

ITEM #0601060A – BEAM END REPAIRS WITH ULTRA HIGH PERFORMANCE CONCRETE – PARTIAL HEIGHT

Description: Work under this item shall consist of all materials, tools, and labor necessary for the performance of all work to form, cast, finish, cure, and test Ultra High Performance Concrete (UHPC) where required per plans for Beam End Repairs with UHPC.

This item also includes surface preparation of existing steel surfaces in contact with UHPC and sealant applied along the exposed interfaces between UHPC panels and steel girders.

The Contractor shall not perform any repair work without prior approval by the Engineer for locations and limits.

Materials: Materials shall conform to the following:

Ultra High Performance Concrete (UHPC): The UHPC shall be mixed on Site from pre-packaged components, pre-proportioned by the UHPC Supplier.

Components: The following materials shall be as recommended by the UHPC Supplier:

- (a) Fine Aggregate
- (b) Cementitious Material and any replacement materials, such as silica fume
- (c) Steel Fibers (must be in accordance with Article 1.06.01 – Buy America)
- (d) Liquid Admixtures (such as super plasticizers or accelerators)

Water: Water for mixing shall meet the requirements of M.03.01-4 and the temperature at mixing shall be per UHPC Supplier recommendations for use in the UHPC mix.

Mix Design: The Contractor shall submit a mix design that meets the following criteria:

Table 1: UHPC Material Properties (after 28 days or as noted)		
Description	Test Method	Acceptance Criteria
Compressive Strength	ASTM C39 (as modified by ASTM C1856)	≥ 14 ksi. at 4 days ≥ 20 ksi. at 28 days
Tensile Strength	Direct Tension	Greater than 0.72 ksi sustained post cracking
Shrinkage	ASTM C157 (initial reading after set)	≤ 800 micro-strain
Chloride Ion Penetrability	ASTM C1202	≤ 250 coulombs
Freeze-Thaw Resistance	ASTM C666 Procedure A (300 cycles)	Relative Dynamic Modulus of Elasticity, RDM > 95%
Flow	ASTM C1437 (as modified by ASTM C1856)	7 to 10 inches

Packaging: The fine aggregate and cementitious material must be premixed and proportioned in bags or supersacks, in accordance with the approved mix design, and shall be identified by batch or lot number.

The UHPC design shall consider, and be suitable for, the sequence, timing, and loading restrictions given elsewhere and as required by the Contractor to achieve construction schedules.

The steel fibers shall have a minimum diameter of 0.008 inches (0.2 mm), a length of 0.5 inches (12.7 mm), and a specified tensile strength of greater than 290 ksi (2000 MPa). The UHPC mix shall consist of a minimum of 2% fiber reinforcement by volume.

Water shall be potable and free from foreign materials in amounts harmful to concrete and embedded steel.

Material of joint seal to be applied along the exposed interfaces between the UHPC panel and the steel girder shall conform to M.03.08 – 5(b) Joint Sealer for Structures.

Construction Methods:

1. Contractor Submittals:

- (a) Mix Design, including proportions of each component, water-to-dry mix material ratio, mixing time, set time, compressive strength properties of the mix at ages of 2, 4, 7, 14, and 28 days, and Certified Test Reports addressing the material properties in Table 1, shall be submitted to the Engineer for approval at least 90 days in advance of the first UHPC placement.
- (b) UHPC Supplier and Technical Representatives: The Contractor shall obtain the services of a Supplier experienced in designing, mixing, placing, curing and testing of UHPC. Technical representatives shall be certified or recognized by the UHPC Supplier in the mixing and placing of UHPC in similar installations. The Supplier and Technical Representatives submittal shall be submitted to the Engineer for approval at least 90 days in advance of the first UHPC placement and shall include the following:
 - i. Name and location of Supplier.
 - ii. Name of UHPC product and a list of bridge projects it was utilized on. For each bridge listed, provide a location, description of how UHPC was used, date of completion of work, the project owner's name, and the name, title and current contact information of a project owner representative.
 - iii. Identification of the potential Technical Representatives (minimum two).
 - iv. UHPC Supplier documentation that the Technical Representatives are qualified to oversee the UHPC operations.
 - v. Work experience of the Technical Representatives: For each Technical Representative, submit a list of projects they attended that included UHPC mixing and placing operations. For each project, provide a location, description, date of completion of work, the project owner's name, and contact information of a project owner representative.

