Civil & Structural Engineering Design Services Pty. Ltd.

**Client:** **Extreme Marquees Pty Ltd**
**Project:** Design check – 6m, 8m , 8m , 10m , 12m , 14m & 16m Single Pole Star Shade Structure for 45km/hr Wind Spead

**Reference:** Extreme Marquees Technical Data

Report by: KZ
Checked by: EAB
Date: 31/03/2017

JOB NO: E-11-265260

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# 1 Introduction

This Certification is the sole property for copyright of Mr. Ted Bennett of Civil & Structural Engineering Design Services Pty. Ltd. and the license holder for the exclusive use of this Certification, Extreme Marquees Pty Ltd.

The following structural drawings and calculations are for the applicable transportable tents supplied by Extreme Marquees Pty Ltd.

The report examines the effect of 3s gust wind of 45 km/hr on 16m Single Pole Star Shade 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 Aluminum 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 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.

**2.9 Design of fabric by others.**

**2.10 No Fabrics or doors should be used for covering the sides of unbraced Folding Marquees due to the lack of bracing within the system and insufficient out-of-plane stiffness of framing.**



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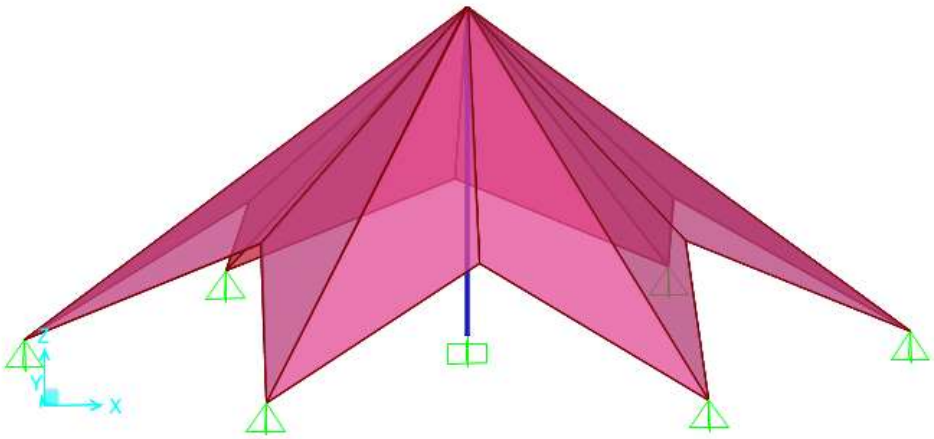
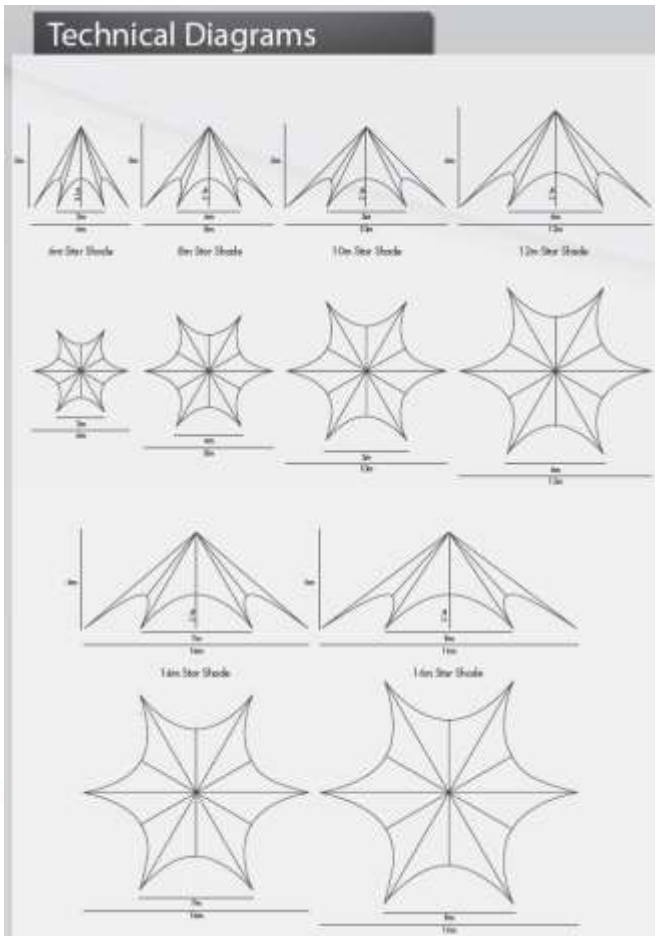
# 3 Specifications

