Bridge over the Cádiz bay, Spain

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Summary

The bridge over the Cádiz Bay has a total length of 3157 m and crosses from Cádiz City to Puertorreal. The main bridge is a cable stayed solution with a main span of 540 m and approach spans of 200 m. and a maximum vertical clearance of 70 m. It will be one of the longest cable-stayed bridge in Europe.

The deck is a trapezoidal box girder 3.0 m deep in a composite construction steel concrete in the bridge over the bay and prestressed concrete in the bridge on the land side. The simply supported deck has a variable depth made of steel with an orthotropic deck. The total width varies from 33.20 to 34.20 m. The bridge will support 2 lanes carriageways for vehicles and 2 tracks carriageway for a tram. The pylon is a double Y shape reinforced concrete structure.

The bridge is currently under construction. The main span will be built by free cantilever system with 20 m long segments. The approach span on the Cadiz side will be built by incrementally launched segments. The approach spans on the Puertorreal side will be constructed span by span with a centering. The simply supported 150 m span will be lifted from a barge.

Keywords: Cable-stayed bridge. Composite Steel-concrete bridge. Prestressed Concrete Bridge. Free cantilever Construction. Incrementally launched bridge. Heavy lifting construction.

1. Introduction

The old aspiration of the city of Cádiz to build a new access that would reach the old town and the Port directly from Puerto Real was fulfill by the authorities of the Spanish Ministry of Public Works and Transport with the launching of the project of the Bridge over the Cádiz Bay. Fig.1.

The Bay navigation canal by the Cabezuela - Puerto Real Quay is 400 m wide and 14 m deep. The port authorities enlarged this horizontal clearance up to 540 m to avoid occupying the Cabezuela Quay shore and to provide for easier ship maneuvering. The pier on the Cabezuela Quay side, is placed as far as 70m into the quay, thus enabling easier loading and unloading operations from the service cranes. As for the vertical clearance the carriageway is placed at a formidable height of 69 m, which makes this bridge one of the world´s highest.

