# New Pumarejo Bridge over the river Magdalena in Barranquilla. Colombia.

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ABSTRACT

The overall length of the new bridge over the River Magdalena amounts to 4 km, distributed between the 1,865 m of the work´s main trunk and the 1,920 m of the different branches on the left riverbank.
The main feature is the 830 m long cable-stayed bridge with a 380 m central span, required to comply with the new navigation requisites.
The entire deck is made of prestressed precast concrete sections. With the aim of unifying the construction solutions for both the main bridge and approach viaducts as well as the secondary branches a precast segmental solution was chosen.

## 1 INTRODUCTION

The new bridge over the Magdalena River is to replace the bridge designed by Eng. Riccardo Morandi in 1972. The purpose of the new bridge is to improve the river navigation conditions and allow the increase of the traffic flow at the crossing. This project is one of the priority actions undertaken by the INVIAS, the Road Department of the Ministry of Public Works of Colombia.
The new navigation conditions require a channel over 300 m wide with no piers within, whereas the need for the passage of vessels makes it necessary to raise the alignment of the new bridge to up to 45 m in height. On the other hand, the expected, medium-term increase in vehicle traffic requires an extremely wide platform, able to accommodate 6 traffic lanes.
Different areas may be distinguished along the work:

- The 830 m long approach viaduct on the right riverbank up to the main navigation channel.
- The main bridge crossing the navigation cannel, spanned by a 830 m long structure with a 380 m long central span.
- The access viaduct on the left riverbank with three, 70 m spans, the last of which serves as the transition element connecting the different branches.
- Finally, four branches that enable diverse links of the vehicle and pedestrian traffic with the city roads.

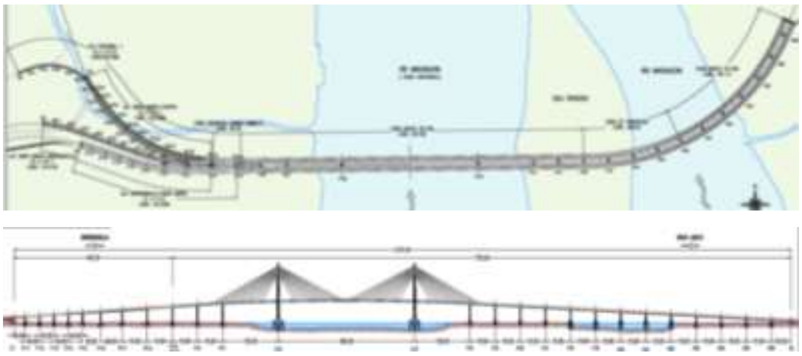

*Fig. 1 Elevation view of the approach spans on the right riverside*

As for the longitudinal configuration of the civil work and in spite of its great length, the deck is continuous from one abutment to the other and is fixed exclusively at the pylons of the cable-stayed bridge, liberating the remaining piers by using pot-type bearings.
The entire deck is made of prestressed concrete. In order to unify the construction procedures, in both the main trunk and the branches, the construction solution proposed was a prefabricated one applying match-cast segments in most of the work.

## 2 APPROACH VIADUCTS

The approach viaduct on the right riverside is 830 m long, and is composed of thirteen spans whose distribution is 12x70+55 m. It has a curved plan with a 461m radius.
The deck width ranges from 35.10 m at the abutments to the 38.10 m at the connection with the cable-stayed area needed to accommodate double carriageways with three lanes each and footpaths on either edges.
The deck cross section is a double-cell box precast girder that laterally extends into cantilevers supported over rectangular, concrete struts every 5 m executed in a second stage. Its depth is 3.65m, the lower slab width amounts to 12.0m, and its outer webs are slightly inclined in order to exceed 16.20 m in width. The variable width of the cross section is thus accommodated through these cantilevers, whereas the central trunk remains the same along the entire bridge.

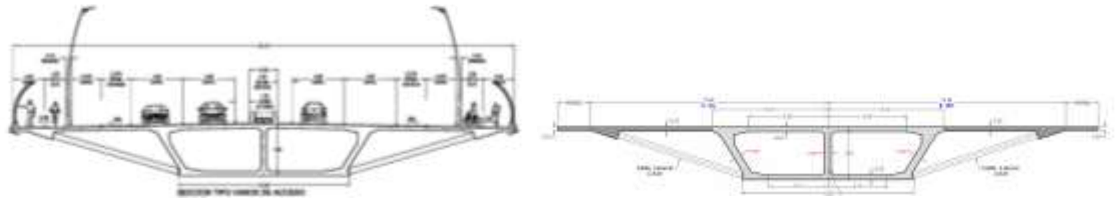

*Fig. 2 Functional and structural distribution of the deck*

The approach viaduct on the left riverbank is composed of another three, 70 m long spans. The two first ones are identical to those of the other approach, and the third one is a special span with a variable plan that gradually widens in order to link up with the four branches into which the platform is divided and connect with the city road network.
The piers are vertical elements made of reinforced concrete with a void, hexagonal cross section. Their longitudinal dimension is constant, 2.50 m, whereas transversely they are variable, widening at the head so as to hold the bearings within.

