TENNESSEE
Hickman Road

TABLE OF CONTENTS

TENNESSEE
Hickman Road

1. DESCRIPTION

Location:	Hickman Road over State Route 840, Dickson County
Open to Traffic:	September 2000
Environment:	Normal over roadway
HPC Elements:	Retaining walls, abutments, bent, girders, and deck
Total Length:	290 ft 8 in
Skew or Curve:	17.5^{o} skew
Girder Type:	BT-72
Span Lengths:	139 ft 4 in and 151 ft 4 in
Girder Spacing:	8 ft 4 in
Girder Strand Grade:	270
Girder Strand Dia.:	9/16 in
Max. No. of Bottom Strands:	50
Deck Thickness:	8-1/4 in
Deck Panels:	Stay-in-place steel deck forms

2. BENEFITS OF HPC AND COSTS

A. Benefits of HPC

Longer span lengths and a more durable structure were the two main reasons for using HPC. Without HPC, structural steel girders would have been used at an additional cost of $825,000 for both Porter Road and Hickman Road bridges.

B. Costs

Beams:	$160/ linear ft
Deck Concrete:	$315/yd^3
Substructure Concrete:	$240/yd^3
Total Cost:	$59/ft^2 excluding pavement at bridge ends

3. STRUCTURAL DESIGN

Design Specifications:	AASHTO Standard Specifications for Highway Bridges, 1996
Design Live Loads:	HS 20-44
Seismic Requirements:	Category A with acceleration coefficient = 0.075
Flexural Design Method:	AASHTO Standard Specifications
Maximum Compressive Strain:	—
Shear Design Method:	AASHTO Standard Specifications
Fatigue Design Method:	None
Lateral Stability Considerations:	See section 10
Allowable Tensile Stress	
—Top of Girder at Release:	—
—Bottom of Girder after Losses:	—
Prestress Loss:	—
Method Used for Loss:	—
Calculated Camber:	—
Concrete Cover	
—Girder:	2 in to center of strand 2-1/4 in to stirrups in web 1 in to top of top flange
—Top of Deck:	2-1/2 in clear
—Bottom of Deck:	1 in clear
—Other Locations:	—
Properties of Reinforcing Steel	
—Girder:	A 615 Grade 60, uncoated
—Deck:	A 615 Grade 60, epoxy coated
Properties of Strand	
—Grade and Type:	Grade 270, low relaxation
—Supplier:	—
—Surface Condition:	—
—Pattern:	Six strands draped at 0.40 span length and eight strands debonded. See section 10 for details. Shorter span: Two strands draped at 0.40 span length and six strands debonded. See section 10 for details.
—Transfer Length:	—
—Development Length:	—

4. SPECIFIED ITEMS

A. Concrete Properties

	Girders	Deck	Substructure
Minimum Cementitious Materials Content:	658 lb/yd^3	658 lb/yd^3	620 lb/yd^3
Max. Water/Cementitious Materials Ratio:	0.43	0.43	0.45
Min. Percentage of Fly Ash:	—	—	—
Max. Percentage of Fly Ash:	—	—	—
Min. Percentage of Silica Fume:	3%	3%	3%
Max. Percentage of Silica Fume:	8%	8%	8%
Min. Percentage of GGBFS:	—	—	—
Max. Percentage of GGBFS:	—	—	—
Maximum Aggregate Size:	—	—	—
Slump (1):	3 $\pm$ 1 in	3 $\pm$ 1 in	3 $\pm$ 1 in
Air Content:	6 $\pm$ 2%	6 $\pm$ 2%	6 $\pm$ 2%
Compressive Strength			
—Release of Strands:	8000 psi	—	—
—Design:	10,000 psi at 28 days	5000 psi at 28 days	4000 psi at 28 days
Chloride Permeability (2): (AASHTO T 277)	< 2500 coulombs at 28 days	< 1500 coulombs at 28 days	< 3000 coulombs at 28 days
ASR or DEF Prevention:	—	—	—
Freeze-Thaw Resistance:	—	—	—
Deicer Scaling:	—	—	—
Abrasion Resistance:	—	—	—
Other:	—	—	—

(1) Specified slump is prior to addition of a high-range water-reducer if used. The maximum slump with a high-range water-reducer added shall be 8 in.
(2) One week moist cured at 73 ^{o}F followed by 3 weeks at 100 ^{o}F $\pm$ 10 ^{o}F.

