Darex Corrosion Inhibitor

Niawiakum River Bridge 101/42 and Palix River Bridge 101/40 Replacement

WA-RD 279.1

Post Construction Report
August 1992

Washington State Department of Transportation
Washington State Transportation Commission
Department of Transportation in cooperation with
U.S. Department of Transportation
Federal Highway Administration

WASHINGTON STATE DEPARTMENT OF TRANSPORTATION

TECHNICAL REPORT STANDARD TITLE PAGE

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Tom H. Roper and Edward H. Henley, Jr.

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Washington State Department of Transportation
Transportation Building
Olympia, WA 98504

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Same

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15. SUPPLEMENTARY NOTES
The study was conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration.

16. ABSTRACT
The Niawiakum River Bridge 101/42 and the Palix River Bridge 101/40 are located on Sign Route 101, within the tidal zone of Willapa Bay. These bridges are subject to continuous salting from the Pacific Ocean water and mist. The bridges will be used as a test site to determine the effectiveness of the concrete admixture Darex Corrosion Inhibitor (DCI) in preventing the corrosion of reinforcing steel in concrete.

DCI is a patented product containing calcium nitrite; manufactured and supplied by W. R. Grace & Co., Inc. DCI, used in sufficient quantities as a concrete admixture, purportedly strengthens the passivating film around the reinforcing steel, thereby preventing corrosion.

The effectiveness of DCI in preventing corrosion will be determined by comparison with control sections located in members of each bridge. The control members were constructed without the DCI admixture. All reinforcement in the control and experimental members is uncoated, and has the same minimum cover requirements as in the DCI-treated members.

The purpose of this experimental project is to assess the long-term effectiveness of DCI as a corrosion inhibitor.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Concrete additives, corrosion inhibitors, calcium nitrite, rebar corrosion protection	

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	18	

DOT FORM 310-022 (11/86) -1216-

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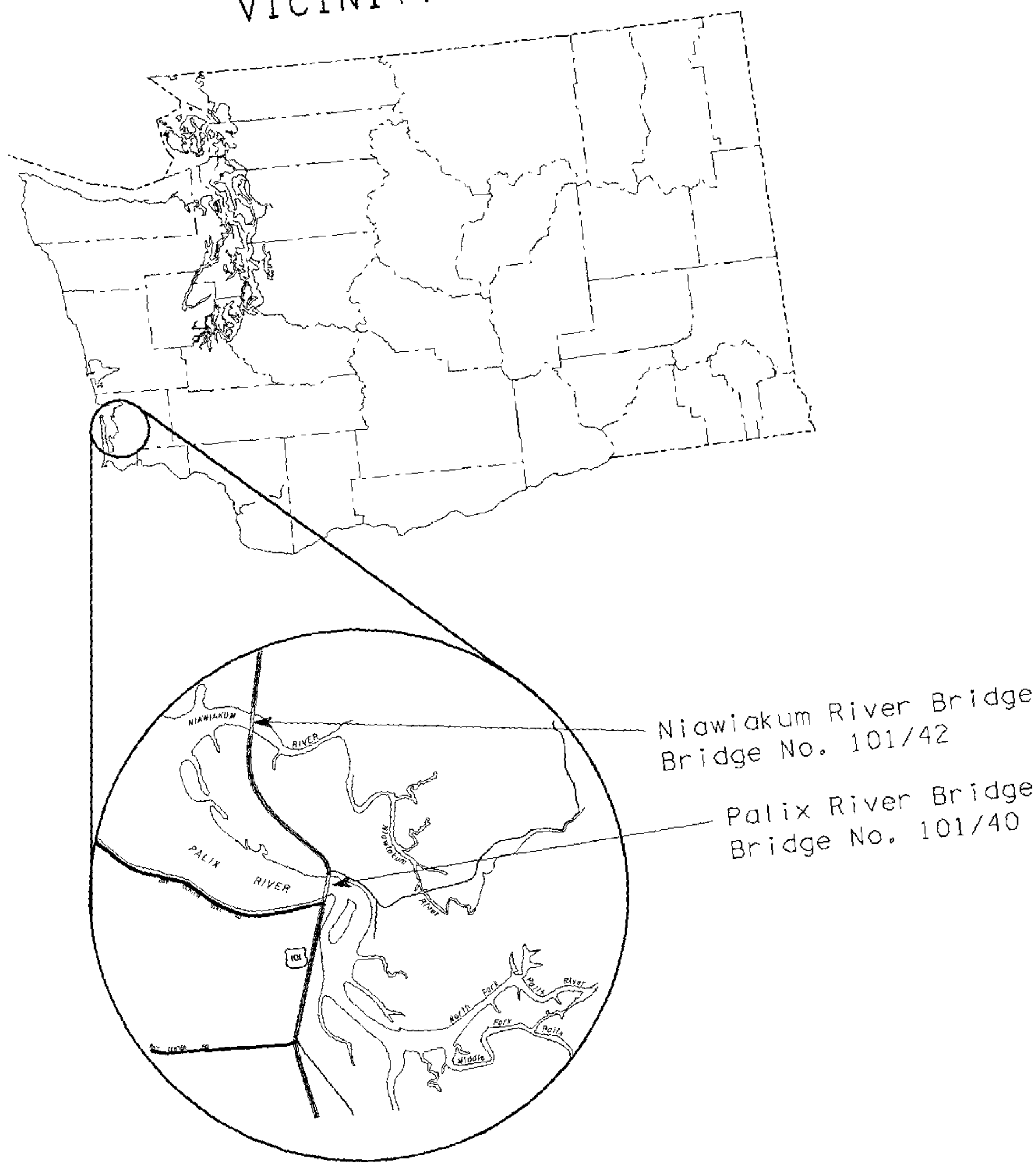
VICINITY MAP



