| ABC-UTC August 2023 Monthly Webinar: First U.S. Bridge with 100% UHPC Superstructure - Michigan's Bricker Road Bridge over Quackenbush Drain | | |
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| **#** | **Questions** | **Responses** |
| | **Design** | |
| 1 | Where did you turn for guidance concerning design and implementation of a nonproprietary UHPC mix design? | We used first principles and also the draft FHWA design guide. |
| 2 | At this site, was there a need for a shallow superstructure due to hydraulic considerations? | No, this was a drain with no such requirements. The shallow structure came from the use of UHPC. The units were 2/3 lighter than the traditional option. |
| 3 | How did you estimate/assess the service life of 150 years? | We estimated the service life based on freeze thaw and chloride penetration material tests. Actually, the estimate is for much longer, but it seemed prudent to go with a smaller number. |
| 4 | In terms of load deformation, how is UHPC different from normal concrete? How is shear failure addressed in UHPC? | UHPC has a larger Young's modulus (about twice) than regular concrete, so UHPC is stiffer. The steel fiber reinforcmeent increases its shear strength greatly. In many cases you may not need stirrups. |
| 5 | Can you comment on the type of rebar used and why? | There was no specific reason for epoxy coating. It was what was available. In general, the UHPC will protect the bars very well due to its microcracking behavior - unlike concrete, which has much larger cracks under service conditions. |
| 6 | Can you comment on the beam depth and camber for the project? | The beam depth was quite shallow due to the strength and high stiffness of UHPC. There was no need for camber. |
| 7 | Is there any movement toward the regular production of UHPC prestressed I-girders? | Not yet, but eventually this will happen due to the compelling properties of UHPC, especially for prestressed construction. |
| 8 | Are more UHPC superstructures being designed at this time? | Yes, there are at least three more in Southeast Michigan going up this year. |

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| | **Construction** | |
| 9 | Can you describe challenges with mixing and placing UHPC? | UHPC takes a bit longer to mix than regular concrete, and it also requires a specific process. However, it is not difficult and we have successfully done it in all kinds of mixers.The material is very fluid, so cross-slopes may be a challenge unless the mix is thixotropic. Also, forms need to be somewhat watertight to prevent the material from flowing out. |
| 10 | Is the UHPC mix design available as a handout? What are the typical properties: air, slump, temperature, etc.? | Please contact Sherif El-Tawil (eltawil@umich.edu) for the details of the mix and the mix protocol. This information is available publicly. |
| 11 | Previously it was said that UHPC is difficult to repair since it doesn't bond easily to itself. How will repairs be performed? | UHPC can be sandblasted and can be repaired quite well. |
| | **Cost** | |
| 12 | What is the square foot cost of the UHPC superstructure, and how do you justify the expected higher construction cost? | We don’t have a square foot cost, but the extreme strength leads to much lighter structures (2/3 less weight), which leads to massive savings in the foundation, transportation, and construction costs. We documented a 30% savings in the up front costs. That is in addition to the massive long-term savings due to the material's extreme durability. You can find more details here: https://hiperfibersolutions.com/wp-content/uploads/2023/07/uhpc-3IISUHPC.pdf |
| 13 | What is the unit cost per cubic yard of UHPC concrete? | From off-the-shelf material, the cost is about $1,377 per yard. Although more expensive than regular concrete, the extreme strength leads to much lighter structures (2/3 less weight), which leads to massive savings in the foundation, transportation, and construction costs. We documented a 30% savings in the up front costs. That is in addition to the massive long-term savings due to the material's extreme durability. You can find more details here:  https://hiperfibersolutions.com/wp-content/uploads/2023/07/uhpc-3IISUHPC.pdf |

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| 14 | What is the cost breakdown (material, labor, design, etc.) for the reported 30% savings? | Most of the savings came from not using piles in the foundations and lower transportation and handling costs. For example, there was no need to rent a crane because the backhoe on site could lift and install the panels. |
| 15 | What is the project delta cost of UHPC versus conventional concrete? | Actually, the project UHPC delta cost was substantially cheaper. Although UHPC is more expensive than regular concrete, the extreme strength leads to much lighter structures (2/3 less weight), which leads to massive savings in the foundation, transportation, and construction costs. We documented a 30% savings in the up front costs. That is in addition to the massive long-term savings due to the material's extreme durability. You can find more details here: https://hiperfibersolutions.com/wp-content/uploads/2023/07/uhpc-3IISUHPC.pdf |
| 16 | In what situations might the use of UHPC be more cost effective than other types of concrete? | UHPC has a range of material properties that are beneficial. For prestressed concrete, the tensile strength is helpful for partial prestressing applications. Although more expensive than regular concrete, the extreme strength leads to much lighter structures (2/3 less weight), which leads to massive savings in the foundation, transportation, and construction costs. We documented a 30% savings in the up front costs. That is in addition to the massive long-term savings due to the material's extreme durability. You can find more details here: https://hiperfibersolutions.com/wp-content/uploads/2023/07/uhpc-3IISUHPC.pdf |
| 17 | Can you provide details on a life-cycle cost comparison of a cast-in-place UHPC deck and a precast UHPC deck using either steel beams or precast Type D NEXT Beams? | We do not have such data yet. This paper has a comparison that may be of interest. See Figure 5. https://hiperfibersolutions.com/wp-content/uploads/2020/05/CI06-El-Tawil.pdf |
| | **General** | |
| 18 | Would you be interested in a carbon-negative cement product that uses saltwater instead of fresh water with high compression and tensile strengths? | Wouldn’t the salt contribute to steel fiber rust? If so, this may not be a good idea. |

