International Conference on Textile Composites and Inflatable Structures
STRUCTURAL MEMBRANES 2009
B. Kröplin and E. Oñate, (Eds)

INTEGRATION AND BALANCE: SEARCHING SHAPES

JUAN CARLOS GÓMEZ DE CÓZAR, ROSA BENITEZ BODES AND SANTIAGO BERMEJO OROZ

Dto. Construcciones Arquitectónicas 1, ETS Arquitectura
Universidad de Sevilla
Avd. Reina Mercedes, 41012 Sevilla, Spain
e-mail: gcozar@us.es, web page: http://www.ndarquitectos.com

Key words: Textile Composites, Innovative Design, Architecture

Summary. This paper, shows the research followed on searching and identification of shapes in order to face the different projects we have done. We used references such as: Architecture before the twentieth century in which the solutions perfectly defined the potential of the materials used and Solutions of the twentieth century used mainly for concrete membranes. In the paper we will include mainly those buildings projected in 2008 that will be finished in 2009.

1 SHAPE AND MECHANICAL BEHAVIOUR

For almost its entire history, the architecture has only been able to use a very limited repertoire of forms. The main limitations have been the possibilities of materials and the inability to predict the behavior of the built forms against any external shock. Most common materials used have always been stone, ceramic and timber[1]. Metals were known, but used in very small format and as auxiliary elements. First in the Roman Empire and subsequently in the Middle Ages, vaulted solutions acquired its greatest expression getting continuity by means of crossing two geometries close to the cylinder and implementing and enforcing this crossing with two prominent arcs differentiated from the rest. From this discovery (the ogive arches), shapes development begun. It was based on a balance between the framework (the ribbed archs) and the fill-resistant (the mesh). This development splits into a double path: Gothic evolves multiplying the arches, almost removing the mesh and the Renaissance transition backs to find seemingly continuous surfaces where nerves are just decorative elements, so this decorative attitude prevails against showing constructive machine[2].

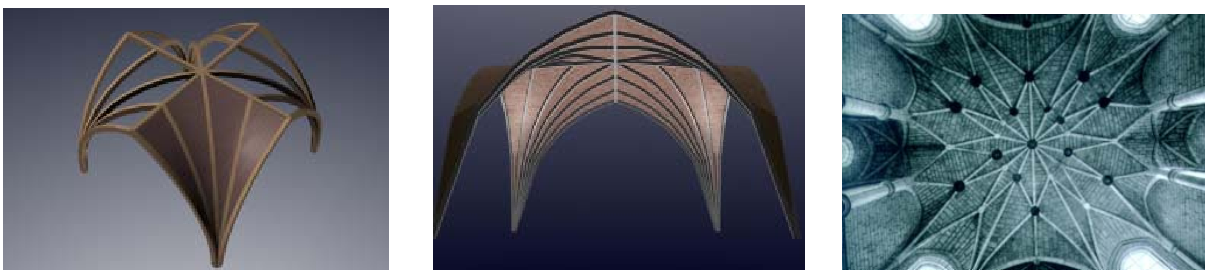


Figure 0: English vaults evolution and Spanish disolution

During this time calculus was limited to simply empirical and geometric rules based on traditional procedures of trial and error that allowed to build a model which could be repeated with sufficient safety. Until the reinforced concrete and steel bar meshes at the end of the XIXth century, this situation remains.

2 SHAPES AND MATERIALS OF THE XXTH CENTURY

The reinforced concrete was born with the aim of changing everything. For the first time humanity has a durable material to build continuous and greatly expands the repertoire of possible shapes to use. Several authors explored this potential. For the first time flat stone floors are built so it is a material that quickly were used in housing architecture. In order to solve long spans they started using single-curvature geometries (cylindrical) and double curvature sinclastic (spheres) based on solutions already solved years ago with traditional materials. Gradually they discovered the possibility of mathematically analyse the behavior of other geometries, first revolution ones (paraboloids and hyperboloids) and later translatory ones (hyperbolic and elliptic paraboloids). The need of building structures of shuttering was solved with ruled surfaces which, thanks to their straight generatives, allowed easily solving complex geometries. Perhaps the author that better understood this situation and made the most possible was Felix Candela[3]. From the hyperbolic paraboloids he built series of buildings where the right choice of shape and material economy are the basic premises and the theoretical concept of membranes is materialized in small thickness constructions.

