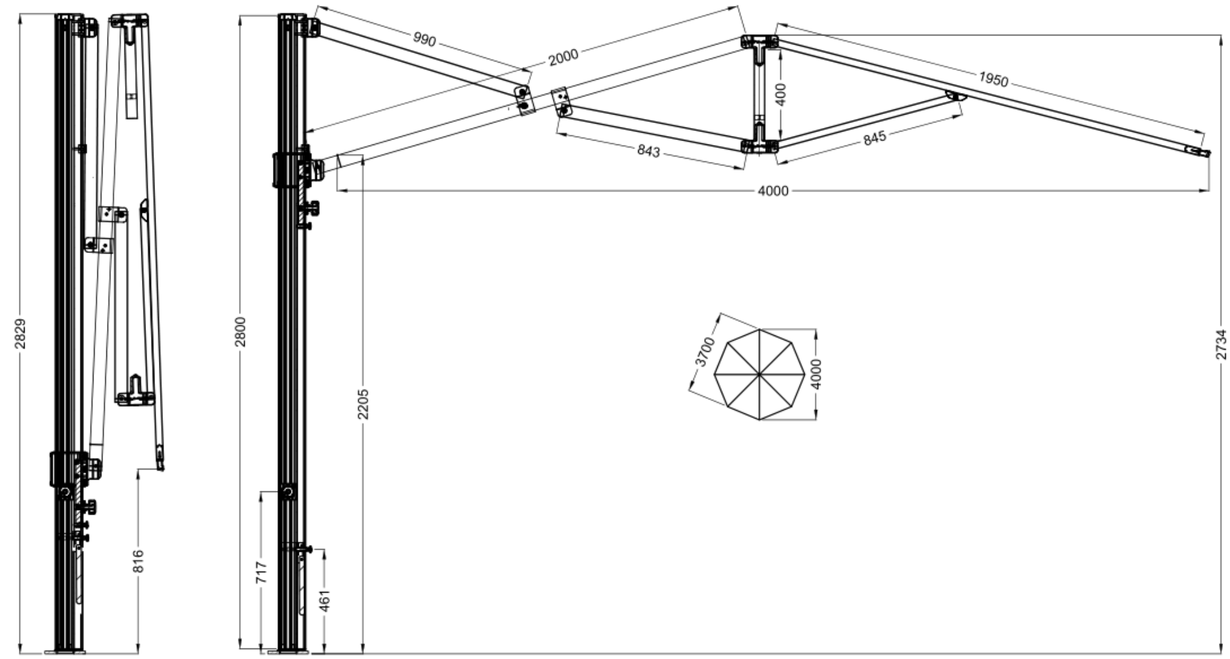
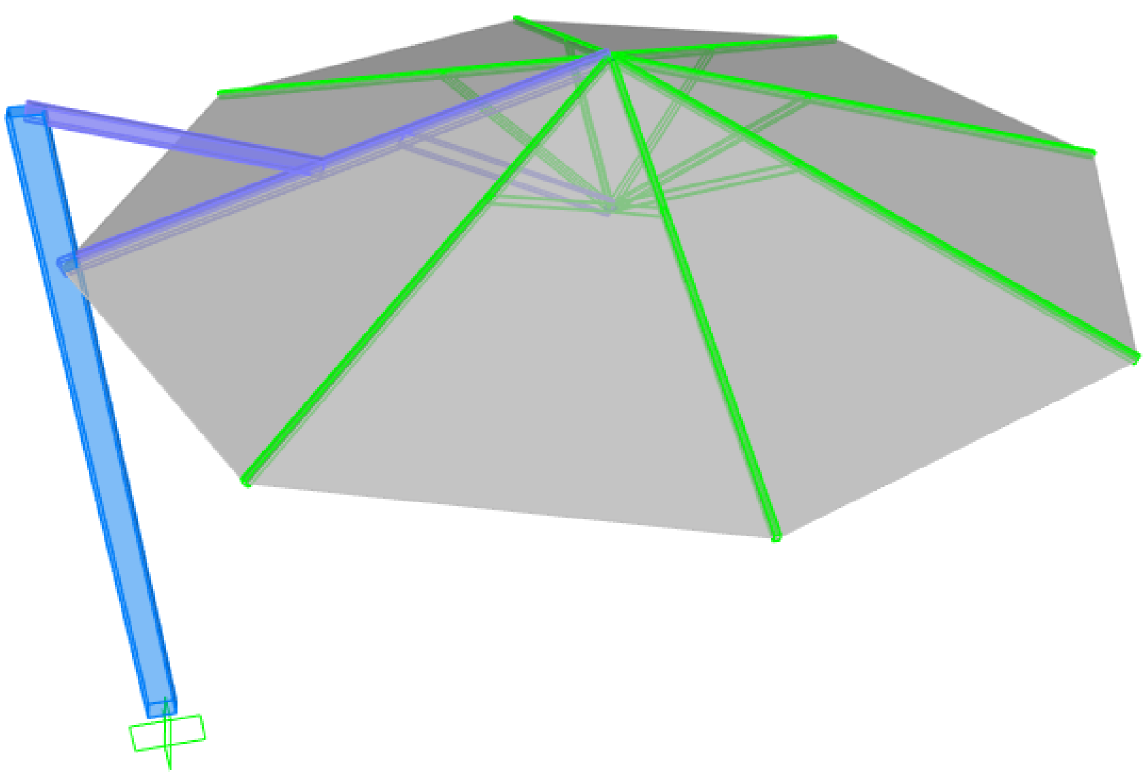
2 Design Overview

2.1 Geometry Data





Isometric view of structures

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2.2 Assumptions & Limitations

- The erected structure is for temporary use only.
- For forecast winds in excess of **(refer to summary)** the umbrella structure should be completely folded
- The structure may only be used in regions with wind classifications no greater than the limits specified in cl. 5 of this report.
- Parameters used for wind calculations:
    - TC 2
    - Wind Region A
- Topographical factors such as erecting the structure on the crest of a hill or on the top of an escarpment may result in a higher wind speed classification. Thus, special considerations should be taken to the topographical location of the installation site.
- Shall the site conditions/wind parameters exceed prescribed design wind actions (refer to cl.8), Prime Consulting Engineers Pty. Ltd. should be informed to determine appropriate wind classifications and amend computations accordingly.

2.3 Exclusions

- Design of fabric
- Wind actions due to tropical or severe tropical cyclonic areas.
- Super imposed loads such as live loads or snow and ice loads.

2.4 Design Parameters and Inputs

2.4.1 Load Cases

1.	G	Permanent actions (Dead load)
3.	Wu	Ultimate wind action (ULS)
4.	Ws	Serviceability wind action (SLS)

2.4.2 Load Combinations

Strength (ULS):

1.	1.35G	Permanent action only
3.	$0.9G+W_u$	Permanent and wind actions
4.	$1.2G+W_u$	Permanent and wind actions

Serviceability (SLS):

2.	$G+W_s$	Wind service actions

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3 Specifications

3.1 Material Properties

Material Properties										
6063-T5	F_{tu}	F_{ty}	F_{cy}	F_{su}	F_{sy}	F_{bu}	F_{by}	E	k_t	k_c
	152	110	110	90	62	317	179	70000	1	1.12

3.2 Buckling Constants

TABLE 3.3(D) BUCKLING CONSTANTS						
Type of member and stress	**Intercept, MPa**		**Slope, MPa**		**Intersection**	
Compression in columns and beam flanges	B_c	119.26	D_c	0.49	C_c	99.33
Compression in flat plates	B_p	134.29	Dp	0.59	C_p	93.61
Compression in round tubes under axial end load	B_t	132.00	D_t	3.62	C_t	*
Compressive bending stress in rectangular bars	B_{br}	194.52	D_{br}	1.26	C_{br}	103.26
Compressive bending stress in round tubes	B_{tb}	183.09	D_{tb}	9.34	C_{tb}	79.80
Shear stress in flat plates	B_s	75.86	D_s	0.25	C_s	124.54
Ultimate strength of flat plates in compression	k_1	0.35	k_2	2.27		
Ultimate strength of flat plates in bending	k_1	0.5	k_2	2.04		

** C_t shall be determined using a plot of curves of limit state stress based on elastic and inelastic buckling or by trial and error solution*

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3.3 Member Sizes & Section Properties

3.3.1 Rectangular Section

MEMBER(S)	Section	b	d	t	y_c	A_g	Z_x	Z_y	S_x	S_y	I_x	I_y	J	r_x	r_y
		mm	*mm*	*mm*	*mm*	*mm²*	*mm³*	*mm³*	*mm³*	*mm³*	*mm⁴*	*mm⁴*	*mm⁴*	*mm*	*mm*
Post	120x85x3	85	120	3	60.0	1194.0	41441.7	34291.3	49329.0	38881.5	2486502.0	1457379.5	2775221.2	45.6	34.9
Cantilever Beam	60x35x3.5	35	60	3.5	30.0	616.0	9420.7	6709.7	11837.0	7987.0	282620.3	117420.3	251961.0	21.4	13.8
Brace 1	60x35x3.5	35	60	3.5	30.0	616.0	9420.7	6709.7	11837.0	7987.0	282620.3	117420.3	251961.0	21.4	13.8
Brace 2	30x20x1.5	20	30	1.5	15.0	141.0	1141.1	894.6	1401.8	1049.3	17115.8	8945.8	17744.2	11.0	8.0
Middle Beam	30x20x1.5	20	30	1.5	15.0	141.0	1141.1	894.6	1401.8	1049.3	17115.8	8945.8	17744.2	11.0	8.0
Brace	100x50x5	50	100	5	50.0	1400.0	34733.3	22466.7	44000.0	26500.0	1736666.7	561666.7	1305401.8	35.2	20.0

3.3.2 Circular Sections

MEMBER(S)	Section	d	t	y_c	A_g	Z_x	Z_y	S_x	S_y	I_x	I_y	J	r_x	r_y
		mm	*mm*	*mm*	*mm²*	*mm³*	*mm³*	*mm³*	*mm³*	*mm⁴*	*mm⁴*	*mm⁴*	*mm*	*mm*
Centre Pole	48x1.8	48	1.8	24.0	261.3	2908.7	2908.7	3843.9	3843.9	69809.9	69809.9	139619.8	16.3	16.3

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4 Design Loads

Self weight	G	self weight
3s 45km/hr gust	W_u	0.096 C_{fig} (kPa)
3s 20km/hr gust	W_s	0.015 C_{fig} (kPa)

5 Wind Analysis

5.1 Ultimate

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Date: 17/01/2022 ***Amendment:*** -

Name	Symbol	Value	Unit	Notes	Ref.
		Input			
Importance level		2			*Table 3.1 - Table 3.2 (AS1170.0)*
Annual probability of exceedance		Temporary			*Table 3.3*
Regional gust wind speed		**50.004**	Km/hr		
Regional gust wind speed	V_R	13.89	m/s		
Wind Direction Multipliers	M_d	1			*Table 3.2 (AS1170.2)*
Terrain Category	TC	2			
Terrain Category Multiplier	$M_{Z,Cat}$	0.91			
Shield Multiplier	M_S	1			*4.3 (AS1170.2)*
Topographic Multiplier	M_t	1			*4.4 (AS1170.2)*
Site Wind Speed	$V_{Site,\beta}$	**12.64**	m/s	$V_{Site,\beta}=V_R*M_d*M_{z,cat}*M_S,M_t$	
Pitch	α	15	Deg		
Pitch	α	-	rad		
Width	B	4	m		

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Length	D	4	m		
Height	Z	2.5	m		
Porosity Ratio	δ	1		*ratio of solid area to total area*	
Wind Pressure					
ρair	ρ	1.2	Kg/m^3		
dynamic response factor	C_{dyn}	1			
Wind Pressure	ρ*C_{fig}	**0.096**	Kg/m^2	$p=0.5\rho_{air}*(V_{des,\beta})^2*C_{fig}*C_{dyn}$	*2.4 (AS1170.2)*
WIND DIRECTION 1 (θ=0)					
External Pressure					
1. Free Roof				*α=0º*	
Area Reduction Factor	K_a	1			*D7*
local pressure factor	K_l	1			
porous cladding reduction factor	K_p	1.00			
External Pressure Coefficient **MIN**	$C_{P,w}$	-0.3			
External Pressure Coefficient **MAX**	$C_{P,w}$	0.4			
External Pressure Coefficient **MIN**	$C_{P,l}$	-0.4			
External Pressure Coefficient **MAX**	$C_{P,l}$	0			
aerodynamic shape factor **MIN**	$C_{fig,w}$	-0.30			
aerodynamic shape factor **MAX**	$C_{fig,w}$	0.40			
aerodynamic shape factor **MIN**	$C_{fig,l}$	-0.40			
aerodynamic shape factor **MAX**	$C_{fig,l}$	0.00			
Pressure Windward **MIN**	P	**-0.03**	**kPa**		
Pressure Windward **MAX**	P	**0.04**	**kPa**		
Pressure Leeward **MIN**	P	**-0.04**	**kPa**		
Pressure Leeward **MAX**	P	**0.00**	**kPa**		
WIND DIRECTION 2 (θ=90)					
External Pressure					
4. Free Roof				*α=180º*	*D7*
Area Reduction Factor	K_a	1			

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local pressure factor	K_l	1	
porous cladding reduction factor	K_p	1.00	
External Pressure Coefficient **MIN**	$C_{P,w}$	-0.3	
External Pressure Coefficient **MAX**	$C_{P,w}$	0.4	
External Pressure Coefficient **MIN**	$C_{P,l}$	-0.4	
External Pressure Coefficient **MAX**	$C_{P,l}$	0	
aerodynamic shape factor **MIN**	$C_{fig,w}$	-0.30	
aerodynamic shape factor **MAX**	$C_{fig,w}$	0.40	
aerodynamic shape factor **MIN**	$C_{fig,l}$	-0.40	
aerodynamic shape factor **MAX**	$C_{fig,l}$	0.00	
Pressure **MIN (Windward Side)**	P	**-0.03**	**kPa**
Pressure **MAX (Windward Side)**	P	**0.04**	**kPa**
Pressure **MIN (Leeward Side)**	P	**-0.04**	**kPa**
Pressure **MAX (Leeward Side)**	P	**0.00**	**kPa**

