# Civil & Structural Engineering Design Services Pty. Ltd.

**Client:** **Flare Shade**

**Project:** Design check – 4m x 4m, 4m x 5m & 5m x 5m Square Umbrella Structures for 60 km/hr Wind Speed

**Reference:** Flare Shade Technical Data.

Report by: KZ
Checked by: EAB
Date: 12/02/2021
Amendment: B-12/03/2021

JOB NO: D-11-268571-1B

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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, Flare Shade.

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 5m Square 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 umbrella 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.



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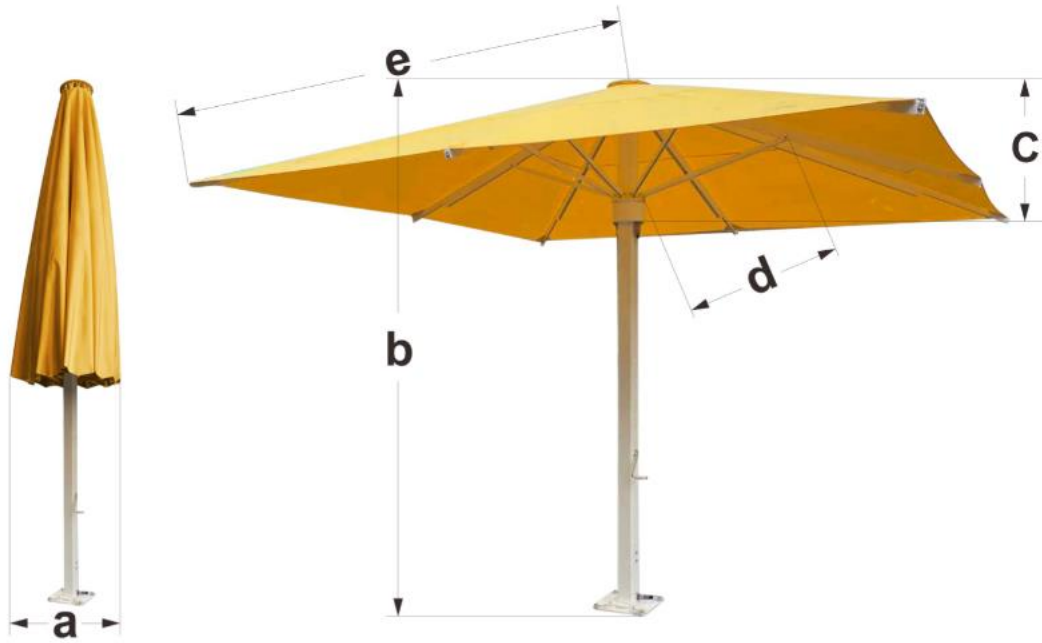
# 3 Specifications

## 3.1 General

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

| Size | Model |
|---|---|
| **5m** | Square Umbrella |




| | RD | | | | SQ | | |
|---|---|---|---|---|---|---|---|
| | Φ4m | Φ5m | Φ6m | Φ7m | 4X4m | 4x5m | 5x5m |
| a | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| b | 3250 | 3250 | 3250 | 3250 | 3250 | 3250 | 3250 |
| c | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 | 1100 |
| d | 880 | 976 | 1190 | 1548 | 2815 | 3180 | 3490 |
| e | 1990 | 2505 | 2980 | 3500 | 2030 | 2030/2500 | 2620 |



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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* |
| 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 Rib1 | 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 |
| Long Rib2 | 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 1 | 30X20X2 | 20 | 30 | 2 | 15.0 | 184.0 | 1437.7 | 1112.5 | 1796.0 | 1336.0 | 21565.3 | 11125.3 | 22088.3 | 10.8 | 7.8 |
| Short Rib 2 | 30X20X2 | 20 | 30 | 2 | 15.0 | 184.0 | 1437.7 | 1112.5 | 1796.0 | 1336.0 | 21565.3 | 11125.3 | 22088.3 | 10.8 | 7.8 |

## 3.3 Buckling Constant

**TABLE 3.3(D)**
**BUCKLING CONSTANTS FOR ALLOY 6061-T6**

| Type of member and stress | Intercept, MPa | | Slope, MPa | | Intersection | |
|---|---|---|---|---|---|---|
| Compression in columns and beam flanges | $B_c$ | 271.04 | $D_c$ | 1.69 | $C_c$ | 65.89 |
| Compression in flat plates | $B_p$ | 310.11 | Dp | 2.06 | $C_p$ | 61.60 |
| Compression in round tubes under axial end load | $B_t$ | 297.39 | $D_t$ | 10.70 | $C_t$ | * |
| Compressive bending stress in rectangular bars | $B_{br}$ | 459.89 | $D_{br}$ | 4.57 | $C_{br}$ | 67.16 |
| Compressive bending stress in round tubes | $B_{tb}$ | 653.34 | $D_{tb}$ | 50.95 | $C_{tb}$ | 78.23 |
| Shear stress in flat plates | $B_s$ | 178.29 | $D_s$ | 0.90 | $C_s$ | 81.24 |
| Ultimate strength of flat plates in compression | $k_1$ | 0.35 | $k_2$ | 2.27 | | |
| Ultimate strength of flat plates in bending | $k_1$ | 0.5 | $k_2$ | 2.04 | | |

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



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# 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 = $1.35 \times G$
= $1.2 \times G + W_u$

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 ($V_{sit,\beta}$) = $V_R M_d (M_{z,cat} M_s M_t)$
$V_R$ = 16.67m/s (60 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)*

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

Height of structure (h) = 2.7 m *(mid of peak and eave)*
Width of structure (w) = 5 m
Length of structure (l) = 5 m
Pressure (P) = $0.5\rho_{air} (V_{sit,\beta})^2 C_{fig} C_{dyn}$
= $0.138 C_{fig}$ kPa



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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 | $M_{Z,Cat}$ | 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 | 24 | Deg | | |
| Pitch | α | 0.42 | rad | | |
| Width | B | 5 | m | | |
| Length | D | 5 | m | | |
| Height | Z | 2.7 | m | | |
| | | ***Wind Pressure*** | | | |
| $\rho$air | $\rho$ | 1.2 | $Kg/m^3$ | | |
| dynamic response factor | $C_{dyn}$ | 1 | | | |
| Wind Pressure | $\rho*C_{fig}$ | **0.138** | $Kg/m^2$ | $p=0.5\rho_{air}*(V_{des,\beta})^2*C_{fig}*C_{dyn}$ | *2.4 (AS1170.2)* |
| | | ***WIND DIRECTION 1 (θ=0)*** ***External Pressure*** | | | |
| ***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 | $C_{P,w}$ | -0.3 | | | |



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| | | | | | |
|---|---|---|---|---|---|
| **MIN** | | | | | |
| 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° | *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** | | |



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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 |

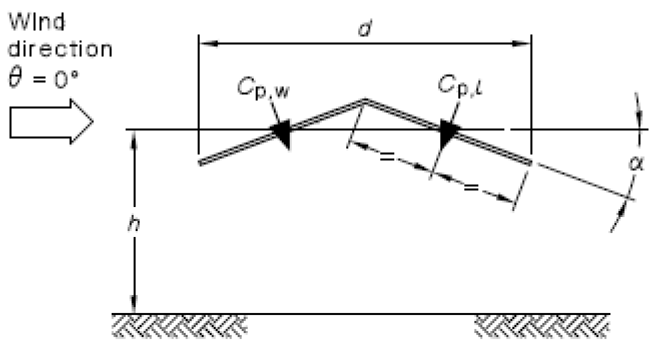


FIGURE D3 PITCHED FREE ROOFS

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*** | | | | | |
| $\rho$air | $\rho$ | 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 x 0.5 = 0.225kN/m**