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| 19 | Do you see any potential for the use of AI (artificial intelligence) with similar projects? | At the moment, we do not see this as being beneficial. However, as AI becomes more powerful, certainly that option might become viable. |
| | **Questions during Webinar** | |
| 20 | Was a link slab used on this project? If so, was it also UHPC? | No, a link slab was not used on this project. |
| 21 | It would appear that the density of UHPC would be higher than normal-weight concrete. What would be a reasonable density assumption for UHPC? | UHPC has a unit weight of 4,200 lb per cubic yard. |
| 22 | On Slide 13, you show multiple small, well-distributed cracks in the flexural UHPC beam. We have seen big cracks in flexural UHPC beams usually near failure. Does the UHPC beam in Slide 13 represent the concrete being in the strain-hardening region of the stress-strain curve? | Yes, that is under service conditions when the UHPC is in the strain hardening region of the stress/strain curve. Failure occurs shortly after localization is initiated. That may limit the ductility of the UHPC system. |
| 23 | How do you justify the significantly higher cost compared to a three-sided precast or cast-in-place culvert that is maintenance free for about 75 years? | Although UHPC is more expensive than regular concrete, the extreme strength leads to much lighter structures (2/3 less weight for our case), which leads to massive savings in the foundation, transportation, and construction costs. We documented a 30% savings in the up front costs. That is in addition to the massive long-term savings due to the material's extreme durability (probably more than twice the life of a 75-year culvert). You can find more details here: https://hiperfibersolutions.com/wp-content/uploads/2023/07/uhpc-3IISUHPC.pdf |
| 24 | The mixing cycle appeared to take 47 minutes. Is this correct, and can you comment on this? | Mixing is a process. You start with the dry components, then add the liquid parts. If the material can be placed in the truck quickly (for example, with an automated plant), mixing will take about 15 minutes. The problem is that precasters don’t yet trust it, and so they load the material manually. |
| 25 | Can you elaborate on the bonding of fresh UHPC against hardened UHPC in the closure region? | We don't have data on that, but I would suspect that it is as good or better than in a regular concrete system. |

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| 26 | Is live-load vibration a problem for the bridge when the section gets to be so thin? | The bridge meets all AASHTO requirements. It is so thin because of the high stiffness of UHPC and the webbed system employed. |
| 27 | How would the thin slab work in conjunction with a TL-4 bridge barrier? | We avoided doing that because we did not want to load the deck in this manner. That is a topic for future research. |
| 28 | Regarding Slide 36, can the longitudinal reinforcement be placed closer together than the required AASHTO bridge specification minimum clear distance? | The longitudinal reinforcement can be placed closer together because there is no large aggregate and because the bond strength between the steel bars and UHPC is extremely high. The transfer length for bars in UHPC is quite short. |
| 29 | Were there any concerns with foundation scour? | We were not concerned with foundation scour in this case. |
| 30 | Why was black reinforcement used in the deck panels instead of epoxy-coated reinforcement? | Black reinforcement was what was available. The bars are highly protected against corrosion in UHPC due to its extreme imperviousness. |
| 31 | Did you use cylinder or cube samples in the compressive strength test? | We use cubes in the compressive strength test. They are convenient to use, and FHWA research showed that they give about the same strength as cylinders. |
| 32 | How light is the bridge compared to the concrete alternative? What type of bearings were used? Were any holddown anchors used because the lightweight bridge dead load could be a concern under uplift wind forces or horizontal stream flow loading? | The bridge panels were about 2/3 lighter than regular concrete panels. And, yes, holddown anchors were used. |
| 33 | Regarding Slide 59, was the thickness of the deck changed to accommodate the guardrail connections? | The guardrails were long span, approved by the Michigan DOT. We did not want to attach them to the thin deck. |
| 34 | What is the effect of winter salt on this type of bridge surface? | A regular wearing surface was used for this bridge. In future bridges, the surface will be grooved and used as is - with no wearing surface. We do not think that winter salt will affect the bridge due to the imperviousness of UHPC. |
| 35 | Does concrete roughening work to bond fresh concrete to hardened UHPC? | Yes, concrete roughening works very well in bonding fresh concrete to hardened UHPC. There is a lot of ongoing research on this topic. |

