Bridge No. 5/718W

Burlington Northern Railroad Overcrossing Bridge

Microsilica Modified Concrete Overlay

WA-RD 164.1

Post Construction Report
February 1989

Washington State Department of Transportation
in cooperation with the
United States Department of Transportation
Federal Highway Administration

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

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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

Washington State has approximately 700 bridge decks that may require a latex modified concrete (LMC) overlay in the next 12 to 15 years. The microsilica concrete overlay is seen as a possible alternative to the increasingly expensive latex modified concrete.

A microsilica modified concrete overlay was placed on Bridge 5/718W in Skagit County. The bridge is a concrete box girder structure with 8,100 square feet of deck area. The ADT on this bridge is 9,150 vehicles per day.

The minimum overlay thickness was 1½ inches. Superplasticizer was added to the mix. The concrete was mixed in a conventional batch plant with the technical representative from the microsilica supplier providing assistance. The microsilica modified concrete overlay was finished and cured as prescribed by WSDOT's specification for LMC overlays.

The microsilica was supplied as a slurry. Force 10,000, produced by W. R. Grace and Company, Cambridge, Massachusetts, was the source of the microsilica.

The long-term performance evaluation of the microsilica-modified concrete will be based on a direct comparison with the LMC overlay to be constructed on Bridge 5/718E. Both bridges are of similar construction, have the same deck area and ADT, and have existing decks with similar levels of chloride contamination. Both overlays were constructed under the same contract.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Bridge deck overlay, concrete additives, bridge deck repairs, microsilica concrete, silica fume	

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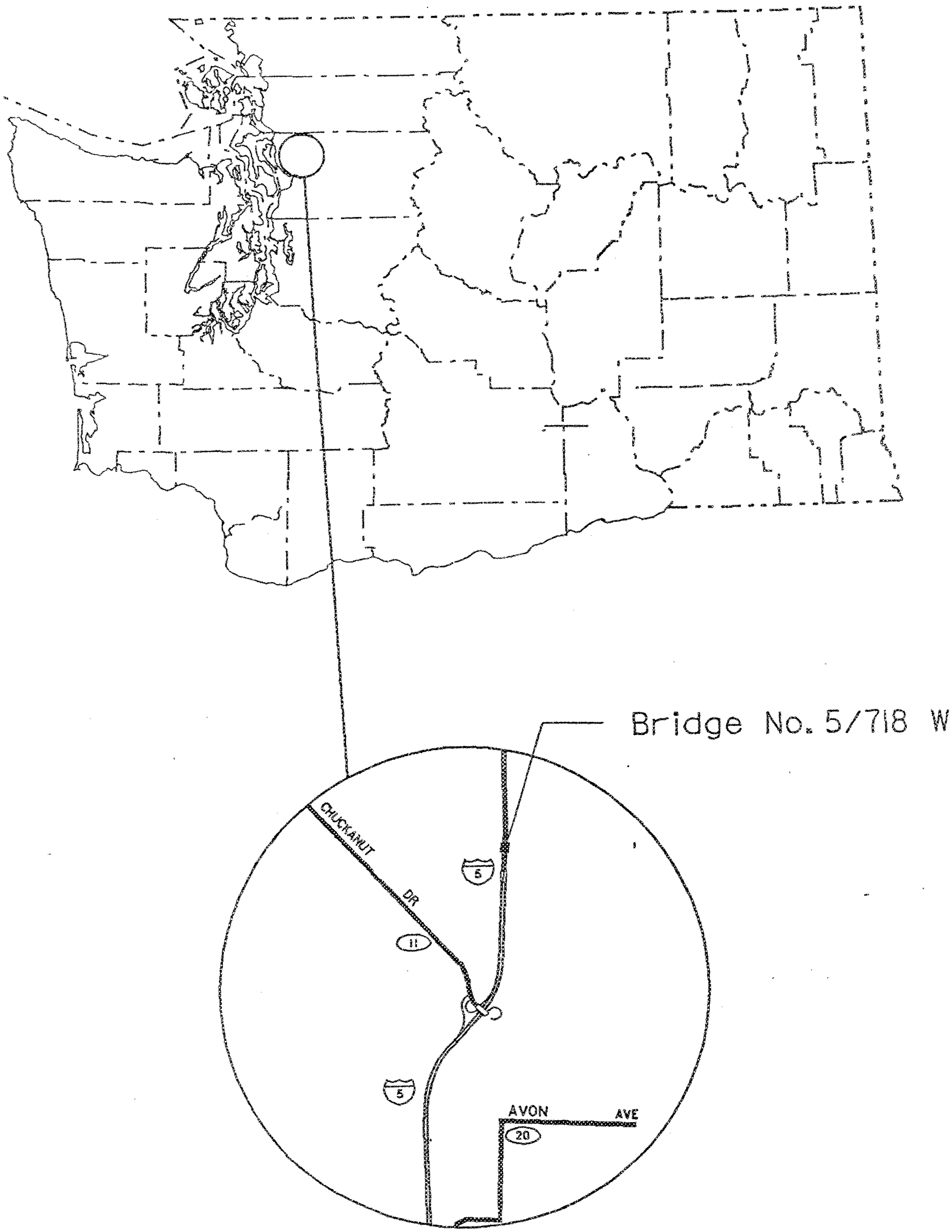


PROJECT SITE

INTRODUCTION TO THE PROBLEM

The deterioration of concrete bridge decks is a major problem on the state's highways. This deterioration is primarily due to chlorides from deicing salts penetrating into the deck and causing corrosion of the reinforcing steel. Overlays of latex modified concrete (LMC) and asphalt concrete with a waterproof membrane (AC/membrane) are presently being used as the primary systems to prevent the intrusion of additional chlorides and moisture on existing bridge decks. Concrete overlays are more durable than the AC/membrane systems. LMC is used on bridge decks with high traffic volumes and high levels of chloride contamination and on decks requiring significant rehabilitation. It is estimated that LMC may be used on an additional 700 bridge decks in Washington State over the next 12 to 15 years.

Latex is a relatively expensive concrete additive. The in-place cost is further increased by the special equipment required to construct LMC overlays. Recent studies have confirmed that LMC is more construction sensitive than conventional Portland cement concrete. In view of this, an alternative concrete overlay protection system is desirable. A system that could be mixed, placed, and finished with conventional concrete labor and equipment should be more economical than LMC and potentially less construction sensitive. Additional cost savings may be realized by having a comparable system that could be bid on a level competitive with the present standard system.

