# Century Lotus Stadium

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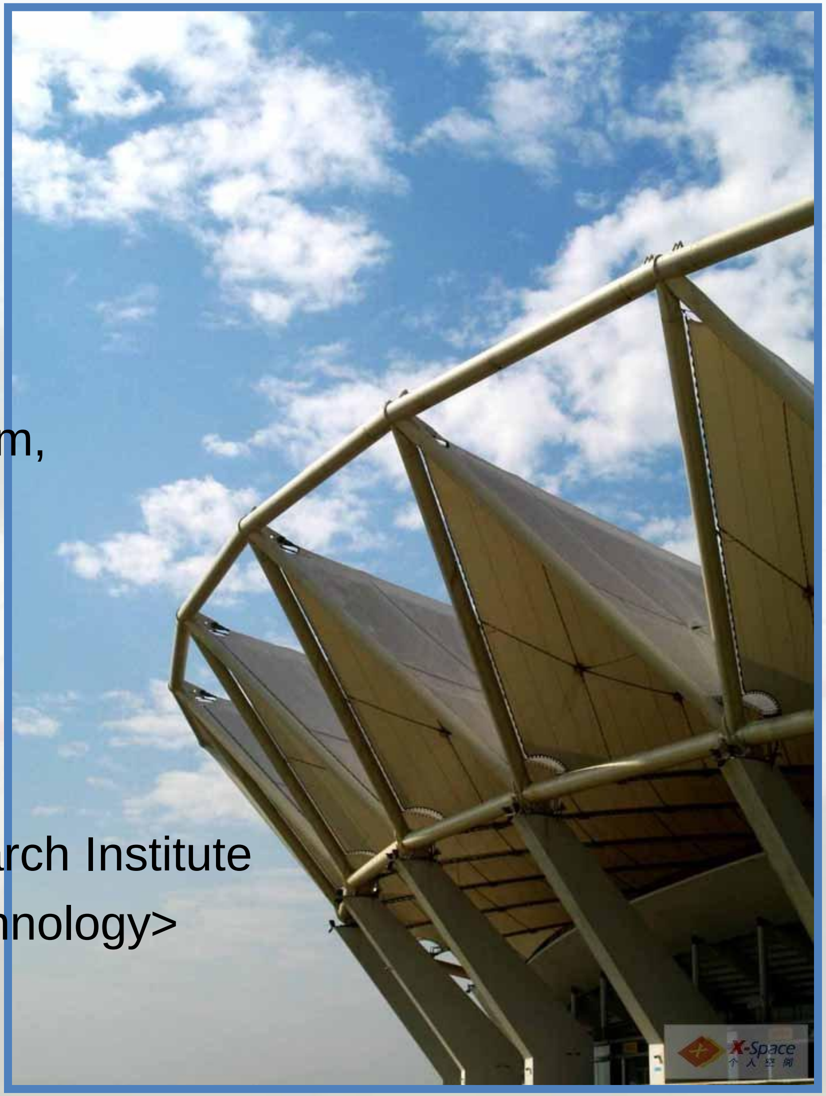
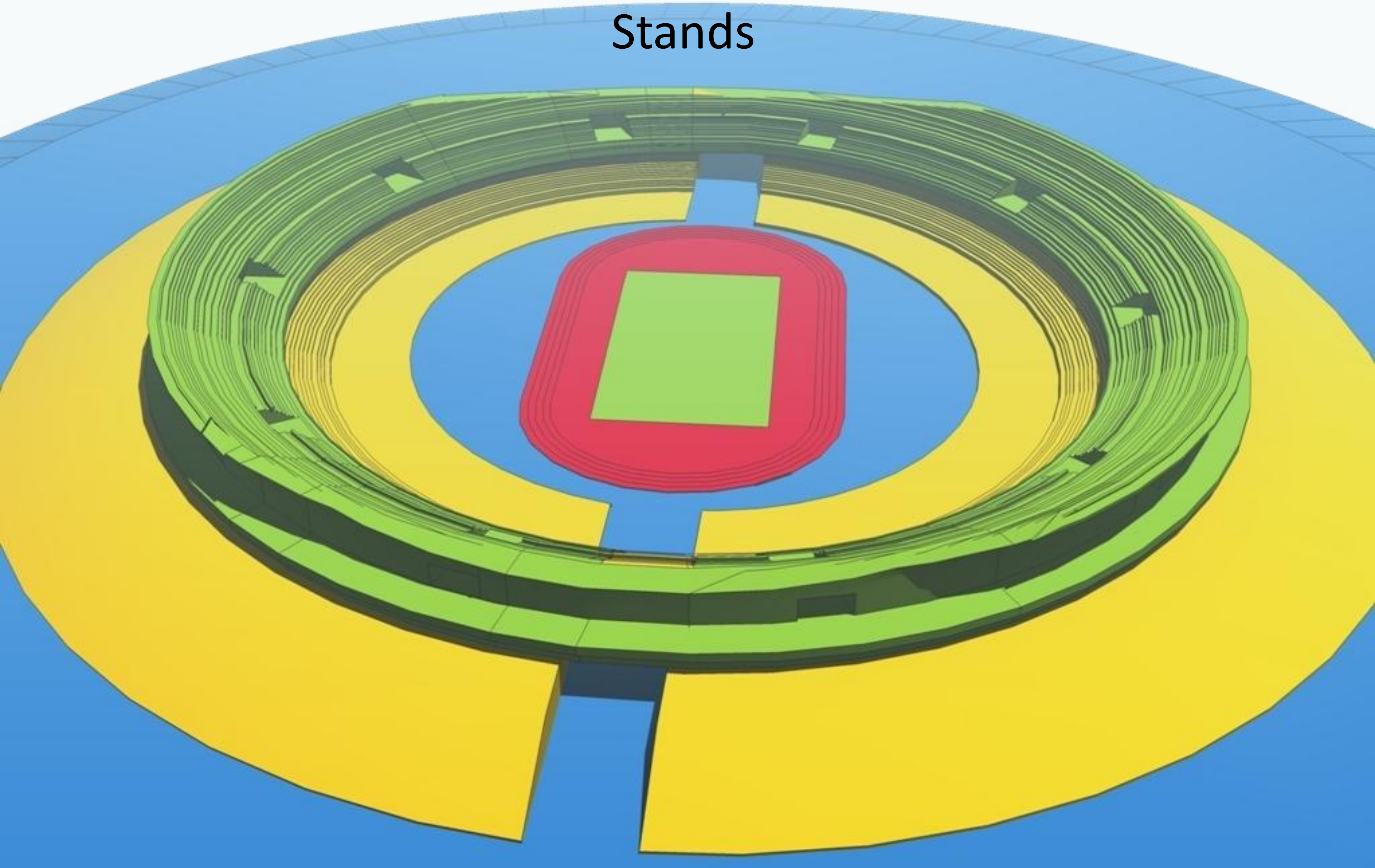
# 1. Background

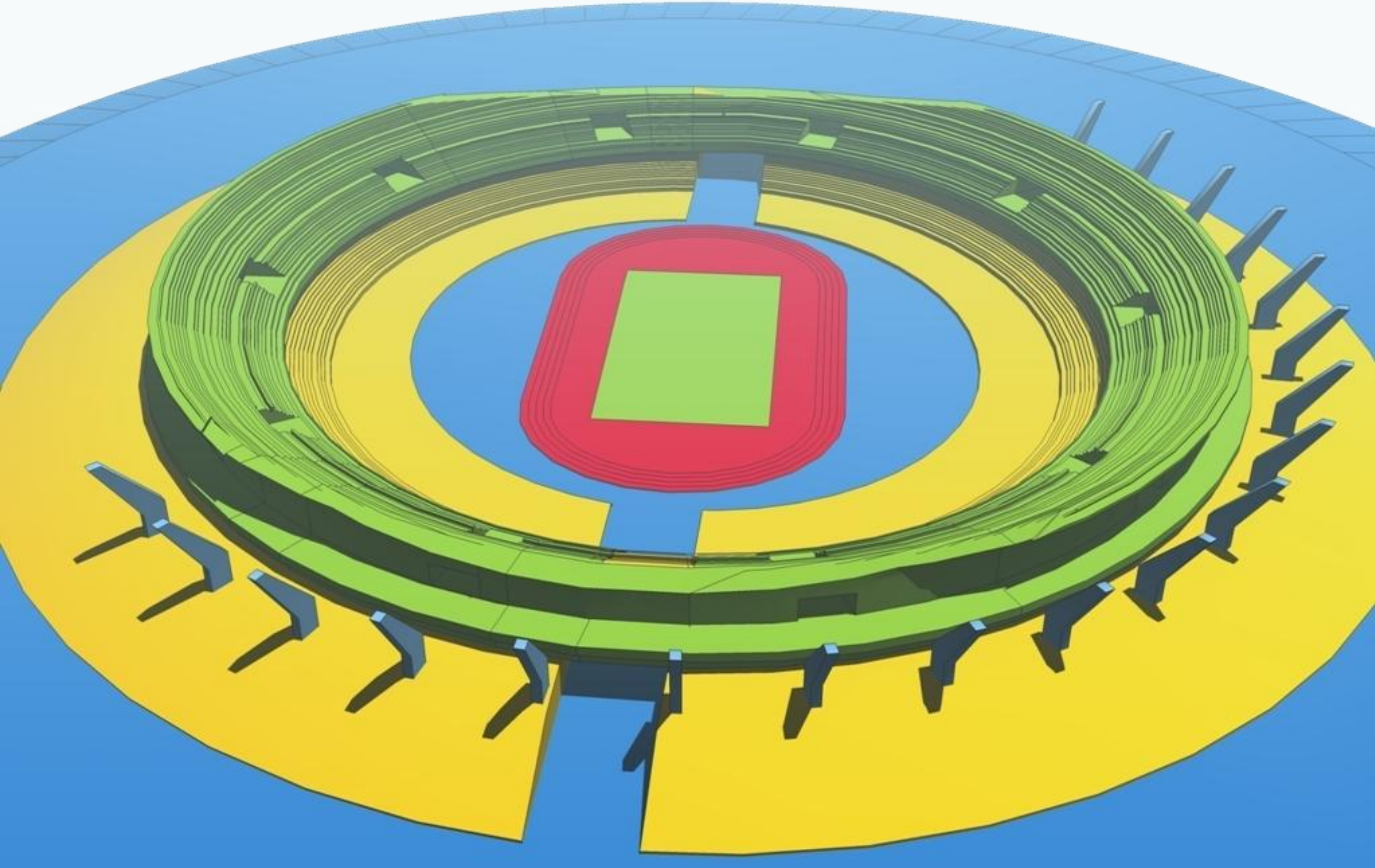


- Property: Stadium
- Purpose:  multi purpose stadium
  mostly for football matches.
- Location: Fosnar, China
- Scale：area 123,125m2,
  height 50m, diameter of roof 310m,
  projected area 53,421m2,
  outdoor training area 20000m2
- holds 36,000 people
- Underground parking spaces:1,100
- Architect: GMP Architekten
  Architecture Design And Research Institute
  <South China University of Technology>
- Construction period：2004-2006
- Funding: 103,000,000 dollars
- The biggest tensioned Cable-Membrane Structures project in the world

