New Pumarejo Bridge over Magdalena River

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Abstract

The New Pumarejo Bridge over Magdalena River in Barranquilla, Colombia, is one of the most relevant bridges built over the past few years in South America. The bridge has a total length of 2173 m without expansion joints, divided in two access viaducts, 618 and 755 m long, and a cable-stayed central stretch of 800 m with a main 380 m long span (Colombia's record). The access viaducts have 70 m long typical spans built by a movable scaffolding system (first realization in Colombia), whilst the cable-stayed stretch is built by free cantilevering from the pylons with 10 m long "in-situ" segments (well above the usual range). 3.65 m high, the cross section has a variable width that reaches 38.1 m in all the central stretch, what makes it the widest bridge in its typology (concrete box girder with central cable-stays).

Keywords: Cable-stayed bridge; free cantilevering; evolutionary construction, post-tensioned box girder.

1 Introduction

Located about 12 km from the mouth of the Magdalena River, and just 30 m downstream from the original 1974 Pumarejo Bridge (Figure 1), the New Pumarejo Bridge serves a dual purpose that has been present for years in Colombia's national development plans. On the one hand, the improvement of the road communication between the departments of the Colombian Caribbean by expanding the capacity of the *Transversal del Caribe* (Route 90), and on the other hand, the adequation of the Magdalena River, Colombia's main fluvial artery, for the circulation of deep draft vessels thanks to the elimination of the current bridge, which is only 16 m high. These 2 objectives define the morphology of the central area of the bridge, which must span a 300 x 40 m navigation channel and have a platform almost 40 m wide to accommodate 3 traffic lanes, a berm, a sidewalk and a bike lane in each sense.

Figure 1. View of the Pumarejo Bridge from 1974

The mentioned characteristics led to a central cable-stayed section with a main span of 380 m (the largest in Colombia), almost 50 m of vertical clearance, and a 38.1 m wide platform, which makes it the widest bridge of the world in its typology (concrete cable-stayed bridge with central suspension) (Figure 2). The high vertical clearance required by the navigation channel and the condition of the administration to place the abutments outside the potentially floodable area, mean that the New Pumarejo Bridge has a total length of 2,173 m, divided into two separate access viaducts on the left and right banks of the river, 618 and 755 m long respectively, and a central cable-stayed section of 800 m (Figures 3 and 4). The location of the expansion joints in the abutments makes it the longest bridge without expansion joints in Colombia (2,173 m) [1, 2].

Figure 2. View of the New Pumarejo Bridge

At the beginning of 2015, the SES Consortium (Sacyr) was awarded with the original project of the Ecopuentes Consortium (with the bridge project by CFC S.L.), proposing its modification to the administration in order to adapt it to the construction habits of the country [3]. The proposed variations mainly affected the erection process of the deck, opting for the execution of the concrete deck *in situ* instead of using the precast segments proposed in the original project. This modification had a great impact on both the structural conception of the deck and on the details of the whole bridge, forcing the drafting of a completely new bridge detailed project, developed by IDEAM for the SES Consortium. The technical control and monitoring of the erection process and the technical support to the SES Consortium were also carried out by IDEAM.

2 Description of the New Pumarejo Bridge over the Magdalena River

2.1 Introduction

The access viaducts are solved by means of 70 m long typical spans executed by means of a movable scaffolding system (MSS), and a variable width platform that reaches the 38.1 m required in the central section. The cable-stayed section has 5 spans, 2 transition spans with the access viaducts, also 70 m long, 2 retaining spans 140 m long and the main span of 380 m, executed by free cantilevering from the pylons. The width of the platform in the central section remains constant and equal to 38.1 m. In the final area of the left bank, the deck is divided into a central trunk and 2 lateral branches that give access to the Barranquilla Port, executed over falsework.

The structural set of the Nuevo Pumarejo Bridge is completed by three walkways, 64 m, 148 m, and 281.5 m long for pedestrian and bicycle traffic.

