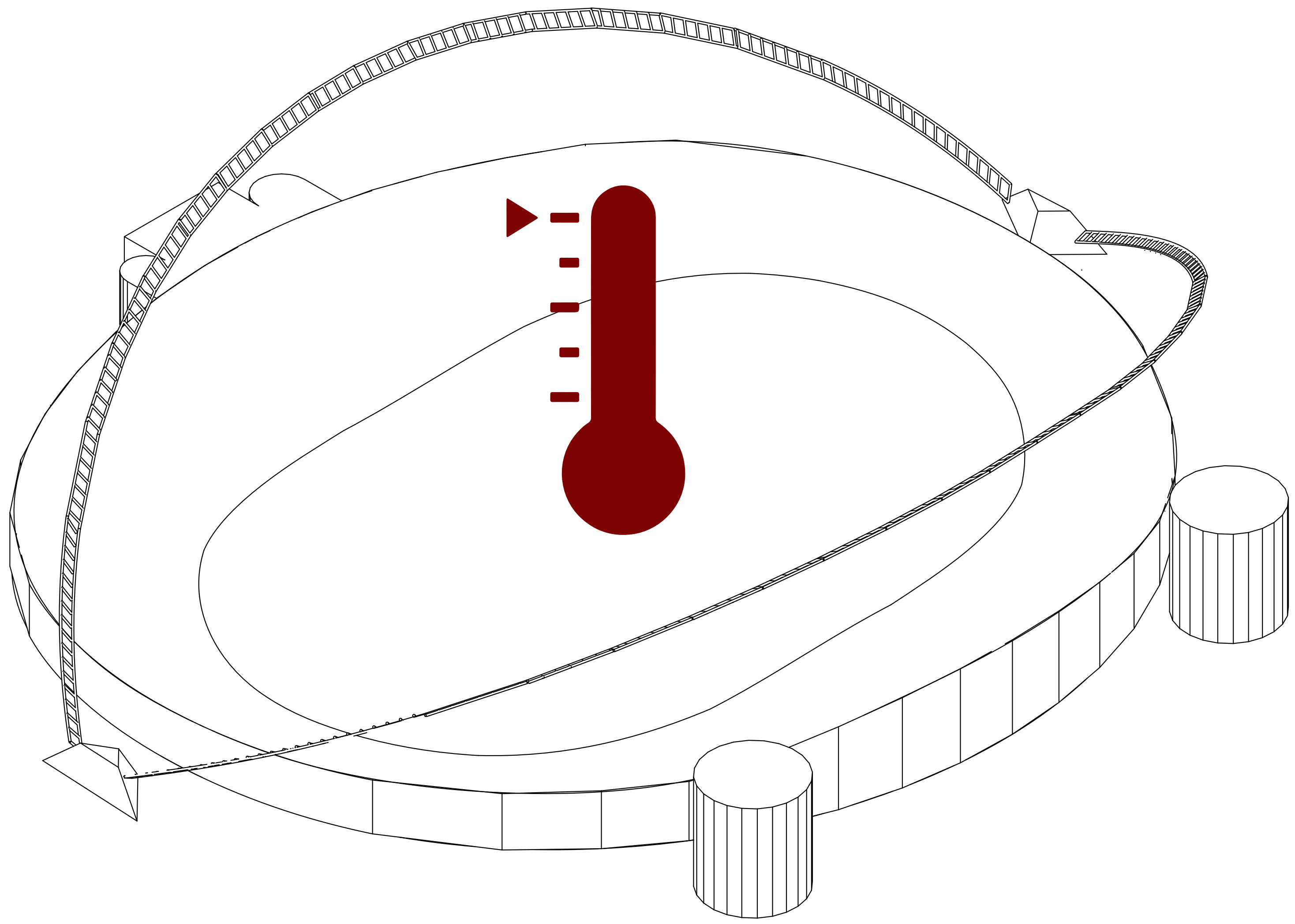
‘‘THE DESIGN OF A MAXIMISED TRANSPARENT ROOF, TO CREATE THE MOST OPTIMAL MICRO CLIMATE FOR THE KHALIFA INTERNATIONAL STADUM IN QATAR’’

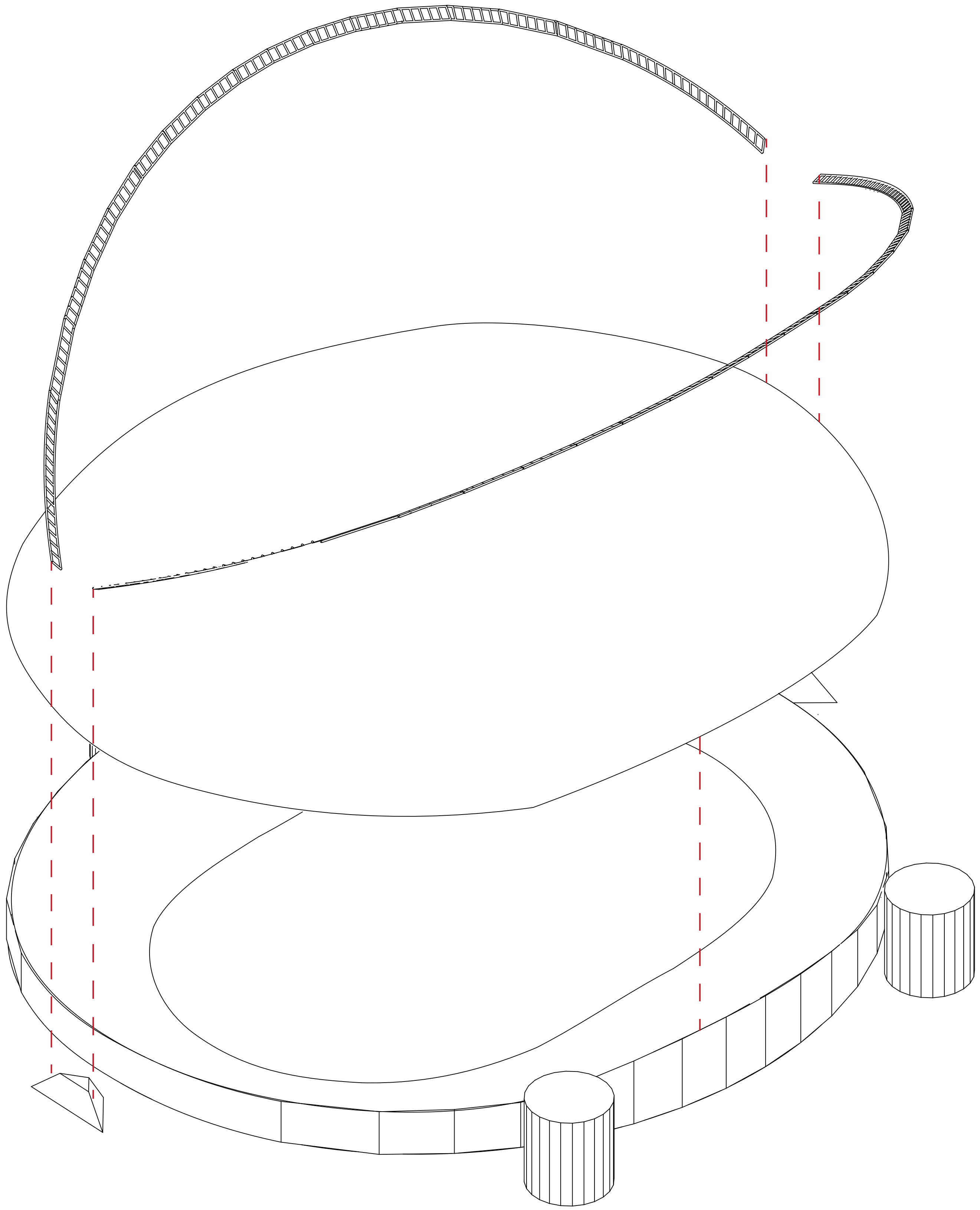
1. BACKGROUND & RESEARCH FRAMEWORK

PLANS QATAR 2022

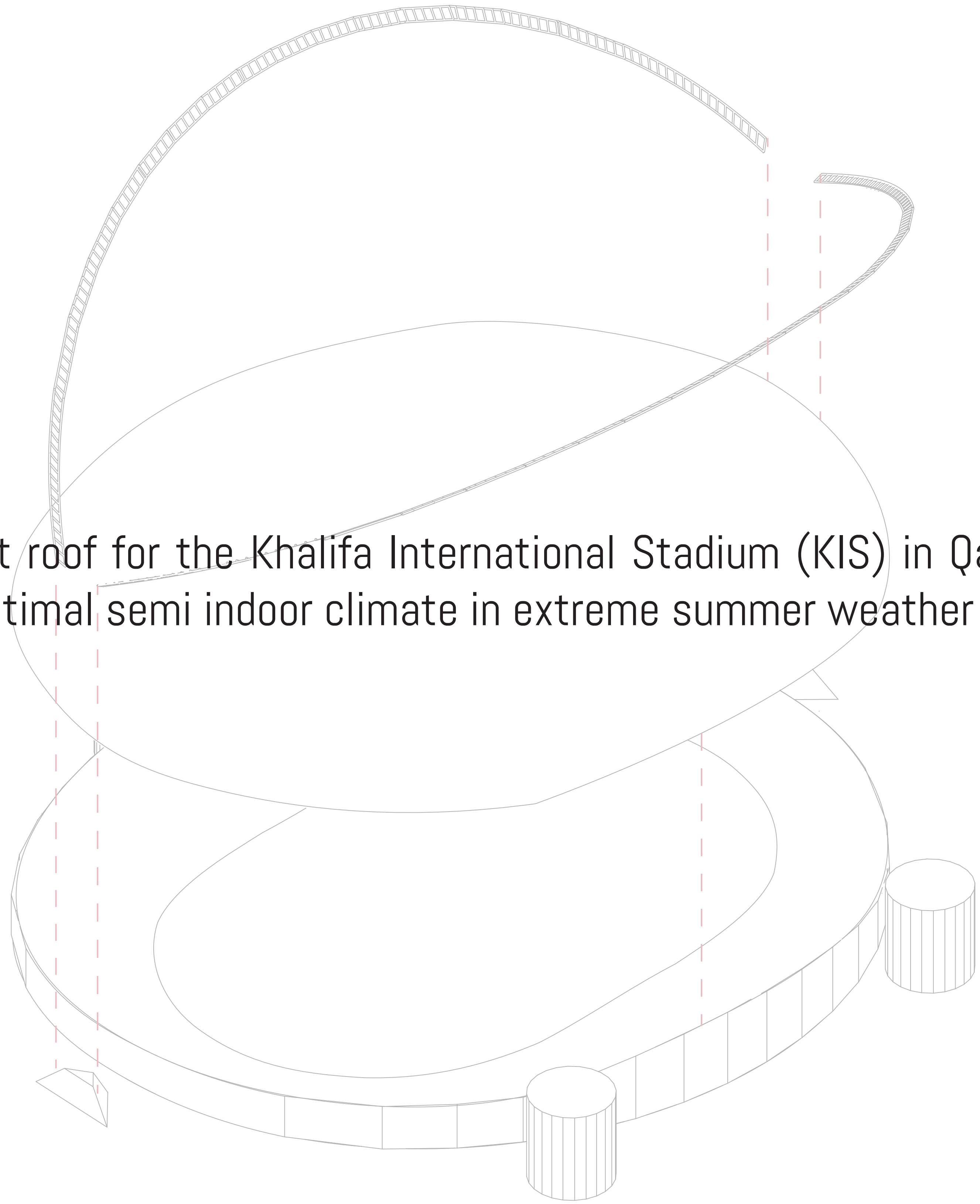
To be transformed

qatar
2022





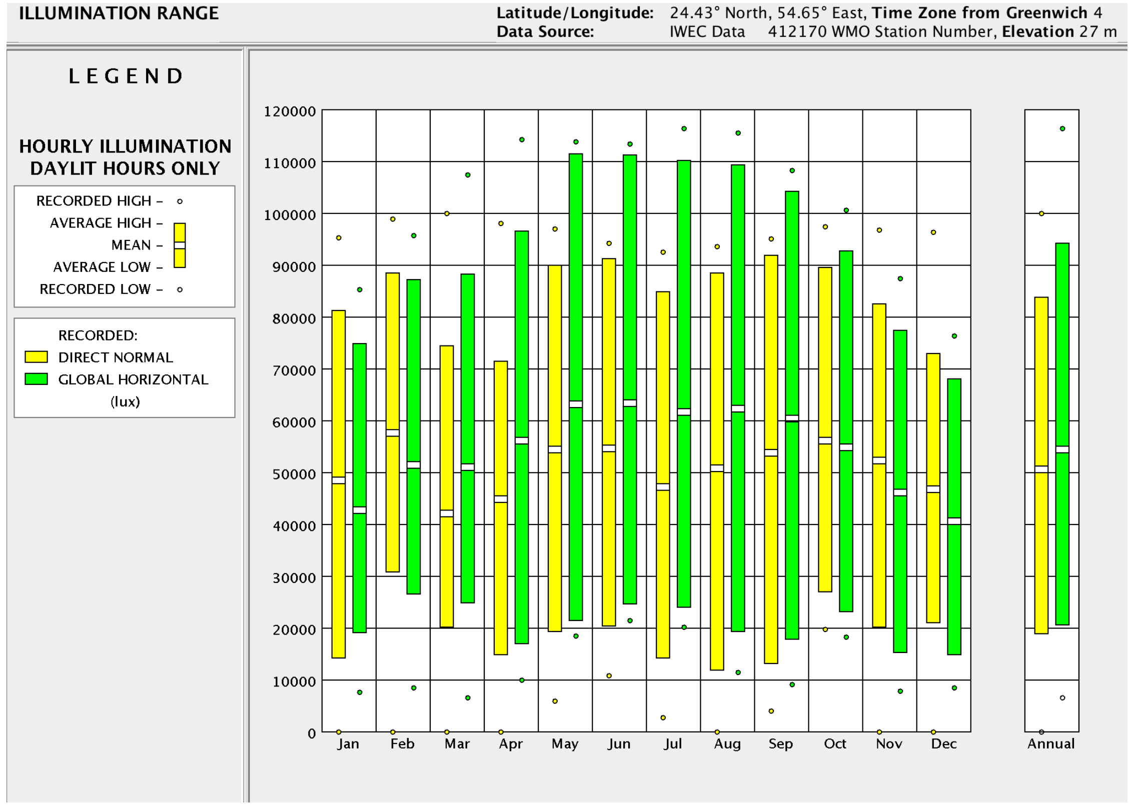
RESEARCH QUESTION

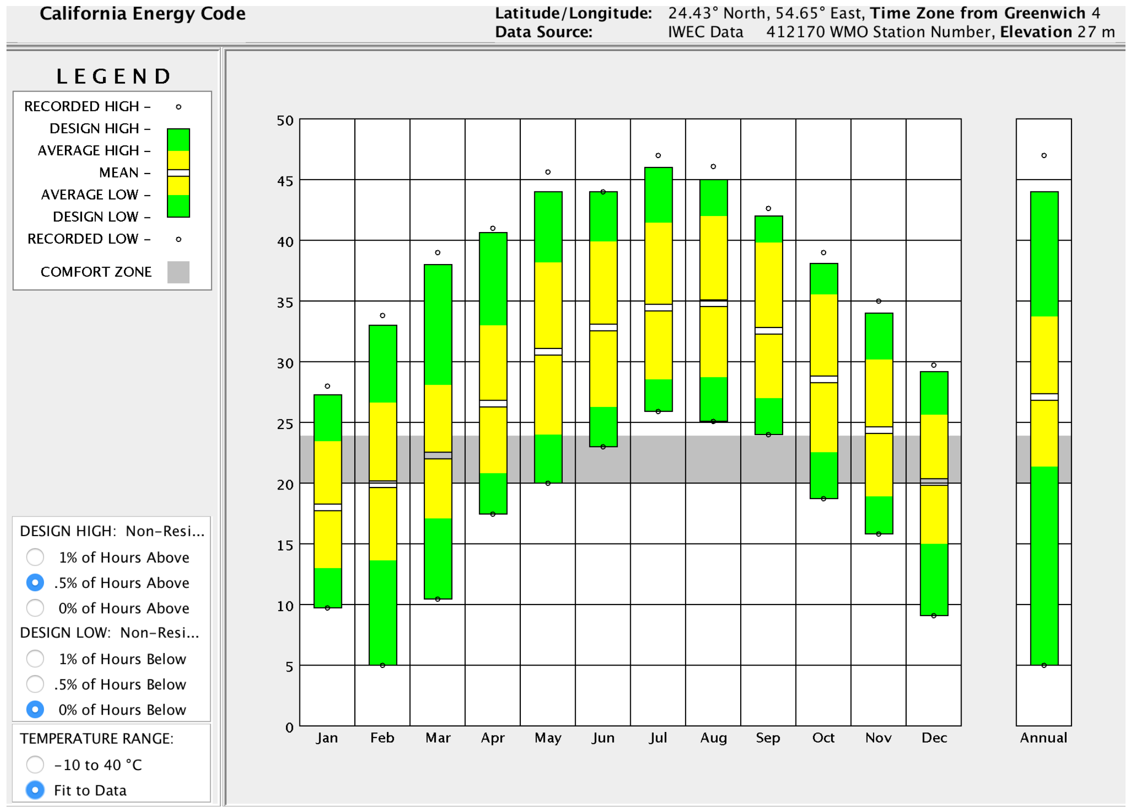


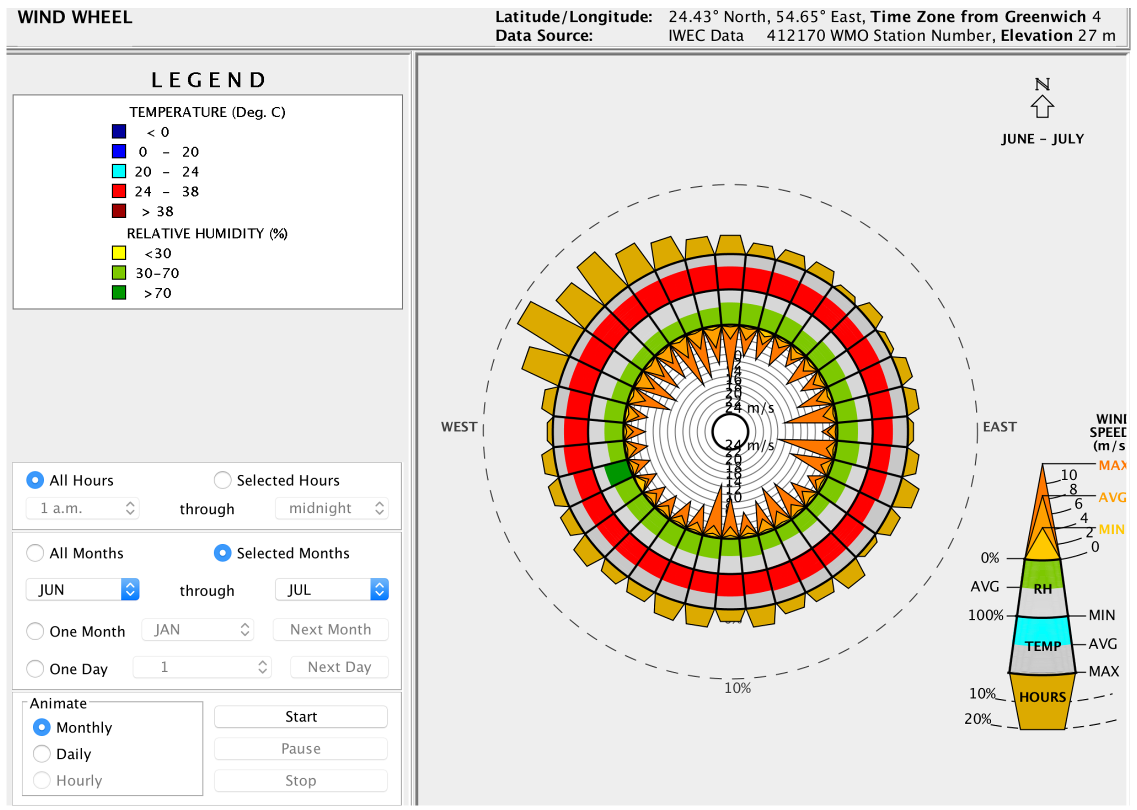
How can a maximised transparent roof for the Khalifa International Stadium (KIS) in Qatar, with efficient use of energy, create an optimal semi indoor climate in extreme summer weather conditions?

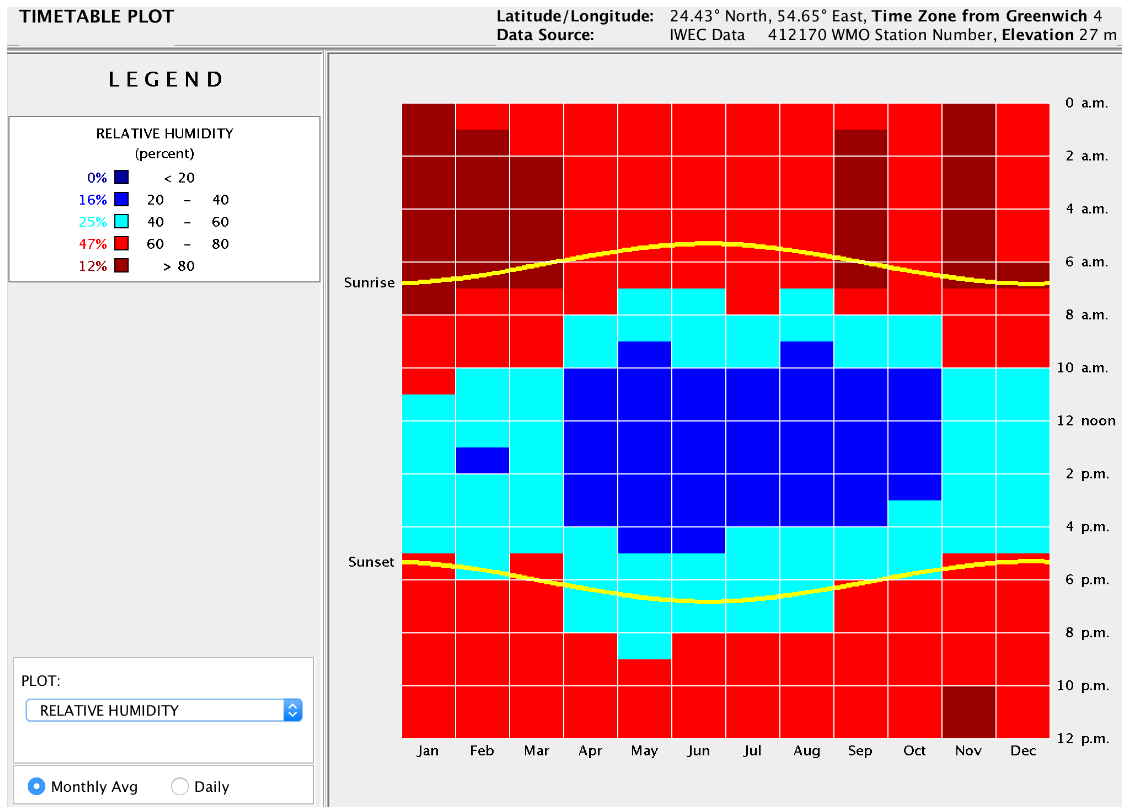
Location: Al-Rayann, Doha, Qatar | *Capacity:* 45,917 | *Function:* Multi-purpose (Football, Track & Field, etc.)

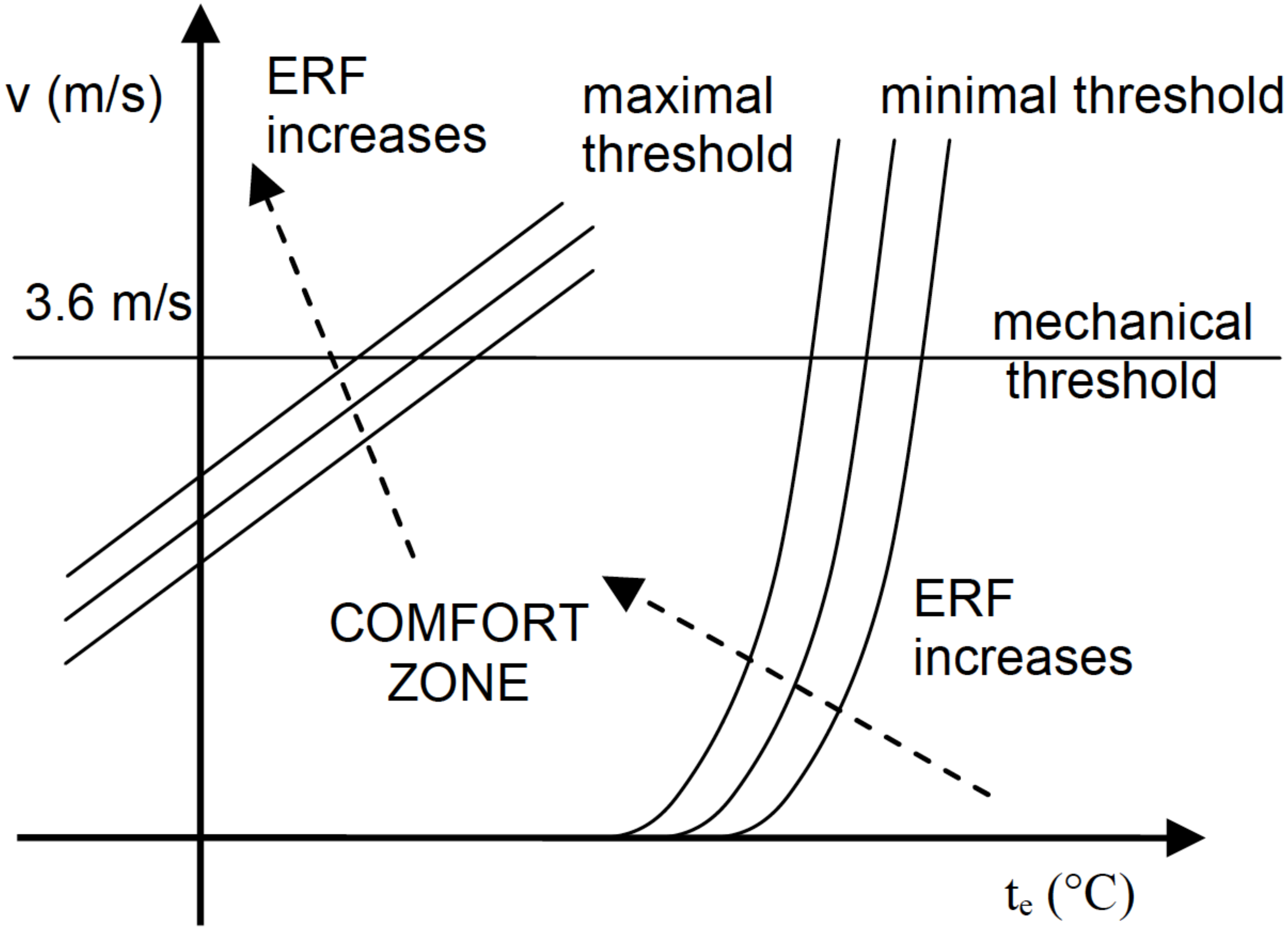
QATAR CLIMATE SITUATION





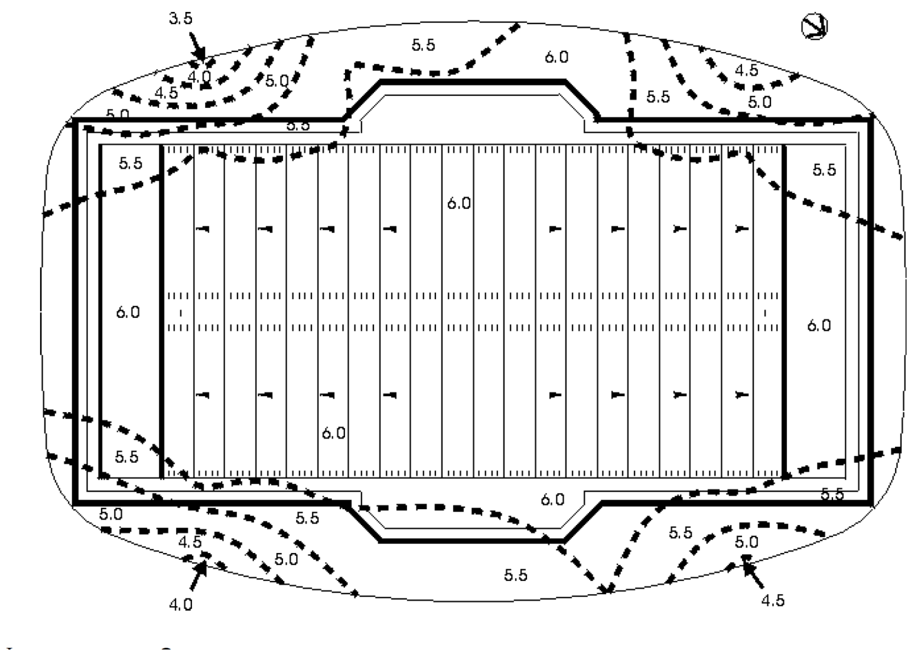


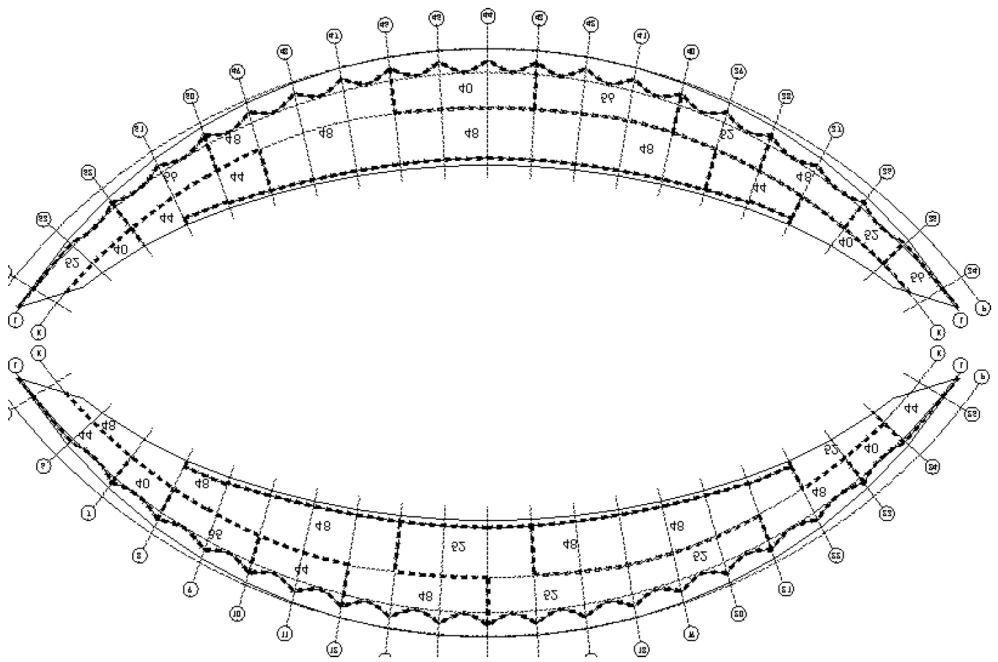



v (m/s)
ERF
increases
maximal
threshold
minimal threshold
3.6 m/s
mechanical
threshold
COMFORT
ZONE
ERF
increases
t_e (°C)

2. CASE STUDIES

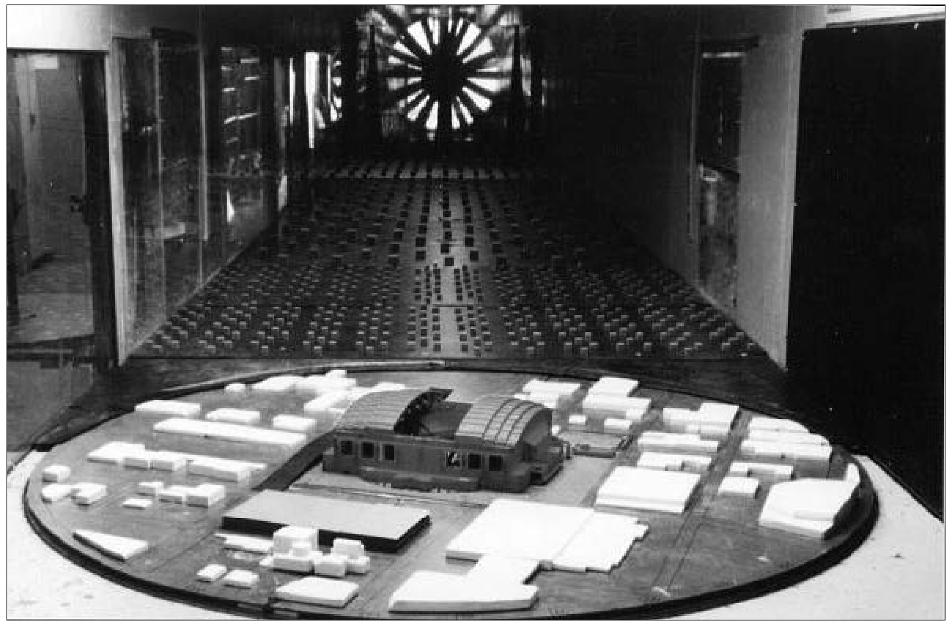
PAUL BROWN STADIUM, CINCINNATI, OHIO, USA



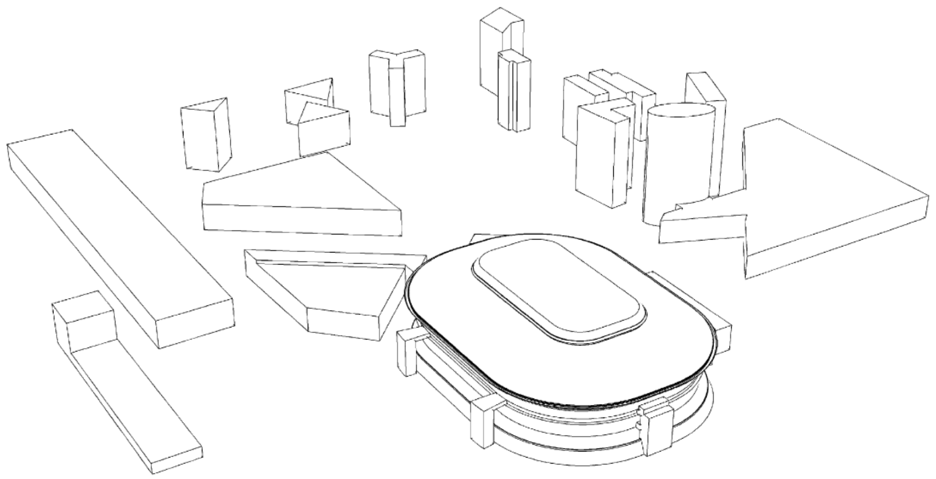



BANK ONE BALLPARK
THE ARIZONA REPUBLIC

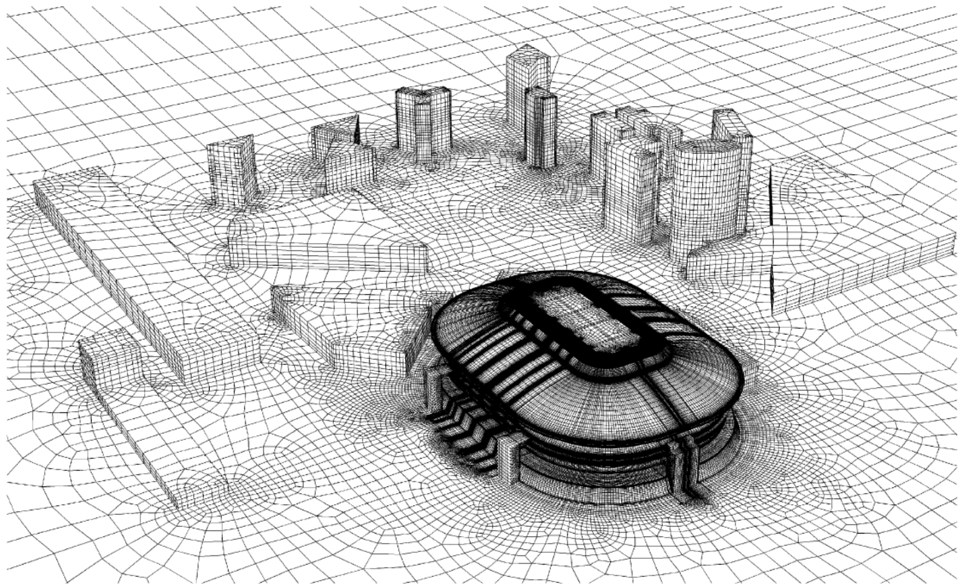

CHASE FIELD



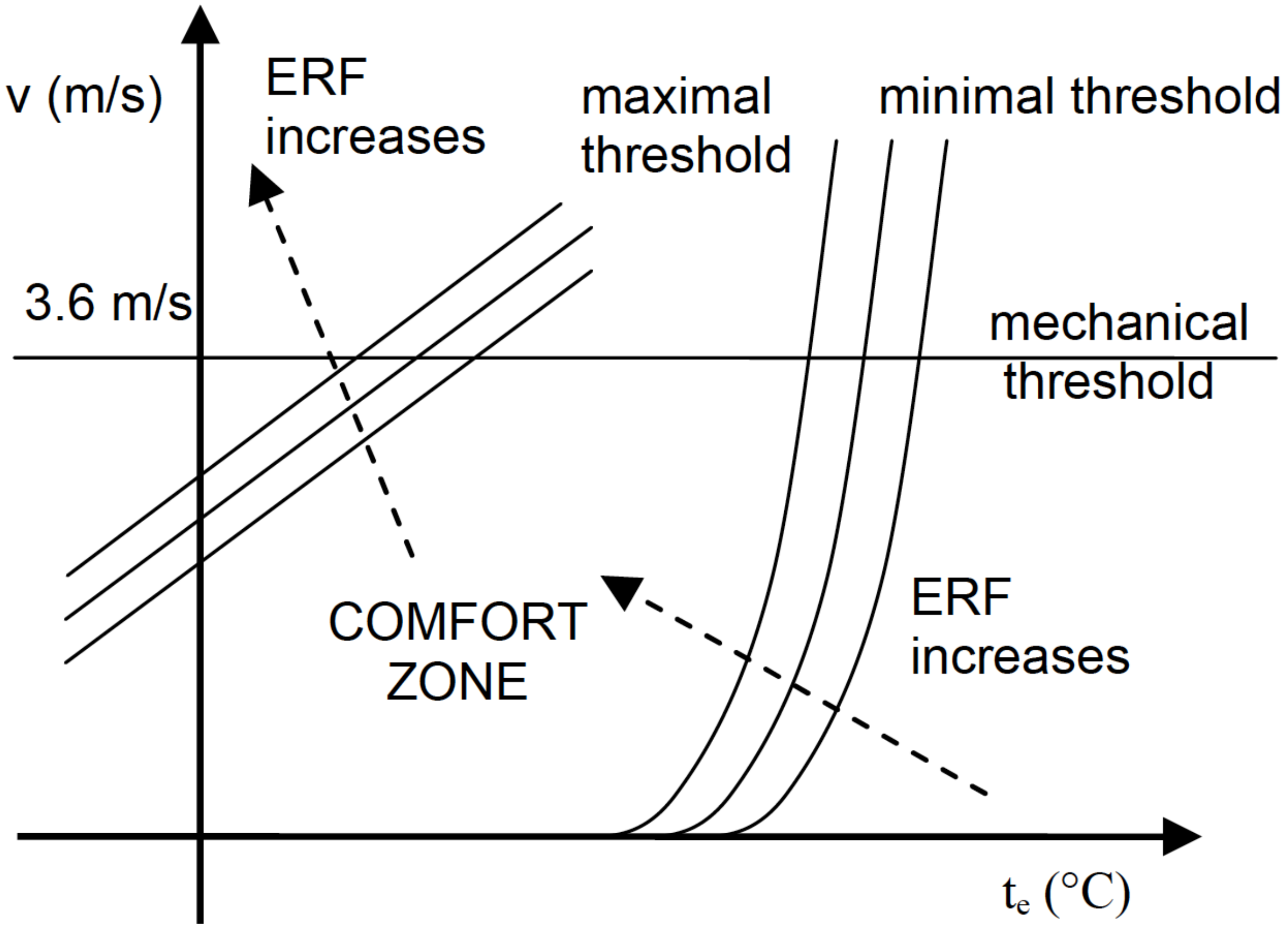
a



b



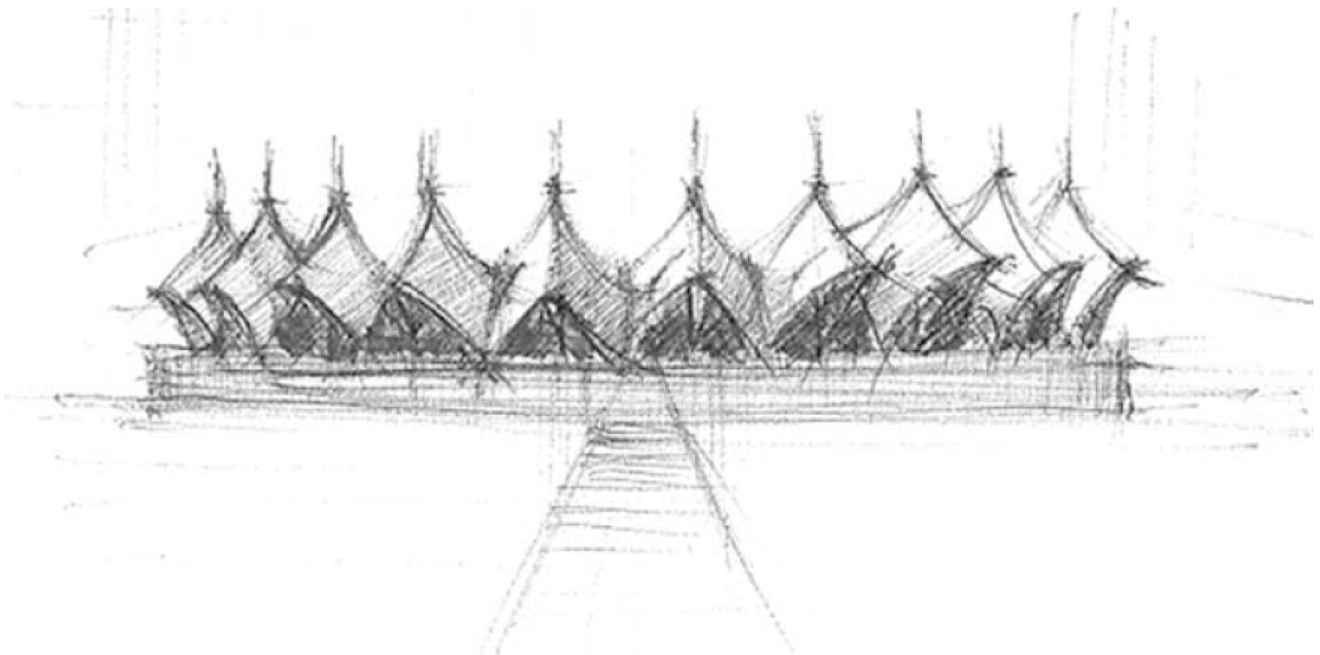
3. CLIMATE DESIGN THEORY RESEARCH: SEMI-INDOOR ENVIRONMENTAL QUALITY

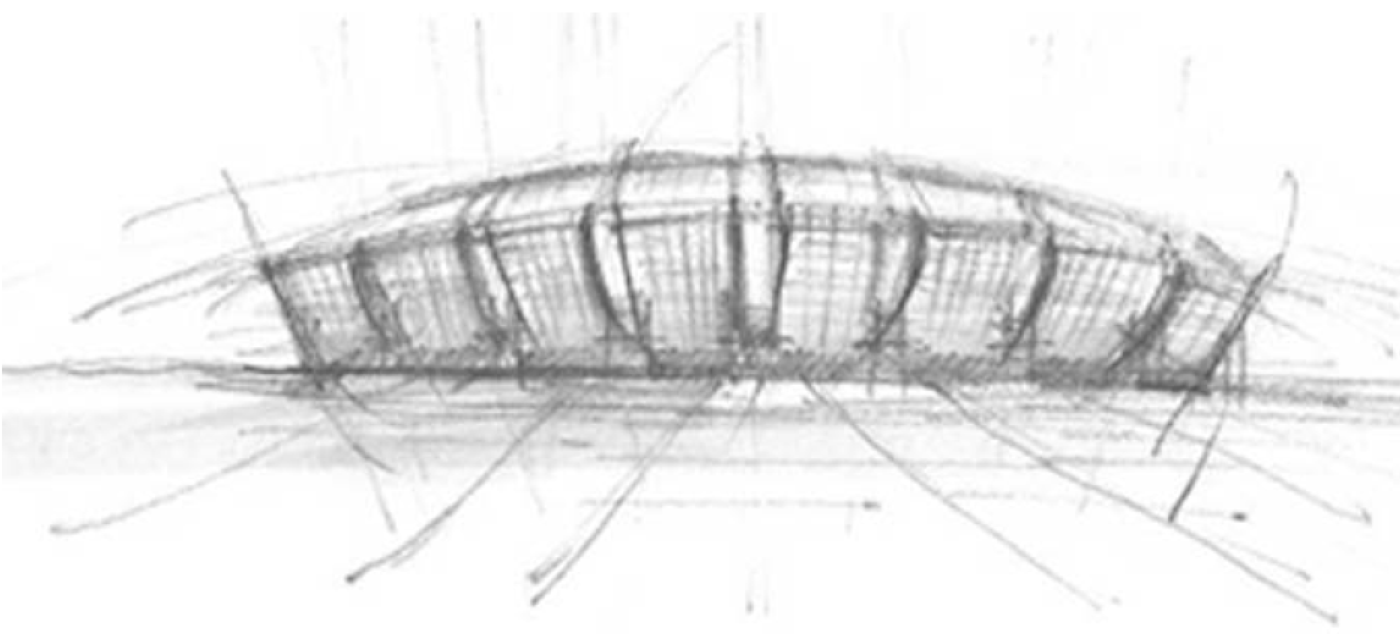


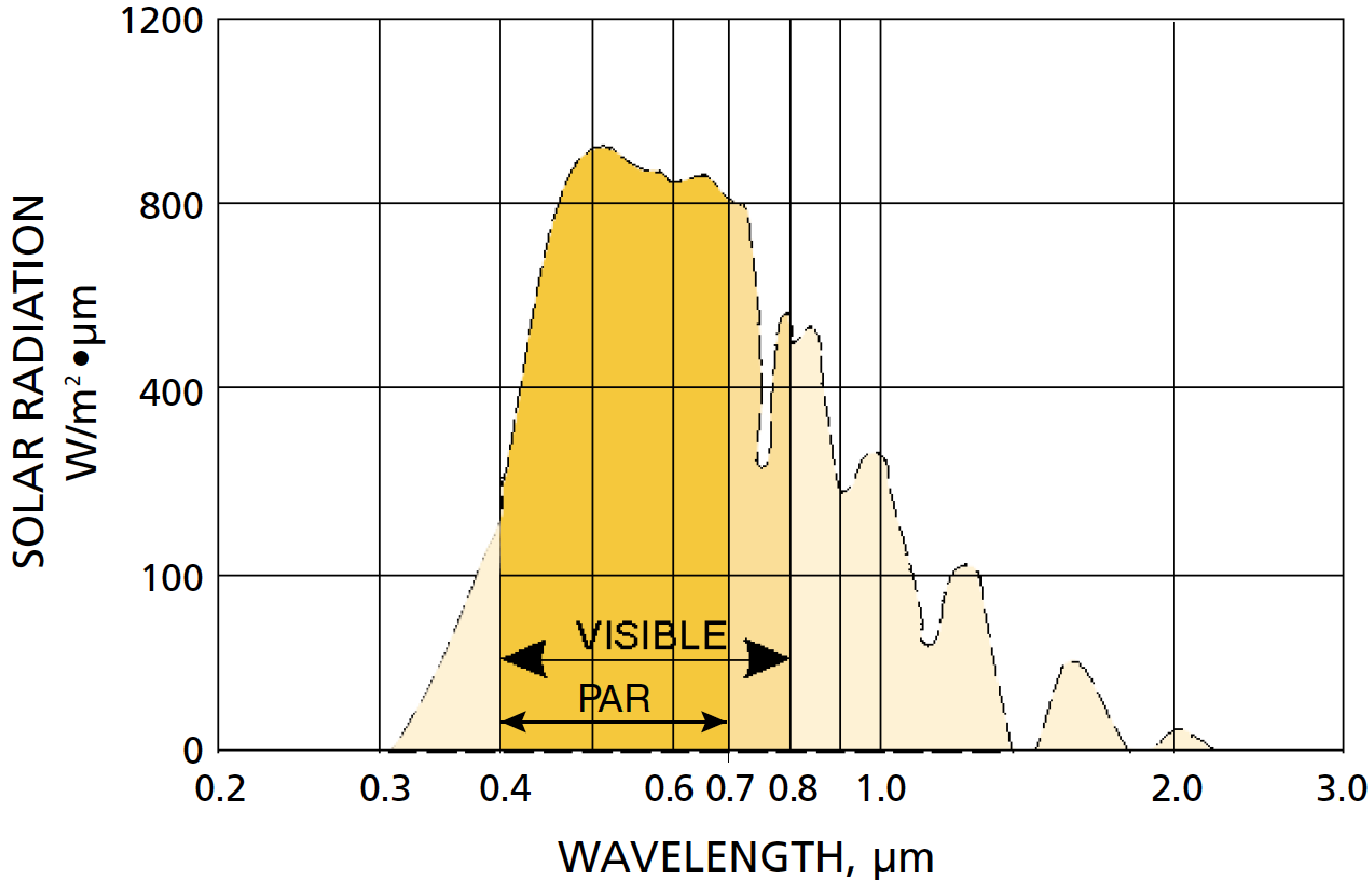
$$WCI = (12.15 + 11.6\sqrt{v} - v)\times(33 - DBT)$$

$$WCT = 33 - 0.03738\times WCI$$

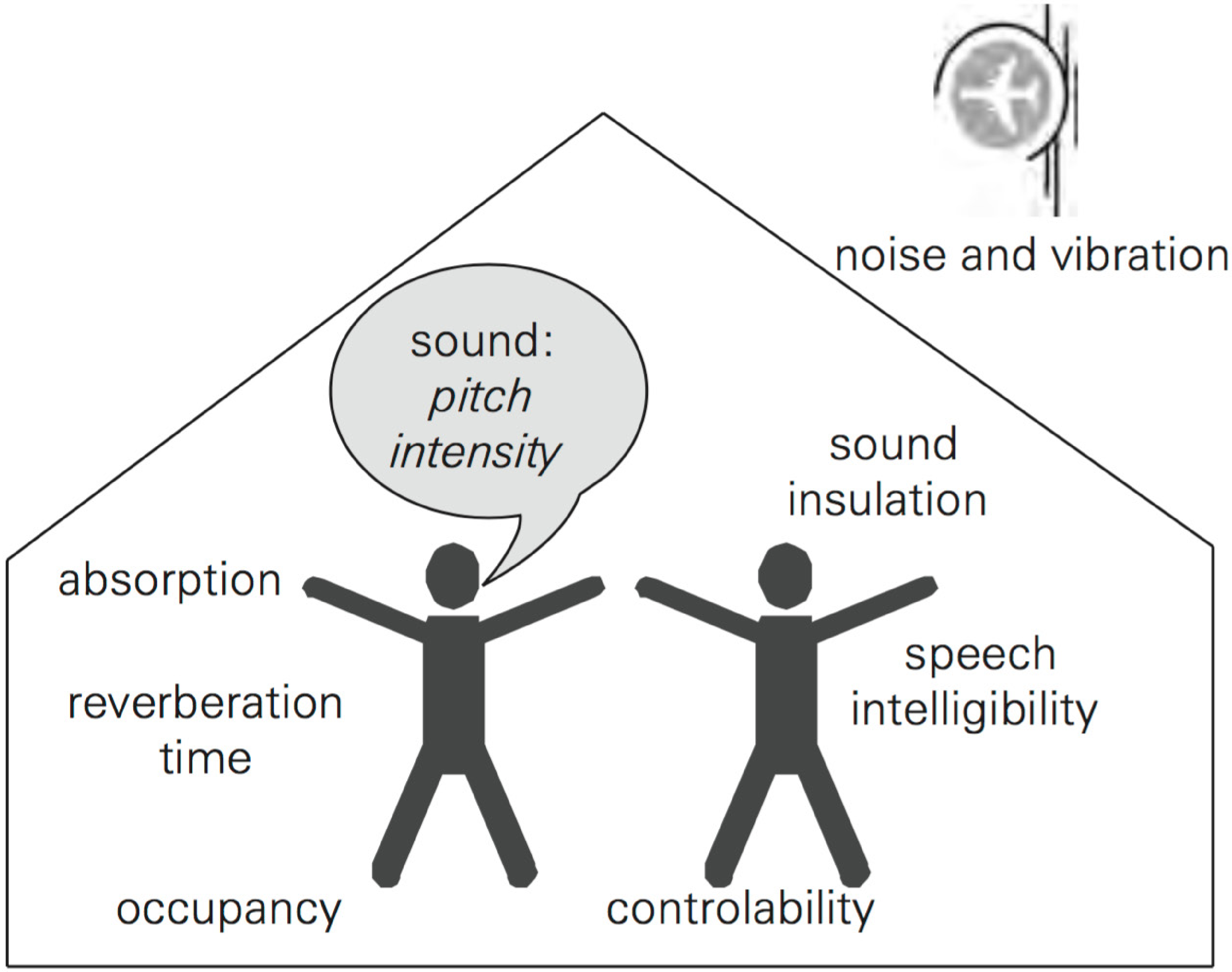
$$DR = (34 - t_a)\cdot(v_a - 0.05)^{0.62}\cdot(3.14 + 0.37\cdot T_u\cdot v_a)\ [\%]$$





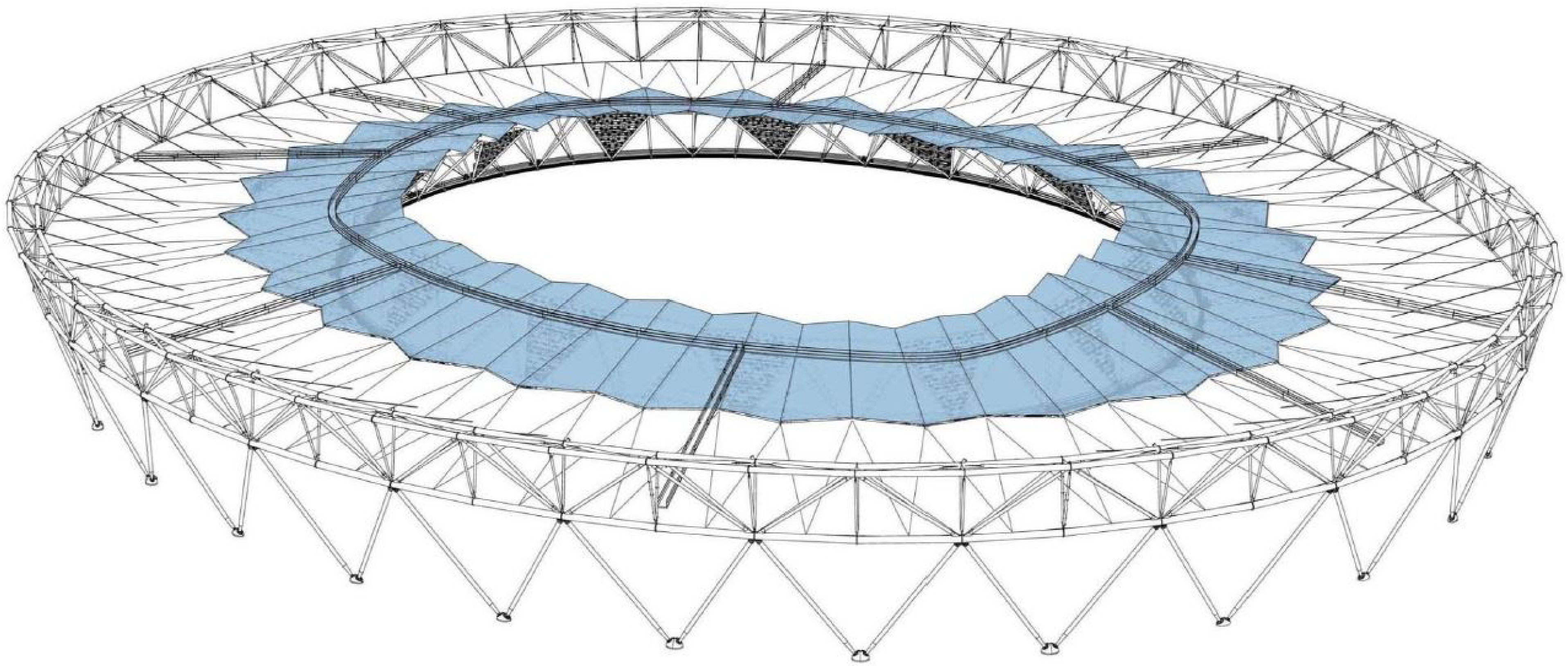


$$PAR = 0.45 \cdot L_{e,\Omega} \left[\frac{Wh}{m^2}\right]$$

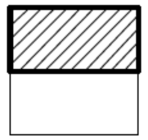
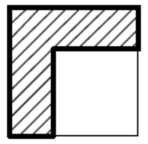
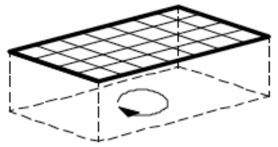


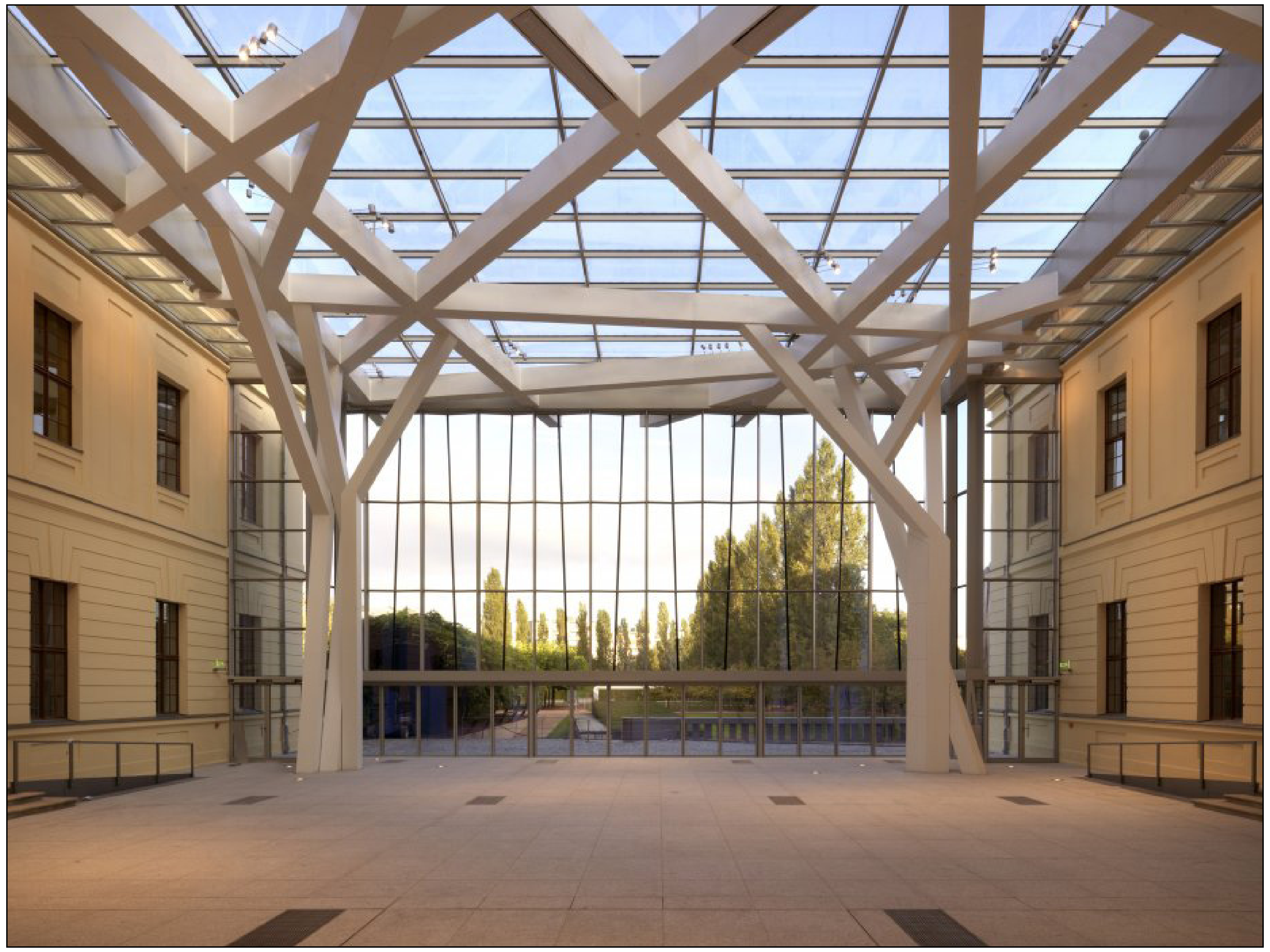
$$T = 0.166 \cdot \frac{V}{A} \text{ [s]}$$

4. STRUCTURAL DESIGN THEORY RESEARCH: STRUCTURAL STADIUM ROOFING



Steel grade and subgrade	f_y: N/mm^2 Nominal thickness of element, t: mm				f_u: N/mm^2 Nominal thickness t: mm
	$t \leq 16$	$16 < t \leq 40$	$40 < t \leq 63$	$63 < t \leq 80$	$3 \leq t \leq 100$
S275JR					
S275J0	275	265	255	245	410
S275J2					
S355JR	355	345	335	325	470
S355J0					
S355J2					
S355K2					
S355JOH	355	345	335	325	470
S355J2H					
S355K2H					

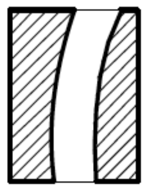
Roof shape		Ground plan		Orientation/Functional form	Load-bearing system/Mechanical form			
Flat				**Glass courtyard**	**One-dimensional**		**Two-dimensional**	
	horizontal					beam		slab



