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

Precast Prestressed Concrete Pavement for Reconstruction and Rehabilitation of Existing Pavements

This TechBrief describes the application of precast prestressed concrete pavement for new construction and for rehabilitation of existing asphalt and concrete pavements. The background of the development of precast prestressed pavement technology is briefly summarized. The details of several field trials of this innovative technology are presented, and recommendations for ensuring successful precast prestressed concrete pavement installation are provided.

BACKGROUND

Precast pavement technology comprises new and innovative construction methods that can be used to meet the need for rapid pavement repair and construction. Precast pavement components are fabricated or assembled off-site, transported to the project site, and installed on a prepared foundation (existing pavement or re-graded foundation). The system components require minimal field curing time to achieve strength before opening to traffic. These systems are primarily used for rapid repair, rehabilitation, and reconstruction of both asphalt and portland cement concrete (PCC) pavements in high-volume-traffic roadways. The precast technology can be used for intermittent repairs or full-scale, continuous rehabilitation.

In *intermittent repair* of PCC pavement, isolated full-depth repairs at joints and cracks or full-panel replacements are conducted using precast concrete panels. The repairs are typically full-lane width. The process is similar for full-depth repairs and full-panel replacement. Key features of this application are slab panel seating and load transfer at joints. An FHWA TechBrief (Tayabji and Hall 2008) describes the application of this technology.

In *continuous applications*, full-scale, project-level rehabilitation or reconstruction of both asphalt and PCC pavements is performed using precast concrete panels. One technology developed for continuous applications is precast prestressed concrete pavement (PPCP). It is based on the experience gained from several cast-in-place prestressed concrete pavement projects constructed during the 1980s in the United States (Tayabji et al. 2001).

Use of precast concrete pavements for reconstruction and rehabilitation is a very viable alternative to conventional cast-in-place concrete pavement construction, especially in situations where high traffic volumes and consideration of the delay costs to users due to lane closures favor reconstruction and rehabilitation solutions that allow expedited opening to traffic. Precast concrete also offers the advantage of being "factory made" in a more controlled environment than cast-in-place construction and thus is potentially more durable and less susceptible to construction and material variability.

FHWA CPTP Initiative.
Recognizing the need for effective, rapid rehabilitation methods, the Federal Highway Administration (FHWA), through its Concrete Pavement Technology Program (CPTP), and the Texas Department of Transportation (TxDOT), sponsored a study during the late 1990s that investigated the feasibility of using a precast prestressed concrete system for pavement rehabilitation. At the conclusion of the study, performed by the Center for Transportation Research at the University of Texas at Austin, a concept for PPCP was developed (Merritt et al. 2001). Under this concept, a series of individual precast panels are post-tensioned together in the longitudinal direction after installation on site. Each of the panels may also be pretensioned in the transverse direction during fabrication.

In 2001, TxDOT constructed the first PPCP pilot project along a frontage road near Georgetown, Texas. Since then, FHWA has been actively promoting the implementation of the PPCP system to State DOTs and is providing engineering support and funding to State DOTs in a series of demonstration projects to advance the use of PPCP (Merritt and Tyson 2006).

THE PRECAST PRESTRESSED CONCRETE PAVEMENT SYSTEM

The basic precast prestressed pavement concept consists of a series of individual precast panels that are post-tensioned together in the longitudinal direction after installation on site. Each panel can be pretensioned in the transverse direction (long axis of the panel) during fabrication, and ducts for longitudinal post-tensioning are cast into each of the panels. The basic features (typical) of the PPCP system are as follows:

1. Panel size: up to 38 ft (11.6 m) wide, typically 10 ft (3 m) long, and 7 to 8 in. (178 to 203 mm) thick (or as per design).
2. Panel types:
   a. Base, joint, and central stressing panels (as originally developed).
   b. Base and joint stressing panels (as installed at a demonstration project in Missouri).
3. Tongue-and-groove transverse epoxied joints.
4. Post-tensioning details:
   a. 0.6-in. (15 mm) diameter 7-wire monostrand tendons, typically spaced at 24 in. (600 mm).
   b. Tendon load: 75 percent of ultimate tendon load, typically.
   c. Prestress force: sufficient to ensure about 150 to 200 lbf/in^2 (1.0 to 1.4 MPa) residual prestress at the mid-point of each series of prestressed panels.
   d. Grouted post-tensioning ducts.
5. Expansion joint spacing: ~ 250 ft (76 m), typically.
6. Base type:
   a. Hot-mix asphalt concrete base with polyethylene sheet over base or asphalt concrete interlayer in the case of an overlay application.
   b. Permeable base (as used in the Missouri demonstration project).
   c. Lean concrete base (as used in the California demonstration project).
   d. Aggregate base (as used in the Iowa demonstration project).
7. Injection of bedding grout to firmly seat panels (after post-tensioning).

