Prime Consulting Engineers Pty. Ltd.

Design Report:

Foundation Design for Dodecagon Umbrella

For

EXTREME MARQUEES

Ref: R-22-254

Date: 27/06/2022

Amendment: -

Prepared by: KZ

Checked by: BG

Email: info@primeengineers.com.au
Web: www.primeengineers.com.au
Address: 21/1-7 Jordan St, Gladesville NSW 2111
Phone: (02) 8964 1818

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Email: info@primeengineers.com.au
Web: www.primeengineers.com.au
Address: 394 Lane Cove Rd, Macquarie Park NSW 2138
Phone: (02) 8964 1818

1 Introduction and Scope:

The report and certification are the sole property of Prime Consulting Engineers Pty. Ltd.

Prime Consulting Engineers have been engaged by Extreme Marquees Pty. Ltd. to carry out foundation design to withstand reactions due to pre-defined design wind actions (by others) on Dodecagon Umbrella structure.

For analysis results of the structure including restrictions & limitations of the structure, refer the original design document no. D-11-268571-2A dated 10/03/2021 prepared by Civil & Structural Engineering Design Services (Appendix 'B').

It should be noted that the outcome of our analysis is limited to the selected items as outlined in this report.

This report shall be read in conjunction with the documents listed in the references (Section 1.2)

1.1 Project Description

The report examines the effect of 3s gust wind (prepared by Civil & Structural Engineering Design Services document no. D-11-268571-2) on proposed pier/foundation. The relevant Australian Standards AS1170.0:2002 General principles, AS1170.1:2002 Permanent, imposed and other actions, AS1170.2:2021 Wind actions and AS1170.3 Snow actions are used. The design check is in accordance with AS4100:1998 steel structures.

1.2 References

- The documents referred to in this report are as follows:
  - Report of results produced through Tekla Tedds 2022 Software.
  - Report of results produced through Inducta RCC Software.
  - The original design document no. D-11-268571-2A dated 10/03/2021 prepared by Civil & Structural Engineering Design Services (Appendix 'B').
- The basic standards used in this report are as follows:
  - AS3600:2019 – Concrete Structures.
  - AS 2159:2009 – Piling - Design and installation
- The program(s) used for this analysis are as follows:
  - Tekla Tedds 2022
  - Inducta RCC

1.3 Notation

AS/NZS	Australian Standard/New Zealand Standard
FEM/FEA	Finite Element Method/Finite Element Analysis

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Web: www.primeengineers.com.au
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Phone: (02) 8964 1818

SLS	Serviceability Limit State
ULS	Ultimate Limit State

2 Design Overview

2.1 Geometry Data

Isometric view of structures

2.2 Assumptions & Limitations

- The erected structure is for temporary use only.
- It is assumed that the piers are found in clayey ground with minimum soil characteristics as below:
  - Cohesion: 10 kPa
  - Friction Angle: 27 degrees
  - Unit weight: 18 kN/m3
  - Bearing capacity: 100kPa
  - Skin friction: 3 kPa

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Web: www.primeengineers.com.au **Phone:** (02) 8964 1818

2.3 Exclusions

- Wind Analysis
- Design of umbrella structure & fabric
- Any loads/reactions other than specified in original design documents (D-11-268571-2A)

2.4 Design Parameters and Inputs

2.4.1 Load Cases

1.	G	Permanent actions (Dead load)
2.	Wu	Ultimate wind action (ULS)
3.	Ws	Serviceability wind action (SLS)

2.4.2 Load Combinations

Strength (ULS):

1.	1.35G	Permanent action only
2.	$0.9G+W_u$	Permanent and wind actions
3.	$1.2G+W_u$	Permanent and wind actions

Serviceability (SLS):

1.	$G+W_s$	Wind service actions

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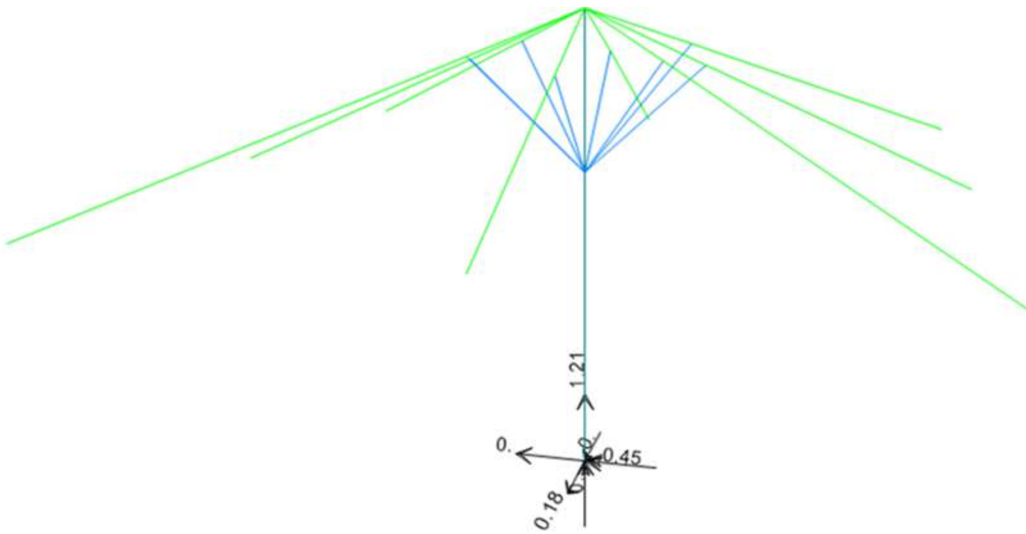
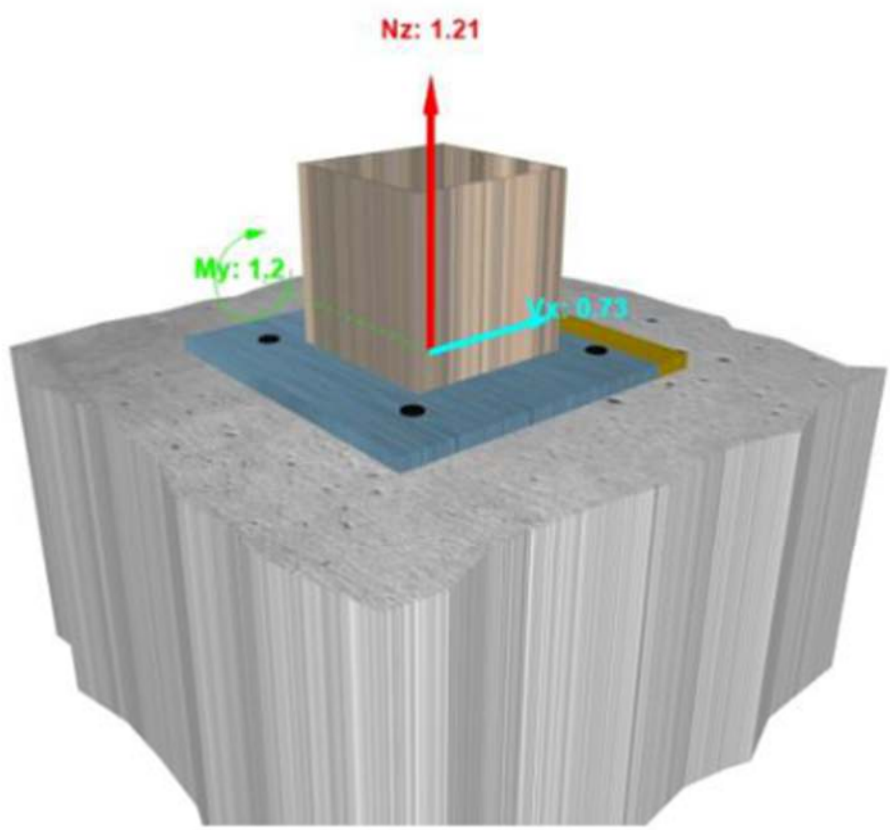
3 Design Loads/Reactions



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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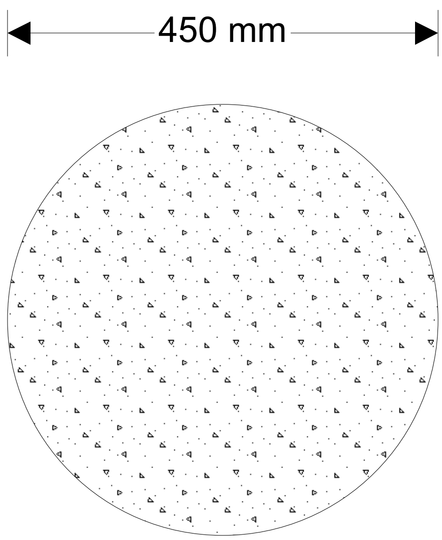
4 Pier Design

PILE ANALYSIS (AS2159)

In accordance with Australian Standard: Piling-Design and installation per AS 2159-2009

Tedds calculation version 1.0.02



Pile details

Installation method Drilled

Shape 450 mm diameter

Length $L = \mathbf{1500}$ mm

Material details

Material Concrete

Concrete strength $f'_c = \mathbf{32}$ MPa

Concrete in situ strength $f_{cmi} = \mathbf{35}$ MPa

Concrete density $\rho = \mathbf{2400}$ kg/m^3

Modulus of elasticity $E = (\rho / 1 \text{ kg/m}^3)^{1.5} \times 0.043 \times \sqrt{(f_{cmi} \times 1 \text{ MPa})} = \mathbf{29910}$ MPa

Geometric properties

Assume top 1.5 x h ineffective (Cl. 4.4.1) Yes

Pile section depth $h = \mathbf{450}$ mm

Bearing area $A_{bearing} = \pi \times h^2 / 4 = \mathbf{1590}$ cm^2

Pile perimeter $Perim_{pile} = \pi \times h = \mathbf{1414}$ mm

Moment of inertia $I = \pi \times h^4 / 64 = \mathbf{201289}$ cm^4

Section modulus $S = \pi \times h^3 / 32 = \mathbf{8946}$ cm^3

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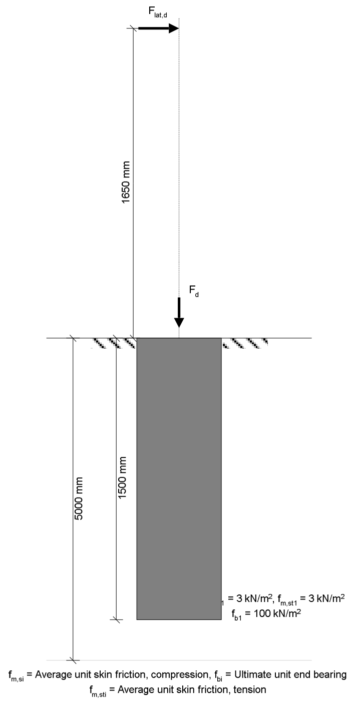

