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# Africa's largest supension bridge

*Mozambique, located on the east coast of southern Africa with a coastline of 2800 km (fig. 2), is rich in natural resources and is rated as the 4th fastest growing economy in Africa. Part of the Mozambique's National Development Master Plan is to improve the transportation network between the capital city Maputo and the south of the country. To achieve this aim, a bridge is being constructed across the Maputo Bay as a connection to South Africa. After its completion in 2018, it will be the longest suspension bridge in Africa with a main span of 680 m and a total length of 1225 m.*

Construction of the Maputo-Katembe Bridge (photo 1 and fig. 3) started late 2014 with a total project value, including the southern link roads, of approx. US$ 700 million. Design and execution is being carried out by China Road & Bridge Corporation (CRBC) and is based on FIDIC's Silver book EPC contract. German consultant GAUFF Engineering is responsible for quality supervision as well as design verification according to the Eurocode.

## Concept of the bridges

The bridge consists of reinforced concrete approach viaducts on the North and South banks of the crossing, which connect to the main span, a suspension bridge constructed of steel box girder sections, with two large subsoil gravity anchor blocks that are filled with sand and concrete. The bridge will carry four traffic lanes, two in each direction, with a design speed of 80 km/h.

**Jörn Seitz**
GAUFF GmbH & Co. Engineering KG,
Nuremberg (Germany)
**Dean Gary Swanepoel**
GAUFF GmbH & Co. Engineering KG,
Maputo (Mozambique)
**B. Pengyu**
China Road and Bridge Corporation
(CRBC), Bejing (China)

1 Maputo construction site: North Approach Bridge with two of the eight piers for the free cantilever bridge that will lead over the anchor block
*credits photos: GAUFF Engineering*
2 Map of Mozambique
3 Visualisation of the finished Maputo Katembe Bridge

The North and South Approach bridges are being constructed using two different design and construction methods influenced by the local urban development. In the north, located in the middle of a very congested central business district and harbour, the approach bridge will be a balanced cantilever 853 m long construction rising up towards the main pylon. The main distances between the piers are 119 m. The Southern Approach Bridge, situated in a totally rural area without any obstructions, will be built using prefabricated post-tensioned T-beams to form its total length of 1234 m (photo 4 and 5). The approach bridges connect on either side to a single-span double-hinged suspension bridge with a centre span of 680 m, supported by hangers attached to two cables, which are draped over the main cable saddles of the towers and connected to the anchor blocks on each side of the river. Side spans are 260 m and 285 m long.

The bridge concept was designed according to Chinese standards with the overall design verified against Eurocode specifications and specifications according to the South Africa Transport and Communications Commission (SATCC). Especially for the pile foundation changes in the amount of reinforcement were required considering considering the requirements by the different codes.

Each gravity anchorage is made up of the foundation, splay-saddle buttress, and anchorage chambers. Some of these chambers are empty, and some are filled with concrete and sand requiring a specific density, all adding to the total weight of the structure. Each shaft has an external diameter of approximately 50 m, a wall thickness of 1.20 m and a wall panel depth of up to 56 m. The deepest anchorage structure was the one on the south side of the crossing; with 37 m it is believed to be one of the world deepest constructed during the last years. Figure 6 gives the structural detail of the shaft and photo 7 shows the final construction stage for the completion of the anchorage block inside of the shaft. Photo 8 illustrates the completion of

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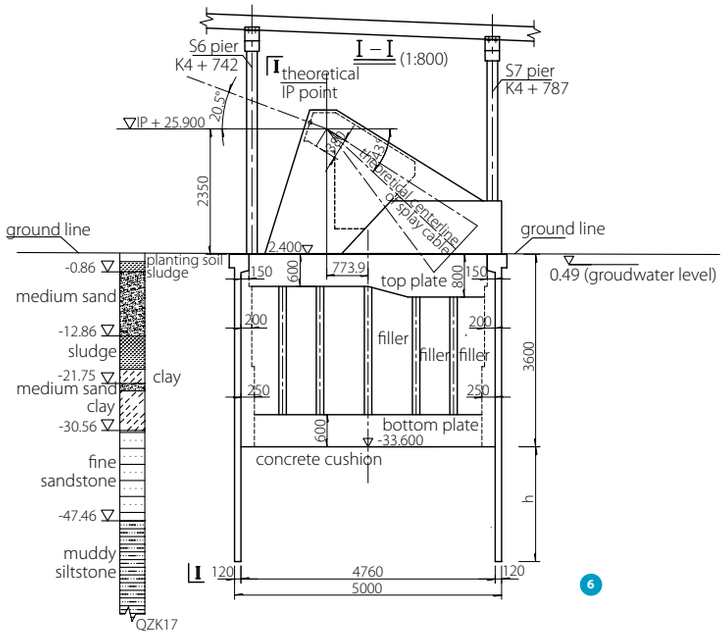


