Bridge over the river Nervión on the Bilbao Donostia line

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Summary

The new bridge of the narrow gauge railway over the river Nervión is to be found at the exit of the Etxebarri station and replaces a three span beam bridge, with piers in the riverbed, which considerably reduced its hydraulic section.

It is a concrete bowstring arch bridge of 80m in span which crosses the river without piers. It has two tracks and has a lateral cantilever of 4.8m for pedestrians and bicycle traffic.

This bridge was constructed parallel to the existing bridge and then slid into its final position to allow the shortest possible interruption to train traffic.

Keywords: Bowstring arch, concrete, hangers, rail bridge, slid, skidded.

1. Introduction

The Bilbao-San Sebastián narrow gauge railway passed over the river Nervión close to the Etxebarri station by means of a bridge of three spans with two piers in the river whose foundations had been increased at different stages and which considerable reduced the waterflow in the riverbed. Furthermore, the deck, formed of simply supported re-enforced concrete beams, was in poor condition. For all these reasons the decision was taken to replace the bridge, with the aim of removing the piers from the riverbed. The solution chosen was a concrete bowstring arch bridge of 80m span.

Fig. 1. Aerial view of the bridge

A fundamental condition of the project was the need to interrupt rail traffic for as short a time as possible. This condition determined the construction process of the bridge. In the first place it was built entirely over provisional abutments in a position parallel to its final location and close to the former bridge. Once it was built, traffic was diverted to pass over it which allowed the existing bridge to be demolished and the final abutments to be built in line with the provisional ones. Once complete, the whole structure was moved on skid shoes to its permanent position; the tracks were moved once more and trains began to cross. The two operations of moving the tracks- the first to pass traffic over the bridge in its provisional position, and the second to slide the bridge and allow traffic to cross in its final position- took less than five days.

2. A general outline of the bridge

The new bridge over the Nervión river has a span of 80m, due to the need to cross the riverbed without introducing piers due to the canalizations introduced for this zone of the river by the Territorial Water Services of the Basque Government. The bridge is to be found at the exit of the Etxebarri station and its height over the riverbed is fixed by the position of the railtracks. This height is low for a span of 80m , which required the building of a single span with above structure bridge, because a simply supported beam would have an excessive depth which would considerably reduce the flow capacity of the river.

Fig. 2. Bridge with river at its highest level

The solution which appeared most appropriate was a bowstring arch bridge in which the deck serves as a tie and with it the horizontal forces of the arch are avoided in its ends. Another advantage of this solution is that it reaches the river banks at its minimum depth and it is raised in the centre of the river, so that it causes minimal impact on the environment and countryside at its ends and the highest point of the structure is over the riverbed. This is important in a semi-urban area as the river zone is now but which will probably become fully urban within a short time.

The material used for the bridge was concrete as was stipulated by the owner. In this case, as well as the advantage of the durability of this material, the increased cost of the construction of a concrete bridge against steel bridge, due to its greater weight, is offset by the lower cost of the material.

3.   General outline of the construction of the bridge

If in the making of any bridge it is fundamental to know how it will be built to know how it will be, in this case it was of the first priority because it was a case of substituting a functioning bridge with as little disruption to the train traffic using it as possible. For this reason, in this process there were two basic steps.

1. The complete demolition of the existing bridge, both superstructure and sub-structure including the foundations.
2. The construction of the new bridge which must be situated in the same place as the original bridge because this is what the track requires.

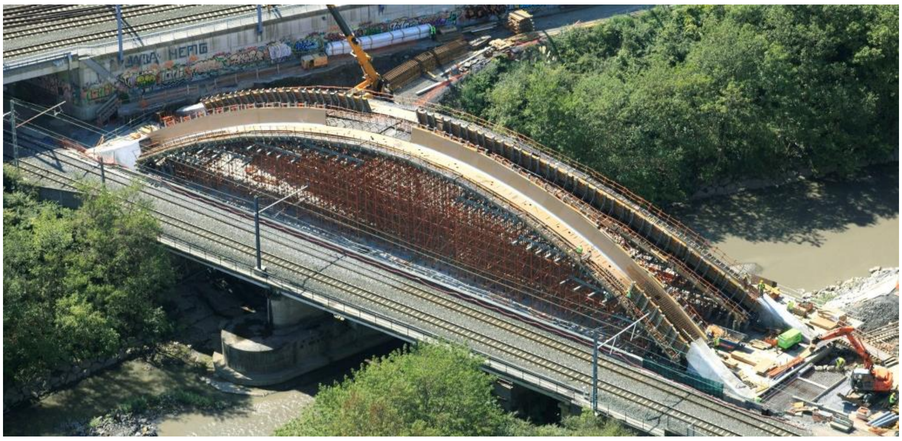

Fig. 3. Construction of the bridge parallel to the existing bridge

If the two actions are carried out in sequence, as at first seemed most logical, the time for which train traffic would be suspended would be more than a year, which was unacceptable to the rail service. This period must be reduced to days, and to achieve this it is necessary that during the demolition of the existing bridge the lines can be diverted over a parallel bridge. For this there are two possibilities.

1. The first possibility is to construct the new bridge in a parallel position to the present bridge and permanently change its position.

Once constructed the traffic would pass over it, the demolition of the original bridge could go ahead, and then the construction of the definitive abutments of the new bridge, which must be aligned with the provisional abutments.

When the provisional abutments and the permanent abutments are joined the new bridge could be slid from its provisional position to its permanent one and once moved the provisional tracks could be replaced by permanent ones.

The sliding operation and the substitution of tracks could be carried out in, at most, five days.

In this way the interruption to the railtracks would affect the rail service for a very short time.

