Assessment of Asphalt Interlayer Designed on Jointed Concrete

Final Report
November 2014

ASPHALT MATERIALS & PAVEMENTS PROGRAM

IOWA STATE UNIVERSITY
Institute for Transportation

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Iowa Department of Transportation
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16. Abstract

Reflective cracking in hot mix asphalt (HMA) overlays has been a common cause of poor pavement performance in Iowa for many years. Reflective cracks commonly occur in HMA overlays when deteriorated portland cement concrete is paved over with HMA. This results in HMA pavement surfaces with poor ride quality and increased transportation maintenance costs. To delay the formation of cracks in HMA overlays, the Iowa Department of Transportation (Iowa DOT) has begun to implement a crack-relief interlayer mix design specification. The crack-relief interlayer is an asphalt-rich, highly flexible HMA that can resist cracking in high strain loading conditions. In this project, the field performance of an HMA overlay using a one inch interlayer was compared to a conventional HMA overlay without an interlayer. Both test sections were constructed on US 169 in Adel, Iowa as part of an Iowa DOT overlay project. The laboratory performance of the interlayer mix design was assessed for resistance to cracking from repeated strains by using the four-point bending beam apparatus. An HMA using a highly polymer modified binder was designed and shown to meet the laboratory performance test criteria. The field performance of the overlay with the interlayer exceeded the performance of the conventional overlay that did not have the interlayer. After one winter season, 29 percent less reflective cracking was measured in the pavement section with the interlayer than the pavement section without the interlayer. The level of cracking severity was also reduced by using the interlayer in the overlay.

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ASSESSMENT OF ASPHALT INTERLAYER DESIGN ON JOINTED CONCRETE

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November 2014

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EXECUTIVE SUMMARY

Reflective cracking in hot mix asphalt (HMA) overlays has been a common cause of poor pavement performance in Iowa for many years. Reflective cracks commonly occur in HMA overlays when deteriorated PCC is paved over with HMA. The differential movement of concrete slabs at PCC joints create microcracks at the bottom of the HMA layer that grow and propagate to the surface. Since the rehabilitation strategy for many distressed PCC pavements in Iowa is to overlay them with HMA, the prevalent reflective cracking distresses has resulted in poor ride quality and increased transportation maintenance costs. To delay the formation of cracks in HMA overlays, the Iowa Department of Transportation has begun to implement a crack-relief interlayer mix design specification. The crack-relief interlayer is an asphalt-rich, highly flexible HMA that can resist cracking in high strain loading conditions. It is designed to have a high volume of asphalt with a low percentage of air voids and to contain a polymer modified binder with a wide temperature performance grade range.

To assess how effective the interlayer is at delaying reflective cracks, the field performance of an HMA overlay using a one inch interlayer was compared to a conventional HMA overlay without the interlayer. Pavement test sections of the two overlay designs were constructed on US 169 just north of the city limits of Adel, Iowa and evaluated for reflective cracking. The laboratory performance of the interlayer mix design was also assessed for resistance to cracking from repeated strains by using the four-point bending beam apparatus.

The laboratory performance test results of the initially designed interlayer failed the minimum 100,000 load cycle criteria in the four-point bending beam but eventually passed the criteria after the polymer modified binder used for the mix design was re-engineered. Rather than using the minimum amount of poly(styrene-butadiene-styrene), or SBS polymer, to formulate the required PG 64-34 binder, a highly polymer modified binder was designed for the interlayer mix. The polymer used was D0243, an SBS polymer design by Kraton, Inc. which can be added to asphalt at higher polymer concentrations without reducing workability. Seven and a half percent of the D0243 was selected to be blended in a base PG 52-34 binder. Once the new highly polymer modified binder was used for the mix design, the average number of load cycles achieved in the bending beam apparatus increased from 18,235 to 201,390, thereby exceeding the 100,000 load cycle criteria.

For the US 169 project, the performance of the interlayer overlay exceeded the performance of the conventional overlay. After one winter season, 29 percent less reflective cracking was measured in the pavement with the interlayer than the pavement without the interlayer. The level of cracking severity was also reduced by using the interlayer. In the non-interlayer section, 41 percent of the total transverse crack lengths measured contained moderate severity cracks. In the interlayer section, 4 percent of the total crack lengths measured contained moderate severity cracks. Thus, the crack-relief interlayer successfully delayed reflective cracking in the HMA overlay. Furthermore, pavement performance improved by using the interlayer in spite of the interlayer not meeting the volumetric and laboratory performance testing requirements – the result of a low asphalt content during production. Had the volumetrics of the interlayer been closer to the mix design targets, the overlay would have likely exhibited less cracking.

One winter season after construction, cores were obtained along transverse cracks in the non-interlayer and interlayer pavement sections. Core samples from the non-interlayer pavement section contained full depth cracks while some core samples from the interlayer pavement section contained cracks that were only in the surface course. Thus, in some areas, the interlayer was effective in delaying cracking from becoming full depth.

The cost of using the interlayer only increased the overlay construction costs by 10.6 percent which demonstrates the economic benefit of using an interlayer for HMA overlays. Based on the substantial reduction in reflective cracking and only marginal cost increases from using the interlayer on US 169, it is recommended that future HMA overlay projects in Iowa consider using a crack-relief interlayer to delay reflective cracking.

The Iowa DOT provided Reflective Crack Delay System Special Provisions (Effective Date May 15, 2012) for the Asphalt Interlayer/I-35 Open House in Cerro Gordo County in August 2012. As of October 2014, the HMA Interlayer Design Criteria and Performance Requirements are included in Materials IM 510 Appendix A.

INTRODUCTION

Background

Distressed portland cement concrete (PCC) pavements in Iowa are commonly rehabilitated with hot mix asphalt (HMA) overlays. HMA overlays are a cost effective measure that extend the life of the existing pavement structure and provide a smooth driving surface. This method of pavement rehabilitation is accomplished by paving one or more lifts of HMA over an existing PCC pavement.

The service life of an HMA overlay is often reduced from reflective cracking occurring at PCC transverse and longitudinal joints. As PCC deteriorates, cracks typically form at the joints which create discrete sections of concrete slabs that contract and expand due to thermal or moisture changes (Mukhtar et al. 1996). This mechanism of differential movement below an HMA overlay induces stress concentrations at the bottom of the HMA overlay that are large enough to initiate microcracks in the HMA at the PCC interface. Over time, the cracks grow and propagate to the surface of the HMA layer. Reflective cracking is generally not load initiated; however, traffic loading can cause a breakdown of the HMA at the initial crack (Huang 2004).

Reflective cracks are initially low-severity cracks (less than 0.25 in thick) and do not influence pavement performance significantly. However, if left unsealed, moisture will infiltrate the pavement and increase the crack width. With the application of traffic loads and heavier axle loads, the cracks will eventually become moderate to severe (greater than 0.75 in thick) and significantly contribute to pavement deterioration (O-Antwi et al. 2007).

