DESIGNER NOTES

*The full text of this Special Provision as presented below is written as a Unit Price Item. However, it can also be used as a Heading within a Lump Sum item, such as Item 995.01, by making the following modifications. The Designer shall modify only the content highlighted in yellow following the instructions below to make this a Lump Sum item heading.*

*Delete “ITEM 909.991” and “CUBIC YARD” from the title. Delete the entire “METHOD OF MEASUREMENT AND BASIS OF PAYMENT” section at the end of this Special Provision.*

*DELETE ALL DESIGNER NOTES, AND REMOVE HIGHLIGHTING PRIOR TO SUBMITTAL*

# ITEM 909.991 ULTRA HIGH PERFORMANCE CONCRETE CUBIC YARD

This specification consists of supplying, mixing, transporting, placing, finishing, and curing of Ultra-High Performance Concrete for link slabs over piers, joint headers, and overlays in accordance with the Contract Documents .

## Materials

Ultra High Performance Concrete shall meet the requirements of Section M4: Cement and Cement Concrete Materials and the requirements specified herein. Ultra High Performance Concrete shall be formulated with hydraulic cement, supplementary cementitious materials, fine aggregate, water, chemical admixtures, and fibers, resulting in a cementitious-based composite material with discontinuous fiber reinforcement and pore structure. Ultra High Performance Concrete shall exhibit enhanced compressive and tensile strengths and increased resistance to creep and shrinkage, chloride ion penetration, and freezing, thawing, and de-icing cycles and shall conform to the Verification Testing Requirements in this specification.

### Constituent Material

All constituent materials incorporated into the Ultra High Performance Concrete shall meet Section M4: Cement and Cement Concrete Materials and the requirements specified herein.

#### Steel Fibers

Steel fibers shall be incorporated into the Ultra High Performance Concrete and meet ASTM A820 Standard Specification for Steel Fibers for Fiber-Reinforced Concrete and the requirements specified herein. Steel fibers shall be made of stainless steel, alloy steel, or carbon steel, and be randomly and uniformly distributed throughout the concrete during batching or at the jobsite, to reduce bleeding, plastic settlement, and cracking and increase tensile and flexural strength. Steel fibers shall be short, discrete lengths of steel with a specified length to diameter ratio and a variety of cross sections, profiles, and types, including hooked ends, straight slit sheet or wire, deformed slit sheet or wire, crimped-end wire, flattened-end slit sheet or wire, machine chip, and melt-extract. Steel fibers shall be categorized as cold-drawn wire fibers, cut sheet fibers, melt-extracted fibers, mill cut fibers, and modified cold-drawn fibers.

**Types of Steel Fibers**

|  |  |
| --- | --- |
| Type | Description |
| Type I | Cold-Drawn Wire Fibers |
| Type II | Cut Sheet Fibers |
| Type III | Melt-Extracted Fibers |
| Type IV | Mill Cut Fibers |
| Type V | Modified Cold-Drawn Fibers |

#### Synthetic Fibers

In addition to the specified requirement of steel fibers, synthetic fibers may be incorporated into the Ultra High Performance Concrete to control the rheology of the material for applications where the slope (grade) of the placement is of concern. Polypropylene fibers shall meet ASTM D7508 Standard Specification for Polyolefin Chopped Strands for Use in Concrete and the requirements specified herein. Synthetic fibers shall be acrylic, aramid, carbon, nylon, polyester, or polyolefins (polyethylene and polypropylene). Polypropylene fibers shall be produced in monofilament and fibrillated fiber forms. Monofilament polypropylene fibers shall be produced through an extrusion process in which the material is hot draw through a die of circular cross section, generating numerous continuous filaments at one time called a tow. Fibrillated polypropylene fibers shall be produced through an extrusion process in which the die is rectangular. The resulting film sheets of polypropylene shall be slit longitudinally into equal width tapes. To achieve a lattice pattern, the tape shall be mechanically distressed or fibrillated with a patterned pin wheel or split film technique to produce the main and cross fibril networks.

