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VIADUCT OVER RIVER ULLA IN THE HSRL "EJE ATLÁNTICO" IN SPAIN:

An outstanding structure in the field of Composite Steel-Concrete HSRL Bridges.

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1 STEEL AND CONCRETE COMPOSITE BRIDGES IN SPANISH HSRL

Until "Arroyo las Piedras" Viaduct Project ([1], [2]) was awarded, only concrete bridges were allowed in Spanish HSRL. The singular conditions concerning this undertaking were not technically advisable for concrete typologies:

- Length of 1208.90 m, without expansion joints between abutments.
- Piers height up to 93 m.
- Inconvenient foundation conditions, resorting to very long piles.
- Very intense seismic actions.
- Inability to place fixed points in only one abutment.

Fig. 1. View of "Arroyo las Piedras" Viaduct.

"Arroyo las Piedras" Viaduct (Fig. 1) was finished in late 2005, with a characteristic span of 63.50 m, slightly longer than the 63.00 m in the Orgon Viaduct, located at the TGV Mediterranean Line, being the longest span for this typology.

Several composite steel-and-concrete solutions have been chosen over the more conventional concrete alternatives in Spanish HSRL ever since. IDEAM itself is now involved in the project stage of several outstanding steel-and-concrete composite bridges, some of which are to become the most emblematic in HSRL in Spain.

- Viaduct over Ulla River (Atlantic Axis): main span 240 m long.
- Kinatoi Viaduct (Basque Y): 65 m long spans and 95 m high piers.
- Ibaizábal Viaduct (Basque Y): 83.50 m long spans.
- Bergara Viaduct (Fig. 2) (Basque Y): main span 180 m long.

Fig. 2. View of Bergara Viaduct.

- Archidona Viaduct (Cordoba-Granada HSRL): main span 80 m long with central fixed point and a total length between expansion joints of 3115 m.

2 AN UNIQUE SOLUTION FOR AN UNIQUE UNDERTAKING

The new viaduct over the Ulla river, topic of this paper, is the most representative one of all of them. Its construction will begin after the 2008 summer and constitues the most audacious and high-profile intervention in the High Speed Atlantic Railway Line to Galicia and Spain's northwest regions.

Its location, close to the firth of Ulla, in a landscape of outstanding natural beauty and strong environmental limitations, was the object of a project tender among the most renowned Spanish specialists. The proposed alternative presented in this paper was finally chosen.

The project restrictions stressed specially the following aspects:

- The outstanding nature of the project, which required serious consideration of the aesthetic qualities and viaduct integration into the landscape.
- To reduce the number of piers in the water course, within the limits of HSRL bridges, minimizing the impact on the marshes and riversides.
- The erection procedures, that being suitable to the works scale, shall be kept as independent as possible from the river watercourse, to avoid environmental damage as much as possible.
- Visual transparency and minimal bridge interference with the surrounding landscape.

All these determining factors guided the solution to a steel-concrete haunch composite lattice, with double composite work at the hogging zone, three main spans measuring 225 + 240 + 225 meters long, and several approaching spans measuring 120 m long, which means a main span about 20% longer than the current world record, the Nantenbach bridge in Germany, with a single 208 m long span.

3 STRUCTURAL CONCEPT

As it will be later described, the structural solution of steel lattice with double steel-and-concrete composite action adequately solves the previously stated conditions.

The deck was designed as a depth-varying lattice in the five main spans (Fig. 3), ranging from 8.50 m to 17.25 m, and as a constant depth lattice (8.50 m) in the approach spans.

The four central piers, with elegant architectural shapes (Fig 5), are embedded in the lattice deck creating composite frames which bestow the required stiffness upon the three central spans (Fig. 4) in order to withstand the stresses which arise from loads acting on alternate spans within the stringent deformation limitations in HSR bridges.

The lateral piers (Fig. 6) were designed with a lighter cross-section consisting of two separate concrete shafts embedded in the deck and in the foundation. This allowed us to preserve some degree of stiffness against alternate loads as well as the necessary flexibility to permit of temperature and shrinkage imposed displacements.

Fig. 3. Elevation view of Viaduct over river Ulla

Fig. 4. Lateral view of the main span of Viaduct over river Ulla

The structure's design, preserving the structural orthodoxy, has placed special care on the integration of shapes and geometry between the concrete piers and the deck's steel lattice. The smooth depth variation along the deck, with an upward concavity, confers a serene visual integration over the Ulla River's course. The colour choice, pearly grey for concrete and green for the lattice, enhances that effect.

