Full-Scale Accelerated Testing of Ultra-Thin Whitetopping Pavements

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FHWA Contact: James Sherwood, HRDI, (202) 4933150

The FHWA Pavement Technology Program is a comprehensive and focused set of coordinated activities. These activities are grouped under five major areas -- Asphalt; Portland Cement; Pavement Design and Management: Advanced Research; and Long-Term Pavement Performance. The goal of the program is the development, delivery, and utilization of a broad spectrum of improved technologies that will lead to better-performing and more cost-effective pavements. The program is product and end-result oriented with the intent of significantly advancing and improving pavement technology and pavement performance.

U.S. Department of Transportation
Federal Highway Administration

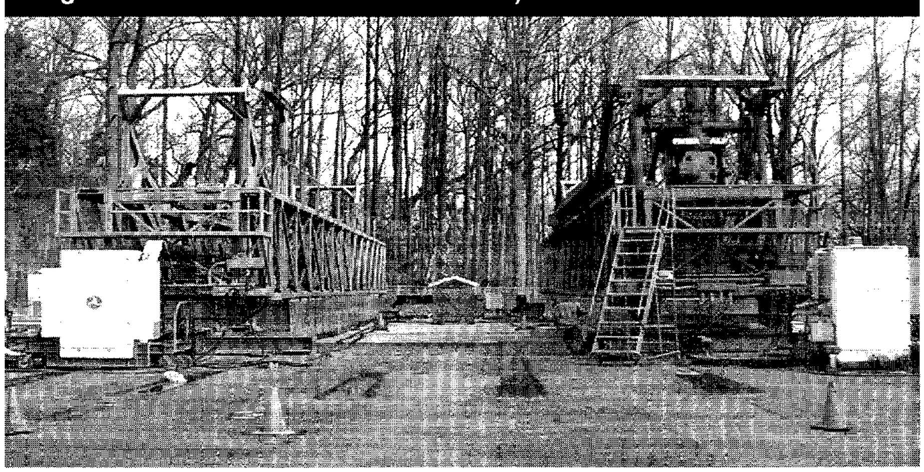
Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296

Introduction

Whitetopping, the placement of portland cement concrete (PCC) overlays on deteriorated asphalt concrete (AC) pavements, has been used for more than 60 years. These overlays have typically been at least 125 mm thick. Recently, however, a new technology known as Ultra-Thin Whitetopping (UTW) has emerged. UTW involves placement of a thin (50- to IOO-mm) concrete overlay to restore AC pavements that have cracked and/or rutted. The first experimental section of UTW was constructed in 1991 on an access road to a landfill in Louisville, Kentucky. Since then, more than 170 UTW projects have been constructed across the United States.

In spring 1998, under a cooperative research agreement with the Federal Highway Administration (FHWA), the American Concrete Pavement Association (ACPA) built eight full-scale lanes of UTW overlay on previously tested AC pavements. The sections were placed at the FHWA's Pavement Testing Facility (PTF) in McLean, Virginia. FHWA began testing the 15-m-long by 4-m-wide sections in May 1998 with one of its two Accelerated

Figure 1. FHWA Pavement Test Facility



Loading Facility (ALF) machines. The second ALF machine was incorporated into the UTW program in November 1998. The tests, which include the collection of data on UTW performance and response, are scheduled to continue through November 1999.

The goals of the study are to validate design equations and mechanistic analysis models (i.e., finite element versus layer theory) recommended in ACPA's design methods for UTW and to document the performance of UTW. The results will help users select materials and establish pavement designs for future UTW projects. This TechBrief provides a summary of the design, instrumentation, and construction of the eight experimental sections of UTW and the results of the project to date.

UTW Performance To Date

The study is specifically aimed at addressing the effects of overlay thickness, joint spacing, and fiber reinforcement on UTW performance. The experiment matrix is shown in table 1.

The overlay thickness and joint spacings are typical values currently employed in UTW designs. Joints are sawed longitudinally and transversely with the same spacing. The fiber concrete is a conventional portland cement concrete with fibrilated polypropylene fiber added to increase resistance to plastic shrinkage cracking and to provide additional tensile strength.

