MEGASTRUCTURE EXPO 2010

Group 3：Yi Liang, Qing Hou, Chuqi Huang, Yang Lu, Cohaul Chen

CONTENT

PROJECT DETAILS

|	
Client	Shanghai World EXPO Land Holding Co. Ltd., Shanghai
Overall concept	SBA GmbH Shanghai / Stuttgart, Li Hong und Bianca Nitsch
Membrane roof and sun valleys	Knippers Helbig Advanced Engineering, Stuttgart / New York
Managing partners	Prof. Dr. Jan Knippers, Dipl.-Ing. Thorsten Helbig
Contributors	Florian Scheible, Florian Kamp, Dirk Richter, Roman Schieber, Johannes Beran
Cooperation	ECADI, Shanghai, China
Energy scheme	Scholze Consulting, Leinfelden-Echterdingen, Germany
Gross floor space	280.000 m²
Surface of membrane roof	65.000 m²
Span	100 m
Surface of free-form member system	30.000 m²
Dimension boulevard	100 x 1.000 m
Realisation period	2006 - 2010
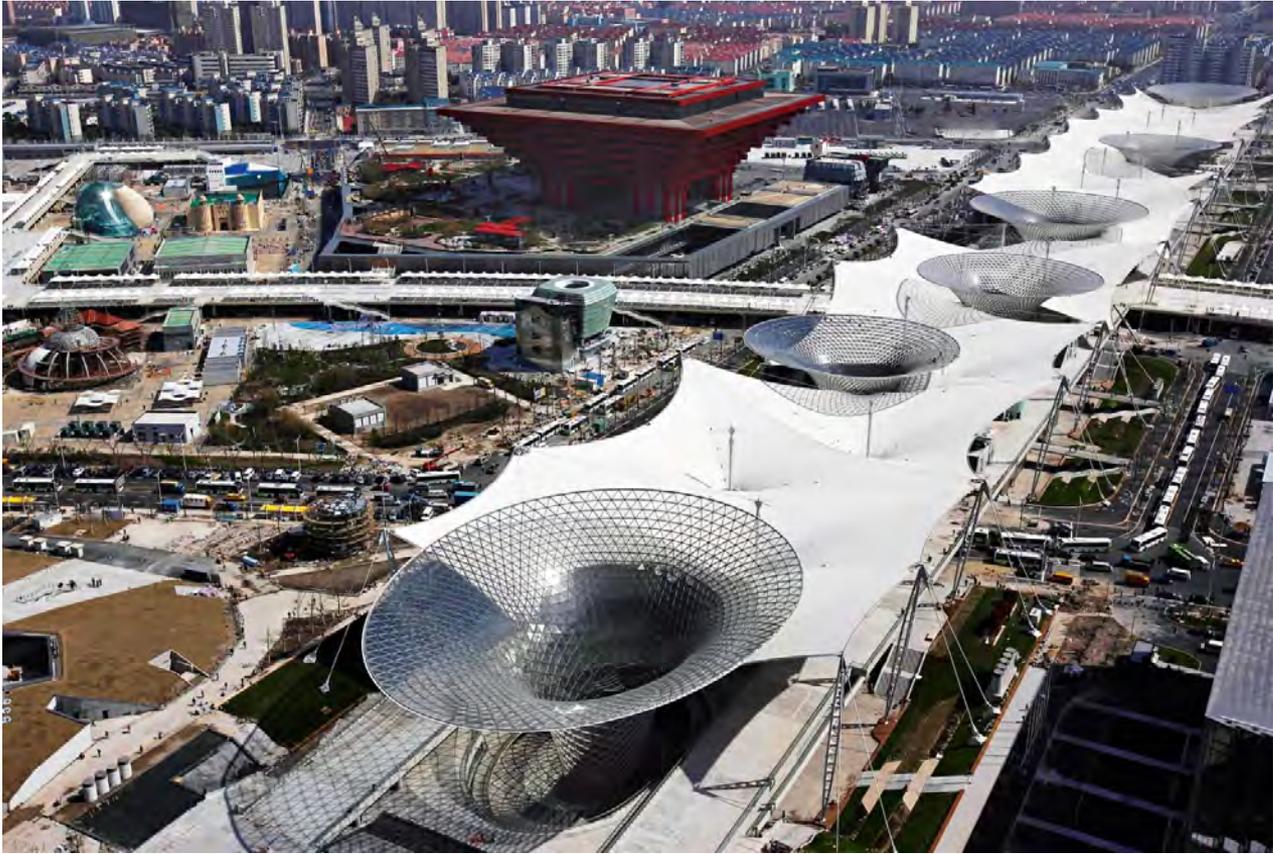
PURPOSE

CONCEPT
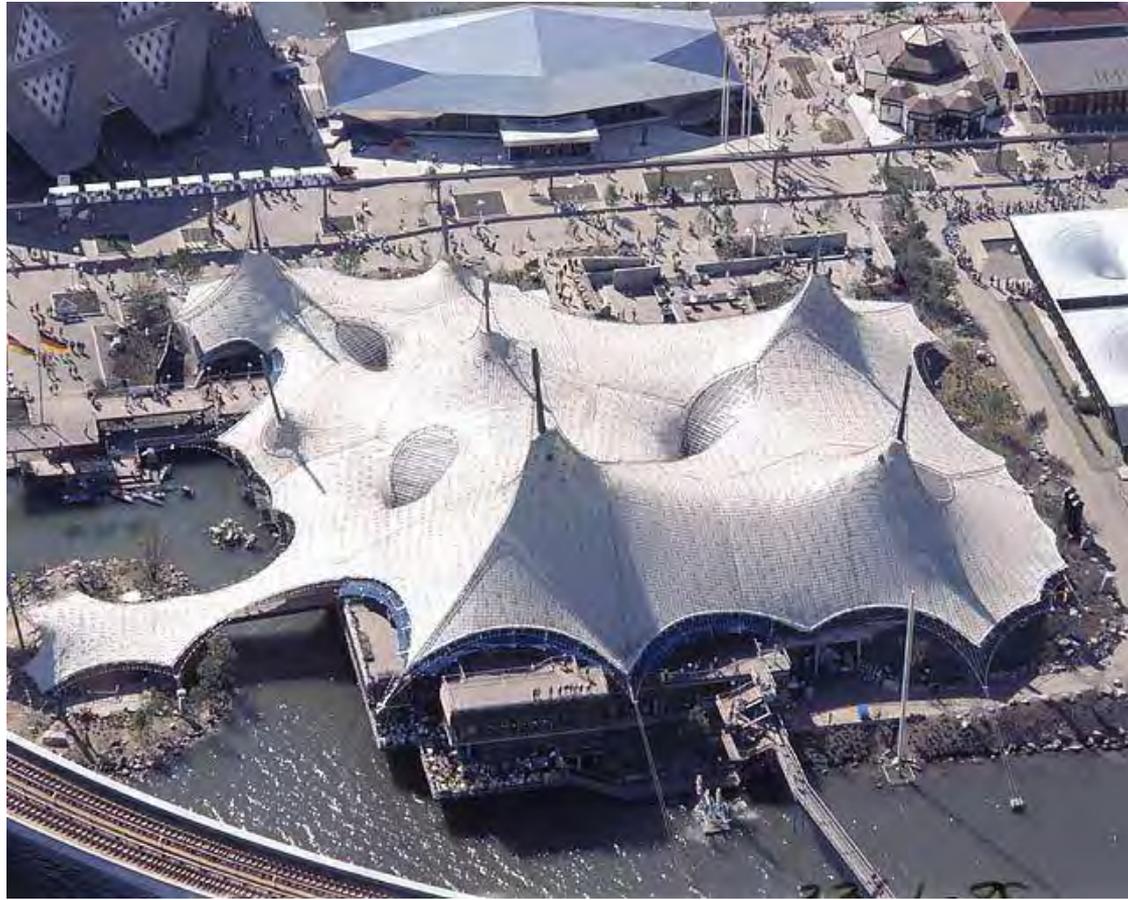
PRECEDENT-German Pavillion ,1967 Montreal