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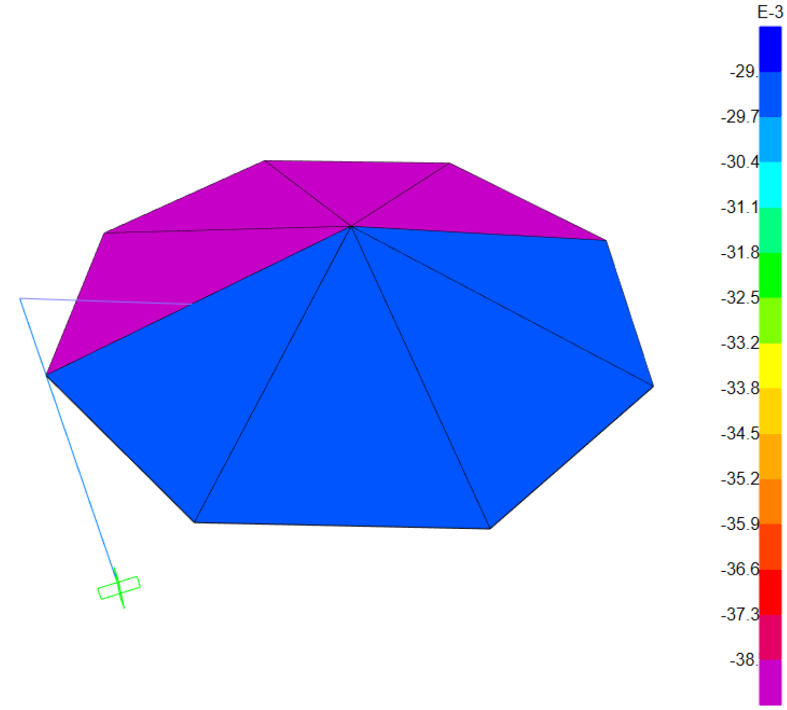
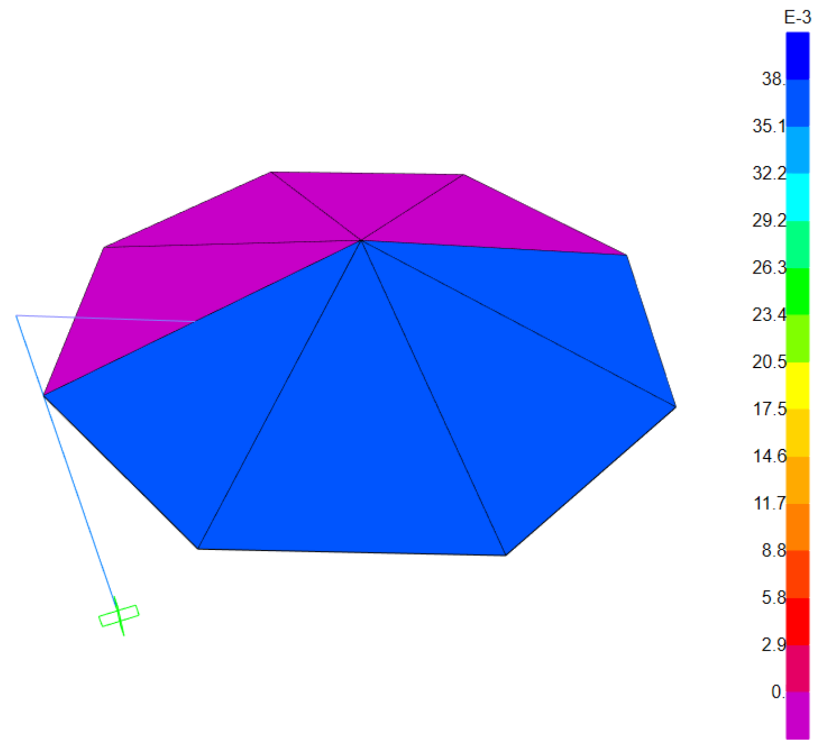
5.2 Load Diagrams

5.2.1 Wind Load Ultimate ($W_{U,min}$)



5.2.2 Wind Load Ultimate ($W_{U,max}$)



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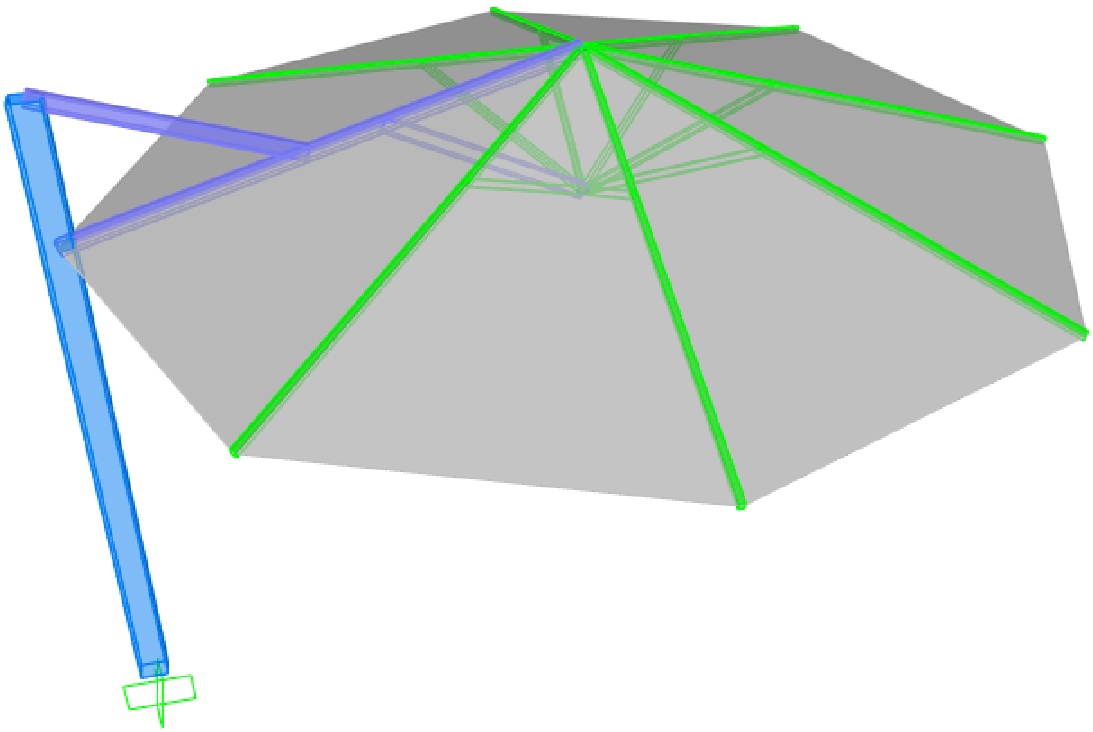
6 Analysis

6.1 3D model



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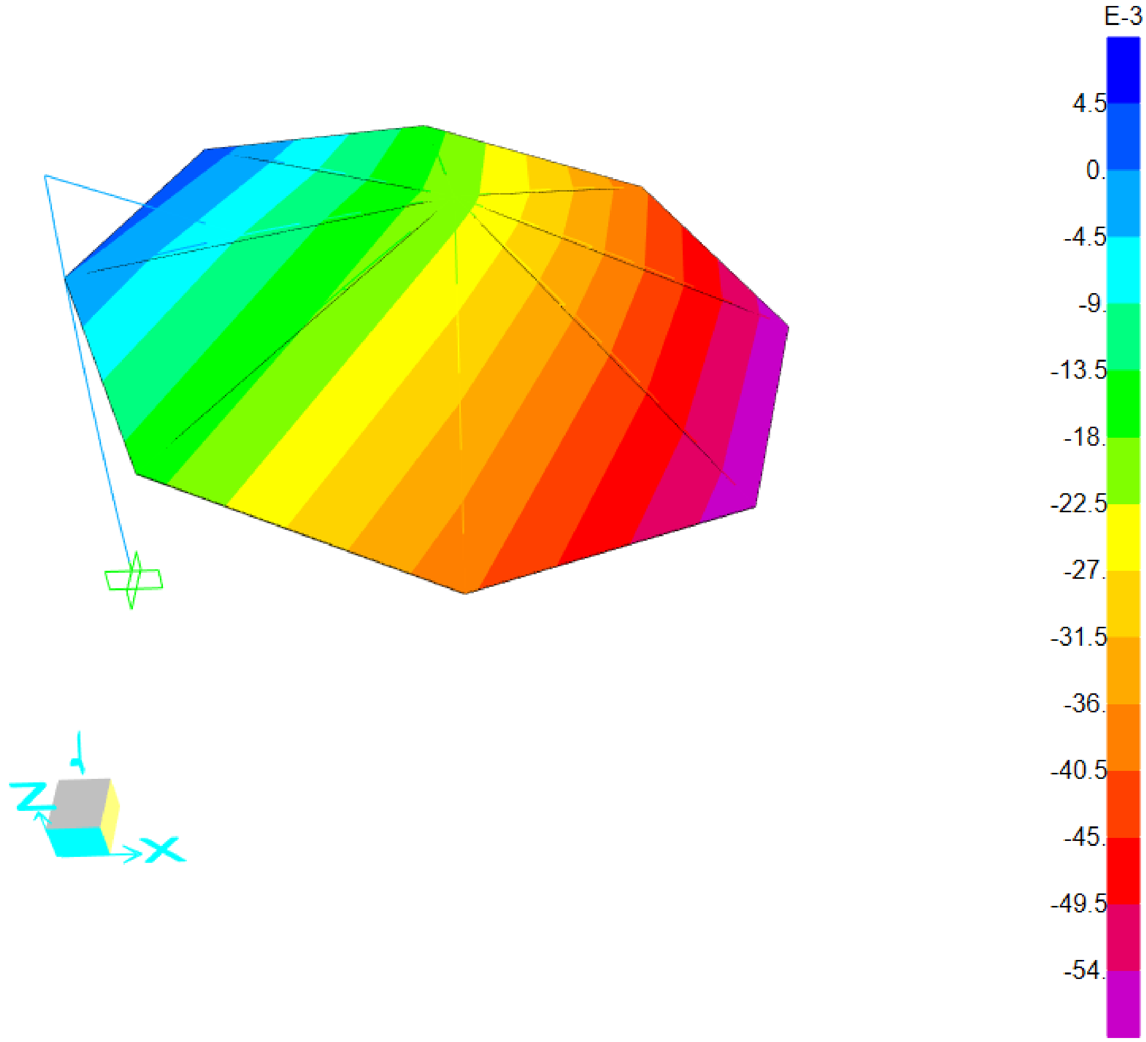
6.2 Results

6.2.1 Maximum deflection (serviceability)



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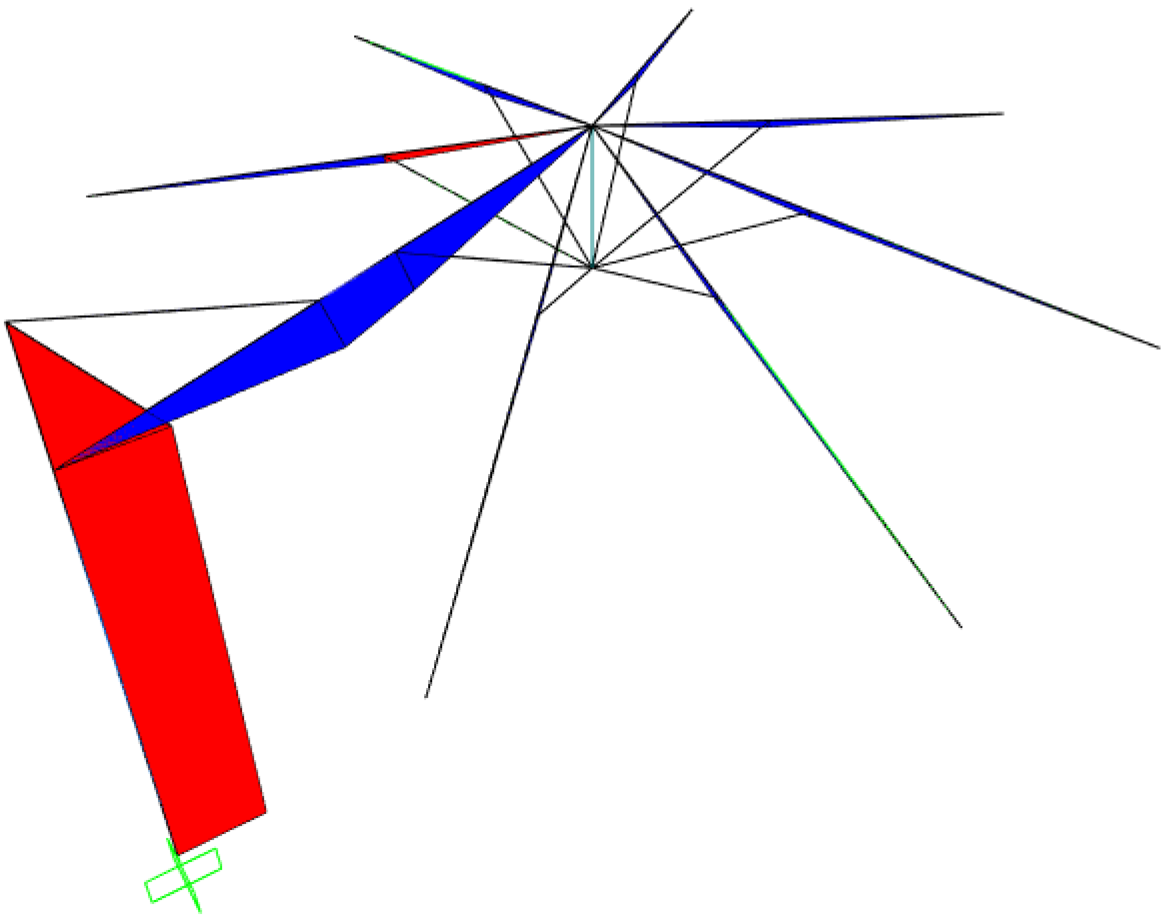
6.2.2 Maximum Bending Moment



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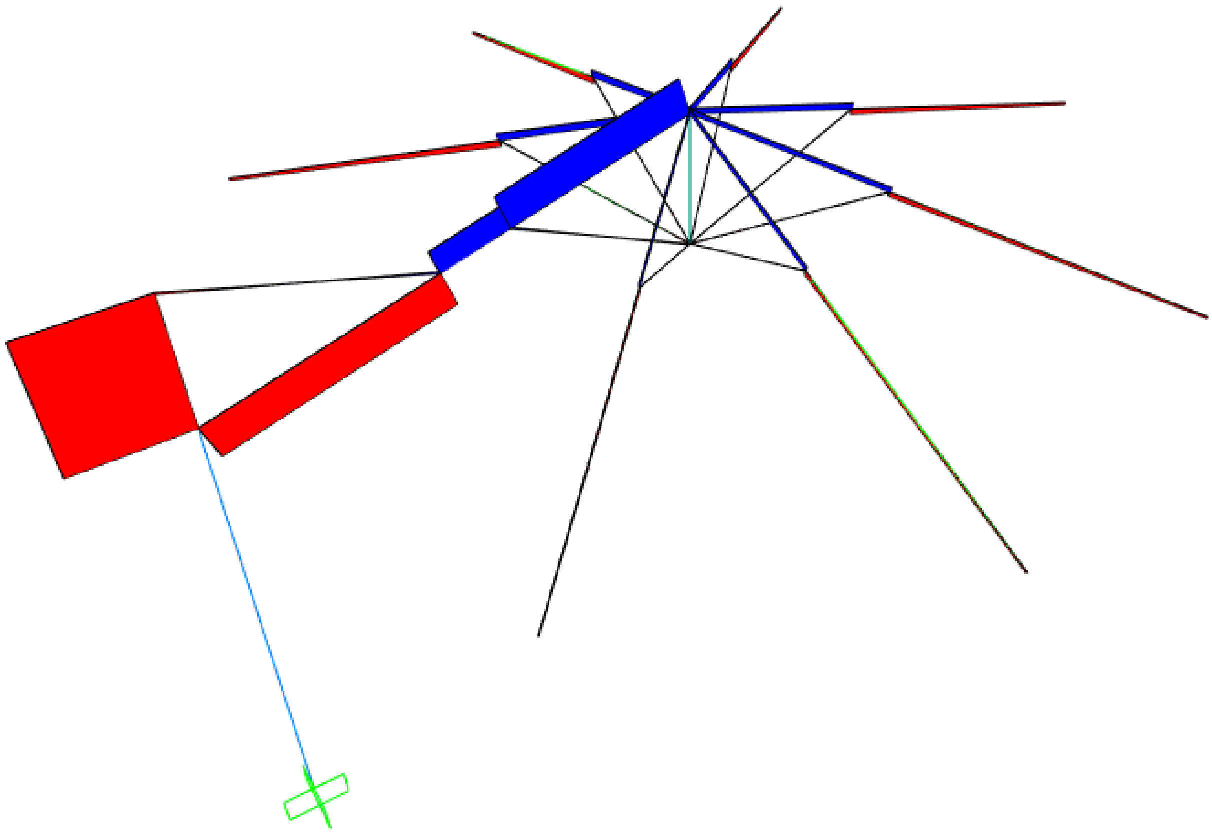
6.2.3 Maximum Shear