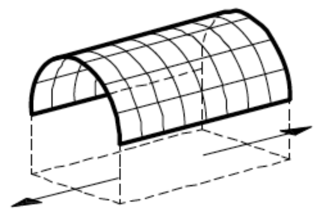
Folded/Curved

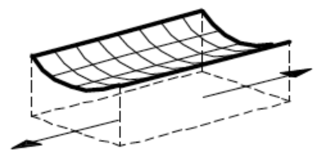
convex curvature

concave curvature



Glass band





Two-dimensional

arch

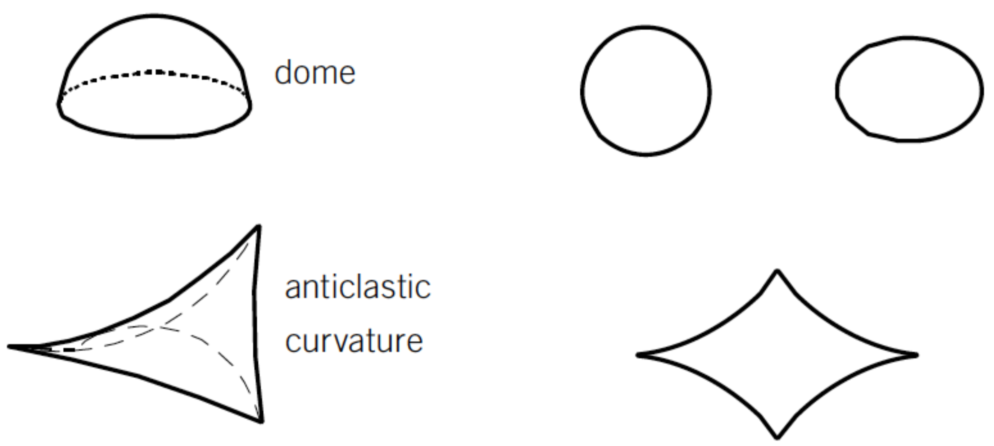
cable

Three-dimensional

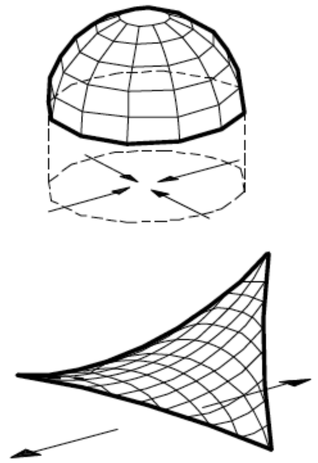
barrel

cable roof/
suspended roof

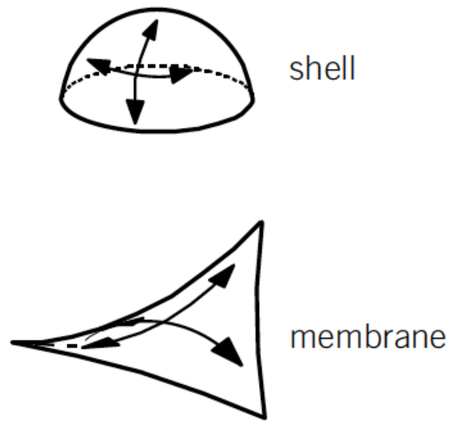
Double folded/Curved



Glass core

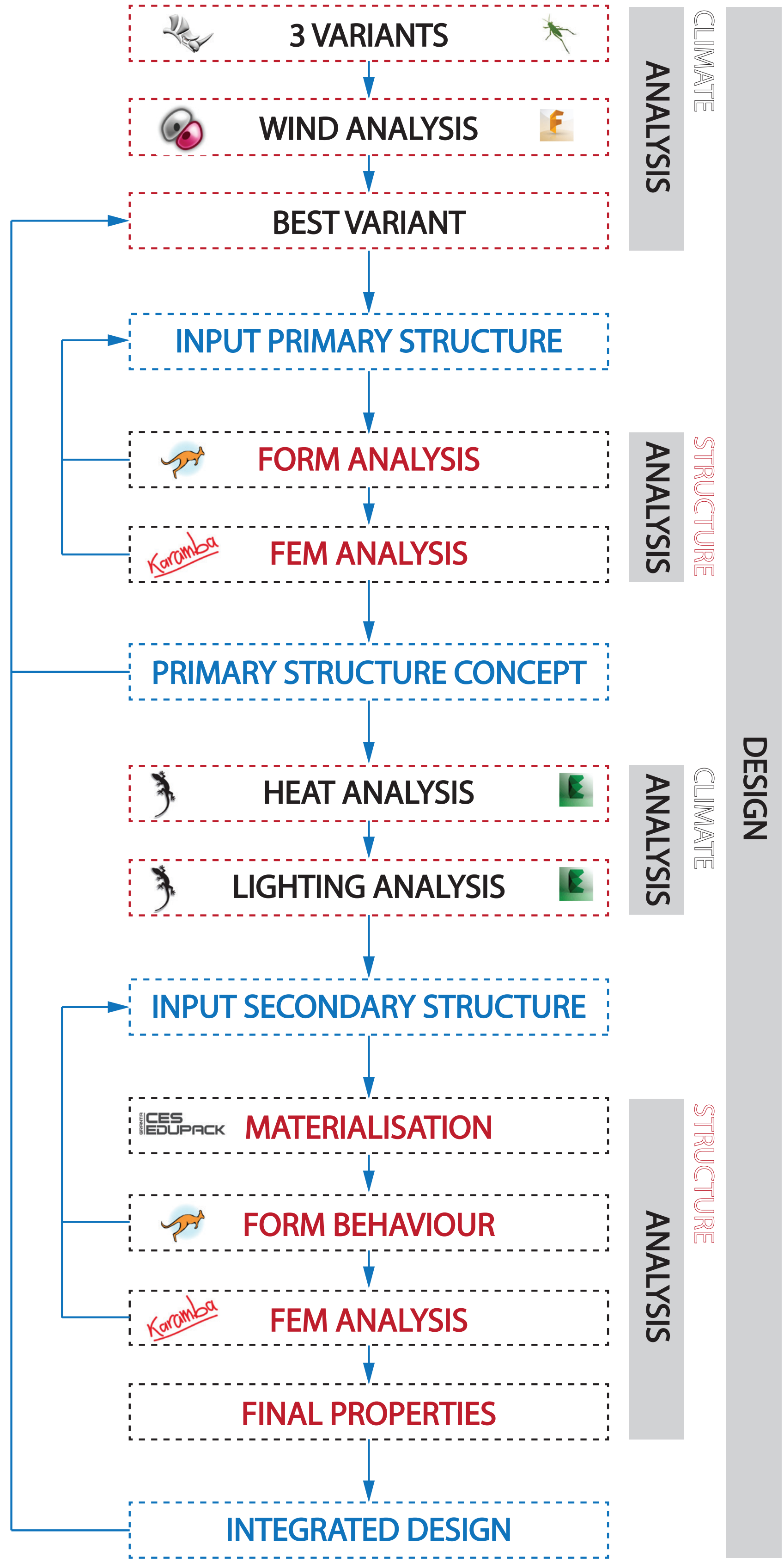


Three-dimensional

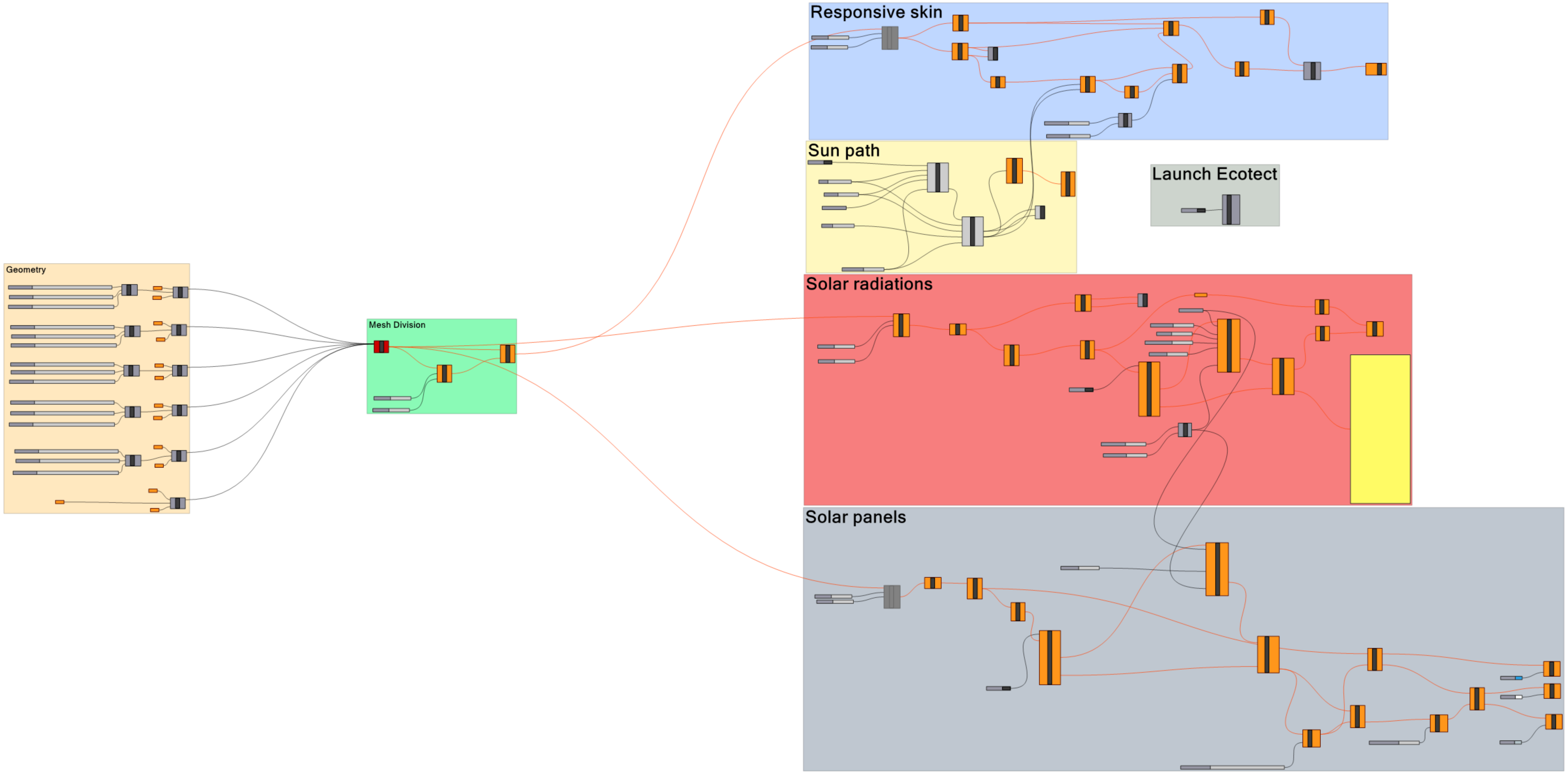


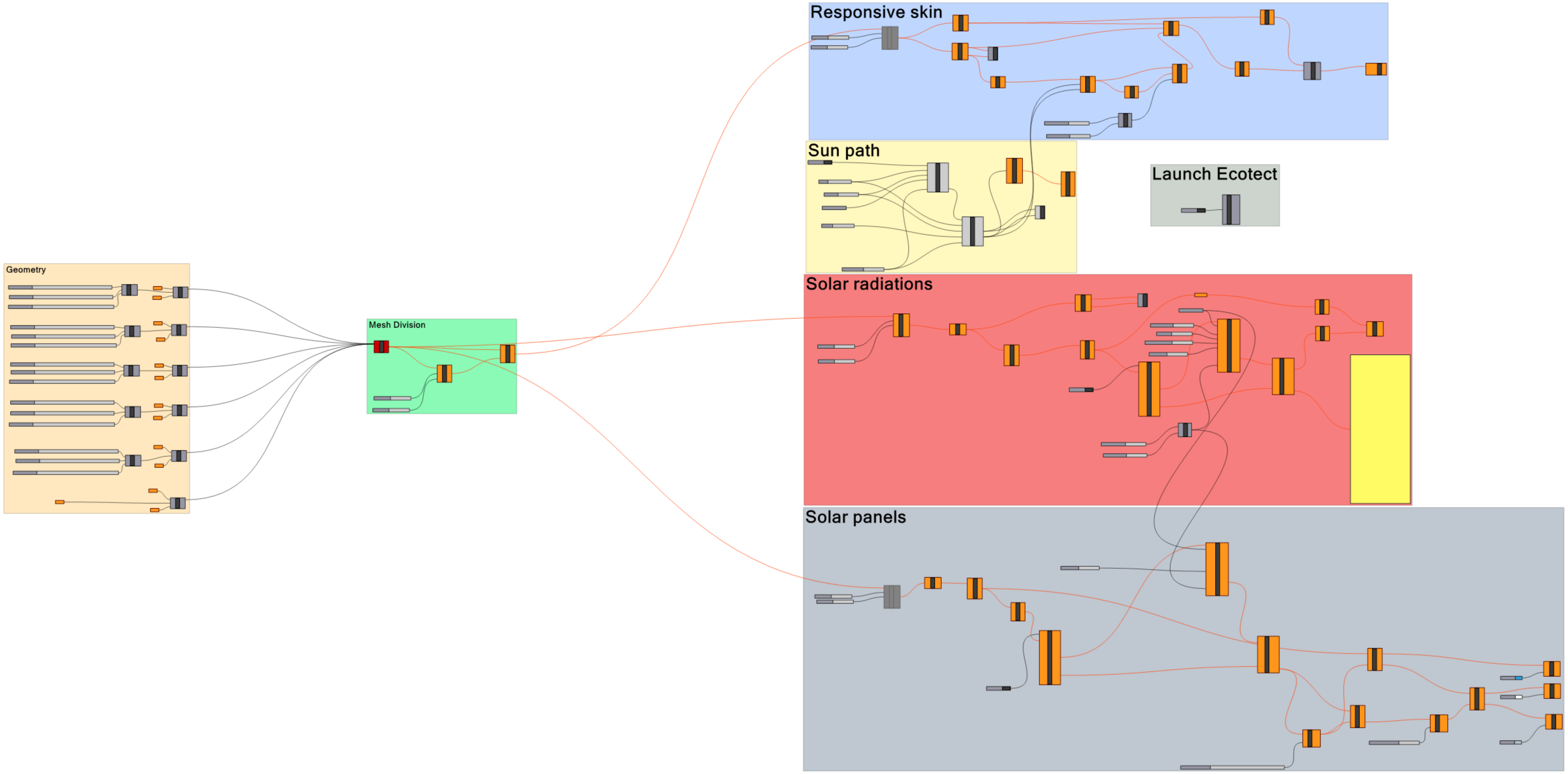
5. ROOF DESIGN ANALYSIS

CLIMATE VS. STRUCTURE ANALYSIS METHODOLOGY



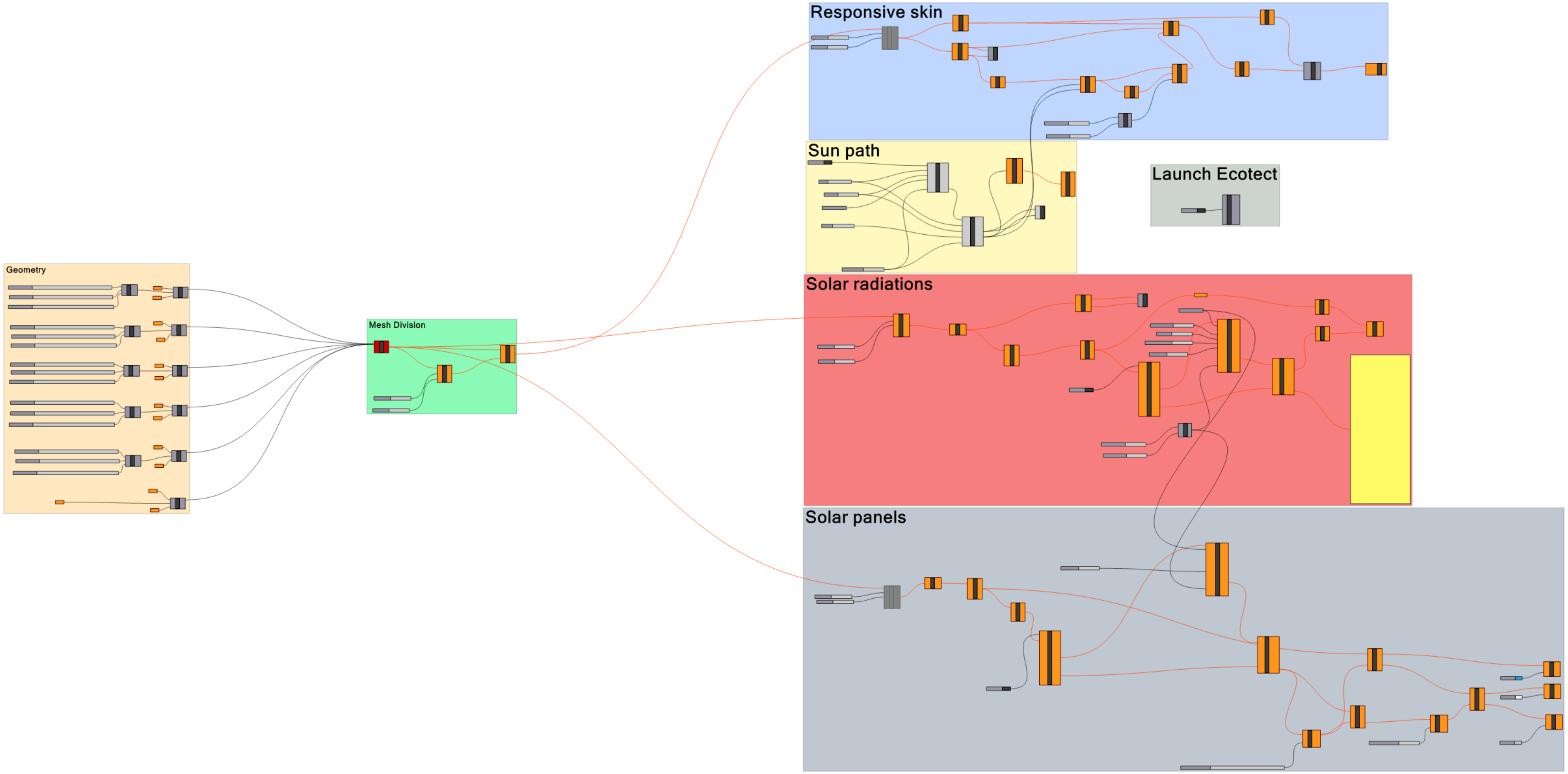
CLIMATE ANALYSIS TOOLS




Geometry
Mesh Division
Responsive skin
Sun path
Launch Ecotect
Solar radiations
Solar panels


grasshopper
GENERATIVE MODELING
FOR RHINO

CLIMATE ANALYSIS TOOLS

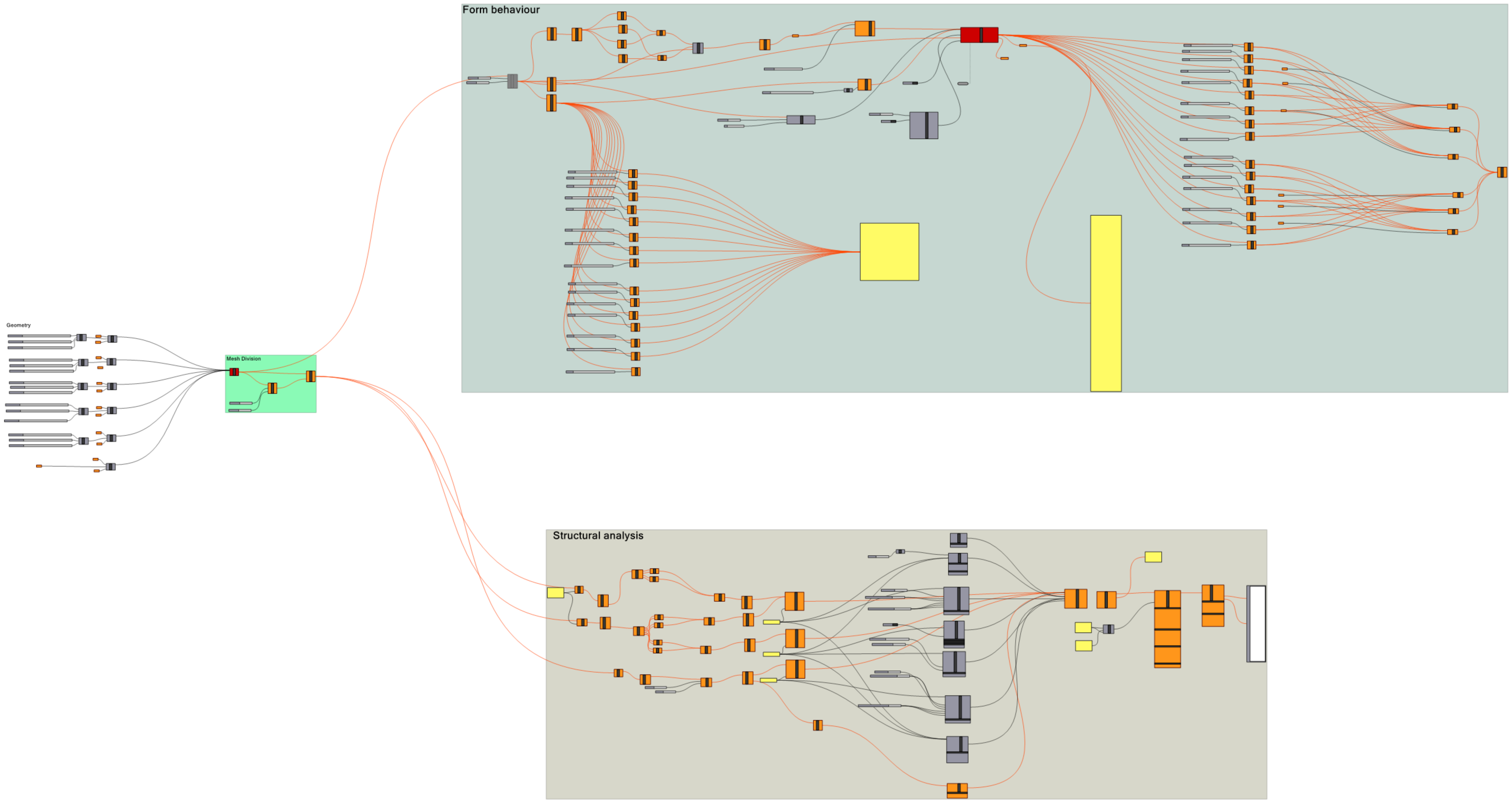


grasshopper
GENERATIVE MODELING FOR RHINO

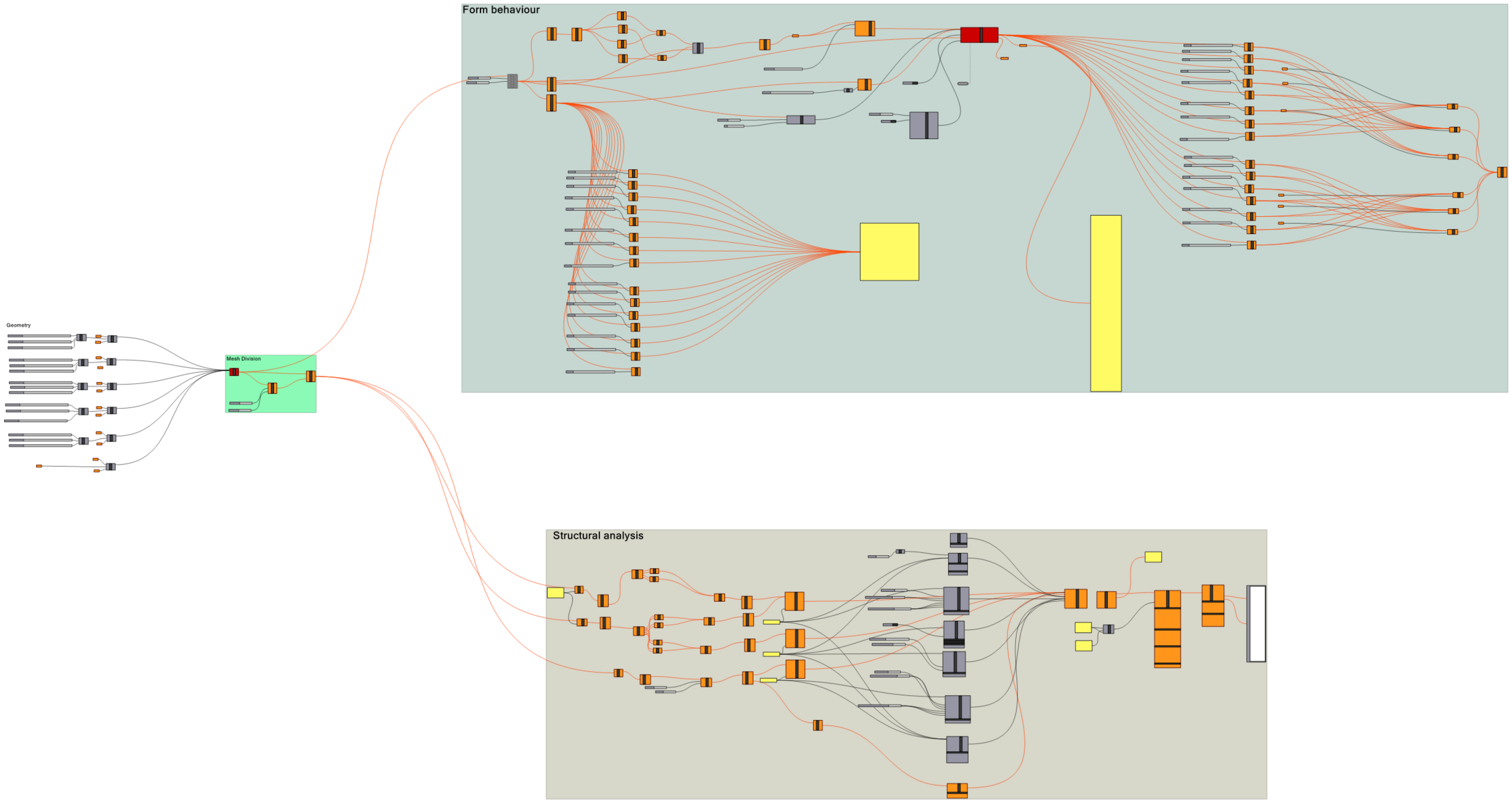
AUTODESK® ECOTECT ANALYSIS

AUTODESK® FLOW DESIGN

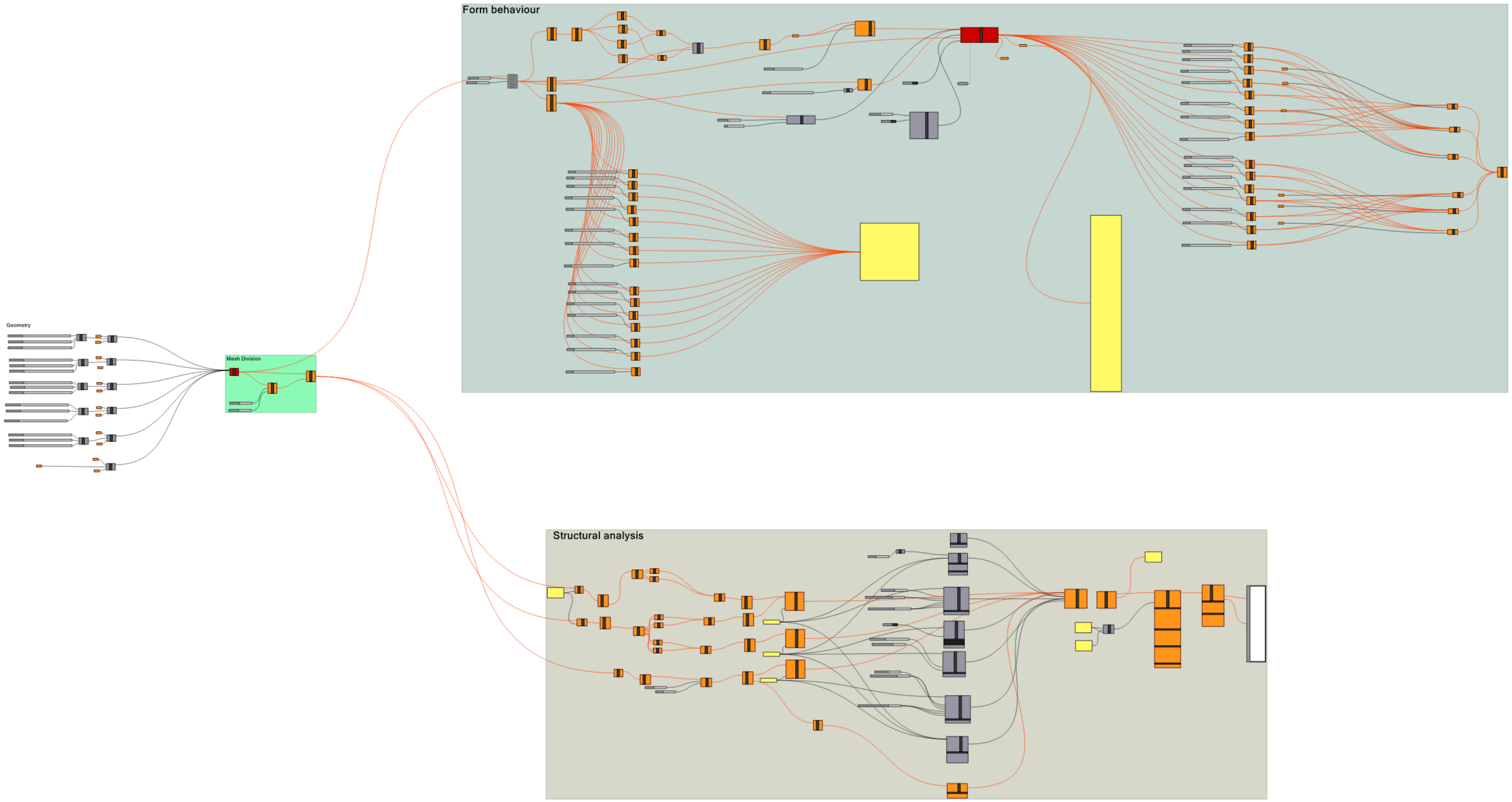
STRUCTURAL ANALYSIS TOOLS



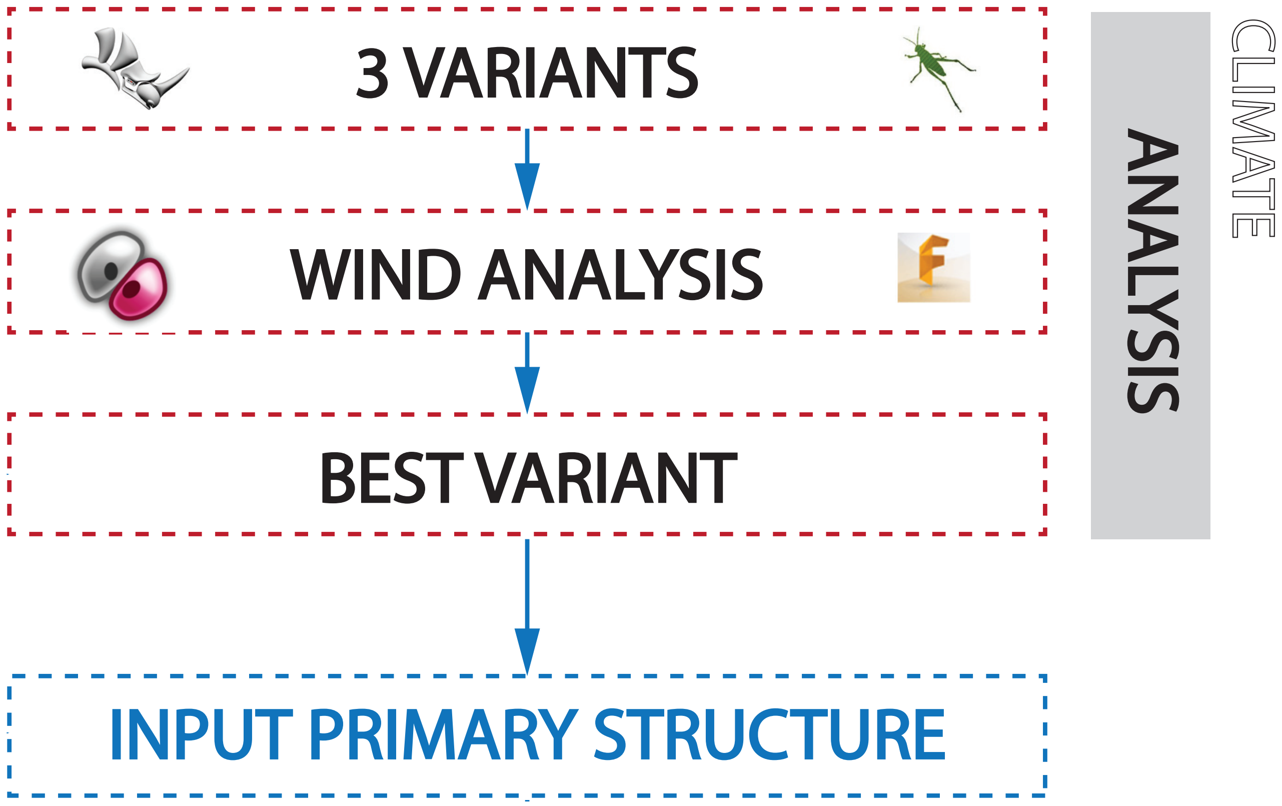
STRUCTURAL ANALYSIS TOOLS



STRUCTURAL ANALYSIS TOOLS

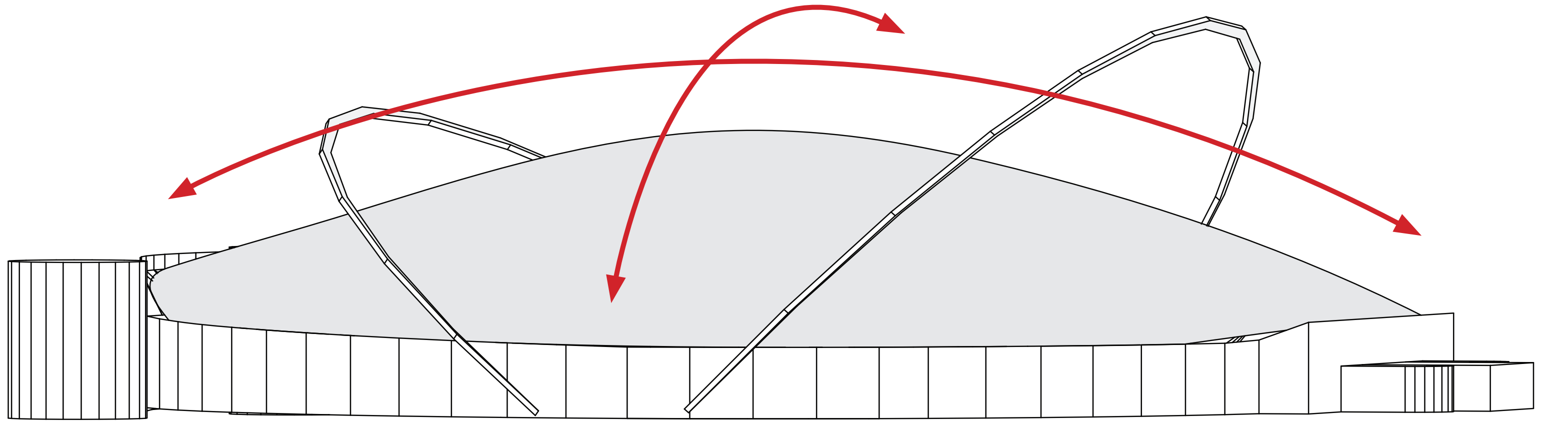


5.1 WIND DESIGN ANALYSIS

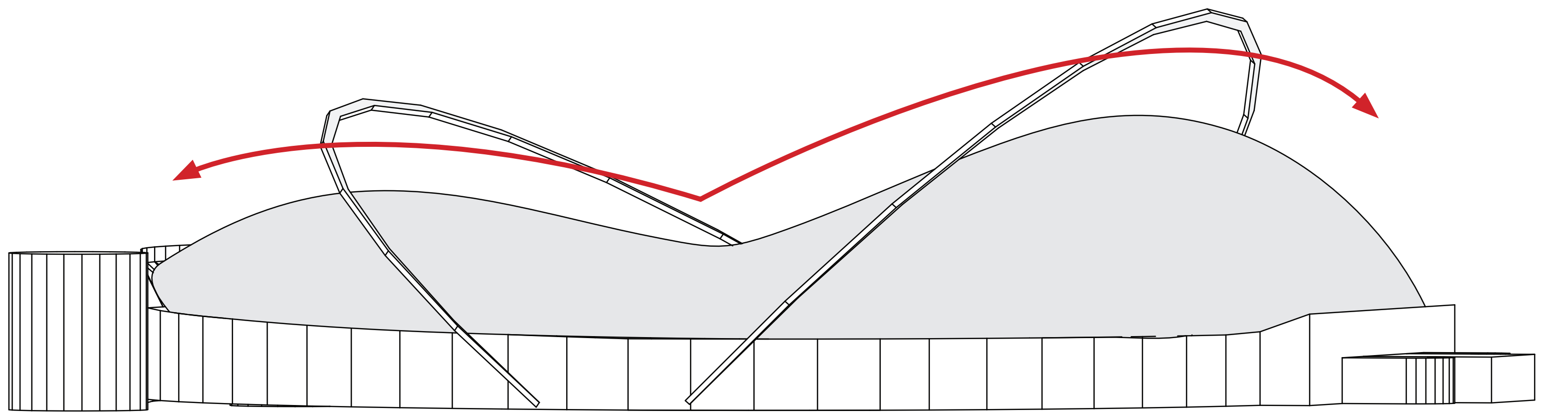


VARIANTS

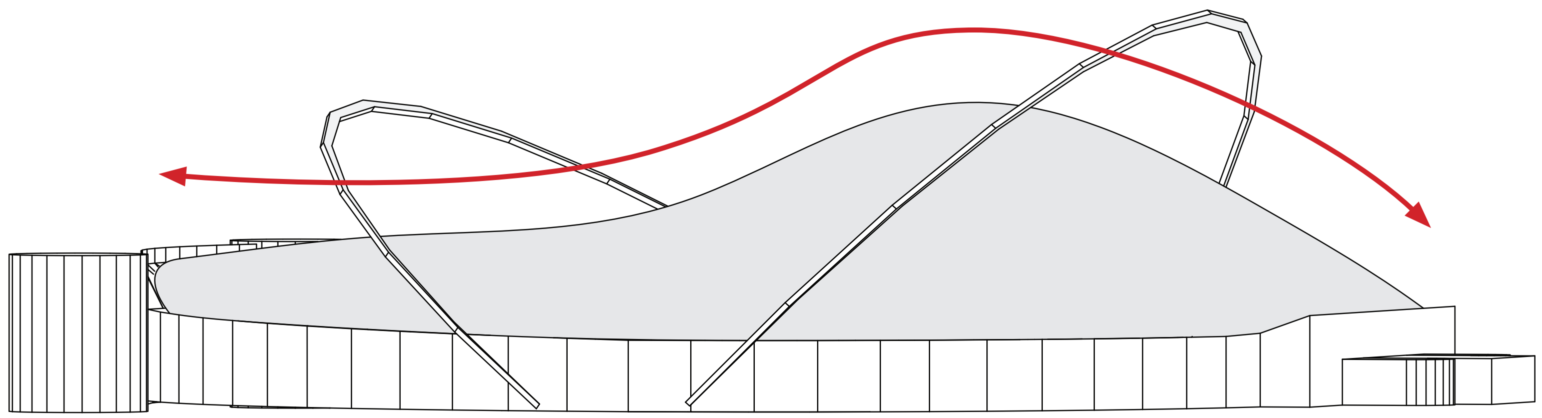
1



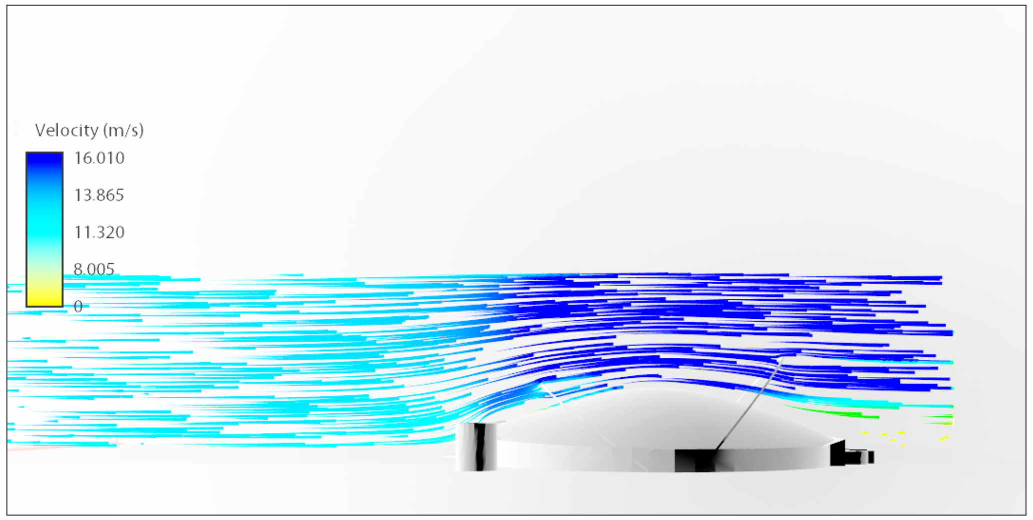
2

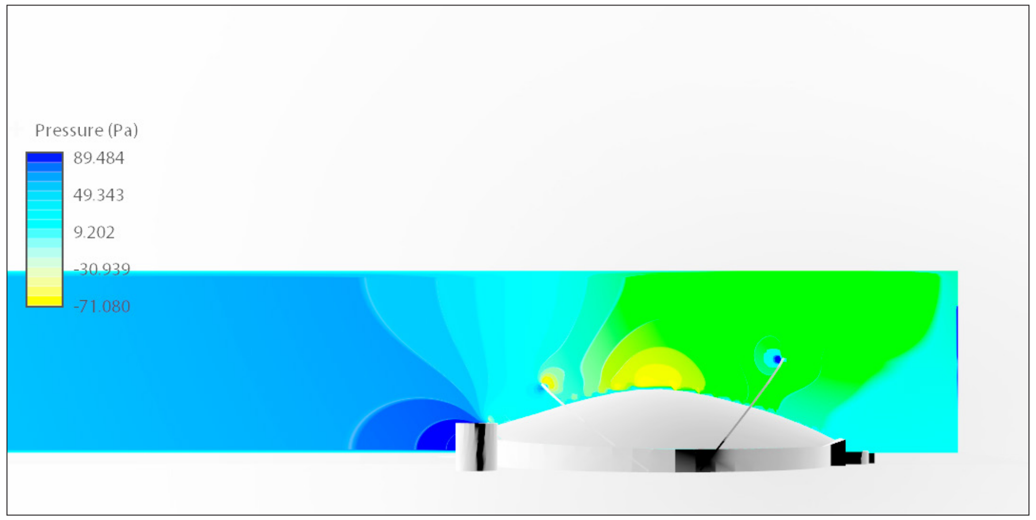


3

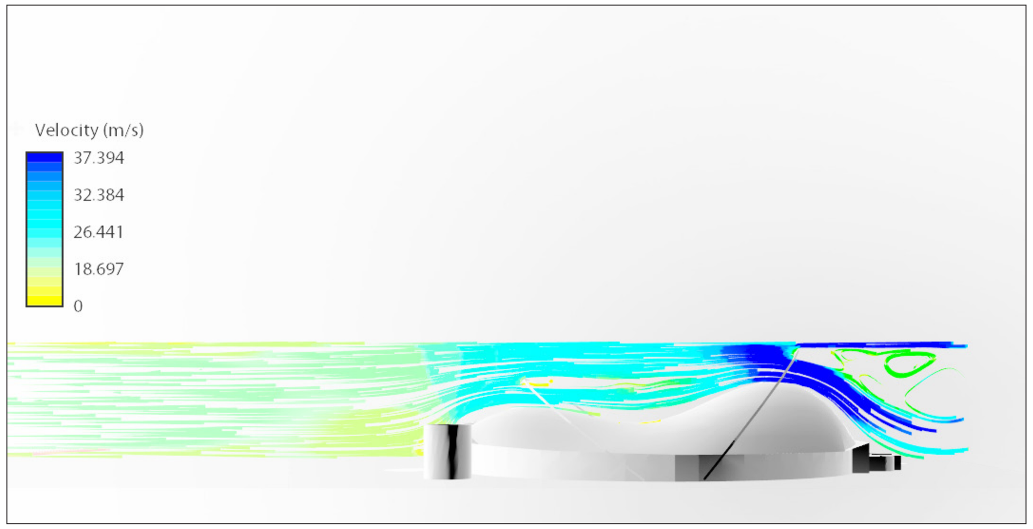


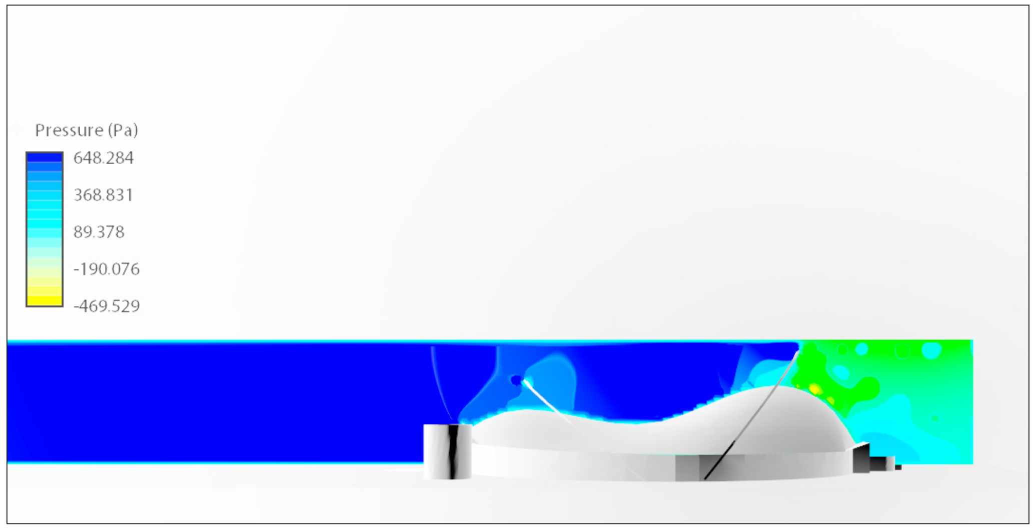
1


Velocity (m/s)
16.010
13.865
11.320
8.005
0

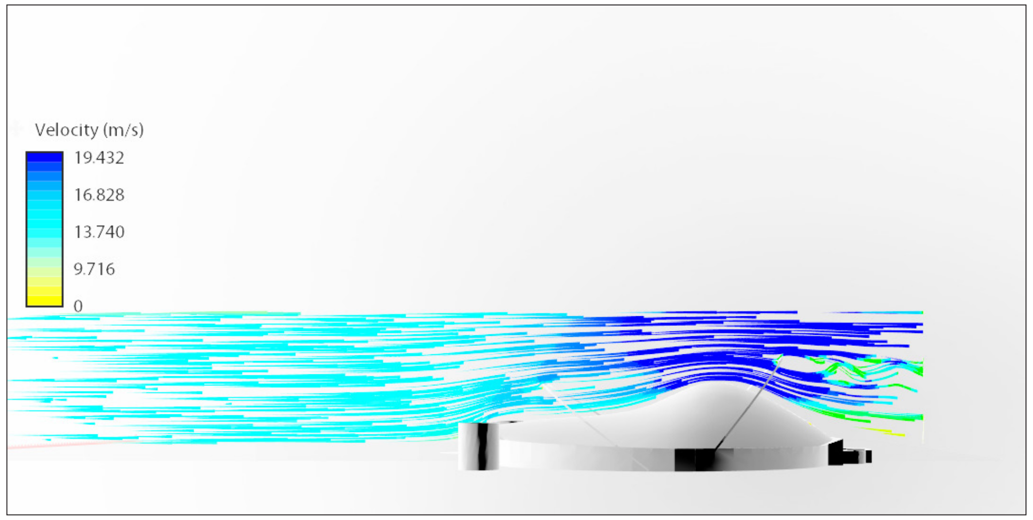

Pressure (Pa)
89.484
49.343
9.202
-30.939
-71.080

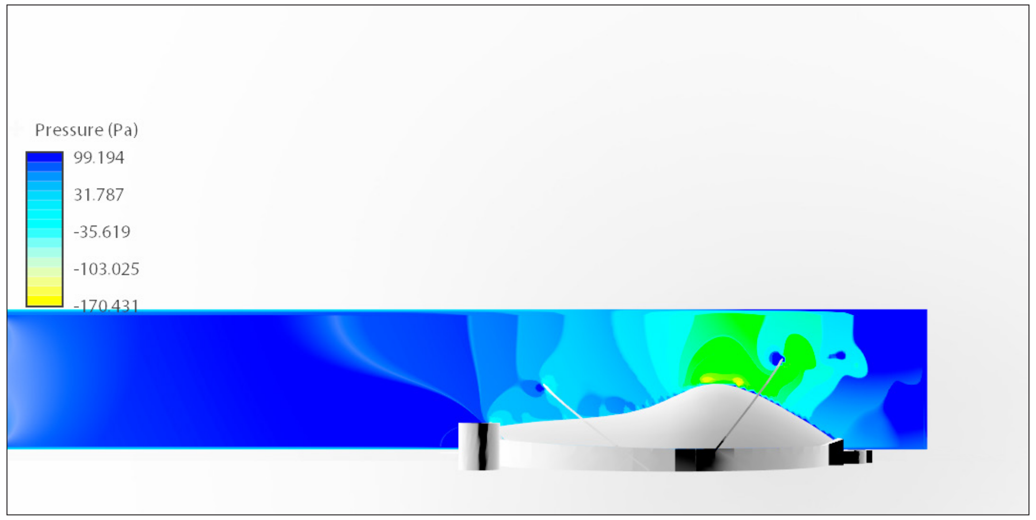
2


Velocity (m/s)
37.394
32.384
26.441
18.697
0

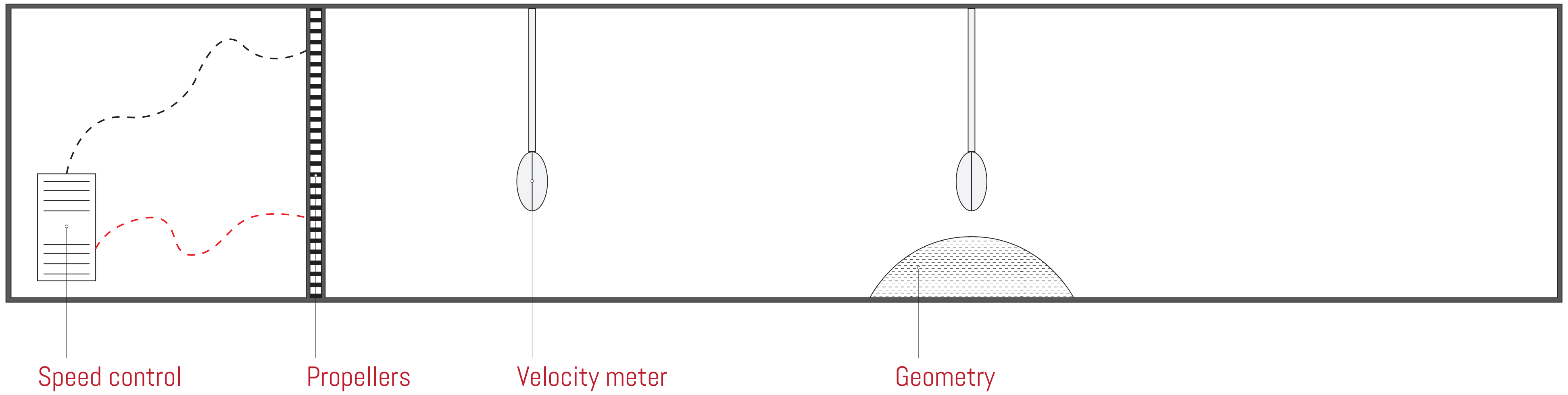

Pressure (Pa)
648.284
368.831
89.378
-190.076
-469.529

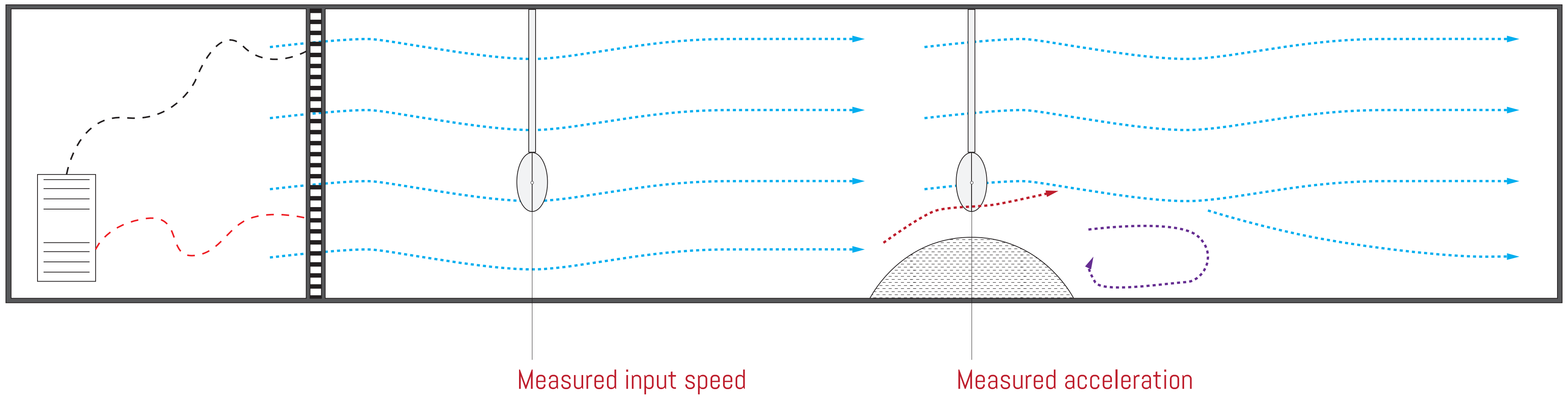
3

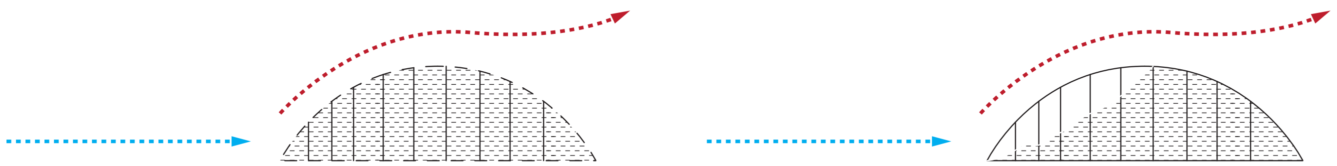

Velocity (m/s)
19.432
16.828
13.740
9.716
0


Pressure (Pa)
99.194
31.787
-35.619
-103.025
-170.431

WIND TUNNEL TESTING: SETUP



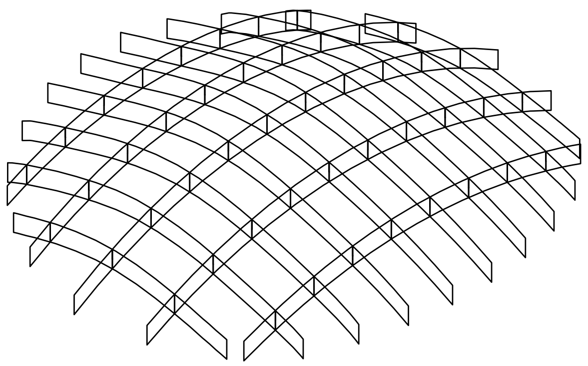


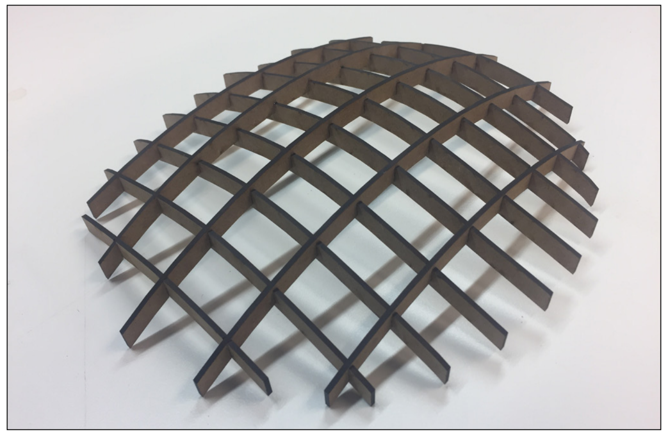


Due to acceleration and underpressure the sand will blow off

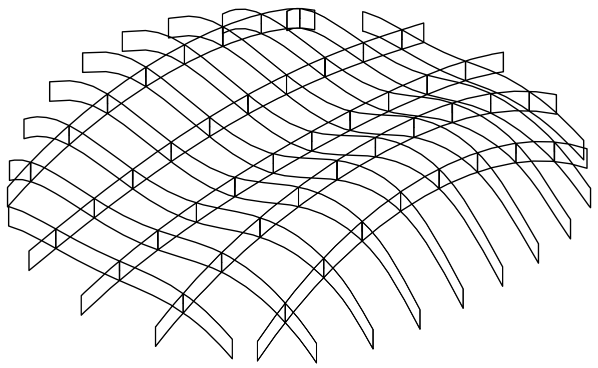
WIND TUNNEL TESTING: FROM COMPUTATIONAL VARIANTS TO TESTING GEOMETRIES

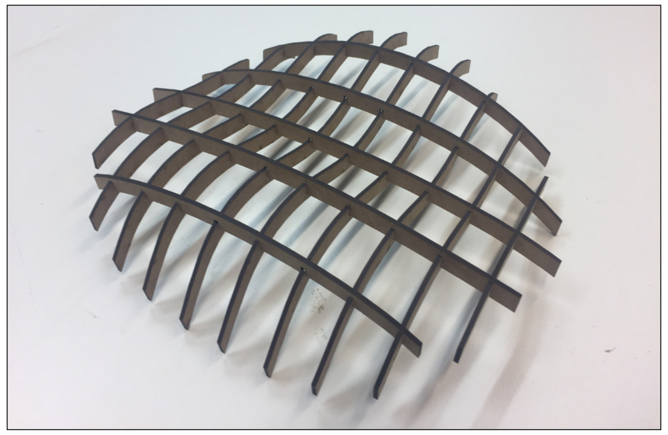
1



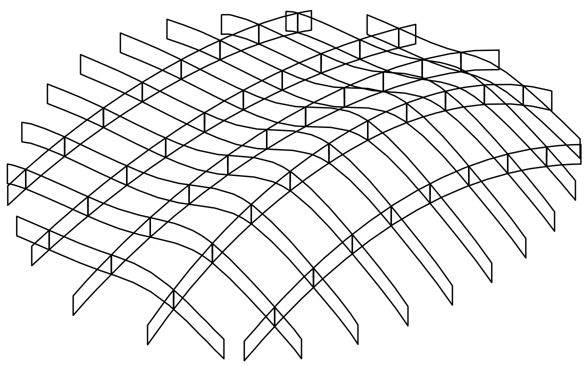


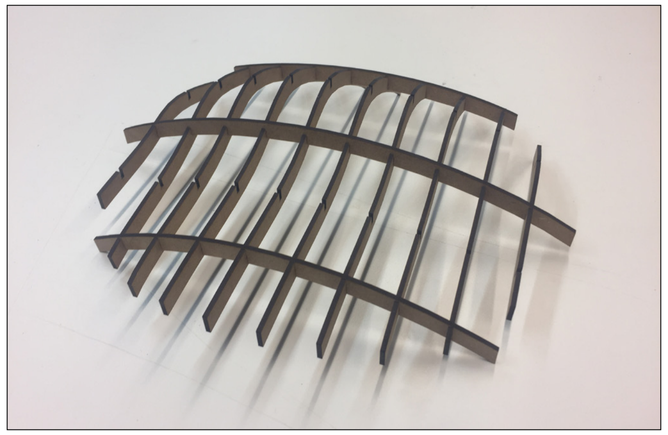
2

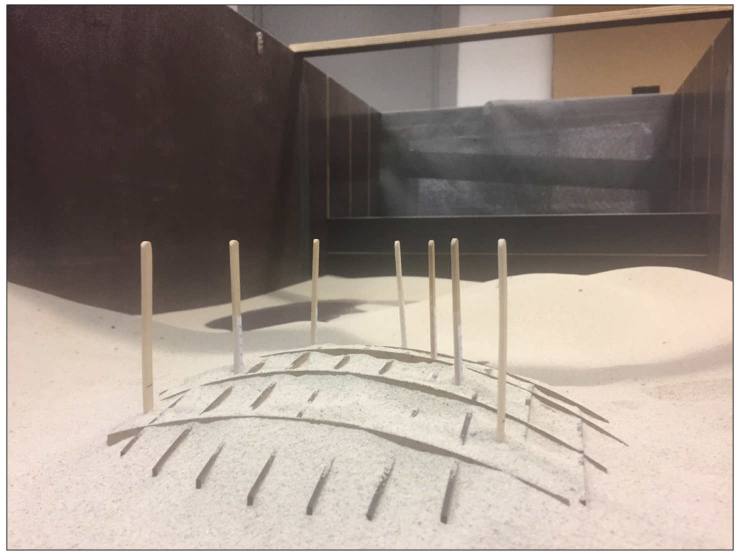


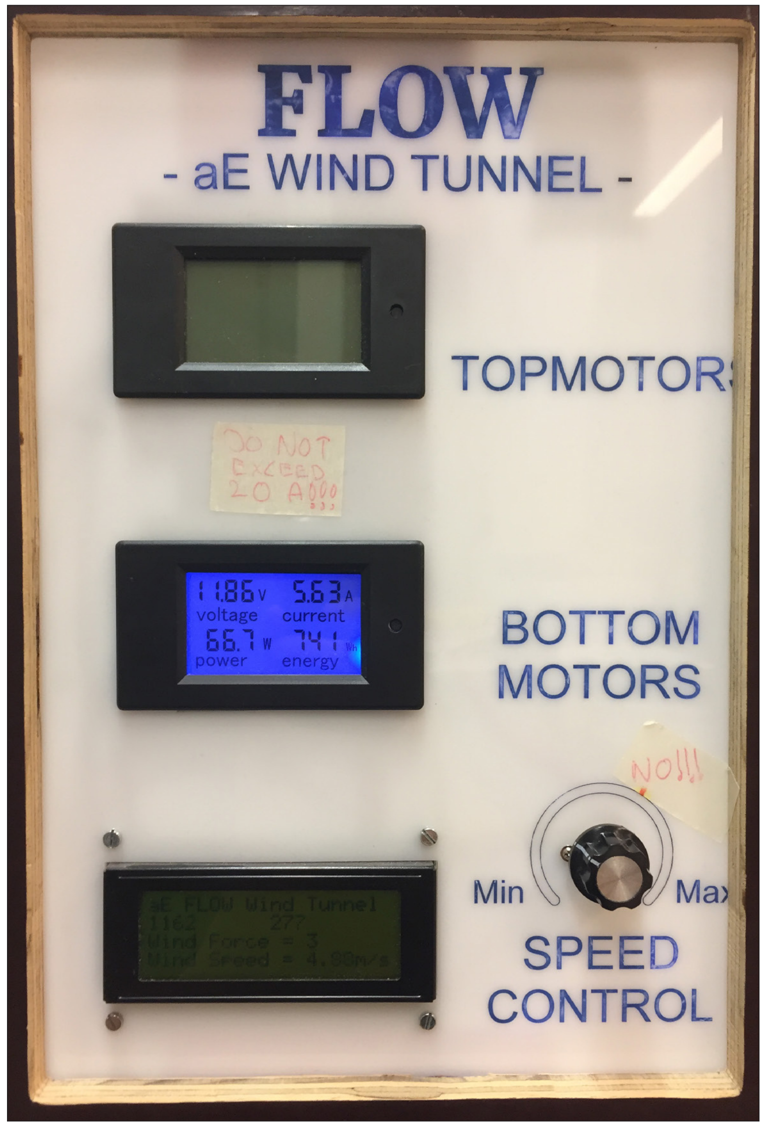


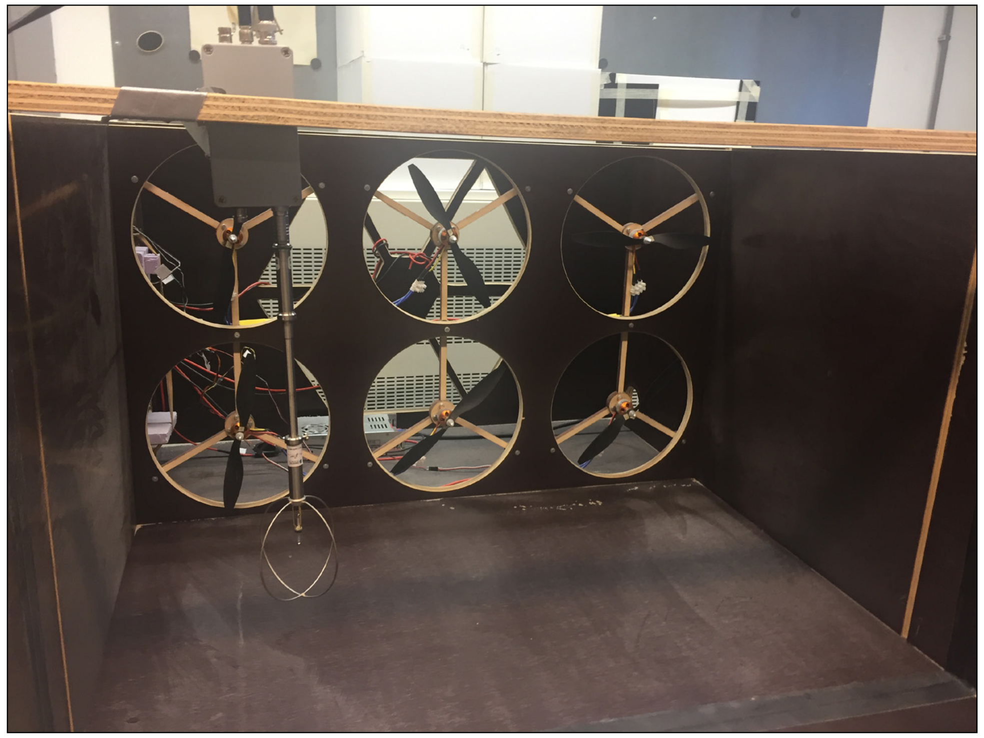
3

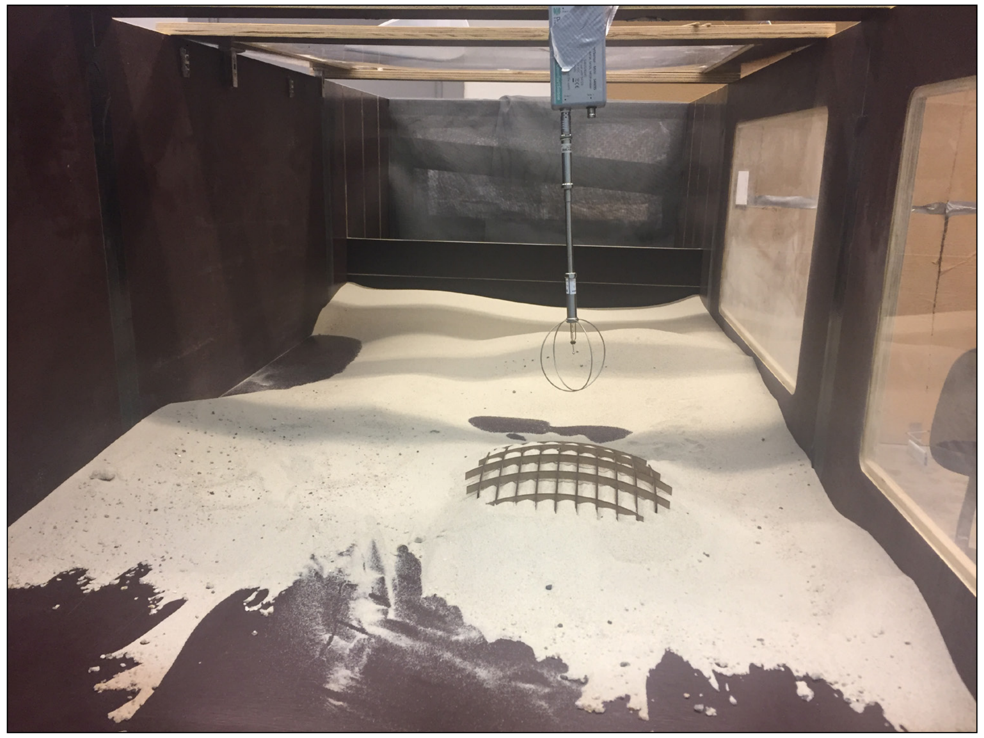




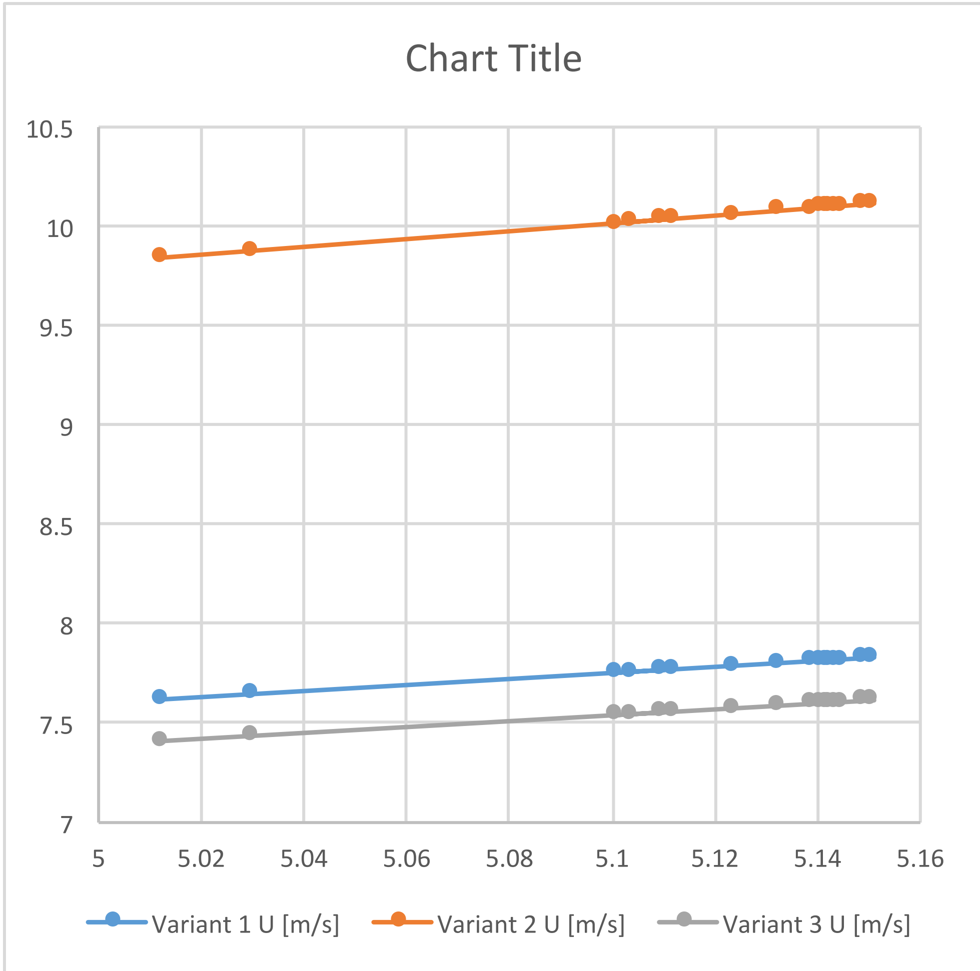






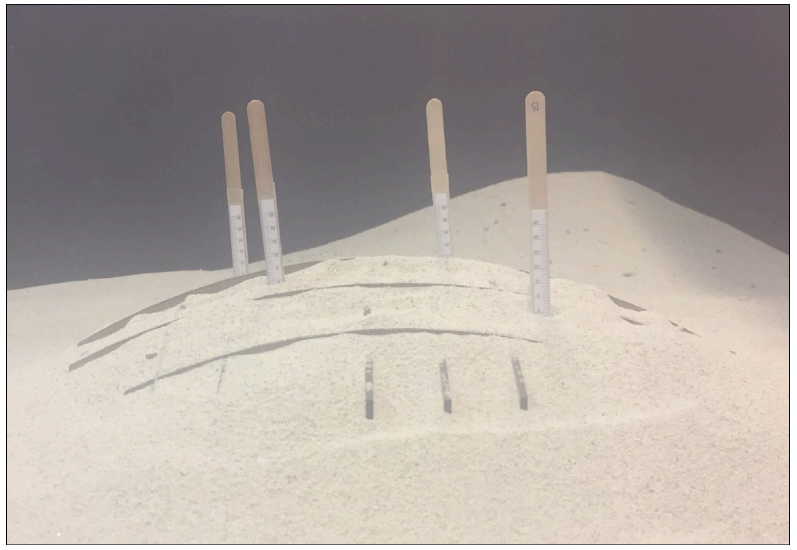


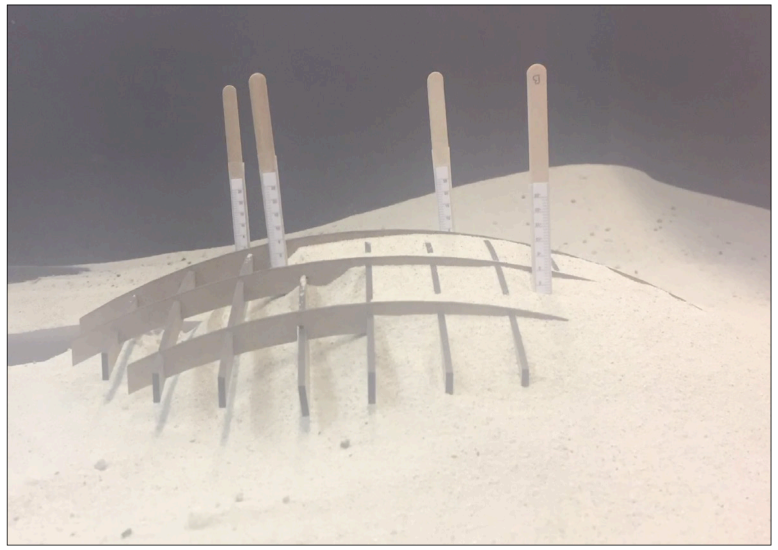
	Start speed	Variant 1	Variant 2	Variant 3
Output probe	*U*	*U*	*U*	*U*
V	[m/s]	[m/s]	[m/s]	[m/s]
3,6300	5,013	7,621	9,844	7,411
3,6300	5,030	7,647	9,877	7,436
3,6423	5,104	7,759	10,023	7,546
3,6959	5,110	7,768	10,035	7,555
3,7002	5,112	7,771	10,038	7,558
3,7017	5,101	7,755	10,017	7,541
3,6937	5,124	7,790	10,062	7,575
3,7104	5,133	7,803	10,080	7,589
3,7169	5,141	7,815	10,095	7,600
3,7227	5,144	7,820	10,101	7,605
3,7248	5,143	7,818	10,099	7,603
3,7241	5,139	7,812	10,091	7,597
3,7212	5,142	7,817	10,097	7,602
3,7234	5,145	7,821	10,103	7,606
3,7256	5,149	7,828	10,111	7,612
3,7285	5,151	7,831	10,115	7,615



