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PERFORMANCE EVALUATION OF AN EXPERIMENTAL SLURRY SEAL EMULSION AS FILLER OF DETERIORATED LONGITUDINAL JOINTS IN CONCRETE PAVEMENT BEING PREPARED FOR ASPHALTIC CONCRETE RESURFACING

MICHIGAN DEPARTMENT OF TRANSPORTATION

TESTING AND RESEARCH DIVISION
RESEARCH LABORATORY SECTION

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Since 1976, the Department has been engaged in testing different slurry sealing mixes in an attempt to seal surface cracks and correct severe surface conditions of old asphalt and concrete pavements.

Slurry seals consist of a finely graded aggregate material, blended with mineral filler, emulsified asphalt, and water is added to achieve a slurry consistency. The mixture is prepared in a specially designed unit and applied without heat to the pavement surface in an average thickness ranging from 1/16 to 1/8 in.

This corrective maintenance has varied from filling cracks and joints to placing leveling wedges on sags and depressions in distressed pavements. During 1977, the Department's Maintenance Division, using a slurry seal machine, repaired 79 miles of surface cracks and completed 39 miles of shoulder wedging in 50 working days. Maintenance forces reported in 1977 that slurry sealing performance had been promising and would hopefully become an acceptable practice with some improvements in equipment and method of operation (1).

In March 1978, the Construction Division recommended that in preparing an old concrete pavement for new asphalt overlay, the conventional practice of longitudinal joint repair, as specified in §4.12 of the 1976 Standard Construction Specifications, should be field tested and compared with the slurry sealing method. During this time, Michigan practice for repairing longitudinal joints and adjacent cracks in existing concrete pavements consisted of three steps: 1) removing asphalt surfacing or old patches and loosening spalled concrete; cleaning out failed joints and adjacent cracks with compressed air; 2) applying a bituminous bond coat on the cleaned surface and filling with bituminous material of the same type as used in the asphalt overlay; and, 3) compacting with a machine vibrator or approved roller. Currently, the average cost of longitudinal joint repair as described above for concrete pavement is about $5/lin ft. In contrast, costs of joint filling with slurry seals average about $0.15/lin ft, which is approximately 1/30 the cost of the conventional practice of longitudinal joint repairs.

Objectives

The main purpose of this experiment was to investigate the effectiveness and limitations of the slurry sealing method in controlling the problem of asphalt surface cracking caused by repaired longitudinal joints in concrete pavements, reflecting through new asphalt overlays. Specifically, this study was designed to evaluate the relative performance of slurry seal treated longitudinal joints compared with conventionally repaired, 31A bituminous, longitudinal joints and with untreated longitudinal joints used as controls. The evaluation study did not include transverse joints.