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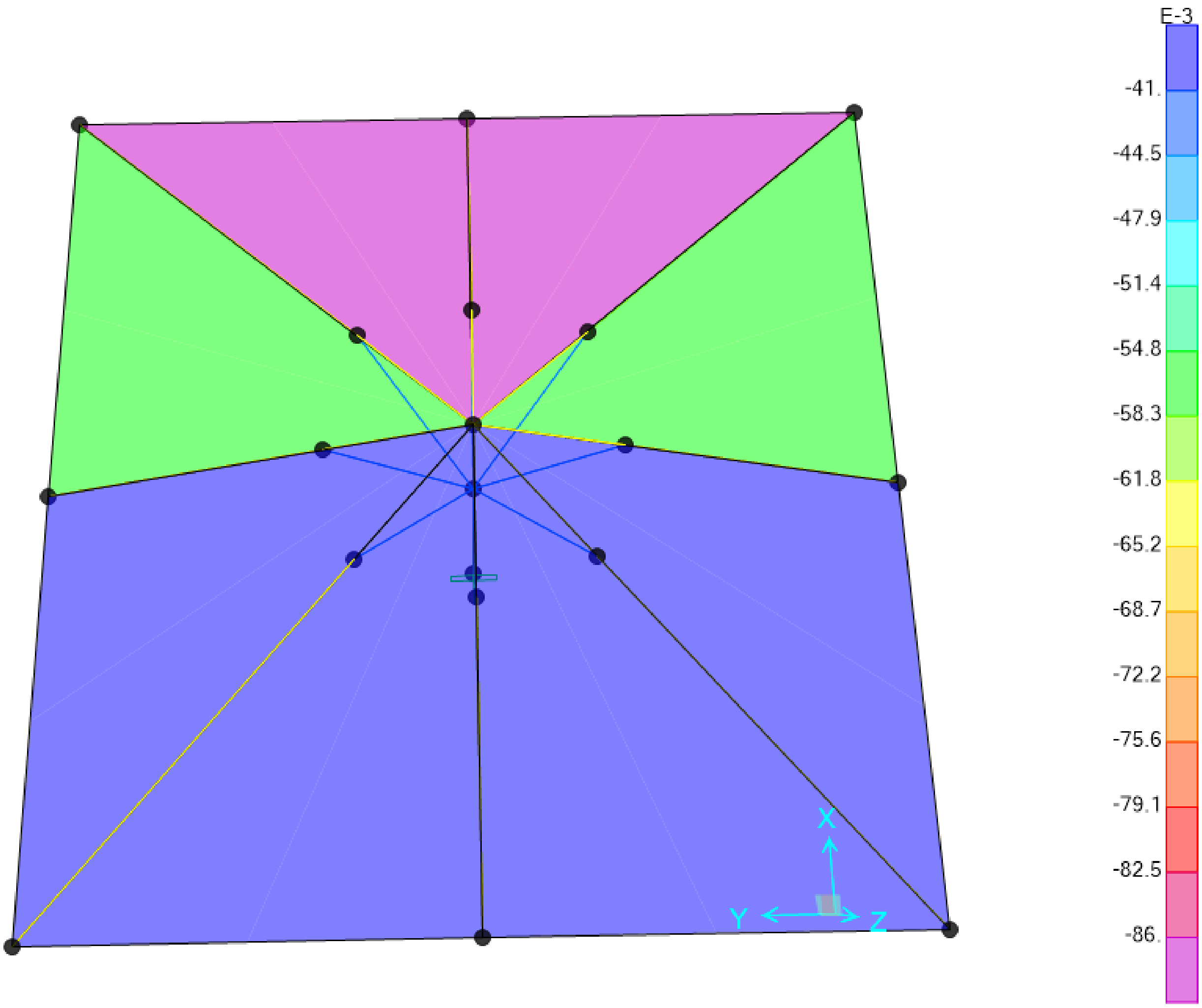
## 5.4 Wind Load Diagrams

### 5.4.1 Wind (min)_Open



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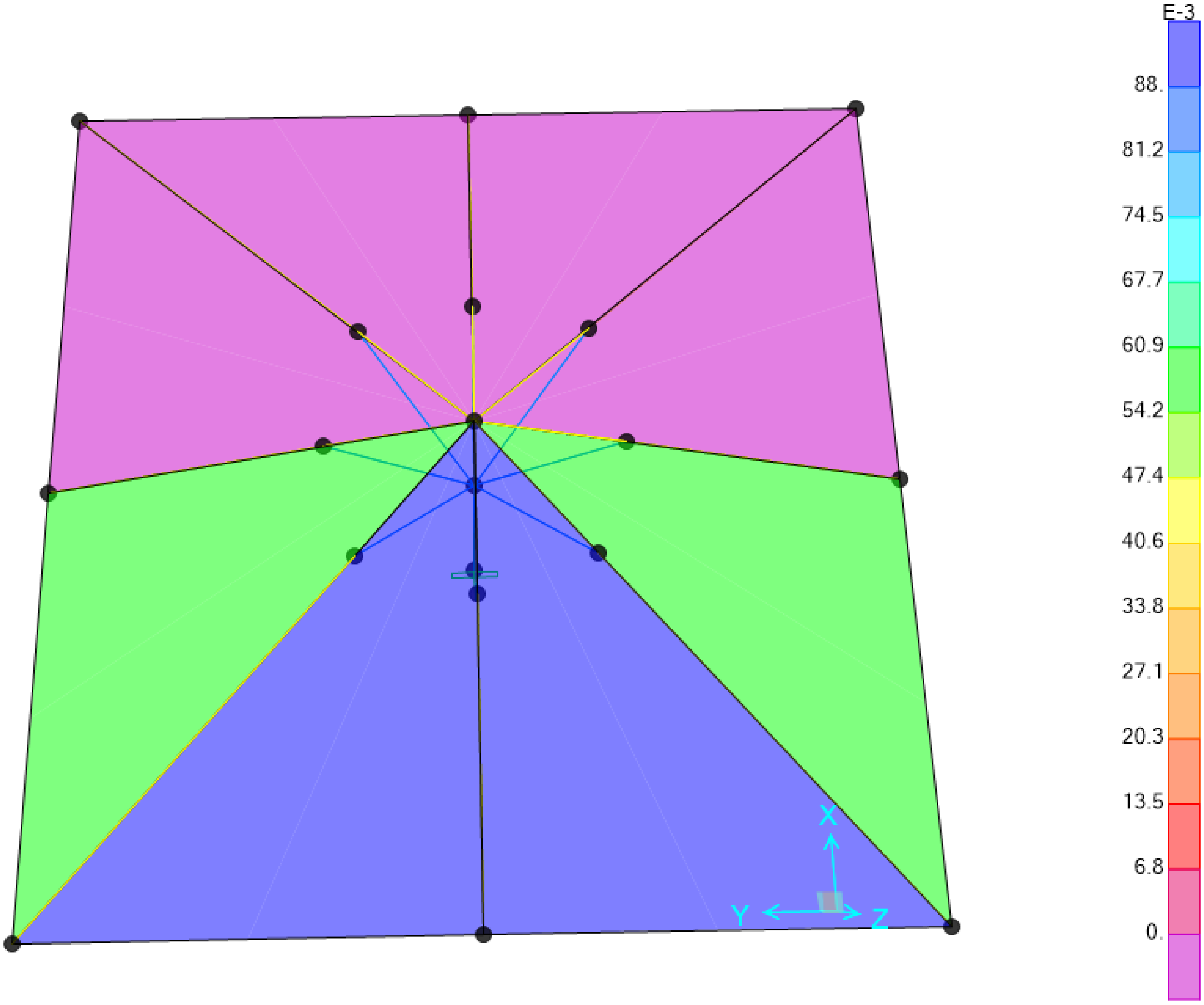
5.4.2 Wind (max)_Open



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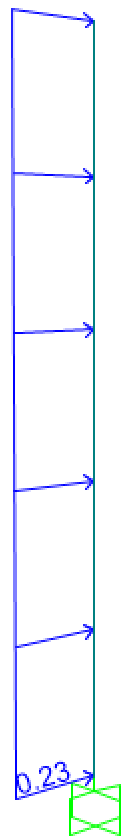
5.4.3 Wind _Closed




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:



