Iowa Department of Transportation

DEVELOPMENTAL SPECIFICATION

FOR

HIGH PERFORMANCE CONCRETE FOR STRUCTURES

Effective Date
January 17, 2007

THE STANDARD SPECIFICATIONS, SERIES 2001, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE DEVELOPMENTAL SPECIFICATIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

01089.01 DESCRIPTION.
This work shall consist of developing and providing high performance concrete (HPC) for bridge substructures and decks when called for in the contract documents. HPC is defined as a concrete mix that provides the following:

- Desired workability
- Minimum average 28 day compressive strength of 5,000 psi (35 MPa)
- Target permeability of 2500 coulombs for the substructure and 1500 coulombs for the deck.

~~This work also includes establishing longitudinal grooving into the hardened concrete of the bridge floor.~~

Sections 2403, 2412, and Division 41 of the Standard Specifications shall apply with the following modifications.

01089.02 MATERIALS.
At the option of the Contractor, other mixes than those described below may be used, provided they meet the requirements of this Developmental Specification and are approved by the District Materials Engineer.

A. Substructure:
For all the substructure HPC mixes the following conditions shall apply:

- Coarse aggregate shall be crushed limestone meeting class 3I durability
- Basic water to cementitious material (w/c) ratio of 0.42, with a maximum w/c ratio of 0.45
- Air content shall be in accordance with Article 2403.03, B, of the Standard Specifications, except the target shall be 6.5%, with a maximum variation of plus 2.0% and minus 1.0%

The HPC mix for the substructure may be a C-4-C15-S35 with a water reducer admixture and a w/c ratio of 0.42, with a maximum w/c ratio of 0.45.

For the substructure HPC mixes other than a C-4-C15-S35, the following conditions shall apply:

- Cement shall be one of the following:
    1. Type IS
    2. Type I(SM) with 15% weight (mass) replacement with Ground Granulated Blast Furnace Slag (GGBFS)

3. Type I/II cement with 35% weight (mass) replacement with GGBFS
4. Type IP, except the absolute volume of cement shall be 0.126

- Minimum cementitious content shall be 624 pounds per cubic yard (370 kg/m^3)
- The maximum fly ash replacement shall not exceed 15% by weight (mass) of the cement
- A high range water reducer may be used with a maximum allowable slump of 8 inches (200 mm) and a target air content of 7.5% ± 2.0%

B. Deck.
For all the deck HPC mixes, the following conditions shall apply:

- Coarse and intermediate aggregate shall be crushed limestone meeting class 3I durability
- Basic w/c ratio of 0.40, with a maximum w/c ratio of 0.42
- Retarding admixture may be required by contract documents or by the Engineer. A water reducing/retarding admixture meeting the requirements of Materials I.M. 403, Appendix B, shall be used in accordance with Section 2403 of the Standard Specifications. When placements require extended working times, the dosage rate shall be increased for the appropriate working time and temperature. For placements requiring normal working times, the dosage rate shall be in accordance with Section 4103 of the Standard Specifications. Other admixtures may be approved by the Engineer.
- Air content shall be in accordance with Article 2403.03, B, of the Standard Specifications, except the target shall be 6.5%, with a maximum variation of plus 2.0% and minus 1.0%

The HPC mix for the deck may have the following characteristics and absolute volumes per unit volume:

Cement	0.118
Fly Ash	15% Replacement by weight (mass)
GGBFS	35% Replacement by weight (mass)
Water	0.148 (w/c ratio of 0.40)
Coarse Aggregate	0.308
Intermediate Aggregate	0.080
Fine Aggregate	0.281
Air	0.065

For the deck HPC mixes other than the mix described in the above table, the following conditions shall apply:

- Cement shall be one of the following:
  1. Type IS
  2. Type I(SM) with 15% weight (mass) replacement with GGBFS
  3. Type I/II cement with 35% weight (mass) replacement with GGBFS
  4. Type IP, except the absolute volume of cement shall be 0.126
- Minimum cementitious content shall be 624 pounds per cubic yard (370 kg/m^3)
- The maximum fly ash replacement shall not exceed 15% by weight (mass) of the cement
- Combined aggregate gradation shall be optimized in accordance with Materials I.M. 532 and meet the limits in Article 2513.03, B, 3, of the Standard Specifications.

