SUNSHADES - SHEETS CALCULATION NOTE

CLIENT:

Masdar CITY مدينة مصدر

PROJECT MANAGEMENT COMPANY:

MORGANTI
MORGANTI INTERNATIONAL DIVISION

LEAD DESIGN CONSULTANT CONSTRUCTION SUPERVISION:

SHEPPARD ROBSON INTERNATIONAL
ARCHITECTURE URBAN DESIGN PLANNING INTERIORS

LOCATION 77 PARKWAY . CAMDEN TOWN . LONDON . NW1 7PU
PHONE +44 0 20 7504 1700 FAX +44 0 20 7504 1701
WEBSITE www.sheppardrobson.com E-MAIL sr.mail@sheppardrobson.com

THIRD PARTY COMMISSION AGENT:

AECOM
AECOM MIDDLE EAST LTD.
P.O.Box 43266, Abu Dhabi United Arab Emirates,
Tel. +971 2 414 6000 Fax. 02 414 6001,
www.aecom.com

MAIN CONTRACTOR:

AL FARA'A GEN. CONT. CO. L.L.C
1980
P.O Box 4157 ABU DHABI, UAE. P.O Box 15915 AL AIN, UAE.
TEL:02-6431333,FAX:02-6431666 TEL:03 7825825 , FAX:03 7825434

ALUMINUM CONTRACTOR:

BELGIUM aluminium & glass
1980

Al Ain (H.O)	TEL. (03) 7213800,	FAX: (03) 7213801
Dubai	TEL. (04) 3313344,	FAX: (04) 3321001
Sharjah	TEL. (06) 5344059,	FAX: (06) 5344078
Abu Dhabi	TEL. (02) 6769101,	FAX: (02) 6769121

E-mail- info@belgiumagi.com

PROJECT NAME

Siemens - Headquarters Masdar City
Plot L-14b Masdar, Abu Dhabi UAE

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SUNSHADES – FAÇADE NORTH-WEST
STRUCTURAL CALCULATION FOR ALULIMUN SHEET

Preamble:

According to comments of document AFG-SX-CN-003-0, the wind loads for the sunshades should be considered as following:

- Central area of the facade : Wind pressure : +1.71 kPa (Facade North-West)
  Wind suction: -1.88 kPa (Facade North-West)
- Corner areas of the façade : Wind pressure : +1.83 kPa (Façade North-West)
  Wind suction: -2.67 kPa (Façade North-West)

However and despite the above mentioned comments, we highlight that the previous wind loads are not applicable for the sunshades (calculation achieved for a partially enclosed building) and that these items should be considered as freestanding walls.
Unfortunately, ASCE 7-05 does not give a method to calculate wind loads for such a shape (depth and ratio of solid area to gross area not applicable).

However, we tried to simulate a calculation according to the below information (most favorable conditions) to compare the result with the previous values approved:

- Wind speed = 44.5m/s
- Topographic factor 1.00
- Directionality factor 1.00
- Building category II / Exposure C / Rigid Structure
- Freestanding wall Inserted in a box according to the following:
  - B Horizontal dimension 1m46
  - L depth dimension 0m01 (average)
  - H vertical dimension 3m35
  - E ratio solid area to gross area 71% (mini allows by ASCE 7-05)
- Base elevation of structure relative to grade 24.65 m (Level 5)
- H Height from grade to top of structure 28.00 m

According to MWRFS, we found a pressure of 2289 Pa (enclosed on Appendix A) which is less than the previous value applied for the ribbon windows (-2 670 Pa). We highlight that this result is not a representation of the reality but it is providing an order of the magnitude for the wind load applied on the sunshades.

Consequently, the structural calculation for the aluminum sheets of the sunshades will be achieved according to the following values:

- Minimum wind pressure found on ribbon windows : 1 710 Pa
- Value found on a concept of freestanding wall 2 290 Pa

The maximum value found on ribbon windows (-2670Pa) will be used only for control in the final stage.

Data:

According to specification, the below alloy will be used for the sunshade sheets:

- ***Aluminum Alloy:*** ***3003 H14***

The physical properties of this alloy defined by the Aluminum Association (AA) are:

- Density : 2730 kg/m^3
- Poisson's Ratio: 0,33
- CTE linear : 23,2µm/m (@Temperature 20°-100°)
- Tensile Strength-Yield: 130MPa (@ Temperature 100°C)
  145MPa (@ Temperature 25°C)
- Elongation at Break: 16% (@ Temperature 25°C -100°C)
- Module of Elasticity: 69.8 GPa
- Fatigue Strength:: 62.1 MPa
- Shear Strength: 96.5 MPa

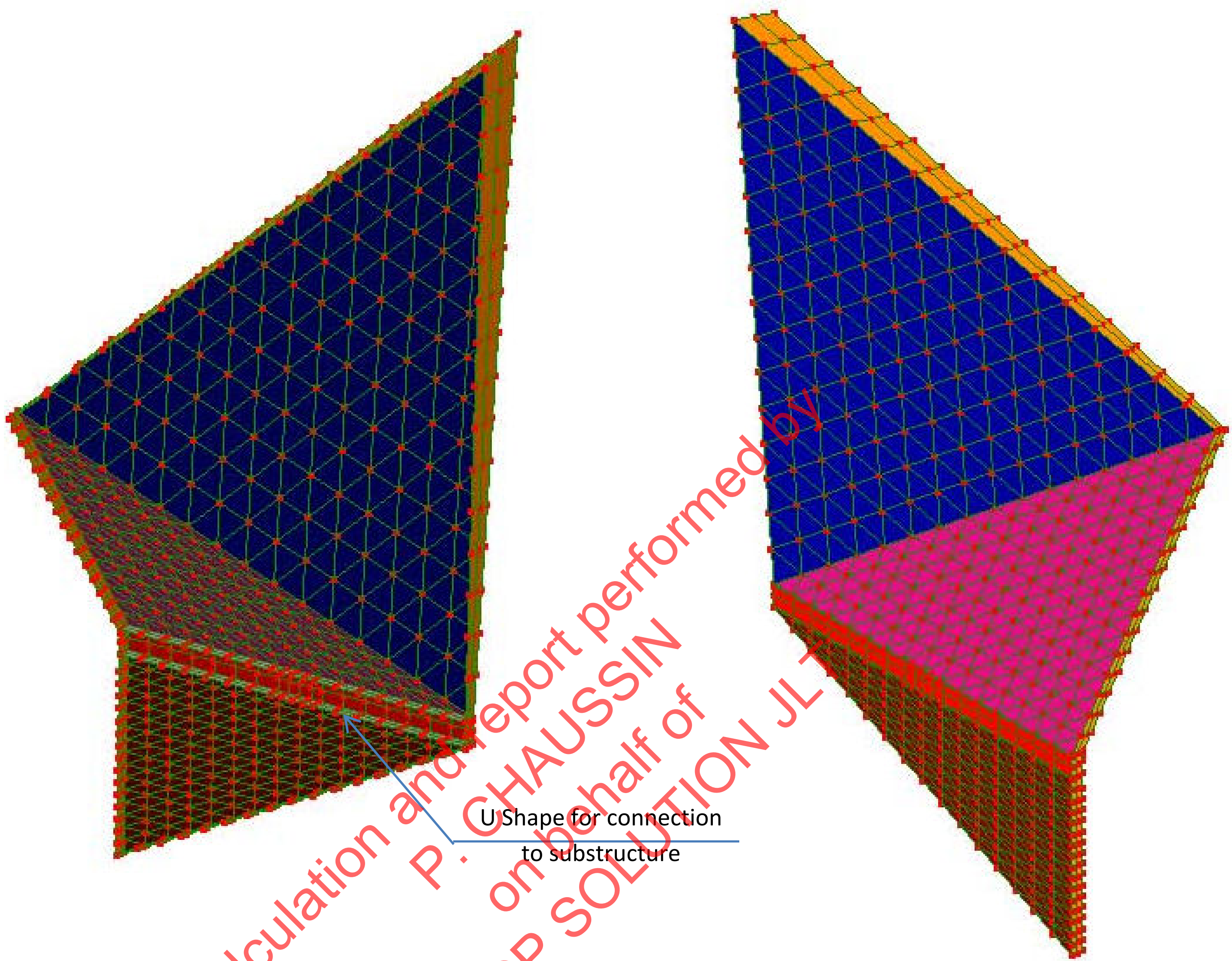
Method of calculation:

