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RT. I-78 SHOULDER REHABILITATION EVALUATION

Final Report

By

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NOTICE

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16. Abstract

This report describes the field evaluation and performance results of several shoulder rehabilitation techniques after six years of service on a six-lane interstate highway through rolling terrain in north central New Jersey. The techniques varied from simple maintenance repairs and slurry sealing to 8" thick tied concrete shoulders. The cost effectiveness of each treatment was determined using an Equivalent Uniform Annual Cost method. Because most of the distress noted in the test sections was water related, the importance of providing and maintaining good surface and subsurface drainage is stressed in the report.

Recommendations on the most cost effective rehabilitation techniques are provided.

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INTRODUCTION

This report summarizes the results of a six-year field evaluation of an experimental shoulder rehabilitation project constructed in 1981 on Route I-78 in Hunterdon and Somerset Counties. The construction phase of the project is documented in a report, "Shoulder Rehabilitation Evaluation (I-78 - Vicinity of Cokesbury Rd. to West of Bunns Rd.)" FHWA/NJ 83/008, August, 1982.

The objective of this study was to determine the relative performance and cost effectiveness of several methods of rehabilitating distressed bituminous shoulders adjacent to portland cement concrete pavements.

Traditionally, rehabilitating shoulders in New Jersey is a small scale maintenance operation which consists of pothole patching and joint sealing. In extreme cases, maintenance forces will construct stronger shoulder sections by removing the existing bituminous concrete and a portion of the subbase and construct a plant mixed lime-fly ash base with a 2" bituminous surface. Previous to this study, on most large scale projects, rehabilitation of the shoulders occurred only when the mainline pavement was overlayed. The shoulders then received the same thickness of bituminous overlay. However, on this project, while the mainline concrete pavement was in good condition and required little maintenance, the shoulders were severely deteriorated. This provided an opportunity to evaluate several shoulder sections which could be utilized on future concrete pavement rehabilitation (CPR) efforts.

PROJECT DESCRIPTION

The original pavement on the test project, Route I-78, Section 3F and 3G was constructed in 1964 as a four-lane divided highway with an approximate length of 8 miles. The mainline pavement consists of 9" thick reinforced portland cement concrete lanes, 12' wide with 3/4" expansion joints spaced at 78'2". The 12' wide outside shoulders consisted of 7" of quarry processed stone base topped with a 2" surface course of fine aggregate bituminous concrete (FABC). In the early 1970's a third inner lane was constructed in each direction.

A condition survey was made by personnel of the Bureau of Geotechnical Engineering and the Bureau of Transportation Structures Research in 1977. That survey revealed that while the mainline concrete pavement was in good condition, portions of both the eastbound and westbound outside shoulders had become severely deteriorated, apparently in large part due to their use as a truck parking area rather than for emergency stopping. It was concluded that until truck parking was eliminated by either increased police enforcement, additional signing or the building of rest areas -- the problem would persist unless a stronger pavement section was provided in the shoulder areas.

Research personnel proposed rehabilitating the severely distressed areas with a stronger shoulder section constructed by milling and hot mix recycling the bituminous surface course and stabilizing the existing base course with cement and/or lime-fly ash additions. They also suggested a 4" thick recycled bituminous mat for use on a non-stabilized base section. Recycling bituminous concrete was in its infancy during the planning stages of this project and it was expected that valuable information could be obtained during the study. At the suggestion of Geotechnical Engineering, a shoulder section of eight inch thick plain portland cement concrete tied to the existing outside portland cement concrete travel lane was included.

Approximately one mile of the shoulder was in good condition except for faulting. In this area, the shoulder was strengthened by placing a 25" wide inlay adjacent to the mainline pavement. The eastbound inlay consisted of a 7" layer of plant-mix lime-fly ash (LFA) placed to the bottom of the 9" concrete mainline slab and topped with a 2" lift of bituminous concrete. The westbound shoulder received a 25" wide, 4" thick bituminous inlay. The repaired shoulders were then covered with a 1/4" slurry seal. The seven sections constructed for this study are shown in detail in Figure 1. Appendix A includes a description of the various materials used in the rehabilitation effort.

