FHWA REPORT NO. FHWA-HIF-18-053

FHWA PROJECT R05 IAP FUNDED PROJECT CASE STUDY

LOUISIANA INTERSTATE-20 RAMP REHABILITATION USING PRECAST CONCRETE PAVEMENT

U.S. Department of Transportation
Federal Highway Administration

July 2018

1. Report No. FHWA-HIF-18-053	2. Government Accession No	3. Recipient's Catalog No
3. Title and Subtitle FHWA Project R05 IAP Funded Project Case Study: Louisiana Interstate-20 Ramp Rehabilitation using Precast Concrete Pavement		5. Report Date July 2018 6. Performing Organization Code
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9. Performing Organization Name and Address Applied Research Associates, Inc. 100 Trade Centre Drive, Suite 200 Champaign, IL 61820		10. Work Unit No. (TRAIS) C6B 11. Contract or Grant No. DTFH61-13-C-00028
12. Sponsoring Agency Name and Address Office of Infrastructure Federal Highway Administration 1200 New Jersey Avenue, SE Washington, DC 20590		13. Type of Report and Period Covered Final Report March 2017 – July 2018 14. Sponsoring Agency Code
15. Supplementary Notes Contracting Officer's Representative: Sam Tyson, P.E.		

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 SHRP2 Implementation Assistance Program (IAP) was created 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. On August 7, 2015, the Federal Highway Administration—in partnership with the American Association of State Highway and Transportation Officials—announced the selection of 21 transportation agencies receiving implementation and technical assistance awards as part of Round 6 of the SHRP2 IAP. The Louisiana Department of Transportation and Development (LADOTD), one of the agencies selected as a lead adopter of Project R05 technology, 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.

17. Key Words Ramp rehabilitation, precast concrete pavement system, construction, pavement rehabilitation, SHRP2, SHRP2 Project R05	18. Distribution Statement No restriction.

Security Classification (of this report): Unclassified	19. Security Classification (of this page): Unclassified	20. No. of Pages 39	21. Price

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ABBREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt concrete
DCP	Dynamic cone penetrometer
DOT	Department of Transportation
FHWA	Federal Highway Administration
FWD	Falling weight deflectometer
GPS	Global positioning system
IAP	Implementation Assistance Program
LADOTD	Louisiana Department of Transportation and Development
PCP	Precast concrete pavement
SHRP2	Strategic Highway Research Program 2

PHOTO CREDITS

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Figure 30. Phillip Sturdivant, Louisiana DOTD

INTRODUCTION

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, yet many of these carry over 100,000 vehicles/day, including a large percentage of trucks. Extended lane closures must therefore 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 PCP technology—including the Illinois Tollway and the California, Illinois, New Jersey, New York, and Utah departments of transportation (DOTs)—and other agencies have constructed demonstration projects. Since the early PCP installations in 2001, there have also been many advances in the design, panel fabrication, and panel installation aspects of PCP technology.

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. Implementation of PCP technology can significantly reduce traffic impacts of roadway repair and reconstruction projects, particularly on heavily traveled routes. The technology is applicable to small segments, enabling flexibility in construction phasing, as well as for use in corridor-wide pavement reconstruction.

SHRP2 PROJECT R05 BACKGROUND

Because the information on PCP technology was not well documented, in 2007 the Strategic Highway Research Program 2 (SHRP2) initiated Project R05 to develop the necessary technical information and guidelines that would encourage the rapid and successful adoption of this new technology. The Project R05 study was conducted from 2008 to 2012. The final report, Precast Concrete Pavement Technology, is available at http://www.trb.org/main/blurbs/167788.aspx. The study demonstrated that the PCP technology is ready for wider implementation and that many of the PCP systems available in the U.S. can meet the needs of highway agencies for rapid renewal of their highway systems. The following products were developed under SHRP2 Project R05:

- Overall findings related to viability of the PCP technology.
- Findings based on SHRP2 field testing.
- Guidelines for PCP project selection.
- Guidelines for PCP system acceptance.
- Guidelines for design of PCP systems.
- Guidelines for PCP fabrication.

- Guidelines for PCP installation.
- Implementation plan for PCP technology.
- Long-term monitoring plan for PCP projects.
- Model specifications.

A review of projects constructed in the U.S. and the SHRP2 field testing indicated that sufficient advances have been made to reliably design and construct PCP systems to achieve five key attributes of successful pavements, as follows:

- 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 jointed PCP systems and post-tensioned PCP systems.
- Panel support—Techniques to provide adequate and uniform base support conditions continue to be improved.
- Efficiency—Panels are thinner than standard cast-in-place concrete and last longer because of prestressing and/or reinforcing elements in the PCP system.

SHRP2 PROJECT R05 PRODUCT IMPLEMENTATION PROGRAM

In 2013, the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) created the SHRP2 Implementation Assistance Program (IAP) to help State DOTs, metropolitan planning organizations, and other interested organizations deploy SHRP2-developed products to deliver more efficient, cost-effective solutions to meet complex challenges. Seven rounds of the IAP were offered between February 2013 and April 2016.

On August 7, 2015, FHWA—in partnership with AASHTO—announced the selection of 21 transportation agencies receiving implementation and technical assistance awards as part of Round 6 of the SHRP2 IAP. The Louisiana Department of Transportation and Development (LADOTD), one of the agencies selected as a lead adopter of Project R05 technology, received an award of $300,000 to help offset the cost of constructing a PCP project that would provide a learning environment for operations such as fabricating panels, setting panels, installing dowel bars, grouting under panel areas, and other related activities needed to implement precast panel installations in Louisiana. The LADOTD also received a User Incentive Award of $75,000 to help support PCP implementation. The User Incentive Award was to be used for activities that promoted the adoption of the PCP technology, such as the development of specifications, standard drawings, training, workshops, and open house events.

