LOUISIANA
Charenton Canal Bridge

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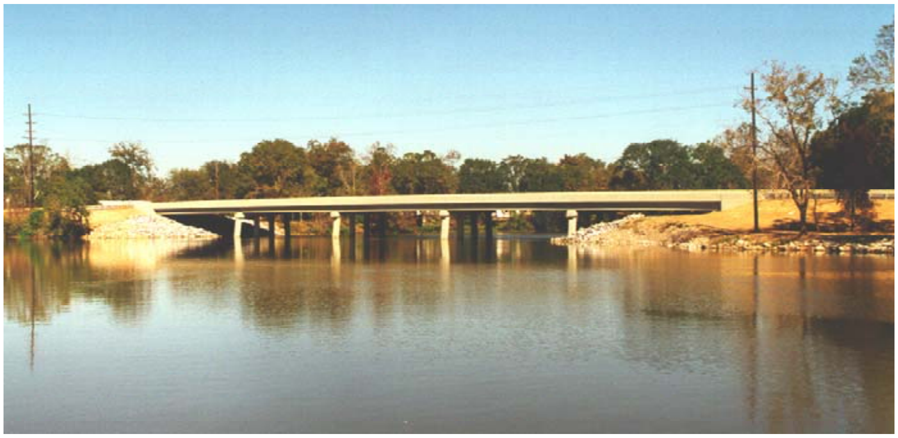
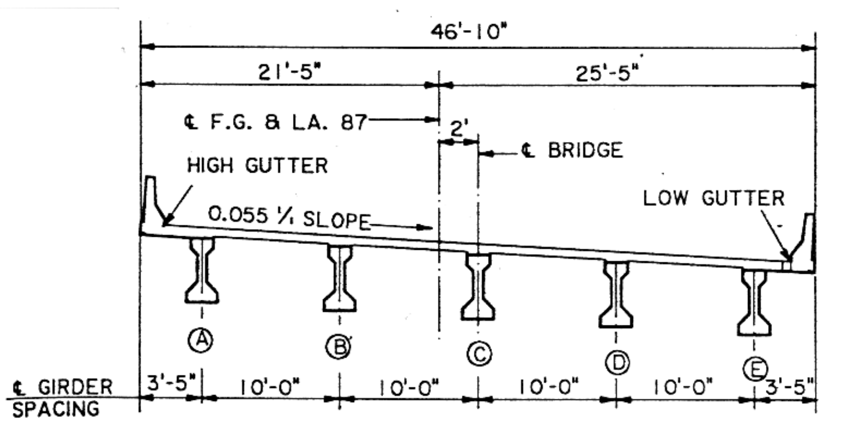
LOUISIANA
Charenton Canal Bridge

1. DESCRIPTION





Location:	LA 87 over Charenton Canal in St. Mary Parish
Environment:	Normal over water
Open to Traffic:	November 1999
HPC Elements:	Piles, pile caps, girders, deck, approach slabs, and barrier rails
Total Length:	365 ft
Skew or Curve:	2913 ft radius
Girder Type:	AASHTO Type III
Girder Span Lengths:	Five spans varying from 71 ft 11-3/8 in to 70 ft 11 in because of the horizontal curve
Girder Spacing:	10 ft 0 in
Girder Strand Grade:	270
Girder Strand Dia.:	0.5 in
Max. No. of Bottom Strands:	34 at 2 in c/c
Deck Thickness:	8 in

Deck Panels: None

The bridge received the ACI Louisiana Chapter 2000 Concrete Project Award of Technical Excellence and 2000 Highway & Bridges Concrete Projects Award of Excellence.

2. BENEFITS OF HPC AND COSTS

A. Benefits of HPC

Design of the girders for a concrete compressive strength of 9000 psi allowed the use of five lines of girders rather than six lines that would have been required with a concrete compressive strength of 6000 psi. The use of high-strength concrete in the piles increased their resistance to compressive and tensile driving stresses and allowed the casting and shipping of longer lengths. Louisiana DOT expects a 75- to 100-year service life for the bridge instead of the normal 50-year service life for concrete structures, because of the added durability of the HPC members.

B. Costs

Total Low Bid for Project:	$2,607,146
HPC Type III Girders:	$148,354 or $82/linear ft
HPC 30-in Piles:	$215,040 or $105/linear ft
Class AA (HPC) Concrete:	$342,122 or $540/yd^3

3. STRUCTURAL DESIGN

Design Specifications:	AASHTO Standard Specifications for Highway Bridges, 1996 and Interim Specifications
Design Live Loads:	HS 20-44 or HST-18 HST-18 consists of axle loads of 12, 24, 24, 24, and 24 kips at spacings of 8, 14 to 30, 8, and 14 to 30 ft
Seismic Requirements:	None
Flexural Design Method:	AASHTO Standard Specifications with f'_c = 9000 psi
Maximum Compressive Strain:	Not available
Shear Design Method:	AASHTO Standard Specifications 9.20
Fatigue Design Method:	Pile caps checked per AASHTO Standard Specifications 8.16.8.3
Lateral Stability Considerations:	Not checked
Allowable Tensile Stress	
—Top of Girder at Release:	200 psi or $7.5\sqrt{f'_{ci}}$ with bonded reinforcement
—Bottom of Girder after Losses:	$6\sqrt{f'_c}$ = 569 psi
Prestress Loss:	49,500 psi (24.4%)
Method Used for Loss:	AASHTO Standard Specifications 9.16.2.1
Calculated Camber:	1-1/16 to 1-13/16 in at release 3/4 to 7/8 in final values
Concrete Cover	
—Girder:	1 in minimum
—Top of Deck:	2 in minimum
—Bottom of Deck:	1 in minimum
—Other Locations:	2 in unless noted otherwise
Properties of Reinforcing Steel	
—Girder:	ASTM A 615, Grade 60, uncoated
—Deck:	ASTM A 615, Grade 60, uncoated
Properties of Strand	
—Grade and Type:	Grade 270, low relaxation
—Supplier:	American Spring Wire Corporation
—Surface Condition:	Not available
—Pattern:	Four strands debonded in each of the lower two rows See 10. DRAWINGS for details
—Transfer Length:	50 diameters = 25 in
—Development Length:	1.6 l_d from AASHTO Standard Specifications 9.28 = 128 in for bonded strands 2.0 l_d = 160 in for debonded strands

4. SPECIFIED ITEMS

A. Concrete Properties

	Girders	Deck
Minimum Cementitious Materials Content:	—	658 lb/yd^3 (1)
Max. Water/Cementitious Materials Ratio:	—	0.40
Min. Percentage of Fly Ash:	—	—
Max. Percentage of Fly Ash:	35	30
Min. Percentage of Silica Fume:	—	—
Max. Percentage of Silica Fume:	10	10
Min. Percentage of GGBFS:	—	—
Max. Percentage of GGBFS (2):	—	50
Maximum Aggregate Size:	—	—
Slump:	$\leq$ 10 in	2-8 in
Air Content:	—	5.5$\pm$1.5%
Compressive Strength		
—Release of Strands:	7000 psi (3)	—
—Design:	10,000 psi by 56 days (4)	4200 psi at 28 days (5)
Chloride Permeability: (AASHTO T 277)	$\leq$ 2000 coulombs at 56 days (4)	$\leq$ 2000 coulombs at 56 days (5)
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:	—	—

(1) Contractor was later allowed to use 611 lb/yd^3.
(2) When blended with cement at point of origin, otherwise 30 percent.
(3) With match curing until test age.
(4) With match curing until release of strand followed by curing alongside the member until test age.
(5) With standard curing until test age.

B. Specified QC Procedures

Girder Production	
Curing:	Natural or heat
Internal Concrete Temperature:	$\leq$ 160 ^{o}F
Cylinder Curing:	Match curing until release, with members, thereafter
Cylinder Size:	4x8 in
Cylinder Capping Procedure:	Neoprene caps with durometer hardness of at least 70
Cylinder Testing Method:	DOTD Designation TR230M/230-95 (6)
Frequency of Testing:	One set of tests per line of girders
Other QA/QC Requirements:	Strands shall be detensioned before the internal concrete temperature has decreased to 20 ^{o}F less than its maximum temperature Two trial girder placements before production
Deck Construction	
Curing:	7 days wet under burlap
Cylinder Curing:	ASTM C 31 Standard Curing
Cylinder Size:	6x12 in
Flexural Strength:	Not specified
Other QA/QC Requirements:	One test slab placement before production

(6) Test method incorporates procedures from AASHTO Test Methods T 22, T 23, and T 231.