- (c) Construction Work Plan: The Contractor shall submit a Construction Work Plan to the Engineer for review and comment at least 90 days in advance of the first UHPC placement, which shall include the following elements:
- i. Formwork
 1. Proposed formwork materials
 2. Proposed formwork for beam end repairs. Methods for accommodating the different deteriorated conditions of the beam ends shall be addressed.
 3. Methods for bracing formwork. Proposed method shall allow the formwork to deflect and rotate with the beam end.
 4. Procedure for installing, sealing and maintaining watertight formwork
 5. Removal of formwork including tools and access to underside of deck
 6. Anticipated production rate
 - ii. Surface preparation
 1. Procedure of power tool cleaning existing steel surfaces in contact with the UHPC in accordance with SSPC-SP 15 "Commercial Grade Power Tool Cleaning" and procedure of power tool cleaning for existing steel surfaces where studs will be applied in accordance with SSPC-SP 11, "Bare Metal Power Tool Cleaning."
 2. Proposed debris shield and debris disposal method.
 - iii. Mixing
 1. Storage plan for UHPC components
 2. Mixers and mixing setup including the type and number of mixers, mixing location, water source, and contingency plan if a mixer malfunctions
 3. Description of equipment for weighing UHPC components
 4. Procedure for controlling UHPC mix temperatures including methods of storing ice
 5. Sample batch identification sheet to be used during UHPC production
 - iv. Placement
 1. Placement sequence and schedule
 2. Equipment for transportation and placement of UHPC
 3. Contingency plan if placement operations are interrupted by weather, equipment malfunctions or other issues
 4. Contractor's approach to achieving the 2% top pitch of UHPC panel.
 - v. Protection and Curing
 1. Procedure to protect UHPC repairs during curing
 2. Cold weather casting plan, if required
 - vi. Grinding
 1. Proposed equipment for finishing new UHPC surfaces.
 2. Method of collecting and disposing of debris
 - vii. Trial placement plan, outlining procedures to be followed and a dimensioned drawing showing the proposed UHPC placement of a representative beam end.
- (d) Contractor Quality Control:
- i. Quality Control Plan, including equipment list, testing setup, the specific load

machine and equipment that will be used for cylinder preparation and testing, sampling methods, frequency and types of tests at least 90 days in advance of the first placement of UHPC.

- ii. The proposed format for test reporting (or an example test report) shall be provided for the Engineer's review and comment at least 90 days in advance of the first placement of UHPC.
- iii. The name and location of the Contractor's proposed AASHTO accredited testing laboratory shall be provided to the Engineer at least 90 days in advance of the first placement of UHPC. The laboratory must have equipment capable of preparing UHPC specimens for testing in accordance with ASTM C1856.

UHPC cylinders require end grinding, not capping. Cylinder grinding is the only allowable method for end preparation. Not all AASHTO accredited testing labs have end grinding capabilities.

- iv. Reports of test results shall be provided to the Engineer within 48 hours of each test.

2. Trial Placement: Construction of a demonstration UHPC Beam End Repair of similar size and scope, herein referred to as "UHPC repair," shall be required using the approved mix design. The intent of the demonstration UHPC repair is to demonstrate the Contractor's ability to properly apply studs on steel beams and cast the UHPC in accordance with the design plans, these Special Provisions and recommendations from the UHPC Supplier. The methods used for the UHPC trial placement, including materials, mixing equipment, formwork and pouring methods shall be the same as those that will be utilized to perform the actual repair in the field. The steel beam in the mockup must be the same material type as the girders in the field. The surface preparation for the area under the studs must meet the same requirements used in the field, which is SSPC-SP 11. The means and methods for applying the studs must be the same as those that will be used in the field including the stud gun(s) used and the person(s) that will apply the studs in the field. The mock-up shall consider the special considerations for shooting studs on weathering steel if applicable, and the contractor must demonstrate in the mockup the ability to form a complete weld collar when applying the studs on both the web and flange. The contractor must demonstrate that the welding method, settings of the machine, and operators' approach ensures the formation of a full weld collar that surrounds the base of the stud with no gaps.

