Virginia Center *for* Transportation
INNOVATION
& RESEARCH

Use of Precast Slabs for Pavement Rehabilitation on I-66

http://www.virginiadot.org/vtrc/main/online_reports/pdf/12-r9.pdf

M. SHABBIR HOSSAIN, Ph.D., P.E.
Senior Research Scientist

CELIK OZYILDIRIM, Ph.D., P.E.
Principal Research Scientist

Final Report VCTIR 12-R9

VIRGINIA CENTER FOR TRANSPORTATION INNOVATION AND RESEARCH
530 Edgemont Road, Charlottesville, VA 22903-2454
www.VTRC.net

Standard Title Page - Report on Federally Funded Project

1. Report No.: FHWA/VCTIR 12-R9	2. Government Accession No.:	3. Recipient's Catalog No.:
4. Title and Subtitle: Use of Precast Slabs for Pavement Rehabilitation on I-66		5. Report Date: June 2012 6. Performing Organization Code:
7. Author(s): M. Shabbir Hossain, Ph.D., P.E., and Celik Ozyildirim, Ph.D., P.E.		8. Performing Organization Report No.: VCTIR 12-R9
9. Performing Organization and Address: Virginia Center for Transportation Innovation and Research 530 Edgemont Road Charlottesville, VA 22903		10. Work Unit No. (TRAIS): 11. Contract or Grant No.: 92733
12. Sponsoring Agencies' Name and Address: Virginia Department of Transportation 1401 E. Broad Street Richmond, VA 23219	Federal Highway Administration 400 North 8th Street, Room 750 Richmond, VA 23219-4825	13. Type of Report and Period Covered: Final 02/18/09 to 11/30/11 14. Sponsoring Agency Code:
15. Supplementary Notes:		

16. Abstract:

Highway agencies continuously strive to expedite pavement construction and repairs and to evaluate materials and methods to provide long-lasting pavements. As part of this effort, agencies have used precast concrete slabs for more than 10 years with successive improvements in processes and systems.

The Virginia Department of Transportation recently used two precast systems along with conventional cast-in-place repairs on a section of jointed reinforced concrete pavement on I-66 near Washington, D.C. One precast system, precast concrete pavement (PCP), used doweled joints. The other precast system, prestressed precast concrete pavement (PPCP), used transversely prestressed slabs post-tensioned in the longitudinal direction.

Both precast systems are performing satisfactorily after 1.5 years of traffic, and the contractor was satisfied with the constructability. In multiple locations, transverse expansion joints in PPCP were observed to be wider than the ½-in width specified; excessively wide joints often compromise joint sealant performance, and erosion from water flowing through such joints may result in eventual loss of support over time. There were a few cracks in the PPCP section, originating mainly from grouting holes, cracks in the block-out patches, cracks and loss of epoxy at lifting hook holes, and corner breaks. There were some mid-slab cracks in the PCP slabs immediately after opening to traffic, but they are still tight and stable after 1.5 years of traffic.

Even though the precast slabs initially cost more than the cast-in-place repairs to construct, the ability to construct the pavement within a short period of lane closure per day and the probability of improved quality control of plant-cast concrete warrant their use. Since this was the first application in Virginia, certain issues occurred and most were overcome, such as matching of slabs and grout leakage. The project was successfully completed and further implementation is recommended.

17 Key Words: Concrete pavement repair, precast slabs, precast prestressed slabs, precast prestressed post-tensioned system		18. Distribution Statement: No restrictions. This document is available to the public through NTIS, Springfield, VA 22161.	
19. Security Classif. (of this report): Unclassified	20. Security Classif. (of this page): Unclassified	21. No. of Pages: 82	22. Price:

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

FINAL REPORT

USE OF PRECAST SLABS FOR PAVEMENT REHABILITATION ON I-66

M. Shabbir Hossain, Ph.D., P.E.
Senior Research Scientist

Celik Ozyildirim, Ph.D., P.E.
Principal Research Scientist

In Cooperation with the U.S. Department of Transportation
Federal Highway Administration

Virginia Center for Transportation Innovation and Research
(A partnership of the Virginia Department of Transportation
and the University of Virginia since 1948)

Charlottesville, Virginia

June 2012
VCTIR 12-R9

DISCLAIMER

ABSTRACT

Highway agencies continuously strive to expedite pavement construction and repairs and to evaluate materials and methods to provide long-lasting pavements. As part of this effort, agencies have used precast concrete slabs for more than 10 years with successive improvements in processes and systems.

The Virginia Department of Transportation recently used two precast systems along with conventional cast-in-place repairs on a section of jointed reinforced concrete pavement on I-66 near Washington, D.C. One precast system, precast concrete pavement (PCP), used doweled joints. The other precast system, prestressed precast concrete pavement (PPCP), used transversely prestressed slabs post-tensioned in the longitudinal direction.

Both precast systems are performing satisfactorily after 1.5 years of traffic, and the contractor was satisfied with the constructability. In multiple locations, transverse expansion joints in PPCP were observed to be wider than the ½-in width specified; excessively wide joints often compromise joint sealant performance, and erosion from water flowing through such joints may result in eventual loss of support over time. There were a few cracks in the PPCP section, originating mainly from grouting holes, cracks in the block-out patches, cracks and loss of epoxy at lifting hook holes, and corner breaks. There were some mid-slab cracks in the PCP slabs immediately after opening to traffic, but they are still tight and stable after 1.5 years of traffic.

Even though the precast slabs initially cost more than the cast-in-place repairs to construct, the ability to construct the pavement within a short period of lane closure per day and the probability of improved quality control of plant-cast concrete warrant their use. Since this was the first application in Virginia, certain issues occurred and most were overcome, such as matching of slabs and grout leakage. The project was successfully completed and further implementation is recommended.

FINAL REPORT

USE OF PRECAST SLABS FOR PAVEMENT REHABILITATION ON I-66

M. Shabbir Hossain, Ph.D., P.E.
Senior Research Scientist

Celik Ozyildirim, Ph.D., P.E.
Principal Research Scientist

INTRODUCTION

The national interest in rapid construction with minimal traffic disruption and longevity of service is echoed in the phrase "get in, get out, and stay out!" The need for fast construction has become a national concern, reflecting the traffic situation in many areas of the nation. In addition, work zones may create unsafe conditions and are inconvenient to the traveling public. For these and other reasons, highway agencies desire long-lasting pavements that will require minimal maintenance. Thus, these agencies are continuously striving to build or repair in an accelerated manner and are evaluating materials and methods to provide long-lasting pavements.

Concrete is a durable paving material that effectively resists heavy and repeated loads, thus providing long-lasting performance. Although pavements are usually designed for 30 years, many concrete pavements have provided service for 40 to 50 years. However, deterioration occurs toward the end of the service life or prematurely because of base failure or defects in materials or construction and is generally repaired using a concrete patch. Depending on the time of repair, patch failure may coincide with the end of the pavement service life. However, because concrete pavements are expected to last much longer than the initial design service life, long-lasting patches would be desirable.

Delays in opening to traffic may occur when concrete is placed at the job site since concrete needs to set and gain strength with time. Currently, in order to construct full-depth patches during the limited lane closure times permitted, conventional high-early-strength concretes are used. Generally, the durability of such patches is compromised in order to meet the high-early-strength requirements (Buch et al., 2003). The high cement contents in conventional high-early-strength concrete patches increase the chance of cracking because of thermal effects and shrinkage (Neville, 1995). The high alkali content because of the high cement content and the lack of a pozzolan may also contribute to alkali-silica reactions (Neville, 1995). The allotted curing time is short because of the time limits on lane closures.

Precast slabs can be cast at a convenient location off site with minimal weather restrictions and better quality control (Tayabji and Hall, 2008). When adequate strength is gained, precast slabs are placed in the pavement in a short period of time (Tayabji and Hall, 2008). Therefore, precast slabs are a viable alternative to cast-in-place (CIP) patches as there is no necessity of curing on site (Hossain et al., 2006). They may provide a higher quality product when strict time constraints are required (Tayabji and Hall, 2008). Precast slabs may also be more economical through the use of less cementitious products and possibly be placed faster than CIP patches, even though transport of the precast sections may add to the cost. Because precast slabs are cast off-site, the desired short lane closure times can be maintained and a quality product achieved as a result of the controlled production environment (Tayabji and Hall, 2008). The reduced lane closure time was demonstrated in Michigan, where a study showed that a typical precast slab could be placed in approximately 3 hours from the time the deteriorated concrete was removed to the time the joints were sealed and the lane was opened to traffic (Buch et al., 2003).

Precast slabs can also be used in large-scale pavement construction. The slabs are usually pre-tensioned in the transverse direction and post-tensioned in the longitudinal direction to extend the service life of the pavement (Merritt and Tayabji, 2009). A study of the feasibility of using precast prestressed concrete pavement (PPCP) to provide improved durability and rapid construction was completed in 2000 by the Center for Transportation Research (CTR) at the University of Texas at Austin (Merritt et al., 2000). This study revealed not only the feasibility of the construction but also the large benefit in terms of economics and durability. Prestressing the slabs can increase durability, reduce slab thickness, and provide efficient load transfer. It reduces the chances of cracking and controls crack and joint widths in both the transverse and longitudinal directions (Merritt et al., 2000).

The feasibility study was followed by an implementation pilot project funded by the Federal Highway Administration (FHWA) and conducted by CTR, which resulted in the construction of a 2,300-ft PPCP near Georgetown, Texas, in the spring of 2002 (Merritt et al., 2002). A total of 339 panels were used. Each panel was 10 ft long, but some were full width (36 ft) and others were partial width. Panels were post-tensioned in 250-ft sections. Each 250-ft section took about 6 hours to place on top of a 2-in-thick hot-mix asphalt leveling course covered with polyethylene sheeting for friction reduction. The constructed surface was smooth, and diamond grinding was not needed.

A second FHWA-funded demonstration project was conducted in California (Merritt et al., 2005). A total of 31 panels were placed in a 248-ft-long segment of roadway. The length of the slabs was 8 ft to facilitate transportation to the construction site. Slabs were set on a lean concrete base covered with polyethylene sheeting to reduce friction. Placement of a 124-ft post-tensioned section took about 3 hours. The surface was diamond ground for smoothness. The pilot and demonstration projects showed that the use of precast slabs in paving applications may fulfill the need for rapid construction of a quality product for longer service life and that prestressing has the potential to extend further the service life of such systems.

PURPOSE AND SCOPE

The purpose of this study was to evaluate the constructability and initial performance of different concrete pavement repair options in a comparative environment.

The objectives of the study were:

1. Document the construction of and lessons learned for each repair option.

2. Measure the initial performance of the repairs for a period of 1.5 years.

The scope of the study was limited to three repair techniques used on a four-lane section of I-66W in Virginia and sections of the nearby two-lane ramp as part of a field demonstration under the FHWA's Highways for LIFE program. The three repair techniques were: traditional CIP repairs, precast concrete pavement (PCP) repairs, and PPCP slab repairs.

METHODS

Overview

Five tasks were performed to achieve the study objectives:

1. Select sites to conduct the comparative evaluation of the three concrete repair options (i.e., CIP, PCP, and PPCP).

2. Determine the properties of the concrete used in the three repair techniques in the fresh and hardened states.

3. Conduct trial installations for the PCP and PPCP systems before construction.

4. Document the construction of and lessons learned with regard to the three concrete repair options, including the trial installations of the PCP and PPCP systems.

5. Measure the initial performance of each of the three types of repairs for a period of 1.5 years.

Site Selection

The project was conducted along a section of I-66W in Fairfax County between Exits 60 and 57 and included the ramp of Exit 57B onto U.S. Route 50W. The distressed condition of pavement along I-66 and the ramp warranted repairs. This location has high traffic volumes, and lane closures for extended time are not permissible. Enforcement of traffic control is difficult in the area because of the traffic conditions. Such constraints prompted the investigation of precast pavement repairs. The geometry at the ramp necessitated the use of PCP that could accommodate super-elevation and curvature. A straight section on I-66 was selected for PPCP to facilitate post-tensioning operations. Other important aspects considered were accessibility to the site for delivery and hauling trucks, storage and operational area for construction equipment such as a crane for installing the slabs, and availability of a nearby precast panel producer.

Description of the Three Repair Systems

Cast-in-Place (CIP) Concrete Repairs

Cast-in-place repairs involve removal of deteriorated sections of concrete pavement and placement of high-early-strength hydraulic cement concrete. This may also include removal and replacement of unstable sub-base material, if necessary. Detailed steps are provided in a VDOT special provision for patching hydraulic cement concrete pavement (see Appendix A).

Precast Concrete Pavement (PCP)

In a PCP system, the defective concrete pavement section is replaced with a precast slab of full width and depth. The removal of damaged slab and repair of the sub-base is similar to CIP repair. Instead of concrete placement on-site, the slabs are cast and cured off-site at a convenient location beforehand and hauled to the site when the pavement section has been prepared to receive the slab. The slabs could be plain or reinforced as required by the design engineer to match the existing pavement. Joint load transfer is reestablished through the use of dowel bars; dowels could be inserted in place (dowel bar retrofit) after placement of the patches or dowels may be cast into slabs during fabrication and grouted afterward (Buch et al., 2003). In a continuous application for the repair of a longer section, as in this study, the system would be similar to a jointed concrete pavement. Although the VDOT bid documents outlined provisions for a generic system (see Appendix B), the successful bidder employed a proprietary system (Fort Miller Co., Inc., 2010) that met the project specifications. This proprietary system uses reinforced slabs that are one lane wide (e.g., 12 ft) and 10 to 16 ft long. Each slab is cast with a three-dimensional control to match the actual highway geometry, including horizontal and vertical curvature. Thicknesses are kept uniform throughout the slab but warped to match the geometry along with carefully graded subgrade. A laser controlled grader is used to control elevation of the subgrade with high accuracy. In addition, bedding grout is pumped through a specially designed distribution system to fill any voids beneath the placed slab to ensure proper support. In this proprietary system, dowel bars are either drilled into the existing pavement or cast into the slab at one end, and the other end of the slab would have inverted slots to receive the dowels. Non-shrink, high-strength grout is pumped into the dowel slot through a port at the surface to secure the dowel bars. A field representative of the proprietary system was present during the construction.

Prestressed Precast Concrete Pavement (PPCP)

The PPCP system also uses a series of precast slabs that are prestressed in the transverse direction (normal to traffic) during production and post-tensioned in the longitudinal direction after installation on site (Merritt and Tayabji, 2009). Prestressing allows for pavement to be used that is thinner than conventional non-prestressed concrete pavement. Typical sizes of individual panels are up to 38 ft wide, 10 ft long, and 7 or 8 in in depth. The subject VDOT project panels were 10 ft long, 8 3/4 in thick, and as wide as 27 ft. There are several variations of post-tensioning options in use by the industry: central stressing and end stressing panels (Merritt and Tyson, 2011). This study used end stressing panels. Under this system, several base panels were tied together with a central anchored panel through three tensioning strands. These strands were anchored at prefabricated slots within two special joint panels at each end of the post-tensioned section. Each section was 100 to 160 ft long.

Determination of Concrete Properties

Mixture Design

Three mixture designs were used for the CIP patches, PCP slabs, and PPCP slabs, with varying cement contents and water–cementitious material ratios (w/cm) of 0.32, 0.34, and 0.36, respectively. PCP slab mixture designs had 172 lb/yd^3 of slag, and PPCP slab mixture designs had 150 lb/yd^3 of Class F fly ash. The design components and proportions of the mixtures are summarized in Table 1.

Table 1. Concrete Mixture Design

Ingredient	CIP Patches (lb/yd^3)	PCP Slabs (lb/yd^3)	PPCP Slabs (lb/yd^3)
Portland cement	846	518	602
Fly ash	---	---	150
Slag	---	172	---
Coarse aggregate	1862	1828	1653
Fine aggregate	1088	1212	1285
Water	267	235	267
w/cm	0.32	0.34	0.36
Air (%)	6 ± 2	6.5 ± 1.5	4-8
Slump (in)	3-7	2-7	7 maximum

CIP = cast-in-place; PCP = precast concrete pavement; PPCP = prestressed precast concrete pavement; w/cm = water-cementitious material ratio.

Tests for Fresh and Hardened Concrete Properties

Concrete properties were determined in accordance with respective ASTM standards (ASTM International, 2009). During CIP repair, cylinders measuring 4 in in diameter by 8 in in height were prepared from each batch, cured for 4 hours in the molds, and tested for compressive strength (ASTM C39). Concretes for both precast systems (PCP and PPCP) were tested at the fresh and hardened states. The fresh concrete tests were slump (ASTM C143), air content by the pressure method (ASTM C231), and density (ASTM C138). Hardened concrete cylinders were cured using radiant heat overnight for high early strength and tested for compressive strength (ASTM C39) and permeability as determined by the rapid chloride permeability test performed in accordance with Virginia Test Method 112 (VDOT, 2007a).

Trial Installations

The contractor conducted trial installations as required by VDOT special provisions for the PCP (see Appendix B) and PPCP (see Appendix C) systems before actual construction began. Because of limited space, the PCP trial installation was performed off-site at the contractor’s facility. The PPCP trial installation was performed at a nearby staging area. For the

PCP trial, six slabs were set and grouted in two rows, three slabs per row. For the PPCP trial section, slabs were set but not grouted after temporary post-tensioning, thus preserving these slabs for use in the actual construction. The main goal of matching the slabs of PPCP was achieved in the trial batches. Henceforth, the remaining slabs were fabricated. The trial batch also indicated issues with aligning and placing the rigid rods in the ducts of the PPCP for the temporary post-tensioning. Thus, a convenient approach, whereby the rods are inserted into the slab before the placement, was planned for the actual construction.

Staff of the Materials Section of VDOT's Northern Virginia District (Shiells and Brown, 2010) evaluated the PCP trial section in accordance with the VDOT special provision for PCP preapproval (see Appendix D). The resulting evaluation report identified the problem areas in construction, including cover depth and grout operations, and instructed the contractor to follow the VDOT special provisions for PCP (see Appendix B). These recommendations were followed during construction.

Documentation of Construction and Lessons Learned

To document the construction, researchers visited the site on multiple occasions to capture different aspects of construction. Researchers specifically observed panel placement, fit-up, post-tensioning (where applicable), and grouting operations. Visual observations and discussion with field personnel led to the determination of lessons learned.

Measurement of Initial Performance of Repairs

The initial performance of the repairs was measured for a period of 1.5 years with the following three measures:

1. visual distress observations

2. ride quality using an inertial profiler

3. load transfer efficiency (LTE) of joints and deflection profile under load using a falling weight deflectometer (FWD).

The performance of only PCP and PPCP sections were evaluated since there was no visible distress in the conventional CIP repairs, which were small isolated areas.

Visual Distress Observations

The pavement sections were visually observed and evaluated for distresses, such as cracks and joint conditions, during and after construction. Similar visual observations were again performed after 1.5 years of traffic.

