

Pre- and Post-Tensioning

- Cable Trusses
- Concrete Beams
- Stressed Membranes

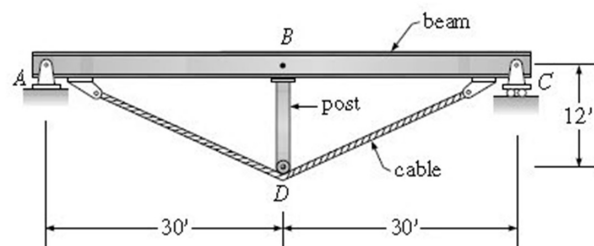


Cable Trusses

- Reduce flexure stress
- Reduce deflection
- Produces stiffer section with less material
- Lighter weight
- Longer spans possible
- Analysis by combined stress



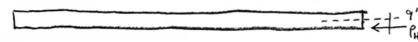
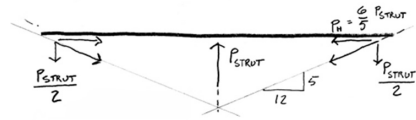
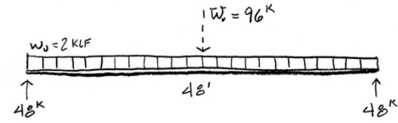
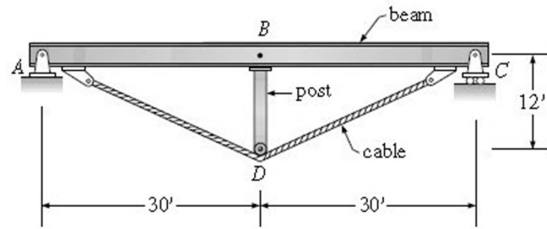
$$f = -\frac{P}{A} \pm \frac{M}{S} \pm \left[\frac{Pe}{S} \right]$$



Cable Truss – stress analysis

determine cable prestress

1. Break beam load into 3 FBDs.
 1. applied load
 2. cable + strut
 3. eccentric load (if any)
2. Solve moment for beam at C.L. for applied load
3. Solve C.L. moments for other 2 FBDs in terms of strut force, P_s
4. Equate the moments from the three moment equations to cancel at the CL
5. Solve for the strut and cable forces.
6. Construct moment diagram for the beam with all loadings combined: applied load + cable at ends + struts.
7. Solve combined stress in beam using interaction equation.



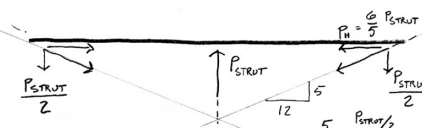
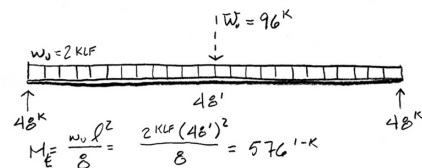
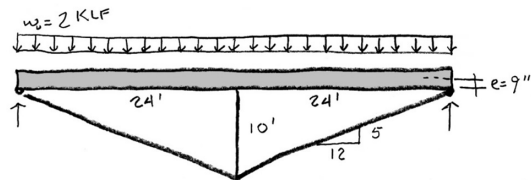
Cable Truss Analysis

Example

Given: truss configuration with applied load

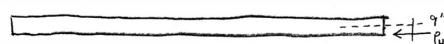
Required: force in the cable which will result in zero moment at the center line, C.L.

