PERFORMANCE, ANALYSIS AND REPAIR OF ULTRA-THIN AND THIN WHITETOPPING AT MN/ROAD

A Paper Submitted to the Transportation Research Board for Publication and Presentation at the 2002 Transportation Research Board Annual Meeting

submitted by

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Word Count: 4,232
ABSTRACT

Thin and ultra-thin whitetopping overlays are becoming a more common method of pavement rehabilitation. It is important to gain information on the types of distresses that occur in the overlays and effective repair techniques. In 1997, the Minnesota Department of Transportation constructed several thin and ultra-thin whitetopping test cells at the Minnesota Road Research (Mn/ROAD) facility. The test cells varied in overlay thickness from 76-mm (3-in) to 152-mm (6-in). The joint spacing of these cells ranged from 1.2-m by 1.2-m (4-ft x 4-ft) to 3.1-m by 3.7-m (10-ft x 12-ft). Over 3.5 years of existence and 4.7 million ESALS, both temperature- and load-related distresses were observed on the 76-mm (3-in) and 102-mm (4-in) thick sections. There were no noticeable distresses in the 152-mm (6-in) sections. Typical distresses included corner breaks, transverse cracks, and reflective cracks. The finite element program ISLAB2000 was used to investigate stress patterns and their relation to the distresses.

Different techniques for repairing ultra-thin whitetopping were investigated. It was determined that using a milling machine with tungsten carbide teeth to remove the concrete greatly reduced the time required per repair. Various techniques were also used to deter reflective cracking. This included the use of various bond-breaking materials and full-depth sawing at strategic locations along the longitudinal joint to prevent cracks from propagating into adjacent panels at misaligned transverse joints.

Four of the six sections had PSIs greater than 3.5 before the repairs, showing a good level of performance has been maintained after 4.7 million ESALS. The two sections that exhibited the largest drop in PSI were the overlays with 1.2-m x 1.2-m (4-ft x 4-ft) panels. The repairs made in sections containing 1.2-m x 1.2-m (4-ft x 4-ft) panels have brought the PSI back up to an acceptable level (PSI>3).

The thin and ultra-thin whitetopping test sections at Mn/ROAD have shown that whitetopping is a viable rehabilitation alternative for asphalt pavements. The importance of choosing an optimum panel size was exhibited. It has also been shown that, when necessary, it is easy to repair ultra-thin whitetopping sections. Various techniques for repairing each type of distress have been summarized.

Key Words: thin whitetopping, ultra-thin whitetopping, repairs, rehabilitation, distresses, inlays
INTRODUCTION

Ultra-thin and thin whitetopping overlays are becoming a more widely accepted rehabilitation alternative in the United States. Ultra-thin whitetopping consists of placing a 50- to 102-mm (2- to 4-in) portland cement concrete (pcc) overlay on an asphalt pavement. Thin whitetopping refers to a 102- to 152-mm (4- to 6-in) overlay. Long-term performance is obtained from the thin overlay by maintaining a good bond between the overlay and the asphalt so load-related stresses can be reduced and using short joint spacings to reduce curling and warping stresses and bending stresses produced by applied loads.(1) As this form of pavement rehabilitation becomes more common, it is important to understand the types of distresses that can occur and how to repair them. Limited experience has been gained to date in the development of repair techniques for ultra-thin whitetopping. Although, a well-documented study was performed on the repair of an ultra-thin whitetopping subjected to accelerated-load testing at the Federal Highway Administration’s (FHWA) Turner-Fairbank Highway Research Center (TFHRC).(2)