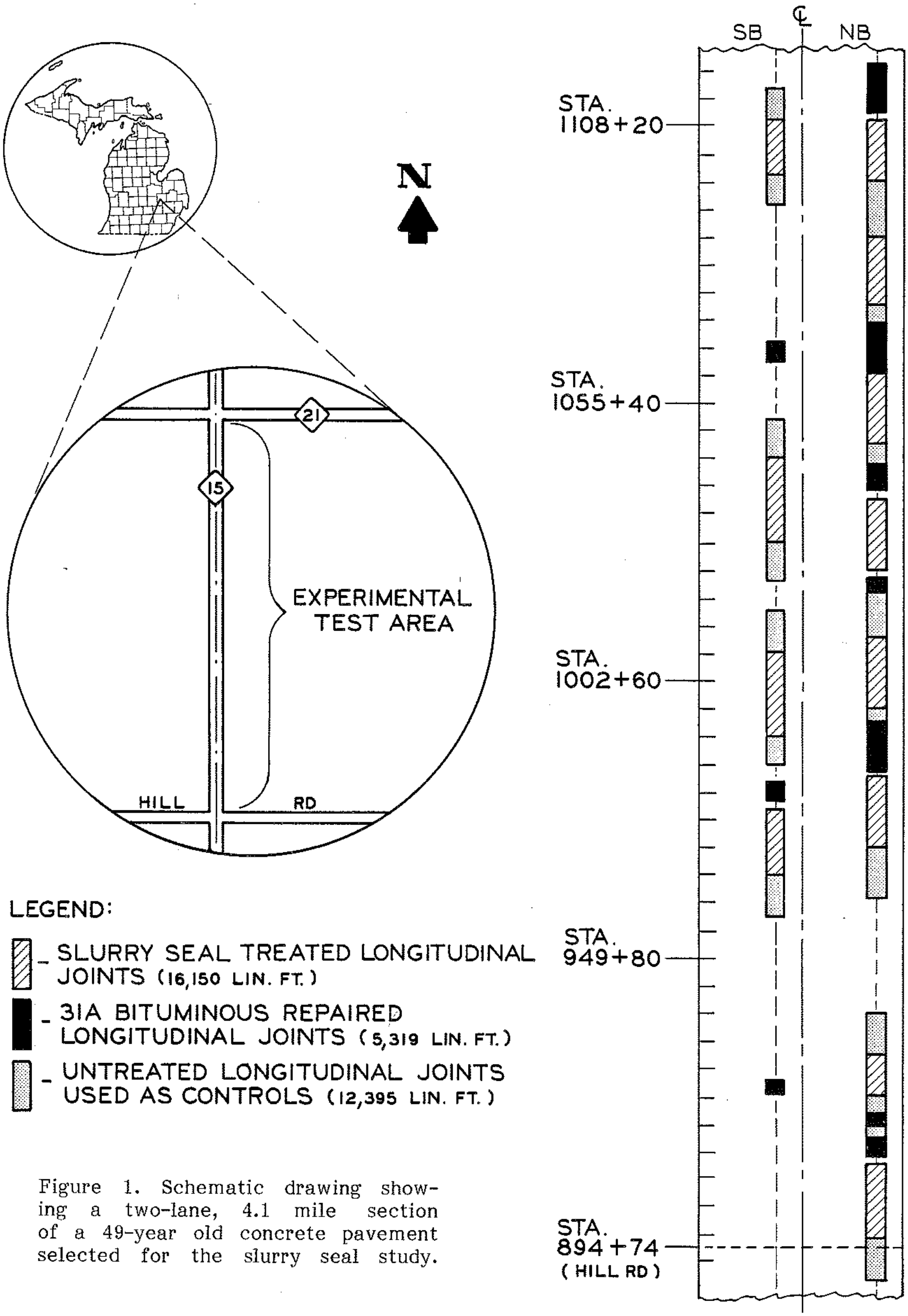


Figure 1. Schematic drawing showing a two-lane, 4.1 mile section of a 49-year old concrete pavement selected for the slurry seal study.

Research Procedure

For a comparative evaluation of the experimental longitudinal joints located under a new asphalt concrete overlay, the information required includes:

1) The project background, characteristics, and existing pavement conditions.

2) The test sections or test strips containing those longitudinal joints to be treated with the experimental slurry sealing emulsion and those to be repaired with conventional 31A bituminous mixture (§4.12) as well as the untreated longitudinal joints to be used as control.

3) The materials and mix design to produce the trial slurry seal, and the equipment and method of applying the slurry seal.

4) The condition surveys and field measurements required to determine joint performance after resurfacing of the test area.

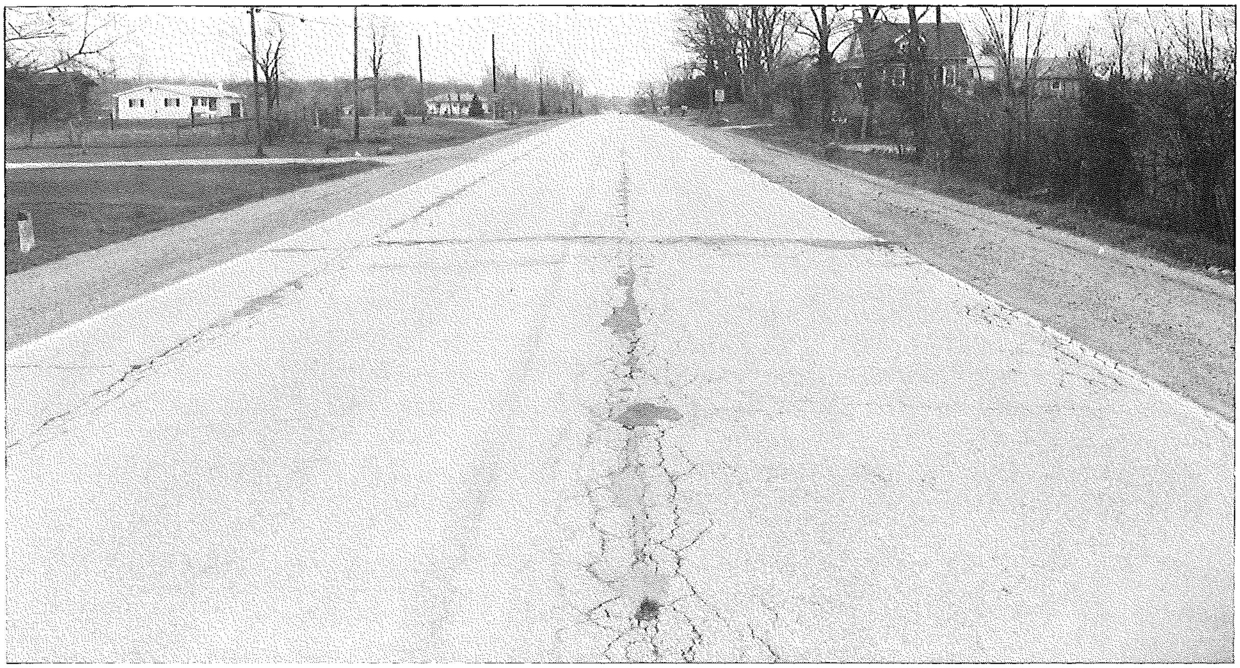
The experimental project was designed as a cooperative effort including W. L. Colbeck, the Construction Division Project Engineer, J. L. Wiser of the Maintenance Division, and Research Laboratory personnel.

Project Description

For this comparative study, a 49 year-old reinforced concrete pavement was selected (Construction Project Mb 25091-12676A) located on M 15 from north of the Oakland-Genesee County Line northerly to M 21 in Atlas and Davison Townships, Genesee County (Fig. 1). The traffic on this route has increased during the past 40 years from 1,800 to 5,000 vehicles per day. The underlying two-lane concrete pavement, constructed in 1929, was 20 ft wide with a 10-8-10 in. cross-section and 1-in. expansion joints at 100-ft intervals without load transfer. In 1960, the original concrete pavement was widened to 24 ft and resurfaced with bituminous concrete. A 4.1 mile section of the project was selected for the experimental layout in preparation for a new bituminous concrete overlay.

Project Site Inspection

A field inspection of the test area revealed badly distressed joints, patches, and surface cracks. All underlying transverse expansion joints had reflected through the 18-year old asphalt concrete resurfacing. Figure 2 shows typical surface distress conditions of the experimental area inspected in September 1978.



Surface cracks, faulted joints, and patching work were common repair tasks performed on the old pavement in preparation for asphalt resurfacing.

Old patching and open cracks, 1/4-in. or more in width on both sides of deteriorated longitudinal joints were frequently found over the test area. The performance of these joints (treated and untreated) following asphalt resurfacing is being periodically monitored.

Figure 2. Typical distress conditions of the existing 49 year old concrete pavement on M 15, south of M 21.

