Paper No. 02-4032

Performance, Analysis, and Repair of Ultrathin and Thin Whitetopping at Minnesota Road Research Facility

Julie M. Vandenbossche and Aaron J. Fagerness

Thin and ultrathin 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 ultrathin whitetopping test cells at the Minnesota Road Research (Mn/ROAD) facility. 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 ultrathin whitetopping were investigated. Various techniques were also used to deter reflective cracking, including 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 present serviceability indexes (PSIs) greater than 3.5 before the repairs, showing that a good level of performance has been maintained after 4.7 million equivalent single-axle loads. The two sections that exhibited the largest drop in PSI were the overlays with 1.2- × 1.2-m (4- × 4-ft) panels. The repairs made in sections containing these panels have brought the PSI back up to an acceptable level (PSI > 3). The thin and ultrathin 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 ultrathin whitetopping sections. Various techniques for repairing each type of distress have been summarized.

Ultrathin and thin whitetopping overlays are becoming a more widely accepted rehabilitation alternative in the United States. Ultrathin 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 by using short joint spacings to reduce curling and warping stresses and bending stresses produced by applied loads (*1–3*). 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 ultrathin whitetopping although a well-documented study was performed on the repair of an ultrathin whitetopping subjected to accelerated-load testing at the FHWA Turner-Fairbank Highway Research Center (*4*).

Minnesota Department of Transportation, 1400 Gervais Avenue, MS 645, Maplewood, MN 55109.

This study identifies typical distresses resulting from live Interstate traffic loads in pavements with different ultrathin whitetopping designs and the methods developed to repair each type of distress. In October 1997, the Minnesota Department of Transportation (Mn/DOT) constructed several ultrathin 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 (*5*). This application is not typical for ultrathin 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 thicknesses were included in the study [76, 102, and 152 mm (3, 4, and 6 in.)] along with three different joint layouts [1.2 × 1.2 m, 1.5 × 1.8 m, and 3.1 × 3.7 m (4 × 4 ft, 5 × 6 ft, and 10 × 12 ft)]. The 152-mm (6-in.) overlay test sections were 53 m (175 ft) long, and all other test sections were 91 m (300 ft) long. All test sections contained polypropylene fibers except for the 76-mm (3-in.) overlay with 1.5- × 1.8-m (5- × 6-ft) panels, which contained polyolefin fibers. All test sections were undoweled except for one of the 152-mm (6-in.) overlays with 3.1- × 3.7-m (10- × 12-ft) panels. A summary of each test section has been provided in Table 1.

DESCRIPTION OF DISTRESSES

A distress survey was performed on the asphalt pavement just before the construction of the whitetopping and has been performed approximately four times a year since the construction. Corner breaks and transverse cracks are the two types of distresses that commonly occur in ultrathin whitetopping. After 3.5 years and over 4.7 million equivalent single-axle loads (ESALs), both temperature- and load-related distresses were observed in the 76- and 102-mm (3- and 4-in.) overlays, whereas no cracking 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% of the traffic (3.7 million ESALs). A summary of the distresses in each test section is provided in Figure 1. 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 percentage of panels that exhibited cracking. As previously mentioned, no cracking has been observed in the 152-mm overlays to date, so distress summary graphs are only provided for the 76- and 102-mm overlays.

TABLE 1 Whitetopping Test Sections at Mn/ROAD

Cell	Overlay Thickness mm	Joint Spacing m	Dowel Diameter mm	Fiber Type
93	102	1.2 x 1.2	none	Polypropylene
94	76	1.2 x 1.2	none	Polypropylene
95	76	1.5 x 1.8	none	Polyolefin
96	152	1.5 x 1.8	none	Polypropylene
97	152	3.1 x 3.7	none	Polypropylene
92	152	3.1 x 3.7	25	Polypropylene

Overlay of 102 mm with 1.2- × 1.2-m Panels

Figure 1*a* summarizes the distress data for the 102-mm (4-in.) overlay with 1.2- × 1.2-m (4- × 4-ft) panels. Since the time of construction, 7% of the panels have exhibited cracking: 34% of the observed distresses are corner breaks, and the remaining 66% are transverse cracks. Most of the corner breaks occurred along the inside longitudinal joint because of its location directly in the inside wheelpath (see Figure 2*c*). Transverse cracks often occur in the outside wheelpath near a transverse joint (Figure 2*a*). At times, these transverse cracks were intercepted by corner breaks that initiated at the intersection of the wheelpath and the transverse joint (Figure 2*b*). Of the cracking in this section, 73% occurred in the driving lane.

