ABC-UTC July 2023 Research Seminar: Design Guidance for UHPC Connections of Precast Girders Made Continuous for Live Load		
#	**Questions**	**Responses**
	Pre-Seminar Questions	
1	Do you have any insight on current unit costs for UHPC? We are currently using around $5,000 per cubic yard in Pennsylvania.	It is currently in that same range of $5,000 per cubic yard in Oklahoma. The non-proprietary UHPC mentioned in the presentation is in the range of $800/ cubic yard for the materials only.
2	Can this concept be applied post-construction?	We tested the idea of a post-construction retrofit with half-scale beams in the laboratory and had positive results. It is important to consider the impact of the additional restraint and negative moment on the prestressed beams near their ends as we saw increased shear cracking in our testing. To my knowledge, it has not been tried in the field for bridges not originally designed for continuity. The Oklahoma implementation project looked at replacing an existing conventional concrete connection with UHPC.
3	Can you comment on the performance of the example project based on the current inspection reports?	We have not had the opportunity to see the inspection reports completed since retrofit for the Wolf Creek bridge, but pictures taken by our team and the Oklahoma DOT engineers indicate no deterioration.
4	Have you studied using UHPC closure pours to restore continuity between beam ends where existing closure pours are ineffective?	For the Oklahoma implementation project described in the presentation and in the December 2022 ABC-UTC Monthly Webinar (https://abc-utc.fiu.edu/mc-events/uhpc-connections-for-accelerated-restoration-of-live-load-continuity-oklahomas-u-s-183-412-bridge-over-wolf-creek/?mc_id=797), we did a load test of cracked contintuity connections and then the UHPC retrofit. We observed a change in behavior between tests indicative of improved continuity.

5	How does the durability/performance of UHPC full continuity connections compare to UHPC link slabs? Would design guidance be similar?	The durability of the two connection types should be similar since both eliminate a potential joint in the bridge deck. The design would be similar, but has some differences since the link slabs are intended to allow rotation and behave as simple spans while the continuity connections are intended to transfer moment. Induced restraint moments are also not a concern for link slabs while they are for continuity connections.
6	How can you determine the prestress degree of UHPC?	We did not examine prestressed UHPC sections in this research. The connections were non-prestressed.
7	How variable is the UHPC mixture, and what factors will affect the mixture of UHPC?	Most proprietary UHPC mixtures are very consistent since they use prebagged materials, but they can be affected by temperature and admixture dosage. The non-proprietary UHPC mixture has been pretty consistent, but it can be affected by temperature, variation between shipments of raw materials, and variation in admixture dosage. We talk about fiber segregation in the presentation, which is also something that can be encountered.
8	Did you use full-sized or scaled beams in your testing? Does the added base skew the results? Also, did the hooked strand test have a sudden failure?	The beams tested in the laboratory were approximately half-scale. It is possible that using a half-scale beam but full-size strands and typical joint width could have affected our results. The field implementation in our past research was on a full-scale bridge. We generally did not see a sudden failure for the hooked strand specimens.
9	What are the seismic performance and constructability issues in high seismic zones?	We did not examine seismic performance in this work, but the high steel requirements in seismic zones could lead to concerns with placement and consolidation.
10	How can this approach be used for precast UHPC girders?	There should not be much change in design for connections of UHPC precast girders compared to those designed for conventional concrete girders.
	Questions during Seminar	
11	How does the continuity/discontinuity affect the shear behavior and design?	We did see additional shear cracking likely due to the restraint of the very stiff UHPC connection. This shear demand should be considered in the design of the shear reinforcement in the girders.

