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FINAL REPORT

Precast Concrete Pavement Technology Implementation

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16. Abstract

Repair and rehabilitation of the aging highway infrastructure continues to be a challenging endeavor for all U.S. highway agencies. Thousands of miles of highway pavements need rehabilitation, and many of these highways carry over 100,000 vehicles/day, including a large percentage of trucks. Extended lane closures must be avoided to prevent compounding congestion—which means rehabilitation work must be completed rapidly. While many projects have been completed using rapid-setting concrete, results have been inconsistent. Precast concrete pavements (PCPs) have been shown to be promising alternatives. The production use of PCP has come a long way over the last 17 years. The technology is gaining wider acceptance in the U.S. for rapid repair and rehabilitation of concrete pavements as well as for heavily trafficked asphalt concrete pavements and intersections. Several U.S. highway agencies have implemented the PCP technology, and other agencies have constructed demonstration projects. In the U.S., the PCP technology is being used for intermittent repairs (full-depth joint repairs or full panel replacement) and for continuous applications (longer length/wider area rehabilitation) with service life expectations of at least 20 years for intermittent repairs and at least 40 years for continuous applications, without significant future corrective treatment.

The Strategic Highway Research Program 2 (SHRP2) Project R05 was conducted from 2008 to 2012 to develop technical information and guidelines that would encourage the rapid and successful adoption of PCP technology. In 2013, the Federal Highway Administration (FHWA) created and managed the SHRP2 Implementation Assistance Program (IAP) to help State highway agencies, metropolitan planning organizations, and other interested organizations deploy SHRP2-developed products to deliver more efficient, cost-effective solutions to meet the complex challenges facing transportation agencies. During 2013, FHWA awarded a technical support contract to support FHWA's efforts to promote wider implementation of PCP by highway agencies.

This report summarizes the current state of the PCP technology and also provides details of the technical assistance provided under the FHWA technical support contract.

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ABBREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt concrete
ARA	Applied Research Associates, Inc.
CRC	Continuously reinforced concrete
DOT	Department of Transportation
ETG	Expert task group
FHWA	Federal Highway Administration
IAP	Implementation Assistance Program
LADOTD	Louisiana Department of Transportation and Development
PCC	Portland cement concrete
PCP	Precast concrete pavement
SHRP2	Strategic Highway Research Program 2
TRB	Transportation Research Board

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INTRODUCTION

Precast concrete pavement (PCP) technology is gaining wider acceptance in the United States for rapid repair and rehabilitation of concrete pavements, as well as for reconstruction of heavily trafficked asphalt concrete intersections. Widespread use in the U.S. is fairly recent, with most projects in service less than about 14 years. Nonetheless, dozens of projects have been constructed, and advances continue to be made in all aspects of the technology, including panel design, fabrication, and installation. PCP technology is being used for intermittent repairs (both full-depth repairs and full panel replacement) and for continuous applications (longer-length/wider-area rehabilitation) with service life expectations of at least 20 years for repairs and at least 40 years for continuous applications, without significant future corrective treatment.

Available PCP systems include jointed PCP with reinforced or prestressed panels installed singly or in a continuous series, as well as PCP that typically incorporates thinner reinforced or prestressed panels installed and posttensioned in a continuous series, resulting in fewer joints. The use of PCP technology can significantly reduce the impacts that roadway repair and reconstruction projects have on traffic, particularly on heavily traveled routes. The technology is applicable to small segments, enabling flexibility in construction phasing, and for use in corridor-wide pavement rehabilitation and reconstruction. A review of projects constructed in the U.S. and field testing of selected projects has shown that sufficient advances have been made to reliably design and construct PCP systems to achieve five key attributes of successful pavements:

- Constructability – Techniques and equipment are available to ensure acceptable production rates for the installation of PCP systems.
- Concrete durability – Plant fabrication of precast panels results in excellent concrete strength and durability.
- Load transfer at joints – Reliable and economical techniques are available to provide effective load transfer at transverse joints in both jointed and prestressed PCP systems.
- Panel support – Techniques to provide adequate and uniform base support conditions are available and continue to be improved.
- Performance/efficiency – PCP panels can be thinner than equivalent cast-in-place concrete pavement slab and last longer because of prestressing and/or reinforcing elements in the PCP systems.

The use of both jointed PCP and posttensioned PCP systems has advanced during the last decade due to a combination of work sponsored by the Federal Highway Administration (FHWA), projects constructed by highway agencies, and innovations by the highway agencies and the construction industry.

During 2008, Strategic Highway Research Program 2 (SHRP2) Project R05 was authorized and funded to develop the necessary information and guidelines that would help encourage the rapid and successful adoption of the new PCP technologies. Under Project R05, the project team reviewed the state of PCP practice, identified gaps in technology, evaluated the performance of constructed PCP projects, interacted with stakeholders, and developed best practices guidelines for project selection and PCP system approval, and for design, fabrication, and installation of

PCP systems. In addition, the project team identified refinements and new applications to advance the implementation of PCP technologies. The Project R05 study, completed in 2012, demonstrated that the PCP technology is ready for wider implementation and that PCP systems available in the U.S. can meet the needs of highway agencies for rapid renewal of their highway systems.

The FHWA, as part of its congressionally mandated role to improve mobility on our nation's highways through national leadership, innovation, and program delivery, has been actively involved in supporting the implementation of PCP technology and is currently supporting wider implementation of PCP technology as part of the SHRP2 Implementation Assistance Program (IAP). The IAP consists of the following two components:

- The FHWA and Applied Research Associates, Inc. (ARA), under FHWA Contract No. DTFH61-13-C-00028, provided technical assistance in the form of guidance, workshops, and peer-to-peer assistance to key highway agency personnel for PCP project selection, design, and construction.
- Project funding was provided to several highway agencies to be applied to the cost of construction of a PCP project and to support in-house training that would lead to agency-wide implementation of the PCP technology.

Contract Scope

The overall scope of the contract involved timely and cost-effective deployment, delivery, and implementation of products developed under the SHRP2 Project R05 study. The principal recipient and end-user organizations for these products included State and toll highway agencies and others government entities, industry organizations, consultants, contractors, research organizations, and academia. The scope of this project, as defined by FHWA based on the SHRP2 solutions implementation plan, is as follows:

- Provide technical support to a limited number of new users of PCP to mitigate perceived implementation risks.
- Heighten awareness of PCP technologies and dispel misunderstandings.
- Develop PCP training modules targeting the needs of highway agencies for key personnel in design, materials, and construction, as well as administrators and chief engineers.
- Improve PCP technology on a continuing basis through research and testing.
- Educate the contractor community, including concrete precasters and concrete paving companies, to address their role in PCP applications.

This report provides a summary of the PCP technology, focused on jointed PCP applications and a summary of activities performed under the FHWA contract, from October 2013 to April 2019.

OVERVIEW OF PCP TECHNOLOGY

Since 2001, several U.S. highway agencies have implemented the PCP technology, and other agencies have constructed demonstration projects. The use of PCP in the U.S. is shown in Figure 1. As shown in the figure, several highway agencies routinely use PCP and have constructed projects requiring several hundreds to several thousand panels. Several other highway agencies have constructed demonstration projects to become familiar with the PCP technology.

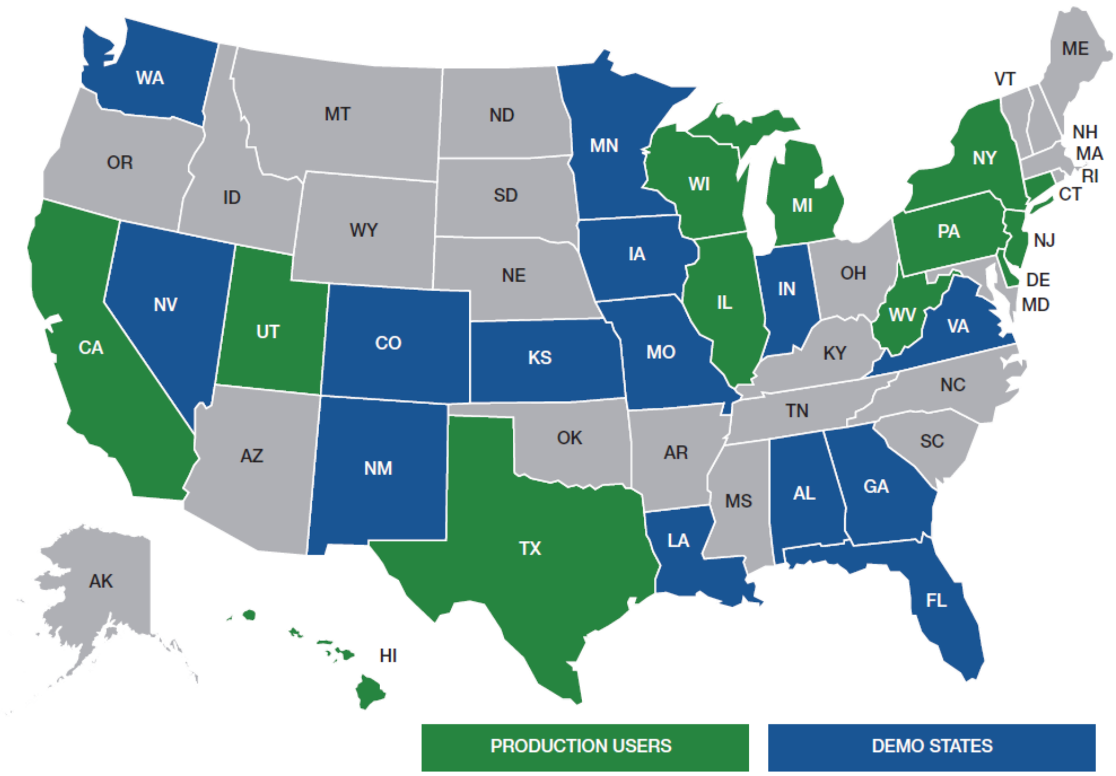


Figure 1. Map. Use of precast concrete pavement in the U.S. as of January 2019.

