POINTE DES SABLES INTERCHANGE
A CAST IN-PLACE PRESTRESSED CONCRETE VIADUCT

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1. Introduction

The project is part of the redevelopment of the Pointe des sables interchange programmed by the Martinique Regional Council to allow for the passage of the future Bus Rapid Transit (BRT) service that will link Fort de France to Lamentin Airport in 2015.
To smooth the flow of traffic, the bus lane (ERW-exclusive right or way) and the two existing slip roads will be grade separated by constructing a 740 m long viaduct comprised of a cast-in-place prestressed box girder deck. The present article describes in detail the viaduct construction phase: the alternative solution, the specific construction methods and the works procedures.

Figure 1 : General view of the viaduct under construction, May 2015

2. Description of the structure

The structure comprises three separate prestressed concrete decks, respectively A, B and C, each serving a different type of traffic and a specific direction of traffic flow (Figure 2):

Deck A (ERW lane), around 320 m long, resting on 10 piers (P2 to P11) and 2 abutments (C1 and C12); 11 spans: 1 x 25 m + 9 x 30 m + 1 x 25 m

Deck B (port exit slip road) has a total length of around 218 m and rests on 7 piers (P2 to P8) and 2 abutments (C1 and C9); 8 spans: 1 x 25 m + 5 x 30 m + 1 x 18 m + 1 x 25 m

Deck C (hospital exit slip road) has a total length of around 170 m and rests on 5 piers (P2 to P6) and 2 abutments (C1 and C7); 6 spans: 1 x 25 m + 4 x 30 m + 1 x 25 m.

The decks rest on elastomeric bearings that partially ensure seismic isolation.

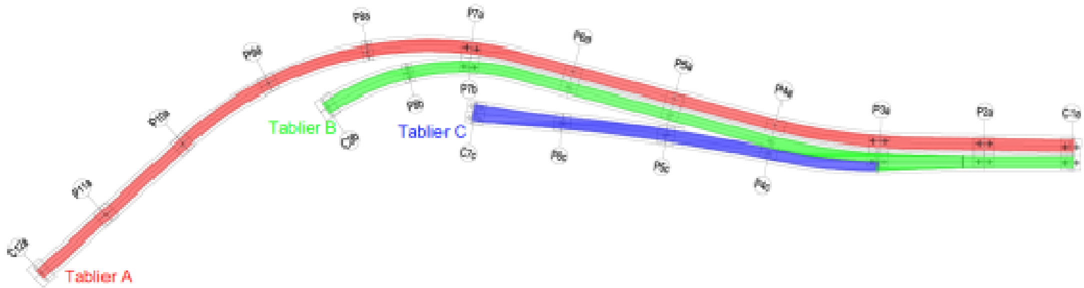

Figure 2: Plan view of the structure

Piers

The foundations of the piers are either spread footings measuring 9 m x 5 m x 1.5 m thick, or on piles (D1200 mm - 15 m long) constructed using a hole auger with a drill mounted on a mobile crawler crane.

Abutments

The abutments made in C35/45 concrete comprise a spread footing or piles (D1200 mm) and an architectural crosshead bearing.
To access the structure, closed-frame type are constructed behind the abutments. Joints separate the structure's abutments from these access ramps.

Deck

The deck structure made in C40/50 prestressed concrete is comprised of a U 1.12 m deep, closed with a 28 cm thick slab with 1.00 m corbels in the standard zone. The box girder is dressed on either side with a metal cornice on the underside of the corbels.

In each span, the U sections are concreted in place with isostatic prestressing steel post-tensioned in the lower concrete slab using four 16T15S cables at the rate of two cables per web.

Two 19T15S continuity cables are placed in the webs, at the rate of one cable per web. They are tensioned after concreting the segments on the piles or abutment.

The slab is poured on steel trays after tensioning the prestressing cables.

The diagram below is an indicative cross-section of the deck in a standard span (Figure 3).

