SAWING JOINTS TO CONTROL CRACKING IN FLEXIBLE PAVEMENTS
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CONTROL CRACKING IN FLEXIBLE
PAVEMENTS

SPECIAL STUDY NO. 315
Progress Report - 1974

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ABSTRACT

Transverse joints were sawed in a deep-strength (12") flexible pavement, which is over a granular subgrade, prior to the opening of the roadway to traffic. This research project was located on the two southbound lanes of Interstate 35 near Stacy. Each of the three test sections is approximately 500 feet long. Joints were sawed at 40, 60, and 100-foot intervals for a total of 30 joints. Two 700-foot control sections, where no joints were sawed, were left between the sawed sections for comparison purposes. After 4-1/2 years or 5 winters of service almost complete crack arresting was accomplished in the test sections where joints were sawed at 40 and 60-foot intervals. A few cracks had formed in the test section where joints were sawed at 100-foot intervals. In contrast, numerous cracks had developed in the control sections.
FOREWORD

This study was conducted to determine if the sawing of joints in flexible pavements would control transverse cracking.

This report describes the field operations and observations during and subsequent to the sawing of control joints in a flexible pavement.

The author wishes to acknowledge the contribution of P. C. Hughes and R. O. Wolters, former Research Project Engineers. Also, R. H. Cassellius, Research Assistant for the collection and analysis of field data. The assistance of personnel from District 9 is greatly appreciated for aid in site selection and the collection of data.
SUMMARY

OBJECTIVE
To evaluate the results and effects of sawing control joints into a newly constructed deep-strength asphalt pavement.

SCOPE
Three types of test sections were created in the south-bound roadway of Interstate 35 near Stacy. Joints were sawed at 40, 60 and 100-foot spacings. Two control sections, i.e. sections where no transverse joints were sawed, were left between the sawed test sections.

The findings expressed in this report are limited to deep-strength bituminous because all test and control sections are located consecutively and on the same type of pavement structure over granular subgrade.

The joints which were sawed at 40 and 60-foot intervals were alternately sealed with hot-rubber asphalt and neoprene seals. The 100-foot spaced joints were all sealed with the hot-rubber asphalt sealant. All joints were sawed to a depth of 3 inches; widths for the liquid sealant joints were 1/4 inch, the neoprene sealed joints were sawed 7/16 inch wide. The sawing and sealing took place in November of 1969, shortly after surface construction was completed.

SUMMARY OF FINDINGS AND CONCLUSIONS

The most important findings and conclusions from this study are listed below. Items 1 and 2 pertain to the principal intent of the study, crack control. Items 3, 4, and 5 apply to materials and joint characteristics, and 6 to costs.

1. After two winters of service, transverse cracking had developed. These cracks were predominantly in the test sections where no joints were sawed.

2. After five winters of service, or the spring of 1974, numerous cracks had formed in the control sections, where transverse joints were not sawed. In the sections where joints were sawed at 100-foot intervals a few random cracks had formed. However, in the test sections where joints were sawed at 40 and 60-foot spacings almost complete crack arresting was accomplished.
3. The seals and the lubricant-adhesive used for installing the neoprene seals was the same type as used when sealing joints in concrete pavements. On the day following the installation of the neoprene seals, the sidewalls of these joints were softening and random swelling was visible. The lubricant used when installing the neoprene seals was analyzed in the laboratory. This analysis showed that the material contained a high percentage of volatiles which probably caused the softening of the bituminous mixture.

4. The joints which were sealed with hot-rubber asphalt failed in adhesion after one winter of service. This was attributed to the joint shape factor, i.e. the ratio of width to depth.

5. Some spalling or raveling of the bituminous mat within the wheel tracks, at the sawed joints, was evident after 4-1/2 years of service. At this time the joints which had been sealed with hot-rubber asphalt were the only joints where the original sawed joints existed. A theory which may have merit is that neoprene compression seals would exert pressure on the joint sidewalls. This may then retard or prevent the slight cracking parallel to the sawed joints which seems to cause the spalling.

6. Various assumptions were made in order to compare costs; these were:

   a. A 17-year pavement life.

   b. Crack filling would be done annually (present maintenance procedures).

   c. Neoprene seals would last for the life of the surface when installed without or with a compatible, lubricant adhesive.

   d. Hot-rubber asphalt sealant would last for three years when installed in a properly designed joint.

   e. Joints sawed at 60-foot intervals.

