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Performance Assessment of Nonwoven Geotextile Materials Used as Separation Layer for Unbonded Concrete Overlay of Existing Concrete Pavement Applications in the U.S.

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ROAD MAP TRACK 6

PROJECT TITLE
Performance Assessment of Nonwoven Geotextile Materials Used as Separation Layer for Unbonded Concrete Overlay of Existing Concrete Pavement Applications in the U.S.

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The Long-Term Plan for Concrete Pavement Research and Technology (CP Road Map) is a national research plan developed and jointly implemented by the concrete pavement stakeholder community. Publications and other support services are provided by the Operations Support Group and funded by the Federal Highway Administration.

Moving Advancements into Practice (MAP) Briefs describe innovative research and promising technologies that can be used now to enhance concrete paving practices. The December 2017 MAP Brief provides information relevant to Track 6 of the CP Road Map: Concrete Pavement Construction, Reconstruction, and Overlays.

This MAP Brief is available at www.cproadmap.org/publications/MAPbriefDecember2017.pdf.

Introduction

Geotextiles fabrics have been used by pavement engineers for many years as a separation layer between full-depth concrete pavements and stiff cement-treated bases (figure 1). Because of the success of using geotextiles in this application, pavement engineers began evaluating nonwoven geotextiles as an alternative to hot-mix asphalt (HMA) separation layers in unbonded concrete overlay applications in the U.S. beginning in 2008. The application has been very successful.

The purpose of this document is to summarize the national performance experience of unbonded concrete overlays constructed since then using geotextile separation layers; provide an overview of lessons learned; and highlight ongoing efforts to optimize the design and construction requirements for concrete overlay applications.

Background

As part of the May 2006 Federal Highway Administration (FHWA) and American Association of State Highway Transportation Officials (AASHTO) sponsored international scanning tour of long-life concrete pavements in Europe, participants examined German pavement systems (Hall et al. 2007). For over 30 years, German engineers have been using nonwoven geotextile materials as separation material between new cement-treated bases and jointed concrete surface layers (figure 2). These pavement systems are of excellent quality and have long lives, even while carrying significant traffic loads.

German engineers also sometimes use nonwoven geotextiles as separation material when they construct unbonded concrete overlays. Before they place the geotextile separation, however, the existing pavement is either rubblized or cracked-and-seated, which is not common U.S. practice.

Nonwoven geotextile separation materials were first standardized in Germany in 2001 and the specifications have evolved over time to reflect continuing improvements by German engineers.

As a result of what was learned in Germany, scanning tour participants recommended

Figure 1. Placement of nonwoven geotextile interlayer

Figure 2. Core from Germany showing nonwoven geotextile interlayer between surface concrete (left) and cement-treated base (right)

to the FHWA that field tests be conducted in the U.S. to examine the effectiveness of nonwoven geotextile material as a separation between cementitious pavement layers.

The participants particularly recommended that the material be evaluated as an alternative to HMA as a separation material between existing concrete pavement and new concrete overlays—but without cracking-and-seating or rubblizing the existing pavement.

Furthermore, as shown in figure 3, unbonded concrete overlays on concrete (UBCOC) have historically been the most common application of unbonded overlays, thus any potential for performance improvements from using nonwoven geotextiles as a separation material could be very significant.

Purpose of Separation Layer

The Guide to Concrete Overlays, Sustainable Solutions for Resurfacing Existing Pavements, 3rd Edition provides excellent design and construction guidance on the separation layer requirements for unbonded concrete overlays over existing concrete pavements. This document is available for a free download from the National Concrete Pavement Technology Center's website: www.cptechcenter.org. The guide provides detailed information on the selection, design details, and construction of concrete overlays using geotextile separation layers. The 2016 Guide Specification for Concrete Overlays contains additional details on specifications and is also available at the above website for a free download.