WIND TUNNEL TESTING: SAND-GEOMETRY BEHAVIOUR

1





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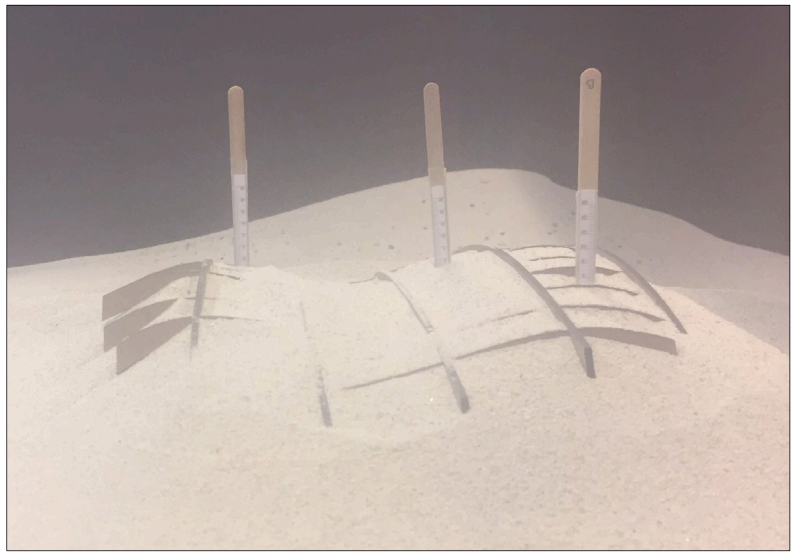

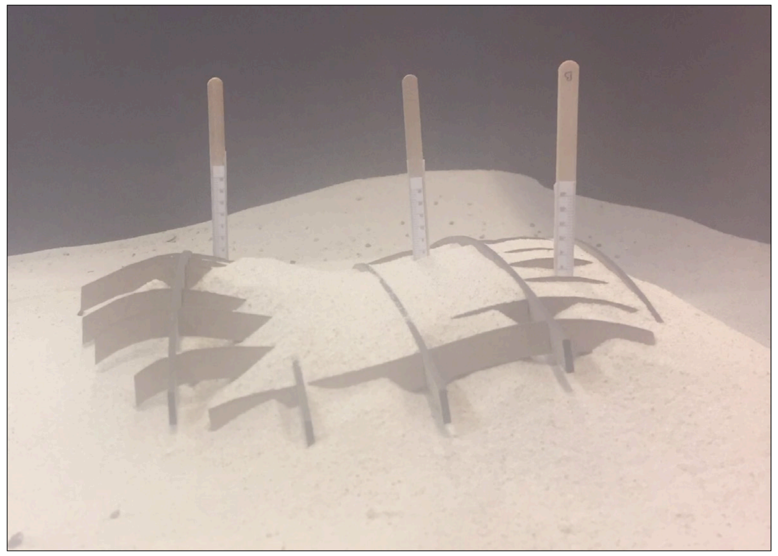

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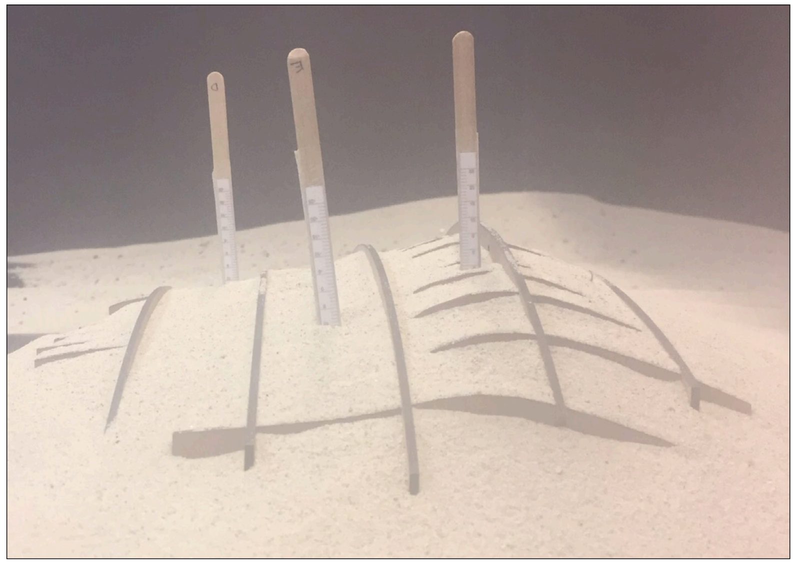
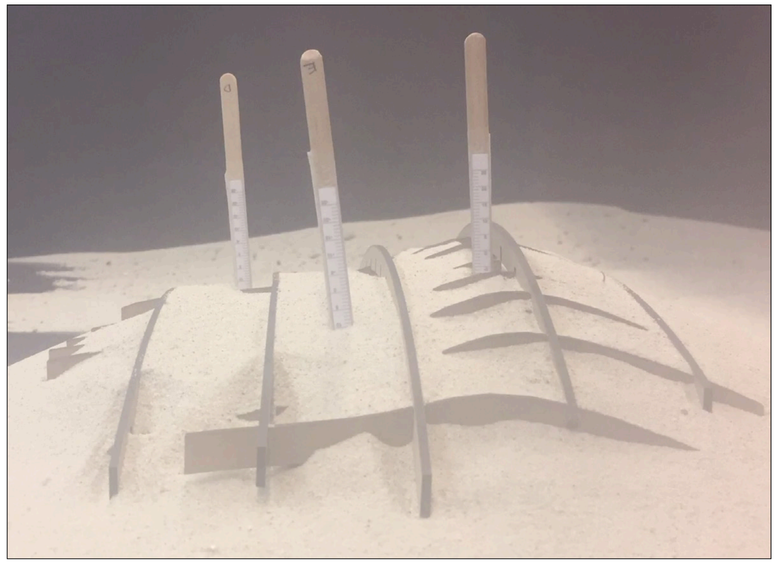
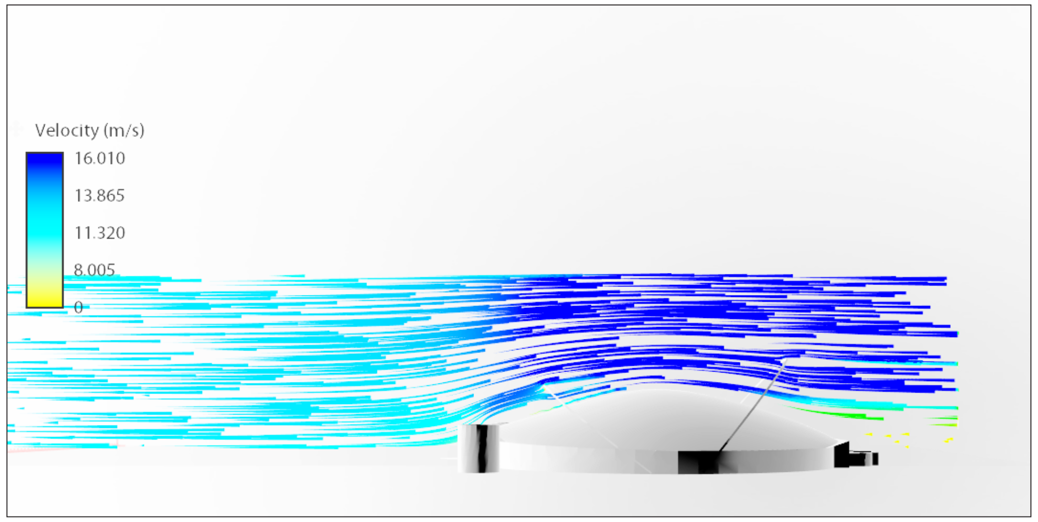
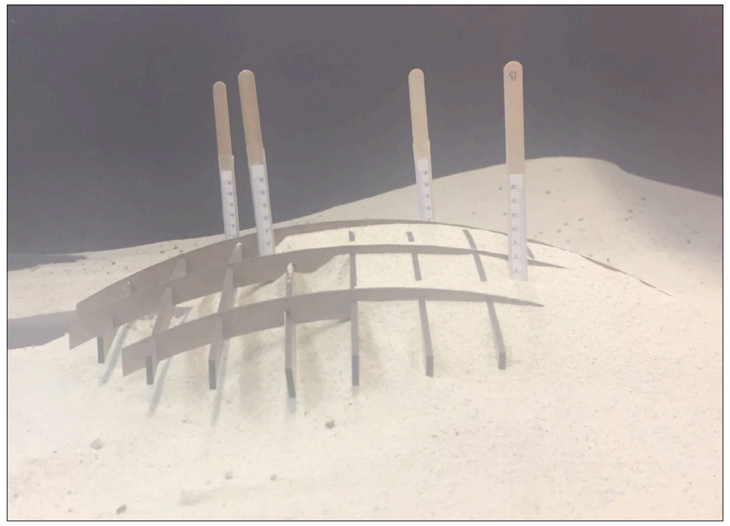




COMPARING METHODS

1





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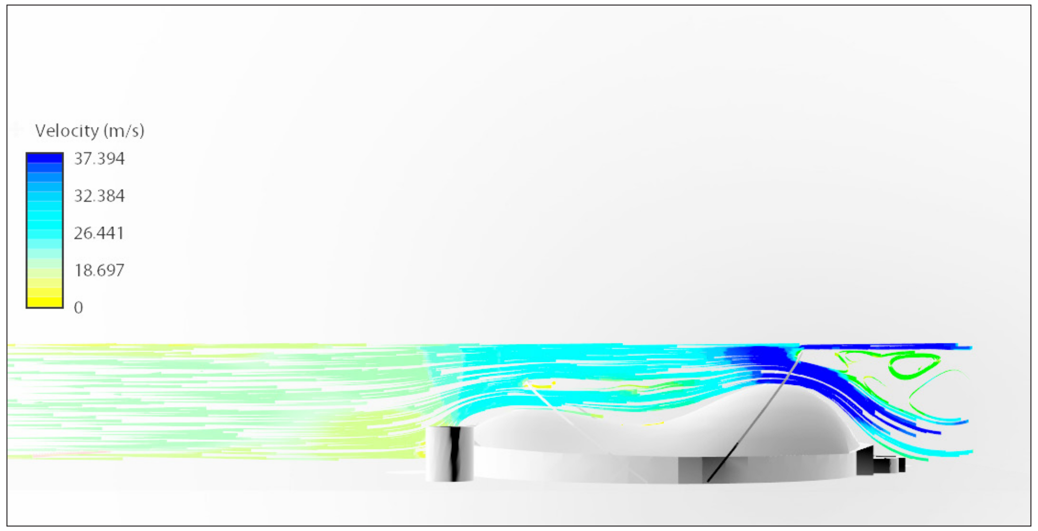

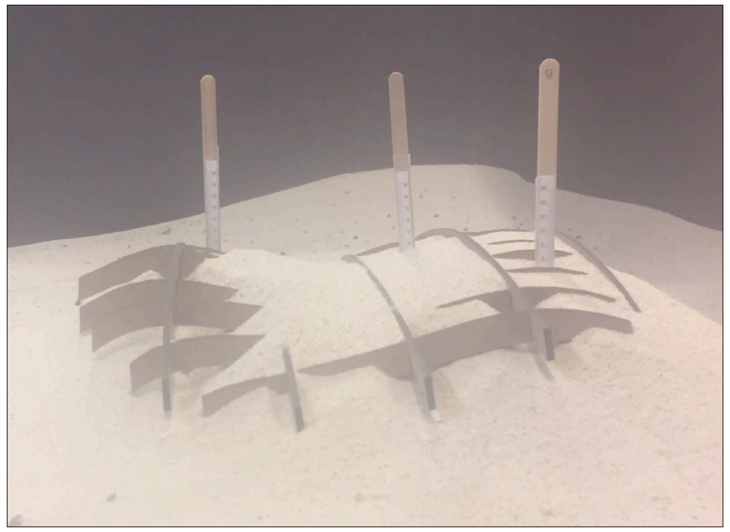

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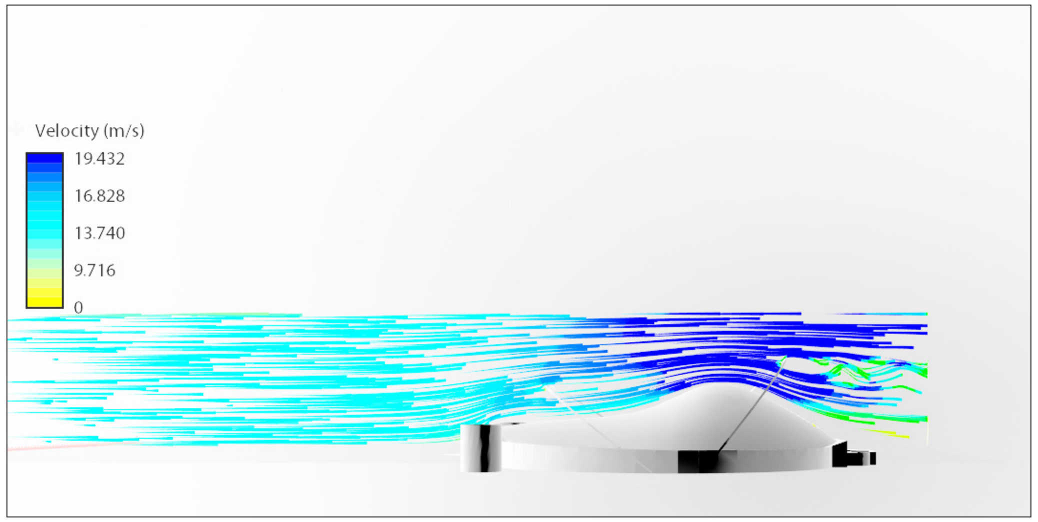
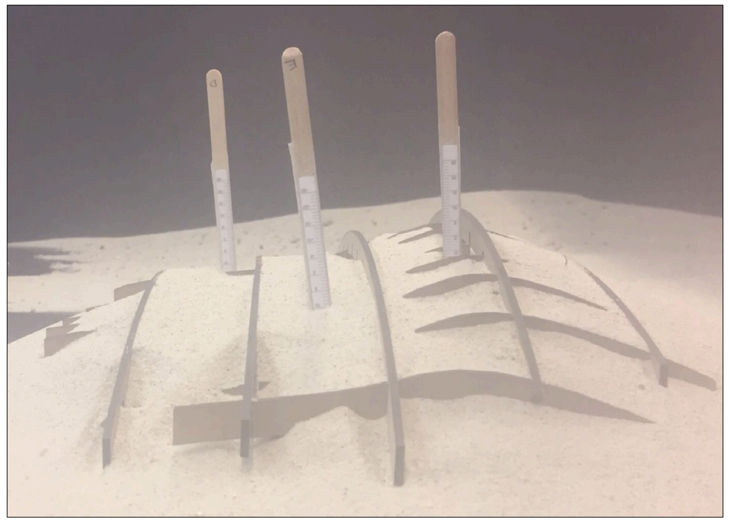
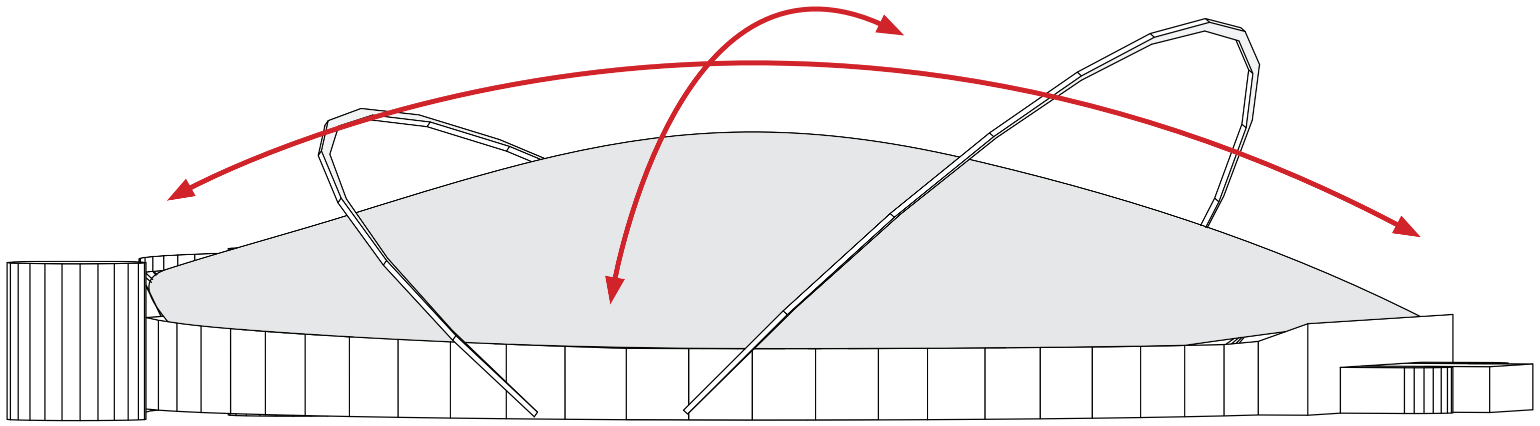
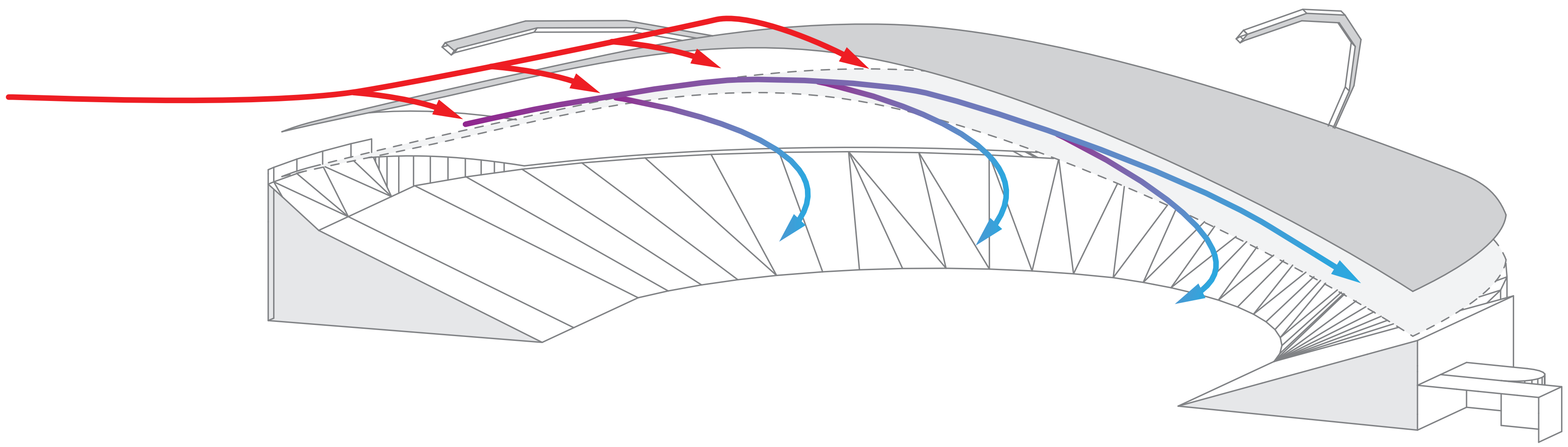


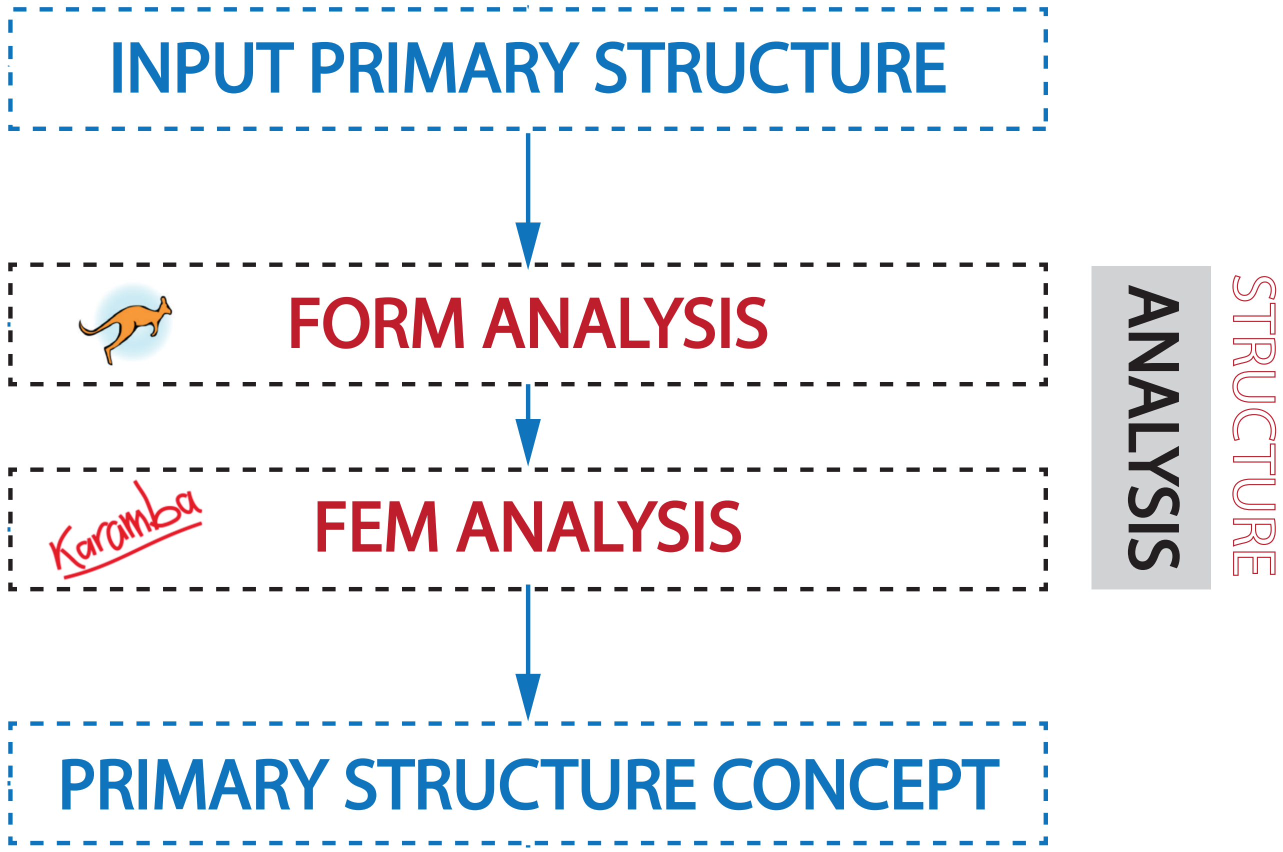


BEST VARIANT

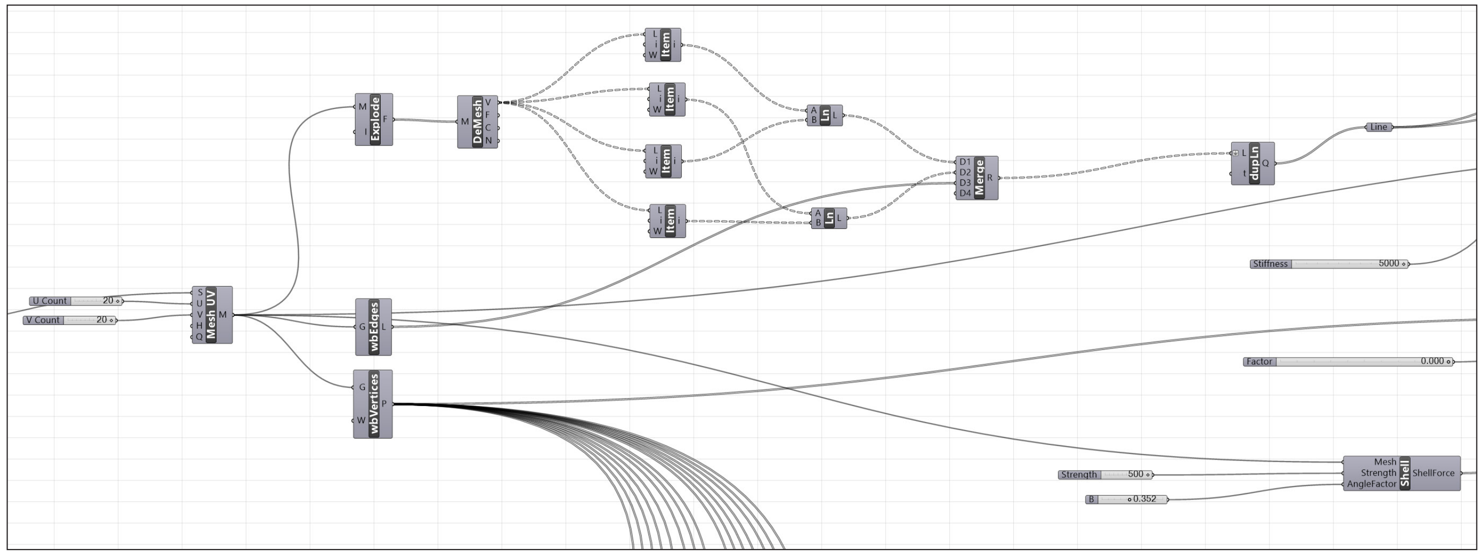


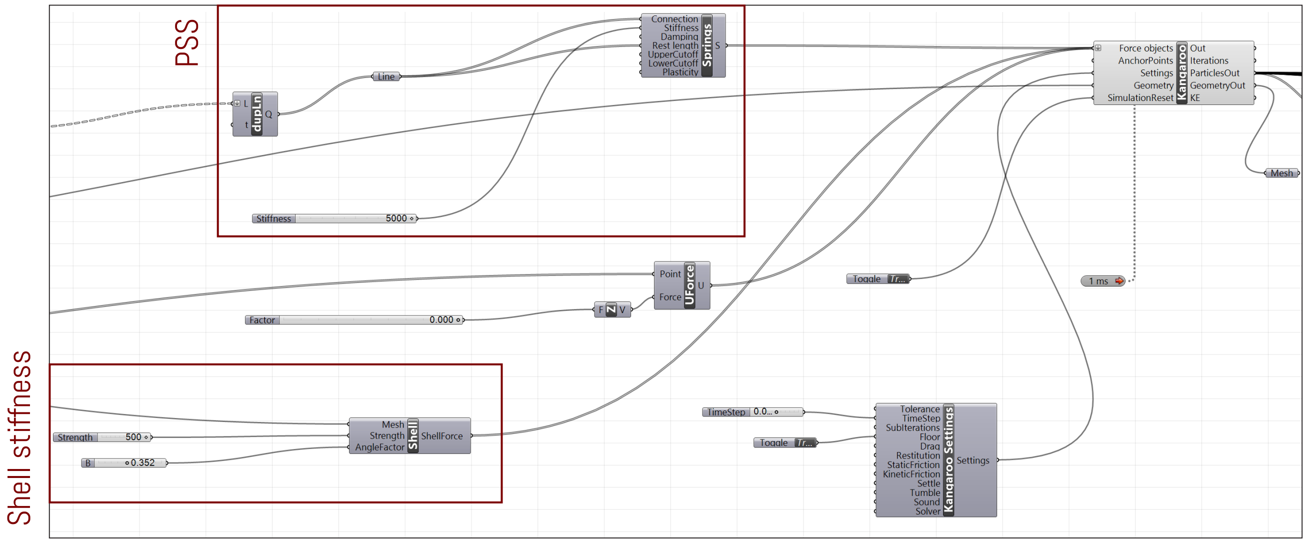
Hot air gets mist-cooled between two structural layers which will result in cold air

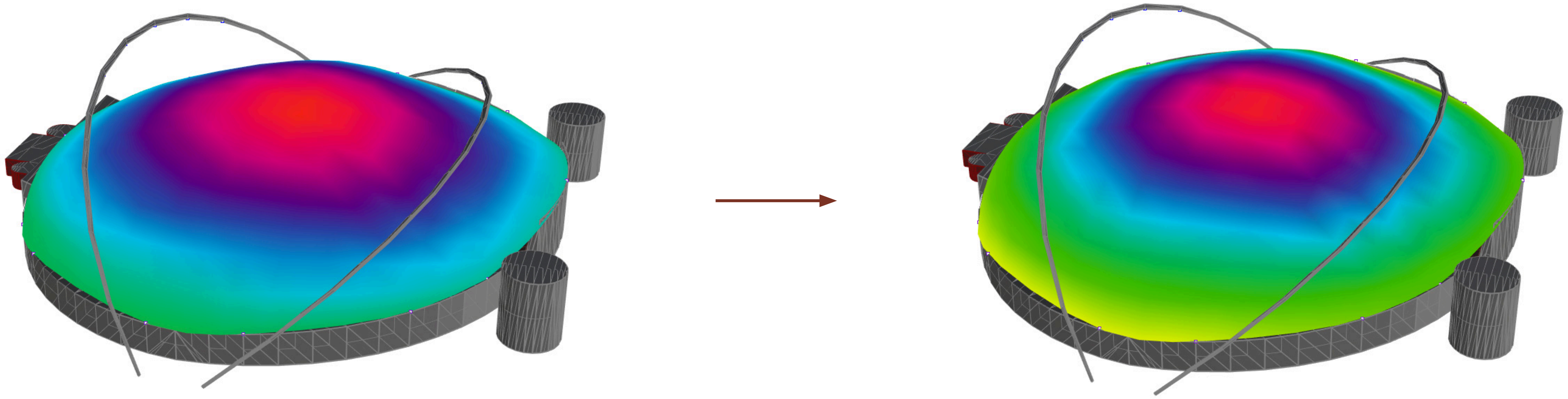



INPUT PRIMARY STRUCTURE
FORM ANALYSIS
Karamba
FEM ANALYSIS
PRIMARY STRUCTURE CONCEPT
ANALYSIS
STRUCTURE

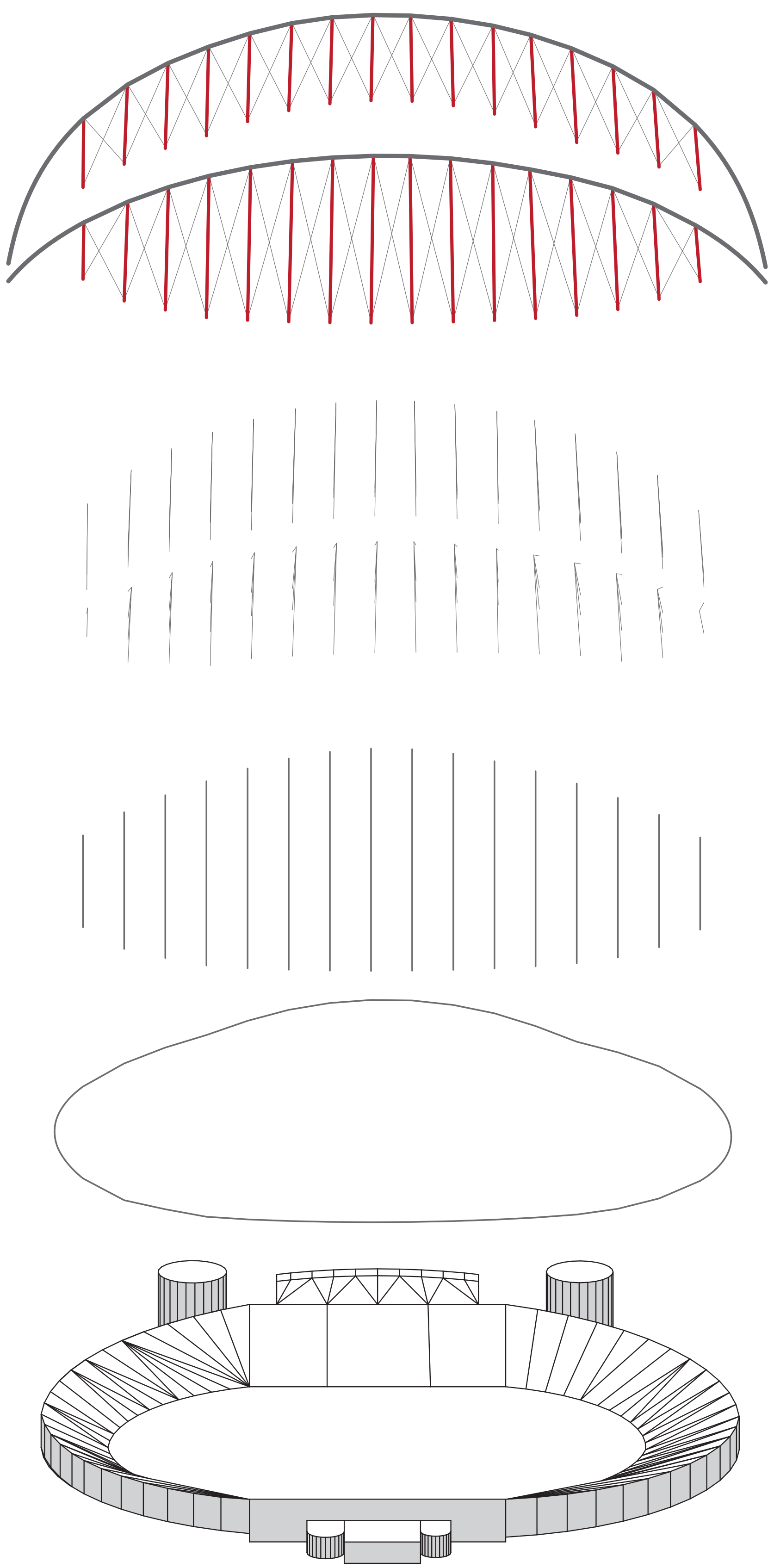
KANGAROO FORM BEHAVIOUR

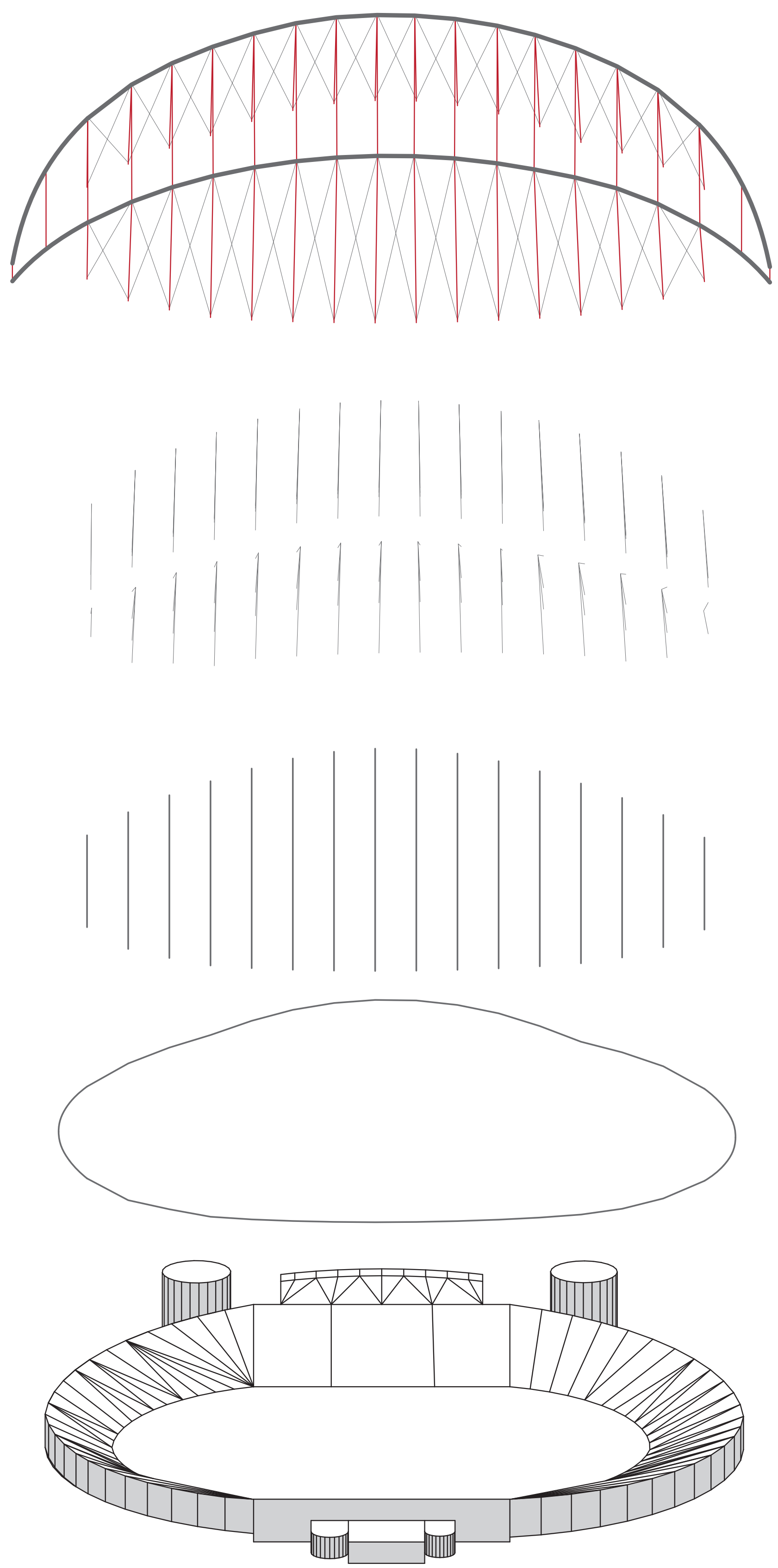


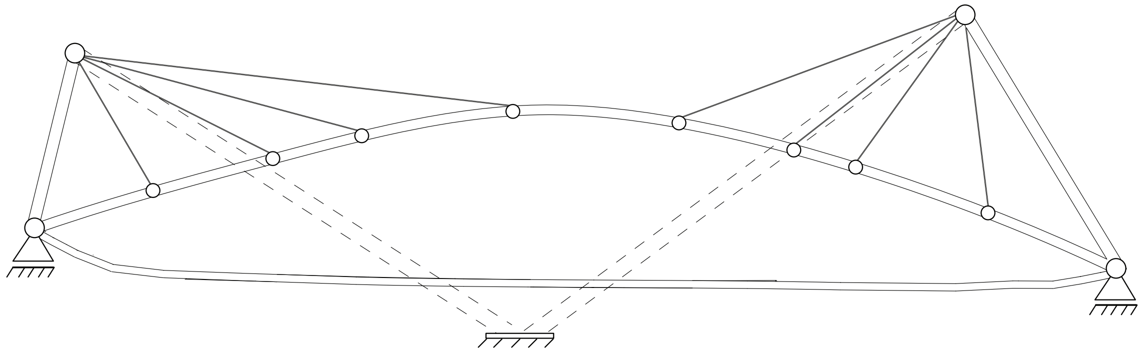


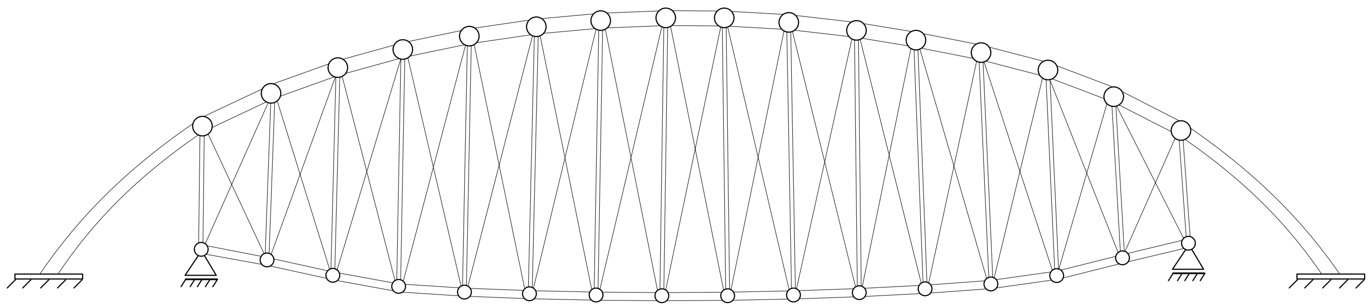


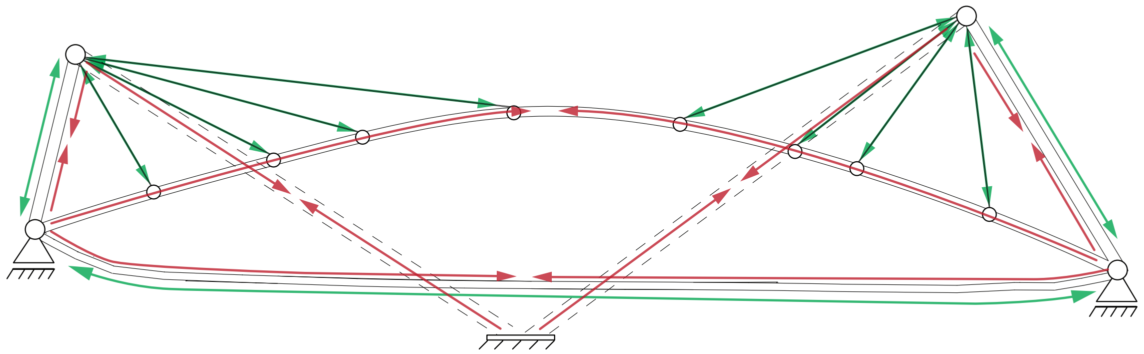
TYPES OF POSSIBLE PRIMARY STRUCTURES

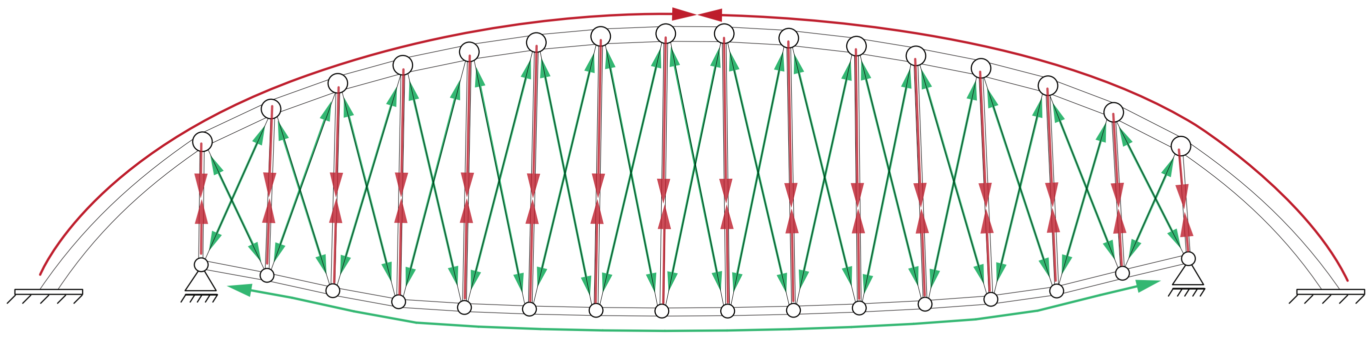










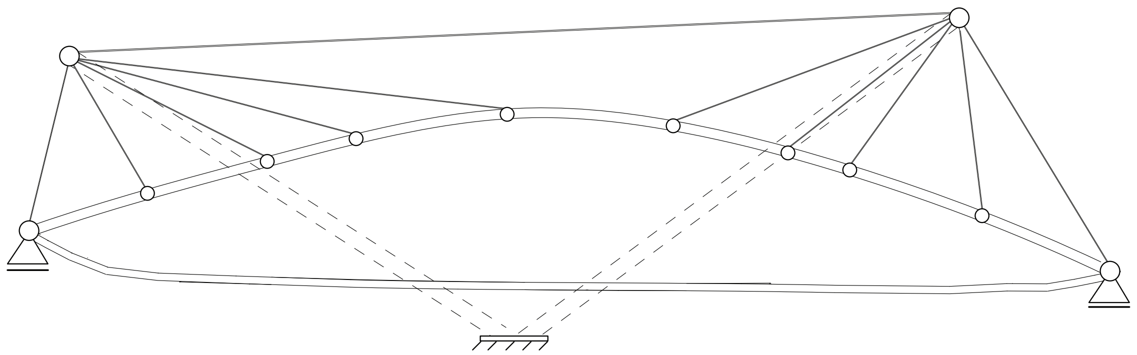


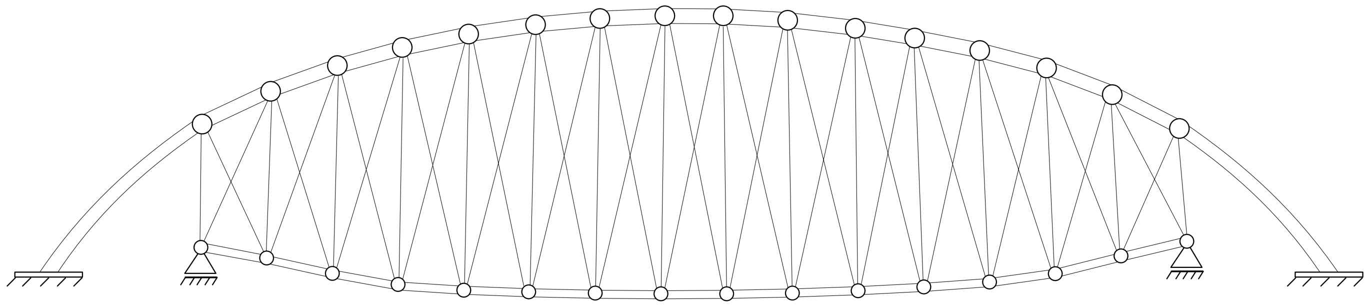
$$S_{buckling} = \frac{\pi^2 \cdot E \cdot I}{L_b^2 \cdot A} \left[\frac{n}{mm^2} \right]$$

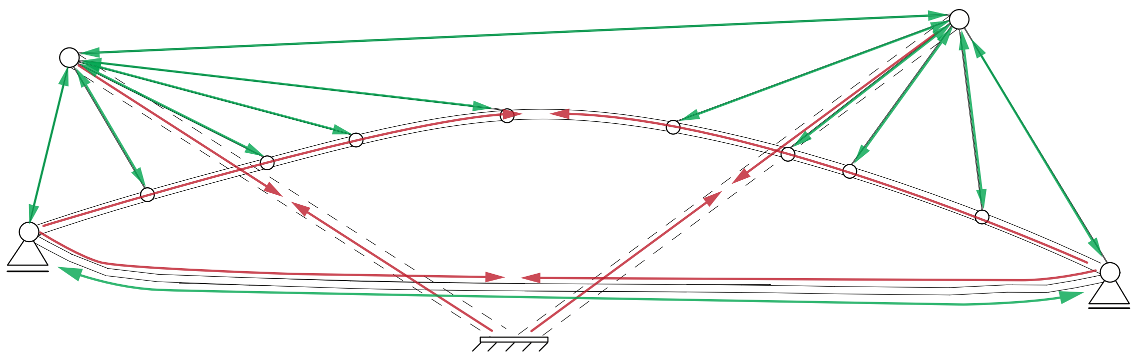
$$S_{buckling} = \frac{\pi^2 \cdot 210000 \cdot 2.9 \cdot 10^{10}}{50000^2 \cdot 2.83 \cdot 10^5}$$

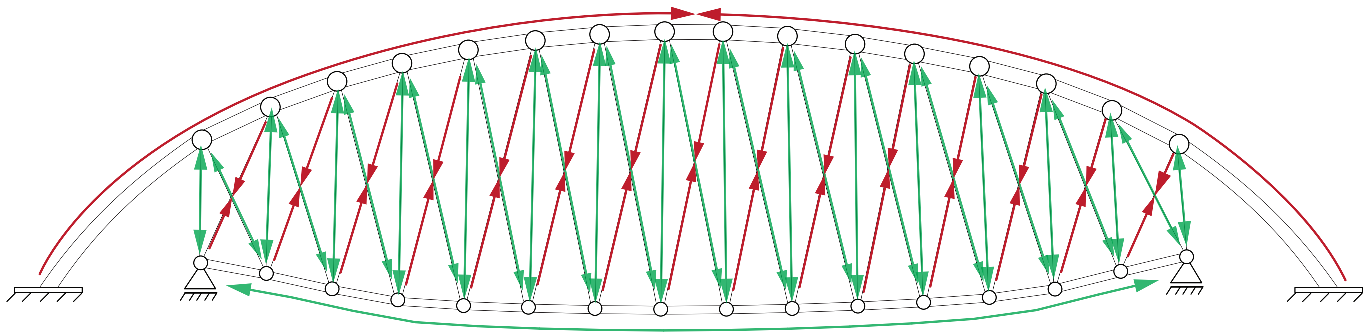
$$S_{buckling} = 84.96 \, \frac{N}{mm^2} \, (MPa)$$

TYPES OF PRIMARY STRUCTURES POSSIBLE: WITH CABLES



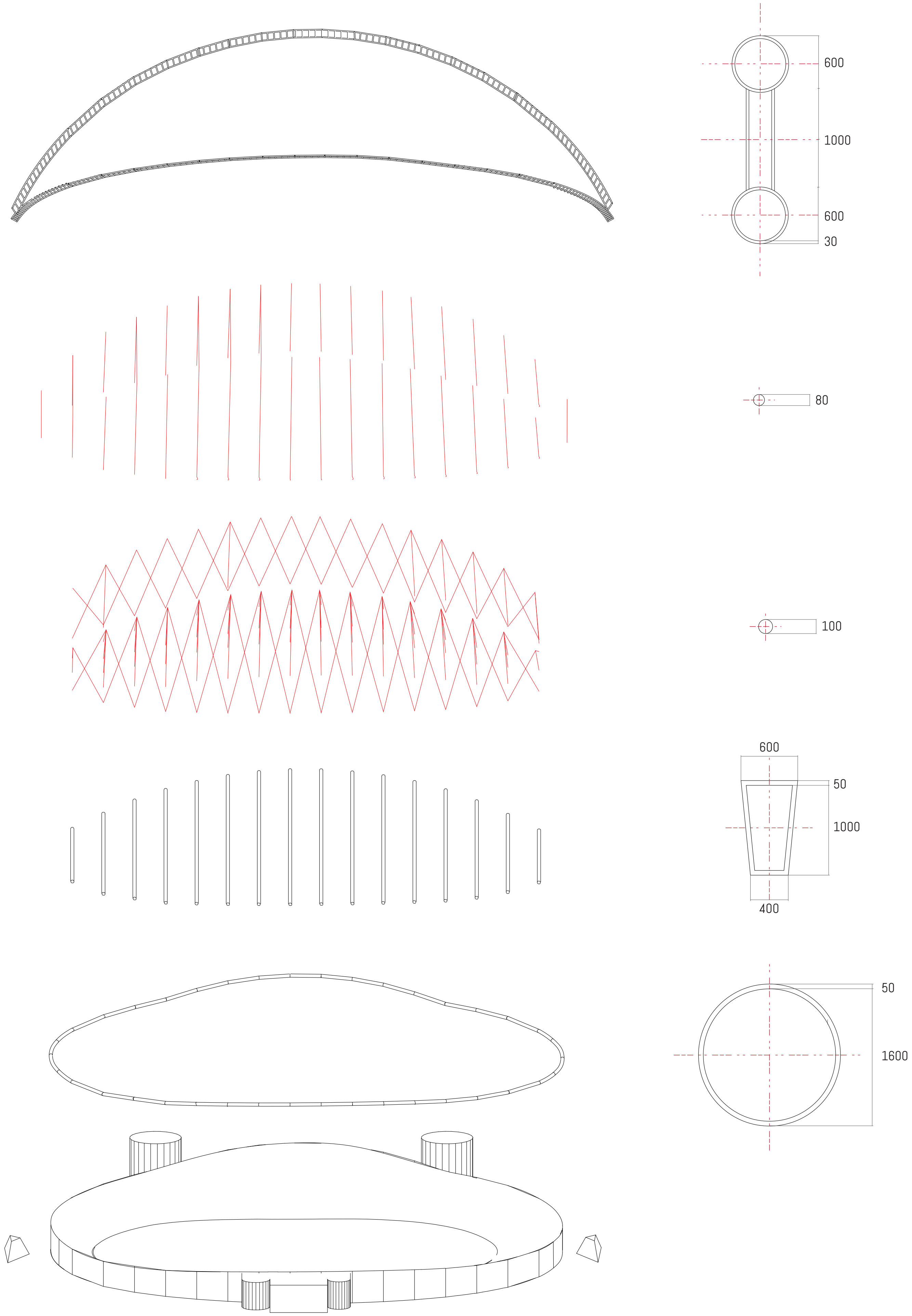




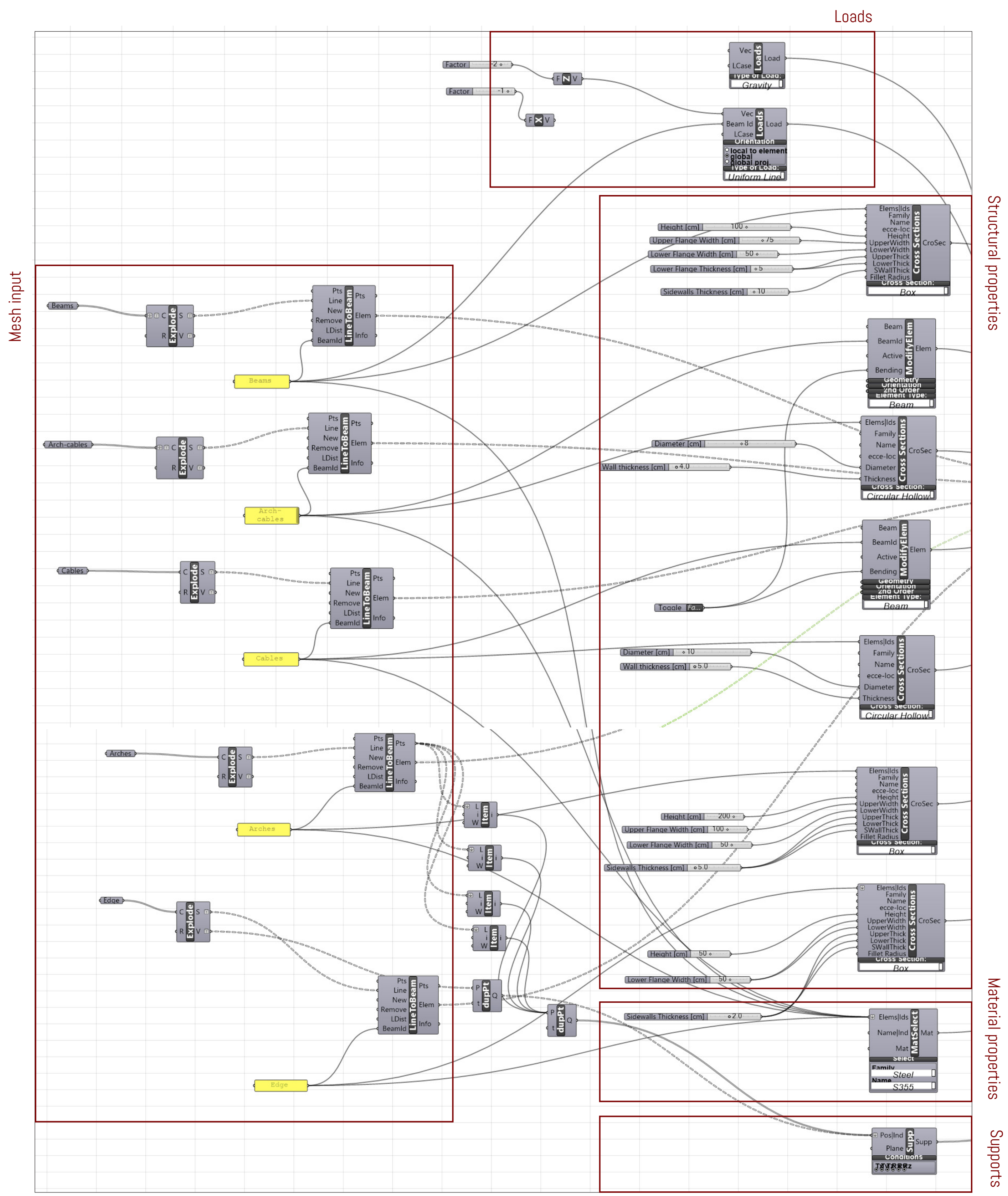


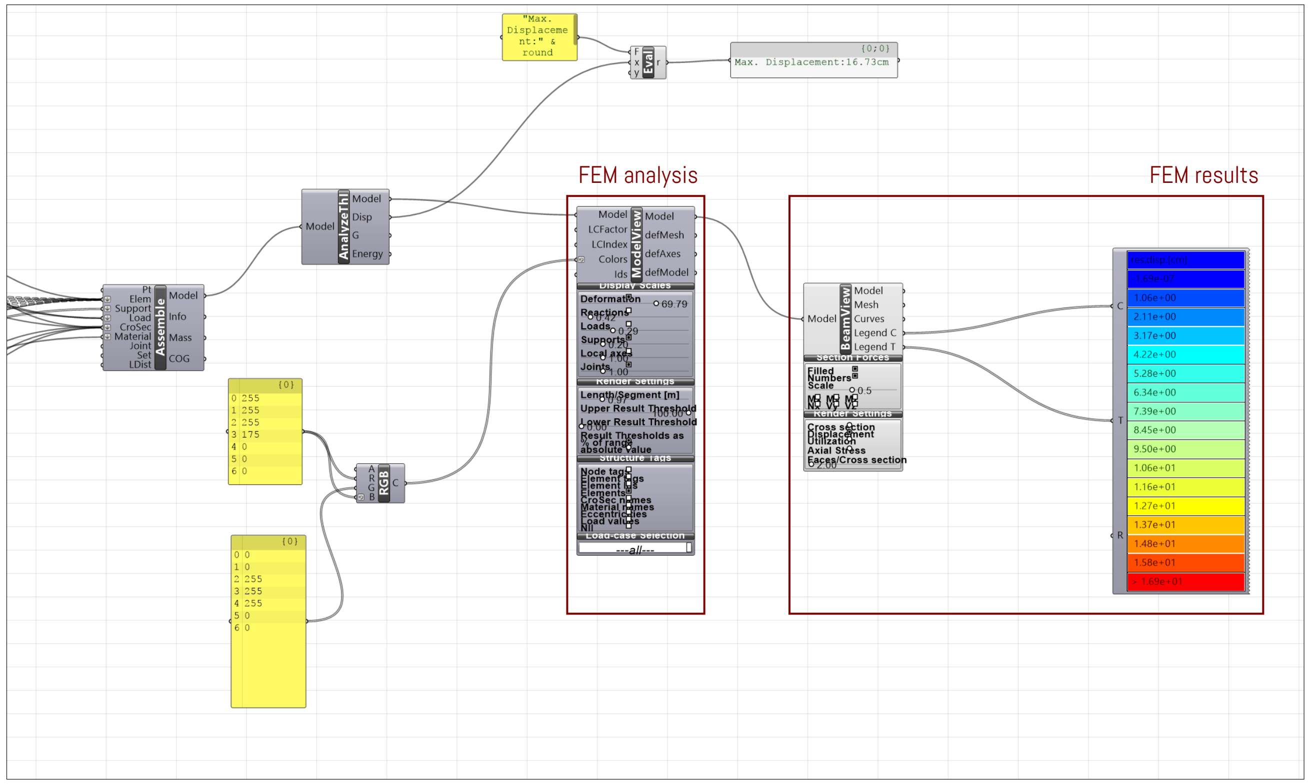
$$S_{buckling} = \frac{\pi^2 \cdot E \cdot I}{L_b^2 \cdot A} \left[\frac{n}{mm^2} \right]$$

