Taking the Bang out of Transverse Cracks: Fly Ash Slurry Injection Method

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ABSTRACT

In this study, the nature and extent of transverse cracking in asphalt pavements on I-70 in Kansas was determined. A pavement investigation was conducted to determine the effectiveness of the fly ash slurry injection (FASI) method (a crack stabilization procedure) to eliminate or minimize the depression (bump) caused by the depressed transverse cracks. The intent of FASI is to fill the subsurface voids at severely distressed transverse cracks to delay depression and reflective cracking. The initial objective of the study was to find a low-cost “maintenance” approach to improve ride by filling the transverse cracks and their associated depression. A variety of products and application procedures were attempted, with variable results. Most attempts had recracked within a year, and depressions soon followed. Ten sections of test pavement were constructed using FASI to fill the voids under the existing pavement adjacent to the transverse cracks, followed by cold milling, cold in-place recycling of the next 4 in., a hot recycle action, and a hot mix asphalt overlay. Pavement roughness values before and after the rehabilitation action were compared. Roughness values (right wheel path IRI [in./mi], westbound and eastbound) were plotted for each year since 1988. The results indicated that a more extensive procedure, which involves using FASI followed by milling and overlaying with hot mix asphalt, has provided several years of excellent service on these ten test sections of I-70 in western Kansas.

Key words: asphalt pavement—fly ash slurry injection—transverse cracking
INTRODUCTION

Pavement profiles and detailed recordings of surface elevations are frequently used to characterize smoothness. Smoothness is an important indicator of pavement riding comfort and safety. From an auto driver’s point of view, rough roads mean discomfort, decreased speed, potential vehicle damage, and increased operating cost. Highway users demand a good pavement condition (Bukowski 1990).

One of the primary causes of increasing roughness in asphalt pavements in Kansas has been the naturally occurring transverse cracks. Asphalt pavement shrinks as it ages, and this causes tension forces great enough to result in transverse cracks. Once a crack is created, the moisture in the crack causes the asphalt to further deteriorate, allowing a depression to develop at each crack (Snethen and Ahmed 1991).

The depressed area usually associated with the crack causes a rough ride and vehicle wear, and the impact load from heavy vehicles causes accelerated deterioration of the pavement structure. Needless to say, it is not a pleasant ride. The Kansas Department of Transportation (KDOT) has been continually faced with the problem of providing a satisfactory ride on the 10,000 mile primary highway system. Since about 75% of the system is asphalt pavement and the transverse cracks occur at intervals of about 50 ft., attempting to reduce or eliminate the effect of cracking and depression is a sizable endeavor.

Transverse cracking of asphalt pavements is a problem across the state of Kansas, with the severity of the problem varying from district to district based on such factors as pavement age, pavement cross section, traffic, asphalt properties, and maintenance procedures. The development of an effective method of filling the cracks and depressions would greatly improve the ride and safety for the motorist using the Kansas system of highways. It also would extend the life of the pavement by reducing the deterioration from water intrusion and from impact loading caused by vehicles bouncing as a result of the “bump,” as well as reducing future maintenance costs.

HISTORY OF TRANSVERSE CRACKS ON I-70 WEST OF SALINA

A review of the history of transverse cracking on I-70 in the western half of Kansas reveals that very wide cracks (top down) developed in cold weather, and no suitable treatments were available from the 1960s through the 1980s. Maintenance forces continually tried to seal the cracks; however, the cracks continued to grow wider and the depression deeper. It was common to have cracks about 60 ft. apart 4 to 5 in. wide, depressed 2 to 3 in., and extended across all lanes.

Transverse cracking of asphalt pavements is a costly pavement distress occurring in Kansas, which experiences cold/freezing temperatures during the winter months. The cracks are caused by low-temperature-induced tensile stresses that exceed the tensile strength of the pavement material. The majority of these cracks occur in the transverse direction, relative to the pavement and with regular frequency along the roadway.

