Accessways to the western Entrance to the "Dos Valiras" tunnel

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Summary

The "Dos Valiras" Tunnel connects the valley of the river Valira del Nord (Northern Valira) with that of the river Valira de Orient (Eastern Valira). At its western extreme it reachs into the Valira del Nord which it crosses by means of two bridges. These bridges give on to a large roundabout which is in great part significantly raised due to its hilly terrain. This has been achieved by means of a structure of pre-stressed concrete divided into six stretches joined by hinges. It is a public work of the greatest import, the most important ever undertaken in Andorra- leaving aside the large tunnels constructed recently

Keywords: cable-stayed bridge, concrete structure, single tower, raised roundabout, successive cantilever construction.

1. Introduction

The structures which form the subject of this report are to be found in La Massana, Andorra at the western end of the "Dos Valiras" Tunnel. The "Dos Valiras" Tunnel connects the valley of the river Valira del Nord (Northern Valira) with that of the river Valira de Orient (Eastern Valira) creating a transport nexus for travel across the country. The two tunnels themselves are independent and separated which necessitated the construction of two parallel cable-stayed bridges which are joined in their final stretch leading to a roundabout of 90m in diameter which is in great significantly raised above the immediate ground level. This has led to the great part of the roundabout being formed of a pre-stressed concrete structure.

Fig. 1. View of the Structure 1

The roundabout is situated on the road from Escaldes to La Massana and one of the conditions laid down for the construction was that traffic should not be interrupted. This necessitated the construction of structure 6 at the beginning so, as the traffic was diverted by it the initial road was demolished, permitting the construction of the other structures which form the roundabout.

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2. Description of the structures

This work has been achieved by means of a pre-tensed concrete structure divided in six stretches, five of which are joined by means of hinges and the sixth is independent.

As has been indicated, the roundabout is in great part elevated, which has been achieved using a series of prestressed concrete structures. The structures which form the roundabout are structures 2,

4 and 6. Apart from the last, which is independent, the others are joined together by hinges. Structure 5 leaves structure 4 of the roundabout in the direction of a future connection which passes under the Anyos bridge.

Fig. 2 View of the roundabout

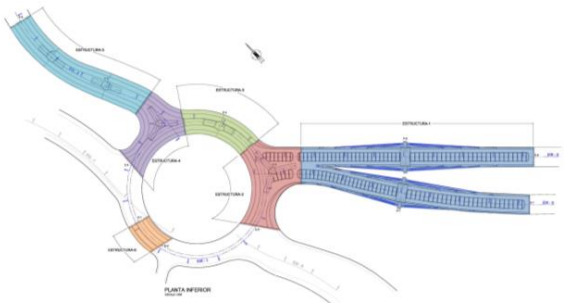

Fig. 3 General plan of the six structures

The fact that the supporting terrain is a hilly area meant the situating of the minimum number of supports in this area which lead to the use of tripods and V shaped piles to achieves short decks spans using few supports.

In the figure 3 is shown the general plan in which the six structures which form the work are situated.

2.1 Structure 1

Structure 1 is the most significant in this work. It is situated at the exit to the tunnels and passes over the "Valira del Nord" river. Due to the fact that the tunnels have two independent mouths a considerable distance apart two separate cable-stayed bridges were designed, each begins at a tunnel exit and they come together at their ends as they connect with the roundabout. The bridges are each single tower with a bundle of four stays arranged along each edge of the deck. These bridges have each two stayed spans of 86m and 70.3m respectively.

Fig. 4. View of the structure 1

The decks have a depth of 13.07m. They are formed by two longitudinal beams joined by transverse ribs. The beams have a trapezoidal form with a depth over its whole length 1.4m, except in the first 20m on each side of the tower where there is a variation in its depth of up to 2.25m. Due to the unbalanced of the spans it was decided to lighten the longitudinal beams of the span between the tunnel and the tower, so as to minimise horizontal unequal forces in the tower. The distance between the transversal ribs is of 3m in the 86m span and of 2.7m in the other span. Both the deck and the ribs are prestressed.