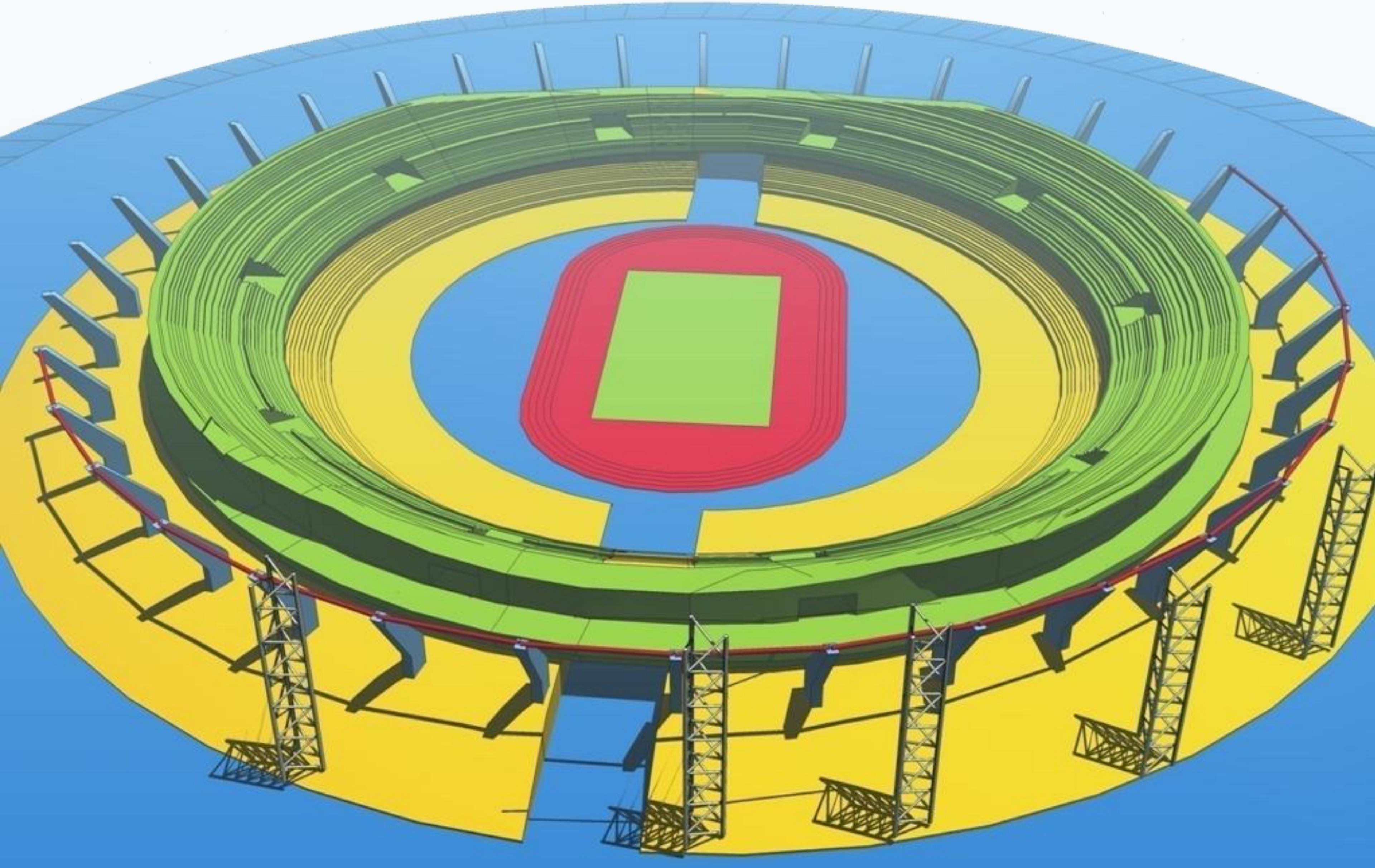
# 2. Structures Layout



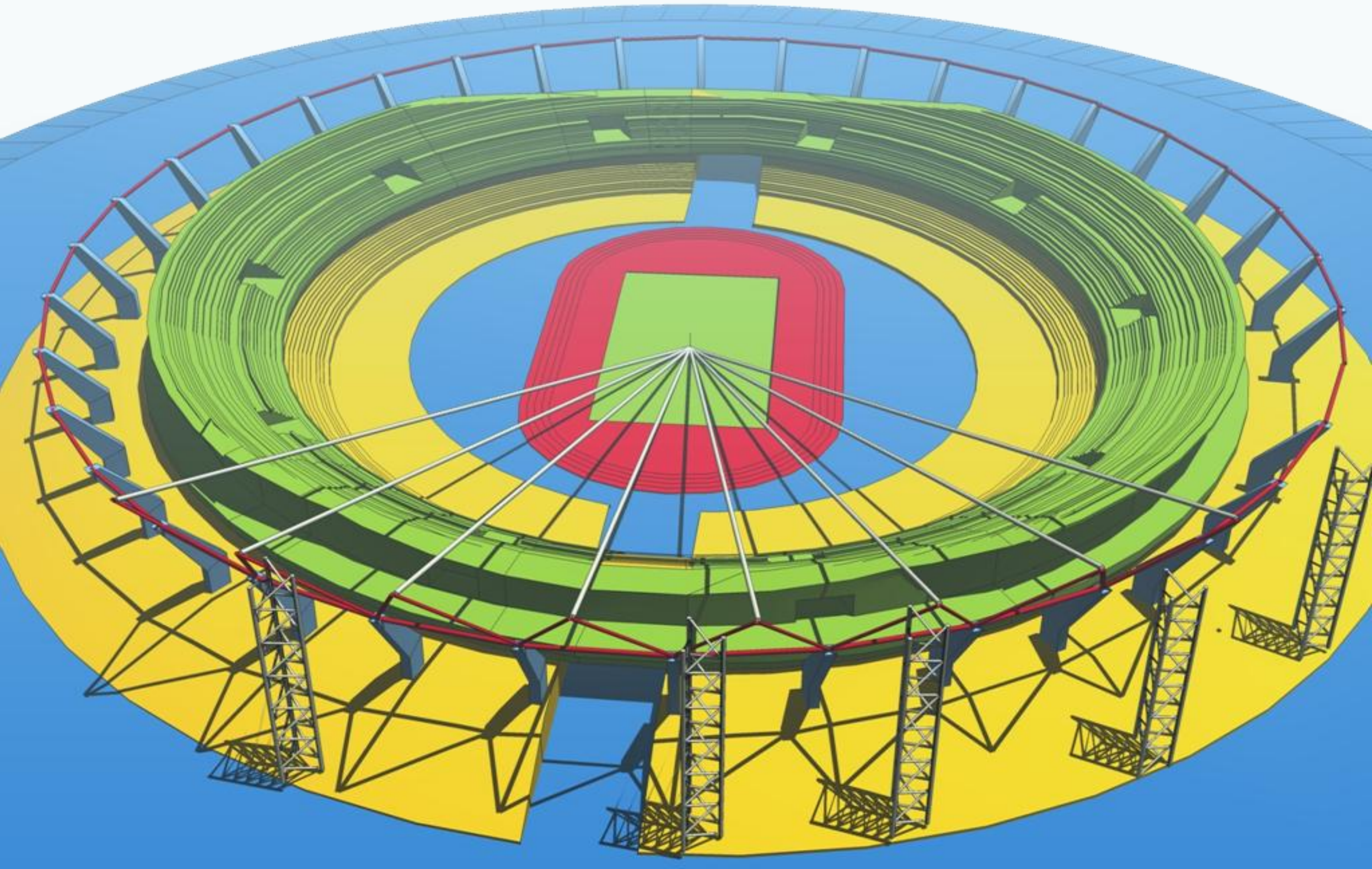
# Columns



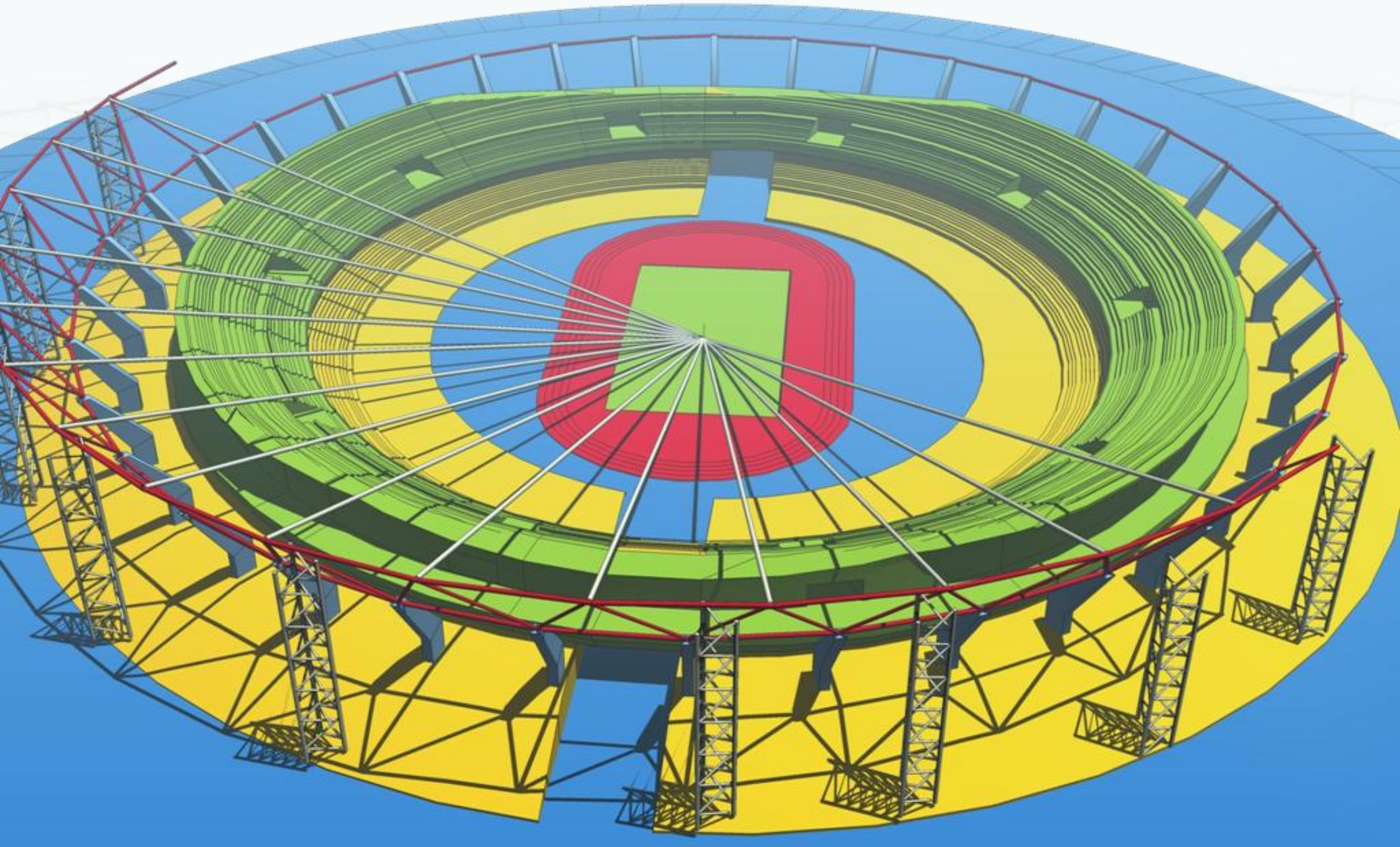
# Lower compression ring



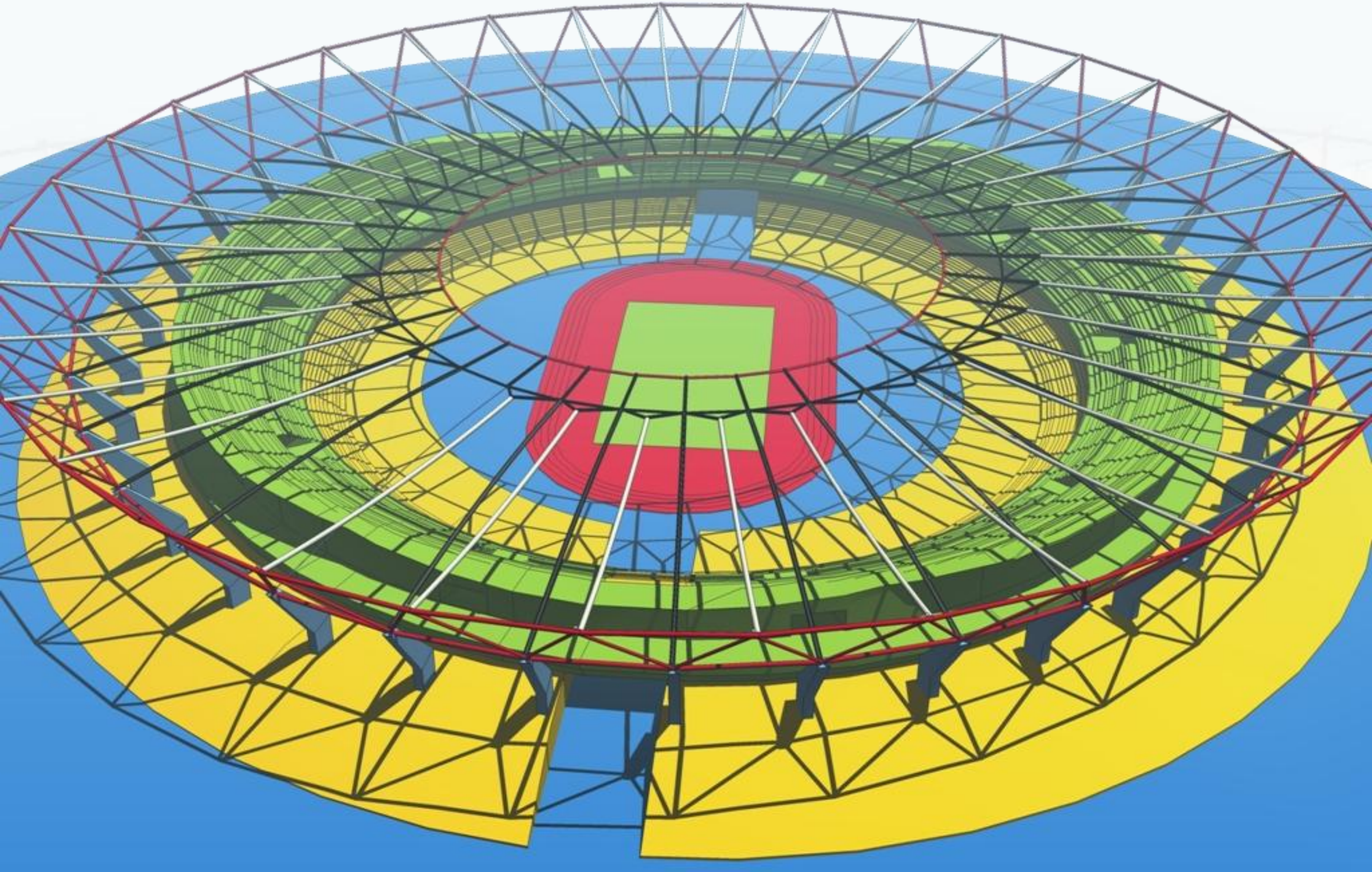
# Upper radial cable and struts



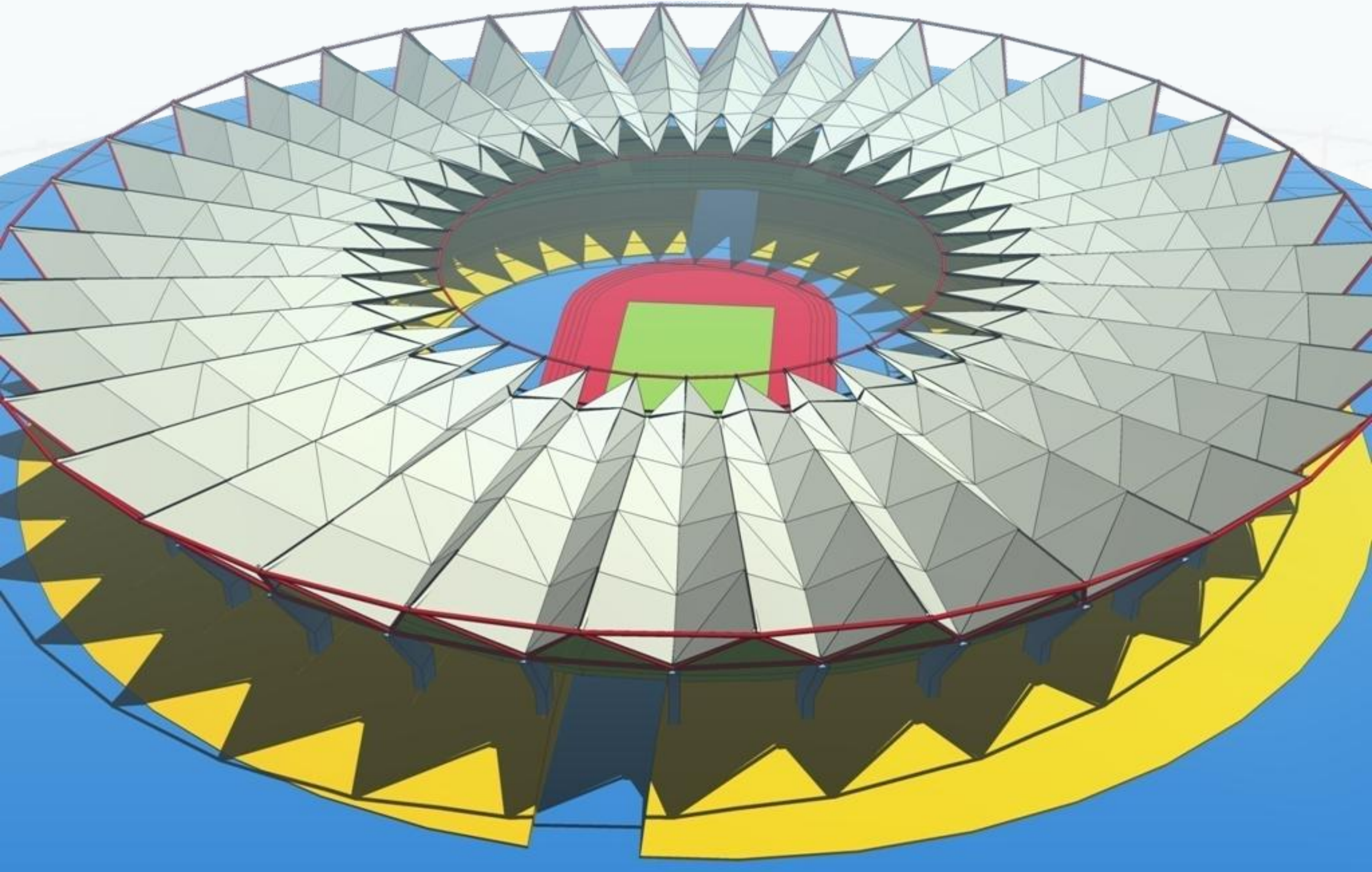
# Upper compression ring



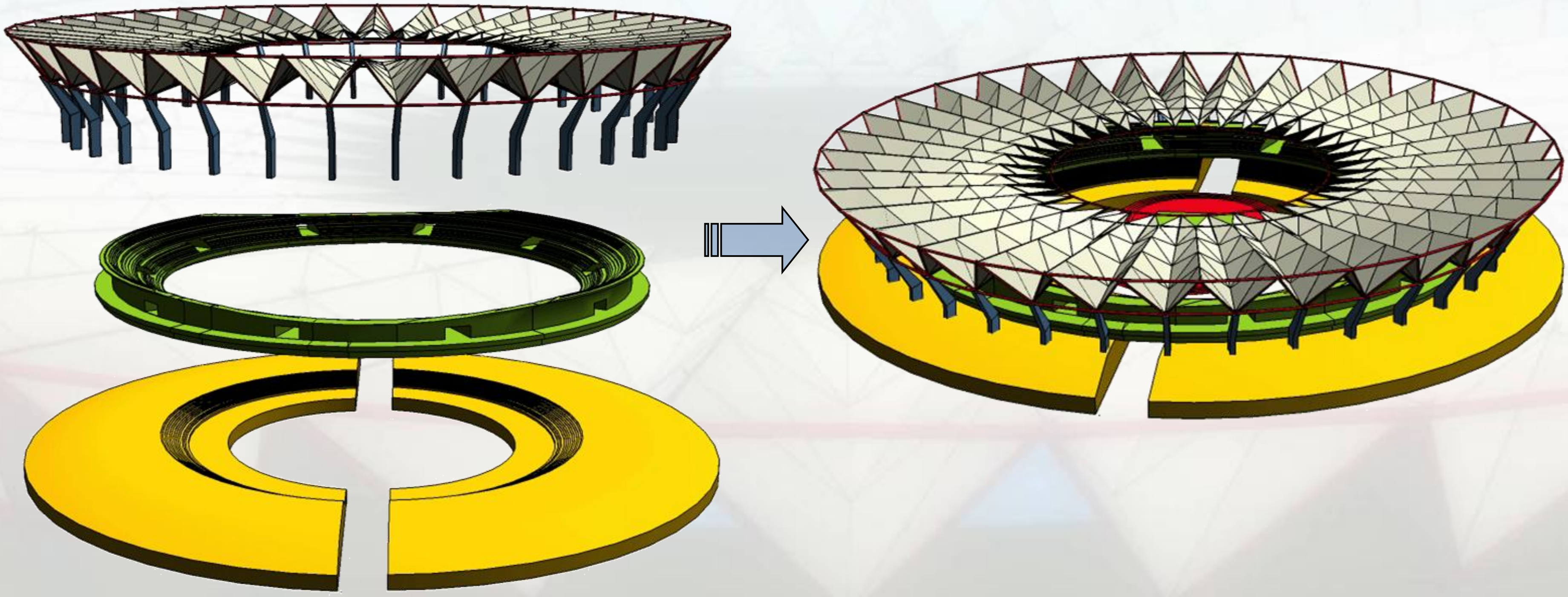
