CONSTRUCTION OF ''LA GRANDE CHALOUPE'' VIADUCT NEW COASTAL ROAD

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1. Introduction

La Grande Chaloupe Viaduct is the structure of Lot MT4 of the New Coastal Road project on Reunion Island. The Contracting Authority, Reunion Regional Council, contracted the Project Management to EGIS. EIFFAGE Génie Civil is the leader of the consortium comprising RAZEL BEC, SAIPEM and NGE Contracting, responsible for construction. The supports are located in the ocean, alongside the eponymously named ravine. The deck, with its overall length of 242 m, is a single-box pre-stressed concrete structure with four webs, built by balanced cantilever method with a form traveller.

Figure 1 : Aerial view of the site

2. Description of the structure

The structure will provide continuity over the Grande Chaloupe and Tamarins ravines and a visual perspective over the ocean. It is the main structure serving the site; its access roads will be built in the second stage.

Part of the New Coastal Road project for which it forms the geographic centre, the structure is 29 m wide overall. It has been designed for two modes of transport:

- *Configuration on commissioning: the deck will carry 2x3 lanes of traffic separated by a central reserve and two outside emergency stopping lanes;*
- *Future configuration: 2x2 lanes of traffic separated by a central reserve and two outside lowered emergency stopping lanes bordered by two rapid transit lanes for light rail.*

Figure 2 : General view of the viaduct under construction

Structural and architectural principles

- *Structural schema*

La Grande Chaloupe Viaduct is a 239 m long structure. It has four spans of 50.5 m, 69.0 m, 69.0 m and 50.5 m (Figure 3).

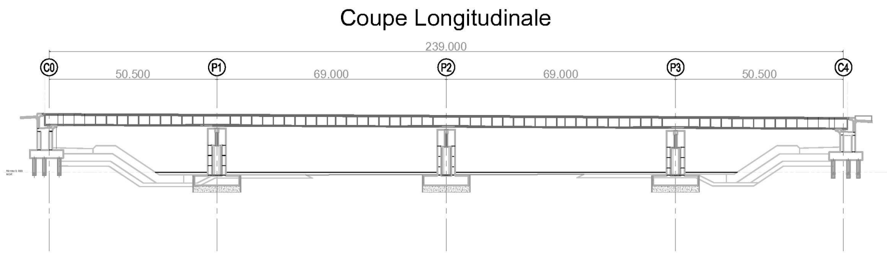

Figure 3 : Elevation of the structure

The plan route for the New Coastal Road at the point of the viaduct is a curve with a radius of 860 m. Its longitudinal profile is a constant downward grade of 0.5% in the Saint Denis - La Possession direction. The transversal profile is roof shaped slightly offset on the structure's centre line, with a slope of 2.5%.

- *Geology*

The site's geology is comprised of large blocks of basalt and pebbles in a weathered or hardpan sand-gravel matrix.

- *Supports*

The height of the piers varies from 16.20 to 17.08 m. Their foundations are placed superficially on blocking concrete anchored in the substratum. Their drums have an elliptical hollow section. The structure's fixed point is located on pier P3.

The abutments rest on piles drilled on embankment built as part of a different contract for the New Coastal Road project.