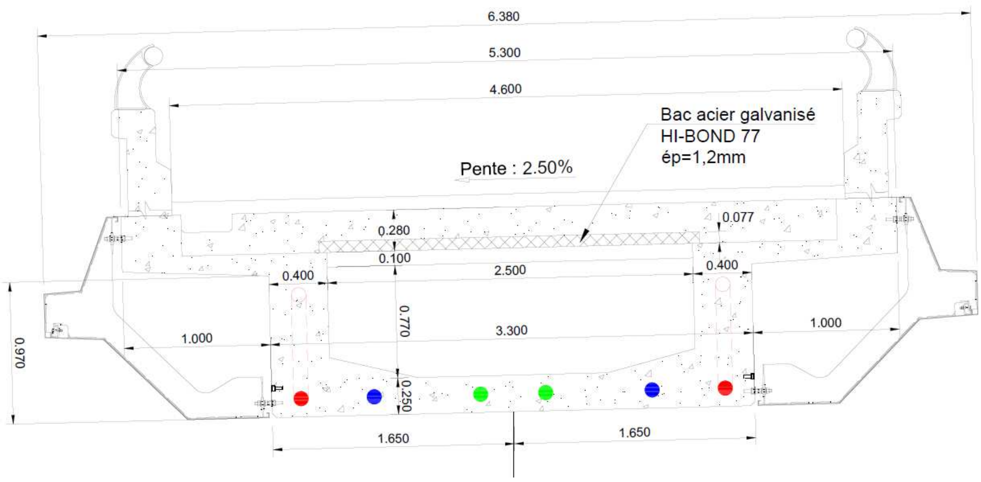

Figure 3: Cross-section of standard deck section with steel tray

3. Preliminary design and construction studies – Alternative solution adopted

The call for tenders was open to alternatives for the foundations and deck. However, the road geometry (longitudinal profile, gradients and banking), the functional cross-section, formwork for the piers and abutments in the basic project could not be altered. The basic project price and construction method studies by the Company for the preparation of the tender proposal rapidly revealed that the multi-core reinforced concrete box (Figure 4) was a relatively costly solution, notably because of the quantity of concrete required, the complexity of the formwork and reduced timeframe for completion of the works. On the other hand, as the structure is located in a region of high seismic activity (zone 5), the significant mass of the deck and the resulting larger seismic response, were highly penalizing for the foundations.

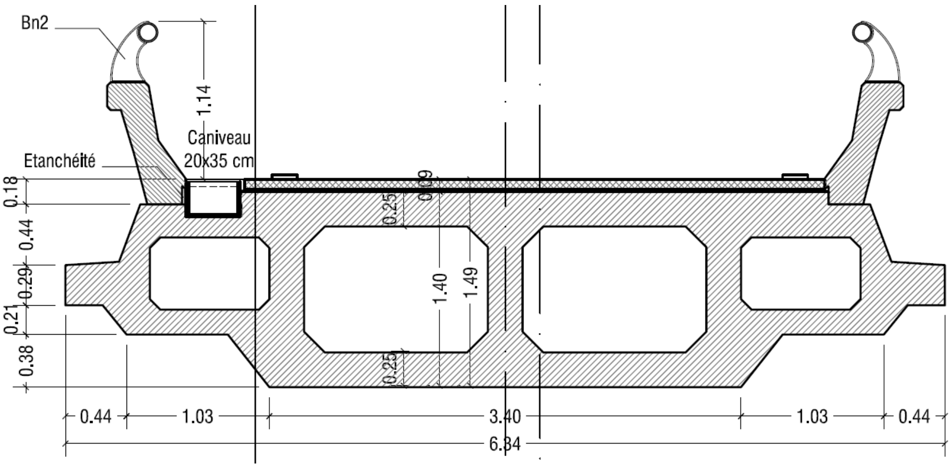

Figure 4: cross-section of the deck in the tendering documents

For these reasons, Eiffage's engineering design office sought to simplify and reduce the weight of the deck by providing each lane with a rib under the top slab. To improve the structure's durability, a prestressed concrete structure was adopted. To limit the quantity of shoring required, it was decided to pour the deck in two phases, the U-trough with the corbels first, and then the slab. The U-troughs with the cables, made continuous after keying on the piers, were then used for casting the top slab in place.

