VIRGINIA
Virginia Avenue, Richlands

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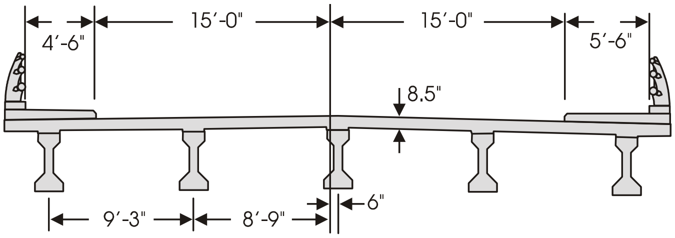
VIRGINIA
Virginia Avenue, Richlands

1. DESCRIPTION



Type III (10,000 psi)

Location:	Virginia Avenue over Clinch River, Richlands
Open to Traffic:	December 1997
Environment:	Normal over river
HPC Elements:	Girders and deck
Total Length:	148 ft
Skew or Curve:	None
Girder Type:	AASHTO Type III
Girder Span Lengths:	Two spans of 74 ft
Girder Spacing:	8 ft 9 in and 9 ft 3 in
Girder Strand Grade:	270
Girder Strand Dia.:	0.6 in
Max. No. of Bottom Strands:	34 at 2 in c/c
Deck Thickness:	8.5 in
Deck Panels:	None

2. BENEFITS OF HPC AND COSTS

A. Benefits of HPC

The original design for the replacement bridge used conventional concrete and had three spans with seven beams per span. The replacement bridge uses two spans with five beams per span. The total cost of the bridge was \$60.43/ft^2 of deck surface. This was lower that the average cost of \$69/ft^2 for similar bridges. Concrete had to meet low permeability requirements, which are expected to result in longer service life with minimal maintenance.

B. Costs

Total Cost: \$60.43/ft^2 of deck surface area

3. STRUCTURAL DESIGN

Design Specifications:	AASHTO Standard Specifications for Highway Bridges, 1992
Design Live Loads:	HS 20-44 or military load
Seismic Requirements:	AASHTO Seismic Performance Category A
Flexural Design Method:	AASHTO Standard Specifications 9.17
Maximum Compressive Strain:	0.003
Shear Design Method:	AASHTO Standard Specifications 9.20
Fatigue Design Method:	None
Lateral Stability Considerations:	Diaphragms at midspan and ends
Allowable Tensile Stress	
—Top of Girder at Release:	$3\sqrt{f'_{ci}}$ = 247 psi
—Bottom of Girder after Losses:	$3\sqrt{f'_{c}}$ = 300 psi
Prestress Loss:	30.81%
Method Used for Loss:	AASHTO Standard Specifications 9.16.2.1
Calculated Camber:	1.08 in
Concrete Cover	
—Girder:	2 in to strand, 1 in to stirrups
—Top of Deck:	2.75 in to center of top bar
—Bottom of Deck:	2.75 in to center of bottom bar
—Other Locations:	Not available
Properties of Reinforcing Steel	
—Girder:	ASTM A 615 Grade 60, epoxy coated
—Deck:	ASTM A 615 Grade 60, epoxy coated
Properties of Strand	
—Grade and Type:	Grade 270, low relaxation
—Supplier:	Not available
—Surface Condition:	Not available
—Pattern:	Draped
—Transfer Length:	50 diameters = 30 in
—Development Length:	1.6 l_d from AASHTO Standard Specifications 9.28

4. SPECIFIED ITEMS

A. Concrete Properties

	Girders	Deck
Minimum Cementitious Materials Content:	635 lb/yd^3	635 lb/yd^3
Max. Water/Cementitious Materials Ratio:	0.40	0.45
Min. Percentage of Fly Ash:	20	20
Max. Percentage of Fly Ash:	25	25
Min. Percentage of Silica Fume:	7	7
Max. Percentage of Silica Fume:	10	10
Min. Percentage of GGBFS:	35	35
Max. Percentage of GGBFS:	50	50
Maximum Aggregate Size:	1 in	1 in
Slump:	0-4 in (1)	2-4 in (1)
Air Content:	4.5 $\pm$ 1.5% (2)	6.5 $\pm$ 1.5% (2)

Note: Minimum and maximum percentages of mineral admixtures only apply if the materials are used.

