December 2017 ABC-UTC Webinar Featured Presentation: Accelerated Bridge Strengthening using UHPFRC		
Q&A Session: Questions		**Responses**
#	**Design**	
1	Can the UHPFRC mix designs incorporate low shrinkage admixtures? Also, is the curing process any different?	Low shrinkage admixtures can be added; they are favorable but not really needed because of the tensile hardening of the UHPFRC. Curing is indispensable in all cases (= basic principle) !
2	Please discuss the shrinkage characteristics of UHPFRC when applied as such thin membranes. Are there any pitfalls to avoid?	The relatively thin UHPFRC layer, monlithically bonded to the concrete substrate, builds up relatively high tensile stresses of about 1ksi, due to shrinkage (autogenous and thermal). Since UHPFRC has a tensile strength higher than 1 ksi and a significant tensile hardening behaviour, these eigenstresses (or eigen-deformations) are resisted without crack formation. The pitfall to avoid is: not to use UHPC with a fiber content less than 3vol.% (fiber slenderness >65), see also slide 3 of my webinar presentation.
3	Is it possible to strengthen a reinforced concrete arch bridge by placing a layer of UHPFRC on top of the existing concrete ribs?	I assume the arch consists of 2 or more ribs. Yes, it is possible to increase the sectional and buckling resistance of the arch rib casting a layer of UHPFRC, probably incorporating some rebars, around the existing RC rib … and in a formwork. (Remark: soon, sprayed UHPFRC will be available which would significantly simplify casting of UHPFRC around the arch rib.)
4	What is the best mix design of UHPFRC to be used in shotcrete to strengthen the bridges, tunnels? How can achieve thixotropic UHPFRC?	Sprayed UHPFRC is currently under development and will soon be available ! It is too early to propose some mix design for sprayed UHPFRC; it is however likely that the mix will be similar to the one used for conventional casting. Sprayed UHPFRC will be very effective for tunnel linings ! // Thixotropic fresh UHPFRC is obtained by adding an additive to the fresh UHPFRC mix, f.ex. in the form of small PVA particles of a certain quantity (to be found out by trial/error).
5	How do you approach the different Young Modulus E of Concrete , UHPFRC and Steel? The existing concrete also is already loaded with self weight. When placing an overlay, how is the shear (friction) in between the layers taken into account?	The modulus of elasticity of UHPFRC is about 30% higher than the one of concrete. When calculating stresses in composite sections, the various moduli of elasticity of the materials (UHPFRC, concrete and steel) are considered according to the basic rules. // Since the (UHPFRC - concrete) interface bond strength is usually higher than the tensile strength of the substrate concrete, the shear stress at the very interface is not determinant. (Remark: Because of the bond, there is no relative displacement and thus friction between the two layers.)

6	When repairing a bridge deck with UHPFRC for waterproofing, what can be done to limit the strain to 1/1000 in the case that the loads would take it to higher strains?	All (reinforced concrete) structures shall fulfill the requirements of codes in terms of structural safety (resistance at ultimate limit state ULS). In practice, this means that the structural elements are subjected to deformations under service conditions (limit state of serviceability SLS) of traffic loading smaller than 1/1000 which is verfied by structural analysis. If, exceptionally, the strain at SLS due to traffic laoding is larger than 1/1000, then the thickness of the UHPFRC layer and thus the stiffness of the structural element (strengthened deck slab) needs to be increased or an additional measure (like water repellent agents or plastic membrane) needs to be taken in order to guarantee water proofing of the element (deck slab) exposed to chloride ions and water.
7	Can UHPFRC be used for repair of structural girder sections, bearing ends?	Yes, since UHPFRC has significantly higher mechanical properties than any repair material or concrete that are (still) applied. UHPFRC is in particular of interest in case of exposed details (high concentrated loads and severe environmental exposure). Hence, UHPFRC can and should be used for all kinds of "repairs", and in particular since it will be soon possible to spray UHPFRC. (You can omit repair mortars as they are more expensive and show lower performance than UHPFRC.)
8	With no theoretical shrinkage, can you shed light on the methodology utilized to determine control joints locations, frequency.	What do you mean by "no theoretical" shrinkage ? UHPFRC shows shrinkage but it can be "handled" without crack formation because of the relatively high tensile strength and strain hardening deformation capacity of the UHPFRC. // What are "control" joints ? in principle, a UHPFRC layer can be continuously cast on a substrate (without any joint) because of the aforementioned properties.
