RILEM-*fib*-AFGC Int. Symposium on Ultra-High Performance Fibre-Reinforced Concrete,
UHPFRC 2013 – October 1-3, 2013, Marseille, France

EXPRESS BRIDGE DECK AND LIGHT DUTY BRIDGE

Yves Brugeaud (1)

(1) MATIERE SAS, Paris, France

Abstract

Bridges and prefabricated beams in concrete pre-stressed by pre-tensioning or made of reinforced concrete are a classical solution for bridging spans of between 6 and 35 m. For short span structures, the custom design solution is not suitable. The cost of the design is disproportionate to the amount of work. The Express bridge deck and light duty bridge are pre-developed structures that offer the designer a means of bypassing the "customized" solution. Progress made in France with ultra high performance fibre reinforced concretes (UHPFRC) allows this material to be used economically in the manufacture of industrialised products. The Express bridge deck and light duty bridge are manufactured from optimised UHPFRC elements, allowing companies to install bridges quickly and easily and guaranteeing maximum durability for customers.

Résumé

Les ponts à poutres préfabriquées en béton précontraint par pré-tension ou en béton armé constituent une solution classique pour les franchissements de portées comprises entre 6 et 35 m. Pour les ouvrages de faible portée, la solution de conception sur mesure n'est pas adaptée. Le coût de la conception est disproportionné par rapport au montant des travaux. Le tablier et la passerelle Express sont des structures pré-étudiées qui offrent au concepteur un moyen de contourner la solution « sur mesure ». Les progrès réalisés en France dans la technologie des bétons fibrées à ultra haute performances (BFUP) permettent d'utiliser économiquement ce matériau dans la fabrication de produits industrialisés. Le tablier et la passerelle Express sont fabriqués à partir d'éléments en BFUP optimisés qui permettent aux entreprises une exécution facile et rapide et garantissent pour les maitres d'ouvrage une durabilité maximale.

1. GENERAL DESCRIPTION

The Express bridge deck and light duty bridge are two techniques used together to produce short-span bridging structures. The two structures are made of longitudinal, reinforced concrete ribs. They are made from pre-stressed, hollow UHPFRC box beams, pre-fitted with a passive reinforcing cage and are filled with concrete on site.

2. DESIGN AND AREA OF USE

2.1 The Express bridge deck

The Express bridge deck is a structure for spanning a breach of up to 12 m, comprising a ribbed, and reinforced concrete slab. It is also a construction method using self-supporting UHPFRC formwork (Fig. 1).

The data for a typical project for an Express bridge deck application are:

- Bridging a gap of up to 12 m.
- A transverse profile for the circulation of light vehicles on a 3 m-wide roadway, combined with pedestrian traffic on 0.5 m-wide pavements on either side of the roadway.
- A skew of 70 to 100 grads.

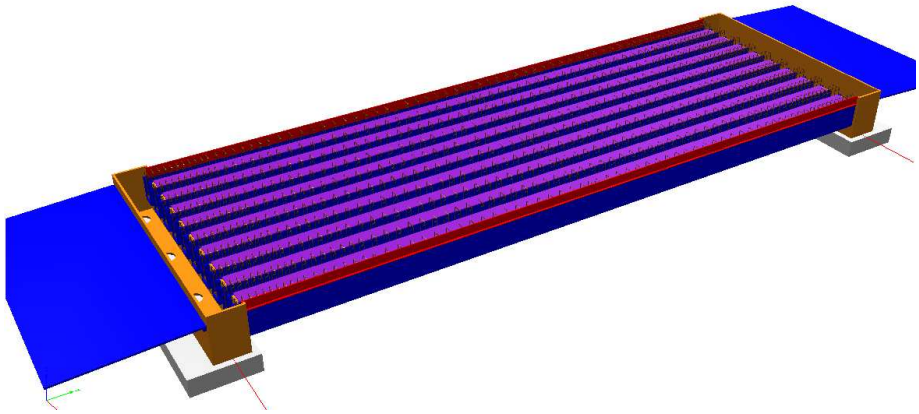


Figure 1: Express Bridge deck. General scheme of the UHPFRC form

Description of the structure

The structure is a statically determined bridge deck comprising a ribbed, reinforced concrete slab. A formwork at each end of the bridge deck links the ribs to each other, thus providing a crossways stiffening function at the supports (crossbeam over abutments).