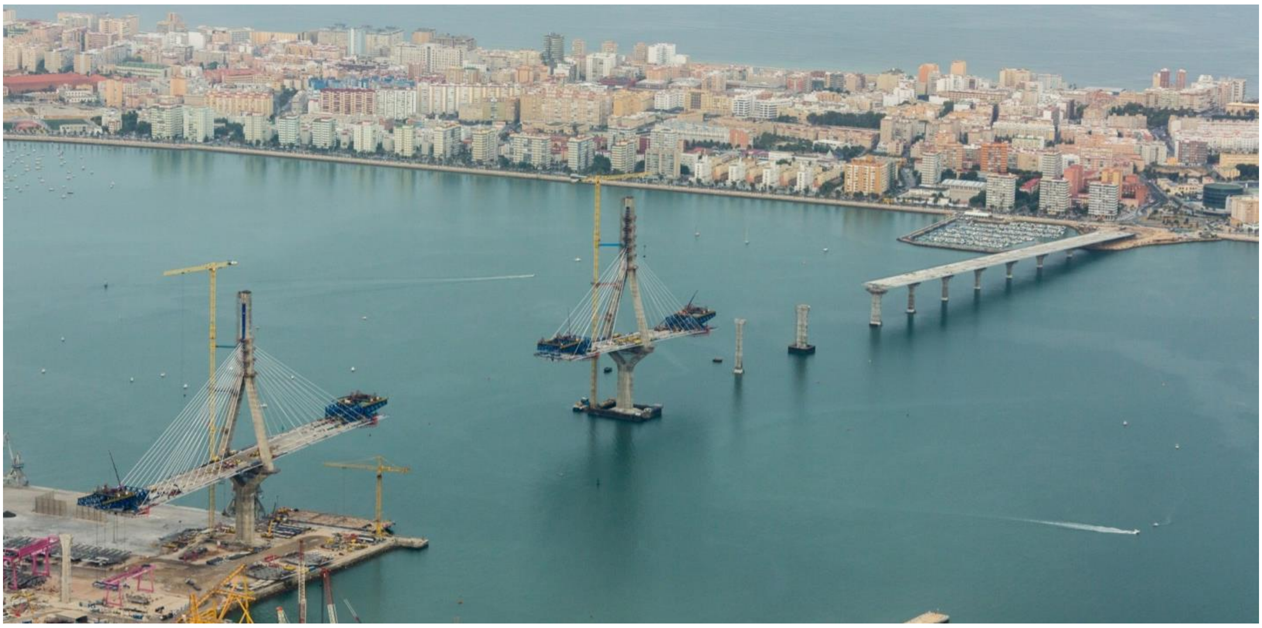

Fig. 1. General view of the bridge

However, at the insistence of Navantia whose factories are located within the Bay, the vertical clearance was set at 100 m for a horizontal clearance of 140 m. This circumstance made us design a bascule bridge that was later modified and replaced by a removable span 150 m long allowing for the possibility of the passage of an exceptionally high vessel.

1.1 The General Outline

The bridge itself can be divided in four separate stretches, depending on their different functional characteristics.

- The Approach Viaduct stretch on the Cadiz side corresponds to the access to the main stretch from Cadiz. Length 570.0 m.
- The Removable Deck stretch. Length 150 m.
- The Main Bridge stretch is the cable-stayed bridge spanning the Navigation Canal and its cable-stayed side spans. Length 1,180 m.
- The Approach Viaduct stretch on the Puerto Real side corresponds to the access to the main stretch from Puerto Real. Length 1,182 m.

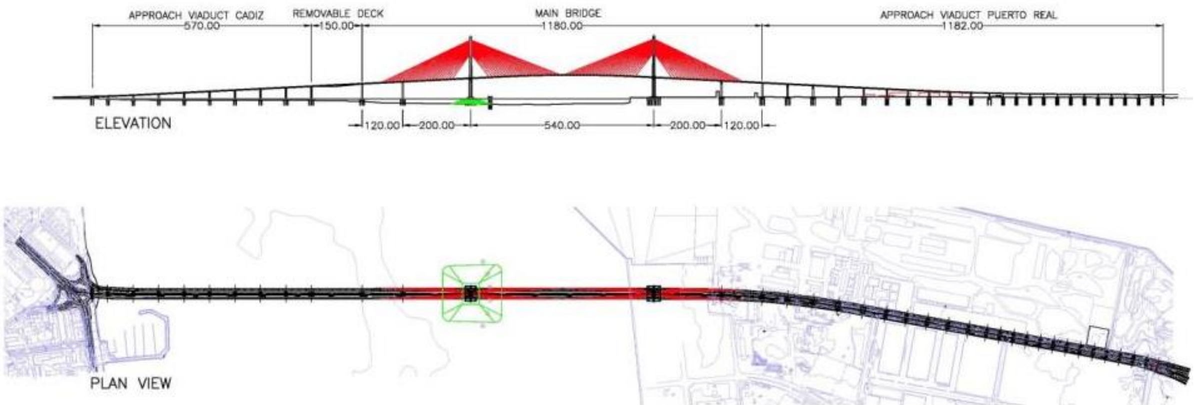

Fig. 2. General elevation

The bridge total length amounts to 3,082 m. It is by far the longest bridge in Spain and one of the longest in the world. Fig. 2.

Fig. 3. Main span image

The main stretch corresponds to the bridge spanning the navigation canal and constitutes the bridge´s main reason for being. That is to provide the city of Cadiz with a new access, spanning the navigation canal, the main entrance to the Port, without interrupting the road traffic, despite the great volume of vessel traffic, not as the case of the Carranza bridge that has to be successively opened and closed thus producing the ensuing road traffic interruption

For the clearance needed the present-day technology recommends the use of a cable-stayed bridge. In this case the 540 m main span and each of the two 320 m long side spans hang by 176 stays from two pylons 180 m high. Fig. 3.

The bridge has been designed in an integral way. The expansion joints have been installed on both abutments and on the removable deck. All the deck is supported over sliding spherical bearings except the removable deck which I supported over elastomeric bearings.