PROJECT SITE

INTRODUCTION

Marine environments can accelerate corrosion of reinforcing steel in concrete structures. Salt water, spray, and salt-laden air in these environments can introduce chlorides into the concrete structures. Chloride contamination in concrete destroys the passivating film around the reinforcing steel, and provides a favorable environment for the development of corrosive anode-cathode relationships on the surface of the steel. The salt and moisture in the concrete serve as the electrolyte. Reinforcing steel will corrode at the anode, with rust expanding and cracking the concrete. Spalls and delamination occur in the concrete, with resulting deterioration. Epoxy coating is being used to protect deformed reinforcing steel. However, a system is needed to protect prestressing steel from chloride-induced corrosion.

Tests in controlled environments have shown Darex Corrosion Inhibitor (DCI) to be effective in preventing the corrosion of reinforcing steel in chloride contaminated concrete. DCI is a patented product containing calcium nitrite, manufactured and supplied by W. R. Grace & Co., Inc. DCI, used in sufficient quantities as a concrete admixture, purportedly strengthens the passivating film around the reinforcing steel, thereby preventing corrosion.

The purpose of this experimental feature project is to assess the long-term effectiveness of DCI as a corrosion inhibitor. The practical application of DCI to precast, prestressed concrete will also be evaluated.

NIAWIAKUM RIVER BRIDGE 101/42

Study Site

This project is located on Sign Route 101, within the tidal zone of Willapa Bay. The existing timber trestle and steel bridge was replaced with a prestressed concrete girder bridge. The structure has 23 spans of approximately 60 feet each (1,375 feet total length) and is 36 feet wide. The superstructure has prestressed double-tee girders throughout. The substructure has 24-inch diameter cast-in-place concrete piles, with concrete crossbeams. The DCI was used in the double-tee girders, the crossbeams, and the piling concrete.

The effectiveness of DCI in preventing corrosion will be determined by comparison with control sections located in several girders, crossbeams, and piles, which were constructed without the DCI admixture. All reinforcement in the control and experimental members is uncoated and has the same minimum cover requirements as in the DCI-treated members. Electric lead wires were installed in a number of the treated members and in all the control members to facilitate future half cell monitoring of the corrosion potential of the reinforcing steel.

DCI was added into the concrete mix used in all experimental piles (minimum from 25' below ground to top), all experimental crossbeams, and all experimental double-tee girders, in accordance with the manufacturer's (W. R. Grace & Co., Inc.) specifications. The locations of the bridge components selected for this test program are as follows:

Component	Location	Min. DCI Req'd (gal./cu. yd.)
Control Piles	All 5 piles @ Piers 4, 5, 14, & 15	None
Control Crossbeams	All crossbeams @ Piers 4, 5, 14, & 15	None
Control Girders	Girders 3A, 5A, 13A, 15A, 4E, & 14E	None
Experimental Piles	All piles except @ Piers 4, 5, 14, & 15	5.4
Experimental Crossbeams	All crossbeams except @ Piers 4, 5, 14, & 15	4.0
Experimental Girders	All girders except 6 exterior control girders (1 each in spans 3, 4, 5, 13, 14, 15)	4.0

Installation Procedures

All concrete for piling and crossbeams was placed using a crane with a 1.5 cu. yd. bucket with tremie pipe. DCI was added to the concrete at the plant; approximately 20 minutes from the jobsite.

Placement of DCI concrete began August 5, 1990. No concrete was placed December 30, 1990, through February 15, 1991, as the contractor was completing the steel shell pile driving. DCI concrete placement was completed on April 5, 1991.

Approximately 8,150 gallons of DCI were used in the Niawiakum River Bridge.

Construction Problems

The concrete supplier, Dennis Company, had a quality control representative on the project to test material and adjust as necessary.

