NEW UHPFRC DECK SLAB FOR THE GRAND PONT IN THOUARÉ-SUR-LOIRE (FRANCE). HOW TO EXTEND THE LIFE OF A 19TH CENTURY METALLIC STRUCTURE BRIDGE

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Abstract

The operation of rehabilitation and improvement of the level of service of the "Grand Pont" of Thouaré-sur-Loire involves the complex realization of a new integral UHPFRC deck-slab. This very thin slab, made up of prefabricated elements, connected on site with UHPFREC joints, allows relieving the deck of half of its own weight. The gain in thickness also enables to reinforce the 135-year-old steel structure, which has been completely conserved, by superimposing new metallic beams without changing the finished level of the roadway. This bridge part offers an optimized functioning in mixed cross-section thanks to the transversal connection of UHPFRC slabs. These qualities have led to the acceleration of the overall constructive process, which has been appreciated by the socioeconomic environment of the project.

Résumé

L'opération de remise en état et d'amélioration du niveau de service du grand pont de Thouaré-sur-Loire fait appel à la réalisation innovante d'un tablier intégral en BFUP. Cette dalle très fine, constituée d'éléments préfabriqués et clavetés sur chantier a permis de délester le tablier de la moitié de son poids propre. Le gain d'épaisseur a également permis de renforcer la charpente métallique, vieille de 135 ans et intégralement conservée, par superposition d'une pièce de pont neuve sans modifier le niveau fini de la chaussée. Cette pièce de pont présente un fonctionnement optimisé en section mixte grâce à la connexion transversale de la dalle en BFUP. Ces qualités ont conduit à l'accélération du processus constructif global, apprécié par l'environnement socio-économique du projet.

1. DESCRIPTION AND PATHOLOGY

The Grand Pont is a structure that enables the RD 37 road to cross the river Loire between Thouaré-sur-Loire and Saint-Julien-de-Concelles Dating back 1882, it is a metal lattice work "frame" type bridge, supported by brick jack arches or reinforced concrete slabs (Fig. 1). This structure, located on the northern branch of the Loire, has a total length of 393 meters, and is divided into seven 45-metre spans with two 38.25-metre spans on the river banks. The floor beams, spaced 1.80 meters apart, support the 4.80 meter wide central part, the rough-cast brick jack arches with lime concrete use the lower angle bars as support, the upper surface of which is flush with the upper flange plate. This bridge provides a road crossing 4.60 meters wide, with two traffic lanes, edged with pavements with a useful width of 0.77 meters.

Although the structures have been properly and regularly maintained, anti-corrosion protection on the metal framework in particular, they are nonetheless presenting significant pathologies relating mainly to a lack of waterproofing. In fact, rainwater flows along the edges of the pavements, leaking into the body of the embankment and percolates through the lime concrete into the brick jack arches. So over the years, the roughcast mortar is being washed away and the bricks are splitting up, accentuated by periods of frost and thaw. A number of bricks can be seen to be sinking, as well as brick fragments falling off. When the water comes out of the brick jack arches, it continues to cause damage by creating damp on the overhead part of the floor beam. Major localised corrosion can also be seen along the tympanum of the arch, with a significant loss of material with frequent and extensive perforations. The organised monitoring of the structure, by annual inspections and more detailed periodic inspections (the last of which was in 2013), has enabled the damage to be monitored and the structure's level of service to be guaranteed. With this in mind, car traffic over the Grand Pont at Thouaré has become heavier and has reached saturation point, with mainly commuter traffic now reaching 10,500 vehicles per day. The road weights permitted to cross here are limited to vehicles less than 3.5 tonnes, with a similar existing limit on the RD37 road going through the village of Thouaré-sur-Loire, with an exemption of vehicles less than 8 tonnes (2 + 6) used for agricultural purposes on the island and with an exemption of less than 16 tonnes (6 + 10) for service vehicles (winter maintenance) and emergency vehicles accessing the island. The structure was in fact sized in accordance with the load regulations of the time, with two lanes of 8-tonne wagons crossing

Figure 1: General view of the structure

2. PROGRAM

Given the risk of a brick jack arch collapsing or a floor beam breaking, the structure was placed under more frequent monitoring and a repair programme was drawn up at the end of 2014, along with the initial budgetary decisions. Initially, the brick jack arch ends where they were joined to the most damaged floor beams, with a repair to these floor beams by bolting on reinforcing sheet metal (except spans 5 and 6), rebuilding the brick masonry, the construction of concrete blinding to act as waterproofing and a surface course in tarmac, with a complete repainting of the structure, as the last time it was painted was almost 30 years ago. The budget allocated to these works was set at €4.8 million excluding taxes, with a completion deadline of 12 months, and no complete blocking of traffic. It was also requested that the possibility of the later addition of two overhangs was looked into, each with a useful width of 2 metres enabling pedestrians and cyclists to cross in the same direction on either side of the cage.