2.2 Cable-stayed section

The cable-stayed section of the New Pumarejo Bridge is approximately centered on the left arm of the Magdalena River. The needs of the navigation channel led to the definition of a central cable-stayed span 380 m long suspended from two pylons of about 125 m high. The retaining spans are 140 m long, which provides a retaining span to main span ratio of 0.37. The transition spans between the cable-stayed section and the access viaducts are maintained with the standard configuration of 70 m. Therefore, the cable-stayed section has a 70+140+380+140+70 m span distribution (Figures 5 and 6).

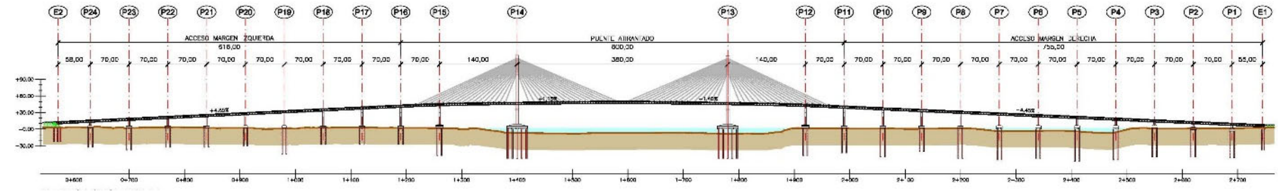

Figure 3. Elevation view of the New Pumarejo Bridge over the Magdalena River

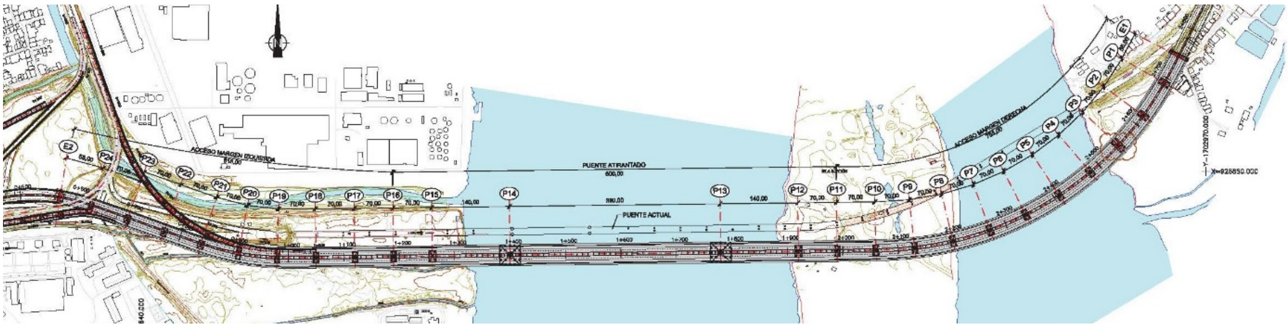

Figure 4. Plan view of the structure of the New Pumarejo Bridge

The suspension system has a symmetrical semi-fan configuration. It is made up of two parallel vertical staying planes located on the axis of the deck 1.45 m apart from each other, with 17 pairs of stays on each side of the pylons. The stays are anchored at the midpoint of the deck's cross section, maintaining a constant 10 m longitudinal spacing between pairs. The deck is also supported on the pylons, which allows creating a 45 m cable-free window, 22.5 m on each side of the pylon. In this way, the furthest cable pairs are anchored at the deck 182.5 m from the pylons.

2.2.1 Deck

The deck`s cross section consists of a 3.65 m deep concrete box girder, which results in a main span to depth ratio of 104.1. The webs of the box girder have a 32º inclination with respect to a vertical plane, with a width between webs equal to 12 m on the bottom of the deck and approximately 16 m on the upper face of the deck.

The total width of the platform in the cable-stayed section is 38.1 m, so it is necessary to complete the section with large wings more than 11 m long (Figure 7). This is achieved through the provision of transverse ribs every 5 m, supported on exterior and interior struts that transmit the vertical load to the base of the webs. The support system of the upper slab is completed with three longitudinal beams, two on the edge of the deck and one on the axis, coinciding with the position of the insertion of the struts in the rib (Figure 7). In this way, it is possible to maintain a reduced upper slab thickness in most of the cable-stayed section, equal to 0.25 m, increasing it only in the 55 m adjacent to the pylons, due to the high compressions carried by this area. The thickness of the web and the bottom slab have a minimum value of 0.40 m and 0.25 m respectively in most of the cable-stayed section, increasing their value to 0.50 m and 0.60 m, respectively, in the areas near the pylons.

