Covering "Les Arenes de Nimes" with an air-inflated Fabric Structure

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1. Situation

In 1986, the municipal authority of Nimes considered to build a new town hall in the center of the "ville romaine". These intentions finally could not be realized because of problems with suitable sites. Besides there was no need for a town hall during summer time: The ancient arena, built nearly 2000 years ago, still is the center of the cultural life within this period. Within the last years it even became more attractive because of a number of events and activities.

Together with a team of architects, we therefore started to develop and to design a structure which should cover the central part of the arena.

2. Structure

The ancient arena is classified as a historical monument. Therefore all modifications of the existing structure have been prohibited. In addition, the designers have been asked to develop a structure which was not able to be seen from the surrounding streets, and, which has to be removed totally from the arena during summertime.

The structure therefore has been designed under the imperative of a quick annual erection and dismantling procedure. Reduction of deadload became a necessity. The design yielded to a lightweight structure which is able to be installed within 21 days, designed to withstand a windspeed of 200 km/h and able to carry a snow load of 360 to - more than twice the deadweight of the new building.

The (loadbearing) structure is composed out of 3 parts: 30 columns with a height of 9.80 m have been placed along the perimeter of an ellipse. They carry an elliptic steel-ring which is fixed excentrically onto the top of the columns. An air inflated cushion with a span of 60 x 90 m has been arranged within the ellipse defined by the ring. Fig.1.

The air inflated cushion consists out of PVC-coated PETP-fabric membranes. Several single membranes may be distinguished : The upper membrane, the lower membrane (layed onto a reinforcing cable net), the sealing membrane and the high - translucent covering membrane. Fig.2.

The upper as well as the lower membrane are edged by 30 garland cables. These cables transfer the forces from the membrane to the columns resp. the steel-ring. Therefore the steel-ring acts as a compression element. Although the ring is loaded with compression forces in the range of more than 400 tons, it could be realized as a hollow box beam with a cross-section of only 300 x 500 mm: Global stability is ensured by the cushion.

The upper and the lower membrane are connected by a so called "sealing membrane". This membrane completes the cushion. It is fixed onto the upper as well as onto the lower membrane. It may be opened along its equator using a loop-fastener, and, to ensure proper air-tightness, an additional zip.

Because the cushion is fixed onto the ring at only 30 points, a translucent "covering membrane" has been spanned from the upper membrane to the steel-ring, in order to close the eye-shaped openings.

An inclined facade spans from the upper steel-ring to a lower facade-ring. It completes the building. The facade had to be transparent because we wanted to use the ancient masonry outside the new building as a scenery. Therefore we developed a facade which consists out of about 450 hollow box beams. These beams show a rhombus-shaped cross-section, realized by 3 mm Polycarbonate-plates. An internal aluminium web reinforces the transparent beam. The beams have to carry the same severe wind and snow loading as the main structure. Therefore detailed analysis and loading tests have been carried out. They showed that the deformations of the elements still remain within the limits defined by the french building codes.

The beams can be rotated by 90 degrees around their axis. Because of their rhombus-shaped cross-section, the entire facade can be opened this way, creating a natural ventilation.

The loadbearing capacity of the cushion is guaranteed by the internal pressure. The level of the internal pressure has been defined in order to carry full snow loading resp. to avoid flattering of the fabric, even under heavy wind loading.

While the first type of loads had been defined by the French building codes, detailed wind tunnel tests have been carried out in order to obtain the most realistic wind load distribution. Studies of positive/negative pressure situations within the auditorium, caused by different opened/closed door arrangements, have completed the table of windloads finally.

Nonlinear finite element analysis has been applied to evaluate the loadbearing behaviour of the structure in detail and to confirm the choice of the levels of the air-pressure within the cushion.

