GEORGIA
State Route 920

TABLE OF CONTENTS

SECTION **PAGE**

1. DESCRIPTION **2**

2. BENEFITS OF HPC AND COSTS **3**
- **A. Benefits of HPC** **3**
- **B. Costs** **3**

3. STRUCTURAL DESIGN **4**

4. SPECIFIED ITEMS **5**
- **A. Concrete Properties** **5**
- **B. Specified QC Procedures** **6**

5. CONCRETE MATERIALS **7**
- **A. Approved Concrete Mix Proportions** **7**
- **B. Measured Properties of Approved Mix** **8**

6. CONCRETE MATERIAL PROPERTIES **9**
- **A. Measured Properties from QC Tests of Production Concrete for Girders** **9**
- **B. Measured Properties from QC Tests of Production Concrete for Deck—Stage I** **9**
- **C. Measured Properties from Research Tests of Production Concrete for Girders** **10**
- **D. Measured Properties from Research Tests of Production Concrete for Deck—Stage I** **14**

7. OTHER RESEARCH DATA **15**

8. OTHER RELATED RESEARCH **19**

9. SOURCES OF DATA **23**

10. DRAWINGS **24**

11. HPC SPECIFICATIONS **26**

GEORGIA
State Route 920

1. DESCRIPTION

Location:	SR 920 (Jonesboro Road) over I 75
Open to Traffic:	Stage I – February 2002
Environment:	Normal over road
HPC Elements:	Girders and deck
Total Length:	107.5 m
Skew or Curve:	27^{o} and 31^{o} skew with horizontal curve
Girder Type:	AASHTO Types II and IV
Girder Span Lengths:	16.25, two at 38.75, 13.75 m
Girder Spacing:	2225 and 2309 mm for Type II 2251 and 2286 mm for Type IV
Girder Strand Grade:	270
Girder Strand Dia.:	15.2 mm
Max. No. of Bottom Strands:	56
Deck Thickness:	205 mm for Type II 200 mm for Type IV
Deck Panels:	Galvanized steel deck panels

2. BENEFITS OF HPC AND COSTS

A. Benefits of HPC

High performance concrete enabled the Georgia DOT to design the spans for this bridge using an optimum beam spacing and a minimum depth with AASHTO Type IV girders. Use of conventional strength concrete girders would have required the use of five additional girders, which would have required a grade change and the purchase of additional, very expensive, rights-of-way.

B. Costs

Total Cost:	\$1,957,460
Cost per m^2:	\$632.25
Type II Girders:	\$288/linear meter
Type IV Girders:	\$460/linear meter

3. STRUCTURAL DESIGN

Design Specifications:	AASHTO Standard Specification for Highway Bridges, 1996
Design Live Loads:	MS 18 and/or military loading
Seismic Requirements:	AASHTO Seismic Performance Category A
Flexural Design Method:	Allowable stresses
Maximum Compressive Strain:	—
Shear Design Method:	AASHTO Standard Specifications 9.20
Fatigue Design Method:	None
Lateral Stability Considerations:	Intermediate concrete diaphragms
Allowable Tensile Stress	
—Top of Girder at Release:	$3\sqrt{f'_{ci}} = 268$ psi (1.85 MPa)
—Bottom of Girder after Losses:	$6\sqrt{f'_{c}} = 600$ psi (4.14 MPa)
Prestress Loss:	0.44 GPa for Type IV
Method Used for Loss:	AASHTO Standard Specification 9.16.2
Calculated Camber:	120 mm
Concrete Cover	
—Girder:	29, 50, and 54 mm
—Top of Deck:	70 mm
—Bottom of Deck:	25 mm
—Other Locations:	—
Properties of Reinforcing Steel	
—Girder:	Shear reinforcement – Grade 420, epoxy coated Other – Grade 420, uncoated
—Deck:	Top Layer – Grade 420, epoxy coated Bottom Layer – Grade 420, uncoated
Properties of Strand	
—Grade and Type:	ASTM A416, Grade 270, low relaxation
—Supplier:	Strand-Tech Martin
—Surface Condition:	Clean
—Pattern:	12 strands draped in Type IV Straight strands in Type II
—Transfer Length:	457 mm
—Development Length:	2057 mm

4. SPECIFIED ITEMS

A. Concrete Properties

	Girders	Deck
Minimum Cement Content:	386 kg/m^3	386 kg/m^3
Max. Water/Cement Ratio:	0.33	0.35
Min. Percentage of Fly Ash:	0	0
Max. Percentage of Fly Ash:	15 (1)	15 (1)
Min. Percentage of Silica Fume:	5 (1)	5 (1)
Max. Percentage of Silica Fume:	10 (1)	10 (1)
Min. Percentage of GGBFS:	—	—
Max. Percentage of GGBFS:	0	0
Maximum Aggregate Size:	19 mm	19 mm
Slump:	50-180 mm	50-125 mm
Air Content:	3.5-6.5%	3.5-6.5%

(1) See 11. HPC Specifications for details.

	Girders	Deck
Compressive Strength		
—Release of Strands:	55 MPa	
—Design:	70 MPa at 56 days	50 MPa at 56 days
Chloride Permeability: (AASHTO T 277)	$\leq$ 3000 coulombs at 56 days	$\leq$ 2000 coulombs at 56 days
ASR or DEF Prevention:	Not specified	Not specified
Freeze-Thaw Resistance:	Not specified	Not specified
Deicer Scaling:	Not specified	Not specified
Abrasion Resistance:	Not specified	Not specified
Other:	Not specified	Not specified

B. Specified QC Procedures

Girder Production	
Curing:	—
Internal Concrete Temperature:	—
Cylinder Curing:	Match curing for release strengths ASTM C 31 Standard Curing
Cylinder Size:	100x200 mm
Cylinder Capping Procedure:	Neoprene pads
Cylinder Testing Method:	AASHTO T 22
Frequency of Testing:	Two sets of cylinders per bed
Other QA/QC Requirements:	None
Deck Construction	
Curing:	Wet for 7 days
Cylinder Curing:	ASTM C 31 Standard Curing
Cylinder Size:	100x200 mm
Flexural Strength:	Not specified
Other QA/QC Requirements:	6x5-m demonstration slab

5. CONCRETE MATERIALS

A. Approved Concrete Mix Proportions

	Girders	Deck Stage I	Deck Stage II
Cement Brand:	Blue Circle (2)	Southern Cement	Southern Cement
Cement Type:	I	I	I
Cement Composition:	—	—	—
Cement Fineness:	3700 Blaine	3500 Blaine	3500 Blaine
Cement Quantity:	475 kg/m^3	386 kg/m^3	362 kg/m^3
GGBFS Brand:	—	—	—
GGBFS Quantity:	—	—	—
Fly Ash Brand:	Boral	None	Boral
Fly Ash Type:	F	—	F
Fly Ash Quantity:	59 kg/m^3	—	61 kg/m^3
Silica Fume Brand:	Force 10000	Euclid MSA	Euclid MSA
Silica Fume Quantity:	44 kg/m^3	7 kg/m^3	15 kg/m^3
Fine Aggregate Type:	Natural sand	Natural sand	Natural sand
Fine Aggregate FM:	2.35	2.35	2.35
Fine Aggregate SG:	2.63	2.62	2.62
Fine Aggregate Quantity:	553 kg/m^3(3)	821 kg/m^3	748 kg/m^3
Coarse Aggregate, Max. Size:	3/4 in	3/4 in	3/4 in
Coarse Aggregate Type:	granite gneiss	granite gneiss	granite gneiss
Coarse Aggregate SG:	2.62 (3)	2.67	2.67
Coarse Aggregate Quantity:	1069 kg/m^3 (3)	1008 kg/m^3	1008 kg/m^3
Water:	146 L/m^3 (3)	134 L/m^3	144 L/m^3
Water Reducer Brand:	WRDA 35	Eucon WR 91	Eucon WR 91
Water Reducer Type:	A and D	A	A
Water Reducer Quantity:	1.04 L/m^3	0.75 L/m^3	0.56 L/m^3
High-Range Water-Reducer Brand:	Daracem 19	Eucon 1037	Eucon 1037
High-Range Water-Reducer Type:	A and F	A and F	A and F
High-Range Water-Reducer Quantity:	5.8 L/m^3	5.54 L/m^3	3.06 L/m^3
Retarder Brand:	—	—	—
Retarder Type:	—	—	—
Retarder Quantity:	—	—	—
Corrosion Inhibitor Brand:	—	—	—
Corrosion Inhibitor Type:	—	—	—
Corrosion Inhibitor Quantity:	—	—	—
Air Entrainment Brand:	Daravair 1000	Euco AEA 92	Euco AEA 92
Air Entrainment Type:	Saponified Rosin	Synthetic Organic Chemical	Synthetic Organic Chemical
Air Entrainment Quantity:	155 mL/m^3	0.63 L/m^3	0.46 L/m^3
Water/Cementitious Materials Ratio:	0.25	0.34	0.34

(2) Lafarge Cement for last two girders.
(3) Quantities were changed slightly when source of coarse aggregate was changed for the last two girders.