3. DESIGN

The announcement of the operation caused a significant amount of local reaction regarding the need, and the length of time required, for closing the Grand Pont in Thouaré, and the need for pedestrians and cyclists to cross the Loire. So the design phase had the benefit of prioritising the needs associated with the project: keeping within costs, due to a very tight budget, optimising the period for closing the bridge and making it safe, and confirmation of the possibility of adding overhangs for cyclists and pedestrians in the medium term. The first stage consisted of reviewing the operating loads programme, based on the provisional Lecroq SETRA 1982 document, to achieve a distributed load of 1240 daN per metre of deck representing two lanes of 3.5 tonne vehicles, at the passing point of two 8--tonne (2 + 6) vehicles, a single 19-tonne (6 + 13) vehicle corresponding to an urban bus, an exceptional load of two 12-tonne (4 + 8) vehicles passing (accidental situation) and for the overhangs, 500 daN per m^2, in accordance with the Eurocodes. It quickly became obvious that repairing all the jack arches in the same way, or its alternative, the reinforced concrete slab, would not enable a sufficient reserve load-bearing capacity to allow pedestrians and cyclists to cross the structure. So we had to go back over our previous projects and call on new technical solutions that met our structural requirements (a significant saving in dead weight and the possibility of building the overhangs) and geometric requirements (maintaining the current road level), whilst keeping to costs and to the deadline (dealing with all the floor beams whilst coming into contact with the existing assemblies as little as possible).

The idea of using UHPFRC for its mechanical qualities met the first two requirements because the sizing of a continuous full-width slab (roof shaped) resting on the floor beams resulted in a constant thickness of 9 cm. Surfaced with a gravel bonding and placed at the current level of the roadway, it allowed a space of 20 to 25 cm over the existing floor beam which enabled a new separate metal section to be inserted, bolted to the sound ends of the floor beam, and which alone can withstand all the road overloads. The exact geometry of this reformed and welded section comprised a flange greater than 30 cm which enabled precast UHPFRC slabs to be fitted, then their concreting joints using Nelson dowels (working in a mixed cross-section) and plate welded at its end, whose dimensions do not exceed 220 x 220 mm^2 so as to enable a bracket to be fitted across the multiple lattice.

The economical optimization during the construction phase led to the realization of a metallic profile of constant inertia from an expanded and reinforced standard profile. The UHPFRC slabs must then follow the shape of the pavement slope and thus have a thickness varying from 7 cm to

11.7 cm on the shore of the structure. This new design (Fig. 2) allowed casting these slabs upside down in order to have a horizontal free surface.