When the rib+struts set coincides with the anchor point of one of the cable pairs in the deck, the interior struts in addition to transmitting the local loads of the top slab to the base of the webs, must transmit the vertical component of the cables. Therefore, the interior struts in these sections have a specific design, which allows them transmitting the load from the pair of central cables to the webs (Figure 7).

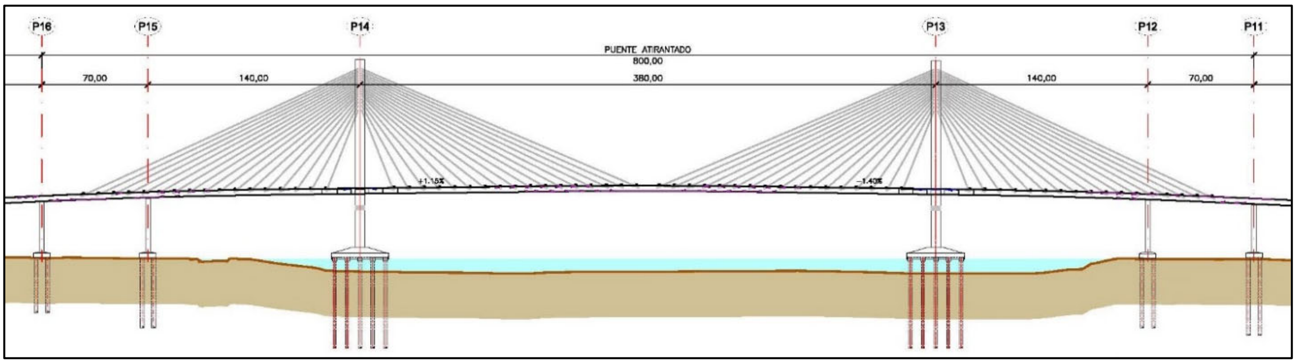

Figure 5. Elevation view of the cable-stayed section of the New Pumarejo Bridge

Figure 6. Side view of the cable-stayed section of the New Pumarejo Bridge built

2.2.2 Pylons and retaining piers

The pylons have a single shaft with a constant longitudinal depth of 6 m and almost 125 m high, which crosses the deck by means of a complex intersection that allows the deck to be supported by the pylon on the 3 directions of space and for the transversal rotations, but free for the longitudinal rotations. The transmission of the forces from the cables to the pylon is carried out by means of an embedded metallic box connected by shear connectors to the pylon.

The pylon under deck is approximately 35 m high, conditioned by the vertical clearance required by the navigation channel. It has a hollow rectangular cross section, with a variable transverse width between 8.85 m and 6.6 m. The palm tree-shaped pier-cap grows to 12.4 m through a formal configuration very similar to that of the rest of the piers.

Above the deck the mast has a height of almost 90 m and a constant transversal width of 4.9 m. The cables are anchored to the mast from a height of 51.5 m to a height of 79 m above the deck, providing an approximate mast height to main span ratio of 0.17.

