Civil Structural Engineering Design Services

Client: **Easy Signs Pty Ltd**

Project: Design check – 2m × 2m Umbrella for 60km/hr Wind Speed

Reference: Easy Signs Technical Data

Report by: AL

Checked by: EAB

Date: 27/03/2023

Amendment Date:

JOB No: D-1162

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1 Introduction

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The report examines the effect of 3s gust wind of 60 km/hr on 2m × 2m Umbrella as the worst-case scenario. The relevant Australian Standards AS1170.0:2002 General principles, AS1170.1:2002 Permanent, imposed, and other actions and AS1170.2:2021 Wind actions are used. The design check is in accordance with AS/NZS 1664.2:1997 Aluminium Structures.

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 tent, the temporary erected structure should be dismantled.

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 tent 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.

3 Specifications

3.1. General

Category	
Material	6063-T5

Size	Model
2m × 2m	Umbrella

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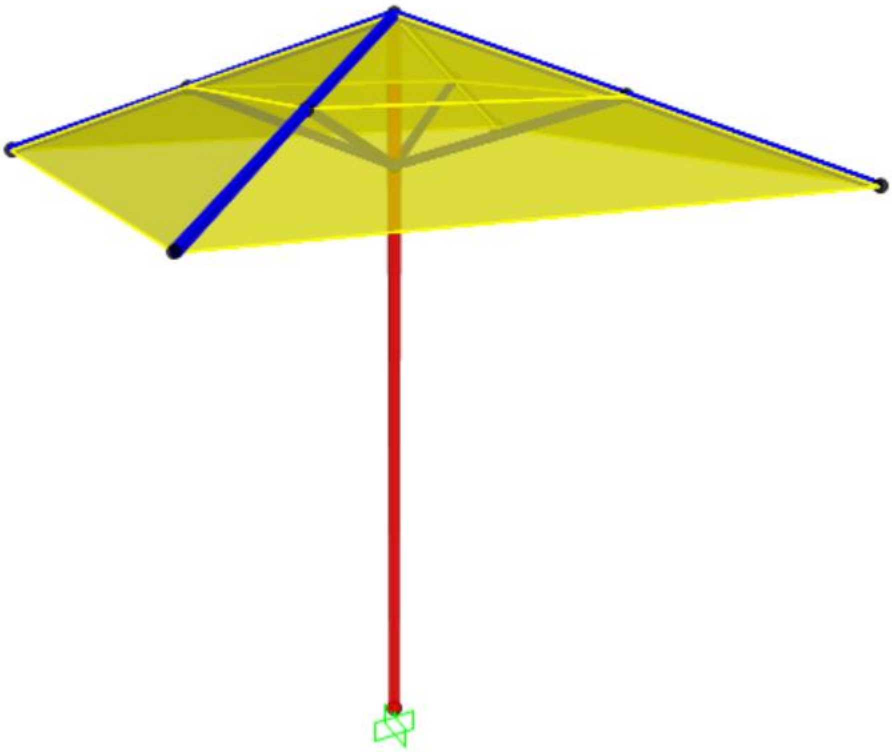

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3.2. Section Properties

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*
Scissor Beam	22x12x1	12	22	1	11.0	64.0	361.9	250.2	452.0	292.0	3981.3	1501.3	3335.1	7.9	4.8
Upright Support	HEX 45x1	45	45	1	22.5	131.5	1350.0	1350.0	1670.0	1670.0	26400.0	26400.0	52700.0	14.2	14.2

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	0.138C_{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 = $0.9 \times G + W_u$

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 = 16.67 m/s (60 km/hr) *(regional 3 s gust wind speed)*

$M_d = 1$

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$M_s = 1$

$M_t = 1$

$M_{z,cat} = 0.91$ *(Table 4.1(B) AS1170.2)*

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

Height of structure (h) = 2.44 m *(mid of peak and eave)*

Width of structure (w) = 2 m

Length of structure (l) = 2 m

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

= $0.138C_{fig}$ kPa

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	$M_{Z,Cat}$	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	$V_{Site,\beta}$	**15.17**	m/s	$V_{Site,\beta}=V_R*M_d*M_{z,cat}*M_S,M_t$	
Pitch	α	18	Deg		
Pitch	α	0.31	rad		
Width	B	2	m		
Length	D	2	m		
Height	Z	2.44	m		
		Wind Pressure			
ρair	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)*

