Tagus Crossing at Carregado (Portugal): A project respectful of its sensitive environment

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**ABSTRACT:** The Tagus Crossing at Carregado in Portugal is located in the Tagus river alluvial valley, which is one of the most fertile Portuguese agricultural areas. The crossing is approximately 11,700 m long, carrying a double 3 lane carriageway with 30 m of total width. It is made of three main structures: the 1700 m long North Viaduct, the 970 m long Tagus Bridge and the 9200 m long South Viaduct. Additionally to these main structures the environmental sensitivity of the agricultural ground occupation imposed the construction of a set of significant complementary works: an 8 m wide 9200 m long side road along the South Viaduct to serve the construction site, including 18 pontoons to overcome local waterlines, dikes and irrigation existing infrastructures. In this paper a description of the project is made with emphasis in the design and construction aspects associated with the limitation of impacts on the adjacent sensitive environment.

1 **INTRODUCTION**

The New Tagus River Crossing at Carregado, Portugal, now known as Ponte da Leziria, is a 12 km long bridge opened to traffic on July 2007. It was built to allow the A10 Motorway to cross the Tagus river between Carregado and Benavente, linking several motorways on the northern region of Lisbon. This bridge is owned by BRISA-Auto-Estradas de Portugal, the largest Portuguese motorway operator, which launched a design and build tender on September 2003, with a 21 months construction delay.

The bridge crosses one of the most environmentally sensitive areas of Portugal: the Tagus river alluvial valley – the Leziria plain. Simultaneously it is located in the highest seismic risk area of the country.

2 **THE BRIDGE**

The bridge has three main structures: the North Viaduct, 1700 m long, the Tagus Bridge, 972 m long and the South Viaduct, 9230 m long. The deck is 30 m wide, with two times three lanes. The height varies from about 10 to 26 m.

The North Viaduct is composed by four viaducts with current spans of 33 m. It has a slab on girder cast in situ deck, 2 m high, with four beams, monolithically connected to 1.5 m diameter pier-piles. It was build with form travellers. Over the North Railway line it has a special 62 m span which was achieved converting the slab on girder deck into a double caisson of variable depth over the piers.

The South Viaduct is composed by twenty two viaducts, with a total length of 9230 m. The deck is a slab on precast U girders with current spans of 36 m. It is rigidly connected to 1.5 m diameter pier-piles which reach more than 50 m deep. In a precast unit on site TACE (the contractor) cast 1032 U beams, four per day, with lengths between 14 and 42 m and weighting up to 120 t. They were transported through a 9.2 km parallel service road and placed by crane.

The Tagus Bridge (Fig. 1) has a total length of 972 m, with spans of 95 + 127 + 133 + 4 × 130 + 95 m. The deck is a single box girder for the full width, in prestressed concrete, with large cantilever slabs, cast
in second phase, supported on steel struts. The girder depth varies from 8 m over the piers to 4 m at mid-span.

3 THE ENVIRONMENTAL CONDITIONS

The environmental strict demands conditioned the design. Along the 9.2 km long south viaduct there are only three points were discharge of water from the bridge deck to the main water lines was allowed. This viaduct crosses fourteen channels and water lines. A longitudinal drainage system collects the water and conveys it in to retention basins were it is treated before final discharge into the main rivers.

Place of the piers inside the water lines (excepting only the Tagus River) or touching the protection dikes was not allowed. This has conditioned the span distribution.

To minimize the environmental impact of construction activities and to be able to meet the short construction schedule a precast solution for the south viaduct deck was chosen. A 9200 m parallel road was built to allow the transportation of the precast elements. It was necessary to build 18 small to medium size bridges to overcome local waterlines, dikes and irrigation and drainage existing infrastructures (Fig. 2).

All the excavation products were placed only on authorized landfills.

During the construction period the water quality was continuously monitored.

There were three construction yards, occupying a total of more than 220,000 m². The precast facility where the 1032 beams were made was located in the main yard. There were four concrete batch plants with production ranges from 80 to 120 m³/h. One of these plants fed a 700 m long concrete pumping line placed over a provisional footbridge to allow the concrete delivery to six of the seven piers on the Tagus river bed.

4 THE GEOTECHNICAL CONSTRAINTS

The site is a large alluvial valley. All along the bridge the geological formations are, from top to bottom:

- a medium clay top layer, approximately 1 m thick, (in the river bed 4 to 5 m of soft sand);
- soft clays 20 to 30 m thick
- sand and gravel, 4 to 15 m thick;
- Miocene formations of over consolidated clays and dense silt sands.