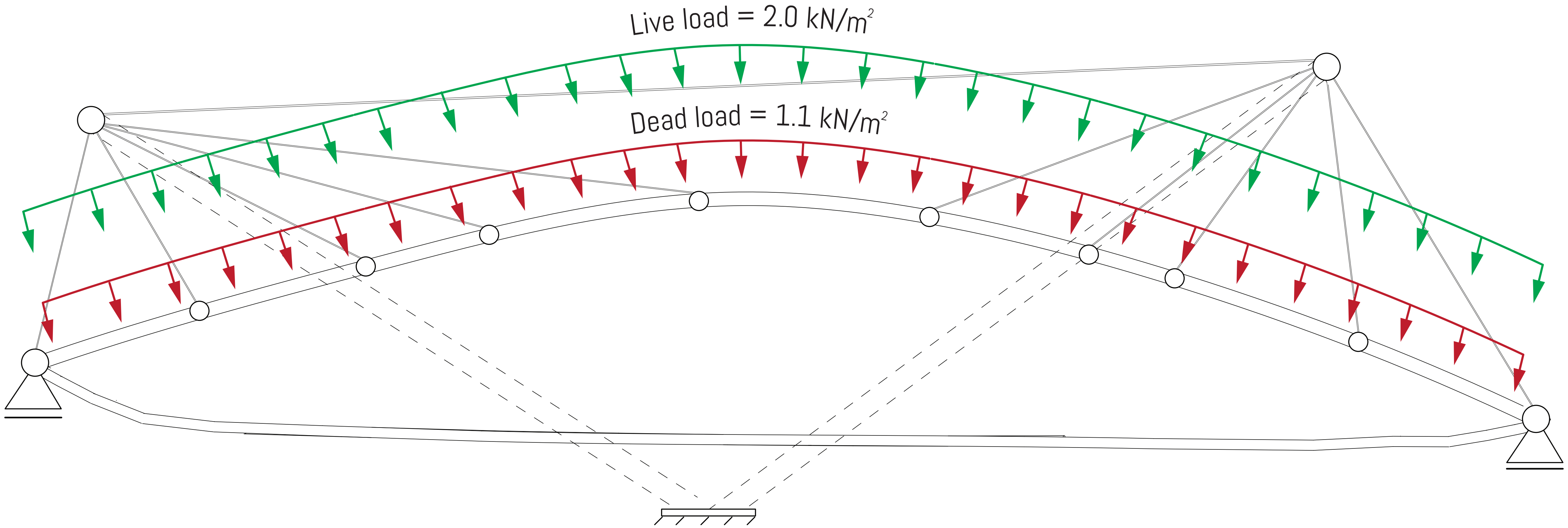
STRUCTURAL PROPERTIES



FEM ANALYSIS

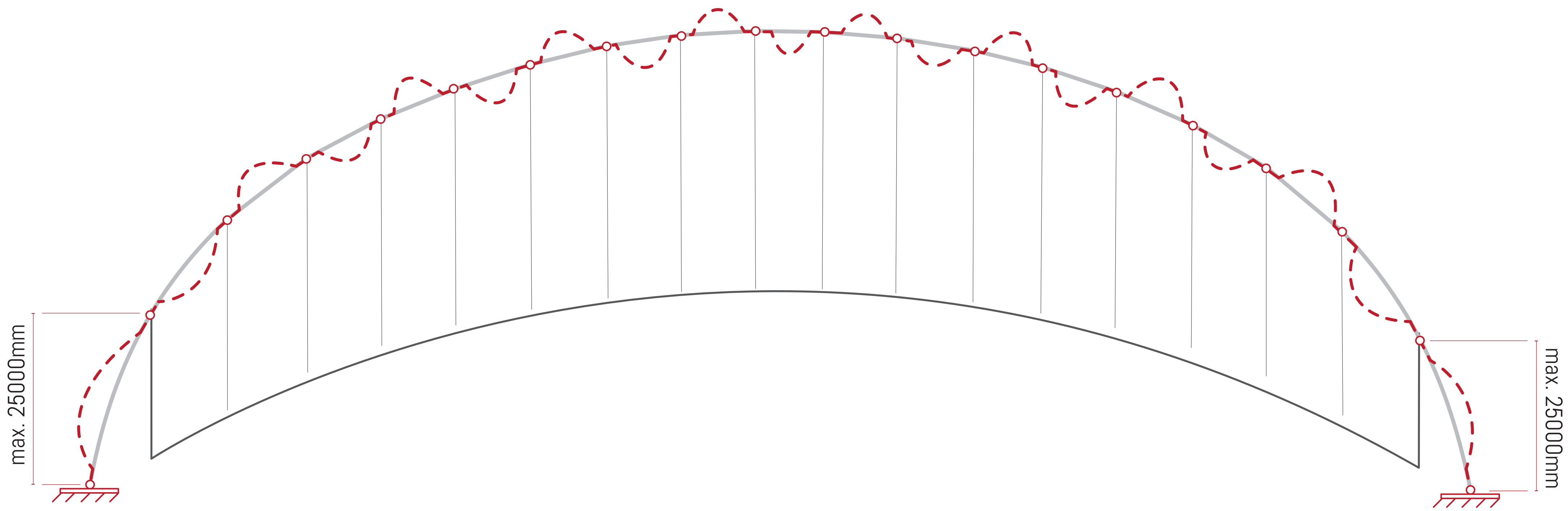


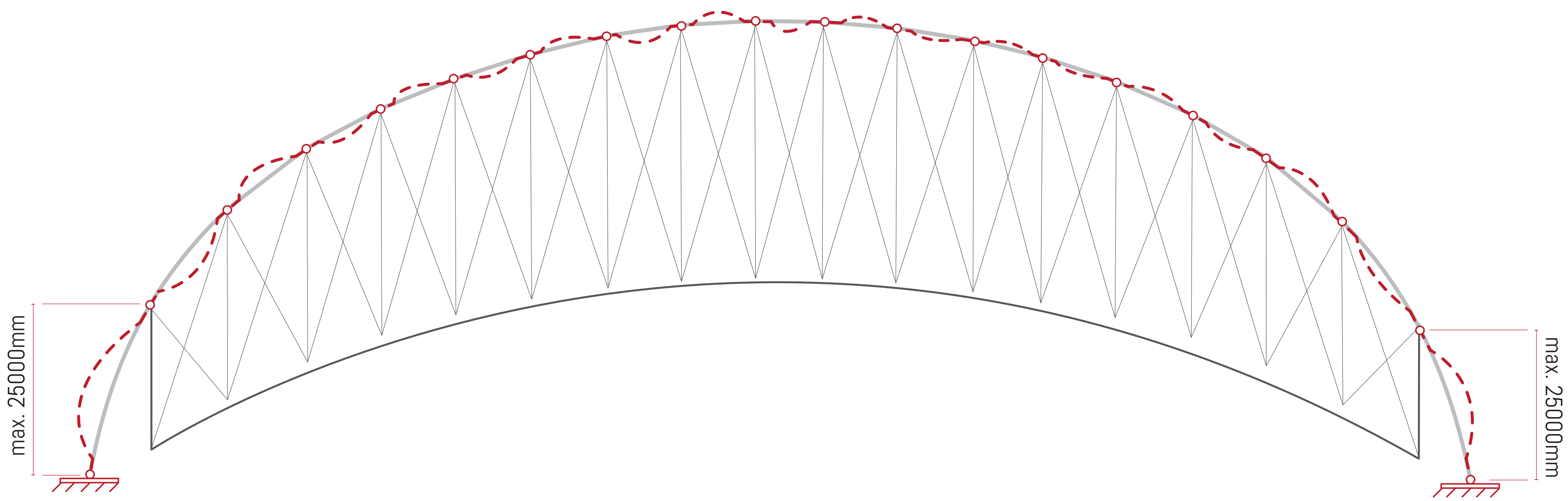




Live load = 2.0 kN/m²
Dead load = 1.1 kN/m²

FEM ANALYSIS: BUCKLING BEHAVIOUR ARCHES

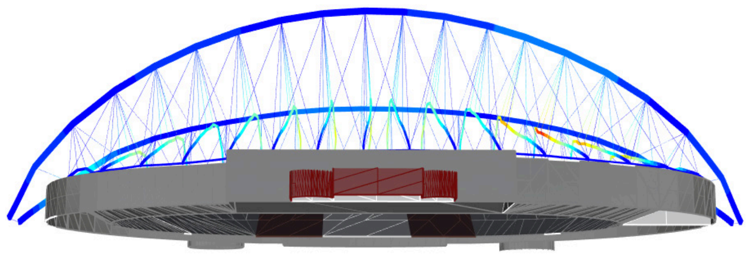




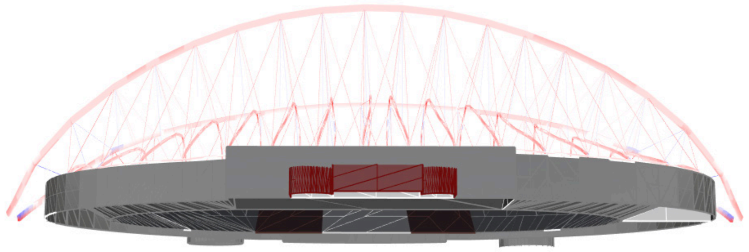
FEM ANALYSIS: BUCKLING BEHAVIOUR ARCHES

$$S_{buckling} = \frac{\pi^2 \cdot E \cdot I}{L_b^2 \cdot A} \left[\frac{n}{mm^2}\right] \qquad S_{buckling} = \frac{\pi^2 \cdot 210000 \cdot 8.9 \cdot 10^{10}}{0.5 \cdot 25000^2 \cdot 2.1 \cdot 10^6} \qquad S_{buckling} = 436 \frac{N}{mm^2}$$

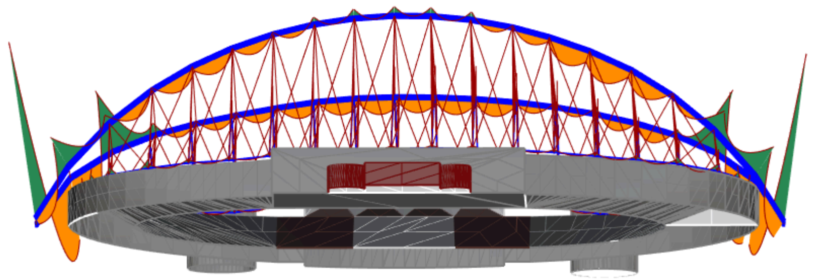
Max. deformation = 4.2cm



Max. axial stress = 69 MPa

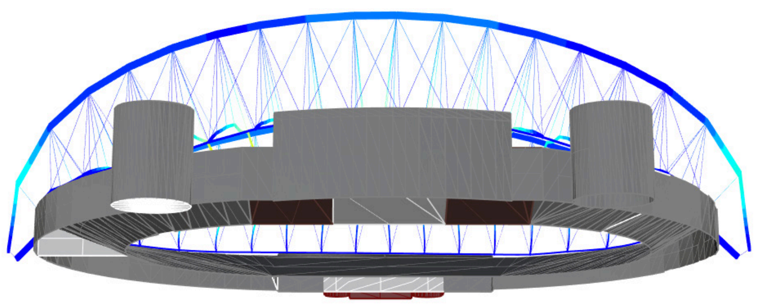


Max. bending moment 400 kNm

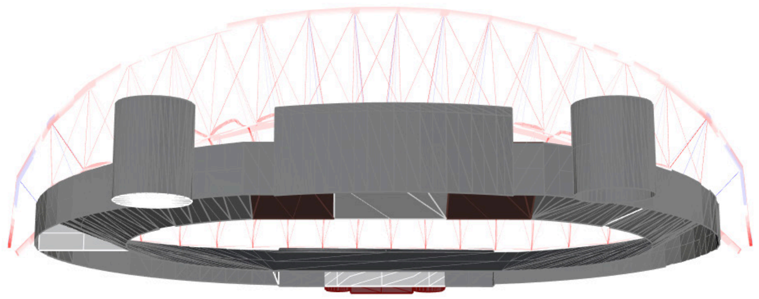


$$U.C. = \frac{\sigma_m \cdot 1.2 \cdot 1.5}{S_{buckling}} \qquad U.C. = \frac{69 \cdot 1.2 \cdot 1.5}{436} = 0.29 < 1$$

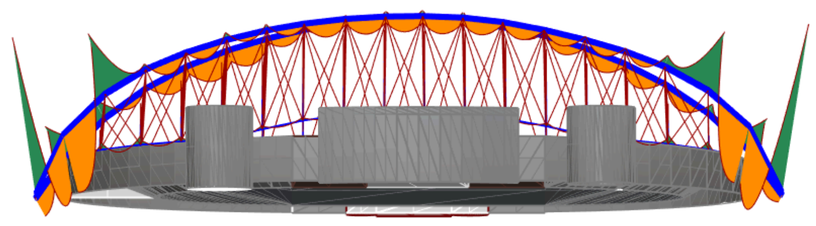
Max. deformation = 6.1cm



Max. axial stress = 110 MPa

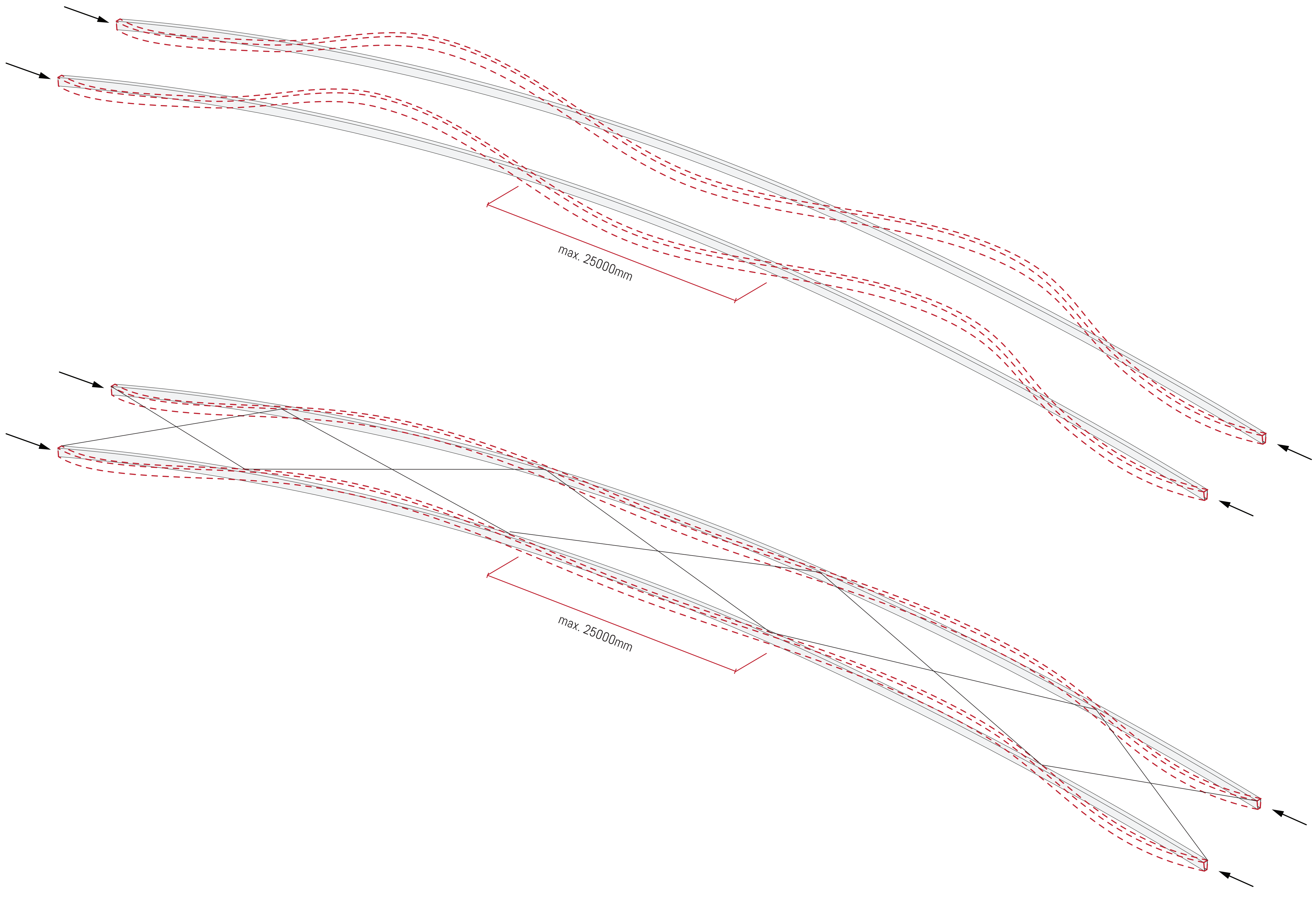


Max. bending moment 7900 kNm



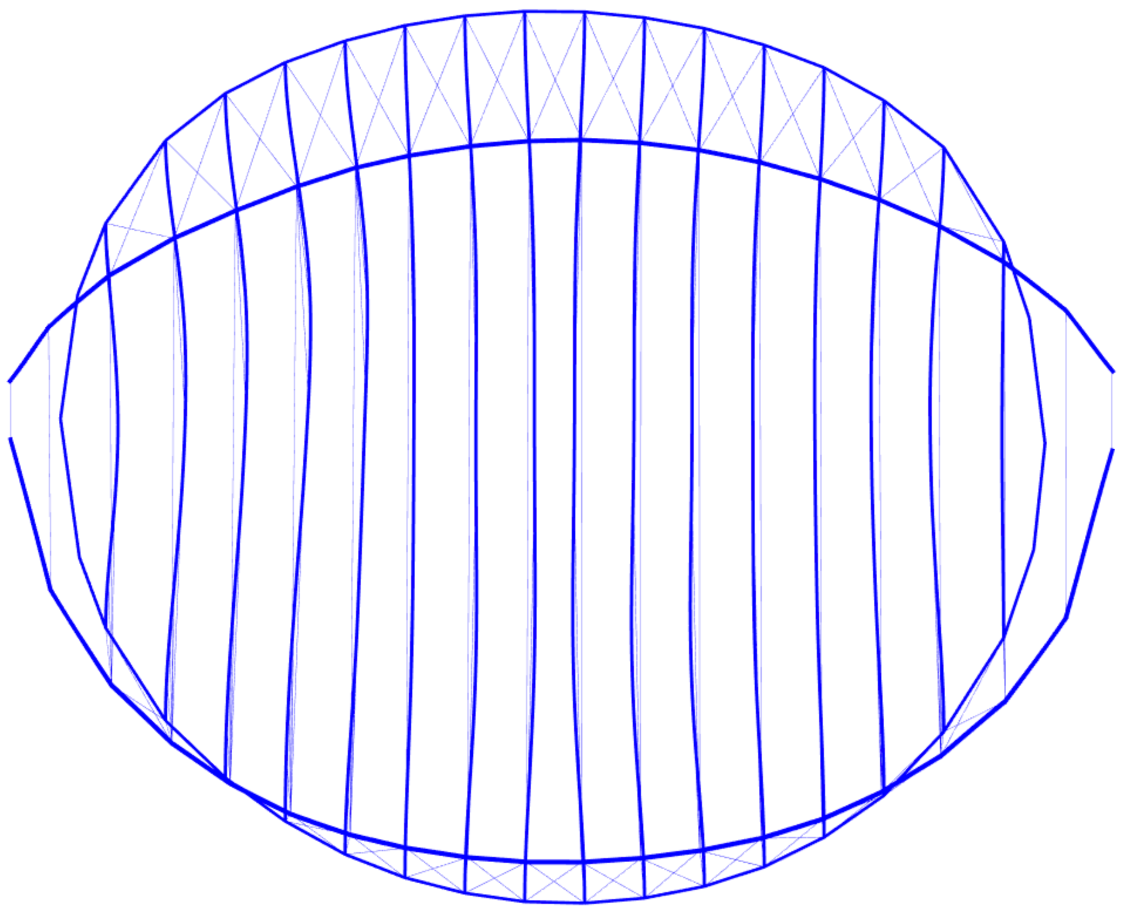
$$U.C. = \frac{\sigma_m \cdot 1.2 \cdot 1.5}{S_{buckling}} \qquad U.C. = \frac{110 \cdot 1.2 \cdot 1.5}{436} = 0.45 < 1$$

FEM ANALYSIS: BUCKLING BEHAVIOUR BEAMS



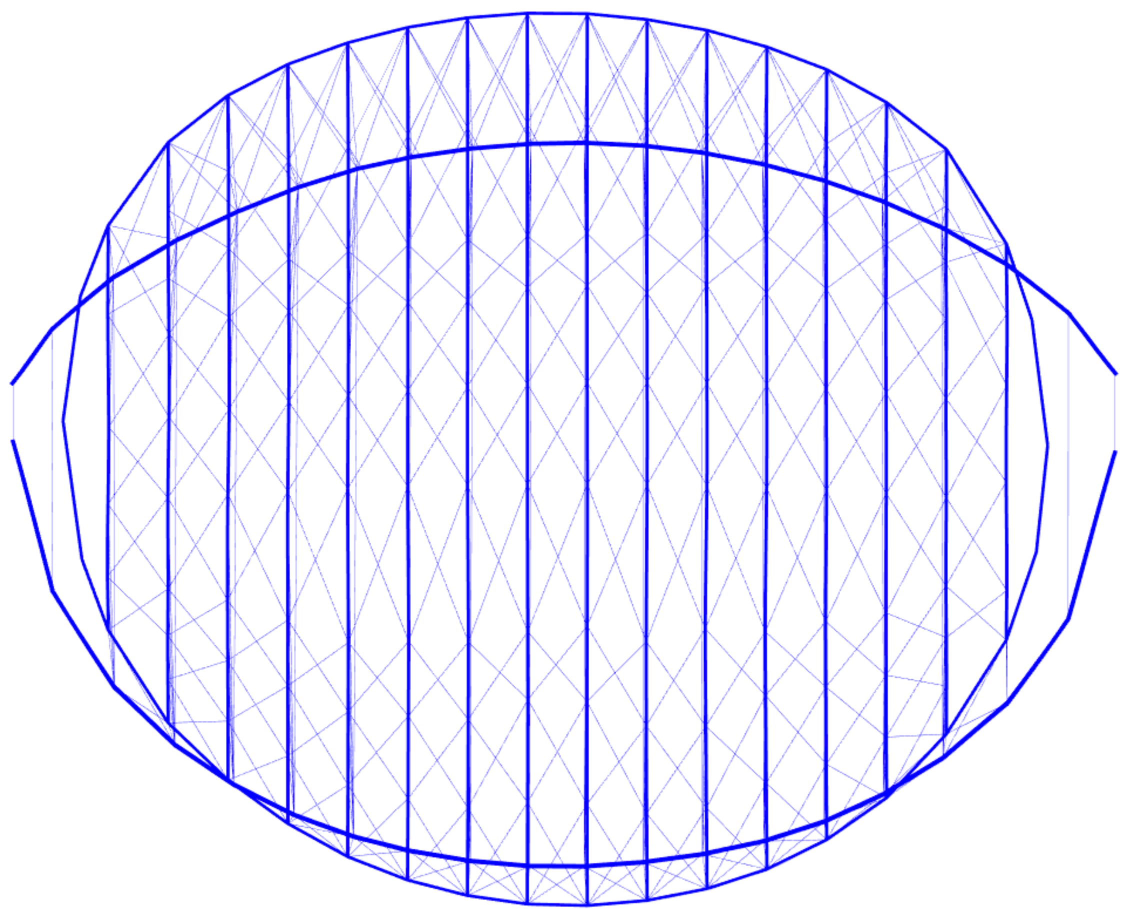
$$S_{buckling} = \frac{\pi^2 \cdot E \cdot I}{L_b^2 \cdot A} \left[\frac{n}{mm^2} \right] \qquad S_{buckling} = \frac{\pi^2 \cdot 210000 \cdot 2.35 \cdot 10^{10}}{25000^2 \cdot 1.5 \cdot 10^5} \qquad S_{buckling} = 519.5 \frac{N}{mm^2}$$

Max. deformation = 17.5cm



Max. axial stress = 193 MPa

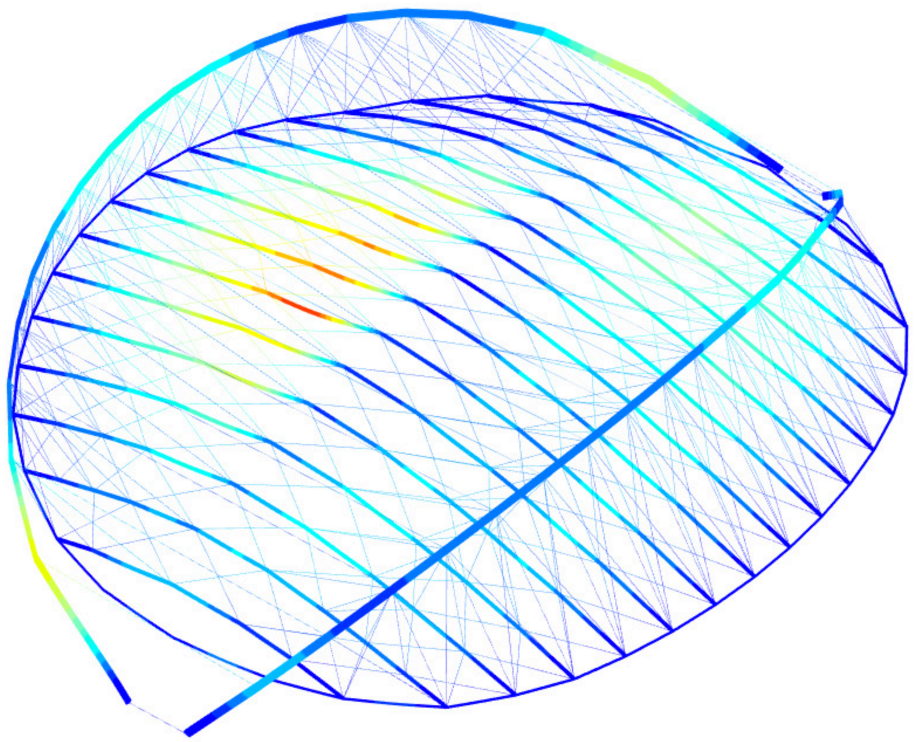
Max. deformation = 7.6cm



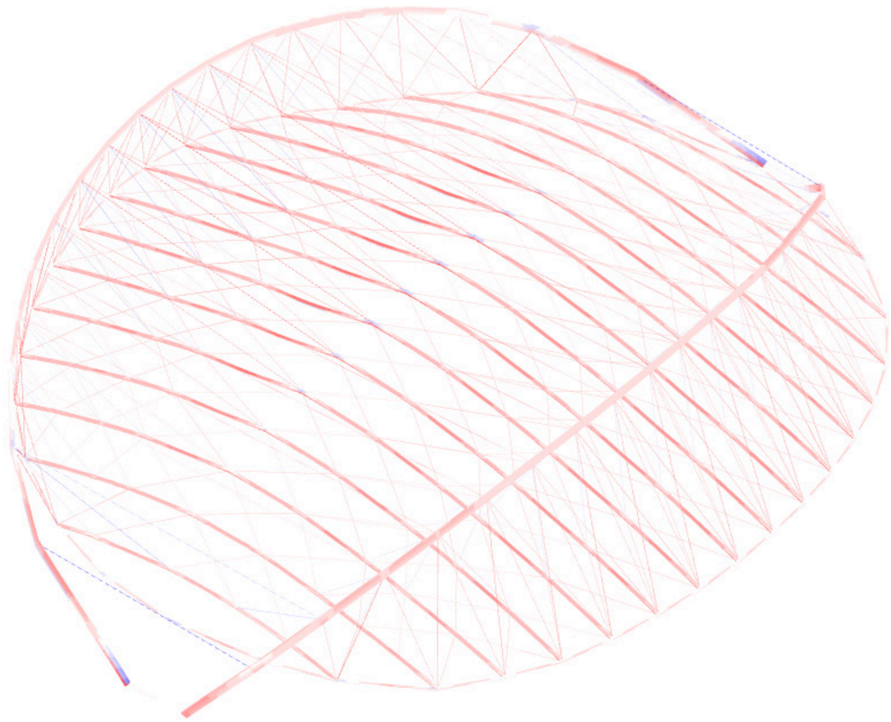
Max. axial stress = 107 MPa

$$U.C. = \frac{\sigma_m \cdot 1.2 \cdot 1.5}{S_{buckling}} \qquad U.C. = \frac{107 \cdot 1.2 \cdot 1.5}{519.5} = 0.37 < 1$$

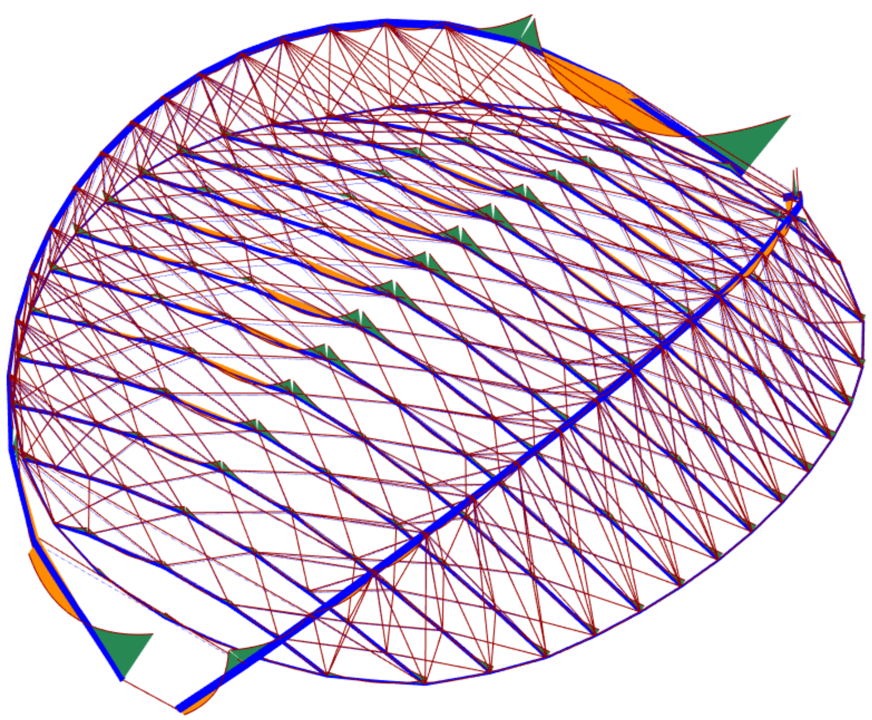
FEM ANALYSIS: FINAL RESULTS



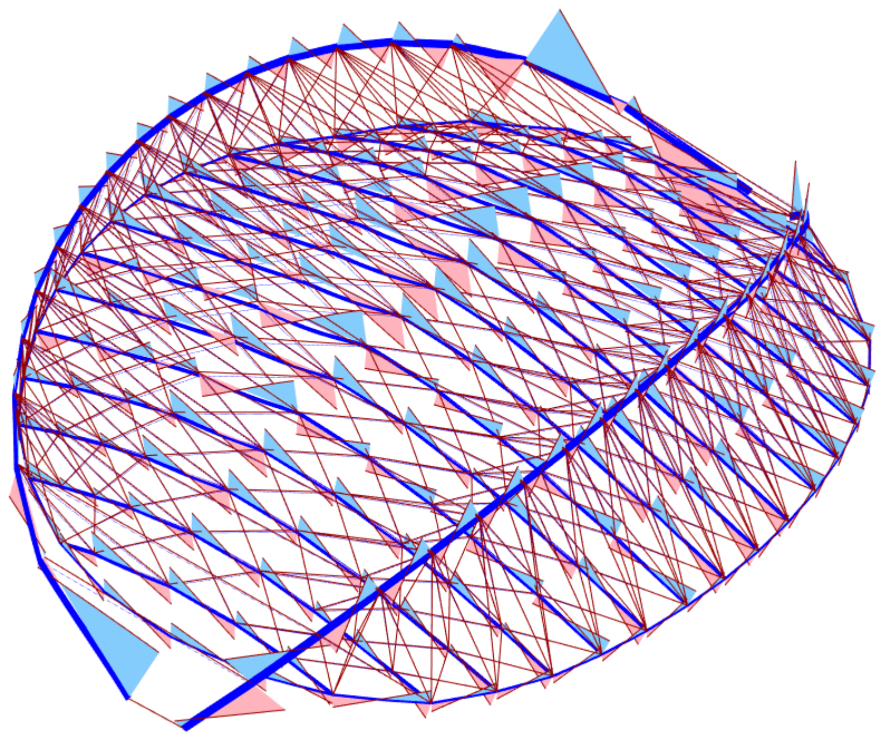
Max. deformation = 7.6cm



Max. axial stress = 110 MPa

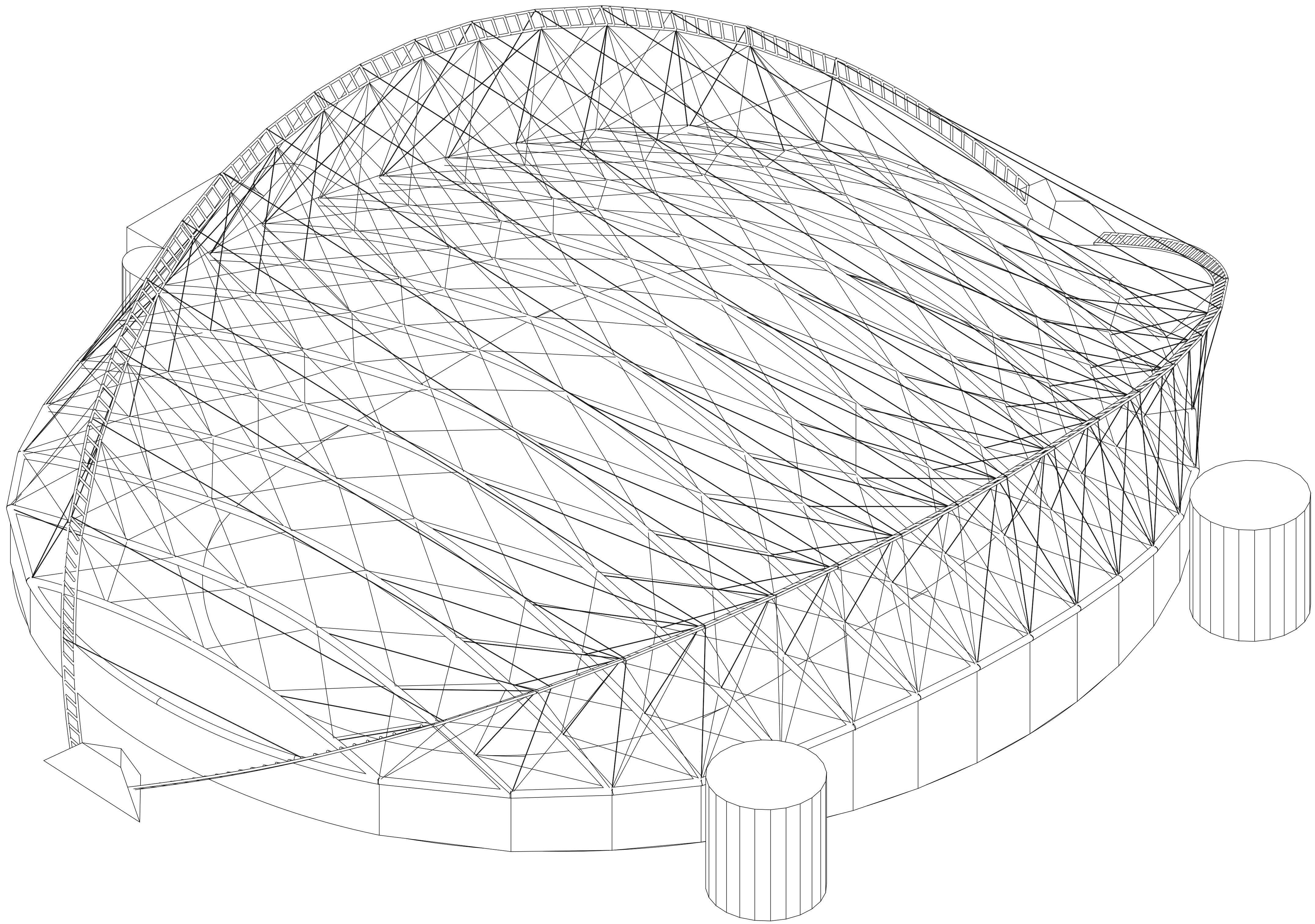


Max. bending moment = 7900 kNm

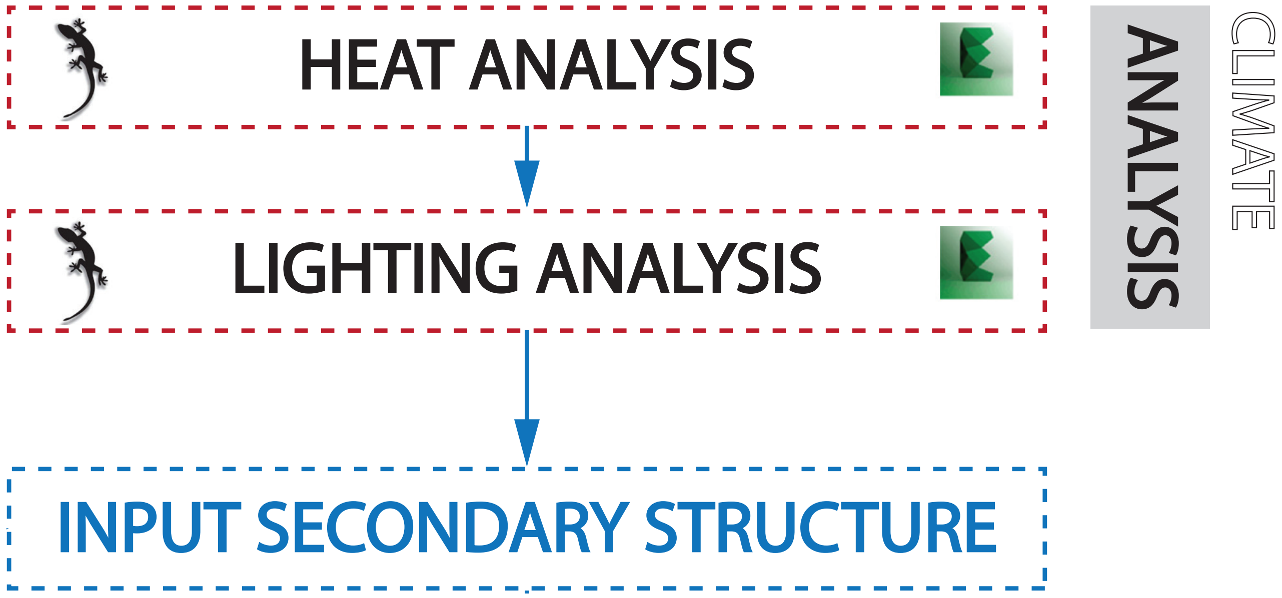


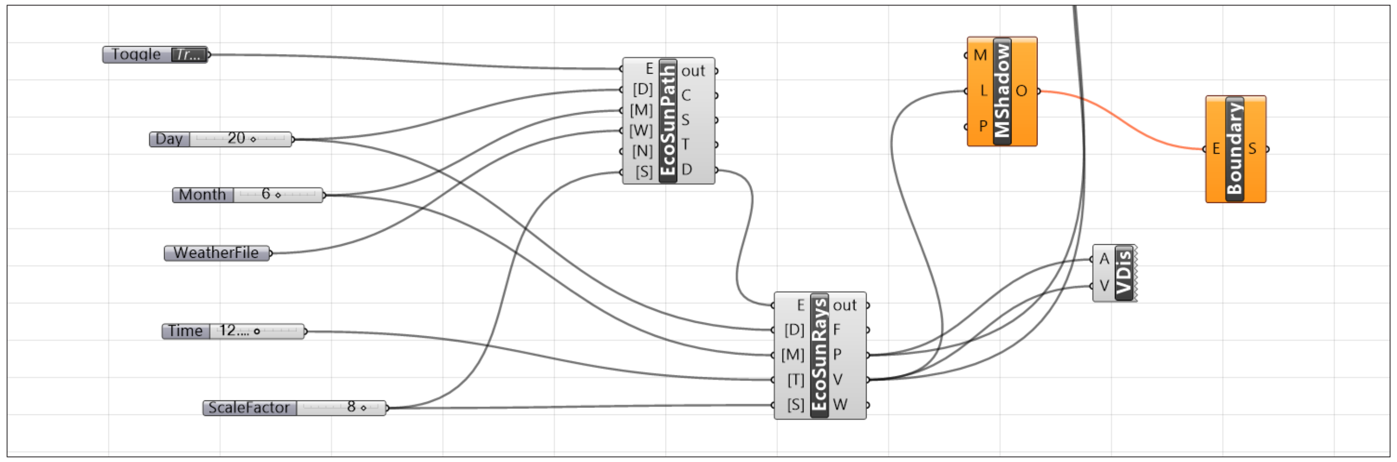
Max. shear force = 360 kN

PRIMARY STRUCTURE CONCEPT DESIGN



5.3 HEAT & LIGHTING DESIGN ANALYSIS

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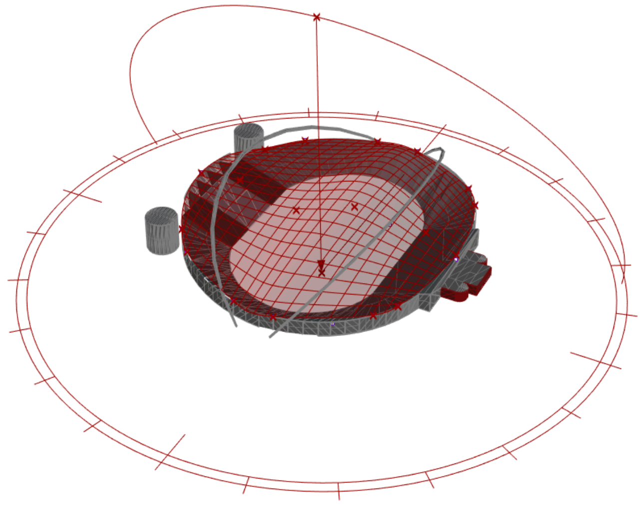
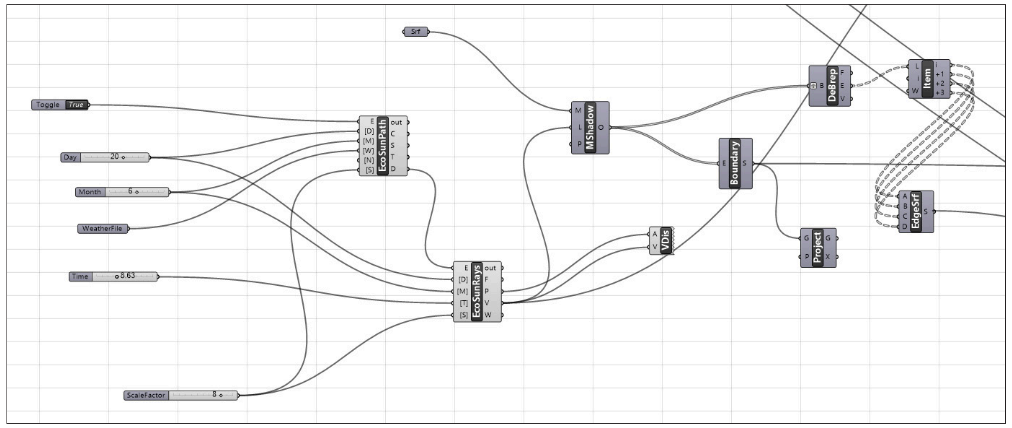
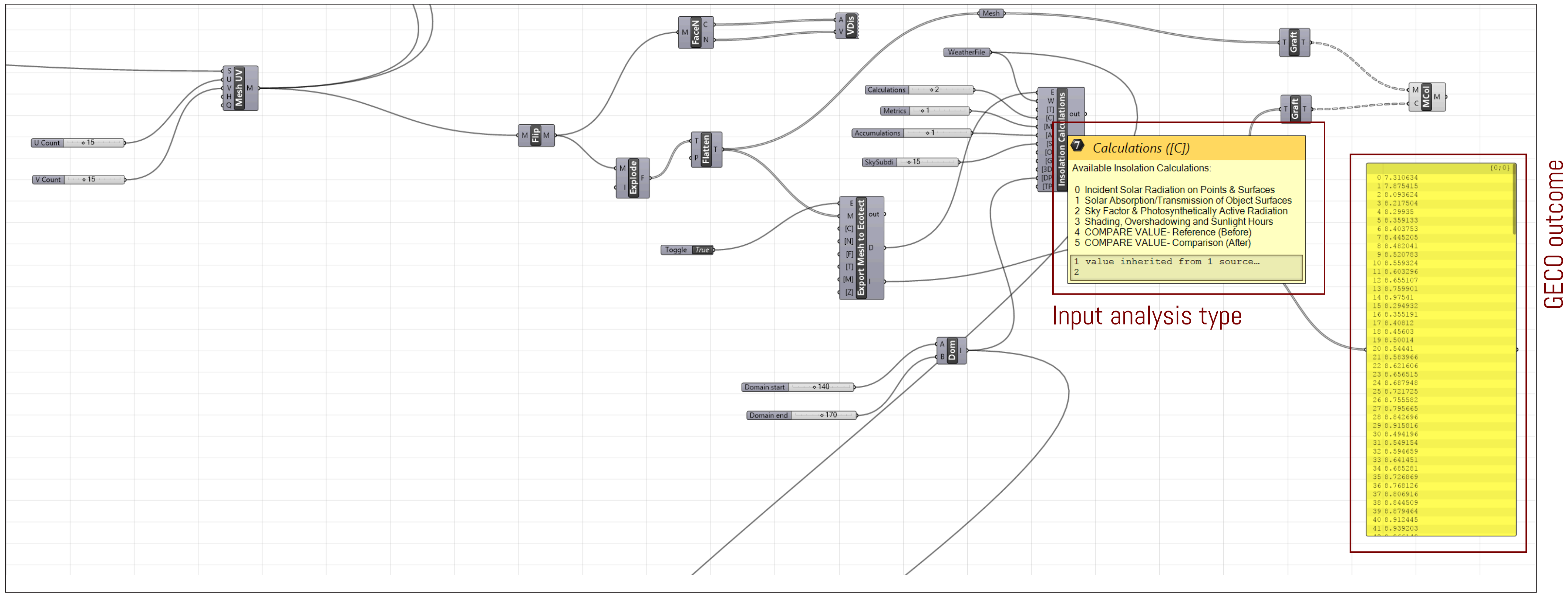
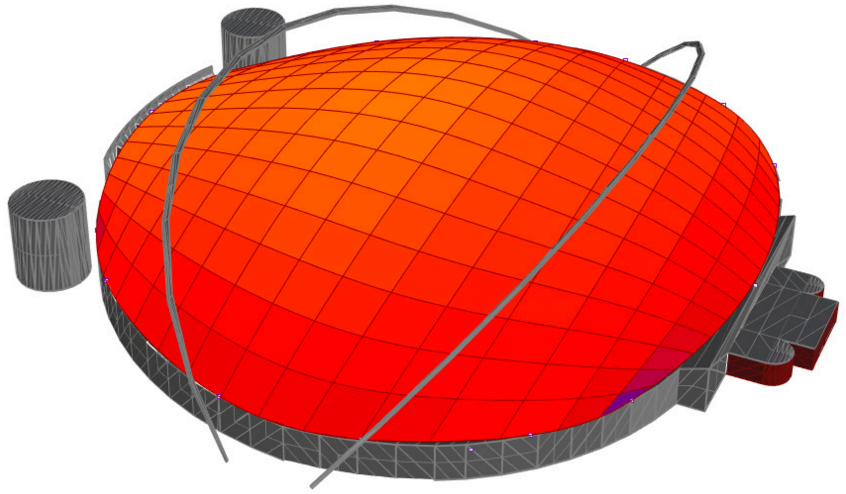
WeatherFile
Time
ScaleFactor
EcoSunPath
EcoSunRays
MShadow
Boundary
VDis

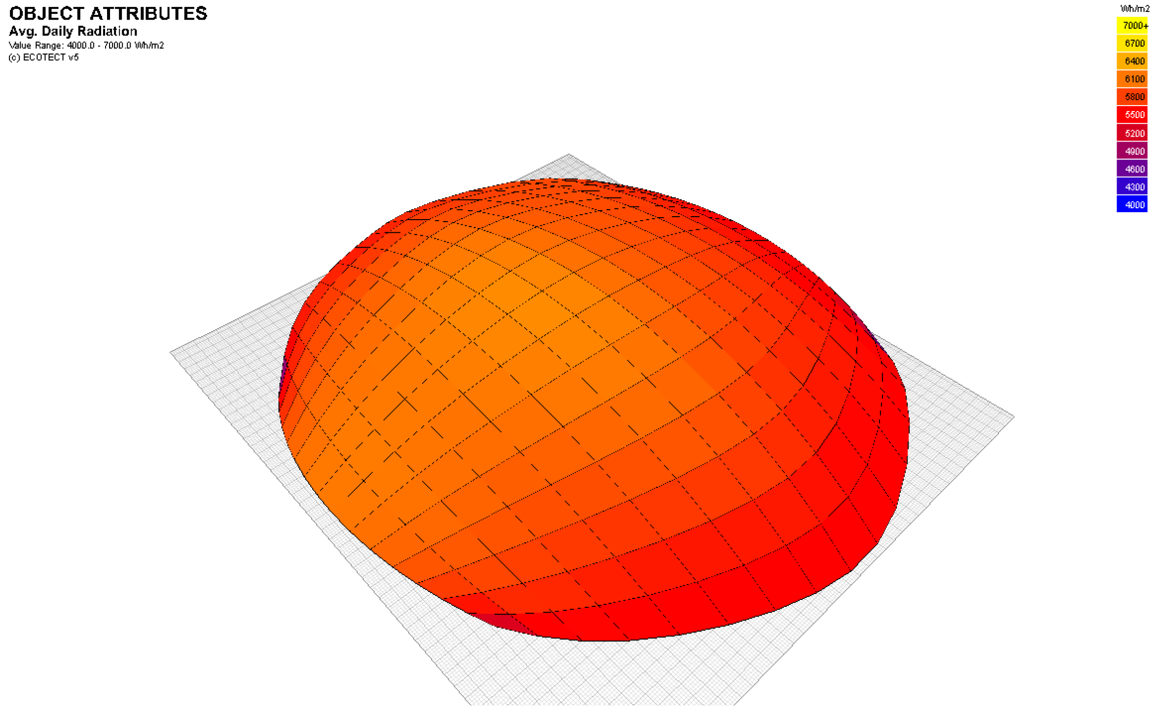




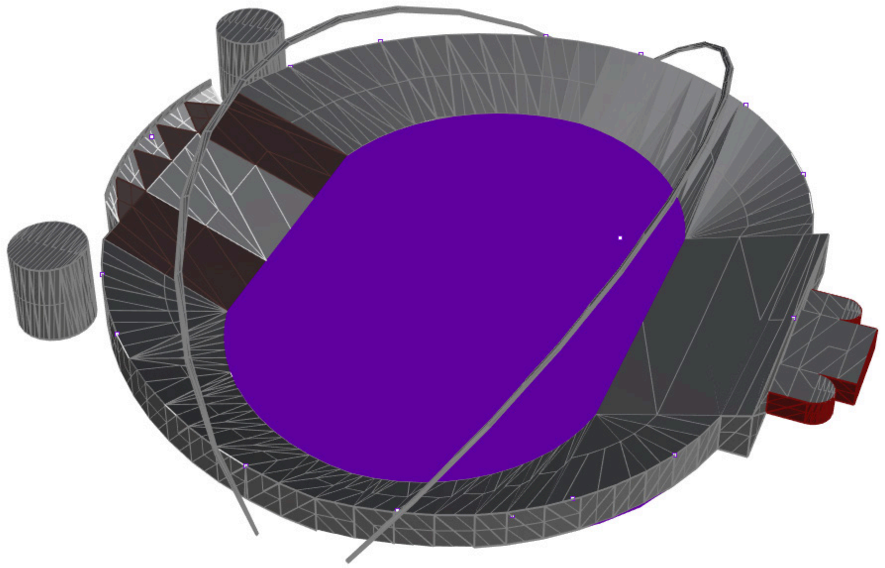

Mesh UV
U Count
V Count
Flip
Explode
Flatten
FaceN
VDis
Mesh
WeatherFile
Calculations
Metrics
Accumulations
SkySubdi
Toggle
Export Mesh to Ecotect
Insolation Calculations
Graft
MCol
Dom
Domain start
Domain end
Calculations ([C])
Available Insolation Calculations:
0 Incident Solar Radiation on Points & Surfaces
1 Solar Absorption/Transmission of Object Surfaces
2 Sky Factor & Photosynthetically Active Radiation
3 Shading, Overshadowing and Sunlight Hours
4 COMPARE VALUE- Reference (Before)
5 COMPARE VALUE- Comparison (After)
1 value inherited from 1 source...
Input analysis type
GECO outcome

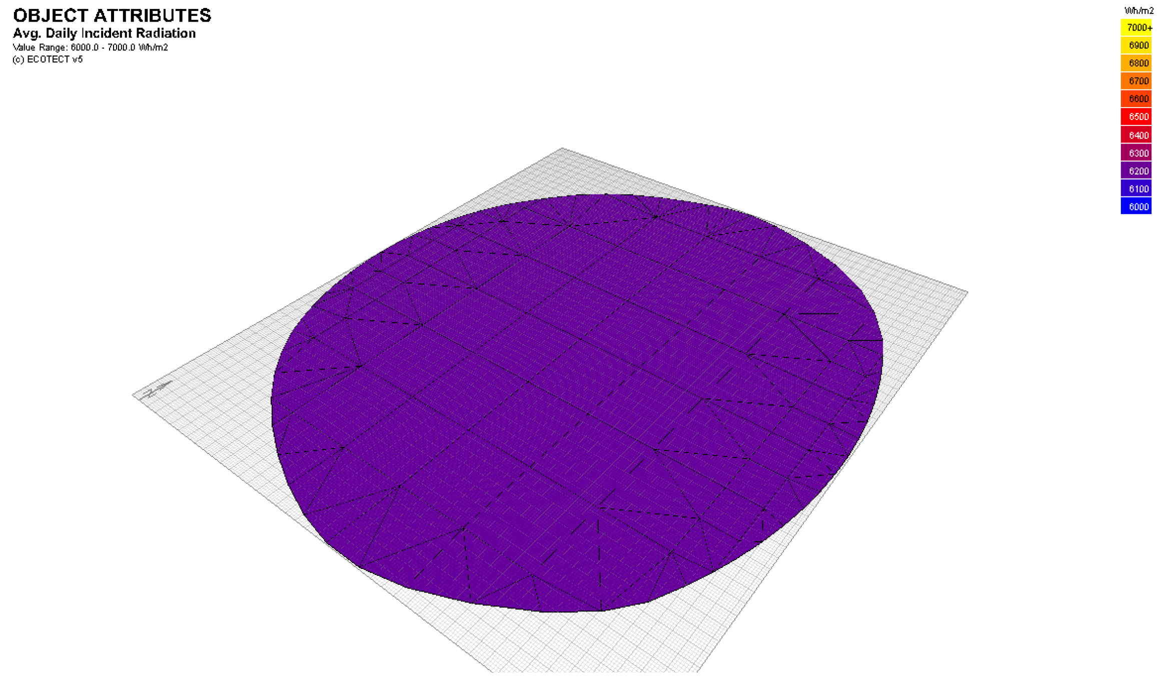
5200 to 6400 Wh/m²



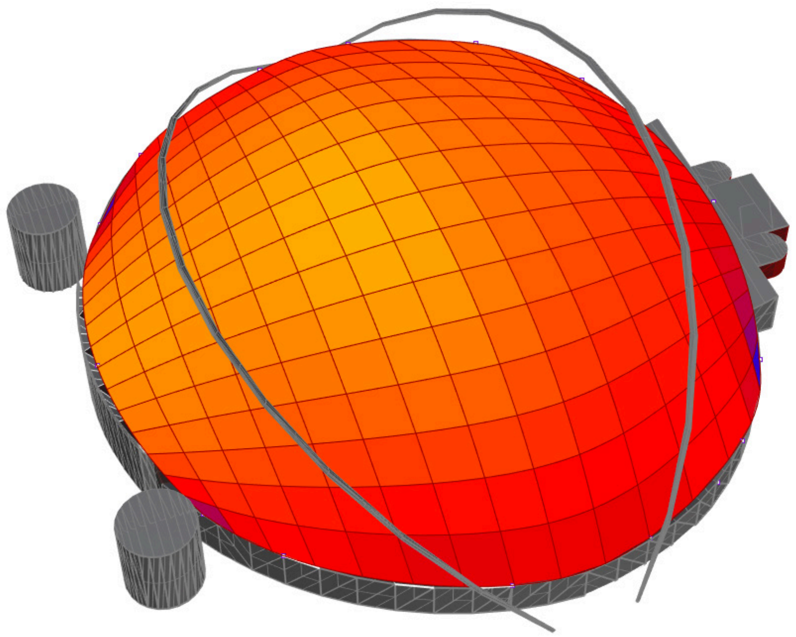


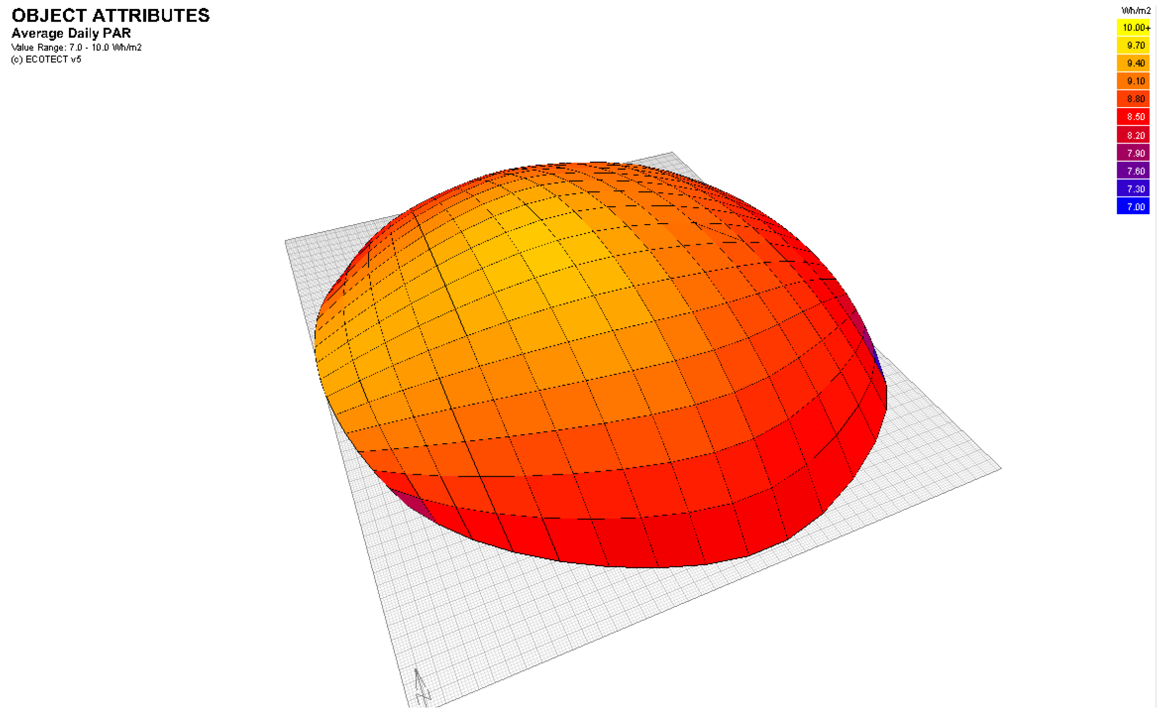
6200 Wh/m²



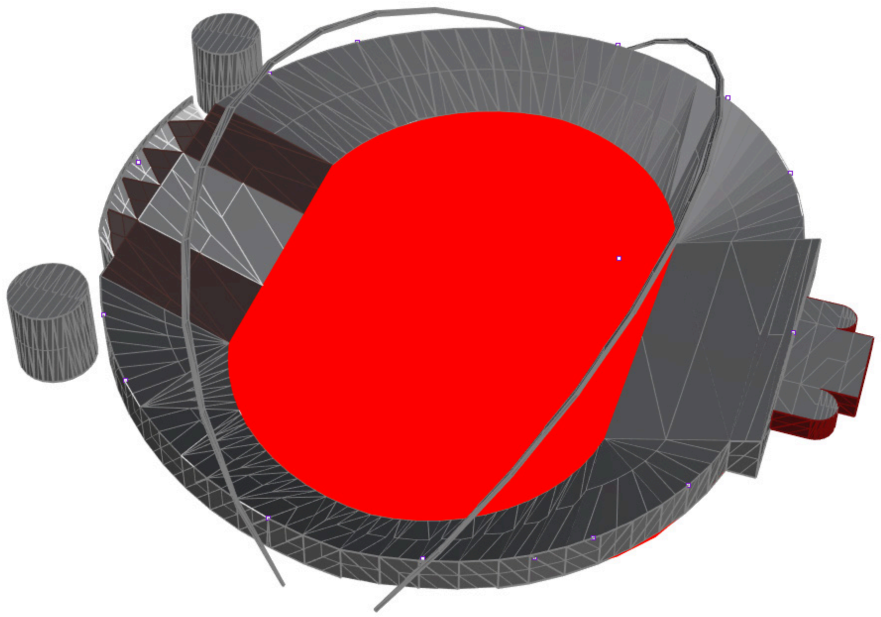


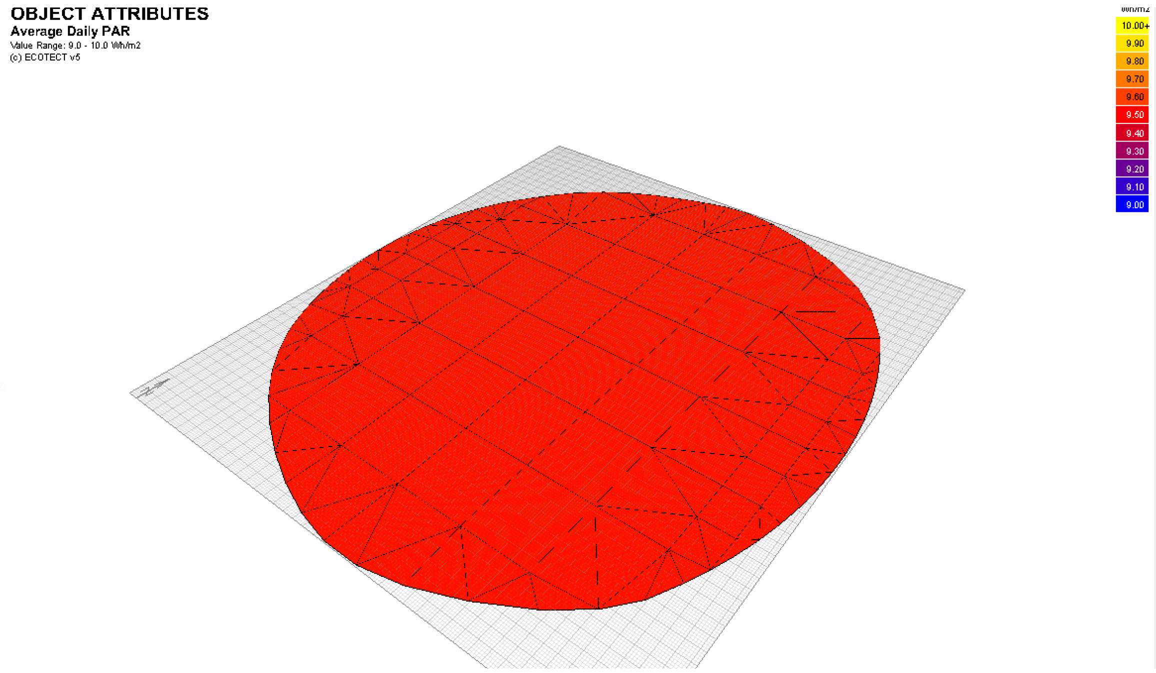
8.5 to 9.7 Wh/m²

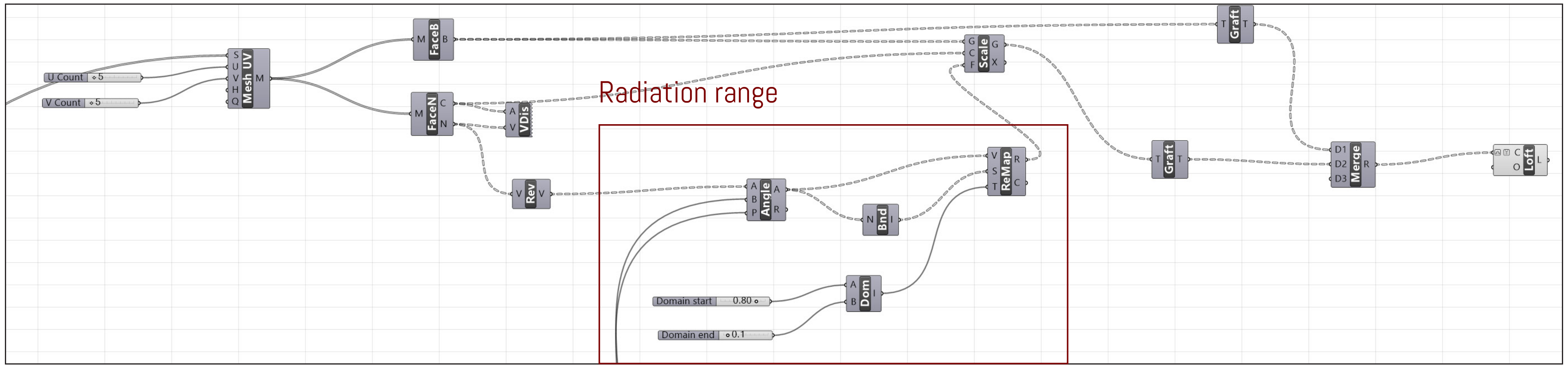


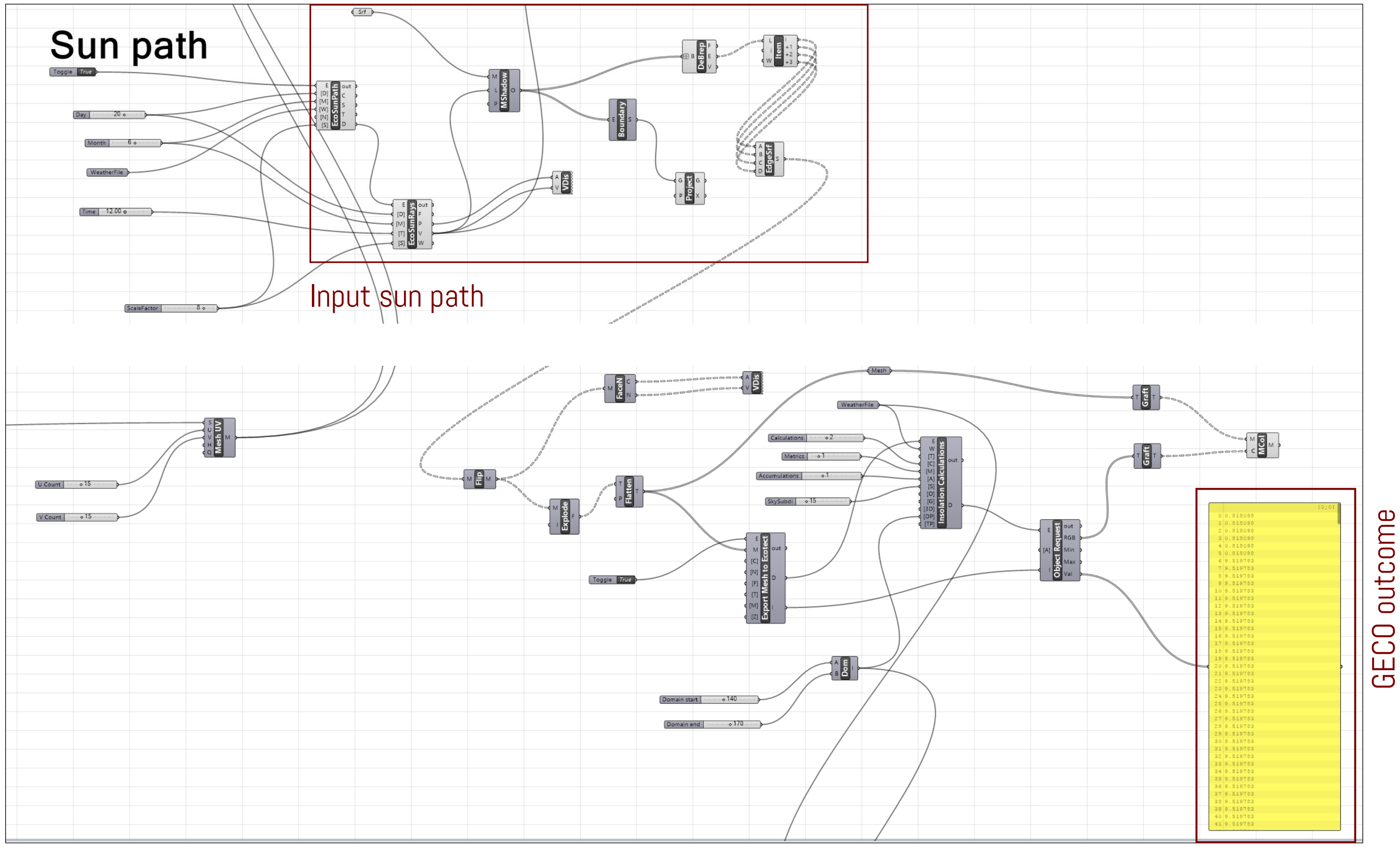


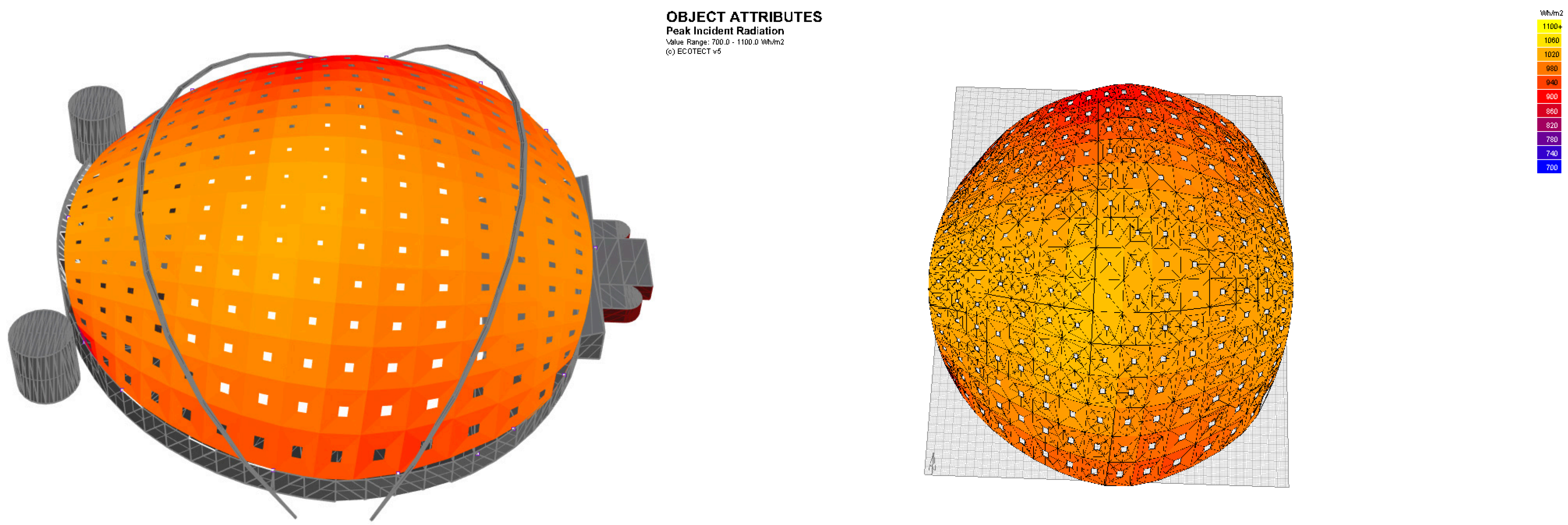
7.6 Wh/m²

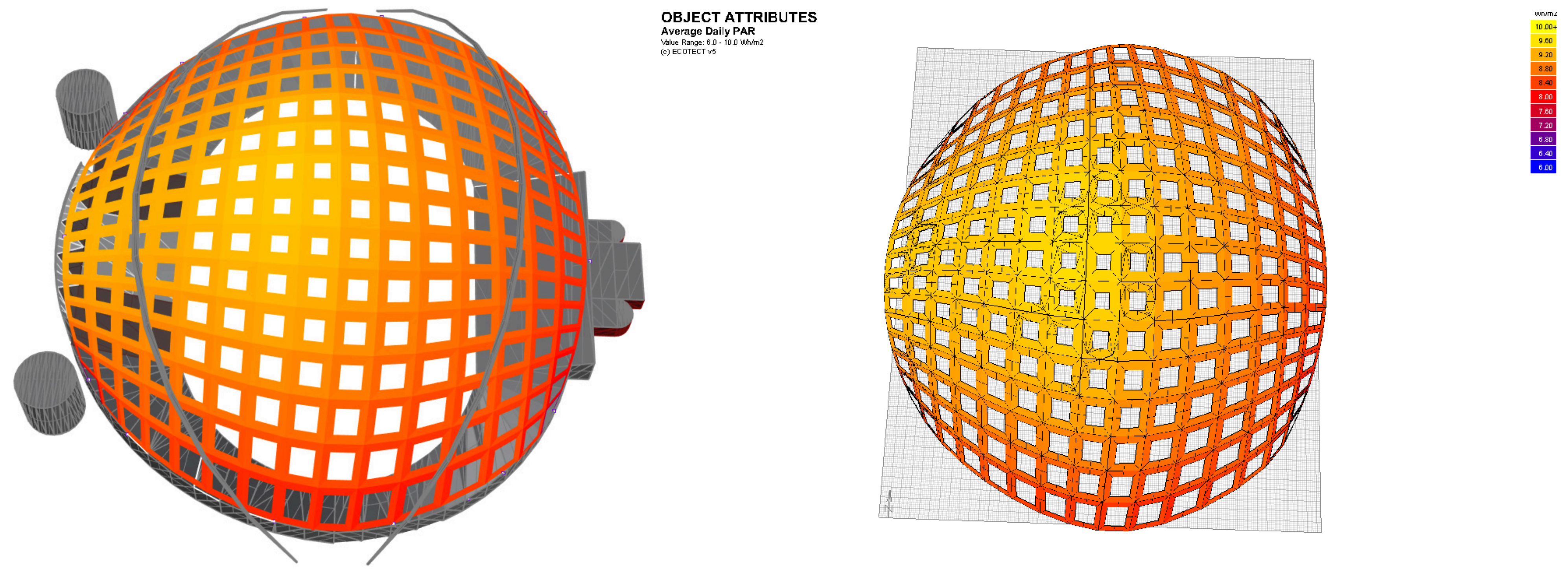


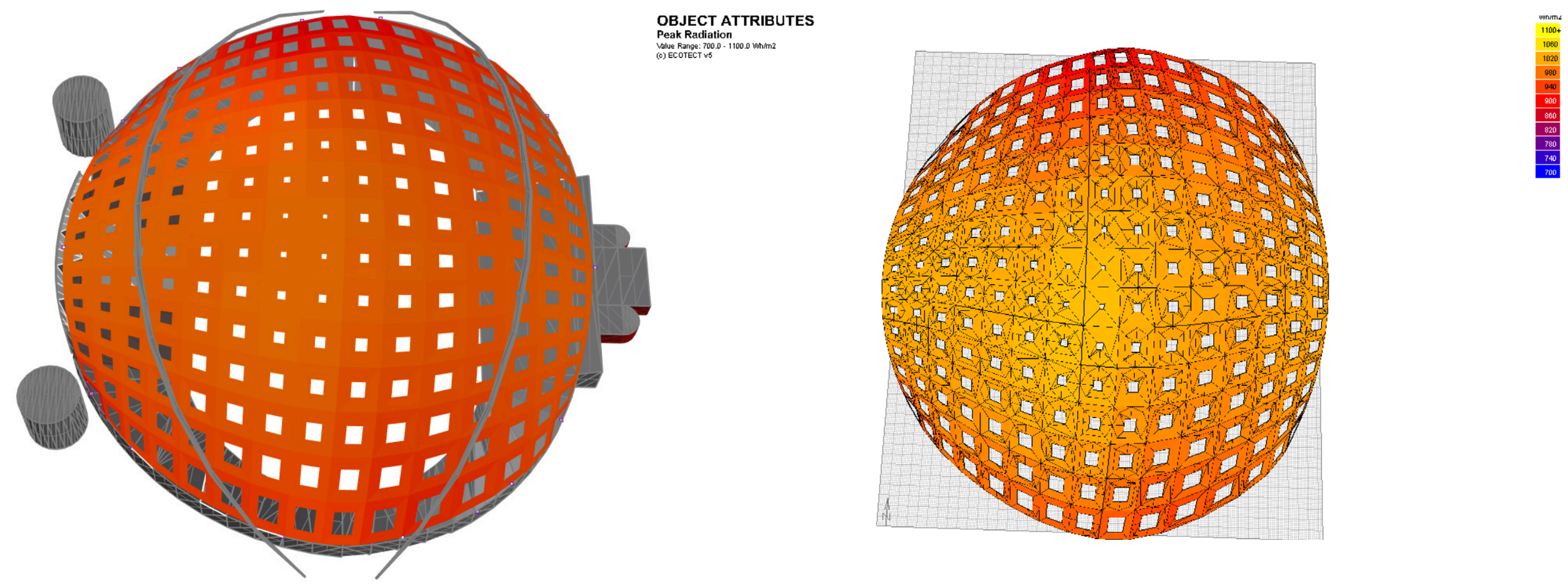



Radiation range
U Count
V Count
Mesh UV
FaceB
FaceN
VDis
Rev
Angle
Bnd
ReMap
Dom
Domain start 0.80
Domain end 0.1
Scale
Graft
Graft
Merge
Loft

