WASHINGTON
State Route 18

TABLE OF CONTENTS

SECTION **PAGE**

1. DESCRIPTION 2

2. BENEFITS OF HPC AND COSTS 4
- **A. Benefits of HPC 4**
- **B. Costs 4**

3. STRUCTURAL DESIGN 5

4. SPECIFIED ITEMS 6
- **A. Concrete Properties 6**
- **B. Specified QC Procedures 7**

5. CONCRETE MATERIALS 8
- **A. Approved Concrete Mix Proportions 8**
- **B. Measured Properties of Approved Mix 9**

6. CONCRETE MATERIAL PROPERTIES 10
- **A. Measured Properties from QC Tests of Production Concrete for Girders 10**
- **B. Measured Properties from QC Tests of Production Concrete for Deck 12**
- **C. Measured Properties from Research Tests of Production Concrete for Girders 13**
- **D. Measured Properties from Research Tests of Production Concrete for Deck 15**

7. OTHER RESEARCH DATA 16

8. OTHER RELATED RESEARCH 23

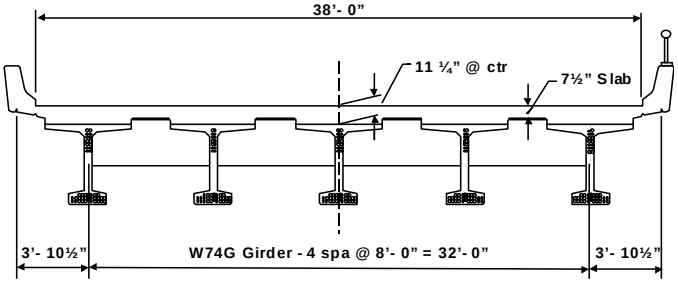
9. SOURCES OF DATA 24

10. DRAWINGS 25

11. HPC SPECIFICATIONS 26

WASHINGTON
State Route 18

1. DESCRIPTION



Location:	Eastbound lanes of State Route 18 over State Route 516 in King County
Open to Traffic:	March 1998
Environment:	Normal over a road
HPC Elements:	Girders and deck
Total Length:	297 ft
Skew or Curve:	40° skew at both ends
Girder Type:	WSDOT W74G
Girder Span Lengths:	80, 137, and 80 ft
Girder Spacing:	8 ft 0 in
Girder Strand Grade:	270
Girder Strand Dia.:	0.6 in
Max. No. of Bottom Strands:	40 in long span 14 in short spans
Deck Thickness:	7.5 in
Deck Panels:	None

The bridge received an Award of Excellence for design and construction in the Portland Cement Association Sixth Biennial Bridge Awards Competition, 1998.

2. BENEFITS OF HPC AND COSTS

A. Benefits of HPC

High performance concrete was specified for the prestressed concrete girders to improve durability and strength of the concrete. The use of high-strength concrete allowed the number of lines of girders to be reduced from seven to five. This resulted in a savings of 594 ft of girders.

B. Costs

Girders – \$153/linear ft for a total cost of \$218,700. Material cost increment for HPC for girders was about \$20/yd^3.

Deck – \$250,000

3. STRUCTURAL DESIGN

Design Specifications:	AASHTO LRFD Specifications First Edition and WSDOT office practices
Design Live Loads:	HL-93
Seismic Requirements:	Zone C with an acceleration coefficient of 0.25 g
Flexural Design Method:	AASHTO LRFD Specifications 5.7.3
Maximum Compressive Strain:	
Shear Design Method:	AASHTO LRFD Specifications 5.8.3
Fatigue Design Method:	
Lateral Stability Considerations:	All girders over 130-ft long shall be braced laterally to prevent tipping or buckling
Allowable Tensile Stress	
—Top of Girder at Release:	0.200 ksi
—Bottom of Girder after Losses:	0 ksi
Prestress Loss:	41.1 ksi
Method Used for Loss:	WSDOT modified rate of creep method
Calculated Camber:	3.15 in at release and 1.74 in final calculated by modified rate of creep method
Concrete Cover	
—Girder:	1 in
—Top of Deck:	2-1/2 in
—Bottom of Deck:	1 in
—Other Locations:	1-1/2 in
Properties of Reinforcing Steel	
—Girder:	AASHTO M 31 Grade 60, uncoated
—Deck:	AASHTO M 31, epoxy coated in top layer AASHTO M 31, uncoated in bottom layer
Properties of Strand	
—Grade and Type:	270 low relaxation
—Supplier:	—
—Surface Condition:	—
—Pattern:	14 strands draped at 0.4 of span length in the long span 6 strands draped at 0.4 of span length in the short spans
—Transfer Length:	30 in
—Development Length:	101 in

4. SPECIFIED ITEMS

A. Concrete Properties

	Girders	Deck (1)
Minimum Cementitious Materials Content:	—	735 lb/yd^3
Max. Water/Cementitious Materials Ratio:	—	0.39
Min. Quantity of Fly Ash:	—	75 lb/yd^3
Max. Quantity of Fly Ash:	25%	75 lb/yd^3
Min. Percentage of Silica Fume:	—	—
Max. Percentage of Silica Fume:	—	—
Min. Percentage of GGBFS:	—	—
Max. Percentage of GGBFS:	—	—
Maximum Aggregate Size:	1/2 in	3/4 in
Slump:	$\leq$ 7 in	—
Air Content:	—	6%
Compressive Strength		
—Release of Strands:	7400 psi for long span 5000 psi for short spans	—
—Design:	10,000 psi at 56 days or 9500 psi at 28 days	4000 psi at 28 days
Chloride Permeability:	$\leq$ 1000 coulombs at 56 days	Not specified
(AASHTO T 277)		Not specified
ASR or DEF Prevention:	Not specified	Not specified
Freeze-Thaw Resistance:	Information only	Not specified
(AASHTO T 161)		
Deicer Scaling:	Not specified	Not specified
Abrasion Resistance:	Not specified	Not specified
Other:	—	Type A water reducer required

(1) Contracting agency provided the mix design.

B. Specified QC Procedures

Girder Production	
Curing:	—
Internal Concrete Temperature:	—
Cylinder Curing:	Match cure until release
Cylinder Size:	4x8 in
Cylinder Capping Procedure:	—
Cylinder Testing Method:	—
Frequency of Testing:	—
Other QA/QC Requirements:	Manufacture of two 20-ft-long test girders and two pullout blocks
Deck Construction	
Curing:	Two coats of curing compound and wet cured using quilted blankets or burlap for 14 days
Cylinder Curing:	—
Cylinder Size:	—
Flexural Strength:	—
Other QA/QC Requirements:	—

5. CONCRETE MATERIALS

A. Approved Concrete Mix Proportions

	Girders	CIP Deck
Cement Brand:	Holnam	Lonestar
Cement Type:	III	I
Cement Composition:	—	—
Cement Fineness:	—	—
Cement Quantity:	728 lb/yd^3	660 lb/yd^3
GGBFS Brand:	—	—
GGBFS Quantity:	—	—
Fly Ash Brand:	—	—
Fly Ash Type:	C	C
Fly Ash Quantity:	222 lb/yd^3	75 lb/yd^3
Silica Fume Brand:	Rheomac SF100	—
Silica Fume Quantity:	50 lb/yd^3	—
Fine Aggregate Type:	—	—
Fine Aggregate FM:	—	—
Fine Aggregate SG:	2.63	—
Fine Aggregate Quantity:	890 lb/yd^3	1100 lb/yd^3
Coarse Aggregate, Max. Size:	1/2 in	1/2 in
Coarse Aggregate Type:	Gravel	—
Coarse Aggregate SG:	2.66	—
Coarse Aggregate Quantity:	1870 lb/yd^3	1700 lb/yd^3
Water:	265 lb/yd^3	290 lb/yd^3
Water Reducer Brand:	MBL 82 or WRDA 82	—
Water Reducer Type:	A	A
Water Reducer Quantity:	29 fl oz/yd^3	6 fl oz/yd^3
High-Range Water-Reducer Brand:	Rheobuild 1000	—
High-Range Water-Reducer Type:	A and F	—
High-Range Water-Reducer Quantity:	215 fl oz/yd^3	—
Retarder Brand:	—	—
Retarder Type:	—	—
Retarder Quantity:	—	—
Corrosion Inhibitor Brand:	—	—
Corrosion Inhibitor Type:	—	—
Corrosion Inhibitor Quantity:	—	—
Air Entrainment Brand:	—	—
Air Entrainment Type:	—	—
Air Entrainment Quantity:	—	—
Water/Cementitious Materials Ratio:	0.27	0.39

B. Measured Properties of Approved Mix

	Girders	Deck
Slump:	6 in	6 to 9 in
Air Content:	1%	5.7%
Unit Weight:	149.1 lb/ft^3	158 lb/ft^3
Compressive Strength: (AASHTO T 22)	10,730 psi at 56 days	5300 psi at 28 days
Chloride Permeability: (AASHTO T 277)	1010 coulombs at 56 days	2800 coulombs at 56 days
Freeze-Thaw Resistance: (AASHTO T 161)	100%	—
Abrasion Resistance:	—	4.5%

6. CONCRETE MATERIAL PROPERTIES

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

Cement Composition: —
Actual Curing Procedure for Girders: Steam
Maximum Girder Temperature: —
Air Content: 1%
Unit Weight: 159.1 lb/yd^3

Slump and Compressive Strength:

Casting Date	Slump, in	Release Age, hours	Compressive Strength, psi		
			Release	28 days	56 days
3/6/97	3-1/2, 5-1/4	24	8400 7600	11,040 11,125	12,170 11,140
3/10/97	2-3/4, 5-1/2	24	7680 7460	10,760 11,840	12,360 12,110
3/12/97	6, 4	24	7280 7710	10,990 11,150	12,720 12,190
3/14/97	4-3/4, 4-3/4	60	8380 8060	11,525 10,200	12,910 12,560
3/18/97	6, 3-1/4	22	8060 8110	11,180 11,210	11,600 11,410
3/24/97	5, 6	20	7490 7160	12,951 10,761	12,880 12,100
3/26/97	5-1/2, 5-1/2	20	8250 7780	11,620 11,849	12,300 11,460
3/28/97	4, 5	60	9940 9850	12,503 11,595	12,570 11,530
4/2/97	4-1/2, 5	18	7920 7670	11,289 11,275	12,460 11,940
4/4/97	4-1/2, 4-1/2	56	9020 9260	11,216 11,325	13,030 12,940
Average	4-3/4		8150	11,370	12,220

Curing Procedure for Cylinders: Match cure until release

Chloride Permeability:
(AASHTO T 277)

Date Cast	Cylinder Size, in	Chloride Permeability (2), coulombs
3/12/97	4x12	655
3/12/97	4x12	538
4/2/97	4x8	382
4/2/97	4x8	408
Average	—	496

(2) Concrete age between 10 and 13 months.