**Types of Polypropylene Fibers**

|  |  |
| --- | --- |
| Type | Description |
| A | Macro Cut |
| B | Micro Cut |
| C | Hybrid |
| D | Multi-Length |
| E | Graded |

### Mix Design Formulation

Producers of Ultra High Performance Concrete shall report proposed mix design formulations onto the Department issued mix design sheet in its entirety and submit to the Department for evaluation. Mill certifications and technical data sheets of the constituent materials incorporated into the proposed mix design formulation shall accompany the mix design formulation submission. Mix design formulations shall be designed with precise proportions of constituent materials, yielding 27.0 ft3 (1 cubic yard) of cement concrete. Water-cementitious (w/cm) ratio of less than or equal to 0.25 All required mix design targets shall be reported on the Department issued mix design sheet for each proposed mix design. Additionally, Producers supplying manufactured, prepackaged, preblended, and preformulated Ultra High Performance Concrete products shall submit the product’s technical data sheet to the Department for review. At a minimum, the product’s technical data sheets shall include:

1. Product Name
2. Manufacturer, including address and contact information
3. Packaging
4. Yield
5. Product Description, including an overview of the product and its intended application(s) and use(s).
6. Technical Data, including quality characteristics and corresponding performance criteria with the AASHTO and/or ASTM standard test methods identified.
7. Recommended Equipment
8. Instructions, including surface preparation, mixing, forming, placing, finishing, curing, and protection from adverse conditions, such as precipitation, cold conditions, and hot conditions.
9. Limitations
10. Storage and Shelf Life
11. Safety

Proposed mix design formulations and technical data sheets will be evaluated for quality and conformance to the requirements specified herein.

### Verification Testing

Upon Department Acceptance of the mix design evaluation, Producers proposing new mix design formulations shall select an AASHTO accredited independent laboratory to conduct mix design verification testing. The sampling and testing conducted by the independent laboratory shall be witnessed by the Department. Mix design verification test results shall be within the limits specified in Table M4.06.8-3. Additionally, manufactured, prepackaged, preblended, and preformulated Ultra High Performance Concrete products shall meet the requirements and performance criteria of the product’s technical data sheet.

**Verification Testing Requirements**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Property | Method | Quality Characteristic | | Limits | |
| Min. | Max. |
| Thermal | T 309 | Concrete Temperature (°F) | ≤ 5 min. | 50[1] | 90[1] |
| 15 min. | 50[1] | 90[1] |
| T 336 | Coefficient of Thermal Expansion (µε/°F) | | – | 8.5 |
| Uniformity | C1437[2] | Flow (in.) | | Target -1.5 | Target +1.5 |
| Strength | T 22[3] | Compressive Strength (psi) | 12 Hours | Informational | |
| 24 Hours | Informational | |
| 3 Days | Informational | |
| 7 Days | Informational | |
| 28 Days | 18000 | – |
| 56 Days | Informational | |
| T 397 | Direct Tension Cracking Strength | 28 Days | 720 | – |
| Direct Tension Sustained Post-Cracking Tensile Strength | 28 Days | [4] | – |
| C1583[5] | Direct Tension Bond Strength (psi) | 28 Days | [6] | |
| C469 | Modulus of Elasticity (ksi) | 28 Days | 6000 | – |
| Durability | T 358[7]  or  T 402[7] | Surface Chloride Ion Penetration Resistance (kΩ-cm) | 7 Days | Informational | |
| 28 Days | 254 | – |
| Uniaxial Chloride Ion Penetration Resistance (kΩ-cm) | 7 Days | Informational | |
| 28 Days | 127 | – |
| Shrinkage Cracking Resistance | C1581 | Restrained Shrinkage | 28 Days | No Cracking[8] | |
| Creep | C512 | Creep Coefficient | | – | 0.8 |
| Specific Creep (millionths/psi) | | – | 0.30 |
| [1] Or otherwise identified in the Manufacturer’s technical data sheet.  [2] Test method shall be modified and conducted without drops per ASTM C1856.  [3] Three (3) 3 x 6 in. cylinders shall be cast and tested per ASTM C1856 for each age specified.  [4] Test result shall be greater than or equal to the Direct Tension Cracking Strength test result.  [5] For applications where bond strength to the substrate or the tensile strength of either the overlay or substrate is desired.  [6] Assume bond to an exposed aggregate concrete surface. 100% failure in a concrete substrate with compressive strength greater than or equal to 4000 psi shall be attained.  [7] Three (3) 4 x 8 in. cylinders shall be cast and tested without the steel fibers for each age specified. An additional sample set may be cast and tested with the steel fibers for informational purposes only.  [8] Cracking is defined as the sudden decrease in compressive strain greater than 30 µε. | | | | | |