B. Specified QC Procedures

Girder Production	
Curing:	—
Internal Concrete Temperature:	—
Cylinder Curing:	Alongside members until release followed by AASHTO T 23 standard curing
Cylinder Size:	6x12 in
Cylinder Capping Procedure:	—
Cylinder Testing Method:	AASHTO T 22
Frequency of Testing:	—
Other QA/QC Requirements:	—
Deck Construction	
Curing:	Fogging followed by membrane curing, wet burlap, and vapor barrier. Wet cure for 7 days.
Cylinder Curing:	Fog room
Cylinder Size:	6x12 in
Flexural Strength:	—
Other QA/QC Requirements:	Two trial batches with a test slab

5. CONCRETE MATERIALS

A. Approved Concrete Mix Proportions

	Girders	CIP Deck
Cement Brand:	River Cement	Lonestar
Cement Type:	I	I
Cement Composition:	—	—
Cement Fineness:	—	—
Cement Quantity:	747 lb/yd^3	293 kg/m^3
GGBFS Brand:	—	—
GGBFS Quantity:	—	—
Fly Ash Brand:	Mineral Resources	Mineral Resources
Fly Ash Type:	C	C
Fly Ash Quantity:	249 lb/yd^3	91 kg/m^3
Silica Fume Brand:	—	Rheomac SF 100
Silica Fume Quantity:	—	30 kg/m^3
Fine Aggregate Type:	Red sand	Sand
Fine Aggregate FM:	—	—
Fine Aggregate SG:	—	2.61
Fine Aggregate Quantity:	974 lb/yd^3	662 kg/m^3
Coarse Aggregate, Max. Size:	3/4 in	1 in
Coarse Aggregate Type:	—	Crushed limestone
Coarse Aggregate SG:	—	2.63
Coarse Aggregate Quantity:	1439 lb/yd^3	1074 kg/m^3
Other Aggregate, Max Size:	No. 11	—
Other Aggregate, Type:	—	—
Other Aggregate, SG:	—	—
Other Aggregate, Quantity:	481 lb/yd^3	—
Water:	248 lb/yd^3	138 l/m^3
Water Reducer Brand:	—	Polyheed N
Water Reducer Type:	—	A
Water Reducer Quantity:	—	—
High-Range Water-Reducer Brand:	Rheobuild 3000 FC	Rheobuild 1000
High-Range Water-Reducer Type:	A and F	A and F
High-Range Water-Reducer Quantity:	5-15 fl oz/yd^3	—
Retarder Brand:	—	—
Retarder Type:	—	—
Retarder Quantity:	(3)	—
Corrosion Inhibitor Brand:	—	—
Corrosion Inhibitor Type:	—	—
Corrosion Inhibitor Quantity:	—	—
Air Entrainment Brand:	—	Micro-Air
Air Entrainment Type:	—	Surfactant
Air Entrainment Quantity:	—	—
Water/Cementitious Materials Ratio:	0.25	0.36

(3) Retarder to be added when ambient temperature is 75 °F or higher.

B. Measured Properties of Approved Mix

	Girders	Deck
Slump:	—	—
Air Content:	—	—
Unit Weight:	—	—
Compressive Strength:	—	—
Chloride Permeability: (AASHTO T 277)	—	—

6. CONCRETE MATERIAL PROPERTIES

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

Cement Composition: —
Actual Curing Procedure for Girders: Steam
Average Slump: —
Maximum Girder Temperature: —
Air Content: —
Unit Weight: —

Compressive Strength, psi:
(AASHTO T 22)
The following strengths were measured by TN DOT.

Batch No.	28 days			56 days			84 days	112 days
	4x8 in	4x8 in	6x12 in	4x8 in	4x8 in	6x12 in	6x12 in	6x12 in
	bc	mc	bc	bc	mc	bc	bc	bc
BT7	12,300	12,186	11,740	11,592	12,796	12,020	11,208	11,201
	12,742	11,238	10,791	11,755	12,473	10,336	11,783	11,699
BT8	11,259	10,982	10,678	11,456	11,193	11,261	11,329	11,391
	12,292	11,410	11,561	12,729	11,387	12,872	12,261	12,284
BT9	10,382	10,245	10,129	11,111	11,203	10,952	10,820	10,714
	10,679	10,195	9452	11,662	11,284	11,031	11,798	11,683
BT10	—	—	10,084	—	—	10,873	11,268	11,521
	—	—	9797	—	—	10,643	10,422	10,860
Average	11,609	11,043	10,529	11,718	11,723	11,249	11,361	11,419

bc = bed cured.
mc = match cured.

Compressive strengths were also measured by the girder fabricator. See Excel file for data.

