FHWA REPORT NO. FHWA-HIF-18-003

FHWA PROJECT R05 IAP FUNDED PROJECT CASE STUDY

MOBILE RAMP PRECAST CONCRETE PAVEMENT DEMONSTRATION PROJECT

U.S. Department of Transportation
Federal Highway Administration

December 2017

1. Report No.	2. Government Accession No	3. Recipient's Catalog No
FHWA-HIF-18-003		

4. Title and Subtitle
FHWA Project R05 IAP Funded Project Case Study: Mobile Ramp Precast Concrete Pavement Demonstration Project

5. Report Date
December 2017

6. Performing Organization Code

7. Authors
Shiraz Tayabji, Ph.D., P.E.

8. Performing Organization Report No.

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 2016 – December 2017

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 15 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 Alabama Department of Transportation, 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. 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.

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

Security Classification (of this report): Unclassified	19. Security Classification (of this page): Unclassified	20. No. of Pages 31	21. Price

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

MODERN METRIC CONVERSION FACTORS

Conversion factors both to and from the modern metric International System of Units (SI) can be found at: http://www.fhwa.dot.gov/publications/convtabl.cfm.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

ABBREVIATIONS AND ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt concrete
DOT	Department of transportation
FHWA	Federal Highway Administration
FMC	Fort Miller Company, Inc.
FWD	Falling weight deflectometer
IAP	Implementation Assistance Program
PCP	Precast concrete pavement
SHRP2	Strategic Highway Research Program 2

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 16 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 Caltrans, Illinois Tollway, and the 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.

The 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 Alabama DOT, 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 Alabama.

This case study report provides details of the PCP implementation to rehabilitate a distressed asphalt concrete (AC) ramp at Exit 2 of I-165, intersecting with Alt US 90 (New Bay Bridge Road), in Mobile, Alabama. The ramp was rehabilitated in September 2017.

PROJECT DETAILS

PROJECT DESCRIPTION

Alabama DOT selected a distressed AC ramp at Exit 2 of I-165, intersecting with Alt US 90 (New Bay Bridge Road), in Mobile, Alabama, for implementation of the PCP technology. This exit carries heavy truck traffic into the Port of Mobile. Figure 1 shows the locations of the ramp and the left turning lanes at Exit 2 of I-165. The exit ramp merges with West Rebel Road just before the intersection with Alt US 90. The right turn lane at the intersection is off West Rebel Road.

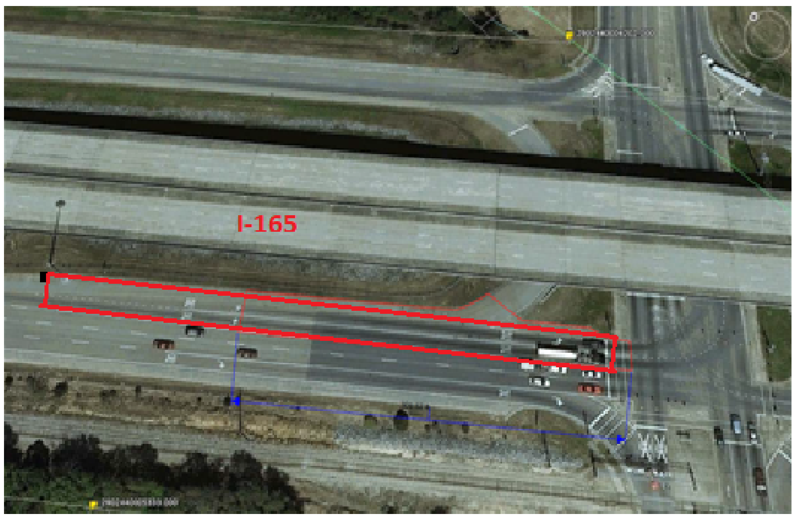

Figure 1. Photo. Ramp locations at Exit 2, I-165, in Mobile.

The exit ramp's two left turning lanes onto Alt US 90 (New Bay Bridge Road) had experienced heavy rutting in the past due to the heavy truck traffic. A complete shutdown of these lanes for an extended period of time (longer than a work day) was not considered feasible, as this intersection is a corridor for traffic utilizing the Port of Mobile. In the past, the DOT repaired the rutting using the mill and fill technique, including heater scarification (hot in-place recycling). However, rutting up to about 4 inches deep reappeared within a few months, requiring frequent maintenance operations along the left turn lanes. Figure 2 shows the rutting in the existing asphalt pavement near the intersection stop line.

The DOT had considered replacing the left turn ramp lanes with a 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 DOT to consider use of PCP to provide a long-lasting solution for the distressed AC ramp lanes.

Figure 2. Photo. Deep rutting in the AC pavement at the intersection stop line.