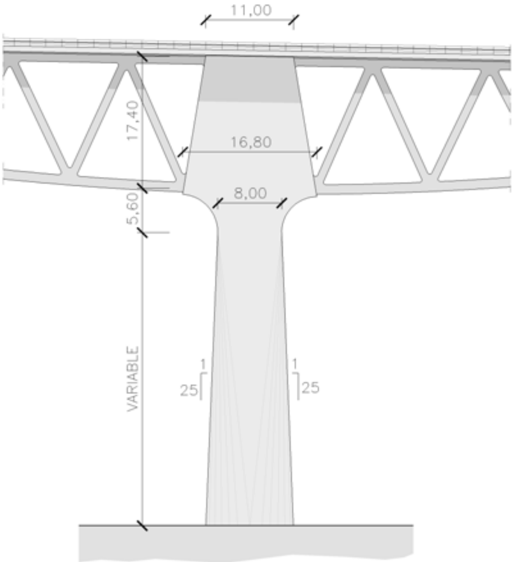

Fig. 5. View of the two inner piers P-6 and P-7

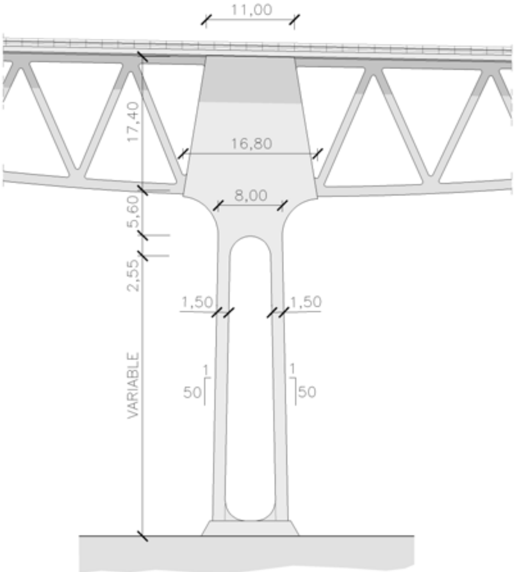

Fig. 6. View of the outer piers P-5 and P-8

4 STRUCTURE OVERVIEW

The resulting viaduct is 1620 m long with a span distribution of 50 + 80 + 3x120 + 225 + 240 + 225 + 3x120 + 80 (lenght in meters). (Fig. 7)

The main spans are solved with a double lattice depth-varying deck, with a steel depth under the upper concrete slab ranging from 8.5 m at the midspan section to 17.25 m at the section over pier. The lattices, which are modulated in 15 m long segments, are separated 6 m, measured between the upper flange midpoints of the upper members, showing a 1H/17.5V outward slope. The adjacent spans giving access to the depth-varying main ones have been designed to keep the lattice scheme but with constant depth. (Fig.8).

Both the upper and lower members cross-sections are parallelogram-shaped girders, measuring 0.80 m wide and 1.00 m deep the upper and 1.20 m the lower. Diagonal members are also parallelogram-shaped, with main dimensions of 0.8 wide and 1.00 m deep.

The upper member shows a boxed beam head embedded in the concrete slab which lodges the connection, allowing a shear transference closer to the center of gravity of the composite upper member and avoiding the appearance of local forces and moments in the upper joints.

Plate thickness is variable and, as a rule of thumb, plates thicker than 80 mm have been avoided. The steel quality is S-355-J2G3 for the approach spans and S-460-M and ML for the three main spans.

