TOPS

Targeted Overlay Pavement Solutions

Ultra-Thin Bonding Wearing Course

How-To Document

February 2023

U.S. Department of Transportation
Federal Highway Administration

Every Day Counts
Innovation for a Nation on the Move

NOTICE

NON-BINDING CONTENTS

QUALITY ASSURANCE STATEMENT

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FHWA Project Manager: Tim Aschenbrener; Principal Investigator: Shreenath Rao

16. Abstract
Ultra-thin bonded wearing course (UTBWC) is a thin open-graded asphalt layer placed on a polymer-modified emulsion membrane. A specialized paver places the emulsified asphalt membrane and then 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

AASHTO	American Association of State Highway Transportation Officials
ADT	Average daily traffic
AFT	Asphalt film thickness
ASR	Alkali-silica reactivity
BWC	Bonded wearing course
Caltrans	California Department of Transportation
DOT	Department of Transportation
GHG	Greenhouse gas
IC	Intelligent construction
JMF	Job mix formula
JPCP	Joint plain concrete pavement
MAS	Maximum aggregate size
MnDOT	Minnesota Department of Transportation
MTV	Material transfer vehicle
NCDOT	North Carolina DOT
NMAS	Nominal maximum aggregate size
OBC	Optimum binder content
PCC	Portland cement concrete
PennDOT	Pennsylvania Department of Transportation
PMEM	Poly-modified emulsion membrane
PMTP	Paver-mounted thermal profiler
RQI	Ride quality index
RVD	Ridge-to-valley depth
SHRP	Strategic Highway Research Program
SRL	Skid resistance level
TSR	Tensile strength ratio
UTBWC	Ultra-thin bonded wearing course
UTWC	Ultra-thin wearing course
UTWCEM	Ultra-thin wearing course emulsion membrane
VPD	Vehicles per day
VTrans	Vermont Agency of Transportation
WSDOT	Washington State Department of Transportation

INTRODUCTION

An ultra-thin bonded wearing course (UTBWC) is typically used as a preservation treatment but can also be used as a surface course on a newly constructed pavement. Minnesota Department of Transportation (MnDOT) describes UTBWC as a polymer-modified emulsion membrane (PMEM), followed by a thin layer of a gap or open-graded asphalt mixture (MnDOT, 2022). The product is placed in one pass by a single machine called a spray paver (Figure 1). The process is similar to placing a chip seal, except it uses a thin asphalt mixture instead of aggregate or chips. As the name suggests, the total thickness of the treatment is generally considered thin. MnDOT uses a thickness range from 0.4 to 0.8 inches (10 mm to 20 mm) for a ⅜-inch mixture. UTBWC compaction efforts are minimal compared to dense-graded asphalt overlays. Typically, static rollers are used to “seat” the asphalt into the PMEM. UTBWC placement rates may be faster than conventional asphalt lifts due to reduced thin lift compaction needs.

Related American Association of State Highway Transportation Officials (AASHTO) UTBWC specifications include:

- AASHTO M346 Materials for Ultrathin Bonded Wearing Course.
- AASHTO R108 Ultrathin Bonded Wearing Course Design.

Use of these specifications is not a Federal requirement.

Figure 1. UTBWC is applied using a spray paver. (Source: MnDOT)

The AASHTO specifications include suggestions for UTBWC materials and design. State Departments of Transportation (State DOTs) may have adapted specifications to meet State-specific needs over time. This report focuses on State DOT experiences and successful practices.

Characteristics and Benefits

A spray paver is used to place UTBWCs due to the reliance on the heavy full-coverage tack application. Using a spray paver to apply the treatment in a single pass prevents traffic from driving over the tack coat or bonding material before an asphalt mixture overlay, which may improve bonding to the underlying surface. This document’s Successful Construction Practices section includes more information about spray pavers.

Simultaneous placement of the PMEM and asphalt mixture creates a cohesive preservation treatment. The PMEM seals the existing pavement and bonds the asphalt mixture to the surface. The thick nature of the membrane allows it to migrate, or wick, upward into the mixture and fills the voids in the asphalt aggregate structure, creating a highly cohesive interlayer (Caltrans, 2007; MnDOT, 2018).

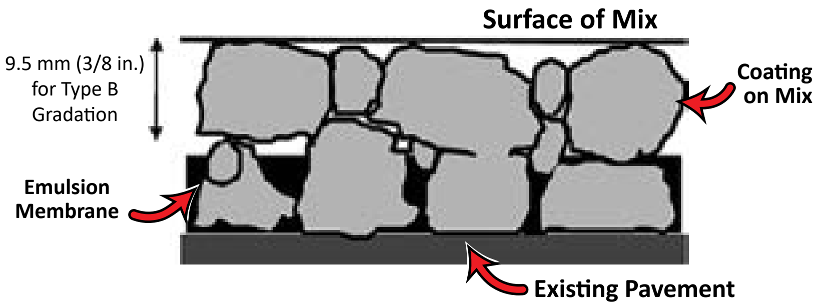

Figure 2. UTBWC bonding mechanism schematic. (Source: MnDOT, 2018)

UTBWC specifications often include three maximum allowable aggregate sizes.[1] The ½-inch and ⅜-inch mixtures are typically coarsely graded and may be used on roadways with higher traffic volumes. Number 4 (4.75 mm) mixtures are finer and may be used on roadways with lower and lighter traffic, such as city streets. Few other preservation treatments are appropriate for high-traffic volumes,[2] which makes UTBWC particularly useful for State DOTs (Peshkin et al., 2011). PennDOT reported UTBWC as a suitable candidate for high-traffic roads with average daily traffic (ADT) of 50,000 and 12 percent truck traffic (PennDOT, 2007).

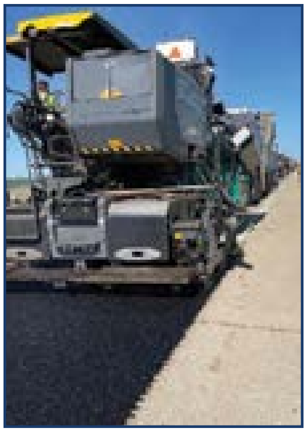

Figure 3. Freshly placed uncompacted UTBWC. (Source: Asphalt Surface Technologies Corp.)

Terminology

UTBWCs have been around for decades, and many State DOTs have developed unique product specifications and terminology though the products are similar.

For example, the Pennsylvania Department of Transportation (PennDOT) calls the mixture ultra-thin wearing course (UTWC) and describes the PMEM as an ultra-thin wearing course emulsion membrane (UTWCEM) (PennDOT, 2021). PennDOT previously referred to the product as an ultra-thin friction course and has used a version of the product for over 20 years. California Department of Transportation's (Caltrans') version of UTBWC is called bonded wearing course (BWC).

History

UTBWC was developed in France in 1986 (Estakhri and Button, 1993; Musa Ruranika and Geib, 2007). Europe reported successful use for preventive maintenance and surface rehabilitation to restore skid resistance and seal the surface. Approximately 40 million square yards were reported to have been placed worldwide by 1997 (MnDOT, 2018).

The first UTBWC sections in the United States were placed by Mississippi, Alabama, and Texas DOTs in the early 1990s (Estakhri and Button, 1993; MnDOT, 2018). The technology was further advanced in the United States by developing new specifications for aggregates, using performance asphalt binders, and developing the asphalt emulsion membrane for improved performance and durability. Further improvements were made to equipment used for application in terms of construction quality and safety (MnDOT, 2018). Since then, other States have used UTBWC under varying product names.

Performance

Many agencies and researchers have measured and documented UTBWC performance since the early 1990s. Some of the main advantages of using UTBWC as a pavement preservation treatment, as noted by several agencies and researchers (MnDOT, 2018; Caltrans, 2007; PennDOT, 2021; Estakhri and Button, 1993; Pavement Preservation, 2014), are shown below:

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[1] Maximum allowable aggregate size described in this report does not meet the definitions for nominal maximum aggregate size (NMAS) or maximum aggregate size (MAS). An example broad band gradation limit for a ½" mixture is 85-100% passing. Therefore, the "maximum allowable" aggregate size is ½-inch, but NMAS and MAS can vary.

[2] Where high traffic is described as rural roadways with ADT values greater than 5,000 vehicles per day (VPD) and urban roadways with ADT values greater than 10,000 VPD (Peshkin et al., 2011).

- Structural Performance:
  - Slows down traffic- and weather-related pavement deterioration.
  - Provides good adhesion to the existing surface, improving pavement performance.
  - Resists cracking by sealing existing low-severity cracking.
  - Resists rutting from stone-on-stone contact between aggregates in asphalt mixture.
  - Improves wear resistance due to the use of high-quality aggregate.
- Functional performance:
  - Reduces tire-pavement noise for urban area applications.
  - Helps maintain ride quality improvements made on existing pavement.
  - Improves visibility by reducing back spray and tire splash.
  - Contributes to safety by improving skid resistance.
  - Reduces salt demand in winter months.
- Constructibility:
  - Allows for rapid application and can be quickly opened to traffic.
  - Avoids the need for milling if the existing surface is without significant irregularities and surface distresses. However, a micro-mill may be necessary for minor repairs and improvements before UTBWC.
  - Results in fewer curb and clearance adjustments due to thin application.
  - May be placed over asphalt mixture and portland cement concrete (PCC) surfaces.

