

Transformable Architecture

Experimental solution for a square mesh deployable cover

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Summary:

This research addresses the problem of dynamic structures seen from their structural morphology and function in the field of architecture. Dynamic structures and specifically scissor systems have great potential as skin for buildings requiring large beams and others changes required for its functionality. Deployable membrane structures as transformable architecture design requires integration between the structural and architectural factors. This new architecture of lightness and tension handle design adaptability and flexibility for conditions of comfort, both exterior and interior. The objective of this research is to study the solution of the enclosures for deployable structures, adopting textile systems for such approaches, and design coordination for the structure and its enclosure.

Keywords: *Deployable structure, scissors system, membrane, transformable*

DEPLOYABLE MEMBRANE STRUCTURES, THE SCISSORS-TYPE SYSTEM

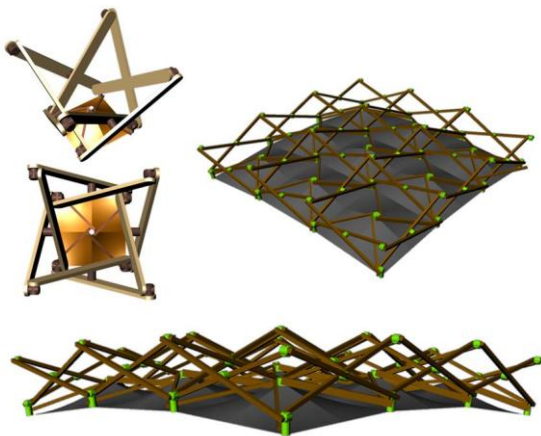


Fig. 01 Model synclastic square mesh.

The proposed design takes a single type of deployable to explore new possibilities for covering membranes. The scissor system is ideally suited, in their movement and structural behavior. Moreover, its application in the field of architecture is so new that there are no possibilities of design, which is appropriate for this research. These

structures have developed a breakthrough from the morphological point of view, and this research was oriented from the structural behavior and enclosure. It is therefore important to note that the system of concern is the scissor system, taking into account the analysis and conclusions of existing projects. This document should be used as a template for the paper. Fonts, sizes and spacing should be used as they are in this document.

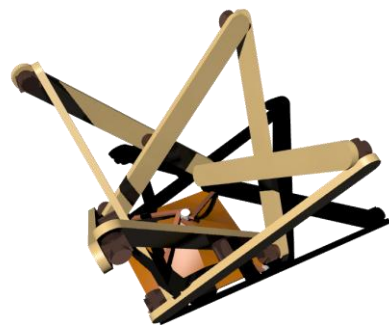


Fig. 02 Model synclastic square mesh.

A scissors consists of two rigid elements hinged together. Its advantage lies in having a single degree of freedom; this means that the system can be stabilized by placing a rigid element. Clustering allows multiple scissors form a complex system, without losing ownership of a single degree of freedom.

Taking as a basis the principles for scissor systems, its exploration is done through groups that allow us to provide enclosures. These groups work with symmetric system scissors both straight and eccentric. These groupings will be termed as meshes and will be linear, triangular and square, exploring different coverage options.

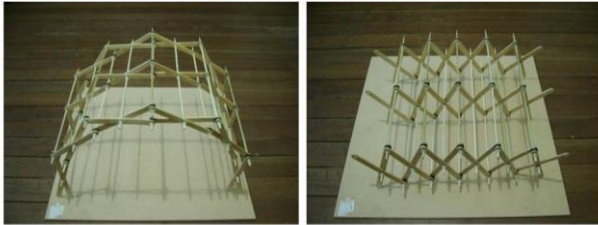


Fig. 03 Model of unidirectional eccentric scissors.

A roller-type system is proposed for the eccentric straight scissors-type system. This system will allow a proper path for the structure without interfering with the fabric. This system is capable of keeping a constant tension in the membrane which leaves no sagging or wrinkling. For the design of the roller type system, it is necessary edge wires as guides during the travel of the structure. The articulation between the fabric and the structure will be circular so that it behaves like a tire, allowing the smooth rolling of the fabric.