2. The deck

2.1 Main span

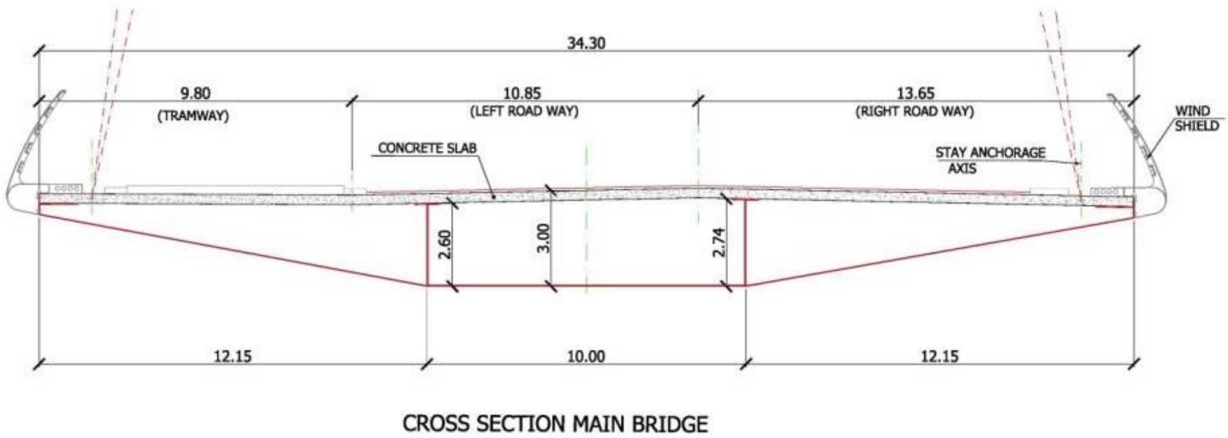

Fig. 4. Main bridge cross section

The deck is 34.3 m wide, divided into four 3.5 m wide traffic lanes, two in each direction, plus two tram tracks, and all the other elements needed to ensure the perfect bridge functionality: shoulders, railings, stay-cables sockets as well as windshields to protect traffic from the wind. The structure of

Fig. 5. Main span erection

the deck must be light-weight, aerodynamic and slender. It is therefore a composite steel concrete structure made of a 3.00 m deep box girder with perfectly rounded edges. Fig. 4.

The main span will be built by free cantilever system with 20 m long segments that will be assembled on the Cabezuela Quay and will then be floated to the bridge and lifted from a barge using crane form travellers placed at the front end of the segments. Fig. 5 and 6. Once lifted, the segments will we welded to the already built deck and to the cable-staying from the tower. The upper slab will then immediately be reinforced and concreted and the stay cables tensioned.

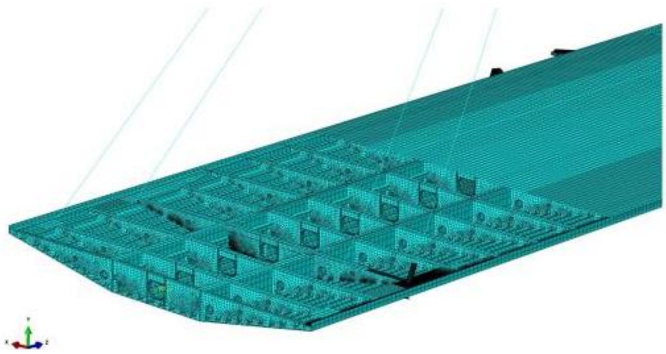

Fig. 6. Main span finite element mode

2.2 Removable deck

This is a removable bridge, design to allow for the passage of vessels exceeding the 69 m height, the maximum possible vessel height permitting the passage under the main bridge. This circumstance is unlikely and will happen few times throughout the bridge life.