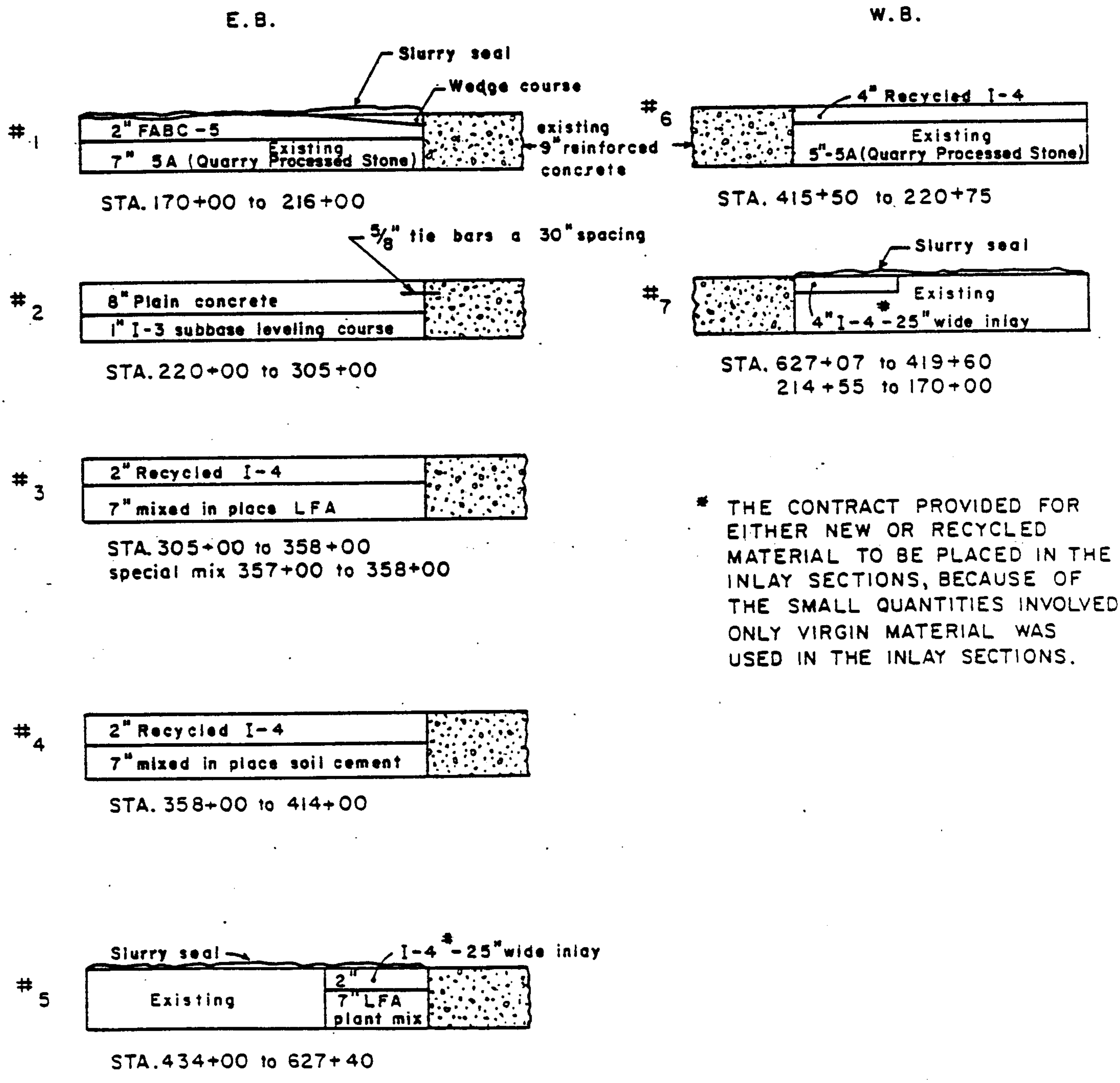
SHOULDER EVALUATION

The final performance evaluation of the various treatments was completed in December 1987. At that time the rehabilitated shoulders had been in service for approximately 6½ years. The evaluation consisted primarily of visual observations and measurements of the amount of cracking and other distress on each of the sections.