Different types of mitigation strategies that help delay reflective cracking have been used with varying levels of success. These include: cracking and seating of the PCC pavement, concrete rubbilization (Chen et al. 2014), placement of a geosynthetic fabric (Button et al. 2006), and sawcutting and sealing of the HMA overlay at the PCC joint locations.

One of the more promising approaches used to delay reflective cracking is incorporating an asphalt-rich, highly flexible, crack-relief HMA interlayer within the asphalt structure that serves as barrier to prevent reflective cracks from either forming or propagating to the surface of the overlay. A crack-relief interlayer usually contains a nominal maximum aggregate size of 4.75mm and is placed either at the bottom of the HMA overlay or between the leveling and surface course mixes. Its asphalt-rich properties result in a lower modulus material that does not add structural value to the pavement system. Therefore, it is not typically placed in a lift thickness greater than one inch (MDOT 2000).

Literature Review

Interlayer HMA mixes should be designed with soft materials that have the ability to dissipate excessive stresses induced by cracks or joints (Baek et al. 2011). This has been successfully accomplished by designing an HMA with a low air void content and high asphalt content that uses a highly polymer modified asphalt binder (Blankenship et al. 200).

In 1998 the Missouri Department of Transportation compared an HMA overlay containing a crack-relief interlayer with a traditional overlay containing no interlayer on Route I-29 (MDOT 2000). After three years of service, the interlayer section contained 36 percent less reflective cracks than the control section (Blankenship et al. 2005). Wisconsin Department of Transportation also documented their use of crack relief interlayers for several overlay projects from 1996 to 2002 (Makowski et al. 2005). In three out of four projects, there was a clear delay of cracking (42 percent average crack reduction) when using a pavement overlay with an interlayer.

In 2003 the Illinois Department of Transportation constructed an HMA overlay with a sand mix interlayer on Illinois Route 130. The sand mix interlayer contained an asphalt content of 8.6 percent using a polymer modified PG76-28. After three years, the pavement section with the sand mix interlayer contained 21 percent less reflective cracks than the control section without the interlayer (Baek et al. 2011).

Similar crack relief interlayer mixes have also been previously used by the Iowa Department of Transportation (Iowa DOT). An overlay containing the STRATA® interlayer system was paved in 2001 on Iowa Highway 9 in Decorah, Iowa. A control section containing no interlayer was also paved for comparison. After four years, the interlayer section contained approximately 54 percent less reflective cracks than the control section (Buttlar 2007).

Some state transportation agencies, such as the Utah DOT, have implanted the use of interlayers by creating construction specifications for designing reflective cracking relief bituminous mixtures (Hajj 2008). The specifications for these mix designs meet general HMA mix design criteria except the mix is designed to a target air void of 0.5 to 2.5 percent at 50 design gyrations along with criteria for VMA, Hveem stability, and flexural beam fatigue testing.

Not all HMA overlays with crack relief interlayers perform comparability or better than HMA overlays without interlayers. Blankenship et al. (2005) demonstrated that well designed overlays containing highly flexible, asphalt-rich interlayers only substantially reduce reflective cracking if the interlayers meet laboratory performance testing criteria on the four-point bending beam following AASHTO T-321. Interlayer mixes tested in the four-point bending beam at 2000 µstrain that experienced a greater than 50 percent reduction in flexural stiffness before reaching 100,000 load cycles did not reduce the crack rate growth in the HMA overlays in two Wisconsin DOT test sections. However, based on the results of Iowa, New Jersey, Illinois, Virginia, and Missouri test sections, interlayer mixes that passed 100,000 load cycles in the four-point bending beam before experiencing a greater than 50 percent reduction in flexural stiffness had reduced the average crack rate growth per year in the test sections by an average of 52 percent.

Project Objectives

In 2012, the Iowa DOT developed a performance-based specification for crack-relief interlayer mix designs. To assess the effectiveness of an interlayer, the Iowa DOT selected an overlay project on US 169 in Adel, Iowa in 2013 for conducting a field performance evaluation project. The project included two test sections: one section was paved with a traditional overlay and a second section was paved with an overlay containing the interlayer. The objectives of this project were to assess the interlayer mix design by conducting laboratory performance testing on the four-point bending beam. Following construction of the overlays, analysis of pavement cracking in both test sections was conducted by surveying the pavement after one winter season and obtaining cores at cracked locations in each test section.

ASPHALT INTERLAYER DESCRIPTION

Mix Design Specifications

The interlayer mix design was engineered to follow the Iowa DOT's Special Provision titled "Special Provisions for Reflective Crack Delay System." The goal of the specification is to create a highly flexible, asphalt-rich HMA that meets laboratory performance criteria in the four-point bending beam. The material requirements and volumetric specifications for the interlayer mix design are listed in Tables 1 and 2.

Table 1. Interlayer mix design specifications

Asphalt Binder	PG+ 64-34
Gradation	Minus 3/8"
Ndesign	50 gyrations
Design Target Air Voids	0.5% to 2.0%
Minimum Voids in the Mineral Aggregate (VMA)	16%
Minimum Voids Filled with Aggregate (VFA)	70% to 95%

Table 2. Interlayer gradation specification

Sieve	Percent Passing
3/8 inch	100%
No. 4	80-100%
No. 8	60-85%
No. 16	40-70%
No. 30	25-55%
No. 50	15-35%
No. 100	8-20%
No. 200	6-14%

The PG+ 64-34 binder specification is designed to ensure the asphalt binder is polymer modified to enhance its elastic properties. The wide performance grade temperature range and polymer modification maximizes the asphalt binder's ability to recover from high levels of stress induced from concrete slab movements at pavement joints. By possessing a maximum low critical failure temperature of -34°C, the binder contains elastic properties at low temperatures to recover from deformations caused by thermal and repeated loading stresses. By possessing a minimum high failure temperature of 64°C, the binder has a high viscosity to resist deformation and plastic flow. The 3/8 inch maximum aggregate size allows for paving thin lifts that are one inches or less.

In addition to volumetric and gradation requirements, the Iowa DOT interlayer mix design specification also contains a performance testing requirement using the four-point bending beam apparatus (Figure 1) in accordance with AASHTO T-321: *Determining the fatigue life of compacted HMA subjected to repeated flexural bending*.

