

## REVISION OF SECTION 601 ULTRA HIGH PERFORMANCE CONCRETE

Revise Section 601 of the Standard Specifications for this project as follows:

**Subsection 601.01 shall include the following:**

This work consists of furnishing and concreting of precast concrete bridge deck panel joints, shear blockouts, closure pour areas, transverse shear key joints, leveling device blockouts, and haunches with Ultra High Performance Concrete (UHPC) at the locations shown on the plans or as directed by the Engineer.

**Subsection 601.03 shall include the following:**

The Contractor shall submit a detailed UHPC Field Installation Plan that clearly demonstrates all the activities and items noted above including the joint locations, pouring sequence, forming details, equipment, equipment placement, labor and labor management, and the UHPC Representative's Experience to the CDOT 30 days prior to the beginning of work for review and approval. One (1) comprehensive submittal package shall be provided. Partial or supplementary submittals will not be accepted.

Materials for Ultra High Performance Concrete shall conform to the following:

The Contractor shall furnish a manufacturer's Certified Test Report (CTR), in accordance with subsection 106.12, conforming that all materials required for the UHPC have been pretested and shall meet all requirements.

High molecular weight methacrylate (HMWM) resin shall be low viscosity and non-fuming, to be used as repair for a leaking joint. It shall be used to seal the joint and any holes, cavities, or voids created by the joint forming at the deck top surface prior to the installation of the waterproofing (membrane) and hot mixed asphalt (HMA) overlay. The container shall include the name of the manufacturer, brand name of the product, and date of manufacture.

Acceptance of HMWM is based on manufacturer certification, and the Contractor providing the certification to the Engineer:

A Certified Test Report shall show that the HMWM conforms to the following:

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|--------------------|--|
| (1) Viscosity      | Less than 25 cps when measured according to ASTM D2849 |
| (2) Density        | Greater than 8.4 lb./gal. @ 77° F.                     |
| (3) Flash Point    | Greater than 200° F.                                   |
| (4) Vapor Pressure | Less than 1.0 mm Hg @ 77° F. (ASTM D 323)              |
| (5) TG (DSC)       | Greater than 136° F (ASTM D3418)                       |
| (6) Gel Time       | Greater than 40 minutes for a 3.527 oz. mass           |
| (7) Percent Solids | Greater than 90 % by weight                            |
| (8) Bond Strength  | Greater than 1522.3 psi (ASTM C882)                    |

Sand shall be commercial quality dry blast sand. 95% of the sand shall pass the #8 sieve, and 95% shall be retained on the #30 sieve.

The container shall include the following information: The name of the manufacturer, the brand name of the product, and the date of manufacture.

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Ultra High Performance Concrete shall be fiber-reinforced, with all components supplied by one manufacturer. Fibers shall be included at a rate of two percent by volume weight content. Materials commonly used in UHPC include the following:

- (1) Fine aggregate
- (2) Cementitious material
- (3) Super plasticizer
- (4) Accelerator
- (5) Steel fibers

The material shall meet the performance requirements according to Table 601-1A in order to be considered a UHPC for this project. Test data substantiating these results shall be submitted in a CTR to the Engineer at least 30 days prior to UHPC placement conducted by an AASHTO accredited lab.

The Contractor shall assure the proper storage of premix, fibers, and additives as required by the supplier's specifications in order to protect materials against loss of physical and mechanical properties.

Materials are to be installed in accordance with all safety and weather conditions required by the manufacture.

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**Table 601-1A  
 UHPC MATERIAL REQUIREMENTS**

