

# FLUVIAL BANK PERGOLAS FOR INTERNATIONAL EXPO “WATER AND SUSTAINABLE DEVELOPMENT” PERFORMED IN ZARAGOZA IN THE SUMMER OF 2008

GUILLERMO CAPELLÁN<sup>\*</sup>, SANTIAGO GUERRA<sup>\*</sup> AND JOSÉ M. LASTRA<sup>†</sup>

<sup>\*</sup>Arenas&Asociados, Ingeniería de Diseño, SLP  
Hernán Cortés nº 19, 1º D, 39003 Santander, Spain  
e-mail: [gcapellan@arenasing.com](mailto:gcapellan@arenasing.com), [sguerra@arenasing.com](mailto:sguerra@arenasing.com), web page: <http://www.arenasing.com>

<sup>†</sup>Lastra&Zorrilla, arquitectura textil  
Ala Este 7/8 Torre. Buzón 98. Isla de Toralla. 36331 Corujo-Vigo. Spain  
e-mail: [jmlastra@arquitectil.net](mailto:jmlastra@arquitectil.net) - Web page: <http://www.arquitectil.net>

**Key words:** Cable Net Structures, Textile Composites.

**Summary.** For the International Expo “Water and Sustainable Development” that took place in the Ebro Banks during summer of 2008 in Saragossa, it was proposed the construction of two tensile structures which mission was casting area shadows over the Event Audience.

## 1 THE IDEA

Due to the Saragossa summer heat, coinciding with the period in which the Exhibition would be developed, in the planning period of whole the Exhibition ground, it was thought that would be suitable to provide shaded areas to the audience.

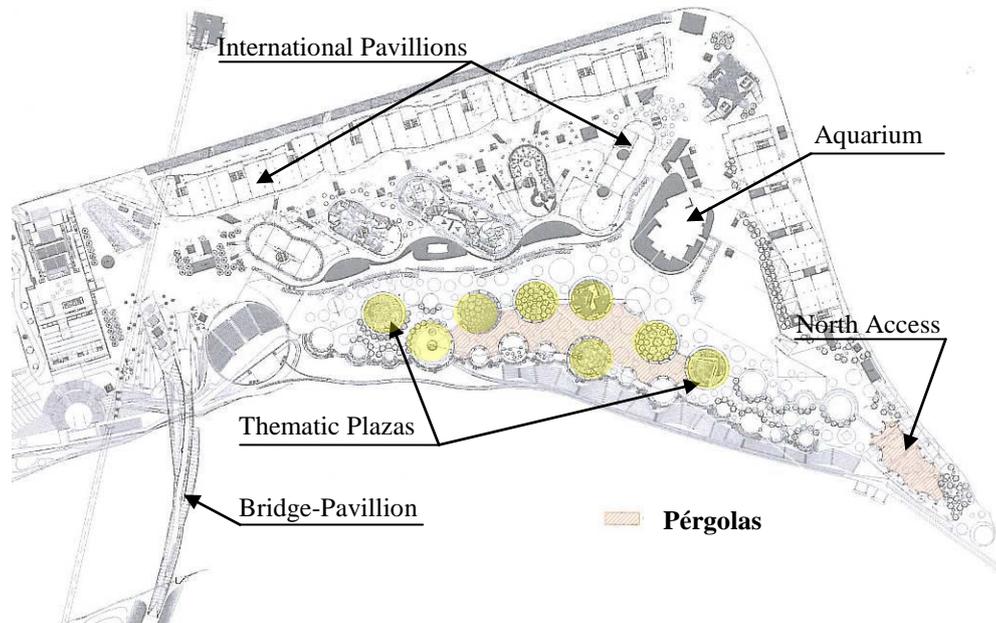


Figure 1: Situation of Pergolas

Among the public spaces in the showground, were chosen for providing shaded areas, the North Access and the hollow among the Thematic Plazas. “Batllé i Roig, arquitectes”, proposed the construction of two cable net structures with colored textile dots that would cast shadows over the ground. The cable net would be supported by a steel frame. All these things were collected in a Basic Project.

The former Pergola, which was named Entrance Pergola, covering a surface of 2362 m<sup>2</sup>, was settled, as it was said, in the North Access and its mission was protecting from sun to the spectators before their entrance in the exhibition site. The latter, that was named Inner, was built among the Thematic Plazas, providing architectural unity to all of them and generating a shaded and refreshing area, thanks to the water vaporizers provided in the pergolas. Its planar surface was of 7500 m<sup>2</sup>.

## **2 CONSTRUCTION OF THE PERGOLAS**

In base to the Basic Project, Expo published the competition for the construction of the Pergolas, which was adjudicated in order to their technical and economical offer to the Joint Venture “Mecanasa – Comercial Marítima”.

Due to the degree of development of the project, it was needed the help of engineering assistance for building the Pergolas, which was made by Arenas&Asociados, that had helped previously to the Joint Venture with the technical offer.

In the next sections will be exposed different issues concerning with the erection of the Pergolas.

### **2.1 Building Project**

As previously was said, it was needed to redefine the entire project of the structure, because it had been redacted in a short time, although the architectural conceptual idea was really brilliant. But the engineering concepts were not quite rights.

Arenas&Asociados had to recalculate whole the structures, making changes over the initial structural designs that improved the behavior of the tensile structures and the aesthetic of the Pergolas, being that fact appreciated by the architects and the Expo technicians.

The first of the improvements consisted in the supression of the hinges designed in the Basic Project in the mast of the steel frame supporting structure, which was the original idea desired by the architects.