### Packaging, Marking and Storage

For all Ultra High Performance Concrete to be mixed on site deliver product in original, unopened moisture-proof bags with the manufacturer’s name, date of manufacture, and clearly marked with the information described below. Store the material in a dry and weather protected enclosure in full compliance with the manufacturer's recommendations. Material must be used within the manufacturer’s recommended shelf life.

All containers must be marked with the following information:

1. Packaging date and material expiration date.
2. Weight of each bag and number of bags in each pallet.
3. Storage temperature.
4. Mix components, proportions, yield, and mixing procedure.

## Construction

### Pre-Placement Meeting

Prior to the placement of the Ultra High Performance Concrete, the Contractor shall arrange for an pre-placement meeting. The Contractor’s staff, Manufacturer’s Representative, MassDOT Inspectors, MassDOT Research and Materials Representatives and the Design Engineer shall attend the meeting. The objective of the meeting is to clearly outline the procedures of all on-site activities and testing of the material.

### Mockup

A mockup shall be completed that matches the application intended a minimum of 30 days in advance of the anticipated construction. The intent of the mockup is to demonstrate proficiency in workmanship and forming related to the application. The mockup shall be a full-scale representation of the proposed application and replicate the form pressure created by the ULTRA HIGH PERFORMANCE CONCRETE. The mockup shall take place at a location approved by the engineer and be performed in the presence of Department personnel. The Contractor shall complete the mockup testing of the ULTRA HIGH PERFORMANCE CONCRETE and receive the Engineer’s approval before production placement of Ultra High Performance Concrete.

The mockup shall be placed against an existing concrete surface that has been prepared in accordance with the surface preparation requirements.

Cure all material using the same method of curing proposed to be used in the field. The temperature during the curing shall be within 18° Fahrenheit of the low end of the proposed temperature range for curing in the field.

Mockup dimensions are provided in the table below. The length dimension shall have the slope applied.

**Mockup Dimensions**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Application** | **Slope** | **Length** | **Width** | **Thickness** |
| Joint Header | Maximum Transverse Cross slope of Roadway | 4’-0” | 6” | 2” |
| Link Slab | Maximum Transverse Cross slope of Roadway | 4’-0” | 24” | 4” |
| Overlay | Maximum of cross slope or profile | 4’-0” | 4’-0” | 2” |

Once the mockup has cured sufficiently the edges of the Ultra High Performance Concrete shall be measured and not vary more than +/- ¼” from the thickness required for the mock up. If the Contractor does not achieve the required tolerance, procedures must be changed to ensure the material can meet the tolerance, and the test slab repeated. Subsequent failures must be followed by placement of a new test slab, until the Contractor is successful.

The Contractor may request a waiver of the mockup requirements if they have performed a similar application in the presence of MassDOT that was deemed satisfactory. The request shall be made a minimum of 90 days in advance of anticipated construction. The request shall cite the previous application and project with a comparison to the proposed application and project. At a minimum the time of year / temperature, volume, batching, mixing, and placement methods shall be identified for each project.

### Surface Preparation

When the Ultra High Performance Concrete is cast against existing concrete, the existing concrete surface shall be repaired in advance of placement. The existing concrete remaining to bond to the Ultra High Performance Concrete shall be sound.

Any existing or proposed concrete must be roughened to an amplitude of minimum average amplitude of ¼ to 3/8 inches of the exposed aggregate finish for all surfaces in contact with the Ultra High Performance Concrete. The Contractor shall submit the method proposed for approval in advance of the pre-placement meeting.

