

WHITETOPPING: CONCRETE OVERLAYS OF ASPHALT PAVEMENTS

An Economic Solution to Pavement Rehabilitation Needs

Due to increased traffic congestion and reduced highway construction budgets, engineers are seeking economical, effective techniques to rehabilitate concrete pavements. One proven solution is a thin concrete overlay called “whitetopping.”

Whitetopping is a rehabilitation alternative for flexible pavements, which overlays an existing flexible Hot Mix Asphalt (HMA) pavement with Portland Cement Concrete (PCC) Surface.

Current pavement design methods treat overlays on existing asphalt roadways similar to concrete pavements placed on traditional aggregate base layers. Design thickness tends to be greater than seven inches, requiring existing



shoulders, bridges, and intersecting roadways to be raised. The end result is a large initial construction cost. Recent field experience with ultra-thin and thin (three to six inch thickness range) whitetoppings show, however, that they offer a highly durable wearing course with significant structural capacity.

MnROAD Studies Field Performance of Whitetopping Design Methods

For the past 15 years whitetopping has been increasing in popularity in the U.S. However, few rationally based design methods are available for these overlays, particularly those based on mechanistic-empirical research born out of actual field performance. The study of the performance of thin and ultra-thin concrete overlays at the Minnesota Road Research Project (MnROAD) is working towards the development of such performance based design methods.

In 1997, three thin (TWT) and three ultra-thin (UTW) concrete overlay test sections were constructed on MnROAD’s interstate facility. By locating them on the interstate, traffic-related distress could be accelerated. In 2004, after enduring more than 6 million concrete equivalent single axles loads (CESALs), the UTW test sections needed to be replaced due to severe surface distresses. Later that year, four new thin concrete overlay test sections were constructed in their place.

The table below summarizes the experimental designs studied at the MnROAD facility. The lessons learned in studying varying design options are discussed in the following section.



THIN (TWT) AND ULTRA-THIN (UTW) CONCRETE OVERLAY EXPERIMENTAL DESIGNS AT MNROAD

Cell #	Type	PCC thickness (in)	HMA thickness (in)	Panel size (ft)	Sealed joints	Fiber reinforcement type	Year Start-End
92	TWT	6	7	10 x 12*	Y	Polypropylene	1997-present
93	UTW	4	9	4 x 4	Y	Polypropylene	1997-2004
94	UTW	3	10	4 x 4	Y	Polypropylene	1997-2004
95	UTW	3	10	5 x 6	Y	Polyolefin	1997-2004
96	TWT	6	7	5 x 6	Y	Polypropylene	1997-present
97	TWT	6	7	10 x 12	Y	Polypropylene	1997-present
60	TWT	5	7	5 x 6	Y	None	2004-present
61	TWT	5	7	5 x 6	N	None	2004-present
62	TWT	4	8	5 x 6	Y	None	2004-present
63	TWT	4	8	5 x 6	N	None	2004-present
(14)	TWT	6	Var.	6 x 6*	N	None	2008-present

* Transverse joints in Cell 92 contain dowel bars. Selected joints in Cell 14 contain flat dowels.

The Experimental Plan

PANEL SIZE

Panel size and thickness can have a major effect on the performance of a thin concrete overlay.

As the panel thickness decreases, so should the overall panel size.

This design consideration lessens the panels' tendency to curl up and results in the panel simply deflecting downward under heavy loading. To confirm this theory, several panel sizes and thicknesses have been studied at the MnROAD facility:

- Three UTW panel sizes: 4 x 4-foot, 5 x 6-foot, and 10 x 12-foot
- Two thicknesses: 3 inches and 4 inches

SMALLER PANEL SECTIONS: 4' X 4'

Two UTW test sections consisting of 4x4-foot panels — one 3 inches and one 4 inches thick—both demonstrated corner cracking in locations near the wheelpaths. Heavy loads concentrated near the edge of the thin panels exceeded their load capacity.



MnROAD 3 inch thick UTW 4 x 4-foot section after five million CESALS. The driving lane is on the left side.

The 4-inch thick UTW test section exhibited approximately 75% less cracks than the 3-inch thick section. The following photo shows the typical crack pattern experienced by the 4x4-foot panel sizes.

MEDIUM PANEL SECTIONS: 5' X 6'

A 3-inch thick UTW test section, consisting of larger 5x6-foot panels, was also tested. This section also experienced approximately 75% less cracking when compared to the 3-inch, 4x4-foot panels.

Surface distress in the UTW section with 5 x 6-foot panels occurred mostly near the driving lane shoulder. Cracking in 5x6-foot panels was caused mainly by the thin concrete overlay debonding from the hot-mixed asphalt (HMA) layer. Once a crack is initiated, repetitive heavy traffic loading propagates further cracking, which eventually results in a large area of distress.

Pavement failure in an UTW 5x6-foot panel is illustrated below.



MnROAD UTW 5 x 6-foot section after five million CESALS (November 2003). The driving lane is on the left side.

LARGE PANEL SECTIONS: 10' X 12'

Two 6-inch TWT concrete overlay test sections, with larger 10x12-foot wide panel sizes were analyzed. Both test sections experienced minor longitudinal cracking in several panels. The tendency of the larger panels to crack into 6-foot wide panels supports current theory that a panel size of 6x6 feet is optimal for most thin concrete overlays. In fact, a test section with 6 inch thickness and 5-foot-long by 6-foot-wide panels, continues to demonstrate the best performance of the original MnROAD concrete overlay test sections constructed in 1997.