B. Measured Properties of Approved Mix

	Girders	Deck Stage I	Deck Stage II
Slump:	152 mm	114 mm	150 mm
Air Content:	4.0%	5.9%	5.0%
Unit Weight:	2375 kg/m^3	2356 kg/m^3	2390 kg/m^3
Compressive Strength:	58.7 MPa at 1 day 66.3 MPa at 2 days 73.5 MPa at 7 days 79.0 MPa at 14 days 88.3 MPa at 28 days 91.6 MPa at 56 days	44 MPa at 3 days 50 MPa at 7 days 57 MPa at 14 days 62 MPa at 28 days 69 MPa at 56 days	50 MPa at 7 days 57 MPa at 28 days 65 MPa at 56 days
Chloride Permeability: (AASHTO T 277)	270 coulombs at 56 days	1650 coulombs	1100 coulombs

6. CONCRETE MATERIAL PROPERTIES

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

Cement Composition:	—
Actual Curing Procedure for Girders:	—
Average Slump:	90-152 mm
Maximum Girder Temperature:	—
Air Content:	3.0 to 5.0%
Unit Weight:	2323 kg/m^3
Compressive Strength:	—
Curing Procedure for Cylinders:	—

B. Measured Properties from QC Tests of Production Concrete for Deck – Stage I

Cement Composition:	—
Actual Curing Procedure for Deck:	Soaker hoses, burlap-polyethylene cover
Slump:	100 to 172 mm
Air Content:	3.2 to 6.5%
Unit Weight:	2390 kg/m^3
Compressive Strength:	53.4 MPa at 56 days
Curing Procedure for Cylinders:	Moist cured
Chloride Permeability:	3963 coulombs at 56 days

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

Slump and Air Content (4):

Girder No.	Slump, in	Air Content, %
1.4	5-1/4	4.0
1.5	5	3.5
1.5	4-1/2	3.5
2.4	4	4.7
2.4	5-1/4	—
2.4	3	3.8
2.5	5	5.5

(4) Values reported by girder fabricator.

Unit Weight of Hardened Concrete: 146.9 lb/ft^3 at 56 days

Compressive Strength (5), psi:

Initial Curing (6)	Age, days			
	1	7	28	56
Span 1 – Type II Girders				
Insulated	10,434	11,055	12,276	12,435
ASTM	7700	10,641	12,435	13,379
ASTM (7)	—	12,647 (8)	—	15,228
Match	10,819	—	—	12,795
Span 2 – Type IV Girders				
Insulated	7401	10,324	11,928	12,453
ASTM	6343	10,081	12,527	13,157
ASTM (7)	—	10,892 (8)	—	13,677
Match	10,109	—	—	12,047

(5) ASTM C 39 with 4x8-in cylinders. Specimens tested by researchers were hand ground and tested with neoprene pads.

(6) Insulated – Placed in insulated box 6 hours after casting until 24 hours and then stripped and stored at 73 ^{o}F and 100% RH.
ASTM – ASTM C 31 Initial Curing and then stripped and stored at 73 ^{o}F and 100% RH.
Match – Match cured during first 24 hours and then stripped and stored at 73 ^{o}F and 100% RH. Tested by fabricator at one day and by researchers at 56 days.

(7) Made and tested by fabricator. Specimens cured in a lime saturated water bath.

(8) Tested at 8 days.

Modulus of Elasticity (9):

Span	Age, days	Initial Curing, (10)	Compressive Strength, psi	Modulus of Elasticity, ksi
1	1	Insulated	10,434	3436
2	1	Insulated	7401	3397
1	56	Insulated	12,435	5031
2	56	Insulated	12,453	4911
1	56	ASTM	13,379	4983
2	56	ASTM	13,157	4962

(9) ASTM C 469 with 6x12-in cylinders.
(10) Insulated – Placed in insulated box 6 hours after casting until 24 hours and then stripped and stored at 73 ^{o}F and 100% RH.
ASTM – ASTM C 31 Initial Curing and then stripped and stored at 73 ^{o}F and 100% RH.

Poisson's Ratio: 0.17 at 1 day
0.15 at 56 days

Modulus of Rupture (11):

Span	Age, days	Initial Curing, (12)	Compressive Strength, psi	Modulus of Rupture, psi
1	56	Insulated	12,435	1184
2	56	Insulated	12,453	1266
1	56	ASTM	13,379	1169
2	56	ASTM	13,157	1272

(11) ASTM C 78 with 4x4x14-in beams.
(12) Insulated – Placed in insulated box 6 hours after casting until 24 hours and then stripped and stored at 73 ^{o}F and 100% RH.
ASTM – ASTM C 31 Initial Cured and then stripped and stored at 73 ^{o}F and 100% RH.

Chloride Permeability:

Span	Specimens	Age, days	Chloride Permeability (13), coulombs
2	2-in-thick slices from 4x8-in cylinders ASTM Standard Cure	56	225 222 174 170
1	Core	> 28	200
2	Core	>28	200

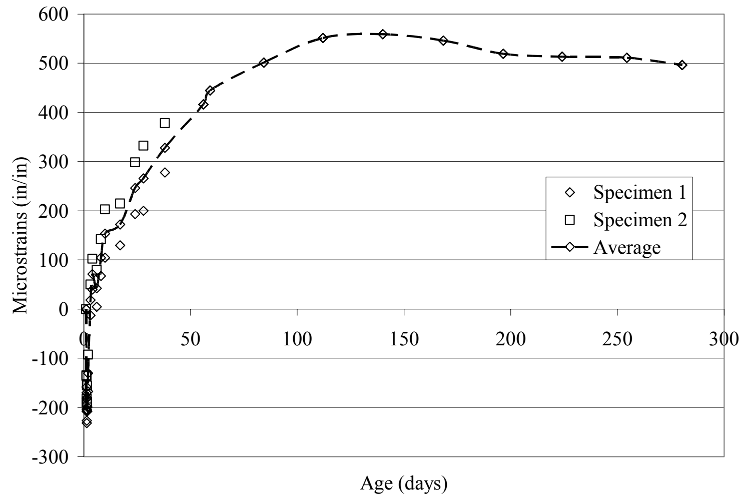
(13) ASTM C 1202.

Creep:

Average Total Creep Strains (14)

(14) Average creep strain of four 4x15-in cylinders loaded at 1 day. Total strain includes elastic shortening, thermal shortening, creep, and shrinkage. Concrete represents girder concrete in span 2.

Shrinkage:



Shrinkage Strains (15)

(15) Shrinkage of individual 4x15-in cylinders beginning at 1 day. Concrete represents girder concrete in span 2.

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

Unit Weight of Hardened Concrete: Span 1 – 145.1 lb/ft^3 at 56 days
Span 2 – 144.8 lb/ft^3 at 56 days

Compressive Strength (16), psi:

Span	Age, days				
	1	3	7	28	56
1	2073	3922	4813	5719	6230
2	2497	4411	5268	6715	6880

(16) ASTM C 39 with 4x8-in cylinders.

Modulus of Elasticity:

Span	Compressive Strength, psi	Modulus of Elasticity (17), ksi
1	6230	3546
2	6880	3673

(17) ASTM C 469 with 6x12-in cylinders tested at 56 days following ASTM C 31 Final Cure.

Chloride Permeability:

Span	Chloride Permeability (18), coulombs
1	4447 6162 4384 5195
2	4162 4170 3790 5160

(18) ASTM C 1202 tested at 56 days.

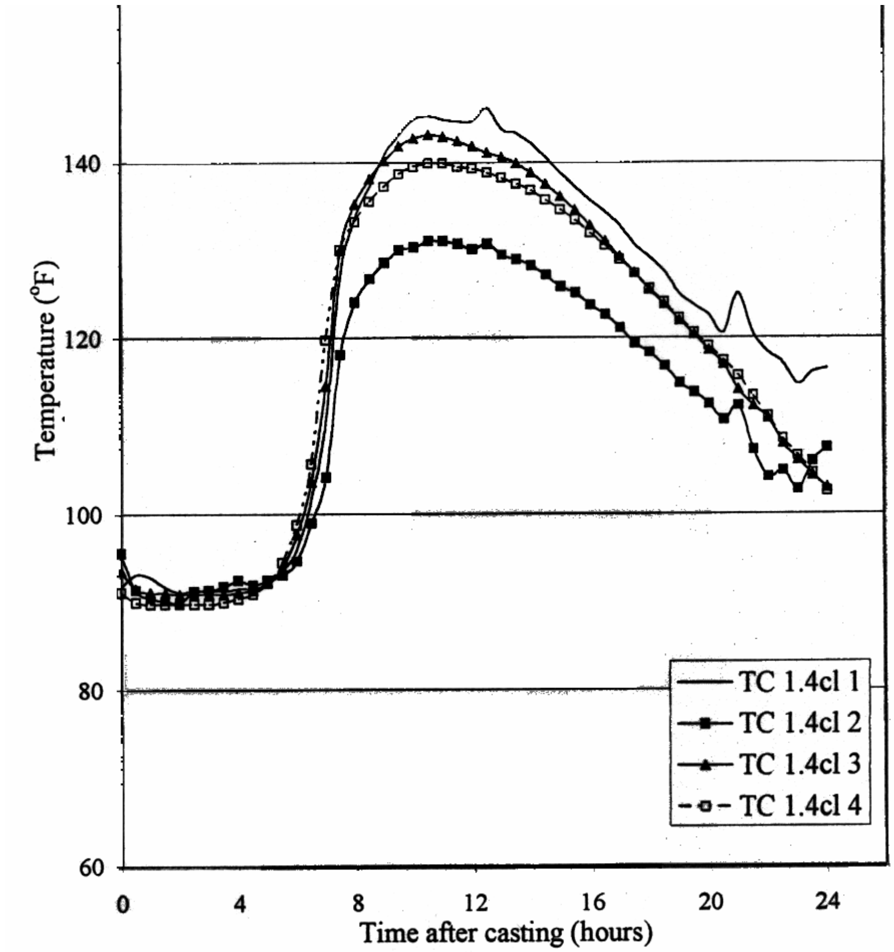
7. OTHER RESEARCH DATA

Strand Forces:

