Civil & Structural Engineering Design Services Pty. Ltd.

Client: **Ultrashade**
Project: Design check – 6m Octagon Umbrella Structures for 80 km/hr Wind Speed
Reference: Ultrashade Technical Data.

Report by: KZ
Checked by: EAB
Date: 26/06/2019
Amendment: 23/04/2020

JOB NO: U-11-267166-2B

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1 Introduction

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The following structural drawings and calculations are for the applicable transportable umbrella structures supplied by Ultrashade .

The report examines the effect of 3s gust wind of 80 km/hr on 6m Octagon Umbrella structure as the worst-case scenario. 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 AS/NZS 1664.1:1997 Aluminum Structures Limit State Design.

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2 Design Restrictions and Limitations

2.1 The erected structure is for temporary use only.

2.2 It should be noted that if high gust wind speeds are anticipated or forecast in the locality of the umbrella, the temporary erected structure should be folded.

2.3 For forecast winds in excess of **(refer to summary)** the structure should be completely folded.

(Please note that the locality squall or gust wind speed is affected by factors such as terrain exposure and site elevations.)

2.4 The structure may only be erected in regions with wind classifications no greater than the limits specified on the attached wind analysis.

2.5 The wind classifications are based upon category 2 in AS. Considerations have also been made to the regional wind terrain category, topographical location and site shielding from adjacent structures. Please note that in many instances topographical factors such as a location on the crest of a hill or on top of an escarpment may yield a higher wind speed classification than that derived for a higher wind terrain category in a level topographical region. For this reason, particular regard shall be paid to the topographical location of the structure. For localities which do not conform to the standard prescribed descriptions for wind classes as defined above, a qualified Structural Engineer may be employed to determine an appropriate wind class for that the particular site.

2.6 The structures in no circumstances shall ever be erected in tropical or severe tropical cyclonic condition.

2.7 The structure has not been designed to withstand snow and ice loadings such as when erected in alpine regions.

2.8 For the projects, where the site conditions approach the design limits, extra consideration should be given to pullout tests of the stakes and professional assessment of the appropriate wind classification for the site.

2.9 Design of fabric by others.

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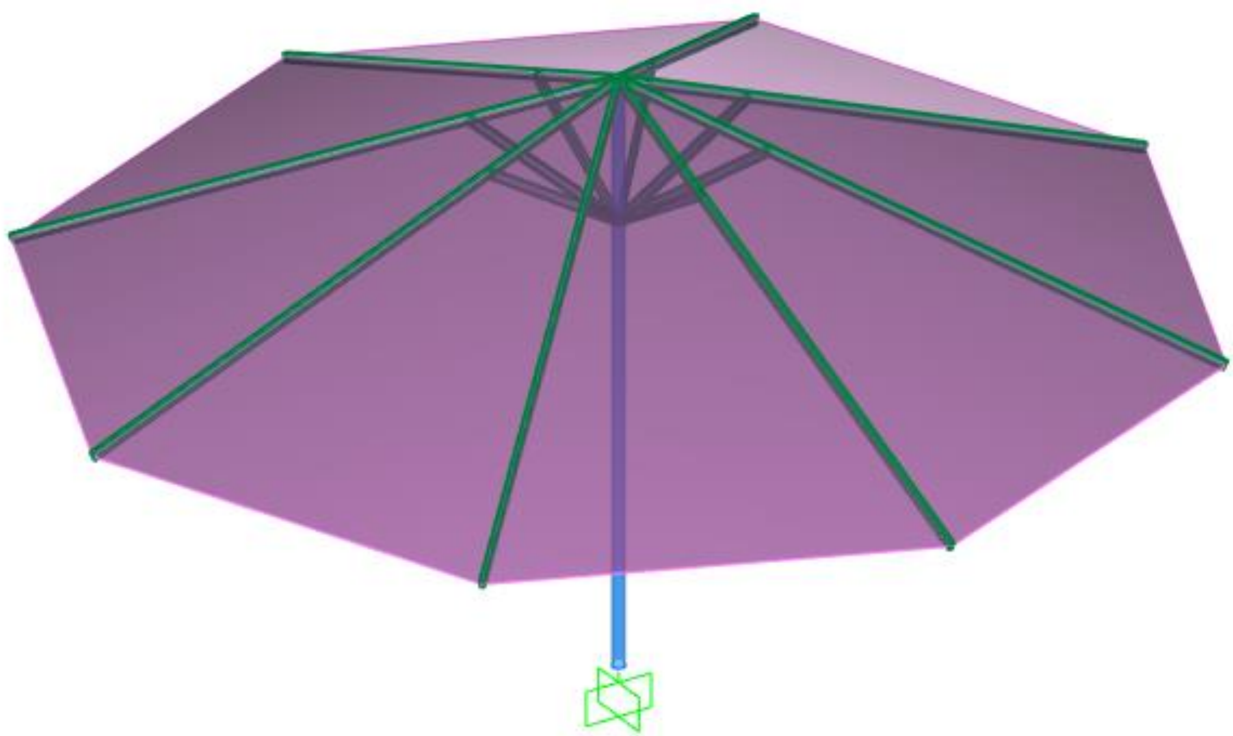
3 Specifications

3.1 General

Tent category	
Material	Aluminum 6061T6

Size	Model
6m	Octagonal Umbrella



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3.2 Section Properties

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	mm^2	mm^3	mm^3	mm^3	mm^3	mm^4	mm^4	mm^4	mm	mm
Arms	50x25x3	25	50	3	20.0	246.0	5021.7	3196.4	6429.0	3841.5	125542.0	39954.5	92970.1	22.6	12.7
Braces	50x25x3	25	50	3	20.0	246.0	5021.7	3196.4	6429.0	3841.5	125542.0	39954.5	92970.1	22.6	12.7

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	mm^2	mm^3	mm^3	mm^3	mm^3	mm^4	mm^4	mm^4	mm	mm
Post	82.5x5	82.5	5	41.3	1217.4	22249.2	22249.2	30072.9	30072.9	917780.7	917780.7	1835561.4	27.5	27.5