HMA separation layers have been used successfully for many years, but performance of the overlay is at times compromised due to stripping of the asphalt and accumulation of permanent deformation in the HMA layer under traffic. The motivation for trying geotextile materials includes improving drainage between the overlay and the underlying pavement, reducing cost, and increasing speed of construction.

Separation layer design and specification requirements are summarized below.

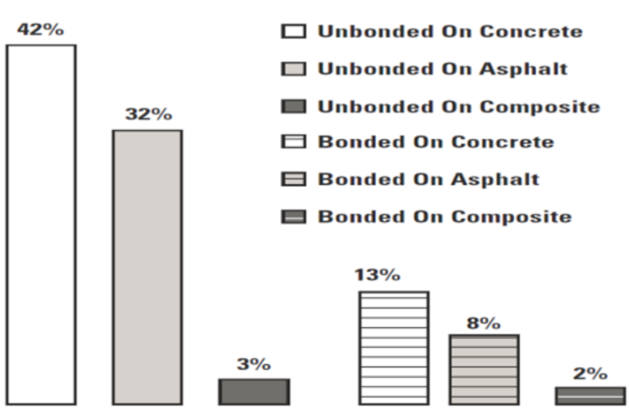

Figure 3. Percentage of bonded and unbonded concrete overlays by pavement type constructed from 1900-2010

Separation Layer Design

The separation layer design is one of the primary factors influencing the performance of unbonded overlays of concrete pavements. The separation layer provides a shear plane that helps prevent cracks from reflecting up from the existing pavement into the new overlay. In addition, the separation layer prevents bonding of the new pavement with the existing pavement, so both are free to move independently.

There are three properties that should be considered in the selection and design of the separation layer:

1. Isolation from movement of the underlying pavement—a shear plane that relieves stress, mitigates reflective cracking, and may prevent bonding with the existing pavement.
2. Drainage—the separation layer either must be impervious so that it prevents water from penetrating below the overlay or must channel infiltrating water along the cross slope to the pavement edge
3. Bedding—a cushion for the overlay to reduce curling and warping and bearing stresses and the effects of dynamic traffic loads and to prevent keying from existing faulting

The most common separation layer has historically been a conventional nominal 1 in. thick well-drained asphalt surface mixture, which provides adequate coverage over irregularities in the existing pavement. The separation layer is not intended to provide significant structural enhancement. Thus, the placement of an excessively thick layer should be avoided.

Stripping of a dense graded asphalt separation layer has led to premature failure of some unbonded overlays. The failure consists mainly of cracking of the concrete due to the loss of support from the stripping of the asphalt binder. In locations where water and heavy truck traffic will be present, drainage of an asphalt separation layer becomes especially important.

Since the initial field trials in 2008, nonwoven geotextile separation layers have been used on an increasing basis and have proven to be effective at satisfying the separation layers requirements.

Geotextiles Separation Specifications

Most specifications currently either refer to the nonwoven geotextile requirements of AASHTO M288, with a Class 2 degree of survivability or table 3 from the Guide Specification for Concrete Overlays (shown on the following page). Current guidance on the typical weight and thickness of the nonwoven geotextile for various overlay thickness is as follows:

- Overlays ≤ 4 in. thick = 13.3 oz/yd^2, 130 mils thick (3.3 mm)
- Overlays ≥ 5 in. thick = 14.7 oz/yd^2, 170 mils thick (4.3 mm)
- 16.2 oz/yd^2 is typically not used except for very thick overlays

Table 3 from Guide Specification for Concrete Overlays, showing Geotextile Separation Layer Material Requirements (Fick and Harrington 2015)

