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Ephemeral tensile structure: Membrane House

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Abstract

This paper discusses the Membrane House as a small-scale prototype of tensile structures. It is born for the need of establishing long-term shelters in the worrying current situation with regard to contingency resources. It is a very versatile prototype working as social space and it offers many functions for inhabiting. It won the first prize at eme3 "Contingency and Praxis" competition at November 2016 (Figure 1). Its ephemeral condition responds to the necessity to ease its transportation and assembly by using a construction solution based on integrity and coherence and following principles of low-tech manufacturing. The stretched fabric is combined with elongated timber sections working under compression, and conveys stability to the inner structure. The geometry of the prototype is composed of hexagonal and pentagonal modules, offering the space a character that combines spatiality of the dome and functionality of the vault. This paper describes the Membrane House design process, the tools used for its design and its complete structural development. The authorship of the prototype belongs to LHRC architects collective, which the author of the paper is part of and with whom she works on research and different projects of similar concerns and principles. This prototype contributes to tensile structures development, being part of the new contemporary architectural social paradigm and finding its own morphology and beauty following the logic of loads in tensile structures, as well as offering an efficient response in optimizing its construction materials to its full potential with low market cost.

Keywords

Prototype, Shelter, Tensile structure, Membrane, Low-tech manufacturing.

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Introduction

Tensile fabric membrane structures have geometric shapes generated by a tensioned equilibrium. This makes to define them as natural structures, as they are governed by the structural principles found in nature (Casiopea). They are structures generated by systems of linear loads of compression and tension. Structure and form are intimately linked. The curvature of the shape in tensile membranes provides structural stability and higher stiffness. In these structures the membrane has an important structural function. It is the element that works in tension together with the cables of the system, while there is a support structure of rigid timbers that works under compression. The complementation of these loads generates a state of equilibrium (Bögle, *et al.*, 2003). This balanced system provides stability that, combined with the lightness of the structure, leads to very attractive architecture. These characteristics of simplicity and efficiency have been translated into a very beautiful aesthetic product that offers a functional response to the needs of the contemporary urban scene (Pinto, 2012). It is presented as an alternative to the architecture of last decades, being much more coherent, respectful and contextualized (Ishii, 1999).

What makes a big difference in how we create architecture in respect to the traditional way of design is that the morphology, or form, of this prototype is defined during the process and not predetermined. Actually, it is an undertaking to reach the state of balance in the system of elements that conform the structure by modifying parameters according to design requirements. What is exciting about this design process is the result of a maximum structural efficiency, the perfect state of equilibrium, the maximum utilization of the material properties of each element and its maximum exploited potential, therefore there is no excess or missing element, when we obtain the final form (Carrió, 1991). These shapes are generated using self-training processes (invented by Frei Otto in the new school of design in the 50's) and based on the concept of "minimum surfaces". They are defined by having the smallest surface and they require the least amount of potential energy due to their shape within a given set of "boundaries". Their main feature is that they have a uniform distribution of loads everywhere (Otto, 1969).

The shape that a tensile structure adopts is not given by geometric considerations as regulated surfaces, but by the equilibrium position reached by the tensile fabric as a result of its internal forces, external live loads (like wind and snow) and edge constraints given by the support structure. There are different methods of form-finding, but they can be divided in two: numerical or analog-physical. At the beginning of textile architecture, hand models were used during the process of design and even today they are still very useful tools for design, although there is lack of precision to facilitate the intuitive understanding of the designer. Frei Otto proposed a physical analogy method with soap bubbles based on the principles of superficial tensions of water. Even though they act as uniform tensions, they behave facing the equilibrium of tensions similarly to a textile surface in a state of tension. Then the edges of these bubbles were built with thread or wire to obtain geometric shapes with soap (Figure 2).

Another analog method on the search of forms is based on models made of elastic fabrics, which reproduce forms of equilibrium, when they are subjected to tensile efforts similarly to those that would generate a structure on true scale. Some of the advantages of this method are: The curvature is better controlled, products can be applied to stiffen or increase the curvature locally, and they work very well for data gathering destined to the cut of patterns. Nevertheless, this process is done with much more precision nowadays thanks to WinTess3 software (Figure 3).

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In the case of the Membrane House, this second analog-physical method is applied. The manufacture of a model was the origin of the form found, the support to find that morphology was used as well to understand the structural operation of the system. A model was made of wooden sticks and articulated nodes that allowed length variations on the sticks that conformed the structure. Then the lycra fabric provided rigidity to the set generating the form to work on later. After drawing the support structure in 3D with Autocad and Rhinoceros, the surface that covers this structure (the membrane) was subjected to analysis with WinTess3 and through this calculation was verified that the system was in stable equilibrium.

Once this process of form-finding has been completed, we proceed to define the materiality of the set, seeking only homogeneous construction solutions and using nearby material resources. We work under principles of low-tech architecture, which means recognition of techniques and construction materials of the past, in order to maintain the current efficiency of the building in the future, while keeping in mind the environmental impact derived from the activity (Huelva). It arises from a way of making architecture according to the environment, based on structural and material efficiency, which generates functional solutions with great aesthetic appeal. Because the beauty of forms is nothing more than the consonance of human perception with a morphology that establishes a clear analogy with nature. These forms that are defined by themselves and are found directly in the process of design, are pure natural forms. The human eye identifies them as a beautiful result. In this way the conjunction of simplicity, efficiency, functionality, beauty and temporary nature adapted to the use, leads to results of design, which will generate a new paradigm in current architecture (Cirugeda, 2007) (Figure 4).

Figure 1.
Membrane House at eme3 "Contingency and Praxis" competition in November 2016

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Figure 2.
A method based on a physical analogy with soap bubbles, proposed by Frei Otto

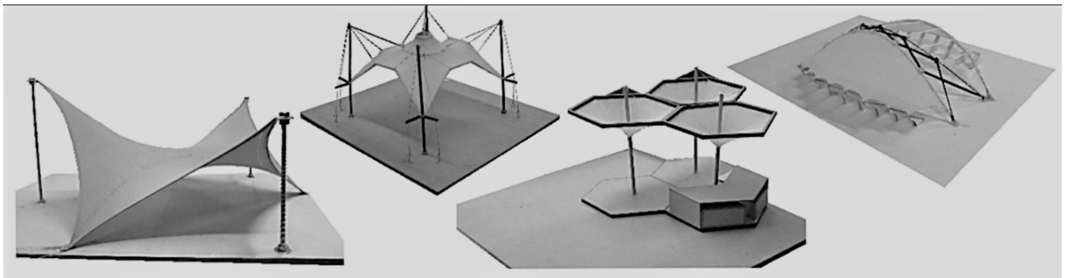

Figure 3.
Models made of elastic fabrics

Figure 4.
MH won the first prize at eme3 "Contingency and Praxis" competition
Picture by Simon García ARQFOTO

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Description of the Prototype

Designed as a Refuge

The Membrane-House was born in response to the necessity of long-term shelters in the current refugee crisis given that in many worrisome cases, life on refugee camps continues for years. Facing these facts, the refuge must not restrict itself exclusively to serving contingency, but based on its ephemeral condition, it should facilitate life and bring back to the users a space, where they can develop their cultural habits and to which they have been forced to renounce (Figure 5).