Several State DOTs have documented the expected treatment life of UTBWC. For example, MnDOT reports 10 to 14 years on a stretch of US 169. These calculations are based on a ride quality index (RQI) trigger value of 2.5.[3] MnDOT found that the pavement roughness of a control section without UTBWC deteriorated more than five times faster than sections with UTBWC (Musa Ruranika and Geib, 2007). Other State DOT experiences with UTBWC treatment life include:

- PennDOT reported that UTBWC sections remain in good to fair condition after 6 to 10 years of service (PennDOT, 2007).[4]
- Texas DOT reported a UTBWC on US 281 in very good condition 12 years after application (Estakhri, C. K., and Button, J. W. 1993).
- Caltrans reported that UTBWC on Lark Ellen in LA County was performing well 9 years after application (Caltrans, 2007).
- North Carolina DOT (NCDOT) found UTBWC to provide 6 to 10 years of service life (Corley-Lay and Mastin, 2007).[5]

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3 MnDOT's RQI scale ranges from 0 to 5, with 0 indicating a very poor pavement.

4 The performance indicators typically considered by PennDOT include rutting, transverse cracking, smoothness, and skid resistance.

5 Based on criteria of a pavement condition rating of 70 before intervention.

- Washington State DOT (WSDOT) saw no change to ride quality, minimal wear and rutting, and UTBWC effectively reduced the frequency and severity of cracking after 6 years of service (WSDOT, 2008).

Some State DOTs noticed a reduction in reflective pavement crack growth. While MnDOT reported some cracking on UTBWC surfaces 7 years after construction, the cracks remained "tight" or thin over time compared to the typical crack growth of other surface lifts (Musa Ruranika and Geib, 2007). Although some transverse cracks had reflected through, ride quality remained acceptable. NCDOT reported similar findings on cracks observed in UTBWC on jointed plain concrete pavement (JPCP). They attributed it to the characteristic ability of the polymer-modified asphalt emulsions to bond and hold high-quality thin lift material together (Corley-Lay and Mastin, 2007).

Another benefit MnDOT found is that UTBWC improved the quality and service life of striping and pavement markings compared to other pavement preservation treatments. The increased service life of striping and pavement markings demonstrates UTBWC's cost effectiveness (MnDOT, 2022).

PROJECT DESIGN AND PLANNING

This section describes project design and development phase considerations, such as establishing project selection criteria, pavement evaluation, cost benefits, existing pavement design and repair, and other project-specific considerations.

An important part of any pavement preservation treatment is timing. A pavement preservation treatment like UTBWC can provide a long-term preservation strategy if applied when the pavement is still in good condition and considered structurally sound. The FHWA TechBrief *Use of Thin Asphalt Overlays for Pavement Preservation* (FHWA, 2019) suggests including the typical time between project design and construction during preservation treatment planning. The time window between planning and construction can be significant. Because pavement condition decreases over time, considering this window helps ensure construction occurs when the pavement is still in good condition and the full preservation benefits are received.

Figure 4 shows FHWA's suggested timing for preservation treatments. The left-most line represents the pavement life, and the right line shows the extended pavement life with a preservation treatment applied within the suggested time frame. The thin horizontal dashed line represents a threshold between fair and poor conditions, typically triggering rehabilitation or reconstruction. The chart shows that the pavement life is extended with a properly placed preservation treatment to delay the need for rehabilitation or reconstruction.

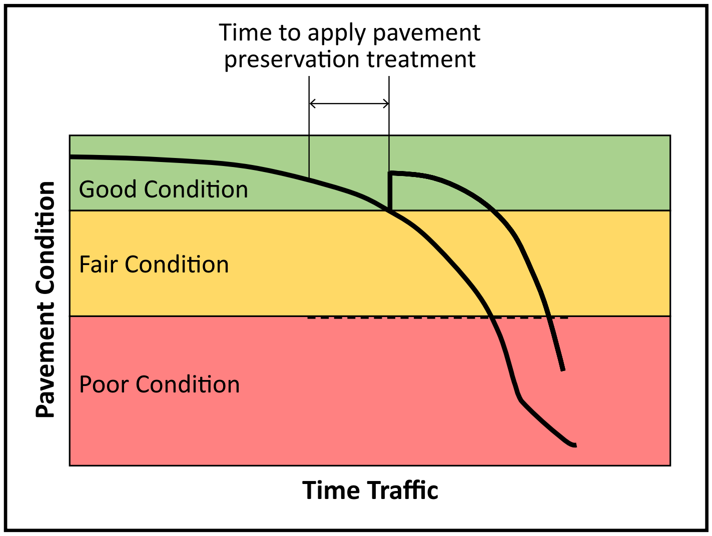

Figure 4. Pavement preservation timing. (Source: FHWA)

Project Selection Criteria

Project selection criteria depend primarily on the pavement's existing condition. UTBWCs can be used on roadways with all traffic volumes. UTBWC placement rates are typically faster than conventional overlays because of the reduced compaction needs for thin lifts and are useful where speed of construction and user delays are concerns. These factors, combined with other advantages such as the reduced need for curb, gutter, and other urban infrastructure adjustments, make UTBWC suitable for nearly any roadway. UTBWCs are reported to perform well over both asphalt mixture and concrete surfaces (MnDOT, 2022; PennDOT, 2022).

MnDOT design policies (Musa Ruranika and Geib, 2007) do not consider UTBWCs as structural lifts during pavement design. However, the surface treatment adds asphalt thickness compared to other preservation treatments. MnDOT recommends using UTBWC structurally sound pavements to seal cracks wider than a quarter inch. Figure 5 shows the placement of UTBWC on top of a micro-milled surface.

NCDOT has used UTBWC on projects requiring ride and noise improvements. NCDOT reports a 6.7-dB average drop in noise level by placing UTBWC over other ride quality improvements on JPCP in an urban street with heavy truck traffic (Corley-Lay and Mastin, 2007).

Caltrans considers UTBWC a viable application for treating structurally sound but worn pavements, with some ability to slow reflection cracking due to its membrane and gap- or open-graded aggregate structure (Caltrans, 2007). Caltrans uses UTBWC on projects that require improvements related to pavement surface characteristics such as skid resistance, noise dampening, and splash-and-spray control (Caltrans, 2007). UTBWC is more commonly used in District 4 (San Francisco Bay Area) and other coastal districts in California since these regions experience cooler temperatures and fog, especially during nighttime paving operations. Therefore, Caltrans considers UTBWC, a single-pass application, to be extremely useful as a pavement preservation tool (Caltrans, 2022).

Figure 5. ¾-inch UTBWC on a micro-milled surface. (Source: MnDOT)

Many State DOTs have established thresholds and decision-making processes in their pavement management system for pavement preservation treatments, including thin overlays. Decision-making processes and pavement considerations for candidate projects vary among State DOTs. An example provided in the Caltrans guidance document for UTBWC considers distress type and extent defined in Strategic Highway Research Program (SHRP) Manual P-338 for each asphalt mixture and PCC pavement, as shown in Table 1 (Caltrans, 2007).

Table 1. Distress and application considerations for Caltrans project selection example.

Pavement Type	Cracking	Patching/ Potholes	Surface Deformation	Surface Defects	Joint Deficiencies
AC	1. Longitudinal Transverse (Medium) 2. Block (Moderate) 3. Edge (Moderate	Patches: Moderate Potholes: Moderate	Rutting: <0.5 in. Shoving: No	Bleeding: Moderate Polished Agg: OK Raveling: Severe	N/A
PCC	1. Corner Breaks (Moderate) 2. Materials Related Distress (Low) 3. Longitudinal (Moderate) 4. Transverse (Moderate)	N/A	Studded tire or chain wear (Low)	Map cracking and scaling: <12 yd^2 to 120 yd^2	Spalling: Moderate

Note: For PCC, a BWC will not treat blowups, pumping, faulting of joints or crack widths > 3/8 in.

PennDOT limits the candidate pavements to those with low-severity cracking or raveling, infrequent corrugations, settlements, heaves or slippage cracks, and medium-severity rutting (PennDOT, 2021). PennDOT has also used UTBWC to prevent moisture infiltration into concrete pavements to arrest or retard alkali-silica reactivity (ASR). Concrete pavements with ASR are patched using suitable material (asphalt mixture or PCC), followed by UTBWC (PennDOT, 2022). PennDOT District 1 reports using UTBWC to restore friction on concrete pavements (PennDOT, 2022).

UTBWC typically is not a solution for structurally inadequate pavements. According to the MnDOT Pavement Preservation Manual, UTBWC is not recommended where structural failures exist (e.g., significant fatigue cracking, deep rutting) or if there is high-severity thermal cracking (MnDOT, 2020). UTBWC should not be used on rigid pavements with blowups, pumping, or faulting problems (Hanson, 2001).

A thorough pavement evaluation can identify and quantify all existing distress and structural repairs as part of a long-term pavement preservation strategy. Additional needs, such as improvements to ride quality, skid resistance, and drainage, can be considered during the project development stage.

