EVALUATION OF BITUMINOUS OVERLAY ON MECHANICALLY CRACKED/SHATTERED PCC PAVEMENT

Investigation No. 208

January 1993

Prepared by

Harris B. Baker, P.E.
Research Project Engineer

Harvey S. Allen, P.E.
Research Project Engineer

Gerald Teig, E.S.
Research Assistant

Michael R. Buth, Graduate Engineer
Research Assistant

Physical Research Section
Office of Materials Research and Engineering
Minnesota Department of Transportation
FOREWORD

This report evaluates the effect of cracking, breaking, or shattering pcc pavements before overlay as a means of reducing the amount and severity of reflected cracking. This investigation was expanded from Special Study No. 375, "Evaluation of Variable Thickness of Bituminous Overlay on Cracked Pcc Pavement." A report on this study was issued in 1981.

DISCLAIMER

The contents of this report reflect the views of the authors and do not necessarily reflect the official views or policies of the Minnesota Department of Transportation. This report does not constitute a standard specification or regulation.
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td></td>
</tr>
<tr>
<td>BACKGROUND</td>
<td></td>
</tr>
<tr>
<td>EVALUATION</td>
<td></td>
</tr>
<tr>
<td>CONSTRUCTION</td>
<td></td>
</tr>
<tr>
<td>DISCUSSION</td>
<td></td>
</tr>
<tr>
<td>APPENDIX A</td>
<td></td>
</tr>
<tr>
<td>APPENDIX B</td>
<td></td>
</tr>
</tbody>
</table>
LIST OF FIGURES

FIGURE

1. Project Locations .........................................................
2. Hader Test Sections Locations ...........................................
3. Fergus Falls Test Section Locations ......................................
4. Belle Plaine Test Section Locations .....................................
5. T.S. 6 Design ..................................................................
6. Mankato Test Section Locations ...........................................
7. Brainerd Test Section Locations ...........................................
8. Jordan Test Section Locations .............................................
9. Hader Reflected Joints ........................................................
10. Hader Reflected Cracks .....................................................
11. Hader Reflected Joints and Cracks .......................................
12. Fergus Falls Reflected Joints ..............................................
13. Fergus Falls Reflected Cracks .............................................
14. Fergus Falls Reflected Joints and Cracks ..............................
15. Belle Plaine Reflected Joints .............................................
16. Belle Plaine Reflected Cracks ..............................................
17. Belle Plaine Reflected Joints and Cracks ..............................
18. Mankato Reflected Joints ...................................................
19. Mankato Reflected Cracks ...................................................
20. Mankato Reflected Joints and Cracks ...................................
21. Cores of Cracked Pcc Pavement ...........................................

LIST OF TABLES

TABLES

1. Present Serviceability Ratings ............................................
2. Deflection Measurements ...................................................
3. Project Summary ............................................................
4. Overlay Thickness Summary ...............................................
SUMMARY OF FINDINGS AND CONCLUSIONS

1. There seems to be no benefit in hairline cracking pcc pavements before bituminous overlay. Reflective cracking of the original joints and cracks was delayed in some of the hairline cracked test sections. However, the delayed reflected cracks deteriorated faster than those in the control sections. It took an average of six years after construction for the delayed reflected cracks in the hairline cracked sections to reach the same severity as those in the control sections.

2. The observed data does not conclusively show any benefit to rubbelizing pcc pavement before bituminous overlay. Original joint and crack reflectance in one rubbelized test section was delayed approximately three years longer than in the control section. However, joints and cracks in other rubbelized sections reflected sooner than in the control sections.

3. Hairline cracking a pcc pavement does not significantly reduce the concrete modulus value. Backcalculations of layer moduli from Falling Weight Deflectometer (FWD) data on bituminous over hairline cracked pcc gave very high modulus values (from two to five million psi) for the upper layer (bituminous and pcc combined). The measured deflections were so small (less than 2 mils) that the backcalculation program (EVERCALC) gave somewhat erroneous results.

4. Backcalculated moduli for rubbelized pcc (Spec. - nine inch max. size) from FWD data ranged from 90,000 - 150,000 psi.

5. The average 1992 statewide successful bid price for hairline cracking was $40/station. The average 1988 statewide successful bid price for rubbelizing was $300/station.

6. Thicker bituminous overlays seemed to delay reflective cracking for longer periods of time.

7. Overlay thickness is a factor in pavement smoothness. One test section with an overlay thickness of less than three inches experienced a rapid drop of PSR after three years.
RECOMMENDATIONS

1. The first 500' after a reference point (in the increasing direction) of all new crack or rubbelize and overlay projects should be a control section (no cracking or rubbelizing).

2. Research involving more aggressive cracking should be attempted, especially on reinforced concrete sections.

3. Pavement cracking or rubbelizing should not be specified on existing pcc pavements where differential frost heaving is a matter of record.