In the beginning of the project, the supplier's quality control was extremely lax (no air tests run prior to placing load; slump test was not rerun after making adjustment; etc.). Also, very poor judgment was used by the person performing quality control when making adjustments to the mix (adjusting for air content by adding air entraining agent without taking into account the effect of increased slump on air content when slump was also being adjusted; adding water in three to four small increments and mixing between each rather than making a single adjustment; etc.). Use of DCI compounded the supplier's quality control problems, as neither the contractor nor the supplier was prepared for the accelerating effect of the DCI. With time, quality control procedures improved.

Several problems were encountered on this project as a result of the accelerant effect of DCI on concrete set time. The problems encountered are as follows:

1) Rapid loss of slump (3-3/4 inches in 1 hour) was noted in the concrete containing DCI. This made proper concrete placement and consolidation difficult to achieve. Warm ambient temperatures (70° F) amplified the slump problems by accelerating the set of the concrete.

2) Contractor contended that excessive concrete buildup occurred in the drum of the concrete trucks due to the accelerated set time of the DCI concrete. This caused problems with achieving adequate mixing of the concrete and additional expense for cleaning the trucks. This problem appeared to resolve itself when the contractor began washing out the drum immediately after emptying.

3) The project engineer was advised by W. R. Grace & Co., Inc., the manufacturer of DCI, that the use of warm water in mixing concrete to achieve minimum 60° F concrete in cold weather may cause the concrete with DCI to

flash set. W. R. Grace & Co., Inc., had no recommendation for mitigating this effect. A change order was issued to allow a deviation in the minimum temperature for concrete placement from 60° F to 50° F.

Literature was available from W. R. Grace & Co., Inc., regarding expected slump loss vs. time at various temperatures. This literature also provided a recommended dosage of water-reducer retarder required to counteract the effect of DCI on slump. However, per discussions with the contractor, he was apparently not aware of this information prior to the beginning of placement of the DCI concrete, and had not allowed sufficient money in his bid to cover the cost of the admixtures required to counteract the DCI. The problems, as noted in 1 and 2 above, may have been greatly reduced, or possibly eliminated, had the contractor and supplier been aware, at the time of the bid, of the effect of DCI and the measures required to mitigate this effect.

To offset the set acceleration effect of the DCI, the contractor elected to add W. R. Grace & Co., Inc.'s water-reducing retarder, Daratard No. 40 (or on some occasions Daratard No. 17), to the concrete at no additional expense to the state (5 to 8 oz. per 100 lb. of cement).

There were no reported problems with loss of slump or the set acceleration effect of DCI with the concrete in the precast units manufactured in precast yards.

Acceptance Testing

No acceptance testing of the DCI was required by the special provisions. DCI was added to the concrete in accordance with the manufacturer's recommendations and the amount per cubic yard required by the special provisions.

No special chemical tests were performed on the DCI or the concrete. The normal concrete tests for slump, air, yield, and compressive strength were performed.

A manufacturer's certificate ticket is given to the project engineer's office, certifying the contents of the concrete. Spot checks at the plant, by a state inspector, are routinely done to check the contents of the concrete.

Conclusions and Recommendations

It would have been extremely helpful if information on DCI and its effect on concrete had been made available to the project engineer's office. This information would have allowed the project engineer to deal with the contractor's concerns more quickly and efficiently. Also, some of the problems encountered could have been anticipated and, possibly, reduced.

There is some concern about the applicability of DCI in this area, due to its limitations in cold weather.

PALIX RIVER BRIDGE 101/40

Study Site

This project is located on Sign Route 101, within the tidal zone of Willapa Bay. The existing timber trestle and steel bridge across the Palix River was replaced with a prestressed concrete girder bridge. The structure has eight spans of approximately 124 feet each (997 feet total length) and is 36 feet wide. The seven intermediate piers consist of 4-foot diameter cast-in-place concrete shafts.

DCI was added to all the shafts in Pier 5, and to all the girders in all spans except the control girders in Spans 4, 5, and 6. DCI was added to the concrete members in amounts recommended by the manufacturer. W. R. Grace & Co., Inc., recommended minimum doses of DCI of 5.4 gal./cu. yd. for the shafts and 3.6 gal./cu. yd. for the girders. Reinforcement in the control and experimental shafts was uncoated and has normal concrete cover. Reinforcement in all the girders was uncoated and has the normal minimum cover. Plans and specifications also required the installation of electrical lead wires to the experimental and control section members in Piers 5 and 6, and Spans 4, 5, and 6, with connections to an easily accessible junction box for future half cell monitoring.

The effectiveness of DCI in preventing corrosion will be determined by comparison with control members located in the shafts of Pier 6, the upstream (east) girder in Span 5, and the downstream (west) girders in Spans 4 and 6.

DCI was added into the concrete mix used in all experimental shafts and experimental girders in accordance with the manufacturer's specifications. The locations of the bridge components selected for this test program are as follows:

Component	Location	Min. DCI Req'd (gal./cu. yd.)
Control Shafts	All 3 shafts @ Pier 6	None
Control Girders	Girders 4A, 5E, & 6A	None
Experimental Shafts	All 3 shafts @ Pier 5	5.4
Experimental Girders	All girders except control girders	3.6

Installation Procedures

Concrete for shafts inside the steel casing was placed using a concrete pump. Concrete for shafts above the steel casing and pier cap was placed using a crane and bucket. DCI was added to the concrete at the batch plant; approximately five minutes from the jobsite.