The ramp rehabilitation work consisted of fabricating, furnishing, and installing precast concrete panels in accordance with the project plans and specifications. The work included performing a field survey, preparing the required submittals, removing the existing AC pavement, grading and compacting the existing base layer, placing panels, setting panels at the designated elevation using leveling lifts, installing dowel grout in the dowel bar slots and along joint gaps, installing grout bedding under the panels, and performing finishing activities.

The project specification required the use of a grout-supported PCP system. 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 1/2 inch between the panel bottom and the base surface. The gap is filled with a rapid setting high strength grout material. The DOT elected to use two-lane-wide panels, 25 feet in width, to eliminate an open longitudinal joint between the two lanes. The contractor elected to use panels with bottom dowel bar slots (developed and patented by the Fort Miller Company, Inc. [FMC]) and fitted with leveling lifts developed by FMC for this project.

The project details are as follows:

- Alabama DOT Project No.: TIDP-IMI165 (302).
- Project owner: Alabama DOT.
- Prime contractor: McElhenney Construction Company LLC, Theodore, Alabama.
- Project plans and specifications prepared by: Alabama DOT.
- Panel precaster: Universal Precast, Inc., Theodore, Alabama.
- Precast panel developer: Fort Miller Co., Inc., Schuylerville, New York.
- Field inspection service for Alabama DOT: Thompson Engineering, Mobile, Alabama.
- Panel leveling lifts: Supplied by the Fort Miller Co., Inc.
- Dowel slot grout: ProSpec Slab Dowel Grout manufactured by H.B. Fuller Construction Products, Inc., Aurora, Illinois.
- Panel bedding grout: ProSpec Slab Bedding Grout manufactured by H.B. Fuller Construction Products, Inc., Aurora, Illinois.

Figure 3 shows the precast panel layout for the ramp.

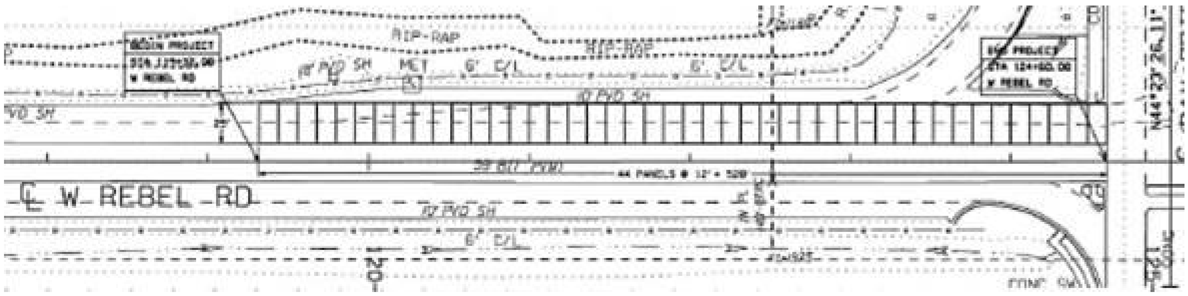

Figure 3. Diagram. Panel layout at the two left turn lanes at the ramp.

PRECAST CONCRETE PAVEMENT SYSTEM DETAILS

In early 2014, Alabama DOT began to investigate possible implementation of the PCP technology for rapid rehabilitation of distressed pavements. In July 2014, the FHWA sponsored a 1-day workshop, "PCP Technology: State of Practice and Applications," in Montgomery, Alabama. The workshop provided attendees with the most 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 Alabama DOT staff. Subsequently, during August 2015, Alabama received the SHRP2 IAP award of $300,000 to help offset the cost of constructing a PCP project.

The DOT identified the Exit 2 ramp off I-165 in Mobile as a candidate for implementing the PCP technology. During December, 2015, FHWA conducted a workshop in Mobile for the Mobile Area Office DOT staff. The FHWA PCP implementation team members and the DOT staff visited the Exit 2 site and discussed the logistics of installing PCP at that site. Based on discussion during the site visit, it was recommended that the use of two-lane-wide panels would be an effective solution, as it would eliminate an open longitudinal joint between the two lanes.

During 2016, Alabama DOT carried out site studies and traffic counts and developed plans and specifications for the PCP project. Cores were obtained to verify AC depth along the section to be rehabilitated, and borings were taken to verify the base and subbase quality and thicknesses.

Alabama DOT developed a new specification item, Section 451 – Precast Concrete Pavement System, to be incorporated in the Alabama Standard Specifications. This section covers the design, furnishing, and installation of the PCP system as shown in the plans. The required geometric details and fabrication details of the pavement panels and the required details of the installation of the pavement system are included in this work. The following key panel requirements were specified:

1. Provide at least four lifting points per precast panel.
2. Prestressing of the panels at the precast plant by pretensioning is acceptable.
3. Provide for either a double mat of reinforcement or pretensioning in the longitudinal and/or transverse direction. The percent of steel to be used will be a minimum of 0.18 percent of the concrete cross-sectional area, uniformly distributed across the length or the

width of the panel, as applicable. The maximum center-to-center bar spacing in both directions shall be 12 inches.