Based on these assumptions, costs for sawing and sealing with neoprene would be approximately the same as for the present maintenance practice of crack filling. The cost for sawing and sealing with hot-rubber asphalt is considerably higher.
RECOMMENDATIONS

At the present time it appears that the sawing of joints at 40 and 60-foot intervals does control random transverse cracking of deep-strength pavement structures. For economical reasons the 60-foot spacings should be considered over the 40-foot spacings. However, problems were encountered with materials and joint dimensions. If lubricant-adhesive is used when installing the neoprene seals it must be compatible with the bituminous material. The adhesion failure of the hot-rubber asphalt sealant was somewhat expected because of the joint shape factor used. It is generally felt that a shape factor of approximately 1/2 to 1 be used.

These problems should be researched further before more definite recommendations can be made on the sawing of joints in flexible pavements.
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INTRODUCTION

The infiltration of water, dirt, and other foreign materials into cracks in bituminous pavements creates a major problem for highway maintenance engineers. Rapid pavement deterioration may take place if these cracks are left unsealed. If this deterioration takes place, a decrease in serviceability will be evident. Also the load carrying capability of the structure will be greatly reduced at these cracks. These deficiencies could then lead to costly repairs or even overlays prior to reaching the anticipated life of the roadway surface.

If is felt that uniformly spaced sawed joints could be sealed more efficiently than the random, crooked cracks which now form by themselves. To verify this, joints were sawed at 40, 60, and 100-foot intervals in some recently completed bituminous pavement in 1969. These joints were then filled with hot-rubber asphalt or neoprene joint sealing material. This research project is located on the southbound roadway of Interstate 35, which is the main arterial between the Twin Cities Metropolitan Area and Duluth. Average daily traffic is 8,700. Assuming that 50 percent of the traffic is carried by the southbound roadway, the average daily traffic over the test sections would be 4,350.

This report describes the work performed and observations made during the five-year period which followed. The main purpose of this study is to determine if the sawing of control joints will reduce or eliminate uncontrolled cracking of flexible pavements. However, this study does not endeavor to recommend the types of materials and joint dimensions which should be used when sawing and sealing these control joints.
PROJECT LAYOUT

Prior to the opening of Interstate 35 near Stacy a segment of the southbound roadway, approximately 3000 feet in length, was selected for this test project. Because this test project would be divided into five sections, a portion of roadway of uniform topography was selected. Figure 1 is the layout of the five test sections.

The newly constructed roadway was a deep-strength bituminous section with a Minnesota Highway Department specifications 2351 wearing course. Figure 2 shows a typical cross-section of the roadway.
Figure 1. Layout of test sections.
(1) The upper 3" of the inplace 12" granular material has been stabilized with asphalt emulsion SS-1

1-1/2" Modified asphaltic concrete wearing course Spec. 2351
2" Asphalitic concrete binder course (Type C) Spec. 2351
4-1/2" Plant-mixed bituminous base (25' wide) Spec. 2331
4" Bituminous treated base (27' wide) class 5 Spec. 2204

* See appendix

Figure 2. Cross-section of roadway.
CONSTRUCTION PROCEDURES

Joints were all sawed to a depth of 3 inches with a diamond edge circular blade power cutter. Following is a description of the forming of the control joints:

1. Test Section 1 consists of 14 joints at 40 foot spacings. Seven joints were sawed 1/4 inch wide and seven were sawed 7/16 inch wide. The two joint widths were sawed alternately.

2. Test Section 2 is a control section and contains no joints.

3. Test Section 3 consists of ten joints spaced at 60 feet. As in Test Section 1, 1/4 inch and 7/16 inch joints were sawed alternately.

4. Test Section 4 is a control section and contains no joints.

5. Test Section 5 consists of six joints spaced at 100 feet. All six were sawed 1/4 inch wide.

A preformed neoprene seal manufactured by the D. S. Brown Company -- meeting Minnesota Highway Department specifications 3721 -- was installed in the 7/16 inch joints. These joints were blown out with air and the seals were installed with a machine called a rubber tucker; the lubricant-adhesive was furnished by the Contractor.

The 1/4 inch joints were sealed one week later with a hot-rubber asphalt produced by W. R. Meadows Inc. meeting Minnesota Highway Department specifications 3723. Figure 3 shows one of these joints two weeks after it was sealed.

In order to determine joint movements, reference pins were placed, one on each side of each joint. These were placed between the wheel tracks in the outside lane.

It had been intended to saw the joints through the surface and the shoulders, but the shoulders were not sawed at this time because shoulder construction had not been completed.
Figure 3. Sawed joint sealed with hot-rubber asphalt sealant.
EVALUATION AND RESULTS

Evaluation was primarily by visual observations. Periodic field surveys were made shortly after installation and in the late winter or spring of the following years.