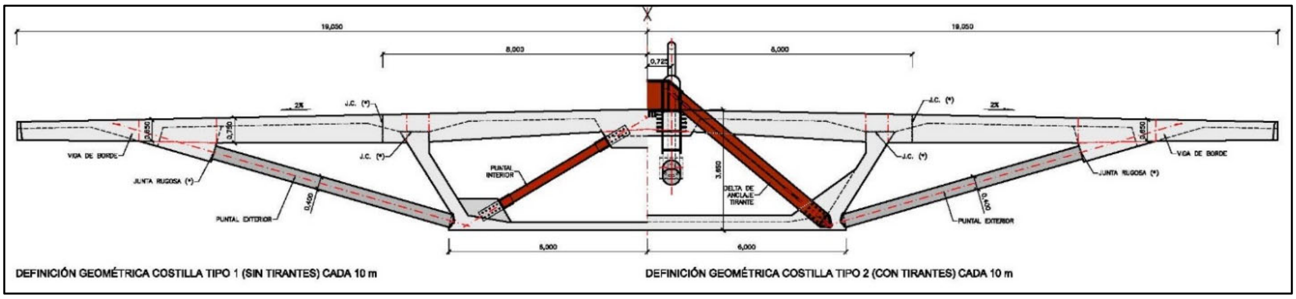

Figure 7. Deck cross section at a rib without cable anchors (left) and at a rib with cable anchors (right)

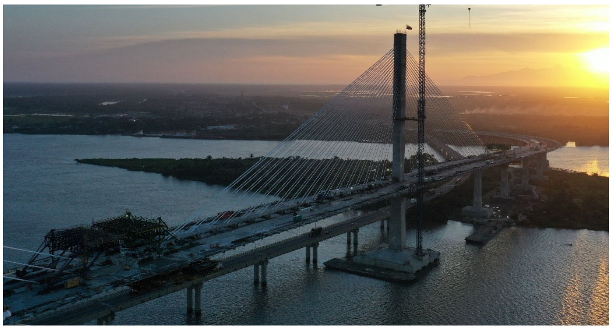

Figure 8. View of the P13 pylon during the execution of the cable-stayed section

The foundation of the pylon consists of 20 piles with a 2.8 m diameter connected to a 40 m side and 6.5 m height pile cap (Figure 9). The free length of the piles to the riverbed is approximately 15 m, and due to their position in the river, the use of maritime means has been required for their execution [2]. The pile cap protects the pylon from the direct impact of the deep draft vessels that will circulate along the river after the elimination of the Pumarejo Bridge from 1974.

Figure 9. P14 pylon foundation during its execution

Formally, the retaining piers are conceived as conventional piers, although they receive much lower vertical loads during the operation phases of the bridge, which can become lifting forces in many cases since the retaining piers constitute the main anchor point of the pylon-tips. The lifting forces have been supported by means of a very common solution in modern cable-stayed bridges, that consists of anchoring the deck to the retaining piers by means of vertical prestressing (Figure 10). The need for additional weight in these piers to avoid unwanted tension in the piles is achieved by placing a poor concrete weight over the pile cap.

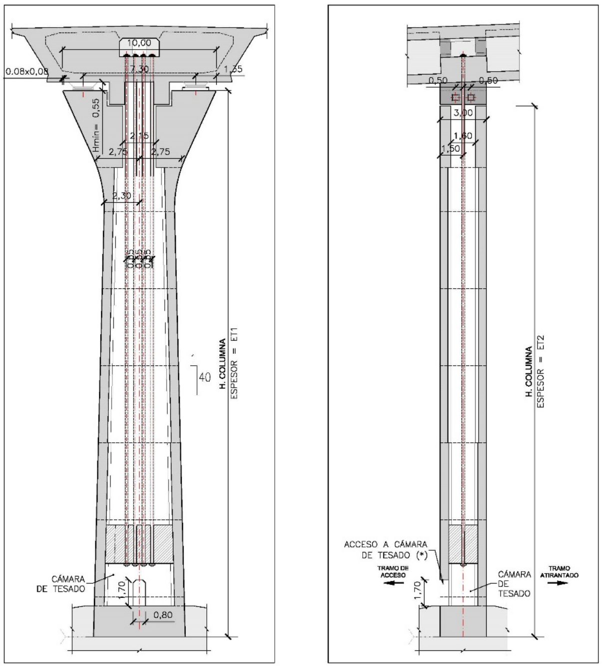

Figure 10. Cross section and longitudinal section of the retaining piers

2.3 Access viaducts

2.3.1 Deck

The deck is solved by means of a concrete box section 3.65 m deep, formally almost identical to that of the cable-stayed section (Figure 11), achieving for the typical span of 70 m a depth to span ratio of 1/19. The cross section and the support of the upper slab are solved in a similar way to that described for the cable-stayed section, with struts and ribs arranged every 5 m. The thickness of the webs and the bottom slab varies from 0.525 m and 0.25 m respectively in midspan, to 0.90 m and 0.60 m, respectively, in the pier region.