4. Provide a grout-supported system that is 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 shall be ½ inch minimum, 1 inch maximum.
5. Load transfer slots at transverse joints shall be one of the following methods:
    a. Dowel slots at the panel bottom at one transverse edge and embedded dowels at the other transverse edge, as detailed in the accepted fabricator shop drawings.
    b. Conventional dowel slots at one transverse edge and embedded dowels at the other transverse edge, as detailed in the accepted fabricator shop drawings. These surface slots shall be patched during the same lane closure as the one used for placing the panels using the details provided in the accepted fabricator shop drawings.
    c. Narrow-mouthed dowel slots at the surface, as detailed in the accepted fabricator shop drawings. This technique allows the panels fabricated with surface dowel slots to be left in place in the repair area without immediately patching the slots.
    d. Minimum dowel bar diameter shall be 1-¼ inches or panel thickness/8, whichever is greater, and spacing shall be as shown in the plans.
    e. To facilitate transporting of the panels, one dimension (length or width) shall be limited to a maximum dimension of 12 feet (dimension includes any embedded dowel or tie bar length protruding from the panel)

The project plans required use of dowel bars only at the wheel paths, four dowel bars per wheel path, as shown in Figure 4.

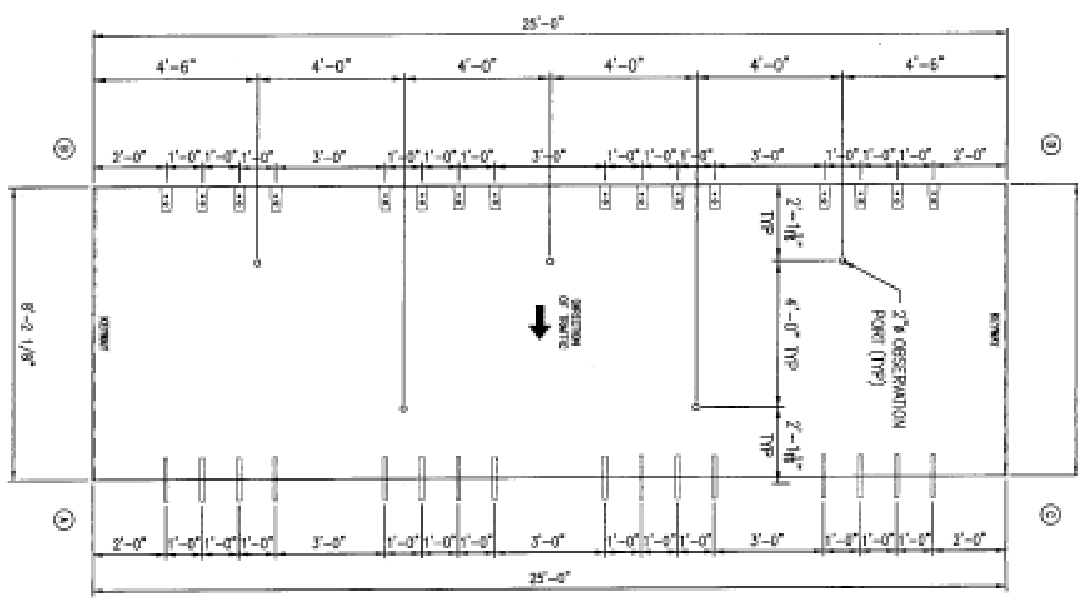

Figure 4. Diagram. Location of the dowel bars across the two-lane-wide panel.

The project was awarded during April 2017.

PRECAST PAVEMENT DETAILS

The original left turning pavement was an AC pavement. The details of the ramp rehabilitation are as follows:

- Existing AC pavement.
    - AC thickness: 6.0 inches.
    - Processed aggregate base: 6 inches.
    - Granular subbase: 10 inches.
    - Shoulder (adjacent to the left turning lanes): 6-inch-thick AC
- Length of panel installation: 531.5 feet.
- Total number of panels installed: 65.
    - Panel thickness: 9 inches.
    - Panel width: 25 feet.
    - Length of standard panel: 8 feet 2-1/8 inches.
    - Panels to be set over the prepared base using FMC-supplied leveling lifts.
- Base for the PCP: Regraded and compacted existing granular base.
- Bedding layer over the base: Sand-cement mixture, 1 to 2 inches thick.
- Joint load transfer.
    - 14-inch-long dowel bars spaced at 12 inches in clusters of four dowel bars/wheel path for each of the four wheel paths,
    - Dowel diameter of 1-1/4 inches.
- Dowel bar slot grout: A minimum compressive strength of 2,500 psi before the panels are open to traffic and a minimum compressive strength of 4,000 psi at 28 days.
- Panel bedding grout: A minimum compressive strength of 4,000 psi at 28 days.
- Finishing activity: Mill approaches and departures area AC pavement and place new AC surface to match the PCP grade.