According to the geometry of the sunshades, a Finite Element Analysis has been carried out.to control the deformation and the stress applied on these items.

3D-Model:

For the 3D-Model, the following rules have been used:

- No deformations/movements of the substructure connecting the sunshades to the building.
- The 3D-model is based on a membrane (surface) with a thickness of 3mm in compliance with specification.(other thickness will be applied according to the result, if require)
- The physical properties above described are defined for all directions (isotropic material)
- The mesh has been designed with triangular and quadratic elements (3 or 4 nodes).



AXIONOMETRIC VIEW FROM OUTSIDE

AXIONOMETRIC VIEW FROM INSIDE

Hypothesis about the fixing system:

In a first step, the calculation has been carried out in compliance with the fixing system identified in the tender drawings.

Accordingly, two central nodes connected to the tubular structure are fixed in the three directions. The other nodes axe fixed only in two directions (X-axis free to allow thermal expansion). (see Fig1)

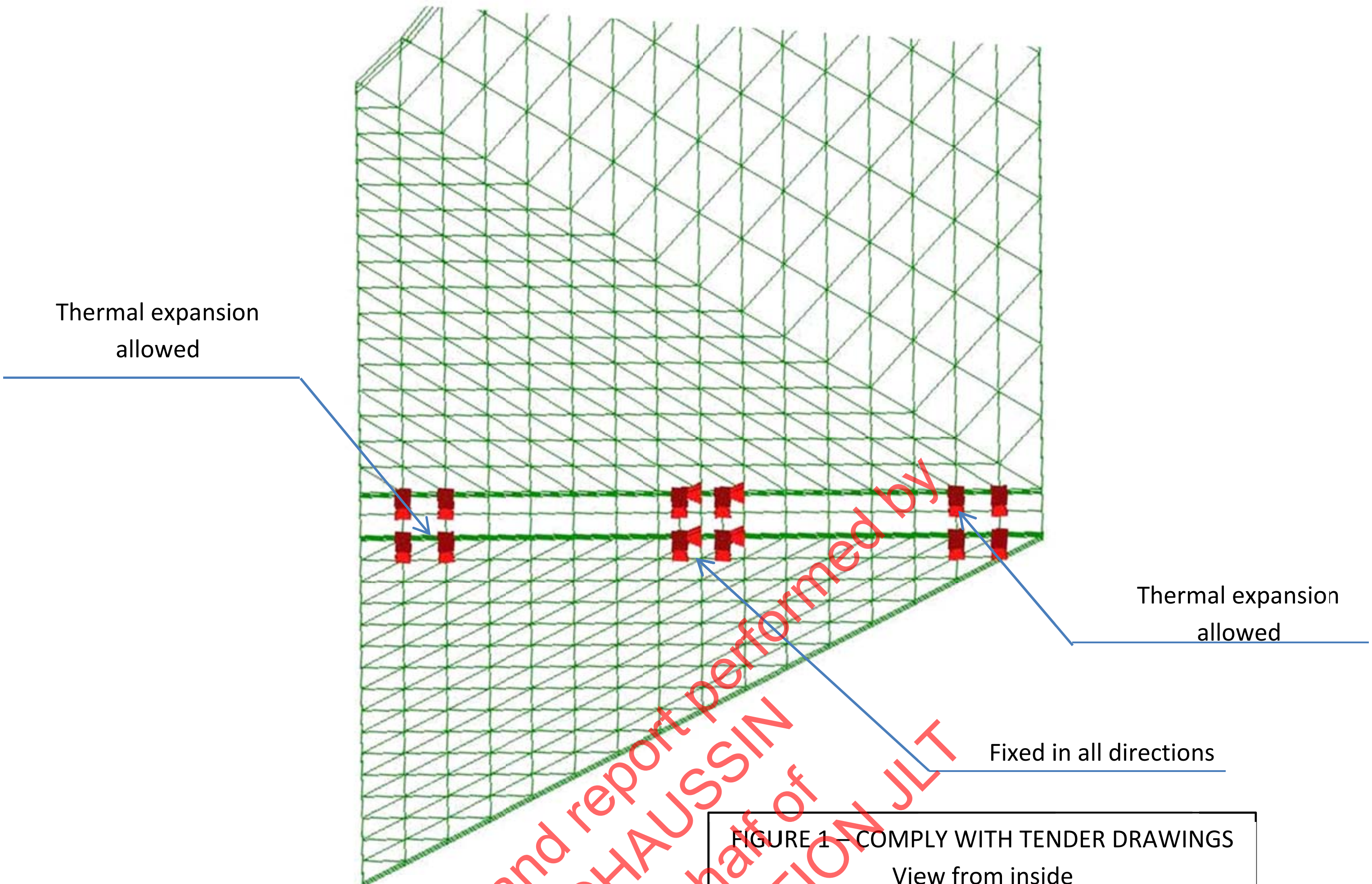


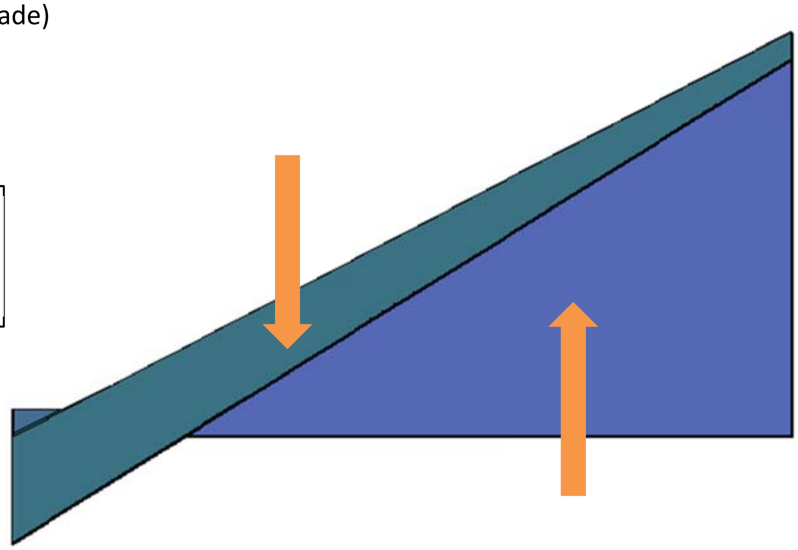
FIGURE 1 – COMPLY WITH TENDER DRAWINGS
View from inside