Preexisting transverse cracks in the asphalt were surveyed before 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 preexisting cracks that reflected through the overlay: 19% of the transverse cracks in this test section are reflective. The reflective 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 before 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 existing temperature cracks in the asphalt.

The present serviceability index (PSI) for the 102-mm (4-in.) overlay with 1.2- × 1.2-m (4- × 4-ft) panels was above 2.25 just before 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 concrete pavement had high-severity cracking. The roughness of these panels had a significant effect on the calculated international roughness index (IRI) and therefore on the PSI since the test section is short [less than 60 m (200 ft)]. Past experience has shown that increasing the overlay thickness to at least 152 mm (6 in.) at the beginning and end of the ultrathin whitetopping (the first and last row of panels) will reduce cracking in the panels at the point that traffic is coming on and going off the overlay.

Overlay of 76 mm with 1.2- × 1.2-m Panels

Figure 1*b* summarizes the distress data for the 76-mm (3-in.) overlay with 1.2- × 1.2-m (4- × 4-ft) panels. This test section developed a greater number of corner breaks and transverse cracks than the other sections, with 30% of the panels exhibiting distress after 4.7 million ESALs: 83% of the distressed panels are located in the driving lane, 87% of the observed distresses are corner breaks, and the remaining 13% are transverse cracks; 47% of the transverse cracks are reflective. This test section developed the same cracking pattern as the 102-mm (4-in.) overlay with 1.2- × 1.2-m panels because the joint layout was the same. Adding 25 mm (1 in.) to the thickness of the 102-mm (4-in.) overlay significantly reduced the percentage of distressed panels compared with the 76-mm (3-in.) overlay.

Overlay of 76 mm with 1.5- × 1.8-m Panels

Figure 1*c* summarizes the distress for the 76-mm (3-in.) overlay with 1.5- × 1.8-m (5- × 6-ft) panels. The performance of this test section to date has been comparable with that of the 102-mm (4-in.) overlay with 1.2- × 1.2-m (4- × 4-ft) panels, which is significantly better than the other 76-mm (3-in.) overlay with 1.2- × 1.2-m panels. Only 8% of the panels in the 76-mm overlay have developed cracks, of which

