Membrane for Contemporary Art Museum Tehran

2019

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Tensile Structure For Contemporary Art Museum Entrance

Final-Thesis

A thesis submitted in partial fulfillment
of the requirements for the degree of

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IMS BAUHAUS® Archineer® Institutes e.V.
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Faculty of Architecture,
Facility Management and Geo Information

by

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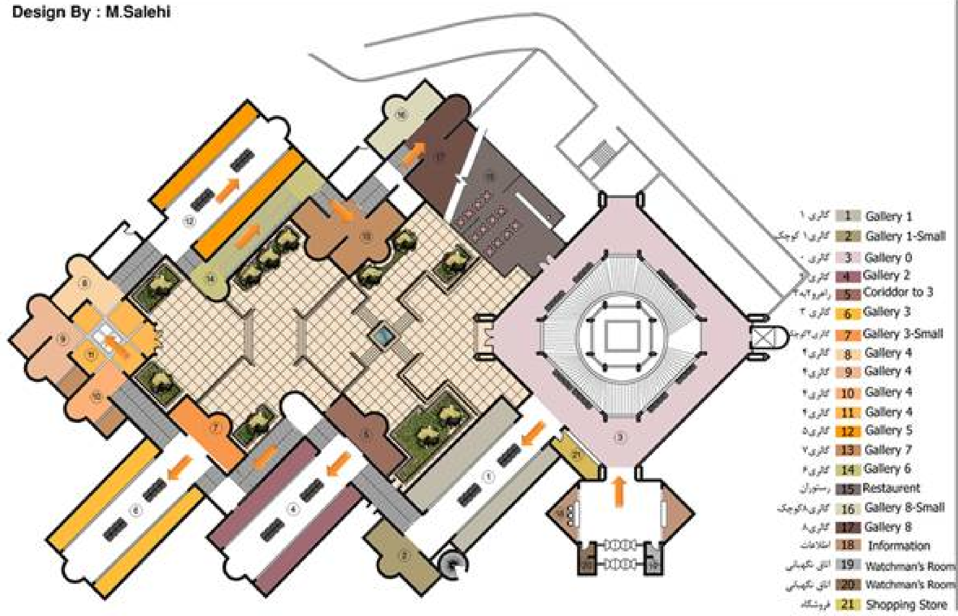
Statement

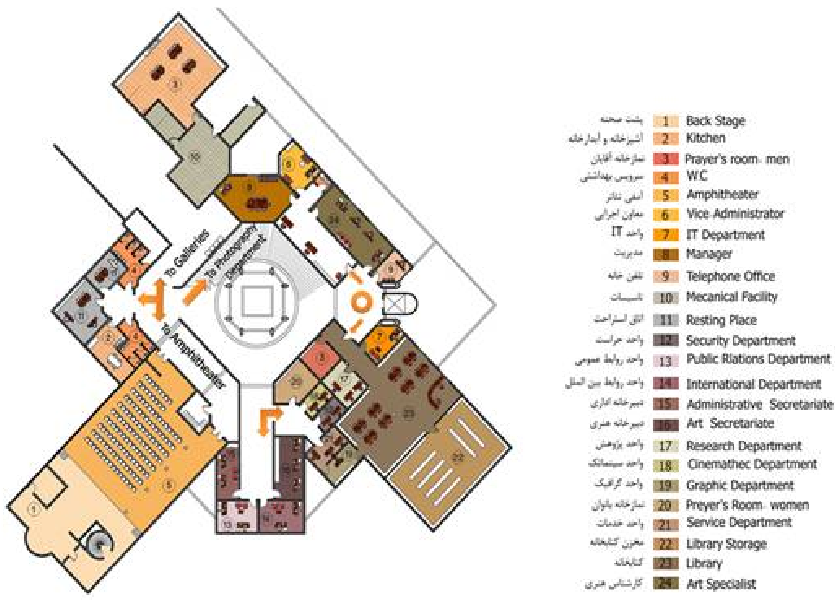
I hereby declare that the work presented in this Final thesis, entitled: “Tensile Structure For Contemporary Art Museum Entrance’, is entirely my own and that I did not use any sources or auxiliary means other than those referenced.

Tehran, 08.2019

Sareh Soltani

Design By : M.Salehi





The contemporary art museum situated in the center of Tehran, in a 2000 square meter of the sculpture park, is one of the most beautiful and iconic buildings of Iran's contemporary architecture.
Inspired by traditional architecture and its ideology, Kamran Diba designed this center in 1977 and since then it has hosted a variety of national and international art activities.
Wind catchers as skylights, Hashti, Charsou are examples of applying traditional features in modern architecture.
The building itself is a successful example of postmodern architecture, complimenting and completing the urban and landscape around it.

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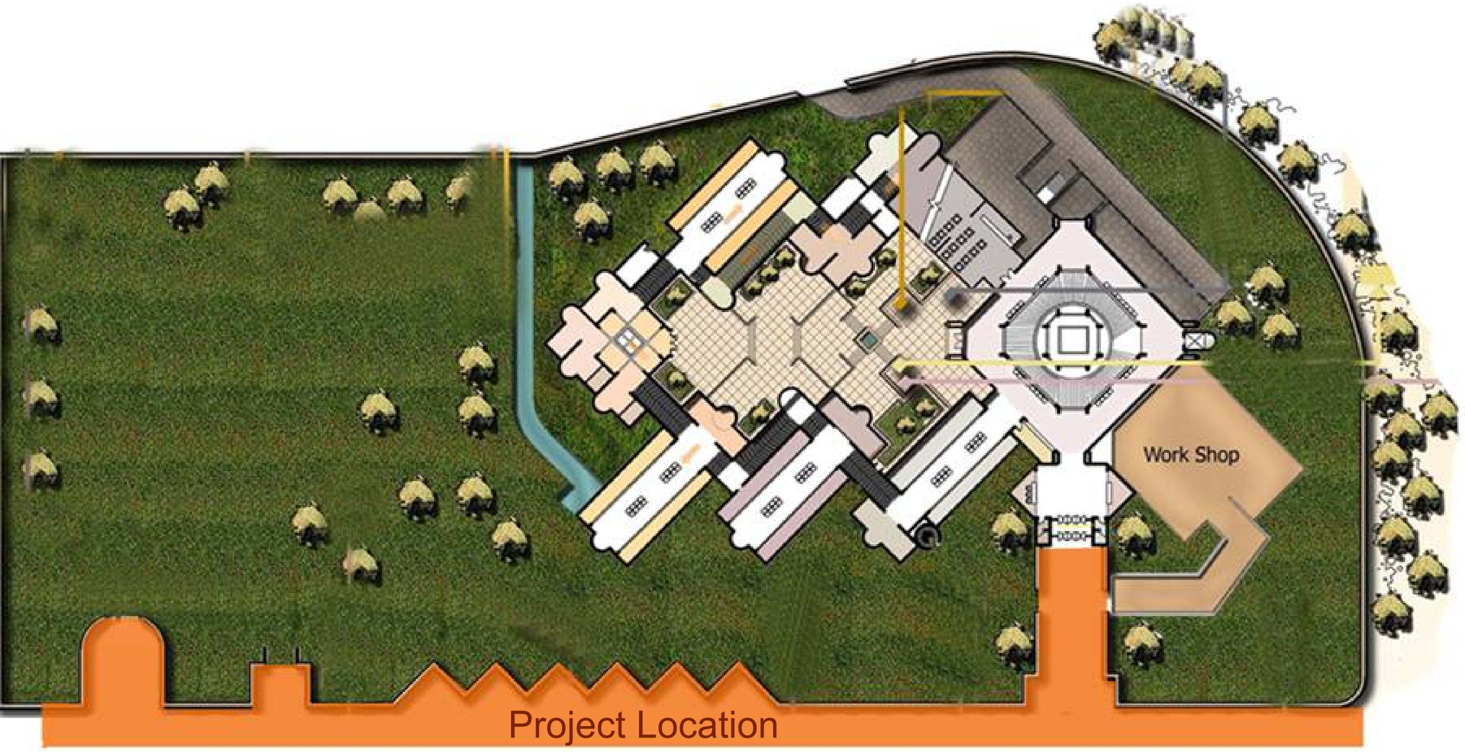
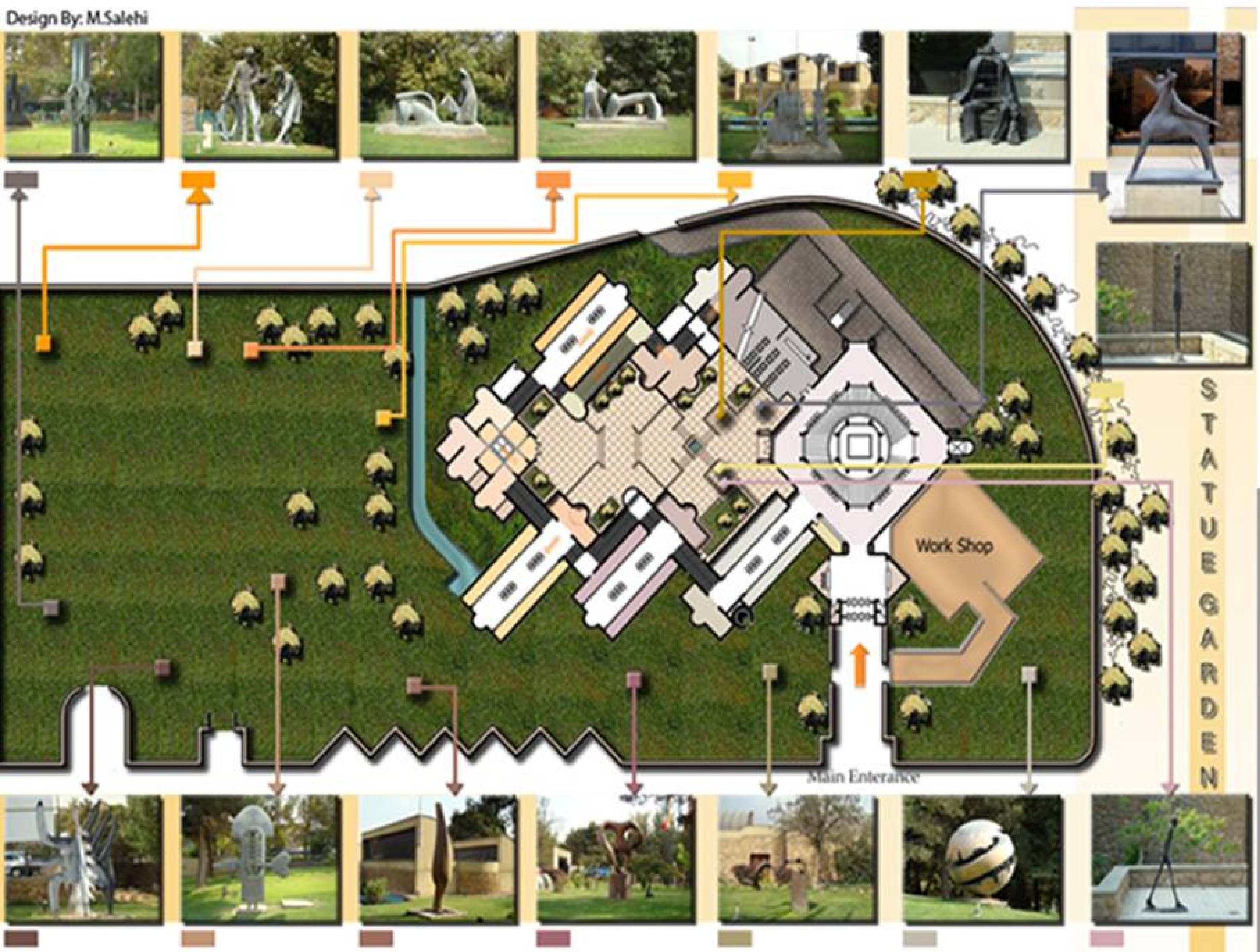
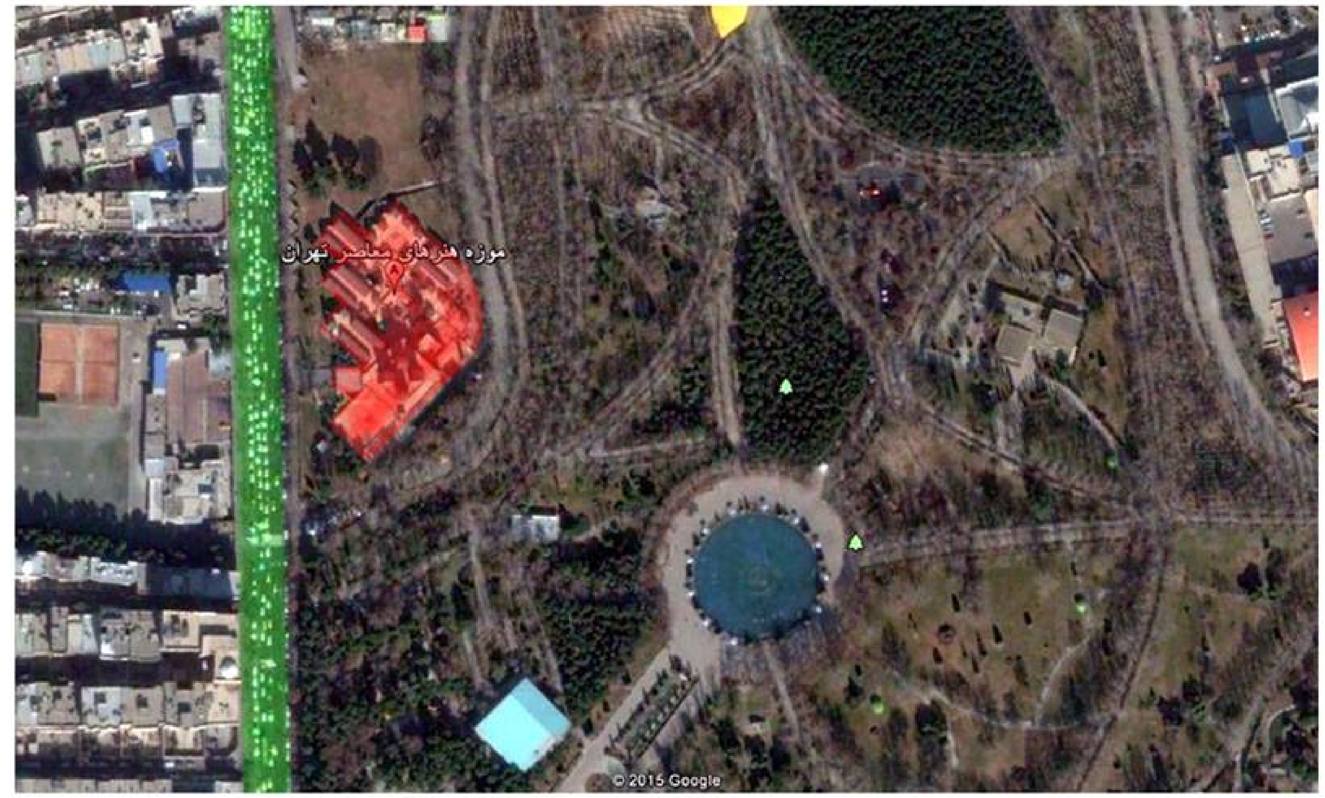






As the museum is located on the east of Kargar street and west of Laleh park, it has two entrances as well, one facing the street and another on the opposite side, toward the park. The building's length is alongside the street with the sculpture park ahead.

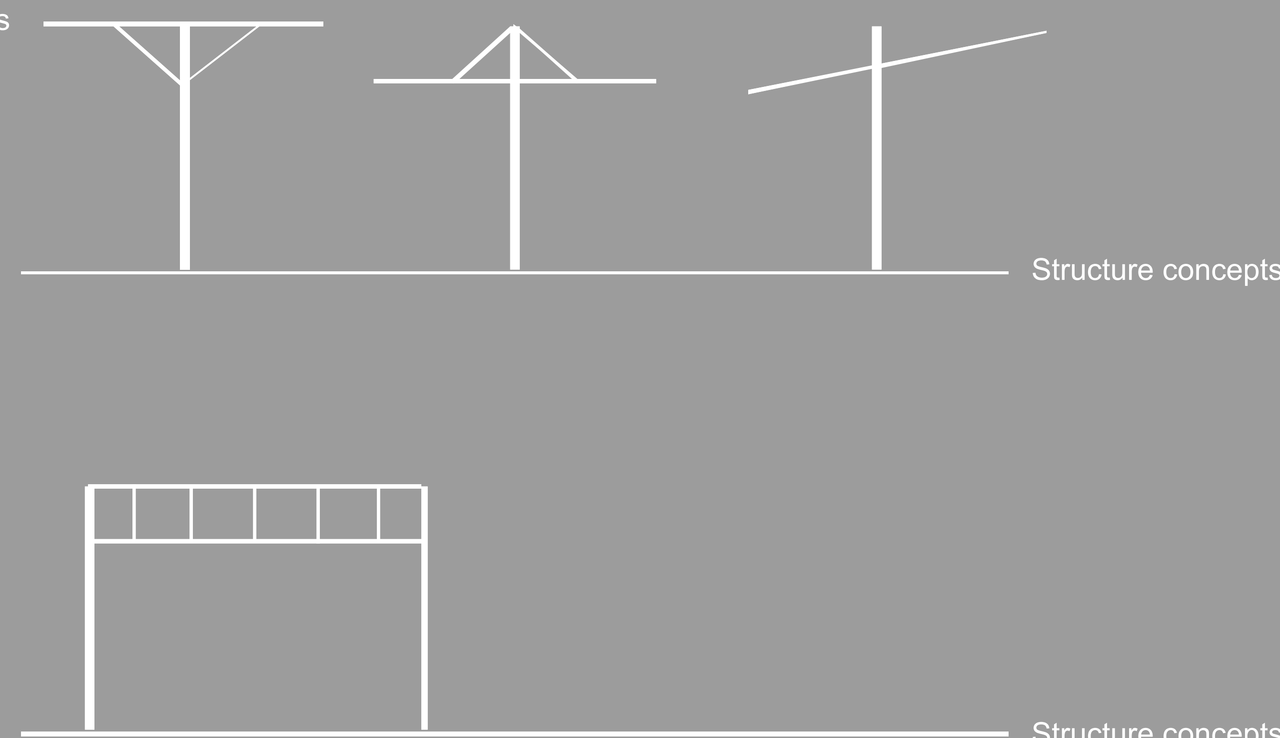
The border between the street on the west and the site is designed to let the passengers view the sculptures and the building like the visitors.

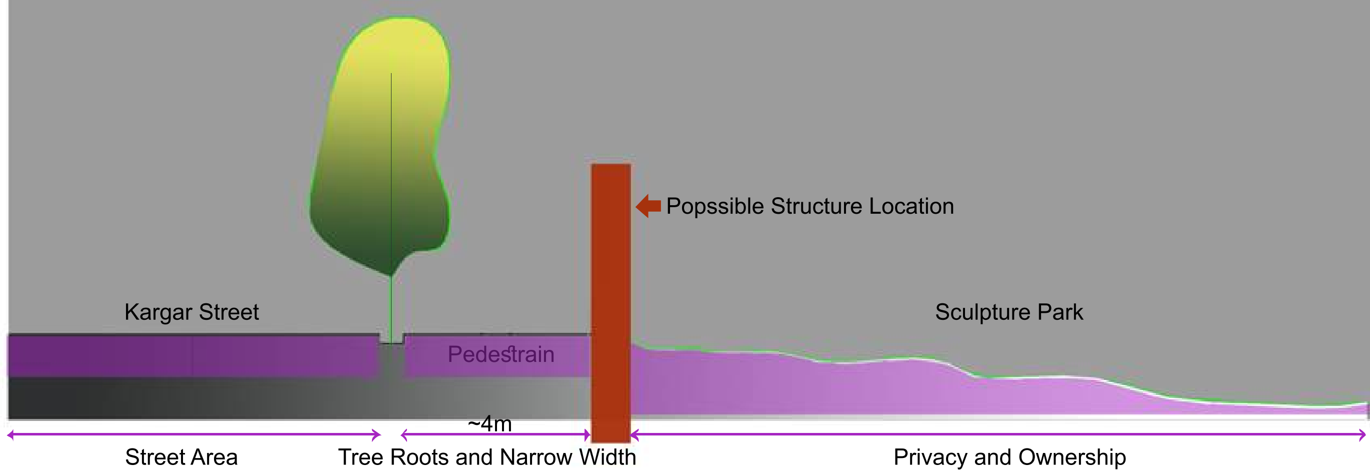
The area between the main entrance and the park on the north is the project's location.

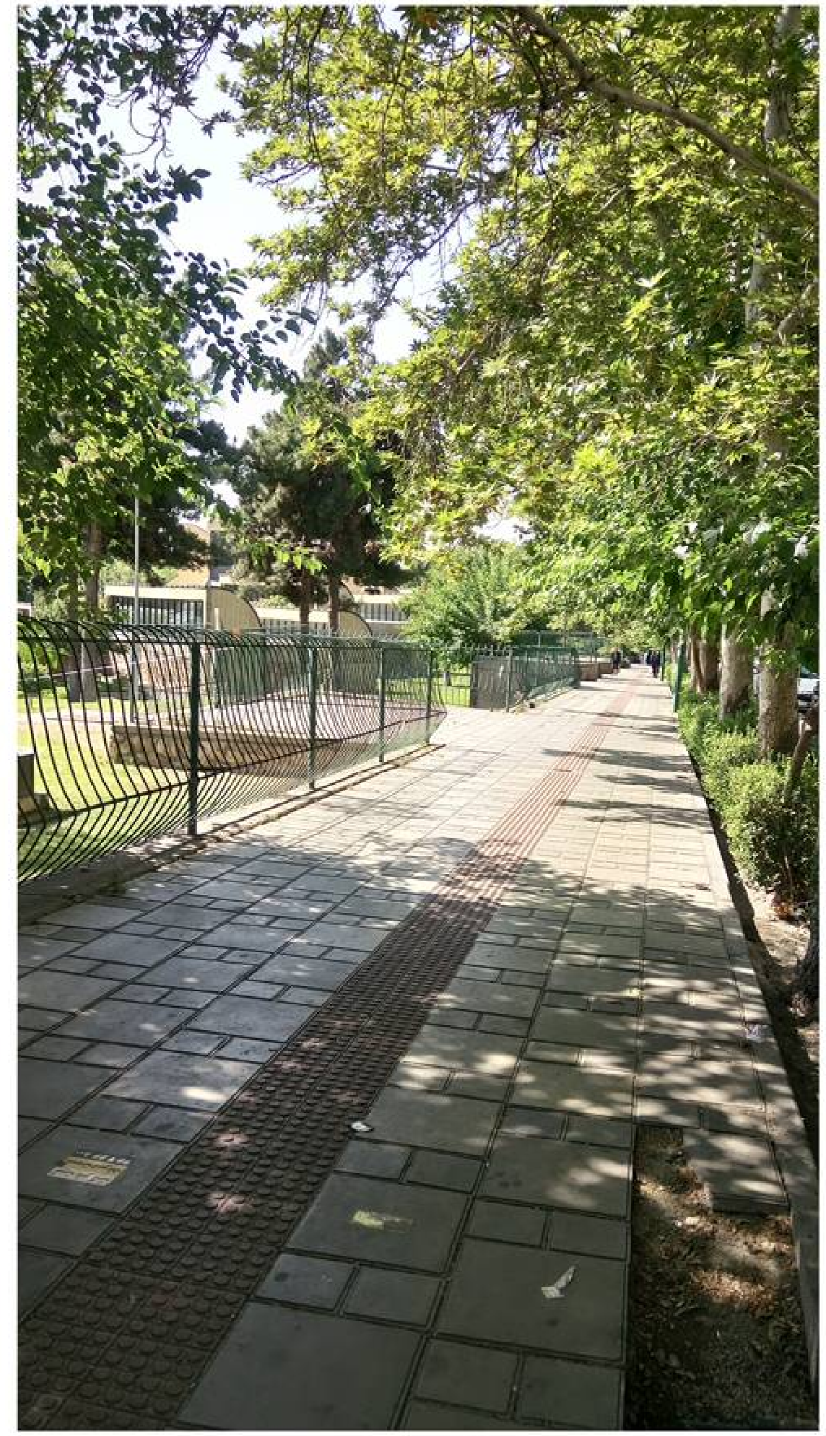
The goal is to cover this area with a prestigious membrane structure to:

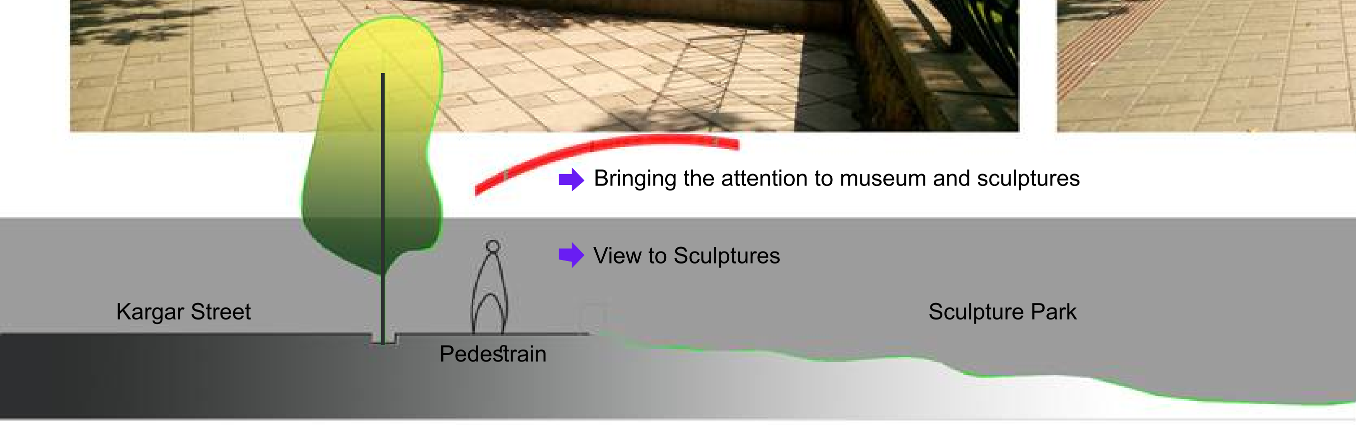
- Add up to this building a new contemporary feature which renews and complement the existing artistic architectural atmosphere with a modern and advanced structure.
- Cover the passage of visitors from extreme heat so that they could stand a few moments to rest, catch a breath and enjoy the scenery.
- Draw more the attention of people toward the building and the sculptures.

As shown in the pictures above, the passage between the two entrances is narrow. On the left side, there are trees between pedestrian and street. On the right, the border between museum site and pedestrian.
To cover this area one essential issue is the location of the structure. The structure should not damage the trees, nor narrow the pedestrian, neither violate the privacy and ownership of the museum.
This is a technical issue which determines if the project is realistic or not.
The diagram on the left shows that with all the assumed conditions, the only suitable area to install the structure is the borderline between the museum site and the pedestrian.
The width does not allow for more than one column. Therefore, the overall concept of the structure is one column that holds the roof as a hanging surface.

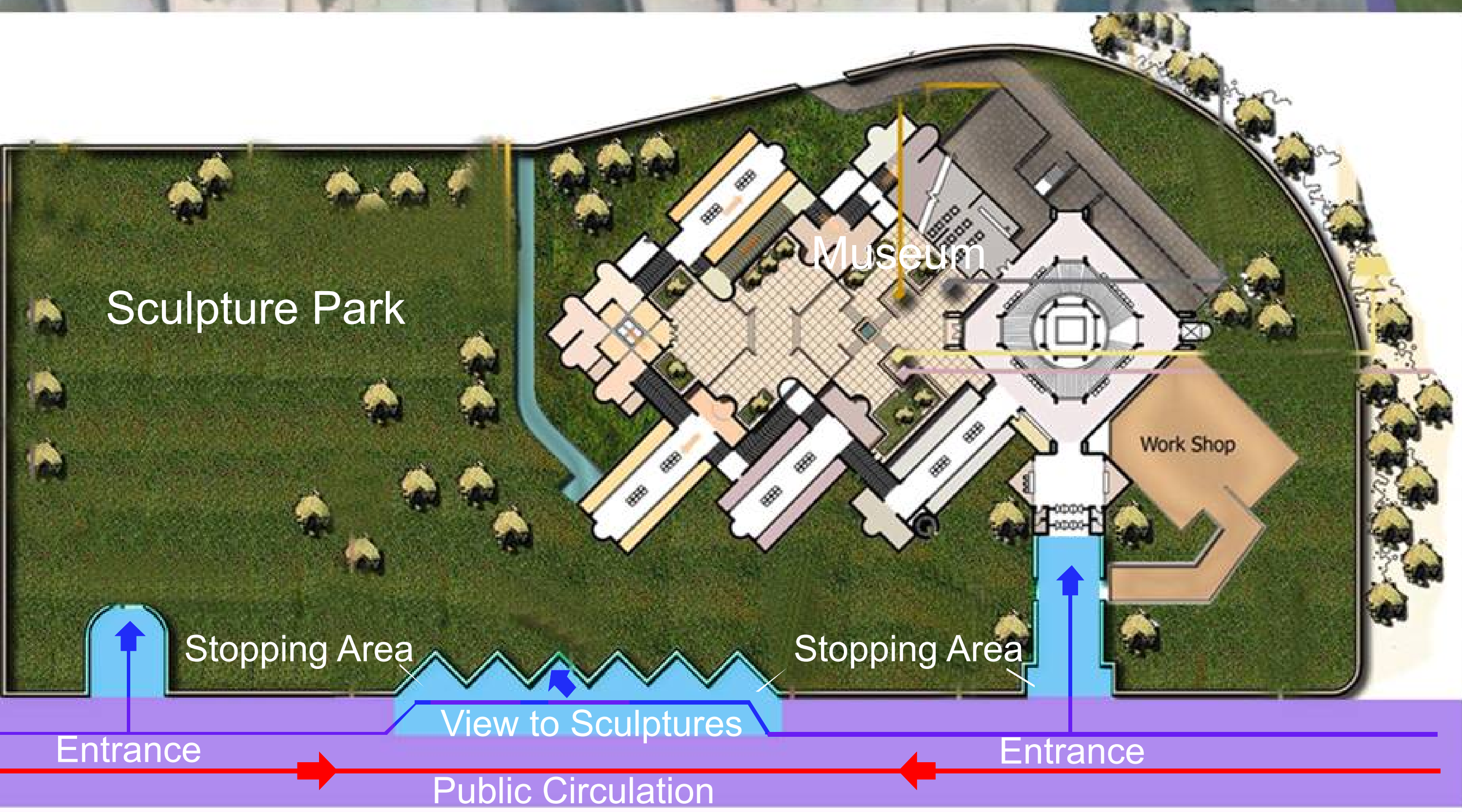








One of the approaches of this project is to draw the attention of passengers toward the museum and sculptures. To achieve it, the shape of the membrane is a determining element. The diagram shows how the surface along the road emphasizes the view on the east. That is also a reason for extending the surface to the site where there is no passenger.

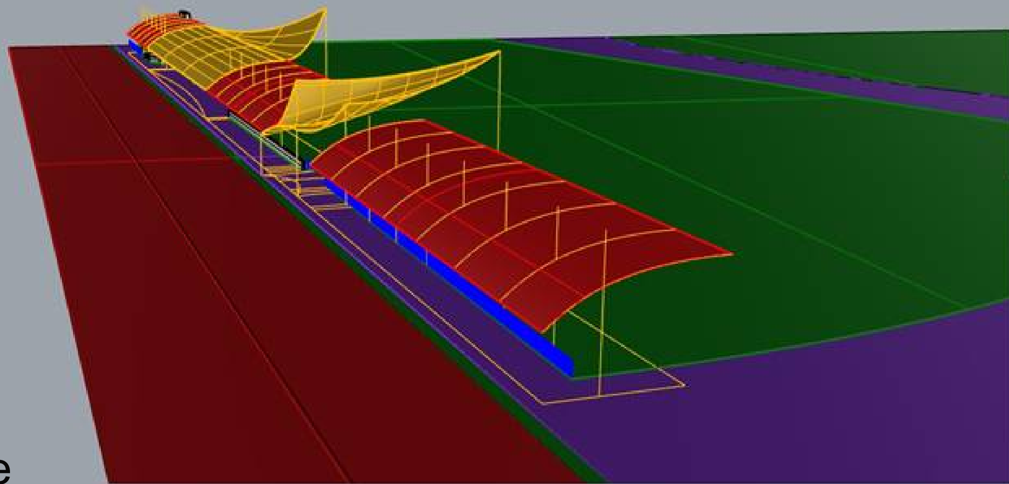


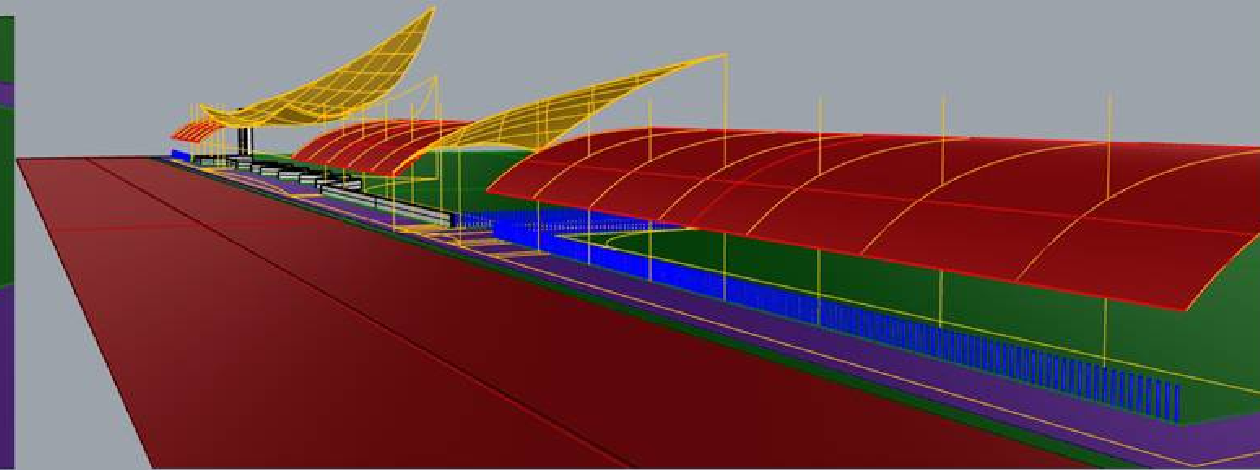
Site Analysis

On the south, there is a wide pedestrian from the entrance of the park which connects two entrances of the museum. From that entrance to the north one, the membrane covers the road.
Along the route, there are two areas with different characteristics, labeled as stopping areas. One is the entrance to the museum and the other is part of the pedestrian in the middle of the route, where the pedestrian is wider to let passengers stop or sit by the side.
To emphasize the quality and function of them, the concept design of the membrane differs from the design of the coverage over the road.
Finding a suitable form of structure for these areas is the major challenge of this project. In the next pages, different approachs and forms tested for these spots, are presented.
Sheltering passengers from heat and rain, especially extreme sommer heat is another goal of this project. From studying traditional architecture with a sustainable approach, we know that covering a vast area will result in a few degrees that the temperature in the shadow area will be lower than the area aside without any shadow. This will cause movement in the air, which passengers will perceive as a gentle breaze.
It will bring comfort and make them slow their pace for a while.
In traditional architecture, this method in the center areas consists of the usage of water as well.

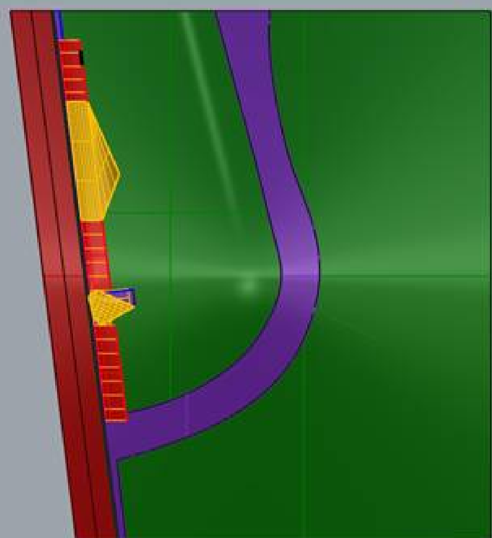
Sketch-01

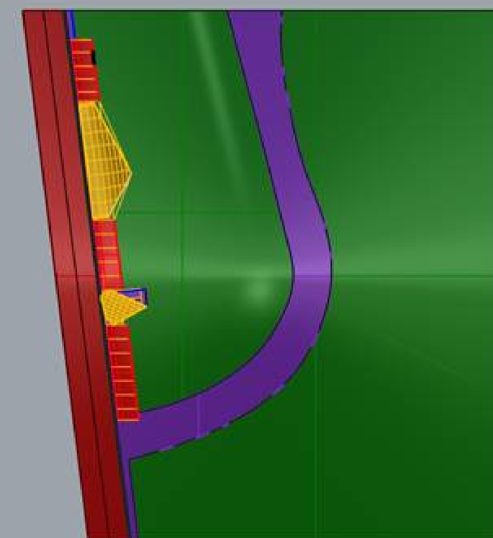
Sketch-02



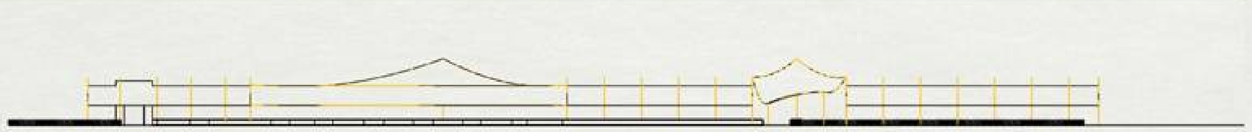


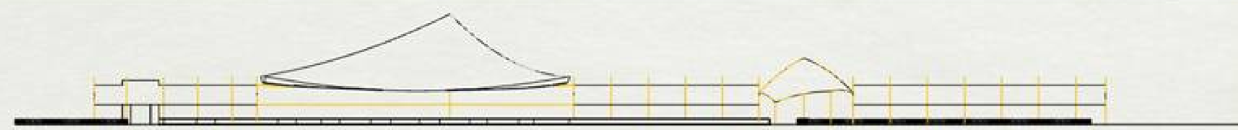
Prespective



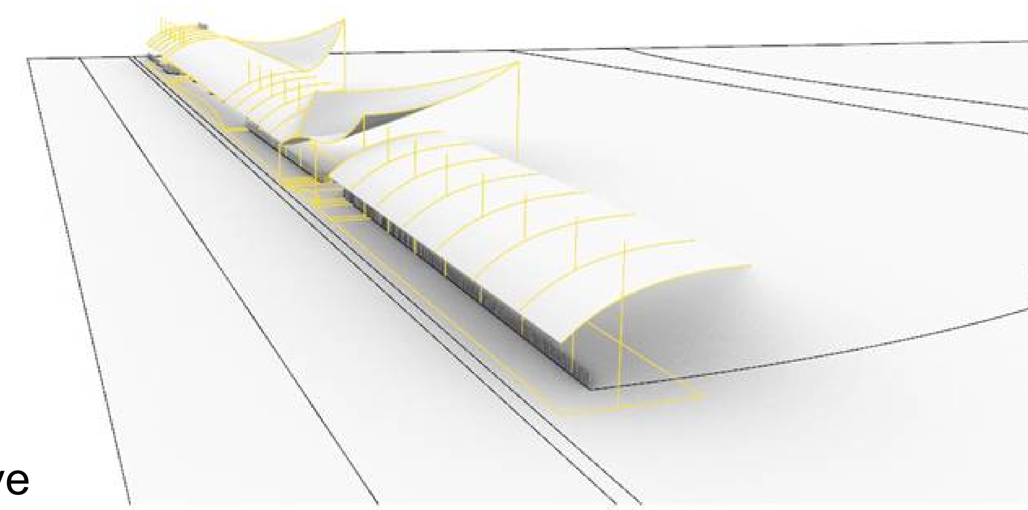


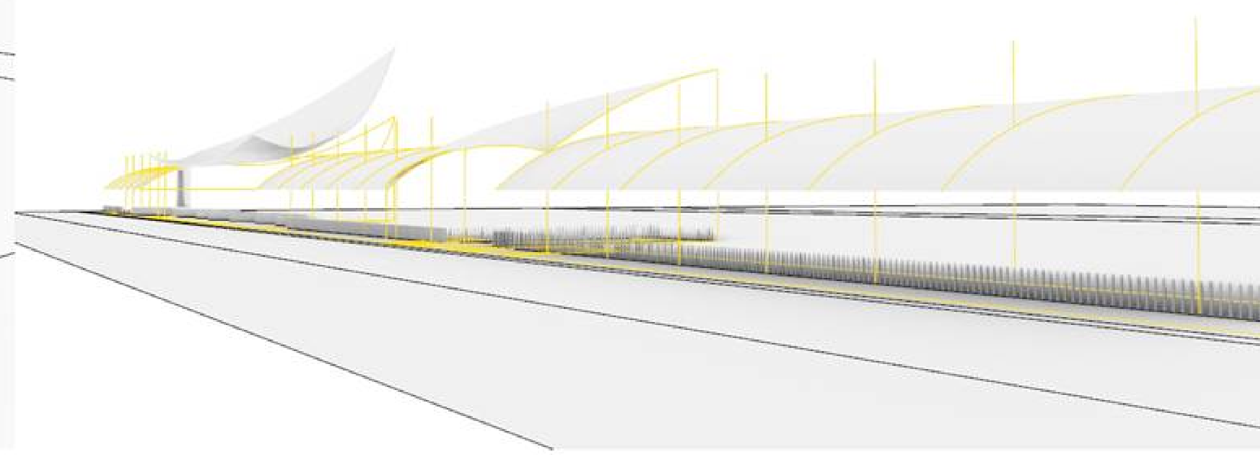
Plan





Elevation



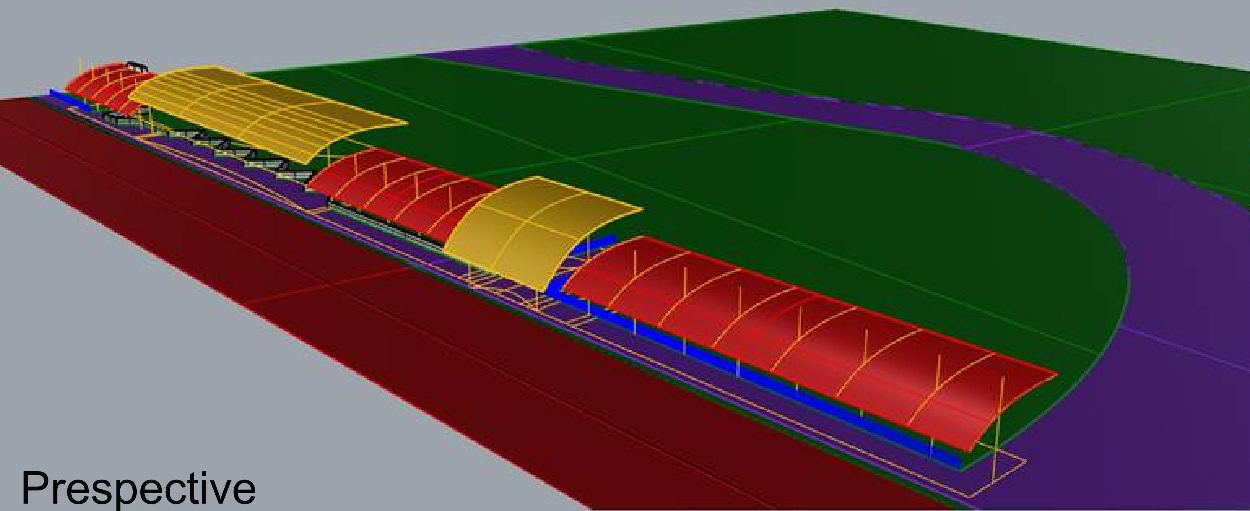


Prespective

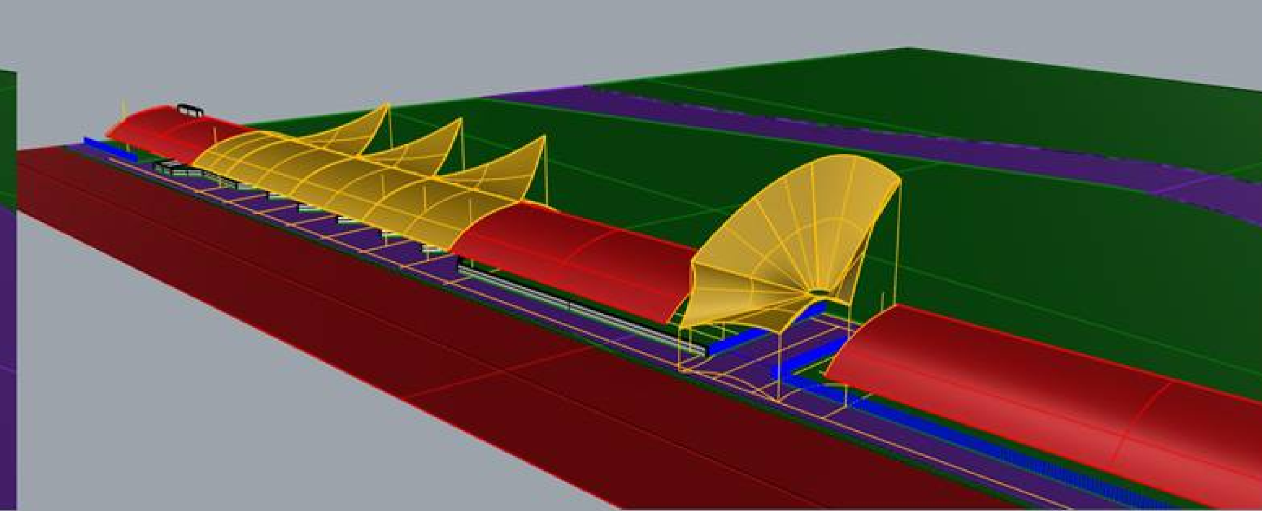
Form Analysis

In sketch 01 the cover on the slope area, is a continuation of the membrane with an uplift toward the sculptures.
In Sketch 02, the structure is a seperate higher membrane with the same approach to increase the effect.
In both sketches, the design of the entrance area is a separate structure which tends to invite those who circulate the pedestrian and those who enter from the street.
As shown in the images, in plan and elevation views, changing the concept does not affect the quality of the space, but in the perspective view the influence is more apparent.

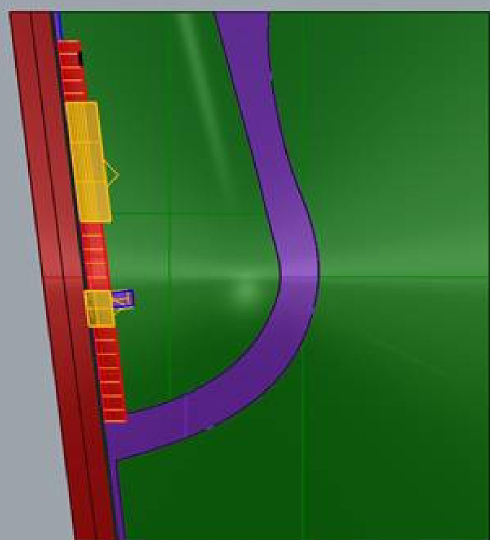
Sketch-03

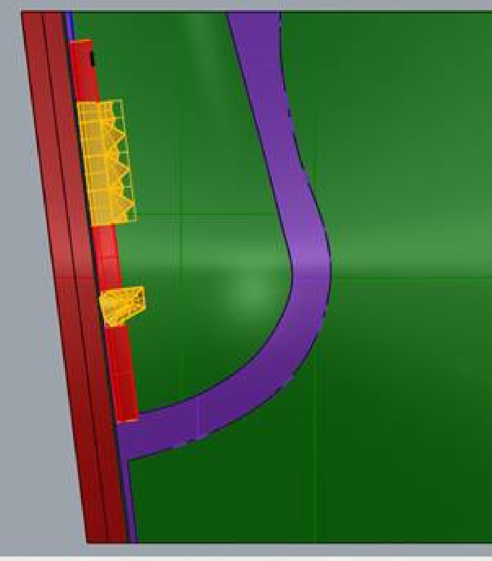


Sketch-04

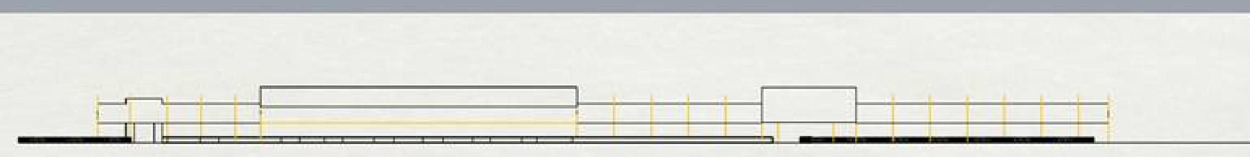


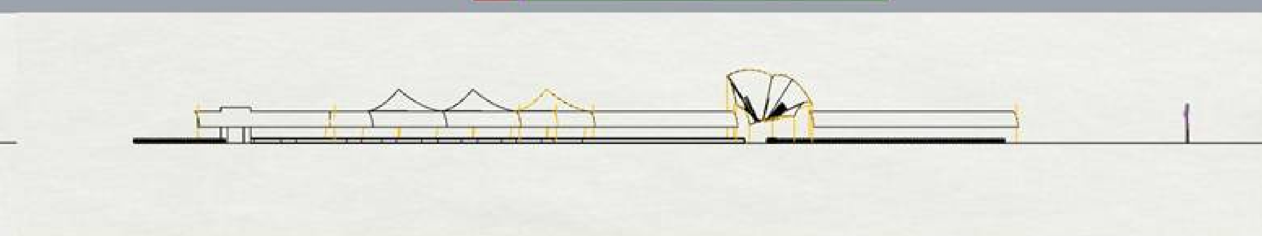
Prespective



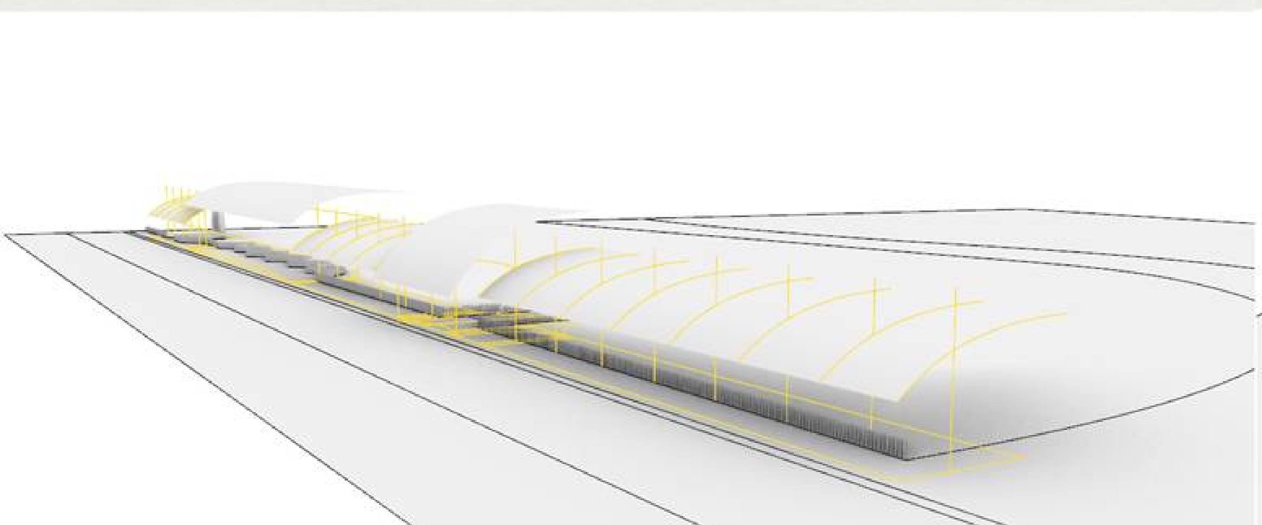


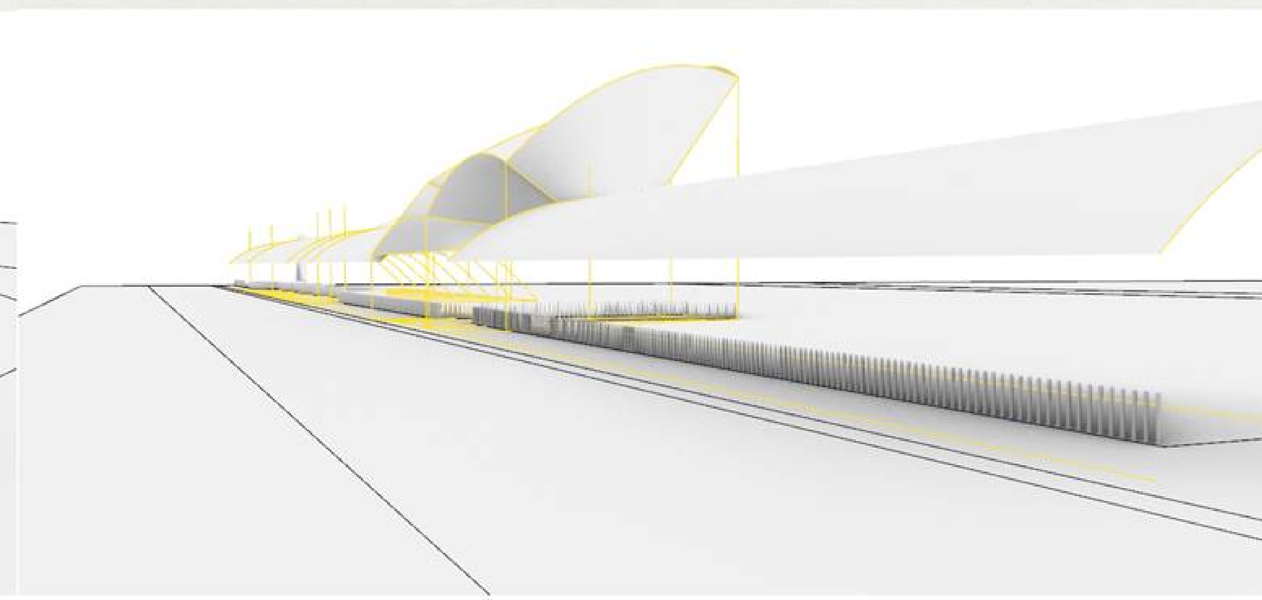
Plan





Elevation





Prespective

Form Analysis

In sketch 03 the cover on the stope area, is a continuation of the membrane to increase the harmony between the structure of the passing area and stopping area. The structure has risen to differentiate the quality of space. In sketch 04, the design of the entrance area has changed to give the space a unique feature.