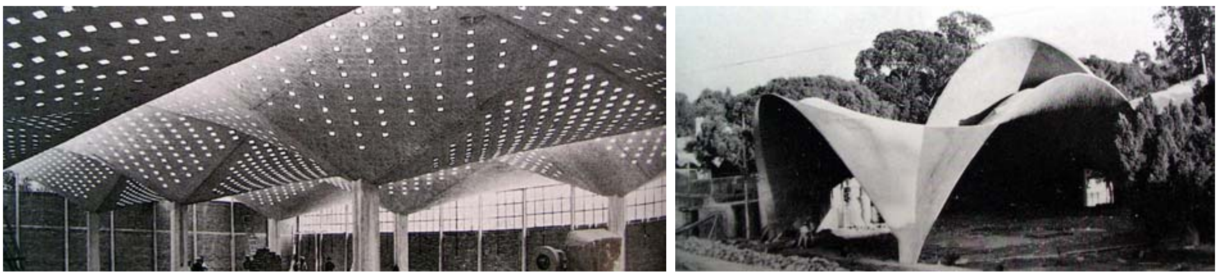
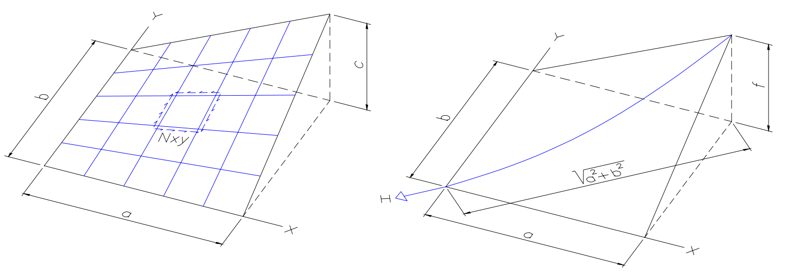


Figure 2: Felix Candela shell's. High life (Mexico 1955), Hotel Casino de la Selva (Mexico,1958)

In this context, first buildings solved with textile membranes appeared in the mid-XXth century. As it happened to other new materials, first shapes remembered ephemeral structures associated to nomadic civilizations.
Frei Otto[4] made a huge qualitative leap by creating a formal code own to this kind of buildings. But they are associated with ephemeral buildings with non-permanent attributes.
If it was possible to build shells, using textile membranes it becomes faster and we do not require temporary shuttering, only when using prestressing.

It is easy to prove that for uniform vertical actions and equilateral hyperbolic paraboloids of square shape in plan, the mathematical formulation that were traditionally used for concrete membranes and the ones used for textile membranes offer identical results.



$$Nxy = \rho \frac{ab}{2c} ; H = \frac{qL^2}{8f}$$

$$q = \frac{\rho}{2} ; L^2 = 4\left(a^2 + b^2\right); f = c$$

$$H = \frac{\rho}{2} \frac{4\left(a^2 + b^2\right)}{8c} = \frac{\rho\left(a^2 + b^2\right)}{4c}$$

$$a = b \rightarrow H = \rho \frac{a^2}{2c} = Nxy$$

Figure 3: Stresses in shells and cable mesh

3 NEW TIMES, NEW ARCHITECHTURE

Nowadays, the situation is complex. For the first time in history we have materials, constructive proceedings and tools for control and calculation for, in theory, every shape. But world has changed. Today our society is both global and immediate. Everything is fastly developed and any consumer product (and architecture is one of them) has a very limited life. Years ago we detected this situation and we thought about the possibility of buildings which could transform and be adapted as time goes on, and which could be assembled and disassembled quickly and easily. Once defined our way of producing architecture, we have focused on searching own shapes for specific problems, solved with certain materials. The two projects show below raise this issue. We have designed solutions, which, although they have a very complex geometry, they have been built quickly, and thanks to their modulation, can also be repaired and/or renewed quickly and easily. Both solutions are based on the generation of a resistant and rigid framework which subdivides space into several parts which are covered with textile membranes. The searching for balance between the mesh and the cover has been the fundamental design task of the two projects.

4 COVER OF AN OFFICE BUILDING

It seeks to cover the central courtyard of an office building in San José de la Rinconada (Sevilla). The courtyard has a trapezoidal shape in plan with a simple symmetry. Its major axis length is approximately 30.0 m, perpendicular sides have, respectively, 20.0 and 12.0 m. Therefore the surface to cover is over 600.0 m2. The customer sued the cover should allow natural lighting and ventilation directly in the central area and at the perimeter had to be completely opaque and resistant to protect the perimeter galleries below. With the assumptions imposed, it has been projected a symmetric solution with respect to the major axis based on a central arch supported at the perimeter of the deck. The different panels, 6 in total, are based on hyperbolic paraboloids with free edges solved with high-strength cables.