Prior to placement all existing concrete surfaces shall be cleaned of all laitance, dirt, grease, oil, and other contaminants, and all standing water. The surface of the concrete shall be thoroughly cleaned, roughened, and ponded with clean water to achieve Saturated Surface Dry (SSD) condition then it shall be blown off with oil free compressed air.

Surface preparation at the edge of the construction joint for the Ultra High Performance Concrete shall be roughed to remove any unconsolidated material and expose the fibers. A set retarder may be applied to the form surfaces prior to setting to facilitate this. The construction joint shall be dried in advance of the next placement to ensure freestanding water does not remain since the Ultra High Performance Concrete is essentially impermeable.

### Formwork

Formwork shall be demonstrate adequate during mock up testing and shall be in accordance with the Ultra High Performance Concrete manufacturer’s recommendations. Forms shall be constructed from non-absorbent material that are properly sealed and capable of resisting the hydrostatic pressures from Ultra High Performance Concrete in the unhardened state.

Formwork shall be fit in advance of placement and shall include top forming when used in joint or link slab applications. Top forming shall include air relief holes along the length of the form to confirm the Ultra High Performance Concrete has fully filled the void and all air is pushed out of the formwork.

In the case of joint headers or other applications in which no reinforcing is used, the formwork shall be independent per span in which the Ultra High Performance Concrete is bonding to and shall not be tied to anything except the superstructure of the span. This includes adjacent spans, backwalls, and other substructure components. If the formwork is tied between two spans (i.e. in the case of a link slab) reinforcing shall be utilized and the ambient temperature differential expected from the initial pour to the hardened state shall be less than 15 degrees.

Formwork on either side of a bridge expansion joint shall be independent, to ensure that the formwork does not incur forces due to the thermal movement of the bridge. In the case of the elimination of an expansion joint (i.e. in the case of a link slab), in which case the formwork is required to tie between spans, reinforcing shall be utilized and the ambient temperature differential expected from the initial pour to the hardened state shall be less than 15 degrees.

Formwork shall not be removed until the concrete has sufficiently hardened to prevent Ultra High Performance Concrete deflection or damage upon removal. All formwork removal shall be per the manufacturer’s recommendations.

### Batching, Mixing, and Delivery

Perform batching and mixing in accordance with the manufacturer’s technical data sheet and recommendations. A batch ticket shall be submitted for each batch produced on-site or off-site. Discharge time restrictions shall be per the Manufacturer’s technical data sheet and recommendations.

### Placement

The Ultra High Performance Concrete shall be placed within the workability duration of the manufacturer’s technical data sheet and recommendations. This shall include any travel time for Ultra High Performance Concrete arriving on site premixed.

Place the Ultra High Performance Concrete in accordance with the approved construction work plan. Do not use internal vibration during Ultra High Performance Concrete placement. The use of rodding of Ultra High Performance Concrete is allowed at the locations where successive pours meet. Keep the Ultra High Performance Concrete at the manufacturer’s recommended temperature range during the placement.

The placement shall be such that the number of construction joints is minimized. Any joints shall be included in the pre-placement submissions and shall be approved by the Engineer.

Ultra High Performance Concrete shall be placed such that the Ultra High Performance Concrete flows to lower elevations which fill prior to higher elevations to ensure completely filled forms.

During placement, the discharge of material shall be monitored to prevent of segregation of the material. Ensure that fibers are evenly distributed and do not form clumps within the material.

### Temperature Control of the Material.

During batching and placement keep the temperature of the Ultra High Performance Concrete within the manufacturer’s technical data sheet . When hot conditions are present, add ice to the mix as recommended by the Ultra High Performance Concrete manufacturer’s representative, but do not exceed the allowable specified water to cementitious material ratio.