## 3.1 General

| **Tent category** | |
|---|---|
| **Material** | Aluminum 6061T6 |

| **Size** | **Model** |
|---|---|
| **16m** | 16m Single Pole Star Shade |






| Item | Specification | | | | | |
|---|---|---|---|---|---|---|
| Size | 6m | 8m | 10m | 12m | 14m | 16m |
| Height | 5m | 5m | 5m | 6m | 6m | 6m |
| Clearance | 2.1m | 2.1m | 2.1m | 2.1m | 2.1m | 2.1m |
| Centre Pole | Aluminium | | | | | |
| Feet & Pins | Steel | | | | | |
| PVC Fabric | 580GSM Imported Belgian PVC | | | | | |
| Poly Fabric | PVC enforced polyester | | | | | |
| Package includes: | Steel Pins, PVC Transportation Bag | | | | | |
| Engineer Certification | Engineer Structural Certficate, Resistance of Fabrics to Water Penetration Test, Ultra Violet Protection Test, Fire Action Analysis | | | | | |



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### 3.2 Section Properties

| 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* |
| Upright Support | D63x2.5 | 63 | 2.5 | 31.5 | 475.2 | 6913.5 | 6913.5 | 9155.8 | 9155.8 | 217774.5 | 217774.5 | 435548.9 | 21.4 | 21.4 |

## 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 45km/hr gust | W | 0.078 $C_{fig}$ | 1.0 | 0.078 $C_{fig}$ |

### 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 = $0.9 \times G + W_u$

## 5 Wind Analysis

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

### 5.1 Parameters

Terrain category = 2
Site wind speed ($V_{sit,\beta}$) = $V_R M_d (M_{z,cat} M_s M_t)$
$V_R$ = 12.50m/s (45 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)*

$V_{sit,\beta}$ = 11.38 m/s



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Height of structure (h) = 4 m *(mid of peak and eave)*
Width of structure (w) = 16 m
Length of structure (l) = 16 m
Pressure (P) = $0.5\rho_{air}\ (V_{sit,\beta})^2\ C_{fig}\ C_{dyn}$
= $0.078C_{fig}$ 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 | | 45 | Km/hr | | *Table 3.1 (AS1170.2)* |
| Regional gust wind speed | $V_R$ | **12.50** | 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 | $V_{Site,\beta}$ | **11.38** | m/s | $V_{Site,\beta}=V_R*M_d*M_{z,cat}*M_S,M_t$ | |
| Pitch | α | 30 | Deg | | |
| Pitch | α | 0.52 | rad | | |
| Width | B | - | m | | |
| Length | D | - | m | | |
| Height | Z | 4 | m | | |
| ***Wind Pressure*** | | | | | |
| $\rho$air | $\rho$ | 1.2 | $Kg/m^3$ | | |
| dynamic response factor | $C_{dyn}$ | 1 | | | |
| Wind Pressure | $\rho*C_{fig}$ | **0.078** | $Kg/m^2$ | $\rho=0.5\rho_{air}*(V_{des,\beta})^2*C_{fig}*C_{dyn}$ | *2.4 (AS1170.2)* |
| ***WIND DIRECTION 1&2*** | | | | | |
| ***External Pressure*** | | | | | |
| ***4. Free Roof*** | | | | $\alpha=0^o$ | |



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| | | | | | |
|---|---|---|---|---|---|
| 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** | $C_{P,w}$ | 0.8 | | | |
| External Pressure Coefficient **MIN** | $C_{P,l}$ | -0.7 | | | |
| External Pressure Coefficient **MAX** | $C_{P,l}$ | 0 | | | |
| aerodynamic shape factor **MIN** | $C_{fig,w}$ | -0.30 | | | |
| aerodynamic shape factor **MAX** | $C_{fig,w}$ | 0.80 | | | |
| aerodynamic shape factor **MIN** | $C_{fig,l}$ | -0.70 | | | |
| aerodynamic shape factor **MAX** | $C_{fig,l}$ | 0.00 | | | |
| | | | | | |
| Pressure Windward **MIN** | P | **-0.02** | **kPa** | | |
| Pressure Windward **MAX** | P | **0.06** | **kPa** | | |
| Pressure Leeward **MIN** | P | **-0.05** | **kPa** | | |
| Pressure Leeward **MAX** | P | **0.00** | **kPa** | | |