Stratum details

Stratum	Geomaterial	Thickness, $t_{stratai}$ (mm)	Ultimate unit bearing, f_{bi} (kN/m²)	Average skin friction, compression, $f_{m,si}$ (kN/m²)	Average skin friction, tension, $f_{m,sti}$ (kN/m²)	Strength reduction factor, comp. $\phi_{c,g}$	Strength reduction factor, tension $\phi_{t,g}$
1	Cohesive	5000	100	3	3	0.5	0.5

Design action details

Design action, compression $F_{c,d}$ = **0.7** kN

Design action, tension $F_{t,d}$ = **1.2** kN

Design action, lateral $F_{lat,d}$ = **0.7** kN

Service level design action, lateral $F_{lat,ds'}$ = **0.7** kN

Axial compression resistance

Design ultimate axial bearing resistance $R_b = A_b$ ´ f_b = **15.9** kN

Design ultimate axial friction resistance per stratum

Stratum 1 $R_{s1} = f_{m,s1}$ ´ $Perim_{pile}$ ´ $((L - D_{strata1}) - (1.5$ ´ $h - D_{strata1}))$ = **3.5** kN

Design ultimate axial friction resistance, total $R_s = R_{s1}$ = **3.5** kN

Design ultimate axial geotechnical strength, comp $R_{d,ug} = R_b + R_s$ = **19.4** kN

Geotechnical strength reduction factor $\phi_{c,g}$ = **0.5**

Design geotechnical strength in compression $R_{d,g} = \phi_{c,g}$ ´ $R_{d,ug}$ = **9.7** kN

$F_{c,d} / R_{d,g}$ = **0.075**

PASS - Design ultimate axial resistance exceeds factored axial load

Axial uplift resistance

Design ultimate axial friction uplift resistance per stratum

Stratum 1 $R_{st1} = f_{m,st1}$ ´ $Perim_{pile}$ ´ $((L - D_{strata1}) - (1.5$ ´ $h - D_{strata1}))$ = **3.5** kN

Design ultimate axial friction uplift resistance, total $R_{st} = R_{st1}$ = **3.5** kN

Design ultimate axial geotechnical strength, uplift $R_{d,ug,st} = R_{st}$ = **3.5** kN

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Geotechnical strength reduction factor $\phi_{t,g}$ = **0.5**

Design geotechnical strength in uplift $R_{d,g,st} = \phi_{t,g} \times R_{d,ug,st}$ = **1.7** kN

$F_{t,d} / R_{d,g,st}$ = **0.686**

PASS - Design ultimate axial uplift resistance exceeds factored axial uplift load

Lateral analysis properties (Brinch Hansen method)

Pile head fixity Free

Eccentricity of applied action e_{actual} = **1650** mm

Lateral action duration Long-term

Lateral stratum details

Overburden pressure, $p_{ozSi} = \sum_{i=1}^{n} \gamma'_i \times t_{stratai}$

Stratum	Cohesion, c_i (kN/m^2)	Friction angle, ϕ_i (degrees)	Unit weight of soil, γ_i (kN/m^3)	Overburden pressure, p_{ozSi} (kN/m^2)
1	10	27	18	90

Resisting soil is divided into 10 segments to determine lateral resistance

From iteration, assume depth of point of rotation X = **1062** mm

Distance from lateral action to ground $e = e_{actual}$ = **1650** mm

Sum of moments about point of load application near zero

$\Sigma M_{tr} = M_{trS1} + M_{trS2} + M_{trS3} + M_{trS4} + M_{trS5} + M_{trS6} + M_{trS7} + M_{trS8t} + M_{trS8b} + M_{trS9} + M_{trS10}$ = **0** kNm

Sum of moments about point of rotation

$\Sigma M_X = M_{XS1} + M_{XS2} + M_{XS3} + M_{XS4} + M_{XS5} + M_{XS6} + M_{XS7} + M_{XS8t} + M_{XS8b} + M_{XS9} + M_{XS10}$ = **54** kNm

Ultimate soil lateral resist. (Tomlinson Eqn 7.52) $R_{d,ug,lat} = \Sigma M_X / (e + X)$ = **19.9** kN

Lateral resistance factor $\phi_{lat,g}$ = **0.5**

Ultimate lateral action capacity $R_{d,g,lat} = \phi_{lat,g} \times R_{d,ug,lat}$ = **10** kN

$F_{lat,d} / R_{d,g,lat}$ = **0.073**

PASS - Ultimate lateral load capacity exceeds factored lateral load

Lateral deflection

Virtual point of fixity, from iteration $V_{zf} = R_{d,ug,lat} - P_{LatS1} - P_{LatS2} - R \times P_{LatS3}$ = **0** kN

$z_f = (2 + R) \times L / 10$ = **409** mm

Actual lateral deflection at top of pile $\delta_{Lat} = (F_{lat,ds'} \times (e + z_f)^3) / (3 \times E \times I)$ = **0.04** mm

Allowable lateral deflection $\delta_{LatAllow}$ = **25** mm

$\delta_{Lat} / \delta_{LatAllow}$ = **0.001**

PASS - Allowable lateral deflection exceeds actual lateral deflection

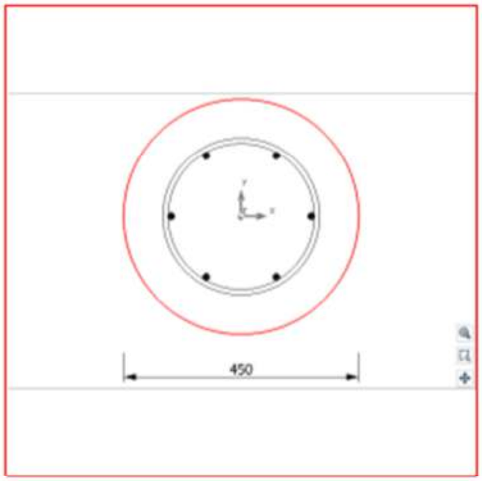
Email: info@primeengineers.com.au **Address:** 394 Lane Cove Rd, Macquarie Park NSW 2138
Web: www.primeengineers.com.au **Phone:** (02) 8964 1818

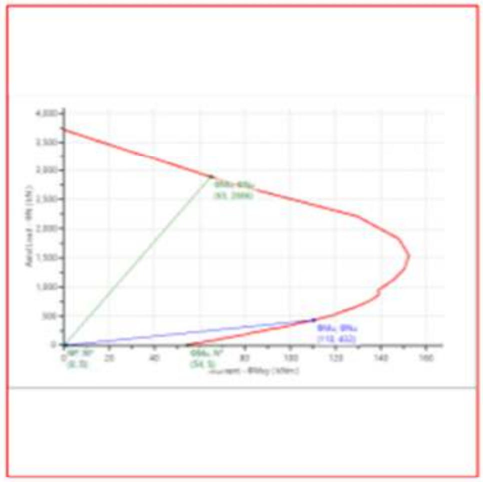
5 Reinforcement Design

RCC v1.2.4 **INDUCTA**

27/06/2022 01:42

File Name: C:\Us ... Zia\OneDrive - Prime Consulting Engineers Pty Ltd\PCE Data\Jobs\Jobs for





Dimensions, mm, D: 450
Bracing: Braced in X Braced in Y
Eff. Le(m), X: 3 Y: 3 (H: 3m)

f'c, MPa: 40
Cover, mm: 75
Long. Bar D, mm: 12
Steel Strength, MPa: 500
Cover, mm: 75
Bars Total: 6

Design Load: Ultimate
N*, kN: 4.7 (Top) 4.7 (Btm)
M*x, kNm: 0.01 (Top) 0.01 (Btm)
M*y, kNm: 1.2 (Top) 0 (Btm)
V*x, kN: 0.75 (Top) 0.75 (Btm)
V*y, kNm: 0 (Top) 0 (Btm)
β3: 1 (Top) 1 (Btm)
βd: 1
Apply Min M: Yes

Design Load: Fire
N*f, kN: 0 (Top) 0 (Btm)
M*fx, kNm: 0 (Top) 0 (Btm)
M*fy, kNm: 0 (Top) 0 (Btm)
βd: 0
FRP, min: 90
Exposed on more than one side
lo.fi = 0.5*Lu: No
Mmin with single curvature: No

See next page for Design Log

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RCC v1.2.4 **INDUCTA**

```
27/06/2022 01:42

COLUMN DESIGN - AS 3600 - 2018 AMDTs No. 1 & No. 2

WARNING: Steel Area < 1%

STRENGTH
===============================================================================

 Design Code: AS 3600 - 2018 AMDTs No. 1 & No. 2

 RADIUS OF GYRATION
  rxy = 112.5 mm

 APPLIED AXIAL LOAD:
   N = 4.7 kN

 MINIMUM MOMENT:
   Mxy_top = 0.1 kNm
   Mxy_btm =-0.1 kNm

 APPLIED MOMENT:
   Mxy_top = 1.2 kNm
   Mxy_btm = 0.0 kNm

 DESIGN MOMENT:
   Mxy_top = 1.2 kNm
   Mxy_btm =-0.1 kNm

 RATIO OF SMALLER END BENDING MOMENT TO LARGER END BENDING MOMENT:
 (forced bending in single curvature)
 xy: M1*/M2* = -0.09
   Single Curv. in XY

 SLENDERNESS:
   Lexy /rxy = 26.7 ≤ 465.2
   Short Column in xy

 MOMENT MAGNIFICATION FACTORS:
   δxy_top = 1.000
   δxy_btm = 1.000

 M-N POINTS:

   XY-XY
   Squash Load Point      : Nuo = 5,715 kN      ΦNuo = 3,715 kN        (Φ = 0.65)
   Decompression Point    : Nudxy = 3,680 kN    ΦNudxy = 2,208 kN      (Φ = 0.60)
                            Mudxy = 216 kNm     ΦMudxy = 129.7 kNm     (Φ = 0.60)
   Balance Point          : Nubxy = 1,580 kN    ΦNubxy = 948 kN        (Φ = 0.60)
                            Mubxy = 231 kNm     ΦMubxy = 138.8 kNm     (Φ = 0.60)
   Pure Bending Point     : Muoxy = 63 kNm      ΦMuoxy = 53.8 kNm      (Φ = 0.85)
   Pure Tension Point     : Nuot = -330 kN      ΦNuot = -281 kN        (Φ = 0.85)


 MOMENT CAPACITY AT DESIGN LOAD, N*: 4.70 kN
```