For evaluation purposes, the existing distressed longitudinal joint areas and adjacent cracks in the original asphalt resurfacing under study were grouped into three severity levels of reflection cracking as follows:

1) Low-Severity Reflection Cracking (Fig. 3) - A nonfilled longitudinal crack, opened less than 3/8 in. and extending roughly parallel to the pavement centerline, or a longitudinal crack, filled but opened to any width with the filler in good condition.

2) Medium-Severity Reflection Cracking (Fig. 4) - A nonfilled longitudinal crack, up to 3 in. wide, possibly surrounded by light random cracking and extending roughly parallel to the pavement centerline; or a longitudinal crack, filled but opened to any width and surrounded by light random cracking.

3) High-Severity Reflection Cracking (Fig. 5) - A filled or nonfilled longitudinal crack opened to any width and surrounded by major or severe random cracking or broken pavement, or a longitudinal crack, nonfilled and opened more than 3 in.

Experimental Layout

Before the new asphalt overlay was placed, a total of 28 test strips and 10 repair locations showing surface cracking conditions ranging from low to high distress severities (Figs. 3, 4, and 5) were selected for the experimental layout as follows:

1) Twelve test strips covering distressed longitudinal joints were cleaned out by compressed air and treated with the experimental slurry emulsion. With one exception, each slurry strip was 32 in. wide, 1/2 in. thick, and 0.25 miles long (Fig. 6).

2) Sixteen adjacent strips, about 0.25 miles long each, were left untreated to be used as a control. In this case, joint clean-out was the only surface preparation for the asphalt overlay. Both the slurry seal treated and untreated longitudinal joints covered surface cracking conditions ranging from low to medium distress severities (Figs. 3 and 4).

3) Ten locations totaling 5,319 lin ft of deteriorated longitudinal joints were cleaned out and repaired with conventional 31A bituminous material 4.12 as described in Appendix A. The 31A bituminous repaired longitudinal joints covered surface cracking conditions exhibiting a high distress severity level (Fig. 5). Figure 1 shows the experimental layout.

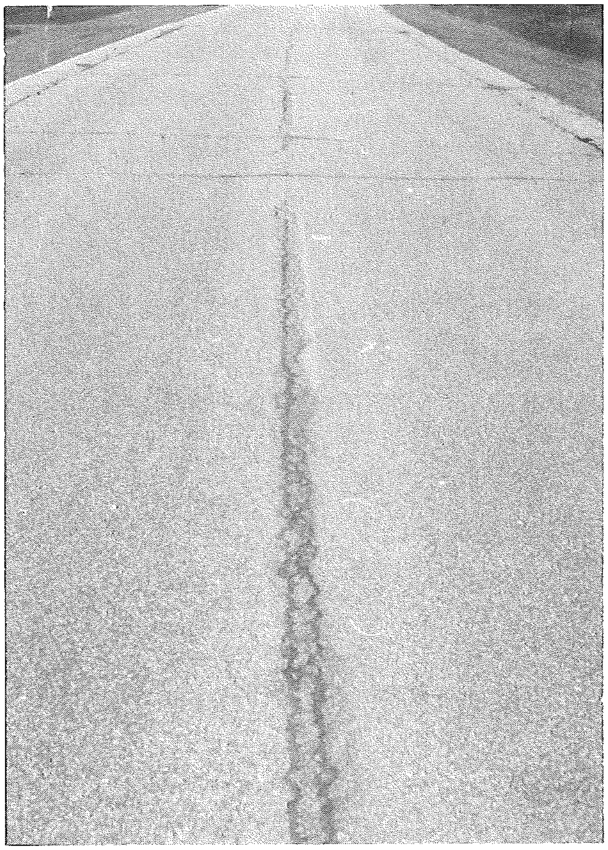


Figure 3. Low-Severity Longitudinal Joint Reflection Cracking.

Figure 4. Medium Severity Longitudinal Joint Reflection Cracking.