PROPOSED SOLUTION

In recent years, condensed silica fume, or microsilica, has been added to concrete to obtain high strengths and very low permeability. Microsilica is a byproduct recovered during the production of ferrosilicon and silicon metal. Microsilica, approximately 100 times finer than Portland cement, fills the voids in the concrete, making it less permeable.

Microsilica is also a highly reactive pozzolan, generally containing more than 85 percent silica. The chemical reaction between silica, water, and calcium hydroxide forms calcium silica hydrate, a major cementious product similar to those produced by the reaction of Portland cement and water. The normal hydration of Portland cement produces 20 to 25 percent calcium hydroxide. The addition of microsilica to Portland cement and water provides for the formation of additional calcium silica hydrate, thereby improving the strength and durability of the concrete.

The results of laboratory testing indicate that the permeability of concrete containing microsilica is comparable to the permeability of LMC. Compressive strengths have reached as high as 15,000 psi in WSDOT laboratory tests.

Concrete containing microsilica can be produced in any concrete batch plant and mixed in standard ready mix trucks. The use of a superplasticizer with microsilica is recommended to provide a workable mix for field placement.

STUDY SITE

The microsilica modified concrete overlay was placed on Bridge 5/718W in Skagit County. The bridge is a concrete box girder structure with 8,100 square feet of deck area. The ADT on this bridge is 9,150 vehicles per day.

Data from a September 1985 survey shows the bridge deck has a chloride content exceeding 2 lbs/CY at the rebar level in 64 percent of the deck area. The survey also recorded approximately 16 square feet of delaminations.

The minimum overlay thickness was 1½ inches. Superplasticizer in combination with a water reducer added to the mix. The concrete was mixed in a conventional batch plant with the technical representative from the microsilica supplier providing assistance. The microsilica modified concrete overlay was finished and cured as prescribed by WSDOT's specification for LMC overlays.

The microsilica was supplied as a slurry. Force 10,000, produced by W. R. Grace and Company, Cambridge, Massachusetts, was the source of the microsilica.

The long-term performance evaluation of the microsilica modified concrete will be based on a direct comparison with the LMC overlay to be constructed on Bridge 5/718E. Both bridges are of similar construction, have the same deck area and ADT, and have existing decks with similar levels of chloride contamination. Both overlays were constructed under the same contract.

CONSTRUCTION SUMMARY

Bridge 5/718W was overlaid in two phases to facilitate movement of traffic. The west half of the bridge was overlaid on September 9 and the east half on October 1, 1987.

A self-propelled Bidwell finishing machine equipped with a rotating cylindrical drum screed was used to place the microsilica modified concrete. The concrete was furnished and delivered to the job site by Concrete Nor'West in regular ready mix concrete trucks. The loads were limited to 4 cubic yards per truck as required by the special provisions. The nominal thickness of the overlay was 1½ inches.

Force 10,000 (the microsilica additive), water reducer, and approximately two-thirds of the maximum recommended amount of superplasticizer were added to each load at the plant. Additional superplasticizer was added at the job site as necessary.

Placement of the west half bridge overlay began at 12:30 a.m. and was completed at 7:00 a.m. The slump and air content of the concrete were very inconsistent.

The pour for the last half of the bridge began at 9:20 a.m. and was completed at 2:45 p.m. Again, the slump and air content of the concrete were very inconsistent. During this pour, the slump was very low for the first few loads. It was discovered that the plant man had neglected to add the water reducer at the plant as had been specified.

A representative from Grace Company, the supplier of the microsilica additive, was present on the job site for both pours.

Cure

As soon as finishing operations were completed, the concrete was immediately covered with saturated burlap. The burlap was then covered with white polyethylene sheeting. After 42 hours of wet cure, the polyethylene plastic sheeting was removed and the burlap was resaturated and left to dry for a 6-hour transition cure. The burlap was then removed and the dry cure commenced. The dry cure was accomplished in 48 hours. No adjustments to the specified wet or dry cure times were necessary as the temperature at the overlay surface remained above 50°F throughout the curing period.

Observations

In general, the microsilica modified concrete placement went smoothly and is very similar to placing latex modified concrete. The main difference between the two operations is that microsilica modified concrete is delivered from a central batch plant. This, of course, is conducive to a breakdown in communication between the plant and the job site, and any adjustments may take longer to effect. It is recommended that on future projects, prior to any pour, it is made certain that close communication can and will be maintained between the concrete plant and the job site. The contractor should be required to provide a means of direct communication such as a radio or telephone. This requirement should be included in the specials.

It is important that the contractor have enough microsilica and admixtures to complete the pour (allowing for rejected loads). This should be discussed in the pre-pour conference.

The bid for overlaying the microsilica modified concrete was $25/yd^2, and the bid for overlaying the latex modified concrete was $38.50/yd^2.

MIX DESIGN SPECIFICATIONS AND QUALITY CONTROL TEST RESULTS

Mix Design

The concrete shall be a workable mix, uniform in composition and consistency. Mix proportions per cubic yard shall be:

Portland cement	658	pounds
Microsilica fume	52	pounds
Fine aggregate	1540	pounds
Coarse aggregate	1540	pounds
Air	6% ± 1%	
Maximum water/cement ratio	0.33	max.

The concrete shall have a slump of 5 ± 1 inches unless it is being placed on a deck with a gradient in excess of 6 percent, in which case the slump shall be limited to 3± inches.

Water reducing admixtures, air entraining admixtures, and superplasticizers shall be added as recommended by the supplier of the microsilica admixture.

Slump and Air Content

Specifications required the slump to be 5 ± 1 inches and the air content to be 6 percent ± 1 percent. Variations in these values occurred at the job site. For example, the slump ranged from 2 inches to as much as 9 inches. See Appendix B for test results and Appendix C for a personal account of the problems involved.

Compression Strength and Permeability

Compression strength of the microsilica concrete at 28 days was about 12,000 psi. The rapid chloride permeability test showed coulomb values of 200± for the concrete cylinders made from the mix and 500± for cores taken from the deck. The deck values compare with the LMC and dense concrete values seen in the past.

Skid Resistance and Bond Strength

Friction numbers were in the acceptable range from 40 to 49. New Portland cement concrete will typically be between 40 and 50.

Bond values ranged from 36 psi to 234, with an average of 107 psi. These values are less than the mean bond strength of 203 psi for LMC and 141 psi for low slump dense concrete overlays previously tested in Washington State.