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RCC v1.2.4 **INDUCTA**

27/06/2022 01:42

```
  TOP
    XY-XY     Muxy = 64.2 kNm    ΦMuxy = 54.5 kNm    Ductile in XY.

  BTM
    XY-XY     Muxy = 64.2 kNm    ΦMuxy = 54.5 kNm    Ductile in XY.

  TOP   Φxy: 0.85
        (M*xy / ( Φxy · Muxy ))  =  0.022
        Safety Factor for Bending (resultant): 45.39 OK

  BTM   Φxy: 0.85
        (M*xy / ( Φxy · Muxy ))  =  0.002
        Safety Factor for Bending (resultant): 515.10 OK


 MOMENT & AXIAL CAPACITY (ΦMu, ΦNu)
   Loading Line Intersection with M-N Curve

   TOP
   ΦMuxy = 110.3 kNm     ΦNuxy = 432.0 kN
 Safety Factor for Bending in xy: 91.92 OK
     Load as % of Capacity in xy: 1.09%  OK


   BTM
    ΦMuxy = 64.9 kNm  ΦNuxy = 2,886.3 kN
 Safety Factor for Bending in xy: 614.10 OK
     Load as % of Capacity in xy: 0.16%  OK


FIRE
================================================================================
Design Code: AS 3600 - 2018 AMDTs No. 1 & No. 2

 AXIS DISTANCE
   as = 91.00 mm

 MINIMUM MOMENT - FIRE:
   Mxy_top = 0.0 kNm
   Mxy_btm = 0.0 kNm

 APPLIED MOMENT - FIRE:
   Mxy_top = 0.0 kNm
   Mxy_btm = 0.0 kNm

 DESIGN MOMENT - FIRE:
   Mxy_top = 0.0 kNm
   Mxy_btm = 0.0 kNm

 No Fire Load - Fire check will not be performed
```


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RCC v1.2.4 **INDUCTA**

27/06/2022 01:42

```
CONFINEMENT OF THE CORE
==============================================================================
 Design Code: AS 3600 - 2018 AMDTs No. 1 & No. 2 Cl. 10.7.3

   Tie Diameter: 10mm
   f'c ≤ 50 MPa
   Cl. 10.7.3.1(a) Confinement deemed to be provided if:
   Cl. 10.7.4.3(b) - Sc = min (b, 15db)
   Sc = Smax_core = 180 mm



SHEAR
==============================================================================
 Design Code: AS 3600 - 2018 AMDTs No. 1 & No. 2 Section 8

 SHEAR FORCE:
   V*xy_top = 0.8 kN
   V*xy_btm = 0.8 kN
   Note: V* < 0.001 kN taken as V* = 0 kN


Top
 Shear combined in XY
   bv = 357 mm
   dv = 324.00 mm
   θv = 29.22 °
   kv = 0.382
   ks = 0.786
   2 Legs - R10
   ΦVu.max = 683.3 kN - Eqn. 8.2.3.3(1)

   V*x = 0.8 kN
   ZONE WHERE:  Vx,Top < ksΦVuc
   Smax_col  = 180 mm
   Smax_beam = (none needed for shear)
   Smax = 180 mm  where  Vx,Top < ksΦVuc - Cl. 10.7.4.3
   Asv = 160 mm²
   Asv.min = 130 mm² - Cl.  8.2.1.7
   Asv ≥ Asv.min
   ΦVuc = 209.5 kN - Eqn. 8.2.4.1
   ΦVus = 96.5 kN  - Eqn. 8.2.5.2(1)
   ΦVu = ΦVuc + ΦVus = 306.0 kN  - Cl. 8.2.3
   ΦVu = V*x,Top
   Safety Factor = 408
   Ss = 180 mm


   Additional long. tensile forces caused by shear - Cl. 8.2.7
   ΔFtd  = -1.3 kN
```


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RCC v1.2.4 **INDUCTA**

27/06/2022 01:42

```
 Shear combined in XY

Btm
 Shear combined in XY
   bv = 357 mm
   dv = 324.00 mm
   θv = 29.00 °
   kv = 0.400
   ks = 0.786
   2 Legs - R10
   ΦVu.max = 680.0 kN - Eqn. 8.2.3.3(1)

   V*x = 0.8 kN
   ZONE WHERE:  Vx,Btm < ksΦVuc
   Smax_col  = 180 mm
   Smax_beam = (none needed for shear)
   Smax = 180 mm  where  Vx,Btm < ksΦVuc - Cl. 10.7.4.3
   Asv = 160 mm²
   Asv.min = 130 mm² - Cl.  8.2.1.7
   Asv ≥ Asv.min
   ΦVuc = 219.6 kN - Eqn. 8.2.4.1
   ΦVus = 97.4 kN  - Eqn. 8.2.5.2(1)
   ΦVu = ΦVuc + ΦVus = 317.0 kN  - Cl. 8.2.3
   ΦVu = V*x,Btm
   Safety Factor = 423
   Ss = 180 mm


   Additional long. tensile forces caused by shear - Cl. 8.2.7
   ΔFtd  = -1.4 kN



 Shear combined in XY


   Max Tie Spacing
   S = min(Ss, Sc) = 180 mm



SUMMARY
===============================================================================

 File Name  :
 Date       : 27/06/2022 01:41
 Design Code: AS 3600 - 2018 AMDTs No. 1 & No. 2

 GEOMETRY
 Bracing              : Braced in X      Braced in Y
 Unsupported Length, Lu: 3 m
 Effective Length, Le  : X: 3 m     Y: 3 m
```


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RCC v1.2.4 **INDUCTA**

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27/06/2022 01:42

 Dimensions            : A: 450 mm

 STEEL
 f'sy (long)           : 500 MPa
 f'sy (ties)           : 250 MPa
 NOTE: f'sy is capped at 600 MPa to Cl. 1.1.2(d)

 CONCRETE
 f'c                   : 40 MPa
 Cover                 : 75 mm
 Spalling Factor       : 1
 Area Gross            : 159,043 mm²
 Area Concrete         : 158,383 mm²
 Area Long. Steel      : 660 mm²   (0.41 %)

 COLUMN DESIGN SUMMARY
 Area Gross            : 159,043 mm²
 Vol. Gross            : 0.48 m³
 Area Concrete         : 158,383 mm²
 Area Long. Steel      : 660 mm²   (0.41 %)
 Volume Tie            : 0.0012 m³
 Volume Long. Steel    : 0.0020 m³
 Volume Steel          : 0.003 m³
 Steel Weight          : 25 kg
 Steel Dosage          : 52 kg/m³