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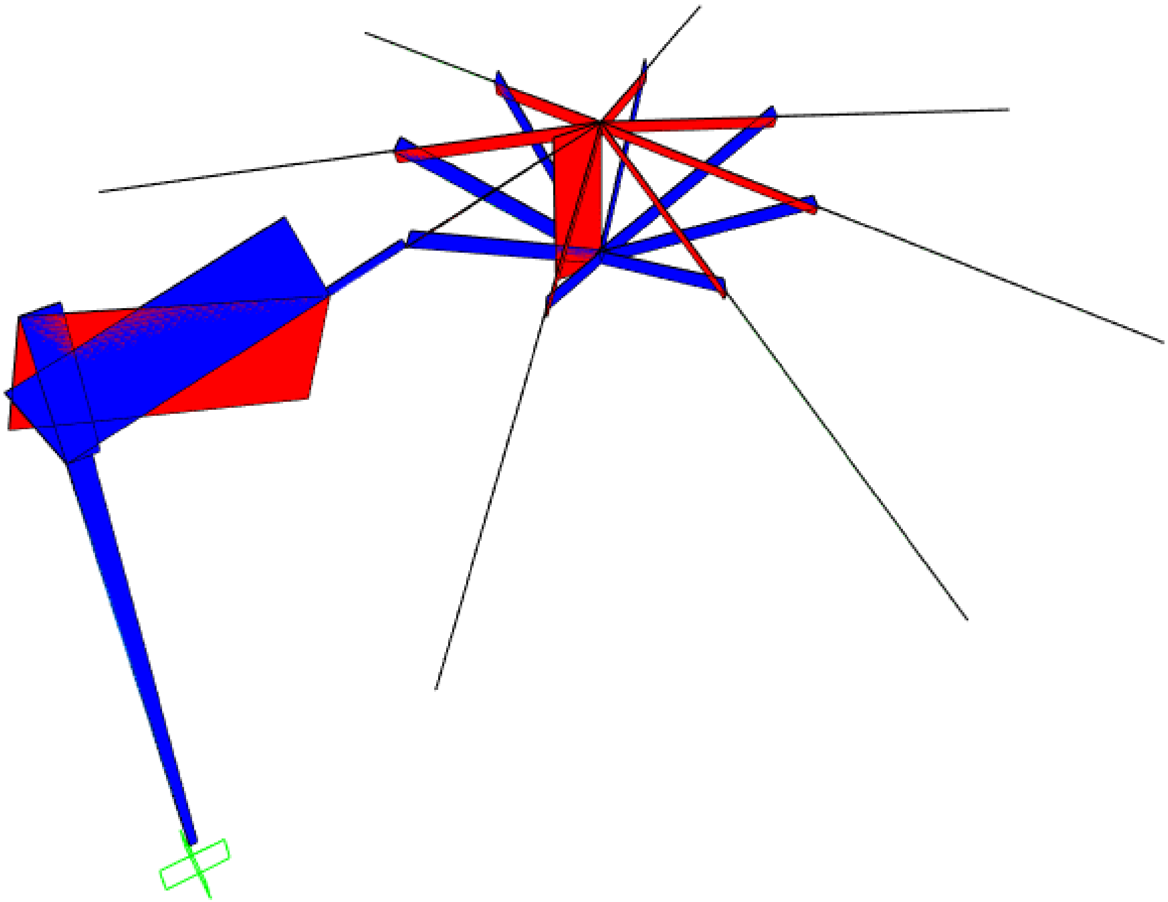
6.2.4 Maximum Axial Force



6.2.5 Maximum Reactions

TABLE: Joint Reactions						
OutputCase	F1 KN	F2 KN	F3 KN	M1 KN-m	M2 KN-m	M3 KN-m
1.2G+Wmax	4.849E-13	-0.046	0.539	-0.0685	-0.7973	-0.0912
0.9G+Wmin	-3.177E-13	-0.011	-0.136	-0.0162	0.4824	-0.0216

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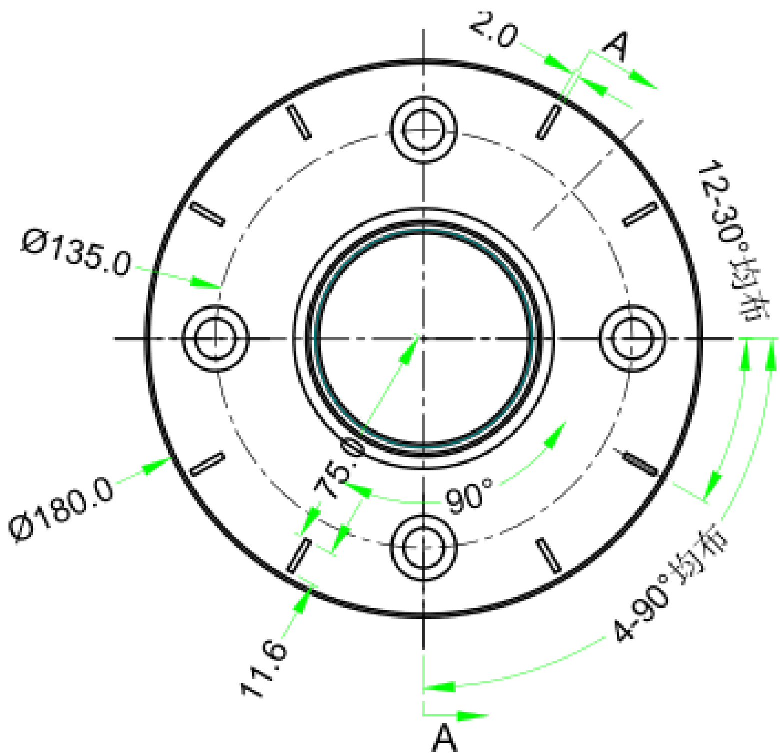
7 Aluminium Design

All members pass for the defined design wind actions. Refer to Appendix 'B' for section capacities and factor of safeties.

8 Anchorage Design

8.1 Bolted Structure

Refer to Appendix 'C' for details.



Base Plate Radius: 90mm
Edge distance: 25mm
Assumed Concrete Slab Thickness: 180mm
Maximum Tensile Force on bolts: 5.66kN
Design of supporting concrete slab is by others.

Use 4/HLA-Z1 M10 bolt by All Fasteners

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8.2 Weighted structure

Base Plate Holder: 850mm x 850mm x 70mm

Design forces:

M* = 0.8 kN.m
P = -0.54 kN

0.94 x 0.85 = W/2 x 0.85 + 0.54 x 0.85/2 → W = 1.34kN

150kg ballast is required to be distributed evenly on the 850 x 850 x 70 base plate holder

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9 Summary and Recommendations

- The 4m Round Cantilever Umbrella Structure as specified is capable of withstanding 3s gust wind speed up to **50km/hr**.
- The umbrella structure is required to be folded for forecast winds in excess of **20km/hr** to avoid any potential permanent deformation/buckling due to excessive deflection as a result of higher wind speeds.
- The anchorage system described in **Cl. 8** (150kg ballast or 4/HLA-Z1 M10 bolt) is required to resist against uplift & overturning forces due to design wind loads.

Yours faithfully,

Prime Consulting Engineers Pty. Ltd.

Kevin Zia, BEng, Meng, MIEAust, CPENG NER

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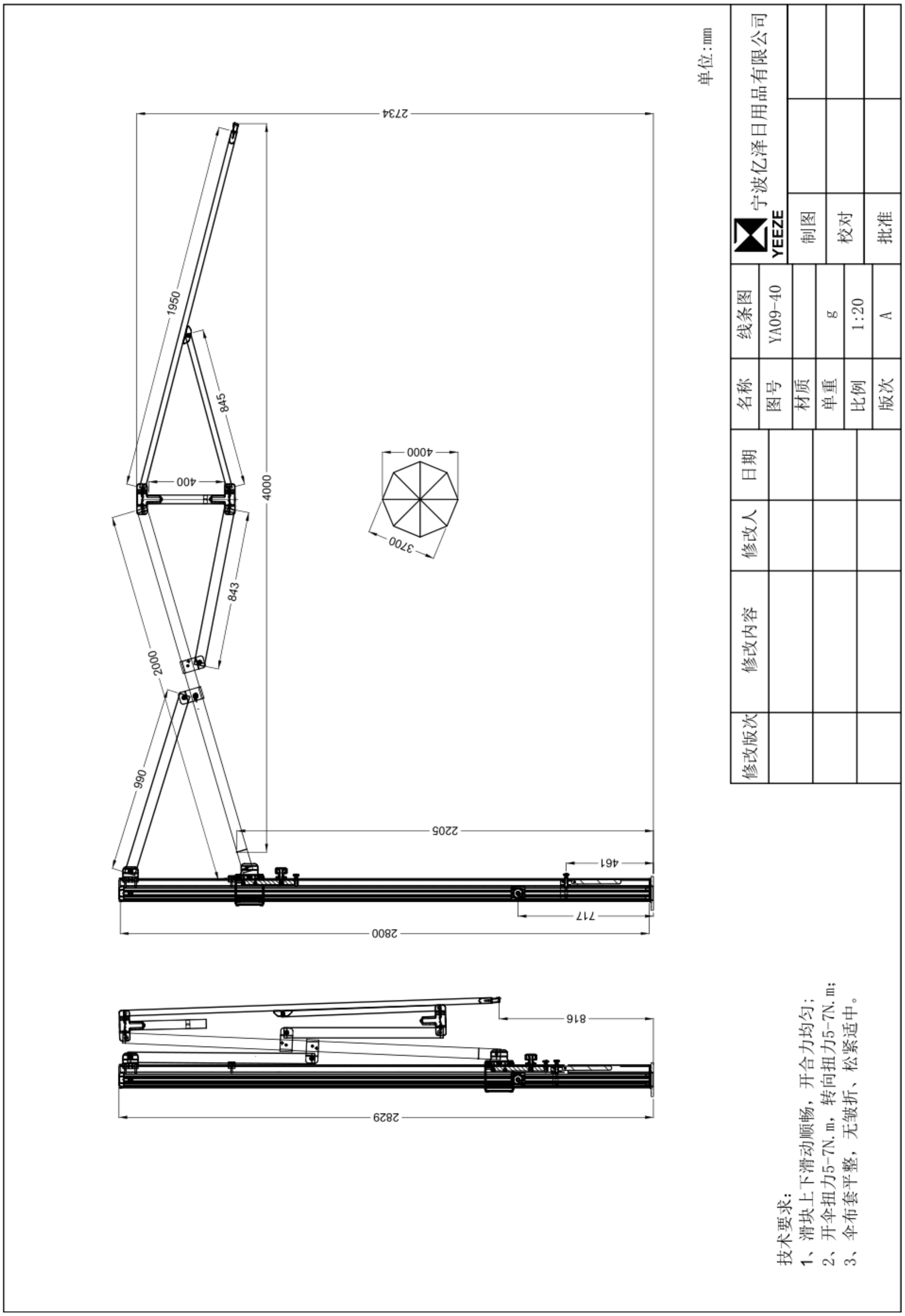
10 Appendix A – Detail Drawings



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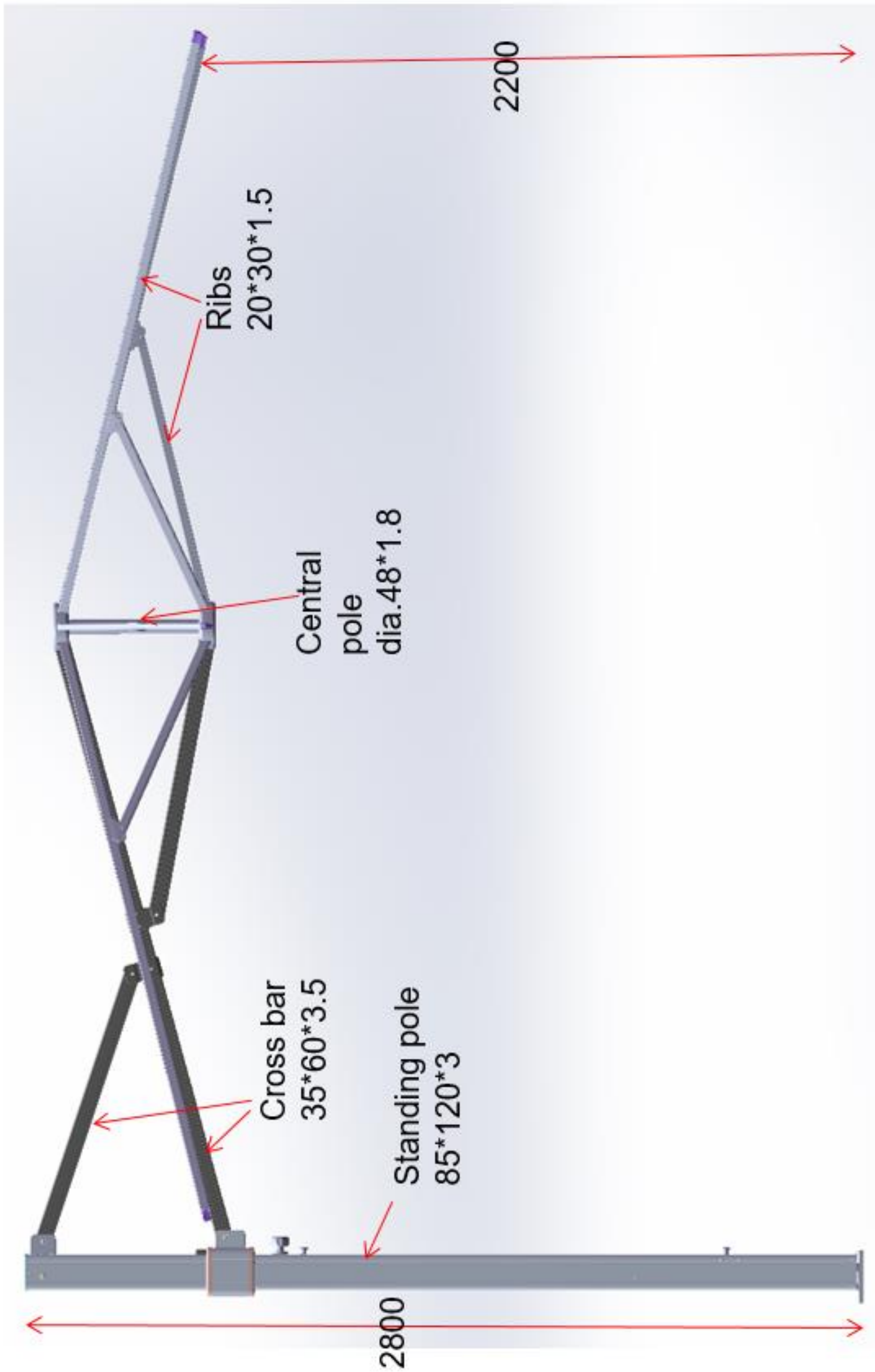
Tubes and connectors