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

Cement Composition: —
Actual Curing Procedure for Deck: 14 days wet curing
Curing Procedure for Cylinders: AASHTO T 23 Initial and Standard Curing
Slump, Air Content, and Compressive Strength:

Laboratory ID Number	Approx. Slump, in	Air Content, %	Compressive Strength (3), psi
135556	3	6.8	5080, 5000
135557	3-1/2	5.9	4880, 4840
135558	3-1/4	4.6	5430, 5470
135559	3-1/2	5.5	5320, 5470
135560	2-3/4	5.6	5650, 6110
135561	3-1/4	4.6	6390, 6290
135562	3-1/2	6.1	5390, 5530
Average	3.3	5.6	5490

(3) 6x12-in cylinders stored in an insulated box for 24 hours, then transported to the laboratory, and tested at 28 days.

Abrasion Resistance (4):
(ASTM C 944-95)

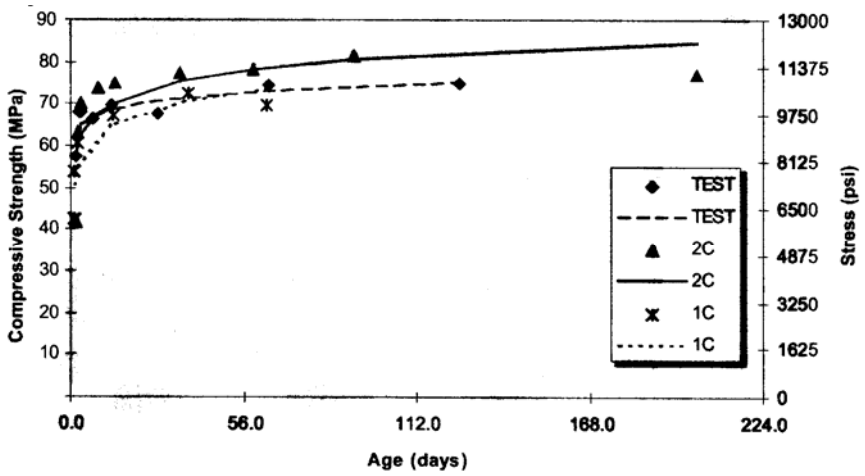
Cylinder ID	Surface	Cumulative Weight Loss, gms		
		Cycle 1	Cycle 2	Cycle 3
EF-D 118	Top	1.5	1.9	3.7
	Middepth	0.9	1.0	1.1
EF-D 303	Top	1.0	2.5	3.1
	Middepth	0.4	0.5	1.7
EF-D 309	Top	0.9	2.7	3.2
	Middepth	0.3	1.4	1.5
Average	Top	1.13	2.37	3.33
	Middepth	0.53	0.97	1.43

(4) Abrasion test consisted of 3 cycles of 2 minutes duration each with an applied load of 22.1 lb. Test specimens were made from 6x12-in cylinders cut in half at midlength to produce an upper and lower test specimen. The test was performed on the original cylinder top surface of the upper test specimen and on the upper cut surface of the lower test specimen.

Chloride Permeability: (AASHTO T 277) 2338, 2164, 3434 coulombs at a concrete age between 3-1/2 and 6-1/2 months

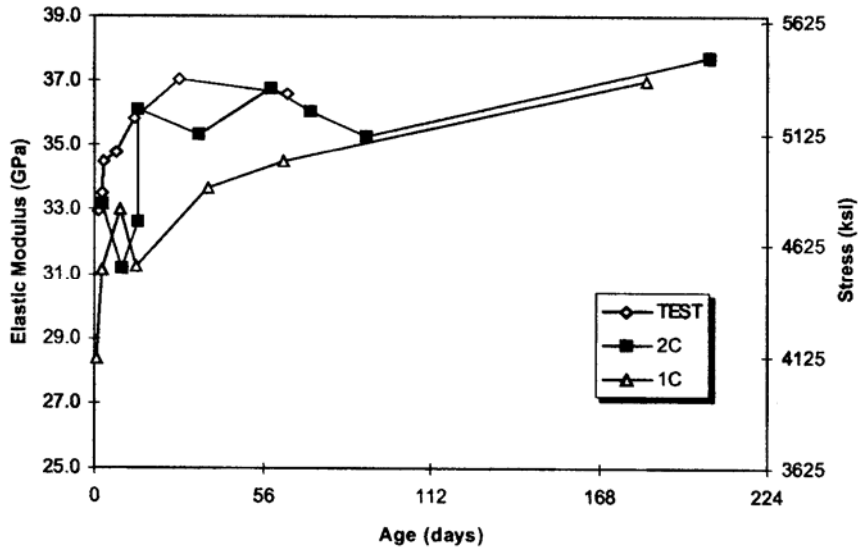
C. Measured Properties from Research Tests of Production Concrete for Girders

Compressive Strength (5):
(AASHTO T 22)



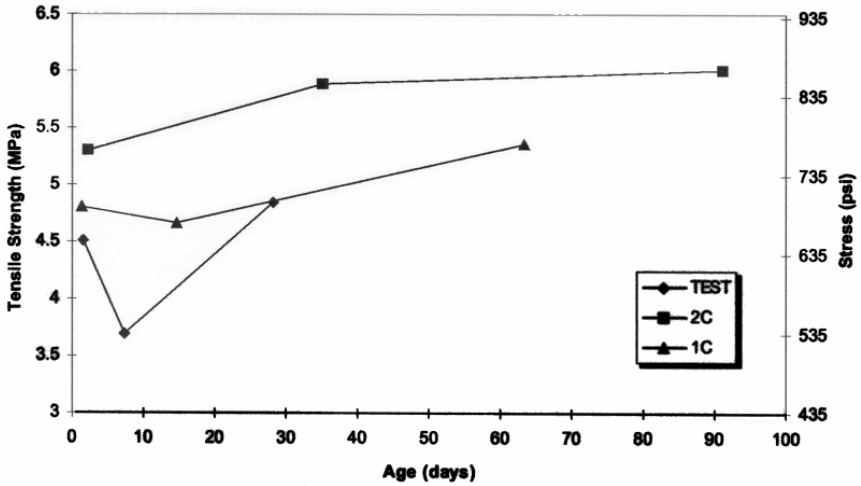
(5) 6x12-in cylinders cured initially in an insulated box and then in the laboratory. Test identifies data from the test girder. 1C and 2C identify data from the middle girder of Spans 1 and 2. See section 10 for girder layout.

Modulus of Elasticity (6):
(ASTM C 469)



(6) 6x12-in cylinders cured initially in an insulated box and then in the laboratory. Test identifies data from the test girder. 1C and 2C identify data from the middle girder of Spans 1 and 2. See section 10 for girder layout.

Splitting Tensile Strength (7):
(ASTM C 496)



(7) 6x12-in cylinders cured initially in an insulated box and then in the laboratory. Test identifies data from the test girder. 1C and 2C identify data from the middle girder of Spans 1 and 2. See section 10 for girder layout.

Coefficient of Thermal Expansion (8):

Test girder:	$5.9 \times 10^{-6}/^{o}F$
Girder 1C:	$5.4 \times 10^{-6}/^{o}F$
Girder 2C:	$5.6 \times 10^{-6}/^{o}F$

(8) Measured on a 6x12-in cylinder submerged in heated water over a temperature range of 48 to 104 ^{o}F.

Creep:

Girder	Date Cast	Cylinder Dia., mm	Applied Stress (9), MPa	Total Strain (10), mill.		Approx. Age, days
				Unsealed (11)	Sealed	
Test	12/11/96	152	20.7	2400	1680	301
1C	4/2/97	152	20.7	2610	2510	189
1C	4/2/97	152	27.6	3280	3970	189
1C	4/2/97	152	13.8	1840	1620	189
2C	3/12/97	152	27.6	3430	2670	310
2C	3/12/97	102	27.6	3790	3790	210

(9) Cylinders were loaded at an age close to that corresponding to release of the prestressing strands.
(10) For a discussion of separating the total strain into elastic shortening, creep, and shrinkage, see report by Fekete et al. listed in section 9.
(11) Measured creep coefficient for 152-mm-diameter cylinders after 6 months under load ranged from 1.64 to 2.72.