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

Cement Composition: —
Actual Curing Procedure for Deck: —
Compressive Strength:
(AASHTO T 22)

Batch No.	Compressive Strength (4), psi			
	7 days	14 days	28 days	56 days
1	5040	6220	6940	7740
	4810	6290	6780	7770
2	3880	5250	5950	6790
	3670	5110	5840	6780
3	4230	5570	7020	6950
	4090	5670	6230	7150
Average	4287	5685	6460	7197

(4) 6x12-in cylinders.

Curing Procedure for Cylinders: Moist cured

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

Compressive Strength:
(AASHTO T 22)

Batch No.	Age, days	Curing (5)	Compressive Strength (6), psi
BT7	28	bc	11,842
	56	bc	10,836
BT8	28	bc	11,813
	56	bc	12,122
BT9	28	bc	10,439
	56	bc	9553
BT10	1	bc	8246
			8224
		mc	8439
			7978
		mc	8800
			7850
	3	bc	9496
			9151
	7	bc	9311
			9537
	14	bc	9876
			10,072
	28	bc	10,093
			10,498
	56	bc	10,728
			11,033

(5) bc = bed cured.
mc = matched cured.
(6) 4x8-in cylinders.

Modulus of Elasticity:
(ASTM C 469)

Batch No.	Modulus of Elasticity (7), ksi		
	28 days		56 days
	bc	mc	bc
BT7	6803	—	6821
BT8	6918	—	6899
BT9	6550	—	6696
BT10	6094	6394	6462
	6239	6267	6127

bc = bed cured.
mc = matched cured.
(7) 4x8-in cylinders.

Batch No.	Modulus of Elasticity (8), ksi					
	At Release			3 days	7 days	14 days
	bc (9)	mc (9)	mc	bc (9)	bc	bc
BT10	6328	6478	6534	6522	6773	6730
	6148	6147	6128	6162	7230	6192

bc = bed cured.
mc = match cured.
(8) 4x8-in cylinders.
(9) Measured by fabricator.

Splitting Tensile Strength:
(AASHTO T 198)

Batch No.	Splitting Tensile Strength (10), psi		
	28 days		56 days
	bc	mc	bc
BT7	889	—	870
BT8	817	—	1019
BT9	984	—	905
BT10	916	831	—
	—	818	—

bc = bed cured.
mc = match cured.
(10) 4x8-in cylinders.

Chloride Permeability:
(AASHTO T 277)

Batch No.	Chloride Permeability (11), coulombs
BT7	252
	387
BT8	471
	440
BT9	541
	585

(11) All specimens were bed cured and tested at 56 days by the fabricator.

Batch No.	Chloride Permeability, coulombs				
	28 days		56 days		
	bc (12)	mc (12)	bc (12)	mc (12)	mc
BT10	890	783	449	953	756
	1589	1098	840	1341	1617

bc = bed cured.
mc = match cured.
(12) Measured by fabricator.
Average chloride permeability at 56 days for bed-cured specimens = 496 coulombs.

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

Modulus of Elasticity and
Tensile Strength:

Batch No.	Modulus of Elasticity (13), ksi		Splitting Tensile Strength (14), psi	
	28 days	56 days	28 days	56 days
1	4866	5129	826	720
	4718	5284	797	737
2	4211	4511	647	693
	4099	4469	665	709
3	4415	4545	762	686
	4622	4600	797	658
Average	4489	4756	749	701

(13) ASTM C 469. 4x8-in moist cured cylinders.
(14) AASHTO T 198. 4x8-in moist cured cylinders.

Chloride Permeability:
(AASHTO T 277)

Batch No.	Chloride Permeability (15), coulombs	
	28 days	56 days
1	289 (16)	237 (16)
	1311	550
2	356 (16)	311 (16)
	1658	832
3	306 (16)	259 (16)
	1407	739
Average	317 (16)	269 (16)
	1459	707
Match Cure Edge	508 (16)	748
	3972	—
Match Cure Center	660 (16)	1502
	4055	—