5.2. Pressure Coefficients (C_{fig})

WIND DIRECTION 1 (θ=0)					
External Pressure					
4. Free Roof				*α=0°*	
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**	$C_{P,w}$	0.5			
External Pressure Coefficient **MIN**	$C_{P,l}$	-0.5			
External Pressure Coefficient **MAX**	$C_{P,l}$	0			
aerodynamic shape factor **MIN**	$C_{fig,w}$	-0.30			
aerodynamic shape factor **MAX**	$C_{fig,w}$	0.50			
aerodynamic shape factor **MIN**	$C_{fig,l}$	-0.50			
aerodynamic shape factor **MAX**	$C_{fig,l}$	0.00			
Pressure Windward **MIN**	P	**-0.04**	**kPa**		
Pressure Windward **MAX**	P	**0.07**	**kPa**		
Pressure Leeward **MIN**	P	**-0.07**	**kPa**		
Pressure Leeward **MAX**	P	**0.00**	**kPa**		

WIND DIRECTION 2 (θ=90)					
External Pressure					
4. Free Roof				*α=180°*	*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**	$C_{P,w}$	0.5			
External Pressure Coefficient **MIN**	$C_{P,l}$	-0.5			
External Pressure Coefficient **MAX**	$C_{P,l}$	0			
aerodynamic shape factor **MIN**	$C_{fig,w}$	-0.30			
aerodynamic shape factor **MAX**	$C_{fig,w}$	0.50			
aerodynamic shape factor **MIN**	$C_{fig,l}$	-0.50			
aerodynamic shape factor **MAX**	$C_{fig,l}$	0.00			
Pressure **MIN (Windward Side)**	P	**-0.04**	**kPa**		
Pressure **MAX (Windward Side)**	P	**0.07**	**kPa**		
Pressure **MIN (Leeward Side)**	P	**-0.07**	**kPa**		
Pressure **MAX (Leeward Side)**	P	**0.00**	**kPa**		

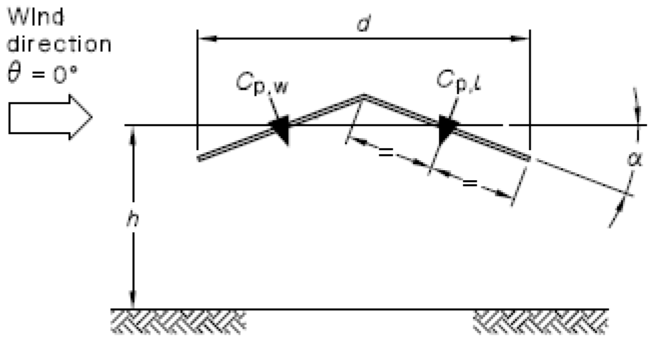
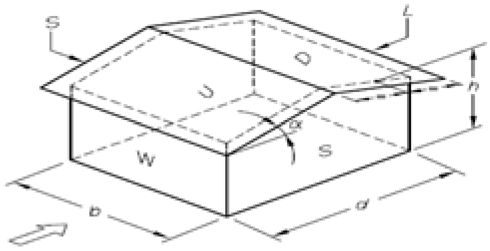
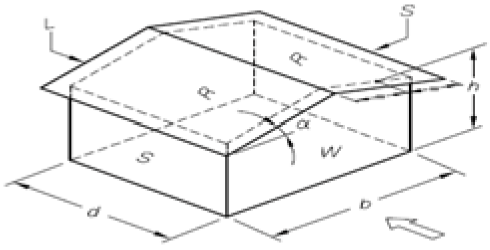