The pressure within the cushion is provided by four blower units. Two of them, equipped with a sound absorbing system, are powered by electric engines. The remaining two blowers are diesel-powered. One engine is sufficient to guarantee the proper air-pressure within the cushion. An air-pressure measurements device manages the speed of the active blower. During the blowing up of the cushion (end of erection), all 4 blowers are running parallel. Caused by their huge capacity of 75 000 m^3/hour, they are able to inflate the cushion within 25 minutes.

3. <u>The Membranes</u>
All membranes are composed out of PVC-coated PETP-fabrics. This material has been chosen because of its good ability to be folded and stored each year, its high loadbearing capacity and because of the good behaviour of the material and its joints under the influence of environmental effects.

Different qualities of materials have been chosen, depending on the forces they have to carry as a structural element:

The upper membrane is a quality type GÜWA IV. Yarn is 1670 dtex, weave is P 3/3. The greycloth-weight is about 490 gr/sqm, total weight is about 1300 gr/sqm. The tensile strength is 149/128 kN/m (short term loading, 23 degrees).

The strips of the cut material have been joined using an 80 mm HF-welding and, in addition, four backstitch sewings. The entire upper membrane has a surface of about 4000 sqm.

Material tests have been carried out in order to achieve a guaranteed high level of strength of the joints. For the upper membrane, tests have been done for all types of joints at 23 and 70 degrees.

The lower membrane is a quality type GÜWA II. Yarn is 1100 dtex, weave is P 2/2. The greycloth-weight is 275 gr/sqm, total weight is 900 gr/sqm. The tensile strength is 104/116 kN/m. The single strips have been joined using an 60 mm HF-weld. The strength of the lower membrane is less then the strength of the upper one: The lower membrane is laid onto a cable net. Therefore the span of the membrane is in the range of 7 by 7 m only. The entire lower membrane with about 4000 sqm, as well as the upper one, has been delivered as one piece.

The sealing membrane also is a quality type GÜWA II. It has been fixed onto the upper resp. the lower membrane using an 60 mm HF-weld.

The translucent covering-membrane is a grid-fabric (wide-meshed fabric). Weave is L1/1, total weight is 700 gr/sqm.

Tensile strength is 40/36 kN/m. The single strips have been joined using a 40 mm HF-weld.

4. Cutting pattern

In order to realize the shape of the cushion as precise as possible, the evaluation of the cutting pattern has been done using computer-based methods.

For these procedures, the entire surface of the cushion (incl. sealing membrane) has been transfered into a digital surface model. Based on this model, the single strips of the membrane have been designed under the aspects of their maximum width and under the aspect of an optimum seam-layout.

For the upper as well as for the lower membrane, a so called "mixed-pattern" has been chosen. This means that there is a radial strip arrangement at the edges and a parallel arrangement of strips in the center area of the surfaces.

Totally, the upper membrane consists out of 144 strips with a maximum length of 84 m and a maximum width of 2.50 m. The lower membrane consists out of 140 strips, the sealing membrane is composed out of 92 strips and the translucent covering membrane consists out of 124 strips.

5. <u>List of persons and firms involved:</u>

Maitrise d'ouvrage	: Ville de Nimes
Design, analysis and detailing by architects and engineers	: LAB F AC F. Geipel, N. Michelin, Paris and Stuttgart Schlaich Bergermann und Partner, Stuttgart
Steel contractor	: Baudin Chateauneuf, Chateauneuf sur Loire, Groupement des Metalliers du Gard, Nimes
Membranes	: Stromeyer Ingenieurbau, Konstanz
Material by	: Verseidag, Krefeld Hammersteiner, Hückelhoven
Facade	: Merlo, Torino
Material by	: General Electric France, Paris
Conception of the Montage	: IF, Konstanz