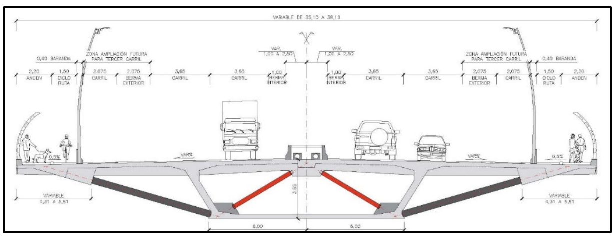

Figure 11. Typical cross section in access viaducts

2.3.2 Foundations and substructure

The low bearing capacity of the upper soils at the bridge site made it necessary the use of deep foundations with piles with typical diameters of 2.0 m. These piles have a variable length between 35 m and 55 m, depending on their location in the bridge layout, until they reach the underlying rock stratum.

The shaft of the piers of the access viaducts (Figure 12) has a hollow rectangular section with table thicknesses between 0.40 m and 0.60 m and a constant longitudinal dimension (3 m), while its width is variable, increasing from a minimum of 4.60 m on the bottom face of the pier-cap toward the pier-base.

Figure 12. Piers of the right access viaduct during its execution

The pier-cap has a palm tree shape in the transverse direction, increasing from 4.60 m at its junction with the shaft, to 10.0 m at the top face. It has a central opening to accommodate the seismic cap that hangs from the deck.

2.4 Branches and walkways

The branches have a width of 10.3 m and average spans around 50 m. The northern branch has a total length of 292.5 m divided into 6 spans and the southern branch has 9 spans and a total length of 369.475 m.

The walkways that complete the structure are composite structures with isostatic spans between 30 and 40 m, 3.85 m wide and a typical depth of 1.40 m (1.20 m of metal + 0.20 m of upper compression slab).

3 Erection process

The construction process of the New Pumarejo Bridge [4] faces several challenges, the most important of which is undoubtedly the work in and on the Magdalena River, which requires the execution of piles by maritime means, concreting of pile caps from pontoons etc… (Figure 13) [1], [2], [3].

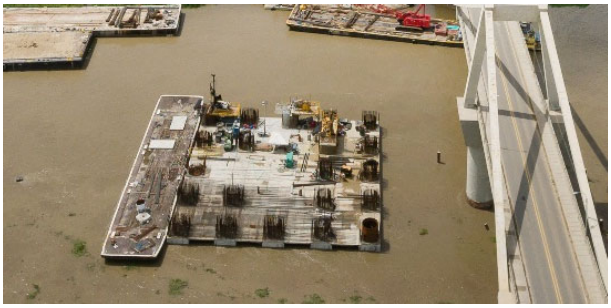

Figure 13. P14 pile cap during its execution

The deck is executed by three different methods, adapted to the requirements in each area: *in-situ* execution on falsework, span-by-span execution by means of a movable scaffolding system (MSS, designed expressly for this work) and construction by free cantilevering. That of the New Pumarejo Bridge has been the first MSS construction in Colombia, and with the execution of a 16 m wide box girder with a typical weight of 40 t/m and 70 m spans, one of the most important in the world up to the date. The form travelers used in the cable-stayed section, also expressly designed for the New Pumarejo Bridge, capable of executing 10 m long and 16 m wide segments with a weight of 535 t, are at the forefront worldwide in this type of processes.

3.1 Access viaducts

The deck begins to be executed on the left bank, by means of the *in-situ* execution of span E2-P24 and 15 m of the next span over falsework. At this point the span-by-span execution of the deck begins by means of a MSS [1], up to 15 m from pier P16. At that moment, the MSS is dismantled and taken to span 2 on the right bank, where, after the *in-situ* execution of spans E1-P1 and P1-P2 on falsework, it begins to erect the deck span by span until it reaches pier P11 + an overhang of 15 m.