	Girders	Deck
Compressive Strength		
—Release of Strands:	6800 psi	—
—Design:	10,000 psi at 28 days	5000 psi at 28 days
Chloride Permeability: (AASHTO T 277)	1500 coulombs at 28 days (3)	2500 coulombs at 28 days (3)
ASR or DEF Prevention:	ASR (4)	ASR (4)
Freeze-Thaw Resistance:	Not specified	Not specified
Deicer Scaling:	Not specified	Not specified
Abrasion Resistance:	Not specified	Not specified
Other:	—	—

(1) Maximum of 7 in when a high-range water-reducing admixture (HRWR) is used.
(2) Target air content is increased by 1 percent when a HRWR is used.
(3) Virginia uses a curing procedure of one week at 73 ^{o}F and three weeks at 100 ^{o}F with the AASHTO T 277 test.
(4) Cement shall be Type II with a maximum alkali content of 0.40% or Type I-P, unless otherwise specified in the contract. Fly ash or granulated iron blast-furnace slag shall not be added to concrete when Type I-P cement is used. Fly ash, granulated iron blast-furnace slag, silica fume, or other VDOT approved mineral admixtures shall be used with Types I, II (if above 0.40% alkali content), or III cements.

B. Specified QC Procedures

Girder Production	
Curing:	Steam
Internal Concrete Temperature:	$\leq$ 190 ^{o}F
Cylinder Curing:	Steam
Cylinder size:	4x8 in
Cylinder Capping Procedure:	Neoprene caps with a durometer hardness of 70 in steel rings
Cylinder Testing Method:	AASHTO T 22
Frequency of Testing:	One set of cylinders from each end of the bed
Other QA/QC Requirements:	—
Deck Construction	
Curing:	Moist (wet burlap covered with plastic sheeting for 7 days)
Cylinder Curing:	Moist
Cylinder Size:	4x8 in
Flexural Strength:	Not specified
Other QA/QC Requirements:	Air, slump, and concrete temperature to be measured

5. CONCRETE MATERIALS

A. Approved Concrete Mix Proportions

	Girders	Cast-in-Place Deck
Cement Brand:	Not available	Not available
Cement Type:	I	I
Cement Composition:	Not available	Not available
Cement Fineness:	Not available	Not available
Cement Quantity:	752 lb/yd^3	560 lb/yd^3
GGBFS Brand:	—	—
GGBFS Quantity:	—	—
Fly Ash Brand:	—	Not available
Fly Ash Type:	—	F
Fly Ash Quantity:	—	140 lb/yd^3
Silica Fume Brand:	Not available	—
Silica Fume Quantity:	75 lb/yd^3	—
Fine Aggregate Type:	Crushed limestone	Natural sand
Fine Aggregate FM:	3.00	2.80
Fine Aggregate SG:	2.75	2.65
Fine Aggregate Quantity:	1350 lb/yd^3	1004 lb/yd^3
Coarse Aggregate, Max. Size:	1/2 in	1 in
Coarse Aggregate Type:	No. 7 limestone	No. 57 quartzite
Coarse Aggregate SG:	2.76	2.65
Coarse Aggregate Quantity:	1671 lb/yd^3	1724 lb/yd^3
Water:	235 lb/yd^3	315 lb/yd^3
Water Reducer Brand:	—	—
Water Reducer Type:	—	—
Water Reducer Quantity:	—	—
High-Range Water-Reducer Brand:	Rheobuild 1000	—
High-Range Water-Reducer Type:	A and F	—
High-Range Water-Reducer Quantity:	207 fl oz/yd^3	—
Retarder Brand:	Pozzolith 122 R	Daratard 17
Retarder Type:	D	D
Retarder Quantity:	25 to 30 fl oz/yd^3	21 fl oz/yd^3
Corrosion Inhibitor Brand:	—	—
Corrosion Inhibitor Type:	—	—
Corrosion Inhibitor Quantity:	—	—
Air Entrainment Brand:	MBAE-90	Daravair 1000
Air Entrainment Type:	Anionic surfactant	Saponified rosin
Air Entrainment Quantity:	7 fl oz/yd^3	5 fl oz/yd^3
Water/Cementitious Materials Ratio:	0.28	0.45

B. Measured Properties of Approved Mix

	Girders	Deck
Slump:	Not available	Not available
Air Content:	Not available	Not available
Unit Weight:	—	—
Compressive Strength:	Not available	5520 psi at 28 days
Chloride Permeability: (AASHTO T 277)	Not available	612 coulombs at 28 days

6. CONCRETE MATERIAL PROPERTIES

A. Measured Properties from QC Tests of Production Concrete for Girders

Cement Composition:	Not available
Actual Curing Procedure for Girders:	Steam
Average Slump:	6.6 in
Maximum Girder Temperature:	161 ^{o}F
Average Air Content:	4.4%
Unit Weight:	—
Compressive Strength:	8840 psi at 18 hours 11,200 psi at 28 days
Curing Procedure for Cylinders:	Alongside girders on the precasting bed

B. Measured Properties from QC Tests of Production Concrete for Deck(5)

Cement Composition:	Not available
Actual Curing Procedure for Deck:	After screeding, a curing compound was applied. When the surface was hard enough to walk on, wet burlap covered with white plastic sheeting was applied and remained in place for seven days.
Average Slump:	3.6 in
Average Air Content:	5.8%
Compressive Strength:	5400 psi at 28 days
Chloride Permeability:	1457 coulombs at 28 days
Curing Procedure of Cylinders:	—

(5) Concrete samples taken before pumping.