Control Bridge

The LMC overlay that was placed on the parallel bridge (5/718E) under this contract will be tested in 1989 to obtain a direct comparison with the performance of the microsilica modified concrete overlay.

RECOMMENDATIONS

It is suggested that a pre-pour conference among all people directly involved with the pour be required in the special provisions. Items to be discussed should include:

Mix design.
Additive - What, when, who, how much, and the effect on the mix.
Communication during the pour.
Aggregate - moisture content.
Mixing trucks - travel time, adequate number, etc.
Mix specifications (slump, air, water/cement ratio) and condition resulting in load rejection.

WSDOT Materials Lab should provide the necessary testing equipment and, if necessary, training for the inspectors to use the equipment.

APPENDIX A

TEST PLAN

EXPERIMENTAL PROJECT
MICROSILICA-MODIFIED CONCRETE FOR BRIDGE DECK OVERLAYS
TESTING AND ANALYSIS COSTS
(Total Costs for Two Bridges)

Responsible Unit	Work Item	Pre-Construct.	Post Construct.	YEAR[1] 1	2	4	6	8	Totals
HQML[2]	Chloride Sampling	(4 hrs) $ 488			(4 hrs) $ 588	(4 hrs) $ 712		(4 hrs) $ 1,048	$ 2,836
HQML	Chloride Lab Testing	(18 samples) $ 126			(18 samples) $ 153	(18 samples) $ 185		(18 samples) $ 271	$ 735
HQML	Half-Cell Testing	(4 hrs) $ 488			(4 hrs) $ 588	(4 hrs) $ 712	(4 hrs) $ 864	(4 hrs) $ 1,048	$ 3,700
HQML	Bond Testing		(2 hrs) $ 244			(2 hrs) $ 356		(2 hrs) $ 524	$ 1,124
HQML	Delamination Testing		(1 hr) $ 122	(1 hr) $ 134	(1 hr) $ 147	(1 hr) $ 178	(1 hr) $ 216	(1 hr) $ 262	$ 1,059
HQML	Rapid Chloride Perm. Sampling		(4 hrs) $ 488						$ 488
HQML	Rapid Chloride Perm. Lab Testing		(4 samples) $ 660						$ 660
HQML	Air Void Analysis		(4 samples) $1,200						$ 1,200
HQML	Visual Inspection	(3 hrs) $ 366	(4 hrs) $ 488	(1 hr) $ 134	(2 hrs) $ 294		(2 hrs) $ 432		$ 1,714
HQML	Skid Resistance @ $108/hr		(1 hr) $ 108	(1 hr) $ 119	(1 hr) $ 131	(1 hr) $ 158	(1 hr) $ 191	(1 hr) $ 231	$ 938
HQML	Travel Time	(5 hrs) $ 610	(5 hrs) $ 610	(5 hrs) $ 670	(5 hrs) $ 735	(5 hrs) $ 890	(5 hrs) $1,080	(5 hrs) $ 1,310	$ 5,905
HQBB[3]	Analysis and Reporting		(40 hrs) $1,100	(8 hrs) $ 242	(8 hrs) $ 266	(20 hrs) $ 805	(8 hrs) $ 390	(40 hrs) $ 2,358	$ 5,161
Dist	Traffic Control @ $400/day	(2 days) $ 800	(2 days) $ 800	(1 day) $ 440	(2 days) $ 968	(2 days) $1,171	(1 day) $ 709	(2 days) $ 1,715	$ 6,603
	TOTALS	$2,878	$5,820	$1,739	$3,870	$5,167	$3,882	$ 8,767	$32,123
TOTAL CONTRACT FUNDING			$8,698						$-8,698
						Total Experimental Feature Funding			$23,425

1 10 percent annual inflation rate assumed

2 Headquarters Materials Lab time and equipment at $122/hr

3 Headquarters Bridge Branch time at $27.50/hr

APPENDIX B

TEST RESULTS

MICRO SILICA FUME CONCRETE
BRIDGE 5/718W
TEST DATA

July 12, 1988

CONTRACT 3288 BRIDGE #5/718W BNNR O'XING

MICRO SILICA OVERLAY

DESIGN DATA

SLUMP 5" +/- 1"