This case study report provides details of the PCP implementation to rehabilitate the distressed concrete pavement along the eastbound entrance ramp onto I-20 at LA 169, in Greenwood, Louisiana. The ramp was rehabilitated during several weekends during May and June 2018.

LADOTD PCP IMPLEMENTATION ACTIVITIES

In early 2014, LADOTD began to investigate possible implementation of the PCP technology for rapid rehabilitation of distressed pavements. In June 2015, the FHWA PCP Implementation Team conducted a 1-day technical workshop on PCP technology in Baton Rouge. The workshop, "PCP Technology: State of Practice and Applications," provided attendees with up-to-date information on the best practices related to precast pavement technology and provided guidance on selecting candidate projects for PCP applications, developing project-specific design and construction requirements, and PCP system acceptance. The workshop was followed the next day with a meeting between the FHWA PCP Implementation Team members and senior LADOTD staff to discuss project-specific issues concerning candidate projects for implementation of precast concrete pavement technology in Louisiana. In August 2015, Louisiana received the SHRP2 IAP award of $300,000 to help offset the cost of constructing a PCP project and a User Incentive Award of $75,000 to support activities that promoted the adoption of the PCP technology.

During the fall of 2015, LADOTD staff identified several highway sections as potential candidates for a PCP demonstration project. The eastbound distressed concrete pavement ramp onto I-20 at LA 169, in Greenwood, was selected. In November 2015, a 1-day technical workshop on PCP technology was conducted in Shreveport for the local district staff. In March 2016, LADOTD sponsored a half-day seminar on PCP technology for contractors, precasters, and LADOTD staff in Baton Rouge.

In April 2016, as part of in-house training, 10 LADOTD staff members visited Caltrans's District 7 in Los Angeles to meet with Caltrans staff and to conduct site visits to several constructed PCP projects and one PCP project under construction. In addition, the LADOTD staff visited two precast plants. The trip was arranged in cooperation with FHWA to allow Caltrans District 7 to share their experiences related to implementation of the PCP technology for rapid rehabilitation of high-volume traffic highway pavements.

Finally, as part of the ramp project in Greenwood, LADOTD staff members from different districts were invited to observe the panel installation activities.

PROJECT DETAILS

PROJECT DESCRIPTION

LADOTD selected the distressed concrete pavement along the eastbound entrance ramp onto I-20 at LA 169, in Greenwood, for implementation of the PCP technology. This entrance ramp, with separate incoming right turn and left turn forks, carries heavy truck traffic into the Port of Shreveport. Figure 1 shows the locations of the ramp. The existing ramp exhibited a significant amount of slab cracking and had been designated for rehabilitation. The existing ramp condition is shown in figure 2.

Figure 1. Map. Eastbound ramp location at LA 169, in Greenwood. (The map is the copyright property of Google® Earth™ and can be accessed from https://www.google.com/earth.

Figure 2. Photos. Cracking in the existing concrete pavement along the ramp.

The LADOTD had considered replacing the eastbound ramp with a new concrete pavement but was concerned about the extended lane closure that would be required. The availability of the SHRP2 IAP funding and the availability of technical support from FHWA led the LADOTD to consider using PCP, requiring only short-period ramp closures, to provide a long-lasting solution for the distressed concrete pavement ramp. The LADOTD carried out an investigation of the support condition under the existing pavement. The investigation included coring and borings, dynamic cone penetrometer (DCP) testing, and drainage evaluation. Based on the findings of the investigation, the LADOTD decided to remove the existing base as well as a portion of the subgrade and designed an improved support for the precast panels, as discussed later.

The project notice of contract execution was issued on March 15, 2017, with a notice to proceed set as May 15, 2017. The ramp rehabilitation work consisted of fabricating, furnishing, and installing precast concrete panels in accordance with the project plans and specifications. The project specification required the use of a grout-supported PCP system and use of panels with bottom dowel slots. The grout-supported systems typically use a leveling system to set the panels at the desired elevation while maintaining a gap of about 1/4 to 1 inch (6 to 25 mm) between the panel bottom and the base surface. The gap is filled with a rapid-setting high-strength grout material. Panels included rectangular panels and non-rectangular (non-planar) panels. The contractor selected panels with bottom dowel bar slots and fitted with leveling lifts.

The contracted work included the following:

1. Performing a field survey.
2. Preparing the required submittals.
3. Removing the existing concrete pavement, base, and a portion of the subgrade.
4. Placing geogrid fabric, ballast rock, geo-fabric, and base layer.
5. Placing precast panels.
6. Setting panels at the designated elevation using leveling lifts.
7. Installing grout in the dowel bar slots and along joint gaps.
8. Installing grout bedding under the panels.
9. Performing finishing activities.

PRECAST CONCRETE PAVEMENT SYSTEM DETAILS

LADOTD developed a new specification item, NS-Precast Concrete Pavement System, dated January 2017, to be used for the demonstration project. The specification covered the qualifications for the PCP system to be used, the furnishing of the submittals, including shop drawings, and availability of technical assistance and training to be provided by the PCP system developer. The following key requirements were specified:

- PCP system off-site trial installation for a non-approved PCP system.
- Contractor trial installation (first night of the panel placement).
- Use of at least four lifting points per precast panel.

- Use of a grout-supported system capable of being adjusted to grade using a set of leveling bolts and supported by these bolts during the placement of cementitious bedding material between the panel bottom and the base. The thickness of the bedding grout was specified to be at least ½ inch (12 mm) and no more than 1 inch (25 mm).
- Use of panels with bottom slots for installing dowel bars and tie bars.