This study identifies typical distresses resulting from live interstate traffic loads in pavements with different ultra-thin whitetopping designs and the methods developed to repair each type of distress. In October 1997, the Minnesota Department of Transportation (Mn/DOT) constructed several ultra-thin and thin whitetopping test sections on a 343-mm (13.5-in) asphalt pavement on I-94 at the Minnesota Road Research (Mn/ROAD) facility.(3) This is not a typical application for ultra-thin whitetopping but it provided the opportunity to evaluate the performance of these types of pavements under accelerated load conditions. The top of the asphalt was milled to the depth of the overlay so the original elevation of the pavement surface could be maintained. Six test sections were constructed. Three different overlay thickness were included in the study (76-mm [3-in], 102-mm [4-in], and 152-mm [6-in]) along with three different joint layouts (1.2-m x 1.2-m [4-ft x 4-ft], 1.5-m x 1.8-m [5-ft x 6-ft] and 3.1-m x 3.7-m [10-ft x 12-ft]). The 152-mm (6-in) overlay test sections are 53 m (175 ft) in length and all other test sections are 91 m (300 ft). All test sections contained polypropylene fibers except for the 76-mm (3-in) overlay with 1.5-m x 1.8-m (5-ft x 6-ft) panels, which contained polyolefin fibers. All test sections are undoweled except for one of the 152-mm (6-in) overlays with 3.1-m x 3.7-m (10-ft x 12-ft) panels. A summary of each test section has been provided in table 1.

DESCRIPTION OF DISTRESSES

An distress survey was performed on the asphalt pavement just prior to the construction of the whitetopping and approximately four times a year since its construction. Corner breaks and transverse cracks are the two types of distresses that commonly occur in ultra-thin whitetopping. After 3.5 years and over 4.7 million ESALs, both temperature- and load-related distresses were observed in the 76-mm and 102-mm (3-in and 4-in) overlays, while no cracking has occurred in the 152-mm (6-in) overlays. The majority of the distresses developed in the driving lane, as expected, which was loaded with 79 percent of the traffic (3.7 million ESALs). A summary of the distresses in each test section is provided in figures 1.a through 1.c. Each graph contains three pieces of data for each point in time that a distress survey was performed: the number of corner breaks that developed since the previous survey was performed, the number of transverse cracks that developed since the previous survey was performed, and the cumulative
percent of panels that exhibited cracking. As previously mentioned, no cracking has been observed in the 152-mm (6-in) overlays to date, so distress summary graphs are only provided for the 76-mm (3-in) and 102-mm (4-in) overlays.

**102-mm (4-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels**

Figure 1.a contains a summary of the distress data for the 102-mm (4-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels. Seven percent of the panels exhibited cracking since the time of construction. Thirty-four percent of the observed distresses are corner breaks and the remaining sixty-six percent are transverse cracks. Most of the corner breaks occurred along the inside longitudinal joint due to its location directly in the inside wheel-path. See figure 2.c. Transverse cracks often occur in the outside wheel-path near a transverse joint. See figure 2.a. At times, these transverse cracks were intercepted by corner breaks that initiated at the intersection of the wheel-path and the transverse joint. See figure 2.b. Seventy-three percent of the cracking in this section occurred in the driving lane.

Pre-existing transverse cracks in the asphalt were surveyed prior to the construction of the whitetopping test cells. This survey was used along with the distress data collected for each whitetopping section to determine the percentage of pre-existing cracks that reflected through the overlay. Nineteen percent of the transverse cracks in this test section are reflective. A reflective crack is shown in figure 3. The crack in the asphalt shoulder in figure 3 marks the location of a temperature crack that extended across both lanes in the existing asphalt pavement prior to the construction of the inlay. This crack propagated up through the concrete inlay in the driving lane during the first winter following construction and in the passing lane during the second winter following construction. The presence of reflective cracks emphasizes the need to take extra precautions during construction to match up the transverse joints in the overlay with the exiting temperature cracks in the asphalt.

The PSI for the 102-mm (4-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels was above 2.25 just prior to the repairs. This test section was at the end of the whitetopping sections and adjacent to a 191-mm (7.5-in) concrete pavement test section. The six end panels adjacent to the 191-mm (7.5-in) concrete pavement had high severity cracking. The roughness of these panels had a significant effect on the calculated International Roughness Index (IRI) and therefore the present serviceability index (PSI) since the test section is short (less than 60 m [200 ft]). Past experience has shown increasing the overlay thickness to at least 152-mm (6-in) at the beginning and end of the ultra-thin whitetopping (the first and last row of panels) will reduce cracking in the panels where traffic is coming on and off of the overlay.