AIR 6% +/- 1%

AIR ENTRAINING AGENT SIKA AER

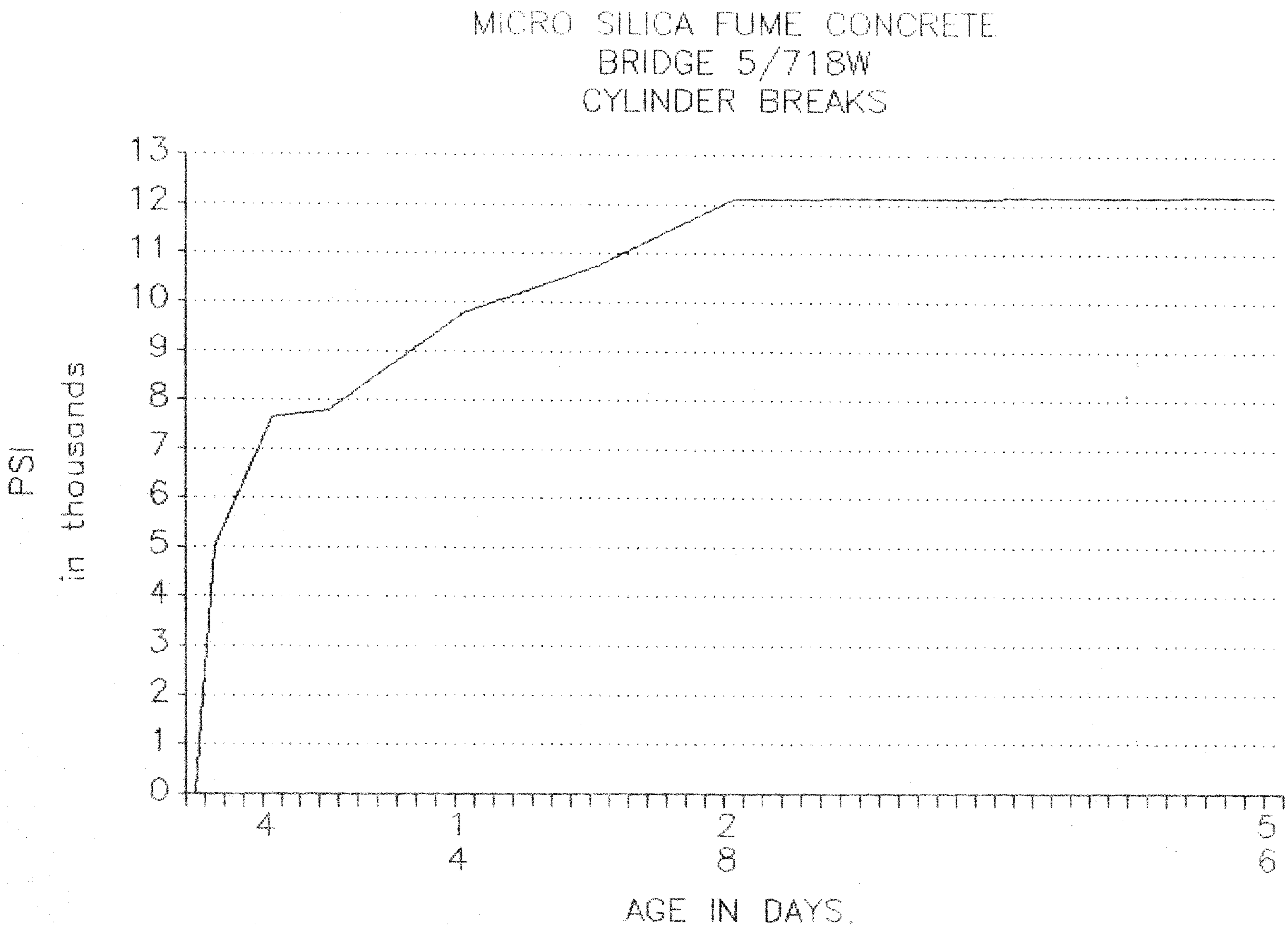
WATER REDUCER PLASTOCRETE

7 SACK MIX + 52# MICRO SILICA

.33 WATER/CEMENT RATIO MAX

TEST DATA 10/1/87

TRUCK #	3	TRUCK #	5	TRUCK #	10	TRUCK #	12
SLUMP	7"	SLUMP	7"	SLUMP	9"	SLUMP	5.5"
AIR	3.0%	AIR	4.2%	AIR	6.0%	AIR	5.3%
YIELD	7.08	YIELD	7.05	YIELD	7.01	YIELD	6.97
AIR TEMP	68	AIR TEMP		AIR TEMP		AIR TEMP	80
CONC TEMP	75	CONC TEMP		CONC TEMP		CONC TEMP	79


MICRO SILICA FUME CONCRETE
BRIDGE 5/718W
CYLINDER BREAKS
PSI
in thousands
13
12
11
10
9
8
7
6
5
4
3
2
1
0
4
14
28
56
AGE IN DAYS.

MICRO SILICA FUME CONCRETE
BRIDGE 5/718W
TEST DATA

August 15, 1988

RAPID CHLORIDE PERMIABILITY

	COULOMBS	SAMPLE THICKNESS
CORE 2	480	1 3/4"
CORE 15	677	2"
CYL 23	218	2"
CYL 24	202	2"

BOND TESTING

CORE	STATION & OFFSET		THICKNESS	LOAD	PSI	DIA
3	0+44	6' RT	1 5/8"	448	36	4"
4	0+70	7' RT	1 5/8"	1064	85	4"
8	0+98	7' RT	1 5/8"	1008	80	4"
9	1+18	6.5' RT	2"	325	103	2"
10	1+37	5' RT	1 3/4"	325	103	2"
11	1+56	7' RT	1 1/2"	735	234	2"

FRICTION TESTING

DATE	LANE	AVE	RANGE
7/28/88	1	41	40-44
	2	47	45-49

AIR VOID ANALYSIS ON TEST CYLINDE

NUMBER	% AIR
22	3.3
23	2.7
24	3.1

APPENDIX C

PERSONAL OBSERVATIONS OF
THE BATCH PLANT AND
MIXING OPERATIONS

Trip to inspect the first microsilica overlay:

Ingo Goller
Francis Rickert

Arrived at the project site about 9:45 on the evening of September 8, 1987.

The contractor's men were still adjusting the screed rail near the north end of the bridge and approach slab. The rail had to be extended and lowered along the west side. We talked to state inspectors Beth Warfield and Jack Larson about the progress on this project.

At about 10:30, Francis and I went to the Concrete Nor'West batch plant to see the operations there. The microsilica, Grace Force 10,000, and the superplasticizer, Grace WRDA 19, were set up to be added to the concrete trucks by hand. According to the Grace salesman David Perry, the Force 10,000 weighs 11.5 pounds with 5.5 pounds of microsilica and 6 pounds of water. Shortly after we got to the batch plant, a call from the contractor came in advising the plant personnel that it would be about one more hour before everything was ready for the overlay.

We met John Hayes at the batch plant, and after he and the plant personnel reviewed the mix design, they went out to sample the aggregate piles. About 11:30, the contractor called to send the first truck. We observed the mix truck being loaded and went back to the bridge.

When the truck arrived at the bridge, it stopped at the south end and a sample was taken for testing. The slump was 9 inches and no air test was conducted. The contractor decided to use this concrete thinking that the slump would be in specification by the time the finish machine spread the concrete. The truck backed to the north end and began to discharge the concrete.

The finishing operation was the typical finish with a Bidwell finishing machine, except the drag pan was not used at this time because the concrete was too wet. After placing about two yards of this concrete, the truck was pulled off of the bridge and went back to the plant. The second truck was already at the south end of the bridge and was being tested. Slump was 6 inches and air was 6½ percent. All the concrete from this truck was placed on the deck in about 25 minutes.

Truck No. 3 (second round for truck No. 2) did not arrive for about 50 minutes after truck No. 2 was done. When it did arrive, the concrete mix was tested at a 2-inch slump and 4½ percent air. The contractor again made the decision to use the concrete as it had arrived. Information from the concrete plant led us to believe that some mix water was withheld to account for the wash water in the mixing drum. When the slump appeared to decrease to about ½ inch to 1 inch (about three yards of concrete had been placed), one gallon of water was added to the remaining mix to bring up the workability. Total time to place the concrete in truck No. 3 was 45 to 50 minutes.

The fourth truck (second round for truck No. 1) had arrived back at the bridge before truck No. 3 was completely discharged. Slump in this truck was adjusted to 5 inches by adding about four gallons of water. Air was tested at 4½ percent, which is ½ percent too low. All concrete in truck No. 4 was placed in 25 minutes.