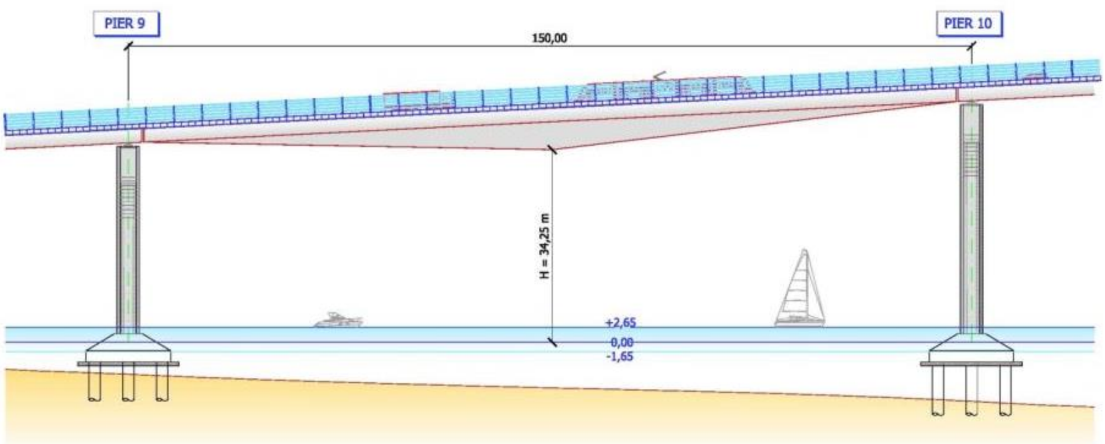

Fig. 7. Removable deck elevation

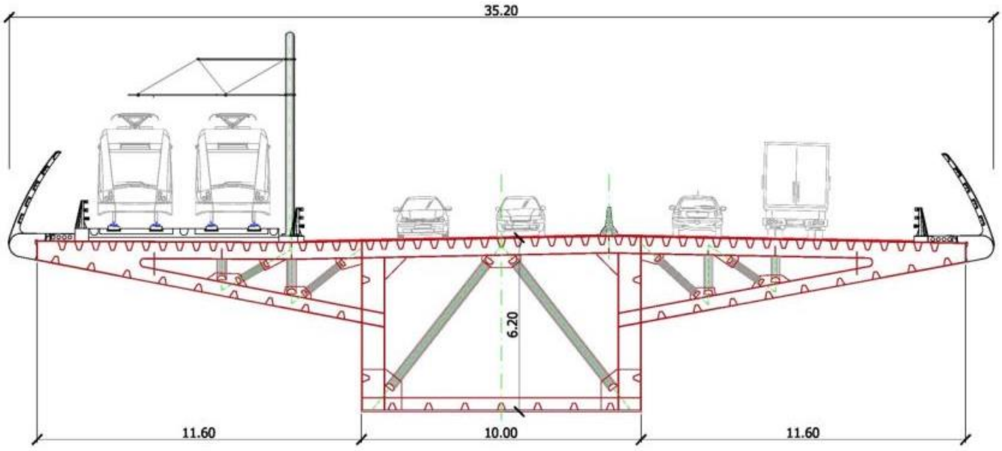

Fig. 8. Removable deck cross section

Fig. 9. Removable deck

The bridge type chosen in this case is a simply supported one with a variable cross section ranging from 3.0 m, over the supports, to 8.0 m at midspan. Fig. 7, 8, 9.

2.3 Approach Viaducts

The approach viaduct on the Cadiz side is 570.0 m long with 75 m spans and one 45.00 m end span on the city side. The width of this stretch amounts to 30.5 m and the longitudinal slope is 5%.

The design is due to the fundamental idea of the bridge as a whole: a slender, aerodynamic deck, a composite steel-concrete structure.

The construction of this viaduct is carried out by incrementally launching the steel structure together with a part of the concrete slab.

The approach viaduct on the Puerto Real side has a 5% slope. Its total length is 1,182 m and its width 30.5 m. The whole stretch is made of prestressed concrete.

This stretch can be divided into three sub-stretchs. The one on the side of the cable-stayed bridge is made up of three 75m spans whose cross section is externally identical to that of the approach viaduct on the Cadiz side only in this case it is made of prestressed concrete. Fig. 8. The piers are identical to those on the Cadiz side.

El second sub-stretch is made up of the following spans: 75.0+68.0+4x62.0+54.0 m

The reason behind this second sub-stretch is the presence of axial traffic flow under the bridge and the access to the factories along this thoroughfare, which made it necessary to design portal-frame shaped piers with a 13.5 m clearance between the supports. The shape of all the elements is owed to the general design of the piers. In this case the double trapezoid general shape of the typical pier is divided in two trapezoids, one on each pier of the frame. Fig. 10.The height of the piers varies from 13 m to 34 m.

The deck is exactly the same as in the already described sub-stretch.