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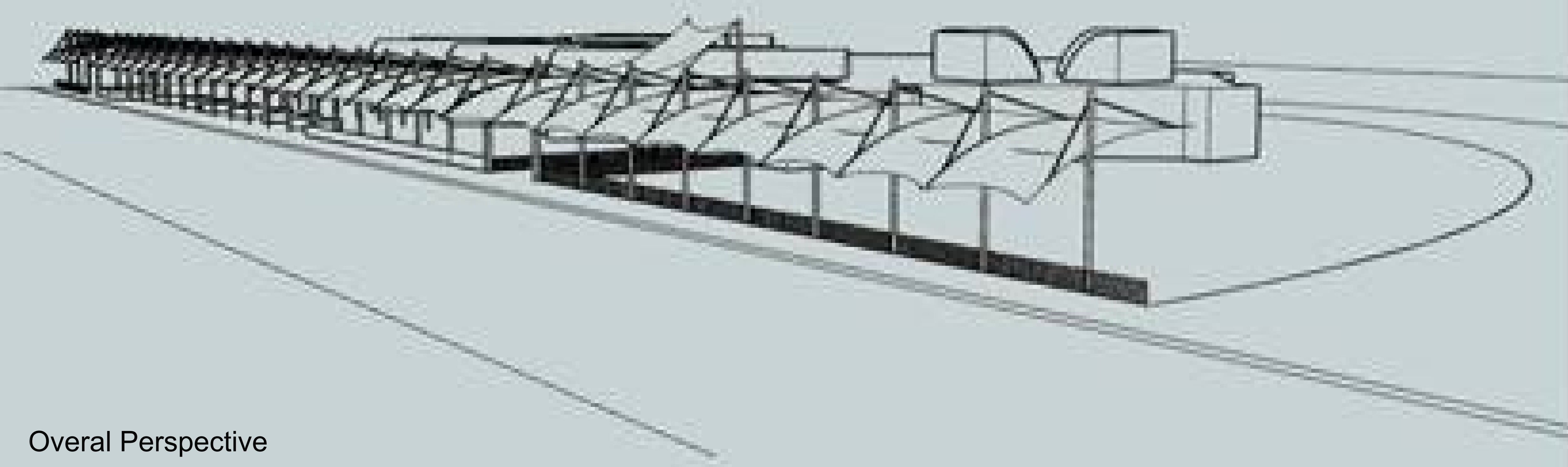
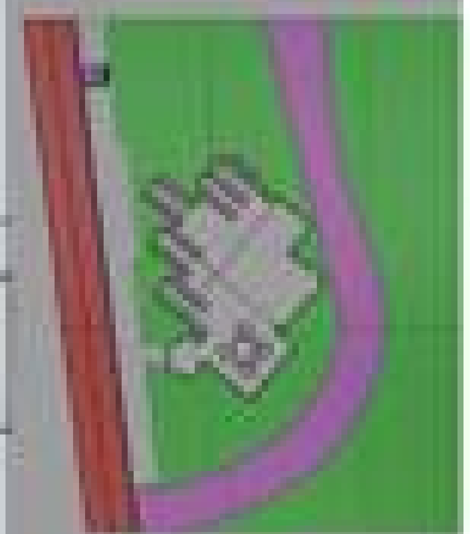
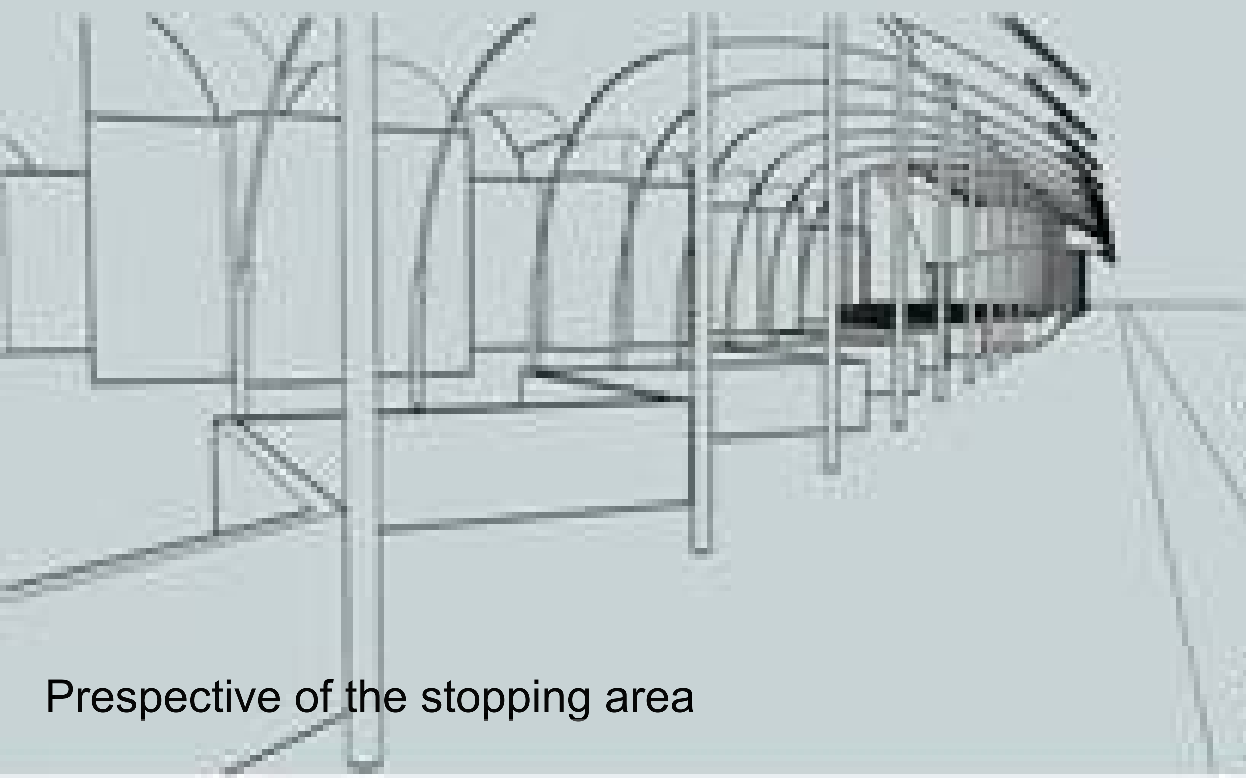


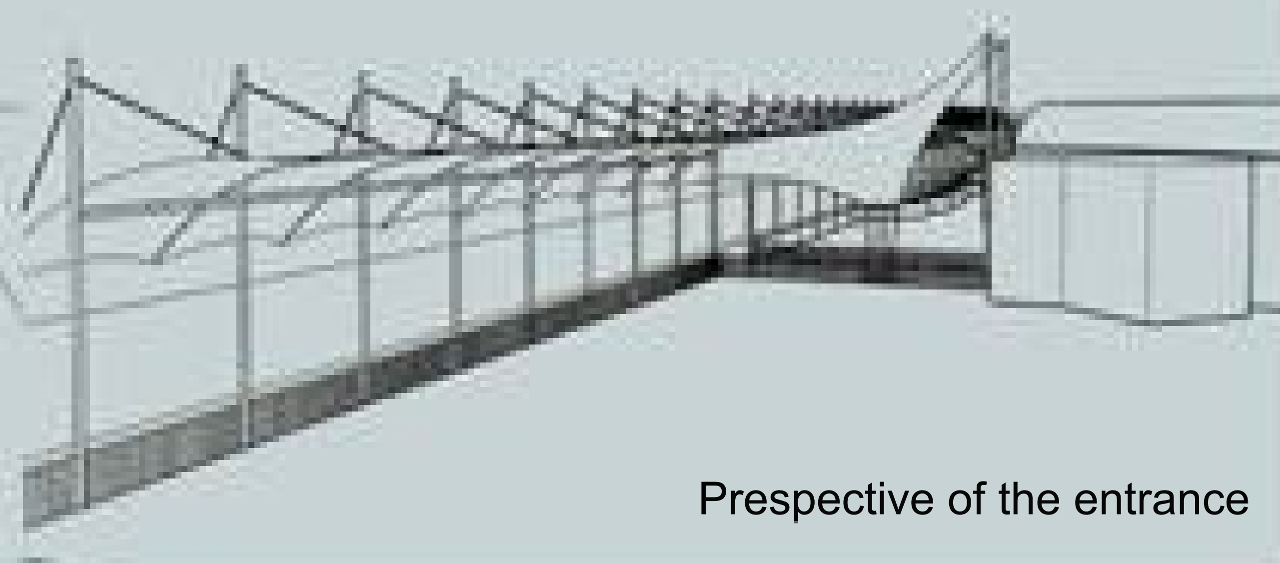
Overal Perspective

This is the final concept for the project. The concept of stopping area and entrance is continuity of the passing area with their characteristic.
The structure above the entrance is inviting and with the converse cone brings attention toward the doors.
The structure over the stopping area in the middle continues inside the sculpture park to extend and rap the view over the landscape.

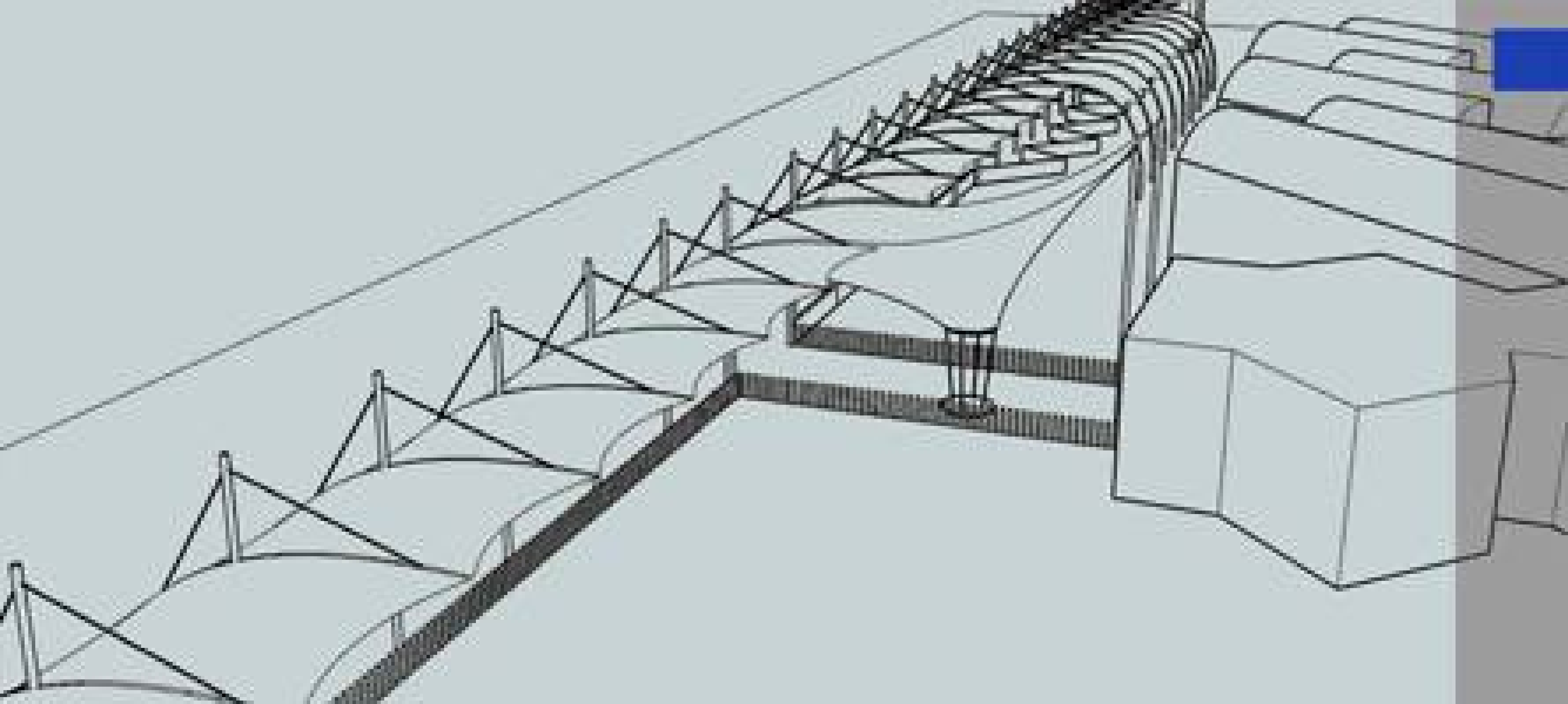




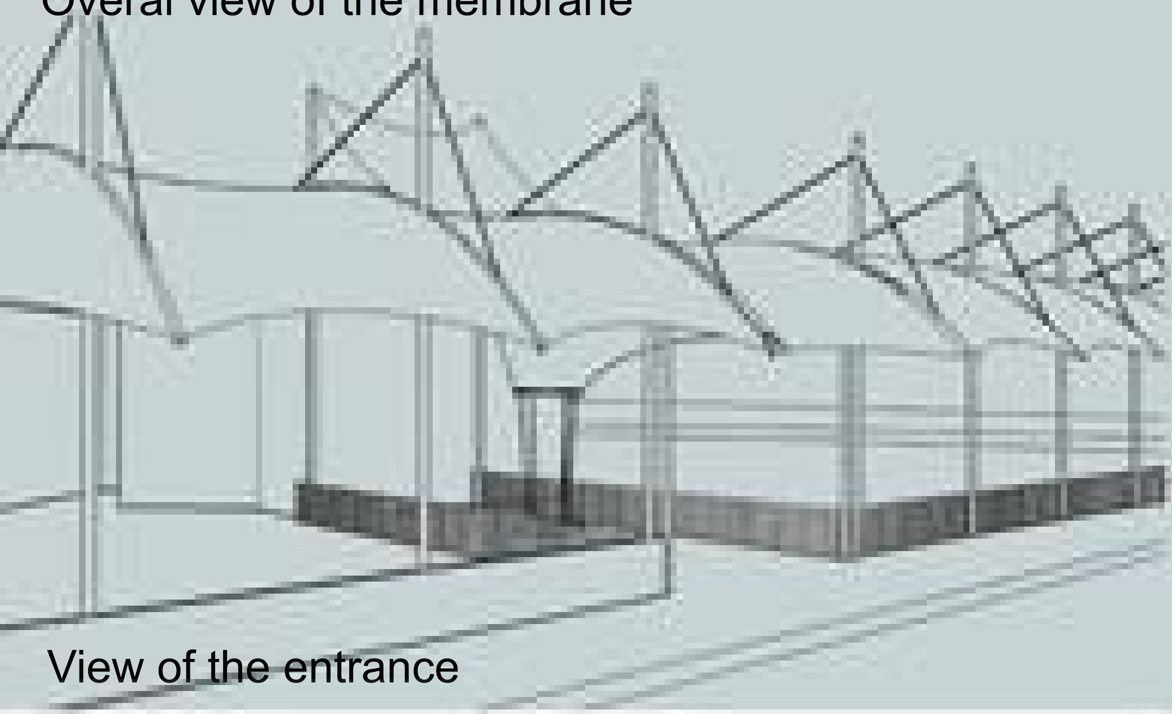
Prespective of the stopping area

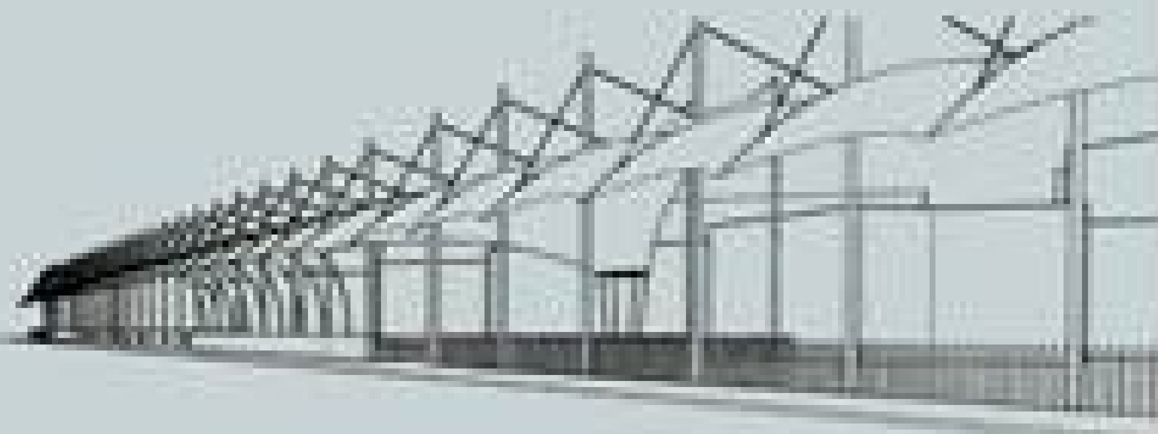


Prespective of the entrance



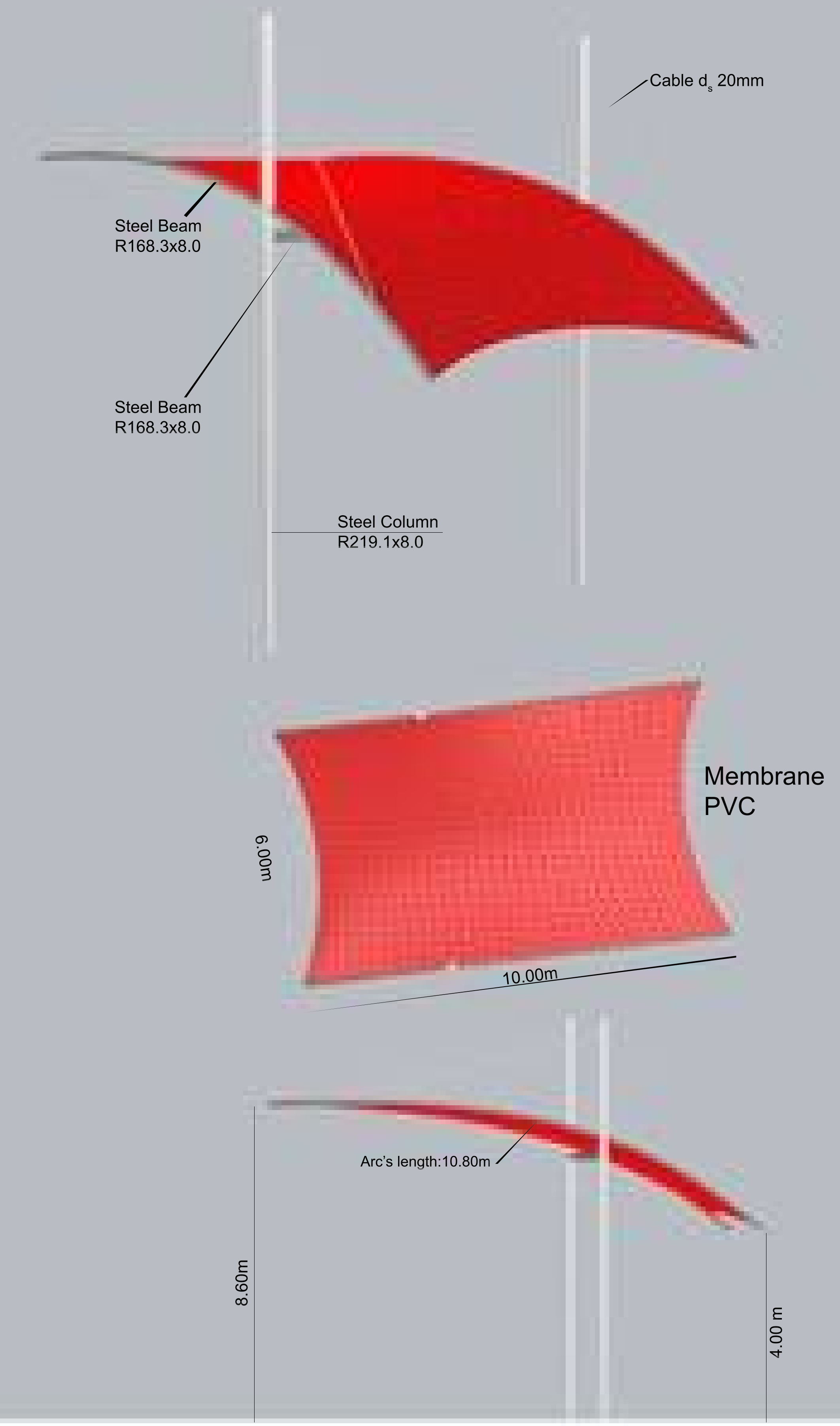
Overal view of the membrane



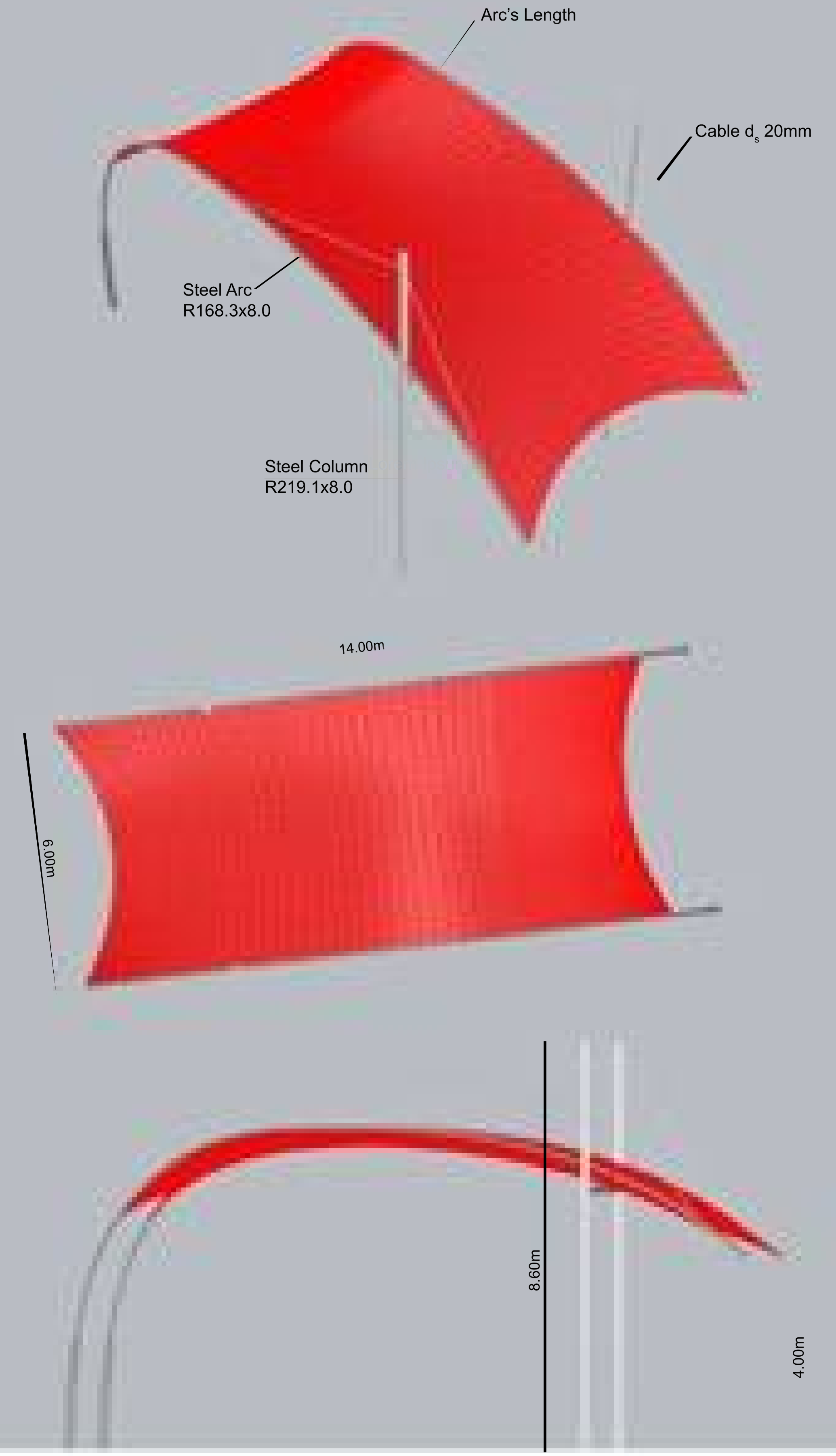


View of the entrance

Structure of passing area



Structure of stop area



The structure of the passage area consists of columns at the 6-meter axis and trusses that are hanged from above by cables to the columns.
To increase the solidity of structure a truss is applied between columns to bind them together.
The structure is not calculated. It is rather an over stimation based on similar projects.

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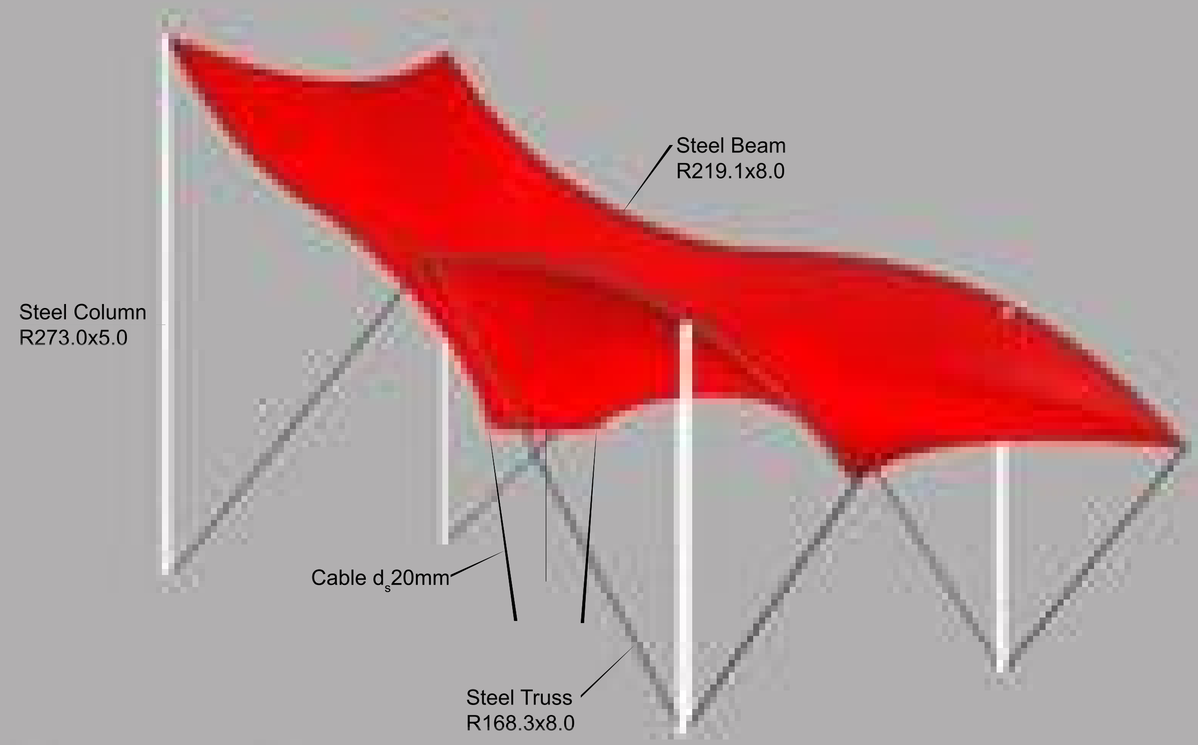
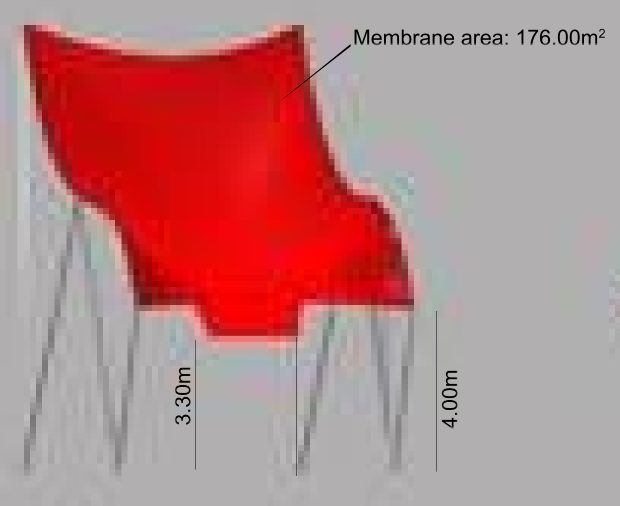
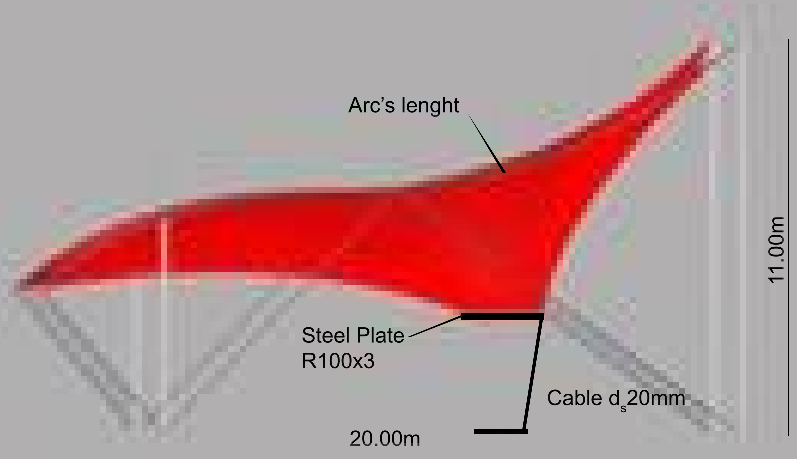
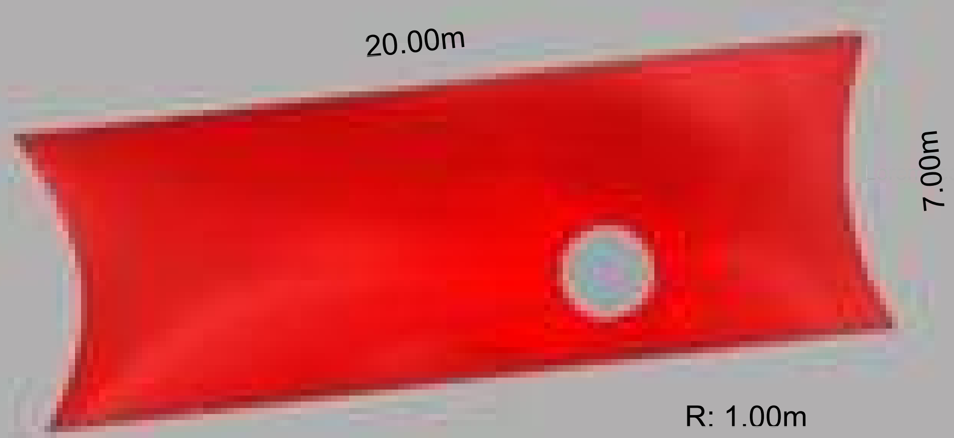
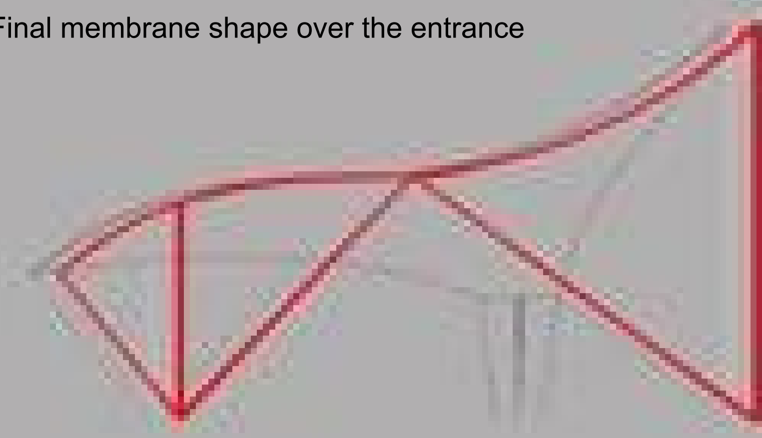






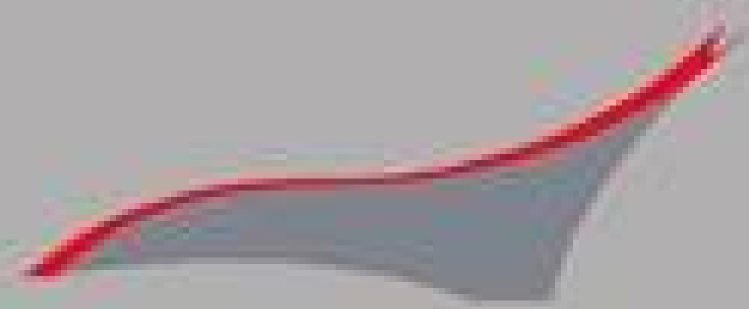


Final membrane shape over the entrance



Adjusting the arc by columns and truss

Pointing down to bring the attention to the entrance



Sky line toward the entrance

This is the structure over the entrance
There is a movement from the street to the entrance to invite people inside.
With the reverse cone which brings focused light amidst the shadows, it diverts the attention to the museum doors.
The structure is not calculated. It is rather an over stimation based on similar projects.

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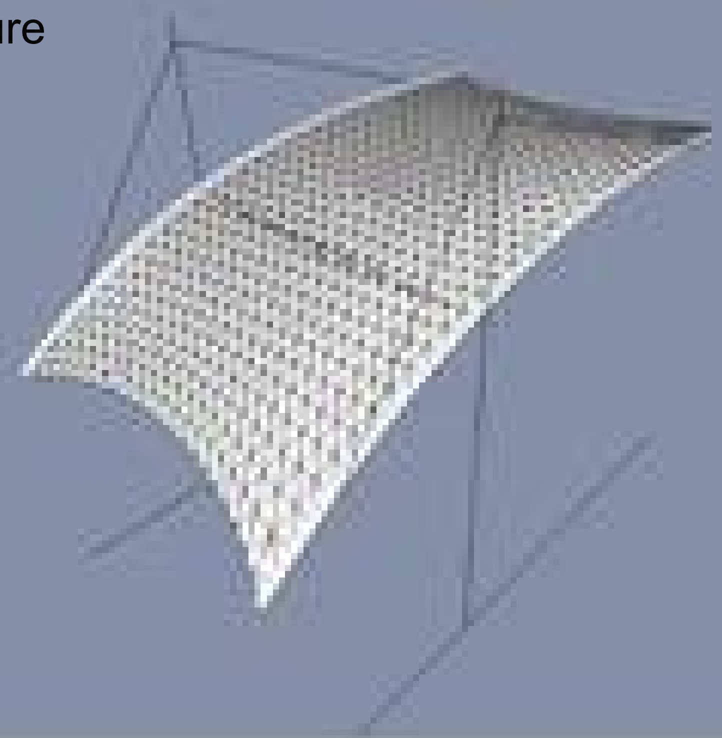
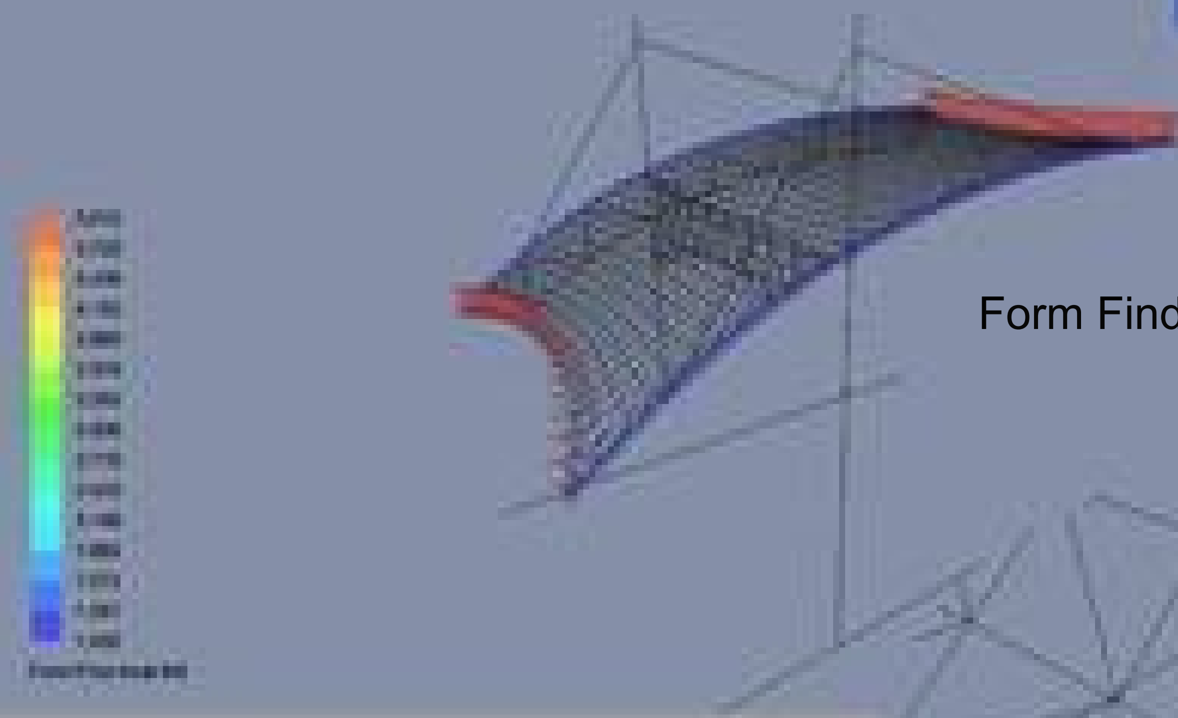
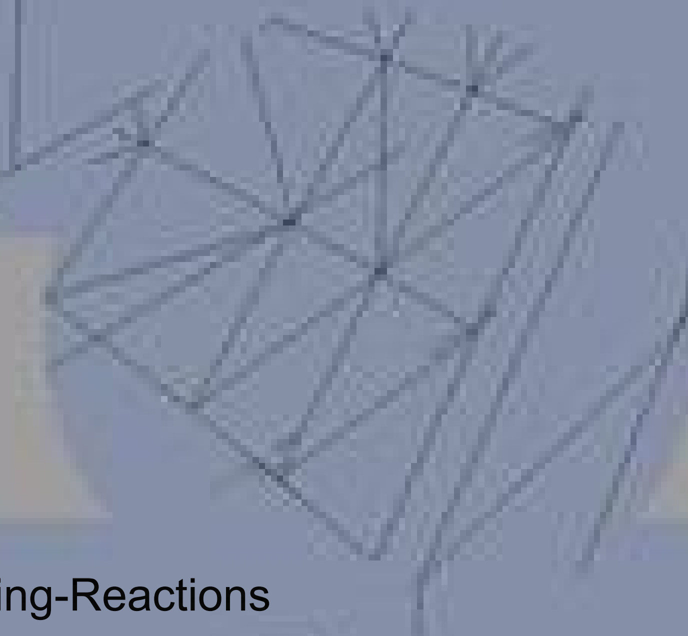
Passage Structure



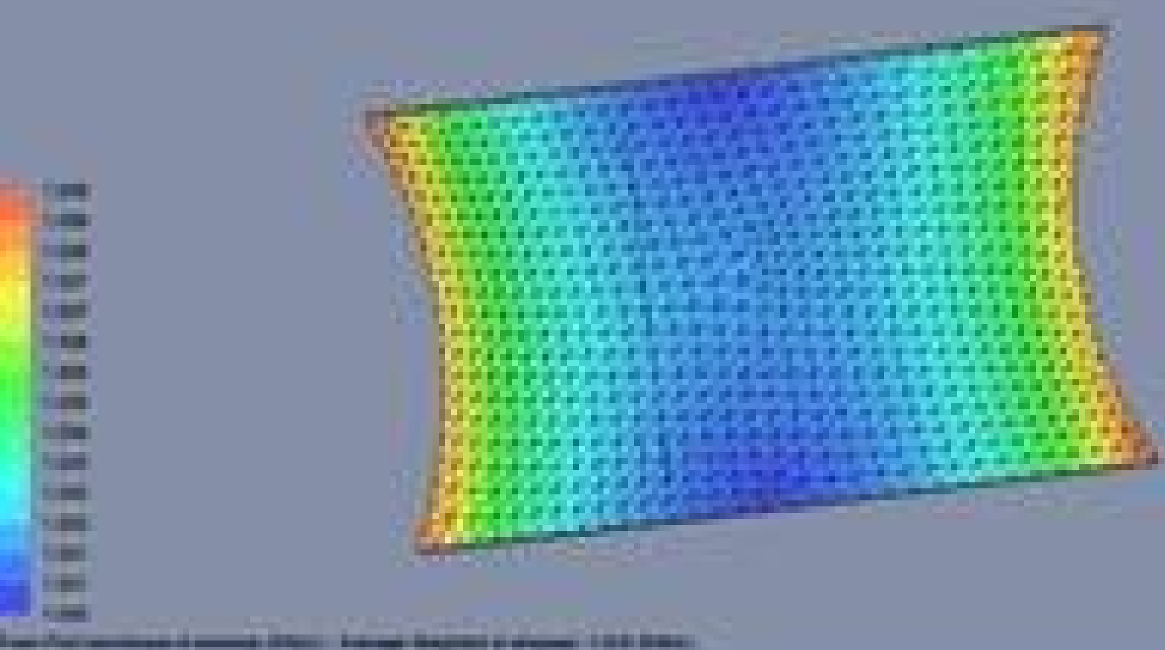


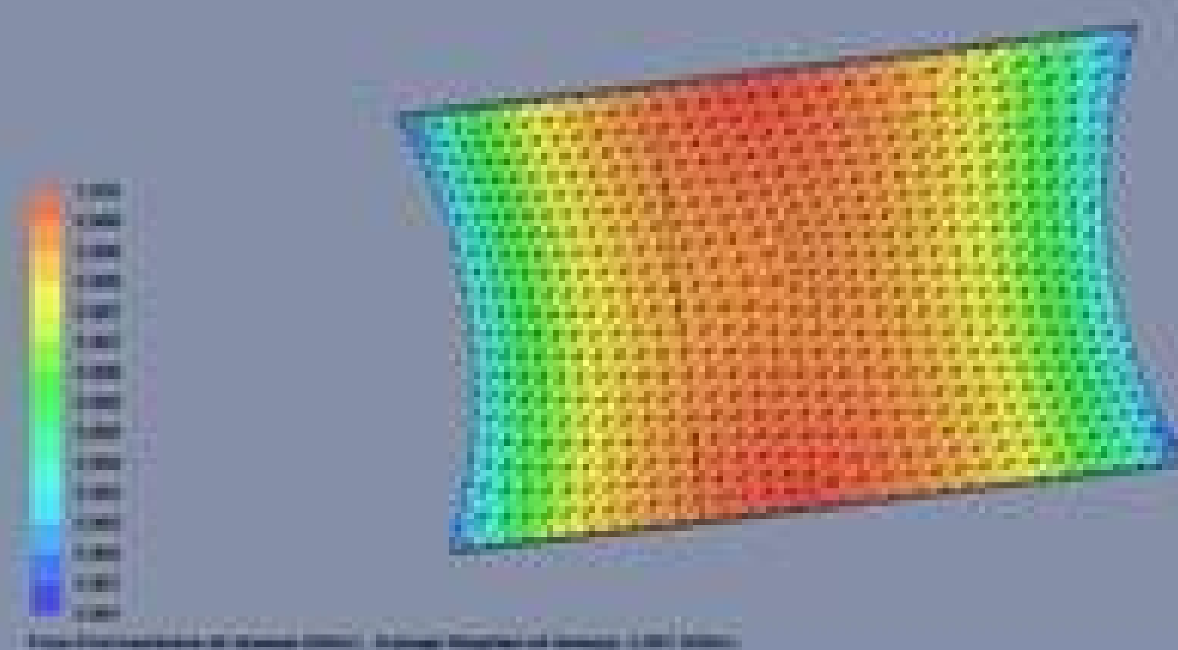
Form Finding-Axial Forces



Pretention: 10
Cables: 16mm
Beams: CHS-114.3x5.4
Membrane: Preconstraint 702- Ferrari
Warp/ weft Stress: 1/1
Max. Sress: 1.00 Kn/m

Form Finding-Reactions

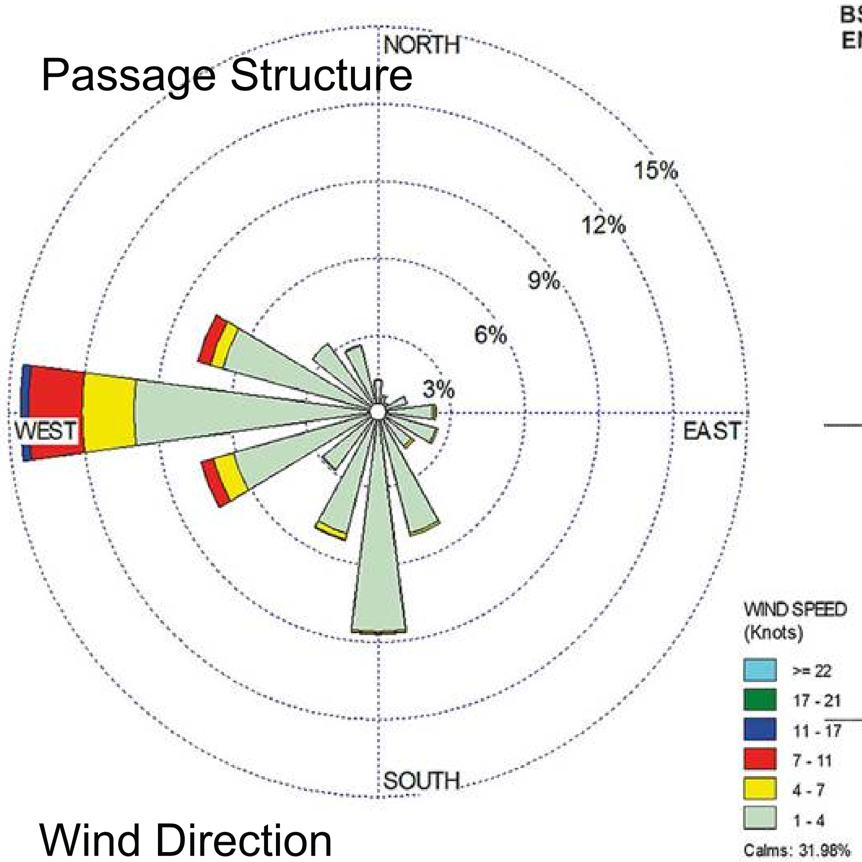




Form Finding-S1

Form Finding-S2

Passage Structure



Wind Direction

BS EN 1991-1-4:2005+A1:2010
EN 1991-1-4:2005+A1:2010 (E)

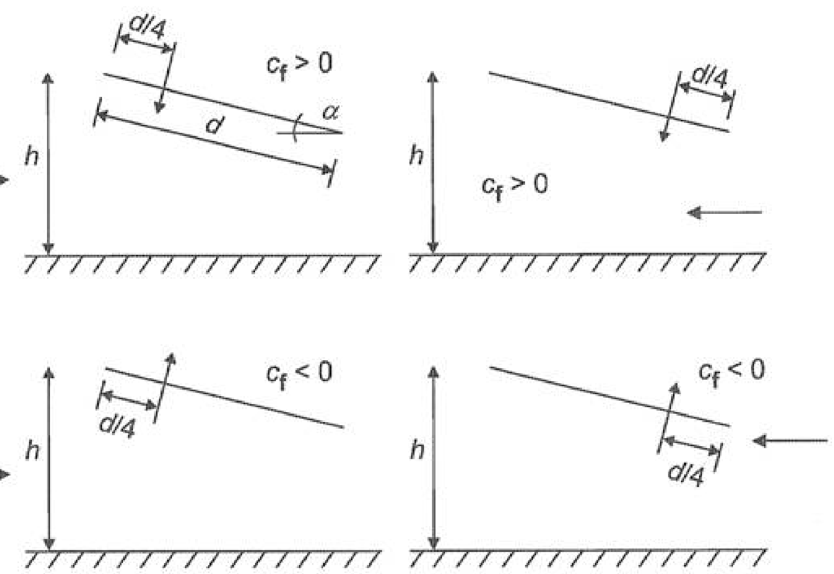
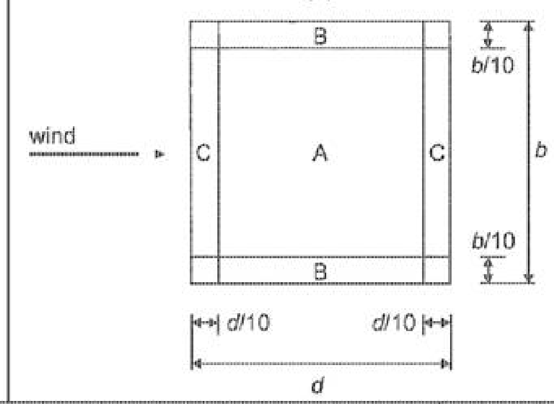


Figure 7.16 — Location of the centre of force for monopitch canopies

BS EN 1991-1-4:2005+A1:2010
EN 1991-1-4:2005+A1:2010 (E)

Table 7.6 — $c_{p,net}$ and c_f values for monopitch canopies



Roof angle α	Blockage φ	Overall Force Coefficients c_f	Net Pressure coefficients $c_{p,net}$ Zone A	Zone B	Zone C
0°	Maximum all φ	+ 0,2	+ 0,5	+ 1,8	+ 1,1
	Minimum φ = 0	- 0,5	- 0,6	- 1,3	- 1,4
	Minimum φ = 1	- 1,3	- 1,5	- 1,8	- 2,2
5°	Maximum all φ	+ 0,4	+ 0,8	+ 2,1	+ 1,3
	Minimum φ = 0	- 0,7	- 1,1	- 1,7	- 1,8
	Minimum φ = 1	- 1,4	- 1,6	- 2,2	- 2,5
10°	Maximum all φ	+ 0,5	+ 1,2	+ 2,4	+ 1,6
	Minimum φ = 0	- 0,9	- 1,5	- 2,0	- 2,1
	Minimum φ = 1	- 1,4	[AC2] - 1,6 [AC2]	- 2,6	- 2,7
15°	Maximum all φ	+ 0,7	+ 1,4	+ 2,7	+ 1,8
	Minimum φ = 0	- 1,1	- 1,8	- 2,4	- 2,5
	Minimum φ = 1	- 1,4	- 1,6	- 2,9	- 3,0
20°	Maximum all φ	+ 0,8	+ 1,7	+ 2,9	+ 2,1
	Minimum φ = 0	- 1,3	- 2,2	- 2,8	- 2,9
	Minimum φ = 1	- 1,4	- 1,6	- 2,9	- 3,0
25°	Maximum all φ	+ 1,0	+ 2,0	+ 3,1	+ 2,3
	Minimum φ = 0	- 1,6	- 2,6	- 3,2	- 3,2
	Minimum φ = 1	- 1,4	- 1,5	- 2,5	- 2,8
30°	Maximum all φ	+ 1,2	+ 2,2	+ 3,2	+ 2,4
	Minimum φ = 0	- 1,8	- 3,0	- 3,8	- 3,6
	Minimum φ = 1	- 1,4	- 1,5	- 2,2	- 2,7

NOTE + values indicate a net downward acting wind action
- values represent a net upward acting wind action

WIND CALCULATION

Basic wind speed $V_{b,0}$= 27.60 m/s
Directional factor C_{dir}= 1.00
Seasonal factor C_{season}= 1.00
$V_b = V_{b,0} x C_{dir} x C_{season}$
V_b= 27.60 m/s
The orography factor $C_o(z)$ = 1.00
The roughness length Z_o= 1.0
(terrain category IV, Table 4.1)
Minimum height of structure Z_{min}= 3.00
Maximum height of the structure Z_{max}=7.00
Train Factor Kr = $0.19 (Z_o/ Z_{o,II})^{0.007}= 0.19(1.0/0.5)^{0.007}=0.2$
The Train roughness factor $C_r(z)$=Kr . ln(z/z_0)= 0.2xln(7/1)=0.39
Density of air [kg/m³] ρ= 1.25 kg/m³
The peak velocity pressure $q_p(z) = c_e(z) x q_b$
$c_e(z)$=1.2 (figure 4.2-Ilustration of exposure factore $C_e(z)$)
Mean wind velocity $V_m(z) = C_r(z) x C_o(z) x V_b$=0.39x1.0x27.60=10.76
Turbulence Intensity $I_v(z) = k_I / C_o(z) x \ln(z/z_0)$= 1.0/ 1.0x1.95=0.51
The peak velocity pressure $q_p(z) = [1+7.I_v(z)] x 1/2 x \rho x V_m^2(z)$=0.332 kn/m²
Wind action $W_e = q_p(z) x c_{pe}$

Zone A: -0.99
Zone B: -1.25
Zone C: -1.19

SNOW LOAD

snow load shape coefficient μ = 0.8
(Angle of pitch of roof <30)
exposure coefficient C_e = 1
Thermal coefficient C_t = 1
Characteristic value of snow load
Sk = 0.85 kN/m2 on the ground
Snow loads on roofs S = 0.68 kN/m2

LOAD COMBINATION

ULS
1.35Selfweight +1.5 Wind
1.35Selfweight +1.5 Snow
1.35Selfweight +1.35 Wind +1.35 Snow