Once an open crack in asphalt has formed, the space tends to open further in cold periods and to close in warm periods (lateral movement primarily in response to thermal changes). Based on research, most crack movement occurs in a six- to eight-month Period, with a peak opening about the end of February or early March. Crack motion is generally consistent with temperature changes. Crack movements are a consequence of the changes in the thermal regime of the total pavement structure. These changes are in proportion to the average daily temperature and are not necessarily a direct reflection of spot surface or air temperatures taken usually during the warmer part of the day. The magnitude of lateral crack movement is a function not only of temperature changes, but also other factors. These include
environmental effects, aging, and type of mix. However, the magnitude of the crack opening is not a function of the distance between adjacent cracks (Bukowski 1990).

A review of the literature shows that water is needed for bacteria to grow and deteriorate the asphalt. A soft, loosely bound asphaltic cement is often present between the rubble and sound materials. This seems to indicate a cause and effect relationship between bacteria and asphalt deterioration, since the rubble and loosely bound material (rubble-like deteriorated material) contained bacteria. The soil is the main habitat for bacteria. The bottom of the pavement tends to stay moist longer than would the exposed soil without the asphalt road above it. The soil-asphalt interface provides a great environment for bacterial existence. A crack in the asphalt allows air and water to contact the crack interface and provides more surface area of asphalt available to the bacteria. Therefore, full-depth hot mix recycling would be more effective than partial depth recycling in retarding bacterial decay at cracks and would likely destroy bacteria that are already in the pavement (Ramamurti and Jayaprakash 1987).

RESEARCH STUDY 91-3

A Type B research study, 91-3 (NCP #4C2C2152, KsDOT 91-3, RE-0706), “Taking the Bang out of Transverse Cracks: Fly-ash Slurry Injection Method,” began in FY 1991 as part of the annual Highway Planning and Research Work Program. The initial objective of the study was to evaluate a low-cost “maintenance” approach that had been used previously to fill transverse cracks and the associated depression. A variety of products and application procedures were used to fill transverse cracks and the associated depressed area in highways that did not need structural rehabilitation, except for the cracks that had been previously treated with variable results but had not been documented. Most attempts had recracked within a year, and further deterioration soon followed.

In the present study, the major objectives of the research included the following: (1) determine the nature and extent of transverse cracking asphalt pavements on I-70 in Kansas and (2) determine the effects of the fly ash slurry injection (FASI) maintenance action (a crack stabilization procedure) to eliminate or at least reduce the bump caused by the transverse crack and the depression on asphalt pavements. The intent of the FASI action was to fill the voids at severely distressed transverse cracks and thus delay reflective cracking.

FLY ASH SLURRY INJECTION METHOD

There are many miles of existing pavement that are in fine condition in terms of surface friction, ruts, shoving, map cracking, and other forms of distress, but which have continually enlarging transverse cracks. Filling the crack and depression would greatly improve ride and safety. It would reduce wear on vehicle suspension and preserve existing pavement by reducing the water intrusion into the crack and reducing the impact loads created by vehicles bouncing through the bump (Bukowski 1990).

Asphaltic concrete overlays and other maintenance actions temporarily correct the riding surface, but as reflection cracks appear the degradation continues and the depression is again formed. A need therefore exists to identify a procedure which would retard or eliminate the cracking and degradation of the new overlay.

By 1985, most of the pavement on I-70 west of Salina, Kansas, to Colorado had been overlaid two or more times during its 15- to 25-year life and ranged from about 10 to 24 in. thick. Each overlay provided a new riding surface and filled most of the depressions and cracks. However, on some overlays within weeks, the crack would reappear and the depression would start to grow. Therefore, a review of existing
KDOT policies and procedures for crack sealing and crack filling was conducted. A summary printout of the data in the Pavement Management Information System provided an indication of the severity of transverse cracking on the state primary highway system. Data was collected on the cost and performance of current repair efforts.