Once past the tower the two structures come together in the final stretch to converge into structure 2 the elevated roundabout. In this zone the width of the structure is 24.6m.

Fig. 5. Structure 1. Lower view of the bridge

The towers have a V shape and they are brought together in the area of deck support by means of a transverse beam. The height of the towers is 45.75m from the upper face of the pile cap while the transverse beam is situated at 26.3m. In this beam as well as supporting the deck vertically fixes the structure longitudinally, for which reason there is one short bracket, for each longitudinal beam, on each side of it. Each of the towers has foundations of 12 piles 1.5m in diameter. The arms of the towers measure 1.7m transversally and 2.7m longitudinally with a longitudinal thickness of 0.3m and 0.4m transversally. The dimensions of the towers are fixed, in great part, by the necessity of working in their interiors during the installation of the stays.

Due to the geometry of the layout in plan one of the structures is straight while the other has a curve and a counter curve so that it can come together with the first. This layout means that we have bending moments in the towers which have obliged us to prestress them. This prestressing is tensed from the lower part of the towers, having the lower anchors arranged in the pile cap that at the project were not accessible. This required us to have the strands lined up from the start which was a complication during the construction of the tower. To avoid this problem live anchors were used in both the upper and lower faces of the pile cap, and for access to these galleries were constructed using prefabricated elements which were filled in once the prestressing had been finalized. The towers were constructed using a climbing formwork.

From the geometry of the stays it might be thought to be an extradosed bridge, but this is not the case. The height of the towers above the deck is what it would be for an extradosed bridge but to achieve this the rigidity of the deck would have to be greater. In our case we have a deck slenderness of approximately 1/100 while to function as an extradosed bridge it should be of the order of 1/50, that is to say a depth double that available and for this reason the behaviour of the stays is that of a cable stayed bridge.

2.2 Structure 2

Fig. 6. Structure 2

Structure 2 is part of the roundabout which emerges from the abutments placed parallel to the Escaldes-La Massana road and has a branch which leads to structure 1, which is supported by this one. In the plane it has three arms for which reason a tripod has been used as the supporting element encastred in the deck. The structure's width is variable depending on the various arms. The width in the area of the roundabout is 16m, except close to the stirrup where it widens to 27.6m to provide a smooth transition to the existing road. The width of the branch leading to structure 1 is 24.6m.

The deck has a hollow-core prestressed concrete section of 1.2m in depth throughout the structure except in the area where it joins with structure 1, which is variable, reaching a depth of 1.4m like the cable-stayed structure. The transverse section is formed of a central nucleus of 4.5m wide which is extended in cantilevers in which the reduction of the depth is made tow longitudinal stepts. It is lightened by means of longitudinal hollows of different sizes.

The tripod has an average height of 22m and each of its arms is of variable depth from 2.05m at the base and 0.85m where it meets the deck, and a constant width of 3.5m. Each arm

cross-section begins with an irregular pentagon formed of a rectangle 3.5m wide and 1.1m in depth, as well as an isosceles triangle of 0.95m in height. In the following sections the isosceles triangle is reduced to form trapezoid until it disappers, while the lower rectangle varies its depth from 1.1m at the base to 0.85m at the deck. The foundations of the tripod is made of 12 piles, each 1.5m in diameter.

2.3 Structure 3

Fig. 7. Structure 3

Structure 3 has a length of 49.25m with two spans of 24,62m, and, as in structure 2, the deck is a section of hollow-core prestressed concrete of a constant depth of 1.2m and a width of 16m. Structure 3 is supported on structures 2 and 4 by hinges. The pile is V shaped, and is encastred in the deck. The section of each arm is a rectangle 3.5m wide and of variable depth, 1.4m at the base and 1m in the deck- The foundations are made of 4 piles of 1.5m diameter.