SLS
1.0Selfweight +1.0 Prestress+1.0Snow
1.0Selfweight +1.0Prestress+1.0 Wind
1.0Selfweight +1.0Prestree+1.0Wind +1.0 Snow

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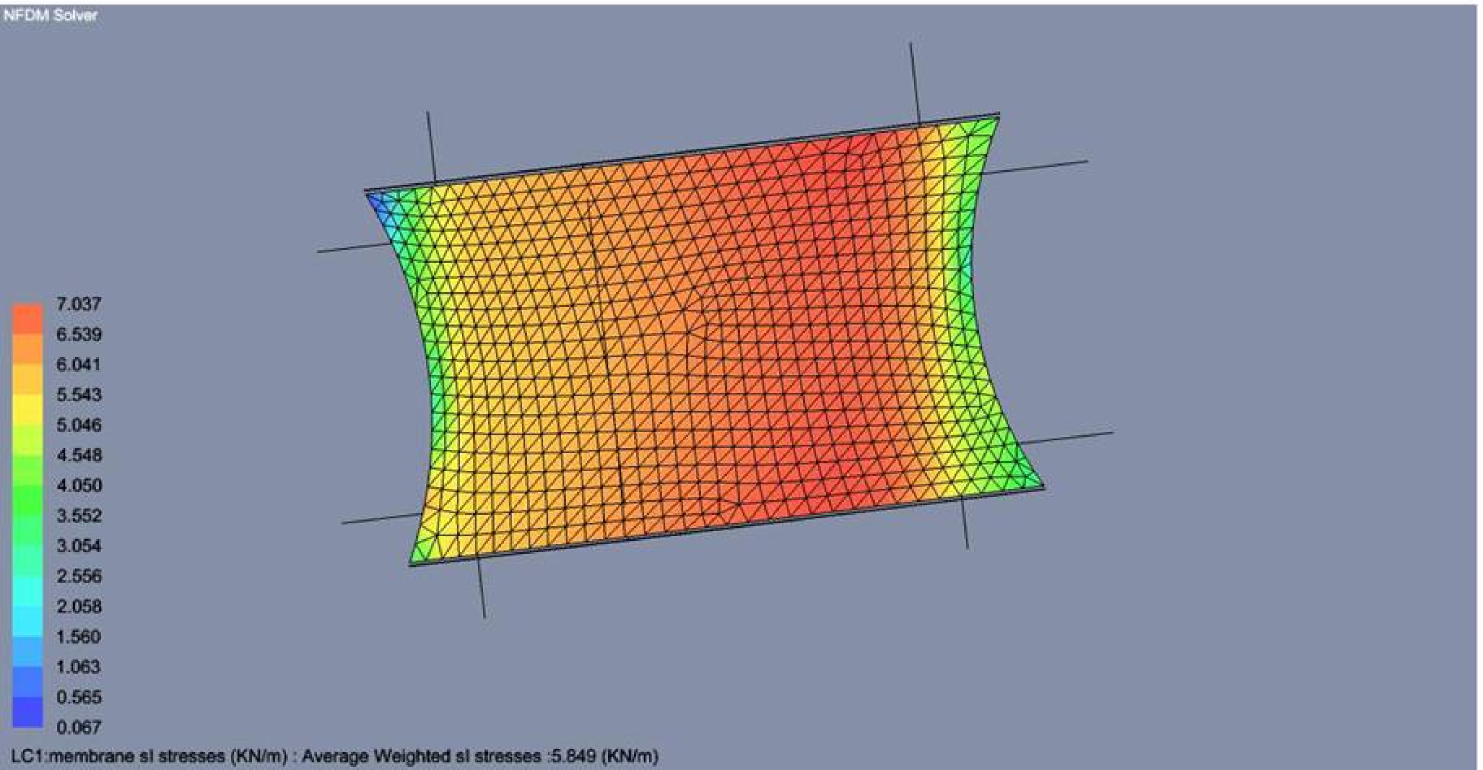
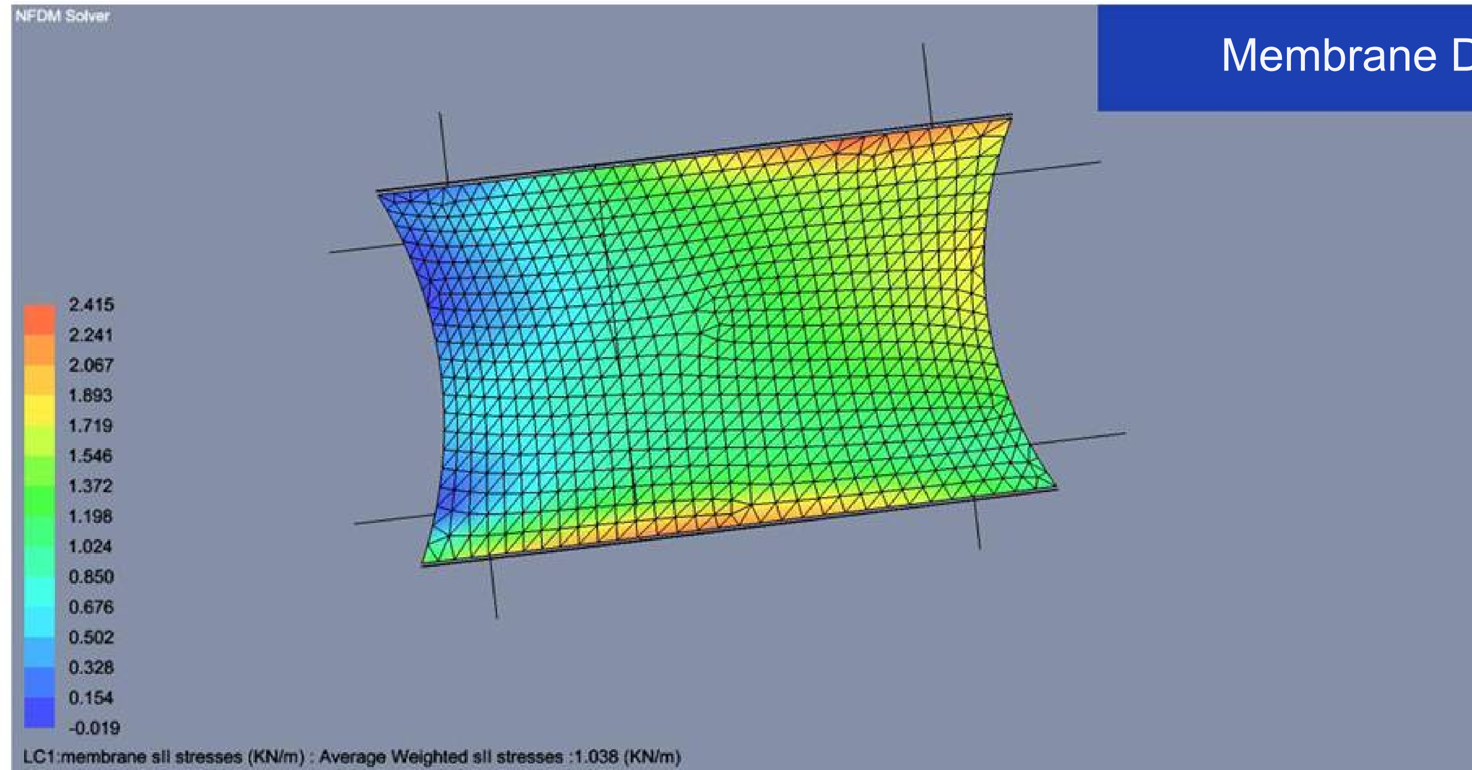
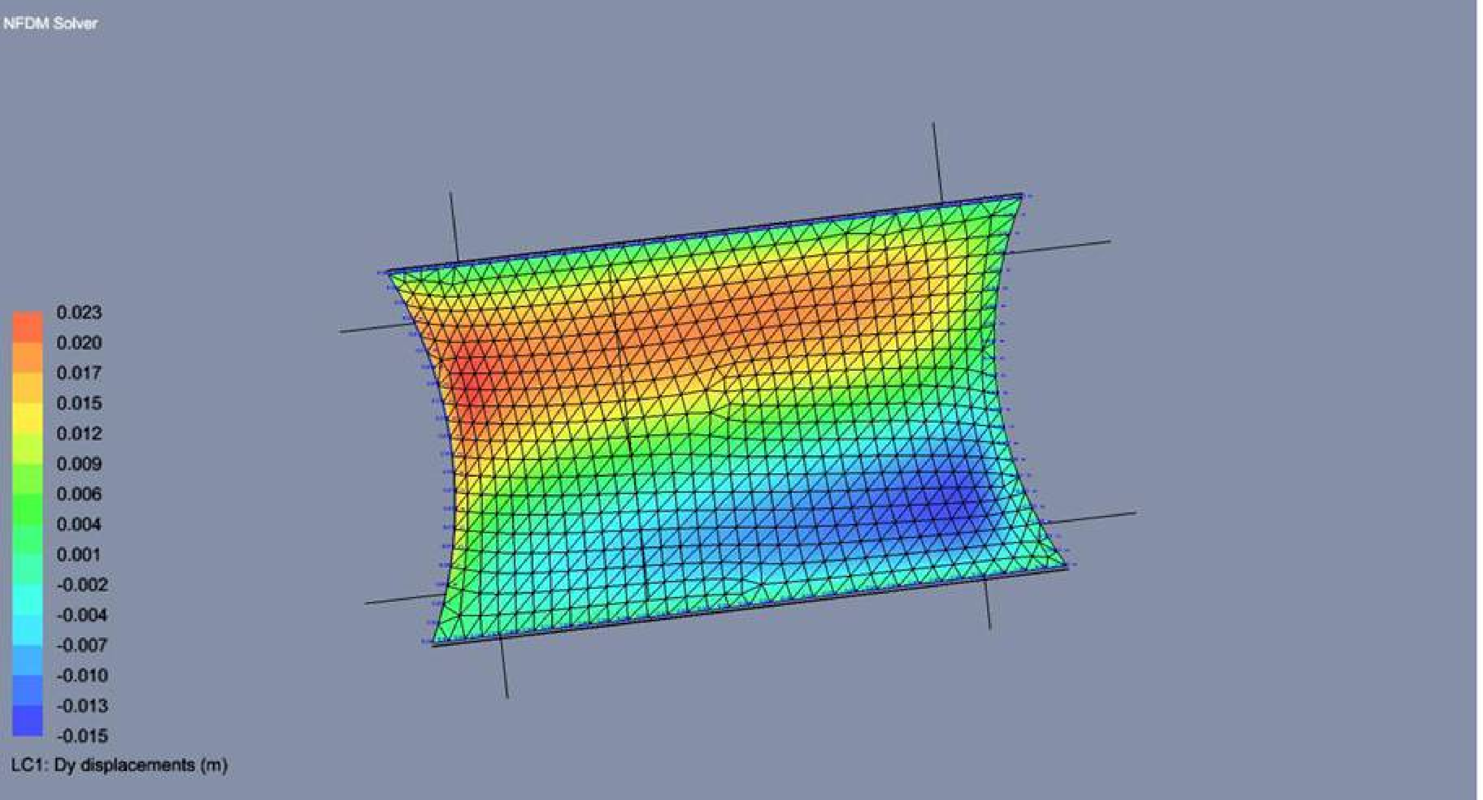
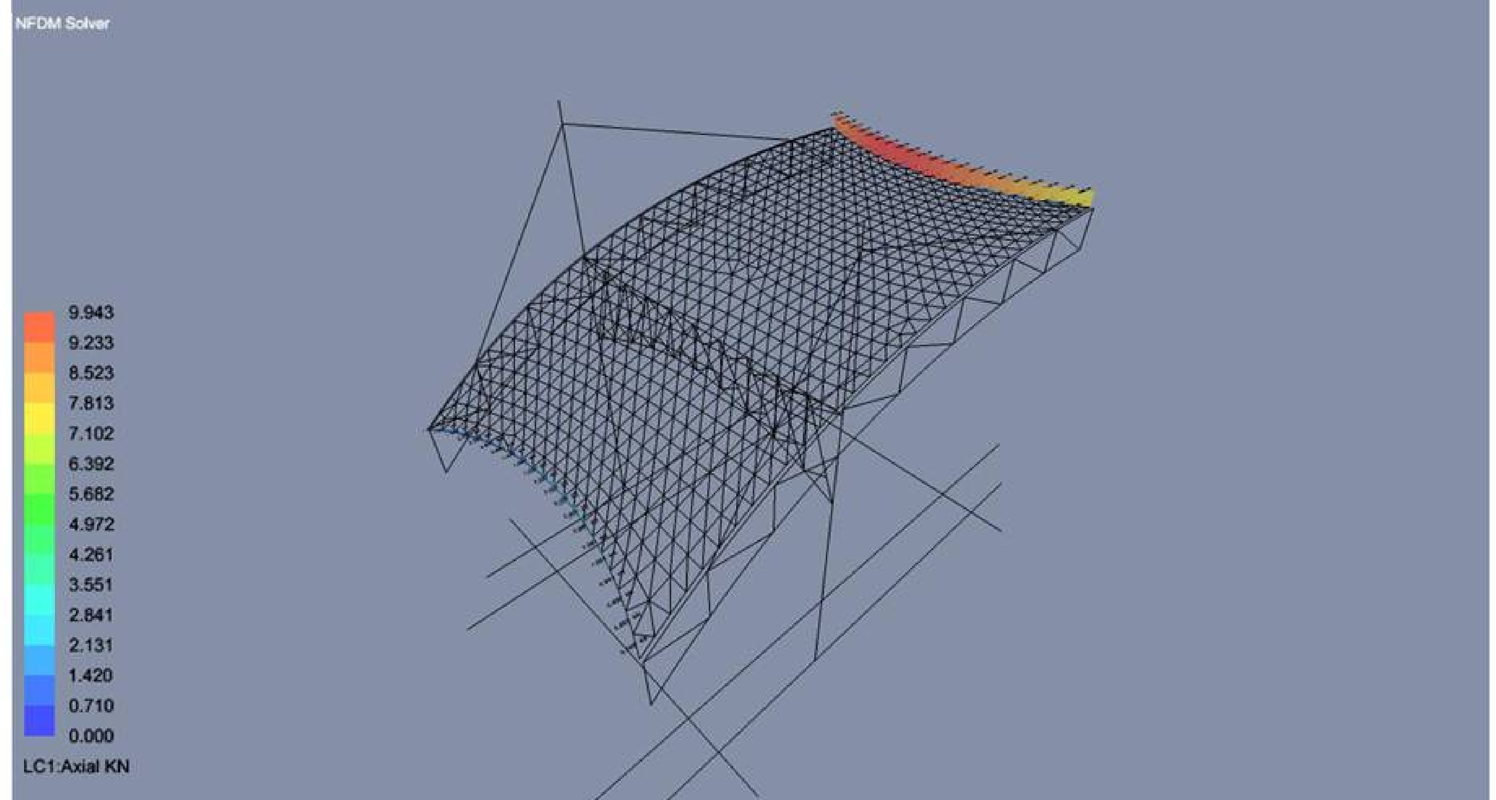




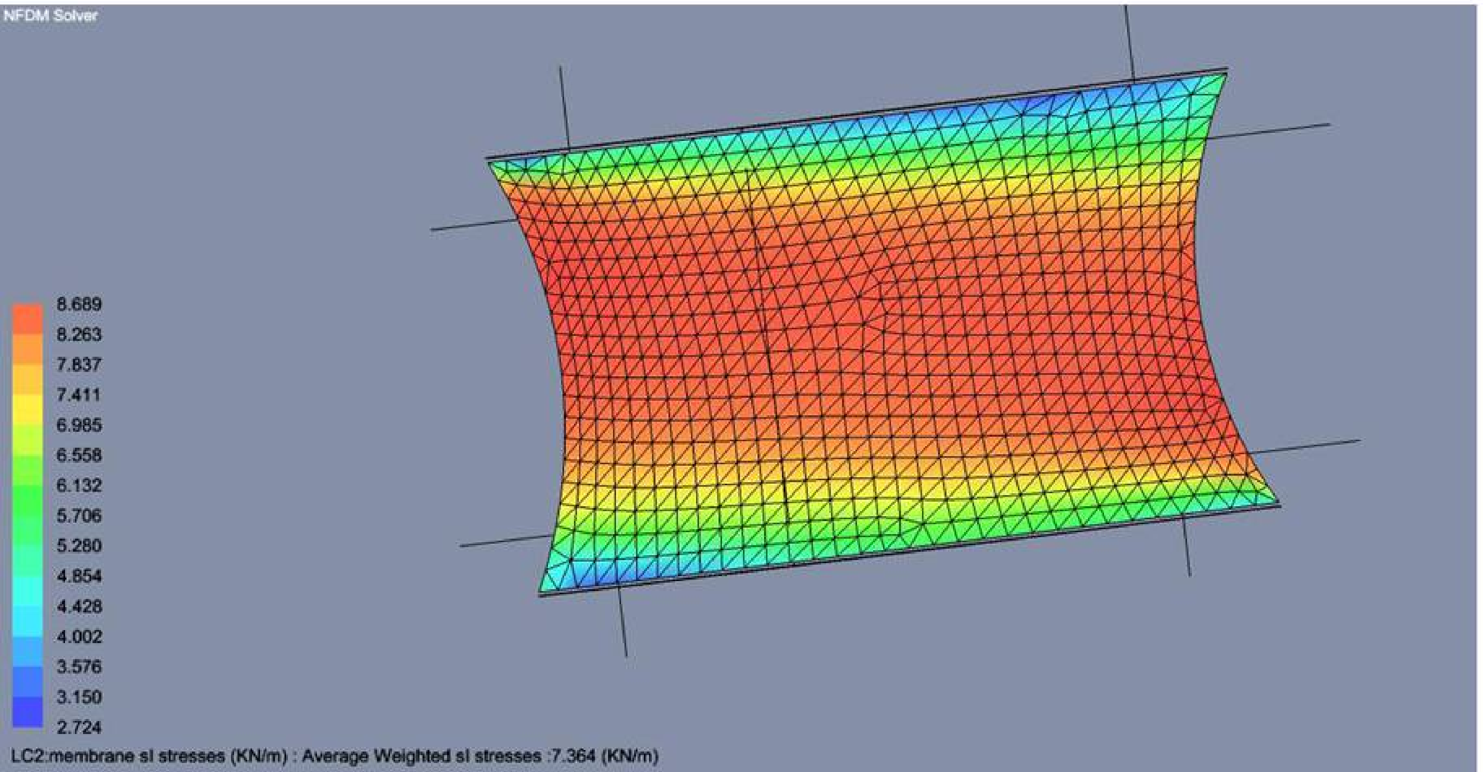


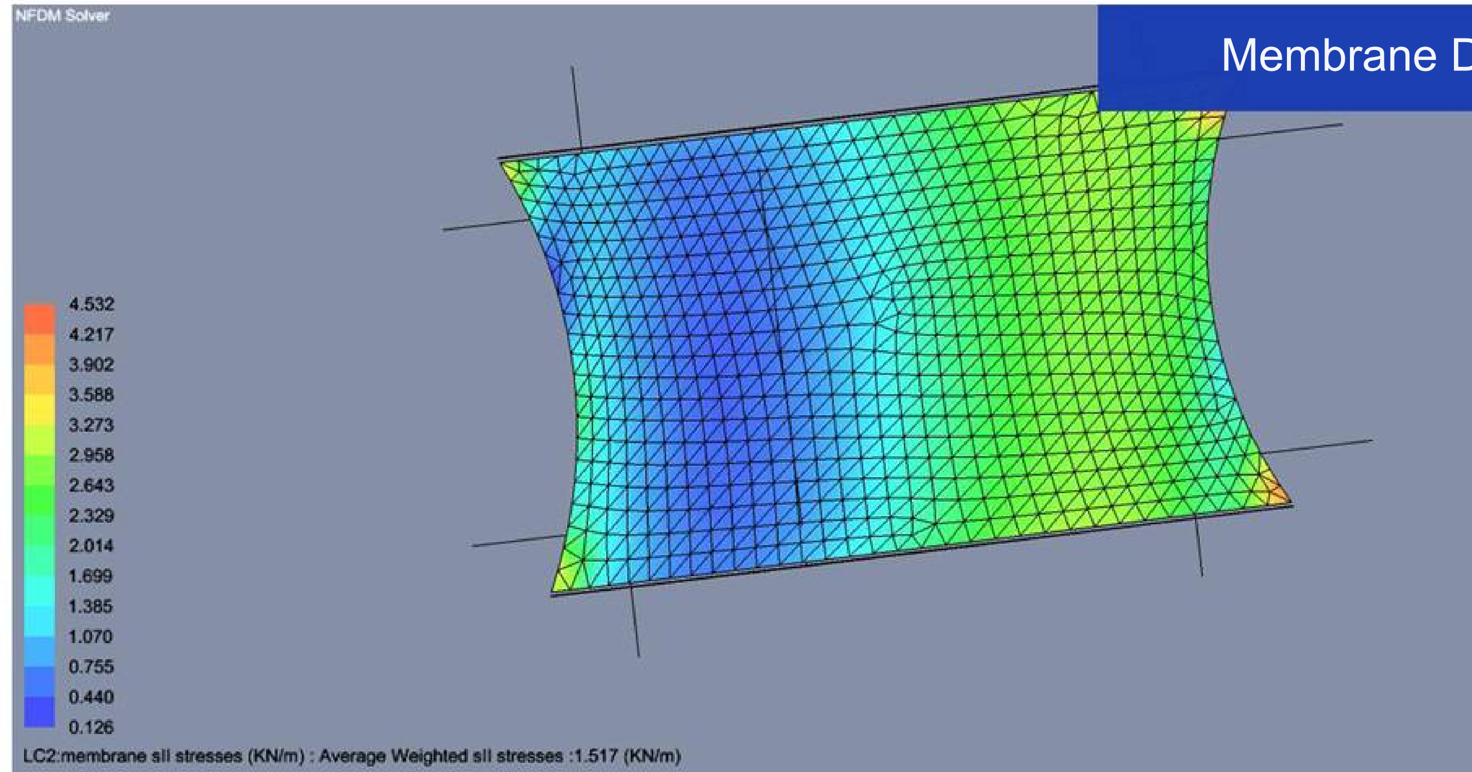


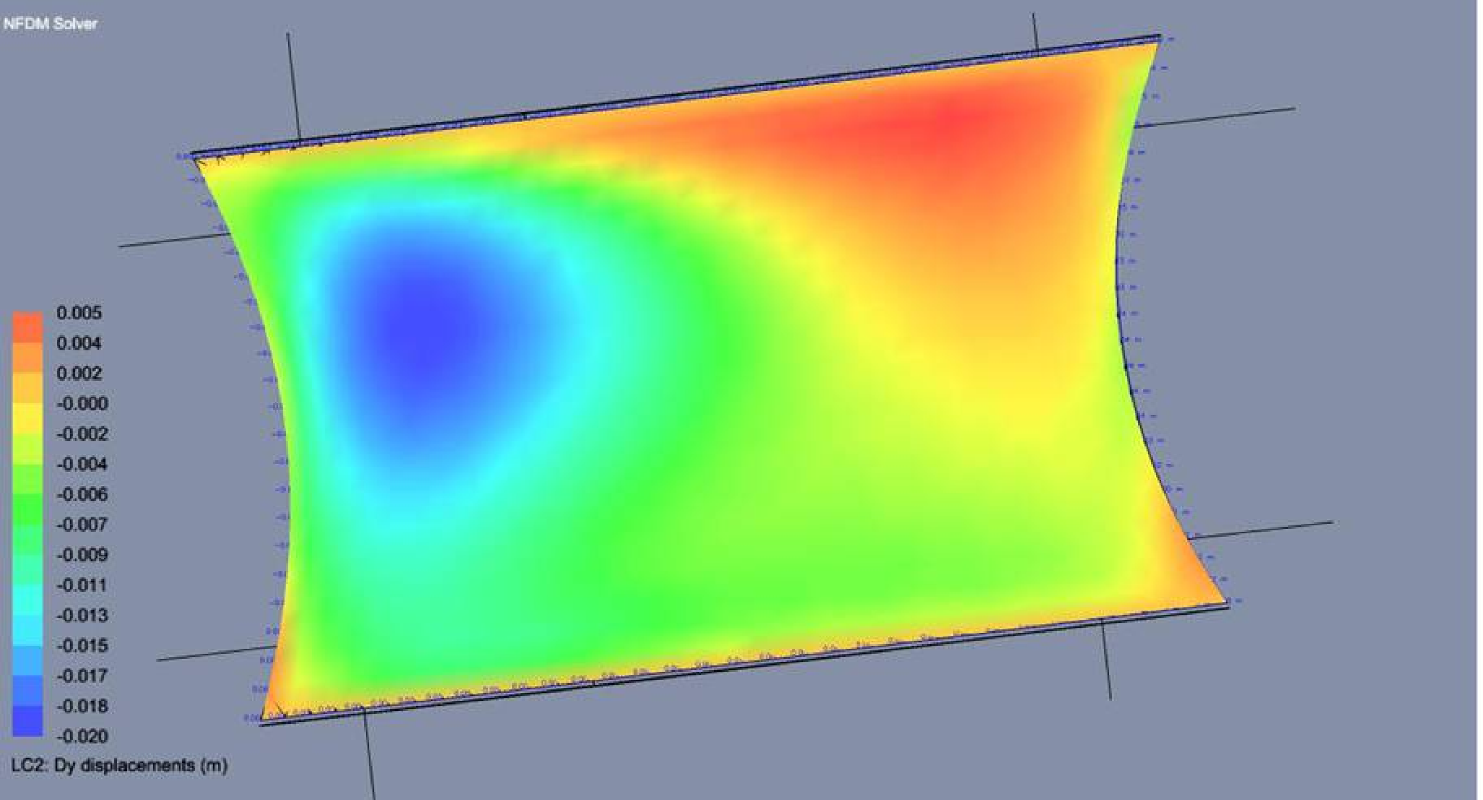
SLS-LC1

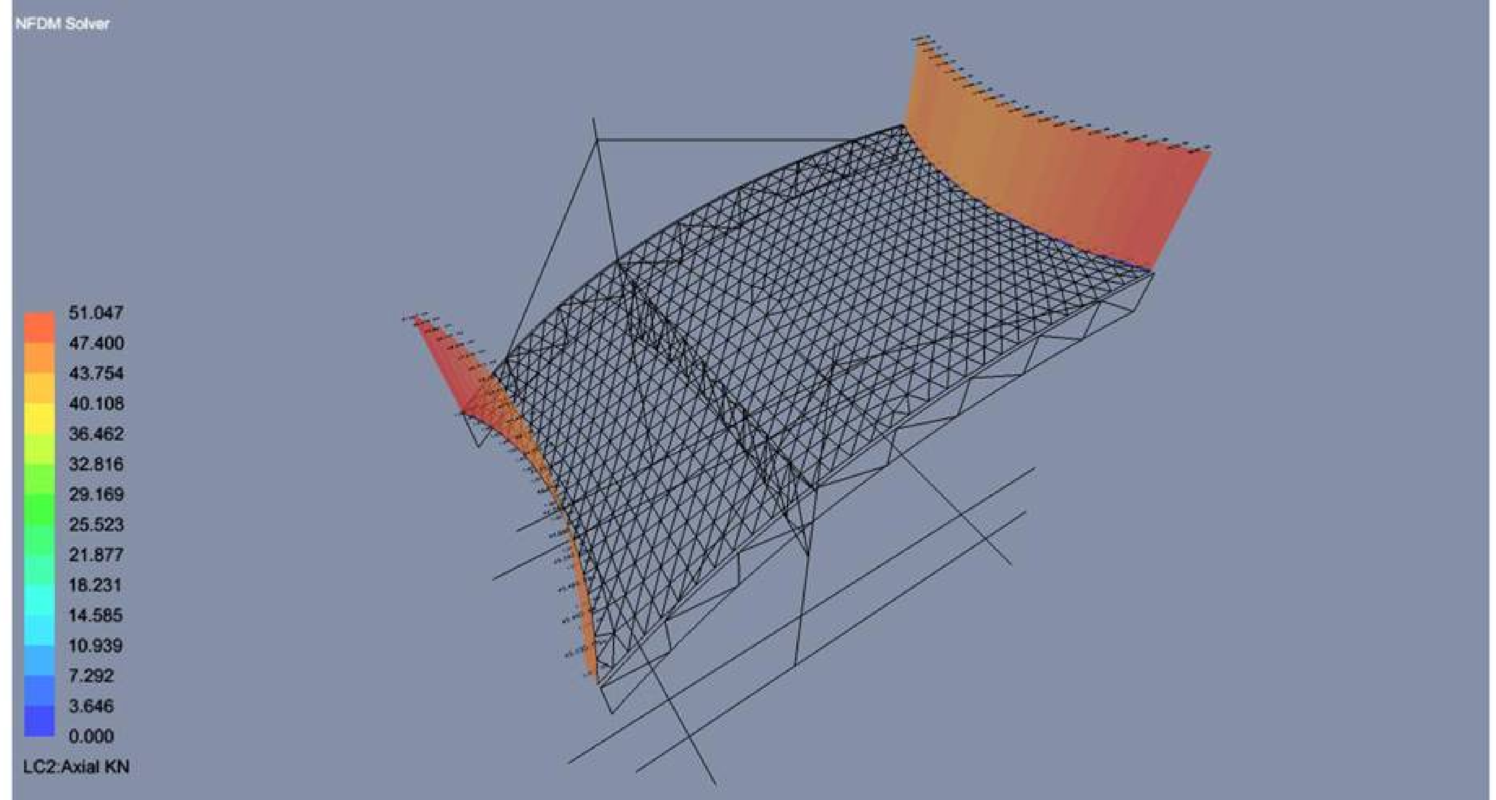
1.0 SELFWEIGHT + 1.0 PRESTRESS + 1.0 SNOW

S1-MAX.: 7.037 Kn/m²
S2-MAX.: 2.415 Kn/m²
DEFORMATION MAX.: 0.023 m
AXIAL FORCE MAX.: 9.943 Kn





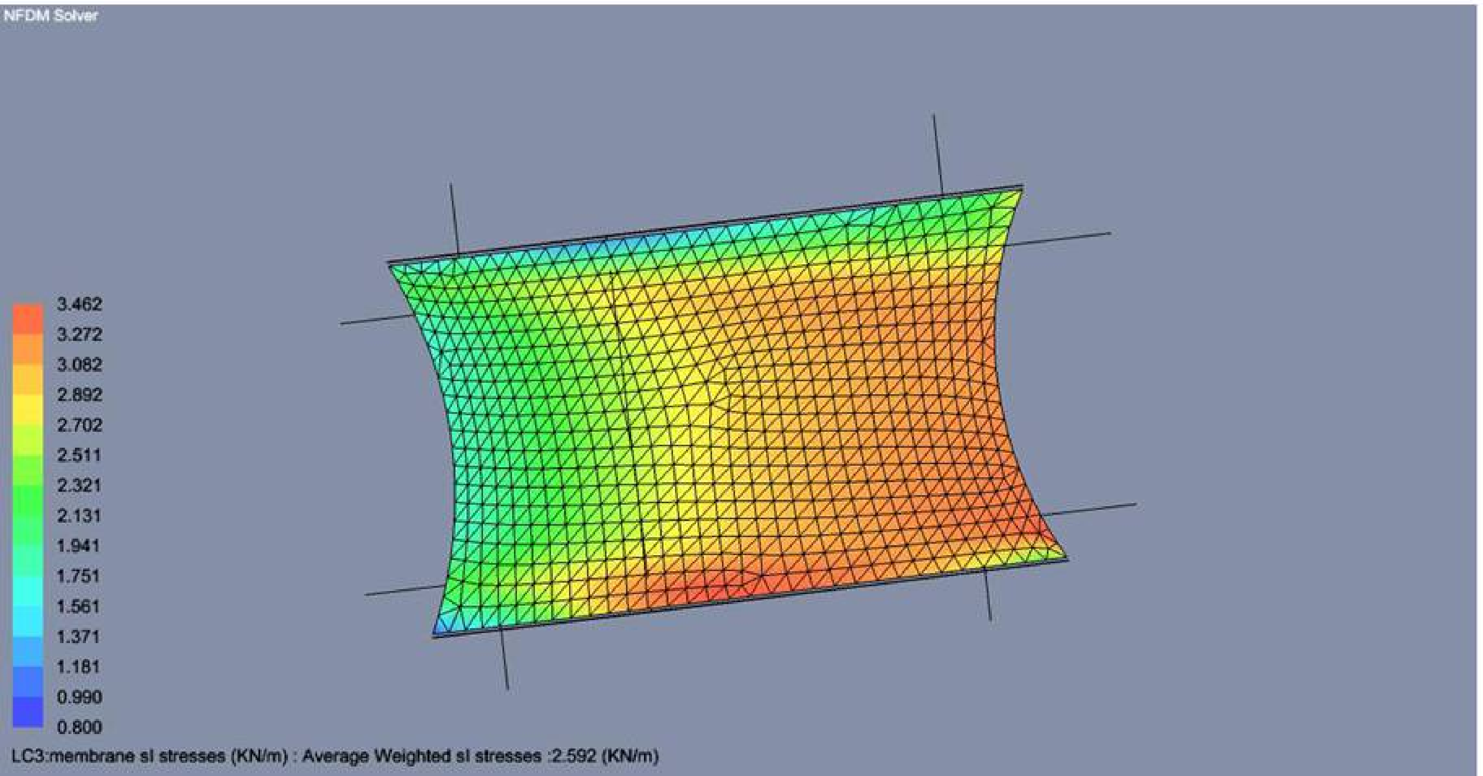


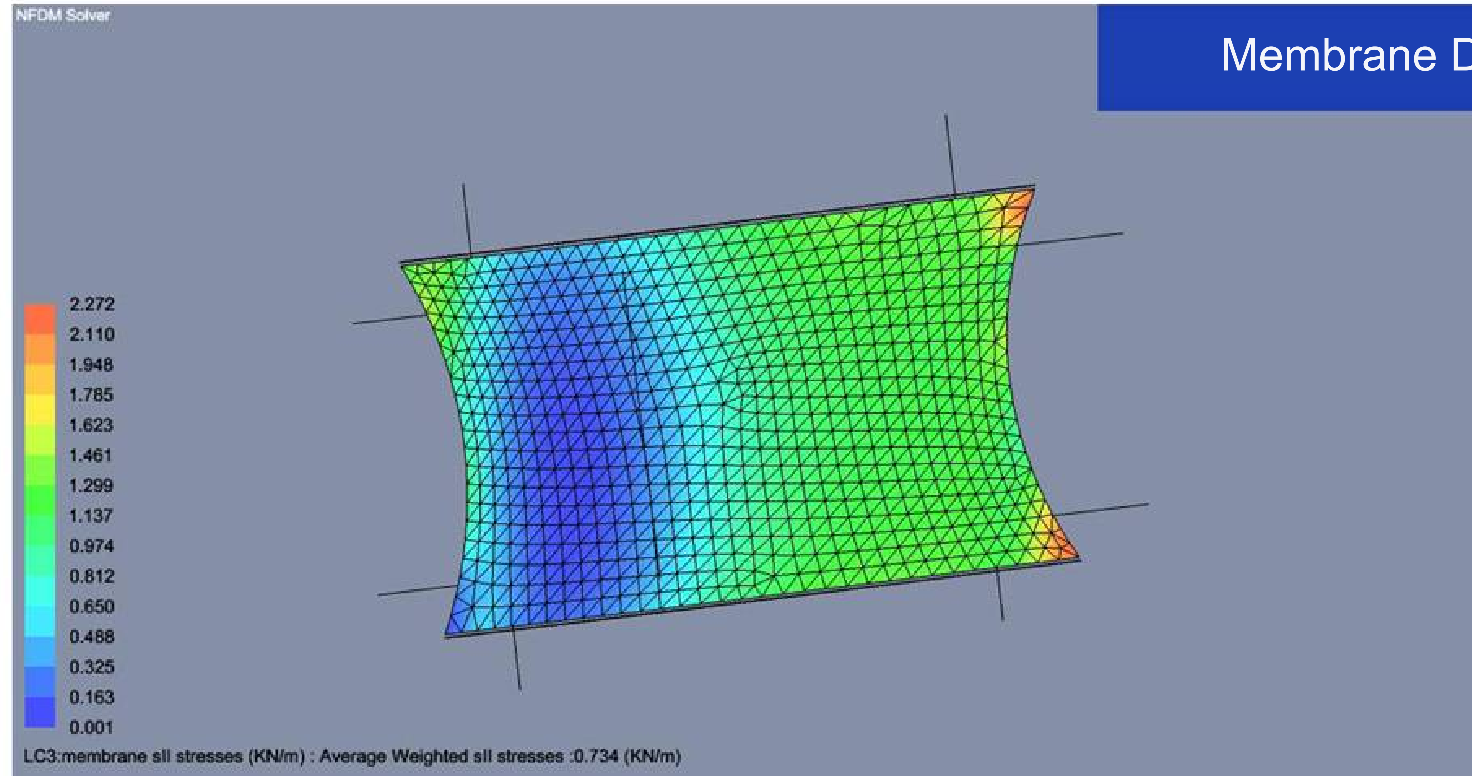


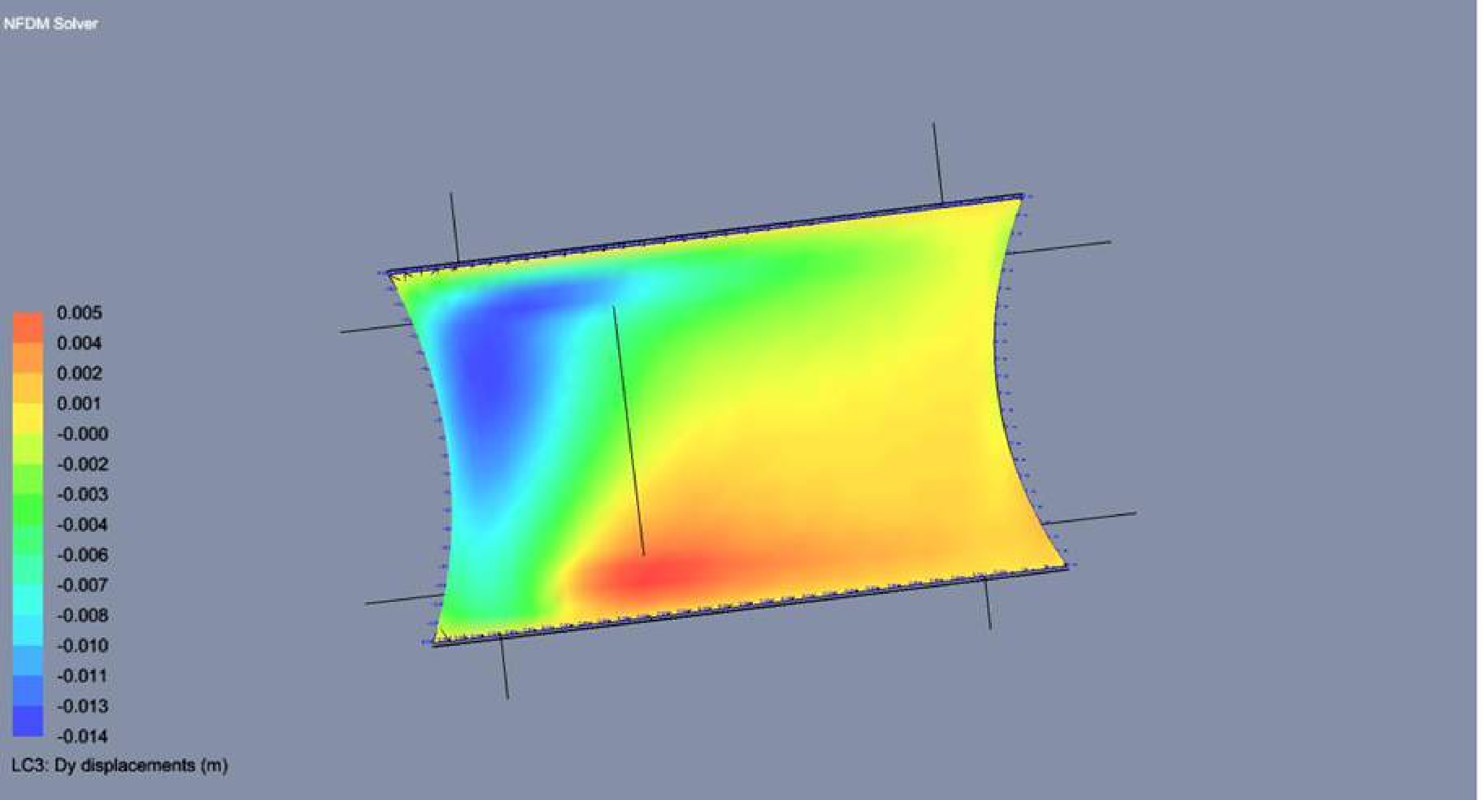
SLS-LC2

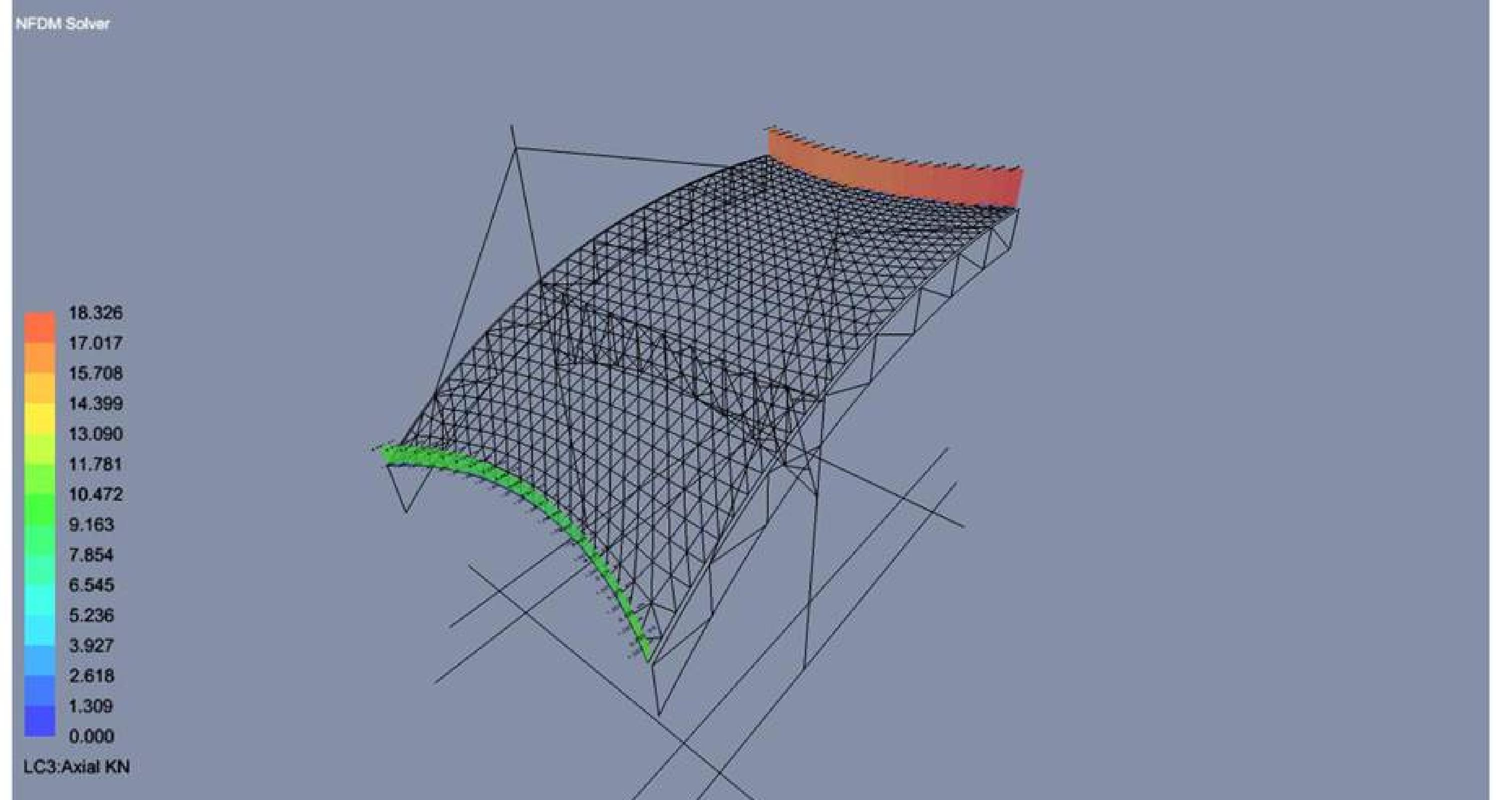
1.0 SELFWEIGHT + 1.0 PRESTRESS + 1.0 WIND

S1-MAX.: 8.689 Kn/m²
S2-MAX.: 4.532 Kn/m²
DEFORMATION MAX.: 0.005 m
AXIAL FORCE MAX.: 51.047 Kn









SLS-LC3

1.0 SELFWEIGHT + 1.0 PRESTRESS + 1.0 SNOW + 1.0WIND

S1-MAX.: 3.462 Kn/m^2
S2-MAX.: 2.272 Kn/m^2
DEFORMATION MAX.: 0.005m
AXIAL FORCE MAX.: 18.326 Kn

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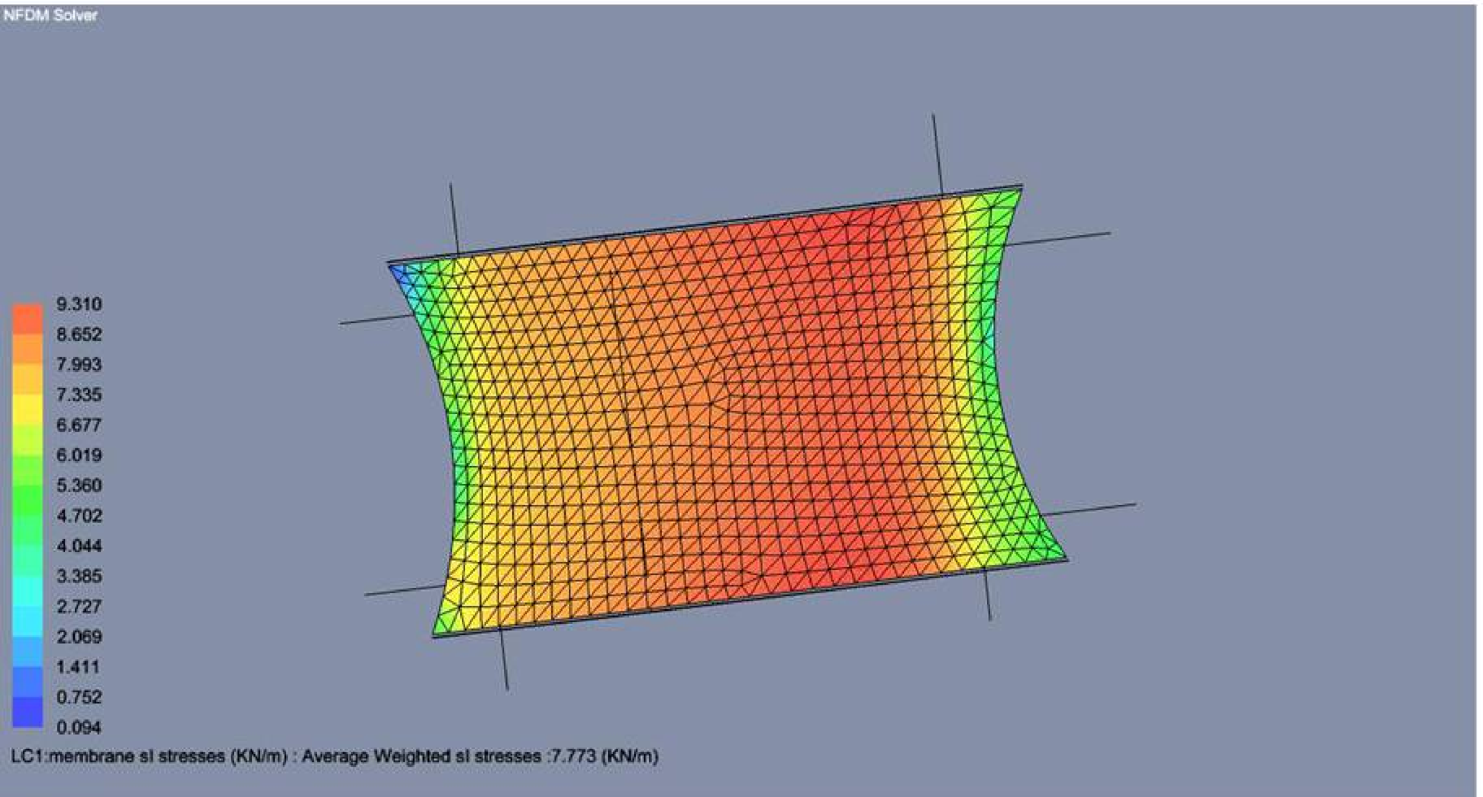
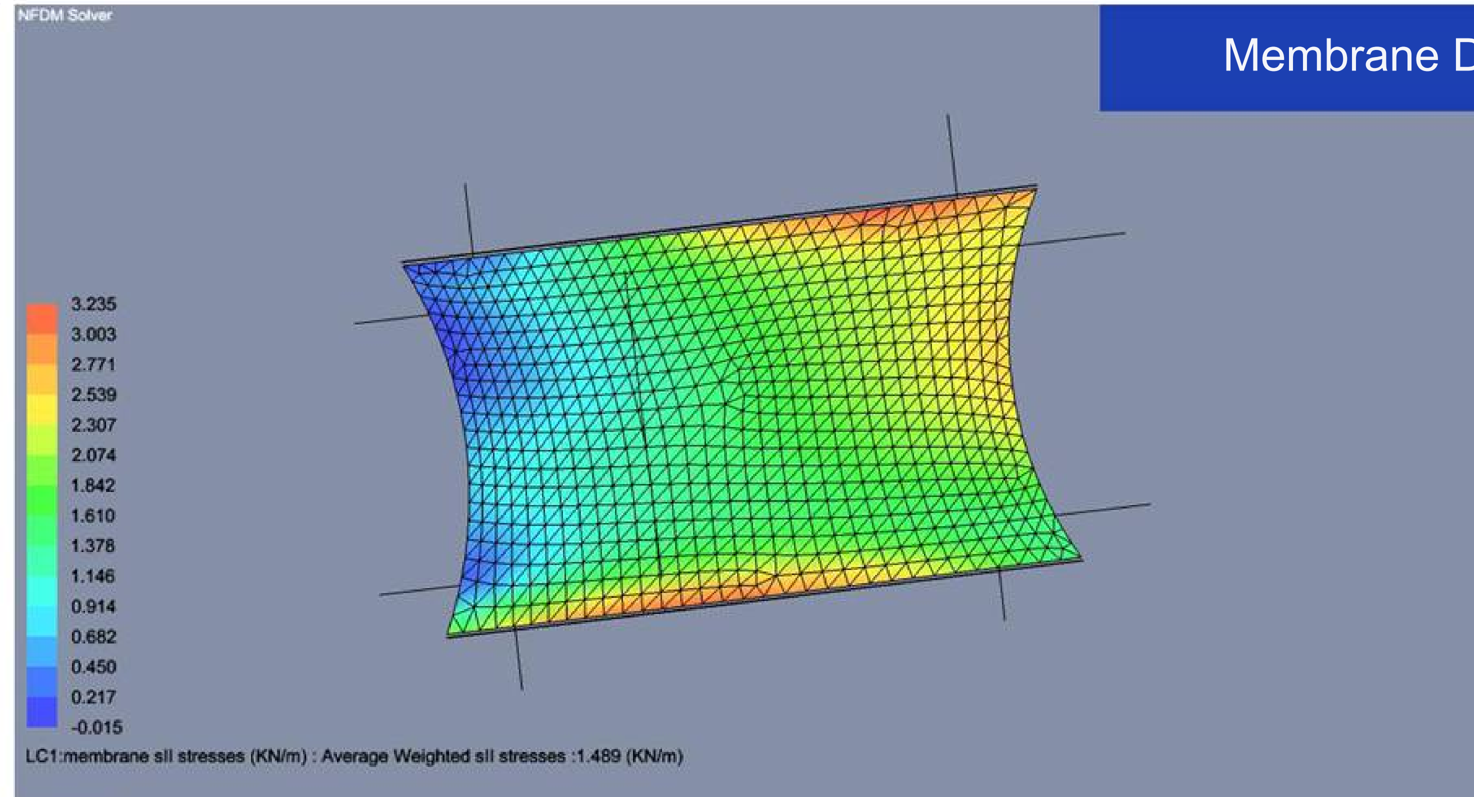
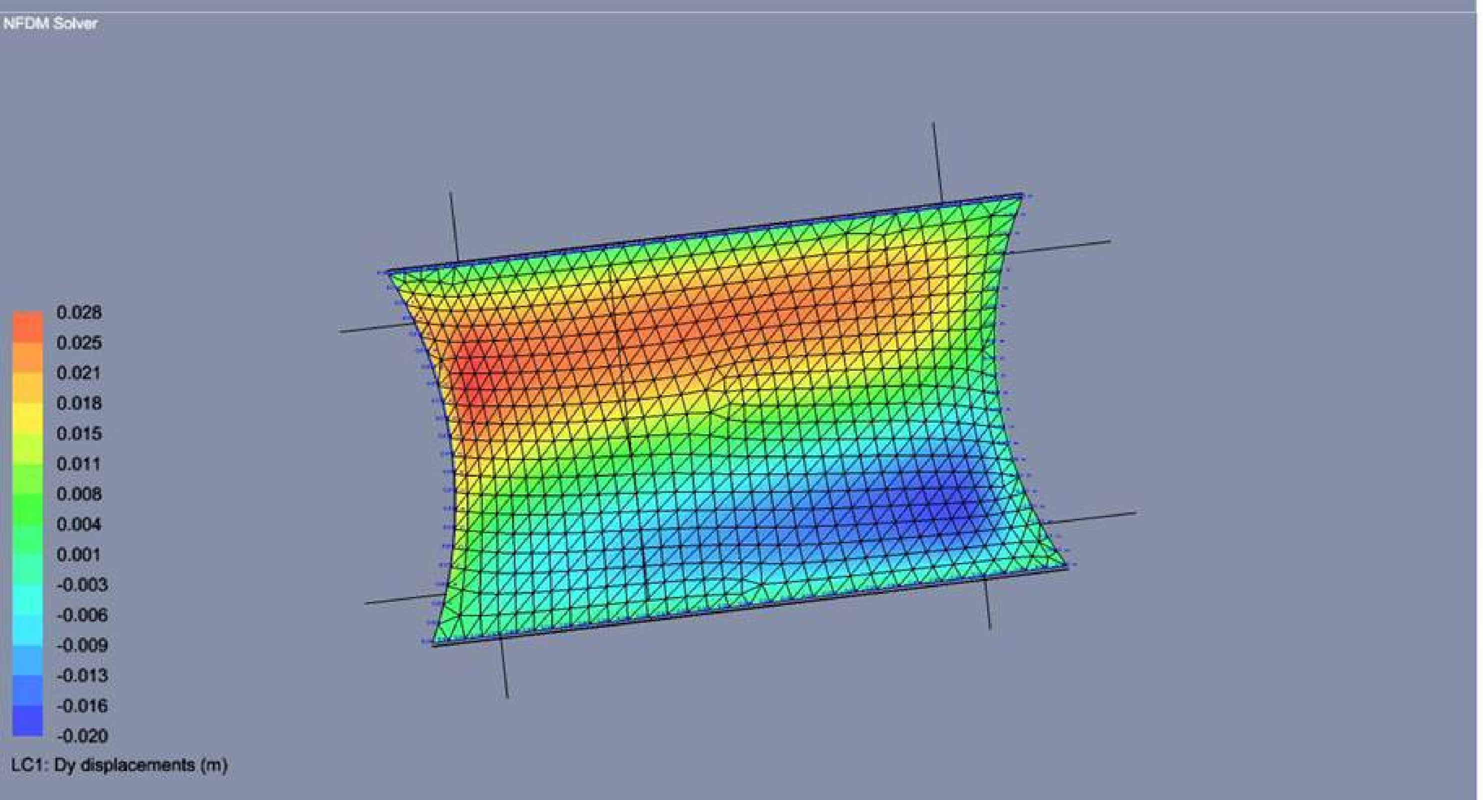
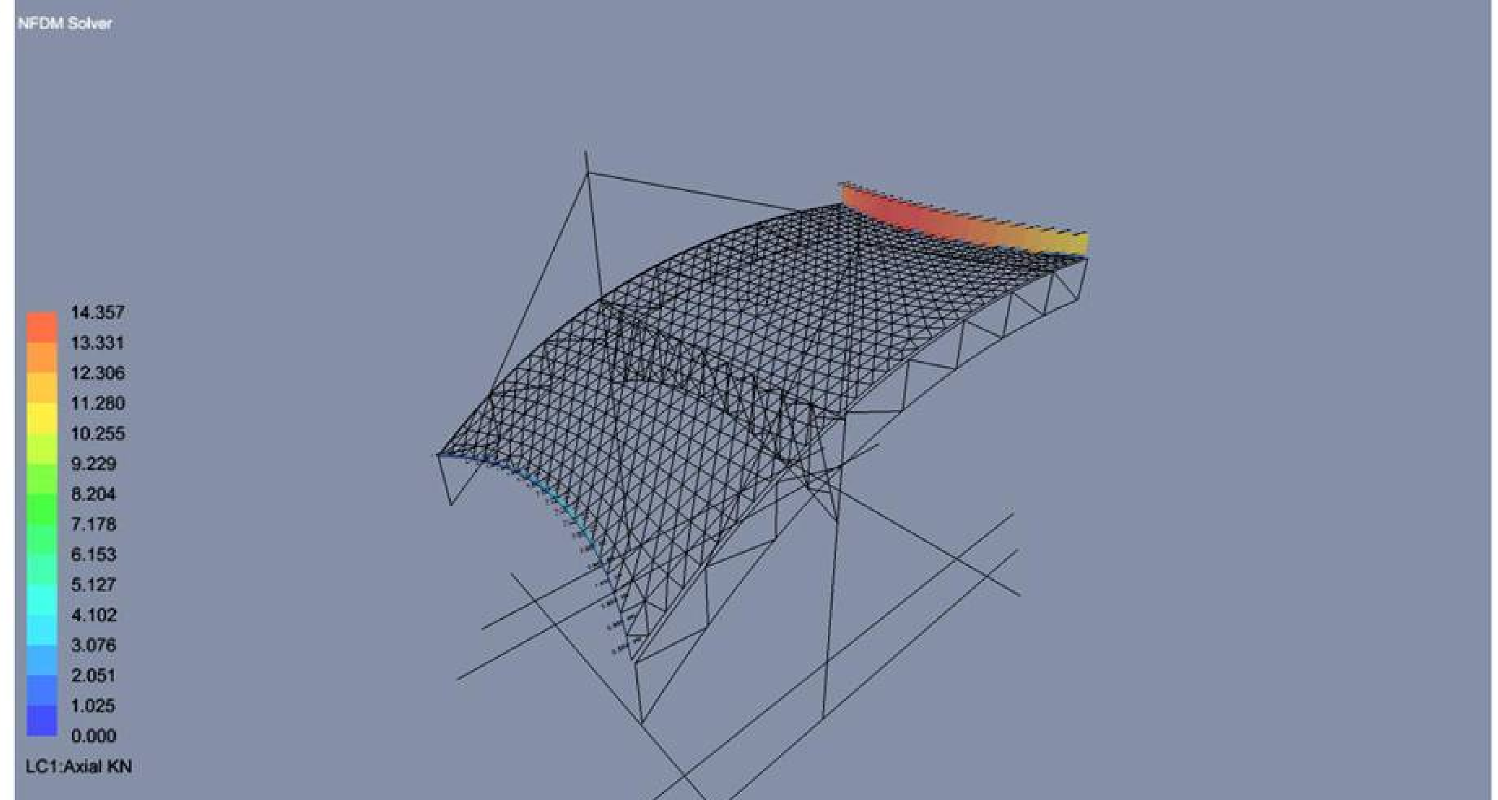




