Evaluation of Bonding Between Ultra-Thin Portland Cement Concrete and Asphaltic Concrete

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Ultra-thin whitetopping (UTW) has evolved as a viable rehabilitation technique for deteriorated asphalt cement concrete (ACC) pavements. Numerous UTW projects have enabled researchers to identify key elements responsible for the successful performance of UTW. They include foundation support, interface bonding condition, portland cement concrete (PCC) thickness, fiber reinforcement usage, and joint spacing. Interface bonding condition is the most important of these elements because it enables the pavement to act as a composite structure; thus, reducing interface stresses and allowing an ultra-thin PCC overlay to perform adequately. The impact that external variables on the elements and the interaction between elements in UTW performance has not been thoroughly investigated. The objective of HR-559 by the Iowa DOT and ISU/CCE was to investigate the interface bonding condition between an ultra-thin PCC overlay and an ACC base over time, considering ACC surface preparation, PCC thickness, fiber reinforcement usage, and joint spacing variables. The goal of identifying potential debonding between the layers of pavement was researched in laboratory testing using instrumented flexural test beams and mechanical loading machines. In full scale field-testing interface strains at the PCC/ACC interface were measured four time each year and the falling weight deflectometer deflection responses were measured at some 35 locations annually along a 7.2 mile Iowa Department of Transportation UTW project HR-559. This paper reflects on the results of the field deflection testing portion of that work. Key words: ultra-thin, overlays, rehabilitation, whitetopping.

INTRODUCTION

The use of the ultra-thin portland cement concrete pavement overlay for rehabilitation of asphaltic concrete pavements has grown rapidly since the first test was conducted in Kentucky at the entrance to a landfill. Questions still remain regarding the development of a design procedure and guidelines on when to apply such a treatment. The Iowa Highway 21 project in Iowa County, constructed in 1994, was a way of evaluating the variables of base preparation, overlay thickness, joint spacing and the use of synthetic fiber reinforcement on an in service pavement site. Base preparations included milling, brooming, and cold in place recycling. Depths of concrete included 2, 4, and 6 inches with joint spacings of 2x2, 4x4, 6x6, 12x12, and 12x15 feet.

PROJECT GOALS

A key to the successful performance of the ultra-thin pavement overlay is the development and retention of bond between the portland cement concrete and asphaltic concrete. Much of the literature makes estimates of the bond strength required at the interface, but it has not been successfully measured in the field. In this project the research sought to determine the bond strength to maintain a composite section through three methods. The methods included the use of direct shear laboratory testing of cores obtained from the finished pavement, monitoring of static strains at the interface over time and annual deflection measurements at selected locations.

DATA COLLECTION

A total of 53 cores were extracted from eight separate test section locations in Spring 1997 by the representatives of the research staff and the Iowa DOT. Each of the sections used in this effort were those of the two inch design depth. A total of three cores were extracted in the interior corner of slabs in the outer wheel path and three more were taken in the center of slabs in the same wheel path area. In two sections additional cores were extracted in cracked or miss aligned joint areas. Care was taken not to break the bond at the interface due to the twisting action of the drill during extraction. This is a limitation in this type of testing, but it was relatively successful in this case. In the cases were the core separated in the asphalt, it occurred at a point some 1-3 inches below the interface. This may have represented the asphalt layer construction interface. It did provide a thick enough layer of asphaltic concrete on the portland cement concrete to be tested in the Iowa DOT Shear Testing Device.

The second method of bond strength detection has been the monitoring of strain gages mounted vertically 1 inch into the overlay on a metal post anchored in the asphalt and in the corner of a overlay slab. Two such posts were located in the corner of some 35 separate slabs. In each case the post is located to allow bending in the longitudinal slab direction and the other post to measure transverse slab movement. The gages were monitored multiple times per day for the first two weeks after construction and then quarterly to date. This part of the work is ongoing.