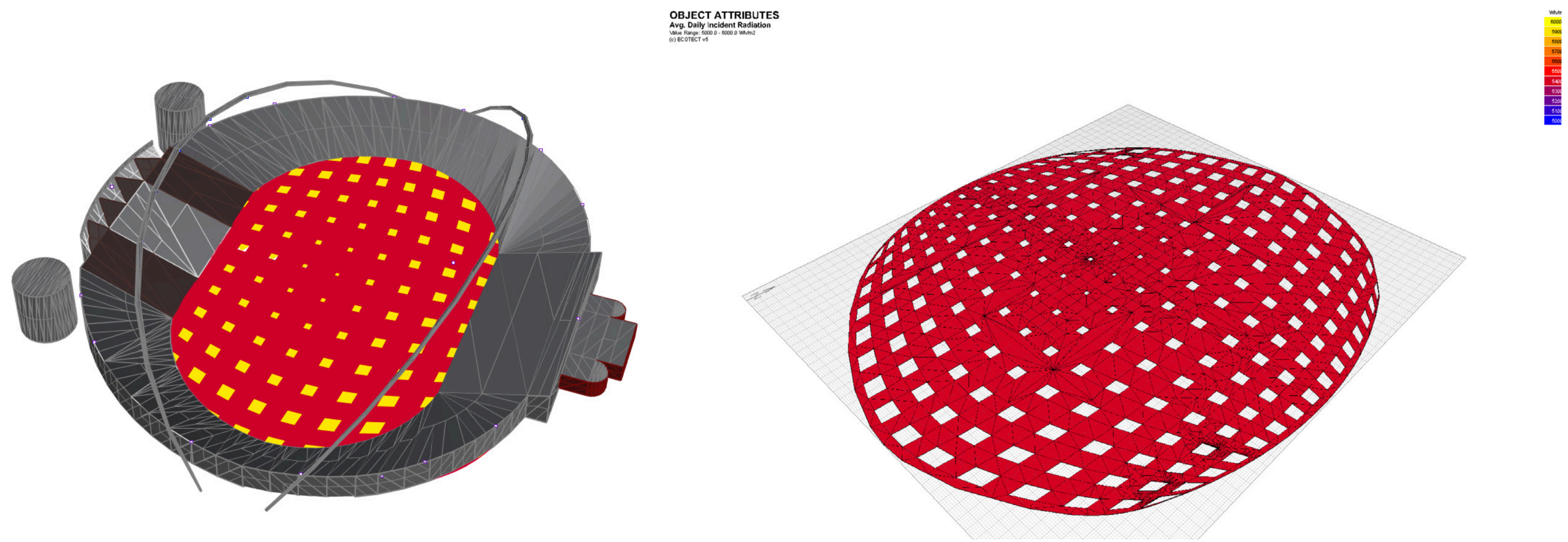

Sun path
Input sun path
GECO outcome


OBJECT ATTRIBUTES
Peak Incident Radiation
Value Range: 700.0 - 1100.0 Wh/m2
(c) ECOTECT v5
Wh/m2
1100+
1060
1020
980
940
900
860
820
780
740
700

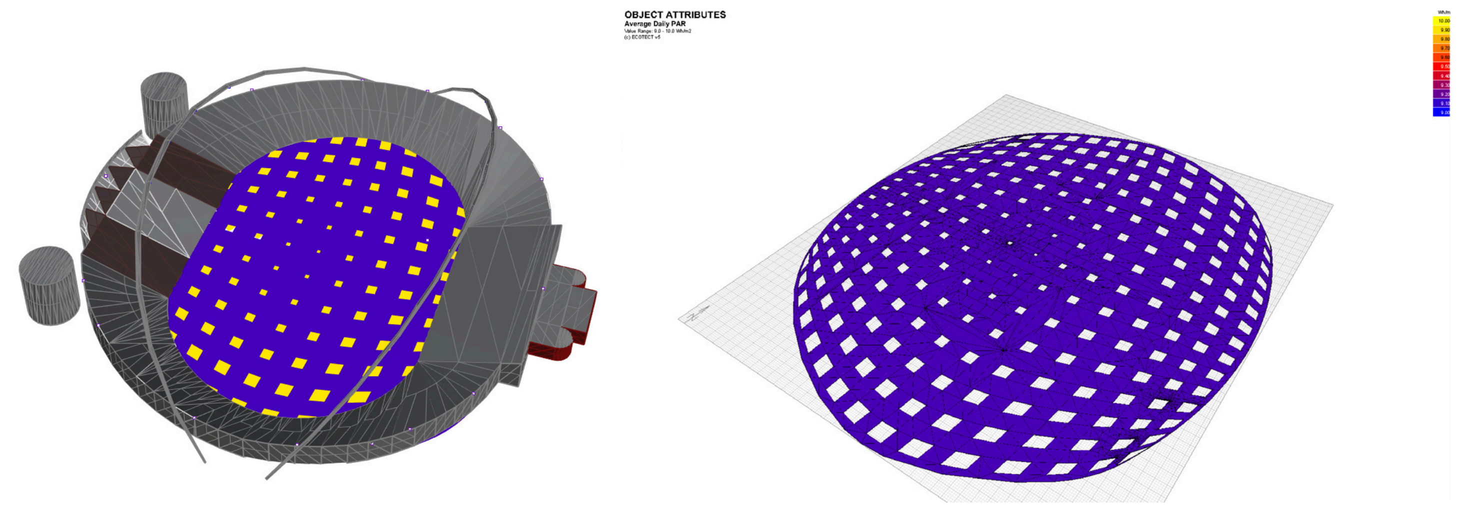

OBJECT ATTRIBUTES
Average Daily PAR
Value Range: 6.0 - 10.0 Wh/m2
(c) ECOTECT v5
10.00+
9.60
9.20
8.80
8.40
8.00
7.60
7.20
6.80
6.40
6.00



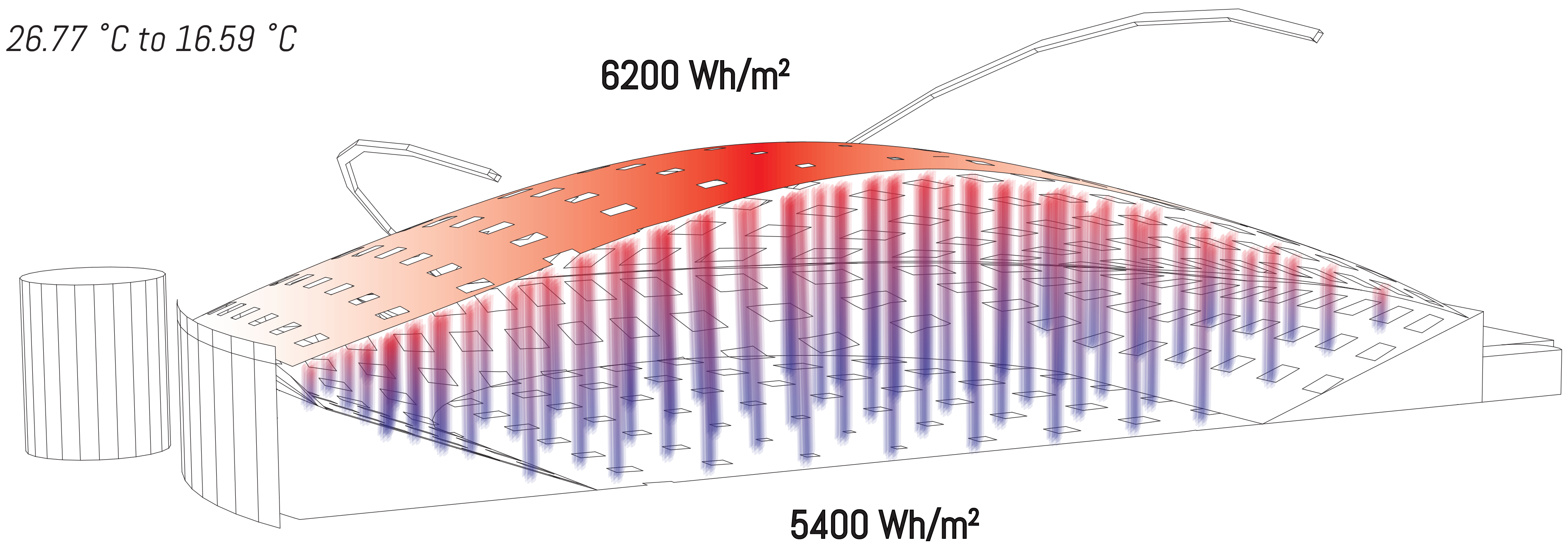
5400 Wh/m²



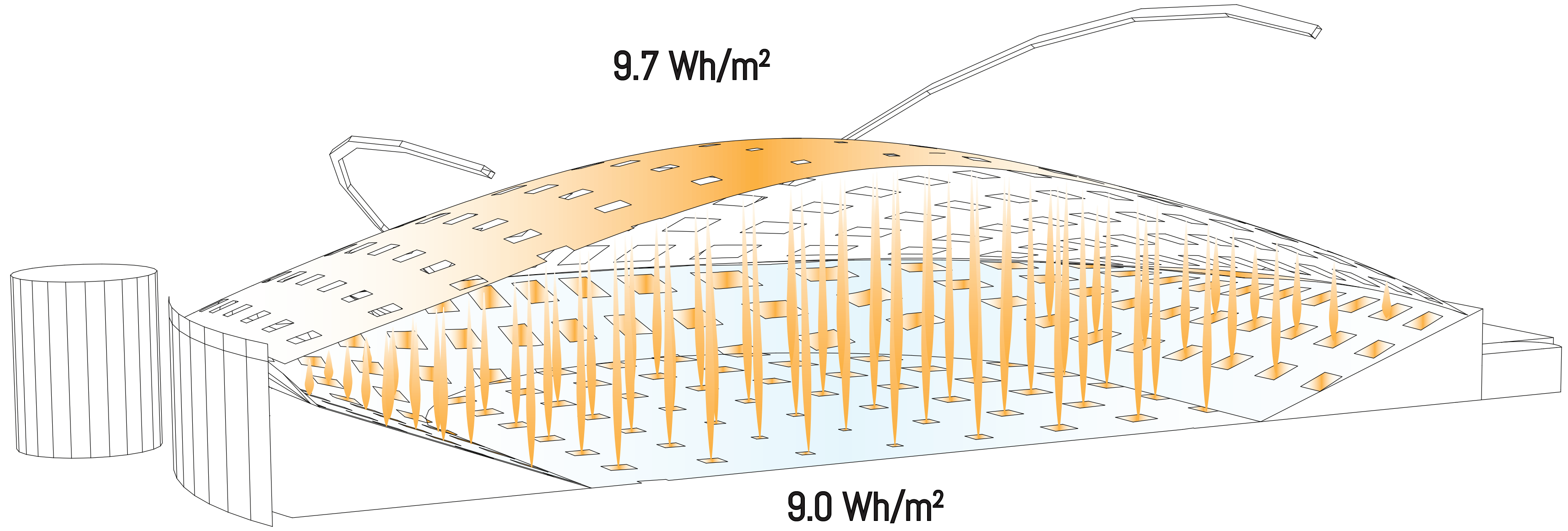
9.0 Wh/m²



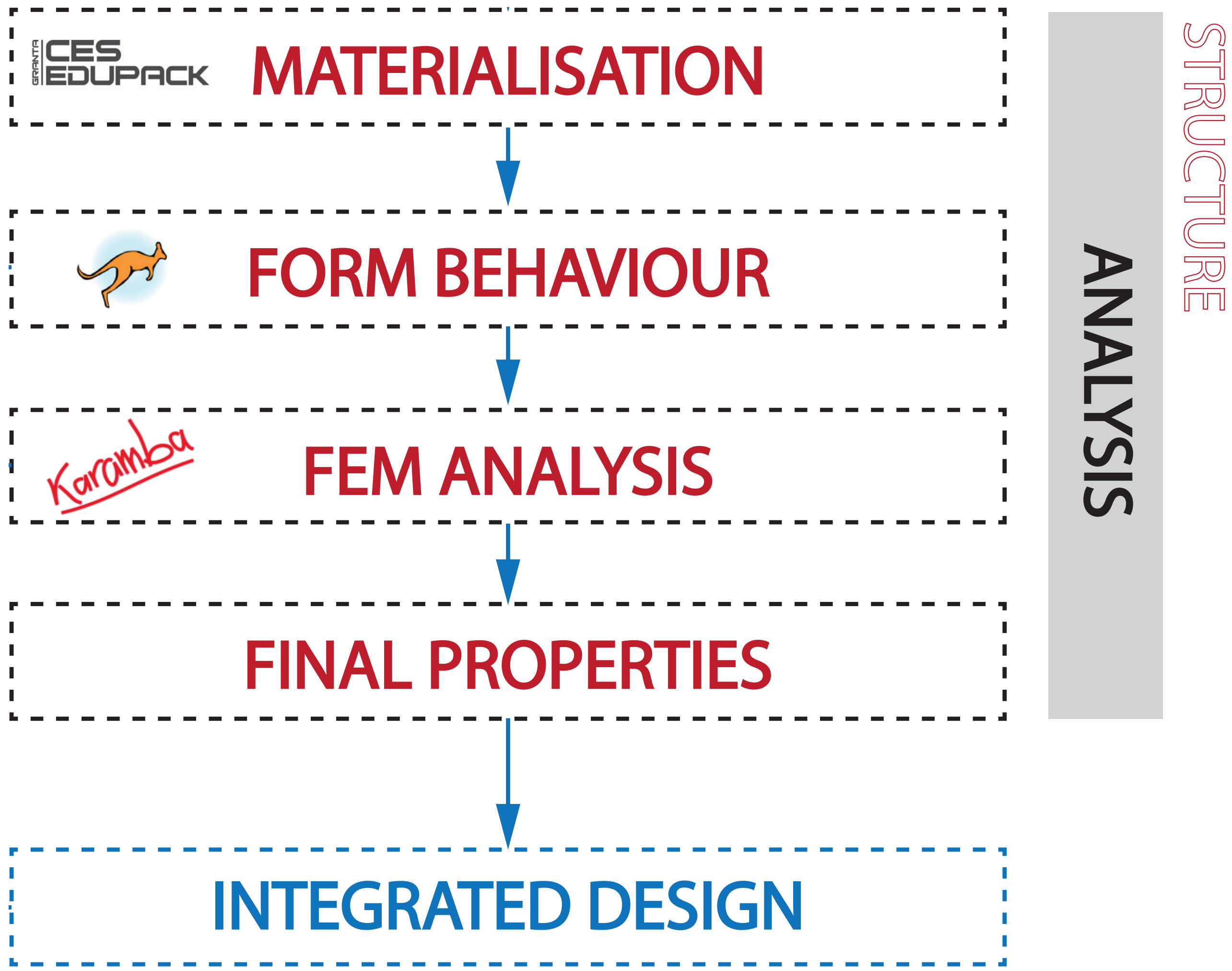
HEAT & LIGHTING CONCEPT DESIGN



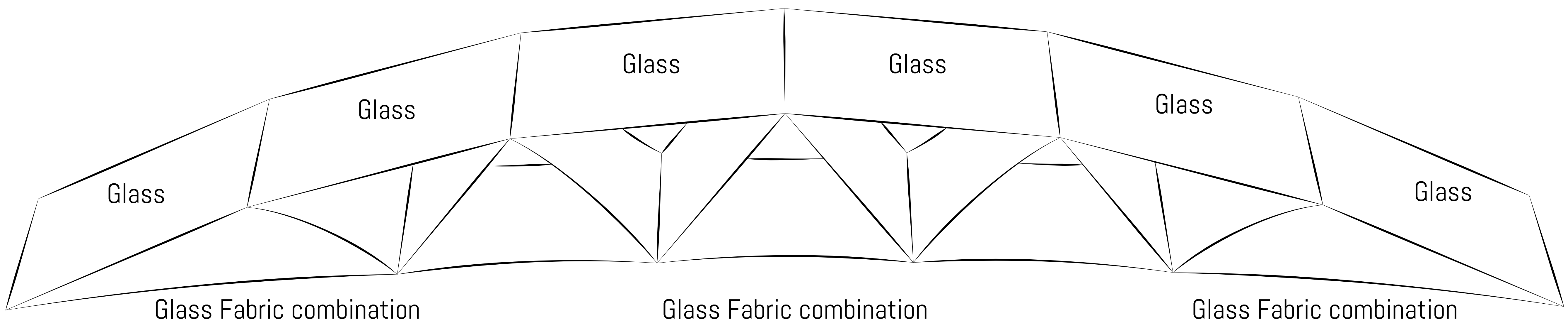
99 W/m² > 52 W/m²



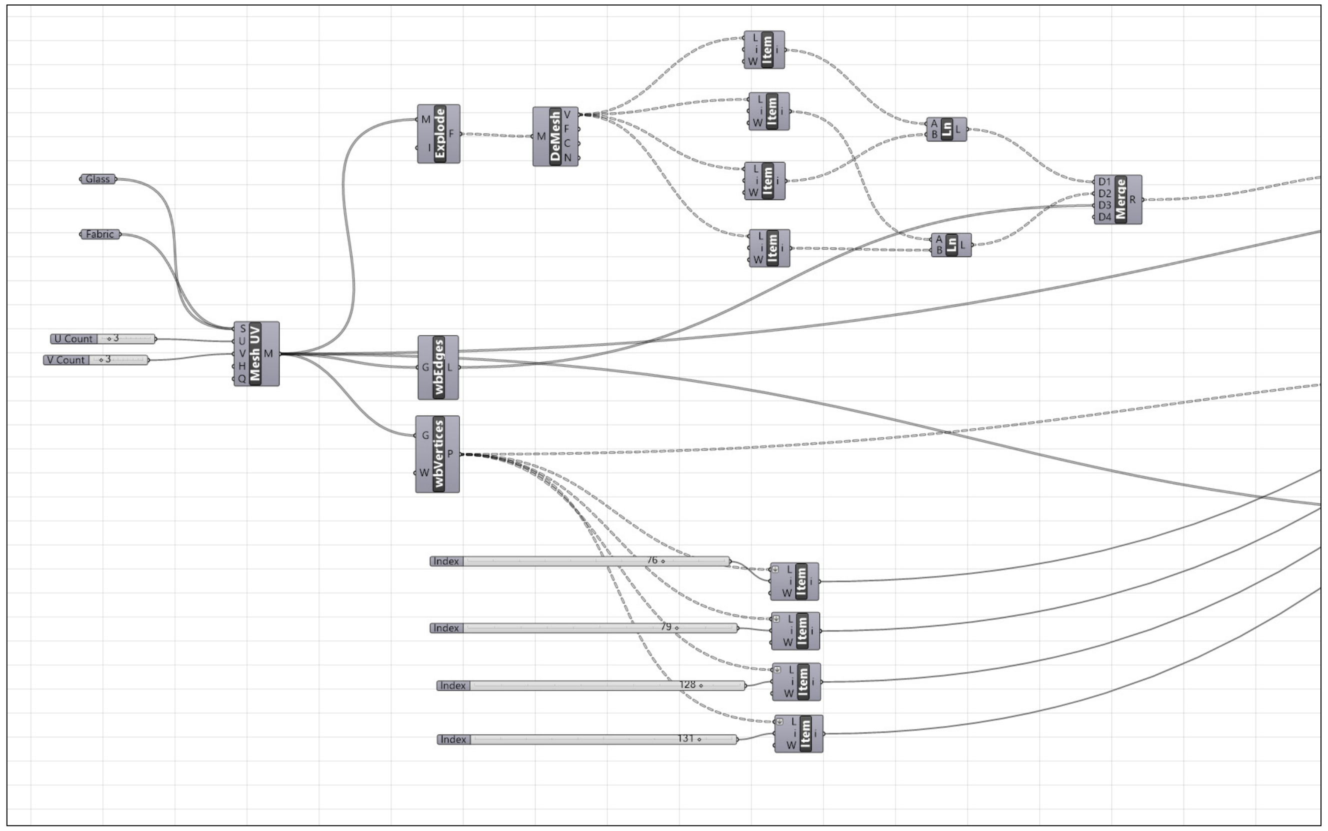
5.4 SECONDARY STRUCTURE DESIGN ANALYSIS

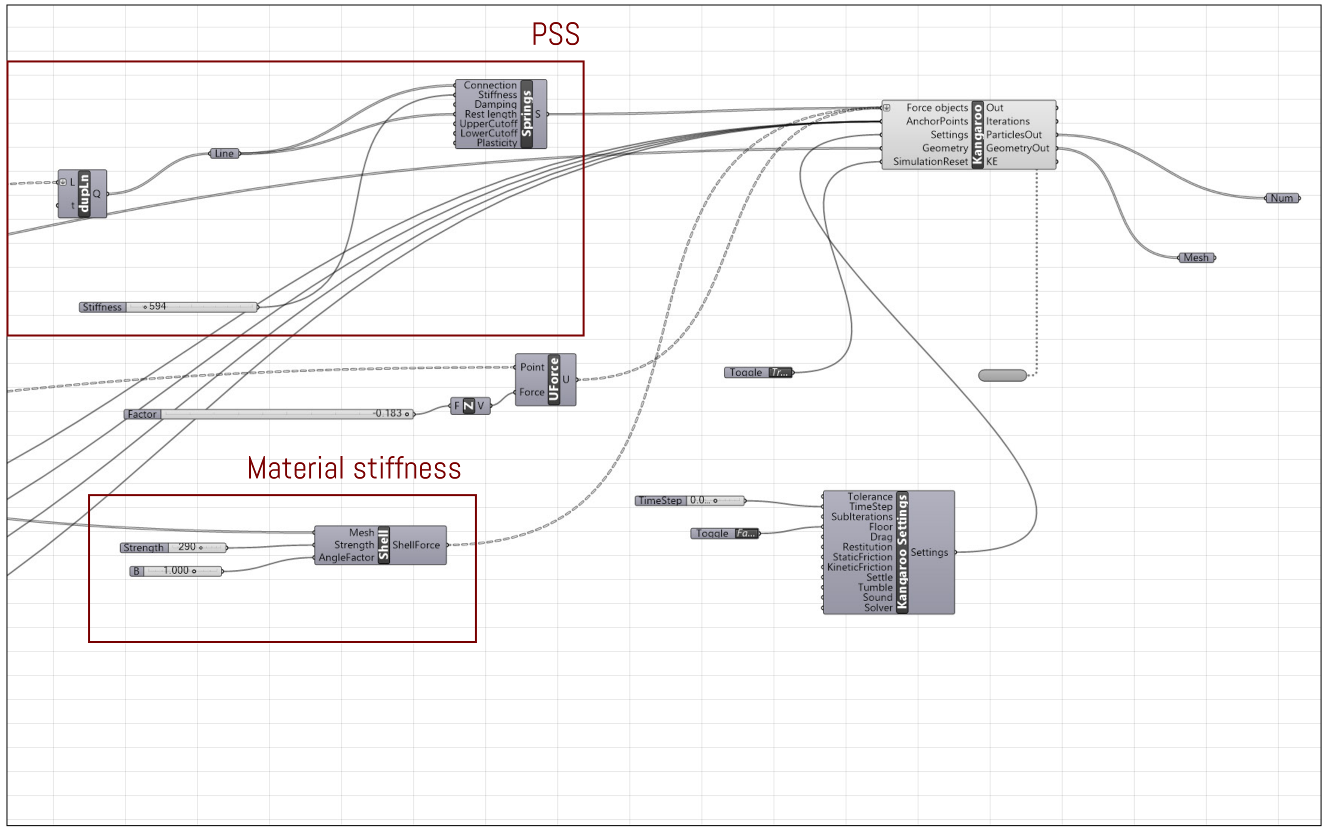


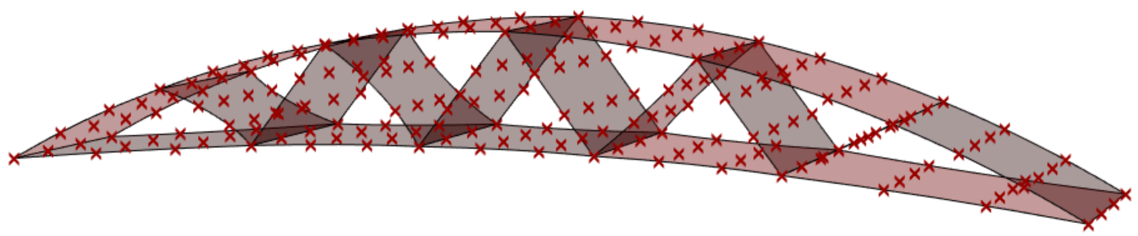
TYPE OF STRUCTURE

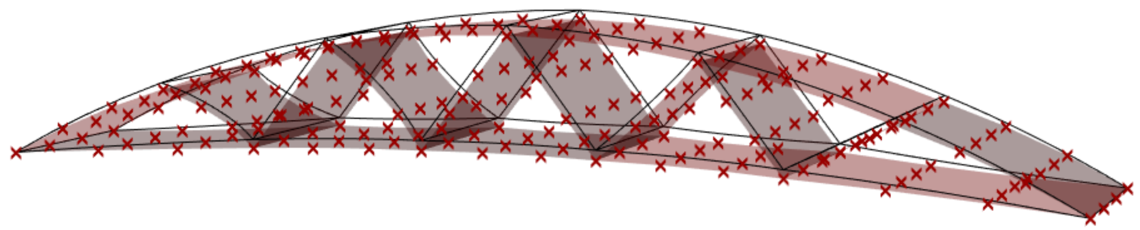


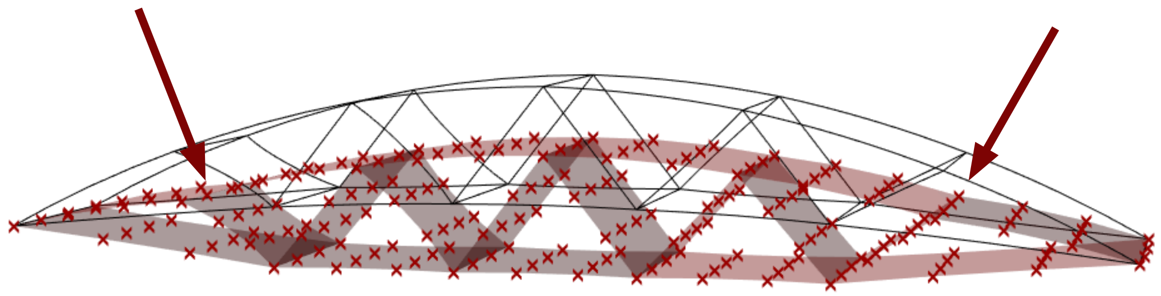
KANGAROO FORM BEHAVIOUR

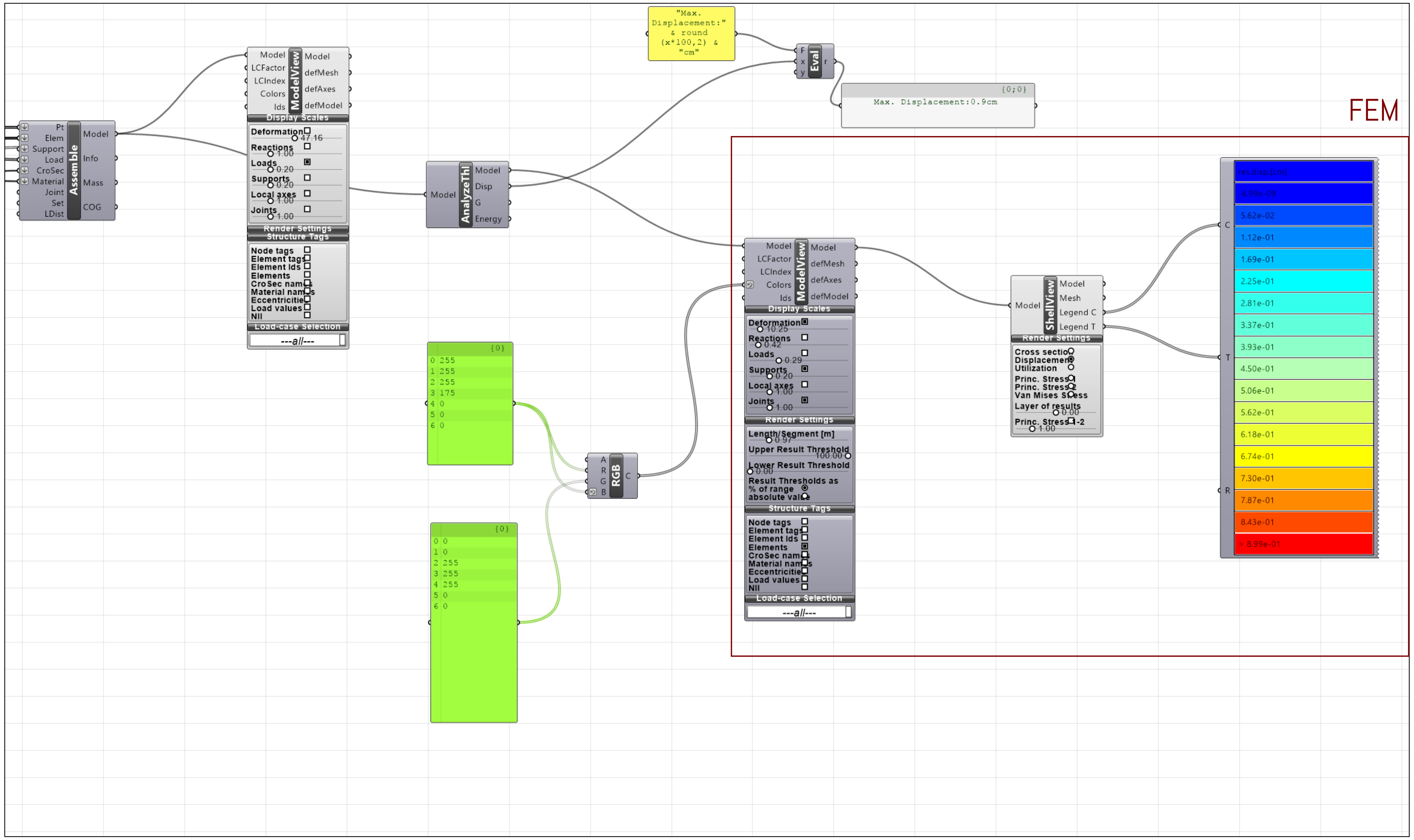




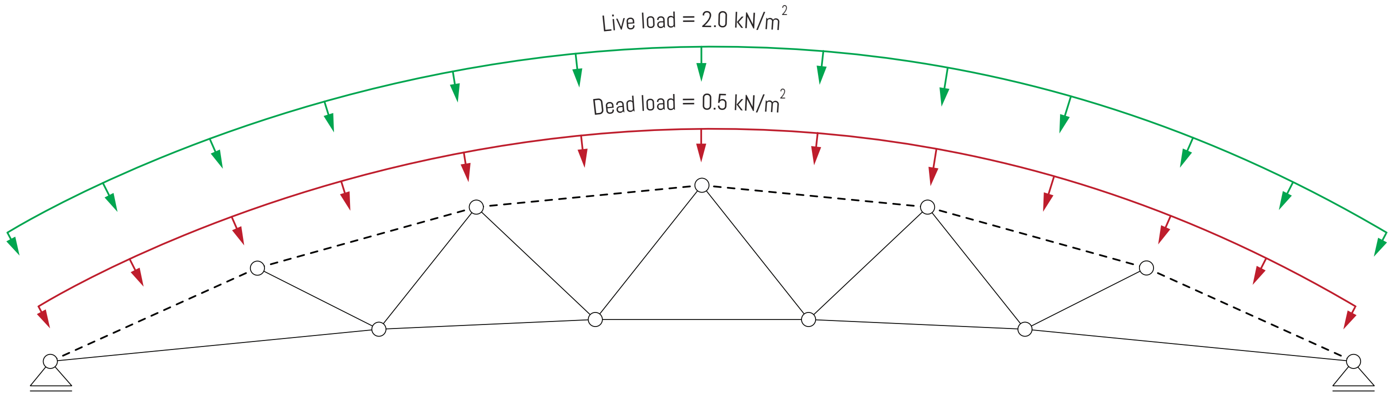


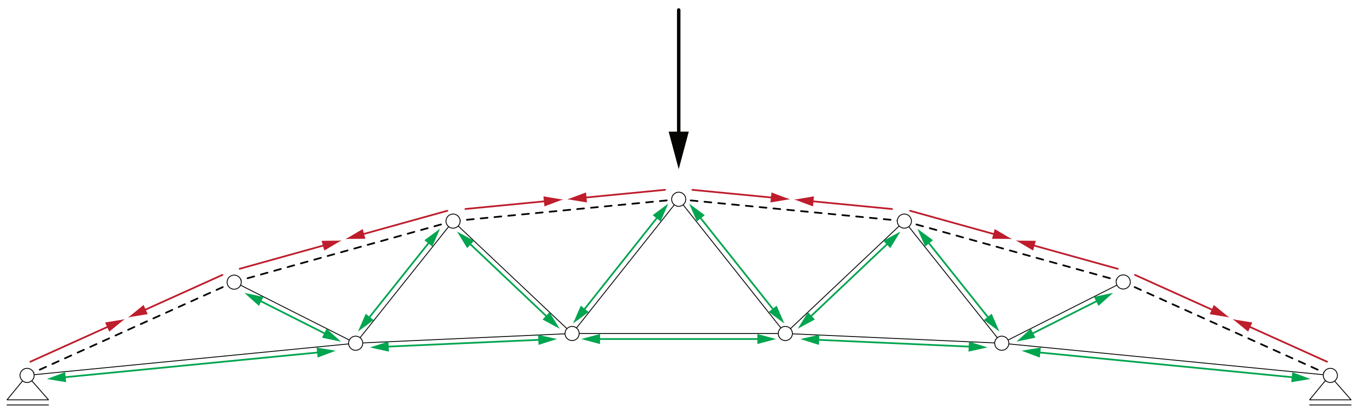


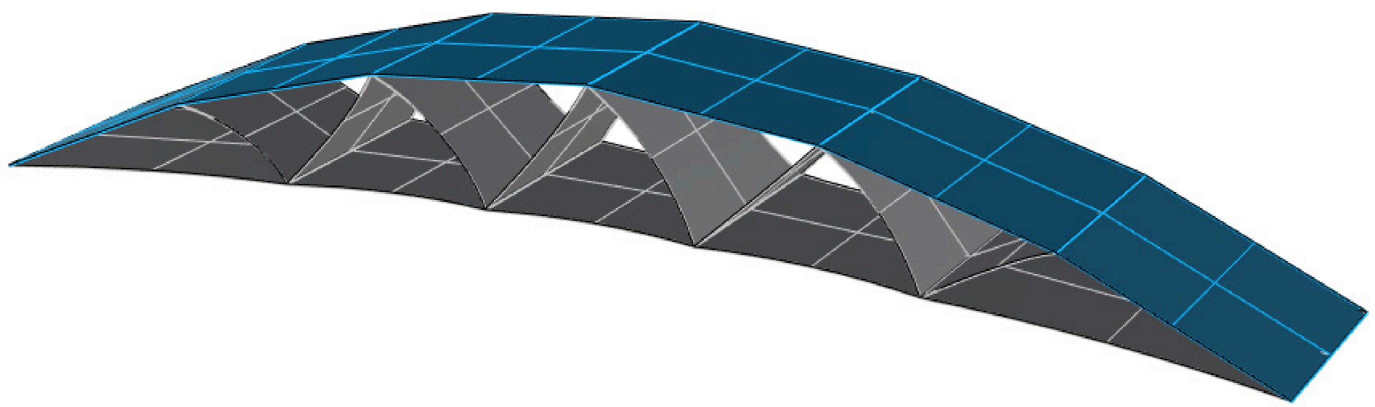


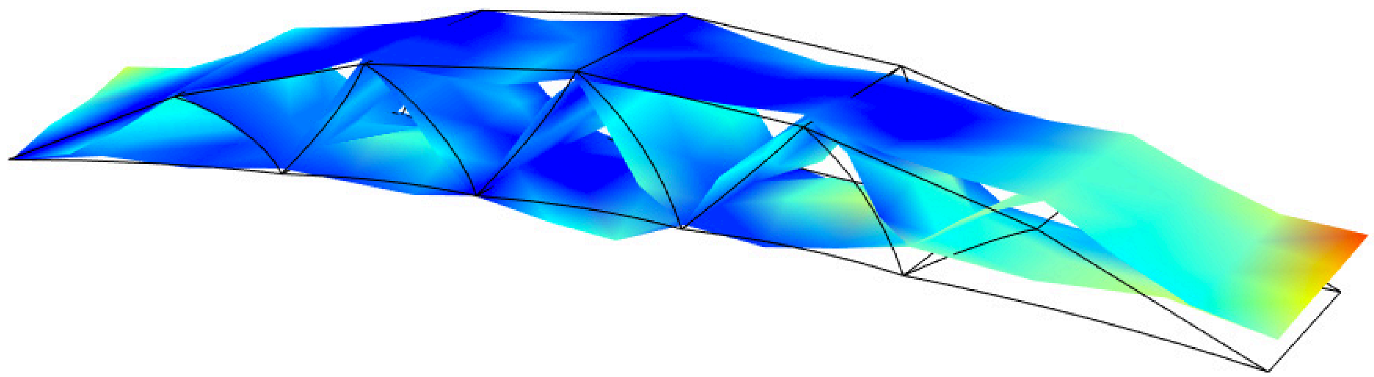


FEM
"Max. Displacement:" & round (x*100,2) & "cm"
Eval
Max. Displacement:0.9cm
Assemble
ModelView
AnalyzeThI
ShellView
RGB
Display Scales
Render Settings
Structure Tags
Load-case Selection



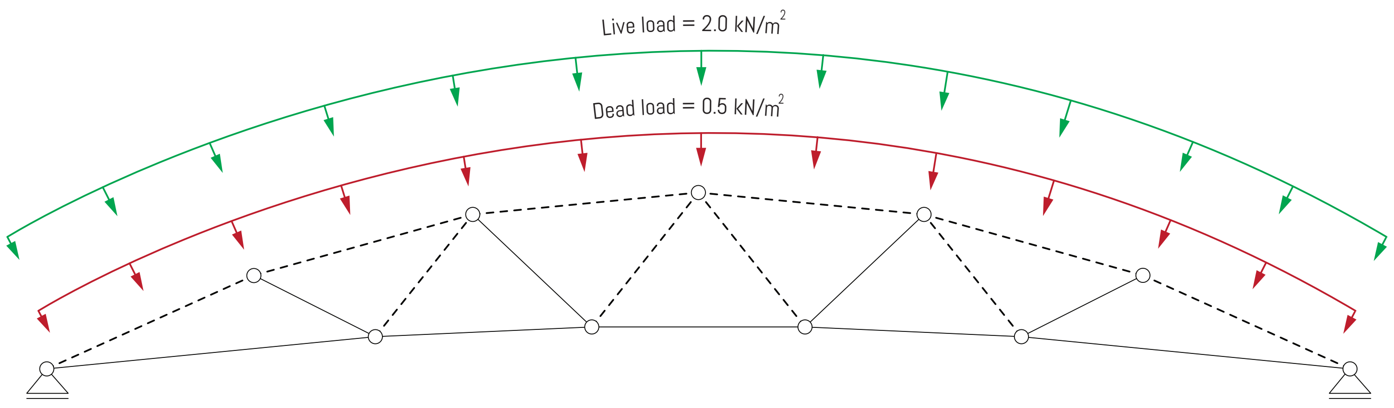


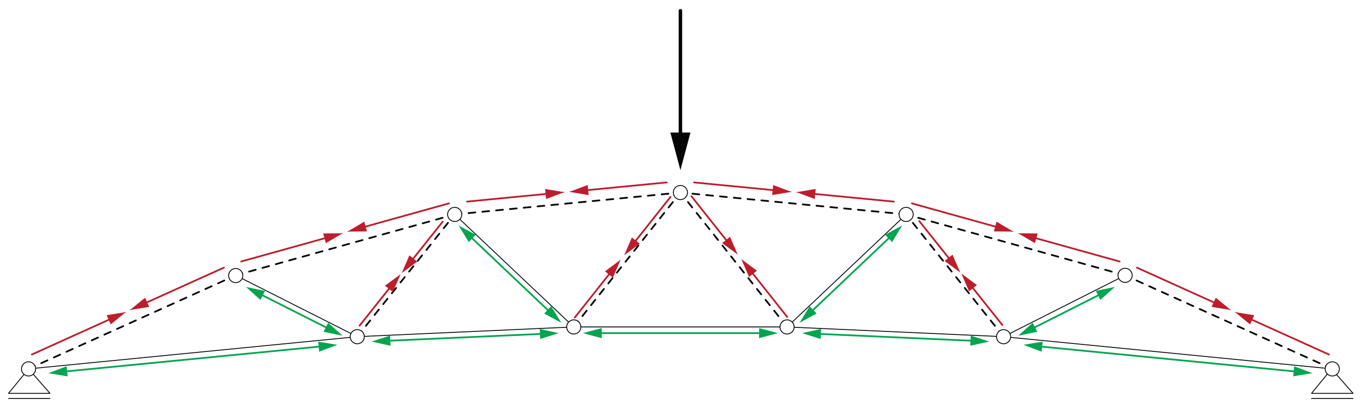


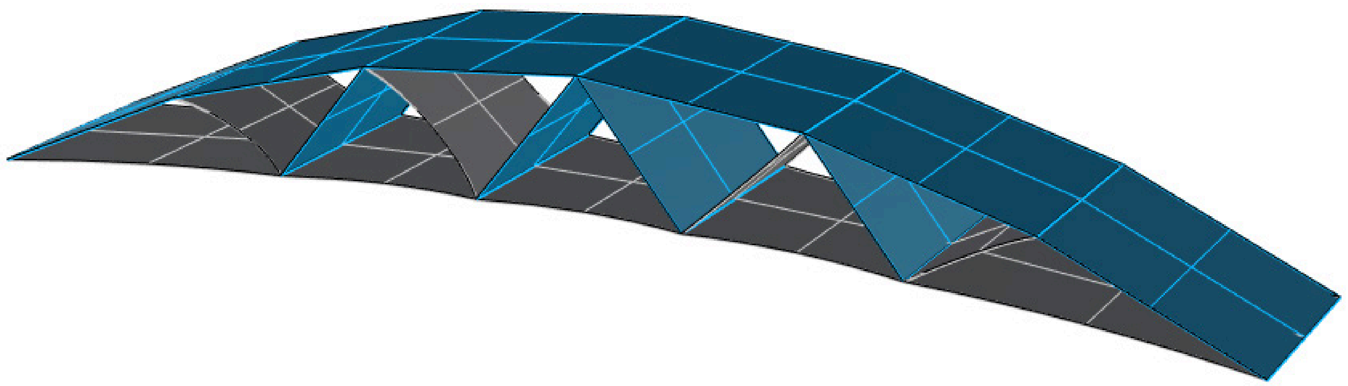


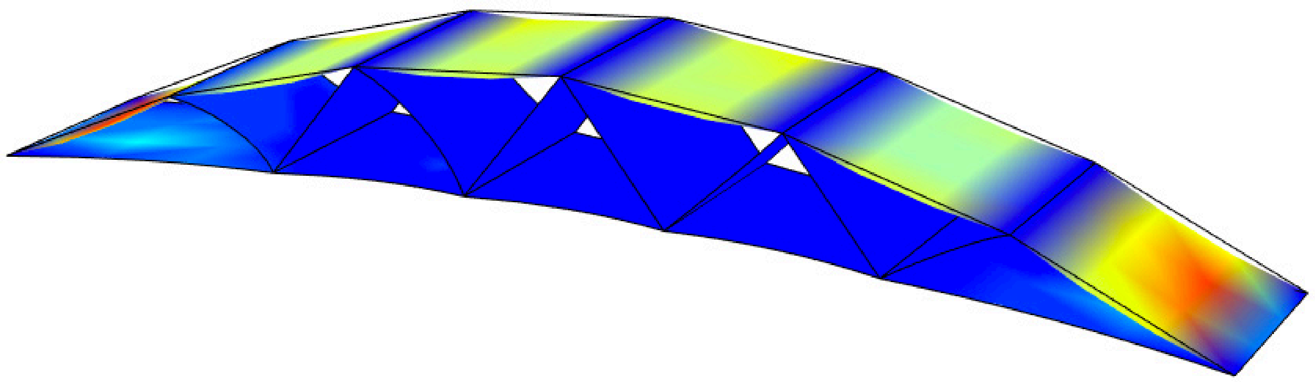
Max. deformation = 15cm

VARIANTS: GLASS FABRIC WEB WITH ONLY PLANAR GLASS PLATES



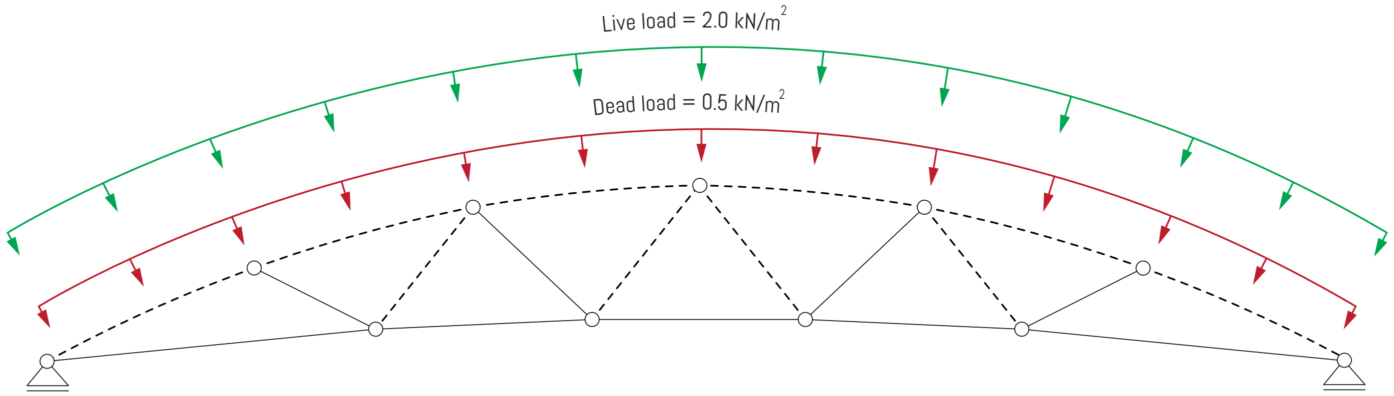


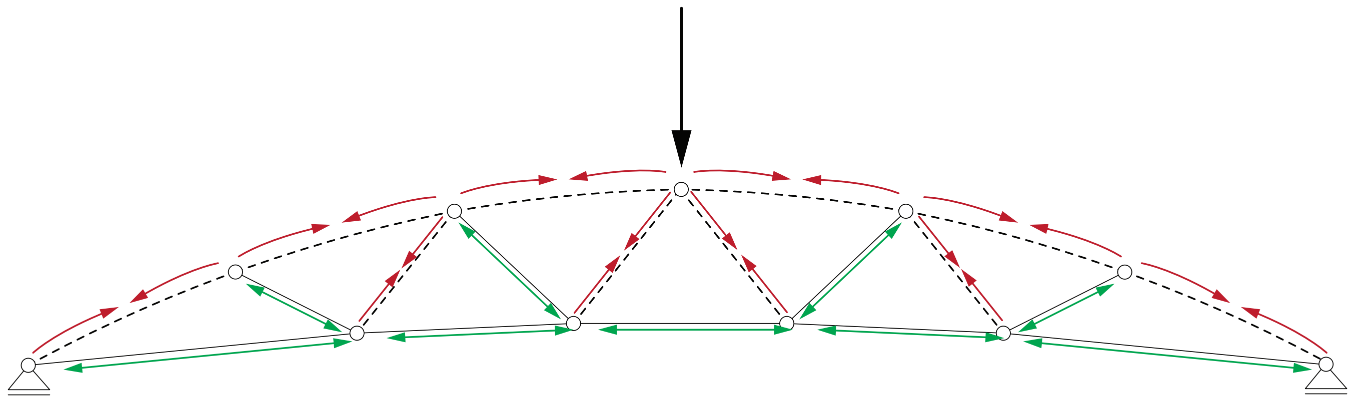


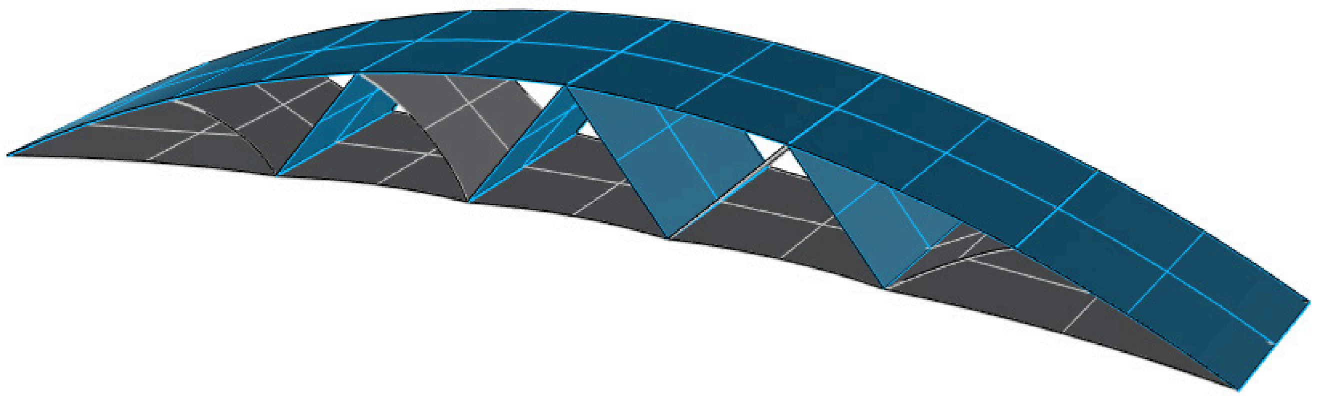


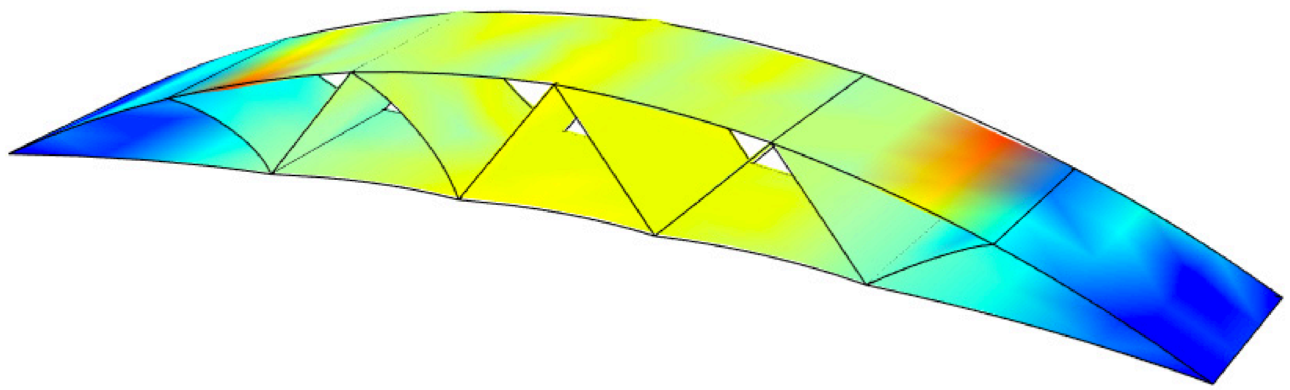
Max. deformation = 1.5cm

VARIANTS: GLASS FABRIC WEB WITH CURVED GLASS PLATES



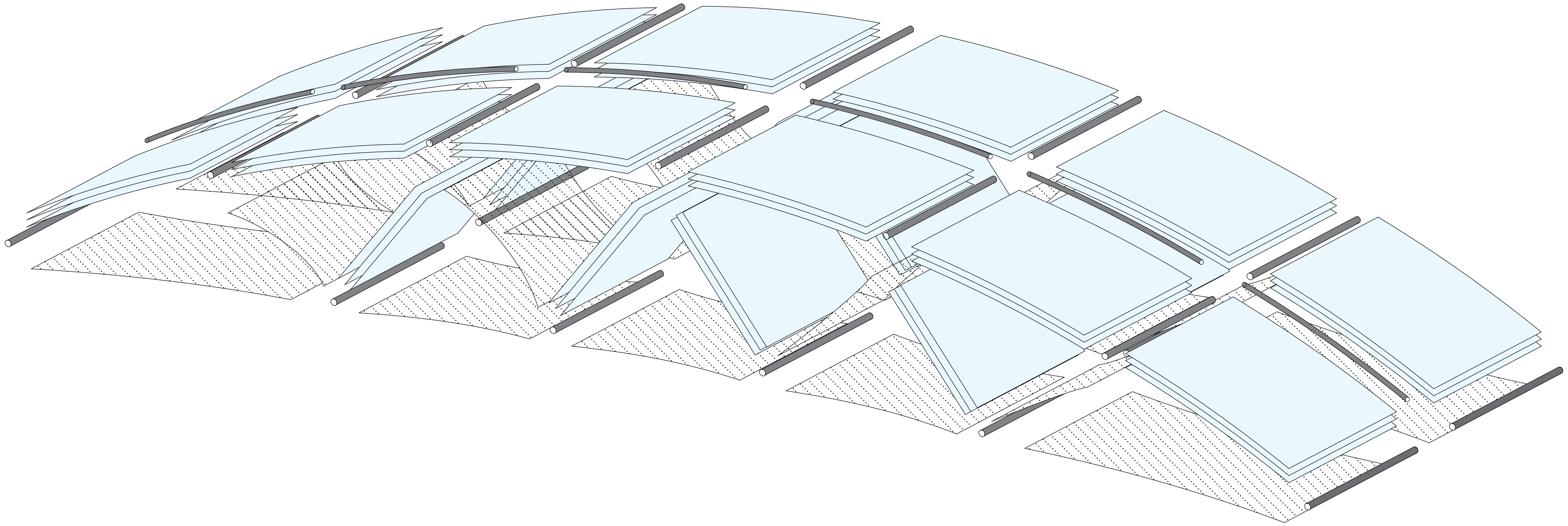




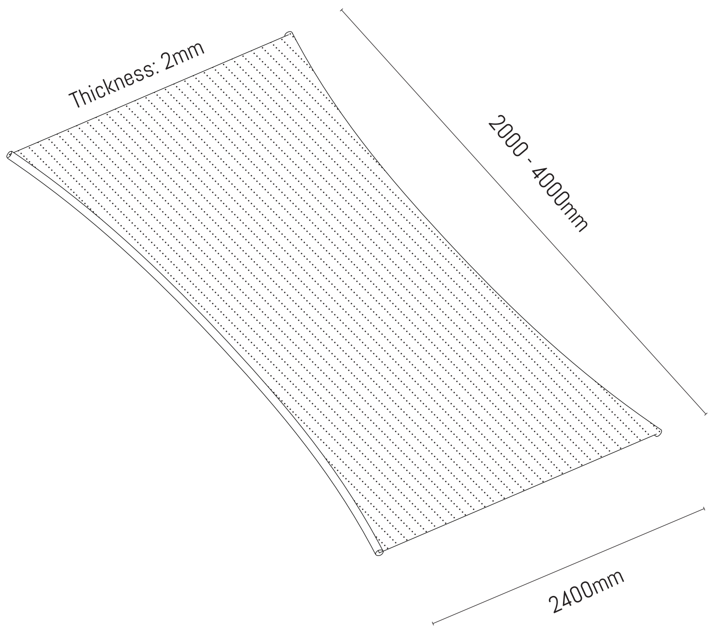


Max. deformation = 0.4cm

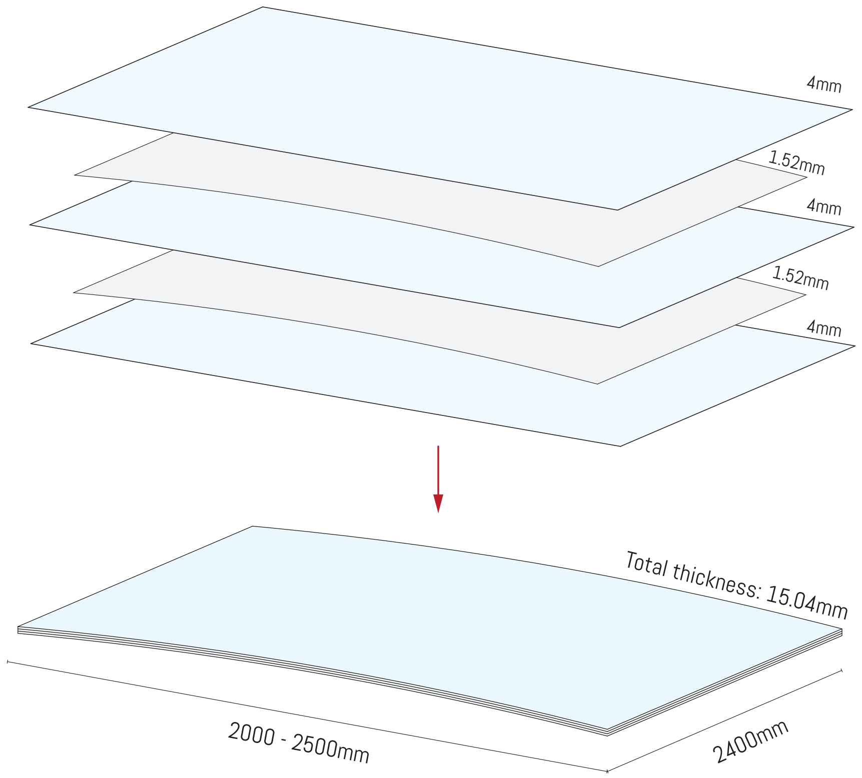
STRUCTURAL PROPERTIES



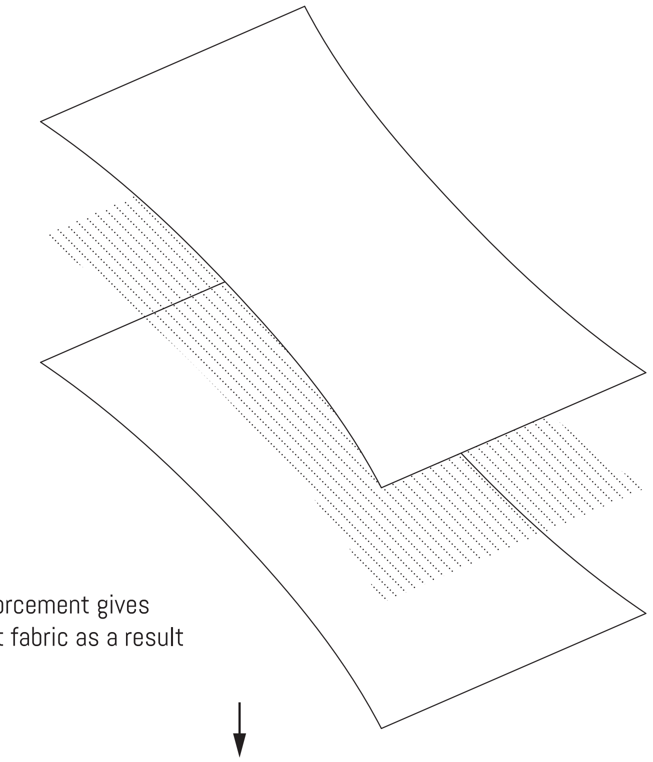
Use of cables to reinforce
the woven PTFE at the edges