Load Cell No. (19)	Load Cell Force, kips	Jacking Force, kips	Force from Extension, kips
Span 1 – Type II Girders			
1	38.74	44.50	40.59
2	40.87	44.50	40.59
3	39.35	44.50	40.59
4	43.95	44.50	40.59
5	42.60	44.50	40.59
6	42.06	45.00	40.59
7	42.36	44.30	40.59
8	42.73	45.00	40.59
9	42.52	45.00	40.59
10	44.00	44.50	40.59
Average	41.92	44.63	40.59
Span 2 – Type IV Girders			
1	37.89	44.80	43.69
2	39.89	44.70	43.69
3	40.77	44.80	43.69
4	39.34	44.80	43.69
5	42.55	44.80	43.69
6	41.75	44.80	43.69
7	42.63	44.80	43.69
8	44.68	44.80	43.69
9 (20)	41.69	42.19	41.08
10 (20)	40.38	42.29	41.08
Average	41.16	44.28	43.16

(19) See section 10 for location of load cells.
(20) Load cell reading adjusted for additional forces caused by draping.

Curing Temperatures:



See section 10 for location of thermocouples.

Transfer Length:

Girder No.	Bent	Transfer Length (21), in
Type II Girders		
1.4	West	18.7
	East	15.6
1.5	West	15.9
	East	15.2
Type IV Girders		
2.4 (22)	West	23.7
	East	28.5
2.5 (22)	West	24.2
	East	32.7

(21) Transfer length was taken at 95 percent of the average maximum strain.
(22) Cracks occurred at the ends of some Type IV girders and are reported to have contributed to the longer transfer lengths on the Type IV girders.

Camber, in:

Time after Transfer, days	Girder No.			
	1.4	1.5	2.4	2.5
At Transfer	0.54	0.60	2.13	1.84
1	0.65	0.73	2.63	2.34
2	0.66	0.74	2.70	2.48
3	0.69	0.75	—	2.48
7	0.70	0.77	2.75	2.48

Direct Pullout Capacity:

Strand	Load, kips
1	59.28
2	60.52
3	57.19
4	59.03
Average	59.00

0.6-in-diameter strands embedded 20 in.

Live Load Test:

Static live load tests were made on two occasions using two fully loaded dump trucks. The first set of tests took place on January 28, 2002. Trucks were positioned at seven different locations. The second set of tests took place on July 14, 2002. Trucks were positioned at four locations. Deflections and strains were measured during both tests.

Test results and comparisons with calculated values are provided in the report listed in section 9.

8. OTHER RELATED RESEARCH

Meyer, K. F., Kahn, L. F., Lai, J. S., and Kurtis, K. E., "Behavior of High-Strength/High Performance Lightweight Concrete Prestressed Girders," Georgia Institute of Technology, Structural Engineering, Mechanics and Materials Research Report No. 02-5, June 2002, 358 pp.

Executive Summary: This report presents findings of a study that developed and tested high-strength lightweight concrete (HSLC) mixes having strengths from 8,000 psi to 12,000 psi made using slate lightweight aggregate. Based on optimized mix designs, six pretensioned AASHTO Type II girders were constructed using 8,000 psi and 10,000 psi slate HSLC and were prestressed using 0.6-in-diameter LOLAX strands tensioned to 75 percent of strand ultimate stress. The strands received no special preparation prior to girder casting.

After initial curing for approximately 24 hours, transfer length measurements were taken from time of release until the beams reached an age of 14 days. The current AASHTO and ACI code provisions conservatively predicted transfer length for slate HSLC; modifications of the current code specification for transfer length was not necessary for slate HSLC.

A direct pullout test was performed on both concrete design strengths to determine the bond between the slate lightweight concrete and the prestressing strand. A somewhat lower bond stress developed between the prestressing strand and the lightweight concrete when compared to similar strengths of normal weight concrete. However, the average pullout strength for both series exceeded the minimum required value for 0.6-in-diameter strand of 43.2 kips.

Tests were conducted on each girder end to determine development length characteristics. The distance from the girder end to the load point was varied from between 70 and 100 percent of the AASHTO specified development length. Strand slip was measured on each test. The current AASHTO and ACI code provisions conservatively predicted development length for slate HSLC; modifications of the current code specification for transfer length was not necessary for slate HSLC.

Tests were conducted on the center span of each girder to examine shear characteristics of HSLC. The combined center span and girder end shear results showed the current *AASHTO Standard Specification* provided a conservative prediction of concrete and ultimate shear capacity when shear steel capacity was capped at a yield strength of 60 ksi. The alternate design procedure listed in *ACI 318* Section 11.4.2.2 for predicting concrete shear strength produced some unconservative predictions for concrete compressive strengths over 10,000 psi. The current *AASHTO LRFD Specifications* provided a conservative prediction of ultimate shear capacity for slate HSLC.

An evaluation of girder flexural behavior showed the current prediction of cracking stress and cracking moment, when examined for slate HSLC, showed indications of becoming unconservative as concrete compressive strengths approached 11,000 psi. The use of a lambda factor (λ) of 0.85 for slate HSLC produced conservative results on average for compressive strengths below 11,000 psi. The modulus of rupture test, ASTM C 78, did not accurately predict the cracking stress of HSLC girders. The current AASHTO procedure for ultimate moment calculation was conservative for slate HSLC girders with normal weight concrete decks having a compressive strength under 6000 psi.

Mitchell, A. D. and Kahn, L. F., "Shear Friction Behavior of High Strength Concrete," Georgia Institute of Technology, Structural Engineering, Mechanics and Materials Research Report No. 01-3, January 2001, 183 pp.

Executive Summary: This report presents research on the shear friction behavior of high-strength concrete particularly for use in the design of precast, prestressed concrete composite beams. The principal objective was to evaluate the current AASHTO/ACI code provisions for predicting interface shear when high-strength concrete is used. Fifty push-off specimens were tested with uncracked, pre-cracked, and cold-joint interfaces. Concrete strengths varied from 6,800 to 17,900 psi with reinforcing ratios between 0.37 and 1.47 percent. The primary conclusion was that the AASHTO/ACI code provisions give a conservative estimate for interface shear when high-strength concrete is used. Additionally, an equation is proposed that more accurately predicts the shear friction strength of cold-joint and uncracked interfaces for high-strength concrete.

Kahn, L. F., Lai, J. S., Reutlinger, C., Dill, J., and Shams, M., "Direct Pull-Out Capacity, Transfer and Development Length of 0.6-inch Diameter Prestressing Strand in High-Performance Concrete," Task 5, Final Report, Use of High-Strength/High Performance Concrete for Precast Prestressed Concrete Bridges in Georgia, Georgia Institute of Technology, Structural Engineering, Mechanics and Materials Research Report No. 00-6, April 2000, 412 pp.

Summary: Grade 270, low-relaxation, 0.6-in-diameter prestressing strands were shown to exhibit reliable bond performance when used to pretension AASHTO Type II girders made with Grade 2 (10,000 psi) and Grade 4 (14,000 psi) high performance concrete (HPC). The bond performance of the prestressing strand with the HPC was evaluated by determining the direct pull-out capacity, transfer and development lengths.

Twelve direct pull-out tests were conducted on untensioned strand samples cast into two HPC blocks. The direct pull-out test results indicated that the strands were capable of reaching the yield stress before failure.

Transfer lengths were measured at each end of four AASHTO Type II girders. Two girders were fabricated with each grade of HPC. The average transfer length was 17.6 and 14.6 in for the Grade 2 and Grade 4 HPC girders, respectively.

The development length was experimentally determined to be 80 in after performing development length tests at each end of the four AASHTO Type II girders. The development length was determined as the critical embedment length that separated the flexural and shear/bond failures.

Both grades of HPC had similar bond characteristics. The measured transfer and development lengths were compared with expressions proposed by several previous research programs. It was concluded that the current AASHTO specifications conservatively predicted the strand transfer and development lengths.

Shams, M. K. and Kahn, L. F., "Time-Dependent Behavior of High-Performance Concrete," Task 3, Use of High-Strength/High Performance Concrete for Precast Prestressed Concrete Bridges in Georgia, Georgia Institute of Technology, Structural Engineering, Mechanics and Materials Research Report No. 00-5, April 2000, 395 pp.

