Arch Bridges
ARCH'04
P. Roca and E. Oñate (Eds)

ARCHED STEEL STRUCTURE THAT SUPPORTS THE COVER OF SANTA CATARINA´S MARKET IN BARCELONA

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Key words : wood arcs, steel arcs, covers, markets;

Abstract. *The structure of the cover of Santa Catarina´s market is a mixed structure of steel and wood. The structure is composed by a set of different wood arch's different between them, of straight axis and curve, supported in tubular steel beams of variable section. These beams, as well, they hang in its central part from a set of three tightened circular arches through a set of vertical hangers. The wood arches are either tri-articulated, or bi-articulated. The steel arches are tightened by means of cables with the purpose of controlling the vertical deformations. The supports of the metallic arcs are sliding.*

1.- INTRODUCTION

The Institute of Markets of Barcelona, employee of the City council, directs a process of remodeling old markets around the city. Santa Caterina´s market is located in the center of an old neighborhood that carries the same name.

The winning architect of the project, Enric Miralles, along with his wife Benedetta Tagliabue, conceived the cover like a curved and light surface that floated on a set of cables. Its outer surface should have been formed by ceramic mosaics that find its roots in the "trencadis" of Gaudí.

The initial idea was materializing in itself while they proceed to conceive the structure and the calculations were initiated (end of 1997). It was finally fixed like a set of wood arch's supported like steel beams, supported as well by three metallic arcs through a set of hangers.

Photo 1 - General perspective under construction

2.- GENERAL DESCRIPTION OF THE STRUCTURE

The support on level zero is made by means of a set of 13 pillars:

Metallic pillars: Four pillars formed by beams of doubled metallic tubes in the main facade. Two pillars, inferior half of concrete, superior half beam of doubled steel tubes without bracing.

Pillars and concrete beam: Laterally, in perpendicular sense to the facade, 2 post-tensed trusses of concrete are executed. One of 80 m sustained by 4 pillars of concrete and another one of 30 ms sustained by 3 pillars of section 0.90 x 0.90 m.

V shaped beams: Taking advantage of the V shape of the zone of the inferior edges of the cover, 6 metallic beams were generated that were from the façade to the opposite end. They are distributed of the following way: The 2 extreme ones are parallel to the market and the concrete beams. The 4 power stations become broken in their route and form a pair of 2 rhombuses. Of the central pillars of facade 2 beams of each one are born, and at the pillars of the inner patio 2 beams to one and 3 to another one arrive. The sixth beam is floating hold on by a set of lateral props.

Props: They are the set of bars that hold laterally the cover uniting the extreme of the metallic beams with the lateral concrete truss.

Wood arches: The space between the metallic beams is completed with wood arches, tri-articulated the most inclined and bi-articulated the reduced arch's.

Metallic arches: The length between the supports gives rise to a considerable deflection that is precise to compensate. For it they have designed a set of 3 arches that through 12 of them hang maintaining them altogether the 4 central beams. The support points of each arch are united to a cable set trims in their base. The tensioning one of these cables puts the load through the arcs, hoisting the beams to its position and allowing as well to diminish the metallic efforts in beam and pillars. These arch's have the particularity that they leave and they enter through the cover intermingling itself with it.

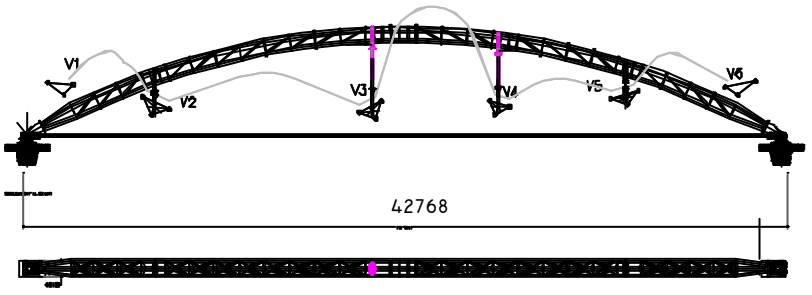

Fig. 1.- General cross section of cover by the steel arches, wood arches and steel beams

3.- THE CENTRAL STEEL ARCH´S

3.1.- The arch:

The three arch's have a length of 42.78 m between supports, with a height of 6.02 m respect with its base (1/7 relation), and a radius along its axis of 41.44 m (approximately 60º). The section of the arch is composed by three tubes of 219.1 mm of diameter and 25 mm of thickness arranged in a shape like an equilateral triangle, with its base located in the superior part.

The tubes are united between them by means of one disposition of bars and billets type "Howe", in which the inclined bars (tubes of 80 mm in diameter and 12 mm of thickness) work under compression and the vertical elements, which are billets of 15 mm of thickness, work under traction.

The verification to buckling (local instability of bars or general of the set) as opposed to combination of vertical and horizontal loads on the hangers was made by means of classical formulation and nonlinear computational analysis.

Photo 2 - General perspective of the arch's

3.2.- Supports and Cables:

Structurally the arch's have a precise support at their ends. One of them is a support guided in the plane of the arch and the other one is fixed with freedom of rotating (type "pot"). By designing using this procedure the deformation of the arch's do not transmit horizontal effects on the concrete beams.

With the purpose of absorbing the horizontal stresses in the supports at the arch's, it was then proceed to the tensioning of these ones by a pair of tendons in each and one of them, as well formed by 19 cables of 0.6 in (15.24 mm) each one, working to one tension in service approximately around 3000 kN. The directional support of an end, allows that the horizontal stresses due to the tensioning of the arch's acts over the concrete beams that serve as supports are minimum (Photo 9).

