PROJECT AWARDS: WINNERS AND FINALISTS

SAICE – MURRAY & ROBERTS STEEL

CATEGORY: INTERNATIONAL PROJECTS

Cunene River Bridge, Xangongo

INTRODUCTION

The new Cunene River Bridge is an excellent feat of engineering achieved under extremely challenging conditions. The bridge links the major cities of Lubango and Ondjiva in south-western Angola, and replaces a host of temporary structures that were used to span the Cunene River after the last permanent structure had been destroyed early in the Angolan conflict. The strategic location of the old bridge as the main link between Angola and other southern African countries made it a prime target during the civil war.

The Angolan Roads Agency (INEA) appointed Aurecon, together with its joint venture partners Gabeng and BKS, for the design and preparation of bid documents. This joint venture was also responsible for site supervision. The Angolan Government invested approximately US$49 million in the project. Construction on the 880 m long bridge began in January 2007, and its inauguration took place on 14 September 2009.

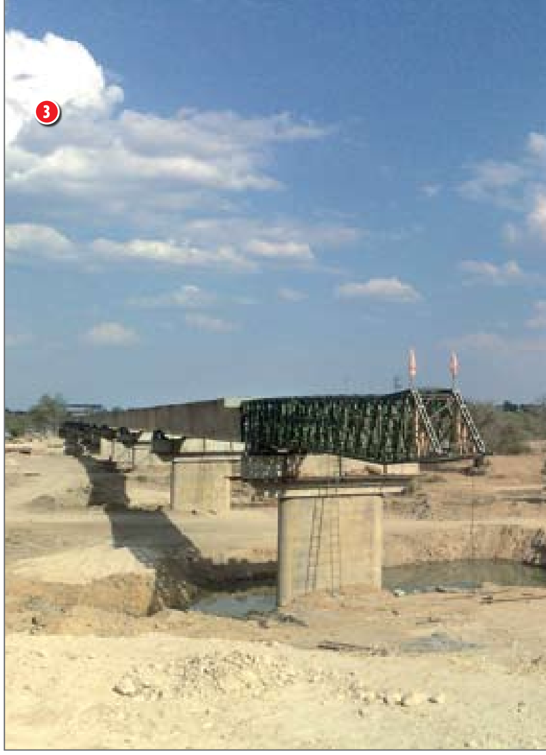
1 Construction of the new bridge over the Cunene River at Xangongo in Angola – view of completed concrete substructure

CUNENE RIVER BRIDGE, XANGONGO

WINNER – International Projects category

KEY PLAYERS

Client Institudo de Estradas de Angola
Professional Team Aurecon in joint venture with BKS and Gabeng
Main contractor China Road and Bridges Corporation



Logistical and natural challenges on this project included landmines, floods during the rainy seasons, the width of the river, lack of skilled labour, difficulty in the acquisition of building materials due to the distance from commercial centres, lack of good aggregates, long supply lead times, importation procedures and border delays.

PROJECT OVERVIEW

The crossing site for the new bridge is located 20 m downstream of the remains of the original bridge structure over the Cunene River, northwest of the village of Xangongo in the Cunene Province. The bridge spans a perennial river channel of approximately 100 m and then crosses the flood plain of the river for a distance of 780 m to the start of an embankment which traverses the remainder of the flood plain. The plain is regularly inundated during the rainy season, which starts from approximately November each year and lasts to the end of March of the following year. For a large part of this period, the flood plain is often inaccessible due to the high level of the river.

DESIGN APPROACH AND AESTHETICS

From the start it was clear that the poor foundation conditions would lead to a bridge configuration with fairly long spans and a deck as light as possible. It was found that a 50 m span length and a composite steel/concrete deck type offered the most economical solution.

The design concept, using precast slab deck and manufactured steel girder sections, also meant that the new bridge could be completed in the shortest time possible.