It was designed for the eme3 "Contingency and Praxis" competition, under conditions of concrete volume and functionality. The volume should not exceed a surface of 2x3 m in plan, being able to expand by 50 cm on all its perimeter without touching the ground, and being able to reach a maximum height of 4 m. The triangulated geometry allows to optimize the space, providing a maximum capacity of interior space and adjusting itself to these dimensions. The functional requirements respond to the ease of transportation and the speed of assembly, as well as provide a suitable space to be used in refugee camps, where conditions are already so hostile to the inhabitants, and improve the quality of life in them (Willemin, 2004).

A membrane is applied with structural and enclosure functions and works as wall and ceiling offering thermal protection, insulation and privacy. Linked to a simple timber structure based on the geodesic dome principle, it modifies its form to adapt to a daily use and terrains of different characteristics. The tensioned fabric is combined with timber elements that work in compression to give rise to an efficient structure that optimizes to the maximum its materials with low market cost (Figure 6).

Morphology and Structure

The Membrane House is a prototype, whose geometry corresponds to the triangulation of a regular geodesic dome that works through compression of the timber sections, which compose the support structure. It is stabilized by a tensile membrane linked to all the joints (nodes) of the structure and makes it work as unique structural system. The membrane is made up of triangular patterns according to the triangulation of the structural timber sections and it has the strength and lightness adapted to the rest of the structure.

The primary structure has three timber sections (S, M, L) that form the morphology of the Membrane House, which is symmetrical, with respect to the longitudinal axis. It does not complete the symmetry with respect to the transverse axis, because of the existence of an access point where the door timber profiles have special dimensions. The timber sections used for the construction of the Membrane House are included in Table 1 and shown in Figure 7.

The Membrane-House structure is designed to persist. It is made up of 84 structural timber sections of pine wood treated for outdoor application, with an estimated life of 15 years, and a tensile membrane with insulation and waterproofing coating. The combination of these two elements, wood and membrane, in addition to triangulation, give high rigidity to the whole. By means of the tensegrity principle, the compression of the wood is combined with the tension of the fabric. Both elements need each other to consolidate the shape of the prototype. The combination of hexagonal and pentagonal modules confers to the space certain longitudinality, remaining halfway between the

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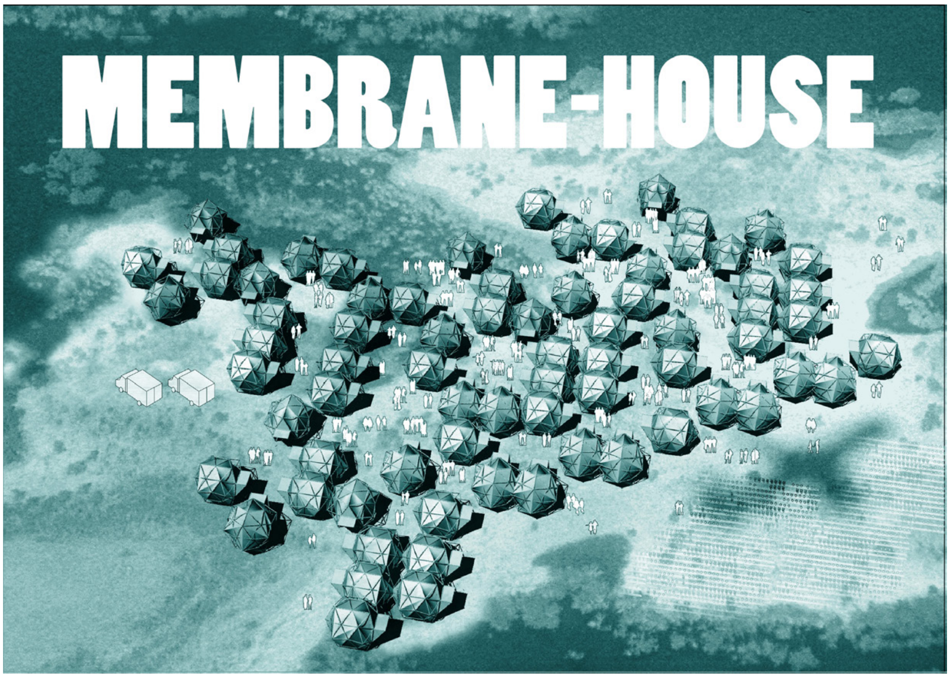

Figure 5.
Membrane House as emergency shelter

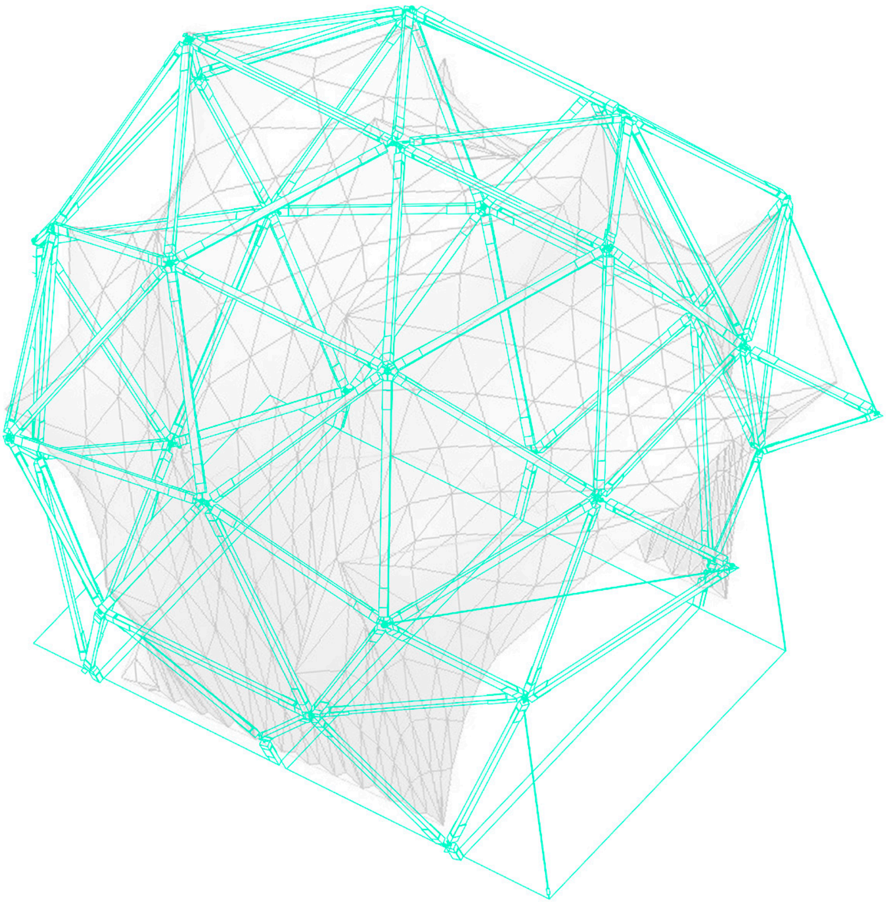

Figure 6.
The tensioned fabric is combined with timber members that work in compression