FORM STUDIES

FORM STUDIES - BASIC SECTION
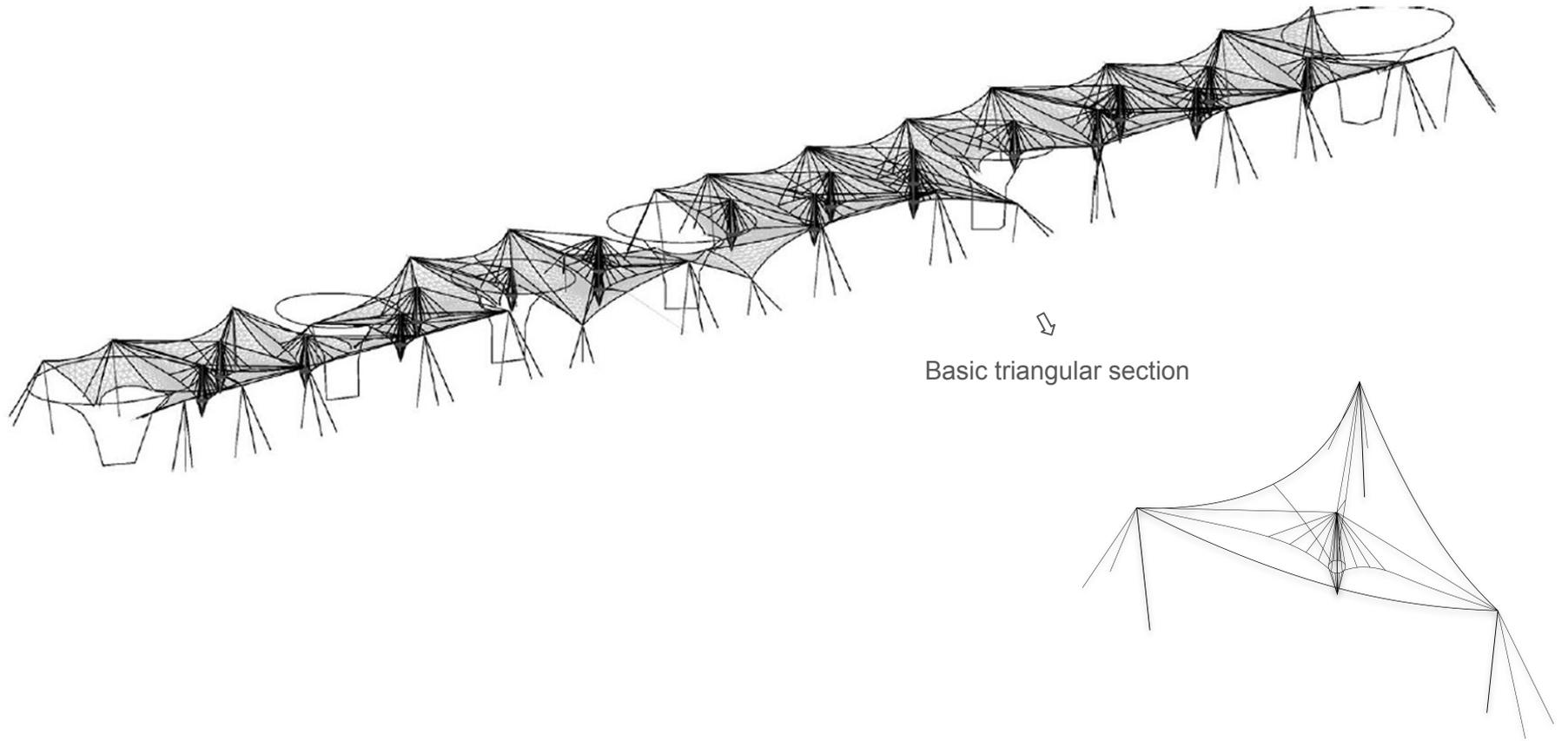
Basic triangular section

FORM STUDIES - BASIC SECTION

Masts ——

Cables ——

FORM STUDIES - BASIC SECTION

FORM STUDIES - BASIC SECTION

FORM STUDIES - BASIC SECTION
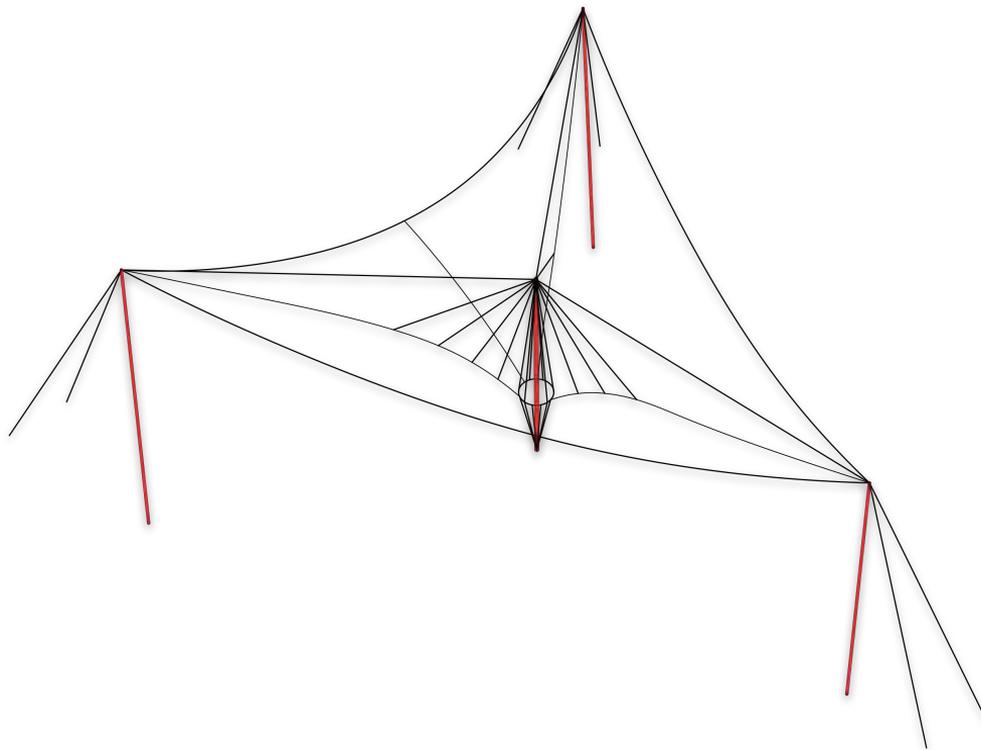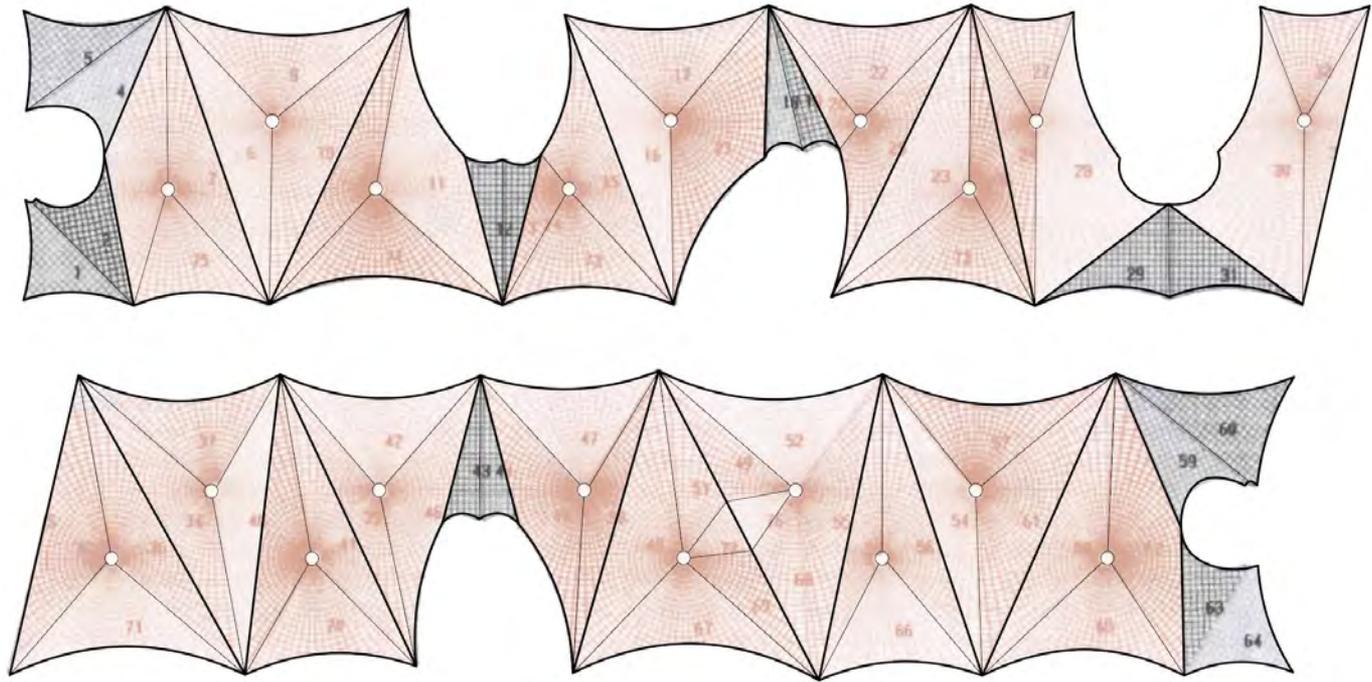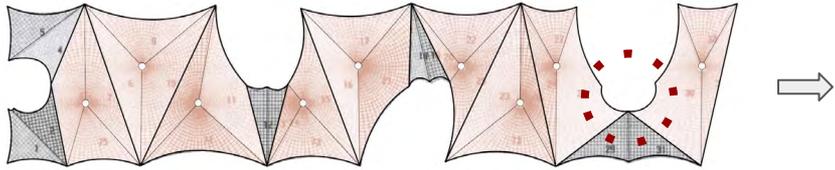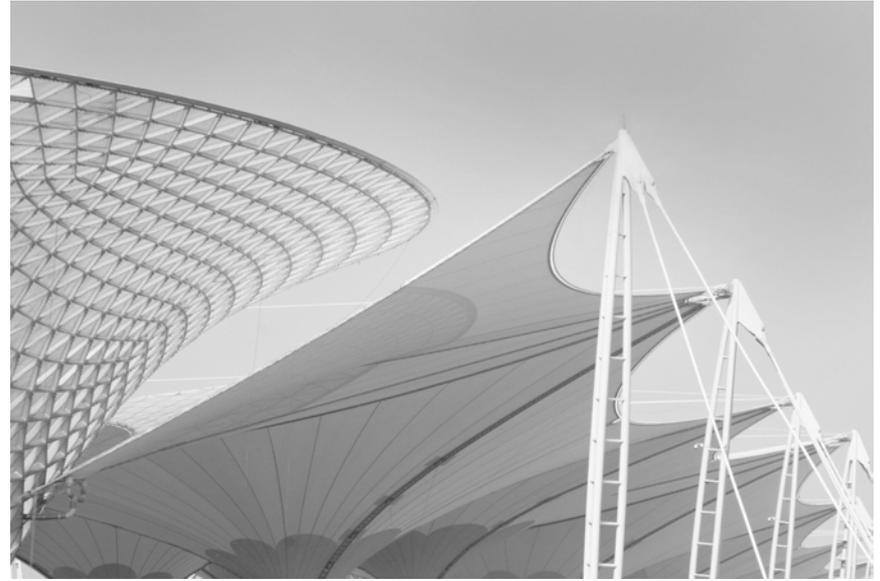
**PTFE Membrane**

The applied membrane is PTFE-glass membrane. It has a tensile strength of 8,000 N / 5cm, which is equivalent to 16 t relating to a strip of 1 m width.

