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EXPO'98 PORTUGUESE NATIONAL PAVILION
A LARGE USE OF LIGHT WEIGHT STRUCTURAL CONCRETE

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ABSTRACT
The Portuguese National Pavilion is a special building that shall provide conditions for the reception of delegations of most world nations that will be present at EXPO'98 - LISBON INTERNATIONAL EXPOSITION.

The pavilion is a two bodied construction consisting of the main building and the canopy which covers the Ceremonial Square housing official events.

The main building is a 4 storey multipurpose building roughly rectangular 90 meters long by 60 meters wide, with a inner courtyard. The structural solution of the building consists in peripheral reinforced concrete shear walls starting from the basement walls and, in the interior, in a steel framed structure with composite steel and light weight concrete slabs allowing future rearrangement of the areas.

The canopy structure is a 20 centimetre thick parabolic membrane slab measuring in plan approximately 65 meter by 50 meter and hanging from steel prestressed cables anchored along the two short sides into anchorage slabs laying on the top of a reinforced concrete structure of fins and shear walls. The use of light weight concrete provided a good way to reduce that horizontal forces at the same time being adequate to provide the appropriate strength and stiffness to assure the convenient distribution of thrust forces

Keywords: Canopy, Concrete, Presstress, Roof

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1. INTRODUCTION

Portugal being host of EXPO'98 - LISBON INTERNATIONAL EXPOSITION, the Portuguese National Pavilion shall provide conditions for the reception of delegations of most world nations that will be present on that event.

The pavilion is a two bodied construction consisting of the main building and the canopy. The main building is a 3 storey multipurpose building 90 meters long by 60 meters wide, with a inner courtyard, and during the EXPO'98 will house high quality reception facilities and the exhibition of some interesting features of Portuguese history and after EXPO'98 will be used as a museum or public offices. The canopy is a large roof covering the 75 meters long and 53 meters wide "Ceremonial Square" where the reception of delegations will be held.

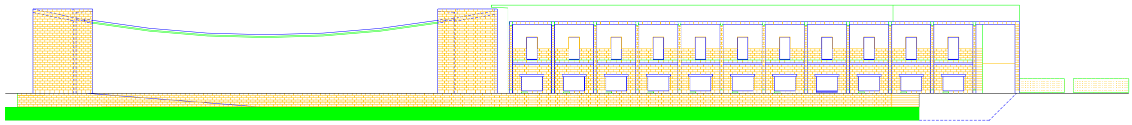

Figure 1 - Main Façade of Portuguese National Pavilion at Waterfront

The structural solution of the building consists in peripheral reinforced concrete walls starting from the basement walls that will provide the stability of the building against lateral forces (wind and earthquake forces) and, in the interior, a steel framed structure with composite steel and light weight concrete slabs allowing future rearrangement of the areas.