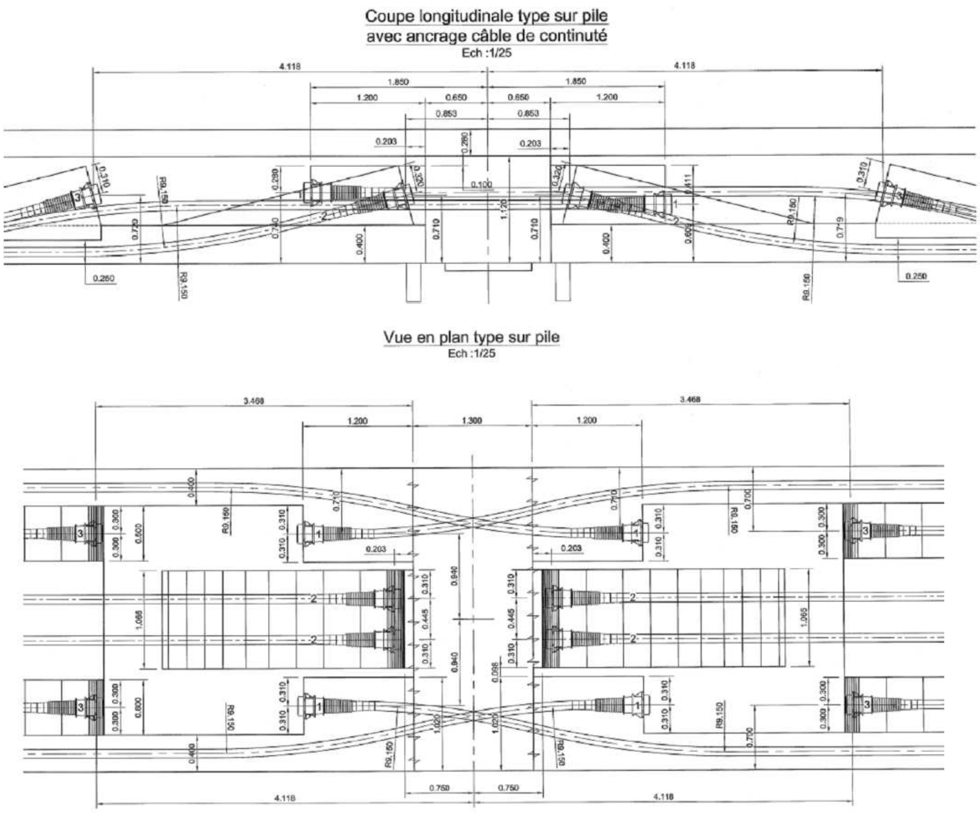

Figure 5 : Prestressing arrangement

The prestressing steel (Figure 5), for which the anchorage blocks are located inside the U-trough, was separated into two families:

- *Isostatic cables for removing trough formwork*
- *Continuity cables.*

The deck acquired the appearance of a mono-, bi- or tri- trough box girder depending on the lanes carried.

As for the foundations, the reduced deck weight meant it was possible to optimise the number and length of the piles and, in some cases, to switch to spread foundations. This resulted in switching 10 piers and abutment foundations on piles to spread foundations, and a significant reduction in the length of D1200 mm drilled piles.

4. Construction methods and works procedures

As the interchange carries over 130 000 vehicles a day, the viaduct's construction phasing was ordered in such a way as to maintain traffic.

4.1 Works scheduling

The overall timeframe for the works is 21 months, broken down into three phases defined by successive traffic deviations depending on the works progress (Figure 6):

- ***Execution of the half-footings of Viaduct A from C1 to P7: duration 3 months***

This phase involved shifting utility networks and traffic deviation to free up the footprint for work on bearings C1 to P7 of Viaduct A. The footings for Viaducts A/B/C being shared from C1 to P7, the footings were poured in halves using coupled concrete joints.

- ***Execution of the footings, piers and decks of Viaducts B and C: duration 14 months***

Traffic was detoured onto the semi-footings for Viaduct A to free up the footprint for the supports shared by Viaducts B and C. This stage involved creating the footings, piles and decks for Viaducts B and C to put Viaduct C in service.