Pavement evaluation should identify the cause of surface distresses, such as load and non-load-related cracking, rutting, raveling, and weathering in terms of type, extent, and severity, using the agency guidelines. Other characteristics like ride quality, skid resistance, and drainage may be evaluated case by case. Assets such as bridges, curbs and gutters, ramps, utilities, driveways, and other structures also should be surveyed to assess their impacts on the application.

Pavement Design, Thickness Criteria, and Repair Strategies

Design

FHWA's Guidance for Highway Preservation and Maintenance memorandum issued in February 2016 describes pavement preservation as treatments that do not add structural capacity and restore the overall condition of the pavement. Since UTBWC is categorized as a pavement preservation treatment, any structural capacity increase is generally not considered, and a conventional pavement design methodology is not applicable. However, thin asphalt overlays may increase structural capacity if placed before structural damage occurs (FHWA 2019). Some States use UTBWC as a newly constructed pavement structure surface course.

Thickness

UTBWC thickness is typically less than 1 inch and depends on factors such as gradation type, application considerations, etc. The general rule-of-thumb for thickness design is 1.5 to 2.0 times thicker than the nominal maximum aggregate size. Caltrans summarizes gradation and lift thickness options with application considerations, as summarized in Table 2. PennDOT specifies placement of UTBWC between ½-inch to ¾-inch depending on the mixture type, further described in the Materials and Mixtures section. MnDOT uses a thickness of 0.4 to 0.8 inches for its ⅜-inch mixture.

Table 2. Caltrans UTBWC gradation selection characteristics.

Characteristics	1/2" Gradation	3/8" Gradation	No.4[A] Gradation
Recommended Lift Thickness	1"	3/4"	5/8"
High Traffic	Excellent	Excellent	Good
City Streets	Excellent	Excellent	Excellent
Residential Streets	Good	Excellent	Excellent
Bicycle Traffic	Fair	Good	Excellent
Pedestrian Traffic	Fair	Good	Excellent
Noise Mitigation	Fair	Good	Excellent
Reflective Cracking Mitigation	Excellent	Good	Fair
Release to Traffic	Excellent	Excellent	Excellent

[A] No. 4 gradation only applies to BWC Gap Graded mix.

Repairs and Surface Preparation

Repairs and corrections to the profile should be planned and completed before the UTBWC placement. Recommendations based on NCDOT, PennDOT, Caltrans, and MnDOT procedures for surface preparation are as follows:

- JPCP surfaces:
  - NCDOT found that high ride quality was maintained through slab replacements, spall repairs, and asphalt mixture patching on the existing pavement (Corley-Lay and Mastin, 2007).
  - PennDOT emphasizes using UTBWCs on good pavement, repairing JPCP distresses as needed, and resealing transverse and longitudinal joints on concrete before applying the preservation treatment (PennDOT, 2022).
- Asphalt pavement surfaces:
  - For flexible pavements, all areas with potholes and other surface distresses should be properly repaired, and rutting over ½-inch be milled or filled using means and methods preferred by the agency before UTBWC application (Hanson, 2001).
  - MnDOT found good pavement performance and service life results when the existing surface was micro-milled before UTBWC application (MnDOT, 2022).

- All pavement surfaces:
  - NCDOT suggests that if the roadway profile needs to be reshaped to remove dips or to re-establish a cross slope, a leveling course should be applied before the UTBWC (Corley-Lay and Mastin, 2007).
  - Caltrans suggests cracks wider than ¼-inch be filled or sealed. However, the agency cautions against using over-banding crack sealing methods as it may result in strips that reflect through the finished pavement (Caltrans, 2007).

Micromilling

UTBWC alone does not typically improve ride quality or address significant surface distress (Ulring and Hossain, 2022). MnDOT began investigating the performance of micromilling pavements combined with preservation surface treatments in 2013. Micromilling can improve ride, remove oxidized pavement surfaces and surface defects (cracks, ruts, raveling), improve the bonding of layers, and re-establish or improve cross slope and drainage. MnDOT describes micromilling as a process similar to conventional pavement milling with the following considerations:

- The milling drum has about three times the number of teeth as a typical milling drum.
- The spacing of teeth is approximately 3/16 of an inch compared to the 5/8 inch spacing of conventional milling teeth.
- Micromilling is ideal for removing approximately one inch of pavement.
- Micromilling has a lower ridge-to-valley depth (RVD), as illustrated by Figure 6.
- The resulting surface using the tighter lacing pattern is a smoother finished surface, as illustrated in Figure 7.

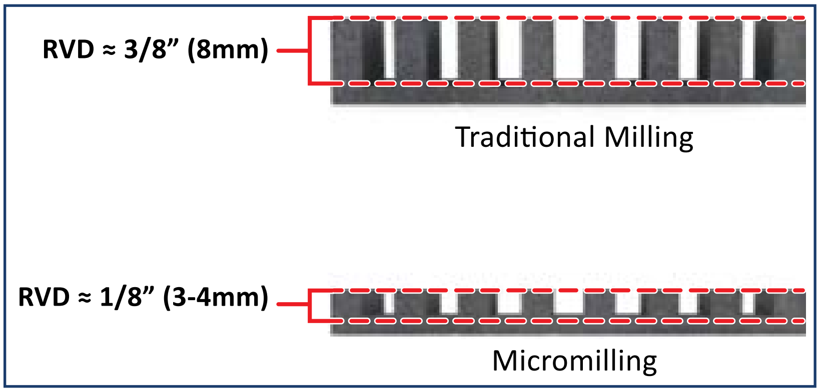

Figure 6. RVD for conventional and micromilling examples. (Source: MnDOT)

Figure 7. Micromilled surface. (Source: MnDOT)

The surface roughness created by conventional milling is unsuitable for thinner overlays because the roughness depth is close to or more than the thickness of thinner layers. The risk with conventional milling and thin overlays is that the RVD will reflect through the overlay as it is compacted under traffic loads. It also increases the risk of surface delamination of the overlay after exposure to traffic (Hajj et al., 2018). When using an open-graded UTBWC, larger RVD from conventional milling can result in water entrapment, which may cause stripping of the asphalt mixtures and potholes (Hajj et al., 2018).

MnDOT data shows ride quality can significantly improve with micromilling and UTBWC combined. After five years, there was an average improvement of 34 percent on one highway compared to the pre-treatment Mean Ride Index. On another interstate project, micromilling and UTBWC improved the ride quality to a value above its original construction.

MnDOT plans to continue to monitor the combined preservation treatment of micromilling and UTBWC and recommends adding micromilling when the following conditions are met (Ulring 2021):

- RQI[6] is 3.0 or below.
- International roughness index is greater than 105 inches/mile.
- Pavement has an oxidized surface, cupped cracks,[7] rutting, raveling, or poor drainage.

Cost and Benefit-Cost Ratio

UTBWC cost is typically based on the square yards of the area. A 2011 SHRP 2 report estimates the average cost of UTBWC to range between $4.00 and $6.00 per square yard (Peshkin et al., 2011). MnDOT estimates UTBWC in Minnesota at $4.50 per square yard and an extra $1.25 per square yard if micromilling is added (Urling, 2021). MnDOT reports that thin surface treatments, including UTBWC, are more effective (considering annualized lane-mile costs) than conventional mill and overlays. Pairing UTBWC with micromilling removes minor surface distresses, provides a clean surface for bonding, and contributes to a longer-lasting treatment, leading to fewer pavement interventions, reduced user disruptions, and lowered associated costs.

UTBWC costs may be higher than other preservation treatments, but other preservation treatments may not be suitable for roads with high traffic volumes. However, UTBWC is comparable and may cost less than conventional mill-and-overlay preservation treatments. According to PennDOT, UTBWC is more cost-effective than a 1.5-inch Superpave overlay despite no increase to the structural value. Estimated costs for preservation treatments compared to UTBWC are shown in Table 3.

[6] MnDOT's RQI scale ranges from 0 to 5, with 0 indicating a very poor pavement.

[7] Cupping refers to the depression of pavement at the crack.

Table 3. PennDOT estimated costs for preservation treatments on asphalt-surfaced pavements.

Treatment	Relative Cost ($ to $$$$)[8]	Estimated Unit Cost
Crack filling	$	$0.10 to $1.20/feet
Crack sealing	$	$0.75 to $1.50/feet
Slurry seal	$$	$0.75 to $1.00/square yard
Microsurfacing (single course)	$$	$1.50 to $3.00/square yard
Chip seal (single course)	$$ $$$	$1.50 to $2.00/square yard (conventional) $2.00 to $4.00/ square yard (polymer-modified)
UTBWC	**$$$**	**$4.00 to $6.00/square yard**
Thin hot mix asphalt overlay (dense graded)	$$$	$3.00 to $6.00/square yard
Cold milling and thin hot mix asphalt overlay	$$$	$5.00 to $10.00/square yard
Ultra-thin hot mix asphalt overlay	$$	$2.00 to $3.00/square yard
Hot in-place recycling	$$/$$$	$2.00 to $7.00/square yard
Cold in-place recycling (excluding overlay)	$$	$1.25 to $3.00/square yard
Profile milling	$	$0.35 to $0.75/square yard
Ultra-thin whitetopping	$$$$	$15.00 to $20.00/square yard

State DOTs may see a higher initial bid cost when introducing UTBWC use. For example, the Vermont Agency of Transportation's (VTrans') first BWC project was in 2006. The cost for the project at that time was $7.00 per square yard. Despite the high costs, the performance exceeded expectations, and future BWC projects were slated for 2007 and 2008. Over time, pricing efficiencies continued to be realized, and in 2013, the cost had dropped to an average of $4.17 per square yard (Pavement Preservation, 2014).