4 Design Loads

4.1 Ultimate

		Distributed load (kPa)	Design load factor (-)	Factored imposed load (kPa)
Live	Q	-	1.5	-
Self weight	G	self weight	1.35, 1.2, 0.9	1.2 self weight, 0.9 self weight
3s 80km/hr gust	W	0.245 C_{fig}	1.0	0.245 C_{fig}

4.2 Load Combinations

4.2.1 Serviceability

Gravity = $1.0 \times G$

Wind = $1.0 \times G + 1.0 \times W$

4.2.2 Ultimate

Downward = $1.35 \times G$

= $1.2 \times G + W_u$

Upward = $0.9 \times G + W_u$

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5 Wind Analysis

Wind towards surface (+ve), away from surface (-ve)

5.1 Parameters

Terrain category = 2

Site wind speed ($V_{sit,\beta}$) = $V_R M_d (M_{z,cat} M_s M_t)$
V_R = 22.22m/s (80 km/hr) *(regional 3 s gust wind speed)*
M_d = 1
M_s = 1
M_t = 1
$M_{z,cat}$ = 0.91 *(Table 4.1(B) AS1170.2)*

$V_{sit,\beta}$ = 20.22 m/s

Height of structure (h) = 2.65 m *(mid of peak and eave)*
Width of structure (w) = 6 m
Length of structure (l) = 6 m
Pressure (P) = $0.5\rho_{air} (V_{sit,\beta})^2 C_{fig} C_{dyn}$
= $0.245C_{fig}$ kPa

5.2 Pressure Coefficients (C_{fig})

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		**80**	Km/hr		*Table 3.1 (AS1170.2)*
Regional gust wind speed	V_R	**22.22**	m/s		
Wind Direction Multipliers	M_d	1			*Table 3.2 (AS1170.2)*
Terrain Category Multiplier	$M_{Z,Cat}$	0.91			*Table 4.1 (AS1170.2)*
Shield Multiplier	M_S	1			*4.3 (AS1170.2)*
Topographic Multiplier	M_t	1			*4.4 (AS1170.2)*
Site Wind Speed	$V_{Site,\beta}$	**20.22**	m/s	$V_{Site,\beta}=V_R*M_d*M_{z,cat}*M_S,M_t$	
Pitch	α	22.5	Deg		
Pitch	α	0.39	rad		
Width	B	4.8	m		
Length	D	4.8	m		

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Height	Z	2.65	m		
Wind Pressure					
ρair	ρ	1.2	Kg/m^3		
dynamic response factor	C_{dyn}	1			
Wind Pressure	ρ*C_{fig}	**0.245**	Kg/m^2	*$\rho=0.5\rho_{air}*(V_{des,\beta})^2*C_{fig}*C_{dyn}$*	*2.4 (AS1170.2)*
WIND DIRECTION 1 (θ=0) ***External Pressure***					
4. Free Roof				*$\alpha=0^o$*	
Area Reduction Factor	K_a	1			*D7*
local pressure factor	K_l	1			
porous cladding reduction factor	K_p	1			
External Pressure Coefficient **MIN**	$C_{P,w}$	-0.3			
External Pressure Coefficient **MAX**	$C_{P,w}$	0.6			
External Pressure Coefficient **MIN**	$C_{P,l}$	-0.6			
External Pressure Coefficient **MAX**	$C_{P,l}$	0			
aerodynamic shape factor **MIN**	$C_{fig,w}$	-0.30			
aerodynamic shape factor **MAX**	$C_{fig,w}$	0.60			
aerodynamic shape factor **MIN**	$C_{fig,l}$	-0.60			
aerodynamic shape factor **MAX**	$C_{fig,l}$	0.00			
Pressure Windward **MIN**	P	**-0.07**	**kPa**		
Pressure Windward **MAX**	P	**0.15**	**kPa**		
Pressure Leeward **MIN**	P	**-0.15**	**kPa**		
Pressure Leeward **MAX**	P	**0.00**	**kPa**		
WIND DIRECTION 2 (θ=90) ***External Pressure***					
4. Free Roof				*$\alpha=180^o$*	*D7*
Area Reduction Factor	K_a	1			
local pressure factor	K_l	1			

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porous cladding reduction factor	K_p	1	
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	**-0.07**	**kPa**
Pressure **MAX (Windward Side)**	P	**0.10**	**kPa**
Pressure **MIN (Leeward Side)**	P	**-0.10**	**kPa**
Pressure **MAX (Leeward Side)**	P	**0.00**	**kPa**

5.2.1 Pressure summary

WIND EXTERNAL PRESSURE	Direction1		Direction2		
	Min (Kpa)	Max (Kpa)		Min (Kpa)	Max (Kpa)
W	-0.074	0.147	W	-0.0736	0.0981
L	-0.147	0.000	L	-0.0981	0.0000

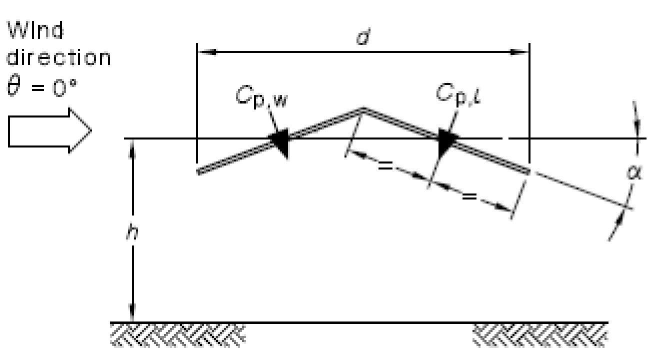

FIGURE D3 PITCHED FREE ROOFS

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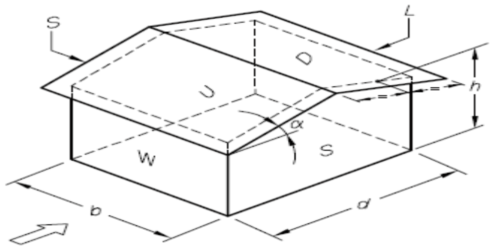
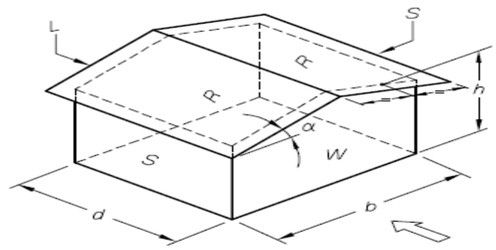