# MEMBRANE STRUCTURAL SYSTEM
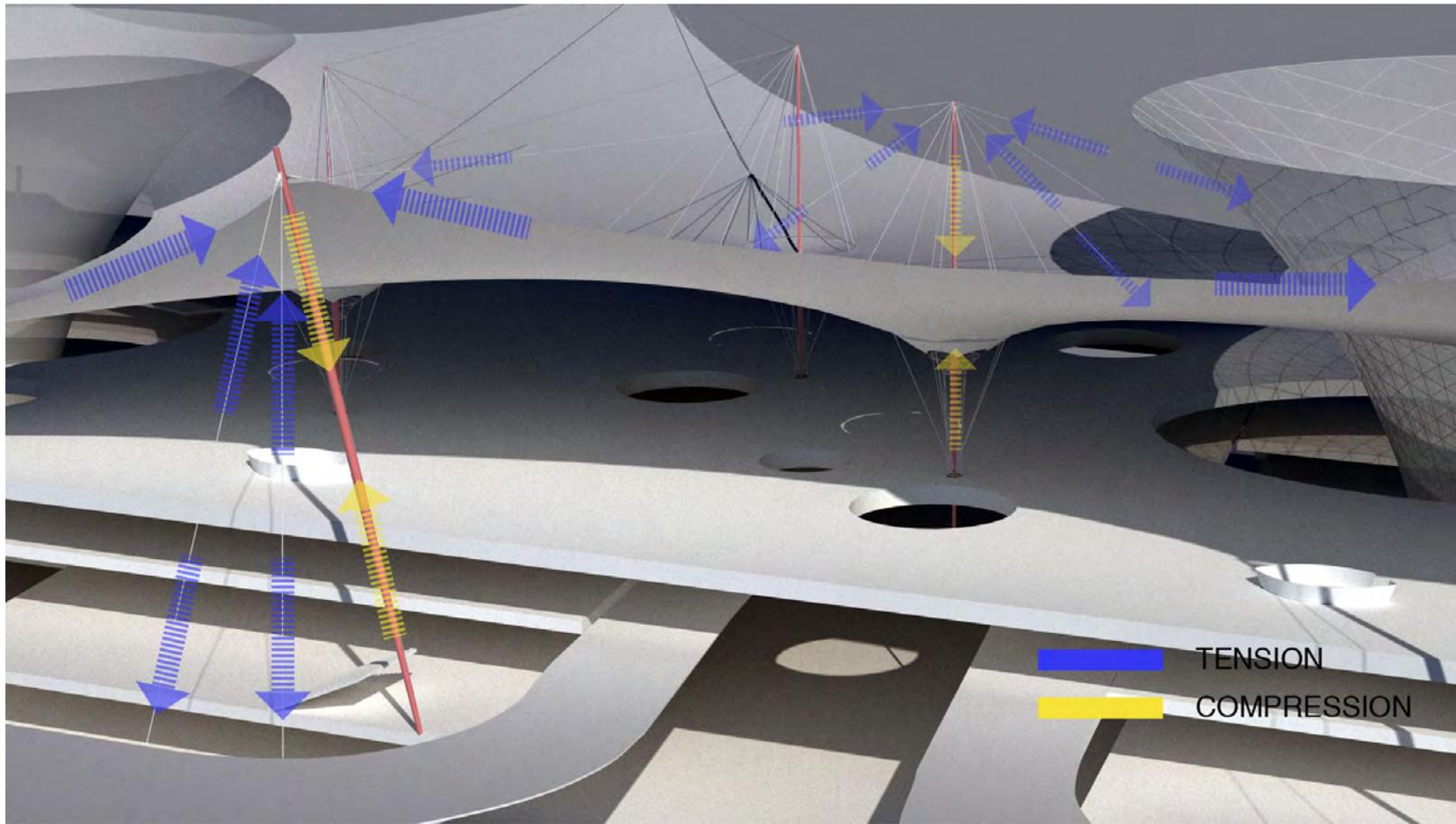
TENSION

COMPRESSION

MEMBRANE STRUCTURAL SYSTEM
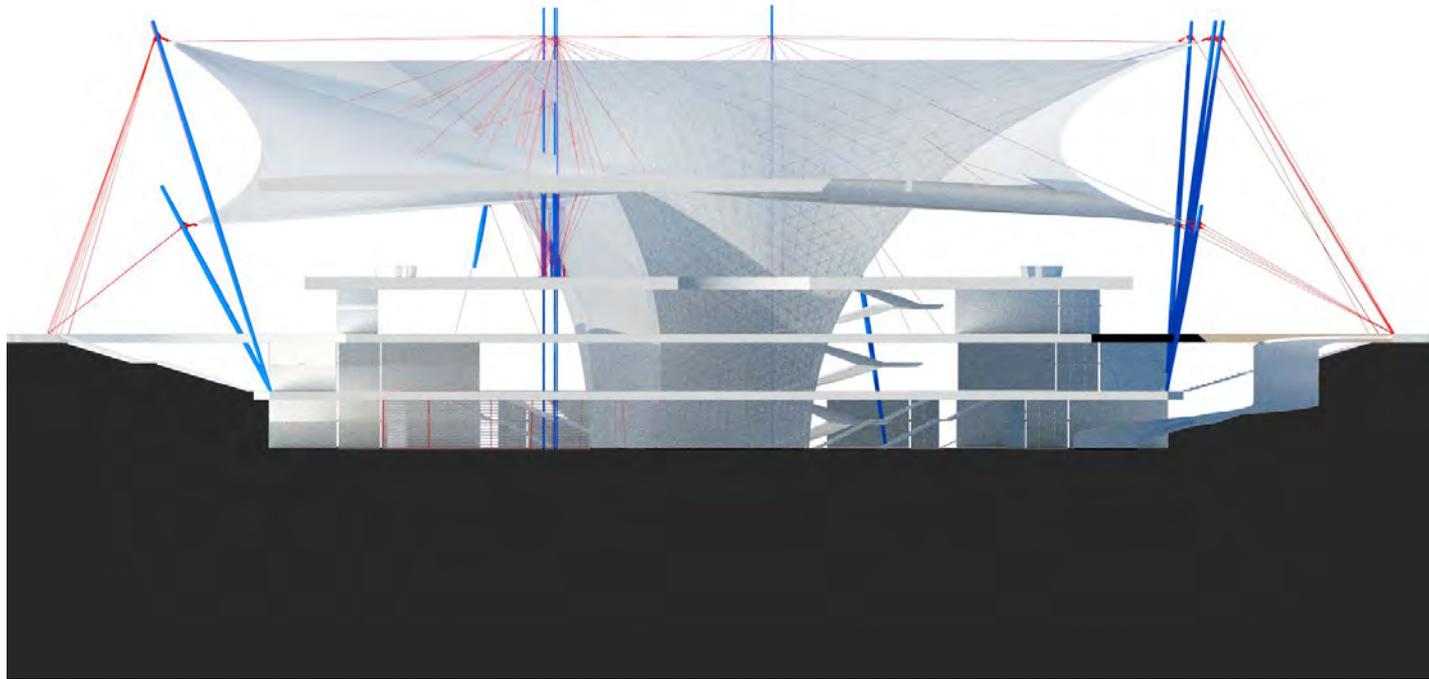
MEMBRANE STRUCTURAL SYSTEM
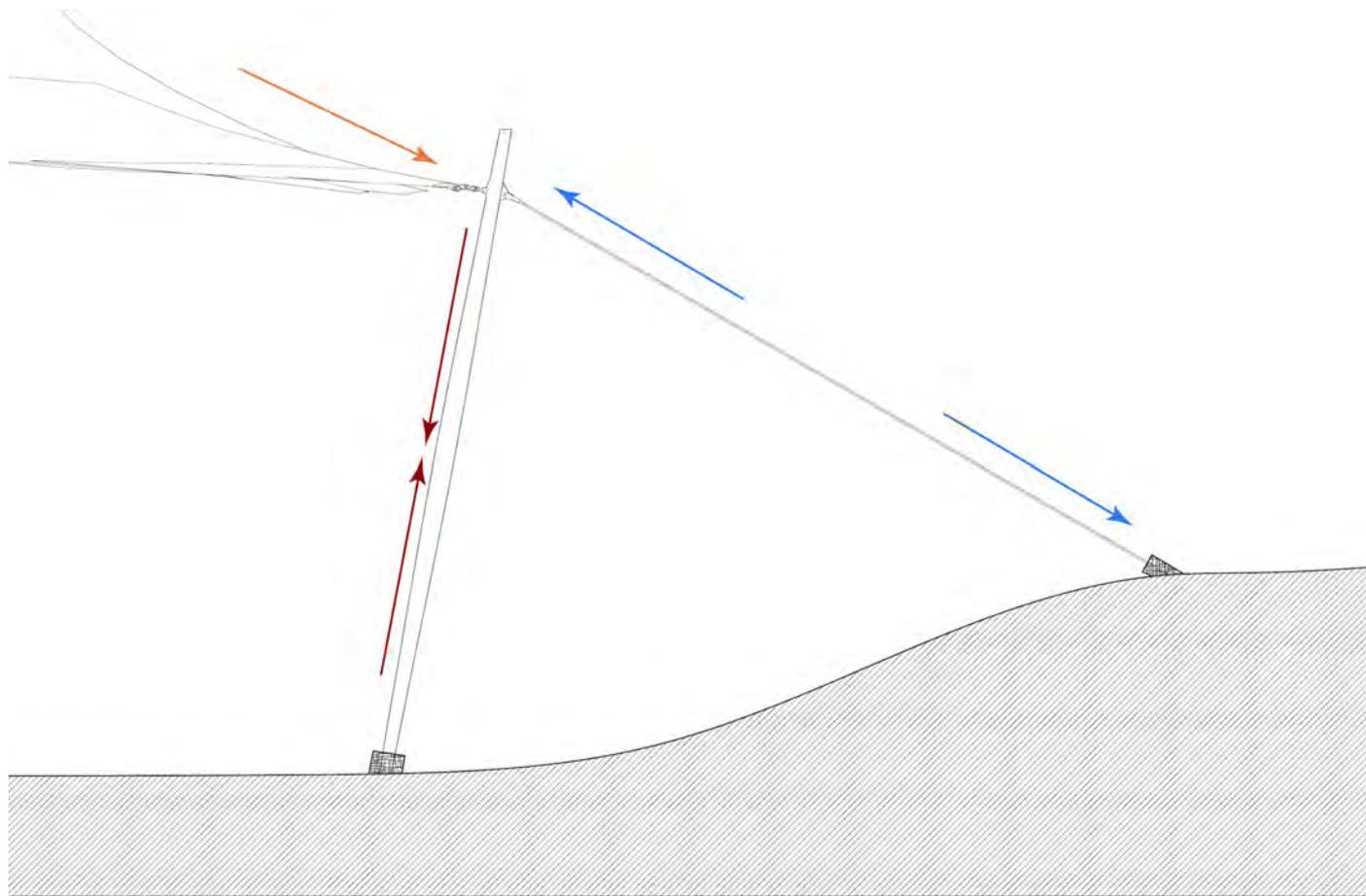
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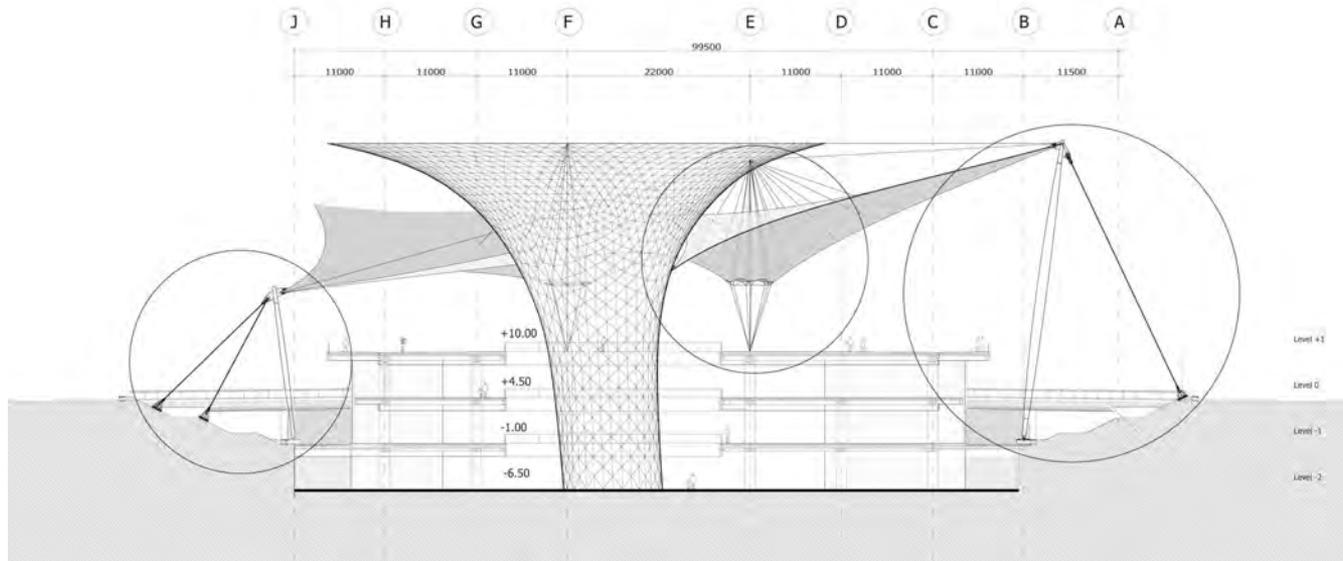
MEMBRANE STRUCTURAL SYSTEM

