VIII International Conference on Textile Composites and Inflatable Structures
STRUCTURAL MEMBRANES 2017
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IMPORTANCE OF THE CONTEXT FOR THE DESIGN OF THE MEMBRANE STRUCTURES

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Key words: ETFE cushion, PTFE membrane, PVC membrane.

Summary. This work underlines the importance of the context for the design of membrane structures. There are many aspects that can influence the design and it is difficult to summarize all of them in few points, especially because structural membranes are mainly chosen by clients and architects because of their capability to reach shapes and limits that other structural types are not able to.

However, three main aspects should always be considered while designing a membrane structure: shape, environment and installation. The architects, designers and engineers mainly focalize their attention in one of them together with others like: light, space, structure, ecc., but I believe that these aspects need to be always simultaneously evaluated. The shape is important following the architectural signature and the aesthetical result. The second aspect, environment, can be considered as: natural environment (respect of the Nature), architectural environment (harmony with the existing surrounding), and comfort environment (respect of the comfort for the users). The third aspect that is frequently neglected or underestimated on earlier design stages is the method of installation and how this can influence the result of the final structure.

In order to exemplify each of the three mentioned aspects, this work presents three different membrane projects executed by Taiyo Europe. In these three projects, each one of the mentioned aspects was particularly emphasized. The first project, where the shape aspect was particularly important, is the ETFE skylight of the Podium Zaha Hadid realized in Milano (Italy). The second one, where the environment was prevalent, is the PTFE roof covering the prehistorical temple of Tarxien (Malta). The third one is the Cardo and Decumano PVC structure realized for Milano Expo 2015, in this project the installation method was essential once several different structures were being simultaneously executed in a very narrow space.

By these examples this work emphasizes the importance of carefully assessing that the shape, environment and installation conditions during the entire develop of a membrane structure.

1 INTRODUCTION

Membrane structures are well known for its ability to span large distances in a structurally efficient and lightweight manner, simultaneously offering a large array of shapes, visual and architectural effects which no other material could efficiently provide (Figure 1 and Figure 2).

Figure 1: Millennium Dome Greenwich, London (UK), PTFE coated fiberglass fabric, completed in 1998.

Figure 2: Municipal Waste Management Department parking cover, Munich (Germany), triple layer ETFE cushions incorporated with photovoltaic cells, completed in 2011.

The design of such systems is however a complex procedure, consisting on an iterative assessment of different aspects related to the structure; e.g. the intended shape and the loading criteria must be concomitantly analyzed, as the flexibility of the structure also means that applied loads impact the shape; the location where the structure will be installed influence the installation methodology, which in turns may (both) affect the shape.

The design process of a membrane structure may include the following tasks: conceptual design; physical modelling; computer modelling; form finding; analysis; fabrication design and cutting pattern generation; installation design; and maintenance concept.

As a successful journey starts with making a first step on the right direction, following it will be further explored the importance of a holistic approach during the concept design.

2 CONCEPTUAL DESIGN OF MEMBRANE STRUCTURES

The conceptual design usually commences with an intent and a sketch developed by the creator (usually represented by the architect). This intent provides the basis for the following conceptual design, which includes tasks such as material selection identification, form finding, environmental impact, comfort assessment, preliminary installation concept and a cost-benefit analysis.

Several contextual dimensions in which the membrane structure is inserted impact the conceptual design. This work focus will further assess three of them: the shape desired; the environment in which the structure will be implemented; and the future installation context.

3 SHAPE

Architects and designers are often looking for a type of material that can be as much versatile as possible in order to follow the desired shapes that, most of the time, are their brand of identification.

This was the case of the podium in CityLife Milano, where the archistar Zaha Hadid has the necessity to create a skylight on the podium of her tower in order to spread the sun light inside the shopping center. She was also looking for a material able to be transparent and light because the almost 200 m tower above the podium had to be visible from inside and the steel structure should not be dominating. Moreover, the solution had to be thermal insulated in order to guarantee the inner comfort and, especially, had to follow the rotundity of the building. The membrane structure, in this such case the ETFE, is the perfect material that can reply to all these requirements, especially when it is used as multilayer cushions able to have thermal and optical proprieties similar to the glass, but with a self-weight that is practically neglectable.

The main shape of the roof was identified by 16 different beams each one realized by two straight segments connected by an arch, this geometry, that can appear simple, is however quite complicate to obtain because the convexity of the arch is going against the natural shape of inner layer, so only with an accurate form finding and the proper cutting pattern it is possible to reach this required result.

Figure 3: Top view of the CityLife Zaha Hadid's podium.

