CONCRETE PAVEMENT

CPTP

TECHNOLOGY PROGRAM

TechBrief

The Concrete Pavement Technology Program (CPTP) is an integrated, national effort to improve the long-term performance and cost-effectiveness of concrete pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, industry, and academia, CPTP's primary goals are to reduce congestion, improve safety, lower costs, improve performance, and foster innovation. The program was designed to produce user-friendly software, procedures, methods, guidelines, and other tools for use in materials selection, mixture proportioning, and the design, construction, and rehabilitation of concrete pavements.

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U.S. Department of Transportation
Federal Highway Administration

Thin Whitetopping— the Colorado Experience

INTRODUCTION

"Whitetopping" refers to the use of a concrete overlay to resurface a distressed asphalt pavement. Conventional whitetopping (conventional concrete overlay placed directly over an existing asphalt pavement) has a long history of use, and the practice is well established. However, of recent origin are whitetopping techniques that depend on a bond between the concrete resurfacing and the existing asphalt pavement surface (typically milled). These bonded whitetoppings incorporate thinner concrete resurfacing and shorter joint spacing. Two types of bonded whitetoppings may be used:

- [a] Ultrathin whitetopping (UTW)—concrete surface thickness ranging from 50 to 100 mm (2 to 4 in.) with joint spacing ranging from 0.6 to 1.2 m (2 to 4 ft).
- [a] Thin whitetopping (TWT)—concrete surface thickness ranging from 100 to 150 mm (4 to 6 in.) with joint spacing of 1.8 m (6 ft), as illustrated in Figure 1.

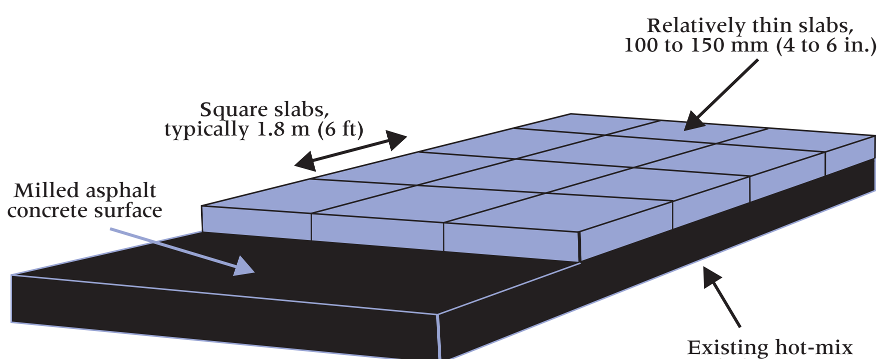

Figure 1. Thin whitetopping.

Since the early 1990s, the use of bonded whitetoppings has grown significantly in the United States as well as in other countries. For specific applications and service life requirements, well-designed and well-constructed bonded whitetoppings appear to provide satisfactory performance. The Colorado Department of Transportation (CDOT) started experimenting with TWT in the 1990s. CDOT has constructed many successful TWT projects and has conducted several studies to develop design and construction guidelines for TWT. One of these studies, co-funded under the Concrete Pavement Technology Program (CPTP), which operates in the Federal Highway Administration's (FHWA's) Infrastructure Office of Pavement Technology, resulted in a mechanistic-based design procedure for TWT. This TechBrief provides details of CDOT's experience with TWT.

DEVELOPMENT

CDOT's work with TWT began in June 1990, when its first whitetopping project was constructed on State Highway (SH) 68, north of Denver in CDOT's Region IV. CDOT was seeking an economical alternative to repeated placement of a 50-mm (2-in.) asphalt concrete (AC) overlay every 8 to 10 years. Concrete pavements have a history of good performance in Colorado, and the benefits of lower maintenance and much longer service life—which translate to fewer traffic disruptions—encouraged the department to investigate the feasibility of TWT.

The trial TWT project consisted of two 91-m (300-ft) test sections placed over an existing AC pavement: a 90-mm-thick (3.5-in.) section with 2.0 by 2.0 m (6.5 by 6.5 ft) slab panels, and a 125-mm-thick (5-in.) section with 3.7 by 4.0 m (12 by 13 ft) panels, as shown in Figure 2. No treatment was applied to the existing AC surface prior to placing the concrete overlay, and no dowel or tie bars were used. After 3 years of service, cracking developed on the 125-mm-thick (5-in.) section with the larger panels, but the 90-mm-thick (3.5-in.) section with the smaller panels performed well with almost no deterioration (Lowery 2005). The excellent performance of the 90-mm (3.5-in.) test section led to further research and eventual development of the TWT design procedure and guidelines for large-scale implementation.