4. Rubbelizing pcc pavements prior to overlay should not be considered over weak subgrade soils, especially if the soil is periodically above optimum moisture content.

- Consider on a case by case basis. Don't

- Composite section - Try
PAVEMENT CRACKING

INTRODUCTION

The need for new rehabilitation designs is very important as the funding of both maintenance and construction projects becomes increasingly difficult to obtain. Individual engineers often have to recommend what the design thickness of a bituminous overlay on a pcc pavement should be based solely on their past experience.

This investigation was undertaken in order to evaluate methods of reducing the amount and severity of reflective cracking of pcc pavements. This part of the study evaluates the concepts of cracking or breaking (shattering) existing pcc pavements before overlay to reduce reflective cracking. Some of the questions to be answered are:

1. Is cracking/breaking the old pcc pavement an economical method of reducing reflective cracking?
2. Which is more effective in reducing reflective cracking, cracking or shattering the existing pcc pavement?
3. What is the most effective transverse crack spacing?
4. What is the most effective/economical overlay thickness?
5. What is the most effective degree of breaking/shattering?
6. What effects do different soil types have on the success of cracked pcc pavement overlays?

BACKGROUND AND SCOPE

This portion of the study includes six projects which contain test sections which were cracked by a spade type drop hammer. Several of the projects also contain test sections which were shattered before overlay. PB-4 and Wirtgen Breaking methods were both used in order to shatter the selected sections. Future reports will cover breaking and other methods used to try to slow cracking in more detail. The six projects being evaluated are:

1. S.P. 2506-39 (TH 52=20) located on TH 52 near Hader in Goodhue County.
2. S.P. 5614-23 (TH 59=3) located on TH 59 near Fergus Falls in Ottertail County.
3. S.P. 7007-16 (TH 169=5) located on TH 169 near Belle Plaine in Scott County.
4. S.P. 0708-22 (TH 60) located on TH 169 and TH 60 near Mankato in Blue Earth County.


Locations of the projects are shown in Figure 1.

![Figure 1. Project locations.](image)

The Brainerd Project is the oldest of the six projects. It is located on TH 371, from 2.5 miles north of Little Falls to Paul Street in Brainerd.

The original 8-7-8 concrete road was constructed in 1926 and consisted of two 9.0' driving lanes. The pavement had two rebars situated longitudinally on the outside edges and also one on each side of the centerline joint. Transverse rebars were located at each contraction joint, as well as at a tied centerline. In 1956, a portion of one side of the roadway was widened by 6.0'. This extension was not tied on to the existing pavement. The remainder of the pavement was replaced by two 12.0', 9-7-9 concrete driving lanes. In 1969, the shoulders were paved with bituminous for the
length of the job and the sections which had 6.0' added to them were overlaid with 2-3/4" of bituminous.

**Figure 2.** Test Sections, S.P. 1809-39, Brainerd

The pavement was rehabilitated in 1986 with a 4.5" overlay placed on all test sections. The project consists of 7 test sections of varying design including a latex additive to the northbound shoulder. The designs of the sections are as follows:

- **Test Section 1:** New York saw and seal, breaking
- **Test Section 2:** New York saw and seal, no breaking
- **Test Section 3:** PB-4 breaking
- **Test Section 4:** Wirtgen breaking
- **Test Section 5:** 3.0' crack spacing
- **Test Section 6:** 5.0' crack spacing
- **Test Section 7:** Control, no breaking

The subgrade soils are predominately fine sands, loamy sand and sandy loam. The AASHTO Group Classifications are A-3, A-1-b, and A-2-4, respectively. The topsoil is loamy sand and averages 3.0" thick.

The predicted Equivalent Standard Axle Loadings (ESAL) was 994,000.

The sections to be included in the Hader Project were originally constructed about the same time as the Brainerd Project was built. This project was originally observed under Special Study 375, "Evaluation of Variable Thicknesses of Bituminous Overlay on Cracked Pcc Pavement." The project is on TH 52 and approximately 10 miles in length with limits from 1.5 miles north of the junction of C.S.A.H. 1 to 3.2 miles south of TH 52 at Hader. When this
project was incorporated into Investigation 208, Special Study 375 was terminated.

The original pcc pavement was placed in 1930. The concrete slab is 20.0' wide with a 9-7-9 thickness design. Reinforcing consisted of one reinforcing bar down each edge and centerline tie steel.