Ride Quality

A high-speed inertial profiler was used to measure the ride quality of the PCP and PPCP sections. An International Roughness Index (IRI) was obtained using this profiler for the 0.01-mi segments. This vehicle-mounted device can operate at highway speeds along with regular traffic and measures two IRI values on a single pass along the two wheel paths in a lane. The profiler uses a narrow band, single-point laser to measure the profile elevations. Diamond grinding usually creates small ridges and depressions; a narrow beam laser can easily measure inside and outside pavement grooves, ridges, and depressions, thereby potentially yielding an inaccurately high IRI value. Therefore, a wide footprint laser was also used to measure IRI. FHWA's Turner-Fairbank Highway Research Center, Office of Infrastructure R&D, conducted the test using an Ultra-Light Inertial Profiler (ULIPr), which uses a wide laser footprint that takes the average measurement over a 4-in width.

Load Transfer Efficiency of Joints and Deflection Profile Under Load

LTE and deflection profile under load were measured using an FWD. Measurements were taken immediately after construction and after 1.5 years of traffic. In accordance with the American Association of State Highway and Transportation Officials (AASHTO) 1993 *Guide for Design of Pavement Structures* (AASHTO, 1993), four load levels (6, 9, 12, and 16 kips) were used to measure deflection, and as part of the analysis quick void detection was performed. Two to four drops (impacts) were used at each load level. Four drops were used in the test immediately after construction, and two drops for the 1.5 year measurement since no increase in deflection was expected beyond 2 drops. Load was dropped on the approach side of the slab for all LTE measurements except the expansion joints of PPCP during 2011 where both approach and leave sides were used.

RESULTS AND DISCUSSION

Site Description

Two sections on I-66 in Northern Virginia were selected for the comparison of the CIP, PCP, and PPCP systems:

1. the two-lane ramp on I-66W to U.S. Route 50W (Exit 57B) was repaired using both PCP and CIP concretes

2. all four lanes of a 1,020-ft mainline section of I-66W just west of Jermantown Road were repaired using PPCP slabs.

The existing pavement structure was built in the early 1960s with the following components:

- 9 to 11 in of jointed reinforced concrete
- 6 in of plain aggregate sub-base

- 6 in of cement-stabilized subgrade.

In 2008, the mainline I-66 was reported to carry an average daily traffic of 184,000 vehicles per day, 5% of which were trucks (VDOT, 2008).

Concrete Properties

All batches of CIP concrete achieved the 2,000 psi compressive strength in 4 hours as required by the project special provision (see Appendix A) except for Batch 2, which reached 1,990 psi, as indicated in Table 2. The compressive strengths for PCP slabs were higher than the 4,000 psi design strength (see Appendix B) at both 7 and 28 days. Compressive strength requirements for PPCP systems were 3,500 psi for de-tensioning and 5,000 psi at 28 days (see Appendix C). The achieved strengths were also higher than these specified values.

Table 3 summarizes the fresh and hardened concrete properties for PCP and PPCP slabs. It is important to note that the CIP cylinders were cured in molds until the 4-hour test, but the cylinders for both precast systems were cured using radiant heat overnight for high early strength. Concrete placed in both precast systems exhibited satisfactory workability, air

Table 2. Compressive Strength (psi) for Cast-in-Place Concrete at 4 Hours

Batch	Cylinder 1	Cylinder 2	Cylinder 3	Average
1	2,430	-	-	2,430
2	1,990	-	-	1,990
3	2,590	2,030	-	2,310
4	2,390	2,150	-	2,270
5	2,670	2,070	-	2,370
6	2,070	2,630	2,070	2,257
7	2,230	2,790	2,150	2,390
8	2,350	2,070	-	2,210
9	2,030	2,350	-	2,190
10	2,310	2,350	-	2,330
11	2,590	2,790	-	2,690
12	3,180	3,260	-	3,220
13	2,390	2,550	-	2,470
14	2,310	-	-	2,310
15	2,790	-	-	2,790

Table 3. Fresh and Hardened Concrete Properties for PCP and PPCP Slabs

	PCP Slabs			PPCP Slabs		
Property	Average	Standard Deviation	No. of Observations	Average	Standard Deviation	No. of Observations
Slump (in)	7.1	**0.4**	8	6.9	1.1	125
Air content (%)	5.8	**0.9**	8	5.5	0.8	124
Density (lb/ft^3)	-	-	-	148.3	3.5	124
1-day strength (psi)	-	-	-	4,983	700	96
7-day strength (psi)	6,441	598	39	7,207	831	26
28-day strength (psi)	7,604	644	39	7,660	744	22
Permeability (Coulombs)	1493	242	8	601[a]	-	2

PCP = precast concrete pavement; PPCP = prestressed precast concrete pavement.
[a]Based on tests of 1 set of 2 cylinders.

contents, and strength in accordance with the project special provisions (see Appendices B and C). The concrete for the PCP system had low permeability values that averaged 1493 Coulombs; this was expected, as the mixture contained 25% slag cement and had a low w/cm. The concrete for the PPCP system had a very low average value of 601 Coulombs.

Documentation of Construction and Lessons Learned

Documentation of Construction

Overview

As described previously, the exit ramp (57B) from I-66W to U.S. Route 50W was repaired using both CIP and PCP concrete. The ramp was 3,552 ft long. CIP patches 9 in thick were placed in the left lane, for a total of 1,023 yd^2 of concrete pavement. The section of CIP repairs was unreinforced except that it was connected to the existing lane by dowels and to the adjacent lane by tie bars. PCP slabs, which were 8¾ in thick to accommodate the leveling course, were placed in the right lane for a total of 4,710 yd^2 of concrete pavement consisting of 224 panels. Generally, the panels were each approximately 16 ft long. The PCP slabs were reinforced and were tied to each other by dowels and to adjacent lanes by tie bars. Grout was used for the dowel locations, and base grout was used to fill underneath the slabs. The shoulders were milled and resurfaced with asphalt.

As described previously, PPCP slabs were placed on all four lanes, including the right auxiliary shoulder, of the mainline study section of I-66W. The total length was 1,020 ft, and a total of 5,780 yd^2 of concrete pavement consisting of 102 panels, each 10 ft long, was placed. The thickness of the existing concrete ranged from 9 to 11 in. The new slabs to be placed were 8¾ in thick. The PPCP slabs also contained conventional reinforcement but were supplemented by bonded prestressed strands and post-tensioned strands in ducts. The strands perpendicular to the centerline of the roadway (perpendicular to traffic) were pre-tensioned at the plant, and those parallel to the traffic were post-tensioned in the field. Grout was used to fill the post-tensioning ducts and secure the strands. The slabs were also tied to the adjacent lanes by prestressing strands. Strands were only grouted inside the duct, but no tensioning was involved. First, the two left lanes were removed and replaced with two lanes, each 12 ft wide. Second, the right lane and the auxiliary shoulder were replaced with monolithic 27-ft-wide precast panels. Base grout was used to fill underneath the slabs.

Removal of Existing Pavement and Base Preparation

The edges of the slab to be removed were identified and marked, and vertical saw-cuts were made. Then the cut pieces were removed by an excavator. In general, removal of slabs was easy. However, a few panels broke, making the removal difficult.

For the CIP patches, saw-cutting and removal operations were usually performed in one night and the removed area was temporarily covered with wood blocks to carry traffic the next day. Most removal was possible with only a single-lane closure; only a few instances required both lanes to be closed for a few minutes at a time to facilitate pulling of slabs. Concrete placement was usually performed during the next working night.

Slab removal operations for PCP systems were similar to those for CIP installation. Unlike CIP repair, PCP panel installation and demolition occurred the same night; removal was performed during early working hours, and precast panels were installed toward the second half of the night. Although major preparation of the pavement base was not needed, a layer of No. 10 aggregate was compacted as a leveling course before placement of the PCP slabs. Some of the steps for base preparation are shown in Figure 1. This leveling was important in order to achieve a smoother surface and to ensure the elevation matched those of surrounding panels. Specially designed hand-operated leveling equipment (Fort Miller Co., Inc., 2010) was used in this proprietary system. The thickness of the PCP slab was about ¼ in less than that of the existing slabs in order to accommodate the leveling course.

Figure 1. Base Preparation Before Slab Installation: (a) *cast-in-place repair,* no base preparation, existing cement treated aggregate; (b) *precast concrete pavement,* special leveling equipment; (c) *prestressed precast concrete pavement* (PPCP), compacted with roller; (d) *PPCP,* non-woven geosynthetic over base.

In the mainline, PPCP slab removal was similar to that with other repair options except in the outside lane (auxiliary shoulder lane) where the asphalt drainage layer was stuck to the base of the existing concrete slab and discarded with it. A compacted layer of No. 21A crushed stone, in accordance with VDOT specifications (VDOT, 2007b), was used to fill this unexpected void. As with the PCP panels, No. 10 aggregate was used to level the base layer for the remainder of the sections before a non-woven geotextile drainage fabric, complying with VDOT specifications (VDOT, 2007b), was installed as a separation layer to minimize friction. No shifting or tracking of geotextile was observed during slab installation.

Cast-in-Place Repair

After the existing slab was removed, four dowel bars were placed in pre-drilled holes in each wheel path and permanently secured to the existing slab using a high-viscosity epoxy. Then fresh concrete was placed in the patches on the left lane of the ramp. A longitudinal joint was cut between the shoulder and the CIP prior to opening to traffic on the same day. Transverse joints were cut, formed, and sealed all at one time when CIP patching was completed for the entire left lane of the ramp.

PCP Panel Installation

PCP slabs were placed sequentially to build a jointed concrete pavement in the right lane of the ramp. As described previously, each slab was 12 ft wide and 10 to 16 ft long. One transverse end had pre-installed dowel bars, and the other end had inverted dovetail slots to receive the dowel bar from the preceding slab. The longitudinal face contained inverted slots to receive the pre-installed tie bars from the existing left lane. Figure 2 shows the construction steps for PCP. A non-shrink, high-early-strength grout, which is resistant to cycles of freezing and thawing, was used to secure the dowels and tie bars. This grout was highly fluid to ensure complete filling of the slot when injected through the grout port at the surface. Project special provisions required the grout to achieve a compressive strength of 2,500 psi in 2 hours (see Appendix B). The existing (old) longitudinal joint was so deteriorated that it left large spotted areas without concrete along the joint after the new slabs were installed against the old surface. These areas required patching, which was a challenging task. There were large gaps through the longitudinal joint in some places. Since filling these areas had not been planned, dowel grout was used to fill these spaces. As this ramp was on a curvature, matching the adjacent slabs was a challenge, but it was successfully met. To accommodate the roadway horizontal and vertical curvature, slabs with special geometry, called warped slabs, were cast.

PPCP Panel Installation

As described previously, four lanes on I-66 were replaced using prestressed slabs, each 10 ft long. First, the inside two 12-ft lanes were installed, and then the outer lane along with the shoulder was repaired using one 27-ft-wide slab. The entire system consisted of several types of slabs: joint slabs, anchor slabs, base slabs, and closure pours. Several prestressed slabs were post-tensioned together, creating sections 100 to 160 ft long. There were seven such sections totaling 1,020 ft: five 160-ft intermediate and two 110-ft end sections. The sections were tied to one another with a doweled expansion joint. At both ends of each section, there were joint slabs

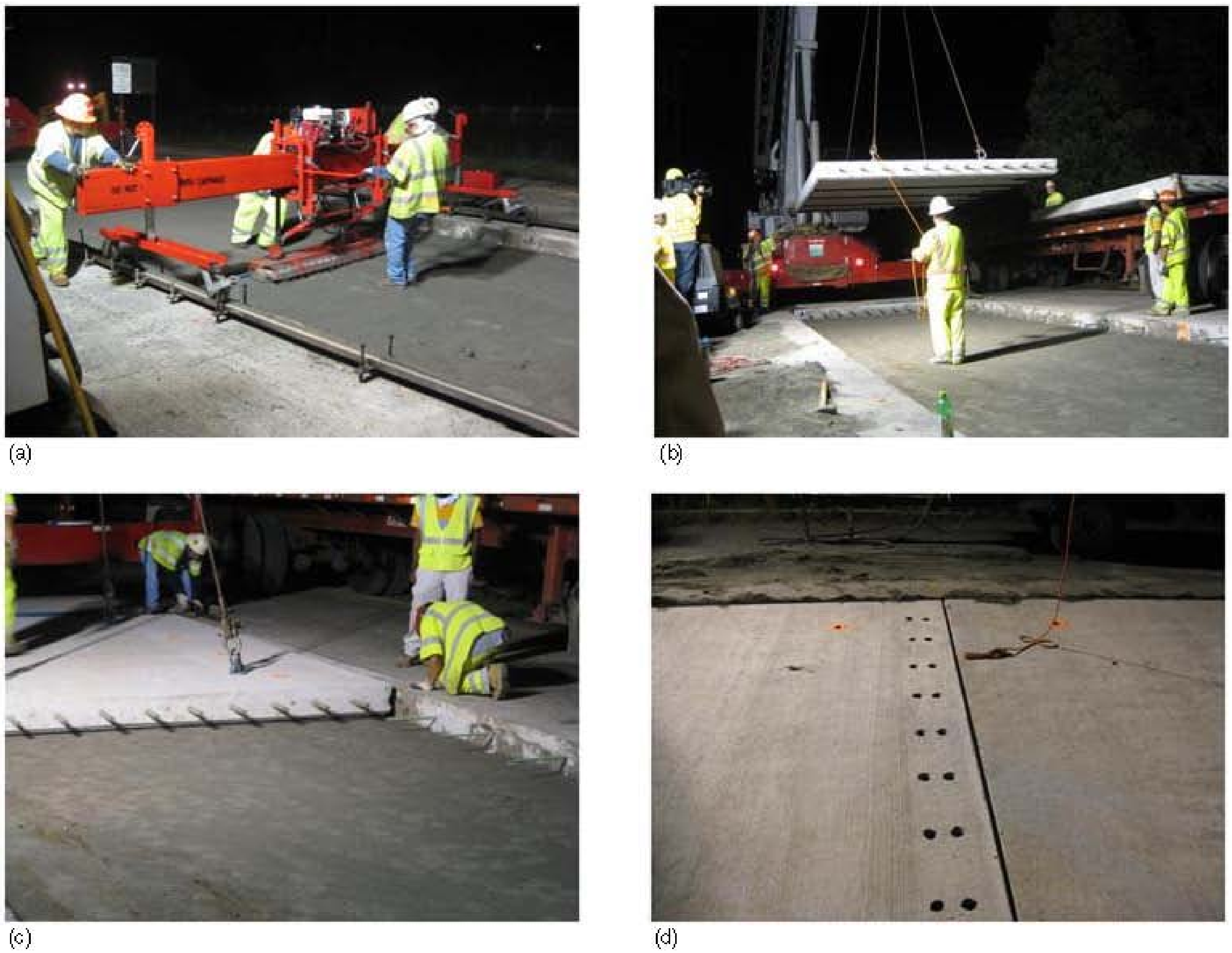


Figure 2. Precast Concrete Pavement Installation: (a) base preparation and leveling; (b) slab installation and alignment; (c) slab alignment; (d) grout ports for dowel bar, tie rod, and under the slab.

containing five block-out slots for longitudinal post-tensioning. Each joint slab comprised two 5-ft slabs joined together by dowel bars with a preformed expansion joint. At the middle of each post-tensioned section, one anchor slab was pinned to the ground at four places to prevent the slabs from moving or shifting because of traffic. Each anchor point was a 4-in concrete drilled shaft embedded at least 25 in into the ground. Base slabs were used to fill in between anchor and joint slabs. Each slab had five ducts for post-tensioning. Two ducts were used for temporary tensioning of adjacent slabs as soon as they were placed; threaded dowel bars were used for such tensioning. Epoxy-coated strands were used in the other three ducts to post-tension a section (10 to 16 slabs together) permanently after installation. These strands were flexible to facilitate pushing (or insertion) through several slabs. Initially, a two-part chuck was used to anchor the strand after post-tensioning. One of the strands came loose from a chuck under normal traffic when an asphalt patch was used to cover the block-outs temporarily for opening to traffic the next morning. To ensure safety, thereafter a three-part chuck was used to secure strands, and block-outs were also permanently covered with rapid set material before opening to traffic on the morning following construction. In addition, epoxy coating was thereafter removed from the strand at the chucks for a better grip. Figure 3 shows the steps to install PPCP.

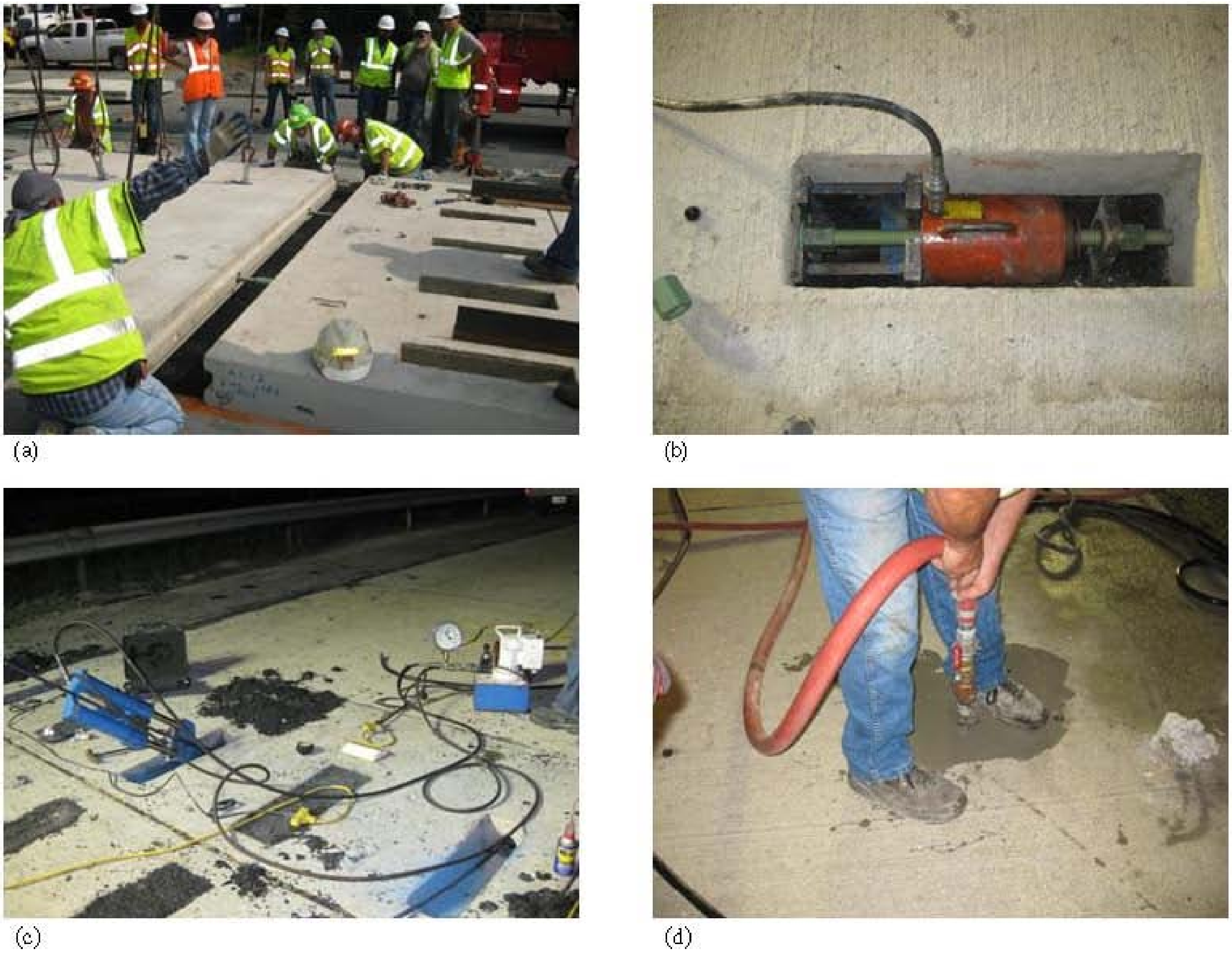


Figure 3. Prestressed Precast Concrete Pavement Installation: (a) slab alignment; (b) temporary post-tensioning of threaded bars; (c) permanent post-tensioning; (d) grouting operation.