Figure 1 illustrates the design concept underlying this precast pavement technology. The base panels make up the majority of the post-tensioned pavement section and are placed between the joint panels and central stressing panels, if used. All of the panels have continuous tongue-and-groove keyways along the transverse face of the panels (see figure 2). The joint panels are located at the ends of

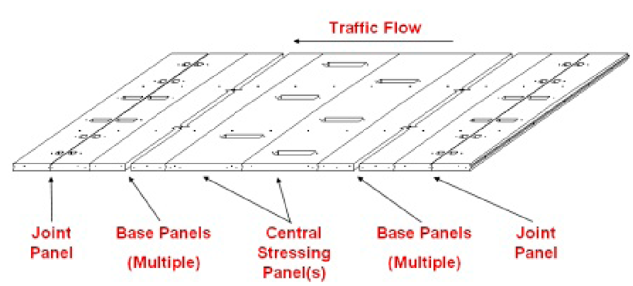

Figure 1. PPCP design details and panel types.

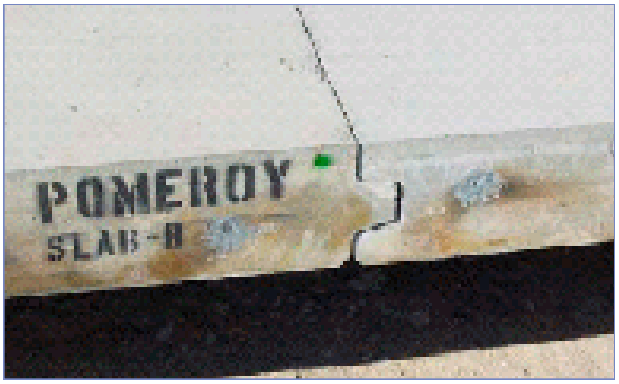

Figure 2. Tongue-and-groove keyway.

Figure 3. PPCP panel being placed over polyethylene sheet placed over a base.

each post-tensioned section of pavement. The joint panels contain dowelled expansion joints that allow the expansion and contraction movements of the post-tensioned section. The joint panels also contain the post-tensioning anchorage for the longitudinal post-tensioning tendons. The anchors are cast into the joint panels on either side of the expansion joint. Blockouts or pockets cast into the joint panels provide access to the post-tensioning anchors. Figure 3 shows the placement of a panel on a prepared base.

When the central stressing panels are used, the post-tensioning strands are fed into the ducts at the large blockouts cast into the central stressing panels. Strands are fed in either direction from each blockout down to the anchors in the joint panels. The strands from either side of the blockout are then coupled together and tensioned. The post-tensioning can also be applied at the joint panels without use of the central stressing panels. At the Missouri project, discussed later, post-tensioning was performed at the joint panels.

PAVEMENT DESIGN CONSIDERATIONS

The following factors need to be considered:

1. The PPCP systems require placement of the panels on a smooth base or interlayer to ensure that the friction between panel and base is as low as possible. Otherwise, a larger portion of the prestressing force is consumed in overcoming this friction.

2. The PPCP base and the foundation need to be of high quality and stiff to minimize slab deflections at the expansion joint.

3. The PPCP can be designed to achieve a minimum residual prestress of about 150 to 200 lbf/in^2 (1.0 to 1.4 MPa) at mid-length of the series of post-tensioned slabs. This residual prestress adds to the concrete's flexural strength and allows use of PPCP systems that are about 3 to 4 in. (75 to 100 mm) less in thickness than conventional concrete pavements for the same traffic loading and environmental conditions.

4. The PPCP systems can be designed to incorporate expansion joints at 250 to about 400 ft (50.8 to 76.2 m). The longer joint spacing requires use of more prestressing tendons (more prestressing force) to balance the higher prestress losses due to longer prestressing lengths involved. The prestress losses are due to panel/base friction, tendon friction, steel relaxation, and concrete creep and shrinkage.