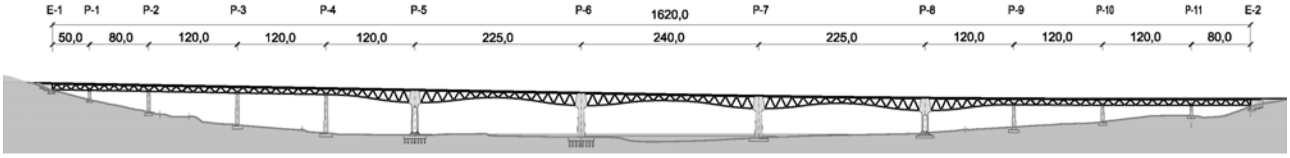

Fig. 7. Elevation view of the Viaduct

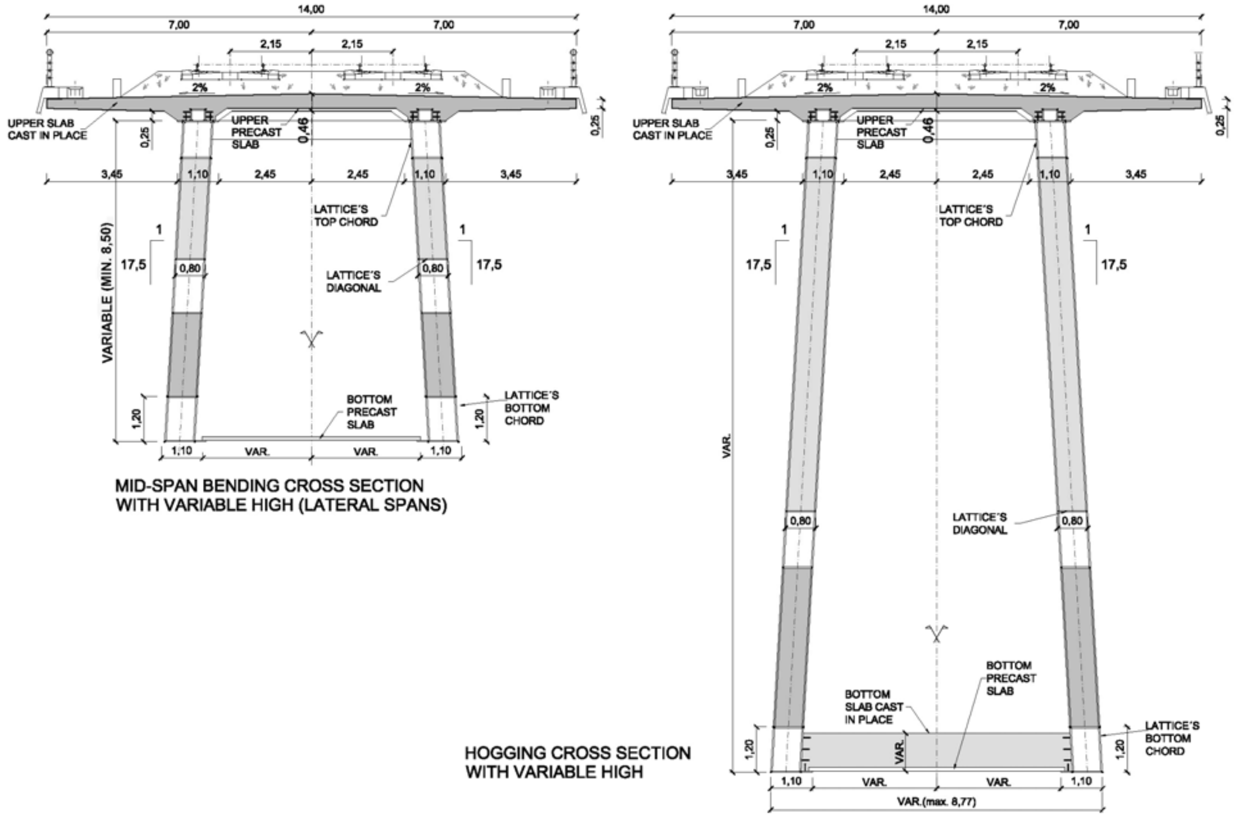

Fig. 8. Cross sections

The concrete depth-varying slab (0.46 m high at the mid point and 0.25 m at the edges) is placed directly over the steel upper member, configuring a composite cross-section structure. The slab, made of cast in place C35/45 concrete, is poured over precast concrete plates bridging the space between steel upper members of both lattices. The lateral cantilever part of the slab is cast using a movable formwork.

Along the hogging zone, and therefore compression zone in the lattice lower member, a C50/60 concrete slab is arranged between members, allowing a double composite action strength mechanism. The thickness of this lower slab ranges from 0.30 m to 1.10 m.

Along the sagging zone, the deck's lower face is closed visually using precast concrete plates, with no structural role but to create a path to allow inspection and maintenance.

Piers show a double typology well differenced. Firstly, the four main piers (from P5 to P8) are embedded in the deck, configuring a frame which increases the structure stiffness and enhances its behaviour regarding horizontal forces. These calyx-shaped piers are formed by a trapezium head measuring 17.5 m high and 11.00 to 16.00 wide, and a shaft measuring 8.00 m wide, growing with a 1H:25V slope in piers P6 and P7 and a 1H:50V slope in piers P5 and P8. The average height of the piers, measured up to the lattices'lower member, is about 42 m (60 m up to the crowning point).