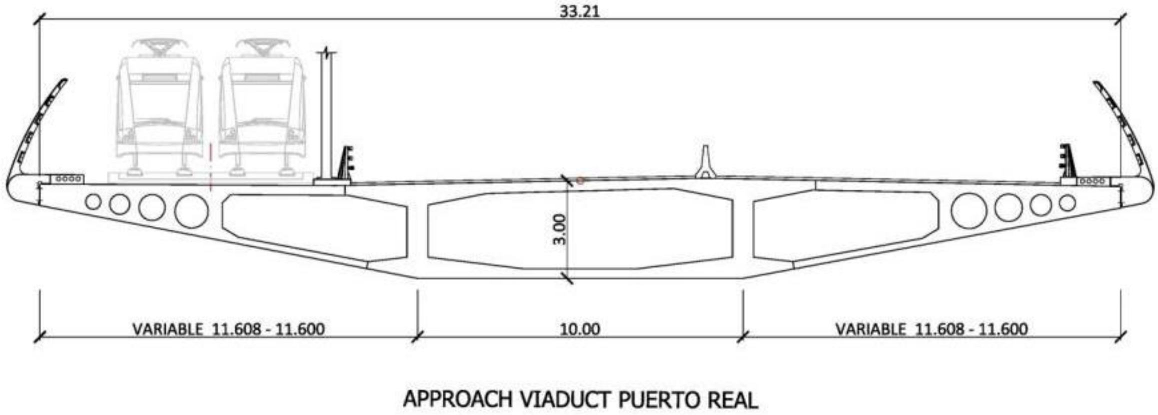

Fig. 10. Approach viaduct Puerto Real cross section

The third sub-stretch by the abutment 2 on the Puerto Real side changes. Its typical span is 40 m while the span over the abutment is 32 m due to the fact that the pier height drops radically as the piers get closer to the abutment.

The approach viaduct on the Puerto Real side is built span by span, with construction joints placed at each quarter-span, using a centering.

3. Pylons

3.1 Elevation

The cross section of the pylon corresponds to two trapezoids that follow the axis of the pylon anits braces, and vary in dimension in the direction of the cross section of the bridge keeping the external line from the lateral view. Fig. 11