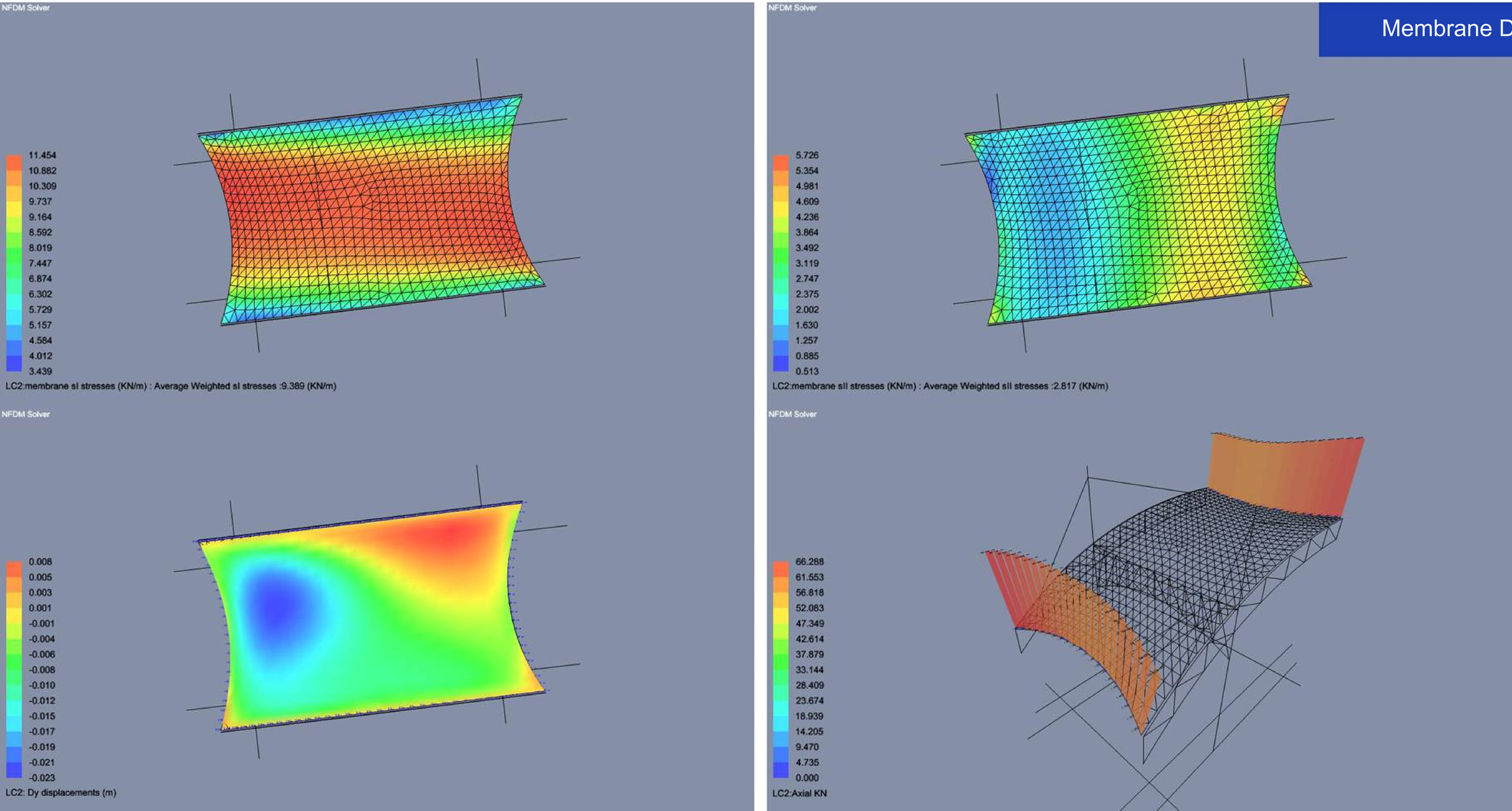




ULS-LC1

1.35 SELFWEIGHT + 1.35 PRESTRESS + 1.5 SNOW

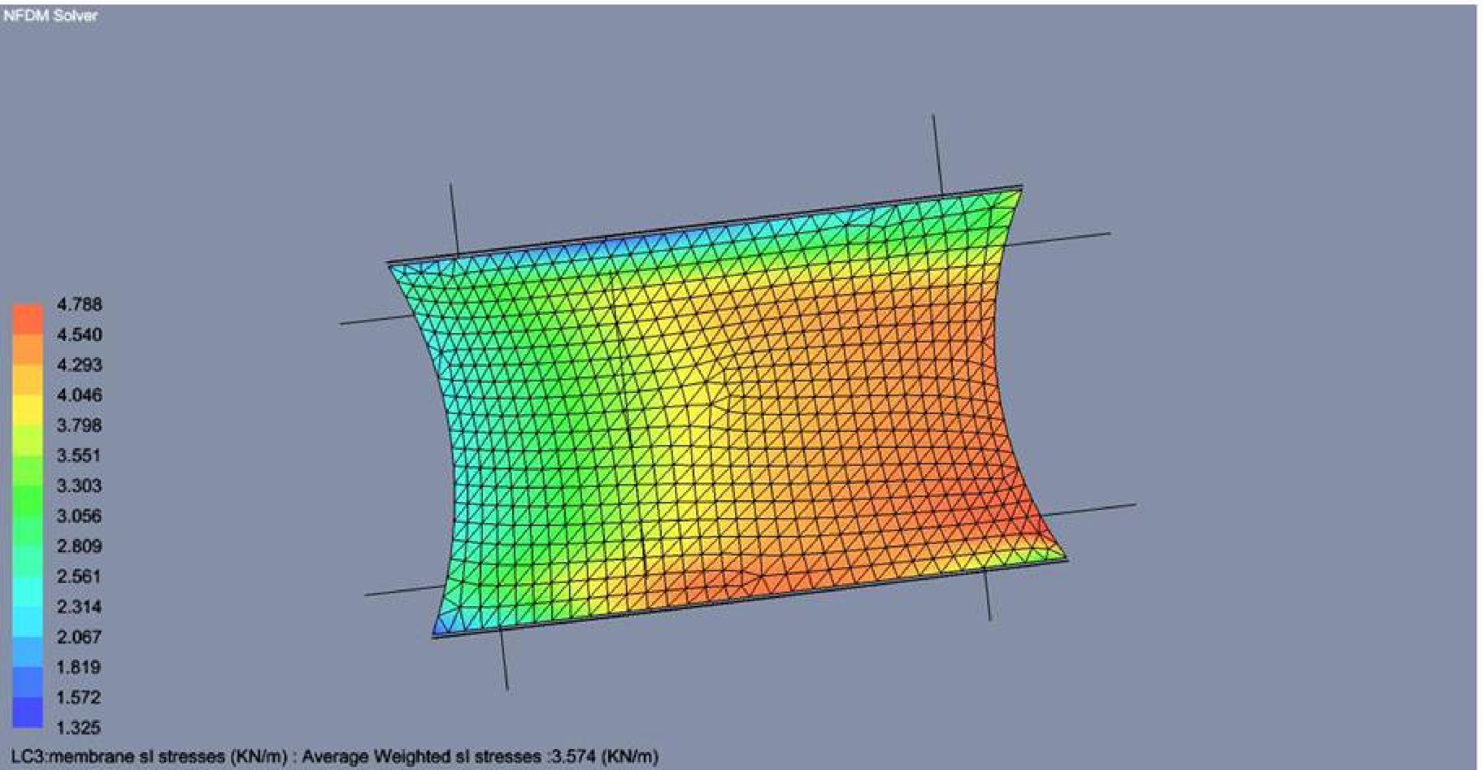
S1-MAX.: 9.310 Kn/m²
S2-MAX.: 3.235 Kn/m²
DEFORMATION MAX.: 0.028m
AXIAL FORCE MAX.: 14.357 Kn

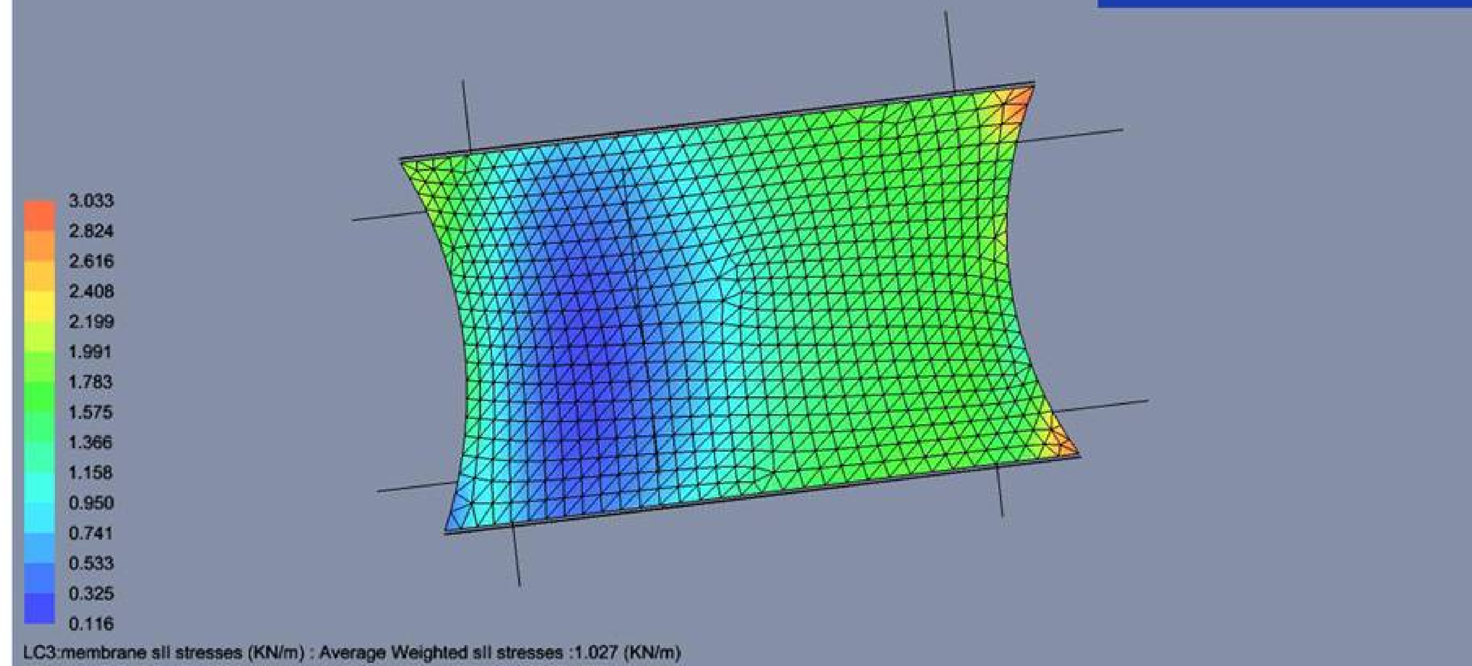


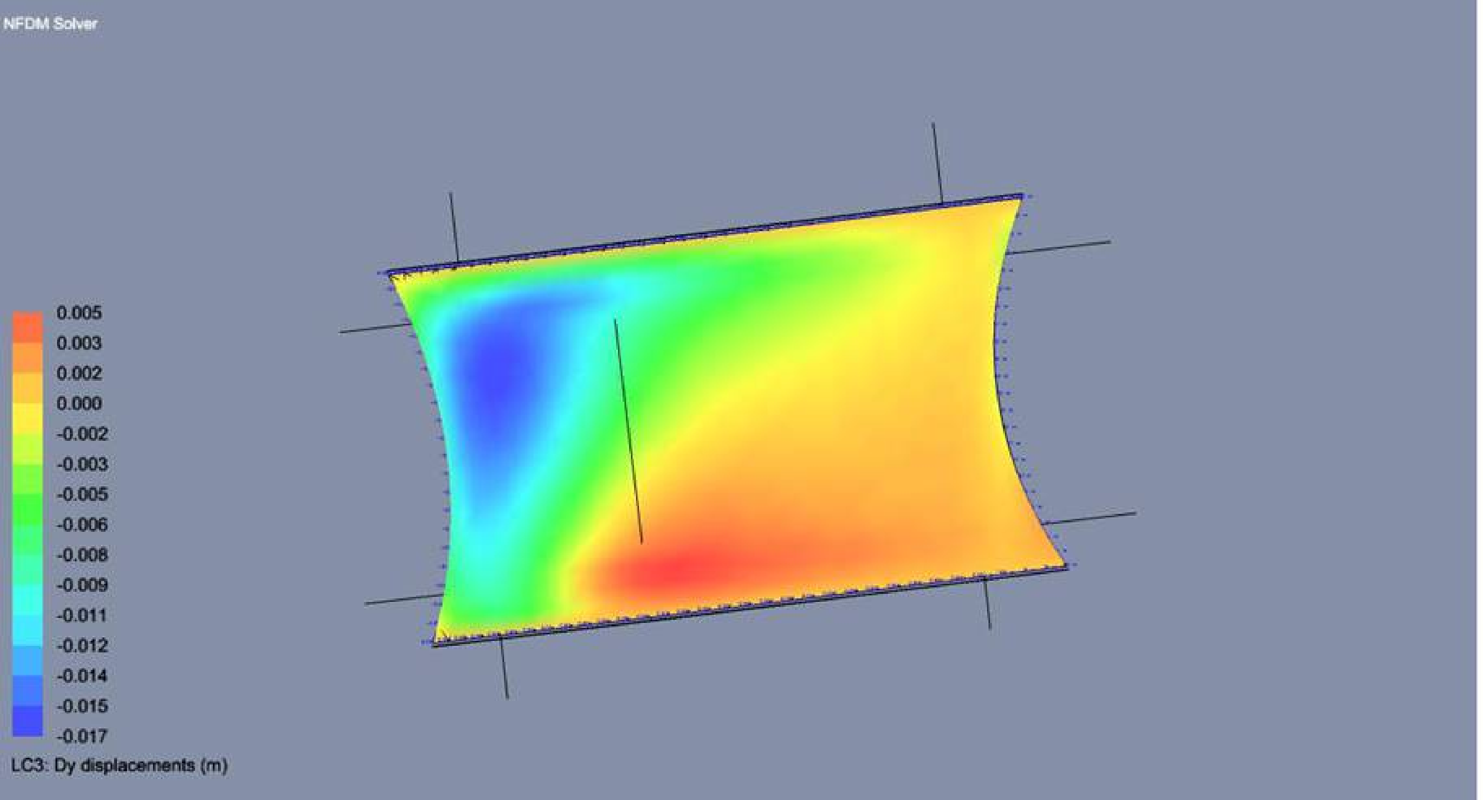
ULS-LC2

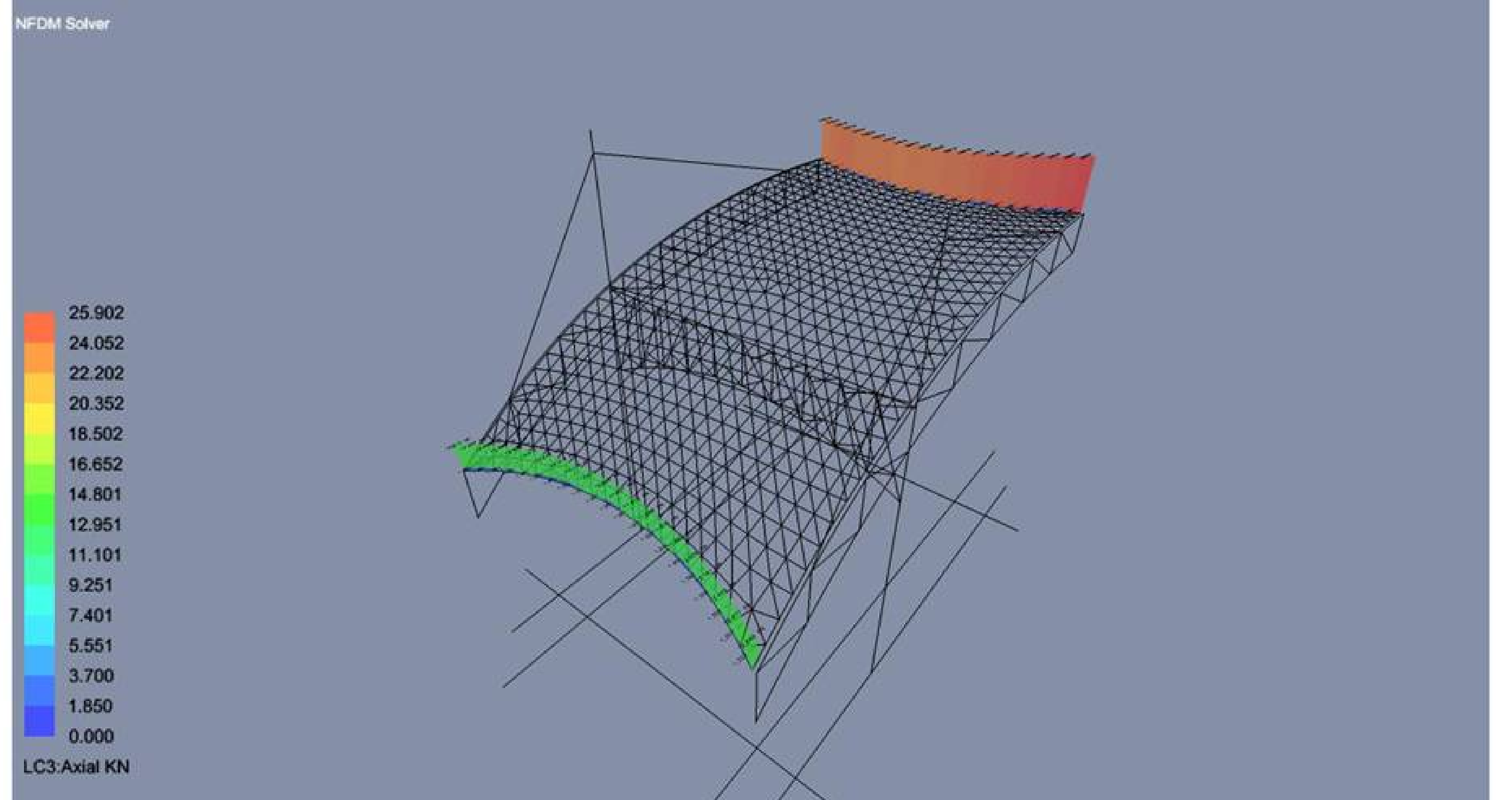
1.35 SELFWEIGHT + 1.35 PRESTRESS + 1.5 WIND

S1-MAX.: 11.454 Kn/m^2
S2-MAX.: 5.726 Kn/m^2
DEFORMATION MAX.: 0.008m
AXIAL FORCE MAX.: 66.288 Kn









ULS-LC3

1.35 SELFWEIGHT + 1.35 PRESTRESS + 1.5 WIND + 1.5SNOW

S1-MAX.: 4.788 Kn/m²
S2-MAX.: 3.033 Kn/m²
DEFORMATION MAX.: 0.005m
AXIAL FORCE MAX.: 25.902 Kn

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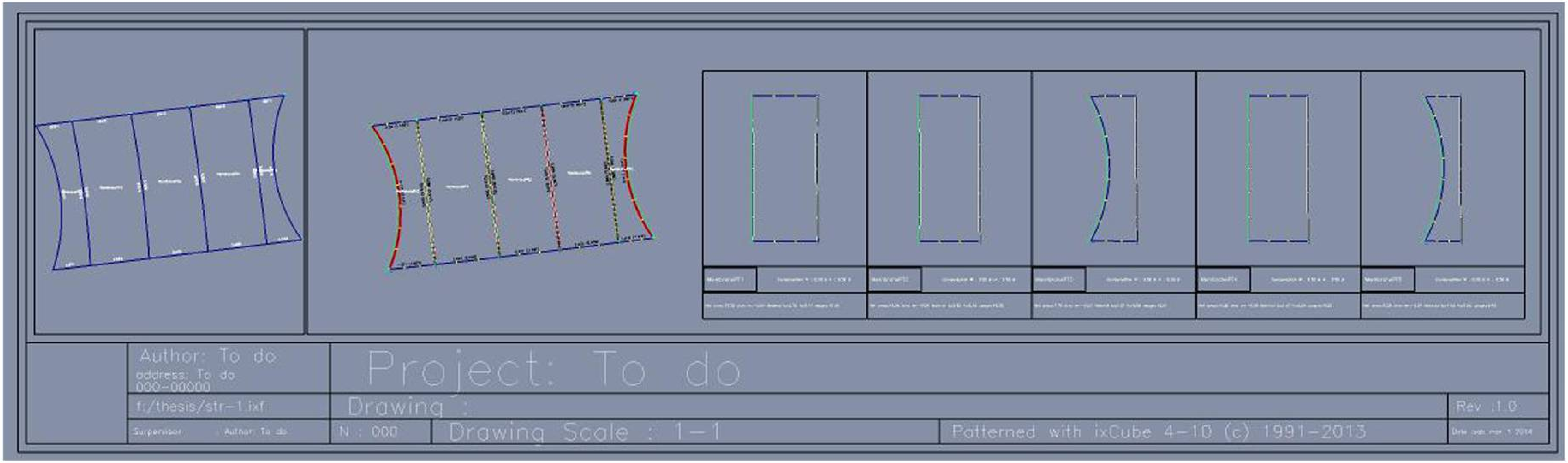


PATTERNING

Fabric

max SI: 11.454 Kn/m²
max SII: 5.766Kn/m²
VALMEX product. FR700 Type I
Tensile Strength: 60/60 kn/m²

Fabrication

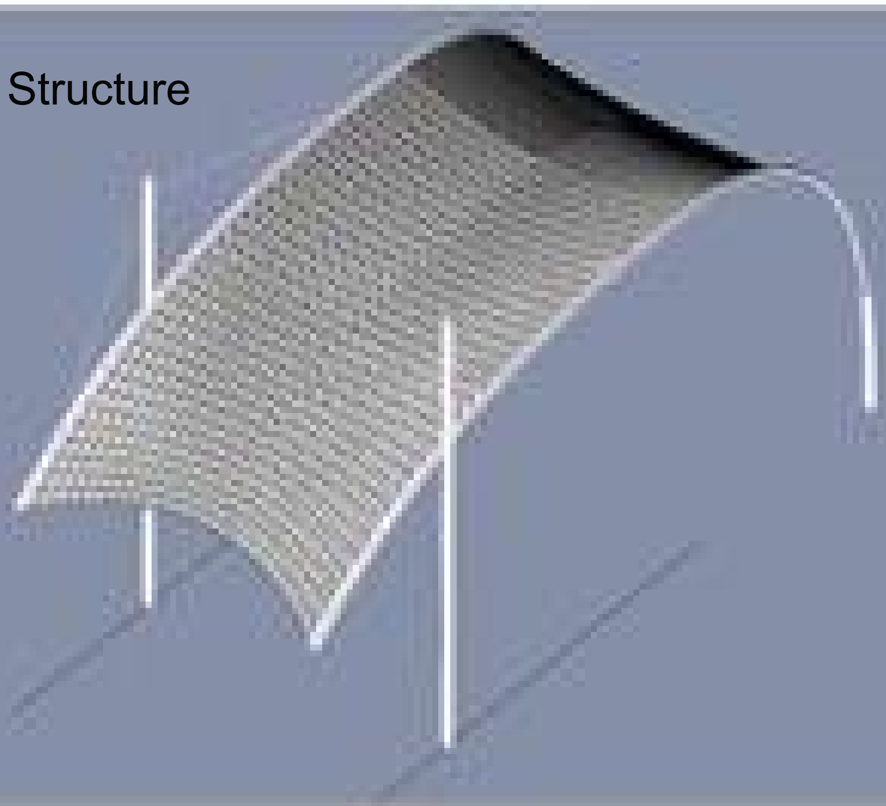
Compensation: 0.5/0.5
Overlapped welding: 50mm

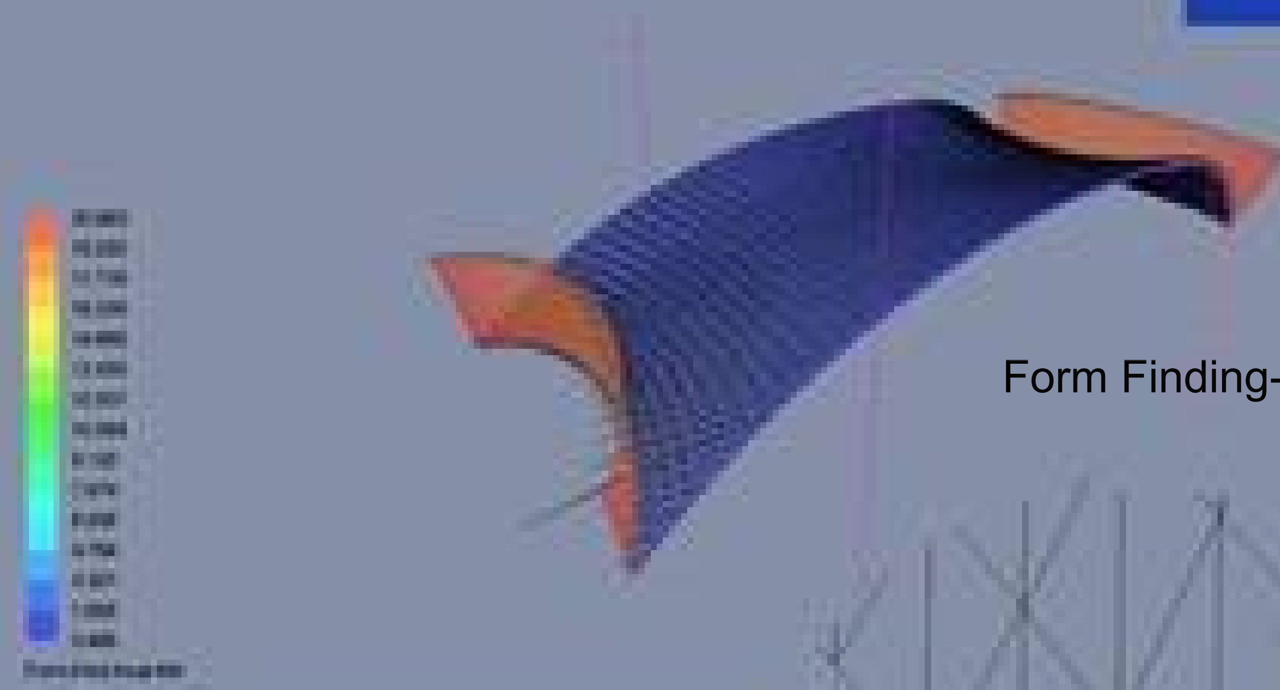
Stress-Verifications ($S_d \leq R_d$)

$F_{u.k}/Y_{m.uls}.A_{res}$
$Y_{m.uls}$ =1.4
A_{res} for permanent load= $A_0 \times A_1 \times A_2 \times A_3 \times A_4$ = 1.2×1.7×1.2×1.2×1.0=2.94
A_{res} for Snow load= $A_0 \times A_2$ = 1.2×1.2=1.44
Ares for Wind load= $A_0 \times A_1 \times A_2$ = 1.2×1.7×1.2=2.45
WARP R_d for permanent load= 60/(1.5×1.4×2.94)=9.718
WEFT R_d for permanent load= 60/(1.5×1.4×2.94)=9.718
WARP R_d for Snow load= 60/(1.6×1.4×1.44)=18.604
WEFT R_d for Snow load= 60/(1.6×1.4×1.44)=18.604
WARP R_d for Wind load= 60/(1.5×1.4×2.45)=11.661
WEFT R_d for Wind load= 60/(1.5×1.4×2.45)=11.661

Permanent load: S_d max.:1.594 < R_d: 9.718
Snow load: S_d max.: 9.310< R_d: 18.604
Wind load: S_d max.: 11.454< R_d: 11.661

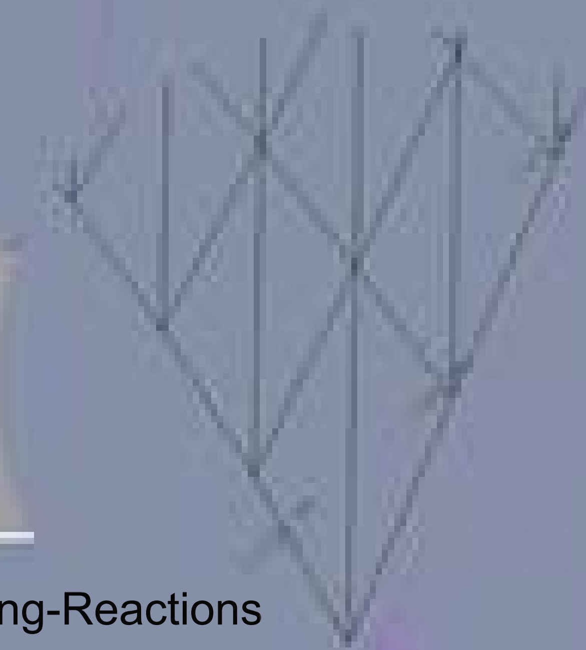
Stop Area Structure



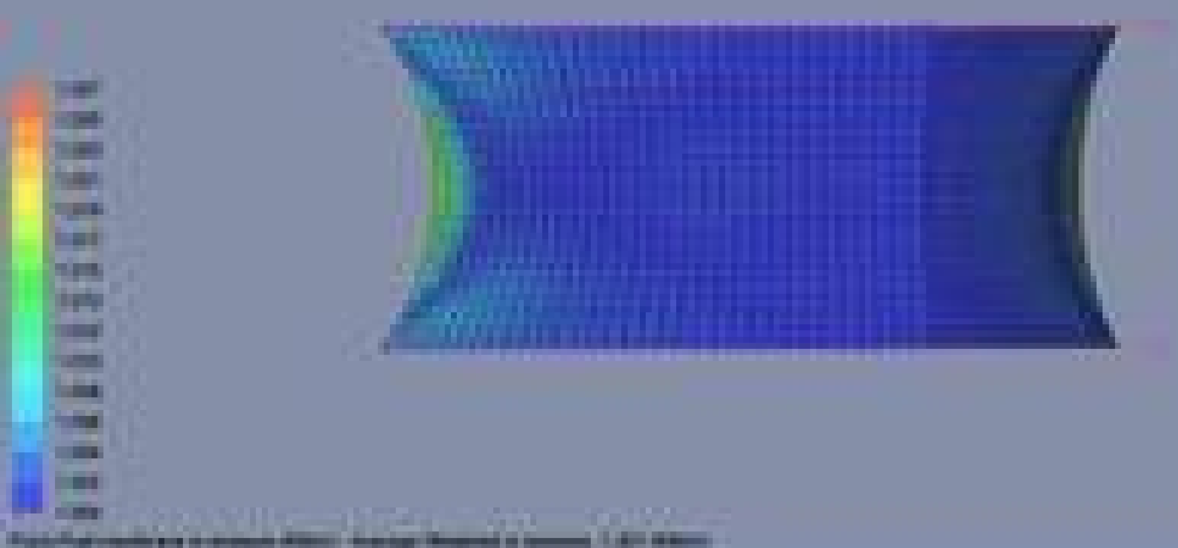


Form Finding-Axial Forces

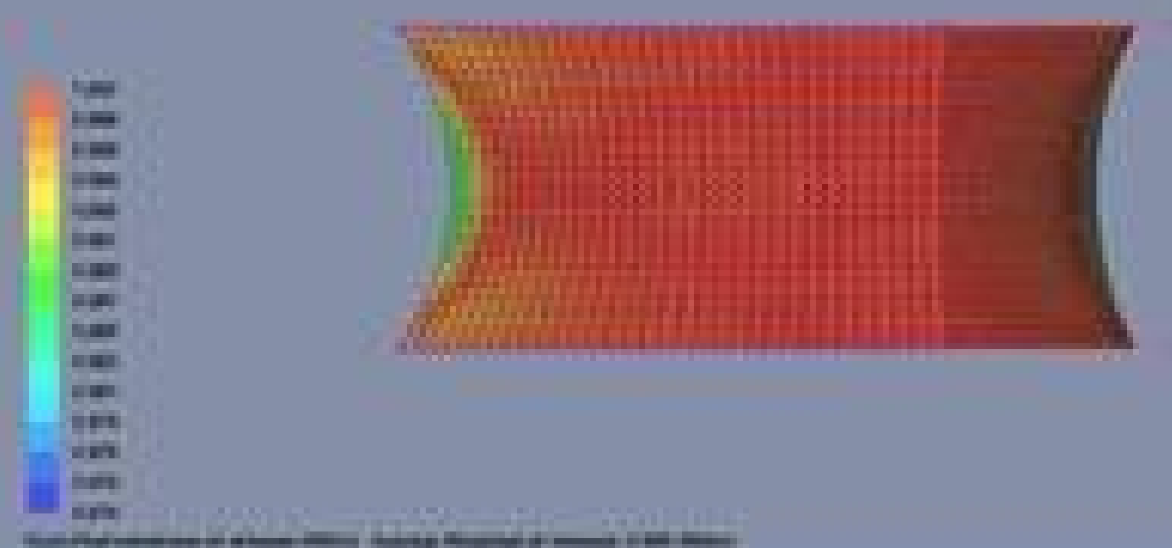
Pretention: 20
Cables: 16mm
Beams: CHS-114.3x5.4
Membrane: Preconstraint 702- Ferrari
Warp/ weft Stress: 1/1
Max. Sress: 1.027 Kn/m



Form Finding-Reactions

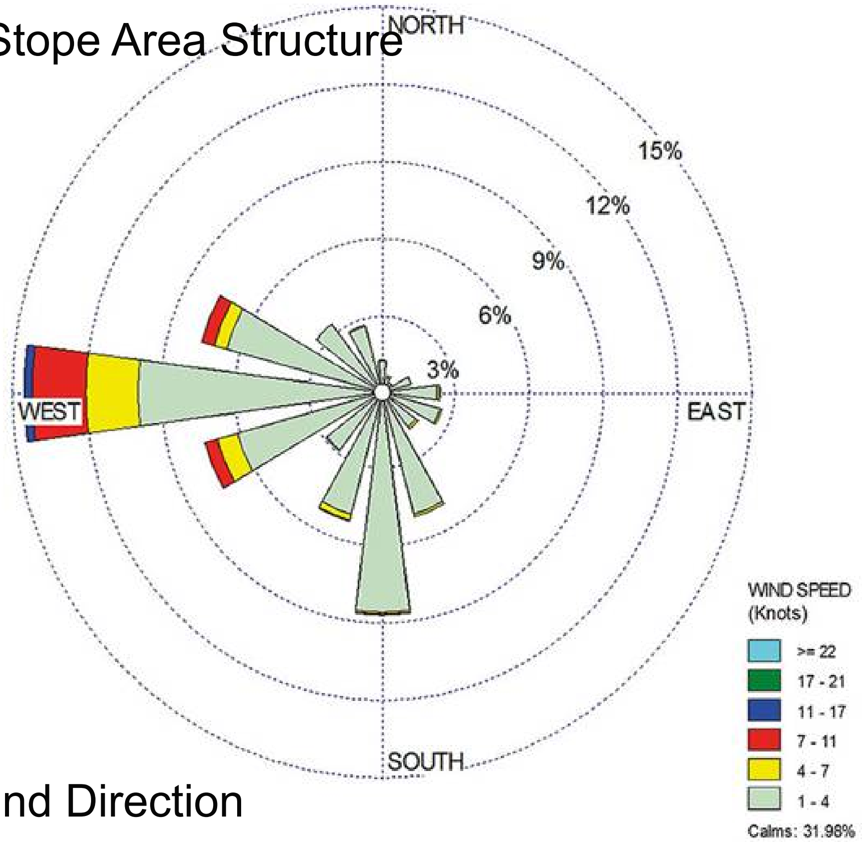


Form Finding-S1



Form Finding-S2

Stope Area Structure



Wind Direction

BS EN 1991-1-4:2005+A1:2010
EN 1991-1-4:2005+A1:2010 (E)

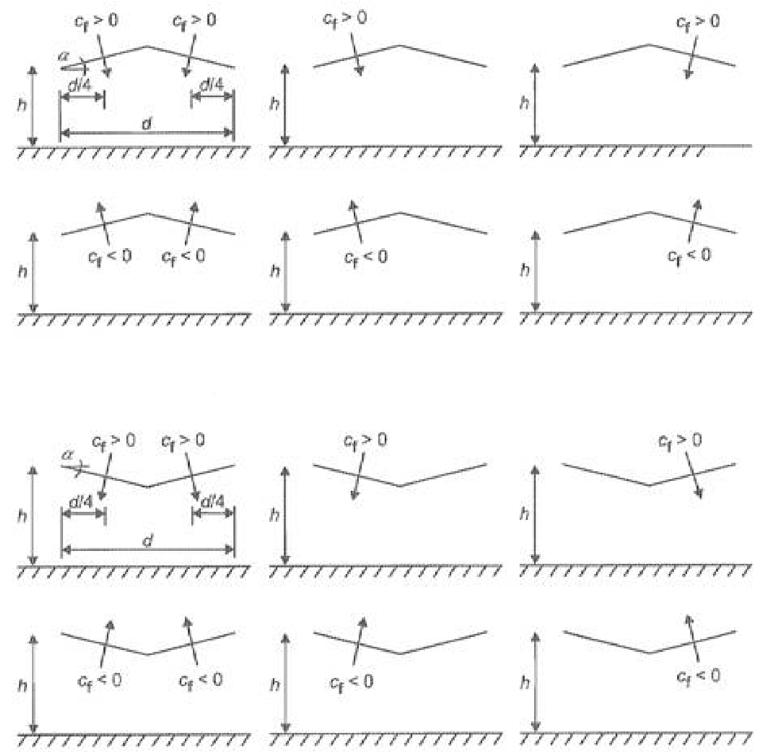
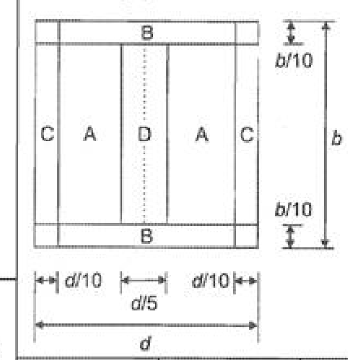


Figure 7.17 — Arrangements of loads obtained from force coefficients for duopitch canopies

BS EN 1991-1-4:2005+A1:2010
EN 1991-1-4:2005+A1:2010 (E)

Table 7.7 — $c_{p,net}$ and c_f values for duopitch canopies



Roof angle α [°]	Blockage φ	Overall Force Coefficient c_f	Net pressure coefficients $c_{p,net}$ Zone A	Zone B	Zone C	Zone D
- 20	Maximum all φ	+ 0,7	+ 0,8	+ 1,6	+ 0,6	+ 1,7
	Minimum φ = 0	- 0,7	- 0,9	- 1,3	- 1,6	- 0,6
	Minimum φ = 1	- 1,3	- 1,5	- 2,4	- 2,4	- 0,6
- 15	Maximum all φ	+ 0,5	+ 0,6	+ 1,5	+ 0,7	+ 1,4
	Minimum φ = 0	- 0,6	- 0,8	- 1,3	- 1,6	- 0,6
	Minimum φ = 1	- 1,4	- 1,6	- 2,7	- 2,6	- 0,6
- 10	Maximum all φ	+ 0,4	+ 0,6	+ 1,4	+ 0,8	+ 1,1
	Minimum φ = 0	- 0,6	- 0,8	- 1,3	- 1,5	- 0,6
	Minimum φ = 1	- 1,4	- 1,6	- 2,7	- 2,6	- 0,6
- 5	Maximum all φ	+ 0,3	+ 0,5	+ 1,5	+ 0,8	+ 0,8
	Minimum φ = 0	- 0,5	- 0,7	- 1,3	- 1,6	- 0,6
	Minimum φ = 1	- 1,3	- 1,5	- 2,4	- 2,4	- 0,6
+ 5	Maximum all φ	+ 0,3	+ 0,6	+ 1,8	+ 1,3	+ 0,4
	Minimum φ = 0	- 0,6	- 0,6	- 1,4	- 1,4	- 1,1
	Minimum φ = 1	- 1,3	- 1,3	- 2,0	- 1,8	- 1,5
+ 10	Maximum all φ	+ 0,4	+ 0,7	+ 1,8	+ 1,4	+ 0,4
	Minimum φ = 0	- 0,7	- 0,7	- 1,5	- 1,4	- 1,4
	Minimum φ = 1	- 1,3	- 1,3	- 2,0	- 1,8	- 1,8
+ 15	Maximum all φ	+ 0,4	+ 0,9	+ 1,9	+ 1,4	+ 0,4
	Minimum φ = 0	- 0,8	- 0,9	- 1,7	- 1,4	- 1,8
	Minimum φ = 1	- 1,3	- 1,3	- 2,2	- 1,6	- 2,1
+ 20	Maximum all φ	+ 0,6	+ 1,1	+ 1,9	+ 1,5	+ 0,4
	Minimum φ = 0	- 0,9	- 1,2	- 1,8	- 1,4	- 2,0
	Minimum φ = 1	- 1,3	- 1,4	- 2,2	- 1,6	- 2,1
+ 25	Maximum all φ	+ 0,7	+ 1,2	+ 1,9	+ 1,6	+ 0,5
	Minimum φ = 0	- 1,0	- 1,4	- 1,9	- 1,4	- 2,0
	Minimum φ = 1	- 1,3	- 1,4	- 2,0	- 1,5	- 2,0
+ 30	Maximum all φ	+ 0,9	+ 1,3	+ 1,9	+ 1,6	+ 0,7
	Minimum φ = 0	- 1,0	- 1,4	- 1,9	- 1,4	- 2,0
	Minimum φ = 1	- 1,3	- 1,4	- 1,8	- 1,4	- 2,0

NOTE + values indicate a net downward acting wind action

- values represent a net upward acting wind action

WIND CALCULATION

Basic wind speed $V_{b,0}$= 27.60 m/s
Directional factor C_{dir}= 1.00
Seasonal factor C_{season}= 1.00
$V_b = V_{b,0}\, x C_{dir} x C_{season}$
V_b= 27.60 m/s
The orography factor $C_o(z)$ = 1.00
The roughness length Z_o= 1.0
(terrain category IV, Table 4.1)
Minimum height of structure Z_{min}= 3.00
Maximum height of the structure Z_{max}=7.00
Train Factor Kr = $0.19\ (Z_o/ Z_{o,II})^{0.007}$= $0.19(1.0/0.5)^{0.007}$=0.2
The Train roughness factor $C_r(z)$=Kr . $\ln(z/z_0)$= 0.2xln(7/1)=0.39
Density of air [kg/m³] ρ= 1.25 kg/m³
The peak velocity pressure $q_p(z) = c_e(z) x q_b$
$c_e(z)$=1.2 (figure 4.2-Ilustration of exposure factore $C_e(z)$)
Mean wind velocity $V_m(z) = C_r(z) x C_o(z) x V_b$=0.39x1.0x27.60=10.76
Turbulence Intensity $I_v(z) = k_l / C_o(z) x \ln(z/z_0)$= 1.0/ 1.0x1.95=0.51
The peak velocity pressure $q_p(z) = [1+7.I_v(z)]x1/2x\rho x V_m^2(z)$=0.332 kn/m²
Wind action $W_e=q_p(z) x c_{pe}$

Zone A: -0.46
Zone B: -0.63
Zone C: -0.46
Zone D: -0.66

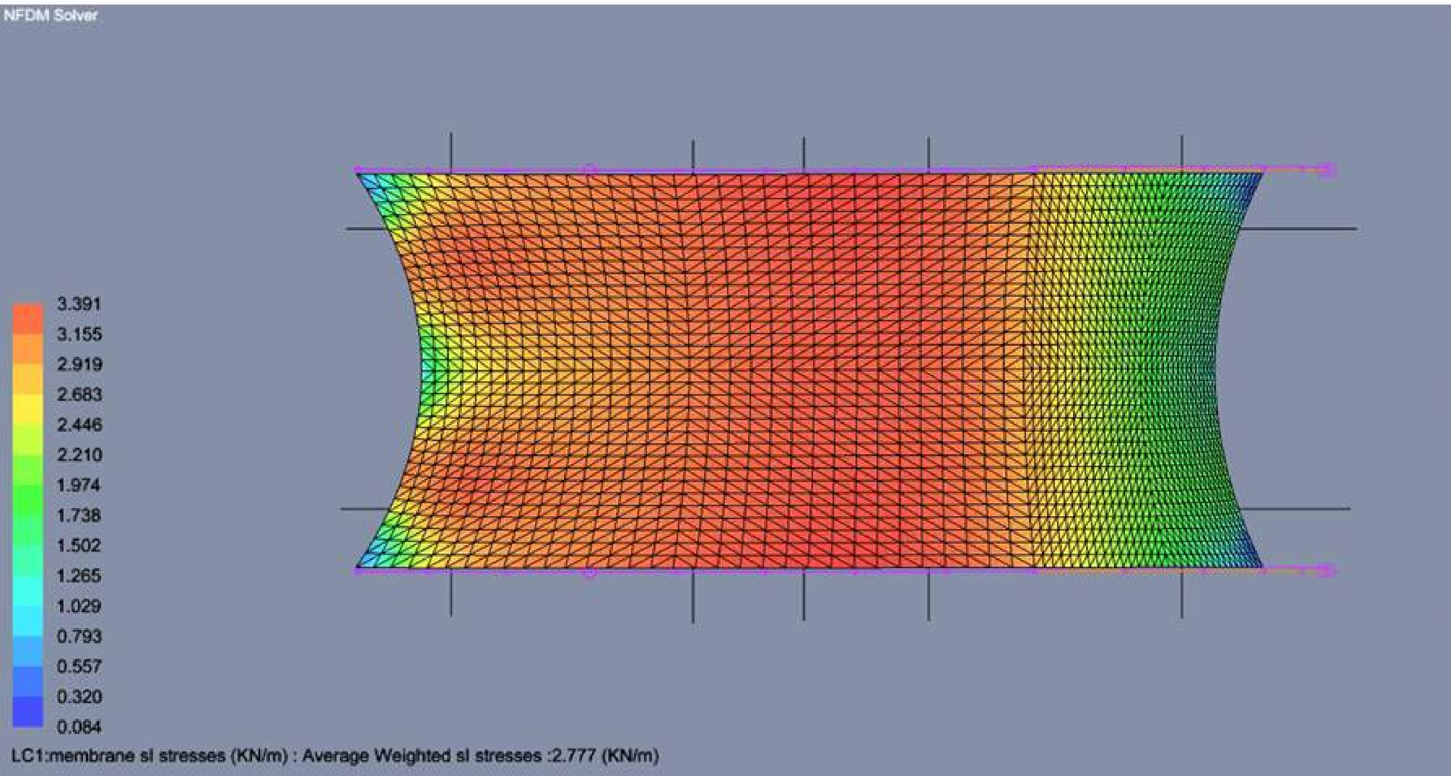
SNOW LOAD

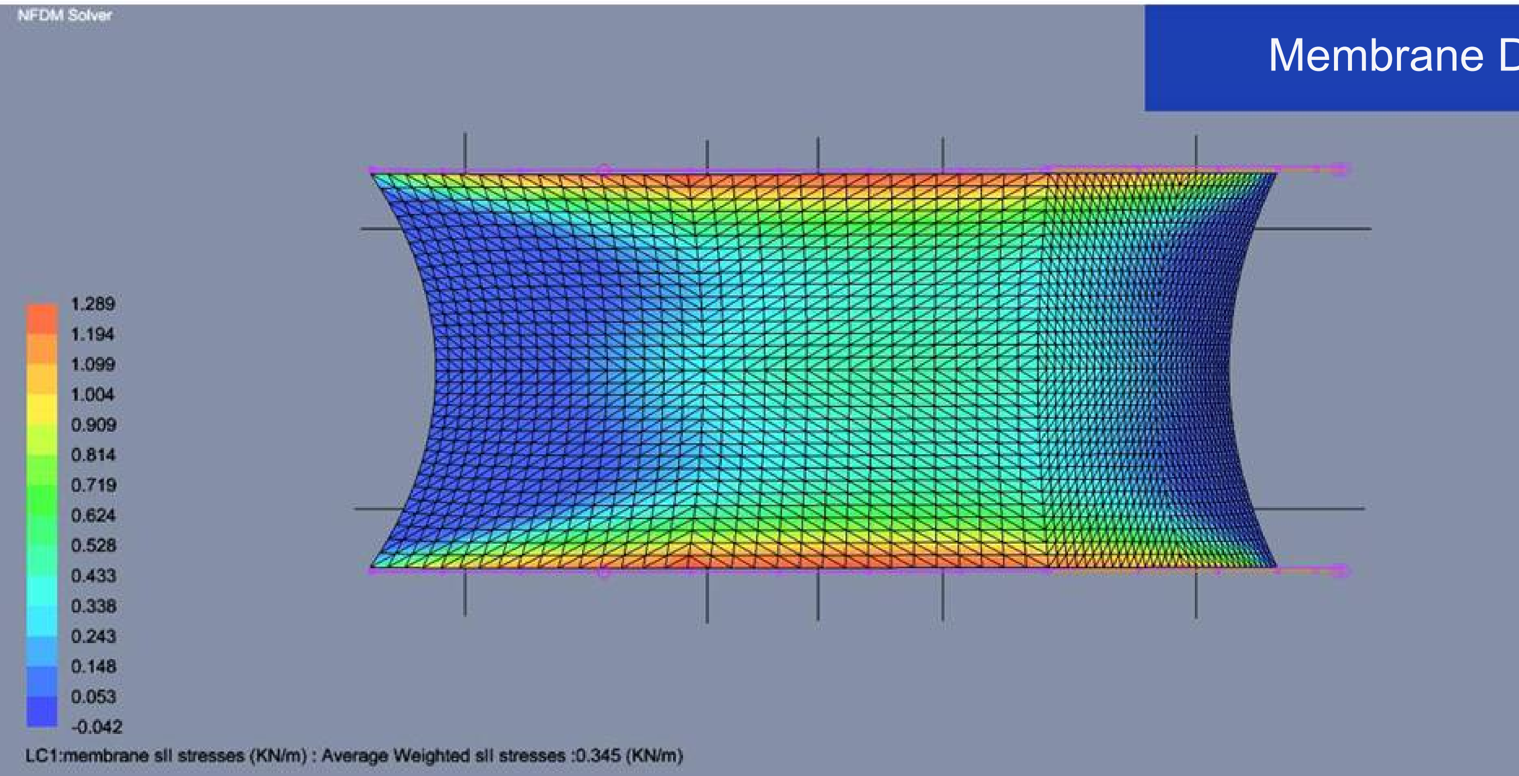
snow load shape coefficient μ = 0.8
(Angle of pitch of roof <30)
exposure coefficient C_e = 1
Thermal coefficient C_t = 1
Characteristic value of snow load
Sk = 0.85 kN/m2 on the ground
Snow loads on roofs S = 0.68 kN/m2