VTrans' positive experiences with BWC have made it the go-to treatment within the pavement preservation program. The maintenance division reported excellent performance in keeping "good roads good." Other cost benefits include reduced salt demand during winter, and VTrans reports the mix as highly cost-effective (Pavement Preservation, 2014).

Sustainability

In addition to economic benefits, UTBWC may have environmental benefits. According to a paper published at the First International Conference on Pavement Preservation, pavement preservation treatments have significantly reduced energy use and greenhouse gas (GHG) emissions compared to conventional rehabilitation and reconstruction strategies (Chehovits and Galehouse, 2010). The paper includes estimated energy use and greenhouse gas emissions for several preservation treatments. Although UTBWCs are not included in the list of preservation treatments, greenhouse gas emissions from UTBWC may be estimated by looking at other similar treatments, such as chip seals and thin asphalt lifts.

[8] $ - low cost, $$ - moderate cost, $$$ - high cost, $$$$ - very high cost.

UTBWCs may further reduce GHGs by introducing warm-mix technologies. Warm mix asphalt is produced at a lower temperature, reducing GHGs during production (Chehovits and Galehouse, 2010). None of the UTBWC specifications reviewed for this report included warm-mix asphalt options, so more information on the construction and performance of warm-mix UTBWCs may be helpful.

Other Considerations

Over time, State DOTs have found other tips and tricks to improve the treatment life of UTBWCs. Some additional design and planning considerations include:

PennDOT found that UTBWC is more cost-effective and constructible on long stretches. Small areas, such as medians or small patches, are difficult to place (PennDOT, 2022).

Some DOTs place UTBWC between existing rumble strips across the travel lanes. Due to the thin lift, the longitudinal transition at the rumble strip does not need to be recessed but can be feathered or tapered to minimize drop-off (Pavement Preservation, 2014). MnDOT allows for a half-inch maximum vertical edge and the shoulder pavement edge. An example of a UTBWC longitudinal tie-in is shown in Figure 8 (Burnham et al., 2022).

Figure 8. Micromilled surface.
(Source: Burnham et al.)

MIXTURES AND MATERIALS

UTBWC comprises two products, a PMEM and an asphalt mixture using high-quality aggregate and polymer-modified asphalt binder. The following section describes these products.

Polymer-Modified Emulsion Membrane

A PMEM is flexible and promotes bonding over various climactic conditions and surfaces. The emulsion should be designed to break rapidly after spraying to ensure no water is trapped. Application viscosity is important; the material should be thin enough to be easily sprayed at the correct rate but thick enough not to flow away and form a continuous membrane (Caltrans, 2007).

Many DOTs apply standard emulsion specifications, such as stability, binder content, viscosity, and torsional recovery for the PMEM. The residual properties indicate polymer presence and the base asphalt grade used. MnDOT, PennDOT, and Caltrans do not specify the emulsion type but set requirements on performance tests. VTrans specifies a CRS-1P emulsion that meets additional testing requirements. CRS-1P is described as a polymer-modified, cationic, rapid-setting, water-based emulsified asphalt designed for use as a bituminous binder for chip seals or stress-absorbing membrane interlayers (Martin Asphalt Company, 2006; Walker Emulsions, 2022).

Examples of UTBWC PMEM requirements for MnDOT, PennDOT, VTrans, and Caltrans are summarized in Tables 4 and 5 and are divided by emulsion and residue tests (MnDOT, 2020a; PennDOT, 2018; VTrans, 2018; Caltrans, 2018). These are not Federal requirements.

Table 4. Example UTBWC PMEM requirements – tests on emulsion.

PMEM Test	Caltrans	PennDOT	MnDOT	VTrans
Saybolt furol viscosity at 25˚C (seconds) AASHTO T59	20-100	20-100	20-100	N/A
Sieve test on original emulsion at delivery (max, %) AASHTO T59	0.05	0.10	0.05	N/A
24-hour storage stability (max, %) AASHTO T59	1	1	1	N/A
Residue by evaporation/distillation (min, %) AASHTO T59	63[9]	63	63	63
Oil distillate by distillation (max, %) AASHTO T59	N/A	N/A	2	N/A
Demulsibility, 12 oz, 0.8 percent dioctyl sodium sulfosuccinate (min, %) AASHTO T59	N/A	55	60	N/A
Particle Charge Test AASHTO T59	N/A	Positive	N/A	N/A

Table 5. Example UTBWC PMEM requirements – tests on residue from distillation.

PMEM Test	Caltrans	PennDOT	MnDOT	VTrans
Torsional recovery at 25˚C (min, %)	40[10]	N/A	N/A	N/A
Penetration at 25˚C (0.01 mm) AASHTO T49	70-150	60-150	60-150	60-150
Elastic recovery (min, %) AASHTO T 301	N/A	58	60	65
Solubility in trichloroethylene (min, %) AASHTO T 44	N/A	97.5	97.5	97.5
Ash content (max, %) AASHTO T 111	N/A	1	N/A	N/A

Aggregates

UTBWC mixes are generally placed in ½-inch to 1-inch lifts. The MAS for UTBWC mixtures typically ranges from No. 4 to ½-inch. The gradation of the aggregates can be either gap- or open-graded. Aggregates for UTBWC are typically held to higher standards for abrasion and toughness due to the stone-on-stone structure for rutting resistance. For example, MnDOT requires using "Class A" rock for UTBWC, described as crushed igneous bedrock consisting of basalt, gabbro, granite, gneiss, rhyolite, diorite, and andesite. Gravel from other sources (metamorphic bedrock or natural gravel deposits) is prohibited.

Since PennDOT uses UTBWC applications to improve skid resistance, the coarse aggregates must meet a minimum skid resistance level (SRL) as classified in PennDOT's Bulletin 14 (PennDOT, 2021). Table 6 shows the classification used by PennDOT for skid resistance aggregates. SRL E is used on roadways with an ADT of 20,000 and above. Blends of aggregate classes are permitted for lower ADT categories.

[9] California Test 331

[10] California Test 332

Table 6. PennDOT skid resistance aggregate types.

SRL	Aggregate Type
E	• Sandstones and siltstones • Loyalhanna Limestone sources (calcareous sandstones) which consistently contain more than 30% + #200 acid insoluble residue • Gneisses and igneous rocks which contain high amounts of micas • Several quartzite sources sheared, so they have softer, sheared microcrystalline quartz surrounding the remaining intact quartz grains • Gravels which contain either a. < 10% carbonates, < 15% chert, and high percentages of dirty sandstone and siltstones or b. < 10% carbonates, < 15% chert, and high percentages of dirty sandstone and siltstones.
H	• Argillites • Diabases, gneisses, granites and granodiorites, basalts, and gabbros which do not contain large amounts of micas; • Open hearth slag and blast furnace slag • Metamorphic quartzites (no difference in hardness between quartz cement and quartz grains) • Sandy limestones • A few coarsely crystalline dolomites (e.g., the Ledger dolomite) • Gravels which contain either: a. > 25% and < 34% total carbonates, and < 10% chert, b. > 15% chert and < 25% chert, and < 10% carbonates, or c. large amounts of quartzite.
G	• Siliceous limestone and dolomite • Limestones and dolomites with consistent wide textural variation (i.e., they always contain finely to moderately or coarsely crystalline dolomite or limestone) • Gravels that contain more than 34% carbonates and more than 10% chert • Serpentinites
M	• Many dolomites and some limestones are not consistently finely textured all the time.
L	• Most limestone and some finely textured dolomites contain minimal, if any, acid-insoluble residue retained on the #200 sieve.

Example UTWBC aggregate suitability properties required by Caltrans, PennDOT, MnDOT, and VTrans are summarized in Table 7 (Caltrans, 2018; PennDOT, 2020; MnDOT, 2020b; VTrans 2018). Other States may have unique requirements based on location, climate, and other factors.

Table 7. Example aggregate suitability properties.

Aggregate Test	Caltrans	PennDOT	MnDOT	VTrans
Percent of fracture coarse aggregate (min, %) AASHTO T 335	90, 2 face	• 95, 1 face, ADT<20,000 • 100, 1 face, ADT>20,000 • 85, 2 face	N/A[11]	• 95, 1 face • 90, 2 face
Percent of fracture fine aggregate (min, %) AASHTO T 335	85[12]	N/A	N/A[11]	N/A
LA Abrasion (max, %) AASHTO T 96	• 12, @100 rev. • 35, @500 rev.	• 35, ADT<5,000 • 30, ADT>5,000	40[13]	30
Flat or Elongated (max, %) ASTM D 4791	25, 5:1	10, ratio not specified	25, 3:1[14]	25, 3:1
Sand equivalency (min, %) AASHTO T 176	47[15]	45	45	60
Fine aggregate angularity (min, %) AASHTO T 304 Method A	45	N/A	N/A	N/A
Soundness loss (max, %) AASHTO T104	N/A	10[16]	• 14[17], ½” sieve • 18[17], ⅜” sieve • 23[17], No.4 sieve • 18[17], composite	12[18]
Clay lumps and friable particles (max, %) AASHTO T 112	N/A	N/A	0.5[19]	2
Insoluble residue test on minus No. 200 (max, %) MnDOT procedure 1221	N/A	N/A	10	N/A
Uncompacted void content (min, %) AASHTO T 304	N/A	40	40[20]	45
Methylene blue (max, %) AASHTO T 330	N/A	10	N/A	10
Micro-Deval (max, %) AASHTO T 327	N/A	18	N/A	N/A
Absorption (max, %) AASHTO T 85	N/A	2	N/A	N/A

[11] Not specified – but source rock must be crushed igneous bedrock, indicating all fractured faces.