Precast concrete pavement can be defined as follows:

> PCPs incorporate precast concrete panels that are fabricated or assembled off-site and cured off-site until the concrete has reached the desired strength. The panels are then transported to the project site and installed over a prepared foundation (new or re-graded existing base). The pavement components require minimal field curing or time to achieve strength before opening to traffic. PCPs are primarily used for rapid repair, rehabilitation and reconstruction of asphalt and concrete pavements where work can only be done during night-time short lane closures, typically from about 8 p.m. to about 5 a.m. the next morning.

PCP Applications

PCPs are used for intermittent (localized) repairs and for continuous applications. The intermittent repairs are for full-depth repairs at joints and cracks or for full slab replacement, as shown in Figure 2. Continuous applications of PCP, as shown in Figure 3, include reconstruction of distressed freeway lanes, ramps, and busy intersections.

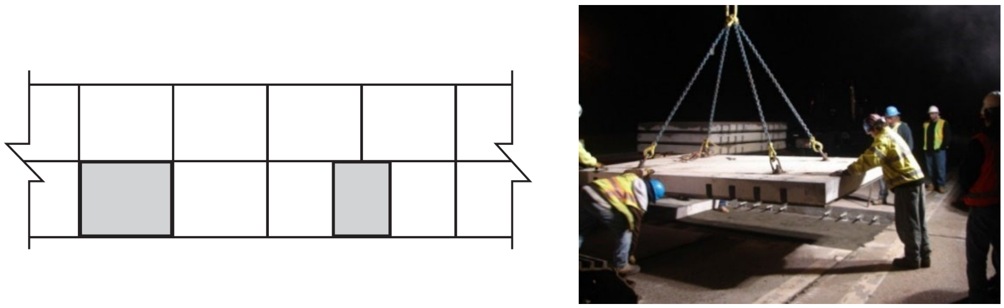


Figure 2. Diagram and photo. Examples of intermittent repairs.

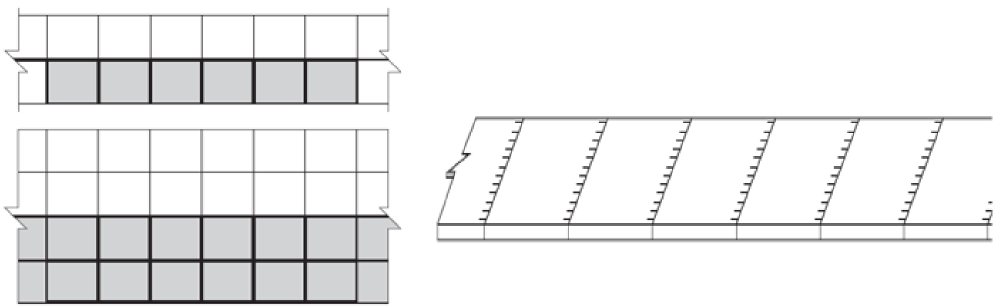


Figure 3. Diagrams. Examples of continuous application of PCP.

The panels used for PCP may be reinforced or prestressed. As discussed later, several different panel types have been developed and are in routine use, and all panel types are engineered to provide load transfer at transverse joints and to ensure good bedding support over the base.

PCP Technical Considerations

There are several different PCP systems available for intermittent repair and continuous applications. Although these systems may differ with respect to certain aspects of design, fabrication, and installation, they share many common features and requirements. The differences in the systems typically relate to the panel design, primarily how the load transfer is achieved at transverse joints and the provisions for placing the panel over the prepared base (support condition). The key design and construction features for PCP include:

- Concrete requirements.
- Joint spacing.
- Support conditions.
- Load transfer at joints.
- Panel reinforcement and prestressing.
- Panel production and installation rates.

Concrete Requirements

Concrete mixture requirements for PCP panels are similar to those specified by highway agencies for cast-in-place concrete pavements. An advantage of PCP is that early age concrete volume changes associated with drying shrinkage are not a concern, since these effects take place over a smaller panel length and typically before panel installation. In addition, many of the concerns related to cast-in-place concrete, such as hot- or cold-weather placement, placement during rainfall, equipment breakdown, concrete delivery delays, and stop-and-go operations, are not applicable to PCP panel fabrication. Fabrication of panels in well-monitored precast concrete plants is a significant benefit of using PCP. A typical PCP concrete specification should include the following requirements, similar to those used for cast-in-place concrete:

- Concrete strength (at 14 or 28 days):
  - Flexural strength for design purposes—650 psi (4.5 MPa).
  - Compressive strength for acceptance purposes—4000 psi (27.5 MPa).
- Maximum water-cementitious materials ratio—0.45 for pavement exposed to cycles of freezing and thawing, 0.50 for other pavements.
- Air content—As appropriate for the maximum aggregate size used and severity of exposure (climatic region).
- Durability—Concrete must be durable and should not be susceptible to materials-related distress, such as alkali-silica reactivity, sulfate attack, or D-cracking.
- Surface texture.

The strength at stripping the panel from the form is also an important consideration. To maintain daily panel production, precasters generally strive to strip panels at about 16 hours after casting, and the concrete compressive strength at the time of form stripping is required to be at least 2,500 psi (17.2 MPa). In California, many precasters use steam curing to achieve rapid strength gain.

Joint Spacing

Joint spacing is an important design parameter for PCP. For isolated repairs, the transverse pavement joint spacing may be limited by the extent of the repair. For continuous applications, transverse pavement joint spacing is often based on traditional cast-in-place pavement joint spacing but also may be limited by panel fabrication, shipping, and structural performance requirements. Joint spacing details for PCP repair and continuous application include:

- Intermittent repairs—PCP panels used for intermittent applications typically cover a single lane width. The panel dimension in the direction of traffic may range from a minimum of 6 ft (1.8 m) to about 15 ft (4.6 m). The shorter panels are generally used to correct joint-related or crack-related distress.
- Continuous applications—PCP panels used for continuous applications can cover a single lane width, with panel dimensions of about 12 to 13 ft (3.6 to 4.0 m), or a double lane width, with panel dimensions of 24 ft (7.3 m) or more. Panels may also incorporate a shoulder segment. The panel dimension in the direction of traffic is generally 15 ft (4.6 m) for 8- to 10-inch (200- to 250-mm) thick panels, resulting in transverse joint spacing

matching that of typical cast-in-place jointed concrete pavement and which has provided good performance throughout the U.S. PCP joint spacing can increase up to 20 ft (6.1 m) for 10- to 12-inch (250- to 305-mm) thick panels. It is important to note that one panel dimension needs to be less than 12 ft (3.65 m) because of overload permitting requirements. If the panel width is more than 12 ft (3.65 m), then the panel length, including exposed dowel bars, needs to be limited to 12 ft (3.65 m).

Overall Panel Support Condition

For PCP repair or rehabilitation (reconstruction) applications, support alternatives include reusing an existing base or installing a new base. An existing granular base may be reworked, trimmed, graded, and compacted, and a thin bedding material can then be used to level the base grade. If not damaged in the process of removing the existing slab, an existing stabilized base (cement treated soil or lean concrete), may be used as is. It also may be trimmed to accommodate the panel thickness. In either case, a thin bedding layer is needed to provide a level surface for setting the panels. A new base may be needed if it is determined that the existing base will be damaged during existing slab removal or will not serve the long-term needs of the new PCP. This option is common when PCP is used to rehabilitate existing hot-mix asphalt pavements. The new base type may include dense-graded, free-draining granular base, or rapid-setting lean concrete base.

Many PCP applications, particularly in California, have successfully used rapid-setting lean concrete base material. The compressive strength requirements for this material are:

- 500 psi (3.4 MPa) minimum within 1 hour of placement to allow installation of panels.
- 750 psi (5.2 MPa) minimum to 1200 psi (8.3 MPa) maximum at 7 days.

