X International Conference on Textile Composites and Inflatable Structures
STRUCTURAL MEMBRANES 2021
K.-U.Bletzinger, E. Oñate, R. Wüchner and C. Lázaro (Eds)

SIRQUE: A NEW PERMANENT CIRCUS TENT WITH INSULATED DOUBLE LAYER MEMBRANE IN NEXON - FRANCE

NICOLAS PAULI [*†]

[*] Laboratoire Innovation Forme Architecture Milieux (LIFAM)
School of Architecture of Montpellier
ENSAM, 179 rue de l'Esperou, F-34093 Montpellier Cedex 5, France
e-mail: nicolas.pauli@montpellier.archi.fr, web page: http://www2.montpellier.archi.fr/lifam/

[†] Abaca Lightweight Structures Engineers
5 rue Marceau, 34000 Montpellier, France
e-mail: bet.abaca@wanadoo.fr - Web page: http://www.abaca-engineers.com

Key words: Double layer membrane, insulated membrane, ventilated skin, permanent circus

Summary. The paper describes the design, fabrication and erection of the permanent circus tent with rockwool isolated tensile roof of the National Circus Centre of Nexon Nouvelle Aquitaine "SIRQUE". It is installed in the national heritage site of the castel of Nexon (France).

1 INTRODUCTION

The National Circus Centre of Nexon Nouvelle Aquitaine "SIRQUE" "*Pole National des arts du cirque*" exists since 1986; the aim of the association is to organize circus events, welcome artists in creation residence and host a circus school for children. At the beginning of '80, the association used a "traditional" 4 masts circus tent (king and queen poles with a circular 13m diameter track), and install in 2001 a doubly-curved big top (4 king poles, circular cupola, and still 13m diameter track) as a permanent housing of the activities (fig. 1 and fig. 2).

Figure 1: Initial classical circus tent

Figure 2: First permanent doubly-curved circus tent

As the circus tent of 2001 year wasn't isolated and became a harmed and out of use building, the Limousin county decided to give to the SIRQUE a new permanent circus with the following up to date constrains:

- high degree of thermal control (U=0.2 W/m²K)
- high carrying load for technical/artistic devices (10 tons)
- new grandstand of 400 seats

The design of the permanent circus began in 2018 and it has been delivered in 2021. The architects designers of the project is ADH Architects, Benoite Doahzan located in Bordeaux, France. Abaca is the project engineers for the steel structures, roof membranes, tensile and steel walls, grandstands. Membrane manufacturer is VSO, Artigues près Bordeaux, France, and steelworks has been realized and installed by SIRC, Bischwiller, France.

2 CONCEPT

2.1 General concept

The size of the circus tent is 40x18m; height is 11m. The floor surface is 650sqm; 3D surface of the membrane is 1100sqm. It has a global "cylindrical" form with an end in a quarter of "sphere" (Fig. 3). Its structure is composed of 7 arches and 5 half arches made of steel. The design includes a large technical truss to be used as mother-grill.

Four opaque sky-domes are positioned at the top of the roof; they are adapted to the fire safety rules and needed for ventilation of the internal space.

The rear façade is a vertical made of vertical beam with 2 layers textile envelope.

The peripheral vertical wall of 3m.30m height, made of rigid isolated sandwich panels, closes the internal space. A truck doors h3.30m and four public doors h2.30m are designed in the walls. (Fig. 4 and fig. 5)