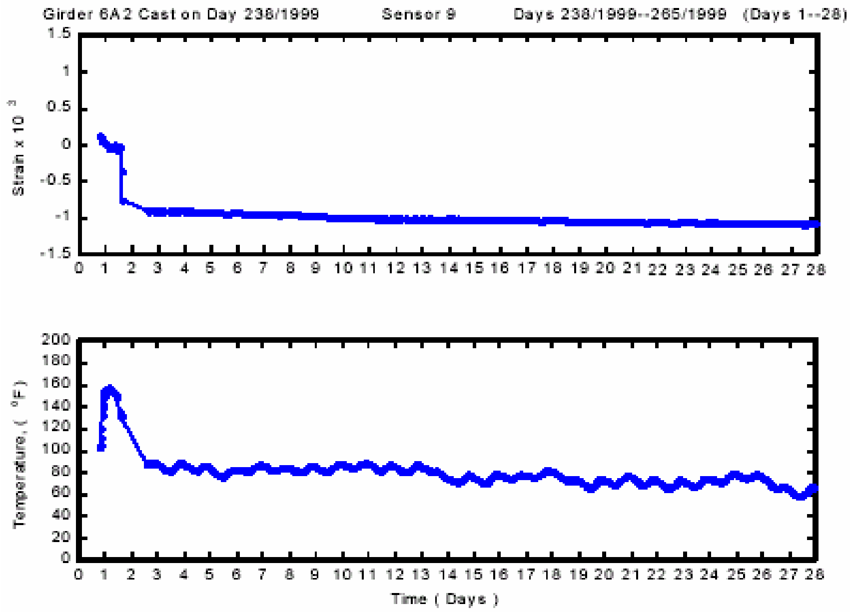
(15) All specimens were moist cured except as noted.
(16) Cured in water at 100 ^{o}F.

7. OTHER RESEARCH DATA

Strains and Temperatures:

Strain and temperatures were measured at 14 locations in each of two girders. See section 10 for details of instrumentation locations.

The following graph is typical of the data presented in the final report.



Camber:

Age, Days	Camber, in	
	6A2	6B2
11	5.1	5.5
18	4.5	4.7
28	4.6	5.0
32	5.2	5.3
42	5.3	5.6
56	5.6	5.5
70	5.3	5.2
84	5.2	5.2
97	5.2	5.1
112	5.1	5.1
117	5.6	5.7
143	5.5	5.5
172	6.0	6.0

See section 10 for girder locations.

Live Load Tests:

Live load tests using a 66,000 lb dump truck were made on the bridge. The following summary is taken from the final report:

> Although the TnDOT Truck used for the load test did not have axle spacing corresponding to standard AASHTO Truck, the truck weight of 66 kips was close to 72 kips for AASHTO Standard Truck. In the case of PR Bridge, the abutment at eastern end has significantly shorter piles than the ones under the western end abutment. As a result, the abutment movement recorded during the load test was found to be less in the case of east abutment than the west abutment. On the other hand, the abutment rotations, though small, for east abutment was found to be more than that for west abutment. This is partly because the short piles under the east abutment behaved more as pinned base and partly because the east abutment is taller. On the other hand, the tall piles under the west abutment developed fixed end condition near the lower end and hence behaved more as a shear column. As each of the load cases considered lasted for about 30 minutes, which was found to be long enough time to cause appreciable rise in temperature affecting all the measurements and sensor readings. As the rise in temperature tended to cause upward deflection counteracting the downward deflection in the loaded span, the net deflection was not only smaller but also tended to be upwards because the deflection due to big enough temperature change (say, $\geq 10\ ^{o}F$) was found to be larger in magnitude than the downward deflection due to truck load. The deflection values due to individual effects of temperature change and truck load were found to be significantly smaller than the AASHTO limitation of Span/800. This test clearly demonstrated the role of pile foundation under the abutments in abutment movement due to temperature change and live load. It was, however, noted that temperature change has more influence than live load. The live load distribution coefficients based on the test data were found to be significantly different from the predicted values, say, by AASHTO recommended lever rule.

8. OTHER RELATED RESEARCH

Not available.