Hydrology and hydraulics

The Cunene River at this location has a catchment area of 52 400 m^2. The maximum measured flood occurred in 1951. The peak flood was estimated to be 14 180m^3/s and more than 50 years later a higher flood has not been recorded. A free board of 2 m above the maximum recorded flood level was provided.

The river is not very stable and the main channels shift after each flood season. Therefore the bridge had to have an opening long enough to accommodate the different main channel positions.

UNIQUE FEATURES

It was important to the Client that the new bridge should be completed by the deadline. This had an influence on many aspects of the design philosophy. The contractor's construction sequencing and turnaround times played a significant part in the detailed design of the bridge works. In this region, concrete aggregate is scarce and has to be hauled from a long distance to the site. This led to the design of an economic solution in the form of a composite deck. The special features of the bridge include:

Composite construction

The choice of a composite construction design utilising structural steel box girders and a concrete deck had the following advantages:

- Reduced weight of the structure which in turn reduced the size of foundations required
- Structural steel substructure could be manufactured in parallel with the construction of the concrete substructure
- Reduced construction period required for launching of structural steel box girders and no staging and formwork required

Once the structural steel box girders had been launched into position on the concrete substructure, construction of the concrete deck could continue uninterrupted and was not affected by the flooding river.

Concrete precast decking

The concrete deck consists of 1 384 precast concrete elements with *in situ* cast strips in-between. This method reduced construction time, as a large proportion of the deck could be manufactured while the construction of the box girders and substructure was in progress. Construction time of the concrete deck was considerably reduced thanks to the speed of placing the precast elements, and the reduced requirement for formwork before fixing of reinforcement and placing of concrete in the connection strips. Eventually a monolithic continuum deck slab was provided to form the composite section.

Steel box girders

A comprehensive quality assurance regime was put in place to ensure that the highest standards and quality of workmanship was maintained. The contractor engaged a special team of quality control inspectors from the China National Construction Steel Quality Supervision and Test Centre to conduct quality control testing both in the factory and on site. All welds were radiographically and

2 Girders being transported in Angola
3 Launching in progress
4 Precast concrete deck panels on girders
5 Completed bridge open to traffic

ultrasonically tested in the factory and on site to ensure the integrity of each weld. Since the girders would spend a long time at sea while being shipped from China to Angola, a comprehensive corrosion protection coating was specified for the structural steel girders.

The use of steel box girders ensured that the biggest part of the bridge could be fabricated in workshop conditions with limited on-site welding. This ensured the quality of workmanship, while the testing of welding was better controlled. Furthermore, the relative light-weight steel construction ensured that the main structural element of the bridge could be launched from one side. The partially precast concrete deck slab with *in situ* infill panels was advantageous toward the overall construction programme. The manufacturing of precast panels started at the same time as the construction of the steel box girder. Only after the construction of the *in situ* concrete infill, did the structure behave in a composite manner.

Unusual construction aspects

Foundation

Using a temporary fill, a working platform on the flood plain was created so that piling work would not come to a halt during the five months of the year when the flood plain was inundated. This enabled the 110 friction piles to be constructed in the shortest time possible. End tipping was the chosen method for the piling works of the bridge abutments. The same method was also used for the piers in the secondary channels of the river.

Deck construction

The construction of 142 box girder sections began in China while, at the same time, 1 384 precast concrete deck slabs were being constructed on site in Xangongo village, Angola. Before shipping the girder sections to Namibe Port in south-western Angola, the girders were pre-assembled in the fabricator's yard in China to ensure fit-up and alignment of all girder sections. The position of each girder section was noted and marked to ensure proper fit-up and alignment when assembling and welding the girders on site. Upon arrival in Angola, the girder sections were trucked 600 km to site – a challenging logistical undertaking in its own right. An assembly and welding yard was set up on site at one end of the bridge to weld the consecutive girders together. All site welds were ultrasonically and radiographically examined on site to ensure the integrity of each weld. The sections were then incrementally launched using hydraulic jacks from the one end of the bridge.