9	UHP(FR)C is normally a patent product as Densit, Durocorit or could one self-design a mix with a fine grade aggregates, additives, etc., or is this option too time consuming in test trials?	No, UHPFRC is not or no longer a patent product. You can fabricate your own UHPFRC mix; you can find easily UHPFRC mixes on the internet. Of course, the development of such an own mix using local materials requires some effort and time … but look at your (cost) benefit !
10	Is UHPFRC a viable option for a bridge deck overlay? Would the benefits of material only be applicable if it was the entire deck?	It is most efficient (also in terms of costs) to cast a layer of UHPFRC on the entire bridge deck ! In this way, durability and thus long future service duration of the bridge is obtained. See slides 6 to 9 and 13 of my webinar presentation; clear project objectives, when enhancing existing bridges, are most important !
11	How was the material(s) specified - performance or perscriptive specification?	The Swiss Standard SIA 2052 is used as specification, see slide 10 of my presentation.
	Fibers & Rebar	
12	Please discuss the relative contributions of the fibers and the cementitious material to the success of the technology.	Fibers provide the ductility and strength to UHPFRC; the cementitious matrix (consisting of powders and small particles) provides - among others - the compactness and thus waterproofness of the UHPFRC, leading to the high durability.

13	Fibers or rebars versus fibers and rebars?	Clearly: "fibers and rebars" - the fibers provide ductility and crack-free UHPFRC under service conditions, and the rebars are an effective additional reinforcement to significantly increase the ultimate resistance of UHPFRC elements.
14	Do you reduce the existing rebar area to take account of existing corrosion? How do you ensure the bond? Applied to bottom, how?	In principle, rebar area reduction due to corrosion always needs to be considered ! Bond between steel rebar and UHPFRC is high if the corroded rebar is cleaned/sandblasted. // Fresh UHPFRC can also be applied to the bottom surface of a concrete substrate … using a formwork.
15	Have you considered PVA fibres in the UHPFRC mix ?	No, PVA fibers are too "soft", the modulus of elasticity of ordinary PVA fibers is significantly smaller than the one of steel, … and thus PVA fibers are only activated when deformations are high, actually too high for structural elements ! Currently, we are conducting tests with synthetic fibers with relatively high modulus of elasticity but the mechanical performance is not as good as for UHPFRC with steel fibers.
16	In reinforced concrete the bars are installed in the designed direction and location. How can we make sure fibers are not concentrated in one side of the element and on the other side we don't have enough fibers to bring tensile resistance?	Fiber concentration effects in fresh UHPFRC are due to insufficient mixing of the fresh UHPFRC ! The presence of rebars cannot affect fiber concentration. Rebars can however affect the fiber orientation, depending on the possible flow of the fresh UHPFRC material around the rebars. In most cases, this fiber orientation effect does not significantly affect mechancial properties of the R-UHPFRC, in particular when using strain hardening UHPFRC containing at least 3vol% of fibers (with a slenderness of >65).
17	Did the reinforcement bars used on the Chirron Viaduct have any corrosion resistance (epoxy, galvanizing, etc.)? The reinforcement appears to be plain reinforcement with some surface corrosion.	There is no need to use rebars with improved corrosion resistance because the surrounding UHPFRC provides a nice alcaline environment (and thus passivation of steel) and protects the rebar from ingress of water and chloride ions. Yes, we used "plain" steel reinforcement on the Chillon viaducts and all other applications ! (Here is another advantage of UHPFRC: you can use low-cost rebars !) see also answers to questions 30 and 32.
18	The question is about when not using rebars in UHPC.	For structural applications, the use of steel rebars is most effective when the structural resistance needs to be increased significantly. In case of using UHPFRC for waterproofing (durability) purposes only, there is no need to add any rebars. See slide 8 of my presentation.
19	Possibility of using UHPFRC mix with High Fiber Volume Fraction, say 5%, instead of R-UHPFRC?	We casted already UHPFRC mixes with 6Vol% of fibers … but it is more effective (also from the viewpoint of costs) to add single steel rebars to the UHPFRC layer in order to increase the ultimate resistance of structural elements.

20	What is the minimum coverage of rebar? Also, since this is reinforced with steel fibers, is there rusting concerns on the surface?	The recommended rebar cover is 10mm (at bit less than 1/2 inch). // Fibers sticking their nose at the very surface are produce small corrosion dots. These "freckles" are hardly visible (even on chloride ion exposed UHPFRC surfaces) … but may nevertheless pose an aesthetic problem. However, these corrosion dots at the surface do not present any durability issue (as no water can ingress the UHPFRC).
