

IBT/ABC-UTC October 2023 Monthly Webinar Ferpectle Concrete Bridge in Switzerland Rehabilitation Utilizing UHPFRC

#	Questions	Responses
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**\*Please note that these responses are those of the Presenter and are not endorsed by the IBT/ABC-UTC.\***

**Design**

1	Can you comment on the potential benefits of combining UHPFRC with prestressing methods?	New UHPFRC structures are up to four times lighter than prestressed reinforced concrete structures. Thus, the efficiency of prestressing is significantly higher in the case of prestressed lightweight UHPFRC structures, reducing also the amount of prestressing steel.
2	How was the overhang issue resolved? Was the width reduced for calculation of the section?	In the hand calculation, we determined the effective width using traditional formulas valid for reinforced concrete structures.
3	What is the Modulus of Elasticity & Shear Strength of UHPFRC used in the design calculations?	Modulus of Elasticity: 7'000 ksi / Ultimate Direct Shear Strength of UHPFRC is about 0,7 ksi
4	What were the effects of temperature gradients on the girders?	We analysed and verified temperature effects on the modified structural system due to the UHPFRC strengthening by means of Finite Element Analysis. The results confirmed that temperature effects are relatively small.
5	Can you comment on the specifications? And can a copy be provided?	The UHPFRC standard and specifications are solely performance based. The Swiss UHPFRC standard is available.
6	Do you have other design examples where this type of design was used?	Yes, in Switzerland, several bridges have already been improved/strengthened by UHPFRC intervention with the objective to change the structural system, in most cases by closing/locking (dilation) joints.
7	Was consideration given to using non-corrosive reinforcing steel in the bridge deck?	No! UHPFRC is waterproof and crack free, no water is penetrating into the UHPFRC material. Consequently, there is no need to put so-called "non-corrosive" steel, but conventional reinforcement steel is appropriate.
8	Was there a check to see if cross-joint reinforcement might be required?	Yes, the flow of forces through working joints was analysed and sufficient resistance capacity was validated with the result that cross-joint rebars are necessary.
9	Do construction joints used during staged construction need to roughened?	Yes, the contact surface needs to be treated to become clean and micro-rough. Usually, a high pressure water jet is used.
10	What are the reinforcing steel cover requirements?	The minimum UHPFRC cover is 2/3 inch, motivated by the mechanical requirement of appropriate stress transfer between rebar and UHPFRC.
11	What is the minimum thickness of UHPFRC for reinforcement?	On slabs in buildings, a minimum UHPFRC thickness of one inch has already been realized in several cases.

12	Is UHPFRC used for deck overlays? If yes, is hydrodemolition the preferred deck demolition method?	Only tensile strain hardening UHPFRC is used for deck overlays in Switzerland (and also in the USA). Hydrodemolition is by far the preferred concrete substrate preparation on bridges.
13	What is the unit weight of the UHPFRC concrete?	The unit weight of UHPFRC is approximately 4% higher than the unit weight of traditional reinforced concrete.
14	Is there a lightweight UHPFRC concrete available on the market?	Not to my knowledge. What would be the interest? UHPFRC structures are lightweight structures and need to be optimised with respect to the lowest weight. A hypothetical lightweight UHPFRC would probably be of lower strength and thus more concrete volume would be needed.
15	Did you precamber the girders prior to UHPFRC placement?	No, the calculated deflections were sufficiently small to neglect this item.
16	Regarding the interface between the superstructure fabricated with the original concrete and the cantilever slab built with UHPFRC, the rigidity of both materials is very different. Is there a risk of concentration of forces at the interface that would generate cracks in the structure?	This item has been analysed by Finite Element Analysis, showing that the existing concrete (which significantly gained in strength over time) could resist the imposed compressive stress. No cracks were expected or observed.
17	Have you had any applications where the higher tensile strength of the UHPFRC was the main focus of the rehabilitation project, for example, to address the flexural and/or shear cracks in a structure? Can you comment on this?	In all "overlay" applications, the high tensile strength and ductility (strain hardening) of UHPFRC is necessary to avoid cracking of the UHPFRC layer, which is the basic requirement of UHPFRC application on bridge decks to guarantee durability of the original reinforced concrete structure. Also, the tensile strength of UHPFRC is considered in sectional analyses.
18	Was there any special treatment to ensure bond between stage 1 and stage 2 of UHPFRC?	Yes, the usual working joint detail had been designed to ensure the necessary stress transfer and watertightness of the UHPFRC layer on the original concrete slab.
19	Was creep and shrinkage consider in the design?	Yes, structural analysis showed that deformations due to creep and shrinkage are acceptable and can be resisted by the composite UHPFRC - concrete structure.
20	Can we use UHPFRC as a deck slab instead of just an overlay?	Yes, in cases of severely deteriorated reinforced concrete slabs (on steel structures), the entire slab should be replaced by a (lightweight) UHPFRC slab (instead of a reinforced concrete slab which has already proven its non-durability).
21	What is the UHPFRC resistance to chloride ion penetration?	UHPFRC is watertight under tensile strain up to 0,1%. No water and thus chloride ions penetrate into the UHPFRC which has been shown by several tests. Therefore, it is not possible to give a value of "chloride penetration coefficient" like it is done for concrete.
22	Did you use UHPFRC for the curb, especially since it was cast separately? Was it required for strength?	Yes, also the curbs were cast in UHPFRC, in particular for durability reasons since they will be exposed to high amount of deicing salts. (Reinforced concrete would never be durable !)