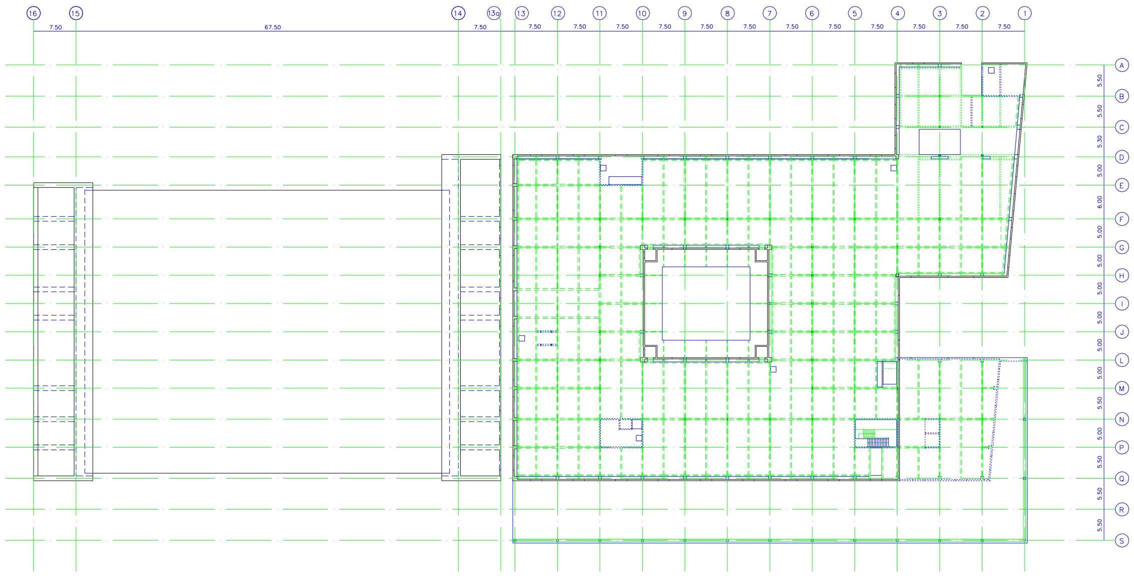

Figure 2 - Plan View of Canopy and Building

The canopy structure is a 20 centimetre thick parabolic membrane slab measuring in plan approximately 65 meter by 50 meter and hanging from steel cables anchored along the two short sides into anchorage slabs on the top of a reinforced concrete structure of fins and shear walls. The small sag (3 meters against the 67.5 meters distance of supports) will induce large horizontal thrust on the top of the fins. The use of light weight concrete provided a good way to reduce that horizontal forces at the same time being adequate to provide the appropriate strength and stiffness to assure the convenient distribution of thrust forces. That was important to guaranty the 30 centimetres longitudinal slope for rain-water run-off, being known that if it acted as in independent strips, one error of 1% in the cable force would cause a deviation 10% of the longitudinal slope. Special study of the light weight concrete was made to obtain the adequate strength and to achieve the construction of the membrane in one only pour of concrete to avoid visible construction joints

2. GENERAL DESCRIPTION OF THE STRUCTURAL SOLUTION

2.1 The Building

The structure of the building should provide the possibility for easy major modifications of its inside in a early future.

Starting from a basement floor with a raft foundation over concrete piles and surrounded by reinforced concrete retaining walls, a mesh of concrete columns, spaced of 8 meters on centre, supports the ground floor solid concrete slab.

Figure 3 - View from inside

From the ground floor starts a different kind of structure. On the periphery of the building reinforced concrete shear walls give continuity to the underground retaining walls and provide the strength against horizontal forces acting on the building (wind and earthquake forces) and also giving support to the upper floors structure. Inner to this concrete walls a steel construction solution was chosen using a steel framed structure with composite steel and light weight concrete slabs as the more suitable for future modifications of the floor layout by adding or removing slab panels (see figure 3).

2.2 The Canopy

From two opposite mat foundations over concrete piles and connected by struts grows a structure composed by reinforced concrete fins and shear walls, on top of which lay two anchorage reinforced concrete slabs whose closer borders are 67.5 meters distant.

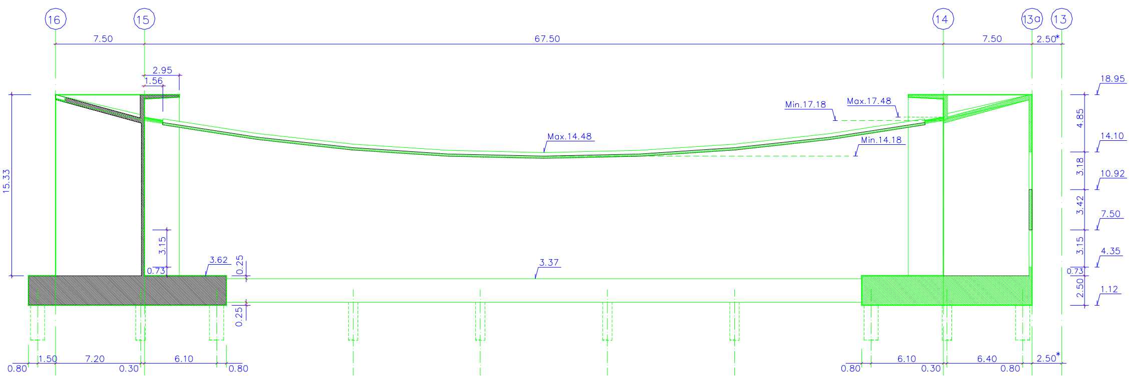

Figure 4 - Cross Section of the Canopy Structure

The canopy structure is a 20 centimetre thick parabolic membrane slab measuring in plan approximately 65 meter by 50 meter and hanging from steel cables anchored along the two short sides into anchorage slabs. The steel cables are unbounded and have an aerial trajectory on each side of the canopy (see figure 5), releasing the canopy from the supporting structure enabling a perfect control of its behaviour and isolating the canopy from induced earthquake vibrations.

The small sag (3 meters against the 67.5 meters distance of supports) will induce large horizontal thrust on the top of the fins. The use of light weight concrete provided a good way to reduce that horizontal forces at the same time being adequate to provide the appropriate strength and stiffness to assure the convenient distribution of thrust forces. That was important to guaranty the 30 centimetres longitudinal slope for rain-water run-off, being known that if it acted as in independent strips, one error of 1% in the cable force would cause a deviation 10% of the longitudinal slope. Special study of the light weight concrete was made to obtain the adequate strength and to achieve the construction of the membrane in one only pour of concrete to avoid visible construction joints