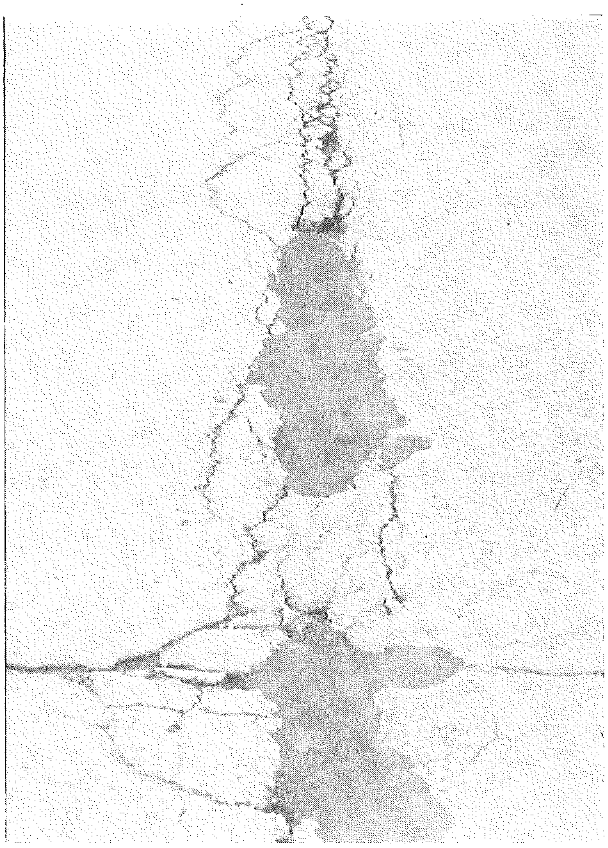
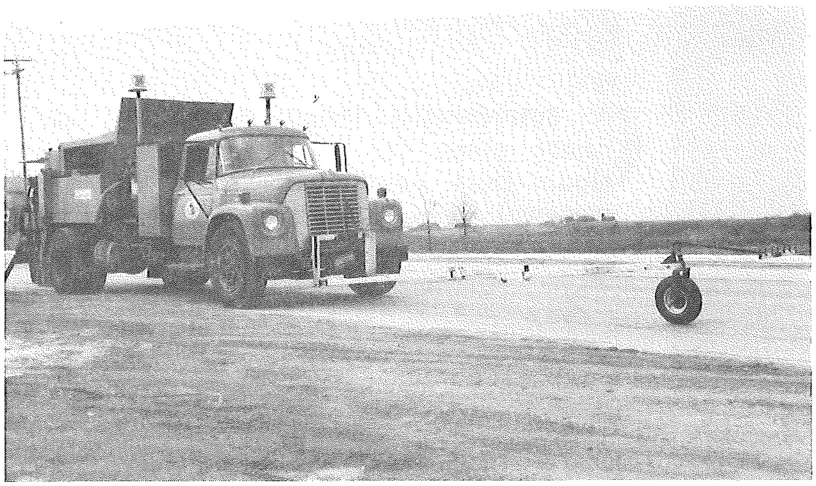
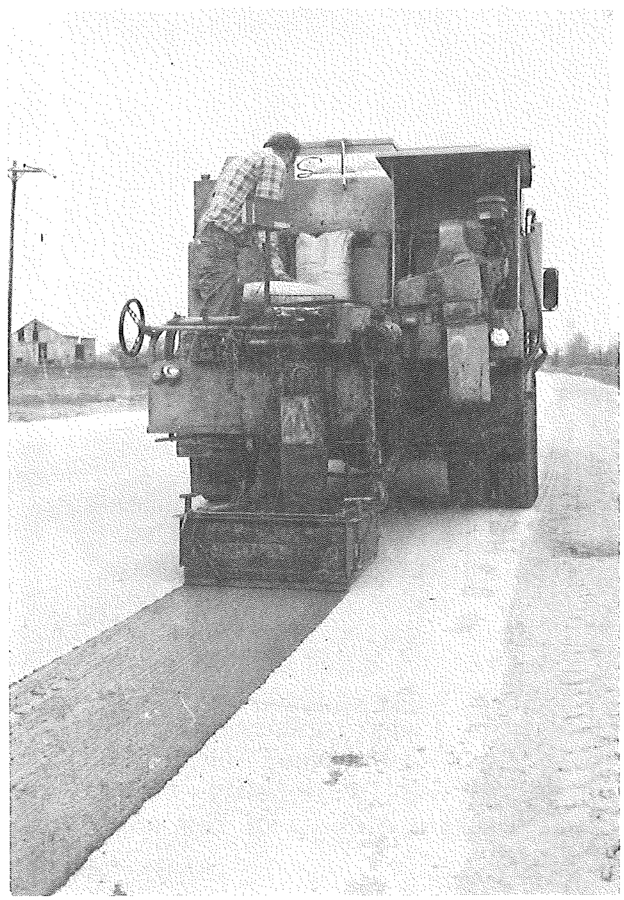


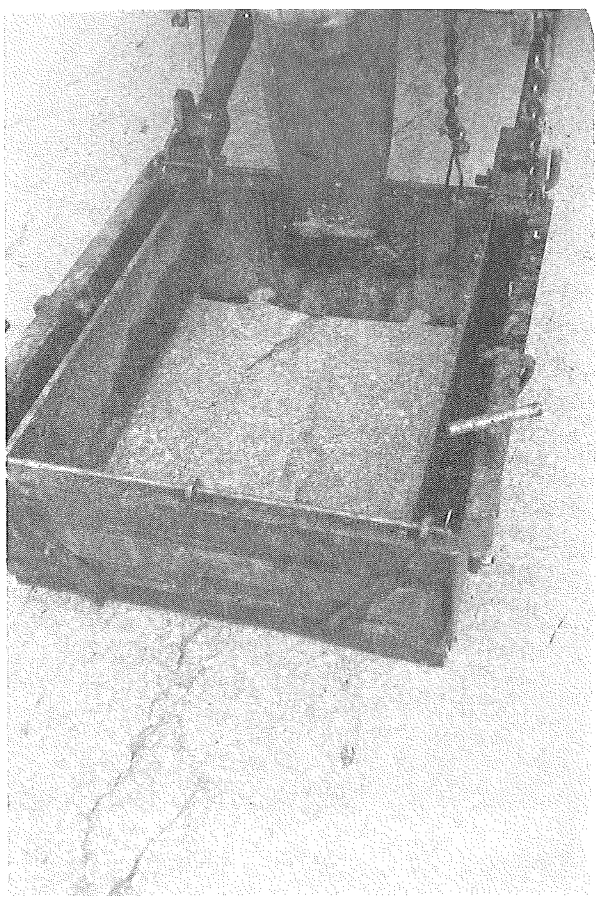
Figure 5. High-Severity Longitudinal Joint Reflection Cracking.



The slurry seal equipment mounted on a truck included materials storage, a mixer, and a spreader section. For better control of lateral spreading operation a bogie wheel was attached to the truck front.

Spreading cold slurry seal over a longitudinal joint. The machine moving at 2 miles/hr deposited a slurry strip, 32-in. wide and 1/2-in. thick. The sealing operation required three trained men.

