TOPS

Targeted Overlay Pavement Solutions

Ultra-Thin Bonded Wearing Course Case Study

March 2023

U.S. Department of Transportation
Federal Highway Administration

Every Day Counts
Innovation for a Nation on the Move

NOTICE

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16. Abstract: Ultra-thin bonded wearing course is a thin open-graded asphalt layer placed on a polymer-modified emulsion membrane. A specialized paver places the emulsified asphalt membrane and the poly-modified asphalt mixture on the surface in a single pass. It is used as a treatment method on asphalt pavements to correct surface distresses such as raveling or minor cracking or restore surface characteristics such as friction and smoothness.

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LIST OF ACRONYMS

- **AADT** Average daily traffic
- **AFT** Adjusted film thickness
- **ADA** Americans with Disabilities Act
- **BAB** Bituminous aggregate base
- **FHWA** Federal Highway Administration
- **HMA** Hot mix asphalt
- **JMF** Job mix formula
- **MnDOT** Minnesota Department of Transportation
- **MRI** Mean roughness index
- **OAC** Optimum asphalt content
- **PQI** Pavement quality index
- **RP** Reference post
- **RQI** Ride quality index
- **TRS** Transportation Research Synthesis
- **UTBWC** Ultra-thin bonded wearing course

ULTRA-THIN BONDING WEARING COURSE

This document is one of five case studies highlighting FHWA's Every Day Counts initiative known as [Targeted Overlay Pavement Solutions (TOPS)](). TOPS aims to integrate innovative overlay procedures into practices to improve performance, lessen traffic impacts, and reduce the cost of pavement ownership.

OVERVIEW

An ultra-thin bonded wearing course (UTBWC) is a thin asphalt overlay that uses a gap-graded aggregate and polymer-modified emulsified asphalt. An example of a freshly paved UTBWC section is shown in Figure 1.

Figure 1. Freshly paved UTBWC section. (Source: MnDOT)

UTBWC is a high-performance surface treatment and preservation tool that addresses mild to moderate distresses and surface deficiencies. Typical lift thickness ranges from 0.4 to 0.8 inches. UTBWC is used to restore ride quality while sealing and protecting the underlying pavement. The underlying pavement should be structurally sound and in "good" condition with only minor distresses. The polymer-modified membrane seals the existing pavement surface by providing high binder content at the interface of the existing pavement and the gap-graded hot mix asphalt (HMA) in one pass. The gap-graded HMA is made from high-quality aggregates. The open surface texture reduces splash and spray, allowing flow through the surface laterally (MnDOT, 2018). Various studies have also shown that this treatment increases surface friction (Estakhri and Button, 1993; FHWA, 2015). A UTBWC schematic is shown in Figure 2.

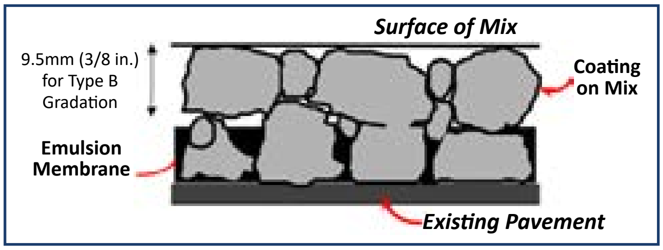

Figure 2. UTBWC schematic. (Source: MnDOT)

BACKGROUND

UTBWC was developed in France in 1986 and subsequently patented. Once the patent expired, several State transportation departments became interested and developed specifications to meet their own needs.

A Texas Department of Transportation UTBWC specification was evaluated in 1993, following its installation on US 281 and SH 46 in the San Antonio District. (Estakhri and Button, 1993). Early performance data showed that UTBWC significantly increased the skid resistance of the pavement. The US 281 ride quality was not changed considerably because it had a very good ride score before treatment, while the SH 46 ride quality was improved. Researchers noted that quality control procedures used for conventional HMA jobs may not be acceptable for UTBWC (Estakhri and Button, 1993).

UTBWC mixture performance is noticeably sensitive to changes in mixture proportions (Estakhri and Button, 1993). For this reason, specifications with performance-based criteria relating to workmanship quality may be appropriate (Estakhri and Button, 1993). After three years of service, the UTBWC pavement surface was in excellent condition. Between 1992 and 1995, more than one million square meters of UTBWC were placed in the northeastern United States (Estakhri and Button, 1993). UTBWC advantages compared to the control section surfaces are listed in Table 1.