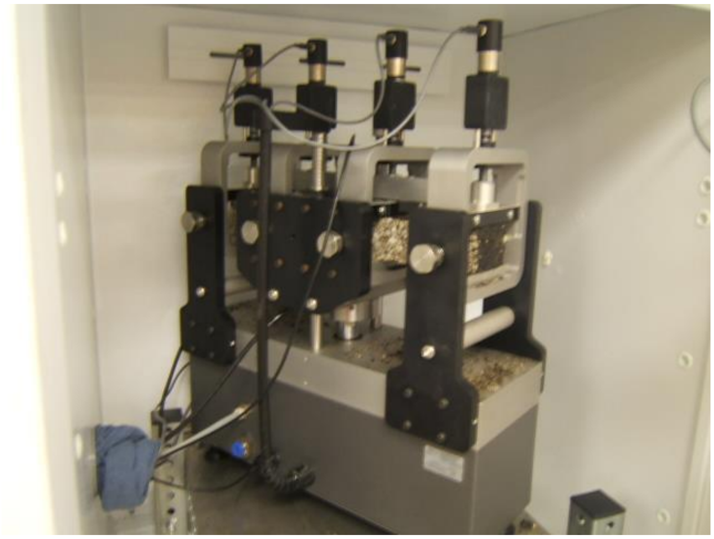

Figure 1. Iowa State University's four-point bending beam

The four-point bending beam test was conducted at Iowa State University's (Iowa State) Advanced Asphalt Laboratory on two replicate hot mix asphalt specimens for fatigue resistance. Specimens were fabricated using aggregates and asphalt binder supplied by Des Moines Asphalt, Inc. An aggregate batch representative of the mix design was mixed with the asphalt binder at 135°C. After two hours of oven aging at 135°C, the mix was compacted in a linear kneading slab compactor to fabricate an asphalt slab within +/-1.0 percent of the design air voids of 2.0 percent. The slab was subsequently saw cut into beam specimens. Specimens were conditioned and tested in a 20°C environmental test chamber. Two replicate beam specimens were tested in the four-point bending beam in a cyclic loading condition at 2000µstrain with a 10Hz rate of loading. Cyclic loading of the specimens was complete until the specimens either obtained 50 percent of their initial flexural stiffness or passed the Iowa DOT specification of 100,000 load cycles without obtaining 50 percent of their initial stiffness. The initial flexural stiffness was determined as the average flexural stiffness of the first 200 cycles.

Mix Design Assessment

Des Moines Asphalt, Inc. designed the interlayer mix for the project which contained an asphalt content of 7.38 percent and an air void content of 1.5 percent (Table 3).

Table 3. Interlayer mix design properties

Asphalt Content	7.38%
Air Voids	1.5%

The initial binder supplied during the mix design phase, supplied by Bituminous Materials in Tama, Iowa, contained two percent poly(styrene-butadiene-styrene), or SBS polymer. Initial performance testing of the mix design at Iowa State (discussed in the next section) indicated the mix did not meet the four-point bending beam testing requirements of passing 100,000 load cycles (Figure 2).

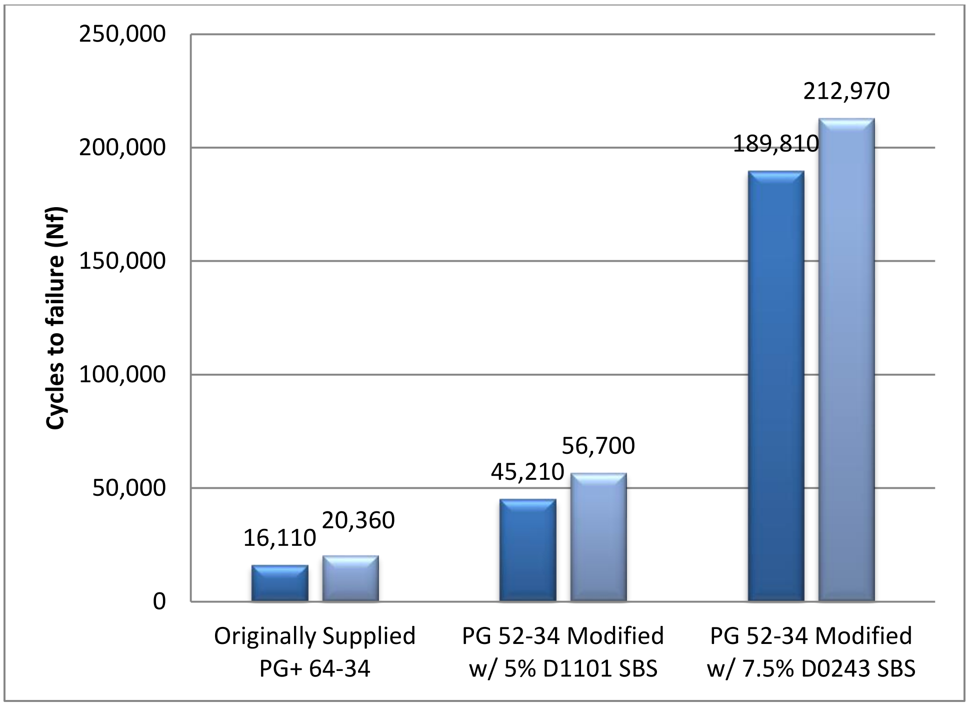

Figure 2. Four-point bending beam results on different interlayer mixes

The research team at Iowa State proposed that either the gradation of the mix design should be adjusted to achieve a higher binder content at a 1.5 percent air void level or the polymer content should be increased to five percent. Due to time constraints, the second option was pursued.

A second mix design sample was then batched in the laboratory using a binder modified with five percent SBS polymer. The binder was prepared at Iowa State's laboratory using a PG 52-34 for the base asphalt and Kraton D1101 SBS for the polymer. Using a laboratory shear mill, the D1101 polymer was blended with the base asphalt for three hours at 180°C. No crosslinking agent was added during the process. The performance of the new mix design in the four-point bending beam improved, but it still not meet the minimum 100,000 load cycle requirement (Figure 2).

At this point in the project, the Iowa State research team proposed the asphalt binder be modified with Kraton D0243 polymer, a new SBS polymer manufactured by Kraton, Inc. that can be formulated with asphalt binder as high as seven to eight percent. High-polymer modified mixes using this polymer have demonstrated superior fatigue resistance (Willis et al. 2012). Improved mix performance results from the polymer forming a continuous elastomeric network within the binder. A third mix design was then batched in the laboratory using the same PG 52-34 base binder modified with 7.5 percent D0243. Procedures recommended by Kraton were followed for preparing the polymer modified binder in the laboratory. No crosslinking agent was added during the process.

The asphalt mix design using the high-polymer modified binder passed the 100,000 load cycle requirement in the four-point bending beam (Figure 2). A regression analysis of the flexural stiffness data was performed in accordance with AASHTO T-321 on each of the two beams that were tested (Figures 3 and 4).