Hypotheses about Wind directions:

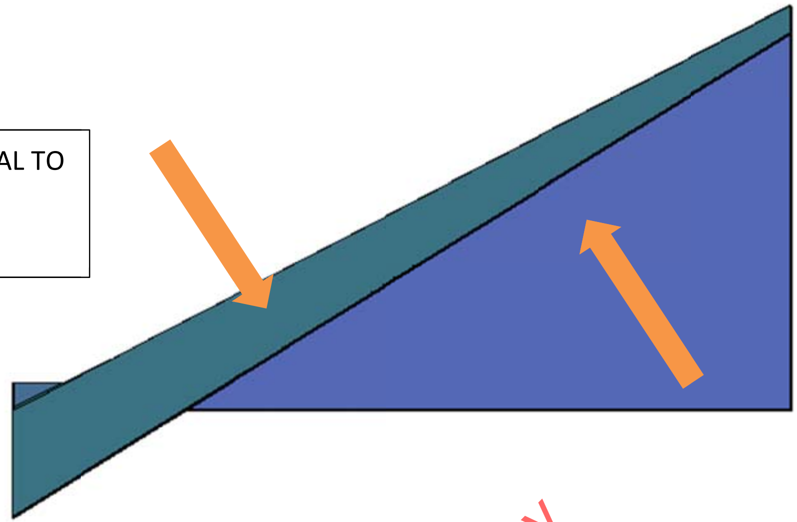
According to information extracted from the Engineering Design Report of the Tender Documents (Addendum 2) the wind direction is covering a large segment of angles.
Therefore, the simulation has been carried out with the following wind directions:

- Normal to the façade (Normal to the lower panel of the Sunshade)
- Normal to the larger panel of the façade (32° with the perpendicular of the façade)

WIND PRESSURE/SUCTION
NORMAL TO FAÇADE
CASE 1

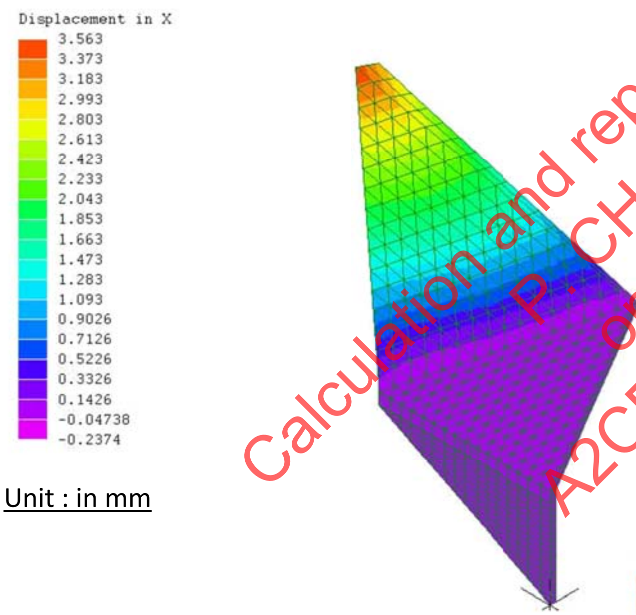


WIND PRESSURE/SUCTION NORMAL TO LARGER FACE OF SUNSHADE
CASE 2

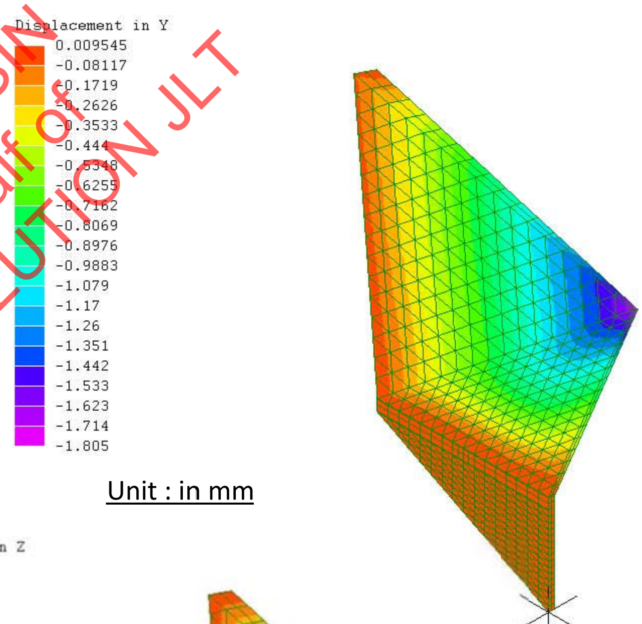


Results:

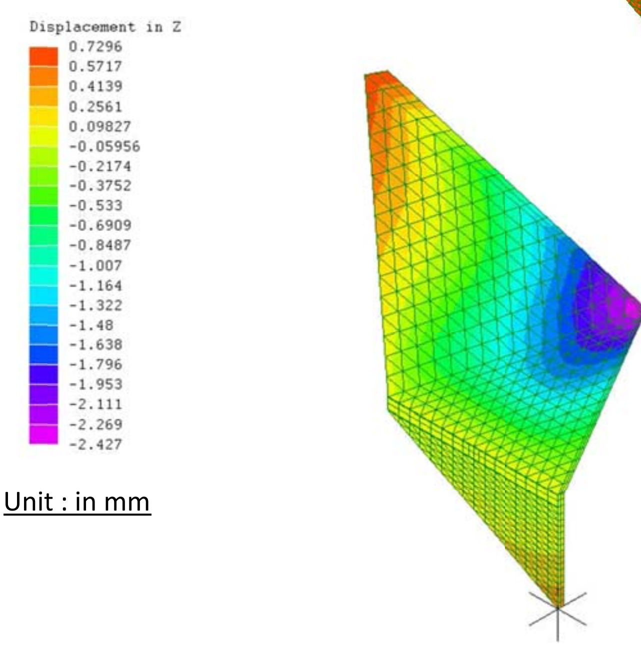
A preliminary calculation was achieved without wind loads to control the impact of the self-weight on the sunshade deflection. The deflection found is represented below on the three directions.



