The Loko Oweto Bridges on the Benue River in Nigeria are intended to connect the north and south of the country with an upgraded road system. The project includes two bridges, each 1,835m long, and two approach bridges of 220m. The water level of the river rises up to 8m between seasons and creative solutions were required to address this in the design and construction of the project. The longer bridges have 22 spans which are typically 85m long.

Nigeria has an estimated population of 180 million and is divided between north and south, more or less along the line of the equator, the influence of which is reflected in various ways. The north is a savannah, close to the Sahara Desert, and the south is rainy and tropical and therefore green and fertile. From an economic viewpoint, the south is rich in natural resources such as oil and tin, hence the majority of the country’s industry and wealth is in the south. Another difference is in religion, with Muslims in the north and Christians in the south. This unofficial partition is reflected by a certain degree of tension in the population as regards religion, authority and economic imbalance.

The Nigerian government decided to invest in improving the connection between the parts of the republic to develop the economy and the living conditions of the population. Since wide rivers physically divide the country, it was necessary to increase the number of river crossings and the Loko-Oweto bridges form part of these efforts, promoted by the Nigerian Ministry of Works.

Work on the superstructure of the second of two bridges being built over the Benue River in Nigeria started last autumn, and is due for completion in October this year. Micha Petri reports

The project is a design-build project being carried out by contractor Reynolds Construction Company working with consultant Kedmor Engineers, who designed the bridges. The project included all the design stages, from preliminary, final and detailed design documents through to construction supervision for the four bridges. Several alternatives were presented to the Nigerian Ministry of Works and, following their approval, the design began. The detailed design has been controlled by the ministry’s local engineers.

The bridge is located in a remote area which is rural and tribal with few transportation routes and no asphalt, electricity or running water. People live in huts made of mud and twigs; those living in the villages surrounding the bridge site make their living mostly from farming and fishing. In order to make the site more independent, wells were drilled, an electricity station was built and a concrete plant was established.

The new link will cross the Benue River, which is the main tributary to the Niger River; it is about 1,400km long and runs from Cameroon in the north to its connection with the Niger near the city of Lokoja. It is a main water transportation route; at the peak of the rainy season it can be as wide as 1.7km, which is reduced to just a few hundred metres in the dry season. Between the two seasons the water level varies by up to 8m.

The project is heavily influenced by these changes and it was necessary, for all work stages, to consider construction methods and equipment that would enable the execution of the works whether in deep river water or dry ground. The bridge design was also influenced by the fact that there is no option of placing shuttering or scaffolding on the ground, resulting in the balanced cantilever method being chosen.

The site soil is characterised by a top layer consisting mainly of sand with thin layers of clay to a depth of about 18m, and then a thick layer of limestone more than 40m in depth. Deep piles formed of bentonite in a steel casing were chosen for the bridge foundations to suit the layers of soil and the need to drill them in the flowing river water. Four pile load tests were carried out at the site to confirm the ground data obtained from 23 logs drilled at the bridge pier locations.

Calculation of the scour round the bridge columns and piles was carried out using the formula of Colorado State University, and this revealed that for a group of round piles, in the flow and water depth of this river, the local maximum scour expected at mid piers is 7m and the additional global scour at the bridge location is a few tens of cm more. Bridge and piles were calculated taking into account the scour and also neglecting the scour in terms of sensitivity of pile stiffness and capacity in the horizontal direction.

**DIVIDED NO MORE**

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The longer Loko Oweto bridges each have 22 spans with 20 typical spans of 85m length and two end spans each 67.5m long. Each bridge will carry two traffic lanes and a pedestrian footway, on a slab width of 12m. In plan they have a straight alignment and the vertical alignment is parabolic in order to provide a vertical clearance of 8m above the high water level and 12m at the centre of the bridge for shipping.

There are two parallel bridges, each carrying two lanes; the east bridge carries two lanes for northbound traffic, and the west bridge two lanes for southbound.

The superstructure is a hollow box cross-section with variable depth ranging from 4.5m at the columns to 2.4m at the centre of the span and at the end spans. The bottom curve of the slab is parabolic and it was designed to optimise the stresses during the construction stages. The hollow box cross-section has transverse cantilevers of 3.3m on each side, and the webs are vertical so that with the change of height, the bottom flange width is a constant 4.6m. The superstructure is designed to be built using the balanced-cantilever, cast-in-situ method. Two form travellers are installed, one on each side of the 14m long pier top. Each traveller casts seven segments 4.85m long, and the closure segment of 3.1m brings the total span length up to 85m.

In order to allow a temporary restraint between deck and columns during segment casting, before reaching continuity, the deck is vertically stressed against the columns using four cables of 100t each. At this stage, temporary concrete blocks are cast between bearings in order to reduce the load on the bearings. This provides the capacity to accommodate an unbalanced segment if necessary.