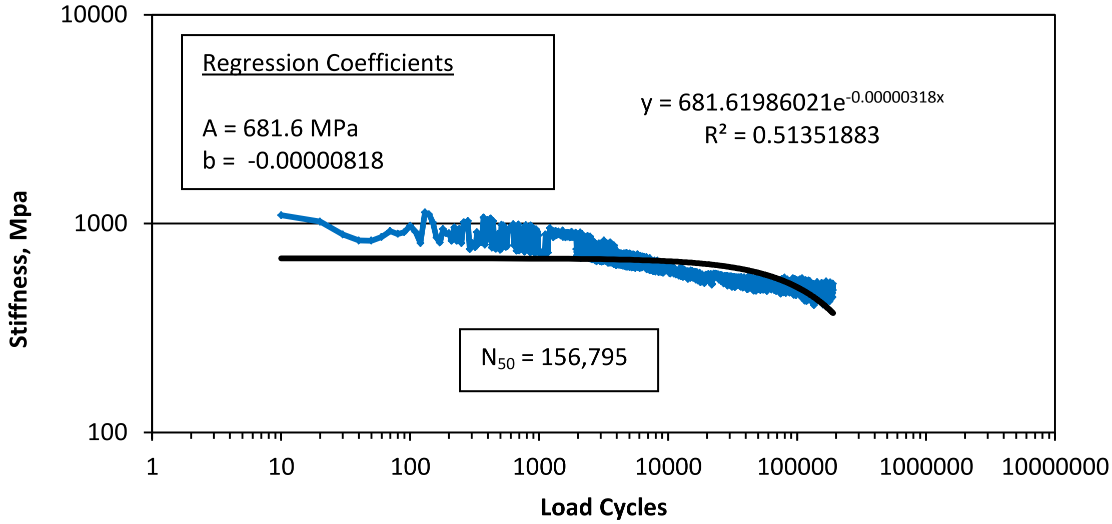

Figure 3. Stiffness versus load cycles (repetitions), beam-1

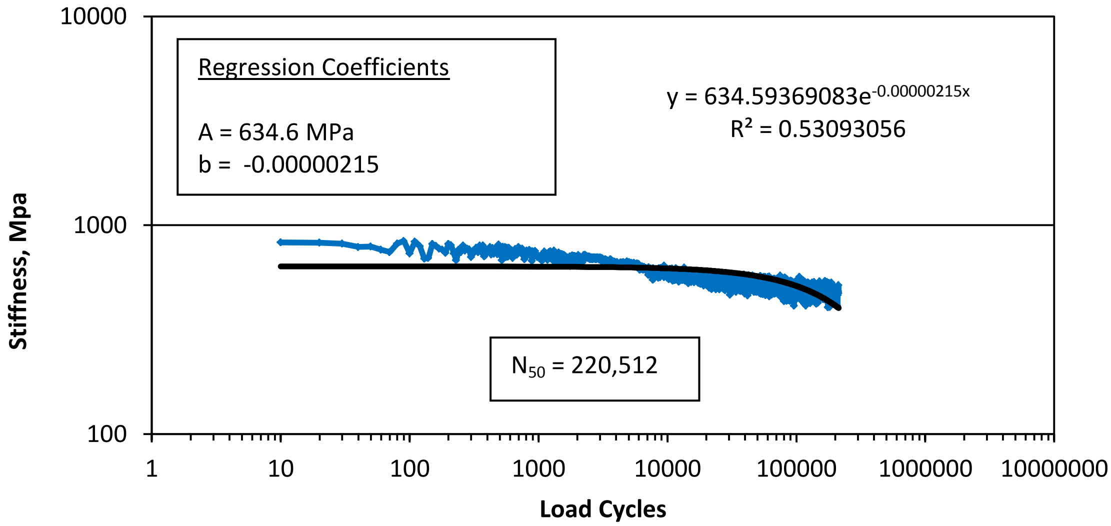

Figure 4. Stiffness versus load cycles (repetitions), beam-2

The regression analysis results are presented in Table 4.

Table 4. Four-point bending beam results on interlayer mix design using 7.5 percent polymer

	Beam-1	Beam-2	Average
Air Voids	1.9	1.7	1.8
µStrain	2000	2000	
Initial Flexural Stiffness (@ 200 Load Cycles) (Mpa)	790	828	
Failure Flexural Stiffness (50% of Initial) (Mpa)	395	414	
Load Cycles at end of test	212,970	189,810	
Flexural Stiffness at end of test (Mpa)	505	513	
Regressed Failure Load Cycles	156,795	220,512	244,623

For the two beam samples tested, both the number of load cycles and the regressed failure number of load cycles exceeded the minimum fatigue life of 100,000 load cycles. The average regressed failure load cycles for the two beams was 244,623. Once the mix design with the 7.5 percent polymer modified binder passed the four-point bending beam results, the interlayer was approved by the Iowa DOT for paving.

PAVEMENT CONSTRUCTION

Construction of the interlayer was completed by Des Moines Asphalt and Paving on August 23, 2013 (Figure 5).

Figure 5. Interlayer paving on US 169

The project was located on US 169 just north of the Adel, Iowa city limits, from the North Raccoon River to the South Raccoon River for a total length of 0.75 miles. The interlayer was part of Iowa DOT project MP-169-4(706)—76-25, an HMA resurfacing project which consisted of overlaying eight inches of a jointed concrete pavement with four inches of HMA. The project was divided into two sections: the northbound and southbound lane from station 101+63.5 to 121+39.5 was paved with a two inch surface course over a two inch intermediate course; the northbound and southbound lane from station 121+39.5 to 141+15 was paved with a two inch surface course over the one inch interlayer over a one inch intermediate course (Figures 6 and 7).