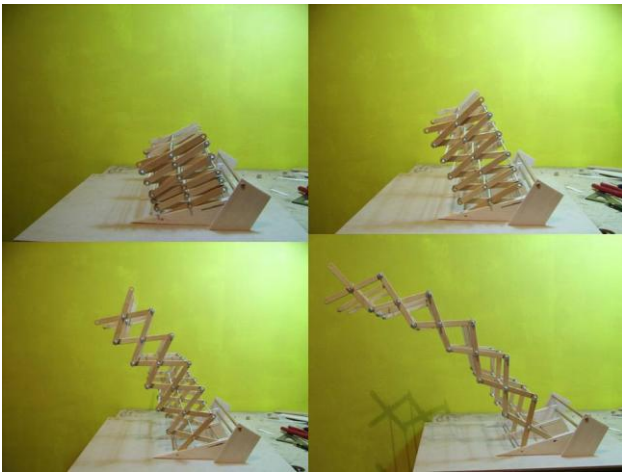


Fig. 04 Model of eccentric scissors system.

The straight scissors system presents a problem during their movement. Cavities may form during the folding and unfolding process of the structure so therefore the system may fail. The pro-posed roller system will maintain a constant tension, keeping the fabric from misbehavior. Note that the mechanism must be exerting force in the opposite direction of the deployment of the structure.

EXPLORACION ...

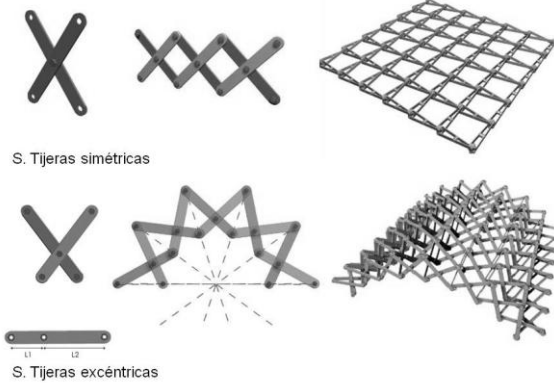


Fig. 05 Explorations scissors system.



Fig. 06 Model of eccentric scissors system with membrane.

SYMMETRIC SQUARE NETWORK

For the symmetric square mesh, the stiffness of the structure is achieved by using a system that restricts the movement. This design allows the membrane to have a guide path during the folding and unfolding process so that there is no interference with the structure. Likewise, this folding guides the fabric. Cutting should be radial direction, following the greatest stresses of the structure. The module also requires edge wires for system stabilization.

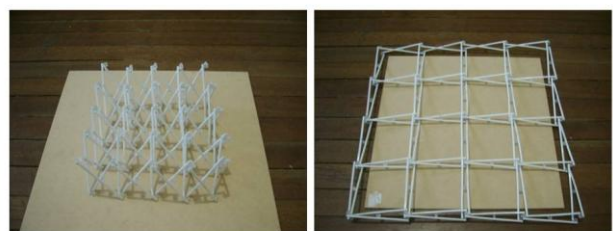


Fig. 07 Model physics mesh symmetrical square scissors.

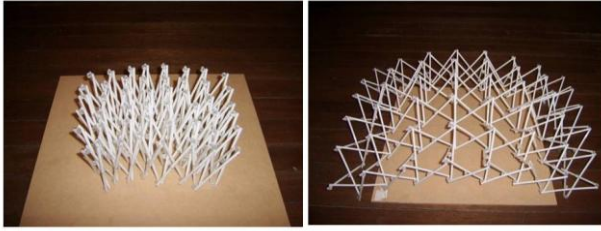


Fig. 08 Physical Mockup square mesh eccentric scissors.

The module works as an independent object, but it is necessary to verify the modules behave as does the membrane, or there is some variation. With the development of the model, it was verified that the fabric retains the same behavior of the module. A double-curved surface is formed at the junctions of each module, which is acceptable for the stability of the membrane structure, but it generates drainage issues at the junction of the four modules.

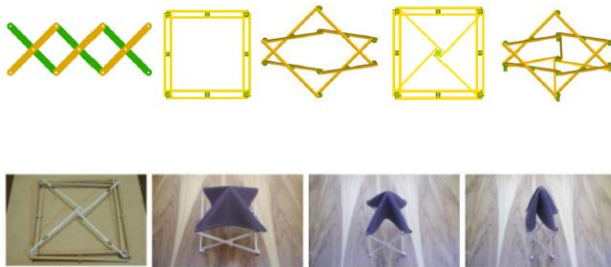


Fig. 09 Model with stiffening membrane system.

The development of the mesh allowed us to see how the system that stiffens the membrane with the main structure must be in the opposite direction to the main scissors tissue, to allow the correct folding and unfolding the structure.



Fig. 10 Model with stiffening membrane system.

The architectural application of the symmetrical square mesh gives many possibilities which can be viewed from the standpoint of temporary architecture due to drainage

issues involved. The proposed design is based on the repetition of a mesh with treelike support. The proposal for an exhibition pavilion gives clear indication of its application in temporal architecture.