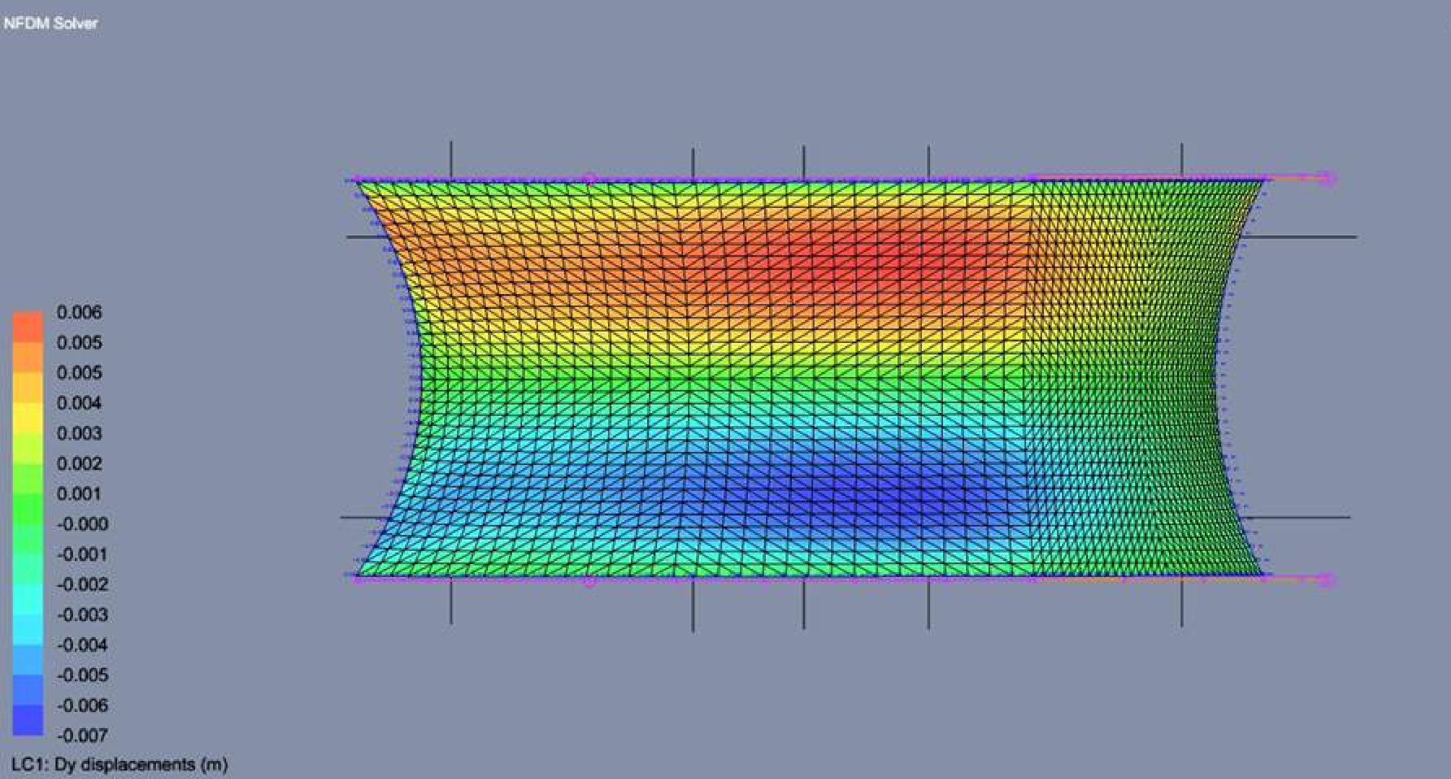
LOAD COMBINATION

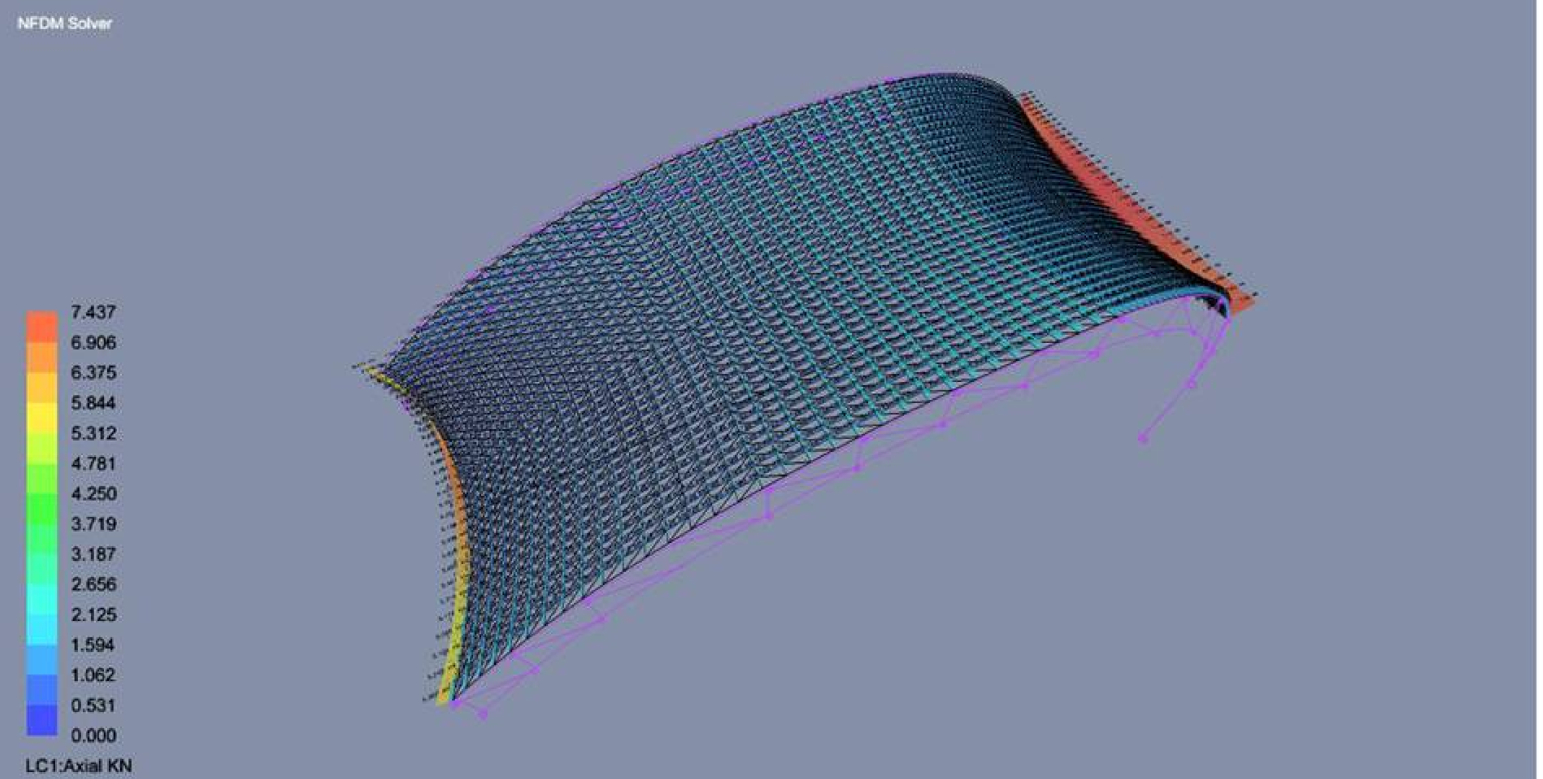
ULS
1.35Selfweight +1.35Prestress +1.5 Wind
1.35Selfweight +1.35Prestress +1.5 Snow
1.35Selfweight +1.35Prestress +1.5 Wind +1.5 Snow

SLS
1.0Selfweight +1.0Prestress + 1.0 Wind
1.0Selfweight +1.0Prestress +1.0 Snow
1.0Selfweight +1.0Prestress +1.0Wind +1.0 Snow





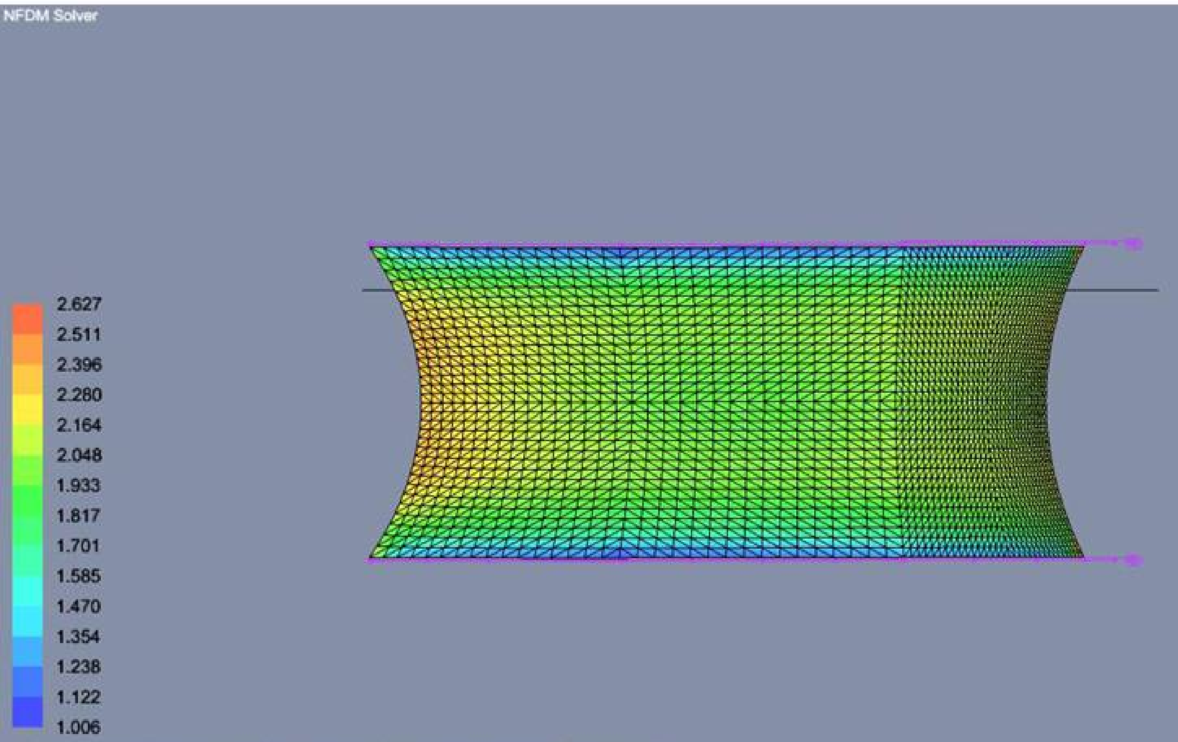




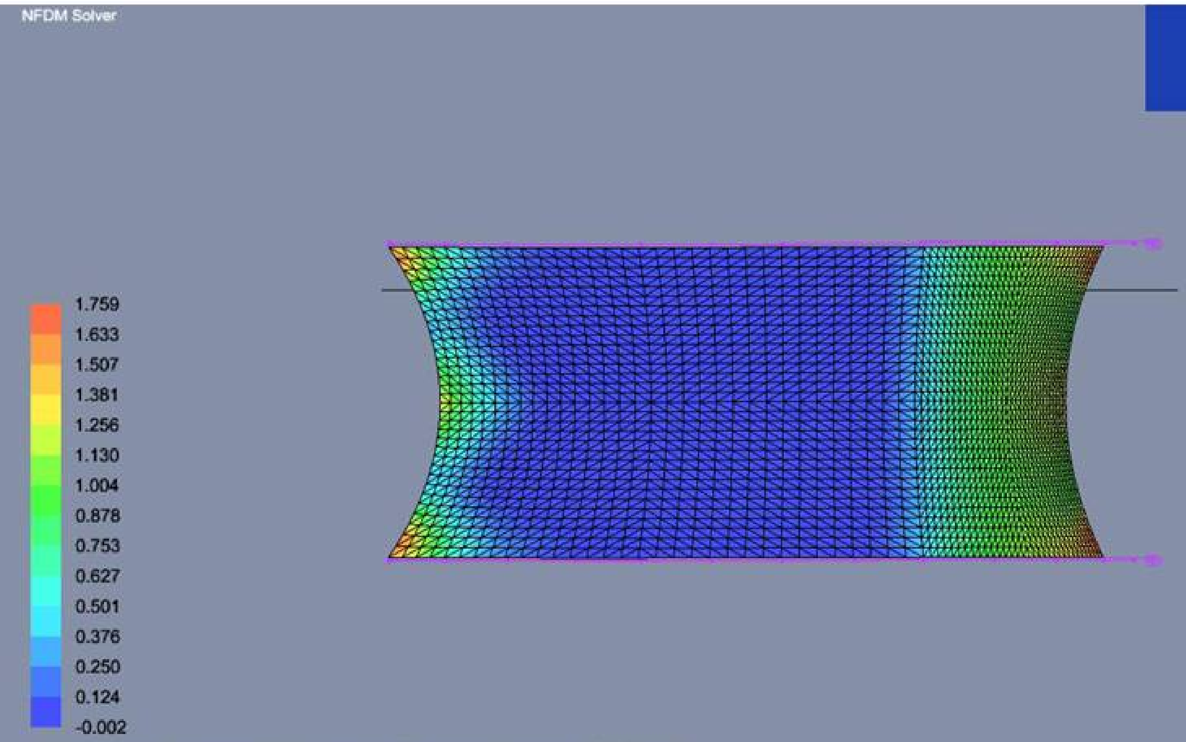
SLS-LC1

1.0 SELFWEIGHT + 1.0 PRESTRESS + 1.0 SNOW

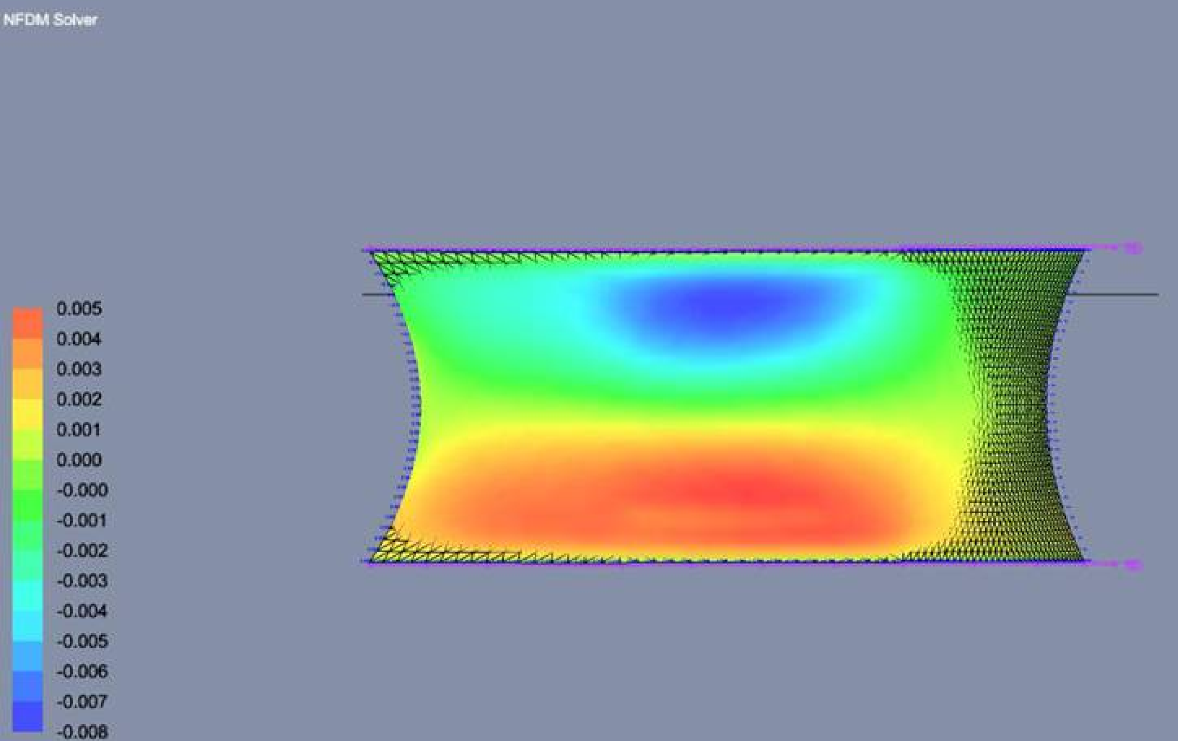
S1-MAX.: 3.391 Kn/m²
S2-MAX.: 1.289 Kn/m²
DEFORMATION MAX.: 0.006 m
AXIAL FORCE MAX.: 7.437 Kn



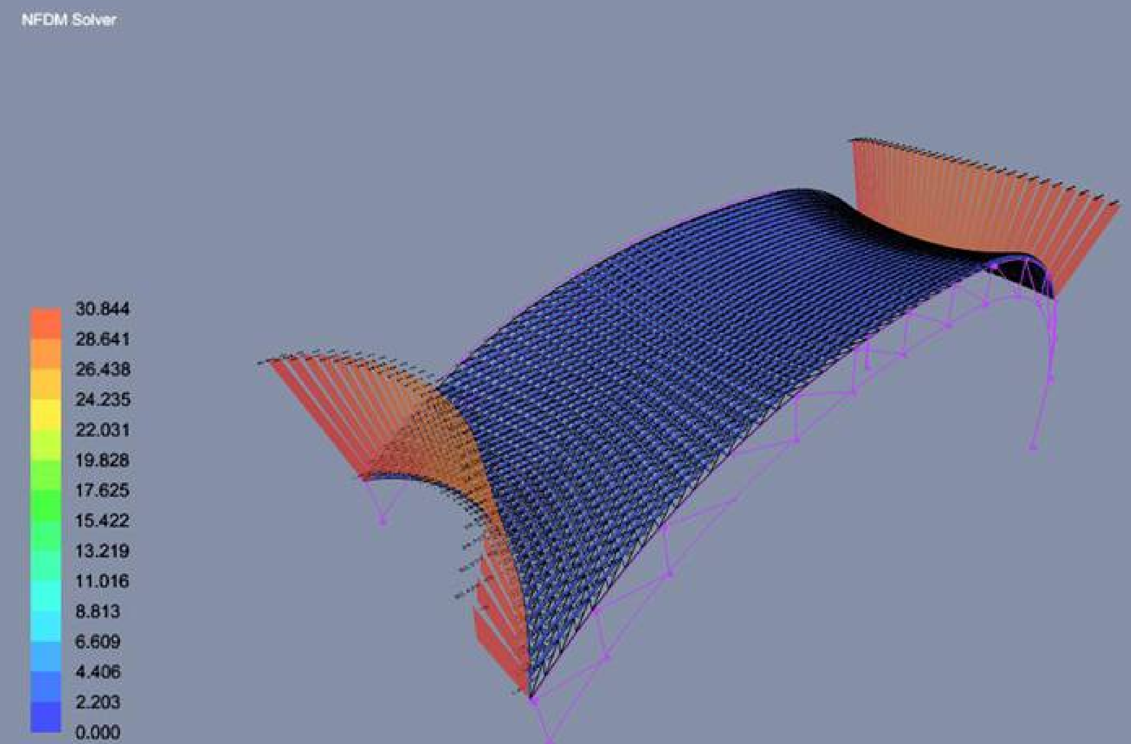
LC2:membrane sI stresses (KN/m) : Average Weighted sI stresses :1.868 (KN/m)



LC2:membrane sII stresses (KN/m) : Average Weighted sII stresses :0.285 (KN/m)



LC2: Dy displacements (m)

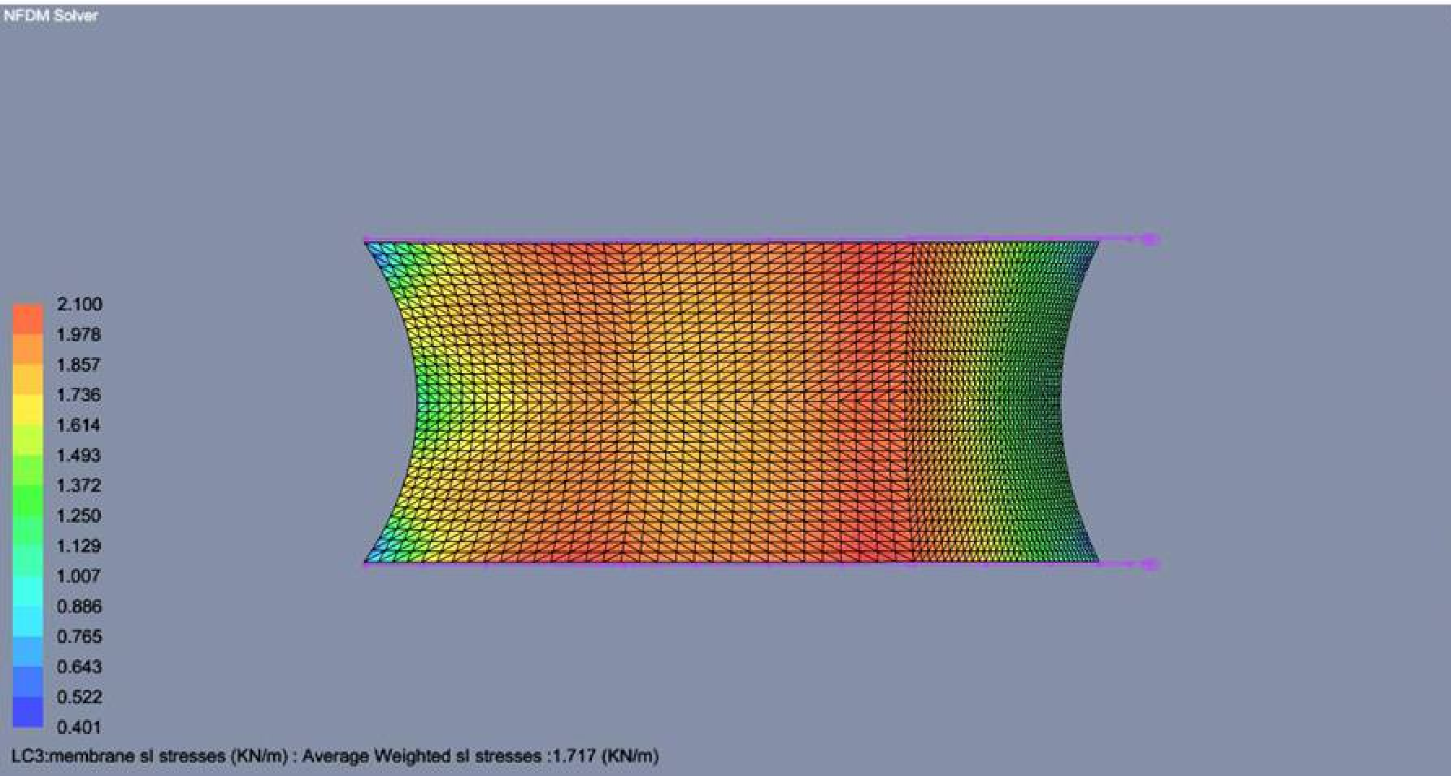


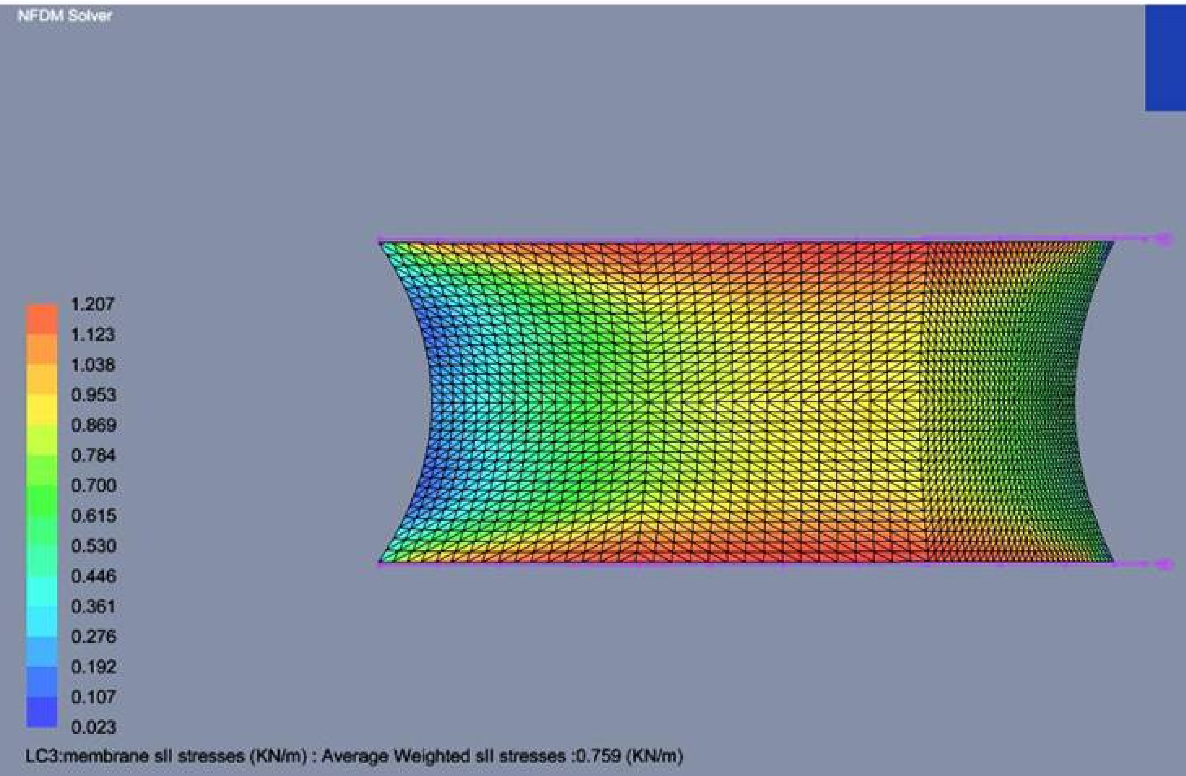
LC2:Axial KN

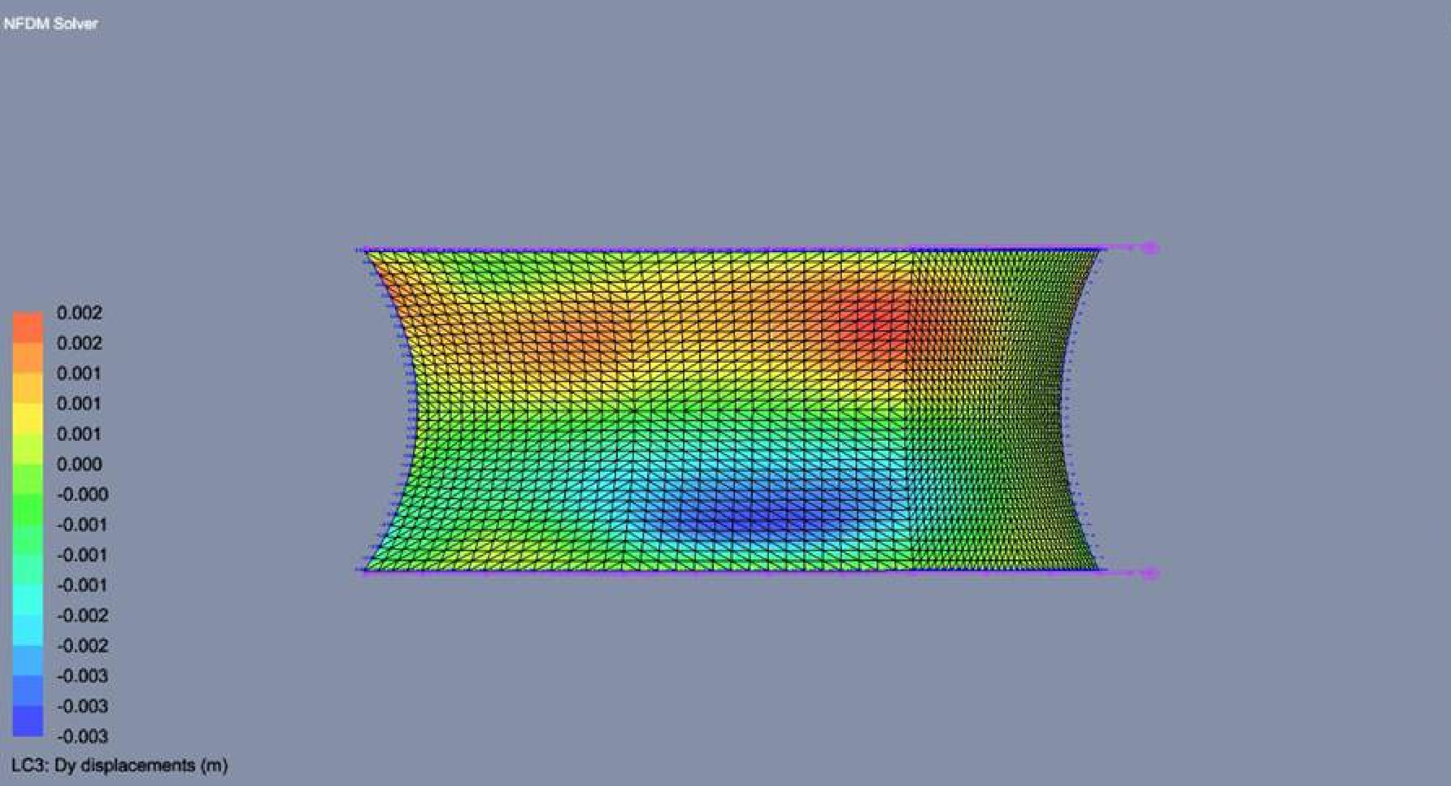
SLS-LC2

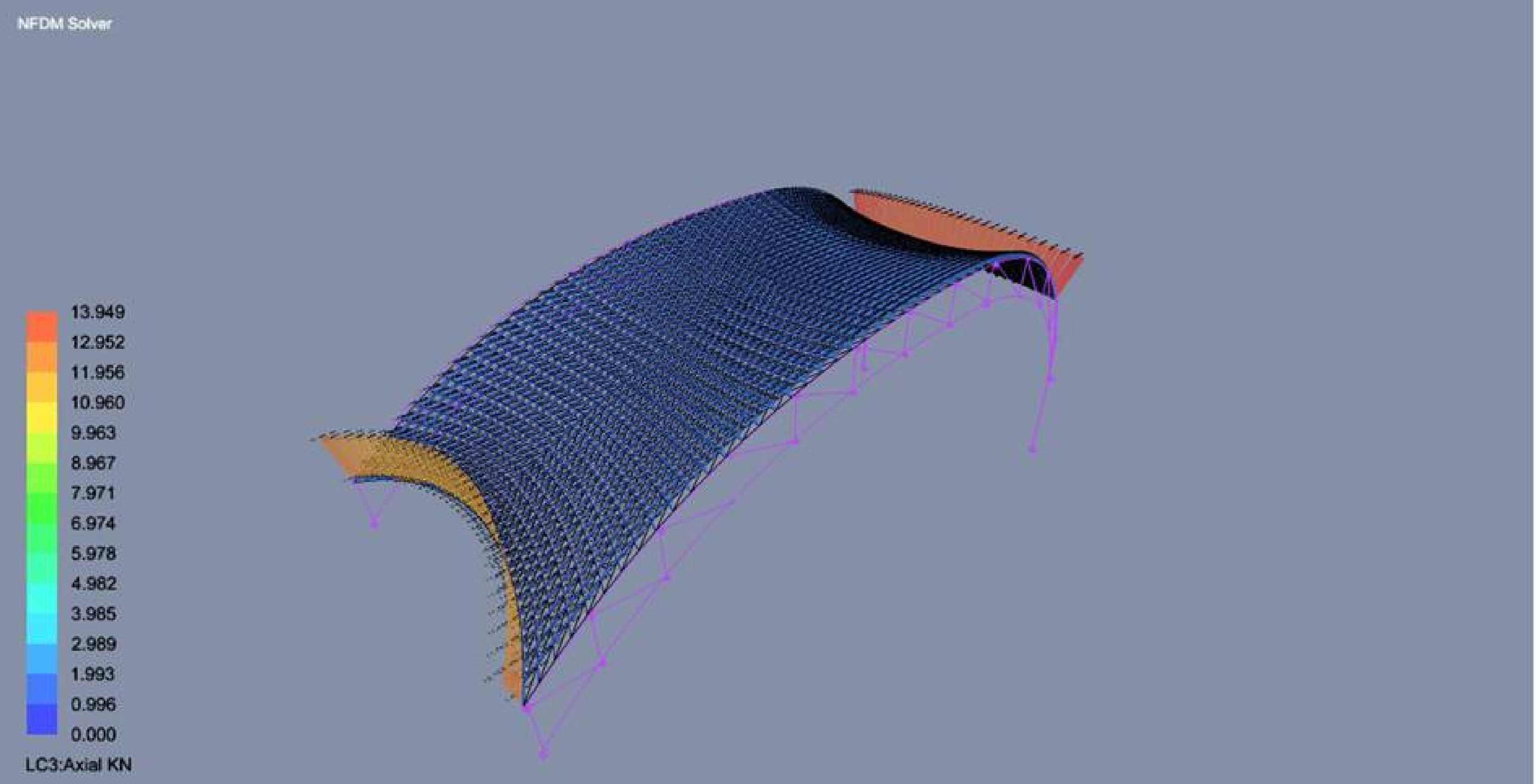
1.0 SELFWEIGHT + 1.0 PRESTRESS + 1.0 WIND

S1-MAX.: 2.627 Kn/m^2
S2-MAX.: 1.759 Kn/m^2
DEFORMATION MAX.: 0.005 m
AXIAL FORCE MAX.: 30.844 Kn





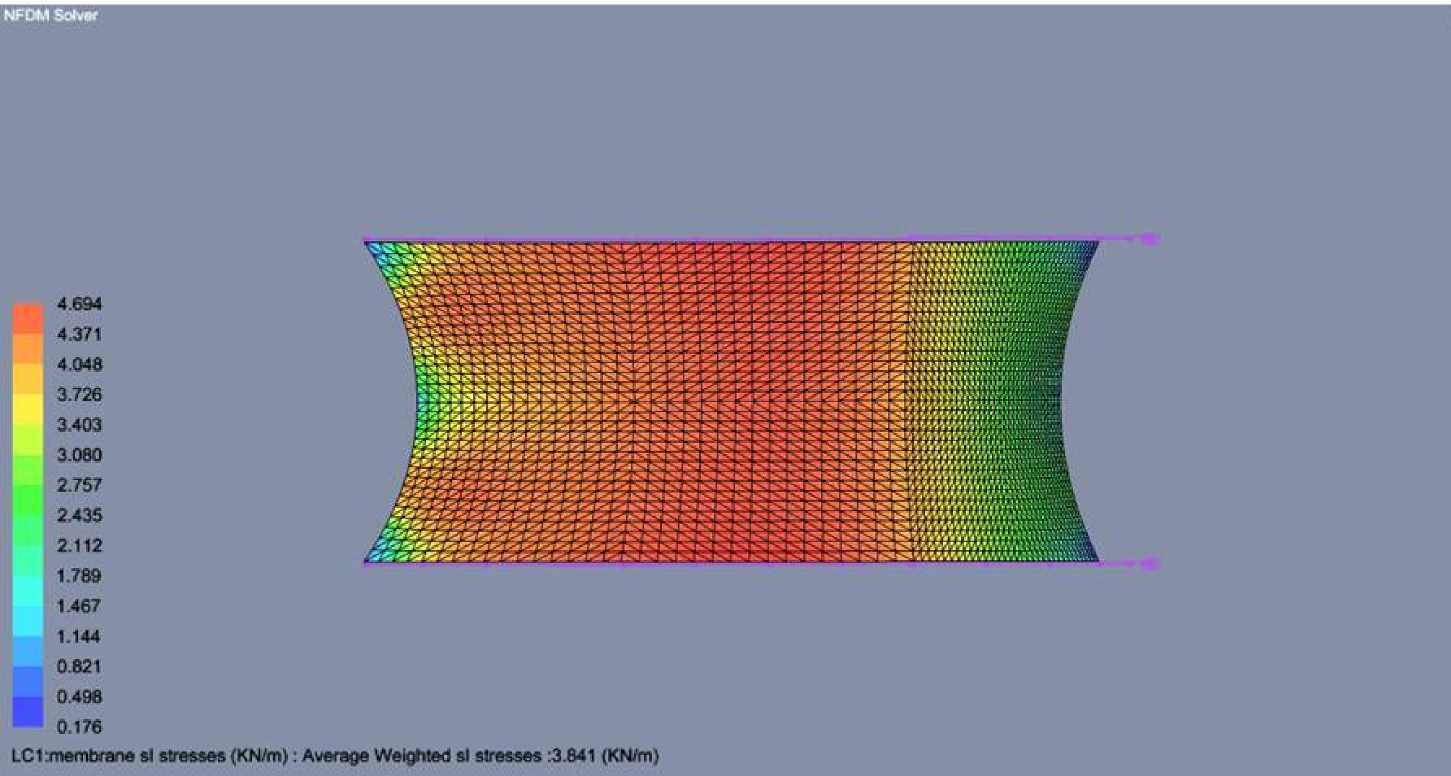


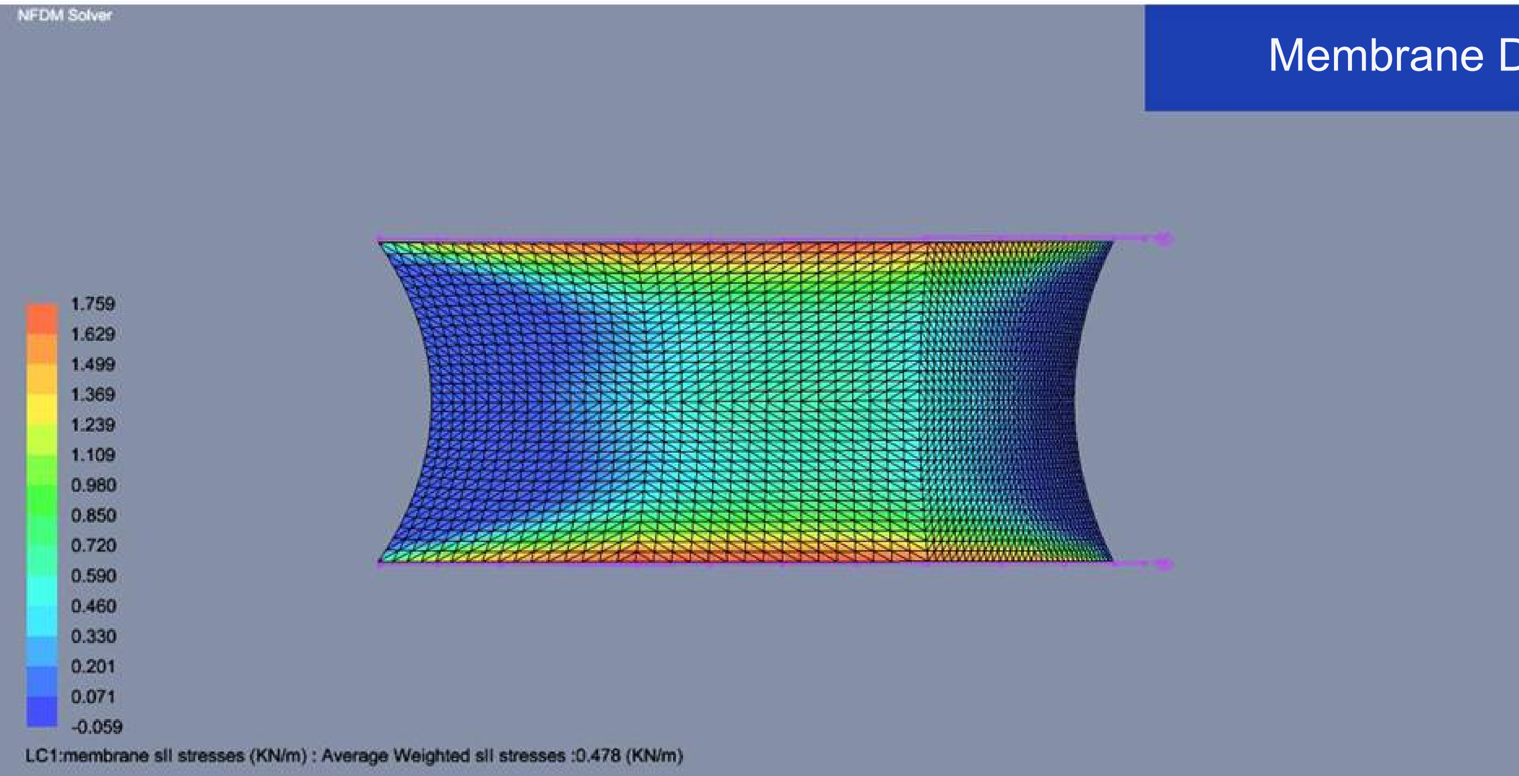


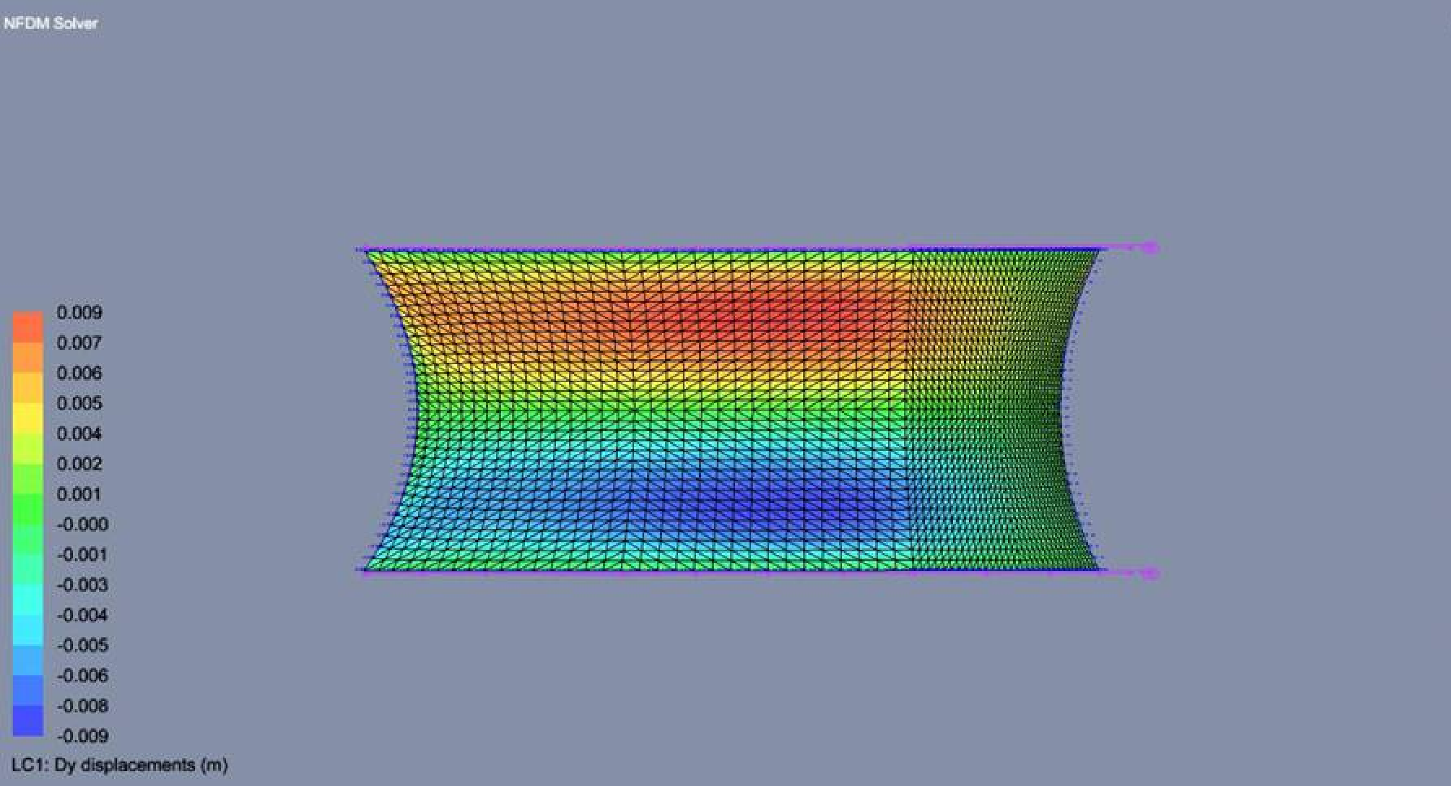
SLS-LC3

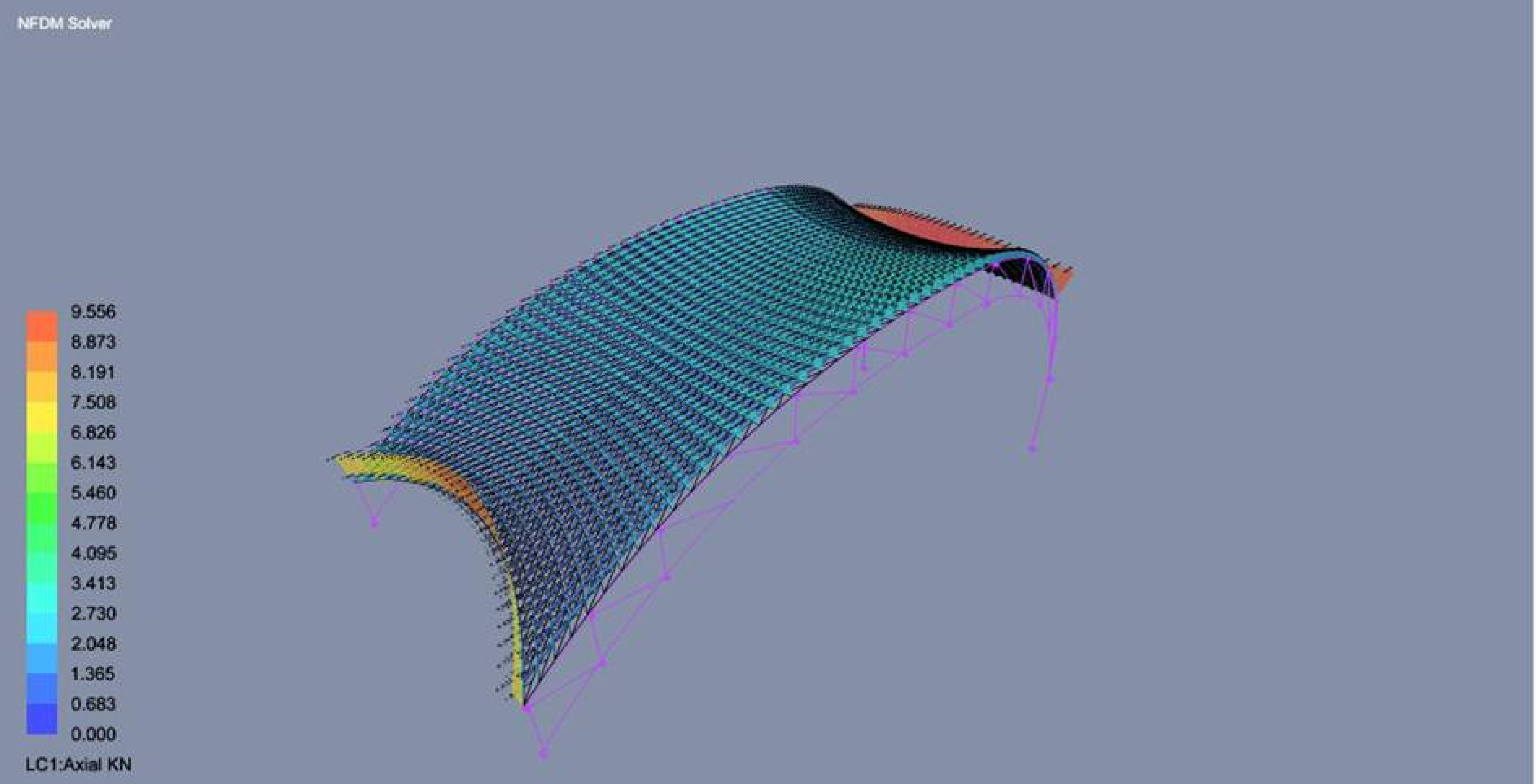
1.0 SELFWEIGHT + 1.0 PRESTRESS + 1.0 WIND + 1.0 SNOW