2.4 Structure 4

Structure 4 is the same type as structure 2 and similar in that it has three branches. One emerges from the roundabout to reach a abutments situated on the edge of the existing road, and another serves as a support for structure 5. Just as in the structure 2 it is supported by a tripod which is encastred in the deck. The width of the structure is variable depending on the zone. In the area of the roundabout it is 16m wide, except closer to the abutments where it opens to 24.8m to provide a smooth transition to the existing road. On the branch leading to structure 5 the width is 19m.

Fig. 8. Structure 4. Tripod

The deck is prestressed concrete with a hollow section of 1.2m in depth. The central zone has a width of 4.5m which varies with the width of the section, while the depth variation of the cantilevers is achieved in two steps.

The tripod has a height of 13m and each of the arms has a variable depth, from 2.05m at the base to 0.85m where it meets the deck; with a constant width of 3.5m. Its geometry is the same as that of structure 2. The foundations of the tripod are 9 piles of 1.5m in diameter.

2.5 Structure 5

Fig. 9. Structure 5

Structure 5 is supported on structure 4 and is the beginning of a future branch which will run under the Anyos bridge. The structure's length is 94.9m. The deck has a variable width from 19m in the zone where it is supported by structure 4 to 16m at the abutment. The section is prestressed hollow-core slab of constant depth of 1.2 with a central zone of variable width, while the cantilever which are stepped, in the same way as in the other structures, are kept constant.

As has been mentioned before, to reduce the number of supports on the ground and to maintain a constant depth of 1.2m V shaped piles have been used. These create spans of 25.7+42.1+27.1m The arms of the V are separated in their upper part by 19.65m. The section of the arms is a 3.5m wide rectangle of variable depth from 1.2m at the base to 0.8m at the deck. In the project, as in the other structures, the foundations were made of piles of 1.5m in diameter. During the construction the construction company asked to change the piles for micro-piles 114,3mm in diameter and 6.8mm thickness, using a total of 121 micro-piles in pile1 and 144 micropiles in pile 2.

2.6 Structure 6

Structure 6 is the only one of the group which is independent. It is situated on the western part of the roundabout and is a simply supported one span bridge of 28.65m in length with the same section as the other structures of the roundabout and the same 16m width.

3. Construction process

Fig. 10. Construction of Structure 1

For this project two distinct procedures were used for the construction of different structures, one for section 1 and the other for the rest.

In the design stage the plan was to construct structure 1 using successive compensating cantilevers, concreted in situ using bridge cranes on both sides of the towers. Due to fixed construction time it was necessary to use four bridge cranes. The construction company asked for a process change so that the span of 70m which gave access to the roundabout would be built using a formwork including the 0 segment of the span in the tunnels going forward with cantilever only in this access section to the tunnels which has a span of 86m, which meant to keep the spans balanced the first 20m of the span, on the tunnel side was built over formwork.

The towers were constructed by means of a climbing formwork and their interior zone constructed with a permanent steel formwork due to the anchorage geometry.

The length of the cantilever segments was 6m. The pretensing was carried out using bars of steel of 85/105 quality. This prestressing had to be removed when the

structure was finished and so provisional anchors were placed in the first section above the deck, so that the bars could be released and the anchoring structure removed at the end of the process.

The concreting of the joint segment with the section on the tunnel side built on formwork was carried out using the crane as a way of fit together the rotations and movements of both sections. Once joined the next step was the tensing of the prestress cables in the section which gave access to the tunnels. The section leading to the roundabout had been prestressed when it was built over the formwork. In the area of the towers the two prestressings crossed.

The rest of the structures were constructed using conventional formworks. So as not to condition the construction of the structures by how they supported each other it was decided to prefabricate the hinges in such a way that once the structures were almost finished, all but the hinge area, the hinges would be lifted into place and the sections joined by concreting.