Summary: Two grades of high performance concrete (HPC) were investigated for more than a year in order to determine their time-dependent mechanical properties as well as their time-dependent structural responses in precast, prestressed girders. The design compressive strengths for the two grades of HPC were 10,000 and 14,000 psi at 56 days for the Grade 2 and Grade 4 HPC, respectively. The corresponding minimum average 56-day compressive strengths (according to ACI 318) were 11,400 and 15,400 psi for Grade 2 and Grade 4 HPC, respectively.

In addition to a large number of compressive strength and modulus of elasticity tests, 20 creep and shrinkage tests were conducted. Test variables included the concrete age at time of load applications (12 hours to 28 days), applied stress ratio (0.16 to 0.6 of the ultimate strength at loading), and the initial curing method (ASTM curing and heat curing). The inaccuracy of the current creep and shrinkage models with respect to HPC was illustrated. A new model for predicting creep and shrinkage strains of HPC is proposed. The new model compared favorably with published data.

The time-dependent prestress loss and camber of four 33 ft 5-1/2 in long, AASHTO Type II girders and six 9 in x18 in x14 ft beams were monitored for more than a year. Test results indicated that the current *AASHTO LRFD Specifications* and the *PCI Design Handbook* significantly overestimate the time-dependent prestress loss and deflection of HPC precast beams. A step-function method and time-step analysis, using the proposed creep and shrinkage model, were found to predict the responses within $\pm$ 10 percent. Modifications to the *AASHTO LRFD Specifications* on prestress losses are proposed to account for the characteristics of HPC. The modified provisions compared favorably with published data.

Saber, A. and Kahn L. F., "Analytical Investigation," Task 1, Use of High-Strength/High Performance Concrete for Precast Prestressed Concrete Bridges in Georgia, Georgia Institute of Technology, Structural Engineering, Mechanics and Materials Research Report No. 99-2, November 1997, 702 pp.

Summary: A series of bridge designs were performed to determine the maximum span capabilities for concrete strengths ranging from 6 to 15 ksi, and girder spacing from 5 to 11 ft. Designs were compared to provide a better understanding of the benefits and trends that accompany the use of high-strength concrete for precast, prestressed girders. AASHTO Type I through Type IV and several NU girder cross-section shapes were considered. Other parameters investigated were strand size and strength (0.5-in modified, 0.6-in strand with f_{pu} of 270 and 300 ksi), strand cover, strand spacing (1.75 and 2 in). The stability of long prestressed girders was investigated for two cases: (1) during construction of the deck and (2) during lifting of the girders.

The results of these designs showed an increase in maximum span with increasing concrete strength for the sections and girder spacing considered. The maximum span increased between 20 to 45 percent when f'_c was increased from 6 to 14 ksi. The span increased between 15 to 25 percent when the f'_c increased from 6 to 9 ksi. The use of 0.6-in strands resulted in significantly longer maximum spans than those found using 0.5-in modified strands. Further, the 0.6-in strands were effective in utilizing concrete with higher strength.

For a given span length, an increase in concrete strength enables a minor reduction in strands due to the increased allowable stresses corresponding with the increased concrete strength. Increased span lengths may be achieved with high-strength concrete by increasing the number of strands (amount of prestress) in the cross section. As more and more strands are added to the cross section, their effectiveness is reduced as they are placed further up in the cross section, resulting in a lower eccentricity.

The decrease in concrete strength at release (from 75 to 65 percent f'_c) had a more pronounced effect on the maximum spans for closer girder spacing than for wider girder spacing. For the case where girders are placed at 11-ft spacing, the reduction in maximum spans ranged between 6 and 3 percent for the concrete strength range from 6 to 15 ksi. While, for girders that are placed at 5-ft spacing, the reduction in maximum spans was up to 9 percent for the concrete strength range between 6 and 15 ksi.

In nearly all designs using both 0.5- and 0.6-in strand and HPC ranging from 6 to 15 ksi, the L/800 deflection limit of AASHTO article 9.11.3 for live load was satisfied. The few design cases where the girder deflection exceeds the AASHTO allowable were limited to long span girders with f'_c greater than 11 ksi and girders at 5-ft spacing.

The HPC girders will be stable during bridge deck construction, handling, and erection. The maximum spans for HPC girders are not limited by the lifting spans and the stresses induced during handling and erection.

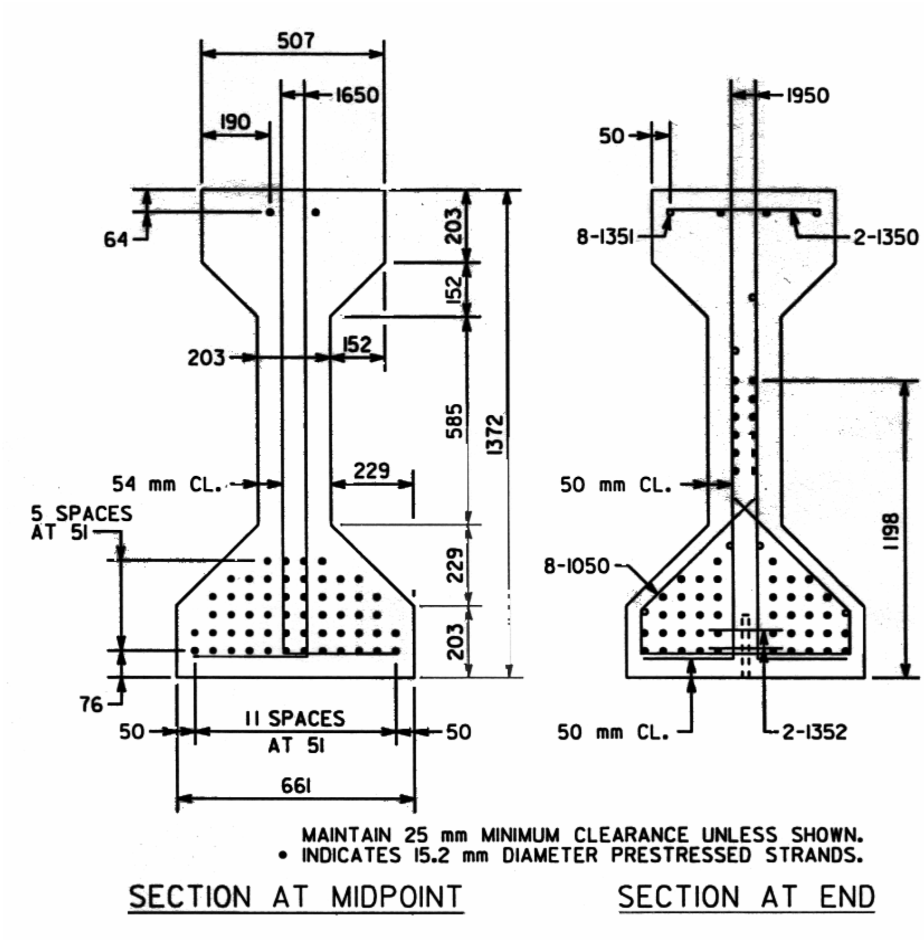
9. SOURCES OF DATA

Slapkus, A. and Kahn, L., "Evaluation of Georgia's High Performance Concrete Bridge, Task 6, Use of High-Strength/High-Performance Concrete for Precast Prestressed Concrete Bridges in Georgia," Georgia Institute of Technology, Structural Engineering, Mechanics and Materials Research Report No. 03-3, August 2002, 382 pp.

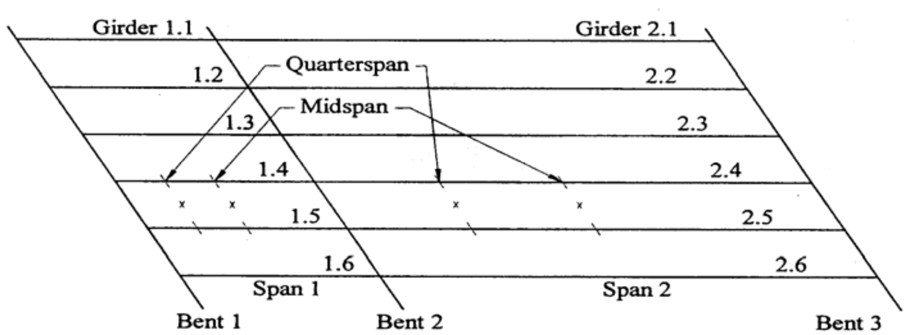
Liles, P. V., State Bridge Engineer, Department of Transportation, State of Georgia, Atlanta, GA.

Kahn, L. F., Georgia Institute of Technology, Atlanta, GA.