S1-MAX.: 2.100 Kn/m²
S2-MAX.: 1.207 Kn/m²
DEFORMATION MAX.: 0.002 m
AXIAL FORCE MAX.: 13.949 Kn





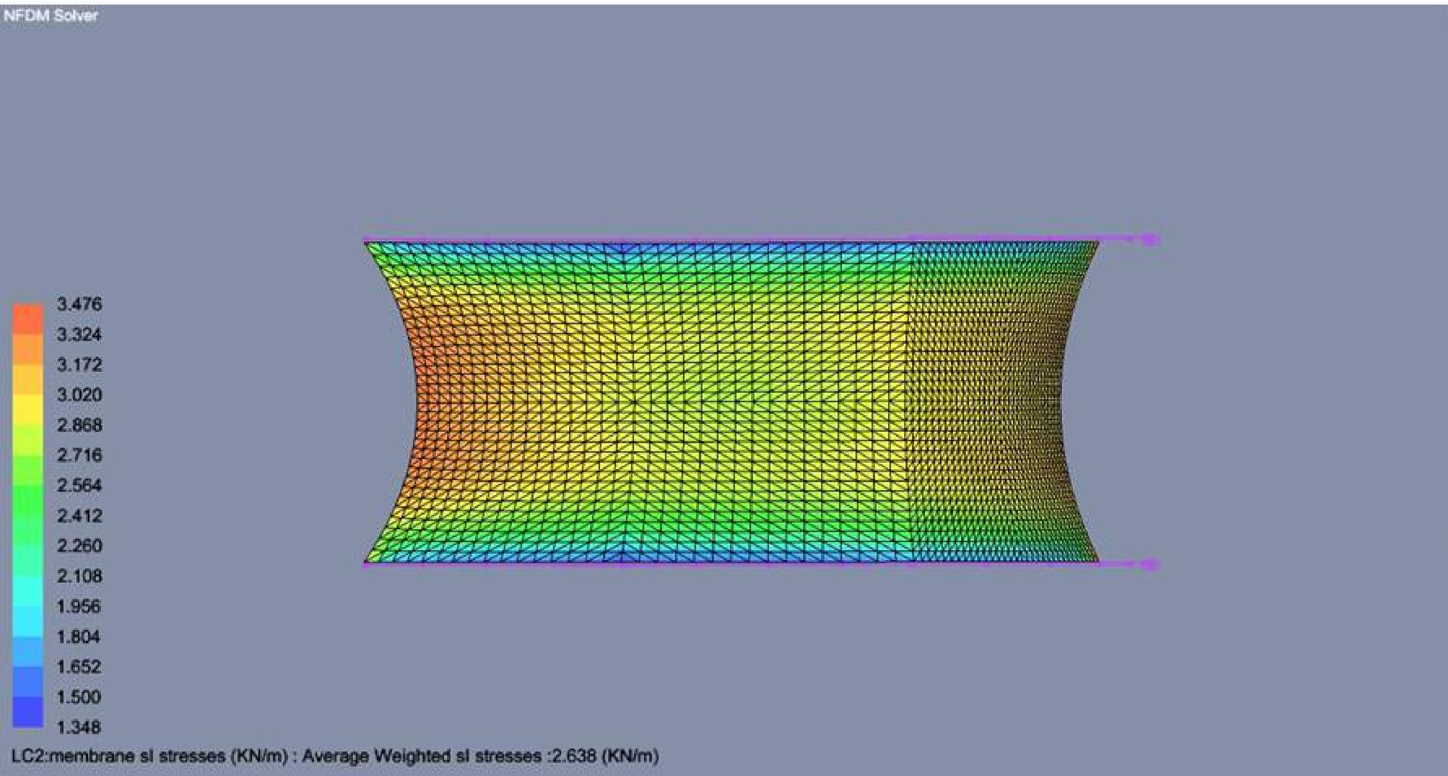


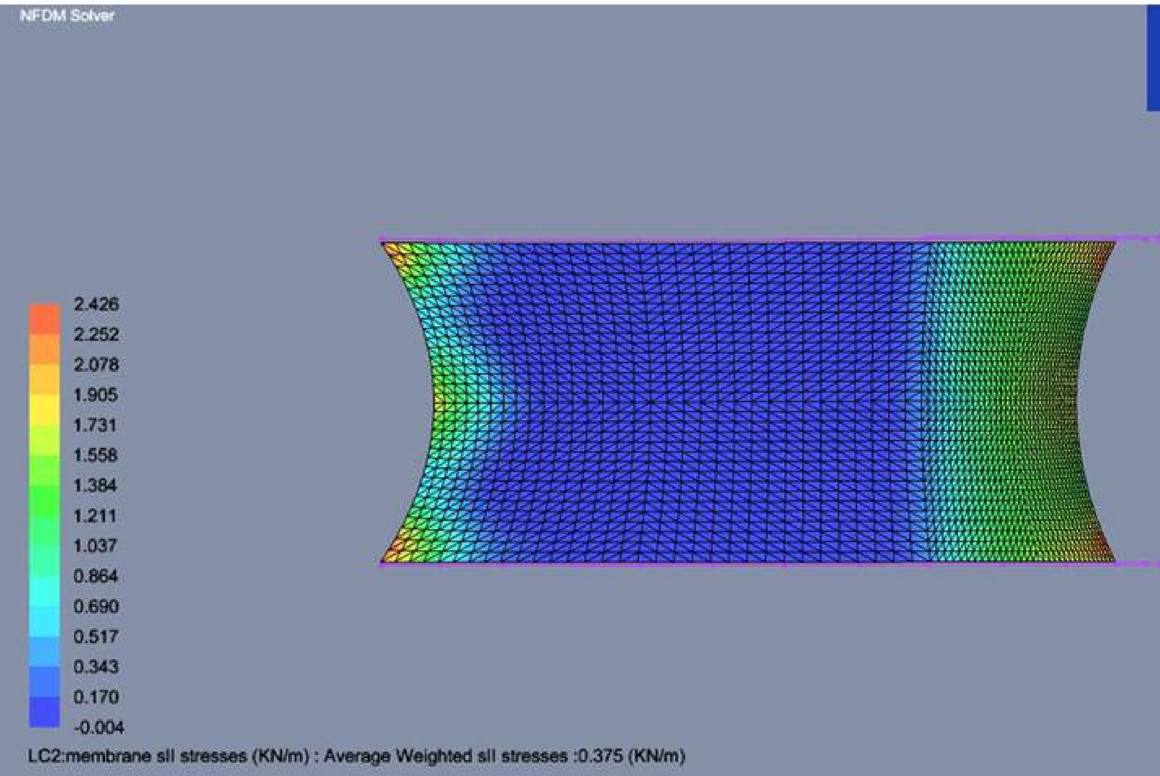


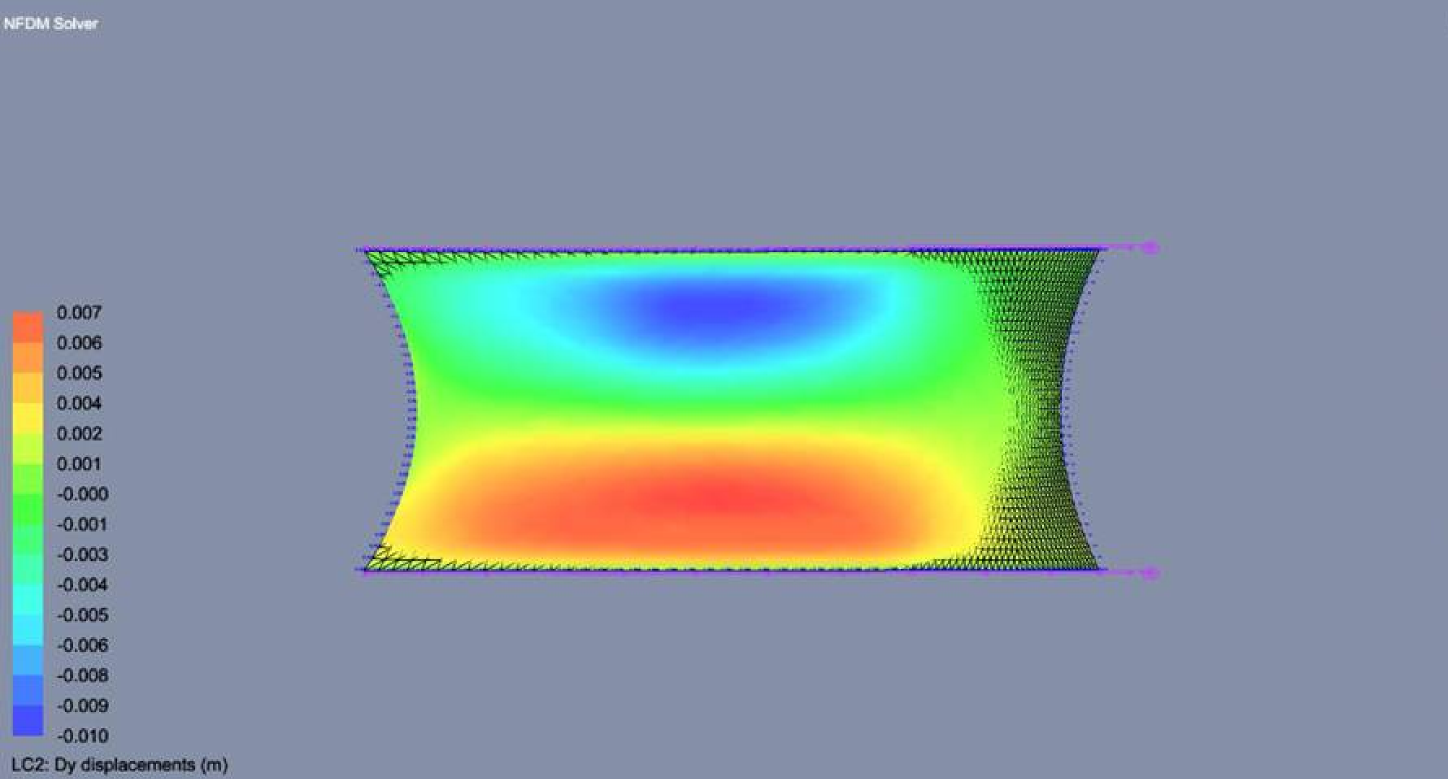
ULS-LC1

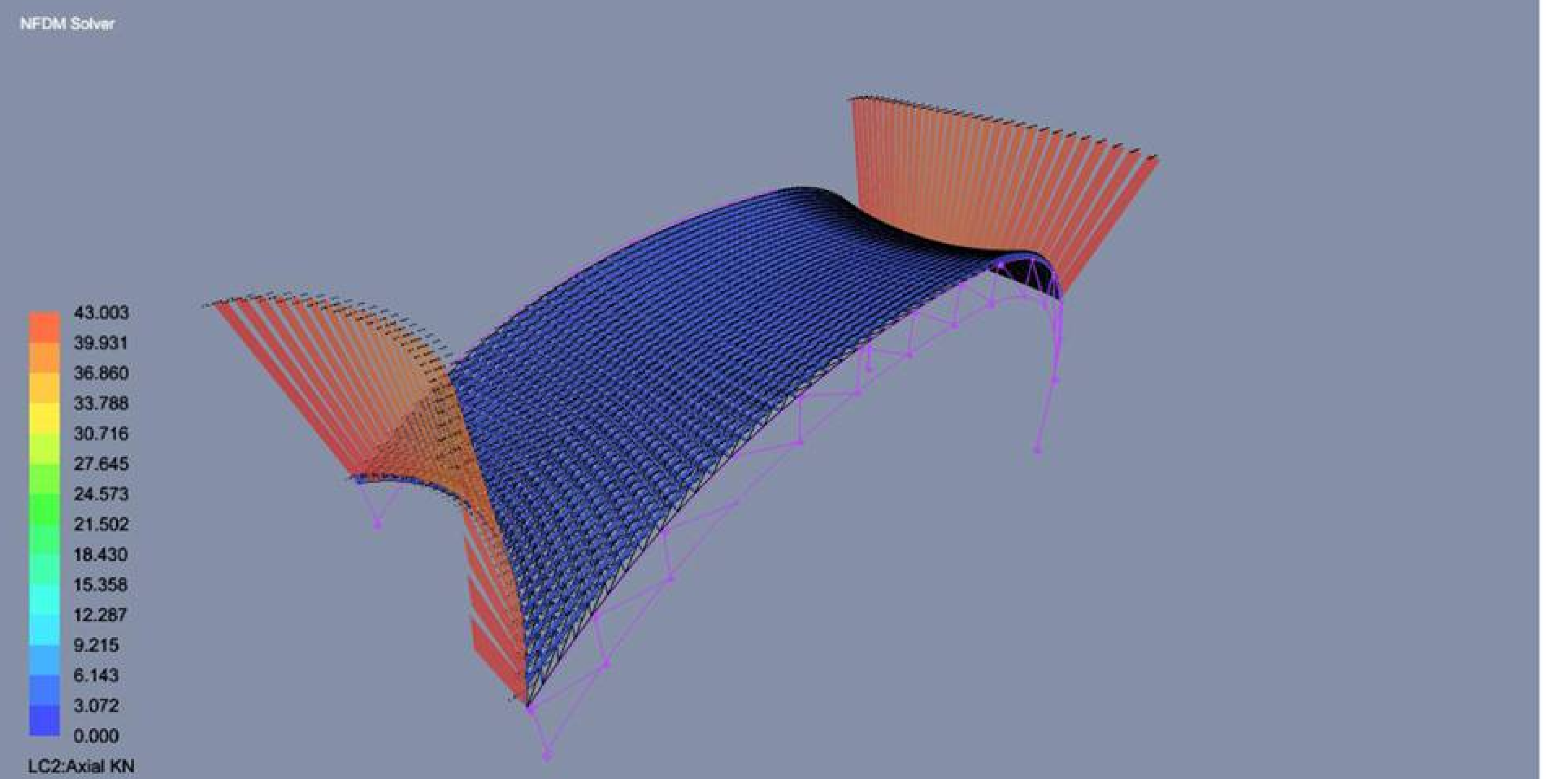
1.35 SELFWEIGHT + 1.35 PRESTRESS + 1.5 SNOW

S1-MAX.: 4.694 Kn/m^2
S2-MAX.: 1.759 Kn/m^2
DEFORMATION MAX.: 0.009 m
AXIAL FORCE MAX.: 9.556 Kn









ULS-LC2

1.35 SELFWEIGHT + 1.35 PRESTRESS + 1.5 WIND

S1-MAX.: 3.476 Kn/m²
S2-MAX.: 2.426 Kn/m²
DEFORMATION MAX.: 0.007 m
AXIAL FORCE MAX.: 43.003 Kn

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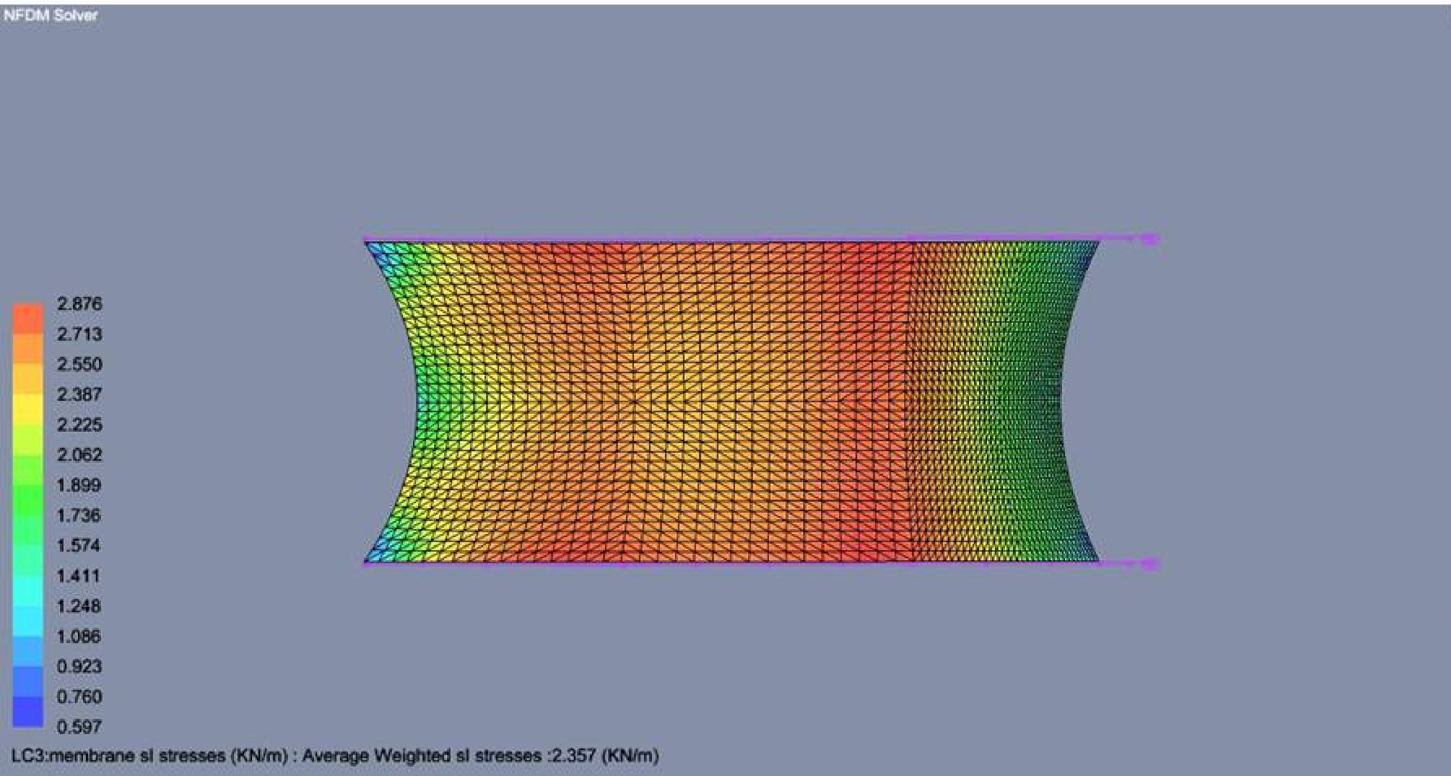
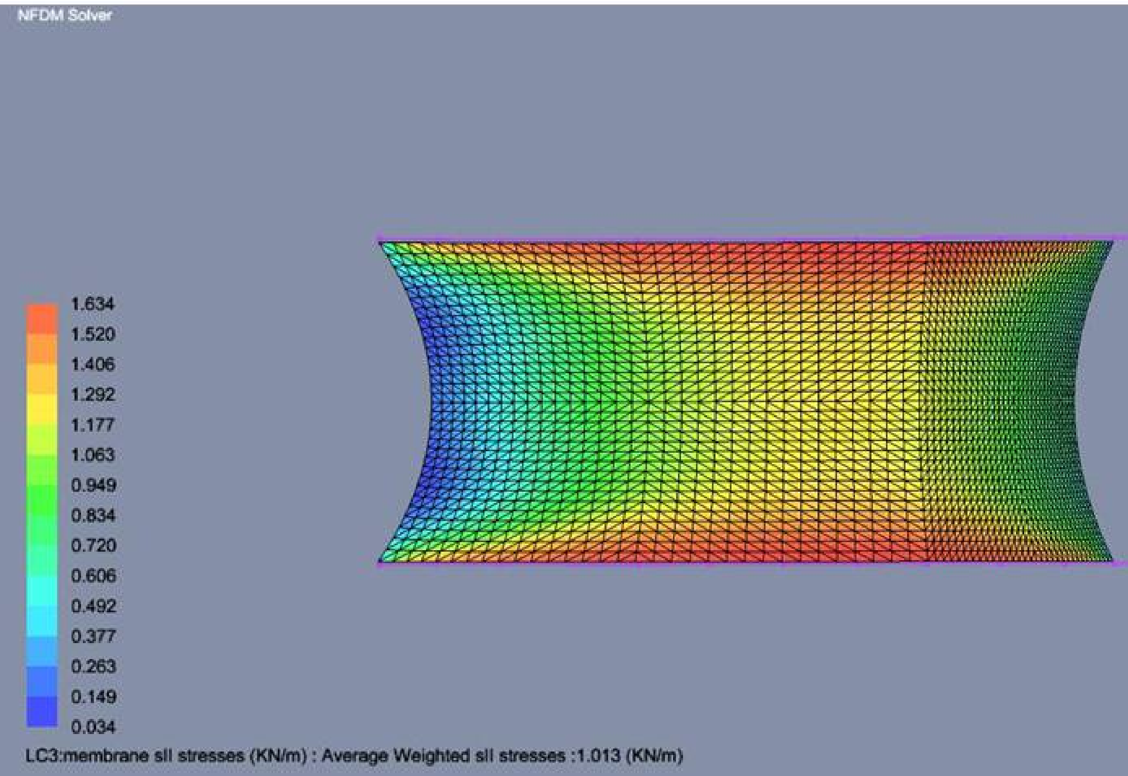
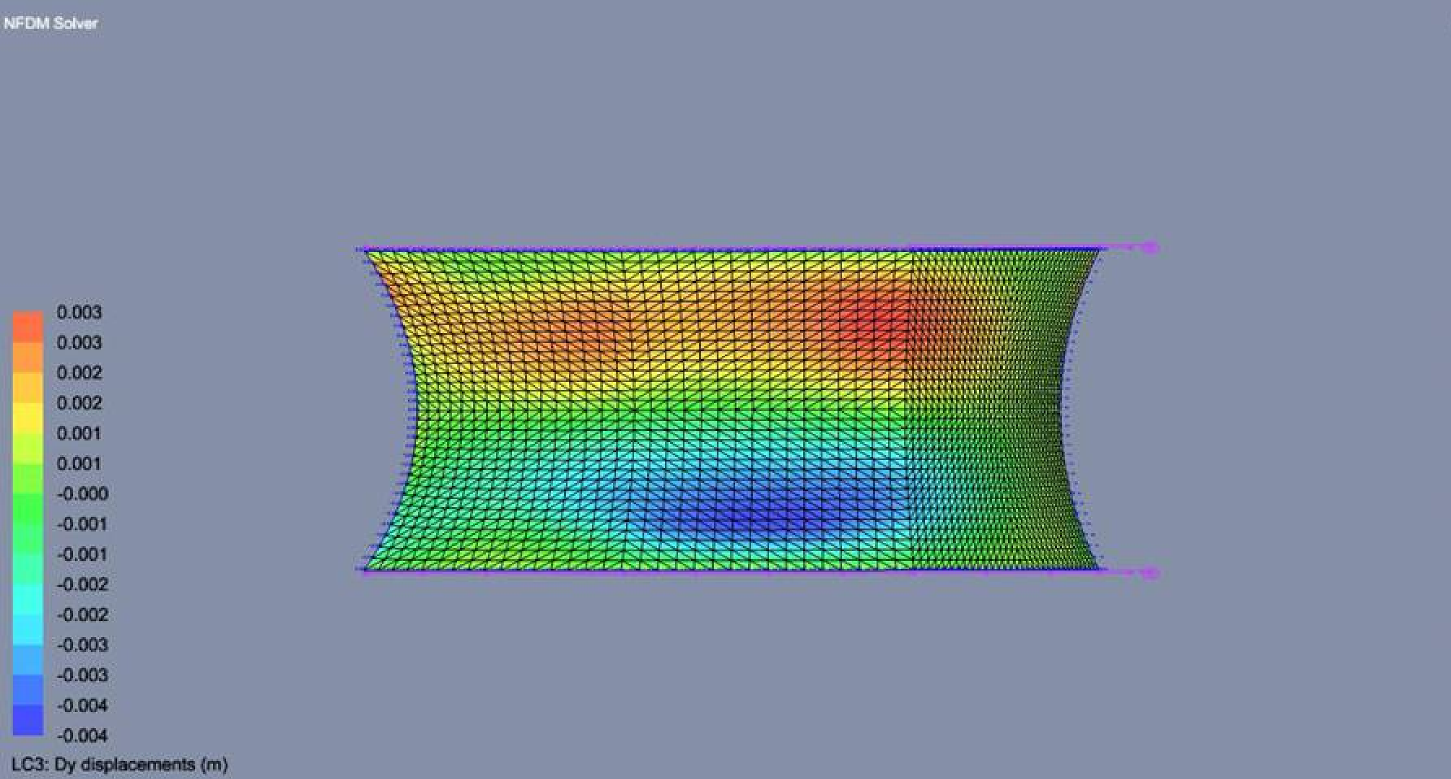
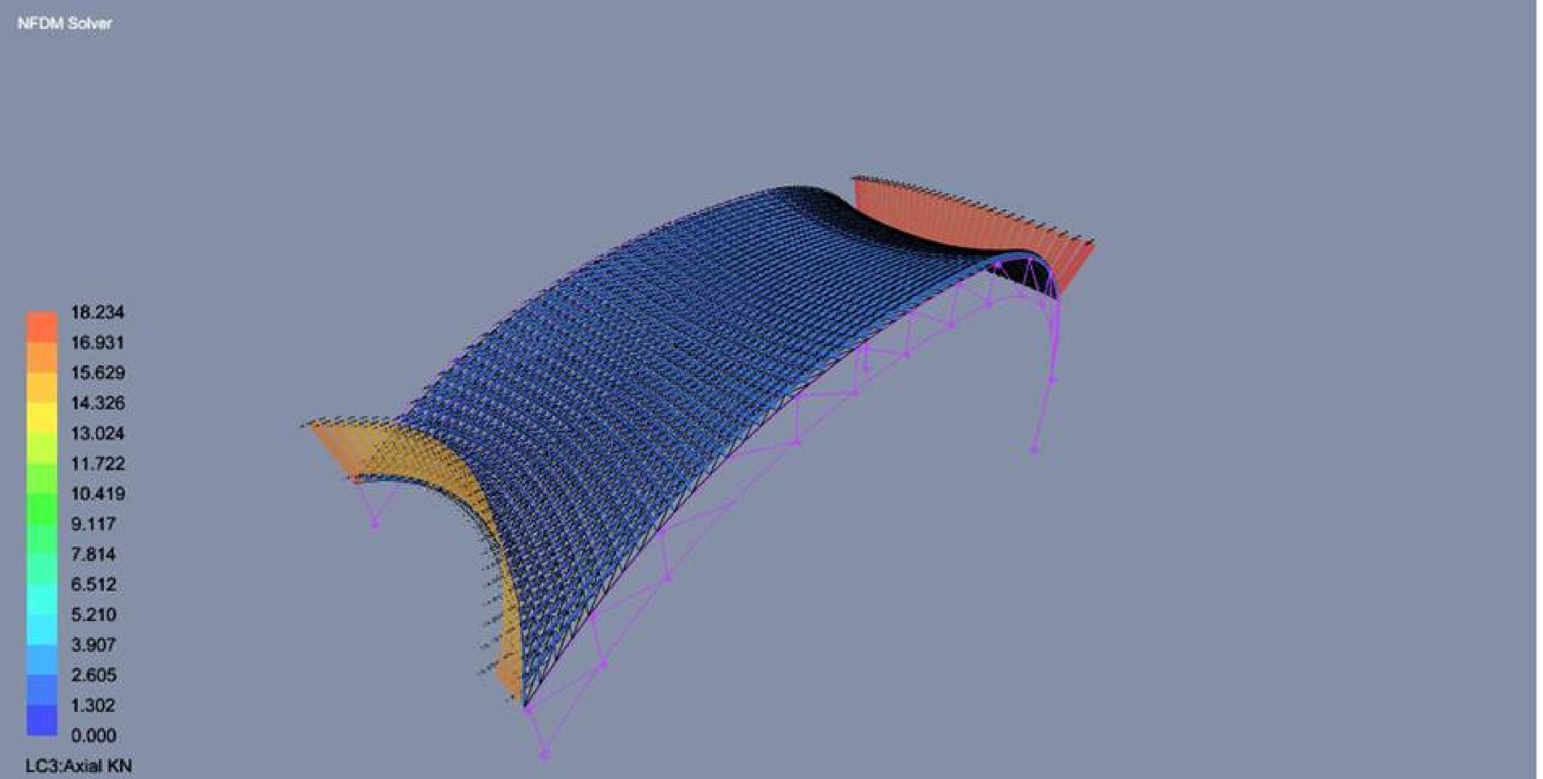




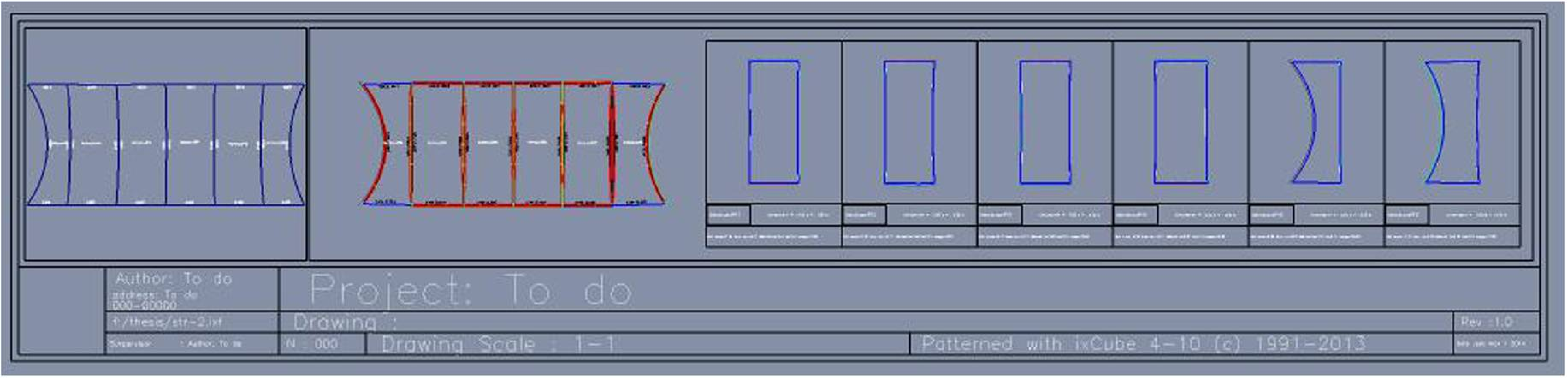




ULS-LC3

1.35 SELFWEIGHT + 1.35 PRESTRESS + 1.5 WIND + 1.5 SNOW

S1-MAX.: 2.876 Kn/m²
S2-MAX.: 1.634 Kn/m²
DEFORMATION MAX.: 0.003 m
AXIAL FORCE MAX.: 18.234 Kn



PATTERNING

Fabric

max SI: 4.694 Kn/m²
max SII: 2.426 Kn/m²
VALMEX product. FR700 Type I
Tensile Strength: 60/60 kn/m²

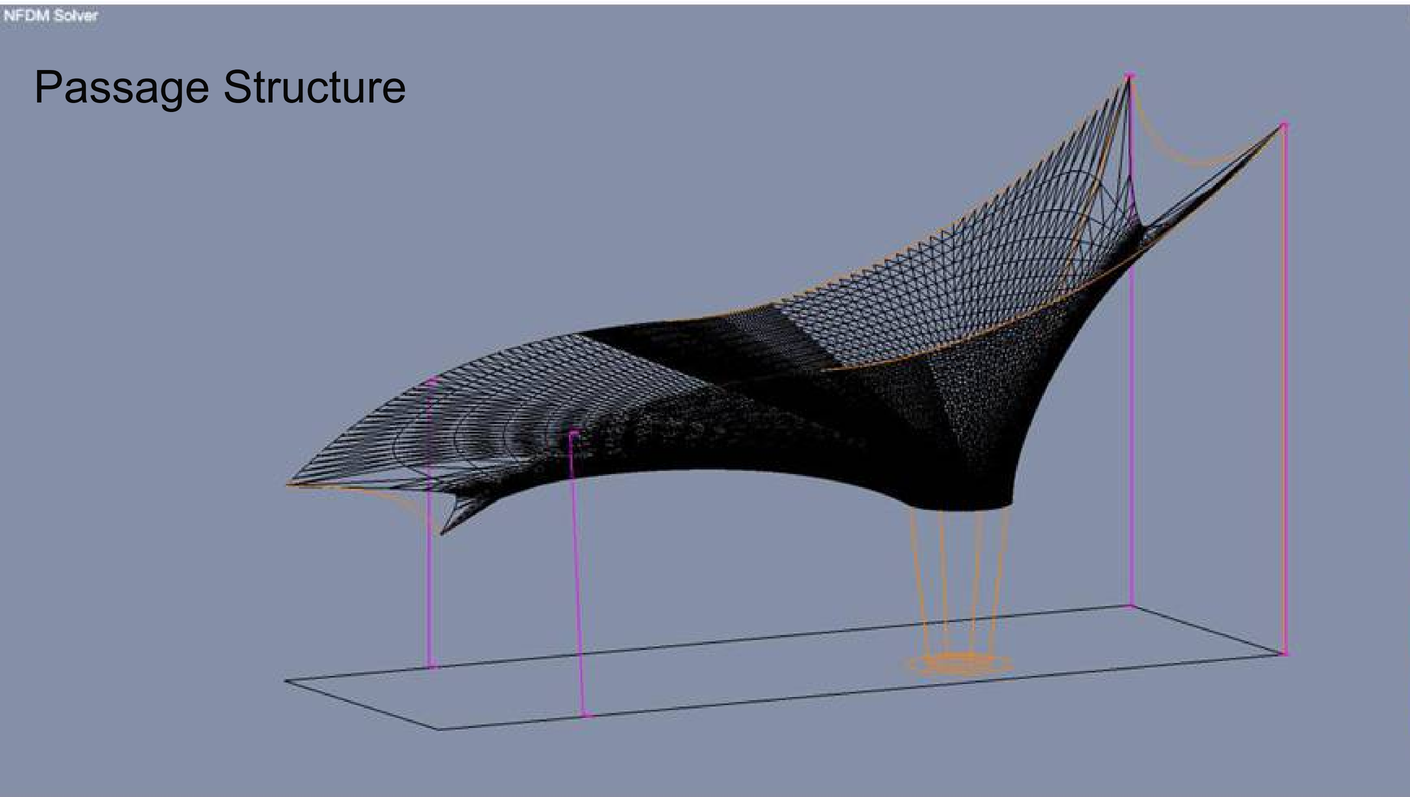
Stress-Verifications ($S_d \leq R_d$)

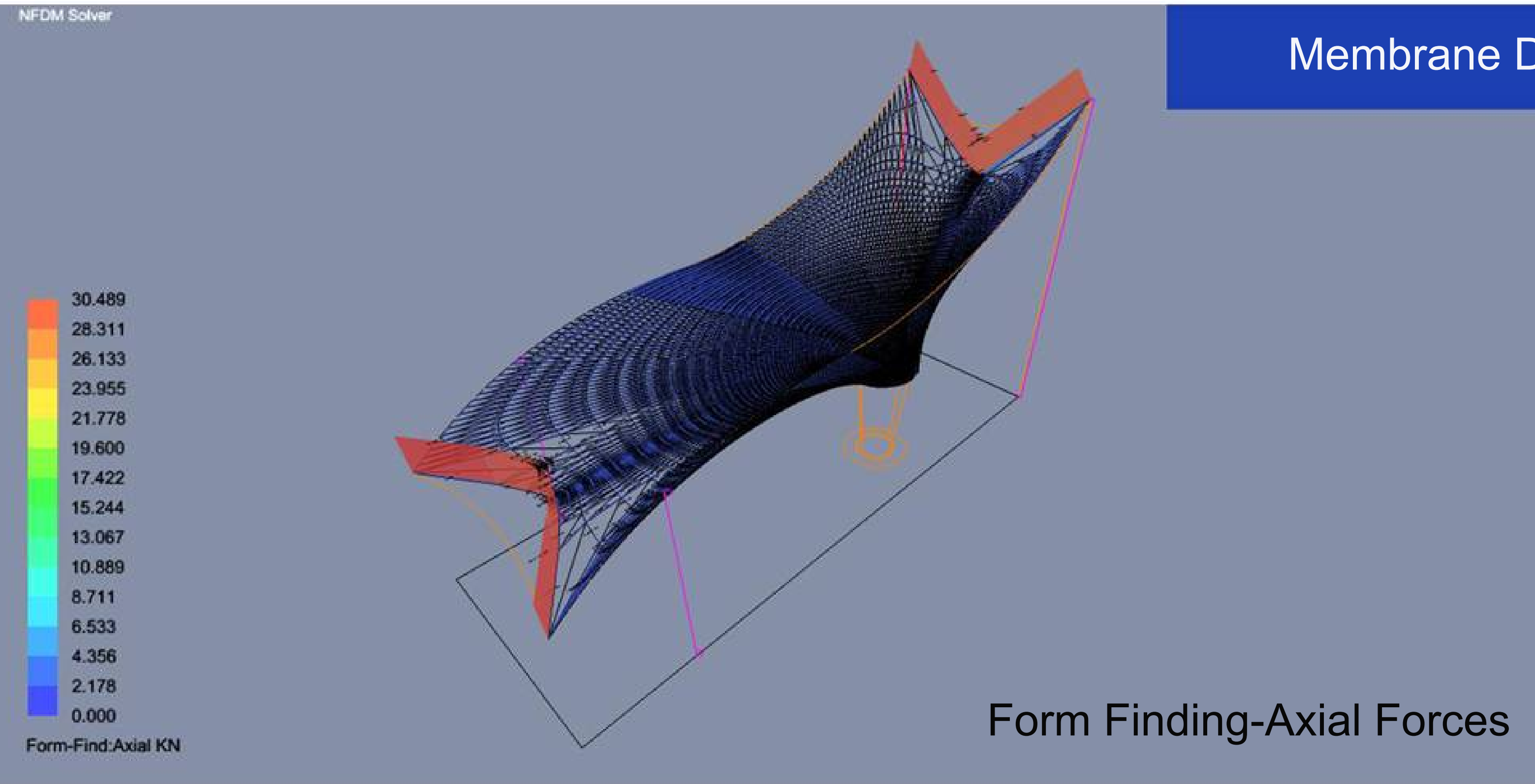
$F_{u.k}/Y_{m.uls}.A_{res}$
$Y_{m.uls} = 1.4$
A_{res} for permanent load= $A_0 \times A_1 \times A_2 \times A_3 \times A_4$ = 1.2×1.7×1.2×1.2×1.0=2.94
A_{res} for Snow load= $A_0 \times A_2$ = 1.2×1.2=1.44
Ares for Wind load= $A_0 \times A_1 \times A_2$ = 1.2×1.7×1.2=2.45
WARP R_d for permanent load= 60/(1.5×1.4×2.94)=9.718
WEFT R_d for permanent load= 60/(1.5×1.4×2.94)=9.718
WARP R_d for Snow load= 60/(1.6×1.4×1.44)=18.604
WEFT R_d for Snow load= 60/(1.6×1.4×1.44)=18.604
WARP R_d for Wind load= 60/(1.5×1.4×2.45)=11.661
WEFT R_d for Wind load= 60/(1.5×1.4×2.45)=11.661

Fabrication

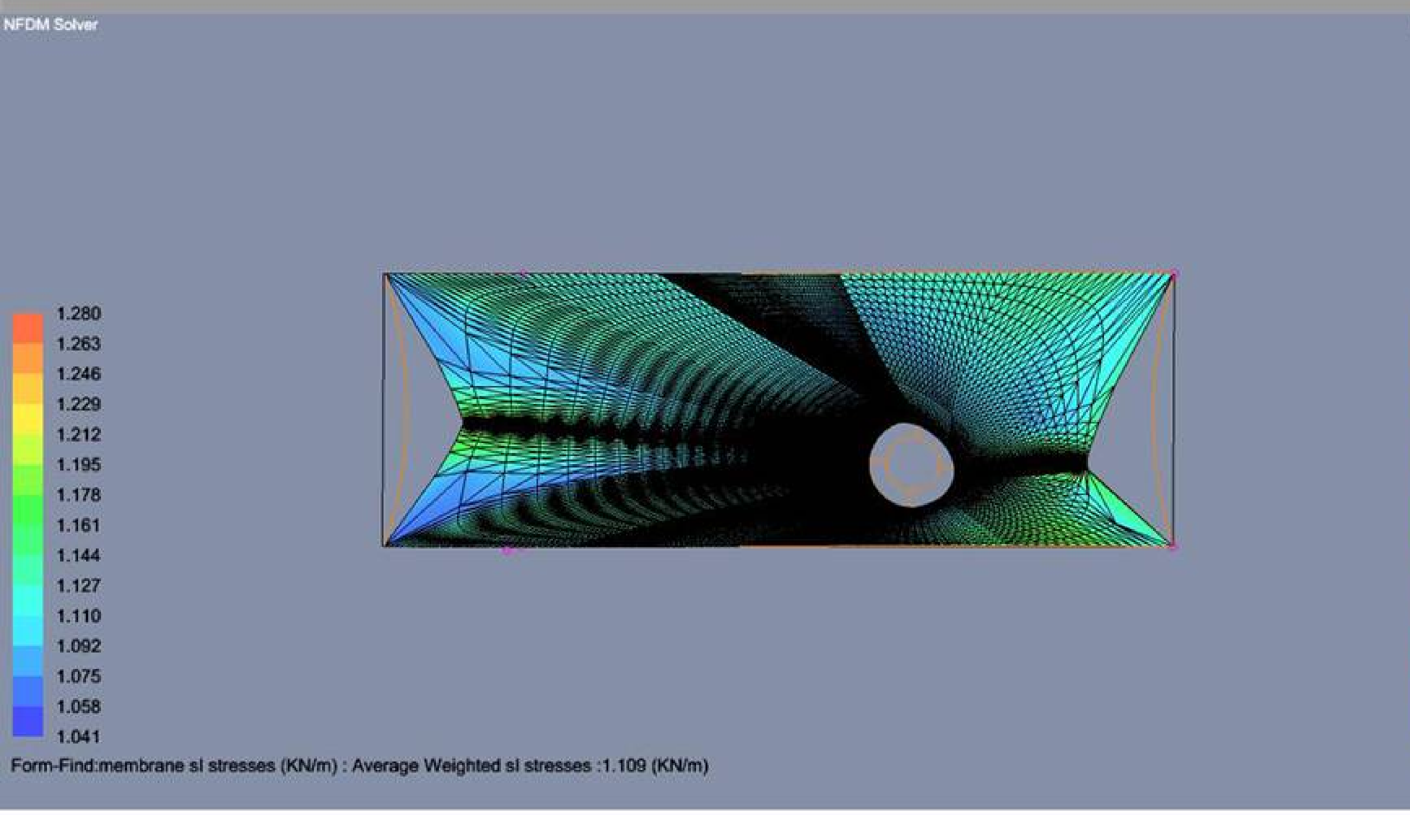
Compensation: 0.5/0.5
Overlapped welding: 50mm

Permanent load: S_d max.:1.537 < R_d: 9.718
Snow load: S_d max.: 4.694< R_d: 18.604
Wind load: S_d max.: 3.476< R_d: 11.661

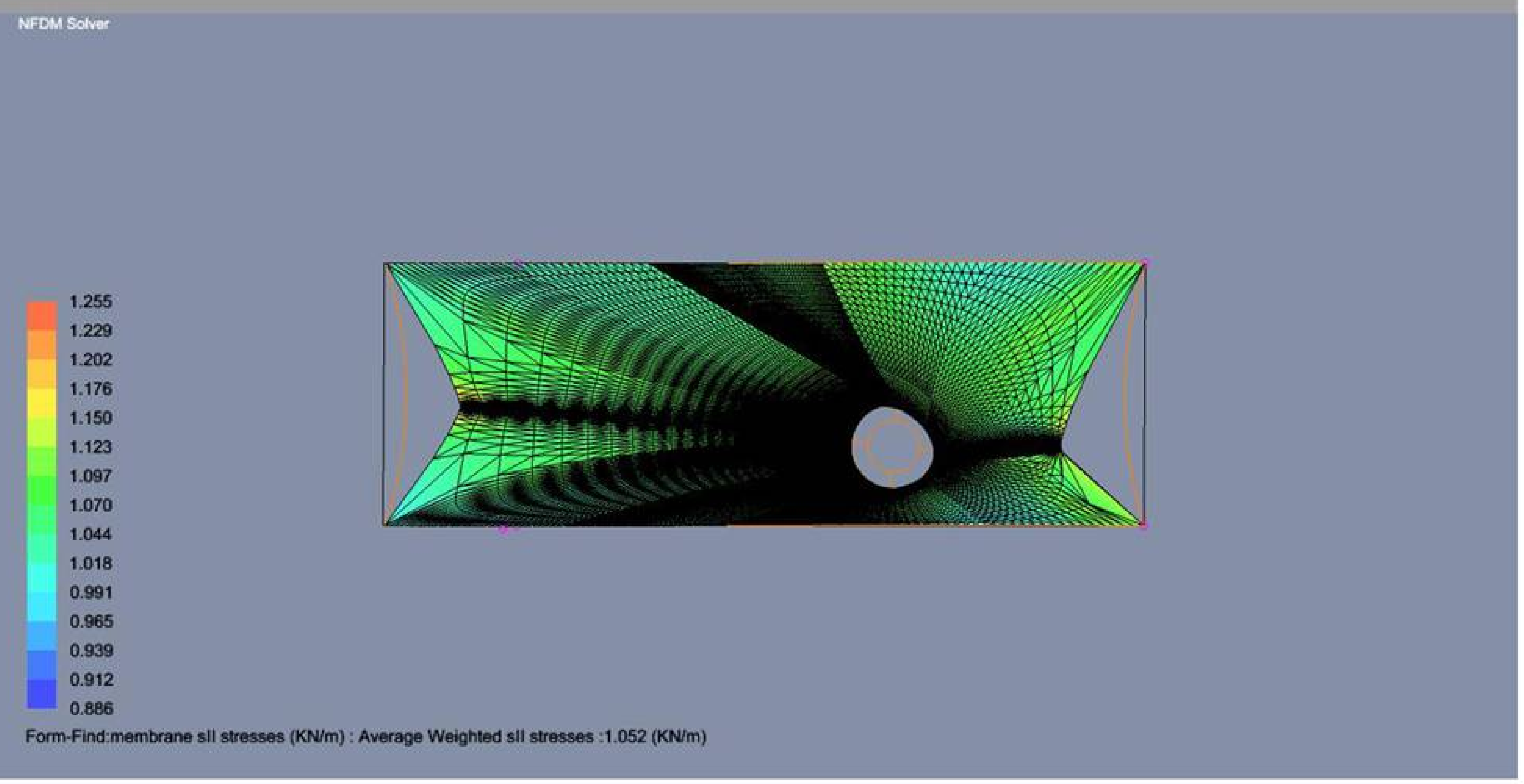




Pretention: 30
Cables: 16mm
Beams: CHS-114.3x5.4
Membrane: Preconstraint 702- Ferrari
Warp/ weft Stress: 1/1



Form Finding-S1



Form Finding-S2

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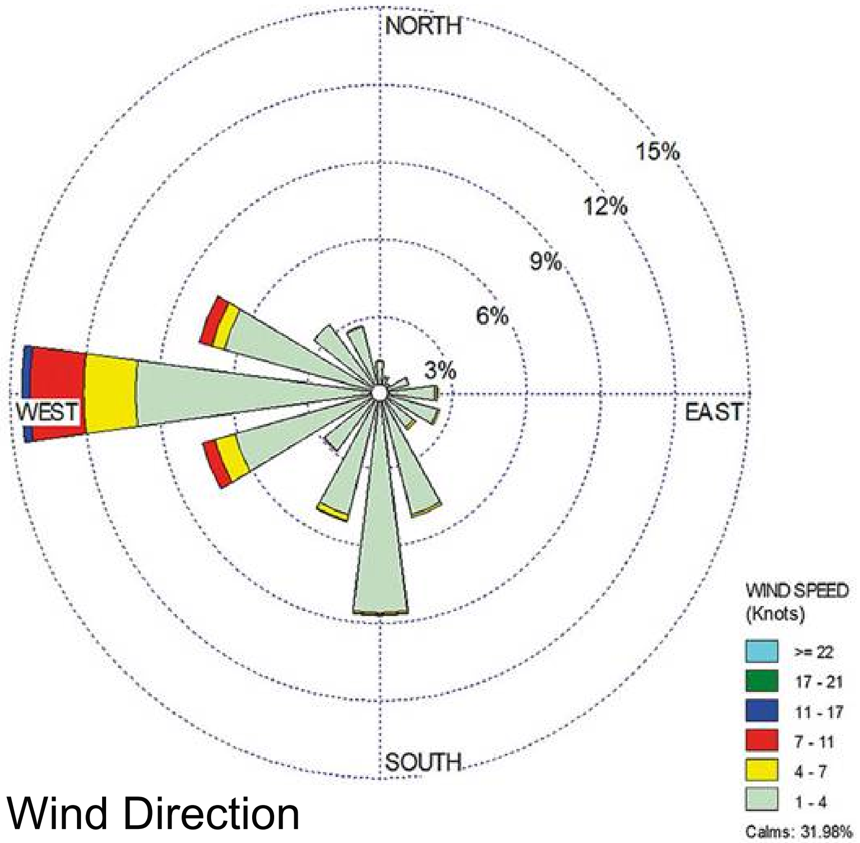
Entrance Structure



Wind Direction

External C_p Values for Conical Structures		Zones A	B	C	D
	Angle of slope of membrane to horizontal /deg.	A	B	C	D
Open sided structure	40	+0.4/-0.2	-0.15	-1.0	-0.6
Closed structure	40	+0.75/-0.6	-0.41	-1.0	-0.7

Fig. A1.1 Wind Tunnel Model

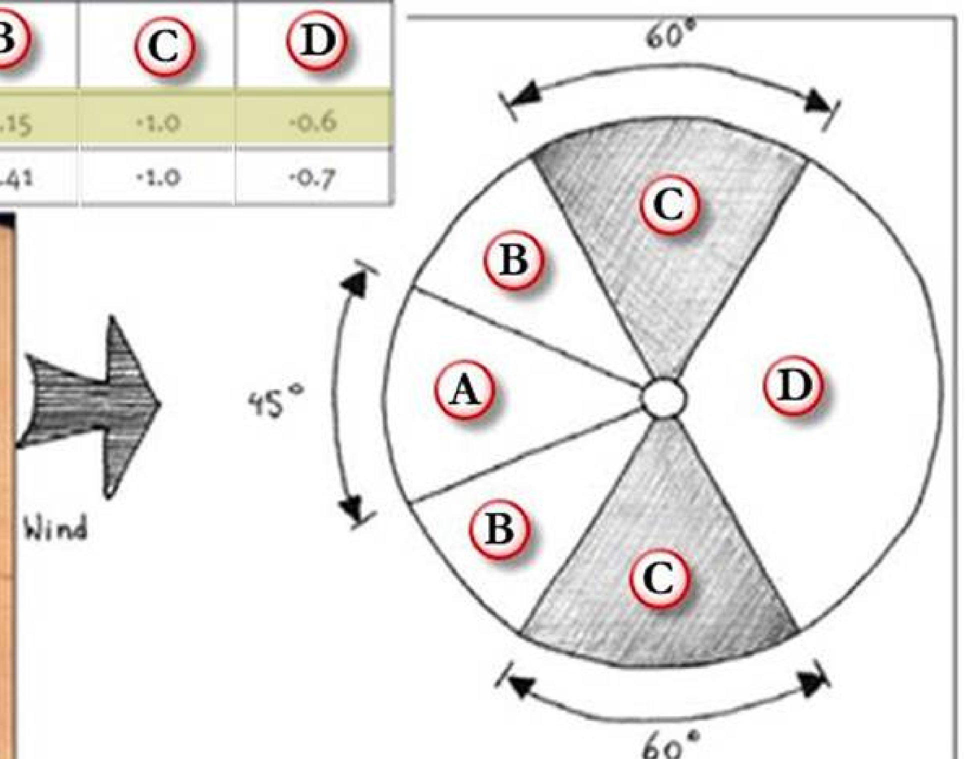


Fig. A1.2 Conical C Zones Definition

WIND CALCULATION

Basic wind speed $V_{b,0}$= 27.60 m/s
Directional factor C_{dir}= 1.00
Seasonal factor C_{season}= 1.00
V_b= $V_{b,0}$ xC_{dir}xC_{season}
V_b= 27.60 m/s
The orography factor $C_o(z)$ = 1.00
The roughness length Z_o= 1.0
(terrain category IV, Table 4.1)
Minimum height of structure Z_{min}= 3.50
Maximum height of the structure Z_{max}=11.00
Train Factor Kr = 0.19 $(Z_o/ Z_{o,II})^{0.007}$= $0.19(1.0/0.5)^{0.007}$=0.2
The Train roughness factor $C_r(z)$=Kr . ln(z/z_0)= 0.2xln(7/1)=0.48
Density of air [kg/m³] ρ= 1.25 kg/m³
The peak velocity pressure $q_p(z) = c_e(z)xq_b$
$c_e(z)$=1.2 (figure 4.2-Ilustration of exposure factore $C_e(z)$)
Mean wind velocity $V_m(z) =C_r(z)xC_o(z)xV_b$=0.48x1.0x27.60=13.25
Turbulence Intensity $I_v(z) =k_I/ C_o(z)xln(z/z_0)$= 1.0/ 1.0x2.40=0.42
The peak velocity pressure $q_p(z) = [1+7.I_v(z)]x1/2x\rho xV_m^2(z)$=0.432 kn/m²
Wind action $W_e=q_p(z)xc_{pe}$

Zone A: +0.17
Zone A: -0.09
Zone B: -0.06
Zone C: -0.43
Zone D: -0.26

SNOW LOAD

snow load shape coefficient μ = 0.8
(Angle of pitch of roof <30)
exposure coefficient C_e = 1
Thermal coefficient C_t = 1
Characteristic value of snow load
Sk = 0.85 kN/m2 on the ground
Snow loads on roofs S = 0.68 kN/m2

LOAD COMBINATION

ULS
1.35Selfweight +1.35 Prestress +1.5 Wind
1.35Selfweight +1.35 Prestress +1.5 Snow
1.35Selfweight +1.35 Prestress +1.5 Wind +1.5 Snow

SLS
1.0Selfweight +1.0 Prestress+1.0Snow
1.0Selfweight +1.0Prestress+1.0 Wind
1.0Selfweight +1.0Prestree+1.0Wind +1.0 Snow