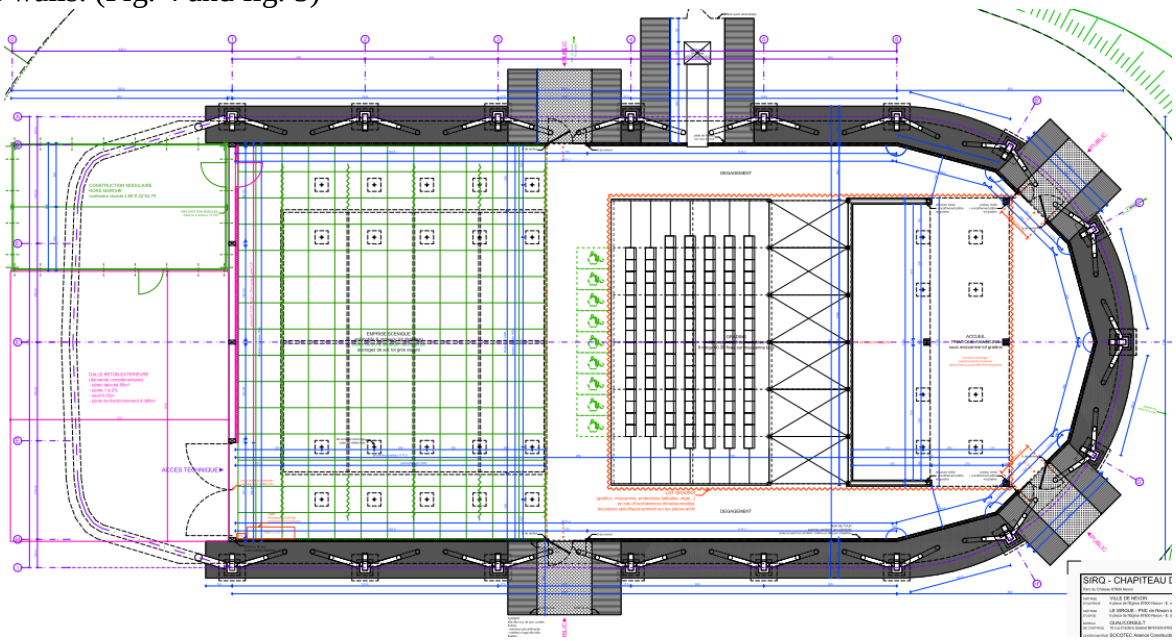

Figure 3: Ground plane of the circus tent


Figure 4 and 5: Outside views of the permanent circus tent

2.2 Isolated ventilated double skin concept

The envelop concept has been used successfully by the author for the auditorium of CIRCA in Auch city (France) [1]. It is based on the use of 2 textiles skins with a distance of 300mm, with a 140mm rockwool insulation layer (U=0.2 W/m²K) put in between, naturally laying on the internal membrane, and just maintained in place by straps.

This solution is opaque; which is acceptable for circus tent.

To avoid condensation accumulation, ventilation between the two skins has to be designed. For this purpose, venting areas has been design, according to the standard 1/500 of the surface of the panels. For the lower intake areas, a grid is disposed in the closing steel plate. For the upper exhaust areas, a textile grid is adopted at the ridge of the building (Fig. 6 in red).