FIGURE D3 PITCHED FREE ROOFS



Direction 1



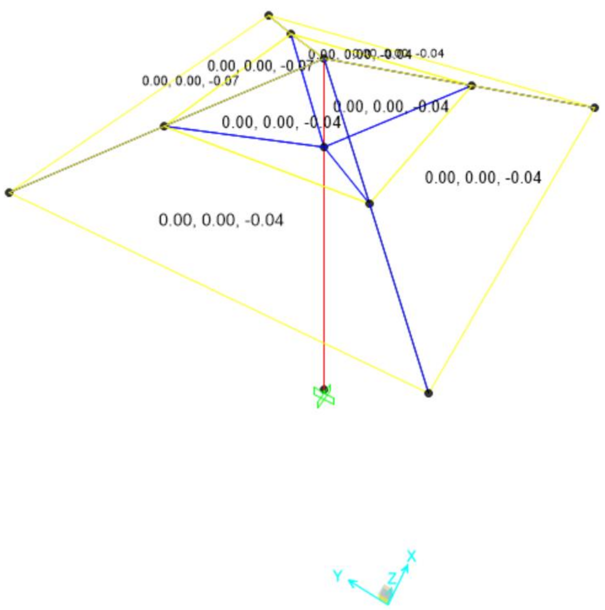
Direction 2

5.3. Pressure summary

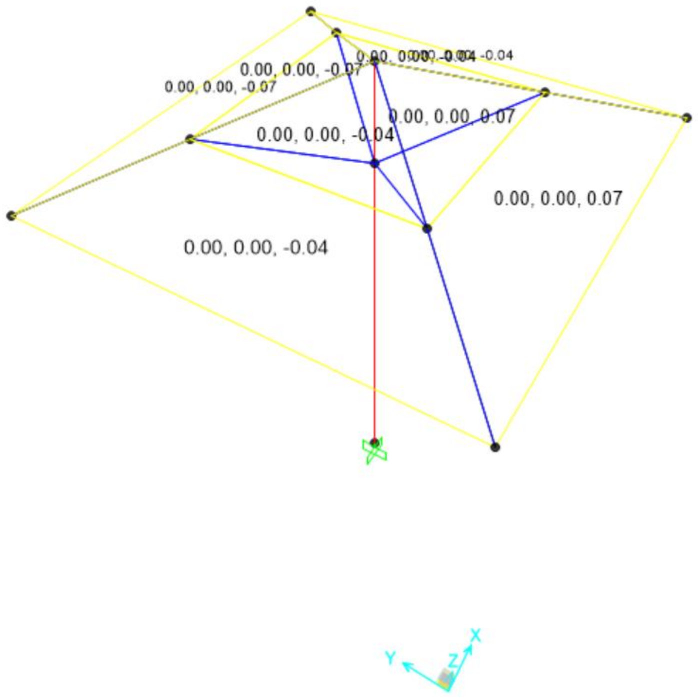
WIND EXTERNAL PRESSURE	Direction1		Direction2		
	Min (Kpa)	Max (Kpa)		Min (Kpa)	Max (Kpa)
W	-0.04	0.07	W	-0.04	0.07
L	-0.07	0.00	L	-0.07	0.00

5.4. Wind Load Diagrams

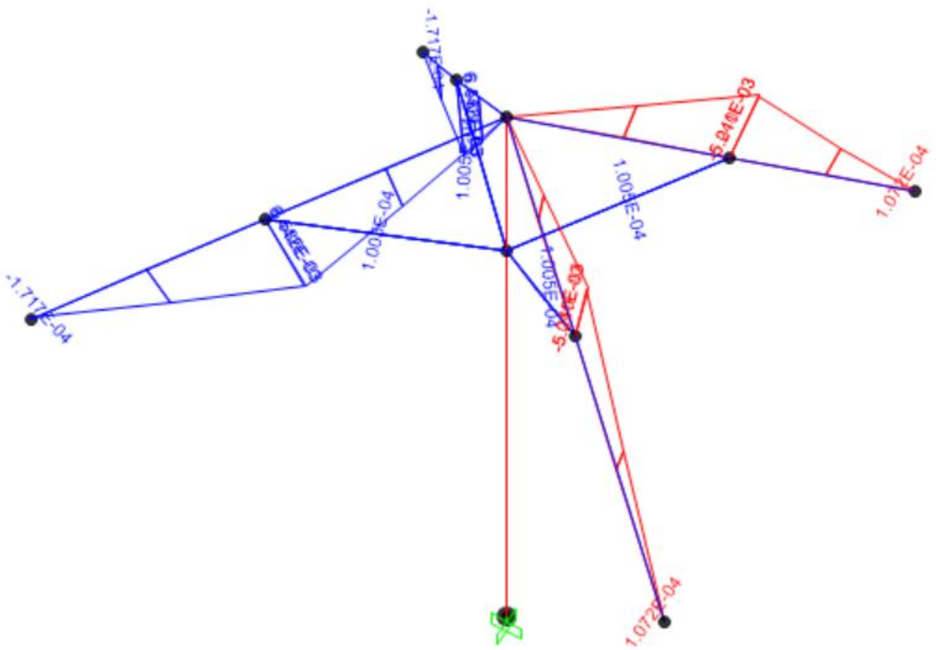
5.4.1. Wind 1 (kPa)