The cable tension of 3000 kN have is main purpose to control vertical deflections of the arches, by means of the hangers, and the seteel beams.

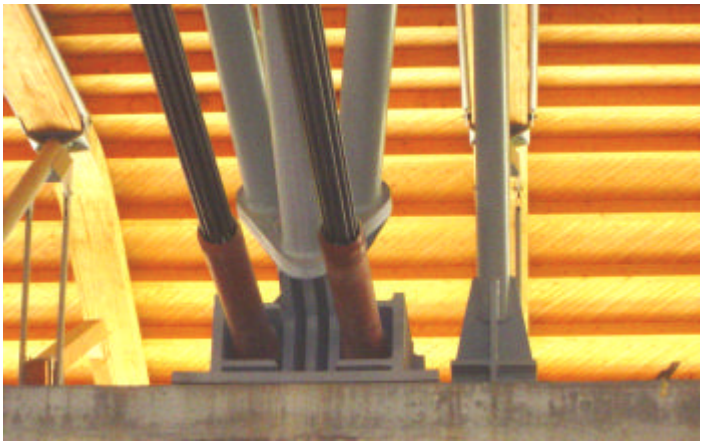

Photo 3 - Supports at the arches

Photo 4 - Supports of the arches

3.3.- The Bracing:

The arch's lean on two points at their ends; therefore, they are unstable compared to the horizontal stresses. The bracing between the arch's has been solved by means of inertia bars that to a certain distance from the arch's, these ones are opened in two props, one directed to a tube CHS 219.25 x 25 superior and the other to the inferior one (Photo 7 and 8).

The disposition of the stays constitutes spatially building the framework for in crossings that favors the rigidity.

Photo 5 - General view

Photo 6 - Bracing of the Arch's

Photo 7 and 8 – Union of hangers to the arches and anchorage of the braces

3.4.- The Hangers:

From the great arch's, 12 hangers descend (4 per arc) that unite the arch with metallic beams constituting, thus, a set of vertical elastic supports. The situation of the hangers in each arch is different to each other, as well as its length, due to the variations in plant and elevation of the beams.

Photo 9 - Union of the hangers to the steel beams

4.- THE WOOD ARCH´S

4.1.- General Description:

The curved shape of the cover is executed by means of wood arch's that constitute the ribs of the closing. This wood is structural, and its section is of 200 x 400 mm in a flat beam. The arches are all different in length and shape. They are comprised in general by two flat aprons and one superior part curved. The arches are articulated in the base with the purpose of not transmitting moments between the parts of wood and the metallic beams.

4.2.- Tri-articulated Arch's:

The more inclined arch's are tri-articulated with the main purpose of releasing tensions in their center due to their own movements of wood, as well as, for constitutive reasons because given its spread it agrees that they are independent pieces. The span varies between 3.80 m and 4.70 m. At the same time, the height over their base is between 3.80 m and 4.70 m.

Photo 10 – Tri-articulated Arches

4.3.- Bi-articulated Arch's:

The reduce arch's are bi-articulated to favor their rigidity, because they form part of the central rhombuses that work like a great horizontal beam, and also because working under compression they should avoid secondary deformations due to the moment originated by the decentralization between axis and the semi-arch's. The maximum span is 10.94 m with a height of 1.69 m. At ends of the covering, the spans of the arches decrease in length.

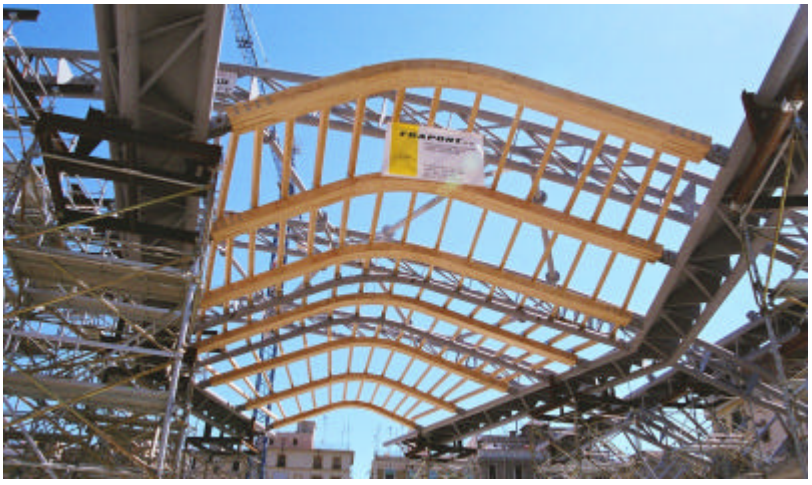

Photo 11 - Bi-articulated Arches

4.4.- Special Arches:

They are formed for the entrance of the main spans. The axis of the arches varies.

Photo 12 - Special Arcs

Photo 13 - General view indoors

5.- Materials Used

The type of steel used is S355J2. The concrete used for the reinforced concrete C45/55 according to the Eurocode. The wood sections are type MC-30, and resist to flexion up to 30 MPa.

6.- Conclusions:

- The steel and the wood are materials that can be combined to form suitable resistant structures that encompass the new modern architectural tendencies.
- Wood and steel make a good combination, as materials capable of achieving complicated shapes.
- The lightness of wood and strength of steel propitiates the construction of structures of low weight, and aesthetic form.

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