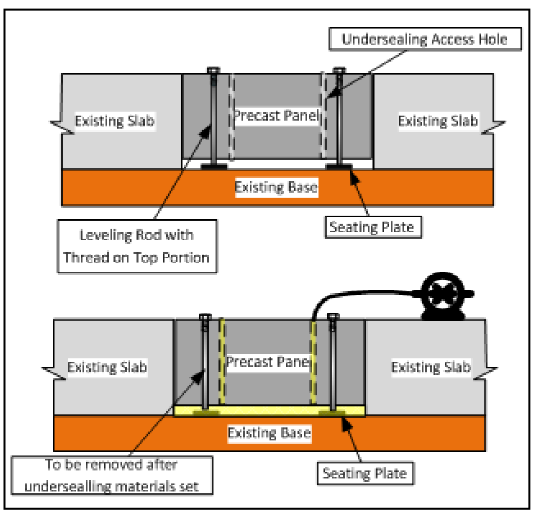
Bedding Layer

The bedding layer (or interlayer) is important to ensure uniform contact between the smooth bottom of a panel and the graded/finished base. The choice of this interlayer material is affected by the way the panels are installed. Panels may be placed directly on grade (grade-placed option) or may be set over a thin layer of bedding grout (grout-supported option) using leveling lifts, as discussed below:

- Grade-placed option—Panels are placed over a thin layer of cemented granular material or cemented sand for grade-placed systems, as shown in Figure 4. The bedding layer is about 1/2 inch (13 mm) and is placed over the graded and compacted base. Because this method provides little means for adjustment, surface grinding of the panels is normally required to meet pavement smoothness requirements at transverse joints.
- Grout-supported option—Under this option, panels are set about ¼ to ½ inch (6 to 13 mm) over the completed base using leveling lifts. Then, a fast-setting flowable cementitious grout is used to fill the gap under the panel, as shown in Figure 5. The grout is introduced through grout ports at the panel surface. The compressive strength requirement for the grout is about 500 psi (3.5 MPa) at the time of opening to traffic and about 3,000 psi (20.7 MPa) at 28 days. A higher 28-day strength is specified in

California. Because the level of the panel surface can be adjusted to match the adjacent pavement and adjacent panels, surface grinding of the panels may not be necessary to meet smoothness requirements at joints.

Figure 4. Photo. Cement-treated bedding layer placement.



a) Schematic

b) Panel leveling lift hardware

Figure 5. Schematic and photo. Grout supported panel placement.

Subsealing

Subsealing is performed when using the cemented granular bedding layer to fill any voids that may exist under the panels. The subsealing material, typically a fast-setting cementitious grout, is free-flowing and is introduced through grout ports at the panel surface. For both subsealing materials, the compressive strength requirement is about 500 psi (3.5 MPa) at the time of opening to traffic.

Load Transfer at Transverse Joints

Load transfer at transverse joints is also an important design feature. Load transfer requirements for jointed PCP systems are similar to the provisions for dowel bar retrofitting in existing concrete pavements. Essentially, load transfer is provided by dowel bars installed in slots or ducts fabricated along one transverse side of a panel. One patented system consists of dowel slots formed in the bottom surface of the panel. Other systems have dowel slots formed in the top surface of the panel. The surface slots typically incorporate a narrow mouth at the surface and may be fully open at the surface or open along a partial length of the slot.

The following techniques/features associated with dowel bar slots are commonly used in the U.S.:

- Dowel bar slots at the panel bottom—This feature is part of a proprietary PCP system and incorporates dowel bar slots at the slab bottom (Figure 6). A flowable, high-strength grout is used to fill the slots and the vertical gap along the transverse joints. Some specifications require filling of the longitudinal joint gap with the dowel slot grout. The slot locations in a panel are fabricated to match the locations of the projecting dowel bars in an existing pavement or a new adjacent panel.

Figure 6. Photo. A PCP panel with dowel bar slots at the bottom.

- Narrow-mouth dowel bar slots at the panel surface (Figure 7)—The slots are about 1 inch (25 mm) wide at the surface and flare out to about 3 inches (75 mm) in width about 1 inch (25 mm) below panel mid-depth. The slots are up to 15 to 18 inches (380 to 460 mm) long for repair application and about 7 to 9 inches (178 to 230 mm) for continuous applications.
    - For repair applications, the dowel bars are placed into the slots just before the slab is placed on the base/bedding. The bars do not project from the panel edge during panel installation. Later, 7- to 9-inch (178- to 230-mm) long predrilled holes in the existing pavement are partially filled with epoxy and the dowels are inserted into the holes by sliding them from the slots in the PCP panel.
    - For continuous applications, dowels are cast into one edge of the panel and the slots are fabricated in the opposite edge. During panel installation, the panel is lowered to about its final elevation and then shifted horizontally so that the dowels advance into the slot in the previously placed panel.

For either application type, the final step is filling the dowel bar slots with grout.

Figure 7. Photos. A repair made using the Illinois Tollway version of surface slot panels.

- A California developed PCP system—In this system, dowel bars are pre-placed in 18-inch (450-mm) long narrow-mouth slot/duct combination. The slot portion is open at the surface (Figure 8). After the panel is installed, the dowel bar is pushed into a 9-inch (225-mm) long circular hole in the adjacent panel or existing slab. The dowel bar slot/ducts are then patched using a fast-setting high strength repair material.

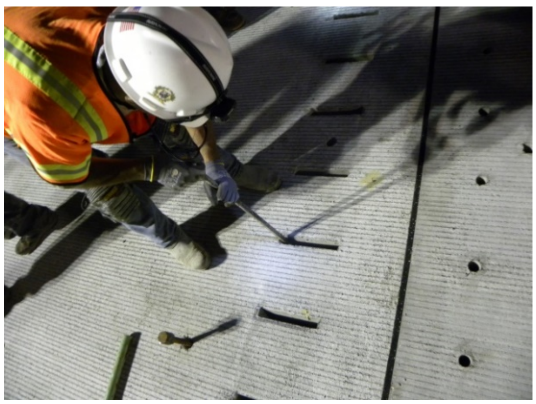


Figure 8. Photo. A panel with partially open narrow slots at the surface.

- California generic teardrop surface slot feature—This system is similar to the system using flared surface slots, but the slot shape may be different. A version of the slot shape is as shown in Figure 9(a). Surface slots are located on one transverse side of each panel, and dowel bars are embedded at the opposite edge. During panel installation, the panel is lowered to about its final elevation and then shifted horizontally so that the dowels advance into the flared bottom portion of the slot in the previously placed panel; see Figure 9(b). The slots are then patched using a fast-setting high strength repair material.

a) Shape of slots b) Panel installation

Figure 9. Photos. California teardrop-shaped surface slots.

Dowel Bar Features

Dowel bars used in highway pavement construction are smooth, cylindrical, solid steel bars. In addition, corrosion protection is typically provided in the form of a fusion-bonded epoxy coating. Dowel bar features critical to long-term PCP performance include:

- Dowel diameter—For precast panels less than 10 inches (250 mm) thick, a dowel diameter of 1-1/4 inches (32 mm) is recommended. For slab thicknesses between 10 and 14 inches (250 and 360 mm), a dowel diameter of 1-1/2 inches (38 mm) is recommended.
- Dowel length—Typical dowel length used in the U.S. for cast-in-place paving is 18 inches (450 mm). However, since precise locations of the dowel bars are known in PCP, the use of 14- or 15-inch (355- to 380-mm) long dowel bars is considered adequate, allowing for embedment of about 7 inches (178 mm) at each side of the joint and accounting for a joint width of up to 1/2 inch (12 mm).
- Dowel spacing—Dowels are typically placed at a spacing of 12 inches (300 mm); however, a cluster of four dowels per wheel path, spaced at 12 inches (300 mm), is considered adequate for both intermittent and continuous applications.

Dowel Bar Slot Patching Material

The dowel bar slots are patched right after the panel installation; that is, during a single lane closure. The joint slot grout or patching material needs to develop strength rapidly. Typical strength requirements are 2,500 psi (13.7 MPa) within 1 hour or by the time of opening the PCP section to early morning traffic. The dowel bar slot grout or patching materials are typically rapid-setting proprietary materials and may be free-flowing cementitious or polymer-based, with or without aggregate.

Panel Reinforcement

To mitigate any cracking that may develop due to lifting and transporting operations, a double mat of reinforcement is typically used for jointed PCP panels. While the reinforcement is not necessary for pavement performance, it will keep any cracks that develop tight, thus extending the service life of the panels. The amount of reinforcement is typically at least about 0.18 percent of the panel cross-sectional area in both directions. For pretensioned panels, a single layer of reinforcement, transverse to the pretensioning strands, is used. All steel used in the precast pavement system must be protected against corrosion. The requirements for steel and steel cover should follow established highway agency practices.

A typical reinforcement arrangement for a jointed PCP panel is shown in Figure 10. Typically, six to eight panels may be fabricated in an indoor plant facility. Views of a long outdoor prestressing bed capable of fabricating over 30 panels per shift are shown in Figure 11.

Figure 10. Photo. Typical reinforcement layout for a precast panel.

Panel Fabrication Considerations

The panels are fabricated in accordance with the approved fabricator shop drawings. Panel fabrication involves the following steps:

1. Setting up the formwork
2. Installing the hardware (reinforcement, prestressing steel and related hardware as per design, lifting inserts, etc.)
3. Provisions for blockouts and grout ports for dowel bars and tiebars or other joint-related devices
4. Provisions for panel undersealing or panel bedding grout ports
5. Placing concrete
6. Finishing concrete and applying surface texture
7. Applying curing compound to the surface
8. Stripping forms, removing dowel and tie-bar slot blockouts, opening up grout ports, etc.
9. Applying curing compound to panel sides
10. Storing panels at the plant, typically for a period of at least 14 days.

Concrete should be produced in accordance with the requirements of ASTM C94 and concrete plants supplying the concrete should be certified by the highway agency or in accordance with the requirements of National Ready Mixed Concrete Association's QC3 checklist.

It should be noted that once panel installation work begins, 15 to 20 panels may be needed per night for repair applications and 40 to 50 panels may be needed for continuous applications. Therefore, a good backlog of panels needs to be fabricated before the panel installation work can begin.

a) View of prestressing bed

b) Panel hardware

c) Concrete placement

Figure 11. Photos. Panel production using long outdoor prestressing beds.