5. CONCRETE MATERIALS

A. Approved Concrete Mix Proportions

	Piles and Girders	Pile Caps and Deck
Cement Brand:	Holnam	Lone Star Industries Aucem
Cement Type:	III	IS
Cement Composition:	See Page 32	See Page 32
Cement Fineness:	See Page 32	See Page 32
Cement Quantity:	691 lb/yd^3	306 lb/yd^3 (7)
GGBFS Brand:	—	Lone Star Industries Aucem
GGBFS Quantity:	—	305 lb/yd^3 (7)
Fly Ash Brand:	Bayou Ash, Inc.	—
Fly Ash Type:	C	—
Fly Ash Quantity:	296 lb/yd^3	—
Silica Fume Brand:	—	—
Silica Fume Quantity:	—	—
Fine Aggregate Type:	Natural sand	Natural sand
Fine Aggregate FM:	2.69	2.32
Fine Aggregate SG:	—	—
Fine Aggregate Quantity:	1135 lb/yd^3	1176 lb/yd^3
Coarse Aggregate, Max. Size:	1/2 in	1 in
Coarse Aggregate Type:	No. 78 limestone	No. 57 crushed limestone
Coarse Aggregate SG:	—	—
Coarse Aggregate Quantity:	1803 lb/yd^3	1900 lb/yd^3
Water:	247 lb/yd^3	238 lb/yd^3
Water Reducer Brand:	Hunt Process Corp. HPS-R	—
Water Reducer Type:	D	—
Water Reducer Quantity:	60 fl oz/yd^3	—
High-Range Water-Reducer Brand:	Hunt Process Corp. HPS-HRWR-SP	—
High-Range Water-Reducer Type:	F	—
High-Range Water-Reducer Quantity:	150 fl oz/yd^3	—
Retarder Brand:	—	Monex LR
Retarder Type:	—	A and D
Retarder Quantity:	—	36.7 fl oz/yd^3
Corrosion Inhibitor Brand:	—	—
Corrosion Inhibitor Type:	—	—
Corrosion Inhibitor Quantity:	—	—
Air Entrainment Brand:	—	Monex Air 31
Air Entrainment Type:	—	Salt of benzyl sulfonate
Air Entrainment Quantity:	—	4.0 fl oz/yd^3
Water/Cementitious Materials Ratio:	0.25	0.39

(7) Preblended by cement supplier.

B. Measured Properties of Approved Mix

	Piles and Girders	Pile Caps and Deck
Slump:	7-3/4 in	4 in
Air Content:	2%	5%
Unit Weight:	—	—
Compressive Strength:	8706 psi at 24 hours 9747 psi at 3 days 10,824 psi at 7 days 12,204 psi at 28 days 12,057 psi at 56 days	2357 psi at 3 days 4067 psi at 7 days 5033 psi at 15 days 5680 psi at 28 days
Chloride Permeability: (AASHTO T 277)	1079 coulombs at 56 days	4115 coulombs at 7 days 1834 coulombs at 14 days 1592 coulombs at 21 days 1657 coulombs at 28 days 1019 coulombs at 56 days

6. CONCRETE MATERIAL PROPERTIES

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

Cement Composition: See Page 32

Actual Curing Procedure for Girders: Natural heat of hydration except for Span 3 where a small amount of steam was used on the second night because release strengths were not achieved by 24 hours

Slump and Temperature:

Span		1	2	3	4	5
Slump, in	Initial	6	8-1/4	8-1/4	8-3/4	6-1/4
	Later	3-1/2	6-3/4	6	6	5-3/4
Max. Internal Concrete Temperature, ^oF		—	133	142	135	147

Compressive Strength:

All 4x8-in cylinders match cured until release and air cured near girders after release.

Span (8)	Release Age, hours	Strength, psi		
		Release	28 days	56 days
1	24	7618	10,213	11,043
2	21.5	7983	11,504	11,663
3	40	7816	10,600	10,502
4	21	7383	11,545 (9)	10,958
5	23.5	9852	11,230	12,023
Average	—	8130	11,018	11,238

(8) Five girders from each span were cast at the same time.
(9) Measured at 42 days.

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

Cement Composition: See Page 32

Actual Curing Procedure for Deck: Fogging 4 to 6 hours followed by covering with burlap that was maintained wet with garden sprinklers for 7 days

Compressive Strength:

All 6x12-in cylinders were standard cured per ASTM C 31. Cylinders remained on site for 2 days.

Span	Concrete Age	
	28 days	58 days
1	5349 psi	5406 psi
2 and 3	5537 psi	5765 psi
4 and 5	5592 psi	6185 psi
Average	5493 psi	5785 psi

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

Compressive Strength, Modulus of Elasticity, Modulus of Rupture, Chloride Permeability, and Coefficient of Thermal Expansion:

Curing (10)	Specimen Size	Girder No.	Age				
			Release	7 days	28 days	56 days	90 days
Compressive Strength, psi							
Match	4x8-in cyl.	3A	9108	8907	10,619	11,345	12,042
		3B	8205	9849	10,521	11,404	12,424
		3C	8514	9103	11,164	12,180	11,574
		3D	7627	9141	9958	-	11,761
		Average	8364	9250	10,566	11,643	11,950
Field	6x12-in cyl.	3A	6472	8357	9081	9583	10,224
		3B	6839	8588	10,485	10,600	11,601
		3C	7785	7996	9666	10,283	10,524
		3D	6996	8136	9205	9925	10,321
		Average	7023	8269	9609	10,098	10,668
Modulus of Elasticity (ASTM C 469), ksi							
Match	4x8-in cyl.	3A	5800	6056	5746	6005	6012
		3B	5748	5537	5587	5742	5773
		3C	5630	6057	6215	6180	6127
		3D	5387	5985	5600	-	6168
		Average	5641	5909	5787	5976	6020

Field	6x12-in cyl.	3A	5013	5850	6053	6053	6278
		3B	5432	5524	5743	5907	6230
		3C	5438	5997	5956	5841	5794
		3D	5413	6381	5815	6090	5595
		Average	5324	5938	5892	5973	5974
Modulus of Rupture (AASHTO T 97), psi							
Field	6x6x20 in	3A	779	764	966	-	-
		3B	753	814	916	-	-
		3C	673	808	910	-	-
		3D	808	929	885	-	-
		Average	753	829	919	-	-
Chloride Permeability (AASHTO T 277), coulombs							
Field	4x8-in cyl.	3A	-	-	-	1352	-
		3B	-	-	-	1272	-
		3C	-	-	-	1286	-
		3D	-	-	-	1508	-
		Average	-	-	-	1355	-
Coefficient of Thermal Expansion (CRD C-39), millionths/^{o}F (11)							
Field	6x12-in cyl.	3A	4.68	-	4.35	-	4.03
		3B	4.75	-	4.37	-	4.67
		3C	4.73	-	4.72	-	4.23
		3D	4.90	-	4.43	-	4.37
		Average	4.77	-	4.47	-	4.33
Overall Average = 4.52							

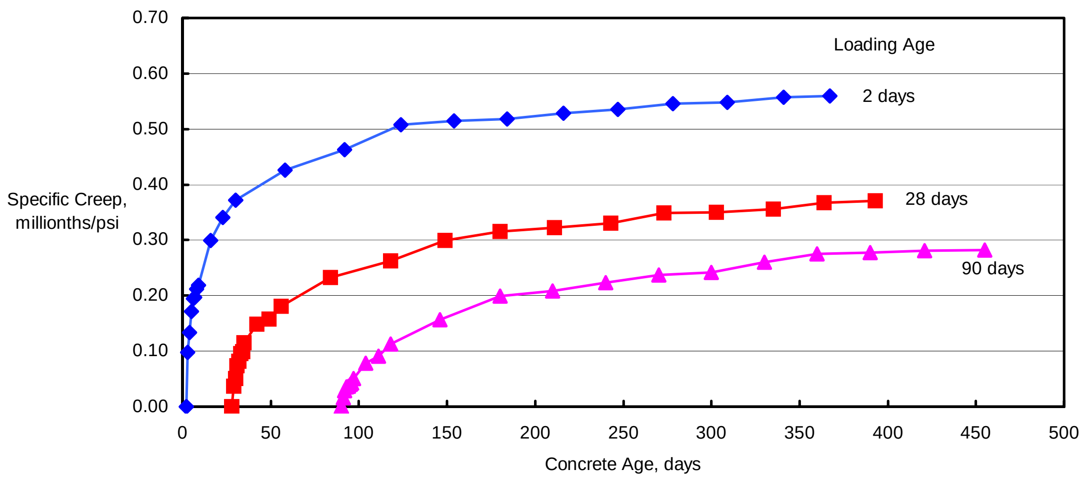
(10) Match-cured specimens were match cured until release and then stored in an outdoor environment near the girders until test age. Field-cured specimens were initially cured beneath the covers over the girders and then stored in an outdoor environment near the girders until test age.
(11) Release values measured at 2 days.