Alignment was a problem in a few slabs. To locate or match the duct holes, vertical cores were drilled at the slab joints to reveal the holes and advance the strands. One misaligned joint and core location is shown in Figure 4.

The use of post-tensioned transverse tendons was planned to tie all the lanes together. Although transverse tendon ducts were oval in shape to facilitate the alignment, ducts were still misaligned after construction such that slabs could not be pulled together across the entire pavement width while under traffic. VDOT engineers and contractors decided to push the strand through the first two slabs (12-ft slabs) and grout it in-place without any post-tensioning. A part (about 3 ft) of the strand from the 27-ft slab was brought into the middle slab and grouted together with an already existing strand in the middle slab. Transverse strand grouting and under-slab anchoring were performed to keep the lanes together and prevent any lateral movement.

Post-tensioning strand ducts were grouted but leaked, since the foam gaskets at the ends did not provide a watertight connection. The duct diameter was small compared to the strand size, leaving very little room to inject the grout. The completion of the grouting operation could not be verified because grouts did not come through the successive ports; however, some came through the transverse and longitudinal joints. Figure 5 shows the gaskets and a leaked transverse

Figure 4. Prestressed Precast Concrete Pavement: *left,* slab misalignment; *right,* coring to reveal duct location.

(a) (b)

Figure 5. Prestressed Precast Concrete Pavement System: (a) gasket in strand duct; (b) grout leaking through transverse joints.

joint. Lift hook holes on the surface were filled initially with rapid set patching material and then covered with epoxy.

Diamond Grinding

Despite the tight tolerances specified in the project special provisions (see Appendices B and C) for the casting of slabs, there were elevation mismatches in both the PCP and PPCP sections. Diamond grinding was performed according to the project special provision (see Appendix E) on both sections to eliminate such elevation differences. This grinding operation was included in the construction bid to achieve good ride quality.

Lessons Learned

Trial Installations

Trial installations were helpful in identifying construction-related problems such as matching the panels, grouting, and base preparation. This trial also provided some experience for the contractor in this demonstration since this was the first application for the contractor. If grouting operations had been included in the trial installation of PPCP, measures could possibly have been planned to stop grout leakage in the actual construction.

Cast-in-Place Repair

CIP is the conventional repair method that has been widely used by VDOT. It did not require any special handling, and construction was not monitored by the research team. No difficulties or complications during construction were reported.

PCP System Repair

The ramp had several curved sections, and building it with the PCP system was challenging. This PCP system had a 3-D geometric control during production. Despite this control and the support from the field representative of the system, there were some mismatches and gaps between slabs that were greater than expected. These gaps were filled with dowel grout, and joints were cut and sealed. Bond breakers were used on the vertical face of the slab on one side at a transverse joint. However, the joint cutting was done on the face without bond breaker for some of the grout-filled joints. As a consequence, pieces of grout came loose as one side had bond breaker and the other side was cut. More careful control of joint cutting operations during production is required to prevent such gaps from occurring.

The alignment of the post-tensioning duct between successive slabs was difficult on multiple occasions. Larger duct holes could have alleviated the problem. All the required reinforcement and post-tensioning ducts were difficult to fit into the 8¾ in thickness of the slab while maintaining the cover depth of 2 in. Since a greater cover depth would be desirable in harsh environments, thicker slabs may be needed, but this could create problems with excavating the existing sub-base layers.

Some corner and edge breaks occurred during slab installation when the contractor tried to match the slabs. Tighter tolerance in slab dimensions during production, along with care in installation, might be needed to avoid such breaks.

Another concern during construction was the longitudinal joint. Because the existing longitudinal joint was significantly damaged, repairing only one lane using the precast slabs turned out to be not a good idea. The initial decision to repair only one lane was based on available funding. There was a wide gap between the lanes in several places along the damaged joint. As this condition was not anticipated, there was no provision in the contract to address it. The gaps, in some places as much as 2 in wide, were eventually filled using dowel grout. During planning, longitudinal joint conditions should have been considered in selecting single-lane repair with PCP. In some cases, it may be better to repair both lanes at the same time with PCP to eliminate the longitudinal joint.

About 25% of the PCP slabs showed mid-slab cracks immediately after construction. Although these cracks were very tight, they appeared to be full depth, as observed in a few cores taken through the cracks shown in Figure 6. The causes of these cracks are likely related to any of the following issues: poor compaction of the leveling base course, poor slab fabrication or handling, and the allowing of traffic on the PCP system before the dowel bars were secured. Another contributing factor to these early cracks was attributed to the fact that the precast slabs were tied longitudinally to the existing lane using tie bars. The existing left lane was a jointed reinforced concrete pavement, and the joints for the newly constructed right lane did not align with the joints in the left lane. As a consequence, a few of these joints in the left lane propagated through the new PCP slabs on the right lane as mid-slab transverse cracks; transmission of cracks may be attributed to restraint and dimensional changes resulting from shrinkage and thermal cycles. The factors cited that could cause these cracks should be addressed in future projects.

(a) (b)

Figure 6. Precast Concrete Pavement System: (a) mid-slab crack; (b) core showing full-depth crack.

PPCP System Repair

During grouting of the post-tensioning strand, leakage occurred, since the foam gaskets at the ends did not provide a watertight connection. Some sort of positive coupling was needed to keep the grout in the duct.

Lift hook holes on the surface were filled initially with rapid set patching material and then covered with epoxy. The durability of such a thin layer of epoxy is questionable under high traffic. The epoxy was observed to be coming off after 1.5 years under traffic.

Although the repaired PPCP section was straight, panel mismatches were still observed. Undesirable gaps were left between slabs in both the longitudinal and transverse directions. Post-tensioning eliminated most of the gaps in the transverse joints. The use of tie bars in the longitudinal joint was not practical because of construction (slab placement) sequencing. Transverse post-tensioning was planned to tie all the lanes together, but this was also not practical because of duct alignment issues and difficulty in pulling all the slabs together under traffic. Although transverse strands were used, they were only grouted in-place without any tensioning. As there was no post-tensioning between lanes, the gaps in the longitudinal joint were sealed with hot-poured joint sealant. A survey in May 2011 showed that some of the longitudinal joints were as wide as ½ in and sealant was depressed or missing in some places. Better tying of the slabs between lanes is needed in future installations to prevent excessive joint width and failure of the joint sealant.

Satisfaction with Construction

All three repair techniques were successfully constructed using only night time construction and complied with the unique placement requirements specified in the project special provisions. Those involved with the project, including the contractor and FHWA and VDOT personnel, did not report any unresolved issues related to constructability with either PCP or PPCP. The contractor did not face any serious difficulty in the completion of either system. The parties involved agreed that the precast technologies would be a viable option for future projects where high traffic volumes make rapid pavement repair/replacement desirable.

Initial Performance of Repairs

Surface Distresses

As described previously, about 25% of the slabs in the PCP section showed mid-slab cracks immediately after construction. In a survey in September 2011 after 1.5 years of traffic, about the same percentage of slabs had mid-slab cracks. These cracks looked tight and seemed to be stable. Some of the cracks were tested for LTE and were found to have more than 85% LTE. Acceptable LTE at joints is 80% or more (see Appendix D), and LTEs at mid-slab were higher than 80%, indicating acceptable load transfer and tight cracks. The deflections under load were less than 10 mils except for two locations with deflections as high as 13 mils under a 16k load. Few of the longitudinal joints showed severe damage such as pop-outs and cracks. In general, transverse joints were in good condition except for the wide grout-filled joints where some pop-outs were obvious because of joint cutting done on the wrong side of the bond breaker, as described previously. Figure 7 shows the condition of grout-filled joints after 1.5 years. One other observation of note is that the asphalt shoulder had settled more than 1 in at several locations.

The PPCP section used transverse expansion joints at 160-ft intervals except for the two end sections, which were 110 ft long. There was a total of eight expansion joints, and they were specified (see Appendix C) to be filled with a ½-in preformed compressed expansion joint system. But in several locations, joints were more than ½ in wide. Therefore, hot-poured sealant was used to seal them. The May 2011 visual survey revealed that these expansion joints were up to 2 in wide and in poor condition, with seal loss and accumulated debris. Table 4 summarizes the condition of the expansion joints at 1.5 years.

Figure 7. Deteriorated Condition of Grout-Filled Joints in Precast Concrete Pavement: (a) transverse; (b) longitudinal

Table 4. Condition of Expansion Joints in PPCP at 1.5 Years

Joint No.	Type	Width (in)	Condition of Joint Sealant
1	P	¾	Good condition
2	H	1	Bulging out on left corners of L4 and L3; right corner of L3 missing or depressed
3	H	1¼	Separating from edge in L3; depressed seal in L3 and L4; bulging seal on L4 left side
4	H	1	Depressed and separating from edge; L3 1¼ in wide LWP depressed; L2 1½ in wide
5	P	2	Depressed and filled with debris; overall good condition
6	P	1-1 ½	Depressed and filled with debris; L4 LWP filled with H; overall good condition
7	P	1½	Depressed; L4 middle segment patched with H
8	P	½	Depressed but in good condition

PPCP = prestressed precast concrete pavement; P = preformed seal; H = hot-poured elastomeric seal; L = lane numbered from outside; LWP = left wheel path.

There were very few cracks in the PPCP section; the cracks mainly originated from grout holes, cracks in the block-out patches, and corner breaks; one very small area showed map cracks.

Ride Quality

As discussed previously, ride quality was measured as IRI using VDOT's narrow beam laser inertial profiler immediately after construction and after diamond grinding of the PCP and PPCP sections. Although diamond grinding helped eliminate panel elevation differences, it did not improve IRI roughness as measured by narrow laser. To verify this finding, a wide beam leaser ULIPr was also used, resulting in average IRI values that were lower for the same section immediately after construction. This device was again used to measure the roughness of the PCP section on the ramp in September 2011. Average IRI values are summarized in Table 5.

Table 5. Average Ride Quality in Terms of the International Roughness Index (in/mi)

		I-66 Mainline			Ramp I-66W to U.S. Route 50W		
		PPCP Section		Existing Pavement	PCP Section		CIP Section
Lane[a]	Date Tested[b]	Narrow Laser	Wide Laser	Narrow Laser	Narrow Laser	Wide Laser	Narrow Laser
1	Nov. 2009B	120	-	120	-	-	-
	Nov. 2009A	117	-	118	109	82	-
	Dec. 2010	-	-	-	101	-	-
	Sept./ Oct. 2011	99	-	111	92	84	-
2	Nov. 2009B	-	-	-	-	-	-
	Nov. 2009A	91	-	139	-	-	-
	Dec. 2010	82	-	123	-	-	168
	Oct. 2011	86		154	-	-	165
3	Nov. 2009B	97		114			
	Nov. 2009A	95	80	116	-	-	-
	Dec. 2010	70	-	116	-	-	-
	Oct. 2011	73		153	-	-	-
4	Nov. 2009B	107	-	124	-	-	-
	Nov. 2009A	103	96	125	-	-	-
	Dec. 2010	84	-	126	-	-	-
	Oct. 2011	83		128			

IRI = International Roughness Index; PPCP = prestressed precast concrete pavement; PCP = precast concrete pavement; CIP = cast-in-place.

[a] Lane numbering starts from the outer lane. Lane 1 is a peak hour lane for the I-66 mainline. The ramp has only 2 lanes (numbered 1 and 2 in the table).

[b] 2009B = PPCP section IRI before diamond grinding; 2009A = PPCP section IRI after diamond grinding.

According to VDOT specifications (see Appendix B), the IRI limit is 70 in/mile, which was not enforced for the project but was determined for future reference.

Two sets of measurements were completed immediately after construction before opening to traffic in November 2009. The first set (narrow laser only) was performed before diamond grinding, and the second set (both narrow and wide laser) after diamond grinding. The availability of the equipment dictated whether the narrow or wide laser was used. Two more sets of measurements were taken with the narrow laser in December 2010 and September-October 2011. Measurements were also taken with the wide laser in September 2011 on the PCP section only. After 1 year of traffic, the measured values with the narrow laser indicated improved ride quality for the PPCP section, as shown in Table 5, whereas that for the existing pavement remained about the same or deteriorated. The ride quality of the PCP section as measured with the wide laser (ULIPr) decreased slightly (approximate 2-point increase in IRI) after 1.5 years of traffic.

Load Transfer Efficiency of Joints and Deflection Profile Under Load

One of the main concerns with regard to a jointed concrete pavement is the load transfer across joints. Since PCP and PPCP systems are jointed pavements, LTEs were measured using FWD testing, as previously described. The LTEs of portions of the PCP and PPCP sections were determined as part of quality control / quality assurance testing immediately after construction before opening to traffic in November 2009. Although, the target LTE was above 80%, the LTE for a few locations was as low as 70%. As the relative differences between the two deflections (D1 and D3) were low, those joints were accepted as adequate (see Appendix D). The air temperature during the November 2009 testing was around 65° F.

FWD testing was conducted again in May 2011 for the PPCP section at the expansion joints and the intermediate joints after approximately 1.5 years of service; the air temperature was around 81° F during the test. The intermediate joints are in compression because of post-tensioning; therefore, these joints are expected to be tight unless there is evidence of loss of prestressing. LTEs for the PPCP section are plotted in Figure 8 for eight expansion joints and a few intermediate joints. Limited data obtained after construction in September 2009 are also included. In general, LTE was measured from the approach side except for the expansion joints in 2011, for which both the approach and leave sides were measured. Most LTEs were above 80%. Three intermediate joints had a low LTE, at about 79%, but there was no evidence of prestressing loss. The joint with the existing pavement had an LTE of 74%. These joints need to be monitored. The condition of expansion joints deteriorated after 1.5 years under traffic, as shown in Table 4. This condition also calls for close monitoring. The LTEs for the approach and leave sides are compared in Figure 9. The LTEs for one-half of the expansion joints were less than 80% for at least one side of the joint; the LTE for expansion joint No. 7 was less than 70% on the approach side.

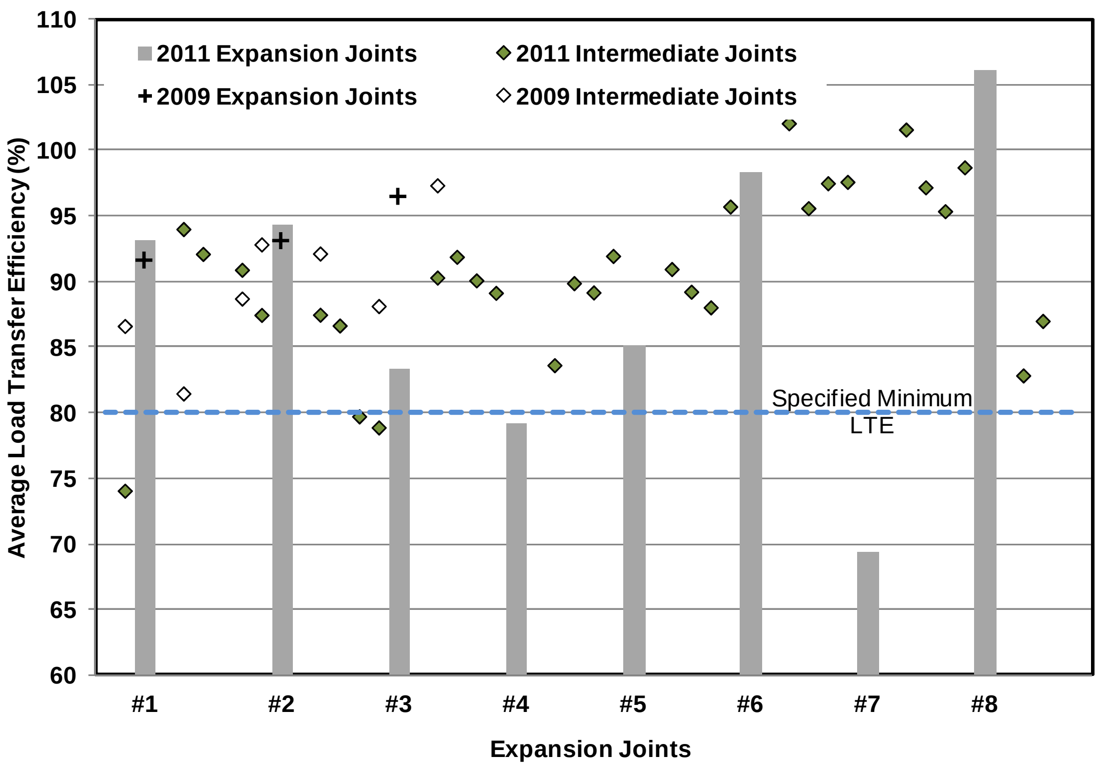


Figure 8. Load Transfer Efficiency Results for Prestressed Precast Concrete Pavement Section on I-66W

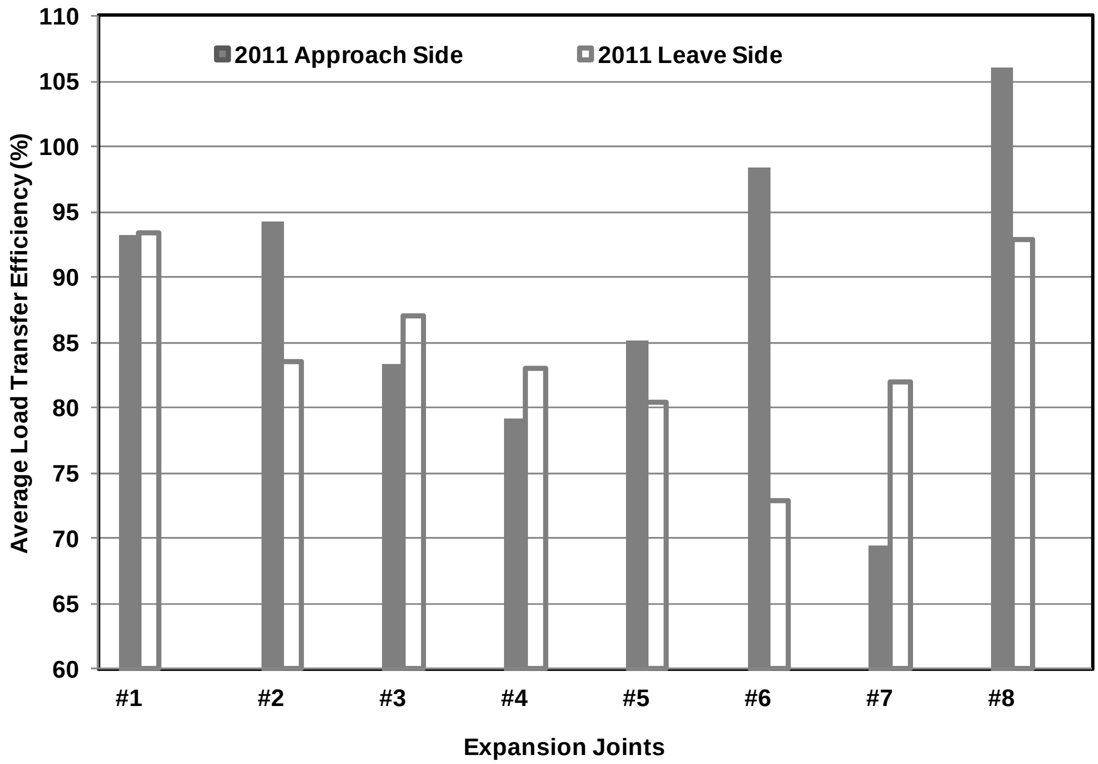


Figure 9. Comparison of LTE on Approach and Leave Sides for Prestressed Precast Concrete Pavement Expansion Joints

The deflections under load were also analyzed, and the results are shown in Figure 10. The deflections at the mid-slabs and the edges (near the joint) of the intermediate slabs were below 10 mils. But the figure shows that the deflections under the edges of expansion joint slabs were high, indicating curling or the presence of voids. According to AASHTO's1993 pavement design guide (AASHTO, 1993), a deflection intercept at zero load in a load versus deflection plot greater than 2 mils indicates lack of support under the concrete pavement. Table 6 summarizes the zero intercept for all expansion joints. All expansion joints except No. 1 had zero-load-deflection ranges from 3.6 to 8.4 mils, indicating the presence of voids or curling of the slab. Though no direct evidence was gathered, one possible cause of loss of support could be erosion of fines caused by water flowing through failed joint sealants, which was an observed problem. Other forms of expansion joints and connections between two successive sections have been tried elsewhere in a demonstration project in California (Caltrans and FHWA, 2011); a large gap was left between two successive sections, and a gap slab was used to join them.