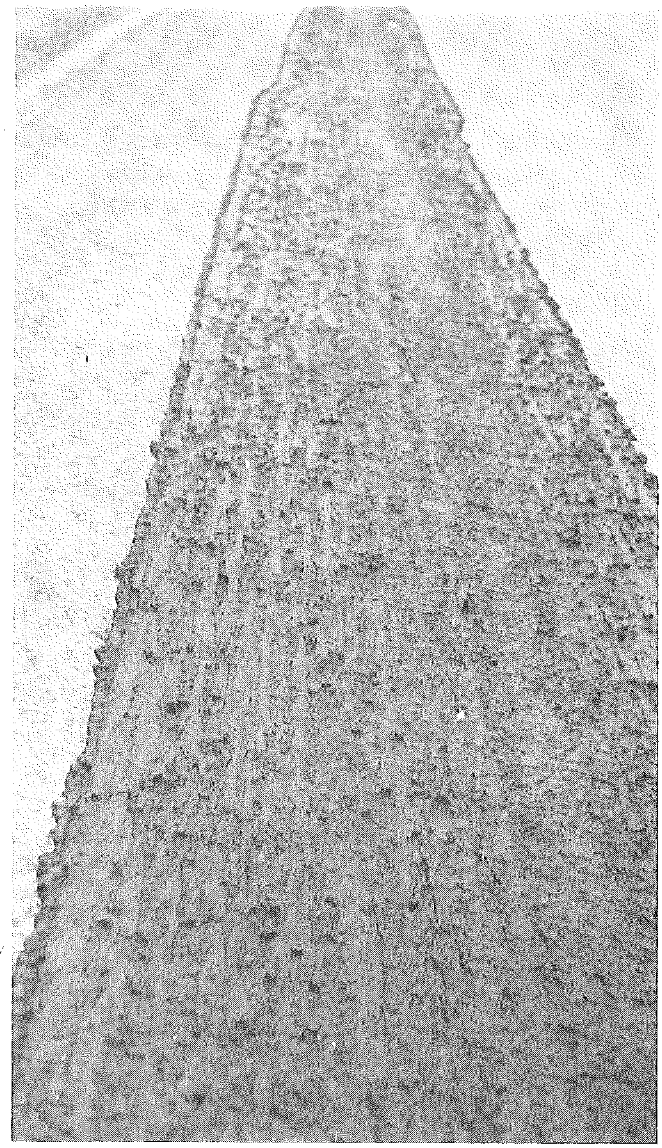




The spreader box and a squeegee deposited the slurry seal in controlled amounts.

Figure 6. Truck-mounted slurry seal equipment applying sealant to a longitudinal joint under study.

A deteriorated longitudinal joint already clean for slurry seal application. Dust, dirt and other foreign material were removed from the failed area by compressed air.



The distressed longitudinal joint after the slurry seal application. In a single pass at an application rate of about 8 lb/sq yd; the slurry machine covered 3.0 miles of test strips the same day as planned. Traffic control was maintained for at least two hours until the slurry was sufficiently cured to prevent pick-up of the mixture.

Figure 7. Typical faulted longitudinal joint before and after slurry seal treatment. Twelve of these treated joints, each 32-in. wide and 0.25 miles long, are being periodically observed following asphalt resurfacing of the test area.

The Slurry Seal Application

A slurry seal, in general, is a mixture of emulsified asphalt, well-graded fine aggregate, mineral filler, and water (2, 3, 4). As joint and crack filler material, the slurry mixture used in the test area consisted of:

> 2 parts 31C limestone chips
> 1 part No. 10 limestone screenings
> 20 percent emulsion SS1H, by weight
> 2 percent portland cement (filler), by weight, and
> the amount of water needed to obtain a uniform
> mixture of free-flowing consistency.

The maintenance people involved in the project ascertained that the selected slurry mix design was appropriate for the longitudinal joint and crack filling operations under study. This slurry mix design was developed in the Maintenance Division based on two years of field experience with bituminous emulsions for highway pavements (1).

Before the slurry seal was applied, the test strip area was cleaned out with compressed air, blowing out dust, dirt, and loose aggregate from deteriorated joints and cracks. The slurry seal equipment used in the project was a travel blending unit, truck mounted, with a towed spreader-box attached (Fig. 6). All the slurry ingredients were proportioned, mixed while the truck is running and applied without heat, to longitudinal joints and surface cracks within each test strip. A single bogie wheel extending from the truck front aided the slurry operator in keeping the spreader box in the desired lateral position during the filling operation. All the aggregate material and asphalt emulsion used in the slurry mixture were stored at an accessible location about two miles from the project site. The slurry machine carried enough mix material to last about an hour, after which it took about half an hour for the reloading round trip. Under sunny weather and air and pavement temperatures over 60 F, the slurry machine, in a single pass, covered three miles of test strips the same day at an application rate averaging 8 lb/sq yd. Figure 7 shows a typical 'before and after' slurry filling operation.

Frequently, slurry seal factors such as compatibility between aggregates and asphalt emulsions, variations in mix proportions, mixing water and blending time present some problems in slurry seal operations (5, 6, 7). In this project, field problems in the setting characteristics of the slurry emulsion were easily corrected. On the other hand, the only problem encountered in this work was keeping the traffic off the treated strips during the two hours curing time. Although some motorists knocked off the traffic cones and drove through, very little damage was caused to the fresh slurry.

Asphalt Overlay

After surface cracks and defective joints were repaired and the experimental layout completed (Fig. 1), the 4.1-mile test section of the project was resurfaced (October 21, 1978). The resurfacing job consisted of two-course construction: a leveling course using 25A coarse aggregate applied at a rate of 130 lb/sq yd and a Type C bituminous concrete wearing course using 25A coarse aggregate applied at a rate of 120 lb/sq yd. The resurfacing work was conducted as specified in §4.12 of the 1976 Standard Construction Specifications and in Supplemental Specifications included in the Project Proposal. Project data are summarized in Appendix B.

Visible Longitudinal Cracking

Since completion of the resurfacing project in October 1978, three detailed longitudinal crack surveys were made over the 3-1/3 year period following asphalt overlay of the experimental project. Figure 8 summarizes the results of the December 1979, April 1981, and March 1982 crack surveys.