It is important to note that the evaluations of relative performance were complicated by the fact that certain of the sections were subjected to more severe service/environmental conditions than others. For example, in the areas where only a wedge course and slurry seal was used, the existing shoulders were relatively dry and in good condition before the rehabilitation. On the other hand, in areas where the lime-fly ash and soil cement stabilization were used, the existing shoulders were severely distressed, manifesting water-related problems, (e.g., wet subgrades, pumping, etc.). Since these drainage problems were not addressed during the rehabilitation, they undoubtedly contributed to the relatively early distress noted on these sections. Accordingly, due to these differences in service environment, precise comparisons of service life among the test sections cannot be made.

The following describes the present condition of each of the "experimental" sections.

Figure 1. SHOULDER SECTIONS



1. Wedge Course and Slurry Seal

Approximately one mile of the shoulder rehabilitation was accomplished by placing a thin wedge of hot mix bituminous concrete on the shoulder area near the edge of concrete pavement. This was done as a leveling course to correct the approximately 1" fault where the shoulder area had settled. Other than the minor fault at the pavement/shoulder joint, the area was in a good enough condition at the time of construction to permit patching and slurry sealing of the shoulder. In general, the area is currently in fair condition, with some of the wedge course having peeled or delaminated from the asphalt surface. The joint between the concrete and the shoulder has opened approximately 1" over 15% of the length of the section. Figure 2 depicts the raveling at the edge, while Figure 3 shows some of the transverse cracking occurring in the section.

2. Concrete Shoulders*

As might be expected, the 1.5 miles of shoulder which was replaced with 8" thick concrete, has remained in excellent condition. Only a few small hairline cracks were observed, with one large crack reflecting through from an inlet. Figure 4 shows the overall condition of the concrete shoulder, while Figure 5 depicts the hairline cracks. It should be noted that the addition of the concrete shoulder has eliminated pumping in the adjoining truck lane.

*Plain concrete was tied at 18" intervals to the existing pavement. New Jersey Type A transverse expansion joints were used at 78'2" intervals to match existing joints. These joints are 3/4" wide and contain stainless steel clad load transfer dowels with a 12" spacing.

3. <u>2" Recycled Bituminous Concrete (I-4 Mix) over 7" Mixed In-Place LFA</u>

The one mile section of mixed-in-place lime-fly ash base is severely alligator cracked throughout about half of its length as shown in Figure 6. In addition, about 70% of the pavement shoulder/joint has broken apart, spalled, and opened more than 1" as noted in Figure 7. This section was constructed in an extremely wet area and the mainline pavement continues to pump severely. The area also serves as a stopping point for numerous trucks.

4. <u>2" Recycled Bituminous Concrete (I-4) over 7" Mixed In-Place Soil Cement</u>

The 1.1 mile section of mixed-in-place soil cement has remained in relatively good condition as can be seen in Figure 8. There are a few isolated areas of alligator cracking on this shoulder, however, the pavement/shoulder joint has failed over approximately 8% of the length as noted in Figure 9. The area does not appear to be as poorly drained as the section where the LFA material was used. In addition, trucks are not using the area as a rest stop as much as was observed on the LFA section.

5. <u>2" Recycled Bituminous Concrete (I-4) and Slurry Seal over 7" LFA Inlay</u>

This 4 mile section employed a 25" wide inlay 7" deep of plant mixed LFA overlayed with 2" of the I-4 recycled bituminous concrete material. The entire shoulder was then slurry sealed. Approximately half of the total length of the outside edge of shoulder is alligator cracked. The mainline/shoulder joint has failed in approximately 5% of the section as illustrated in Figure 10. In addition, the inlay seam has opened up for approximately 66% of the length. There is an excessive amount of free water in the area, as evidenced by the extensive pumping shown in Figure 11.

6. 4" Recycled Bituminous Concrete (I-4 Mix)

This 3.5 mile section was reconstructed using 4" of recycled I-4 hot mixed bituminous concrete. The section has remained in relatively fair condition. As illustrated in Figure 12, there is very little alligator cracking noted on the section, however a few of the areas are ravelling (probably due to the poor mix conditions noted during construction). The mainline/shoulder edge is generally in good condition, with only about 1% of the section showing joint distress (see Figure 13).

7. Slurry Seal over 4" Bituminous Concrete (I-4 Mix) Inlay

The final section on the project consisted of 3.5 miles of a 25" wide, 4" thick I-4 inlay along the pavement/shoulder edge. The entire shoulder was then slurry sealed. This section is exhibiting alligator cracking over about one-third of its length (Figure 14). Additionally, the inlay seam has opened up for approximately 43% of the length of the section. While the concrete pavement continues to pump in this area, the mainline/shoulder joint has remained in relatively good shape (Figure 15).