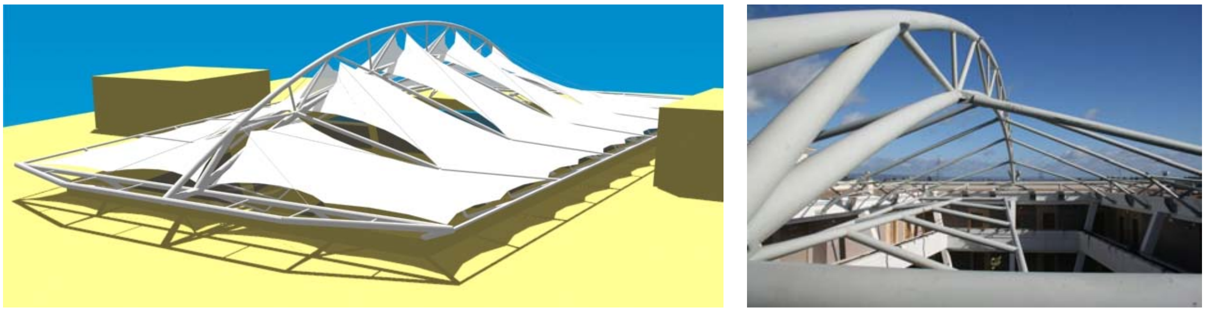


Figure 3: Model image and structure view

5 COVER OF AN AUDITORIUM

We were asked for a solution to cover the Auditorio Municipal de Gines (Seville). The proposed solution must allow, at least, leave the stalls found in summer. The area covered is approximately 1000.0 m2 and has a very irregular and closed perimeter that makes difficult to find a modular solution. The solution proposed is based on the imposition of a central compact geometry set (with a dome covered with removable pieces of membrane) and a perimetral ruled geometry that solves the join with the irregular perimeter (covered with metalic sheet).The dome has been solved with a main order of arches of the same curvature, and a second order that divides the length of the arcs in 4 equal parts. The fixed cover has been solved with several supports and beams (all different) that support a cover of plain sheet. The stiffeners raised between the beams of the deck provide it a great rigidity and define it as an element to resists the thrusts of the central dome.

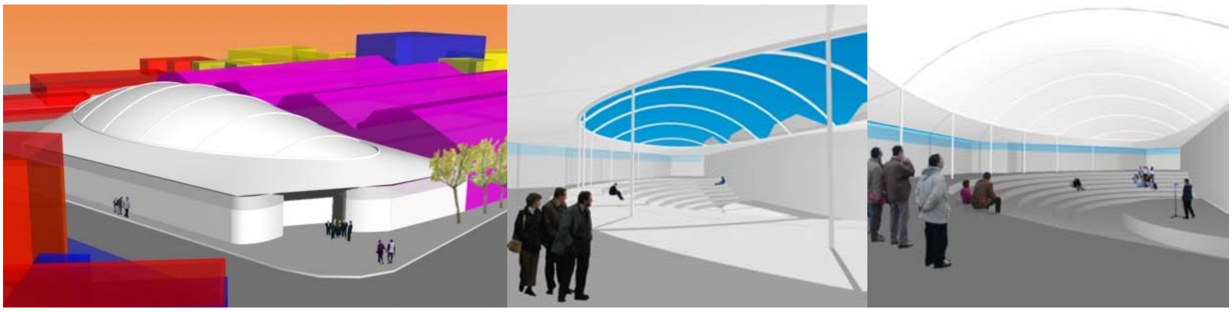


Figure 4: Inside and outside views (3d model)

REFERENCES

[1] L'architettura di Leon Batista Alberti. Tradotta in lingua fiorentina da Cofirmo Bartoli. Venecia, 1565.
[2] J.C. Gómez de Cózar, *Cul de lampe: Adaptación y disolución del gótico en el Reino de Sevilla*, IUACC Universidad de Sevilla, 2009.
[3] Candela, Félix. *En defensa del formalismo y otros escritos.* Xarait. Madrid, 1985.
[4] Conrad Roland*. Frei Otto: Estructuras.* Editorial Gustavo Gili, Barcelona 1973.