FWD measurements for the PCP section were taken after construction during November 2009 for the first 85 slabs and again in September 2011 for every 7th slab of the entire right lane. LTE values were greater than 80% except at two joints, and the deflection under load was below 10 mils for most joints. The zero intercepts ranged from -0.8 to 1.1 in 2009 and -1.47 to 1.01 in 2011, indicating no voids or curling immediately after construction or after 1.5 years of traffic. No seal was specified (see Appendix B) in the transverse joints of the PCP. Some of the mid-slab cracks were tested for LTE in September 2011 and were found to have more than 87% LTE, indicating good load transfer because of slab reinforcement. A LTE of more than 80% is considered acceptable for the joints (see Appendix B).

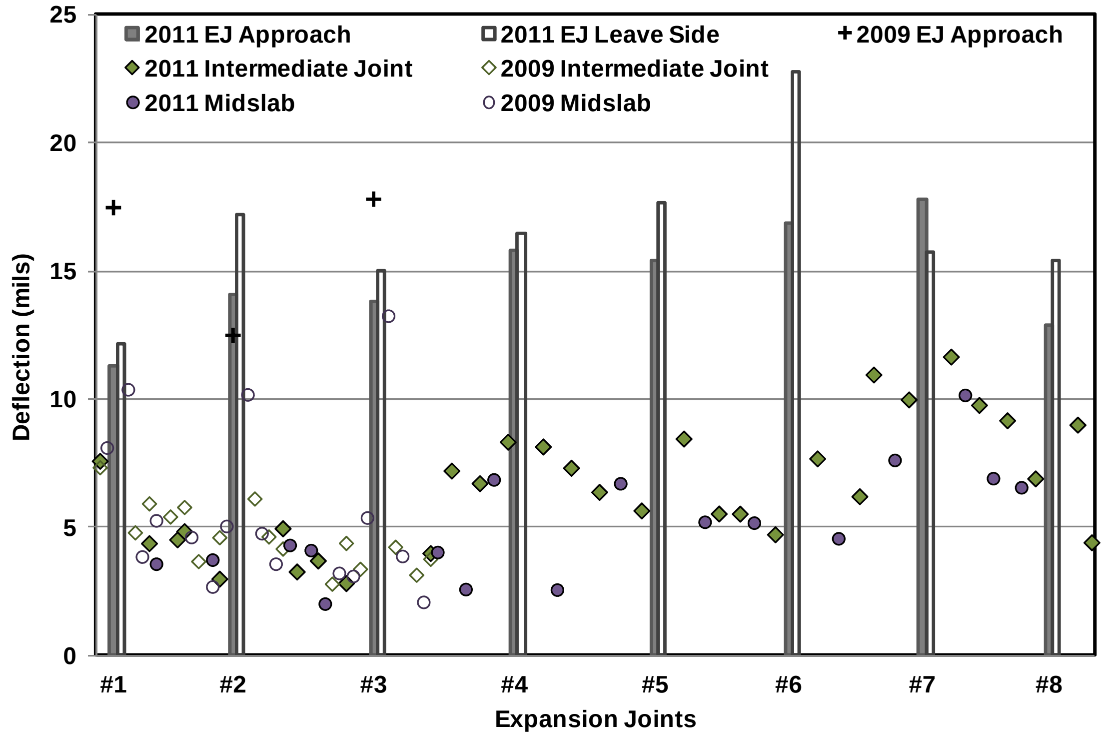


Figure 10. Deflection under Load Results for Prestressed Precast Concrete Pavement Section on I-66W

Table 6. Expansion Joint Load Transfer Efficiency (LTE) for PPCP

Exp. Joint[a]	Tested Side	Date Measured: 11/10/2009					Date Measured: 05/26/2011				
		Deflection, mils					Deflection, mils				
		D_1	D_3	Diff.	Zero Load Intercept	LTE (%)	D_1	D_3	Diff.	Zero Load Intercept	LTE (%)
1	App.	17.46	15.99	1.47	3.4	91.6	11.32	10.55	0.77	1.1	93.2
	Leave						12.16	11.35	0.81	1.9	93.4
2	App	12.41	11.54	0.87	0.9	93.0	14.10	13.29	0.81	3.6	94.3
	Leave						17.21	14.38	2.83	4.5	83.6
3	App	17.69	17.07	0.62	3.0	96.5	13.81	11.52	2.30	4.9	83.4
	Leave						14.97	13.02	1.95	5.4	87.0
4	App						15.82	12.53	3.29	5.6	79.2
	Leave						16.46	13.67	2.79	6.2	83.5
5	App						15.43	13.14	2.30	4.7	85.1
	Leave						17.64	14.20	3.45	6.2	80.5
6	App						16.83	16.55	0.28	5.3	98.3
	Leave						22.77	16.61	6.16	8.4	73.0
7	App						17.81	12.36	5.45	5.3	69.4
	Leave						15.75	12.90	2.85	8.4	81.9
8	App						12.86	13.63	-0.78	5.5	106.0
	Leave						15.39	14.30	1.09	6.1	92.9

PPCP = prestressed precast concrete pavement; Exp. = expansion; D_1 = Deflection under load; D_3 = Deflection at 12 in from load; Diff. = difference; App. = Approach.
The load level for all data was approximately 9,000 lb, and the lane tested was the second from the left. [a]No measurements were taken during the 2009 data collection for Expansion joints 4 through 8.

SUMMARY OF FINDINGS

- *Removal of existing pavement panels was generally easy*. It was possible to lift a cut panel as one piece. However, sometimes panels broke into pieces, making removal difficult.

- *Mid-slab cracking was observed in the PCP slabs on the ramp right after construction.* Compaction of base, slab fabrication, early traffic, and longitudinal ties with the existing lane are believed to be contributing causes.

- *In the PPCP systems, the alignment of the duct holes between adjacent panels was an issue for longitudinal post-tensioning*. In a few panels, ducts were misaligned such that strands could not be pushed through. The slabs had to be cored near the joint to reveal the duct holes and advance the strands.

- *Post-tensioning was not feasible in transverse tying of lanes*. To tie all the lanes together, post-tensioning in the transverse direction was planned; however, it was not practical under traffic to push the strands in the transverse direction through all three slabs (two 12-ft slabs and one 27-ft slab) at the end of the construction. Thus, strands were pushed through the first two 12-ft slabs and grouted in place without post-tensioning. About 3 ft of the strand from the 27-ft slab was brought into the middle slab, and they were thus grouted together. It is expected that these grouted strands along with under-slab anchoring can keep these lanes together and prevent lateral movement.

- *Grout for post-tensioning ducts leaked from the ducts at the panel joints*. Positive coupling was not provided at the joints, and leaks occurred. On many occasions, grout did not flow from successive ports.

- *Alignment of slabs was an issue in PPCP systems*. A small misalignment resulted in significant deviation and gaps because of the cumulative effect of 10 to 16 slabs in the long stretch of each post-tensioned section.

- *Corner cracks occurred in the PPCP panels*. When the slabs touch each other at the ends, large stresses under traffic cause breaking, especially at the corners.

- *Strand slippage occurred in PPCP during post-tensioning.* Ends of the epoxy-coated strands were stripped of epoxy to promote gripping of post-tensioning chucks. In the initial installations, slippage was noticed, prompting better stripping of epoxy and the use of three-piece chucks.

- *The thin layer of patching material in lifting hook holes is showing some cracking and spalling*. Lift holes on the surface of the panels in PPCP were filled with rapid set patching materials, and some of them have already started to break loose after 1.5 years of traffic.

- *The thickness of the PPCP panels as designed was an issue*. The required layers of reinforcement and the ducts in PPCP slabs restricted the top cover depth to no greater than 2 in for a slab 8¾ in thick. Although 2 in clear cover was allowed in this project, a 2.5-in cover depth, as required in bridge decks for improved protection against corrosion in the harsh environment, would be preferable. However, increasing the design slab thickness could create additional challenges with excavating the existing sub-base layers.

- *Expansion joints in PPCP were wider than the specified ½ in at 50ºF to 90ºF (see Appendix C).* Expansion joints in the PPCP system were wide, and there was some evidence of loss of support underneath. In a recent demonstration project in California (Caltrans and FHWA, 2011), an alternative system of jointing was successfully tried and is expected to result in information for future use; a large gap was left between two successive sections, and a gap slab was used to join them.

- *Specialized handling and inspection are required for post-tensioning operations in PPCP.* The mismatch of slabs, the couplers at the joints, the strand surface, and the chucks used have an effect on the success of the post-tensioning operation. Structural inspection experience to address these factors is most appropriate for these systems.

- *Adequate storage areas were an issue for the PCP and PPCP systems.* The project site had high traffic volumes and limited space to store equipment and materials. A nearby lot was selected for storage. This was an inconvenience for the contractor.

- *Precast panel replacement generally has a higher initial cost than traditional CIP repairs (see "Costs and Benefits Assessment" section).*

- *The constructability of both precast systems was viewed as satisfactory by everyone involved in the project, including the contractor and FHWA and VDOT personnel.* The challenges of night placement and unique placement requirements were successfully met. The contractor did not face any serious difficulty in the completion of either system.

CONCLUSIONS

- *PCP and PPCP systems can be successfully implemented to repair concrete pavement in high-volume traffic areas where disruption to traffic is costly in terms of user delays and difficult to achieve without major delays or where closure of lanes is limited.*

- *Precast slabs have the advantage of being prepared under more controlled environments at the plant without the need for high early strengths that may adversely affect durability.*

- *The PPCP system helps with crack control but requires more complex construction practices than does the PCP system.*

- *To be successful, PCP and PPCP systems require a workforce skilled in precast operations, including match-casting and casting of "warped" sections to conform to horizontal and vertical curvature of the roadbed; placement and setting of precast sections in the field; post-tensioning; and duct and under-slab grouting operations.*

- *Operations involving base preparation; fabrication, placement, and matching of slabs; and grouting operations require close adherence to specifications to ensure successful installation and adequate performance.*

- *Design of prestressed post-tensioned concrete pavement sections requires additional attention to reinforcement detailing not normally required with conventional concrete pavements.* In most pavements ,design of the slab thickness is empirical, based primarily on anticipated traffic loading. Post-tensioned concrete slabs contain more congested reinforcement, which provides additional constraints to accommodate prestressed reinforcement ducts, non-prestressed reinforcement, and appropriate clear concrete cover to ensure durability.

- *Transverse post-tensioning through three lanes (slabs) together is not feasible. Instead, grouting of shorter strand sections without post-tensioning seems to be a viable solution, but its success needs to be evaluated in the long term.*

- *Positive coupling of post-tensioning strand ducts in the PPCP system is needed to prevent grout leakage*.

RECOMMENDATIONS

1. *VDOT's Materials Division and Maintenance Division and the related district sections should consider PCP and PPCP systems as options when fast construction and longevity are sought in pavement construction and repairs.* A trial installation is recommended at the beginning of each project for such construction.

2. *VDOT's Materials Division should consider the following modifications to the PCP system in future implementations:*

   a. *Specified tolerances for slab dimensions, particularly for location and size of tongue-and-bell keyway details, should be strictly enforced to ensure proper fitting of slabs can be achieved during placement.* Otherwise, gaps between slabs may occur or cracks and edge spalls within the slabs can occur.

   b. *Quality assurance in plants and the field should be directed toward minimizing mid-slab cracking during production, handling, delivery, and installation.*

   c. *Adequate storage areas for construction equipment and precast slabs need to be considered during planning*.

3. *VDOT's Materials Division should consider the following modifications to the PPCP system in future implementations:*

   a. *Specified tolerances for slab dimensions, particularly for location and size of tongue-and-bell keyway details, should be strictly enforced to ensure proper fitting of slabs can be* *achieved during placement.* Otherwise, gaps between slabs may occur or cracks and edge spalls within the slabs can occur.

b. *Adequate storage area for construction equipment and precast slabs need to be considered during planning.*

c. *The use of post-tensioning ducts greater in size than that (1 in by 1.5 in) specified in this project needs to be considered.* For post-tensioning, it was difficult to advance the strands though the ducts because of the small size and misalignments. This also made the grouting operation difficult. Duct size should be selected to permit adequate space for grout around the strands, based on strand diameter selected.

d. *When slab thickness is selected, the location and size of reinforcement and ducts and the proper cover depth should be considered.* Slab thickness should be specified to accommodate post-tensioning ducts, non-prestressed reinforcement, and adequate clear cover to ensure protection against corrosion.

4. *The materials and maintenance personnel in VDOT's Northern Virginia District should monitor the long-term performance of the sections constructed in this project, with particular attention to failure of expansion joint seals, opening of intermediate joints, development of cracks, and load transfer between precast panels or other evidence of loss of support.*

5. *VCTIR should continue evaluating new means and methods for improved installation of precast systems including demonstration projects by other states and new improvements by the industry.*

COSTS AND BENEFITS ASSESSMENT

Cost and Production Rate

The project was completed on time without any major overruns; therefore, the bid prices from the contractor are used here for the unit cost of each option and are presented in Table 7. The overall working or lane closure hours were about 7 to 8 hours per night. Because of the time and effort required to establish and remove traffic control on the I-66 mainline, the actual work hours were approximately 6 hours per night for both the mainline and ramp. According to an estimation by staff of VDOT's Northern Virginia District (Shiells and Brown, 2010), production rates for each of the systems were as follows:

1. *CIP:* 53 yd^2 per night
2. *PCP:* 256 yd^2 per night
3. *PPCP:* 160 to 180 yd^2 per night.

These production rates are also summarized in Table 7. The PCP and PPCP systems were diamond ground, at a cost of \$8/yd^2. The need for at least 3 to 4 hours of curing time in CIP repair slowed down the production significantly. In comparing these production rates, it is

Table 7. Unit Bid Price and Production Rate for the Three Systems

System	Unit Bid Price, $/yd^2	Total Area Repaired, yd^2	Production Rate per Night with 6 hours of Working		
			No. of Slabs	Lane-feet	Surface Area, yd^2
CIP	225	1023		40	53[a]
PCP	350	4,710	12 (each slab: 16 ft x 12 ft)	192	256
PPCP	410	5,780	12 (each slab: 10 ft x 12 ft)	120	160
			6 (each slab: 10 ft x 27 ft	120	180

CIP = cast-in-place; PCP = precast concrete pavement; PPCP = prestressed precast concrete pavement.
Note: The approximate thickness of each PCP and PPCP slab was 9 in.
[a]As this was a small job, the production rate may not be representative.

important to consider that the precast technologies were new to the contractor and the overall CIP project quantities were relatively small. Therefore, higher production rates are possible in all cases. PCP is a proprietary system that has been used extensively in other states (Fort Miller Co., Inc., 2010). Both precast systems were built as continuous pavement in this demonstration; the production rate for PCP may vary or be lower if used for spot repair. It is important to note that the PPCP system is not suitable for spot repair because of the requirement for post-tensioning between slabs.

Benefits

Precast technology could be used as another tool for pavement repair in areas with high traffic volumes where extended lane closure is not permitted. The potential benefits of this technology are more rapid replacement of pavement sections, higher production rates and associated reductions in traffic control expenses, and reduction of congestion and impacts on the traveling public.

To perform a proper cost-benefit analysis, it would be necessary to determine the actual life cycle cost of each system. Though both precast systems are expected by the industry to have a longer service life because of better production control of the precast slabs, the systems have not been in service long enough to assess the actual service life.

ACKNOWLEDGMENTS

The authors thank VDOT’s Materials Division; VDOT’s Northern Virginia District Materials Office; FHWA’s Office of Pavement Technology, Highways for LIFE Program, and Turner-Fairbank Highway Research Center; and Fugro Consultants, Inc., for their generous input of information and their contribution in conducting some of the field tests for this study. The continuous technical assistance of Mr. Samuel S. Tyson from FHWA is greatly appreciated. The authors also acknowledge the help and guidance of Mr. David P. Shiells, Northern Virginia District Materials Engineer, throughout the project. The sponsorship of FHWA’s Highways for LIFE Program for this demonstration is greatly appreciated.

REFERENCES

American Association of State Highway and Transportation Officials. *Guide for Design of Pavement Structures.* AASHTO GDPS-4. Washington, DC, 1993.

ASTM International. *Annual Book of ASTM Standards Concrete and Aggregate,* Vol. 04.02. West Conshohocken, PA, 2009.

Buch, N., Barnhart, V., and Kowli, R. Precast Concrete Slabs As Full-Depth Repairs: Michigan Experience. In *Transportation Research Record: Journal of the Transportation Research Board,* No. 1823. Transportation Research Board of the National Academies, Washington, DC, 2003, pp. 55-63.

Caltrans and FHWA. Caltrans Precast Concrete Pavement Open House, San Francisco, CA, June 15, 2011. http://www.fhwa.dot.gov/hfl/partnerships/pdfs/caltrans_fhwa_precast.pdf. Accessed June 13, 2012.

Fort Miller Co., Inc. Super-Slab®, 2010. http://www.super-slab.com/. Accessed June 15, 2012.

Hossain, S., Ozyildirim, C., and Tate, T.R. *Evaluation of Precast Patches on U.S. 60 Near the New Kent and James City County Line*. VTRC 06-R22. Virginia Transportation Research Council, Charlottesville, 2006.