The second change was the introduction of boundary cables instead of connecting the cable net to the horizontal tubular steel beams connecting the mast, which was geometrically impossible. The boundary cables gave a softer aspect to the cable net, which seems float in the air.

These changes were the most remarkable, because included design modifications, but it was needed to analyze every aspect concerning with the erection of the Pergolas, including revision and reinforcement of micropiles foundations that had been previously built to the adjudication of the works to the Joint Venture, because they were in another contract.

## 2.2 The Cable Net

The Pergolas consist in a supporting steel frame, the cable nets and the textile dots. In this section, these three elements will be described.

### *The steel frame*

The steel frame is composed by masts and horizontal beams, being both elements built by means of tubular steel S-355 elements. The masts were designed as tripods, with a principal strut element and two tie secondary elements, but due to its conception, these elements have flexural forces too. The tripods couldn't be changed in conceptual design so it was necessary thought mechanism for resisting the external actions.

The masts have a height of 7.70 meters, and are organized in plazas by means of two horizontal tubular beams, which have the connecting plates with the cable net.

### *The cable net*

The cable net is the result of  $\varnothing 26$  mm galfan boundary cables, and  $\varnothing 16$  mm inox net cables making a 2x2 m grid, being inside this grid the colored textile dots. Due to singularity of connections between net cable and boundary cables, singular connecting systems and clamps had to be designed in the building project, but with a successfully result.

### *The textile dots*

Inside the cable net, textile dots were installed with the purpose of casting shadow. These dots had a diameter of 160 cm and were made by an inox steel frame surrounding a circular textile disc of Soltis 92 made by Ferrari.

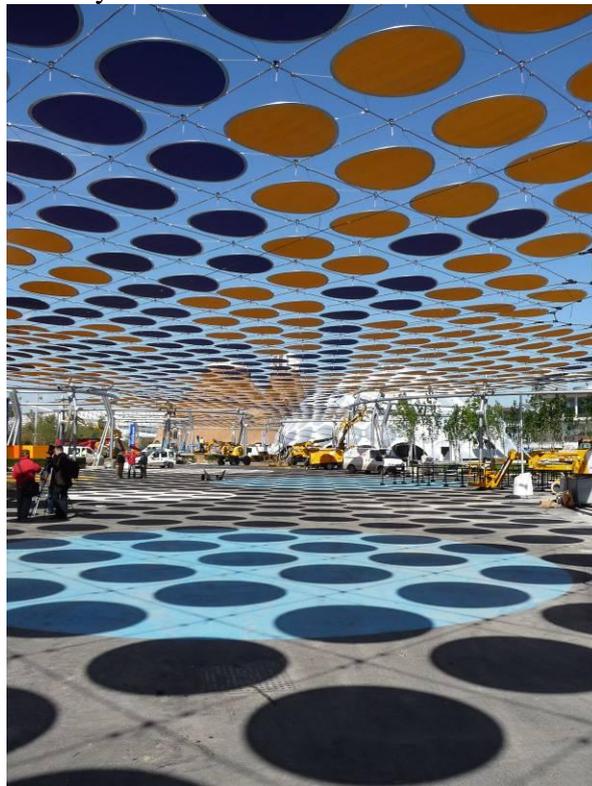


Figure 2: Inner Pergola

### 2.3 Erection of the Pergolas

As the foundations were built before the Pergolas contract were adjudicated to the Joint Venture, some design questions of the Pergolas were conditioned by the execution of foundations, such as orientation of mast, which weren't properly orientated in some cases, due to a non rigorous calculation in the Basic Project. This matter supposed upper stress levels in mast, but this issue wasn't really important compared with the damaged suffered in the anchorage rebars due to construction traffic in the Expo showground. Almost 80% of rebars had to be replaced, slowing down the erection process.

Once the anchorage bars were replaced, masts, which were welded in workshop, could be erected. The masts were threaded in the anchorage bars, leveling out its final position by means of topographical tools. This issue was especially important, because small leveling errors in base plates had a big repercussion in the mast heads due to its high of 7.70 m, and could affect negatively to the cable net in a way of over or under tension of whole the net, including the need of manufacturing new cables, which was impossible for the limited time for completing the erection process. All the masts and horizontal steel tubular beams between them were erected by small cranes thanks to its low weight.

As the masts were organized in "plazas", it wasn't necessary wait for completing all of them for installing the cable net. The cable net had to be installed beginning with the boundary cables, which were tensioned by mean of wrenches to the length defined in the Building Project. This could be done thanks to have used fork connectors with threaded fittings in the boundary cables.

Trying to reduce the Pergolas erection period, all the boundary cables were marked in workshop by means of color code referring to the different clamps needed for the net cables. This decision was successfully, being thanked by the erecting team.

While the boundary cables were installed and tensioned, the net cables were erected and tensioned in a first stage, just for sustaining its self weight. Once all boundary cables and net cables were erected, the net cables were tensioned in a second stage by means of wrenches to the length defined.

All the tensioning process in the North Access Pergola was controlled by means of strain gauges, measuring the 50% of the net cables. The results were completely satisfactory, corroborating the theoretical calculation. These results were extrapolated to the Inner Pergola, because supposed an erection process validation.

With the cable net tensioned, the textile dots were installed, connecting the cable links forks to the textile frame and to the cable net butterflies. As the cable net was tensioned had taking account the dots weight, the cable links were tensioned while they were installed.

Finally, the led illumination and the water vaporizers were installed, completing the erection of the pergolas, which took less than one and a half month.

### 2.4 Conclusion

At first, during Expo Planning, it was thought in a temporary use of the Pergolas, only for the Exhibition period, but thanks to the good appearance of the Pergolas, and the success reached among the visitors, it was decided giving them a permanent service life in nowadays.