[12] Passing No. 4 sieve and retained on No. 8 sieve, one fractured face.

[13] According to Los Angeles Rattler Test Method MnDOT Procedure 1210.

[14] According to MnDOT Procedure 1208.

[15] Reported value must be the average of three tests from a single sample. The use of a sand reading indicator is required, as shown in AASHTO T 176 Figure 1.

[16] According to PennDOT Test Method No. 10

[17] According to MnDOT Procedure 1219, magnesium sulfate.

[18] Sodium sulfate.

[19] According to MnDOT procedure 1209, Lithological Summary.

[20] According to MnDOT Procedure 1206.

Coarse aggregate, fine aggregate, and mineral filler are combined to meet job mix formula (JMF) gradations. PennDOT and many other States use three UTBWC gradation bands. PennDOT's Type A mixture comprises a gap-graded aggregate gradation with a No. 4 maximum allowable aggregate size. Type B and C are coarser and slightly more open, with a maximum allowable aggregate size of ⅜-inch and ½-inch, respectively. VTrans uses a similar approach with Type A, B, and C gradation bands, with the same corresponding maximum allowable aggregate sizes as PennDOT but with unique design limits. Caltrans uses a similar approach but has three unique gradations, similar to PennDOT and VTrans, for each open-graded and gap-graded mixture. MnDOT specifications include a ⅜-inch design gradation. A few example gradations are illustrated in Figure 9 to show how each State DOT uses varying design limits. Individual State DOT specifications can be referenced for more information on DOT gradation design limits.

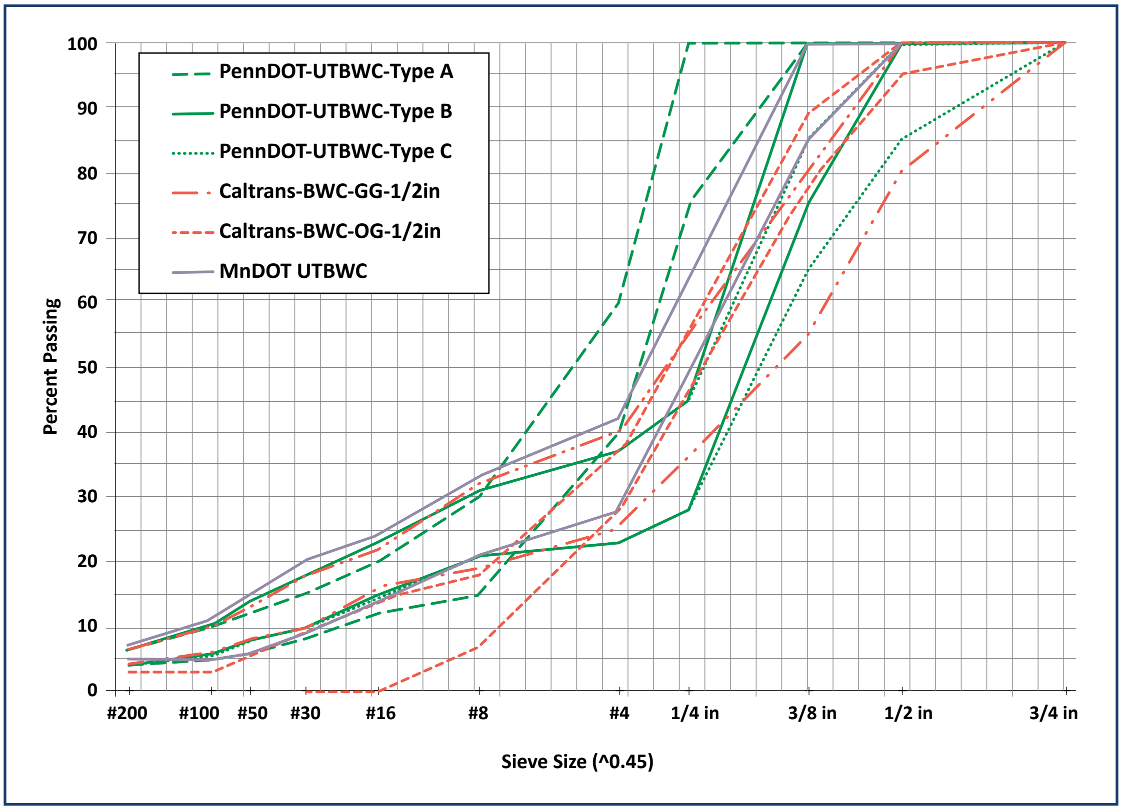

Figure 9. UTBWC example gradations. (Sources: PennDOT, Caltrans, MnDOT)

Asphalt Binders

The asphalt binder grade is selected based on climate and traffic. Both modified and unmodified binders have been used in UTBWC (Hanson, 2001).

Caltrans requires polymer-modified binders for use in UTBWC gap-graded and open-graded mixtures. In addition, Caltrans also allows asphalt rubber binders in UTBWC. MnDOT specifies using a performance-graded binder, PG58V-34, and VTrans requires PG70-28. MnDOT, Caltrans, VTrans, and PennDOT do not have special considerations for the asphalt binder compared to other asphalt mixtures.

Recycled Materials

State DOTs typically do not permit recycled materials such as reclaimed asphalt pavement and recycled asphalt shingles in UTBWC, especially on roadways with a high volume of heavy trucks. MnDOT prohibits using recycled materials, including glass, concrete, bituminous, shingles, ash, and steel slag, in UTWBC mixtures (MnDOT, 2020b).

Additives

Typical additives used in UTBWC are used to improve and meet the minimum specifications for the mixture's moisture susceptibility. The typical additives include liquid antistrips, hydrated lime, mineral filler, and fly ash.

States typically require antistrip additives for aggregate sources with known or tested moisture susceptibility. For example, VTrans requires anti-strip for granite and quartzite aggregates.

Mixture Design and Testing

UTBWC mixtures are typically designed to meet a minimum calculated asphalt film thickness (AFT) and maximum draindown and are tested for moisture susceptibility. The UTBWC mixture design requirements for MnDOT, PennDOT, VTrans, and Caltrans are shown in Table 8, and each test method is described in the following sections.

Table 8. UTBWC mixture design example requirements for MnDOT, PennDOT, VTrans, and Caltrans.

Aggregate Test	Caltrans	PennDOT	MnDOT	VTrans
Asphalt content (%)	>4.9	• 4.5-5.8, Type A • 4.5-5.7, Type B and C	4.8-6.0[21]	• 4.9-5.8, Type A[22] • 4.8-5.6, Type B[22] • 4.6-5.6, Type C[22]
Adjusted asphalt film thickness (ATF) (min., microns)	12[23]	10[24]	10.5[25]	N/A[26]
Draindown (max, %) AASHTO T 305	0.10[27]	0.10	0.10	0.10[28]
Tensile strength ratio (min at 7-8% voids, %) AASHTO T 283	N/A	80	80[29]	N/A

[21] According to MnDOT Laboratory Manual Methods 1853 or 1852.

[22] Determined based on a minimum film thickness of 10.0 microns when calculated using the effective asphalt in conjunction with the surface area of aggregates according to the formula in Figure 13.

[23] According to Asphalt Institute MS-2 Table 8.1.

[24] According to PennDOT Bulletin 27, section 12.4.1.

[25] According to MnDOT Laboratory Manual Methods 1854.

[26] AFT of 10 microns is used to establish AC.

[27] At the manufacturer's instructed mixing temperature.

[28] Tested according to AASHTO T 305 and again at the design asphalt content plus 0.50%. Temperatures shall be mixing temperatures plus 60˚F not to exceed 360˚F.

[29] According to MnDOT Laboratory Manual Methods 1813.

Asphalt Film Thickness

AFT is a calculation based on the effective asphalt binder content of the mixture. The film thickness calculation, FT, used by Caltrans is shown below. Film thickness is typically calculated for three asphalt binder contents, and the optimum binder content (OBC) is determined based on the minimum film thickness. The mix typically needs to also meet the draindown and moisture susceptibility specifications in Table 8.

$$FT = \left(\frac{P_{be}}{SA \times G_b \times 1000} \right) 10^6$$

where:

FT = Film thickness in µm

P_{be} = Effective asphalt content by total weight of mix using *MS-2 Asphalt Mix Design Methods*

SA = Estimated surface area of the aggregate blend in m^2/kg from Table 8.1 in the Asphalt Institute *MS-2 Asphalt Mix Design Methods*

G_b = Specific gravity of asphalt binder

Asphalt Content

States use various methods for determining the optimum asphalt content. VTrans uses the formula below based on a minimum film thickness (S) of 10.0 microns. The aggregate surface area (As) is calculated by multiplying the percent passing by supplied design factors (Table 9) and summing the resulting values.

$$W_{EA} = A_S \times S \times G_{BA}$$

where:

W_{EA} = Weight of effective asphalt binder (pounds per pound of aggregate)

A_S = Surface area of aggregate (square yards per pound of aggregate*)

S = Minimum film thickness of asphalt (microns)

G_{BA} = Specific gravity of asphalt

*Surface area of aggregate is calculated by multiplying the percent passing for the design by the factors in Table 9 for each sieve size and summing the resultant values.

