Modern arch bridge for SANRAL nominated for
Fulton Award

By John Woodburn, Stefanutti Stocks Coastal contracts director

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Stefanutti Stocks Coastal completed construction of the new Olifants River arch bridge for SANRAL in 2018. The new 166-metre long bridge with its 93-metre long arch, formed part of the N7 upgrade (from a single to a dual carriageway) in the vicinity of the Olifants River near Trawal Klawer. The road infrastructure upgrade contract also included the construction of a new road.

Arch bridges

The arch is an extremely efficient structural form and has been used for bridges for a very long time, with possibly the oldest known arch bridge still in use today being the Mycenean Arkadiko bridge built in Greece around 1300 BC. While most of the earlier arch bridges were constructed from stone, this bridge type is also suited to modern construction techniques and materials.

The Olifants River Bridge uses the ancient structural form in an innovative way, making use of modern materials and analysis techniques to provide an aesthetically pleasing structure. “It has some unique design features and construction techniques, and we believe that this together with the attention to detail, in both the design and construction, as well as the quality of the concrete finishes makes this bridge a testament to excellence in the use of concrete,” says Stefanutti Stocks Coastal contracts director John Woodburn.

The construction method adopted at the Olifants River Bridge is better known as the Cruciani system. This system consists of timber truss segments and was developed in the 1950s and mainly used in Austria for the construction of almost one hundred arch bridges. For spans such as at the Olifants River Bridge the segments are erected by crane and after construction is complete the falsework is removed and spoiled.

Arch springing point foundations

When masonry was the preferred material for the construction of arches, their shape had to be carefully chosen to avoid tension forces in the arch. A shape close to a semi-circle was found to be effective.

For the Olifants River Bridge, it had to fit the road alignment and the rise was therefore limited to around fourteen metres, which is only around fifteen per cent of the span. This means that significant moments are generated at the arch springing points. The arch could be reinforced to deal with these forces, but the forces had to be transferred to the ground through the foundations. The magnitude of the moments at the supports depends on the rotational stiffness provided by the supporting material (which is not necessarily elastic) and varies based on the loading.

Forces at arch springing points

A comprehensive geotechnical investigation found competent rock at the support locations. A weathered zone below the southern support influenced the design and called for two different conditions. An iterative process was followed, where the geotechnical engineers were provided with design loads, based on an assumed rotational stiffness, to model the rotational stiffness. The structural model was then updated with a revised stiffness until the results were close enough.

Arch falsework

A proposed construction methodology was provided as part of the construction drawings, however, it was Stefanutti Stocks’ responsibility to design and supply this portion of the works and it appointed BPH Engineers to design the steel structure to support the formwork during concreting of the arch. This structure had to comply with strict deflection requirements and they managed to limit this to such an extent during construction that no pour strips were required as foreseen in the drawings. A deflection of 85mm over the ninety-three-metre span was expected and five monitoring points were observed carefully as the concreting progressed. The temporary support structure performed better than anticipated and a maximum deflection of 58mm was measured.

Temporary arch/sliding of the steel truss

The steel truss was designed to be able to support the concrete for the first arch, and then to be slid into a new position for the second arch. Prior to installation and sliding, all steel-on-steel sliding surfaces were coated with graphite grease to reduce friction and the subsequent sliding force required during sliding of the truss.

Ninety-five ton cylinder jacks were used to pull the arch to the second position and each cylinder was extended simultaneously. Stroke lengths were monitored to ensure cylinders were not over extended and movement at the centre and ends was monitored constantly as it was important to ensure the jacks were “pulling” the truss evenly. A pulling force of up to 90kN or 19 ton was required for the truss to be “pulled” into position from two locations at the end supports on the sliding rails.

The hydraulic jacks were then relocated from a transverse jacking orientation to end-to-end jacking, forcing the truss inwards to take up position under the new permanent arch.

Arch springing points

Even though three boreholes were drilled at each arch springing point foundation, the rock level was highly variable and unexpected foundation conditions were found at each position.

Northern arch springing foundation

When the foundation was inspected before concreting, a weathered zone was found just below the foundation level. This could result in unacceptable vertical deflection and the rock therefore had to be removed to the level of the weathered zone and replaced with mass concrete.

The level of the rock behind the support position also varied substantially and would not have been able to resist the expected loads. Additional horizontal load capacity was provided by means of a mass concrete support behind the foundation, tied into the rock by means of rock anchors.

Social upliftment

Stefanutti Stocks Coastal employed their entire unskilled labour force from the local community. “We embarked on a skills training programme over the duration of the project and after completion have left as many skilled people as possible behind, who we hope will be employed for future projects in the surrounding areas,” says Woodburn. Clerical people, both wage and administrative, were employed from the community and of those employed many gained permanent employment positions and have moved to new projects along with Stefanutti Stocks. The ultimate silver lining was not only achieving the CPG target of a sixteen-million Rand spend in local employment, but more than doubling it with a total employment spend of thirty-three-million Rand.

It is always difficult to quantify the actual spend in the community, but it would be fair to say that the project supported all business sectors in the nearby towns – including plant hire, fuel supply, aggregate purchase, signage, transport and accommodation, and the list goes on and on – with additional millions spent supporting local suppliers.

“The joint efforts of all stakeholders, a combination of innovation in design and construction, and the extreme care taken with regard to details and concrete finishes resulted in an aesthetically pleasing structure that will leave a legacy behind that all who were involved in this project should be very proud of,” concludes Woodburn.

Captions:

1. A present day photograph of the Arkadiko Bridge in Greece.
2. A diagram illustrating the Cruciani system, that was utilised for the arch of the Olifants River Bridge.
3. The temporary support structure designed by BHP Engineers for Stefanutti Stocks Coastal and erected on site in Klawer in the Western Cape.