SUPER SIZED

With foundations in place and piers and abutments virtually complete, all efforts are now focussed on the superstructure of a major new river crossing in Colombia. José María Sánchez de Muniáin reports from site

One of the first challenges for building the 2.8km-long Pumarejo Bridge was meeting the required seismic resistance in difficult geological conditions

The slender and complex superstructure of the Pumarejo Bridge is dictating the pace for what is claimed to be Colombia's largest infrastructure project, now past the halfway mark. The Alberto Pumarejo Bridge will span the River Magdalena, carrying Highway 90 from the Atlántico and Magdalena areas of the city of Barranquilla, Colombia's fourth largest city, onwards to the city of Santa Marta. When it opens to traffic - completion is currently scheduled for spring 2019 - it will replace the existing Laureano Gómez Bridge whose 15m clearance over the river has been hampering navigation to and from the Caribbean Sea, some 10km further north, for 34 years.

The US$220 million project consists of a 2.8km-long crossing which has an 800m-long cable-stayed bridge; a 755m-long viaduct on the east bank and a 618m-long viaduct on the west; plus two access roads. The main cable-stayed span, which is 380m long and 38.1m wide, is supported by two 133m-high towers. The bridge superstructure is a concrete box girder with cantilevered sides supported by prefabricated concrete struts placed at 5m intervals. The deck will carry six lanes of traffic as well as a 1.5m-wide bicycle lane and a 2.2m footway.

The construction contract was awarded by the National Roads Institute of Columbia (Invias) to the SES Puente Magdalena consortium, which comprises Esgamo Ingenieros Constructores, Sacyr Chile and Sacyr Construcción. Detailed design is being provided by Ideam; the bridge's original design was by the Ecopuentes consortium, formed by IV Ingenieros Consultores, Estructurador Colombia, and Jorge Alfonso Fandiño.

Different construction methods are being adopted for the deck; a movable scaffold system and wing traveller for the viaducts, formwork travellers for the cable-stayed section and continuous shoring for the access roads.

When *Bd&e* visited the site last month *(January)* the project was estimated to be around 25% behind schedule; according to local reports, this was due to difficulties experienced in installing the 64 piles, up to 2.8m in diameter and 55m to 60m deep under the Magdalena River, to form the foundations for the towers. Earlier in 2017 a 70m-long overhead movable scaffolding system had been erected on site - the first time such technology has been used in Colombia. What effect is this equipment having on the project and its new completion date in the first quarter of 2019?

Sacyr's project director Juan Pablo Durán Ruiz leads the work on site - he is a Spaniard who has been living in the country for more than six years and who freely admits to now feeling 'Colombianised'. Under the gaze of circling vultures we begin the tour on the east side of the river, from where we can see a crane next to one of the bridge towers in the distance. This crane is the first indication that everything in this project is super-sized; with a lifting capacity of 48t, it is one of two that were imported from Spain specially for this project.

Reflecting on the initial part of the project, Durán Ruiz agrees that the foundations for the towers were quite a challenge, involving 6,000m3 of concrete and deep piles due to the geological conditions. "We have 12m of water and then it is sand. We had to reach a layer of coralline strata and, in addition, take into consideration the required seismicity resistance calculations of the bridge," he recalls. Some sections of the bridge have 800kg of steel per m3 of concrete to meet the requirement for seismic events with a 1,000 year return period; rather than neoprene bearings, the towers have spherical bearings supplied by specialist Maurer.

If this were a standard sized cable-stayed bridge with a deck around 11m wide, then the contractor might be confident that the most challenging part was now in the past. Unfortunately as very little - if anything - of the Pumarejo Bridge is standard sized, there are still significant hurdles to clear.

For one, the bridge concrete box girder deck is up to 38m wide and 3.6m deep, a ratio of almost 1:10. For another, the approach bridges have variable gradients both transversely and longitudinally. In some sections the transverse inclination is as high as 7%, making it look more like a race-track than a bridge, remarks Durán Ruiz drily.