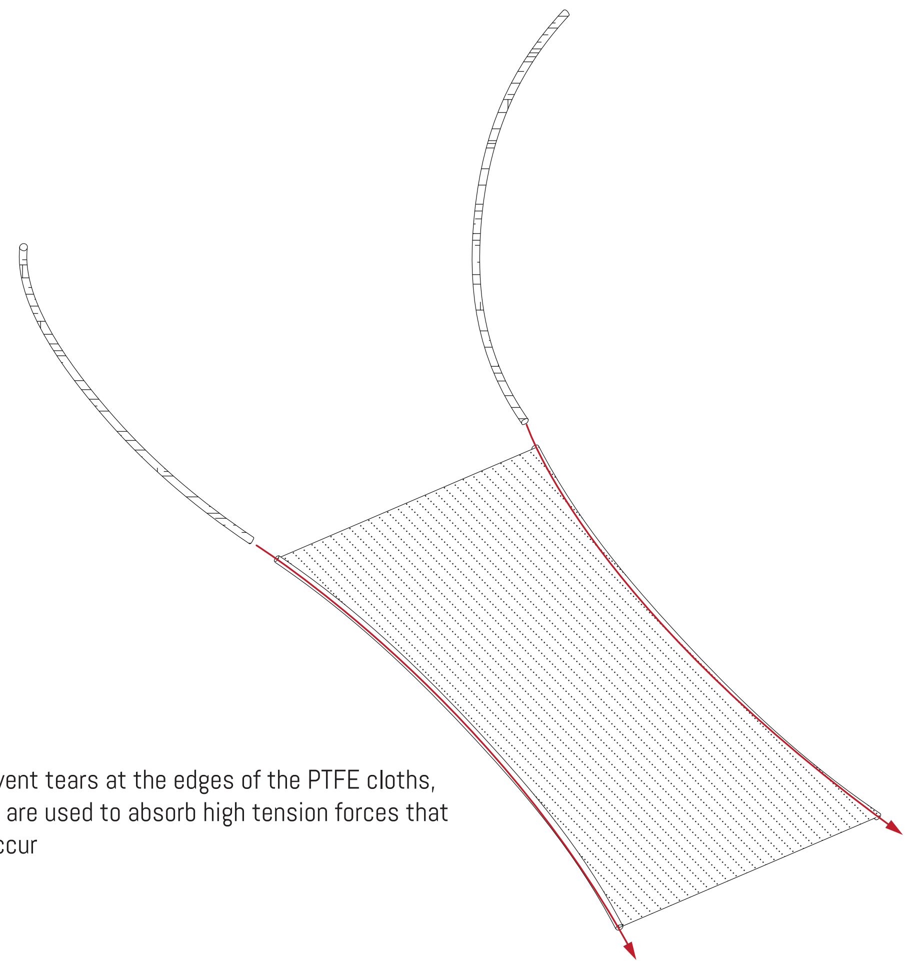
Alkali aluminosilicate panels laminated with Sentryglas interlayers



STRUCTURAL PROPERTIES: HEMP REINFORCED PTFE



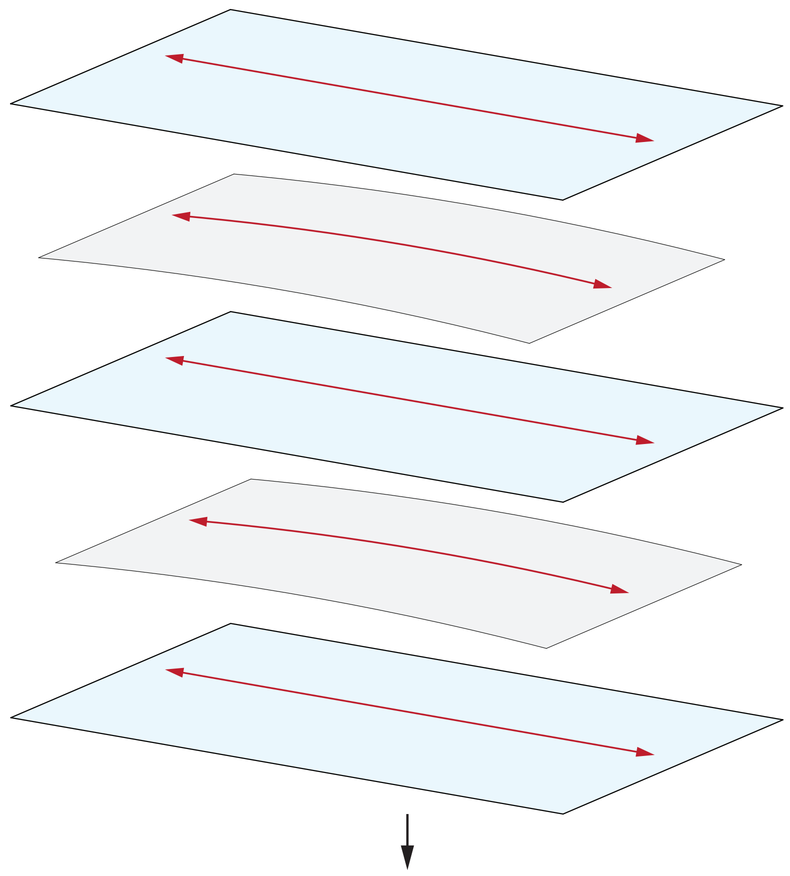
Woven PTFE with hemp reinforcement gives
high strength and translucent fabric as a result



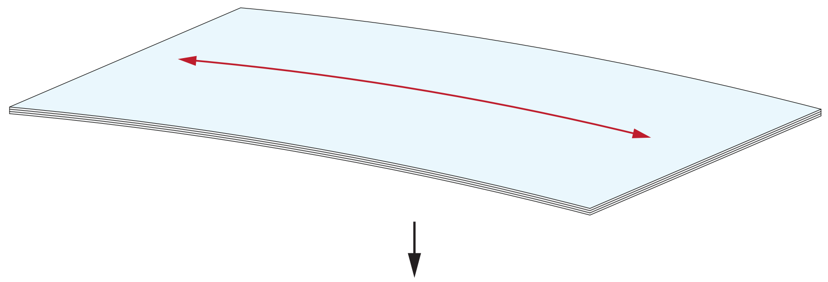
To prevent tears at the edges of the PTFE cloths,
cables are used to absorb high tension forces that
may occur

STRUCTURAL PROPERTIES: ALKALI ALUMINOSILICATE

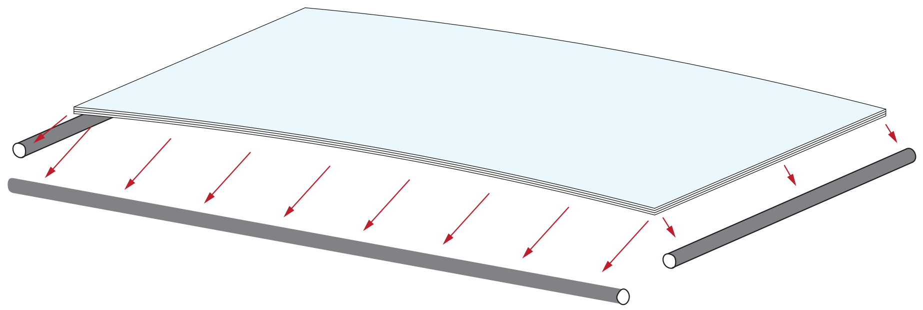
Planar glass surfaces laminated to pre-bended SentryGlas foils



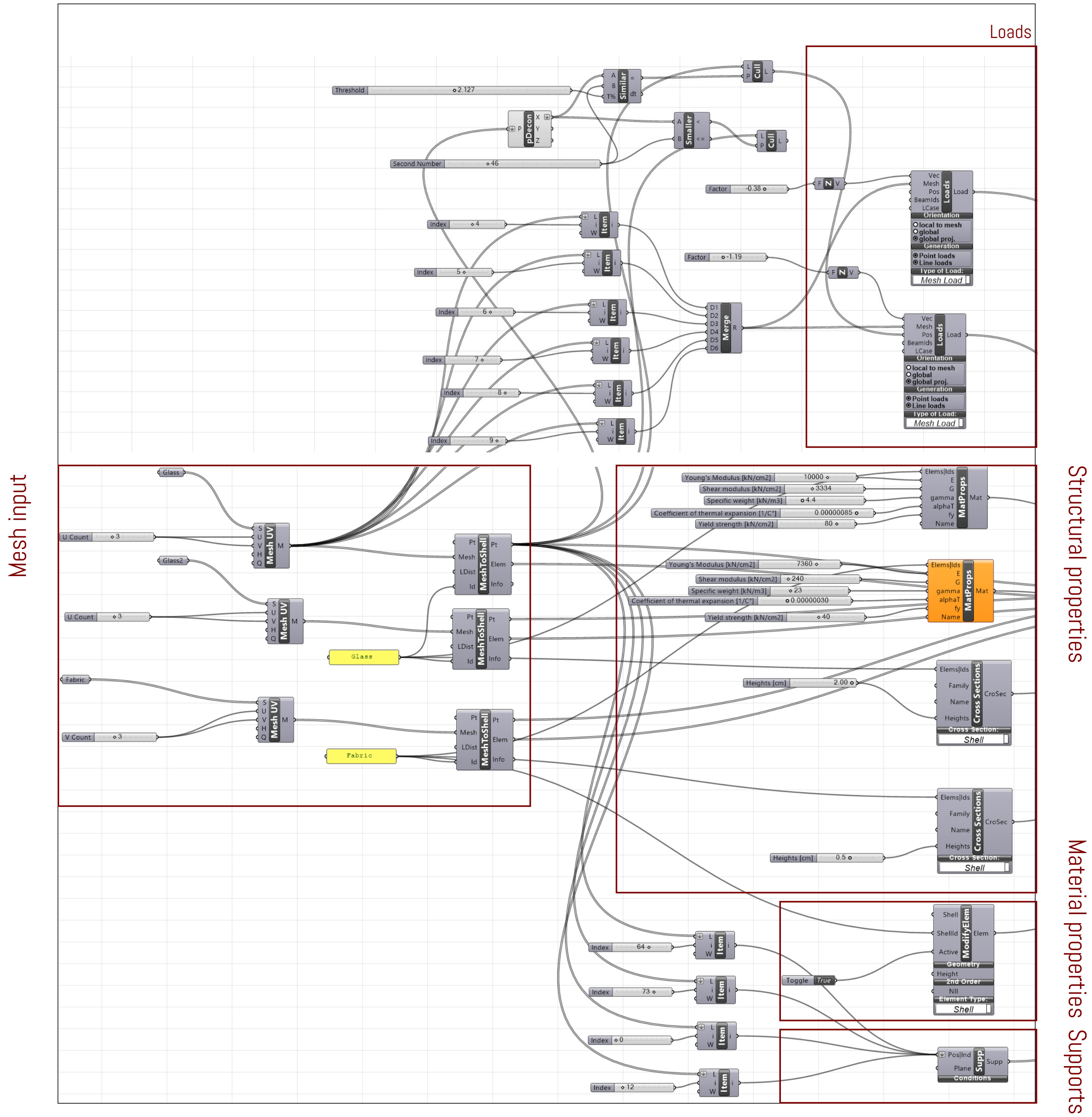
Resulting in a cold bended panel with small distortion

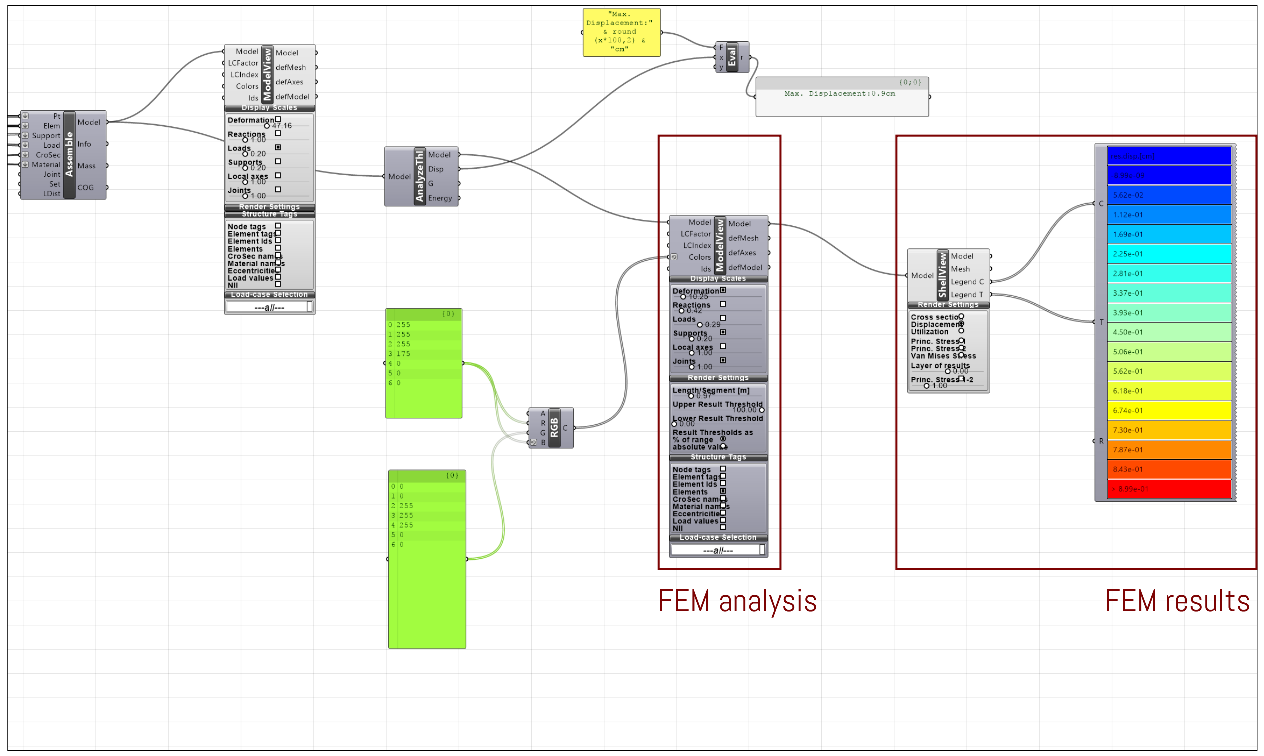


The pre-bended SentryGlas safety interlayers create a single curved plate, however to prevent increasing distortion the curvature the glass plate gets clamped in metal strips on its short and long side

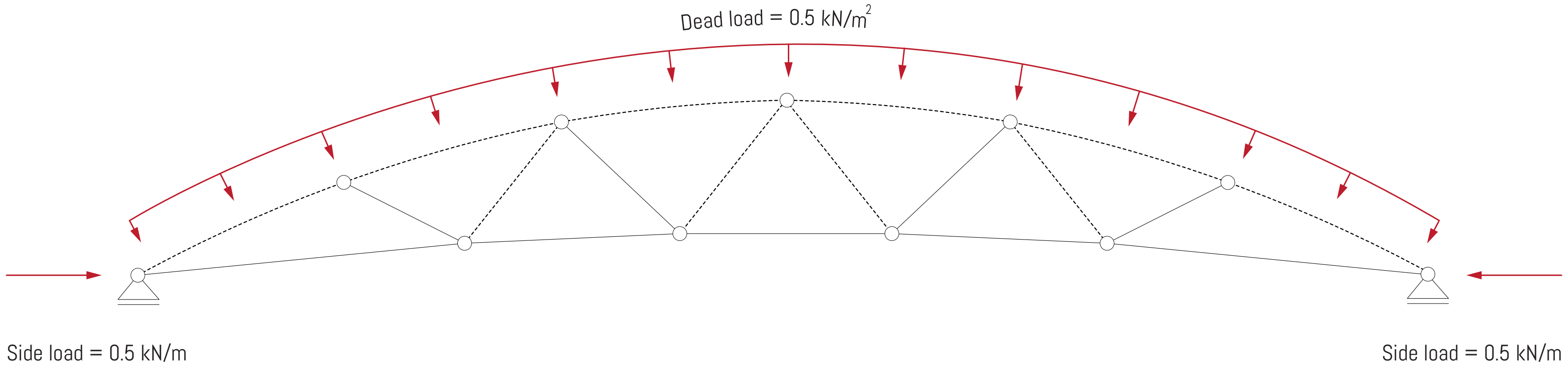


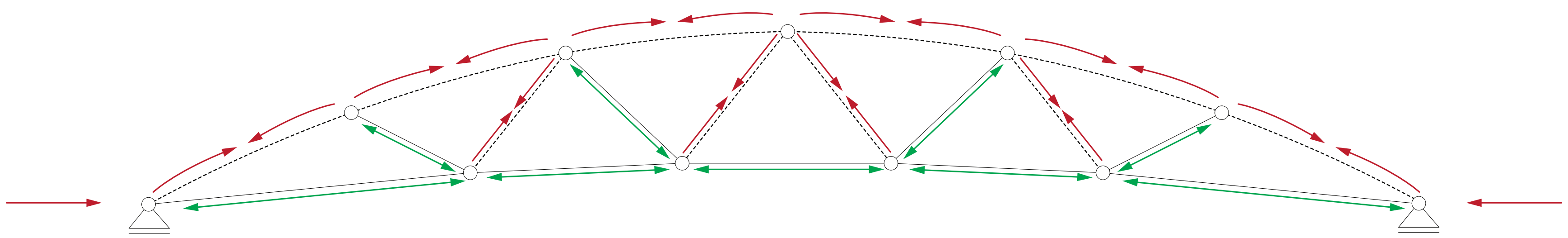
FEM ANALYSIS

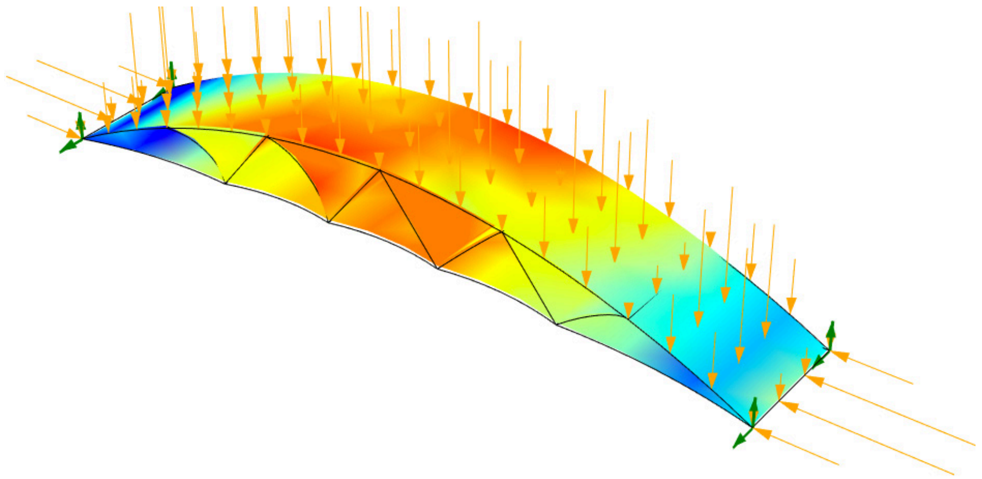




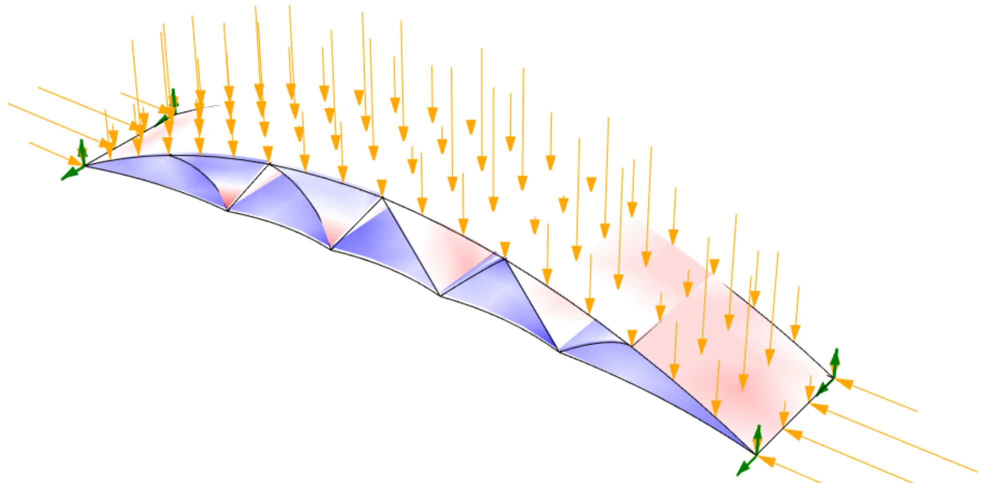
FEM ANALYSIS: DEAD & SIDE LOADS WITH TENSION COMPRESSION BEHAVIOUR

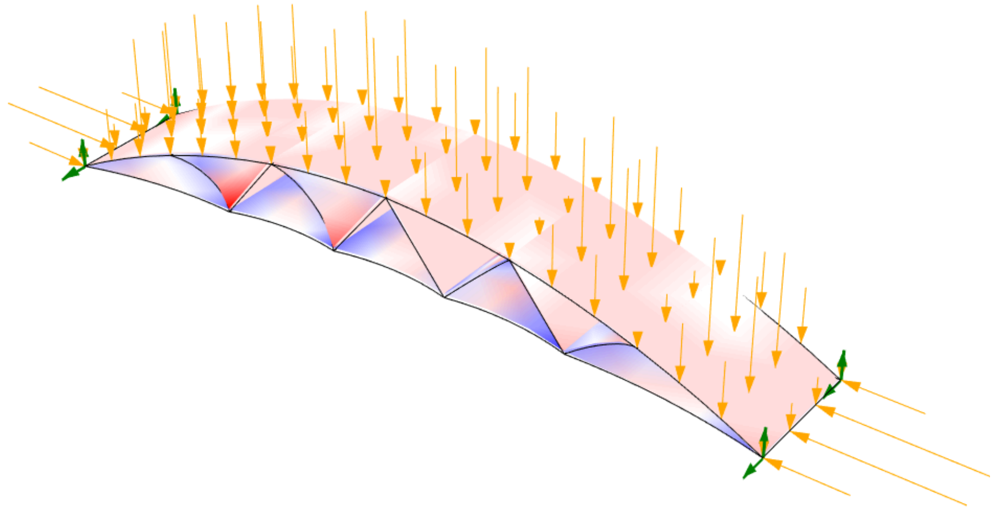






Max. deformation = 0.7cm

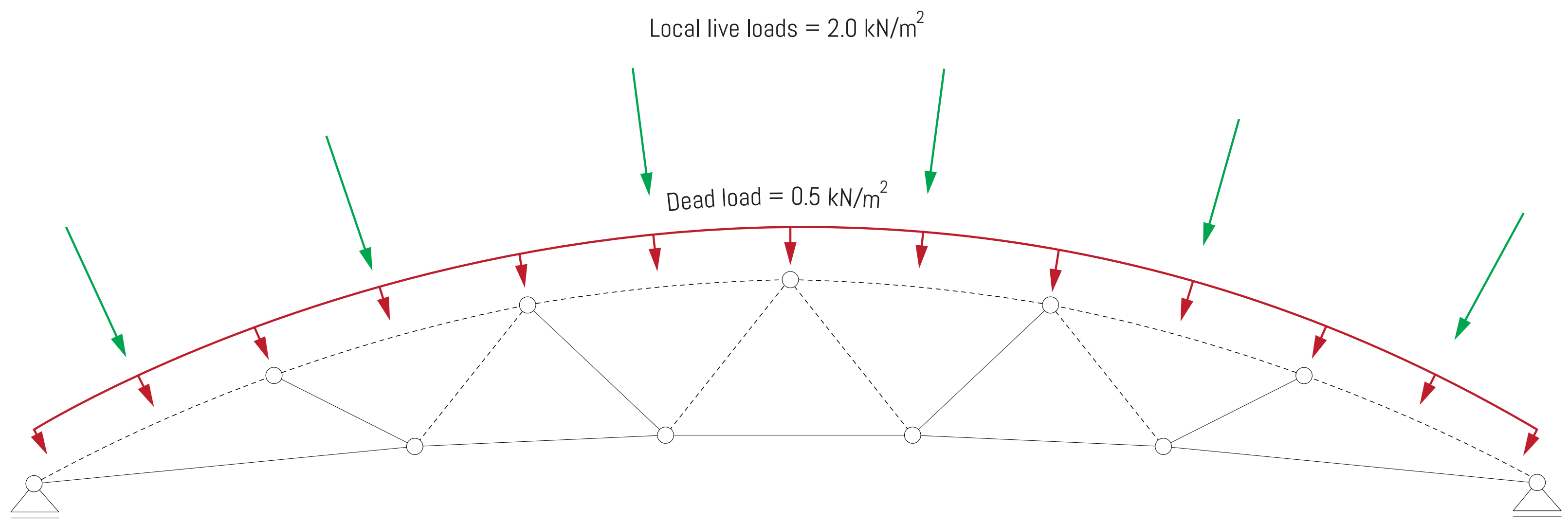


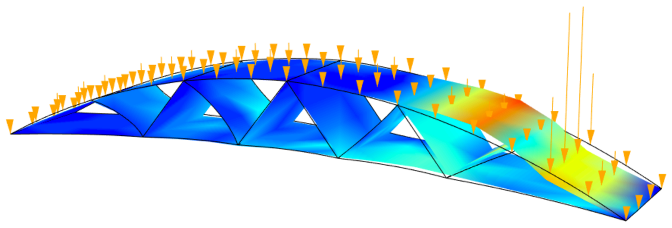


Max. compression stress = 0.88 MPa

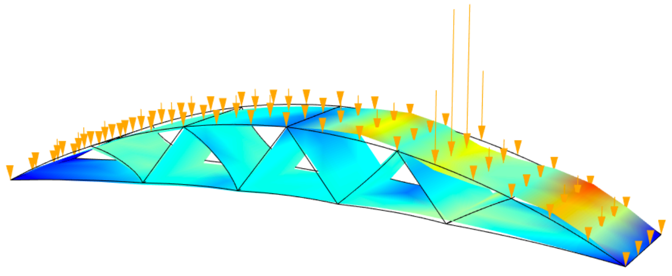
Max. tensile stress = 0.088 MPa

FEM ANALYSIS: LOCAL LIVE LOADS WITH BUCKLING BEHAVIOUR

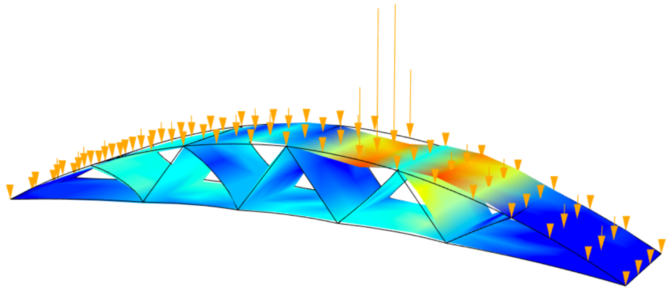




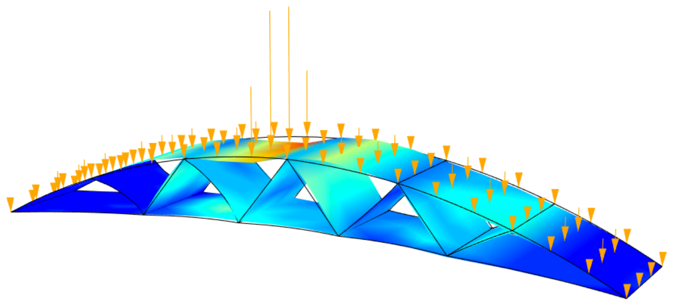
Max. deformation = 1.98cm



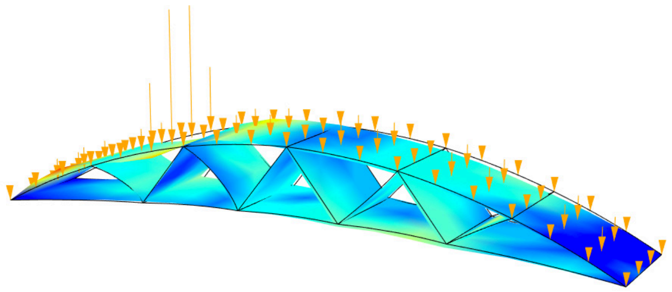
Max. deformation = 1.42cm



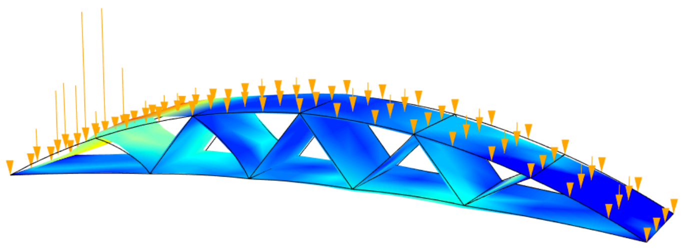
Max. deformation = 1.56cm



Max. deformation = 1.54cm

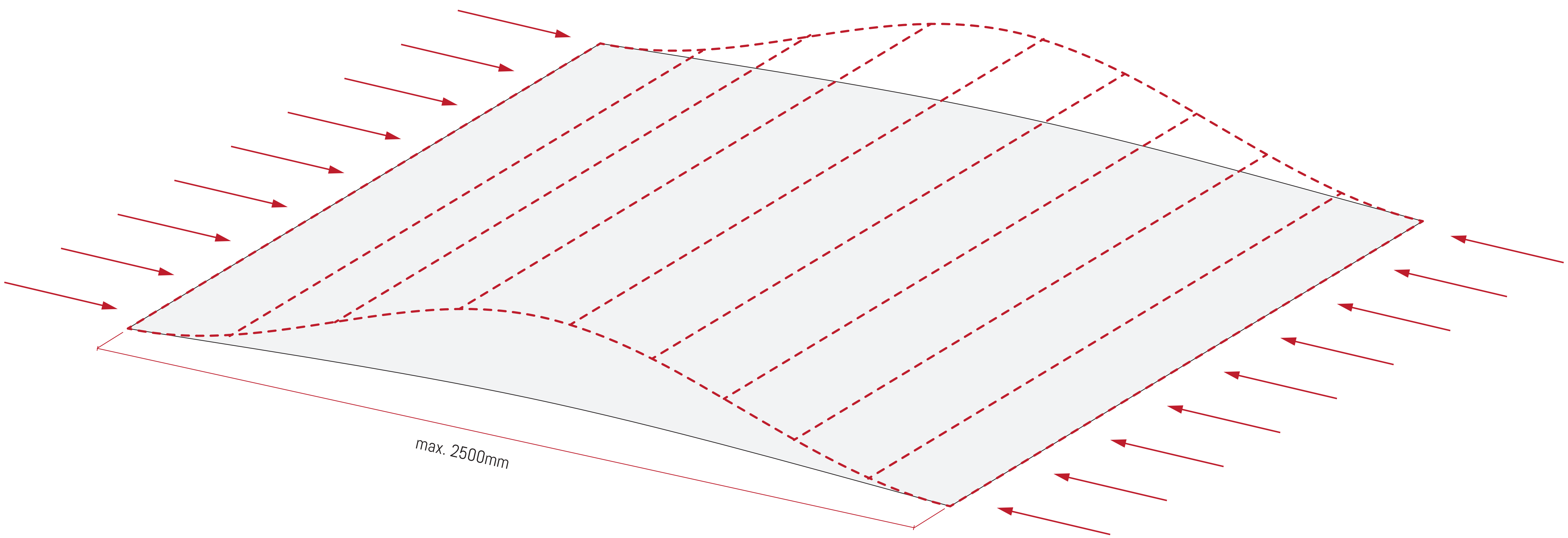


Max. deformation = 1.44cm



Max. deformation = 1.98cm

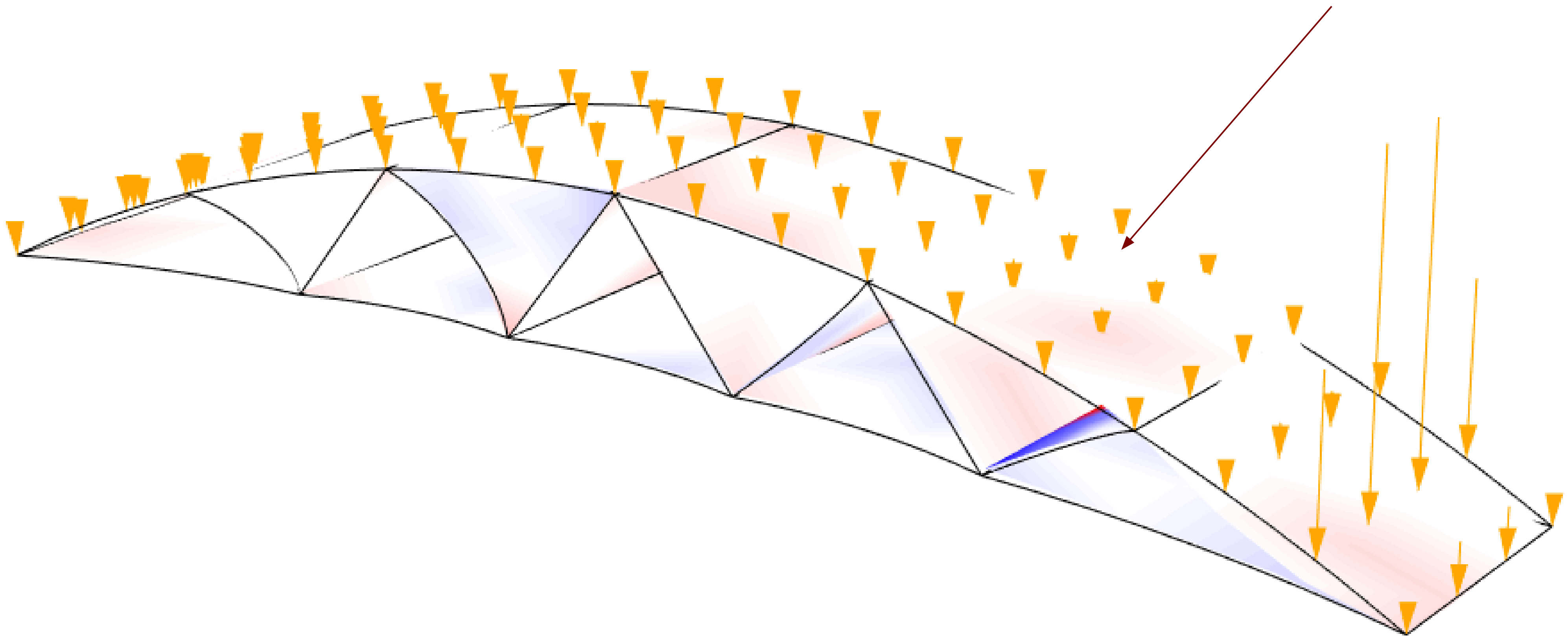
FEM ANALYSIS: LOCAL LIVE LOADS WITH BUCKLING BEHAVIOUR



$$S_{buckling} = \frac{\pi^2 \cdot E \cdot I}{L_b^2 \cdot A} \left[\frac{n}{mm^2} \right] \qquad S_{buckling} = \frac{\pi^2 \cdot 71700 \cdot 70.8 \cdot 10^4}{1250^2 \cdot 37600} = 8.94 \ \frac{N}{mm^2} \ (MPa)$$

$$S_{buckling;u;d} = \frac{1 \cdot 0.881 \cdot 1.29 \cdot 1 \cdot 8.94}{1.6} = 6.35 \ \frac{N}{mm^2} \ (MPa)$$

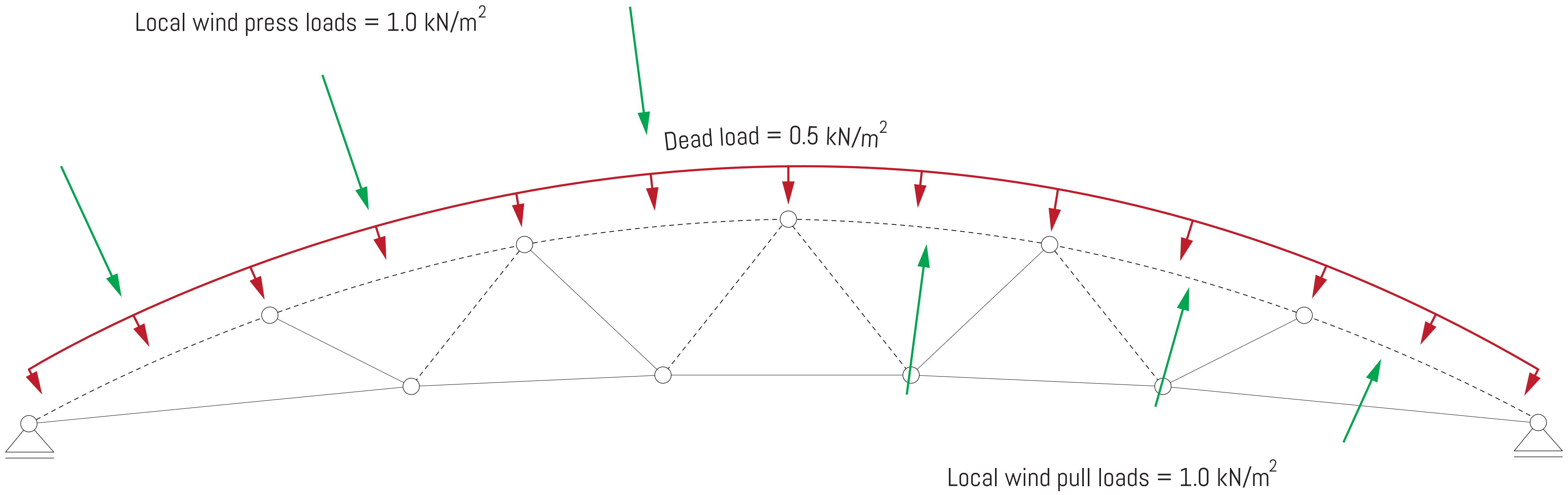
FEM ANALYSIS: LOCAL LIVE LOADS WITH BUCKLING BEHAVIOUR

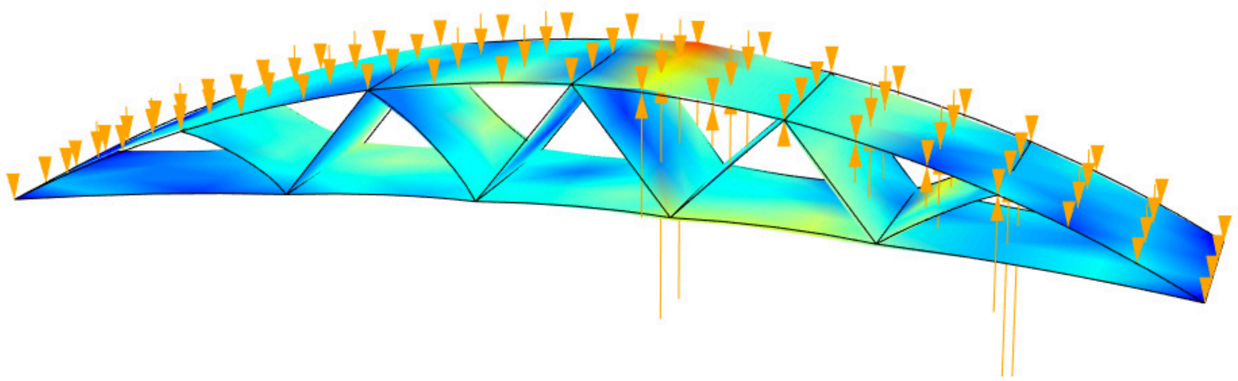


Max. compression stress = 4.7 MPa

$$U.C. = \frac{\sigma_m}{S_{buckling}} \leq 1$$

$$U.C. = \frac{4.7}{6.35} = 0.74 < 1$$





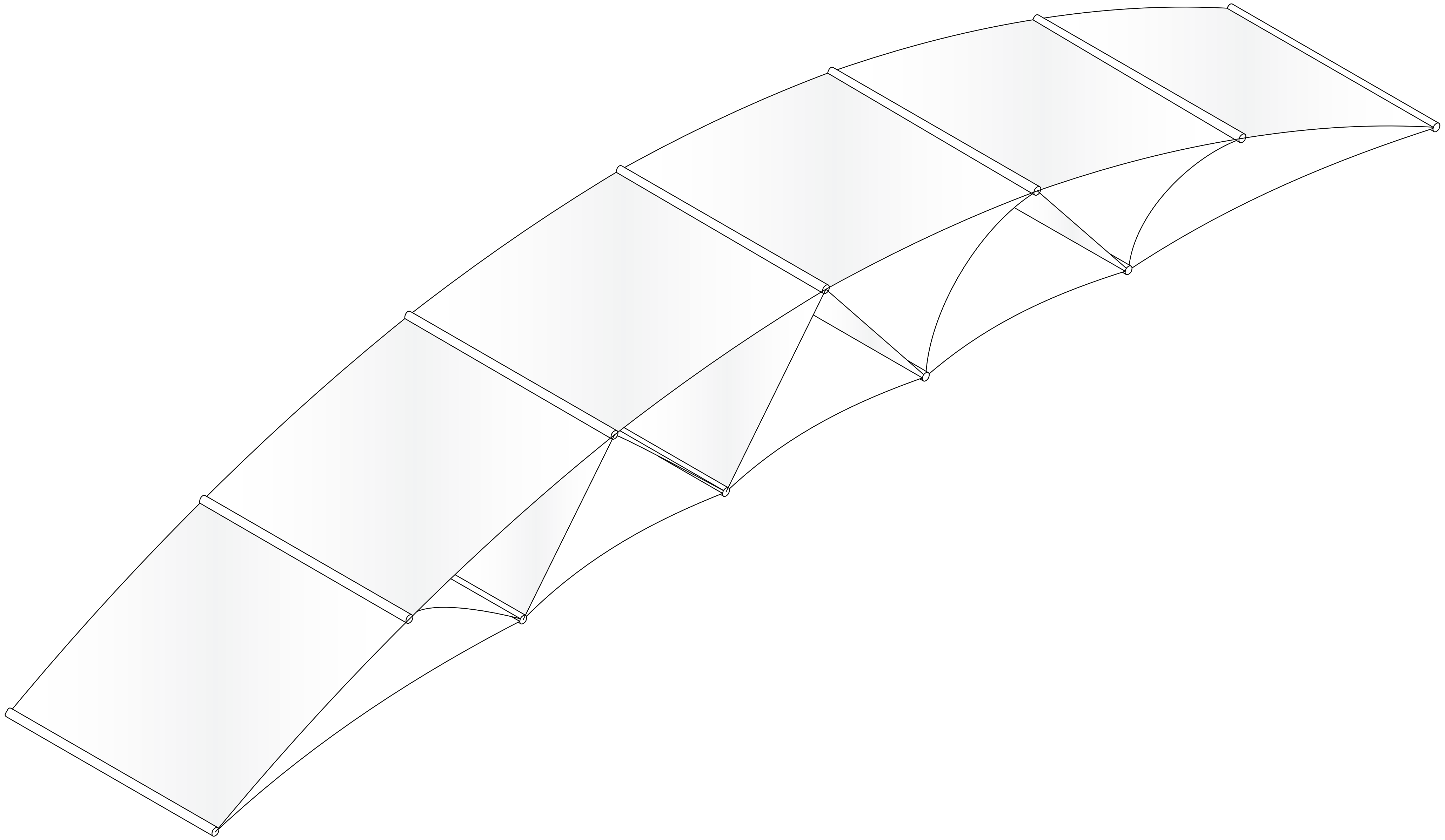
Max. deformation = 0.7cm

Max. compression stress = 3.5 MPa

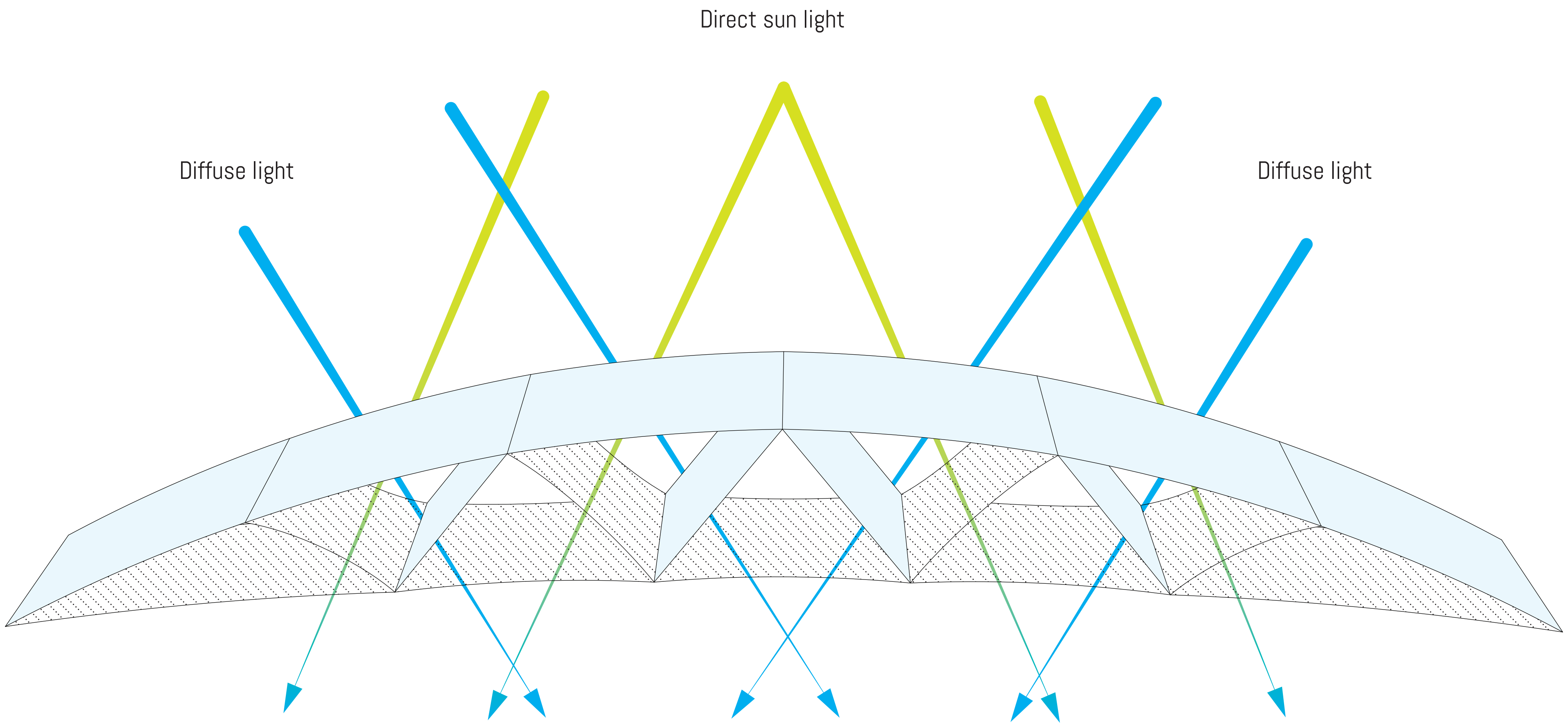
$$U.C. = \frac{\sigma_m}{S_{buckling}} \leq 1$$

$$U.C. = \frac{3.5}{6.35} = 0.55 < 1$$

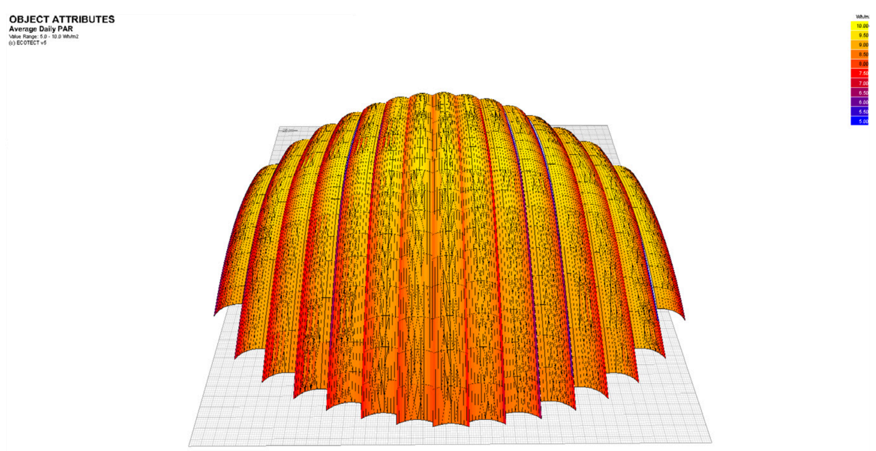
SECONDARY STRUCTURE CONCEPT DESIGN

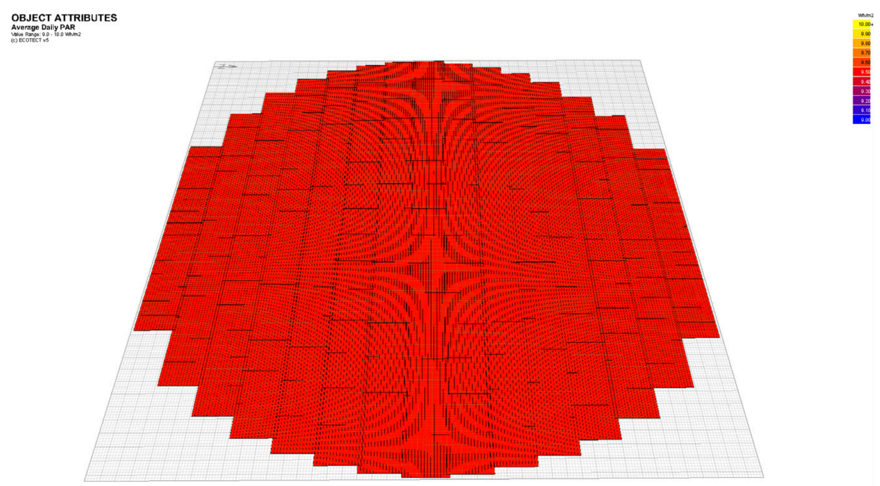


6. DESIGN



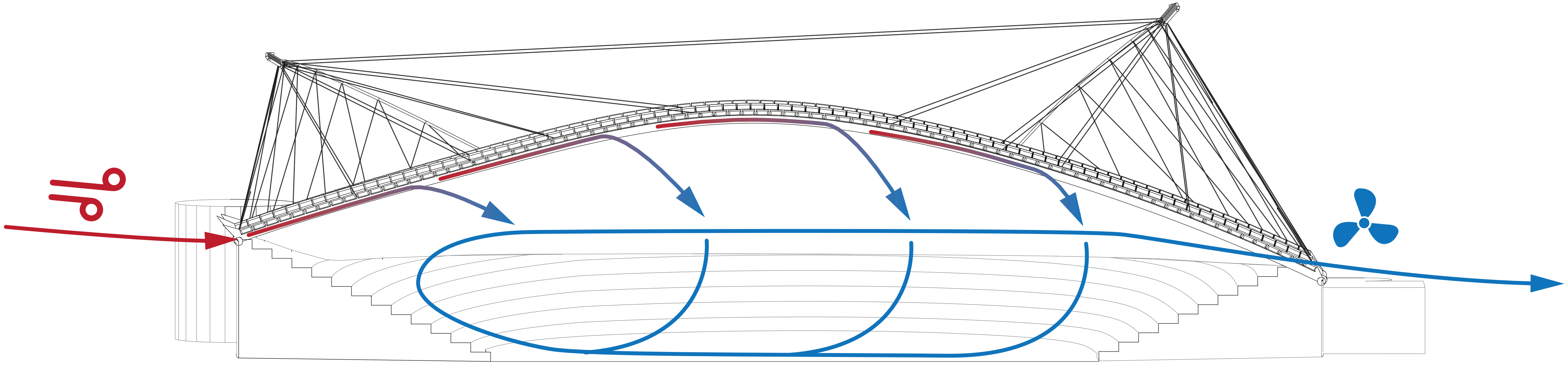
Direct sun light gets filtered and diffuse light is allowed to go through



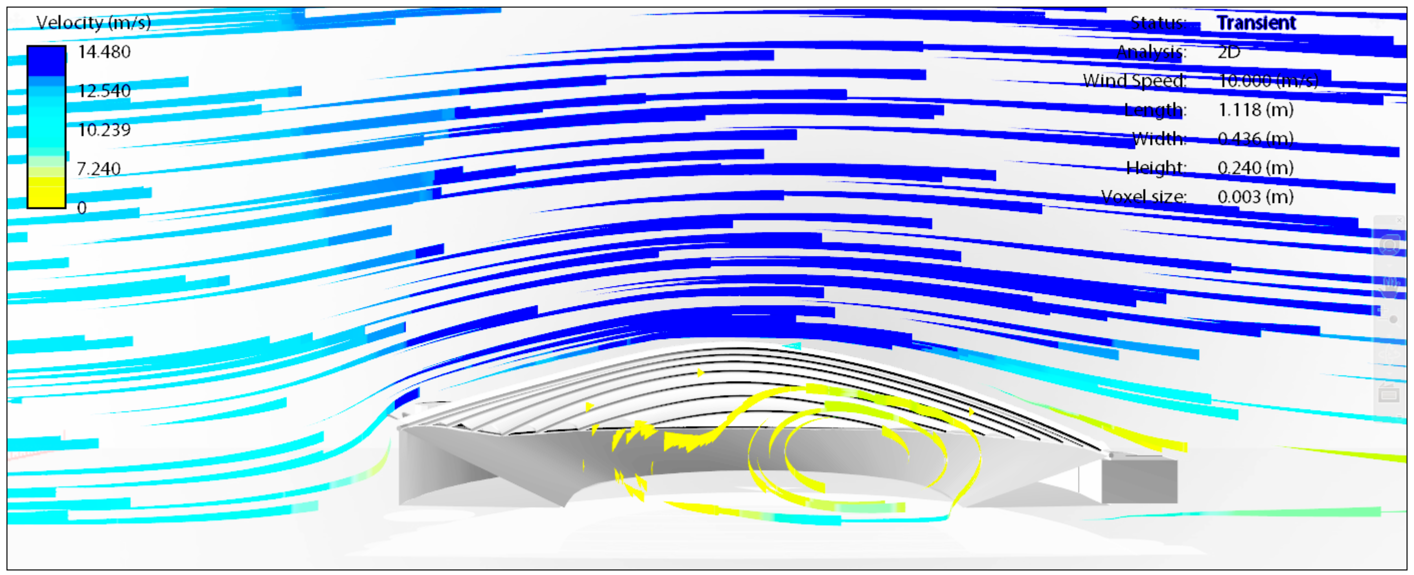


9.5 Wh/m^2

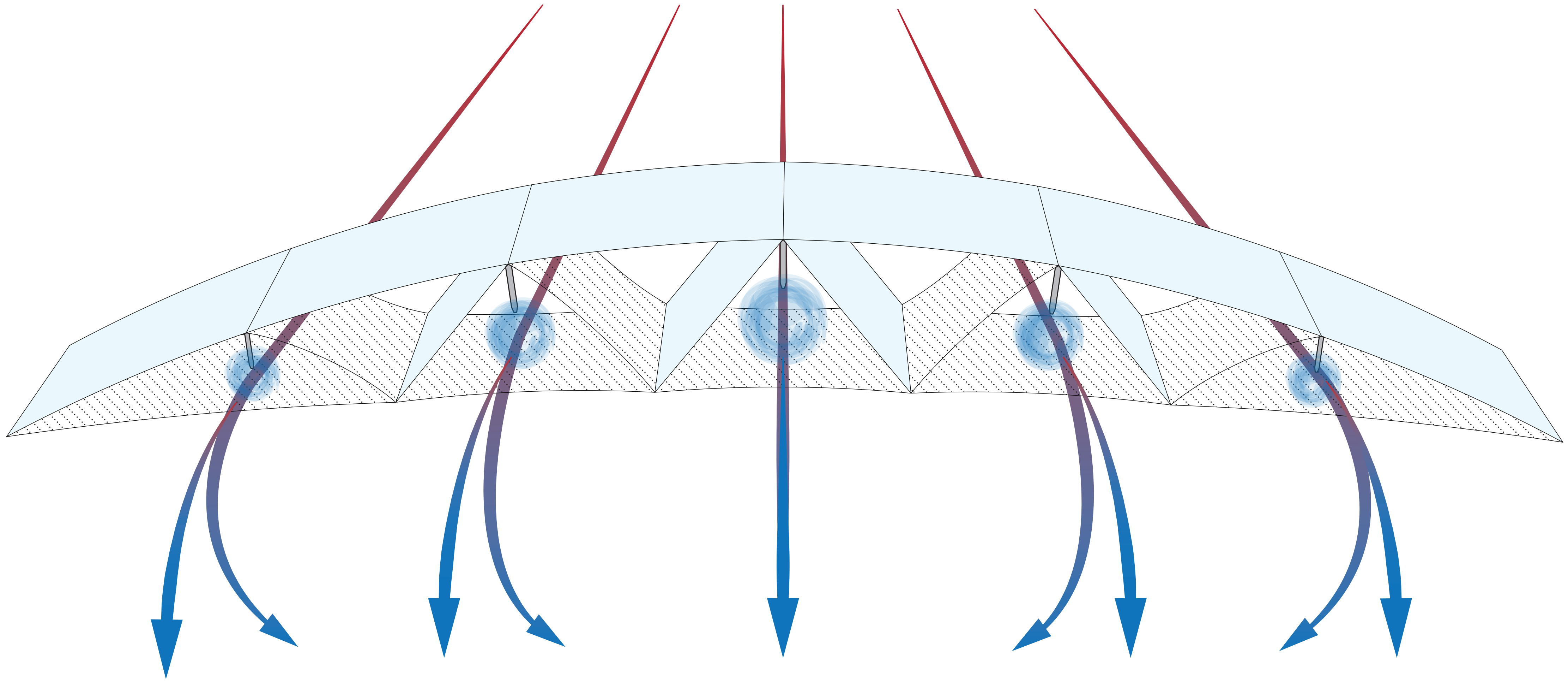
Wind can get in roof cavity due to inlets at the west side of the stadium



To make air circulation possible the air has to get mechanically extracted at the east side of the stadium

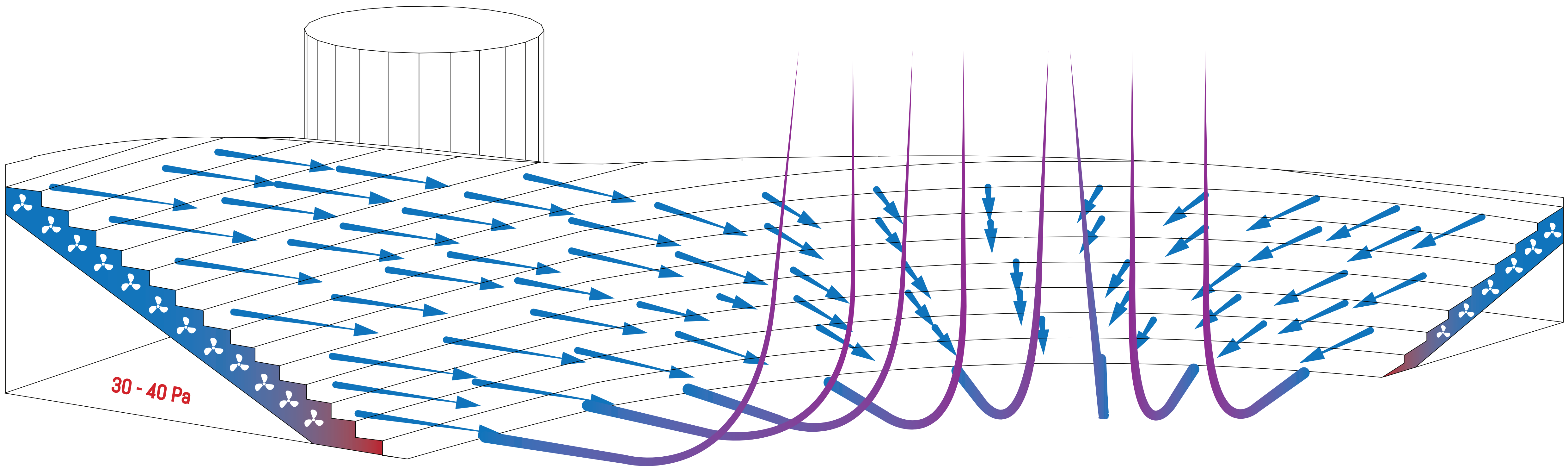


The mist cooling system humids the air (with 5 °C water) in the cavity and will lower the temperature of the hot wind up to 25 °C

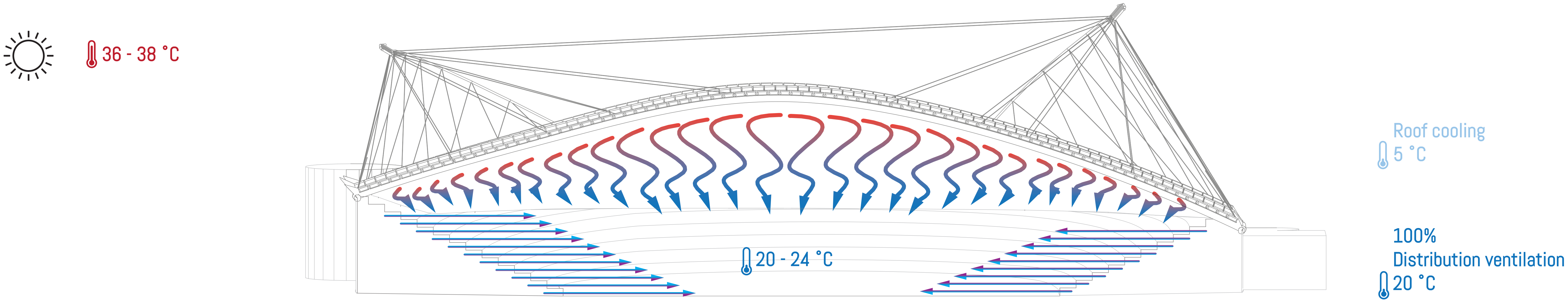


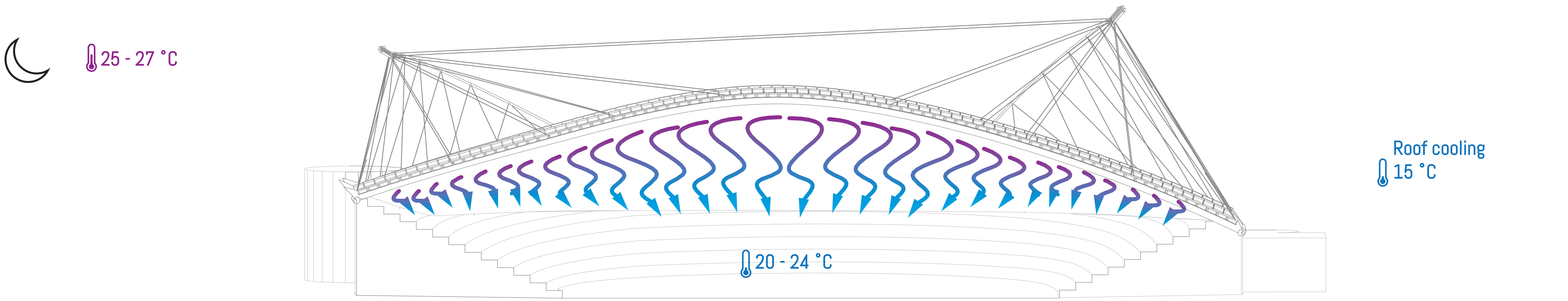
The cooled wind fals down into the stadium through small openings between the arch structures

Mechanical airconditioning units underneath the stands blow cold air against the stands that actas a large grill which divides the air equally over the stands. The cold air gives comfort and maintains the quality of the grass