- ***Execution of the piles and deck for Viaduct A: duration 4 months***

Traffic was then transferred to the deck of Viaduct C to free up the footprint for the supports and deck of Viaduct A.

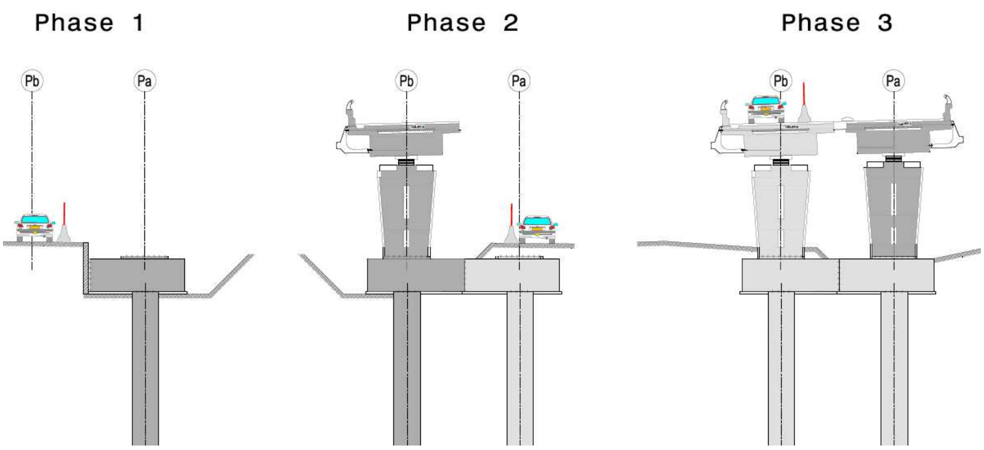

Figure 6 : Works phasing

4.2 Execution of the supports

Despite its elliptical form and central void topped by a crosshead, it was decided to concrete the piers in a single pass using negative formwork clamped on two shells. This solution made it possible to ensure optimum facing and saved considerable schedule time.

As the climate is tropical, the solution using timber formwork was rejected. Given the number of repeated uses (20), the skins of timber formwork, while less costly, would have to be changed after each 5 uses.

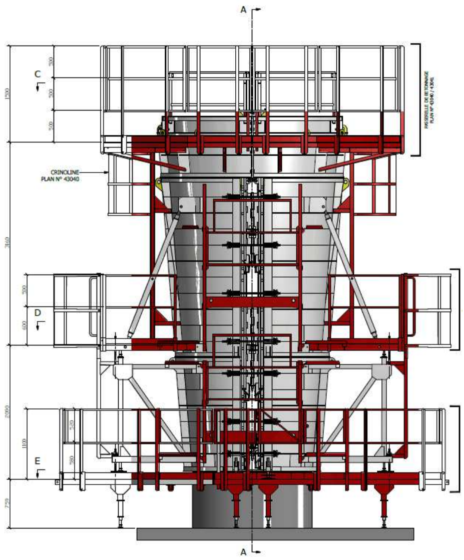

Figure 7: Formwork tool

Figure 8: Pier formwork

Given the dense reinforcements for the piers (explicable by the reduced section of the concrete at the pier base), particular attention was paid to the position and verticality of the projecting reinforcements (40 HA40) in order to ensure the installation of the pile drum's prefabricated reinforcement cages using a template.

The rate of progress for piers initially expected to be 7 days was reduced to 4 days by introducing a second set of interior tooling.

4.3 Execution of the decks

The synoptic for the decks erection is as follows (Figures 9 and 10):

- *Construction of piers P1, P2 and P3*
- *Concreting in place for the U-trough of span N (between piles P1 and P2)*
- *Tensioning of isostatic prestressing cables (16T15S) in span N, the concrete strength required being 30MPa*
- *Renoving span N formwork*
- *Concreting U-troughs for N+1 and N+2*
- *Concreting the segments on piers (1, 2 and 3)*
- *Tensioning of continuity prestressing cables (19T15S) on the two consecutive spans N et N+1 as soon as the strength of the concrete of the segments on piERS reaches 30MPa*
- *Close the troughs using steel trays*
- *Concrete the slabs*