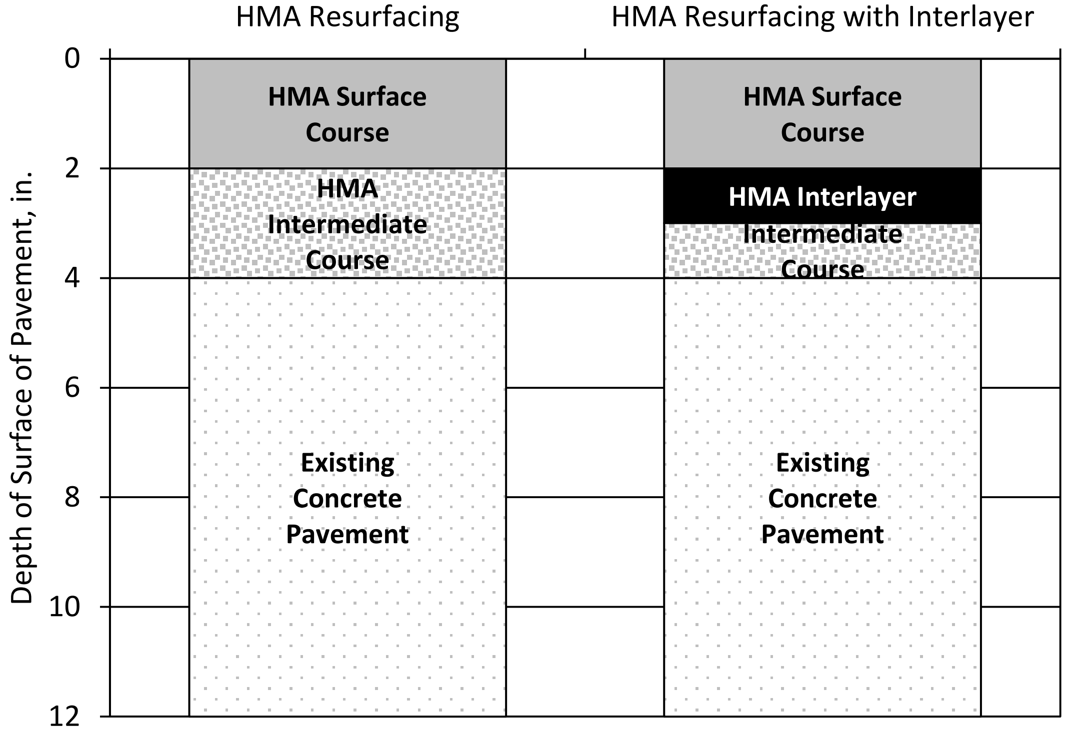

Figure 6. Cross sections of US 169 HMA resurfacing

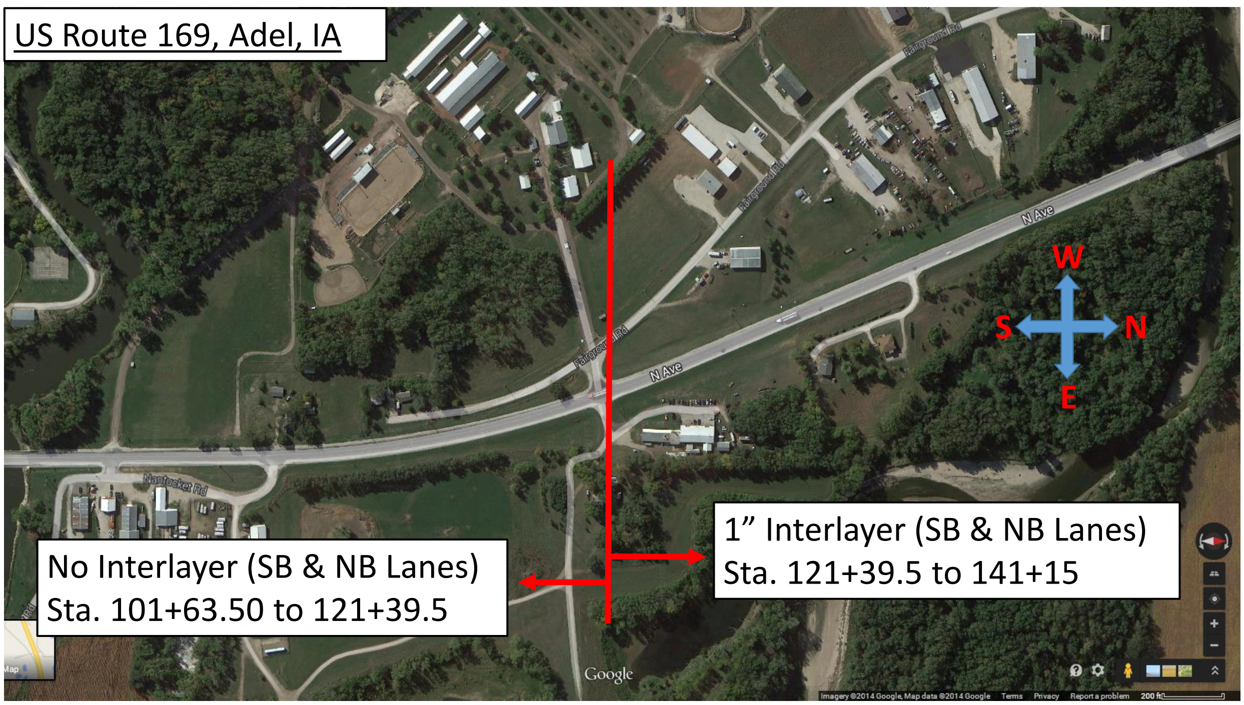

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Figure 7. Satellite view of US 169 project limits

A sample of the field produced mix was obtained by the contractor and split between the Iowa DOT and Iowa State. As shown in Table 5, quality assurance testing conducted by the Iowa DOT revealed the laboratory air voids of the field mix sample was 4.8 percent, which was much higher than the 1.0 percent production tolerance.

Table 5. Quality assurance testing results

Mix Design Target Values	Quality Assurance Test Results
1.5% air voids	4.8% air voids
7.38% asphalt content	6.25% (plant flow meter) 6.12% (laboratory ignition furnace)

The reason for the high air voids is evident from the low asphalt content as measured by the reading from the asphalt flow meter at the HMA production plant. The asphalt content was 6.25 percent which was outside the production tolerance of 0.3 percent. Iowa State's laboratory verified the low asphalt content by testing the split sample in the ignition furnace. A 6.12 percent asphalt content was measured after calibrating the furnace with a dry aggregate batch of the mix design.

Producing the interlayer with high air voids and a low asphalt content resulted in the interlayer mix failing the four-point bending beam 100,000 load cycle requirement. The average load cycles at 50 percent initial stiffness was only 63,985 for the interlayer mix (Table 6).

Table 6. Four-point bending beam results on field produced interlayer

	Beam-1	Beam-2	Average
Air Voids	2.3	2.4	2.4
μStrain	2000	2000	
Initial Flexural Stiffness (@ 200 Load Cycles) (Mpa)	1510	1593	
Flexural Stiffness at end of test (Mpa)	684	710	
Load Cycles at 50% of Initial Stiffness	66,120	61,850	63,985

A reduction in asphalt content resulted in a material with a higher air void content and a higher flexural stiffness. In a strain-controlled test environment, an increase in these two variables will reduce the fatigue life of the pavement (Cooper and Pell 1974). Had the volumetrics been closer to the intended design, the performance of the interlayer in the four-point bending beam would have improved.

POST-CONSTRUCTION ASSESSMENT

Pavement Condition Survey

Before and after pictures of the asphalt intermediate (base) course paving were captured by Google Street View. Figure 8 shows a screen capture of the PCC pavement on US 169 in the future non-interlayer section, dated August 2011, two years before the overlay project.

Figure 8. Pre-construction view of non-interlayer section on US 169

Transverse and longitudinal joint deterioration can be seen in the screen capture. Joint deterioration of this magnitude is the primary cause of reflective cracking in HMA overlays, thereby, making this overlay project a perfect candidate to evaluate the effectiveness of a crack-relief interlayer.

Figure 9 shows a screen capture of the same location in August 2013, at least three to four weeks after the intermediate course was paved for the overlay project.

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Figure 9. Post-construction view of intermediate course in non-interlayer section on US 169

In the non-interlayer pavement section, the intermediate course overlay is two inches thick. The screen capture shows the intermediate HMA course to be in good condition.

Similar screen captures were obtained from Google Street View images for the interlayer overlay section as well (Figures 10 and 11).