Table 1. Potential UTBWC advantages compared to other surface treatments.
(Source: Estakhri and Button)

Surface Treatment	UTBWC
Chip Seal	• Provides excellent chip retention • Allows for reshaping of existing pavement, such as minor rut-filling • Smooths corrugations and other minor surface irregularities • Creates less tire and pavement noise • Suitable for use on high-traffic volume roads • Provides greater resistance to damage caused by braking and steering • Presents a higher probability of success in cool, wet weather
Microsurfacing	• Can be reopened to traffic quickly • May have better adhesion to the underlying surface due to heavy tack coat • Provides greater surface macrotexture • Improves surface drainage characteristics—reduced splash and spray due to open surface texture
Dense-Graded Thin Overlay	• May have better adhesion to the underlying surface due to heavy tack coat • Improves rut resistance due to high-quality crushed materials • Provides greater surface macrotexture • Improves surface drainage • Protects underlying pavement from surface water

MINNESOTA CASE STUDY

UTBWC was first introduced to Minnesota in 1999. A private company that acquired the patent promoted the idea of UTBWC in the United States and encouraged the Minnesota Department of Transportation (MnDOT) to place a trial section (MnDOT, 2022). UTBWC was developed as a preventive maintenance option to extend pavement life (MnDOT, 2018). A relatively thick polymer-modified emulsion membrane is sprayed onto the existing pavement surface. After that, it is immediately covered with a thin gap-graded HMA placed with a spray paver.

Figure 3. UTBWC paving. (Source: MnDOT)

A MnDOT Transportation Research Synthesis (TRS) conducted in 2018 and 2019 identified many UTBWC locations in Minnesota. UTBWC sections in metro and non-metro areas are highlighted in Figure 4.

UTBWC is one of 10 treatments in the MnDOT pavement preservation program. MnDOT's guidelines for selecting a pavement preservation treatment are based on factors such as pavement type, condition, traffic, and feasibility. The purpose of a pavement preservation program is to maintain or restore a pavement's surface characteristics to extend its service life, which minimizes network life cycle costs. According to MnDOT, pavement preservation treatments:

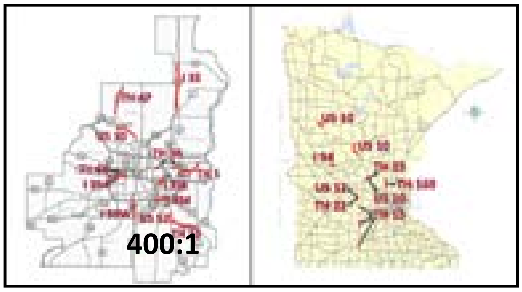

Figure 4. MnDOT UTBWC section in metro and non-metro areas. (Source: MnDOT)

- Keep good pavement in good condition when applied at the right time.
- Increase customer satisfaction due to smoother pavements and fewer construction delays.
- Reduce costs. They are less expensive than mill and overlay, which reduces overall life cycle costs.
- Increase safety due to the correction of safety-related distresses, including rutting, loss of friction, and poor surface drainage.

MnDOT's pavement management system includes decision trees in its Highway Performance Management Applications software to help choose preservation strategies (MnDOT, 2020). MnDOT's preservation manual does not list UTBWC in the decision tree. However, it identifies UTBWC as an alternative to seal coats, microsurfacing, and thin-lift overlays.

While UTBWC costs more than microsurfacing, seal coats, and thin-lift overlays, its performance period is expected to last 7 to 12 years (MnDOT, 2020). This is, on average, one-third more life than other treatments. According to MnDOT, the product performed well on many test sections requiring little to no intervention for up to 10 years in some cases (MnDOT, 2022). In 2020, MnDOT reviewed the cost to apply UTBWC on two projects—Highway 59 and Highway 19, spanning 17.8 miles in total. UTBWC construction costs were $4.55 per square yard for a pavement depth of three-fourths of an inch. This cost aligns with the $5.00 per square yard published in the MnDOT Pavement Preservation Manual.

MnDOT's pavement condition data encompasses three indices, ride quality index (RQI), surface rating, and pavement quality index (PQI) (MnDOT, 2011). This case study refers to RQI, a ride or smoothness index ranging from 0.0 to 5.0, where the higher value means smoother pavement. Most new construction projects have an initial RQI slightly over 4.0. Pavements are also typically designed for a "terminal" RQI value of 2.5. Major rehabilitation will be needed at 2.5 RQI (MnDOT, 2011). MnDOT categorizes RQI into several categories: 4.1 to 5.0 (Very Good), 3.1 to 4.0 (Good), 2.1 to 3.0 (Fair), 1.1 to 2.0 (Poor), and 0.0 to 1.0 (Very Poor).

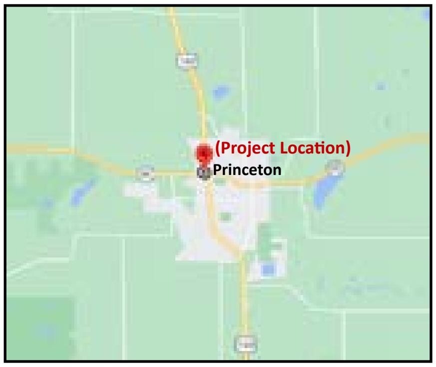

Figure 5. US 169 northbound project location.

U.S. Highway 169 (US 169) near Princeton (Figure 5) was Minnesota's first UTBWC project, initially constructed in 1977 with 11 inches of bituminous layers over a bituminous aggregate base (BAB). This was a two-lane highway with an annual average daily traffic (AADT) of approximately

15,900, including four percent truck traffic. A thin bituminous overlay was added to the original structure 16 years later.

