Viaduct over the Tera River on the HSR line Madrid-Galicia, Zamora (Spain)

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Summary

The Tera Viaduct is situated over the Tera River between km points 710+697.500 and 711+342.500 of the north-northeast corridor of the Madrid-Galicia high-speed railway line. It is therefore 645 m long with a span distribution of 60-75-150-75x5-60. Such arrangement, with one large 150 m span, is determined by the crossing of the Tera River, spanned by an arch. The deck is supported in the arch keystone, which enables constant modulation of the spans throughout the whole viaduct, keeping the same deck cross section and using incremental launching as construction method. The metal section arch was installed by rotating the semi-arches.

Keywords: Incremental launching, prestressed concrete, arch rotation, metal arch, S460 steel.

1. Project rationale

The work is located on the stretch awarded to the construction division of ACCIONA, of the north-northeast corridor of the HSR line Madrid-Galicia, running in the north of the province of Zamora. The most remarkable point of this stretch is the crossing of the Tera River, in an area containing a reservoir for a hydroelectric power station. The solution proposed in the awarded project envisioned a viaduct with a support in the middle of the riverbed, which proved difficult to perform due to the great depth of the river and the limitations imposed by the power station operators, Confederation and Iberdrola, concerning any action that may affect the water level.

ACCIONA called on CFC to develop a construction variant containing a solution that both companied had used in numerous high-speed railway viaducts in which they had worked together, with an incrementally launched bridge technique designed and patented by ACCIONA that uses a kind of rack and pinion system for the deck pulling operation.

The modulation of this work was well solved with spans about 75 m long. Such length is large for incrementally launched bridges and yet it is perfectly applicable when high resistance concretes are used. In a previous work of CFC 90 m long span had been already reached. This span accounts for a half of the crossing over the river, allowing us to span the Tera without supports, using an arch whose keystone serves as the deck support. We were thus able to keep the same construction solution of incremental launching in the entire civil work.

CFC carried out the construction project of the bridge and led the project management of the entire civil engineering complex execution that took place between 2010 and 2013.

2. Bridge description

2.1 Layout

The work layout is straight in plan with a constant slope in elevation. The total length amounts to 645 m with a span distribution of 60-75-150-75x5-60. There is a very steep slope on the right river margin, so a pier had to be embedded here. The slope gradually increases on the left margin. The maximum pier height reached 42 m, which makes 75 m spans suitable both formally and financially.