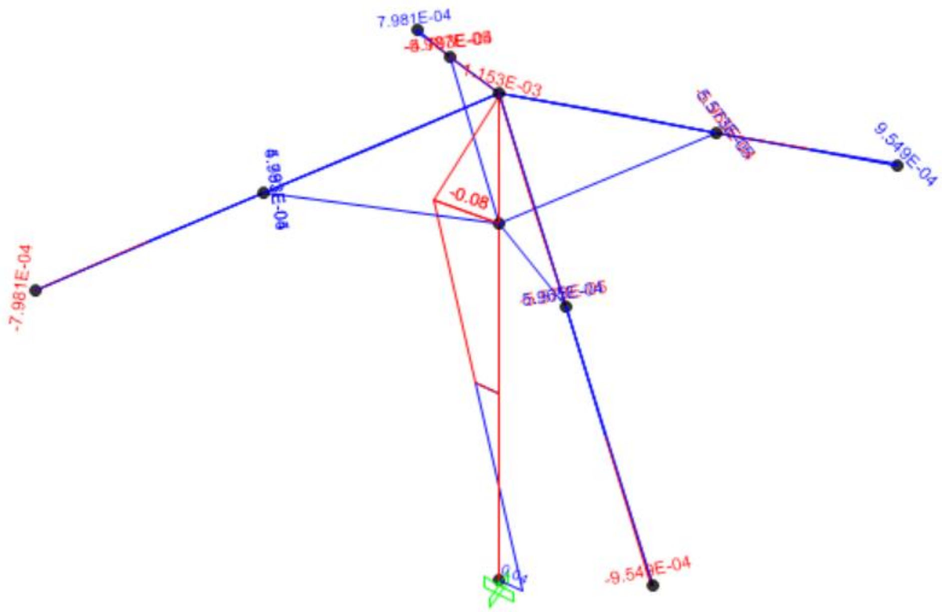
5.4.2. Wind 2 (kPa)