Merritt, D.K., McCullough, B.F., Burns, N.H., and Schindler, A.K. *The Feasibility of Using Precast Concrete Panels to Expedite Highway Pavement Construction.* Research Report No. 1517-1. Center for Transportation Research, University of Texas at Austin, 2000.

Merritt, D.K., McCullough, B.F., and Burns, N.H. *Construction and Preliminary Monitoring of the Georgetown, Texas, Precast Prestressed Concrete Pavement.* Research Report 1517-01-IMP. Center for Transportation Research, University of Texas at Austin, 2002.

Merritt, D.K., McCullough, B.F., and Burns, N.H. Design-Construction of a Precast, Prestressed Concrete Pavement for Interstate 10, El Monte, California. *PCI Journal*, Vol. 50, No. 2, March-April 2005, pp. 18-27.

Merritt, D.K.. and Tyson, S.S. Sustainable Pavements with Precast Prestressed Concrete. In *TRB 90th Annual Meeting Compendium of Papers DVD.* Transportation Research Board of the National Academies, Washington, DC, 2011.

Merritt, D., and Tayabji, S. *Precast Prestressed Concrete Pavement for Reconstruction and Rehabilitation of Existing Pavements*. FHWA-HIF-09-008. Federal Highway Administration, Washington, DC, 2009. http://www.fhwa.dot.gov/pavement/concrete/pubs/if09008/if09008.pdf. Accessed July 9, 2012.

Neville, A.M. *Properties of Concrete*, 4th Ed. Pearson Education Limited, New York, 1995.

Shiells, D.P., and Brown, E.R. *Highways for LIFE: I-66 Pre-cast Concrete Pavement Demonstration Project*. Presented at the Virginia Concrete Conference, Richmond, Virginia, March 4-5, 2010. .http://www.virginiadot.org/business/resources/Materials/Virginia_Concrete_Presentations/2010/1G_-_I-66_Highways_for_LIFE_ACPA_VA_Concrete_Conference_3-4-1.pdf. Accessed June 14, 2012. http://www.virginiadot.org/business/materials-conferences.asp

Tayabji, S., and Hall, K. *Precast Concrete Panels for Repair and Rehabilitation of Jointed Concrete Pavements*. FHWA-HIF-09-003. Federal Highway Administration, Washington, DC, 2010. http://www.fhwa.dot.gov/pavement/concrete/pubs/if09003/if09003.pdf. Accessed July 9, 2012.

Virginia Department of Transportation. *Virginia Test Method 112: Electrical Indication of Concrete's Ability to Resist Chloride Ion Penetration.* Richmond, 2007a. http://www.virginiadot.org/business/resources/Materials/bu-mat-VTMs.pdf. Accessed June 14, 2012.

Virginia Department of Transportation. *Road and Bridge Specifications.* Richmond, 2007b. http://www.virginiadot.org/business/const/spec-default.asp. Accessed June 14, 2012.

Virginia Department of Transportation. *Average Daily Traffic Volumes with Vehicle Classification Data on Interstate, Arterial and Primary Routes*. Richmond, 2008. http://www.virginiadot.org/info/resources/AADT_PrimaryInterstate_2008.pdf. Accessed June 5, 2012.

APPENDIX A

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS FOR PATCHING HYDRAULIC CEMENT CONCRETE PAVEMENT

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS FOR
PATCHING HYDRAULIC CEMENT CONCRETE PAVEMENT

November 14, 2008

I. DESCRIPTION

This work shall consist of removing designated areas of defective concrete pavement, replacing subbase material where required, and placing concrete pavement with or without reinforcement in accordance with these provisions and in conformity with the original lines and grades as shown on the plans or as established by the Engineer.

The following is a description of each patch type:

Jointed Concrete Pavement Patch, Type I patching shall consist of full depth, full lane width concrete pavement repairs equal to 6 feet in length and less than 15 feet in length. The patch is non-reinforced, with dowels at the transverse joints.

Jointed Concrete Pavement Patch, Type II patching shall consist of full depth, full lane width concrete pavement repairs 15 feet or greater in length. The patch is reinforced with steel wire fabric and has dowels at the transverse joints and longitudinal tie bars as shown in Figures 1 & 2 (Attached).

Jointed Concrete Pavement Patch, Type III patching shall consist of partial depth concrete pavement repairs that extend no deeper than one-third the slab thickness and extend no more than one-half the lane width. Type III patches shall not be used at existing joints or cracks.

Continuously Reinforced Concrete Pavement Type IV shall consist of full depth repairs. Patches shall be of the following types:

Type IV-A patches shall be full lane width and not less than 6 feet long.

Type IV-B patches shall be partial lane width and not less than 6 x 6 feet.

Type IV patches less than 15 feet in length will not require tie bars.

II. MATERIALS AND EQUIPMENT

A. Materials

The Contractor shall prepare sufficient trial batches of the hydraulic cement concrete mix in the presence of the Engineer to verify the strength and workability of the mix design. The mix shall be shown to be capable of achieving a target opening to traffic strength of 2000 psi when tested in accordance with AASHTO T-23 and T-24.

Subbase material shall conform to the requirements of Section 208 of the Specifications.

Reinforcing steel, dowels, tie bars, hook bolts, and welded wire fabric shall conform to the requirements of Section 223 of the Specifications.

Joint sealer and filler shall conform to the requirements of Section 212 of the Specifications.

Load transfer devices shall be fabricated of steel and shall be of an approved type and design.

Curing materials shall conform to the requirements of Section 220 of the Specifications or be used in accordance with the manufacturer's recommendation.

Epoxy compounds shall conform to the requirements of Section 243 of the Specifications.

Asphalt concrete shall conform to the requirements of Section 211 of the Specifications, except that material may be accepted by certification and visually inspected at the job site by the Engineer.

B. Equipment

Saw cutting equipment shall be capable of sawing neat vertical faces along the patch boundaries. The use of a carbide-toothed wheel saw shall not be permitted for sawing the patch boundaries. A carbide-tipped wheel saw may be used for additional saw cuts provided that a minimum 3-inch clearance from the sawed boundary is maintained.

III. CONSTRUCTION METHODS

Designated defective pavement shall be removed full depth and undisturbed portions of the existing pavement adjacent to the area to be patched shall be left with straight vertical sides.

The existing pavement to be removed shall be sawed full depth along the transverse and longitudinal boundaries, including the lane and shoulder/lane joints as shown on the plans or as directed by the Engineer. Additional saw cuts inside the patch boundaries will be permitted to facilitate the concrete removal operation.

Concrete sawn full depth to be removed shall be lifted out by means of chains, lift-pins, or other approved devices. Concrete breaking in-place shall not be permitted. During the removal operations, utmost care shall be exercised to minimize disturbance and damage to the base material, and the adjacent pavement and shoulder.

Unsuitable subbase material, concrete and reinforcing steel shall be removed and disposed of off the project in accordance with Section 106.04 of the Specifications. After the old concrete has been removed from the patch area, the subbase shall be dressed to the satisfaction of the Engineer. When unsuitable subbase or subgrade material is encountered, it shall be removed, and if replaced brought to grade with specified material, and compacted to the satisfaction of the Engineer.

Where cement-stabilized material is present and is found to be sound, excavation below the top of the cement stabilized material will not be required.

All excavated areas shall be patched the same day. In the event the excavated area has not been patched and cured within the lane closure time restriction, it shall be temporarily filled with asphalt concrete as approved by the Engineer.

The excavated area shall be thoroughly cleaned of loose material and debris and moistened prior to the placement of hydraulic cement concrete.

Existing pavements shall not be removed if such removal will result in hydraulic cement concrete being placed when the ambient air temperature is below 32° F, unless approved by the Engineer. The hydraulic cement concrete temperature at the time of placement shall not be less than 70° F and not more than 95° F, unless approved by the Engineer.

Hydraulic cement concrete shall be deposited on the sublayer, spaded, tamped, and internally vibrated so that it completely fills the area of the patch. Finishing of the plastic hydraulic cement concrete shall conform to the requirements of Section 316 of the Specifications, except that the final surface shall be textured similar to that of the adjoining pavement. The patch and the existing pavement shall be tested for smoothness by means of a 10-foot straightedge laid parallel to the centerline of the road surface, and irregularities in the patch in excess of ¼ inch shall be corrected.

Immediately after straight edging and texturing, the hydraulic cement concrete shall be moist-cured with wet burlap and insulating blankets.

When patching 2 lanes simultaneously, the longitudinal joint shall be reestablished by sawing. Joints shall be sealed with silicone unless otherwise permitted by the Engineer.

Within 24 hours after completion of a patch area, any bituminous concrete shoulders damaged during pavement repair operations shall be reconstructed in accordance with the requirements of Section 315 of the Specifications with full depth Type SM-9.5A asphalt concrete to match the finished shoulder grade. In the event traffic is to be permitted on the patch area prior to reconstruction of the shoulder, the Contractor shall first make such temporary repair to the shoulder as is necessary to avoid any hazardous condition.

The Department will stencil all patches with the date and project identification.

Additional construction methods specific to partial depth repairs are noted under the section headed Type III.

TYPES I AND II

Where the existing joint dowel assembly is to be removed, the existing concrete shall be saw cut full depth and removed a minimum of 1 foot on either side of existing transverse joints. Minimum length of removal shall be 6 feet in accordance with that shown in Figure 1. (Attached)

Oversawing into the adjacent slabs or shoulder shall be kept to the minimum amount necessary to ensure that full depth cuts in the corners have been achieved. All oversawing shall be cleaned and filled with joint sealant.

Any areas damaged during concrete sawing and removal operations shall be repaired to the satisfaction of the Engineer by extending the patch boundary or repairing spalls at the Contractor's expense. Spalls greater than ¼ inch wide and 2 inches long and over ½ inch in depth below the pavement surface shall be repaired using an approved epoxy mortar.

Bond breaking material approved by the Engineer shall be placed at the longitudinal joint for Type I patches as shown in Figure 2 (Attached).

Type I and Type II patches shall be installed in accordance with the requirements of Standard PR-2 unless otherwise noted herein.

Where dowels are required, holes slightly larger than the diameter of the dowels shall be drilled 9 inches into the face of the existing slab starting 6 - 12 inches from either edge and then on 12 inch centers. There shall be four dowels placed in from each pavement edge for a total of eight per joint. The holes shall be located at a depth as shown in Figure 1. The dowels shall be carefully aligned (within ¼ inch) with the direction of the pavement and parallel to the plane of the surface. A quick setting, non-shrinking mortar or a high viscosity epoxy shall be used to anchor the dowels in the holes. The holes shall be completely filled around the dowels so as to minimize vertical movement of the dowels and ensure that the dowels are permanently fastened to the existing concrete. The epoxy or grout is to be put into the hole in sufficient quantity so that when the bar is inserted, the material completely fills the annular space around the bar. A grout retention ring shall be used as shown in Figure 1.

The surface edges of all patches shall be tooled, formed and/or sawed, and cleaned to result in a properly dimensioned reservoir for sealant. All transverse and longitudinal joints at pavement repair locations shall be filled with silicone in accordance with manufacturer's recommendations unless otherwise permitted by the Engineer. Joints at pavement repair locations shall be cleaned and sealed prior to the winter shutdown unless otherwise directed by the Engineer.

TYPE III

Partial depth patches shall be sawed a minimum depth of 2 inches around the perimeter of the patch area to provide a vertical face at the edges. Concrete within the patching area shall be broken out with a pneumatic hammer not heavier than a 35-pound class or by other methods approved by the Engineer. Edge spalls greater than ¼ inch wide and 2 inches long and over ½ in depth below the pavement surface shall be repaired using an approved epoxy mortar. The area of failure shall be removed by equipment that will not damage the adjacent sound pavement. The exposed faces of the concrete shall be free of loose particles, oil, dust, and other contaminants before placement of patch material. All residues shall be removed just prior to placement of the concrete bonding agent. Bonding agent shall be an approved cement mortar mixture or any other approved agent.

TYPE IV-A&B

Care shall be taken to minimize damage to the adjacent concrete during concrete removal. Should excessive edge chipping occur during removal, it shall be the Contractor's responsibility to resaw, remove, and replace the damaged pavement at the Contractor's expense. Chipping or spalling that exceeds 2 inches wide and 3 inches long or chipping or spalling less than 2 inches wide and 3 inches long that affects more than 10 percent of the joint will be considered excessive.

Existing pavement shall be removed by sawing the exterior transverse patching limits to a depth of 2 to 3 inches. Care shall be taken to avoid saw cutting the steel reinforcement. Longitudinal limits shall be cut full depth. When necessary, the shoulders shall be cut a sufficient depth and width to facilitate forming paving edge. The concrete in the end sections shall be removed full depth by methods that will not bend nor gouge the reinforcing steel nor damage the adjacent concrete that is to remain in place as approved by the Engineer. Full depth interior saw cuts shall be used to cut the existing reinforcing steel and to define the limits of the end sections. The existing reinforcing steel shall be cut to leave the overlap length required by the PR Standard for the original pavement design depth, a minimum of 25 times the diameter of the existing reinforcing steel, plus two (2) inches minimum clearance between the lapped reinforcing steel and the transverse face of the existing pavement. The center section of concrete shall be removed full depth as shown elsewhere in this provision.

The reinforcement in the end sections shall be carefully straightened after the breakout of the concrete and cleaned of all concrete and rust scale prior to placement of the concrete. If 3 adjacent bars or more than 3 bars total are corroded or damaged, either a new exterior transverse saw cut extending the end sections to establish the appropriate end section lengths of undamaged steel or some other corrective method as approved by the Engineer shall be required. If damage to the reinforcement occurs due to the Contractor's operation, the corrective measures shall be performed at no cost to the Department.

Replacement will be in accordance with the Specifications for placing continuously reinforced (steel bar) concrete pavement and the applicable original design of standards PR-3, PR-4, PR-5, PR-6, PR-7, PR-8 and PR-9. Transverse faces of all pavements shall be thoroughly cleaned and moistened prior to placement of new concrete.

IV. WARRANTY

The Contractor shall provide a one-year warranty from the date of final acceptance on all hydraulic cement concrete patches. The Department will stencil all patches with the installation date and project identification. The Department will monitor patches installed throughout the warranty period for compliance and acceptability. The Contractor shall remove and replace any patch that fails due to materials or workmanship before the end of the warranty period and shall do so within 14 days after Department notification unless otherwise directed by the Department. Failure of a patch is defined by the medium or high severity occurrence of longitudinal cracking, transverse cracking, transverse joint spalling, longitudinal joint spalling, corner breaks, joint faulting or other undesirable distress as described and measured in the 2003 Distress Identification Manual for the Long-Term Pavement Performance Program. The Engineer shall notify the Contractor of the date for the warranty inspection and the Contractor shall be present at the inspection.

If notified regarding a failed patch, the Contractor may request a review by the Department. This review will be conducted to determine if the patch failure is a result of materials or workmanship based on a visual inspection. Further inspection may be required as directed by the Department. Failures not related to materials or workmanship are excluded from this warranty.

V. MEASUREMENT AND PAYMENT

Patching hydraulic cement concrete pavement will be measured in square yards of pavement surface area, complete-in-place, and will be paid for at the contract unit price per square yard for the type and depth specified, which price shall be full compensation for saw cutting pavement to the required depth, removing and disposing of existing concrete, preparing of sublayer, furnishing and installing preformed expansion material, furnishing and installing steel dowels, furnishing and installing reinforcing steel as specified, furnishing, placing, finishing, and curing special design concrete, cleaning and sealing joints, patch area protection, and for all materials, labor, tools, equipment, and incidentals necessary to complete the work

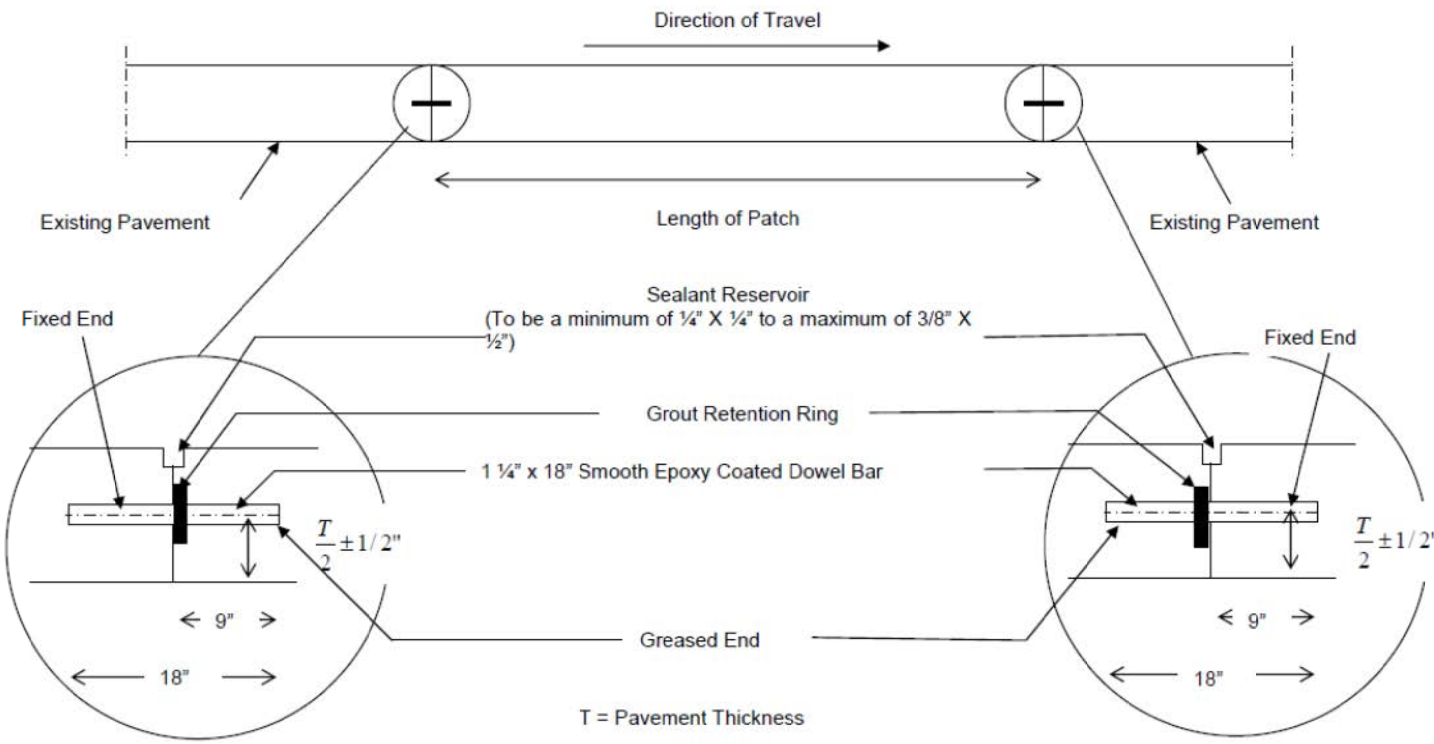
Payment will be made under:

Pay Item	Pay Unit
Patching Hydraulic Cement Concrete Pavement (Type and ____" Original Design Depth)	Square Yard

In areas where the Engineer deems the sublayer insufficient to support the patch, the sublayer shall be excavated to sound material and replaced with Aggregate 21B at a cost of $30.00 per ton. This shall be full compensation for excavation and disposal of unsuitable sublayer, and for furnishing, placing, and compacting aggregate material.