Shrinkage:

Girder	Date Cast	Specimen Size	Shrinkage (12), mill.	Approx Age, days
Test	12/11/96	152-mm cyl.	370	301
Test	12/11/97	76x102x406 mm	730 (13)	90
1C	4/2/97	152-mm cyl.	570	189
1C	4/2/97	152-mm cyl.	860 (13)	189
1C	4/2/97	76x102x406 mm	500 (13)	90
2C	3/12/97	152-mm cyl.	570	210
2C	3/12/97	102-mm cyl.	570	210
2C	3/12/97	76x102x406 mm	620 (13)	90

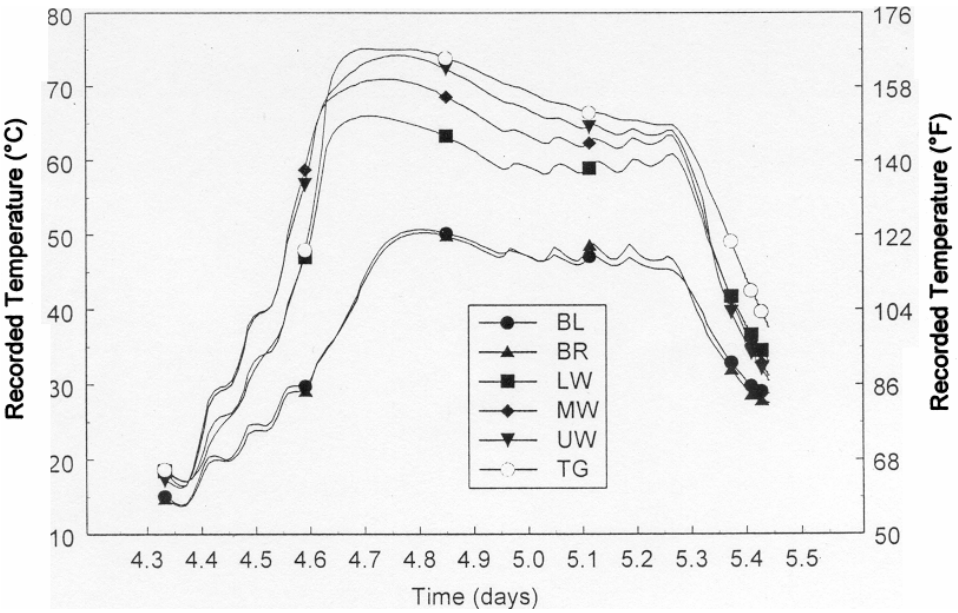
(12) Shrinkage measurements were started at the same time as the corresponding creep tests except for Test Girder prisms, which began after 7 days moist curing. Except as noted, measurements were made using a mechanical strain gage.
(13) Measurements made using a comparator and studs embedded in the ends of the specimen.

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

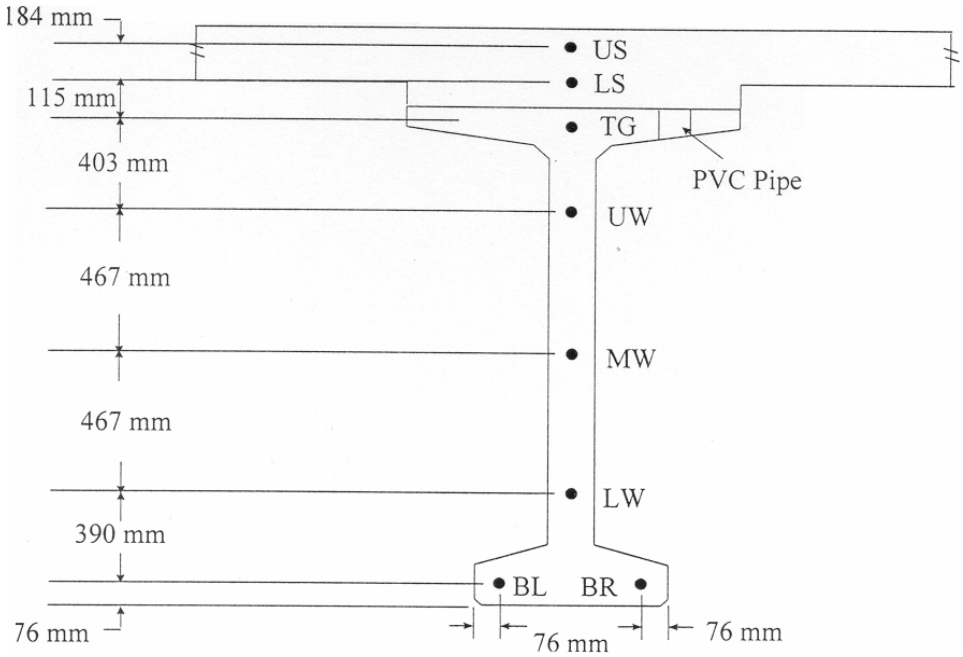
Not available.

7. OTHER RESEARCH DATA

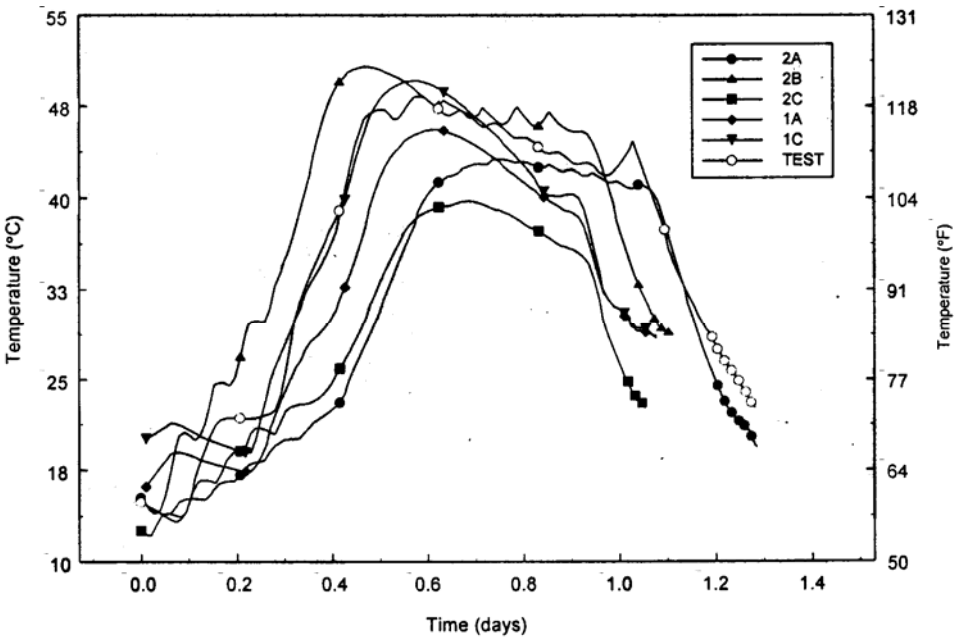
Curing Temperatures:



Midspan of Girder 2B

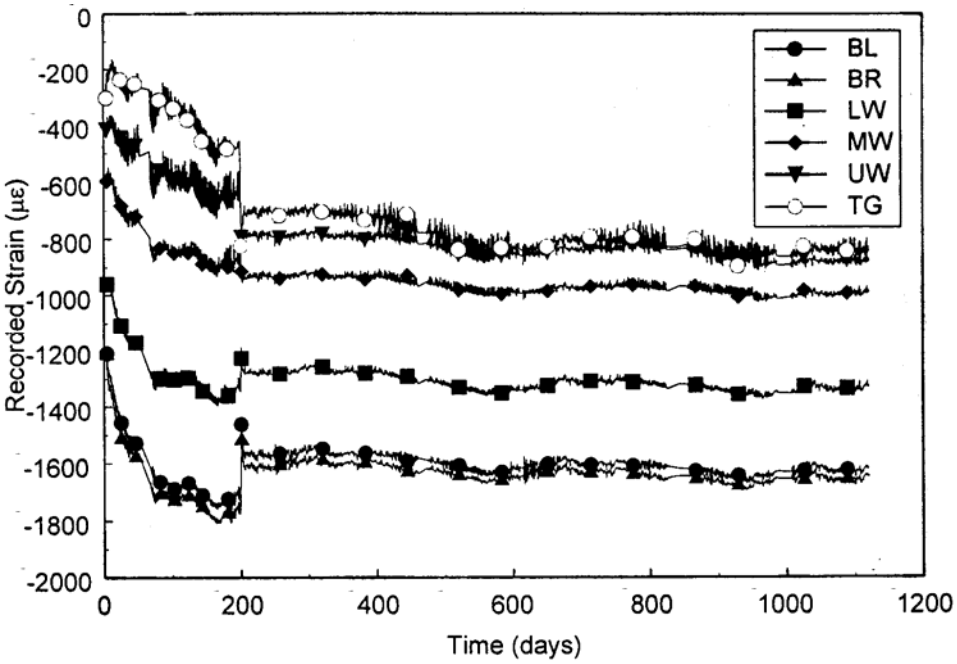


Measurement Locations

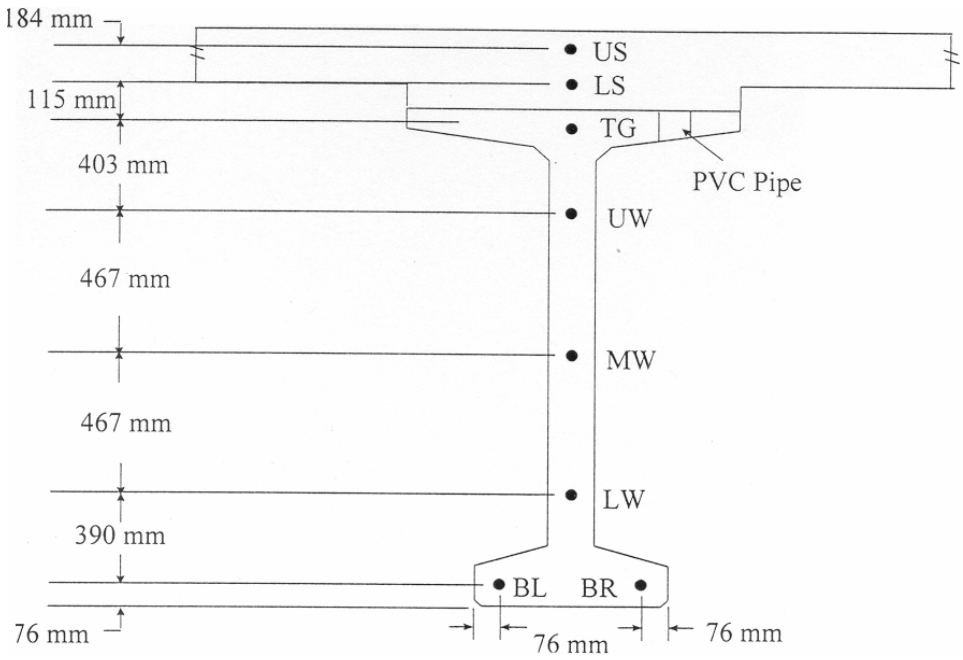


Midspan Temperatures at Location BL for Six Girders
(See section 10 for girder layout.)