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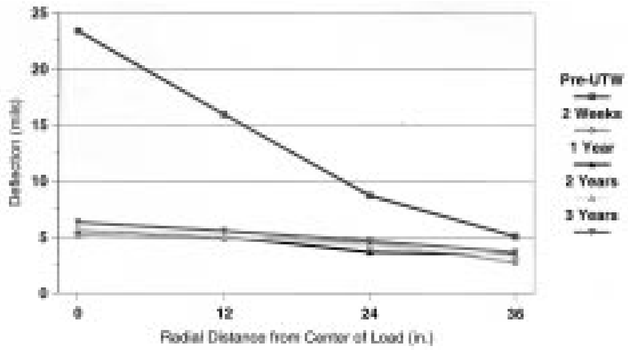

FIGURE 1 Deflection basins for station 2374+50.

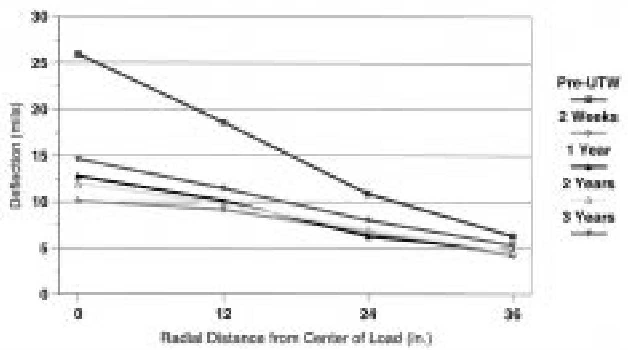

FIGURE 2 Deflection basins for station 2391+50.

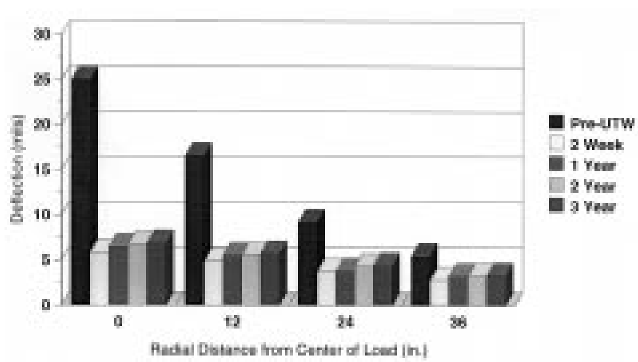

FIGURE 3 Combined average deflections for each testing. period.

The third method of detecting relative bonding of the layers employed the use of the FWD. In this case the unit owned by ERES Consultants of Champaign, Illinois has been employed on an annual basis to test at the midslab and transverse joint locations in the outer wheel path at each of the strain gage locations. Testing is accomplished during August of each year, early in the day to reduce the chance of joint lockup during testing. In this test a load of known magnitude representing a 9,000 pound wheel load is dropped on a bearing pad imparting a load into the slab. The response or deflection is measured at a point under and known distances in front of the loading pad. Testing began with measurement of the existing asphaltic concrete surface prior to the overlay construction and has continued to date.

ANALYSIS

In the case of the direct shear test, the core is loaded into a ring to maintain its shape. It is mounted in a vertical position such that the interface of the two paving materials is at the bottom of the ring. A plate is moved horizontally against the asphalt layer to shear it from the concrete surface. The amount of force required to accomplish the asphalt removal is recorded as the resisting force or shear strength at the interface.

In the case of the FWD deflection data, ERES Consultants Inc. staff used a computer program was used to back calculate the modulus of elasticity for the portland cement and asphaltic concrete layers, the cement treated base, aggregate treated subbase and the subgrade. The deflection data gathered by the FWD each year formed the data set for analysis. Their software can only assume a fully bonded or unbonded interface condition. Modulus seed values and acceptable modulus ranges are established for each material layer based on previous material knowledge. Modulus values obtained from assuming the bond, no bond condition were compared for each of the layers at each test location. Deflection basins showing a difference of greater than 5% were considered suspects for debonding. The results were then compared to visual distress survey information collected on a quarterly basis by the research staff.