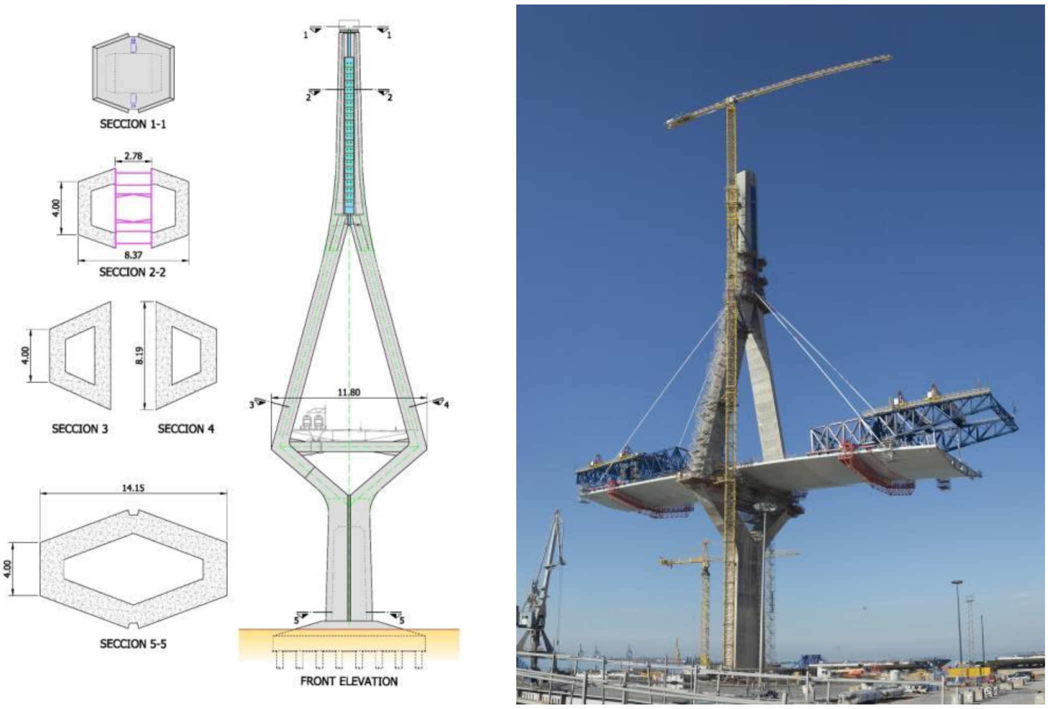

Fig. 11.Pylons

3.2 Stay-Cables Anchoring Structure on the Tower

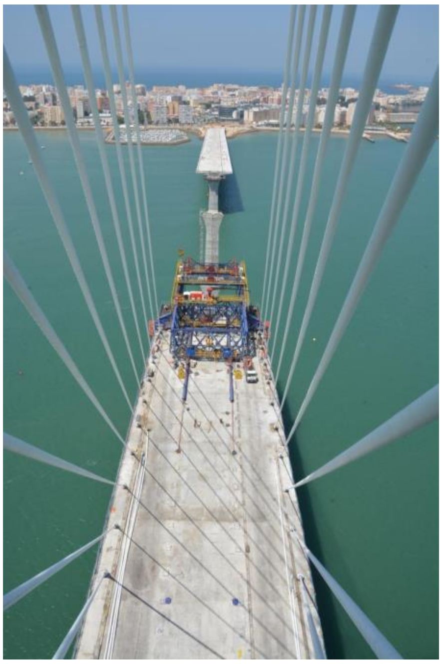

Fig. 12. Stay-cables view

Initially, the upper vertical part of the towers consisted of a prestressed concrete structure. The concrete of the inner cavity had blisters to hold the stay-cables upper anchorages, with transverse prestressing arranged at each level.

However, in order to make the installation and execution of the towers easier while intending to keep the modifications of the outer shape and dimensions to the minimum the use of steel cases was proposed in the vertical mast. The function of these cases would be also part of the resistant cross section of the mast, which structural type would therefore be composite. and the of transverse prestressing could be eliminated. This metal structure would be placed in a first stage of the execution and would later be concreted.

The feasibility of this new typology was studied by means of a tridimensional finite elements model. The tensional state obtained through this model, once the transverse prestressing is removed, proves the convenience of removing the concrete on the tower front faces from which the stay cables exit the tower, slightly increasing the thickness of the metal plates of the cases in this area..

The steel cases on the towers are 2.70 m wide (perpendicular to the deck axis) and 5.40 m long (parallel to the bridge axis). A module or a steel case is defined for each level of stay cables on the tower.

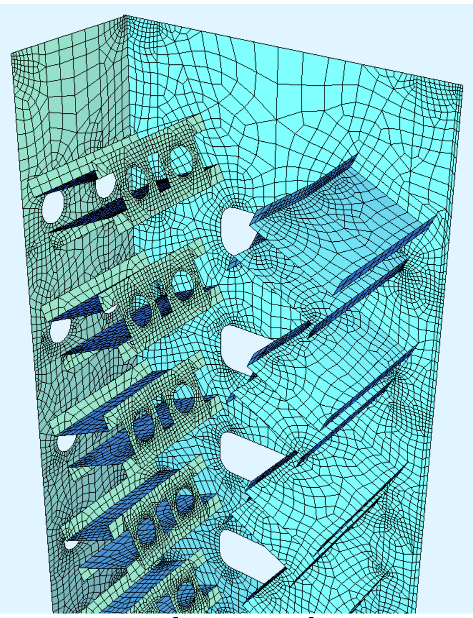

Fig. 13. Steel cases in the upper part of the pylon

In order to provide the lodging for the upper anchors on the inside a system of steel metal beams were devised welded to the two parallel loads of the steel cases. The stay-cables load can thus reach the whole structure from the anchorages. These beams have a 2.70 m span and their cross section is made of a double C-shaped profiles. Fig. 13.