Loading of two sections has been completed. Initial performance results include:

- Lane 12 (conventional PCC, thick section, short joint spacing): After 290,000 80-kN equivalent single-axle loads (ESALs), the first and next-to-last slabs cracked; after 420,000 ESALs, the second slab cracked. When no other significant distresses were found in the test area after application of 460,000 ESALs, the weight on the ALF axle was increased and loading was continued. No additional cracking occurred before the test was terminated at 3,150,000 ESALs. The predicted design life for this section was 2,000,000 ESALs.

- Lane 11 (fiber-reinforced PCC, thick section, short joint spacing): Loading of this section is in progress, with the proposed sequence being identical to that for Lane 12. Similar to Lane 12, the first and second slabs are showing some cracking, perhaps from dynamic loading where the ALF tires first touch down. No other distresses have been found (as of this writing) after 470,000 ESALs. The predicted design life for this section is 1,400,000 ESALs.

- Lane 9 (fiber-reinforced PCC, thick section, long joint spacing): Cracks were discovered in four of the eight slabs after 117,000 ESALs (the 1.83-m joint spacing divides the test section longitudinally into eight slabs). Loading was terminated after 1,000,000 ESALs, with significant cracking in all eight slabs. The predicted design life for this section was 1 ,000,000 ESALs.

Readers should be very cautious in drawing conclusions from this initial data. The experiment has been designed to allow the direct comparison of the results between test lanes, but laboratory testing and data analysis need to be completed to correct for conditions (e.g., variations in materials and construction or variations in underlying AC pavement support) that may have distorted the results. The results from the project will be continually updated on the UTW Web page at http:\\tfhrc.fhwa.dot.gov.

Table 1. ALF test plan lane assignment.

UTW Thickness (mm)	Joint Spacing (m)	Fiber Concrete	Plain Concrete
64	1.22	Lane 5	Lane 6
	0.91	Lane 7	Lane 8
89	1.83	Lane 9	Lane 10
	1.22	Lane 11	Lane 12

Experiment Design

The basic experiment matrix is shown in table 1. The UTW was placed over 200-mm-thick AC pavements that were in various stages of rutting distress after extensive testing with the ALF machines at different times during the previous 5 years. The pavement sections had been built with seven different AC mixtures as part of an experiment to validate the Superpave performance grading asphalt binder system. Prior to placement of the UTW overlays, the AC in each section was milled to either of two depths to remove the surface ruts and to provide for a final pavement thickness, after overlaying, of 200 mm.

Data will be collected for key parameters in the UTW design procedure, including the layer moduli, PCC flexural strengths, bond strengths, and the percentage of fatigue life consumed for the existing AC pavements. The design factorial will provide pavement performance data to test the accuracy of the UTW design equations. Fatigue cracking, faulting, and roughness data will be used to calibrate models. Pavement response data (deflections and strains) will be compared to theoretical calculated values. Pavement response data will also be used to study the effects of load transfer and bond strengths on UTW performance.

Portland Cement Concrete Mixture Design

The PCC mixture was designed by the Virginia Ready-Mix Concrete Association. The concrete mixture contained 363 kg/m^3 of cementitious material, 50 percent of which is Type I cement per AASHTO M-85 and 50 percent of which is Grade 120 slag per AASHTO M-302. The aggregate was a No. 7 crushed stone with a 12.5-mm top size per ASTM C-33. Use of a mid-range water reducer was proposed to achieve a design slump of 178 mm while maintaining a water-cementitious material ratio of 0.45. The target entrained air content was 4.5 to 7.5 percent, while target strengths were 27,600 kPa in compression and 4,500 kPa in flexure. A 7-day moist cure was specified. As noted above, fibrilated polypropylene fiber (1.78 kg/m^3) was used in half of the sections.

UTW Construction

The construction of the UTW began with milling of the existing rutted AC pavements to the desired depths. Lanes 5 through 8 and 9 through 12 were to have 64 and 89 mm of surface removed, respectively. The milling machine ground in the transverse direction at the ends of the 15-m-long lanes. This construction feature helped to ensure a uniform thickness of the UTW up to the ends of the test sections. After milling, the AC surface was brushed and washed. A total of 96 falling-weight deflectometer tests were conducted, with measurements made before and after the pavements were milled, at three stations and at two temperatures.