 DESIGN CHECKS SUMMARY
 Strength              : Performed, OK
    Safety Factors: top
    XY: 91.92
    Safety Factors: btm
    XY: 614.10
 Fire                  : Not Performed
 Core Confinement:     : Satisfied
 Shear                 : Performed, OK
```


Email: info@primeengineers.com.au
Web: www.primeengineers.com.au
Address: 394 Lane Cove Rd, Macquarie Park NSW 2138
Phone: (02) 8964 1818

6 Summary and Recommendations

- The 450mm dia pier as specified is capable of withstanding pre-defined reactions (by others). Refer Appendix 'A' for detail drawings.
- For assumed soil properties, refer Cl.2.2.

Yours faithfully,

Prime Consulting Engineers Pty. Ltd.

Kevin Zia, BEng, Meng, MIEAust, CPENG NER

Email: info@primeengineers.com.au **Address:** 394 Lane Cove Rd, Macquarie Park NSW 2138
Web: www.primeengineers.com.au **Phone:** (02) 8964 1818

7 Appendix A – Detail Drawings

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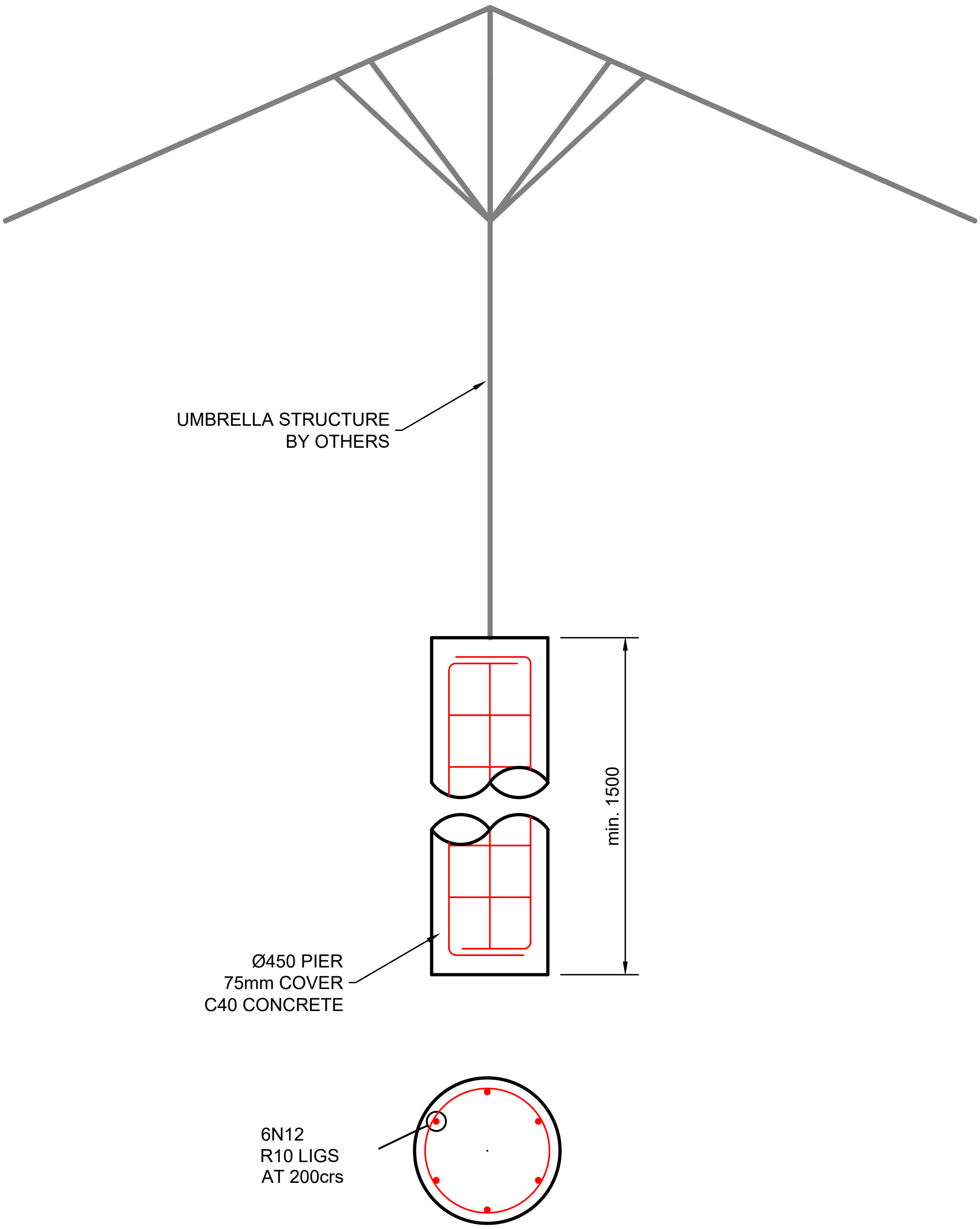
Web: www.primeengineers.com.au **Phone:** (02) 8964 1818



ELEVATION

SCALE 1:25

Issue	Description	Date	Design	Check
0	FOR CC	27/06/2022	KZ	BG

Client: EXTREME MARQUEES

Project
FOUNDATION DESIGN FOR UMBRELLA STRUCTURE

STRUCTURAL DRAWINGS

Size	Scale U.N.O
A4	1:100
DWG no.	Sheet no.
S-22-254	S01

KEVIN ZIA (MIEAust, CPEng, NER)
Prime Consulting Engineers Pty Ltd

Prime Consulting Engineers
CIVIL - STRUCTURAL - HYDRAULICS A.B.N. 34 641 874 795
U 21 / 1 JORDAN STREET GLADESVILLE NSW 2111
e: info@primeengineers.com.au w: www.primeengineers.com.au
p: 02 8964 1818 m: 0466 053 516

8 Appendix B – Original Report

Email: info@primeengineers.com.au
Web: www.primeengineers.com.au
Address: 394 Lane Cove Rd, Macquarie Park NSW 2138
Phone: (02) 8964 1818

Civil & Structural Engineering Design Services Pty. Ltd.

Client: **Flare Shade**

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

Reference: Flare Shade Technical Data.

Report by: KZ
Checked by: EAB
Date: 10/03/2021
Amendment: A-12/03/2021

JOB NO: D-11-268571-2

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3 Wanniti Road BELROSE NSW 2085 Tel: 02 9975 3899 Fax: 02 99751943
Email: hited@bigpond.net.au **Web:** www.civilandstructural.com.au

1 Introduction

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The following structural drawings and calculations are for the applicable transportable umbrella structures supplied by Flare Shade Pty. Ltd.

The report examines the effect of 3s gust wind of 60 km/hr on Aluminium components of the 6m Round (Dodecagon) Umbrella structure as the worst-case scenario. The relevant Australian Standards AS1170.0:2002 General principles, AS1170.1:2002 Permanent, imposed and other actions and AS1170.2:2011 Wind actions are used. The design check is in accordance with AS/NZS 1664.1:1997 Aluminum Structures Limit State Design.

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2 Design Restrictions and Limitations

2.1 The erected structure is for temporary use only.

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

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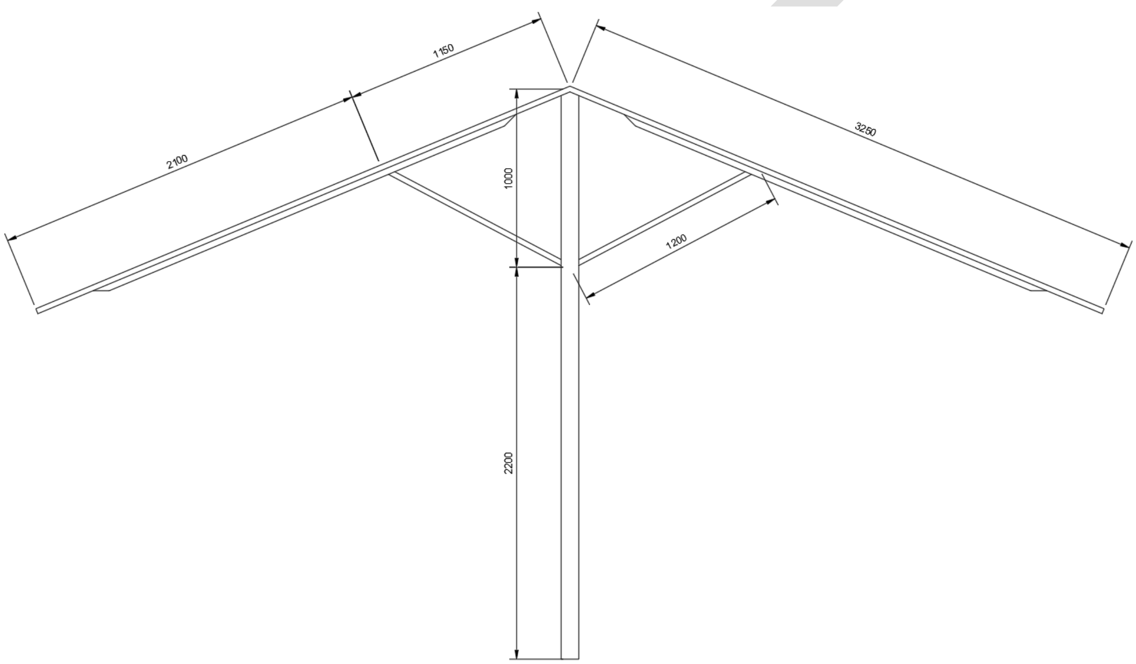
3 Specifications

3.1 General

Tent category	
Material	Aluminum 6061T6

Size	Model
6m	Round (Dodecagon)



3.2 Section Properties

MEMBER(S)	Section	b	d	t	y_c	A_g	Z_x	Z_y	S_x	S_y	I_x	I_y	J	r_x	r_y
		mm	*mm*	*mm*	*mm*	*mm²*	*mm³*	*mm³*	*mm³*	*mm³*	*mm⁴*	*mm⁴*	*mm⁴*	*mm*	*mm*
Pole	105x105x3.9	105	105	3.9	52.5	1577.2	51252.3	51252.3	59823.7	59823.7	2690745.4	2690745.4	4030120.9	41.3	41.3
Long Rib	40x20x2+35x30x3	20	75	2	37.5	364.0	5035.0	3578.6	7191.7	4786.3	180869.7	62626.1	38065.7	20.4	12.0
Short Rib	40x20x2+35x30x3	20	75	2	37.5	364.0	5035.0	3578.6	7191.7	4786.3	180869.7	62626.1	38065.7	20.4	12.0

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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*

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 = $1.35 \times G$

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= $1.2 \times G + W_u$

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

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		

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Width	B	5	m		
Length	D	5	m		
Height	Z	2.7	m		

Wind Pressure

ρair	ρ	1.2	Kg/m^3		
dynamic response factor	C_{dyn}	1			
Wind Pressure	ρ^*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				*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**	$C_{P,w}$	0.64			
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 (θ=90)

External Pressure

4. Free Roof				*α=180°*	*D7*