## 3 MAIN BRIDGE

The solutions proposed for the crossing of the river´s main branch, situated next to the left margin and where the 300 m navigation channel lies is a symmetrical cable-stayed bridge with two towers and a 380 m central span, whose highest point above the water surface reaches 45 m. It is 830m de long, and is composed of five spans whose distribution is 70-155-380-155-70, the three central ones hanging from as many central, cable-staying towers by means of double stay cables anchored in the cross section axis.

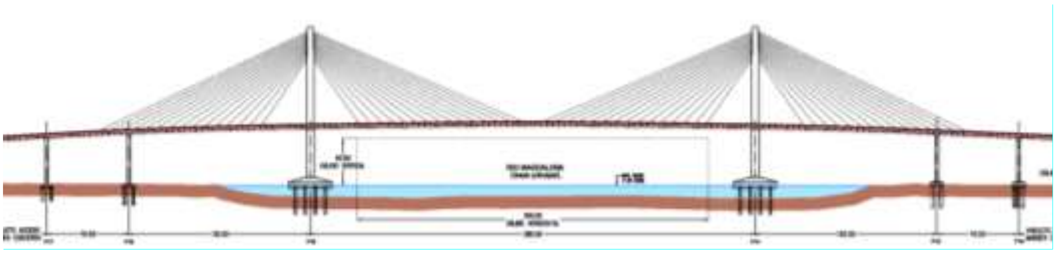

*Fig. 3 Elevation and general view of the cable-stayed stretch.*

The cable-staying configuration is a classical semi-harp with 40 m windows without cables in areas near the towers where the deck is rigidly supported. Intermediate piers are not arranged on the compensation span, there is only one pier at the extreme end. The proportion of this span in relation to the central one (0.40 of the main span) is the guarantee of an adequate performance of the cable-staying system as well as of the bending moments in the deck and the pylon under asymmetrical loads.

In order to avoid high concentrated forces in a single stay, the retaining force is not provided by means of a single stay but it is distributed in the last four cables that are anchored on either side of the anchor pier, at the same time enabling a symmetrical configuration of the cable-staying with a better formal result. The vertical up-lift forces produced by the live loads acting on the main span are countered by concrete fillings within the box girder.

The pylon and the deck have a stiff connection; that way the longitudinal action (earthquakes, braking actions…) of the entire bridge are resisted by these.

The deck cross section is practically identical to that of the approach spans, with a constant, 38.10 m width, increased from 35.10 m in order to make room for the cable-staying tower.

*Fig. 4 Functional and structural cross sections of the cable-stayed stretch.*

The stay cables, anchored every 10 m in the bridge axis, are made up of 0.6” strands with a triple level protection: (wax filling, galvanized and high density polyethylene (HDPE) coating), with units ranging from 35 to 58 chords.

The cables are anchored in the axis of the cross section solid triangular anchor blocks located above the intersections on either side of the central web. Transverse diaphragms are installed at these sections in order to transfer the loads from the outer webs to the central stays.

Cables are anchored inside the pylon by means of steel box section structures connected to the pylon concrete walls. The anchorages are supported on transverse beams fixed to the steel box sections, that are inclined according to the angle of each stay cable.

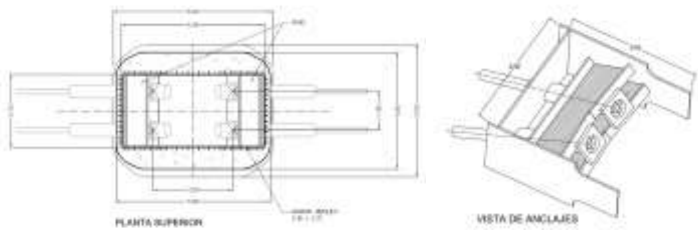


*Fig. 5 Stay cables´ anchorages in the tower.*

The vertical cable-staying towers are placed on the median strip while the cable-staying is arranged along the centre of the deck. Their overall height is 130.15 m and they are made up of a 40.95 m pier below the deck and a 89.20 m high mast above the deck. Such a disposition produces a very sleek and elegant bridge compelling us to design a deck which has torsional stiffness in order to counteract the effect of the eccentric load that cannot be countered by the cable-staying.

