Example Construction Checklist: UHPC Connections for Prefabricated Bridge Elements

FHWA Publication: FHWA-HIF-18-030
FHWA Contacts: Ben Graybeal, HRDI-40, 202-493-3122, benjamin.graybeal@dot.gov
Mark Leonard, DTSRCLAK, 720-963-3747, mark.leonard@dot.gov

Introduction

This example checklist for the construction of ultra-high performance concrete (UHPC) connections for prefabricated bridge elements is intended as technical assistance to bridge owners. The checklist provides items bridge owners may want to consider when developing their agency's inspection procedures for the construction of UHPC connections. Additional technical assistance on the construction of UHPC connections can be found in publication FHWA-HRT-14-084.(1)

This document follows the flow of a project construction schedule, in phases of Pre-Award; Preconstruction; Prototype Casting; Field Casting; Post-Placement; and Project Closeout. Each phase contains subsections with introductory text and checklists, specific to UHPC only. This document is not intended to provide an overall bridge construction checklist, nor is it intended to replace proper training on UHPC. Personnel using this construction checklist should be knowledgeable in bridge construction and UHPC technology.

Depending on the type of UHPC connection and the project specifications, not all the items in the following checklists may be applicable. The user will need to determine which items are pertinent to their specific project.

Where applicable, the appropriate UHPC test standard is referenced or specified.

Terminology

ASTM – American Society of Testing and Materials
QA/QC – Quality assurance and quality control
SSD – Saturated surface dry
UHPC – Ultra-high performance concrete

Table of Contents:

U.S. Department of Transportation
Federal Highway Administration

April 2018

Phase I: Pre-Award

The pre-award checklist is used at the bid opening to determine if the contractor has met the minimum qualifications in the project specifications.

If this information is required by the project specifications, and it is not validated during pre-award, then it would be included in the preconstruction submittals. If the agency has a prequalified list of approved suppliers, some of the requirements of this section may have been previously submitted and would not be required in the project specific submittals.

UHPC Material Acceptance

- ☐ Material supplier meets project specifications for:
  - ○ Minimum experience
  - ○ Technical field staff with adequate experience (for example, minimum of three years of concrete production and quality assurance experience)
- ☐ UHPC materials meet project specifications for:
  - ○ Strength properties (in accordance with ASTM C1856/C1856M) [(2)]
  - ○ Durability properties (in accordance with ASTM C1856/C1856M) [(2)]
  - ○ Other properties required by the project specifications
- ☐ UHPC supplier has supplied all test data required by the project specifications

Contractor and Subcontractor Acceptance

- ☐ Contractor meets the project specifications for minimum years of experience
- ☐ Subcontractor meets the project specifications for minimum experience

Testing Laboratory's Acceptance

Note: The agency may have the general contractor confirm that these requirements are met.

- ☐ Testing laboratory meets project specifications for minimum experience (for example, three years testing experience or having been trained by a person with three years of experience in UHPC – currently there is not a nationally recognized certification specific to testing UHPC)
- ☐ Testing laboratory has equipment for:
  - ○ End grinding of cylinders (in accordance with ASTM C1856/C1856M) [(2)]
  - ○ Testing 3" x 6" cylinders (in accordance with ASTM C1856/C1856M) [(2)]
  - ○ Testing flexural prisms (in accordance with ASTM C1856/C1856M) [(2)]

Phase II: Preconstruction

The following are items an agency may elect to have the contractor submit for agency approval before construction. Following the award of the contract, a preconstruction meeting should be held to review the submittals.

A full review of all submittals should be completed in accordance with the agency's normal procedural requirements, and a confirmation given to the contractor of acceptance.