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Area Reduction Factor	K_a	1	
local pressure factor	K_l	1	
porous cladding reduction factor	K_p	1	
External Pressure Coefficient **MIN**	$C_{P,w}$	-0.3	
External Pressure Coefficient **MAX**	$C_{P,w}$	0.4	
External Pressure Coefficient **MIN**	$C_{P,l}$	-0.4	
External Pressure Coefficient **MAX**	$C_{P,l}$	0	
aerodynamic shape factor **MIN**	$C_{fig,w}$	-0.30	
aerodynamic shape factor **MAX**	$C_{fig,w}$	0.40	
aerodynamic shape factor **MIN**	$C_{fig,l}$	-0.40	
aerodynamic shape factor **MAX**	$C_{fig,l}$	0.00	
Pressure **MIN (Windward Side)**	P	**-0.04**	**kPa**
Pressure **MAX (Windward Side)**	P	**0.06**	**kPa**
Pressure **MIN (Leeward Side)**	P	**-0.06**	**kPa**
Pressure **MAX (Leeward Side)**	P	**0.00**	**kPa**

5.2.1 Pressure summary

WIND EXTERNAL PRESSURE	Direction1		Direction2		
	Min (Kpa)	Max (Kpa)		Min (Kpa)	Max (Kpa)
W	-0.041	0.088	W	-0.041	0.055
L	-0.086	0.000	L	-0.055	0.000

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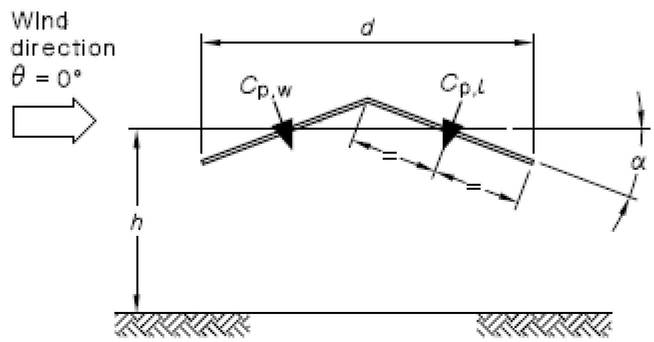

FIGURE D3 PITCHED FREE ROOFS

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			

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Wind Pressure					
ρair	ρ	1.2	Kg/m^3		
dynamic response factor	C_{dyn}	1			
Wind Pressure	ρ*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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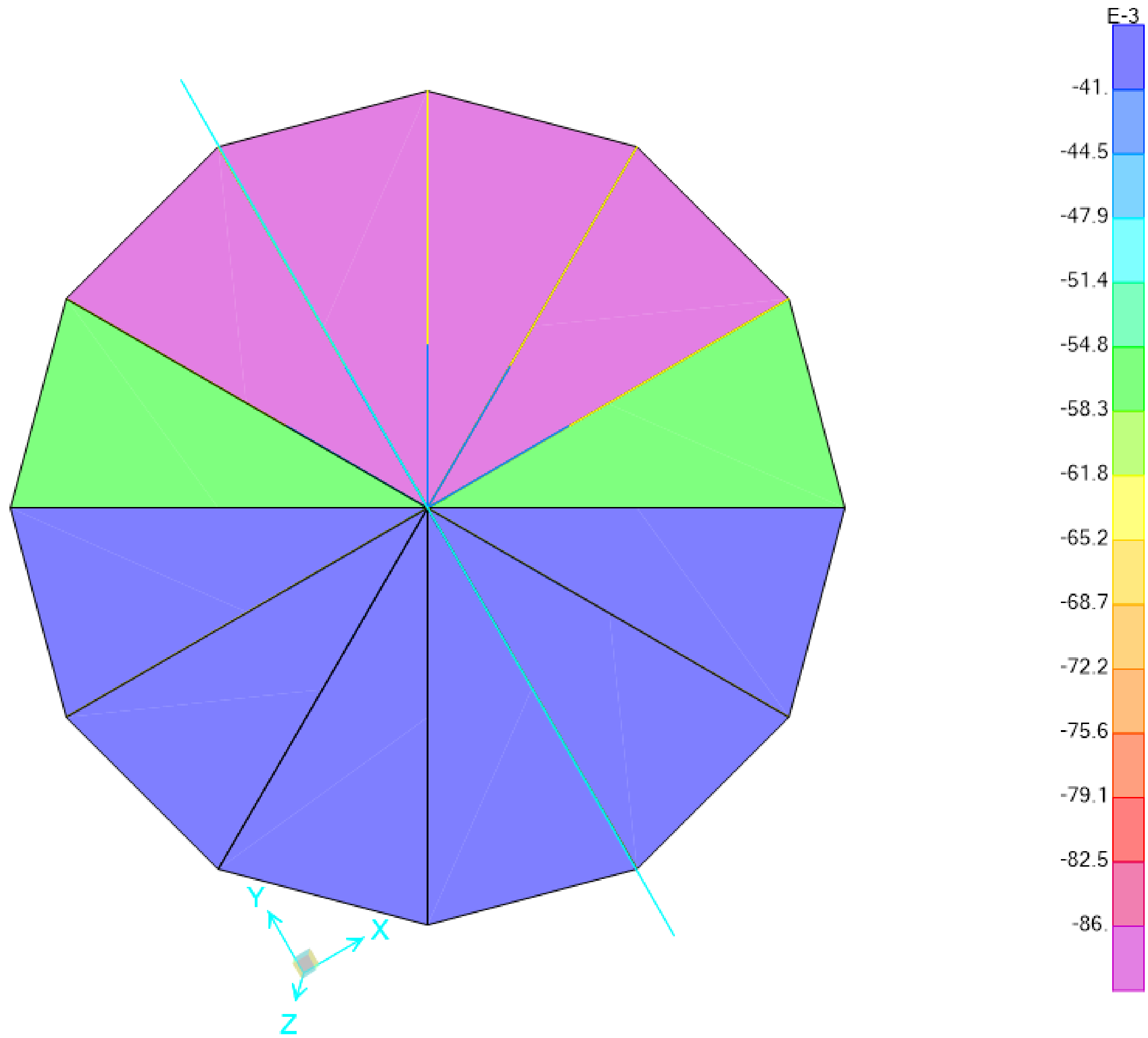
5.4 Wind Load Diagrams

5.4.1 Wind (min)_Open



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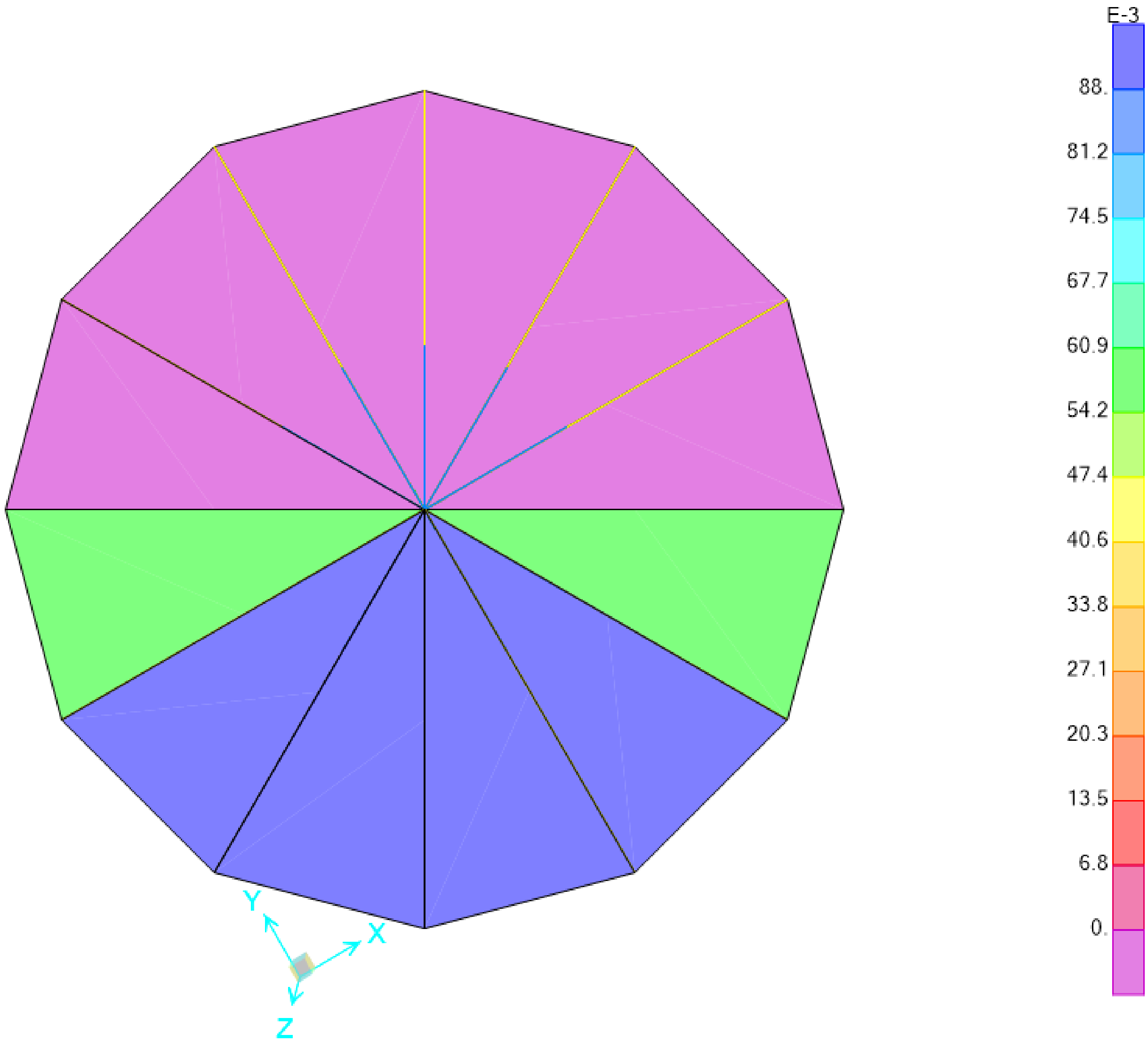
5.4.2 Wind (max)_Open



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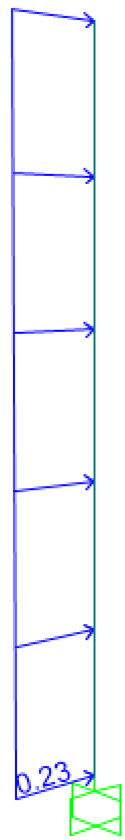
5.4.3 Wind _Closed



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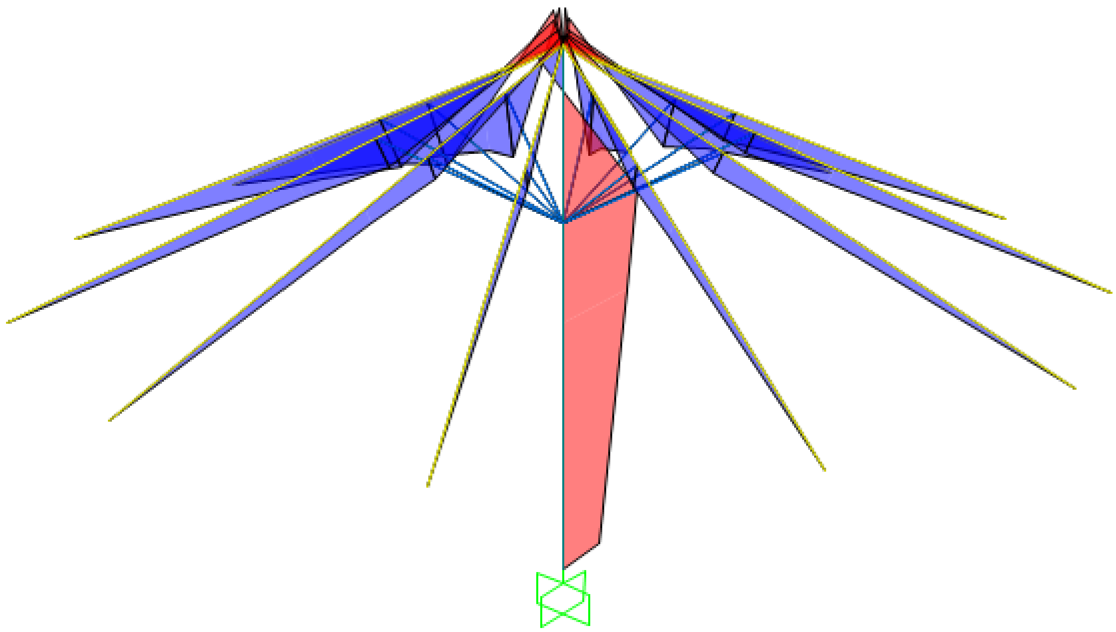
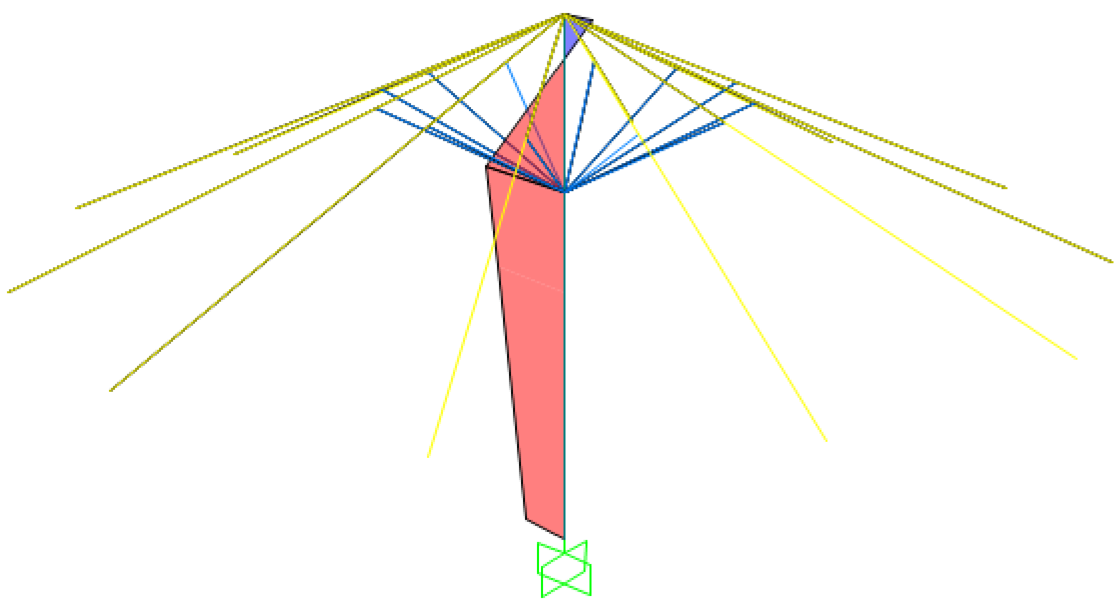
5.4.4 Max Bending Moment due to critical load combination in major axis



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



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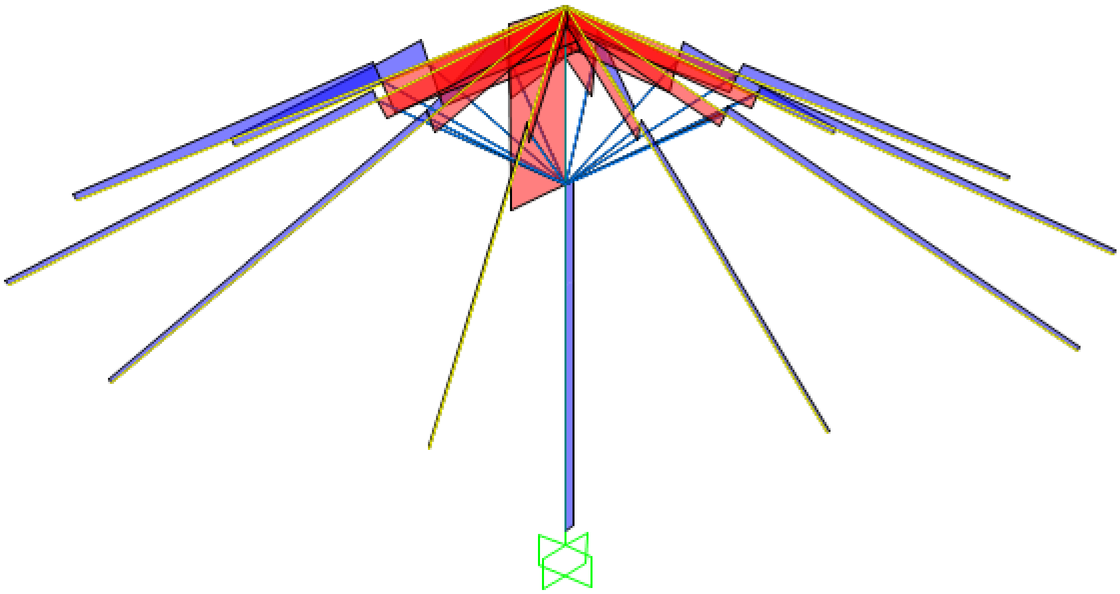
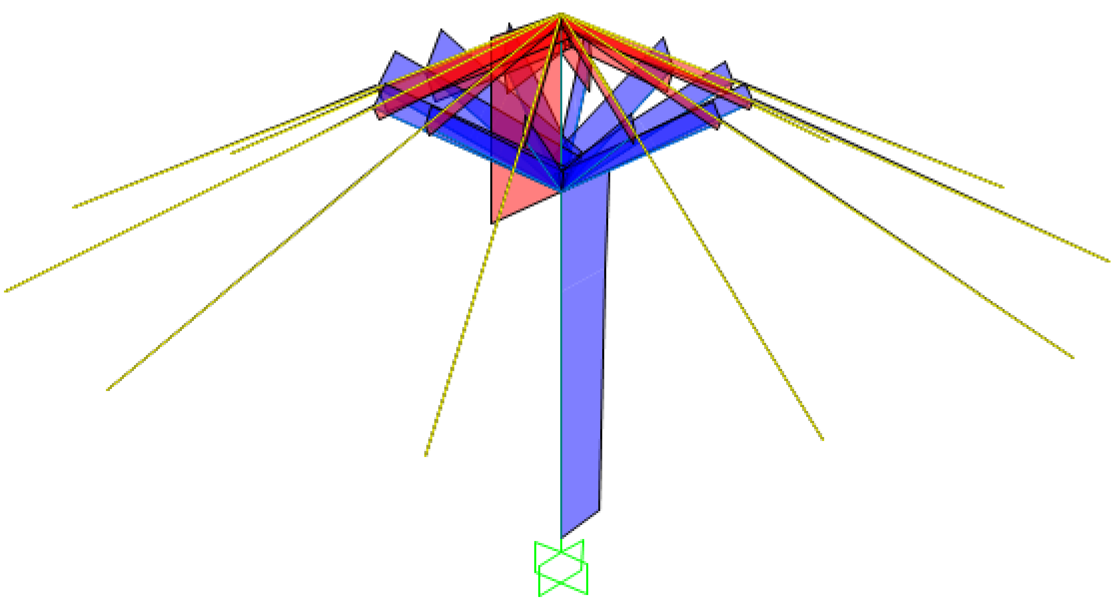
5.4.6 Max Shear in due to critical load combination



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



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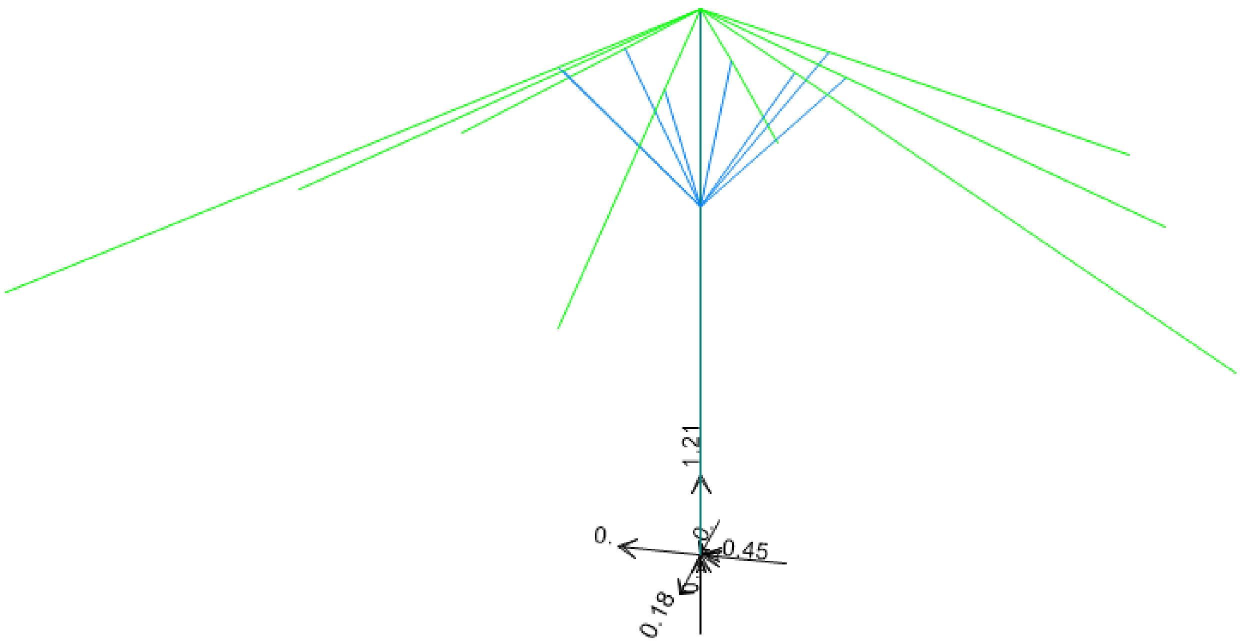
5.4.8 Max reactions



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	=	1.886	kN	*compression*	
	P	=	0	kN	*Tension*	
In plane moment	M_x	=	0.7111	kNm		
Out of plane moment	M_y	=	1.2317	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	**=**	1577.16	mm^2		
In-plane elastic section modulus	Z_x	**=**	51252.293	mm^3		
Out-of-plane elastic section mod.	Z_y	**=**	51252.293	mm^3		
Stress from axial force	$\mathbf{f_a}$	**=**	P/A_g			
		=	**1.20**	**MPa**	*compression*	
		=	**0.00**	**MPa**	*Tension*	
Stress from in-plane bending	$\mathbf{f_{bx}}$	**=**	M_x/Z_x			
		=	**13.87**	**MPa**	*compression*	
Stress from out-of-plane bending	$\mathbf{f_{by}}$	**=**	M_y/Z_y			
		=	**24.03**	**MPa**	*compression*	
Tension						
***3.4.3** Tension in rectangular tubes*						

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	ϕF_L	**=**	**228.95**	**MPa**		
		OR				
	ϕF_L	**=**	**222.70**	**MPa**		

COMPRESSION

***3.4.8** Compression in columns, axial, gross section*

1. General … 3.4.8.1

Unsupported length of member	L	=	3200	mm		
Effective length factor	k	=	1.00			
Radius of gyration about buckling axis (Y)	r_y	=	41.30	mm		
Radius of gyration about buckling axis (X)	r_x	=	41.30	mm		
Slenderness ratio	kLb/ry	=	53.26			
Slenderness ratio	kL/rx	=	77.47			
Slenderness parameter	λ	=	1.447			
	D_c*	=	90.3			
	S_1*	=	0.33			
	S_2*	=	1.23			
	ϕ_{cc}	=	0.783			
Factored limit state stress	**ϕF_L**	**=**	**90.08**	**MPa**		

2. Sections not subject to torsional or torsional-flexural buckling … 3.4.8.2

Largest slenderness ratio for flexural buckling	kL/r	**=**	77.47			

***3.4.10** Uniform compression in components of columns, gross section - flat plates*

1. Uniform compression in components of columns, gross section - flat plates with both edges supported … 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	**ϕF_L**	**=**	**193.63**	**MPa**		

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Most adverse compressive limit state stress	F_a	=	90.08	MPa		
Most adverse tensile limit state stress	F_a	=	222.70	MPa		
Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.01		PASS	
BENDING - IN-PLANE						
***3.4.15** Compression in beams, extreme fibre, gross section rectangular tubes, box sections*						
Unbraced length for bending	L_b	=	2200	mm		