# Lower radial cable and tension ring



# Roof



# 3. Structure Analysis



# 3.1 Roof Structure

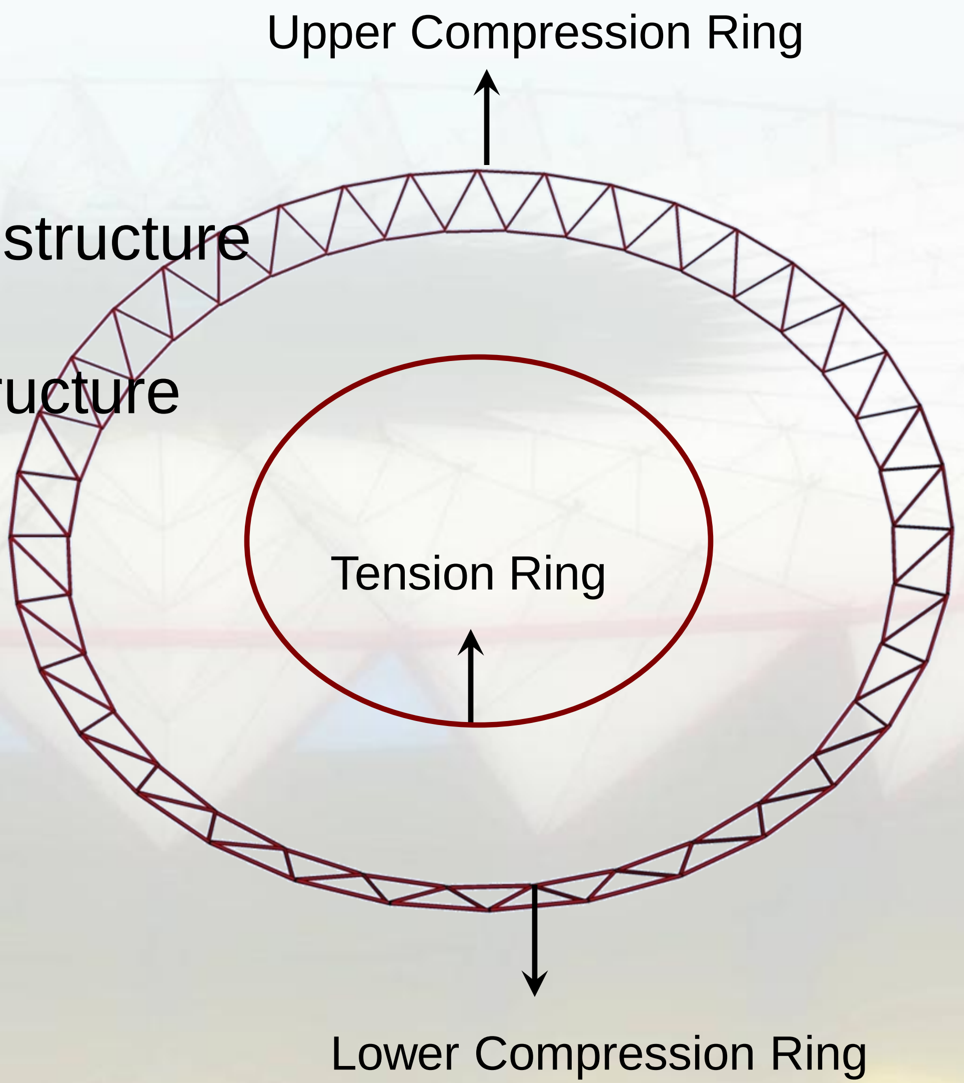
## 3.1.1 Rings

### Tension Rings

- In the interior of the roof structure
- Add stability
- Adjust the membrane structure

### Compression Rings

- fixed joints with struts
- carry the compressive force radial cables.

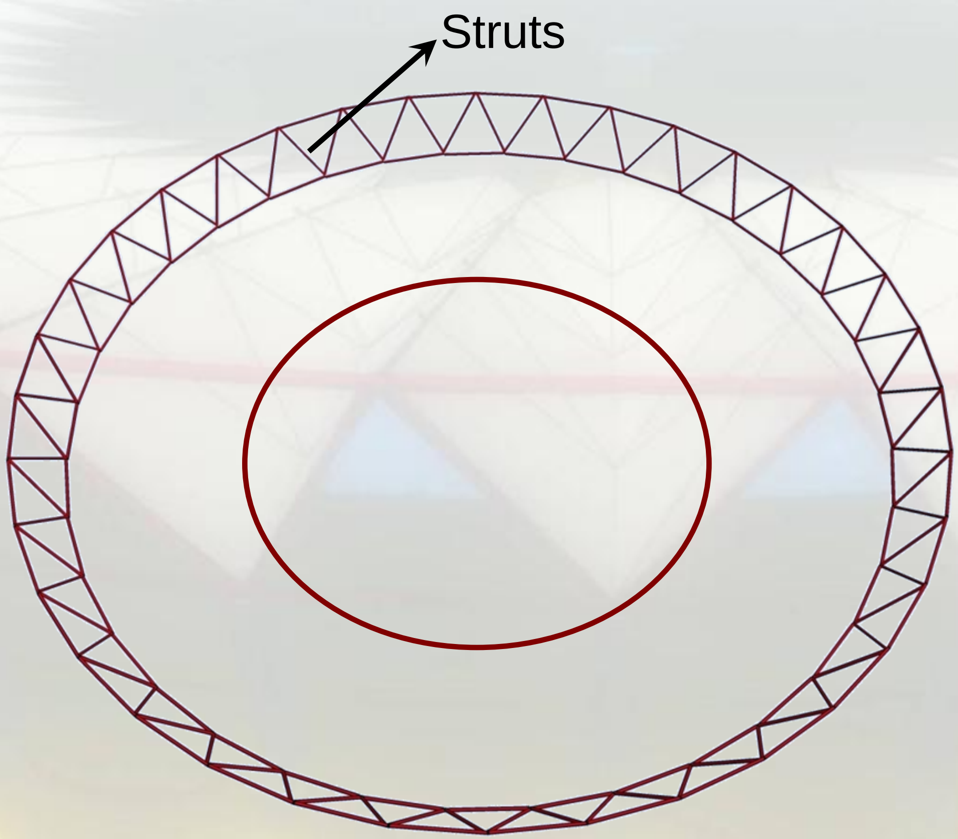


# 3.1 Roof Structure

## 3.1.2 Strut

- Connect the compression ring