Construction Submittals

- ☐ Schedules
- ☐ General arrangement and layout drawings for all prefabricated elements
  - ○ Showing rebar, stud, and other connectors' projections into connection space
  - ○ Showing rebar, studs, and other connectors' laps and spacing (laps in contact with each other or a minimum clear spacing of 1.5 times fiber length)
- ☐ Shop drawings for prefabricated elements
- ☐ Drawings for handling & storage of prefabricated elements
- ☐ Erection/installation/assembly drawings
  - ○ Crane size and placement with reach and capacity information
  - ○ Prefabricated element installation sequencing
  - ○ Prefabricated element permanent (e.g. angle iron) or temporary (e.g. shims or other) supports
- ☐ UHPC connection formwork drawing
- ☐ UHPC connection casting procedure
  - ○ Sequence drawing (UHPC placement sequence and schedule; anticipated bulkhead locations; contingency plan if pouring operations are interrupted by weather; equipment malfunctions; other issues)
  - ○ Mixers and setup (type and number of mixers; site locations; contingency plan if a mixer malfunctions)
  - ○ Storage details for UHPC raw materials
  - ○ Weighing equipment for UHPC materials
  - ○ Procedures for ensuring SSD connection interfaces prior to UHPC placement
  - ○ Procedure for controlling UHPC mix temperatures (if using ice, provide information on storage of ice)
  - ○ QA/QC plan (include: equipment list, test setup, sampling method, frequency and type of tests)
  - ○ Curing procedures (to minimize any moisture loss from the fresh UHPC and maintain appropriate environment)
  - ○ Heating procedures (if appropriate due to environment and/or schedule)
- ☐ Product Material Safety Data Sheets

Maturity Method Procedures

Note: If specified or to be used – UHPC strength development curves are especially appropriate for accelerated construction projects requiring strength in less than 12 hours)

- ☐ Strength/maturity curves
- ☐ Maturity system details
- ☐ Locations and details of thermocouples for recording temperatures

Prototype Casting Submittals

- ☐ Schedules
- ☐ Drawings of prototype casting setup

Preconstruction Meeting

- ☐ Preconstruction meeting held to discuss schedule, delivery, QA/QC, etc. as well as contingencies for weather, equipment malfunctions, etc.

Phase III: Prototype Casting

The purpose of the prototype casting is for the UHPC contractor to benefit from self-learning. Prototype casting provides valuable lessons for contractors with little experience using UHPC, and even for the most experienced and qualified contractors. The prototype casting also provides an advance trial of the project specific details and methods for all parties involved in the project.

The project specifications may also require a trial batch prior to a full prototype casting. For a trial batch follow the relevant section requirements of the prototype casting checklist.

During the post prototype casting review, the checklist provides several critical items to confirm. During this review ensure any lessons learned during the prototype casting are incorporated into the field casting phase and a new set of submittals are prepared, reviewed and approved before commencing the field casting phase.

Construction Prototype Casting

- ☐ Prototype is assembled in accordance with the prototype casting drawing submittal

Personnel

- ☐ All personnel are wearing proper personal protective equipment (for example: vests, safety boots, hardhats, glasses/goggles, and dust masks where required)
- ☐ UHPC material supplier personnel on-site have been preapproved (see the pre-award checklist for more information)

Safety

- ☐ Material safety data sheets (MSDS) for the UHPC are available
- ☐ All on-site personnel received a safety briefing by UHPC supplier and contractor
- ☐ Material supplier has reviewed the batching, transporting and casting procedure with the on-site personnel

Environmental

- ☐ Operations are compliant with local environmental regulations
- ☐ Rejected batches of UHPC have a designated disposal area (rejected batches are dumped in predesignated plastic or metal bins, then should be removed when hardened)
- ☐ Waste water or clean up water from mixers or other sources disposed of in accordance with environmental regulations

UHPC Materials (pre-batching check for raw materials stored on-site)

- ☐ Premix
  - ○ Material Identity Card provided (supplied by premix supplier or designer of UHPC mixture)

UHPC Materials (cont.)

- ○ Correct product provided (product on-site matches product submittals)
- ○ Quantities are sufficient for prototype casting
- ○ Shelf life has not been exceeded (production date stamp on package or shipping tag: product is within time limit stated on Material Identity Card)
- ○ Stored properly – kept clean and dry

☐ Fiber Reinforcements

- ○ Correct product provided (product on-site matches product submittals)
- ○ Quantities are sufficient for prototype casting
- ○ No signs of deterioration (excessive corrosion, such that balling occurs in the fibers)
- ○ Stored properly – kept clean and dry

☐ Chemical admixtures

- ○ Correct product provided (product on-site matches product submittals and Material Identity Card)
- ○ Quantities are sufficient for prototype casting
- ○ Color changes are acceptable (refer to ASTM C494, C1017 & C1622 for more information) [3 -5]
- ○ No signs of deterioration (refer to ASTM C494, C1017 & C1622 for more information) [3 -5]

☐ Water

- ○ Quantity is sufficient for prototype casting
- ○ Quality is acceptable (potable)

☐ Ice (in hot weather up to 100 percent ice may be used in place of water)