Property	Requirements	Test Procedure
Geotextile Type	Nonwoven, needle-punched, no thermal treatment to include calendaring†	EN 13249, Annex F (Certification)
Color*	Uniform/nominally same color fibers	(Visual Inspection)
Weight (mass per unit area)	≥ 450 g/m^2 (13.3 oz/yd^2) ≥ 500 g/m^2 (14.7 oz/yd^2) ≤ 550 g/m^2 (16.2 oz/yd^2)	ISO 9864 (ASTM D 5261)
Thickness under load (pressure)	[a] At 2 kPa (0.29 psi): ≥ 3.0 mm (0.12 in.) [b] At 20 kPa (2.9 psi): ≥ 2.5 mm (0.10 in.) [c] At 200 kPa (29 psi): ≥ 0.10 mm (0.04 in.)	ISO 9863-1 (ASTM D 5199)
Wide-width tensile strength	≥ 10 kN/m (685 lb. /ft.)	ISO 10319 (ASTM D 4595)
Wide-width maximum elongation	≤ 130 percent	ISO 10319 (ASTM D 4595)
Water permeability in normal direction under load (pressure)	≥ 1 x 10-4 m/s (3.3 x 10-4 ft/s) at 20 kPa (2.9 psi)	DIN 60500-4 (modified ASTM D 5493)
In-plane water permeability (transmissivity) under load (pressure)	[a] ≥ 5 x 10-4 m/s (1.6 x 10-3 ft/s) at 20 kPa (2.9 psi) [b] ≥ 2 x 10-4 m/s (6.6 x 10-4 ft/s) at 200 kPa (2.9 psi)	ISO 12958 (ASTM D 6574) or ISO 12958 (modified ASTM D 4716)
Weather resistance	Retained strength ≥ 60 percent (70% average)	EN 12224 (ASTM D 4355 @ 500 hr. exposure for grey, white, or black material only)
Alkali resistance	≥ 96 percent polypropylene/polyethylene	EN 13249, Annex B (Certification)

U.S. Project Experience

Since 2008, geotextile separations have been used on more than 10 million square yards of concrete overlays and have proven to be effective at satisfying the separation layer requirements. Minnesota, for example, has adopted this use broadly, with over 3 million square yards of nonwoven geotextiles used in UBCOC applications to since 2010. Many other states are also using geotextile separation layers routinely while others are considering it (figure 4).

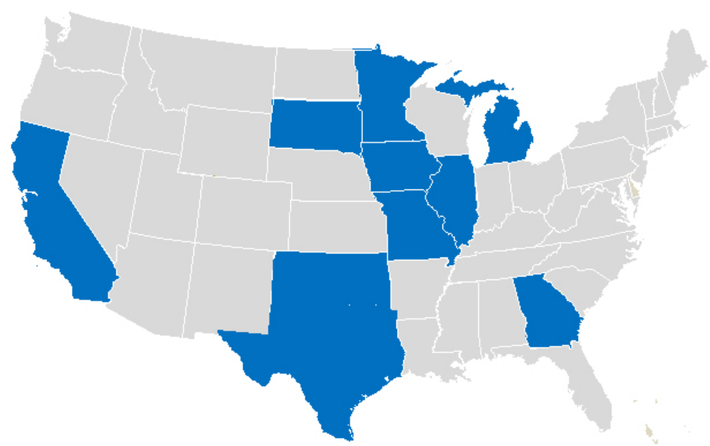

Figure 4. States known to use nonwoven geotextile separation layers on unbonded concrete overlays over concrete since 2008

Overall Performance

Nonwoven geotextile separation layers have worked effectively when overlaying either a jointed plain concrete pavement (JPCP) or continously reinforced concrete pavement (CRCP) with a JPCP overlay. There have been no known or documented performance failures attributed to the geotextile. One minor concern was observed on a 4 in. UBCOC overlay constructed in Michigan in 2011. On that project, it appears that relatively thick nonwoven geotextile (14.7 oz/yd^2 4.3 mm) was used as a separation layer for a thin overlay (4 in.), which resulted in noise from the concrete slabs moving relative to each other at the joints under traffic. Although the noise was audible over the normal traffic noise for a 2 week period, the biggest concern was the loss of some aggregate interlock in the transverse joints due to a grinding action from vertical movement. Within two weeks of construction, the noise subsided and overall performance has been good.