The results of the performance evaluation are summarized in Table 1. As evident from the photographs and discussion, much of the observed distress referred to in this tabulation is water related. Most of the test sections were poorly drained. This study thus clearly confirms that any long-term solution to the shoulder performance problems must contain measures to alleviate excess water in the pavement section.

Figure 2. Ravelling/blockcracking at edge of wedge course

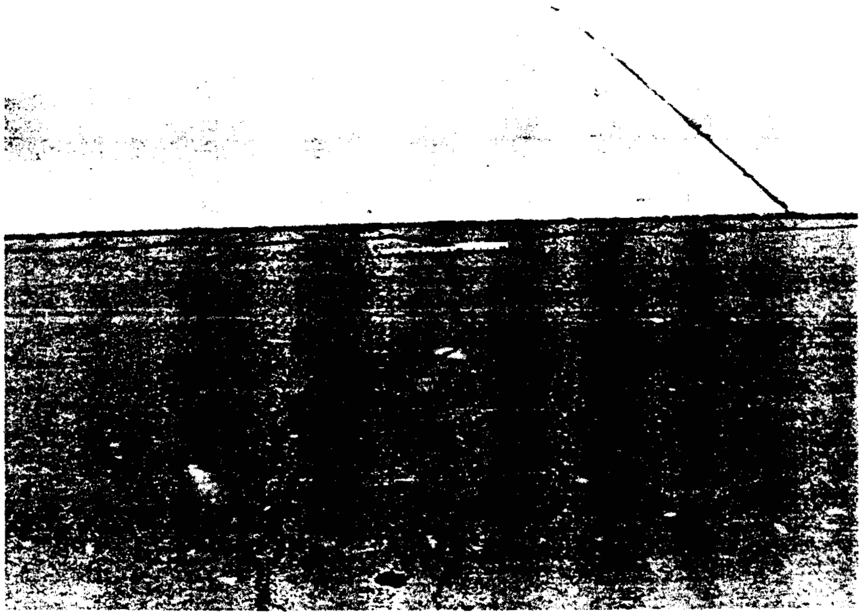