Panel Installation Considerations

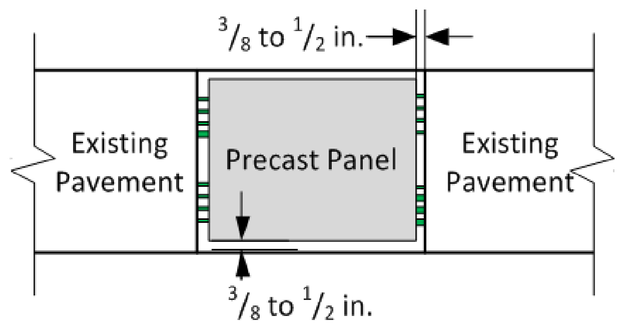
The panel installation rate is one of the most critical factors for considering use of the PCP technology, as it sets lane-closure requirements. The panel installation activities conducted during a given lane closure, typically from about 8 p.m. to about 5 a.m. the next morning, include:

- Removing the existing pavement.
- Drilling and grouting the dowel bars for repair applications (based on system design).
- Preparing the base and bedding layer.
- Placing the panels.
- Underslab grouting for systems using leveling lifts or subsealing.
- Grouting/patching slots.
- Installing transition sections between the PCP and existing pavements. For a given lane closure for continuous application, a temporary transition panel or a dummy panel is used at the end of the PCP installation.

For intermittent repairs located within a given lane closure area, the typical production rate is about 15 to 20 panels per nighttime lane closure. Ideally, two crews are used for repair installations with one crew preparing the repair area, including drilling and epoxy-grouting the dowel bars, and the second crew installing the panels. For continuous applications, a higher panel installation rate per nighttime lane closure can be achieved since work is performed along a longer rehabilitation area. The typical production rate for continuous panel installation is about 40 to 50 panels per night or about 600 to 800 ft (183 to 245 m) of installed length. Greater production can be achieved using longer panels.

Repair Area Considerations

For intermittent repairs, the repair work are needs to be slightly larger than the panel, as shown in Figure 12. This is to allow for the panel to be fitted easily into the work area.



(1 in. = 25.4 mm)

Figure 12. Diagram. Intermittent repair area dimensions.

Continuous Application Considerations

For continuous application, the area to be worked during any lane closure depends on the number of panels to be installed during that lane closure. The work area layout is shown in Figure 13. The longitudinal width of the work area is equal to the panel width plus 1 to 1-1/2 inch (25 to 37 mm). The length of the work area must accommodate the total length of the panels less one panel, plus ¼ to ½ inch (6 to 13 mm) for each transverse joint gap except for the last panel for that night, and for the last panel, the total gap that needs to be available is the panel length plus 1 inch (25 mm) to allow the last panel to fit in easily.

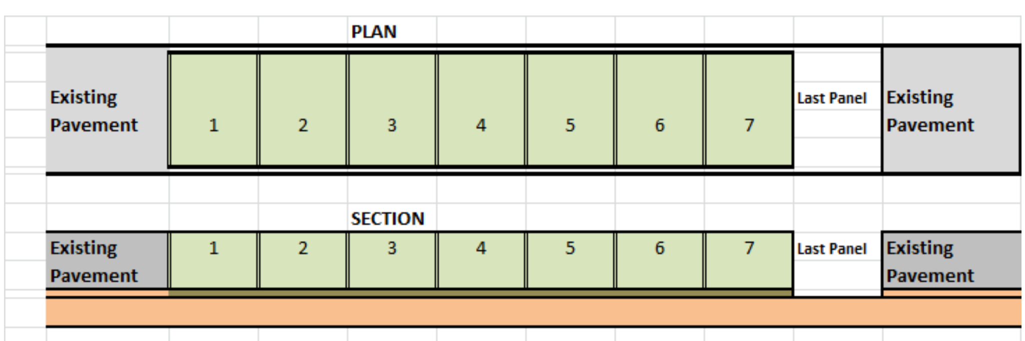


Figure 13. Illustration. Work area for continuous panel placement.

Quality Requirements

Successful PCP projects require proper enforcement of quality during panel fabrication and during panel installation, as follows:

- Materials quality.
    - Granular base material—compaction control.
    - Rapid-setting lean concrete base—compressive strength.
    - Bedding grout—compressive strength using cubes and tested at 1 hour or until 500 psi (3.5 MPa) strength is achieved and also tested at 7 days.
    - Dowel slot grout—compressive strength using cubes and tested at 1 hour or until 2,500 psi (35.8 MPa) strength is achieved and also tested at 7 days.
- Fabricated panel.
    - Panel dimensional tolerance—several parameters are typically specified.
    - Surface texture.
- Panel installation.
    - Smoothness, as per agency requirements.
    - Joint elevation difference (less than 1/8 inch [3 mm]).
    - Joint gap (tightness) not to exceed ½ inch (13 mm).
    - Deflection testing (at joints and interior)—highway agencies are beginning to include this requirement.

FHWA/SHRP2 IMPLEMENTATION ASSISTANCE PROGRAM PROJECTS

SHRP2 Project R05 was conducted from 2008 to 2012 to develop technical information and guidelines that would encourage the rapid and successful adoption of PCP technology. In 2013, FHWA implemented the SHRP2 IAP to help highway agencies to deploy SHRP2-developed products. The FHWA, in partnership with the American Association of State Highway and Transportation Officials (AASHTO), selected several transportation agencies to receive implementation assistance awards (up to $300,000) to help offset the cost of constructing a PCP project. Several agencies received awards in the amount of $75,000 to implement an in-house technology transfer program to support implementation of the PCP technology. The agencies receiving support under the IAP are listed in Table 1.

Table 1. Agencies receiving IAP support.

Highway Agency	Assistance Opportunity
Alabama DOT	Lead Adopter - $300,000
Connecticut DOT	Lead Adopter - $150,000 and Technical Assistance - $75,000
Florida DOT	Lead Adopter - $300,000
Hawaii DOT	Lead Adopter - $300,000
Indiana DOT	Technical Assistance - $75,000
Kansas DOT	Lead Adopter - $300,000
Louisiana DOTD	Lead Adopter - $300,000 and Technical Assistance - $75,000
Pennsylvania DOT	Technical Assistance - $75,000
Texas DOT	Lead Adopter - $300,000
Virginia DOT	Technical Assistance - $75,000
Wisconsin DOT	Lead Adopter - $300,000

In addition to the highway agencies listed in Table 1, FHWA also provided technical support to highway agencies in each state highlighted in Figure 1.

Details of the PCP projects constructed in Alabama, Connecticut, Florida, Hawaii, Kansas, Louisiana, Texas, Washington State and Wisconsin are described in the following case study reports:

- Alabama Case Study - Mobile Ramp Precast Concrete Pavement Demonstration Project. https://www.fhwa.dot.gov/pavement/concrete/pubs/hif18003.pdf. Alabama Department of Transportation received an award of $300,000 to help offset the cost of constructing a PCP project. This case study report provides details of the 2017 PCP use for rehabilitation of a distressed asphalt concrete ramp at Exit 2 of I-165, intersecting with Alt US 90 (New Bay Bridge Road), in Mobile, Alabama.
- Connecticut Case Study - New Britain Bus Pads Precast Concrete Pavement Demonstration Project. https://www.fhwa.dot.gov/pavement/concrete/pubs/hif17015.pdf. The Connecticut Department of Transportation received an award of $150,000 to help offset the cost of constructing a PCP project. This case study report provides details of the 2016 PCP use

for rehabilitation of two distressed asphalt concrete bus pads along a section of the busway of CTfastrak, a bus rapid transit system, in New Britain, Connecticut.

- Florida Case Study – Florida I-10 Precast Concrete Bridge Approach Slab Demonstration Project https://www.fhwa.dot.gov/pavement/concrete/pubs/hif18057.pdf. The Florida Department of Transportation received an award of $300,000 to help offset the cost of constructing a PC project. This case study report provides details of the 2018 project that used PC panels for rehabilitation of the east-side bridge approach slab along westbound I-10 near Quincy, Florida.
- Hawaii Case Study - Honolulu Interstate H1 Precast Concrete Pavement Demonstration Project. https://www.fhwa.dot.gov/pavement/concrete/pubs/hif17001.pdf. Hawaii Department of Transportation received an award of $300,000 to help offset the cost of the implementation of PCP technology in the State. This case study report provides details of the 2015 PCP implementation on a concrete pavement rehabilitation project along a section of Interstate H1 in the Honolulu area.
- Kansas Case Study – Leavenworth Precast Concrete Pavement Demonstration Project https://www.fhwa.dot.gov/pavement/concrete/pubs/hif17005.pdf. Kansas Department of Transportation received an award of $300,000 to help offset the cost of the implementation of PCP technology in the State. This case study report provides details of the 2015 PCP use for rehabilitation of two distressed concrete pavement intersections and a bridge approach section along US 73 in Leavenworth, Kansas.
- Louisiana Case Study – Louisiana I-20 Ramp Rehabilitation Using Precast Concrete Pavement https://www.fhwa.dot.gov/pavement/concrete/pubs/hif18053.pdf. The Louisiana Department of Transportation and Development (LADOTD) received an award of $300,000 to help offset the cost of constructing a PCP project. The LADOTD also received a User Incentive Award of $75,000 to help support PCP implementation. This case study report provides details of the 2018 PCP use for rehabilitation of the distressed eastbound concrete pavement ramp onto I-20 at LA 169, in Greenwood, Louisiana.
- Texas Case Study - Texas Precast Concrete Pavement Intersection Demonstration Project. https://www.fhwa.dot.gov/pavement/concrete/pubs/hif17017.pdf. The Texas Department of Transportation received an award of $300,000 to help offset the cost of constructing a PCP project. This case study report provides details of the 2016 PCP use for rehabilitation of a distressed asphalt concrete pavement at the intersection of Route 97 and Route 72 in McMullen/LaSalle County, Texas.
- Washington State DOT Case Study - Interstate 90 Rehabilitation with Precast Concrete Pavement, FHWA-HIF-19-026, March 2019. (Web link to be added.) Washington State Department of Transportation (WSDOT) received a grant in the amount of $1,000,000 from FHWA's Center for Accelerating Innovation for a concrete replacement demonstration project using precast concrete panels on eastbound I-90. This PCP project was under construction during April 2019.