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Figure 7.
Types of timbers and assembly process

Table 1.
Timber sections implemented for the construction of the Membrane House

Type of timber	Original size (cm) section 40x40 mm	Enlarged length (cm) and reduced section to 36x36 mm	Quantity
XS / XL (door)	80 /160	88 / 168	2 / 2
S1	106	114	8
S2	111	119	4
S3	98	106	4
M / MH	118	125 / 129	50 / 6
L1	124	132	4
L2	126	134	4

spatiality of the dome and the functionality of the vault.

As the timber sections are connected to each other, the structure could collapse in different directions, but in this case, the membrane linked to the nodes confers the required stability to reach the equilibrium position. In fact, the membrane was calculated and designed for this position and it was created in parallel to the timber sections' configuration. Therefore, the assembly must just follow this notion of complementarity between compressed and tensioned elements. This implies that the membrane needed to be anchored to the timber framework nodes, while it was built.

The whole structure rests on a wooden base designed according to the given dimensions (2x3 m) with seven anchoring points, where the structure is fixed and supported. These points are solved in construction with similar details as to the construction details designed for the nodes, for maintaining the integrity and construction coherence of the whole system (Figure 8).

Functionality

The prototype is designed to be assembled in a short period of time and to be transported easily, since only two of its pieces (XL for the door) are 1.40 m long, while the fabric is transported in folded position. The design also allows to replace pieces separately, if one of them

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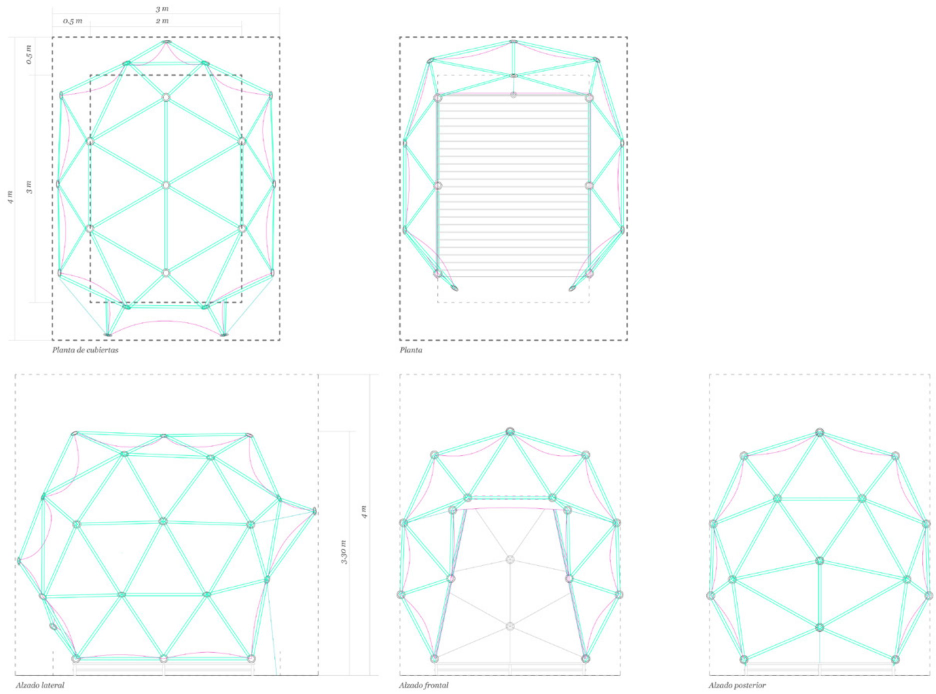

Figure 8.
Membrane House drawings

is damaged during its operational life, while being able to last several years.

The refuge is conceived as a unit within larger groups, offering the possibility to include both private and public spaces. Therefore, a different way of approaching emergency architecture is suggested: instead of generating large public spaces divided later by their users, it offers to start from a smaller module that can work as a "room", "living room", "workshop", or "shower". The neutrality of the given space allows to host different functions that, articulated together, form a whole living area. To carry out a variety of activities, different artifacts could be arranged hanging from the structure, allowing diverse situations: double heights, furniture, water tanks, storage spaces, etc. Actually, during the 5 months that the prototype has been exhibited next to the M.A.C.B.A in Barcelona, it has been used for leisure activities and events such as concerts, music sessions, activities for children, workshops, showing its versatility as a social space, which offers a variety of functions, when the prototype is not inhabited (Figure 9).

Design process

Physical model and virtual model

The design process begins with the most traditional method of form-finding, that of hand models. The node is designed with flexible materials, in order to observe the variation of the morphology of the structure through the relative position of the angles formed between the linear elements that correspond to the structure. The length of the elements can change according to the position of equilibrium offering different sizes of timber sections in a simple way (inserting them closer or further from the node) to reach the ideal position. Once this flexible structure is found, it is stable, because the nodes block any movement. Then the fabric (represented as lycra in the model) is placed joining all its vertices from the inside and forming a surface in homogeneous tension that makes the structure rigid, while also complemented by the compression of the timber sections (Figure 10).