The bridge has a total of 21 piers; each one is formed of two concrete columns with rounded edges, in accordance with the properties for structures located in a flowing river. The use of a pair of columns in each axis ensures the stability of the deck during segment construction and eliminates the need for temporary support towers to stabilise the deck, which would be necessary if each axis had a single column. The column height varies from the ends to the bridge centre. The columns include a lower section with a height of 5.7m and a thickness of 2.3m; the height of this section was designed to keep the column ‘shoulders’ above the highest water level and to enable the temporary support system to be located above water. Above the bottom section, a top column section is cast; its height varies along the bridge and its thickness is 1.8m. The highest columns at the centre of the bridge are 17.5m tall. On top of the columns, bearings are installed or the pier segment is cast directly, as required by the longitudinal static scheme of the bridge. The structure has been divided into three sections with lengths 620m, 955m and 620m by installing expansion joints at the centre of specific spans. Each bridge section is continuous; at the middle, at two axes, the columns are connected monolithically to the deck and at the rest, the columns have sliding pot bearings. The columns are cast on 2m-high pile caps with a hydrodynamic rounded geometry. Each pile cap connects three piles. The abutments are based on piles and include wing walls at the embankments.

The pier columns include three piles, 1.8m in diameter and 32m long. Abutments have four piles with a diameter of 1.8m and a length of 40m.

The global modelling of the bridge was carried out using Bentley RM Bridge software in order to calculate the loads acting on the structure and its components in accordance with the British Standard BS5400 and loads due to the construction stages.

Calculation of construction stages and stressing was also done with the RM software, which includes modules designated for segmental bridge design including camber design, taking into account the additional weight of each new segment as wet concrete (ranging from 120t to 80t); the form traveller weight of 60t; and the time schedule which is required to cast the sections.

The products of these calculations, as well as the drawings, are the ‘geometry control’ documents submitted as manuals, with each segment identified along with the relevant casting levels and stressing data. Surveys carried out before casting verify the correct level and, after casting and stressing, an additional measurement is performed whereby the designer decides whether level corrections are necessary. During construction the measurement data is documented and the bridge geometry constantly monitored.

Calculation of deck in the transverse direction was carried out using Lusas finite element software at a number of 3D models which referred to the support conditions and various static heights of the deck. Transverse direction and the local behaviour of the cross section are designed as reinforced concrete. Values of reinforcing steel required in this calculation are summed together with reinforcing values which were required at the longitudinal calculation and reinforcement details were designed combining these two calculations.

Bridge elements were also calculated to withstand barge collision loads according to AASHTO LRFD bridge design specifications for a design speed of 15km/h.

The dramatic changes in width and water level of the river throughout the seasons impact every aspect of the project. Construction stages have to be planned to provide access to the different parts of the bridge. This can be via barge, for which deep water is required, or by land, which is possible only with the lowering of the water level. At shallow water there is an access problem for some of the bridge sections.

During mobilisation for marine works, RCC procured a fleet of 11 barges capable of carrying cranes and equipment, one of which also carries a floating concrete plant. The fleet includes tug boats, taxi boats and docks to transport workers and equipment.
The bridge piles are cast in the river water using steel casing pipes 16m in length. In order to cast the pile caps above water level, prefabricated concrete moulds were designed to be installed on the casing pipes above the river. These prefabricated concrete forms are supported on the casing perimeter, and reinforcing steel is arranged inside them and the pile caps are cast without the need for stable soil or forms. The internal element height is 2m and it has a total length of 10.6m, composed of four interconnected parts.

For casting pier segments above the columns, a temporary support girder system was designed to be supported on the column shoulders. The system includes four main composite girders and a set of secondary composite girders located under the scaffolding tower legs. This platform enables work to be carried out above water level in all seasons. These girders are used at an early stage to support the column forms from the pile cap shoulders.

The bridge is divided into three sections along its length to accommodate the axial deformations generated by temperature, creep and shrinkage. For a balanced cantilever bridge it is not recommended to locate expansion joints above the piers since the construction method requires continuity at the pier. Hence expansion joints are placed at the middle of the spans between piers 8-9 and 15-16 so that the concrete deck will have a gap of 570mm. The expansion joint at mid-span is designed to allow free movement in the axial direction but provide continuity for moment, shear and torsion.

A range of alternatives was considered for creating the right conditions of isolation and continuity. The solution selected was to install two steel girders inside the deck, fixed at one edge of the deck and at the other end installed in steel sleeves that allow the girder to slide in a similar manner to a piston. Connection on each side is at two points so that the ‘force couple’ allows the transfer of moments and shear, and due to the presence of two parallel girders creates continuity for torsion.

The girders are 11.8m long, 1.3m high and 700mm wide. After installation they are fully cast with concrete to improve their capacity as a composite cross-section. The final stage includes installation of a girder expansion joint which allows the required deformations — several centimetres daily and over the life of the bridge will be up to 30cm. The superstructure is complete on all bridges except the main western structure, and parapets are currently being installed.

On the final bridge, the superstructure construction is in progress with completion expected in October this year.

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