- Wisconsin Case Study - Madison Beltline Precast Concrete Pavement Demonstration Project.
  https://www.fhwa.dot.gov/pavement/concrete/pubs/hif17003.pdf. Wisconsin Department of Transportation received an award of $300,000 to help offset the cost of the implementation of PCP technology in the State. This case study report provides details of the 2014 PCP use for repair of distressed concrete pavement along sections of the Madison Beltline Highway (US 12).

PCP TECH BRIEFS

The following Tech Briefs were developed to provide current information on PCP technology and FHWA's PCP technology implementation efforts:

- Precast Concrete Pavement Technology Resources, 2019.
  (Web link to be added). This Tech Brief provides a summary of the technical resources available to engineers and planners seeking an understanding of PCP technology. Weblinks are provided for access to recent documents covering a range of PCP topics.
- Precast Concrete Pavement Implementation by U.S. Highway Agencies, 2019.
  https://www.fhwa.dot.gov/pavement/concrete/pubs/hif19011.pdf. This Tech Brief describes the actions taken by 29 highway agencies in the US to implement the use of PCP for repair and rehabilitation of asphalt and concrete pavements. Individual agencies are at various stages of PCP implementation, with some just beginning to develop specifications and to identify projects where PCP can most effectively be used, and others monitoring the performance of one or more in-service PCP projects and planning for additional applications of PCP.
- Jointed Precast Concrete Pavement Panel Fabrication and Installation Checklists, 2019.
  https://www.fhwa.dot.gov/pavement/pubs/hif19016.pdf. This Tech Brief includes the following JrPCP panel fabrication and installation related checklists:

  A. Fabricated Panel Pre-Shipping Checklist.
  B. Panel Post-Shipping (At-Site) Checklist.
  C. On-Site Equipment Checklist.
  D. On-Site Materials Checklist.
  E. Work Area Preparation Checklist.
  F. Panel Placement Checklist.
  G. Dowel Bar and Tie Bar Slot Grouting Checklist.
  H. Dowel Bar Slot Patching Checklist (if grout not used).
  I. Clean-up Operation and Opening to Traffic Checklist.

  This guide set of checklists for the construction of JrPCP is intended for highway agency construction personnel. However, the checklists should be of use for the contractor personnel too. The checklists presented here follow the flow of typical JrPCP project construction activities. The checklists are not intended to replace the agency's QA and the contractor's QC activities, but rather to supplement and reinforce these activities to ensure a quality product is constructed. Agency and contractor personnel using the checklists should be knowledgeable in JrPCP construction and JrPCP technology. Depending on the type of JrPCP being used for a specific project and the project plans and specifications, not all the items in the checklists may be applicable. The user will need to determine which items are pertinent to their specific project.
- Guide Specification for Jointed Precast Concrete Pavement, 2019.
  https://www.fhwa.dot.gov/pavement/concrete/pubs/hif19017.pdf. This guide specification presents considerations for the use of jointed JrPCP based on the best

practices observed from experiences of numerous highway agencies. This document provides best practices for the use of JrPCP. It does not provide any Federal requirements other than those stipulated in statue or regulation.

- Load Transfer Systems for Jointed Precast Concrete Pavements, 2015. https://www.fhwa.dot.gov/pavement/concrete/pubs/hif16008.pdf. Transverse joint faulting negatively affects the ride quality of jointed concrete pavements. A pavement design feature that has been found to have a significant impact on joint faulting is the use of load transfer devices, typically round dowel bars, at transverse joints. The load transfer features currently used at transverse joints in JrPCP are described in this Tech Brief.
- Precast Concrete Pavement Bedding Support Systems, 2015. https://www.fhwa.dot.gov/pavement/concrete/pubs/hif16009.pdf. For new construction, as well as for repair applications, pavement support is critical to the long-term performance of PCP systems. The proper seating of the panels on the base is a critical design and construction element. All PCP applications require an "interlayer" of material between the base and the bottom of the precast panels since these two surfaces will not match each other perfectly. To compensate for this, a bedding layer (interlayer) must be used to serve as grade control and as void filler to ensure the panels are fully supported. This Tech Brief describes the technical considerations for bedding support and current bedding support practices for PCP.
- Precast Concrete Panels for Rapid Full-Depth Repair of CRC Pavement to Maintain Continuity of Longitudinal Reinforcement, 2018. https://www.fhwa.dot.gov/pavement/concrete/pubs/hif18050.pdf. This Tech Brief describes a recently implemented method for rapid overnight full-depth repairs of continuously reinforced concrete (CRC) pavements using precast concrete panels. This method, developed by the Illinois Tollway, uses continuous longitudinal reinforcement throughout the repair area to make the method applicable for repairing multiple lanes or large areas, as well as for isolated repairs for long-term performance with minimal impact to traffic. The Illinois Tollway has successfully utilized this method for a high traffic-volume expressway in the Chicago metropolitan area. The repair work was carried out during nighttime closures during October 2017.

PCP WORKSHOPS

PCP Best Practice Workshops were developed and delivered beginning in early 2014. The 1-day workshops were intended to provide highway agencies and other stakeholders with the most updated information on the best practices related to precast pavement technology and provide guidance on selection of candidate projects for PCP applications, development of project-specific design and construction requirements, and PCP system acceptance. Attendance ranged from about 30 to 50. All attendees were awarded certificates of training. Workshops were delivered for the following agencies:

- Hawaii DOT—January 28, 2014, in Honolulu.
- Nevada DOT—April 23, 2014, in Carson City.
- Alabama DOT—July 16, 2014, in Montgomery, followed by a meeting with Alabama DOT senior staff the next day to discuss possible PCP projects in the State.
- Florida DOT—September 29, 2014, in Gainesville, followed by a meeting with Florida DOT senior staff the next day to discuss possible PCP projects in the State.
- Hawaii DOT—December 2014 in Honolulu. A just-in-time training workshop on PCP panel fabrication and installation for the Hawaii DOT, consultant staff, and contractor staff.
- Texas DOT—February 25, 2015, in Austin, for District 1 staff.
- Hawaii DOT—March 2015 in Honolulu. The workshop was conducted for Hawaii DOT and FHWA staff, consultant staff, and the contractor staff involved with the SHRP2/FHWA IAP funded demonstration project along a section of Hawaii H1.
- Louisiana DOTD—June 16, 2015, in Baton Rouge, followed up with a technical meeting with senior staff the next day to discuss project specific applications of precast concrete pavements statewide.
- Connecticut DOT—July 8, 2015, in Newington. The workshop was followed by a meeting with Connecticut DOT senior staff the next day to discuss possible PCP projects in the State.
- Louisiana DOTD—November 5, 2015, in Shreveport, with a visit to the proposed site for the PCP demonstration project.
- Pennsylvania DOT—November 18, 2015, in Norristown.
- Alabama DOT—December 2, 2015, in Mobile, with a visit to the proposed site for the PCP demonstration project.
- North Carolina DOT—February 5, 2016, with a visit to the proposed site for the PCP demonstration project.
- Louisiana DOTD—March 3, 2016, in Baton Rouge, for industry stakeholders.
- Florida DOT—April 13, 2016, in Chipley. Workshop was focused on bridge approach slab applications.
- Connecticut DOT—May 2016, in Newington, for Connecticut DOT and consultant staff focused on the proposed PCP demonstration project.
- Pennsylvania DOT—November 18, 2016, in Harrisburg with statewide DOT staff participation.
- National Precast Concrete Association—February 2, 2017, in San Diego, California. The workshop was organized in coordination with the National Precast Concrete Association.

The association promoted the workshop to precasters and about 35 precasters attended the workshop.

- New Mexico DOT—March 22, 2017, in Albuquerque, with a visit to the proposed site for the PCP demonstration project.
- Illinois DOT—July 12, 2017, in Schaumburg.
- Caltrans District 8—September 7, 2017, in Fontana.
- South Carolina DOT—January 18, 2018, in Columbia.
- Indiana DOT—April 6, 2018, in Indianapolis.
- Washington State DOT—May 31, 2018, in Seattle. This was a Just-in-Time Training workshop for the upcoming PCP demonstration project along I-90.
- Virginia DOT—September 27, 2018, in Charlottesville.
- New Mexico DOT—October 17, 2018, near Anthony, with a visit to the proposed site for a PCP project.

A typical outline for the one-day PCP Best Practices workshop is given below.