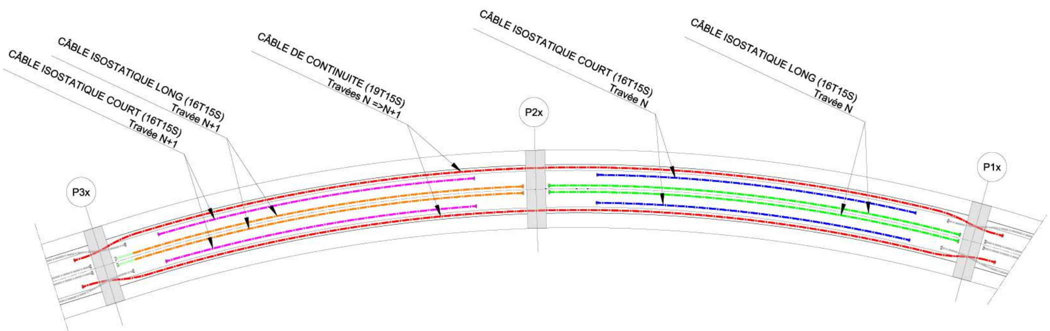

Figure 9 : Prestressing – Plan view

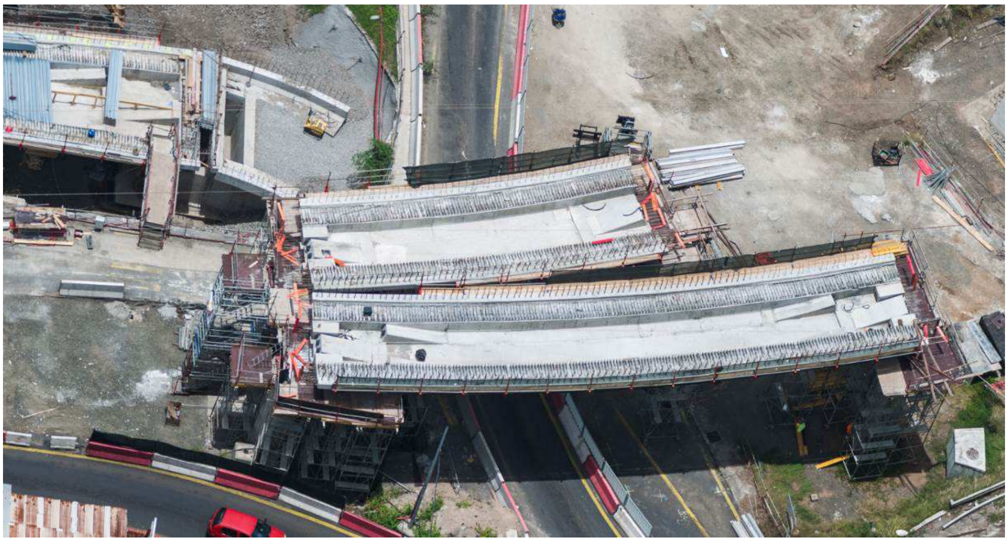

Figure 10: View of the box girders

4.4 Provisions adopted

The construction of a post-tensioned prestressed concrete structure such as this is made very complex by the highly constrained nature of the environment:

- *underground and overhead utilities*
- *proximity of local residents – limited footprint*
- *tropical climate*
- *proximity of the road network with Motorway A1 and its interchange.*

<u>Proximity of underground utilities (63 kV high-voltage power lines, water mains and service lines, wastewater, telecom, fibre, etc.)</u>

The Company made sure it requested each of its subcontractors to compile a list of the utilities around their excavation or drilling sites prior to the commencement of any work, based on the declaration of intended commencement of works for the utilities within the relevant zone, earthworks drawings overlaid with existing and detoured utilities and the equipment used.

