



Civil & Structural Engineering Design Services Pty. Ltd.

Client: Flare Shade

Project: Design check – 4m, 5m & 6m Round (Dodecagon) Umbrella Structures for 60 km/hr Wind Speed

Reference: Flare Shade Technical Data.

Report by: KZ
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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 Flare Shade Pty. Ltd.

The report examines the effect of 3s gust wind of 60 km/hr on Aluminium components of the 6m Round (Dodecagon) 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.



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. The umbrella with temporary anchorage system must be stored in an enclosed building however the umbrella with permanent anchorage system can remain folded on site. (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 AS1170.2. 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 professional assessment of the appropriate wind classification for the site.
- 2.9 Design of fabric is by others.

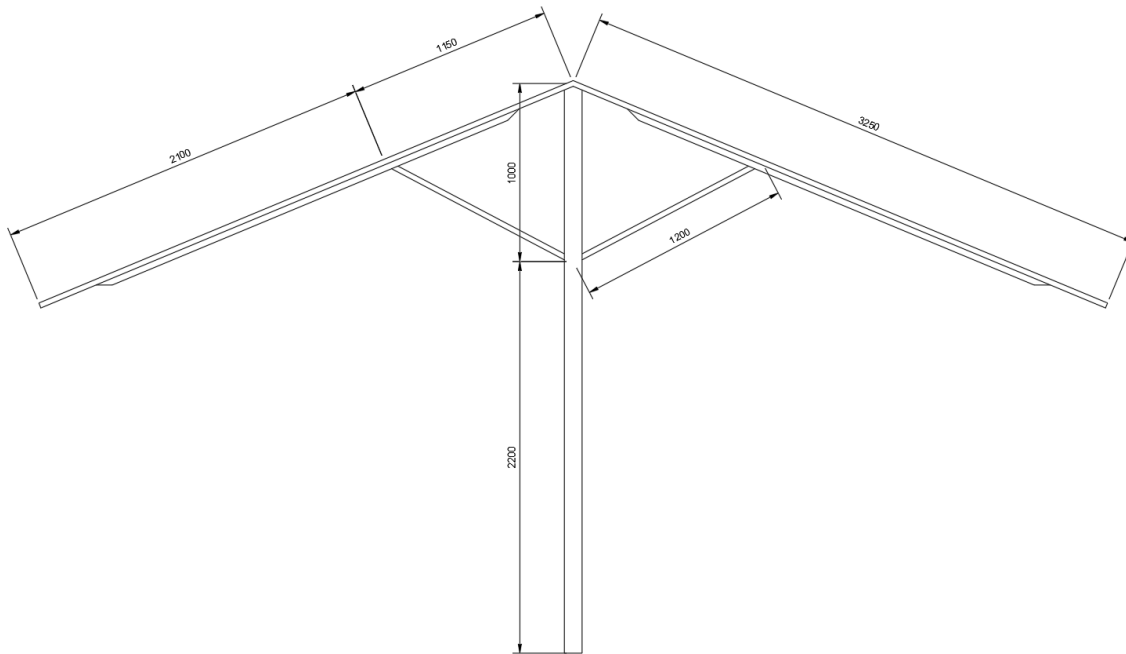


3 Specifications

3.1 General

Tent category	
Material	Aluminum 6061T6

Size	Model
6m	Round (Dodecagon)



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
Pole	105x105x3.9	105	105	3.9	52.5	1577.2	51252.3	51252.3	59823.7	59823.7	2690745.4	2690745.4	4030120.9	41.3	41.3
Long Rib	40x20x2+35x30x3	20	75	2	37.5	364.0	5035.0	3578.6	7191.7	4786.3	180869.7	62626.1	38065.7	20.4	12.0
Short Rib	40x20x2+35x30x3	20	75	2	37.5	364.0	5035.0	3578.6	7191.7	4786.3	180869.7	62626.1	38065.7	20.4	12.0



3.3 Buckling Constant

TABLE 3.3(D) BUCKLING CONSTANTS FOR ALLOY 6061-T6			
Type of member and stress	Intercept, MPa		Slope, MPa
Compression in columns and beam flanges	B_c	271.04	D_c 1.69
Compression in flat plates	B_p	310.11	D_p 2.06
Compression in round tubes under axial end load	B_t	297.39	D_t 10.70
Compressive bending stress in rectangular bars	B_{br}	459.89	D_{br} 4.57
Compressive bending stress in round tubes	B_{tb}	653.34	D_{tb} 50.95
Shear stress in flat plates	B_s	178.29	D_s 0.90
Ultimate strength of flat plates in compression	k₁	0.35	k₂ 2.27
Ultimate strength of flat plates in bending	k₁	0.5	k₂ 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

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 60km/hr gust	W	0.138 C_{fig}	1.0	0.138 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 = $1.35 \times G$



$$= 1.2 \times G + W_u$$

$$\text{Upward} = 0.9 \times G + W_u$$

5 Wind Analysis

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

5.1 Parameters

Terrain category = 2

$$\text{Site wind speed } (V_{\text{sit},\beta}) = V_R M_d (M_{z,\text{cat}} M_s M_t)$$

$$V_R = 16.67 \text{ m/s (60 km/hr)}$$

(regional 3 s gust wind speed)

$$M_d = 1$$

$$M_s = 1$$

$$M_t = 1$$

$$M_{z,\text{cat}} = 0.91$$

(Table 4.1(B) AS1170.2)

$$V_{\text{sit},\beta} = 15.17 \text{ m/s}$$

$$\text{Height of structure (h)} = 2.7 \text{ m}$$

(mid of peak and eave)

$$\text{Width of structure (w)} = 5 \text{ m}$$

$$\text{Length of structure (l)} = 5 \text{ m}$$

$$\text{Pressure (P)} = 0.5 \rho_{\text{air}} (V_{\text{sit},\beta})^2 C_{\text{fig}} C_{\text{dyn}}$$

$$= 0.138 C_{\text{fig}} \text{ kPa}$$

5.2 Pressure Coefficients (C_{fig}) – Open Condition

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		60	Km/hr		Table 3.1 (AS1170.2)
Regional gust wind speed	V_R	16.67	m/s		
Wind Direction Multipliers	M_d	1			Table 3.2 (AS1170.2)
Terrain Category Multiplier	$M_{z,\text{cat}}$	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	$V_{\text{Site},\beta}$	15.17	m/s	$V_{\text{Site},\beta} = V_R * M_d * M_{z,\text{cat}} * M_s * M_t$	
Pitch	α	24	Deg		
Pitch	α	0.42	rad		