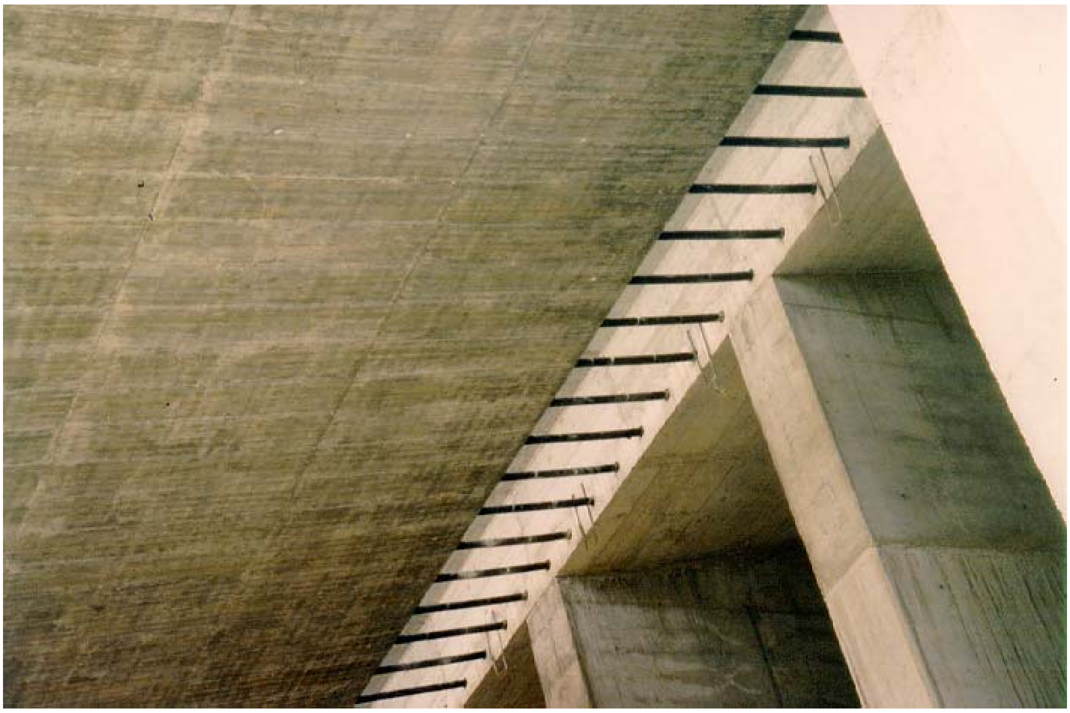

Figure 5 - Detail of Canopy, Cables and Fins

Figure 6 - General View of Canopy

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3. THE USE OF LIGHT WEIGHT CONCRETE

To reduce the dead weight of the structure a special concrete was studied, with a mass density lower than 1800 kg/m^3, concrete that must reach a minimum strength LC25 and being to be pumped at distances up to 60 meters.

The formula for this concrete used:

- Portland Cement Type I 42.5
- Flying Ashes (from Sines Power Plant)
- Silica Fumes (MS 610 from MBT)
- Natural Sand (Siliceous)
- Expanded Clay (LECA 2-4)
- Superplastifier (Rheobuilh 561)

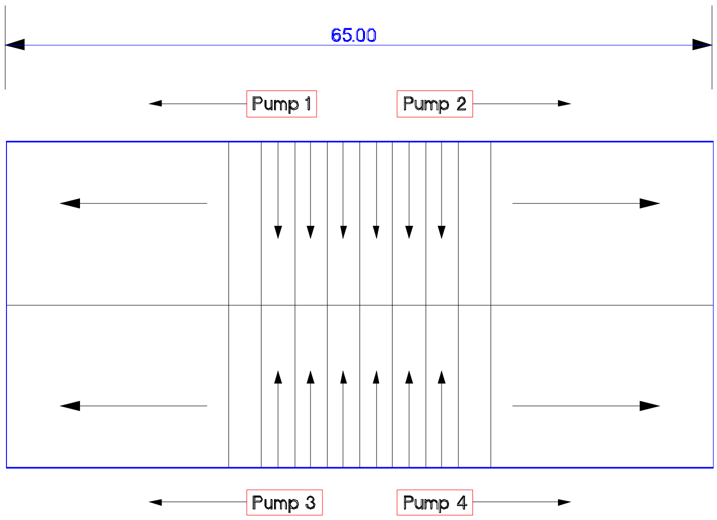

Figure 7 - Scheme for Pouring Concrete for Canopy

Special concern was taken with the absorption of water by expanded clay and the consequent modifications of the concrete properties. Several tests were made to obtain the best results.

Preliminary tests showed that even the diameter of the pump ducts could affect the results by the warming of the concrete as a consequence of friction against the wall of the ducts.

Figure 8 - Pouring Concrete

The operations of pouring the concrete over the more than 3900 sq. m of falsework started with a central strip 2.5 meters wide and continued with the help of 4 concrete pumps with a production of 80 cu. m per hour according to the scheme shown in Fig. 7. The average delay at working joints was no more than 45 minutes in order to get a full continuity in the bottom surface of the concrete.