**76-mm (3-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels**

Figure 1.b depicts a summary of the distress data for the 76-mm (3-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels. This test section developed a greater number of corner breaks and transverse cracks than the other sections, with thirty percent of the panels exhibiting distress after 4.7 million ESALs. Eighty-three percent of the distressed panels are located in the driving lane. Eighty-seven percent of the observed distresses are corner breaks and the remaining thirteen percent are transverse cracks. Forty-seven percent of the transverse cracks are reflective. This test section developed the same
cracking pattern as the 102-mm (4-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels because the joint layout was the same. Adding an additional 25 mm (1 in) to the thickness of the 102-mm (4-in) overlay significantly reduced the percentage of distressed panels compared to the 76-mm (3-in) overlay.

76-mm (3-in) overlay with 1.5-m x 1.8-m (5-ft x 6-ft) panels

Figure 1.c summarizes the distress for the 76-mm (3-in) overlay with 1.5-m x 1.8-m (5-ft x 6-ft) panels. The performance of this test section to date has been comparable to the 102-mm (4-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels, which is significantly better than the other 76-mm (3-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels. Only eight percent of the panels in the 76-mm (3-in) overlay have developed cracks, of which seventy-five percent are located in the driving lane. Eighty-two percent of the observed distresses are corner breaks and the remaining eighteen percent are transverse cracks. All of the corner breaks are located in the outside panels. The corner cracks tended to initiate where the wheel path intersects the transverse joint, as was observed for the overlays with the 1.2-m x 1.2-m (4-ft x 4-ft) joint layout. All of the transverse cracks in this test section were reflective cracks. The 76-mm (3-in) overlay with 1.5-m x 1.8-m (5-ft x 6-ft) panels is performing well with a PSI above 3.68 before the repairs were completed.

The 76-mm (3-in) overlay with 1.5-m x 1.8-m (5-ft x 6-ft) panels was the only test section to contain polyolefin fibers. All of the other test sections contain polypropylene fibers. The type of fiber used does not appear to affect the performance of the whitetopping until after a crack has developed. The polyolefin fibers seem to maintain the integrity of the crack better than the polypropylene fibers.

FACTORS AFFECTING PERFORMANCE

The amount of cracking and the cracking pattern that occurred in each section is directly influenced by the joint layout. The longitudinal joint of a 1.2-m x 1.2-m (4-ft x 4-ft) joint layout is located in the inside wheel path. This resulted in corner cracking for both the 76-mm and 102-mm (3-in and 4-in) overlays. The performance of the 76-mm (3-in) overlay with 1.5-m x 1.8-m (5-ft x 6-ft) panels was significantly better than the 76-mm (3-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels because the longitudinal joints were located outside of the wheel paths, thereby reducing the edge loads. A comparable performance was obtained with the 76-mm (3-in) overlay with 1.5-m x 1.8-m (5-ft x 6-ft) panels and the 102-mm (4-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels. This indicates that an optimum joint layout can provide an increase in the performance of the overlay equivalent to increasing the thickness of the overlay by 25 mm (1-in). The 76-mm (3-in) overlay with 1.5-m x 1.8-m (5-ft x 6-ft) panels is also more economical than the 102-mm (4-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels because less concrete is needed and there are fewer joints to construct and maintain.

Reducing the panel size will reduce the curling/warping and load-related flexural stress. The finite element program ISLAB2000 was used to model two panel sizes (1.2-m x 1.2-m [4-ft x 4-ft] and 1.5-m x 1.8-m [5-ft x 6-ft]) for the 72-mm (3-in) overlay test sections at Mn/ROAD. ISLAB2000 is a two-dimensional finite element program with the capability of modeling two-layered multislab pavement systems. The concrete overlay and asphalt layer were modeled as fully bonded. The maximum principal tensile
stress produced by temperature gradients for each test section was determined for three different gradients and summarized in table 2. The maximum tensile stress generated in each panel size was within 0.01 MPa (1 psi), indicating that the two panel sizes respond similarly to temperature gradients of the same magnitude. A significant reduction in panel size will reduce the curling/warping and flexural stress. Although, the combined temperature- and load-related stress can still be higher in the smaller panels if the longitudinal joint lies in the wheelpath resulting in corner/edge loadings.