5.4.3. Max Bending Moment due to critical load combination in major axis (kNm)



5.4.4. Max Bending Moment in minor axis due to critical load combination (kNm)



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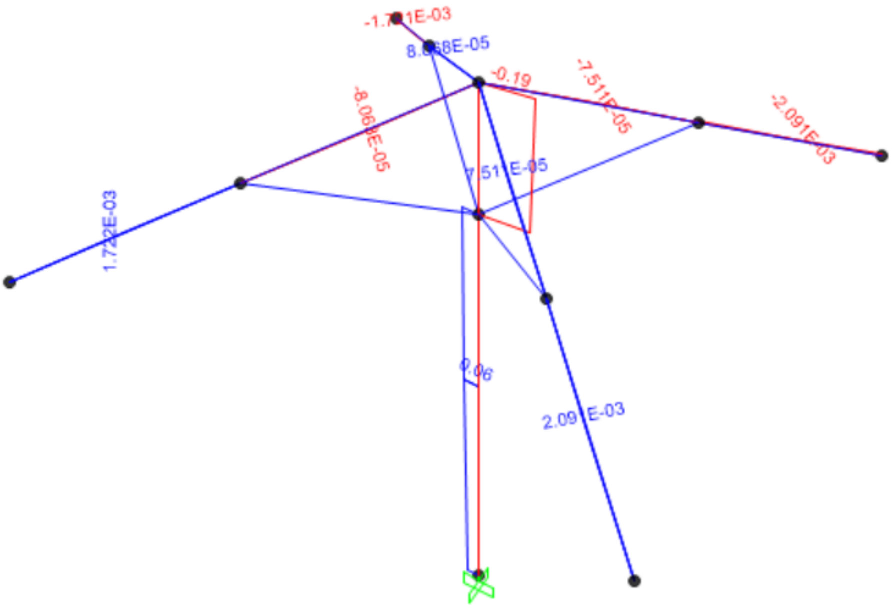
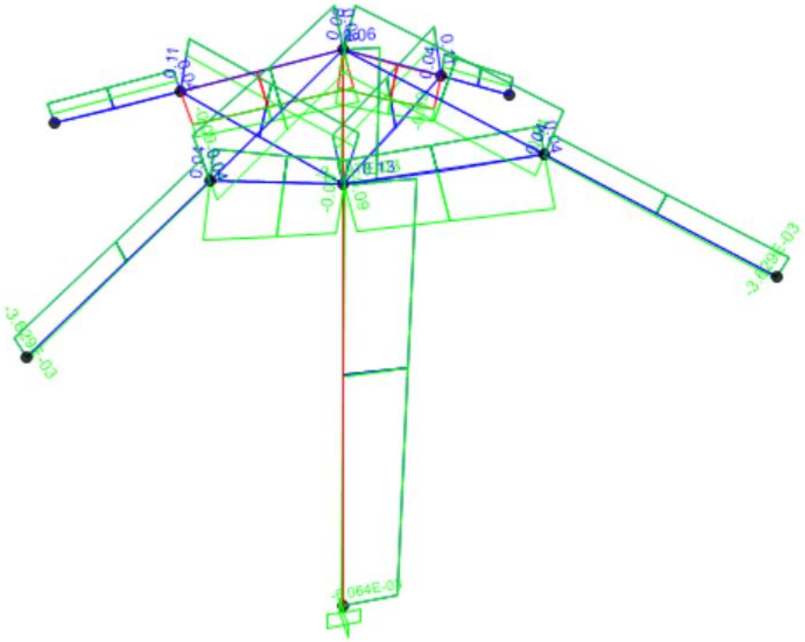
5.4.5. Max Shear in due to critical load combination (kN)

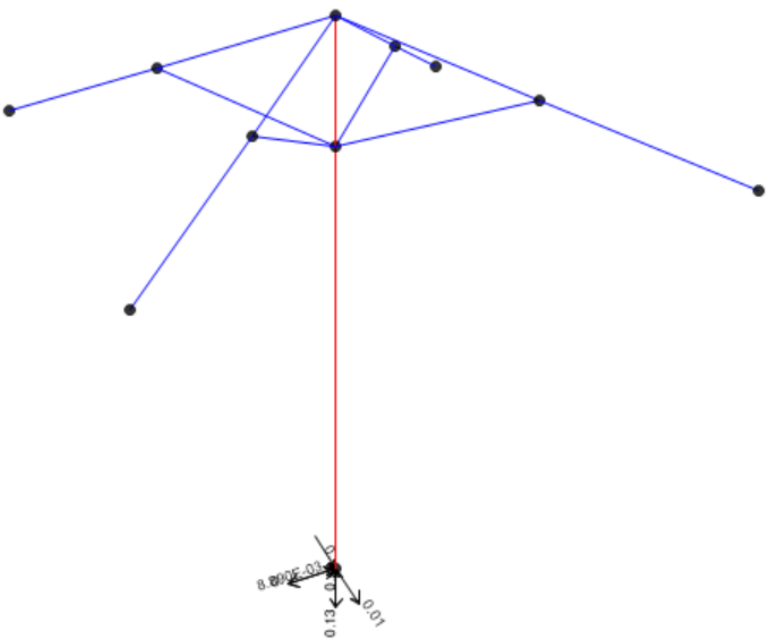


5.4.6. Max Axial force in upright support and roof beam due to critical load combination (kN)



5.4.7. Max reactions (kN)

N = 0.13 kN



6. Checking Members Based on AS/NZS 1664.2 Aluminium Structures

6.1. Scissors Beams

NAME	SYMBOL		VALUE	UNIT	NOTES	REF
22x12x1	**Scissor 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}	=	62	MPa	*Ultimate*	
	F_{by}	=	179	MPa	*Yield*	
Modulus of elasticity	E	=	70000	MPa	*Compressive*	