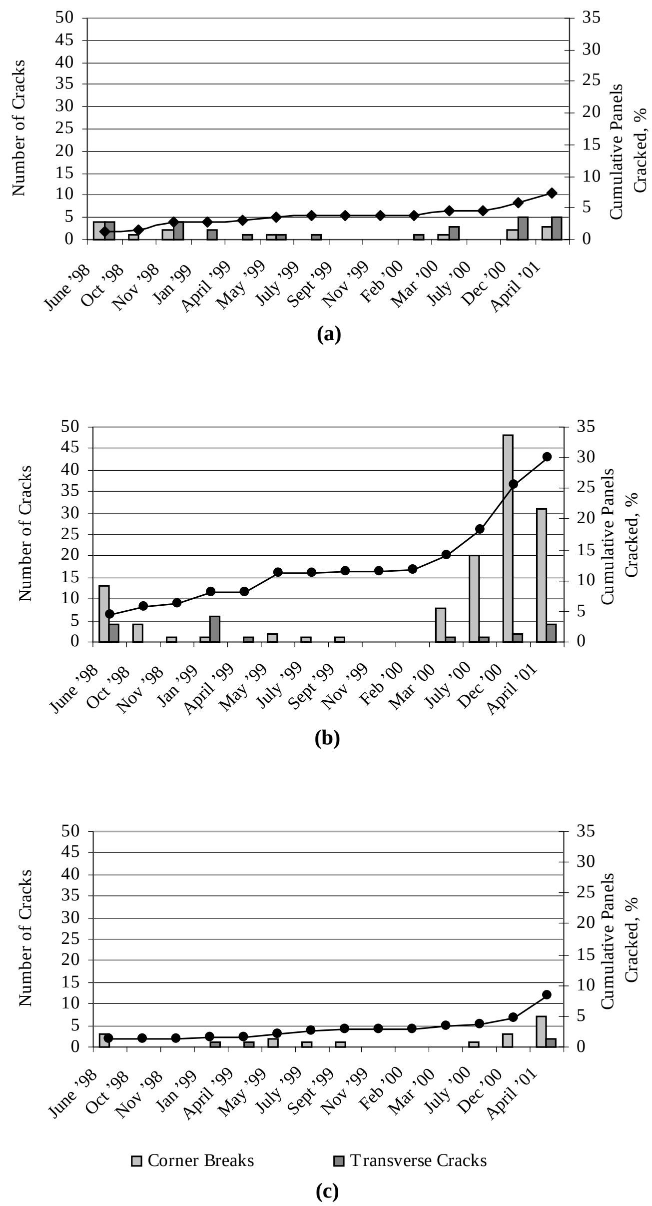
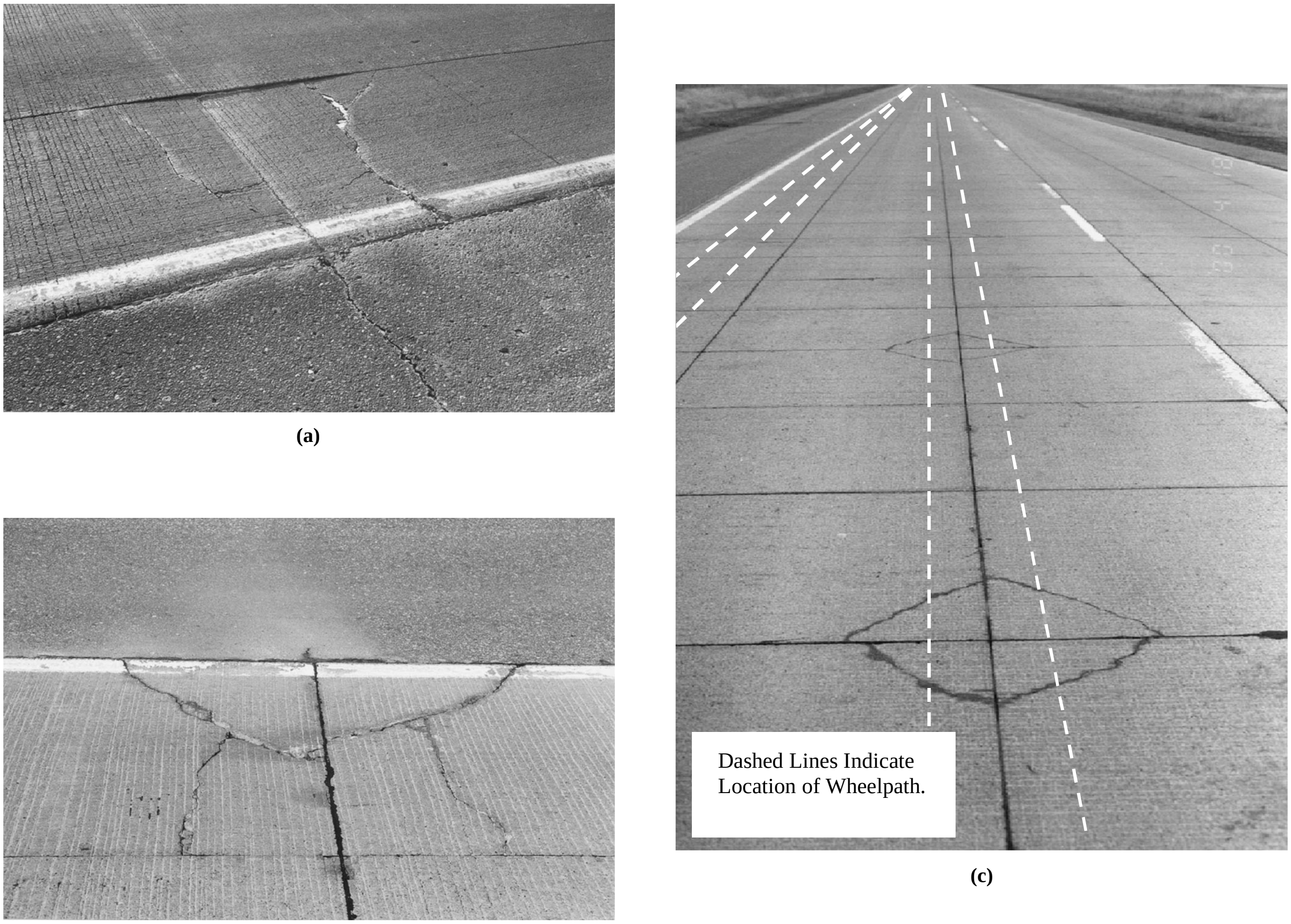