As part of a UTBWC trial in 1999 and 2000, MnDOT resurfaced sections from reference post (RP) 183 to RP 185.3 and from RP 180.845 to RP 183 (Musa Ruranika and Geib, 2007). An adjacent control section, extending from RP 185.3 to RP 187, was also included in this study and was mostly left in its original condition without any major intervention.

Existing pavement distresses on the bituminous pavement included transverse cracks. The surface was prepared prior to UTBWC placement. This included crack sealing with crumb rubber, three-eighths of an inch gap-graded granite aggregates, PG 70-28 binder, and polymer-modified asphalt emulsion membrane. The overlay material was placed using a special paver, which spread the asphalt emulsion and HMA in a single pass. Compaction sealed the asphalt into the emulsion membrane. After the UTBWC application, MnDOT collected data on the trail and control sections to determine UTBWC benefits.

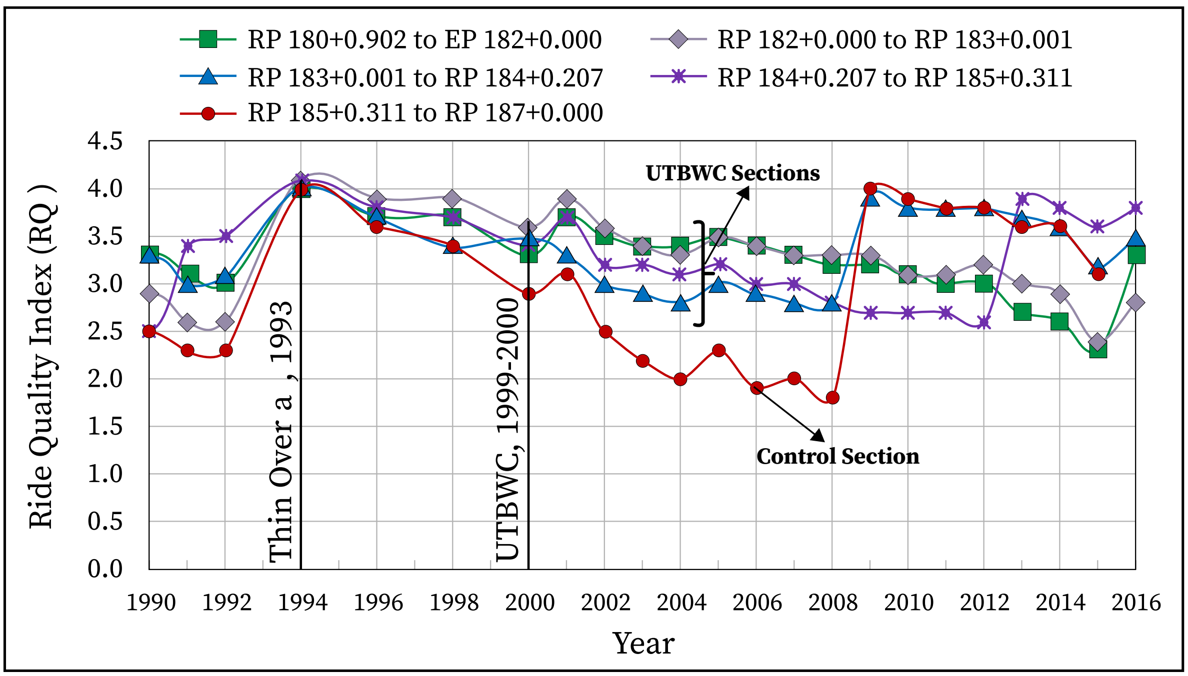

Figure 6. UTBWC and crack sealed RQI performance. (Source: MnDOT)

Figure 6 provides an RQI and surface age snapshot from 1990 to 2016. In 1993, all five sections were treated with a thin overlay resulting in an RQI of approximately 4. After about six years, the trial sections were overlaid with UTBWC, while only routine maintenance treatments, like crack sealing and pothole repairs, were completed on the control section. After seven years of service life, the average RQI for the UTBWC sections was 3.2 (good condition). RQI for the controlled section was 1.9 (poor condition), a candidate for major rehabilitation or reconstruction according to MnDOT pavement management system guidelines. Among the four UTBWC sections, two sections from RP 180+0.902 to RP 183+0.001 showed good performance with only maintenance patching in 2012 and 2016. The UTBWC section from RP 183+0.001 to RP 184+0.207 was milled and overlaid in 2009 after 10 years of service, and the UTBWC section from RP 184+0.207 to 185+0.301 was milled and overlaid in 2013, after 14 years of service. The control section (RP 185+0.311 to 187+0.000) was milled and overlaid in 2009. Maintenance patching was also performed on the control section in 2013 and 2016. Figure 7 shows an overview of the 7-year-old pavement section, and Figure 8 shows the transverse cracks and longitudinal edge cracking reflecting through the UTBWC.

Figure 7. UTBWC overlay section after seven years of service. (Source: Musa Ruranika and Geib)

MnDOT proposed and constructed additional test sections in 2004 and 2005 in the Minneapolis-St. Paul area to demonstrate the design's effectiveness (MnDOT, 2010). All examples that follow are based on the information provided by MnDOT.