- ○ Quantity is sufficient for prototype casting
- ○ Stored properly – freezing temperature maintained

Formwork

- ☐ Formwork is installed as shown on the shop drawing submittals
- ☐ Forms are clean and clear of debris and buildup of old concrete
- ☐ Formwork appears to be tightly sealed and designed to support the full hydrostatic pressure head of the UHPC in its plastic state
- ☐ UHPC connection pours have been broken into isolated sections as shown on the submittals.
- ☐ Top forms for deck-level connections are prepared and adequate hold downs for the top forms are available
- ☐ Top forms for deck-level connections are set at a minimum of ¼” (6 mm) above the top of deck to allow for overfilling, in accordance with project specifications
- ☐ Chimneys for maintaining hydrostatic head are prepared and ready for installation with proper attachments

Prefabricated Elements

- ☐ Surface texture is acceptable in connection areas that will be in contact with UHPC
- ☐ Precast concrete surfaces in connection areas are SSD
- ☐ The seal between the prefabricated elements and the supporting structures or adjacent elements are tight (grout tight – UHPC typically does not contain coarse aggregates, and seals need to be better than conventional practices and designed to support the full hydrostatic pressure head of the UHPC in its plastic state)
- ☐ Prefabricated element rebar, studs or other connectors extend the proper distance into the connections, have proper lap splice length, and have a minimum clear distance of 1.5 times the fiber length to other objects, including to lapping rebar, or are in full contact with lapping rebar

Equipment

- ☐ Mixers (preferably a minimum of 2)
  - ○ Size is adequate to provide a continuous flow of UHPC for placement
  - ○ In proper working condition
  - ○ Clean and free of a buildup of old concrete
  - ○ Power supply is adequate and power is connected to mixers with the correct polarity such that mixers rotate in the correct direction (an electrician may be required – only required for mixers with electric motors)
  - ○ Charging point screen is used over mixer (check size of mesh opening [max 1.5”x1.5”] and safety switch – for UHPC with longer fibers, mesh size opening may need to increased)
  - ○ Fins and blades are clean, with an acceptable level of wear, and properly spaced
  - ○ Gates working properly, tightly sealed and clean (not leaking)
- ☐ Buggies, wheelbarrows and hoppers
  - ○ Clean and free of a buildup of old concrete
  - ○ Gates (if available) working properly and tightly sealed
  - ○ Sprayed with a thin layer of approved form release to prevent buildup and facilitate cleanup (caution: apply lightly to avoid contamination of the UHPC)

QA/QC

- ☐ QA/QC drawings and procedures are readily available on site and at the job office
- ☐ QA/QC testing area is located close to the mixers on a level surface not impacted by vibrations from equipment and protected from disruptions due to the construction process and environmental conditions
- ☐ Testing equipment
  - ○ Slump flow apparatus (ASTM C1856/C1856M) [(2)]
  - ○ 3” x 6” cylinder molds (including six extra molds) (ASTM C1856/C1856M) [(2)]
  - ○ Other molds or testing equipment if required by the project specifications (ASTM C1856/C1856M) [(2)]
  - ○ Thermometer

QA/QC (cont.)

- ○ Funnel and 3” x 6” hand scoop for casting and placing of samples
- ○ Camera

☐ Batching records (as required by the project specifications – the following is an example)

- ○ Name and location of batch plant (if not batched on-site)
- ○ Date
- ○ Name of contractor (if applicable)
- ○ Name of batcher
- ○ Specific job designation
- ○ Amount of UHPC in cubic yards or metres (per batch and total)
- ○ Mass of each material component added to mixer
- ○ Mixer identification number and/or batch number
- ○ Time of water addition
- ○ Time of discharge
- ○ Mixing time
- ○ Temperature (batch and ambient)
- ○ Flow
- ○ Material identification and supplier
- ○ Amount of water added after initial batching
- ○ Amount of admixture added after initial batching
- ○ Batch from which the cylinder specimens were collected

☐ Testing frequency (as required by the project specifications – the following are example minimums)

- ○ Slump flow – every batch (ASTM C1856/C1856M) [(2)]
- ○ Temperature – every batch meets project specifications
- ○ Cylinders – at least one set of tests shall be performed for the prototype (ASTM C1856/C1856M) [(2)]:
  - ◊ Three cylinders for early compressive strength (minimum strength of UHPC before applying construction loads to connection, as specified by the owner)
  - ◊ Three cylinders for 28-day compressive strength
  - ◊ Three cylinders for compressive strength when thermal treatment is specified