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	k_t	=	1			T3.4(B)
	k_c	=	1			
FEM ANALYSIS RESULTS						
Axial force	P	=	0.086	kN	*compression*	
	P	=	0	kN	*Tension*	
In plane moment	M_x	=	0.0064	kNm		
Out of plane moment	M_y	=	0	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	=	64	mm^2		
In-plane elastic section modulus	Z_x	=	361.93939	mm^3		
Out-of-plane elastic section mod.	Z_y	=	250.22222	mm^3		
Stress from axial force	$\mathbf{f_a}$	=	P/A_g			
		=	**1.34**	**MPa**	*compression*	
		=	**0.00**	**MPa**	*Tension*	
Stress from in-plane bending	$\mathbf{f_{bx}}$	=	M_x/Z_x			
		=	**17.68**	**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*						
	$\mathbf{\phi F_L}$	**=**	**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

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Unsupported length of member	L	=	1484	mm	
Effective length factor	k	=	1.00		
Radius of gyration about buckling axis (Y)	r_y	=	4.84	mm	
Radius of gyration about buckling axis (X)	r_x	=	7.89	mm	
Slenderness ratio	kLb/ry	=	306.40		
Slenderness ratio	kL/rx	=	188.15		
Slenderness parameter	λ	=	3.866		
	D_c*	=	39.0		
	S_1*	=	0.24		
	S_2*	=	1.25		
	ϕ_{cc}	=	0.950		
Factored limit state stress	**ϕF_L**	**=**	**6.99**	**MPa**	
2. Sections not subject to torsional or torsional-flexural buckling					… 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	=	306.40		
***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'	=	10		
	t	=	1	mm	
Slenderness	b/t	=	10		
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	=	6.99	MPa	

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Most adverse tensile limit state stress	F_a	=	104.50	MPa		
Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.19		PASS	
BENDING - IN-PLANE						
***3.4.15** Compression in beams, extreme fibre, gross section rectangular tubes, box sections*						
Unbraced length for bending	L_b	=	1484	mm		
Second moment of area (weak axis)	I_y	=	1.50E+03	mm^4		
Torsion modulus	J	=	3.34E+03	mm^3		
Elastic section modulus	Z	=	361.9393 9	mm^3		
Slenderness	S	=	480.08			
Limit 1	S_1	=	21.80			
Limit 2	S_2	=	3854.05			
Factored limit state stress	**ϕF_L**	=	**86.70**	**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'	=	10	mm		
	t	=	1	mm		
Slenderness	b/t	=	10			
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}	=	86.70	MPa		

Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.20		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	=	**86.70**	**MPa**		
Most adverse out-of-plane bending limit state stress	F_{by}	=	86.70	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	=	6.99	MPa		… 3.4.8
	F_{ao}	=	104.50	MPa		… 3.4.10
	F_{bx}	=	86.70	MPa		… 3.4.17
	F_{by}	=	86.70	MPa		… 3.4.17
	f_a/F_a	=	0.192			
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	=	20	mm		
	t	=	1	mm		
Slenderness	h/t	=	20			
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)*						
Clear web height	b	**=**	10	mm		
	t	**=**	1	mm		
Slenderness	b/t	**=**	10			
Factored limit state stress	**ϕF_L**	**=**	**58.90**	**MPa**		
Stress From Shear force	**f_{sy}**	**=**	V/A_w			
			0.18	**MPa**		
Most adverse shear capacity factor (Major Axis)	f_{sx}/F_{sx}	=	0.00	**MPa**		
Most adverse shear capacity factor (Minor Axis)	f_{sy}/F_{sy}	**=**	0.00	**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.,	0.40	≤	1.0		PASS	