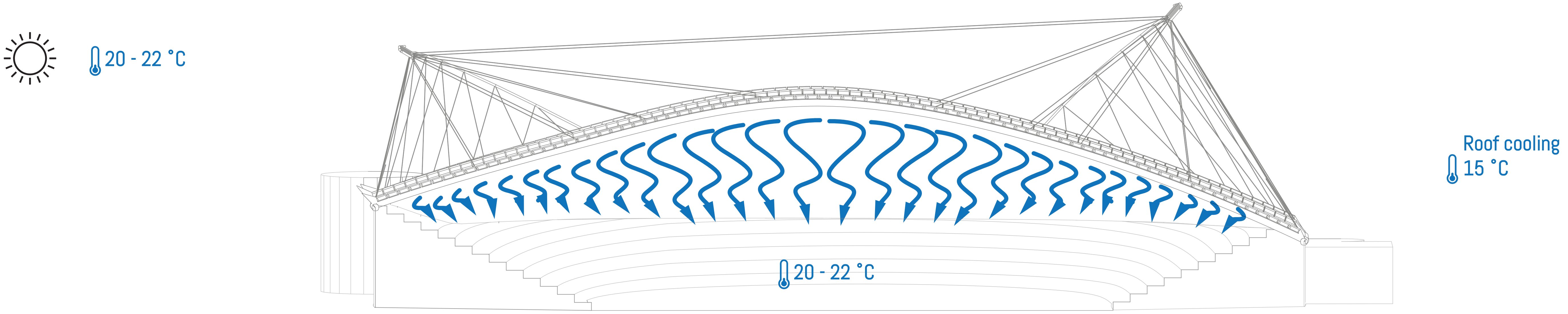


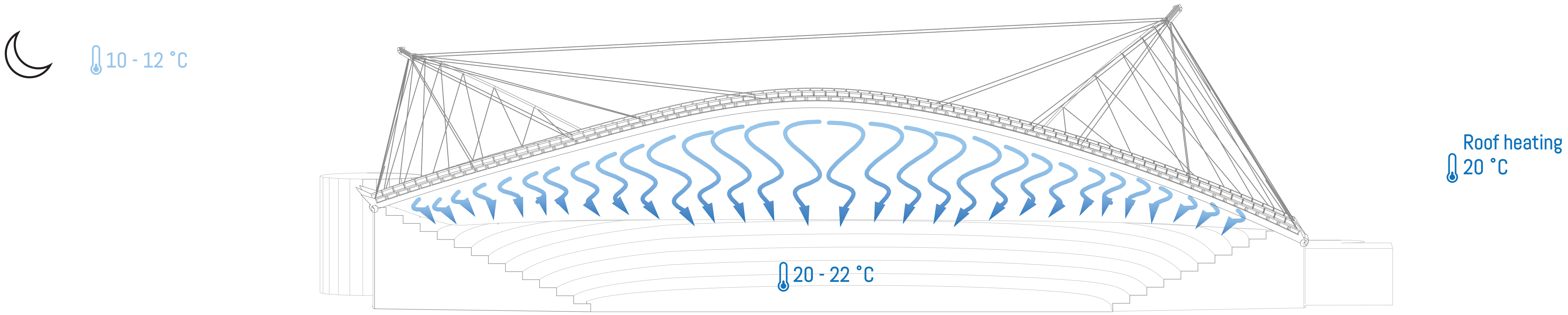
SUMMER


36 - 38 °C
20 - 24 °C
Roof cooling
5 °C
100%
Distribution ventilation
20 °C

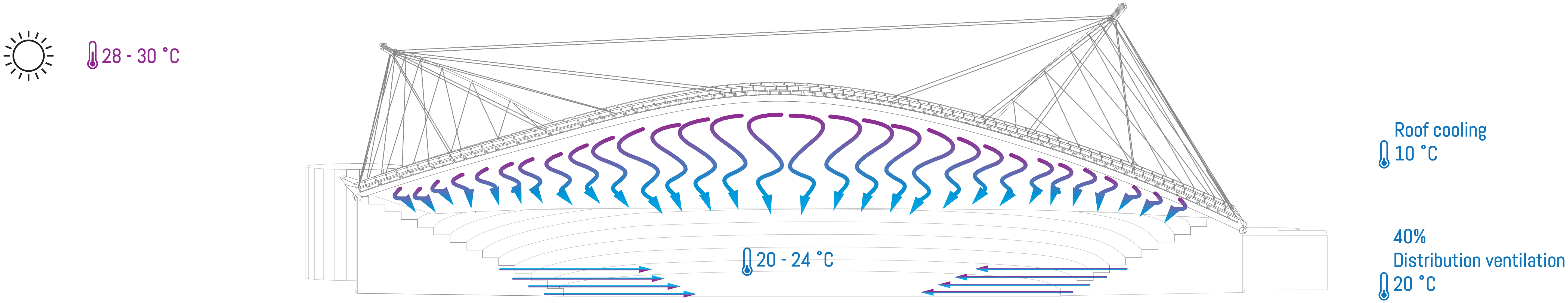

25 - 27 °C
20 - 24 °C
Roof cooling
15 °C

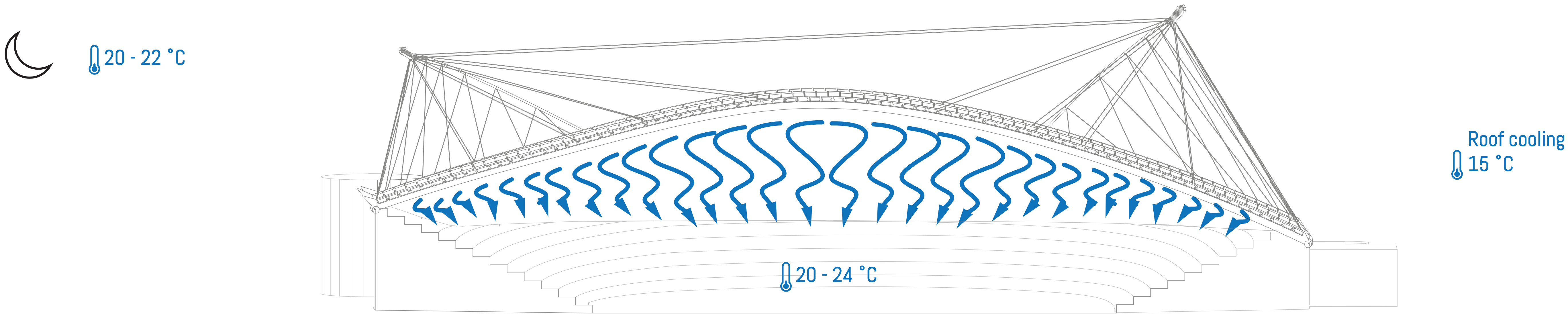
WINTER



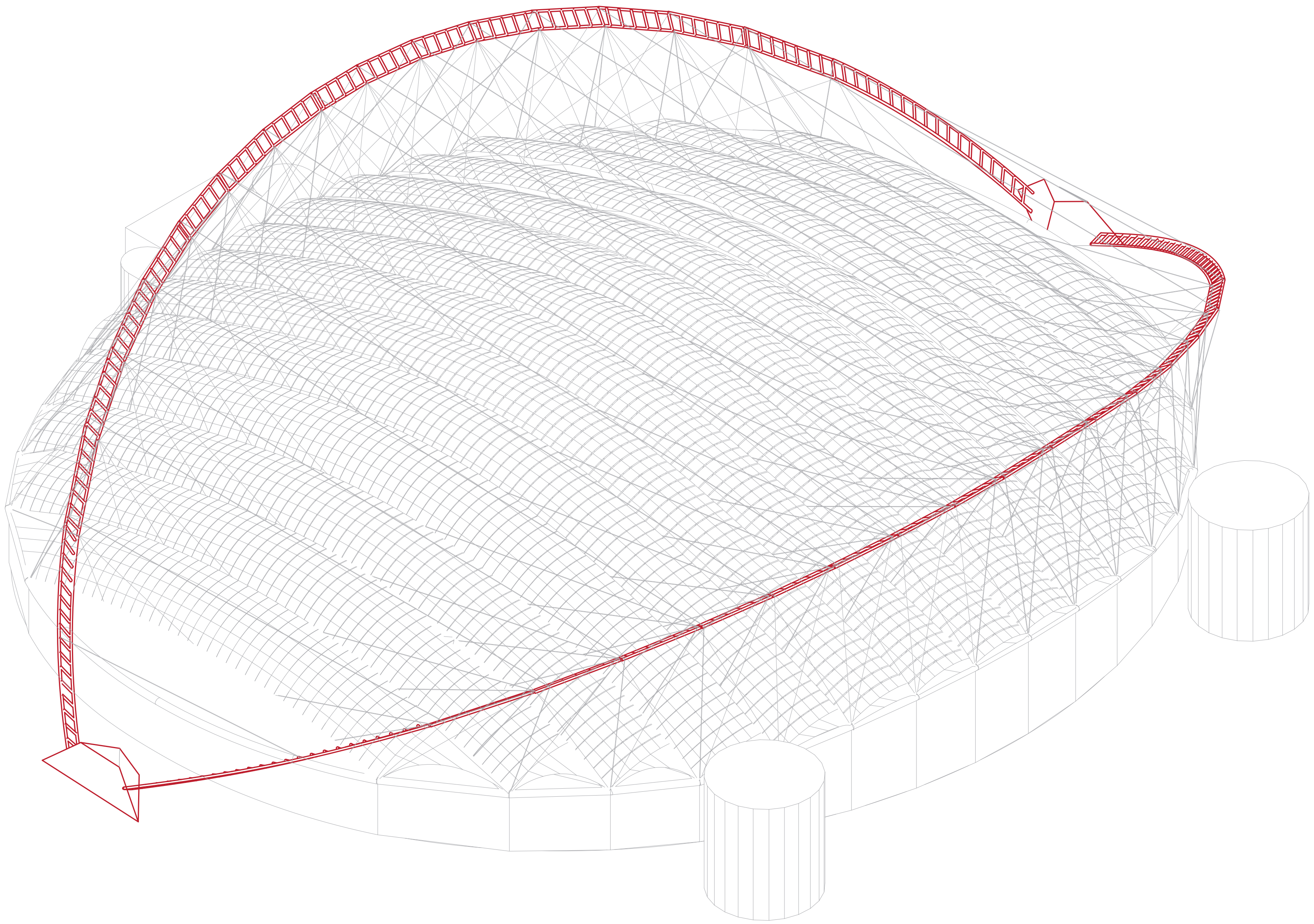


SPRING/AUTUMN





STRUCTURAL DESIGN: BUILD UP STRUCTURE



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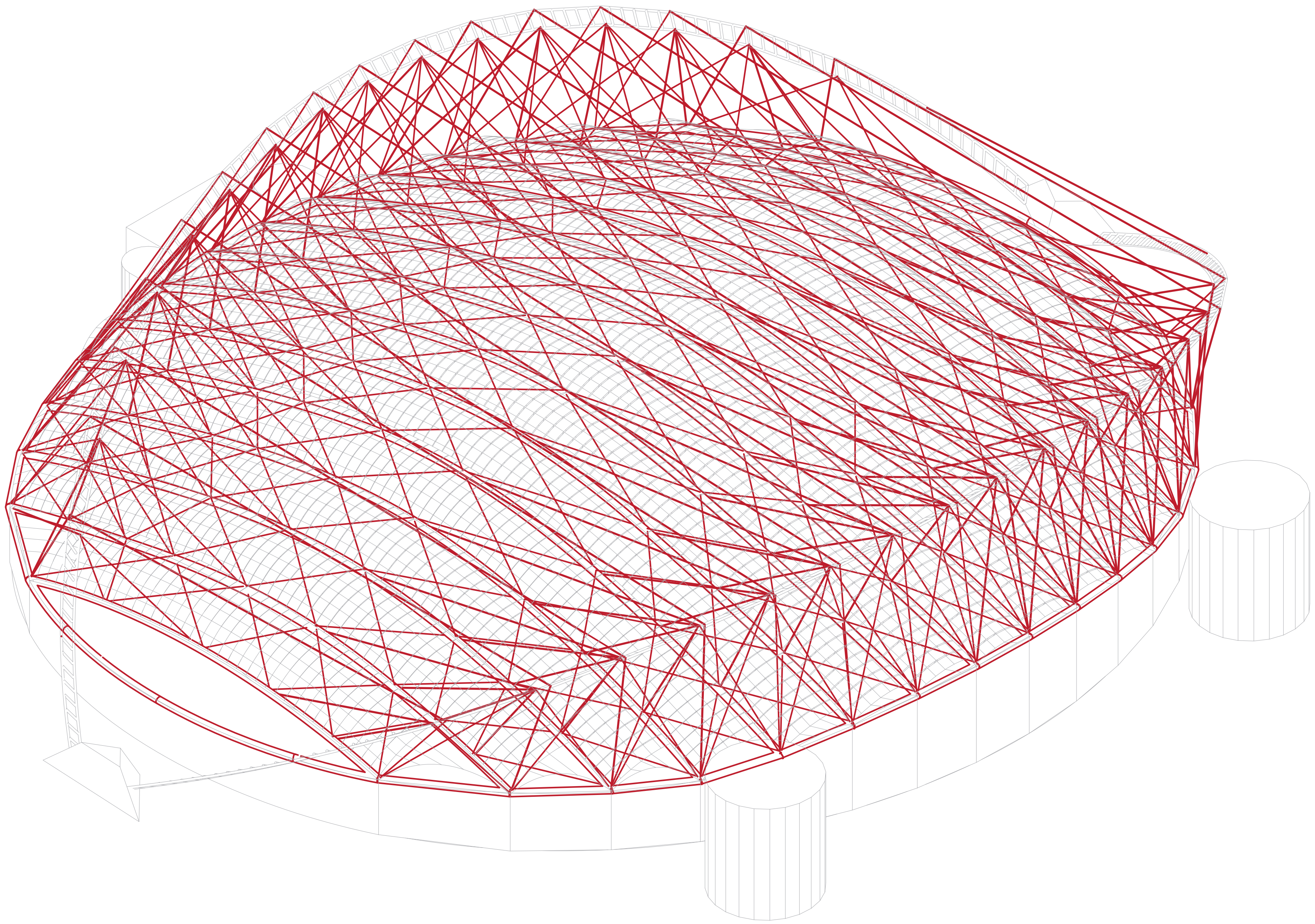

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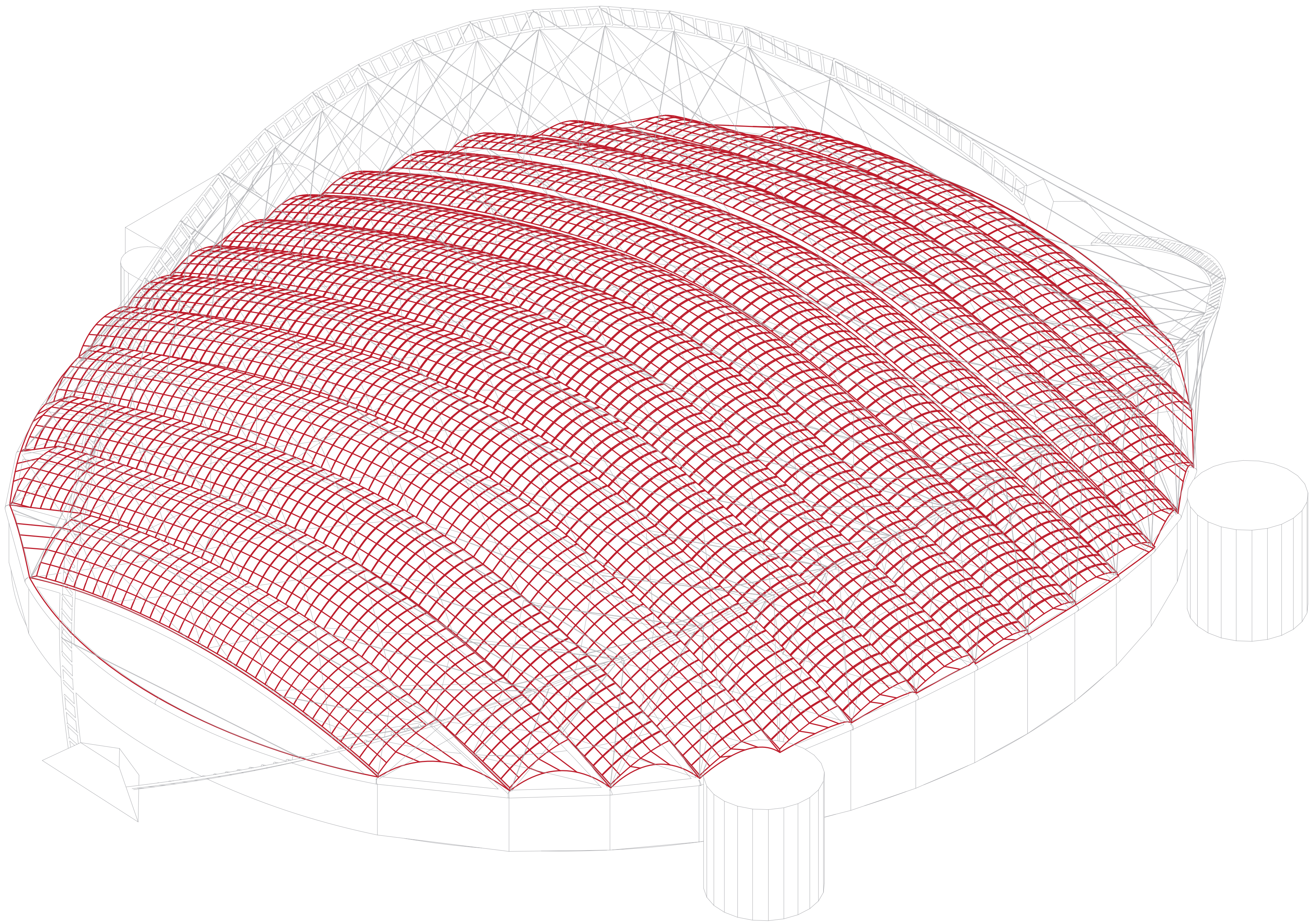

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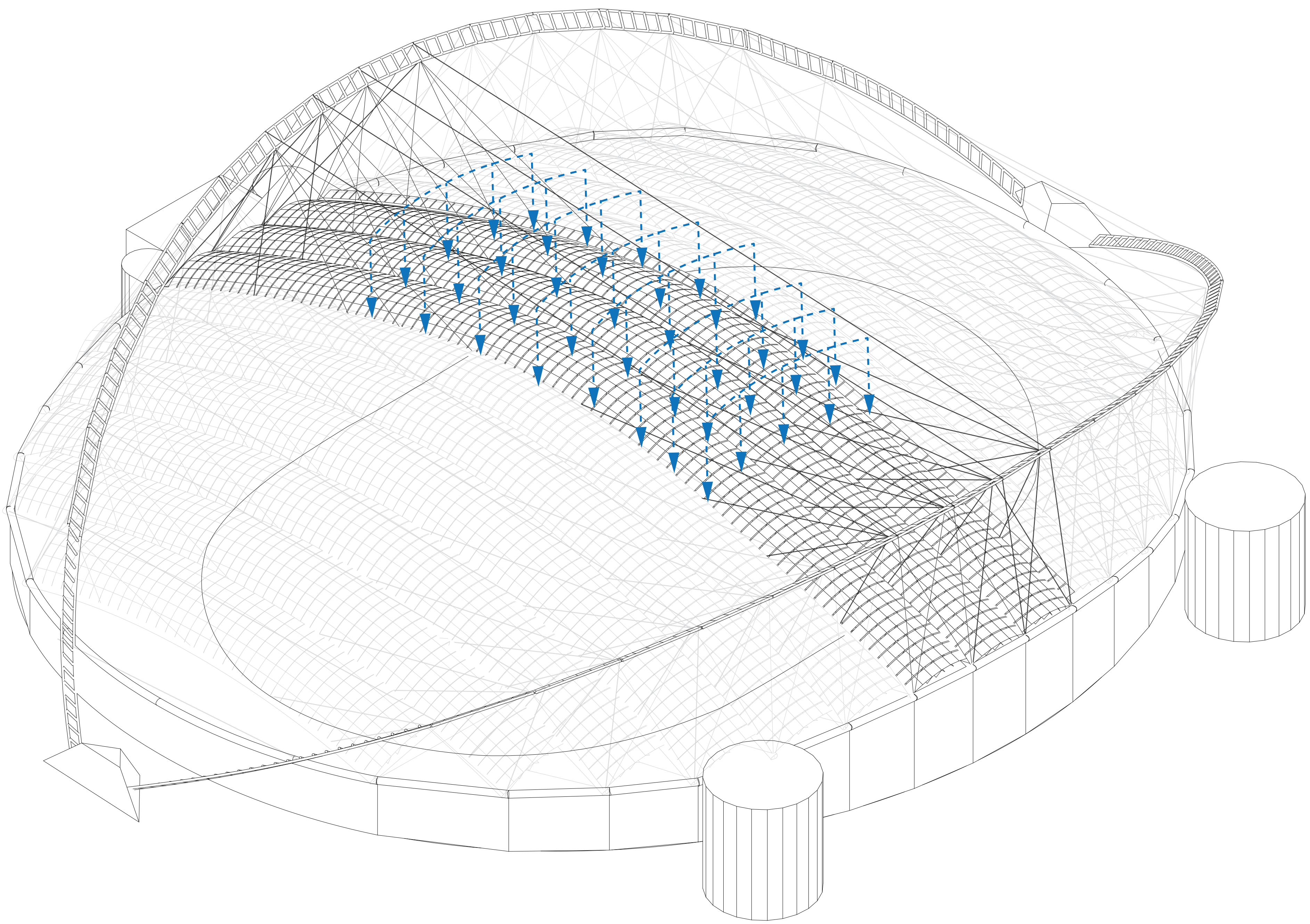

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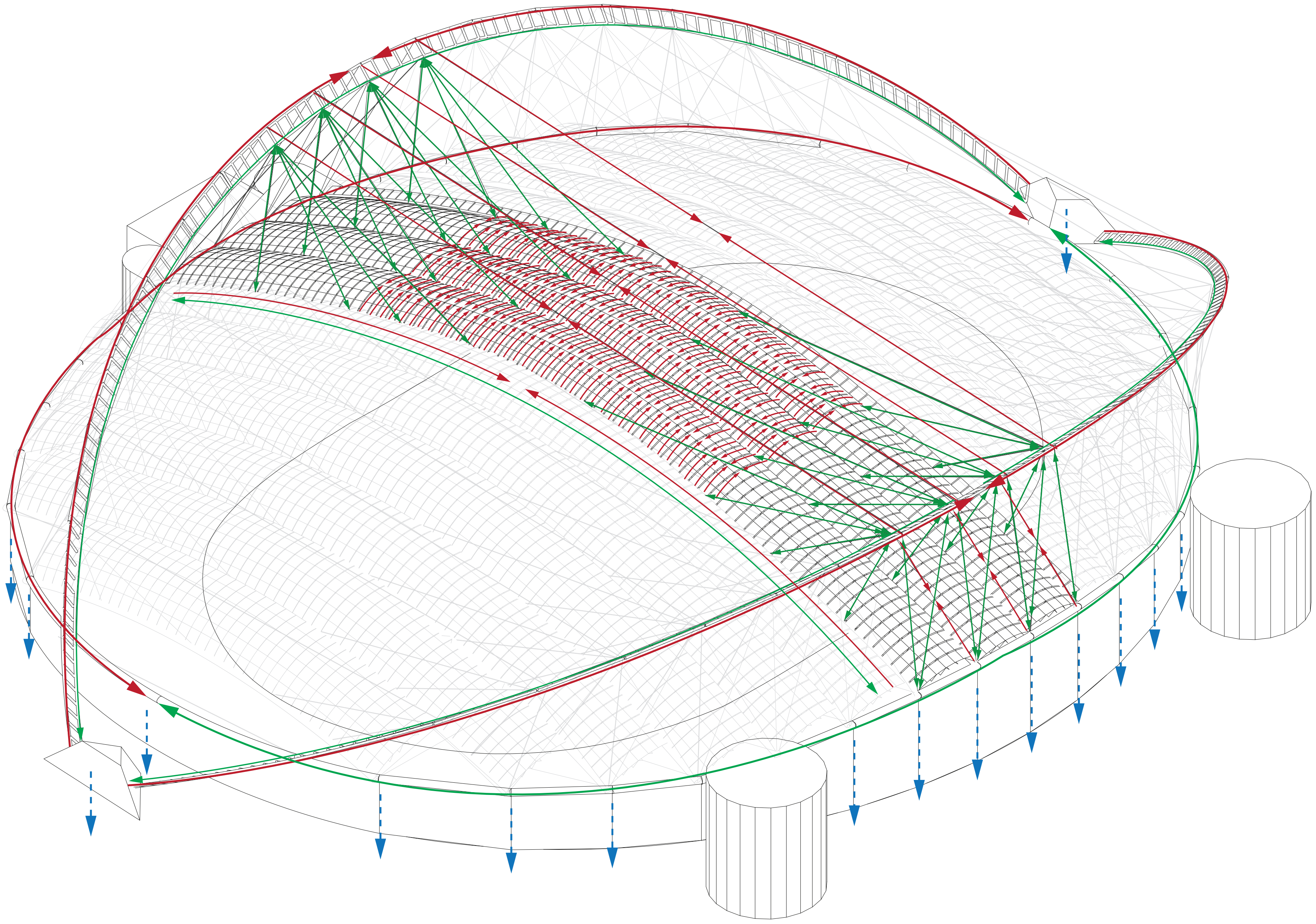
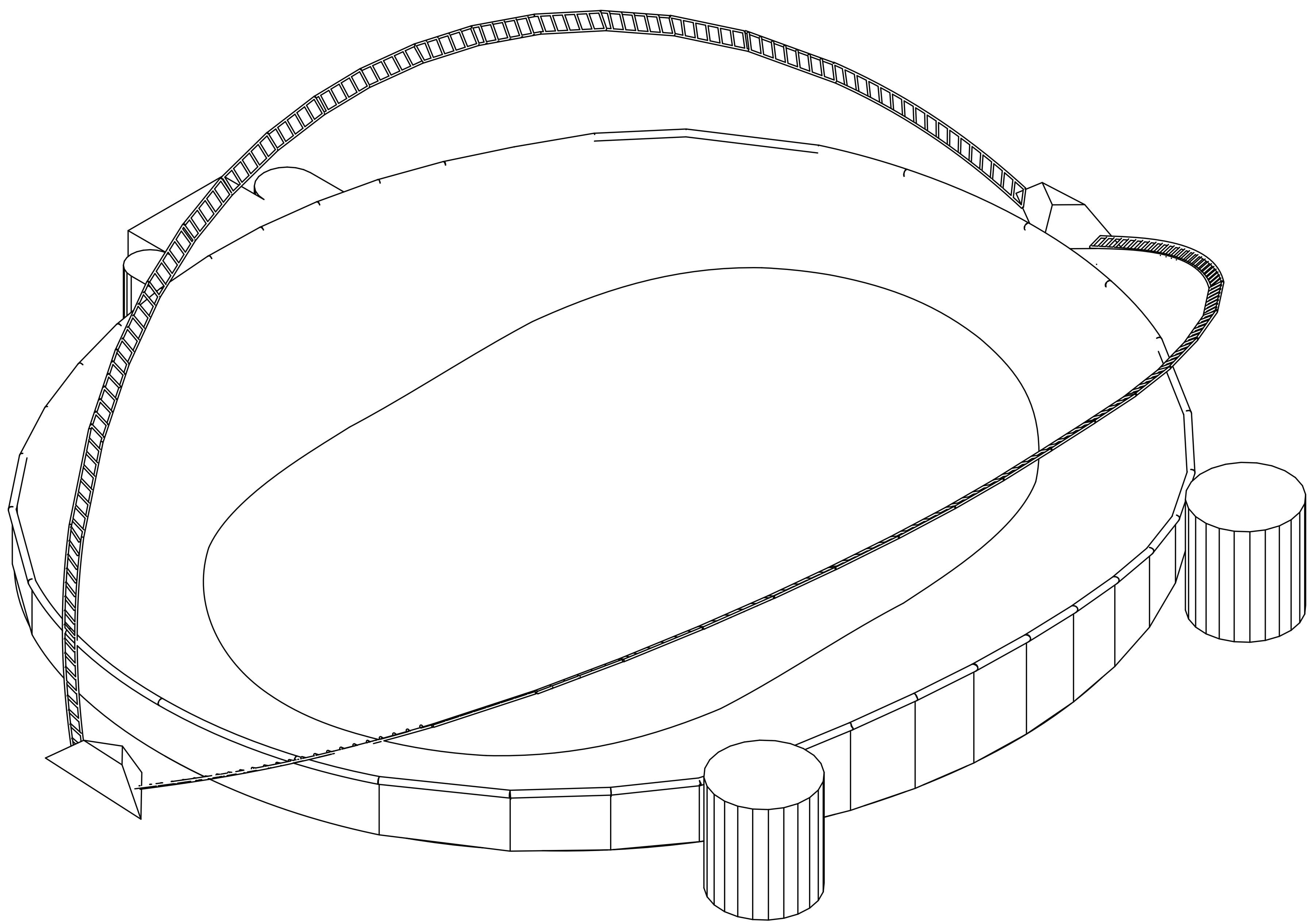
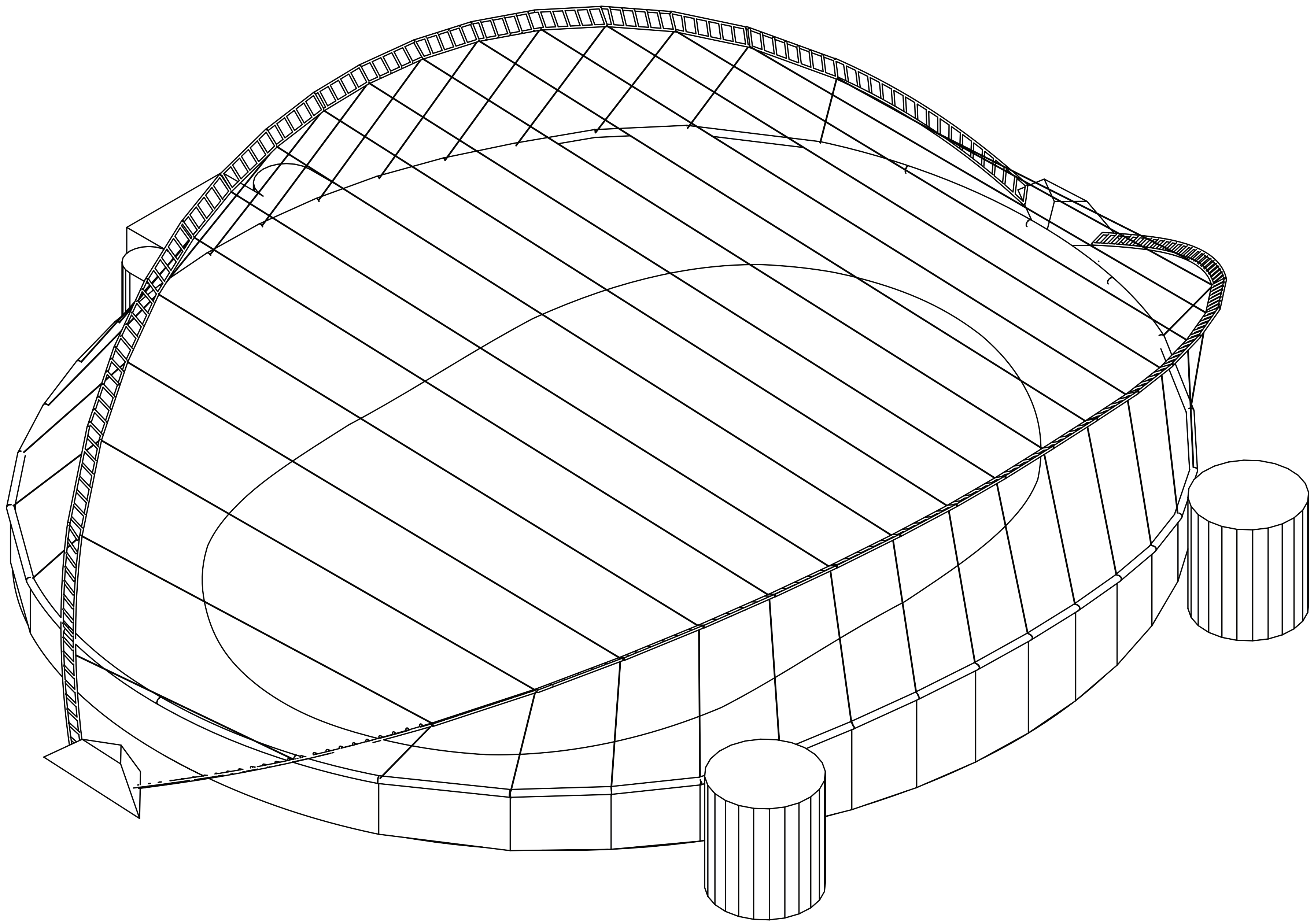
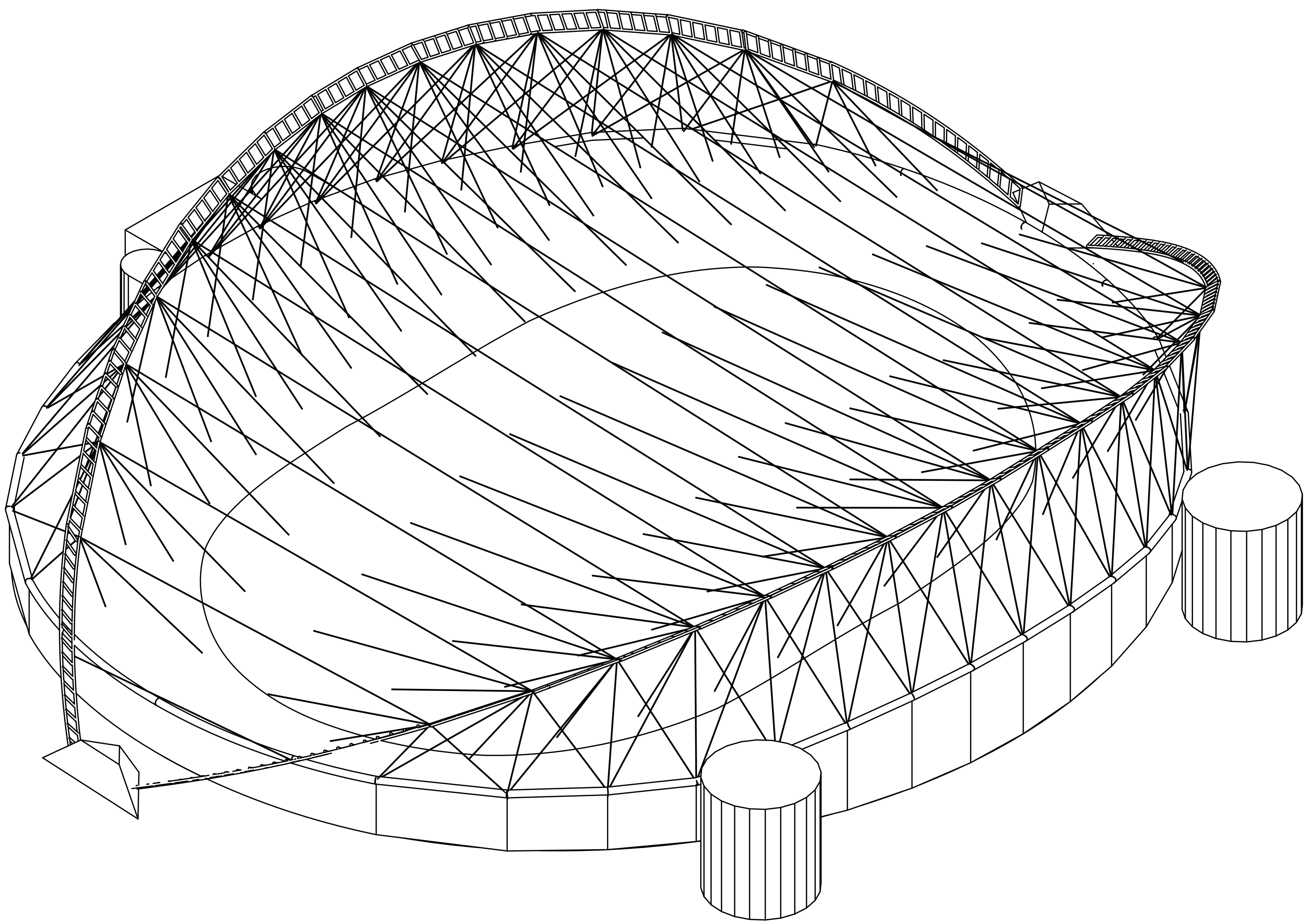
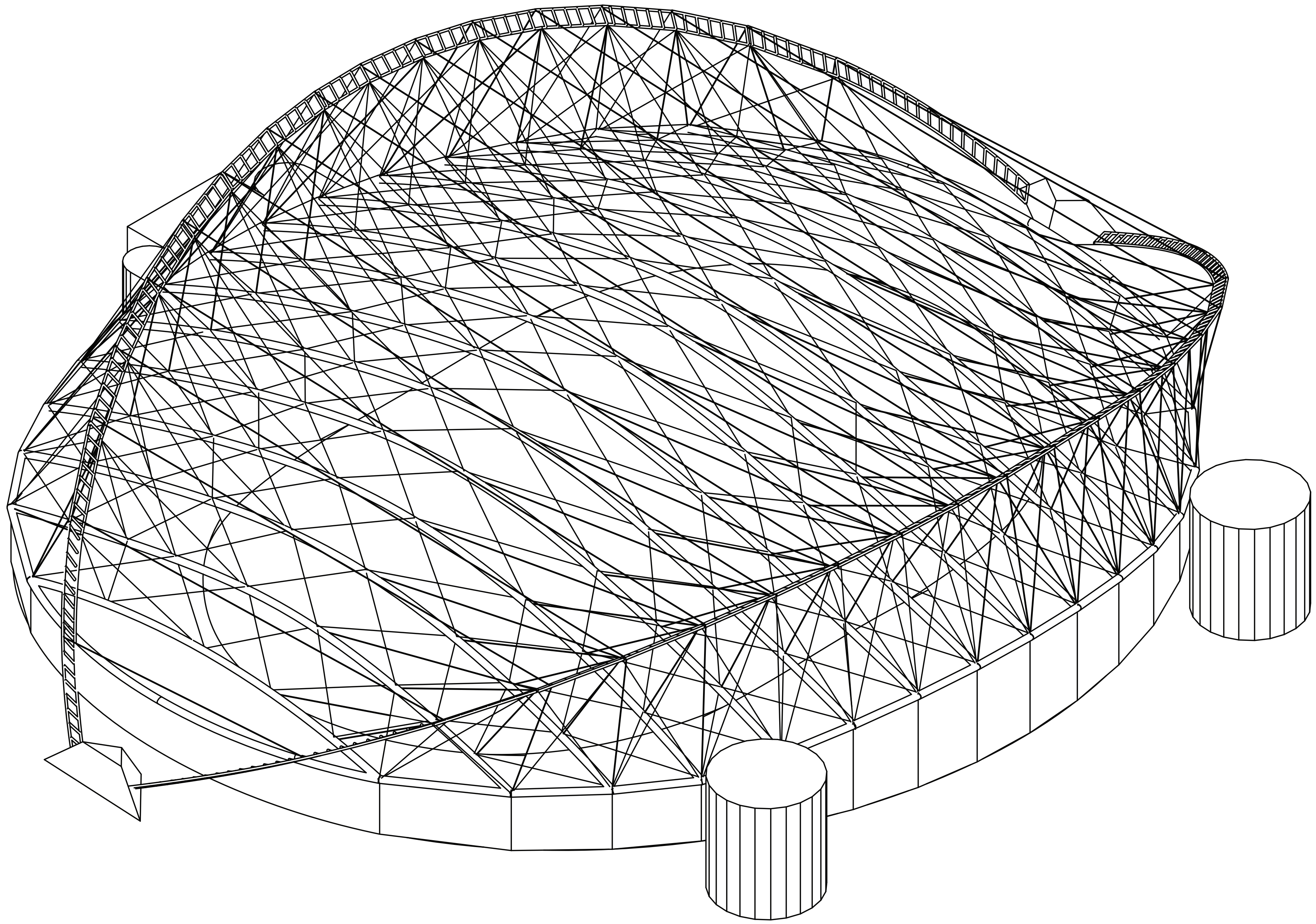


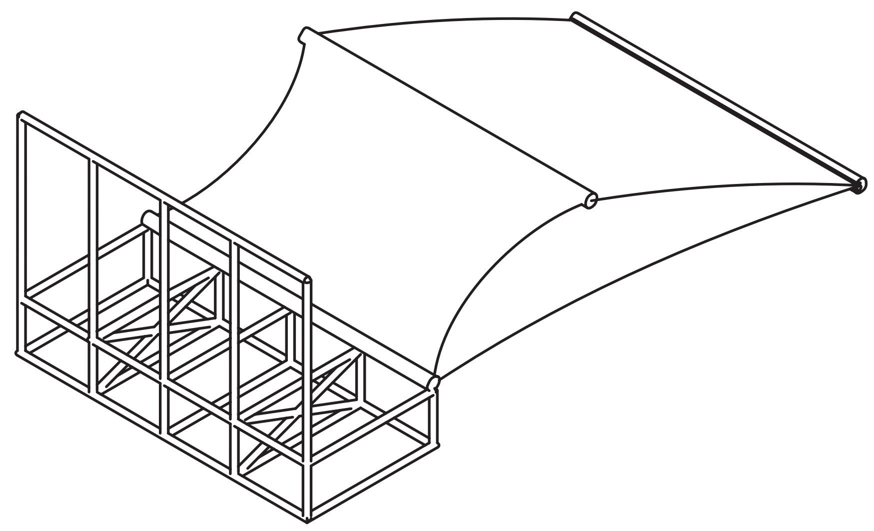


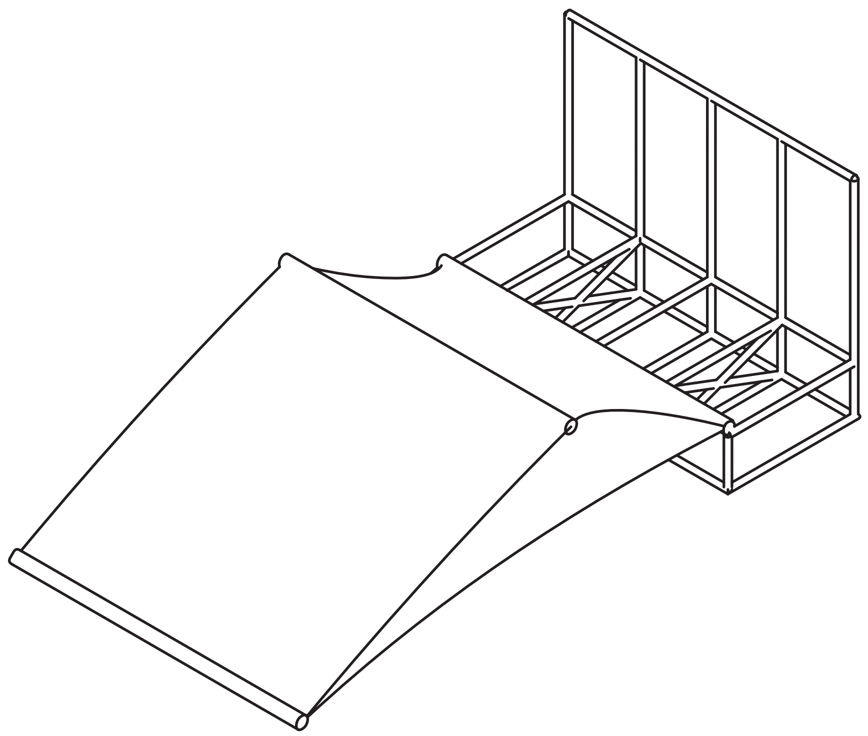




STRUCTURAL DESIGN: BUILDING SEQUENCE







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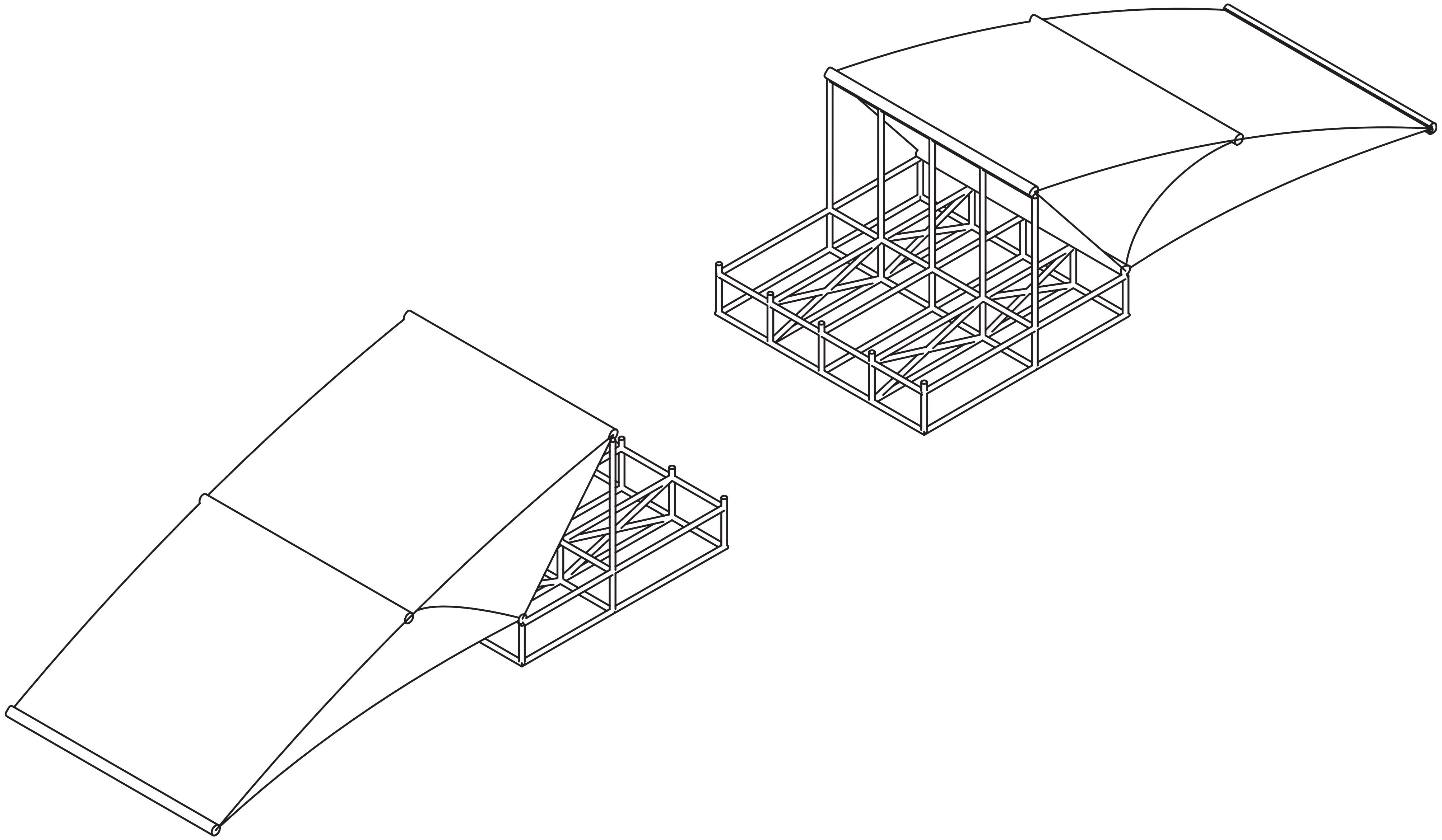
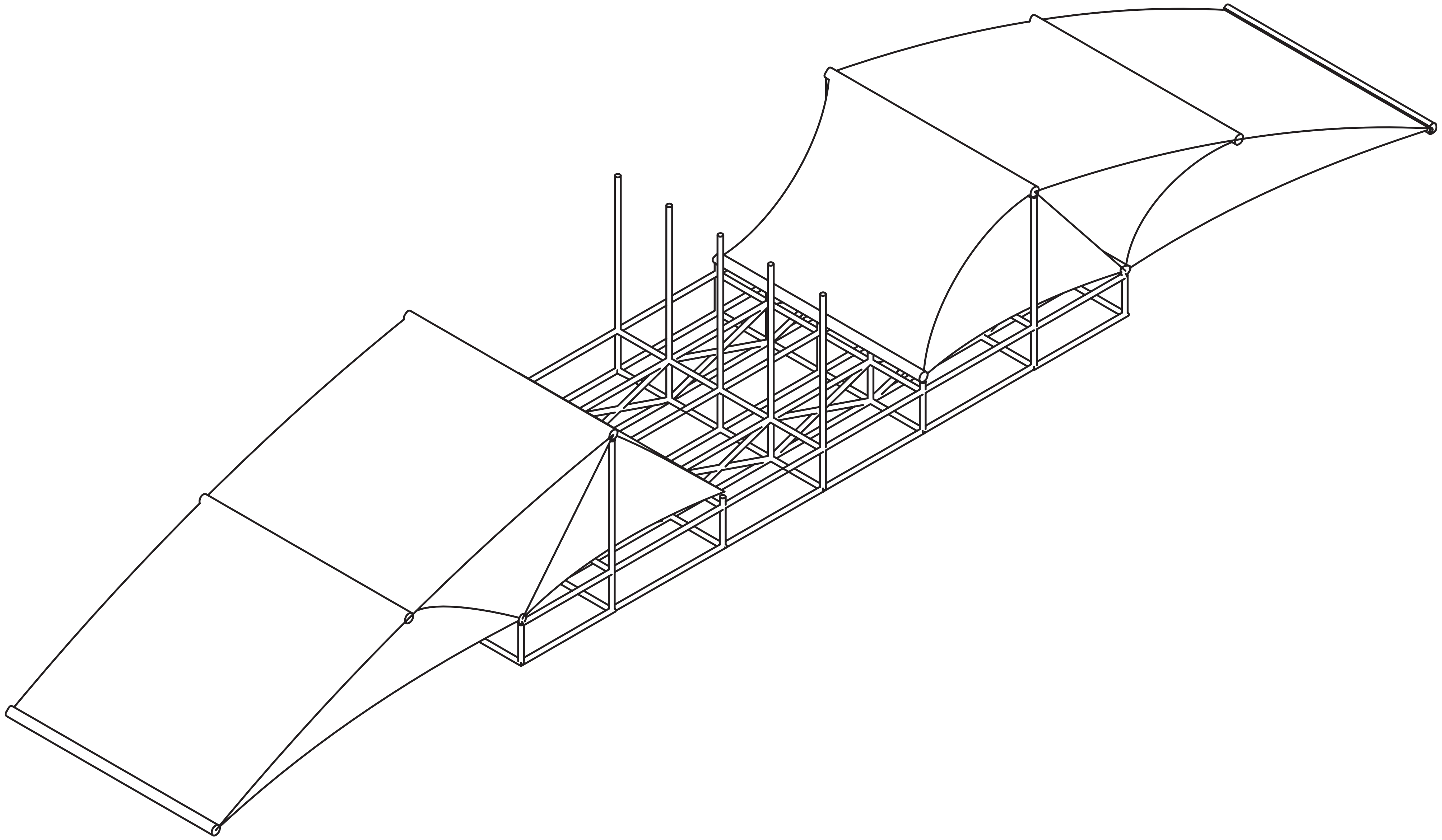
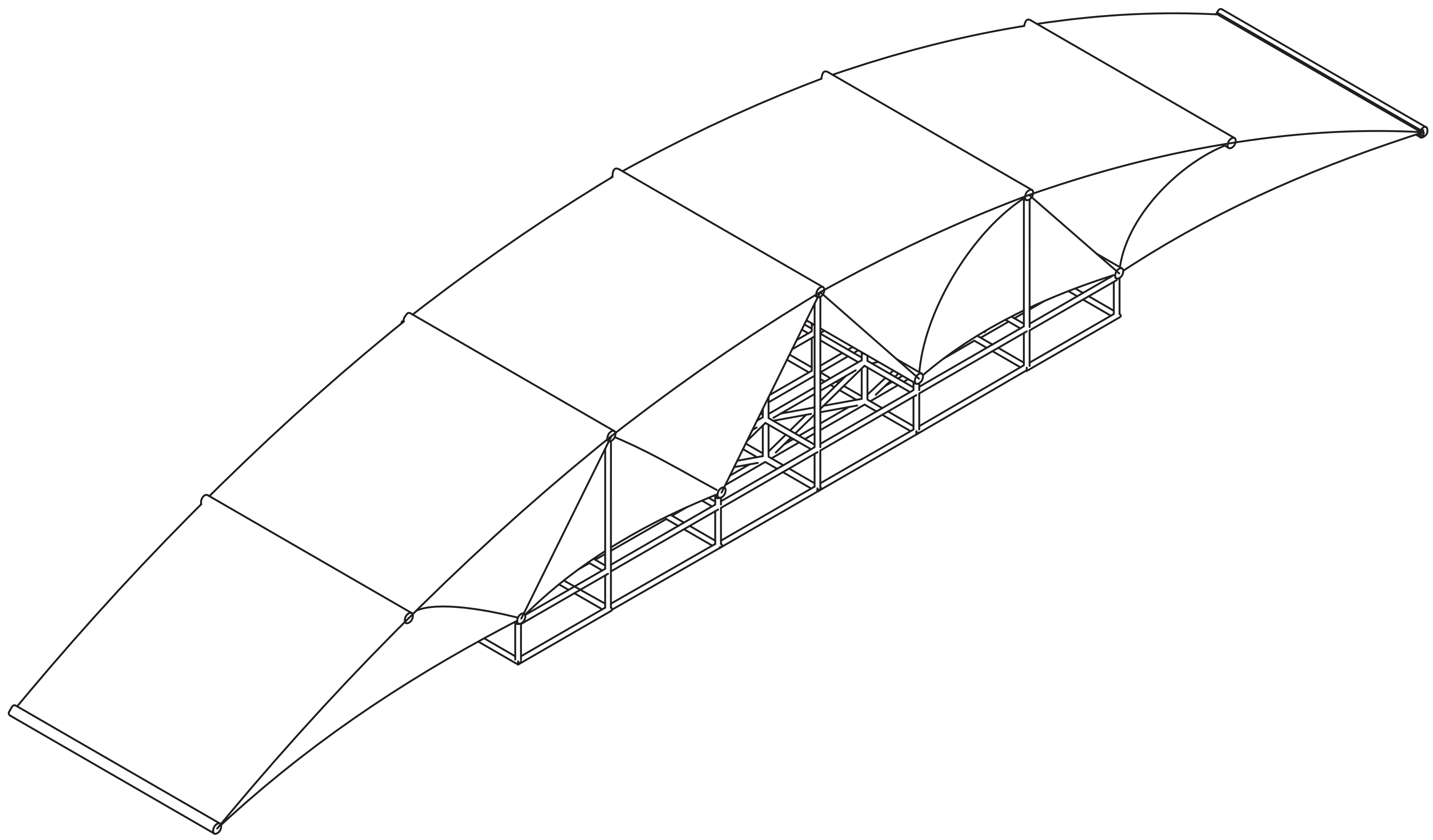
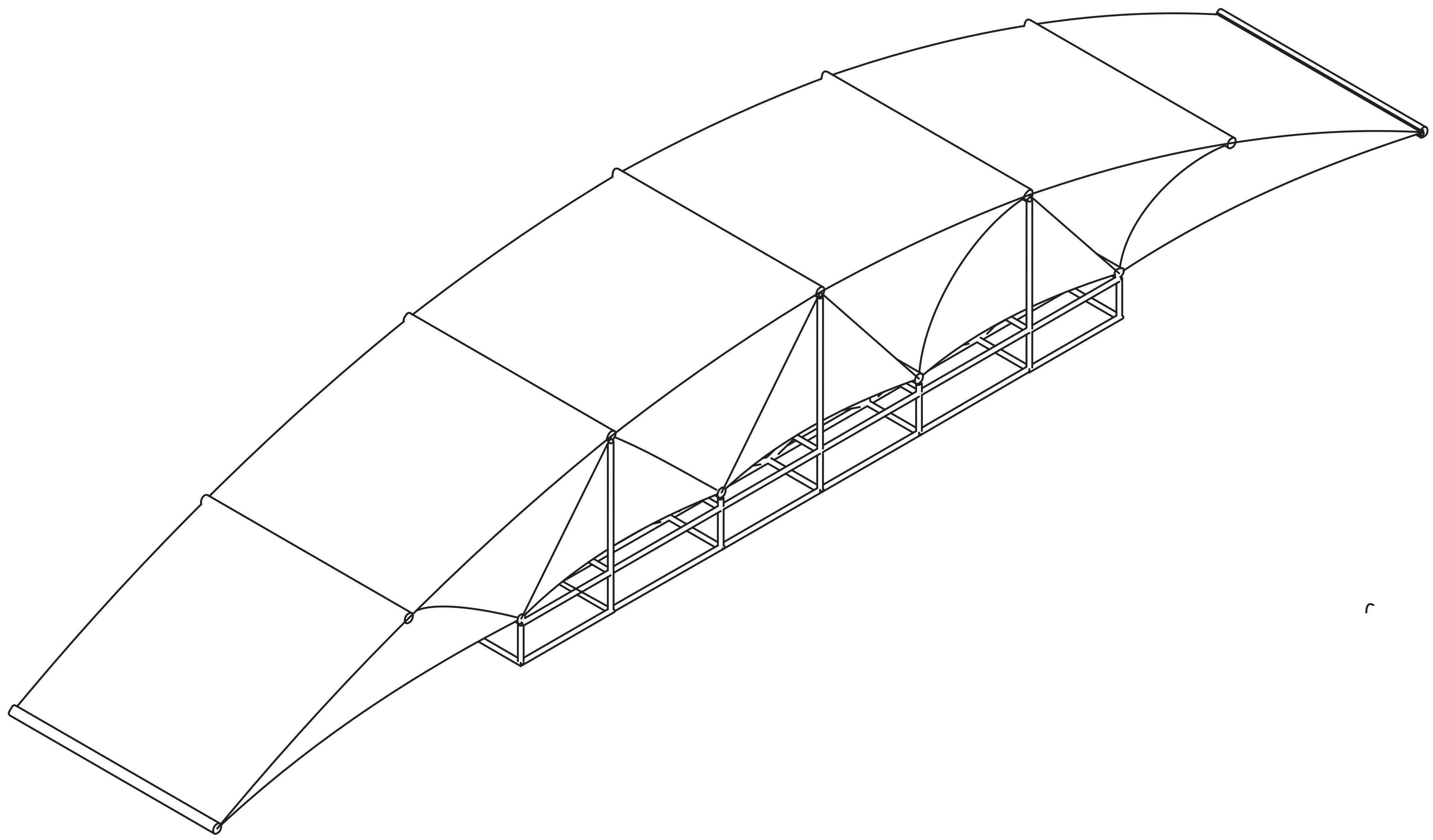
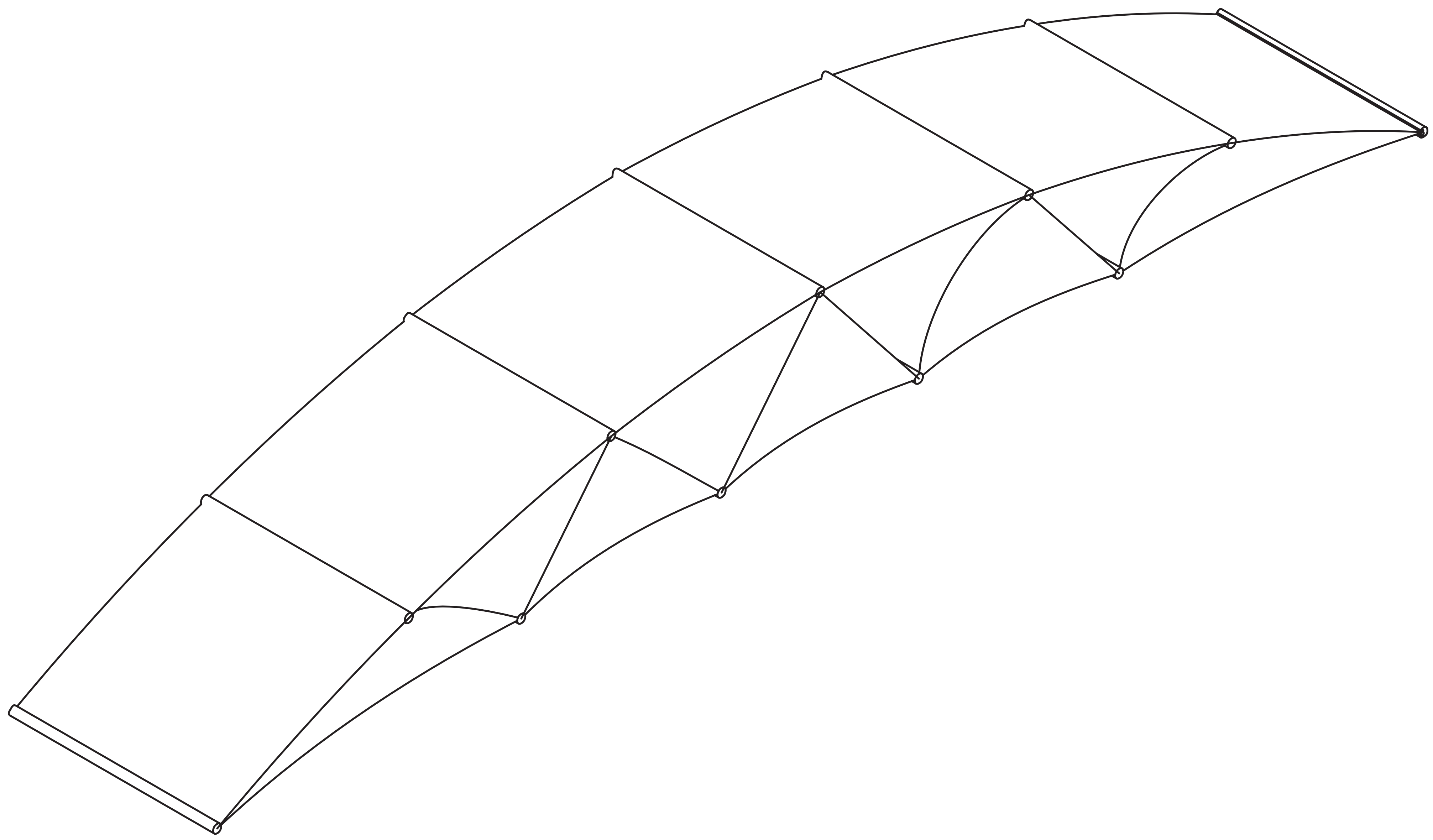
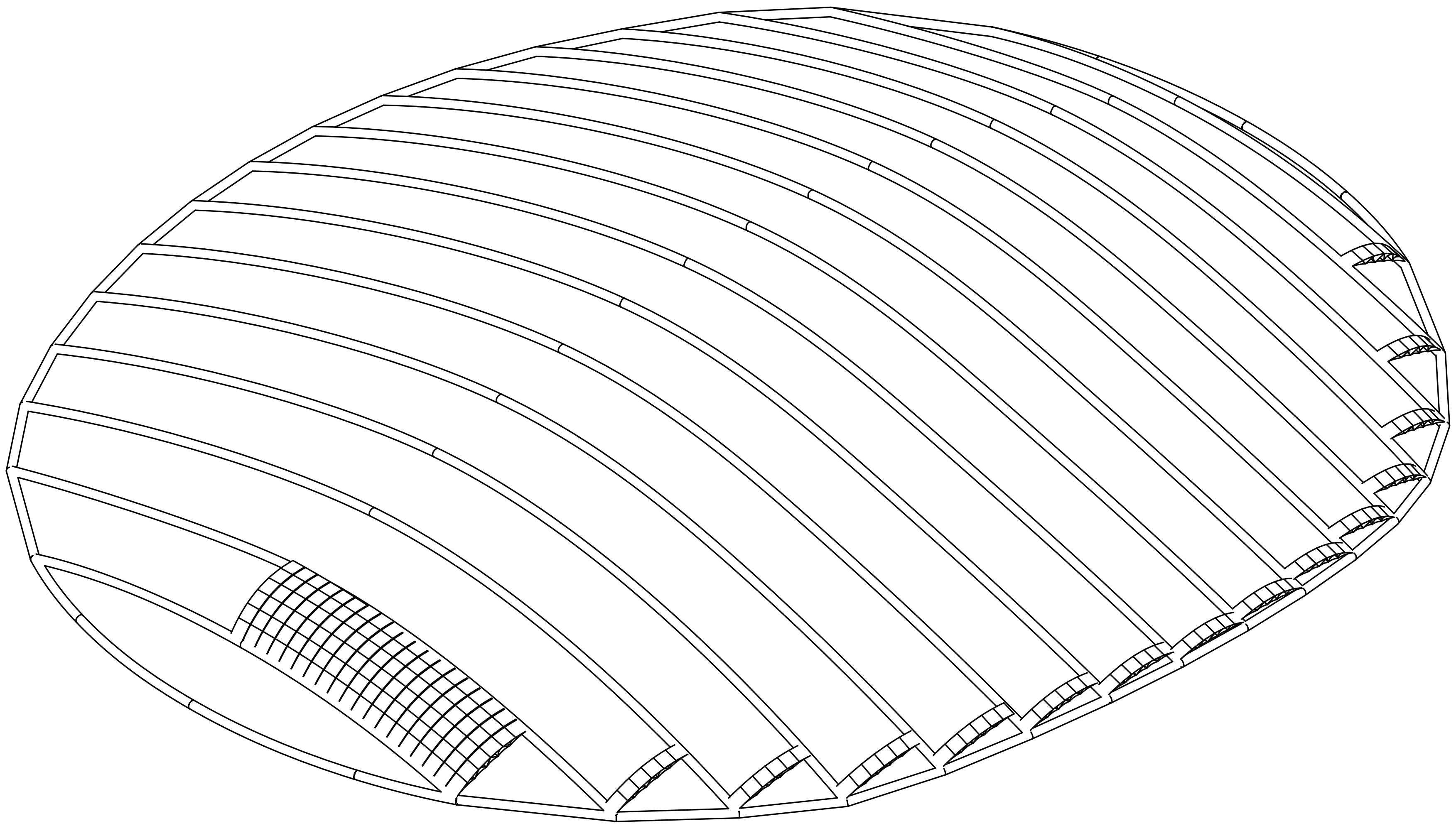