The steel girder used for the trial placement shall consist of a deteriorated girder (without the concrete deck), with either induced or natural deterioration, with visible section loss in the web and bottom flange, similar to that which will be encountered on the actual bridge beam ends. The UHPC pouring method for the trial placement shall use the method approved to be used for the UHPC pour on the actual bridge beam ends.

Following the surface preparation and application of the shear studs, and prior to forming, the weld collars will be reviewed by representatives from the Department. If more than one stud gun and/or person are used in the mockup, the contractor must track what personnel and

equipment was used to apply each stud and report this information to the Department during the inspection of the studs. After inspection and approval of the shear stud placement, the beam end may be formed. A watertightness test shall be performed at least one week prior to pouring of the UHPC, to ensure proper sealing of the formwork and the prepared steel girder surfaces. The test must be reviewed and approved by the Engineer prior to placement of UHPC within the UHPC repair trial placement. Representatives from the Department must be onsite for casting of the repair and made aware of the casting date a minimum of 2 weeks in advance. Following placement and sufficient curing of the UHPC, the trial placement will be visually inspected by the Engineer to ensure there are no gaps at the UHPC repair joint interface.

- The Contractor shall perform flow tests in accordance with ASTM C1437 (using modifications described in ASTM C1856) during trial placement. The Contractor shall cast five sets of three 3 in. by 6 in. cylinders, in accordance with ASTM C1856, during trial placement for determination of compressive strength. The five sets shall be tested in accordance with ASTM C39 (as modified by ASTM C1856) at 2, 4, 7, 14, and 28 days by the identified and approved AASHTO accredited testing laboratory using the approved preparation methods and equipment that will be used for the project. The trial placement shall be performed at least 2 months prior to the placement of UHPC for beam end repairs.

The completed UHPC repair trial placement and test results shall be submitted for review and approval by the Engineer a minimum of 28 days prior to placement of UHPC for the beam end repairs. The UHPC repair trial placement shall remain the property of the Contractor after acceptance and shall be removed from the Site prior to completion of construction activities.

- 3. Pre-Placement Meeting:** The Contractor shall arrange a pre-placement meeting to be held on Site after the approval of all submittals in advance of the trial placement. The meeting shall be attended by the UHPC Supplier's Technical Representatives, the Contractor's staff, any subcontractors involved in the work operation, and representatives from the Department. The objective of the meeting will be to review the Project plans, Contractor's Construction Work Plan and to review the procedures for mixing, placing, curing and testing of the UHPC, as well as the specifics of the trial placement.
- 4. Safety:** The Contractor shall make UHPC material safety data sheets (MSDS) available and shall provide a safety briefing to all on-Site personnel prior to UHPC placement. Proper personal protective equipment shall be used (including, at a minimum, goggles, dust masks, and respirators) as recommended by the UHPC supplier and as required by the MSDS based on proximity to specific operations.
- 5. Storage:** The Contractor shall assure the proper storage of dry premixed components, steel fibers and admixtures as recommended by the Supplier and the following:
 - (a) All dry premixed components shall be stored on raised pallets, with vapor barrier between the pallets and the ground surface to prevent moisture ingress and shall be covered thoroughly.

- (b) Steel fibers shall be stored with the same protection as the dry premixed components. Rusted fibers shall not be used in mixing.
 - (c) Liquid admixtures shall be stored in sealed containers above freezing temperatures and shall be protected from direct sunlight.
- 6. Formwork:** Formwork shall be non-absorbing, watertight and of sufficient rigidity and strength to safely support all loads imposed. The design and fabrication of forms and support systems shall be in accordance with 6.01.03 and shall follow approved installation drawings. Formwork shall be properly sealed to contain the fluidity of the UHPC.