<table>
<thead>
<tr>
<th>STA.</th>
<th>TS 3</th>
<th>1.75&quot; OVERLAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>STA. 877-00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STA. 874-95</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STA. 870+60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STA. 864+30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STA. 864+00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STA. 859+00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xf 63 - STA. 858+70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STA. 754+59</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xf 65 - STA. 750+70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STA. 644+10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xf 69 - STA. 639+10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 3. Test Sections, S.P. 2506-39, Hader**

The roadway was redesigned in 1964 and the old pavement became the southbound roadway of a divided highway. This project is a rehabilitation of that roadway. The plan called for a 5.0' bituminous widening on the median side of the roadway and a bituminous overlay.

The project includes three different sections with a variable depth of bituminous leveling course of 1, 2 and 3 inches minimum and a 3/4" bituminous wearing course. The 2 and 3 inch minimum leveling courses were each 2 miles long and added by supplemental agreement. The existing pcc pavement was cracked at 5.0' intervals for all tests sections. The test section designs included the following:

Test Section 1: 1.75" overlay
Test Section 2: 2.75" overlay
Test Section 3: 3.75" overlay
Test Section 4: Control, no cracking, ?.?" overlay
Test Section 5: New construction
Specifications for cracking are listed in Appendix A.

The subgrade soils are predominately clay loams and silty-clay loams. They are in the AASHTO Group classifications of A-4 and A-6. Group Index numbers ranged between 7 and 9 with the range of R-values being between 18 and 33.

Traffic and loading forecast predicted the 20 year Equivalent Standard Axle Load (ESAL) to be 3,348,000 based on the highway being a 10-ton single axle (80,000 lb) route.

Construction began during the 1981 season and was completed in 1982. Test section locations are shown in Figure 3.

The Fergus Falls Project is on TH 59 and runs north from I-94 Fergus Falls, a distance of approximately 4 miles. The pcc pavement was placed in 1932. The concrete slab is 20.0' wide and has two 5/8" reinforcing bars on each edge and centerline tie steel. A 3.0" bituminous overlay was added in 1967.

In this construction project the existing bituminous overlay was removed and the roadway was widened on each side of the pcc pavement with a 3.0' wide by 9.0" deep section of Mn/DOT Specification No. 2331 bituminous base. The concrete slab was then cracked and overlaid with a new 4.0" bituminous overlay. The test sections were laid out in the following manner:

Test Section 1: 5.0' Crack spacing
Test Section 2: 5.0' Crack spacing, Longitudinal steel cut
Test Section 3: Regrade section, 11" full-depth bituminous
Test Section 4: 2.5' Crack spacing
Test Section 5: 5.0' Crack spacing
Test Section 6: Control, no cracking

Specifications for cracking are listed in Appendix A.

The subgrade soils are clay and plastic silty loams. They are in the AASHTO Group classifications of A-4 and A-6. Group Index numbers varied from 0 to 11 with R-values from 11.5 to 17.0.

Traffic axle loading forecast predicted the 20-year ESAL to be 976,000 based on the highway being a 10 ton (80,000 lb) route.

Construction of the project was done in 1982. Test section locations are shown in Fig. 3.

The Belle Plaine Project is on TH 169 near the city of Belle Plaine in Scott County. The limits are 0.55 miles south of the city limits to 0.1 miles south of County Road 66. The pcc pavement was completed in 1956. The pavement is a 9-7-9 nonreinforced, thickened edge design with 12.0" of sand-gravel subbase, the panel length is 20.0'.

The project design was to crack the existing pcc pavement at a 3.0' spacing with no crack closer than 5.0' from a joint or existing transverse crack. A bituminous overlay of 5.75" placed over all sections. Section designs were as follows:

Test Section 1: 1.5' Crack spacing
Test Section 2: Control, no cracking
Test Section 3: 3.0' Crack spacing

The specifications for cracking are listed in Appendix A.

The subgrade soils are mixed; consisting of sandy loam, clay loam, sand, fine sand, loamy very fine sand, and very fine sandy loam. The design R-value was 13.5.

Traffic axle loading forecast predicted the 20-year ESAL to be 8,600,000 based on the highway being a 10-ton (80,000 lb) route.

Construction of the rehabilitation project was done in 1982. Test section locations are shown in Figure 4.

The Mankato Project is on TH 60 and TH 169 south of Mankato in Blue Earth County. The construction limits were from 700' west of the junction with County Road 115 to 165 feet west of Hawley Street in LeHillier.
Figure 5. Test Sections, S.P. 7007-16, Belle Plaine

The pcc pavement is reinforced, 8.0" thick, 24.0' wide and was constructed over 5.0 to 9.0 inches of aggregate base. It was constructed in 1961. Existing pcc panels are 40.0' in length.

The project design was cracking at 3.0' intervals, included edge drains and a 6.25" overlay on all sections. The edge drains were 3.0" corrugated polyethylene pipe, which was wrapped in filter fabric and installed a minimum of 3.0' deep on either side of the existing pcc pavement.