The day following the installation of the neoprene seals, with a mat temperature of 76° F. and air temperature of 64° F., the width of the joints varied from 7/16 to 5/8 inch. On this same day random mat swelling was noted along the joints. These swells were as much as 1/4 inch higher than the adjacent mat. Where this had occurred, the mat had become softened about 2 to 2-1/2 inches in both directions from the joint sidewalls. This problem seemed to occur where an excess of lubricant had been used for the installation of the neoprene. Even where this swelling was not apparent the joint sidewalls were soft the full length of the joint.

Two days after installation, with a mat temperature of 49° F., the bituminous mat appeared rigid. Later in the day when the mat temperature was 76° F., the 2351 wearing course was very soft; it had the characteristics of freshly laid bituminous mix before compaction.

After checking into this problem it was resolved that the softening was caused by the high percentage of volatiles in the lubricant-adhesive. The swelling was then caused by the upward and outward pressure exerted by the preformed neoprene on the softened bituminous sidewalls.

A field survey was conducted approximately two weeks after installation; no cracking was evident at this time in any of the five test sections. Two of the 18 joints sealed with the rubber asphalt showed slight adhesion failures. As expected, extensive damage was visible on all 12 of the neoprene joints, as shown in Figure 4. The bituminous surface had raveled out randomly (3-5 inches) in each direction from the joint sidewall. In these raveled out portions of the joints, the neoprene was loose because the bituminous mixture had been “kicked out” to a depth of about 1 inch. At this time ice and foreign materials were present in these joints. It appeared that snowplow blades had literally sheared off the swells which were evident the day following the installation of the neoprene seals.

In the spring following installation, or after one winter of service, a second field survey was made. Only one crack had formed in the test project. This was in Test Section 4, approximately a foot long, on both sides of where a core had been cut out of the surface as shown in Figure 5. At this time the data as shown in Table 1 were obtained. These average joint movements, type of joint seal failure and percent of seal failure were obtained at +28° F. air temperature and +33° F. mat temperature.

-7-
Figure 4. Neoprene sealed joint two weeks after installation.

Figure 5. Random crack developed at a core.
Table 1. Joint conditions after one winter of service.

<table>
<thead>
<tr>
<th>Test Section</th>
<th>Joint Spacing</th>
<th>Sealing Material</th>
<th>Original Joint Width</th>
<th>Average Movement of Joint*</th>
<th>Type of Failure</th>
<th>% Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40'</td>
<td>Hot rubber asphalt</td>
<td>1/4”</td>
<td>+0.07”</td>
<td>Adhesion</td>
<td>71</td>
</tr>
<tr>
<td>1</td>
<td>40'</td>
<td>Neoprene</td>
<td>7/16”</td>
<td>+0.16”</td>
<td>Deterioration of joint sidewall due to lubricant</td>
<td>100</td>
</tr>
</tbody>
</table>
| 3            | 60'           | Hot rubber asphalt | 1/4”                 | +0.06”                    | Adhesion & Cohesion | Adhesion = 62  
                        |               |                  |                      |              | Cohesion = 17  
                        |               |                  |                      |              | 79        |
| 3            | 60'           | Neoprene         | 7/16”                | +0.11”                    | Deterioration of joint sidewall due to lubricant | 100       |
| 5            | 100’          | Hot rubber asphalt | 1/4”                 | +0.08”                    | Adhesion        | 79        |

*From time of installation

Figure 6 shows a neoprene sealed joint in the spring of 1970. In July of 1970 these joints were replaced with a bituminous patch as shown in Figure 7 by a Minnesota Highway Department maintenance sealing crew. The original surface was cut approximately 6 inches on both sides of the original joint, patched with hot mix and rolled with a steel roller. The liquid sealed joints, which had for all practical purposes failed, were left as constructed.

The February 1971 field trip revealed some random transverse cracking. This cracking was predominantly in the sections where no joints had been sawed. Figure 8 is a layout of the five test sections showing the sawed joints and the random cracking which has occurred to this date, i.e. February 1971.

Figure 9 shows one of the corner cracks that had occurred. As previously mentioned in this report, the plan had been to saw the bituminous shoulders at each controlled joint. This was never done because the shoulder construction was incomplete when the surface sawing took place. However it was noticed during this survey that cracks had developed through the shoulders at each sawed joint as shown in Figure 10.
Figure 6. Neoprene sealed joint after one winter of service.

Figure 7. Neoprene sealed joint replaced with a bituminous patch.
Figure 8. Layout showing sawed joints and random cracks after two winters
Figure 9. Corner crack which developed at sawed joint.