Direction 1

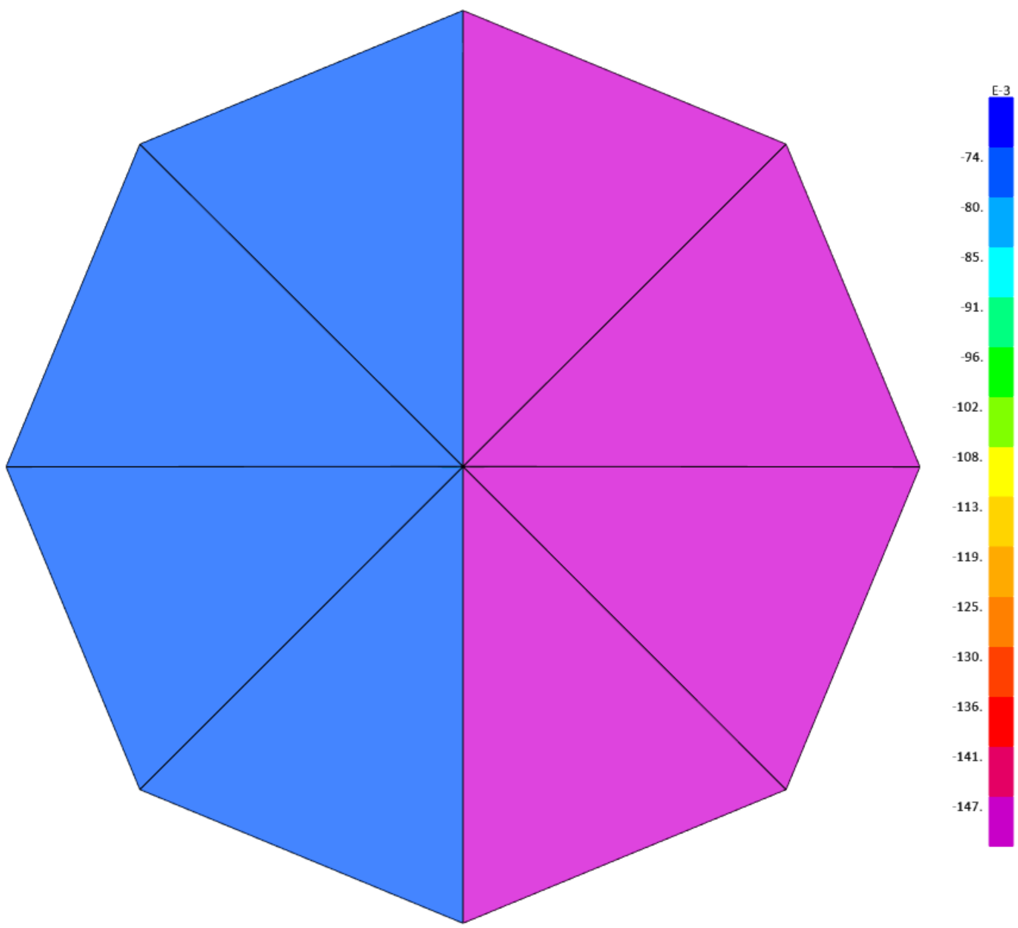


AS1170.2

Direction 2

5.3 Wind Load Diagrams

5.3.1 Wind 1(case 1)



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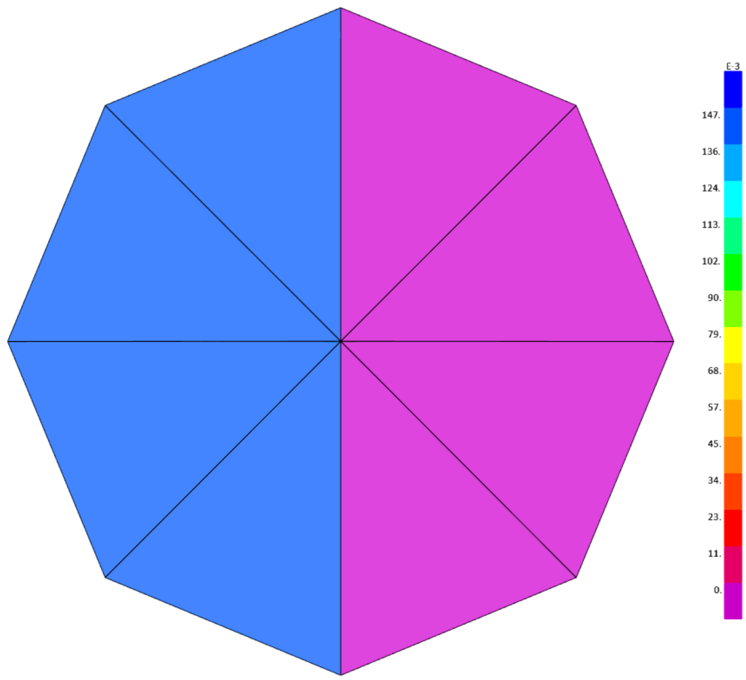
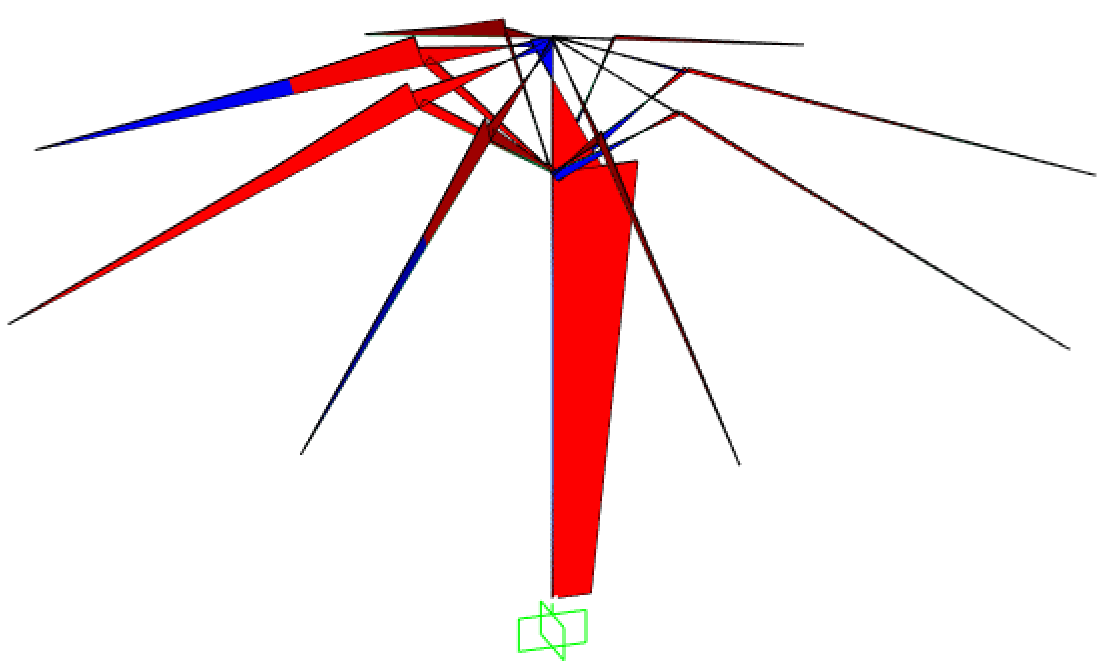
5.3.2 Wind 1(case 2)



