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Alain Huynh-Tuong[1], Jean-Roch Lucas[2], Miodrag Stanković[3]

REHABILITATION OF THE A36 WARREN-TYPE VIADUCT

Summary: A first in France: waterproofing of a rehabilitated highway Viaduct using Ultra-High Performance Fiber-Reinforced Concrete (UHPFRC). The rehabilitation of the Viaduct above Saône canal, on the A36 highway in France, provided an opportunity to implement an innovative waterproofing solution for a road bridge, based on the use of UHPFRC. The bridge structure, made of Warren truss girder, consists of a steel framework supporting a concrete deck. Subjected to heavy traffic and high temperatures gradients, the bridge exhibited advanced deterioration of its waterproofing and asphalt pavement system. As part of the overall rehabilitation works, Freyssinet removed the existing paving system – too sensitive for the temperature rises generated by the steel structure – and replaced it with an UHPFRC overlay system. This intervention was carried out under strict operational constraints, minimizing traffic disruption and optimizing construction timelines. The Viaduct above Saône canal project demonstrates the relevance of UHPFRC as a high-performance, durable rehabilitation solution, perfectly suited to the operational requirements of modern motorway infrastructure.

Keywords: UHPFRC, durability, waterproofing, service life

SANACIJA VIJADUKTA A36 SA REŠETKOM TIPA WARREN

Rezime: Prvi put u Francuskoj: hidroizolacija korišćenjem betona sa ultra visokim performansama ojačanog vlaknima (UHPFRC) za saniranje vijadukta na auto-putu. Sanacija vijadukta preko kanala Sona, na autoputu A36 u Francuskoj, pružila je priliku za implementaciju inovativnog rešenja hidroizolacije drumskog mosta zasnovanog na upotrebi UHPFRC. Konstrukciju mosta čini čelični rešetkasti nosač tipa Warren koji nosi betonsku ploču. Usled teškog saobraćaja i velikih temperaturnih gradijenata, na mostu je došlo do preteranog propadanja hidroizolacije i asfaltne kolovozne konstrukcije. U okviru radova na sanaciji mosta, *Freyssinet* je uklonio postojeću asfaltnu kolovoznu konstrukciju, koja je bila isuviše osetljiva na porast temperature uzrokovan čeličnom konstrukcijom, i zamenio je sistemom UHPFRC. Ova intervencija je sprovedena pod strogim operativnim ograničenjima, minimizirajući prekide u saobraćaju i optimizujući vremenske okvire izvođenja. Projekat vijadukta iznad kanala Sona pokazuje značaj UHPFRC-a kao visokokvalitetnog i trajnog rešenja za sanaciju, savršeno prilagođenog operativnim zahtevima moderne infrastrukture auto-puta.

Ključne reči: UHPFRC, trajnost, hidroizolacija, eksploatacioni vek

[1] Freyssinet International & Cie, alain.huyng@freyssinet.com
[2] Freyssinet International & Cie, jean-roch.lucas@freyssinet.com
[3] Freyssinet Serbia, miodrag.stankovic@freyssinet.com

1. INTRODUCTION

The rehabilitation of the viaduct crossing the Saône diversion canal on the A36 motorway represents a first in France, through the adoption of a waterproofing system made of ultra-high performance fiber-reinforced concrete (UHPFRC) (Fig. 1). Previously mainly used for structural applications, this material was employed here as a waterproofing layer, highlighting the potential of UHPFRC for functions traditionally assigned to polymer-based or bituminous systems.

Figure 1: Bridge overview (source Freyssinet)

Located in Côte-d'Or, between Beaune and Dole, the structure is a 100 m long single-span highway viaduct. It consists of two composite steel–concrete decks, supported by extradosed steel Warren-type trusses. Built in the early 1980s, the structure plays a strategic role on the A36 motorway while crossing a navigable canal.

This configuration imposed particularly stringent operational constraints, as neither motorway traffic nor inland waterway navigation could be interrupted during the works.