<u>Proximity of overhead utilities (63 kV power lines)</u>

As part of the structure to be built lies under a 63 kV power line (deck 11 m from the line), the construction methods had to be adapted to keep to a strict minimum any shutdown of the power lines. Some work (such as the concreting phasing or delivery of the reinforcement cages), meant encroaching on the 5 m power line safety zone and in such cases it is unavoidable to have the power shut down. For work outside this 5 m safety zone, lifting machinery was equipped with a magnetic field sensor. Mounted on the end of the telescopic boom, it cut crane movement and alerted the operator with audible and visual alarms as soon as the boom encroached within 5 m of the power line. In addition to these safety measures, a crane operator log was created and electricity supervisors were trained.

<u>Proximity of local residents</u>

As the worksite footprint was reduced, lifting machinery had to select accordingly. The trough formwork was equipped with wheels (formwork weight of 750 kg) so that it could be shifted on the scaffolding plates to areas within reach of the mobile cranes. (Figure 11).
The lost formwork for the surface slabs, initially planned as reinforced concrete pre-slabs, had to be replaced with steel trays that could be manoeuvred by hand. This helped reduce the lifting operations required.

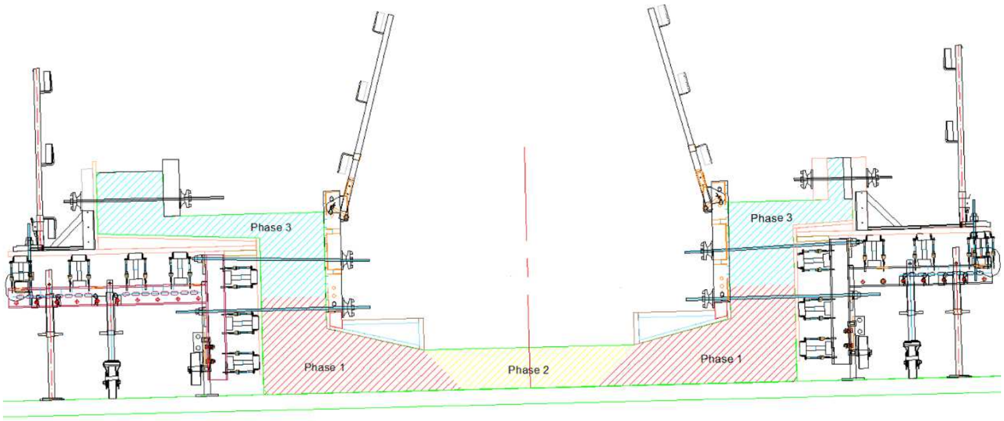

Figure 11 : Girder formwork

Tropical climate – Effect on prestressing work

The level of ambient humidity, sea spray drift and temperatures being higher in France's overseas territories, the Company had to take special care with storage of the strand reels and prestressing ducts to prevent the steel from corrosion. The ducts and reels were therefore protected under tarpaulins sprayed with soluble oil once a fortnight. The Superstressem concrete injected into the ducts after the cables had been tensioned (Figure 12) was stored in a refrigerated container and mixed with water cooled to 5 °C to delay the slurry's temperature rise when being used (30 °C max.).