After 3D model analysis, each member is checked based on adverse load combination.
In this regard the maximum bending moment, shear and axial force due to adverse load combinations for each member are presented as below:

5.3.3 Max Bending Moment due to critical load combination in major axis



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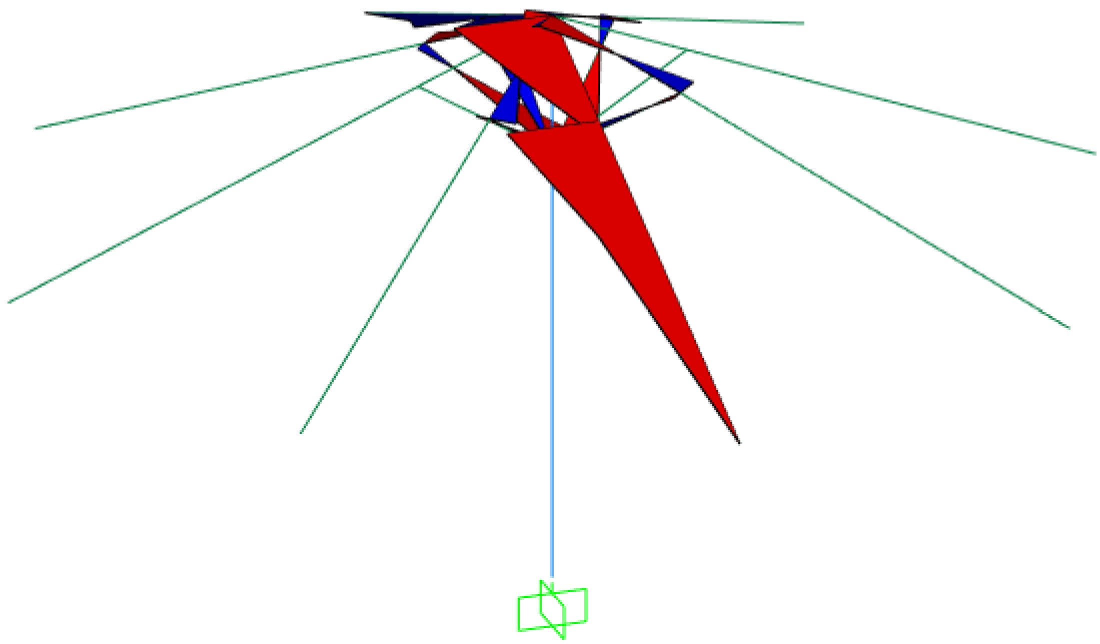
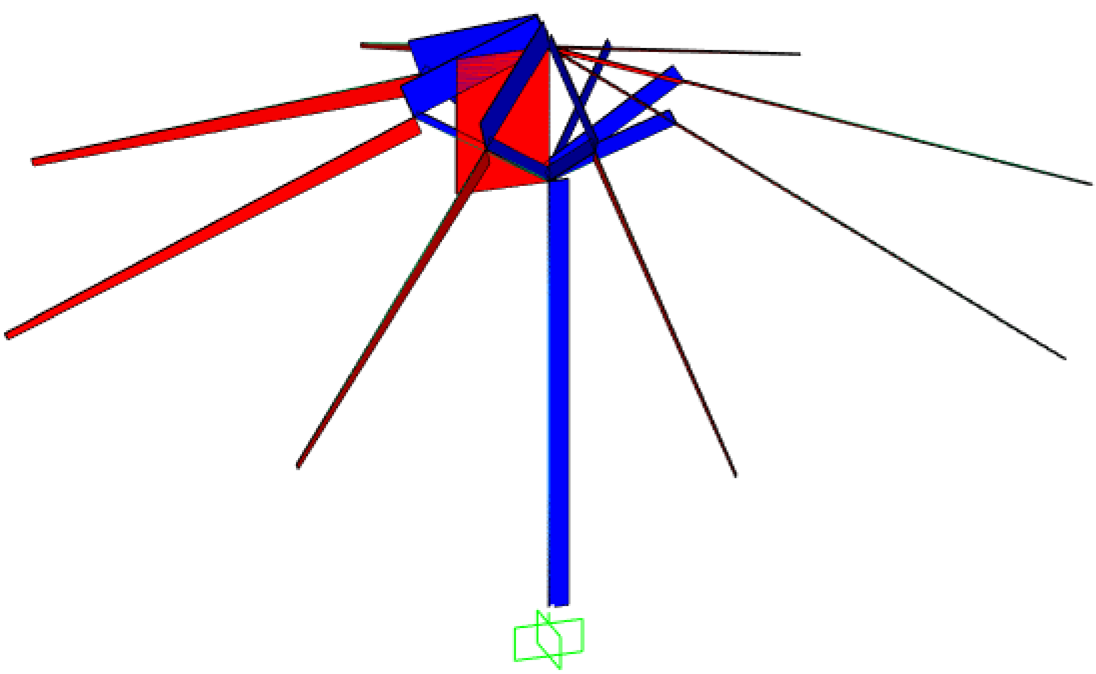
5.3.4 Max Bending Moment in minor axis due to critical load combination