A watertight test shall be performed at each beam end repair location at least one week prior to pouring of the UHPC to ensure proper sealing of the formwork. In the case that the formwork fails the watertight test, the Contractor shall reseal the formwork and repeat the test. Formwork at each beam end shall be approved by the Engineer prior to pouring of the UHPC. After the Contractor has proven their ability to properly install and seal the formwork, the watertight test may be waived as approved by the Engineer. Prior to pouring of the UHPC, the beam ends will be visually inspected by the Engineer to ensure that there is no remaining water in the beam end. Pouring of UHPC in beams ends with visibly ponded water will not be allowed. The Contractor shall take the necessary measures to ensure that the beam ends are dry prior to pouring of the UHPC.

The Contractor shall provide the means to drain the formwork after the watertight test is performed. The formwork shall extend 2 inches beyond the desired UHPC panel height. Formwork removal shall not begin until a representative cylinder test demonstrates that the compressive strength has reached 12 ksi.

- 7. Surface Preparation:** The existing structural steel surfaces to be in contact with UHPC as shown on the plans shall be power-tool cleaned according to SSPC-SP 15 "Commercial Grade Power Tool Cleaning." The existing steel surfaces where studs will be applied shall be power-tool cleaned in accordance with SSPC-SP 11, "Bare Metal Power Tool Cleaning". The power tools (needle guns, grinders, etc.) shall be equipped with HEPA vacuum attachments. Before the power tool cleaning, all dissolvable foreign matter, such as oil, grease, and dust shall be removed by wiping or scrubbing the surface with rags or brushes wetted with solvent in accordance with the provisions of SSPC-SP 1 "Solvent Cleaning." Clean solvent and clean rags or brushes shall be used for the final wiping. The cleaned surface shall be accepted by the Engineer. If the surface is determined to meet the requirements of SSPC-SP 15 and the surface in the location of the studs is determined to meet the requirements of SSPC-SP 11, UHPC repair operations can commence. Chemical stripping and abrasive blast cleaning will not be permitted. All foreign materials such as dirt, dust, loose rust scale, sand, bird droppings, and all materials loosened or deposited on the steel surface by cleaning operations shall also be completely removed by vacuuming before any repair operations commence.

Failure by the Contractor to properly prepare and clean surfaces for UHPC beam end repair in accordance with the specifications shall be cause for rejection by the Engineer. All surfaces

that are rejected shall be cleaned to the satisfaction of the Engineer in accordance with the specifications, at no additional cost to the State.

Storage and Disposal of Collected Debris: All of the debris resulting from the surface cleaning operations shall be contained and collected. All the debris and rust shall be stored in leak-proof storage containers at the Project site. Debris storage shall be in accordance with Connecticut Hazardous Waste Management Regulations. The storage containers and storage locations shall be reviewed by the Engineer and shall be located in areas not subject to ponding. Storage containers shall be placed on pallets and closed and covered with tarps at all times except during placement, sampling, and disposal of the debris.

Prior to generation of any hazardous waste, the Contractor shall notify the Engineer of its selected hazardous waste transporter and disposal facility. The Contractor must submit to the Engineer: (1) the transporter's current U.S DOT Certificate of Registration and (2) the transporter's current Hazardous Waste Transporter Permits for the State of Connecticut, the hazardous waste destination state and any other applicable states. The Engineer will then obtain an EPA ID number that will be forwarded to the Contractor. Any changes in transporter or facility shall be immediately forwarded to the Engineer for review.

The Contractor shall conform to the latest requirements of the Hazardous Waste Management Regulations prepared by the DEEP's Hazardous Waste Management Section, subject to regulations of Section 22a-449(c) of the Connecticut General Statutes.