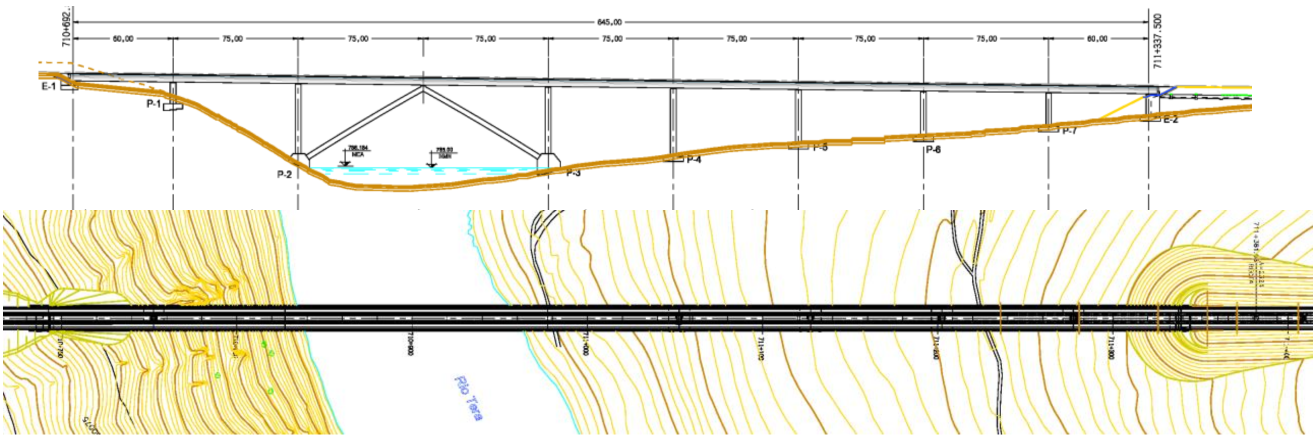

Fig. 1. General elevation and plan view

2.2 Deck

The deck dimensions and proportions are those typical for railway bridges built by incremental launching: the 14 m wide platform is placed on a box section, constant depth girder, made of prestressed concrete, with a slenderness of 1/18 of the span (4.40 m). The lower slab is 5.20 m wide, while slightly slanted webs are able to achieve a width exceeding 6.50 m. Such arrangement optimizes both longitudinal and transverse performances by placing the axes of each one of the tracks as close as possible to the axes of the webs. This minimizes the transverse bending of the upper slab, and at the same time reduces the dimensions of the lower slab.

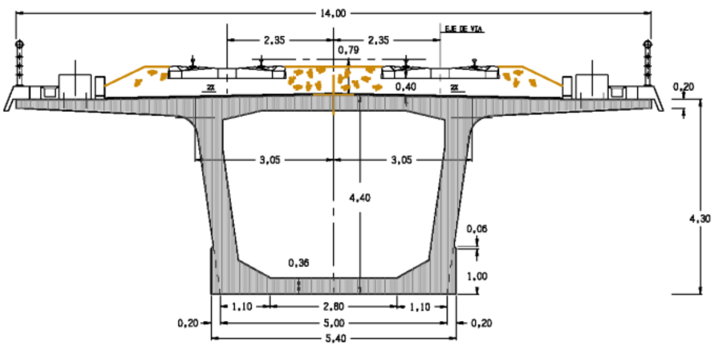

Fig. 2. Typical deck cross section

The thickness values of the upper slab range from 0.30 and 0.50 m, while the typical thickness of the lower slab is 0.36 m, increasing to reach 0.76 m over the piers. The webs are 0.50 m thick. The characteristic strength of the concrete is 60 Mpa.

The same as in any other incrementally launched bridge, two groups of prestressing cables are arranged. A set of straight cables provide due compressions to control variable stresses on the concrete during the launching stages. A second set of undulating cable groups, which are loaded once the launching has concluded, provide the additional capacity to resist final loads on the structure under service conditions.

Construction cables providing central prestressing are arranged in both upper and lower slabs in groups connecting three segments further connected using continuous anchorages. These are loaded in the prefabrication yard, with a disposition adapted to the sectional forces during construction, which as we know oscillate outside the area of influence of the launching nose, ranging from pl2/12 to pl2/24. In terms of total axial force of the prestressing this amounts to 56% of the total value.

