VI International Conference on Textile Composites and Inflatable Structures
STRUCTURAL MEMBRANES 2013
K.-U.Bletzinger, B. Kröplin and E. Oñate (Eds)

CENTRAL COURTYARD COVER DEPARTMENTAL EDUCATIONAL INSTITUTION ENRIQUE PARDO PARRA

S. GONZALEZ*, J. GONZALEZ* AND N. TORRES†

* AR KLEING. Ingenieros, Ltda.
C/62 No. 26 - 10 Off. 202. Bogotá, Colombia
Email: kleincolombia@gmail.com - Web page: http://www.kleincubrimientosespeciales.com

† PhD. Student UPC
Universidad Politécnica de Cataluña. Barcelona Tech
C / Pere Serra, 1-15 08173. Barcelona, Spain
e-mail: natalia.paola.torres@estudiant.upc.edu

Key words: Courtyard, cover, forming process, tensile structure, membrane, assembly.

Summary. The following proposal for a “tensile structure” is originated by the need to generate a better use of the central courtyard of the school Enrique Pardo Parra, by using a textile cover which protects the 700 students from the sun and rain in recreational and cultural events. Project development must consider a number of demands given by the existing building and the climatic conditions of the place. The end result is a symmetric membrane, inspired by the logo of the character "Batman" with independent masts arranged symmetrically ground articulated with different lengths corresponding to the proposed architecture and geometry of the membrane. This paper presents the design experience starting from the initial approach to the constructive concept, analyzing the different aspects of design, installation steps, and final construction, using resources such as models, digital models, functional prototypes, which complemented the development of construction details , the pattern and assembly strategy for the structure.

1 INTRODUCTION

Departmental Educational Institution Enrique Pardo Parra, located in the town of Cota 26 km from Bogotá, Colombia invited in 2012 several proponents for design and construction. AR KLEIN ENGINEERS LTD, is hired by one of the proponents to execute the design of a lightweight cover for your central courtyard with the aim of creating a covered space outside the classroom to protect them from the rain and high temperatures and to allow the realization of cultural and sporting events, regardless of the prevailing weather.

The school has no indoor sports areas, theatres or additional facilities for these activities and could not afford within its budget to build a sports centre or additional building conventional for this type of event. The College has generated a central courtyard cloister spatial configuration, which is used to propose a cover from a tensile structure that would allow height variability, not darken the atmosphere and the approach of few supporting elements unlike other structural proposals raised.

Figure 1: Air photography. Central courtyard uncovered and covered

Once the site of implantation of the deck was defined, there were some school characteristics, design determinants generated by the existing construction and climatic conditions of the place. In this direction one of the first limitations was that the tensile structure proposal was not supposed to be supported to the existing school building, because the building's maintenance report to date, had found some cases of fissuring in the main structure from reinforced concrete frames covered with masonry, and a worsen condition was not desired. For this reason, we proposed a completely independent structure to the structure of the school, using the outside area to locate the anchor masts and cables tensile structure.

The shape definition should take into account the climatic conditions of the place. Cota's population has long record rainy seasons ranging from three to four months of winter season, with frequent hailstorms. This determines the importance of the geometry of the membrane for proper water drainage and prevents rain water damming on canvas, plus all this cross winds from the middle mountain in great force winds blast.

2 FINDING THE FORM

2.1 Design concept

The architectural image that is achieved starts from a striking idea that was appealing to the students. The membrane shape is inspired by the logo of the character "Batman", getting in the front view image of the superhero symbol. This image was considered close to the emotions of students, differentiating their school, compared to some others in the region with one similar to the very students of this age, something furtive, yet attractive.

The designer wanted to give the impression of movement of its "wings", at a time when the wind passes through the deck. Inside, the intention was to link the classroom spaces, and show it more like a sports arena, since within the same construction there will be spaces for reading and reflection.

Figure 2: Scale models inspired by the logo "Batman"

Based on this concept, layouts and models made to scale were performed to see the first approaches to the definition of the form, inclinations and location points of the support structure. It tries to choose the direction of escape of water and the height of the masts central to shaping the final form.

2.2 Definition of the form

The nominal area to be covered corresponds to the central square of the campus with dimensions of 32 x 30 meters. Digital modeling is done through Rhino Membrane software design always retrofitted with physical modeling; both were indispensable tools for the conceptual design of the tensile structure.