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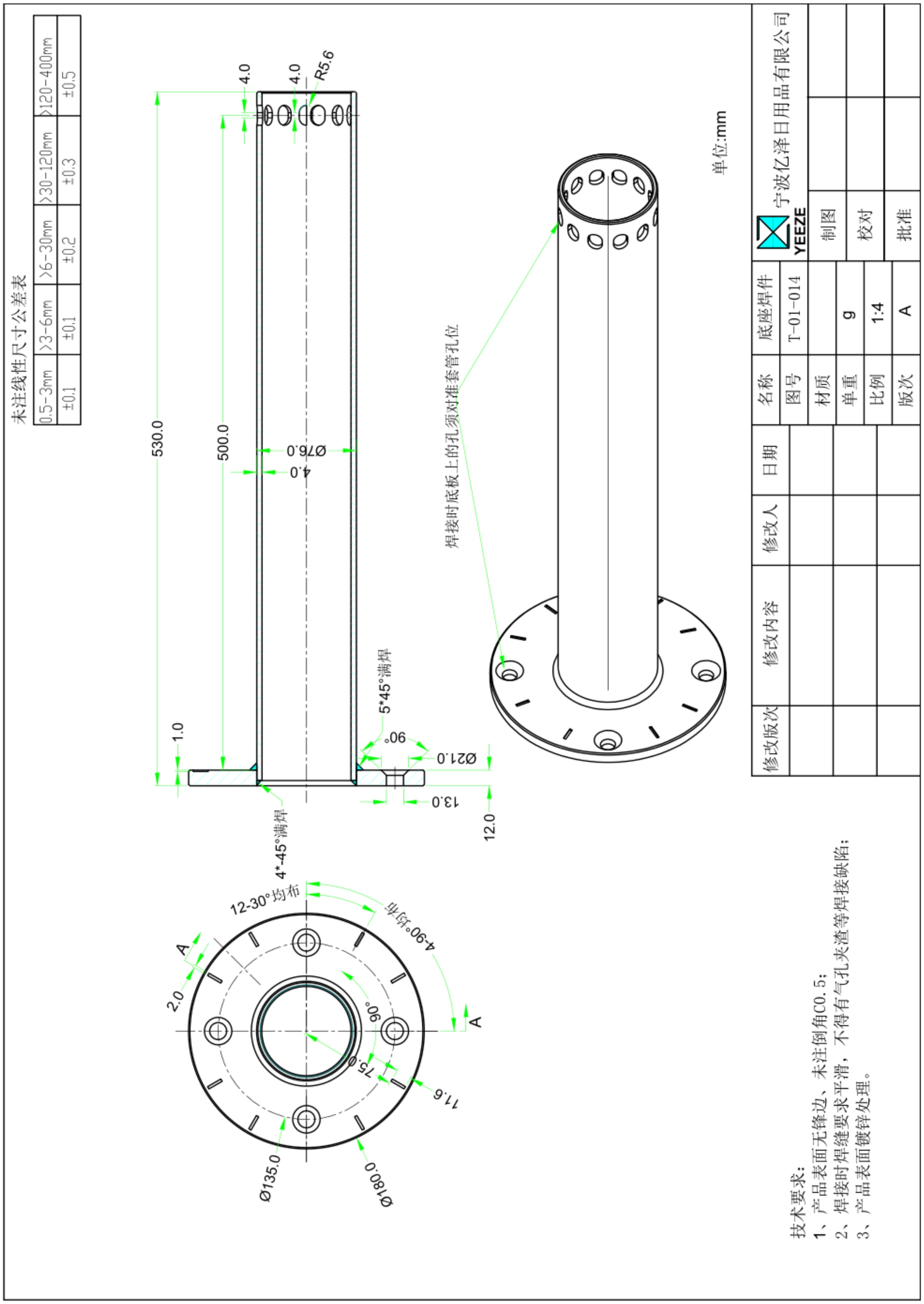

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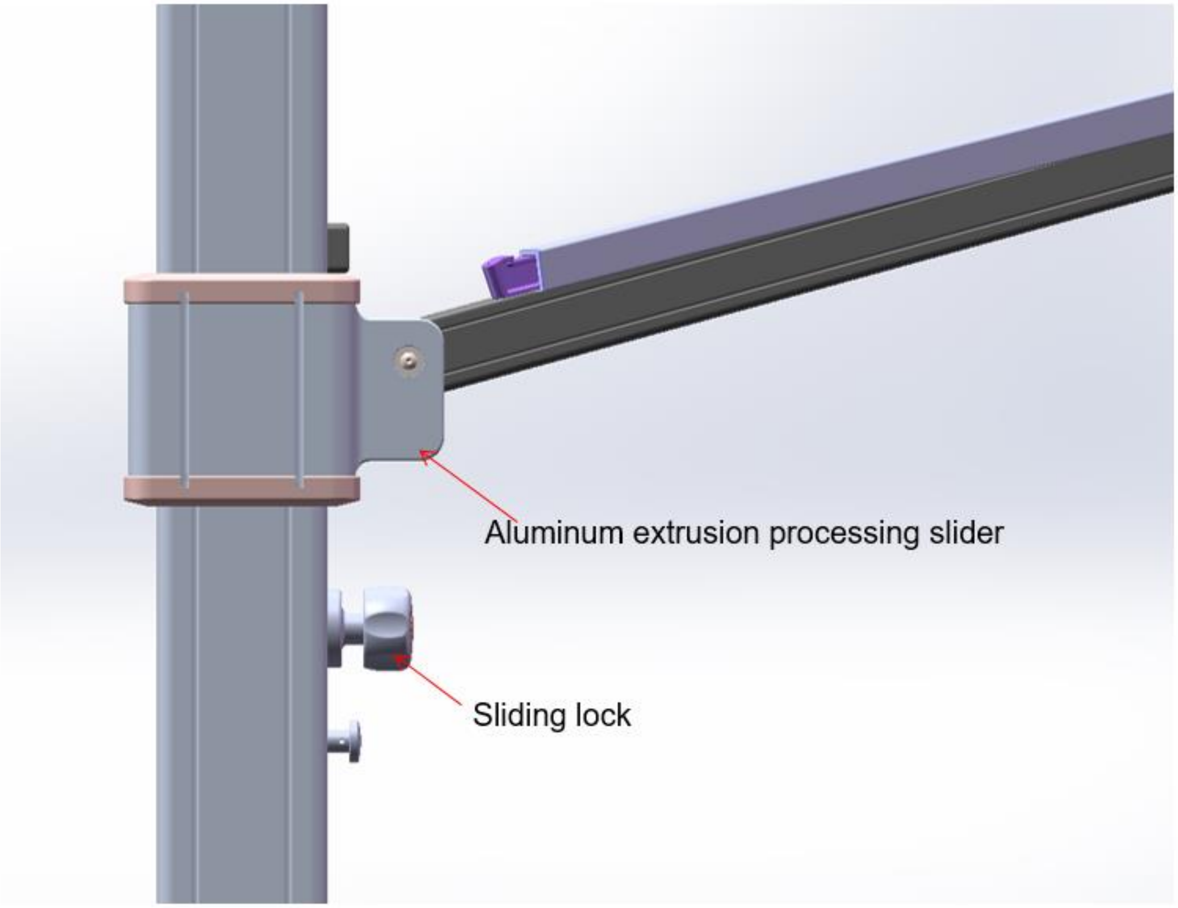

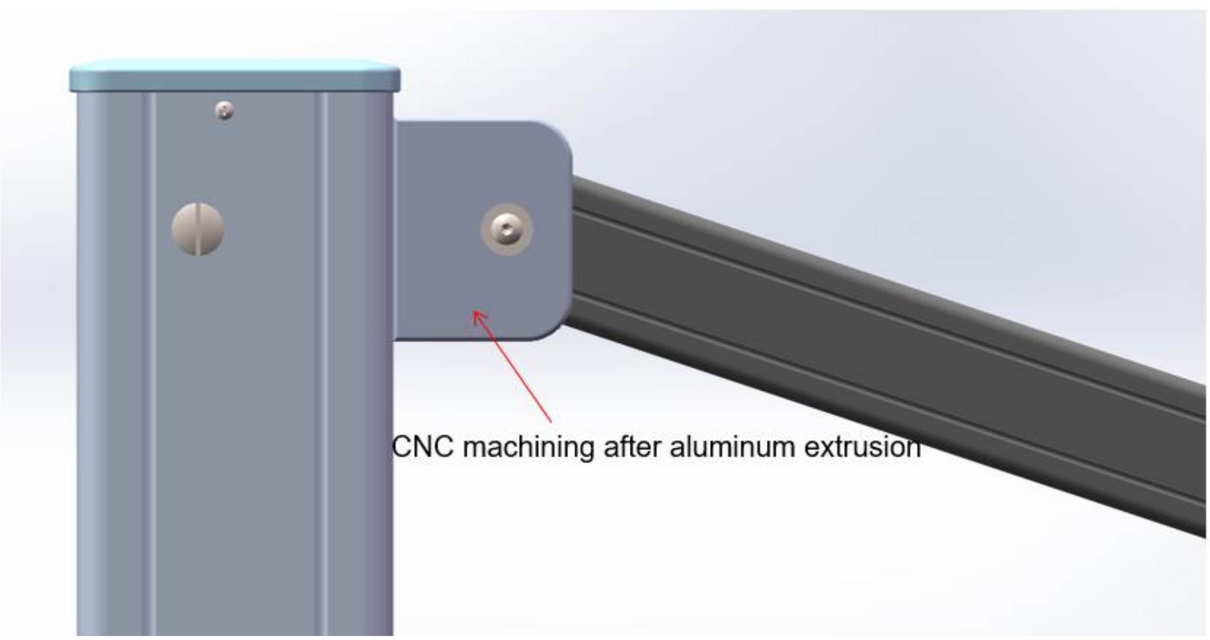

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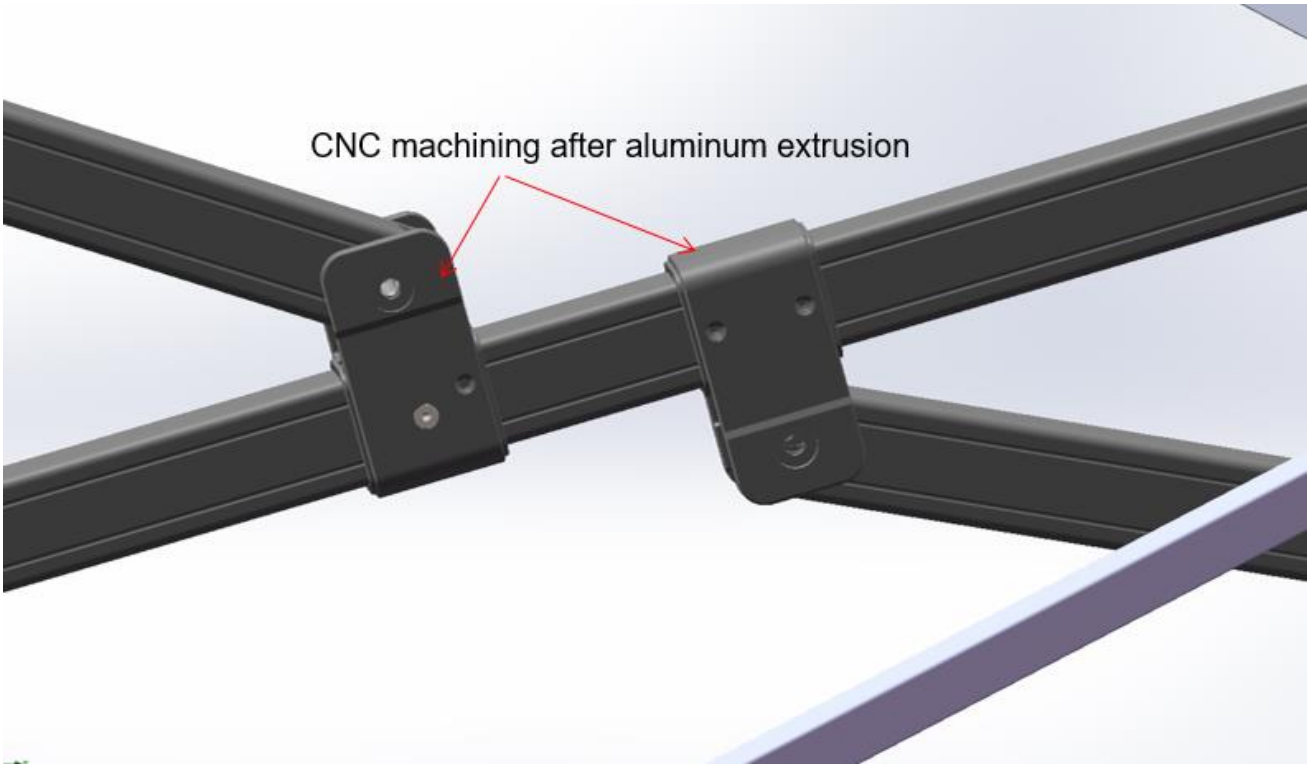

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11 Appendix B – Section capacity

11.1 Checking Members Based on AS1664.1 ALUMINIUM LSD

11.1.1 Post

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NAME	SYMBOL		VALUE	UNIT	NOTES	REF
120x85x3	**Post**					
Alloy and temper	6063-T5					AS1664.1
Tension	F_{tu}	=	152	MPa	*Ultimate*	T3.3(A)
	F_{ty}	=	110	MPa	*Yield*	
Compression	F_{cy}	=	110	MPa		
Shear	F_{su}	=	90	MPa	*Ultimate*	
	F_{sy}	=	62	MPa	*Yield*	
Bearing	F_{bu}	=	317	MPa	*Ultimate*	
	F_{by}	=	179	MPa	*Yield*	
Modulus of elasticity	E	=	70000	MPa	*Compressive*	
	k_t	=	1			T3.4(B)
	k_c	=	1			
FEM ANALYSIS RESULTS						
Axial force	P	=	0.455	kN	*compression*	
	P	=	0	kN	*Tension*	
In plane moment	M_x	=	0.7973	kNm		
Out of plane moment	M_y	=	0.1688	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	**=**	1194	mm^2		
In-plane elastic section modulus	Z_x	**=**	41441.7	mm^3		
Out-of-plane elastic section mod.	Z_y	**=**	34291.282	mm^3		
Stress from axial force	$\mathbf{f_a}$	**=**	P/A_g			
		=	**0.38**	**MPa**	*compression*	