9. SOURCES OF DATA

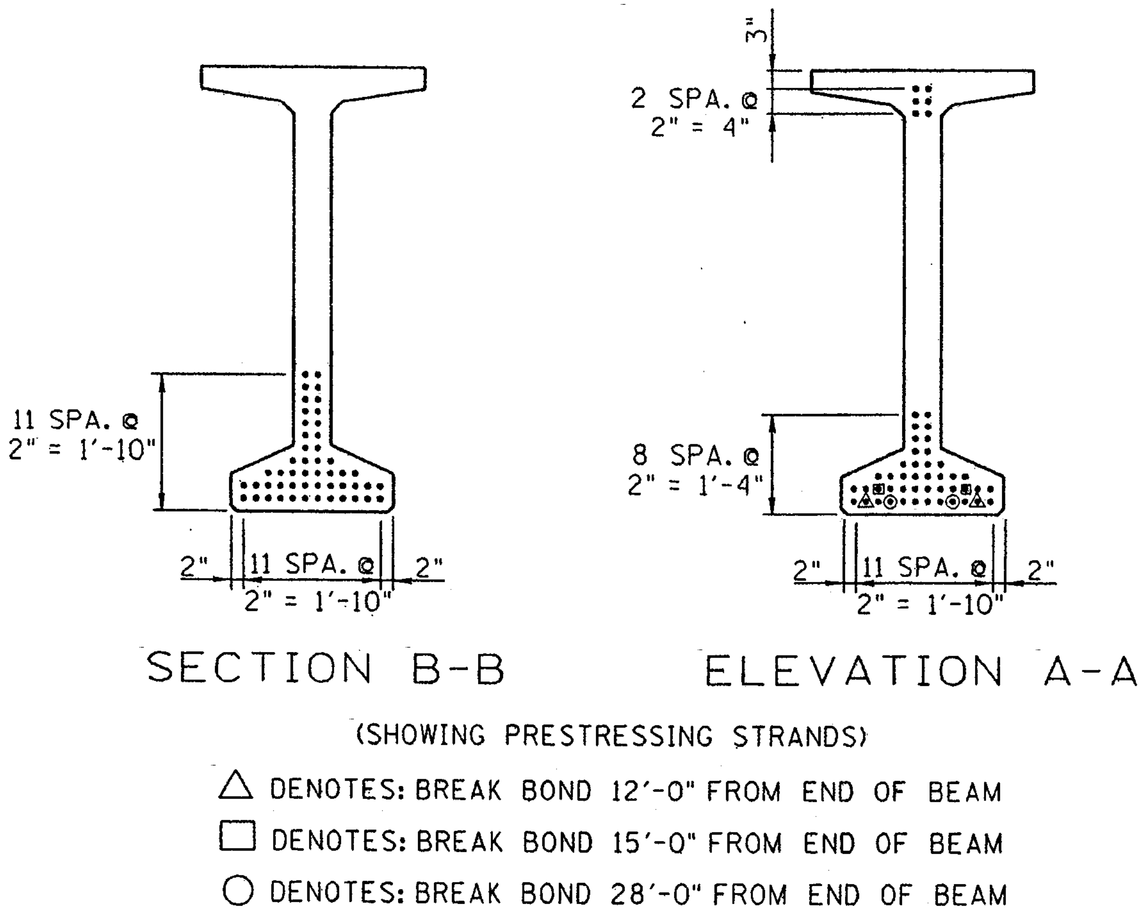
Basu, P. K. and Knickerbocker, D., "High Performance Concrete Bridges," Final Report to TN DOT Project No. TNSPR-RES1162, Vanderbilt University, March 2002, 359 pp. plus appendices.

Holloran, M., "Tennessee's HPC Bridge Projects," *HPC Bridge Views*, Issue No. 10, July/August 2000, pp. 2.

Maybee, A., "HPC—The Fabricator's Viewpoint," *HPC Bridge Views*, Issue No. 10, July/August 2000, pp. 3.

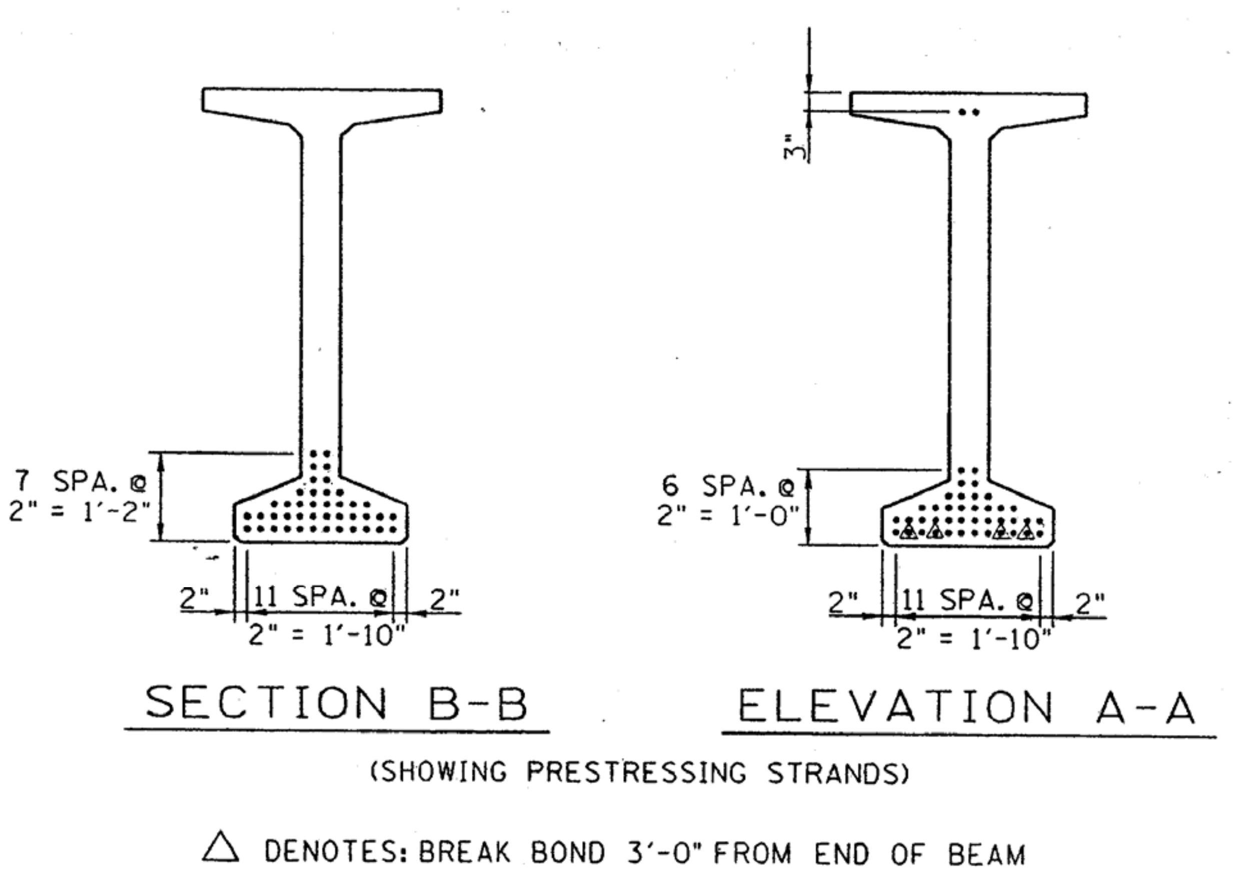
Mark Holloran, Tennessee Department of Transportation, Nashville, TN.