01089.03 CONSTRUCTION.

A. Trial Batch Concrete.
A trial batch is required only when a Contractor proposes HPC mixes other than the C-4-C15-S35 mix described in Article 01089.02, A of this Developmental Specification; or the mix described in the table in Article 01089.02, B of this Developmental Specification. When a trial batch is required, the Contractor shall make one or more trial batches of concrete. The HPC mix design shall be developed by an Iowa DOT PCC Level III Certified Technician.

The District Materials Engineer shall be afforded ample opportunity to witness the trial batching. The District Materials Engineer shall be given notice and mix proportions 7 calendar days prior to this event. The trial batch shall be made at least 30 calendar days prior to planned placement and shall be a minimum of 3 cubic yards (3 m^3) in size. The batching sequence of the materials shall be established during the trial batch. The concrete shall be transported a distance comparable to the distance from the ready mix plant to the placement site. Concrete used for testing purposes shall be representative of the entire batch while having a slump within 1 inch (25 mm) of the maximum slump allowed, an intended in place air content of 6% ± 1%, and a w/c ratio that will be typical in substructure and deck placement. The Contractor shall perform the following tests for each trial batch:

Specific Gravity of Each Individual Aggregate	Materials I.M. 307
Gradation of Each Individual Aggregate	Materials I.M. 302
Unit Weight of Plastic Concrete	Materials I.M. 340
Slump of Plastic Concrete	Materials I.M. 317
Air Content of Plastic Concrete	Materials I.M. 318

1. Substructure.
The Contractor shall evaluate the mix workability for the intended application and method of placement.

2. Deck.
The Contractor shall cast one or more test slabs. The slabs shall be 8 feet by 4 feet (2.4 m by 1.2 m) in area and be 4 inches (100 mm) thick. The concrete shall be placed and consolidated using methods typical for bridge deck pours. The concrete shall be finished by hand and the Contractor shall evaluate the mix workability and finishability for the intended application and method of placement.

The Contractor shall submit a trial batch report to the District Materials Engineer no later than 7 calendar days after trial batching. The report shall include the following:

Cover Page	Contractor and Producer Name Project Number Date and Location of HPC Trial Batch Date Submitted Signature of Contractor/Producer Representative
Material Source Information	Brand, Type, and Source
Material Proportion Information	Specific Gravity Relative % of Each Individual Aggregate Target Combined Gradation % Passing (Materials I.M. 531) Target Combined Gradation Charts (Materials I.M. 532) Design and As Mixed Batch Weights (Mass) (SSD) Design and As Mixed w/c Ratios
Mix Properties	Unit Weight (Mass) of Plastic Concrete Air Content of Plastic Concrete Slump

The District Materials Engineer will cast samples and transport them to the Central Materials Laboratory for testing. Trial batch concrete will be tested for permeability and strength. All samples will be cast, cured, and handled in accordance with Materials I.M. 315. Two permeability and nine strength samples will be cast in 4 inch by 8 inch (100 mm by 200 mm) cylinder molds.

Permeability samples will be stripped of their molds and wet cured to an age of 7 calendar days in a moist room. After 7 calendar days, the samples shall be submerged in water heated to 100ºF (38ºC)

until an age of 28 days. One sample shall be obtained from each cylinder and tested in accordance with AASHTO T 277 at 28 days. The target value of permeability is 2500 coulombs for the substructure and 1500 coulombs for the deck, or less based on the average of two tests.

Strength samples shall be stripped of their molds and wet cured until their break age. Strength samples shall be tested in accordance with AASHTO T 22. Three cylinders shall be tested for strength at each age of 7, 28, and 56 days. The average 28 day compressive strength shall be equal to or greater than 6,400 psi (45 MPa) for the substructure and 5,000 psi (35 MPa) for the deck.