Reinforced Precast Panels

The contractor elected to use panels incorporating bottom dowel bar slots based on a patented technology developed by FMC. 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.
- Grout ports over the dowel bar slots.
- Grout ports for the bedding grout.
- Foam gaskets that line the dowel slots.
- Panel surface finishing as per the project plans and specification requirements.

Leveling Lift System

Alabama DOT 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 by FMC and served a dual purpose. The leveling lift system consists primarily of a base plate (11-3/8 by 11-3/8 by 1/2 inches thick), a threaded insert (Dayton Superior P1 Four Strut Lift Inserts), and a leveling bolt. 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 FMC lift system is shown in figures 5 and 6.

Figure 5. Photo. The leveling lift system – base plate and Dayton Superior Insert.

Figure 6. Photo. The leveling lift system placed in the panel formwork.

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 at the time of opening to traffic and 4,000 psi at 28 days. The contractor elected to use the ProSpec Slab Dowel Grout. This grout can achieve compressive strength of 2,000 psi at 2 hours and 3,500 psi at 3 hours at a temperature of 45 °F.

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 at the time of opening to traffic and 2,500 psi at 7 days. The grout is pumpable and 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 at 45 minutes and 5,500 psi at 28 days when tested in the laboratory at a temperature of 72 °F.

Panel Installation

The following are the installation steps for the PCP system used at the project:

1. Mark repair limits.
2. Remove existing AC pavement.
3. Prepare existing base (grade and compact).
4. Place sand-cement mixture to provide a uniform and level grade for the base. The mixture was applied dry and surface wetted.
5. Place panels over the prepared base layer, with the bottom slots located over the dowel bars in previously placed panels. The first and last panels were set against the existing AC pavement face.
6. Maintain the transverse joint widths as specified.
7. After the sand-cement mixture has hardened, engage the leveling lifts and raise the panels to the desired elevation. For the ramp project, the requirement was to have the panel surface to match the AC pavement surface in the adjacent lane.
8. Grout the bottom slots and the transverse joint gaps for each panel.
9. Apply the bedding grout.
10. Remove the leveling bolts.
11. Perform finishing activities.
12. Open to traffic.

The project specification required the panels to be installed within the following tolerances:

- The vertical differential between adjacent precast panels across any joint to be ¼ inch or less.
- Transverse joint width between adjacent panels to not exceed 1/2 inch.
- Longitudinal joint width at the adjacent AC lane to not exceed 1/2 inch.

CONSTRUCTION STAGING AND TRAFFIC-RELATED REQUIREMENTS

Panels shipped every work night from the precast plant located in Theodore, a distance of about 16 miles from the project site. Two panels were shipped per truck. A three-lane closure was established during the nightly installation work, which allowed one lane along the ramp to be opened to traffic exiting at Exit 2. The traffic management is shown in figure 7.

Before the panel installation work started, Alabama DOT conducted extensive public awareness activities related to possible disruption to night-time traffic making the left turn at the intersection. There was no direct impact on traffic making right turns off the adjacent West Rebel Road. Overall, during the many nights of the panel installation, the low level of nighttime traffic exiting at Exit 2 proceeded smoothly through the work zone and the intersection, and no traffic-related incidents were reported.

Figure 7. Photo. Traffic management at the project site.

PANEL FABRICATION

The panels were fabricated based on shop drawings prepared by FMC and approved by Alabama DOT. All panels were rectangular in shape, and only three panel types were used, as follows:

- First panel, designated as Panel Type A, at the beginning of the precast pavement section along the exit ramp (first panel to be installed).
    - Smooth transverse joint face abutting the existing AC pavement.
    - Embedded dowel bars along the opposite transverse joint face.
- End panel, designated as Panel Type C, at the intersection (last panel to be installed).
    - Smooth transverse joint face abutting the intersecting AC pavement.
    - Dowel bar bottom slots along the opposite transverse joint face.
- All remaining 63 panels, designated as Panel Type B.

- Dowel bar bottom slots along the one transverse joint face.
- Embedded dowel bars along the opposite transverse joint face.

All panels were provided with a sawcut at mid-width to serve as a crack control joint. Key panel fabrication requirements from the project specification are given below:

- Concrete mixture to meet the following strength requirements:
  - Minimum compressive strength of 2,500 psi for form stripping.
  - Minimum compressive strength for shipment to the project site of 4,000 psi.
  - Minimum compressive strength of 4,000 psi at 28 days.
  - Minimum flexural strength of 650 psi at 28 days.
- Use of epoxy-coated steel reinforcement.
- Use of a leveling lift system.
- All panels to meet the geometric tolerances given in table 1.
- Application of curing to the panel surface soon after concrete placement and application of curing to the bottom and all four sides of the panel soon after formwork removal.