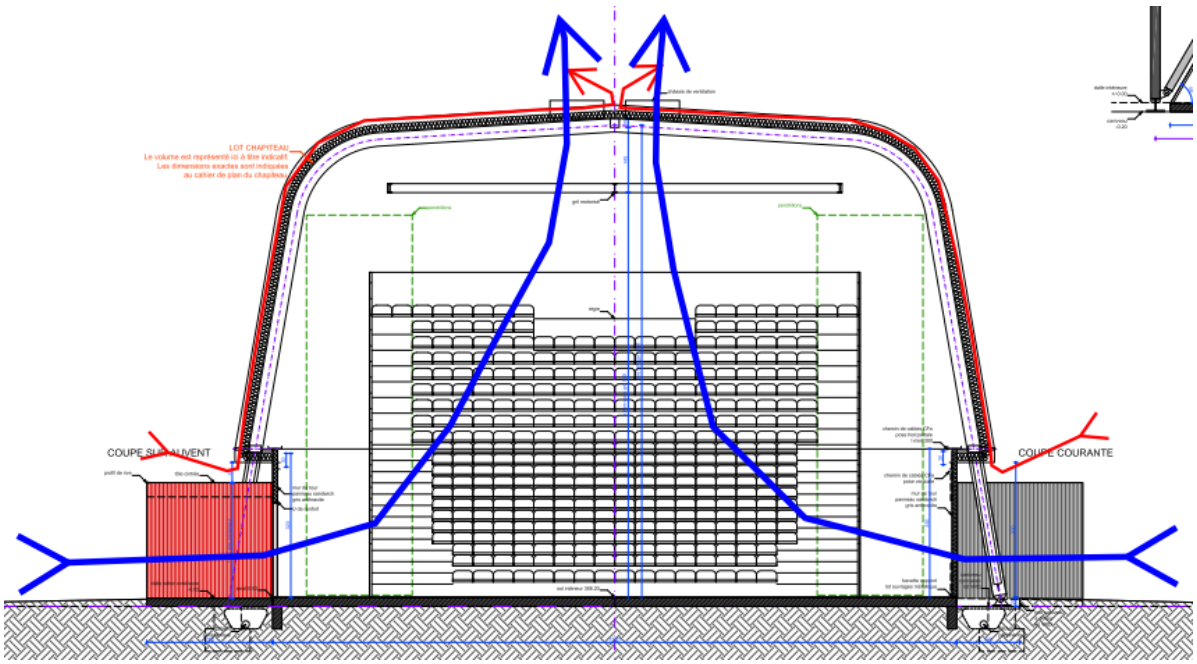

Figure 6: Ventilation for the internal space (blue) and ventilation for inter-membrane space (red)

To complete the design, the internal insulation has to be protected from the condensation droplet. For this purpose, the rookwool layer is fasten on a waterproof textile in order to drive the condensats lower thar the insulation zone.

For internal thermal control, sky-domes are used as ventilation device of the internal space slaved to the temperature and the hygrometric level measured inside the auditorium (see Fig. 6 in blue).

The used membrane are Polyester/PVC membrane from Ferrari : standard 702S opaque Grey/Black for the internal skin and standard 702S opaque Red, White or Grey for the external skin. The fabric supporting the insulation is a standard white 702S.

2.3 FormFinding, behaviour under climatic loads and cutting patterns of the membranes

The forms finding of the two membrane (Fig. 7) have been done using the Force Density Method [2] using our home made software under AutoCad_ARX.

The curvatures in each point of the membrane have been computerized to avoid any contact between the internal skin and the structure. The curvatures have been checked to remains in the standard values.

Despite the symmetry sensation, the overall surface consisting à 18 modules is made from 5 different modules (times 2 for each layer).

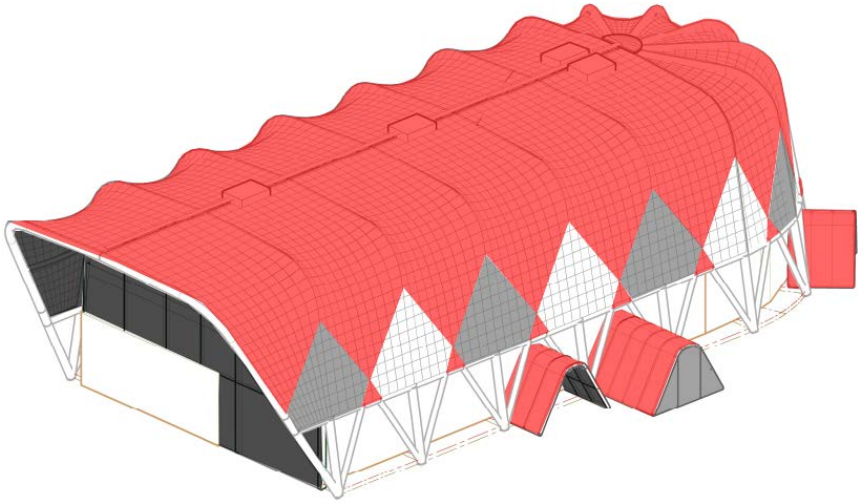

Figure 7: Form Finding of the 2 layers of the tensile skin

The behaviour analysis under climatic loads has been realized using a cable net model under Robot Structural Analysis Software (RSA) from AutoCad. The internal skin had only prestress loads with the own weight of the insulation. The external membrane has been loaded with required climatic load extract from Eurocode 1 and its French Annexes. The anchoring loads have been gathered and applied in another model of the steel structure; they have been also sorted for the dimensioning of the steel connecting parts.