Figure 4: Top view of the ETFE skylight.

Figure 5: Inner view of the ETFE skylight.

4 ENVIRONMENT

The environment is the second point here analyzed; in the last period, this is becoming one of the key point regarding the choice of the materials and the architectural and static solutions. The environmental aspects can be studied from multiple points especially because many disciplines are including them in their studies. Here below it is possible to find three of these aspects especially related to our project realized in Malta for the archeologic site of Tarxien.

4.1 Natural environment

The Megalithic Temples of Tarxien was accepted as a UNESCO World Heritage site in 1992 and soon was clear to the Heritage Malta that the limestone used to realize the temples were slowly but inexorably deteriorate by the UV radius and the rain. It was therefore necessary to

cover the 3000 m^2 site with a structure able to have the biggest span and the lowest number of supports in order to be as less invasive as possible and to preserve the rest of the finds not yet discovered and safeguarded them for the next generations.

Also in this case a membrane structure is used, particularly a fiberglass PTFE that, because of its neglectable self-weight and high resistance, can be supported only by two steel arches with a span of 70 m.

Figure 6: View of the PTFE roof from outside (Tarxien temple site)

4.2 Architectural Environment

To protect the archeologic site was mandatory, but on the same time it was necessary to find a solution harmoniously inserted in the architectural environment of the city of Tarxien. It is why the total height of the structure was imposed by the municipality, and the modern shape of the new structure had to be in harmony with the shape of the existing surrounding buildings.

Figure 7: Top view (of the Tarxien temples site).

4.3 Comfort environment

The site is receiving almost 65.000 people per year and normally the peak of the visits is during summer time, it is why the choice of the PTFE membrane was dictated also by the necessity to have a product able to stop the sun radiation but not the translucency in fact, this kind of material is able to block almost the entire part of the UV light spectrum but about the 12% of the visible light is still passing through it. This means that the prehistorical finds and visitors even if with a comfortable light, they are not exposed to the direct energy of the sun.

Figure 8: View of the PTFE roof from inside.

5 INSTALLATION

When everything is design by the Architects and Engineers, there can be a last aspect that can call into question the entire project if it was not properly considered, this is the installation methodology. Most of the time, the membrane structures are used to cover huge surfaces, cantilevers or spans, and these can be translated with the necessity to adopt heavy equipment or a numerous team that need space and a proper time and sequence to complete the work.

The job site of the Milano Expo 2015 was particularly indicative from this point of view, in fact in the last months, almost 6.500 laborers were working in the entire area and almost all of them need to pass along the Cardo and Decumano streets to reach their pavilions. On the same time, our team was occupied to install 2.900 ton of steel and 65.000 m^2 of PVC canopy to cover the Cardo and Decumano.

Figure 9: Top view of the Decumano.

The method of installation had to consider that the 14 m height columns had to be installed without using the surface dedicated for the pavilions jobsites, this means that only the surface of the Cardo and the Decumano with their 35m width can be used, but on the same time it was possible to close these streets only for few hours in order to permit the flow of the other workers.

Considering these restrains, the entire structure was designed in order to be lifted in the quickest way: the columns were fixed on the base with a hinge connection and between them with an upper support and lower tension cables connected by hangers.

Figure 10: View of the crossing between Cardo and Decumano

All the expedients studied during the design phase permitted to install one complete modulus composed by about 90 ton of steel and 2.000 m^2 of membrane in less than one week, and the 5 axes of columns where lifted in less than 5 hours.

This kind of result is possible to reach only with the proper knowledge of an experience company, otherwise this last step of the project, if not proper studied and developed, can be extremely demanding especially from the financial point of view.

Figure 11: View of the Decumano during installation

6 CONCLUSIONS

By the three-example illustrated here above, it is clear and evident how the described aspects: shape, environment and installation are mutually and simultaneously important during the design of a membrane structure. It is also important to note that none of these aspects can be neglected, for instance, the Tarxien project was used in this article to focalize the environment,

but the shape of this structure was likewise important during the design in order to respect the landscape restrains, and the installation aspect were likewise important because the existing archeological finds cannot be touched.

The same mutual connection between shape, environment and installation can be found in the Zaha Hadid and Milano Expo projects and, in general, in all the projects related to the membrane structures.

Although not complete and exhaustive, this work brings an awareness to the importance of a holistic understanding and assessment on the different dimensions involved on the design of a tensile structure.

Moreover, it also emphasizes the importance of bringing to the team an specialist in implementing such membrane structures in an early stage, ensuring to the best the right first steps towards the successful execution of the structure

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