Inner mast
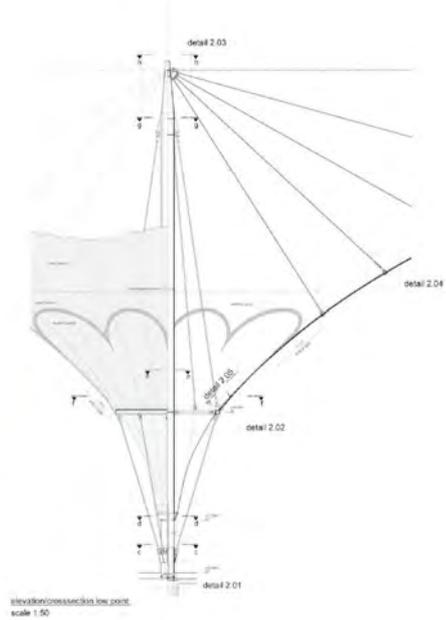
The inner masts, which have a diameter of 600mm, take a major part of the vertical loads.

Inner mast

Mast head

Cable connection

Inner ring

detail 2.03: mast head
scale 1:10

detail 2.04: cable connection
scale 1:10

detail 2.02: inner ring
scale 1:10

elevation/crosssection low point
scale 1:50

Inner mast

Drainage

detail 2.05

detail 2.02

Horizontal section
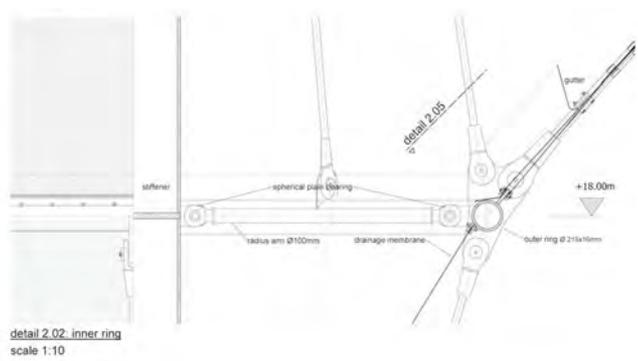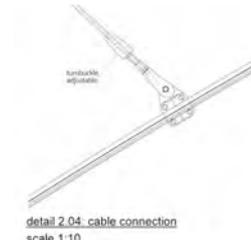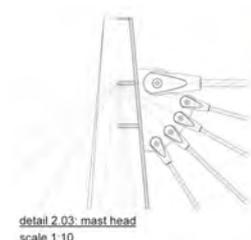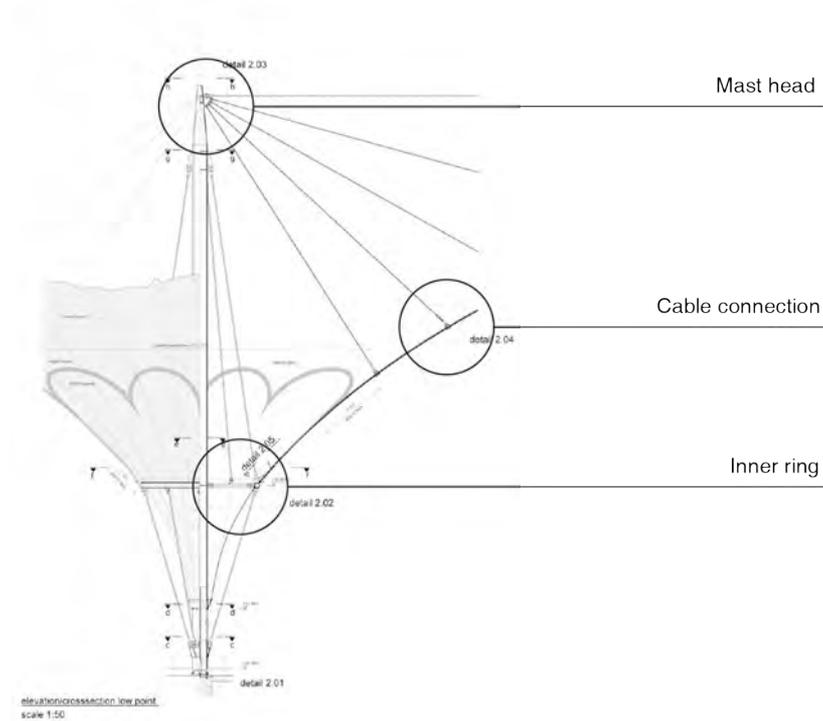
Base point
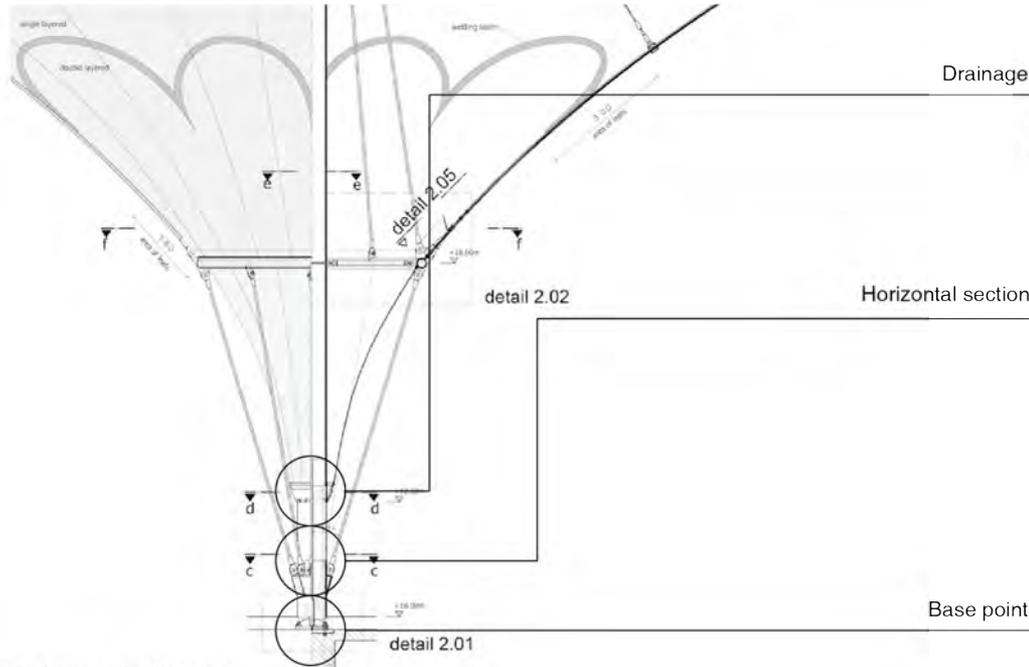
detail 2.01