Creep and Shrinkage
(ASTM C 512)

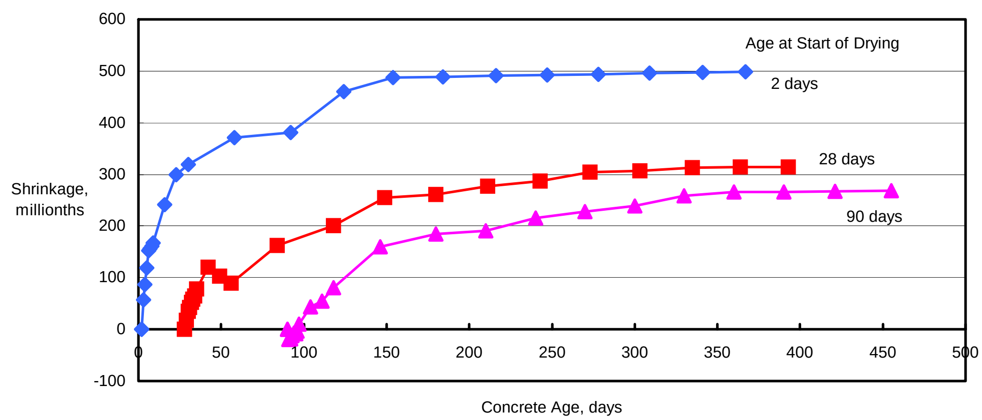
Specimen: 6x12-in cylinder
Loading: 2450 psi applied at concrete ages of 2, 28, and 90 days
Curing: Inside molds until concrete loading age, then at 73 F 50% RH

See Excel file for data.

Creep vs Concrete Age



Shrinkage vs Concrete Age



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

Curing (12)	Specimen Size	Span No.	Concrete Age		
			7 days	28 days	90 days
Compressive Strength, psi					
Field	6x12-in cyl.	3	3086	4455	4861
			3275	4462	4896
			3086	4258	5142
		Average	3149	4392	4966
Modulus of Elasticity (ASTM C 469), ksi					
Field	6x12-in cyl.	3	3514	4042	4424
			3450	4278	4342
			3579	4162	4526
		Average	3514	4161	4431
Coefficient of Thermal Expansion (CRD C-39), millionths/^{o}F					
			11 days	28 days	140 days
Field	6x12-in cyl.	3	3.6	6.5	5.2
			2.4	5.9	4.4
			3.4	4.5	5.3
		Average	3.1	5.6	5.0
Grand Average					4.6

(12) All specimens were cured on site in the molds for seven days and in air on site thereafter.

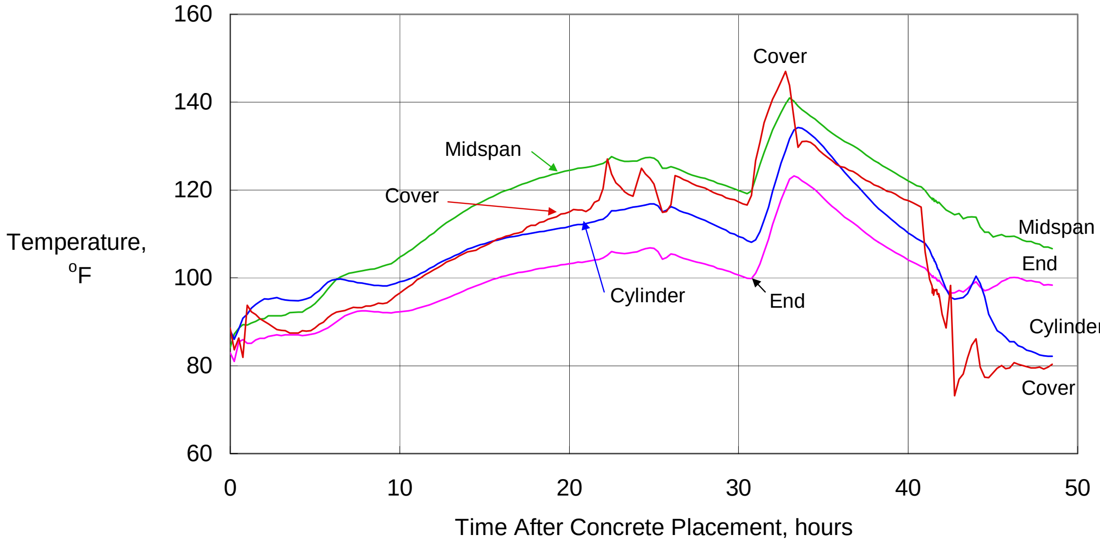
Chloride Permeability, coulombs:
(AASHTO T 277)

	Concrete Age		
Span No.	28 days (13)	56 days (13)	56 days (14)
1	1348	1075	824
	1361	1469	-
	1328	-	-
	1269	-	-
Average	1327	1272	824
2	1917	1394	1037
	2428	1269	1123
	2118	-	-
	2297	-	-
Average	2190	1332	1080
3	1347	1867	1061
	1467	1754	1159
	1766	-	-
	1539	-	-
Average	1530	1811	1110
4	1548	1155	876
	1653	1479	-
	1420	-	-
	1474	-	-
Average	1524	1317	876
5	1705	1568	795
	2284	884	851
	2140	-	-
	1598	-	-
Average	1932	1226	823
Overall Average	1700	1390	965
North			939
Approach Slab			677
Average	-	-	808
South			909
Approach Slab			793
Average	-	-	851

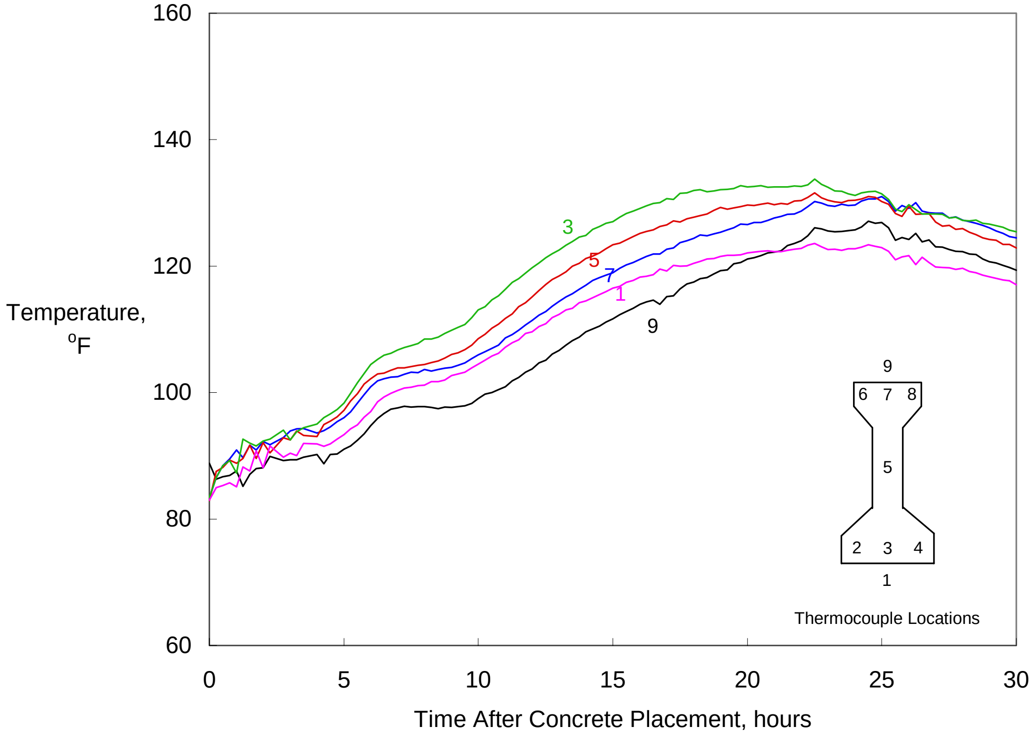
(13) Specimens cut from 4x8-in cylinders that were cured on site in the molds for seven days and in air thereafter.
(14) Specimens cut from 4x8-in cores.