Based on UTW test section performance at MnROAD, optimum panel size will keep channelized wheel loadings away from the edges of ultra-thin panels. Also, there is a significant performance difference between a 3 and 4 inch thick concrete surface layer for the same panel size.

It needs to be reemphasized that MnROAD provides accelerated traffic loading, and typical UWT and TWT applications are located on lower volume roadways.

REFLECTIVE CRACKING

Reflective cracking is a phenomenon that occurs when the concrete overlay 'reflects' the pattern of cracks and joints present in the underlying pavement structure.

Along with corner cracking, reflective cracking was noticed at MnROAD for test sections with a concrete layer thickness less than 6 inches.

This behavior was evident in the original 3- and 4 inch UTW test sections constructed in 1997 and the 4 and 5-inch-thick TWT test sections constructed in 2004.

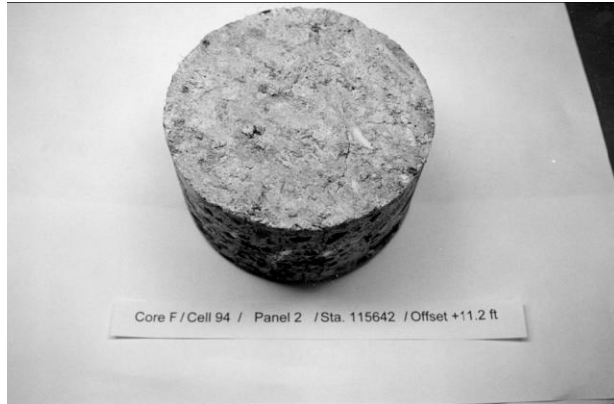
Current theories suggest the underlying HMA becomes stiff enough in the wintertime to exceed the strength of the bonded thin concrete overlay.

INTERLAYER BONDING

Ultra-thin concrete overlay performance relies heavily on the composite action, or bonding, between the older HMA and the new concrete layer. Milling of the HMA and careful surface cleaning during construction enhances bonding between the layers.

Understanding the strength and longevity of the bond between the concrete overlay and the older HMA will be the key to developing better design methods. Toward this effort, core samples and test pits at MnROAD were forensically examined. They showed clear evidence that debonding of the ultra-thin whitetopping from the hot-mix asphalt layer led to cracking, and eventually surface distress (Burnham 2005).

The following photo of a MnROAD UTW core sample (and its location in the slab) shows significant loss of interlayer bond. Debonding between the layers always occurs first near panel edges or cracks. This is likely due to asphalt stripping and/or freezing and thawing action from the increased amount of available moisture entering through the crack.



Bottom view of Core “F”, showing loss of bond between the UTW and HMA layers. Core shown upside down.

The small polypropylene fibers in the MnROAD test sections seemed to provide little benefit to the performance of the concrete layer. The larger polyolefin fibers did not prevent cracking, but did appear to retain small broken pieces of concrete. (Burnham 2005)

LOAD TESTING

Besides exposure to live interstate traffic and Minnesota’s extreme weather, the MnROAD test sections are periodically load tested by specific test vehicles (80,000 pound MnROAD 5-axle semi tractor trailer) and nondestructive devices (Falling Weight Deflectometer (FWD)).

Notable results from load testing include (Vandenbossche, et al 1998, 1999, 2001, 2002):

- Strain measurements indicate composite action or bonding between the layers
- As temperature increases in the HMA layer (and therefore resilient modulus decreases) strains measured in the concrete layer increase.

These observations confirm the importance and effect of interlayer bonding in whitetopping systems.

FIBERS IN CONCRETE MIX

The original UTW and TWT test sections at MnROAD had concrete surface layers containing synthetic fibers. These fibers were inserted to strengthen the concrete, reduce shrinkage cracking, and provide reinforcement across cracks.

Given their less than satisfactory performance, and substantially higher initial cost, non-structural fiber reinforced mixes have not been used in newer TWT test cells at MnROAD.

JOINT FAULTING

The 6-inch thick MnROAD test section with large (10x12-foot) panels and undoweled transverse joints is experiencing significant joint faulting under interstate traffic. Another undoweled, large paneled whitetopping test site in the City of North Mankato, Minnesota, has demonstrated similar joint faulting

behavior. Causes for the faulting are under investigation, but could be related to rocking of the relatively lightweight panels after they have become unbonded.

An adjoining MnROAD test section, with identical thickness and panel size, was constructed with doweled joints, and is experiencing virtually no joint faulting after 12 years of traffic.

Design Recommendations

Under interstate traffic loads, the best performing and most economical test section at MnROAD has been the 6-inch-thick concrete over 7 inches of existing HMA, installed with 5 x 6-foot panels.

This recommendation follows the national trend toward 6-inch thick concrete overlays, placed with 6x6-foot panels on higher volume roadways.

Possible Applications

With the noted design considerations, whitetopping can be an effective solution for many applications. They have been successfully used on interstate highways, state primary and secondary roads, intersections, etc. as well as major airport and general aviation runways, taxiways, and aprons (Mack, Hawbaker and Cole, 1998).

Future Studies

The three remaining original thin concrete overlay test sections at MnROAD are approaching their 12th year in operation. In addition, the test cells constructed in 2004 continue to be monitored.

A new thin concrete overlay (6-inches x 6-foot x 6-foot design) was constructed over one of the original MnROAD full-depth HMA cells in 2008.

A six-state sponsored study to develop a rational design method for thin and ultra-thin concrete overlays began in 2008. MnROAD performance data will serve as a large basis for that study.

For more information:

For further information on Whitetopping or Thin and Ultra-thin Concrete Overlays, please contact:

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