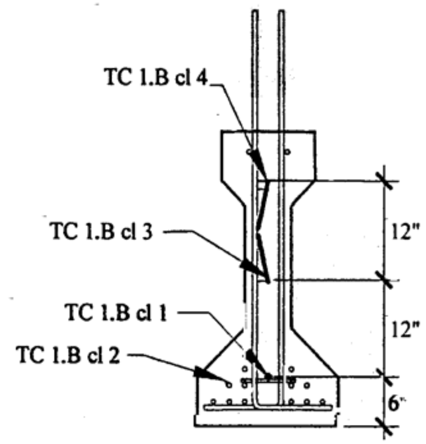
10. DRAWINGS



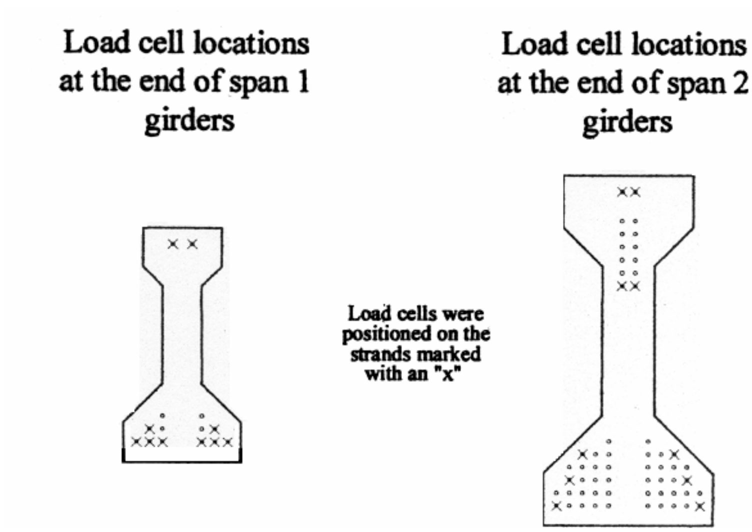
Type IV Girder



Instrumented Spans and Girder Identification



Span 1 Thermocouple Locations



Load Cell Locations

February 22, 1999

11. HPC SPECIFICATIONS **METRIC**

SPECIAL PROVISION
NH-IM-75-2(194) HENRY
P.I. NO. 311840

SECTION 500 – CONCRETE STRUCTURES

Delete Subsection 500.02 and substitute the following:

500.02 MATERIALS: All materials shall meet the requirements of the following Specifications:

*Coarse Aggregate	800.01
Fine Aggregate	801.02
Dampproofing or Waterproofing Material (Bituminous)	826.01
**Portland Cement	830.01
**Portland-Pozzolan Cement	830.03
Admixtures:	
Air-Entraining Admixtures	831.01
Retarding Admixtures	831.02
Water Reducing Admixtures	831.02
Fly Ash	831.03
Microsilica (Silica Fume)	831.03
Curing Agents	832
Joint Fillers and Sealers	833
Special Surface Coating	836
Linseed Oil	870.07.B
Mineral Spirits	870.07.D
Water	880.01
***Graded Aggregate	815.01
Graffiti Proof Coating	838.01

*Coarse aggregate may be either Class A or B of the designated size except when Limestone or Dolomite is used in bridge structures. When Limestone or Dolomite is used in bridge length structures, Class A coarse aggregate is required.

**For High Performance Concrete only Types I and III Portland Cement will be allowed. Types I or II Portland Cement or Type IP Portland Pozzolan Cement shall be used unless otherwise specified. Air-entraining cement shall not be used.

***The gradation requirements of graded aggregate are modified to require 30 to 45 percent by weight passing the 2.00 mm sieve.

Delete Subsection 500.03 and substitute the following:

500.03 CLASSES AND USES OF CONCRETE:

A. General: Classes and specific requirements for each class of concrete are tabulated in the Concrete Mix Tables 500.03.T.1 and 500.03.T.2. The specific class of concrete to be used in a particular component of a structure will be shown on the Plan or called for in the Specifications. Various classes of concrete for specified uses shall be as follows:

Class AAA HPC -	Prestressed Concrete
Class AA HPC -	Bridge Superstructure Concrete
Class AA1 -	Precast Concrete as called for on Plans

Note No. 1: This class may be used as high-early strength concrete if approved by the Engineer. The Engineer may approve the use of Type III cement in concrete used for this purpose. The Engineer may also specify the rate of compressive strength development when this concrete is used to expedite the contract.

Additional compensation will not be given for this concrete when it is used at the request of the Contractor.

Class AA -	Precast Concrete as called for on plans
Class A -	General Purposes
Class B -	Massive sections or lightly reinforced sections or miscellaneous non-structural concrete.
Class CS -	(Portland Cement Concrete Subbase).

Note No. 2: Class CS (Portland Cement Concrete Subbase)- this class to be used as a subbase where required by the Plans. Concrete subbase may be composed of a mixture of Portland Cement and graded aggregate or Portland Cement, aggregate and sand.

B. ADMIXTURES: Additives are required when specified herein or as directed by the Engineer.

1. AIR-ENTRAINING ADMIXTURES: Air entraining additives are required for all bridge structure concrete except Seal Concrete and non-exposed footings. The agent may be used in other concrete to improve workability when job or material conditions dictate. When used as an option to improve workability or when required, the amount of entrained air shall not exceed the upper limit of entrained air content requirement in Tables 500.03.T.1 and 500.03.T.2.

2. RETARDING ADMIXTURES: Concrete retarding additives shall be used in bridge concrete when the average temperature is above 18°C (average of expected high and the predicted low). Normally, the additives will not be required for bridge curbs, handrails, crosswalks or other appurtenances constructed separately from the decks. The use of retarders may be waived by the Engineer in substructure concrete when concrete can be placed within one (1) hour after batching.

3. WATER REDUCING ADMIXTURES: Water reducing agents may be used in Class AA HPC concrete for bridge decks when conditions do not require the use of a retarder. The agent may be used in other concrete when job or materials conditions dictate a reduction in water requirements or when minimal retardation of set is desired. Type “F” water reducing admixtures may be allowed by the Laboratory when requested by the Contractor.

4. FLY ASH: Fly Ash may be used as an additive in all classes of concrete listed in Concrete Mix Table 500.03.T.1 to promote workability and plasticity. Fly ash may be used as a partial replacement for Portland Cement in all concrete provided the following limits are met:

   a. The quantity of cement replaced shall be no more than 15% by weight.

b. Cement shall be replaced by fly ash at rate of 1.0 kg to 1.5 kg of fly ash to 1.0 kg of cement.

c. The fly ash mix shall conform to the provisions of Subsections 500.03 and 500.04.

d. Type IP cement shall not be used in mixes containing fly ash.

Water-cement ratio shall be calculated based on the total cementious material in the mix including fly ash.

e. For concrete classes listed in Concrete Mix Table 500.03.T.2, fly ash may be used as an additive in Class AAA HPC and Class AA HPC. For these classes only Class "F" fly ash shall be allowed and the following limits shall be met:

1. The quantity of fly ash shall be no more than 15% by weight.
2. The fly ash mix shall conform to the provisions of Subsections 500.03 and 500.04.

5. GRANULATED IRON BLAST-FURNACE SLAG: When high-early strengths are not desired, Granulated Iron Blast-Furnace Slag may be used as a partial replacement for Portland Cement in all classes of concrete listed in Concrete Mix Table 500.03.T.1, provided the following limits are met:

a. The quantity of cement replaced shall be no more than 50% by weight.

b. Cement shall be replaced by slag at the rate of 1.0 kg of slag to 1.0 kg of cement.

c. The slag mix shall conform to the provisions of Subsection 500.03 and 500.04.

d. Water-cement ratio shall be calculated based on the total cementious material in the mix including Granulated Iron Blast-Furnace Slag.

e. Type IP cement or fly ash will not be permitted in slag mixes.

f. Granulated Iron Blast-Furnace Slag shall not be used in High Performance Concrete mixtures listed in Table 500.03.T.2.

6. MICROSILICA (SILICA FUME): Silica fume may be used as an additive in Class AAA HPC and Class AA HPC at addition rates not to exceed 10% and 5% of the cement content respectively.

CONCRETE MIX TABLE
500.03.T.1

CLASS OF CONCRETE	COARSE AGGREGATE[2] SIZE NO.	MINIMUM CEMENT FACTOR[6] (kg/m^3)	MAXIMUM WATER/CEMENT RATIO (kg/kg)	SLUMP ACCEPTANCE[5] LIMITS (mm) LOWER	UPPER	ENTRAINED AIR ACCEPTANCE[3 & 7] LIMITS (%) LOWER	UPPER	MINIMUM COMPRESSIVE STRENGTH AT 28 DAYS (MPa)
"AAA"	67,68	400	0.440	50	100	2.5	6.0	35
"AA1"	67,68	400	0.440	50	100	2.5	6.0	30
"AA"	56,57,67	375	0.445	50	100	3.5	7.0	25
"A"	56,57,67	360	0.490	50	100	2.5	6.0	20
"B"	56,57,67	280	0.660	50	100	0.0	6.0	15
"CS"[4]	56,57,67	165	1.400		90	3.0	7.0	7
GRADED AGG.*								

HIGH PERFORMANCE CONCRETE MIX TABLE
500.03.T.2

CLASS OF CONCRETE	COARSE AGGREGATE SIZE NO.	MINIMUM CEMENT FACTOR (kg/m^3)	MAXIMUM WATER/CEMENT RATIO[7] (kg/kg)	SLUMP ACCEPTANCE[8] LIMITS (mm) LOWER - UPPER		ENTRAINED AIR ACCEPTANCE LIMITS (%) LOWER - UPPER		MINIMUM COMPRESSIVE STRENGTH[9] AT 56 DAYS (MPa)	MAX. CHLORIDE PERMEABILITY[10] AT 56 DAYS (COULOMBS)
"AAA HPC"	67	386	0.33	50	180	3.5	6.5	70	3000
"AA HPC"	67	386	0.35	50	125	3.5	6.5	50	2000

NOTE:

1. Portland Cement may be partially replaced with fly ash as provided in Subsection 500.03.B.4 or Granulated Iron Blast-Furnace Slag as provided in Subsection 500.03.B.5.
2. Specific gravity of coarse aggregate may be specified.
3. Lower limit is waived when air entrained concrete is not required.
4. The mixture will be capable of demonstrating a laboratory compressive strength at 28 days of 7 MPa + 0.18R*. Compressive strength will be determined based upon result of six cylinders prepared and tested in accordance with AASHTO T 126 and T 22.