Second moment of area (weak axis)	I_y	=	2.69E+06	mm^4		
Torsion modulus	J	=	4.03E+06	mm^3		
Elastic section modulus	Z	=	51252.293	mm^3		
Slenderness	S	=	68.48			
Limit 1	S_1	=	0.39			
Limit 2	S_2	=	1695.86			
Factored limit state stress	**ϕF_L**	=	**211.40**	**MPa**		... 3.4.15(2)
***3.4.17** Compression in components of beams (component under uniform compression), gross section - flat plates with both edges supported*						
	k_1	=	0.5			T3.3(D)
	k_2	=	2.04			T3.3(D)
Max. distance between toes of fillets of supporting elements for plate	b'	=	97.2	mm		
	t	=	3.9	mm		
Slenderness	b/t	=	24.923077			
Limit 1	S_1	=	12.34			
Limit 2	S_2	=	46.95			
Factored limit state stress	**ϕF_L**	=	**193.63**	**MPa**		
Most adverse in-plane bending limit state stress	F_{bx}	=	193.63	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.07		PASS	
BENDING - OUT-OF-PLANE						
NOTE: Limit state stresses, ϕF_L are the same for out-of-plane bending (doubly symmetric section)						

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Factored limit state stress	**ϕF_L**	=	**193.63**	**MPa**		
Most adverse out-of-plane bending limit state stress	**F_{by}**	=	193.63	MPa		
Most adverse out-of-plane bending capacity factor	**f_{by}/F_{by}**	**=**	0.12		PASS	
COMBINED ACTIONS						
***4.1.1** Combined compression and bending*						… 4.1.1(2)
	F_a	=	90.08	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	=	0.013			
Check:	$f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$					… 4.1.1 (3)
i.e.	0.21	$\leq$	1.0		PASS	
SHEAR						
***3.4.24** Shear in webs (Major Axis)*						… 4.1.1(2)
Clear web height	h	**=**	97.2	mm		
	t	**=**	3.9	mm		
Slenderness	h/t	**=**	24.923077			
Limit 1	S_1	**=**	29.01			
Limit 2	S_2	**=**	59.31			
Factored limit state stress	**ϕF_L**	**=**	**131.10**	**MPa**		
Stress From Shear force	**f_{sx}**	**=**	V/A_w			
			0.12	**MPa**		
***3.4.25** Shear in webs (Minor Axis)*						
Clear web height	b	**=**	97.2	mm		
	t	**=**	3.9	mm		
Slenderness	b/t	**=**	24.923077			
Factored limit state stress	**ϕF_L**	**=**	**131.10**	**MPa**		
Stress From Shear force	**f_{sy}**	**=**	V/A_w			

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			0.21	**MPa**	

6.2 Long Rib

NAME	SYMBOL		VALUE	UNIT	NOTES	REF
40x20x2+35x30x3	**Long Rib**					
Alloy and temper	6061-T6					AS1664.1
Tension	F_{tu}	=	262	MPa	*Ultimate*	T3.3(A)
	F_{ty}	=	241	MPa	*Yield*	
Compression	F_{cy}	=	241	MPa		
Shear	F_{su}	=	172	MPa	*Ultimate*	
	F_{sy}	=	138	MPa	*Yield*	
Bearing	F_{bu}	=	138	MPa	*Ultimate*	
	F_{by}	=	386	MPa	*Yield*	
Modulus of elasticity	E	=	70000	MPa	*Compressive*	
	k_t	=	1			T3.4(B)
	k_c	=	1			
FEM ANALYSIS RESULTS						
Axial force	P	=	0	kN	*compression*	
	P	=	0.543	kN	*Tension*	
In plane moment	M_x	=	0.2954	kNm		
Out of plane moment	M_y	=	0.0005742	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	**=**	364	mm^2		
In-plane elastic section modulus	Z_x	**=**	5035	mm^3		
Out-of-plane elastic section mod.	Z_y	**=**	3578.6	mm^3		
Stress from axial force	$\mathbf{f_a}$	**=**	P/A_g			
		=	**0.00**	**MPa**	*compression*	
		=	**1.49**	**MPa**	*Tension*	
Stress from in-plane bending	$\mathbf{f_{bx}}$	**=**	M_x/Z_x			
		=	**58.67**	**MPa**	*compression*	
Stress from out-of-plane bending	$\mathbf{f_{by}}$	**=**	M_y/Z_y			
		=	**0.16**	**MPa**	*compression*	
Tension						
***3.4.3** Tension in rectangular tubes*						
	$\mathbf{\phi F_L}$	**=**	**228.95**	**MPa**		

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		OR			
	ϕF_L	**=**	**222.70**	**MPa**	
COMPRESSION					
***3.4.8** Compression in columns, axial, gross section*					
1. General					… 3.4.8.1
Unsupported length of member	L	=	3250	mm	
Effective length factor	k	=	1.00		
Radius of gyration about buckling axis (Y)	r_y	=	12.02	mm	
Radius of gyration about buckling axis (X)	r_x	=	20.40	mm	
Slenderness ratio	kLb/ry	=	191.35		
Slenderness ratio	kL/rx	=	159.31		
Slenderness parameter	λ	=	3.57		
	D_c*	=	90.3		
	S_1*	=	0.33		
	S_2*	=	1.23		
	ϕ_{cc}	=	0.950		
Factored limit state stress	**ϕF_L**	**=**	**17.93**	**MPa**	
2. Sections not subject to torsional or torsional-flexural buckling					… 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	**=**	191.35		
***3.4.10** Uniform compression in components of columns, gross section - flat plates*					
1. Uniform compression in components of columns, gross section - flat plates with both edges supported					… 3.4.10.1
	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	**ϕF_L**	**=**	**228.95**	**MPa**	
Most adverse compressive limit state stress	F_a	=	17.93	MPa	