Weighing & Batching

- ☐ Mix design available at the mixer
- ☐ Scales available
- ☐ Procedure reviewed by batching personnel
- ☐ Temperature is within project specifications
- ☐ Flow is within project specifications
- ☐ All ingredients are properly mixed

Transporting

- ☐ Wheelbarrows, buggies or buckets are available and the size, quantity and condition are acceptable – no leaks or excessive buildup of old concrete
- ☐ Methodology of moving the fresh UHPC from the mixer to the connection location is predetermined
- ☐ Pathway from mixer to filling points (connections) are safe, clearly marked and clear of obstacles or uneven surfaces that may cause segregation during transporting of the UHPC

Placing

The following are typical steps for filling connections. The contractor may decide to try an alternative method; however, the alternative method should be validated in the prototype casting.

- ☐ Chutes or funnels to direct the filling are available
- ☐ The connection areas to be filled with UHPC are clean and free of debris
- ☐ All surfaces of precast elements in contact with UHPC are SSD
- ☐ Filling started from low point, placing fresh material into previously placed material
- ☐ UHPC placed into connection area in a manner that prevents discontinuous flow and unintended cold joints – separate pours are intermixed with a rod where needed
- ☐ Top forms on deck-level connections are installed as filling of connection proceeds
- ☐ Top forms tapped with a hammer to determine if connections are full (sound of tap will change – hollow vs solid)
- ☐ Chimneys added at high points (chimneys may also be added at connection intersections)
- ☐ A hydrostatic head is maintained in chimneys
- ☐ Formwork checked periodically for leaks during casting – including at underside of the deck
- ☐ Chimneys checked periodically to ensure they are adequately filled with UHPC
- ☐ Forms for deck-level connections tapped periodically with a hammer to ensure they are full

Curing

- ☐ Top forms on deck-level connections installed immediately after filling connections with UHPC

Post Prototype Casting Acceptance

- ☐ Mixing procedures were acceptable
- ☐ Transporting and placing methods were acceptable
- ☐ Formwork did not leak during or after casting
- ☐ All connections are full to proper height and acceptable (for deck-level connections the top forming method was acceptable and procedures ensured adequate pressure against top forms)
- ☐ All batches of UHPC were tested for temperature and flow
- ☐ Compressive strength met specifications
- ☐ All documentation for prototype casting was received
  - ○ QA/QC documents signed and dated by responsible party
- ☐ Contractor team held a prototype casting debriefing
- ☐ Prototype casting was accepted

Phase IV: Field Casting

To obtain high quality connections it is important that the field casting operations are properly executed. The purpose of the previous phases of the checklist were to help ensure proper preparation for field casting. The field casting checklist is used during construction to help ensure, and document, that the field casting operations are conducted in accordance with the project specifications.

Many of the checklist items to consider in the Phase III Prototype Casting checklist also apply to the Phase IV Field Casting checklist.

Placement

- ☐ All changes from the lessons learned during the prototype casting have been made to the QA/QC drawings, installation/assembly drawings, formwork drawings and other submittals prior to commencement of field casting

Personnel

- ☐ All personnel are wearing proper personal protective equipment (for example: vests, safety boots, hardhats, glasses/goggles, and dust masks where required)
- ☐ UHPC material supplier personnel on-site have been preapproved (see the pre-award checklist for more information)
- ☐ Two persons clearly designated, lead and assistant, to track documentation for batching, weather conditions, and site issues

Safety

- ☐ Material safety data sheets (MSDS) for the UHPC are available
- ☐ All on-site personnel received a safety briefing by UHPC supplier and contractor
- ☐ Material supplier has reviewed the batching, transporting and casting procedure with the on-site personnel

Environmental

- ☐ Operations are compliant with local environmental regulations
- ☐ Rejected batches of UHPC have a designated disposal area (rejected batches are dumped in predesignated plastic or metal bins, then should be removed when hardened)
- ☐ Waste water or clean up water from mixers or other sources disposed of in accordance with environmental regulations

UHPC Materials (pre-batching check for raw materials stored on-site)

- ☐ Premix
  - ○ Material Identity Card provided (supplied by premix supplier or designer of UHPC mixture)
  - ○ Correct product provided (product on-site matches product submittals)

UHPC Materials (cont.)