Approval will be based on trial batch mix properties and submittal of a trial batch report. The District Materials Engineer may waive the trial batch testing provided satisfactory mix properties have been achieved through testing of previous trial batches or production placements.

B. Production Concrete.
The Contractor shall notify the District Materials Engineer 48 hours prior to placement of production concrete. Only approved HPC mixes shall be used for production concrete. If a mix other than the mix described in Article 01089.02 of this Developmental Specification is to be used, it shall have the same materials, proportions, and properties (including slump, air content, and w/c ratio) as established in the trial batch.

The Contractor shall test production concrete for strength. These test results shall be used for acceptance. Strength samples shall be cast, cured, and handled in accordance with Materials I.M. 315 by an Iowa DOT PCC Level I Concrete Field Testing Technician or Technician Grade I (in accordance with ACI CP-2). At the site the Contractor shall ensure the cylinders are cured properly with wet burlap and plastic. The cylinders shall not be moved for 16 hours and remain at the site for a maximum of 1 calendar day before being transported to a certified laboratory for final curing and testing. Nine strength samples shall be cast in 4 inch by 8 inch (100 mm by 200 mm) cylinder molds for each placement. The slump, air content, and w/c ratio (adjusted for all water) of the concrete shall be documented for the cylinders cast.

Strength samples shall be tested by a certified lab in accordance with AASHTO T 22. Three cylinders shall be tested for strength at each age of 28 and 56 days. For acceptance, the average 28 day strength shall be equal to or greater than 5,000 psi (35 MPa).

Test results shall be submitted to the Engineer and the District Materials Engineer no later than 1 working day after testing is completed. As a minimum, the submittal shall clearly indicate the project number, location, Contractor, producer, structural element constructed, slump, air content, w/c ratio (adjusted for all water), date sampled, date tested, break age, individual compressive strengths, and average compressive strengths. In addition, the plant report for the pour shall be attached to the submittal.

The District Materials Engineer may obtain random verification strength samples. Strength samples will be tested at the Central Materials Laboratory in accordance with AASHTO T 22. A set of four cylinders shall be cast, cured, and handled in accordance with Materials I.M. 315. Three cylinders shall be tested for strength at 28 days. The remaining cylinder shall be tested for permeability on a random basis by the Central Materials Laboratory. The testing will be conducted as described in Article 01089.03, A, of this Developmental Specification.

C. Non Complying Strength.
When the average 28 day compressive strength does not meet or exceed the specified strength, the Contractor shall propose evaluation methods to determine the in place concrete strength. The proposal shall be submitted to the Engineer. The Engineer shall be notified 48 hours in advance of any sampling and testing and will witness the sampling and testing of the in-place concrete. The Engineer will review the results and determine corrective action required. The Contractor shall be responsible for the cost of evaluation and any corrective action required.

D. Placing Concrete.
Fly ash and GGBFS shall be allowed throughout the year provided protection is provided in accordance with Section 2403 and Article 01089.02 of this Developmental Specification.

If concrete is to be placed by pumping, the pump line shall have a section reduction to reduce the exit velocity of the pumped concrete and minimize damage to epoxy coated reinforcement. Measures for reducing exit velocity of the concrete shall be submitted to the Engineer for approval prior to placement by pumping.

Epoxy coated reinforcement shall be protected from damage caused by placing and handling equipment.

For the deck, placing of concrete floors will not be allowed to begin if the theoretical rate of evaporation exceeds 0.1 lb/ft^2 per hour (0.5 kg/m^2 per hour). The theoretical evaporation rate shall be monitored at a maximum interval every 3 hours during the placement at a location as near the deck as possible. If the rate exceeds 0.15 lb/ft^2 per hour (0.75 kg/m^2 per hour) the placement shall be ceased at the next location acceptable to the Engineer.

~~**E. Surface Finish (Deck only).**~~
~~Article 2412.06 of the Standard Specifications shall apply with the following exceptions:~~
~~Delete the third and fourth sentences of the fourth paragraph that requires grooving to be placed in the plastic concrete.~~

~~F~~E. Curing.