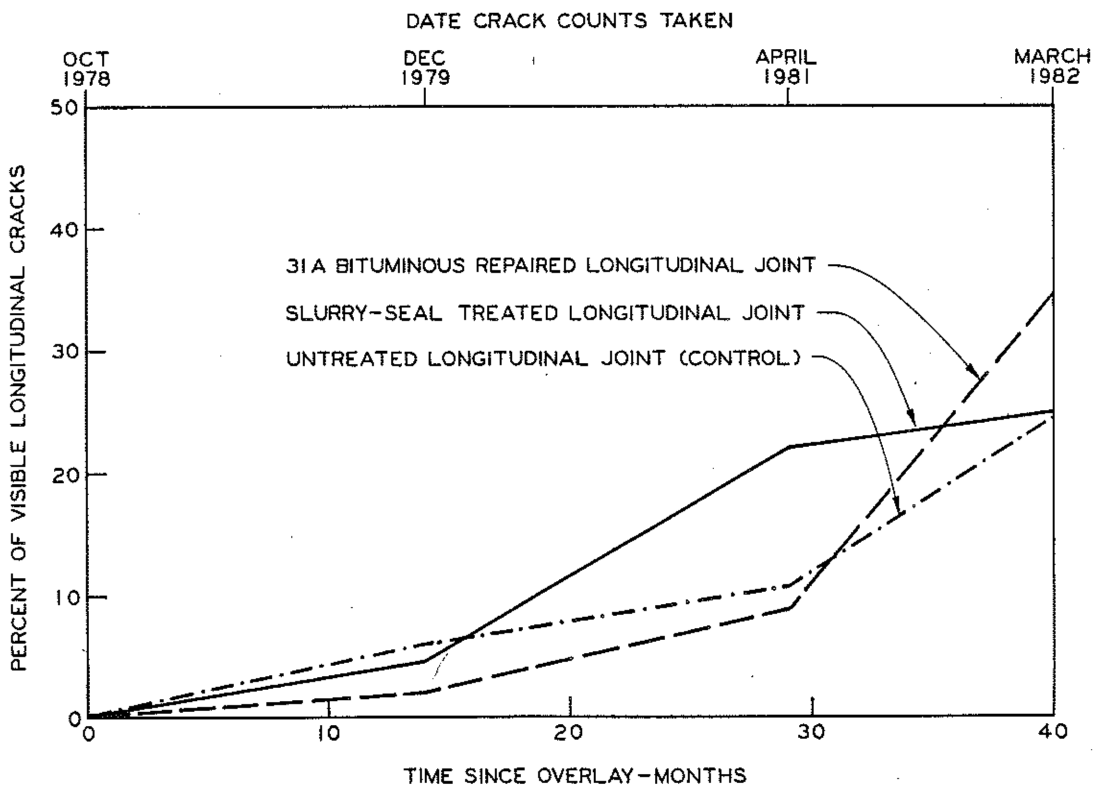


Figure 8. Rate of increase of visible longitudinal cracks through asphaltic concrete resurfacing after the third winter of 1981-82.

Longitudinal reflection cracking visible under dry surface conditions and located directly over the underlying joints, was expressed in terms of percentages of the length of longitudinal joints in the old surfaces. After three winters of pavement service, the resurfacing project has developed visible longitudinal cracking as follows: a) The crack growth shows an average yearly increase in longitudinal reflection cracking of about 10.5 percent for 31A bituminous repaired joints and about 7.5 percent for slurry seal treated joints and also for untreated, control joints; b) The longitudinal cracks which have reflected through the new overlay, were classified as low severity reflection cracking as defined earlier (Fig. 3).

Conclusions

After three winters of pavement service, both slurry seal treated and untreated longitudinal joints (control) have shown similar crack-resistance properties with an annual increase in crack formation averaging 7.5 percent. On the other hand, 31A bituminous repaired joints have shown a 3.0 percent greater annual crack growth than that for either slurry-seal treated or untreated longitudinal joints (10.5 percent vs. 7.5 percent). This might be expected since the 31A bituminous repair areas covered surface cracking conditions of greater serverity (Fig. 5) than the slurry seal treated areas or the untreated repair areas (Figs. 3 and 4). At this point, there does not appear to be any advantage in placing the slurry seal, since the unsealed cracks are reflecting at an equal proportion.

After three winters of pavement service, all visible longitudinal cracking reflecting through the asphalt overlay was rated as Low Severity Reflection Cracking (Fig. 3).

In general, the experimental slurry seal operation presented no apparent difficulties in proportioning, mixing, and spreading the trial emulsion and in filling cracks and deteriorated longitudinal joints with the slurry machine. However, this slurry seal application was limited to a single slurry mix design without taking into account variations in mix proportions, aggregate types, asphalt emulsions, added water, and mixing time, all these factors which affect consistency and setting characteristics of the slurry emulsion (5, 6, 7).

Recommendations

If slurry seals are to be used for various purposes, the mixtures must be adapted to each job. The first step should be preparation of laboratory trial mixes to determine the proper job mix formula for the intended field treatment. This practice is highly recommended for any future work with slurry seal emulsions.

Finally, condition surveys of the test site should be continued for the next year or so or until enough data is obtained to determine whether there is any longer term merit of slurry seal treatment ($0.15/lin ft) compared with no treatment, or with the conventional practice of longitudinal joint repair ($5/lin ft). The inspection sheet and attached definitions and illustrative photos repeated for reference (Appendix A) might be useful in identifying longitudinal cracking and distress severity levels in future condition surveys of the test area.

REFERENCES

1. "Mechanical Crack Filling Report," MDOT Maintenance Division, Methods Unit Operations Section, December 1977.

2. "Slurry Sealing," Construction Leaflets CL-22, The Asphalt Institute, January 1978.

3. "Asphalt Surface Treatments and Asphalt Penetration Macadam," Manual Series No. 13 (MS-13), The Asphalt Institute, January 1975.