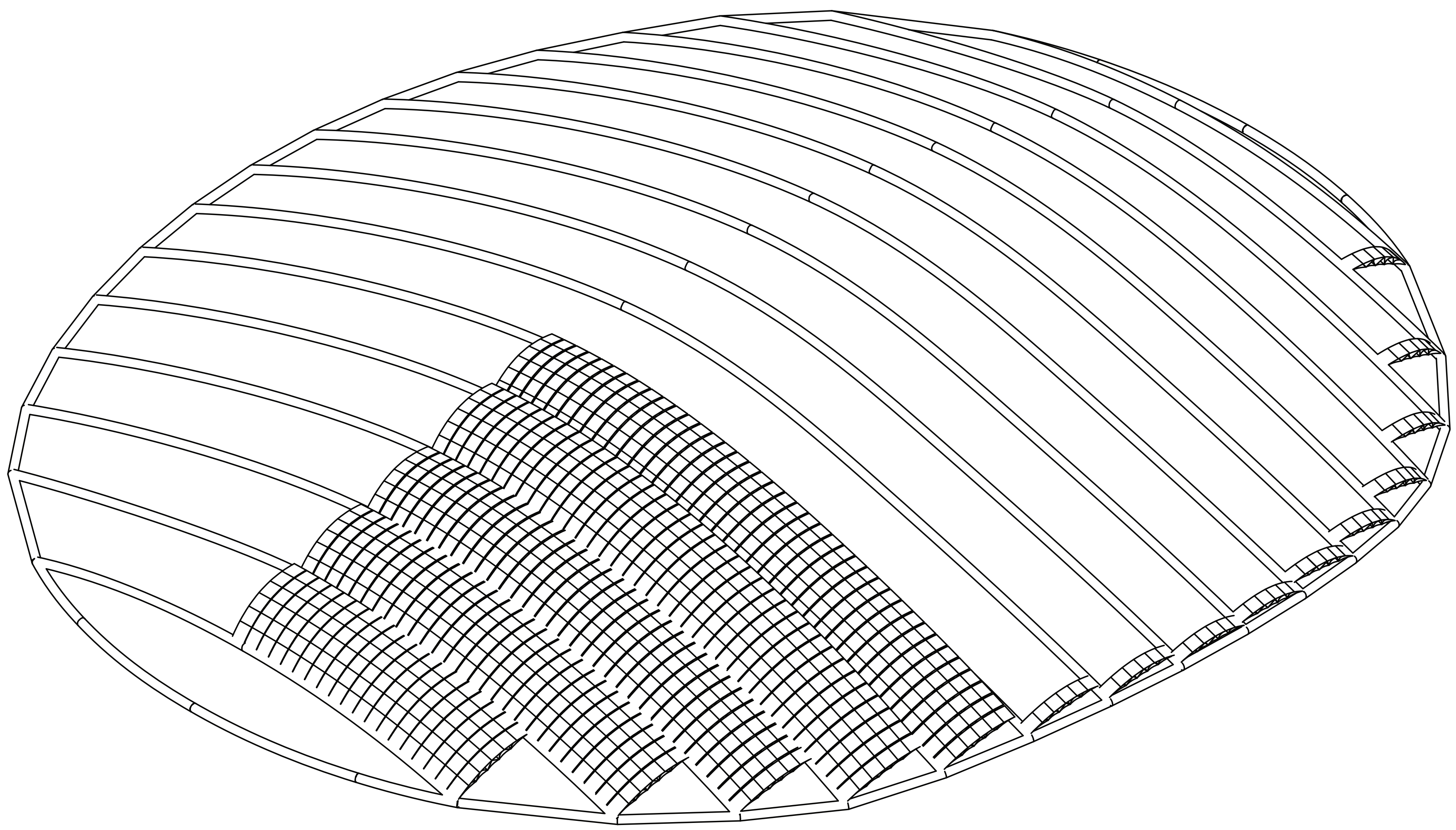


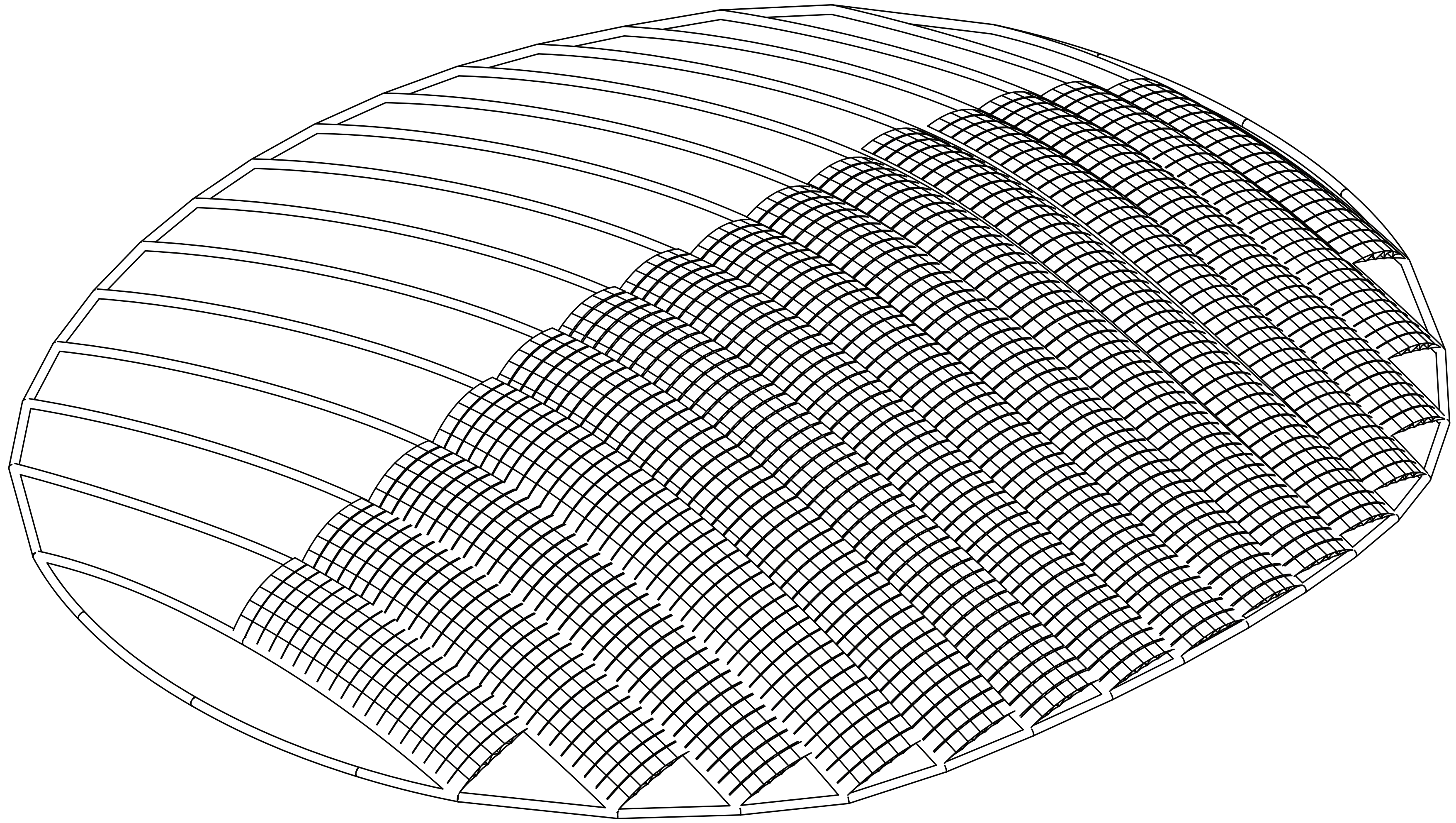


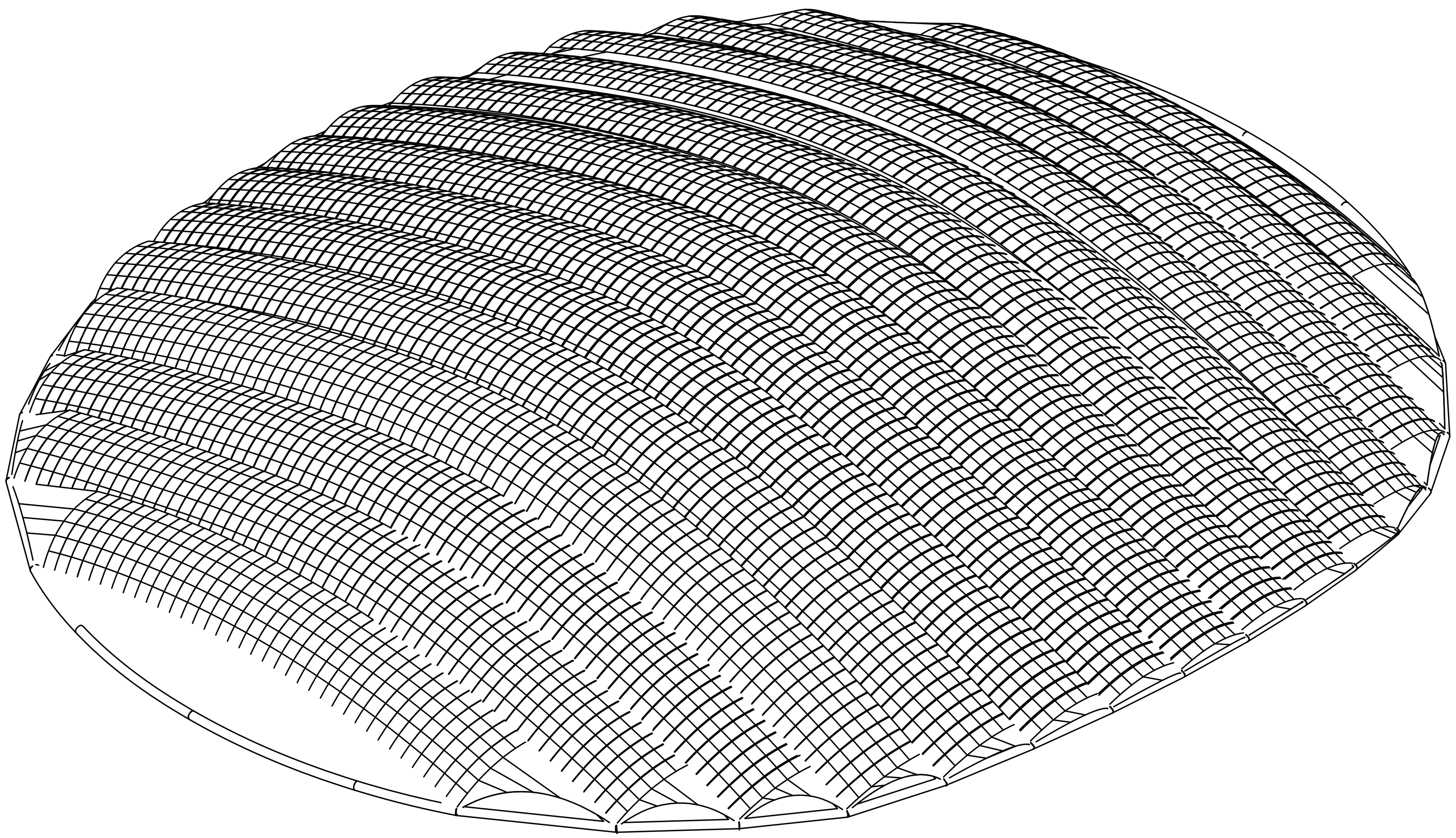


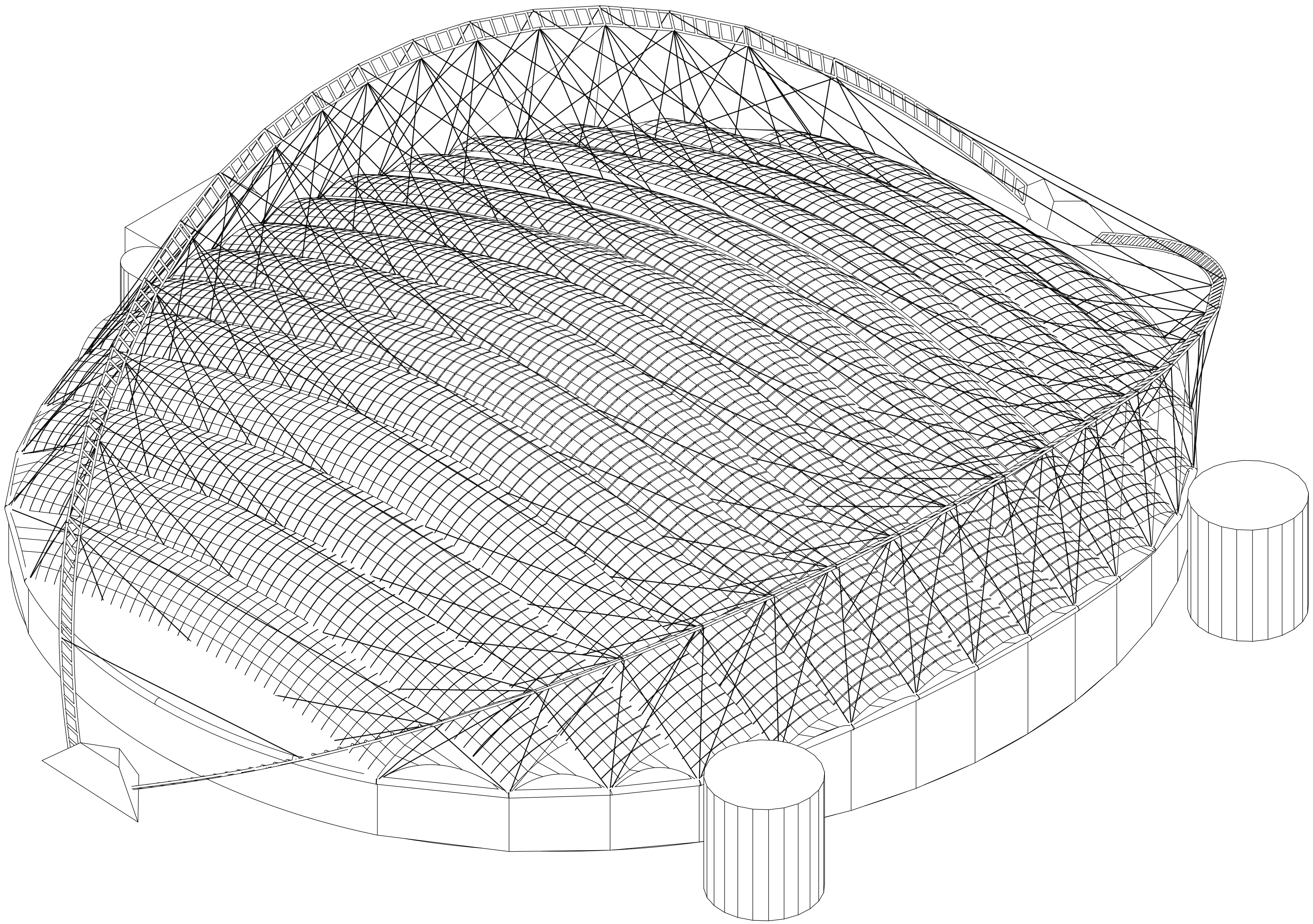










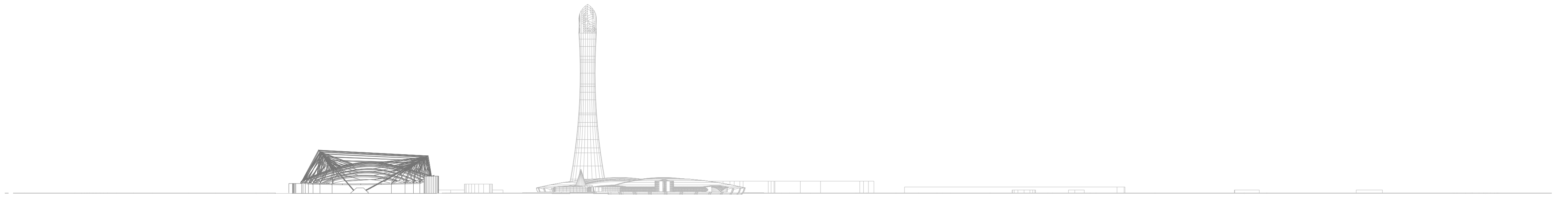


7. ELABORATION

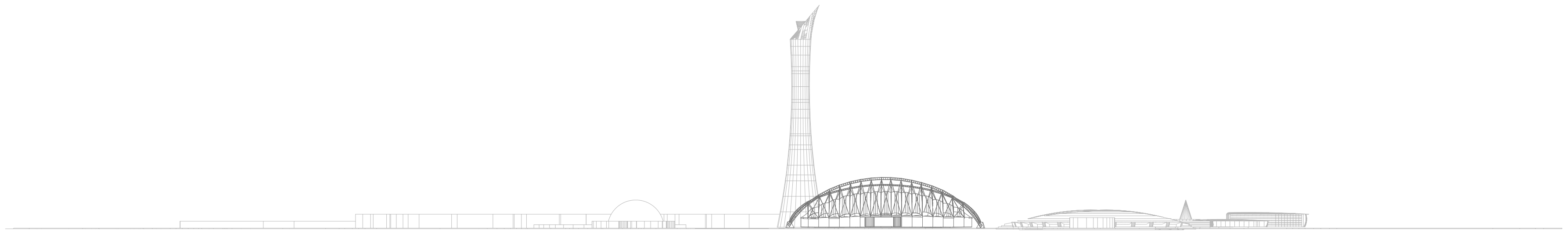
CONTEXT

CONTEXT

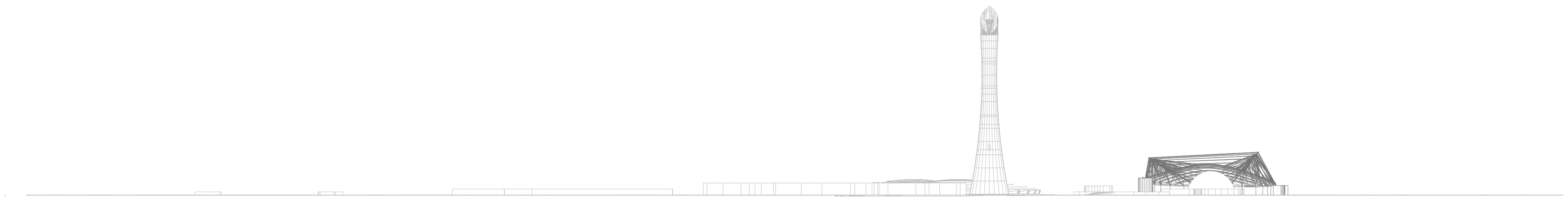
North



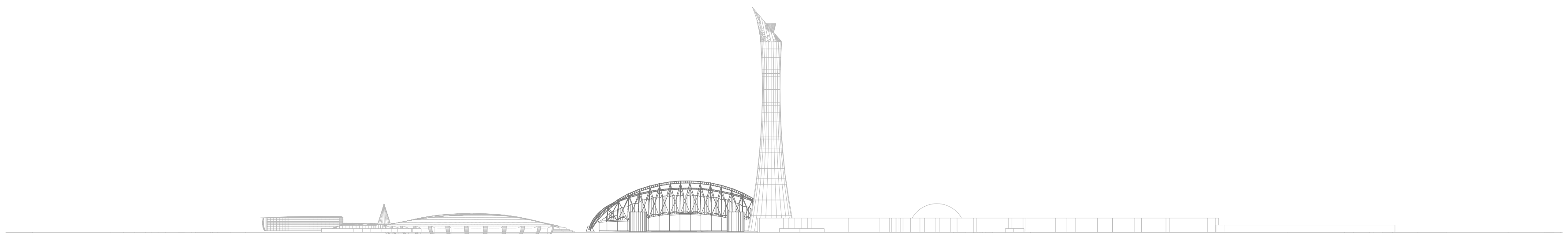
East



South

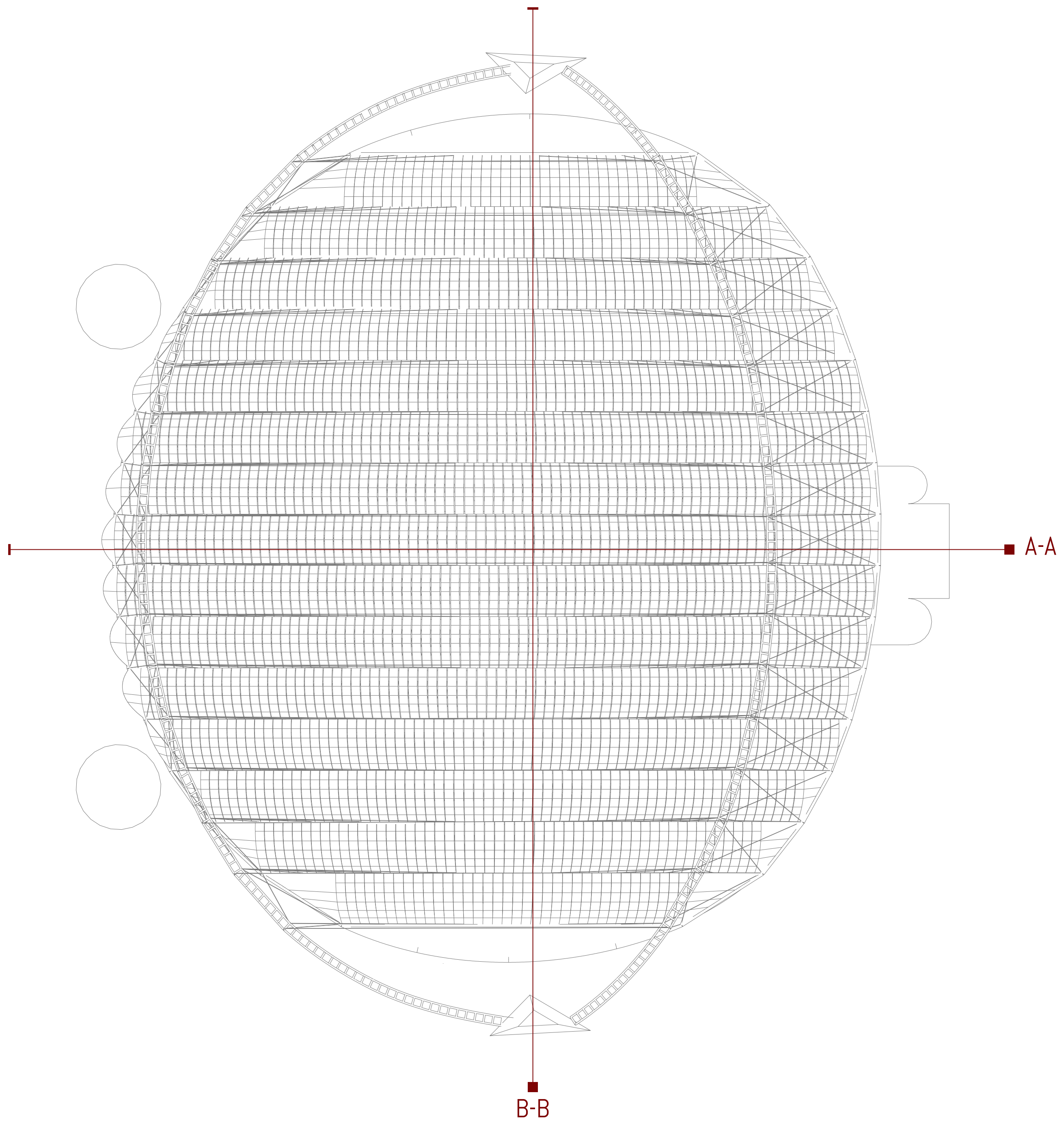


West

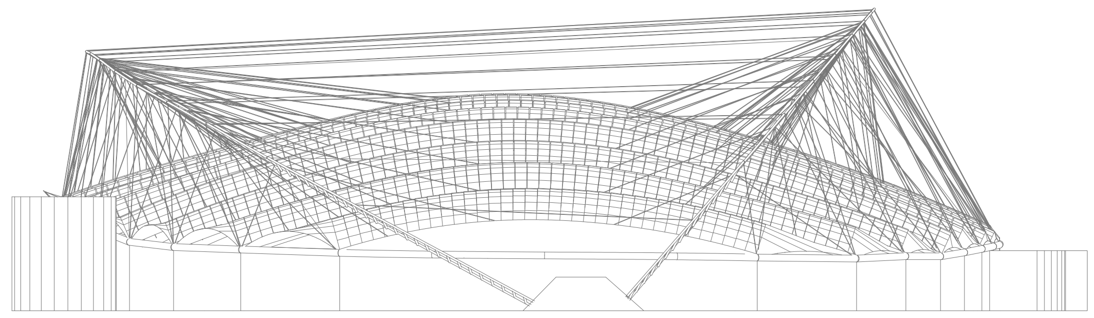


PLAN & ELEVATIONS

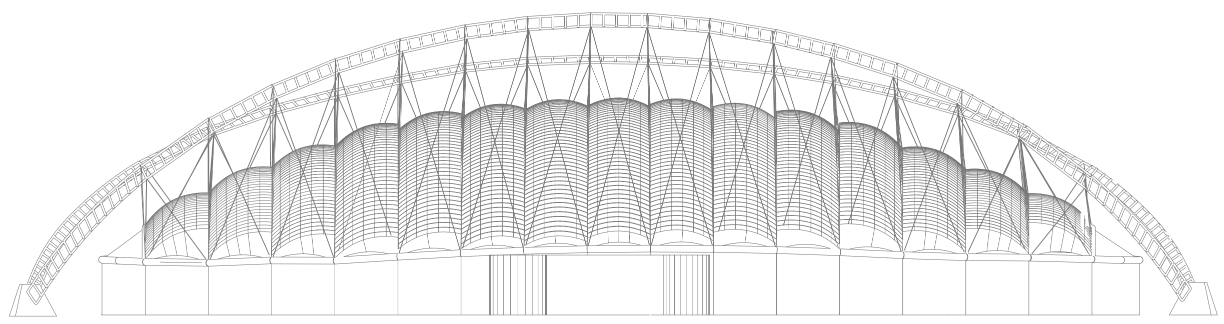
Plan



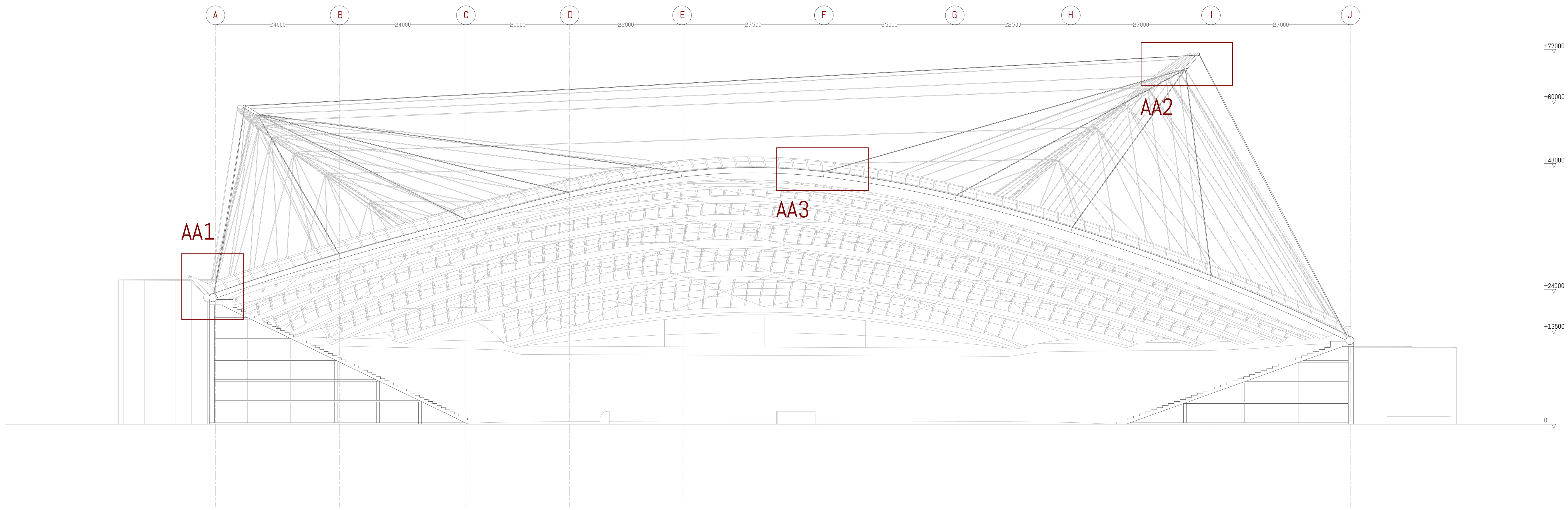
Short side elevation



Long side elevation



SECTION AA



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I
J
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24000
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27500
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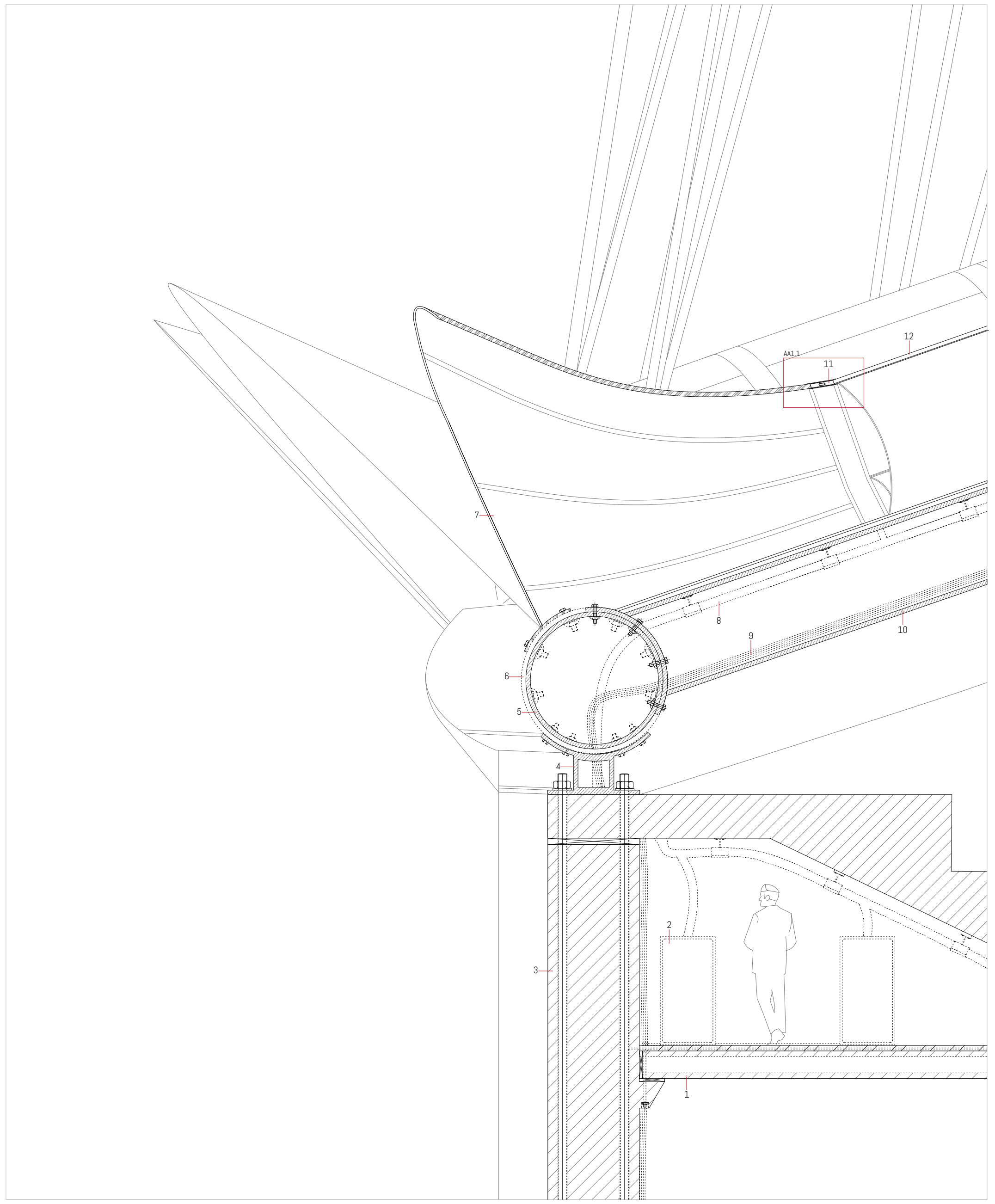
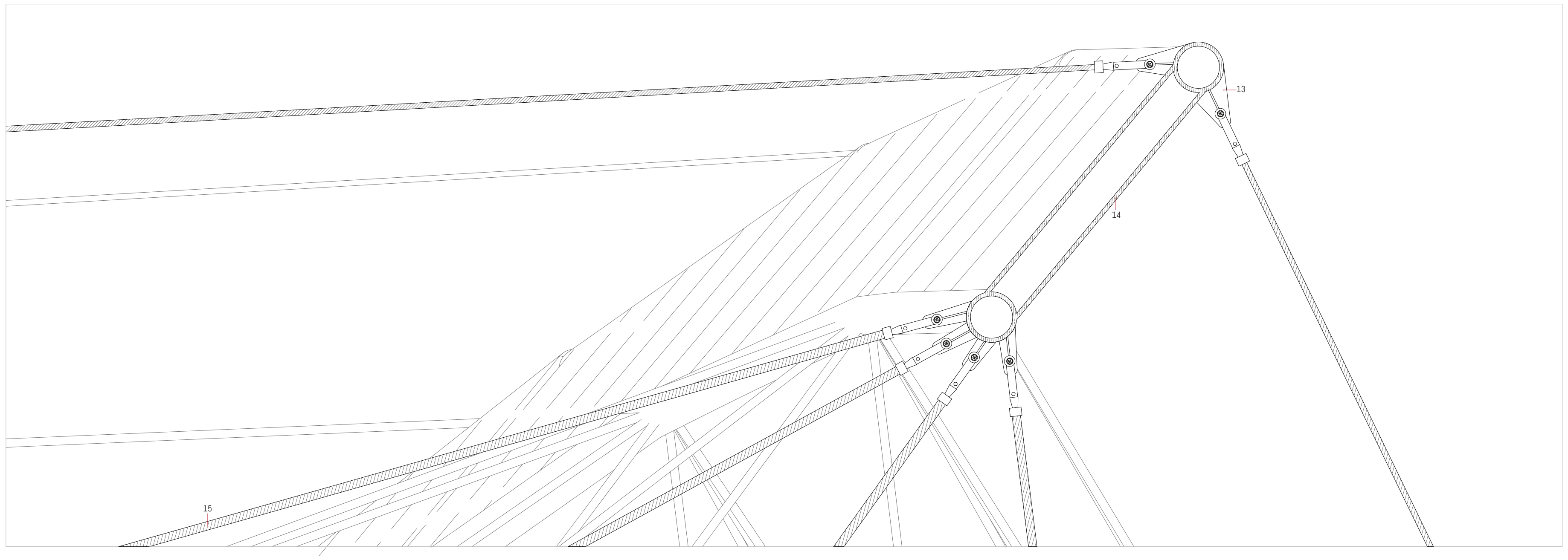
22500
27000
27000
+72000
+60000
+48000
+24000
+13500
0
AA1
AA2
AA3

DETAIL AA

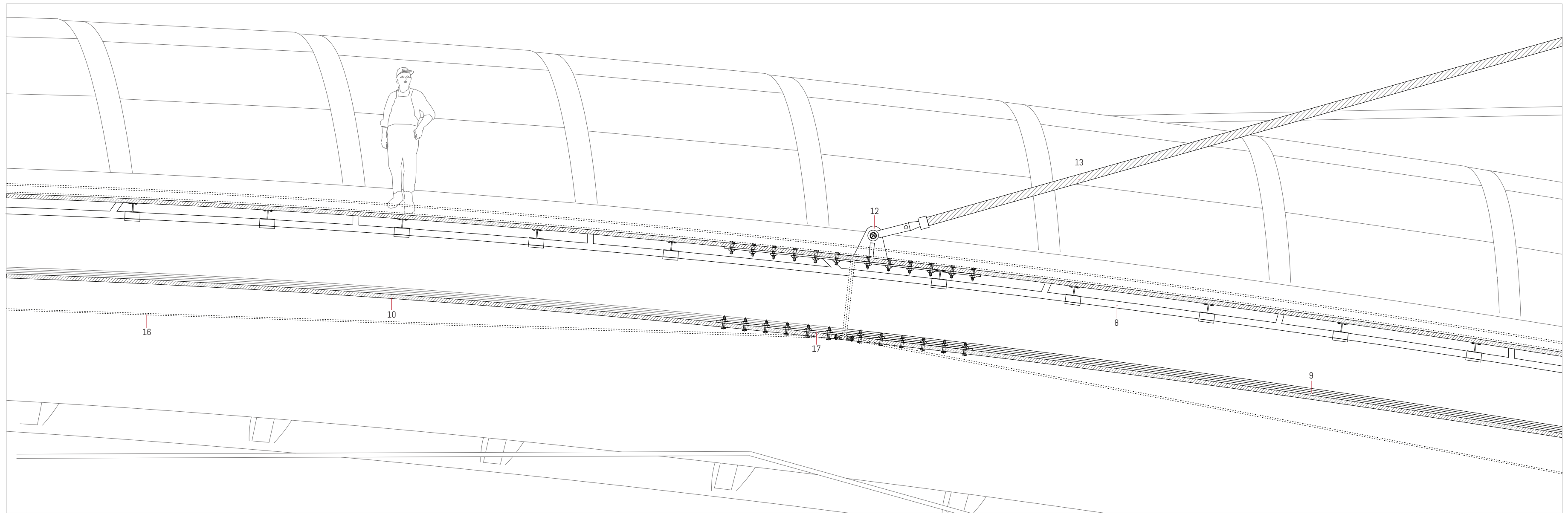
DETAIL AA1 **1:20**



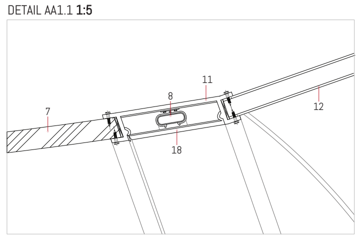
DETAIL AA2 **1:20**



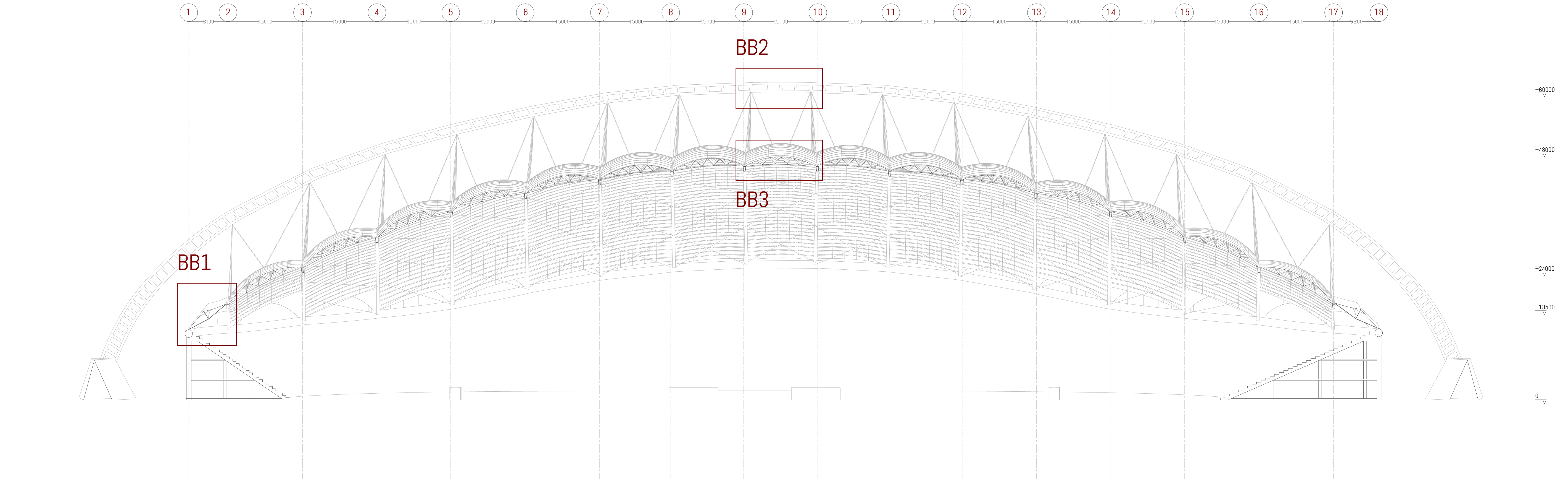
DETAIL AA3 **1:20**



DETAIL AA1.1 **1:5**



SECTION BB



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17
18
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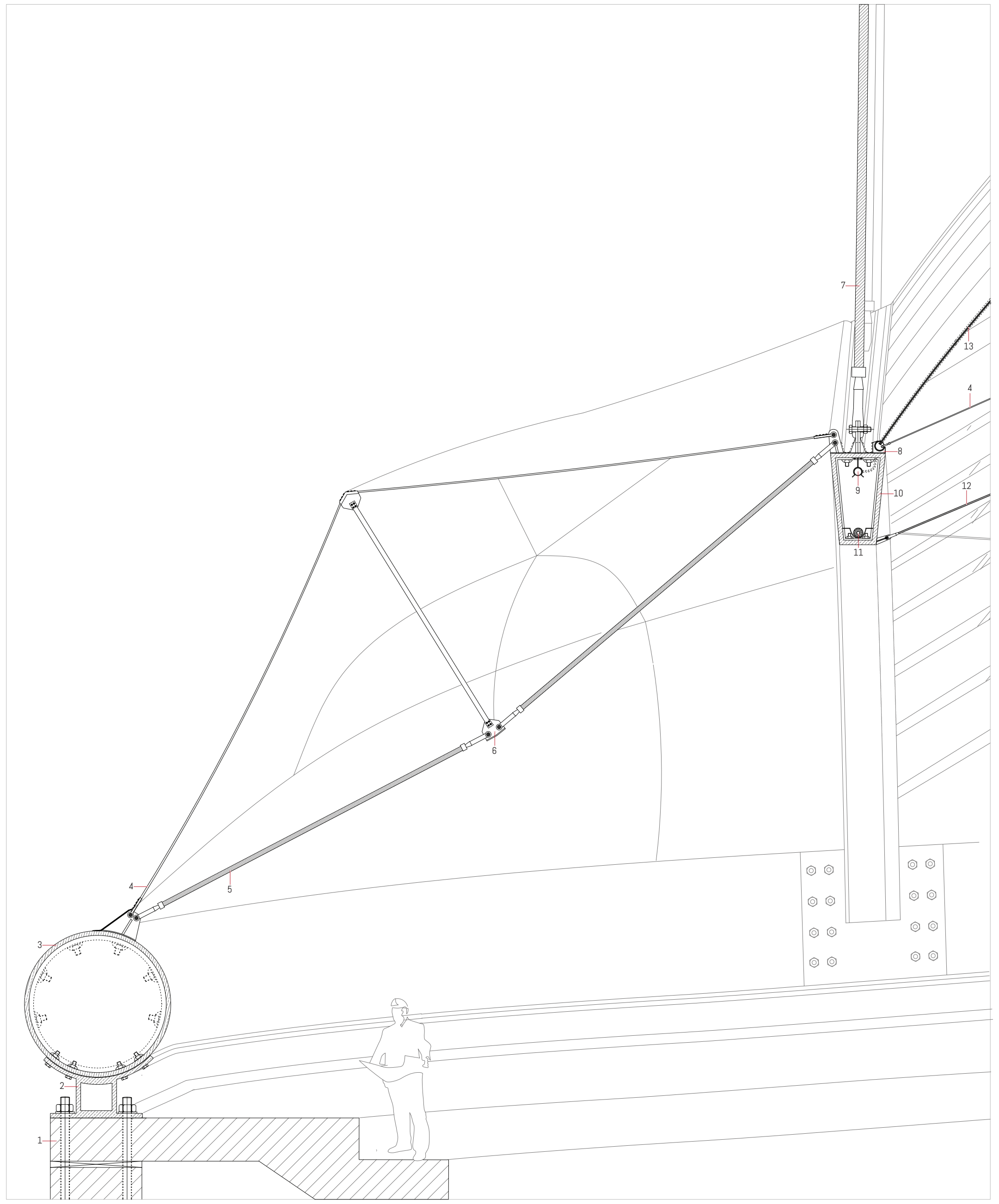
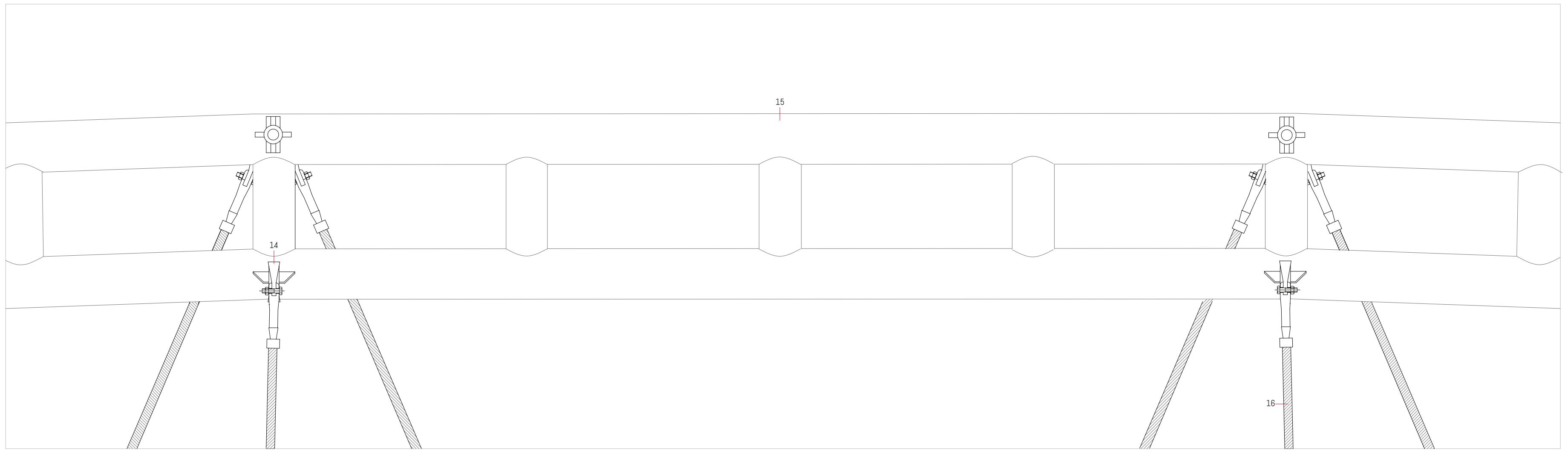
BB2
BB3
+60000
+48000
+24000
+13500
0

DETAIL BB

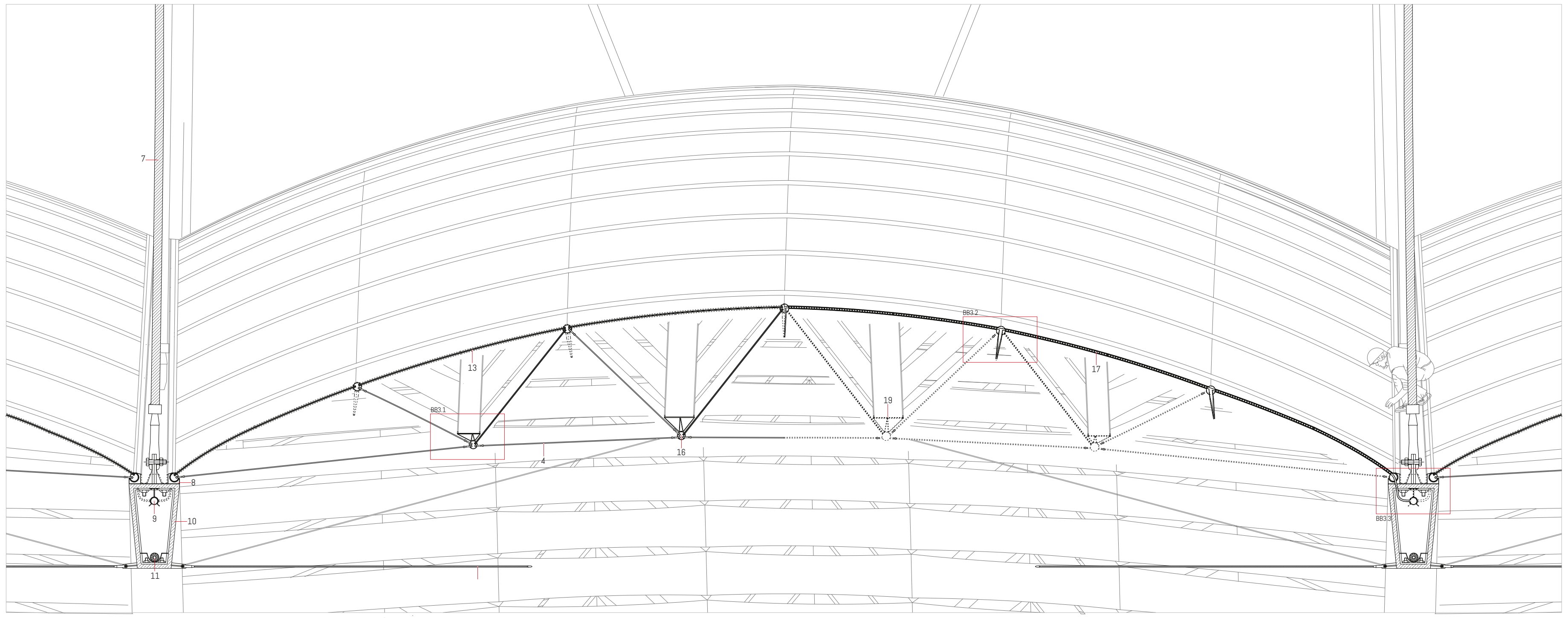
DETAIL BB1 **1:20**



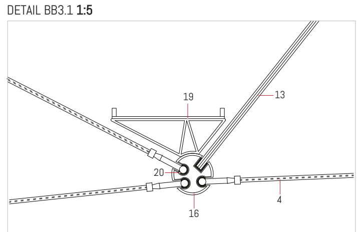
DETAIL BB2 **1:20**



DETAIL BB3 **1:20**



DETAIL BB3.1 **1:5**



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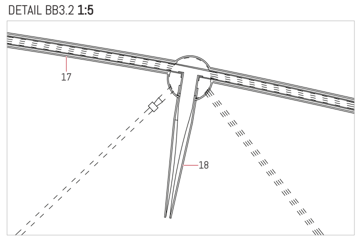
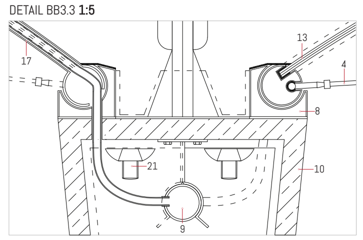
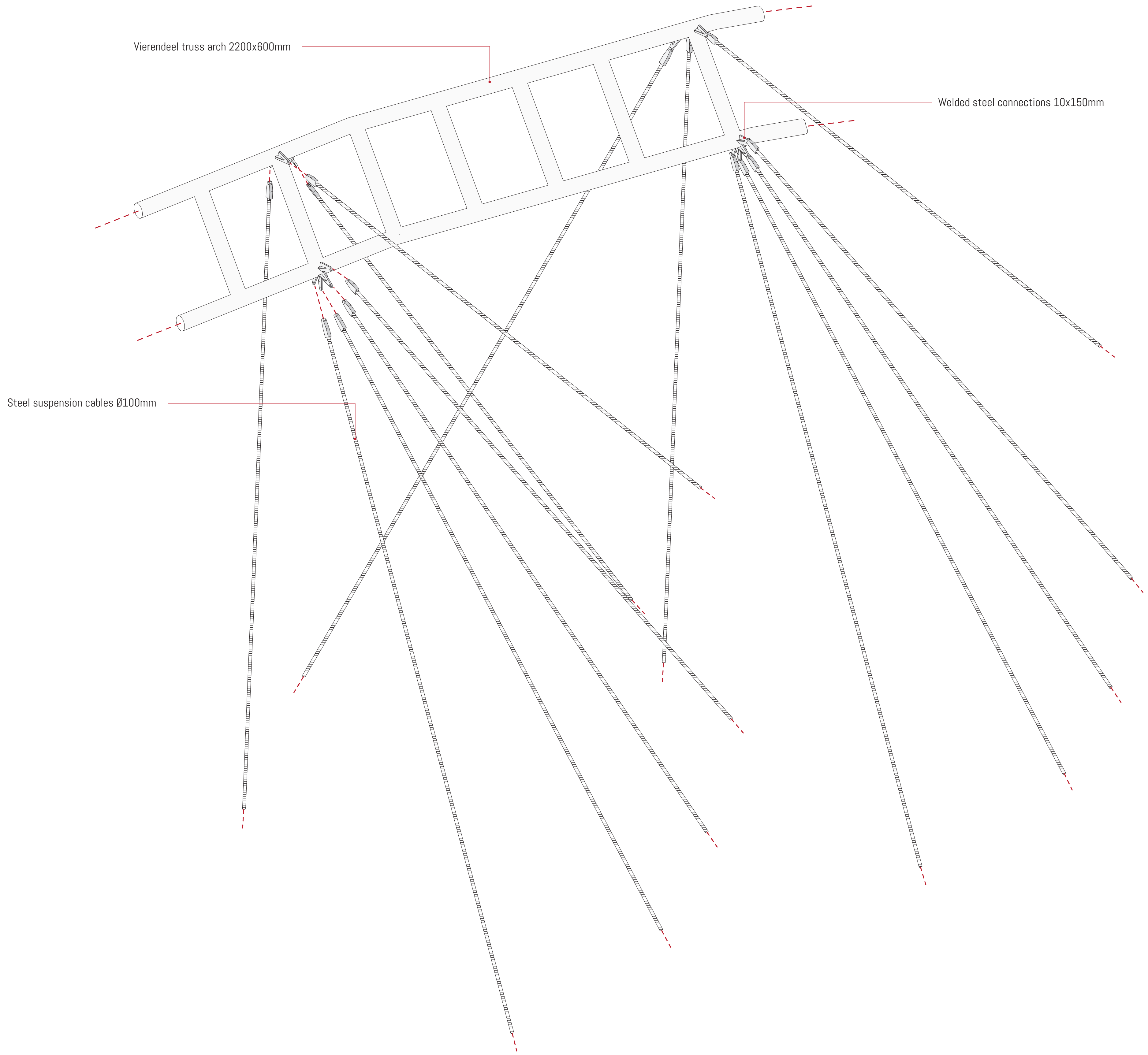


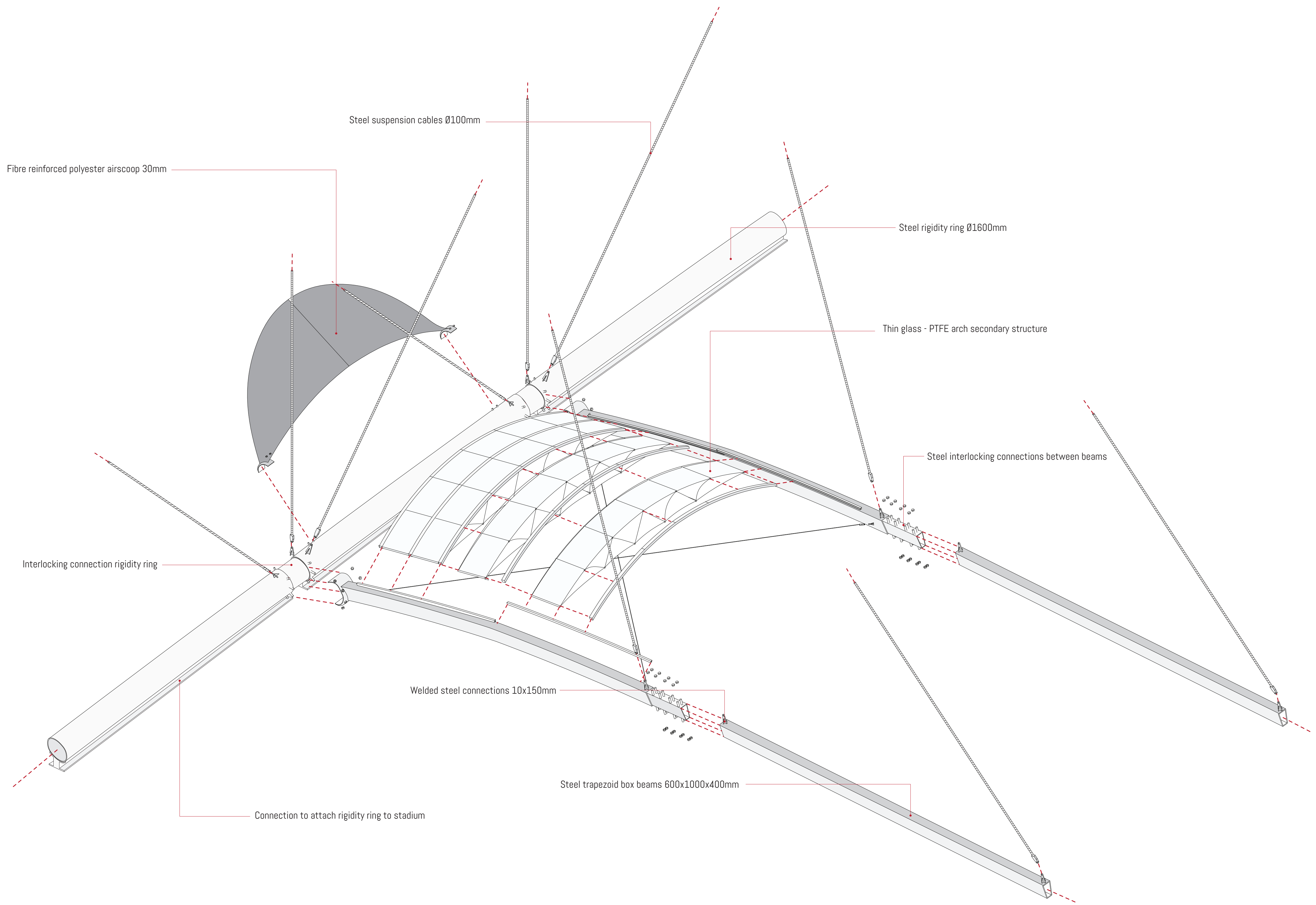
DETAIL BB3.3 **1:5**



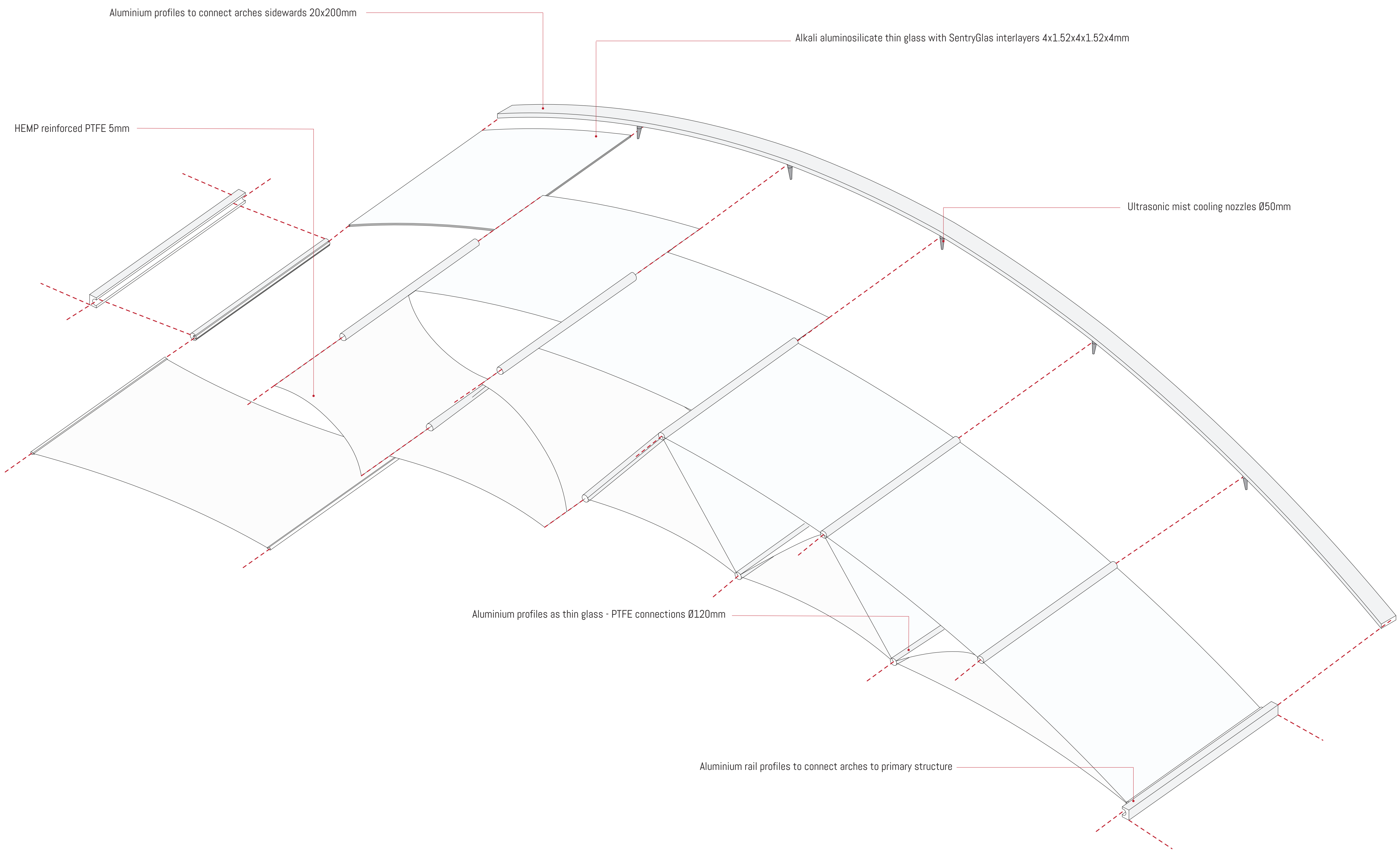
DETAIL AA2+BB2



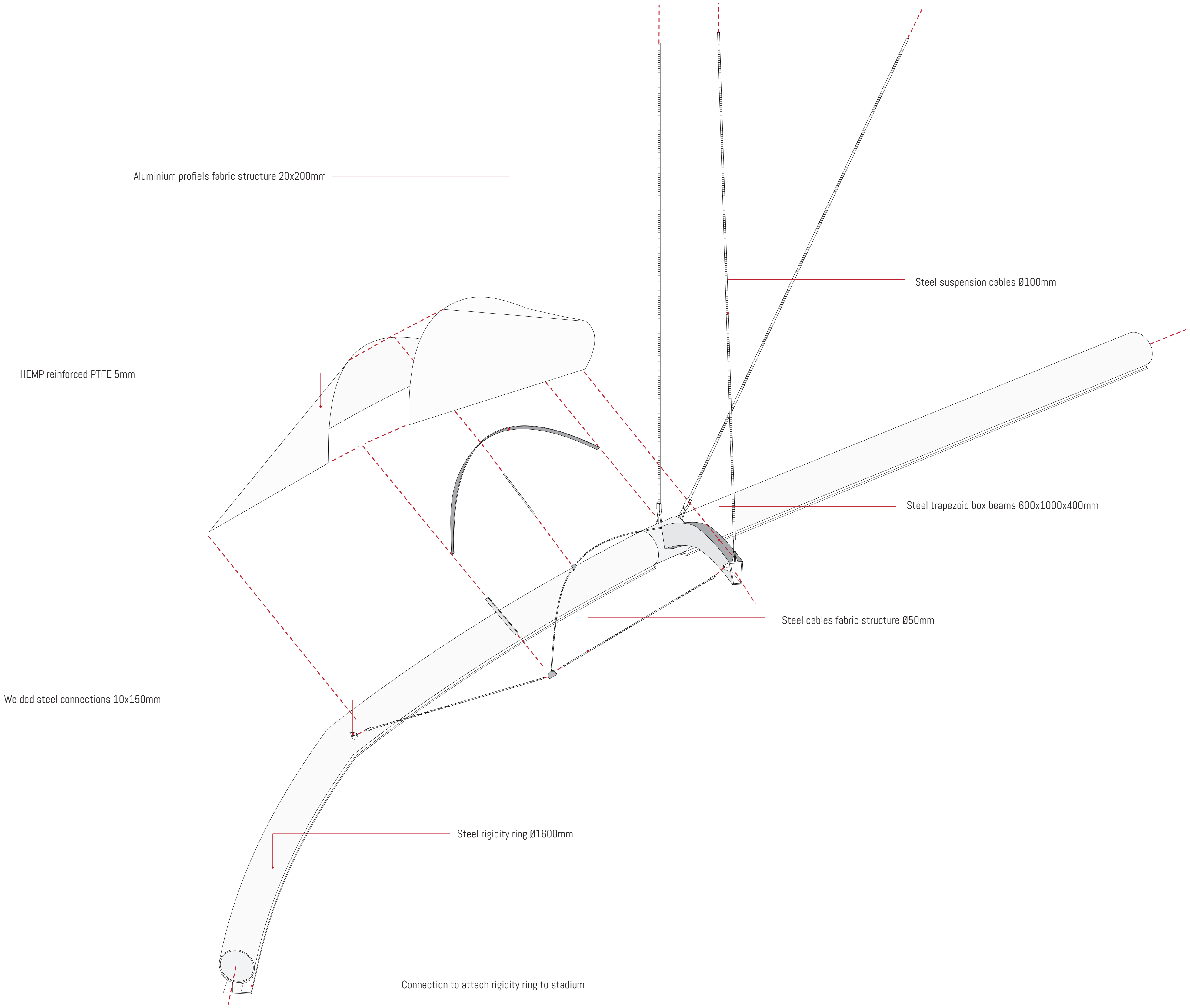
DETAIL AA1+BB1



DETAIL BB3


Aluminium profiles to connect arches sidewards 20x200mm
Alkali aluminosilicate thin glass with SentryGlas interlayers 4x1.52x4x1.52x4mm
HEMP reinforced PTFE 5mm
Ultrasonic mist cooling nozzles Ø50mm
Aluminium profiles as thin glass - PTFE connections Ø120mm
Aluminium rail profiles to connect arches to primary structure

DETAIL BB1



Aluminium profiels fabric structure 20x200mm
Steel suspension cables Ø100mm
HEMP reinforced PTFE 5mm
Steel trapezoid box beams 600x1000x400mm
Steel cables fabric structure Ø50mm
Welded steel connections 10x150mm
Steel rigidity ring Ø1600mm
Connection to attach rigidity ring to stadium

8. CONCLUSIONS

CLIMATE DESIGN: A STRUCTURAL DESIGN STIMULATOR FOR OPTIMAL S-IEQ

Wind design, the engine of aerothermal quality

Heat design, the solution to aerothermal quality

Lighting design, the solution to natural turf

Climate Design KIS Structural Design

STRUCTURAL DESIGN: AN INNOVATIVE ROOF DRIVEN BY CLIMATE DESIGN

Primary steel structure, a wind based aerodynamic design

Secondary glass structure, a lighting and heat based shading design

INFLUENCE OF PARAMETRIC DESIGN ANALYSIS