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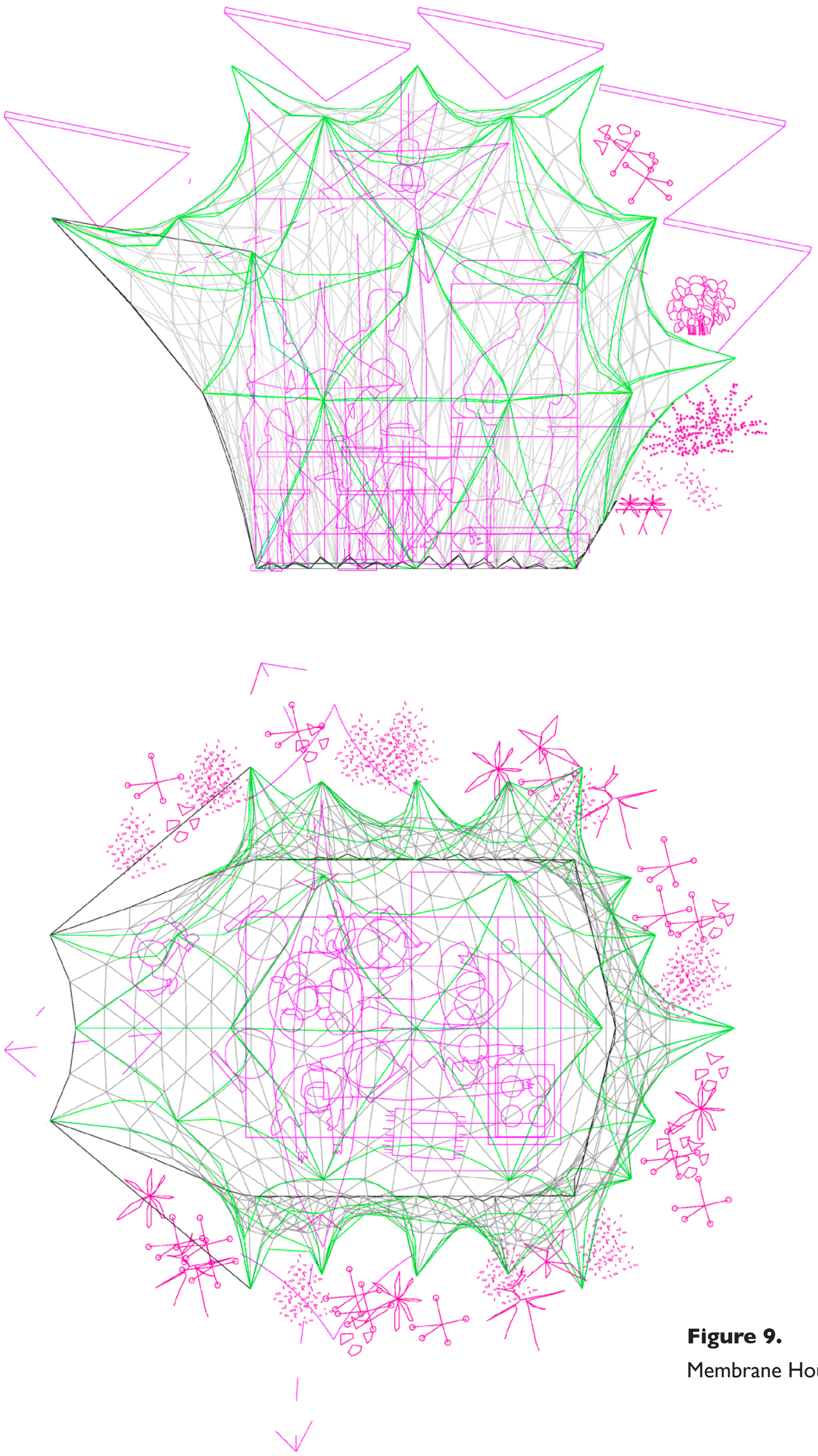

Figure 9.
Membrane House functionality

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Once the scaled model is made, the found shape is transferred to the digital model. The plans are drawn in Autocad and the 3d model of the structural timber sections' framework is made in Rhinoceros, from where we extract the dimensions of the elements with precision. Then by using this digital model we proceed to calculate the textile membrane with Wintess 3 (WinTess3). The calculation made using this program is explained on the third point of this section.

Construction Details

We focus in every point of the structure, where a constructiion detail has to be solved and we seek to obtain a constructional homogeneity that gives coherence to the whole system. The materials used for the Membrane House are timber and fabric, elements that work very well with the cables, anchors and metal nodes.

- The nodes of the structure are the connection points of the timber sections that correspond to the triangulated framework and the vertices of the membrane. Therefore the nodes work as articulations between the timber sections exerting tension in the same direction as the membranes, perpendicularly to the direction of their free movement.
- The structure is connected to the base at seven points that are fixed to the perimeter edge beams, in every corner and in the middle of the three sides excluding the entrance. These points are free of movement on the vertical plane (rotation from the anchoring point at 180 ° in positive) but not on the horizontal plane.
- The seam of the patterns has in some sections a pronounced curve, which requires precise sewing. Therefore, it is made a single line of seam is waterproof, resists the tension of the membranes and guarantees durability of the prototype.

Under these conditions, an efficient solution is established being affordable for quick assembly. The assembly has been made by hands, not necessarily qualified. The materials can be easily obtained in the market, optimizing the resources and the construction impact, while following a "low-tech" philosophy (Figure 11).

The structure works under the principle of tensegrity, as an open system that has to be affixed to a base to reach equilibrium (Oliveira Pauletti, 2011). This base is formed by a wooden perimeter that is divided in six pieces, two of 2.30 m in the crosswise sides and another four of 1.65 m that are composed two by two in the longitudinal sides of 3.30 m. The base imposes a fixed settling to the ground in one position. The weight of this perimeter edge beams with the wooden flooring provide adequate stability to the system, without the need of concrete or fundations, and it can adapt to different ground conditions. The perimeter edge beam supports five beams in crosswise position, where the wooden flooring rests, offering a cozy and multifunctional floor in line with the esthetic set of the Membrane House.

Calculation

Once the model of the support structure is drawn in Autocad and Rhinoceros 3d, unifying the dimensions of the timber sections, the framework is exported in dxf as auxiliary lines to proceed to the analysis of the membrane. This process is carried out thanks to the program WinTess3, which works in three different phases: form-finding, calculation of the structure and pattern design of the fabric (Foster and Mollaert, 2009).