1. Divide the truss into 3 Free Body Diagrams:
 1. applied load
 2. cable + strut
 3. eccentric load (if any)



$$M_E = \frac{P \cdot l}{4} = \frac{P_{strut} \cdot 48'}{4}$$

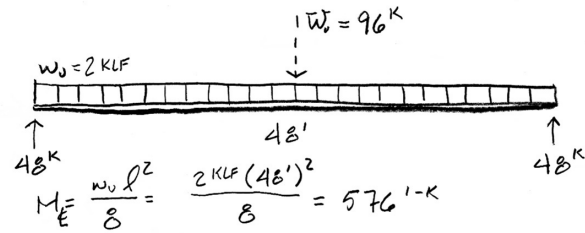
$$M_E = P_{strut} (12)$$



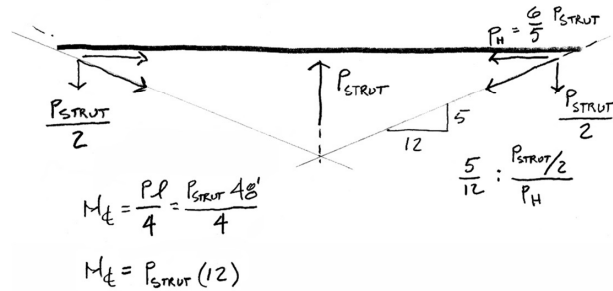
$$M_E = P_e = \frac{6}{5} P_{strut} \times 9 = 10.8 P_{strut}$$

Cable Truss Analysis

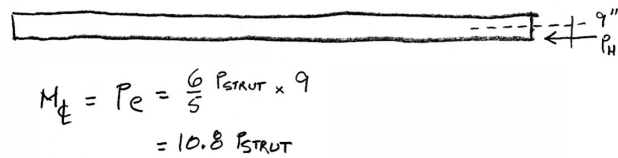
- Find the C.L. moment based on applied load alone.



- Find the C.L. moment for the cable and strut in terms of the strut force, P_{strut} . Write the components of the cable force in terms of P_{strut}

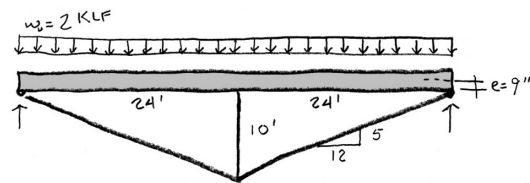


- Find the C.L. moment for the eccentric cable load in terms of P_{strut}



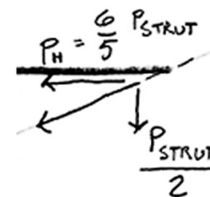
Cable Truss Analysis

- Set the sum of the C.L. moments equal to zero and solve for the strut force, P_{strut}



$$\begin{aligned}
 + M_U - M_{\text{STRUT}} - M_e &= 0 \\
 576 - 12 P_{\text{STRUT}} - 10.8 P_{\text{STRUT}} &= 0 \\
 22.8 P_{\text{STRUT}} &= -576 \text{ K-FT} \\
 P_{\text{STRUT}} &= 25.26 \text{ K}
 \end{aligned}$$

- Sum the cable components to find the total cable force.

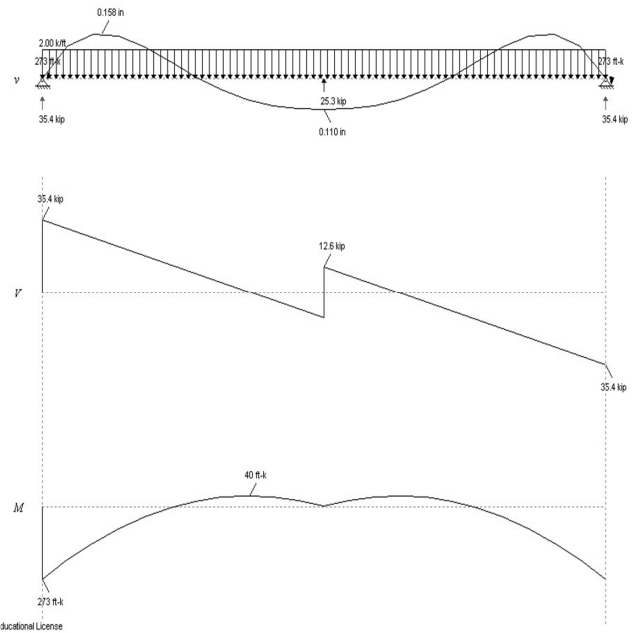
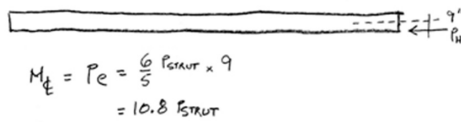
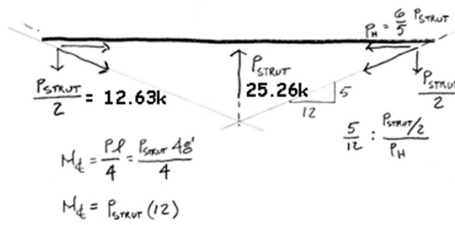
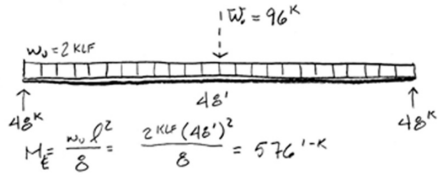
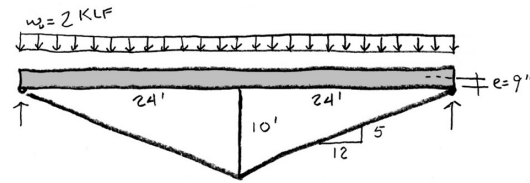