Characteristic Property	Test Method	Curing Method	Test Age	No. of Specimen	Test Result	Additional Notes
Compressive Strength	ASTM C 39*	Moist cured per ASTM C192*	36 hours** or 4 days	3	14 ksi min.	N/A
Compressive Strength	ASTM C 39*	Moist cured per ASTM C192*	28 days	3	18 ksi min.	N/A
Static Modulus of Elasticity	ASTM C 469*	Moist cured per ASTM C 192*	28 days	3	6,000 - 9,000 ksi	End grind cylinders per ASTM C1856
Splitting Tensile Strength	ASTM C 496	Moist cured per ASTM C 192*	28 days	3	750 psi min.	4 in. x 8 in. cylinder; no fibers
Flexural Tensile Toughness	ASTM C 1609*	Moist cured per ASTM C 192*	28 days	3	Pp > P1	12 in. span
Long-Term Shrinkage	ASTM C 157*	Per test method	28 days	3	Less than 800 microstrain	Initial reading after set
Chloride Ion Penetrability	ASTM C 1202*	Moist cured per ASTM C 192*	56 days	3	Less than 500 coulombs	No fibers
Scaling Resistance	ASTM C 672	Per test method	28 days	3	y < 3	50 cycles
Abrasion Resistance	ASTM C 944*	Moist cured per ASTM C 192*	28 days	3	Less than 0.1 ounces	Ground surface, 3 x 2-min.
Freeze-Thaw Resistance	ASTM C 666*	Moist cured per ASTM C 192*	14 days	3	RDM > 95%	300 cycles
Alkali-Silica Reaction	ASTM C 1260	Per test method	16 days	3	Less than 0.10%	N/A
Steel Fibers	ASTM A 820	N/A	N/A	N/A	Greater than 300 ksi tensile strength	Type I; 0.008 in. diameter x 0.5 in. length

\* As modified by ASTM C 1856.

\*\*For an early high-strength UHPC mix only.

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A bond test and pullout test shall be submitted for approval by the Engineer. The bond test and pullout test are "application-based" tests that verify that the UHPC is capable of performing as intended for the proposed application, which in this case is for closure pour and transverse joints between precast elements. The bond test and/or pullout test sample can be fabricated during the project mockup and tested thereafter prior to UHPC placement in the bridge.

A bond test shall be performed in accordance with ASTM C 1583. A concrete panel at least 3-foot square and 6 inches deep shall be cast using the same concrete as the precast elements. The concrete shall have achieved the design compressive strength of the precast panels. The surface preparation of the concrete panel (e.g. exposed aggregate finish, pre-wetting, etc.) shall replicate the surface preparation proposed for the field-installed precast elements. A 0.5 to 1.5 inches thick layer of UHPC shall be applied to the concrete panel. At least three bond tests shall be performed on the concrete panel and UHPC. The bond test shall be performed after 14 days of moist curing the UHPC. The bond test passes if failure occurs in the concrete panel, not the UHPC or bond interface. All three bond tests must pass for the UHPC to be accepted.

The pullout test shall be performed in accordance with ASTM E488 using three cylinders (12 inches diameter and 7 ½ inches deep) made of UHPC with one 32 inches long epoxy-coated reinforcing bar cast in the center of the circular face. The axis of the bar shall be perpendicular to the formed surface. The bars shall be the same size of the bars detailed on the plans for the splice and embedded 8 times the bar diameter. The cylinders shall be wet cured and the test shall be performed as soon as practical after the UHPC has achieved 14 ksi compressive strength. The test passes if the bars yield or fracture without the UHPC failing and without the bars pulling out of the UHPC.

Results of all the bond and pullout tests shall be conducted by an AASHTO accredited testing lab on the same UHPC mix design used by the project and shall be submitted to the Engineer for approval prior to UHPC placement in the bridge.

The Contractor shall provide to the Engineer a list of bridge projects in which the proposed UHPC material has been used as joint fill between precast concrete elements. The Engineer reserves the right to reject a proposed UHPC material which lacks a proven track record in precast concrete joint filling in bridge applications.

The Contractor shall submit to the Engineer the following items for review and approval:

- (1) Manufacturer qualifications: The manufacturer of the UHPC shall be ISO 9001:2000 certified and have a quality assurance program independently audited on a regular basis.
- (2) Contractor qualifications: The Contractor shall be qualified in the field of precast deck panel grouting with at least 5 or more years of experience in similar project types. The Contractor shall maintain qualified technical personnel at the site who have received product training by a manufacturer's representative for a minimum of one day during a Mockup Test. If the Contractor does not have 5 years of experience, a manufacturer's representative shall be on-site during the placement of UHPC.

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- (3) UHPC Field Installation Plan: Install materials in accordance with an approved installation plan that details the batching sequence, joint locations including bulkhead locations where needed, and placement sequencing. All safety and weather conditions required by the manufacturer shall be in compliance with applicable rules and regulations of local, state and federal authorities having jurisdiction.