7. OTHER RESEARCH DATA

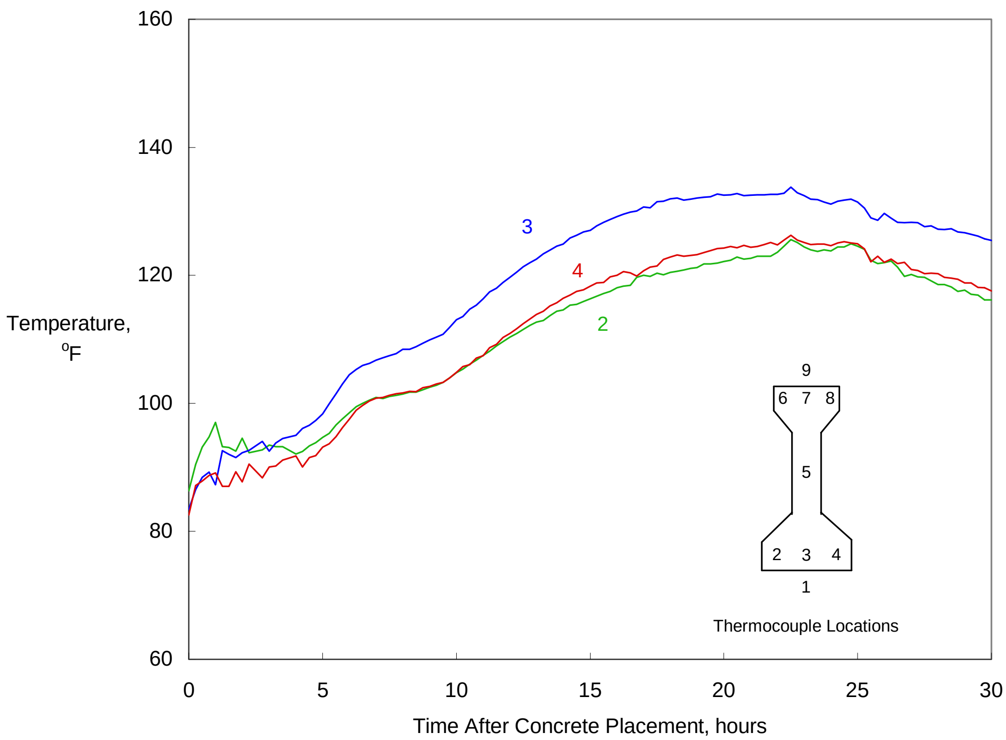
Temperature during Curing:



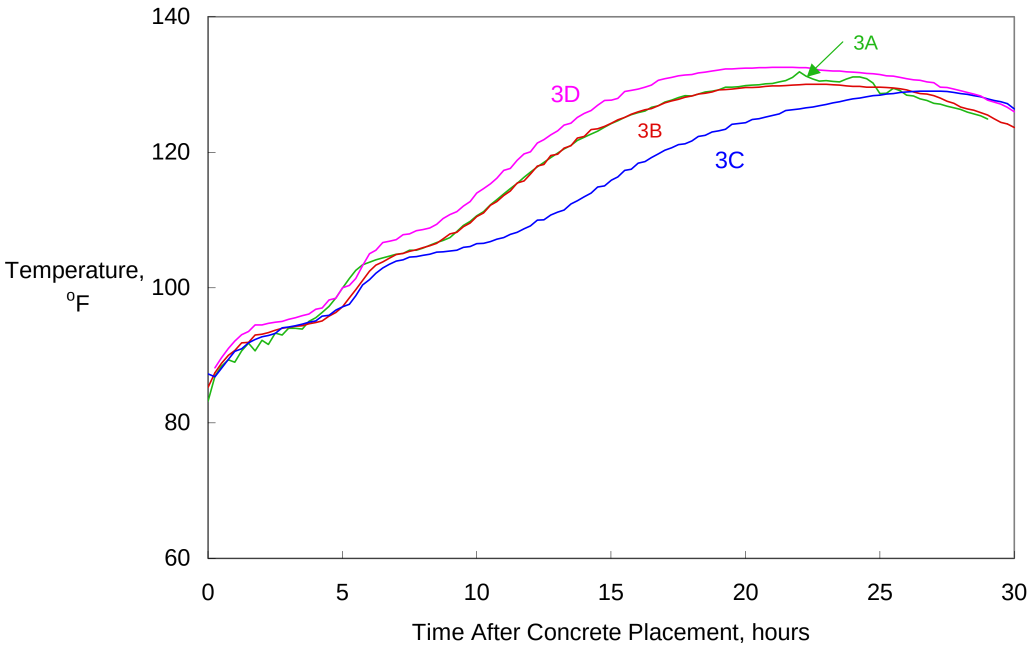
"Midspan" and "End" represent the average temperatures measured on nine thermocouples at midspan and end of one girder, respectively.
"Cylinder" represents the average temperature of three concrete cylinders cured under the covers.
"Cover" represents the temperature under the covers measured with a single thermocouple.
Additional heat was applied to the girder between 30-1/2 and 32-3/4 hours after concrete placement.



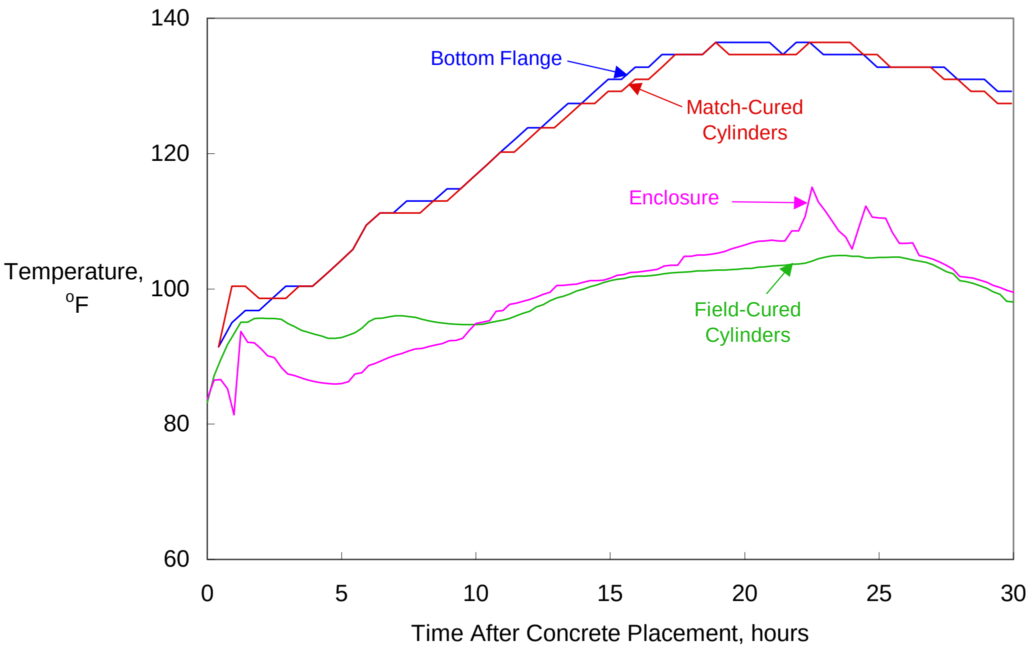
Temperatures were measured along the vertical centerline at midspan.



Temperatures were measured across the bottom flange at midspan.