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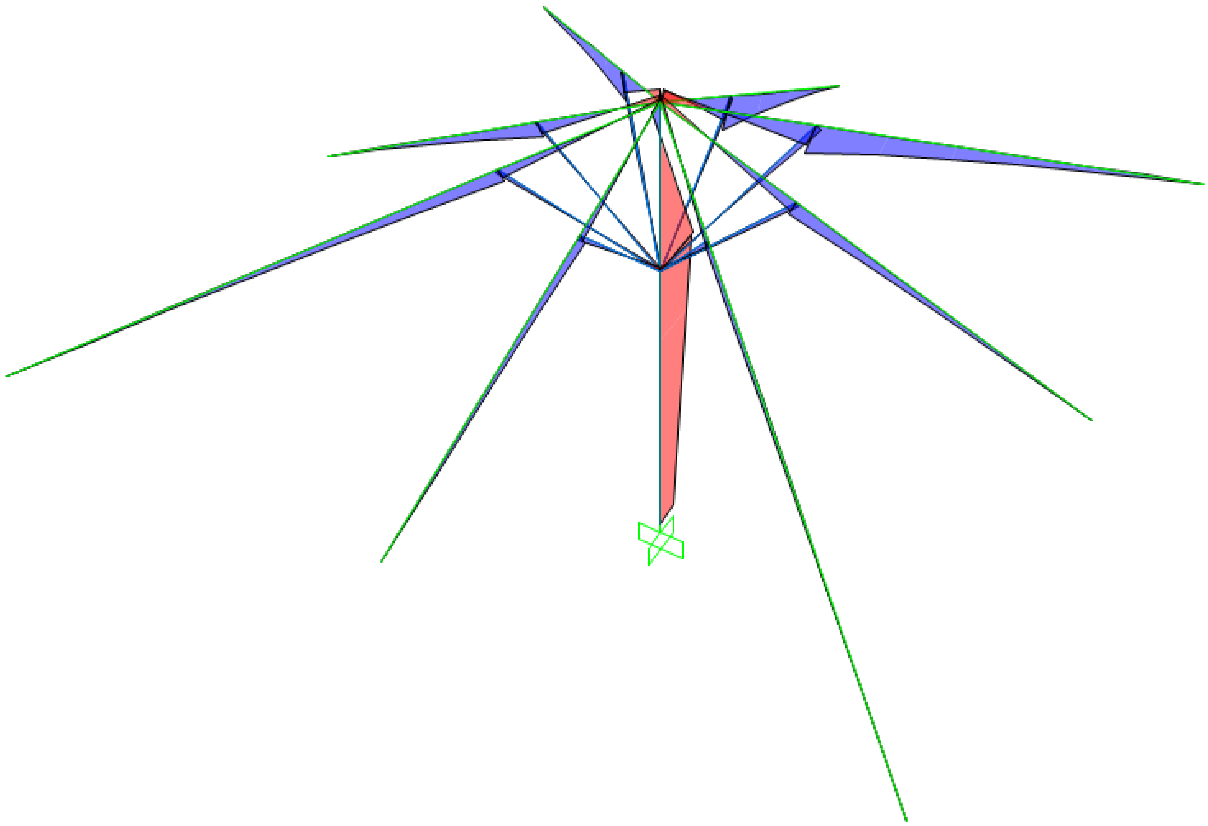
5.4.4 Max Bending Moment due to critical load combination in major axis





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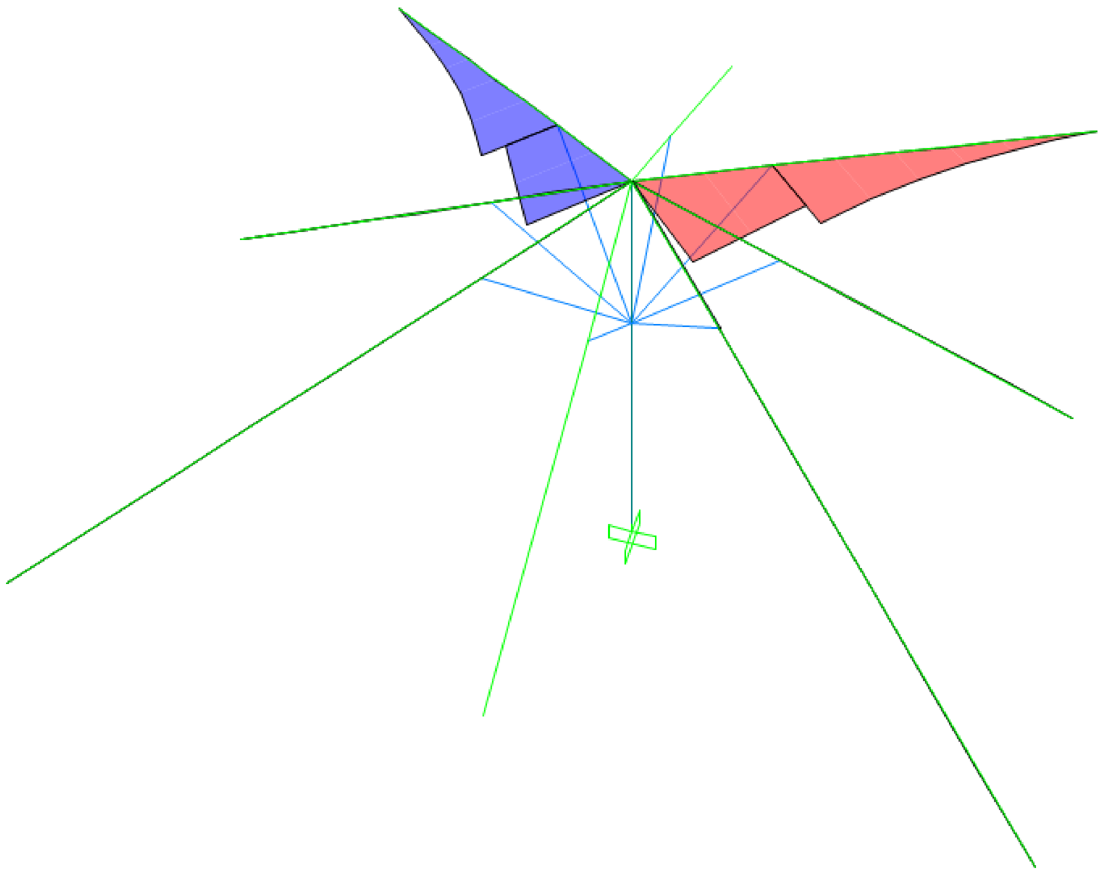
5.4.5 Max Bending Moment in minor axis due to critical load combination





