THE ULTRATHIN WHITETOPPING OPTION

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ABSTRACT

In 1994, Iowa built 11.6km (7.2 miles) of ultrathin whitetopping on a segment of Iowa Highway 21. Research was carried out under Iowa Highway Research Board Project Number HR-559 for five years and TR-432 for an additional five years. When considering ultrathin as an overlay option, is how long is the performance life and what are the rehabilitation options? Some 41 sections of pavement including three overlay depths, four joint patterns, three surface preparations, and fiber usage were constructed.

The methods employed in the rehabilitation and success of each are discussed. Deflection testing, visual surveys, coring, and direct shear testing have continued over the seven years. Analysis of the data have identified ways to estimate accurately the overlay performance in terms of bond strength retained.

INTRODUCTION

Each engineer looks for cost effective ways to build, maintain, and extend the life of the pavement that is selected for a given roadway. In the past this theory often resulted in asphaltic concrete being the only alternative overlay procedure vs. total reconstruction of a portland cement concrete pavement. In response to these needs, engineers developed the bonded/unbonded overlay with portland cement concrete and whitetopping of asphaltic concrete road surfaces. Each of these worked well for roads needing substantial improvements in load carrying capacity. The same alternatives did not meet the need for thin overlays to meet surface rutting and short to medium life extensions at competitive costs to other overlay products.

Work done in Louisville, Kentucky in 1991 proved that an ultrathin 100mm maximum depth (4 inches or less) portland cement concrete overlay could effectively be placed with fasttrack methods and provide services for large volumes of heavy vehicles for extended periods of time. Iowa engineers saw a need to extend this research to a long section of roadway with multiple variables representing construction and operational needs.

RESEARCH OBJECTIVES

The objectives for this research must be considered in light of the two projects. The first project, HR-559, contained the following objective for the construction of the overlay and five year evaluation:

1. Evaluation of the interface bonding condition between the PCC overlay and the ACC base over time in relationship to the variables of base surface preparation, overlay thickness, joint spacing, and use of synthetic fiber reinforcement.

The objectives of the TR-432 project were directed at learning about possible overlay rehabilitation methods and extended overlay life and included:

1. Evaluation of conventional methods of slab removal and asphalt surface preparation methods for subsequent overlays of portland cement concrete in the remove and replacement areas.
2. Evaluation of the existing asphaltic concrete surface under the remove and patch areas of the rehabilitation areas and evaluation of the joint formation in the areas of patching.
3. Evaluation of the polypropylene fiber enhanced concrete at the 75mm (3 inches) overlay depth to determine the cost/benefit of its inclusion.
4. Performance evaluation of the rehabilitated ultrathin whitetopping sections and the extended performance of the existing ultrathin sections with and without patching.
5. Validation of existing ultrathin whitetopping design procedures of the Portland Cement Association (PCA) and American Concrete Paving Association (ACPA) for application in Iowa.

RESEARCH SITE

An 11.6km (7.2 mile) test site, on U.S. Highway 21, between U.S. Highway 6 and Iowa Highway 212, near Belle Plaine, Iowa was selected for the research site. The roadway cross section was constructed between 1958 and 1987. It consists of a 7.3m (24 feet) wide roadway and 2.7m (9 feet) granular shoulders. The pavement section consists of 610mm (24 inches) of select subgrade materials beneath 150mm (6 inches) of granular material, beneath 180mm (7 inches) of cement treated sand sealed with a chip seal, and 75mm (3 inches) of Type B asphaltic cement concrete. Longitudinal subdrains were added as part of the whitetopping project.

The project is located in rolling terrain which is made up of soils that have moderate to high shrink/swell properties, usually poorly drained and fall in the AASHTO classifications of A-6(6) to A-7-6(20). Frost penetration in the area averages 1.52m (60 inches) and rainfall averages 0.88m (31 inches) per year. Average temperatures range from –6 to 24 degrees Celsius (20 to 75 degrees Fahrenheit) annually.

Traffic on the route consists of an average two-way daily traffic (ADT) of 1,090 and average two-way daily truck traffic (ADTT) of 142. It includes a large portion of rural agricultural vehicles and long haul bulk material trucks.

The existing surface exhibited minor rutting in the wheel paths of less than 15mm (½ inch) and isolated alligator cracking in the outside wheel path area.

WHITETOPPING CONSTRUCTION

The 1994 construction included subdividing the project into three subsections for surface asphaltic cement concrete (ACC) base preparation. One third of the project was rotomilled to a depth of 10mm (¼ inch) to remove existing road surface oils and to provide a clean surface to enhance bond. The milled material was used for shoulder fill. The second portion (one third) of the project was broomed and asphaltic concrete patches placed in the deteriorated areas prior to overlay. For the third portion of the project, the surface was removed to a depth of 75mm (3 inches), cold in place recycled, relaid, and compacted on the original pavement area.