C. Measured Properties from Research Tests of Production Concrete for Girders

Air Content, Slump, Concrete Temperature, and Air Temperature:

Batch No.	1	2
Air, %	4.0	5.1
Slump, in	5.0	6.2
Concrete Temp. at Time of Placement, ^oF	85	89
Air Temp., ^oF	74	78

Compressive Strength, Modulus of Elasticity, Flexural Strength, Splitting Tensile Strength, Chloride Permeability, and Shrinkage:

Test	Specimen			Batch No. (6)	
	Size	Age	No.	1	2
Compressive Strength (7), psi	4x8 in	1 d (8)	2	9470 (9)	9710
		1 d	3	9820	9580
		28 d	3	10,510	10,910
		56 d	3	10,720	10,540
		1 yr	3	10,920	11,150 (10)
Modulus of Elasticity (11), ksi	4x8 in	1 yr	3	6300	5900 (10)
Splitting Tensile Strength (12), psi	4x8 in	28 d	3	5.66	5.71
Chloride Permeability (13), coulombs	2x4 in	28 d	2	122	127
Shrinkage (14), %	3x3x11-1/4 in	1 yr	3	0.033	0.045

(6) Specimens were steam cured and then air cured in the same manner as the beams.
(7) AASHTO T 22 with neoprene pads in steel end caps.
(8) Match cured until release and then tested. All other specimens stored alongside beams initially and stored outdoors thereafter.
(9) One of the specimens had a corner break and a strength of 8360 psi.
(10) Values are the average of two specimens.
(11) ASTM C 469.
(12) AASHTO T 198 (ASTM C 496).
(13) AASHTO T 277 (ASTM C 1202). Cured one week at 73 ^oF and three weeks at 100 ^oF.
(14) AASHTO T 160 (ASTM C 157).

Chloride Ion Penetration:
(AASHTO T 259)

Batch No.	Depth, in			
	0.5	1.0	1.5	2.0
1	2.16 lb/yd^3	0.45 lb/yd^3	0.43 lb/yd^3	0.38 lb/yd^3
2	3.63 lb/yd^3	0.52 lb/yd^3	0.49 lb/yd^3	0.44 lb/yd^3

Chloride contents are after one year of ponding 3x12x12-in specimens.

Freezing and Thawing:
(AASHTO T 161, Proc. A)

Batch No.	Weight Loss, %	Durability Factor	Scaling Resistance
1	1.31	26	0.69
2	0.20	91	0.35

Concretes were tested at age 2 months for 300 cycles using 2% NaCl in the water. Specimen size was 3x4x16 in.

D. Measured Properties from Research Tests of Production Concrete for Deck

Air Content, Slump, Concrete Temperature, and Air Temperature:

Batch No.		1	2
Air, %	Before Pumping	5.5	6.0
	After Pumping	3.5	4.5
Slump, in	Before Pumping	3.7	—
Concrete Temp. at Time of Placement, ^{o}F		72	78
Air Temp., ^{o}F		57	60

Compressive Strength, Modulus of Elasticity,
Splitting Tensile Strength, and
Chloride Permeability:

Concrete samples taken after pumping.

Test	Specimen			Batch No.		
	Size	Age	No.	1	2	Average
Compressive Strength (15), psi	4x8 in	7 d	3	4160	4360	4260
		28 d	3	6150	6380	6265
		56 d	3	6630	6790	6710
		1 yr	3	8115	7995	8055
Modulus of Elasticity (16), ksi	4x8 in	1 yr	3	5120	5360	5240
Splitting Tensile Strength (17), psi	4x8 in	28 d	3	570	645	608
Chloride Permeability (18), coulombs	2x4 in	28 d	2	1261	1375	1318

(15) AASHTO T 22 with neoprene pads in steel end caps.
(16) ASTM C 469.
(17) AASHTO T 198 (ASTM C 496).
(18) AASHTO T 277 (ASTM C 1202). Cured one week at 73 ^{o}F and three weeks at 100 ^{o}F.