CABLE FORCE

$$\sqrt{\left(\frac{6}{5} P_{\text{STRUT}}\right)^2 + \left(\frac{P_{\text{STRUT}}}{2}\right)^2} = 32.84 \text{ K}$$

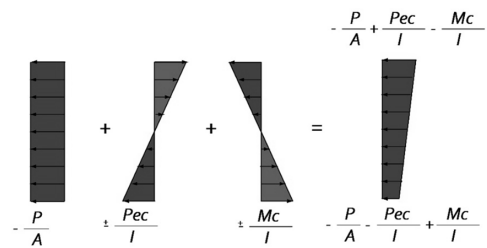
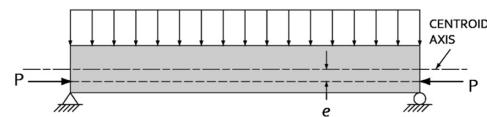
Cable Truss Analysis

7. find end reactions and calculate shear & moment

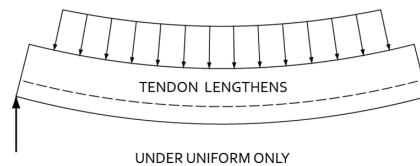
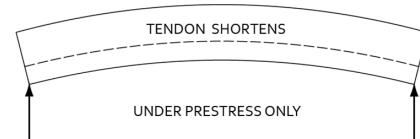


Pre-stressed Concrete

- More concrete active in resisting moment
- Produces stiffer section with less material
- Lighter weight
- Longer spans possible
- Analysis by combined stress



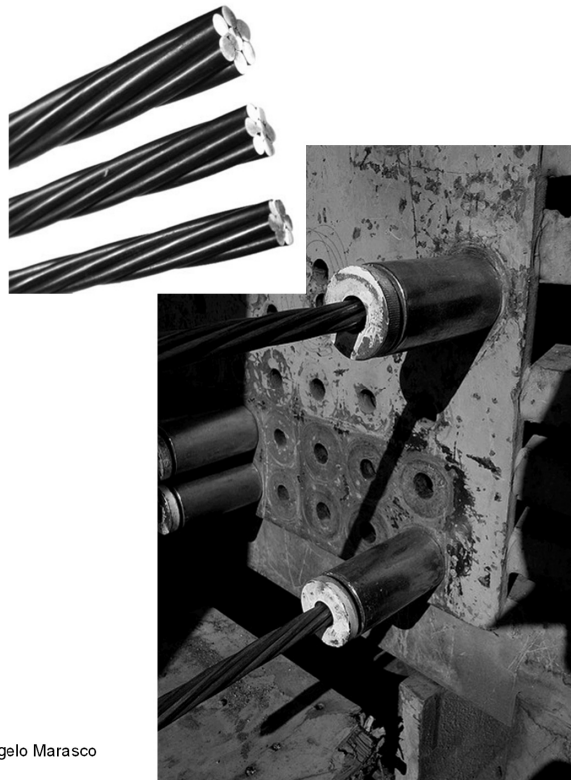
$$f = -\frac{P}{A} \pm \frac{Pec}{I} \pm \frac{Mc}{I}$$



Pre-stressed Concrete

Steel:

high strength wires 250 or 270 ksi
 wire diameter 0.105 – 0.276
 used in strands of bundled wire
 most common is 7 wire strand



Concrete:

higher strength 5 – 10 ksi
 to reduce creep and strain
 reduced cracking
 stiffer sections