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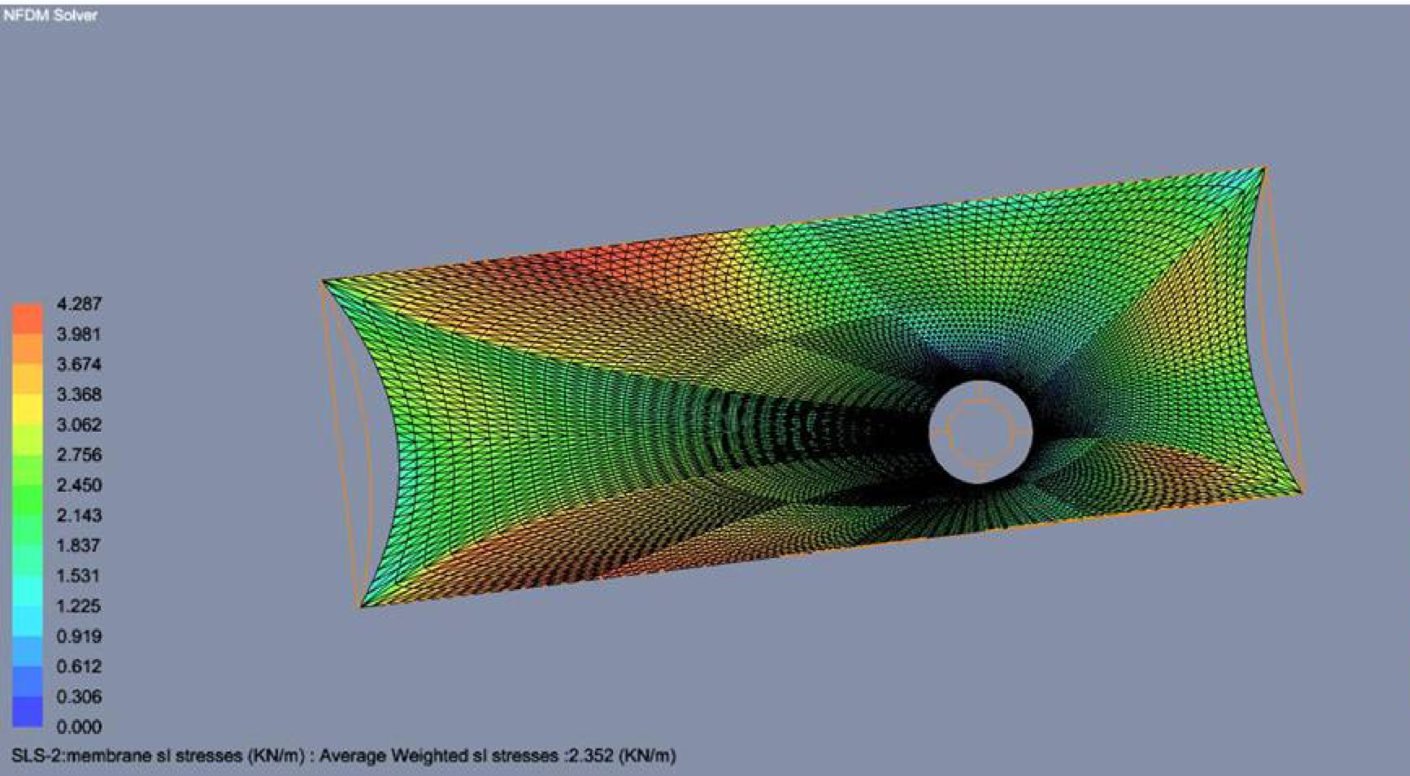
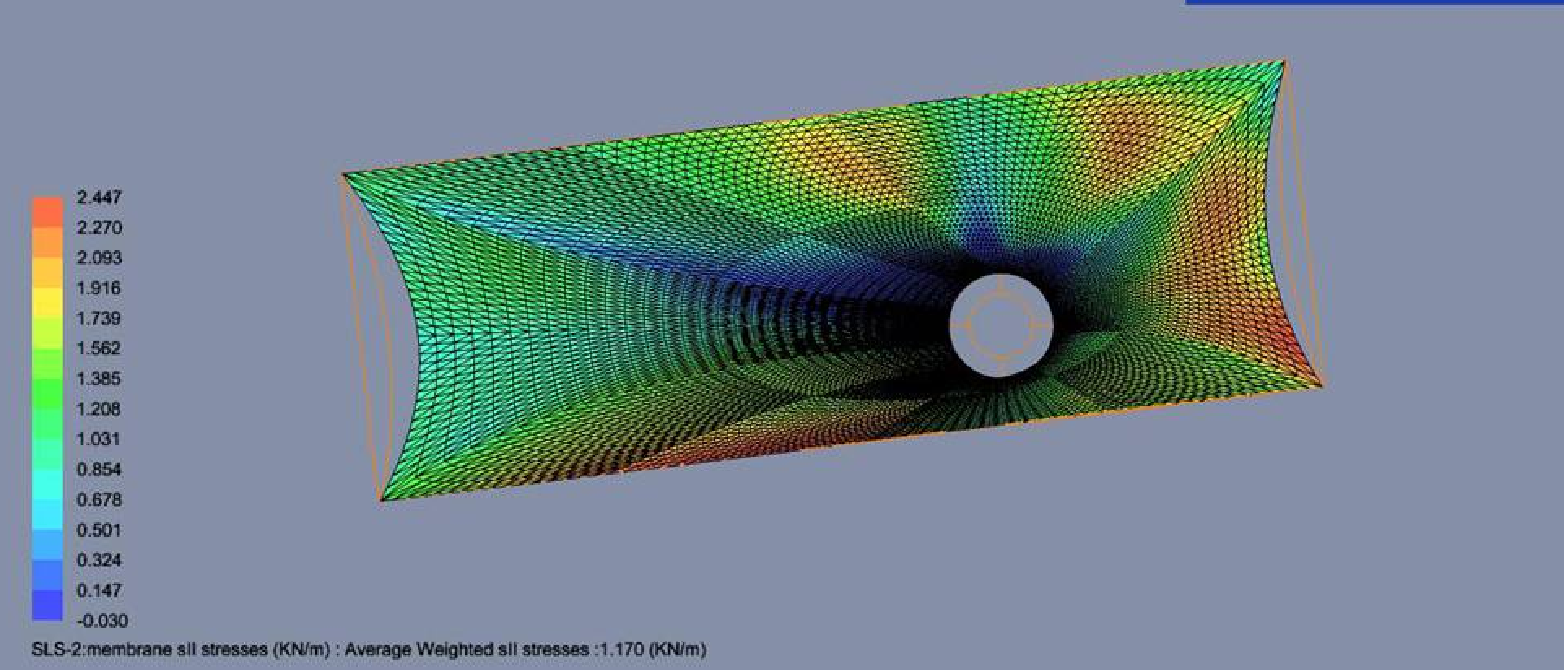
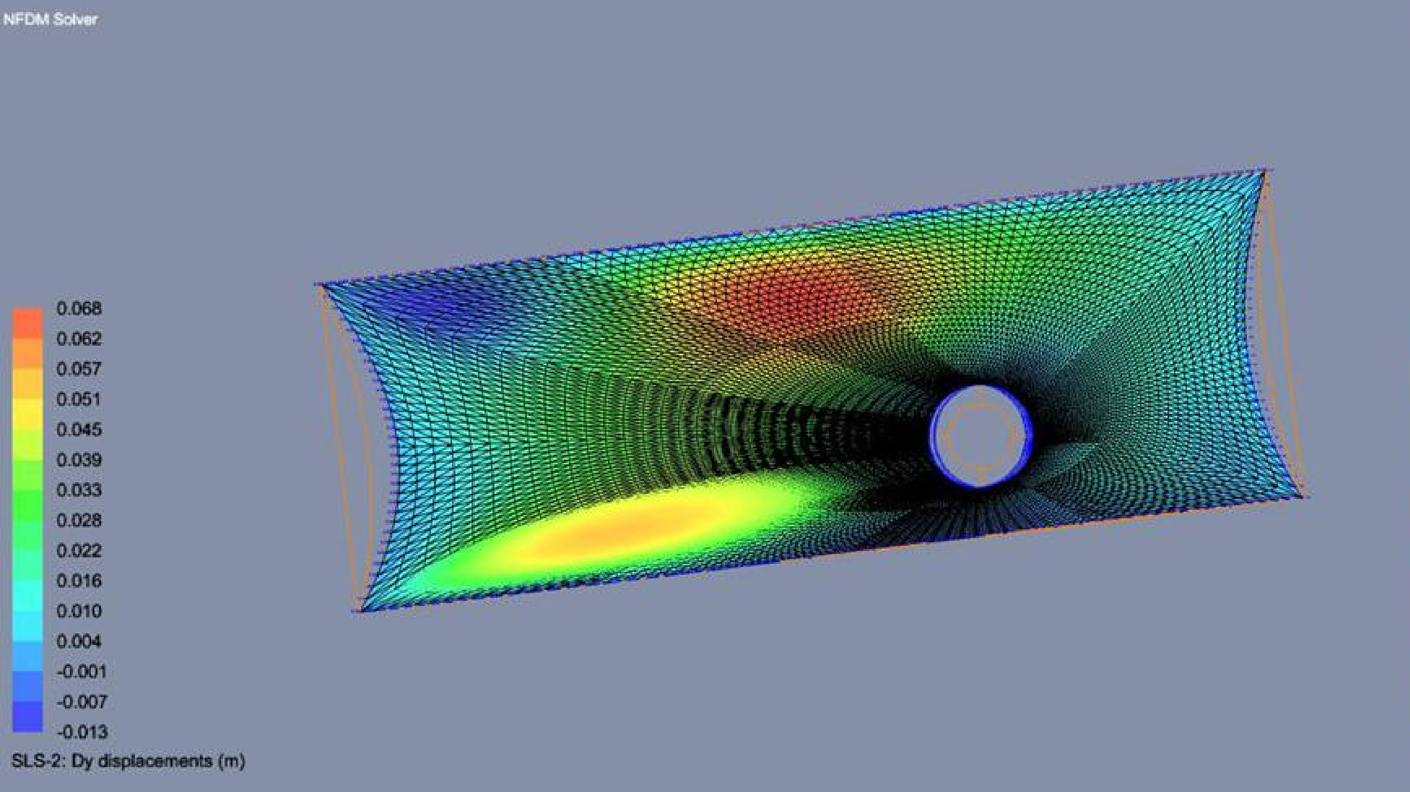
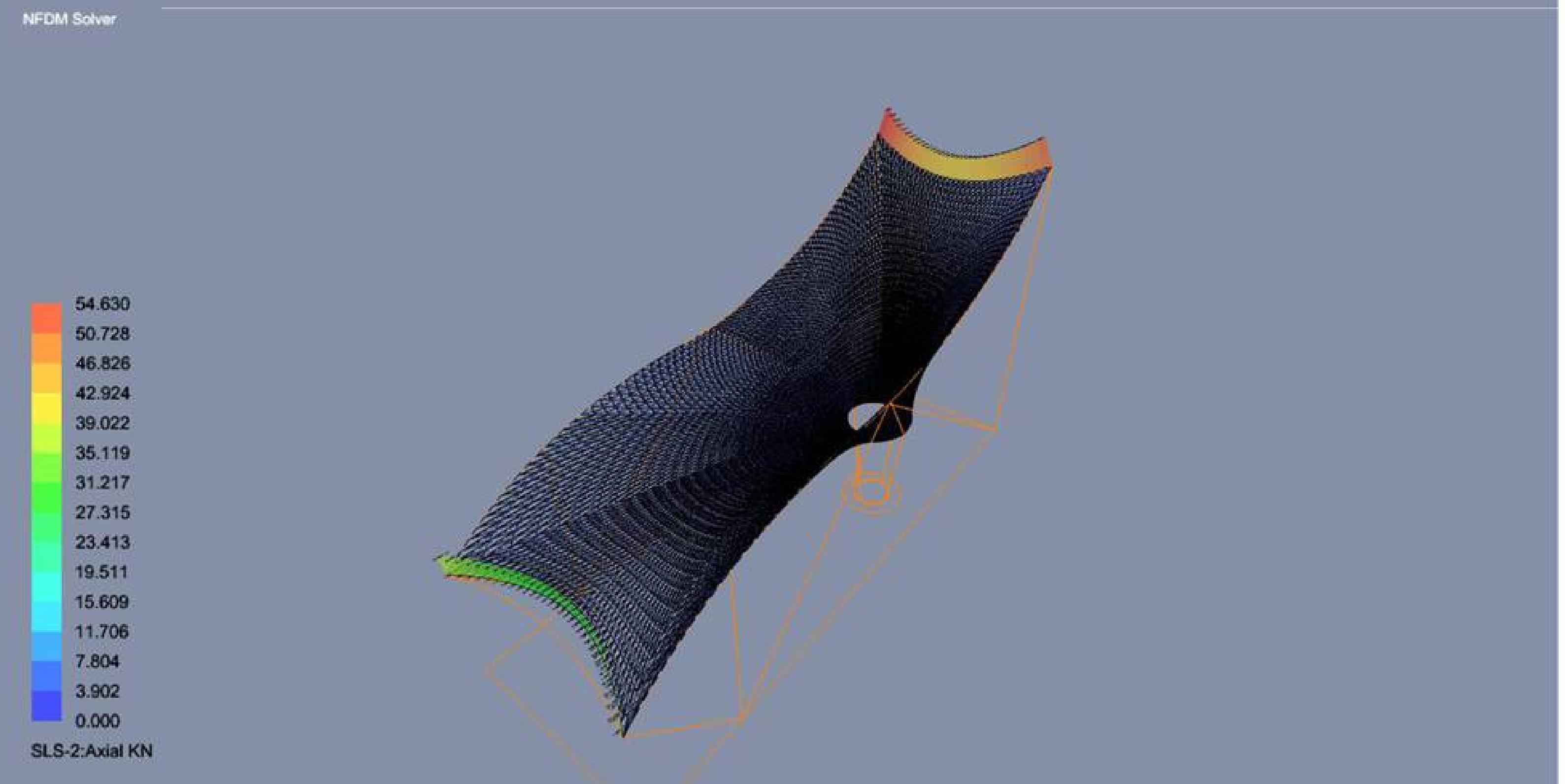




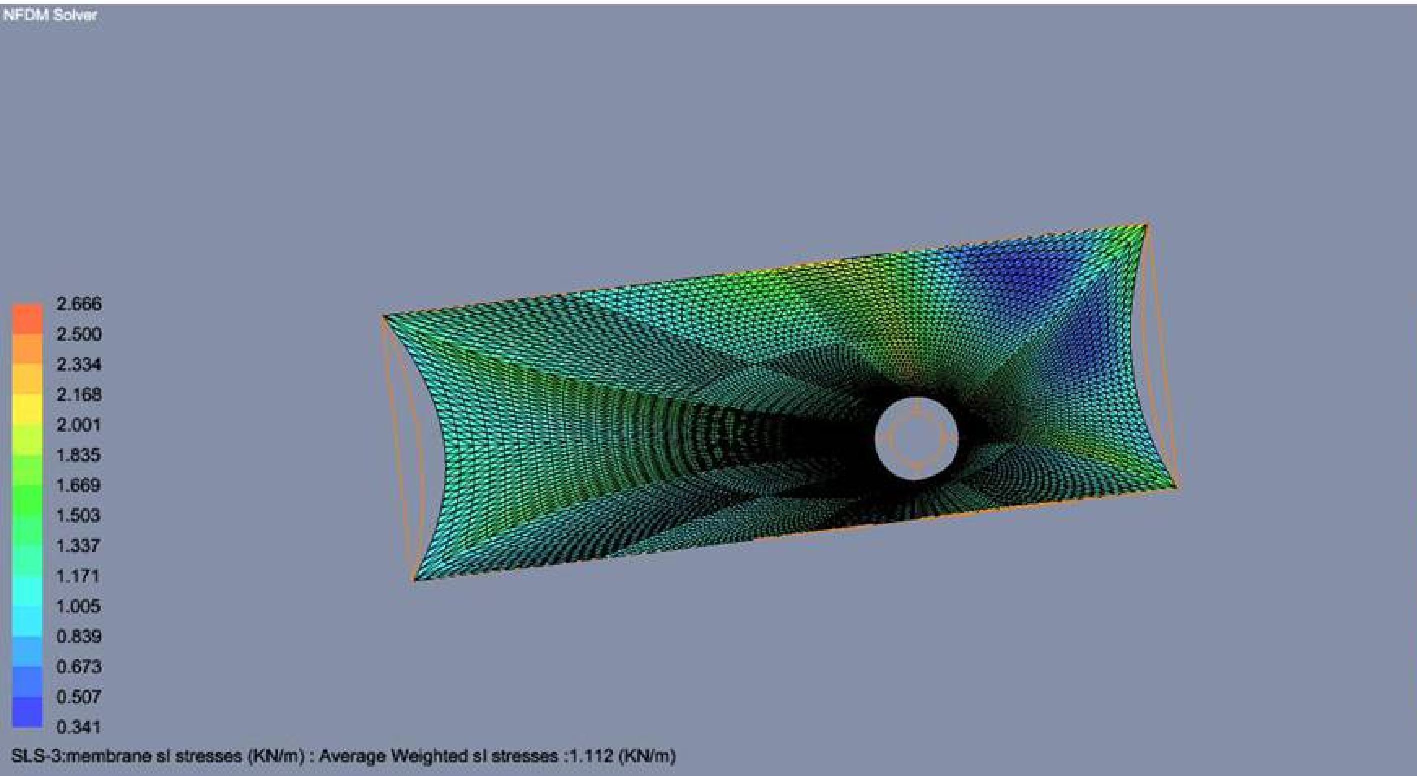


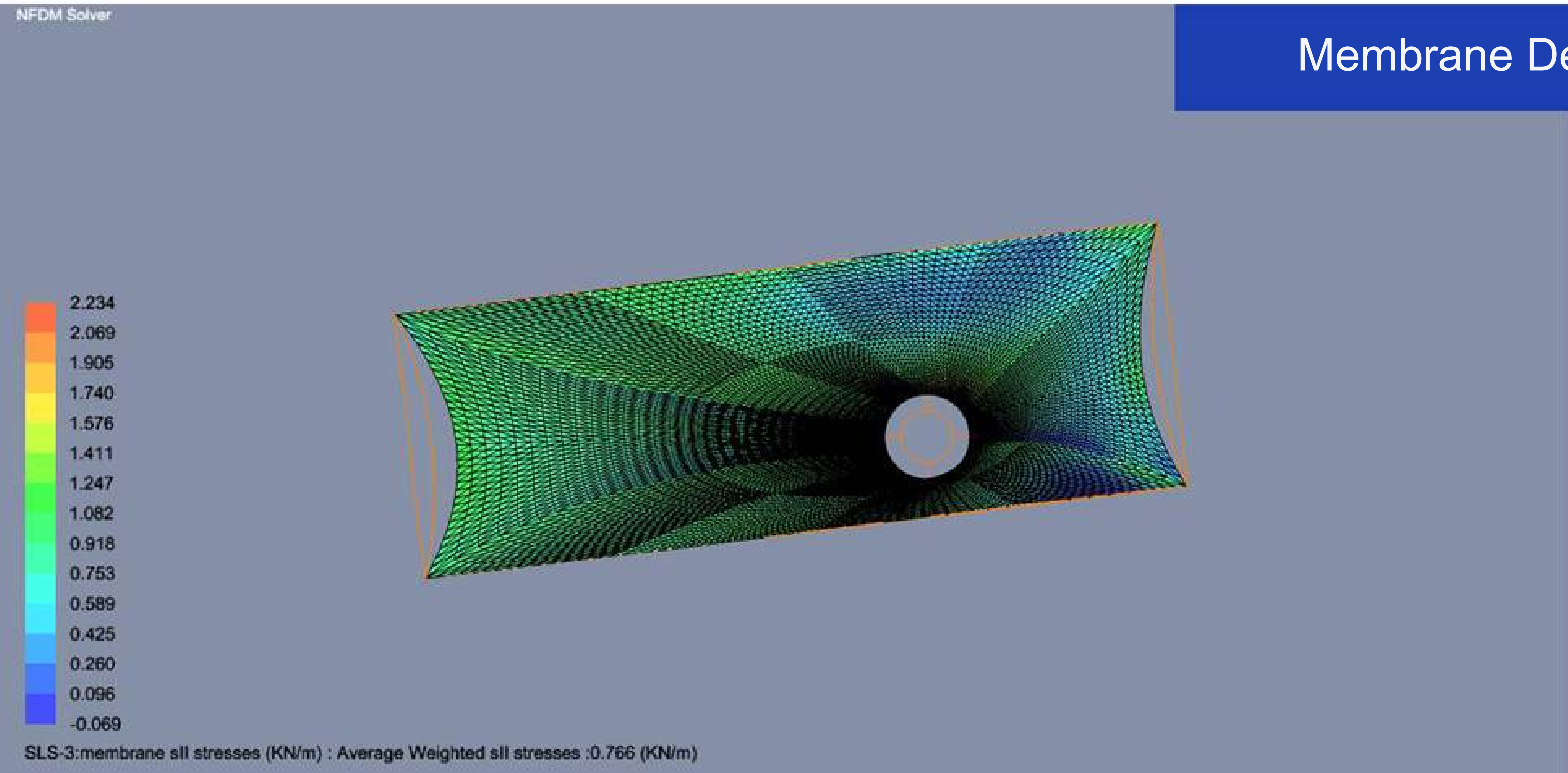


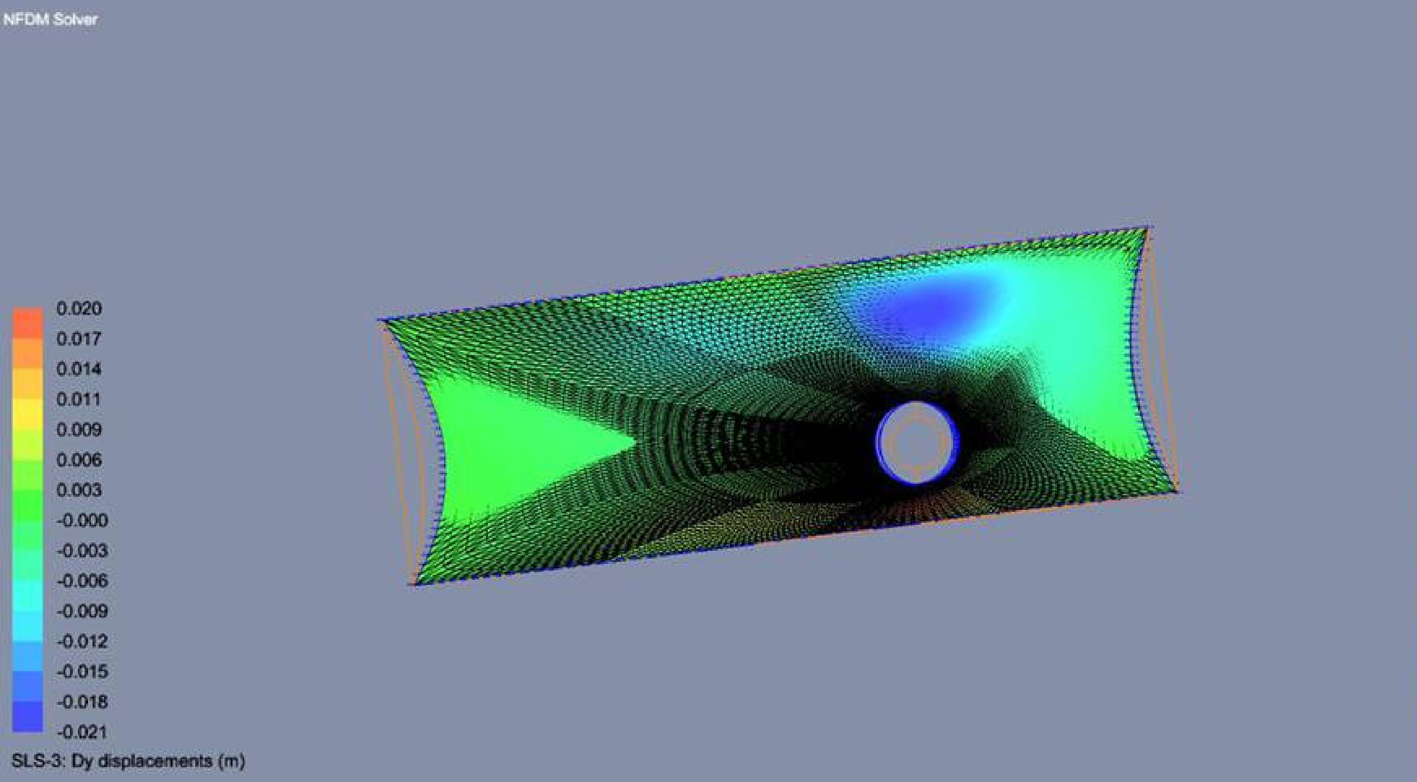
SLS-LC1

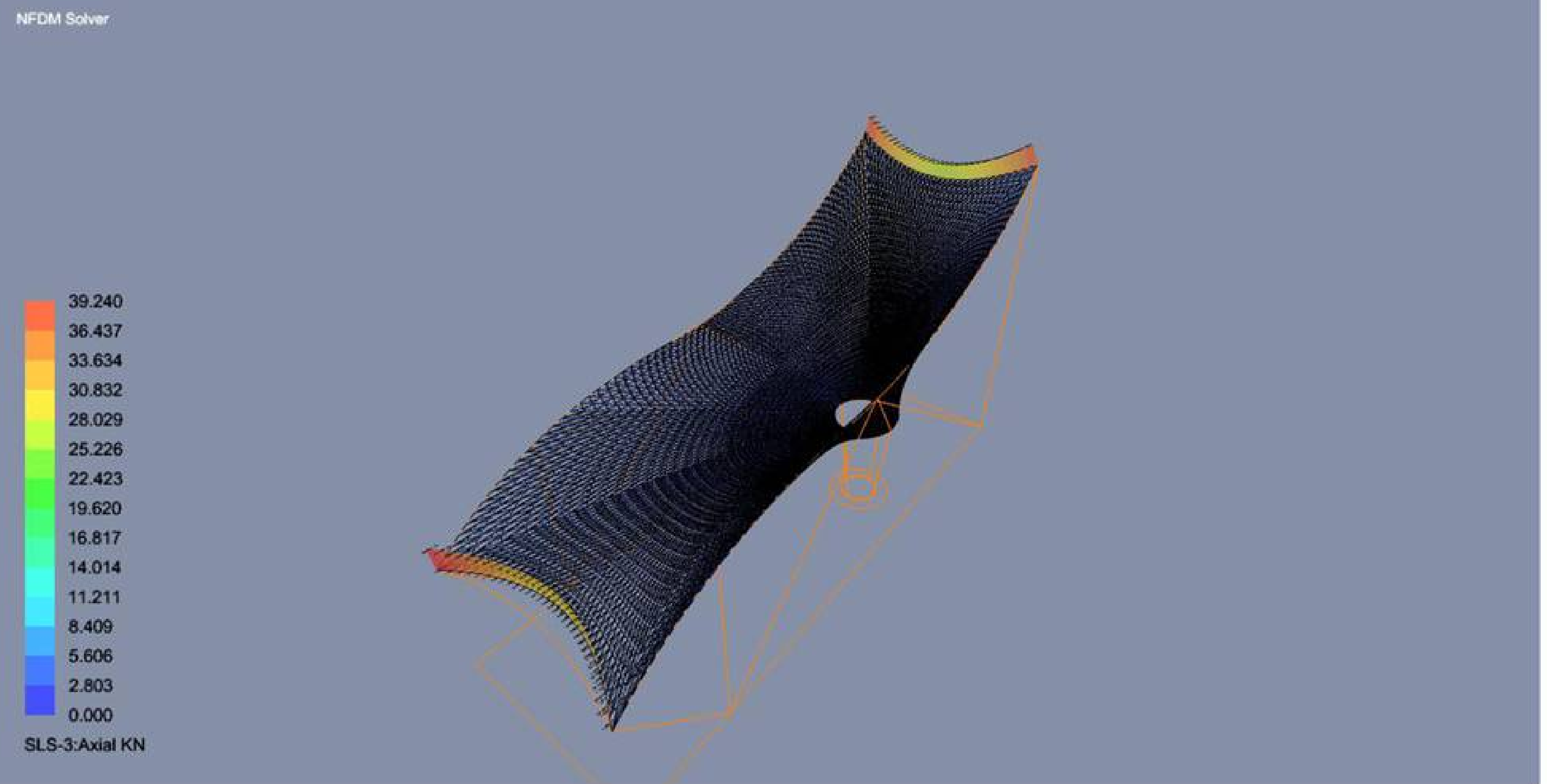
1.0 SELFWEIGHT + 1.0 PRESTRESS + 1.0 SNOW

S1-MAX.: 4.287 Kn/m^2
S2-MAX.: 2.447 Kn/m^2
DEFORMATION MAX.: 0.068 m
AXIAL FORCE MAX.: 54.630 Kn





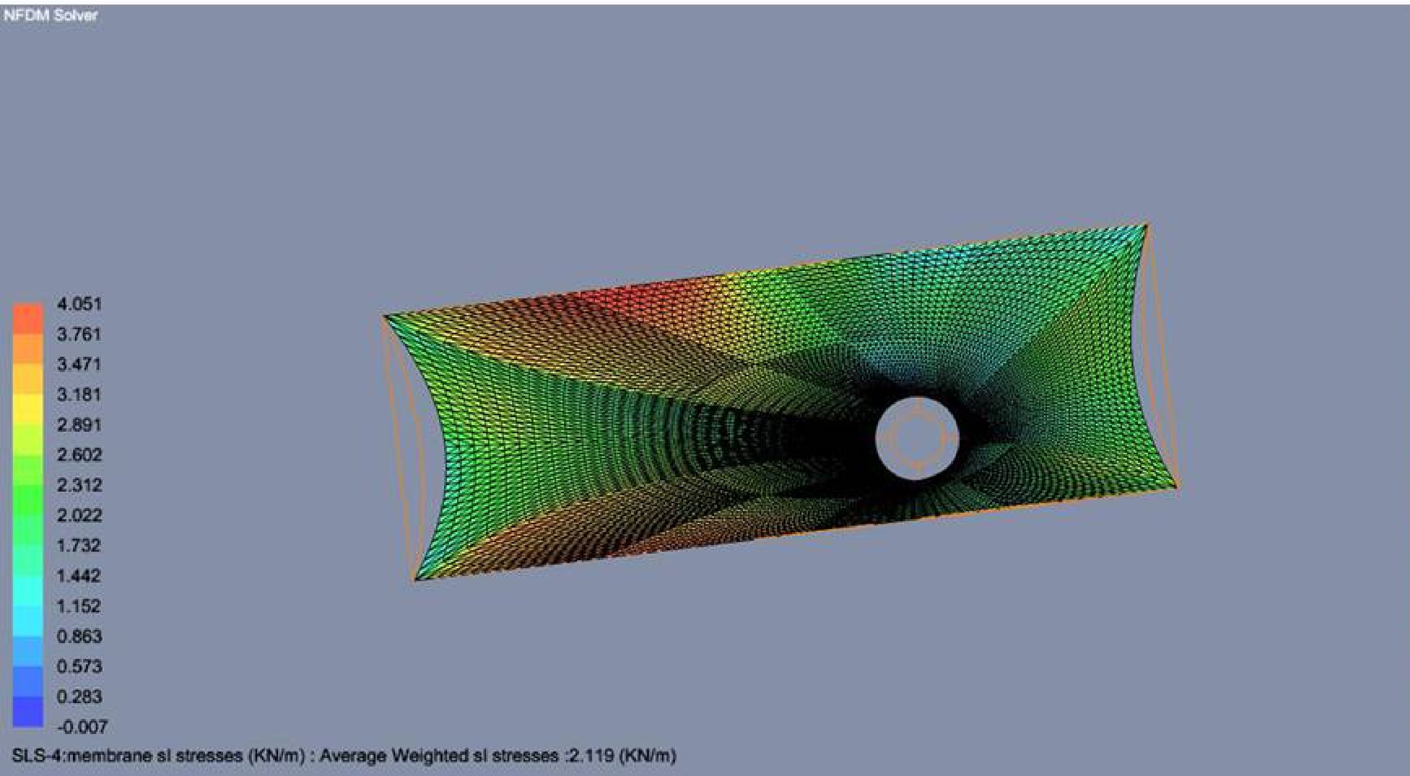


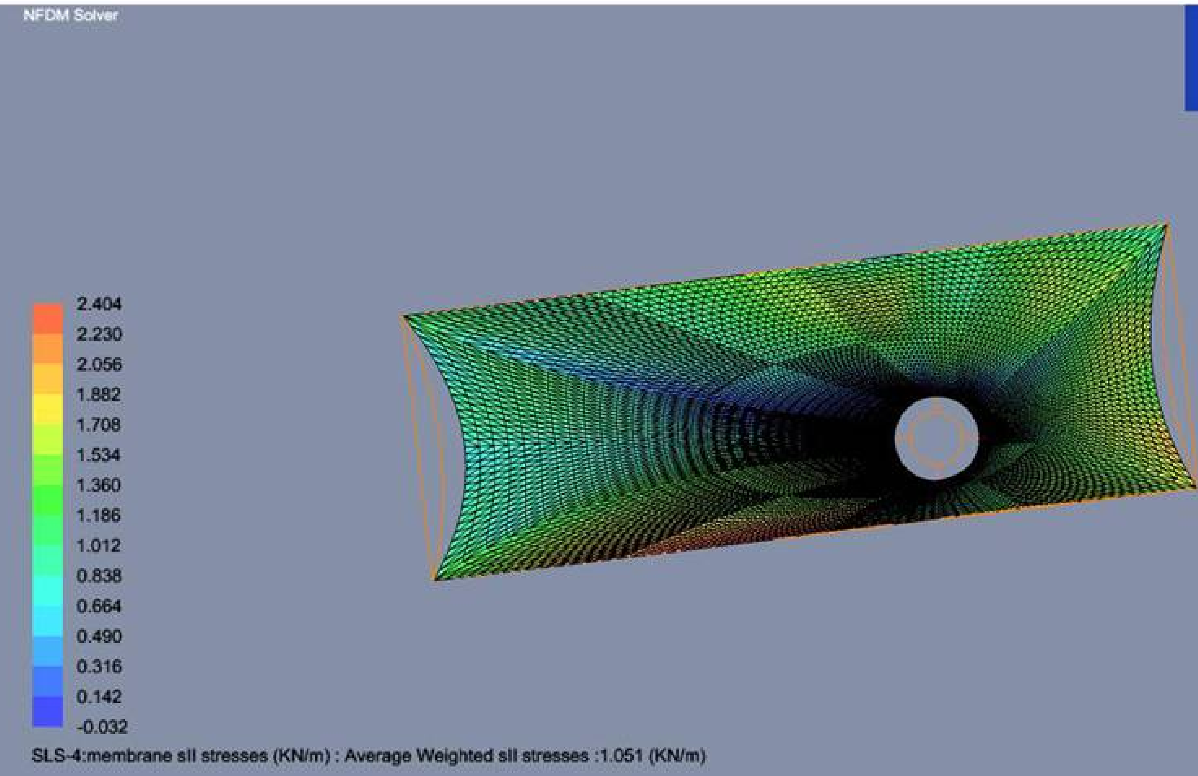


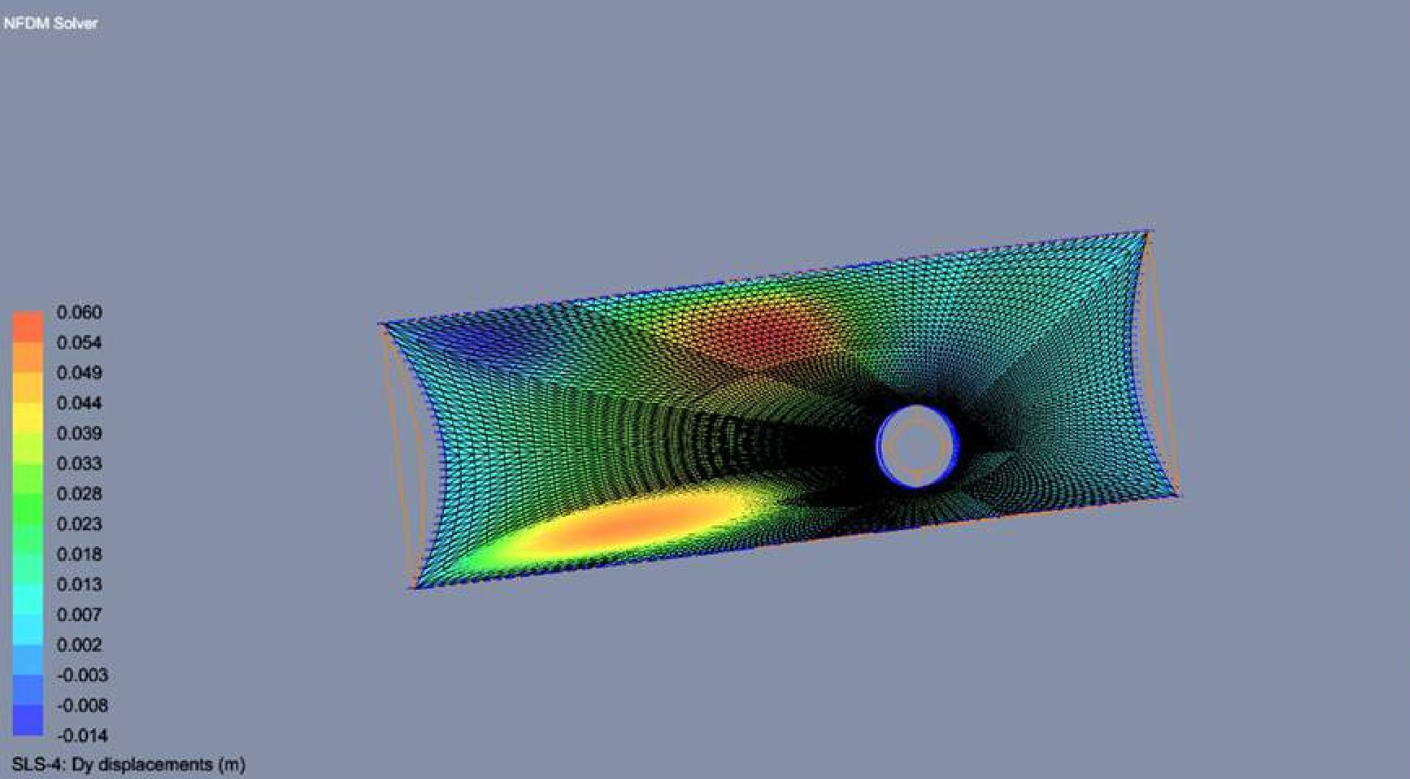
SLS-LC2

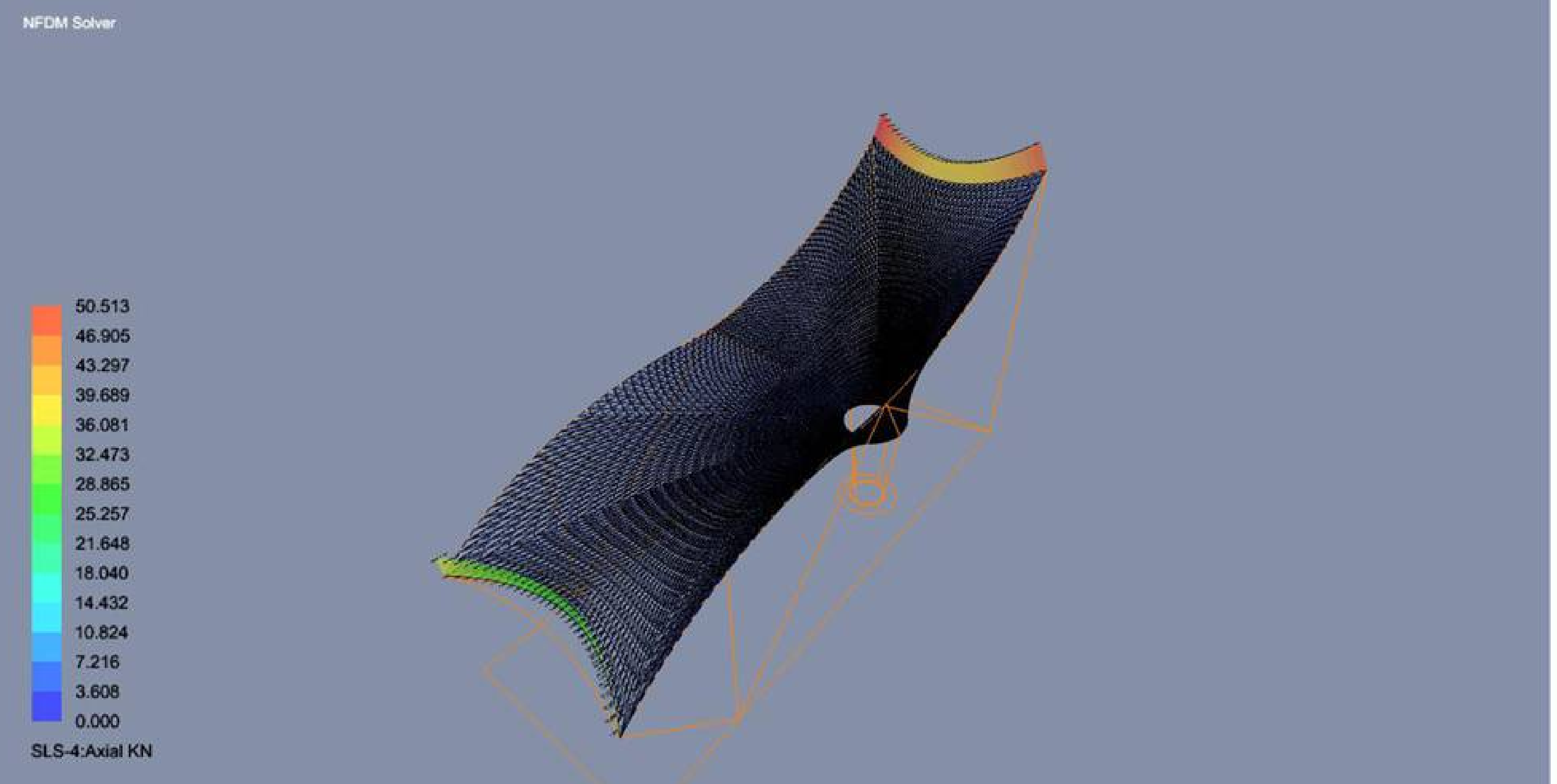
1.0 SELFWEIGHT + 1.0 PRESTRESS + 1.0 WIND

S1-MAX.: 2.666 Kn/m²
S2-MAX.: 2.234 Kn/m²
DEFORMATION MAX.: 0.020m
AXIAL FORCE MAX.: 39.240 Kn





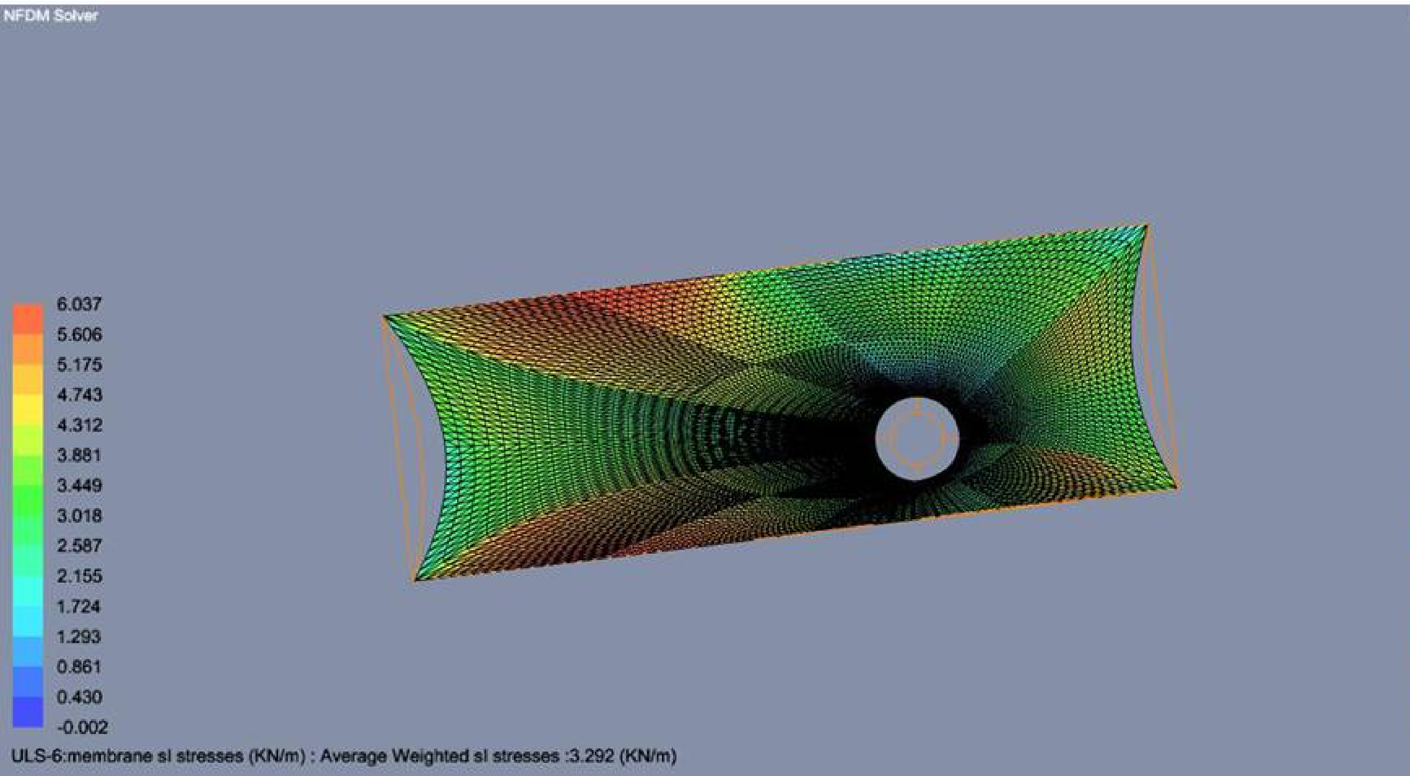


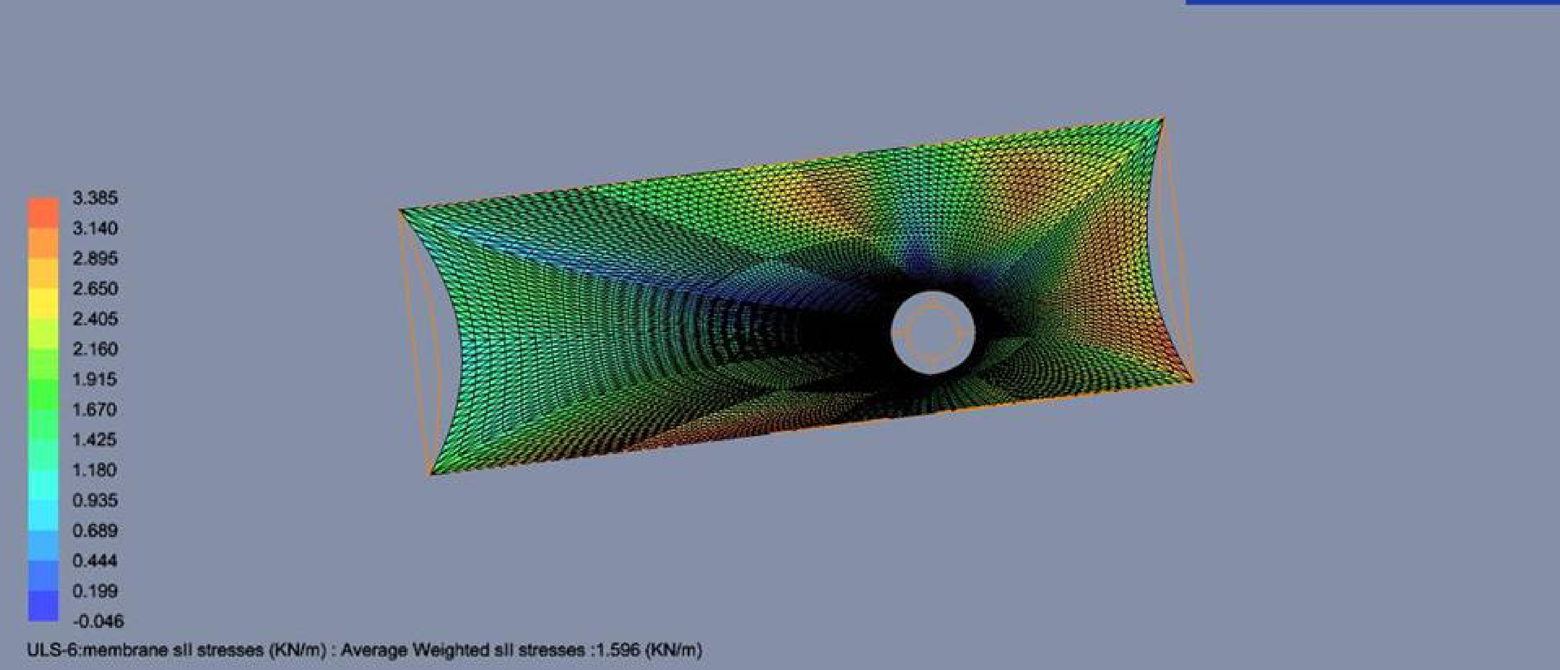


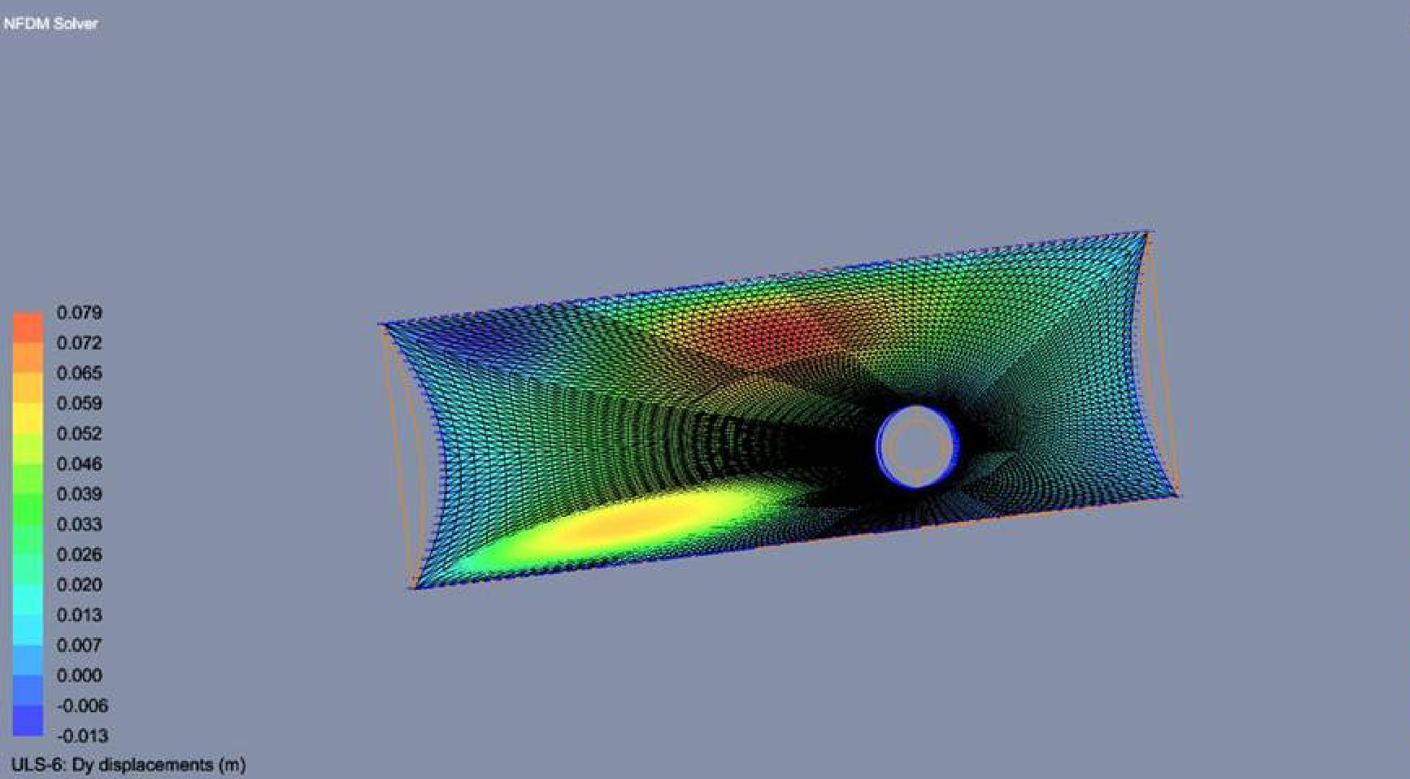
SLS-LC3

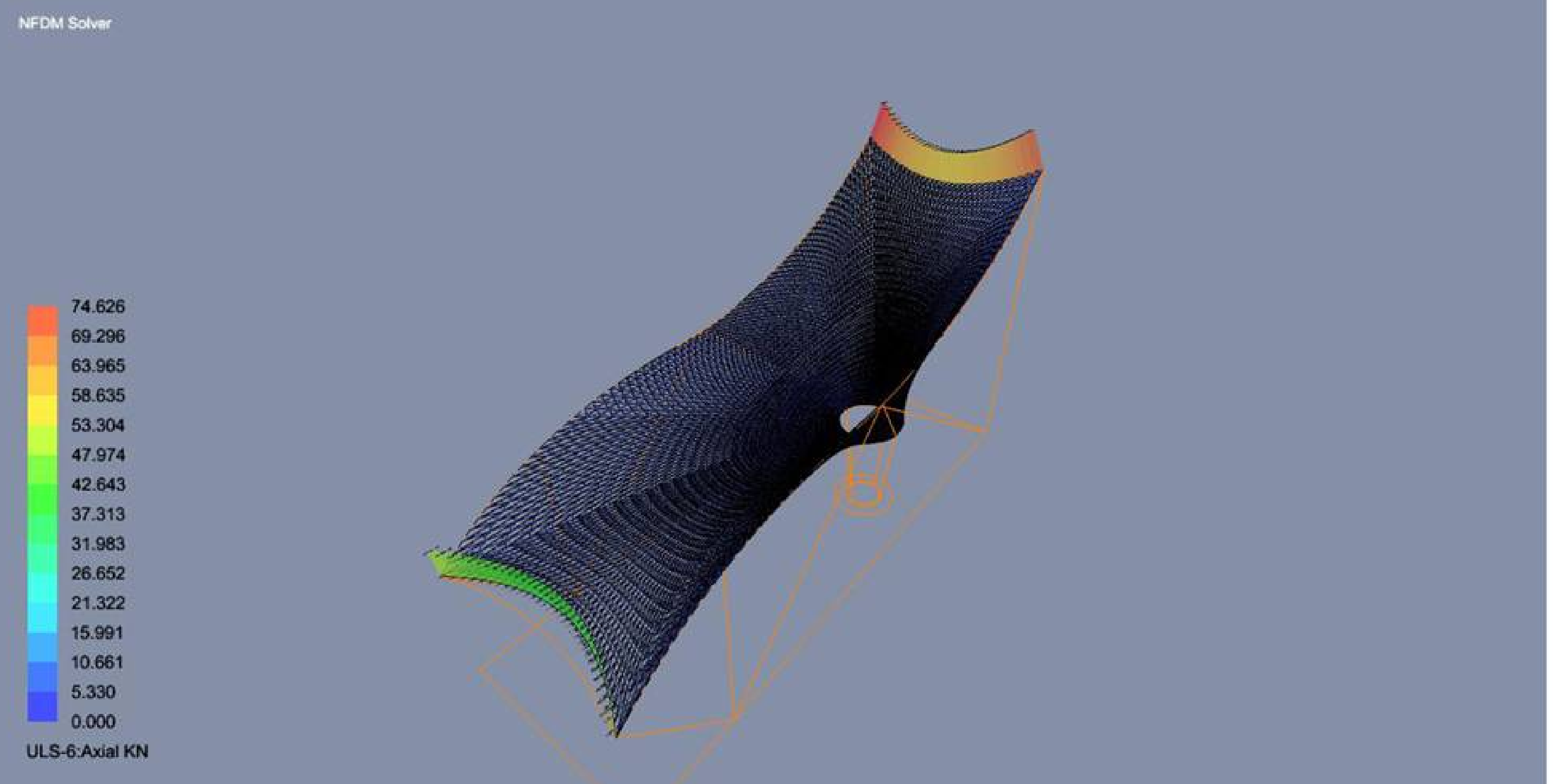
1.0 SELFWEIGHT + 1.0 PRESTRESS + 1.0 WIND + 1.0SNOW