- Resist compression and buckling



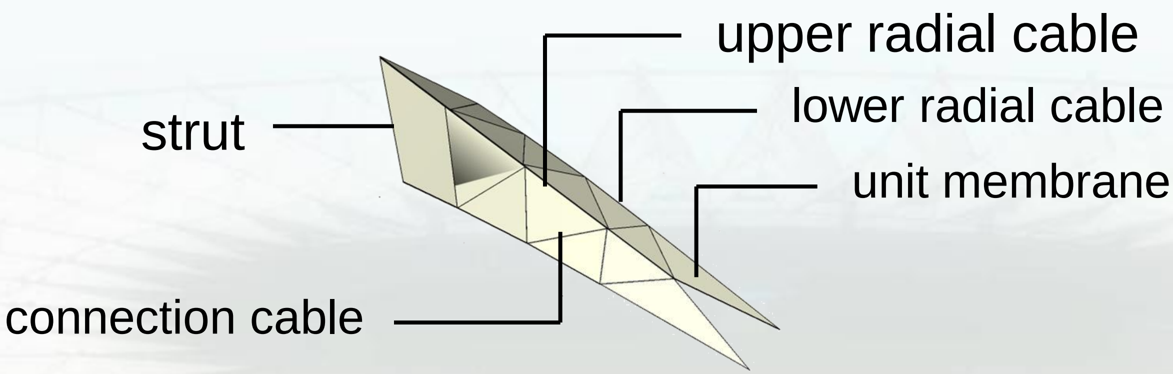
# 3.1 Roof Structure

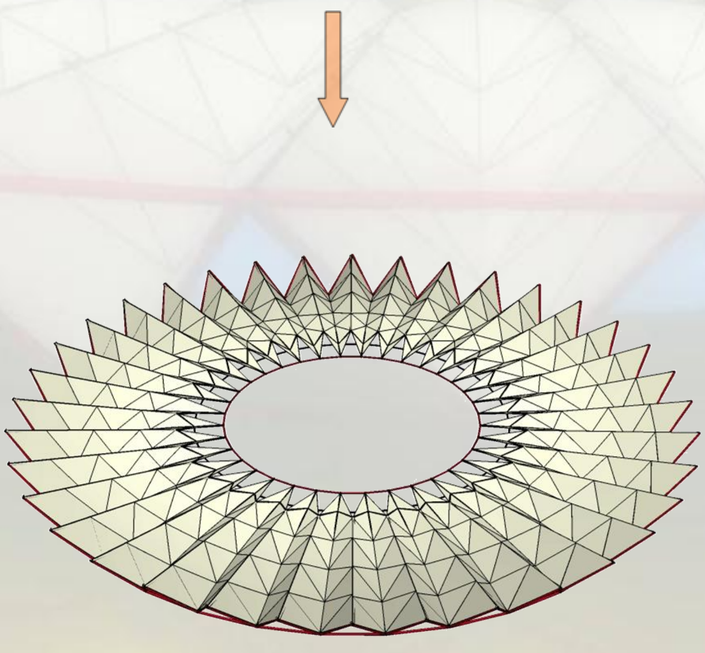
## Formula——Take Upper compression ring for example

- $W=0.006165x\ d^2$
- Diameter of the steel tube=1000mm
- $W=0.006165x\ d^2=0.006165x1000x1000=6165kg/m$
- Radius= 155m
- Perimeter= 2πr= 2πx155=973.4m
- Weight= W x Perimeter x Gravity acceleration =6165 kg/m x 973.4mx9.8N/kg=58810KN