FIGURE 1 Distresses occurring on (*a*) 102-mm overlay with 1.2- × 1.2-m panels, (*b*) 76-mm overlay with 1.2- × 1.2-m panels, and (*c*) 76-mm overlay with 1.5- × 1.8-m panels.



(a)

(b)

(c)

FIGURE 2 Ultrathin whitetopping with 1.2- × 1.2-m panels: (*a*) load-related transverse cracks, (*b*) load-related corner breaks and transverse cracks, and (*c*) corner cracks in wheelpath.

75% are located in the driving lane; 82% of the observed distresses are corner breaks and the remaining 18% are transverse cracks. All of the corner breaks are located in the outside panels. The corner cracks tended to initiate where the wheelpath intersects the transverse joint, as was observed for the overlays with the 1.2- × 1.2-m joint layout. All of the transverse cracks in this test section were reflective cracks. The 76-mm overlay with 1.5- × 1.8-m panels is performing well, with a PSI above 3.68 before the repairs were completed.

The 76-mm overlay with 1.5- × 1.8-m 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 do.

FACTORS AFFECTING PERFORMANCE

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

Reducing the panel size will reduce the curling and warping and load-related flexural stress. The finite element program ISLAB2000 was used to model two panel sizes, 1.2- × 1.2-m and 1.5- × 1.8-m, 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 is summarized in Table 2. The maximum tensile stress generated in

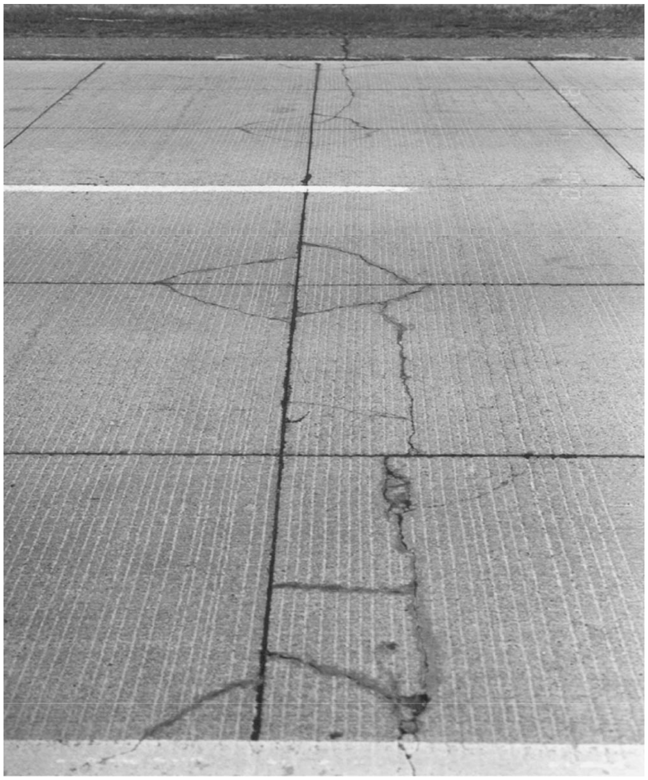


FIGURE 3 Reflective cracking in ultrathin whitetopping.

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 would reduce the curling and warping and flexural stress although the combined temperature- and load-related stress could still be higher in the smaller panels if the longitudinal joint lies in the wheelpath and corner or edge loadings result.

ISLAB2000 was also used to model the Mn/ROAD test section containing a 76-mm (3-in.) overlay with 1.2- × 1.2-m (4- × 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 plot indicates that 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 emphasize the need to consider the location of the wheelpath with respect to the longitudinal joints when the optimum panel size is determined. Although a 0.6- × 0.6-m (2- × 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 × 0.9 m (3 × 3 ft).