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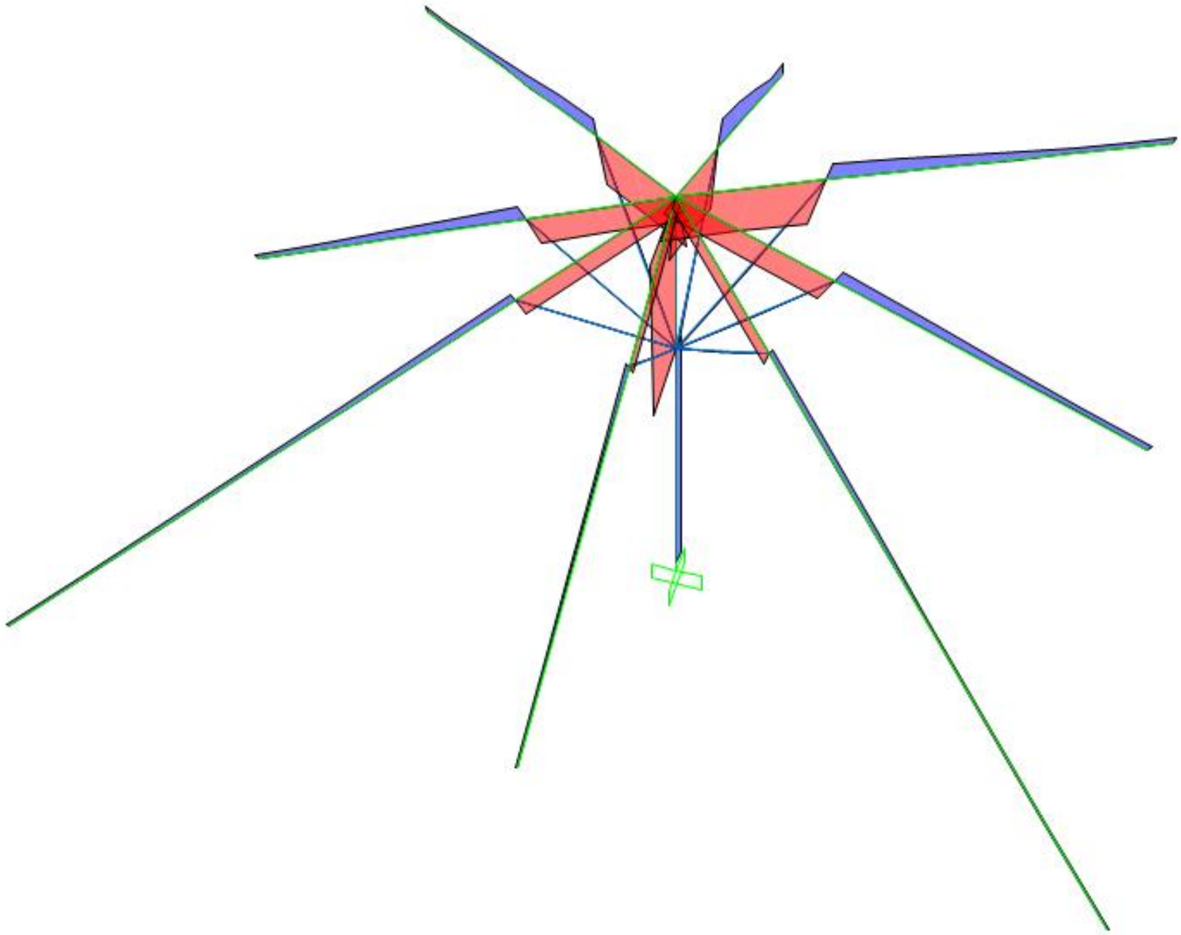
5.4.6 Max Shear in due to critical load combination





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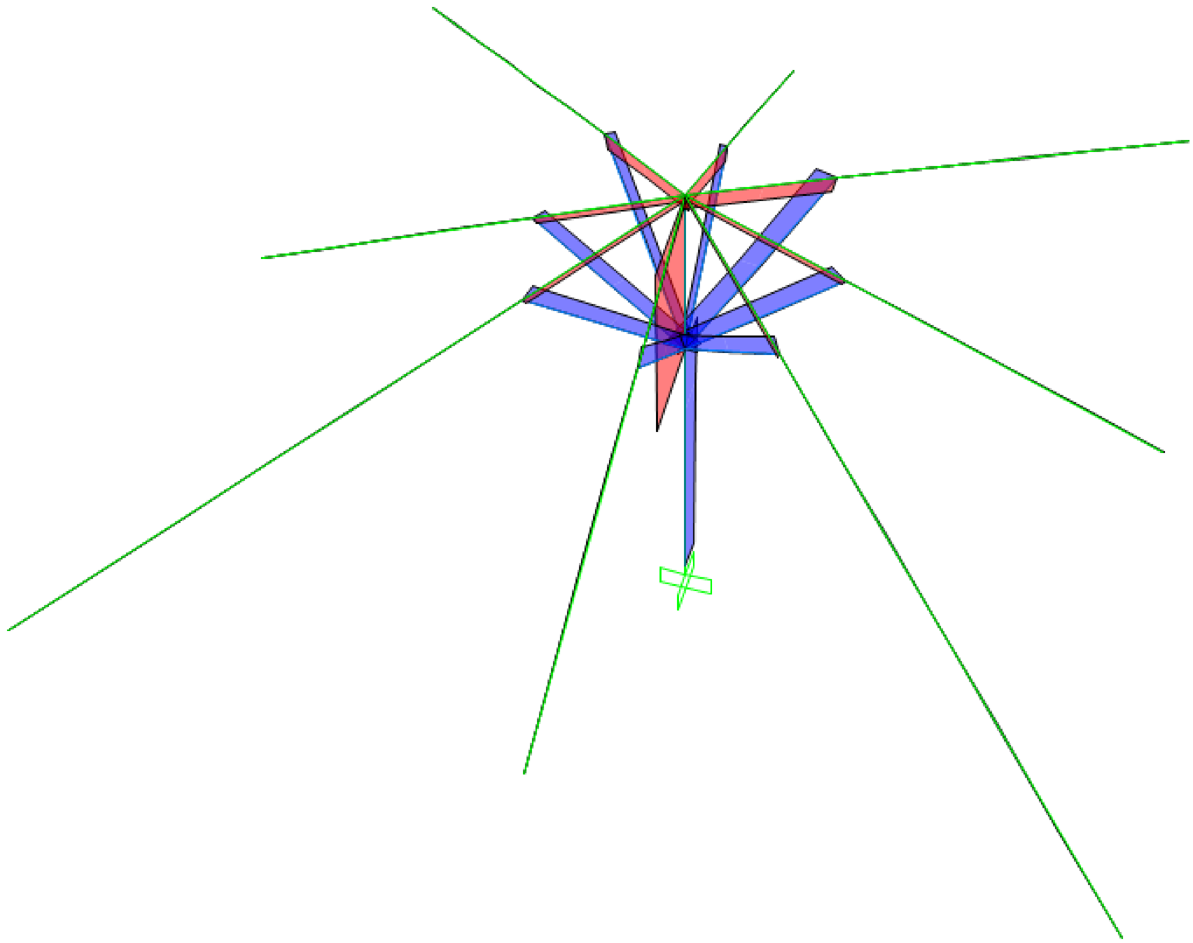
5.4.7 Max Axial force in upright support and roof beam due to critical load combination





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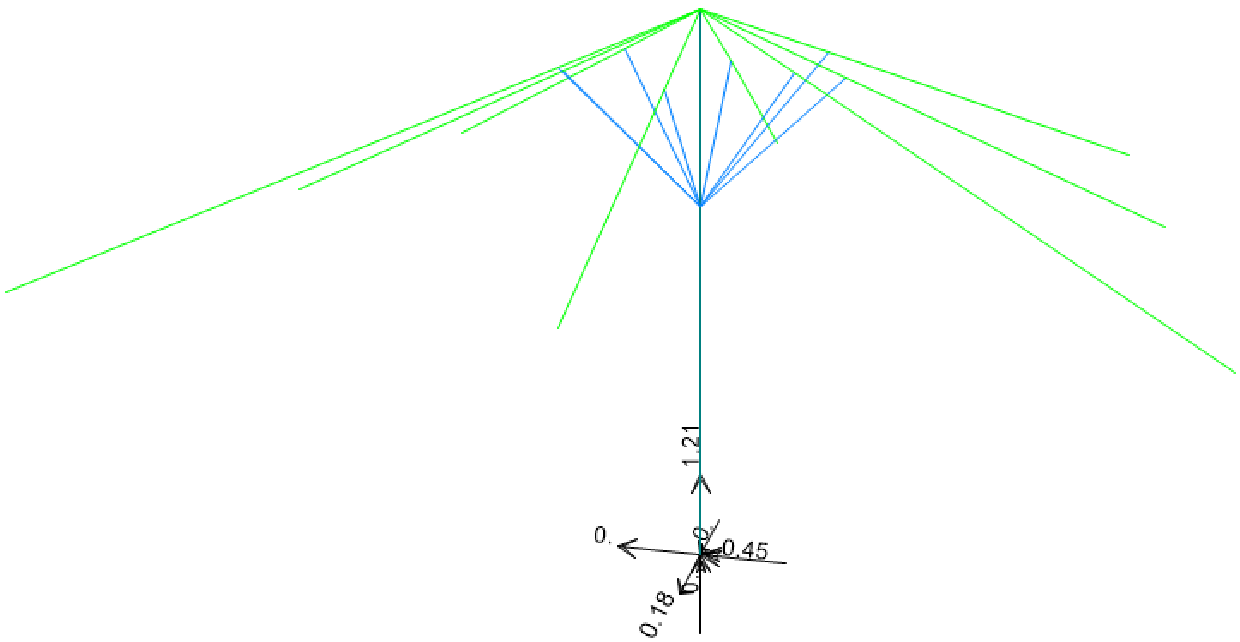
5.4.8 Max reactions