2. The second possibility is to construct a provisional bridge parallel to the present one to carry the rail traffic.

Once the traffic had been diverted to the provisional bridge the existing bridge would be demolished and a new bridge built in its final position which would carry the rail traffic when finished.

Upon studying both possibilities, the first was chosen because it was more economic to slide the provisional bridge plus the provisional piers, than the construction of a provisional and a permanent bridge, using the existing bridge to support the formwork.

With the adopted system the disruption time to the rail service would be reduced to two operations.

1. The first consisted of connecting of the diversion over the parallel bridge with the existing tracks, which could be done in one night.
2. The second consisted of the sliding of the bridge and the substitution of the provisional tracks with the final ones. As was said before, this could be done in less than a week.

The layout of the provisional track, and the wall on the left hand side, which supports the raised track of the metro line to its siding sheds, made it necessary to construct the new bridge side by side with the original, and required the demolition of the pedestrian access way to place it in its provisional position. This meant the disruption of pedestrian traffic on this bridge during the construction of the new bridge.

4. Description of the bridge

Fig. 4. General view of the bridge.

The superstructure of the bridge is formed of the arches and the deck which form a unit connected by the lattice arrangement of hangers. This structure is supported on the abutments on micropiles.

The deck is formed of two longitudinal beams situated in the planes of the arches, which are inclined at 16º from the vertical. The depth and width of these beams is 1.5m and their section has the form of a parallelogram due to the inclination of the planes of the arches. They are solid in section. They only have the hollows necessary to locate the anchorages of the hangers. Their axis are separated by 12.5m to allow the gauges of the two tracks of the narrow gauge railway which pass over them. These beams are connected by the deck slab, of depth 0.25m and by the transversal ribs place every 2.25m which are of variable depth, with the same depth in the centre as the longitudinal beams.

On the downstream side, the deck is extended by a cantilever 5.4m in length from the axis of the lateral beam. This cantilever is formed of a slab of 0.25m depth and ribs each 2.5m, an extension of the ribs that are situated between the longitudinal beams. This allows the passage of pedestrians and bicycles. It has an effective width of 4.5m.


Fig. 5 Lower view of the deck

The longitudinal beams act as ties of the arch and are formed of 18 prestressed cables of 24 strands of 0.6". Of these 18 cables , 10 are placed in the downstream beam from which extends the lateral cantilever, and 8 in the upstream beam, which is not extended.

The section of the arches has the same depth and width as the beams, 1.5 x 1.5 and the same parallelogram shape. Its parameters are in the same plane as the beams, so that the outside face of the arch and the beam on the upstream side are in the same plane. On the downstream side this plane is disrupted by the pavement cantilever.

The arches are of reinforced concrete of solid section, except for the cavities which had to be left for the anchors of the hangers.

The hangers are arranged in a lattice pattern because it is a more efficient solution than vertical hangers, reducing the bending moments in the arch and in the deck. They are formed of cables of 0.6" which vary from 3 to 15 strands. Their anchors are located, both in the beams of the deck and in the arches , in anchorages in such a way that they are not apparent from the outside. All of the hangers can easily be replaced in case it is necessary because their anchors are accessible.

5. Construction process of the bridge

Fig. 5. Provisional tracks over the bridge

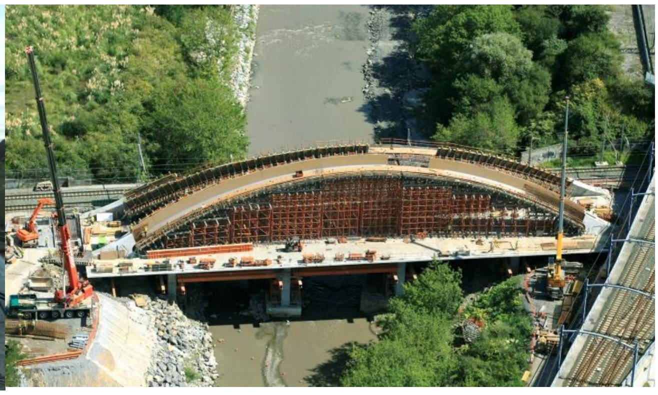

Fig. 6. Construction of the arch using a formwork

The construction of the bridge in its provisional location was planned in the project as a launching of the deck without the arch using the provisional piers as extensions of the piers of the present bridge without reducing the hydraulic section of the river. During the construction, the construction company decided to construct it on a formwork supported on the provisional piers . So that the formwork was protected by the present bridge, the new bridge was constructed 50cm above its final height and then lowered using jacks.

Four provisional piers were located between the abutments to support the formwork leaving spans of the order of 16m. These piers were aligned with those of the current bridge.

Once the deck had been constructed over the formwork, it was removed and the deck was supported on the provisional piers. Later the arch was built over a formwork supported on the deck.

When the arch was finished and the hangers tensed the provisional supports were removed and the provisional tracks put in place to divert the traintracks over the new bridge so that the original bridge was left free of traffic. This allowed it to be demolished. After that the abutments of the new bridge were constructed as extensions of the provisional ones.

Fig. 7. Demolition of the existing structure

The next operation consisted of the skidding and jacking of the bridge from its initial to its final position. This operation was carried out using skid shoes of 750 tonnes in each abutments. Each skid shoe had a vertical double jack 750t and 600mm and a horizontal jack of 60t. The skid shoes slids on 30m teflon coated tracks. The total weight of the bridge to be slid was 3,750t.

Fig. 8. Jacking and sliding of the bridge. Skid shoes and tracks

Once the sliding was finished the bridge was lowed into its final position, supported on its permanent supports. Finally the provisional tracks were replaced by the permanent tracks and traffic flow over the new bridge commenced.