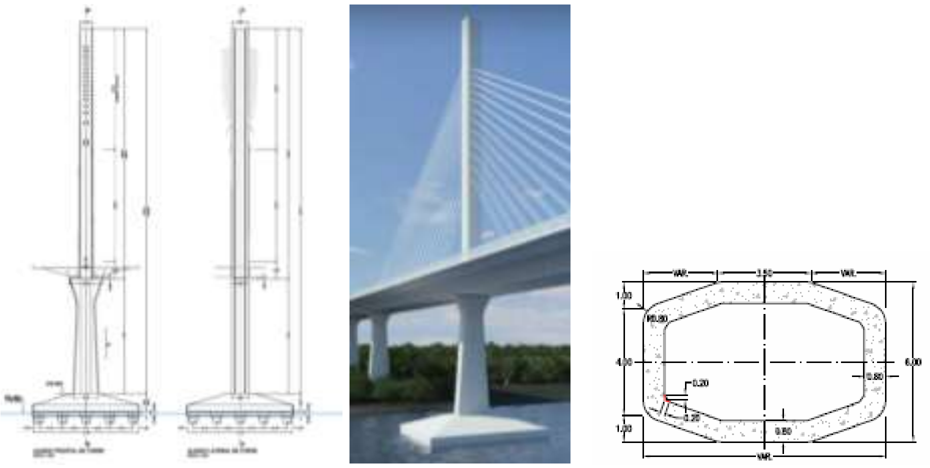

*Fig. 6 Elevation views and cross sections of the cable-staying tower*

The pier geometry below the deck is variable, similar to that of the piers on the approach viaducts.

## 4 BRANCHES

The roads on the left margin are connected with the bridge through four branches with a curved plan layout. Three of these are intended for vehicle traffic (Barranquilla-Santa, Santa Marta-Barranquilla, Santa Marta-Puerto) and one for pedestrian traffic.

The smaller height of the deck above ground level in civil works such as this one enables their modulation with shorter spans. The typical span adopted in this case was a 40 m long one. The number of spans is variable depending on the branch. These are connected with the trunk by means of two transition spans, 50 and 60 m long, respectively.

The cross section of the branches for vehicle traffic is made up of a single, prefabricated, central, 6.70 m wide box girder. To accommodate the required platforms the branches are completed with variable cantilevers, one of which is supported on struts.

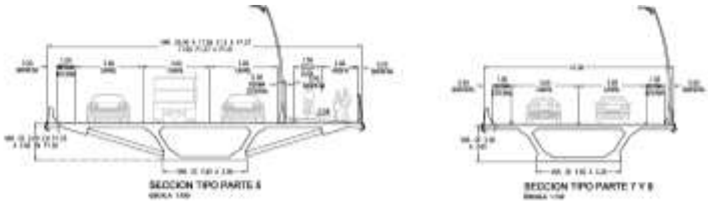

*Fig. 7 Typical cross sections of the deck on different branches.*

## 5 CONSTRUCTION

### 5.1 *Approach spans*

Diverse construction procedures were compared. All of these are suitable for the construction of prestressed concrete, 70 m long spans and their different modalities: cantilevered system or span-by-span construction, built both in-situ (using form travellers or movable falsework) and with prefabricated segments (lifting frames at the advance front, segment launching gantries, span-by-span launching gantries).

A comparative study carried out in collaboration with the firm BERD showed that the most competitive construction procedure for this civil work was the span-by-span method with prefabricated segments, even in spite of the enormous loads to be resisted by the launching gantry.

One element that proved beneficial for this decision was the extensive deck surface potentially suitable for prefabrication, given the fact that the approaches and the main bridge share the same cross section. Also, the branches could be standardized based on a typical cross section. This meant additional advantages: apart from the favorable execution schedule, we could also reuse the auxiliary equipment (the prefabrication yard, transport elements, segment launching gantries).

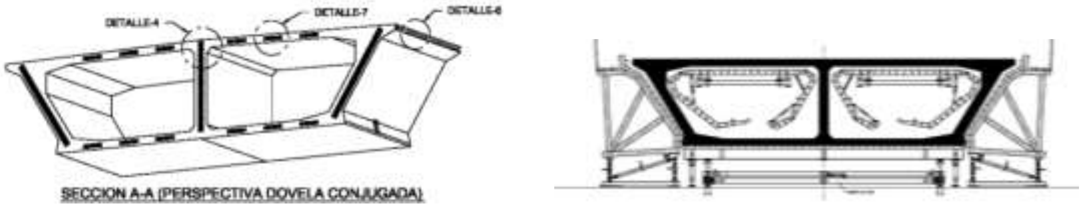


*Fig. 8 Scheme of the prefabricated segments and the casts.*

The prefabricated segments are installed by means of heavy-duty launching girders with the help of a detailed study of BERD, which proved the feasibility of the proposal.