The Guide to Concrete Overlays, 3rd Edition, and the Guide Specification for Concrete Overlays both currently recommend a thinner 13.3 $oz./yd^2$ geotextile when the overlay thickness is ≤4 inches. The Minnesota DOT at their MnROAD Research Facility is conducting research to further optimize fabric thickness on thinner overlays and is currently evaluating an 8 oz/yd^2 nonwoven geotextile under a 3 inch concrete overlay.

It is also worth noting that geotextile separation layers are not recommended when placing a continuously reinforced concrete overlay over a CRCP. The Texas Department of Transportation has evaluated the use of geotextile between CRCP and subbase layers through work conducted by the Texas A&M Transportation Institute. Although this work was on a new full-depth CRCP section and not a CRCP overlay, the conclusion was that this is a questionable application of geotextiles and may not result in the desired pavement performance. This is likely due to the reduced interlayer friction from the geotextile, which resulted in longer, undesirable crack spacing. The recommended separation layer for CRCP is HMA (Zollinger et al. 2014).

Construction Lessons Learned

The Guide to Concrete Overlays, 3rd Edition, provides additional detail and suggestions for the successful installation of geotextile separation material. Important considerations include the following:

- Overlap sections of the nonwoven geotextile material a minimum of 6 in. and a maximum of 10 in., and ensure that no more than three layers overlap at any point (figure 5).
- The geotextile should be either extend past the edge of the pavement a minimum of 4 in. or tied into a longitudinal underdrain system to provide positive drainage.
- Fabric Placement
  - Sweep the pavement surface clean before placing the geotextile
  - Place the material as shortly before paving as possible (ideally no longer than 2 to 3 days) to reduce the potential for it to be damaged.
  - Roll the material onto the base or other surface, keeping the nonwoven geotextile tight to minimize wrinkles or folds
  - Roll out sections of the material in a sequence that will facilitate good overlapping, prevent folding or tearing by construction traffic, and minimize the potential that the material will be disturbed by the paver (Note: If an unavoidable wrinkle or fold occurs, it may be cut and laid flat and secured to the pavement.)
- Construction traffic on the geotextile should be limited to only that necessary to facilitate concrete paving. Leave temporary gaps in the geotextile where trucks are crossing and making sharp turns. Reduce the travel speed of construction vehicles. If damage due to haul trucks occurs, it should be cut out and replaced.
- Thermal considerations
  - White or light colored fabric can be used in hot and sunny weather condition to help prevent heat buildup in the underlying pavement.
  - In colder weather (spring and fall), black-colored fabric helps maintain a warmer temperature in the underlying pavement which helps with hydration of the overlay concrete.
- There are several options for anchoring the geotextile, such as using nails and washers at 6 ft c/c each direction or adhesive (figures 6 and 7). Several states have also been experimenting with using hot pour.

Cost savings

There appears to be significant time and cost savings when geotextile material is used for the separation layer as compared to the more traditional HMA separation layer. There are likely several factors that are contributing to the net savings including material cost, speed of installation, and more efficient project execution.

Figure 5. Overlap of nonwoven geotextile material section

Figure 6. Securing geotextile (pins/nails) with washer

Figure 7. Securing geotextile with spray adhesive

Actual bidding results from two projects are summarized below:

Illinois I-72

The 3.2 mile UBCOC overlay of an existing CRCP pavement was bid using a 1.25" HMA separation in the EBL and a 15 oz/yd^2 nonwoven geotextile in the WBL. EBL with HMA separation cost $506,450.12 versus the WBL with the Geotextile separation cost of $339,564.37 for a project saving of $166,886.75.

North Carolina – Greensboro Eastern Loop

On March 8, 2017 the North Carolina DOT approved the use of a 15 oz/yd^2 geotextile fabric separation under a Value Engineering Proposal (VEP) resulting in the construction cost savings of $555,969.31 over the original design of a permeable asphalt drainage layer. A total of 210,600 yd^2 of geotextile fabric was used on this 5 miles project.