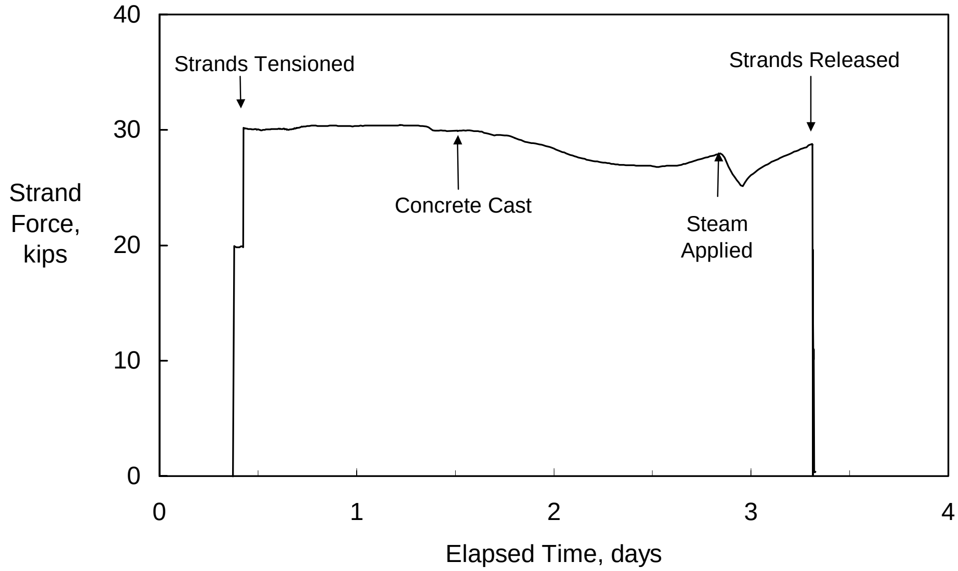


Temperature is the average temperature at midspan of four girders.



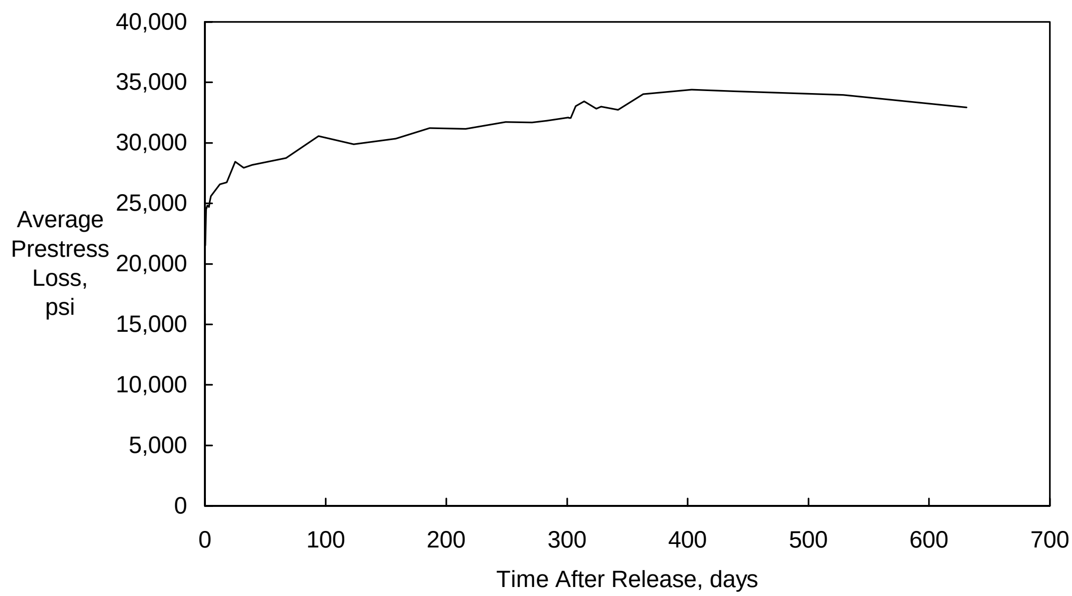
Match-cured cylinders were matched to the temperature in the bottom flange.
Field-cured cylinders were stored under the covers.

Strand Forces during Curing:



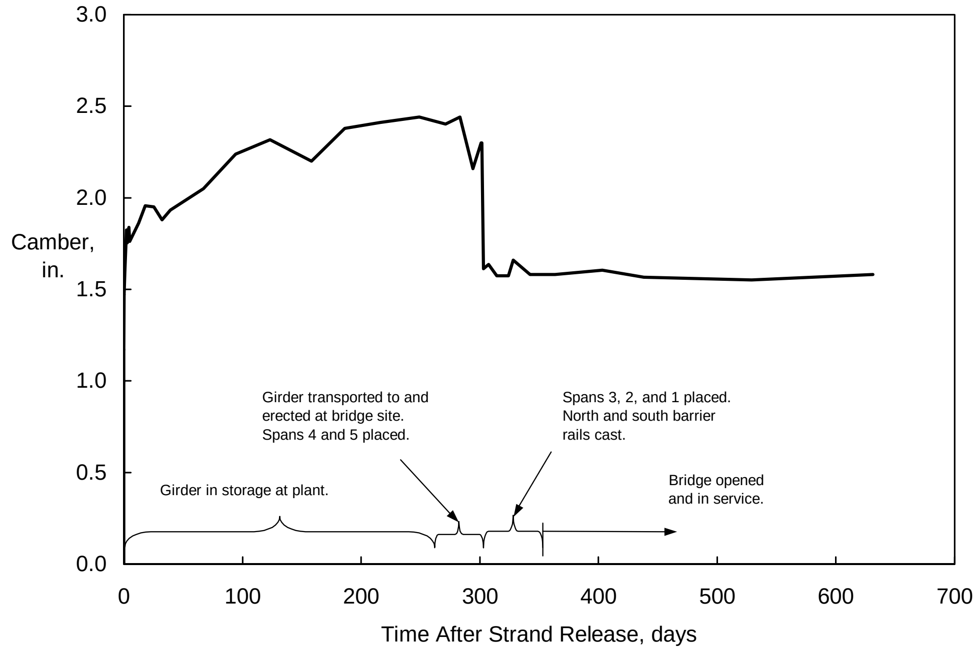
Strand force is the average force measured on six load cells at the dead end of the prestressing bed.

Prestress Loss:



Average prestress loss is the average loss measured near midspan on four girders. For each girder, three gages were located at the center of gravity of the prestressing strands.

Camber:



Camber is the average value at midspan relative to the ends as measured on four girders

8. OTHER RELATED RESEARCH

Bruce, R. N., Russell, H. G., Roller, J. J., and Martin, B. T., "Feasibility Evaluation of Utilizing High Strength Concrete in Design and Construction of Highway Bridge Structures," Final Report - Louisiana Transportation Research Center, Research Report No. FHWA/LA-94-282, Baton Rouge, LA, 1994, 168 pp.

Abstract: The scope of the project included a literature search, a survey of regional fabrication plants, a study of mix designs in the laboratory and in the field, fabrication and testing of full-size concrete specimens, and analysis of the test results. The test program included flexural tests of three 24-in (610-mm)-square concrete piles, flexural and shear tests of three 54-in (1.37-m)-deep prestressed concrete bulb-tee girders, field driving of a 130-ft (39.6-m)-long prestressed concrete pile, and fatigue testing of a 54-in (1.37-m)-deep prestressed concrete bulb-tee girder. The report concluded that the provisions of the *AASHTO Standard Specifications for Highway Bridges* are conservatively applicable to members with concrete compressive strengths up to 10,000 psi (69 MPa).

9. SOURCES OF DATA

Bruce, R. N., Russell, H. G., Roller, J. J., and Hassett, B. M., "Implementation of High Performance Concrete in Louisiana Bridges," Final Report—Louisiana Transportation Research Center, Research Report No. 310, Baton Rouge, LA, June 2001, 55 pp.

Russell, H. G. and Fossier, P. B., "Design and Construction of the Charenton Canal Bridge, Charenton, Louisiana," *Symposium Proceedings, PCI/FHWA/fib International Symposium on High Performance Concrete*, Orlando, FL, Precast/Prestressed Concrete Institute, Chicago, IL, 2000, pp. 697-706.

