KEY WORDS: Temporary, Tensairity, air supported, optimized structure.

SUMMARY. For an around-the-world traveling pavilion, designed by Silvain Dubuisson Architecte, Tentech engineered a light weight roof structure based on the so-called Tensairity principle, commissioned by Buitink Technology and Highpoint Structures. Rhino's Grasshopper was used as a a starting-point for form-generation and engineering and greatly eased the process to create workshop drawings and patterning of the fabric.

1 THE PROJECT

The roof structure is part of the main pavilion for exposition WAVE, organized by BNP Paris-Bas, starting in Parc de la Villette, Paris. The exposition shows people dealing with current challenges around the world. Economic, social en environmental themes are approached with a multitude of initiatives and a collective ingenuity. They prove that solution exist. All these people share the same positive and innovative attitude creating new economic movements, such as sharing-economy, co-creation, the maker movement, the inclusive economy, and the circular economy.

In his design and materialization, architect Silvain Dubuission, aimed to reflect the enthusiasm, experimentally and fluidity of these movements. He uses a collage of materials, geometries and techniques. A simple wooden floor, stainless cladding and the inflated UFO-shaped roof based on a meandering torus, a central sphere and a membrane stretched between the torus and levitated by the central sphere.

The geometry of the project was well defined by the architect. The concept of the torus, the central sphere, dimensions and materialization as well as the wish to use an inflated structure to magnify the unconventional and temporary image.

Beginning the engineering process, the design was rationalized using Rhino's Grasshopper and slightly twitched to create a more stable and feasible shape. The initially arbitrary shape became a clearly defined geometry described with few parameters. During the further process, the Grasshopper model could be altered to create structural data, patterning data and workshop drawings.
The structure of the roof works as a tensile compression ring; the torus works as the compression ring for the membrane. Tensairity appeared convenient to increase the buckling of the torus.

2 TENSAIRITY

Tensairity is a term noted by Pedretti and Luchsinger. The term is a combination of tension, air and integrity and reflects the relationship with tensegrity. It's a method to create inflated structural elements, with a relatively low air pressure. A tensairity beam can be considered an underslung cable beam. In an underslung cable beam the horizontal tension and compression elements are separated and pushed apart by vertical pressure elements. In Tensairity, the vertical pressure elements are replaced by air pressure. The horizontal tension and compression elements are maintained. In 2009 Wever and Luchsinger demonstrated the lower horizontal tension element, the underslung cable, could be replaced with a mesh fabric and demonstrated the increased buckling resistance of the concept.
Experience with Tensairity for Tentech was gained in 2012 with the engineering of a large shelter for events, commissioned by Buitink Technology, in cooperation with ABT. A design with eight spindle shaped Tensairity beam, and with membranes stretched in between.
3 STRUCTURAL CONCEPT

The structural system works as a tensile compression ring. The donuts spread the roof membrane and the central sphere’s pressure controls its tension. Both donuts and sphere are supported by columns.

The compression ring is built from the three Tensairity elements, a pressure element in the top, the fabric web and air pressure. The roof membrane is attached to the top of the torus, the horizontal force in this point is transferred to a steel pressure ring which in its turn is stabilized by the pressurised air beam, increasing the buckling resistance of the complete beam.

Inside the air beam, a second steel beam is placed in the bottom. This beam does not have the function to increase the torus' capacity, but to distribute the point loads of twelve supporting columns. The two steel beams are also starting-points during the assembly of the structure. The torus is built from two separate membranes, the inside and outside, and are joined along the upper and lower steel beam. The air tightness is achieved by stacking rubber and PE strips, bolted together.

4 STATICAL ANALYSIS

The statical analysis is performed with the program EASYBEAM combined with the closed volume module EASYVOL (Technet GmbH, Berlin). To analyse the full behaviour of the structure, both the supporting structure and the torus-roofstructure were modelled.
To prevent bending moments in the supporting structure caused by the horizontal stabilizing forces, it is chosen to use wind bracings. It was relatively easy to mask the wind bracings within the carpentry sidewalls. Figure 5 shows in blue all the compression elements; in red the wind bracings and supporting cables for the central column are shown.

The central column also functions as an axis. The tension cables attached to the central column can be seen as spokes that transfer by tension the horizontal forces from the one side of the structure to the other side. By doing this, the forces are equally spread over the whole structure. Moreover it stabilizes the central column in case of emergency.

An equal distribution of the forces inside the structure was necessary because of the way the foundation was made. Since it has to be a demountable and relocatable pavilion, the foundation and floor system is based on weight. The floor itself is build up out of steel profiles and at specific spots, concrete plates (Stelcon plates) of 2 x 2m are inserted in the floor system. They are even shown to the audience since the architect wanted to express a certain ‘under construction’ atmosphere. And because it is possible to obtain Stelcon plates (or similar) all over the world, it is not necessary to transport the Stelcon plates but they can be purchased on site.
5 CONCLUSION

The Inno-wave-tion project shows us Tensairity is a feasible method of constructing temporary structure and the use of Rhino’s Grasshopper eases the engineering process of such structures. The combination of Tensairity and Grasshopper has revealed a new path of building striking new shapes.

6 REFERENCES


Figure 7: Flooring system with location of concrete plates