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



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# 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 | = | 1.52 | kN | *compression* | |
| | P | = | 0 | kN | *Tension* | |
| In plane moment | $M_x$ | = | 1.133 | kNm | | |
| Out of plane moment | $M_y$ | = | 4.145E-14 | kNm | | |
| *DESIGN STRESSES* | | | | | | |
| *Gross cross section area* | $A_g$ | **=** | 1577.16 | $mm^2$ | | |
| In-plane elastic section modulus | $Z_x$ | **=** | 51252.293 | $mm^3$ | | |
| Out-of-plane elastic section mod. | $Z_y$ | **=** | 51252.293 | $mm^3$ | | |
| Stress from axial force | $\mathbf{f_a}$ | **=** | $P/A_g$ | | | |
| | | **=** | **0.96** | **MPa** | *compression* | |
| | | **=** | **0.00** | **MPa** | *Tension* | |
| Stress from in-plane bending | $\mathbf{f_{bx}}$ | **=** | $M_x/Z_x$ | | | |
| | | **=** | **22.11** | **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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| | | | | | |
|---|---|---|---|---|---|
| | **$\phi F_L$** | **=** | **228.95** | **MPa** | |
| | | **OR** | | | |
| | **$\phi F_L$** | **=** | **222.70** | **MPa** | |
| *COMPRESSION* | | | | | |
| ***3.4.8** Compression in columns, axial, gross section* | | | | | |
| *1. General* | | | | | … 3.4.8.1 |
| Unsupported length of member | L | = | 3250 | 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/ry | = | 52.05 | | |
| Slenderness ratio | kL/rx | = | 78.68 | | |
| Slenderness parameter | λ | = | 1.470 | | |
| | $D_c$* | = | 90.3 | | |
| | $S_1$* | = | 0.33 | | |
| | $S_2$* | = | 1.23 | | |
| | $\phi_{cc}$ | = | 0.786 | | |
| Factored limit state stress | **$\phi F_L$** | **=** | **87.68** | **MPa** | |
| *2. Sections not subject to torsional or torsional-flexural buckling* | | | | | … 3.4.8.2 |
| Largest slenderness ratio for flexural buckling | kL/r | **=** | 78.68 | | |
| ***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' | **=** | 97.2 | | |
| | t | **=** | 3.9 | mm | |
| Slenderness | b/t | **=** | 24.923077 | | |
| Limit 1 | $S_1$ | **=** | 12.34 | | |
| Limit 2 | $S_2$ | **=** | 32.87 | | |
| Factored limit state stress | **$\phi F_L$** | **=** | **193.63** | **MPa** | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| Most adverse compressive limit state stress | $F_a$ | = | 87.68 | 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 | $L_b$ | = | 2150 | 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 3 | $mm^3$ | | |
| Slenderness | S | = | 66.92 | | | |
| Limit 1 | $S_1$ | = | 0.39 | | | |
| Limit 2 | $S_2$ | = | 1695.86 | | | |
| Factored limit state stress | **$\phi F_L$** | = | **211.62** | **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 7 | | | |
| Limit 1 | $S_1$ | = | 12.34 | | | |
| Limit 2 | $S_2$ | = | 46.95 | | | |
| Factored limit state stress | **$\phi F_L$** | = | **193.63** | **MPa** | | |
| Most adverse in-plane bending limit state stress | $F_{bx}$ | = | 193.63 | MPa | | |
| Most adverse in-plane bending capacity factor | $f_{bx}/F_{bx}$ | = | 0.11 | | PASS | |
| *BENDING - OUT-OF-PLANE* | | | | | | |
| *NOTE: Limit state stresses, $\phi F_L$ are the same for out-of-plane bending (doubly symmetric section)* | | | | | | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| Factored limit state stress | **$\phi F_L$** | = | **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 | **$f_{by}/F_{by}$** | **=** | 0.00 | | PASS | |
| COMBINED ACTIONS | | | | | | |
| ***4.1.1** Combined compression and bending* | | | | | | … 4.1.1(2) |
| | $F_a$ | = | 87.68 | MPa | | … 3.4.8 |
| | $F_{ao}$ | = | 193.63 | MPa | | … 3.4.10 |
| | $F_{bx}$ | = | 193.63 | MPa | | … 3.4.17 |
| | $F_{by}$ | = | 193.63 | MPa | | … 3.4.17 |
| | $f_a/F_a$ | = | 0.011 | | | |
| Check: | $f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$ | | | | | … 4.1.1 (3) |
| i.e. | 0.13 | ≤ | 1.0 | | PASS | |
| SHEAR | | | | | | |
| ***3.4.24** Shear in webs (Major Axis)* | | | | | | … 4.1.1(2) |
| Clear web height | h | **=** | 97.2 | mm | | |
| | t | **=** | 3.9 | mm | | |
| Slenderness | h/t | **=** | 24.92307 7 | | | |
| Limit 1 | $S_1$ | **=** | 29.01 | | | |
| Limit 2 | $S_2$ | **=** | 59.31 | | | |
| Factored limit state stress | **$\phi F_L$** | **=** | **131.10** | **MPa** | | |
| Stress From Shear force | **$f_{sx}$** | **=** | $V/A_w$ | | | |
| | | | **0.18** | **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 | **$\phi F_L$** | **=** | **131.10** | **MPa** | | |
| Stress From Shear force | **$f_{sy}$** | **=** | $V/A_w$ | | | |



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| | | | | | |
|---|---|---|---|---|---|
| | | **0.00** | **MPa** | | |

6.2 Long Rib1

| NAME | SYMBOL | | VALUE | UNIT | NOTES | REF |
|---|---|---|---|---|---|---|
| **40x20x2+35x30x3** | **Long Rib1** | | | | | |
| 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 | = | 0.568 | kN | *Tension* | |
| In plane moment | $M_x$ | = | 0.4338 | kNm | | |
| Out of plane moment | $M_y$ | = | 0.0214 | 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 | $\mathbf{f_a}$ | **=** | $P/A_g$ | | | |
| | | **=** | **0.00** | **MPa** | *compression* | |
| | | **=** | **1.56** | **MPa** | *Tension* | |
| Stress from in-plane bending | $\mathbf{f_{bx}}$ | **=** | $M_x/Z_x$ | | | |
| | | **=** | **86.16** | **MPa** | *compression* | |
| Stress from out-of-plane bending | $\mathbf{f_{by}}$ | **=** | $M_y/Z_y$ | | | |
| | | **=** | **5.98** | **MPa** | *compression* | |
| *Tension* | | | | | | |
| ***3.4.3** Tension in rectangular tubes* | | | | | | |



