PRECAST SEGMENTAL BRIDGES IN TENERIFE, CANARY ISLANDS, SPAIN: SIMPLICITY IN CONSTRUCTING A WIDE DECK

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ABSTRACT

Six bridges on the island of Tenerife, Spain, were designed to have a deck width of 16.5m (54.13ft), which is 3.5m – 4.5m (12ft – 15ft) wider than a conventional single-celled, box girder bridge deck. The requirement of a wide deck posed challenges affecting the design and the construction process. An innovative solution was applied to the design and construction of these six bridges, with 96m (314.96ft) of longest span.

Ordinarily, casting a single-celled segment with this width would require auxiliary equipment for constructing long overhangs, such as large falsework supported by second phase gantries, which can be an obstacle for site traffic (Figure 12). In this case, partial segments were precast and put into place using a single gantry. The partial segments are made of a conventional, precast deck with a width of 11.3m (37.07ft) with the addition of the new strut design that supports the longer overhang of the deck. Overhangs were partially precast, and finished in situ.

This innovative solution, that can be applied both for constructing wide decks for new bridges and for widening existing structures, only requires light equipment once the segments are placed, and do not disturb site traffic during its execution.

Keywords: Segmental, Precast, Widening, Casting yard, Struts, Cantilever.

1. GENERAL DESCRIPTION OF VIADUCTS

Figure 1: Barranco Rodrigo II Viaduct

The design of the viaducts described in this document have been jointly developed by the Ferrovial Technical Office civil works team and Torroja Ingeniería. The following table is an overview of the six viaduct dimensions:

Table 1 Viaducts main dimensional characteristics `

Viaduct	Length (m)	Spans (m)	min/max depth (m)	max Pier height (m)
Tejina	153.60	76.30 + 76.30	2.5/6.00	49.15
Niagara	153.60	76.30 + 76.30	2.5/6.00	49.35
Rodrigo I	106.40	53.20 + 53.20	2.5/4.75	22.50
Rodrigo II	138.91	69.31 + 69.60	2.5/6.00	22.00
Rodrigo III	216.30	60.15 + 96.00 + 60.15	2.5/4.75	64.05
San Juan	201.96	52.98 + 96.00 + 52.98	2.5/4.75	63.30

Therefore, the maximum slenderness of the decks is 1/20 at piers and 1/38.5 at mid-span.

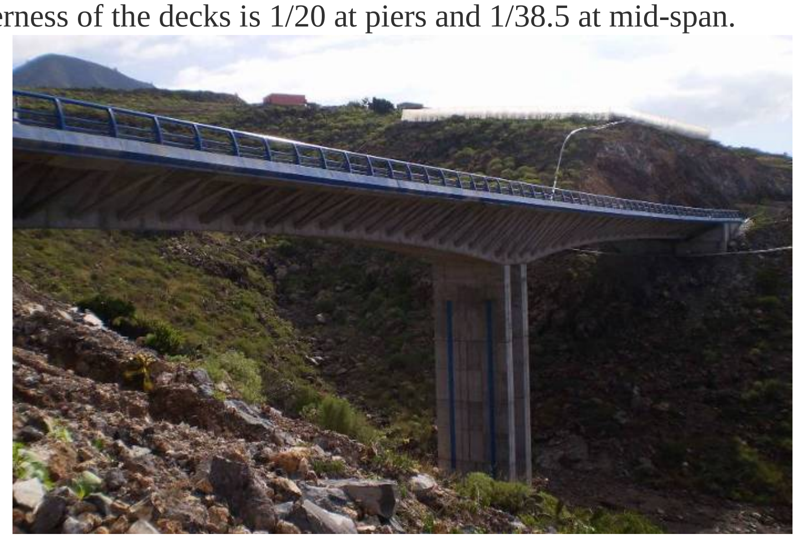

Figure 2: Barranco Rodrigo I and Barranco Rodrigo II viaducts.

2. CROSS-SECTION DESIGN

The Barranco de Rodrigo II Viaduct will be used as an example to explain the design and details of the adopted solution.