5. The prestressing tendon size (diameter) and spacing should be selected to achieve the desired stress level at slab ends and at mid-length of the post-tensioned panels. The U.S. experience is based on use of 0.6 in. (15 mm) diameter, Grade 270 7-wire stress-relieved tendons for highway applications.

6. The AASHTO (2004) mechanistic–empirical design procedure can be used to determine the required thickness of the PPCP using only the "fatigue cracking" distress criteria. The flexural strength used should be the concrete's flexural strength plus the residual prestress at mid-length of the post-tensioned series of the panels.

7. The expansion joint should be designed to allow for large slab end movements (typically 2 to 3 in. [51 to 76 mm], depending on environmental conditions) and to provide desired load transfer across the wider joints.

PANEL FABRICATION AND INSTALLATION CONSIDERATIONS

PPCP panels are typically mass-produced in advance of the installation and therefore require storage space at the fabrication plant or at a staging area for the project. Typically, the panels are transported from the plant directly to the project site, minimizing intermediate handling. The panels may weigh about 15 to 18 T (13,608 to 16,329 kg) each and therefore require a heavy mobile crane at the project site to lift them off the trucks and onto the prepared base. As the panels are installed, partial prestressing is applied to position each panel in proper alignment with the previously placed panel and to ensure tight epoxy-bonding of the tongue-and-groove joints. The installation steps are summarized below:

1. Prepare base or interlayer if an overlay application.
2. Place polyethylene sheet over the base/interlayer.
3. Install the joint panel and successive base and central prestressing panels, as required.
4. As each panel is installed, apply epoxy to the tongue-and-groove faces of adjacent panels.
5. Apply partial post-tensioning to each successively placed panel to ensure a tight fit at the tongue-and-groove transverse joints and to align the panels in correct position.
6. When all panels to be post-tensioned are in place, thread the tendons through the tendon ducts and apply the designated prestressing force at each tendon. The prestressing force may be applied at the central stressing panel or at each end joint panel (design option).

THE TEXAS PILOT PROJECT

The first PPCP project was constructed in Georgetown, Texas, during 2001 (Merritt 2001). Texas DOT placed approximately 2,300 ft (700 m) of two-lane pavement (plus shoulders) on the frontage road along I-35. The project layout and panel systems used are shown in figure 4. The project details are as follows:

Constructed: Fall 2001

Project location: Northbound I-35 frontage road near Georgetown, Texas

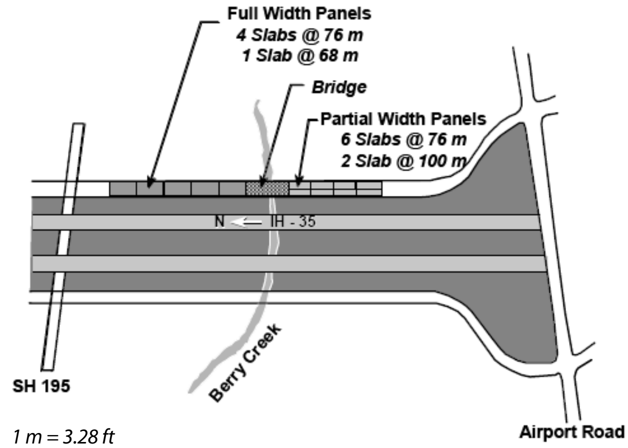

Figure 4. Georgetown PPCP project layout.

Project length: 2,300 ft (701 m) (2 lanes plus shoulders)

Panel dimensions: 10 ft x 36 ft (3.1 m x 11.0 m), 10 ft x 20 ft (3.1 m x 6.1 m), and 10 ft x 16 ft (3 m x 4.9 m)

Panel thickness: 8 in. (200 mm)

Number of panels: 339

Number of post-tensioned sections: 7 at 250 ft (76.2 m), 1 at 225 ft (68.6 m), 1 at 325 ft (99.1 m)

Panel installation rate: 25 panels/6 hours

Features: Both full-width and partial-width construction. Project was the first application of precast prestressed concrete pavement on a large scale.