Figure 2. The first thin whitetopping project in Colorado, on SH 68 near Ft. Collins (Ardani 2005).

Following the successful demonstration on SH 68, a second experimental project was constructed in 1994 to evaluate the effects of milling and joint spacing on performance of TWT. Four 61-m (200-ft) test sections were constructed on SH 83 just south of Denver, all with 125-mm (5-in.) TWT. Two sections were placed after milling, and the other two without milling. Two different panel sizes were used: 1.8 by 1.8 m (6 by 6 ft) and 3.0 by 3.6 m (10 by 12 ft). The longitudinal joints in all test sections were tied to prevent slippage, a lesson learned from the first project (Ardani 2005). Additional test sections were constructed in 1996 and 1997 to evaluate the effects of various factors, including the effects of overlay thickness; AC pavement condition (new versus old); and thickness, surface preparation, and joint spacing.

In 1997, CDOT initiated a research project to develop guidelines for the design and construction of TWT, including a mechanistic-based thickness-design procedure. As a part of the study, 11 slabs at 3 different projects were instrumented with strain gauges to measure the structural response of TWT and to determine the critical load location. The instrumented slabs were load tested with 89-kN (20-kip) single-axle and 180-kN (40-kip) tandem-axle loads (Figure 3). The measured pavement responses were used to calibrate theoretical stresses in developing the guidelines for thickness design of TWT (Tarr, Sheehan, and Okamoto 1998). In 2001, a followup study was initiated in cooperation with FHWA's CPTP to validate and revise the original guidelines, developed in 1998. Additional field

Figure 3. Load testing an instrumented slab with a 180-kN (40-kip) tandem axle (Ardani 2005).

testing was conducted on newly constructed and instrumented TWT pavements. The design procedure was modified based on the new data and analysis results, and the revised guidelines were completed in 2004 (Sheehan, Tarr, and Tayabji 2004).

CDOT GUIDELINES FOR TWT

The CDOT guidelines for design and construction of TWT are based on the lessons learned over the years and the research conducted for the development of the mechanistic-based thickness design procedure. Conclusions from the CDOT experience and research include the following:

- A good bond between the concrete overlay and the underlying AC pavement is essential to obtain good performance.
- Milling and thorough cleaning of the AC surface prior to overlaying is recommended to enhance the bond. Effective bonding due to milling reduces the concrete stress in the TWT by about 25 percent.
- Concrete does not bond well to a new AC pavement, milled or not. Thus, TWT is not recommended on a newly constructed AC surface.

Although the original, 1998 guidelines recommended a minimum AC thickness of 125 mm (5 in.) after milling and a minimum subgrade modulus of reaction (k-value) of 40 MPa/m (150 psi/in.), the revised 2004 design procedure does not incorporate limits on minimum AC thickness and k-value. However, it is generally accepted that AC thickness of at least 75 mm (3 in.) should be available after the milling operation.

Thickness Design

CDOT has adopted a mechanistic design procedure for TWT that was developed based on field load testing and theoretical analyses (Tarr et al. 1998; Sheehan et al. 2004). Two types of pavement failure are considered in the design procedure, PCC fatigue under joint or corner loading and AC fatigue under joint loading. Based on extensive finite-element analysis, closed-form regression equations were developed for the calculation of critical PCC stress and AC strain for the fully bonded condition. The fatigue damage is calculated by determining the damage contribution by each axle-load group for single and tandem axles, or by using equivalent 80-kN (18-kip) single-axle loads. The thickness design can be accomplished using a spreadsheet.

Design Features

Based on field experience and research findings, CDOT has adopted the following practice for TWT:

- Concrete thickness: 100 to 150 mm (4 to 6 in.), depending on truck traffic.
- Concrete panel size: 1.8 by 1.8 m (6 by 6 ft).
- Concrete strength: similar to conventional concrete pavement.
- Concrete mixture: CDOT Class P concrete (29 MPa [4,200 psi] at 28 days, 4 to 8 percent air content, maximum 0.44 w/cm ratio). Laboratory trial mixture must produce 28-day flexural strength of 4.5 MPa (650 psi).
- Milling and cleaning AC surface prior to overlaying.
- Deformed tie bars across the longitudinal joints, spaced at 900 mm (36 in.).