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Most adverse tensile limit state stress	F_a	=	222.70	MPa		
Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.01		PASS	
BENDING - IN-PLANE						
3.4.15 *Compression in beams, extreme fibre, gross section rectangular tubes, box sections*						
Unbraced length for bending	L_b	=	2300	mm		
Second moment of area (weak axis)	I_y	=	6.26E+04	mm^4		
Torsion modulus	J	=	3.81E+04	mm^3		
Elastic section modulus	Z	=	5035	mm^3		
Slenderness	S	=	474.37			
Limit 1	S_1	=	0.39			
Limit 2	S_2	=	1695.86			
Factored limit state stress	**ϕF_L**	=	**180.43**	**MPa**		... 3.4.15(2)
3.4.17 *Compression in components of beams (component under uniform compression), gross section - flat plates with both edges supported*						
	k_1	=	0.5			T3.3(D)
	k_2	=	2.04			T3.3(D)
Max. distance between toes of fillets of supporting elements for plate	b'	=	16	mm		
	t	=	2	mm		
Slenderness	b/t	=	8			
Limit 1	S_1	=	12.34			
Limit 2	S_2	=	46.95			
Factored limit state stress	**ϕF_L**	=	**228.95**	**MPa**		
Most adverse in-plane bending limit state stress	F_{bx}	=	180.43	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.33		PASS	
BENDING - OUT-OF-PLANE						
NOTE: Limit state stresses, ϕF_L are the same for out-of-plane bending (doubly symmetric section)						
Factored limit state stress	**ϕF_L**	=	**180.43**	**MPa**		

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Most adverse out-of-plane bending limit state stress	F_{by}	=	180.43	MPa		
Most adverse out-of-plane bending capacity factor	f_{by}/F_{by}	=	0.00		PASS	
COMBINED ACTIONS						
***4.1.1** Combined compression and bending*						… 4.1.1(2)
	F_a	=	17.93	MPa		… 3.4.8
	F_{ao}	=	228.95	MPa		… 3.4.10
	F_{bx}	=	180.43	MPa		… 3.4.17
	F_{by}	=	180.43	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.	0.33	$\leq$	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	**ϕF_L**	=	**124.53**	**MPa**		
Stress From Shear force	**f_{sx}**	=	V/A_w			
			0.51	**MPa**		
***3.4.25** Shear in webs (Minor Axis)*						
Clear web height	b	=	16	mm		
	t	=	2	mm		
Slenderness	b/t	=	8			
Factored limit state stress	**ϕF_L**	=	**131.10**	**MPa**		
Stress From Shear force	**f_{sy}**	=	V/A_w			
			0.89	**MPa**		

6.3 Short Rib

NAME	SYMBOL	VALUE	UNIT	NOTES	REF

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40x20x2+35x30x3	**Short Rib**					
Alloy and temper	6061-T6					AS1664.1
Tension	F_{tu}	=	262	MPa	*Ultimate*	T3.3(A)
	F_{ty}	=	241	MPa	*Yield*	
Compression	F_{cy}	=	241	MPa		
Shear	F_{su}	=	172	MPa	*Ultimate*	
	F_{sy}	=	138	MPa	*Yield*	
Bearing	F_{bu}	=	138	MPa	*Ultimate*	
	F_{by}	=	386	MPa	*Yield*	
Modulus of elasticity	E	=	70000	MPa	*Compressive*	
	k_t	=	1			T3.4(B)
	k_c	=	1			
FEM ANALYSIS RESULTS						
Axial force	P	=	0.827	kN	*compression*	
	P	=	0	kN	*Tension*	
In plane moment	M_x	=	0	kNm		
Out of plane moment	M_y	=	0.0009583	kNm		
DESIGN STRESSES						
Gross cross section area	A_g	=	364	mm^2		
In-plane elastic section modulus	Z_x	=	5035	mm^3		
Out-of-plane elastic section mod.	Z_y	=	3578.6	mm^3		
Stress from axial force	f_a	=	P/A_g			
		=	**2.27**	**MPa**	*compression*	
		=	**0.00**	**MPa**	*Tension*	
Stress from in-plane bending	f_{bx}	=	M_x/Z_x			
		=	**0.00**	**MPa**	*compression*	
Stress from out-of-plane bending	f_{by}	=	M_y/Z_y			
		=	**0.27**	**MPa**	*compression*	
Tension						
3.4.3 *Tension in rectangular tubes*						
	ϕF_L	=	**228.95**	**MPa**		
		OR				
	ϕF_L	=	**222.70**	**MPa**		

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COMPRESSION						
***3.4.8** Compression in columns, axial, gross section*						
1. General						… 3.4.8.1
Unsupported length of member	L	=	1200	mm		
Effective length factor	k	=	1.00			
Radius of gyration about buckling axis (Y)	r_y	=	12.02	mm		
Radius of gyration about buckling axis (X)	r_x	=	20.40	mm		
Slenderness ratio	kLb/ry	=	99.83			
Slenderness ratio	kL/rx	=	58.82			
Slenderness parameter	λ	=	1.86			
	D_c*	=	90.3			
	S_1*	=	0.33			
	S_2*	=	1.23			
	ϕ_{cc}	=	0.841			
Factored limit state stress	**ϕF_L**	**=**	**58.30**	**MPa**		
2. Sections not subject to torsional or torsional-flexural buckling						… 3.4.8.2
Largest slenderness ratio for flexural buckling	kL/r	=	99.83			
***3.4.10** Uniform compression in components of columns, gross section - flat plates*						
1. Uniform compression in components of columns, gross section - flat plates with both edges supported						… 3.4.10.1
	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	**ϕF_L**	**=**	**228.95**	**MPa**		
Most adverse compressive limit state stress	F_a	=	58.30	MPa		