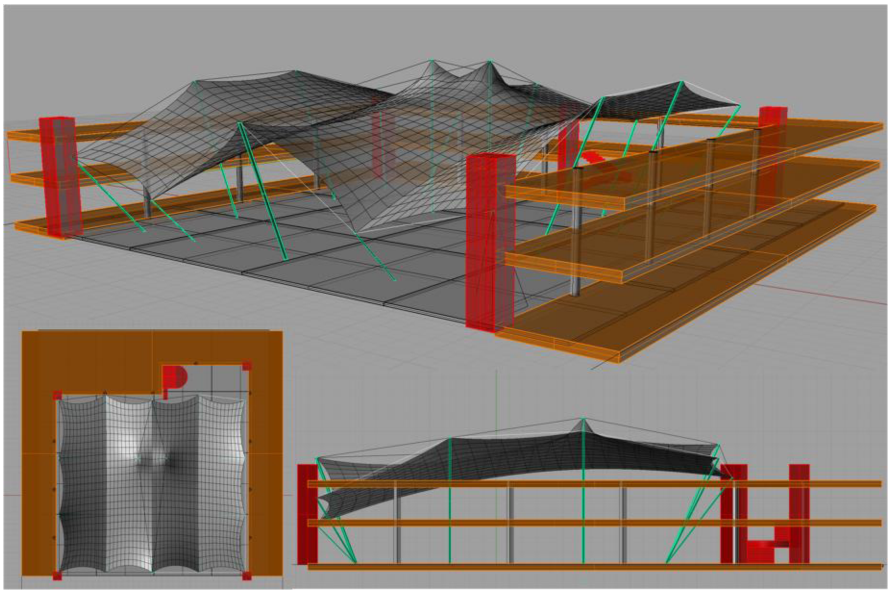

Figure 3: Definition of form. Rhino Membrane software

One of the main challenges in the search process was to define the height of the two central masts that simulated the bat ears. There, the membrane generates a cone shape in each of these high masts. The definition of the shape at these points needed to achieve a proportionate height for geometry and space to cover, where an architectural use was intended for different sports activities and likewise maintain the architectural set. Cones finally lowered enough to have an adequate safety factor in the stresses produced by its own shape and not significantly affect the initial geometry of the membrane.

The result from a top view is almost a square, symmetrical elevation with two high points in the center amounting shaped cones and variable height lows distributed on the perimeter of the membrane, achieving a maximum height of 12 meters and a minimum height of 3 meters.

3 STRUCTURAL BEHAVIOR

Continuing the calculation step, we analyzed the structural behavior of the tensile structure under different external loads software platform MPanel Meliar Desing. At this stage it was very important to define the wind profiles and the loads generated pressure and suction. As the deck is immersed in the heart of the school, the wind profiles could be very erratic especially in wind directions SE - NW so there were several models to account for this effect.

The loads generated by rain and hail, and their combinations, showed possible sites where the fabric was a little strained and clothing effect could generate wrinkles.