ORDER NO.: C03
CONTRACT ID. NO.: C00089579M01

TYPE I AND TYPE II JOINTED CONCRETE PATCHES



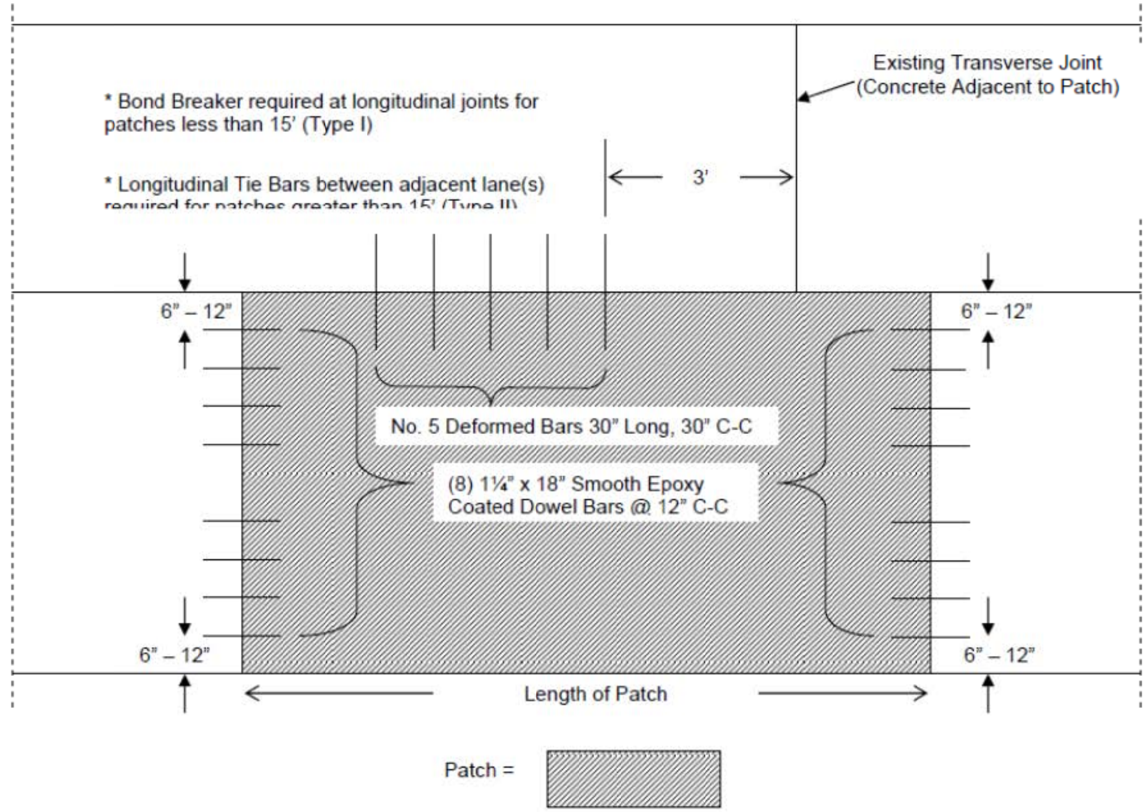
NOTE: If the length of patch is greater than 15 feet, re-establish joint in center of patch with the standard dowel basket and if the distance between remaining joints is greater than 15 feet, steel wire mesh shall be placed in a manner which will provide for a final location in the middle third of the slab thickness, maintaining a minimum of 2 inches of concrete cover.

FIGURE 1

142

ORDER NO.: C03
CONTRACT ID. NO.: C00089579M01

TYPICAL TYPE I AND TYPE II PATCHES

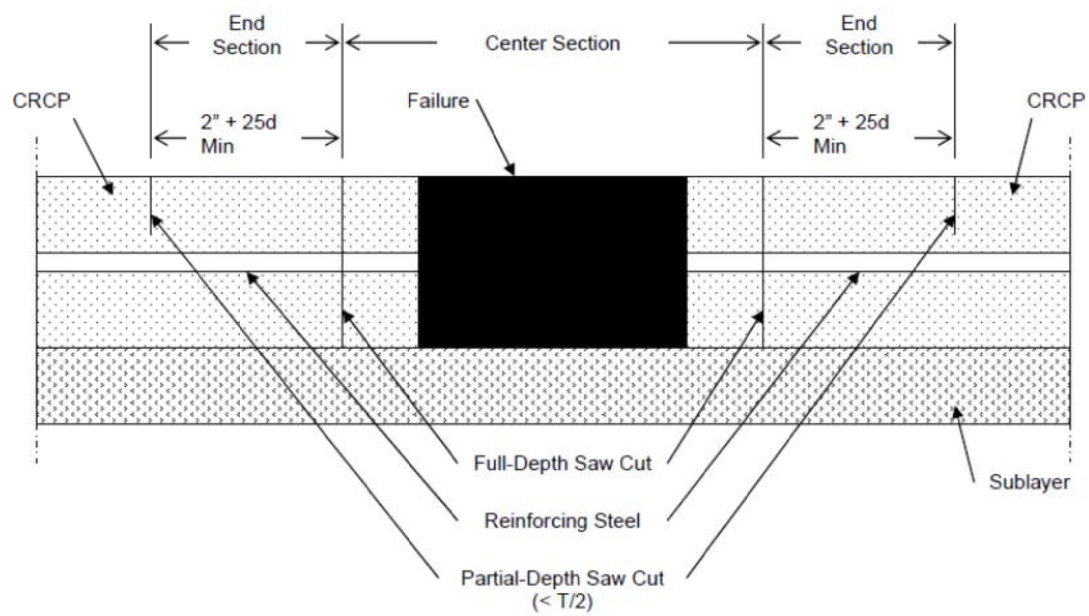


Typical Load Transfer Steel Layout for Patching Jointed Concrete Pavement

FIGURE 2

143

TYPICAL SECTION ELEVATION VIEW OF TYPE IV-A&B PATCHES



NOTE: Longitudinal Tie Bars Necessary for Patches Greater Than 15'.
T = Pavement Thickness
d = existing reinforcing steel diameter

FIGURE 3

APPENDIX B

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS FOR PRECAST CONCRETE PAVEMENT

ORDER NO.: C03
CONTRACT ID. NO.: C00089579M01

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS FOR
PRECAST CONCRETE PAVEMENT

March 23, 2009

Description

This provision shall cover the design, fabrication, installation, and grouting of precast concrete panels for pavement reconstruction.

PRECAST PANEL DESIGN

The Contractor shall be responsible for design all aspects of the precast concrete panels to replace existing pavement by matching existing pavement cross-slopes and grades. Where the existing pavement has minor variations in cross-slope from a uniform cross-slope, the contractor may propose a uniform cross-slope that most closely matches the average existing cross-slope, except where differences occur between super-elevated and normal sections. The precast panels shall be reinforced with steel and provide for a minimum concrete design strength of 5,000 psi at 28 days and air entrainment for paving concrete in accordance with Section 217 of the Road and Bridge Specifications. In addition, all concrete shall be low permeability. For plain concrete slabs, the contractor shall include any reinforcing steel necessary to prevent damage during lifting, transportation and installation. Joint load transfer, equivalent to the load transfer identified on standard PR-2, shall be provided for all longitudinal and transverse joints including the joints between precast panels and the existing pavement. The Contractor shall submit shop drawings showing the that proposed precast concrete slab design is equivalent to the existing concrete pavement with supporting calculations within 21 days of Notice to Proceed for review and approval of the Engineer. The Engineer will accept, or reject, the shop drawings, or re-submitted shop drawings, within 21 days of receipt. The contract completion date will not be extended for rejection of shop drawings due to errors or omissions deemed to be the responsibility of the Contractor.

PRE-CAST PANEL SYSTEM APPROVAL

Pre-approved pre-cast concrete slab systems are listed on the Department's Materials Division's List No. 67, Approved Pre-cast Concrete Pavement Systems. Approval of other systems is contingent upon submission of the information outlined in the special provision for "Pre-cast Concrete Pavement System Approval". The Department estimates that review of alternate system submittals could take up to 4 weeks. The Contractor should consider the potential impact on schedule when making a decision to submit an alternate system.

Materials

Materials shall conform to the requirements of the 2007 VDOT Road and Bridge Specifications referenced herein, except where noted in these Special Provisions.

Precast Panel Fabrication

Plant Certification

The precast manufacture plant supplying the precast panels shall be on the Department's Materials Division's Approved List No. 34, "Concrete Precast producers on QA/QC Program".

Tolerances

Tolerances for precast panels, regardless of type shall be as shown below in Table 1.

Table 1
Tolerances for Precast Panels

Length (parallel to long axis of panel)	+/- 1/4"
Width (normal to long axis of panel)	+/- 1/8"
Nominal Thickness	+/- 1/8"
Squareness (difference in measurement from corner to corner across top surface, measured diagonally)	+/- 1/8"
Horizontal Alignment (upon release of stress)–Deviation from straightness of mating edge of panels	+/- 1/8"
Vertical Alignment–Camber (upon release of stress)	+/- 1/8"
Deviation of ends (horizontal skew)	+/- 1/8"
Deviation of ends (vertical batter)	+/- 1/8"
Keyway Dimensional Tolerance	+/- 1/16"
Vertical Dowel Alignment (parallel to bottom of panel)	+/- 1/8" [1]
Horizontal Dowel Alignment (normal to expansion joint)	+/- 1/8"
Dowel Location (deviation from shop drawings)	+/- 1/4" Vertical[1] +/- 1/4" Horizontal
Dowel Embedment (in either side of expansion joint)	+/- 1"
Position of lifting anchors	+/- 3"[2]
Position of reinforcement, including tie-bars (unless tolerance otherwise provided in plans)	+/- 1/4"[3]

1. Measured from bottom of panel
2. From position shown in precast shop drawings
3. Unless different tolerance shown in plans

Concrete Mixture

The concrete mixture used shall meet the strength requirements set forth in Section 217.07 for Class A4 concrete. Class A4 concrete shall reach design strength prior to shipment. The mixture shall be workable enough to achieve the required surface finish as described below. The installation Contractor must approve the coarse aggregate to be used by the precast fabricator with specific consideration given to requirements for diamond grinding of the finished surface of the precast panels. Aggregate shall be non-polishing.

Steel Reinforcement

Steel reinforcement shall conform to the requirements of Section 223. Provide a minimum 2" of cover for all reinforcement. Provide a mat of reinforcing steel with a minimum steel to concrete area of 0.0014 and a maximum center-to-center bar spacing of 18 inches in each direction.

Lifting Anchors

Lifting anchors shall be approved by the Engineer prior to use. Final locations of the lifting anchors shall be determined by the precast concrete producer and shown on the precast shop drawings. Unless otherwise approved, lifting anchors shall be galvanized threaded coil inserts which can be left unpatched prior to opening the pavement to traffic. The top of the lifting anchors shall be recessed a minimum of 1/2-inch from the surface of the panel. All inserts shall be grouted prior to completion of the project.

Dowels

Dowels shall conform to the requirements of Section 316.04(g)(5), and may be epoxy coated, solid stainless steel, or stainless steel clad. The entire length of the dowel shall be coated with graphite grease or other approved bond breaker prior to placement of concrete for the Joint Panels.

Dowels shall remain parallel to the bottom surface of the panel and normal to the expansion joint during casting. Dowel baskets shall not be used to support the dowels in the forms. Dowel expansion caps shall provide for a minimum of 1.5 inches of free movement of the dowel end (within the expansion cap).

Finishing

Unless otherwise approved by the Engineer, the top surface of the panels (driving surface) shall receive a light broom finish or a multi-ply damp fabric (burlap) which shall be dragged over the concrete surface to provide a gritty texture. The texture shall be applied in a timely manner after final screeding such that the desired texture depth is achieved without disturbing the underlying concrete or turning over aggregate.

Placement in forms

Concrete formwork and placement procedures shall conform to the requirements of Section 405.05 with the exception that only metal (non-aluminum) forms will be permitted. Concrete shall be placed in a single lift (i.e., placed in a single operation) and distributed in such a manner that embedded items such as reinforcement, ducts, dowels, anchors, and lifting devices are not dislodged by the concrete mass. Proper consolidation must be achieved such that honeycombing or segregation of the concrete does not occur and all spaces around embedded items and around the panel forms are filled.

Curing

Curing of the precast panels shall conform to the requirements of Section 405.05. The Contractor shall submit the proposed curing methods and procedures for approval prior to placing concrete. Curing shall commence immediately after the surface finishing operation and as soon as marring of the concrete surface will not occur.

Membrane curing, in accordance with Section 316.04(j)(1), may be permitted at the discretion of the Engineer. A minimum two applications of the curing membrane, applied immediately after surface texture finishing, shall be required for membrane curing. Membrane curing residue shall be removed from all adjoining surfaces prior to shipment of the panels to the jobsite.

Curing shall be maintained on the sides and top surface of the panels for a minimum of 72 hours from the beginning of curing operations, or until the required 28-day compressive strength is achieved. While in the forms, the forms will be considered to provide adequate curing for the edges (vertical faces) of the panels. If any part of the form is removed, the exposed surface shall receive curing in accordance with Section 316.04(j). Removal of panels from the forms to a storage area shall be done in such a manner that curing is not interrupted for more than four hours for any member.

The precast panels shall be protected from cold and hot weather in accordance with Section 316.04(j).

Form Removal and Storage

Panels shall be removed from the forms in such a manner that no damage occurs to the panel. Form removal shall conform to the requirements of Section 405.05. Any materials forming blockouts in the panels shall be removed such that damage does not occur to the panel or the blockout.

Panels shall be stored in such a manner that adequate support is provided to prevent cracking or creep-induced deformation (sagging). Supports beneath the panels shall be located at approximately the same location as the lifting anchors. Panels shall be stacked no higher than five panels per stack, with adequate support between panels. Panels shall be stacked such that individual panels or stacks of panels are not touching one another. Panels stored for long periods of time (longer than one month) shall be checked at least once per month to ensure creep-induced deformation does not occur.

Lifting and Handling

Panels shall be handled and shipped in accordance with Section 405.05. Lifting anchors cast into the panels shall be used for lifting and moving the panels at the fabrication plant. The angle between the top surface of the panel and the lifting line shall not be less than sixty degrees (60°), when measured from the top surface of the panel to the lifting line. Damage caused to any Joint Panel, including bending of dowel bars, as a result of inadequate bracing shall be repaired at the expense of the Contractor to the satisfaction of the Engineer.

Transportation

Panels shall be transported in such a manner that the panel will not be damaged during transportation. Panels shall be properly supported during transportation such that cracking or deformation (sagging) does not occur. If more than one panel is transported per truck, proper support and separation must be provided between the individual panels.

Repairs

Repairs of damage caused to the panels during fabrication, lifting and handling, or transportation shall be addressed on a case-by-case basis and must be approved by the Engineer prior to implementation. Damage within acceptable limits caused to the top surface (driving surface) or to keyed edges of the panels shall be repaired using an approved repair method at the fabrication plant at the expense of the Contractor. Repetitive damage to panels shall be cause for stoppage of fabrication operations until the cause of the damage can be remedied.

Demonstration of Panel Fit

The precast fabricator shall initially fabricate only three panels and assemble these panels at the fabrication plant to demonstrate the fit of the panels. The panels shall be assembled over a level surface that will not cause damage to the panels during or after assembly. Joints between panels should not be more than 1/8-inch wide when assembled. Any problems with fitting the panels caused by imperfections in the panels shall be corrected prior to proceeding with panel fabrication. Panel fabrication may commence following the trial assembly with approval from the Engineer.

Removal of Existing Pavement

A. Removal Method

Existing PCC pavement shall be removed by sawcutting and lifting out the existing pavement. Rubblization, power breaking, or other impact methods which may damage the underlying base shall not be used.

Timing of Removal

Sawcutting the existing pavement for removal may be completed up to 7 days prior to commencement of removal. Sawcutting and removal shall be completed in accordance with Section 509. Sawcutting depth should not exceed the actual pavement slab thickness by more than 1 inch. Oversawing into the adjacent slabs or shoulder shall be kept to the minimum amount necessary to ensure that full depth cuts in the corners have been achieved. All oversawing shall be cleaned and filled with joint sealant.

Additional Removal

No more than 12 inches of additional pavement may be removed beyond the amount of precast concrete panels to be installed during each operation. If the gap between the end of the precast concrete panels installed during a nightly operation and the existing pavement exceeds one inch, it shall be temporarily covered or filled with a suitable material such as bituminous cold-patch materials which can be removed prior to installing additional precast concrete panels panels. Temporary fill material shall be removed completely from the gap, and the end of the precast concrete panels shall be protected from adhesion of the temporary fill material. The cost of temporary fill materials shall be included in the price bid for precast concrete panels slabs.

Base Preparation

The precast panels shall be placed over a prepared base. The surface shall be free from debris and other materials that prevent the panels from fully resting on the base. The Contractor may elect to place additional leveling material depending on the thickness of his slab design to facilitate base preparation.

A. Grade Control for Placement

Grade control shall be established for placement of the base material using string lines, laser guidance, or other comparable methods.

Surface Test

The finished surface of the base material directly beneath the precast pavement shall provide full support beneath the panels. The evenness of the surface of the base material shall be checked in both the longitudinal and transverse direction by the Contractor using 10-ft straightedge. The variation of the surface shall be such that a 6-inch diameter circular plate, 1/8-inch thick cannot be passed beneath the straightedge. Any areas of the base surface not conforming to this smoothness requirement must be corrected at the Contractor's expense; pay adjustments shall not be permitted.

Panel Installation on Site

The Contractor shall allow up to 4 site visits by large groups of up to 50 people per visit for the purposes of reviewing on-site installation procedures and processes. The Contractor shall provide sufficient traffic control to accommodate 1 bus and 1 van within the work zone for these site visits. The Contractor shall also co-ordinate with representatives of the Federal Highway Administration (FHWA) for the purposes of documenting construction processes and procedures.

A. Equipment

The Contractor shall have all equipment required for panel installation, and grouting on-site prior to beginning panel installation. Lifting and transporting equipment shall not damage the prepared base material prior to or during panel installation. Any damage to the prepared base material will be repaired at the Contractor's expense to the satisfaction of the Engineer.

Placement Technique

Panels shall be installed one at a time, and shall be installed in such a manner that the base material is not damaged during installation. The angle between the top surface of the panel and the lifting line attached to each lifting anchor shall not be less than 60 degrees (60°), when measured from the horizontal surface of the panel to the lifting line.

Panels may be aligned in the longitudinal direction (parallel to the roadway centerline) using the face of the adjacent existing pavement as the control line. Alternatively, the centerline of the panels shall be aligned to a line laid out by a surveyor (provided by the Contractor) on the surface of the base prior to installation of the panels. Panels may be offset to correct horizontal misalignment of the centerline of the panels, but not more than 1/4-inch between any two adjacent panels. Shims may not be used in the joints between panels to correct alignment.