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| 36 | How is the deck effective in flexural tension if rebars are placed at the mid-plane of the deck? | The span between the webs is only two feet, so the flexural strength is sufficient. UHPC has steel fibers, which also boost flexural strength. |
| 37 | Will future UHPC projects from St. Claire County be let in an open tender for contract bids? | There are no specific plans to do so now, but this could happen in the future. |
| 38 | How does UHPC align with the climate change action plan for transportation infrastructure? | UHPC is extremely durable, and by lengthening the repair or replacement cycle, UHPC is actually a material with a low carbon footprint. Figure 5 in this paper shows this idea schematically: https://hiperfibersolutions.com/wp-content/uploads/2020/05/CI06-El-Tawil.pdf |
| 39 | Do you have any life-span concerns related to the dry-cast modular block walls? | That is a good question. The bridge may outlast the modular walls. We are still at the start of the UHPC era, so questions like this are still being asked. |
| 40 | Can the UHPC be placed with a pump truck? | We have not done so yet, but others have been able to pump UHPC. |
| 41 | What is the maximum bridge span for triple-tee girders? | That depends on the design. It seems to be optimal for spans up to 30 ft. Beyond that, the composite tub girder systems seem to be quite efficient. |
| 42 | Does UHPC exhibit better performance in terms of durability relative to an ordinary concrete with a very low E/C ratio? | Yes, UHPC exhibits better performance in terms of durability relative to ordinary concrete. The reason is that UHPC has a high packing density that makes it quite impervious to the ingress of water or chloride ions. |
| 43 | Will steel fibers be a problem after wearing and exposure? | The steel fibers will not be a problem. Whatever sticks out will rust and fall off quickly. Steel fibers inside the UHPC are highly protected by the impervious nature of UHPC. |
| 44 | Were the rebars designed, or was minimum area of steel used? | The bars were designed to work with the steel fibers to resist the load. |
| 45 | Can you describe the differences between the moment strength calculation methods? How easy are they to use? Is this an iterative calculation? | We used a simple moment curvature analysis for flexural strength computations. You can also use the newly approved FHWA guide specifications (approved by AASHTO). |

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| 46 | What design codes were used in the UHPC girder design? | We used first principles and also the draft FHWA design guide. These have now been adopted by AASHTO. |
| 47 | Have you started using UHPC for longer spans in Michigan, for example, casting girders and box girders with UHPC? | Yes, the composite UHPC/tub girders work well for spans in the 30- to 50-ft range. We have not yet cast longer girders with UHPC. |
| 48 | Is shrinkage an issue for structural elements cast with UHPC? | Shrinkage is not really an issue for UHPC structural elements. The steel fibers greatly reduce the effect of shrinkage. |
| 49 | Can you discuss using UHPC in prestressed concrete design? | UHPC is well suited for prestressed concrete design. The high tensile strength is beneficial for partial prestressing, and the high compressive strength means that you can use shallower sections. The tensile strength of the material also means that you can reduce or eliminate shear reinforcement. Overall, UHPC is very useful in prestressed concrete design. |
| 50 | Can you discuss the field test procedures for UHPC? | We typically measure spread of UHPC to ascertain that it is well mixed. That is the only field test we do. |
| 51 | Besides proof of concept for advancing UHPC superstructures, was there a need at this location for a superstructure versus a buried culvert? | The use of this system was a strategic design given the previous structure that was being replaced. |
| 52 | With the new FEMA (Federal Emergency Management Agency) H&H (Hydrologic and Hydraulic) requirements, slimmer structures are needed to reduce the profile impacts. Did hydrologic modeling require such a slim superstructure? | No, that was not the rationale. The slim design resulted from the extreme strength of the material. It was a by-product of the beneficial properties of the material, not a design consideration. |
| 53 | You talked about the maximum strain of the UHPC in tension, but I was wondering about the value of the strain in compression. We normally use 0.3% for the compression strain in ordinary concrete. What is the compression strain value for UHPC? | The compression strain capacity of UHPC is about 0.5%. The extreme strength in compression means that in design, the behavior may be elastic and the stress distribution linear (not plastic as in regular concrete). |
| 54 | If UHPC is self consolidating, how difficult is it to put a cross slope on the final riding surface? | UHPC is quite fluid. You will need a specially design thixotropic UHPC to achieve the cross slope. |
| 55 | How does the UHPC slab work when you need spliced press tubs for longer spans? | This situation may require a different type of system. |