ISLAB2000 was also used to model the Mn/ROAD test section containing a 76-mm (3-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels loaded with a 102 kN (23 kip) truck axle and a 0.44°C/cm (2°F/in) temperature gradient. The principal stress contour plot was generated for the top of the slab and is provided in figure 4. The stress contour plot indicates corner breaks would develop in the inside wheelpath along the longitudinal joint and that transverse cracking would develop in the outside wheelpath near the transverse joint. This theoretical cracking pattern matches the actual cracking pattern that developed for this test section at Mn/ROAD. The high tensile stresses that develop along the longitudinal joint in the inside wheelpath emphasizes the need to consider the location of the wheelpath with respect to the longitudinal joints when determining the optimum panel size. Although a 0.6-m x 0.6-m (2-ft x 2-ft) joint layout was not included in this study, both the outside and inside wheelpaths lie directly on the longitudinal joints, thereby increasing corner stresses. The outside longitudinal joint also lies in the wheelpath for a joint layout of 0.9-m x 0.9-m (3-ft by 3-ft).

Many of the transverse cracks appearing in the overlays are a result of previously existing temperature cracks in the asphalt reflecting up through the concrete. Reflective cracking is a function of both uniform temperature- and load-related stresses. The thermal contraction of the asphalt in the winter creates a stress concentration at the bottom of the concrete in the region near the tip of the crack in the asphalt. The magnitude of the tensile stress at the bottom of the concrete is then increased as a result of vehicle loads, thereby causing the crack in the underlying asphalt to propagate up through the concrete overlay.

The 152-mm (6-in) overlays did not experience any reflective cracking. Thirty-two percent of the pre-existing cracks in the asphalt propagated up through the overlay in the 76-mm (3-in) section with 1.5-m x 1.8-m (5-ft x 6-ft) panels. In the 76-mm (3-in) section with 1.2-m x 1.2-m (4-ft x 4-ft) panels, fifty-six percent of the pre-existing cracks reflected through the overlay. Fifty percent of the cracks reflected up through the concrete in the 102-mm (4-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels. All but two of the reflective cracks developed during the spring and winter. It is possible that these two cracks also initiated during the winter or spring but were not noticed until the following summer. Reflective cracking typically occurred earlier in the driving lane than in the passing lane indicating the volume of traffic accumulated affects the development of reflective cracks.

The panel size and overlay thickness also affect the development of reflective cracking. The section with the shortest joint spacing and the thinnest overlay (76-mm [3-in] overlay with 1.2-m x 1.2-m [4-ft x 4-ft] panel spacing) experienced the highest percentage of cracks reflecting through the overlay while no cracking occurred in the 152-mm (6-in) overlays. The 102-mm (4-in) overlay with the same panel size (1.2-m x 1.2-m [4-ft x 4-ft]) had a slightly lower percentage, but this difference might not be
statistically significant. The 76-mm (3-in) section with larger panels (1.5-m x 1.8-m [5-ft x 6-ft]) had the lowest percentage of thermal cracks propagating through the overlay among the three ultra-thin test sections. As previously discussed, the load-related stress is higher in the ultra-thin overlays with 1.2-m x 1.2-m (4-ft x 4-ft) panels because the longitudinal joint lies in the wheelpath. The load related stresses coupled with thermal stresses generated during the colder months of the year work together to promote the reflection of cracks from the asphalt into the overlay.