elevation/crosssection low point
scale 1:50

detail 2.06: drainage
scale 1:10
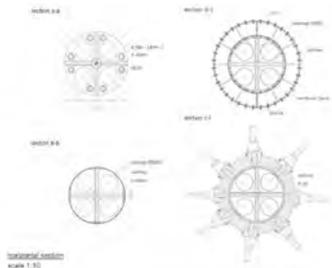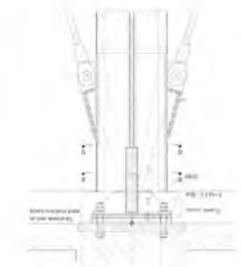
detail 2.01: base point
scale 1:10

Exterior mast
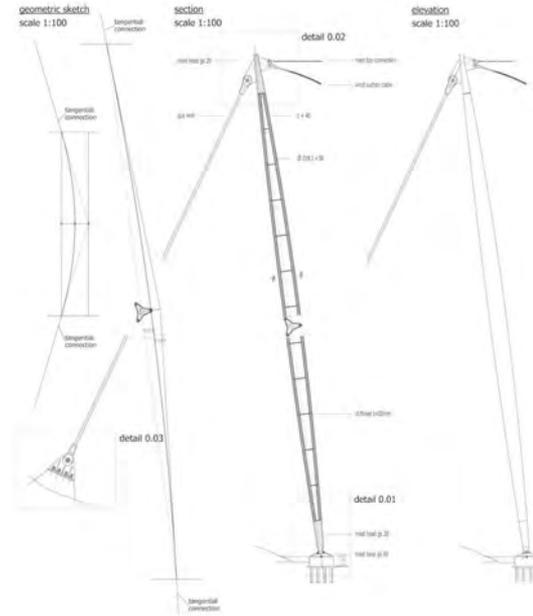
Exterior masts include long masts and short masts, which are 35 or 38 m and 17m long.

Exterior mast

Mast head

Exterior mast

geometric sketch
scale 1:100

section
scale 1:100

elevation
scale 1:100

detail 0.02

Bracing

Bearing point

detail 0.03

detail 0.01
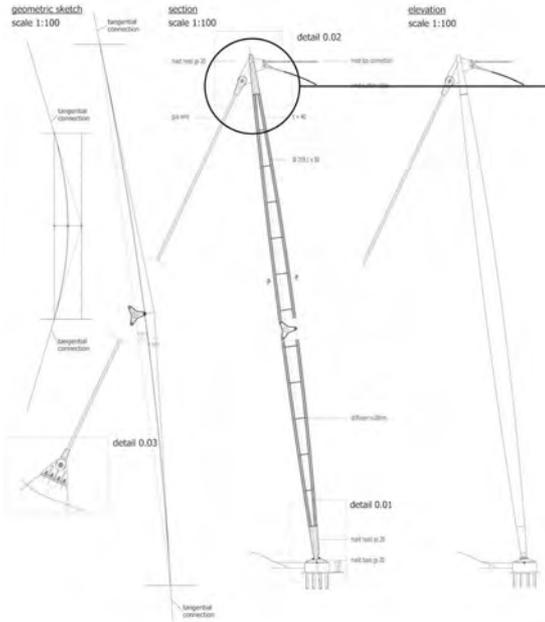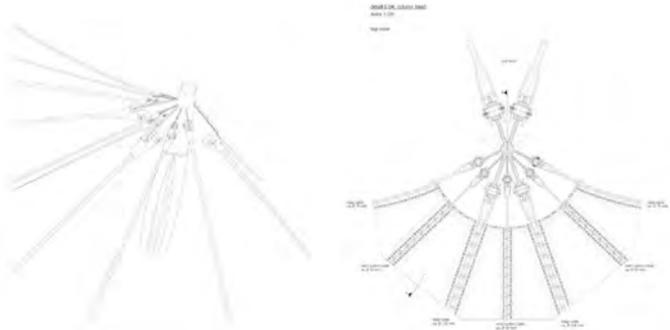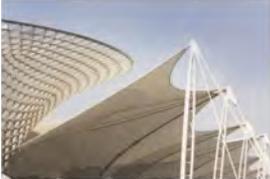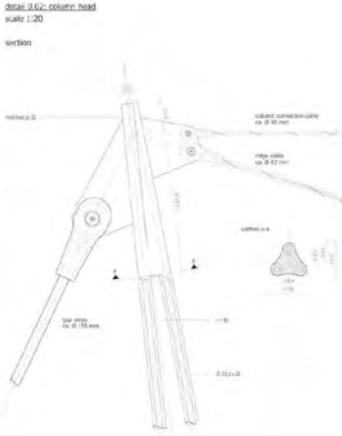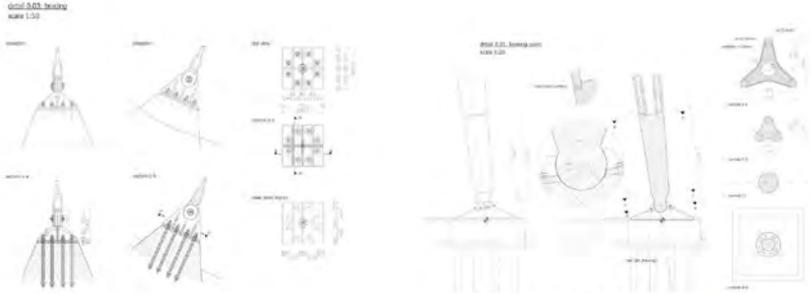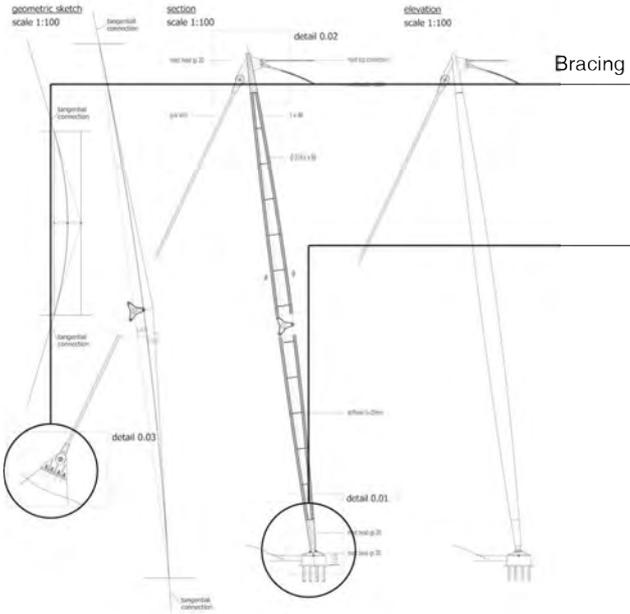
Connection to Sun Valley