Figure 8. Transverse cracking (left) and longitudinal edge cracking (right). (Source: Musa Ruranika and Geib)

Interstate 394

Built in 1991, Interstate 394 is 9.8 miles and runs east to west from downtown Minneapolis to Interstate 494 in the Minneapolis suburb of Minnetonka. The existing pavement structure included 9.75 inches of HMA with a BAB in most of the highway (MnDOT, 2022). A small section from RP 7.9 to RP 7.6 has an underlying concrete base. There are three lanes in each direction for most of the highway.

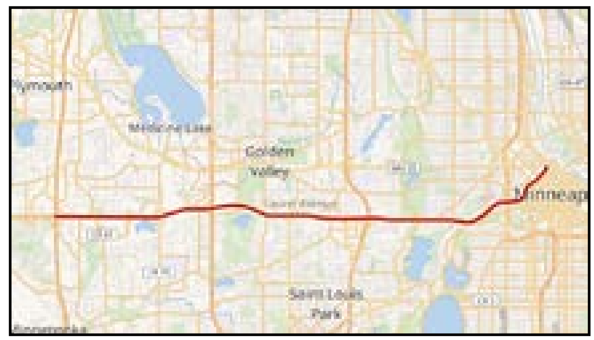

Figure 9. I-394 project location. (Source: Google Maps)

In 2004, 13 years after initial construction, a thin 1.5-inch mill and overlay was completed. In 2016, 12 years after the thin mill and overlay, micromilling and a UTBWC were applied. The RQI jumped from 3.0, fair condition, to 3.7, good condition. Initially, this highway was designed at a 20-year design life. Without this pavement preservation treatment, the RQI could have dipped to 2.5, making this section of the interstate a candidate for major rehabilitation. This highway has now exceeded its design life yet remains in good condition. At 30 years, the average RQI in both directions was approximately 3.9 (Figure 10). This indicates that this highway is performing well.

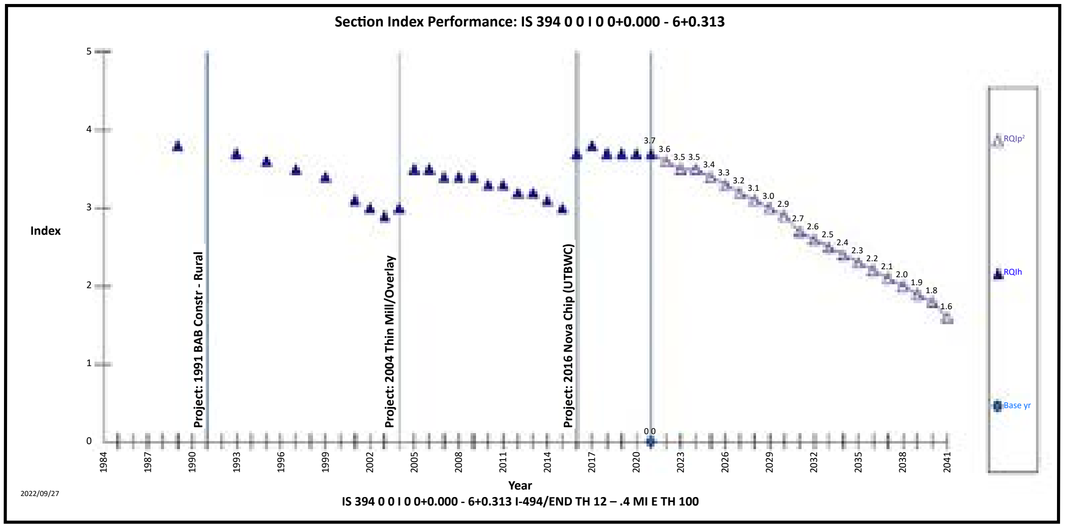

Figure 10a. I-394 EB pavement performance. (Source: MnDOT)

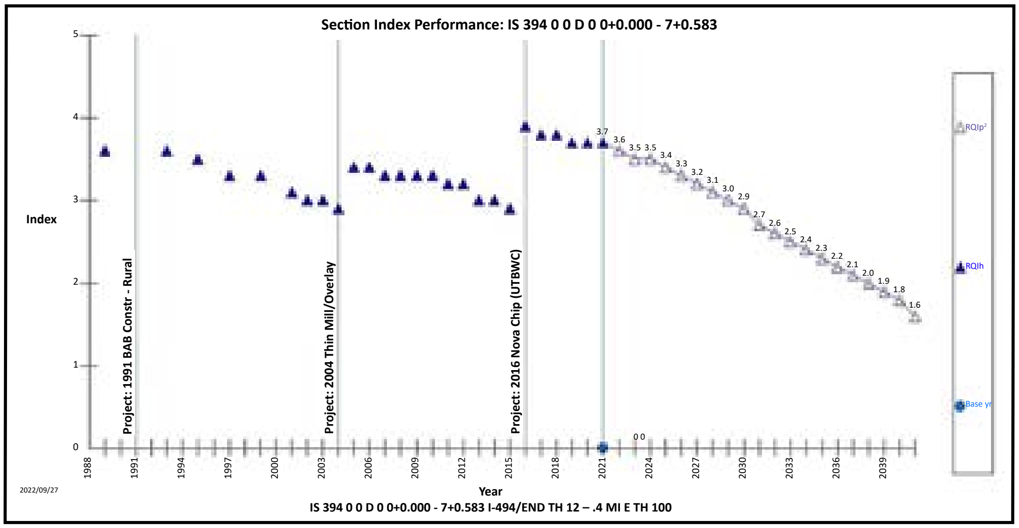

Figure 10b. I-394 WB pavement performance. (Source: MnDOT)