Unit : in mm



Unit : in mm



Unit : in mm

Sheet thickness: 3mm

FIGURE 2

The displacement magnitude found is important and it already demonstrates that the top of the sunshades will be very sensitive to pressure and that the lack of constraints in this area will certainly deeply affects the stability of the sunshades.

However, a calculation was achieve with these constraint conditions and a wind pressure of 1 710 Pa normal to the façade. The results are shown on the below representation:

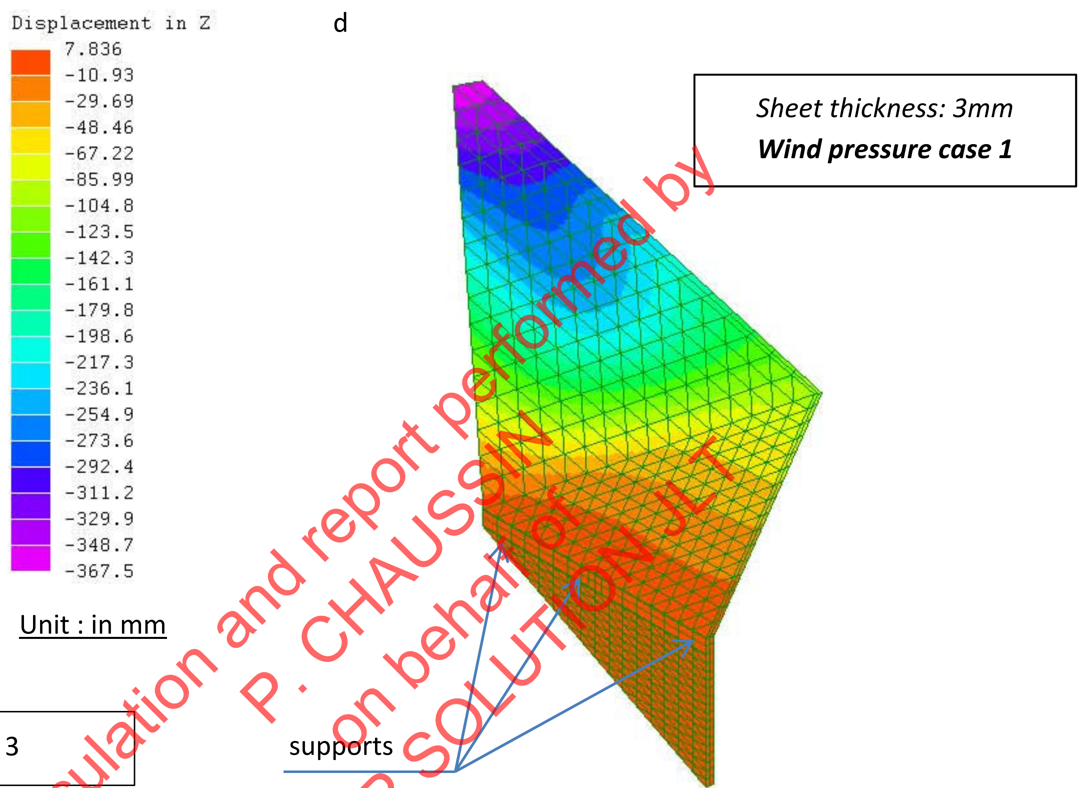


FIGURE 3

The displacement of the top of the sunshade is around 20 times more important than the acceptable value defined in the specification (19mm max). This design is not stable and it requires to be modified.

Analysis to solve the instability:

According to previous information, a new calculation has been achieved with additional constraints to fix the top of the sunshade (in the three directions). We highlight that this analysis is considering only the aluminum sheet and will not analyze how to build the substructure to match such hypotheses.

The results found are shown in the above representation on the following page:

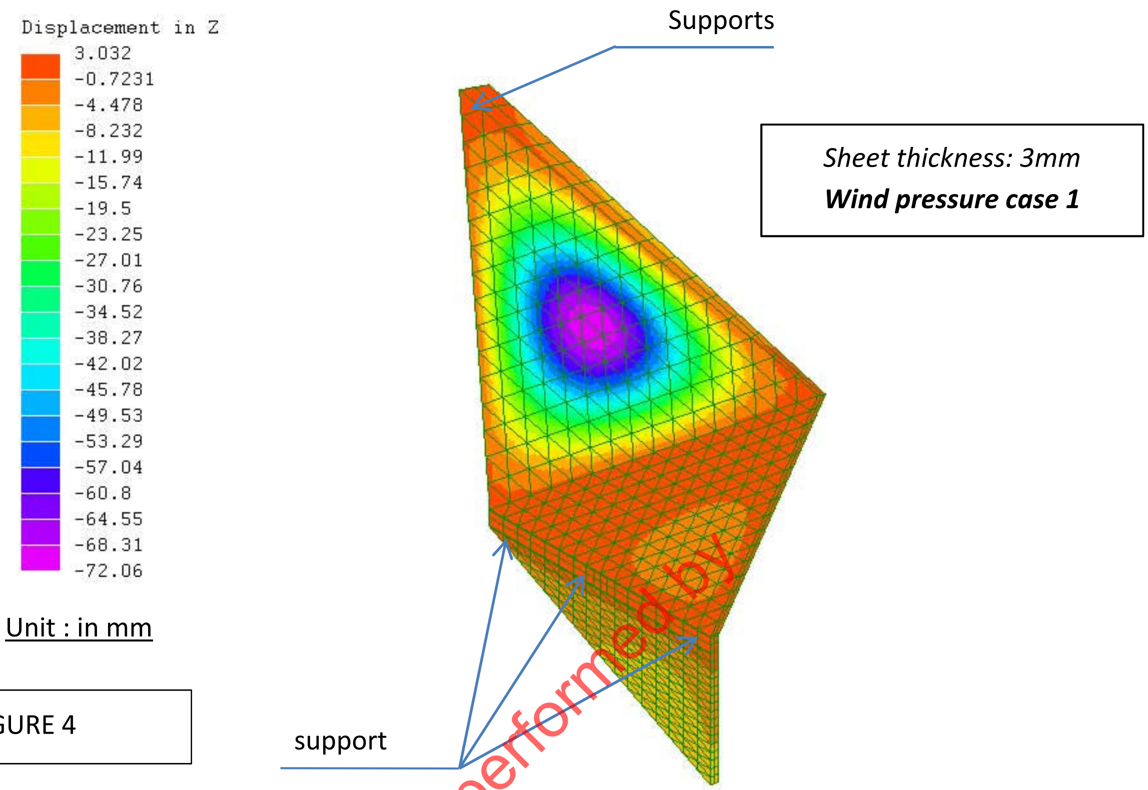


FIGURE 4

The result demonstrates that fixing the top of the sunshade solve a part of the difficulties met in the first calculation. **However, it also demonstrates that the thickness of the aluminum sheet is not able to accept such a load.**

A new calculation was achieved with a thickness of 5mm for the aluminum sheet. The result is shown on the following representation:

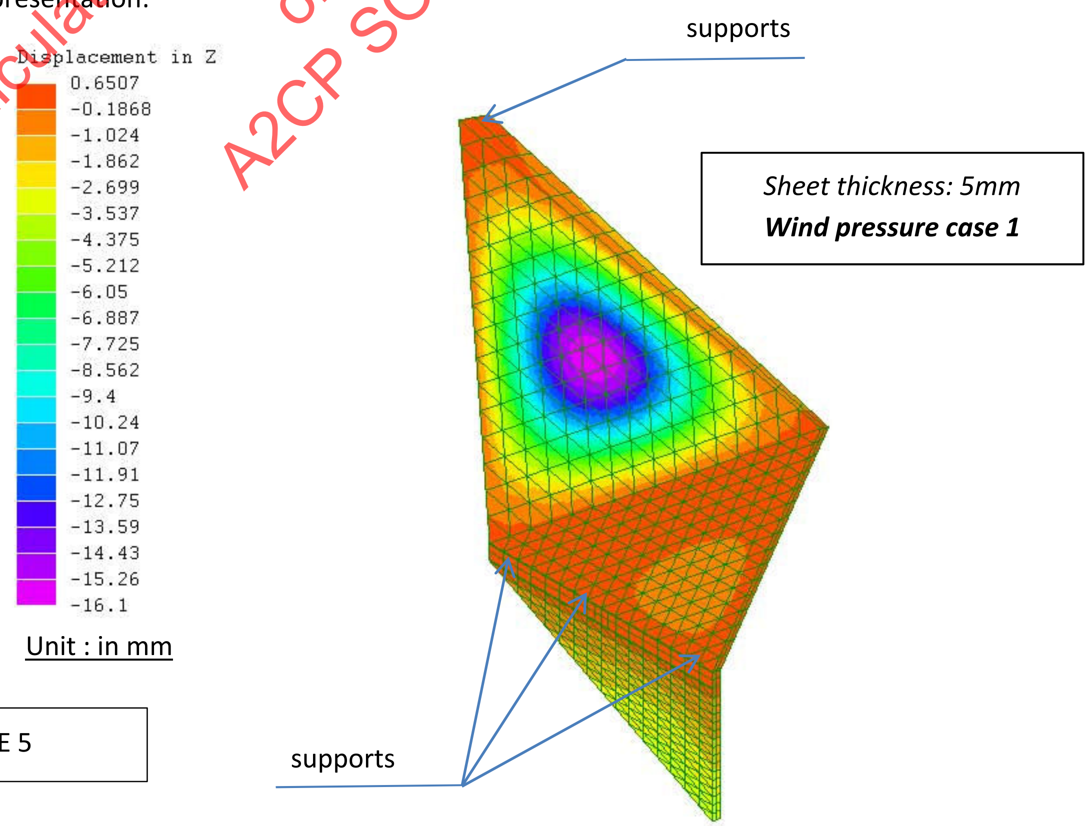


FIGURE 5

The result shows that a thickness of 5mm will accept the load used for the calculation. However, this load is normal to the façade and is not representing the worst case (Wind pressure normal to the larger face of the sunshade)

Another calculation was achieved with the same wind pressure but with a wind direction normal to the larger face of the sunshade. The results are shown on the below representation:

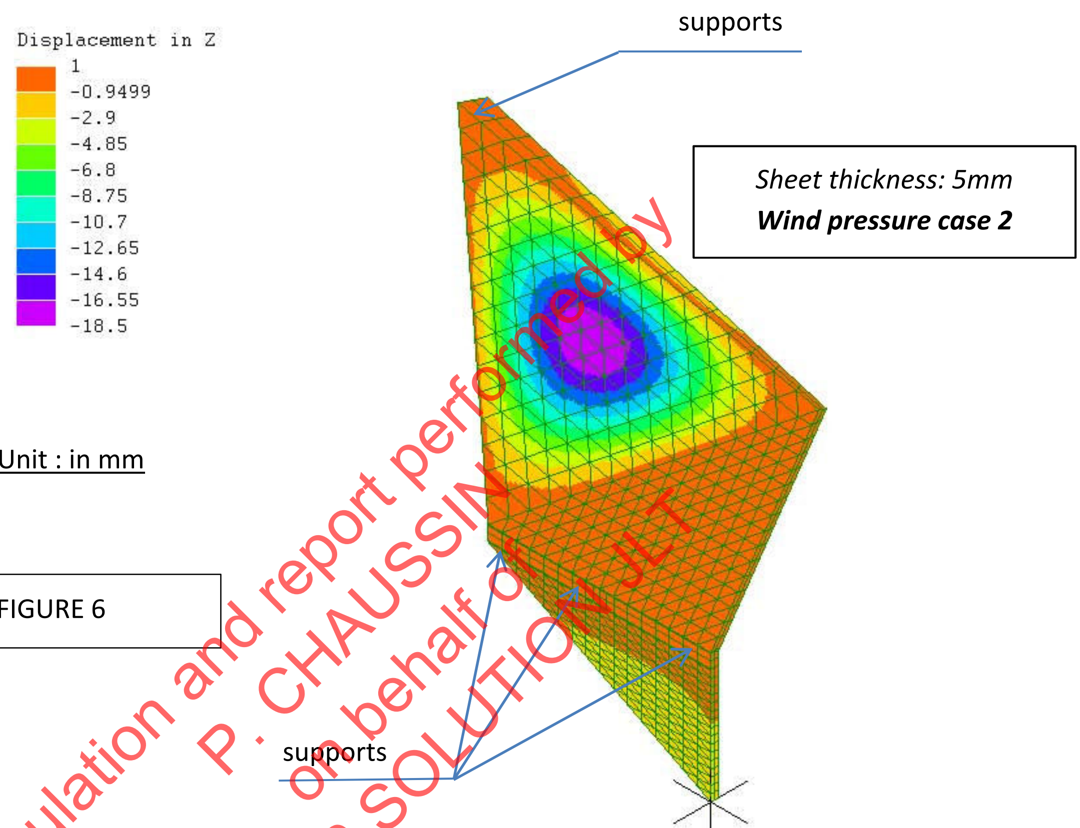
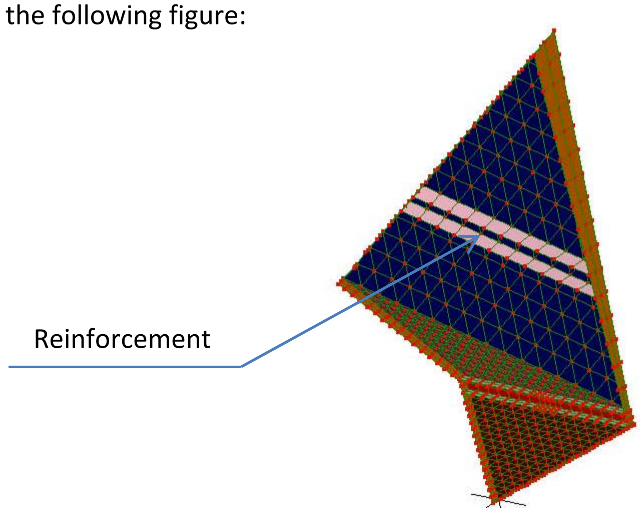