Initially, the development has been limited to an isostatic span; multi-span bridges are planned for 2014.

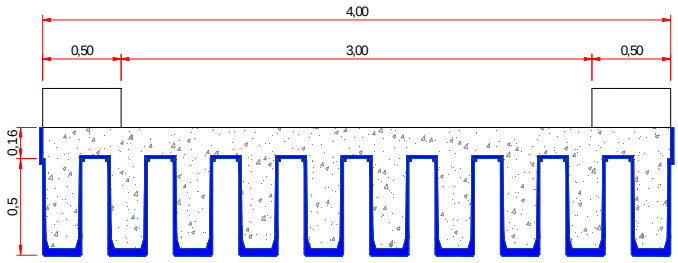


Figure 2: Express bridge deck. Typical transverse cross-section

The bridge deck may be placed directly on to micro-piles or, if using Freyssinet bearing systems, on superficial foundations. The total height of the bridge deck is 66 cm, 50 cm of beams and 16 cm of levelling. The number of ribs varies between 7 and 10, depending on the span (Fig. 2).

Design codes and assessment

The slab and ribs are checked to the following standards: traffic loads as per NF EN 1991-2 and its national annex; verification of the reinforced concrete sections as per NF EN 1992-2 and its national annex. "Traditional" bridge equipments are taken into consideration in the justifications (waterproofing layer, road surface, barriers, etc.). A class 2-traffic is considered according to NF EN 1991-2 and appendix. Loads LM1, LM2 and concomitant pedestrian loads are applied to it. Cracking is limited to 0.3 mm for reinforced concrete elements and 0.2 mm for UHPFRC elements. During the execution phase on site, UHPFRC elements are checked under construction loads defined in NF EN 1991-1-6 and in accordance with AFGC Recommendations for UHPFRC [1, 2]. Design is approved by initial type testing as required by NF EN 15050 and NF EN 13369.

Materials

UHPFRC box beams and formwork:

The material used for the hollow longitudinal beams, the permanent formwork plates between the ribs and the spacer formwork is UHPFRC with 150 MPa characteristic compressive strength and 8 MPa mean tensile strength. The hollow longitudinal ribs are pre-stressed by pre-tensioning using four strands of type T13 – 1860. These UHPFRC elements are heat treated.

Reinforced concrete used to fill the ribs and for the slab:

The concrete filling between the spacers and longitudinal ribs is C30/37. The passive steels are type B500B.

2.2 The Express light duty bridge

The Express light duty bridge comprises longitudinal beams combining reinforced concrete and UHPFRC walls and a UHPFRC slab. Depending on the width of the cross profile, the bridge can comprise two or three longitudinal beams with the same span limits as the Express bridge deck, i.e. a gap of 12 m. The deck width is 2.40 m.

Description of the structure

The structure (Fig. 3) consists in a statically-determined span made of reinforced concrete beams linked to each other by a pre-stressed UHPFRC slab. At support, a cross-beam links the beams together.

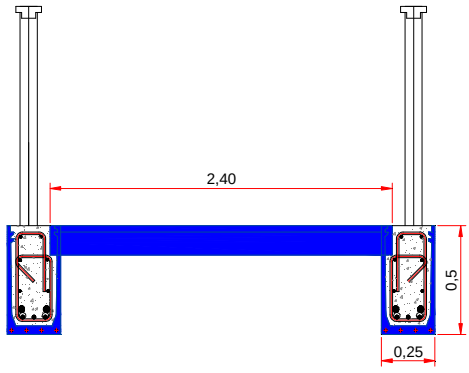


Figure 3: Express light duty bridge. Typical transverse cross-section

Design codes and assessment

As with the Express bridge deck, design is done using the following regulations: traffic loads as per NF EN 1991-2 and its national annex; verification of the reinforced concrete sections to NF EN 1992-1-1 and NF EN 1992-2 and its national appendix. The structure is subjected to a distributed surface load of 5 kN/m² and also to the concentrated load of 10 kN on a square surface of 10 cm per side. It should be noted that a 10 kN concentrated load has been shown to be critical to design the bridge deck. This is the reason why it is made of pre-