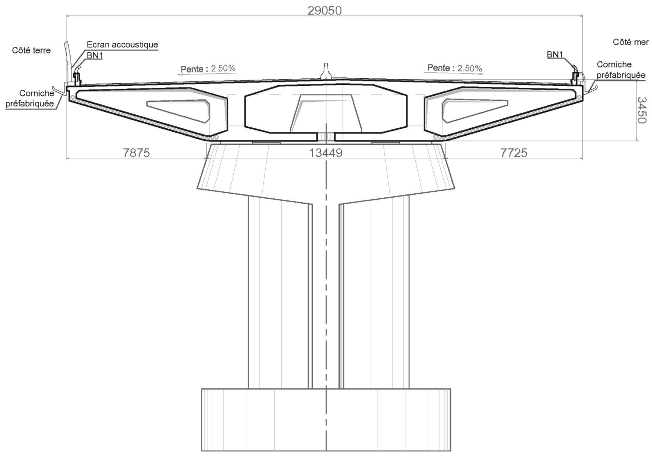

Figure 4 : Cross section on pier

- *Deck*

The deck is, like the access viaducts to the Pont de Normandie or the Saint-Cloud Viaduct, composed of a pre-stressed concrete box girder with four webs. The pre-stressing is double: longitudinal and transversal. This type of section makes it possible to combine the stiffness needed with finesse echoing that of an aeroplane wing. Despite its significant width, the deck affords the advantage of a constant height of 3.45 m allowing for its discreet integration with the landscape as desired by the architectural firm Lavigne et Chéron.
It is the first structure of this type to be calculated using the Eurocodes calculation standards, the previous examples having been designed using the French BAEL (Reinforced Concrete Limit State) rules. Given the structure's complexity linked to the form of the box girder and its plan curvature, the deck calculations were made using a three-dimensional model with finite elements. This made it possible to understand the deck's behaviour better.

3. Worksite preparation

The preparation period started on 20 January 2014. The preparatory work is of considerable importance for any project. This is all the more so for this viaduct over a ravine in a sensitive geological and ecological context, and for which the supports are located some 20 metres from the shore.

The additional soil investigation, essential for a G3 level geotechnical assignment associated with construction studies, could only start after obtaining the various permits issued by the state services in charge of the maritime domain. The latter introduced a series of specific maritime prefectural decisions for all the New Coastal Road construction work.

In order to carry out the relevant boreholes, dewatering behind riprap, a prerequisite for the works platforms, provided access to the future support locations. Performed behind an anti-suspended solids curtain designed to retain any suspended fines, these seaward projections had to take account of the potential heavy swells that can occur at this point in the Indian Ocean.

In an aggressive marine environment, compliance with the concrete performance criteria (durability over a period exceeding 100 years) involved several experts developing specific formulas for the concrete. The limit values for porosity to water, gas permeability, penetrability and the capacity to block the diffusion of chloride ions were studied and applied in the formulation process and concrete production.

4. Works

- *Sea footings*

The sea pier footings were installed sheltered by superimposed cylindrical metal sections mechanically assembled on site. Their installation required earthworks, the footprint of which impacted heavily on the working areas because of the low slope gradients: from 3/2 to 4/1 depending on the exposure to the swell.

Compared to cofferdams with buttered sheetpiles, the installation of cylindrical metal sections causes little submarine noise problems. On the other hand, this approach requires more extensive earthworks.

Figure 5 : View of the cofferdam

In order to ensure the stability of these cofferdams, a 1.90 m thick concrete plug was anchored in the substratum with some twenty micro-piles 10 to 20 m in length. This system, repeated for each pier, made it possible to overcome the problems of under-pressure generated by the swell.

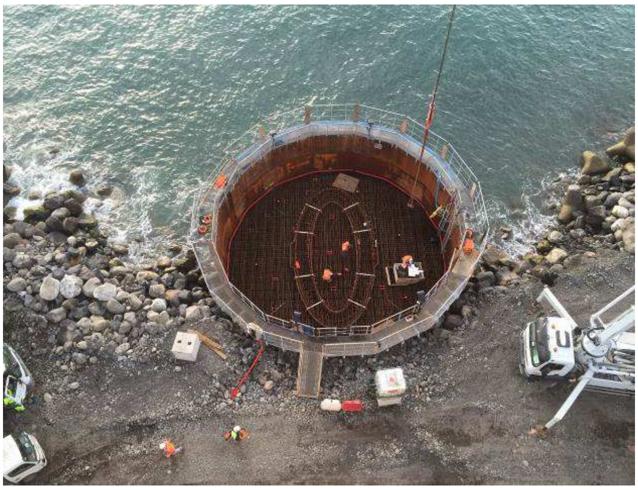

Figure 6 : Reinforcement of P2 footing

In the case of pier P2, a geotechnical anomaly was detected under the footing. This silt-sand lens, without any impact of the structure's expected subsidence, required extending some of the micro-piles.