For this project, it was decided to use both full-width (36 ft [11 m]) and partial-width (16 ft and 20 ft [5 m and 6 m]) panels for the frontage road to test the concept for partial-width panel construction. The partial-width panels were tied together transversely through post-tensioning with an additional post-tensioning duct cast into each of the partial-width panels. The precast, pretensioned panels were placed over a well-finished hot-mix asphalt leveling course overlain with polyethylene sheets and then post-tensioned together in the longitudinal direction. The tongue-and-groove connection at the transverse joints ensured satisfactory vertical alignment during installation. The installation of the PPCP system is shown in figure 5.

As the contractor became more familiar with the construction process, approximately 25 panels—equaling 250 ft (76 m) of pavement—were installed

Figure 5. Installation of the precast prestressed concrete pavement system in Georgetown, Texas.

in a 6-hour period. Texas DOT found that post-tensioning, completed after the panels were installed, generally took just a few hours for each section of pavement. Aside from demonstrating the efficacy of placing the slabs on grade, the Georgetown project demonstrated the viability of post-tensioning the panels together in place. The project also showed that match-casting, which is commonly used for precast segmental bridge construction, was not required to ensure a tight fit between panels and to align the post-tensioning ducts. Because match casting is not necessary, the manufacturer can fabricate the panels faster, and shipment and installation are simplified.

The Georgetown pilot project presented many challenges for precast pavement implementation (Merritt 2001). The most difficult aspect of the project was considered to be the meshing of precast concrete and concrete pavement specifications. This required flexibility on the part of both the precast supplier and Texas DOT. This pilot project also represented unknown territory for the contractor, precast supplier, and Texas DOT. Flexibility and a willingness to develop new techniques on the part of all parties were essential for the success of this project. After almost 7 years (as of November 2008), the project is performing well and no maintenance-related issues have been reported.

THE CALIFORNIA DEMONSTRATION PROJECT

The Caltrans demonstration project used the PPCP system as a part of the widening project on I-10 to provide high-occupancy vehicle lanes and reduce traffic congestion. Most of the construction work was completed at night. The construction added 27 ft (8 m) of traffic lanes and 10 ft (3 m) of shoulder to the existing lanes on the eastbound direction. The project details are as follows:

Constructed: April 2004

Project location: Eastbound I-10, El Monte, California

Project length: 248 ft (76 m) (2 lanes plus shoulder)

Panel dimensions: 8 ft x 37 ft (2.4 x 11.3 m)

Panel thickness: 10 to 13 in. (254 to 330 mm)

Number of panels: 31

Number of post-tensioned sections: 2 at 124 ft (37.8 m)

Panel installation rate: 15 panels/3 hours

Features: Nighttime construction. Change in cross slope cast into the panel surface.

Photographs of the installation are shown in Figure 6. The project was located on a section of the Interstate that had no change in vertical curvature and very minimal horizontal curvature. The longitudinal geometry of the pavement was simple, but the pavement cross section was more complex, with a change in cross slope from 1.5 percent in the traffic lanes to 5 percent in the shoulders, which required variable thickness in the panel.

THE MISSOURI DEMONSTRATION PROJECT

The Missouri DOT evaluated the feasibility of using the PPCP as an alternative solution for rapid pavement construction and rehabilitation. The project details are as follows:

Completed: December 2005

Project location: Northbound I-57 near Sikeston, Missouri (~ 10 mi (16 km) north of I-55/I-57 interchange)

Figure 6. PPCP installation along I-10 in El Monte, California.

Project length: 1,010 ft (307.9 m) (2 lanes plus shoulders)

Panel dimensions: 10 ft x 38 ft (3.0 m x 11.6 m)

Panel thickness: 5.75–11 in. (146–280 mm)

Number of panels: 101

Number of post-tensioned sections: 4 at 250 ft (76.2 m)

Panel installation rate: 12 panels/6 hours

Features: Pavement crown cast into the panel surface. Noncontinuous keyways between panels

The existing pavement was a jointed reinforced concrete pavement with 61.5-ft (18.8 m) joint spacing. The cross section consisted of an 8-in. (203 mm) slab resting on a 4-in. (102 mm) granular base. The new PCPP cross section consists of a concrete slab of variable thickness ranging from 10.9 in. (275 mm) at the peak crown to 7 in. (178 mm) at the edge of the inside shoulder and 5.6 in. (142 mm) at the edge of the outside shoulder. The variable thickness was necessary to accommodate the 2 percent crown. The PCPP slab rests on a 4-in. (102 mm) permeable asphalt base. The panels were fabricated in Memphis and transported to the project site, a distance of over 200 miles (320 km). Two panels were fabricated each day. Figure 7 illustrates the construction process of the precast panels.