stressed UHPFRC. Cracking is limited to 0.3 m for reinforced concrete elements and 0.2 mm for UHPFRC elements. During the execution phase on site, UHPFRC elements are checked under construction loads defined in NF EN 1991-1-6 and in accordance with AFGC recommendations for UHPFRC [1, 2]. Their design is approved for initial type testing.

Materials

UHPFRC box beams and decking

The material used for the longitudinal horizontal ribs and the decking is the same UHPFRC as for the Express bridge deck: it is a UHPFRC mix with 150 MPa characteristic compressive strength and 8 MPa mean tensile strength. The hollow longitudinal ribs are pre-stressed by pre-tensioning with four strands T13-1860 [1]. These UHPFRC elements are heat treated.

The slab is pre-stressed transversally with strands of type T9.3 – 1860. The slab is also heat-treated.

Main reinforced concrete beams

The concrete filling between the spacers and longitudinal ribs is C30/37 (30 MPa-concrete). The passive steels are of type B500B.

2.3 Design summary

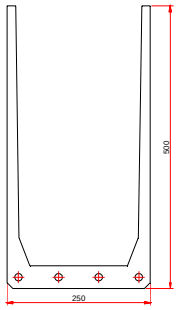
The Express deck and light duty bridge are reinforced concrete structures and designed as such. The pre-stressed UHPFRC box beam is used as a formwork and supports the dead load of the concrete during casting. It also plays the role of a protective layer for the structure during service life. In the current state of testing, the structural strength of the pre-stressed box beam is ignored for checking the structure with respect to serviceability.

3. CONSTITUTIVE ELEMENTS MADE OF UHPFRC

3.1 The pre-stressed, hollow UHPFRC box beam

The beam is 25 cm wide and 50 cm high. It is a pre-stressed UHPFRC element. It acts as formwork for the Express bridge deck's ribs and the main beams for the Express light duty bridge.

For the Express bridge deck, the two box beams laid on the bank are lifted up on the outer wing by the height of the infill, i.e. 16 cm. They are delivered to site with the passive reinforcing steels for the reinforced concrete beams; these are concreted on site at the same time as the infill. For the Express light duty bridge, the inner wing of the boxes is designed to take the deck plates' load during concrete casting.

a) 

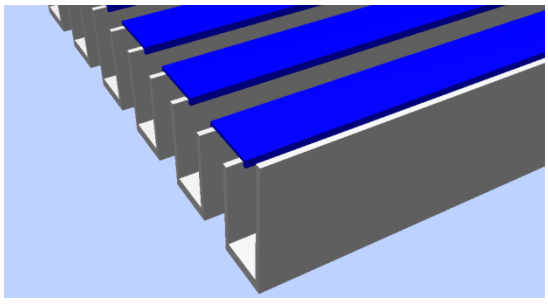
b) 

Figure 4: Pre-stressed UHPFRC channel a) cross-profile b) assembled elements

3.2 The spacer casing

This is the formwork for the spacer and the temporary support for the pre-stressed, hollow UHPFRC box beams. It comprises five UHPFRC walls joined together with structural glue. The bottom is drilled for linking to the foundations and the side facing the gap is cut out to the dimensions of the box beams.