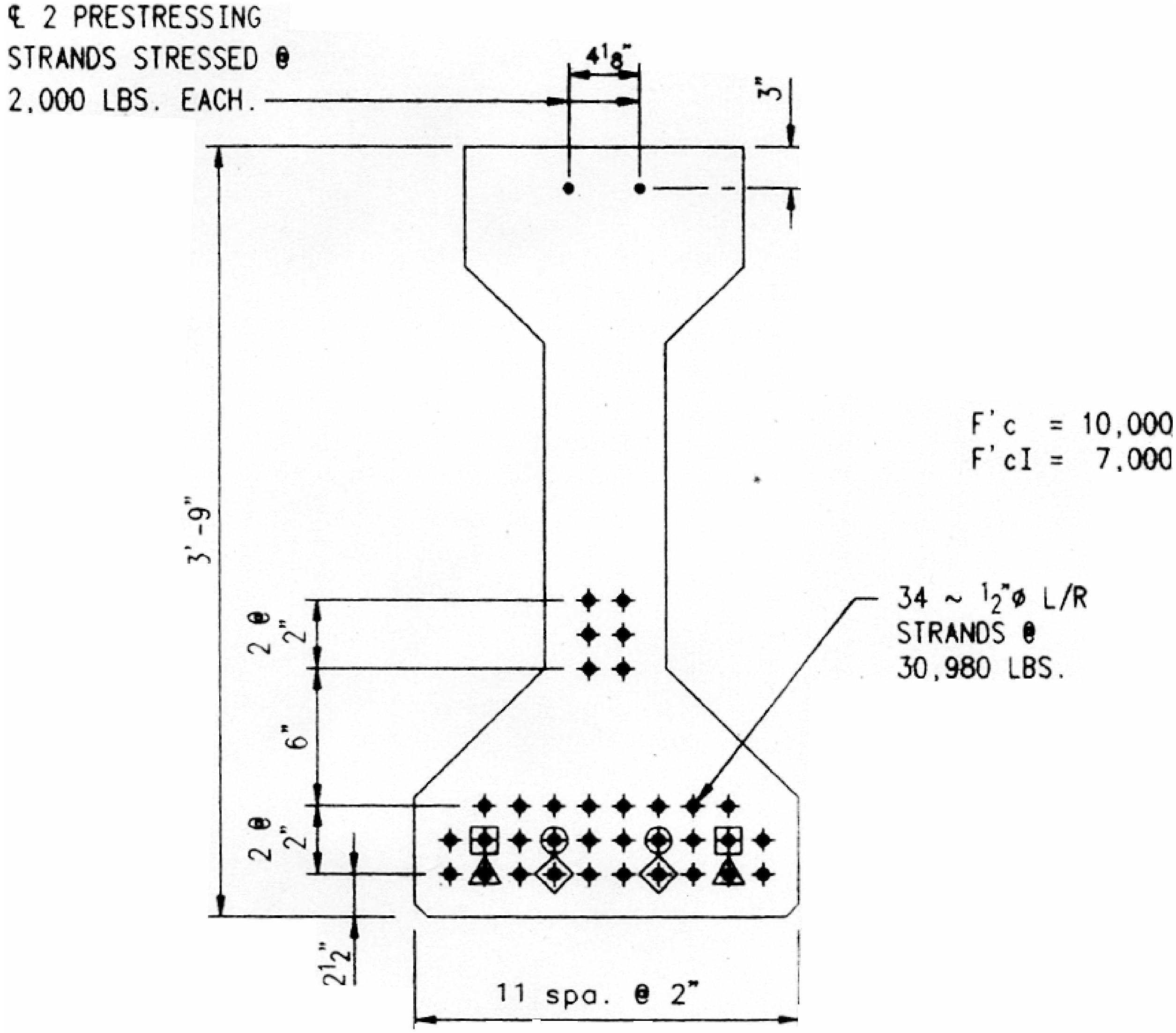
Roller, J. J., Hassett, B. M., and Bruce, R. N., "Evaluation of High Performance Concrete in Louisiana's First HPC Bridge," *Symposium Proceedings, PCI/FHWA/fib International Symposium on High Performance Concrete, Orlando, FL,* Precast/Prestressed Concrete Institute, Chicago, IL, 2000, pp. 707-718.

Fossier, P., "Charenton Canal Bridge—Louisiana's First HPC Bridge," *HPC Bridge Views*, Issue No. 8, March/April 2000, pp. 1.

Bruce, R. N., Russell, H. G., and Roller, J. J., "Implementation of High Performance Concrete in Louisiana Bridges," Interim Report - Louisiana Transportation Research Center, Research Report No. 310, Baton Rouge, LA, February 1998, 67 pp.

Paul B. Fossier, Jr., Louisiana Department of Transportation and Development, Baton Rouge, LA.

10. DRAWINGS



STRAND PATTERN – P34-0

◈ ~ DENOTES STRANDS TO BE DEBONDED 21'-0" FROM EACH END OF GIRDER

▲ ~ DENOTES STRANDS TO BE DEBONDED 18'-0" FROM EACH END OF GIRDER

◉ ~ DENOTES STRANDS TO BE DEBONDED 15'-0" FROM EACH END OF GIRDER

▣ ~ DENOTES STRANDS TO BE DEBONDED 12'-0" FROM EACH END OF GIRDER

11. HPC SPECIFICATIONS

STATE PROJECT NO. 241-02-0040

SPECIFICATIONS FOR USE OF HIGH PERFORMANCE CONCRETE (HPC) ON THE CHARENTON CANAL BRIDGE

The design and construction of the Charenton Canal Bridge is part of a project to implement the use of High Performance Concrete (HPC) in Louisiana bridges. A research team headed by Tulane University and including Henry G. Russell, Inc. and Construction Technology Laboratories, Inc. (CTL) is assisting DOTD and Louisiana Transportation Research Center (LTRC) in the implementation program. The success of both the construction project and the research project requires that the researchers play an integral part in the construction process and that the contractor and subcontractors cooperate fully with the researchers. The following section describes special provisions required of the contractor and outlines the role of the researchers and LTRC in various aspects of the construction process. Details of the research program are given in "Implementation of High Performance Concrete in Louisiana Bridges - Interim Report."

COORDINATION OF WORK WITH CONTRACTORS: All aspects of the researchers' work shall be coordinated with the contractor. The contractor shall take all actions necessary to incorporate the research activities into the development of the construction schedule. The researchers shall cooperate with the contractor and shall minimize all delays.

Attendance at an open meeting prior to bid letting, where the researchers, DOTD and LTRC give presentations on details concerning the HPC bridge is mandatory for all contractors. It is also recommended that the prestressed concrete girder fabricator and the deck concrete contractor bidding on this contract also attend. After letting, a preconstruction meeting will be held with the contractor, pertinent subcontractors, researchers and sponsors (see page D-7.)

At all times, including during construction, coordination between the contractors' and researchers' representatives will be required to ensure implementation of the necessary measures for design and control of HPC. The researchers will be provided access to the work area, will install the instrumentation and will be responsible for measurements. Facilities necessary for installing and protecting the instrumentation and equipment will be provided by the contractor.

DEFINITION OF HIGH PERFORMANCE CONCRETE (HPC): For this contract, the cast-in-place concrete used for the approach slabs, barrier slabs and deck slab shall be high performance concrete Class AA (HPC). Bent caps shall be Class A (HPC). The precast concrete used in the prestressed concrete piles and girders shall be high performance concrete Class P (HPC).

HIGH PERFORMANCE CONCRETE MIX DEVELOPMENT: The researchers and LTRC will provide technical expertise to assist the contractor in developing and evaluating the HPC mix design and curing cycle. The design and control of the HPC will be in accordance with the Standard Specifications, Special Provisions and Contract Plans.

LABORATORY AND FIELD TESTING FOR RESEARCH: During HPC girder and deck construction, HPC specimens in addition to those required by the specifications and contract

plans will be made by the researchers and/or LTRC personnel. The contractor shall make the necessary provisions to allow sampling of the HPC as described in "Implementation of High Performance Concrete in Louisiana Bridges - Interim Report."
Concrete specimens made by the researchers at the precasting plant will be stored with the girders at the plant and at the bridge site. Concrete specimens made at the bridge site will be stored alongside the bridge deck at the bridge site. Contractor shall provide adequate space for storage and proper containers to protect cylinders from damage during shipping of specimens to CTL for testing. Contractor shall pay shipping costs.

STRUCTURAL MONITORING: The researchers have developed an instrumentation program to monitor the structural performance of the bridge and its components as described in "Implementation of High Performance Concrete in Louisiana Bridges - Interim Report." The contractor shall make available selected components and provide access to various locations to allow researchers to attach instrumentation and lead wires. It is planned to instrument four girders that will be cast in one bed at the same time. Instrumentation will also be installed in the deck. With proper planning and coordination, installation of instrumentation and data collection will not cause any significant delays to the contractor.