Fifteen minutes after the fourth truck was finished, the fifth truck arrived. Slump and air tests were not conducted when the truck first arrived. The truck backed up to the pour location and began to discharge concrete. Slump looked high, so the slump and air tests were arranged for. State inspector indicated that if the concrete was out of specification, the load would be rejected.

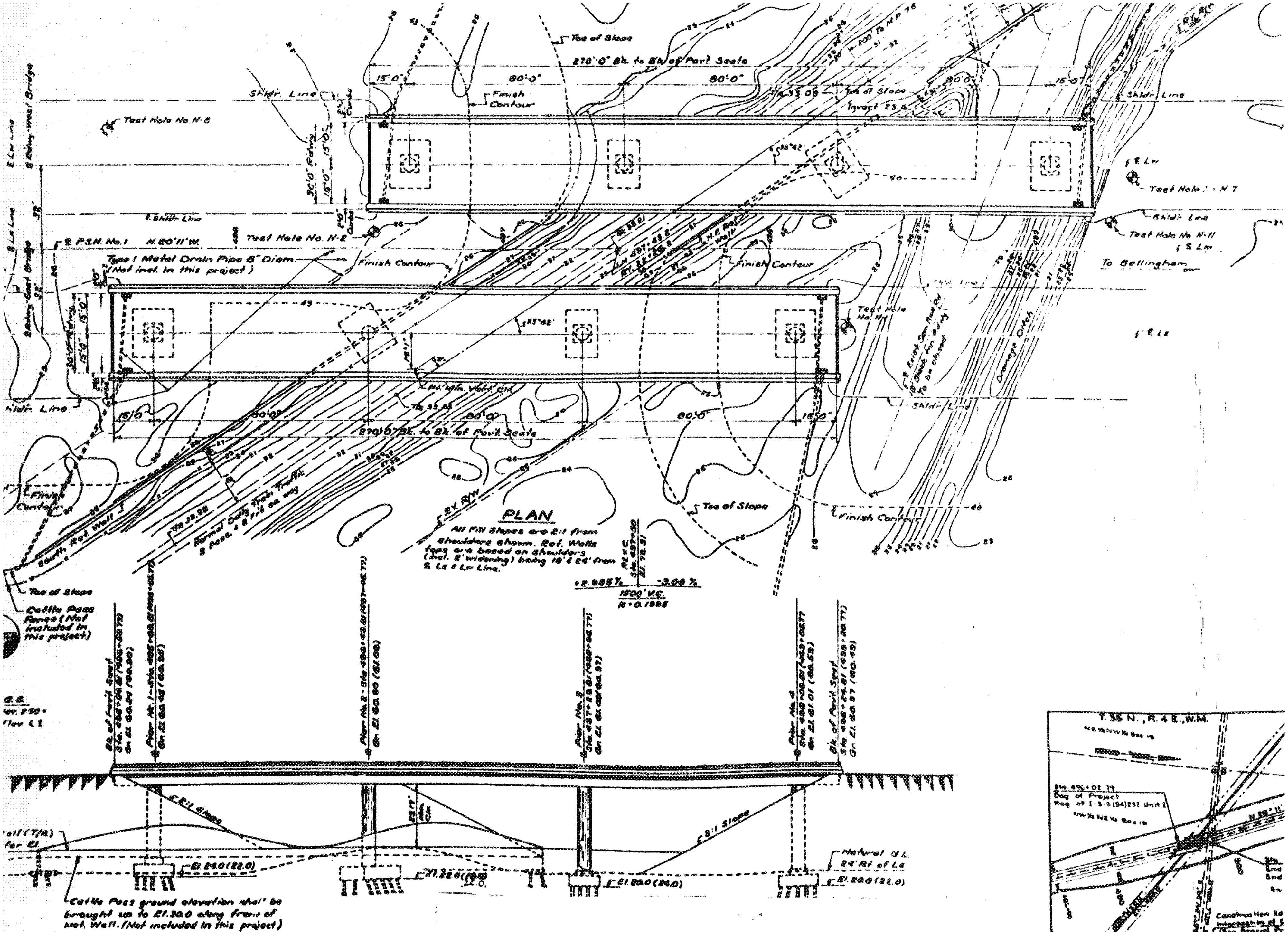
At this time, we left the project site to return to Olympia. Time was 2:45.

Comments by Francis Rickert

With regard to the first truck, it is possible that there was wash water remaining in the drum from the last pour that day. The stiff mix (2-inch slump) for the third truck was caused by holding back mix water to compensate for wash water in the drum. The drivers had been instructed not to wash out after each round; therefore, there was no wash water to compensate for and not enough water was added at the plant. The fifth truck had excessive slump; this could be due to varying moisture of the aggregate stockpile or possibly a bad water metering system at the plant. Because of the use of superplasticizers, any problem with the water content of the mix is exaggerated.