9:00 a.m. Welcome and Introductions

1. NMDOT DOT

9:10 a.m. Part 1 - Implementation of Precast Concrete for Rapid Renewal of Pavements – Sam Tyson, P.E., FHWA, Washington, DC

9:25 a.m. Part 2 - Overview of Precast Concrete Pavement (PCP) Technology – Shiraz Tayabji

- Concrete Pavement Fundamentals
- PCP Background
- Precast pavement applications
    - Intermittent repairs
    - Continuous applications
    - PCP Systems (Jointed precast concrete pavement system)
- US implementation overview
- Overview of non-US PCP use and systems

10:30 – 10:50 a.m. (Break)

10:50 a.m. Part 3 - PCP Technical Considerations – Shiraz Tayabji

- General details
- Concrete requirements
- Jointing and load transfer
- Support condition
- Non-planar/trapezoidal panels
- Design Considerations
- Grouts, patching materials and epoxy use

11:30 a.m. Part 3 - Performance of PCP – Shiraz Tayabji

- Accelerated load testing of a jointed system by Caltrans
- Field evaluations under SHRP2 Project R05
- Recent project experience

12:00 noon – 1:00 pm (Lunch)

1:00 p.m. Part 4 - NMDOT Albuquerque Intersection PCP Project – NMDOT

1:20 p.m. Part 5 - Panel Fabrication – Shiraz Tayabji

- Plans and specification highlights
- Shop drawings
- The process for jointed panels
- Concrete & panel QA/QC

1:50 p.m. Part 6 - Construction Considerations – Jointed Precast Concrete Pavement Systems – Shiraz Tayabji

- Specification highlights
- Intermittent/repair applications
- Continuous applications
- Field QA/QC

Part 6A - Construction checklists

2:45 p.m. Part 7 - Case Studies – Shiraz Tayabji

- Repair applications (Full-depth repairs) using PCP
- Continuous applications – Jointed PCP
- FHWA/SHRP2 funded demo project case studies
- Lessons learnt

End of Workshop (~3:30 p.m.)

PCP TECHNOLOGY IMPLEMENTATION EXPERT TASK GROUP

An Expert Task Group (ETG) was organized with participants from highway agencies, industry, and academia, representing all key stakeholders. The ETG membership was proposed to FHWA and was finalized based on feedback received from FHWA. The ETG membership was categorized as follows:

- PCP user agencies.
- PCP demo project agencies.
- PCP non-user/non-demo agencies.
- Academia.
- National associations.
- Precasters.
- Contractors.
- Suppliers.
- FHWA.
- The FHWA R05 implementation team.

As of the last ETG meeting held October 23-24, 2018 in Washington, DC, the ETG membership consisted of the following:

ETG Members

1. PCP User Agencies:
    - Dulce Feldman, Caltrans
    - Steve Norton, Connecticut DOT
    - Jim Pappas, Delaware DOT
    - Edward Sniffen, Hawaii DOT
    - Cynthia Williams, Illinois Tollway
    - Phillip Sturdivant, LADOTD
    - Scott Nussbaum, Utah DOT
    - Robert Blight, New Jersey DOT
2. PCP Demonstration Project Agencies:
    - Bouzid Choubane, Florida DOT
    - Tommy Nantung, Indiana DOT
    - Jeff Mann, New Mexico DOT
    - Andy Naranjo, Texas DOT
    - Shabbir Hossain, Virginia DOT
    - Jeff Uhlmeyer, Washington State DOT
3. Academia:
    - Tyson Rupnow, Louisiana State University/LTRC
    - Jeff Roesler, University of Illinois (Pavements)
4. National Associations:
    - Kayla Hanson, National Precast Concrete Association (NPCA)
    - Ken Fleck, Prestress-Precast Concrete Institute (PCI) Pavements Committee
    - Leif Watne, American Concrete Pavement Association (ACPA)

- Tom Montalbine, NPCA Pavements Committee

5. Precasters:
   - Peter J. Smith, The Fort Miller Company (New York State)
   - Tim Heraty, Utility Concrete (Chicago Area Precaster)
   - Mike Hein, Confab (California Precaster)
   - Stephanie Loud, Mountain West Precast (Utah Precaster)
6. Contractors: None
7. Suppliers:
   - Gary Whitfield, H.B. Fuller Construction Products, Inc.
8. FHWA:
   - Sam Tyson
9. The FHWA PCP Implementation Team:
   - Shiraz Tayabji

The following ETG meetings have been held, as authorized by FHWA:

1. The FHWA Offices, Washington, DC, March 5 and 6, 2014.
2. San Antonio, Texas, June 23 to 25, 2015.
3. Kansas City, Missouri, April 5 and 6, 2016.
4. Burbank, California, February 1, 2017.
5. The FHWA Offices, Washington, DC, October 23 and 24, 2018.

On the average, about 25 ETG members and about 10 to 20 visitors attended the meetings. Presentation handouts were distributed electronically to all ETG members after each meeting. A technical report presenting the highlights of each meeting of the ETG was submitted to FHWA and distributed to ETG members. Also, approved travel related expenses were reimbursed to the agency/academia members of the ETG.

The ETG meeting agenda for the final meeting of the ETG is given below:

October 23, 2018

8:00 a.m.: Welcome – the FHWA Senior Staff
8:10 a.m.: Self-introductions and House-keeping – Sam Tyson
8:20 a.m.: SHRP2 Project R05 Implementation Program Update – Sam Tyson
8:35 a.m.: SHRP2 Project R05 Technical Assistance Contract – Shiraz Tayabji

- Project Scope
- Summary of activities to-date & remaining activities (2018)

9:00 a.m.: SHRP2 Implementation Assistance Program Rounds 3 & 6 Funded Projects – Sam Tyson

- Hawaii – Hawaii H1 pavement rehabilitation, 2015/2018 (Ed Sniffen) - 20
- Texas – AC Intersection rehabilitation, 2016 (Andy Naranjo) – 20
- Connecticut – AC bus pads rehabilitated, 2016 (Steve Norton) – 20
- Alabama – I-165 AC ramp rehabilitation in Mobile, 2017 (TBD) - 20
- Louisiana – Shreveport I-20 ramp rehabilitation, 2018 (Phillip Sturdivant) - 20

- Florida – Chipley I-10 WB bridge approach slab, 2018 construction (Bouzid Choubane) – 20
- Discussion - 20

10:00 a.m.: Break - 20
10:20 a.m.: SHRP2 Implementation Assistance Program Round 3 & 6 Funded Projects – Sam Tyson (continued)
11:45: Lunch (on your own, preferably in the FHWA cafeteria)
1:00 a.m.: Other First Time Implementation of PCP – Shiraz Tayabji

- Washington State: I-90 PCP project, 2018 – Jeff Uhlmeyer - 20
- New Mexico: Albuquerque Intersection, 2019 - Jeff Mann - 20

1:40 p.m.: Production Users of Precast Pavement Technology – Shiraz Tayabji

- Caltrans – Debbie Wong – 20
- Delaware – (TBD) – 20
- Illinois Tollway – Cynthia Williams - 20
- New Jersey – Robert Blight – 20
- Discussion - 20

(Break at about 2:30 pm – 20)
3:45 p.m.: The FHWA Volpe Survey of PCP Implementation – Gregory Bucci – 30
4:15 p.m. – Discussion
4:30 p.m. – End of Day-1 Meeting

October 24, 2018

8:00 a.m.: Open Discussion 1: Agency Focus – Sam Tyson

- Lessons Learnt, gaps in technology, future directions (All agencies)

9:00 a.m.: Open Discussion 2: Industry Focus – Shiraz Tayabji

- Industry perspectives on status of PCP implementation & way forward
    - NPCA Perspectives – Tom Montalbine - 10
    - PCI Perspectives – Ken Fleck – 10
    - ACPA Perspective – Leif Watne - 10
- Industry updates (new systems, new components, new applications, etc.) - 30

10:00 a.m.: Break
10:30 a.m.: Improving PCP Best Practices – Shiraz Tayabji

- Generic plans and specifications
- QC/QA - What should we be testing and evaluating?
- Improving production/installation efficiencies

11:30 a.m.: Action Items and Future PCP Technology Championing – Sam Tyson
12:00 noon: Meeting adjourned

For this last ETG meeting, the focus was on the agencies' experience over the last 5 or so years with respect to precast concrete pavement implementation/use, new applications considered, improvements made in plans/specs/construction inspection, successes and issues that may have developed and how resolved. As shown in the agenda above, on the first day of the ETG meeting, highway agencies presented information concerning their first-time experiences in designing and constructing precast concrete pavement for rapid rehabilitation applications, including mainline pavement, intersections, bus pads, exit and access ramps, and bridge approach panels. Most of these agencies are expected to continue with production use of PCP.

Several highway agencies have adopted PCP technology for routine use, and several of those agencies shared their experiences. In addition, Mr. Greg Bucci from FHWA's John A. Volpe National Transportation Systems Center presented results of a nationwide evaluation of the precast concrete pavement technology implementation. On the second day of the ETG meeting, industry groups that have cooperated in advancing PCP technology led the discussion.

OTHER TECHNICAL SUPPORT

PCP Technical Support

Technical support for IAP Funding Supported Agencies was provided. The technical support typically included the following:

- Candidate demonstration project site selection.
- Development of plans and specifications.
- Meetings and discussions with agency consultants.
- Review of shop drawings.
- Construction related support during the first night of panel installation.
- Preparation of case study report for each demonstration project funded under the IAP.