Chloride Ion Penetration:
(AASHTO T 259)

Batch No.	Depth, in			
	0.5	1.0	1.5	2.0
1	10.79 lb/yd^3	1.09 lb/yd^3	0.94 lb/yd^3	0.28 lb/yd^3
2	11.76 lb/yd^3	1.19 lb/yd^3	0.36 lb/yd^3	0.30 lb/yd^3

Chloride contents are after one year of ponding 3x12x12-in specimens.

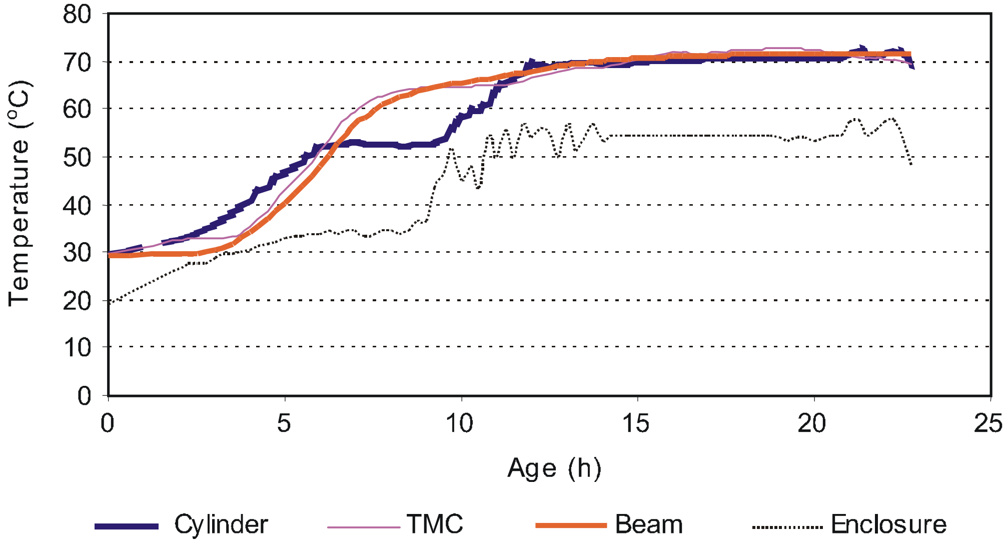
Freezing and Thawing:
(AASHTO T 161, Proc. A)

Batch No.	Weight Loss, %	Durability Factor	Scaling Resistance
1	0.74	109	0.75
2	0.88	107	0.69

Concretes were moist cured for two weeks and air dried until tested at age 6 months using 2% NaCl in the water. Specimen size was 3x4x16 in.

7. OTHER RESEARCH DATA

Curing Temperatures (19):



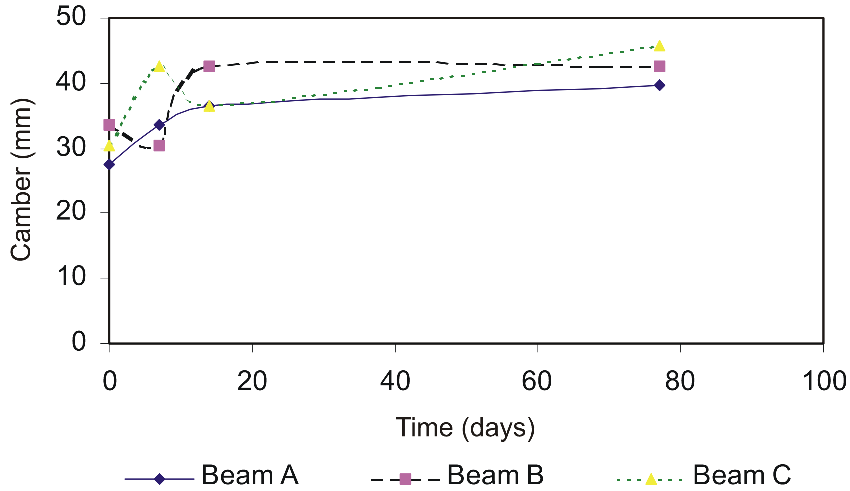
(19) Cylinder temperature is that of a cylinder stored next to the girder under the enclosure.
TMC is the temperature of a match-cured cylinder.
Enclosure is the temperature under the enclosure covering the girder. The erratic readings may be the result of opening the enclosure for inspection.

Transfer Length: Transfer length was measured on three instrumented beams.

Beam	End	Transfer Length, in
A	Live	14.2
	Dead	15.4
B	Live	12.4
	Dead	12.2
C	Live	14.8
	Dead	12.2

Load Test: A load test was conducted on one beam. The purpose of the test was to determine the amount of residual deflection in the beam after removal of a maximum load equal to 95 percent of the calculated load to cause a flexural crack. The result was reported in terms of percentage of the midspan deflection recovery to the deflection at the maximum load. The beam was considered to be adequate if a recovery of 90 percent or greater was achieved. The instantaneous recovery was 98.5 percent. At 30 minutes after removing the load, recovery was 100 percent. No cracks were seen in the beam.