Liquefiable sand layers under strong earthquake actions were present in the majority of the crossing extension. Due to the particular geotechnical environment –35 to 60 m thick alluvial soils, layers of mud and soft clay more than 10 m thick with low Vs values and low damping ratios – amplification effects of the seismic motion might occur. This situation not being covered by the EC8 design spectra, detailed studies of the soil behaviour under seismic loads were performed. The study was done using the equivalent linear method, with the seismic load represented by artificial accelerograms computed from EC8 power spectra. This analysis produced both the shear stress induced by the seismic action on the local geology (used for the evaluation of sand liquefaction potential) and the response spectra for structural analysis. This phenomenon was taken into account in the structural design.

This foundation conditions led to the adoption of pile foundations reaching 50 m deep.

On the viaducts the 1.5 m diameter concrete piles were bored and cast-in-place with withdrawable steel tubes. On the bridge the 2.2 m diameter concrete piles where bored and cast in place with lost casing steel tube.

5 DESCRIPTION OF THE WORKS

5.1 North Viaduct

The North Viaduct was cast-in-place, span by span, with three launching girders.
On the North Railway crossing each half deck was transformed on a box girder to span the 62 m railway corridor. This span and the two adjacent spans were cast in place on a classical falsework.

5.2 The Tagus Bridge

The Main Bridge has a total length of 972 m, with spans of $95 + 127 + 133 + 4 \times 130 + 95$ m. The deck is a single box girder for the full width, in prestressed concrete, with large cantilever slabs, cast in second phase, supported on steel tubular struts. The girder parabolically variable depth varies from 8 m over the piers to 4 m at mid-span.

The deck is longitudinally and transversely posttensioned with internal cables. Additional longitudinal posttension with external cables was also provided. The girder was built by the balanced cantilever method with seven pairs of form travellers in six months. The closing operation has included the application of a 19,000 kN force, introducing an initial stress distribution to compensate for creep and shrinkage effects.

Piers are made of double walls 5 m spaced between axles. Piers P1 to P5 are rigidly connected to the deck while P6 and P7, with 7.4 m distance between wall axles are topped by a 2 m thick slab, on which are located longitudinally guided pot bearings.

Large pile footings connect groups of 8 or 10 piles and were built with a precast concrete formwork shell assembled on site and sunk with an automatic hydraulic system. The bored 2.2 m diameter piles reach 44 m and were constructed using permanent lining steel tubes.

There are two types of pile caps. Those of P1 and P2 (10 piles), adjacent to the navigation channel, are 33 m long, 11 m wide and 7.2 m thick. Those piers were designed for the collision of a 3000 t vessel travelling at 15 knots. The remaining pile caps (8 piles) are 27.5 m long, 11 m wide and 4.2 m thick.

Due to the length of deck connected to the piers it was important to minimize the effects of concrete shrinkage. This concrete was to be pumped through a 700 m line. For this propose special C45/55 concrete mixtures were used.

The quality control of the piles included the extensive use of cross-hole tests and a full scale dynamic pile test of two piles to evaluate the lateral skin friction (Fig. 6).

5.3 South Viaduct

The main challenge for this structure was to precast 1032 U beams, some reaching 42 m and weighting up to 120 t and approximately 270,000 m² of pre-slabs in a 16 month period. For this propose the contactor build a precast unit on the main yard were the beams were cast. It produced four beams a day.

The precast unit had four steel forms, equipped with vibrators and steam curing (Fig. 8).

The beams were stocked on the main yard (Fig. 9) and then transported by the parallel road. At first they
were placed by launching girder. After, the contractor changed the method and used moving wheel cranes to place the most part.

The connection between the two beams and pier was then cast, the pre-slabs placed and the first phase of concrete placed on the pier zone. This first phase was then prestressed and the second phase of concrete placed.

Main Quantities:
North Viaduct:
Piles φ1.5 m – 4000 m
Concrete: 45,000 m³
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**6 CREDITS**

Owner: BRISA, Auto-Estradas de Portugal S.A.
Contractor: TACE – Travessa do Tejo ACE
Design: COBA – Engineering and Environmental Consultants
PC&A- Perry da Câmara e Assoc.
CIVILSER- Estudos e Projectos de Eng. Lda
ARCADIS

Architectural Consultant: Charles Lavigne