Similar technical support was provided for Non-IAP Funded Highway Agencies. These agencies included the following:

- Caltrans District 7 and Sacramento HQ offices.
- Delaware DOT.
- New Mexico DOT.
- North Carolina DOT.
- Washington State DOT.

A set of guide checklists for the construction of PCP intended for highway agency and contractor field personnel were developed. The checklists are not intended to replace the agency's quality assurance and the contractor's quality control activities, but rather to supplement and reinforce these activities to ensure a quality product is constructed. The checklists include the following:

- Fabricated Panel Pre-Shipping Checklist.
- Panel Post-Shipping (At-Site) Checklist.
- On-Site Equipment Checklist.
- On-Site Materials Checklist.
- Work-area Preparation Checklist.
- Panel Placement Checklist.
- Dowel Bar and Tie Bar Slot Grouting Checklist.
- Dowel Bar and Tie Bar Slot Patching Checklist (if grout is not used).
- Clean-up Operation Checklist.
- Opening to Traffic Checklist.

Customized versions of the checklists were implemented during late 2018 by the Illinois Tollway.

A guide protocol for deflection testing of JCP was developed. Specifically, the following tests were included in the test protocol:

- Testing at transverse joints.
  - To determine load transfer effectiveness at a joint.
  - To determine relative deflection across a joint.
- Testing at panel interior to characterize panel support.

The load transfer efficiency measure describes the overall measure of the deflection response at a joint and incorporates the influence of the support condition under the panel. The relative deflection measure focuses on the response of the load transfer system only. Both measures are equally important. The actual deflection under load at the joint is also important as it provides useful information on the support condition under the panel. The test protocol, based on use of the falling weight deflectometer, is applicable to intermittent repair panels as well as continuous application of the jointed panels.

PCP Technical Briefings

During the more than five years of the technical support contract, the following technical briefings were provided:

- February 19, 2014 - A technical briefing on the PCP technology was presented at the annual Delaware DOT Materials Workshop, held in Dover, Delaware.
- April 8, 2014 - A briefing on the PCP technology was presented at the Northeast Pavement Preservation Partnership (NEPPP) in Burlington, Vermont.
- June 9, 2014 - A presentation on PCP technology was made at the ASCE Transportation and Development Institute conference, held in Miami, Florida.
- June 15, 2014 – Participation in an ACPA/NPCA sponsored webinar on Innovations in PCP Technology.
- April 2015 – A presentation on Fast Track Precast Concrete Pavements for High Volume Roadways, at ACI’s Spring Convention, held in Kansas City, Missouri.
- July 17, 2015 - A meeting was held with the staff of the Alabama DOT in Montgomery, Alabama on to review Alabama DOT’s plans for PCP implementation in the State.
- July 21, 2015 - A PCP State of Practice and Applications mini-seminar was presented at FHWA’s TFHRC in McLean, Virginia. The attendees included staff from FHWA’s Volpe Center and staff from the TFHRC facility. The mini-seminar provided information on the state of precast concrete pavement technology and provided overview discussion on selection of candidate projects for PCP applications, PCP systems, and PCP applications, and provided a few case studies of PCP use by various agencies.
- August 22, 2015 - A briefing on the PCP technology was provided on to the Kansas DOT, in Topeka, Kansas. The briefing was provided in an open meeting attended by Kansas DOT staff and representatives from precasters, contractors and other PCP related material suppliers.
- September 30, 2015 - A meeting was held with the staff of the Florida DOT in Gainesville, Florida to review Florida DOT’s plans for PCP implementation in the State. The meeting was followed by a site visit to Florida’s PPCP demonstration project.

- October 29, 2015 - An update on the US precast concrete pavement technology was provided at the Fall Convention of the American Concrete Institute, held in Washington, DC.
- January 29, 2016 – Participation in a meeting of National Precast Concrete Association's Pavement Committee, held in Highland, California. A briefing on FHWA activities related to PCP implementation was provided to the committee.
- March 2, 2016 - Participation at the 2016 Louisiana Transportation Conference, held in Baton Rouge. Two presentations – one on PCP technology update and one on the Los Angeles SH 101 PCP project.
- August 11, 2016 – Participation in the Indiana DOT PCP forum, hosted by the Joint Transportation Research Project (JTRP). An overview of the PCP technology as currently practiced in the US and information on PCP projects constructed in California were presented.
- September 2016 – Participation in a workshop conducted at the International Conference on Concrete Pavements, organized by the International Society for Concrete Pavements and held in San Antonio, Texas. The workshop theme was: "Achieving High-Quality Precast Concrete Pavement Installations."
- September 19, 2016 – Participation in the meeting of the Falling Weight Deflectometer User's Group (FWPUG), held in Newark, California. Presented a discussion on "Acceptance Testing for PCP Load Transfer Systems."
- September 29, 2016 – Presented the Kent Seminar to graduate students at the Illinois Center for Transportation at the University of Illinois, Urbana, Illinois. The presentation topic was "Precast Concrete Pavements for Rapid Rehabilitation of High Volume Roadways." The presentation was live broadcast via YouTube to other students at the university and to Illinois DOT offices. The 60 minute presentation summarized current practices related to the use of precast concrete pavement for repair and rehabilitation of high-volume highway pavements in the U.S. Recent improvements for providing load transfer at joints and panel installation will also be discussed and case studies will be presented.
- July 28, 2017 – Presented a 60-minute technical session on precast concrete pavement technology at the PCA Professors Workshop, held in Skokie, Illinois. The PCA workshop was directed at young professors and professors from smaller colleges to expose them to new developments in concrete construction technology.
- September 26 and 27. 2017 – Participation as an invited presenter at the conference organized by TRB and FHWA's UTC program and held in Washington, DC. This annual conference brings together leaders in government, industry and academia to discuss key advances needed to rebuild and retrofit transportation infrastructure to address current deficiencies and emerging needs. A focus for this year's conference was maintaining and extending the useful life of the nation's legacy transportation infrastructure, such as bridges, ports, airports, railways and roads. Presentation on Rapid/Overnight Renewal of America's High Volume Roadways using Innovative Precast Concrete Pavement Technology.
- January 3-4, 2018 – A 30-minute technical presentation on precast concrete pavement technology at the University of New Mexico Pavement Conference held in Albuquerque. The presentation was designed to promote the implementation of PCP within the NM DOT and within the local industry stakeholders.

- January 7, 2018 – A 30-minute presentation at the Workshop on Precast Concrete Pavement Innovations, held at the TRB annual meeting in Washington, DC. The presentation included information on the recently completed PCP case studies that were supported by funding from the FHWA/SHRP2 Implementation Assistance Program.
- May 9-10, 2018 - A 30-minute technical presentation on precast concrete pavement technology at the Northeast Pavement Preservation Partnership (NEPPP)'s 2018 meeting held in Groton/Mystic, Connecticut. Also, a 30-minute overview of PCP current practices and construction quality requirements was presented at FHWA's EDC4 Peer Exchange meeting, held in Groton/Mystic, Connecticut. The meeting was attended by the highway agency personnel attending the NEPPP meeting.
- September 10, 2018 - A 30-minute overview on PCP current practices and construction quality requirements at FHWA's EDC4 Peer Exchange meeting, held in Portland, Oregon. The meeting was attended by the highway agency personnel from western States.

PCP Webinars

Two PCP technology related webinars were organized and presented by TRB during October 2014. The following webinars were presented:

Webinar 1: Planning and Design Considerations for Precast Concrete Pavement (October 8)

Moderator: Dulce Feldman
Presenters:

- Sam Tyson – FHWA Perspective
- Mehdi Parvini, Caltrans – Planning and Project Selection
- Shiraz Tayabji – Design Considerations
- Mike Hein, Con-fab, Lathrop, California – Prestressing System Considerations

Webinar 2: Panel Fabrication and Installation Considerations for Precast Concrete Pavement (October 20)

Moderator: Roger Schmitt
Presenters:

- Sam Tyson – FHWA Perspective
- Shiraz Tayabji – Technical Overview
- Tom Heraty, Utility Concrete Products, LLC, Morris, IL - Jointed Precast Concrete Pavement Panel Fabrication
- Patrick Camp, Procast Products, Inc., Highland, CA - Installation of Jointed Precast Concrete Pavements
- Mike Hein, Con-Fab, Lathrop, CA - Fabrication and Installation of Prestressed Precast Concrete Pavements

The presentations were well attended and received very good feedback from the attendees. For the first webinar, TRB estimated that 229 people attended from 171 sites. Ninety-three percent of sites responding to TRB's post-webinar evaluation stated that they were either satisfied or very satisfied with the webinar. For the second webinar, TRB estimated that 222 attendees joined from 173 sites. Of those who responded to TRB's post-webinar evaluation, 97 percent were either satisfied or very satisfied with the webinar

A 90-minute webinar was presented for the precast concrete community focused on precasters needs and QC/QA issues related to the PCP technology. The webinar was presented on August 31, 2017 in coordination with the National Precast Concrete Association (NPCA). The NPCA promoted the webinar to precasters and allied construction stakeholders. The webinar was free to all interested parties. A total of 207 sites were signed in. According to NPCA, the webinar was very successful.

PCP Technical Sessions at TRB and American Concrete Institute Meetings

Two technical sessions on PCP were organized and delivered at the 94th Annual Meeting of the TRB, held in Washington, DC, in January 2015. The session details are given below.