A mockup test shall be performed by the Contractor at least one week prior to the UHPC placement. The test shall verify that the Contractor is familiar with UHPC operations and troubleshooting installation procedures. A training shall be provided by a manufacturer's representative for a minimum of one day. The mockup shall closely replicate the placement conditions, operations, and dimensions of the UHPC. The Mockup shall be a minimum of 10 feet in length and match the crosslope of the planned joint. If hydrostatic pressure head will be used on the project to consolidate the joints, the pressure head during the mockup shall replicate the maximum pressure head anticipated on the project.

### **Subsection 601.06 shall include the following:**

When batching in warm weather, ice may be required as a full or partial substitute for the mix water to control the UHPC mix temperature to within acceptable limits. If ambient temperatures are expected to drop below 40 °F during UHPC placement and/or initial cure, cold weather placement procedures shall be used. Consult the UHPC supplier in these situations.

### **Subsection 601.09 shall include the following:**

The precast concrete surfaces to be in contact with UHPC shall have a roughened surface consisting of an exposed aggregate finish with an average amplitude of ¼" +/- 1/8". This can be achieved using a form retarder during the panel fabrication process. The precast concrete surfaces shall additionally be cleaned of debris and pre-wetted with water continuously for a minimum of two hours immediately prior to UHPC placement. Standing water shall be removed from the formwork prior to UHPC placement.

### **Subsection 601.12 (a) shall include the following:**

The Contractor shall furnish all labor, equipment, materials, and testing for UHPC including, but not limited, to:

- (1) Plan Submission: The Contractor shall submit a detailed UHPC Field Installation Plan that clearly demonstrates all the activities and items noted above including the joint locations, pouring sequence, forming details, equipment, equipment placement, labor and labor management, and the UHPC representative's experience to the Engineer 30 days prior to the beginning of work for review and approval. The Contractor shall provide one comprehensive submittal package. Partial or supplementary submittals will not be accepted.
- (2) Pre-Pour Meeting: Prior to the initial placement of the UHPC, the Contractor shall arrange for an on-site meeting with the UHPC representative. The Contractor's staff, and the CDOT Engineer and Inspectors shall attend the site meeting. The objective of the meeting shall be to clearly outline the procedures for mixing, transporting, finishing and curing of the UHPC material. The Contractor shall arrange for a

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representative of the UHPC supplier to be on site during the mixing and placement of UHPC. The representative shall be knowledgeable in the supply, mixing, delivery, placement, and curing of the UHPC material.

- (3) Storage: The Contractor shall assure the proper storage of premix, fibers and additives as required by the supplier's specifications in order to protect materials against loss of physical and mechanical properties.
- (4) Forming: The design and fabrication of forms for UHPC shall follow approved installation drawings and shall follow the recommendations of the manufacturer. The forms shall be non-absorptive or coated to prevent absorption of water and shall be installed water-tight to prevent leakage of the UHPC during placement.
- (5) Batching: The Contractor shall follow the batching sequence as specified by the supplier and approved by the Engineer. The mixers used for batching shall be suitable for mixing UHPC and shall be approved for use by the UHPC supplier prior to construction. Pumping shall not be allowed. When batching in warm weather, ice may be required as a full- or partial-substitute for the mix water to control the UHPC mix temperature to within acceptable limits.
- (6) Placing: The material shall be placed starting at the low end of the joint and working toward the high end. The material shall not travel more than 15 feet during placement. A minimum 3" diameter port/pour holes shall be provided, and internal vibration shall not be used during UHPC placement. The surface of the UHPC field joints shall be filled to plus 1/4 inch above the surface of the precast deck panels to prevent low spots from occurring.
- (7) Curing: The UHPC shall not be disturbed until a minimum compressive strength of 10 ksi is achieved. The UHPC shall remain covered during the initial curing phase. The UHPC in the form shall be cured according to Manufacturer's recommendations to attain the required strength shown on the contract documents.
- (8) Finishing: The UHPC shall be grounded flush with the precast panels (using light-weight equipment) after the material has attained a minimum compressive strength of 10 ksi.
- (9) Any and all work required for the successful and satisfactory installation of UHPC.