6.2. Upright Support

NAME	SYMBOL		VALUE	UNIT	NOTES	REF
HEX 45x1	**Upright Support**					
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}	=	62	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	=	0.131	kN	*Tension*	
In plane moment	M_x	=	0.0839	kNm		
Out of plane moment	M_y	=	0	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	**=**	131.5	mm^2		
In-plane elastic section modulus	Z_x	**=**	1350	mm^3		
Out-of-plane elastic section mod.	Z_y	**=**	1350	mm^3		
Stress from axial force	$\mathbf{f_a}$	**=**	P/A_g			
		=	**0.00**	**MPa**	*compression*	
		=	**1.00**	**MPa**	*Tension*	
Stress from in-plane bending	$\mathbf{f_{bx}}$	**=**	M_x/Z_x			
		=	**62.15**	**MPa**	*compression*	
	$\mathbf{f_{by}}$	**=**	M_y/Z_y			
Stress from out-of-plane bending		**=**	**0.00**	**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	=	2440	mm		
Effective length factor	k	=	1.00			
Radius of gyration about buckling axis (Y)	r_y	=	14.17	mm		
Radius of gyration about buckling axis (X)	r_x	=	14.17	mm		
Slenderness ratio	kLb/ry	=	172.21			
Slenderness ratio	kL/rx	=	172.21			
Slenderness parameter	λ	=	2.17			
	D_c*	=	39.0			
	S_1*	=	0.24			
	S_2*	=	1.25			
	ϕ_{cc}	=	0.884			
Factored limit state stress	**ϕF_L**	**=**	**20.60**	**MPa**		
2. Sections not subject to torsional or torsional-flexural buckling						… 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	**=**	172.21			
***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'	**=**	43			
	t	**=**	1	mm		
Slenderness	b/t	**=**	43			
Limit 1	S_1	**=**	12.06			
Limit 2	S_2	**=**	49.94			

Factored limit state stress	**ϕF_L**	=	**79.75**	**MPa**		
Most adverse compressive limit state stress	F_a	=	20.60	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	=	2440	mm		
Second moment of area (weak axis)	I_y	=	2.64E+04	mm^4		
Torsion modulus	J	=	5.27E+04	mm^3		
Elastic section modulus	Z	=	1350	mm^3		
Slenderness	S	=	176.62			
Limit 1	S_1	=	21.80			
Limit 2	S_2	=	3854.05			
Factored limit state stress	**ϕF_L**	=	**92.48**	**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'	=	43	mm		
	t	=	1	mm		
Slenderness	b/t	=	43			
Limit 1	S_1	=	12.06			
Limit 2	S_2	=	71.35			
Factored limit state stress	**ϕF_L**	=	**79.75**	**MPa**		

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Most adverse in-plane bending limit state stress	F_{bx}	=	79.75	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.78		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	=	**79.75**	**MPa**		
Most adverse out-of-plane bending limit state stress	F_{by}	=	79.75	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	=	20.60	MPa		… 3.4.8
	F_{ao}	=	79.75	MPa		… 3.4.10
	F_{bx}	=	79.75	MPa		… 3.4.17
	F_{by}	=	79.75	MPa		… 3.4.17
	f_a/F_a	=	0.010			
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$					… 4.1.1 (3)
i.e.,	0.79	≤	1.0		PASS	
SHEAR						
3.4.24 *Shear in webs (Major Axis)*						… 4.1.1(2)
Clear web height	h	=	43	mm		
	t	=	1	mm		
Slenderness	h/t	=	43			
Limit 1	S_1	=	33.38			
Limit 2	S_2	=	59.31			

Factored limit state stress	**ϕF_L**	=	**56.20**	**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	=	43	mm	
	t	=	1	mm	
Slenderness	b/t	=	43		
Factored limit state stress	**ϕF_L**	=	**56.20**	**MPa**	
Stress From Shear force	**f_{sy}**	=	V/A_w		
			1.70	**MPa**	
Most adverse shear capacity factor (Major Axis)	f_{sx}/F_{sx}	=	0.00	**MPa**	
Most adverse shear capacity factor (Minor Axis)	f_{sy}/F_{sy}	=	0.03	**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., 0.79 ≤ 1.0 PASS

7. Summary and conclusions

a. The 2m × 2m Umbrella as specified has been analyzed with a conclusion that it has the capacity to withstand wind speeds up to and including **60km/hr.**

b. For forecast winds in excess of **60km/hr** – the structure should be completely folded.

c. For uplift due to 60km/hr, 0.13 kN (13kg) holding down weight for upright support is required.

d. The bearing pressure of soil should be clarified and checked by an engineer prior to any construction for considering foundation and base plate.

e. Design of fabric is by others.

Yours faithfully,

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