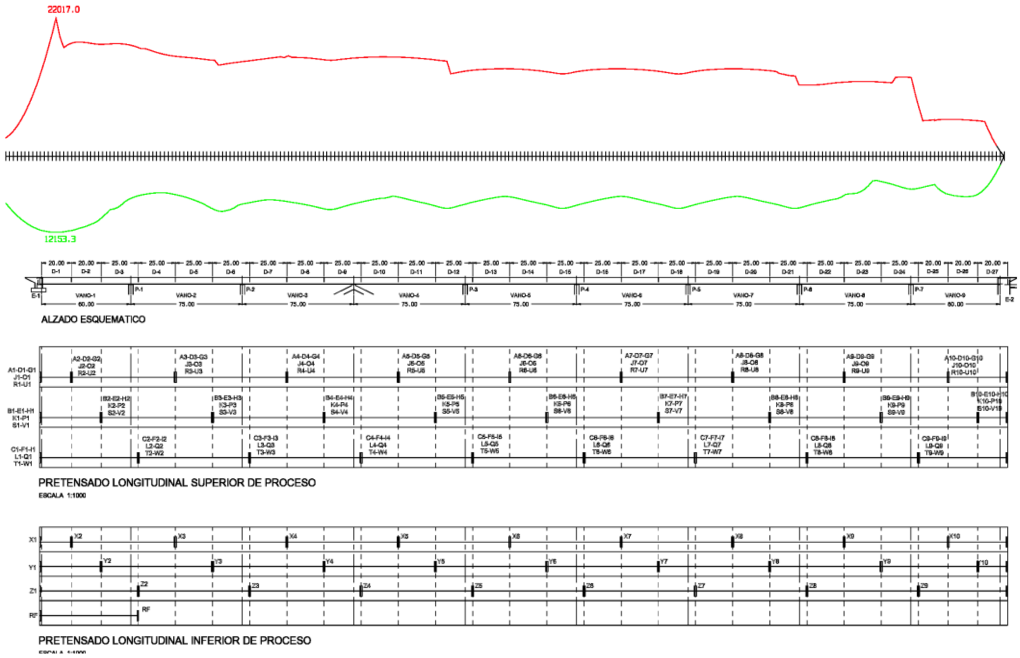

Fig. 3. Bending moments during launching and straight prestressing layout

The curved service cables oscillate along the webs from one web to another. They are anchored in anchor blocks placed at the intersections with the supports. Once the launching is complete, the cables are tensioned from either ends.

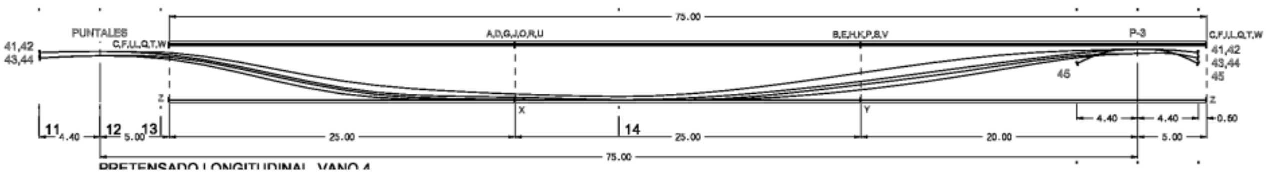

Fig. 4. Ondulating prestressing

In order to avoid problems throughout the launching process due to the empty sheaths that reduce locally the cross section resistance, particular attention is paid to the sheaths distribution and to the local reinforcement in critical sections in the lower slab. In addition, the system usually applied by ACCIONA in its incremental launching bridges, consisting of longitudinal steel plates connected to lower slab corners that makes passing over Teflon bearings easier, contributes to the distribution of the loads on the bottom slab placed over the supports during the launching stages.

2.3 Piers

The deck sits on concrete piers that have a hollow rectangular cross section whose longitudinal dimension is a constant 3.50 m, while the transverse one is variable, with a 1/40 slope running from a neck placed below the pier head and whose minimum dimension amounts to 3.20 m. The upper head is bell shaped, 5.20 m wide, decreasing lineally until reaching the neck area at the height of 7.5 m.

All the supports of the bridge are sphere shaped, with one free unit and another transversely guided one in each pier at Abutment 1. At Abutment 2 both units are free. They can all be inspected through the voids designed at the pier heads that can be accessed from the deck.

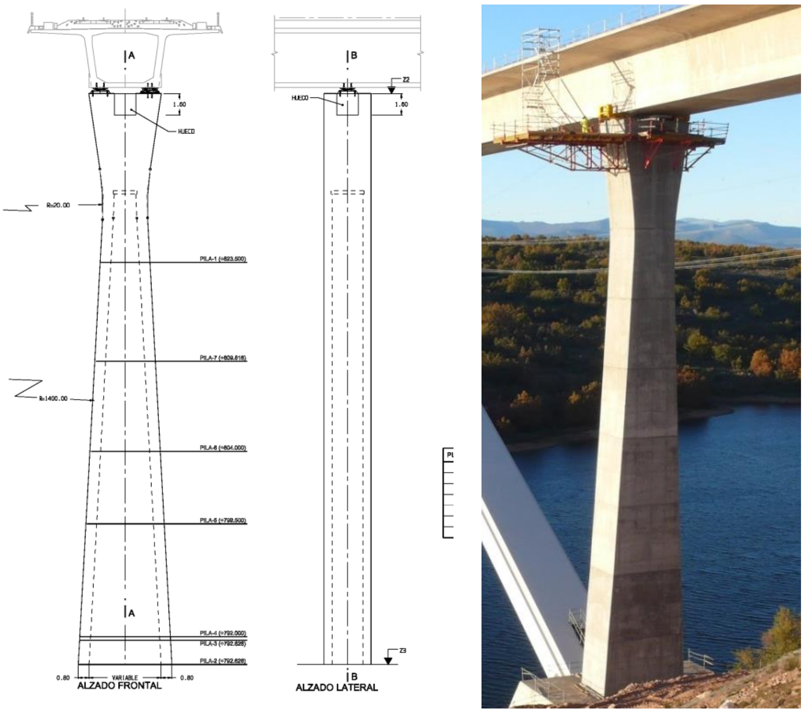

Fig. 5. Piers. Elevation and view

There are no tension problems in any of the pier supports. At the abutments, however, the supports are placed slightly wider apart in order to avoid the tension problems, therefore requiring a transverse beam which is installed in a second stage.