- ○ Quantities are sufficient for casting
- ○ Shelf life has not been exceeded (production date stamp on package or shipping tag: product is within time limit stated on Material Identity Card)
- ○ Stored properly – kept clean and dry

☐ Fiber Reinforcements

- ○ Correct product provided (product on-site matches product submittals)
- ○ Quantities are sufficient for casting
- ○ No signs of deterioration (excessive corrosion, such that balling occurs in the fibers)
- ○ Stored properly – kept clean and dry

☐ Chemical admixtures

- ○ Correct product provided (product on-site matches product submittals and Material Identity Card)
- ○ Quantities are sufficient for casting
- ○ Color changes are acceptable (refer to ASTM C494, C1017 & C1622 for more information) [3 -5]
- ○ No signs of deterioration (refer to ASTM C494, C1017 & C1622 for more information) [3 -5]

☐ Water

- ○ Quantity is sufficient for casting
- ○ Quality is acceptable (potable)

☐ Ice (in hot weather up to 100 percent ice may be used in place of water)

- ○ Quantity is sufficient for casting
- ○ Stored properly – freezing temperature maintained

Formwork

☐ Formwork is installed as shown on the shop drawing submittals

☐ Forms are clean and clear of debris and buildup of old concrete

☐ Formwork appears to be tightly sealed and designed to support the full hydrostatic pressure head of the UHPC in its plastic state

☐ All formwork is made from a non-absorbent material or is coated with a non-absorbent material so that the formwork does not pull moisture from the fresh UHPC

☐ UHPC connection pours have been broken into isolated sections as shown on the accepted submittals

☐ Top forms for deck-level connections are prepared and adequate hold downs for the top forms are available

☐ Top forms for deck-level connections are set at a minimum of ¼" (6 mm) above the top of deck to allow for overfilling, in accordance with project specifications

☐ Chimneys for maintaining hydrostatic head are prepared and ready for installation with proper attachments

Prefabricated Elements

- ☐ Surface texture is acceptable in connection areas that will be in contact with UHPC
- ☐ Precast concrete surfaces in connection areas are SSD
- ☐ The seal between the prefabricated elements and the supporting structures or adjacent elements are tight (grout tight – UHPC typically does not contain coarse aggregates, and seals need to be better than conventional practices and designed to support the full hydrostatic pressure head of the UHPC in its plastic state)
- ☐ Prefabricated element rebar, studs or other connectors extend the proper distance into the connections, have proper lap splice length, and have a minimum clear distance of 1.5 times the fiber length to other objects, including to lapping rebar, or are in full contact with lapping rebar

Equipment

- ☐ Mixers (preferably a minimum of 2)
  - ○ Size is adequate to provide a continuous flow of UHPC for placement
  - ○ In proper working condition
  - ○ Clean and free of a buildup of old concrete
  - ○ Power supply is adequate and power is connected to mixers in the correct polarity such that mixers rotate in the correct direction (an electrician may be required – only required for mixers with electric motors)
  - ○ Charging point screen is used over mixer (check size of mesh opening [max 1.5”x1.5”] and safety switch– for UHPC with longer fibers, mesh size opening may need to increased)
  - ○ Fins and blades are clean, with an acceptable level of wear, and properly spaced
  - ○ Gates working properly, tightly sealed and clean (not leaking)
- ☐ Buggies, wheelbarrows and hoppers
  - ○ Clean and free of a buildup of old concrete
  - ○ Gates (if available) working properly and tightly sealed
  - ○ Sprayed with a thin layer of approved form release to prevent buildup and facilitate cleanup (caution: apply lightly to avoid contamination of the UHPC)

QA/QC

- ☐ QA/QC drawings and procedures (as approved with all revisions from prototype casting) are readily available on site and at the job office
- ☐ QA/QC testing area is located close to the mixers on a level surface not impacted by vibrations from equipment and protected from disruptions due to the construction process and environmental conditions

QA/QC (cont.)