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the massive concrete construction built on the shaft to hold the main cables.

## Piling and diaphragm walls for the anchorage shafts

As there was no comparable project in Mozambique for the design of the bridge foundation piles, the design was based on the findings of a geotechnical investigation, which started two years ahead of the actual construction work. Pile construction for the towers and foreshore bridge piers began in tandem with the anchorage excavation. Before pile production could begin, their bearing capacity was verified using static test loads. Based on this all 331 piles were optimised in diameter and length. A total of 283 piles were constructed for the approach bridges, each with a diameter of 1.50 m and an average depth of 50 m, and 48 piles were installed for the towers, 24 at each tower, and each with a diameter of 2.20 m and length of 110 m at the south tower and 95 m at the north.

The excavation for the piling followed the international reverse-circulation-drilling method. The quality and integrity of the concrete in all piles was verified over their total length using the Crosshole Sonic Logging (CSL) testing method by an independent third party after 28 days. Concrete cubes were manufactured even for 365-day compressive strength tests.

## Pylon, cables and steel box girders

The main structure of the tower is formed of rectangular hollow box sections, with a length of 7.00 m and a width of 5.00 m. The wall thickness of the upper tower is 1.00 m, and this increases to 1.20 m towards the bottom, resulting in a total thickness of 1.80 m at the base. The final height of the tower on the north, Maputo side, will be 135 m and on the south, Katembe side, just one meter higher (fig. 10 and photo 11).

Prefabricated parallel wire strands will be used for the main cables, which are made up of 91 galvanised high-strength steel wires, 5 mm in diameter with a nominal tensile strength of

4 Pylon M2 (south) and piers of the approach bridge
5 Second of 34 piers of the Southern Approach Bridge (December 2016)
6 Cross section of southern shaft with charateristic soil layers
7 Construction stage of the southern anchor block
8 Massive concrete construction of the northern anchor block

1670 MPa, resulting in an outside diameter of 509 mm and a total strand length of 1317 m. The main cables are connected on each side of the bay into the gravity anchorage blocks (photo 9 and 12). The cables are specially protected against corrosion in a permanent airtight system.

For the hangers, galvanised high strength steel wires will be used. The transverse distance between the main cables hangers is 21.90 m and the standard distance between the hangers along the bridges main span orientation is 12 m, with the length of hangers ranging from 73 m at the towers to 3 m at midspan.

The steel box girders are being manufactured in Nantong near Shanghai in China and will be delivered to Maputo by ship by manufacturer ZPMC.

## Special concrete

One of the unusual aspects of the concrete on this project was the addition of up to 40% fly ash. This not only offers immediate cost savings but also long term benefits. The fly ash is produced in and delivered from South Africa and gives the concrete an extremely high durability, a fact which was confirmed by the University of Cape Town's Concrete Materials & Structural Integrity Unit which performed Durability Indexes testing on the samples cored from the bottom slab of the anchorage. The tests performed were the OPI- oxygen permeability, WSI-Water sorptivity Index and the CCI-chloride conductivity index. The results obtained were confirmed as the best test results ever obtained from a site concrete. High workability was of vital