Taking advantage of the great capacity offered by the launching device, the viaduct is fastened against longitudinal loads at Abutment 2, in order to resist the significant braking reactions of the railway. The fixing is carried out using a protuberance that originates at the abutment and enters the deck´s lower slab. The coupling of the two is carried out by means of elastomeric supports with the adequate rotation capacity. This system introduces bending moments in the deck cross section, taken into account when designing the dimensions.

2.4 Arch over the Tera River

The most remarkable part of the viaduct is the 150 m long span supported on an arch which, due to its virtually straight geometry, appears to be composed of two struts. Concrete and metal solutions were compared. The metal solution with high-strength steel (S460) proved to be more advantageous. In this situation, the strut´s dead load is of little consequence, and therefore the arch geometry generated from the antifunicular loads results mainlyy from the point load in the keystone. The curvature of the semi-arches is therefore very small and its front view resembles a straight element.

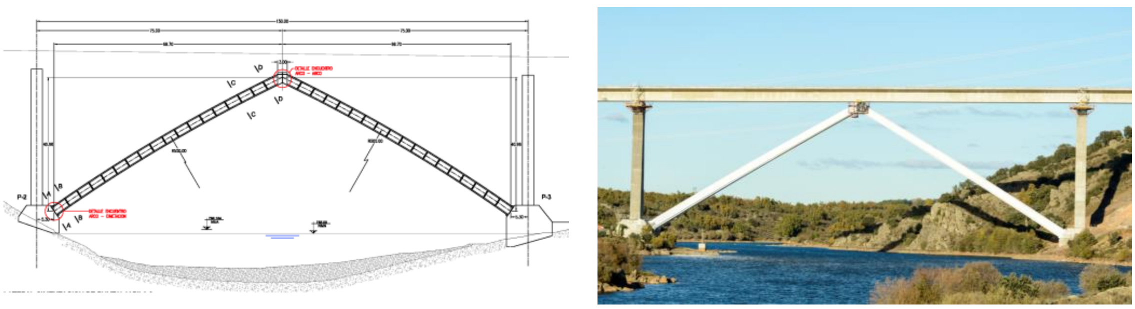

Fig. 6. Arch elevation

The cross section is rectangular with beveled corners in order to create shadows bring out the edges. The typical plate attached to the walls is 15 mm thick with longitudinal T-shaped stiffeners and transverse K-shaped diaphragms placed every 4 m.

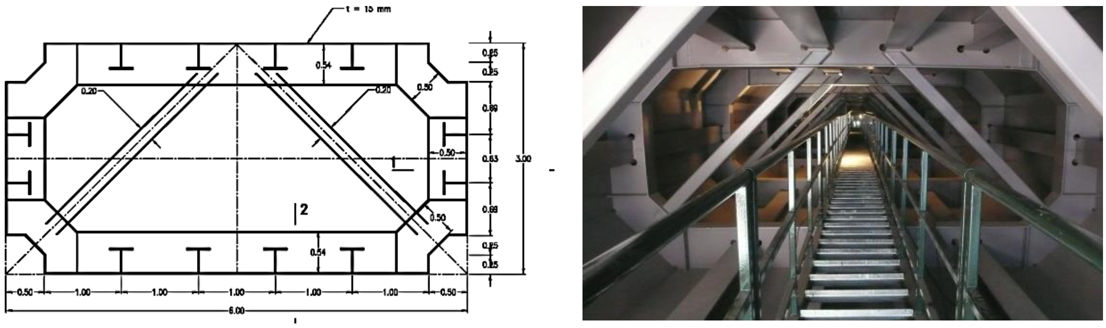

Fig. 7. Steel arch cross section

3. Construction process

3.1 Deck launching

The constructions process of the bridge deck is carried out by incremental launching from Abutment 2. The segments are 25 m long, since the prefabrication yard had the capacity for 3 segments, which correspond to one complete span. The prefabrication cycle achieved was that of one segment per week, including launching.