For several years, the wearing course of the viaduct exhibited recurrent deterioration. Despite repeated repair works, including an intervention in 2018, the defects persisted. In 2020, partial debonding and creep phenomena of the waterproofing–asphalt system were observed, particularly on the slow lane. These degradations made a fundamental intervention unavoidable, going beyond conventional maintenance solutions.

2. DESCRIPTION OF THE CASE STUDY

The analysis of the observed damage revealed a specific phenomenon referred to as the "radiator effect", resulting from the combination of two initial design deficiencies. On the one hand, the combined thickness of the concrete slab and the waterproofing–asphalt system was insufficient to allow efficient heat dissipation during summer conditions. On the other hand, the extradosed steel girders promoted heat conduction and thermal accumulation beneath the deck.

This thermal accumulation, combined with significant daily and seasonal temperature variations, accelerated the creep and debonding mechanisms affecting the waterproofing–asphalt system.

In light of these findings, the concessionaire decided to replace the entire waterproofing system of the viaduct, seeking a solution that would be durable, adapted to the severe thermal constraints of the structure and compatible with continuous heavy motorway traffic.

It was essential not to increase the self-weight of the structure in order to avoid any structural strengthening, which required in particular maintaining a limited asphalt thickness.

Finally, the works had to be completed within a tight schedule, compatible with operational constraints, while ensuring a high level of quality control.

Conventional waterproofing systems were assessed (liquid-applied systems, single-layer prefabricated membranes, combined membrane–resin solutions), but none fulfilled all the specified requirements simultaneously. The operator therefore turned to an innovative solution, widely applied in Switzerland but never previously implemented in France: the use of a UHPFRC overlay directly providing the waterproofing function on the deck soffit (extrados).

3. SOLUTION ADOPTED

UHPFRC is a highly technical material, characterized by exceptional compactness and extremely low permeability, providing effective protection of existing structures against aggressive environments, particularly in the presence of chloride ions.

The compactness of UHPFRC is such that it is now considered a viable waterproofing solution for bridge decks, offering the advantages of a service life exceeding 50 years, the creation of a mineral-to-mineral interface with the existing concrete substrate and a durable and reliable adhesion.

In France, the use of UHPFRC is governed by the following national standards:

- NF P18-470 – Ultra-High Performance Fiber-Reinforced Concrete: specifications, performance, production and conformity (2016);
- NF P18-710 – National Annex to Eurocode 2: design rules specific to UHPFRC (2016);
- NF P18-451 – Concrete structures execution: specific requirements for UHPFRC (2018).

The waterproofing layer, 3.5 cm thick, was made of UHPFRC with a minimum characteristic compressive strength of 130 MPa, a strain -hardening tensile behavior, achieved through a sufficient content of steel fibers. This behavior allows the material to develop multiple fine cracks without forming macro-cracks, while maintaining very low permeability, even under combined effects of traffic loads, imposed thermal deformations, and restrained shrinkage.

Current experience indicates that a steel fiber content between 3.0% and 4.0% by volume is appropriate for UHPFRC overlays designed to perform a waterproofing function on existing structures, excluding localized reinforcement required for stitching construction joints.

The selected UHPFRC exhibited a Type T2 tensile behavior (slightly strain-hardening) according to NF P18-470, with an elastic limit exceeding 7 MPa, an ultimate tensile strength above 10 MPa, an improved water porosity class (Dp+) and an improved chloride ion diffusion class (Dc+).

Given the 2% longitudinal slope of the deck, a specific mix design incorporating controlled thixotropy was developed to ensure material stability on the slope while maintaining adequate leveling capability.

4. UHPFRC PRODUCTION

The UHPFRC was produced using a dedicated mobile batching plant, equipped with a high-energy planetary mixer, calibrated weighing systems, and an automated batching unit ensuring full traceability of each batch through weight tickets.

At the start of each production shift, a UHPFRC engineer adjusted the first batch by fine-tuning admixture dosages, in order to achieve the target consistency despite daily variations in ambient temperature and humidity.