Camber:



Midspan camber versus time for three bridge beams

8. OTHER RELATED RESEARCH

Prior to construction, a test program was initiated to develop the desired concrete and to determine the structural feasibility of using HPC beams with 0.6-in-diameter strands spaced at 2 in. Two full-scale prestressed concrete beams with composite deck slabs were fabricated and tested.

Mixture proportions for concrete used in the beams and slabs were as follows:

Ingredient	Beams	Slabs
Cement Type I/II, lb/yd^3	765	635
Silica Fume, lb/yd^3	75	45
Fine Aggregate, lb/yd^3	1205	1515
Coarse Aggregate, lb/yd^3	1800	1608
Water-Cementitious Materials Ratio	0.28	0.36
Fine Aggregate Type	Crushed limestone	Crushed limestone
Coarse Aggregate Max. Size, in	3/8	3/4
Coarse Aggregate Type	No. 8 limestone	No 67 limestone
High-Range Water-Reducer Brand	Melment 50	Melment 50
High-Range Water-Reducer Type	A and F	A and F
High-Range Water-Reducer Quantity	210 fl oz/yd^3	190 fl oz/yd^3
Retarder Brand	Daratard 17	Daratard 17
Retarder Type	D	D
Retarder Quantity	25 fl oz/yd^3	25 fl oz/yd^3

Concrete properties for the two beams and slabs were as follows:

Property	Beam 1	Beam 2	Slab
Slump, in	4.7	6.8	7.0
Air Content, %	4.0	5.3	5.0
Max. Internal Concrete Temp., ^{o}F	161	159	—
Compressive Strength, psi			
19 hours (Steam Cured)	8520	7970	—
19 hours (Match Cured)	9880	8900	—
1 day (Moist Cured)	—	—	4030
28 days (Steam for 1 day and Air Cured)	10,160	10,620	—
28 day (Moist Cured)	—	—	11,770
28-day Results			
Modulus of Elasticity, ksi	6170	6180	6430
Splitting Tensile Strength, psi	745	790	940
Flexural Strength, psi	1230	1375	1205
Chloride Permeability, coulombs	159 (20)	152 (20)	310 (21)

(20) AASHTO T 277 (ASTM C 1202) Steam cured and air dried in the same way as the girders.
(21) AASHTO T 277 (ASTM C 1202). Cured one week at 73 ^{o}F and three weeks at 100 ^{o}F.

Measured transfer lengths at each beam end were as follows:

Beam	1 End A	1 End B	2 End A	2 End B
Transfer Length, in	21.8	12.8	15.3	10.6

The beams were tested using a concentrated load located at various distances from the beam end. The following results were obtained:

Test Beam	Load Location from end, ft	Cracking Load, kip		Ultimate Load, kip	
		Predicted	Measured	Predicted	Measured
1 End A	7.74	200	220	300	360
1 End B	6.76	263	300	372	430
2 End A	5.74	220	270	408	430
2 End B	5.74	202	280	408	490

Both measured transfer and development lengths were much lower than those predicted by AASHTO equation 9.32.

9. SOURCES OF DATA

Ozyildirim, C. and Gomez, J., "HPC in Virginia's Bridge Structures," *Symposium Proceedings, PCI/ FHWA/fib International Symposium on High Performance Concrete*, Orlando, FL, Precast/Prestressed Concrete Institute, Chicago, IL, 2000, pp. 741-750.

Ozyildirim, C. and Gomez, J., "High-Performance Concrete in the Richlands Bridge in Virginia," *Transportation Research Record No 1698*, Transportation Research Board, Washington, DC, 2000, pp. 17-23.

Ozyildirim, C. and Gomez, J., "High-Performance Concrete in a Bridge in Richlands, Virginia," VTRC 00-R 6, Virginia Transportation Research Council, Charlottesville, VA, 1999, 40 pp.

Gomez, J., Cousins, T., and Ozyildirim, C., "Use of High-Performance Concrete in a Bridge Structure in Virginia," *Symposium Proceedings*, *PCI/FHWA International Symposium on High Performance Concrete*, New Orleans, LA, Precast/Prestressed Concrete Institute, Chicago, IL, 1997, pp. 590-598.

Ozyildirim, C. and Gomez, J., "Virginia's Bridge Structures with High Performance Concrete," *Symposium Proceedings*, *PCI/FHWA International Symposium on High Performance Concrete*, New Orleans, LA, Precast/Prestressed Concrete Institute, Chicago, IL, 1997, pp. 681-690.