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		=	**0.00**	**MPa**	*Tension*	
Stress from in-plane bending	f_{bx}	=	M_x/Z_x			
		=	**19.24**	**MPa**	*compression*	
Stress from out-of-plane bending	f_{by}	=	M_y/Z_y			
		=	**4.92**	**MPa**	*compression*	
Tension						
3.4.3 *Tension in rectangular tubes*						
	ϕF_L	=	**104.50**	**MPa**		
		OR				
	ϕF_L	=	**129.20**	**MPa**		
COMPRESSION						
3.4.8 *Compression in columns, axial, gross section*						
1. General						… 3.4.8.1
Unsupported length of member	L	=	2800	mm		
Effective length factor	k	=	1.00			
Radius of gyration about buckling axis (Y)	r_y	=	34.94	mm		
Radius of gyration about buckling axis (X)	r_x	=	45.63	mm		
Slenderness ratio	kLb/ry	=	62.97			
Slenderness ratio	kL/rx	=	61.36			
Slenderness parameter	λ	=	0.795			
	D_c^*	=	39.0			
	S_1^*	=	0.24			
	S_2^*	=	1.25			
	ϕ_{cc}	=	0.833			
Factored limit state stress	ϕF_L	=	**73.54**	**MPa**		
2. Sections not subject to torsional or torsional-flexural buckling						… 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	=	62.97			
3.4.10 *Uniform compression in components of columns, gross section - flat plates*						
1. Uniform compression in components of columns, gross section - flat plates with both edges supported						… 3.4.10.1
	k_1	=	0.35			T3.3(D)
Max. distance between toes of fillets of supporting elements for plate	b'	=	79			
	t	=	3	mm		
Slenderness	b/t	=	26.333333			

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Limit 1	S_1	=	12.06			
Limit 2	S_2	=	49.94			
Factored limit state stress	**ϕF_L**	=	**93.08**	**MPa**		
Most adverse compressive limit state stress	F_a	=	73.54	MPa		
Most adverse tensile limit state stress	F_a	=	104.50	MPa		
Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.01		PASS	
BENDING - IN-PLANE						
***3.4.15** Compression in beams, extreme fibre, gross section rectangular tubes, box sections*						
Unbraced length for bending	L_b	=	2200	mm		
Second moment of area (weak axis)	I_y	=	1.46E+06	mm^4		
Torsion modulus	J	=	2.78E+06	mm^3		
Elastic section modulus	Z	=	41441.7	mm^3		
Slenderness	S	=	90.67			
Limit 1	S_1	=	21.80			
Limit 2	S_2	=	3854.05			
Factored limit state stress	**ϕF_L**	=	**95.00**	**MPa**		… 3.4.15(2)
***3.4.17** Compression in components of beams (component under uniform compression), gross section - flat plates with both edges supported*						
	k_1	=	0.5			T3.3(D)
	k_2	=	2.04			T3.3(D)
Max. distance between toes of fillets of supporting elements for plate	b'	=	79	mm		
	t	=	3	mm		
Slenderness	b/t	=	26.333333			
Limit 1	S_1	=	12.06			
Limit 2	S_2	=	71.35			
Factored limit state stress	**ϕF_L**	=	**93.08**	**MPa**		
Most adverse in-plane bending limit state stress	F_{bx}	=	93.08	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.21		PASS	

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BENDING - OUT-OF-PLANE						
NOTE: Limit state stresses, ϕF_L are the same for out-of-plane bending (doubly symmetric section)						
Factored limit state stress	ϕF_L	=	**93.08**	**MPa**		
Most adverse out-of-plane bending limit state stress	F_{by}	=	93.08	MPa		
Most adverse out-of-plane bending capacity factor	f_{by}/F_{by}	=	0.05		PASS	
COMBINED ACTIONS						
***4.1.1** Combined compression and bending*						… 4.1.1(2)
	F_a	=	73.54	MPa		… 3.4.8
	F_{ao}	=	93.08	MPa		… 3.4.10
	F_{bx}	=	93.08	MPa		… 3.4.17
	F_{by}	=	93.08	MPa		… 3.4.17
	f_a/F_a	=	0.005			
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$					… 4.1.1 (3)
i.e.	0.26	$\leq$	1.0		PASS	
SHEAR						
***3.4.24** Shear in webs (Major Axis)*						… 4.1.1(2)
Clear web height	h	=	114	mm		
	t	=	3	mm		
Slenderness	h/t	=	38			
Limit 1	S_1	=	33.38			
Limit 2	S_2	=	59.31			
Factored limit state stress	ϕF_L	=	**57.60**	**MPa**		
Stress From Shear force	f_{sx}	=	V/A_w			
			0.00	**MPa**		
***3.4.25** Shear in webs (Minor Axis)*						
Clear web height	b	=	79	mm		
	t	=	3	mm		
Slenderness	b/t	=	26.333333			
Factored limit state stress	ϕF_L	=	**58.90**	**MPa**		
Stress From Shear force	f_{sy}	=	V/A_w			

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			0.05	**MPa**			
Most adverseshear capacity factor (Major Axis)	f_{sx}/F_{sx}	=	0.00	**MPa**			
Most adverseshear capacity factor (Minor Axis)	f_{sy}/F_{sy}	**=**	0.00	**Mpa**	PASS		
COMBINED ACTIONS							
***4.4** Combined Shear, Compresion and bending*							
Check:	$f_a/F_a + f_b/F_b + (f_s/F_s)^2 \leq 1.0$						
i.e.	0.21	≤	1.0		PASS		

11.1.2 Cantilever Beam

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Job no. 21-174-3 **Date:** 17/01/2022

NAME	SYMBOL		VALUE	UNIT	NOTES	REF
60x35x3.5	**Cantilever Beam**					
Alloy and temper	6063-T5					AS1664.1
Tension	F_{tu}	=	152	MPa	*Ultimate*	T3.3(A)
	F_{ty}	=	110	MPa	*Yield*	
Compression	F_{cy}	=	110	MPa		
Shear	F_{su}	=	90	MPa	*Ultimate*	
	F_{sy}	=	62	MPa	*Yield*	
Bearing	F_{bu}	=	317	MPa	*Ultimate*	
	F_{by}	=	179	MPa	*Yield*	
Modulus of elasticity	E	=	70000	MPa	*Compressive*	
	k_t	=	1			T3.4(B)
	k_c	=	1			
FEM ANALYSIS RESULTS						
Axial force	P	=	1.261	kN	*compression*	
	P	=	0	kN	*Tension*	

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In plane moment	M_x	=	0.4219	kNm		
Out of plane moment	M_y	=	0.0738	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	**=**	616	mm^2		
In-plane elastic section modulus	Z_x	**=**	9420.677 8	mm^3		
Out-of-plane elastic section mod.	Z_y	**=**	6709.733 3	mm^3		
Stress from axial force	$\mathbf{f_a}$	**=**	P/A_g			
		=	**2.05**	**MPa**	*compression*	
		=	**0.00**	**MPa**	*Tension*	
Stress from in-plane bending	$\mathbf{f_{bx}}$	**=**	M_x/Z_x			
		=	**44.78**	**MPa**	*compression*	
Stress from out-of-plane bending	$\mathbf{f_{by}}$	**=**	M_y/Z_y			
		=	**11.00**	**MPa**	*compression*	
Tension						
3.4.3 *Tension in rectangular tubes*						
	ϕF_L	**=**	**104.50**	**MPa**		
		OR				
	ϕF_L	**=**	**129.20**	**MPa**		
COMPRESSION						
3.4.8 *Compression in columns, axial, gross section*						
1. General						… 3.4.8.1
Unsupported length of member	L	=	2050	mm		
Effective length factor	k	=	1.00			
Radius of gyration about buckling axis (Y)	r_y	=	13.81	mm		
Radius of gyration about buckling axis (X)	r_x	=	21.42	mm		
Slenderness ratio	kLb/ry	=	148.48			
Slenderness ratio	kL/rx	=	95.71			
Slenderness parameter	λ	=	1.87			
	D_c^*	=	39.0			
	S_1^*	=	0.24			
	S_2^*	=	1.25			
	ϕ_{cc}	=	0.842			
Factored limit state stress	**ϕF_L**	**=**	**26.39**	**MPa**		

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2. Sections not subject to torsional or torsional-flexural buckling						… 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	=	148.48			
***3.4.10** Uniform compression in components of columns, gross section - flat plates*						
1. Uniform compression in components of columns, gross section - flat plates with both edges supported						… 3.4.10.1
	k_1	=	0.35			T3.3(D)
Max. distance between toes of fillets of supporting elements for plate	b'	=	28			
	t	=	3.5	mm		
Slenderness	b/t	=	8			
Limit 1	S_1	=	12.06			
Limit 2	S_2	=	49.94			
Factored limit state stress	**ϕF_L**	=	**104.50**	**MPa**		
Most adverse compressive limit state stress	F_a	=	26.39	MPa		
Most adverse tensile limit state stress	F_a	=	104.50	MPa		
Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.08		PASS	
BENDING - IN-PLANE						
***3.4.15** Compression in beams, extreme fibre, gross section rectangular tubes, box sections*						
Unbraced length for bending	L_b	=	2050	mm		
Second moment of area (weak axis)	I_y	=	1.17E+05	mm^4		
Torsion modulus	J	=	2.52E+05	mm^3		
Elastic section modulus	Z	=	9420.677 8	mm^3		
Slenderness	S	=	224.56			
Limit 1	S_1	=	21.80			
Limit 2	S_2	=	3854.05			
Factored limit state stress	**ϕF_L**	=	**91.34**	**MPa**		… 3.4.15(2)
***3.4.17** Compression in components of beams (component under uniform compression), gross section - flat plates with both edges supported*						
	k_1	=	0.5			T3.3(D)
	k_2	=	2.04			T3.3(D)

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Max. distance between toes of fillets of supporting elements for plate	b'	=	28	mm		
	t	=	3.5	mm		
Slenderness	b/t	=	8			
Limit 1	S_1	=	12.06			
Limit 2	S_2	=	71.35			
Factored limit state stress	**ϕF_L**	=	**104.50**	**MPa**		
Most adverse in-plane bending limit state stress	F_{bx}	=	91.34	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.49		PASS	
BENDING - OUT-OF-PLANE						
NOTE: Limit state stresses, ϕF_L are the same for out-of-plane bending (doubly symmetric section)						
Factored limit state stress	**ϕF_L**	=	**91.34**	**MPa**		
Most adverse out-of-plane bending limit state stress	**F_{by}**	=	91.34	MPa		
Most adverse out-of-plane bending capacity factor	**f_{by}/F_{by}**	=	0.12		PASS	
COMBINED ACTIONS						
4.1.1 *Combined compression and bending*						… 4.1.1(2)
	F_a	=	26.39	MPa		… 3.4.8
	F_{ao}	=	104.50	MPa		… 3.4.10
	F_{bx}	=	91.34	MPa		… 3.4.17
	F_{by}	=	91.34	MPa		… 3.4.17
	f_a/F_a	=	0.078			
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$					… 4.1.1 (3)
i.e.	0.69	$\leq$	1.0		PASS	
SHEAR						
3.4.24 *Shear in webs (Major Axis)*						… 4.1.1(2)
Clear web height	h	=	53	mm		
	t	=	3.5	mm		

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Slenderness	h/t	=	15.142857			
Limit 1	S_1	=	33.38			
Limit 2	S_2	=	59.31			
Factored limit state stress	**ϕF_L**	=	**58.90**	**MPa**		
Stress From Shear force	**f_{sx}**	=	V/A_w			
			0.86	**MPa**		
***3.4.25** Shear in webs (Minor Axis)*						
Clear web height	b	=	28	mm		
	t	=	3.5	mm		
Slenderness	b/t	=	8			
Factored limit state stress	**ϕF_L**	=	**58.90**	**MPa**		
Stress From Shear force	**f_{sy}**	=	V/A_w			
			0.33	**MPa**		
Most adverseshear capacity factor (Major Axis)	f_{sx}/F_{sx}	=	0.01	**MPa**		
Most adverseshear capacity factor (Minor Axis)	f_{sy}/F_{sy}	=	0.01	**Mpa**	PASS	
COMBINED ACTIONS						
***4.4** Combined Shear, Compression and bending*						

Check: $f_a/F_a + f_b/F_b + (f_s/F_s)^2 \leq 1.0$

i.e. 0.57 ≤ 1.0 — PASS

11.1.3 Brace (typ.1)

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NAME	SYMBOL		VALUE	UNIT	NOTES	REF
60x35x3.5	**Brace 1**					
Alloy and temper	6063-T5					AS1664.1
Tension	F_{tu}	=	152	MPa	*Ultimate*	T3.3(A)
	F_{ty}	=	110	MPa	*Yield*	
Compression	F_{cy}	=	110	MPa		

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Shear	F_{su}	=	90	MPa	*Ultimate*	
	F_{sy}	=	62	MPa	*Yield*	
Bearing	F_{bu}	=	317	MPa	*Ultimate*	
	F_{by}	=	179	MPa	*Yield*	
Modulus of elasticity	E	=	70000	MPa	*Compressive*	
	k_t	=	1			T3.4(B)
	k_c	=	1			
FEM ANALYSIS RESULTS						
Axial force	P	=	0.104	kN	*compression*	
	P	=	0	kN	*Tension*	
In plane moment	M_x	=	8.674E-19	kNm		
Out of plane moment	M_y	=	0.1795	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	**=**	616	mm^2		
In-plane elastic section modulus	Z_x	**=**	9420.6778	mm^3		
Out-of-plane elastic section mod.	Z_y	**=**	6709.7333	mm^3		
Stress from axial force	$\mathbf{f_a}$	**=**	P/A_g			
		=	**0.17**	**MPa**	*compression*	
		=	**0.00**	**MPa**	*Tension*	
Stress from in-plane bending	$\mathbf{f_{bx}}$	**=**	M_x/Z_x			
		=	**0.00**	**MPa**	*compression*	
Stress from out-of-plane bending	$\mathbf{f_{by}}$	**=**	M_y/Z_y			
		=	**26.75**	**MPa**	*compression*	
Tension						
3.4.3 *Tension in rectangular tubes*						
	$\mathbf{\phi F_L}$	**=**	**104.50**	**MPa**		
		OR				
	$\mathbf{\phi F_L}$	**=**	**129.20**	**MPa**		
COMPRESSION						
3.4.8 *Compression in columns, axial, gross section*						
1. General						… 3.4.8.1
Unsupported length of member	L	=	1000	mm		
Effective length factor	k	=	1.00			
Radius of gyration about buckling axis (Y)	r_y	=	13.81	mm		

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Radius of gyration about buckling axis (X)	r_x	=	21.42	mm		
Slenderness ratio	kLb/ry	=	72.43			
Slenderness ratio	kL/rx	=	46.69			
Slenderness parameter	λ	=	0.91			
	D_c*	=	39.0			
	S_1*	=	0.24			
	S_2*	=	1.25			
	ϕ_{cc}	=	0.808			
Factored limit state stress	**ϕF_L**	**=**	**67.56**	**MPa**		
2. Sections not subject to torsional or torsional-flexural buckling						… 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	=	72.43			
***3.4.10** Uniform compression in components of columns, gross section - flat plates*						
1. Uniform compression in components of columns, gross section - flat plates with both edges supported						… 3.4.10.1
	k_1	=	0.35			T3.3(D)
Max. distance between toes of fillets of supporting elements for plate	b'	=	28			
	t	=	3.5	mm		
Slenderness	b/t	=	8			
Limit 1	S_1	=	12.06			
Limit 2	S_2	=	49.94			
Factored limit state stress	**ϕF_L**	**=**	**104.50**	**MPa**		
Most adverse compressive limit state stress	F_a	=	67.56	MPa		
Most adverse tensile limit state stress	F_a	=	104.50	MPa		
Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.00		PASS	
BENDING - IN-PLANE						
***3.4.15** Compression in beams, extreme fibre, gross section rectangular tubes, box sections*						
Unbraced length for bending	L_b	=	1000	mm		
Second moment of area (weak axis)	I_y	=	117420.33	mm^4		