These gradients prevented an underslung MSS from being used for the 1,190m-long approaches. Instead, an overhead system and a specially-designed wing traveller, both manufactured and supplied by Berd, are currently in operation and were clearly visible even from a distance, dominating the work site. The M1-70-S was manufactured in Turkey and delivered to Colombia in 120 containers where it was assembled on site. It has overhead trusses fitted with Berd's Organic Prestressing System that consists of Enerpac hydraulic jacks, prestressing cable of 80 monostrands, sensors and control unit.

It is this organic prestressing system that enables the 70m-long spans of the Pumarejo Bridge to be cast in one go. As the concrete is poured into the formwork and the system deflects under the weight of concrete, the prestressing system measures the deflection, calculates the prestressing force needed to reduce the mid-span deflection, and prompts the system to introduce it. In this way, the OPS increases the load capacity of the scaffolding system.

However when *Bd&e* visited, things were relatively quiet on the east side of the river, as a result of a change in the construction programme. The MSS had originally been intended to begin its work here, because the alignment was simpler than on the west side. On the east side, the constant curvature of the approach viaduct leads into

a straight section. This would have given the construction team a better opportunity to get to know the equipment that is making its debut in Colombia.

However, due to a combination of right-of-way acquisition issues and local access permits, which have caused a three-month delay, a change of plan was necessary. Amongst other changes, it required construction of an embankment on the opposite side of the river to provide somewhere for the MSS to be assembled at its new starting place. To make up for lost time, the first two spans on the east side that were initially intended to be built using the MSS are being constructed instead on continuous shoring. The first span was completed in December last year and the next section is expected to be finished in March. Once the MSS has finished the spans it is building on the west bank, it will be dismantled and shipped over to the east side on barges.

As we head back to the other side, crossing the existing cable-stayed Laureano Gómez Bridge, Durán Ruiz comments that the 45m clearance of the new bridge will enable larger ships to call at the port and boost its development. This may not seem like a particularly generous clearance by modern standards, but the Magdalena River is only a maximum of 10m deep at this point, so Panamax-sized ships would not have been able to use the shipping route even with a higher bridge deck.

Even at 30°C and 90% humidity there is a hive of activity on the west bank of the river around the imposing MSS and indeed Durán Ruiz confirms that well over 100 people are working on it. The M1-70-S MSS is in position on its fourth span, with reinforcement cages being inserted into the formwork, ready for the next 610m^3 concrete pour of the 16m-wide, 70m-long U-section of the deck.

Each 2,700t box-girder span is being poured in two sections, with the 390m^3 of concrete upper slab following the U-section. Seventeen spans will be formed in this way, eight on one side of the Magdalena River, nine on the other. "The MSS is a good piece of equipment, but the problem is that it is a complex project," says Durán Ruiz. On a normal project, cycle times could be expected to be around eight to ten days, 15 at the longest, but the complex geometry of this deck means that each cycle is taking over 30 days. When works starts on the opposite side of the river, where the alignment is more regular, he believes it may be possible to cut cycle times to 26 days. On the west side, however, the alignment of the deck is more complex, first curving one way, then the other, with varying inclinations and radii of curvature.

From the outside of the box girder it is impossible to appreciate the details, so we climb down a ladder into the superstructure of the previous span constructed by the MSS. The huge section reveals multiple ribs, supports, connectors and wedges throughout. "There are thousands of different details to place the formwork around," says Durán Ruiz, "It is not only the steel reinforcement; after that we have to place the struts and all the ribs for the upper slab, which are all different."

Could a different design have been used? "With the curves, the inclines, and everything that they entail, it would have been very difficult to homogenise it. But, like everything in life, the learning process gradually provides more opportunities to speed up the process," says Durán Ruiz.

Subcontractor Construgomes is responsible for operating the machinery and building the deck. Luis Nogueiro, leading the deck construction engineering team, expands on why the cycle times are so much longer than usual, bearing in mind that this MSS was designed to achieve 14-day cycles. He emphasises the enormous challenge of using the MSS, a construction technology that is ideally suited for long, repetitive spans, on a project where each span is completely different to the previous one. Achieving nine or ten-day cycles with 60m-long spans, which he experienced first hand at the Rio Corgo Viaduct in Portugal, is "completely impossible here".