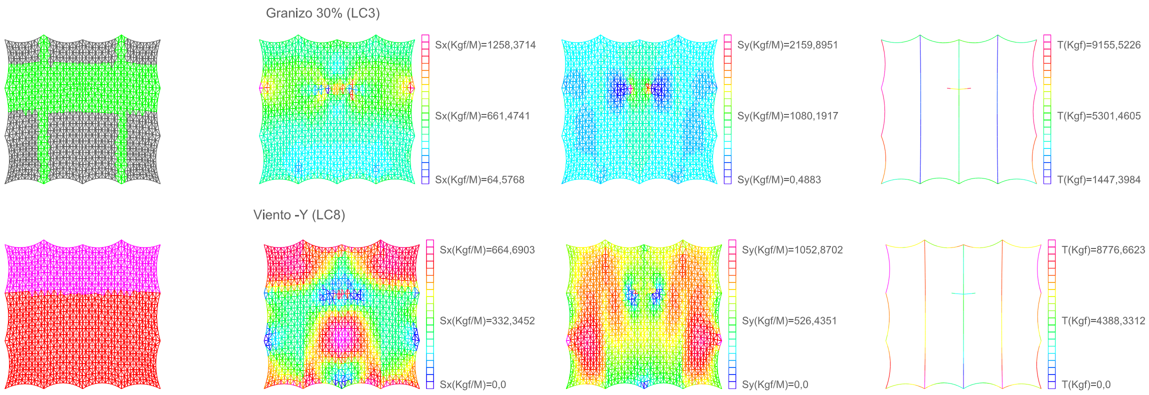

Figure 4: Analysis of structural behavior under loads of wind, rain and hail

The work was very thorough and required several geometric adaptations, prioritizing the prestressed cables that stress the structure, on the slopes and at the height structural elements to achieve a satisfactory deformation response. Parabolic profiles were initially used in the fabric, so that the weighing cable that would go on these profiles could have a catenary consistent, not too deep nor too smooth. Stressing a fraction of the load that can endure, you got a very suggestive and "pre-stressed" the whole deck. For wind suction, this weighing cable, would take most stresses produced by the suction, while the others would take the inverted efforts by effect of the pressure, leaving this cable only its initial pretension. Also as mentioned above, the cones' heights were modified on efforts to try and prevent over-stress to the fabric and finally achieve a good balanced structure.

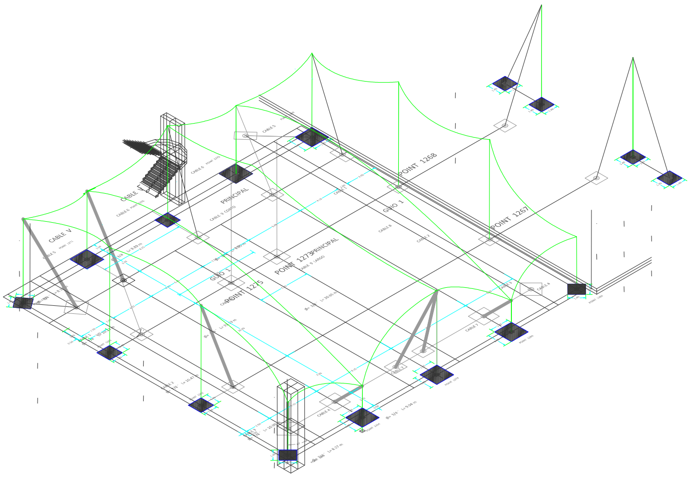

Figure 5: Isometric. Main structure, masts and cables

4 PATTERN

The Membrane area of 1100 m². The decision to define how many patterns and dimensions conformed the membrane was taken from the process of assembly and transportation of the structure, based on a model made 1:10 scale, which facilitated the understanding of many construction details and the thinking about the mounting strategy. It was clear that by the dimensions of the pedestrian entrances of the school, it was impossible to use a crane for lifting PH membrane. For this reason, the membrane is divided transversely into two equal parts, to facilitate the lifting of the same structure with a limited workforce and mechanical equipment that could enter the access in question. Once the two sections are reinforced membranes, bind both sides, before the elevation through a rack.

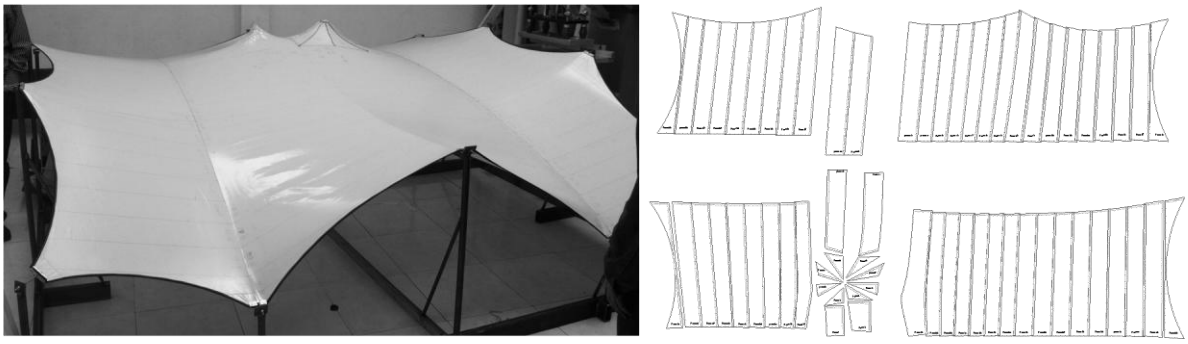

Figure 6: 1:10 scale model. Observation and analysis of pattern for the cones

A total of 64 patterns set with a between width of 1.10 -1.30 meters and 8 meters of lengths longer. Each of the strips of the membrane was sealed according to industry standards with sealing width is 5 cm.