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5.2.1 Pressure summary

| WIND EXTERNAL PRESSURE | Direction1&2 | |
|---|---|---|
| | Min (Kpa) | Max (Kpa) |
| W | -0.02 | 0.06 |
| L | -0.05 | 0.00 |

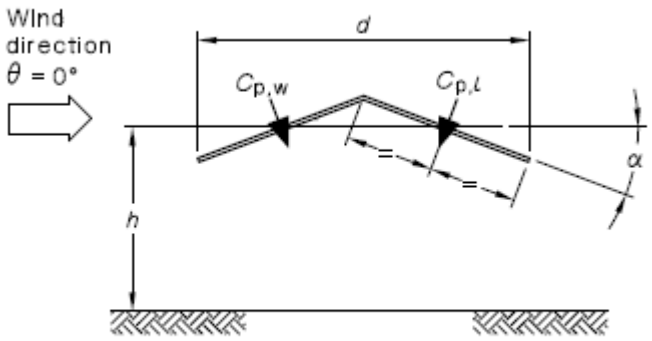
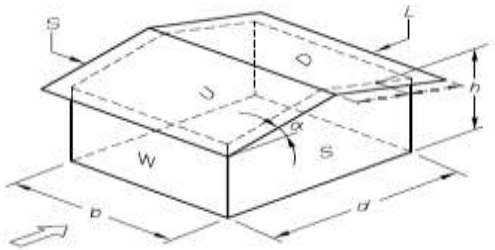
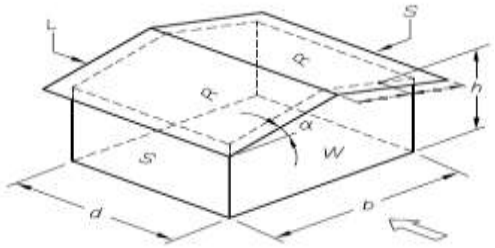



FIGURE D3 PITCHED FREE ROOFS




Direction 1




Direction 2

AS1170.2



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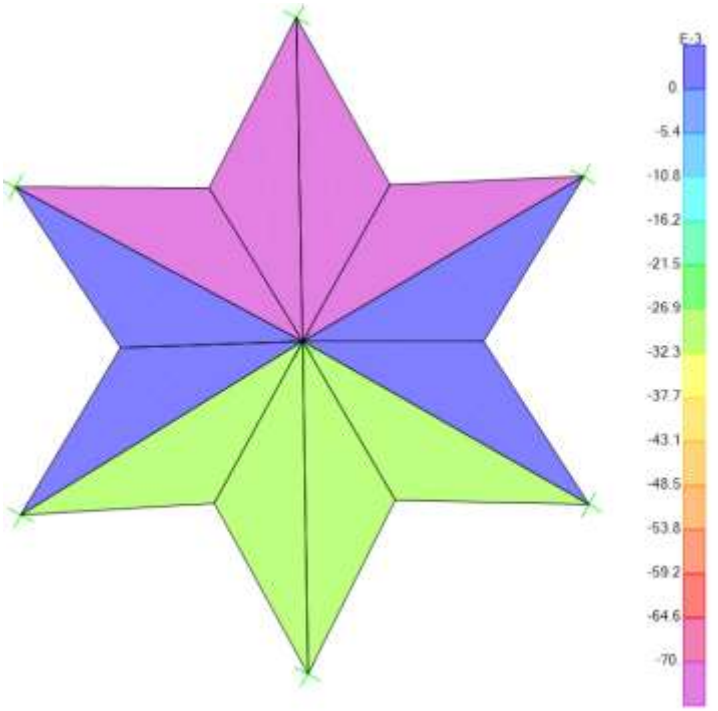
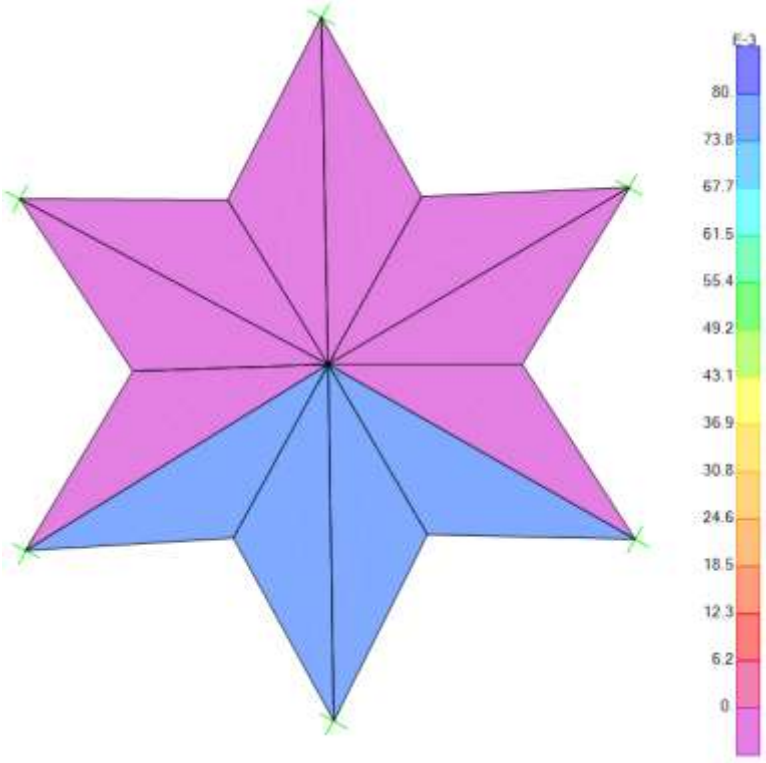
5.3 Wind Load Diagrams