21	At sagging area of the bridge, no longitudinal rebar installed for installation of transversal reinforcements?	At sagging zones there is no need for longitudinal rebars since the fibers guarantee the transversal reinforcement. Transversal rebars may be installed by using single rebars as space holders and positioners.
22	Slide 7: why using reinf in top layer of UHPFRC ? Also, the cover over the top reinf mat in conventional conc is not adequate if you consider the joint between the two materials.	The rebars in the UHPFRC layer contribute significantly to increase the structural resistance. Like all over Europe, I assume that in the US truck weights increased over decades are road traffic loads are nowadays much higher than assumed for the design; consequently, there is a need to increase the structural resistance of existing bridges. // Specifications regarding rebar cover steming from conventional reinforced concrete codes do not apply in the present case, since UHPFRC is a waterproof layer.
	Construction	
23	Are there issues with sealing the formwork for the UHPC pours?	Care is required when sealing edges of formworks in order to avoid leaks and the formation of "mustache" consisting of fibers.
24	How difficult is it to place UHPFRC in hot weather, ie., in Florida?	No particular difficulty for temperature until 35°C (95 Fahrenheit); for temperatures >95F, the workability of the fresh UHPFRC needs to be adapted by chemical additives. The competent UHPFRC suppliers knows what to do in case of such high temperatures !
25	How does the quality (surface preparation and damage/deterioration) of the ex. deck surface affect the bond to the UHPFRP?	Surface preparation by high pressure water jetting (hydro-demolition) is most important; in addition, before casting the concrete substrate surface needs to be wetted just before casting the UHPFRC. If these two simple requirements are respected the bond between the UHPFRC and the concrete substrate is perfect, i.e., the tensile strength at the interface is higher than the tensile strength of the substrate concrete.
26	What are the cold temperature limitations of UHPFRP and how can they be mitigated?	Casting of UHPFRC at low temperatures needs to follow the same rules as for concrete.
27	Construction in the summer time with such reduced water cement ratio poses an issue with the factor of heat. Comment?	You probably refer to the "summer hole" (in compressive strength) of concrete ? There is no issue like this with UHPFRC ! Please see also answer to question 24.

28	Can UHPFRC be milled or otherwise treated to enhance friction on roadway surfaces?	Yes, the hardened UHPFRC surface can be milled. The resulting surface however shows discovered fibers and will get a "rusty" color. That's why I recommend to process an imprint on the fresh UHPFRC surface in order to obtain the required profile for skid resistance; it is also possible to spread pea gravel on the fresh UHPFRC surface to obtain skid resistance. These finishing methods require preliminary testing as they depend on the workability of the fresh UHPFRC.
29	How much time is required for a typical deck re-surfacing with UHPFRC and factors affecting schedule? Lessons learned?	This depends on the logistics and equipments … and of course of the surface to be cast ! For example, it is possible to cast about 100 cubic yd of fresh UHPFRC per day using a casting machine, see 15, 18 and 19 of my webinar presentation. // The most important lesson is simple and self-evident: good preparation and precision in performing the works is key for success ... obviously, this applies to all (construction) works and projects !!
	Durability	
30	What is the durability for UHPFRC?	Excellent, because of the optimized highly compact matrix of UHPFRC and the consumption of all water during hydration. UHPFRC has no capillary pores and is dense, thus avoiding penetration of water and chloride ions. Several studies in the literature confirm the excellent durability of UHPFRC.
31	How long has UHPFRC be used in the bridge projects? What's the long-term performance?	UHPFRC has been used in bridge projects for 20 years; the long term performance is excellent because of the high durability; see answer to question 30.
32	The description states an overlay of UHPFRC addresses problems such as rebar corrosion; please explain how. Similar question: How does it perform in a chloride-rich environment?	In case of active rebar corrosion showing damage by spalling of the cover concrete, the rebar is discovered and the RC element reconstituted using UHPFRC (instead of repair mortar); the rebar is repassivated and corrosion is stopped, see slides 25 to 28 of the webinar presentation. In the case of initial corrosion activity (no visible signs) the UHPFRC layer provides a waterproofing barrier that stops further ingress of humidity and the corrosion process is slowed down and finally stopped due to drying of the RC element.
33	Does UHPFRC have a function of waterproofing? Can this technology be applied to parking garages?	UHPFRC is waterproof and thus also is a barrier for chloride ions, see answers 30 and 32 above. The UHPFRC technology has thus a high potential to enhance parking garages.