   *Where R = difference between the largest observed value and the smallest observed value for all compressive strength specimens at 28 days for a given combination of materials and mix portions prepared together.
5. Designed slump may be altered by the Laboratory when Type "F" water reducers are used.
6. Minimum cement factor shall be increased by 30 kg/m^3 when Size No. 7 Coarse Aggregate is used.
7. For High Performance Concrete the maximum water-cement ratio shall not include the addition of fly ash and/or silica fume.
8. For High Performance Concrete slump acceptance shall be determined after the addition of high-range water reducer.
9. For High Performance Concrete the minimum compressive strength at 56 days shall be determined using 100 mm diameter x 200 mm high cylinders.
10. For High Performance Concrete chloride permeability tests on mixtures shall be conducted as outlined in AASHTO T-277 on specimens cured for 56 days.

Delete Subsection 500.04 and substitute the following:

500.04 QUALITY OF CONCRETE:

A. GENERAL: The Contractor shall be responsible for concrete mix designs, batching, mixing, delivering and placing concrete in accordance with the Specifications. Concrete mixes shall meet requirements of the Concrete Mix Tables 500.03.T.1 and 500.03.T.2. Properties of concrete will be determined by the applicable method in the Sampling, Testing and Inspection Manual.

B. CONCRETE MIX DESIGNS: Concrete mix designs shall be submitted to the Office of Materials and Research at least 90 days prior to using the proposed mix. Any change in the mix design or in the source of components or admixtures shall be submitted to the Office of Materials and Research for approval at least 90 days prior to the date of use. Mix proportions that contain materials from approved sources and produce concrete that meets these Specifications will be approved. Concrete mix design proportions may be approved by a method listed below.

1. SPECIFIC PROPORTIONS: The Contractor may request approval of specific concrete mix design proportions for designated classes of concrete. Request shall contain at least the following information:
   a. The source of each material.
   b. The apparent specific gravity of cement and fly ash if used, bulk specific gravity (saturated surface dry) of each aggregate and the percent absorption of each aggregate.
   c. The amount of each material required per cubic meter of concrete.
   d. Proportions of admixtures per cubic meter of concrete and limitations as accompany the use thereof.
   e. The proposed slump and air content of the design.
   f. Evidence that the proposed mixture will conform to provisions of Subsections 500.03 and 500.04.
2. READY TO MIX DESIGN PROPORTIONS: Ready mix concrete plants that are approved in accordance with Laboratory SOP, Quality Assurance for Ready Mix Concrete Plants in Georgia, are authorized to submit concrete mix designs for approval. The Contractor may secure approved concrete mix designs from authorized ready mix concrete plants.
3. LABORATORY DESIGN PROPORTIONS: Laboratory design proportions are available for commonly used materials combinations. The Contractor may obtain these mixes by directing a written request to the State Highway Materials and Research Engineer. Request shall be for specific classes of concrete and shall specify the source of all ingredients.

   The Contractor may select a combination of materials from approved sources and request the Laboratory to determine a mix that meets requirements in Table 500.03.T.1. The proportions will be established for strength and workability under laboratory conditions.
4. CEMENT FACTOR: The minimum cement factor for each class of concrete is established in Tables 500.03.T.1 and 500.03.T.2. Concrete mixes shall contain sufficient cement to produce adequate workability within the specified water-cement ratio.
5. COMPRESSIVE STRENGTH: Concrete mix designs (Table 500.03.T.1), which do not have a performance record of use by the Department, shall be required to meet minimum laboratory strength requirements. Laboratory acceptance strength shall be determined by at least eight compressive test specimens prepared and cured in accordance with AASHTO T 126. The specimens shall be made from two or more separate trial batches. An equal number of specimens shall be made from each batch. The minimum acceptance strength shall be:

$$X = f'c + 2.0s$$

where: X is the minimum average strength or acceptance strength, f'c is the required minimum compressive strength for each class of concrete from the Concrete Mix Table 500.03.T.1 and s is the average standard deviation of all 28 day specimens made in the field representing concrete of a given class from all ready mix plants. The standard deviation has been determined as follows:

Class of Concrete	s
B	2.5
A	4.5
AA	4.3
AA-1	3.7
AAA	3.4

High Performance Concrete mix designs (Table 500.03.T.2), which do not have a performance record of use by the Department, shall be required to meet minimum laboratory strength requirements. Laboratory acceptance strength shall be determined by at least eight (8) 100 mm diameter x 200 mm high compressive test cylinders prepared and cured in accordance with AASHTO: T-126. The cylinders shall be made from two or more separate trial batches. An equal number of cylinders shall be made from each batch. The minimum acceptance strength shall be:

$$X = f'c + 6.9$$

Where: X is the minimum average strength or acceptance strength, f'c is the required minimum compressive strength at 56 days for each class of High Performance Concrete as shown in Concrete Mix Table 500.03.T.2

When job site test specimens fail to meet the compressive strength requirements shown in Tables 500.03.T.1 and 500.03.T.2, final acceptance or rejection of concrete in place shall be determined by coring or non-destructive testing.

6. BATCHING CONTROLS: Concrete shall be batched in accordance with proportions of an approved mix design. The Contractor will take the action necessary to ensure that concrete materials are from the designated sources and that batch weights are corrected to account for surface moisture in aggregates. Batching control tests shall be conducted in accordance with procedures in the Sampling, Testing and Inspection Manual.

7. ACCEPTANCE TOLERANCES: Measurements for acceptance tolerances will be made immediately before concrete is placed in the forms. The applicable tests shall be conducted in accordance with procedures established in the Sampling, Testing and Inspection Manual. Acceptance tolerances for each class of concrete are listed in the Concrete Mix Tables.

Delete Subsection 500.05.B.3 and substitute the following:

500.05.B.3 MEASURING MATERIALS:

3. MEASURING MATERIALS:

   a. CEMENT: Bulk cement shall be measured by weight on scales to an accuracy of plus or minus one percent of the designated weight. If the Engineer permits the use of bag cement, the batch shall be so proportioned that only whole bags will be used.

b. AGGREGATES: All aggregates shall be measured by weight on scales to an accuracy of plus or minus two percent of the designated weight and the Contractor shall be responsible for ensuring that proper aggregate surface moisture corrections are applied.

c. WATER: Water may be measured by volume or weight. The measuring system shall be constructed to be independent of fluctuation in water pressure and it shall measure the designated amount within an accuracy of plus or minus one percent. Measuring systems shall have outside taps and valves to facilitate plant calibrations. Wash water shall not be used as mixing water.

(1) ADDING WATER TO HIGH PERFORMANCE CONCRETE: For High Performance Concrete all water shall be added at the concrete plant and additions at the jobsite shall not be permitted. A portion of the high-range water reducer shall be added at the concrete plant and as jobsite conditions dictate redosing will be allowed subject to the approval of the Engineer, but not to exceed manufacturer’s dosage rate.

(2) ADDING WATER AT THE JOBSITE: Preferably all water will be added at the concrete plant and indiscriminate additions at the jobsite will not be permitted. However, with the Engineer’s approval, small additions of water may be added at the jobsite when placement conditions require concrete of a more workable consistency than is delivered. The Contractor will determine the quantity of water required to provide the necessary consistency. The Engineer will not approve additions of water that will cause the total amount of water to exceed the maximum water/cement ratio established in the Concrete Mix Table 500.03.T.1. Neither will water be added to concrete that has begun to set, due to excessive mixing, or to concrete that has exceeded mixing or haul time limitations.

When water is added at the jobsite, it shall be done under carefully controlled conditions. The delivery vehicle shall be positioned in a manner that will not affect the measuring operation. Water shall be carefully measured and injected into the mixer with sufficient force to facilitate uniform mixing. Additions of water shall be made before an appreciable amount of concrete has been discharged. Repeated additions of water will not be permitted after discharge of concrete begins.

After water is added at the jobsite, the concrete shall be mixed 30 additional mixing revolutions. All mixing shall be completed before the total revolutions at mixing speed exceed 150.

The addition of any quantity of water sufficient to produce a slump in excess of that specified in the Concrete Mix Table 500.03.T.1 shall be cause for rejection of concrete. The Contractor shall bear all cost related to the rejection and removal of rejected concrete.

d. VOLUMETRIC PROPOTIONING: Concrete ingredients may be proportioned volumetrically when non-air entrained concrete is used in miscellaneous concrete, non-exposed footings, or culverts smaller than bridge culvert size.

