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Past, present and future of space frame market: LANIK experience.

Luis IRISARRI, Juan MARTINEZ, Josu GOÑI.

Lanik Investigación A.I.E.
Mundaiz 8, 20012 San Sebastian, Spain
lirisarri@lanik.com

Abstract

The market of the structures in general and space frames in particular has changed in the last years. This evolution has been linked to develop the new technologies and the increase of aesthetic requirements of architects and clients.

This document treats the past, present and future of the space frame market based on the experience of LANIK company, leader in Spain in this kind of structures. It analyses the causes of these changes, and determines tendencies for the future space frames.

In the past, space frames were very simple, with a general modulation to get bars and nodes as much equal as possible. All the space frames seem to be very similar and with very few aesthetic possibilities.

With the new technologies revolution, computers and CAD-CAE-CAM systems, the design of space frames changed drastically; very complex geometry with all components, bars and nodes, completely different.

However other important revolution is based on the new requirements of clients and architects that need more adaptable structures, asking for retractable roofs, or transparent structures, using glass and cables.

Some special projects require the combination of several kinds of structures, the mixed structure, which combines conventional steel structure, space frame, cables, etc. This evolution can be seen in the catalogue of LANIK realizations, some of the most emblematic projects are shown in this document.

Keywords: Space frame, retractable roof, single layer, shell structure, glass or transparent structure.

1. Introduction

The market of space frame structures has evolved very quickly in the last twenty years. There are several reasons for this revolution, but the most important ones have been the followings:

The fist one consists in the use of computers in every stage of the process from initial design to final construction. And the second one is based on the necessity of giving solutions to architects demands, which require a great deal of knowledge and creativity. For these reasons the space frame market has evolved from initial flat squared module “hand made” structures to single layer shells and retractable roofs.

In the next chapters the development of LANIK in the space frame market will be exposes. However, prior to this exposition, it is necessary to make a short presentation of this firm.

LANIK is a Spanish company founded in San Sebastian in 1977. The main object of the firm is to give response to the concepts and requirements from architects and designers with advanced solutions and high quality standards and flexibility. Their solutions include the global process from the initial idea to construction: design, calculation, production and assembling on site.

LANIK is the leader company in Spain in space frames, retractable roofs and single layer frames, with a vast experience of more than twenty years in these kinds of structures. The company has developed four main activities along these years: laminated timber structures (1984), space frames (1989), retractable roofs (1995), and single layer frames (2005); and has patented ORTZ and SEO joint systems for space frames, PARPADO system for retractable roofs, and SLO system for single layer structures.

2. Initial stage of space frames. Simple “hand made” structures.

Some decades ago, before general use of computers, the design of space frames was limited to very simple configurations of flat and uniform structures with square or rectangular module, with very few different kinds of elements.

The calculations were made by hand, or using big computers of the best universities, so only simple and not optimized solutions were considered. Besides, as material lists and workshop drawings were made by hand, only structures with repetitive elements were designed.

In those days these kinds of structures were considered as very modern typologies and many examples were built in Spain. As an example the roof structure for the Las Palmas de Gran Canarias airport, see Figure 1. Only two different bar lengths were considered using ORTZ structural system.

Figure 1: Las Palmas de Gran Canaria airport. Square module. Only two kinds of bars.

3. Development of space frames: General use of computers.

Around twenty years ago, the use of computers led to a revolution in the design of space frames. With the aid of a computer and a suitable own software, LANIK was capable of developing very complex geometries from the conceptual design to the final construction.

The use of computer is generalized in every task in the development of a space frame project: the geometry is generated using a commercial CAD software, which is linked to a calculation software. Once the structure is designed and calculated, a suitable CAM software generates automatically the lists of materials, workshop drawings, and CNC programs. There is a link between office and production without human transmission, avoiding possible errors and spending a huge amount of work.

3.1. Palau D’Esports Sant Jordi, Barcelona

Arata Isozaki was one of the first architects to understand and take advantage of the opportunities offered by the new technologies. A forerunner of this new conception was the Barcelona City Council project for the Sports Complex for the 1992 Olympic Games.