The cutting patterns have been realized using our home made software under AUtoCad_ARX. Beyond the classical 3D->2D projection, our tools allow to adopt and control the reductions and compensations to take into account to avoid wrinkles. 28 different panels for internal layer and 40 different panels for external layer were needed to realize the whole skins. Data's have been transferred numerically to manufacturer for automatic cutting under Lectra Systems.

3 DETAILING

3.1 Lacing devices

The membranes are laced all along their peripheral edges on upper (h11.00m) and lower (h3.30m) tensioning beams upon a 33mm diam hollow section (Fig 8 and 9). A lacing tube level is corresponding to the inner membrane; and 300mm higher, another lacing tube level corresponds to external membrane

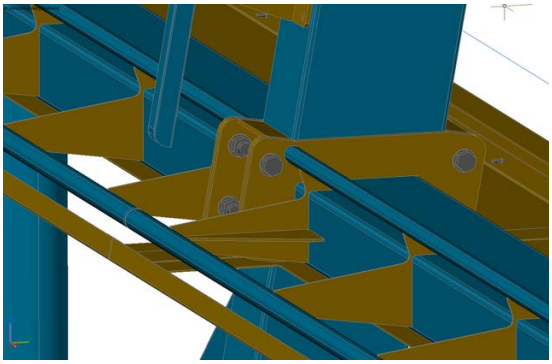

Figure 8: Lower lacing tubes

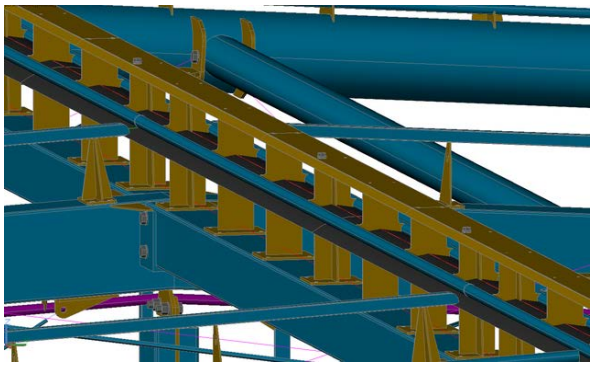

Figure 9 : Upper lacing tubes

3.2 An internal membrane realized in one piece

In order to avoid moisture pass through from the inside of the building into the rockwool, the internal skin has to be perfectly waterproof. Thus, the internal membrane is realized in 1 piece of 1100sqm creating a watertight barrier between in and out. (Fig. 10 and 11).

Figure 10: View of the steel frame

Figure 11 : First layer memb. during installing (Video caption)

3.3 Spacers for the isolated layer

Lacing pipes for insulation and external membrane are then fastened (screwed) upon the steel frames after the first membrane is placed. A Neoprene join is place between each steel plate of the spacer on the frame to control the passage of water vapour (Fig. 12).

The insulation is realized with a 140mm Rockwool fastened upon a 750g/sqm PES/PVC membrane. To ensure the waterproofing of the textile support, a specific bolting system has been developed and successfully tested (Fig. 13).

The supporting panels and the rockwool panels have been cut according the 3D geometry, as the internal or external membranes. Fitting devices have been added to allow regular fastening on the arches steel pipes (see Fig. 12).