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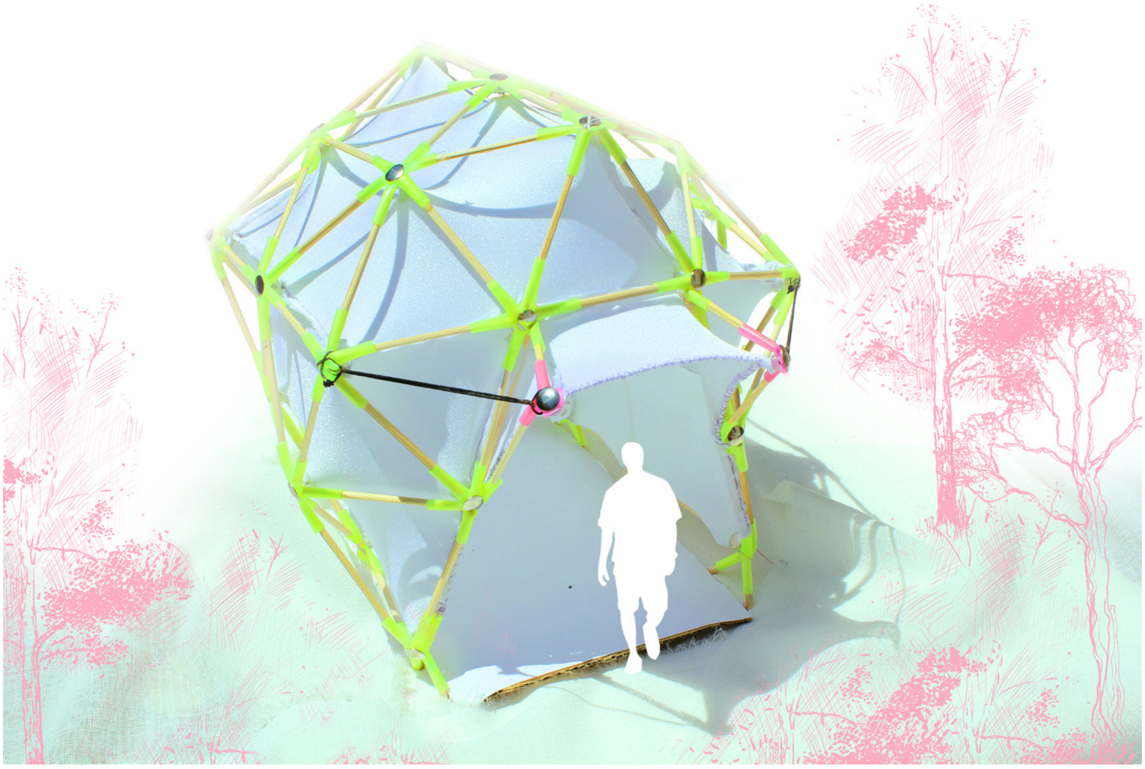

Figure 10.
Hand model

- Form-finding: We start the design of the mesh, establishing its characteristics of geometry and density, using in this case triangular divisions and an adequate density according to the scale of the prototype. Then we export the auxiliary lines from the geometry to represent the support structure and we decide about its connection points to the mesh. We introduce in WinTess3 the position of these points, as well as the mechanical properties of the selected fabric for the construction. The program creates with this information the shape of the membrane under the established conditions. The curvature of the lines of the surface can be controlled making it more or less accentuated. This means that we decide about the tension to which these edge lines will be subjected. In reality, these lines could be headlines, or as it is in this case, the seams between patterns of a tensile surface (Figure 12).

- Calculation of the structure: WinTess3 uses the matrix method to analyze tensile structures made of bars that are understood as linear elements that can support different stresses. To analyze the membrane the program decomposes the mesh that has been described in the previous phase. In this phase of calculation, working already on the found shape, we apply the wind and snow loads to which the structure will be subjected, in order to find the equilibrium state of the system. Following this we can define already the auxiliary cables of the structure, the dimension of the elements that compose it and the efforts that are generated in the mooring to the base. Then we use this data to define the construction details (Figure 13).

- Membrane pattern design: To design the double-curvature surface, it is necessary to join patterns obtained from a flat membrane that is served in rolls of 180 cm width. In this phase, the aesthetic quality

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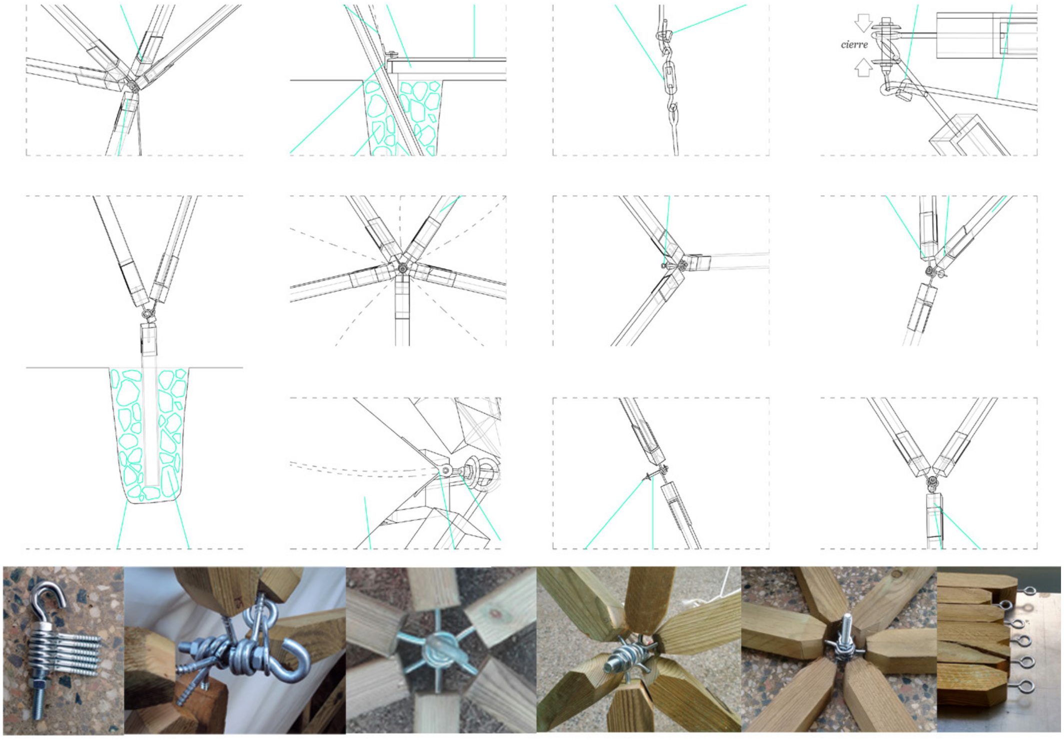