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Width	B	5	m		
Length	D	5	m		
Height	Z	2.7	m		
Wind Pressure					
ρ_{air}	ρ	1.2	Kg/m ³		
dynamic response factor	C_{dyn}	1			
Wind Pressure	$\rho * C_{fig}$	0.138	Kg/m ²	$\rho = 0.5 \rho_{air} * (V_{des,\beta})^2 * C_{fig} * C_{dyn}$	2.4 (AS1170.2)
WIND DIRECTION 1 ($\theta=0$)					
External Pressure					
4. Free Roof				$\alpha = 0^\circ$	
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	$C_{P,w}$	0.64			
External Pressure Coefficient MIN	$C_{P,l}$	-0.62			
External Pressure Coefficient MAX	$C_{P,l}$	0			
aerodynamic shape factor MIN	$C_{fig,w}$	-0.30			
aerodynamic shape factor MAX	$C_{fig,w}$	0.64			
aerodynamic shape factor MIN	$C_{fig,l}$	-0.62			
aerodynamic shape factor MAX	$C_{fig,l}$	0.00			
Pressure Windward MIN	P	-0.04	kPa		
Pressure Windward MAX	P	0.09	kPa		
Pressure Leeward MIN	P	-0.09	kPa		
Pressure Leeward MAX	P	0.00	kPa		
WIND DIRECTION 2 ($\theta=90$)					
External Pressure					
4. Free Roof				$\alpha = 180^\circ$	D7



Area Reduction Factor	K_a	1	
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	$C_{P,w}$	0.4	
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	-0.04	kPa
Pressure MAX (Windward Side)	P	0.06	kPa
Pressure MIN (Leeward Side)	P	-0.06	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	-0.041	0.088	W	-0.041	0.055
L	-0.086	0.000	L	-0.055	0.000

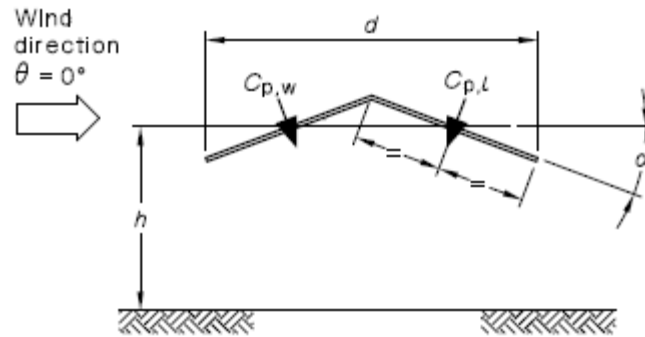


FIGURE D3 PITCHED FREE ROOFS

5.3 Pressure Coefficients (C_{fig}) – Closed Condition

Name	Symbol	Value	Unit	Notes	Ref.
Input					
Importance level		3			Table 3.1 - Table 3.2 (AS1170.0)
Annual probability of exceedance		1:50			Table 3.3
Regional gust wind speed		140.4	Km/hr		Table 3.1
Regional gust wind speed	V_R	39.00	m/s		
Wind Direction Multipliers	M_d	1			Table 3.2 (AS1170.2)
Terrain Category Multiplier	$M_{Z,Cat}$	0.91			Table 4.1
Shield Multiplier	M_S	1			4.3 (AS1170.2)
Topographic Multiplier	M_t	1			4.4 (AS1170.2)
Site Wind Speed	$V_{Site,\beta}$	35.49	m/s	$V_{Site,\beta} = V_R * M_d * M_{Z,Cat} * M_S * M_t$	
Pitch	α	0	Deg		
Pitch	α	0.000	rad		
Width	B	0.5	m		
Width Span	S_w	0.5	m		
Length	D	0.5	m		
Height	Z	2.7	m		
	h/d	5.40			
	h/b	5.40			