SHRP High Performance Concrete Bridge Showcase Notebook, Richmond, VA, June 24-26, 1997.

H. Celik Ozyildirim, Virginia Transportation Research Council, Charlottesville, VA.

10. DRAWINGS

Not provided for this bridge.

11. HPC SPECIFICATIONS

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION FOR
LOW PERMEABILITY CONCRETES

August 29, 1994
Rev: May 21, 1996c

SECTION 217 of the Specifications is amended as follows:

Section 217.02(a) is replaced with the following:

Cement shall conform to the requirements of Section 214 and shall be Type II with a maximum alkali content of 0.40% or Type I-P, unless otherwise permitted herein or otherwise specified in the contract. Fly ash or granulated iron blast-furnace slag shall not be added to concrete when Type I-P cement is used. Fly ash, granulated iron blast-furnace slag, silica fume, or other approved mineral admixtures shall be used with Types I, II (if above 0.40% alkali content) or III cements as specified herein.

Types I, II, and III cements may be used with latex modified portland cement concrete, however latex will not be permitted in Class A5 concrete.

Granulated iron blast-furnace slag shall replace from 35% to 50% by weight of the design cement content.

Other mineral admixtures shall be used in accordance with the requirements shown on the approved list of mineral admixtures.

Section 217.02 is amended to replace (h) and (i) with the following:

(h) **Fly ash** shall conform to the requirements of Section 241. Class F fly ash shall be between 20% and 25% by mass of the cementitious material. However, no more than 15% of the portland cement of a standard mixture shall be replaced.

(i) **Granulated iron blast-furnace slag** shall conform to the requirements of Section 215.

Section 217.02 is amended to add the following:

(k) **Silica fume** shall conform to the requirements of AASHTO M307 or ASTM C1240. Silica fume shall replace between 7% and 10% by mass of the cementitious material. Only silica fume at the rate of 3% to 7% may be added to all combinations to reduce the early permeability after the approval of the Engineer.

Section 217.08 is amended to add the following:

(c) **Quality Assurance for Low Permeability Concrete (for Concrete in Bridges Only):**

General:

At least two trial batches (using job materials) with permissible combination of cementitious materials shall be prepared, and test specimens shall be cast by the contractor and tested by the Department for permeability and strength at least a month before the field application. The permeability samples shall be cylindrical specimens with a 100-mm (4-in) diameter and at least 100-mm (4-in) in length. They shall be moist cured as the strength cylinders for acceptance except that the last 3 weeks of cure shall be at 38 °C ± 6 °C (100 °F ± 10 °F). Cylinders shall be tested at 28 days in accordance with AASHTO T 277 or ASTM C 1202. The test value shall be the result of the average values of tests on two specimens from each batch. Permeability values obtained from trial batches shall be 500 coulombs below the maximum values specified in Table II-17.

Acceptance Tests:

A quality assurance and acceptance procedure that provides for periodic tests of the field concrete for permeability using AASHTO T 277, shall be established. This should include provisions for testing frequency; the range of coulomb values for which full or partial payments would be made; and the values that would require corrective measures to be taken (or rejection of the concrete) should be stated. The following are quality assurance procedures for field evaluations.

A lot shall be a day's production of concrete for the job and shall be used for statistical acceptance procedure for bridge concrete. For each set of cylinders made for compressive strength tests, two additional cylinders shall be made for the permeability test.

For all classes of concrete, initially one set of permeability cylinders shall be tested for each lot in accordance with AASHTO T 277. If the average coulomb value for this test is less than the coulomb value shown in Table II-17, the lot will be accepted at the full bid price.

If the average test result exceeds the coulomb value in Table II-17, payment for the concrete in that element (in-place cost) shall be reduced 0.02 percent for each coulomb above the coulomb value in Table II-17, however, the reduction in price will not exceed 20% of the bid price of the concrete. Concrete with a coulomb value that exceeds the maximum required in Table II-17 by 1000 coulomb will be rejected. However, bridge deck with the coulomb value exceeding the maximum required by over 1000 coulomb may be accepted by the Engineer at 80% of the bid price if it has the required strength and meets other specification requirements, and the contractor applies, at his own expense, an approved epoxy concrete overlay to the top of the deck. In such case deck grooving will not be required. The adjustment to the roadway grade shall be made as required by the Engineer at the Contractor's expense.

Similarly, concrete in abutments and pier caps with coulomb value exceeding the maximum required in Table II-17, by more than 1000 coulomb may be accepted at 80% of the bid price if it has the required strength and meets other specification requirements, and the contractor applies at his own expense, an approved epoxy, conforming to Type EP-3B and EP-3T (of Section 243.02), on top of the pier cap or abutment seat.