Table 1. Panel geometric tolerances.

Material	**Proportion**
Length and width	+/- ¼ inch
Thickness	+/- 1/16 inch
Squareness of corner in plan view	+/- ¼ inch over 12 inches
Squareness of sides in section view	+/- ¼ inch over the thickness
Local smoothness of any surface	+/- ¼ inch over 10 feet in any direction

The concrete was produced at the precast plant. As part of the panel fabrication process, the concrete was regularly tested for fresh properties and for strength. The concrete typically exceeded the design compressive strength of 4,000 psi at 28 days and typically exceeded 3,500 psi 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. No additional curing was applied after the form stripping.

Two panels were fabricated per work day. The panels were stored at the precast plant and were delivered to the project site each night of panel placement. Figure 8 shows the panel formwork setup, and figure 9 shows a view of the panel bottom showing gasket around dowel bar slots. The gasket is used to prevent the dowel slot grout from flowing into the under-panel area. Figure 10 shows the panels in storage at the plant awaiting shipment to the project site. The panels were stored a minimum of 14 days at the plant.

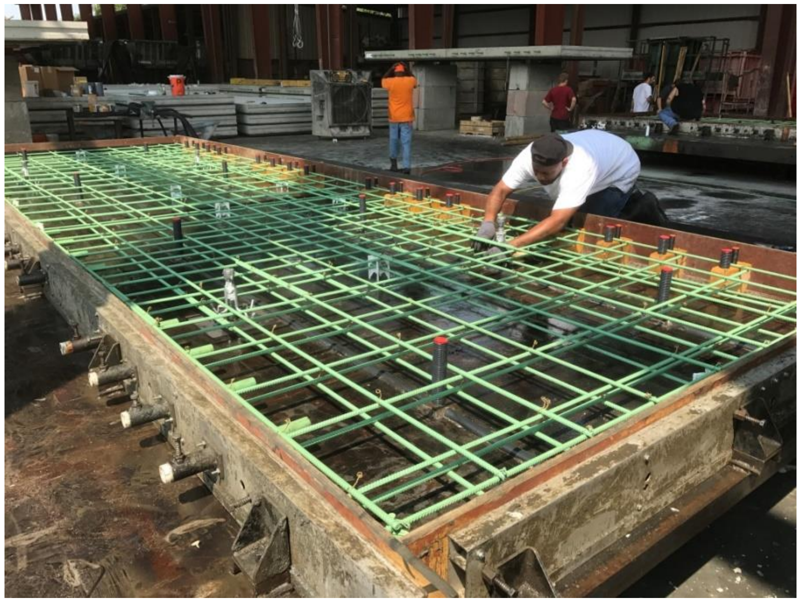

Figure 8. Photo. Panel formwork setup.

Figure 9. Photo. View of the panel bottom showing gasket around dowel bar slots.


Figure 10. Photo. Stored panels awaiting shipment to the project site.

PANEL INSTALLATION

Panel installation began during the night of September 5, 2017, with the construction of the test section. Production panel placement began during the night of September 17, 2017, and the last group of panels was placed during the night of September 27, 2017. Production paving was delayed by about 10 days due to Hurricane Irma, which passed over the area on September 10.

Test Section Installation

The contractor had planned to install four panels during the first night, September 5, 2017, to serve as the test section. The test section installation was supervised by a representative of FMC. The planned test section installation logistics were as follows:

1. Start lane closures at about 7 pm.
2. Mark the repair area boundary.
3. Make full-depth sawcuts along the perimeter of the repair area for the test section and for the whole repair area.
4. Remove the 6-inch-thick AC surface.
5. Scarify the base layer at the surface and remove about 3 inches of the base to allow for the 9-inch-thick panel, about an inch of the sand-cement leveling layer and about a ½-inch-thick bedding grout under the panel.
6. Grade and compact the base layer.
7. Place the sand-cement mixture over the graded base in a dry state. Compact the sand-cement layer and lightly spray the surface of this layer with water.
8. After a period of time to allow for the stiffening of the sand-cement layer, install the panels. Set the panels directly on the sand-cement layer.
9. Open the section with the installed panels to traffic by about 6 am the next morning.
10. The next night, raise the panels to the desired elevation by engaging the leveling lifts.
11. Grout the dowel bar slots and the transverse joint gap.

12. Grout the gap under the panels.
13. Perform finishing activities.
14. Install the section with the grouted dowel bar slots and the bedding grout to traffic by 6 am the next morning.

However, not everything went according to the plan, as detailed below.

While the AC removal was straightforward, the contractor found it difficult to scarify the upper portion of the well-compacted existing granular base layer using the excavator equipment, as shown in figure 11. The bucket teeth could not penetrate the granular base surface. As a result, the contractor excavated the full depth of the base layer, intermixing it with the subbase and the subgrade, as shown in figure 12. The intermixed material was used as the base layer.