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Torsion modulus	J	=	251961.03	mm^3		
Elastic section modulus	Z	=	9420.6778	mm^3		
Slenderness	S	=	109.54			
Limit 1	S_1	=	21.80			
Limit 2	S_2	=	3854.05			
Factored limit state stress	**ϕF_L**	=	**94.37**	**MPa**		… 3.4.15(2)
3.4.17 *Compression in components of beams (component under uniform compression), gross section - flat plates with both edges supported*						
	k_1	=	0.5			T3.3(D)
	k_2	=	2.04			T3.3(D)
Max. distance between toes of fillets of supporting elements for plate	b'	=	28	mm		
	t	=	3.5	mm		
Slenderness	b/t	=	8			
Limit 1	S_1	=	12.06			
Limit 2	S_2	=	71.35			
Factored limit state stress	**ϕF_L**	=	**104.50**	**MPa**		
Most adverse in-plane bending limit state stress	F_{bx}	=	94.37	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.00		PASS	
BENDING - OUT-OF-PLANE						
NOTE: Limit state stresses, ϕF_L are the same for out-of-plane bending (doubly symmetric section)						
Factored limit state stress	**ϕF_L**	=	**94.37**	**MPa**		
Most adverse out-of-plane bending limit state stress	**F_{by}**	=	94.37	MPa		
Most adverse out-of-plane bending capacity factor	**f_{by}/F_{by}**	=	0.28		PASS	
COMBINED ACTIONS						
4.1.1 *Combined compression and bending*						… 4.1.1(2)
	F_a	=	67.56	MPa		… 3.4.8
	F_{ao}	=	104.50	MPa		… 3.4.10

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	F_{bx}	=	94.37	MPa		… 3.4.17
	F_{by}	=	94.37	MPa		… 3.4.17
	f_a/F_a	=	0.002			
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$					… 4.1.1 (3)
i.e.	0.29	≤	1.0		PASS	
SHEAR						
***3.4.24** Shear in webs (Major Axis)*						… 4.1.1(2)
Clear web height	h	=	53	mm		
	t	=	3.5	mm		
Slenderness	h/t	=	15.142857			
Limit 1	S_1	=	33.38			
Limit 2	S_2	=	59.31			
Factored limit state stress	ϕF_L	=	**58.90**	**MPa**		
Stress From Shear force	f_{sx}	=	V/A_w			
			0.01	**MPa**		
***3.4.25** Shear in webs (Minor Axis)*						
Clear web height	b	=	28	mm		
	t	=	3.5	mm		
Slenderness	b/t	=	8			
Factored limit state stress	ϕF_L	=	**58.90**	**MPa**		
Stress From Shear force	f_{sy}	=	V/A_w			
			0.54	**MPa**		
Most adverseshear capacity factor (Major Axis)	f_{sx}/F_{sx}	=	0.00	**MPa**		
Most adverseshear capacity factor (Minor Axis)	f_{sy}/F_{sy}	=	0.01	**Mpa**	PASS	
COMBINED ACTIONS						
***4.4** Combined Shear, Compresion and bending*						
Check:	$f_a/F_a + f_b/F_b + (f_s/F_s)^2 \leq 1.0$					
i.e.	0.29	≤	1.0		PASS	

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11.1.4 Brace (typ.2)

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NAME	SYMBOL		VALUE	UNIT	NOTES	REF
30x20x1.5	**Brace 2**					
Alloy and temper	6063-T5					AS1664.1
Tension	F_{tu}	=	152	MPa	*Ultimate*	T3.3(A)
	F_{ty}	=	110	MPa	*Yield*	
Compression	F_{cy}	=	110	MPa		
Shear	F_{su}	=	90	MPa	*Ultimate*	
	F_{sy}	=	62	MPa	*Yield*	
Bearing	F_{bu}	=	317	MPa	*Ultimate*	
	F_{by}	=	179	MPa	*Yield*	
Modulus of elasticity	E	=	70000	MPa	*Compressive*	
	k_t	=	1			T3.4(B)
	k_c	=	1			
FEM ANALYSIS RESULTS						
Axial force	P	=	0.182	kN	*compression*	
	P	=	0	kN	*Tension*	
In plane moment	M_x	=	0	kNm		
Out of plane moment	M_y	=	0.0103	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	=	141	mm^2		
In-plane elastic section modulus	Z_x	=	1141.05	mm^3		
Out-of-plane elastic section mod.	Z_y	=	894.575	mm^3		
Stress from axial force	$\mathbf{f_a}$	=	P/A_g			
		=	**1.29**	**MPa**	*compression*	
		=	**0.00**	**MPa**	*Tension*	
Stress from in-plane bending	$\mathbf{f_{bx}}$	=	M_x/Z_x			
		=	**0.00**	**MPa**	*compression*	
	$\mathbf{f_{by}}$	=	M_y/Z_y			

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Stress from out-of-plane bending		=	**11.51**	**MPa**	*compression*	
Tension						
3.4.3 *Tension in rectangular tubes*						
	ϕF$_L$	=	**104.50**	**MPa**		
		OR				
	ϕF$_L$	=	**129.20**	**MPa**		
COMPRESSION						
3.4.8 *Compression in columns, axial, gross section*						
1. General						… 3.4.8.1
Unsupported length of member	L	=	950	mm		
Effective length factor	k	=	1.00			
Radius of gyration about buckling axis (Y)	r_y	=	7.97	mm		
Radius of gyration about buckling axis (X)	r_x	=	11.02	mm		
Slenderness ratio	kLb/ry	=	119.27			
Slenderness ratio	kL/rx	=	86.23			
Slenderness parameter	λ	=	1.50			
	D_c*	=	39.0			
	S_1*	=	0.24			
	S_2*	=	1.25			
	ϕ_{cc}	=	0.791			
Factored limit state stress	**ϕF$_L$**	=	**38.40**	**MPa**		
2. Sections not subject to torsional or torsional-flexural buckling						… 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	=	119.27			
3.4.10 *Uniform compression in components of columns, gross section - flat plates*						
1. Uniform compression in components of columns, gross section - flat plates with both edges supported						… 3.4.10.1
	k_1	=	0.35			T3.3(D)
Max. distance between toes of fillets of supporting elements for plate	b'	=	17			
	t	=	1.5	mm		
Slenderness	b/t	=	11.333333			
Limit 1	S_1	=	12.06			
Limit 2	S_2	=	49.94			

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Factored limit state stress	**ϕF_L**	=	**104.50**	**MPa**		
Most adverse compressive limit state stress	F_a	=	38.40	MPa		
Most adverse tensile limit state stress	F_a	=	104.50	MPa		
Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.03		PASS	
BENDING - IN-PLANE						
***3.4.15** Compression in beams, extreme fibre, gross section rectangular tubes, box sections*						
Unbraced length for bending	L_b	=	950	mm		
Second moment of area (weak axis)	I_y	=	8945.75	mm^4		
Torsion modulus	J	=	17744.206	mm^3		
Elastic section modulus	Z	=	1141.05	mm^3		
Slenderness	S	=	172.08			
Limit 1	S_1	=	21.80			
Limit 2	S_2	=	3854.05			
Factored limit state stress	**ϕF_L**	=	**92.59**	**MPa**		... 3.4.15(2)
***3.4.17** Compression in components of beams (component under uniform compression), gross section - flat plates with both edges supported*						
	k_1	=	0.5			T3.3(D)
	k_2	=	2.04			T3.3(D)
Max. distance between toes of fillets of supporting elements for plate	b'	=	17	mm		
	t	=	1.5	mm		
Slenderness	b/t	=	11.333333			
Limit 1	S_1	=	12.06			
Limit 2	S_2	=	71.35			
Factored limit state stress	**ϕF_L**	=	**104.50**	**MPa**		
Most adverse in-plane bending limit state stress	F_{bx}	=	92.59	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.00		PASS	

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BENDING - OUT-OF-PLANE						
NOTE: Limit state stresses, ϕF_L are the same for out-of-plane bending (doubly symmetric section)						
Factored limit state stress	**ϕF_L**	=	**92.59**	**MPa**		
Most adverse out-of-plane bending limit state stress	**F_{by}**	=	92.59	MPa		
Most adverse out-of-plane bending capacity factor	**f_{by}/F_{by}**	=	0.12		PASS	
COMBINED ACTIONS						
***4.1.1** Combined compression and bending*						… 4.1.1(2)
	F_a	=	38.40	MPa		… 3.4.8
	F_{ao}	=	104.50	MPa		… 3.4.10
	F_{bx}	=	92.59	MPa		… 3.4.17
	F_{by}	=	92.59	MPa		… 3.4.17
	f_a/F_a	=	0.034			
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$					… 4.1.1 (3)
i.e.	0.16	≤	1.0		PASS	
SHEAR						
***3.4.24** Shear in webs (Major Axis)*						… 4.1.1(2)
Clear web height	h	=	27	mm		
	t	=	1.5	mm		
Slenderness	h/t	=	18			
Limit 1	S_1	=	33.38			
Limit 2	S_2	=	59.31			
Factored limit state stress	**ϕF_L**	=	**58.90**	**MPa**		
Stress From Shear force	**f_{sx}**	=	V/A_w			
			0.01	**MPa**		
***3.4.25** Shear in webs (Minor Axis)*						
Clear web height	b	=	17	mm		
	t	=	1.5	mm		
Slenderness	b/t	=	11.333333			
Factored limit state stress	**ϕF_L**	=	**58.90**	**MPa**		
Stress From Shear force	**f_{sy}**	=	V/A_w			

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			0.15	**MPa**		
Most adverseshear capacity factor (Major Axis)	f_{sx}/F_{sx}	=	0.00	**MPa**		
Most adverseshear capacity factor (Minor Axis)	f_{sy}/F_{sy}	**=**	0.00	**Mpa**	PASS	
COMBINED ACTIONS						
***4.4** Combined Shear, Compresion and bending*						
Check:	$f_a/F_a + f_b/F_b + (f_s/F_s)^2 \leq 1.0$					
i.e.	0.16	≤	1.0		PASS	

11.1.5 Middle Beam

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Job no. 21-174-3 **Date:** 17/01/2022

NAME	SYMBOL		VALUE	UNIT	NOTES	REF
30x20x1.5	**Middle Beam**					
Alloy and temper	6063-T5					AS1664.1
Tension	F_{tu}	=	152	MPa	*Ultimate*	T3.3(A)
	F_{ty}	=	110	MPa	*Yield*	
Compression	F_{cy}	=	110	MPa		
Shear	F_{su}	=	90	MPa	*Ultimate*	
	F_{sy}	=	62	MPa	*Yield*	
Bearing	F_{bu}	=	317	MPa	*Ultimate*	
	F_{by}	=	179	MPa	*Yield*	
Modulus of elasticity	E	=	70000	MPa	*Compressive*	
	k_t	=	1			T3.4(B)
	k_c	=	1			
FEM ANALYSIS RESULTS						
Axial force	P	=	0	kN	*compression*	
	P	=	0.137	kN	*Tension*	
In plane moment	M_x	=	0.0457	kNm		

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Out of plane moment	M_y	=	0.0042	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	=	141	mm^2		
In-plane elastic section modulus	Z_x	=	1141.05	mm^3		
Out-of-plane elastic section mod.	Z_y	=	894.575	mm^3		
Stress from axial force	$\mathbf{f_a}$	=	P/A_g			
		=	**0.00**	**MPa**	*compression*	
		=	**0.97**	**MPa**	*Tension*	
Stress from in-plane bending	$\mathbf{f_{bx}}$	=	M_x/Z_x			
		=	**40.05**	**MPa**	*compression*	
Stress from out-of-plane bending	$\mathbf{f_{by}}$	=	M_y/Z_y			
		=	**4.69**	**MPa**	*compression*	
Tension						
***3.4.3** Tension in rectangular tubes*						
	$\mathbf{\phi F_L}$	=	**104.50**	**MPa**		
		OR				
	$\mathbf{\phi F_L}$	=	**129.20**	**MPa**		
COMPRESSION						
***3.4.8** Compression in columns, axial, gross section*						
1. General						… 3.4.8.1
Unsupported length of member	L	=	2050	mm		
Effective length factor	k	=	1.00			
Radius of gyration about buckling axis (Y)	r_y	=	7.97	mm		
Radius of gyration about buckling axis (X)	r_x	=	11.02	mm		
Slenderness ratio	kLb/ry	=	257.37			
Slenderness ratio	kL/rx	=	186.07			
Slenderness parameter	λ	=	3.25			
	D_c*	=	39.0			
	S_1*	=	0.24			
	S_2*	=	1.25			
	ϕ_{cc}	=	0.950			
Factored limit state stress	$\mathbf{\phi F_L}$	=	**9.91**	**MPa**		
2. Sections not subject to torsional or torsional-flexural buckling						… 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	=	257.37			

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***3.4.10** Uniform compression in components of columns, gross section - flat plates*

1. Uniform compression in components of columns, gross section - flat plates with both edges supported						… 3.4.10.1
	k_1	=	0.35			T3.3(D)
Max. distance between toes of fillets of supporting elements for plate	b'	=	17			
	t	=	1.5	mm		
Slenderness	b/t	=	11.333333			
Limit 1	S_1	=	12.06			
Limit 2	S_2	=	49.94			
Factored limit state stress	**ϕF_L**	=	**104.50**	**MPa**		
Most adverse compressive limit state stress	F_a	=	9.91	MPa		
Most adverse tensile limit state stress	F_a	=	104.50	MPa		
Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.01		PASS	
BENDING - IN-PLANE						
***3.4.15** Compression in beams, extreme fibre, gross section rectangular tubes, box sections*						
Unbraced length for bending	L_b	=	2050	mm		
Second moment of area (weak axis)	I_y	=	8945.75	mm^4		
Torsion modulus	J	=	17744.206	mm^3		
Elastic section modulus	Z	=	1141.05	mm^3		
Slenderness	S	=	371.32			
Limit 1	S_1	=	21.80			
Limit 2	S_2	=	3854.05			
Factored limit state stress	**ϕF_L**	=	**88.47**	**MPa**		… 3.4.15(2)
***3.4.17** Compression in components of beams (component under uniform compression), gross section - flat plates with both edges supported*						
	k_1	=	0.5			T3.3(D)
	k_2	=	2.04			T3.3(D)

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Max. distance between toes of fillets of supporting elements for plate	b'	=	17	mm		
	t	=	1.5	mm		
Slenderness	b/t	=	11.333333			
Limit 1	S_1	=	12.06			
Limit 2	S_2	=	71.35			
Factored limit state stress	**ϕF_L**	=	**104.50**	**MPa**		
Most adverse in-plane bending limit state stress	F_{bx}	=	88.47	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.45		PASS	
BENDING - OUT-OF-PLANE						
NOTE: Limit state stresses, ϕF_L are the same for out-of-plane bending (doubly symmetric section)						
Factored limit state stress	**ϕF_L**	=	**88.47**	**MPa**		
Most adverse out-of-plane bending limit state stress	**F_{by}**	=	88.47	MPa		
Most adverse out-of-plane bending capacity factor	**f_{by}/F_{by}**	=	0.05		PASS	
COMBINED ACTIONS						
***4.1.1** Combined compression and bending*						… 4.1.1(2)
	F_a	=	9.91	MPa		… 3.4.8
	F_{ao}	=	104.50	MPa		… 3.4.10
	F_{bx}	=	88.47	MPa		… 3.4.17
	F_{by}	=	88.47	MPa		… 3.4.17
	f_a/F_a	=	0.009			
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$					… 4.1.1 (3)
i.e.	0.52	≤	1.0		PASS	
SHEAR						
***3.4.24** Shear in webs (Major Axis)*						… 4.1.1(2)
Clear web height	h	=	27	mm		
	t	=	1.5	mm		
Slenderness	h/t	=	18			