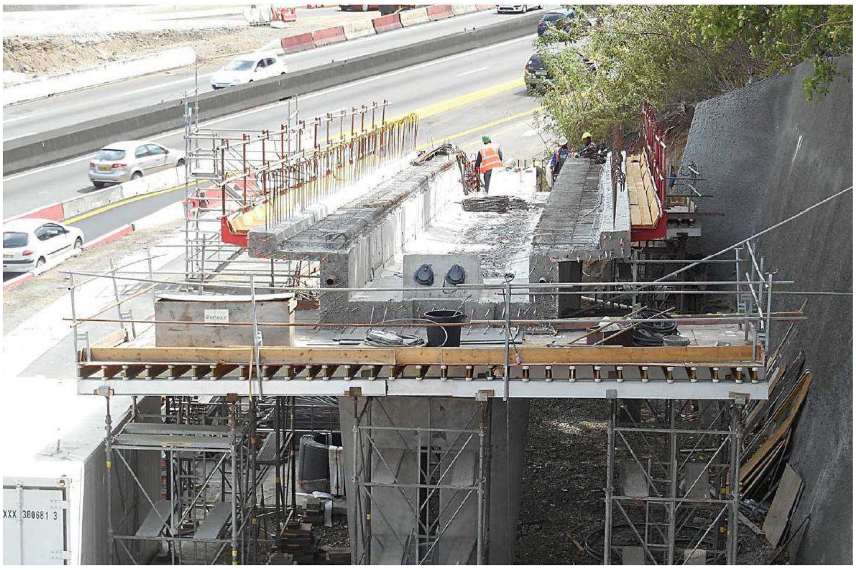

Figure 12: Box girder after rmoval of formwork

Island environment – Adapted human and material resources

Given the geometry of the box girders– single, double or triple, curved, banked at 2.5% with a variable longitudinal slope – it was not possible to use formwork panels. Scaffolding was therefore simplified to its minimum (Figure 13) and comprised of MILLS towers measuring 1.60 x 1.60 m, PHAL P1 type primary beams in aluminium and H20 type timber secondary beams every 20 cm. In an island context, we preferred to train the shoring assembly crew rather than resort to subcontractors, a service that it would have been difficult to outsource given the phasing and access conditions without resulting in complaints.

Furthermore, for each supply a financial comparison was made between purchasing locally or in France. The transport cost and dock dues, and supply lead times (1 month) had to be taken into account.

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Figure 13 : scaffolding on a span

<u>*Proximity of the road network – Installation of deck spans on definitive bearings*</u>

Three of the spans cross over main roads in Fort de France, which had to stay open to traffic for the duration of the works. Thus, given the dimensions of the formwork on the underside of the deck, these spans had to be constructed 1.20 m higher than their final position in order to maintain the road clearance under the structures.

After concreting the troughs on dead shoring, one of the challenges was therefore to remove the scaffolding from these 30 m long spans weighing 165 tonnes and lower them onto their definitive bearings while creating as little disruption as possible for road users and local residents.

The first solution considered was to lift and then deposit each span using two mobile cranes at each end of the span (Figure 14). However, the complexity of the environment (limited available footprint and presence of the 63 kV overhead power lines) as well as the risk of such an operation close to dwellings led <u>the Company</u> to abandon this method.

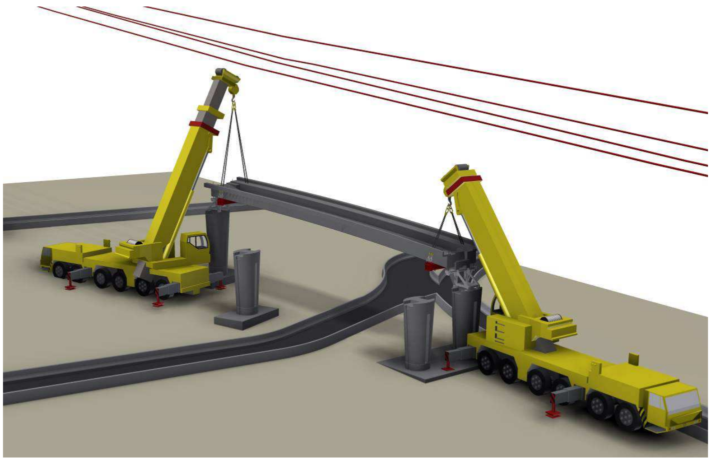


Figure 14 : Solution N°1 Lifting

The 2nd solution examined involved temporarily taking the weight of the span on 4 shoring towers combined with a compensation on beam stacks to deposit it on the definitive bearings by removing the scaffolding. (Figure 15)

However, wedging at a height of 1.20 m combined with the complex form of the spans (plan view radius of 100 m, banking of 2.5% and longitudinal slope of 9.65%) raised stability issues. Furthermore, handling 120 HEB-200 beams each weighing 45 kg would be heavy work for the personnel.

Figure 15 : Solution N°2 – Wedging on beam stacks

Given these findings, it was clear that the main issue was to control the span stability as it was lowered onto its bearings as well as the safety of personnel in the vicinity.
As a result, the Company contacted Coffrage&Quipage to examine a 3rd solution for lowering the spans using sway frames. This involved four metal towers anchored on the structure's piers and combined with a hydraulic system (Figure 16).

