THE HENRI KONAN BEDIE BRIDGE IN ABIDJAN, IVORY COAST

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Introduction

The third bridge in Abidjan [1], called Henri Konan Bedie bridge, is a 1.5 km viaduct overlooking the lagoon Ebrié. It is part of the toll highway linking the northern and southern parts of Abidjan over a length of 6.5 km. It connects two highly urbanized neighborhoods of Abidjan and aims to carry 10,000 vehicles / day while offering a soft circulation for pedestrians and cycles (Fig.1).

Fig.1. The Henri Konan Bédié bridge ©photothèque BYTP

The bridge consists of 60 precast prestressed box girders that are 50 meters long and 1000 tons each. Each bay consists of two coupled box girders supported by a single crosshead founded on two piles of 2 meters in diameter and 80 meters in length on compact sands. This configuration stiffens the structure and distribute the forces in case of ship impacts (Fig.2).

Costing 192M€, the project management is respectively provided by the Socoprim company and the National Bureau of Technical Studies and Development (BNETD). The design and construction were awarded to Bouygues Travaux Publics with for subcontracting Trevi SPA for foundations, Sarens for shifting and box girders installation.

The paper describes the main aspects of the construction of this bridge, focusing on geotechnical issues, the manufacturing of precast box girders and their installation on site. It summarizes several papers written by the authors and published in the journal "Travaux" [1-3].

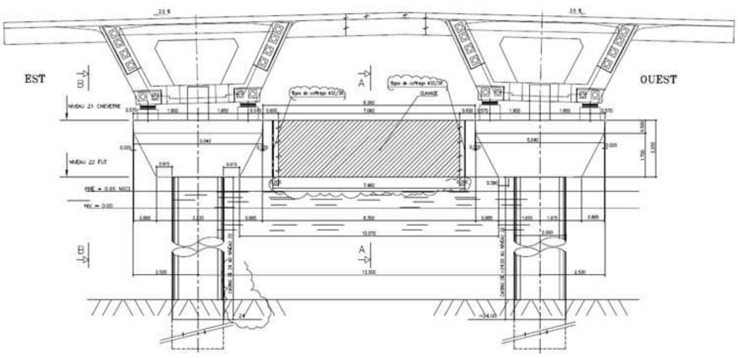

Fig.2. Cross-section of piles and deck ©photothèque BYTP

Geotechnical conditions

The Ebrié lagoon lies within 100 km along the Ivorian coastline. The lagoon system has two exchange points with the Atlantic Ocean: on one hand, in the east, through a natural outlet, located at Grand Bassam where the river Comoé flows and, on the other hand, in the West, through the artificial Vridi channel [2]. These connections provide a regular exchange between the salt water of the ocean and the freshwater of rivers and streams. Sedimentation is permanent and flows can reach speeds in excess of 1 m / s. At the bridge location, the draught is around 5 m.

The first set of investigations, carried out between 1997 and 1998, have helped to build the geotechnical profile given in Fig.3a.