The stiffness of these piers has been optimized in order to restrain deck rotations at the pier section but avoiding that bending moments taken by the pier itself and then transmitted to the foundations were a decisive design constraint.

In this way, piers P5 and P8 at the sides of 225 m spans, have been designed with two detached shafts from base to head, in order to avoid the excessive bending moments arising from the decompensation of a 225 m span next to a 120 m span, and those produced by the temperature and shrinkage displacements, both of them greater than in central piers due to their further distance to the neutral displacement point.

Besides that, side span piers P1 to P4 and P9 to P11 are of a more conventional design. Their box girder cross section with a 0.30 m wall thickness and a 3.50 m x 8.50 m head section, varies in depth both transversally and lenghtwise. The pier height ranges from 52 m to somewhat less than 20 m.

The latter piers and both abutments are crowned with two spherical bearings, totally free one of them and transversally restrained the other. All the bearings will be disposed with the sliding surface horizontal, excepting the A1 abutment ones, which shall be disposed following the i=-1.8% deck slope, in order to avoid undesired displacements. At the A2 abutment, due to the weak slope, the sliding surface will be kept horizontal.

Piers foundation is supported by the existing granite substratum by direct foundation, excepting piers P5 and P6 where the alluvial deposit thickness prevents the use of footings and forces the use of a 1.5 m diameter pile foundation.

5 ERECTION PROCEDURE

The chosen procedure to construct the viaduct shall conjugate a minimal river affection (always reversible) and erection means suitable to the bridge magnitude. P5 pier is located in the tidal range of the firth, close to the Tellería islet but outside it. To build its foundation a precast hollow caisson based access shall be constructed, allowing a water flow trough it. Once the works have been completed, the caissons shall be withdrawn leaving the firth in its original conditions.

P5 to P7 pier foundations are planned to be built with an enclosure perimeter made up of bulk rockfill and whose interior shall be filled with granular material in order to provide a dry and stable platform. As piers P6 and P7 shall be accessed by means of boats, a docking facility must be built using a sheet piling curtain.

All the works carried out in the firth for the pier P5 to P7 foundations and the access path between P4 and P5 shall use a protective suspension particle isolating barrier so that all potential damage to the water course is avoided.

Once the foundations have been completed the piers will be erected by means of a climbing formwork. Once the shaft at piers P5 to P8 is finished the “0” concrete voussoir or pier head will be cast.

Simultaneously the steel lattice wil be built at each one of the three assembly yards. The steel will arrive from the workshop in small pieces (box members and joints) and the transportation could be made by conventional means.

The constant depth spans will be built by lifting segments, using temporary piers, and only occasionally by means of cranes in those cases where the access will be difficult. The segment lenght to be lifted ranges from 25.00 to 40.00 m, depending upon the position of the temporary piers.

The lifting will be done simultaneously on both lattices, so once the final height is reached a simple transverse displacement puts the deck piece on its final position.

Besides that, the voussoirs of the depth-varying spans will be assembled at the building site with the pieces arriving from the workshop, in complete modules measuring 15.00 m long and comprising both lattices. The transportation to its final placement will be made by means of a special platform with multiple axes, accessing the pier base. The voussoirs of piers in water course P6 and P7 are transportated similarly shipping them in a boat.

Once the voussoir has arrived to the pier base, a gantry crane picks up the module close to the pier shaft, translating it to its final position and lifting it to be welded in place. So far, the steel lattices are erected by a succesive cantilever method, from the pier section to the closing key section at midspan. This method ensures independent work at the bridge from the marshes, river and surrounding vegetation.

Once the assembly of the steelwork has been completed, the lower precast concrete plates will be placed and the subsequent lower slab concrete casting done. The next stage will be the temporary piers removal from the side spans and a simultaneous and controlled downward displacement of 0.25 m of the deck at piers P4 and P9 sections.

The upper concrete slab is poured over precast concrete plates bridging the space between steel upper members of both lattices. The lateral cantilever part of the slab is cast using a movable formwork.

Finally, the bulk rockfill protective embankment of piers P6 and P7 will be removed, replacing it with local material from the affected sourroundings. The access path built with concrete caissons will also be removed and the corresponding corrective measures will be taken.

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