Interstate 35 West

In 2004, UTBWC was constructed on a section of the southbound lanes of Interstate 35 West in Bloomington, MN. The trial project spanned RP 9.190 to RP 3.163. This section was comprised of a jointed plain concrete pavement and a bituminous overlay built in 1992. The overall surface condition was intact, with no major cracks except minor reflective cracks along the longitudinal joints.

The section was composed of three adjacent subsections. These subsections had good RQI, according to MnDOT, of 3.3 to 3.5 before construction. After constructing the 0.5-inch UTBWC, the RQI jumped by an average of 7 percent. In 2008, the RQI for those sections ranged from 3.4 to 3.6 (MnDOT, 2010). In 2015, MnDOT placed an unbonded portland cement concrete overlay on the section when the RQI was 3.0 (MnDOT, 2022).

Minnesota State Highway 36

The existing pavement on State Highway 36 (SH 36) consisted of 9.75 inches of HMA over a BAB originally constructed in 2007. The project extended from RP 8.5 to RP 10.5. This State highway is an example of preventive maintenance. A UTBWC was applied in 2012, five years after initial construction. Figure 11 shows that the RQI hovered between 3.6 to 4.0 a decade after initial construction.

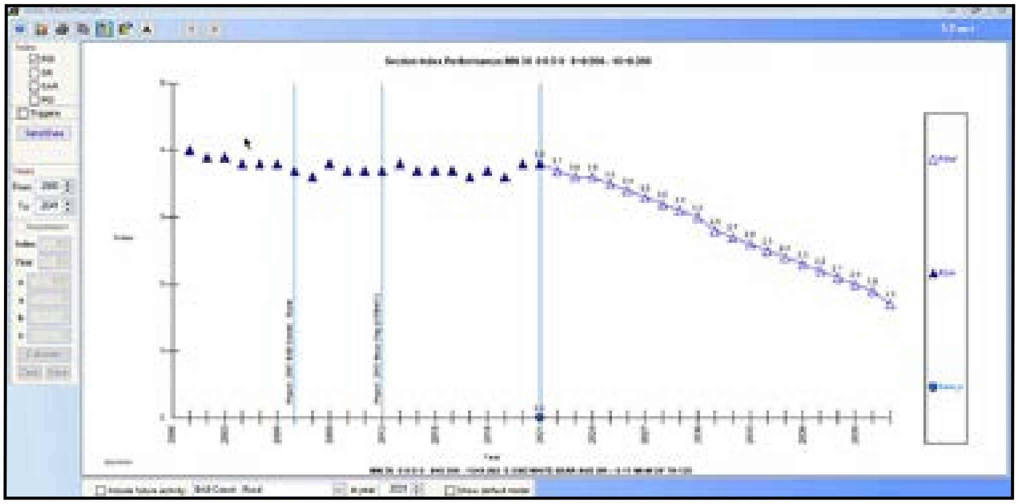

Figure 11. SH 36 pavement performance. (Source: MnDOT)

ONGOING RESEARCH

MnDOT began investigating the performance of micromilling pavements combined with thin bituminous pavement surface treatments in 2013 (MnDOT, 2021). Micromilling is defined as:

A similar process to traditional pavement milling which uses a milling drum having about three times as many teeth as a typical milling drum. The additional teeth provide a tighter lacing pattern and smoother surface, providing a better surface than traditional milling to apply thin pavement surface treatments (MnDOT, 2021).

Figure 12. Micromilled surface. (Source: MnDOT)

UTBWC surface treatments were applied on two highways in Minnesota, I-394 and US 10, as a preservation tool combined with micromilling. Other treatments, such as microsurfacing and chip seal, were also investigated.

This investigation aimed to use data gathered by MnDOT personnel to determine the effectiveness of micromilling with surface treatments to improve ride quality. Ride quality data, known as the mean roughness index (MRI) collected from the left and right wheel paths, showed that ride quality could significantly improve when using UTBWC combined with micromilling prior to placement of the UTBWC. After five years, there was an average improvement of 34 percent on US 10 compared to the pre-treatment MRI. The micromill and UTBWC placed on I-394 improved the ride quality to a level above its original construction. While UTBWC has the highest initial cost of the three treatments investigated, it may be the most cost-effective at improving long-term ride quality. This treatment has an estimated ride improvement and pavement life extension of more than 10 years (Figure 13). Based on a 10-year period, the annual cost would be about $0.68 per square yard or $4,755 per lane mile.