5.3.1 Wind 1(case 1)




5.3.2 Wind 1(case 2)



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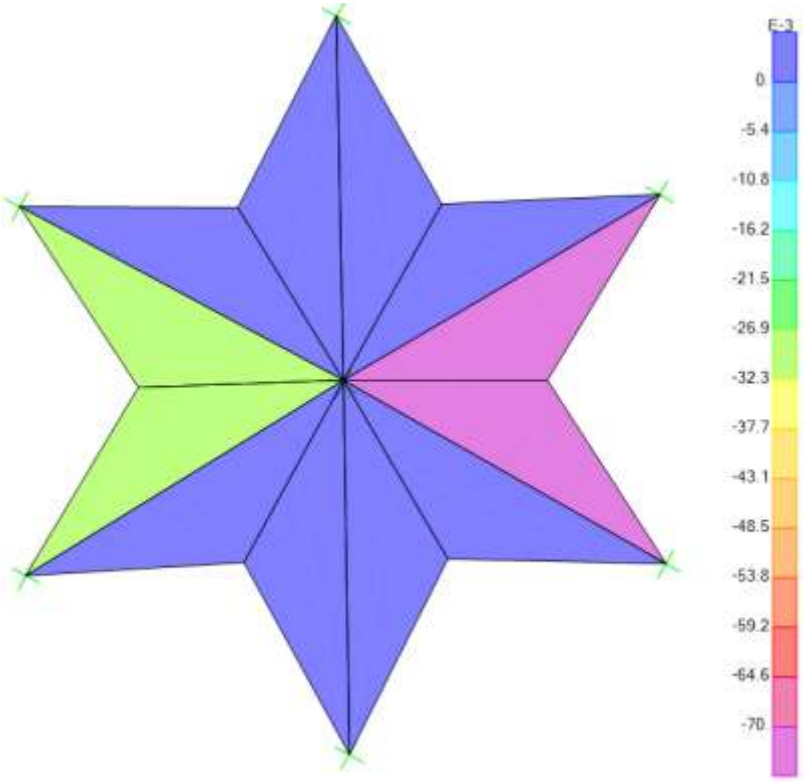
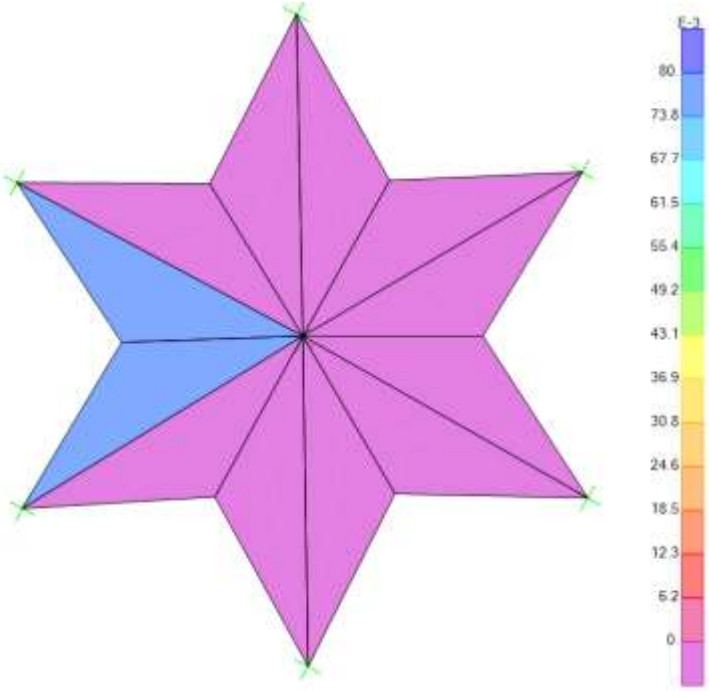
5.3.3 Wind 2(Case1)