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Figure 10. Pre-construction view of interlayer overlay section on US 169

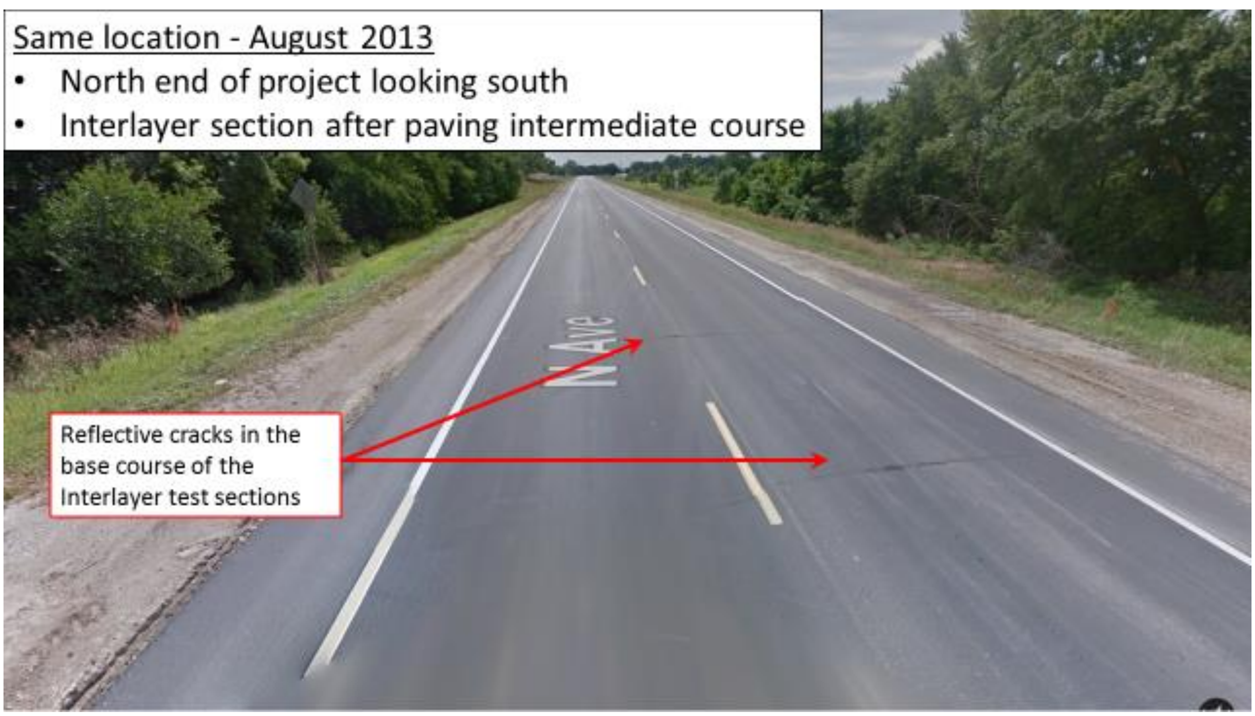

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Figure 11. Post-construction view of intermediate course in interlayer section on US 169

In Figure 10, a high level of joint deterioration can be seen in the future interlayer section. And unlike the non-interlayer section, the intermediate course is already cracking in the same construction season (Figure 11). The difference between the two different overlay sections is the thickness of the intermediate course. The intermediate course in the interlayer section was only one inch thick, not two inches thick, to provide room for the interlayer. This demonstrates just how quickly reflective cracks form in thin overlays (one inches) and is precisely the reason why overlays for distressed PCC pavements are designed to have a certain minimum thickness. In the case of this project, the overlay thickness design was four inches. However, by waiting several weeks between construction of the intermediate course and the surface course, the one-inch course was thin enough to crack prior to paving the second lift.

A pavement condition survey was conducted in April 2014, one winter season after the overlay project was completed, to assess the amount of cracking in the interlayer and non-interlayer overlays. Transverse cracking distresses are evident in the pavement as shown Figure 12.

Figure 12. Reflective cracks in non-interlayer overlay on US 169 in April 2014

The cracks are mostly like reflective cracks since the distance (20 feet) between the cracks exactly matches the joint spacing of the underlying PCC pavement.

Results of the survey are summarized in Figures 13 and 14.

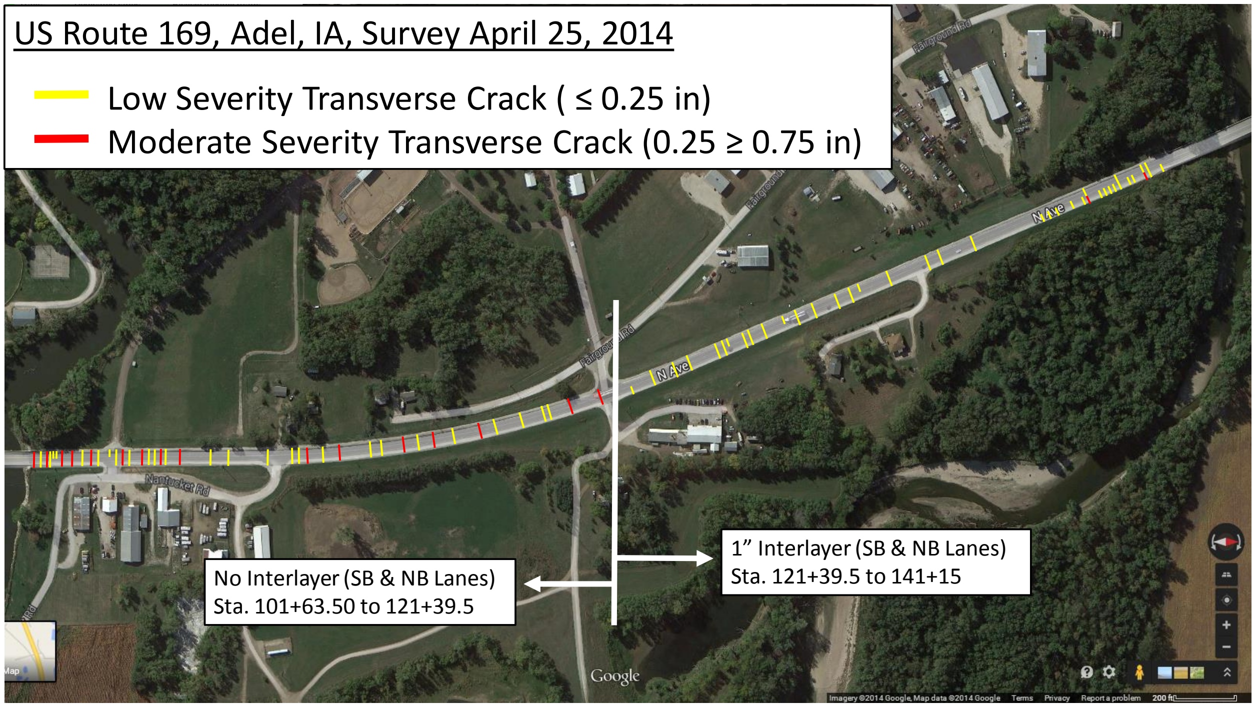

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Figure 13. Satellite view of transverse cracking on US 169