FIGURE 6

The result demonstrates that a wind direction normal to the larger face of the sunshade will be the worst case. Additionally, a thickness of 5mm will not be able to accept higher pressure. Therefore, increasing the thickness of the sheet is not a solution to solve the instability of these sunshades;

Accordingly we carried out a new calculation using a structural reinforcement on the back of the sheet (U shape) as shown on the following figure:



The result is represented on the following figure:

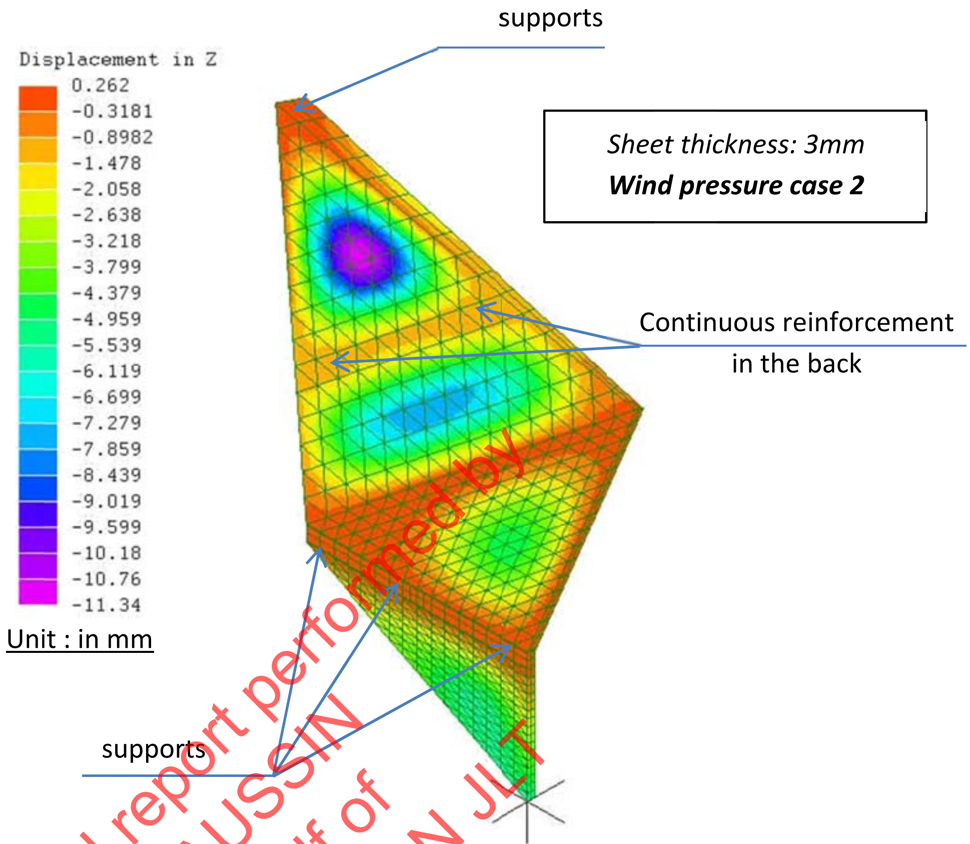


FIGURE 7

The result regarding the displacement magnitude is acceptable for a pressure of 1 710 Pa.

A new calculation was achieved with the same conditions but with a wind pressure of 2 290 Pa.
The result is represented on the figure below.

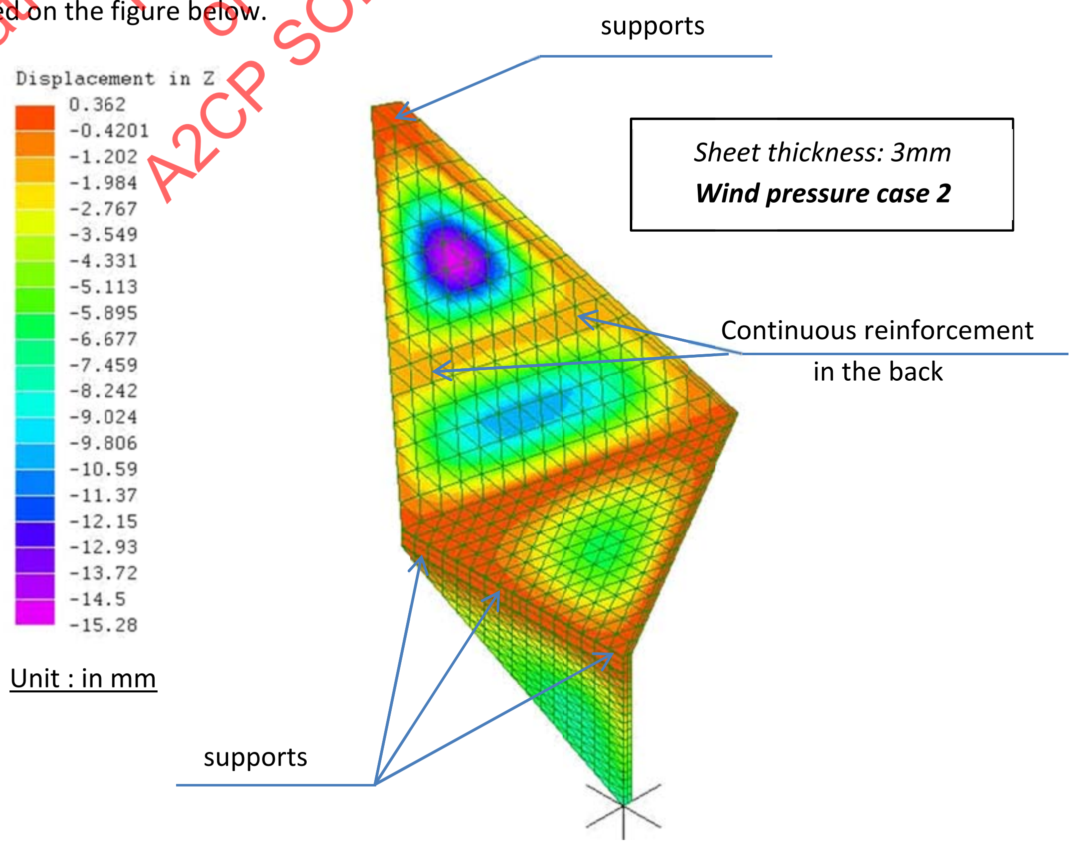


FIGURE 8

The result regarding the displacement magnitude is acceptable for a pressure of 2 290 Pa.