Figure 3. Transverse cracking occurring in slurry seal of wedge course section

Figure 4. Overview of tied portland cement concrete shoulder section

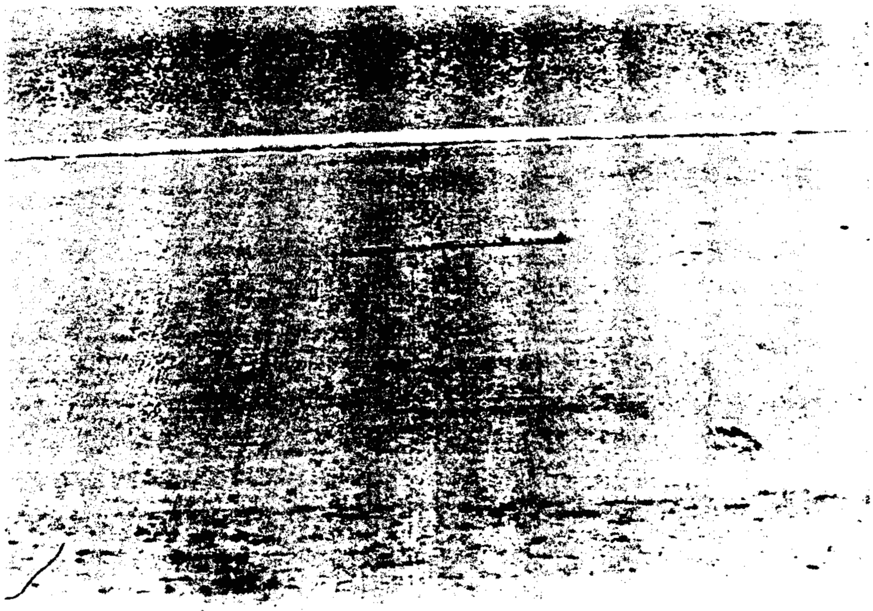


Figure 5. Random hairline cracks in portland cement concrete shoulder section

Figure 6. Alligator cracking on mixed-in-place LFA section

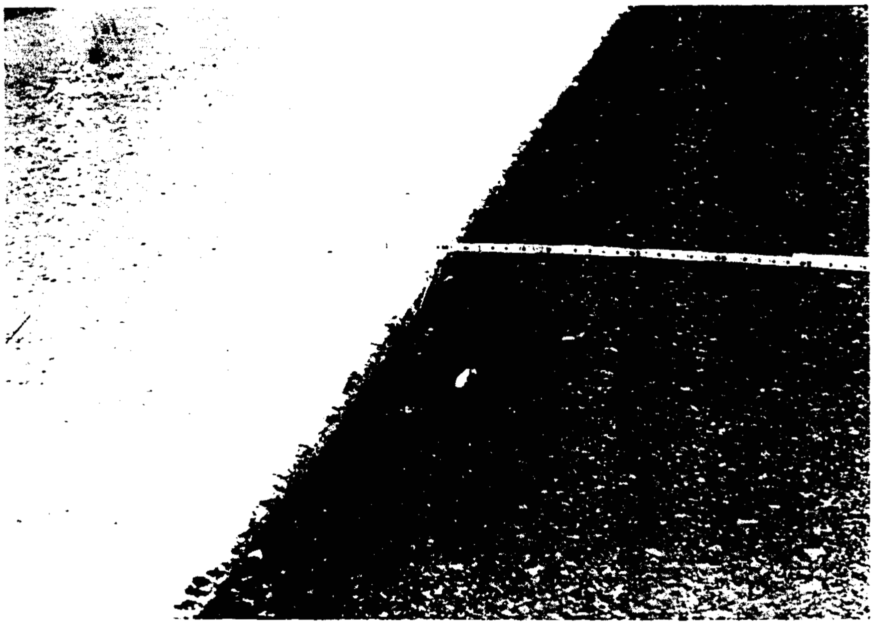


Figure 7. Mainline/shoulder joint failure in mixed-in-place LFA section

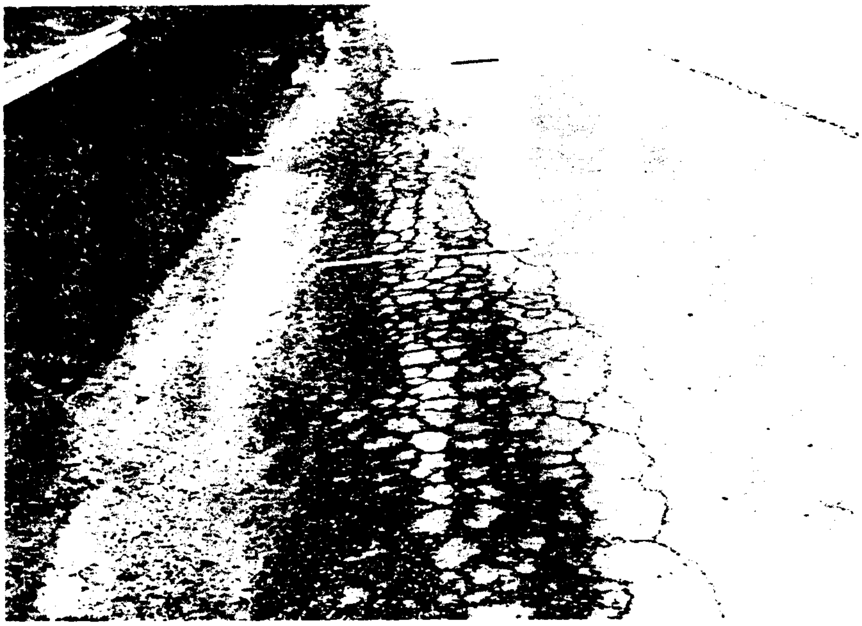


Figure 8. Alligator cracking on soil cement section
(Note excessive water in this area.)