5.3.4 Wind 2(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:



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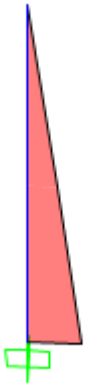
5.3.5 Max Bending Moment due to critical load combination in major axis



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

5.3.7 Max Shear in due to critical load combination



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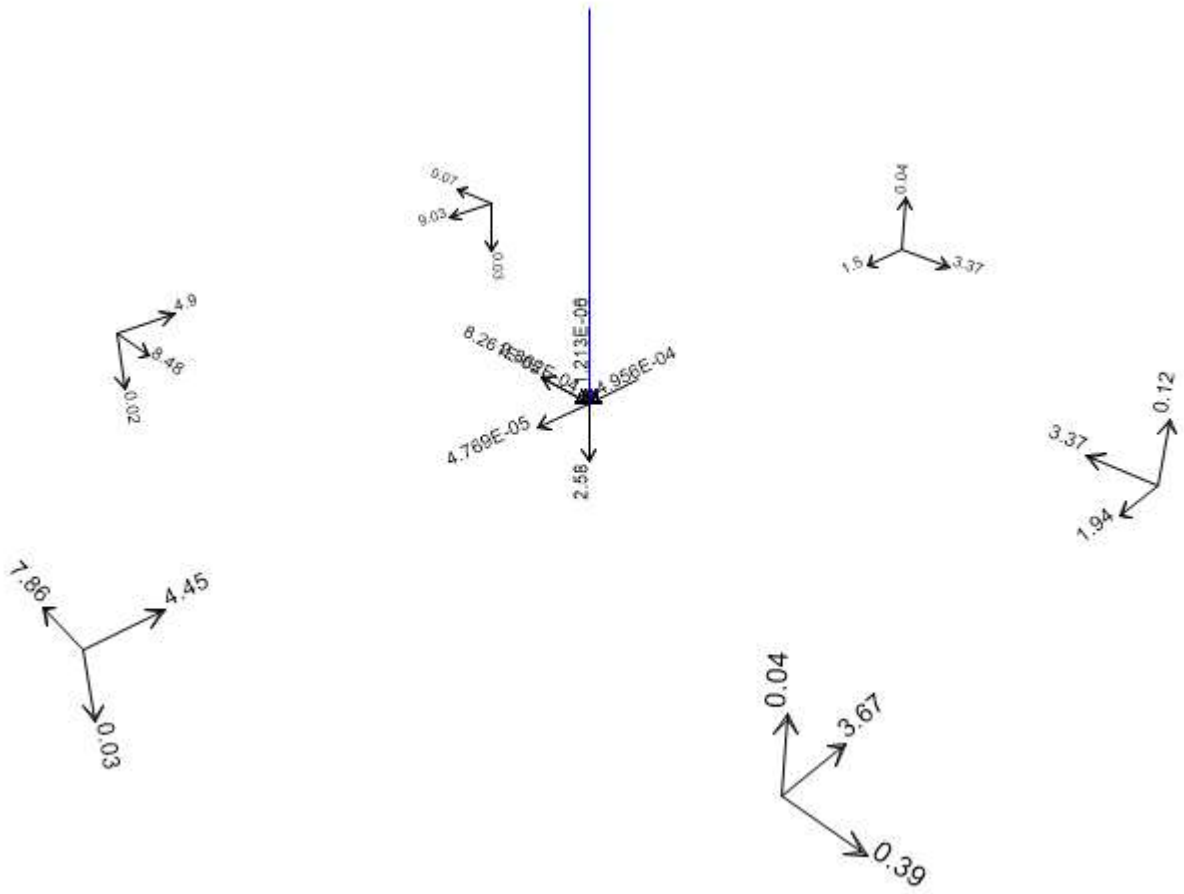
5.3.8 Max Axial force in upright support and roof beam due to critical load combination