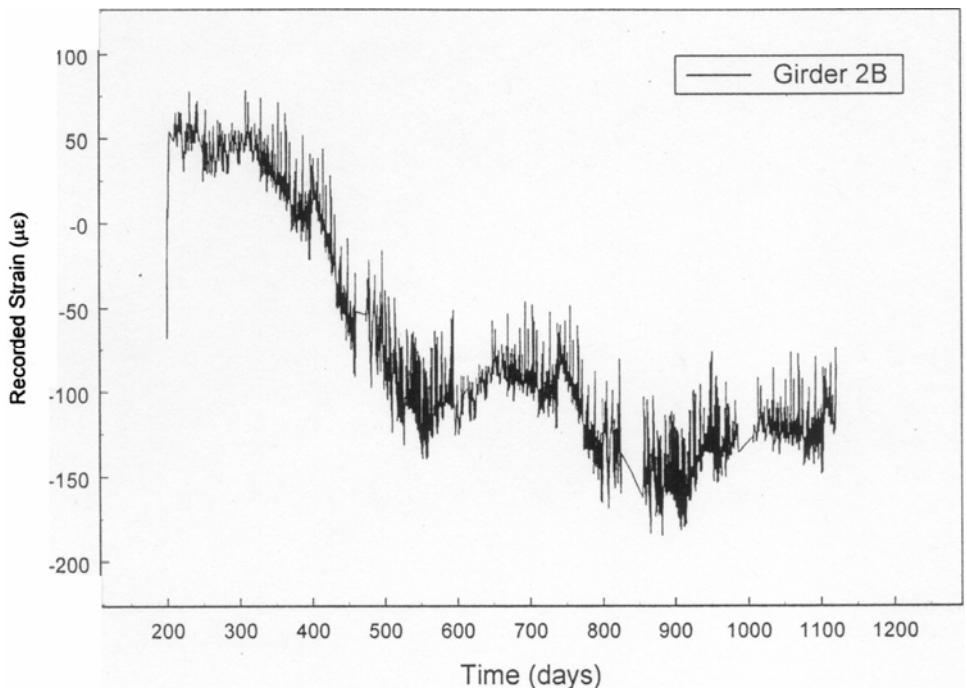
Strains:



Strains at Midspan of Girder 2B

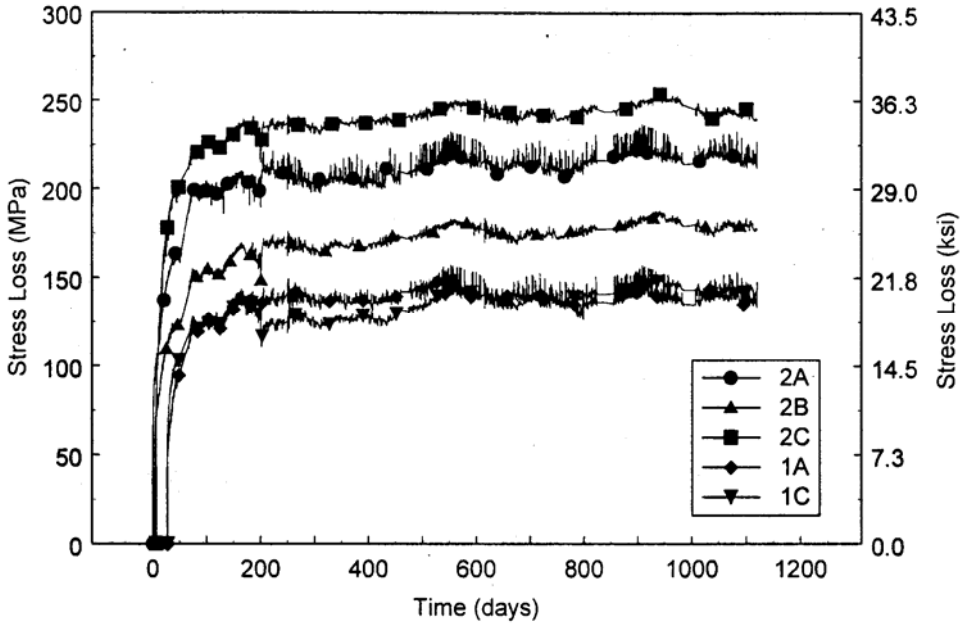


Measurement Locations



Deck Strains for Girder 2B

Prestress Losses:

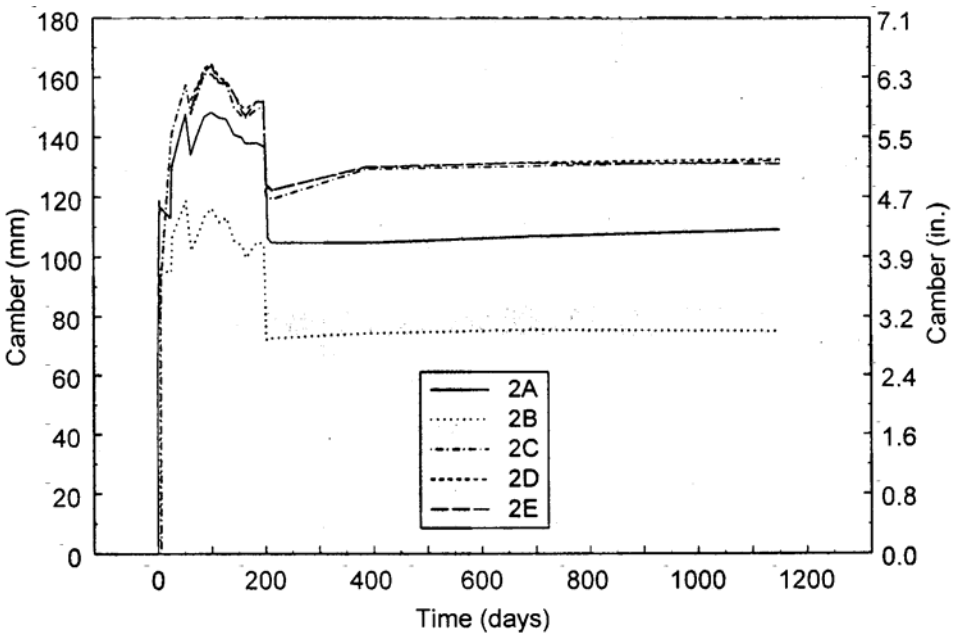


Prestress Losses Due to Creep and Shrinkage

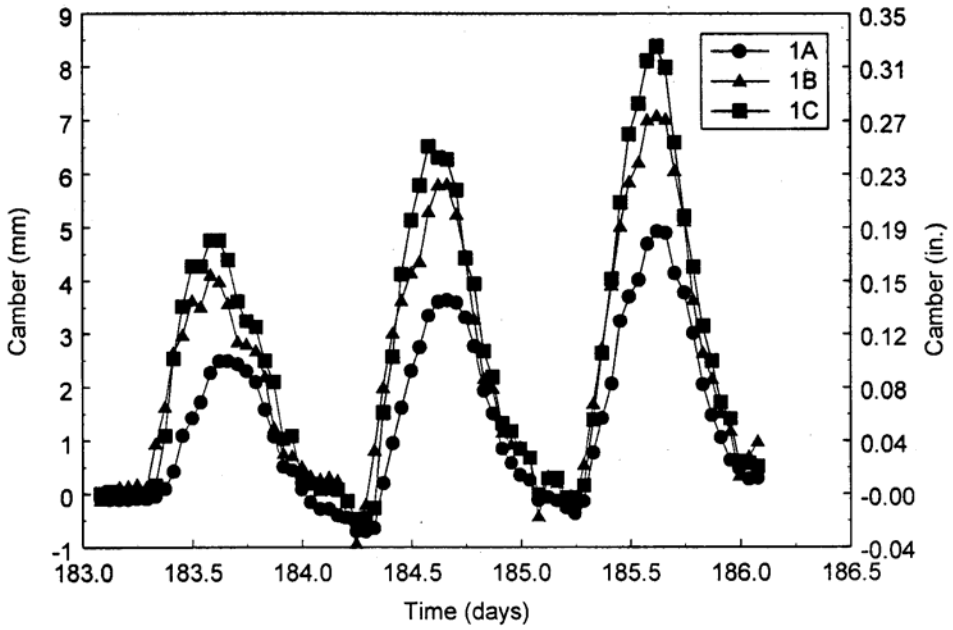
Girder	Span 1			Span 2			
	1A	1C	Average	2A	2B	2C	Average
Total Loss, MPa	220	225	223	397	343	418	386
Percent of Jacking Stress	15.7	16.1	15.9	28.4	24.5	29.9	27.6