A drainage collector, welded upon the isolated layer, can collect residual condensation when appears, and allowing evaporation during day, with the help of (1) at the bottom, a perforated sheet of metal and (2) at the top, Ferrari grid fabric FT381

Fig 12: View of the spacers and isolated layer of membrane

Figure 13: Tensile insulation support: large prototype and water tightness testing of the bolts

3.4 Outer membrane in 3 large pieces

For the outer membrane, a 702 Ferrari finalize the complex, managing a 10cm space with the isolated layer and a venting zone in the upper part to allow air circulation and avoid condensation flows (Fig. 14, 15 and 16).

Fig 14: View of the third layer during installing (video caption)

Fig 15: Upper venting grid (Membrane FT381 Ferrari)

Fig 16: Lower venting grid (steel)

4 CONCLUSION

The proposed paper describes the design, the fabrication and erection of an isolated double layer textile envelope, with steel frame. The key lines of the design are underlined, such as :

- the spacer between the two layer
- the natural venting system between layers,
- the waterproofing of the rockwool support.

All the other skills are part of the well-known knowledges on tensile architecture.

As a result, the building can house, in a very qualitative way, various events, from circus shows to musical concerts, passing through the purpose of the client with the children and non-professional practices (fig 17)

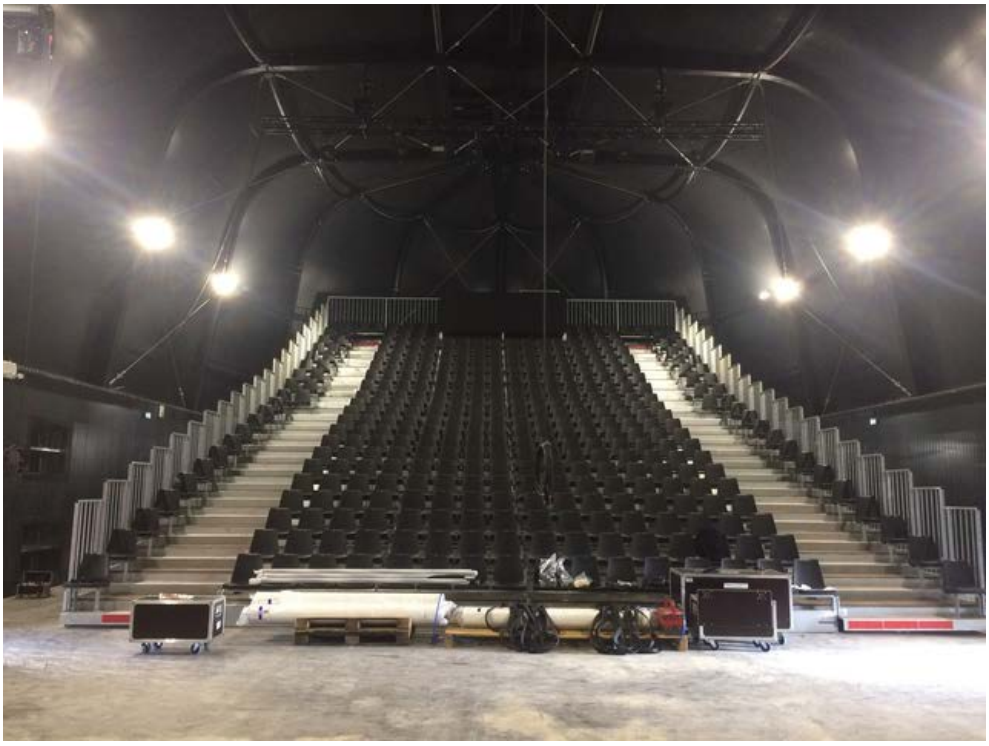

Fig 17 : Inside view of the permanent circus tent

REFERENCES

[1] N. Pauli, *Insulated double layer membrane for auditorium*. Proc. Int. Conf. Structural Membranes 2015 - Textile composites and inflatable structures VI", in Conference ECCOMAS, Barcelone, 2015, pp484-494

[2] H.-J. Schek, *The force density method for form finding and computation of general networks*, Comput. Methods Appl. Mech. Eng., vol. 3, no. 1, pp. 115–134, Jan. 1974.