The reduction in the bid prices mentioned above shall be applied to the total volume of concrete in bridge members (deck slab of a single span, deck slab of a group of continuous spans, pier or abutment) for which any portion of the concrete in the member did not meet the permeability test requirements.

Section 404.03(k) Curing Concrete is amended to add the following:

> **Section 404.03(k)1. Curing Bridge Deck and Overlay Concrete:** Bridge deck and overlay concrete, including latex modified concrete, shall be moist cured for a minimum of 7 days and until 70% **f′c** is reached. Moist curing shall be maintained by wet burlap (keep wet) for the duration of the curing and covered with plastic sheeting. Immediately after screeding and until the application of wet burlap and white plastic sheeting (opaque and transparent sheeting may be used when the air temperature falls below 10 °C (50 °F)), no surface of the freshly placed concrete shall be allowed to dry. During moist curing, the concrete temperature shall be maintained above 10 °C (50 °F) at the outer most surfaces of the concrete mass. Immediately after removing the burlap and plastic sheeting (except for latex-modified concrete), white pigmented curing compound shall be applied while the surface is damp but has no free water standing on it. The application rate shall be 2.4 - 3.6 square meters per liter (100 to 150 sq.ft./gal.).

Section 404.03(l) 1. Weather is amended to replace the 4th paragraph with the following:

Protection shall be provided to prevent rapid drying of concrete as a result of low humidity, high wind, high atmospheric temperatures, or combinations thereof. For bridge deck and overlay concretes, fogging with pressure sprayers sufficient to maintain a moist surface shall be required. The protective measures taken shall maintain an evaporation rate at or below 0.5 kg/sq m/hr (0.10 lb/sq ft/hr) for bridge deck concrete and 0.3 kg/sq m/hr (0.05 lb/sq ft/hr) for concrete overlays. The Contractor shall determine the evaporation rate and take appropriate action. Other preventative measures described in ACI 308 can also be used in addition to fogging. Evaporation retardant films may be applied in a fine mist immediately after screeding to ensure that the surface remains wet until covered. If such materials are used, they shall not be intermixed with the surface mortar. Placement of concrete shall be regulated at a rate such that the finishing operations are able to be completed and the wet burlap and polyethylene sheeting are placed prior to any drying of the concrete.

Section 404.03 is amended to add the following:

(n) **Defective Concrete:** All defective or damaged concrete which occurs prior to the final acceptance of the work shall be repaired or replaced at the Contractor's expense. Defects shall include, but not be limited to, cracking, tearing, and damage or other imperfections.

All visible cracks and construction joints in bridge deck concretes shall be sealed by the contractor using an approved polymer. Concrete shall be at least 28 days old and dry before the application of the polymer. Concrete shall be grooved after the application of the polymer.

Section 404.04 is amended to add the following:

Consolidation: In deck placements, internal vibrators and screeds with vibrating element shall be used. The minimum frequency of the vibrating element shall be 3,000 vibrations per minute. Internal vibration shall be required along the transverse and longitudinal edges and joints, and where the thickness of concrete exceeds 75 mm (3 in).

Section 405.02(a) is amended to add the following:

Prestressed concrete in structures other than those over tidal water shall contain 15 l/m3 (3 gal/yd3) of calcium nitrite only if the coulomb value of the concrete exceeds 1500. Prestressed concrete for structures over tidal water shall contain either 25l/m3 (5.0 gal/yd3) of calcium nitrite if the coulomb value of concrete exceeds 1,500 or 10 l/m3 (2.0 gal/yd3) of calcium nitrite if the coulomb value of concrete is 1,500 or less.

Section 405.05(c) is amended to replace the last sentence with the following:

Both internal vibrators and external form vibrators shall be used for concrete with strength equal or exceeding 55 MPa (8000 psi). The use of external vibration for other concrete will be at the option of the Contractor with approval of the Engineer. Improper placing and vibrating may be cause for rejection.

Section 405.05(f)4. is completely replaced by the following:

> The temperature rise in the curing enclosure shall be uniform, with a rate rise of not more than 27 °C (80°F) per hour. Concrete shall be cured at a steam temperature of not more than 82 °C (180°F), with the steam temperature uniform throughout the curing enclosure, and with a variation of not more than –7 °C (20°F). Maximum concrete temperature during the curing cycle shall be 88 °C (190°F). Approved recording thermometers shall be placed so that temperatures can be recorded at a minimum of two locations spaced at or near the third of the length in each curing enclosure and at least one sensor shall measure the temperature in the concrete.