Disposal of the debris shall be in strict conformance with all Federal E.P.A. and DEEP regulations for hazardous materials.

All necessary forms, including the "Uniform Hazardous Waste Manifest" obtained from the Hazardous Waste Management Section of DEEP, must be filled out, approved and signed by the Department's Project Engineer (Construction), and appropriate copies returned to the Department's Division of Environmental Compliance.

A licensed hazardous waste transporter and a licensed hazardous waste treatment/disposal facility must be secured from lists available from the DEEP and approved by the Department's Division of Environmental Compliance.

The Contractor is liable for any fines, costs, or remediation costs incurred as a result of their failure to be in compliance with this special provision and all Federal, State and Local laws.

- 8. Technical Representatives:** The Contractor shall arrange for two Supplier's Technical Representatives, as approved by the Engineer, to be on Site for the duration of the UHPC mixing and placement operations, inclusive of the trial placement and all UHPC Beam End Repairs. One representative shall remain with the mixing operations and the other representative shall remain with the placement operations. Mixing or placement shall not begin until the Supplier's representative(s) are on-Site and have checked in with the Engineer. The technical representatives shall be knowledgeable in the supply, mixing, delivery,

placement, and curing of the UHPC material.

- 9. Mixing:** In accordance with the approved Mix Design, the UHPC components shall be pre-weighed using a calibrated scale prior to the commencement of mixing. The Contractor shall provide a sufficient number of portable mixing units to maintain the necessary output for mixing and placement of the UHPC. At least one spare mixer shall be provided in case of mechanical failure. Mixing equipment that is not provided by the Supplier must be reviewed by the Supplier for adequacy. The Contractor shall maintain the temperature of the UHPC below 85°F during mixing. Ice and/or chilled water may be added to the mix as recommended by the Supplier's representative. Should the ambient temperature fall below 50°F, the batching water shall be heated to maintain the mix temperature between 50 and 85°F.
- 10. Placement:** Placement of UHPC repair shall be done within limits shown on the plans using the approved mix design. Any changes in repair limits due to field conditions shall be submitted to the Engineer for review and approval.

Prior to the Contractor performing any UHPC repair, the Engineer will perform an inspection to determine the exact limits and locations of all areas to be repaired. The Contractor shall provide scaffolding or other access as required for the Engineer's inspection. The Contractor shall not perform any repair work without prior approval of the Engineer for locations.

Construction loads applied to the bridge during UHPC placement and curing are the responsibility of the Contractor. The Contractor shall submit significant construction loads to the Engineer for review prior to the pre-placement meeting described above.

The UHPC repair for each girder shall be cast using one continuous placement. Cold joints shall not be permitted. The Contractor is alerted to the fact that if multiple panels of UHPC will be poured simultaneously, a positive pressure head shall be maintained between the pipes connecting to the formwork in order to maintain a balanced flow and height of the UHPC in the different cells. Alternatively, the Contractor shall provide a method to control the conveyance of UHPC to a single cell. The pipe used for conveyance of UHPC to the beam end repair location shall be a minimum of 3 inches in diameter for running lengths up to 3 feet. A larger diameter pipe may be required for running lengths larger than 3 feet.

The Contractor shall ensure appropriate initial strength gains to meet the desired project needs. The minimum ambient and patch area surface temperature shall be per the manufacturer's recommendations at the time of UHPC installation.

Adequate measures shall be taken by the Contractor to prevent concrete chips, tools and/or materials from dropping to areas below the structure. All debris shall be promptly swept up and removed from the site. All materials removed shall be satisfactorily disposed of by the Contractor.

Any spills of UHPC material that occur during construction shall be contained and cleaned, and the material shall be satisfactorily disposed of by the Contractor. Cost of cleaning UHPC spills is considered incidental to this work and will not be measured for payment.

If the formwork exhibits evidence of leakage at any location, the Contractor shall take remedial measures necessary to stop further leakage. The UHPC shall not be internally vibrated. Cold weather placement procedures are required when the ambient temperature falls below 50°F.