The different strength mechanisms arranged on the towers cannot be studied using a single structural analysis model, which makes it necessary to use different modelling depending on the element to be studied. Thus, the global study of the towers is carried out using a bar model elaborated for the bridge as a whole. This model gives us the distribution of stresses for the ELS and ELU load combinations. The dimensioning of the metal girders within the box girders is carried out using a bar model isolated for each level of stay-cables for the configuration of a simply supported girder, given the fact that these girders are welded only at the extremes to the metal plates of the mast box girders.

Once the global safety of the different cross sections of the towers is guaranteed, the need arises to check the tension level of the different structural elements in the areas prone to undergo concentration of local stresses, such as the anchor plates, discontinuities on the metal beams, points of union between metal elements and areas of connection between the vertical mast concrete and the steel box girders. To this end, a shell type finite elements model was performed in which all structural elements of the towers are modelled using plane elements with the combined properties of membrane and plates, representing the vertical mast, most particularly the transition area between the mast and the slanted shafts along 25.0 m.

Finally, in order to study the local effects likely to appear in the concrete areas near their connection to the steel box girders of the towers, a finite elements model of the vertical mast was developed, in which the concrete is modelled using brick-type elements. This model enabled us to study and integrate local stresses that appear in the area of connection between concrete and steel due to the frame effect in both vertical and transversal planes. These stresses, once properly integrated, have been used to complete the dimensioning of the ELU of the connection as well as to define the reinforcements necessary for the transverse concrete reinforcement, not only in the areas with connecting studs but also on the sides of the composite cross section parallel to the bridge axis.

4. The Piers

The piers are the same along the whole bridge: the shape varies in the same way in all of them regardless of their height that ranges from 8 m to 52.5m. The double rhombus shape has a 10.5 m width at the base of the highest pier and 4.2 m at the “waist” which is where the pier head opens to end up regaining the 10.5 m width. The transverse dimension is 4 m at the center and 2.9 m at the edge. The surface is therefore warped. Fig. 14, 15.

In the case of the cross section of the piers at Puerto Real approaching viaduct, the double trapezoid general shape of the typical pier is divided in two trapezoids, one on each pier of the frame. The height of the piers varies from 13 m to 34 m.

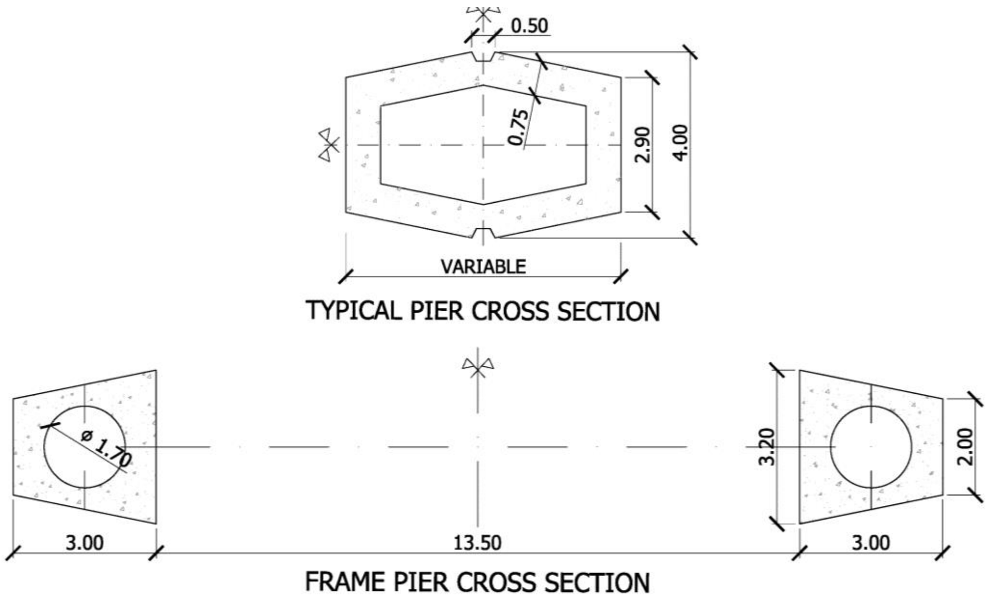

Fig. 14. Pier cross section

Fig. 15. Typical pier

5. Conclusion

The Bridge over the Cádiz Bay is a formidable long bridge that follows an integral idea.

6. References

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