5.3.9 Max reactions




Max Reaction N* = 2.6kN



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

## 6.1 Centre Pole

| NAME | SYMBOL | | VALUE | UNIT | NOTES | REF |
|---|---|---|---|---|---|---|
| **D63x2.5** | **Upright Support** | | | | | |
| 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 | = | 3.847 | kN | *compression* | |
| | P | = | 0 | kN | *Tension* | |
| In plane moment | $M_x$ | = | 0.0005723 | kNm | | |
| Out of plane moment | $M_y$ | = | 0.0009913 | kNm | | |
| *DESIGN STRESSES* | | | | | | |
| *Gross cross section area* | $A_g$ | = | 475.16589 | $mm^2$ | | |
| In-plane elastic section modulus | $Z_x$ | = | 6913.4751 | $mm^3$ | | |
| Out-of-plane elastic section mod. | $Z_y$ | = | 6913.4751 | $mm^3$ | | |
| Stress from axial force | $f_a$ | = | $P/A_g$ | | | |
| | | = | **8.10** | **MPa** | *compression* | |
| | | = | **0.00** | **MPa** | *Tension* | |
| Stress from in-plane bending | $f_{bx}$ | = | $M_x/Z_x$ | | | |
| | | = | **0.08** | **MPa** | *compression* | |
| Stress from out-of-plane | $f_{by}$ | = | $M_y/Z_y$ | | | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| bending | | = | **0.14** | **MPa** | *compression* | |
| *Tension* | | | | | | |
| ***3.4.3*** *Tension in round or oval tubes* | | | | | | 3.4.3 |
| | **$\phi F_L$** | = | **267.87** | **MPa** | | |
| | | **OR** | | | | |
| | **$\phi F_L$** | = | **276.15** | **MPa** | | |
| *COMPRESSION* | | | | | | |
| ***3.4.8*** *Compression in columns, axial, gross section* | | | | | | |
| *1. General* | | | | | | 3.4.8.1 |
| Unsupported length of member | L | = | 6000 | mm | | |
| Effective length factor | k | = | 1 | | | |
| Radius of gyration about buckling axis (Y) | $r_y$ | = | 21.41 | mm | | |
| Radius of gyration about buckling axis (X) | $r_x$ | = | 21.41 | mm | | |
| Slenderness ratio | kLb/ry | = | 280.27 | | | |
| Slenderness ratio | kL/rx | = | 280.27 | | | |
| Slenderness parameter | λ | = | 5.23 | | | |
| | $D_c$* | = | 90.3 | | | |
| | $S_1$* | = | 0.33 | | | |
| | $S_2$* | = | 1.23 | | | |
| | $\phi_{cc}$ | = | 0.950 | | | |
| Factored limit state stress | **$\phi F_L$** | **=** | **8.36** | **MPa** | | |
| *2. Sections not subject to torsional or torsional-flexural buckling* | | | | | | 3.4.8.2 |
| Largest slenderness ratio for flexural buckling | kL/r | **=** | 280.27 | | | |
| ***3.4.11*** *Uniform compression in components of columns, gross section* | | | | | | |
| *Uniform compression in components of columns, gross section - curved plates with both edges, walls of round or oval tube* | | | | | | 3.4.11<br>T3.3(D) |
| mid-thickness radius of round tubular column or maximum mid-thickness radius | $R_m$ | = | 30.25 | | | |
| | t | **=** | 2.5 | mm | | |
| Slenderness | $R_m/t$ | **=** | 12.1 | | | |
| Limit 1 | $S_1$ | **=** | 0.24 | | | |
| Limit 2 | $S_2$ | **=** | 672.46 | | | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| Factored limit state stress | **$\phi F_L$** | **=** | **221.14** | **MPa** | | |
| Most adverse compressive limit state stress | $F_a$ | **=** | 8.36 | MPa | | |
| Most adverse tensile limit state stress | $F_a$ | **=** | 267.87 | MPa | | |
| Most adverse compressive & Tensile capacity factor | $f_a/F_a$ | **=** | 0.97 | | PASS | |
| *BENDING - IN-PLANE* | | | | | | |
| ***3.4.13*** *Compression in beams, extreme fibre, gross section round or oval tubes* | | | | | | |