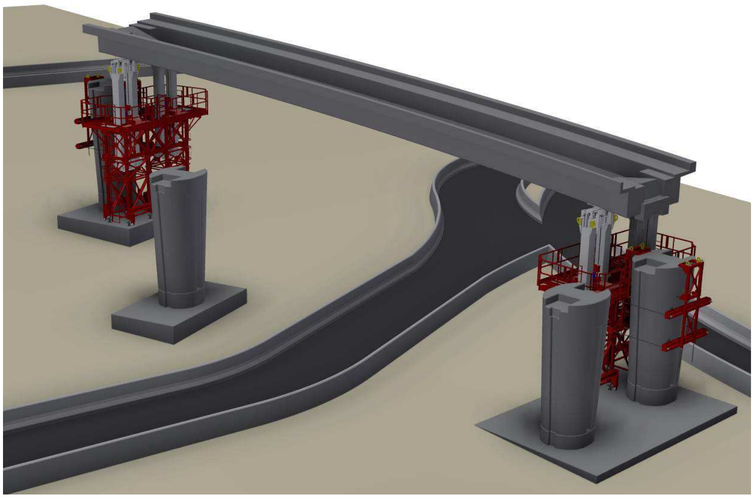
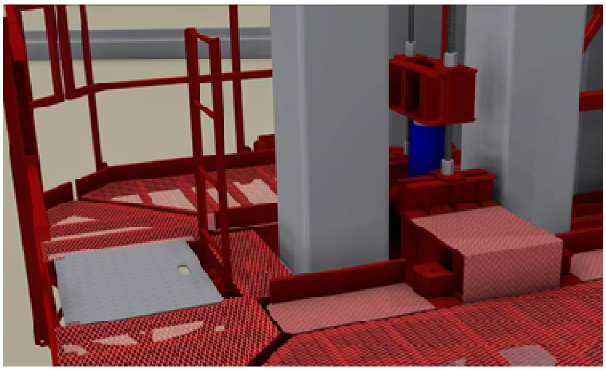


Figure 16 : Solution N°3 – Lowering system (Coffrage&quipage)

The span rests on swing frames through the intermediary of rocker bearings that adapt to the angled under surface of the deck, in order to spread the stress while ensuring stability. At each end of the span, 2 swing frames are placed 2.9 m apart in order to maintain the concrete span's centre of gravity on the system's stress bearing area.

Each swing frame is equipped with a slide combined with a 100 tonne hydraulic jack with a travel distance of 200 mm and 2 rigging bars. The principle is to lower the span in successive drops of 20 cm simultaneously on each of the 4 swing frames, lowering the loads using the jacks and the rigging bars (Figure 17). Transferring the loads at the end of each cycle frees the jacks in order to begin a new 20 cm lowering cycle. The concrete span lowering operation is therefore completed in 6 cycles, finally bringing the span to rest on its definitive bearings in one hour (Figure 18).



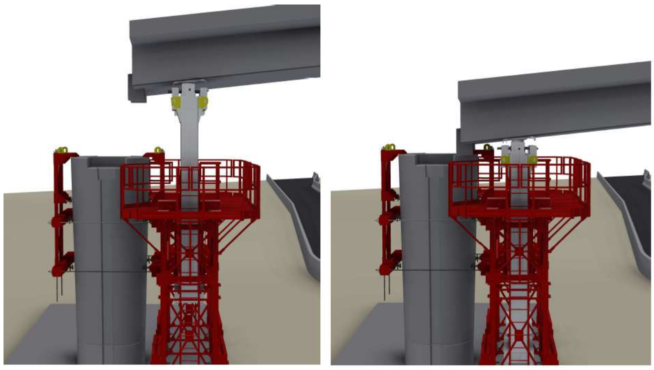


Figure 17: Lowering control mechanism (Coffrage&Equipage)   Figure 18 : Deck before and after lowering operation

This mechanism is classified as a lifting apparatus and was designed in accordance with the Machinery Directive 2006/42EC. In addition to its primary lifting function, particular attention was paid to integrating ergonomics in the workstation.