Figure 11. Photo. Excavator trying to scarify the granular base.


Figure 12. Photo. Intermixing of the base, subbase and subgrade materials.

After the placement of the base layer, several hours elapsed while the FMC representative provided instructions to the contractor staff for setting up the FMC-supplied base layer grading equipment.

The grading equipment consisted of a 28-foot-long beam that should have been set on railings placed just outside the 25-foot-wide work area. However, the railing meant to be set over the adjacent AC lane surface was set within the repair area, as shown in figure 13. This required the contractor staff to spend time to grade along the inside perimeter by hand.

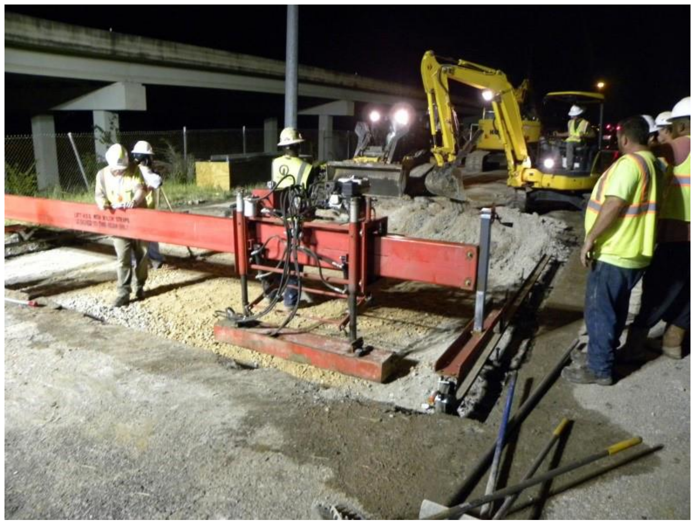

Figure 13. Photo. Base grading beam railing setup within repair area.

After the base layer was compacted and graded, the dry sand-cement mixture was placed, as shown in figure 14. However, it started raining. The repair area was covered up with a polyethylene sheet, as shown in figure 15, to protect the repair work area. This delayed the installation of the panels, as the sand-cement mixture layer had to be regraded.

Figure 14. Photo. Placement of the dry sand-cement mixture.

Figure 15. Photo. Covering up of the work area.

As a result, only two of the four panels were installed during the first night. These panels were installed just after 4 am. Because excess AC had been removed, a gap remained between the second panel and the adjacent AC in the two turn lanes. The contractor filled the gap full-depth with hot-mixed AC early the next morning. The AC was roller compacted, as shown in figure 16. However, this activity did not delay the opening to traffic of the turn lanes that morning. Figure 16 also shows the two panels that were placed.

Figure 16. Photo. AC patch at the end of the second precast panel.

During the next night, September 6, the contractor removed the AC patch, cleaned the embedded dowel bars of the second panel, and installed four more panels of the test section. The dowel bar slots were grouted, and the panels were lifted to the desired elevation using leveling bolts and the bedding grout was applied. The four panels were opened to traffic by about 6 am.

For subsequent panel installation, the contractor used two dummy panels with matching dowel slots to be placed over the embedded dowel bars of the last panel of each night's installation. The two panels were about 12-1/2 feet wide and 3 feet long, as shown in figure 17.

Figure 17. Photo. Dummy panels for use at end of each night's installation.

Alabama DOT conducted falling weight deflectometer (FWD) testing of the four panels the following week. The FWD joint deflection data indicated low deflections at the transverse joints under a load of 9,000 lbf. The maximum deflections at the joint were less than 5 mils, and maximum relative deflections across adjacent sides of joints were less than 1 mil.

Production Panel Installation

Based on the evaluation of the test section and the results of the FWD testing, Alabama DOT authorized the contractor to proceed with installation of the remaining panels. Production panel placement began during the night of September 17, 2017, and ended during the night of September 27, 2017. Production paving was delayed by about 10 days due to Hurricane Irma, which passed over the area on September 10, 2017. Six to 10 panels were installed during the first few nights. After that, 10 to 14 panels were installed each night.

The panel installation process followed steps similar to those discussed for the test section installation. Some specific details related to the production paving are as follows:

1. Lane closures began at about 7 pm.
2. The contractor placed the rails for the base grading equipment outside the work area.
3. The contractor used dummy panels at the end of each night's panel placement.
4. Panels were placed directly over the sand-cement layer each night. The dowel bar slot grouting and the bedding grout application under the panels were done the next night.
5. The work area was opened to traffic the next morning by about 6 am.

Figure 18 shows the base preparation. As discussed for the test section installation, the contractor intermixed the base, subbase, and the subgrade material and used the intermixed material as the base layer. Figure 19 shows the sand-cement layer grading. Figure 20 shows the compaction and water spraying of the sand-cement layer.