Concrete placement at Pier 5 began on November 13, 1990. Concrete placement for the shafts and cap was completed on January 23, 1991. Time for this work was extended by 6 weeks due to problems with voids in the shafts.

Approximately 3,750 gallons of DCI were used in the Palix River Bridge.

Construction Problems

Concrete placement on this project should have preceded concrete placement on the Niawiakum River Bridge project. However, due to problems with constructing the foundation, concrete placement using DCI on the Niawiakum project was well under way prior to beginning concrete placement with DCI on this project. As a result, the project engineer was aware of the potential problems with using DCI, and could offer the contractor advice on offsetting the accelerant effect of the DCI.

A problem with excessive voids in the shafts was encountered. The contractor chose to form the shaft above the elevation specified for removal of the steel casing. Once the shaft concrete was pumped into place, the forms were removed. At this time, voids in the shaft concrete were discovered. They covered up to 80 percent of the shaft circumference, as much as 1 foot into the shaft, and extended the length of the formed shaft down several feet into the area of the shaft encased in the steel casing.

There were no change orders directly related to using DCI on this project.

Acceptance Testing

No acceptance testing of the DCI was required by the special provisions. DCI was added to the concrete in accordance with the manufacturer's recommendations and the amount per cubic yard required by the special provisions.

No special chemical tests were performed on the DCI or the concrete. The normal concrete tests for slump, air, yield, and compressive strength were performed.

A manufacturer's certificate ticket is given to the project engineer's office, certifying the contents of the concrete. Spot checks by a state inspector at the plant are routinely done to check the contents of the concrete.

Conclusions and Recommendations

There does not appear to be a problem during construction in using DCI in concrete, as long as the personnel are aware of the set accelerant effect and compensate accordingly.

APPENDIX A

TEST PLAN

Niawiakum River Bridge Replacement
Experimental Feature

DAREX CORROSION INHIBITOR

TESTING AND ANALYSIS COSTS

Responsible Unit	Work Item	Post-Construction	Year[1] 3	6	9	12	15	Total
HQ ML[2]	Half Cell Tests		2 hrs $ 670	2 hrs $ 844	2 hrs $ 1,063	2 hrs $ 1,340	2 hrs $ 1,688	$ 5,605
HQ ML	Chloride Testing		3 hrs $ 1,005	3 hrs $ 1,266	3 hrs $ 1,595	3 hrs $ 2,010	3 hrs $ 2,531	$ 8,407
HQ ML	Delam Survey		3 hrs $ 1,005	3 hrs $ 1,226	3 hrs $ 1,595	3 hrs $ 2,010	3 hrs $ 2,531	$ 8,407
HQ Bridge Office	Visual Observation		2 hrs $ 670	2 hrs $ 844	2 hrs $ 1,063	2 hrs $ 1,340	2 hrs $ 1,688	$ 5,605
HQ ML	Rebar Depth		2 hrs $ 670					$ 670
HQ Bridge Office[3]	Analysis and Report Writing	8 hrs $ 220	8 hrs $ 277	8 hrs $ 349	8 hrs $ 439	8 hrs $ 554	40 hrs $ 3,489	$ 5,328
	TOTALS	$ 220	$ 4,297	$ 4,569	$ 5,755	$ 7,254	$11,927	$34,022
	Total Contract Funding	$ 220						-220
					Total Experimental Project Funding			$33,802

(1) 8 percent annual inflation rate assumed.

(2) Headquarters Materials Lab time and equipment at $226/hour. This cost includes the use of the Under Bridge Inspection Vehicle with a driver and traffic control.

(3) Headquarters Bridge Office time at $27.50/hour.

Palix River Bridge Replacement
Experimental Feature

DAREX CORROSION INHIBITOR

TESTING AND ANALYSIS COSTS

Responsible Unit	Work Item	Post-Construction	Year[1] 3	6	9	12	15	Total
HQ ML[2]	Half Cell Tests		2 hrs $ 670	2 hrs $ 844	2 hrs $ 1,063	2 hrs $ 1,340	2 hrs $ 1,688	$ 5,605
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	TOTALS	$ 220	$ 4,297	$ 4,569	$ 5,755	$ 7,254	$11,927	$34,022
	Total Contract Funding	$ 220						-220
				Total Experimental Project Funding				$33,802

(1) 8 percent annual inflation rate assumed.