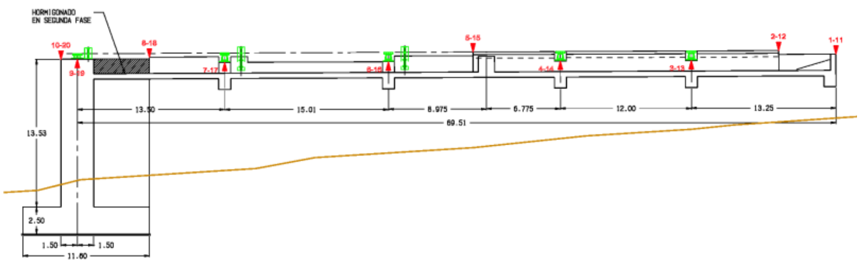

Fig. 8. Prefabrication yard at abutment 2

The metal launching nose is 45 m long, which represents 64% of the maximum span, a customary value to help optimize the forces in the deck. The connection with the deck is carried out by means of vertical and horizontal prestressing bars.

Fig. 9. Launching nose

3.2 Semi-arch rotation

Fig. 10. Vertical erection of the semi arch

The most remarkable part of the construction process of this work was the installation of the semi-arches, performed by rotation. The semi-arches were placed vertically over their springs over provisional hinges. Using provisional stay cables anchored in the contiguous pier foundations, the semi-arches were then rotated until meeting at the keystone, where they were duly welded together. Subsequently, the springs were blocked against the foundations and the provisional hinges were embedded in the concrete.

The semiarches were divided into two segments and installed using powerful cranes. Once connected, they were then stabilized by the piers which began at the same springs using provisional rotation fastenings.

The upsetting of balance in order to initiate rotation is achieved by using pairs of jacks placed at the upper portion of the pier.

The back stays are anchored in a revolving frame that holds within the retention hydraulic unit. The anchoring of the stay cables in the semi-arches was carried out using auxiliary frames that were dismantled once the rotation was completed.

A control and correction system of the displacements of the arch´s twist hinges is arranged using hydraulic jacks at the provisional lower hinges. The cable is gradually released from the jacks to produce the rotation of the semi-arches until having them facing one another at midspan where they are fixed using provisional bolted embedding.

Fig. 11. Retention hydraulic frame, auxiliary frame on the semi arch, provisional hunger

The corrections of the semi-arch position are achieved in two ways:

The twists of the arch cross section are corrected modifying the load in every stay cable. The other method used is the sliding system activated by the hydraulic jacks arranged at the arch springer. This system enables longitudinal displacement of the semiarches, while providing a rotation of the vertical axis.

Once the position of the arch closure is determined, the fixing and welding at midspan are carried out, the hinges are locked at the arch springs and the void left on them is concreted.

Fig. 12. View of the tilting manoeuvre and the deck launching over the arch

4. Summary sheet

Dimensions

Total length: 645 m (60-7x75-60)

Width: 14.0 m

Depth: 4.30 m

Deck

Concrete H-60: 7529 m3 (0.83 m3/m2)

Prestressing Y1860: 651 T (72 kg/m2)

Reinforcement AP 500 S: 1694 T (187 kg/m2)

Arch

Span 150 m. Sag 40 m

Steel S460: 600 T (285 Kg/m2 en 150 m)

5. Technical data sheet

Property

- *ADIF:* Manuel Puga, Agustín Fernández, Agustín Álvarez,

Constuction

- *ACCIONA:* Antonio Muñoz, Antonio Garrayo, David Higueras, José M. Álvaro
- Specialised subcontractors:
    - Metal arch: Torrejón-Megusa Workshops: Manolo García.
    - Rotation:

        ALE: José Luis Salamanca

        ACCIONA INGENIERIA: Manuel Biedma, F. Javier Martínez

Project

- CARLOS FERNANDEZ CASADO S.L.: Javier Manterola, Javier Muñoz-Rojas , Antonio Martínez, Sara Fernández

Project and execution supervisión

José Mª Olaguibel / INECO