A few panels exhibited full-depth hairline longitudinal cracking at the fabrication plant. It is believed that the panels may have experienced "thermal shock" during removal of the panels from the forms. The temperature and strain data collected during the fabrication process did indicate high and rapid changes in concrete temperature during fabrication.

THE IOWA DEMONSTRATION PROJECT

During August–September 2006, the Iowa DOT installed precast bridge approach slabs on SR 60 near Sheldon. This was a new bridge construction, and therefore no traffic closure restriction was needed during installation. The approach slabs were tied to the bridge abutments as part of an integral approach slab. The approach slab panels were designed to accommodate a 30-degree bridge skew. The project details are as follows:

Constructed: August–September 2006

Project location: Highway 60 near Sheldon, Iowa

Project size: 4,307 ft^2 (400 m$^{2)}$ (2 approach slabs, each ~77 ft (23.5 m) long and 2 lanes wide)

Number of panels: 12 typical panels, 4 skewed panels

Panel dimensions: Typical panels: 14 ft x 20 ft (4.3 m x 6.1 m); skewed panels: 14 ft x variable length (8.8–25 ft [4.3–7.6 m])

Panel thickness: 12 in. (305 mm)

Number of post-tensioned sections: 2 at ~77 ft long x

Figure 7. Installation of the precast panels at the Missouri project (left, staging of trucks and installation crane; center, final post-tensioning; right, completed project).

Figure 8. Installation of the PPCP bridge approach on SR 60 (left and center, installation of precast bridge approach slab; right, completed approach slab).

28 ft wide (23.5 m long x 8.5 m wide)

Panel installation rate: ~15 minutes/panel

Features: First use of precast prestressed concrete pavement for bridge approach slabs. Two-way post-tensioned partial-width panels.

The precast panels were placed on a granular base. Partial-width, rather than full-width, precast panels were utilized to simulate lane-by-lane construction for future applications. Longitudinal post-tensioning was completed from the ends of each approach slab, while transverse post-tensioning was completed from the outside edge of the pavement. The installation and completed project are shown in figure 8.

THE DELAWARE DEMONSTRATION PROJECT

During early 2009, the Delaware DOT will be using the PPCP system to rehabilitate pavement along northbound Route 896 at the approach to the intersection with Route 40 (left and right turn lanes). The design includes PPCP panels 8 in. (203 mm) thick over a 4-in. (102 mm) pervious concrete base. The panels will be 10 ft (3 m) long and 24 ft (7.3 m) wide. The DOT plans to have the 3,115 yd^2 (2,848 m^2) of PPCP installed using restricted working hours of 7:30 p.m. to 5:30 a.m., Sunday evening through Friday morning.

SUMMARY

As discussed above, precast concrete pavement technology is ready for implementation. With respect to continuous applications, both generic and proprietary systems are available (see sidebar below). The short-term performance of the installed PPCP systems indicates that PPCP systems can provide rapid

INDUSTRY INITIATIVES

Parallel to FHWA's efforts, several organizations in the United States initiated independent development activities to refine precast concrete pavement technologies. These technologies have certain proprietary features and require licensing for product use. Privately developed technologies include the following:

1. The Fort Miller Super Slab system. For information, contact Peter J. Smith (psmith@fmgroup.com) or Michael Quaid (mquaid@fmgroup.com).

2. The Uretek Stitch-in-Time system. For information, contact Mike Vinton (mike.vinton@uretekusa.com).

3. The Kwik Slab system. For information, contact Malcolm Yee (info@kwikslab.com).

Since about 2001, the Fort Miller system has been used on several production projects (continuous and intermittent) for repair and rehabilitation applications. In continuous application, this system simulates conventional jointed plain concrete pavement sections. The Kwik Slab system has been used on a limited basis in Hawaii. This system simulates long jointed reinforced concrete pavement sections. In addition to the proprietary precast concrete pavement systems, generic systems have also been used and are under development.

reconstruction and rehabilitation that will be durable. While precast pavements may have a higher first cost, the rapid installation that minimizes lane closures and the long-term durability can easily offset the higher initial costs.

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