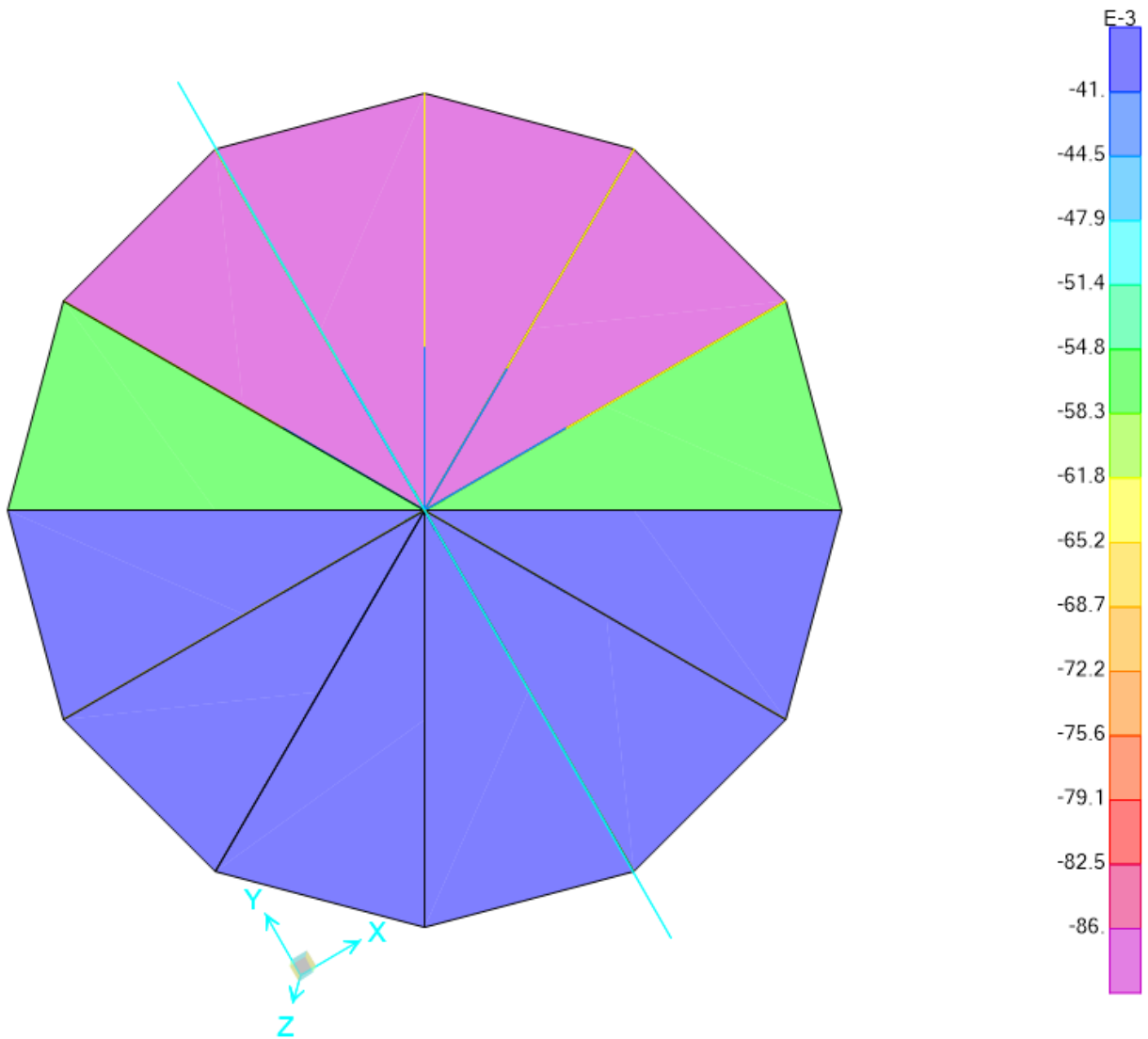
Wind Pressure					
ρ_{air}	ρ	1.2	Kg/m ³		
dynamic response factor	C_{dyn}	1			
Wind Pressure	$\rho * C_{fig}$	0.756	Kg/m ²	$\rho = 0.5 \rho_{air} * (V_{des,\beta})^2 * C_{fig} * C_{dyn}$	2.4 (AS1170.2)
External Pressure					
1. Windward Wall					
External Pressure Coefficient	$C_{P,e}$	0.6			Table 5.2 A
Area Reduction Factor	K_a	1			Table 5.4
combination factor applied to internal pressures	$K_{C,e}$	1			
local pressure factor	K_l	1			
porous cladding reduction factor	K_p	1			
aerodynamic shape factor	$C_{fig,e}$	0.6			
Wind Wall Pressure	P	0.45	kPa		