Table 9. VTrans aggregate surface area factors (SY/lb).

Sieve Designation	Type A	Type B	Type C
¾ inch (19.0 mm)	—	—	0.41
½ inch (12.5 mm)	—	0.41	0
⅜ inch (9.50 mm)	0.41	0	0
No. 4 (4.75 mm)	0.41	0.41	0.41
No. 8 (2.36 mm)	0.82	0.82	0.82
No. 16 (1.18 mm)	1.64	1.64	1.64
No. 30 (0.600 mm)	2.87	2.87	2.87
No. 50 (0.300 mm)	6.14	6.14	6.14
No. 100 (0.150 mm)	12.29	12.29	12.29
No. 200 (0.075 mm)	32.77	32.77	32.77

For UTBWC OG mixtures, Caltrans requires the optimum binder content to be determined according to California Test Method 368. The drainage characteristics of the mixture are measured in the lab at various asphalt contents and plotted in Figure 10 to determine the OBC corresponding to the maximum drainage line of 4 percent. This OBC may be adjusted based on the polymer or rubber modifier used in the design asphalt binder.

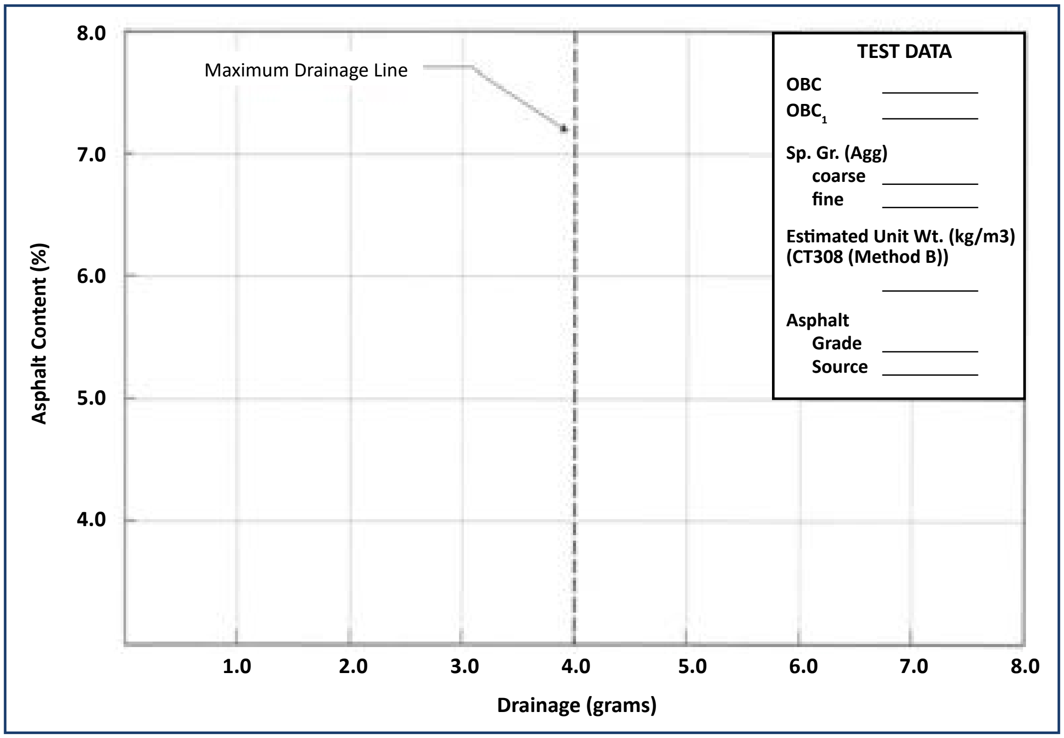

Figure 10. California Test 368 open graded OBC worksheet.

Draindown

The draindown test is conducted to estimate the susceptibility of asphalt binder during production storage, transport, and placement of the UTBWC mixture. Draindown is measured using a sample of asphalt mixture in a wire basket (Figure 11) and by placing it in an oven for a specified time at the production temperature. The material that drains from the mixture, either binder or a combination of binder and fine aggregate, is reported as draindown as a percentage of the weight of the mixture.

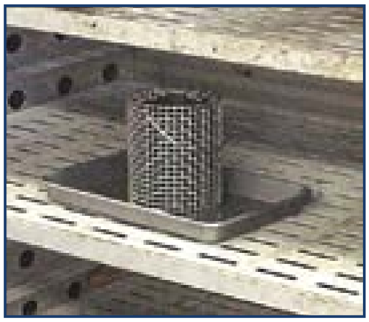

Figure 11. Draindown basket used in AASHTO T 305. (Source: INDOT)

Moisture Susceptibility

Moisture susceptibility of UTBWC mixtures can be measured in the lab using the tensile strength ratio (TSR). Agencies can use the results from the test to require additives such as hydrated lime or liquid anti-stripping chemicals to improve resistance to moisture damage. Specimens are compacted to a specified air void level, are moisture conditioned, and are subject to freeze-thaw cycles. These specimens are then tested for indirect tensile strength (Figure 12) and compared to the control specimens to determine the TSR.

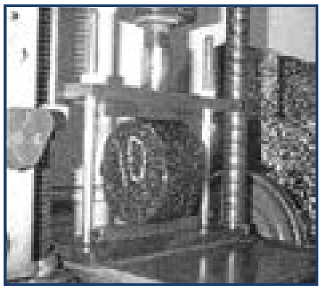

Figure 12. Tensile Strength Ratio AASHTO T 283. (Source: INDOT)

CONSTRUCTION SPECIFICATIONS

UTBWC construction specifications typically include materials, production, storage, transportation, surface preparation, placement, and compaction requirements. UTBWC construction practices may be unique compared to conventional overlays since specialized paving equipment is used.

Materials

Project specifications typically include materials requirements for the PMEM and the asphalt mixture. The specifications should include the materials requirements previously summarized in this document's Mixtures and Materials section.

Surface Preparation

Surface preparation includes spot repairs, micromilling, crack sealing, or other repairs dictated by existing pavement evaluation. Evaluation of the existing surface and identification of distress for repairs are discussed in the Project Design and Planning section of this document.

Sweeping and cleaning the surface to remove debris from milling or other pre-overlay repair operations is an important aspect of surface preparation. If micromilling is not used, the existing striping may need to be removed before the application of UTBWC. MnDOT and PennDOT specify the removal of thermoplastic and tape traffic markings greater than 0.2 inches thick (MnDOT, 2020; PennDOT, 2018).

Clean, debris-free surfaces are necessary to ensure good bonding of the UTBWC mixture to the existing surface. The pavement surface can be cleaned with pressurized water or a vacuum system (Hanson, 2001). Caltrans requires the pavement to be swept with a rotary broom equipped with metal or nylon stock (Caltrans, 2007).

UTBWC application on wet surfaces could impact emulsion setting properties, which might impact bonding or long-term performance.

Manhole covers, drains, grates, catch basins, and other utility services must be protected and covered before applying UTBWC.

Production, Storage, and Transportation

Example specifications for several DOTs (PennDOT, MnDOT, Caltrans, VTrans) include production tolerances for asphalt content, film thickness, and gradation. For example, JMF production tolerances for UTBWC in MnDOT specifications are shown in Table 10. The production tolerances are based on the accepted mix design target values but shall not exceed the mix design requirements in Table 8. According to the specifications, MnDOT stops production if the limits in Table 10 are exceeded.

Table 10. MnDOT job mix formula limits UTBWC production requirements.

Gradation	Broad Band Limits*
Asphalt Content	±0.4
Adj. AFT	-0.5

*Note: The above limits shall not exceed the UTBWC mixture requirements in Table 2353.2-1

VTrans includes gradation production tolerances as follows:

- Sieves ⅜ inch to ¾ inch – approved target plus or minus 4 percent.
- Sieves No. 16 to No. 4 – approved target plus or minus 3 percent.
- Sieves No. 200 to No. 30 – approved target plus or minus 2 percent.

Caltrans requires the mixing temperatures not to exceed 351 degrees Fahrenheit and limits the storage time in the silos to a maximum of 12 hours (Caltrans, 2007). Hanson (2001) suggests the maximum storage time should not exceed 4 hours as a caution against the draindown of asphalt binder.

UTBWC specifications for hauling equipment usually reference typical successful practices for asphalt mixtures. For example, VTrans specifications require the contractor to submit a "best practices" plan for minimizing segregation, including haul truck loading and dumping practices.