The stiffness of the asphalt and quality of the bond between the concrete overlay and the asphalt also has a significant effect on the performance of the overlay. Temperatures ranging between 38°C (100°F) and -15°C (4°F) have been measured using thermocouples embedded in the middle of the asphalt layer during construction. Cores were taken from the asphalt pavement after each lift was placed and used to develop the relationship between resilient modulus and temperature. Using this relationship, the resilient modulus of the asphalt at these two temperatures is 1,160 MPa (168,000 psi) and 10,900 MPa (1,580,000 psi), respectively. When the temperature is higher, the asphalt below the concrete provides less support. The overlay must then bear a larger portion of the load, resulting in higher stresses. The relationship between changes in strain with changes in resilient modulus was characterized for the 76-mm (3-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) by applying a 40 kN (9 kip) falling weight deflectometer load in the outer wheelpath adjacent to the transverse joint when the asphalt was at different temperatures. The strains were measured at the bottom of the concrete overlay and 25 mm (1 in) from the top of the concrete. The results are provided in figure 5. Figure 5 shows strain increases significantly when the resilient modulus is below 3,000 MPa (435,000 psi). The strain is close to zero when the resilient modulus is around 4,000 MPa (580,000 psi), and the entire concrete overlay is in compression when the resilient modulus is above 4,000 MPa (580,000 psi). The resilient modulus is 4,000 MPa (580,000 psi) when the asphalt temperature is 6°C (43°F) and 3,000 MPa (435,000 psi) when temperature is 11°C (51°F). The average monthly temperature is greater than 6°C (43°F) for seven months of the year in Minnesota and greater than 11°C (51°F) for five months of the year. Therefore, compressive stresses will be generated at the bottom of the overlay under an applied load the majority of the time for four months of the year. The bottom of the overlay will be in tension under an applied load the majority of the time for five months of the year. Figure 5 illustrates the importance of considering seasonal affects when determining the design life of ultra-thin whitetopping.

Over time, the combined stiffness of the overlay and the asphalt cross-section can decrease. There are three means by which the stiffness of this monolithic section can be reduced; the overlay debonds at the interface between the asphalt and concrete, delamination occurs between lifts within the asphalt, or the asphalt ravel. This also leads to less support from the underlying pavement, higher stresses in the overlay and potentially cracking. The mode of deterioration will dictate the depth of repair required if cracking does occur. These three modes of deterioration are shown in figure 6. Figure 6 shows the bottom portion of a panel from an ultra-thin whitetopping after it had been removed with a backhoe. The photo was from a section of ultra-thin whitetopping being repaired on U.S. 169, near Mankato, Minnesota in October 1998.
REPAIRING ULTRA-THIN WHITOPPING

Repairs were made on three of the six Mn/ROAD test sections on June 20, 2001 after over 4.7 million ESALs had been accumulated. The repairs were made to thirteen different areas in the ultra-thin whitetopping test sections. In the section with a 76-mm (3-in) overlay and 1.5-m by 1.8-m (5-ft by 5-ft) joint spacing, four panels were repaired (two locations). Eighteen panels were repaired (six locations) in the section with a 76-mm (3-in) overlay and 1.2-m by 1.2-m (4-ft by 4-ft) joint spacing. Nineteen panels were repaired (five locations) in the section with a 102-mm (4-in) overlay and 1.2-m by 1.2-m (4-ft by 4-ft) panels.

Saw cuts were made parallel to the joints at a distance of 150 mm (6 in) inside the perimeter of the repair area. The sawing was performed to protect the bond between the concrete overlay and the underlying asphalt in adjacent panels during the milling process. The concern was that the milling machine would pull up the surrounding panels and damage the bond between the concrete and asphalt. No cuts were made along the shoulders. A chop saw and a walk-behind saw were used to make the cuts to the depth of the overlay. It took approximately 2 hours to complete this portion of the sawing. These saw cuts were later found to be unnecessary because the milling did not disturb the adjacent panels when the milling machine was kept 150 mm (6 in) from the edge of the panel.