### Protection from Adverse Conditions.

Protect the Ultra High Performance Concrete in accordance with the manufacturer’s recommendations. This shall include protection from the following adverse conditions in accordance with the manufacturer’s technical data sheet and recommendations:

1. Hot and Dry Weather
2. Rainy Weather
3. Cold Weather

### Finishing

Finishing shall be performed in accordance with the manufacturer’s technical data sheet and recommendations. Screeding and Initial Curing “Evaporation Reducer” application simultaneously is an acceptable practice. The “Evaporation Reducer” product shall be reviewed and approved by the Ultra High Performance Concrete manufacturer prior to application.

In areas not exposed to environment no additional finishing is needed. In areas exposed to environment, final finishing is required.

### Grinding

To adjust any elevations or remove over pour grinding may be performed. Perform grinding of the Ultra High Performance Concrete surface after the Ultra High Performance Concrete is sufficiently hardened per the manufacturer’s recommendations or as shown in the Contract Documents. Suspend all grinding if significant fiber pullout is observed during grinding operations. Take corrective actions to prevent the recurrence of the problem which requires the Engineer’s approval prior to implementation.

### Surface Texturing

Ultra High Performance Concrete utilized on the surface of the bridge deck shall be textured to meet the requirements of Part II Subsection 901.66 H.

### Curing

Cure and cover the Ultra High Performance Concrete in accordance with the manufacturer’s recommendations. The roadway may be reopened to vehicular traffic once the Ultra High Performance Concrete has reached 70% of its compressive strength.

## ConTRACTOR QUALITY CONTROL

Quality Control (QC) shall be established, maintained, and performed by the Contractor to monitor, assess, and adjust manufacturing, production, fabrication, and construction processes, to maintain continuous control of the process, and to ensure that the final material or product will meet the specified level of quality.

### Quality Control Plan

At a minimum of 30 days prior to construction, the Contractor shall submit a contract-specific Quality Control Plan (QCP) for each applicable contract work item to the Department for review and approval. The QCP shall document all Quality Control personnel and procedures utilized to maintain control of all production and placement processes. The QCP for each contract work item shall meet the NETTCP Model Quality Control Plan standard format and requirements specified by the Department.

### Quality Control Laboratory

The Contractor’s Quality Control Laboratory shall be qualified through the AASHTO Accreditation Program (AAP) or as approved by the Department. The Contractor shall have all required sampling, testing, and inspection equipment on site and available for use during all phases of production. The equipment shall meet all applicable AASHTO or ASTM standards, maintain required calibration schedules, and be in acceptable working condition.

### Quality Control Organization.

The Contractor’s Quality Control organization shall be comprised of trained, experienced, and qualified Production Personnel, Quality Control Technicians, and Quality Control as specified herein. Production Personnel, Quality Control Technicians, and Quality Control Managers shall maintain continuous communication to ensure conformance to specification requirements and to dictate corrective action for non-conformance.

### Quality Control Records, Documentation, and Analysis.

The Contractor shall organize, maintain, and retain Quality Control documentation, including Quality Control plans for contract work items, personnel qualification and certification records, laboratory accreditation and certification records, daily diaries, record books, databases, Department and Contractor correspondence, random sampling location report forms, test report forms, inspection report forms, certificates of compliance, non-conformance report forms, corrective actions, control charts, quality level analysis, Quality Control test result summary sheets, material quantities produced or placed by lot and sublot, and other Quality Control documentation per the Department Approved Quality Control Plan and as specified herein. All QC records and documentation shall be made available to the Engineer within 48 hours and upon the request of the Department. At a minimum, the Contractor shall maintain a filing system for the following QC records and documentation:

1. QC Laboratory Qualifications (AASHTO Accreditation or Department Approval)
2. Qualifications and Certifications for QC Manager(s) and QC Technician(s)
3. Department Approved Quality Control Plan
4. Department Approved Mix Design Sheet(s) and Approval Letter(s)
5. Technical Data Sheets
6. Batch tickets
7. QC Inspection Report Forms (IRFs)
8. QC Test Report Forms (TRFs)
9. QC and Department Non-Conformance Reports (NCRs)
10. Department Deficiency Reports (DRs)
11. QC and Production equipment calibrations, verifications, and maintenance documentation.