LOUISIANA STANDARD SPECIFICATIONS FOR ROADS AND BRIDGES: For this project, the *Louisiana Standard Specifications for Roads and Bridges,* 1992 Edition, is amended with respect to the Subsections cited below:

<u>Subsection 105.05 Cooperation by Contractor</u>

Add the following paragraph:

The contractor shall provide access to selected components and access to various locations to allow researchers to install instrumentation and lead wires and to collect data. The precast concrete producer shall provide 110v electrical power at required locations for use by the researchers. The contractor shall make the necessary provisions to allow sampling of concrete by the researchers. The contractor shall provide adequate space for the manufacture and storage of test specimens at the precast plant and bridge site. The contractor shall be responsible for shipping test specimens to the researchers' facilities.

<u>Subsection 805.02 Materials</u>

Add the following class of concrete:

Concrete Class	Use
P (HPC)	High-strength concrete precast bridge members
AA(HPC)	High performance concrete cast-in-place superstructure
A (HPC)	High performance concrete cast-in-place substructure

<u>Subsection 805.10 Curing</u>

Add the following paragraphs:

For Class AA (HPC) concrete used in the bridge deck, barrier rails, approach slabs and barrier slabs, the contractor shall comply with ACI 302—Guide for Concrete Floor and Slab Construction, ACI 308—Standard Practice for Curing Concrete and ACI 305—Hot Weather Concreting. As a minimum, if silica fume is used, the contractor shall under finish concrete by limiting finishing operations to screeding, bull floating and grooving. Continuous fogging above the surface of the concrete during the finishing operation shall be required. Fogging shall continue until the surface will support wet burlap without deformation. Free-standing water on the concrete surface prior to concrete final set shall not be allowed to occur.

As soon as the surface will support the burlap without deformation, apply prewetted burlap to the textured concrete surface. The concrete shall be kept continuously wet with a fog nozzle system or soaker hoses for seven curing days as defined in Subsection 805.11 and until a concrete compressive strength of 3,200 psi is reached. Materials, equipment and labor necessary for continuous curing will be supplied by the contractor. The use of polyethylene sheeting or plastic coated burlap blankets shall not be permitted.

The Project Engineer may require placement to be made at night or during early morning hours if satisfactory surface finish cannot be achieved. Weather conditions (current and forecasted) shall be within limits of Subsection 901.11.

Subsection 805.11 Removal of Falsework and Forms

Add the following to the second paragraph:

Supporting forms and falsework for HPC bridge decks, approach slabs, barrier rails, and barrier slabs shall not be removed until both criteria determined by Methods 1 and 2 are met.

Add the following to Method 1:

Concrete Class	Compressive Strength (psi)
AA (HPC)	3200
A (HPC)	3200

Subsection 805.13 (e) (1) Striking Off

Replace last paragraph with the following:

Addition of water to the surface of Class AA (HPC) and Class A (HPC) concrete to assist in finishing shall not be permitted.

Subsection 805.14 (e) Curing

Revise as follows:

To establish adequacy of curing methods and to determine whether concrete has attained the required compressive strength, a minimum of eight test cylinders shall be made from the last batch of concrete and match cured under the same condition as the corresponding member. Three cylinders will be tested no later than 56 calendar days after casting to determine that the required strength has been achieved. The remaining five cylinders may be tested at any time as required by the contractor. However, no more than three cylinders will be tested in one day. If all five cylinders have been tested and concrete has not attained required strength, the members involved shall be held at the plant until the 56-day cylinders are tested. If the average 56-day concrete cylinder strength has not achieved the required strength, all members involved will be subject to rejection. Acceptance will be made in accordance with the Department's manual entitled "Application of Quality Assurance Specifications for Precast-Prestressed Concrete Plants." Curing methods other than heat curing shall be in accordance with Subsection 805.10. Hot weather concrete limitations as stipulated in Subsection 901.11(b) shall not be applicable for heat curing; however, precautions such as cooling of forms will be required.

Heat curing shall be done under a suitable enclosure to contain the heat in order to minimize moisture and heat losses. Initial application of heat shall begin only after concrete has reached its initial set as determined by ASTM C 403. When used, steam shall be at 100 percent relative humidity. Application of heat shall not be directly on concrete. During application of heat, concrete temperature shall be increased at a rate not to exceed 40 ^{o}F per hour until the desired concrete temperature is achieved. The concrete temperature shall not exceed 160 ^{o}F. Heat

curing may continue until concrete reaches release strength. At the contractor's option, the application of heat may be reduced or discontinued to ensure that the concrete temperature does not exceed 160 ^{o}F. If structural defects occur, the defective members will be rejected.
Contractor shall detension strands before the internal concrete temperature has decreased to 20 ^{o}F less than its maximum temperature. Two recording thermometers showing time-temperature relationship in the concrete shall be furnished for each 200 ft of bed. For girders, one thermometer shall be located at the center of gravity of the top flange and one at the center of gravity of the bottom flange. For piles, one thermometer shall be located in the top half of the pile and one in the bottom half. Both thermometers shall be located midway between the outside comers of the pile and the nearest edge of the center void. If a void is not provided, only one thermometer shall be provided at the center of gravity of the cross section.

<u>Subsection 805. 14 (f) Transportation and Storage</u>

Replace fourth paragraph with the following:

Prestressed members shall be held at the plant for at least 28 days after casting and until the concrete has attained the specified compressive strength. Specified compressive strength shall be attained no later than 56 days after casting.

<u>Subsection 805.14 (g) Pretensioning Method</u>

Replace the first paragraph with the following:

Prestressing strands shall be accurately held in position and stressed by approved jacks. A record shall be kept of the jacking force and tendon elongation produced. Several units may be cast in a continuous line and stressed at one time. Sufficient space shall be left between ends of members to permit access for cutting strands after concrete has attained required strength. Sufficient free strand shall be left in the line to ensure that cracking of the girders does not occur as the temperature of the girders decreases prior to detensioning of the strand. No bond stress shall be transferred to concrete nor shall end anchors be released until concrete has attained specified release strength as shown by cylinders made in accordance with DOTD TR 226 and match cured identically with members and tested in accordance with DOTD TR 230. Strand shall be cut or released in such order that lateral eccentricity of prestress will be a minimum in accordance with approved shop drawings.

<u>Subsection 810.02 Materials</u>

Concrete for bridge rail shall be Class AA (HPC).

<u>Subsection 810.03 Construction, Fabrication, Erection and Painting</u>

Replace the first sentence of the second paragraph with the following:

After completing the deck pour, a minimum of 7 days shall elapse before placing of reinforcing steel and form for railings.

<u>Subsection 901.01 General</u>

Add a new paragraph as follows:

Concrete Class P (HPC) shall conform to the following requirements:

Average Compressive Strength at 56 days	10,000 psi
Slump	$\leq$ 10 in.

Concrete slump shall be selected by contractor to ensure that concrete does not segregate. Permeability (total charge passed) shall be less than or equal to 2,000 coulombs at 56 days.

Concrete Class AA (HPC) and Class A (HPC) shall conform to the requirements of Table 1 and the following:

Permeability (Total Charge Passed) shall be less than or equal to 2,000 coulombs at 56 days.

If used, silica fume shall be added as early as possible in the concrete batching and as directed by a technical representative of the admixture supplier to ensure uniform distribution.

High-range water-reducers may be used to control slump, water/cementitious material ratio and proper distribution of fly ash or silica fume. Admixtures shall be plant added. Retempering at the jobsite, if necessary, will be permitted. Air entraining and set controlling admixtures may be used. All admixtures shall be compatible. Compatibility shall be demonstrated with trial batches. Admixtures containing chlorides shall not be used.

Specimens for compressive strength testing and permeability testing shall be manufactured by the contractor and supplied to LTRC for testing.