TRB Session 271: Precast Concrete Pavement Innovations and Case Studies (Monday (1/12/15) morning)

Moderator: Sam Tyson, Federal Highway Administration, Washington, DC
Presentations:

- Shiraz Tayabji, Applied Research Associates, Inc., Elkridge, MD—Status of Precast Concrete Pavement Innovations in the US
- Debbie Wong, Caltrans, Los Angeles, CA—Innovations for Jointed Precast Concrete Pavement Applications
- Brent Koch, Con-Fab, Lathrop, CA—Innovations for Posttensioned Precast Concrete Pavement Applications
- Peter Smith, Fort Miller Company, Schuylerville, NY—A Removable Precast Concrete Pavement Application in New York City

TRB Session 684: SHRP2 Project R05 Precast Concrete Pavement Technology Implementation (Tuesday (1/13/15) afternoon)

Moderator: Shiraz Tayabji, ARA
Presentations:

- Sam Tyson, Federal Highway Administration, Washington, DC—SHRP2 Precast Concrete Pavement Implementation
- Andy Naranjo, Texas DOT, Austin, TX—Texas DOT's Energy Roads Intersection Application
- Steve Gillen, Illinois Tollway, Downers Grove, IL—Precast Panels for Bridge Approach Slab Rehabilitation
- David Layton, Wisconsin DOT, Madison, WI—Mainline Repair and Rehabilitation using Precast Panels
- Pratt Kinimaka, Hawaii DOT, Honolulu, HI—Jointed and Posttensioned Precast Concrete Pavement Applications in Hawaii

- Rick Kreider, Kansas DOT, Topeka, KS—Precast Concrete Pavement Application in Kansas

Both sessions were well attended, and the attendee questions indicated that the sessions were helpful in disseminating current information on precast concrete pavement technology.

Two technical sessions were organized and delivered at the April 2016 convention of the American Concrete Institute, held in Milwaukee, Wisconsin. The sessions presented the current developments and best practices related to PCP design, panel fabrication and panel installation processes. In the first session, subject matter experts presented new PCP innovations being implemented in the US. In the follow-up session, experts from several highway agencies presented the implementation details related to new PCP applications by their agencies. The sessions provided a state-of-the-art review of implementable PCP technology and innovations being considered to reduce costs and increase efficiency of construction. There were over 50 attendees at each session.

Session 1 (April 17): Precast Concrete Pavements: Best Practices & Innovations, Part 1
Session Moderators: Shiraz Tayabji

Presentation # 1: Overview of Precast Concrete Pavement Practices and Recent Innovations
Presenter: Shiraz Tayabji, Ph.D., P.E., Applied Research Associates, Inc.

Presentation # 2: The FHWA/SHRP2 PCP Implementation Assistance Program
Presenters: Sam Tyson

Presentation # 3: Recent Innovations in Jointed Precast Concrete Pavement Systems
Presenter: Peter Smith, PE, The Fort Miller Co., Inc.

Presentation # 4: The FHWA/SHRP2 PCP Implementation Assistance Program Projects
Presenters: Shiraz Tayabji

Session 2 (April 17): Precast Concrete Pavements: Best Practices & Innovations, Part 2
Session Moderators: Sam Tyson

Presentation # 1: Precast Concrete Pavement Implementation in Wisconsin
Presenter: David Layton, P.E., Wisconsin DOT - SW Region

Presentation # 2: Precast Concrete Pavement Implementation by the Illinois Tollway
Presenter: Steve Gillen, Illinois Tollway

Presentation # 3: Precast Concrete Pavement Implementation in California
Presenter: Mehdi Parvini, Caltrans

Presentation # 4: The Los Angeles SH 101 Pavement Rehabilitation Using Precast Concrete Panels

Presenter: Shiraz Tayabji

PCP Open House and PCP Project Site Visits

Kansas DOT Open House

Support was provided to the Kansas DOT staff with the planning for the April 5 Open House for the PCP demo project in Leavenworth. There were about 75 attendees, including 15 from the FHWA PCP ETG. The Open House program is summarized below:

Kansas DOT Precast Concrete Pavement Open House
Leavenworth, Kansas, Wednesday, April 6, 2016

AGENDA

9:00 – 9:05 a.m.	Introduction and Welcome by KDOT Catherine Patrick, KDOT Director of Operations
9:05 – 9:15 a.m.	Welcome by FHWA Tom Deddens, The FHWA Kansas Division The FHWA/SHRP 2 Implementation Assistance Program Overview Sam Tyson, FHWA HQ
9:15 – 9:45 a.m.	Precast Concrete Pavement Implementation Overview Shiraz Tayabji, Applied Research Associates, Inc.
9:45 – 10:00 a.m.	Leavenworth PCP Project Overview Paul Gripka, KDOT Design-Build Project Manager
10:00 – 10:20 a.m.	BREAK
10:20 – 10:45 a.m.	Precaster Perspective – Leavenworth Project Overview Dave Junk, Precast Concrete Consultant, The Fort Miller Co., Inc.
10:45 – 11:15 a.m.	Concrete Production & Panel Placement (Incl. Video) Will Lindquist, KDOT Concrete Research Engineer
11:15 – 11:45 a.m.	Concrete Production and Placement Lessons Learned Cretex & Miles
12:00 – 1:15 p.m.	LUNCH
1:15 – 1:30 p.m.	Site Visit Instructions
1:30 – 3:00 p.m.	Site Visit

A handout summarizing the key aspects of the Leavenworth PCP demonstration project was prepared and was distributed at the Open House.

Visit to Caltrans District 7

A site visit to the Los Angeles area for Louisiana DOTD and Connecticut DOT staff was planned and coordinated. The site visit took place April 27 to 30, 2016 and allowed the two DOT staff to meet with Caltrans District 7 staff and to visit precasting facilities, several constructed PCP and one PCP project (SH 101) under construction (nighttime visit). The logistic for the visit is summarized below:

April 27 (Wednesday) – arrive by mid-afternoon/evening.

- Evening – Met with Caltrans District 7 staff – Review PCP use for pavement maintenance/repair in District 7 (by Ms. Debbie Wong, Caltrans)

April 28 (Thursday)

- 9:00 a.m. – Met at District 7 HQ – Meet with District 7 key PCP involved staff and local FHWA staff
  - Review history of PCP implementation at the district level and Statewide
  - Briefly discussed Caltrans plans and specs, current version
- Briefly discussed key completed, on-going, and upcoming PCP projects and scopes and key details of these projects
- Lunch
- Afternoon (1:30 to 5:00 p.m.) – Visited several PCP completed projects; vehicles provided by Caltrans

April 29 (Friday)

- 10:00 a.m. – Visited ProCast precast plant in Highland; brief meeting and visit to the plant. Also, visited the Oldcastle precast plant nearby.
- Night (11:00 p.m. to 4:00 a.m.) – Visited one PCP project under construction (SH-101).

The visit to Caltrans District 7 was considered very helpful by both the LADOTD and the Connecticut DOT staff. Both agencies are planning to incorporate the Caltrans approach for PCP implementation in their upcoming PCP projects.

SUMMARY

In less than 17 years of experience with PCP systems, significant advances have been made in both design and construction. Current PCP systems can be installed rapidly and can be expected to provide long-term service. However, as with any new technology, there is room for new systems and refinements to improve speed of panel installation and to reduce overall cost. Producers and contractors with no prior PCP construction experience are successfully installing precast panels. Although a few projects have encountered panel installation quality related issues, the use of PCP by highway agencies is considered a success. Over the last 17 years, all stakeholders working together, have made a positive difference in supporting wider implementation of the PCP technology, resulting in cost-effective, rapid, and longer-lasting pavement repair/rehabilitation options for agencies

Under the FHWA Contract No. DTFH61-13-C-00028, technical support was provided to FHWA for timely and cost-effective deployment, delivery, and implementation of PCP related products developed under the SHRP2 Project R05 study. The principal recipient and end-user organizations for these products included State and toll highway agencies and others government entities, industry organizations, consultants, contractors, research organizations, and academia. At the end of December 2018, after 5 years of work under the FHWA contract, the state of PCP implementation is as follows:

- New agencies implementing PCP: Alabama DOT (2017), Connecticut DOT, Florida DOT (2018), Hawaii DOT (2015), Kansas DOT (2015), Indiana DOT (2018), Louisiana DOTD (2018), New Mexico DOT (2019), Washington State DOT (2018), and Wisconsin DOT (2015).
- Agencies using PCP as an approved pavement repair/rehabilitation treatment: Caltrans, Connecticut DOT, Delaware DOT, Hawaii DOT, Illinois DOT/Illinois Tollway, Indiana DOT, Michigan DOT, New Jersey DOT/New Jersey Turnpike, New York State DOT/New York State Thruway, PennDOT/Pennsylvania Turnpike, Texas DOT, Utah DOT, and West Virginia DOT.
- Agencies with previous PCP demonstration projects: Iowa DOT, Missouri DOT, Nevada DOT, and Virginia DOT.
- Agencies evaluating PCP use: Arkansas DOT, District of Columbia DOT, and South Carolina DOT.

The significant contributions and support by all PCP stakeholders over the more than 5 years of the FHWA contract is acknowledged. Specifically, the support and discussion provided by the many ETG members is gratefully acknowledged. In addition, the support and feedback provided by many highway agencies during the preparation of the IAP funded case study reports is greatly appreciated.