Total Observed Prestress Losses at Three Years

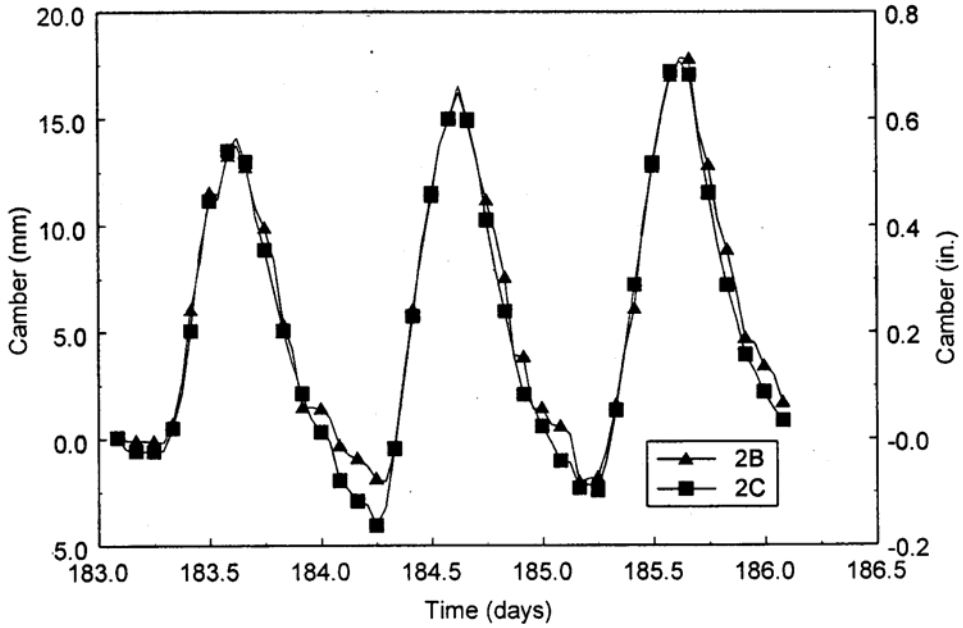
Camber:



Camber History for Span 2 Girders

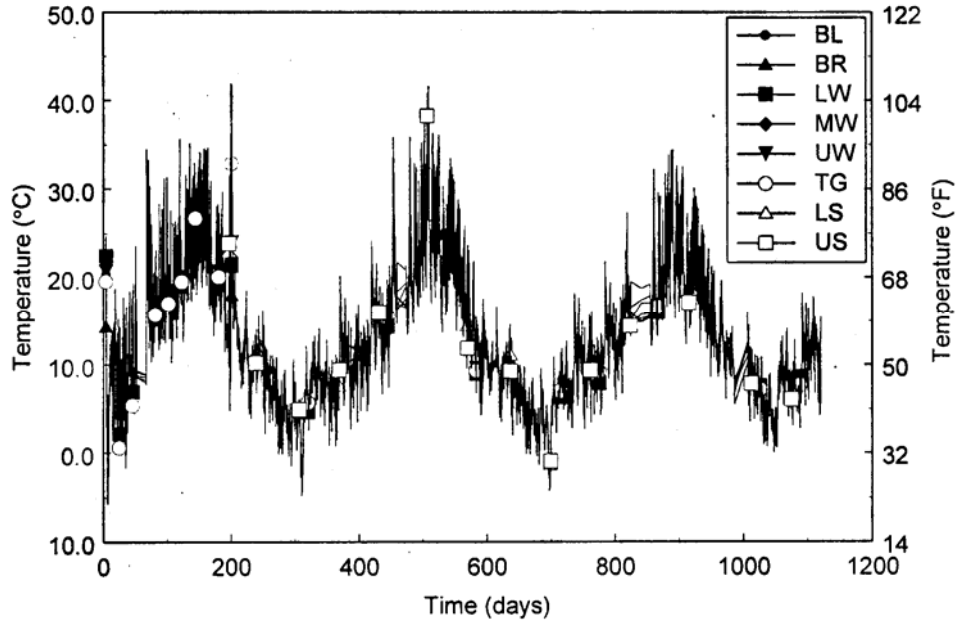


Daily Camber Readings for Span 1

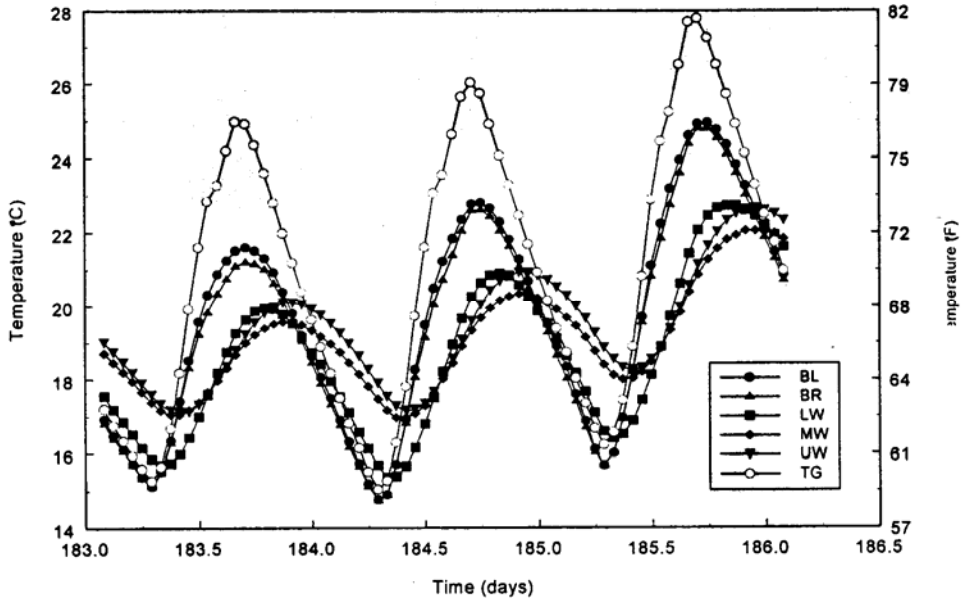


Daily Camber Readings for Span 2

Temperatures:



Seasonal Temperatures at Midspan of Girder 2B



Daily Temperatures at Midspan of Girder 2B

8. OTHER RELATED RESEARCH

Prior to fabricating the production girders, a 20-ft-long test girder was fabricated for the precaster to gain experience with using the HPC mix and for the researchers to gain experience installing the instrumentation under field conditions. Some measurements from the test girders are included in this compilation. Others are available in the project report listed in section 9.

9. SOURCES OF DATA

SHRP High Performance Concrete Bridge Showcase Notebook, Belleview, WA, August 18-20, 1997.

Prussack, C., "Covington High Performance Concrete Bridge," Symposium Proceedings, *PCI/FHWA International Symposium on High Performance Concrete*, New Orleans, LA, Precast/Prestressed Concrete Institute, Chicago, IL, 1997, pp. 515-520.

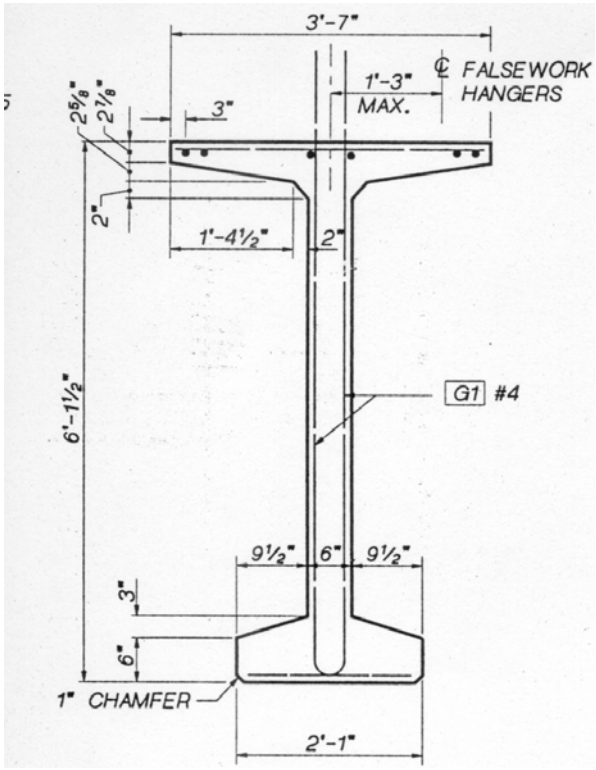
Fekete, E., Barr, P., Stanton, J., Eberhard, M., and Janssen, D., "High Performance Concrete in Washington State SR 18/SR 516 Overcrossing: Interim Report on Material Tests," FHWA, U.S. Department of Transportation, Report No. DTFH71-96-TE036-WA-28, April 2000, 74 pp.

Barr, P., Eberhard, M., Stanton, J., Khaleghi, B., and Hsieh, J. C., "High Performance Concrete in Washington State SR 18/SR 516 Overcrossing: Final Report on Girder Monitoring," Washington State Transportation Center, December 2000, 151 pp.

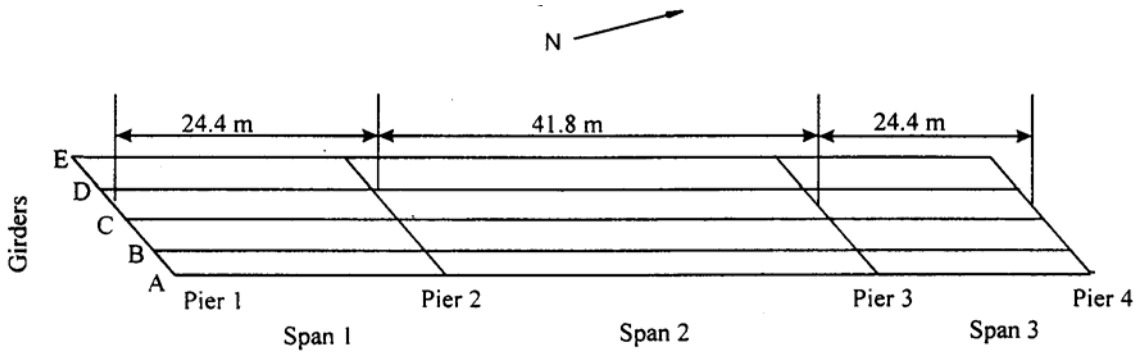
Khaleghi, B. and Weigel, J., "HPC Bridge Decks in Washington State," *HPC Bridge Views*, Issue No. 15, May/June 2001.