# 3.1 Roof Structure

## 3.1.3 Folded Membrane Unit

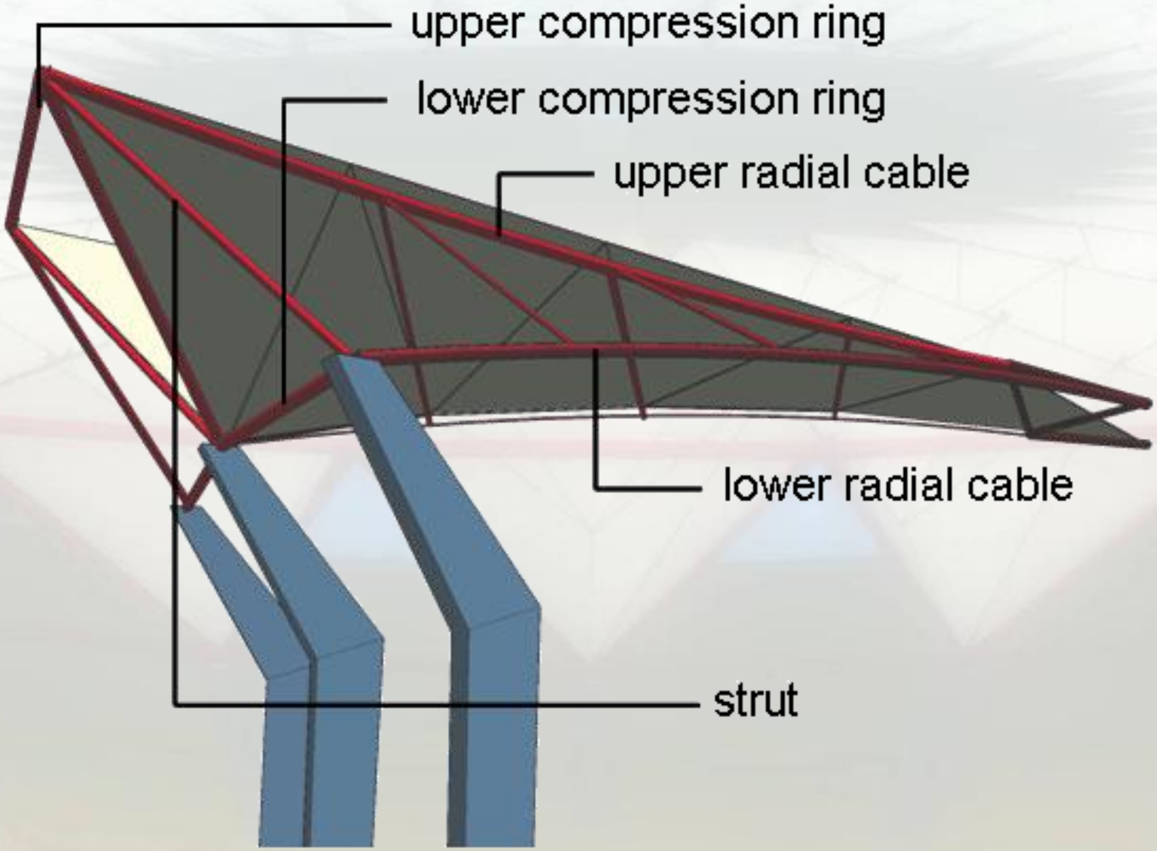


# 3.1 Roof Structure

## 3.1.3 Folded Membrane Unit

### 3.1.3.1 Regarding the stability of the unit

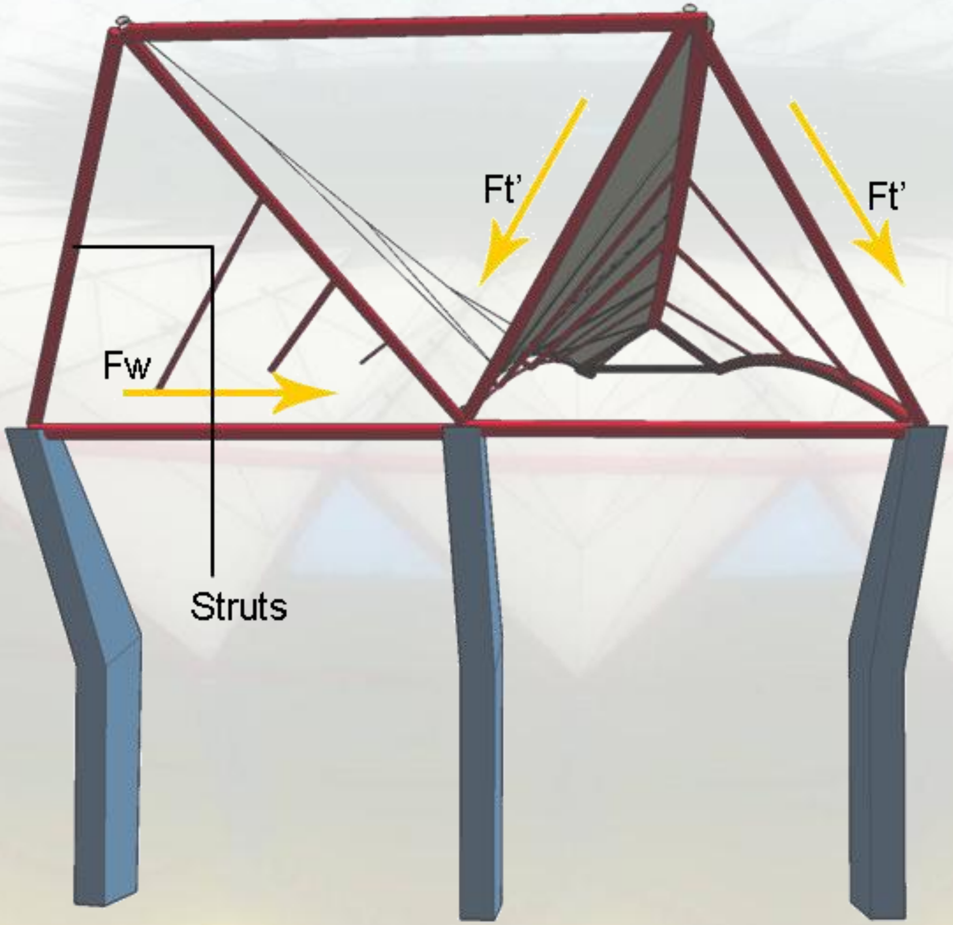


# 3.1 Roof Structure

## 3.1.3 Folded Membrane Unit

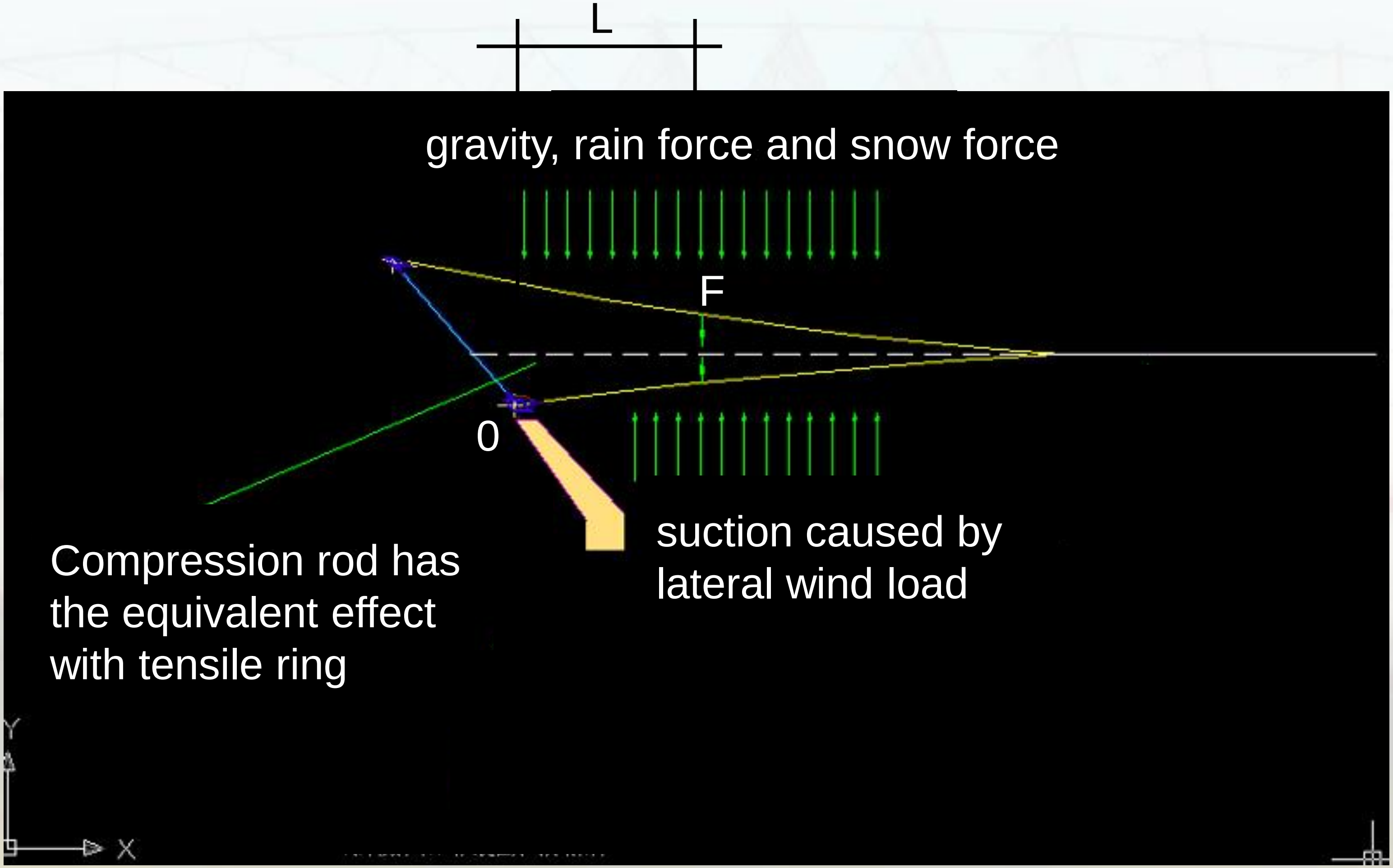
### 3.1.3.2 From the View of Force Analysis of Every Unit