Additional cost information from other states also supports the potential for significant cost savings.

Iowa – 2015-2017 bid prices

Bid results in Iowa during 2015 to 2017 ranged from $2.07 to $2.45 per square yard installed. Using Iowa bid prices during this same period, the cost for a 1 in. thin asphalt separation layer would be $4.86 per square yard.

2016 Survey on Concrete Overlay Costs

A survey was conducted by the National Concrete Pavement Technology Center in 2016 involving 8 states (Colorado, Iowa, Illinois, Michigan, Minnesota, Missouri, Oklahoma, and South Dakota) to determine current costs to build concrete overlays. As part of survey four of the states (Illinois, Iowa, Missouri, and South Dakota) had constructed concrete overlays using geotextile separation material. The average cost was $2.72 per square yard installed.

Case History Examples

The National Concrete Pavement Technology Center is developing a more in-depth overview of the performance history of UBCOC overlays that used nonwoven geotextile as the separation layer material. This report will be available in early 2018.

For the purposes of this MAP Brief, an update is provided on the first two overlays constructed in the U.S.: Route D in Missouri, and I-40 in Oklahoma. A case study from Minnesota DOT is also included. MnDOT has built more overlays using geosynthetic separation layers that any other state at this time.

Case Study #1: Route D, Missouri

Information on the Overlay

Overlay type	UBOL
Year constructed	2008
Project size	45,000 yd2 (3.5 center line miles)
Thickness	5 in.
Dowels	No
Joint spacing	6 ft.
Joint sealing	Unsealed
Integral widening	No
Contractor	Clarkson Construction
Owner	Missouri DOT
Performance concerns related to separation	No
Overlay repairs to date	Minor FD patching at transition

Project Information	
Route	Route D
Application	Highway
Year of original construction	1986
Existing pavement type	JRCP
• Faulting (in.) • Transverse cracking (%) • Spalling (%) • Corner breaks (%) • Longitudinal cracking (%)	Severe "D" cracking
CRCP-Punchouts (#/mile)	N/A

Discussion

Route D in Missouri was the first project built in the U.S. after the FHWA/AASHTO International Scan on Long-Life Pavements. Even though the nonwoven geotextile did not fully comply with current specifications, the project is performing very well.

a) Route D before overlay placement

b) Route D after overlay placement (2008)

c) Route D current pavement condition (2017)

Information on Geotextile Fabric (Route D, Missouri)	
Specification	Nonwoven Geotextile, Propex (Gortex 1201 and Gortex 1601: both had thermal treatment which is not recommended by current specifications but were used due to availability)
Weight	~ 12 oz./yd2 & 15 oz./yd2
Color	Black
Anchored with pins or adhesive	Nails and washers
Moisture outlet (daylighted or subdrains)	Daylight

Performance Information (Route D, Missouri)	
Traffic volume (ADT)	9,300
Truck traffic (%)	5%
Current condition description	The overlay is in excellent condition. A November 2015 survey indicated only 69 of the 9768 panels were cracked or spalled for a 0.7% failure rate after 7 years of service. Both the 12 oz. /yd2 and 15 oz. /yd2 separations appear to be performing equally at this point.

Case Study #2
I-40, Oklahoma

Information on the Overlay

Overlay type	UBOC
Year constructed	2009 & 2010
Project size	681,000 yd² (107,355 yd² UBCO)
Thickness	10 in.
Dowels	Yes
Joint spacing	15 ft.
Joint sealing	Yes - silicone
Integral widening	Yes
Contractor	Duit Construction Company
Owner	Oklahoma DOT
Performance concerns related to separation	None
Overlay repairs to date	None