2.1. DESIGN

The design of the segments was constrained by the necessity of three lanes plus hard shoulders and barriers, hence, a deck width of 16.50m (54.13ft). A single-celled box girder would be appropriate for widths not exceeding 12 or 13m (39-42ft) wide, but this would mean a maximum of two lanes including hard shoulders and barriers, which was not what the project required.
This atypical section width had to be taken into account, while simultaneously keeping maximum weight of the segments strictly below 820 kN (184.25 Kip); this being the maximum weight that the launching gantry could handle. In addition to these constraints, the number of operations performed "in situ" on the deck had to be kept to a minimum. This was necessary to maintain onsite traffic, but it also increased the weight of each segment as a consequence. To stay within the limits of the launching gantry, the entire segment could not be precast. That being said, most of the volume of the segments was precast, leaving only a small portion to be cast in situ. With these requirements and restrictions in mind, the design of the cross section was determined mainly by three factors: resistance, geometry, and ease of construction.
For medium and large span precast segmental bridges, a box girder design with variable depth is suitable. A precast segmental cantilever erection process was chosen for these large-span bridges in order to reduce the number of piers and minimize the environmental impact on the ravines.

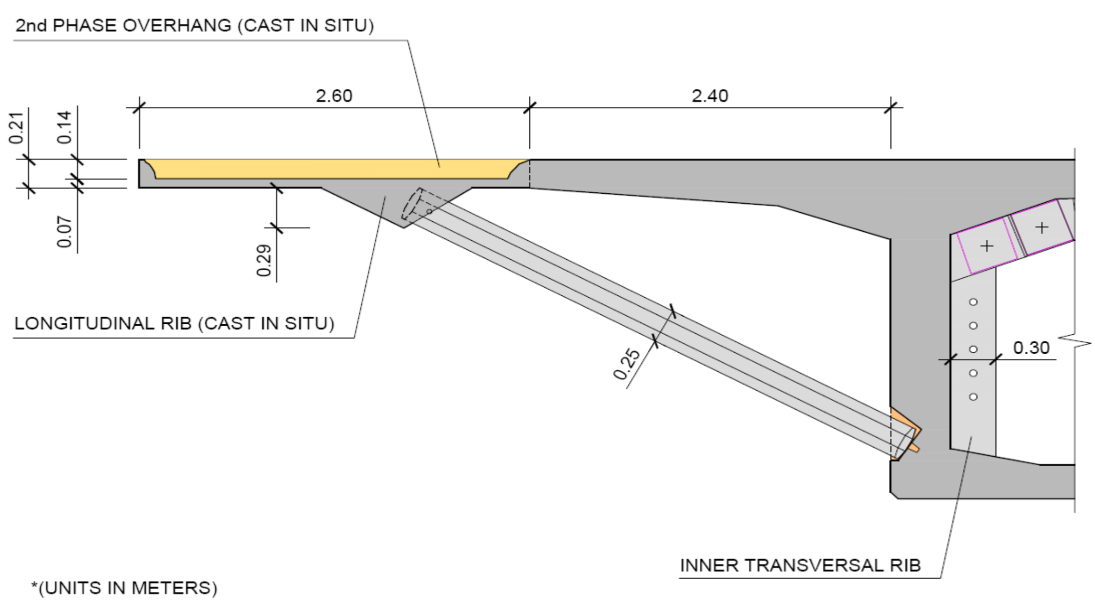

Figure 3: General Cross Section of the Deck

All these requirements where satisfied by adding lateral slabs to the overhangs of a conventional box girder to make the entire deck wider. Longitudinal ribs were also added to stiffen the connection between the struts and the deck, all together creating 5.0m long overhangs on each side of the box section. Struts arranged in a V-shape connected these ribs to the bottom flange of the box girder. The struts transferred the load of the lengthened overhang to the bottom flange. As previously stated, one of the goals on the job site was to minimize in situ casting without exceeding the weight limits of the gantry.
Therefore, only part of the additional overhang was precast. A conventional box girder section is shown in Figure 3 with the additional overhang length supported by a strut. The area highlighted in yellow is the longitudinal rib and the portion of the additional overhang that was precast. The area shaded in gray shows the portion of the deck that was completed in situ. Figure 4 shows the longitudinal rib with supporting struts on the Barranco de Rodrigo II Viaduct.