Volumetric proportioning will require the equipment, calibration and operation of the equipment to be approved by the Engineer and the operator to be certified by the Office of Materials and Research. Equipment specifications established in ASTM C 685 shall be required. The concrete producer shall conduct calibration tests at intervals not exceeding six months. Also the equipment shall be calibrated for each new concrete mix prior to production.

e. ADMIXTURES: Admixtures shall be measured by weight or volume. As measured, admixtures shall be within plus or minus three percent of the required amount.

Delete Subsection 500.05.B.6.b and substitute the following:

500.05.B.6 MIXING AND DELIVERY:

b. HAUL TIME LIMITATIONS: High Performance Concrete shall reach its final position in the forms within one (1) hour after cement has been added to the aggregates. All other concrete shall reach its final position in the forms within one (1) hour after the cement has been added to the aggregates, unless retarders or water reducers are used, in which case a time limit of up to one and one half (1.5) hours will be allowed.

Subsection 500.06 Add the following at the end of this Subsection:

500.06: PRODUCTION AND PLACEMENT CAPACITY REQUIREMENTS:

D. DEMONSTRATION SLAB: Prior to beginning deck placement operations, the Contractor shall construct a demonstration slab using the proposed HPC mix design for the concrete deck at a location adjacent to the new bridge to be approved by the Engineer. This demonstration slab shall be a mock-up of the bridge deck. The Contractor shall submit plans and procedures for the demonstration slab to the Engineer for approval 14 days prior to construction of the slab. The demonstration slab shall be constructed 30 days prior to the first deck pour of the new structure. The minimum dimension of the demonstration slab shall be 6.0 meters transverse by 5.0 meters longitudinal. The demonstration slab shall have the same bar reinforcement, same slab thickness and forming as Spans 2 and 3 of the proposed bridge. The Contractor shall use the same equipment and operations proposed for the bridge deck to successfully demonstrate forming, delivery, placement, screeding, finishing and curing of the demonstration slab. Failure to properly construct an acceptable demonstration slab shall result in the rejection of this portion of work with the requirement that a new demonstration slab shall be constructed. The demonstration slab shall be removed and disposed of by the Contractor after acceptance by the Engineer.

Delete Subsection 500.08.F

500.08.F PRESTRESSED CONCRETE DECK PANELS FOR HIGHWAY BRIDGES: Delete this Subsection

Subsection 500.11.B Add the following at the end of this Subsection:

500.11.B EQUIPMENT:

10. INSTRUMENTATION: High Performance Concrete instrumentation shall be installed by the Department on this bridge. The instrumentation shall consist of strain gauges, thermocouples, wiring, etc. to be cast into the concrete deck and beams. The Contractor shall allow the Department full access to the work area for installation and monitoring of the instrumentation. The Contractor shall take care so as not to damage the instrumentation. Instrumentation damaged by the Contractor shall be replaced at no cost to the Department.

Delete Subsection 500.12.C and substitute the following:

500.12.C CURING BRIDGE DECK CONCRETE:

C. CURING BRIDGE DECK CONCRETE: Bridge deck concrete shall be cured by of the following methods:

1. Immediately after the water sheen disappears and the surface finish is applied, a film of water shall be kept on the surface by fogging. The application of moisture shall be delayed if surface damage occurs. The surface shall be kept wet up to the time sheet curing covers are applied. Curing covers shall be thoroughly soaked on the fabric side and applied with the white-poly side up as soon as the concrete has set sufficiently to prevent damage. Sheet material for curing concrete shall meet requirements of AASHTO M 171, and shall be two layers. The bottom layer shall be polyethylene film and the top layer shall be white burlap polyethylene sheet or a white copolymer material coated over a layer of absorbent non-woven, synthetic fabric. It shall meet Specification requirements for reflection and moisture retention. The curing sheets shall contain no holes or tears and shall cover the entire surface of the deck. The curing covers shall be placed so that adjoining sheets overlap at least 450 mm. All laps and/or side edges shall be weighted to prevent displacement of covers before curing is completed. Weighting and overlapping shall be performed so as to ensure contact between the curing sheets and concrete surface. Soaker hoses shall be placed under the covers and used to keep the concrete surface continually moist for the entire seven (7) day curing period.

   a. The equipment used for supplying additional moisture by fogging shall consist of a heavy duty pump capable of delivering 7.6 liters of water per minute to a 1.6 mm diameter tip at an air pressure of 700 kPa and consuming approximately 0.6 mm^3/min of compressed air. An example of a suitable assembly is the Alemite Pump 7878-A. A 10 mm I.D. hose of sufficient length to reach all areas of the deck shall also be furnished.

   b. The spray gun and tip to provide the atomized spray or fog shall be adjustable so as to provide various patterns to conform to changing finishing conditions. An example of this type of equipment is the Gun Jet No. 43 with a 120-2 Multee Jet Nozzle.

c. As an alternate to the equipment described above, the Contractor may substitute other equipment, which has been demonstrated as being capable of equal performance.

2. The surface of parapets, sidewalk, end post and horizontal and vertical faces of curbs are not considered to be part of the bridge deck and may be cured by either method specified in Subsection 500.12.B. Curing Method, unless the surfaces are to receive a special surface coating as permitted in Subsection 500.13.B.3.b. Surfaces to receive a special surface coating shall not be cured with membrane-forming curing compounds. Surface to receive Protection Surface Treatment (75% boiled linseed oil and 25% mineral spirits solution) shall not be cured with membrane-forming curing compounds that contain acrylics.

3. The Department will allow the use of a surface moisture evaporation retarder as a supplement to other bridge deck curing procedures subject to an acceptable performance of the product during the construction of the demonstration slab. If used, the evaporation retarder shall require the approval of the Engineer and shall be applied per the manufacturer's recommendations.

Add to Subsection 500.18:

500.18. MEASUREMENT AND PAYMENT:

I. DEMONSTRATION SLAB: Payment for the demonstration Slab shall be per lump sum basis including site preparations, placement, removal and disposal. Payment will be made upon completion of an acceptable demonstration slab.

J. INCIDENTAL ITEMS: The provision for coordination of the Work to accommodate installation of the Department supplied instrumentation is considered to be an incidental item. No separate payment will be made for these items.

Payment will be made under:

Item No. 500. Demonstration Slab...per Lump Sum
Item No. 500. Superstructure Concrete Class _____,
Bridge No. ____..per Lump Sum
Item No. 500. Concrete Handrailing
(designation) ....per Linear Meter
Item No. 500. Class ___ Concrete ....per Cubic Meter
Item No. 500. Class ___ Concrete,
High Early Strength ....per Cubic Meter
Item No. 500. Class "B" Concrete Base
Or Pavement Widening...per Cubic Meter
Item No. 500. Class ___ Concrete including
Reinforcement Steel..per Cubic Meter
Item No. 500. Class A Concrete – Filler..per Cubic Meter
Item No. 500. Class ___ Concrete Retaining Wall............................per Cubic Meter
Item No. 500. Grooved Concrete... per Square Meter
Item No. 500. Concrete Barrier...per Cubic Meter

OFFICE OF MATERIALS AND RESEARCH

SPECIAL PROVISION
NH-IM-75-2(194) HENRY
P.I. NO. 311840

SECTION 507 – PRESTRESSED CONCRETE BRIDGE MEMBERS

Delete Subsection 507.04.F and substitute the following:

507.04.F HANDLING, STORAGE AND FABRICATION:

1. In handling, beams must be maintained in an upright position at all times and must be picked up at points within 900 mm from their ends. Disregarding this requirement could lead to collapse of the member.
2. Tops of beams are to be rough floated at approximately the initial set. Entire top of beams shall be scrubbed transversely with a coarse brush to remove all laitance and to produce a roughened surface for bonding to slab. Concrete fins or projections shall be removed to produce a vertical face at the edge of the beam.
3. The Contractor shall submit shop drawings on standard plan size 550 mm x 900 mm sheets showing complete details of beam including the following:
   a. Non-prestressed reinforcement.
   b. The method of retaining depressed strands in place.
   c. Calculations for determination of the strand elongation required to produce the specified pretensioning force.
   d. Detensioning schedule.
   e. Increased length of beam due to vertical alignment.
4. Entire end of beams, including strand ends, shall be covered with 3 mm epoxy mortar after detensioning is completed.
5. The strands shall meet all the requirements of ASTM A 416, Grade 270.
6. PRE-POUR CONFERENCE FOR BEAM FABRICATION – Two (2) weeks prior to the beginning of beam fabrication, the Engineer in conjunction with the Laboratory will schedule a pre-pour conference with the Contractor and the Contractor’s beam supplier. Topics of discussion shall include concrete batching, mixing, placement procedures, curing quality control procedures, instrumentation and any other details pertinent to the Work.

7. High Performance Concrete instrumentation shall be installed by the Department on this bridge. The instrumentation shall consist of strain gauges, thermocouples, wiring, etc. to be cast into the beams. The Contractor shall allow the Department full access to the work area for installation and monitoring of the instrumentation. The Contractor shall take care so as not to damage the instrumentation. Instrumentation damaged by the Contractor shall be replaced at no cost to the Department.