Figure 9. Mainline/shoulder joint failure at
soil cement section

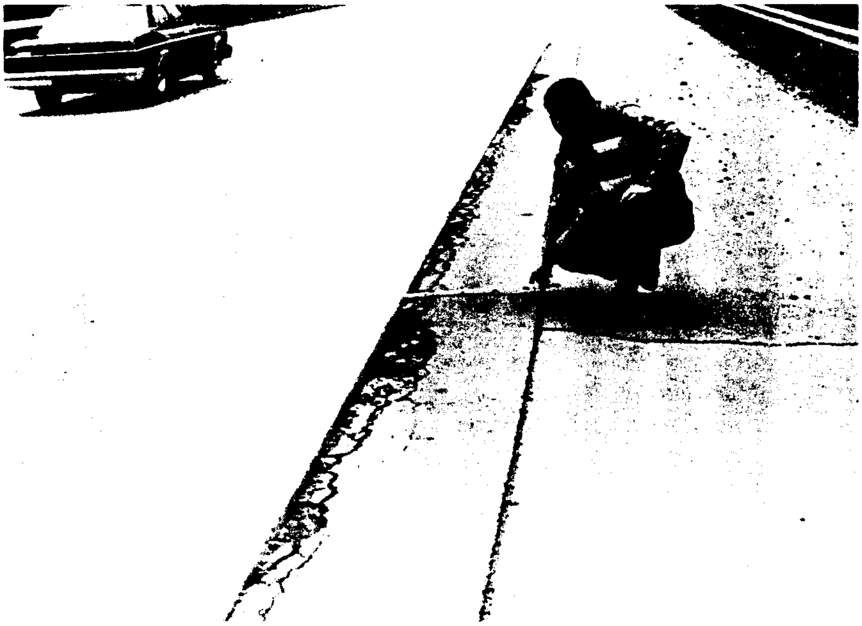


Figure 10. Mainline/shoulder joint failure in LFA inlay section

Figure 11. Pumping slabs in LFA inlay section

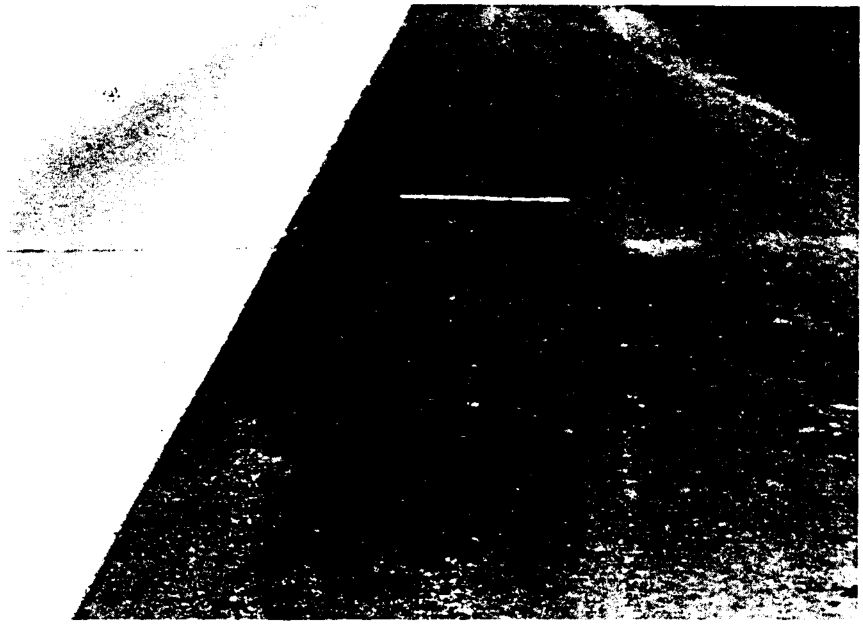


Figure 12. Surface ravelling in recycled I-4 section

Figure 13. Mainline/shoulder edge failures in recycled I-4 sections

Figure 14. Alligator cracking in I-4 inlay section
(Note standing water in truck pull-off area at shoulder edge.)