Precast Pavement Details

The details of the ramp rehabilitation are as follows:

- Existing concrete pavement.
  - Slab thickness: 9.0 inches (229 mm). A portion of the existing concrete pavement was overlaid with asphalt concrete (AC).
  - Stabilized aggregate base: 9 inches (229 mm).
  - Granular subbase: 10 inches (250 mm).
- Total number of panels installed: 260.
  - Panel thickness: 10.5 inches (267 mm).
  - Roadway width for panel installation: Variable. About 26 to 30 feet (7.9 to 9.1 m) for the main ramp, about 29 feet (8.8 m) for the left-turn fork, and 30 feet (9.1 m) for the right-turn fork.
  - Panel width: variable; 16 feet (4.9 m) maximum specified.
  - Panel length: variable; 15 feet (4.6 m) maximum specified.
  - Panel dimension limitation: One dimension to be not greater than 12 feet (3.7 m).
  - Panel type: planar and non-planar.
  - Panels to be set over the prepared base using FMC-supplied leveling lifts.
- Support under the panel.
  - Crushed stone base course (Class II): 18 inches (450 mm).
  - Geo-fabric.
  - Ballast rock: 6 inches (150 mm).
  - Geogrid.
  - Subgrade.
- Panel concrete – Class P1.
  - Form stripping compressive strength: 2,500 psi (17.2 MPa).
  - 28-day flexural strength: 650 psi (4.5 MPa).
- Joint load transfer using bottom slots.
  - 14-inch-long (355-mm-long) plastic-coated dowel bars spaced at 12 inches (300 mm).
  - Dowel diameter: 1-1/2 inches (38 mm).
- Longitudinal joint tie-bars: Headed No. 6 tie-bolts and bottom slots.
- Dowel bar slot grout: A minimum compressive strength of 2,500 psi (17.2 MPa) before the panels are open to traffic and a minimum compressive strength of 6,000 psi (41.3 MPa) at 28 days.
- Panel bedding grout: A minimum compressive strength of 500 psi (3.4 MPa) at 1 hour or before the panels are open to traffic and a minimum of 2,500 psi (17.2 MPa) at 7 days. Efflux time (ASTM C939) to be 15 to 30 seconds.
- Bearing (base) plates for use with leveling lifts.

    - Type A: 11-3/8 by 11-3/8 inches (297 by 297 mm) by ½ inch (12 mm) thick; for panels weighing greater than 20,000 pounds (9,000 kg).
    - Type B: 9 by 9 inches (228 by 228 mm) by 3/8-inch (18 mm) thick; for panels weighing 20,000 pounds (9,000 kg) or less.
- Lifting and leveling bolt diameter: 1-1/4 inches (32 mm).
- Joint sealing: All joints were required to be sealed.

Figure 3 shows the precast panel layout for the ramp developed by the contractor. As noted earlier, the project included both planar (rectangular) and non-planar panels. The non-planar panels were used to accommodate the curved portions of the ramp pavement. The use of non-planar panels, with location-specific geometry, requires a detailed roadway survey and locating of each unique non-planar panel at the correct location during panel installation.

Reinforced Precast Panels

The contractor elected to use reinforced panels incorporating bottom dowel bar slots. The panels incorporated the following features:

- Transverse joint load transfer system that uses bottom slots. One transverse side of the panel has the bottom dowel slots, and the other side has embedded dowel bars, except for end panels.
- A set of four lifting inserts and leveling lifts per panel, embedded with bearing plates for the leveling lift system.
- Grout ports over the dowel bar slots.
- Ports for bedding grout.
    - Four ports for panels less than 12 feet (3.7 m) long.
    - Six ports for panels equal to or longer than 12 feet (3.7 m).
- Foam gaskets that line the bottom perimeter of the panel on three sides and behind the dowel slots for the fourth side. The foam gasket keeps the dowel slot grout from flowing into the panel bottom area.
- Panel surface finishing as per the project plans and specification requirements.

The panel dimensions varied based on location along the ramp, as follow:

- Right-turn fork:
    - Three panels across the 30-foot-wide (9.1-m-wide) fork roadway.
    - Panel width typically about 10 feet (3.1 m), with a few panels about 20 feet (6.1) wide; panel length nominally about 8 feet (2.4 m).
- Left-turn fork:
    - Three panels across the 29-foot-wide (8.8-m-wide) fork roadway.
    - Panel width typically about 10 feet (10.1 m), with a few panels about 20 feet (6.1 m) wide; panel length nominally about 8 feet (2.4 m).
- Main ramp:
    - Three panels across the 26-foot-wide (7.9-m-wide) (nominal) first segment and two panels across the 26-foot-wide (7.9-m-wide) (nominal) remaining segment.

- For the first segment, panel width was about 10 feet (9.1 m) nominally. For the second segment, panels were nominally 10 feet (9.1 m) and 16 feet (4.9 m) wide.
- Panel length varied from about 8 feet (2.4 m) to about 12 feet (3.7 m).