TABLE 2 ISLAB2000 Results of Stresses Generated by Linear Temperature Gradients in 76-mm Ultrathin Whitetopping at Mn/ROAD

Cell	Panel Size	Maximum Tensile Stress, MPa		
		+0.66 °C / cm	+0.22 °C / cm	-0.33 °C / cm
94	1.2 m x 1.2 m	0.505	0.168	0.318
95	1.5 m x 1.8 m	0.507	0.169	0.308

Many of the transverse cracks appearing in the overlays are a result of previously existing temperature cracks in the asphalt that reflect 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 reflective cracking: 32% of the preexisting cracks in the asphalt propagated up through the overlay in the 76-mm section with 1.5- × 1.8-m (5- × 6-ft) panels. In the 76-mm section with 1.2- × 1.2-m (4- × 4-ft) panels, 56% of the preexisting cracks reflected through the overlay. In the 102-mm (4-in.) overlay with 1.2- × 1.2-m panels, 50% of the cracks reflected up through the concrete. 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 that the volume of traffic accumulated affects the development of reflective cracks.

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 overlay with 1.2- × 1.2-m panel spacing) experienced the highest percentage of cracks reflecting through the overlay, whereas no cracking occurred in the 152-mm (6-in.) overlays. The 102-mm (4-in.) overlay with the same panel size (1.2 × 1.2 m) had a slightly lower percentage, but this difference might not be statistically significant. The 76-mm section with larger panels (1.5 × 1.8 m) had the lowest percentage of thermal cracks propagating through the overlay among the three ultrathin test sections. As previously discussed, the load-related stress is higher in the ultrathin overlays with 1.2- × 1.2-m 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 the quality of the bond between the concrete overlay and the asphalt also have 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 moduli of the asphalt at these two temperatures are 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 overlay with 1.2- × 1.2-m panels 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, which shows that 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

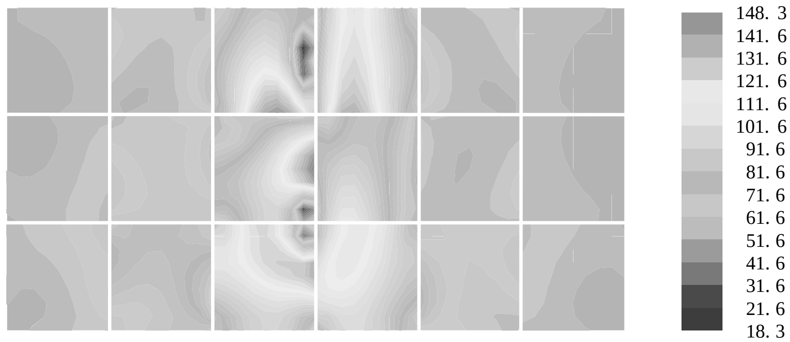


FIGURE 4 Theoretical stresses due to 102-kN axle load and 0.44°C/cm temperature gradient (76-mm overlay with 1.2- × 1.2-m joint spacing).

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 the temperature is 11°C (51°F). The average monthly temperature is greater than 6°C (43°F) for 7 months of the year in Minnesota and greater than 11°C (51°F) for 5 months of the year (*6*). Therefore, compressive stresses will be generated at the bottom of the overlay under an applied load the majority of the time for 4 months of the year. The bottom of the overlay will be in tension under an applied load the majority of the time for 5 months of the year. The data in Figure 5 demonstrate the importance of considering seasonal effects when the design life of ultrathin whitetopping is determined.

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 ravels. This decrease in stiffness 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, in which the bottom portion of a panel from an ultrathin whitetopping section is shown after it had been removed with a backhoe. The photograph was from a section of ultrathin whitetopping being repaired on US-169 near Mankato, Minnesota, in October 1998.

REPAIRING ULTRATHIN WHITETOPPING

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 13 different areas in the ultrathin whitetopping test sections. In the section with a 76-mm (3-in.) overlay and 1.5- × 1.8-m (5- × 5-ft) joint spacing, four panels were repaired (two locations). Eighteen panels were repaired (six locations) in the section with a 76-mm overlay and 1.2- × 1.2-m (4- × 4-ft) joint spacing. Nineteen panels were repaired (five locations) in the section with a 102-mm (4-in.) overlay and 1.2- × 1.2-m panels.