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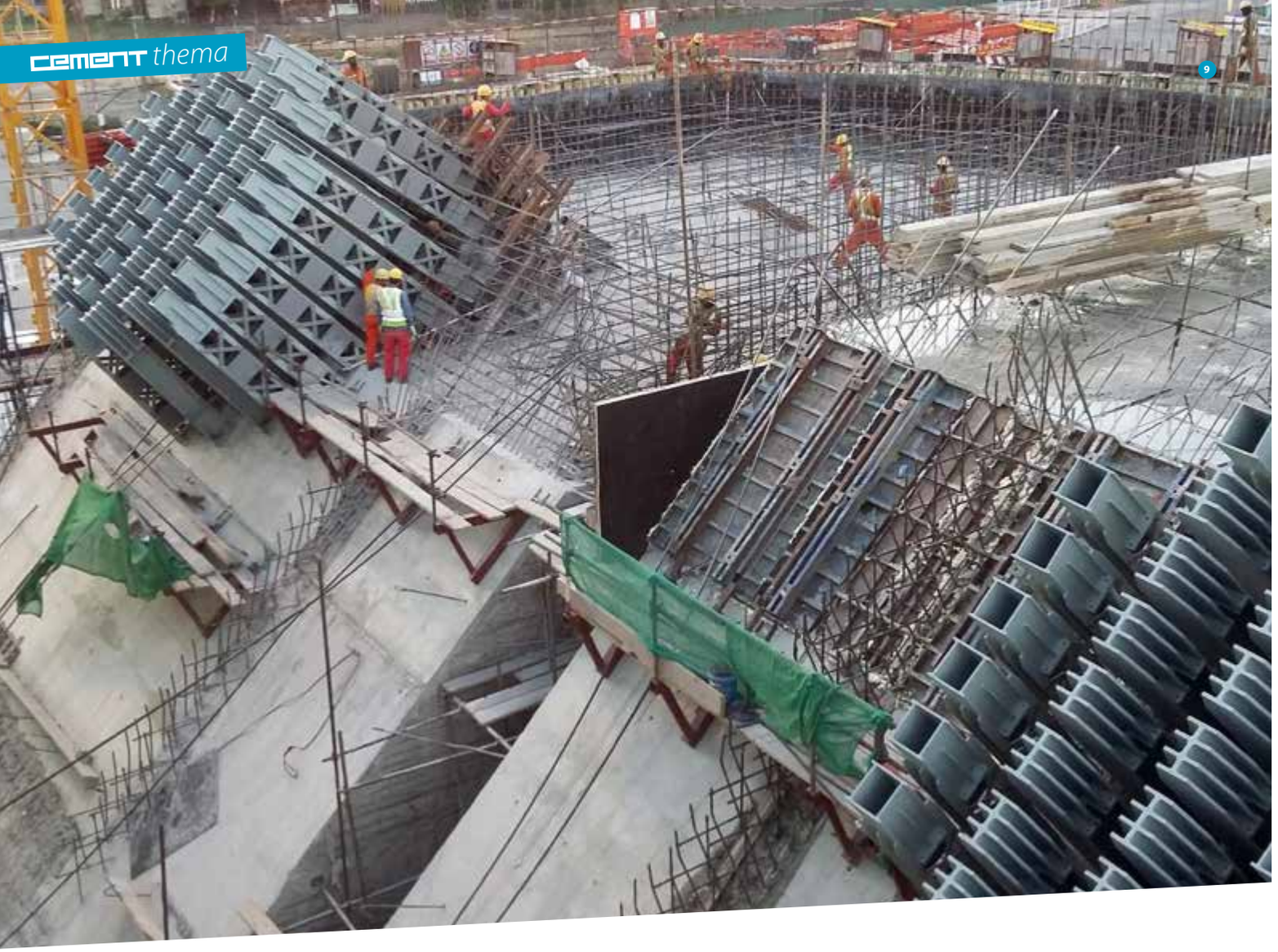
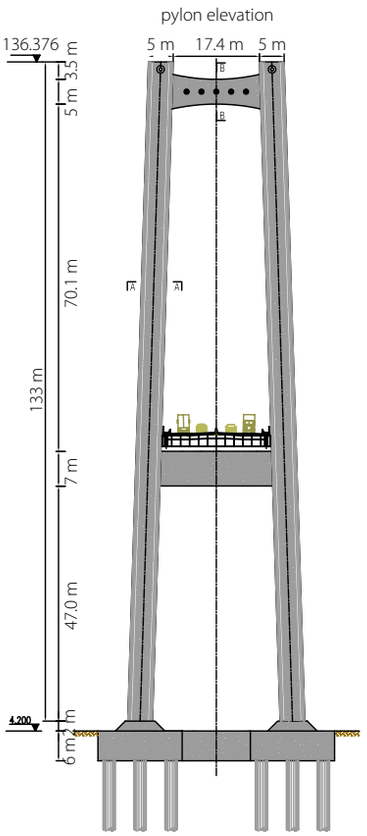
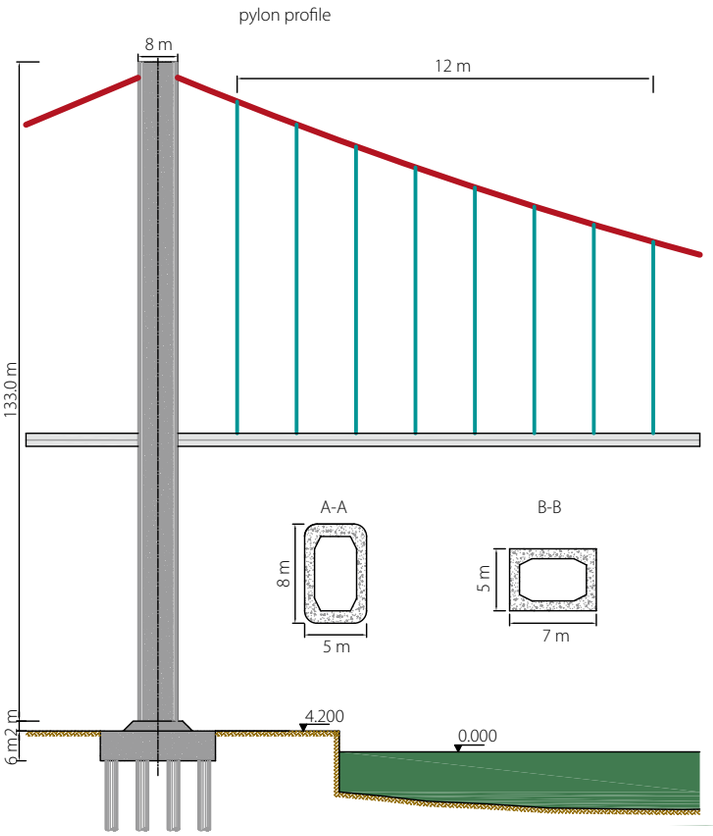