Photo by Angelo Marasco

Pre-stressed Concrete

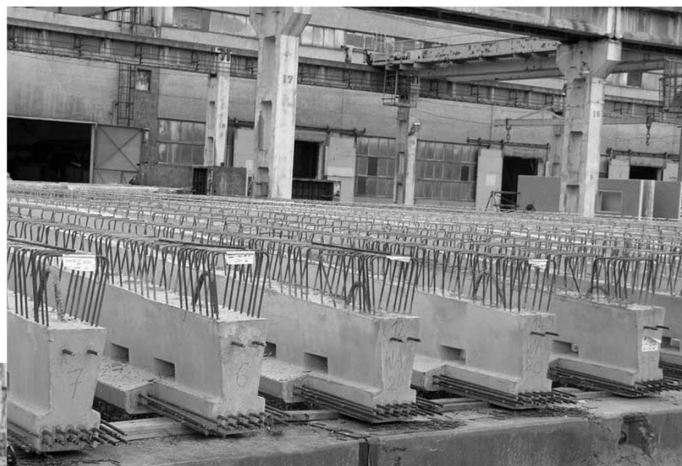
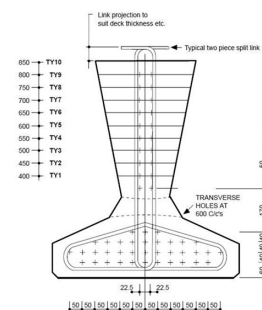


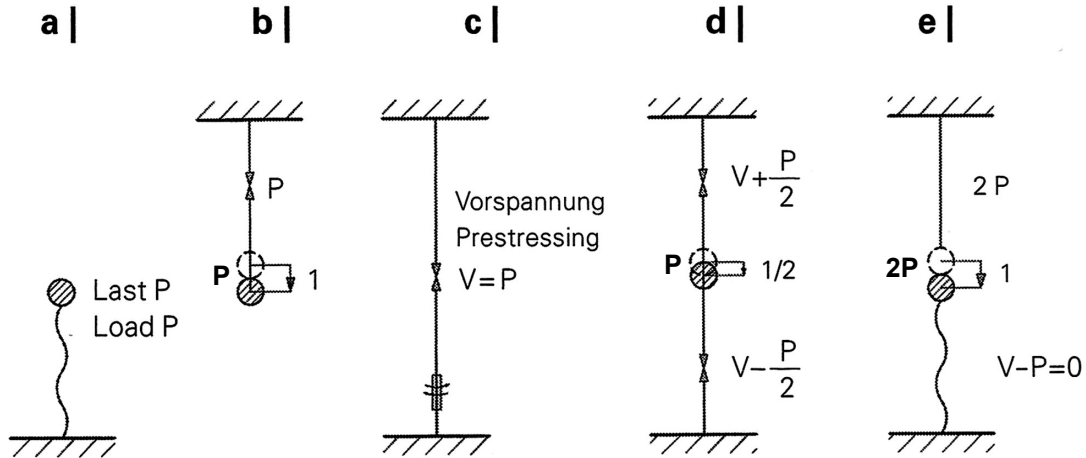
Photo by MACRETE



Pre-stressing

Reducing deformation

(b) carries P and deflects 1
 (e) carries 2P and deflects 1
 what makes the difference?