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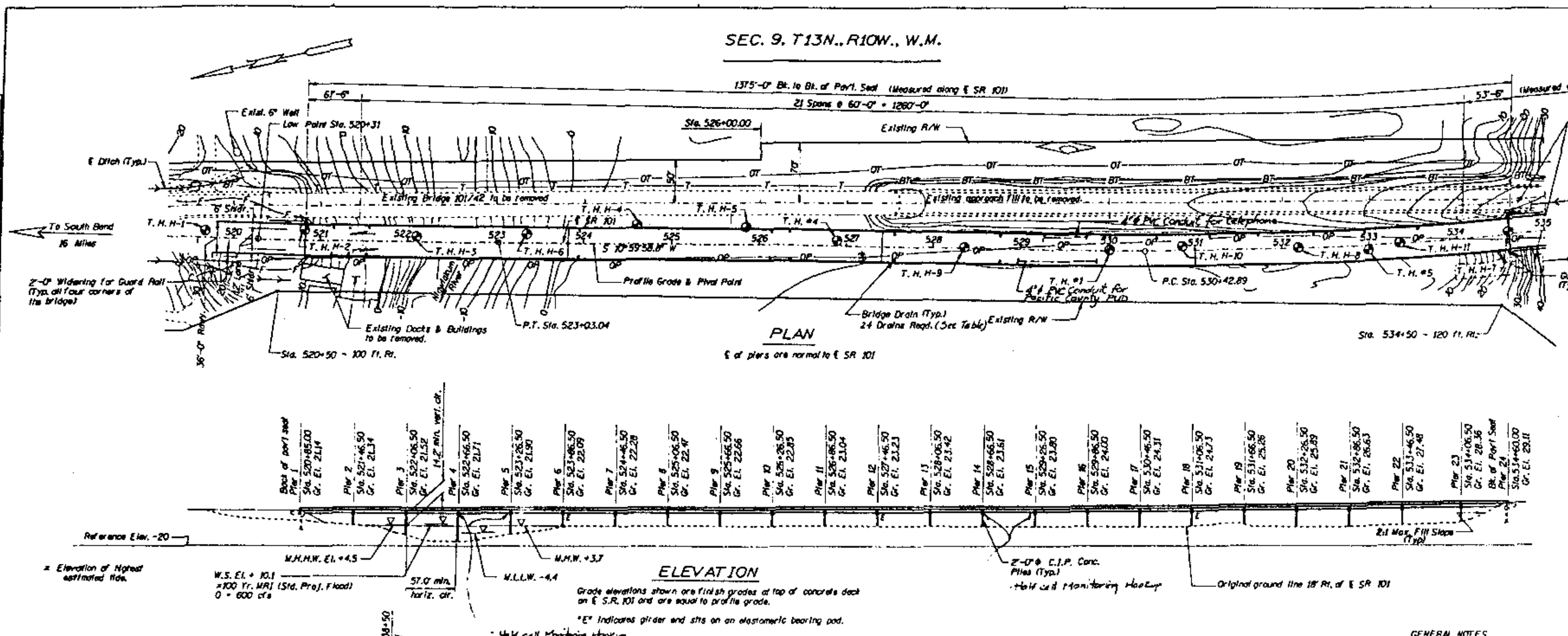
(3) Headquarters Bridge Office time at $27.50/hour.

APPENDIX B

GENERAL LAYOUTS

SEC. 9, T13N., R10W., W.M.



BRIDGE DRAIN LOCATIONS		
STATION	CURB LINE	
521+16	LEFT	RIGHT
521+36	LEFT	RIGHT
521+56	LEFT	RIGHT
525+96	LEFT	RIGHT
526+16	LEFT	RIGHT
526+86	LEFT	RIGHT
527+56	LEFT	RIGHT
528+76	LEFT	RIGHT
529+56	LEFT	—
529+96	LEFT	—
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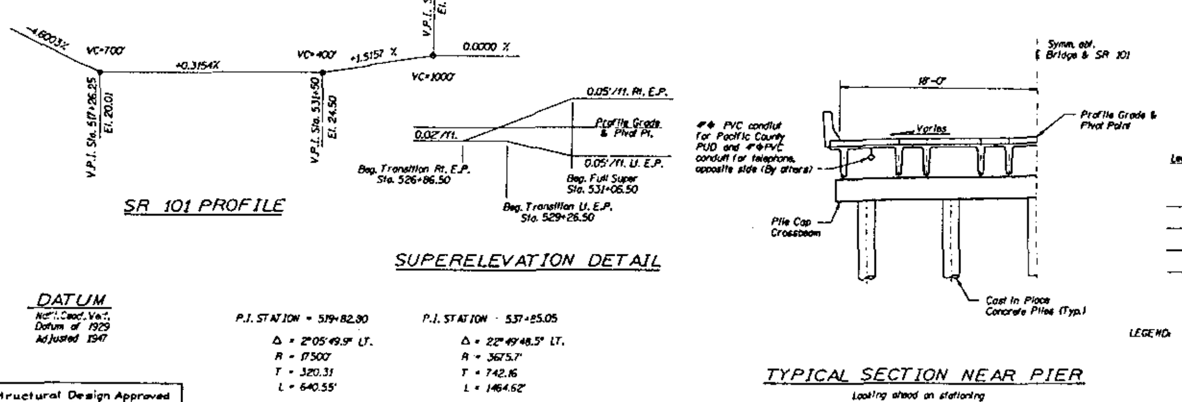