APPENDIX D

GENERAL LAYOUT

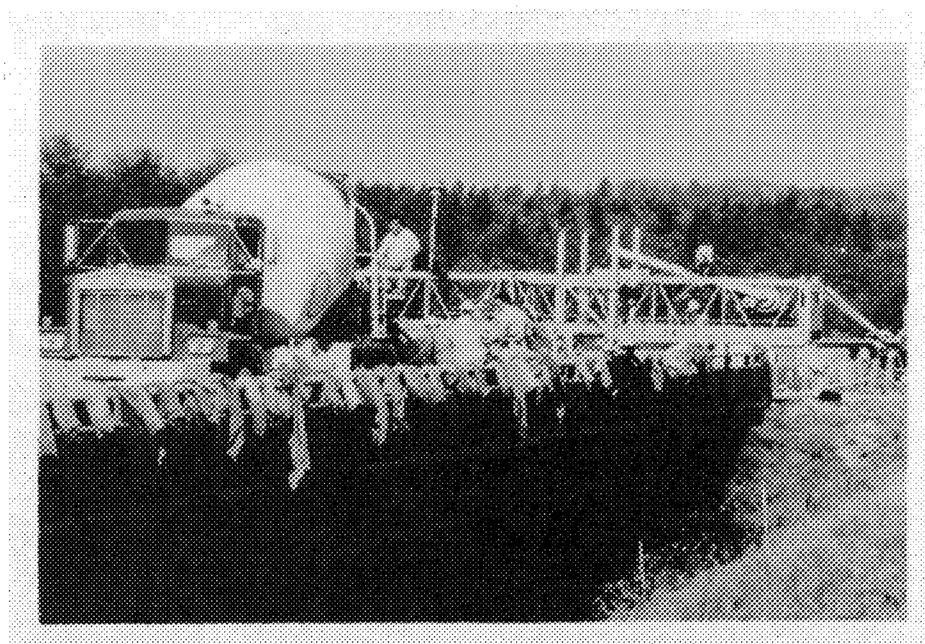


Bridge No. 5/718W

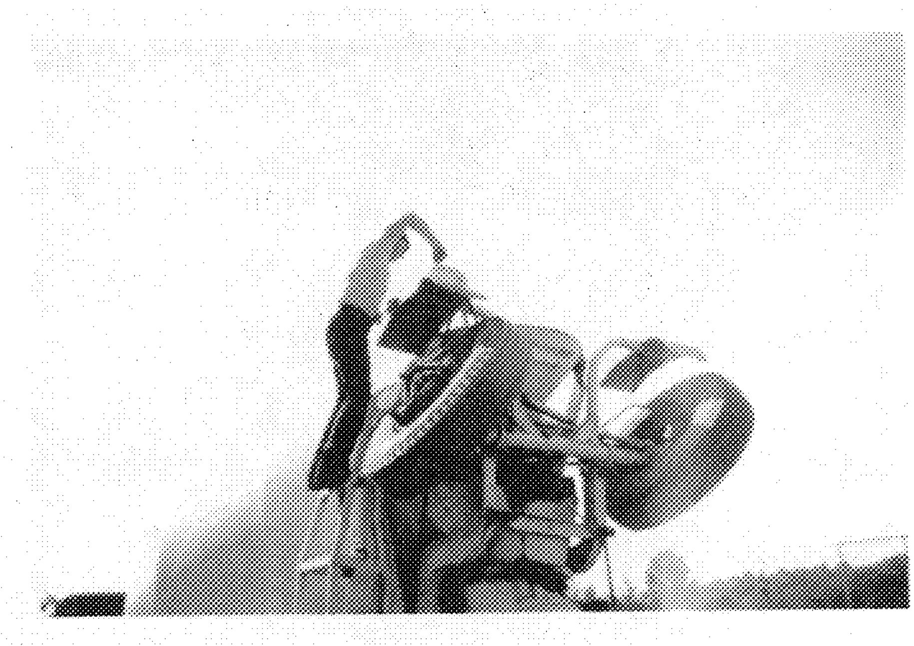
APPENDIX E

PROJECT PHOTOGRAPHS

Visqueen placed to protect deck

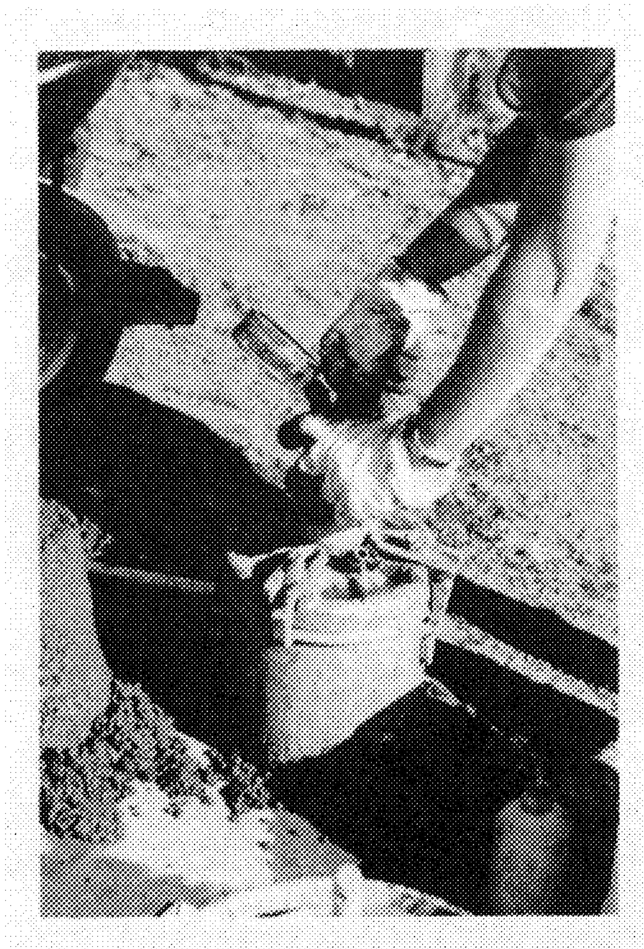


Wet burlap at the ready on the rail

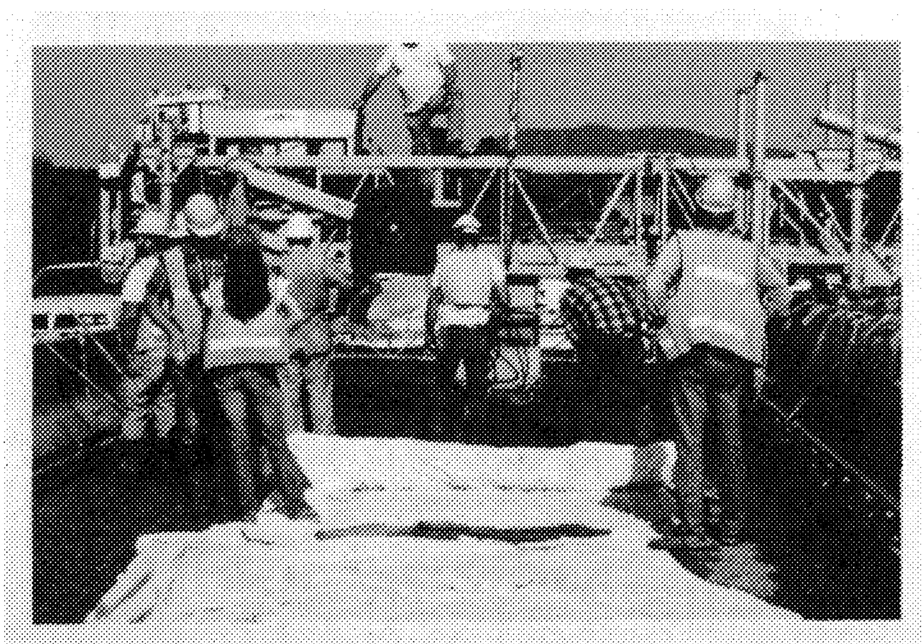