Figure 18. Photo. Base preparation for the production panel installation.

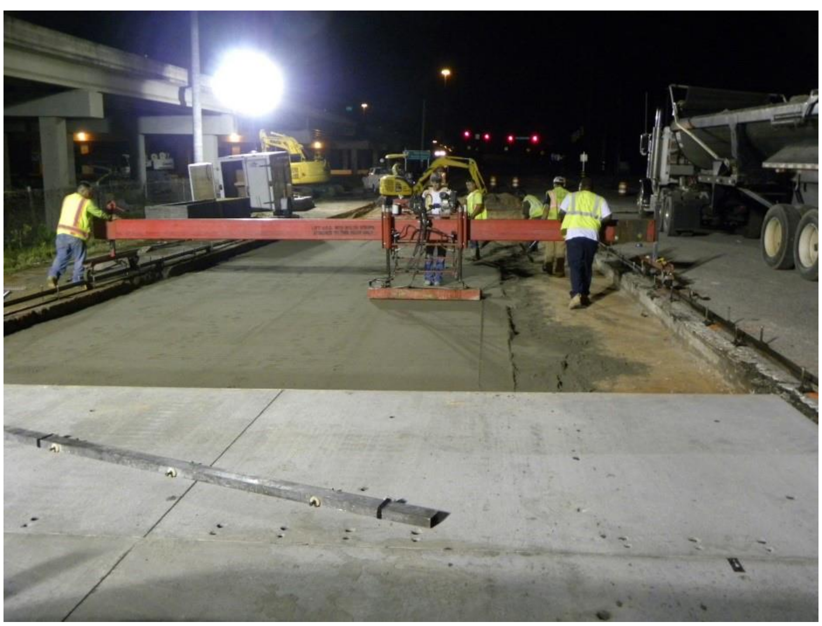

Figure 19. Photo. Sand-cement layer grading for production panel installation.

Figure 20. Photo. Compaction and water spraying of the sand-cement layer.

Panel placement typically began after midnight. Figure 21 shows the panel being installed. Figure 22 shows the use of leveling bolts to set the panel elevation.

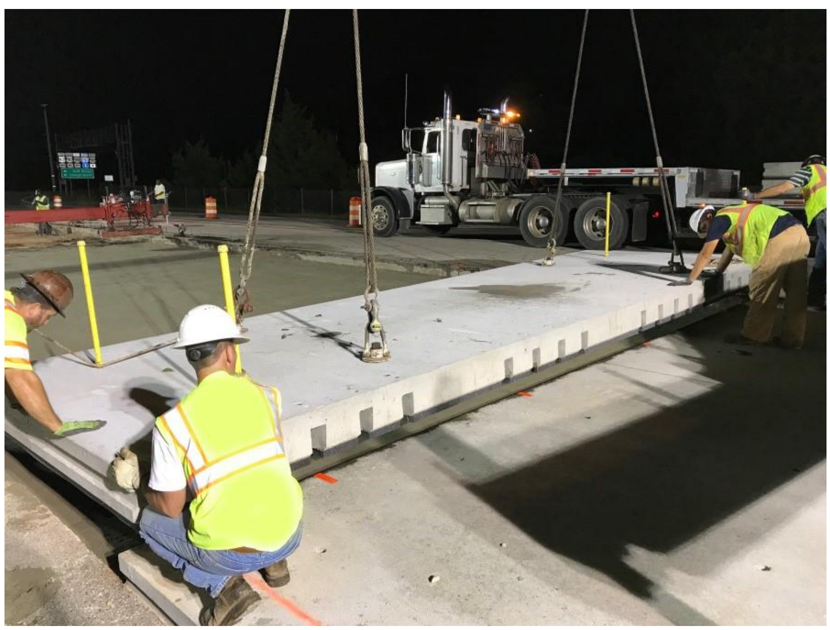

Figure 21. Photo. Placement of a panel.

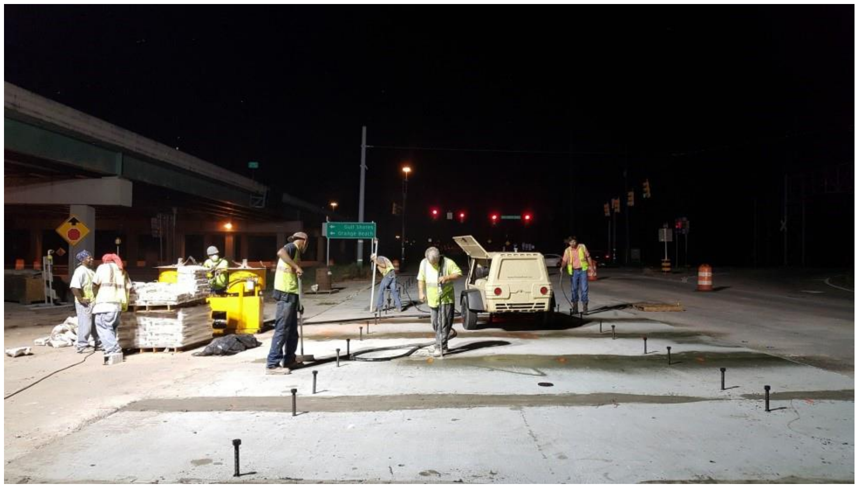

Figure 22. Photo. Using leveling bolts to set panel elevation.