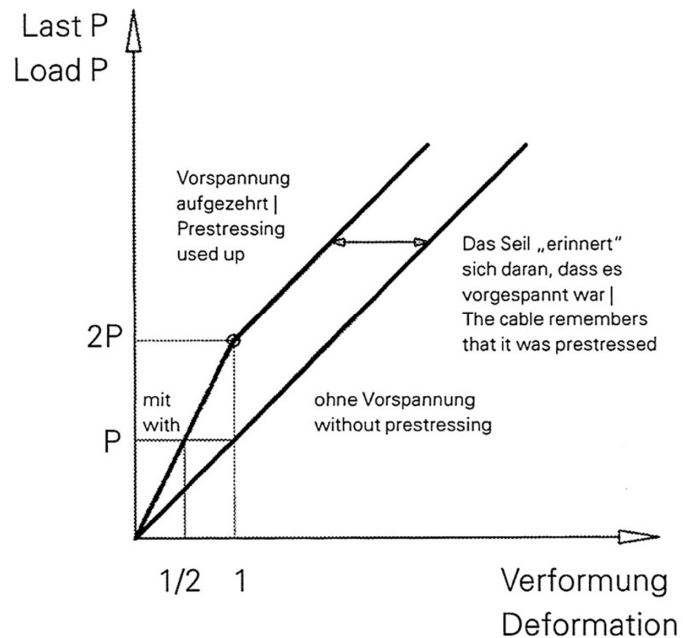
Jörg Schlaich, *Light Structures*

Pre-stressing

increasing stiffness

and

reducing deformation



Jörg Schlaich, *Light Structures*

Expo '67, Montreal

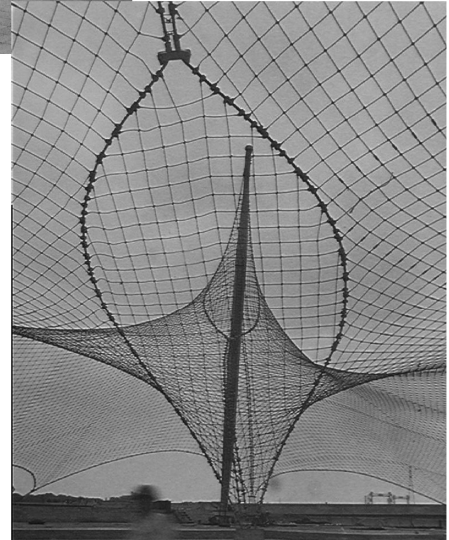
Frei Otto
German Pavilion



University of Michigan, TCAUP



Structures II



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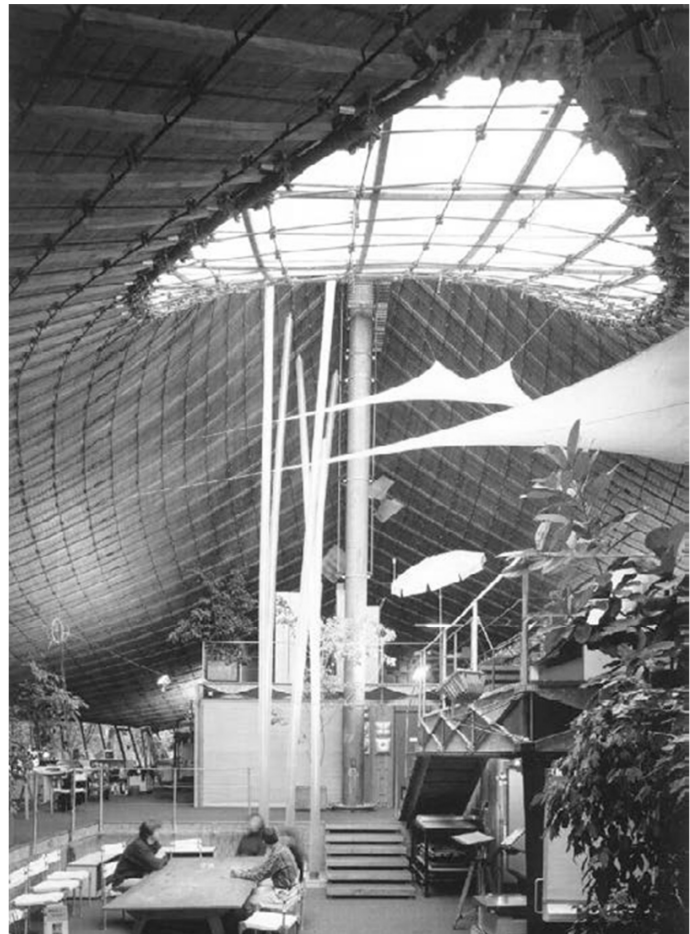
Institute for Lightweight Structures – IL (now ILEK)

University of Stuttgart



Frei Otto, IL building, University of Stuttgart

University of Michigan, TCAUP



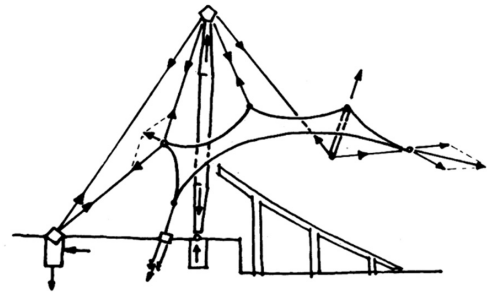
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Stressed Membrane