| Unbraced length for bending | $L_b$ | = | 6000 | mm | | |
| Second moment of area (weak axis) | $I_y$ | = | 2.18E+05 | $mm^4$ | | |
| Torsion modulus | J | = | 4.36E+05 | $mm^3$ | | |
| Elastic section modulus | Z | = | 6913.4751 | $mm^3$ | | |
| | $R_b/t$ | = | 12.10 | | | |
| Limit 1 | $S_1$ | = | 44.07 | | | |
| Limit 2 | $S_2$ | = | 78.23 | | | |
| Factored limit state stress | **$\phi F_L$** | = | **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 | $R_b$ | **=** | 30.25 | mm | | |
| | t | **=** | 2.5 | mm | | |
| Slenderness | $R_b/t$ | **=** | 12.1 | | | |
| Limit 1 | $S_1$ | = | 2.75 | | | |
| Limit 2 | $S_2$ | = | 78.23 | | | |
| Factored limit state stress | **$\phi F_L$** | = | **221.14** | **MPa** | | |
| Most adverse in-plane bending limit state stress | $F_{bx}$ | = | 221.14 | 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, $\phi F_L$ are the same for out-of-plane bending (doubly symmetric section)* | | | | | | |
| Factored limit state stress | $\phi F_L$ | = | **221.14** | **MPa** | | |
| Most adverse out-of-plane bending limit state stress | $F_{by}$ | = | 221.14 | 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 |
| | $F_a$ | = | 8.36 | MPa | | 3.4.11 |
| | $F_{ao}$ | = | 221.14 | MPa | | 3.4.11 |
| | $F_{bx}$ | = | 221.14 | MPa | | 3.4.18 |
| | $F_{by}$ | = | 221.14 | MPa | | 3.4.18 |
| | $f_a/F_a$ | = | 0.969 | | | |
| Check: | $f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \le 1.0$ | | | | | 4.1.1 |
| i.e. | 0.97 | ≤ | 1.0 | | PASS | |
| SHEAR | | | | | | |
| ***3.4.24*** *Shear in webs (Major Axis)* | | | | | | 3.4.24 |
| | R | = | 31.5 | mm | | |
| | t | = | 2.5 | mm | | |
| Equivalent h/t | h/t | = | 52.49 | | | |
| Limit 1 | $S_1$ | = | 29.01 | | | |
| Limit 2 | $S_2$ | = | 59.31 | | | |
| Factored limit state stress | $\phi F_L$ | = | **107.33** | **MPa** | | |
| Stress From Shear force | $f_{sx}$ | = | $V/A_w$ | | | |
| | | | **0.00** | **MPa** | | |
| ***3.4.25*** *Shear in webs (Minor Axis)* | | | | | | 3.4.25 |
| Clear web height | R | = | 31.5 | mm | | |
| | t | = | 2.5 | mm | | |
| Equivalent h/t | h/t | = | 52.49 | | | |
| Factored limit state stress | $\phi F_L$ | = | **107.33** | **MPa** | | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| Stress From Shear force | $f_{sy}$ | = | $V/A_w$ | | | |
| | | | **0.00** | **MPa** | | |

# 7 Summary

## 7.1 Conclusions

a. The 16m Single Pole Star Shade Structure as specified has been analyzed with a conclusion that it has the capacity to withstand wind speeds up to and including **45km/hr.**
b. For forecast winds in excess of **45km/hr** – the structure should be completely dismantled.
c. For uplift due to 45km/hr, 3 kN (300kg) holding down weight for centre pole is required.
d. For resisting against lateral force due to 45km/hr, corner pegs are required provide 13kN lateral resistance.
e. The bearing pressure of soil should be clarified and checked by an engineer prior to any construction for considering foundation and base plate.
f. **No Fabrics or doors should be used for covering the sides of unbraced Folding Marquees due to the lack of bracing within the system and insufficient out-of-plane stiffness of framing.**
**g. Design of fabric by others**

Yours faithfully,

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