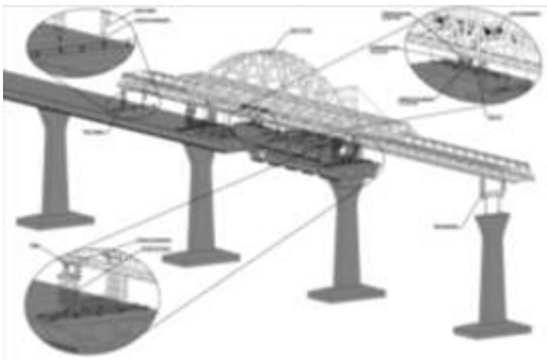

*Fig. 9 Launching gantry scheme developed by BERD for the span-by span construction*

In order to reduce the weight of the suspended elements and facilitate their installation, in a first phase only the central box girder is prefabricated and put in place, whereas the cantilevers on struts are built in a second, in-situ phase utilizing transverse form travelers.

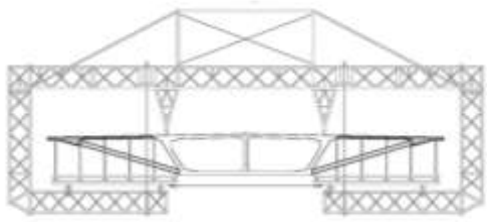

*Fig. 10 Transverse form traveller for the side cantilevers constructione*

As with the approach spans, the branches were also built applying the span-by-span method with prefabricated segments smaller in size than those used in the trunk. These segments were standardized, which allowed the use of the same cast and the same device in all the branches.

5.2 *Cable-stayed stretch*

Cable-stayed deck it is built by symmetrical balanced cantilevers. Prefabricated segments are transported on barges and lifted by means of lifting frames at the advance front. The progression is symmetrical beginning at the cable-staying towers and connecting the subsequent segments to the previous ones by means of prestressing bars.

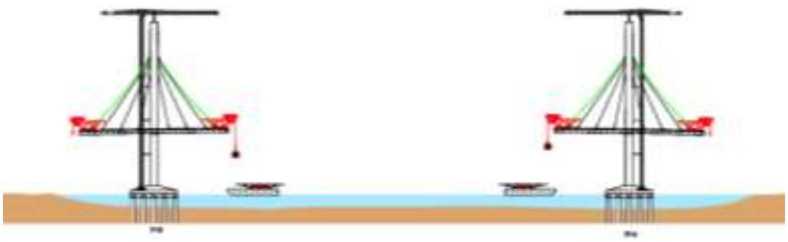

*Fig.10  Construction of the cable-stayed bridge by balanced cantilevers.*

The built-in union at the towers guarantees the stability during construction, eliminating the need for auxiliary “tie-down” elements, with a maximum lag of one, 5.0 m segment.

The segments of this area are to be installed using the cantilevers already prefabricated in the yard due to the fact that the additional weight and size of these elements are not critical as is the case in the approach spans.

## 6 CONCLUSIONS

The new crossing over the Magdalena River will be the largest bridge built to date in Colombia and the one having the longest span. The technical complexity implied in the execution of a civil work of such a magnitude offers the chance to introduce into the country some of the most advanced and innovative systems currently offered by bridge engineering science for a construction that is cost-effective, fast and safe. This civil work therefore has a two-fold interest since it can also showcase other works to be undertaken within the ambitious plan of infrastructure development implemented by the Government.

The hallmark elements that summarize this civil work are:

- Configuration of the civil work with the continuous deck along the entire structure of the bridge, the approach viaducts, the main bridge and the branches, unifying the construction procedures and granting a uniform and singular image to the whole.
- Usage of a single cross section for the central trunk of the work with a multi-cell box girder, completed with cantilevers over struts.
- Development of a structure of branches based on a central box girder identical for all the branches, completed with varied cantilevers.
- Central span with a cable-stayed stretch of remarkable dimensions, destined to become a distinctive element of the city and the country alike.
- Application of advanced, highly mechanized, bridge construction techniques (prefabrication, launching gantries, self-climbing formworks…etc).

*Fig.11 Aerial view.*