Figure 11.
Construction details

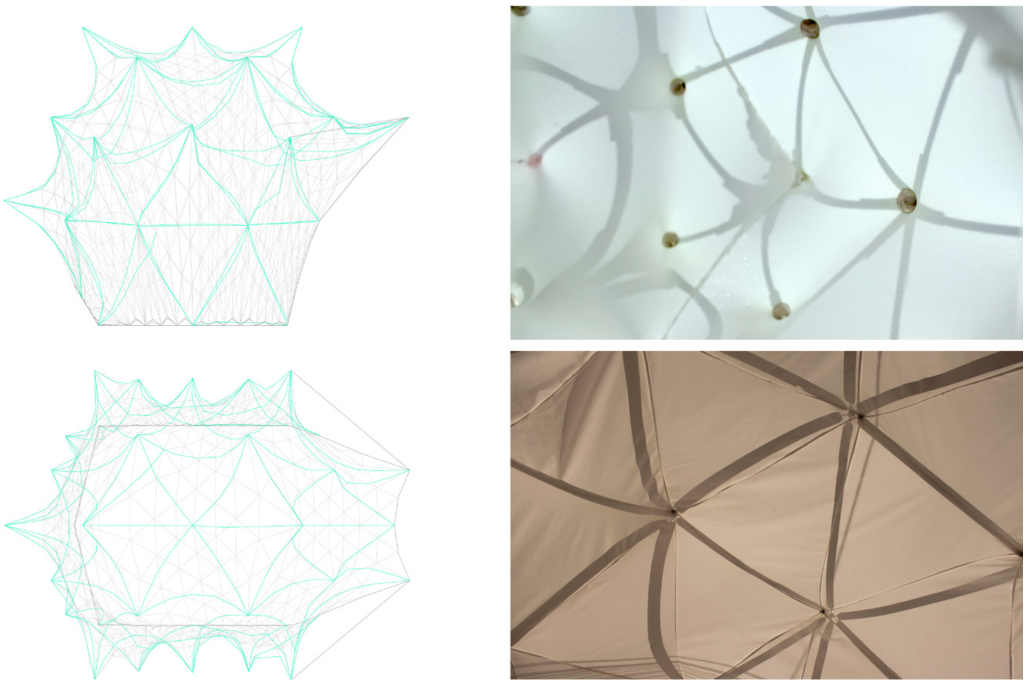

Figure 12.
Membrane House morphology; hand model membrane and real membrane

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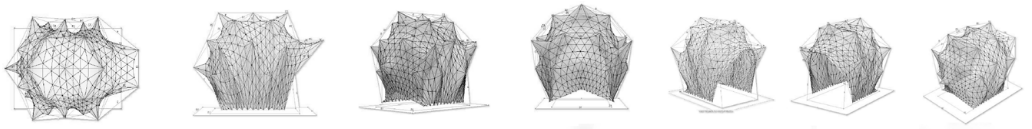

Figure 13.
Structural analysis

of the tensile membrane depends on how this process is carried out and even the structural behavior can be affected by this process. The main requirement on the pattern design phase is that the seams of the pattern and their connection points should follow the geodesic lines of the double-curvature surface of the membrane. Once these points are fixed and the direction of the surface is given, the next step is to draw those geodesic lines extracted from the surface and define them geometrically as the shortest lines lying on a given surface and connecting two given points. In the case of the Membrane House these geodesic lines are drawn by making the triangulation of the surface and using a logic that follows the geometric scheme of the structural timber sections. From these lines that define the perimeter of the modules we proceed to design the patterns. There are several methods to generate patterns, in this case the most appropriated method is to draw triangles out of diagonal lines that connect the internal points of the geodesic lines. For more precision, we decide to use small size triangles according to the already determined appropriate density. Once all the patterns have been designed, they have to be placed on the blueprint taking into account the roll width and the offset needed for sewing, which is to be of a single seam line. Being a symmetrical prototype, the half part is made and the other half is inverted. The pattern for the lower flap that closes the membrane with the base is drawn separately, and the respective construction details are solved in all areas where necessary. This information and the membrane rolls are given to the company that carries out the garment-making. To join the patterns, nowadays welding with high frequency could be applied, although these could also be joined through gluing or sewing, even if they are not widely used. For this prototype, it was decided for the sewing method, because the patterns have very curved sides and the unit would need to be composed of very short segments. This would suppose an effort and an increase of cost for this process that is not in accordance with principles raised in the design and general assembly process of the prototype. It is established that the simple seam has a durability guarantee according to the rest of the structure (Figure 14).

Implementation / Construction Process

After performing isolated tests for every single detail to check the operation of the elements, the construction process begins with the collecting of the material for the structure. The pieces of wood are obtained at the Vivre en Bois (Granollers) and we cut, sand and prepare the ones which form the triangulated structure and those that make up the base. A textile architecture company called TP Arquitectura Textil for the garment-making and the details of the membrane are solved in certain areas, such as the lower flap, the door and the buttonholes that allow the function of the detail of the node. The patterns already drawn and worked on Autocad are sent to the company once exported from the calculation in WinTess3.

The material used for the membrane (Tejera Parra, 2011; Rogier and Orpana 2000) (membrane model: Precontraint 502 Satin in white) was donated by the textile fabric manufacturer company Serge Ferrari. This material has very good durability (more than 15 years for which the wood is treated), low maintenance and appropriate translucency and tensile strength for this commitment (Figure 15).

After cutting the wood for the structural timber sections to a 40x40 mm, and making them sharper at the end to fit in the nodes, the ends are drilled with holes that are smaller in diameter than the eyebolts placed on these ends. Two types of eyebolts are used in the connection of the vertices, some of them with open head (like a hook) for are the ones that join the timber sections in the node and are placed with the head looking to the inside, and those with closed head, which cross

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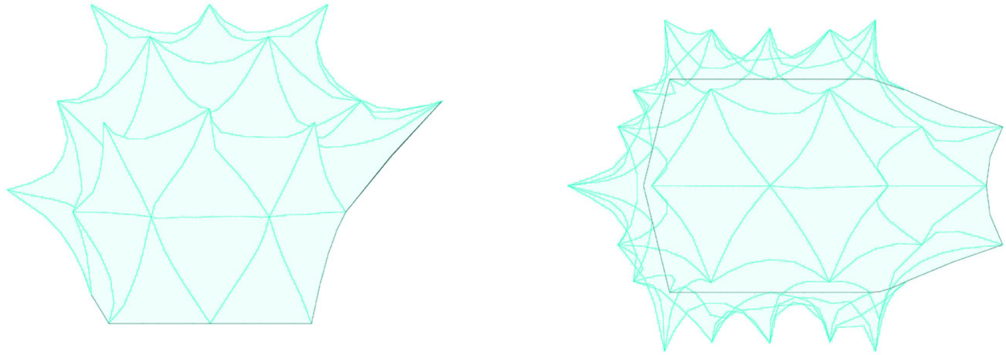

Figure 14.
Membrane pattern design, with WinTess 3

the membrane grommets, leaving the head out to be hooked up in the eyebolts of the structure vertices. A section of flexible PVC tube is placed in every bolt to make a perfect fitting in the buttonhole of the membrane, so it remains isolated and protected from water. In addition, the flexibility of these pieces enables the connections to appear as controlled articulation.

The wood is cut to assemble the base, where the built structure is planned to rest. This base has fittings to be disassembled into six pieces that are in scale with the rest of the elements of the folded set. The pieces that compose the perimeter have wooden elements in their inner part, to receive the transversal beams, on which the wooden flooring is supported. These beams are cut and assembled to fit easily and safely at the base. The wood used on the flooring was donated by Vivre en Bois, the supplier of the rest of the wood for the prototype as well. The strips are cut with four different dimensions and twice varnished. They are then placed respectively and screwed to the five lower beams.