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Limit 1	S_1	=	33.38			
Limit 2	S_2	=	59.31			
Factored limit state stress	**ϕF_L**	=	**58.90**	**MPa**		
Stress From Shear force	**f_{sx}**	=	V/A_w			
			0.55	**MPa**		
***3.4.25** Shear in webs (Minor Axis)*						
Clear web height	b	=	17	mm		
	t	=	1.5	mm		
Slenderness	b/t	=	11.333333			
Factored limit state stress	**ϕF_L**	=	**58.90**	**MPa**		
Stress From Shear force	**f_{sy}**	=	V/A_w			
			0.15	**MPa**		
Most adverseshear capacity factor (Major Axis)	f_{sx}/F_{sx}	=	0.01	**MPa**		
Most adverseshear capacity factor (Minor Axis)	f_{sy}/F_{sy}	=	0.00	**Mpa**	PASS	
COMBINED ACTIONS						
***4.4** Combined Shear, Compresion and bending*						
Check:	$f_a/F_a + f_b/F_b + (f_s/F_s)^2 \leq 1.0$					
i.e.	0.46	$\leq$	1.0		PASS	

11.1.6 Centre Pole

Job no. 21-174-3 **Date:** 17/01/2022

NAME	SYMBOL		VALUE	UNIT	NOTES	REF
48x1.8	**Rafter**					
Alloy and temper	6063-T5					AS1664.1
Tension	F_{tu}	=	152	MPa	*Ultimate*	T3.3(A)
	F_{ty}	=	110	MPa	*Yield*	
Compression	F_{cy}	=	110	MPa		
Shear	F_{su}	=	90	MPa	*Ultimate*	
	F_{sy}	=	62	MPa	*Yield*	

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Bearing	F_{bu}	=	317	MPa	*Ultimate*	
	F_{by}	=	179	MPa	*Yield*	
Modulus of elasticity	E	=	70000	MPa	*Compressive*	
	k_t	=	1.0			T3.4(B)
	k_c	=	1.1			
FEM ANALYSIS RESULTS						
Axial force	P	=	0.353	kN	*compression*	
	P	=	0	kN	*Tension*	
In plane moment	M_x	=	0	kNm		
Out of plane moment	M_y	=	0	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	**=**	261.25485	mm^2		
In-plane elastic section modulus	Z_x	**=**	2908.7461	mm^3		
Out-of-plane elastic section mod.	Z_y	**=**	2908.7461	mm^3		
Stress from axial force	$\mathbf{f_a}$	**=**	P/A_g			
		=	**1.35**	**MPa**	*compression*	
		=	**0.00**	**MPa**	*Tension*	
Stress from in-plane bending	$\mathbf{f_{bx}}$	**=**	M_x/Z_x			
		=	**0.00**	**MPa**	*compression*	
Stress from out-of-plane bending	$\mathbf{f_{by}}$	**=**	M_y/Z_y			
		=	**0.00**	**MPa**	*compression*	
Tension						
***3.4.3** Tension in rectangular tubes*						3.4.3
	$\mathbf{\phi F_L}$	**=**	**122.27**	**MPa**		
			OR			
	$\mathbf{\phi F_L}$	**=**	**160.21**	**MPa**		
COMPRESSION						
***3.4.8** Compression in columns, axial, gross section*						
1. General						3.4.8.1
Unsupported length of member	L	=	400	mm		
Effective length factor	k	=	1.00			
Radius of gyration about buckling axis (Y)	r_y	=	16.35	mm		
Radius of gyration about buckling axis (X)	r_x	=	16.35	mm		
Slenderness ratio	kLb/ry	=	24.47			
Slenderness ratio	kL/rx	=	24.47			

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Slenderness parameter	λ	=	0.309			
	D_c*	=	39.0			
	S_1*	=	0.54			
	S_2*	=	1.25			
	ϕ_{cc}	=	0.935			
Factored limit state stress	**ϕF_L**	**=**	**91.85**	**MPa**		
2. Sections not subject to torsional or torsional-flexural buckling						3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	=	24.47			
***3.4.11** Uniform compression in components of columns, gross section - flat plates*						
Uniform compression in components of columns, gross section - curved plates with both edges, walls of round or oval tube						3.4.11
	k_1	=	0.35			T3.3(D)
mid-thickness radius of round tubular column or maximum mid-thickness radius	R_m	=	23.1			
	t	=	1.8	mm		
Slenderness	R_m/t	=	12.833333			
Limit 1	S_1	=	1.69			
Limit 2	S_2	=	672.46			
Factored limit state stress	**ϕF_L**	**=**	**103.88**	**MPa**		
Most adverse compressive limit state stress	F_a	=	91.85	MPa		
Most adverse tensile limit state stress	F_a	=	122.27	MPa		
Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.01		PASS	
BENDING - IN-PLANE						
***3.4.13** Compression in beams, extreme fibre, gross section round or oval tubes*						
Unbraced length for bending	L_b	=	400	mm		
Second moment of area (weak axis)	I_y	=	6.98E+04	mm^4		
Torsion modulus	J	=	1.40E+05	mm^3		
Elastic section modulus	Z	=	2908.7461	mm^3		
	R_b/t	=	12.83			
Limit 1	S_1	=	17.65			
Limit 2	S_2	=	79.80			

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Factored limit state stress	**ϕF_L**	=	**122.27**	**MPa**		3.4.13
3.4.18 *Compression in components of beams - curverd plates with both edges supported*						
	k_1	=	0.5			T3.3(D)
	k_2	=	2.04			T3.3(D)
mid-thickness radius of round tubular column or maximum mid-thickness radius	R_b	=	23.1	mm		
	t	=	1.8	mm		
Slenderness	R_b/t	=	12.833333			
Limit 1	S_1	=	10.67			
Limit 2	S_2	=	79.80			
Factored limit state stress	**ϕF_L**	=	**101.17**	**MPa**		
Most adverse in-plane bending limit state stress	F_{bx}	=	101.17	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.00		PASS	
BENDING - OUT-OF-PLANE						
NOTE: Limit state stresses, ϕF_L are the same for out-of-plane bending (doubly symmetric section)						
Factored limit state stress	**ϕF_L**	=	**101.17**	**MPa**		
Most adverse out-of-plane bending limit state stress	**F_{by}**	=	101.17	MPa		
Most adverse out-of-plane bending capacity factor	**f_{by}/F_{by}**	=	0.00		PASS	
COMBINED ACTIONS						
4.1.1 *Combined compression and bending*						4.1.1
	F_a	=	91.85	MPa		3.4.11
	F_{ao}	=	103.88	MPa		3.4.11
	F_{bx}	=	101.17	MPa		3.4.18
	F_{by}	=	101.17	MPa		3.4.18
	f_a/F_a	=	0.015			
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$					4.1.1
i.e.	0.01	≤	1.0		PASS	
SHEAR						
3.4.24 *Shear in webs (Major Axis)*						3.4.24

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	R	=	24	mm		
	t	=	1.8	mm		
Equivalent h/t	h/t	=	29.58			
Limit 1	S_1	=	33.38			
Limit 2	S_2	=	59.31			
Factored limit state stress	ϕF_L	=	**58.90**	**MPa**		
Stress From Shear force	f_{sx}	=	V/A_w			
			0.00	**MPa**		
***3.4.25** Shear in webs (Minor Axis)*						3.4.24
Clear web height	R	=	24	mm		
	t	=	1.8	mm		
Equivalent h/t	h/t	=	29.58			
Factored limit state stress	ϕF_L	=	**58.90**	**MPa**		
Stress From Shear force	f_{sy}	=	V/A_w			
			0.00	**MPa**		
Most adverseshear capacity factor (Major Axis)	f_{sx}/F_{sx}	=	0.00	**MPa**		
Most adverseshear capacity factor (Minor Axis)	f_{sy}/F_{sy}	=	0.00	**Mpa**	PASS	
COMBINED ACTIONS						
***4.4** Combined Shear, Compression and bending*						4.4

Check: $f_a/F_a + f_b/F_b + (f_s/F_s)^2 \leq 1.0$

i.e. 0.01 ≤ 1.0 PASS

11.1.7 Summary Forces

MEMBER(S)	Section	b	d	t	Vx	Vy	P	Mx	My
		mm	mm	mm	kN	kN	kN	kN.m	kN.m
Post	120x85x3	85	120	3	-0	0.046	-0.455	0.7973	-0.1688
Cantilever Beam	60x35x3.5	35	60	3.5	0.442	-0.167	-1.261	-0.4219	0.0738
Brace 1	60x35x3.5	35	60	3.5	0.008	-0.277	-0.104	-8.674E-19	0.1795
Brace 2	30x20x1.5	20	30	1.5	-0	0.018	-0.182	0	0.0103
Middle Beam	30x20x1.5	20	30	1.5	-0.07	-0.018	0.137	-0.0457	-0.0042

MEMBER(S)	Section	d	t	Vx	Vy	P	Mx	My
		mm	mm	kN	kN	kN	kN.m	kN.m
Centre Pole	48x1.8	48	1.8	0	0	-0.353	0	0

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12 Appendix 'C' – Anchorage Design

AFOS 2.0.3 (12012022) - Extended report

ALLFASTENERS

Company:	Prime Consulting Engineers Pty. Ltd.	E-mail:	info@primeengineers.com.au
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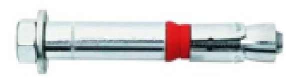
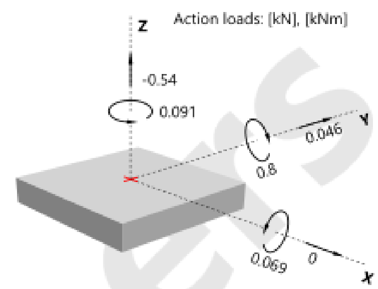
Address:	21/1-7 Jordan St, Gladesville	Fax:	
Project:	4m Round Cantilever Umbrella	Date:	1/21/2022
Comments:		Page:	1 / 7

1. Input Data

Selected anchors:

- HLA-Z1 M10
  Sleeve anchor
  Zinc plated
  Design based on AS 5216
- Assessment ETA-02/0030 (SZ)
  Issued by DIBt, on 9/13/2019
- Effective anchorage depth h_{ef} = 80 mm
- Drilled hole Φ x h_0 = 15.0 x 104 mm





Base material:

- Cracked concrete, Thickness of base material h=180mm
  Strength class 32MPa, f'_c=32.0N/mm²
- Wide concrete reinforcement
  Rebar spacing a≥150mm for all Ø or a≥100mm for Ø≤10mm
- No edge and stirrup reinforcement
- Hammer drilled hole

Action loads:

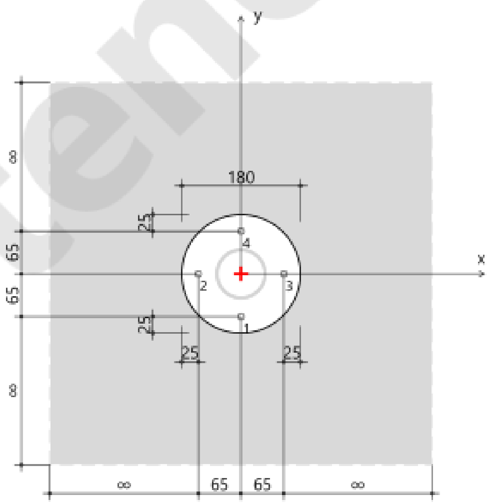
- Predominantly static and quasi-static design loads

Installation:

- Base plate lies on the concrete surface directly
- Without gap filling

Base plate:

- G250, E=200000N/mm²
  f_y=250N/mm², ϕ_s=0.741, f_{yd}= $\phi_s \cdot f_y$
- Assumed: elastic plate
- Current thickness: 12.0mm
  σ/f_{yd} =48.1/185.2=26.0%
- Circle
  Diameter: 180 mm

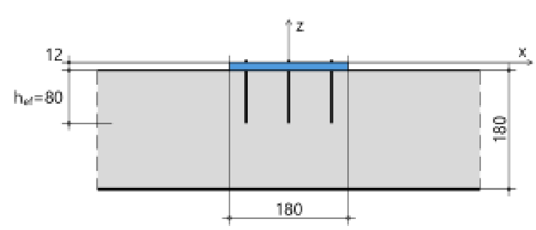


Profile:

- Circular Hollow Section: 76.1x3.2 CHS
  H x W x T x FT [mm]: 76 x 76 x 3.2 x 0.0
  Action point [mm]: [0, 0]
  Rotation counterclockwise: 0°
- No profile stiffness

Coordinates of anchors [mm]:

No.	x	y	Slotted hole L-x	Slotted hole L-y
1	0.0	-65.0		
2	-65.0	0.0		
3	65.0	0.0		
4	0.0	65.0		



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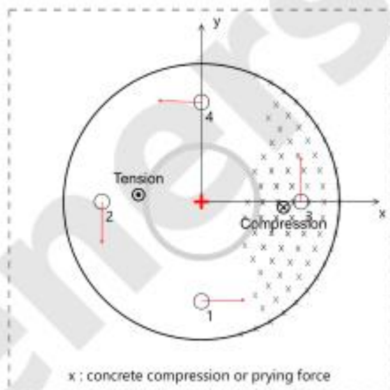
Load cases, design load: [kN], [kNm]

Active	No.	N_z	V_x	V_y	M_z	M_x	M_y	Utilization	Decisive
⦿	1	-0.54	0.0	0.046	0.091	0.069	0.8	38.3%	⊛
	2	0.136	0.0	0.011	0.022	0.016	0.482	23.8%	

2. Anchor internal forces [kN]

Tension load of anchors is calculated with elastic base plate.
Assumed: Anchor stiffness factor 0.50 ⟶ Anchor spring constant C_g = 70.8 kN/mm.
Assumed: coefficient for concrete bedding factor b = 15.0 ⟶ concrete bedding factor Cc = b · fc = 480.0 N/mm³

Anchor No.	Tension N_i	Shear V_i	Shear x	Shear y
1	1.205	0.350	0.350	0.012
2	5.141	0.339	0.000	-0.339
3	0.000	0.362	0.000	0.362
4	1.779	0.350	-0.350	0.012

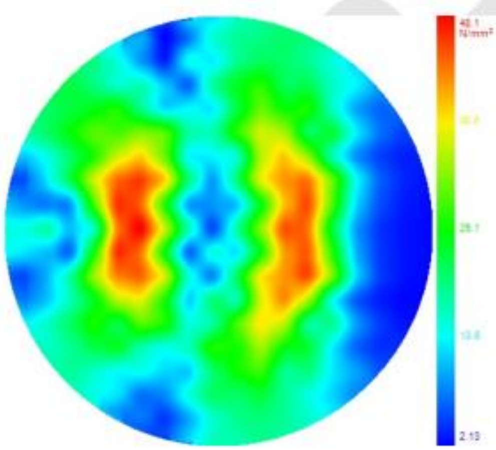


Maximum plate displacement into concrete (x/y=50.0/0.0): 0.007 [mm]
Maximum concrete compressive stress: 3.15 [N/mm²]
Mean concrete compressive stress: 1.14 [N/mm²]
Resultant tension force in (x/y=-41.1/4.6): 8.125 [kN]
Resultant compression force in (x/y=53.6/-3.7): 8.665 [kN]
Remark: The edge distance is not to scale.

