MEGASTRUCTURE EXPO 2010

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PROJECT DETAILS
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<th>Client</th>
<th>Shanghai World EXPO Land Holding Co. Ltd., Shanghai</th>
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<td>Overall concept</td>
<td>SBA GmbH Shanghai / Stuttgart, Li Hong und Bianca Nitsch</td>
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<td>Membrane roof and sun valleys</td>
<td>Knippers Helbig Advanced Engineering, Stuttgart / New York</td>
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<td>Managing partners</td>
<td>Prof. Dr. Jan Knippers, Dipl.-Ing. Thorsten Helbig</td>
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<td>Contributors</td>
<td>Florian Scheible, Florian Kamp, Dirk Richter, Roman Schieber, Johannes Beran</td>
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<td>Cooperation</td>
<td>ECADI, Shanghai, China</td>
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<td>Energy scheme</td>
<td>Scholze Consulting, Leinfelden-Echterdingen, Germany</td>
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<td>Gross floor space</td>
<td>280,000 m²</td>
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<td>Surface of membrane roof</td>
<td>65,000 m²</td>
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<tr>
<td>Span</td>
<td>100 m</td>
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<tr>
<td>Surface of free-form member system</td>
<td>30,000 m²</td>
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<td>Dimension boulevard</td>
<td>100 x 1,000 m</td>
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<td>Realisation period</td>
<td>2006 - 2010</td>
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PRECEDENT-German Pavilion, 1967 Montreal
FORM STUDIES
FORM STUDIES - BASIC SECTION
Basic triangular 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
MEMBRANE STRUCTURAL SYSTEM
MEMBRANE STRUCTURAL SYSTEM
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

MEMBRANE STRUCTURAL SYSTEM - INNER MAST
Inner mast
Exterior mast

Exterior masts include long masts and short masts, which are 35 or 38 m and 17 m long.
MEMBRANE STRUCTURAL SYSTEM - EXTERIOR MAST

Exterior mast

Bracing

Bearing point
Connection to Sun Valley

Connection type I

Connection type II

MEMBRANE STRUCTURAL SYSTEM - CONNECTION TO SUN VALLEY
STRUCTURAL ANALYSIS
After trying out Karamba for utilization analysis, we realized that Karamba cannot be used for cable-membrane structure analysis.
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

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
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- Elastic Modulus: 976 kN/m

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
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

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

- Membrane reinforcement of welds at drop-down point:
  - There's a double membrane reinforcement at drop-down point.

Suspension point

Reinforcement zone

Suspension point

Membrane reinforcement on suspension points

Wind suction cable

The center mast

Stabiliser cable

SUN VALLEY & CONSTRUCTION
SUN VALLEY
In total there are 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
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.
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.
The making process of the membrane.  

On site assembling of the membrane.
CONSTRUCTION WORKERS
CONSTRUCTION WORKERS