Delete Subsection 507.06 and substitute the following:

507.06 PAYMENT

A. BEAMS: The quantity of beams, determined as provided in Subsection 507.05.A, will be paid for at the Contract Price per linear meter of each different type designation, complete in place.

B. DECK UNITS: The quantity of deck units, determined as provided in Subsection 507.05.B, will be paid for at the Contract Price per span of each different nominal span length, complete in place.

C. CAPS: The quantity of caps, determined as provided in Subsection 507.05.C, will be paid for at Contract Price per each, complete in place.

D. Prestressed Concrete Box Beams, measured as specified above, will be paid for at the Contract Unit Price bid per linear meter. Such payment shall be full compensation for furnishing and erecting the beam.

E. PARTIAL PAYMENTS: Material allowance payments for bridge beams will be determined and paid for in accordance with the requirements of Subsection 109.07.

Upon completion of the erection in its final manner and position, 95% of the Contract Price will be included for payment on the next statement.

If there is no field rubbing or painting required, the 95% may be increased to 100%. If such work is required, the remaining 5% of the Contract Price will be included on the next statement following the satisfactory completion of such work.

F. INCIDENTAL ITEMS: The provision for coordination of the Work to accommodate installation of the Department supplied instrumentation is considered to be an incidental item. No separate payment will be made for this item.

Payment will be made under:

Item No. 507. PSC Beam (Type ___), ... per Linear Meter
Item No. 507. Box Beam (Depth/Strands).. per Linear Meter
Item No. 507. PSC Deck Units ____ meter Span .... per Span
Item No. 507. PSC Caps .... per Each

OFFICE OF MATERIALS AND RESEARCH

February 22, 1999

METRIC

SPECIAL PROVISION
NH-IM-75-2(194) HENRY
P.I. NO. 311840

SECTION 865 – MANUFACTURE OF PRESTRESSED CONCRETE BRIDGE MEMBERS

Delete Subsection 865.02 and substitute the following:

865.02 MATERIALS:

Concrete, Class AAA HPC .... Section 500
Steel Bars for Reinforcement 853.01
Pretensioning Steel Wire Strand 853.02
Post-Tensioning Steel Wire 853.03
Post-Tensioning Steel Bars 853.04
Plain Steel Bars – Threaded Ends 853.05
Portland Cement 830.01
Fine Aggregate for Mortar 801.02
Aluminum Powder 835.01
Self-Lubricating Bronze Bearing and Expansion
Plates and Bushings 857.03
Primer Coats 870
Elastomeric Pads 885.01
Epoxy Resin Adhesive 886
Microsilica (Silica Fume) 831.03

A. PORTLAND CEMENT

Portland cement shall be Type I, Type II or Type III and shall meet requirements of AASHTO M 85 for low alkali cement. Type II cement shall be used in the concrete to cast pile for specific locations and it shall be so noted on the Plans.

B. COARSE AGGREGATE

Specific sizes of coarse aggregate may be specified and approved for precast/prestressed concrete products.

Unconsolidated limerock coarse aggregate shall be excluded from use in precast/prestressed concrete piling and from use in any portion of a structure which comes in direct contact with water.

C. MICROSILICA (SILICA FUME)

Silica fume may be used as an additive at addition rate not to exceed 10% of the cement content.

D. SLUMP LIMITATION

Slump shall be in accordance with Subsection 500.03. The maximum slump shall be 180 mm provided there is no segregation of the concrete mixture.

E. MIXING

Mixing of concrete shall be in accordance with Subsection 500.05.B.6 except that with the addition of HRWR the following shall apply. The HRWR shall be dosed at the casting yard under the direct supervision of the producer's Quality Control. HRWR manufacturer's recommended dosage may not be exceeded. After dosing, the concrete shall be additionally mixed at mixing speed for a minimum of 70 revolutions. Maximum revolutions at mixing speed and agitation speed shall not exceed 360 revolutions. After Plasticizer has been added, no additional mixing water will be permitted.

F. EPOXY COATED REINFORCEMENT STEEL AND WIRE

When the top mat of steel in a bridge deck is to be epoxy-coated, the shear steel in the prestressed concrete beams shall also be epoxy-coated in accordance with Section 514.

Delete Subsection 865.03.A and substitute the following:

865.03 MANUFACTURE

A. GENERAL REQUIREMENTS:

1. ERECTION DRAWINGS: The Contractor shall furnish the Engineer erection drawings covering the placement of superstructure units when the units are not interchangeable with respect to transverse placement within a span or with respect to the reversal of ends within a span.
2. PLANT INSPECTION:

   a. NOTICE TO BE GIVEN TO ENGINEER: The Engineer shall be given ample notice before the beginning of work so that all of the plant facilities that are involved in the production can be inspected. No member shall be manufactured until all facilities are approved.

   b. FACILITIES FOR INSPECTION: The Inspector shall be allowed free access to all parts of the premises that are a part of the production process.

   c. INSPECTOR'S AUTHORITY: The Inspector will have the authority to reject materials or quality of work which do not meet the Specifications, but in cases of dispute, the Contractor may appeal to the Engineer, whose decision will be final.
3. REJECTIONS: The acceptance of any materials or finished members by the Inspector shall not prevent them from being rejected later if they are found to be defective. Rejected material and quality of work shall be replaced promptly or made good at the expense of the Contractor.
4. PROVISIONS FOR TESTING: The Contractor shall furnish and maintain sufficient testing equipment so that the Inspector can conduct the following tests at the casting yard:

MATERIAL	METHOD OF TEST
Fine Aggregate	AASHTO T 27
Coarse Aggregate	AASHTO T 27

Hardened Concrete* GDT-35

*Cylindrical molds shall be available for use on each casting bed. The Contractor shall also provide and maintain a machine and other accessories such as capping molds, heating pots and capping compound sufficient to test compression specimens in accordance with AASHTO T 22. All materials to be furnished for testing shall be furnished free of cost to the Department and shall be furnished well in advance of the anticipated time of use. No additional compensation will be made to the Contractor if the work is delayed awaiting approval of the materials furnished for testing.

5. FACILITIES FOR THE INSPECTOR: The Contractor shall furnish for the sole use of the Inspector, a suitable field laboratory in accordance with Subsection 106.04, 106.11 and Section 152.
6. INSTRUMENTATION: High Performance Concrete instrumentation shall be installed by the Department on this bridge. The instrumentation shall consist of strain gauges, thermocouples, wiring, etc. to be cast into the beams. The Contractor shall allow the Department full access to the work area for installation and monitoring of the instrumentation. Instrumentation damaged by the Contractor shall be replaced at no cost to the Department.

Delete Subsection 865.03.H.3.c and substitute the following:

865.03.H.3.c DETENSIONING OPERATION:

c. DETENSIONING OPERATION:

(1) GENERAL: Before any detensioning operations are started, the pattern and schedule for releasing the strands shall be submitted for advance approval. Forms which tend to restrict the horizontal or vertical movement of the member shall be stripped or loosened prior to stress release. When steam curing is used, strand release shall be done with special care because of dimensional changes due to temperature and shrinkage. Where possible, the pretensioned strand shall be released while units are moist and warm. In deflected strand construction, the hold down devices within the member or members shall be released immediately upon the discontinuation of the steam curing.

(2) STRESS RELEASE STRENGTH: Unless otherwise specified on the Plans or in the Special Provisions, stress may be transferred to the concrete based upon the following minimum strength, as determined by cylinders cast of the same concrete and age requirements: Concrete I-Beams, Box Beams, Flat Slab Deck Sections or Tee Slab Deck Sections, 30 MPa and 18 hours.

Piling: 28 MPa

Other Members: As specified on the Plans.

METHOD OF CURING FOR RELEASE STRENGTHS: Temperature match curing (“Sure Cure” or equivalent methods) shall be required for specimens used to determine when stress may be transferred to the concrete for High Performance Concrete units.

(3) MULTIPLE STRAND RELEASE: When this method of release is used, either a symmetrical group of strands or all of the strands shall be released simultaneously. The load on the strands shall be removed from the anchorage and placed on the jacking system. The jack or jacks shall be gradually released until the strands are released.

(4) SINGLE STRAND RELEASE: When this method of release is used, each strand shall be heated and allowed to pull itself apart in the sequence of the approved pattern and schedule of release. No cutting will be allowed.

(5) DRAPED STRAND RELEASE: Draped strand shall be released in accordance with the method in which the weight of the beam is compared with twice the total amount of the vertical components of the hold down forces. One of the following two methods shall be used:

Method I. When the beam weight is less than twice the above amount and vertical restraints are not sufficient to counteract the vertical components of the hold down forces, the release shall be as follows:

(a) Each draped strand at the end of each member shall be heated to failure in the sequence of the approved pattern and schedule of release.

(b) Hold downs shall be released and hold down bolts removed.

(c) Straight strands shall be released as noted in Subsection 865.03.H.3.c.(3) and (4).

Method II. When the beam weight is more than twice the above amount, the release shall be as follows:

(a) Hold down devices within the beam shall be released.

(b) Strands shall be released from the top to the bottom by either heating or jacking in the sequence of the approved pattern and schedule of release.

OFFICE OF MATERIALS AND RESEARCH