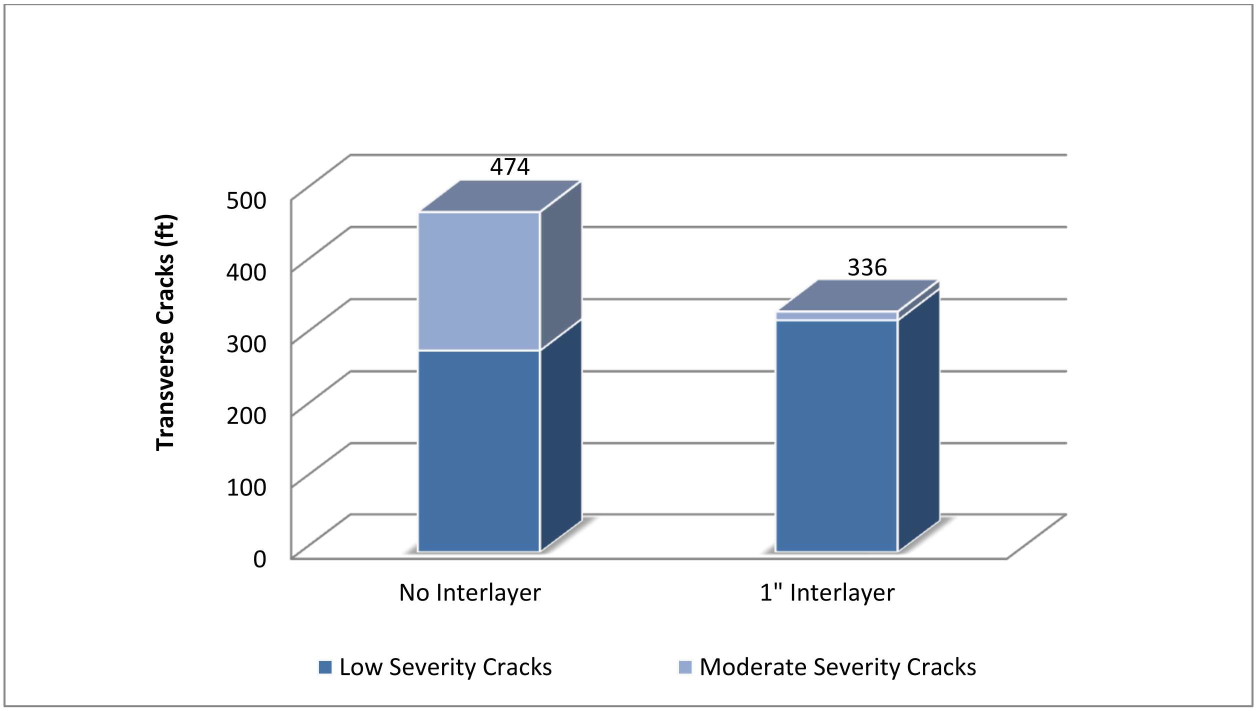

Figure 14. Total transverse cracking in traffic lanes

Transverse cracks were measured in both the interlayer section and non-interlayer section. The below average temperatures Iowa experienced in 2013-2014 winter season may have accelerated the severity of the cracking distresses between the end of construction in August 2013 and the pavement survey in April 2014. After one winter season, more cracking occurred in the pavement with the traditional overlay than in the pavement with the crack-relief interlayer. 474 linear feet of transverse cracking was measured in the traffic lanes of the interlayer section compared to 336 transverse cracking in the non-interlayer test section. These results are particularly positive for the interlayer test section since the quality assurance and performance testing results of the field produced mix (Table 5 above) revealed the interlayer was low on asphalt content and high on air voids with an air void level similar to a traditional HMA mix design. The four-point bending beam tests also revealed the interlayer did not meet the performance testing requirement. Nevertheless, the interlayer test section still contained 29 percent less reflective cracking than the non-interlayer test section. Even less cracking would exist in the interlayer overlay had the volumetrics of the interlayer been closer to the intended mix design targets.

Not only do the results of the survey demonstrate that more cracking occur in the non-interlayer section, but also the severity level of the cracking was greater in the non-interlayer section. In the non-interlayer section, 41 percent of the total transverse crack lengths measured contained moderate severity cracks. In the interlayer section, 4 percent of the total crack lengths measured contained moderate severity cracks. Moderate severity cracks have a width between 0.25 and 0.75 inches while low severity cracks have a width less than 0.25 inches.

Pavement Core Samples

Subsequent to the pavement condition surveys, cores were obtained at four transverse crack locations: two in the interlayer section and two in the non-interlayer section. Broken concrete and joint sealant material at the bottom of each HMA core confirmed the cracks were above PCC joints and are indeed reflective. A full depth crack was found in the first core obtained from the interlayer section as shown in Figure 15a.

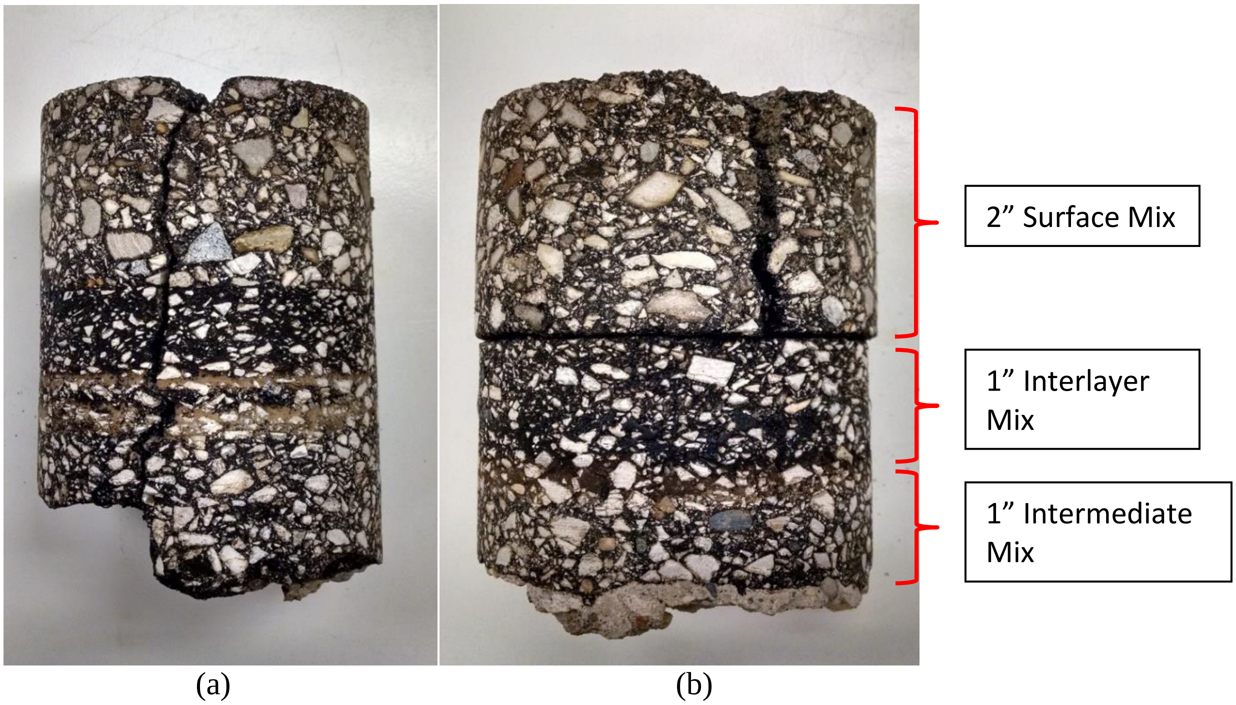

Figure 15. Cores obtained from pavement section with interlayer in southbound lane (a) Sta. 140+12 (b) Sta. 137+85