ECCENTRIC SQUARE NETWORK

The network of squares form a curvature very suitable for roofing large beams since it allows for a proper drainage of the entire surface. The module to be developed is based on the same principle of that of the flat network module, previously analyzed. The difference lies in the fact that its eccentricity allows for a curved surface. The stiffening of the fabric will be disposed at the bottom of the structure to pick up the fabric from the inside. The membrane will be available at the bottom, giving architectural qualities for both the inside and the outside. It is important to know the necessary curvature giving by the design, since the eccentricity that is applied to each scissor depends upon this. The larger the eccentricity the greater the curvature.

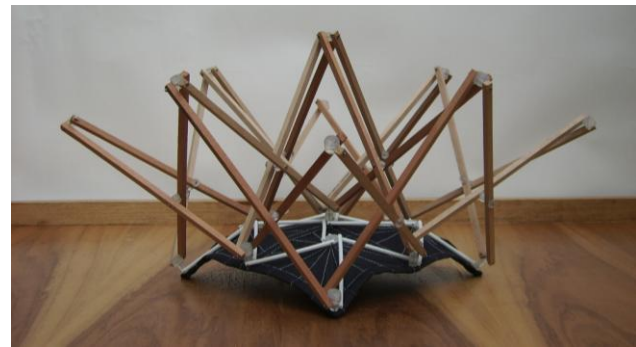


Fig. 11 Model with stiffening membrane system synclastic.

The stiffening structure must be placed in the opposite direction to the fabric main structure, to allow proper folding and deployment of the system. This also allows the membrane to guide the folding and unfolding process, preventing it from tangling with the structure. The proportion with respect to the symmetrical deployment of the mesh is 1 to 4. The model allows the user to see the axes of movement of the structure which gives us the possibility of a support. The stiffening system should be a reciprocal structure that does not allow movement in the opposite direction.

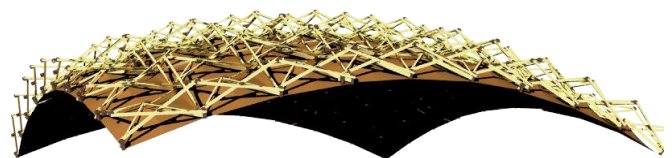


Fig. 12 Cover with membrane system.

This module provides a cover that could adapt to climate change in addition to spatial and aesthetic qualities to architectural design, which also solves technical problems such as the drain-age. For these reasons, this proposal is efficient and aesthetic from an architectural point of view.

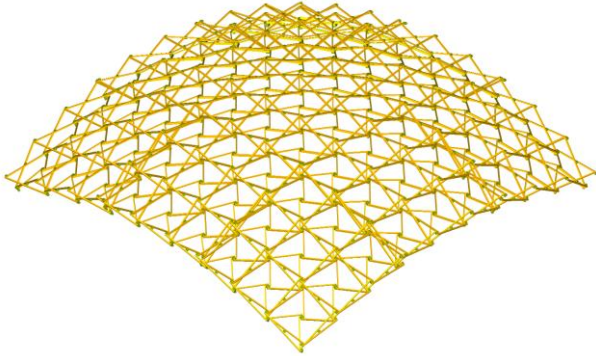


Fig. 13 Mesh eccentric scissor system.

This type of mesh is based on the group of asymmetrical scissors that rotate around a center point, closing the circle when they meet. If the group is woven in two directions and to the same direction of rotation, we would be inscribing a circle when the scissors meet. Therefore the axes of the mesh are made out by arcs drawn about its center.

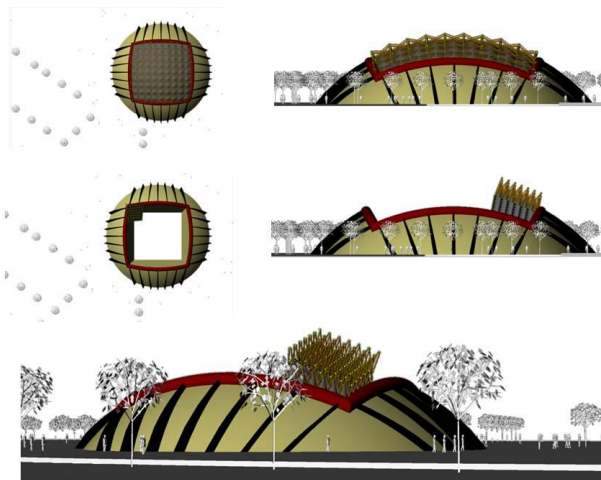


Fig. 14 Sports center with indoor synclastic.