Bijan Khaleghi, Washington State Department of Transportation, Olympia, WA.

10. DRAWINGS



WSDOT W74G



Girder Layout

11. HPC SPECIFICATIONS

Prestressed Concrete Girders

Aggregates and Proportioning

The second paragraph of Section 9-19.1 is revised to read as follows:

(*****)
The Contractor shall submit a Contractor-Provided mix design for high performance concrete to the Engineer for approval in accordance with

Section 6-02.3(2)A. The Contractor-Provided mix design for high performance concrete shall conform to the following:

1.	Freeze-Thaw Durability in accordance with AASHTO T 1 161	Report results - for information only
2.	Chloride Permeability in accordance with AASHTO T 277	1000 coulombs max. (56 days)
3.	Minimum Compressive Strength in accordance with AASHTO T 22	10,000 psi (56 days)

The Contractor may substitute testing for minimum compressive strength at 28 days for requirement number 3, provided that the 28 day compressive strength is equal to or greater than 95 percent of the specified 56 day compressive strength.

The Contractor shall test a minimum of three specimens for each of the tests specified. Molds for the freeze-thaw durability test will be supplied to the Contractor by the University of Washington researchers. The test specimens for the chloride permeability and compressive strength tests shall be 4 inch by 8 inch cylinders cast in molds supplied by the Contractor in accordance with Section 6-02.3(5)D. The Contractor shall include the results of all tests in the high performance concrete mix design submittal to the Engineer.

The Contractor shall cast 3 six inch by twelve inch cylinders at the same time as the other mix design test cylinders using the Contractor-Provided mix design, and shall submit these cylinders to the Engineer at least ten days prior to the Contractor's scheduled testing of the four inch by eight inch cylinders. The Contractor shall confirm the Contractor's scheduled testings with the Engineer three days prior to performing the test.

Approval of the mix design will not preclude any requirements for the concrete placed in the girders.

Construction Requirements

(*****)
Section 6-02.3(1) through, 6-02.3(3)D and Section 6-02.3(4)E through 6-02.3(5)M are deleted in their entirety and replaced with the following:

6-02.3(1) Classification of Structural Concrete
The class of concrete to be used shall be as noted in the Plans and these Specifications. The numerical class of concrete defines the specified compressive strength at 28 days. The letter designations following the class of concrete identify specific uses, as follows:

LS for Low Shrink applications
P for Piling applications
W for Underwater applications
D for Deck applications

The Contractor may request, in writing, permission to use a class of concrete with a higher compressive strength than specified. The Contractor shall bear any added costs that result from the change, including the Contracting Agency's cost of preparing and processing any resultant change order(s).

6-02.3(2) Proportioning Materials
The total Chloride ion (Cl-) content of the mixed concrete shall not exceed 0.06 percent of cementitious material for prestressed concrete nor 0.10 percent of

cementitious material for reinforced concrete. Cementitious material shall be the weight of cement plus fly ash and microsillica, if used.

Concrete for bridge decks and bridge approach slabs shall use only Class 1 fine aggregate. Concrete for slip-formed barrier may use Class 1 or 2 fine aggregate.

Unless otherwise specified, the Contractor shall use Type I or II Portland cement in all concrete.

The use of fly ash for all classes of concrete mixes is optional except as specified elsewhere. Fly ash, if used, shall not exceed 25 percent by weight of the total cementitious material in the concrete mix and all concrete within a class in a structure shall have the same proportion of fly ash. The water/cement ratio shall be calculated on the total cementitious material.

As an alternative to the use of cement and fly ash as separate components, a blended hydraulic cement, Type IP(MS) or Type I (PM) (MS), may be used. The blended cement shall be produced such that the maximum fly ash content of the cementitious material is 25 percent.

6-02.3(2)A Contractor-Provided Mix Design

The Contractor shall provide a mix design for all classes of concrete except as specified elsewhere.

For concrete designated as LS (Low Shrink) or concrete designated as W (underwater placement), the maximum water cement ratio shall be 0.38. For concrete Class 5000LS and Class 6000LS, the Contractor-provided mix design water/cement ratio shall not exceed 0.36.

The Contractor's submittal of a mix design shall provide a unique identification for each mix design and shall include the mix proportions per cubic yard and the proposed sources. Concrete placeability, workability, and strength shall be the responsibility of the Contractor. The Contractor shall notify the Engineer in writing of any mix design mass modifications.

Fine aggregate shall conform to Section 9-03.1(2) Class 1 or Class 2

Coarse aggregate shall conform to Section 9-03.1(3), Grading No. 2, 5, or 6, or to Section 9-03.1(4). The nominal maximum size aggregate shall be 3/4 inch for all classes except Class 3000, 4000P, and 4000W. The nominal maximum size aggregate for Class 3000 and 4000W shall be 1-1/2 inches. The nominal maximum size aggregate for Class 4000P shall be 1/2 inch.

Water reducing/retarding admixture for the concrete Class 4000P shall conform to the requirements of Section 9-23.6 Type D. High range water reducing admixtures shall conform to the requirements of Section 9-23.6 Type G.

6-02.3(2)B Commercial Concrete

Where concrete Class 3000 is specified for nonstructural items, such as culvert headwalls, plugging culverts, concrete pipe collars, pipe anchors, luminarie bases, pedestals, cabinet bases, guardrail anchors, sign post foundations, fence post footings, sidewalks, curbs and gutters, the Contractor may use commercial concrete. Commercial concrete shall not be used for bridges, retaining walls, box culverts, or foundations for high mast luminaries, mast arm traffic signals, cantilever signs, and sign bridges. For items not listed, the Contractor may use commercial concrete if approved by the Engineer.

Commercial concrete shall conform to the following:

Cementitious Material, Pounds per Cubic Yard, minimum (Not more then 25 percent. of cementitious material may be fly ash.)	500 pounds
Coarse Aggregate Nominal Maximum Size	1 1/2 inches
Fine Aggregate	Class 1 or 2

Mix design submittal will not be required for commercial concrete. For commercial concrete, the Contractor may use mobile mixers that measure material by volume.

6-02.3(2)C Contracting Agency-Provided Mix Designs
The following mix designs shall be utilized on this project at the locations specified:

The roadway deck of SR 516 O'xing 18/25S:

Concrete Class 4000D	
28 day strength (psi)	4000
Cement (lbs. per cubic yard)	660
Fly Ash (lbs. per cubic yard)	75
Fine Aggregate Class 1 (lbs. per cubic yard)	1100
Course Aggregate #5 (lbs. per cubic yard)	1700
Maximum Water(lbs. per cubic yard)	290
Maximum Water/Cement Ratio	0.39
Percent Air Entrainment	6.0
Water Reducer Type A	Req'd

Aggregate weights are based on a specific gravity of 2.67. Actual Weights will be adjusted for varying specific gravities.

6-02.3(2)D Lean Concrete
Lean concrete shall meet the following requirements:

Ingredients	**Amount per Cubic Yard**
Portland cement	145 to 200 pounds
Fine aggregate Class 1 or 2	3400 pounds

Coarse aggregate may be substituted for up to 50 percent of the fine aggregate.

Slump	6 to 9 inches

If requested by the Contractor, the proportions may be adjusted with the approval of the Engineer.

6.02.3(3) Admixtures
Concrete admixtures shall be added to the concrete mix at the time of batching the concrete or in accordance with the manufacturer's written procedure and as approved by the Engineer. A copy of the manufacturers written procedure shall be furnished to the Engineer prior to use of any admixture. Any deviations from the manufacturer's written procedures shall be submitted to the Engineer for approval. Admixtures shall not be added to the concrete with the modified procedures until the Engineer has approved them in writing.

6-02.3(3)A Compatibility
Admixtures from different manufacturers shall not be used together unless the Contractor provides written documentation verifying that the admixtures are compatible in combination with all other ingredients of the concrete.

6-02.3(3)B Air-Entrainment Admixture

An air entraining admixture shall be used to air entrain concrete. Air entrained cement shall not be used.

6.02.3(3)C Water-Reducing Admixtures
A water reducing admixture shall be used on Contracting Agency provided mixes as listed in Section 6-02.3(2)C.

The Contractor may use a set retarding admixture or a combination water reducer and retardant admixture in all Contractor provided mixes. Use of set retarding or reducer/retarder admixtures in Contracting Agency provided mix designs requires the Engineer's approval.

6-02.3(3)D High-Range Water Reducing Admixture
A high-range water reducer (superplasticizer) may be used in all Contractor provided mix designs. The use of a high-range water reducer shall be submitted as a part of the Contractor's concrete mix design.

The Contractor may request the use of a high range water reducer in Contracting Agency-provided mix designs. If the request is approved, the Contractor shall be responsible for the concrete performance as defined in Section 6-02.3(2)A.

6-02.3(4)E Air-Entrainment
Air content shall be between 4.5 percent and 7.0 percent for all concrete, including commericial concrete, placed above the finished ground line. Air entrained concrete will be permitted for use below finished ground line provided the Contractor assumes responsibility for compressive strength.

6-02.3(5) Acceptance of Concrete

Contractor Quality Control Program

The Contractor shall develop a Quality Control Program (QCP) for the testing and acceptance of the concrete which will be utilized on this project. All testing of the concrete shall be the responsibility of the Contractor. The QCP shall insure that all the concrete placed lies within the specification limits for temperature, slump, air content, aggregate gradation and strength.