11. Curing: Curing and cold weather protection shall be per Supplier recommendations and the following:

- (a) Cover the UHPC and keep formwork in place until the Contractor's testing confirms that it has achieved a minimum compressive strength of 12 ksi.
- (b) The concrete in the form shall be cured according to manufacturer's recommendations at minimum temperature of 60°F to attain the design strength.

12. Grinding: Immediately after removal of formwork, the surface of UHPC panels shall be finished using suitable grinding equipment. The Contractor shall be responsible for collection and proper disposal of the debris. Grinding of top surface of UHPC panels may also be required to achieve the slope shown on the plans. The grinding shall not damage the UHPC block or the existing beam. If damage to the UHPC block or existing beam occurs during the grinding process, the Contractor shall repair any damage to the satisfaction of the Engineer at no additional cost to the State.

13. Contractor QC requirements:

- (a) Batch identification: For each batch of UHPC, record the date, start time and end time, amounts of water and ice, and admixtures used.
- (b) Flow tests: The Contractor with the supervision from a material supplier representative shall conduct one flow test per batch of UHPC in accordance with ASTM C1437 (as modified by ASTM C1856) to verify workability and time of setting. The flow shall be 7 to 10 inches. The Contractor shall be responsible for providing an approved flow table constructed according to ASTM C230 for on-site flow testing. Results of all tests shall be sent to the Engineer for review and approval.
- (c) Mix temperature checks: The Contractor with the supervision from a material supplier representative shall conduct one temperature check per batch of UHPC in accordance with ASTM C1064. The temperature of the mix at discharge shall be between 50 and 85°F.
- (d) Compressive strength cylinder specimens: A minimum of 18 cylinders, 3 inches x 6 inches shall be cast for each shift mixed for beam end repairs.

All sets shall be cured initially in the field and shipped to the Contractor's AASHTO accredited testing lab at the end of each UHPC repair shift for final curing, preparation of test specimens (note that cylinder ends must be ground flush prior to testing in

accordance with ASTM C1856), and testing.

All cylinders shall be cured using the same method of curing used in the field. The temperature during curing shall be controlled to represent field conditions. The compressive strength of three cylinders shall be tested at 2, 4, 7, 14, and 28 days after casting. The remaining three cylinders shall be treated as reserves. The compressive strength shall be measured using ASTM C39 (as modified by ASTM C1856). The minimum compressive strength shall be 14 ksi at 4 days and 20 ksi at 28 days. Failure to meet the minimum at any point requires immediate notification to the Engineer and a written corrective action plan to be submitted to the Engineer for approval.

- (e) As-built records: The Contractor shall track and show the placement locations of UHPC production by UHPC repair shift. A PDF copy of the records shall be submitted to the Engineer on a weekly basis.

Results of all laboratory tests, conducted by the Contractor’s AASHTO accredited testing lab, shall be submitted to the Engineer for review. Testing frequency shall be as needed to maintain control of the operation.

Method of Measurement: This work will be measured for payment by the actual volume in cubic feet of concrete placed and accepted by the Engineer. The volume will be calculated based on field measurements of the UHPC repair in place after the forms have been stripped. The volume of the structural steel shall not be included. There shall be no deduction for the welded studs.

Basis of Payment: This work will be paid for at the Contract unit price per cubic foot for “Beam End Repairs with Ultra High Performance Concrete,” complete and accepted in place, which price shall include providing scaffolding or other access for the Engineer’s inspection and for repair monitoring and documentation by The University of Connecticut authorized personnel, surface preparation of existing steel in contact with UHPC, forming, placing, curing, testing, stripping and finishing new concrete, trial placement, debris shields and proper disposal of debris, joint sealant, and all materials, equipment, tools, labor and clean-up incidental thereto.

The unit price shall also include the cost of assistance from Technical Representatives of the UHPC Supplier, including their attendance at the pre-placement meeting.

Pay Item	Pay Unit
Beam End Repairs with Ultra High Performance Concrete – Partial Height	c.f.