In a separate analysis of the raw deflection data provided by ERES, the ISU research staff reviewed the raw deflection basin values over time and for various depths of overlay. Two of the typical plots are shown in Figure 1 for the three inch overlay depth and in Figure 2 for a seven inch overlay depths. These depths represent the depth at one edge of the pavement after overlay construction and exceed the design depths. The design depths were established at the highest point in the asphalt cross section prior to overlay. The pre-UTW line in each graph represents the deflection basin for the asphalt surface prior to overlay. Each of the other lines on the graph represents a deflection basin at this particular station at a given time after construction. Note that the lines for the 7.3 inch pavement basin measured after overlay construction remain relatively constant over time and flat in shape. The overall strength of the concrete is making this section act at as a concrete pavement with an asphalt base only. In the case of the 3.0 inch pavement, the lines have a steeper slope and the deflections at all locations away from the load are increasing over time. If this trend continues, we should be able to predict when it will approach the line representing the asphalt deflections prior to overlay. This should represent a time when the pavement is flexible or the slabs have

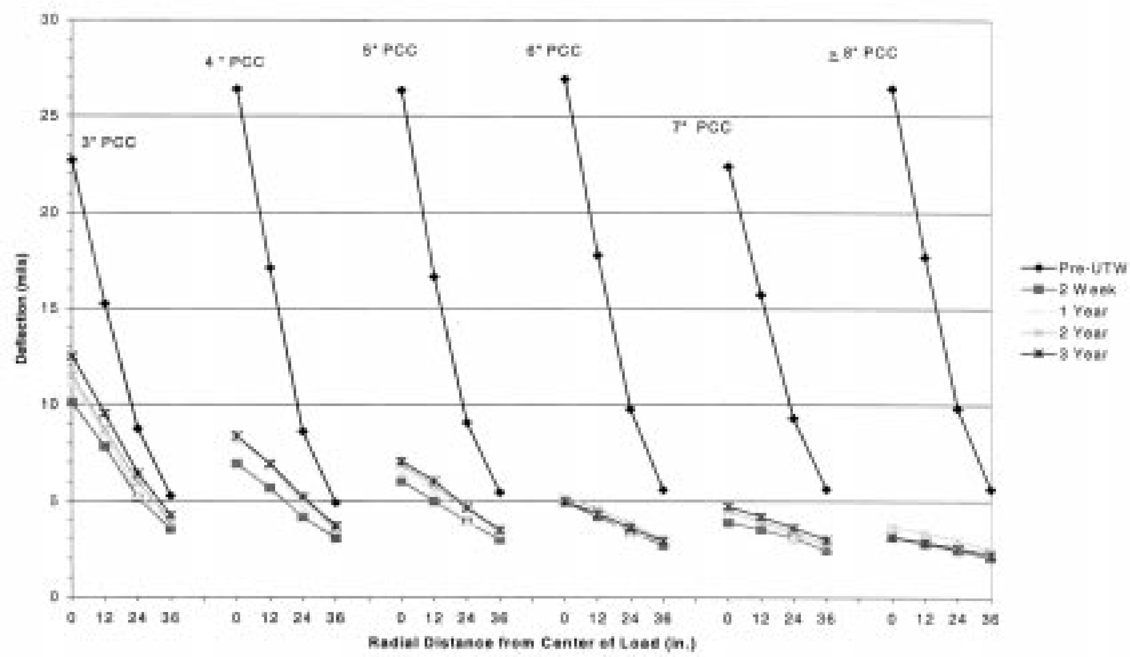

FIGURE 4 Combined average deflection basins of various PCC thicknesses.

lost their interlock and/or bond with the underlying surface of asphalt.

Figure 3 represents the average deflections for the entire population of deflection basins for all depths of overlay. In this graph, the preoverlay deflections represent the asphalt surface response to loading prior to the overlay. Note that there is a small increase in deflections over time in all overlay depths which is considered normal due to the surface wear due to traffic loadings and the effect of the environment.

RESULTS

The direct shear tests provided a wide range of shear values from 35 to 162 psi. This has been typical of values obtained from this type of testing on other Iowa DOT and national whitetopping projects of these depths. The values tend to indicate that the highest average shear values were obtained in the milled areas of base preparation with much lower values being obtained in the patch and cold in place recycle base preparations for the two inch overlay.

Summaries of the average deflection basins for the various overlay depths are shown in Figure 4. The nominal or edge thickness of the overlay is identified above each of the graphs. The deflection basins from all sections exhibiting that edge depth were averaged to provide the data for the after overlay graphs. Note that the graphs for depths of greater than five inches little or no increase in deflection over time or distance from the load location. On the other hand, the depths of three to five inches show increases in deflection over time under the load and a sharper slope between the sensor points. If this trend continues over time, the maximum deflection at any of the sensor points and the slope of the basin should approximate that of the asphalt and represent a loss of bond and free movement of the concrete overlay slabs.