-----strut



-----upper radial cable

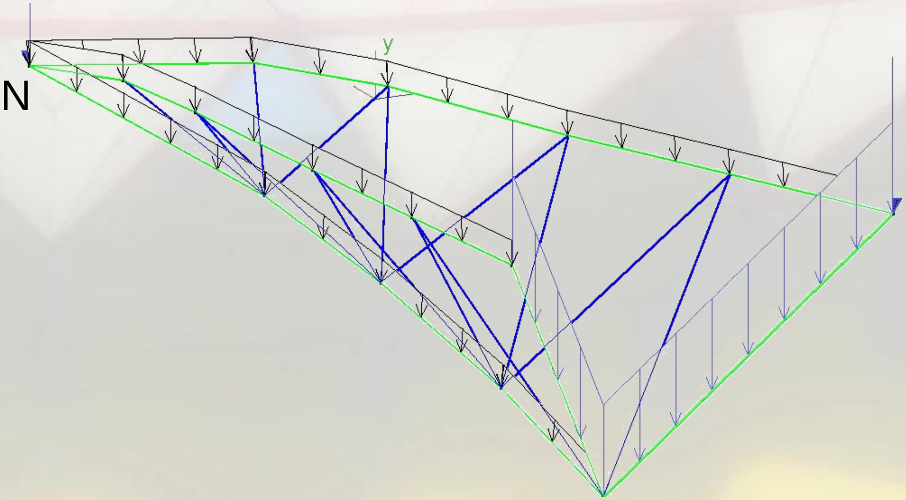
-----lower radial cable

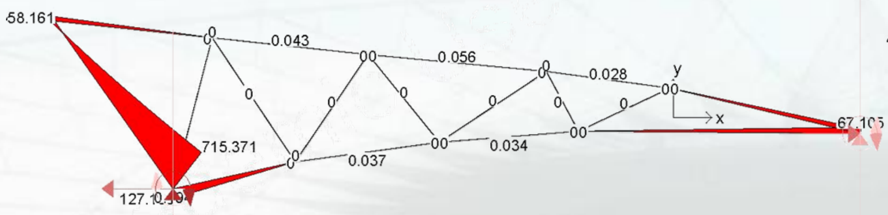


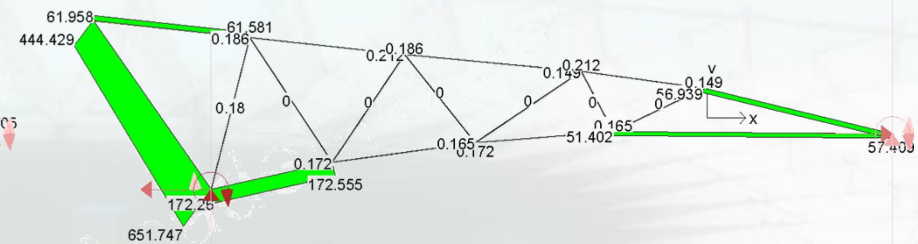
**Struts**
Density of Struts = 25KN/ $m^3$
Diameter of the steel tube=800mm
$A=\pi r^2=\pi(800mm /2 \times 0.001)^2=0.5m^2$
Length of Struts=25000m
$V=A \times L= 0.5\ m^2 \times 25000m=12500m^3$
Weight=V x $\rho$=12500 $m^3$ x 25KN/ $m^3$= 312.5KN

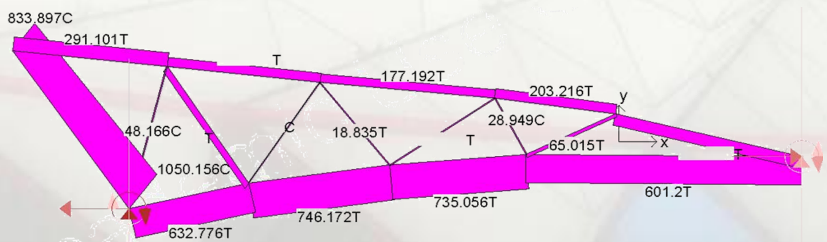
**Upper Radial Cable**
Weight/ unite length = 40.7kg/m
Length of Upper Radial Cable=84.397m
Weight= 40.7kg/m x 84.397m x 9.8N/kg=34KN

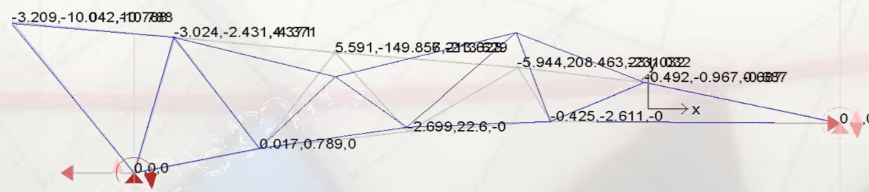
**Lower Radial Cable**
Weight/ unite length = 40.7kg/m
Length of Lower Radial Cable=76m
Weight= 40.7kg/m x 76m x 9.8N/kg=30KN




58.161
0.043
0.056
0.028
715.371
0.037
0.034
67.105

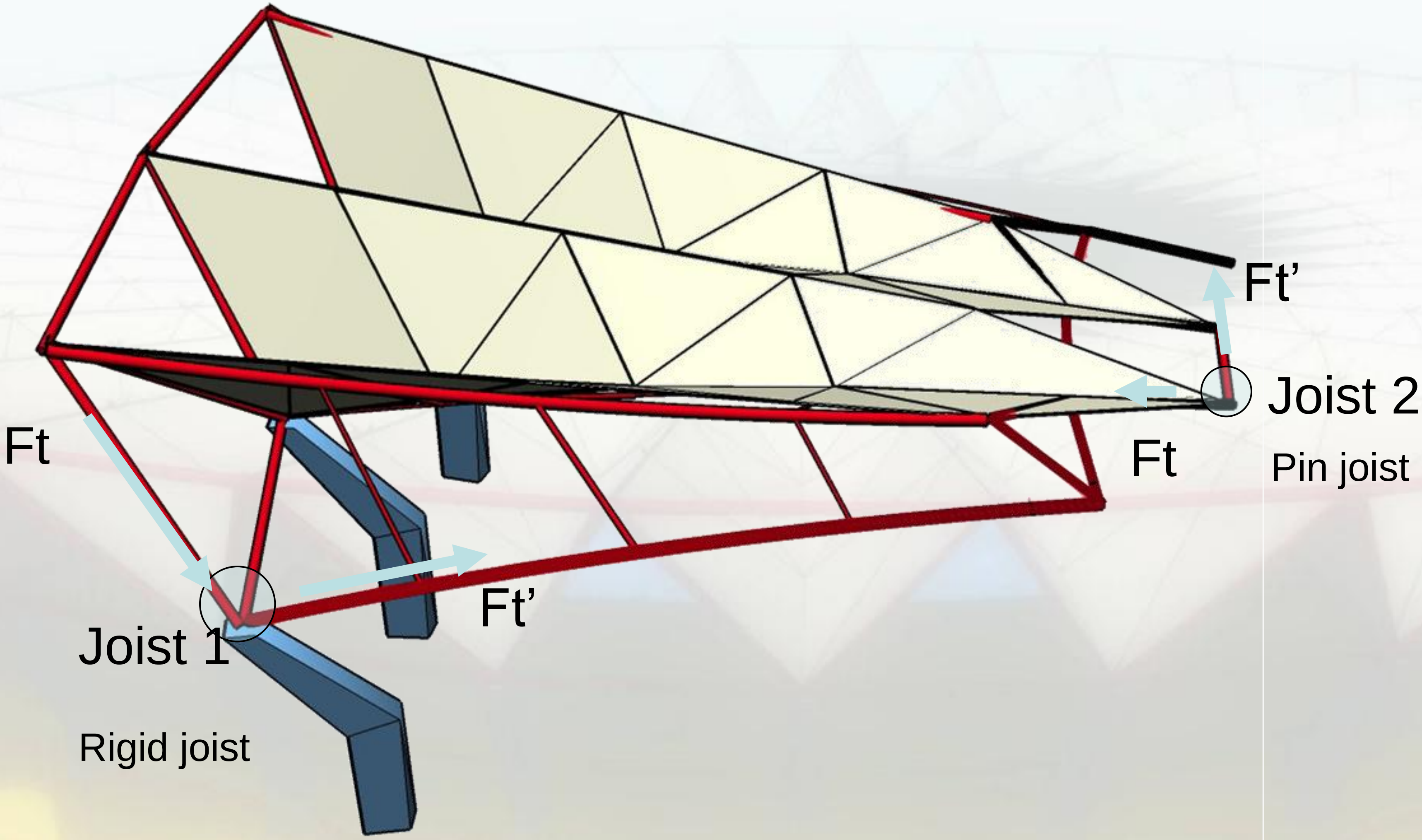


61.958
444.429
61.581
0.186
0.18
0.149
0.212
56.939
0.165
51.402
0.172
172.555
651.747