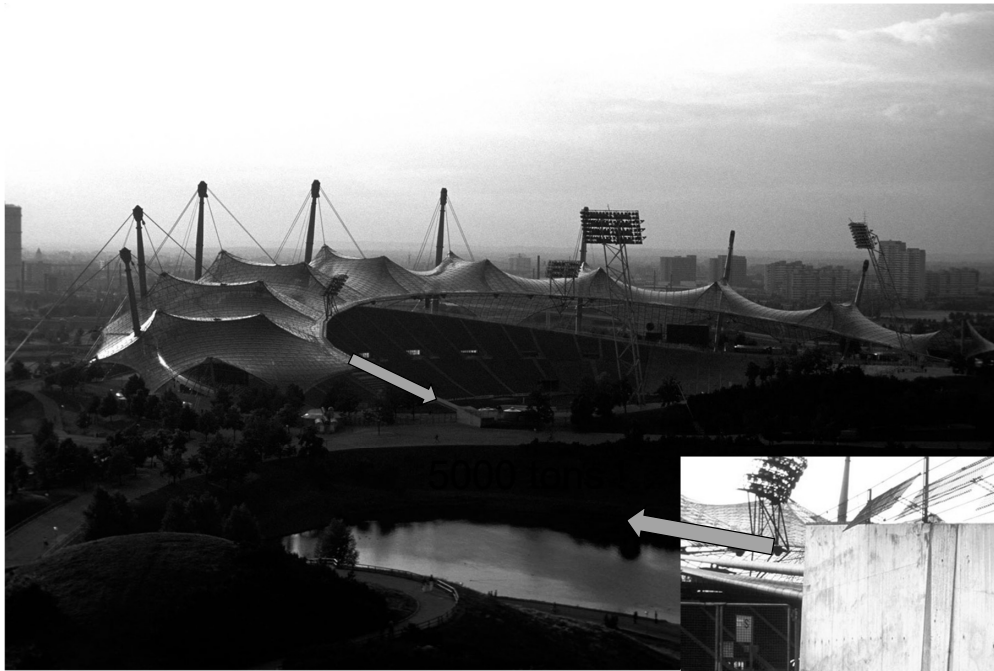
Olympic Buildings, Munich 1972
Eng. Otto, Leonhardt, Schlaich
Arch: Behnisch

- Opposing curvature
- Stressed by anchors and masts



Frei Otto, Munich Soccer Stadium (from back)

Stressed Membrane Olympic Stadium, Munich 1972



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Bundesgartenschau Köln Frei Otto



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Schlaich Bergermann & Partners – Stuttgart VfB Stadium



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Schlaich Bergermann & Partners – Miami NU Stadium