Saw cuts were made parallel to the joints 150 mm (6 in.) inside the perimeter of the repair area 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 h 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 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 from the edge of the panel). The distressed areas were milled

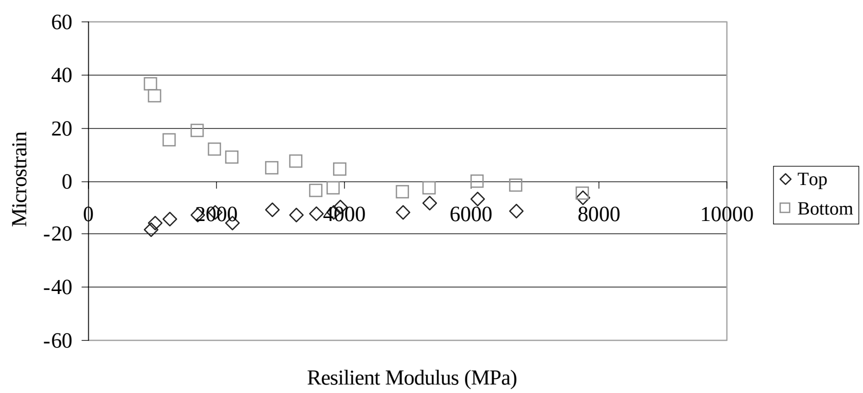


FIGURE 5 Strain directly under 40-kN falling-weight deflectometer load applied in wheelpath adjacent to transverse joint on 76-mm overlay with 1.5- × 1.8-m panels.

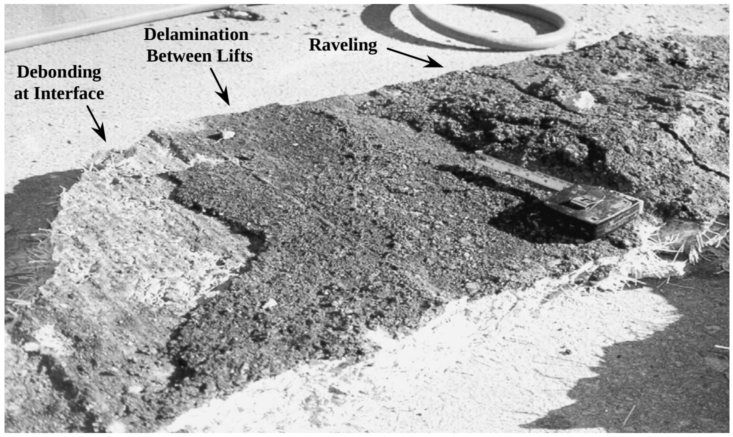


FIGURE 6 Three different modes of debonding between asphalt and concrete overlay.

25 mm (1 in.) below the depth of the overlay into the asphalt. However, some of the repair areas were 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 oversight resulted in the milling of some of the repair areas in the 102-mm overlay only to the interface between the asphalt and concrete instead of 25 mm 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 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. Remilling these repair areas led to further difficulties. The milling machine had to be driven through the repair area during the 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 before milling so that the appropriate milling depth could be estimated on the basis of the integrity of the asphalt beneath the distressed panel. On this basis, an appropriate depth for milling was determined to be 25 mm (1 in.) into the asphalt layer. A total of 49 m^2 (525 ft^2) of pavement was milled. The milling process took approximately 2.5 h to complete, which would have been reduced to 1.5 h if all of the repairs had been 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 30-lb chisel-hammers. It was important to use lightweight hammers to prevent spalling damage to surrounding panels. Cleaning and preparation of the repair areas were accomplished in three steps. The majority of the material was first removed with a skid loader. Then 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 concrete border adjacent to the joints and cleaning the repair areas took approximately 45 person-h, or an average 40 min 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 to place a bond-breaking material over the cracks in the asphalt to prevent cracks from reflecting up into the repaired panel. Two different types of debonding 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 was near the joint. The reflective crack tended to be the working crack, so the new joint made 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 treatment 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 the pieces of 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.