5 STRUCTURE AND MATERIALS

A supporting structure was chosen of steel pipes. The membrane is supported in total by 17 structural steel tubular masts with diameter of10 - 15 inches with varying lengths depending on the design requirement, having masts to a height of 12m and a minimum height of 3m.

The foundation includes reinforced concrete footings, setting the mast to the shoe, fixed initially proposed (without the possibility of rotation) with steel bolts and nuts, while performing the lift and shape of the supporting structure in cables. And then subsequently to expand the covers bolts are removed some prevent rotation and the support is articulated. The wires are of SAE 1070 steel with 6 strands of 19 wires each RRW accordance with standard 410D in diameters of 3/4 to 1 ½ inch.

The base membrane material is polyester yarn coated with a high strength polymer layer. (PVC) Ferrari. Across the membrane is made of a single type of material and of the same series. The membrane will warp and weft stability, tensile strength (warp / weft) greater than or equal to 420/400 daN/5cm, tear resistance greater than 55/50 daN, with a grip 12 daN / 5 cm, the coating thickness of at least 200 microns and 100% recyclable.

Figure 7: Front and inside of the structure

6 MANUFACTURING AND ASSEMBLY

In charge of the company ARTE Y DISEÑO HAWAR S.A. with Quality control from JAM ENGINEERING, SAS has specialized machinery to cut and paste membranes, along with the expertise in mounting this type of structure. The work done to them was constant feed back to devise the best installation strategy, taking into account not only a crane PH could not access the installation site, if not by the size of the income and the type of floor was difficult access for smaller cranes. Once ready, the foundation and the anchors of the masts, the filament and the support structure tied to the steel cables, so that the steel cable structure is now able to withstand lifting of the cover through the same support structure and additional cables. Assembly is done in the morning when there is less wind has low speed and scheduled holiday season to avoid the presence of the student community in the area.

The membrane reaches the mounting place divided into two equal parts, located in its preliminary position, proceeds to join the two parts of the membrane on the ground through the zip fastening system. Together the two sides begin to raise the membrane from the center through the central mast. Funky first rises and extends the left side of the membrane while the right side of timber such that the structure has no asymmetric loads. It was very important to understand the assembly process, to define the best pattern, and decide correctly in many parts divided the membrane, since parties have split over the membrane, the assembly process had more complications at the time of lifting these sections. This way installation coordination was made easier by dividing the membrane into two sections alone to avoid unions that might make mounting a headache caused by asymmetric deformations.

The membrane is stretched as it rises through the external wires and the positioning of the masts. Tightening the perimeter cables is performed in several stages in all lights. The cable length paraboloid is performed accurately in respect to the geometrical shape of the membrane. The structure reaches its final position after thirteen days of installation, additional cables are secured on a single network, subject to the upper deck of the masts and make sure the bolts and nuts so that the structure is stable and secure. The structure was designed to fail membrane, leaving no trace structure of local or general failure. Finally, we take appropriate security measures to visualize tensioner's cables that reach the floor, and have additional structures for the management of rain water flow.

The images below illustrate the assembly process more clearly:

Figure 8: Assembly process structure, masts, anchor plates and cables

Figure 9: Membrane elevation process

Figure 20: Positioning the membrane anchor points, tensioning end

12 CONCLUSIONS

- The main defining feature of this project is dynamics of supported cables that carry the prestressed cables that stress the structure, ensuring the stability of the structure at the time of additional loads.
- It is a self-supporting structure that does not affect existing school building. Thus takes advantage of the outdoor area to locate the main structure based on poles and tensioning cables.
- The architectural image is achieved satisfactory structural lightness and nice architectural space for institutional use, inspired by the wings of the bat symbol character from "Batman". The proposal meets the objective being a lightweight shell, which darkened the central square and to provide students and teachers a useful area for conducting sports and cultural events, protected from rain and sun.
- During the design and structural calculations were definitive analysis of wind profiles and the upper cone geometry to achieve a balance and structure that was not about struggling, achieving proper slopes without affecting the architectural image.
- The overall design lasted a total of five months; two months organized in architectural design and structural calculation, and three months the manufacturing and assembly process. This structure was a good experience to propose structures for the development of recreational and educational activities taking advantage of open spaces and present in the type of faculty, very common in Latin America, and with

limited budget to build conventional structures with the same result.

Figure 3: Central courtyard cover Departmental Educational Institution Enrique Pardo Parra

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