The main structure for the roof of this project was completed in 1988. In addition to its considerable size, 105.6 x 127.8 m, several other features made it somewhat unique for the time at which it was built:

- Its geometric complexity, meaning that it involved a wide variety of components: nodes and bars.

- The conception of a mixed structure in which most of the bolted elements comprising the space grid are strengthened with additional welded elements at points supporting a great deal of strengths. This is a main example of a mixed structure with a main conventional steel structure filled by parts of half-octahedron modulation grid space frame, using the ORTZ system.

- Use of the PANTADOME assembly system, a procedure created by the engineer M. Kawaguchi, according to which the structure temporarily functions as a spatial mechanism permitting its elevation to its final position.

Figure 2: Palau D'Esports Sant Jordi during erection. Complex geometry.

3.2. Palafolls Sports Centre

This building, also a project by Arata Isozaki, is not as remarkable for its size as it is for its extraordinary geometric complexity. Its ground plan forms a semicircle of 70 m of diameter, see figure 3. Despite being smaller, the number of elements forming the roof structure is far greater than those used to make the Palau d'Esports due to the small length of the bars included in the project with a view to achieving the best possible adaptation to the double-curvature of the surface proposed by the architect.

But even more remarkable than the number of elements involved in the structure is the extent to which they vary from one to another (4,612 different kinds of bars out of a total of 14,429 and 1,730 different kinds of spheres out of the 3,298 used to build one of the most representative examples of CAD-CAE-CAM applications). This construction was built in 1991, entirely based on a bolted bar and node system structurally identical to that used to build the Palau.

Figure 3: Palafolls Sports Centre. Complex geometry. All elements are differents.

4. Retractable roofs.

The great amount of bullring buildings in Spain, and the fact that they are used only a few weeks a year, has promoted the construction of retractable roofs which allow an open air space for bull festivals and a closed building for other events as concerts, meetings, etc. LANIK has built more than ten retractable roofs in Spain and Portugal, most of them bullrings. The most representative retractable roofs are the followings:

4.1. "San Sebastian" and "Logroño" twin bullring retractable roofs

The incorporation of a retractable roof to the project for a new bullring in San Sebastián meant that the structure could be used for a variety of activities without detracting from the final purpose for which it had been conceived.

The roof, a circular ground plan with a diameter between supports of 101.3 m, is subdivided into one fixed part and two mobile parts or segments. The fixed part is quasi-ring-shaped, with a central opening larger than the central arena measuring 52 x 50 m.

The mobile parts, which cover the central opening when the roof is in closed stage, consist of two complementary segments which roll back symmetrically over the fixed part into a concealed position, leaving the opening clear. These segments roll back and forwards in a curving motion.

Figure 4: San Sebastian bullring retractable roof.

The fixed part is shaped like a spherical shell and its structure, despite the central opening, is predominantly membrane in behaviour thanks to its dome-like structure, thus achieving remarkable structural efficacy. The mobile segments copy the shell shape imposed by the fixed part but, due to their support, predominantly operate in flexion.

The structure of the fixed part consists of a tetrahedral space grid propitiating harmonious adaptation of the structure to exterior and interior contours alike. The depth of this grid varies, acquiring its greatest depth at the interior contour where the flexion is greater due to the important load concentrations transmitted by the different segment supports.

Each of the mobile segments, 60 Tons weight, covers a surface of 1,300 m² and is supported at four points by means of the corresponding action and rolling elements, as they move over the guides located on the fixed part. Their structure likewise comprises a space grid, although in this case the priority objective was to achieve a minimum weight given that the closing action is based on an upwards movement.

The operation and movement systems for the mobile segments were designed by means of a pinion-rack transmission system. The ensemble is driven by means of 8 motor-reducer sets which always act in unison with their corresponding bogies, thus achieving additional security based on redundant motorizations. The mechanism ensemble is completed with an electronic synchronisation and control unit which turns each segment into an autonomous radio-controlled vehicle.