$$0.45 \times 0.5 = 0.225 \text{ kN/m}$$



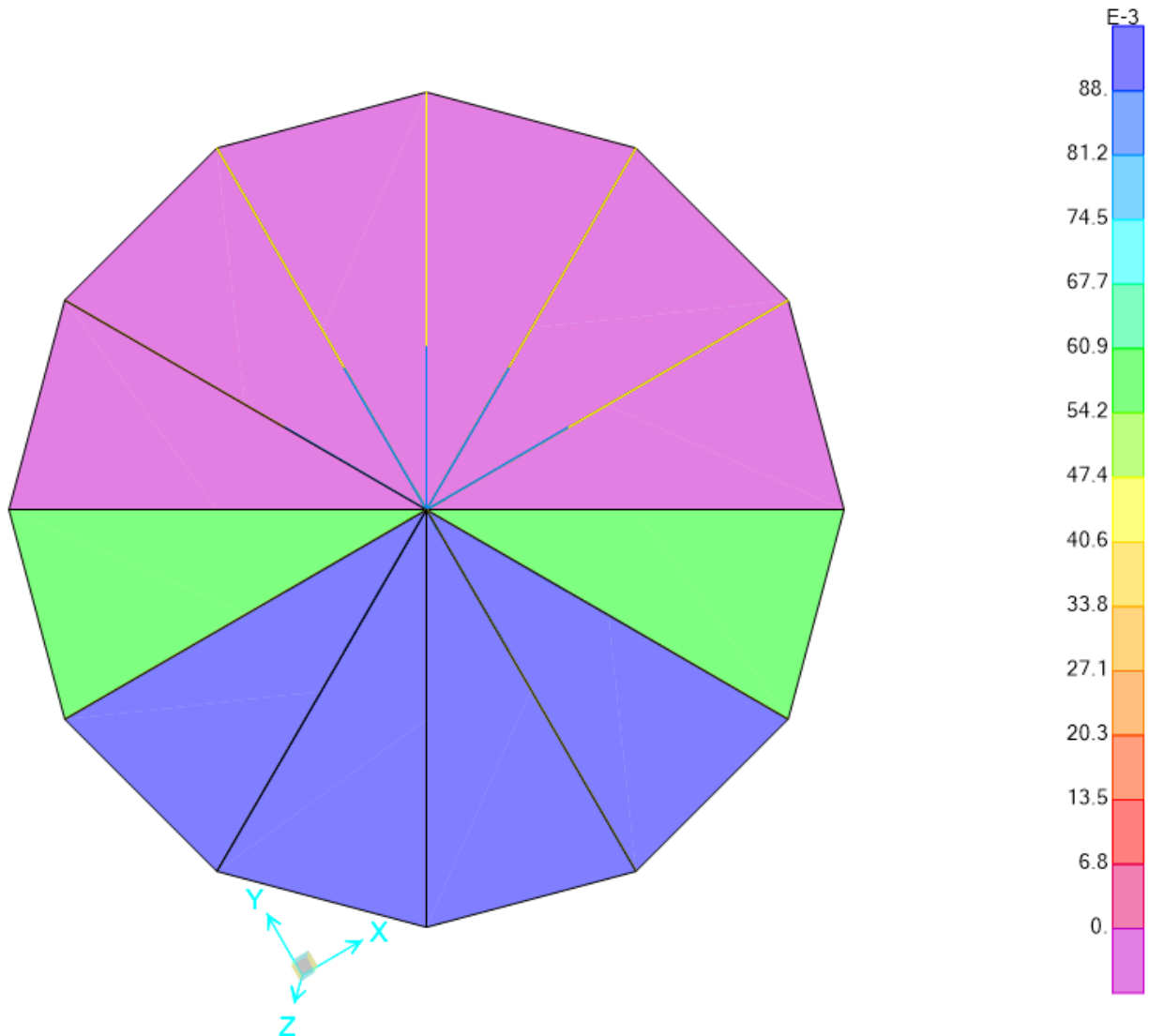
5.4 Wind Load Diagrams

5.4.1 Wind (min)_Open



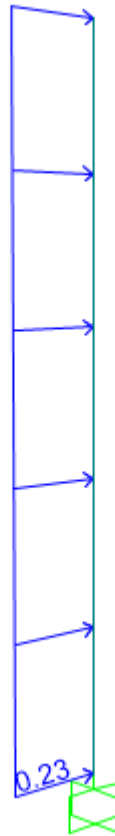


5.4.2 Wind (max)_Open





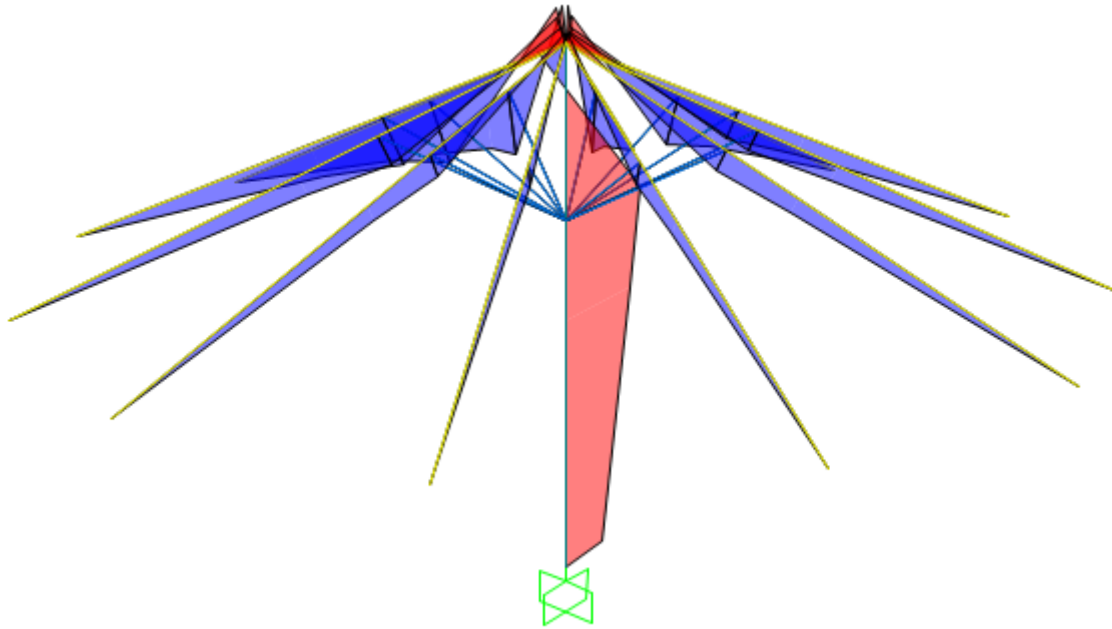
5.4.3 Wind_Closed



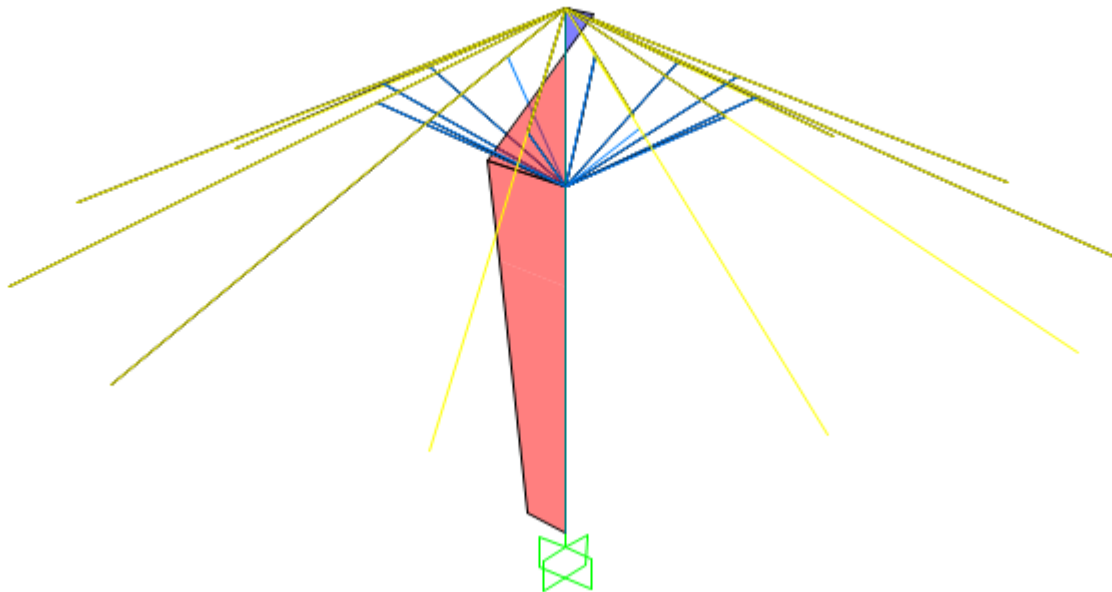
After 3D model analysis, each member is checked based on adverse load combination.
In this regard the maximum bending moment, shear and axial force due to adverse load combinations for each member are presented as below:



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

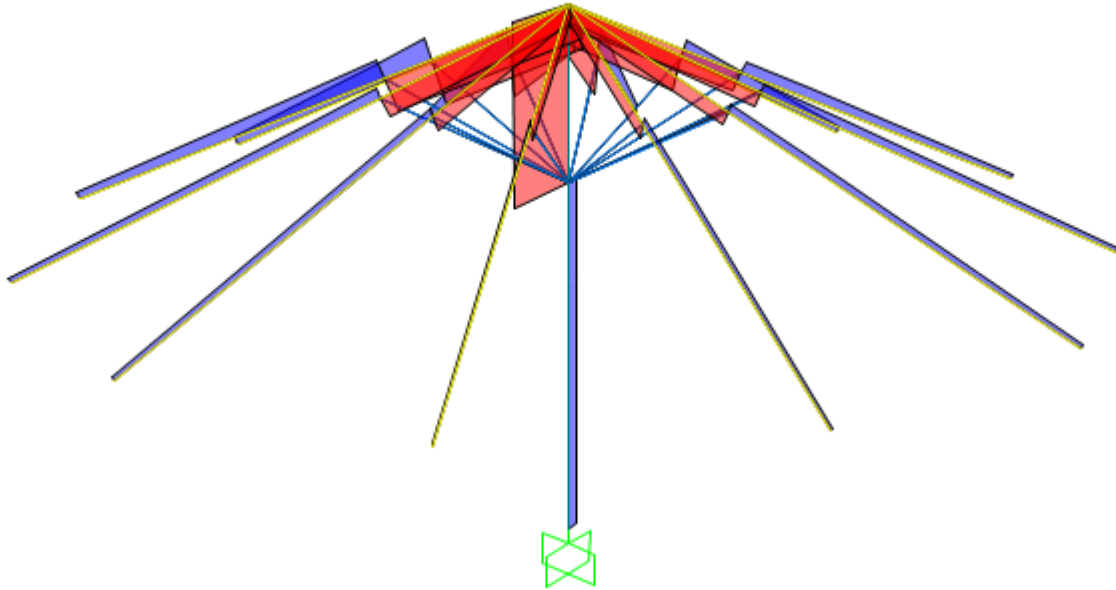


5.4.5 Max Bending Moment in minor axis due to critical load combination

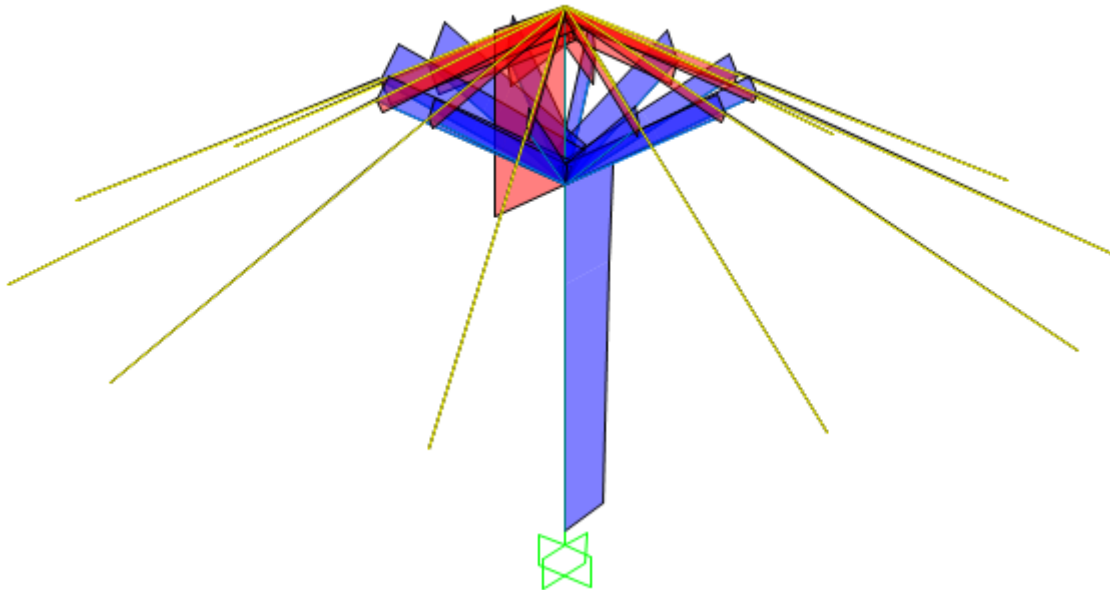




5.4.6 Max Shear in due to critical load combination

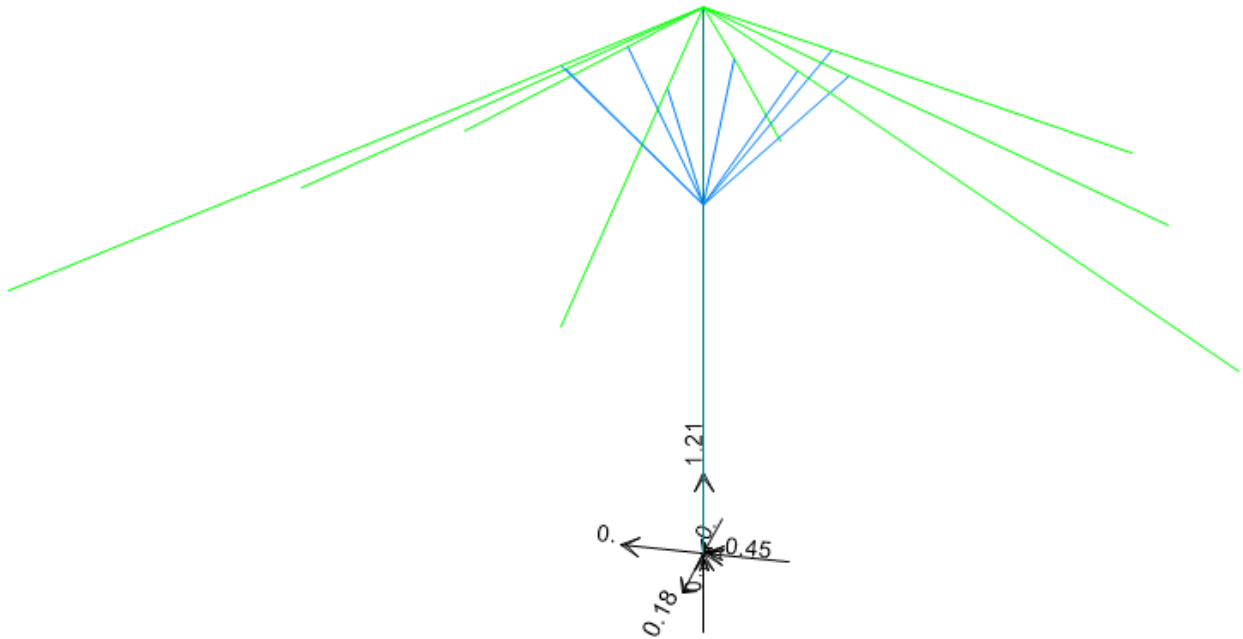


5.4.7 Max Axial force in upright support and roof beam due to critical load combination





5.4.8 Max reactions



Max $F_x = 0.73$ kN
Max $F_y = 0.01$ kN
Max $F_z = 1.21$ kN
Max $M_x = .01$ kN.m
Max $M_y = 1.2$ kN.m