4. Huffman, John E., "Successful Slurry Sealing by Plan, Not by Chance," Public Works, June 1977, pp. 67-70.

5. "Two New Quick-Set Emulsions Developed for Slurry Seal Coats," Roads and Streets April 1969, pp. 138-140.

6. "A Slurry Seal Aid? Faster Cure Emulsions," Highway and Heavy Construction, May 1978, pp. 80-81.

7. "Slurry Sealers Push Quality Program," Highway and Heavy Construction, July 1978, pp. 58-61.

APPENDIX A

1. Locations of longitudinal joint repairs.
2. Field Inspection Sheet.
3. Distress severity of longitudinal cracking. (Repeated for evaluation purposes)

1) <u>31A Bituminous Repair Longitudinal Joints</u>

For the experimental layout (Fig. 1), the following locations of longitudinal joint repair were reported by W. L. Colbeck, Project Engineer:

Station 912+00 to 915+34	8 ft Rt of ℄
Station 918+18 to 919+76	8 ft Rt of ℄
Station 923+32 to 925+85	2 ft Lt of ℄
Station 978+56 to 992+87	8 ft Rt of ℄
Station 980+25 to 983+79	2 ft Lt of ℄
Station 1020+40 to 1021+65	8 ft Rt of ℄
Station 1037+30 to 1041+13	8 ft Rt of ℄
Station 1060+04 to 1069+34	8 ft Rt of ℄
Station 1063+20 to 1066+41	2 ft Lt of ℄
Station 1107+64 to 1117+94	8 ft Rt of ℄

The above repairs (5,319 lin ft) were made by 'plowing out' with ripper tooth on grader, blowing out with compressed air, applying bituminous bond coat, filling with a fine 31A bituminous material, and compacting with a steel roller.

2) Condition Survey of M 15 from Hill Rd Northerly to M 21 (Research (Project 78 TI-467)

Joint Treatment	Distress Severity
1 - slurry seal treated joints	A - Low (Fig. A1)
2 - 31A bituminous repaired joints	B - Medium (Fig. A2)
3 - untreated joints (controls)	C - High (Fig. A3)

Northbound M 15 Eight Feet Right of Centerline

Footage from Hill Rd		Joint Treatment	Lin Ft Longitudinal Cracking	Lin ft Distress Severity A	B	C
0-1365	(1365)	(1)				
1365-1726	(361)	(3)				
1726-2060	(334)	(2)				
2060-2344	(284)	(3)				
2344-2502	(158)	(2)				
2502-2665	(163)	(3)				
2665-3693	(1028)	(1)				
3693-5278	(1585)	(3)				
5741-7133	(1392)	(3)				
7133-8382	(1249)	(1)				
8382-9813	(1431)	(2)				
9813-9917	(104)	(3)				
9917-11352	(1435)	(1)				
11352-12566	(1214)	(3)				
12566-12691	(125)	(2)				
12691-13928	(1237)	(1)				
14256-14639	(383)	(2)				
14639-14936	(297)	(3)				
14936-16220	(1284)	(1)				
16220-16530	(310)	(3)				
16530-17460	(930)	(2)				
17460-18848	(1388)	(1)				
18848-19934	(1086)	(3)				
19934-21290	(1356)	(1)				
21290-22320	(1030)	(2)				

Southbound M 15 Two Feet Left of Centerline

2858-3111	(253)	(2)				
5544-6864	(1320)	(3)				
6864-8184	(1320)	(1)				
8551-8905	(354)	(2)				
8905-9504	(599)	(3)				
9504-11088	(1584)	(1)				
11088-12073	(985)	(3)				
12408-13200	(792)	(3)				
13200-14784	(1584)	(1)				
14784-15576	(792)	(3)				
16846-17167	(321)	(2)				
19561-20169	(608)	(3)				
20169-21489	(1320)	(1)				
21489-21992	(503)	(3)				

Summary of Longitudinal Joint Performance

	Joint Treatment		Longitudinal Cracking		Distress Severity					
					A		B		C	
	Type	Lin ft	Lin ft	%	Lin ft	%	Lin ft	%	Lin ft	%
NB	1	10,342								
	2	4,391								
	3	6,796								
SB	1	5,808								
	2	928								
	3	5,599								
OVERALL	1	16,150								
	2	5,319								
	3	12,395								

3) Distress Severity of Joint Reflection Cracking (Research Project 78 TI-467)

A - Low-Severity Reflection Cracking (Figure A1)

A nonfilled longitudinal crack, opened less than 3/8 in. and extended roughly parallel to the pavement centerline; or a longitudinal crack, filled but opened to any width with filler in good condition.

B - Medium-Severity Reflection Cracking (Figure A2)

A nonfilled longitudinal crack, opened up to 3 in., possibly surrounded by light random cracking and extended roughly parallel to the pavement centerline; or a longitudinal crack, filled but opened to any width and surrounded by light random cracking.

C - High-Severity Reflection Cracking (Figure A3)

A filled or nonfilled longitudinal crack opened to any width and surrounded by major or severe random cracking or broken pavement; or a longitudinal crack, nonfilled and opened more than 3 in.