4.2. "Vitoria" bullring retractable roof

This retractable roof consists of a combination of a conventional steel structure, two main trusses of 8o m length separated by other two trusses of 40 m, and a collection of space frames filling the whole space. The structure is divides in two levels, see figures 5 and 6. In the upper level two mobile space frames of 40x20 meters move following the upper chord of the two main trusses.

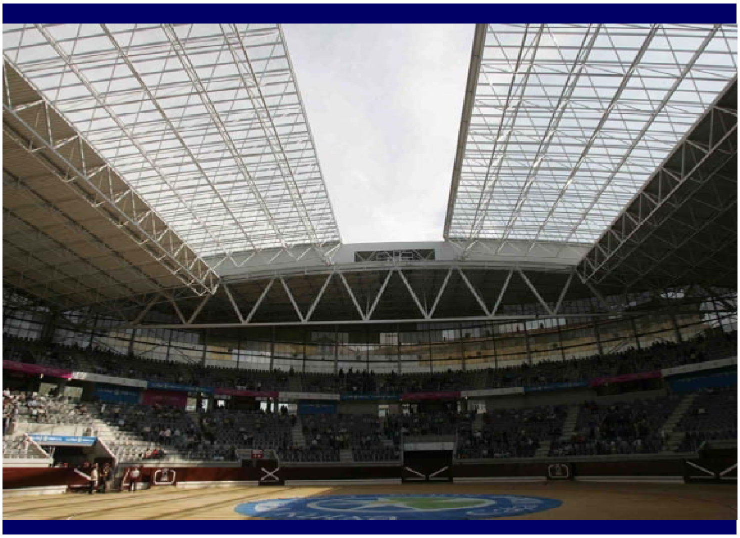

Figure 5: Vitoria bullring mixed retractable roof structure.

Figure 6: Vitoria bullring. Outside view.

This is an example of the new tendency in roof structures, the combination of several kinds of structures, a main conventional structure with parts of space frame filling the whole area.

Another mixed structure and retractable roof example is the new bullring roof in Illescas, Toledo, where a 2600 square meters mobile structure opens or closes to the air the entire bullring as it is shown in figure 7.

Figure 7: Illescas, Toledo. Bullring mixed retractable roof structure.

Apart from retractable roofs, there are other examples of combination of different kinds of structures in the Feria de Valencia and BEC, Bilbao exhibition centre.

5. Transparent structures. Single layer grid shell

In the last years architects and designers in general want to create very transparent structures, trying to hide them as much as possible. These structures generally are enclosed with glass or other transparent materials.

There are several kinds of transparent structures, some of them use cables as the main structure, others are single layer shells, and others even combination between them. In any case, it is necessary to use advanced software with non linear calculation in order to solve problems of stability, dynamics effects, etc.

The activity of LANIK is focus on single layer shells, but transparent structures based on tensioned cables is an important tendency of the market.

5.1. Victoria square dome in Belfast.

Single layer shells are adequate structures for some geometric typologies, as domes and vaults, where curvature helps to support loads with their bars working mainly to axial efforts.

The best configuration is obviously the dome. A good example is the Victoria square commercial centre dome, in Belfast, an appointed dome of 36m diameter in plant, and 22 m height. The high grade of transparency is obtained by means of a big module (bars are around 2.5-3.5m length) with a small profile (tube 120x80mm). However, for the non linear calculations it was necessary to create a complex model with all the surrounding structure to check problems of stability, concentration of efforts, differential deformations, etc. At last, it is a simple and lightweight structure, but solved with very complex design and calculations.

For this project and the followings LANIK developed an own joint system called SLO, Single Layer ORTZ, specially designed for single layer grid shells. This is another tendency, to design new system of connection for the new kinds of structures the market requires.

Figure 8: Victoria square dome in Belfast. Single layer glass grid shell.

Figure 9: Victoria square dome in Belfast. Inside view. Transparency.