The FASI method injects a fly ash slurry into the area below each crack/depression through holes drilled into the pavement on both sides of the crack. The depressions are removed by cold milling the pavement after the slurry cures, and a hot mix bituminous overlay is placed. The technology used is similar to that used for undersealing or mud jacking portland cement concrete pavements. This method would have the added benefit of introducing a material that would retard bacterial growth, potentially stabilize the loose material at the bottom of the crack, and possibly create a “bulb” of material below the crack to help support it.

As noted in Table 1 and Figures 1 through 10, ten sections were constructed, first using FASI to fill the voids under the existing pavement adjacent to the transverse cracks, followed by cold milling, cold in-place recycling for the next 4 in., a hot recycle action, and a hot mix asphalt overlay. For extensively cracked and depressed pavements, milling the surface helps with the leveling of the pavement prior to overlaying.

Table 1. Projects selected for FASI study (I-70 in Western Kansas)

<table>
<thead>
<tr>
<th>No.</th>
<th>Project no.</th>
<th>County</th>
<th>Completion date</th>
<th>Begin M.P.</th>
<th>End M.P.</th>
</tr>
</thead>
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<td>1</td>
<td>K-5982-01</td>
<td>Ellsworth</td>
<td>2000</td>
<td>0</td>
<td>16.945</td>
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<tr>
<td>2</td>
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<td>2000</td>
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<tr>
<td>3</td>
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<td>Gove</td>
<td>1998</td>
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<td>19.254</td>
</tr>
<tr>
<td>4</td>
<td>K-5981-01</td>
<td>Gove</td>
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</tr>
<tr>
<td>6</td>
<td>K-2610-02</td>
<td>Saline</td>
<td>1997</td>
<td>8</td>
<td>14.9</td>
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<tr>
<td>7</td>
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<td>Thomas</td>
<td>1996</td>
<td>0</td>
<td>4.393</td>
</tr>
<tr>
<td>8</td>
<td>K-5908-01</td>
<td>Thomas</td>
<td>1998</td>
<td>4.393</td>
<td>10.342</td>
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</table>

As shown in Figures 1 through 10 and Table 2, pavement roughness values before and after the rehabilitation action were compared. Roughness values (right wheel path IRI [in./mi], westbound and eastbound) were plotted for each year since 1988. Figures 1 through 10 demonstrate that a more extensive procedure, which involves using FASI followed by milling and overlaying with hot mix asphalt, has provided several years of excellent service on ten sections of test pavement of I-70 in western Kansas. As a result, FASI was identified as an effective crack repair procedure that can extend pavement service life and reduce future maintenance costs.

Examination of transverse cracks at the ten field sites confirm that, in most cases, transverse cracks originate at the pavement surface and extend down into and/or through the pavement. The primary cause of transverse cracking is thermal-induced stress that causes contraction of the asphalt concrete surface layer. An average low temperature has been found to have a significant effect on transverse cracking, and average spacing between the cracks decreases with a decreasing average low temperature (Traxler 1966).

Transverse crack depressions are caused by an ingress of water through the cracks in the pavement to the subgrade soils. This causes softening of the subgrade soil and subsequent depression adjacent to the
crack. Additionally, pumping of fines from the base and subgrade through the cracks contributes to the loss of support. The plastic limit of the fine-grained soils has been correlated with crack indexes such as number of cracks per 1,000 ft. This indicates that pavements overlying fine-grained soils have a greater risk of transverse cracking (Hicks, Kimberly, and Moulthrop 1997).

Figure 1. K-5982-01, completion date 2000 with a 70% improvement
Figure 2. K-5983-01, completion date 2000 with a 61% improvement

Figure 3. K-5978-01, completion date 1998 with a 68% improvement
Roughness Trends (for 70-32 K-5981-01, Gove County, I-70, 19.254~37.508 Mile)

Figure 4. K-5981-01, completion date 1999 with a 70% improvement

Roughness Trends (for 70-53 K-5980-01, Lincoln County, I-70, 0~7.247 Mile)

Figure 5. K-5980-01, completion date 1998 with a 63% improvement
Figure 6. K-2610-02, completion date 1997 with a 64% improvement