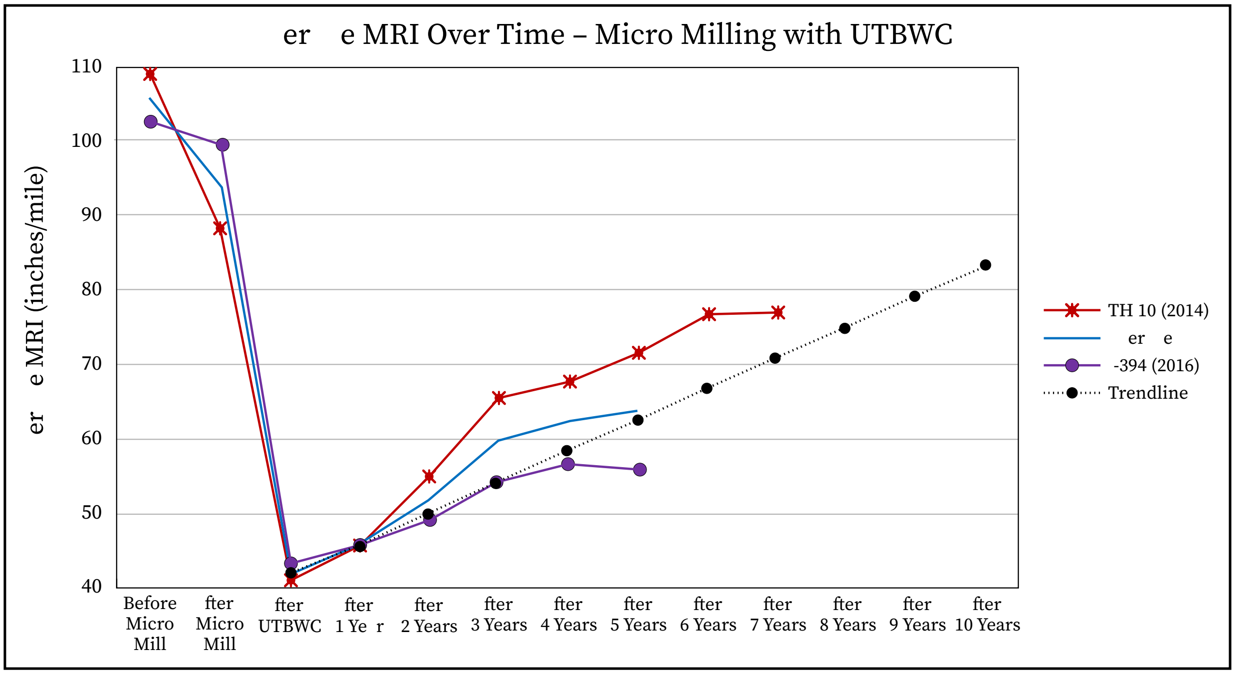

Figure 13. Micromilling with UTBWC performance. (Source: MnDOT)

SPECIFICATION

MnDOT requires contractors to design the UTBWC mixture to meet requirements in the MnDOT Standard Specifications for Construction, 2020 Edition Volume 1 and Volume 2.

Coarse aggregate has to meet MnDOT's requirements outlined in Table 2. Fine aggregate must pass the No. 4 sieve shown in Table 3. MnDOT restricts the use of recycled materials, including glass, concrete, bituminous, shingles, ash, and steel slag (MnDOT, 2020).

Table 2. MnDOT UTBWC coarse aggregate requirements.

Tests	Laboratory Manual Method	Limit, Percent
Flat and elongated ratio at 3:1	1208	≤ 25
Los Angeles Rattler Test (LAR)	1210	≤ 40
Bulk specific gravity	1204	–

Table 3. MnDOT UTBWC fine aggregate requirements.

Tests	Laboratory Manual Method	Limit, Percent
Sand equivalent	AASHTO T 176*	≥ 45
Uncompacted void content (FAA)	Laboratory Manual 1206	≥ 40
Bulk specific gravity	Laboratory Manual 1205	–

**AASHTO 176 "Standard Method of Test for Plastic Fines in Graded Aggregates and Soils by use of the Sand Equivalent Test." This is not a Federal requirement.*

MnDOT requires that the UTBWC polymer-modified emulsion membrane meet specified bituminous materials requirements in Table 4 and Table 5.

Table 4. MnDOT UTBWC polymer-modified emulsion membrane emulsion test requirements.

Test	Method	Minimum	Maximum
Viscosity, Saybolt Furol at 77°F	AASHTO T 59[1]	20 seconds	100 seconds
Storage stability test[2]	AASHTO T 59	–	1%
Sieve test	AASHTO T 59	–	0.05%
Residue by distillation	AASHTO T 59	63%	–
Oil distillate by distillation	AASHTO T 59	–	2%
Demulsibility, 12-ounce, 0.8% dioctyl sodium sulfosuccinate	AASHTO T 59	60%	–

[1] AASHTO T 59 "Standard Method of Test for Emulsified Asphalts," except at no greater than 400°F ± 10°F for 15 minutes.