This QCP shall include as a minimum the following items:

- The Prime Contractor's QCP shall incorporate the QCPs from subcontractors and suppliers that are involved with the handling, placement and finishing of the concrete.
- Flow chart identifing the steps which will occur while handling the concrete from the hauling conveyance to the forms.
- A scheduled pre-placement meeting with the Contracting Agency, Contractor, sub-contractors, supplier, and other interested parties prior to the beginning of concrete placement.
- The Contractor shall provide an American Concrete Institute (ACI) certified testing Technician - Grade 1, to conduct the required quality control testing. The names and qualifications of the tester(s) shall be submitted two weeks prior to placing of any concrete for review and approval by the Engineer.
- Name(s) of the Contractor's representative who accepts or rejects each load of concrete.
- Handling and transportation methods of the concrete cylinders to the designated testing lab.
- Acknowledgment that the Contractor's tester(s) is subject to review by Contracting Agency Independent Assurance Inspection and/or inspectors from the Project Office.

- Acknowledgement that the Contracting Agency may conduct independent testing of the Concrete at any time during the handling and placing.
- Acknowledgment that the Contracting Agency will control the random selection process for identifying which loads shall be tested as listed in WSDOT Test Method 803 section 4.

The Contractor shall submit the QCP to the Engineer for review and approval a minimun of 14 calendar days prior to the placing of any concrete on the project. The approval will be based on the completeness of the QPC and its incorportation of the Special Provisions and Standard Specifications.

6-02.3(5)A General

All Contractor daily test results and placement records shall be submitted to the Engineer no later than 9:00 A.M. the morning following concrete placement. The required information shall include a placement summary sheet and a certificate of compliance for each load of concrete that is delivered. The placement summary sheet shall contain, as a minimum, the information shown on the example in Appendix B.

Concrete which does not meet the requirements of section 6-02.3(4) shall not be placed.

Concrete made in accordance with a Contractor-provided mix design will be accepted based on conformance to the requirement for temperature, slump, air content for concrete placed above finished ground line and the specified compressive strength at 28 days for each sublot.

A sublot is defined as the material represented by an individual strength test. An individual strength test is the average compressive strength of two (2) cylinders from the same sample of material.

Each sublot will be deemed to have met the specified compressive strength requirement when both of the following conditions are met:

1. Individual strength tests do not fall below the specified strength by more than 12 1/2 percent or 500 psi whichever is least.
2. An individual strength test averaged with the two preceding individual strength tests meets or exceeds the specified strength. (For the same class of concrete on the same contract)

When compressive strengths fail to satisfy the above requirements, the Contractor may:

1. Request acceptance, based on the average of Contracting Agency strength data and Contractor/Suppliers test data for the same sublots where the Contractor's results are obtained from an accredited lab, testing cylinders cured under standard conditions for 28 days, and cylinders were fabricated by an ACI certified technician from samples obtained from the same truckload of concrete,

2. Request acceptance of in-place concrete strength based on core results. This method shall not be used if the Engineer determines coring would be harmful to the integrity of the structure. Cores, if allowed, shall be obtained by the Contractor in accordance with AASHTO T 24 and delivered to the Contracting Agency for testing in accordance with AASHTO T 22. If the concrete in the structure will be dry under service conditions, the core shall be air dried at a

temperature 6OF to 80F, and at a relative humidity of less than 60 percent, for seven days before testing and will be tested air dry.

Acceptance for each sublot by the core method requires that the average compressive strength of three cores be at least 85 percent of specified strength with no one core less than 75 percent of specified strength. When the Contractor requests strength analysis by coring, the results obtained will be accepted by both parties as conclusive and supersede all other strength data for the concrete sublot.

If the Contractor elects to core, cores shall be obtained no later than 56 days after initial concrete placement. The Contractor shall drill cores at locations approved by the Engineer. Repair of cored areas shall be the responsibility of the Contractor. The cost incurred in coring, including repair of core locations, shall be borne by the Contractor.

Lean concrete and commerical concrete will be accepted based on a Certificate of Compliance, to be provided by the concrete supplier as described in Section 6-02.3(5)B.

Concrete made in accordance with a Contracting Agency-provided mix design will be accepted based on conformance to the specified requirements for proportioning, temperature, cement factor, air content for concrete placed above finished ground line, slump and its 28 day compressive strengths.

6-02.3(5)B Certification of Compliance

The concrete supplier shall provide a Certificate of Compliance for each truckload of concrete. The Certificate of Compliance shall verify that the delivered concrete is in compliance with the mix design and shall include:

Manufacturer Plant (Batching Facility)
Contracting Agency Contract No.
Date
Time Batched
Truck No.
Initial Revolution Counter Reading
Quantity (Quantity batched this load)
Type of concrete by class and producer design mix number
Cement Producer, Type, and Mill Certification No. (The mill test number as required by Section 9-01.3 is the basis for acceptance of cement.)
Fly Ash,(if used) Brand, Type and Plant of Manufacture
Approved aggregate gradation designation
Mix Design weights per cubic yard and actual batched weights for:

- Cement
- Fly Ash (if used)
- Coarse Concrete Aggregate and moisture content (each size)
- Fine Concrete Aggregate and moisture content
- Water (including free moisture in aggregates)
- Admixtures brand, quantity per/100 wt., and total quantity batched
  - Air-Entraining Admixture
  - Water Reducing Admixture
  - Other Admixture

The Certificate of Compliance shall be signed by a responsible representative of the concrete supplier, other than the driver, affirming the accuracy of the information provided. The Certificate of Compliance shall be a machine produced record containing all of the above information and shall be produced in conformance with the Contractors written QCP.

6-02.3(5)C Conformance to Mix Design

Aggregate masses shall conform within plus or minus 2 percent of the weights for coarse or fine aggregate required by the mix design. The total cementitious material weight shall conform within plus or minus 1 percent of the mix design mass. If the total cementitious material weight made up of different components these component weights shall be within the following tolerances:

1. Portland cement material weight shall conform within plus or minus 1 percent of the mix design weight
2. Fly ash material weight shall conform within plus or minus 5 percent of the mix design weight
3. Microsilica material weight shall conform within plus or minus 10 percent of the mix design weight

Water measured by volume or weight shall conform within plus or minus 1.5 percent of the mix design amount but shall, in no case, exceed the maximum water specified in the mix design.

6-02.3(5)D Test Methods

Quality control testing shall be performed by the Contractor, except the 28 day compressive strength test of the concrete cylinders, in accordance with WSDOT Standard Test Methods as set forth in the WSDOT Laboratory Manual. WSDOT Standard Test Methods to be used with this specification are:

104 Method of Test for Sieve Analysis of Fine and Coarse Aggregates
801 Method of Test for Compressive Strength of Molded Cylinders
803 Method of Sampling Fresh Concrete
804 Method of Test for Slump of Portland Cement Concrete
805 Method of Test for Determination of percent of Entrained Air in Portland Cement Concrete
806 Method of Test for Weight Per Cubic Foot and Cement Factor of Concrete
809 Method of Making, Handling, and Storing Concrete Compressive Test Specimens in the Field
811 Method of Capping Cylindrical Concrete Specimens

A copy of these test methods is included in Appendix B.

The test cylinder molds shall conform to AASHTO M 205, either for reusable steel or plastic molds, or for single use molds, except that paper or cardboard molds shall not be used.

The Engineer may observe any of the sampling and testing performed by the Contractor. If the Engineer observes a deviation from the specified sampling or testing procedures, the Engineer will verbally describe the deviations observed to the Contractor or designated representative immediately. The Contractor shall immediately modify their sampling or test procedure to conform to the method of test as listed in Appendix B.

6-02.3(5)E Point of Placement

Determination of concrete properties for placement shall be made based on samples taken as follows:

- Bridge decks, overlays, and barriers at the discharge of the placement system.
- All other placements at the truck discharge.

It shall be the Contractor's responsibility to provide adequate and representative samples of the fresh concrete for the testing of concrete

properties and making of cylinder specimens. Samples shall be provided as directed in Sections 1-06.2.

6-02.3(5)F WaterlCement Ratio Conformance

The actual water cement ratio shall be determined from the certified proportions of the mix, adjusting for on the job additions. No water may be added after acceptance testing or after placement has begun, except for concrete used in slip forming. For slip-formed concrete, water may be added during placement but shall not exceed the maximum water cement ratio in the mix design, and shall meet the requirements for consistency as described in Section 6-02.3(4)C. If water is added, an air and temperature test shall be taken prior to resuming placement to ensure that specification conformance has been maintained.

6-02.3(5)G Sampling and Testing Frequency

Concrete properties shall be determined from concrete as delivered to the project and as accepted by the Contractor for placement. The Contractor shall test for placement of concrete for slump, temperature, cement factor, air content and aggregates as follows:

Sampling and testing shall be performed before concrete placement from the first truck load. Concrete shall not be placed until tests for slump, temperature, and entrained air and cement factor have been completed by the Contractor and the results indicate that the concrete is within acceptable limits. Except for the first load of concrete, up to 1/2 cubic yard may be placed prior to testing for placement. Sampling and testing shall continue for each load until two successive loads meet all applicable placement test requirements. After two successive tests indicating that the concrete is within specified limits, the sampling and test frequency may decrease to one for every five truck loads. Loads to be sampled, by the Engineer, will be selected in accordance with the random selection process as outlined in WSDOT Test Method 803 Section 4.

When the results for any subsequent acceptance test indicates that the concrete as delivered and approved by the Contractor for placement does not conform to the specified limits, the sampling and testing frequency shall be resumed for each truck load. Whenever two successive subsequent tests indicate that the concrete is within the specified limits, random sampling and testing frequency at one for every five truck loads may resume.

Sampling and testing for a placement of one class of concrete consisting of 40 cubic yards or less shall be as listed above, except:

- Sampling and testing shall continue until one load meets all of the applicable acceptance requirements, and
- After one set of tests indicate that the concrete is within specified limits, the remaining concrete to be placed may be accepted by visual inspection.