A total of 65 test sections were designed for the project. Forty-one sections involved portland cement concrete overlay material. Three sections were built with a 115mm (4.5 inches) asphaltic concrete overlay and 21 sections represented areas of transition in depth of overlay.

Concrete overlay material was placed with a slipform concrete paver to the full 7.3m (24 feet) width in one pass. Grade and depth of the overlay was controlled by stringlines on each side of the pavement. The concrete was centrally mixed at a portable plant on the site and delivered to the front of the paving machine by dump trucks. Surface texture was provided through the use of a burlap drag and transverse texturing machine immediately behind the slipform paving machine. A double application of white pigmented curing compound was applied to the pavement after texturing. Joints were formed with the use of the dry sawing method immediately behind the finishing operation.

REHABILTATION CONSTRUCTION

The rehabilitation areas were identified by a joint effort of the Iowa DOT Maintenance Staff and the research team. Individual slabs or series of slabs were removed in the outer or inner wheel paths in some 25 separate areas. Each of these sites was located in the nominal 50mm (2 inch) depth sections or one of two transition depth areas. In these cases the joints around the damaged slabs were sawed to the depth of the portland cement concrete and the slab removed by various lifting techniques (manually, with lifting hooks and with tractor backhoes or forklifts). The loose material was removed from the damaged area to a depth of 75mm (3 inches). Standard paving mix portland cement concrete was delivered in ready mix trucks to the patching areas, placed, vibrated, finished, and covered with white pigmented curing compound, joints cut to match the original spacing and the patch was covered with insulating blankets.

Three full lane width removal areas were also identified. In one of these areas the instability of the recycled asphalt beneath the overlay was also removed. Removal of the remaining two areas of full lane removal indicated a loss or lack of original bond with the asphalt surface. Portland cement concrete was placed in the same manner, cured, and covered for this repair as in the individual slab repair. Depths of the overlay varied from 50 to 125mm (2 inches to 5 inches) depending on the amount of asphaltic concrete base that was removed to locate a stable base for bond development.

Traffic control was provided by the pilot car method to allow for several work areas in the same lane. The maturity concept was used in conjunction with the blankets to enhance curing and allow for the patching to be done in the mornings and the pavement to be opened to traffic during the nighttime hours.

EVALUATION METHODS

Evaluation of the overlay performance was accomplished through the use of visual distress surveys of four per year for the first five years and two per year for the second five years. Strain gages were installed at the interface between the asphalt base and the portland cement concrete overlay at some 32 locations in a lateral and longitudinal direction near the outside edge of the pavement. Information was obtained from each site three times per year for the first five years of evaluation. Interface temperature and Deflection surveys were and are being conducted each August using both the Falling Weight Deflectometer and the Road Rater. Tests are performed at the same locations as the strain gages. These tests provide both modulus values for the various layers and the load transfer across the joints.

Laboratory tests were also conducted on flexural test beams to replicate the composite sections and the strain gage installations in the field. These beams were then tested in the static and dynamic mode in the laboratory to estimate the level of stain that would induce a crack in the overlay.

Pavement coring was accomplished at specified locations twice during the first five years to obtain shear stress values for the bond at the interface. These tests have been limited to the 50mm (2 inch) depth test sections.

Visual walking distress surveys were conducted on a quarterly basis over the first five years of this project. The same types of surveys will be conducted each spring and fall for the next five years. Distresses are identified as per Strategic Highway Research Program Manual SHRP-P-338 as to type of distress. In this case the data is recorded by test section station location, location on the slab (lane and wheel/non wheel path), and the number of slabs containing the distress.

CONCLUSIONS

<u>Ultrathin Overlay Design</u>

- Strain Gages Results: Some 27% of the gages survived the five year test period. Much of loss was due to damage by outside sources to the wire connections. The gages did identify a pattern of stain over time. The trend indicated that the pavement interface was in compression for the first 480 days, followed by a move to tension until day 720. For the remainder of the period the pavement moved back into compression. Temperatures at the interface followed the same trend of the air temperatures at the pavement surface. The field data did indicate a relationship between the strains and overlay thickness, asphaltic cement concrete (ACC) surface preparation, interface temperature, and age that should be

investigated to a greater degree. It did not show a consistent relationship between strain and joint spacing or fiber reinforcement usage.