Additionally, a control of the stress according to BS8118 (factor 1.2) show that the worst case is applied on node 621 according to the following figure:

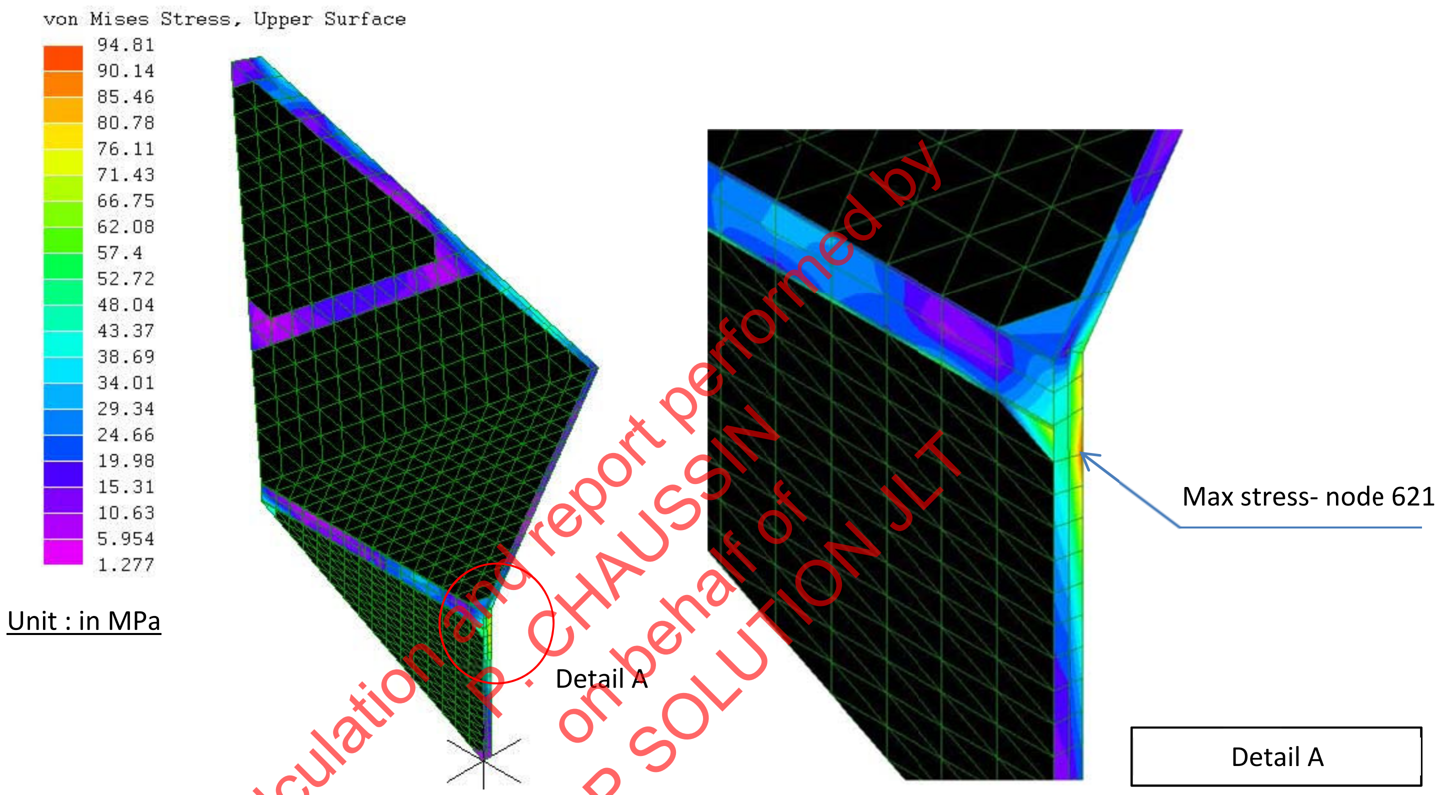


FIGURE 9

The maximum stress is 94.81MPa which is less than the value defined in the Data (130MPa@130°C), so the result is accepted.

A last calculation was achieved to control the displacement for negative pressure. The calculation was carried out with the same constraint conditions than previously defined, a wind pressure of 2290 Pa and a wind direction normal to the larger face of the sunshade.
The results are shown on the figure 10 on the following page.

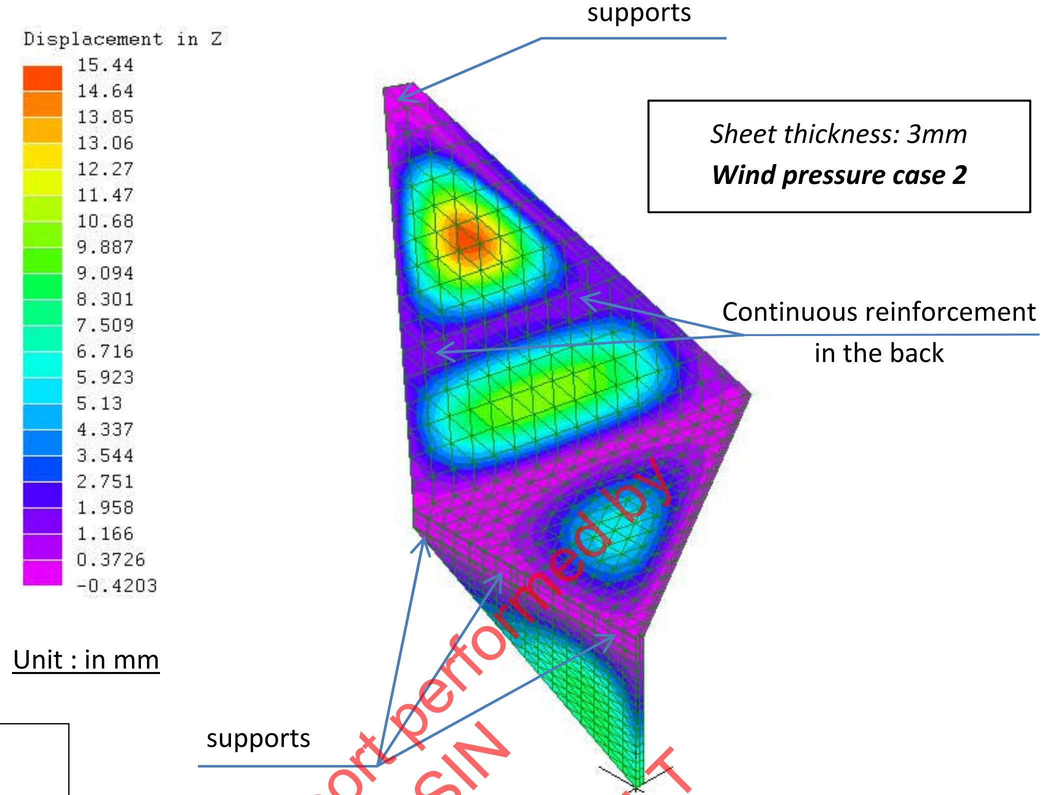


FIGURE 10

Conclusion:

This calculation note demonstrates that the Design suggested for these sunshades is not workable.
It requires a fixed supports for the top of the sunshades and reinforcement in the back of the sheet for the larger panel.