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| | | | | | |
|---|---|---|---|---|---|
| | **$\phi F_L$** | **=** | **228.95** | **MPa** | |
| | | **OR** | | | |
| | **$\phi F_L$** | **=** | **222.70** | **MPa** | |
| *COMPRESSION* | | | | | |
| ***3.4.8** Compression in columns, axial, gross section* | | | | | |
| *1. General* | | | | | … 3.4.8.1 |
| Unsupported length of member | L | = | 3700 | 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 | = | 231.61 | | |
| Slenderness ratio | kL/rx | = | 181.37 | | |
| Slenderness parameter | λ | = | 4.33 | | |
| | $D_c$* | = | 90.3 | | |
| | $S_1$* | = | 0.33 | | |
| | $S_2$* | = | 1.23 | | |
| | $\phi_{cc}$ | = | 0.950 | | |
| Factored limit state stress | **$\phi F_L$** | **=** | **12.23** | **MPa** | |
| *2. Sections not subject to torsional or torsional-flexural buckling* | | | | | … 3.4.8.2 |
| Largest slenderness ratio for flexural buckling | kL/r | = | 231.61 | | |
| ***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' | = | 16 | | |
| | t | = | 2 | mm | |
| Slenderness | b/t | = | 8 | | |
| Limit 1 | $S_1$ | = | 12.34 | | |
| Limit 2 | $S_2$ | = | 32.87 | | |
| Factored limit state stress | **$\phi F_L$** | **=** | **228.95** | **MPa** | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| Most adverse compressive limit state stress | $F_a$ | = | 12.23 | 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 | $L_b$ | = | 2784 | 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 | = | 574.19 | | | |
| Limit 1 | $S_1$ | = | 0.39 | | | |
| Limit 2 | $S_2$ | = | 1695.86 | | | |
| Factored limit state stress | **$\phi F_L$** | = | **175.42** | **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 | **$\phi F_L$** | = | **228.95** | **MPa** | | |
| Most adverse in-plane bending limit state stress | $F_{bx}$ | = | 175.42 | MPa | | |
| Most adverse in-plane bending capacity factor | $f_{bx}/F_{bx}$ | = | 0.49 | | PASS | |
| *BENDING - OUT-OF-PLANE* | | | | | | |
| *NOTE: Limit state stresses, $\phi F_L$ are the same for out-of-plane bending (doubly symmetric section)* | | | | | | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| Factored limit state stress | **$\phi F_L$** | = | **175.42** | **MPa** | | |
| Most adverse out-of-plane bending limit state stress | **$F_{by}$** | = | 175.42 | MPa | | |
| Most adverse out-of-plane bending capacity factor | **$f_{by}/F_{by}$** | = | 0.03 | | PASS | |
| COMBINED ACTIONS | | | | | | |
| ***4.1.1** Combined compression and bending* | | | | | | … 4.1.1(2) |
| | $F_a$ | = | 12.23 | MPa | | … 3.4.8 |
| | $F_{ao}$ | = | 228.95 | MPa | | … 3.4.10 |
| | $F_{bx}$ | = | 175.42 | MPa | | … 3.4.17 |
| | $F_{by}$ | = | 175.42 | MPa | | … 3.4.17 |
| | $f_a/F_a$ | = | 0.007 | | | |
| Check: | $f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$ | | | | | … 4.1.1 (3) |
| i.e. | 0.53 | ≤ | 1.0 | | PASS | |
| SHEAR | | | | | | |
| ***3.4.24** Shear in webs (Major Axis)* | | | | | | … 4.1.1(2) |
| Clear web height | h | = | 71 | mm | | |
| | t | = | 2 | mm | | |
| Slenderness | h/t | = | 35.5 | | | |
| Limit 1 | $S_1$ | = | 29.01 | | | |
| Limit 2 | $S_2$ | = | 59.31 | | | |
| Factored limit state stress | **$\phi F_L$** | = | **124.53** | **MPa** | | |
| Stress From Shear force | **$f_{sx}$** | = | $V/A_w$ | | | |
| | | | **0.80** | **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 | **$\phi F_L$** | = | **131.10** | **MPa** | | |
| Stress From Shear force | **$f_{sy}$** | = | $V/A_w$ | | | |
| | | | **0.00** | **MPa** | | |



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6.3 Long Rib 2

| NAME | SYMBOL | | VALUE | UNIT | NOTES | REF |
|---|---|---|---|---|---|---|
| **40x20x2+35x30x3** | **Long Rib2** | | | | | |
| 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 | = | 0.45 | kN | *Tension* | |
| In plane moment | $M_x$ | = | 0.3878 | kNm | | |
| Out of plane moment | $M_y$ | = | 2.397E-12 | 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 | $\mathbf{f_a}$ | = | $P/A_g$ | | | |
| | | = | **0.00** | **MPa** | *compression* | |
| | | = | **1.24** | **MPa** | *Tension* | |
| Stress from in-plane bending | $\mathbf{f_{bx}}$ | = | $M_x/Z_x$ | | | |
| | | = | **77.02** | **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* | | | | | | |
| | $\mathbf{\phi F_L}$ | = | **228.95** | **MPa** | | |



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| | | | | | |
|---|---|---|---|---|---|
| | | **OR** | | | |
| | **$\phi F_L$** | **=** | **222.70** | **MPa** | |
| *COMPRESSION* | | | | | |
| ***3.4.8*** *Compression in columns, axial, gross section* | | | | | |
| *1. General* | | | | | … 3.4.8.1 |
| Unsupported length of member | L | = | 2731 | 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 | = | 154.16 | | |
| Slenderness ratio | kL/rx | = | 133.87 | | |
| Slenderness parameter | λ | = | 2.88 | | |
| | $D_c$* | = | 90.3 | | |
| | $S_1$* | = | 0.33 | | |
| | $S_2$* | = | 1.23 | | |
| | $\phi_{cc}$ | = | 0.950 | | |
| Factored limit state stress | **$\phi F_L$** | **=** | **27.62** | **MPa** | |
| *2. Sections not subject to torsional or torsional-flexural buckling* | | | | | … 3.4.8.2 |
| Largest slenderness ratio for flexural buckling | kL/r | **=** | 154.16 | | |
| ***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' | **=** | 16 | | |
| | t | **=** | 2 | mm | |
| Slenderness | b/t | **=** | 8 | | |
| Limit 1 | $S_1$ | **=** | 12.34 | | |
| Limit 2 | $S_2$ | **=** | 32.87 | | |
| Factored limit state stress | **$\phi F_L$** | **=** | **228.95** | **MPa** | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| Most adverse compressive limit state stress | $F_a$ | = | 27.62 | 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 | $L_b$ | = | 1853 | mm | | |
| Second moment of area (weak axis) | $I_y$ | = | 62626.1 | mm⁴ | | |
| Torsion modulus | J | = | 38065.7 | mm³ | | |
| Elastic section modulus | Z | = | 5035 | mm³ | | |
| Slenderness | S | = | 382.17 | | | |
| Limit 1 | $S_1$ | = | 0.39 | | | |
| Limit 2 | $S_2$ | = | 1695.86 | | | |
| Factored limit state stress | **$\phi F_L$** | = | **185.54** | **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 | **$\phi F_L$** | = | **228.95** | **MPa** | | |
| Most adverse in-plane bending limit state stress | $F_{bx}$ | = | 185.54 | MPa | | |
| Most adverse in-plane bending capacity factor | $f_{bx}/F_{bx}$ | = | 0.42 | | PASS | |
| *BENDING - OUT-OF-PLANE* | | | | | | |



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*NOTE: Limit state stresses, $\phi F_L$ are the same for out-of-plane bending (doubly symmetric section)*

| | | | | | | |
|---|---|---|---|---|---|---|
| Factored limit state stress | **$\phi F_L$** | = | **185.54** | **MPa** | | |
| Most adverse out-of-plane bending limit state stress | $F_{by}$ | = | 185.54 | 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)

| | | | | | | |
|---|---|---|---|---|---|---|
| | $F_a$ | = | 27.62 | MPa | | … 3.4.8 |
| | $F_{ao}$ | = | 228.95 | MPa | | … 3.4.10 |
| | $F_{bx}$ | = | 185.54 | MPa | | … 3.4.17 |
| | $F_{by}$ | = | 185.54 | MPa | | … 3.4.17 |
| | $f_a/F_a$ | = | 0.006 | | | |
| Check: | $f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$ | | | | | … 4.1.1 (3) |
| i.e. | 0.42 | ≤ | 1.0 | | PASS | |