[2] After standing undisturbed for 24 hours, ensure the surface has a smooth, homogenous color.

Table 5. MnDOT UTBWC polymer-modified emulsion membrane requirements — distillation residue tests.

Test	Method	Minimum	Maximum
Penetration, at 77°F	AASHTO T 49 "Standard Method of Test for Penetration of Bituminous Materials"	60 dmm	150 dmm
Solubility in trichloroethylene	AASHTO T 44 "Standard Method of Test for Solubility of Bituminous Materials"	97.5 percent	–
Elastic recovery, at 77°F	AASHTO T 301 "Standard Method of Test for Elastic Recovery of Asphalt Materials by Means of a Ductilometer"	60 percent	–

Each design shall include the additional design trial points that bracket the optimum asphalt content (OAC) with at least one point at 0.4 percent above and below the OAC. MnDOT requires draindown testing and adjusted asphalt film thickness (AFT) determinations on these trial points. A proposed job mix formula (JMF) must be submitted to the Department Bituminous Engineer for review to meet MnDOT's requirements shown in Tables 6 and 7. The source, pit identification, material descriptions including proportion and gradation, design blend composite gradation, bulk and apparent specific gravities, coarse and fine aggregate water absorption, and test results are required.

Table 6. MnDOT UTBWC aggregate gradation broadband.

Gradation	Gradation Broadband Limits Percent Passing
¾ inch	–
½ inch	100
⅜ inch*	85 – 100
No. 4	28 – 42
No. 8	21 – 33
No. 16	14 – 24
No. 30	9 – 20
No. 50	6 – 15
No. 100	5 – 11
No. 200	3.0 – 7.0

**Typical application rates for ⅜ inch are 65 to75 pounds per square yard.*

Table 7. MnDOT UTBWC mixture requirements.

Test	Criteria	Test Reference
Asphalt Content	4.8-6.0	Laboratory Manual Methods 1853 or 1852
Adjusted AFT (Calculated)	10.5 micrometer minimum	Laboratory Manual Method 1854
Draindown Test	0.10 percent maximum	AASHTO T 305
Lottman (TSR)	80 percent minimum, 7-8 percent voids	Laboratory Manual Method 1813

The JMF properties before paving shall meet MnDOT's requirements in Table 7 and be within the tolerances set in Table 8. These JMF limits are used as materials acceptance criteria based on individual sample testing. MnDOT stops production if the test results vary from the JMF by more than the limits shown in Table 8.

Table 8. MnDOT UTBWC JMF limits.

Gradation	Broadband Limits
Asphalt content	±0.4
Adjusted AFT (calculated)	-0.5

Any new facilities or alterations of existing facilities require compliance with the Americans with Disabilities Act (ADA) under Title 42 – The Public Health and Welfare, subchapter II – Public Services, ADA upgrades must be part of planning UTBWC overlay projects.

CONSTRUCTION

UTBWC construction is unique compared to conventional ultra-thin asphalt overlays. Its multi-layer system is placed in a single pass (University of Arkansas, 2023) with the application of the polymer-modified asphalt emulsion membrane to the pavement surface immediately in front of the paving screed using a self-priming spray paver, as seen in Figure 14. This emulsified membrane helps seal the underlying pavement surface while immediately bonding it to the new asphalt surface.

Typically, UTBWC is capable of withstanding high AADT volumes and truck traffic. UTBWC is usually placed on top of a new mill and overlay or a micromilled surface. Occasionally it is placed directly on an existing asphalt or concrete surface if the overall ride of the existing pavement is in good condition. UTBWC performs poorly on pavements with major distresses, such as high-severity rutting.

Figure 14. HMA placement on asphalt emulsion membrane during UTBWC installation. (Source: MnDOT)

To ensure quality UTBWC placement, MnDOT has established several construction requirements, including:

- The pavement surface and ambient air temperatures must be at least 50 degrees Fahrenheit.
- The paver must be designed and built to apply UTBWC.
- An MnDOT-certified plant must produce the mixture.
- The UTBWC should be at 290 to 330 degrees Fahrenheit, as measured in front of the screed while placing the mixture.
- Localized structural problems must be repaired before overlay application.
- The minimum finished wearing course thickness is ⅝ inch with a maximum ½-inch vertical edge at the adjacent shoulder pavement edge.
- The wearing course should be rolled with steel double drum asphalt rollers with a minimum weight of 11 tons at a minimum of 2 passes before the material temperature has fallen below 185 degrees Fahrenheit. The rollers should be operated in static, non-vibratory mode and cannot remain stationary on freshly placed UTBWC.
- New pavement can open to traffic after the rolling operation is complete and the material has cooled to below 158 degrees Fahrenheit.
- The contractor is responsible for quality control sampling and testing per the Materials Control 2353 schedule. Mix design must be submitted before production. For the bituminous mixture, one sample at a minimum must be tested each day to ensure compliance. Some examples include percent asphalt content and gradation. Asphalt binder and emulsified asphalt samples should be submitted to the MnDOT chemical lab for quality assurance.