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

6.1 Pole

NAME	SYMBOL	VALUE	UNIT	NOTES	REF
105x105x3.9	Pole				
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}	= 172	MPa	Ultimate	
	F_{sy}	= 138	MPa	Yield	
Bearing	F_{bu}	= 138	MPa	Ultimate	
	F_{by}	= 386	MPa	Yield	
Modulus of elasticity	E	= 70000	MPa	Compressive	
	k_t	= 1			T3.4(B)
	k_c	= 1			
FEM ANALYSIS RESULTS					
Axial force	P	= 1.886	kN	compression	
	P	= 0	kN	Tension	
In plane moment	M_x	= 0.7111	kNm		
Out of plane moment	M_y	= 1.2317	kNm		
DESIGN STRESSES					
Gross cross section area	A_g	= 1577.16	mm ²		
In-plane elastic section modulus	Z_x	= 51252.29	mm ³		
Out-of-plane elastic section mod.	Z_y	= 51252.29	mm ³		
Stress from axial force	f_a	= P/A_g			
		= 1.20	MPa	compression	
		= 0.00	MPa	Tension	
Stress from in-plane bending	f_{bx}	= M_x/Z_x			
		= 13.87	MPa	compression	
Stress from out-of-plane bending	f_{by}	= M_y/Z_y			
		= 24.03	MPa	compression	
Tension					
3.4.3 Tension in rectangular tubes					



	ϕF_L	=	228.95	MPa		
	O					
	R					
	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	=	3200	mm		
Effective length factor	k	=	1.00			
Radius of gyration about buckling axis (Y)	r_y	=	41.30	mm		
Radius of gyration about buckling axis (X)	r_x	=	41.30	mm		
Slenderness ratio	kLb/r_y	=	53.26			
Slenderness ratio	kL/r_x	=	77.47			
Slenderness parameter	λ	=	1.447			
	D_c^*	=	90.3			
	S_1^*	=	0.33			
	S_2^*	=	1.23			
	ϕ_{cc}	=	0.783			
Factored limit state stress	ϕF_L	=	90.08	MPa		
2. Sections not subject to torsional or torsional-flexural buckling						
						... 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	=	77.47			
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						
	k_1	=	0.35			... 3.4.10.1 T3.3(D)
Max. distance between toes of fillets of supporting elements for plate	b'	=	97.2			
	t	=	3.9	mm		
Slenderness	b/t	=	24.92307			
			7			
Limit 1	S_1	=	12.34			
Limit 2	S_2	=	32.87			
Factored limit state stress	ϕF_L	=	193.63	MPa		



Most adverse compressive limit state stress	F_a	=	90.08	MPa		
Most adverse tensile limit state stress	F_a	=	222.70	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	=	2.69E+06	mm ⁴		
Torsion modulus	J	=	4.03E+06	mm ³		
Elastic section modulus	Z	=	51252.29	mm ³		
Slenderness	S	=	68.48			
Limit 1	S_1	=	0.39			
Limit 2	S_2	=	1695.86			
Factored limit state stress	ϕF_L	=	211.40	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'	=	97.2	mm		
	t	=	3.9	mm		
Slenderness	b/t	=	24.92307			
Limit 1	S_1	=	12.34			
Limit 2	S_2	=	46.95			
Factored limit state stress	ϕF_L	=	193.63	MPa		
Most adverse in-plane bending limit state stress	F_{bx}	=	193.63	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.07		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	=	193.63	MPa		
Most adverse out-of-plane bending limit state stress	F_{by}	=	193.63	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						
	F_a	=	90.08	MPa		... 4.1.1(2)
	F_{ao}	=	193.63	MPa		... 3.4.8
	F_{bx}	=	193.63	MPa		... 3.4.10
	F_{by}	=	193.63	MPa		... 3.4.17
	f_a/F_a	=	0.013			... 3.4.17
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$					... 4.1.1 (3)
i.e.	0.21	$\leq$	1.0		PASS	
SHEAR						
3.4.24 Shear in webs (Major Axis)						
Clear web height	h	=	97.2	mm		... 4.1.1(2)
	t	=	3.9	mm		
Slenderness	h/t	=	24.92307			
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			
			0.12	MPa		
3.4.25 Shear in webs (Minor Axis)						
Clear web height	b	=	97.2	mm		
	t	=	3.9	mm		
Slenderness	b/t	=	24.92307			
			7			
Factored limit state stress	ϕF_L	=	131.10	MPa		
Stress From Shear force	f_{sy}	=	V/A_w			



0.21 MPa

6.2 Long Rib

NAME	SYMBOL	VALUE	UNIT	NOTES	REF
40x20x2+35x30x3	Long Rib				
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}	= 172	MPa	Ultimate	
	F_{sy}	= 138	MPa	Yield	
Bearing	F_{bu}	= 138	MPa	Ultimate	
	F_{by}	= 386	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	= 0.543	kN	Tension	
In plane moment	M_x	= 0.2954	kNm		
Out of plane moment	M_y	= 0.0005742	kNm		
DESIGN STRESSES					
Gross cross section area	A_g	= 364	mm ²		
In-plane elastic section modulus	Z_x	= 5035	mm ³		
Out-of-plane elastic section mod.	Z_y	= 3578.6	mm ³		
Stress from axial force	f_a	= P/A_g			
		= 0.00	MPa	compression	
		= 1.49	MPa	Tension	
Stress from in-plane bending	f_{bx}	= M_x/Z_x			
		= 58.67	MPa	compression	
Stress from out-of-plane bending	f_{by}	= M_y/Z_y			
		= 0.16	MPa	compression	
Tension					
3.4.3 Tension in rectangular tubes					
	ϕF_L	= 228.95	MPa		