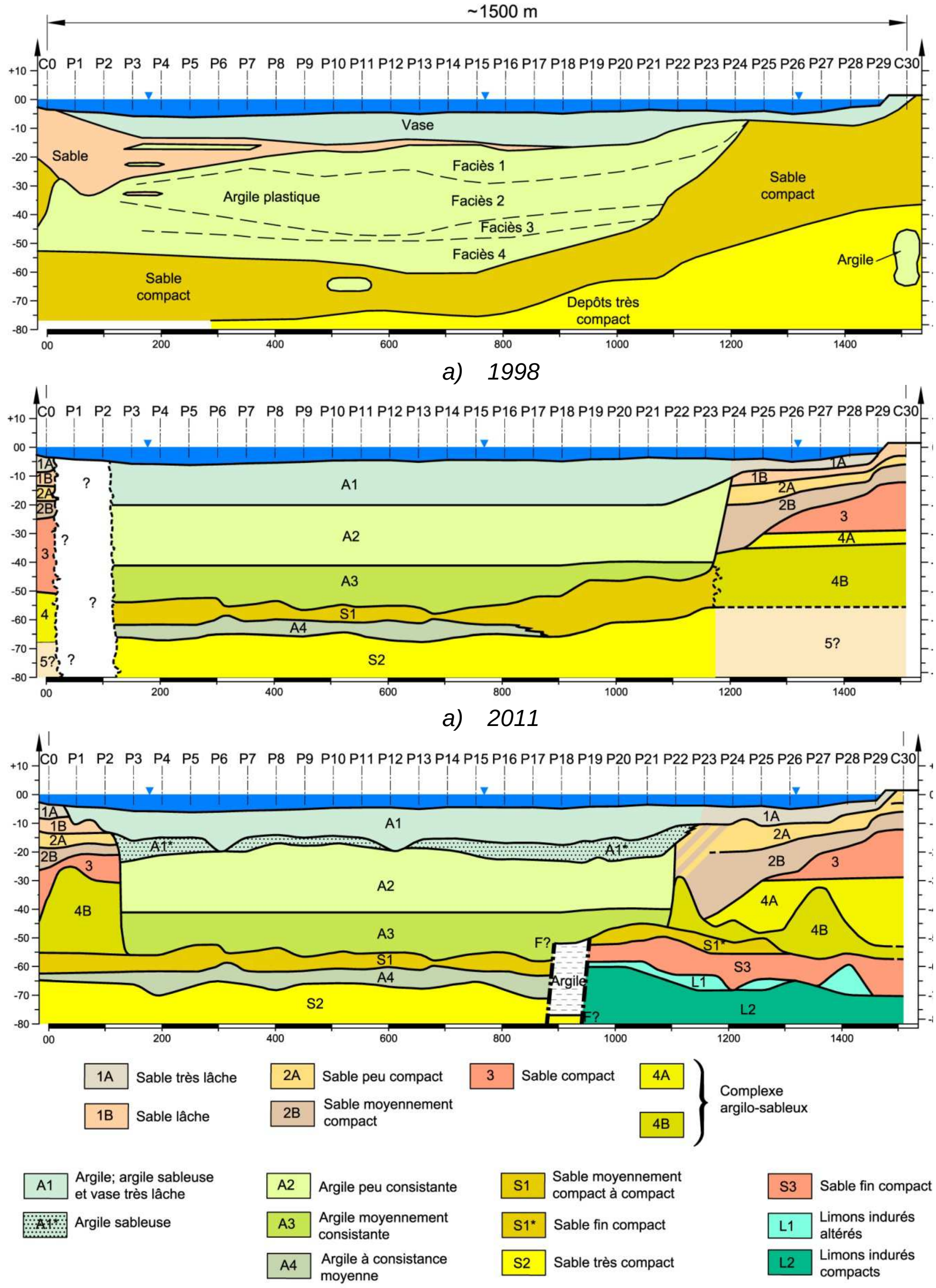

Fig.3. Geological profiles ©photothèque BYTP

In the central part, involving more than 2/3 of the supports, the following stratigraphy had been deduced:

- *10 meters of mud having zero or almost zero consistency;*
- *40 meters of clay which compactness increased with depth;*
- *Beyond the medium to coarse sands good compactness in which had been recognized pockets of clay, of metric thickness, with poor compactness.*

In the southern part of the bridge it had been shown a rise of compact sands. In the northern part, the investigations had recognized alternating sand and clay on multi-metric thicknesses.

In 2011, a new set of investigations was launched to refine the stratigraphy beneath the structure, identify "abrupt" geological transitions to characterize the clay pocket detected in the anchoring layer of the piles (close to two investigation points S6 / S7), and confirm the mechanical characteristics used in different geological formations, including the anchoring layer of piles formed by compact sands. This investigation has allowed to update the geotechnical profile (Fig.3b for the area covering the piles P3 P15).

Surveys in 1998 and 2011 are in good agreement in clay levels, but in the sands, it was necessary to reassess downward the allowable pressure initially set to 3.8 MPa. In addition, the systematic identification by destructive tests revealed the presence of a continuous layer of 5 m of average thickness, interposed in the sands between -60 and -65 NGCI. This clay was characterized by pressuremeter surveys which revealed a mean value of 0.7 MPa.

A soil cut was finally made in 2014 during the execution of each drilled pile. These cuts have helped to update the geotechnical profile and to better understand the complex geology of the site (Fig.3c).

All these studies have validated [2]:

- *Anchor levels of the foundations;*
- *The technical execution of the piles by bored piles, with 2 m diameter and toe injection;*
- *The substitution of clay pockets by the Jet Grouting technique.*

The foundations

Consisting of 2 x 30 precast box girders, the bridge is based on 62 piles that are 2 m in diameter, bored in the mud; each double box girder is supported by a single crosshead based on two piles. The longest piles are 84 m long and are founded on compact sands. Each pile is cased over a length ranging from 17 to 32 m (Figure 4).