12	How did you remove the joint material in the test bridge, without damaging the existing rebar/strand?	The joint material was removed by the contractor using handheld demolition equipment/jackhammers. It is likely that some reinforcement was damaged, but we were not given access to inspect all joints. For those we did inspect, there was little damage.
13	Did joints at the test bridge crack from load on the diaphragm or from corrosion-induced spalling?	The original continuity connections on the test bridge most likely cracked due to restraint moments that formed over time due to creep, shrinkage, and temperature effects. There was no evidence that corrosion was a contributing factor.
14	For retrofit of the existing girders, would we have the "hooked strands" for the positive moment connections?	If the girders were originally designed as simply supported, hooked strands would not be present. In our experimental testing of "retrofit" connections, we used rebar studs epoxied into the exisiting girders, straight bars extended across the gap between girders, and a partial encapsulation of the girder ends. Hooked bars could also be used.
15	Did you have any sudden failure? With the high-strength materials used, did you look into failure because of aggregate interlock failure in the beam?	We did not see any sudden failure in our testing. This is partly due to the type of loading that we used. If the loading was sustained rather than hydraulic, some of the bond failures would result in a sudden collapse. We did not consider the effects of aggregate interlock in the beams.
16	For the new structures, is the use of the UHPC connection between new prestressed precast concrete girders a cost-effective method compared to a conventional concrete connection?	We do not have enough information to give a definitive answer at this time. If indeed the connection does not need to be replaced in time due to simply using UHPC, then yes. However, we do not have long-term data nor did we do an extensive comparison to potential alternative designs using conventional concrete.
17	How was it decided that only two strands should be extended out of the girder ends, and are they capable of developing moments greater than the cracking moment?	The decision to use two strands was made based on constraints of the equipment used for girder construction. If designed using conventional concrete, additional reinforcement was required to develop moments beyond the cracking moment, but the strands embedded in UHPC were able to develop moments exceeding the cracking moment.

18	The deck slab width seemed not to be considered. Do you think this might affect the end conclusion?	An equivalent deck section was designed that had a reduced width, but increased depth to generate the same compression force. The reduced width led to less cover and spacing between bars than would be used in a real structure, which did affect the bond behavior of the lap splice.
19	A research study done in Louisiana showed that the thermal gradient had an important effect on stresses in the detail. Why did you not consider that?	We did not consider any particular source of induced positive moments in our research, only the resulting capacity and performance of the joint details. Temperature gradients are an important source of induced moments.
20	What are the constraints for formwork for UHPC placement for live-load continuity in rehab situations?	Formwork should be watertight and designed for full hydrostatic pressure based on the unit weight of the concrete. Sufficient bracing is needed to ensure adequate formwork performance.
21	Continuity to transfer live load between girders can be achieved by using conventional concrete, not just using UHPC as the speaker discussed. Conventional concrete diaphragms to make the girders continuous for live load can be cast at the same time as the bridge deck, but for UHPC connections, will there need to be two separate placements: UHPC and then conventional concrete?	This is true. Most likely there would need to be a separate placment for the UHPC connections. We believe there is some flexibility in the placement sequence depending on the specific deck design. UHPC connections would also potentially make sense if the bridge utilized precast deck panels.
22	Do you know of any UHPC application experiences in northern remote areas with low winter temperatures, but with construction done in the summer?	I do not, but the individual listed at Question #25 below appears to have experience in this area.
23	Improving the performance and capacity of the detail will only increase the demand on the girder ends. Cracking of prestressed concrete girder ends has long-term effects including shear capacity. Can you comment on this?	This is true. The girder end region capacity is an important consideration for designing connections for live load continuity. The girders must also be designed to withstand the shear and moment induced on them by the connection.

24	The values of the modulus of elasticity between the ordinary concrete and UHPC could be large. Would the difference between the moduli be an issue at the interface between the girders cast with ordinary concrete and the continuity diaphragms cast with UHPC when it concerns the creep, shrinkage, and temperature?	We did not specifically consider this issue in our research. However, it is possible that the difference in stiffness could be an issue at the interface. Some of the experimental observations potentially indicate that the difference in stiffness led to additional cracking in the girders.
25	I have been involved with a project using UHPC concrete for a dam in Northern Ontario, in a very remote region.	This appears to be an answer to Question #22.