- [a] No dowel bars across transverse joints. [a]
- Tied PCC shoulder. [a]

CDOT typically seals all TWT joints. The [a] majority of TWTs in Colorado are 150 mm [a] (6 in.) thick. [a]

CONSTRUCTION

The construction of TWTs involves conventional concrete materials and equipment. The construction consists of three main activities:

- [a] Surface preparation—To promote good bonding, the existing AC surface is milled and thoroughly cleaned prior to placing the overlay. The milling depth is typically 13 to 50 mm (0.5 to 2 in.), depending on the condition of the existing AC pavement. The milled AC surface should be swept multiple times, air-blasted to remove any remaining debris or dust, and wetted prior to concrete placement.
- Concrete placement and curing—Conventional concrete mixtures are used for TWT. High-early-strength mixtures may also be used, if early opening to traffic is needed. Concrete placement and curing is no different for TWT than for conventional concrete paving. In Colorado, slipform pavers are typically used, but fixed forms can also be used.
- [a] Joint sawing and sealing—As with conventional paving, the joints are sawed as soon as the concrete has gained sufficient strength to allow sawing without raveling. Transverse joints are sawed first, using conventional equipment. A gang of concrete saws spaced along a guide bar is used to saw the longitudinal joints (Figure 4). All joints are sealed following conventional practice. In Colorado, the standard practice for joint sealing is to make a single saw cut and to seal with a silicone sealant (Ardani 2006). When multiple lanes are paved separately, it is recommended that transverse joints in the new lane be sawed first at locations that match the cracked joints in the previously placed adjacent lane. This will eliminate the risk of secondary cracking.

The Colorado TWT projects have also demonstrated that with proper planning, TWT can be constructed with minimal disruption to traffic.

Figure 4. Longitudinal joint sawing (Lowery 2005).

COST

CDOT conducted a detailed life-cycle cost (LCC) analysis of TWT to determine if TWT could be justified on the basis of cost (Lowery 2005). The results showed that the cost of TWT is similar to a program of periodic AC overlays based on project cost alone. Considering only the agency cost, the LCC of TWT was only 1 percent more than the AC overlay option. With such a small difference, the LCCs of the two options were considered equivalent. The LCC model assumed that the AC overlay option would require rehabilitation every 10 years with 50-mm (2-in.) AC, which has been the experience in Colorado. For TWT, a 20-year service life was assumed with one grinding, 10 mm (0.375 in.) deep, for smoothness. When user costs are considered, the TWT becomes a more attractive rehabilitation strategy, owing to its longer service life and low maintenance requirements. With consideration of user-delay costs, the LCC of TWT was

11 percent less than the AC overlay option (Lowery 2005).

CASE STUDIES

SH 121, Wadsworth Boulevard (Sullivan 2005)
This section of SH 121 is a four-lane, divided roadway in an urban area with a relatively high traffic count. The average daily traffic (ADT) at the time of the whitetopping (2001) was 30,000 vehicles per day (vpd), with a design ADT for the year 2020 of 40,000 vpd and 3.4 percent trucks. A major concern of CDOT on this project was the volume of traffic carried on the road. TWT helped to minimize traffic interruptions by expediting the construction, as well as by providing a pavement that has a long service life with low maintenance requirements. Compared to complete reconstruction, the construction time was significantly reduced by utilizing the existing asphalt as a base layer.

The design of the TWT for the Wadsworth Boulevard project included a 150-mm-thick (6-in.) concrete overlay and 1.8-m (6-ft) joint spacing in both directions, placed over the existing AC pavement after milling. The project included all four lanes of a 5.6-km (3.5-mi) stretch of SH 121, including two major intersections and many horizontal and vertical curves in the highway geometry. A total of 130,000 m^2 (155,400 yd^2) of TWT was placed in 67 days. A fast-track mix that provided a compressive strength of 17 MPa (2,500 psi) in 24 h was used for intersection paving. The TWT was constructed full width, 11.5 m (38 ft), over the length of the project. The intersections were constructed in three separate 24-h closures. Extensive use of public relations and message boards was a key part of informing the public of closures, and it resulted in positive comments on how fast and efficiently the project was completed. Views of the TWT construction are shown in Figures 5 and 6.

Figure 5. Placing concrete and applying curing compound on SH 121.