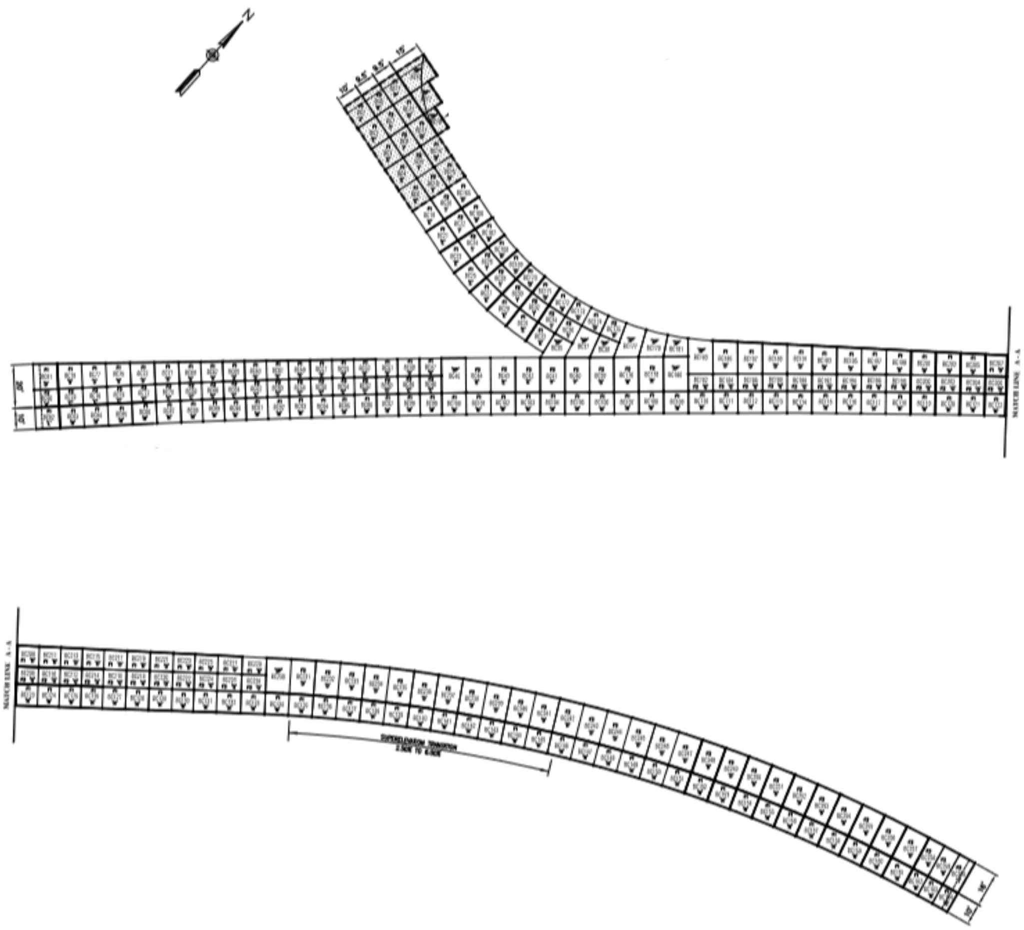

Figure 3. Diagram. Panel layout at the entrance ramp.

Leveling Lift System

LADOTD specified use of a leveling lift system to be fitted in the panels at the precast plant. The lift system is used with grout-supported panel placement. The leveling lift system used for the ramp project was custom-designed for this project and served a dual purpose. The leveling lift system consists primarily of a base plate, a threaded insert (Dayton Superior P1 Four Strut Lift Inserts), and a threaded leveling bolt with a diameter of 1-1/4 inches (32 mm). The plate had two studs to keep the plates affixed to the panel bottom during handling and shipping. With four lifts per panel, the insert is used as a lift insert to handle the precast panels. After the panel has been placed, the inserts are used, using leveling bolts, to set the panels at the desired elevation and to maintain super elevations. The coil insert and the bearing plate for the lift/leveling system are shown in figures 4.

Figure 4. Photo. The leveling lift system – base plate and Dayton Superior Insert.

The project specifications required the panels to meet the tolerances listed in table 1.

Table 1. Panel geometric tolerances.

Length (parallel to long axis of panel)	± 1/4”
Width (normal to long axis of panel)	± 1/4”
Nominal Thickness	± 1/8”
Squareness (difference in measurement from corner to corner across top surface, measured diagonally)	± 3/16”
Horizontal Alignment	± 1/4”
Deviation from straightness of mating edge of panels Vertical Alignment–Camber Deviation of ends (horizontal skew) Deviation of ends (vertical batter)	 ± 1/8” ± 1/8” ± 1/8”
Position of lifting anchors	± 6”
Position of non-prestressed reinforcement, if used	± 1/2”
Position of pretensioned strands, if used	± 1/4”
Dimensions of blockouts/pockets	± 1/4”

Dowel Slot Grout

A high-strength dowel bar grout was specified to fill the bottom slots. The project specification required the bottom slot grout to achieve compressive strength of 2,500 psi (17.2 MPa) at the time of opening to traffic and 6,000 psi (41.3 MPa) at 28 days. The contractor elected to use the ProSpec Slab Dowel Grout. This grout can achieve compressive strength of 2,000 psi (13.8 MPa) at 2 hours and 3,500 psi (24.1 MPa) at 3 hours at a temperature of 45 °F (7 °C).

Bedding Grout

The project specifications required the use of rapid-hardening, free-flowing cementitious grout. The grout was required to achieve a compressive strength of 500 psi (3.4 MPa) at the time of opening to traffic and 2,500 psi (17.2 MPa) at 7 days. The grout provides bedding support for precast concrete panels. The grout exhibits rheological fluid properties allowing small voids between the base and the precast concrete panels to be filled. The contractor elected to use the ProSpec Slab Bedding Grout - Rapid. This grout can achieve a compressive strength of 1,400 psi (9.6 MPa) at 45 minutes and 5,500 psi (37.9 MPa) at 28 days when tested in the laboratory at a temperature of 72 °F (22 °C).

Panel Installation Tolerances

The project specification required the panels to be installed within the tolerances listed in table 2.

Table 2. Panel installation tolerances.

Horizontal Alignment: Longitudinal centerline to surveyed centerline marked on the surface of the base and adjacent panels. Transverse centerline to surveyed marks on adjacent panels	± 1/4” ± 1/4”
Vertical alignment: Top surface of precast panel with respect to top surface adjacent panels at any point	± 1/8”
Gap width at top surface between adjoining panels Note: Maintaining variable transverse joint width more than ½ inch will be cause for stoppage of panel installation operations until the contractor states in writing how he plans to correct this deficiency.	1/2” max transverse and 1/2” max longitudinal

PANEL FABRICATION

The panels were fabricated at a precast plant located in Grand Prairie, Texas, about 200 miles from the project site. The panels were fabricated based on shop drawings prepared by FMC and approved by LADOTD. As part of the panel fabrication process, the concrete was regularly tested for fresh properties and for strength. In addition, the concrete was tested for electrical resistivity at 28 days, a requirement for concrete used on LADOTD projects. The concrete typically exceeded the design flexural strength of 650 psi (4.5 MPa) at 28 days and typically exceeded 2,500 psi (17.2 MPa) at about 16 hours to allow for panel form stripping.