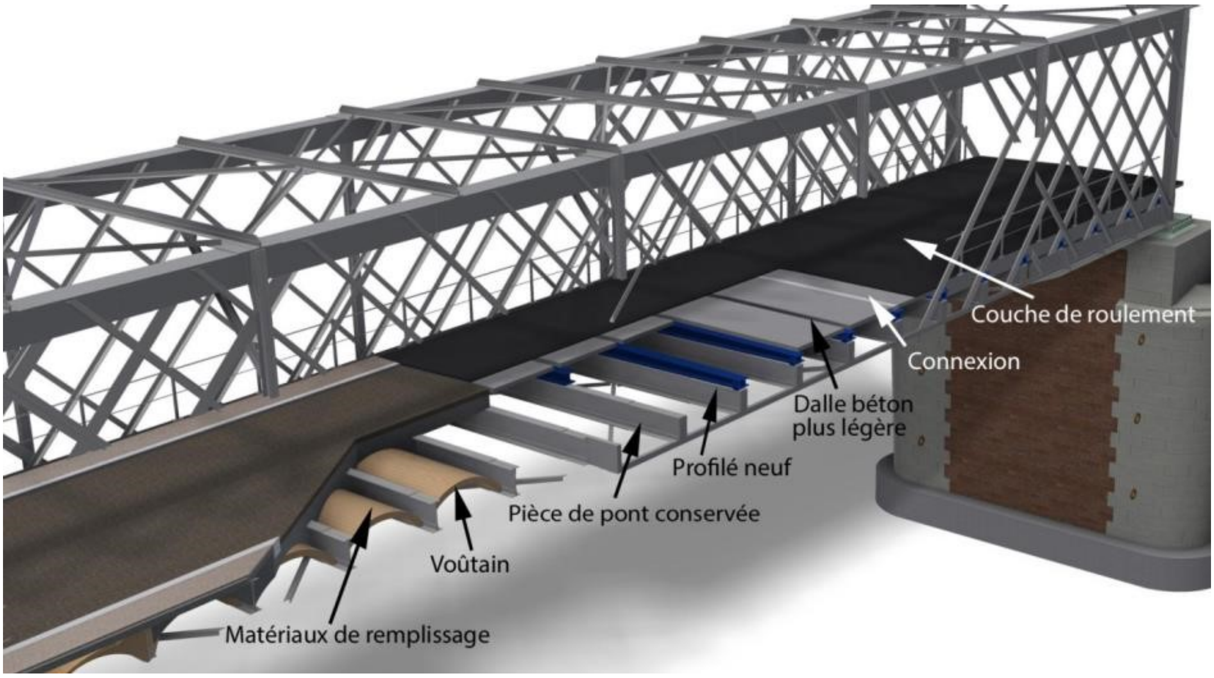

Figure 2: General view of the bridge renovation concept

4. MANUFACTURE OF THE UHPFRC SLAB

218 slabs were required for this site. Each one weighs 2300 kg and measures 6.2 metres long and 1.58 metres wide. The production capacity for the slabs (Fig. 3) was 4 units per day. There were 6 types of slabs for this site, which were standard slabs (2 types for holding the steel in staggered rows), end slabs (with a much shorter length for the junction with the abutment) and special slabs (2 types, identical to the standard slabs but with 2 reservations for the rainwater downpipes).

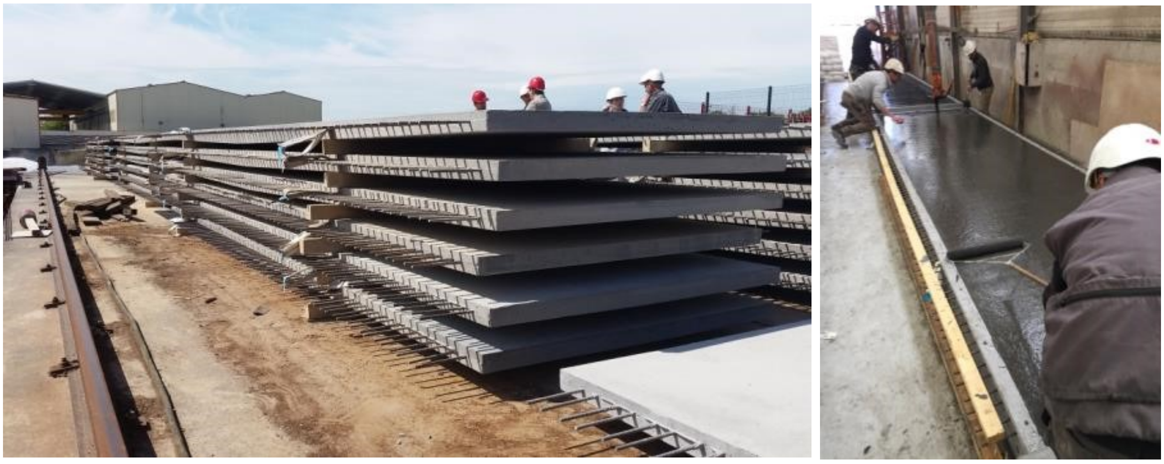

Figure 3 : Illustrations of UHPFRC slab production

5. CONCRETING JOINTS

So as to check that the concrete was properly distributed in the concreting joint area, suitability tests were carried out at the site facilities (Fig. 4) with the purpose of checking that the UHPFRC was properly distributed through the dense reinforcement and the connectors welded to the reformed and welded sections (8 connectors per meter in the central part and twice the quantity on both extremities, 16 mm diameters and 50 mm height).. This also enabled the correct quantities of materials required for the actual volume of the concreting joints to be finalised. Finally, these tests also provided the site teams with the opportunity to familiarise themselves with the preparation of the UHPFRC.