The Contractor shall submit a plan to perform the watertight integrity test at least one week prior to the test. After the joints and blockouts have been ground, each joint and blockout shall be flooded with water for a minimum of 15 minutes. The Contractor shall provide the Engineer safe access for inspecting the underside of the joints. The concrete surfaces under the joint shall be inspected by the Engineer, during this 15 minute period and also for a minimum of 45 minutes after the supply of water has stopped, for any evidence of dripping water or moisture. Water tightness shall be interpreted to be no free dripping water on the underside of the joint. Should the joint system exhibit evidence of water leakage at any place whatsoever, the Contractor shall locate the leak and repair the joint with HMWM in accordance with the following:

- (1) The Contractor shall abrasive blast clean the area to be treated, removing all contaminants from the surface, and clean adjacent surfaces of the leaking joints using compressed air free of oil and moisture.

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- (2) HMWM shall not be applied if rain is expected within 12 hours of completion. HMWM shall be applied to clean, dry surfaces when the surface temperature is at least 50° F, and if near 50° F, rising. The HMWM shall be mixed and applied according to the manufacturer’s instructions and no more than 5 gallons at a time. HMWM shall be poured over the joints.
- (3) When the HMWM surface will be used as a driving surface, sand shall be applied to provide friction. After the HMWM has been applied, at least 20 minutes shall elapse before applying the sand. The sand shall be broadcast at a rate of approximately two pounds per square yard, completely covering the HMWM.
- (4) The sealer must be tack-free before construction traffic is permitted to resume.

This work shall be done at the Contractor's expense and at no time extensions to the project. A subsequent water integrity test may be required subject per the direction of the Engineer after the repair has been made.

Process control tests shall be performed by the Contractor on-site during each day of UHPC casting: The slump flow and mix temperature of each batch shall be recorded in the quality assurance log. A copy of the log shall be submitted to the Engineer.

Traffic shall not be allowed on the bridge until the UHPC has attained a minimum compressive strength of 14 ksi. Portions of bridge deck panels joined with UHPC shall not be opened to traffic until a UHPC compressive strength of at least 14 ksi has been achieved. Strength shall be determined by cylinder compression test.

**Table 601-B  
PROCESS CONTROL TEST REQUIREMENTS**

Test Name	Test Method	Test Result	Test Frequency
Flow Test	ASTM C 1437 as modified by ASTM C1856	7-10 inches, no visual sign of fiber segregation	Every batch, prior to placement
Mix Temperature	ASTM C 1064	55-90* °F	Every batch, prior to placement

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Characteristic Property	Test Method	Curing Method	Test Age	Number of Specimen	Test Result	Sampling Frequency
Compressive Strength	ASTM C 39 as modified by ASTM C1856	Field cured per ASTM C 31 as modified by ASTM C 1856	As needed for formwork removal and grinding	3	10 ksi min.	Every 25 cu. yds., with a minimum of once per day
Compressive Strength	ASTM C 39 as modified by ASTM C1856	Field cured per ASTM C 31 as modified by ASTM C 1856	As needed to fully load the UHPC	3	> 14 ksi	Every 25 cu. yds., with a minimum of once per day

\* Unless otherwise approved by the on-site UHPC representative

The Engineer will perform owner acceptance testing in according to the requiremenets of Table 601-C.

**Table 601-C  
 OWNER ACCEPTANCE TESTING**

Characteristic Property	Test Method	Curing Method	Test Age	Number of Specimen	Test Result	Sampling Frequency
Compressive Strength	ASTM C 39 as modified by ASTM C1856	Standard cured per ASTM C 31 as modified by ASTM C1856	7 days	3		Every 25 cu. yds., with a minimum of once per day
Compressive Strength	ASTM C 39 as modified by ASTM C1856	Standard cured per ASTM C 31 as modified by ASTM C1856	28 days	3	> 18 ksi	Every 25 cu. yds., with a minimum of once per day
Compressive Strength	ASTM C 39 as modified by ASTM C1856	Standard cured per ASTM C 31 as modified by ASTM C1856	56 days, if 22 ksi not reached at 28 days	3	> 18 ksi	Every 25 cu. yds., with a minimum of once per day



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**Subsection 601.19 shall include the following:**

Payment will be made under:

<b>Pay Item</b>	<b>Pay Unit</b>
Concrete (UHPC)	Cubic Foot

Payment shall be full compensation for all labor, equipment, materials, and testing required to complete the item including plan submission, storage, forming, mixing, transporting, casting, curing, and repairs.