Placement Tolerances

Alignment of adjacent panels, as indicated by the reference marks on the top surface of the panels, shall not deviate more than 1/4-inch if the existing remaining pavement is used as the control line. If a pre-surveyed centerline is used for alignment, the panels shall be within 1/4-inch of the pre-surveyed centerline marked on the surface of the base.

Vertical alignment of the panels shall be such that the top surface of an individual panel is no more than 3/16-inch higher or lower than the top surface of an adjoining panel at any point along the joint between the panels.

Expansion Joints

Expansion joint seals shall be provided, where necessary, and shall conform to the requirements of Standard PR-2 and Section 316. The seal for the expansion joints shall be selected by the Contractor and approved by the Engineer. The seal shall be installed according to manufacturer's recommendations. Expansion joints may be sawcut to the necessary width to receive the seal prior to installing the seal. Sawcuts shall not be greater than 3 inches deep to avoid contact with dowel bars.

Unless otherwise approved by the Engineer, expansion joint seals shall be installed prior to opening the pavement to traffic. Any debris in the joint shall be removed using compressed air or other approved technique prior to installing the joint seal.

Longitudinal Joints

Longitudinal joint widths shall not exceed the widths identified on standard PR-2. The longitudinal joints between precast concrete panels and the existing pavement shall be sealed according to Section 316.04(m) using a hot-poured joint sealant or low-modulus silicone rubber joint sealant conforming to the requirement of Section 212.02. The longitudinal joint may be sawcut if necessary to receive the joint sealant, according to Section 326.04(g)(1c).

Transverse Joints

Transverse joints shall not exceed the widths identified on standard PR-2. Transverse joints shall be aligned, wherever possible, with transverse joints in the existing pavement. Where existing panel lengths are greater than proposed precast slab lengths and intermediate joints are required, provide a bond breaking material 12" on either side of the mis-matched joint. Tie bars should not be placed between, or within 16" of mis-matched joints. Dowel slots shall be filled with high strength grout, or other approved material, in accordance with Section 218 of the Road and Bridge Specifications.

Transverse joints between the precast concrete panels and the existing pavement shall be sealed according to Section 316.04(m) using hot-poured joint sealant or low-modulus silicone rubber joint sealant conforming to Section 212.02. The joints may be sawcut if necessary to receive the joint sealant, according to Section 326.04(g)(1c).

Repairs

Damage caused to the precast panels during any part of the panel installation process shall be repaired at the Contractor's expense to the satisfaction of the Engineer. Repairs of damaged areas will be addressed on a case-by-case basis by the Engineer and must be approved by the Engineer prior to implementation. Damage within acceptable limits caused to the top surface (driving surface) or to keyed edges of the panels shall be repaired using approved repair methods and materials. Repetitive damage to panels shall be cause for stoppage of installation operations until the cause of the damage can be remedied.

Voids Beneath Pavement

The pavement shall be inspected during panel installation for voids beneath the precast panels. At the discretion of the Engineer, the Contractor shall be required to stop panel installation and correct imperfections in the base material causing voids beneath the precast panels.

Matching Existing Pavement

The precast panels shall be tied into the existing pavement. The top surface of the precast pavement shall no more than 1/4 inch above or below the surface of the existing pavement. Diamond grinding shall be used bring the top surface of the existing pavement and precast pavement into tolerance if necessary. A single pass of diamond grinding has been specified on the plans for the entire length of the precast concrete slab placement area as well as an additional 50' on either end. All grinding required to achieve a smooth transition between the precast concrete slab and the existing pavement and to meet the requirements of the special provision for rideability shall be included in the price bid for diamond grinding. A maximum of one pass of diamond grinding will be paid.

Trial Installation

The initial on-site panel installation shall be considered a trial installation, if a trial installation has not previously been approved by the Department, and limited to a total of 6 panels or a maximum of 80 square yards. The Contractor shall provide a minimum 15 days advance notice of the trial installation and shall allow the Engineer a minimum of 10 working days to evaluate the trial installation. Additional panels may not be installed until the trial installation has been approved by the Engineer. The Contractor shall install the trial installation and perform all testing required for trial installations as detailed in the Special Provision for Precast Concrete Pavement System Approval. Trial installations that fail to meet contract specifications shall be removed and replaced at no cost to the Department. Payment will only be made for 1 (successful) trial installation.

Underslab Grouting

Underslab grouting shall be used to fill any voids beneath the precast panels that may be present after placing the panels over the prepared base. Underslab grouting shall utilize grout ports cast into each of the panels, spaced so as to provide at least one grout port per 30 sf of slab with grout ports no further than 2 feet from a panel edge. The Contractor shall attempt to pump grout at each port location.

B. Materials

Grout materials shall consist of a mixture of Type I, II or III Portland cement, a fluidifier, fly ash and water. All materials shall be furnished by the Contractor.

The fluidifier shall be a cement dispersing agent possessing such characteristics that will inhibit early stiffening of the pumpable mortar, tend to hold the solid constituents of the fluid mortar in suspension and prevent completely all setting shrinkage of the grout.

Class C fly ash shall be selected from the Department's list of approved Fly Ash sources.

Alternate grout materials may be submitted for review by the Department.

Equipment

Equipment for underslab grouting shall consist of at least the following:

- Equipment for accurately measuring and proportioning by volume or weight the various materials composing the grout,
- A colloidal mixer, capable of operating in a range from 800 rpm to 2,000 rpm and thoroughly mixing the various components of the grout in an approved manner,

- The discharge line shall be equipped with a positive cut-off valve at the nozzle end, and a bypass return line for recirculating the grout back into a holding tank or mixer unless otherwise approved, and
- A stop watch and flow cone conforming to the dimensions and other requirements of ASTM C 939, "Standard Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)."

Proportioning Grout Mixture

The mixture used in underslab grouting shall consist of proportions of Portland cement, fly ash, fluidifier and water. The Contractor shall furnish the Engineer the proposed mixture design meeting the following requirements:

- The grout slurry shall remain fluid and not exhibit a resistance to flow for a minimum of one hour,
- The time of efflux from the flow cone shall be between 11 and 20 seconds. The flow test shall be performed in accordance with ASTM C 939, "Standard Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method),"
- The grout slurry shall achieve initial set in less than 4 hours. The grout slurry shall not be allowed to carry traffic until which time it has set to the satisfaction of the Engineer; or until which set time, as determined by ASTM C 266, "Time of Setting of Hydraulic Cement Paste by Gillmore Needles," has been reached, and
- The 7 day compressive strength of the grout slurry shall not be less than 200 psi.

Procedures

Underslab grouting shall be completed as soon as possible after installation, but not more than 7 days after placement of the precast panels. The Engineer may require grouting to be completed prior to opening the pavement to traffic if significant voids are observed during panel placement.

Slab edges shall be backfilled or sealed to prevent grout leakage from beneath the slab during underslab grouting. The bottom of all expansion joints shall be sealed prior to underslab grouting to prevent grout leakage into the joints. The sealant material shall be compressible such that it will not inhibit free movement of the expansion joints.

Underslab grouting shall require minimal pressure to force the grout beneath the pavement slab. Under no circumstances should underslab grouting cause the pavement slab to lift. Grout shall be pumped into each underslab grout port of each panel. Grout shall be pumped until it flows out of an adjacent grout port or until the line pressure on the grout pump reaches 5 psi. Grouting pressure of 5 psi may be exceeded if the Contractor can demonstrate that slab lift is not occurring at higher pressures.

The fluidity of the grout shall be checked at the beginning of each grouting operation and after each time the grout pump is flushed. Grout fluidity shall be checked in accordance with ASTM C 939, "Standard Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)." Fluidity shall be adjusted to achieve the necessary flow requirements to achieve full undersealing. If excessive bleeding of the grout is observed, the Engineer may require the Contractor to adjust the grout mixture.

Cleanup

Upon completion of grouting, recesses in the surface of the panels at the grout ports shall be filled with an approved mortar and finished flush with the surface of the surrounding pavement. Any grout that flows onto the finished surface of the pavement during the grouting operation shall be immediately flushed from the surface. Any residual grout which hardens on the pavement surface shall be removed using an approved technique to the satisfaction of the Engineer at the expense of the Contractor.

Finished Surface

The finished pavement surface (after installation of all precast panels) shall have an average IRI of less than 70 inches per mile with no individual 0.01 mile section having an IRI greater than 80 inches per mile when tested for rideability in accordance with the Special Provision for Section 316 Rideability for Hydraulic Cement Concrete Pavement. Corrective action to improve the rideability and any necessary re-texturing shall be completed in accordance with the Special Provision for Section 316 Rideability for Hydraulic Cement Concrete Pavement. The pavement may be opened to traffic prior to meeting the final surface smoothness requirements unless the surface conditions are deemed to be hazardous by the Engineer.

XI. MEASUREMENT AND PAYMENT

Pre-cast concrete pavement will be measured in square yards of pavement surface area, complete-in-place, and will be paid for at the contract unit price per square yard for the depth specified, which price shall be full compensation for design, transportation, saw cutting existing pavement to the required depth, removing and disposing of existing concrete, furnishing and placing leveling material, preparation of sub-layer, fine grading, furnishing and installing reinforcing steel, preformed expansion material (if applicable), furnishing and installing steel dowels, furnishing and installing reinforcing steel, furnishing, placing, finishing, and curing pre-cast concrete, furnishing and installing concrete patching material, furnishing and installing under slab and other grout, designing, furnishing and installing expansion joints (if applicable), furnishing and installing mechanical couplers (if applicable), furnishing and installing epoxy (if applicable), furnishing and installing joint sealants, cleaning and sealing joints, demonstration of panel fit at the plant and for all materials, labor, tools, equipment, and incidentals necessary to complete the work as well as allowing on-site visitors and representatives of FHWA.

Payment for Trial Installation includes any additional items not covered under precast concrete pavement such as coring slabs, materials sampling/testing, allowing time for the Department to perform FWD testing and any delays or reduction in productivity associated with the trial installation.

Payment will be made under:

Pay Item	**Pay Unit**
Pre-cast Concrete Pavement (9" Min. Depth)	Square Yard
Trial Installation	Each

In areas where the Engineer deems the sublayer insufficient to support the PPCP, the sublayer shall be excavated to sound material and replaced with Aggregate Base Material, Type I, Size No. 21B at a cost of $30 per ton. This shall be full compensation for excavation and disposal of unsuitable sublayer, and for furnishing, placing, and compacting aggregate material.

APPENDIX C

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS FOR PRECAST PRESTRESSED CONCRETE PAVEMENT

ORDER NO.: C03
CONTRACT ID. NO.: C00089579M01

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS FOR
PRECAST PRESTRESSED CONCRETE PAVEMENT

March 23, 2009

I. DESCRIPTION

This provision shall cover the fabrication, installation, post-tensioning, and grouting of precast prestressed concrete panels for pavement reconstruction. Herein, the term "panel" shall refer to individual precast concrete panels, including Base Panels, Joint Panels, and Anchor Panels. The term "slab" shall refer to a post-tensioned section of precast panels between the expansion joints contained within Joint Panels (Type A).

II. MATERIALS

Materials shall conform to the requirements of the 2007 VDOT Road and Bridge Specifications referenced herein, except where noted in these Special Provisions.

III. PRECAST PANEL FABRICATION

A. Plant Certification

The precast manufacture plant supplying the precast panels shall have Precast/Prestressed Concrete Institute (PCI) certification as per Section 405.03.

B. Tolerances

Tolerances for precast panels, regardless of type shall be as shown below in Table 1.

Table 1
Tolerances for Precast Panels

Length (parallel to long axis of panel)	+/- 1/4"
Width (normal to long axis of panel)	+/- 1/8"
Nominal Thickness	+/- 1/8"
Squareness (difference in measurement from corner to corner across top surface, measured diagonally)	+/- 1/8"
Horizontal Alignment (upon release of stress)–Deviation from straightness of mating edge of panels	+/- 1/8"
Vertical Alignment–Camber (upon release of stress)	+/- 1/8"
Deviation of ends (horizontal skew)	+/- 1/8"
Deviation of ends (vertical batter)	+/- 1/8"
Keyway Dimensional Tolerance	+/- 1/16"
Position of Strands	+/- 1/8" Vertical[1] +/- 1/4" Horizontal
Position of post-tensioning ducts at mating edges	+/- 1/8" Vertical[1] +/- 1/8" Horizontal
Straightness of post-tensioning ducts	+/- 1/4" Vertical[1] +/- 1/4" Horizontal
Vertical Dowel Alignment (parallel to bottom of panel)	+/- 1/8" [1]
Horizontal Dowel Alignment (normal to expansion joint)	+/- 1/8"
Dowel Location (deviation from shop drawings)	+/- 1/4" Vertical[1] +/- 1/4" Horizontal

110

Dowel Embedment (in either side of expansion joint)	+/- 1"
Position of lifting anchors	+/- 3"[2]
Position of non-prestressed reinforcement, including tie-bars (unless tolerance otherwise provided in plans)	+/- 1/4"[3]
Straightness of expansion joints	+/- 1/8"
Initial width of expansion joints	+/- 1/8"
Dimensions of blockouts/pockets	+/- 1/8"

1. Measured from bottom of panel
2. From position shown in precast shop drawings
3. Unless different tolerance shown in plans

C. Concrete Mixture

The concrete mixture used shall meet the strength requirements set forth in Section 217.07 for Class A5 concrete, as per Section 405, "Prestressed Concrete." The mixture will be required to reach a compressive strength of 3,500 psi at release of prestress and 5,000 psi at 28 days, as per Section 405.05. The mixture shall be workable enough to achieve the required surface finish as described below. The installation Contractor must approve the coarse aggregate to be used by the precast fabricator with specific consideration given to requirements for diamond grinding of the finished surface of the precast panels. Aggregate shall be non-polishing.

D. Non-Prestressed Reinforcement

Non-prestressed reinforcement shall be Grade 60 epoxy-coated steel deformed bars conforming to the requirements of Section 223.

E. Pre-stressing Materials

Pre-stressing materials shall conform to the requirements of Section 223. Unless otherwise shown on the plans, all pre-stressing material shall be 0.5-inch Grade 270, 7-wire low-relaxation strand. Pre-sterssing procedures shall conform to the requirements of Section 405.

F. Post-tensioning Materials

All post-tensioning anchors, ducts, strand, and bar shall be selected and specified by the post-tensioning contractor or supplier.

Post-tensioning ducts shall be rigid galvanized corrugated metal or rigid corrugated polypropylene or polyethylene conforming to the requirements of Section 2.7 of the Post-Tensioning Institute's "Specification for Grouting of Post-Tensioned Structures" (published 2003). Unless otherwise shown on the plans, all post-tensioning strands shall be epoxy filled and epoxy-coated 0.6-inch Grade 270, 7-wire low-relaxation strand conforming to the requirements of Section 223 and all post-tensioning bars shall be epoxy-coated 1-inch diameter, Grade 150 low-relaxation threaded bars which can be coupled together with mechanical couplers.

Grout ports shall be located in the Joint Panels (Type A) and Base Panels (Type B), as shown on the panel detail sheets. The grout ports shall have a minimum 1/2-inch inside diameter and shall be compatible with the post-tensioning ducts, providing a water-tight seal between the duct and port. Grout ports shall not protrude from the finished surface of the panels, and shall be located at the extreme ends of each tendon, and not more than 50 feet apart between the ends, unless otherwise approved by the Engineer.

G. Lifting Anchors

Lifting anchors shall be approved by the Engineer prior to use. Final locations of the lifting anchors shall be determined by the precast concrete producer and shown on the precast shop drawings. Unless otherwise approved, lifting anchors shall be galvanized or epoxy coated threaded coil inserts which can be left unpatched prior to opening the pavement to traffic. The top of the lifting anchors shall be recessed a minimum of 1/2-inch from the surface of the panel. All inserts shall be grouted prior to completion of the project.

H. Dowels and Expansion Joints

Shop drawings for the expansion joint detail shall be submitted for approval prior to fabrication of the Joint Panels. The expansion joint shall be able to withstand the expansion and compression requirements specified in 6.7. Dowels for the expansion joints shall conform to the requirements of Section 316.04(g)(5), and may be epoxy coated, solid stainless steel, or stainless steel clad. The entire length of the dowel shall be coated with graphite grease or other approved bond breaker prior to placement of concrete for the Joint Panels. Armored joints shall be fabricated using galvanized steel components.

Dowels shall remain parallel to the bottom surface of the panel and normal to the expansion joint during casting. Dowel baskets shall not be used to support the dowels in the forms. Unless otherwise shown on the plans, the minimum length of dowel embedment on either side of the expansion joint shall be one-half the length of the dowel minus the specified initial width of the expansion joint.

Dowel expansion caps specified in the plans shall be approved by the Engineer prior to use. A minimum of 1.5 inches of free movement of the dowel end (within the expansion cap) shall be provided.

A bond-breaking material shall be used to prevent the two halves of each Joint Panel (Type A) from bonding to each other. Grease, polyethylene sheeting, Styrofoam, or other approved material shall be used for the bond breaker.

I. Finishing

Unless otherwise approved by the Engineer, the top surface of the panels (driving surface) shall receive a light broom finish or a multi-ply damp fabric (burlap) which shall be dragged over the concrete surface to provide a gritty texture.. The texture shall be applied in a timely manner after final screeding such that the desired texture depth is achieved without disturbing the underlying concrete or turning over or dislodging aggregate.

J. Placement in forms

Concrete formwork and placement procedures shall conform to the requirements of Section 405.05 with the exception that only metal (non-aluminum) forms will be permitted. Concrete shall be placed in a single lift (i.e., placed in a single operation) and distributed in such a manner that embedded items such as reinforcement, ducts, dowels, anchors, and lifting devices are not dislodged from their proper placement in accordance with the plan details by the concrete mass. Proper consolidation must be achieved such that honeycombing or segregation of the concrete does not occur and all spaces around embedded items and around the panel forms are filled with concrete.

K. Curing

Curing of the precast panels shall conform to the requirements of Section 405.05. The Contractor shall submit the proposed curing methods and procedures for approval prior to placing concrete. Curing shall commence immediately after the surface finishing operation and as soon as marring of the concrete surface will not occur.

Membrane curing, in accordance with Section 316.04(j)(1), may be permitted at the discretion of the Engineer. A minimum two applications of the curing membrane, applied immediately after surface texture finishing, shall be required for membrane curing. Membrane curing residue shall be removed from all adjoining surfaces prior to shipment of the panels to the jobsite.

Curing shall be maintained on the sides and top surface of the panels for a minimum of 72 hours from the beginning of curing operations, or until the required 28-day compressive strength is achieved. While in the forms, the forms will be considered to provide adequate curing for the edges (vertical faces) of the panels. If any part of the form is removed, the exposed surface shall receive curing in accordance with Section 316.04(j). Removal of panels from the forms to a storage area shall be done in such a manner that curing is not interrupted for more than four hours for any member.

The precast panels shall be protected from cold and hot weather in accordance with the requirements of Section 316.04(j).

L. Form Removal and Storage

Panels shall be removed from the forms in such a manner that no damage occurs to the panel. Form removal shall conform to the requirements of Section 405.05. Any materials forming blockouts in the panels shall be removed such that damage does not occur to the panel or the blockout.