Figure 15. Mainline/shoulder joint is in good condition
on I-4 inlay section

TABLE 1

SUMMARY OF FINAL PERFORMANCE EVALUATION

	Shoulder Test Section	Location (M.P.)	Length (miles)	Cracking at Left Shoulder Edge*	Cracking at Inlay Seam*	Transverse Cracking (Cracks/Mile)	Alligator Cracking at Right Edge*
1.	Wedge Course and Slurry Seal	EB - 20.0 to 21.0	0.90	15.5%	N.A.	101	44%
2.	8" concrete	EB - 21.2 to 22.7	1.50	None	N.A.	2	None
3.	7" LFA, Field Mixed, 2" Recycled I-4	EB - 22.7 to 23.7	1.0	71.4%	N.A.	52	50%
4.	7" Soil Cement 2" Recycled I-4	EB - 23.7 to 24.8	1.1	7.5%	N.A.	None	1%
5.	2" I-4, 7" LFA Inlay Slurry Seal	EB - 24.9 to 28.8	3.9	5%	66%	51	50%
6.	4" Recycled I-4	WB - 24.6 to 20.9	3.7	1.0%	No Inlay	None	None
7.	4" I-4Inlay, Slurry Seal	WB - 28.8 to 25.2	3.6	1%	43%	73	28%

*Percent of Length

SHOULDER TREATMENT COST EFFECTIVENESS

Based on the results of the 1987 condition surveys, an attempt was made to estimated the remaining service life of the test sections. It was estimated that the poorest performing section still had approximately two years of remaining life, for a total expected life of 8 years, while the concrete shoulders were estimated to remain functional for approximately 30 years. An equivalent uniform annual cost (EUAC) for each section was then developed, based on the construction cost of each treatment and its expected life. The results are summarized in Table 2. As can be seen in this table, the least expensive method used was the wedge course slurry seal treatment with an EUAC of $.18 per linear foot.

As previously mentioned, the wedge course and slurry seal treatment was not originally slated for this rehabilitation effort. However, because the shoulders in certain areas were in good condition, it was decided to level the mainline/shoulder joint dropoff with a bituminous concrete wedge and slurry seal the remainder of the shoulder. While being an inexpensive technique, using a wedge course and slurry seal requires that the shoulder being in relatively good condition (i.e., well drained with little or no alligator cracking).

The most expensive shoulder treatment was the tied concrete shoulders with an EUAC of $4.75 per linear foot. This treatment is estimated to have a life of 30 years. It should be noted that the tied concrete shoulder was the only technique which alleviated the pumping of the mainline concrete slabs. The added benefit of extending the mainline pavement life and reducing maintenance costs on the mainline should be considered when computing costs for concrete shoulders. It appears that to be most cost effective, concrete shoulders should be included during the original construction.

TABLE 2

EQUIVALENT UNIFORM ANNUAL COSTS

Test Section	Estimated Total Life (Years)	Construction Cost (Per Linear Ft.) (1981 $)	EUAC Factor I=10%	Equivalent Uniform Annual Cost ($/linear ft.)
8" Concrete	30	44.80	.10608	4.75
7" LFA,Field Mixed 2" Recycled I-4	8	20.71	.18744	3.60
7" Soil Cement, 2" Recycled I-4	12	16.71	.11467	1.92
4" Recycled I-4	16	13.79	.12782	1.76
2" I-4 7" LFA Inlay Slurry Seal	10	4.36	.16275	0.82
4" I-4 Inlay Slurry Seal	10	3.45	.16275	0.60
Wedge Course & Slurry Seal	8	1.17	.18744	0.18

In areas where severe alligator cracking is observed throughout the shoulders, milling the entire shoulder and replacing the material with at least 4" of hot mixed bituminous materials across the entire shoulders is a cost effective technique.

The 4" I-4 inlay and slurry seal technique at an EUAC of $.60 per linear foot not only provides an inexpensive rehabilitation technique (where the remainder of the shoulder is in relatively good condition) but also allows retrofitting longitudinal drains to provide subsurface drainage.

CONCLUSIONS AND RECOMMENDATIONS

I. The Critical Importance of Good Drainage

Most of the shoulder distress noted during this evaluation was directly or indirectly caused by excessive water in the pavement section. To maximize the life of any rehabilitation effort, the drainage problems -- both surface and subsurface water -- must be alleviated. Ditches must be maintained to prevent standing water near the roadway. Curbs, either portland cement or inexpensive bituminous curbing, can channel water and also provide lateral support to the pavement edge. On this project very little alligator cracking was noted when the shoulders contained curbing. In addition, longitudinal underdrains should be included wherever possible to remove subsurface water and prevent pumping.