Project Information (Oklahoma)	
Route	I-40
Application	Interstate highway
Year of original construction	1969 with CRP project in 1992
Existing pavement type	9 in. PCCP over 4 in. fine aggregate bituminous base (FABB)
• Faulting (in.) • Transverse cracking (%) • Spalling (%) • Corner breaks (%) • Longitudinal cracking (%)	• Previously diamond ground, faulting <1/2 in. • <5% • <10% • <10% • ~50%
CRCP-Punchouts (#/mile)	N/A

Discussion

I-40 in Oklahoma was the second project built in the U.S. following the FHWA/AASHTO International Scan on Long-Life Concrete Pavements. The nonwoven geotextile used on this project was actually imported from Europe.

a) I-40 before overlay placement

b) I-40 after overlay placement (2009-2010)

c) I-40 Current pavement condition (2017)

Information on Geotextile Fabric (Oklahoma)	
Specification	AASHTO M288
Weight	15 oz/yd2
Color	Black
Anchored with pins or adhesive	Pins
Moisture outlet (daylighted or subdrains)	Daylight

Performance Information (Oklahoma)	
Traffic volume (ADT)	39,000
Truck traffic (%)	28%
Current condition description	Excellent

Case Study #3
I-94, Minnesota

Project Information	
Route	I-94
Application	Interstate highway
Year of original construction	1973
Existing pavement type	9 in.JPCP
• Faulting (in.) • Transverse cracking (%) • Spalling (%) • Corner breaks (%) • Longitudinal cracking (%) • CRCP-Punchouts (#/mile)	Concrete joint repair performed in 1982 and 1992 Microsurfacing in 2006

Information on the Overlay

Overlay type	UBOC
Year constructed	2013
Project size	272,500 yd2
Thickness	9 in.
Dowels	Yes, 1.25 in.
Joint spacing	15 ft.
Joint sealing	Yes -hot pour
Integral widening	Yes
Contractor	Knife River Corp. (Prime)/PCI Roads (Paver)
Owner	Minnesota DOT
Performance concerns related to separation	None
Overlay repairs to date	None

Discussion

Minnesota DOT and local agencies have used over 3 million square yards of nonwoven geotextile as a separation layer since 2010. They have been a leader in evaluation and optimization of this application and have had excellent results. An example project is the 7.5 mile I-94 overlay near St. Cloud shown on this page.

I-94 current pavement condition (2017)

Information on Geotextile Fabric	
Specification	Propex
Weight	15 oz/yd2
Color	White
Anchored with pins or adhesive	Adhesive
Moisture outlet (daylighted or subdrains)	Daylighted to ditch

Performance Information	
Traffic volume (ADT)	2012 AADT (two way) = 46,800
Truck traffic (%)	2012 HCADT (two way) = 6020, Design ESALS = 74,131,000
Current condition description	Performing well

Summary of Ongoing Development for Optimization of Geotextile Separation

The success of using nonwoven geotextile as a separation layer in UBCOC has resulted in growing interest in optimization of design, specification, and construction procedures for this application. The Minnesota Department of Transportation through their MnROAD research facility, the Iowa Highway Research Board, the National Concrete Pavement Technology Center, along with university and industry partners are currently focused on optimizing the following properties:

- Geotextile thickness requirements for varying overlay thicknesses, especially thinner designs
- Panel size and joint development, especially for lower volume applications
- Quantification of drainage requirements
- Geotextile fabrics ability to limit the potential for faulting
- Construction procedures for securing the geotextile to the existing pavement
- Effect of color on the thermal properties and internal stresses
- Material optimization for end of life recycling

Conclusions

After nearly 10 years of positive project performance, it appears that nonwoven geotextile fabric works very well as a separation material to prevent cracks and other distresses in the underlying pavement from compromising the performance of a new unbonded jointed concrete overlay over existing jointed and continuously reinforced concrete pavements.

There also appears to be significant cost and time saving from using the geosynthetic fabrics as compared to the traditional asphalt separation layer. Because of the successful performance of over 10 million square yards of concrete overlay placed using geotextile separation since 2008, state highway agencies are continuing efforts to optimize material and construction practices for increased value in the future.

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