9 Installation of the steel constructions for the anchorage of the main cables (north side)
10 Details of the pylon
11 Construction of southern Pylon M2 (January 2017)
12 Construction of the southern anchor block



importance to the project during the casting of the anchorage base slabs and pumping the concrete up to heights of 140 m. Laboratory testing confirmed that the concrete was still workable up to 16 hours after the initial mixing. This is directly related to the high quantity of fly ash and a retarder from China specifically formulated for this project. Concrete cube crushing strengths at 28 and 90 days have confirmed a remarkable strength gain. C40 concrete had results of 51.9 MPa and 69.5 MPa at 28 and 90 days respectively.

Producing sustainable concrete and most importantly a sustainable project is particularly important to CRBC and the client. Achieving a balance of social, environmental and economical factors is part of the contractor's quality management system which was developed by GAUFF Engineering following the 'Triple Bottom Line' concept from the United Nations' Bruntland Report. Through this CRBC aspires to produce a sustainable structure as a whole and to promote sustainability across the board. Reduction of its carbon footprint by reducing $CO_2$ emissions is part of the company's mix-design philosophy and is achieved through the use of fly ash as an extender; it has resulted in dramatically lowering the cementitious $CO_2$ emissions of the concrete from an estimated 352.5 kg $CO_2$/t to 229.5 kg $CO_2$/t, a reduction of 35%.

## Summary

For this project, CRBC and GAUFF together with the client have developed a comprehensive quality management monitoring system, which covers all aspects of construction in Maputo and also the extensive production of the complex steel components being manufactured in China.
The calculations using Chinese standards and their verification against Eurocodes were completed in June 2016, alongside the production of piles and diaphragm walls. In the coming 18 months the construction work will focus on steel fabrication for the suspension bridge, erection of the main cables, lifting of the 57 steel box girder segments, and the respective quality monitoring of the production in China.
At the same time the construction of the highly demanding balanced cantilever post tensioned North Approach Bridge will commence (photo 1) as well the installation of the T-beams for the Southern Approach Bridge. Handover of the new bridge to the Mozambique Nation is scheduled to take place early 2018. ☒

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