1. Article 2.2 Mix Design:

a. Need to be specific on where these materials can be sourced from. Need to price materials for bid submission. Even physical properties are provided different raw material will perform differently than the University provided mix design.

b. Preblended/Prebagged: The ability of the mix to be prepackage is very important to ensure the required production for placement of overlay. Having individual material components will prevent continuous overlay installation.

c. The wet sand component will prevent complete prepackaging of the mix.

Response:

The source of the raw materials is shown in Table 1. The price should be consulted by contractors since the price should vary with time and order quantity.

Table 1. Sources of the raw materials

Material	Source/Company
Type III Portland cement	ASTM C 150 Type III Cement
Class C Fly Ash	ASTM C 618 Class C Fly Ash
Undensified Silica fume	Company: Elkem Commercial name: Elkem Microsilica 920 ASTM Website: https://www.elkem.com/silicon-products/construction/concrete/elkem-microsilica-powder/
River Sand (0-4.75 mm)	Company: Capital Sands, Jefferson City Location: Missouri River
Masonry Sand (0-2 mm)	Company: Capital Sands, Jefferson City Location: Missouri River
Lightweight Sand (0-4.75 mm)	Company: Northeast Solite, Shepardsville KY Commercial name: Hydrocure Website: https://northeastsolite.com/?page_id=842
Steel fiber	Company: Hiper Fiber Commercial name: Type A: Straight steel fibers Physical properties: 13 mm in length, 0.2 mm in diameter Website: https://hiperfibersolutions.com/our-fibers/
Superplasticizer	Company: The Euclid Chemical Company Commercial name: PLASTOL 6400 Website: https://www.euclidchemical.com/products/admixtures/high-range-water-reducers/plastol-6400/
Thixotropy modifying admixture	Company: The Euclid Chemical Commercial name: EUCON ABS or AWA P20

Shrinkage-reducing admixture	Company: The Euclid Chemical Commercial name: EUCON SRA Floor Website: https://www.euclidchemical.com/products/admixtures/specialty-admixtures/shrinkage-control/eucon-sra-floor/
Air detraining admixture (EUCON Air Out)	Company: The Euclid Chemical Commercial name: EUCON Air Out Website: https://www.euclidchemical.com/products/admixtures/specialty-admixtures/air-detrainers/eucon-air-out/

(b) The dry materials including Type III cement, Class C fly ash, Silica fume, River sand, and Masonry sand can be preblended and prebagged (excluding the pre-saturated lightweight sand and steel fibers).

(c) The lightweight sand should be pre-saturated and prebagged. Similarly, steel fibers can also be directly added from the bags (e.g., 50 lb bags).

2. Article 2.3 Physical Properties:

a. Stiffness: Based on desired properties, it seems like the mix would be too fluid to place in an overlay (6.5" – 8") and that it would need to be stiffer for this application to hold the slope of the bridge

Response:

(a) The fluidity of UHPC mixture is determined using the min slump flow test. The initial flow before jolting can be reduced by decreasing the SP dosage. The recommended mini-slump flow of UHPC was 5"-6" based on FHWA report [1].

The research team conducted inclined plane test to evaluate the fluidity of thixotropic UHPC with mini-slump flow of 6.5"-8". High fluidity was designed for the ease of placement and enhance the bond strength to the substrate. As shown in Fig. 1, such mixture can stay on a concrete surface sloped at 7% after short rest time (5 min). The range of mini-slump flow can be verified when conducting the mock-up test.

[1] Haber, Z. B., Munoz, J. F., & Graybeal, B. A. (2017). *Field testing of an ultra-high performance concrete overlay* (No. FHWA-HRT-17-096). United States. Federal Highway Administration. Office of Infrastructure Research and Development.

Figure 1. Inclined planes test for fluidity of UHPC mixture

3. Article 2.4 Steel Fibers:

a. Article 2.4.1: The length range (25-38 mm) isn't required. Longer lengths will create issues? The fiber should be 0.5" (13 mm) long and 0.008" (0.2 mm) diameter.

b. Should keep the fiber aspect at 65. The larger aspect will create issues?

Response:

(a) The straight steel fiber measuring 0.5" (13 mm) in length and 0.008" (0.2 mm) in diameter was used. Such fiber dimension was also used in UHPC overlay project of FHWA.

(b) Using longer fibers or fibers with larger length-to-diameter ratio can reduce fluidity of UHPC, which may lead to difficulty in placing and consolidation.

4. Article 2.4.2: Not sure why the fiber supplier is required on-site.

Response:

This is not a requirement from the research team.

5. Article 4.2.1 Mixing:

a. The specified mixing procedure doesn't seem practical for a larger field production. Revisions are needed to ensure the required production.

b. Units used for the speeds specified in article 4.2.1 appear to be a typo (rps à rpm). Otherwise, the speeds specified aren't possible.

c. Larger High shear mixers for field applications do not have the option to operate at the variations of speeds specified in article 4.2.1 (1 rps, 6 rps and 10 rps)

Response:

The mixing procedure specified in the JSP is based on laboratory experiments carried out at Missouri S&T. A similar mixing procedure can be used by the concrete supplier in the lab to finalize the mixture design. The mixing energy and time of mixing are dependent on the type of equipment. The research team will work with contractor to come up with a suitable mixing procedure at the concrete batching plant. This mixing procedure will provide information of the mixing sequence and mixing time in each step.

6. Working Time (Article 4.2): The specified working time of 30 minutes at 70 degrees isn't enough time to place an overlay especially during high summer temperatures. A combination of gaining more time via add mixtures and scheduled placement in cooler temperatures are needed. (I believe I heard these values, but I don't seem them in the JSP. Perhaps these values are based on experience (section 4.2).

   Response:

   The temperature of UHPC at the conclusion is important for the working time. Previous study suggests that the open time can become reduced and the likelihood of surface dehydration can increase when material temperature is higher than 80° F (26°C) [2]. Some recommendations to secure the longer work time are summarized as follow:

   (1) Part of the mixing water can be replaced by dry ice during mixing.

   (2) Prebagged raw materials and mixing water should be stored in a relatively low temperature of 50-60 °F (10-16 °C) – refrigerated units.

   [2] Graybeal, B. (2014). Design and construction of field-cast UHPC connections (No. FHWA-HRT-14-084; HRDI-40/10-14 (750) E). United States. Federal Highway Administration.

7. Will the Contractor be required to provide any facilities or auxillary assistance to Missouri S&T personnel?

   Response:

   The Contractor needs to provide the facilities to construct and cast the mock-up as well as assistance in conducting trial mixtures with the designated mixture. Missouri S&T personnel will have access on the jobsite to conduct their own Q/C testing.