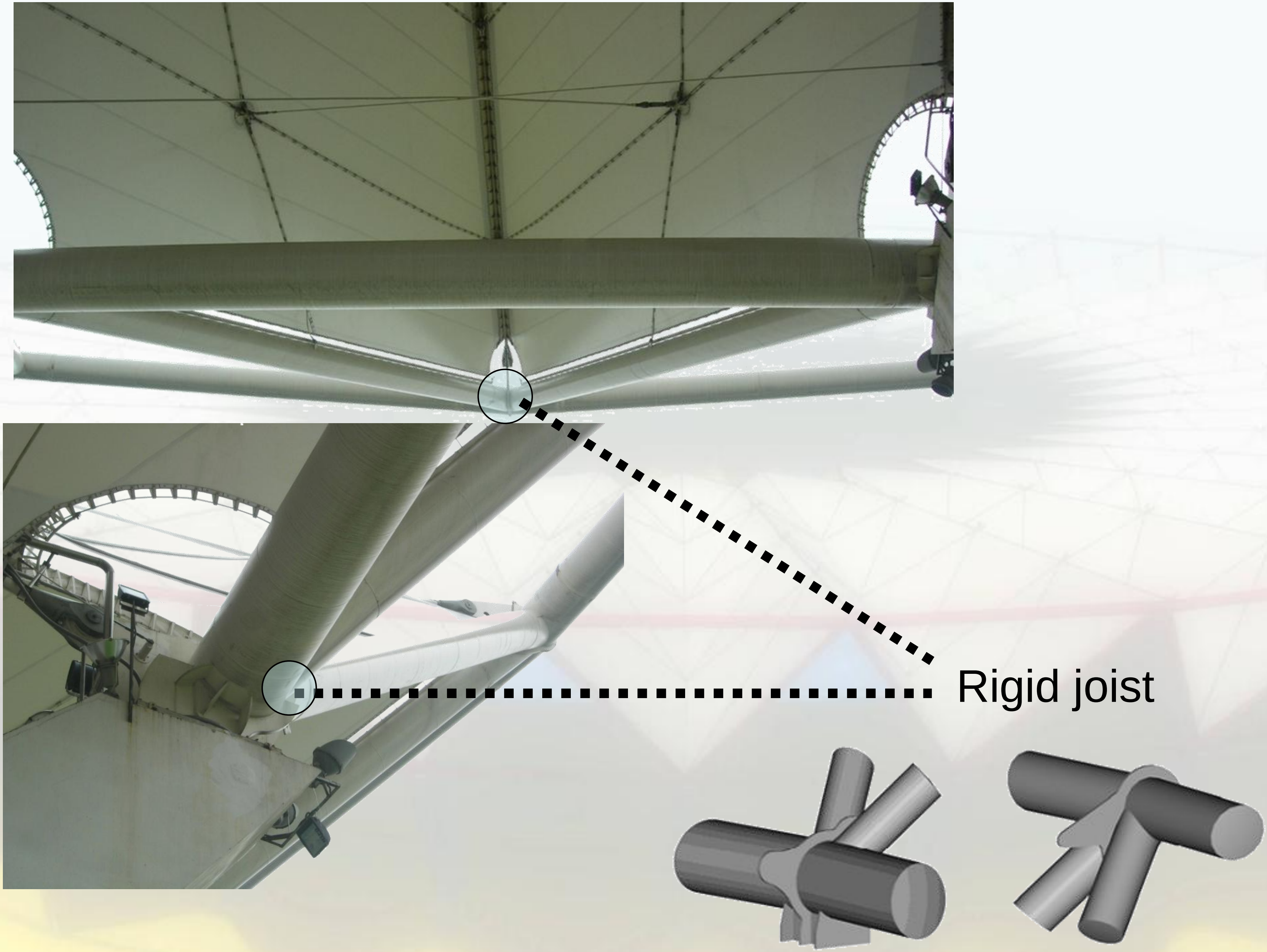


833.897C
291.101T
177.192T
203.216T
48.166C
18.835T
28.949C
65.015T
1050.156C
632.776T
746.172T
735.056T
601.2T



-0.425,-2.611,-0
2.699,22.6,-0
0.017,0.789,0
0,0,0

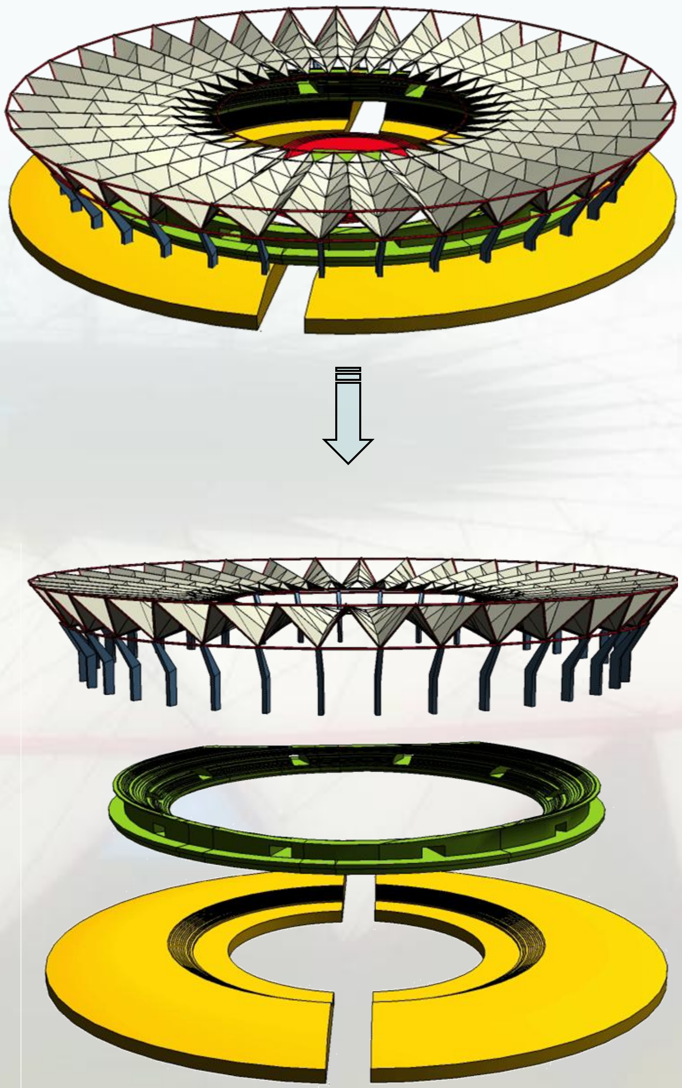
# 3.1.3 Folded Membrane Unit

## 3.1.3.2 As to the construction of separate node




Rigid joist

# 3. 2 Bearing structure



■Stand:

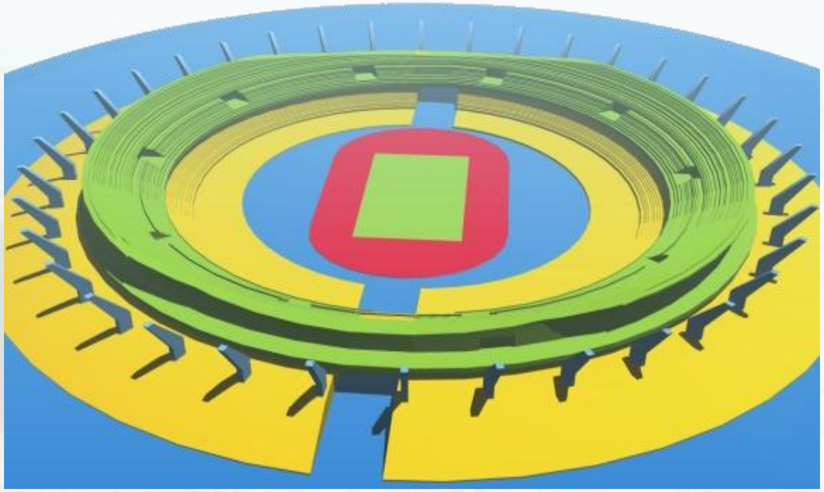
reinforced concrete frame

■ Column:

huge slope reinforced concrete columns

# 3. 2 Bearing structure

## 3.2.1 Columns



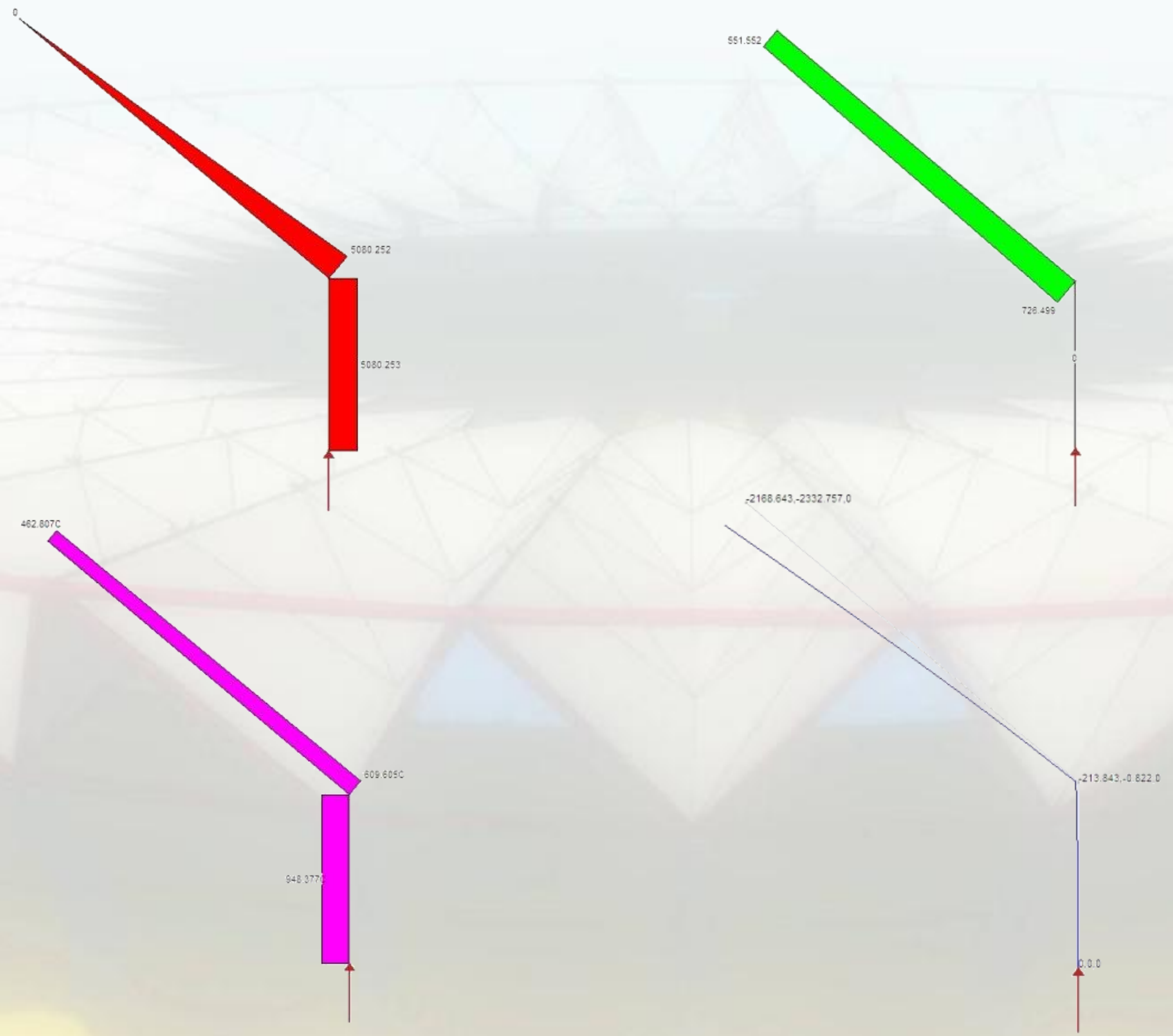
- ■Each huge slope column need to bear over 400 tons compression.
- ■ The columns need to be reinforced.

**The size of the columns:**

Density of Column = 25KN/ $m^3$
V=A x L= $75m^2$ x 1.5m= 112.5 $m^3$
Weight= 25KN/ $m^3$ x 112.5m= 2812.5kN

# 3. 2 Bearing structure

## 3.2.2 Multi-frame Model



# 3.3 Foundation system

According to the geological prospecting report, the soil condition in the construction site is complex and unbalanced distributed.

Table 1: The specific distribution from upper layers to lower layers

| **Soil description** | **Depth of soil layer, m** | **Presumptive bearing capacities from indicated building codes( Chicago, 1995), kPa** |
|---|---|---|
| Inorganic silt | 0-11.5 | 125 |
| Clay, soft | 0～9.1 | 75 |
| Gravel, loose and compact coarse sand | 0～6.7 | 300 |
| Mantle of rock | 0.4-10.6 | 7500 |

# 3.3 Foundation system

- Piles foundation system is adapted.
- Piles are used to distribute loads by end bearing to the soil layer of mantle of rock as deep as seven meters which ensures the balance and stability of the cushion cap supported by piles.
- prestressing plucking-resisted anchor rods are used to enhance the stability of the whole foundation system.