Fig.4. Piles execution ©photothèque BYTP

The casing with a thickness of 12mm, stabilizes the sands of the lagoon but also maintain concrete on a water depth of approximately 5 m. This eliminates the lengthy and costly construction of a cofferdam that would impact the lagoon bed. A pile requires between 200 and 250 m3 of concrete C40 / 50 (Fig.5). The calculation of the piles was carried out so that they worked in friction but essentially at the toe. It is for this reason that each pile was toe injected to increase the mechanical properties of the soil and reach the coefficients used in their design. These deep foundation works were made from June 2013 to February 2014.

It should be noted that prior to the completion of final piles, a test pile was made on dry land close to the abutment C0 to confirm the effectiveness of the toe-injection in terms of load carrying capacity. Unlike traditional load tests that require significant weights to simulate the load of the structure, an Osterberg cell was used. The principle is to place at the pile foot a jack that simulates an equivalent load. The strain gauges and displacement sensors placed throughout the pile provide a continuous monitoring of the load.

Fig.5. Pile grouting ©photothèque BYTP

Fig.6. Formwork for a crosshead beam ©photothèque BYTP

The crosshead

The single crosshead is placed on the two piles and is built in two phases. The first one is to achieve the pile caps with a steel formwork placed on a platform (fixed on the steel liner of the pile). The crosshead connecting the pier caps is then carried out using another steel formwork suspended from the pier caps, avoiding unnecessary overdesign of the platforms by transferring the total weight of the crossbeam (formwork, concrete, reinforcement) on the pier caps (Fig.6) [3].

The reinforcement of the pier caps and crosshead are prefabricated on dry according to a specific gauge). The three components were transferred by barges. Their final installation were made using a 110 t lattice crane cribbed on a pontoon located between two piles. This allowed to work in parallel on two piles with a completed pile every week (Fig.7).

Fig.7. Pile cap ©photothèque BYTP

The box girders

The 60 box girders have been built on two independent prefabrication sites (East and West – Fig.8). Achieving the box girders is done in 3 stages (Fig.9).

Fig.8. Prefabrication areas ©photothèque BYTP

1st stage

The reinforcement, cut into 6 elements (2 SOP and 4 standard parts), is positioned on the formwork base. Prestressing ducts previously positioned in the reinforcement are shielded. SOP formworks are installed at each end. Then the outside formworks faces are translated from a bench to another to be raised with long stroke jacks. Finally the faces of the inner formwork are positioned. Concreting (210 m3) can then be done over a 6 hours period.

2nd stage

24 hours after concreting and thus a 25 MPa strength reached, the SOP is unmolded as well as the internal formwork webs. The external formwork remains in place both to serve as formwork for the upper slab and web fixing part. The slab tables of the internal formwork are placed as well as the reinforcement of the upper slab. Concreting (160 m3) can then be done over a 5 hours period.

3rd stage

The formwork tables of the upper slab are removed through the open hopper. Once all removed, a traditional formwork is placed to fill the hopper. Meanwhile, the ten tendons are tensioned. The box girders are then ripped and placed on their storage pads. Concreting the prestressing sealings is only the remaining operation before finalizing the box girder.

The complete cycle lasted 10 days.

Fig.9. Internal formwork of the segments ©photothèque BYTP

The placement of box girders

After finishing the last operations on the box girders placed on their storage pads, the box girder is transversely ripped on the central translation zone by sliding the Teflon pads. It is then translated longitudinally to the barge using bogies. The barge is connected by two articulated jacks supported by the piercap of the loading dock. They ensure the alignment of rails between the barge and the dock. A set of ballasting and unballasting keeps the height of the barge and its base during this phase. Once loaded, it is jacked and positioned to its final location increased by 50 cm in order to avoid the crossbeam pins. All the operations are made before the low tide cycle. Unjacking is done when the tide is dropping. The fine positioning is +/- 2 cm on temporary supports. There are no more setting in X-Y directions. Only a Z adjustment is done with 4 jacks of 400 t to remove the temporary supports and position the box girder on its final position. It is maintained in Z direction in order to achieve top bosses. These are cast using a shrinkage compensated mortar through blowholes in the bottom slab of the SOP (Fig.10).

Fig.10. Placing a box girder ©photothèque BYTP

Conclusions

The third bridge in Abidjan, or Henri Konan Bédié bridge, was one of the oldest projects in Ivory Coast. Its construction has helped to reduce traffic on the two existing bridges, Felix Houphouet Bojgny and Charles De Gaulle, built 30 years ago, and to improve trade between the northern and southern shores of the Ebrié lagoon.

This bridge is part of a global 6.5 km long motorway project. The construction of the Henri Konan Bédié bridge was obtained as part of a concession gathering design, construction, operation and maintenance of the highway project over 30 years.

References

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