Figure 10. Crack which developed through bituminous shoulder at sawed joint.
Joint movement information was again obtained in February 1971. The air temperature was $+10^\circ$ F. and the mat temperature was $+23^\circ$ F.; these data are shown in Table 2. This was the last survey where this information was gathered because a large number of reference pins had been damaged or removed by snowplowing. It was also felt that due to the high percentage of joint failure, the monitoring of these joints would be discontinued.

**Table 2. Joint conditions after two winters of service.**

<table>
<thead>
<tr>
<th>Test Section</th>
<th>Joint Spacing</th>
<th>Sealing Material</th>
<th>Original Joint Width</th>
<th>Average Movement of Joint*</th>
<th>Type of Failure</th>
<th>% Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>40'</td>
<td>Hot rubber asphalt</td>
<td>1/4''</td>
<td>+0.32''</td>
<td>Adhesion</td>
<td>90</td>
</tr>
<tr>
<td>1</td>
<td>40'</td>
<td>Neoprene</td>
<td>7/16''</td>
<td>+0.10''</td>
<td>Deterioration of joint side-wall due to lubricant</td>
<td>100</td>
</tr>
<tr>
<td>3</td>
<td>60'</td>
<td>Hot rubber asphalt</td>
<td>1/4''</td>
<td>+0.37''</td>
<td>Adhesion &amp; Cohesion</td>
<td>Adhesion = 75, Cohesion = 20, 95</td>
</tr>
<tr>
<td>3</td>
<td>60'</td>
<td>Neoprene</td>
<td>7/16''</td>
<td>**</td>
<td>Deterioration of joint side-wall due to lubricant</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>100'</td>
<td>Hot rubber asphalt</td>
<td>1/4''</td>
<td>+0.43''</td>
<td>Adhesion</td>
<td>97</td>
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</table>

* From time of installation.
** Reference pins were gone.

In January 1972 another crack survey was made. Additional transverse cracking had developed in the control sections; however, no additional cracks had formed in the test sections where the joints had been sawed.

The February of 1973 survey again showed additional cracking in the control sections. Very few additional cracks were noticed in the three test sections with sawed joints. Figures 11 and 12 are layouts of the test section showing the total cracking after three and four winters, respectively.
Figure 11. Layout showing sawed joints and random cracks after three winters of service.
Figure 12. Layout showing sawed joints and random cracks after four winters of service.
To determine if this random cracking was only of the surface course or if the cracks penetrated through the entire bituminous layer, cores were drilled at several cracks. These eight cores, drilled in the spring of 1973, showed that the cracks penetrated the full depth of the bituminous material, except for the very finest and shortest cracks.

The latest crack survey was conducted in April 1974. A plot of these transverse and corner cracks which have developed to date, i.e. all cracking which has occurred on this test project, is shown in Figure 13.

Figures 14, 15, and 16 show crack development by individual test sections, for the three sections where control joints were sawed. This is a repeat of data shown in Figure 8, 11, 12, and 13, but cracks developed in relation to winters of service can be more easily compared.
Figure 13. Layout showing sawed joints and random cracks after five winters of service.
Test Section 1, 14 controlled joints sawed at 40' spacing.

Figure 14. Layout showing sawed joints and random cracks in Test Section 1.
Test Section 3, 10 controlled joints sawed at 60' spacing.

Figure 15. Layout showing sawed joints and random cracks in Test Section 3.
Test Section 5, 6 controlled joints sawed at 100' spacing.

Figure 16. Layout showing sawed joints and random cracks in Test Section 5.
COST ANALYSIS

Between the time this study was initiated and the writing of this report, flexible pavement maintenance procedures have changed. In the past an operation called crack sealing was the usual procedure for maintaining higher traffic volume roads. Today's operation is called crack filling. Sealing was a more involved and costly process; the cracks were routed out, cleaned and sealed with a hot-rubber asphalt sealant. The so-called crack filling operation is much simpler and less costly. This involves only an application of a bituminous material to the random cracks. It is not within the realm of this report to compare the operations involved, performance, and costs of these two maintenance procedures.

A cost comparison, comparing present maintenance procedures vs. sawing of joints, is shown in Tables 3 and 4.

This analysis includes three procedures; 1) the one presently being used by Minnesota Highway Department maintenance, which is crack filling with a liquid; 2) sawing joints and sealing with preformed neoprene (Minnesota Highway Department Specification 3721); and 3) sawing joints and sealing with hot-pour liquid sealer (Minnesota Highway Department Specification 3723).