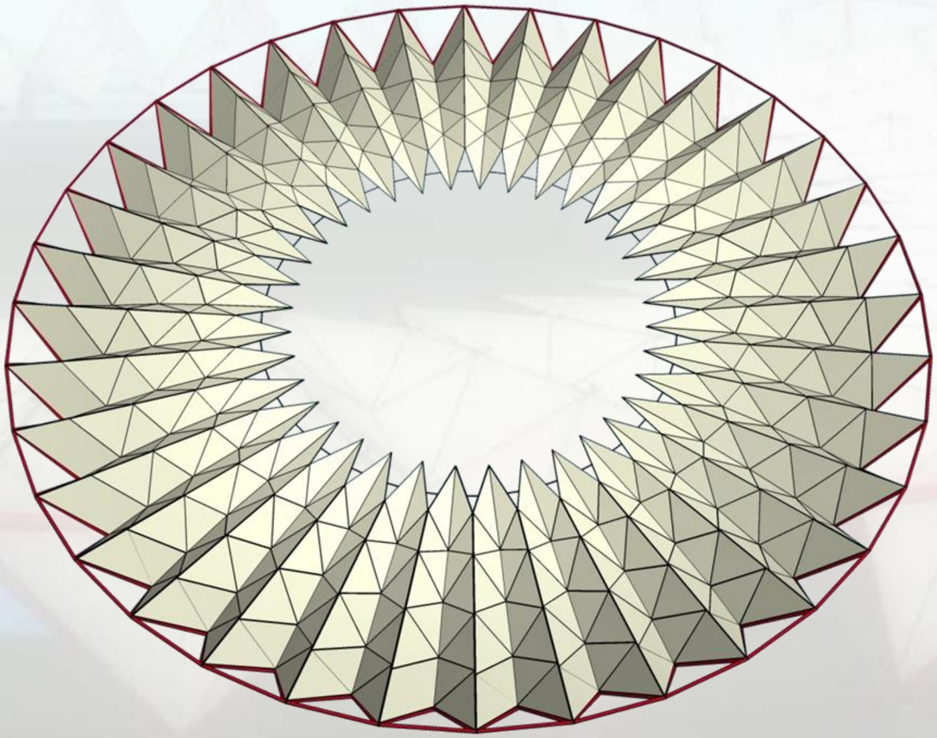
Table 2: The design size and resulting pressure of typical foundation components

| Typical foundation component | Resulting pressure, kPa |
|---|---|
| pile | 1.5 per pile |
| Cushion cap | 21.07 |

# 4. Lateral load

## 4.1. Dynamic Effect of wind

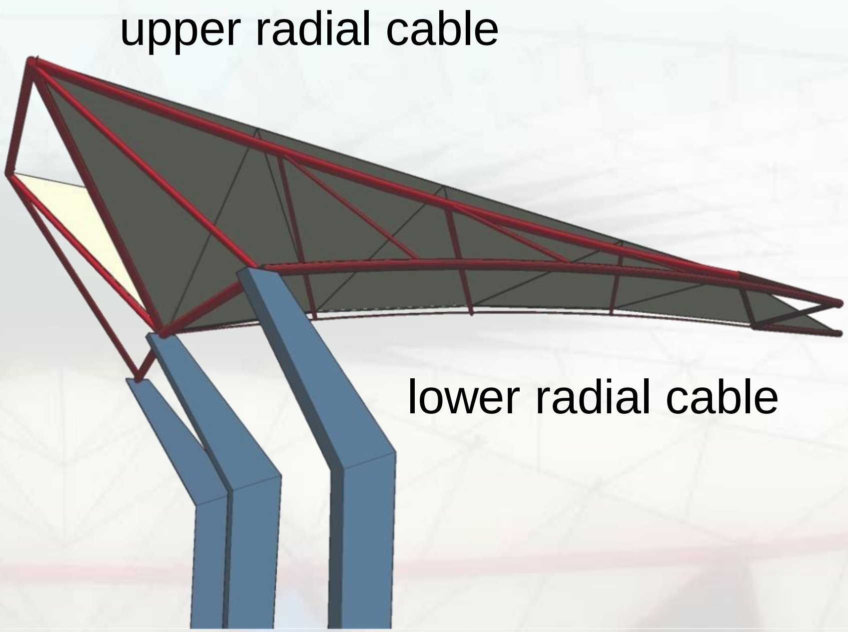
- A critical problem in the design of this cable roof structure is the dynamic effect of wind. As the wind blows over the top of the roof, a suction will be created.
- W=0.25N/$m^2$



# 4. Lateral load

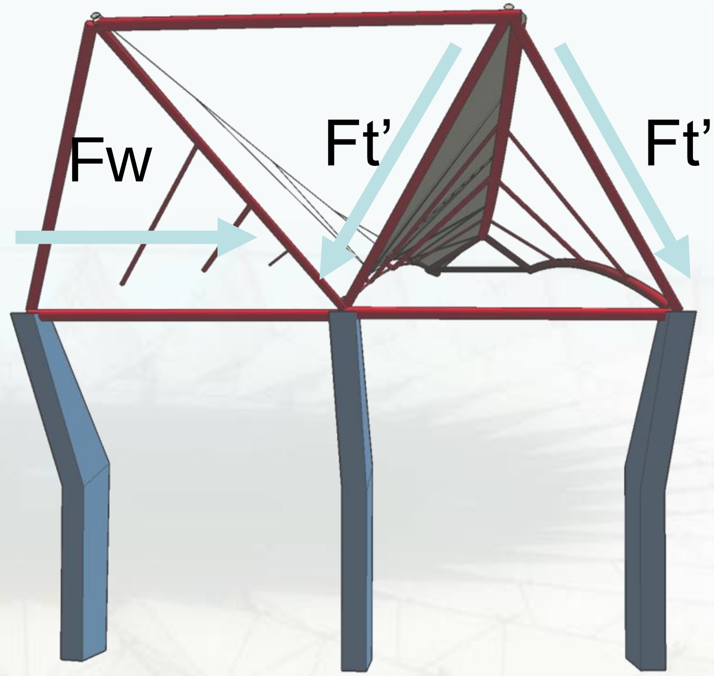
## 4.2. double cable system

■The roof structure consist of two coupled pretensioned cables.



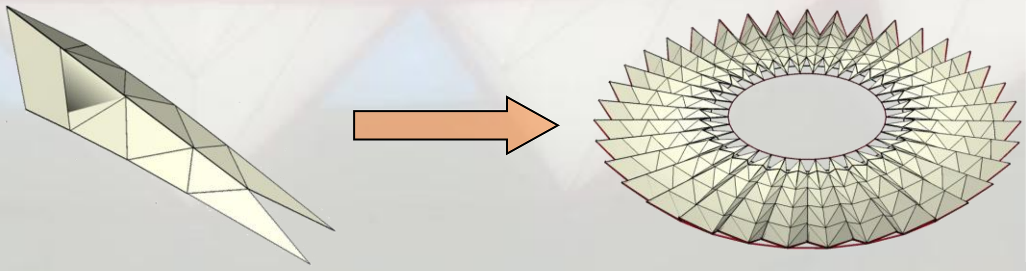

■Advantage of the double cable system

# 4. Lateral load
## 4.3. Struts



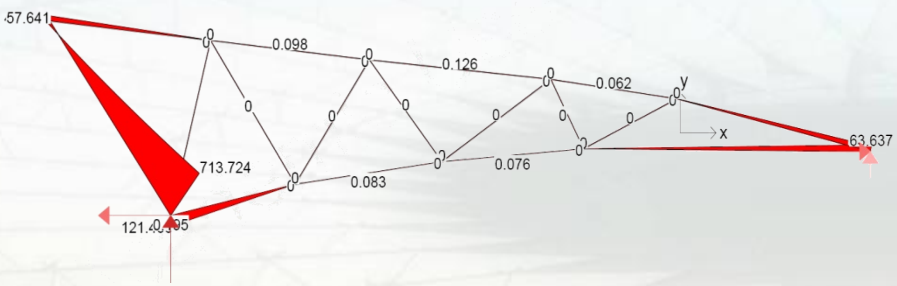

■Struts act as arch, can also carry wind force from lateral direction.

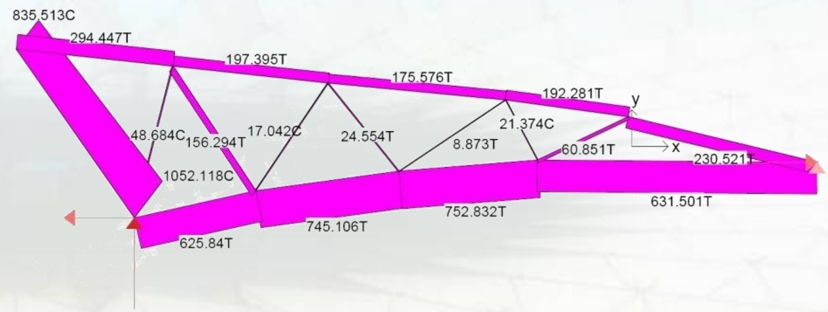
■struts are arranged in the whole ring, which can strengthen the stiffness of the structure

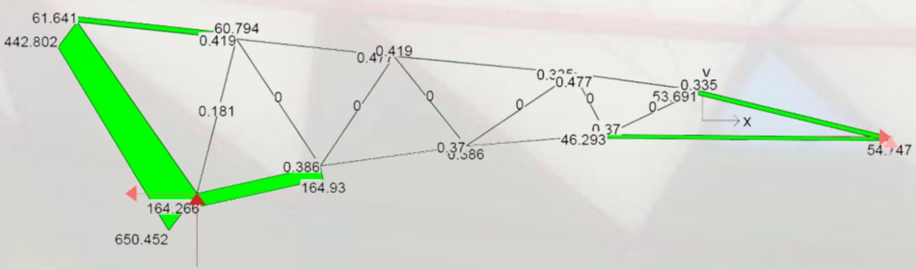


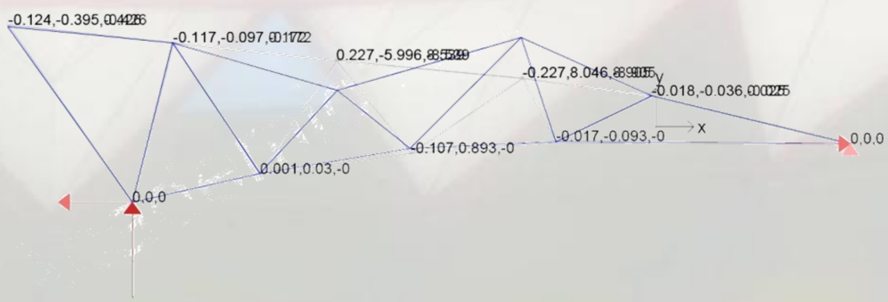
# 4. Lateral load

## 4.4. Multiframe Model



# 5. Materials

| Structural elements | | | Material | Character of Material | Size of elements |
|---|---|---|---|---|---|
| **Roof structure** | Upper compression ring | | Steel tube | Light weight, ductile | R=155m |
| | Lower compression ring | | Steel tube | Light weight, ductile | R=138m |
| | Tension ring | | Steel tube | Light weight, ductile | R=62.5m |
| | Folded membrane units | Upper radial cable | Steel cable | Light weight, ductile, economical | D=800mm L=84.4m |
| | | Lower radial cable | Steel cable | Light weight, ductile, economical | L=76m D=800mm |
| | | Connection cable | Steel cable | Light weight, ductile, economical | – |
| | | Struts | Steel tube filled in C60 concrete | Strong, capable of carrying compression and tension | D=800mm L=25m |
| | | Membrane | PVC-coated polyester | Strong, inexpensive, fire resistant, easily discolor | W=1 ton |
| **Bearing system** | Column | | Reinforced concrete | Strong, capability of carrying compression, not capable of carrying tensile stress | Density=25kN/m$^3$ |
| | Stand | | Reinforced concrete | Strong, capability of carrying compression, not capable of carrying tensile stress | – |
| **Foundation system** | pile | | Reinforced concrete | Strong, capability of carrying compression, not capable of carrying tensile stress | – |

# Thanks!