The panels were cast during early afternoon and wet cured with burlap overnight and up to the time of form stripping the next morning. Curing compound was applied after the form stripping. The precaster typically cast 5 panels per day and averaged about 20 panels per week. Panel precasting began during late October 2017 and was completed by April 2018. The contract required panel installation to begin only after all panels had been cast and cured for 28 days.

The panels were stored at the precast plant during the curing period and were delivered to the staging area near the project a few days before use. Figure 5 is a view of the panel bottom showing gasket behind the dowel bar slots. The gasket is used to prevent the dowel slot grout from flowing into the under-panel area.

Figure 5. Photo. View of the panel bottom showing gasket around dowel bar slots.

CONSTRUCTION STAGING AND CONSTRUCTION TRAFFIC MANAGEMENT

As discussed, the contract required the panel installation to be carried out over five extended weekends. The contractor was allowed to enforce full ramp closure during these weekends. In addtion, the contractor was allowed to perform panel installation-related activities during weekday nights. During the ramp closure, all traffic that would normally use the ramp was diverted to the next eastbound entrance ramp at LA 511, a distance of about 2 miles (3.2 km) along Greenwood Road (US 80). Before the panel installation work started, LADOTD conducted extensive public awareness activities related to possible disruption to nighttime and weekend traffic using the entrance ramp.

Panel Installation Staging

The contract specification allowed for nightly closures and four extended weekend closures. The panel installation work was divided into five stages. Each stage installation was to be carried out over a weekend, between Friday evening (10 pm) and early Monday morning (6 am), under full ramp closure. The five stages are illustrated in figure 6 and listed below:

- Trial section installation, left-turn fork of the ramp, 18 panels.
- Stage 1: Right-turn fork of the ramp, 46 panels.
- Stage 2: Remaining portion of the left-turn fork of the ramp, 62 panels.
- Stage 3: Portion of the main ramp, 76 panels.
- Stage 4: Remaining portion of the main ramp, 58 panels.

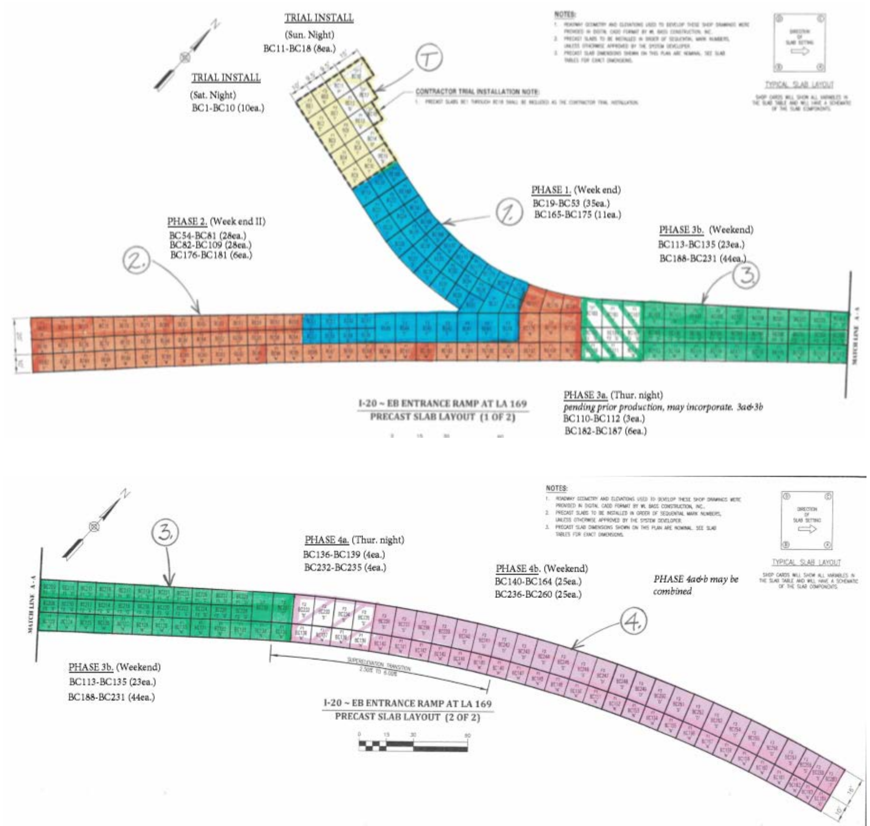

Figure 6. Diagram. Panel installation staging.

The following are the typical installation steps for the PCP system used for each stage:

1. Wednesday/Thursday nights, starting at 10 pm: Mark repair limits and provide full-depth sawcut along the perimeter of the repair area to be worked that weekend.
2. Saturday morning/afternoon:
    a. Remove existing concrete pavement, the base and a portion of the subgrade pavement.
    b. Prepare subgrade base (grade and compact).
    c. Place geogrid.
    d. Place 6 inches (150 mm) of ballast aggregate, grade and compact.
    e. Place geotextile.
    f. Place 18 inches (457 mm) of crushed stone base in two lifts, grade and compact.
3. Saturday evening/Sunday morning:
    a. Place panels over the prepared base layer, with the bottom slots located over the dowel bars in previously placed panels.

   b. Maintain the transverse and longitudinal joint widths as specified.
   c. Use leveling bolts to raise the panels to planned elevation.
   d. Grout the bottom slots and the transverse joint gaps for each panel.
   e. Apply the bedding grout.
   f. Remove the leveling bolts.
4. Sunday afternoon/evening: Perform finishing activities.
5. Monday early morning: Open to traffic by 6 am.