Eight 1,000' research sections were constructed, with the overlay thickness being kept constant. One of the sections was the project design, Test Section 1. The project also included a large variety of unique test sections. The variations of the project design were:

Test Section 1: 3.0' Crack spacing, edge drains
Test Section 2: 3.0' Crack spacing, no edge drains
Test Section 3: Control, no cracking, no edge drains
Test Section 4: Control, no cracking, edge drains
Test Section 5: 1.5' Crack spacing, edge drains
Test Section 6: 3.0' Crack spacing, fine filter agg. seam
Test Section 7: 2 saw cuts/panel, no cracking, edge drains
Test Section 8: Cracking w/ pavement roller breaker, drains

Specifications for cracking are listed in Appendix A.

The subgrade soils are predominately clay loams and clay loam fills. R-values range from 7.9 to 16.6.
Figure 6. Details, Test Sect. 6, S.P. 0708-22, TH 169 Mankato
Traffic axle loading forecast predicted the 20-year ESAL to be 7,900,000 based on a 10 ton (80,000 lb) highway. Test section locations are shown in Figure 6.

Figure 7. Test Sections, S.P. 0708-22, TH 169 Mankato
The final project to be included in the study is the Jordan project which is located on TH 21 in Scott County. The original roadway was constructed in 1956. The pavement was a 9-7-9 concrete which was 24.0' wide and had 8.0' wide gravel shoulders. In 1974 this
portion of TH 21 was rehabilitated with a 1-1/2" bituminous overlay. This first overlay had greatly deteriorated by 1984, having a Condition Rating of 2.2, with a Structural Rating of 1.9.

The 1-1/2" overlay was removed from all future test section locations in 1986 and the five test sections were established. The design of the sections are as follows:

Test Section 1: Control, no cracking, 4.5" overlay
Test Section 2: 3.0' Crack spacing, 4.5" overlay
Test Section 3: Shattering, 4.5" overlay
Test Section 4: Shattering, 5.5" overlay
Test Section 5: Shattering, 6.5" overlay

The subgrade soils mainly consist of plastic sandy loams and clay loam till. The AASHTO Group Classifications are A-, A-.

Traffic axle loading predicted the 15-year ESAL to be on the order of 1,200,000. The assumed subgrade R-value is 15.

Figure 8. Test Sections, S.P. 7002-29, TH 21 Jordan
EVALUATION

CRACK SURVEYS

Test sections were set up in each of the projects to monitor the rate of reflective cracking. A control section with no cracking was included in each project. These sections range from 500 to 1,500 feet in length.

The existing joints and cracks were mapped before overlay. The joints and cracks reflecting through have been mapped regularly since each project was constructed. The percentage reflected is shown in graphs (Figures 7-18). Tables showing the number of cracks and joints, original and reflected are shown in Appendix B.

ROUGHNESS MEASUREMENTS

PSRs (present serviceability ratings) were measured with the PCA Roadmeter originally and later with the Mays Meter. This change was due to a statewide switch to the Mays Meter. All PSR measurements which were taken are shown in Table 1.

DEFLECTION DATA

Nondestructive data measurements were made using the Model 2000 Road Rater and the Dynatest 8000 Falling Weight Deflectometer (FWD). The FWD was used on all new projects after 1982. Since the Road Rater was used for the initial readings on the Hader project, it was used for follow-up readings.

It was originally planned to take measurements before cracking, after cracking, and also after the sections were overlaid. Although the sections were cracked before measurements were able to be taken on the Mankato and Belle Plaine projects, the measurements from the no cracking section were considered as a representative value. Test Section 2 on the Hader project was also cracked before measurements could be made.

No deflection measurements were taken at Fergus Falls.

The deflection data have been normalized to a force of 3 kips for the Road Rater. These measurements were taken at 15 hertz. The FWD data was normalized to a 9 kips load. Test data was gathered at these approximate forces for each machine. However, the force must be standardized to make meaningful comparisons. The deflections were standardized based on a linear relationship between force and deflection. Although the actual relationship may not be exactly linear, the force variation is small and the use of the linear relationship is an acceptable assumption.

No temperature corrections were attempted due to lack of a data
CONSTRUCTION

Pavement cracking was done on projects with spade-type pavement breakers. Sections x was cracked with for the Brainerd project. The existing pcc panels were cracked in the transverse direction at the specified intervals except for control sections. At locations where the panel was already broken, mid panel crack, etc., the proposed crack was eliminated.

On the first project at Hader, the hammer was dropped once and moved the width of the spade and dropped again. This procedure was repeated until the width of the slab was covered. This did not produce a visible crack in most cases. When the procedure was changed to more than one drop, shattering occurred in the top several inches of the pcc pavement. Cores taken over the proposed crack showed hairline cracks in the bottom five inches of the cores.