Connection type I
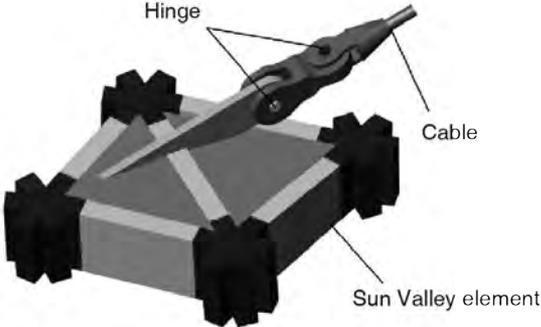
Connection type II
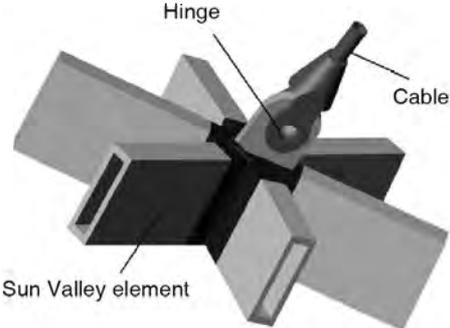
STRUCTURAL ANALYSIS
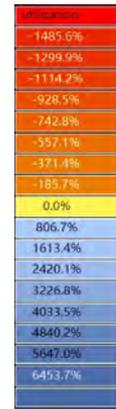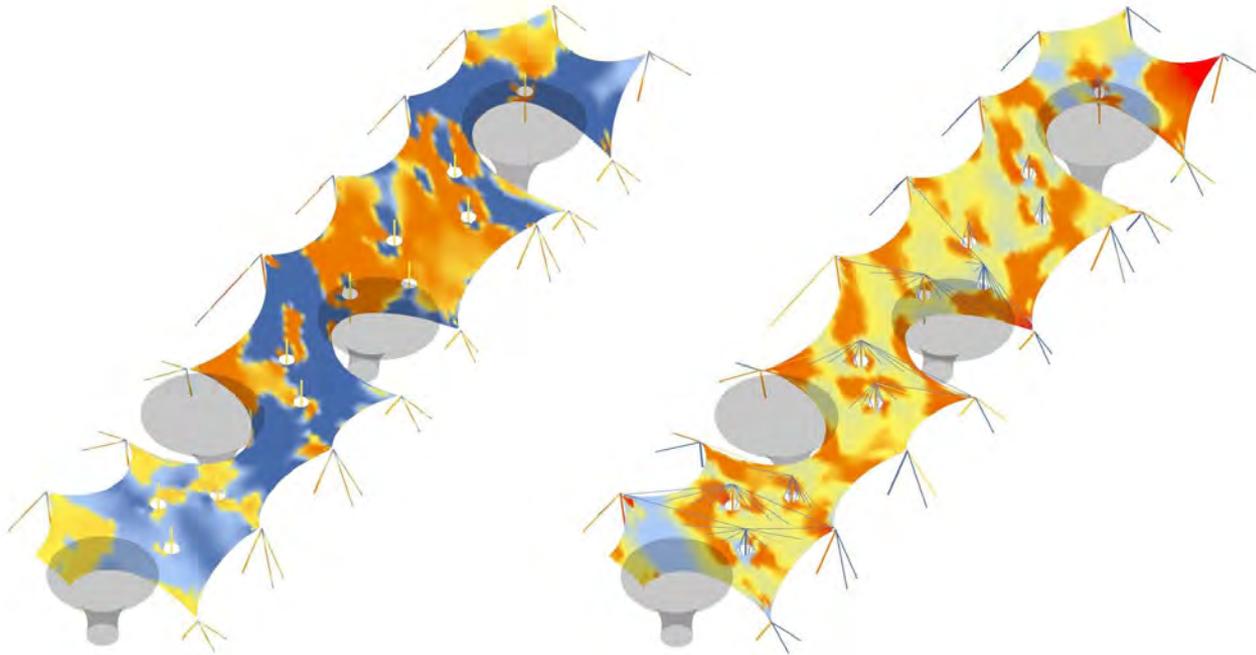
Load case: 0
Type of load: Gravity

After trying out Karamba for utilization analysis, we realized that Karamba cannot be used for cable-membrane structure analysis.

STRUCTURAL ANALYSIS - KARAMBA

Warp

Weft
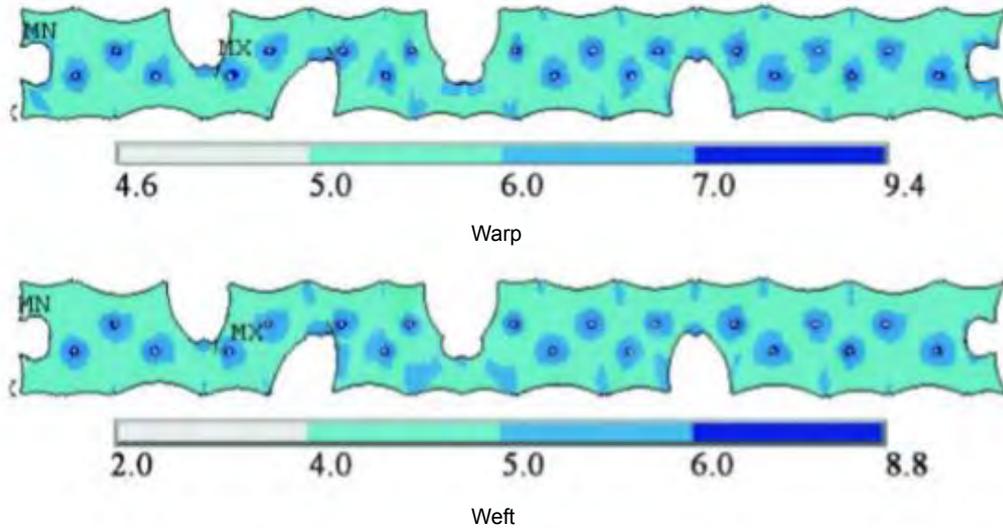
Distribution of membrane's initial prestress (kN/m)

Type of load combination:
Long term:
  1. G + P
  2. G + P + Q
  3. G + P + W
Short term:
  4. G + P + Q + 0.7W

Mechanical property of membrane:
Warp:
  Tensile strength: 173.3 kN/m
  Design value:
    Long term: 21.67 kN/m
    Short term: 43.33 kN/m
  Elastic Modulus: 1362 kN/m
Weft:
  Tensile strength: 156.7 kN/m
  Design value:
    Long term: 19.58 kN/m
    Short term: 39.17 kN/m
  Elastic Modulus: 976 kN/m

STRUCTURAL ANALYSIS - ANSYS

Image resource: WANG Dasui, Weiyu Zhang, et al. "Design and study of an long-span cable-membrane structure for the Expo Axis", Journal of Building Structures, Vol.31 No.5, May 2010
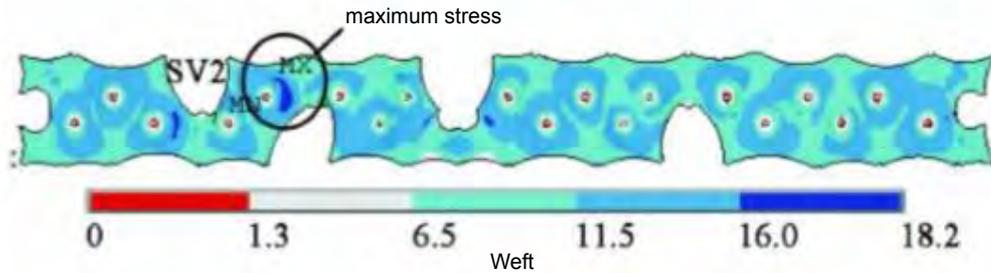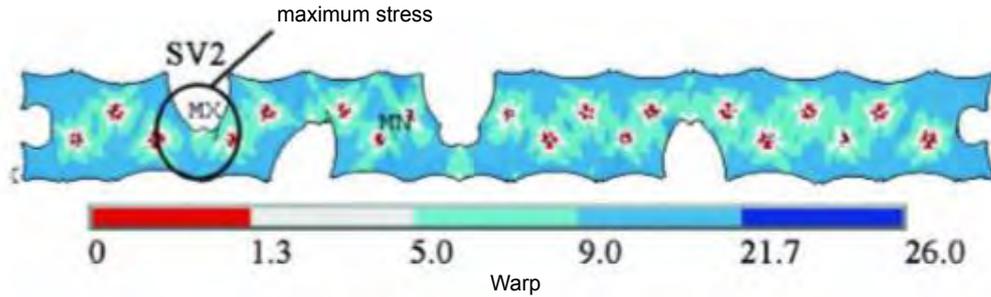
Distribution of membrane's stress under long-term load combination 2 (kN/m)

Type of load combination:
Long term:
  1. G + P
  2. G + P + Q ⇐
  3. G + P + W
Short term:
  4. G + P + Q + 0.7W

Mechanical property of membrane:
Warp:
  Tensile strength: 173.3 kN/m
  Design value:
    Long term: 21.67 kN/m
    Short term: 43.33 kN/m
  Elastic Modulus: 1362 kN/m
Weft:
  Tensile strength: 156.7 kN/m
  Design value:
    Long term: 19.58 kN/m
    Short term: 39.17 kN/m
  Elastic Modulus: 976 kN/m

STRUCTURAL ANALYSIS - ANSYS

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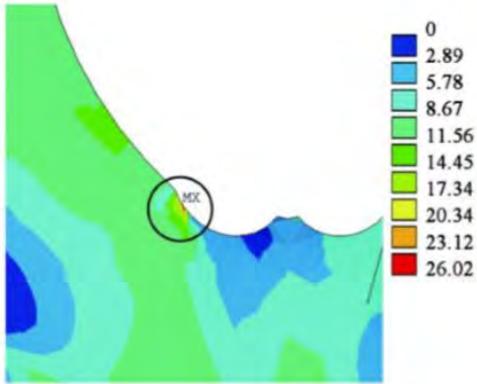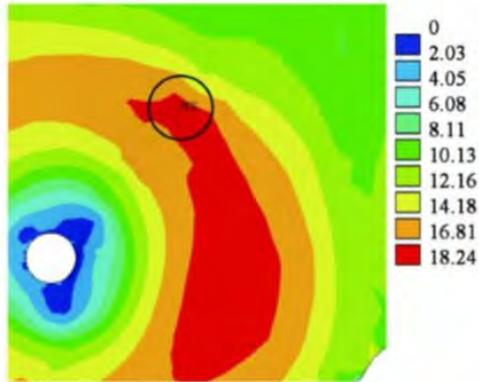
	Warp			Weft	

Details of membrane's maximum stress (kN/m)

Type of load combination:
Long term:
    1. G + P
    2. G + P + Q
    3. G + P + W
Short term:
    4. G + P + Q + 0.7W

Mechanical property of membrane:
Warp:
    Tensile strength: 173.3 kN/m
    Design value:
        Long term: 21.67 kN/m ⇐
        Short term: 43.33 kN/m
   Elastic Modulus: 1362 kN/m
Weft:
   Tensile strength: 156.7 kN/m
    Design value:
        Long term: 19.58 kN/m ⇐
        Short term: 39.17 kN/m
    Elastic Modulus: 976 kN/m