- *Deep foundations*

Unlike the piers, abutments C0 and C4 are respectively set on 33 and 27 piles with a diameter Ø1000. The deep foundations were created using the hole method lined as work progressed, directly on the embankment backfill. This method was chosen to allow work to progress through the component blocks of the embankment and the soils identified in the geotechnical survey missions while limiting the risk of collapse thanks to the lining.

The technique adopted involved continuously performing hammering and rotating the drill head to break and dig through the blocks and rock. The presence of retractable winglets on the drilling bit in particular made it possible:

- *Initially to drill a diameter slightly greater than the external diameter of the tube to facilitate its insertion;*
- *Then, to extract the entire drill tool without being hindered by the tube lining left in place until the end of the concreting.*

Figure 7 : Execution of the piles

- *Support elevations*

Each pier drum was created with a false casting of variable height followed by two successive castings of 3.10 m. A single tool was used for the 9 concrete castings for all piers. It was comprised of:

- *A formwork in two sections: an internal section to form the hollow internal section and the other for the visible parts;*
- *Working platforms resting on the previous casting and allowing for the installation and adjustment of the formwork sections.*

All these operations (formwork, installation of reinforcements, formwork removal, and lifting the work platforms) were carried out using tower cranes or exceptionally an 80-tonne mobile crane for P1.

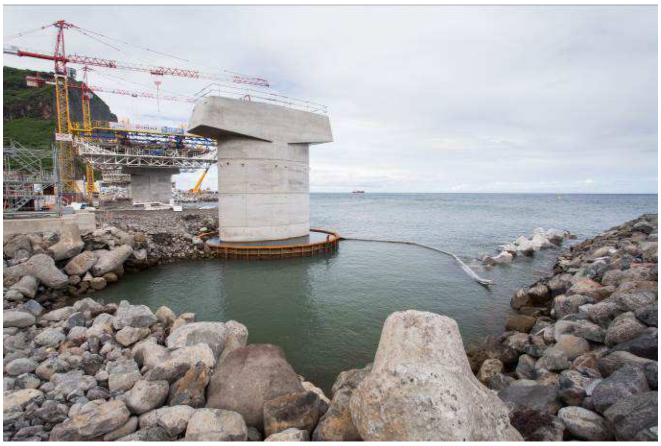

Figure 8 : Pier P1 achieved

The crossheads, 5.0 m high, were installed using specific metal formwork. Their 275 m3 volume combined with the high external diurnal temperatures required taking into account the constraints imposed by the concrete's internal sulphate reaction (ISR). As it was necessary for the concrete's temperature not to exceed 75 °C throughout the entire setting, the crossheads, as for the footings previously, were concreted at night after mixing with gravel cooled with iced water or water mist. In order to allow for effective vibration of the lower section, chimneys were created within the reinforcements.

Each abutment is comprised of a footing, post walls, then a crosshead and a backwall. The structure phasing and dimensions implied creating backwalls after tensioning the external pre-stressing, that is, just before installing the *equipment and superstructures. The abutments have a particular feature linked to the swell inherent to this region: the presence of deflectors designed to reduce water projections caused by the waves thanks to their rounded form.*

In order to decrease the risk of reinforcement corrosion, and in addition to the indicators taken into account for the concrete formulas, the structure is provided with a cathodic protection system:

- *Sacrificial anode for the footings*
- *Active by imposed current for the structure's elevated sections.*

- *Deck*

The deck was built by balanced cantilevers method with a form traveller, from the piers. The pier segments were manufactured beforehand with specific formwork. The segments for the edge spans were built on scaffolding.

To facilitate concreting and lighten the reinforcements for the junction nodes, the choice of work teams focused on the prefabrication of the inclined webs of the box girder. Because of the plan curvature, the prefabricated cores are wider on the land side than on the sea side.