WINTER MAINTENANCE

As discussed, UTBWC was developed as a preventive maintenance option to extend pavement life by placing a thin gap-graded HMA lift over a polymer-modified asphalt emulsion. The gap-graded aggregate also provides safety benefits in wet pavement, snow, and ice conditions.

According to MnDOT, winter maintenance on UTBWC has been a challenge. The in-service UTBWC surfaces have increased time demands and the amount of deicing materials required to achieve a clear and dry pavement surface. This is mainly due to the gap-graded UTBWC rough, popcorn-like surface texture that accumulates ice, frozen slush, and wind-blown snow (MnDOT, 2018).

Regarding winter maintenance, almost the same treatments are being applied on the UTBWCs compared to non-UTBWC pavements, except for higher application rates and frequencies on UTBWC pavements due to the stronger bond of ice and snow on the surface. Several States have reported that after the first winter, they have experienced little to no differences between the UTBWC and non-UTBWC sections in terms of ice and snow (MnDOT, 2019).

Key findings from the MnDOT TRS are discussed below.

- Researchers gathered information from over 40 personnel from eight State DOTs during the study. Most were satisfied with UTBWC performance. Participants said extra winter snow and ice control costs could be more than offset by the extended life and reduced pavement maintenance costs, such as crack sealing and pothole patching.
- Several studies have shown that the temperature and humidity of porous pavements, including UTBWC, differ from dense-graded pavements mainly due to their higher surface area and permeable voids. Porous pavements have been found to get colder faster and stay frozen longer than dense-graded pavements.
- The stronger bond between the UTBWC surface and snow and ice often creates a need for more plowing. The snowplow may induce some damage to the pavement surface.
- Several studies have shown that porous pavements require higher amounts of salt in the snow removal processes.
- In general, applying UTBWC in windy areas causes concern due to the chance of blowing snow. It is suggested that newly surfaced UTBWCs in open rural areas be monitored closely during snow and ice operations for the first few years.

Minnesota DOT maintenance staff reported various observations from different districts in the study (MnDOT, 2019):

- District 3 maintenance staff note that early application of deicing chemicals on UTBWC helped prevent lanes from accumulating compacted snow and ice. Any snow and ice removal cost differences between UTBWC and non-UTBWC segment's were negligible for US 169. This may be partly due to this segment's heavy traffic and relatively high travel speeds. The plow operators and supervisor reported that additional snow and ice resources should not exceed 10 percent for the first two seasons after UTBWC surfacing.
- District 4 staffers treat UTBWC sections and non-UTBWC sections alike. They had issues with UTBWC snow and ice during the first winter requiring additional chemicals and underbody blade work, but they said the additional cost was insignificant. After the first winter, they experienced no differences between the UTBWC and non-UTBWC sections regarding ice and snow.
- According to District 7, UTBWC and non-UTBWC sections are treated with the same material and equipment used on the adjacent routes. The treatment frequency can vary from storm to storm, but generally, all the routes receive the same level of service.
- District 8 was the first to use coarser UTBWC Type B. After some reports regarding snow and ice issues with this type of UTBWC, the district decided to change the gradation to finer Type A and have experienced few, if any, snow and ice problems since then.

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Targeted Overlay Pavement Solutions

Office of Preconstruction, Construction, and Pavements

Brian Fouch
Director
202–366–5915
brian.fouch@dot.gov

Pavement Materials Team

Gina Ahlstrom
Team Leader
202–366–4612
gina.ahlstrom@dot.gov

Pavement Materials Team

Tim Aschenbrener
Asphalt Technical Lead
720–963–3247
timothy.aschenbrener@dot.gov

Resource Center

Robert Conway
Concrete Technical Lead
202–906–0536
Robert.Conway@dot.gov

Contacts for More Information

Federal Highway Administration
Office of Preconstruction, Construction,
and Pavements
www.fhwa.dot.gov/pavement

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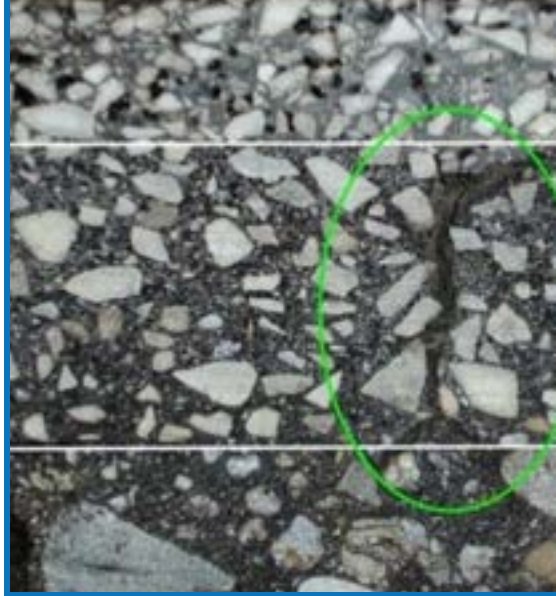

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