- ☐ Testing equipment
  - ○ Slump flow apparatus (ASTM C1856/C1856M) [(2)]
  - ○ 3” x 6” cylinder molds (including six extra molds) (ASTM C1856/C1856M) [(2)]
  - ○ Other molds or testing equipment if specified in the project specifications (ASTM C1856/C1856M) [(2)]
  - ○ Thermometer
  - ○ Funnel and 3” x 6” hand scoop for casting and placing the samples
  - ○ Camera

- ☐ Batching records (as required by the project specifications – the following is an example)
  - ○ Name and location of batch plant (if not batched on-site)
  - ○ Date
  - ○ Name of contractor (if applicable)
  - ○ Name of lead batcher
  - ○ Name of assistant batcher
  - ○ Specific job designation
  - ○ Amount of UHPC in cubic yards or metres (per batch and total)
  - ○ Mass of each material component added to mixer
  - ○ Mixer identification number and/or batch number
  - ○ Time of water addition
  - ○ Time of discharge
  - ○ Mixing time
  - ○ Temperature (batch and ambient)
  - ○ Flow
  - ○ Material identification and supplier
  - ○ Location where batch is placed in the structure
  - ○ Amount of water added after initial batching
  - ○ Amount of admixture added after initial batching
  - ○ Batch from which the cylinder specimens were collected
  - ○ Name of tester and testing assistant(s) (can be the same personnel responsible for batching)

- ☐ Testing frequency (check project specification for frequencies – the following are example minimums)
  - ○ Slump flow – every batch (ASTM C1856/C1856M)
  - ○ Temperature – every batch meets project specifications
  - ○ Cylinders – the following tests shall be performed at least once per production shift (ASTM C1856/C1856M):
    - ◊ Three cylinders for early compressive strength (minimum strength of UHPC before applying construction loads to connection, as specified by the owner)
    - ◊ Three cylinders for 28-day compressive strength
    - ◊ Three cylinders for compressive strength when thermal treatment is specified
    - ◊ Five cylinders for 56-day compressive strength, when specified

Weighing & Batching

- ☐ Mix design available at the mixer
- ☐ Scales available
- ☐ Procedure (as previously accepted) reviewed by batching personnel
  - ○ Weighing and batching personnel know their assigned responsibilities
  - ○ Weighing and batching personnel know the procedures for their assigned responsibilities
- ☐ Temperature is within project specifications
- ☐ Flow is within project specifications
- ☐ Approved batching process followed – confirmed periodically throughout the day
- ☐ All ingredients are properly mixed

Transporting

- ☐ Wheelbarrows, buggies or buckets are available and the size, quantity and condition are acceptable – no leaks or excessive buildup of old concrete
- ☐ Methodology of moving the fresh UHPC from the mixer to the connection location is predetermined
- ☐ Pathway from mixer to filling points (connections) are safe, clearly marked and clear of obstacles or uneven surfaces that may cause segregation during transporting of the UHPC

Placing

The following are typical steps for filling connections. The contractor may decide to try an alternative method; however, a prototype casting should be arranged prior to allowing an alternative placing method. Any lessons learned from the prototype casting should be implemented during the field casting phase.

- ☐ Chutes or funnels to direct the filling are available
- ☐ The connection areas to be filled with UHPC are clean and free of debris
- ☐ All surfaces of precast elements in contact with UHPC are SSD
- ☐ Filling started from low point, placing fresh material into previously placed material
- ☐ UHPC placed into connection area in a manner that prevents discontinuous flow and unintended cold joints – separate pours are intermixed with a rod where needed
- ☐ Top forms on deck-level connections are installed as filling of connection proceeds
- ☐ Top forms tapped with a hammer to determine if connections are full (sound of tap will change – hollow vs solid)
- ☐ Chimneys added at high points (chimneys may also be added at the connection intersections)
- ☐ A hydrostatic head is maintained in chimneys
- ☐ Formwork checked periodically for leaks during casting – including at underside of the deck
- ☐ Chimneys checked periodically to ensure they ae adequately filled with UHPC
- ☐ Forms for deck-level connections tapped periodically with a hammer to ensure they are full

Curing

- ☐ Top forms on deck-level connections installed immediately after filling connections with UHPC
  Or
- ☐ Acceptable curing is applied immediately after casting

Temperature Control and Monitoring (if required)

- ☐ Maturity system or temperature monitoring system, with temperature recording, is installed
- ☐ Adequate number of temperature monitoring points used to represent the connections cast
- ☐ Temperature/strength acceptance criteria is determined

Phase V: Post-Placement

During the post-placement period, it is critical to ensure the UHPC experiences no moisture loss and has maintained a minimum temperature to attain the minimum required compressive strength before loading the connections.