Placement and Compaction

Weather

Specifications typically include weather-related restrictions and requirements. Cold and wet conditions are not favorable to the placement of UTBWC. Caltrans requires the minimum air and pavement temperature requirements to be 45 degrees Fahrenheit and rising but recommends the surface temperature to be above 59 degrees Fahrenheit (Caltrans, 2007). MnDOT and PennDOT require the pavement surface and ambient air temperature to be at least 50 degrees Fahrenheit. Because the PMEM has a heavy application rate, freezing conditions within the first 24 hours of placement could impact the emulsion's curing or rupture the bond between the pavement and the new mix (Caltrans, 2007). Therefore, Caltrans specifications restrict the placement of UTWBC if rain is forecasted or if freezing conditions are anticipated within the first 24 hours of placement. VTrans restricts UTBWC placement before May 15 or after October 15.

Equipment

UTBWC specifications typically include equipment requirements for spray pavers. Typical spray paver requirements include having a receiving hopper, feed conveyor, storage tank for asphalt emulsion, an asphalt emulsion spray bar, and variable width, heated, vibratory, or tamper bar screed (MnDOT, 2020). PennDOT uses pavers with a built-in spray bar in front of the variable-width heated screed unit to perform spreading PMEM and UTBWC within 5 seconds (PennDOT, 2020). Typical specifications restrict wheels or any part of the paving machine from contacting the PMEM before the asphalt mix is placed (MnDOT, 2020; PennDOT, 2020; Caltrans, 2007).

PMEM Application

Caltrans requires the polymer-modified emulsion membrane to be applied between 104-185 degrees Fahrenheit, while MnDOT and PennDOT specify the application rate from 120-180 degrees Fahrenheit.

Application rates may vary based on the following variables:

- Existing surface material (asphalt or concrete).
- Existing surface texture (smooth, milled, etc.).

- Existing surface condition (flushed, aged, oxidized, etc.).
- UTBWC mix type (maximum allowable aggregate size).

AASHTO R 108 includes suggestions for application rates and adjustment factors based on the above-referenced variables, as summarized in Table 11. Use of the specification is not a Federal requirement.

Table 11. Example general PMEM application rate and adjustment factors for surface conditions, adapted from AASHTO R 108.

Rate or Adjustment (gallons/square yard)	½ inch Mixture	⅜ inch Mixture	No. 4 Mixture
General application rate	0.20	0.18	0.14
PCCP, smooth or polished	-0.03	-0.03	-0.03
PCCP, broomed or texture	0	0	0
Flushed asphalt	-0.02	-0.03	-0.03
Dense, unaged asphalt	0	0	0
Open-textured, dry, aged, or oxidized	+0.02	+0.01	+0.01
Milled asphalt	+0.02	+0.01	+0.01

Many of the specifications reviewed for this how-to document showed similar application rates to those listed in Table 11 with considerations for surface properties. Specifications typically include spray rate tolerances. For example, MnDOT specifies a spray rate of 0.20 gallons per square yard plus or minus 0.07 gallons per square yard. Similar to AASHTO R 108, VTrans has different application rates for each mix (Type A [No. 4], B [⅜ inch], and C[½ inch]) but has a ±0.025 gallon per square yard tolerance on all rates.

Typical specifications also include methods to verify the PMEM spray rates. For example, VTrans specifies verification using a daily application rate defined below. VTrans requires that the calculated daily application rate of polymer-modified emulsified asphalt gallons per square yard is within 0.025 gallons per square yard of the projected daily application rate of polymer-modified emulsified asphalt gallons per square yard.

$$R_{DA} = \frac{M_E - M_S}{A}$$

where:

R_{DA} = Daily application rate of polymer-modified emulsified asphalt (gallons/square yard)

M_E = Ending meter reading (gallons)

M_S = Starting meter reading (gallons)

A = Daily area measured for payment under BWC (square yards)

Asphalt Placement and Compaction

Some DOTs require a materials transfer vehicle (MTV) for UTBWC. For example, Caltrans requires an MTV and specifies that it must receive directly from the truck, with no windrows (Caltrans, 2018). The noted benefits of using an MTV include reducing physical and thermal segregation, providing a smoother pavement by allowing continuous paving, and allowing for more uniform mat compaction. The onboard storage capacity is approximately 25 tons, plus the 15 tons held in the paver hopper insert allows the MTV to minimize gaps between delivery trucks to keep the paving operations moving continuously to optimize smoothness. The use of an MTV and spray-paver with a hopper insert is shown in Figure 13.

Figure 13. Use of MTV and spray-paver. (Source: Asphalt Surface Technologies Corporation.)

Mixture temperature is important in thin applications. MnDOT requires UTBWC to be placed at a temperature between 290-330 degrees Fahrenheit as measured in front of the screed (MnDOT, 2020). PennDOT specifies placement temperature requirements based on the asphalt binder grade. PennDOT's P.G. 64-22 temperature placement requirements are 285-330 degrees Fahrenheit and 295-340 degrees Fahrenheit for P.G. 76-22. Similarly, VTrans specifies a placement temperature range of 293-338 degrees Fahrenheit.

UTBWC mixtures are typically not compacted to achieve density but are seated into the PMEM. State DOTs specify rolling in static mode using steel double drum rollers. For example, MnDOT requires a minimum of two passes using a steel double drum roller with a minimum weight of 11 tons before the material temperature drops below 185 degrees Fahrenheit (MnDOT, 2020). PennDOT requires the same rolling process; however, the minimum weight of rollers required is 8 tons (PennDOT, 2020). MnDOT also requires restricting the rollers from remaining stationary on the freshly placed UTBWC.

State DOTs may include a temperature requirement for opening the new UTBWC to traffic. For example, Caltrans allows traffic onto the new surface once rolling is completed and the mix temperature has fallen below 158 degrees Fahrenheit (Caltrans, 2018).

Acceptance and Quality Control

Materials

UTBWC specifications typically feature acceptance and quality control requirements, including tolerances and testing frequencies.

Many DOTs specify acceptance testing for AFT, asphalt content, and gradation for the asphalt mix and testing and verifying PMEM application rates. For example, VTrans has the following acceptance criteria (VTrans, 2018):

- BWC will be tested once per 500 tons of material produced to ensure the requirements are met. BWC will be tested for gradation and asphalt content based on printed ticket weights. Asphalt content must meet the ranges summarized in Table 8, and aggregate gradation must meet the following tolerances:
    - Sieves ⅜ inch to ¾ inch approved target plus or minus 4 percent.
    - Sieves No. 16 to No. 4 approved target plus or minus 3 percent.
    - Sieves No. 200 to No. 30 approved target plus or minus 2 percent.
- Polymer-modified emulsified asphalt will be tested once per production day and per the requirements specified in AASHTO M 316 and Tables 4 and 5.

- The application rate of the polymer-modified emulsified asphalt will also be calculated to ensure target values are within tolerance using the RDA formula previously described. Acceptance sampling and testing will be conducted by Agency personnel per the Agency's Quality Assurance Program.
- If any analyzed sample is outside the testing tolerances or other design criteria defined herein, the Contractor shall make immediate adjustments. After the adjustment, the resulting mix will be sampled and tested for compliance with these specifications. With the permission of the Engineer, the plant may continue production pending the results of these tests. However, if the Engineer deems it is in the project's best interest, the Engineer may stop plant production. In this event, additional adjustments shall be made and tested on trial until the deficiency is corrected.

Most other DOTs have similar acceptance criteria based on AFT, asphalt content, gradation, and application rate of PMEM, although production tolerances, testing frequencies, and quality assurance plans vary.

Smoothness

Some State DOTs include smoothness requirements for UTBWC in specifications. MnDOT uses the standard smoothness requirements for bituminous pavements for UTBWC projects (MnDOT, 2018). However, UTBWCs are not evaluated for areas of localized roughness.

Density

Density specifications are not typically included in project specifications. The compaction efforts aim to "seat" the mix. To achieve "seating," State DOTs typically specify minimum temperature requirements and a prescribed rolling pattern, as described in the Placement and Compaction section.

Price Adjustments

MnDOT applies monetary adjustments for UTBWC. The following sections describe MnDOT's monetary deductions (MnDOT, 2018).

Smoothness

Any smoothness value on the UTBWC indicating corrective work may be assessed a monetary deduction of $400 per 0.1-mile segment.

Material Failures

MnDOT bases material acceptance on individual test results and those exceeding the JMF limits as failing.

MnDOT applies monetary deductions for failing tests per Table 12. MnDOT calculates the quantity of unacceptable material on the tonnage placed from the sample point of the failing test to the sample point when the testing result is back within the JMF. If the failure occurs at the first test after the start of daily production, they include tonnage from the start of production that day, with the tonnage subjected to reduced payment.

Table 12. UTBWC monetary deduction schedule.

Item	Percent*
Asphalt Content, percent	20
Adjusted AFT ≥ 10.5	0
Adjusted AFT 10.4 to 10.0	10
Adjusted AFT 9.9 to 9.1	25
Adjusted AFT ≤ 9.0	R & R[||]
Gradation	5

*Highest monetary deduction applies when there are multiple deductions on a single test.

[||] Remove and replace at no expense to Department.

Notes for Table 12:

- A.C. tolerances are JMF target ± 0.4
- Gradation tolerances are the same design requirements shown in Figure 9.

