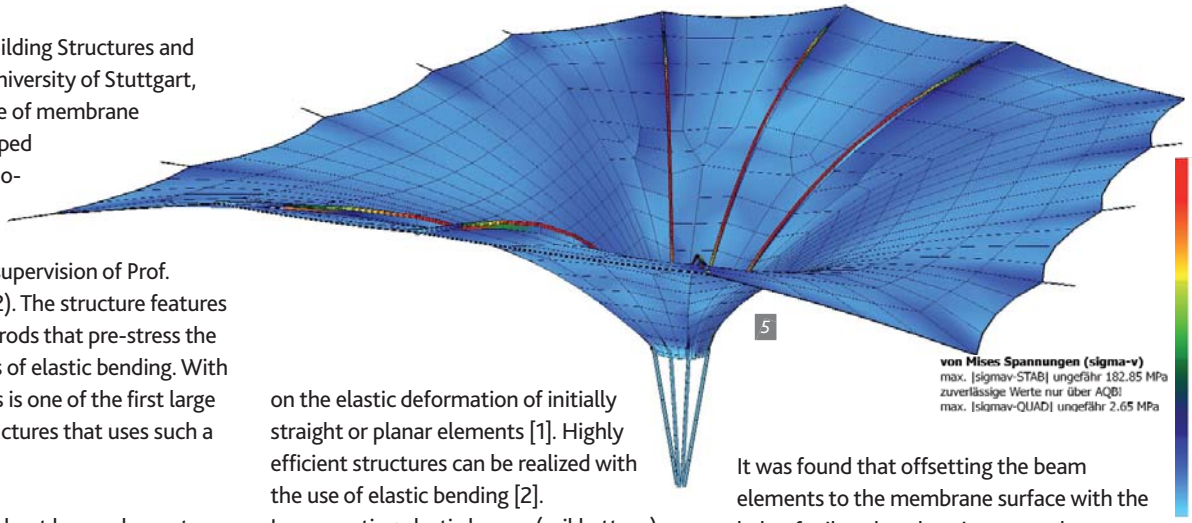
Bending-active membrane structure

At the Institute of Building Structures and Structural Design (University of Stuttgart, Germany) a new type of membrane structure was developed and realized in collaboration with students from the HFT Stuttgart under the supervision of Prof. F. Buchmann (Fig. 1-2). The structure features 7,5m long glass fibre rods that pre-stress the membrane by means of elastic bending. With a span of 11x12m this is one of the first large scale membrane structures that uses such a technique.

The use of elastically bent beam elements as intricate support system in membrane surfaces offers a great potential for new shapes and structurally highly efficient systems in mechanically pre-stressed membranes. While common camping tents have used this technique for a long time, very few membrane structures are known that use bending active support systems in larger scale. The term "bending-active" was introduced by the author to describe curved beam or surface structures that base their geometry on the elastic deformation of initially straight or planar elements [1]. Highly efficient structures can be realized with the use of elastic bending [2].
Incorporating elastic beams (sail battens) in a membrane surface enables free corners to be created which are stabilised solely by the beam which in turn is restrained by the surface. Owing to its elasticity, the beam partially adapts to the curvature of the surface, but can carry compressive forces because it is restrained against buckling by the membrane. As a result tension forces in the corners can be short cut by the beam, which leads to a significant reduction in anchoring forces of the entire membrane structure.



It was found that offsetting the beam elements to the membrane surface with the help of tailored pockets increases the structural stability. In the project shown here the pockets had a maximum offset of 12cm to the membrane surface which gradually diminished towards the corner points in order to tangentially reach the cable edge (Fig. 3).
One of the biggest challenges was the pre-stressing of the membrane; a special pulling device was built in order to connect the corner plates to the end of the glass fibre rods (Fig. 4). PTFE spray was used to reduce friction between the glass fibre rods and membrane pocked in this process.

The form-finding was realized with the finite element Software SOFISTIK which enabled a simultaneous form-finding of the pre-stressed membrane and elastically bent beams into an interdependent equilibrium system (Fig. 5). Special coupling elements where used in order to simulate the offset connection of the beam elements to the membrane surface with tangential slip.
After the successful test setup in Stuttgart (Fig. 2) the structure was mounted by students from HFTStuttgart and the ENA Morocco as a court yard shading for an architecture school in Marrakech in March 2012 (Fig. 1).

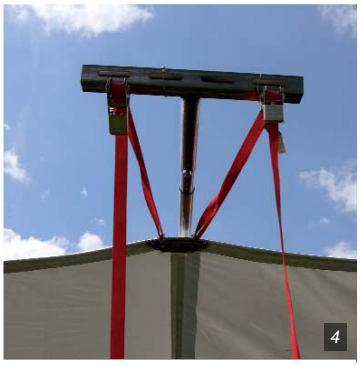


Figure 1. Court yard shading for an architecture school in Marrakech
Figure 2. General view of the bending-active membrane structure , test setup in Stuttgart
Figure 3. Detail of the corner points
Figure 4. Detail of the connection corner plates and end of glass fibre rods
Figure 5. Form-finding with the finite element Software SOFISTIK

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Reference
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[2] Simon Schleicher, Julian Lienhard, Moritz Fleischmann: Forschungspavillon ICD/ITKE - Sommer 2010, Detail online: http://www.detail.de/artikel_forchungspavillon-universitaet-stuttgart_26600_De.htm