10. DRAWINGS



Elevation A-A is at the end of the girder.
Section B-B is at the midspan of the girder.

Longer Span

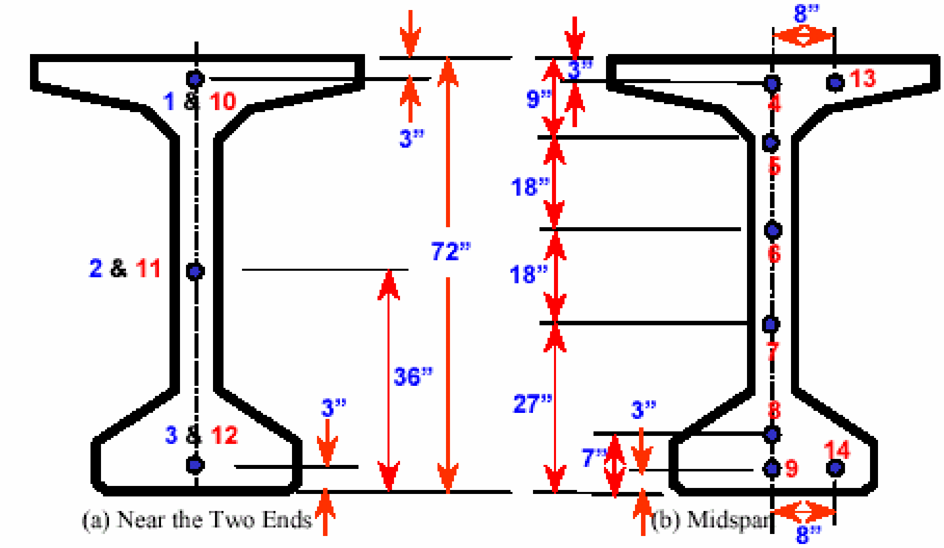


Elevation A-A is at the end of the girder.
Elevation B-B is at midspan of the girder.

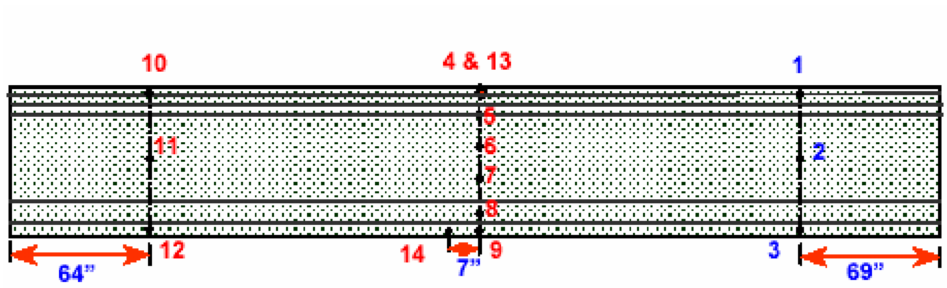
Shorter Span

Lateral Stability:

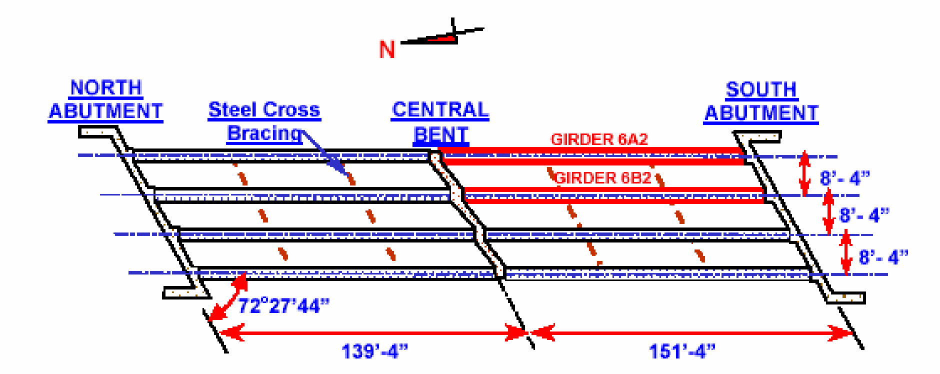
The Contractor is solely responsible for supporting the beams to prevent damage due to twisting or overturning during all phases of construction. It is strongly recommended that the temporary erection diaphragms be installed and the permanent intermediate diaphragms be poured and cured prior to placing any loads on the girders. However, temporary erection diaphragms and permanent intermediate diaphragms must be in place in the span at the time the slab is poured in said span.



Cross-Sectional Location of Sensors



Longitudinal Location of Sensors



Instrumented Girder Locations

11. HPC SPECIFICATIONS

Note: Later corrections are shown in red.

604HP 604HP

S T A T E O F T E N N E S S E E

September 11, 1998
Sheet 1 of 5

Project: SP 22840-3204-04
Porter Road / SR 840
Hickman Road / SR 840
Dickson County

SPECIAL PROVISION

REGARDING

HIGH PERFORMANCE CONCRETE

General Provisions.

For this project, High Performance Concrete (HPC) is defined as the concrete in the cast-in-place deck, deck panels (if used), beams, and substructures for the two bridges at Porter Road over SR 840 and Hickman Road over SR 840. The work shall consist of furnishing, placing, curing, and testing the HPC in accordance with the Standard Specifications, these special provisions, and the notes and details shown on the Plans and on the approved shop drawings. The contractor shall schedule his work such that the bridge decks for these two structures are completed by June 1, 2000.

Materials.

Materials used in this construction shall meet the requirements of the Standard Specifications and these special provisions. The contractor is responsible for selecting the proper proportions to meet these special provisions, the placement conditions, and methods of placement. Silica fume, used in accordance with these special provisions, may be incorporated in the HPC to help achieve the permeability requirement. Silica fume shall conform to the requirements of AASHTO M307 or ASTM C1240. If used, silica fume shall replace between 3% to 8% by mass of the cementitious material. The contractor may use a combination of fly ash and silica fume. The maximum percentage of fly ash substitution shall be in accordance with the Specifications.

604HP 604HP
Sheet 2 of 5

Classification and Proportioning of Concrete.

The cement content, maximum allowable water/cement, the maximum slump, the proper amount of entrained air, the permeability, and the strength requirements for all classes of HPC shall conform to the requirement of these special provisions.

Class of Concrete and Application	Min. 28-day Comp. Strength PSI	Min. lb Cement per C.Y.	Max. Water Cement Ratio lb/lb	Air Content %	Slump* In.	Permeability (Coulombs)
A (HPC) Substructure	4000	620	0.45	6 ± 2	3 ± 1	<3000
D (HPC) CIP Deck	5000	658	0.43	6 ± 2	3 ± 1	<1500
P (HPC) Beams	10000	658	0.43	6 ± 2	3 ± 1	<2500

* Prior to the addition of a high range admixture, if used. The maximum slump with high range admixture added shall be 8 inches.

If deck panels are used, the minimum strength and permeability requirements shall be the same as that for the cast-in-place deck.