Two Caterpillar PR-105 milling machines with 36-cm (14-in) milling heads and tungsten carbide teeth were used to remove the concrete from the center of the repair areas (within the saw cuts made 150 mm (6 in) from the edge of the panel). The distressed areas were milled 25 mm (1 in) below the depth of the overlay into the asphalt. However, some of the repair areas were milled too shallow because the milling operators did not always increase the milling depth after milling the 76-mm (3-in) overlay and before milling the 102-mm (4-in) overlay. This resulted in having some of the repair areas in the 102-mm (4-in) overlay being milled only to the interface between the asphalt and concrete instead of 25 mm (1 in) into the asphalt. The asphalt at the interface was sometimes raveled so additional milling was necessary to expose a solid asphalt surface for bonding to the repair. Several areas needed to be milled twice because there was still some raveling in the asphalt at 25 mm (1 in) below the overlay. Raveling beneath the overlay tended to be more extensive when reflective cracking was present and water could be pumped up from the subgrade. Re-milling these repair areas led to further difficulties. The milling machine had to drive through the repair area while milling resulting in an unevenly milled asphalt surface with ridges in several of the repairs. The ridges were removed with chisel-hammers to reduce any stress concentrations that could develop and to allow for more uniform thermal movements in the concrete overlay.

A core was pulled from the most severely distressed panel prior to milling so the appropriate milling depth could be estimated based on the integrity of the asphalt beneath the distressed panel. An appropriate depth for milling was determined to be 25 mm (1 in) into the asphalt layer based on the integrity of the asphalt at various depths below the overlay. A total of 49 m² (525 ft²) of pavement was milled. The milling process took approximately 2.5 hours to complete. This time would have been reduced to 1.5 hours if all of the repairs were milled to the correct depth on the first pass.

The 150-mm (6-in) wide concrete border adjacent to the joints that remained after milling was removed using thirty-pound chisel-hammers. It was important to use
lightweight hammers to prevent spalling damage to surrounding panels. Cleaning and preparation of the repair areas was accomplished in three steps. The majority of the material was first removed with a skid loader. Afterwards, a vacuum truck was used to remove most of the remaining debris. Finally compressed air was used to thoroughly clean the surface. Removing the 150-mm (6-in) concrete border adjacent to the joints and cleaning the repair areas took approximately 45 person-hours, or an average 40 minutes per repair for a five person work crew.

Repairing areas with corner breaks and transverse cracking consisted of removing the distressed panels using a milling machine and chisel-hammers, as described above, and placing concrete back into the repair area. Repairing panels with reflective cracks presented additional difficulties. Several techniques were implemented to deter the reoccurrence of reflective cracking. The first approach was placing a bond-breaking material over the cracks in the asphalt to prevent cracks from reflecting up into the repaired panel. Two different types of de-bonding materials were tested; duct tape and roofing paper.

Several repairs contained reflective cracks in the overlay that were near the sawed transverse joint. After milling, it was revealed that a crack would still propagate down from the joint into the asphalt even when a full-depth transverse reflective crack is near the joint. The reflective crack tended to be the working crack so the new joint sawed in each repair was sawed over the reflective crack. Small strips of roofing paper were placed over these cracks and stapled to the asphalt as a bond-breaker. This was necessary to prevent reflective cracking in the areas where the meander of the crack would not follow the straight joint sawed into the repair. Roofing paper was used in lieu of duct tape if the cracks tended to meander significantly because pieces of the roofing paper could be tailored to fit the shape of the crack. Duct tape was placed as a bond-breaker over the straight cracks in the asphalt that propagated down from the joints sawed into the overlay during initial construction. The duct tape was also stapled to the asphalt to prevent it from moving while the concrete was being placed. See figure 9.b.

The repair areas were filled with concrete after being cleaned. Two different high-early-strength concrete mixtures were used, one with polyolefin fibers and one without fibers. The repair surface was sprinkled with water just prior to placing the concrete. Curing compound was sprayed on the surface immediately after the concrete was placed and finished. Wet burlene was used to cover the repairs after the concrete had gained sufficient strength to resist scaring on the surface. Approximately three hours after placing the concrete, the joints were sawed 3 mm (0.125 in) wide and to a depth of 38 mm (1.5 in) to 51 mm (2 in) with a walk-behind saw. In locations where the transverse joints were sawed to match existing cracks, the transverse joints did not always line-up in the adjacent panels. The longitudinal joints were sawed to the depth of the overlay between and on both sides of the misaligned transverse joints to ensure the two panels did not bond together; otherwise, the cracks could potentially develop from the misaligned transverse joints into the adjacent panels. See figure 7.b. Compressed air was used to clean debris from the joints after the sawing process was completed and the burlene was re-wetted and placed back over the repairs. Sawing and cleaning the joints and reapplying the wet burlene took approximately 6 person-hours. The joints were cleaned the following morning with a sand blaster and compressed air just prior to sealing. All joints were sealed with a low-modulus asphalt sealant. Figure 8 and 9 are
examples of typical repairs performed on the ultra-thin whitetopping sections at Mn/ROAD.