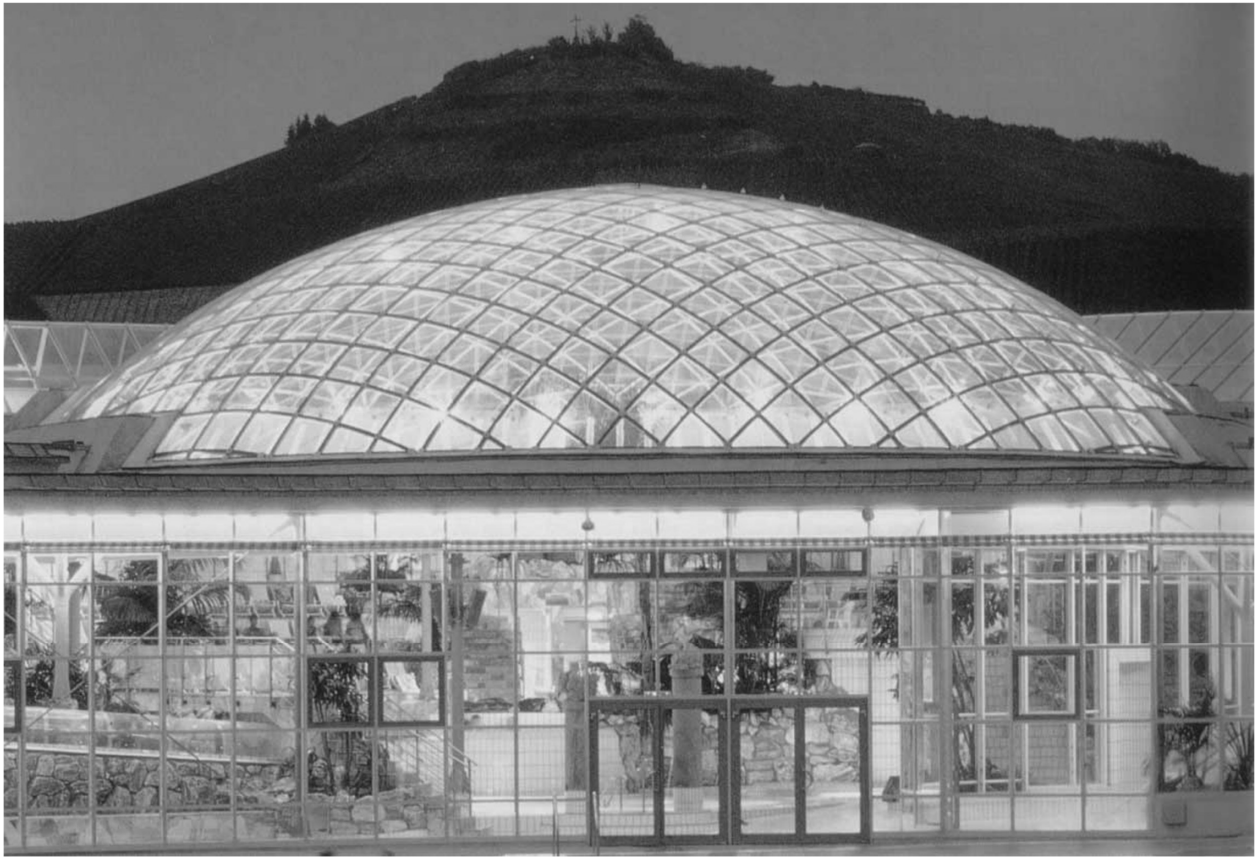


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Schlaich Bergermann & Partners – Neckarsulm Swimming Pool



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Schlaich Bergermann & Partners

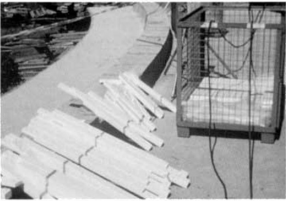
Neckarsulm, 1989



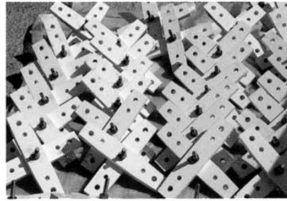
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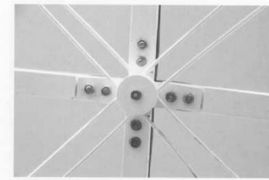
6.14
The slats



6.15
The rotatable joints



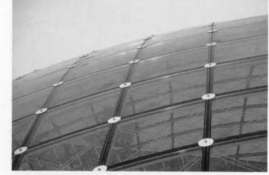
6.16
Assembly of the grid elements



6.17
Close-up of the joint assembly
with diagonal cables installed



6.18
A segment of the grid showing the double
pattern formed by the slats and cables



6.19
A segment of the completed roof
with the spherically-curved glass panes



6.20
Water barrels representing
partial snow load

Schlaich Bergemann & Partners

Neckarsulm Pool

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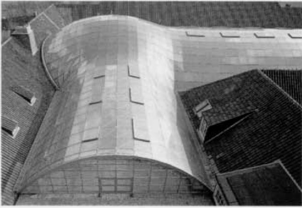
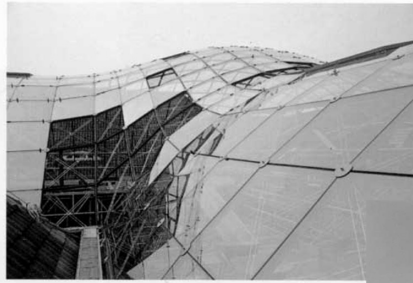
History of Hamburg Museum



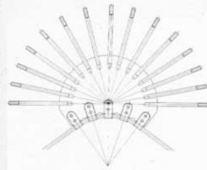
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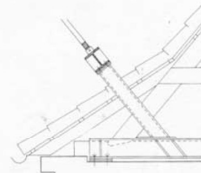
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6.27-6.31
The roof under construction