The penalty for late opening to traffic was $15,000/hour for every hour that the ramp was closed outside of the allowable times.

Panels were shipped to a staging area near the project site, a few days before each weekend's work. The staging area was also used for the aggregate stockpiles and storage of grout bags. A view of the staging area is shown in figure 7.

Figure 7. Photo. Staging area for panels.

PANEL INSTALLATION

The contractor's proposed weekend (Friday/Saturday/Sunday) schedule for the panel installation and the actual installation schedule were as follows:

- Trial section installation, left-turn fork of the ramp, 18 panels.
  - Planned: May 4/5/6.
  - Actual:
    - May 4 and 5: Failed test section installation. Two panels installed and removed.
    - Night of May 10 (Thursday): Ten panels installed. However, some of the bedding grout used was not of the rapid-setting type, which resulted in delay in opening to traffic from the scheduled 6 am to 2 pm. Because the contractor did not have enough supply of the rapid-setting bedding grout

bags, the second night of the trial installation was postponed until the following week.
        - Night of May 19 (Saturday): Eight panels installed.

- Stage 1: Right-turn fork of the ramp, 46 panels.
    - Planned: May 11/12/13.
    - Actual: June 1/2/3.
- Stage 2: Remaining portion of the left-turn fork of the ramp, 62 panels.
    - Planned: May 18/19/20.
    - Actual: June 8/9/10.
- Stage 3: Portion of the main ramp, 76 panels.
    - Planned: May 25/26/27.
    - Actual: June 22/23/24.
- Stage 4: Remaining portion of the main ramp, 58 panels.
    - Planned: June 1/2/3.
    - Actual: June 29/30 and July 1.

The contractor began the trial section panel installation on Friday, May 4. The work area perimeter sawcutting was performed during Friday night. During the afternoon of Saturday, May 5, the contractor began the removal of the existing concrete pavement, the base, and a portion of the subgrade for the 18 panels to be placed. Then, the geogrid, ballast aggregate, geotextile fabric, and base layer were placed. The base layer grading was controlled using a global positioning system (GPS)-based total station survey system. The base layer was compacted and graded. Then, panel placement began. Two panels were installed. However, the contractor realized that the leveling bolts needed to elevate the panels were the wrong size. The bolts available were 1 inch (25 mm) in diameter, instead of the needed 1-1/4 inches (32 mm). Since the panel elevation could not be adjusted, the contractor decided to cancel the trial installation and removed the two panels and covered up the work area with additional base material and 3 inches (75 mm) of AC surfacing to allow the ramp to be opened to traffic the following day (Sunday). The contractor decided to place 10 of the 18 panels during the following Thursday night and the remaining 8 panels of the trial section another night. After review of the installation process and based on discussions with LADOTD, the contractor revised the panel installation schedule as noted above.

The typical panel installation activities are summarized next.

Existing Pavement Removal

1. Full-depth perimeter saw-cutting of the work area.
2. Breaking of the existing concrete slab into large pieces using a hydraulic breaker, as shown in figure 8.
3. Removal of the broken concrete slab, the base, and a portion of the subgrade using excavator equipment with a bucket, as shown in figures 9 and 10. The total depth of the work area after material removal was about 30 inches (760 mm).
4. Grading the subgrade and checking the grade using a GPS-based total station survey system, as shown in figure 11.
5. Placing the geogrid, shown in figure 10, over the graded and compacted subgrade.

6. Placing 6 inches (150 mm) of the ballast aggregate, as shown in figure 12.
7. Placing a geo-fabric over the ballast layer, as shown in figure 13.
8. Placing the 12 inches (300 mm) of the granular base material in two lifts. Figure 14 shows the base being roller compacted. The top lift of the base was surface-wetted before grading and compaction. The base compaction was monitored using a nuclear gage, as shown in figure 15. The base grading was monitored using the GPS-based total station survey system and was also spot checked by the LADOTD staff using survey equipment. The corner points for each panel were located and marked on the base using blue-top hubs (stakes). This is a necessary requirement for installing non-planar panels. The base grade levelness was also checked using a 14-foot (4.3-m) straightedge.

Figure 8. Photo. Existing concrete pavement demolition.

Figure 9. Photo. Broken concrete removal.


Figure 10. Photo. Subgrade excavation and geogrid for placement over subgrade.


Figure 11. Photo. GPS-based total survey station being used to check subgrade grade.


Figure 12. Photo. Ballast aggregate placement.

Figure 13. Photo. Geo-fabric placement over the graded and compacted ballast aggregate.

Figure 14. Photo. Base compaction.

Figure 15. Photo. Base compaction testing using a nuclear gage.

Panel Placement

After the base grades were confirmed and the panel corner locations marked on the base, the panel placement began. The first panel installation for the trial section (left-turn fork) is shown in figure 16. After each panel was placed, headed tie-bolts were threaded into the longitudinal side of the panel, depending on the panel location. Typically, two or three panels were placed side by side before progressing forward. The trial section panel installation (left-turn fork) is shown in figure 17. The completed Stage 1 and Stage 2 (right-turn and left-turn forks) panel installation is shown in figure 18.

Figure 16. Photo. Trial installation first panel.

Figure 17. Photo. Completed left-turn fork (trial section and Stage 2).

Figure 18. Photo. Completed Stage 1 and Stage 2 (right-turn and left-turn forks).

Typical Panel Installation Activities (Stage 3 Example)

1. Compact and grade the granular base. The completed base layer, ready for Stage 3 panel placement, is shown in figure 19.
2. Apply the debonding liquid to the joint face with embedded dowel bars of the previously placed panels, as shown in figure 20.
3. Place the first panel. Figure 21 shows the first panel of Stage 3 placed on the base. The figure shows the embedded dowel bars as well as the inserted treaded headed tie-bolts along the longitudinal side of the panel.
4. Place panels across the width of the roadway. For this segment of Stage 3, three panels were placed across the width of the ramp, as shown in figure 22.
5. Continue panel placement. After all panels for Stage 3 were placed, install the leveling bolts, four per panel, as shown in figure 23, and adjust the panel surface elevation, typically creating a gap of ½ inch (12 mm) below the panel bottom.