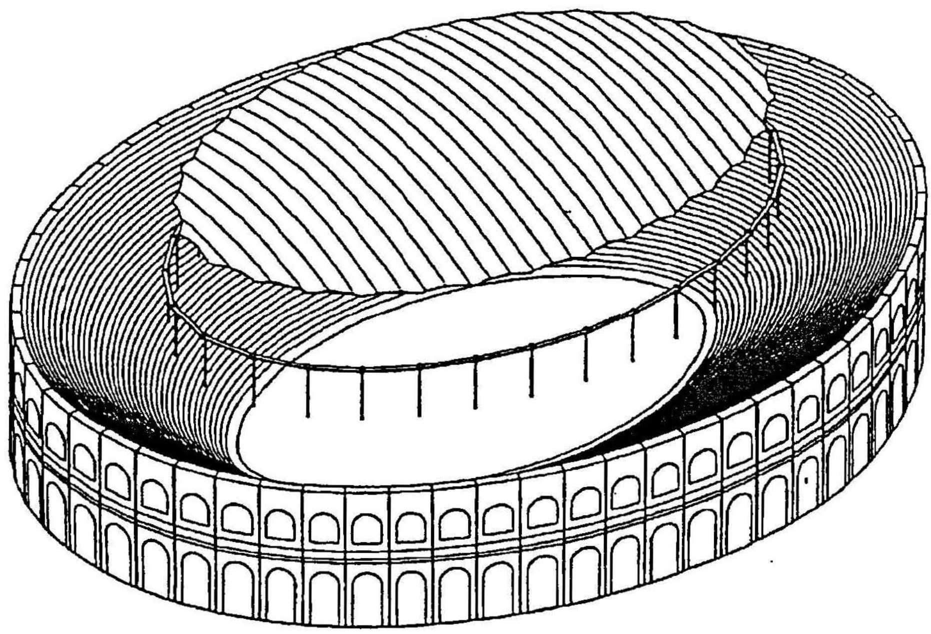

Fig. 1: The main parts of the structure

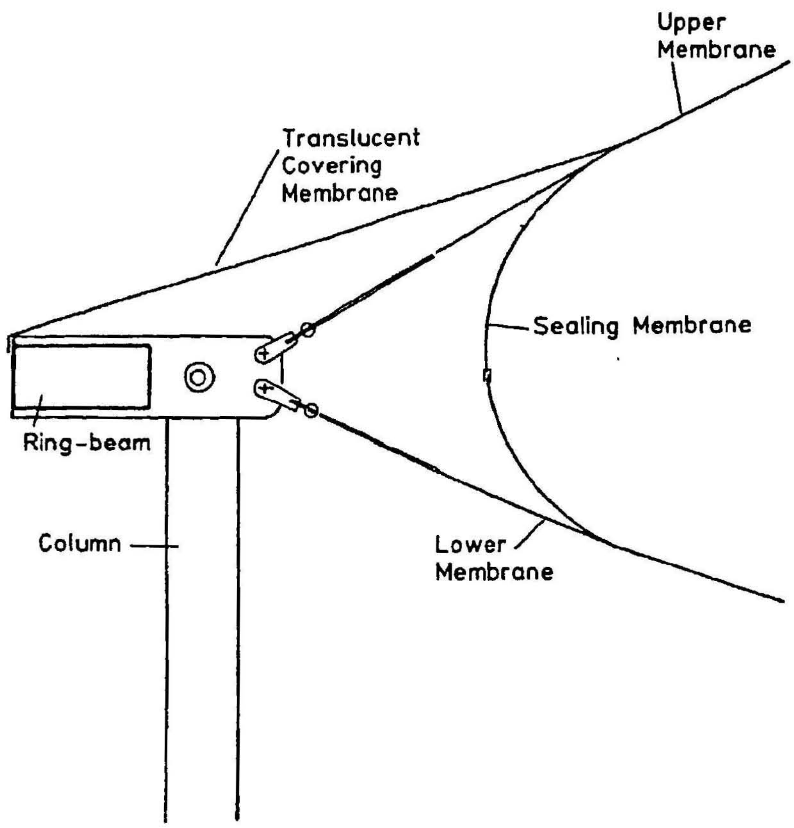

Fig. 2: Detailing of the cushion at its edge.