23	How was the abutment was widened? Is it acceptable to use black reinforcing steel in the UHPFRC layer? Is black reinforcing steel typically used in bridge decks in Switzerland?	The abutment was not widened. Structural analysis showed that torsion due to the wider deck would be carried by the stiffened monolithic structure. In Switzerland, traditional reinforced concrete decks are built using black reinforced steel, and durability is supposed to be guaranteed by thick rebar cover and waterproofing membrane on the reinforced concrete deck.
24	In Switzerland, are deicing salts used?	Yes, we still have cold climate in winter and use significant amount of deicing salts.
25	In UHPFRC, are air entraining admixtures used? If so, do the steel fibers affect the ability of the mix to entrain air?	There is no need to add air entraining admixtures to UHPFRC. Since there is no free water in UHPFRC, the frost resistance is much higher than required for common applications. UHPFRC is not a concrete!

## Construction

26	Caltrans has used UHPC in small batches to splice precast elements. What different methods are used when batching large quantities of UHPFRC?	This is a matter of logistics related to machines, tools and manpower. UHPFRC-experienced contractors (in Switzerland) know how to adapt their logistics as a function of the quantities of UHPFRC to be cast. This issue is similar to traditional concrete construction.
27	How was the non-redundancy of the bridge handled during construction?	In Switzerland, we make no issue of redundancy for double T sections. There was no particular consideration.
28	What did you do to ensure the bond between the old concrete and the UHPFRC?	The well known process needs to be followed precisely: 1) hydrodemolition of the concrete substrate to achieve a clean and rough concrete surface; 2) moist surface of concrete substrate just prior to UHPFRC casting; 3) appropriate casting of UHPFRC and adequate curing. By successfully realising this procedure, sufficient bond is obtained, which is controlled by pull-off tests usually showing fracture in the concrete substrate and not at the interface.
29	Can you describe curing needs for control of shrinkage cracking considering the high early strength of the UHPFRC?	Curing of UHPFRC is similar to curing of concrete: 1) immediately after casting, application of a curing compound, 2) followed by placing a plastic foil or spraying a curing wax or thermal isolating mats in case of cold temperatures, 3) mainting this curing during the required number of days as a function of the outside temperature.
30	Was the additional depth deck removal at the abutment locations also accomplished with Hyrdodemolition?	Yes, all concrete removal was done by hydrodemolition, which is cheapest (in Switzerland).
31	How many days of curing is required to gain adequate strength to open the bridge to traffic?	This depends on the required strength and hours before opening to traffic. It is possible to open the UHPFRC layer to road traffic 20 hours after UHPFRC casting.

32	How was the strength determined prior to opening the bridge to traffic at the completion of Stage 1?	UHPFRC curing duration of four days should be achieved. It was known prior to establishing the construction programme that the UHPFRC will have a sufficient strength to open to traffic after curing. In parallel, the UHPFRC strength was controlled during work by conventional UHPFRC material testing on specimens.
33	What is suitability testing?	As a suitability test, the contractor had to realize successfully UHPFRC casting on a concrete slab element with the slope of 7% corresponding to the slope of the bridge slab. This was also a training method for the contractor's team. (note: suitability testing is similar to a mock-up)
34	When casting stage 1 over two shifts, where was the construction joint located? How was it constructed if UHPFRC is self consolidating?	There are standardized working joint details that had to be installed by the contractor. These UHPFRC working joints are known to function properly.
35	Were there differences in curing times between the deck and abutment diaphragms when cast monolithically?	No

## Cost

35	What is the unit cost of the UHPFRC concrete when compared to standard concrete?	UHPFRC material cost is about 0.4 US \$ / pound, in Switzerland. This price should not be compared with the price of concrete as the performance of the two materials is completely different.
36	What was the total construction cost of the project?	Some relevant cost values: Cost of UHPFRC works including surface preparation, formwork, casting, curing: UHPFRC layer on concrete substrate : 25 US\$ / sq.ft. new cantilever with curb: 3'000 US\$ / cy.yd. material cost: 0.40 US\$ / lb or 1'800 US\$ / cu.yd.
37	What is the cost of the UHPFRC concrete per cubic meter in Switzerland?	See Answer 35
38	What was the square foot cost for the project?	See Answers 35 and 36

## Other

39	Could you please give us more information about the purpose of using optical fiber for monitoring?	The motivation for the monitoring is purely scientific: to better understand the real change in stiffness of the bridge structure after UHPFRC intervention and to compare with the situation before. Also, we would like to improve our material and structural models for structural analysis when UHPFRC is involved, based on in-situ measurements.
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40	Regarding the bond, did you do any tests of bond after a longer time period when the structure was dynamically loaded?	This topic was investigated in research projects consisting of fatigue testing of UHPFRC-concrete composite slab-like elements. No debonding at the interface was observed. Finally, failure occurred in the concrete substrate, not at the interface between UHPFRC and concrete.
41	What is the address of this project? So we can see it on Google Maps. It looks beautiful.	The Ferpecle Bridge is located in the village named "Les Haudères" in Switzerland. The bridge leads over the Ferpecle River.