Figure 6. Cleaning (air blasting) joints prior to applying joint sealant on SH 121.

SH 83, Parker Road (Allen 2005)
Constructed in 2004, this project involved rehabilitation of a 3-km (1.9-mi) section of a six-lane, urban highway. TWT was selected based on LCC analysis. The overlay is 150 mm (6 in.) thick, and the joints were sawed at 6-ft (1.8-m) intervals in both directions. This section of SH 83 is part of a heavily traveled corridor serving southeast metropolitan Denver, with an ADT of 52,000 vpd. CDOT considered user costs a high priority and specified 75 working days for project completion. Project specifications contained provisions for an early completion incentive of $5,000 per day up to $50,000. The roadway

Figure 7. Phased construction of thin whitetopping on State Highway 83 (Allen 2005).

Figure 8. Completed thin whitetopping on SH 83 (Allen 2005).

was returned to its normal six-lane configuration in 65 working days, and the contractor earned the entire incentive. A total of 90,100 m^2 (107,775 yd^2) of TWT was placed.

Construction phasing and traffic control presented a major challenge for this project. Project specifications required maintaining two lanes of through traffic in each direction and access to all businesses and residences throughout construction. To satisfy these requirements, the project was built in two major phases, with end crossovers and head-to-head traffic separated by painted lines and tubular channelizing devices (Figure 7). Speeds were reduced to 72 km/h (45 mi/h) during construction. Major intersections were also constructed in two phases. The specifications allowed full closure of intersections from 7:00 p.m. Friday until 5:30 a.m. the following Tuesday. High-early-strength concrete was used to further reduce the time that intersections were closed. A view of the completed project is shown in Figure 8.

SUMMARY

TWT is a relatively thin concrete overlay that is bonded to the underlying AC pavement. In Colorado, TWT was developed and is used as a low-maintenance, long-life alternative to an AC overlay for more heavily trafficked roadways. Since June 1990, CDOT has constructed numerous test sections and conducted studies to develop and refine guidelines for constructing TWT. The CDOT guidelines for TWT include lessons learned from extensive field trials, as well as research findings.

Economic analysis conducted by CDOT showed that TWT is competitive on project cost alone. With proper planning, TWT can be constructed with minimal disruption to traffic. TWT has been a very successful innovation for CDOT, and Colorado continues to use TWT on a competitive basis for rehabilitation of distressed asphalt pavements.

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Other Resources on Thin Whitetopping

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Distribution—This TechBrief is being distributed according to a standard distribution. Direct distribution is being made to the Resource Centers and Divisions.

Availability—This document is based on the papers authored by Colorado DOT staff and included in the *Proceedings, International Conference on Best Practices for Ultrathin and Thin Whitetoppings*, held in Denver, Colorado, April 2005.

Key Words—Asphalt pavement, concrete pavement, pavement design, pavement construction, pavement rehabilitation, thin whitetopping.

THE CONCRETE PAVEMENT TECHNOLOGY PROGRAM

The Concrete Pavement Technology Program (CPTP) is a national program of research, development, and technology transfer that operates within the Federal Highway Administration (FHWA) Office of Pavement Technology.

The CPTP includes some 30 research and demonstration projects, each of which is delivering products for improved design, construction, repair, and rehabilitation of concrete pavements.

The focus areas for the CPTP include advanced designs, optimized concrete materials, improved construction processes, rapid repair and rehabilitation, and user satisfaction. The CPTP continues to produce implementable products that result in safer, smoother, quieter, and longer lasting concrete pavements. Longer lasting pavements, in turn, contribute to FHWA's success in the areas of safety, congestion mitigation, and environmental stewardship and streamlining.

Technology transfer of products resulting from the CPTP is being accomplished under CPTP Task 65. This 5-year activity was initiated in September 2003 and is overseen by an Executive Expert Task Group (ETG) that includes State department of transportation (DOT) chief engineers and representatives from industry and academia.

An Engineering ETG, made up of pavement and materials engineers from State DOTs, FHWA field offices, plus representatives from industry and academia, reviews the technical aspects of CPTP products.

These products include:

- Guidelines / Technical briefs
- Test protocols / Draft specifications
- Software
- Workshops / Conferences
- Presentations / Videos
- Field demonstrations
- Equipment loans

The delivery of CPTP products, in workshops and other formats, is tailored to meet the needs of each State DOT and its related industry groups. For more information, please contact:

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