5.3.5 Max Shear in due to critical load combination



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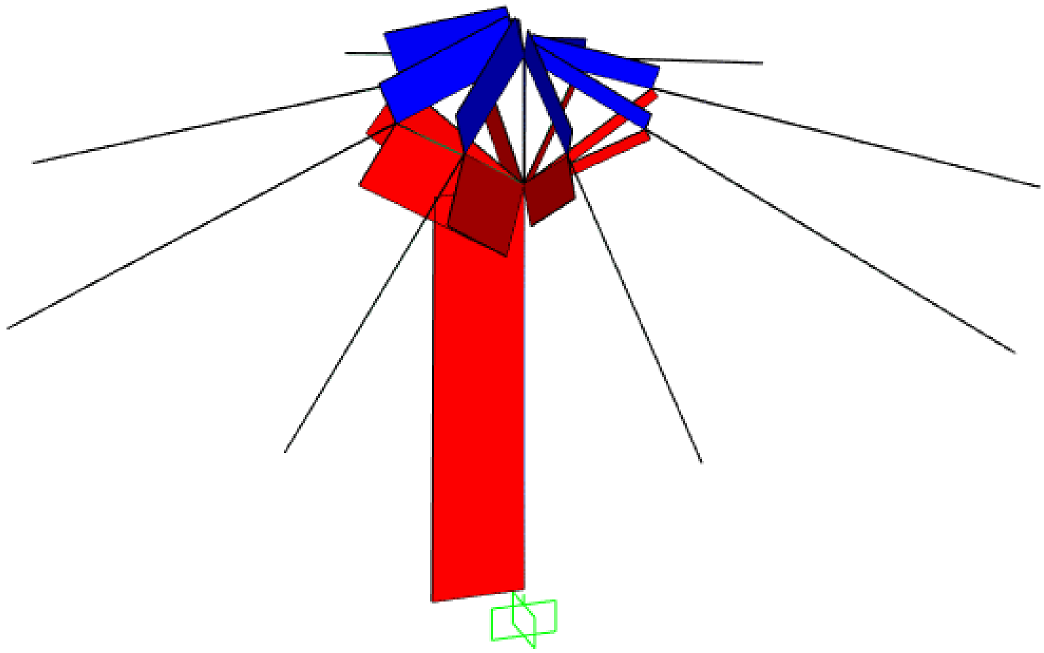
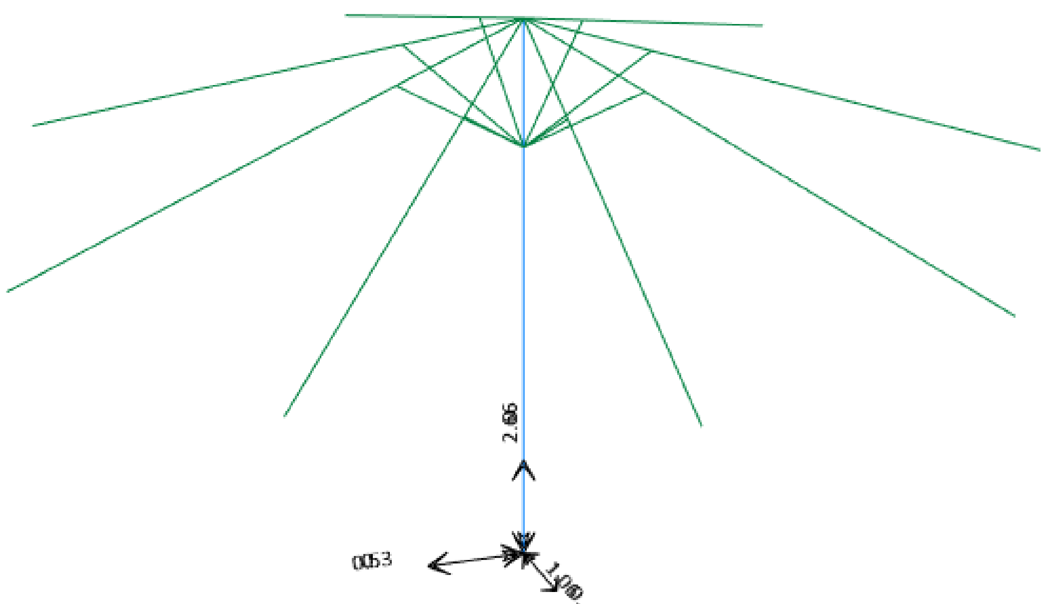
5.3.6 Max Axial force in upright support and roof beam due to critical load combination



5.3.7 Max reactions



Max F_x = 0.54 kN
Max F_y = 0.54 kN
Max F_z = 2.66 kN
Max M_x = 1.06 kN.m
Max M_y = 1.06 kN.m

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6 Checking Members Based on AS1664.1 ALUMINUM LIMIT STATE DESIGN