Superplasticizer being added
to a concrete load

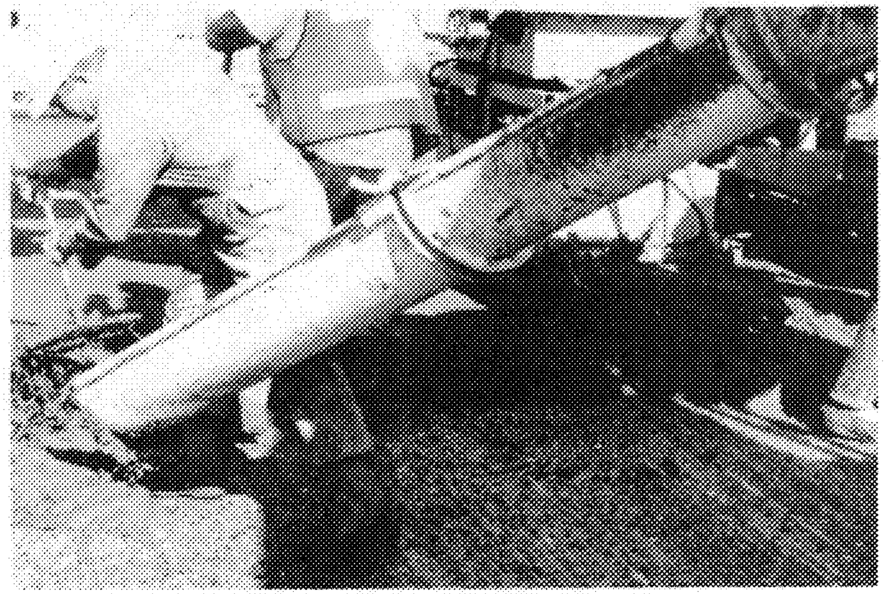
Slump test



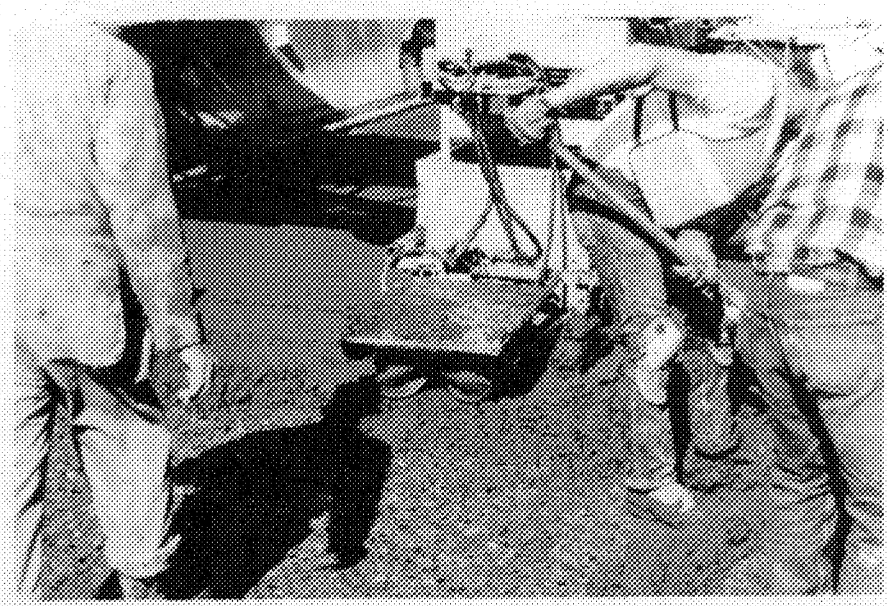
Air entrainment test



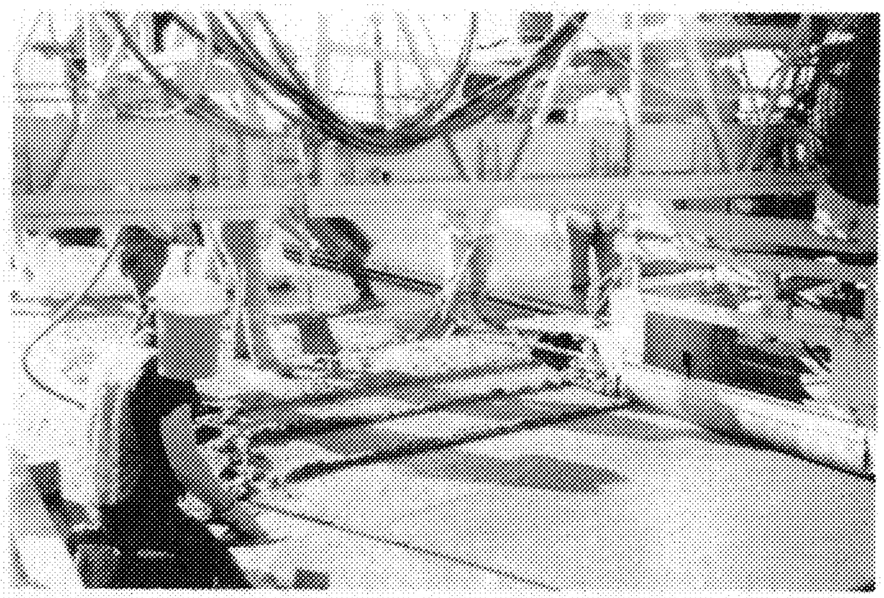
Paving machine



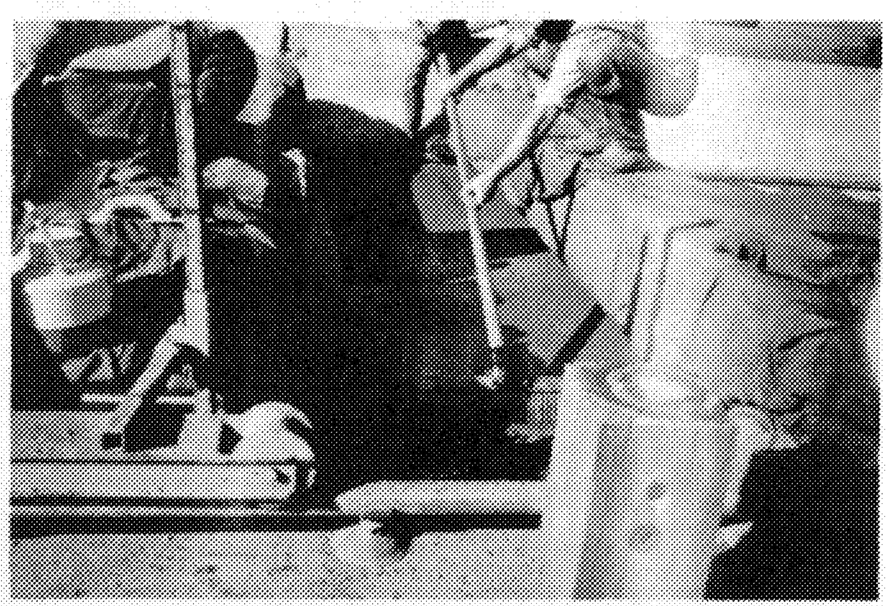
Mix placement from chute
of concrete truck