Figure 7. K-5572-01, completion date 1996 with a 56% improvement
Roughness Trends (for 70-97 K-5908-01, Thomas County, I-70, 4.393–10.342 Mile)

Figure 8. K-5908-01, completion date 1998 with a 71% improvement


Figure 9. M-1775, completion date 1996 with a 60% improvement
Table 2. Pavement roughness values before and after the rehabilitation action

<table>
<thead>
<tr>
<th>No.</th>
<th>Project no.</th>
<th>Completion date</th>
<th>Before rehabilitation</th>
<th>After rehabilitation</th>
<th>Improvement (%)</th>
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<tr>
<td>4</td>
<td>K-5981-01</td>
<td>1999</td>
<td>135</td>
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<td>70</td>
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<tr>
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<td>160</td>
<td>60</td>
<td>63</td>
</tr>
<tr>
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<td>K-2610-02</td>
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<td>135</td>
<td>48</td>
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<td>165</td>
<td>48</td>
<td>71</td>
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<td>9</td>
<td>M-1775-01</td>
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<td>120</td>
<td>48</td>
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<td>10</td>
<td>K-5979-01</td>
<td>1998</td>
<td>160</td>
<td>40</td>
<td>75</td>
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</tbody>
</table>

The FASI technique seems to have been the most successful. The injected fly ash slurry appears to have stabilized the deteriorated material in the vicinity of the crack and has resulted in the elimination of the depression for up to 12 years. This technique has been used in many locations across the state, resulting in improved highway smoothness. The ride from Goodland to Salina has been greatly improved, and the bang from the transverse cracking is gone.
CONCLUSIONS

The FASI technique seems to have been the most successful. The injected fly ash slurry has resulted in the elimination of the transverse crack depressions for up to 12 years. This technique has been used in many locations across the state, resulting in improved highway smoothness. Therefore, the ride has been greatly improved. The major conclusions that can be drawn from the study may be summarized as follows:

1. The results indicated that using FASI to fill the voids under the existing pavement, followed by cold milling and overlaying with hot mix asphalt, has provided the benefit of retarding reflective cracking and providing several years of excellent service on ten sections of I-70 in western Kansas. This method can extend pavement service life and reduce future maintenance costs.
2. FASI was identified as an effective crack filling procedure. Filling the cracks and depression would greatly improve ride and safety. It would reduce the wear on vehicle suspension and preserve existing pavement by reducing the water intrusion in the crack and reducing the impact loads created by vehicles bouncing through the bump.

RECOMMENDATIONS

The following recommendations are considered pertinent to the results of this research investigation:

1. Further comprehensive testing of cracked and uncracked pavement sections should be undertaken to develop a better understanding of actual thermal effects on stress, strain, and stiffness values.
2. Asphalt chemistry and aggregate properties should also be considered in the evaluation.
3. A comprehensive evaluation of preventive and remedial maintenance procedures should be conducted to establish the conditions under which the various procedures perform best and should be considered useful in extending the life of a pavement if applied at the right time.
4. Cracks in asphalt pavements should be repaired as soon as possible after detection. Well-defined cracks with no secondary cracking should be sealed to prevent the incursion of water and noncompressibles.
5. A field and laboratory investigation of pavement materials and highway features should be conducted in order to determine and evaluate the various factors that influence transverse cracking.
6. Cracks and depressions should be studied and inventoried each year. This would provide a means to historically watch and study the crack problems in order to help bring the problems to the attention of management.
7. The effects of various crack sealing procedures on different thicknesses of bituminous overlays should be determined.
8. The FASI injection method must be revamped. One idea is to drill a vertical hole through the crack and then pump the grout. Another idea is to drill an angled hole intercepting the crack in the bottom 1/3 of the pavement. Both of these methods would place more grout in the crack; however, their success would need to be monitored. It is recommended that KDOT collaborate with industry to determine the best method of fly ash slurry injection.
ACKNOWLEDGEMENTS

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