S1-MAX.: 4.051 Kn/m^2
S2-MAX.: 2.404 Kn/m^2
DEFORMATION MAX.: 0.060m
AXIAL FORCE MAX.: 50.513Kn





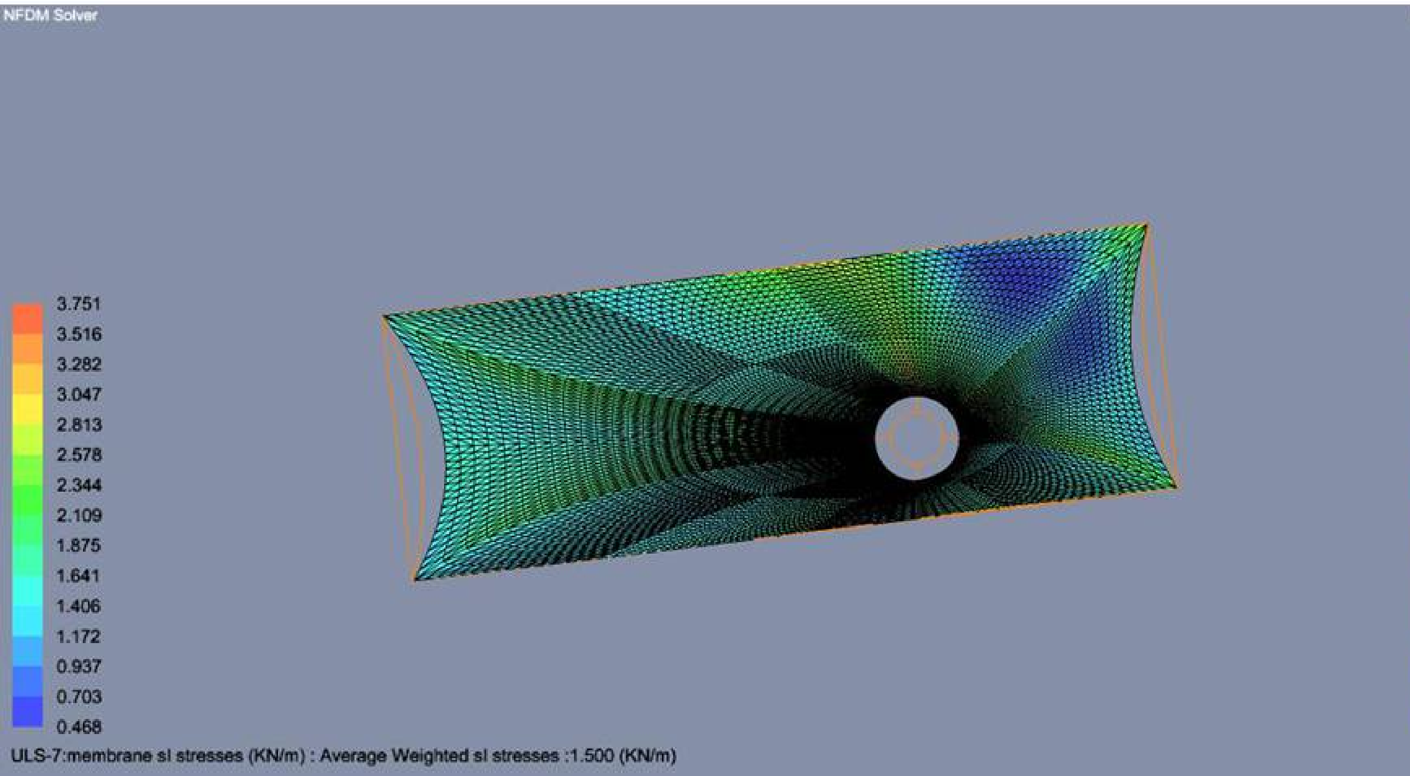


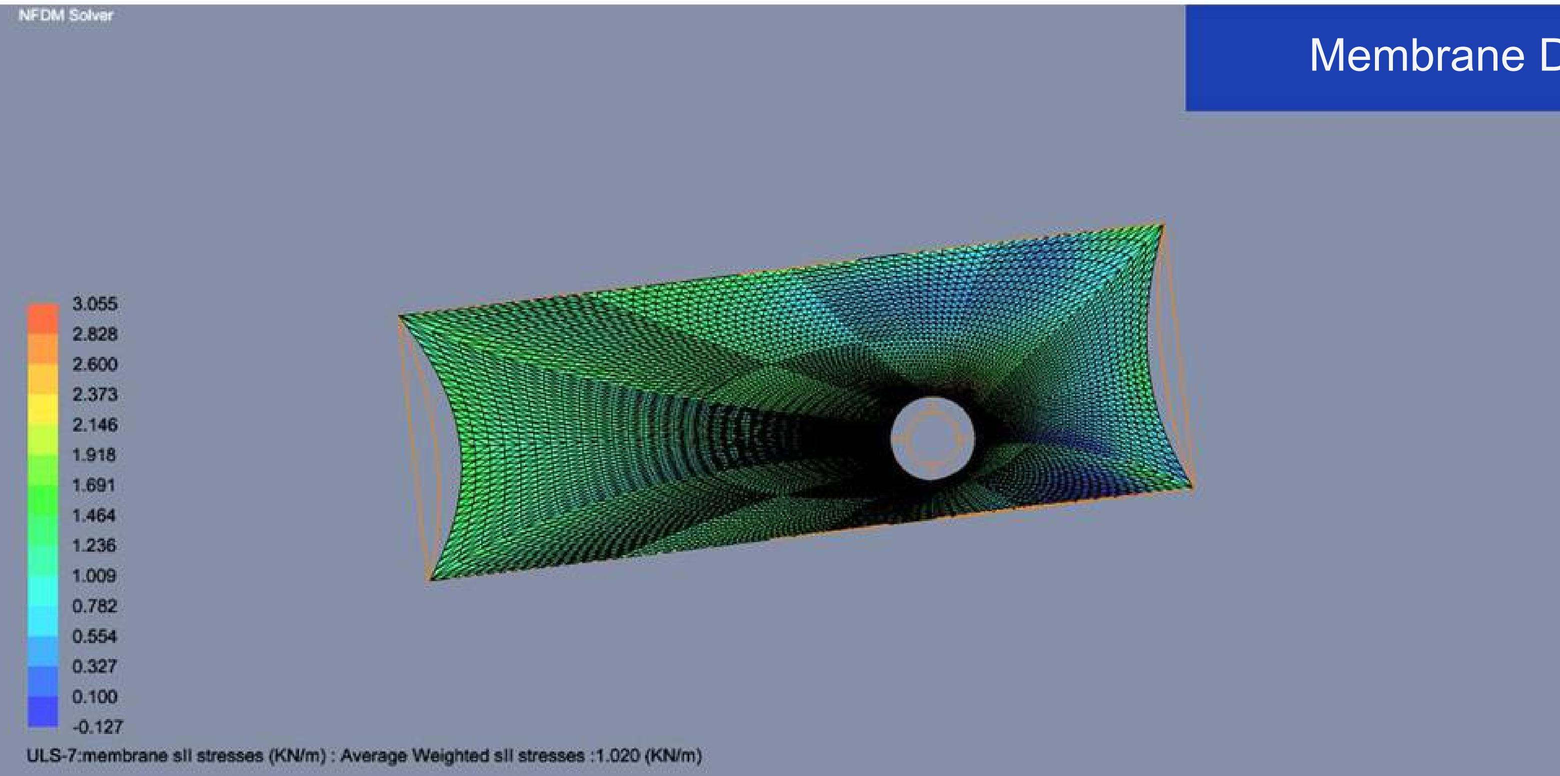


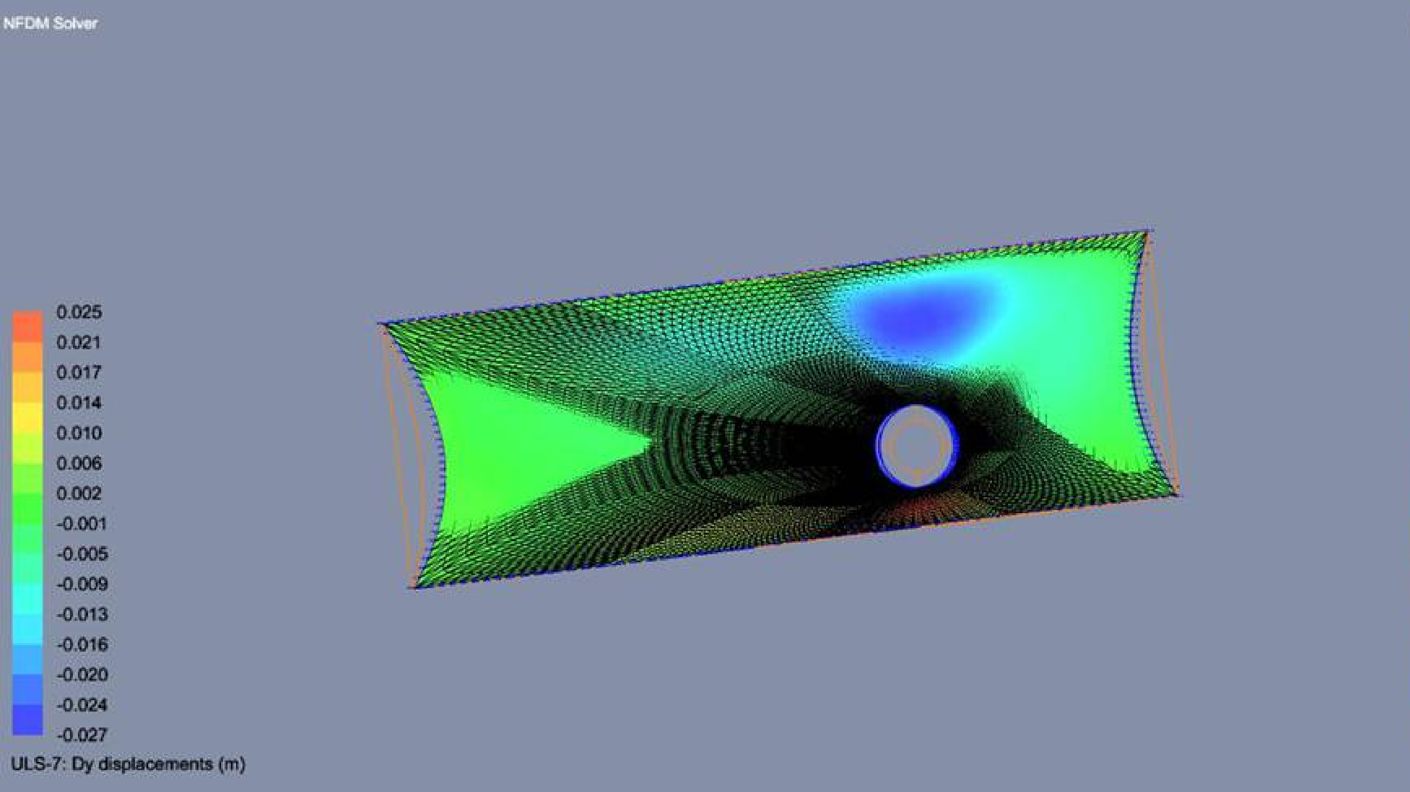
ULS-LC1

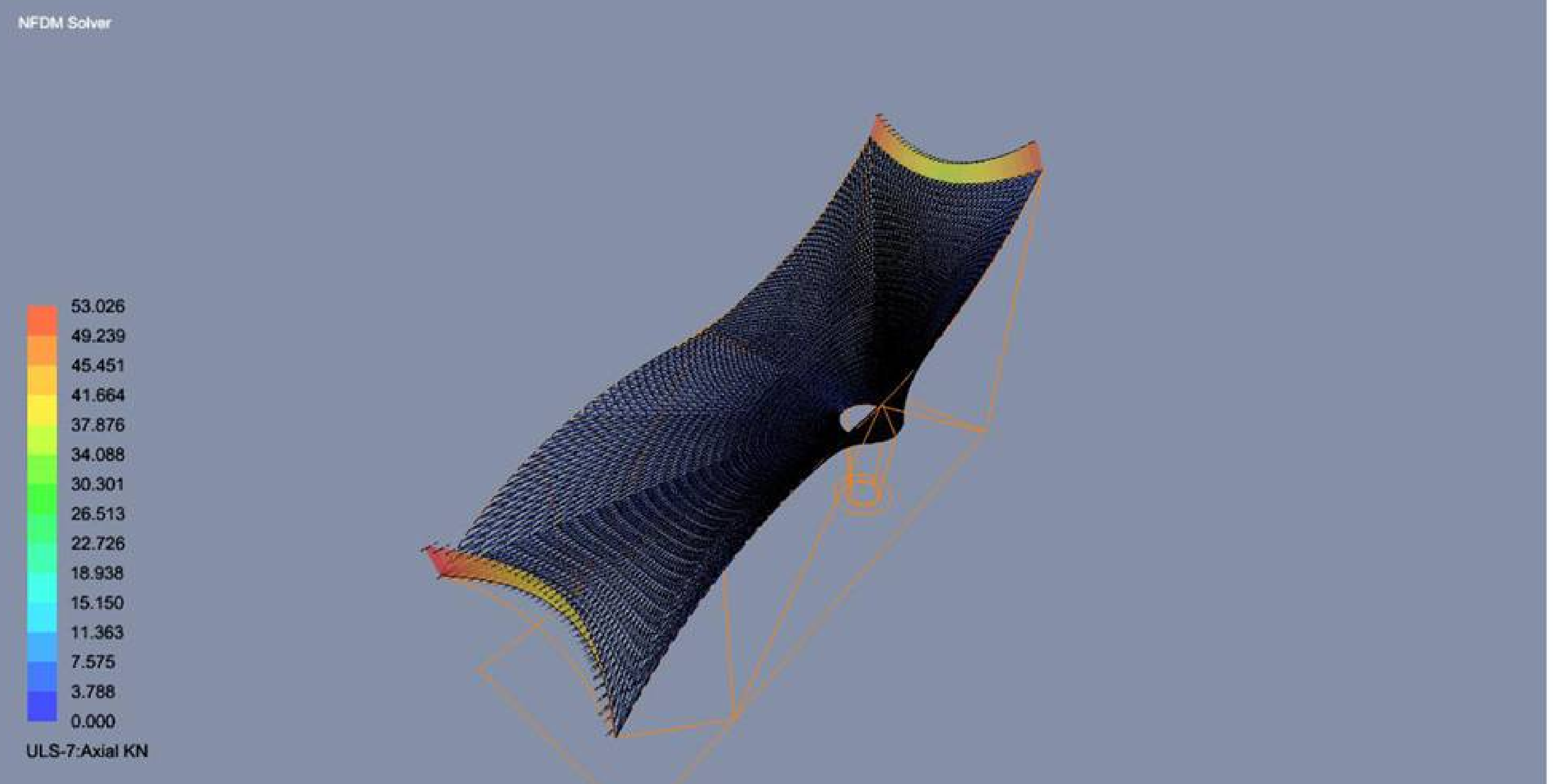
1.35 SELFWEIGHT + 1.35 PRESTRESS + 1.5SNOW

S1-MAX.: 6.037 Kn/m²
S2-MAX.: 3.385 Kn/m²
DEFORMATION MAX.: 0.079m
AXIAL FORCE MAX.: 74.626Kn





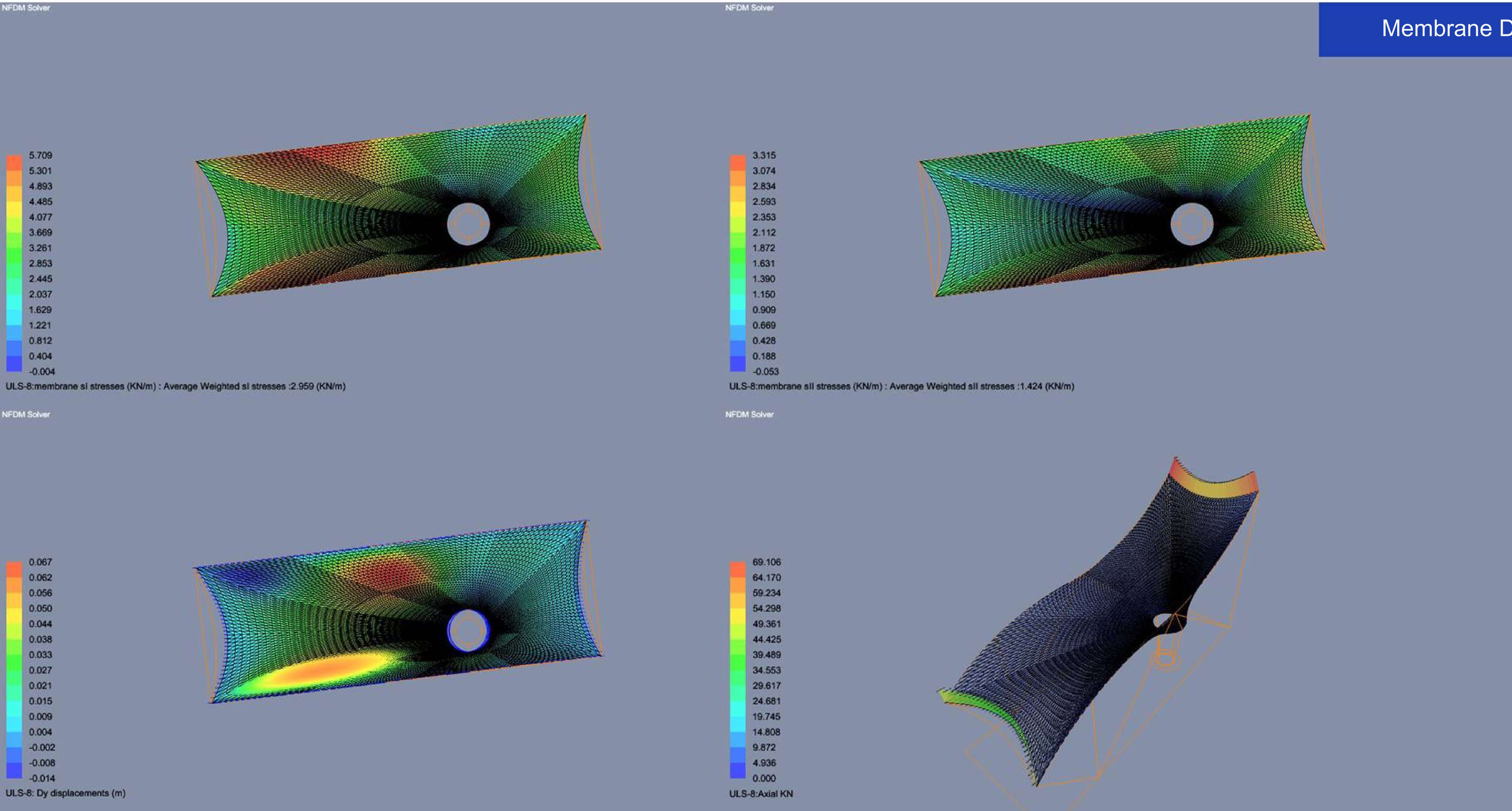




ULS-LC2

1.35 SELFWEIGHT + 1.35 PRESTRESS + 1.5WIND

S1-MAX.: 3.751 Kn/m²
S2-MAX.: 3.055 Kn/m²
DEFORMATION MAX.: 0.025m
AXIAL FORCE MAX.: 53.026Kn



ULS-LC3

1.35 SELFWEIGHT + 1.35 PRESTRESS + 1.5WIND + 1.5SNOW

S1-MAX.: 5.709 Kn/m²
S2-MAX.: 3.315 Kn/m²
DEFORMATION MAX.: 0.067m
AXIAL FORCE MAX.: 69.106Kn

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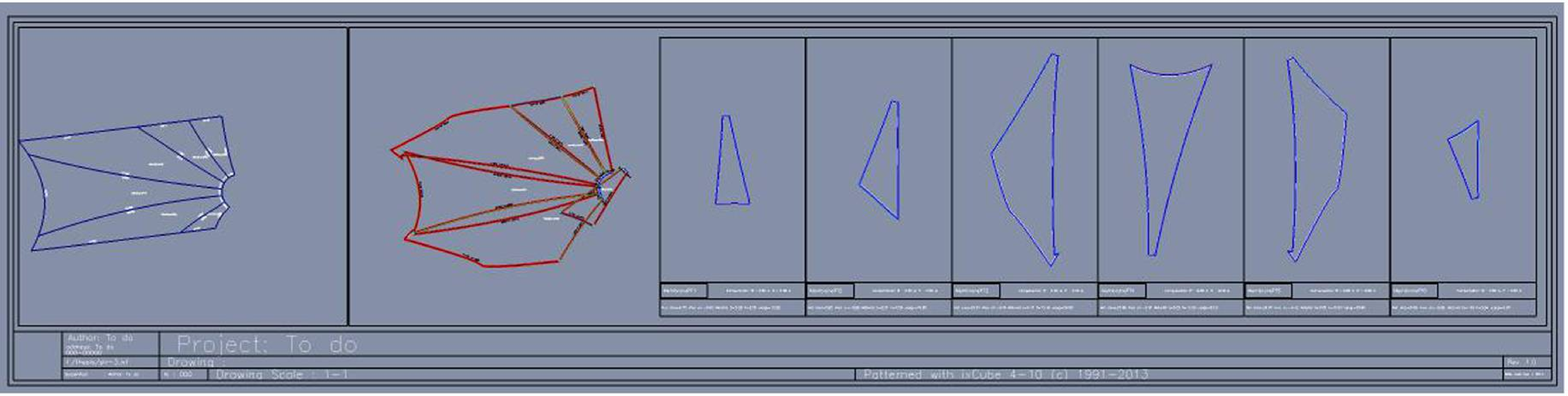


Part of Patterning

Fabric

max SI: 6.037 Kn/m²
max SII: 3.385 Kn/m²
VALMEX product. FR700 Type I
Tensile Strength: 60/60 kn/m²

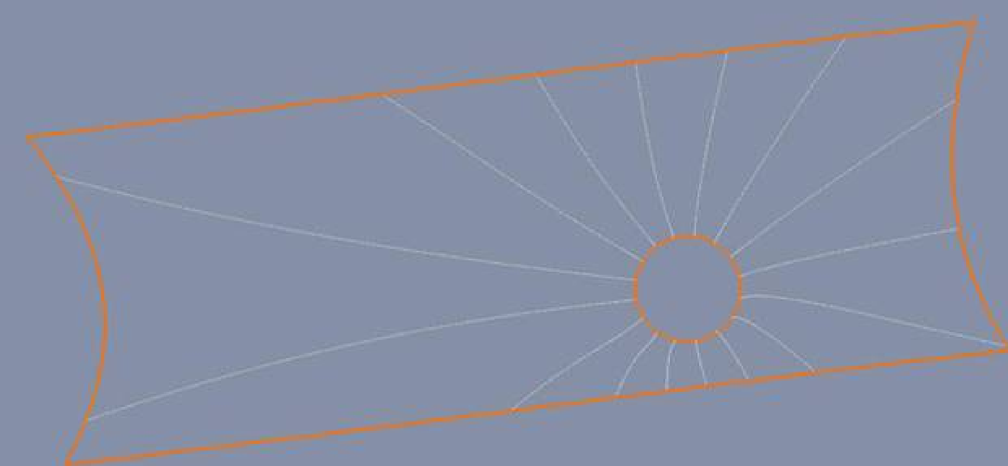
Fabrication

Compensation: 0.5/0.5
Overlapped welding: 50mm

Stress-Verifications ($S_d \leq R_d$)

$F_{u.k}/Y_{m.uls} \cdot A_{res}$
$Y_{m.uls}$ =1.4
A_{res} for permanent load= $A_0 \times A_1 \times A_2 \times A_3 \times A_4$ = 1.2×1.7×1.2×1.2×1.0=2.94
A_{res} for Snow load= $A_0 \times A_2$ = 1.2×1.2=1.44
Ares for Wind load= $A_0 \times A_1 \times A_2$ = 1.2×1.7×1.2=2.45
WARP R_d for permanent load= 60/(1.5×1.4×2.94)=9.718
WEFT R_d for permanent load= 60/(1.5×1.4×2.94)=9.718
WARP R_d for Snow load= 60/(1.6×1.4×1.44)=18.604
WEFT R_d for Snow load= 60/(1.6×1.4×1.44)=18.604
WARP R_d for Wind load= 60/(1.5×1.4×2.45)=11.661
WEFT R_d for Wind load= 60/(1.5×1.4×2.45)=11.661

Permanent load: S_d max.:2.486 < R_d: 9.718
Snow load: S_d max.: 6.037< R_d: 18.604
Wind load: S_d max.: 3.751< R_d: 11.661

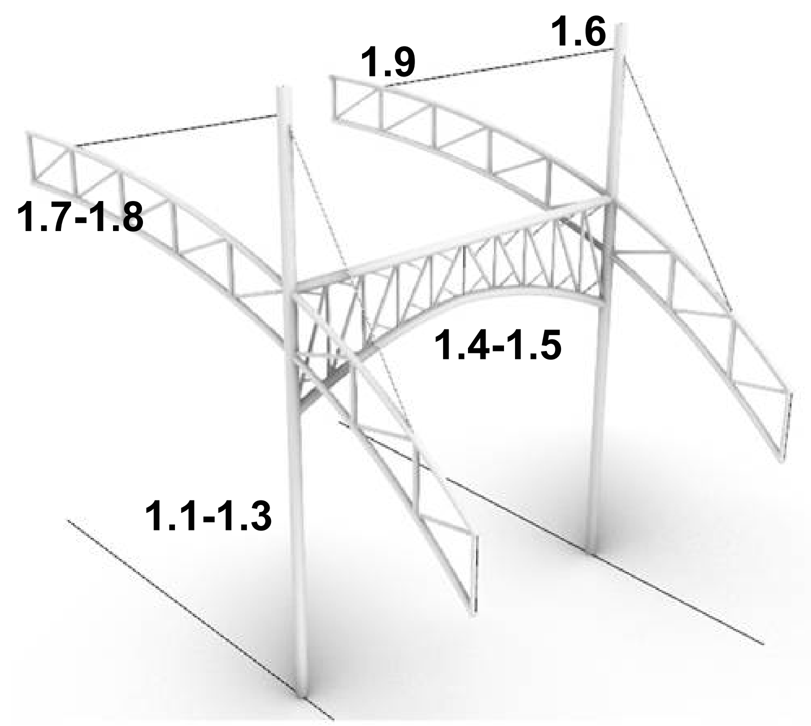


CUT PATTERN

Step 0: Precondition
Survay and erection equipment and machinary
Set storage and transport areas (using part of the nearbye park for the purpose)
Foundation and base plates are instaled on correct position
Fabricated Steels are on site

Step 1: Erection of Structure
Step 1.1: Connect column foot with base plate by a pin/bolt
Step 1.2: Lift the column by a truck crane
Step 1.3: Use a temporary rope to make column stable.
Step 1.4: Lift the arc by a truck crane to the appointed height of the columns
Step 1.5: Connect the arc to the columns by
Step 1.6: Connect one end of the ropes to the top of the column
Step 1.7: Lift the beams by a truck crane
Step 1.8: Hang the beam to the columns by welding
Step 1.9: Connect the other end of the ropes to the beam
Step 1.10: Use tensioning devices to adjust cables

Step 2: Erection of Membrane
Step 2.1: Unfold the pached membrane
Step 2.2: Fix cornerplates to membrane
Step 2.3: Connenct boundry cables to cornerplates
Step 2.4: Fix membrane to keder
Step 2.3: Connenct keder to cornerplates
Step 2.5: lift the membrane by truck
Step 2.6: Pull and conect cornerplates to beams
Step 2.6: Connect membrane edges to the beam
Step 2.7: Use tensioning devices to adjust boundry cables



The assembly and erection of this structure itself is not complicated. However, the site has specific condition.
The road and the pedestrian on west can not be blocked at any time.
The sculpture park on east can not be claimed entirely for construction because it will damage the landscape and the sculptures.
Therefore, scheaming the proccess from the start with time schedule is essential.
Suggestion is to take part of the park on the south as the opperative field and to seperate a road with max. 7m width in sculpture park along the project to do the instalation.
Also it is better to consider doing all the process in the night.

Step 0: Precondition

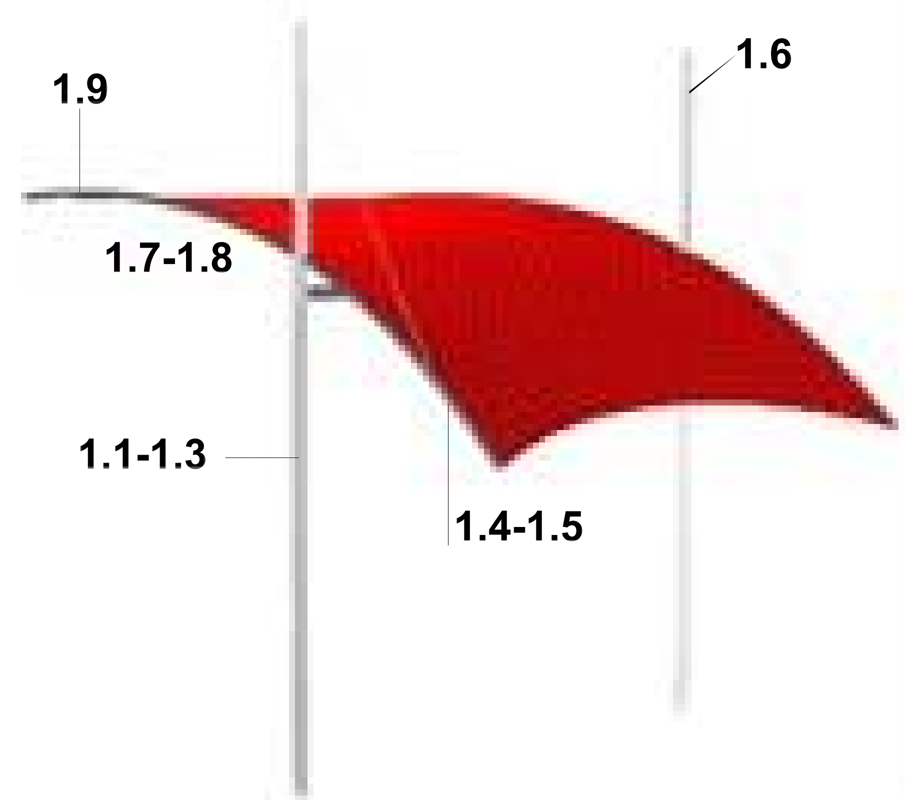
Survay and erection equipment and machinary
Set storage and transport areas (using part of the nearbye park for the purpose)
Foundation and base plates are instaled on correct position
Fabricated Steels are on site

Step 1: Erection of Structure

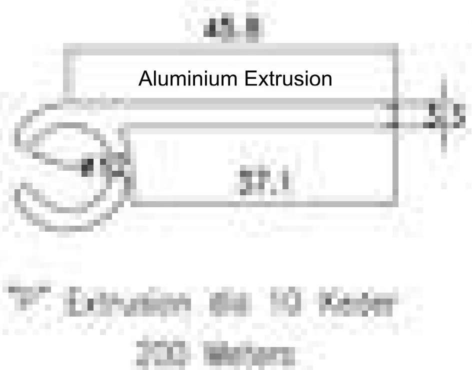
Step 1.1: Connect column foot with base plate by a pin/bolt
Step 1.2: Lift the column by a truck crane
Step 1.3: Use a temporary rope to make column stable.
Step 1.4: Lift the arc by a truck crane to the appointed height of the columns
Step 1.5: Connect the arc to the columns by
Step 1.6: Connect one end of the ropes to the top of the column
Step 1.7: Lift the beams by a truck crane
Step 1.8: Hang the beam to the columns by welding
Step 1.9: Connect the other end of the ropes to the beam
Step 1.10: Use tensioning devices to adjust cables

Step 2: Erection of Membrane

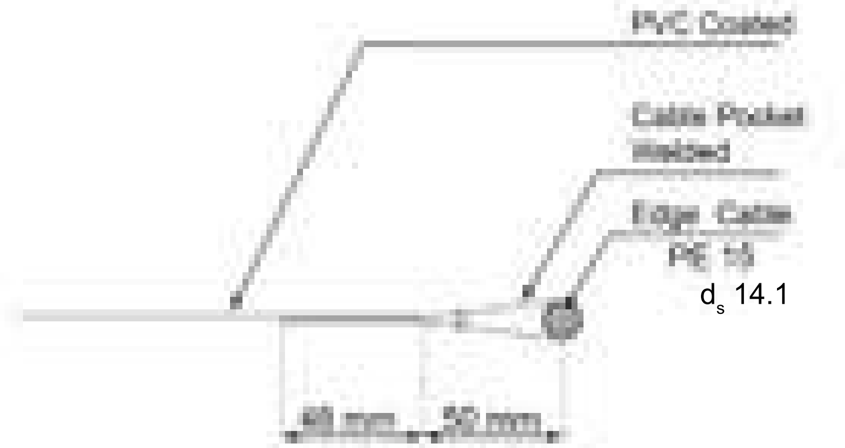
Step 2.1: Unfold the pached membrane
Step 2.2: Fix cornerplates to membrane
Step 2.3: Connenct boundry cables to cornerplates
Step 2.4: Fix membrane to keder
Step 2.3: Connenct keder to cornerplates
Step 2.5: lift the membrane by truck
Step 2.6: Pull and conect cornerplates to beams
Step 2.6: Connect membrane edges to the beam
Step 2.7: Use tensioning devices to adjust boundry cables

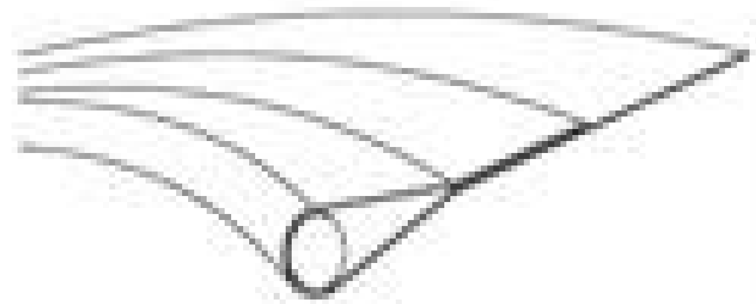


The assembly and erection of this structure itself is not complicated. However, the site has specific condition.
The road and the pedestrian on west can not be blocked at any time.
The sculpture park on east can not be claimed entirely for construction because it will damage the landscape and the sculptures.
Therefore, scheaming the proccess from the start with time schedule is essential.
Suggestion is to take part of the park on the south as the opperative field and to seperate a road with max. 7m width in sculpture park along the project to do the instalation.
Also it is better to consider doing all the process in the night.

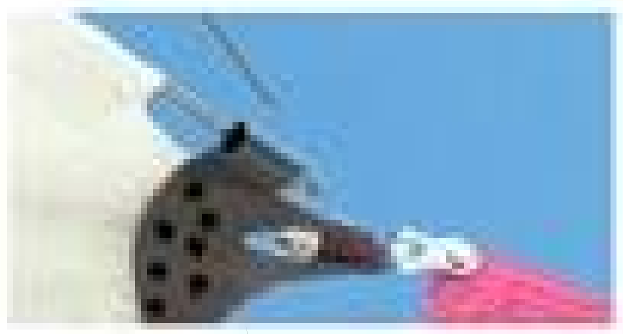


D-02 Boundry Cable- Mechanical Bracket

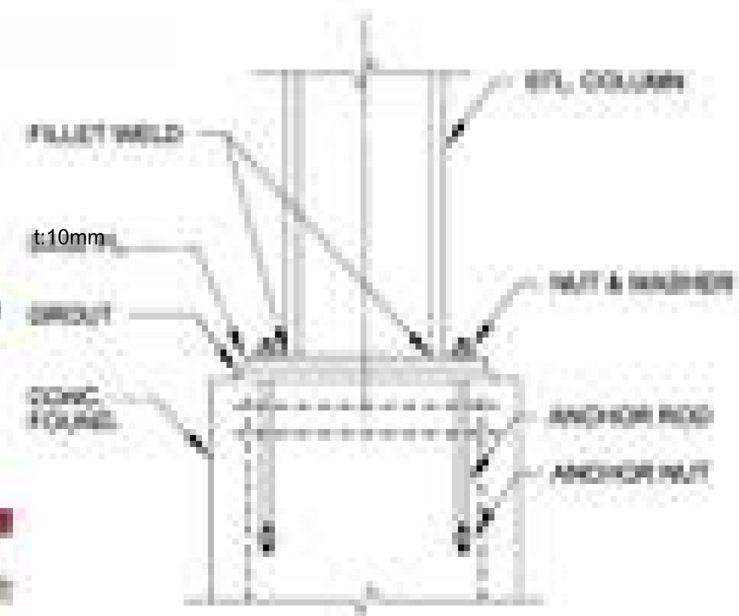


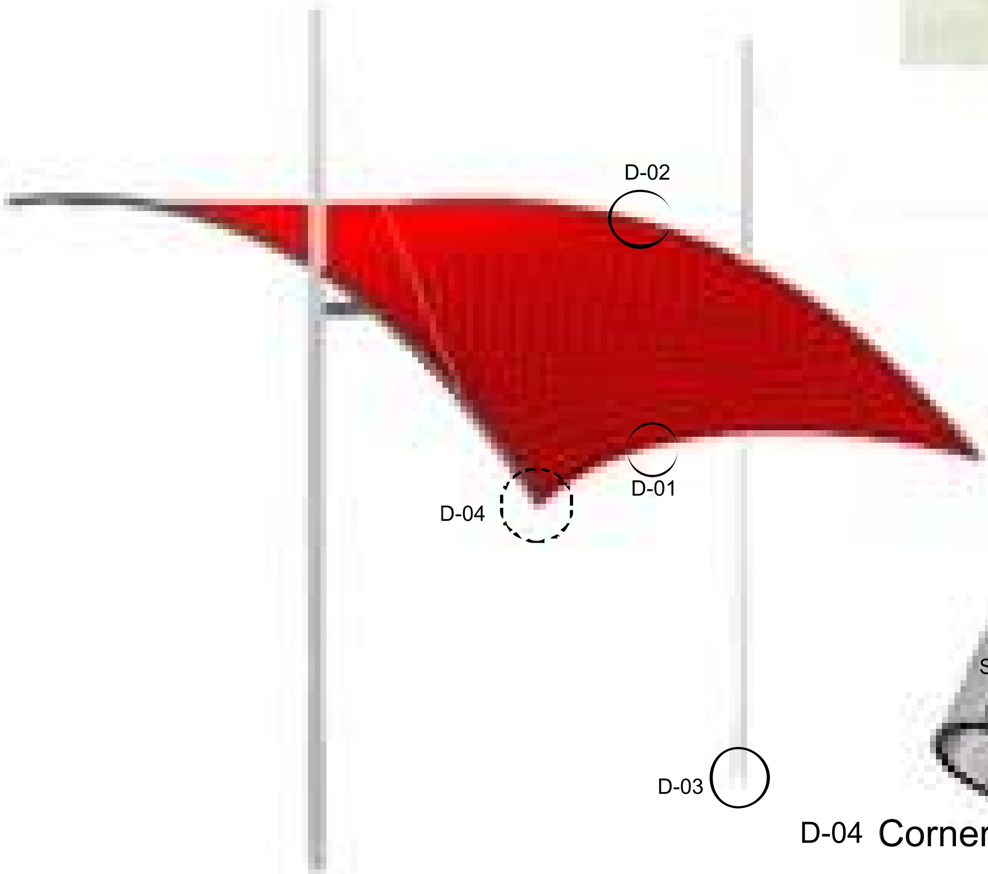


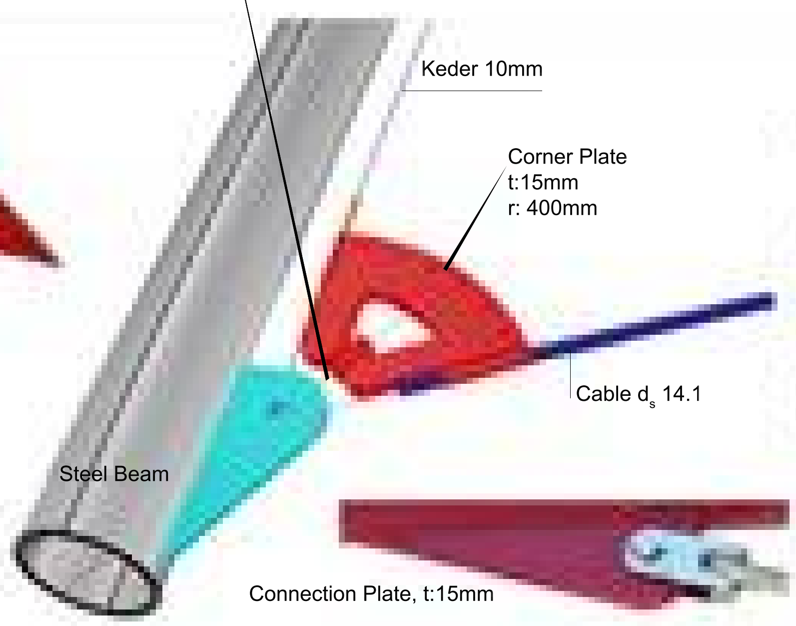
D-01 Boundry Cable- Fabric Pocket



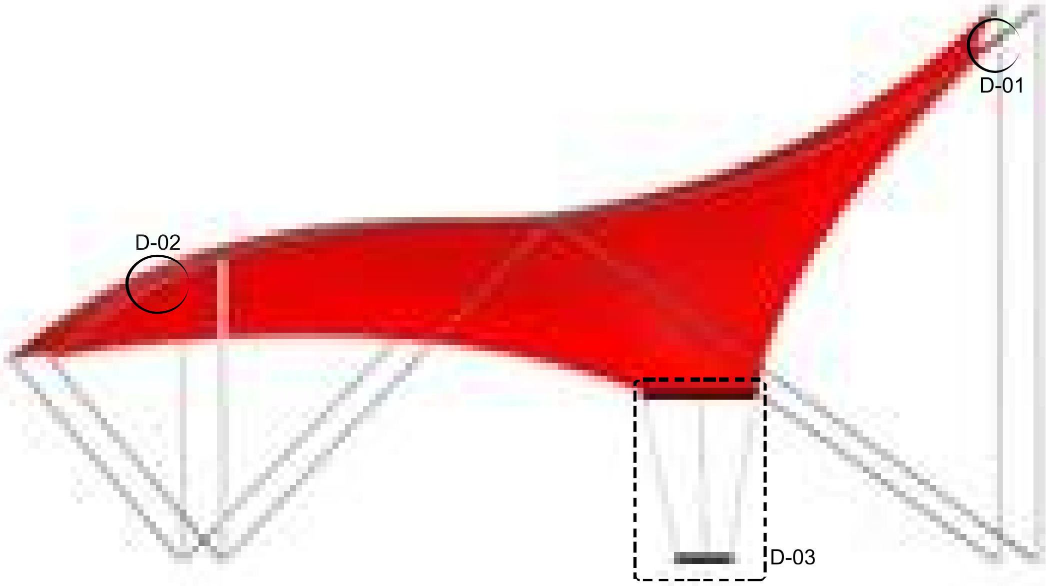
D-03 Column Foundation



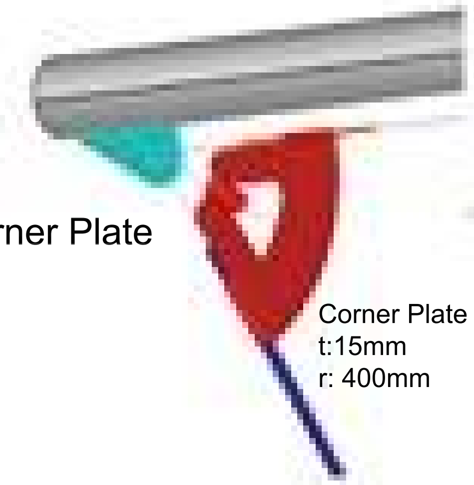


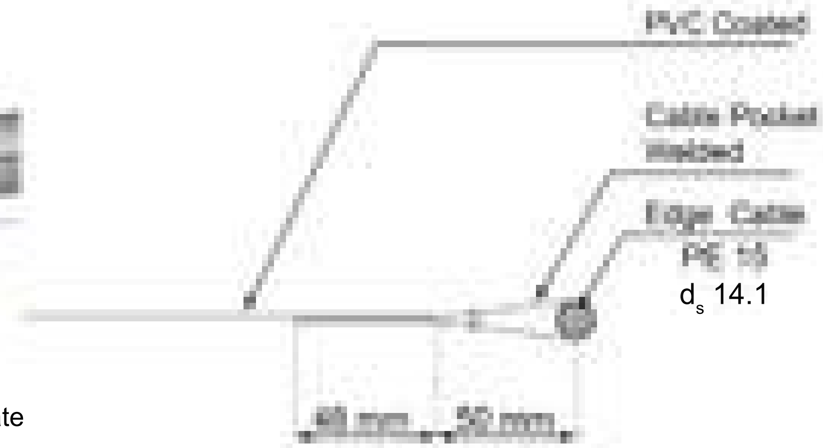


D-04 Corner Plate

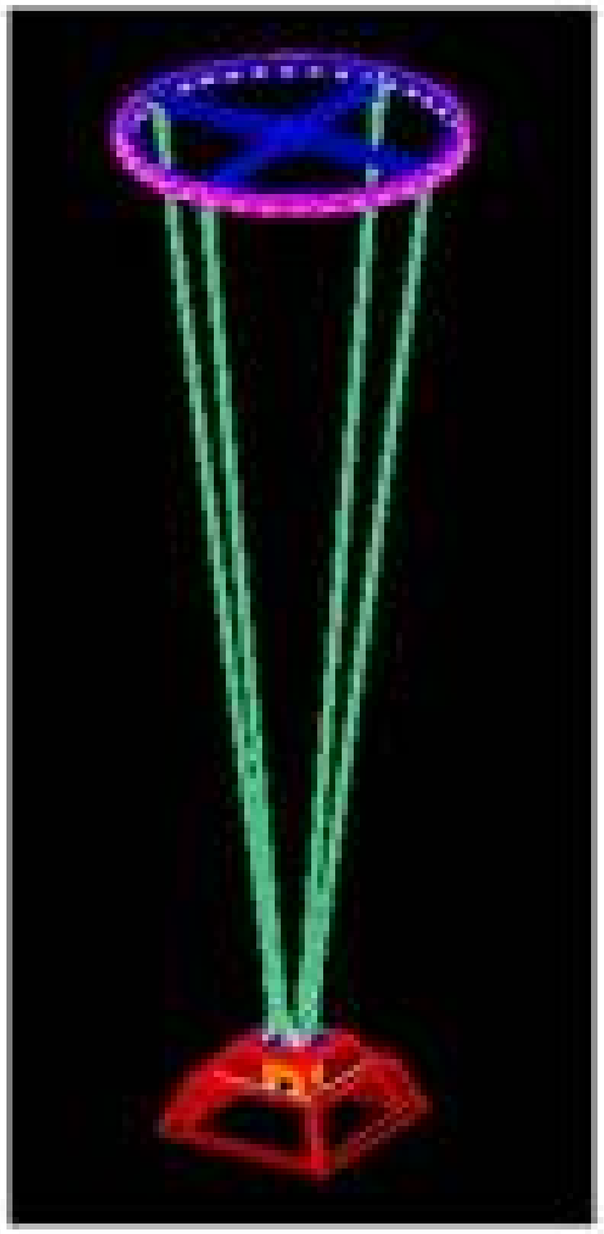


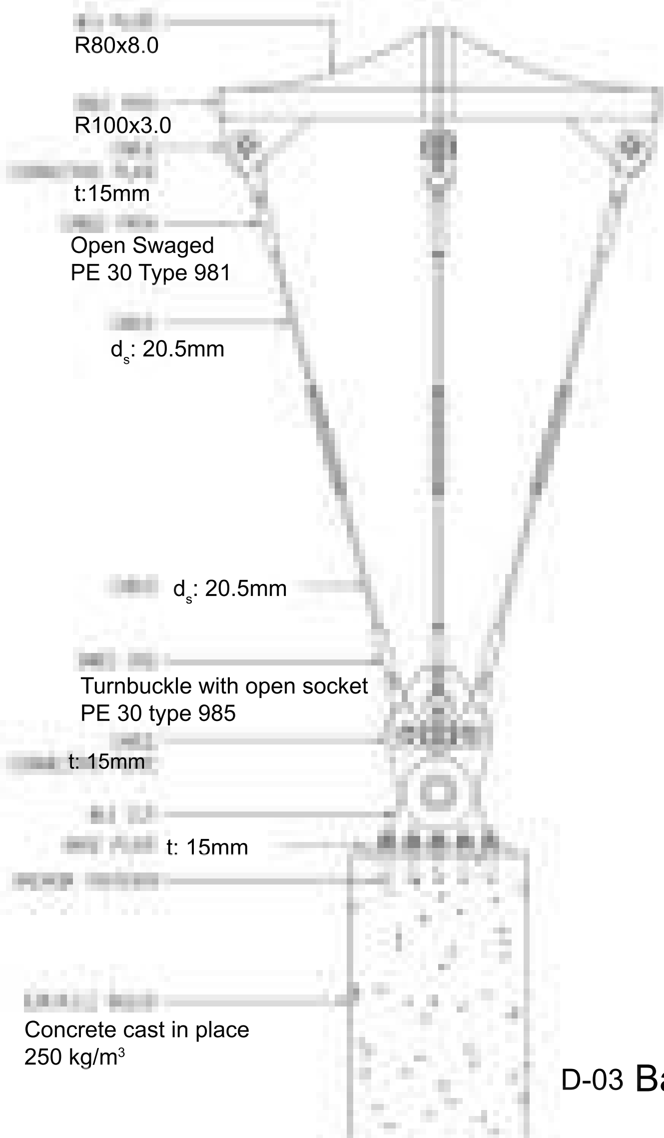
Corner Plate



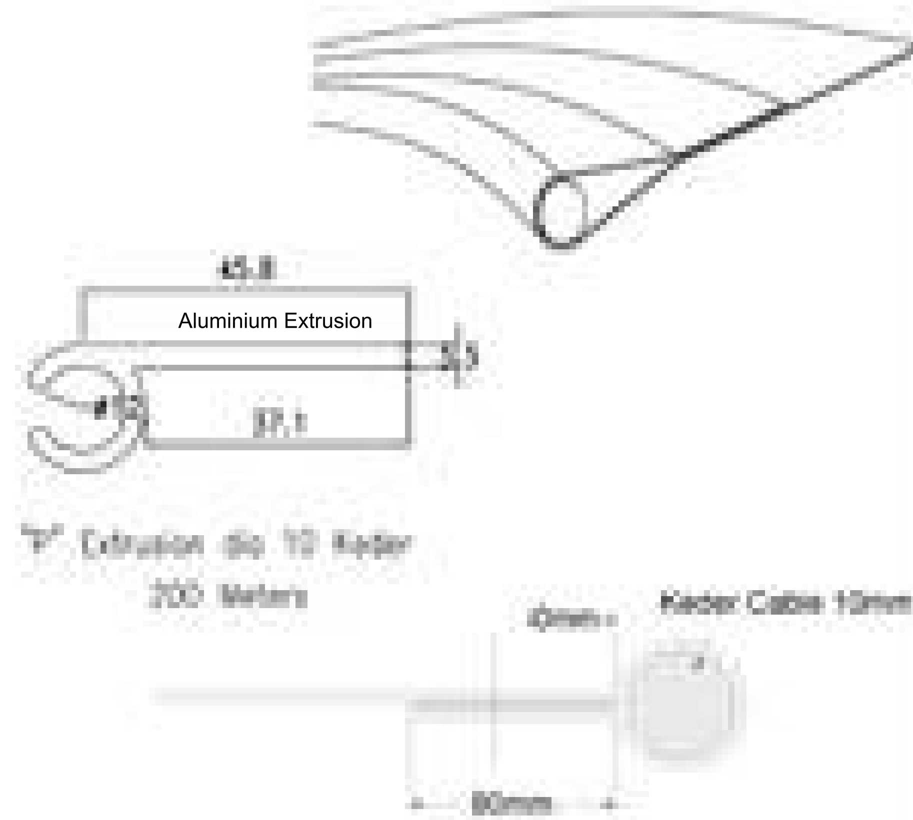


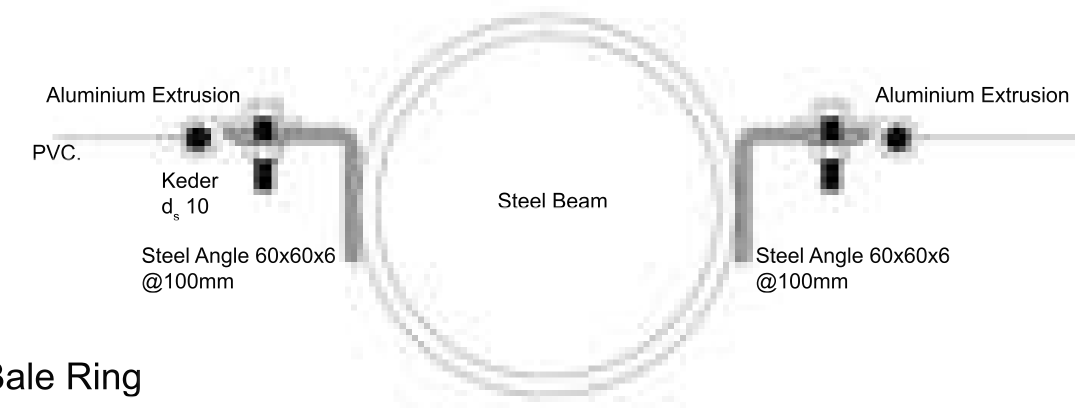
D-01 Boundry Cable- Fabric Pocket





D-03 Bale Ring





D-02 Boundry Cable- Mechanical Bracket

Thank You