Fine aggregate shall be sampled and tested at a rate of one gradation test for each 500 tons or portion thereof.

Coarse aggregate shall be sampled and tested at the rate of one gradation test for each 1000 tons or portion thereof.

6-02.3(5)H Sampling and Testing for Compressive Strength

CONTRACTOR PROVIDED MIX DESIGN

Acceptance testing for compressive strength for concrete produced in accordance with a Contractor-provided mix design shall be conducted at the

same frequency as the placement tests for temperature, consistency, and air content.

CONTRACTING AGENCY PROVIDED MIX DESIGN
For concrete produced in accordance with a Contracting Agency-provided mix design, compressive strength tests specimens shall be made at a frequency of approximately every five truck loads. Specimens for compressive strength testing shall only be made from concrete that is accepted for placement.

All concrete cylinders for the 28 day compressive strength test will be tested by the WSDOT Materials Lab. The Contractor shall be responsible for making, curing, protecting, transporting and delivering the cylinders to the Materials Lab. Delivery will only be accepted Monday through Friday 7:00 A.M. until 3:00 P.M. The contact person and location of the Materials Lab is:

Bob MacPherson
6431 Corson Avenue South BLDG #13
Seattle, WA 98108-9710
Phone: (206) 768-5901

6-02.3(5)K Rejecting Concrete
Rejection by Contractor—The Contractor may, prior to sampling, elect to remove any defective material and replace it with new material at the Contractor's expense. Any such new material will be sampled, tested, and evaluated for placement.

Rejection Without Testing—The Engineer may reject any batch or load of concrete that appears defective in composition, such as cement content or aggregate proportions. Rejected material shall not be incorporated in the project.

6-02.3(5)L Concrete With Non-Conforming Strength (Contractor Design or Commercial)
Concrete produced in accordance with a Contractor-provided mix design or Commercial Concrete with cylinder compressive strengths (fc) which fails to meet acceptance level requirements shall be evaluated for structural adequacy. If the material is found to be adequate, payment will be adjusted in accordance with the following formula:

Pay Adjustment = [2(f'c-fc)(UP)(Q)] / f'c

where f'c = Specified minimum compressive strength at 28 days
fc = Compressive strength at 28 days as determined by WSDOT Test Methods.
UP = Unit contract price per cubic yard for the class of concrete involved.
Q = Quantity of concrete represented by an acceptance test based on the required frequency of testing.

Where these Specifications designate payment for the concrete on other than a per cubic yard basis, the unit contract price of concrete shall be taken as $390 per cubic yard for concrete Class 4000, 5000, and 6000. For concrete Class 3000, the unit contract price for concrete shall be $210 per cubic yard.

Concrete that fails to meet minimum acceptance levels using the coring method will be evaluated for structurally adequacy. If the material is found to be adequate, payment shall be adjusted in accordance with the following formula:

$$\text{Pay Adjustment} = \frac{3.56(0.85f'c - fc\text{-}cores)(UP)(Q)}{f'c}$$

where f'c = Specified minimum compressive strength at 28 days.
fc-cores = Compressive strength of the cores as determined by AASHTO T 22 Method.
UP = Unit contract price per cubic yard for the class or concrete involved.
Q = Quantity of concrete represented by an acceptance test based on the required frequency of testing.

Where these Specifications designate payment for the concrete on other than a per cubic yard basis, the unit contract price of concrete shall be taken as $390 per cubic yard for concrete Class 4000, 5000 and 6000. For concrete Class 3000, the unit contract price for concrete shall be $210 per cubic yard

6-02.3(5)M Concrete With Non-Conforming Strength (Contracting Agency Provided)

Contracting Agency-provided mix design concrete placed in conformance with the specifications which fails to meet the specified 28-day compressive strength (f'c) will be evaluated by the Engineer for acceptance.

The Engineer and the Contractor shall review all the production records, the concrete supplier's Certificates of Compliance, test records, field notes, and the placement records for the concrete in question. If the review confirms that the concrete as produced and placed conforms to the specified requirements, the Contracting Agency will accept the concrete. If, however, the review indicates that the concrete was not produced within the specified requirements and/or was not placed in accordance with the specifications, the concrete in question will be evaluated as concrete, with non-conforming strength in accordance with Section 6-02.3(5)L. The Contractor has the opportunity to supply additional information related to the actual 28 day compressive strength.

Section 6-02.3 is supplemented with the following:

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High Performance Concrete Test Girder

The Contractor shall construct high performance concrete test girders, including cast-in-place concrete deck, as shown in the Plans.

The Contractor shall fabricate the prestressed concrete girders using the Contractor-Provided mix design for high performance concrete in accordance with Sections 6-02.3(2)A and 9-19, and as approved by the Engineer.

The Contractor and prestressed concrete girder fabricator shall allow access before, during, and after girder fabrication and casting for installing girder instrumentation devices by the University of Washington researchers. The conceptual instrumentation plan for the girders is shown in Appendix A, and is presented for the Contractor's information only. The Contractor shall take extreme care to prevent damage to all installed instrumentation devices during all fabrication, storage, and transportation operations, especially while placing and vibrating concrete in the forms. The Contractor shall include a plan with the girder shop plan submittal, as specified in Section 6-02.3(25)A, describing the construction methods to be used and precautions to be enforced to protect all instrumentation during all construction operations.

To ensure complete coordination for the girder instrumentation and testing by the University of Washington researchers, the Contractor shall advise the Engineer of the production schedule for the high performance concrete test girders, including the scheduled prestressed strands release date, in accordance with Section 6-02.3(25).

The Contractor shall place the cast-in-place concrete deck on the girders after releasing the prestressed strands. The Contractor shall cure the cast-in-place concrete deck using two coats of curing compound, conforming to Section 9-23.2, in accordance with Section 6-02.3(11).

The Contractor shall cast sufficient test specimens and cylinders from the same load of concrete used for the appropriate girder and deck, in addition to those required for compressive strength acceptance testing, as follows to provide for additional testing by the University of Washington researchers:

Girder No. 1

Prestress strand pullout block (per Plans)	1
6 inch by 12 inch cylinders (Girder)	34
3 inch by 4 inch by 16 inch beams (Girder)	3
6 inch by 12 inch cylinders (Deck)	8
3 inch by 4 inch by 16 inch beams (Deck)	5

Girder No. 2

6 inch by 12 inch cylinders	12

The Contractor shall furnish molds for all test specimens and cylinders in accordance with Section 6-02.3(5)D, except that molds and guage studs for the 3 inch by 4 inch by 16 inch beams will be supplied to the Contractor by the University of Washington researchers. The Contractor shall consolidate the concrete in all molds in accordance with AASHTO T 23. Except as otherwise specified, the Contractor shall cast, handle, and store all test specimens and cylinders in accordance with WSDOT Test Methods 803, 809, and 811 as specified in Appendix B.

The prestress strands placed in the prestress strand pullout block shall be from the same reel of prestressing strand used in Girder No. 1.

The Contractor shall label each of the test specimens and cylinders by deck or by girder number, and shall also label the girders by girder number. The Contractor shall match cure each of the test specimens and cylinders with the girders in accordance with Section 6-02.3(25)E.

The Contractor is advised that, after removing the forms but before the prestressed strands are released on a girder specified for instrumentation, the University of Washington researchers will require safe access to install instruments and perform measurements, as specified in Appendix A. The Contractor is further advised that, after releasing the prestressed strands and before removing the girder from the casting bed, the University of Washington researchers will require safe access to monitor instruments and perform measurements, as specified in Appendix A.

After releasing the prestressed strands, the Contractor shall deliver all test specimens and cylinders corresponding to that girder to the Department of Civil Engineering Structures Research Laboratory on the University of Washington campus in Seattle, Washington. The Contractor shall contact the Project Engineer at least five working days prior to the scheduled releasing of the prestressed strands to coordinate delivery of the test specimens and cylinders.

After casting and curing the cast-in-place concrete deck on the high performance concrete test girders, the Contractor shall transport the girders, and all remaining test specimens and cylinders for the deck, to the Department of Civil Engineering Structures Research Laboratory on the University of

Washington campus in Seattle, Washington. The Contractor shall contact the Project Engineer at least five working days prior to the anticipated delivery date to coordinate the delivery. The Contractor shall deliver the high performance concrete test girders to the test facility on or after October 1, 1996, but before January 1, 1997.

After the completion of all tests, the high performance concrete test girders and the prestress strand pullout block shall become the property of the Contractor, and shall be disposed of within 14 calendar days of the completion of all tests as specified in Section 2-02.3(1),

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SR 516 O'xing 18/25S Field Research Activities by Others

The Contractor is advised that the SR 516 O'xing 18/25S is part of a research project conducted in part by the University of Washington. In addition to allowing access to the University of Washington researchers for installing instrumentation devices, taking measurements, and furnishing test specimens and cylinders as specified elsewhere in the Special Provisions and Appendix A for the prestressed concrete girders and roadway slab, the Contractor shall:

1. Allow the researchers access to the construction site and to construction records to document construction activities related to the research.
2. Allow access to the bridge for installing instrumentation devices and cables, and data acquisition equipment by the researchers.
3. Furnish an on-site location adjacent to an end pier, subject to the approval of the Engineer, for storage of the data acquisition equipment.
4. Allow the researchers access before, during, and after erecting the prestressed concrete girders and placing the roadway slab to the instrumentation and data acquisition equipment for completing installation, documenting measurements, and inspecting instrumentation.
5. Furnish an electric power supply to the data acquisition equipment and associated lighting.
6. Remove heavy construction equipment from the roadway deck when instrument readings are being taken.

The conceptual instrumentation plan, and a description of the research activities, is shown in Appendix A and is presented for the Contractor's information only.