Sitting in his office, Nogueiro shows a typical section on his computer. "For the first concreting stage, the U-section is not too bad, but the top slab is a complete tangle because of the many ribs, the different cambers, and because the wedges for the tops of the cables are all different."

In addition, each section has to be slightly modified from the original design to

The MSS is forming 70m-long sections in two phases; first the U-section, then the upper slab

Cycle times are expected to shorten when the deck path straightens as it approaches the river


Sacyr designed a continuous scaffolding system for one of the access roads

It is the first time an MSS featuring Berd's Organic Prestressing System has been used in Colombia

also take account of the movement of the overhead MSS; centring supports with the wedges and increasing the size of the webbing.

To illustrate just how challenging the deck is, Nogueiro explains that construction of the first span on the west side, which was built on scaffolding by traditional methods, took seven months.

Notwithstanding these difficulties, with the MSS now working on its fourth span, Nogueiro is confident that the technical aspects of the construction are understood and under control, and believes that two more spans will be completed by end of March. From his perspective, the most difficult challenge is yet to come: the operation of the CM15 wing traveller, also designed and supplied by Berd, which will be used to form the 11m-wide, 15m-long sections on each side of the box girder. This will create what is believed to be the widest deck of its type in Latin America. At the time of visiting, the wing traveller was preparing for construction of the first section.

For the first five spans built with the MSS, the wing traveller formwork will have to be adjusted every 5m due to the varying geometry of the deck. After the sixth span, when the deck's path straightens out, no adjustment will be required. "The transverse inclination is constantly changing. From the point of view of formwork, this is a difficult task because every 5m it is different," says Nogueira. It is slow work, he admits, and points towards an engineer who is sitting silently in front of her computer, finalising the detailing of the formwork for a 5m section further ahead. "But technically speaking it is under control," he says.

The wing traveller is prepared for its debut in forming 11m-wide, 15m-long sections at the sides of the superstructure

The cable-stayed section of the deck will be built using two pairs of form travellers supplied by Construgomes, which will advance as the tower construction rises. These travellers, designed jointly by Sacyr, Construgomes and Berd, are described by Durán Ruiz as 'immense', and for good reason. They can form 10m-long segments, nearly double the length of traditional equipment.

One pair of travellers is already at the site, with assembly due to start at the end of last month *(January)*; the other pair is in Cartagena, en route to the site. After construction of the starter sections at the towers, and once the towers reach the 40m height at which the first steel anchor sections will be installed, the two will begin their work, estimated to be three months from the time of writing.

In the first phase, each pair of travellers will form 16m-wide sections, matching the box-girder cross-section being built by the MSS; the additional 22m which makes up the full deck width will be formed by two wing travellers, also supplied by Construgomes. Nogueira reveals that the equipment had to be specially designed not only because of the monumental width of the deck, but also so that it could be adjusted to a slight transverse inclination.

What are the main challenges remaining for Durán Ruiz, who is upbeat, even in the face of constant pressure from the national press and the client? "We are now picking up the rhythm with the MSS, and the initial problems and technical queries have been overcome. We are hoping that the wing traveller will be straightforward - I won't say simple, because it is a mechanical device."

Given the complexity of the project, contractor Sacyr is limited in options for speeding up the construction process any further. A large tented area has been established on site to enable steel reinforcement for the superstructure to be fixed in sections under cover, ready to be lifted onto the MSS. The second pair of formwork travellers for the cable-stayed deck, which are currently en route to the site, will be additional to what was originally planned, and traditional construction methods have been used to build some spans of the approach decks after the planned assembly of the MSS was derailed by external factors.

"This work is special for all of us," concludes Durán Ruiz, "The MSS is an unusual way of building, the formwork travellers are unlike any others, and the wing travellers are immense. We even had to design our own continuous scaffolding system to construct the access roads, because we couldn't find anything that would adapt to the height and the width"