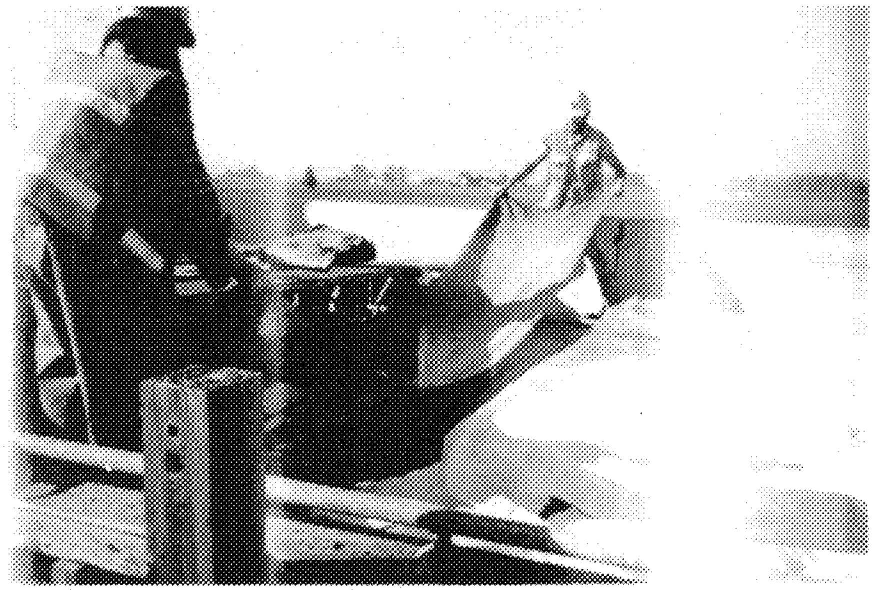
Mix placement - auger



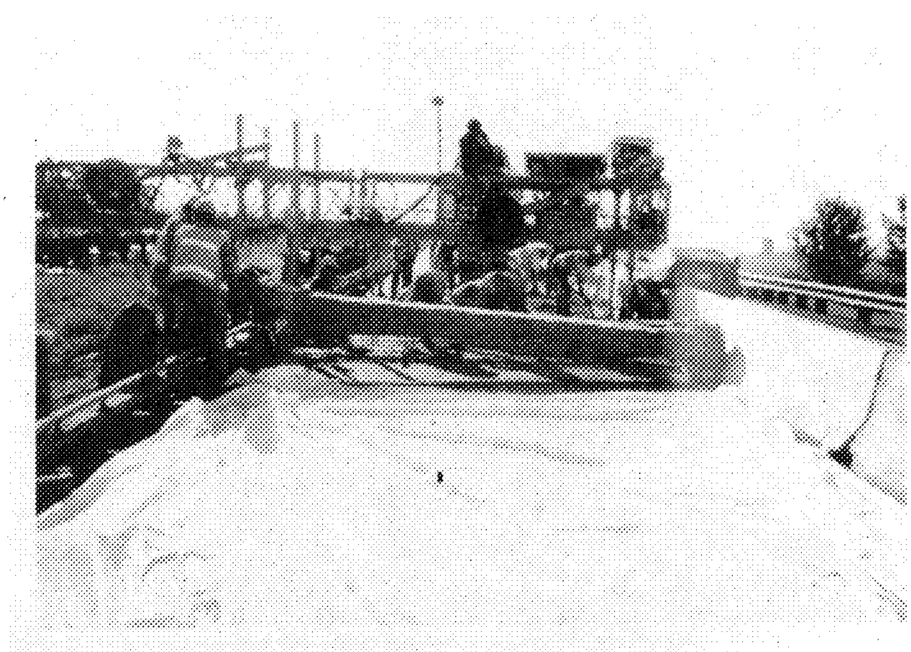
Mix placement - finishing drum



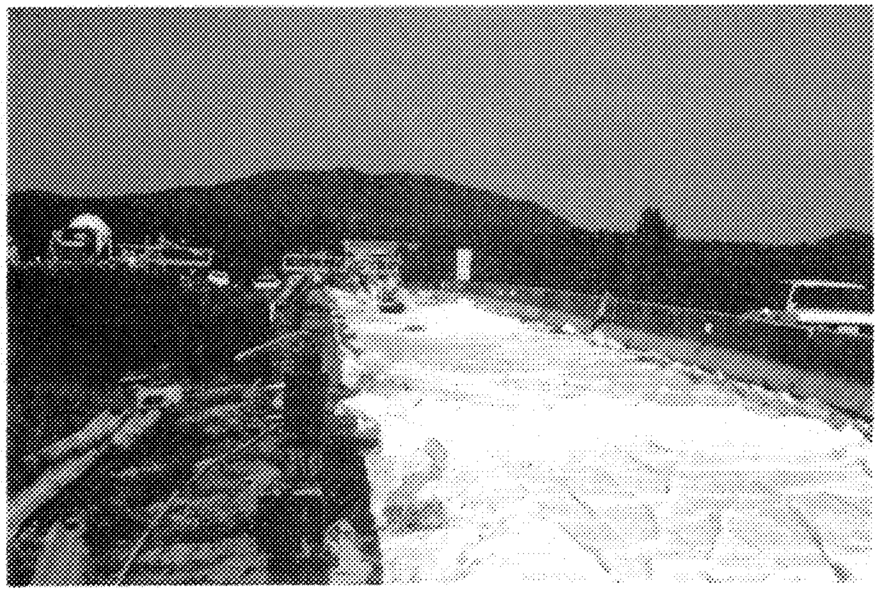
Rake finish



Burlap placement



Visqueen placement



Deck cure under visqueen

Finished roadway deck