CURVE DATA

P.I. STATION = 519+82.80
Δ = 2°05'49.9" LT.
R = 17500'
T = 320.31
L = 640.55'

P.I. STATION = 537+25.05
Δ = 22°49'48.5" LT.
R = 3675.7'
T = 742.16
L = 1464.62'

DATUM

Nat'l. Geod. Vert. Datum of 1929 Adjusted 1947

GENERAL NOTES

ALL MATERIAL AND WORK SHALL BE IN ACCORDANCE WITH THE REQUIREMENTS OF THE STATE OF WASHINGTON, DEPARTMENT OF TRANSPORTATION, STANDARD SPECIFICATIONS FOR ROAD, BRIDGE, AND MUNICIPAL CONSTRUCTION, DATED 1988.

THIS STRUCTURE HAS BEEN DESIGNED IN ACCORDANCE WITH THE REQUIREMENTS OF THE 1983 AASHTO SPECIFICATIONS AND INTERIM SPECIFICATIONS THROUGH 1988. ALL PRESTRESSED CONCRETE ELEMENTS HAVE BEEN DESIGNED FOR SERVICE LOAD STRESSES AND CHECKED FOR THE REQUIREMENTS OF LOAD FACTOR DESIGN. ALL OTHER ELEMENTS HAVE BEEN DESIGNED BY LOAD FACTOR DESIGN.

ALL PILES SHALL BE AS SHOWN ON BRIDGE SHEET 4 AND SHALL BE DRIVEN TO A MINIMUM LOAD BEARING CAPACITY OF ONE HUNDRED TONS. THE CAST-IN-PLACE CONCRETE PILING SHALL MEET THE REQUIREMENTS OF SECTION 6-05.3(4) OF THE STANDARD SPECIFICATIONS UNLESS OTHERWISE SHOWN.

ALL CAST-IN-PLACE CONCRETE SHALL BE CLASS 4000.

UNLESS OTHERWISE SHOWN ON THE PLANS, CONCRETE COVER MEASURED FROM THE FACE OF THE CONCRETE TO THE FACE OF ANY REINFORCING BAR SHALL BE 2 1/2" AT THE TOP OF THE ROADWAY SLAB, 1" AT THE BOTTOM OF THE ROADWAY SLAB, AND 1 1/2" AT ALL OTHER LOCATIONS.

FOOT TRAFFIC ONLY, IS ALLOWED ON PC DOUBLE TEE GIRDERS.

Legend

— OT — Overhead Telephone
— OP — Overhead Power
— BT — Buried Telephone
— T — Telephone Cable (Attached to Existing Bridge)

LEGEND:
B/15 — Identifies Section, View or Detail; Taken or shown on Bridge Sheet 15
B/— — Use dash where Section, View or Detail is taken and shown on the same sheet

P. S. DOUBLE TEE GIRDERS

LOADING: HS-20
OR
TWO 24K AXLES @ 4' CTRS.

Structural Design Approved By Bridge & Structures Branch

Bridge Design Engr.						
Supervisor						
Designed By H Sargent & S Roberts						
Checked By M. Jacobsen & S Roberts						
Detailed By D. Herbert & B Krones						
Bridge Planning Engr.						
Preliminary Plan By						
Architect/Specialist	DATE	REVISION	BY	APP'D		

REGION NO.	STATE	FED. AID PROJ. NO.
10	WASH.	BRF-10(76)
JOB NUMBER 89W112	CONTRACT NO	

SARGENT ENGINEERS INC. Consulting Engineers 320 West Bay Drive OLYMPIA, WASHINGTON 98502