**RIDE QUALITY**

The initial ride (immediately after construction) of both the thin and ultra-thin test sections constructed at Mn/ROAD was excellent. A summary of the International Roughness Index (IRI) and the corresponding present serviceability index (PSI) is provided in table 3. As expected, based on the distress data summarized earlier, the thin whitetopping sections maintained a high IRI and PSI. The PSI measured for the ultra-thin whitetopping sections just prior to the repairs had dropped significantly from the PSI obtained immediately after initial construction. The only exception was the 76-mm (3-in) overlay with 1.5-m x 1.8-m (5-ft x 6-ft) panels, which maintained a PSI above 3.5. The PSI even dropped below the terminal serviceability (PSI=2.5) for the 76-mm (4-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels. The PSI was successfully brought back up to an acceptable level (PSI = 3.12) when the repairs were performed. The concrete was finished high when the repairs were performed, which resulted in a slightly higher IRI (and PSI) then desired. The IRI was still sufficiently low and diamond grinding of the repair areas was deemed unnecessary.

**CONCLUSIONS**

After 4.7 million ESALs, the thin [150 mm (6 in)] whitetopping test sections at Mn/ROAD have not exhibited any distress. Cracking has occurred in the ultra-thin whitetopping test sections. The majority of the cracking was in the driving lane. The two types of distresses observed in the ultra-thin whitetopping are transverse cracks and corner breaks. Reflection cracks also developed from temperature cracks in the underlying asphalt layer. The distress data for the three ultra-thin designs shows that using a joint layout that keeps the longitudinal joints outside of the wheelpaths will increase performance. The finite element program ISLAB2000 was used to show there is not a significant increase in stress generated by a temperature gradient when comparing a 76-mm (3-in) bonded overlay with 1.5-m x 1.8-m (5-ft x 6-ft) panels and a 76-mm (3-in) bonded overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels. A comparison of the distress data collected for the ultra-thin test sections shows a similar performance was obtained between the 76-mm (3-in) overlay with 1.5-m x 1.8-m (5-ft x 6-ft) panels and the 102-mm (4-in) overlay with 1.2-m x 1.2-m (4-ft x 4-ft) panels. This indicates that the thickness of the overlay can be reduced by 25 mm (1 in) if 11.5-m x 1.8-m (5-ft x 6-ft) panels are used in place of 1.2-m x 1.2-m (4-ft x 4-ft) panels because the joints are then located outside of the wheelpath. Other important considerations to the performance of ultra-thin whitetopping are the quality of the asphalt beneath the overlay and the asphalt temperature and stiffness. Both of these factors have a significant effect on the magnitude of the stresses generated in the pavement structure.

This paper presented various techniques for repairing ultra-thin whitetopping. It was determined that using a milling machine with tungsten carbide teeth to remove the concrete greatly reduced the time required per repair. The milling process exposed fractured aggregate particles in the asphalt and a ridged macro-texture surface that promotes good bonding between the asphalt surface and the repair. Various techniques were also used to deter reflective cracking. This included the use of various bond-
breaking materials and full-depth sawing at strategic locations along the longitudinal joint, preventing cracks from propagating into adjacent panels at misaligned transverse joints.

The IRI and PSI of both the thin and ultra-thin whitetopping sections were excellent immediately after initial construction. A drop had occurred in the IRI for the ultra-thin whitetopping sections with 1.2-m x 1.2-m (4-ft x 4-ft) panels, and one section was below the acceptable level. The repairs made in this section have brought the IRI back up to an acceptable level. Four of the six sections had PSIs greater than 3.5 before the repairs showing a good level of performance has been maintained after 4.7 million ESALS.