5.1. Palacio de comunicaciones. Town hall of Madrid.

Nowadays, however, architects want to create organic shapes, free form geometries, that mean very complex structures that are not working so clearly with axial efforts as a shell or membrane. Engineers have to try to do the best solution to get a transparent and economic structure.

The courtyard of the new town hall of Madrid has been recently covered by a single layer glass grid shell. This is a free form roof structure designed by Schlaich Bergermann und Partner office in Berlin, and erected by LANIK only in seven months from September 2008 to march 2009.

The almost 3000 bars, 1050 nodes and 2000 glass panels are completely different from one another, so it is necessary the use of new technologies, computers, specific software, and CNC machines to manufacture and assemble. The average length of the bars is 1.8 m, relatively smaller than Belfast dome, in order to achieve curvatures as much smooth as possible.

This is an example of the tendency and future of space frame: It combines different kinds of structures: A conventional steel structure constituted by an edge beam with brackets that support and transfer efforts to the building, a single layer grid with triangular modulation, a lower net of cables that retain the edge beam, and glass panels with a suitable insulation and solar control.

Figure 10: Palacio de comunicaciones. Town hall of Madrid. Free form structure.

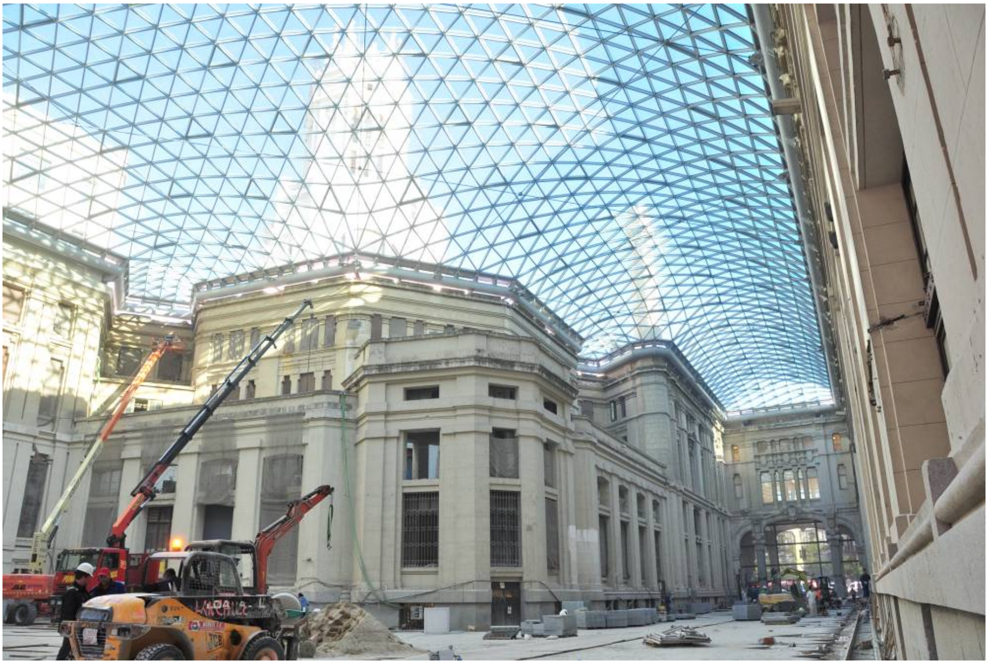

Figure 11: Palacio de comunicaciones. Inside view.

6. Summary.

Following the development of space frame in the past, we can see that the future of the space frames should be based on the followings:

- Complex geometries, solved by specific CAD-CAE-CAM systems.
- Mixed structures: Combination of conventional, cables and space frame structures.
- Retractable structures.
- Transparent structures, using glass or other materials.
- Single layer shells, including free forms.
- A combination of above specifications.

The most representative structure that shows the new tendencies, and combination of them, is the single layer glass grid shell of the courtyard of the new town hall of Madrid, in the Palacio de comunicaciones building.

References

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