Concrete deck slabs

The bridge deck consists of precast concrete panels and *in situ* concrete strips designed to act in a composite fashion with the structural steel box girders. The advantage of constructing the deck using precast panels was that the casting of the panels could commence independently and ahead of the fabrication and launching of the structural steel substructure of the bridge. Since this reduced the time required to complete the bridge, the contractor commenced the fabrication of the precast panels well in advance. The 1 384 precast panels were finished in good time, i.e. before the launching of the box girders had been completed.

At the end of February 2009, the contractor placed the first precast concrete deck panels on the box girder and this process continued without interruption until all the precast panels had been placed. Simultaneously, the contractor commenced aligning and levelling the panels in readiness to fix reinforcement and formwork. The first span of *in situ* concrete deck strips was cast on 30 April 2009 and work progressed smoothly, with the concreting of the deck finally being completed on 10 June 2009.

Dimensions

The new bridge is 880 m long, comprising sixteen spans of 50 m each and two spans of 40 m each. The spans are formed by a composite steel and concrete deck structure, with an overall width of 11 540 m, on piers supported on 1,2 m diameter friction piles, up to 30 m in length, founded in a silty clay, and retaining wall type abutments. The concrete deck, which comprises two traffic lanes of 4,5 m each, is surfaced with a 40 mm thick asphalt carpet. Pedestrian walkways, 1,5 m wide on each side of the deck, are provided with steel guard rails installed on the outer edges of the structure for the full length of the bridge. Pedestrians are protected by 1 m high steel guard rails, which are of the collapsible type so that repairs can be made after impact with relatively little reconstruction.

The design of the piles for the foundations of the bridge was based on the results of a geotechnical investigation which indicated that bedrock with a suitable bearing capacity was present at a depth of approximately 10 m below the river bed. Based on this, an end-bearing oscillator pile was specified for the project. However, when the contractor began the foundation investigation on site to prove the founding depth for the piles, no hard sandstone horizon was encountered at all, despite drilling down to a depth of 60 m

PROJECT CHALLENGES

The following are a few of the many challenges experienced on this complex project:

- Lack of skilled local labour in the region.
- Difficulty in acquisition of aggregates.
- Complexity of construction due to the sophistication of the bridge design.
- Long lines of supply from China and South Africa for the procurement of cement, rebar and other building materials.
- Extremely poor condition of roads which made the 600 km transport from port to bridge site very difficult and time-consuming.
- Communication difficulties – the majority of the contractor's expatriate staff did not speak English and all communication therefore had to take place via an interpreter, who was not a technical person; site meetings often took place in four languages (English, Portuguese, Chinese and Afrikaans).
- The design of the piles for the foundations of the bridge was based on the results of a geotechnical investigation which indicated that bedrock with a suitable bearing capacity was present at a depth of approximately 10 m below the river bed. Based on this, an end-bearing oscillator pile was specified for the project. However, when the contractor began the foundation investigation on site to prove the founding depth for the piles, no hard sandstone horizon was encountered at all, despite drilling down to a depth of 60 m. After consultation with the backstop engineers at Aurecon's office in Pretoria, it was decided to change from an end bearing type pile to a friction type, with a length of between 25 m to 30 m into the highly weathered sandstone and silty clay substrata.

CONCLUSION

Despite all the challenges, the Cunene Bridge was completed successfully and stands proudly in the mighty Cunene River as the longest bridge in Angola. Through the construction of this bridge the uncertainty of commercial and noncommercial transit between the north of Angola and southern Africa has been reduced. During construction the temporary bypass was cut off three times as a result of flood damage to the temporary causeway, bringing traffic to a halt and endangering perishable goods to Angola, as well as the transport of sick people to the main hospital in Ondjiva from the neighbouring villages and towns. □

Source:
http://www.saice.org.za/downloads/monthly_publications/2010/2010-Civil-Engineering-dec/#/0