### Department Acceptance

Acceptance shall be performed by the Department, including consultants under direct contract with the Department independent of the Contractor, to evaluate the degree of compliance with contract requirements, to monitor the Contractor’s Quality Control activities, to determine the corresponding value for a given product and the acceptability of all material produced and placed through Department acceptance sampling, testing, inspection, evaluation, and documentation.

### Acceptance of Quality Control Operating Documents

The Department will review all Quality Control operating documents, including the Quality Control Plans for contract work items submitted by the Contractor. Department approval shall be subject to conformance with the requirements specified herein.

### Monitoring Contractor Quality Control

The Department will monitor the adequacy of the Contractor Quality Control System, to ensure Contractor compliance to all items identified in Quality Control documents, including the Contractor Quality Control Plans for contract work items. Failure to comply with these Quality Control documents may result in work suspension.

### Acceptance Inspection

Acceptance inspection will be performed and reported by qualified Department (or designee) Acceptance Technicians, to visually inspect equipment, environmental conditions, materials, and workmanship, per the requirements specified herein. The results and findings of Acceptance inspection will be documented on the Department’s Inspection Report Forms (IRFs). The Department will conduct immediate initiation of non-conformance reporting for non-conforming inspection results and uncontrolled processes.

### Acceptance Sampling and Testing

Acceptance sampling and testing will be performed and reported by qualified Department (or designee) Acceptance Technicians, to provide quality characteristic data used for Department Acceptance determination, per the requirements specified herein. The results and findings of Acceptance sampling and testing will be documented on the Department’s Test Report Forms (TRFs). The Department will conduct immediate initiation of non-conformance reporting and corrective action for materials with test results not within allowable limits.

Acceptance sampling and testing will be conducted during production per the minimum requirements specified herein. Production test results shall be within the limits specified herein.

**Acceptance Sampling and Testing Requirements**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Property | Method | Quality Characteristic | | Limits | |
| Min. | Max. |
| Thermal | T 309 | Concrete Temperature (°F) | ≤ 5 min. | 50[1] | 90[1] |
| 15 min. | 50[1] | 90[1] |
| Uniformity | C1437[2] | Flow (in.) | | Target -1.5 | Target +1.5 |
| Strength | T 22[3] | Compressive Strength (psi) | 12 Hours | Informational | |
| 24 Hours | Informational | |
| 3 Days | Informational | |
| 7 Days | Informational | |
| 28 Days | 18000 | – |
| 56 Days | Informational | |
| Durability | T 358[4]  or  T 402[4] | Surface Chloride Ion Penetration Resistance (kΩ-cm) | 7 Days | Informational | |
| 28 Days | 254 | – |
| Uniaxial Chloride Ion Penetration Resistance (kΩ-cm) | 7 Days | Informational | |
| 28 Days | 127 | – |
| [1] Or otherwise identified in the Manufacturer’s technical data sheet.  [2] Test method shall be modified and conducted without drops per ASTM C1856.  [3] Three (3) 3 x 6 in. cylinders shall be cast and tested per ASTM C1856 for each age specified.  [4] Three (3) 4 x 8 in. cylinders shall be cast and tested without the steel fibers for each age specified. An additional sample set may be cast and tested with the steel fibers for informational purposes only. | | | | | |

## METHOD OF MEASUREMENT

The Ultra High Performance Concrete shall be measured by the cubic yard and the quantity shall be determined in accordance with dimensions shown on the plans and such alteration of the plans as are specifically ordered by the Engineer in writing. No deduction shall be made for rustications, chamfered corners of dimensions less than 4 in. on the square sides or for anchor bolts or reinforcing bars.

## BASIS OF PAYMENT

Ultra High Performance Concrete will be paid for at the contract unit price per cubic yard under the particular item of Ultra High Performance Concrete required, as shown on the plans or as directed, complete in place and accepted.

The Contractor shall have no claims for special allowances for extra materials or apparent shrinkage due to inaccurate proportioning or control, bulging of forms, spilling, waste or for any other project conditions within their control.

Payment for additional material required to be used in proportioning by volume and in placing of concrete under water shall be included in the contract unit price paid for the designation of Ultra High Performance Concrete specified or directed.