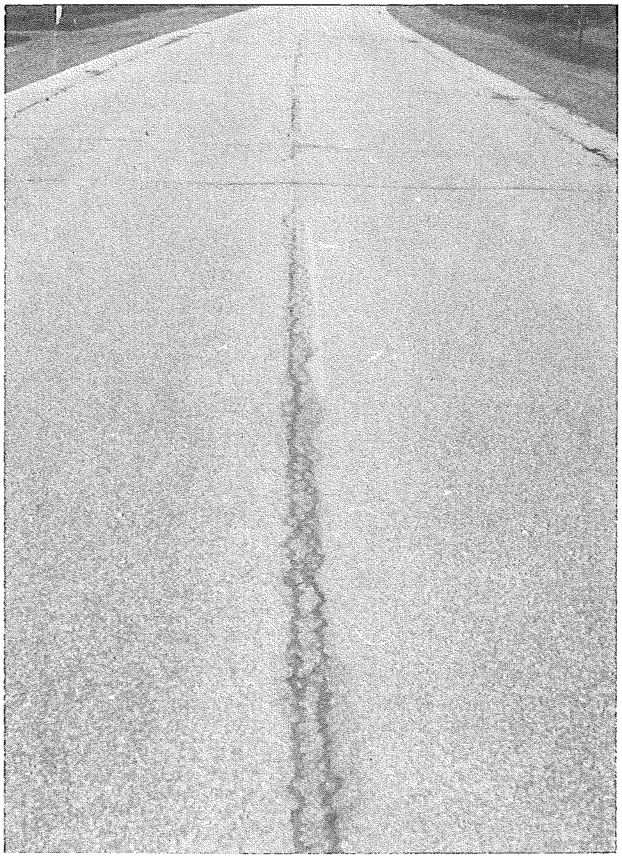


Figure A1. Low-Severity Longitudinal Joint Reflection Cracking.

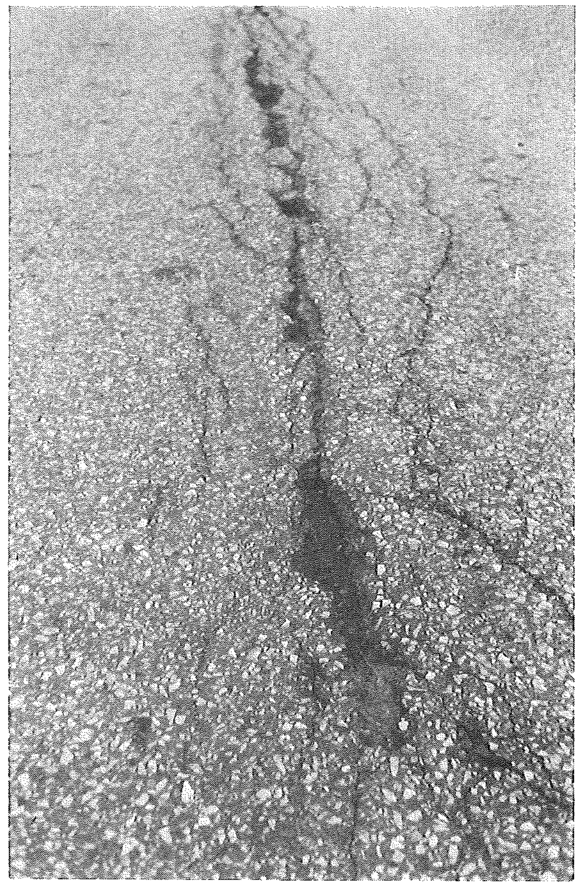


Figure A2. Medium Severity Longitudinal Joint Reflection Cracking.

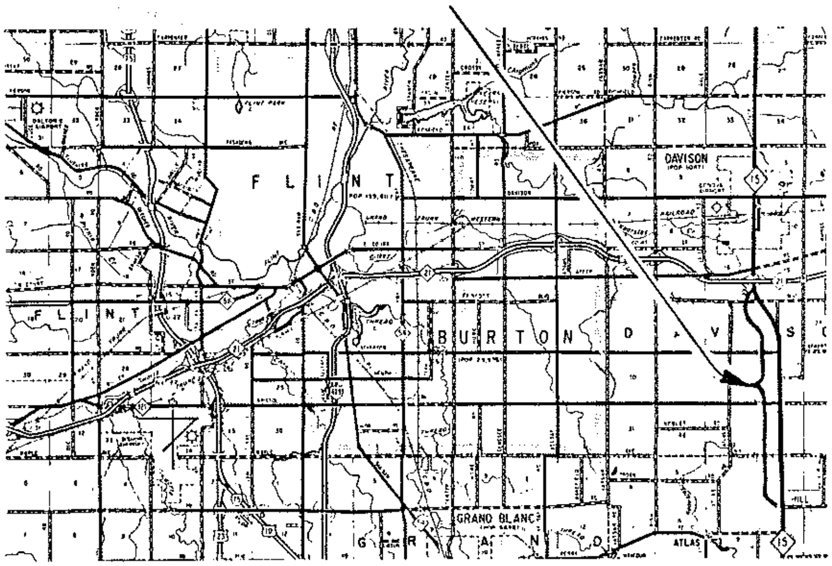
Figure A3. High-Severity Longitudinal Joint Reflection Cracking.

APPENDIX B

SUMMARY OF PROJECT DATA

M 15 Slurry Seal Experiment
(Construction Project Mb 25091-12676A)

Location: On M 15 from north of the Oakland-Genesee County Line northerly to M 21 in Atlas and Davison Townships, Genesee County.



Old Pavement: 8-in. concrete, 20-ft wide, placed over slow-drained subgrade, built in 1929, 100-ft joint spacing without load transfer, resurfaced and widened to 24 ft in 1960.

ADT: 5,000 vehicles in 1970.

Test Area: A 4.1 mile test section included: 1) slurry emulsion treatment, 16,150 lin ft of distressed longitudinal joints; b) conventional 31A bituminous 4.12 repairs, 5,319 lin ft of distressed longitudinal joints; and, c) conventional joint clean out used as controls, 12,395 lin ft of distressed longitudinal joints. The relative merit of the slurry emulsion treatment ($0.15/lin ft) to be compared with conventional methods of longitudinal joint repairs ($5/lin ft).

Construction:

1. Repair of surface cracks and of distressed joints as specified in the proposal or on the plans in preparation for asphalt resurfacing of the 49 year old concrete pavement.
2. Placing 130 lb/sq yd, 4.12 leveling course.
3. Resurfacing with 120 lb/sq yd, 4.12 wearing course.