Quality Assurance for High Performance Concrete

The Contractor shall submit the proposed concrete design to the Engineer for all classes of HPC used in this project. In addition to the requirements of the Specifications, the proposed concrete design submittal shall contain the following:

> source of silica fume (where applicable)
> 28 day permeability (minimum of 2 tests)
> 1 day compressive strength (prestressed concrete only, two specimen sizes, minimum of 3 cylinders each)
> 7 day compressive strength (two specimen sizes, minimum of 3 cylinders each)
> 28 day compressive strength (two specimen sizes, minimum of 3 cylinders each)
> Batching sequence (steps, material ratios, and mixing parameters)

The strength samples shall be made in accordance with the Specifications, except that both 6 in. x 12 in. and 4 in. x 8 in. cylinders shall be made. Although both sample sizes will be tested, only the results of the 6 in. x 12 in. cylinders will be used for strength acceptance. The test value at 28 days shall be the basis for acceptance. However, the contractor shall also make two additional cylinders of each size for 56-day testing by the Department.

The permeability samples shall be cylindrical specimens with a 4 in. diameter and at least 4 in. in length. They shall be moist cured as the strength cylinders for acceptance except that the last 3 weeks of cure shall be at 100°F ± 10°F. Cylinders shall be tested at 28 days in accordance with AASHTO T277 or ASTM C1202. The test value shall be the result of the average of the values from tests on two specimens from each batch. The test value at 28 days shall be the basis for acceptance. However, the contractor shall also make two additional cylinders ~~of each size~~ for 56-day testing by the Department.

In addition to the strength and permeability samples, the contractor shall make specimens for the Department's use in testing Modulus of Elasticity and Splitting Tensile strength of the concrete, when requested.

The HPC for the cast-in-place deck shall be substantiated at least two months prior to deck construction. At least two trial batches (using job materials) with permissible combination of cementitious materials shall be prepared, and test specimens shall be cast by the contractor and tested by the Department for permeability and strength. The contractor shall demonstrate his ability to place the deck concrete by pouring, finishing, and curing a test slab with the trial batches. The contractor shall attend a pre-pour conference to discuss and review his proposed techniques for mixing, transporting, placing, consolidating, finishing, and curing the HPC for this project.

For HPC, additional concrete will be required for making durability specimens for permeability tests. The frequency of durability testing shall be the same as for strength testing. The contractor is responsible for properly making, curing, and transporting all concrete test samples including the permeability cylinders and both size strength cylinders. Specimens for Modulus of Elasticity and Tensile splitting testing shall also be provided by the contractor as requested by the Department.

The deck concrete shall be cured in accordance with the Specifications except as modified in these special provisions. The surface of the freshly placed concrete shall be kept moist, by fogging if necessary, until the membrane curing compound is applied. Wet burlap shall be placed as soon as possible without damaging the concrete surface. A vapor barrier shall be placed over the wet burlap. The vapor barrier shall consist of two layers of at least 6 mil white polyethylene sheets overlapped and held down adequately against the wind. A composite burlap-vapor barrier material may be used subject to approval by the Engineer. The wet cure shall be continuous for 7 days. The burlap shall be frequently checked to insure it is kept wet continuously.

Research Activities.

The contractor and beam fabricator shall cooperate with Department personnel, or their appointed agent, in research activities associated with this project by providing information and test specimens as requested and by permitting access to areas of work for the purpose of instrumenting ~~this structure~~ these structures. Instrumentation in the beams and the bridge deck will be used to gather data. It is anticipated that the instrumentation can be installed concurrently with the contractor's or fabricator's work; however, some delays to the contractor or fabricator may occur. These occasional delays shall not be grounds for claims or contract time extensions.

The concrete for the prestressed concrete beams shall be tested using samples cured both by Specification procedures and by match-curing, subject to the Department's acquisition of the necessary match-curing equipment. Sufficient concrete strength for strand release will be determined based on the tests of the cylinders cured in accordance with the Specifications, unless specified otherwise by the Engineer.

On beams selected by the Engineer, and immediately after release of the strands, the fabricator shall measure the camber at mid-length of the beam. The camber shall be remeasured on the following schedule: 1 day, 3 days, 7 days, 14 days, and every 14 days thereafter until the beam is shipped. The prestressed concrete beams shall be at least 60 days old prior to shipping.

Basis of Payment.

Payment will be in accordance with the Specifications and these special provisions. Use of silica fume as a partial cement replacement shall will not be measured and paid for separately. All costs associated with the use of silica fume and fly ash shall be included in the unit price bid for concrete.

High performance concrete (HPC) that fails to meet the permeability requirement may be accepted at an adjusted price as detailed below:

Coulombs above Required	% of Bid Price Paid
0 to 500	95
501 to 1000	90
1001 to 1500	80
>1501	70

The adjustment shall apply to the volume of concrete represented by the specimen that does not meet the permeability requirement. In the case where a particular volume of concrete meets neither the strength nor the permeability requirement, the percent of bid price paid will be based on the larger of the penalties for strength and permeability according to the Specifications and these special provisions.