Most adverse tensile limit state stress	F_a	=	222.70	MPa		

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Most adverse compressive & Tensile capacity factor	f_a/F_a	=	0.04		PASS	
BENDING - IN-PLANE						
3.4.15 *Compression in beams, extreme fibre, gross section rectangular tubes, box sections*						
Unbraced length for bending	L_b	=	1200	mm		
Second moment of area (weak axis)	I_y	=	62626.1	mm^4		
Torsion modulus	J	=	38065.7	mm^3		
Elastic section modulus	Z	=	5035	mm^3		
Slenderness	S	=	247.49			
Limit 1	S_1	=	0.39			
Limit 2	S_2	=	1695.86			
Factored limit state stress	**ϕF_L**	=	**194.30**	**MPa**		3.4.15(2)
3.4.17 *Compression in components of beams (component under uniform compression), gross section - flat plates with both edges supported*						
	k_1	=	0.5			T3.3(D)
	k_2	=	2.04			T3.3(D)
Max. distance between toes of fillets of supporting elements for plate	b'	=	16	mm		
	t	=	2	mm		
Slenderness	b/t	=	8			
Limit 1	S_1	=	12.34			
Limit 2	S_2	=	46.95			
Factored limit state stress	**ϕF_L**	=	**228.95**	**MPa**		
Most adverse in-plane bending limit state stress	F_{bx}	=	194.30	MPa		
Most adverse in-plane bending capacity factor	f_{bx}/F_{bx}	=	0.00		PASS	
BENDING - OUT-OF-PLANE						
NOTE: Limit state stresses, ϕF_L are the same for out-of-plane bending (doubly symmetric section)						
Factored limit state stress	**ϕF_L**	=	**194.30**	**MPa**		

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Most adverse out-of-plane bending limit state stress	F_{by}	=	194.30	MPa		
Most adverse out-of-plane bending capacity factor	f_{by}/F_{by}	=	0.00		PASS	

COMBINED ACTIONS

***4.1.1** Combined compression and bending* … 4.1.1(2)

F_a	=	58.30	MPa		… 3.4.8
F_{ao}	=	228.95	MPa		… 3.4.10
F_{bx}	=	194.30	MPa		… 3.4.17
F_{by}	=	194.30	MPa		… 3.4.17
f_a/F_a	=	0.039			

Check: $f_a/F_a + f_{bx}/F_{bx} + f_{by}/F_{by} \leq 1.0$ … 4.1.1 (3)

i.e. 0.04 ≤ 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	**ϕF_L**	=	**124.53**	**MPa**
Stress From Shear force	**f_{sx}**	=	V/A_w	
			0.51	**MPa**

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

Clear web height	b	=	16	mm
	t	=	2	mm
Slenderness	b/t	=	8	
Factored limit state stress	**ϕF_L**	=	**131.10**	**MPa**
Stress From Shear force	**f_{sy}**	=	V/A_w	
			0.89	**MPa**

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6.4 Summary Loads

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

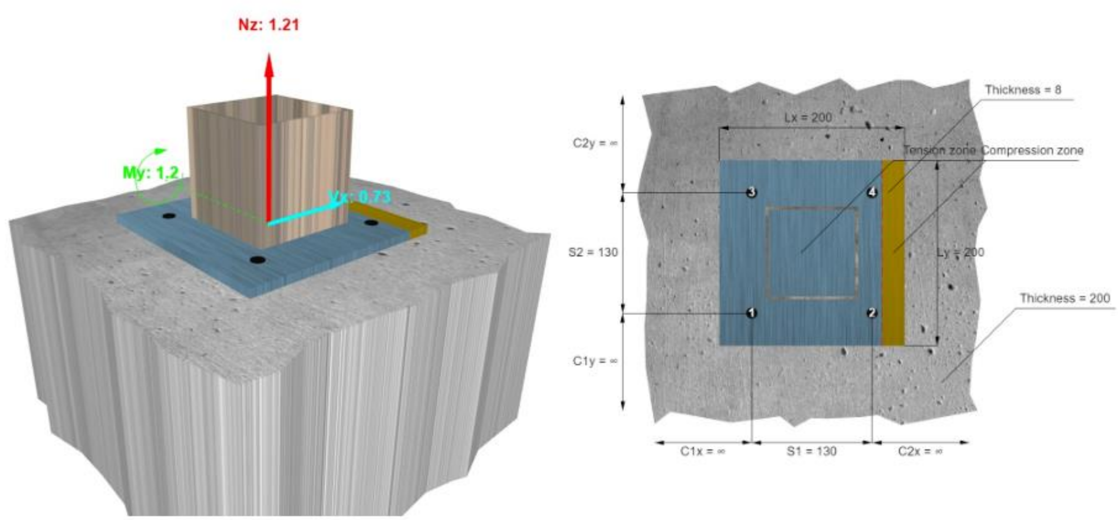
7 Anchor Design

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

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

Anchor size, db	Installation details			Optimum dimensions*		Reduced Characteristic Capacity			
	Drilled hole diameter, d_h (mm)	Anchor effective depth, h (mm)	Tightening torque, T_r (Nm)	Edge distance, e_c (mm)	Anchor spacing, a_c (mm)	Shear (steel) $ØV_{us}$ (kN)***	Tension (concrete), $ØN_{uc}$ (kN)** Concrete compressive strength, f'$_c$		
							20 MPa	32 MPa	40 MPa
M6	8	23	6	80	60	4.5	3.6	4.6	5.1
M6 Flanged	8	23	6	80	60	5.8	3.6	4.6	5.1
M8	10	28	10	100	70	5.8	4.9	6.1	6.9
M10	12	38	20	135	95	7.1	7.7	9.7	10.8
M10 Flanged	12	28	12	100	70	5.8	4.9	6.1	6.9
M12	16 #	48	40	170	120	13.2	10.9	13.8	15.4
M12 Flanged	16	48	40	170	120	13.2	10.9	13.8	15.4
M16	20	63	95	220	160	20.9	16.4	20.7	23.2
M20	25	78	180	275	195	26.3	22.6	28.5	31.9

Geometry :



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7.2 Temporary Installation - 1200 x 1200 x 8 Base Plate

Maximum uplift force at toe: 0.85kN

Self-weight of the base plate: 90kg

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

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

ABN: 62 051 307 852
3 Wanniti Road BELROSE NSW 2085 Tel: 02 9975 3899 Fax: 02 99751943
Email: hited@bigpond.net.au **Web: www.civilandstructural.com.au**

8 Summary

8.1 Conclusions

a. The 6m Round (Dodecagon) umbrella structure as specified has been analyzed with a conclusion that it has the capacity to withstand wind speeds up to and including **60km/hr when open and 140.4km/hr when folded.**

b. For forecast winds in excess of **60km/hr** – the umbrella structure should be completely folded. The umbrella with temporary anchorage system must be stored in an enclosed building however the umbrella with permanent anchorage system can remain folded on site.

c. For uplift due to 60km/hr, anchorage system described in Cl. 7 is required.

Yours faithfully,

E.A. Bennett M.I.E. Aust. NPER 198230

ABN: 62 051 307 852
3 Wanniti Road BELROSE NSW 2085
Tel: 02 9975 3899 Fax: 02 99751943
Email: hited@bigpond.net.au
Web: www.civilandstructural.com.au