Strain gauges were installed in each lane the day prior to PCC placement. Four gauges were glued to the AC surface and 14 gauges were later embedded in the PCC. The PCC mixtures were batched and delivered in ready-mix trucks. FHWA staff sampled and tested the concretes in the plastic states for temperature, slump, air content, and unit weight, and prepared 20 beams and 48 cylinders from each of the 2 concretes (fiber-reinforced and plain).

The UTW was placed on April 3 (fiber-reinforced) and April 7 (plain), 1998. Lumber forms were used, with hand-placement and compaction of the concrete. The surface of the AC was moistened prior to paving. The concrete was poured from booms of the ready-mix trucks that were stationed in the adjacent lanes. The concrete was then shoveled into place. The mixtures were placed by hand around the concrete-embedment strain gauges. A hand-held vibrator was used to consolidate the PCC. A vibrating screed was pulled forward by cables and winches on wheels riding on the forms. A long-handled straight edge, trowels, and shovels were used to level and finish the surface. Texturing was done by burlap drag. A white pigmented spray curing compound was applied to the surface, which was then covered with polyethylene sheets. The joints were sawed at the earliest possible time, from 8 to 12 h after placement. After the forms were removed, UTW thicknesses were measured at the joints.

Accelerated Loading Facility Machines

Loading of the test sections is accomplished with the ALF full-scale pavement test machines; the ALFs are 29-m-long frames with rails to direct rolling wheel loads. The ALF loads the pavement in one direction, with or without lateral wander. A radiant heat system mounted within the machine has been able to maintain mid-depth pavement test temperatures of 10° to 76°C. Loads can be varied between 44 kN and 100 kN; the speed of the load tires is a constant 18.5 km/h (5.1 m/s), with an average load rate of 35,000 repetitions per week. Most of the UTW testing is being conducted with a 54-kN dual-tire load and with no lateral wander. At 44 kN, an ALF applies 1.52 80-kN ESALs per pass to the Lane 11 and

Table 2. Average field and 28-day lab test results vs. design.

Concrete Material Parameter	Design Value	Fiber Concrete	Plain Concrete
Water-cementitious material ratio	0.45	0.30	0.25
Slump (mm)	178	103	83
Density (kg/m^3)	*	2312	2423
Entrained air (%)	4.5 - 7.5	6.7	3.4
Modulus of rupture (kPa)	4,482	5,611	6,735
Compressive strength (kPa)	27,580	39,214	46,988
Modulus of elasticity (MPa)	*	31,526	38,507

* Design values are not established for these parameters.

12 sections; at 54 kN, it applies 3.62 ESALs per pass. Note that the ALF machines apply a constant load over the center 10 m of a test section, but an additional dynamic load of about 60 percent is applied in the area where the wheel first touches down.

Quality Control and Assurance Tests

Results of field tests for slump, unit weight, and air content are given in table 2. A total of 40 beams (150 x 150 x 530 mm) and 96 cylinders (100 x 200 mm) were molded. The 28-day laboratory results are also given in table 2. Note that the plain concrete had about 20 percent higher modulus and strength values than the mixture with fibers; the differences are most likely due to the lower water-cementitious material ratio in the plain concrete and are also reflected in lower slump, lower entrained air, and higher density.

Laboratory tests were also performed after 1, 3, and 7 d to study the cure. Another series of strength tests will be performed with the remaining field-cured specimens when the accelerated load testing begins on each section. Other special parameters of the UTW overlay, such as the bond to the existing pavement, will be measured from laboratory tests and post mortem studies.

The temperature of the concrete was recorded continuously during the first 72 h of curing to help validate the FHWA HIPERPAV program. HIPERPAV is a user-friendly computer program that was developed to prevent uncontrolled cracking in new concrete pavements by selecting the best combination of pavement design, materials, and construction procedures for a given environment.

This study is being performed under a cooperative research agreement between the Federal Highway Administration and the American Concrete Pavement Association.

For more information

Contact James Sherwood, HRDI, (202) 493-3150. For the current project status and the latest results, consult the UTW Web page at http:\\tfhrc.fhwa.dot.gov.