The thin and ultra-thin whitetopping test sections at Mn/ROAD revealed whitetopping is a viable rehabilitation alternative for asphalt pavements. The importance of choosing an optimum panel size has been shown. It has also been shown that, when necessary, it is easy to repair ultra-thin whitetopping sections and various techniques for repairing each type of distress have been summarized.

ACKNOWLEDGMENTS

The authors would like to gratefully acknowledge the Federal Highway Administration and the Minnesota Local Road Research Board for their financial support in conducting this research. The authors would also like to thank Mr. Jack Herndon and the personnel at the Mn/ROAD research Facility, the St. Cloud District 3B Bridge crew for performing the repairs and their colleagues in the Minnesota Department of Transportation Research Office for their assistance during the construction of the test sections and with data collection.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or policies of the Minnesota Department of Transportation. This report does not constitute a standard, specifications or regulations.

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TABLE 1  Description of Whitetopping Test Sections at Mn/ROAD.

<table>
<thead>
<tr>
<th>Cell</th>
<th>Overlay Thickness mm</th>
<th>Joint Spacing m</th>
<th>Dowel Diameter mm</th>
<th>Fiber Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>93</td>
<td>102</td>
<td>1.2 x 1.2</td>
<td>none</td>
<td>Polypropylene</td>
</tr>
<tr>
<td>94</td>
<td>76</td>
<td>1.2 x 1.2</td>
<td>none</td>
<td>Polypropylene</td>
</tr>
<tr>
<td>95</td>
<td>76</td>
<td>1.5 x 1.8</td>
<td>none</td>
<td>Polyolefin</td>
</tr>
<tr>
<td>96</td>
<td>152</td>
<td>1.5 x 1.8</td>
<td>none</td>
<td>Polypropylene</td>
</tr>
<tr>
<td>97</td>
<td>152</td>
<td>3.1 x 3.7</td>
<td>none</td>
<td>Polypropylene</td>
</tr>
<tr>
<td>92</td>
<td>152</td>
<td>3.1 x 3.7</td>
<td>25</td>
<td>Polypropylene</td>
</tr>
</tbody>
</table>

1 in = 25.4 mm
1 meter = 3.28 feet
TABLE 2 ISLAB2000 Results of Stresses Generated by Linear Temperature Gradients in the 76-mm UTW at Mn/ROAD.

<table>
<thead>
<tr>
<th>Cell</th>
<th>Panel Size</th>
<th>Maximum Tensile Stress, MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>+0.66 °C / cm</td>
</tr>
<tr>
<td>94</td>
<td>1.2 m x 1.2 m</td>
<td>0.505</td>
</tr>
<tr>
<td>95</td>
<td>1.5 m x 1.8 m</td>
<td>0.507</td>
</tr>
</tbody>
</table>

°F = °C *(9/5) + 32
MPa = 145 psi
1 in = 2.54 cm
TABLE 3  Roughness Measurements and Present Serviceability Indices Before and After Repairs.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right Wheelpath</td>
<td>Left Wheelpath</td>
<td>Right Wheelpath</td>
</tr>
<tr>
<td></td>
<td>PSI</td>
<td>IRI m/km</td>
<td>PSI</td>
</tr>
<tr>
<td>92</td>
<td>3.89</td>
<td>0.95</td>
<td>3.63</td>
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<tr>
<td>97</td>
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<td>0.74</td>
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<tr>
<td>95</td>
<td>4.14</td>
<td>0.79</td>
<td>4.12</td>
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<tr>
<td>94</td>
<td>4.24</td>
<td>0.72</td>
<td>2.25</td>
</tr>
<tr>
<td>93</td>
<td>4.30</td>
<td>0.69</td>
<td>3.45</td>
</tr>
</tbody>
</table>

1 m = 3.28 ft
1 km = 0.62 mi
FIGURE 1  Distresses occurring on a (a.) 102-mm overlay with 1.22-m by 1.22-m panels; (b.) 76-mm overlay with 1.22-m by 1.22-m panels; (c.) 76-mm overlay with 1.52-m by 1.83-m panels.
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