Figure 19. Photo. Base ready for Stage 3 panel placement.

Figure 20. Photo. Debonding liquid being applied to the joint face with embedded dowel bars.

Figure 21. Photo. Use of headed tie-bolts along the longitudinal side of the panel.

Figure 22. Photo. Stage 3 panel placement – three panels across the roadway width.

Figure 23. Photo. Stage 3 panels with leveling bolts engaged.

Grouting

After the panels were set at the desired elevation, the dowel slot pocket grouting was started. Two grout mixtures were used for grout production, as shown in figure 24. The contractor had to use ice cooled water due to the hot weather at the time of grouting to prevent the grout material setting up quickly and clogging the grout mixers. The grout mixer clogging required frequent cleaning of the grout mixer's auger assembly and the filter screen. Generally, the dowel slot grouting operation proceeded well. The dowel slot grouting operation, using the two surface ports at each dowel slot, is shown in figure 25. Figure 26 shows the sprayed polyurethane foam applied at each outside end of each transverse joint to prevent the dowel slot grout from leaking out of the joint. The grout was also applied full-depth along the transverse joint gaps and the interior longitudinal joint gaps.

Soon after the dowel slot grout had set, typically after about half an hour, the leveling bolts were removed, and the bedding grout operation was started. Before the grout operation commenced and after each cleanup of the grout mixtures, the grout efflux testing was performed, as shown in figure 27. The contract required the efflux time to be 15 to 30 seconds. If the efflux time did not meet the project limits, the grout in the hose was discarded and the grout mix adjusted as necessary to bring the grout flowability into conformance.

After the bedding grout application was completed, the panel surface cleanup was carried out. The work area was opened to traffic a few hours later to ensure that the dowel slot grout and the bedding grout had achieved the required strength levels for opening to traffic.

Grout testing was performed before the start of the panel installation to verify that the two grouts to be used could achieve strength levels needed for opening to traffic and at the specified age of 28 days. Grout testing was required to be conducted throughout the grouting process. Twenty-four cube samples were required to be tested for each grout type at 2 hours, 4 hours, 24 hours, and 28 days.

Grout testing was performed during the trial section installation. However, grout testing was not performed during the production panel placement.

Figure 24. Photo. Two grout mixers used for grouting.

Figure 25. Photo. Stage 3 dowel slot grouting.

Figure 26. Photo. Polymer foam use at ends of transverse joints to prevent grout leakage.

Figure 27. Photo. Efflux testing for the bedding grout.

Deflection Testing and Coring at Dowel Slots

The project specification required deflection testing at the joints of the trial section panels. LADOTD conducted falling weight deflectometer (FWD) testing of the trial section panels on May 23, 2018. The FWD joint deflection data indicated low deflections at the transverse joints under a nominal load of 9,000 lbf (40 kN), indicating good support under the panels. The maximum deflections at the joint were typically less than 5 mils (0.13 mm). The deflection testing also indicated good load transfer across the tested transverse joints.

Cores were also obtained over several dowel-bar and tie-bar slots. All cores indicated good encasement of the dowel bars and the tie-bars by the dowel bar slot grout.

Panel Placement Quality Issues

There were several quality issues that unnecessarily affected panel placement efficiency and the quality of the final product. The more significant issues are summarized below:

- Trial section installation.
    - Wrong size leveling bolts, requiring cancellation of the trial installation.
    - Job site training of the contractor crew with various aspects of the panel placement activities. This resulted in requiring more effort to get the base grade finalized and locating of the corner points for panel placement. As a result, during the next try for the trial section, the contractor decided to place only 10 of the 18 panels designated for the trial section.
- Mis-labeling of the panels. This resulted in the wrong non-planar panels arriving at the work site. The correct panels had to be located, resulting in delays.
- Mismatch between the location of a dowel bar in a previously placed panel and the dowel bar slot of the next panel to be placed. This required widening of the affected dowel bar slot, as shown in figure 28.
- Joint spalling. Several panels exhibited joint spalling because of use of pry bars to guide panels as the panels were being placed over the base. A typical spall is shown in figure 29.

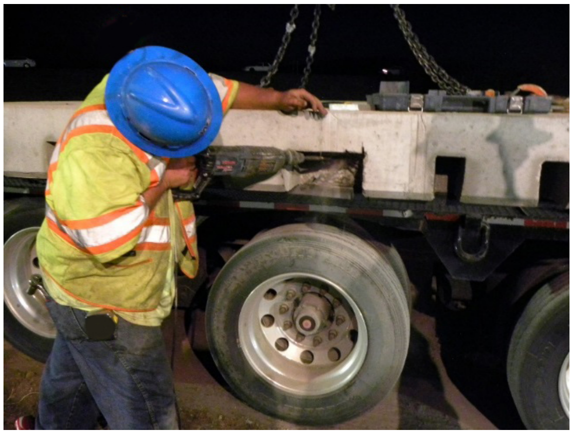

Figure 28. Photo. Panel slot being widened to accommodate mislocated dowel bar.

Figure 29. Photo. Stage 3 panel spalling at a transverse joint.

Finishing Activities

The transitions were constructed between the PCP end panels and the existing asphalt pavement and the concrete pavement. For these transitions, 2 inches (50 mm) of AC was milled from the existing pavement adjacent to the end panels and overlaid with new AC that extended 4 feet (1.2 m) into the step-down section of the end panels. The step-down section of an end panel can be seen in figure 16. The shoulders were reconstructed with thin surfacing of hot-mixed AC and a new granular base.