This indicates the interlayer was susceptible to cracking; however, this was not true for all transverse cracked areas. The photograph of the second core obtained from the interlayer section (Figure 15b) shows no crack in the interlayer mix. While the pavement did crack over the PCC joint, the interlayer was effective in preventing the crack from becoming a full depth crack. No cracks were visible in the intermediate course, but it is possible a microcrack does exist in the intermediate course and will grow with time. Upon recovering this core from the drill bit, the core separated at the surface course and interlayer interface raising the question of possible delamination. Delamination can occur due to insufficient bond strength in the tack coat or moisture infiltration. Based on a literature review of field investigations for overlay systems using an interlayer, delamination of overlays containing crack-relief interlayers has not been reported to have occurred at a higher frequency compared to typical overlays. Since this was the only core that showed signs of delamination, it may be an isolated incident or may have been caused by the force of the core drill.

The cores shown in Figure 16 were obtained in the non-interlayer section over PCC joints. Full depth cracks in both cores indicate the traditional HMA overlay strategy resulted in reflective cracking in the overlay.

(a) (b)

Figure 16. Cores obtained from pavement section with no interlayer in southbound lane (a) Sta. 111+86 (b) Sta. 113+98

ECONOMIC ASSESSMENT

Interlayer mixes will typically cost more than a conventional HMA mixes since highly polymer modified asphalt is used in the design. To determine the additional cost of using an interlayer, the published bid quantities from Des Moines Asphalt were used to analyze the cost differences between the pavement section with and without the interlayer. Since the length of the interlayer pavement section was 1975.5 feet and the length of the non-interlayer section was 1976 feet, the bid quantities were appropriately divided for assessing the cost of the two pavement sections.

The total cost for constructing the HMA overlay without the interlayer was $157,759.03 and the total cost for constructing the HMA overlay with the interlayer was $174,479.61 (Table 7).

Table 7. Interlayer cost comparison from contractor bid tab

Item Description	Quantity (ton)	Unit Price	Amount
Overlay with no Interlayer			
HMA 1/2" Surface Course	817.35	$ 55.00	$ 44,954.25
HMA 1/2" Intermediate Course	826.00	$ 55.00	$ 45,430.00
Asphalt Binder PG 58-28	126.17	$ 534.00	$ 67,374.78
Total			**$ 157,759.03**
Overlay with Interlayer			
HMA 1/2" Surface Course	817.35	$ 55.00	$ 44,954.25
HMA 3/8" Interlayer Course	412.00	$ 74.00	$ 30,488.00
HMA 3/8" Intermediate Course	413.80	$ 74.00	$ 30,621.20
Asphalt Binder PG 58-28	94.53	$ 534.00	$ 50,479.02
Asphalt Binder PG 64-34	24.70	$ 726.20	$ 17,937.14
Total			**$ 174,479.61**

This equates to a 10.6 percent increase in materials and paving costs for constructing an HMA overlay with an interlayer. The benefit of the additional costs was realized from the 29 percent reduction in transverse cracking after the first year of paving with a decrease in the severity of the transverse cracks (41 percent moderate severity vs. 4 percent moderate severity). Furthermore, the reduction in cracking would more than likely have been greater if the field produced interlayer met the volumetric and laboratory performance testing requirements (see Table 5).

CONCLUSIONS AND RECOMMENDATIONS

The Iowa DOT’s crack-relief interlayer specification was structured to create an HMA mix design with a high volume of asphalt and low percentage of air voids. This was accomplished, in part, by specifying a low level of design gyrations (50 gyrations) for laboratory compaction, a minimum VMA of 16 percent, and an air void content less than two percent. Performance testing the interlayer using the four-point bending beam ensured the final design is a highly flexible fatigue-resistant asphalt mixture.

For the US 169 HMA overlay project, the initial interlayer mix design failed the minimum 100,000 load cycle criteria in the four-point bending beam but eventually passed the criteria after the polymer modified binder used for the mix design was re-engineered. Rather than using the minimum amount of SBS polymer to formulate a PG 64-34 binder, a highly polymer modified binder was designed for the interlayer mix. The polymer used was an SBS polymer design by Kraton, Inc. (D0243) which can be added to asphalt at higher polymer concentrations without reducing workability. Seven and a half percent of the D0243 was selected to be blended in a base PG 52-34 binder. Once the new highly polymer modified binder was used for the mix design, the average number of load cycles achieved in the bending beam apparatus increased from 18,235 to 201,390, thereby passing the 100,000 load cycle criteria.

For the US 169 project, the performance of the overlay with the interlayer exceeded the performance of the conventional overlay that did not have the interlayer. After one winter season, 29 percent less reflective cracking was measured in the pavement section with the interlayer than the pavement section without the interlayer. The level of cracking severity was also reduced by using the interlayer in the overlay. In the non-interlayer section, 41 percent of the total transverse crack lengths measured contained moderate severity cracks. In the interlayer section, 4 percent of the total crack lengths measured contained moderate severity cracks. Thus, the crack-relief interlayer successfully delayed reflective cracking in the HMA overlay.

Pavement performance improved by using the interlayer in spite of the interlayer not meeting the volumetric and post construction laboratory performance testing requirements – the result of a low asphalt content during production. Had the volumetrics of the interlayer been closer to the mix design targets, the overlay would most likely have exhibited even less cracking.

Since the cost of using an interlayer only increased the overlay construction costs by 10.6 percent, this project demonstrates the economic benefit of using an interlayer for HMA overlays. Based on the substantial reduction in reflective cracking and only marginal cost increases from using the interlayer on US 169, it is recommended that future HMA overlay projects in Iowa consider using a crack-relief interlayer to delay reflective cracking.

The provisional crack-relief interlayer specification drafted by the Iowa DOT proved to be effective in reducing reflective cracking in the HMA overlay. Therefore, no change in the specification is recommended at this time. However, since the field produced interlayer did not meet the four-point bending beam performance criteria, this project demonstrates the importance of verifying the laboratory fatigue performance of the field produced interlayer.

For future interlayer mixes that do not initially meet the minimum 100,000 load cycle criteria in the four-point bending beam, the number of load cycles the mix design can achieve in the performance test can be increased by improving the elastic and fatigue resistant properties of the binder. Based on the laboratory test results for this project, that can be accomplished by using a high percentage of Kraton D0243 SBS to create a highly polymer modified binder.

The Iowa DOT provided Reflective Crack Delay System Special Provisions (Effective Date May 15, 2012) for the Asphalt Interlayer/I-35 Open House in Cerro Gordo County in August 2012. As of October 2014, the HMA Interlayer Design Criteria and Performance Requirements are included in Materials IM 510 Appendix A.

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