STRUCTURAL ANALYSIS - ANSYS

Result by EASY

Result by ANSYS
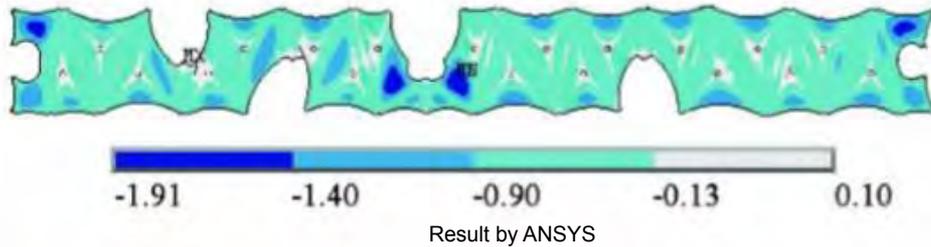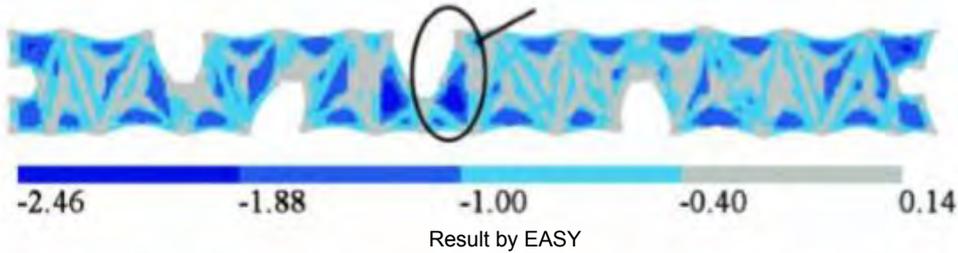
Membrane's displacement under long-term load combination 2 (m)

Type of load combination:
Long term:
      1. G + P
      2. G + P + Q ⇐
      3. G + P + W
Short term:
      4. G + P + Q + 0.7W

Mechanical property of membrane:
Warp:
      Tensile strength: 173.3 kN/m
      Design value:
            Long term: 21.67 kN/m
   Short term: 43.33 kN/m
   Elastic Modulus: 1362 kN/m
Weft:
   Tensile strength: 156.7 kN/m
      Design value:
            Long term: 19.58 kN/m
            Short term: 39.17 kN/m
      Elastic Modulus: 976 kN/m

STRUCTURAL ANALYSIS - EASY & ANSYS
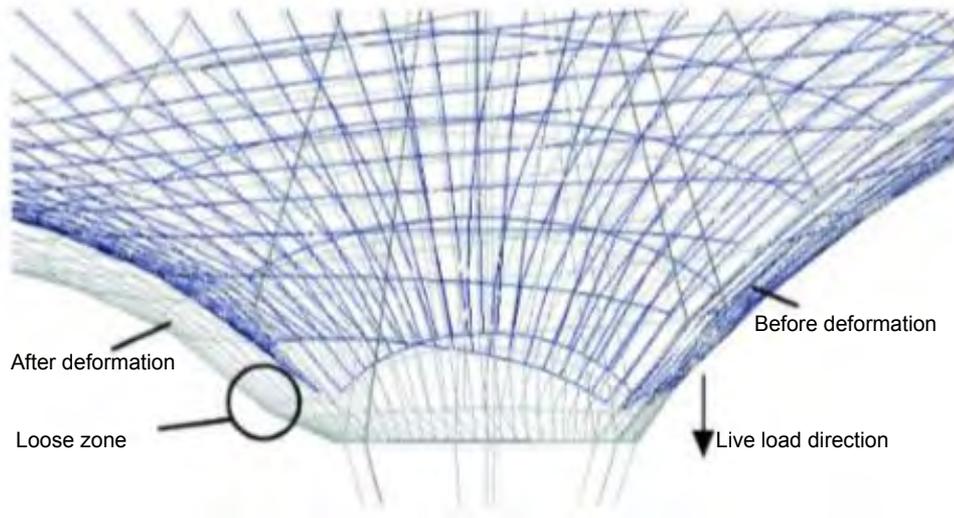
Schematic diagram of drop-down point membrane's displacement under long-term load combination 2

Membrane reinforcement of welds at drop-down point

STRUCTURAL ANALYSIS - REINFORCEMENT

Wind load direction

Loose zone
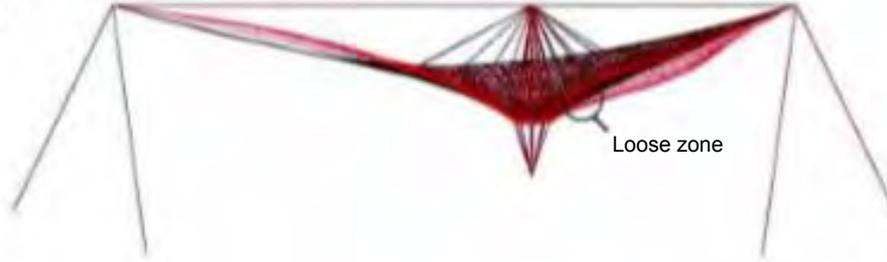
Elevation of membrane's deformation under short term wind load


Reinforcement

Membrane reinforcement of welds at drop-down point

There's a double membrane reinforcement at drop-down point.

STRUCTURAL ANALYSIS - REINFORCEMENT
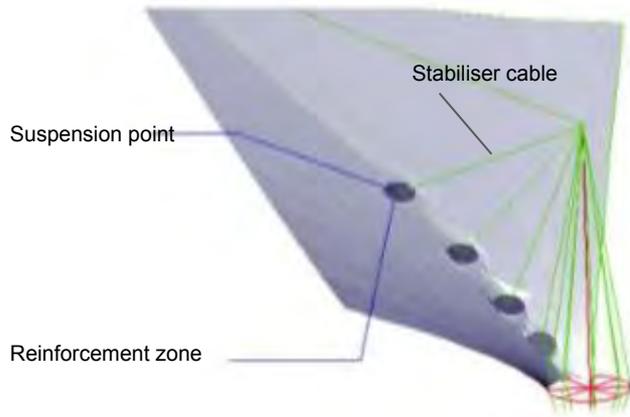
Suspension point
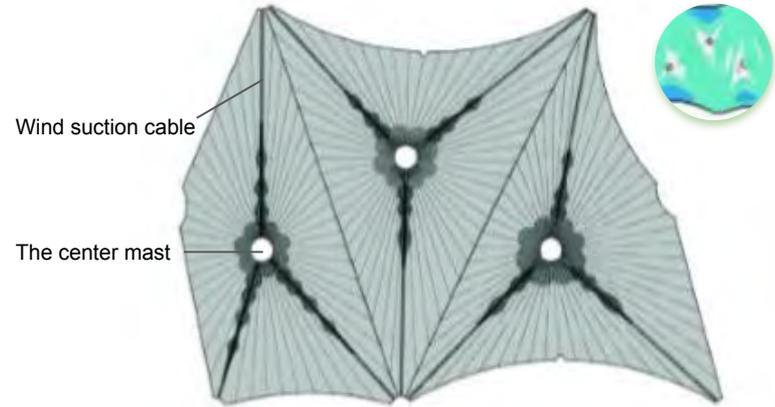
Membrane reinforcement on suspension points

Labels for left figure: Stabiliser cable, Suspension point, Reinforcement zone

Labels for right figure: Wind suction cable, The center mast

## STRUCTURAL ANALYSIS - REINFORCEMENT

SUN VALLEY & CONSTRUCTION
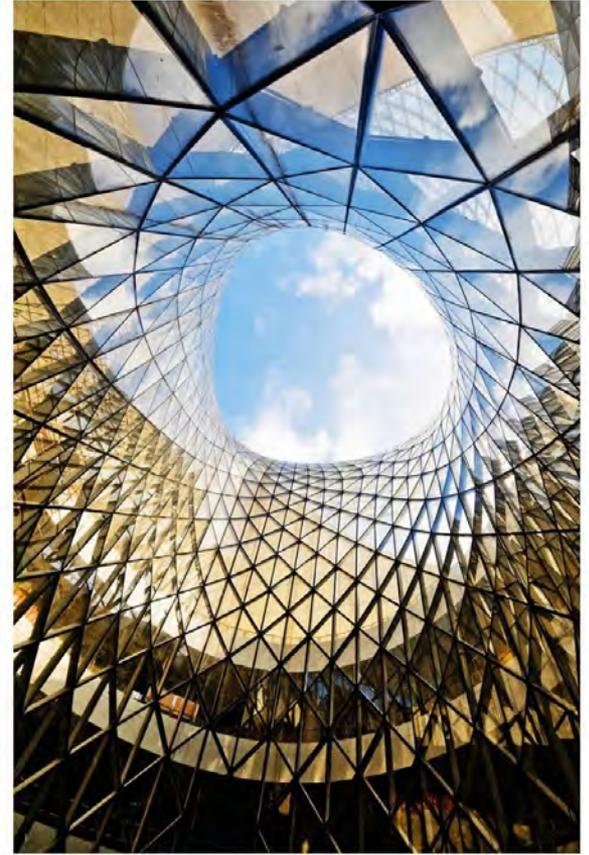
SUN VALLEY

In total there 6 sun valleys. Each of these sun valleys have a surface approximately 5000m2. The diameter at the foot is approximately 16 m and at the upper edge 80 m. The surfaces were optimised in several iteration cycles according to static and design aspects.