The project herein presented is for a sport center located at the Simon Bolivar Park in Bogota. The geometric justification let us appreciate the structural and aesthetic qualities of the proposed deployable membrane structure. The geometry justifies architectural qualities of the roof, maintaining the continuity and forming a ring that contains the deck edge. The cover is picked up on a ring vertex guided by rails that act as guide structure. The roof is supported on the lower shaft to fix the drainage problem, leaving no gaps between the structure and the roof.

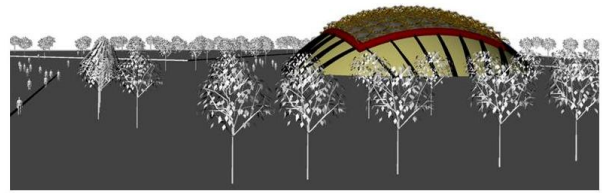


Fig. 15 Sports center with indoor synclastic.

Future Work and Investigations

The purpose of the research is to advance the livability approximations of these structures, and make the most of their processability characteristics, lightweight, fast assembly, and materials in contemporary architecture.

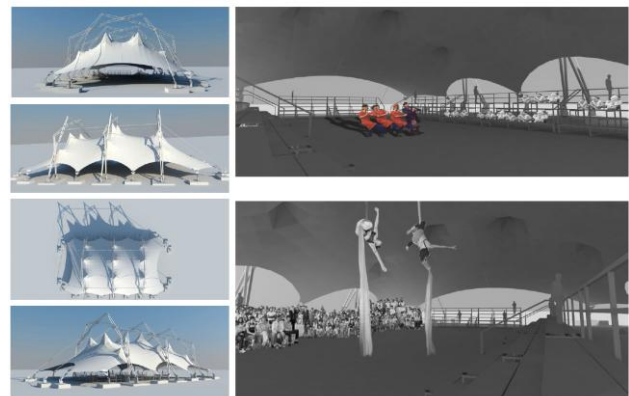


Fig. 16 Spider circus; scissor structure.

It is important to link the supports during digital media, parametric and physical modeling, thus integrating the whole comportment structure, mechanisms and enclosures.



Fig. 17 Model spider circus.

CONCLUSIONS

Deployable membrane structures have four essential design elements: rigid bars, cables, joints and membranes. For the design of deployable membrane structures must be taken into account from the start: its geometry, its movement and its use.

For design purposes, the following considerations should be taken into account since the beginning: geometry, movement, and usage.

The cutting of the membrane in these structures must be consistent with greatest stresses of the structure. One can see those stresses by looking at its movement.

With regards to the retractable roller system, the section of the structure that slides when deploying the system must be opposite to the location of the retractable roller. This will not add eccentricity when the structure is deployed.

It is important to provide a guide cable on the axis of the scissor structure so that some continuity is present during the folding and unfolding process.

For the spatial square networks is necessary a stiffening structure to support the main system and the roof. This will keep the fabric from interfering with the structure and it will provide a suitable bending for the membrane.

The possibilities for stiffening in the square network may be inwards or outwards. It is recommended the one that stiffens out since it gives a better performance. This latter presents problems of drainage and fabric bent.

For the synclastic mesh, the following considerations must be taken into account: the desired curvature, as this determines the eccentricity of the scissors; and the dimension of the fabric to be used.

The internal stiffening mechanism must have a shorter length toward the edges. This enables us to control the deployment limit of the structure and also gives us higher points for drainage purposes. This mechanism will be reciprocal to restrict the overturning of the membrane.

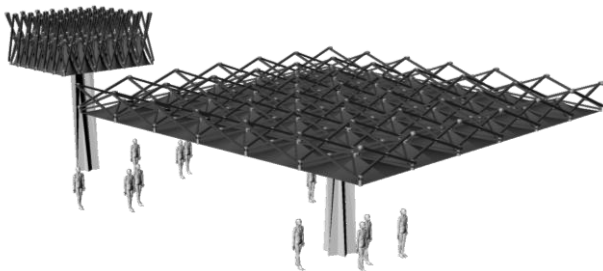


Fig. 18 Flat Pavilion.

The fabric may have two possibilities of cutting, the radial inside-edge, or radial forming circles in its center to edge. We recommend the radial to the edges since it follows the direction of the greatest stresses.

The support for this type of structure must be composed by rails to guide the structure in two directions.

Deployable membrane structures provide greater versatility in designing projects with large beams. Architectural qualities may be equal or even greater than those given by conventional materials and designs.



Fig. 19 Spider circus.

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