Similar relationship between deflection basin information and time can be seen in Figure 5. In this case a specific three inch depth section and a four inch section have been graphed. An additional basin has been added in each case that represents a special deflection taken in an area of the test section that was suspected of being debonded. Potential debonding was identified by the use of a sounding bar on the surface of the pavement. In the first case a small number of sections have lost bond adjacent to the deflection test location. The deflection basin falls in the range of other bonded test slabs in the test section and may be partially bonded.

In the case of the four inch depth section large numbers of corner cracks are indicating some loss of support in this test section. Here the suspect deflection basin falls very close to the asphalt deflection basin. This may account for the large number of interior corner cracks. Debonding may be occurring at this location and not in the outer two thirds of the slabs in the row along the edge of the pavement. Loss of section in the two inch case only happened after the outer edge row of slabs lost bond.

CONCLUSIONS

Further analysis of the direct shear test results is under way to determine if any construction variables may have effected the magnitude and variability of the values. Those results may be an early indicator of the level of bond achieved at construction and could be used to measure the magnitude of the loss over time and the location of the weakest point in the composite section depth.

The use of the measured pavement depths and the deflection basin changes over time may provide an answer on the expected

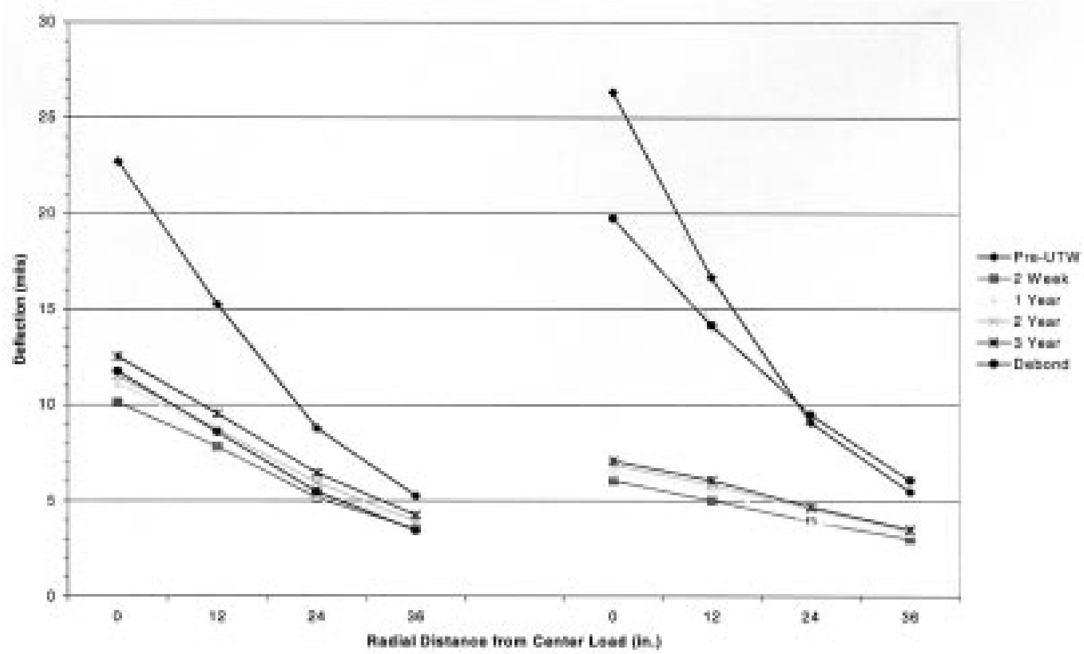

FIGURE 5 Suspected debonding deflection basins compared to combined average deflection basins of similar PCC thickness.

life of the UTW. It may also provide an indication of the effect of various surface preparation treatments on the performance of the UTW.

The use of the deflection basin information and the back calculation of layer moduli by various means as an indication of the level of bonding is still in an experimental stage. There are indications that this type of analysis will direct the engineer to suspect locations. On this project, this method has not provide that level of detail.

ACKNOWLEDGMENTS

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