1. Substructure.
Forms shall remain in place for ~~168~~ 96 hours of curing.

Wet burlap covering shall be in place for ~~168~~ 96 hours.

2. Deck.
Forms shall remain in place for 168 hours of curing.

Water shall be applied to the burlap covering for 168 hours of continuous wet sprinkling system curing.

No curing compound shall be placed on the floor.

Burlap shall be prewetted with sufficient water, prior to placement, to prevent absorption of moisture from the concrete surface. Two layers of pre-wetted burlap shall be placed on the floor immediately after artificial turf drag or broom finish with a maximum time limit of 10 minutes after final finishing. Water shall be applied to the burlap covering for the entire curing period by means of a continuous wet sprinkling system that is effective in keeping the burlap wet during the moist curing period.

Evaporation retardant shall only be used in situations where equipment and/or labor delays, or environmental conditions, prevent adequate protection of the concrete until prewetted burlap is in place. An evaporation retardant including Confilm, Conspec Acquafilm, Evapre, or Sure Film shall be readily available during placement for application as directed by the Engineer. Evaporation retardant shall not be worked into the concrete surface or used as a finishing aid.

~~G~~F. Cold Weather Protection.
Surface temperature of concrete shall be monitored continuously during the curing period with electronic recording type thermometers capable of recording a minimum of one reading per hour. The Contractor shall be responsible for monitoring the temperature and furnishing the information to the Engineer in electronic format as required.

If supplemental housing and heating is used, temperature monitors shall be located in the concrete at the furthest and closest point from the heat source. Maximum temperature at monitor point closest to heat source shall not exceed 150ºF (65ºC).

After required curing period, temperature of air surrounding concrete shall gradually be reduced to outside air temperature in accordance with Article 2403.11 of the Standard Specifications.

1. Substructure.
Concrete and its surface temperature shall be maintained at a temperature of not less than 50ºF (10ºC) for the first ~~168~~ 120 hours after placing. Curing time will not be counted if the concrete temperature falls below 50ºF (10ºC).

2. Deck.
Covering with plastic will not be allowed as a substitute for continuous wet sprinkling system curing.

Concrete and its surface temperature shall be maintained at a temperature of not less than 50ºF (10ºC) for 168 hours of continuous wet sprinkling system curing. Curing time will not be counted if the concrete temperature falls below 50ºF (10ºC).

~~**H. Establishment of Longitudinal Grooving in Concrete.**~~
~~Longitudinal grooving shall be done with a mechanical cutting device into the hardened concrete. Each groove shall be 1/8 inch ± 1/64 inch (3 mm ± 0.5 mm) in width, 1/8 inch ± 1/16 inch (3 mm ± 0.5 mm) in depth, and uniformly spaced at 3/4 inch (20 mm) intervals. Longitudinal grooving shall not be within the area approximately 2 foot (0.6 m) from the curbs.~~

01089.04 METHOD OF MEASUREMENT

A. High Performance Concrete.
The quantity of High Performance Concrete, in cubic yards (cubic meters), will be the quantity shown in the contract documents.

B. Trial Batch Concrete.
Trial batch concrete will be measured as a lump sum item.

~~**C. Longitudinal Grooving in Concrete.**~~
~~The quantity of Longitudinal Grooving in Concrete, in square yards (square meters), will be the quantity shown in the contract documents.~~

01089.05 BASIS OF PAYMENT

A. High Performance Concrete.
The Contractor will be paid the contract unit price for High Performance Concrete per cubic meter (cubic yard). The cost for testing the production concrete shall be included in the contract unit price for High Performance Concrete.

B. Trial Batch Concrete.
The Contractor will be paid the lump sum contract price for Trial Batch Concrete. This payment shall be full compensation for furnishing all materials, tools, and labor for the performance of all work necessary to design, cast, finish, and dispose of any test slabs as indicated.

~~**C. Longitudinal Grooving in Concrete.**~~
~~The Contractor will be paid the contract unit price for Longitudinal Grooving in Concrete per square yard (square meter).~~