6.32
Detail of a "spoked wheel"



6.33
A support point on the old building

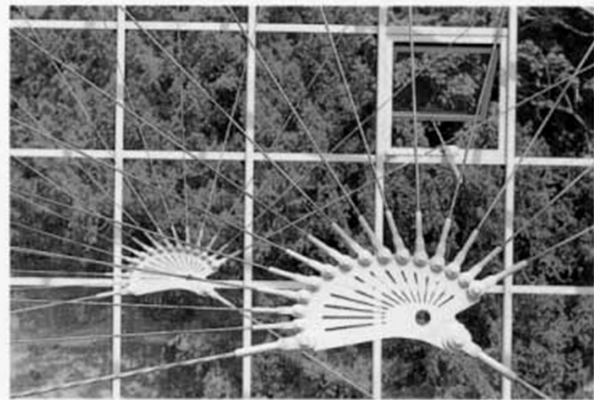


Schlaich Bergemann & Partners – Pool cover for mineral spa, Bad Cannstatt





6.41
Connections of the pretensioned
cable "spokes" to the "rim"



6.40
The hub connections (see the dra-
wing on the cover of this book)

Stressed Membrane

Bosch-Areals, Stuttgart 2001
Eng. Schlaich Bergermann + Parteners

- Opposing curvature
- Stressed by cable spokes



Stressed Membrane

Renaissance Center
Entrance Pavilion
Detroit 2004
SOM

- Point supported glass
- “fish belly” cable truss bacing



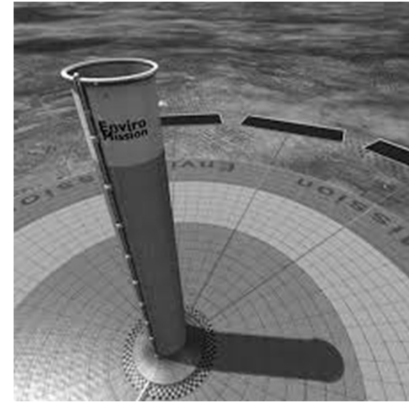
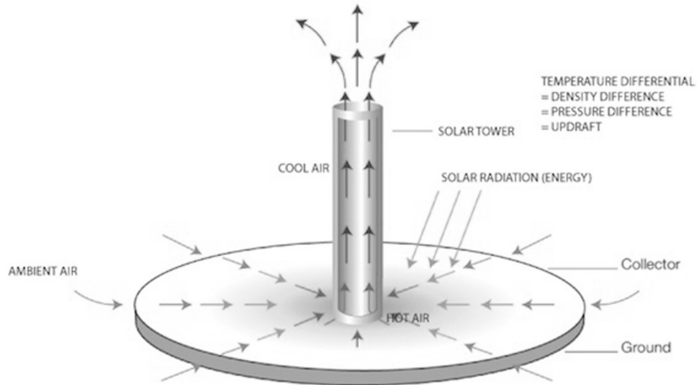
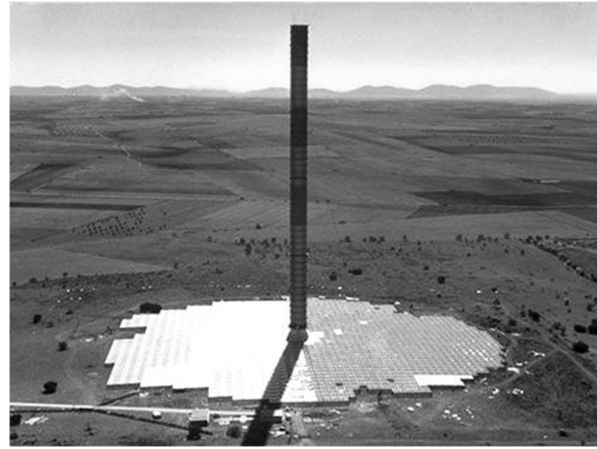
Stressed Membrane

Renaissance Center
Entrance Pavilion
Detroit 2004
SOM



Solar Towers

Enviro Mission



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Structures II

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Solar Towers



Jörg Schlaich, Updraft Solar Chimneys

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