The high weight of the box girder has made it necessary to execute the cross section in an evolutionary way, which allows not to oversize and increase the cost of the auxiliary machinery unnecessarily. Thus, the cross section in the area executed by MSS is completed in three phases: a tub section and the upper slab between webs, executed by MSS, and the wings executed in 15 m laying by means of a wing traveler 2 spans behind the MSS.

The configuration of the used MSS required the execution of the bearing diaphragms of the deck over the piers as a 0 segment that would allow the support of the front legs of the MSS. (Figure 14). The segment 0 was fixed to the pier cap by means of vertical prestressing and provisional support blocks, which were eliminated once the tub section of the adjacent span was poured and had gained enough resistance.

Figure 14. Execution process of the access viaducts with MSS

3.2 Cable-stayed section

Simultaneously with the execution of the access viaducts, the deck of the cable-stayed section was executed by 4 form travelers free cantilevering from the pylons symmetrically a total length of 185/195 m. On the retaining sides, the free cantilevering process had to overcome the 0 segment of the retaining pier, located 140 m from the pylons. From that point the free cantilevering continued the transition spans until the closure against the access viaducts. In the suspension side the main span was completed with a central closing segment.

The significant width of the section forced the free cantilevering of the box girder alone, completing the section 3 segments behind by means of 4 wing travelers that placed the prefabricated struts and executed the wings of the section. The 10 m long *in-situ* segments allowed the distance between cables to be bridged in one go, which enabled the construction to be carried out without construction prestressing. The deck prestressing was only used as continuity prestressing in the center of the main span and in the junction area with the access viaducts (Figure 15 and 16).

Figure 15. Cable-stayed section of the New Pumarejo Bridge during execution

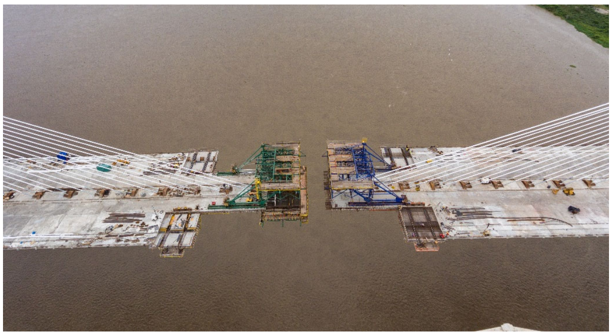

Figure 16. Cable-stayed section just before midspan closure

4 Conclusions

Due to its extraordinary characteristics (38.1 m wide, 380 m main span, 2,173 m total length without expansion joints), the New Pumarejo Bridge is one of the engineering references in South America and the world in the past recent years. Its execution was carried out from 2017 to 2019, being inaugurated in December 2019. The entire process progressed smoothly, largely thanks to the collaboration and joint work between the construction consortium (SES Consortium, Sacyr) and the engineering that developed the detailed design and the execution control (IDEAM) (Figure 17) [5], [6]

Figure 17. View of the New Pumarejo Bridge after its inauguration December 2019

5 Main participants in the project and work

Property: Ministry of Transportation of the Republic of Colombia (Instituto Nacional de Vías).

Construction company: SES Consortium (Sacyr). Project director: Juan Pablo Durán and David Gutiérrez; Boss of technical office: David Ordín and Maite Calleja; Structural specialist: David Ruiz

Technical services: Sacyr. Raquel Caballero, Rüdiger Spengler, Cristian Bernal, Agustín Redero, Rafael Guillén, Fátima Calderón, Jorge Cañizal.

Detailed design: IDEAM. Francisco Millanes, Miguel Ortega, Fernando Ruano, Jokin Ugarte, Ildefonso de la Cruz, Maria João Freitas.

Specialized technical assistance during the execution of the works: IDEAM. Francisco Millanes, Miguel Ortega, Jokin Ugarte, Fernando Ruano, Alberto Suz, Iván Toribio.

6 References

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