	ϕF_L	OR =	222.70	MPa	
COMPRESSION					
3.4.8 Compression in columns, axial, gross section					
1. General					... 3.4.8.1
Unsupported length of member	L	=	3250	mm	
Effective length factor	k	=	1.00		
Radius of gyration about buckling axis (Y)	r _y	=	12.02	mm	
Radius of gyration about buckling axis (X)	r _x	=	20.40	mm	
Slenderness ratio	kLb/ry	=	191.35		
Slenderness ratio	kL/rx	=	159.31		
Slenderness parameter	λ	=	3.57		
	D _c *	=	90.3		
	S ₁ *	=	0.33		
	S ₂ *	=	1.23		
	φ _{cc}	=	0.950		
Factored limit state stress	φF _L	=	17.93	MPa	
2. Sections not subject to torsional or torsional-flexural buckling					... 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	=	191.35		
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 T3.3(D)
	k ₁	=	0.35		
Max. distance between toes of fillets of supporting elements for plate	b'	=	16		
	t	=	2	mm	
Slenderness	b/t	=	8		
Limit 1	S ₁	=	12.34		
Limit 2	S ₂	=	32.87		
Factored limit state stress	φF _L	=	228.95	MPa	
Most adverse compressive limit state stress	F _a	=	17.93	MPa	



Most adverse tensile limit state stress	F_a	=	222.70	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	=	2300	mm		
Second moment of area (weak axis)	I_y	=	6.26E+04	mm ⁴		
Torsion modulus	J	=	3.81E+04	mm ³		
Elastic section modulus	Z	=	5035	mm ³		
Slenderness	S	=	474.37			
Limit 1	S_1	=	0.39			
Limit 2	S_2	=	1695.86			
Factored limit state stress	ϕF_L	=	180.43	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'	=	16	mm		
	t	=	2	mm		
Slenderness	b/t	=	8			
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}	=	180.43	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.33		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	=	180.43	MPa		



Most adverse out-of-plane bending limit state stress	F_{by}	=	180.43	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						
	F_a	=	17.93	MPa		... 4.1.1(2)
	F_{ao}	=	228.95	MPa		... 3.4.8
	F_{bx}	=	180.43	MPa		... 3.4.10
	F_{by}	=	180.43	MPa		... 3.4.17
	f_a/F_a	=	0.007			... 3.4.17
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$					... 4.1.1 (3)
i.e.	0.33	≤	1.0		PASS	
SHEAR						
3.4.24 Shear in webs (Major Axis)						
Clear web height	h	=	71	mm		... 4.1.1(2)
	t	=	2	mm		
Slenderness	h/t	=	35.5			
Limit 1	S_1	=	29.01			
Limit 2	S_2	=	59.31			
Factored limit state stress	ϕF_L	=	124.53	MPa		
Stress From Shear force	f_{sx}	=	V/A_w			
			0.51	MPa		
3.4.25 Shear in webs (Minor Axis)						
Clear web height	b	=	16	mm		
	t	=	2	mm		
Slenderness	b/t	=	8			
Factored limit state stress	ϕF_L	=	131.10	MPa		
Stress From Shear force	f_{sy}	=	V/A_w			
			0.89	MPa		

6.3 Short Rib

NAME	SYMBOL	VALUE	UNIT	NOTES	REF
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40x20x2+35x30x3	Short Rib					
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}	=	172	MPa	Ultimate	
	F_{sy}	=	138	MPa	Yield	
Bearing	F_{bu}	=	138	MPa	Ultimate	
	F_{by}	=	386	MPa	Yield	
Modulus of elasticity	E	=	70000	MPa	Compressive	
	k_t	=	1			T3.4(B)
	k_c	=	1			
FEM ANALYSIS RESULTS						
Axial force	P	=	0.827	kN	compression	
	P	=	0	kN	Tension	
In plane moment	M_x	=	0	kNm		
Out of plane moment	M_y	=	0.0009583	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	=	364	mm ²		
In-plane elastic section modulus	Z_x	=	5035	mm ³		
Out-of-plane elastic section mod.	Z_y	=	3578.6	mm ³		
Stress from axial force	f_a	=	P/ A_g			
		=	2.27	MPa	compression	
		=	0.00	MPa	Tension	
Stress from in-plane bending	f_{bx}	=	M_x/Z_x			
		=	0.00	MPa	compression	
Stress from out-of-plane bending	f_{by}	=	M_y/Z_y			
		=	0.27	MPa	compression	
Tension						
3.4.3 Tension in rectangular tubes						
	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	=	1200	mm		
Effective length factor	k	=	1.00			
Radius of gyration about buckling axis (Y)	r _y	=	12.02	mm		
Radius of gyration about buckling axis (X)	r _x	=	20.40	mm		
Slenderness ratio	kLb/r _y	=	99.83			
Slenderness ratio	kL/r _x	=	58.82			
Slenderness parameter	λ	=	1.86			
	D _c *	=	90.3			
	S ₁ *	=	0.33			
	S ₂ *	=	1.23			
	φ _{cc}	=	0.841			
Factored limit state stress	φF _L	=	58.30	MPa		
2. Sections not subject to torsional or torsional-flexural buckling						... 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	=	99.83			
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 T3.3(D)
	k ₁	=	0.35			
Max. distance between toes of fillets of supporting elements for plate	b'	=	16			
	t	=	2	mm		
Slenderness	b/t	=	8			
Limit 1	S ₁	=	12.34			
Limit 2	S ₂	=	32.87			
Factored limit state stress	φF _L	=	228.95	MPa		
Most adverse compressive limit state stress	F _a	=	58.30	MPa		
Most adverse tensile limit state stress	F _a	=	222.70	MPa		



Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.04	PASS	
BENDING - IN-PLANE					
3.4.15 Compression in beams, extreme fibre, gross section rectangular tubes, box sections					
Unbraced length for bending	L_b	=	1200 mm		
Second moment of area (weak axis)	I_y	=	62626.1 mm ⁴		
Torsion modulus	J	=	38065.7 mm ³		
Elastic section modulus	Z	=	5035 mm ³		
Slenderness	S	=	247.49		
Limit 1	S_1	=	0.39		
Limit 2	S_2	=	1695.86		
Factored limit state stress	ϕF_L	=	194.30 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'	=	16 mm		
	t	=	2 mm		
Slenderness	b/t	=	8		
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}	=	194.30 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	=	194.30 MPa		