Curing

- ☐ Curing maintained until UHPC reached required strength – as required in project specifications (installing formwork, covering with poly sheet, water ponding, or other approved curing methods should commence immediately to prevent the loss of mix water)

Temperature Control and Monitoring

- ☐ Maturity system or temperature recording and monitoring is readily accessible
- ☐ Temperature/strength acceptance criteria is determined and accepted
- ☐ Person responsible for temperature control and monitoring are identified and on-site
- ☐ Approval process for meeting criteria is clear and accountable

QA/QC

- ☐ Maturity (time/temperature/strength) curves used to verify the in-situ compressive strength (It is common to also break cylinders to validate the maturity curves. This normally occurs several hours later, and for accelerated construction, possibly after the structure is loaded.)
  OR
- ☐ Cylinders broken to verify the compressive strength

Timing of Construction Loading

- ☐ Structure not loaded until UPC reached minimum required compressive strength

Formwork Removal

- ☐ Formwork not removed until UHPC reached minimum required compressive strength

Grinding

- ☐ Structure not loaded with grinding equipment until UHPC reached minimum required compressive strength (normally 14,000 psi or 97 MPa, to prevent the grinding operation from damaging the bond of the UHPC to the precast elements, and pulling the fibers out of the UHPC)
- ☐ Grinding commenced as soon as practical after attaining minimum compressive strength (waiting longer than necessary increases the amount of time, and grinding blades, needed to obtain an acceptable surface profile)

Connection Leak Testing (if required by specifications for deck-level connections)

- ☐ Leak testing protocol established
- ☐ Leak testing completed
- ☐ Leak testing passed

Sealing of Leaks (if connection failed leak testing)

The following is an example method. Alternative methods or systems may be used and should be validated on a test section prior to accepting and applying the sealing system.

- ☐ Proper safety procedures are being followed for traffic control and personal protective equipment
- ☐ All grinding has been completed
- ☐ Areas to be sealed have been cleaned of dust and debris with a dust-free shot blaster or grit blaster
- ☐ Areas to be sealed have been vacuumed to remove any dust or debris
- ☐ Areas to be sealed have been blown dry to remove moisture
- ☐ Sealing materials are mixed in accordance with manufacturer's recommendations
- ☐ Sealant is applied immediately after mixing and within manufacture's recommended time frame
- ☐ Sealant is allowed to fully cure in accordance with manufacturer's recommendations

Phase VI: Project Closeout

The project closeout should follow normal closeout procedures and ensure the following aspects are included.

QA/QC Records Review, Documentation and Acceptance

- ☐ Batch records have been received
- ☐ Compressive strength data have been received and accepted
- ☐ Connection leak testing has been completed and accepted (if required by project specifications)
- ☐ All contractor submittals have been received and accepted
  - ○ QA/QC documents signed and dated by responsible party
- ☐ All checklists reviewed and all deficiencies have been resolved

Environmental and End of Project Treatment

- ☐ Any rejected batches of UHPC have been disposed in an acceptable manner

References

1. Graybeal, Benjamin A, “Design and Construction of Field-Cast UHPC Connections,” FHWA-HRT-14-084, Washington, D.C., 2014.

2. ASTM C1856 / C1856M-17, “Standard Practice for Fabricating and Testing Specimens of Ultra-High Performance Concrete,” ASTM International, West Conshohocken, PA, 2017.

3. ASTM C494 / C494M-17, “Standard Specification for Chemical Admixtures for Concrete,” ASTM International, West Conshohocken, PA, 2017.

4. ASTM C1017 / C1017M-13e1, “Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete,” ASTM International, West Conshohocken, PA, 2013.

5. ASTM C1622 / C1622M-10(2016)e1, “Standard Specification for Cold-Weather Admixture Systems,” ASTM International, West Conshohocken, PA, 2016.

Sponsoring Agency – Center for Accelerating Innovation, Federal Highway Administration, 1200 New Jersey Avenue, SE, Washington, DC 20590.

Performing Organizations – This document was developed as part of the FHWA Every Day Counts UHPC Connections for Prefabricated Bridge Elements initiative. It was drafted by Leidos Incorporated under contract number GS00Q14OADU122; and, FHWA Resource Center, 12300 West Dakota Avenue, Lakewood, CO 80228.

Distribution – No restrictions. This document is available online at https://www.fhwa.dot.gov/.

Key Words – Ultra-high performance concrete, UHPC, fiber reinforced concrete, accelerated bridge construction, prefabricated bridge elements and systems, construction guidance.

FHWA-HIF-18-030 **April 2018**