APPROVED

Washington State Department of Transportation

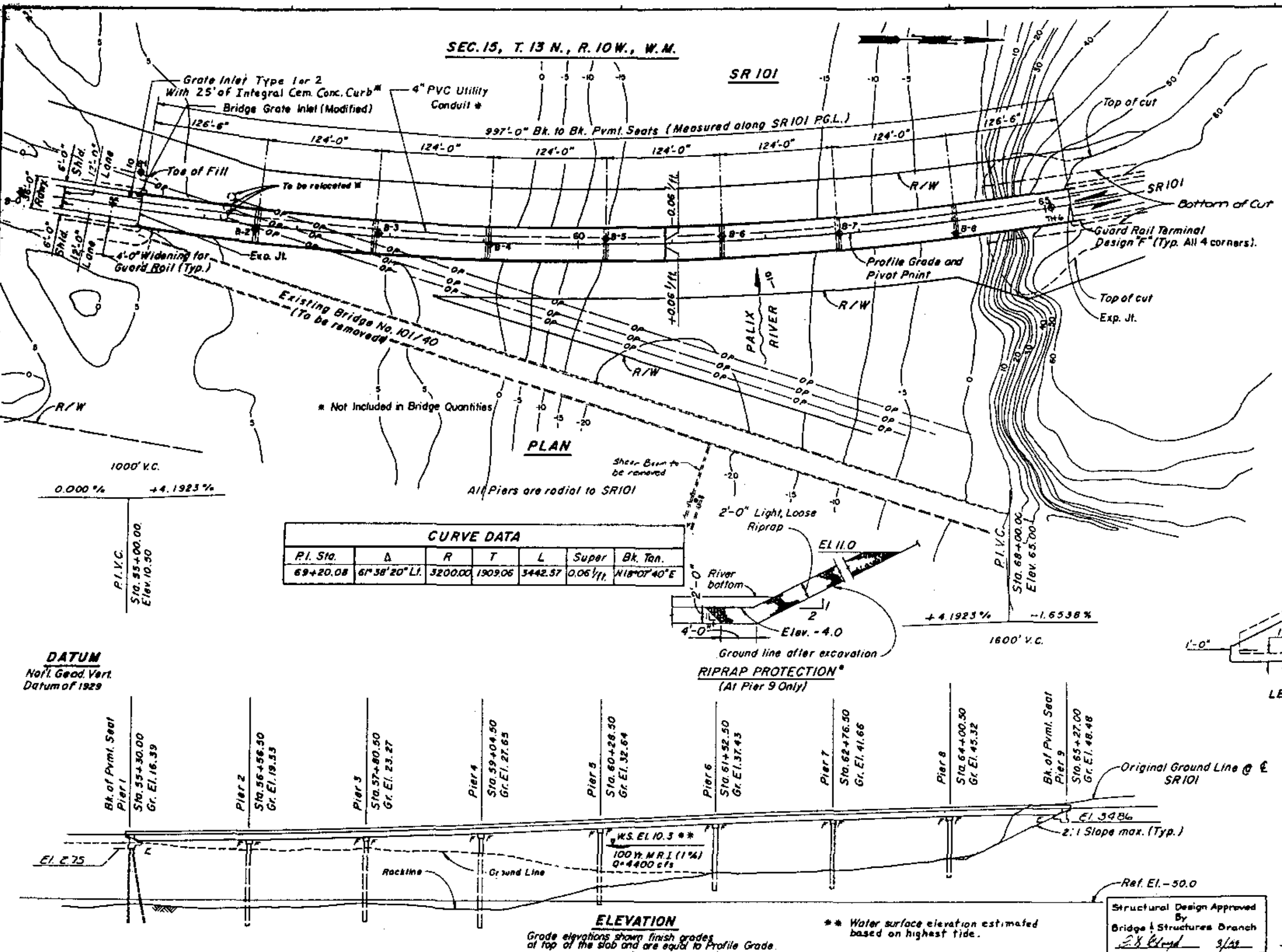
SR 101
NIAWIAKUM RIVER BRIDGE 101/42
LAYOUT

BRIDGE SHEET NO. 1
SHEET 35 OF 44 SHEETS

DOT FORM 221-013

SHEET 1 of 10 — Bridge Deck Protection System 1 with Rust Inhibitor in the double tee girders, the crossbeam and the piling concrete.

12-89 | Mat Incl. in Br. Quant. | 27-JUL-1989
Coast Guard Permit Reqd. No
Permit Target Date



CURVE DATA

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69+20.08	61°38'20" Lt.	3200.00	1909.06	3442.57	0.06'/ft.	N18°07'40"E

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THIS STRUCTURE HAS BEEN DESIGNED IN ACCORDANCE WITH THE REQUIREMENTS OF THE 1983 AASHTO SPECIFICATIONS AND INTERIM SPECIFICATIONS THROUGH 1987. PRESTRESSED GIRDERS HAVE BEEN DESIGNED FOR SERVICE LOAD STRESSES AND CHECKED FOR THE REQUIREMENTS OF LOAD FACTOR DESIGN. ALL OTHER ELEMENTS HAVE BEEN DESIGNED IN ACCORDANCE WITH LOAD FACTOR DESIGN.

SHAFT TIP ELEVATIONS AND SUBSTRUCTURE DETAILS ARE SUBJECT TO CHANGE DEPENDING UPON FOUNDATION MATERIAL ENCOUNTERED. REINFORCING STEEL FOR THE SHAFTS SHALL NOT BE CUT UNTIL FINAL SHAFT TIP ELEVATIONS HAVE BEEN DETERMINED IN THE FIELD AND SUBSTRUCTURE DETAILS HAVE BEEN MODIFIED AS REQUIRED.

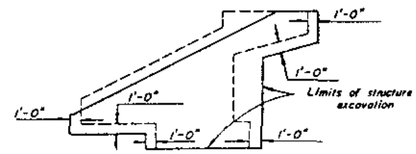
THE CONCRETE IN THE SHAFT SHALL BE CLASS DX EXCEPT AS NOTED. ALL OTHER C.I.P. CONCRETE SHALL BE CLASS AX EXCEPT IN ALL FOOTINGS WHERE CLASS B CONCRETE SHALL BE USED.