Thickness

MnDOT reduces payment if the mat thickness is less than 5/8 inch, greater than 1 inch, or the pavement edge is greater than ½ inch. Any mixture placed outside this requirement is assessed a 50 percent pay reduction or removed and replaced, as determined by the Engineer, full width.

CONSTRUCTION PRACTICES

UTBWCs are thin mixtures and are applied using specialized construction techniques. Some construction considerations and successful practices are summarized in the following sections.

Mixture Production and Productivity

Typically, aggregates for UTBWC consist of coarse aggregate, fine aggregate, and mineral filler.

Aggregate feeder calibrations at the asphalt plant are critical to ensure consistent asphalt (Roberts et al., 1996). Ensuring proper aggregate plant calibrations is not a quality control practice specific to UTBWCs. Still, there are some differences when using thin lift mixtures. Gates can be opened to various heights to change the material's flow rate (Asphalt Institute, 2009). Feeder bin gate openings for fine aggregate piles may differ from those used on coarser piles since the desired opening is based on the aggregate's size (Roberts et al., 1996). Therefore, feeder calibrations should be considered when switching production from coarser mixtures to finer mixtures like UTBWC.

Fine aggregate stockpiles usually contain more moisture than coarse aggregate piles (Newcomb, 2009). Increasing the frequency of stockpile moisture content checks for UTBWC and other fine-graded thin overlay products may be beneficial since moisture can play a significant role in plant consistency and production (Asphalt Institute, 2009). The aggregate is weighed on the belt before drying for drum mix asphalt plants. (Asphalt Institute, 2009). Since the undried material may contain an appreciable amount of moisture that can influence the aggregate's weight, an accurate measurement of the aggregate moisture is important. The moisture measurement is used to adjust the automatic metering system of asphalt. The proper amount of asphalt is added based on the weight of the aggregate minus the measured moisture content. The Asphalt Institute suggests checking moisture twice daily during production and more if there is variation.

Minimizing stockpile moisture content can reduce production costs (Newcomb, 2009). According to FHWA Tech Brief *Thin Asphalt Overlays for Pavement Preservation*, plants generally run slower for fine-graded mixtures than coarse-graded mixtures. One reason is that the higher moisture contents require a longer drying time. There is about a 10 percent savings in fuel with every one percent decrease in moisture content (Newcomb, 2009). Stockpiling practices such as paving underneath the stockpile, sloping the pad to drain water, and covering the stockpiles can reduce production costs (Newcomb, 2009).

Storage and Transportation

UTBWC mixtures can be susceptible to draindown. Care should be taken to avoid long periods of storage time in silos as it may affect the quality of the mixture. Effective communication between the construction/paving and production/plant teams can help avoid long storage times.

Some State DOTs suggest transporting the UTBWC mixture to the construction site using trucks with clean, fully insulated, and tarped haul beds to reduce temperature loss and avoid contamination of the mixture during transport. Using solvents to clean the truck beds can lead to contamination of the mixture resulting in a poor-quality material.

Surface Preparation

Place UTBWC on a structurally sound and well-prepared surface. Preparation includes repairs such as milling or crack sealing if needed. Take measures to address excess crack sealant, especially sealant less than one year old and not properly cured, on the existing surface to keep it from swelling or migrating into the finished surface and causing bumps.

Failure to properly clean debris from milling and repair operations can lead to inadequate bonding of UTBWC with the existing surface. Refer to this document's Project Design and Planning section to learn how MnDOT pairs UTBWC with micromilling.

Test Strip

Test strips can identify any issues in the construction process or the equipment that might need to be addressed before full-scale production is allowed to begin.

Placement and Compaction

UTBWCs are constructed using a spray paver. The specialized application process distinguishes UTBWC from other pavement preservation treatments and thin asphalt mixture overlays.

Spray pavers combine the paving machine and tack (or other bonding agents) distribution machine. Using a spray paver can promote successful bonding since there are no opportunities for construction or road traffic to track dirt and debris or pick up the bonding layer since the emulsion is applied immediately before the asphalt mixture is placed. There are several manufacturers of spray pavers, and spray pavers can be used for conventional asphalt mixture overlays.

An important consideration when using a spray paver is the emulsion tank's capacity; refilling the tank during production will disrupt the paving operation.

UTBWCs do not need the same compaction efforts as conventional overlay mixtures, and many State DOTs specify a rolling pattern of a few static passes. This compaction effort is typically acceptable to “seat” the mixture in the PMEM (Figure 14). However, consistent proper paving temperatures are useful to ensure proper mix seating (Hanson, 2001). Due to the thin-lift and minimal compaction efforts needed, UTBWC placement rates are generally much faster than conventional dense-graded mixtures.

Most State DOTs do not use UTBWC where handwork is required. The thin layer of material cools very quickly, reducing the UTBWC mixture's workability (Caltrans, 2007). Caltrans recommends avoiding handwork on UTBWC as it can impact the smoothness of the finished mat.

Figure 14. UTBWC rolling operations. (Source: Caltrans)

The use of successful practices for joint construction is essential in UTBWC. PennDOT reported issues at centerline joints where UTBWC raveled and sometimes delaminated (PennDOT, 2022). UTBWCs cannot be patched like conventional asphalt mixtures. PennDOT uses a spray patch with layers of aggregates and liquid asphalt to repair UTBWCs when needed (PennDOT, 2022).

Tools to Encourage Quality

Intelligent Construction Technologies

Intelligent construction technologies combine modern science and innovative construction technologies. Examples include intelligent construction (IC) and paver-mounted thermal profiler (PMTP). IC and PMTP allow the contractors to measure real-time temperature and compaction operations during paving, track progress visually, record measured data and machine settings digitally, and report everything from the field using technically advanced equipment.

Balanced Paving Applications

Thin-lift paver speed may be faster compared to conventional, thicker asphalt lifts. Contractors should ensure proper trucking and compaction efforts are available to balance paving operations. Also, compaction efforts may differ from conventional thicker lifts due to shorter compaction windows. Several free tools, including cell phone applications, can help balance paving operations. Such tools consider plant production, number and capacity of trucks, haul times, paver speed, roller parameters, and other variables.

MAINTENANCE

Some cold-weather DOTs have noticed that UTBWCs tend to accumulate more wind-blown snow and ice build-up than conventional asphalt surfaces (MnDOT, 2019). A study in Minnesota found that the temperature and humidity of porous pavements, including UTBWC, are different from dense-graded pavements due to their higher surface area and permeable voids (MnDOT, 2019).

The 2019 literature review performed by MnDOT included the following UTBWC observations by cold-weather State DOTs:

- Some State DOTs reported a stronger bond between the UTBWC and snow/ice than dense-graded surfaces. Therefore, UTBWCs often require higher plowing efforts. Thin lifts like UTBWC are susceptible to snow plow damage, and more plowing could lead to more damage.
- State DOTs reported conflicting experiences with salt levels. Some State DOTs reported that UTBWCs require higher amounts of salt and chemicals to prevent the ice and snow from bonding. However, some State DOTs found that while the number of times UTBWCs needed to be treated increased, smaller quantities of deicer could be applied. For example, VTrans reports a smaller salt demand on UTBWC roads (Pavement Preservation Journal, 2014).
- Some State DOTs reported that more plowing and chemicals were required due to the stronger bond between UTBWCs and snow/ice. However, residual chemicals in the pores weaken the bond for subsequent storms.
- Traffic loads on UTBWCs can affect snow and ice build-up. Typically, higher-trafficked roads do not have as much build-up as rural roads, partly because traffic can increase the effectiveness of deicing materials by pumping them in and out of the pavement.
- Many State DOTs reported that after a year of service, treatment demands on UTBWCs were comparable to dense graded surfaces.

MnDOT resolved some of the winter-related concerns by slightly modifying the UTBWC gradation to produce a surface texture that would reduce the effects observed in the study (MnDOT, 2022).

SUMMARY

Many State DOTs have been using UTBWC as a cost-effective preservation treatment with successful performance. UTBWC is found to be applicable for various roadway conditions, including high traffic volumes and high speeds. UTBWC can be constructed using two main components – PMEM, immediately followed by a gap-graded or an open-graded asphalt mixture. The placement of UTBWC is similar to placing chip seals, but rather than use “chips,” an ultra-thin overlay is placed. In practice, spray pavers place UTBWCs in a single application. State DOTs, including MnDOT, PennDOT, VTrans, and Caltrans, consider UTBWC a cost-effective tool for a long-term pavement preservation strategy.

Regarding compaction, UTBWCs are typically less than 1 inch thick and require fewer roller passes than compacting conventional asphalt overlays. Many State DOTs report using static compaction to “seat” the thin asphalt lift into the PMEM. Due to the thin lift’s reduced compaction efforts, placement rates for UTBWCs are typically faster than conventional overlay paving rates. As a caution, some State DOTs report that UTBWCs should be placed when the existing pavement is structurally sound. UTBWCs can also be paired with micromilling to remove surface distresses and improve ride quality. State DOTs in northern States report that UTBWCs may require unique winter maintenance treatments compared to conventional overlays.

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TOPS

Targeted Overlay Pavement Solutions

Contacts for More Information

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

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

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