Most adverse out-of-plane bending limit state stress	F_{by}	=	194.30	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						
	F_a	=	58.30	MPa		... 4.1.1(2)
	F_{ao}	=	228.95	MPa		... 3.4.8
	F_{bx}	=	194.30	MPa		... 3.4.10
	F_{by}	=	194.30	MPa		... 3.4.17
	f_a/F_a	=	0.039			... 3.4.17
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by}$	$\leq$	1.0			... 4.1.1 (3)
i.e.	0.04	$\leq$	1.0		PASS	
SHEAR						
3.4.24 Shear in webs (Major Axis)						
Clear web height	h	=	71	mm		... 4.1.1(2)
	t	=	2	mm		
Slenderness	h/t	=	35.5			
Limit 1	S_1	=	29.01			
Limit 2	S_2	=	59.31			
Factored limit state stress	ϕF_L	=	124.53	MPa		
Stress From Shear force	f_{sx}	=	V/A_w			
			0.51	MPa		
3.4.25 Shear in webs (Minor Axis)						
Clear web height	b	=	16	mm		
	t	=	2	mm		
Slenderness	b/t	=	8			
Factored limit state stress	ϕF_L	=	131.10	MPa		
Stress From Shear force	f_{sy}	=	V/A_w			
			0.89	MPa		



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6.4 Summary Loads

MEMBER(S)	Section	b	d	t	V _x	V _y	P (Axial)	M _x	M _y
		mm	mm	mm	kN	kN	kN	kN.m	kN.m
Pole	105x105x3.9	105	105	3.9	0.156	0.271	-1.886	-0.7111	-1.2317
Long Rib	40x20x2+35x30x3	20	75	2	0.411	0.00106	0.543	-0.2954	-0.0005742
Short Rib	40x20x2+35x30x3	20	75	2	-0	-0.00106	-0.827	0	-0.0009583

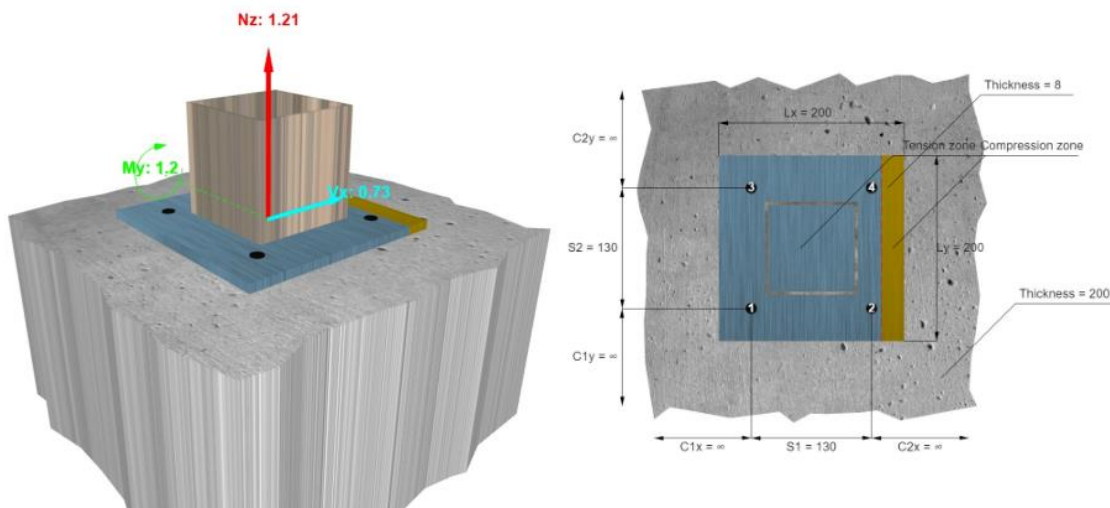
7 Anchor Design

7.1 Permanent Installation - 200 x 200 x 8 Base Plate with Mechanical Anchors (bolted to concrete slab)

Use 4/M10 Dynaset Drop-in Anchor or 4/TRUBOLT XTREM M10x90/10 or equivalent,

Anchor size, db	Installation details			Optimum dimensions*		Reduced Characteristic Capacity			
	Drilled hole diameter, d _h (mm)	Anchor effective depth, h (mm)	Tightening torque, T _r (Nm)	Edge distance, e _c (mm)	Anchor spacing, a _c (mm)	Shear (steel) ØV _{us} (kN)***	Tension (concrete), ØN _{uc} (kN)**		
							Concrete compressive strength, f' _c		
							20 MPa	32 MPa	40 MPa
M6	8	23	6	80	60	4.5	3.6	4.6	5.1
M6 Flanged	8	23	6	80	60	5.8	3.6	4.6	5.1
M8	10	28	10	100	70	5.8	4.9	6.1	6.9
M10	12	38	20	135	95	7.1	7.7	9.7	10.8
M10 Flanged	12	28	12	100	70	5.8	4.9	6.1	6.9
M12	16 #	48	40	170	120	13.2	10.9	13.8	15.4
M12 Flanged	16	48	40	170	120	13.2	10.9	13.8	15.4
M16	20	63	95	220	160	20.9	16.4	20.7	23.2
M20	25	78	180	275	195	26.3	22.6	28.5	31.9

Geometry :





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7.2 Temporary Installation - 1200 x 1200 x 8 Base Plate

Maximum uplift force at toe: 0.85kN

Self-weight of the base plate: 90kg

Thus, required **additional weight** to counteract uplift forces due to design wind speed (60km/hr) = **100kg**

Self-weight of the structure attached to 1200x1200x8 baseplate can counteract uplift forces due to **max. 30km/hr wind.**



8 Summary

8.1 Conclusions

- a. The 6m Round (Dodecagon) umbrella structure as specified has been analyzed with a conclusion that it has the capacity to withstand wind speeds up to and including **60km/hr when open and 140.4km/hr when folded.**
- b. For forecast winds in excess of **60km/hr** – the umbrella structure should be completely folded. The umbrella with temporary anchorage system must be stored in an enclosed building however the umbrella with permanent anchorage system can remain folded on site.
- c. For uplift due to 60km/hr, anchorage system described in Cl. 7 is required.

Yours faithfully,

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