One approximately 5000 m² surface

80m

40m

16m

SUN VALLEY
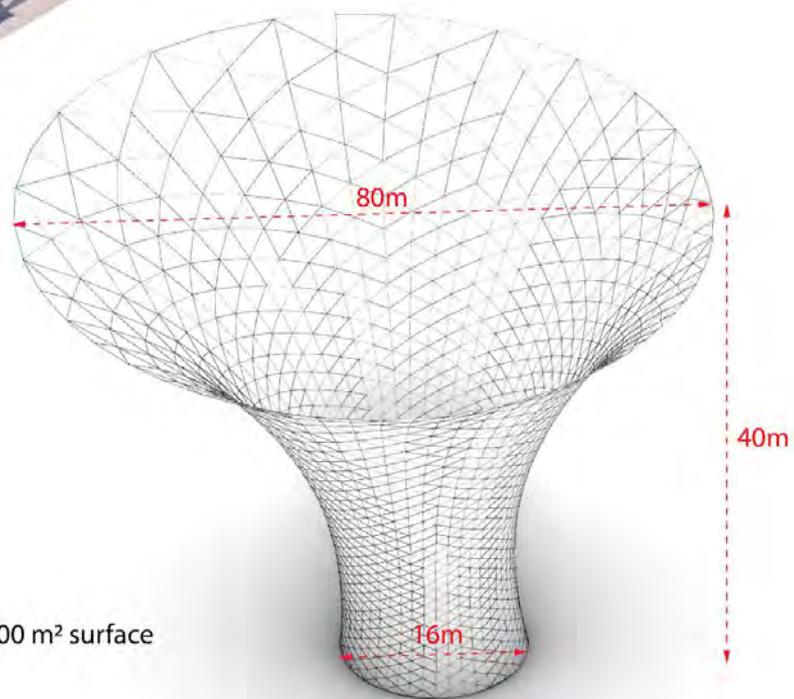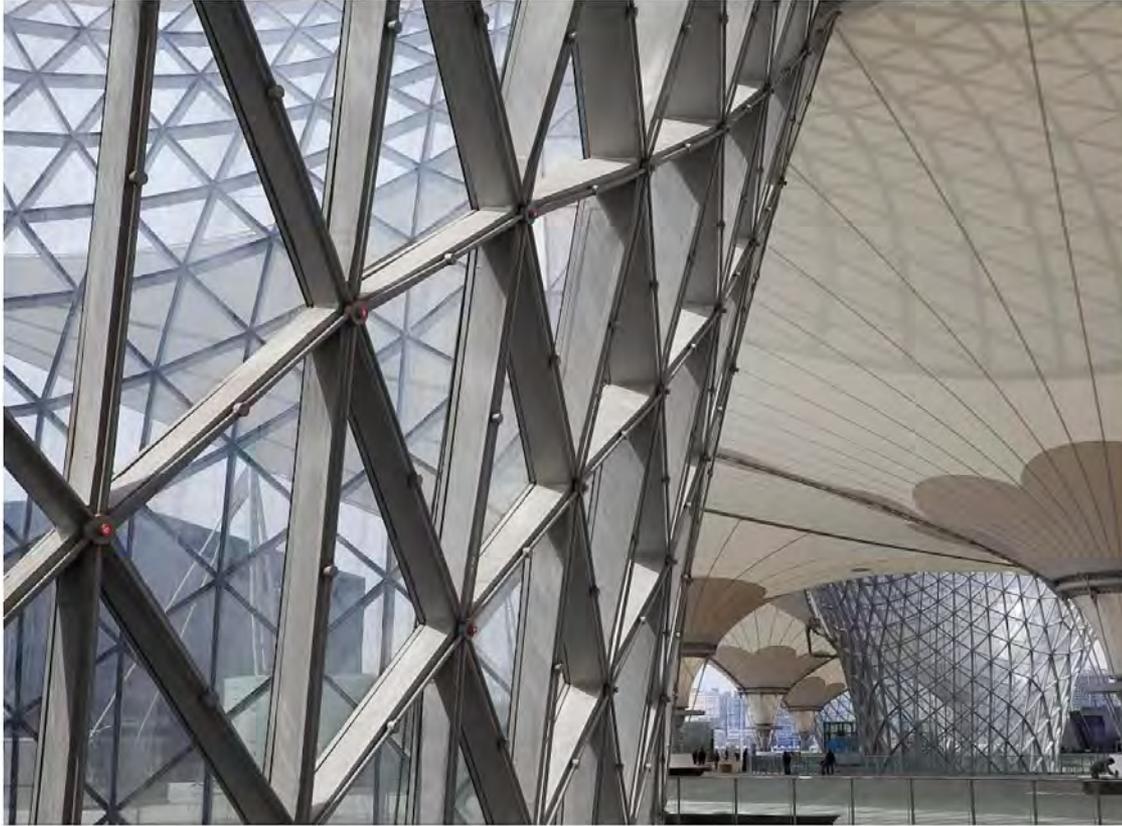
Generating the triangular grid states an interpretation of the principles of dense packaging and multifunctionality as Buckminster Fuller has applied to the US-Pavilion for the Expo 1967 featuring the geodesic dome. In this respect, the sun valleys follow the same approach as the membrane, in terms of natural structures - minimal use of material.

SUN VALLEY

Hinge
Cable
Sun Valley element
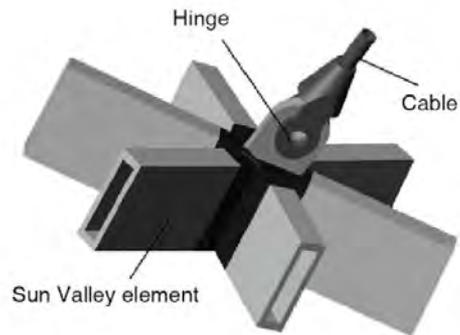
The standard cross-section of 180 x 65 mm expands locally to 500 x 140 mm.
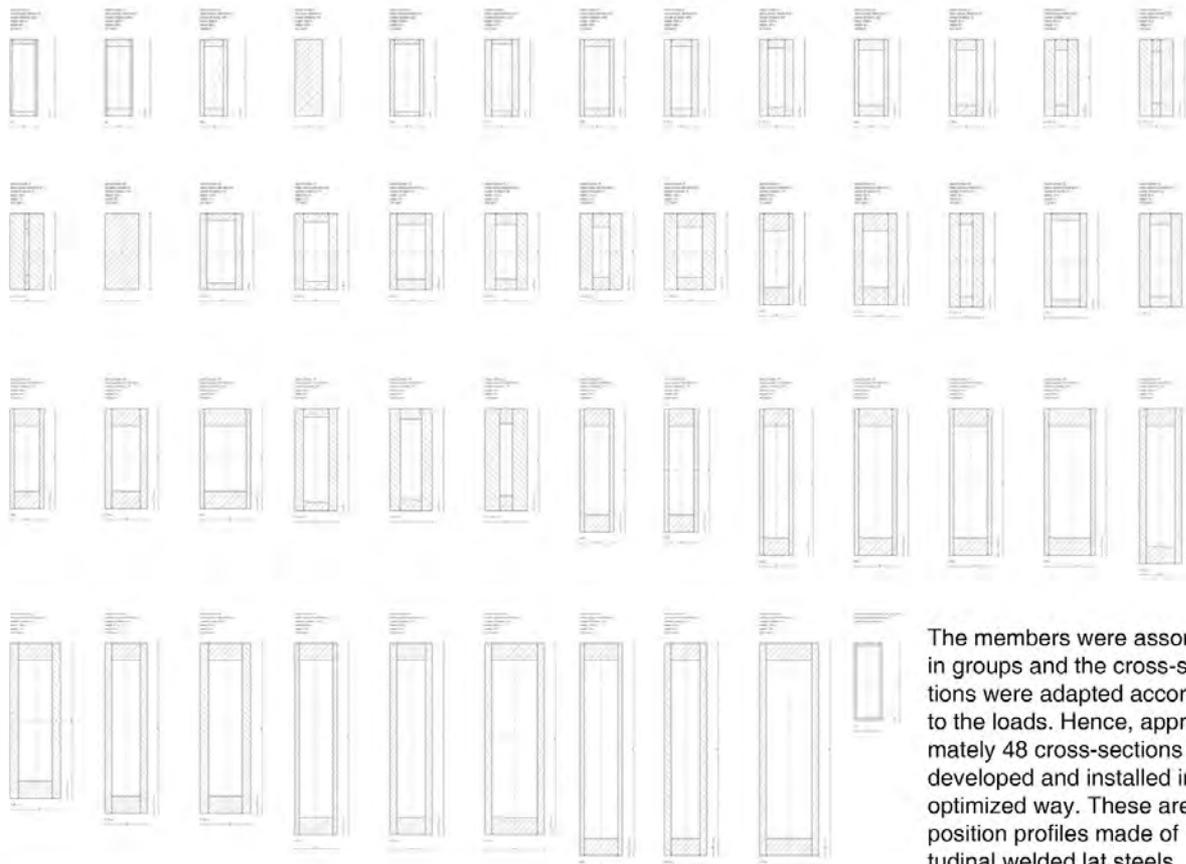
The members were assorted in groups and the cross-sections were adapted according to the loads. Hence, approximately 48 cross-sections were developed and installed in an optimized way. These are composition profiles made of longitudinal welded lat steels.

CONSTRUCTION - SUNVALLY

CONSTRUCTION - SUNVALLY

CONSTRUCTION - SUNVALLY

The making process of the membrane.

On site assmebling of the membrane.

CONSTRUCTION - MEMBRANE

Assembling the mast

Casting Steel Joints

On site installation of the mast

Assemble the mast with the Membrane

CONSTRUCTION - MAST

CONSTRUCTION

CONSTRUCTION WORKERS

CONSTRUCTION WORKERS

20

12

7   19   18

cc

7

16

14

15

c

c

b

THANK YOU