SHEAR

***3.4.24** Shear in webs (Major Axis)* … 4.1.1(2)

| | | | | | | |
|---|---|---|---|---|---|---|
| Clear web height | h | = | 71 | mm | | |
| | t | = | 2 | mm | | |
| Slenderness | h/t | = | 35.5 | | | |
| Limit 1 | $S_1$ | = | 29.01 | | | |
| Limit 2 | $S_2$ | = | 59.31 | | | |
| Factored limit state stress | **$\phi F_L$** | = | **124.53** | **MPa** | | |
| Stress From Shear force | **$f_{sx}$** | = | $V/A_w$ | | | |
| | | | **0.80** | **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 | **$\phi F_L$** | = | **131.10** | **MPa** | | |



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

6.4 Short Rib 1

| NAME | SYMBOL | | VALUE | UNIT | NOTES | REF |
|---|---|---|---|---|---|---|
| **30X20X2** | **Short Rib 1** | | | | | |
| 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 | = | 1.123 | kN | *compression* | |
| | P | = | 0 | kN | *Tension* | |
| In plane moment | $M_x$ | = | 0.0007766 | kNm | | |
| Out of plane moment | $M_y$ | = | 0 | kNm | | |
| *DESIGN STRESSES* | | | | | | |
| *Gross cross section area* | $A_g$ | **=** | 184 | $mm^2$ | | |
| In-plane elastic section modulus | $Z_x$ | **=** | 1437.6889 | $mm^3$ | | |
| Out-of-plane elastic section mod. | $Z_y$ | **=** | 1112.5333 | $mm^3$ | | |
| Stress from axial force | **$f_a$** | **=** | P/$A_g$ | | | |
| | | **=** | **6.10** | **MPa** | *compression* | |
| | | **=** | **0.00** | **MPa** | *Tension* | |
| Stress from in-plane bending | **$f_{bx}$** | **=** | $M_x/Z_x$ | | | |
| | | **=** | **0.54** | **MPa** | *compression* | |
| Stress from out-of-plane bending | **$f_{by}$** | **=** | $M_y/Z_y$ | | | |
| | | **=** | **0.00** | **MPa** | *compression* | |
| *Tension* | | | | | | |



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***3.4.3*** *Tension in rectangular tubes*

| | | | | | |
|---|---|---|---|---|---|
| | **$\phi F_L$** | **=** | **228.95** | **MPa** | |
| | | **OR** | | | |
| | **$\phi F_L$** | **=** | **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) | $r_y$ | = | 7.78 | mm | |
| Radius of gyration about buckling axis (X) | $r_x$ | = | 10.83 | mm | |
| Slenderness ratio | kLb/ry | = | 154.32 | | |
| Slenderness ratio | kL/rx | = | 110.84 | | |
| Slenderness parameter | $\lambda$ | = | 2.88 | | |
| | $D_c$* | = | 90.3 | | |
| | $S_1$* | = | 0.33 | | |
| | $S_2$* | = | 1.23 | | |
| | $\phi_{cc}$ | = | 0.950 | | |
| Factored limit state stress | **$\phi F_L$** | **=** | **27.56** | **MPa** | |
| *2. Sections not subject to torsional or torsional-flexural buckling* | | | | | … 3.4.8.2 |
| Largest slenderness ratio for flexural buckling | kL/r | **=** | 154.32 | | |
| ***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' | **=** | 16 | | |
| | t | **=** | 2 | mm | |
| Slenderness | b/t | **=** | 8 | | |
| Limit 1 | $S_1$ | **=** | 12.34 | | |
| Limit 2 | $S_2$ | **=** | 32.87 | | |
| Factored limit state stress | **$\phi F_L$** | **=** | **228.95** | **MPa** | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| Most adverse compressive limit state stress | $F_a$ | = | 27.56 | MPa | | |
| Most adverse tensile limit state stress | $F_a$ | = | 222.70 | MPa | | |
| Most adverse compressive & Tensile capacity factor | $f_a/F_a$ | = | 0.22 | | 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) | $I_y$ | = | 11125.333 | $mm^4$ | | |
| Torsion modulus | J | = | 22088.348 | $mm^3$ | | |
| Elastic section modulus | Z | = | 1437.6889 | $mm^3$ | | |
| Slenderness | S | = | 220.11 | | | |
| Limit 1 | $S_1$ | = | 0.39 | | | |
| Limit 2 | $S_2$ | = | 1695.86 | | | |
| Factored limit state stress | **$\phi F_L$** | = | **196.36** | **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 | **$\phi F_L$** | = | **228.95** | **MPa** | | |
| Most adverse in-plane bending limit state stress | $F_{bx}$ | = | 196.36 | MPa | | |
| Most adverse in-plane bending capacity factor | $f_{bx}/F_{bx}$ | = | 0.00 | | PASS | |
| *BENDING - OUT-OF-PLANE* | | | | | | |



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*NOTE: Limit state stresses, $\phi F_L$ are the same for out-of-plane bending (doubly symmetric section)*

| | | | | | | |
|---|---|---|---|---|---|---|
| Factored limit state stress | **$\phi F_L$** | = | **196.36** | **MPa** | | |
| Most adverse out-of-plane bending limit state stress | **$F_{by}$** | = | 196.36 | 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) |
| | $F_a$ | = | 27.56 | MPa | | … 3.4.8 |
| | $F_{ao}$ | = | 228.95 | MPa | | … 3.4.10 |
| | $F_{bx}$ | = | 196.36 | MPa | | … 3.4.17 |
| | $F_{by}$ | = | 196.36 | MPa | | … 3.4.17 |
| | $f_a/F_a$ | = | 0.221 | | | |
| Check: | $f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$ | | | | | … 4.1.1 (3) |
| i.e. | 0.22 | ≤ | 1.0 | | PASS | |

SHEAR

| | | | | | | |
|---|---|---|---|---|---|---|
| ***3.4.24** Shear in webs (Major Axis)* | | | | | | … 4.1.1(2) |
| Clear web height | h | = | 26 | mm | | |
| | t | = | 2 | mm | | |
| Slenderness | h/t | = | 13 | | | |
| Limit 1 | $S_1$ | = | 29.01 | | | |
| Limit 2 | $S_2$ | = | 59.31 | | | |
| Factored limit state stress | **$\phi F_L$** | = | **131.10** | **MPa** | | |
| Stress From Shear force | **$f_{sx}$** | = | $V/A_w$ | | | |
| | | | **1.58** | **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 | **$\phi F_L$** | = | **131.10** | **MPa** | | |



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

6.5 Short Rib 2

| NAME | SYMBOL | | VALUE | UNIT | NOTES | REF |
|---|---|---|---|---|---|---|
| **30X20X2** | **Short Rib 2** | | | | | |
| 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 | = | 1.092 | kN | *compression* | |
| | P | = | 0 | kN | *Tension* | |
| In plane moment | $M_x$ | = | 0.0006474 | kNm | | |
| Out of plane moment | $M_y$ | = | 0 | kNm | | |
| *DESIGN STRESSES* | | | | | | |
| *Gross cross section area* | $A_g$ | **=** | 184 | $mm^2$ | | |
| In-plane elastic section modulus | $Z_x$ | **=** | 1437.6889 | $mm^3$ | | |
| Out-of-plane elastic section mod. | $Z_y$ | **=** | 1112.5333 | $mm^3$ | | |
| Stress from axial force | **$f_a$** | **=** | $P/A_g$ | | | |
| | | **=** | **5.93** | **MPa** | *compression* | |
| | | **=** | **0.00** | **MPa** | *Tension* | |
| Stress from in-plane bending | **$f_{bx}$** | **=** | $M_x/Z_x$ | | | |
| | | **=** | **0.45** | **MPa** | *compression* | |
| Stress from out-of-plane bending | **$f_{by}$** | **=** | $M_y/Z_y$ | | | |
| | | **=** | **0.00** | **MPa** | *compression* | |
| *Tension* | | | | | | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| ***3.4.3** Tension in rectangular tubes* | | | | | | |
| | **$\phi F_L$** | **=** | **228.95** | **MPa** | | |
| | | **OR** | | | | |
| | **$\phi F_L$** | **=** | **222.70** | **MPa** | | |
| *COMPRESSION* | | | | | | |
| ***3.4.8** Compression in columns, axial, gross section* | | | | | | |
| *1. General* | | | | | | … 3.4.8.1 |
| Unsupported length of member | L | = | 1100 | mm | | |
| Effective length factor | k | = | 1.00 | | | |
| Radius of gyration about buckling axis (Y) | $r_y$ | = | 7.78 | mm | | |
| Radius of gyration about buckling axis (X) | $r_x$ | = | 10.83 | mm | | |
| Slenderness ratio | kLb/ry | = | 141.46 | | | |
| Slenderness ratio | kL/rx | = | 101.61 | | | |
| Slenderness parameter | λ | = | 2.64 | | | |
| | $D_c$* | = | 90.3 | | | |
| | $S_1$* | = | 0.33 | | | |
| | $S_2$* | = | 1.23 | | | |
| | $\phi_{cc}$ | = | 0.950 | | | |
| Factored limit state stress | **$\phi F_L$** | **=** | **32.79** | **MPa** | | |
| *2. Sections not subject to torsional or torsional-flexural buckling* | | | | | | … 3.4.8.2 |
| Largest slenderness ratio for flexural buckling | kL/r | **=** | 141.46 | | | |
| ***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' | **=** | 16 | | | |
| | t | **=** | 2 | mm | | |
| Slenderness | b/t | **=** | 8 | | | |
| Limit 1 | $S_1$ | **=** | 12.34 | | | |
| Limit 2 | $S_2$ | **=** | 32.87 | | | |
| Factored limit state stress | **$\phi F_L$** | **=** | **228.95** | **MPa** | | |