Subsection 901 Table 1

Add the following:

Structural Class AA (HPC)[m] and Class AA (HPC)[m]		
Average Compressive Strength at 28 days		4200 psi
Grade of Coarse Aggregate	A[n]	
Minimum Bags of Cement (94 lb) per Cu Yd of Concrete[i]		7.0
Maximum Water per Bag of Cement[a i] (Gallons)		4.51P
Total Air Content (Percent by volume)[d]	5.5±1.5%	
Slump Range (Inches)		2-8

m Cement type shall be I, IB or III conforming to Subsection 1001.01

n Aggregates shall conform to Subsection 1003.02.

p Water content shall include weight of water, if any, in the admixtures. Cement content shall include all mineral admixtures.

Revise footnote i as follows:

i For mixes containing combinations of cement, fly ash and silica fume, the minimum cement and maximum water contents shown shall apply to the total cement/fly ash/silica fume content of the mix.

Subsection 901.02 Materials

Add the following:

The use of silica fume conforming to AASHTO M307 with the exception of Loss of Ignition (LOI) which shall not exceed 6.0 percent or ASTM C 1240 shall be permitted.

Subsection 901.06 Quality Control of Concrete

Add the following paragraph:

A representative of the admixture manufacturer shall be present for batching start up and during initial concrete placement.

Subsection 901.06 (a) Mix Design

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Add the following paragraphs:

For Class P (HPC) concrete, the contractor shall make two demonstration trial batches, of at least 3 cu yd, on separate days at the prestressed concrete girder plant to show that the girder concrete sections can be cast with the proposed mix design. Materials used in concrete batches shall be identical to those that will be used in production. These demonstration batches and girders shall be made sufficiently before production girders are cast to demonstrate that design compressive strength can be achieved. Cylinders shall be made and match cured with the girder section. The cylinders shall be cured and tested in the same manner as acceptance cylinders in a production mode. The design trial batch shall meet the minimum design compressive strength before mix design approval will be given. Test results for slump, air content, wet unit weight and compressive strengths at concrete ages of 1, 3, 7, 28 and 56 days shall be submitted. The verified time-temperature history of the concrete during the initial curing period shall be submitted. If requested, the contractor shall furnish materials to the Department for verification of trial mixes.

For Class AA (HPC) and Class A (HPC), the concrete producer shall make trial batches as necessary to determine the proportions of the basic ingredients as well as the amount and proper sequencing of admixtures to produce the required concrete mix. Specimens for compressive strength testing and permeability testing shall be manufactured by the contractor and supplied to LTRC for testing. At least 28 days prior to placement of Class A (HPC) for the bridge cap, contractor shall construct a test slab 12x30 ft. The test slab shall be constructed using the proposed Class A (HPC) concrete and shall be finished and cured in accordance with the proposed procedures for the bridge deck. The Materials Engineer will approve the mix design when trial batching and test slab demonstrate the desired results.

The Contractor shall strictly adhere to the manufacture's written recommendations regarding the use of admixtures, including storage, transportation and method of mixing.

<u>Subsection 901.07 Substitutions</u>

Add the following:

P (HPC)	No substitutions
AA (HPC)	No substitutions
A (HPC)	No substitutions

<u>Subsection 901.08</u>

Add a new subsection as follows:

901.08 (g) Permeability

Permeability of concrete shall be determined in accordance with AASHTO T277 or ASTM C 1202. The permeability samples shall have a 4-in. diameter and a length of at least 4 in. Class A (HPC) and Class AA (HPC) concrete shall be moist cured until testing at 56 days after casting. Class P (HPC) shall be cured using the same procedures of the girders and piles until testing. The average value of three specimens shall be reported.

<u>Subsection 901.08 (a) Cement and Aggregates</u>

Add the following paragraphs:

For Class P (HPC), Class AA (HPC), and Class A (HPC) concretes, the contractor will be permitted the use of silica fume to a maximum of 10 percent by weight of the total combination of cement, fly ash and silica fume.

For Class P (HPC) concrete, the contractor will be permitted the use of fly ash with Type I, I(B), I(C), II or III portland cement up to a maximum of 35 percent by weight for the total combination of cement, fly ash and silica fume.

For Class AA (HPC) and Class A (HPC) concrete, the contractor will be permitted the use of fly ash with Type I, I(B) and III portland cement up to a maximum of 30 percent by weight of the total combination of cement, fly ash and silica fume. A combination of fly ash and silica fume may be used with the total substitution by weight not to exceed 30 percent of the total combination of cement, fly ash and silica fume.

Subsection 901.08 (f) (1) Structural Concrete

Add the following paragraph:

Cylinders by which strength of Class P (HPC) concrete is to be determined shall be cured using the match-curing technique until detensioning of the strand. Thereafter, cylinders shall be cured alongside the members that they represent. For girders, thermocouples for use with the match-curing system shall be placed within 1 in. of the center of gravity of the bottom flange. For piles, thermocouples for use with the match-curing system shall be placed at the center of gravity of the cross section when a void is not present or midway between the outside corner of the pile and the nearest edge of the void in piles with voids.

Subsection 901.12 Acceptance and Payment Schedule

Add the following paragraph:

Acceptance and payment for Class AA (HPC) and Class A (HPC) concrete shall be in accordance with the schedule in Table 2 for Class AA concrete except the concrete will not be accepted and shall be removed if the specified 28-day compressive strength is not achieved by 56 days.

Subsection 1003.02 (a) Fine Aggregate

Add the following sentence at the end:

For Class P (HPC) concrete, other gradations of concrete sand will be permitted if demonstrated in trial mixes to produce the required concrete properties and accepted as part of the proposed mix designs.

Subsections 1003.02(b) Coarse Aggregate

Add the following sentence at the end:

For Class P (HPC) concrete, other gradations of uncrushed and crushed coarse aggregate will be permitted if demonstrated in trial mixes to produce the required concrete properties and accepted as part of the proposed mix design.

Subsection 1009.05 Steel Strand for Pretensioning

Add the following sentence:

The contractor shall obtain certification from the strand supplier that the strand will bond to concrete of a normal strength and consistency in conformation with the prediction equations for transfer and development length given in the *AASHTO Standard Specifications for Highway Bridges.*

TR 226M/226-95

For this project, DOTD Designation: TR 226M/226-95 is amended with respect to the following:

Part H. Apparatus

At the end of the first paragraph of A. Cylinder molds, add the following:

Match-cured cylinders shall have an inside diameter of 100 mm (4 in.) and a length of 200 mm (8 in.).

Add the following new section:

3. Match-cure molds - Sure Cure Cylinder Mould System from Products Engineering.

Section IV. A. Compression Test Specimens

Add the following new section:

I.b. Match-cure molds - Follow manufacturer's instructions.

TR 23OM/230-95

For this project, DOTD Designation: TR 230M/230-95 is amended with respect to the following:

Section II. G. Testing Machines

Add the following at the end of the second paragraph:

For testing Class P (HPC) concrete, the testing machine shall have been calibrated within 6 months prior to the time of testing.

Part IV. Sample

Add the following paragraph:

Match-cure cylinders shall be molded to have a diameter of 102 mm (4.0 in.) and a nominal height of 203 mm (8 in.).

Section V. B. Determining the Cross-Sectional Area

Add a new section as follows:

3. For match-cured cylinders, determine cross-sectional area in accordance with V. B. 2.

Section V. D. Determining Compressive Strength

Add the following to the first paragraph:

Neoprene caps with a durometer hardness of at least 70 shall be used for testing Class P (HPC) concrete.

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CHARENTON CANAL BRIDGE
Cement Compositions

Component	Weight %		
	Girder Span 3	Girder Span 5	Deck Span 3
SiO_2	21.53	20.82	27.98
Al_2O_3	4.19	4.27	7.46
Fe_2O_3	3.68	3.91	2.08
CaO	62.21	62.35	52.03
MgO	2.12	2.57	5.24
SO_3	2.89	3.07	2.70
Na_2O	0.11	0.16	0.14
K_2O	0.41	0.44	0.42
TiO_2	0.25	0.26	0.38
P_2O_5	0.12	0.14	0.04
Mn_2O_3	0.03	0.02	0.15
SrO	0.05	0.04	0.07
L.O.I. (950 ^{o}C)	2.11	1.48	0.46
Total	99.70	99.53	99.13
Alkalies as Na_2O Insoluble Residue	0.38	0.45	0.42
Blaine Fineness (m^2/kg)	470	—	—
Calculated Compounds per ASTM C 150-97			
C3S	48	53	Not reported
C2S	26	20	
C3A	5	5	
C4AF	11	12	
ss(C4AF+C2F)	—	—	