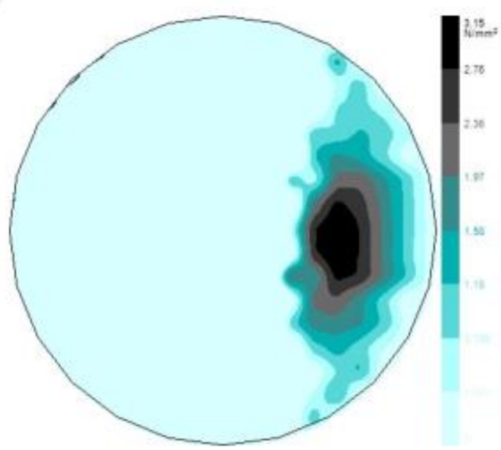
Displacement and rotation of profile on base plate *)
Displacement δ_z (+ve out of concrete): 0.030492 [mm]
Rotation θ_x: 0.000100 [rad]
Rotation θ_y: 0.001051 [rad]

*) Calculated using the best fit plane

Bending stresses in the base plate



Concrete compression stresses under the base plate



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3. Verification at ultimate limit state based on AS 5216

3.1 Tension load

	Related anchor	Action [kN]	Resistance [kN]	Utilization [%]	Status
Steel failure	2	5.141	30.667	16.8	√
Pull-out	2	5.141	13.440	**38.3**	√
Concrete cone failure	1,2,4	8.125	37.701	21.6	√
Concrete cone failure e *)	-	-	-	-	not applicable
Splitting failure	-	-	-	-	not applicable

*) additional proof for the fastening with elastic base plate

Steel failure

$N_{Rd,s} = N_{Rk,s} \cdot \phi_{s,N}$ $\beta_{N,s} = N^* / N_{Rd,s}$

$N_{Rk,s}$ [kN]	$\phi_{s,N}$	$N_{Rd,s}$ [kN]	N^* [kN]	$\beta_{N,s}$
46.0	0.667	30.667	5.141	0.168

Pull-out

$N_{Rd,p} = N^0_{Rk,p} \cdot \psi_c \cdot \phi_{p,N}$ $\beta_{N,p} = N^* / N_{Rd,p}$

$N^0_{Rk,p}$ [kN]	ψ_c	$\phi_{p,N}$	$N_{Rd,p}$ [kN]	N^* [kN]	$\beta_{N,p}$
16.0	1.26	0.667	13.440	5.141	0.383

Concrete cone failure

$N_{Rk,c}=N^0_{Rk,c} \cdot \psi_{A,N} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,N} \cdot \psi_{M,N}$ $N^0_{Rk,c} = k_1 \cdot (f'_c)^{0.5} \cdot h_{ef}^{1.5}$ [N] $\psi_{A,N} = A_{c,N}/A^0_{c,N}$ $N_{Rd,c} = N_{Rk,c} \cdot \phi_{c,N}$

$N^0_{Rk,c}$ [kN]	$A_{c,N}$ [mm²]	$A^0_{c,N}$ [mm²]	$\psi_{A,N}$	k_1	$\phi_{c,N}$	h_{ef} [mm]	$s_{cr,N}$ [mm]	$c_{cr,N}$ [mm]
31.167	104400	57600	1.813	7.7	0.667	80.0	240.0	120.0

$\psi_{s,N}$	$\psi_{re,N}$	$e_{N,x}$ [mm]	$e_{N,y}$ [mm]	$\psi_{ec,N,x}$	$\psi_{ec,N,y}$	$\psi_{ec,N}$	$\psi_{M,N}$	$N_{Rk,c}$ [kN]	$N_{Rd,c}$ [kN]	N^* [kN]	$\beta_{N,c}$
1.0	1.0	19.5	4.6	0.86	0.963	0.829	1.208	56.552	37.701	8.125	0.216

Concrete cone failure for single anchor (additional proof for the fastening with elastic base plate)
Verification is not required.

Splitting

Verification of splitting failure is not necessary, because:

- The smallest edge distance of anchor is $c \geq 1.2\ c_{cr,sp}$.

3.2 Shear

	Related anchor	Action [kN]	Resistance [kN]	Utilization [%]	Status
Steel failure (without l. arm)	3	0.362	38.400	0.9	√
Pry-out	3	0.362	21.509	**1.7**	√
Concrete edge failure	-	-	-	-	not applicable

Steel failure without lever arm

$V_{Rd,s} = V_{Rk,s} \cdot k_7 \cdot \phi_{s,V}$ $\beta_{V,s} = V^* / V_{Rd,s}$

$V_{Rk,s}$ [kN]	k_7	$\phi_{s,V}$	$V_{Rd,s}$ [kN]	V^* [kN]	$\beta_{V,s}$
48.0	1.0	0.8	38.400	0.362	0.009

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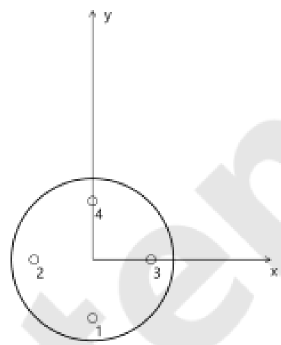
Pry-out failure

$N_{Rk,c}=N^0_{Rk,c} \cdot \psi_{A,N} \cdot \psi_{s,N} \cdot \psi_{re,N} \cdot \psi_{ec,V,cp}$ $N^0_{Rk,c}=k_1 \cdot (f'_c)^{0.5} \cdot h_{ef}^{1.5}$ [N] $\psi_{A,N}=A_{c,N}/A^0_{c,N}$ $V_{Rk,cp}=k_8 \cdot N_{Rk,c}$ $V_{Rd,cp}=V_{Rk,cp} \cdot \phi_{cp,V}$

$N^0_{Rk,c}$ [kN]	$A_{c,N}$ [mm^2]	$A^0_{c,N}$ [mm^2]	$\psi_{A,N}$	$\psi_{s,N}$	$\psi_{re,N}$	h_{ef} [mm]	$s_{cr,N}$ [mm]	$c_{cr,N}$ [mm]	k_1	k_8	$\phi_{cp,V}$
31.167	29813	57600	0.518	1.0	1.0	80.0	240.0	120.0	7.7	2.0	0.667

$e_{V,cp,x}$ [mm]	$e_{V,cp,y}$ [mm]	$\psi_{ec,V,cp,x}$	$\psi_{ec,V,cp,y}$	$\psi_{ec,V,cp}$	$N_{Rk,c}$ [kN]	$V_{Rk,cp}$ [kN]	$V_{Rd,cp}$ [kN]	V* [kN]	$\beta_{V,cp}$
0.0	0.0	1.0	1.0	1.0	16.132	32.264	21.509	0.362	0.017

Related area for calculation of pry-out failure $A_{c,N}$:



Concrete edge failure

Verification for concrete edge failure is not necessary, because there is no concrete edge.

3.3 Combined tension and shear

	Anchor	Tension(β_N)	Shear(β_V)	Condition	Utilization [%]	Status
Steel	2	0.168	0.009	$\beta^2_N + \beta^2_V \le 1.0$	2.8	√
Concrete	2	0.383	0.016	$\beta^{1.5}_N + \beta^{1.5}_V \le 1.0$	**23.9**	√

Anchor-related utilization

A-No.	$\beta_{N,s}$	$\beta_{N,p}$	$\beta_{N,c}$	$\beta_{N,ec}$	$\beta_{N,sp}$	$\beta_{V,s}$	$\beta_{V,cp}$	$\beta_{V,c}$	$\beta_{N,c,max,E}$	$\beta_{V,c,max,E}$	$\boldsymbol{\beta_{combi,c,E}}$	$\boldsymbol{\beta_{combi,s,E}}$
1	0.039	0.090	0.216	0.000	0.000	0.009	0.016	0.000	0.216	0.016	0.102	0.002
2	0.168	0.383	0.216	0.000	0.000	0.009	0.016	0.000	0.383	0.016	0.239	0.028
3	0.000	0.000	0.000	0.000	0.000	0.009	0.017	0.000	0.000	0.017	0.002	0.000
4	0.058	0.132	0.216	0.000	0.000	0.009	0.016	0.000	0.216	0.016	0.102	0.003

$\beta_{N,c,max,E}$: Highest utilization of individual anchors under tension loading except steel failure
$\beta_{V,c,max,E}$: Highest utilization of individual anchors under shear loading except steel failure
$\beta_{combi,c,E}$: Utilization of individual anchors under combined tension and shear loading except steel failure
$\beta_{combi,s,E}$: Utilization of individual anchors under combined tension and shear loading at steel failure

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4. Displacement

Tension loading: $N_k^h = N^{*h} / 1.4$

Short-term displacement: $\delta_N^0 = (N_k^h / N_0) \cdot \delta_{N0}$

Long-term displacement: $\delta_N^\infty = (N_k^h / N_0) \cdot \delta_{N\infty}$

Shear loading: $V_k^h = V^{*h} / 1.4$

Short-term displacement: $\delta_V^0 = (V_k^h / V_0) \cdot \delta_{V0}$

Long-term displacement: $\delta_V^\infty = (V_k^h / V_0) \cdot \delta_{V\infty}$

N^{*h} [kN]	N_0 [kN]	δ_{N0} [mm]	$\delta_{N\infty}$ [mm]	δ_N^0 [mm]	δ_N^∞ [mm]
5.141	7.6	0.5	1.3	**0.242**	**0.628**

V^{*h} [kN]	V_0 [kN]	δ_{V0} [mm]	$\delta_{V\infty}$ [mm]	δ_V^0 [mm]	δ_V^∞ [mm]
0.362	27.5	3.6	5.4	**0.034**	**0.051**

5. Remarks

- Capacity verifications of Section 3 are in accordance with AS 5216. For more complex cases which are outside of AS 5216, the same principles of AS 5216 are still used.
- For connections with a flexurally rigid base plate, it is assumed that the base plate is sufficiently rigid. However, the current anchor design methods (ETAG, Eurocode, AS 5216, ACI 318, CSA A23.3) do not provide any usable guidance to check for rigidity. In the realistically elastic (flexible) base plate, the tension load distribution between anchors may be different to that in the assumed rigid base plate. The plate prying effects could further increase anchor tension loading. To verify the sufficient base plate bending rigidity, the stiffness condition according to the publication "Required Thickness of Flexurally Rigid Base plate for Anchor Fastenings" (fib Symposium 2017 Maastricht) is used in this software.
- For connections with an elastic base plate, the anchor tension forces are calculated with the finite element method with consideration of deformations of base plate, anchors and concrete. Background for design with elastic base plates is described in the paper "Design of Anchor Fastenings with Elastic Base Plates Subjected to Tension and Bending". This paper was published in "Stahlbau 88 (2019), Heft 8" and "5. Jahrestagung des Deutschen Ausschusses für Stahlbeton - DAfStb 2017".
  Anchor shear forces are calculated with the assumption of a rigid base plate. Attention should be paid to a narrow base plate with a width to length ratio of less than 1/3.
- Verification for the ultimate limit state and the calculated displacement under service working load are valid only if the anchors are installed properly according to ETA.
- For design in cracked concrete, anchor design standards/codes assume that the crack width is limited to ≤ 0.3mm by reinforcement. Splitting failure in cracked concrete is prevented by this reinforcing. The user needs to verify that this reinforcing is present in cracked concrete. Generally, concrete structures design standards/codes (e.g. AS 3600) meet this crack width requirement for most structures. Particular caution must be taken at close edge distances where the location of reinforcing is not clearly known.
- Verification of strength of concrete elements to loads applied by fasteners is to be done in accordance with AS 5216.
- All information in this report is for use of Allfasteners products only. It is the responsibility of the user to ensure that the latest version of the software is used, and in accordance with AFOS licensing agreement. This software serves only as an aid to interpret the standards and approvals without any guarantee to the absence of errors. The results of the software should be checked by a suitably qualified person for correctness and relevance of the results for the application.

The load-bearing capacity of the anchorage is: **verified !**

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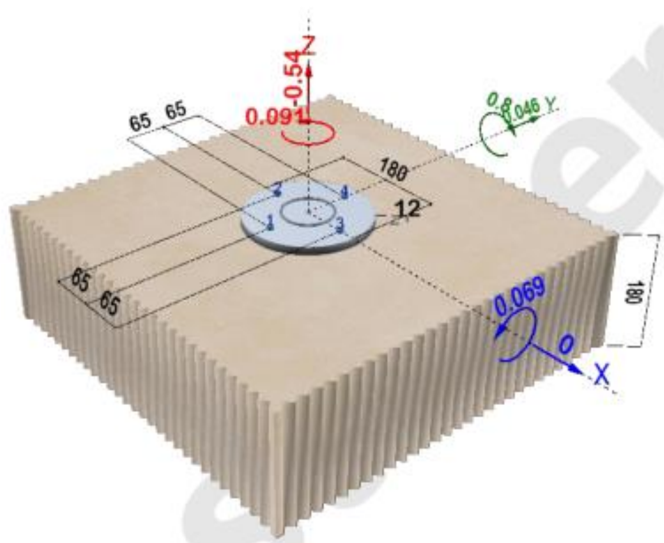
Anchorage figure in 3D:



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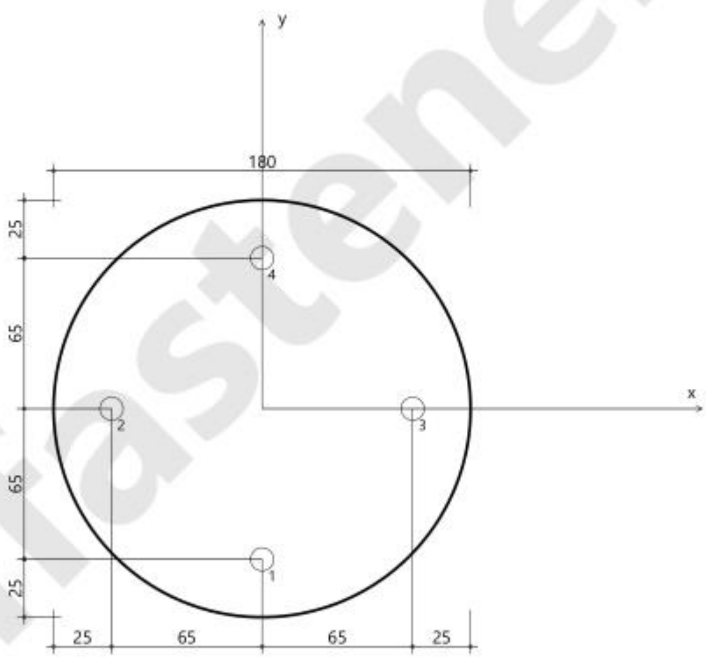
Anchor: **HLA-Z1 M10**

Drilled hole:	$d_0 \times h_0$ = 15 x 104 mm
Embedment depth:	h_{nom} = -
Effective anchorage depth:	h_{ef} = 80 mm
Installation torque:	T_{inst} = 50 Nm

Base plate: **G250**

Thickness:	t = 12 mm
Clearance hole:	d_f = 17 mm



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