A first test of the assembly of the timber structure was made without the membrane and the wooden flooring, but with ropes that connect the nodes from the inside, in order to reach the stability that the membrane gives and fix the positions of the nodes of the triangulated structure. These rope segments are cut in sizes according to the form-found system (Figure 16).

Days before the event of the eme3 contest "Contingency and Praxis" the membrane made in Girona was collected and a test of assembly was performed with all the elements of the prototype. Nevertheless, there was a fault in the percentage reduction of the membrane, since the membrane was not tensioned in the structure. The option of re-sewing a membrane was not feasible. It was estimated that 8 cm of length were missing per timber, in order to attain that the vertices are in the correct position, where the membrane is in its ideal tensile state. Due to lack of time to find a suitable solution, and since there were no larger eyebolts available for that section of wood, the eyebolts of the timber ends were placed a few more centimeters out. The solution for the hooking of the membrane to the nodes of the structure was also modified to stretch the membrane as much as possible: the bolt that joins the eyebolts in the nodes is placed looking to the outside instead of looking inside gaining a few centimeters.

Based on this solution the Membrane House was taken to BAM BioBui (L) t-Espai Txema, the space next to the MACBA that was assigned by the eme3 competition organization for the exhibition celebrated in Barcelona, in November of 2016. The MH was the winner of the competition together with the REme prototype of the Fab Lab Alicante. Following this event, the Membrane House remained five months exposed in the BAM, and it has recently been disassembled to be exhibited in June 2017 in the Festival Innund'art in Girona for which it has been also selected. Afterwards, in July 2017 it will be exhibited in the Art Per Tot Festival in Cerbère (France), and in October 2017 in Mallorca.

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PRECONTRAINT
502 SATIN

Características técnicas	Précontraint 502 SATIN	Normas
Peso	570 g/m²	EN ISO 2286-2
Ancho	180 cm	
Longitud de rollos		
Formato estándar para rollos	40 ml	
Propiedades físicas		
Resistencia a la tracción (urdimbre/trama)	200/200 daN/ 5 cm	EN ISO 1421
Resistencia al desgarro (urdimbre/trama)	20/20 daN	DIN 53.363
Adherencia	7/7 daN/ 5 cm	EN ISO 2411
Tratamiento de superficie		
Acabado	Barniz dos caras PVDF	
Reacción al fuego		
Clasificación	**M2**/NFP 92-507 • **M2**/UNE 23727-90 • **Method 1 and 2**/NFPA 701 • CSFMT19 • **CLASS A**/ ASTME84 • BS 7837 • **B1**/DIN 4102-1 • **CLASSE 2**/UNI 9177-87 • CAN/ULC-S109 • **SchwerbrennbarQ1-Tr1**/ONORM A3800-1 • 1530.2/AS NZS **G1**/GOST 302944-94 • 1530.3/AS NZS • AS NZS 3837 • VKF5.3/SN 198898	
Euroclase	**B-s2,d0**/ EN 13501-1	
Sistemas de gestión		
de la calidad		ISO 9001
Certificados, etiquetas, garantías, reciclabilidad		

Figure 15.
Membrane model: Precontraint 502 Satin in white, by company Serge Ferrari

For future installations the timber sections were replaced with ones that were by 8 cm longer. In addition, the section of these timbers has been reduced to 36x36 mm for providing a lighter structure and contributing to the efficiency of the prototype. The majority of the eye-bolts has also been replaced, since these were forced to solve the scale error between the structure and the membrane. Also the membrane was cleaned and checked. This implies an improvement in the quality of the structure and the state of tension of the membrane.

Conclusions

The experience gained throughout the development of this project, that still continues, serves as great contribution to the theoretical knowledge with regard to tensile structures. It is in the practice where you learn from each of the stages involved in tracking a project, from its successes and failures. It was possible to learn from the scale error between the membrane and the support structure, due to the respective membrane tension calculation and pattern design and the incorrectly calculated reduction of the membrane used in the manufacturing. This error hindered to find the perfect balance, but the solution for this unforeseen was agile even if the cost of this method meant the forcing of the nodes. Thus, this was a very valuable experience from which we learned for the next installations of the Membrane House that has been already tested to claim that it works properly. The scale error is solved in open tensile structures by using supported masts and therefore, with the possibility of tensioning the membrane outwards since this support structure has a movement leeway towards the outside. In the case of the Membrane House, as the structural elements are connected inside to each other, it is not possible to have that movement leeway outwards. Consequently the error was sloved by changing the size of the timber sections.

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Figure 16.
Construction process

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The success that has supposed and still supposes this project in social and architectural context suggests future investigations and interventions in the current panorama under the same premises. The Membrane House project is an exemplar of tensile architecture that starts to grow in the current scene and can expand its field of action in being able to work in many different contexts and in solving situations that society is currently facing and architecture is so far not able to encompass. The new path of the ephemeral, light and low-tech architecture with new structural materials used efficiently and the recycling of discarded materials, changes the way of project designing and claims for a process, where the designer is not the omnipotent figure (Cuchí and Sastre, 2014). This proposes a future on the field of architecture that seeks to respond to needs, by integrating the physical and social environment and making it functional, affordable, coherent and by taking into account all the actors involved in the project in question.

The prototype Membrane House was selected together with other six projects to be built in Barcelona in November 2016 for the event of the competition "Contingency and Praxis" eme3 for the design of a prototype of emergency housing (Figure 17). The project was awarded as the best emergency prototype for "its ability to adapt to different scenarios and its ease of transportation". It has been exhibited in the center of Barcelona, in Carrer Montalegre 4, in front of the MACBA, until March 2017. It was recognized as an adequate prototype for the requirements of contingency architecture, as well as an example of ephemeral architecture that gives rise to innovative social spaces and gathers the conditions for the current needs in a coherent and sustainable way (Figure 18). As recognition for winning the

Figure 17.
Membrane House in the Bio Bui(L)t Espai Txema, close to the MACBA

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Figure 18.
Membrane House interior view