II. Assessment of Individual Techniques

The actual selection of a shoulder rehabilitation technique must be site specific. On any particular project, several techniques may be employed to achieve the maximum cost benefit. To this end the following is recommended:

1. Even projecting a 30-year life, the concrete shoulders were the most expensive rehabilitation technique of those considered here. However, the concrete shoulders were the only technique tried in this study which alleviated

the severe pumping on the mainline pavement. While the cost was high, the long-term benefit of extending the life of and reducing maintenance on the mainline pavement must be considered. During extensive CPR work, tied concrete shoulders might be the most cost effective solution. Clearly, it was not possible to make such long-term evaluations in this study. Concrete shoulders should also be given more consideration for inclusion on new construction, where the additional edge support they provide could add years to the pavement life.

2. Where the shoulder distress is limited to the mainline/shoulder joint, the 2-foot wide I-4 inlay with a slurry seal over the entire shoulder is an appropriate method. The removal of the 2 foot wide strip of bituminous shoulder material adjacent to the mainline will also allow the addition of longitudinal edge drains, which are highly recommended in any rehabilitation effort.

3. In areas where the shoulder is distressed across its entire width, the most cost effective solution is to mill the shoulder and replace it with I-4 bituminous mix 4" thick. The removal of the shoulder material will also allow economical installation of edge drains.

4. The wedge course and slurry seal will provide very economical stop-gap maintenance but cannot be used where deterioration is severe.

5. As described earlier in this report, based on the results of this investigation, the field mixed lime-fly ash section did not perform as well as expected. Problems during construction with fly ash blowing around and with quality control probably influenced the performance of this material. (It should be noted that quality controlled plant mixed LFA base is currently being used with extremely good success by the Department's Maintenance personnel during shoulder rehabilitation.) The LFA inlay section did not perform as well as the 4" bituminous inlay and was more costly. It is therefore recommended that field mix lime-fly ash or the LFA <u>inlay</u> not be used from both cost and performance

standpoints. However, based on continued successful use of plant mixed LFA base by our Maintenance forces, LFA remains a cost-effective shoulder rehabilitation strategy.

6. Although the field mixed soil cement section performed relatively well, problems with the blowing of cement during construction suggests that if used in the future, cement stabilized base should be plant mixed.

III. Recommendations for Future Research

1. The Department is currently evaluating the performance of several new geocomposite edge drains. Preliminary cost and construction results are encouraging. It is recommended that additional projects be selected for evaluating the cost effectiveness of these edge drains.

2. An investigation into the true costs of portland cement concrete shoulders should be undertaken. This will involve extensive preliminary performance data on an existing pavement and after rehabilitation an extensive follow-up monitoring program. This will allow an evaluation of the effect of PCC shoulders on the life of the mainline pavement.

APPENDIX A

Description and Gradations of Materials

Bituminous Concrete (I-4 Mix)

Medium Aggregate Surface Course, 3/4" max. size*, 5% A.C.

Stab. - 2000#, Flow -14, Voids - 4.2%

Slurry Seal - Type II

15.5% CCS - 1H cationic emulsified asphalt, 12 pounds of washed Trap Rock* per sq. yd., 1% portland cement as a mineral filler

Mixed In-Place LFA

85% Quarry Processed Stone*, 12% Type "F" Fly Ash, 3% Hydrated Lime, 28 day U.C.S. - 925 psi

Mixed In Place Soil Cement

95% Quarry Processed Stone*, 5% Type I cement, Density 137 $\#/ft.^3$, 7-day U.C.S. - 910 psi.

Plant Mixed LFA

84.5% Quarry Processed Stone*, 12% Type F Fly Ash, 3.5% Hydrated Lime, 28 day U.C.S. 1850 psi

*See following page for gradations

AGGREGATE GRADATIONS

% Passing

Sieve Size	Bituminous Concrete (I-4)	Trap Rock for Slurry Seal Type II	Quarry Processed Stone (I-5)
2"	--	--	100
1"	100	--	--
3/4"	95 - 100	--	70 - 100
1/2"	75 - 95	--	--
3/8"	65 - 85	100	--
No. 4	35 - 65	85 - 100	30 - 80
No. 8	25 - 50	65 - 90	--
No. 16	18 - 40	45 - 75	--
No. 30	12 - 30	30 - 55	--
No. 50	10 - 23	18 - 35	10 - 35
No. 100	--	10 - 21	--
No. 200	4 - 10	5 - 15	5 - 12
A.C.	4.5 - 9.5	--	--