34	Is UHPFRC suitable for ASR repairs?	It depends on the objective of the intervention. If the ASR can be slowed down by reducing the concrete humidity by drying, then a layer of UHPFRC will be effective since it stops the ingress of water into concrete which is needed to "aliment" the ASR. In the case of advanced ASR and multiple large cracking of the concrete, it will probably too late and no repair method will help effectively ...

35	Claiming that a UHPC overlay is waterproof seems to be bold statement with very little field time/data. What is the basis for claiming it is waterproof? And for how many years can one expect an overlay to be waterproof in a climate with a high number of freeze-thaw cycles?	The waterproof UHPFRC layer statement applies for certain conditions, see my webinar presentation. (It does not apply to some of the UHPC materials, f.ex. those with less than 3vol.% of steel fibers.) UHPFRC is waterproof and thus durable because of the compactness of the material and the absence of communicating capillary pores, see also answers to questions 30 and 32. Since there is no water ingress into UHPFRC, freeze thaw damage can be excluded (as this damage occurs only in materials (like concrete) that absorb water close to the saturation level). Please refer also to several papers in the literature about UHPFRC durability validation testing. And finally: with every year we are getting even more evidence that UHPFRC layer provides the expected durability also in the field ....
36	Bridge deck deterioration is accompanied by deterioration of steel stringers that support the deck. Are there any cases of using UHPFRC on the lower sides of bridge decks as well?	Depending on the given case, the lower side of the bridge deck may remain in its condition that will stabilize once the concrete can dry thanks to the waterproofing effect of the UHPFRC layer on the upper side of the deck. // Steel stringers are rehabilitated more effectively using conventional methods. // It is possible to cast (and spray in the near future) UHPFRC also on the lower side of a deck; however, it is more difficult.
	Costs	
37	What is the cost per CY?	In Switzerland the cost of UHPC (with 3vol.% of steel fibers) is 1'900 US dollars per yd3; please consider also indications given on Slide 11 of the webinar presentation.
38	What is the cost per square foot of deck area?	In Switzerland the cost per square foot of bridge deck surface of a 1 1/2 inch layer is about 25 to 40 dollars, depending on the size of the total surface; see also slides 11, 16 and 23 of the webinar presentation.
39	Cost comparison between UHPFRC and Conventional Concrete Structure?	I assume you refer to new structures. From the already built and soon to be built new UHPFRC structures that I was involved in, the cost of the UHPFRC structure was similar or smaller than the alternative design using reinforced concrete. This is because UHPFRC structures are lightweight structures, can more easily be prefabricated and transported and handled on the construction site, and need smaller foundations ... and construction time is shorter. In addition, material cost is nowadays relatively small compared to costs for workmanship and machines. Of course, the design of a UHPFRC structure needs to exploit the specific properties of UHPFRC, this is of course most decisive !! (just replacing concrete by UHPFRC leads to a bad and expensive project !)
	General	
40	Claims resulting from ABC, traffic and bad weather... how resolved in a general sense?	UHP(FR)C casting is robust with respect to site-conditions: the fresh UHPC is cast at low and high temperatures and has about 2 hours of "open time"; no particular protection is needed. UHPC should not be cast under heavy rainfall !

41	Has it been used in the US?	*Ben Graybeal, FHWA:* In the US there have been 2 overlays completed to date, one in Iowa and one in Delaware. Also, one is scheduled for mid-2018 in Iowa and others are being discussed in various States.
42	Is UHPFRC currently available from suppliers in the U.S.? Are example specifications available?	In the U.S., the company LafargeHolcim supplies UHPFRC (mostly used for joint fillings). By now, there may be some smaller companies developing their UHPFRC … since the UHPFRC technology will become a new technology in the near future, also in the US. Regarding specifications, I prepared one for one DOT and I could send you the Standard we use in Switzerland, see slide 10 of my webinar presentation.
43	Were these demonstration projects?	In Switzerland, demonstration or pilot applications were performed more than 10 years ago. Nowadays the UHPFRC technology to enhance existing concrete structures is well established.
44	This seems to be a great application to enhance and strengthen ppc box beam structures, however too often the agency waits too long and prestressing or post-tensioning strands have already been compromised so badly that we are left with no choice but to replace.	Here you are pointing the finger to a general problem ! It depends on the given case of advanced deterioration of a bridge to answer whether the UHPFRC technology could provide a cost-effective enhancement in such cases.
45	Love that comment - Reinforced Concrete is actually a very primitive material!	It is about time that civil engineers review their evaluation and perception of the performance of concrete structures.