ABC-UTC 2022 In-Depth Web Training: Non-Proprietary Ultra-High-Performance Concrete (UHPC)		
#	**Questions**	**Responses**
	Module 6: The Next Hurdle for UHPC – Structural Design Guidance and Specification Development	
1	Are there case studies and guide specifications available for bridge repair and rehabilitation using UHPC?	Yes. FHWA recently published FHWA-HRT-22-065 *Design and Construction of UHPC-Based Bridge Preservation and Repair Solutions* . It is available for free on the web; use your web browser to search for the report number or title. A link to this publication is also provided in this archive.
	Questions during Module 6	
2	In terms of the UHPC structural design guidance, how much progress has AASHTO T-10 made? Is the framework in place? Will they be balloting a document soon?	AASHTO T-10 has been making good progress toward their goal of producing a Guide Specification for Structural Design with UHPC. FHWA's researchers developed and drafted guidance for their consideration, and T-10 chose to use this draft guidance as the framework upon which they will build. It is possible that the AASHTO Committee on Bridges and Structures (CBS) will ballot a UHPC Guide Specification in 2023.
3	What's the next hurdle? It's clear that UHPC structural design guidance is a necessary step on the path toward UHPC structures. Is there anything else that needs to happen before we start seeing UHPC bridges, etc.?	A guide specification on structural design is a critical step forward. This will allow engineers and owners to have increased resources and comfort when designing UHPC-based solutions. Construction/fabrication guidance is also needed, allowing UHPC-based solutions to be built with less risk and more competition. Once design processes and construction/fabrication guidance are in place, compelling UHPC-based solutions will begin to become more commonplace.
4	Can any damage to UHPC overlays be repaired with regular concrete if UHPC is not available for small top of deck repairs?	Interesting question. Conventional concrete is not likely to be a good long-term repair for a damaged UHPC overlay. UHPC overlays tend to be relatively thin, often around two inches. It is unlikely that a conventional concrete overlay would perform well as a 2-inch thick overlay. If a UHPC overlay were to be damaged, and if a replacement UHPC-based repair was not available, I would suggest that a specialty concrete patching material should be considered.

5	In the photo showing the tensile test, why is the crack not normal to the direction of applied tension? The diagonal crack seems to indicate some sort of shear slip? Can you please elaborate on the test results?	In a direct tension test of a strain-hardening fiber reinforced concrete, many tightly-spaced cracks form prior to the occurrence of localization. Localization occurs when fibers begin to pull out of the matrix. The fiber pullout will occur in the fibers that are highly stressed relative to their embedment length. Individual fibers that are pulling out might be crossing different cracked planes. As the localization process progresses, individual local crack widenings will begin to join together to form a mechanism where one dominant crack appears. This crack may or may not align with one of the original tightly-spaced cracks that existed prior to localization. The photo in the presentation shows a crack that looks somewhat "diagonal"; in AASHTO T 397 UHPC direct tension tests, we see localization cracks that are horizontal, diagonal, U-shaped, and even Z-shaped.
6	Do the shear connectors from the precast concrete beam to the deck require any special design considerations due to the two different concrete compressive strengths of the deck and the beams?	Interfaces (such as the location between a deck and a girder) should be designed based on the resistance mechanisms provided by the materials at and crossing the interface. UHPC is generally stronger and stiffer than conventional concrete; it also may be smoother. In simple terms, the composite connection should be designed considering which material is the substrate, the roughening provided to the substrate material, the friction coeffient between the materials, and the reinforcement crossing the interface.
7	Smaller cross sections would produce larger beam deflection. Can you shed some light on the UHPC beam deflection characteristics?	UHPC cross-sections would likely be slimmer than those commonly used with conventional concrete. However, we might also use more reinforcement (e.g., 0.7-inch-diameter strands at 2-inch spacing); also, the elastic modulus of UHPC is approximately 2x that of conventional concrete. All things considered, optimal solutions using UHPC will likely have lesser flexural stiffness and thus structural solutions will likely express more deflection per equivalent span length. If this level of deflection is problematic, the designer can easily change the proportions of the section to address the issue.

8	How conservative is the recommended shear equation for UHPC? Is it more reliable at predicting behavior than equations for NWC (normal weight concrete)?	The proposed beam shear formulation relies more heavily on engineering mechanics (and less heavily on calibrated empirical relationships) than common conventional concrete formulations. As such, it is reasonable to assume that the prediction of the capacity coming from the "concrete" part of the resistance will be more accurate. Separately, in an LRFD formulation, the conservatism in the capacity calculation comes from the application of a reduction factor (or safety factor) to ensure that the predicated capacity is less than that which will likely be provided in the structure. Since there have been relatively few physical tests of UHPC beam shear behavior, engineering judgement will be used to ensure that an appropriate reduction factor is selected. With time (and lots more experimental tests), the reduction factor may be adjusted.
9	Can any lab do the new tension test? Are there special fixtures required?	The short, simple answer is no, this test is not one that any lab can easily run today. Yes, special fixtures are required. The test requirements are very similar to those required for the tension testing of metals. The testing machine needs to operate under displacement control, and fixtures to grip the test specimen are required. The AASHTO T397 test directly measures the tensile stress-strain response of a UHPC-class material; this response is a critical part of understanding the behavior of the material, a key step in appropriately designing structural components.
10	If fibers are failing by pullout along a somewhat random plane relative to the applied force, how are you determining the theta angle denoted in the shear equations?	The UHPC shear resistance model is based on the same engineering mechanics fundamentals that form a starting point for the Simplified Modified Compression Field Theory that is used in the current AASHTO LRFD for conventional concrete design. A membrane element is assumed to exist in the web, then compatibility equations describing stress and strain are derived. Via engineering mechanics (and mathematical calculations) we solve for the angle theta. (Normally theta is thought of as the angle of inclination of the diagonal compressive stress, but in the context of UHPC it is more intuitive to think of it as the angle of the localizing crack across which the principle tensile stress acts.)

	Question during Module 4	
11	FHWA is recommending UHPC for partial-depth overlays. How are they overcoming the boundary stress and electro-chemical reactions?	Rehabilitating existing, deteriorated bridge decks is a challenging situation. The decks commonly require rehabilitation due to chloride contamination in the concrete, reinforcing bar corrosion, delaminations, etc. Full deck replacement is certainly an option, but partial deck replacement is generally far less intrusive and far less costly. The important question becomes: "Is a partial depth deck replacement a cost effective solution?" For a partial depth deck replacement to be effective, it needs to slow or stop the continuing deterioration of the deck (e.g., rebar corrosion), and it needs to compositely bond to the remaining "original" deck. FHWA researchers have looked at both of these topics. We are encouraging the use of practices that provide a strong likelihood of good bond between the substrate concrete and the UHPC overlay. We are encouraging the use of practices that slow the electro-chemical reactions. And UHPC inherently offers a level of resiliency that should decrease the chance that minor additional distress in the substrate concrete will manifest as an overlay failure. See FHWA-HRT-22-065 and FHWA-HRT-22-087 for more information. Links to these publications are also provided in this archive.