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| | | | | | | |
|---|---|---|---|---|---|---|
| Most adverse compressive limit state stress | $F_a$ | = | 32.79 | MPa | | |
| Most adverse tensile limit state stress | $F_a$ | = | 222.70 | MPa | | |
| Most adverse compressive & Tensile capacity factor | $f_a/F_a$ | = | 0.18 | | PASS | |
| *BENDING - IN-PLANE* | | | | | | |
| ***3.4.15*** *Compression in beams, extreme fibre, gross section rectangular tubes, box sections* | | | | | | |
| Unbraced length for bending | $L_b$ | = | 1100 | mm | | |
| Second moment of area (weak axis) | $I_y$ | = | 11125.333 | mm$^4$ | | |
| Torsion modulus | J | = | 22088.348 | mm$^3$ | | |
| Elastic section modulus | Z | = | 1437.6889 | mm$^3$ | | |
| Slenderness | S | = | 201.77 | | | |
| Limit 1 | $S_1$ | = | 0.39 | | | |
| Limit 2 | $S_2$ | = | 1695.86 | | | |
| Factored limit state stress | **$\phi F_L$** | = | **197.80** | **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 | **$\phi F_L$** | = | **228.95** | **MPa** | | |
| Most adverse in-plane bending limit state stress | $F_{bx}$ | = | 197.80 | MPa | | |
| Most adverse in-plane bending capacity factor | $f_{bx}/F_{bx}$ | = | 0.00 | | PASS | |
| *BENDING - OUT-OF-PLANE* | | | | | | |



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*NOTE: Limit state stresses, $\phi F_L$ are the same for out-of-plane bending (doubly symmetric section)*

| | | | | | | |
|---|---|---|---|---|---|---|
| Factored limit state stress | **$\phi F_L$** | = | **197.80** | **MPa** | | |
| Most adverse out-of-plane bending limit state stress | **$F_{by}$** | = | 197.80 | 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) |
| | $F_a$ | = | 32.79 | MPa | | … 3.4.8 |
| | $F_{ao}$ | = | 228.95 | MPa | | … 3.4.10 |
| | $F_{bx}$ | = | 197.80 | MPa | | … 3.4.17 |
| | $F_{by}$ | = | 197.80 | MPa | | … 3.4.17 |
| | $f_a/F_a$ | = | 0.181 | | | |
| Check: | $f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$ | | | | | … 4.1.1 (3) |
| i.e. | 0.18 | ≤ | 1.0 | | PASS | |
| SHEAR | | | | | | |
| ***3.4.24** Shear in webs (Major Axis)* | | | | | | … 4.1.1(2) |
| Clear web height | h | = | 26 | mm | | |
| | t | = | 2 | mm | | |
| Slenderness | h/t | = | 13 | | | |
| Limit 1 | $S_1$ | = | 29.01 | | | |
| Limit 2 | $S_2$ | = | 59.31 | | | |
| Factored limit state stress | **$\phi F_L$** | = | **131.10** | **MPa** | | |
| Stress From Shear force | **$f_{sx}$** | = | $V/A_w$ | | | |
| | | | **1.58** | **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 | **$\phi F_L$** | = | **131.10** | **MPa** | | |



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

### 6.6 Summary Loads

| MEMBER(S) | Section | b | d | t | Vx | Vy | P (Axial) | Mx | My |
|---|---|---|---|---|---|---|---|---|---|
| | | mm | mm | mm | kN | kN | kN | kN.m | kN.m |
| **Pole** | 105x105x3.9 | 105 | 105 | 3.9 | 0.242 | 1.3E-13 | -1.52 | -1.133 | 4.145E-14 |
| **Long Rib1** | 40x20x2+35x30x3 | 20 | 75 | 2 | 0.719 | 0.014 | 0.568 | -0.4338 | 0.0214 |
| **Long Rib2** | 40x20x2+35x30x3 | 20 | 75 | 2 | 0.683 | 1.3E-12 | 0.45 | -0.3878 | 2.397E-12 |
| **Short Rib 1** | 30X20X2 | 20 | 30 | 2 | 2E-19 | 0 | -1.123 | 0.0007766 | 0 |
| **Short Rib 2** | 30X20X2 | 20 | 30 | 2 | -0 | 0 | -1.092 | 0.0006474 | 0 |

# 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) | Tension (concrete), $ØN_{uc}$ (kN)** | | |
| | | | | | | $ØV_{us}$ (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 |



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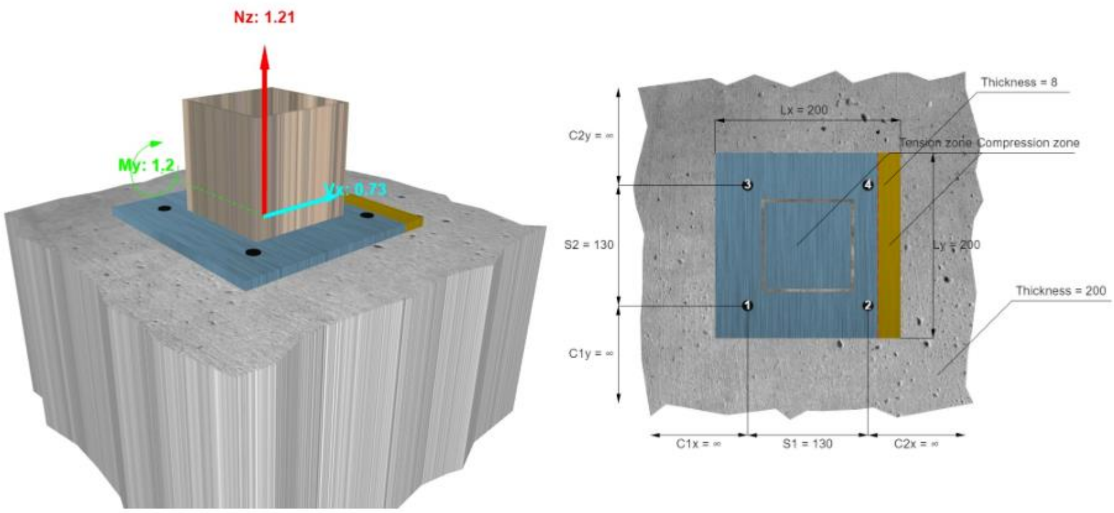
Geometry :




## 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.**



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# 8 Summary

## 8.1 Conclusions

a. The 5m Square 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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