6.1 Arms

NAME	SYMBOL		VALUE	UNIT	NOTES	REF
50x25x3	**Arms**					
Alloy and temper	6061-T6					AS1664.1
Tension	F_{tu}	=	262	MPa	*Ultimate*	T3.3(A)
	F_{ty}	=	241	MPa	*Yield*	
Compression	F_{cy}	=	241	MPa		
Shear	F_{su}	=	165	MPa	*Ultimate*	
	F_{sy}	=	138	MPa	*Yield*	
Bearing	F_{bu}	=	551	MPa	*Ultimate*	
	F_{by}	=	386	MPa	*Yield*	
Modulus of elasticity	E	=	70000	MPa	*Compressive*	
	k_t	=	1.0			T3.4(B)
	k_c	=	1.0			
FEM ANALYSIS RESULTS						
Axial force	P	=	0	kN	*compression*	
	P	=	0.021	kN	*Tension*	
In plane moment	M_x	=	0.8122	kNm		
Out of plane moment	M_y	=	1.095E-07	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	**=**	246	mm^2		
In-plane elastic section modulus	Z_x	**=**	5021.68	mm^3		
Out-of-plane elastic section mod.	Z_y	**=**	3196.36	mm^3		
Stress from axial force	$\mathbf{f_a}$	**=**	P/A_g			
		=	**0.00**	**MPa**	*compression*	
		=	**0.09**	**MPa**	*Tension*	
Stress from in-plane bending	$\mathbf{f_{bx}}$	**=**	M_x/Z_x			
		=	**161.74**	**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*						

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	ϕF_L	**=**	**228.95**	**MPa**	
		OR			
	ϕF_L	**=**	**222.70**	**MPa**	
COMPRESSION					
***3.4.8** Compression in columns, axial, gross section*					
1. General					… 3.4.8.1
Unsupported length of member	L	=	3240	mm	
Effective length factor	k	=	1		
Radius of gyration about buckling axis (Y)	r_y	=	12.74	mm	
Radius of gyration about buckling axis (X)	r_x	=	22.59	mm	
Slenderness ratio	kLb/ry	=	191.46		
Slenderness ratio	kL/rx	=	143.42		
Slenderness parameter	λ	=	3.576		
	D_c*	=	90.3		
	S_1*	=	0.33		
	S_2*	=	1.23		
	ϕ_{cc}	=	0.950		
Factored limit state stress	**ϕF_L**	**=**	**17.90**	**MPa**	
2. Sections not subject to torsional or torsional-flexural buckling					… 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	**=**	191.46		
***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'	**=**	19		
	t	**=**	3	mm	
Slenderness	b/t	**=**	6.333333 3		
Limit 1	S_1	**=**	12.34		
Limit 2	S_2	**=**	32.87		
Factored limit state stress	**ϕF_L**	**=**	**228.95**	**MPa**	

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Most adverse compressive limit state stress	F_a	=	17.90	MPa		
Most adverse tensile limit state stress	F_a	=	222.70	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	=	2440	mm		
Second moment of area (weak axis)	I_y	=	4.00E+04	mm^4		
Torsion modulus	J	=	9.30E+04	mm^3		
Elastic section modulus	Z	=	5021.68	mm^3		
Slenderness	S	=	402.08			
Limit 1	S_1	=	0.39			
Limit 2	S_2	=	1695.86			
Factored limit state stress	**ϕF_L**	=	**184.39**	**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'	=	19	mm		
	t	=	3	mm		
Slenderness	b/t	=	6.333333 3			
Limit 1	S_1	=	12.34			
Limit 2	S_2	=	46.95			
Factored limit state stress	**ϕF_L**	=	**228.95**	**MPa**		
Most adverse in-plane bending limit state stress	F_{bx}	=	184.39	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.88		PASS	
BENDING - OUT-OF-PLANE						
NOTE: Limit state stresses, ϕF_L are the same for out-of-plane bending (doubly symmetric section)						

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Factored limit state stress	**ϕF_L**	=	**184.39**	**MPa**		
Most adverse out-of-plane bending limit state stress	**F_{by}**	=	184.39	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(2)
	F_a	=	17.90	MPa		… 3.4.8
	F_{ao}	=	228.95	MPa		… 3.4.10
	F_{bx}	=	184.39	MPa		… 3.4.17
	F_{by}	=	184.39	MPa		… 3.4.17
	f_a/F_a	=	0.000			
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$					… 4.1.1 (3)
i.e.	0.88	≤	1.0		PASS	
SHEAR						
***3.4.24** Shear in webs (Major Axis)*						… 4.1.1(2)
Clear web height	h	**=**	44	mm		
	t	**=**	3	mm		
Slenderness	h/t	**=**	14.666667			
Limit 1	S_1	**=**	29.01			
Limit 2	S_2	**=**	59.31			
Factored limit state stress	**ϕF_L**	**=**	**131.10**	**MPa**		
Stress From Shear force	**f_{sx}**	**=**	V/A_w			
			2.54	**MPa**		
***3.4.25** Shear in webs (Minor Axis)*						
Clear web height	b	**=**	19	mm		
	t	**=**	3	mm		
Slenderness	b/t	**=**	6.3333333			
Factored limit state stress	**ϕF_L**	**=**	**131.10**	**MPa**		
Stress From Shear force	**f_{sy}**	**=**	V/A_w			

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			0.00	**MPa**		

6.2 Brace

NAME	SYMBOL		VALUE	UNIT	NOTES	REF
50x25x3	**Braces**					
Alloy and temper	6061-T6					AS1664.1
Tension	F_{tu}	=	262	MPa	*Ultimate*	T3.3(A)
	F_{ty}	=	241	MPa	*Yield*	
Compression	F_{cy}	=	241	MPa		
Shear	F_{su}	=	165	MPa	*Ultimate*	
	F_{sy}	=	138	MPa	*Yield*	
Bearing	F_{bu}	=	551	MPa	*Ultimate*	
	F_{by}	=	386	MPa	*Yield*	
Modulus of elasticity	E	=	70000	MPa	*Compressive*	
	k_t	=	1.0			T3.4(B)
	k_c	=	1.0			
FEM ANALYSIS RESULTS						
Axial force	P	=	2.036	kN	*compression*	
	P	=	0	kN	*Tension*	
In plane moment	M_x	=	0.3201	kNm		
Out of plane moment	M_y	=	0.0089	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	**=**	246	mm^2		
In-plane elastic section modulus	Z_x	**=**	5021.68	mm^3		
Out-of-plane elastic section mod.	Z_y	**=**	3196.36	mm^3		
Stress from axial force	$\mathbf{f_a}$	**=**	P/A_g			
		=	**8.28**	**MPa**	*compression*	
		=	**0.00**	**MPa**	*Tension*	
Stress from in-plane bending	$\mathbf{f_{bx}}$	**=**	M_x/Z_x			
		=	**63.74**	**MPa**	*compression*	
Stress from out-of-plane bending	$\mathbf{f_{by}}$	**=**	M_y/Z_y			
		=	**2.78**	**MPa**	*compression*	
Tension						
***3.4.3** Tension in rectangular tubes*						