Figure 4: View of the Longitudinal Rib of the Overhang Support

2.2. DETAILS OF THE ADOPTED SOLUTION

2.2.1. Strut connection to the segment lower slab

In order to support the lower end of the struts, there is a recess on the outside face of the box section of each segment. The position of the recess coincides with the position of the inner, transversal rib (the dimensions also shown in Figure 3).
The lower supports of the struts were installed at the same distance from the bottom of each segment and at the same distance from the edge of the overhang at the top. Since the

segments vary in height the angle of the struts also varies, so all together, the struts create a ruled surface (Figure 4).

Since the struts are connected to the segments at an angle, both horizontal and vertical forces are applied to the box sections. The horizontal forces (in the transverse direction of the segment) that are created by the struts are canceled out by the equal and opposite reaction produced by the symmetrical struts on the other side of the segment. This leaves two “hanging” vertical forces on each side at the bottom of the segment creating tension in the webs of the box section. In order to transfer the vertical load from the bottom of the flange to the top, vertical stirrups were installed in the center of the inner transverse rib of each segment to support the strut recess. Now, the vertical loads created by the struts can be considered as vertical loads applied to the top of the deck rather than loads “pulling” from the bottom of the segments.

Figure 5: Strut Support Recess

2.2.2. Strut connection to the cantilever

The connection between the upper end of the strut and the longitudinal rib is fully constrained, or a fixed connection. The geometry of the longitudinal rib depends on the angle of the strut and therefore varies from segment to segment.

The forces on the top end of the strut are created by the load on the additional overhang width. Due to the geometry of the strut, horizontal forces are created in the deck both transversely and longitudinally, while the vertical force is transferred to the bottom of the segment through the strut. The longitudinal component of the reactions of the struts at the deck is cancelled out by the same component of the adjacent segment. However, the transversal reactions require ties connecting the rib to the original precast segment to resist the transversal forces created in the top slab. The ties are included in the part of the precast portion of the overhang to prevent damage to the section during construction and to resist the self-weight of the overhang.

2.2.3. Longitudinal reinforcement

Although the longitudinal reactions at the top of the strut do not require reinforcement throughout the entire bridge, there are local bending moments in each segment in the longitudinal direction. These moments are concentrated in the longitudinal rib due to the alignment with the strut support and its high stiffness. By placing the strut supports at the edges of the segment, there is a negative moment at each end and a positive moment in the middle. The installation of longitudinal reinforcement for the local bending moments is quite easy since the concrete is cast in two phases.