- Deflection Results: Pavement deflections were dramatically reduced with the addition of the portland cement concrete (PCC) overlay. The results of annual testing indicated an increase in deflection over time at each of the test sites. The increase in deflection over time becomes greater as the overlay thickness is decreased as would be expected. The result does allow the highway agency to use the deflection measurements and selected direct shear test to identify local areas that might be subject to debonding and to predict remaining life in the composite section. The data also indicated that the milled and patch-only surface preparations provided the best levels of deflection reduction over time. The addition of fiber reinforcement did improve the level of deflection reduction in the ultrathin sections while providing only small reductions in the deflections in the thicker pavement overlays.
- Pavement Coring and Direct Shear Testing: Cores taken immediately after construction and three years into the test period indicated a large variation in the direct shear stress values. This follows data that has been collected on other projects in the nation. Test cores were obtained from nine separate sites and visually indicated full bonding of the ACC and PCC in all but one case. Seventy-five percent of the cores contained at least one inch of ACC to allow for proper shear testing. Higher shear strengths were related to the milled surface preparation. Over 70% of the cores sheared at a depth into the ACC and not at the interface indicating that bond was achieved and was being retained over time. Deflection results and coring also verified that isolated instability in the recycled ACC surface material resulted in loss of bond and PCC overlay distress in one area of the project.
- Visual Distress Surveys: Predominant distress types identified in the ultrathin sections are longitudinal cracking, transverse cracking, corner cracking, and fractured slabs. Longitudinal cracking (2.9% of slabs) was concentrated in the outside wheel path and in the 50mm x 1.2m (2 inches x 4 feet) slabs. Transverse cracking (less than 1% of slabs) was found in only one test section and related to the time of the joint sawing and weather conditions. Corner cracking (2.6% of slabs) was identified in the outer wheel path, slab or near the wheel path longitudinal joint in the 50mm x 1.2 m (2 inches x 4 feet) slabs, and in the areas of unstable ACC base. Fractured slabs (1.6% of slabs) resulted over time from a combination of the above noted distresses and primarily in the areas of unstable ACC base in the 50mm x 1.2m (2 inches x 4 feet) slabs. No significant distress levels were identified in the 100mm (4 inches), 150mm (6 inches), or 200mm (8inches) slab thickness. Debonding did occur in two isolated areas due to a combination of excess moisture in the subgrade, large increases in air temperature, and a layer of dust that was present on the ACC surface at the time of the overlay.

<u>Ultrathin Whitetopping Rehabilitation</u>

- Removal of damaged slabs was successfully accomplished by sawing the joint to the full depth of the overlay on each side of the slab. The damaged slabs were removed by hand methods (large bar), lifting pins, or by the assistance of a backhoe bucket or forklift type forks being placed under the slab as the machine moved forward.
- The damaged area was cleaned of loose material to a depth of 75mm (3 inches) below the roadway surface with air operated chisels and compressed air.
- Conventional concrete was used to patch the damaged areas and finished with hand methods. The depth of the new overlay material was established nominally at 75 mm (3 inches).

Curing was accomplished with the aid of white pigmented curing compound and thermo blankets, and strength gain was monitored with maturity methods. Blankets were removed once during the curing period allow for the development of the joints to match the joints on the adjoining slabs.

- Removal, replacement, curing, and opening to traffic can be accomplished during daylight hours with conventional concrete procedures and the use of the pilot car traffic control technique.

Ultrathin Whitetopping Performance

- Ultrathin pavement overlays provide an alternative to asphalt overlays in terms of load carrying capacity. They eliminate rutting of the surface.
- Surface distresses have been minimal over the first seven years of the project and are often associated with construction type solutions.
- Bonding was successfully accomplished and retained between the ACC and PCC overlay.

RECOMMENDATIONS

The following items should be considered in the design of an ultrathin overlay as a result of this research project:

1. A thorough knowledge of the ACC layers and their characteristics can aid the designer in determining the potential weak point in the composite design and may direct the removal depth of the surface prior to overlay.
2. Surface preparation should consider milling of the existing surface or adequate cleaning prior to overlay. This removes road debris, soils, and vehicle deposits from the surface and provides good bonding surface.
3. Grade control should be checked thoroughly prior to and during the overlay where the nominal depth of the overlay is to be less than 100 mm (4 inches).
4. Joint spacing of 0.6m (2 feet) is adequate for the 50mm (2 inches) nominal thickness of overlay when longitudinal and transverse depth control is adequately monitored.
5. Fiber reinforcement is recommended for overlay depths of less than 100mm (4 inches) to retain continuity of the slab in case cracking occurs.

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