Each batch was subjected to fresh-state quality control, complemented by regular tests on hardened concrete, ensuring a high level of control over mechanical and durability-related properties.

A steel fiber content of 3.75% by volume, combined with thixotropic behavior, may lead to inhomogeneity risks, notably the formation of fiber clusters ("fiber balls") if the paste rheology is inadequate or fiber dispersion is insufficient. As such defects are incompatible with the required performance, systematic visual inspection during placement was implemented to ensure their detection and prevention.

Figure 2: UHPFRC Batching plant (source Freyssinet)

5. EXECUTION OF WORKS

After milling of the asphalt layer and removal of the existing waterproofing system, the concrete substrate was prepared by hydro demolition, in order to remove approximately 15 mm of deteriorated concrete and achieve sufficient macro-roughness to ensure optimal adhesion of the UHPFRC layer.

The substrate was then pre-wetted to saturation, without free-standing water, and maintained in this condition until UHPFRC placement.

The 3.5 cm thick UHPFRC layer was placed by standard concreting procedures, without mechanical connectors. To prevent cold joints, particular attention was paid to remarrying the material between successive batches.

Due to the thixotropic nature of the material, thickness control required the use of a full-width vibrating screed. Immediately after placement, the surface was protected by the application of a curing compound.

After hardening, the UHPFRC surface was prepared to create micro-roughness, then impregnated with a bonding primer before placing a 5 cm asphalt layer, restoring the original roadway level without increasing the structural self-weight.

To ensure continuous and uniform waterproofing of the deck extrados, the UHPFRC layer was extended over the lateral beams.

Figure 3: Leveling ruler for overlay INSTALLEMENT (source Freyssinet)

The design and execution of construction joints were identified as a key factor in waterproofing continuity. Vertical butt joints were prohibited in favor of horizontal overlaps of at least 120 mm, following principles similar to those used for prefabricated membrane waterproofing systems. The minimum reinforcement ratio crossing construction joints was set at 2.4% of the UHPFRC cross-sectional area. Prior to placing subsequent layers, the underlying UHPFRC surface was systematically cleaned and prepared to ensure adequate micro-roughness.

More generally, particular care was devoted to all singular points, including waterproofing upstands, connections to scuppers and drains, and details around expansion joint nosings.

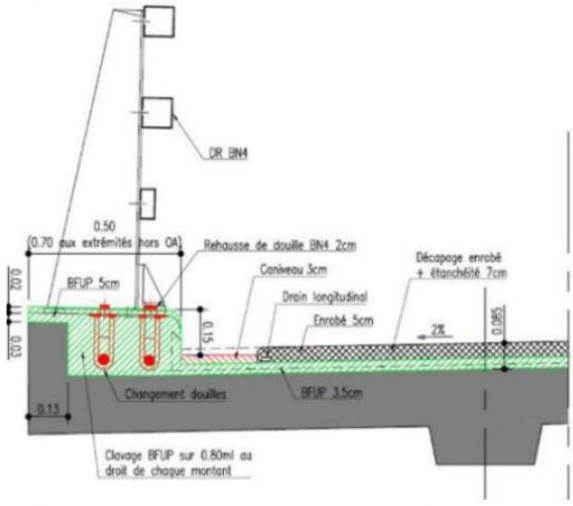

Figure 4: Overlay construction detail for waterproofing continuity (source Freyssinet)

6. CONCLUSION

The works, carried out in spring 2021, were completed within eleven weeks, with traffic maintained through mid-project traffic switching.

In total:

- approximately 150 m³ of UHPFRC were placed,
- incorporating 44 tonnes of steel fibers,
- over a deck surface area of approximately 2,500 m².

This operation demonstrates the importance of a thorough mastery of UHPFRC, both in terms of intrinsic material properties and implementation conditions, which is essential for the success of such a project.

Upon completion, the owner estimated that the service life of this waterproofing solution could be two to three times longer than that of conventional systems.

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