Costs were based on estimated 1973 prices. Following is a list of the unit prices which were used:

a. $76 per lane mile for filling random cracks (procedure presently being used).

b. $1628 per lane mile for sawing and sealing with preformed neoprene.

c. $1140 per lane mile for sawing and sealing with hot pour liquid.

d. $1140 per lane mile for preparing and resealing a previously sawed joint using hot pour liquid.

Various assumptions were made in order to show the cost comparisons in Tables 3 and 4. These assumptions are listed below.

a. A 17-year pavement life.
b. Under the present method of random crack filling, this operation would be done annually.

c. The preformed neoprene seal would last for the life of the surface (17 years) when installed without, or with a compatible, lubricant-adhesive.

d. The liquid hot-pour in properly designed sawed joints would last for three years.

e. Four lane divided highway with bituminous shoulders, 10 feet outside and 3 feet inside or a total transverse width of 74 feet.

f. Joints sawed at 60 foot intervals through surface and shoulders.

Table 3. Cost comparison, one mile of roadway for 17 years, 1973 prices.

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<th>Construction</th>
<th>Maintenance</th>
<th>Total</th>
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<td>$5,168</td>
<td>$5,168</td>
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<tr>
<td>Sawed Joints</td>
<td>$6,512*</td>
<td>0</td>
<td>$6,512</td>
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<tr>
<td>Neoprene Seals</td>
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<tr>
<td>Sawed Joints</td>
<td>$4,560*</td>
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<td>Liquid Hot Pour</td>
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*These construction costs are based on the assumptions that both surface and shoulders are sawed and sealed. If only the surface is sawed and sealed these costs could be reduced approximately 35 percent.

As pointed out, these costs are based on 1973 prices; also, future inflation has not been considered when arriving at these costs.

Table 4 shows a comparison between the present method and the neoprene sealed joints when an inflation rate of 4 percent annually is assumed. This shows that when an inflation factor is taken into account, the sawed joints sealed with neoprene is the most economical system.
Table 4. Cost comparison, one mile of roadway for 17 years, 1973 prices.

<table>
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<tr>
<th></th>
<th>Construction</th>
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<td>Sawed Joints</td>
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<td>Neoprene Seals</td>
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*These construction costs are based on the assumptions that both surface and shoulders are sawed and sealed. If only the surface is sawed and sealed these costs could be reduced approximately 35 percent.
CONCLUSIONS AND RECOMMENDATIONS

After 4-1/2 years of service the sawing of joints is controlling the amount of random transverse cracking in the flexible pavement on this test project, as shown in Figure 13. In Test Sections 1 and 3, where controlled joints were sawed at 40 and 60-foot intervals, very little random cracking developed.

During the spring of 1974, when the information shown in Figure 13 was obtained, a crack survey was conducted adjacent but outside the limits of this research project. Several miles were surveyed and cracks which transversed the total surface width (24 feet) were recorded. The amount of cracking outside of the limits of the project compared to comparable cracking in the control sections (Test Sections 2 and 4).

Figures 14, 15, and 16 show the random cracking at various periods of time, it will be noted that crack development, shown in Figure 16, has not been gradual. Figure 17 is a graph showing the approximate linear feet of cracking which has occurred in Test Section 5.

One of the problems was some spalling or raveling of the bituminous wearing course. This occurred in the wheel tracks at the sawed joints and was evident after 4-1/2 years of service; this condition is shown in Figure 18.

As for the materials and joint dimensions used, this project emphasized some of the problems that can be encountered when sealing flexible pavements.

The lubricant-adhesive, the same type as used when neoprene is installed in concrete pavements, was used but was not compatible to the bituminous mixture. Neoprene sealed joints in flexible pavements should not necessarily be ruled out for future use because of this experience. Other methods of installing neoprene are available, such as using soap and water as a lubricant.

The failure by adhesion of the hot-rubber asphalt sealed joints was expected. It is generally felt that a joint shape factor (ratio of width to depth) of a sawed joint or the sealant shape should be approximately 1/2 to 1. On this project the shape factor was 1/12 to 1 (width of 1/4 inch and a depth of 3 inches). With the temperatures we have in Minnesota we cannot expect any type of liquid seal to perform adequately in joints having these dimensions. The amount of movement at the joints, shown in Table 2, indicates that the joint seal material was expected to undergo over 100 percent extension at extremely cold temperatures (at about -20°F). At such temperatures the joint seal material does not have enough extensibility. This places a very large stress on the bond at the seal-sidewall interface and normally results in an adhesion failure.
Figure 17. Approximate linear feet of random cracking which developed in Test Section 5 (500' long).
Figure 18. Spalling at sawed joint in wheel track.
APPENDIX

MODIFIED ASPHALTIC CONCRETE WEARING COURSE

Composite Aggregate Gradation

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