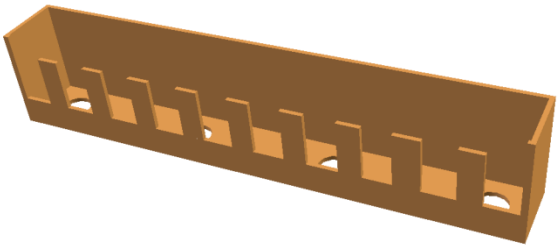


Figure 5: UHPFRC Spacer casing

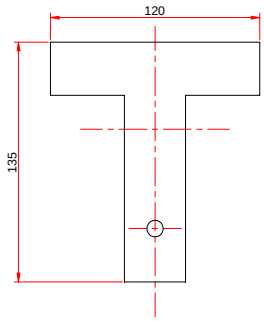


Figure 6: UHPFRC T-shaped beams for the deck

3.3 The horizontal formworks

The horizontal formworks are UHPFRC plates used as formwork for the Express bridge deck infill. They are T-shaped and are supported on the wings of the boxes.

3.4 Decking

The deck plate on the Express light duty bridge consists in UHPFRC pre-stressed T-shaped beams (Fig. 6). They are 13.5 cm high and 12 cm wide. The T-shaped beams are supported by the light duty bridge's longitudinal beams and are linked to them during the second phase concreting. It may be noted that, for the light duty bridge application, the UHPFRC deck plate and the hollow box beams may be self-coloured chestnut brown.

4. CONSTRUCTION METHOD

The Express bridge deck is built in the following steps.

- Positioning of the spacer casings with their passive reinforcing steels on the foundations.
- Pouring of the first phase concrete up to the lower edge of the longitudinal boxes.
- Positioning of the longitudinal UHPFRC box beams and their passive reinforcing steels.
- Positioning of the horizontal formworks for the infill between the hollow longitudinal box beams.
- Reinforcement of the infill.
- Pouring of the second phase concrete into the box beams, the infill is in addition to the rest of the height of the spacer.
- Installation of equipment: either a waterproofing layer and a surface paving layer, or an UHPFRC topping layer.

The Express light duty bridge is built in the following steps.

- Positioning of the spacer casings with their passive reinforcing steels on the foundations.
- Pouring of the first phase concrete up to the lower edge of the longitudinal box beams.
- Positioning of the two hollow UHPFRC beams with the passive reinforcing steels.
- Pouring of the second phase concrete in the longitudinal box beams and the spacer up to the bottom edge of the decking plates.

- Fitting of the decking plates between the partly concreted hollow longitudinal box beams.
- Pouring of the third phase concrete for keying the decking to the main beams,
- Installation of equipment, barriers and coping.

5. ADVANTAGES

5.1 For project managers

The Express bridge deck and light duty bridge are pre-engineered structures, which reduces the engineering costs which, for this type of structure, are disproportionate to the cost of the work. Their design in reinforced concrete is based on a simple, commonly used technique and therefore accessible to the great majority of the design offices.

5.2 For construction companies

The construction of the Express bridge deck and light duty bridge is characterised by:

- Easy handling for the main structural elements, due to the reduced weight of the UHPFRC elements: the pre-stressed hollow UHPFRC box beam weighs 71 kg per linear metre and the associated passive reinforcing steel cage approximately 31 kg per linear metre. The total weight is therefore 100 kg per linear metre or 1200 kg for a 12 m span. An item of this weight can be handled by common Mécalac type machine.
- The deck plates and embedded formwork between the boxes are light enough for being carried by hand.
- The deletion of time-consuming formwork and formwork removal phases.

5.3 For clients

All parts of the Express bridge deck and light duty bridge that come into contact with the environment are protected by an UHPFRC "skin", the thickness of which varies between 15 and 40 mm. This protection reduces maintenance requirements to the bare minimum and increases the durability of the structure.

5.4 For export

The Express bridge deck has been designed, so that all the constituent elements can be packed into a 40-foot container. Packed in this way, normal road transport and, above all, sea transport becomes possible.

6. CONCLUSION

Based on a both simple and innovative design, the Express bridge deck and light duty bridge are structures whose speed and efficiency of construction result directly from their simplicity of design. The performance of UHPFRC as a material, combined with pre-stressing, allows the expected durability of structures produced to be significantly improved.

REFERENCES

[1] AFGC-Sétra, ‘Ultra-high performance fibre-reinforced concretes. Interim recommendations’, 2002.
[2] AFGC, ‘Ultra-high performance fibre-reinforced concretes. Recommendations’, 2013.