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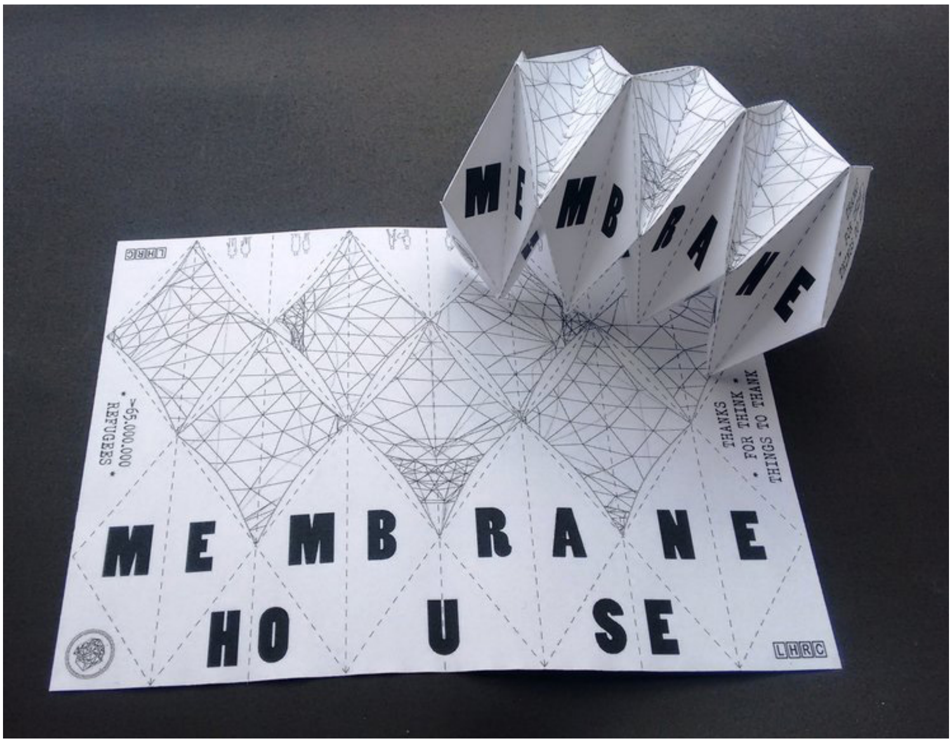

Figure 19. Origami post-card for Verkami rewards

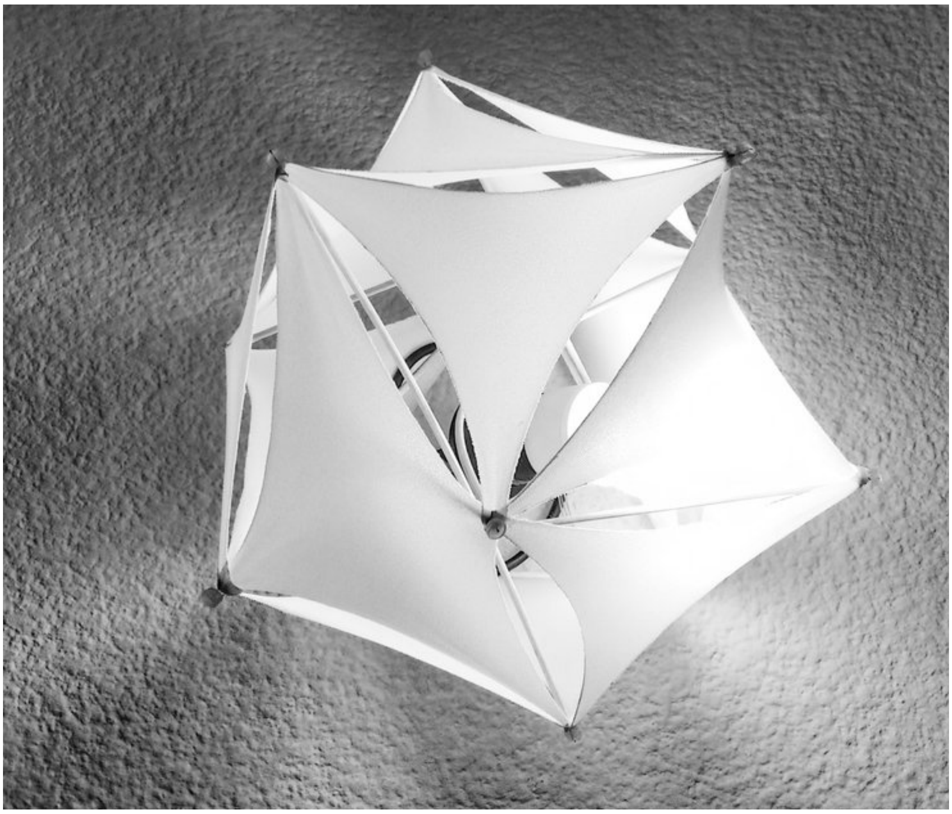

Figure 20. Tensegrity lamp for Verkami rewards

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competition, an entry was published in METALOCUS magazine together with photographs taken by Simón García (ARQFOTO) (Membrane House in Metalocus). The Membrane House has been selected for the Innund'art Festival that will take place in Girona in June 2017, as well as for the Art per tot festival that will take place in Cerbere (France) in July-August 2017 and in Mallorca in October 2017.

Acknowledgments

It is necessary to express gratitude to all the sponsors, who participated in the Verkami project, thanks to whom it was possible to build the Membrane House (The Verkami Project). All people who participated in the crowd funding for this project were rewarded according to their contributions: The thank-you cards were designed as origami paper structure to be assembled and used as postcards, ornaments or jigsaw puzzles (Figure 19). The lamp covers were tensegrity structures made of lycra and wooden sticks that can be sent folded and every sponsor can use them as decoration for their houses (Figure 20). The poster is a beautiful thank for all those who admire the Membrane House and want to have a memory of it displayed on their walls (Figure 21). The rest of the rewards are: The possibility of renting the Membrane House for a specific event and the possibility of attending a Low Tech-Tensile structures course to be taught at BAM BioBui (L) t-Espai Txema in June 2017, space, where the Membrane House has been exhibited for 5 months. It is necessary to dedicate also thanks for the support given, for having requested the permanence of the prototype and for having carried out different activities in it, allowing its diffusion in Barcelona city center. Finally, more than thanks is a recognition, to every member of LHRC architecture collective, which I belong, and from where we have carried out the whole process of design, construction, assembly and dissemination of the Membrane House. We are still involved in different ways on the research and actions on social space issues. We share a way of making and thinking architecture from the responsibility, the low cost and the efficiency of the materials. This has led us to delve into the field of light architecture under the premise of searching for intelligent and unconventional forms (Figure 22). Special thanks to Victoria Polanco, member of LHRC collective for her assistance on the writing and translation of this paper.

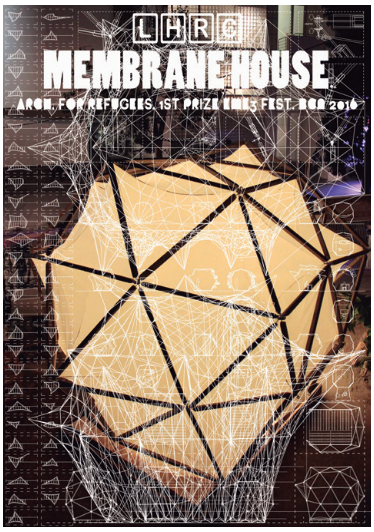

Figure 21.
Poster for Verkami rewards

Figure 22.
Membrane House, Architecture collective LHRC

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