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	ϕF_L	**=**	**228.95**	**MPa**	
		OR			
	ϕF_L	**=**	**222.70**	**MPa**	
COMPRESSION					
3.4.8 *Compression in columns, axial, gross section*					
1. General					… 3.4.8.1
Unsupported length of member	L	=	860	mm	
Effective length factor	k	=	1		
Radius of gyration about buckling axis (Y)	r_y	=	12.74	mm	
Radius of gyration about buckling axis (X)	r_x	=	22.59	mm	
Slenderness ratio	kLb/ry	=	67.48		
Slenderness ratio	kL/rx	=	38.07		
Slenderness parameter	λ	=	1.26		
	D_c*	=	90.3		
	S_1*	=	0.33		
	S_2*	=	1.23		
	ϕ_{cc}	=	0.756		
Factored limit state stress	**ϕF_L**	**=**	**114.77**	**MPa**	
2. Sections not subject to torsional or torsional-flexural buckling					… 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	**=**	67.48		
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'	**=**	19		
	t	**=**	3	mm	
Slenderness	b/t	**=**	6.3333333		
Limit 1	S_1	**=**	12.34		
Limit 2	S_2	**=**	32.87		
Factored limit state stress	**ϕF_L**	**=**	**228.95**	**MPa**	

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Most adverse compressive limit state stress	F_a	=	114.77	MPa		
Most adverse tensile limit state stress	F_a	=	222.70	MPa		
Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.07		PASS	
BENDING - IN-PLANE						
3.4.15 *Compression in beams, extreme fibre, gross section rectangular tubes, box sections*						
Unbraced length for bending	L_b	=	860	mm		
Second moment of area (weak axis)	I_y	=	4.00E+04	mm^4		
Torsion modulus	J	=	9.30E+04	mm^3		
Elastic section modulus	Z	=	5021.68	mm^3		
Slenderness	S	=	141.72			
Limit 1	S_1	=	0.39			
Limit 2	S_2	=	1695.86			
Factored limit state stress	**ϕF_L**	=	**203.08**	**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'	=	19	mm		
	t	=	3	mm		
Slenderness	b/t	=	6.333333 3			
Limit 1	S_1	=	12.34			
Limit 2	S_2	=	46.95			
Factored limit state stress	**ϕF_L**	=	**228.95**	**MPa**		
Most adverse in-plane bending limit state stress	F_{bx}	=	203.08	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.31		PASS	
BENDING - OUT-OF-PLANE						
NOTE: Limit state stresses, ϕF_L are the same for out-of-plane bending (doubly symmetric section)						

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Factored limit state stress	**ϕF_L**	=	**203.08**	**MPa**		
Most adverse out-of-plane bending limit state stress	**F_{by}**	=	203.08	MPa		
Most adverse out-of-plane bending capacity factor	**f_{by}/F_{by}**	**=**	0.01		PASS	
COMBINED ACTIONS						
***4.1.1** Combined compression and bending*						… 4.1.1(2)
	F_a	=	114.77	MPa		… 3.4.8
	F_{ao}	=	228.95	MPa		… 3.4.10
	F_{bx}	=	203.08	MPa		… 3.4.17
	F_{by}	=	203.08	MPa		… 3.4.17
	f_a/F_a	=	0.072			
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$					… 4.1.1 (3)
i.e.	0.40	≤	1.0		PASS	
SHEAR						
***3.4.24** Shear in webs (Major Axis)*						… 4.1.1(2)
Clear web height	h	**=**	44	mm		
	t	**=**	3	mm		
Slenderness	h/t	**=**	14.66666 7			
Limit 1	S_1	**=**	29.01			
Limit 2	S_2	**=**	59.31			
Factored limit state stress	**ϕF_L**	**=**	**131.10**	**MPa**		
Stress From Shear force	**f_{sx}**	**=**	V/A_w			
			2.54	**MPa**		
***3.4.25** Shear in webs (Minor Axis)*						
Clear web height	b	**=**	19	mm		
	t	**=**	3	mm		
Slenderness	b/t	**=**	6.333333 3			
Factored limit state stress	**ϕF_L**	**=**	**131.10**	**MPa**		
Stress From Shear force	**f_{sy}**	**=**	V/A_w			

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			0.00	**MPa**		

6.3 Post

NAME	SYMBOL		VALUE	UNIT	NOTES	REF
82.5x5	**Post**					
Alloy and temper	6061-T6					AS1664.1
Tension	F_{tu}	=	262	MPa	*Ultimate*	T3.3(A)
	F_{ty}	=	241	MPa	*Yield*	
Compression	F_{cy}	=	241	MPa		
Shear	F_{su}	=	165	MPa	*Ultimate*	
	F_{sy}	=	138	MPa	*Yield*	
Bearing	F_{bu}	=	551	MPa	*Ultimate*	
	F_{by}	=	386	MPa	*Yield*	
Modulus of elasticity	E	=	70000	MPa	*Compressive*	
	k_t	=	1.0			T3.4(B)
	k_c	=	1.0			
FEM ANALYSIS RESULTS						
Axial force	P	=	2.603	kN	*compression*	
	P	=	0	kN	*Tension*	
In plane moment	M_x	=	2.3522	kNm		
Out of plane moment	M_y	=	7.786E-13	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	**=**	1217.3672	mm^2		
In-plane elastic section modulus	Z_x	**=**	22249.229	mm^3		
Out-of-plane elastic section mod.	Z_y	**=**	22249.229	mm^3		
Stress from axial force	$\mathbf{f_a}$	**=**	P/A_g			
		=	**2.14**	**MPa**	*compression*	
		=	**0.00**	**MPa**	*Tension*	
Stress from in-plane bending	$\mathbf{f_{bx}}$	**=**	M_x/Z_x			
		=	**105.72**	**MPa**	*compression*	
Stress from out-of-plane bending	$\mathbf{f_{by}}$	**=**	M_y/Z_y			
		=	**0.00**	**MPa**	*compression*	
Tension						