Additionally we already inform you that the sunshades connected to the walkways of the staircases areas are presenting the same instability and require to be modified. An additional report will also demonstrate this issue.

APPENDIX A

MECAWind Version 2.1.0.5 per ASCE 7-05

Developed by MECA Enterprises, Inc. Copyright 2012 www.mecaenterprises.com

Date	: 4/6/2012	Project No.	:
Company Name	:	Designed By	:
Address	:	Description	:
City	:	Customer Name	:
State	:	Proj Location	:

File Location: C:\Program Files\MECAWind\Default.wnd

Detailed Wind Load Design(Method 2) per ASCE 7-05

Basic Wind Speed(V)	= 44.50 m/s	Structure Type	= Other
Structural Category	= II	Exposure Category	= C
Natural Frequency	= N/A	Flexible Structure	= No
Importance Factor	= 1.00	Kd Directional Factor	= 1.00
Damping Ratio (beta)	= 0.01		
Alpha	= 9.50	Zg	= 274.32 m
At	= 0.11	Bt	= 1.00
Am	= 0.15	Bm	= 0.65
Cc	= 0.20	l	= 152.40 m
Epsilon	= 0.20	Zmin	= 4.57 m
B - Horizontal Dim.	= 1.46 m	Ht- Grade to Top of Sign	= 28.00 m
W - Sign Depth	= 0.01 m	S - Vertical Sign Dim.	= 3.35 m
Bs- Ratio of B / S	= 0.44	Sh- Ratio of S / Ht	= 0.12
E - Solidity Ratio	= 71.00 %		

Gust Factor Category I Rigid Structures - Simplified Method

Gust1: For Rigid Structures (Nat. Freq.>1 Hz) use 0.85 = 0.85

Gust Factor Category II Rigid Structures - Complete Analysis

Zm: 0.6*Ht = 16.80 m
lzm: Cc*(33/Zm)^0.167 = 0.18
Lzm: l*(Zm/33)^Epsilon = 168.87 m
Q: (1/(1+0.63*((B+Ht)/Lzm)^0.63))^0.5 = 0.91
Gust2: 0.925*((1+1.7*lzm*3.4*Q)/(1+1.7*3.4*lzm)) = 0.88

Gust Factor Summary

Not a Flexible Structure use the Lessor of Gust1 or Gust2 = 0.85

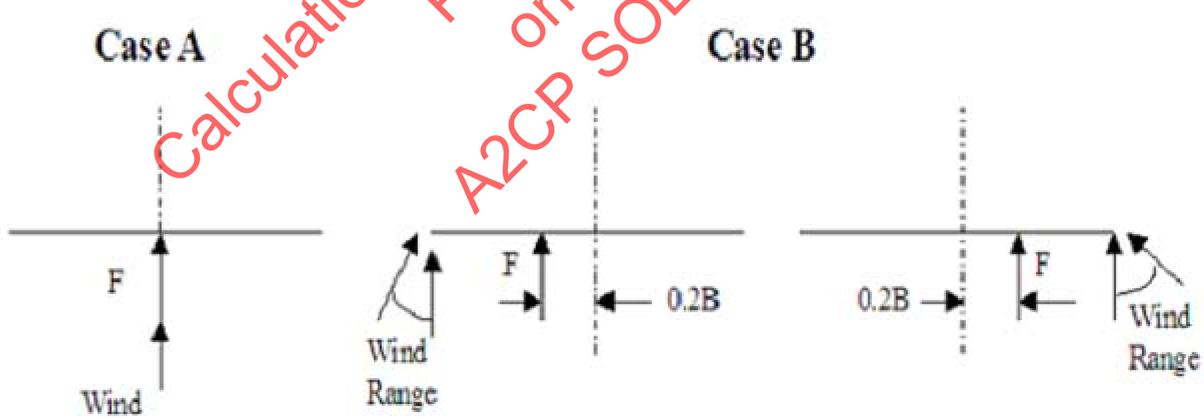
Design Wind Pressure - Other Structures

Elev m	Kz	Kzt	qz KPa	W_Pres_Cf(1.56) KPa
28.00	1.42	1.00	1.725	2.289
27.43	1.42	1.00	1.721	2.283
26.82	1.41	1.00	1.717	2.278
26.21	1.41	1.00	1.712	2.272
25.60	1.41	1.00	1.708	2.266
24.99	1.40	1.00	1.704	2.260
24.38	1.40	1.00	1.699	2.255
23.77	1.40	1.00	1.695	2.249
23.16	1.39	1.00	1.690	2.243
22.56	1.39	1.00	1.686	2.237
21.95	1.38	1.00	1.681	2.230
21.34	1.38	1.00	1.676	2.224
20.73	1.38	1.00	1.672	2.218
20.12	1.37	1.00	1.667	2.212
19.51	1.37	1.00	1.662	2.205
18.90	1.36	1.00	1.657	2.199
18.29	1.36	1.00	1.652	2.192
17.68	1.36	1.00	1.647	2.186

17.07	1.35	1.00	1.642	2.179
16.46	1.35	1.00	1.637	2.172
15.85	1.34	1.00	1.632	2.166
15.24	1.34	1.00	1.627	2.159
14.63	1.34	1.00	1.622	2.152
14.02	1.33	1.00	1.616	2.145
13.41	1.33	1.00	1.611	2.137
12.80	1.32	1.00	1.605	2.130
12.19	1.32	1.00	1.600	2.123
11.58	1.31	1.00	1.594	2.115
10.97	1.31	1.00	1.589	2.108
10.36	1.30	1.00	1.583	2.100
9.75	1.30	1.00	1.577	2.092
9.14	1.29	1.00	1.571	2.085
8.53	1.29	1.00	1.565	2.077
7.92	1.28	1.00	1.559	2.069
7.32	1.28	1.00	1.553	2.060
6.71	1.27	1.00	1.546	2.052
6.10	1.27	1.00	1.540	2.044
5.49	1.26	1.00	1.534	2.035
4.88	1.26	1.00	1.527	2.026
4.27	1.25	1.00	1.520	2.017
3.66	1.25	1.00	1.513	2.008
3.05	1.24	1.00	1.507	1.999
2.44	1.23	1.00	1.500	1.990
1.83	1.23	1.00	1.492	1.980
1.22	1.22	1.00	1.485	1.971
0.61	1.22	1.00	1.478	1.961

Note: W_Pres_Cf is Wind Pressure based on Cf(Force Coefficient)

Figure 6-20: Wind Loads for Solid Signs & Freestanding Walls



Cf - Force Coefficient	=	1.56
Rd - Reduction Factor (1-(1-E)^1.5)	=	0.84
Kz	=	1.42
Kzt	=	1.00
Qz	=	1.725 KPa
Wind Pressure at Elevation 28 m	**=**	**2.289 KPa**

Notes: 1) Signs with openings comprising < 30% of gross area are considered solid signs
2) Force Coefficients for solid signs with openings shall be multiplied by Rd
3) Case C only applies when Bs >= 2