A few days after the ramp panel installation was completed, the contractor performed diamond grinding of the entire project. Diamond grinding of the surface was specified to achieve the specification requirement for surface smoothness. In addition, the contractor performed transverse grooving along the entire project as required by the project specification. After the grooving was performed, all transverse and longitudinal joints were sealed.

A view of the completed entrance ramp, after grinding and grooving, is shown in figure 30.


Figure 30. Photo. Completed precast pavement installation.

LESSONS LEARNED

This project was an important first step in the implementation of PCP technology in Louisiana. As part of getting ready for the first PCP project, the LADOTD carried out several activities, as previously discussed and summarized below:

- Participation in FHWA-sponsored workshops on PCP best practices.
- Development of a provisional specification for PCP.
- Meeting with industry stakeholders to review PCP implantation plans and the provisional PCP specification.
- Visiting PCP projects and precast plants in the Los Angeles area and meeting with Caltrans personnel to review Caltrans's experience with PCP implementation.

Based on the experience gained at the Greenwood PCP project, the LADOTD expects to review the provisional PCP specification and incorporate appropriate modifications to improve the efficiency and quality of panel placement. Some of the items that will be addressed are described below.

Materials Check

As discussed previously, the contractor had to cancel the trial section installation because the leveling bolts brought to the project site were the wrong size, 1 inch (25 mm) in diameter of the required 1-1/4 inches (32 mm). This error could have been easily corrected if the contractor had done a mock-up run at the staging area to train his crew.

In addition, during the trial installation, after the bedding grout had been placed, the contractor discovered that some of the bedding grout bags used were not of the rapid-setting type. The discovery was made because grout cube samples prepared at the project site did not set for several hours. It required over 10 hours for the bedding grout to achieve the opening to traffic strength of 500 psi (3.4 MPa). As a result, the ramp opening was delayed from the scheduled 6 am to 2 pm.

Shop Drawings

Panel quantity overran because of slight differences on every edge panel. The proposed panels were anywhere from 2 or 3 inches (25 to 75 mm) wider to 6 or 8 inches (150 to 200 mm) wider. The CAD drawings for shop drawings need to be referenced into the LADOTD's design file.

Transverse Joint Gap

Joint gaps between the panels were specified to be 1/8 to ½ inch (3 to 12 mm). However, a 1/8-inch (3 mm) gap is difficult to get enough dowel grout to pump into and fill the joint gap. These narrow joints had to be refilled later. The minimum joint width should be specified to be ¼ inch (6 mm) for bottom slot panels.

Panel Labeling

Panel number/label should be scribed/stamped into the panel surface. This could help alleviate the panel mislabeling issues encountered at this project.

Base Smoothness and Grout Bedding Use

Possibly consider use of a rapid-setting lean concrete base, which would allow for easier/faster/smoother base grading and for better panel placement. The lean concrete base can be placed over the existing re-worked base, as appropriate.

Pry Bar Use

Panel guiding when setting the panel needs to be done with pry bars in port holes or wooden wedges at the bottom of the panels only. Use of wedges or pry bars at the top of the panels results in edge spalling and should be prohibited.

Grout Testing

The grout testing during panel placement needs to be better defined to ensure the proper number of grout cubes are prepared and tested at various ages to determine the right time for opening the work area to traffic.

Specification Wording

It is important to clearly define the intent of specification items so that there can be no misinterpretation of specification items. Otherwise, contractors may try to interpret ambiguous specifications in their favor.

Dummy Panel Use

Require use of dummy panels for the gap between installation nights. Use of cold mix to fill the gap can damage the embedded dowel bars at the end panels.

Joint Sawing and Sealing

This item needs to be clearly stated in the contract documents, and the cost should be incidental to panel installation cost.

Trial Section Installation

The trial installation should not be used as an opportunity to train contractor staff or to try out various equipment and processes. Contractor staff training and verification of the construction processes should be done off-site before the trial section construction.

Grout Mixers

Contractors need to ensure that the grout can be produced at the required rate on a continuous basis without clogging and without the grout setting up in the mixer. The grout clogging has not been an issue at PCP projects installed in other States.

Grout testing needs to be performed for each night of panel placement to monitor the quality of the grouts.

Non-Planar Panels

Use of non-planar panels unnecessarily complicated panel placement. In addition, the panel shop drawings were complicated. The casting process was slow and required an extension of the panel fabrication period. It also caused problems during the installation (multiple mislabeled panels and multiple panels where the dowel bars and dowel bar pockets did not line up). The number of non-planar panels in a project should be limited to the smallest number feasible.

SUMMARY

The use of the PCP technology on a production pavement rehabilitation project was an important step for LADOTD. This was the first application of the PCP technology by the LADOTD, and they expect to use the experience and findings from this demonstration project to refine specifications and plans for production use of PCP technology at future pavement repair and rehabilitation projects along roadways with high traffic volumes, where work can only be performed during nighttime lane closures and where treatments need to provide long-life service.

The ramp rehabilitation project in Greenwood is considered a successful implementation of the PCP technology on a production basis by an agency that had not constructed a PCP project previously.

ACKNOWLEDGMENTS

The support of the following LADOTD staff during the project planning phase, during data collection for this report, and during the construction site visit is gratefully acknowledged:

- Phillip Sturdivant – Project Engineer.
- Kevin Blunck – Area Engineer.
- Jason Lacombe – Project Manager.
- Tyson Rupnow – Associate Director of Research, Louisiana Transportation Research Center.
- Ray Mumphry – Assistant Bridge Engineer.
- John Eggers – Headquarters Area Construction Engineer.
- Casey Allen – Fabrication Engineer.
- Matthew Jones – Area/Site Manager Engineer.

The support of Mr. Benjamin Thomas, formerly Project Manager at LADOTD, is also gratefully acknowledged.