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***3.4.3** Tension in rectangular tubes*					3.4.3
	ϕF_L	**=**	**267.87**	**MPa**	
		OR			
	ϕF_L	**=**	**276.15**	**MPa**	
COMPRESSION					
***3.4.8** Compression in columns, axial, gross section*					
1. General					3.4.8.1
Unsupported length of member	L	=	3240	mm	
Effective length factor	k	=	1		
Radius of gyration about buckling axis (Y)	r_y	=	27.46	mm	
Radius of gyration about buckling axis (X)	r_x	=	27.46	mm	
Slenderness ratio	kLb/ry	=	89.96		
Slenderness ratio	kL/rx	=	118.00		
Slenderness parameter	λ	=	2.204		
	D_c*	=	90.3		
	S_1*	=	0.33		
	S_2*	=	1.23		
	ϕ_{cc}	=	0.889		
Factored limit state stress	**ϕF_L**	**=**	**44.09**	**MPa**	
2. Sections not subject to torsional or torsional-flexural buckling					3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	**=**	118.00		
***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	=	38.75		
	t	**=**	5	mm	
Slenderness	R_m/t	**=**	7.75		
Limit 1	S_1	**=**	0.24		
Limit 2	S_2	**=**	672.46		
Factored limit state stress	**ϕF_L**	**=**	**241.84**	**MPa**	

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Most adverse compressive limit state stress	F_a	=	44.09	MPa		
Most adverse tensile limit state stress	F_a	=	267.87	MPa		
Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.05		PASS	
BENDING - IN-PLANE						
***3.4.13** Compression in beams, extreme fibre, gross section round or oval tubes*						
Unbraced length for bending	L_b	=	2470	mm		
Second moment of area (weak axis)	I_y	=	9.18E+05	mm^4		
Torsion modulus	J	=	1.84E+06	mm^3		
Elastic section modulus	Z	=	22249.229	mm^3		
	R_b/t	=	7.75			
Limit 1	S_1	=	44.07			
Limit 2	S_2	=	78.23			
Factored limit state stress	**ϕF_L**	=	**267.87**	**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	=	38.75	mm		
	t	=	5	mm		
Slenderness	R_b/t	=	7.75			
Limit 1	S_1	=	2.75			
Limit 2	S_2	=	78.23			
Factored limit state stress	**ϕF_L**	=	**227.45**	**MPa**		
Most adverse in-plane bending limit state stress	F_{bx}	=	227.45	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.46		PASS	
BENDING - OUT-OF-PLANE						

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NOTE: Limit state stresses, ϕF_L are the same for out-of-plane bending (doubly symmetric section)

Factored limit state stress	ϕF_L	=	**227.45**	**MPa**		
Most adverse out-of-plane bending limit state stress	F_{by}	=	227.45	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	=	44.09	MPa		3.4.11
	F_{ao}	=	241.84	MPa		3.4.11
	F_{bx}	=	227.45	MPa		3.4.18
	F_{by}	=	227.45	MPa		3.4.18
	f_a/F_a	=	0.049			

Check: $f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$ — 4.1.1

i.e. $0.51 \leq 1.0$ — PASS

SHEAR

***3.4.24** Shear in webs (Major Axis)* — 3.4.24

	R	=	41.25	mm
	t	=	5	mm
Equivalent h/t	h/t	=	32.28	
Limit 1	S_1	=	29.01	
Limit 2	S_2	=	59.31	
Factored limit state stress	ϕF_L	=	**127.78**	**MPa**
Stress From Shear force	f_{sx}	=	V/A_w	
			0.88	**MPa**

***3.4.25** Shear in webs (Minor Axis)* — 3.4.24

Clear web height	R	=	41.25	mm
	t	=	5	mm
Equivalent h/t	h/t	=	32.28	
Factored limit state stress	ϕF_L	=	**127.78**	**MPa**
Stress From Shear force	f_{sy}	=	V/A_w	
			0.00	**MPa**

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6.4 Summary Loads

MEMBER(S)	Section	b	d	t	Vx	Vy	P (Axial)	Mx	My
		mm	mm	mm	kN	kN	kN	kN.m	kN.m
Arms	50x25x3	25	50	3	-0.52	4.4E-08	0.021	-0.8122	1.095E-07
Braces	50x25x3	25	50	3	0.327	-0.043	-2.036	-0.3201	0.0089

MEMBER(S)	Section	d	t	Vx	Vy	P (Axial)	Mx	My
		mm	mm	kN	kN	kN	kN.m	kN.m
Post	82.5x5	82.5	5	0.534	4.5E-12	-2.603	-2.3522	7.786E-13

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7 Summary

7.1 Conclusions

a. The 6m octagon umbrella structure as specified has been analyzed with a conclusion that it has the capacity to withstand wind speeds up to and including **80km/hr.**

b. For forecast winds in excess of **80km/hr** – the structure should be completely folded.

c. For uplift due to 80km/hr, **280kg** (2.8 kN) holding down weight or or 4/M12 HST3 M12 hef1, h_{nom} = 60mm Mechanical Anchor or alternatively HIT-HY 200-R + HIT-V-F (8.8) M12, h_{eff} = 70mm chemical anchors to concrete slab supplied by HILTI Australia is required.

d. The bearing pressure of soil should be clarified prior to any construction.

Yours faithfully,

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