Figure 23 shows the panel installation at the intersection with the last panel yet to be installed. Figure 24 shows the installation of the last panel at the intersection. Figure 25 shows the completed precast pavement installation.

The small gaps at the beginning and end of the precast concrete pavement section were filled with hot-mixed AC material. The longitudinal gap between the precast pavement and the adjacent AC lane was also filled with hot-mixed AC. The shoulder was reconstructed with hot-mixed AC.

The dowel slot grout achieved average cube compressive strength of over 5,000 psi at 7 days. The bedding grout achieved average cube compressive strength of over 5,500 psi at 7 days.

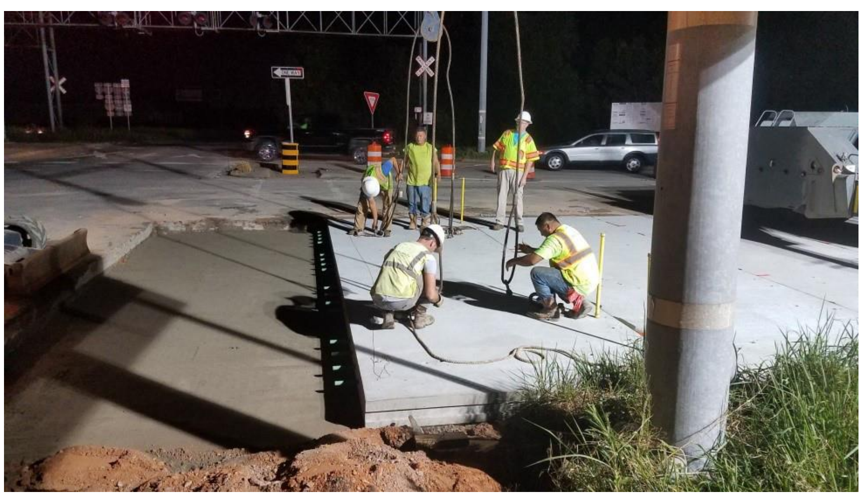

Figure 23. Photo. Panel installation near the intersection.

Figure 24. Photo. Last panel being installed at the intersection.

Figure 25. Photo. Completed precast pavement installation.

Summary

The use of the PCP technology on a production pavement rehabilitation project was an important step for Alabama DOT. This was the first application of the PCP technology by the DOT, and Alabama DOT expects 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.

It should be noted that, as discussed in the report, the installation of the panels was interrupted by Hurricane Irma that passed over Mobile on September 10, 2017. The hurricane resulted in the flooding of a tunnel along a nearby section of I-10 and the I-10 traffic was detoured onto I-165 and exited at Exit 2 over a period of 3 days. The hurricane also delayed the re-start of the panel installation. According to the DOT, this was a unique aspect to the use of the precast concrete pavement technology – that construction can stop mid-project and started right back after the emergency without the traveling public even realizing it.

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

PHOTO AND DIAGRAM CREDITS

Cover Page – Top left………………………………………….. Lyndi Blackburn, Alabama DOT
Cover Page – Top right………………………. Shiraz Tayabji, Applied Research Associates, Inc.
Cover Page – Bottom center…………………………………. Lyndi Blackburn, Alabama DOT
Figure 1…………………………………………..… Map data: Google, Google Earth imagery
Figure 2…………………………………………………… Lyndi Blackburn, Alabama DOT
Figure 3……………………………….………………. Project specification, Alabama DOT
Figure 4……………………………….………………. Project specification, Alabama DOT
Figure 5……………………………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 6……………………………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 7……………………………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 8……………………………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 9……………………………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 10…………………..………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 11…………………..………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 12…………………..………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 13…………………..………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 14…………………..………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 15…………………..………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 16…………………..………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 17…………………..………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 18…………………..………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 19…………………..………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 20…………………..………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 21…………………..………………… Shiraz Tayabji, Applied Research Associates, Inc.
Figure 22…………………..……………………..………… Lyndi Blackburn, Alabama DOT
Figure 23…………………..……..…… Jay Davison, Thompson Engineering, Mobile, Alabama
Figure 24…………………..……..…… Jay Davison, Thompson Engineering, Mobile, Alabama
Figure 25…………………..……………………..………… Lyndi Blackburn, Alabama DOT