FALSEWORK SHALL BE CAREFULLY RELEASED TO PREVENT IMPACT OF UNDUE STRESSES IN THE STRUCTURE.

UNLESS OTHERWISE SHOWN ON THE PLANS, CONCRETE COVER MEASURED FROM THE FACE OF THE CONCRETE TO THE FACE OF ANY REINFORCEMENT BAR SHALL BE 2 1/2 INCHES AT THE TOP OF THE ROADWAY SLAB, 1 INCH AT THE BOTTOM OF THE ROADWAY SLAB AND 2 INCHES AT ALL OTHER LOCATIONS.

STEEL HP PILES AT PIER 1 SHALL BE DRIVEN TO SUFFICIENT DEPTH TO DEVELOP A CAPACITY OF 75 TONS PER PILE.

FOR SPREAD FOOTING AT PIER 9, A BEARING CAPACITY OF 3 TONS PER SQ. FT. IS USED.



LEGEND:

- Identifies Section, View or Detail — Taken or shown on Bridge Sheet 15
- Use dash where Section, View or Detail is taken and shown on the same sheet.

P.C. GIRDER CONTINUOUS FOR LIVE LOAD

LOADING: HS-20 OR TWO 24K AXLES @ 4' C'TRS.

Structural Design Approved By Bridge & Structures Branch
E.H. Lloyd 3/89

DESIGNED	C.K. Yu		
DRAWN	J. Hills		
REVIEWED			
CHECKED	H. Oskarsson		
PROJ. ENGR.	R. Stoddard		
DIST. ADM.			
DATE	REVISION	BY	APP'D

REGION NO. 10 | STATE WASH | FED. AID PROJ. NO. BRF-101(95)
JOB NUMBER 89W034
CONTRACT NO.

DRC CONSULTANTS, INC.

Washington State Department of Transportation

SR 101
PALIX RIVER BRIDGE 101/40

LAYOUT

1

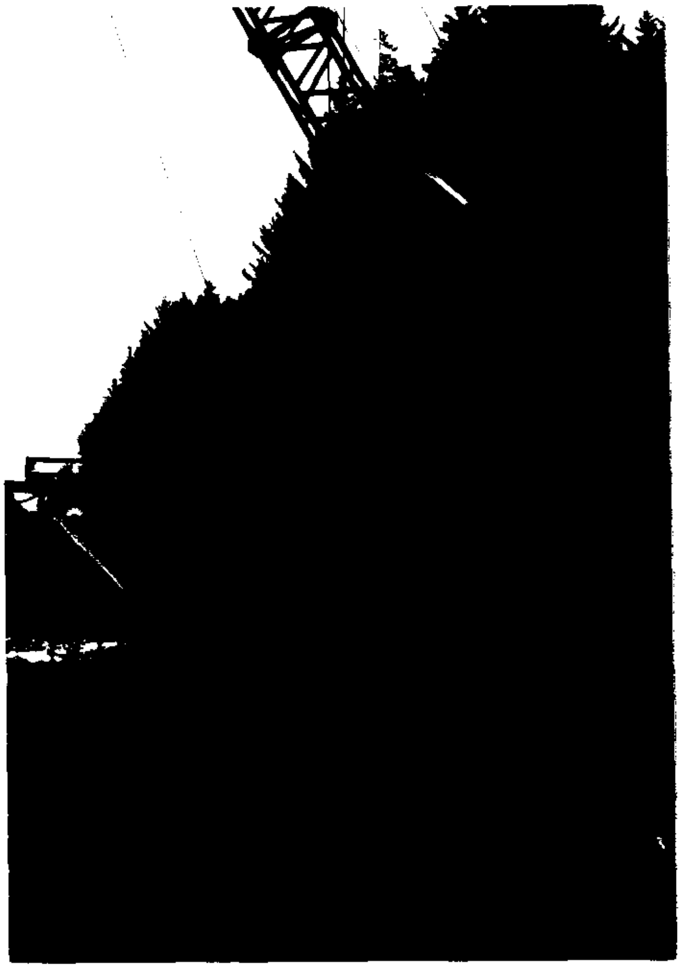
SHEET 43 OF 57 SHEETS

SR 101 JOB NO. 1557 SHEET 1

DOT FORM 221-012

APPENDIX C

PROJECT PHOTOGRAPHS



Niawiakum River Bridge

Photo 1

~~Method of concrete placement common to concrete with and without D.C.I~~.

~~Contract 3743~~

Placing DCI concrete or plain concrete by crane, bucket and tremie pipe

Photo 2

~~Finishing pier cap using D.C.I. concre~~te.

~~Contract 3743~~

Finishing pier cap using DCI concrete