TABLE II-17 Requirements for Hydraulic Cement Concrete of the Specifications is replaced by the following:

TABLE II-17
Requirements for Hydraulic Cement Concrete
(English Units)

Class of Concrete	Design Min. Laboratory Compressive Strength at 28 Days (f'c) (psi)	Design Max. Laboratory Permeability at 28 Days (Coulombs)	Nominal Max. Aggregate Size (in)	Min. Cementitious Content (lb/cu yd)	Max. Water/Cementitious Mat. (lb Water/lb Cement)	Consistency (in of slump)	Air Content (%)[1]
A5 Prestressed and other special designs[2]	5,000 or as specified on the plans	1,500	1	635	0.40	0-4	4 1/2 +/- 1 1/2
A4.5	4,500	2,500	1	635	0.45	2-4	6 1/2 +/- 1 1/2
A4 General	4,000	2,500	1	635	0.45	2-4	6 1/2 +/- 1 1/2
A4 Post & rails[3]	4,000	2,500	0.5	635	0.45	2-5	7 +/- 2
A3 General	3,000	3,500	1	588	0.45	1-5	6 +/- 2
A3 Paving	3,000	3,500	1	564	0.49	0-3	6 +/- 2
B2 Massive or lightly re-inforced	2,200	N.A.	1	494	0.58	0-4	4 +/- 2
C1 Massive Un-reinforced	1,500	N.A.	1	423	0.71	0-3	4 +/- 2
T3 Tremie seal	3,000	N.A.	1	635	0.49	3-6	4 +/- 2
Latex hydraulic cement concrete overlay[4]	3,500	1,500	0.5	658	0.40	4-6	5 +/- 2
Silica fume concrete overlay	5,000	1,500	0.5	658[5]	0.40	4-7	6 +/- 2

[1] When a high-range water reducer is used, the target air content shall be increased 1% and the slump shall not exceed 7 inches.
[2] When Class A5 concrete is used as the finishing bridge deck riding surface, or when it is to be covered with asphalt concrete with or without waterproofing, the air content shall be 5 1/2 +/- 1 1/2%.
[3] When necessary for ease in placement, aggregate No. 7 shall be used in concrete posts, rails, and other thin sections above the top of bridge deck slabs.
[4] The latex modifier content shall be 3.5 gallons per bag of cement. Slump shall be measured approximately 4.5 minutes after discharge from the mixer.
[5] Minimum 7% silica fume replacement by weight of the total cementitious material.
Note: Contractor may substitute a higher class of concrete for that specified at his expense.

TABLE II-17
Requirements for Hydraulic Cement Concrete
(Metric units)

Class of Concrete	Design Min. Laboratory Compressive Strength at 28 Days (f'c) (MPa)	Design Max. Laboratory Permeability at 28 Days (Coulombs)	Nominal Max. Aggregate Size (mm)	Min. Cementitious Content (kg/cu m)	Max. Water/Cementitious Mat. (kg Water/kg Cement)	Consistency (mm of slump)	Air Content (%)[1]
A35 Prestressed and other special designs[2]	35 or as specified on the plans	1,500	25	375	0.40	0-100	4 1/2 +/- 1 1/2
A30 General	30	2,500	25	375	0.45	50-100	6 1/2 +/- 1 1/2
A30 Post & rails[3]	30	2,500	13	375	0.45	50-125	7 +/- 2
A25 General	25	3,500	25	350	0.45	50-125	6 +/- 2
A25 Paving	25	3,500	25	335	0.49	0-75	6 +/- 2
B20 Massive or lightly re-inforced	20	N.A.	25	295	0.58	0-100	4 +/- 2
C15 Massive Un-reinforced	15	N.A.	25	250	0.71	0-75	4 +/- 2
T20 Tremie seal	20	N.A.	25	375	0.49	75-150	4 +/- 2
Latex hydraulic cement concrete overlay[4]	25	1,500	13	390	0.40	100-150	5 +/- 2
Silica fume concrete overlay	35	1,500	13	390[5]	0.40	100-175	6 +/- 2

[1] When a high-range water reducer is used, the target air content shall be increased 1% and the slump shall not exceed 175 millimeters.

[2] When Class A35 concrete is used as the finishing bridge deck riding surface, or when it is to be covered with asphalt concrete with or without waterproofing, the air content shall be 5 1/2 +/- 1 1/2%.

[3] When necessary for ease in placement, aggregate No. 7 shall be used in concrete posts, rails, and other thin sections above the top of bridge deck slabs.

[4] The latex modifier content shall be 13.25 liters per bag of cement. Slump shall be measured approximately 4.5 minutes after discharge from the mixer.

[5] Minimum 7% silica fume replacement by mass of the total cementitious material.

Note: Contractor may substitute a higher class of concrete for that specified at his expense.