Figure 9 : Prefabricated webs

Figure 10 : Form travellers on pier P2

The segments on piers were concreted in three phases. They were reinforced with reinforced concrete spacers provisionally nailed on the pier crossheads. Their length, greater than that of the standard segments, enabled the installation of a pair of form travellers. The latter were then used to install the segment cantilevers measuring 3.25 m and comprising 56 to 70 m3 of concrete, that is weighing between 140 and 175 tonnes. The segments were concreted successively, then pre-stressed by tensioning the cables of the overhanging segment until interdependent with the previous segment

The deck ends were created using heavy scaffolding bearing on the platforms at the head of the abutments.
The various sections were then keyed and made interdependent by tensioning the continuity internal and external cables running the whole length of the deck. The longitudinal pre-stressing required a total of 296 x 27T15s cables for a total length of 8450 m.

Le hourdis supérieur est également précontraint transversalement à l'aide de câbles 5T15s espacés d'environ 45 cm, soit un total de 523 câbles d'une longueur de 29m.
Les corniches de l'ouvrage, conçues géométriquement comme un caniveau, assurent l'assainissement longitudinal de la chaussée. Elles sont préfabriquées sur site et clavées dans les encorbellements de l'ouvrage.
(Encart spécifique) Cycle d'une paire de voussoirs à l'équipage mobile

The upper slab is also pre-stressed transversally using 5T15s cables every 45 cm, that is a total of 523 cables for a total length of 29 m.
The structure cornices, designed geometrically like a gutter, provide longitudinal water collection from the pavement. They are prefabricated on site and keyed into the deck corbels.

Each form traveller comprises:

- *A pair of main plate girders anchored to the previous segment and maintaining the formwork tool assembly during concreting*
- *Rails allowing for their displacement*
- *Two transversal lattice girders*
- *A mould base suspended using Macalloy or Artéon bars allowing for the installation of the reinforcements and prefabricated webs on trolleys*
- *A series of interior formwork on box girders*
- *A set of platforms allowing for completely safe movement of personnel.*

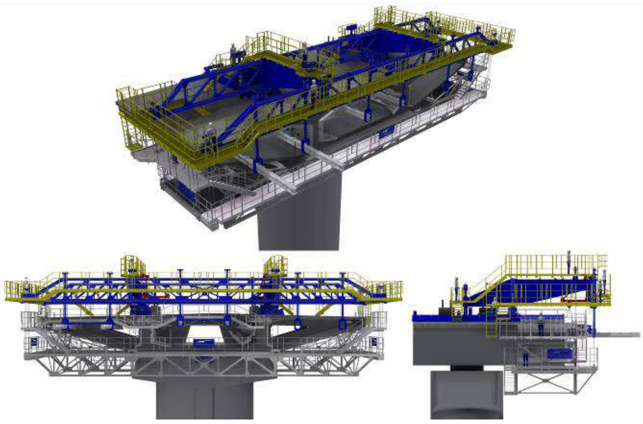

Figure 11: 3D model of the traveller

They operate in parallel, each driven by their own hydraulic system.
The traveller adjustments prior to concreting is a crucial step for this method. Construction studies have, in this case, determined the deflection at each inspection step taking into account:

- *The works progress, concreting in particular*
- *The age of the concrete and its rheology*

The deformations induced by the pre-stressing cables

5. Environment

The island's cyclonic context started to be felt from the weekend of 10 to 12 January 2015 with the passage of cyclone Bansi, and then again with tropical cyclone Haliba on the following 10 March which caused damage to the platforms and remedial trench work.

Located in a sensitive marine environment, the construction zone was the subject of real-time acoustic monitoring in the sea together with turbidity readings.

The presence of Barau's petrel, a species of seabirds endemic to the island and very sensitive to light pollution, meant there were periods when lighting could not be used and highly specific lighting had to be used at those times when it was allowed.