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 before placement of 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 3 h after the concrete was placed, 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 that the two panels did not bond together; otherwise, cracks could potentially develop from the misaligned transverse joints into the adjacent panels. Compressed air was used to clean debris from the joints after the sawing process was completed and the burlene was rewetted and placed back over the

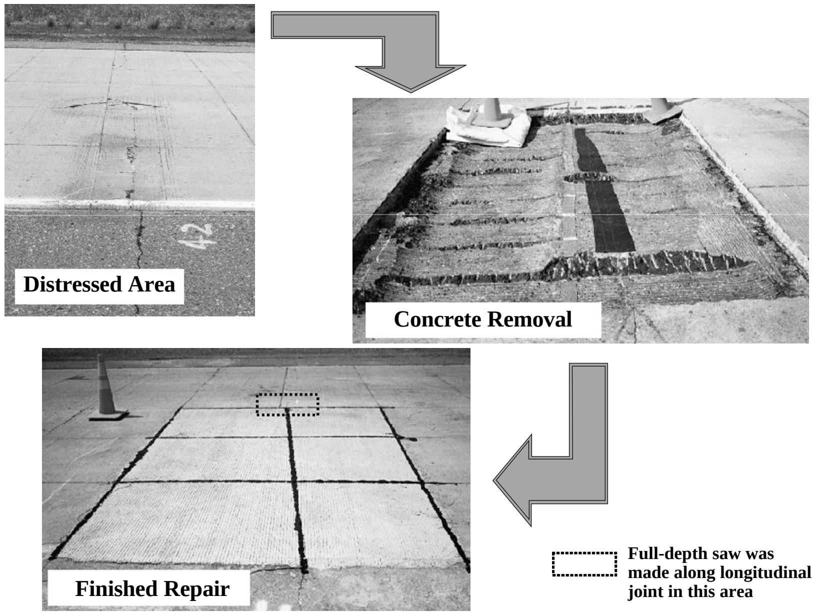


FIGURE 7 Repairing reflective cracks in ultrathin whitetopping.

repairs. Sawing and cleaning the joints and reapplying the wet burlene took approximately 6 person-h. The joints were cleaned the following morning with a sand blaster and compressed air just before sealing. All joints were sealed with a low-modulus asphalt sealant.

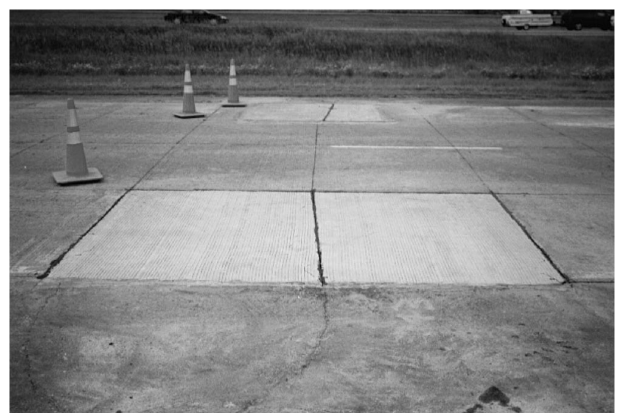
Figures 7 and 8 show examples of typical repairs performed on the ultrathin whitetopping sections at Mn/ROAD.

RIDE QUALITY

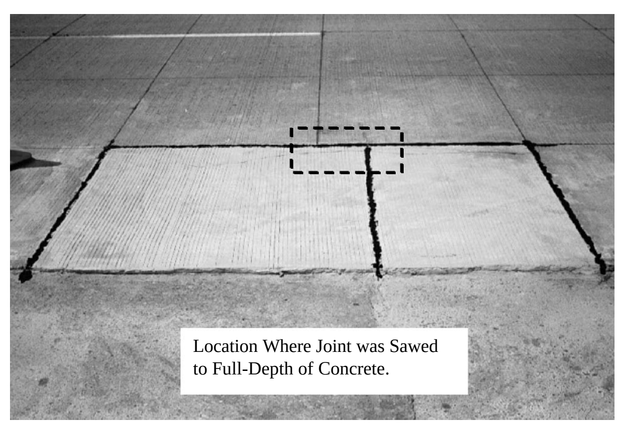
The initial ride (immediately after construction) on both the thin and ultrathin test sections constructed at Mn/ROAD was excellent. A summary of the IRIs and the corresponding PSIs is provided in Table 3. As expected, from the distress data summarized earlier, the thin whitetopping sections maintained a high IRI and PSI. The PSI measured for the ultrathin whitetopping sections just before the repairs had dropped significantly from that obtained immediately after initial construction. The only exception was the 76-mm (3-in.) overlay with 1.5- × 1.8-m (5- × 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 overlay with 1.2- × 1.2-m (4- × 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) than 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 ultrathin whitetopping test sections. The majority of the cracking was in the driving lane. The two types of distresses observed in the ultrathin whitetopping are transverse cracks and corner breaks. Reflection cracks also developed from temperature cracks



(a)



(b)

FIGURE 8 Repairs on Mn/ROAD: (*a*) joint sawed directly over existing crack in asphalt and (*b*) longitudinal joint sawed to depth of overlay to prevent cracking.