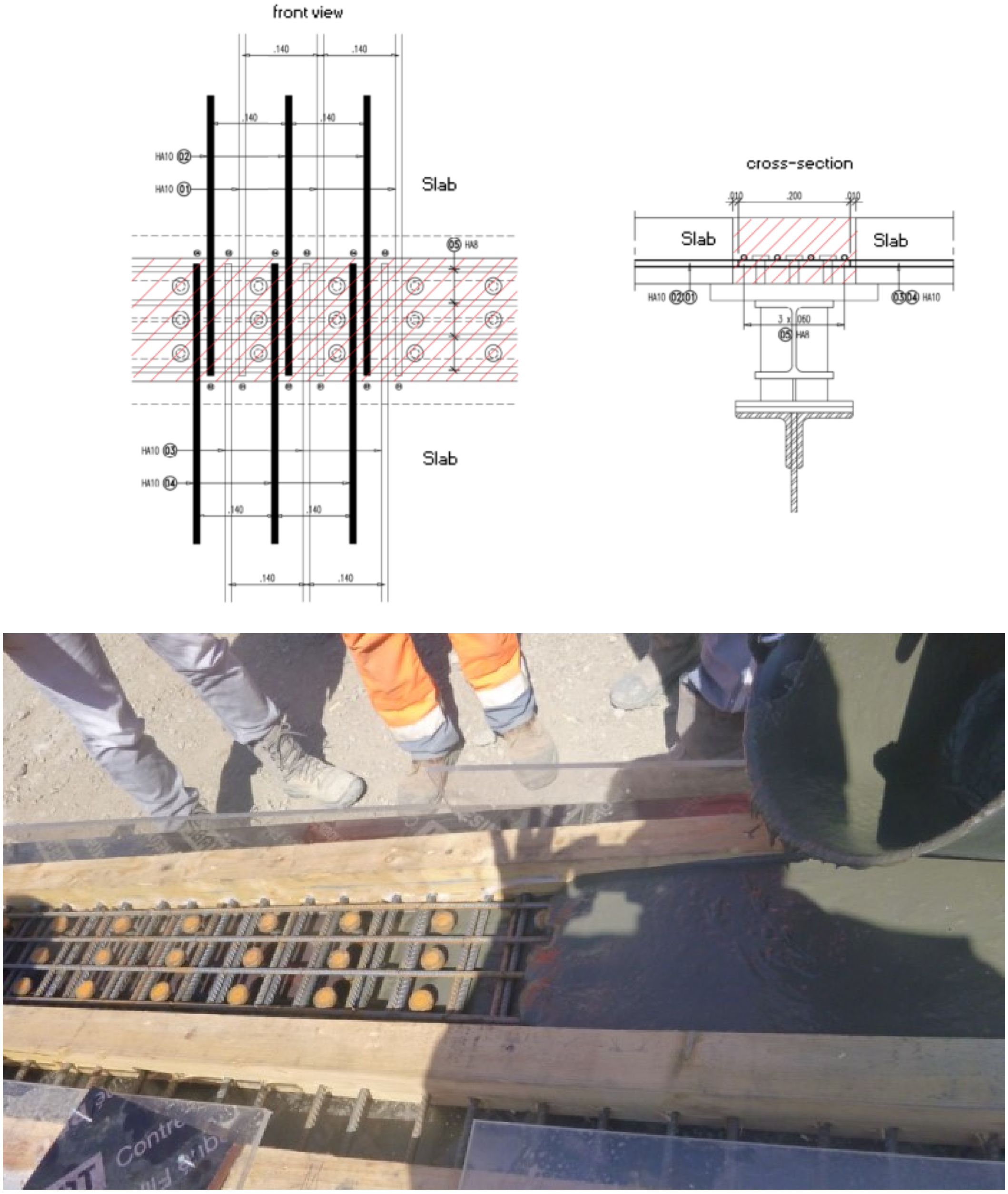

Figure 4: First test of field cast UHPFRC connection

6. METHODOLOGY

The slabs were transported to the site in instalments so as to comply with the wide load regulations (Fig. 5). They were also moved into this position by the power shovel so as remain as far as possible from the existing cage. The slabs were then tipped using a special tool for placing them flat. When they were tipped, they were then ready to be positioned in their final place. When several slabs were in place on the metal sections, the concreting joints could then be done (Figs. 6-8). Once this cycle was completed, the pavements could be erected on the slabs, as well as the bonding to enable traffic to move on the structure.

Figure 5: Delivery of the slabs to the construction site

Figure 6: Installation of the reformed and welded sections

Figure 7: Laying the first slab

Figure 8: Slabs in place

7. CONCLUSION

Rebuilding the deck in UHPFRC slabs enabled the inherent difficulties of the project (reducing the weight of the structure, very tight scheduling, etc.) to be overcome whilst enabling us to improve the daily life of the users by the creation of the overhang. The advantages of this constructive solution meant that there were much fewer operations on the existing framework which reduced the uncertainties of the site, handling lightweight parts appropriate to the difficult conditions relating to the geometry of the cage, using precast for shortening the site's deadlines and a significant saving in dead weight. 2300 tons of brick and pavement materials were replaced by 600 tons of BFUP slabs and road surfacing materials.

This example of bridge renovation project leads the way to many other concrete applications. There are numerous metallic structures that must be preserved for aesthetical, historical or operational aspects whose carrying capacity needs to be drastically improved (urban bridge or why not railway structures).

It is already planned to duplicate this technical solution on the bridges of Mauves sur Loire, representing 600 meters of deck (identical to the Grand Pont of Thouaré-sur-Loire), located five kilometres upstream, starting from 2019. On this occasion, it would probably be appropriate to optimize the design of the UHPFRC slab by conceiving for example an embossed structure and to rework the interface between the prefabricated part and the part casted on site (field cast connection).

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