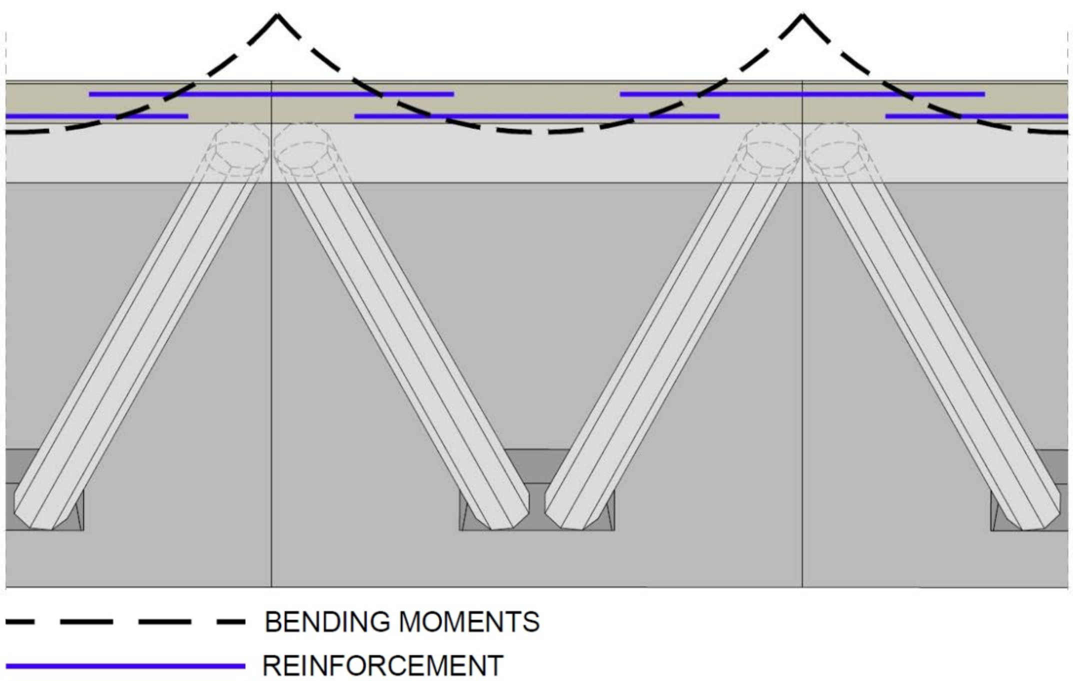

Figure 6: Longitudinal Reinforcement

The longitudinal reinforcement required to resist the positive moment in the middle of the section must be placed at the bottom of the flange section. This reinforcement does not cross the segment joint and therefore is included in the precast portion of the segment. The longitudinal reinforcement required to resist the local negative moment at each edge must be placed at the top of the overhang and also must go through the each of the segment joints. This reinforcement is installed during the in situ casting of the overhang slabs.

3. CONSTRUCTION PROCESS

The construction process began when the segments were precast in a casting yard near the job site. The segments were cast in two phases. In the first phase a segment with conventional dimensions was cast. In the second phase, struts were installed and part of the additional overhang section was cast.

Once the segment core had been constructed, the struts were made-to-order based on the dimensions of the segment. The struts were then installed into the lower strut support. Once the struts were in place, the longitudinal rib and 7cm of the total 21cm of the overhang thickness were cast.

Figure 7: Phase 1 Completed

After the overhang add-on was precast, the strut union with the main segment was completed by filling it with concrete and filling the recess with epoxy. The precast part of the segment was finished and ready to stock.

Figure 8 & 9: Preparation of the Segment to Complete the Second Phase of the Precast

Segments were then placed one by one using a launching gantry to apply the segmental cantilever construction method. There were no major issues during this part of the construction process even though the segments were considerable in size and weight.

Figure 10: Stocked Segments in the Casting Yard

Figure 11: Placement of the Precast Segments

Once all the segments were in place and connected, the longitudinal reinforcement was laid out and the remaining slab of the overhang was cast in situ, only needing light equipment for pouring the concrete. Refer to Figure 12 as an example of the alternative construction method that would be necessary for building single-celled wide decks. The logistic problems for site traffic are clearly shown in this figure.

Figure 12: Alternative solution. Example of Secondary Gantries with Elaborate Falsework[3]

Finally, the finishing touches, such as laying the pavement and installing guard rails and barriers, were carried out to complete the bridge.

Figure 13: In Situ Casting.

4. CONCLUSION

The design of these single-celled, box girder bridges is unique and has a relatively simple building procedure for a deck that is wider than the conventional widths. Alternative procedures would have needed large auxiliary equipment to construct a wide deck. The method that was used in Tenerife allowed minimal in situ casting and the completion of the deck was performed with light equipment that does not interfere with the rest of the construction. The erection method itself is a conventional cantilever segmental procedure. The only thing out of the ordinary was launching 16.50m (54.13ft) wide segments.

We have the ambition to develop this design in the future. It is hoped that a deck may be "widened" further and that the ability to launch a 23m (75.46ft) wide single cell segment with strut supported cantilevers is not beyond us. A deck of that size could accommodate a dual carriageway with the corresponding shoulders and barriers and it is believed that this is an achievable possibility.

5. REFERENCES

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6. DATA BLOCK

Project Name: *Nueva carretera Adeje-Santiago del Teide y conexión con el Puerto de Fonsalía*		
Main figures:		
Project Budget	*167.836.150 €*	
Viaducts budget	11.749.492 €	
Prestressing steel	471.677 *kg*	*(29.5 kg/m²)*
HP-50 Concrete in segments	10.013 *m³*	*(0.63 m³/m²)*
B500S passive reinforcement in the deck:	2.052.918 *kg*	*(205 kg/m³)*