TABLE 3 Roughness Measurements and PSIs Before and After Repairs

Cell	After Initial Construction (11/1997)		Before Repair (5/15/2001)				After Repair (7/9/2001)			
	Right Wheelpath		Left Wheelpath		Right Wheelpath		Left Wheelpath		Right Wheelpath	
	PSI	IRI m/km	PSI	IRI m/km	PSI	IRI m/km	PSI	IRI m/km	PSI	IRI m/km
92	3.89	0.95	3.63	1.14	3.58	1.18	N/A	N/A	N/A	N/A
97	4.21	0.74	3.94	0.92	3.85	0.98	N/A	N/A	N/A	N/A
96	4.41	0.63	3.89	0.95	3.58	1.18	N/A	N/A	N/A	N/A
95	4.14	0.79	4.12	0.80	3.68	1.10	4.18	0.76	3.51	1.23
94	4.24	0.72	2.25	2.43	3.49	1.25	2.94	1.72	3.03	1.64
93	4.30	0.69	3.45	1.28	2.25	2.43	3.53	1.22	3.12	1.56

in the underlying asphalt layer. The distress data for the three ultrathin designs show that using a joint layout that keeps the longitudinal joints outside of the wheelpath will increase performance. The finite element program ISLAB2000 was used to show that there is no significant increase in stress generated by a temperature gradient when a 76-mm (3-in.) bonded overlay with 1.5- × 1.8-m (5- × 6-ft) panels is compared with a 76-mm bonded overlay with 1.2- × 1.2-m (4- × 4-ft) panels. A comparison of the distress data collected for the ultrathin test sections shows that similar performance was obtained between the 76-mm overlay with 1.5- × 1.8-m panels and the 102-mm (4-in.) overlay with 1.2- × 1.2-m panels. This finding indicates that the thickness of the overlay can be reduced by 25 mm (1 in.) if 1.5- × 1.8-m panels are used in place of 1.2- × 1.2-m panels because the joints are then located outside of the wheelpath. Other important considerations in the performance of ultrathin 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.

Various techniques for repairing ultrathin whitetopping were discussed. 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 macrotexture surface that promotes good bonding between the asphalt surface and the repair. Various techniques were also used to deter reflective cracking, including 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.

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

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

ACKNOWLEDGMENTS

The authors gratefully acknowledge the FHA and the Minnesota Local Road Research Board for their financial support in conducting this research. The authors also thank Jack Herndon and the personnel of 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.

REFERENCES

1. Mack, J. W., L. D. Hawbaker, and L. W. Cole. Ultrathin Whitetopping: State-of-the-Practice for Thin Concrete Overlays of Asphalt. In *Transportation Research Record 1610,* TRB, National Research Council, Washington, D.C., 1998, pp. 39–43.
2. Vandenbossche, J. M. The Measured Response of Ultrathin and Thin Whitetopping to Environmental Loads. Presented at the 7th International Conference on Concrete Pavements, Orlando, Fla., Sept. 2001.
3. Wu, C. L., S. M. Tarr, T. M. Refai, M. A. Nagi, and M. J. Sheehan. *Development of Ultrathin Whitetopping Design Procedure.* Research and Development Series No. 2124. Portland Cement Association, Skokie, Ill., 1998.
4. Construction Technology Laboratories, Inc. *UTW Pavement Repair Demonstration.* Innovative Pavement Research Foundation, Falls Church, Va., 2001.
5. Vandenbossche, J. M., and D. L. Rettner. *The Construction of US-169 and I-94 Experimental Whitetopping Test Sections in Minnesota.* Minnesota Department of Transportation, St. Paul, April 1998.
6. Microsoft Network: http://www.intellicast.com/weather/msp/climate.html. Accessed 1997.

Publication of this paper sponsored by Committee on Pavement Rehabilitation.