Panels shall be stored in such a manner that adequate support is provided to prevent cracking or creep-induced deformation (sagging). Supports beneath the panels shall be located at approximately the same location as the lifting anchors. Panels shall be stacked no higher than five panels per stack, with adequate support between panels. Panels shall be stacked such that individual panels or stacks of panels are not touching one another. Panels stored for long periods of time (longer than one month) shall be checked at least once per month to ensure creep-induced deformation does not occur.

M. Unobstructed Ducts

After removal from the forms and prior to shipment, the precast fabricator shall check for obstructions and residual water in all post-tensioning ducts. The post-tensioning ducts shall be checked for obstructions by feeding a post-tensioning strand or bar of the same size as that specified for final post-tensioning completely through each duct. If the strand or bar does not slide freely through the duct, the cause of the obstruction shall be remedied, at the expense of the Contractor, before the panel is shipped. Compressed air shall be used to remove any residual water (from concrete placement or curing operations) from the ducts prior to shipment.

N. Lifting and Handling

Panels shall be handled and shipped in accordance with the requirements of Section 405.05. Lifting anchors cast into the panels shall be used for lifting and moving the panels at the fabrication plant. The angle between the top surface of the panel and the lifting line shall not be less than sixty degrees (60°), when measured from the top surface of the panel to the lifting line.

Provision shall be made to secure the two halves of each Joint Panel (Type A) together such that the expansion joint remains closed or at a uniform specified width during handling and transportation. A plan for securing the two halves of the Joint Panels together shall be submitted for approval by the Engineer prior to fabrication of the Joint Panels. The fastening technique shall prevent the expansion joint from opening or closing during lifting and handling and shall not rely upon the dowel bars to resist hinging at the expansion joint. Damage caused to any Joint Panel, including bending of dowel bars as a result of inadequate bracing shall be repaired, or if severe, replaced at the expense of the Contractor to the satisfaction of the Engineer.

O. Transportation
Panels shall be transported in such a manner that the panel will not be damaged during transportation. Panels shall be properly supported during transportation such that cracking or deformation (sagging) does not occur. If more than one panel is transported per truck, proper support and separation must be provided between the individual panels. Panels shall be lying horizontally during transportation, unless otherwise approved by the Engineer.

P. Repairs
Repairs of damage caused to the panels during fabrication, lifting and handling, or transportation shall be addressed on a case-by-case basis and must be approved by the Engineer prior to implementation. Damage within acceptable limits caused to the top surface (driving surface) or to keyed edges of the panels shall be repaired using an Engineer approved repair method at the fabrication plant at the expense of the Contractor. Repetitive damage to panels shall be cause for stoppage of fabrication operations until the cause of the damage can be remedied.

Q. Demonstration of Panel Fit
The precast fabricator shall initially fabricate only three panels and assemble these panels at the fabrication plant to demonstrate the fit of the panels. The panels shall be assembled over a level surface that will not cause damage to the panels during or after assembly. Post-tensioning will not be required for this trial assembly, and epoxy will not be required in the joints between panels. Joints between panels should not be more than 1/8-inch wide when assembled. Any problems with fitting the panels caused by imperfections in the panels shall be corrected prior to proceeding with panel fabrication. Panel fabrication may commence following the trial assembly with approval from the Engineer.

IV. REMOVAL OF EXISTING PAVEMENT

A. Removal Method
Existing PCC pavement shall be removed by sawcutting and lifting out the existing pavement. Rubblization, power breaking, or other impact methods which may damage the underlying base shall not be used.

B. Timing of Removal
Sawcutting the existing pavement for removal may be completed up to 7 days prior to commencement of removal. Sawcutting and removal shall be completed in accordance with Section 509. Sawcutting depth should not exceed the actual pavement slab thickness by more than 1 inch.

C. Additional Removal
No more than 12 inches of additional pavement may be removed beyond the amount of PPCP to be installed during each operation. If the gap between the end of the PPCP installed during a nightly operation and the existing pavement exceeds one inch, it shall be temporarily covered or filled with a suitable material such as bituminous cold-patch materials which can be removed prior to installing additional PPCP panels. Temporary fill material shall be removed completely from the gap, and the end of the PPCP shall be protected from adhesion of the temporary fill material. The cost of temporary fill materials shall be included in the price bid for PPCP slabs.

V. BASE PREPARATION

The precast panels shall be placed over a prepared base as shown on the plans. The surface shall be free from debris and other materials that prevent the panels from fully resting on the base.

A. Grade Control for Placement
Grade control shall be established for placement of the base material using string lines, laser guidance, or other comparable methods.

B. Surface Test

The finished surface of the base material directly beneath the precast pavement shall provide full support beneath the entire area of the panels. The evenness of the surface of the base material shall be checked in both the longitudinal and transverse direction by the Contractor using 10-ft straightedge. The variation of the surface shall be such that a 6-inch diameter circular plate, 1/8-inch thick cannot be passed beneath the straightedge. Any areas of the base surface not conforming to this smoothness requirement must be corrected prior to placement of the precast panels. The Contractor will not be allowed to proceed unless such deficiencies are corrected to within the tolerances specified herein. Such correction shall be at the Contractor's expense; pay adjustments will not be permitted.

VI. PANEL INSTALLATION ON-SITE

The Contractor shall allow up to 4 site visits by large groups of up to 50 people per visit for the purposes of reviewing on-site installation procedures and processes. The Contractor shall provide sufficient traffic control to accommodate 1 bus and 1 van within the work zone for these site visits. The Contractor shall also co-ordinate with representatives of the Federal Highway Administration (FHWA) for the purposes of documenting construction processes and procedures.

A. Equipment

The Contractor shall have all equipment required for panel installation, post-tensioning, and grouting on-site prior to beginning panel installation. Lifting and transporting equipment shall not damage the prepared base material prior to or during panel installation. Any damage to the prepared base material will be repaired at the Contractor's expense to the satisfaction of the Engineer.

B. Friction Reducing Membrane

A single layer friction reducing membrane will be placed over the prepared base material, beneath the precast panels, as shown on the plans. A geotextile drainage fabric meeting the requirements of Section 245.03 (c) shall be used as the friction reducing membrane unless otherwise specified. Provision shall be made to prevent folds and creases in the sheeting beneath the panels. The surface of the prepared base shall be free from loose debris which may puncture the sheeting. Any tears or punctures in the sheeting shall be repaired to the satisfaction of the Engineer prior to placement of the precast panels over the sheeting. Provision shall be made to prevent the material from becoming pinched in the joints between individual precast panels during panel installation.

C. Temporary Post-Tensioning

Panels shall be temporarily post-tensioned together in the longitudinal direction during installation to ensure closure of transverse joints between panels and to provide temporary longitudinal prestress between consecutive panel installation operations prior to final longitudinal post-tensioning.

Unless otherwise specified, temporary post-tensioning shall be completed after placement of no more than two adjacent panels. Temporary post-tensioning tendons shall be stressed to maintain a minimum clamping pressure of 30 psi across the full width of the pavement between consecutive panel installation operations.

Bar tendons shall be used for temporary post-tensioning by coupling bars from adjacent panels together. The post-tensioning contractor or supplier shall specify the anchorage and temporary stressing details to be used for temporary post-tensioning. Any damage to the precast panels during temporary post-tensioning shall be repaired at the Contractor's expense to the satisfaction of the Engineer prior to installation of additional panels.

The anchor access pockets in the Joint Panels shall be used for the temporary post-tensioning tendons, and shall be covered when the pavement is open to traffic between consecutive panel installation operations.

D. Transverse Joints Between Panels

Unless otherwise shown in the plans, epoxy shall be applied to the adjoining surfaces of the precast panels prior to assembly. The epoxy material shall be suitable for bonding hardened concrete to hardened concrete and shall be approved by the Engineer prior to use. Epoxy shall be of a consistency that it can be applied a minimum of 1/8-inch thick, and shall be proportioned and applied according to the manufacturer's recommendations.

Epoxy shall be applied to both faces of adjoining panels, and shall be kept a minimum of 1/2-inch away from duct openings. The set time of the epoxy shall be such that the minimum clamping pressure can be applied through temporary or final post-tensioning before the epoxy hardens. Excess epoxy squeezed out of the joint onto the driving surface of the precast pavement during assembly and/or post-tensioning shall be removed before it hardens.

A compressible foam or neoprene gasket shall be placed around the opening of each post-tensioning duct as shown in the project plans. The seal shall be continuous around each duct opening and shall be compressible such that it will permit the joints between panels to close completely. The seal shall not cover any part of the opening to the duct and shall not inhibit the flow of grout. Damaged gaskets shall be replaced prior to panel installation.

Alternatively, duct couplers which provide a positive, water-tight connection between ducts of adjacent panels may be used with approval of the Engineer.

E. Placement Technique

Panels shall be installed one at a time, and shall be installed in such a manner that neither the base material nor the friction reducing material is damaged during installation. The angle between the top surface of the panel and the lifting line attached to each lifting anchor shall not be less than 60 degrees (60°), when measured from the horizontal surface of the panel to the lifting line.

Panels may be aligned in the longitudinal direction (parallel to the roadway centerline) using the face of the adjacent existing pavement or new PPCP as the control line. Alignment of the ducts between panels shall be continuously checked using a reference mark on the top surface of the panels at adjoining edges directly above a given post-tensioning duct.

Alternatively, the centerline of the panels shall be aligned to a line laid out by a surveyor (provided by the Contractor) on the surface of the base prior to installation of the panels. Panels may be offset to correct horizontal misalignment of the centerline of the panels, but not more than 1/4-inch between any two adjacent panels. Shims may not be used in the joints between panels to correct alignment.

F. Placement Tolerances

Unless otherwise indicated on the plans, alignment of adjacent panels, as indicated by the reference marks on the top surface of the panels, shall not deviate more than 1/4-inch if the existing remaining pavement is used as the control line. If a pre-surveyed centerline is used for alignment, the panels shall be within 1/4-inch of the pre-surveyed centerline marked on the surface of the base.

Vertical alignment of the panels shall be such that the top surface of an individual panel is no more than 3/16-inch higher or lower than the top surface of an adjoining panel at any point along the joint between the panels. The width of the gap between adjoining panels at the top surface of the joint shall be no more than 1/8 inch after completion of temporary post-tensioning.

G. Expansion Joints
Expansion joint seals shall be provided as shown in the plans and shall conform to the requirements of Section 420 for preformed elastomeric joint seals. The seal for the expansion joints shall be selected by the Contractor and approved by the Engineer. The seal shall be installed according to the manufacturer's recommendations. Expansion joints may be sawcut to the necessary width to receive the seal prior to installing the seal. Sawcuts shall not be greater than 3 inches deep to avoid contact with the dowel bars.

Expansion joint seals shall be able to accommodate (from the initial width at installation) expansion/stretch of 1 inch and compression of 1/2-inch. The width of the expansion joint at the level of the dowels may be adjusted on-site as necessary. The initial joint width (as shipped from the precast producer) shall be based on the estimated daily average ambient temperature during construction according to Table 2.

Table 2
Initial Expansion Joint Widths for Panel Type A

Daily Average Ambient Temperature (F)	**Initial Expansion Joint Width** ***(PPCP Slab Lengths = 150'-160')***
T ≤ 50°F	0.75"
50°F < T < 90°F	0.5"
T ≥ 90°F	0.25"

Unless otherwise approved by the Engineer, expansion joint seals shall be installed prior to opening the pavement to traffic. Any debris in the joint shall be removed using compressed air or other approved technique prior to installing the joint seal.

H. Longitudinal Joints
The longitudinal joints between PPCP sections shall be sealed according to the requirements of Section 316.04(m) using a hot-poured joint sealant or low-modulus silicone rubber joint sealant conforming to the requirement of Section 212.02. The longitudinal joint may be sawcut if necessary to receive the joint sealant in accordance with the provisions of Section 326.04(g)(1c).

I. Transverse Joints
Transverse joints between the PPCP and existing pavement shall be sealed according to the requirements of Section 316.04(m) using hot-poured joint sealant or low-modulus silicone rubber joint sealant conforming to the requirements of Section 212.02. The joints may be sawcut if necessary to receive the joint sealant in accordance with the provisions of Section 326.04(g)(1c).

J. Protection of Expansion Joint Ends
Exposed open ends of the expansion joints shall be sealed or covered to prevent the intrusion of debris and incompressible materials. Cover plates or sealing material shall not inhibit free movement of the expansion joints. Expansion joints shall be cleared of debris prior to installation of cover plates or sealing material.

K. Filling Pockets
Anchor access pockets (Panel Type A) shall be filled only after completion of final longitudinal post-tensioning and prior to underslab grouting and grouting of the post-tensioning tendons. The pockets shall be filled with an approved patching material that meets the requirements of Section 509 except that only non-chloride accelerators will be permitted. High-early-strength hydraulic cement concrete using only non-chloride accelerators may be permitted if the pavement is to be opened to traffic within 6 hours of placement of the patching material. The fill material shall be

finished flush and textured to match the surface of the surrounding concrete, and shall be wet mat cured until the pavement is opened to traffic, at which point membrane curing shall be applied.

L. Repairs

Damage caused to the precast panels during any part of the panel installation process shall be repaired at the Contractor's expense to the satisfaction of the Engineer. Repairs of damaged areas will be addressed on a case-by-case basis by the Engineer and must be approved by the Engineer prior to implementation. Damage within acceptable limits caused to the top surface (driving surface) or to keyed edges of the panels shall be repaired using approved repair methods and materials. Repetitive damage to panels shall be cause for stoppage of installation operations until the cause of the damage can be remedied.

M. Voids Beneath Pavement

The pavement shall be inspected during panel installation for voids beneath the precast panels. At the discretion of the Engineer, the Contractor will be required to stop panel installation and correct imperfections in the base material causing voids beneath the precast panels.

N. Matching Existing Pavement

The precast panels shall be tied into the existing pavement as shown on the plans. The top surface of the precast pavement shall be no more than 1/4 inch above or below the surface of the existing pavement. Diamond grinding shall be used to bring the top surface of the existing pavement and precast pavement into tolerance if necessary. A single pass of diamond grinding has been specified on the plans for the entire length of the PPCP slab placement area as well as an additional 50' on either end. All grinding required to achieve a smooth transition between the PPCP slabs and the existing pavement and to meet the requirements of the Special Provision for Rideability shall be included in the price bid for diamond grinding. A maximum of one pass of diamond grinding will be paid. Subsequent passes required to meet the criteria specified herein shall be at the Contractor's expense.

O. Mid-Slab Anchors

Mid-slab anchors (Panel Type C) shall be provided as shown on the plans to anchor the middle of each precast pavement slab to the underlying base/subbase. Alternative mid-slab or end-slab anchors may be used with the approval of the Engineer. Mid-slab anchors shall be installed only after completion of final longitudinal post-tensioning. Mid-slab anchors shall be filled with an approved patching material meeting the requirements of Section 509 except that only non-chloride accelerators will be permitted. High-early-strength hydraulic cement concrete using only non-chloride accelerators may be permitted if the pavement is to be opened to traffic within 6 hours of placement of the patching material. The fill material shall be finished flush and textured to match the surface of the surrounding concrete, and shall be wet mat cured until the pavement is opened to traffic, at which point membrane curing shall be applied.

P. Grouting of Mechanical Couplers for Tie Bars

Adjacent sections of PPCP panels shell be tied across the longitudinal joints using grout-filled mechanical couplers as shown on the plans. The couplers shall be grouted using procedures and grout material recommended by the manufacturer. Grouting of the mechanical couplers shall be completed only after completion of final longitudinal post-tensioning of the sections being tied together.

VII. POST-TENSIONING

The Contractor, or sub-contractor, who performs post-tensioning shall have a minimum 2 years of experience with post-tensioning work of similar nature to the work identified on the plans, this provision and the Specifications. The Contractor, or sub-contractor, shall furnish to the Engineer for review and acceptance, a certification detailing the date, location, owner's name and contact information and description of previous post-tensioning work. The Contractor shall use the post-tensioning system shown in the plans. The post-tensioning contractor or supplier shall develop and provide final details for all post-tensioning materials, stressing pocket dimensions, equipment, and stressing procedures prior to fabrication of the precast panels. Shop drawings showing the post-tensioning anchorage details, stressing sequence, elongation calculations, and jacking forces shall be developed by the post-tensioning contractor or supplier and submitted to the Engineer for approval prior to panel fabrication.

A. Materials

Low-relaxation, Grade 270, epoxy filled and epoxy coated 7-wire strands with a 0.6-inch nominal diameter shall be used for the longitudinal strand tendons. Low-relaxation, Grade 150, epoxy filled and epoxy coated threaded bars which can be coupled together with mechanical couplers, shall be used for the two bar tendons in each slab.

B. Tendon Installation

Longitudinal post-tensioning strands shall be inserted into the ducts at the Joint Panels (Type A), as shown on the plans. Strands shall be either pushed or pulled through the ducts by hand or using an approved mechanical strand pusher. Provision shall be made to prevent separation of the individual wires from the strand during strand insertion.

Longitudinal post-tensioning bars shall be inserted in the ducts of each panel just prior to installation of the panel. A coupler shall be used to couple the bar from the panel being installed to the bar extending from the adjoining panel already in place.

C. Tendon Stressing

Both ends of each of longitudinal post-tensioning tendon shall be stressed. Tendons shall be stressed to 75% of the guaranteed ultimate tensile strength of the strand or bar supplied. The tendon stressing sequence shall be approved by the Engineer prior to the start of post-tensioning. Stressing of the strand tendons shall be completed in a single stage unless otherwise approved. Tendon elongations shall be measured and recorded by the Contractor, or sub-contractor during the stressing operation. Such logs shall be provided to the Engineer.

After completion of post-tensioning, the tails of the post-tensioning strands shall be trimmed, and an approved grease cap will be used to cover and seal the end of the strand and post-tensioning anchor prior to filling the stressing pockets. Bar tendons shall be trimmed to the appropriate length specified by the post-tensioning contractor or supplier prior to filling the stressing pockets.

D. Faulty Anchors and Wire Failures

In the event of a faulty post-tensioning anchor, the Contractor shall submit a repair or alternate stressing strategy for approval by the Engineer. No wire failures will be accepted. The Contractor shall provide and install a new strand in the event of a wire failure.

VII. TENDON GROUTING

Unless otherwise shown on the plans, the longitudinal post-tensioning system shall consist of grouted tendons.

A. Materials

The grout mixture shall be a pre-packaged grout conforming to the requirements for Class C grout specified by the Post-Tensioning Institute's "Specification for Grouting of Post-Tensioned Structures" (published 2003). Grout shall be proportioned with water according to the manufacturer's recommendations.

B. Equipment

Grouting equipment shall consist of at least the following:

- Equipment for accurately measuring and proportioning by volume or weight the various materials composing the grout,
- A colloidal mixer, capable of operating in a range from 800 rpm to 2,000 rpm and of thoroughly mixing the various components of the grout in an approved manner,
- A positive action pump capable of forcing grout into the post-tensioning ducts. The injection pump shall be capable of continuous pumping at rates as low as 1-1/2 gal. per minute,
- The discharge line shall be equipped with a positive cut-off valve at the nozzle end, and a bypass return line for recirculating the grout back into a holding tank or mixer unless otherwise approved, and
- A stop watch and flow cone conforming to the dimensions and other requirements of ASTM C 939, "Standard Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)."

C. Procedures

A grouting plan shall be submitted to the Engineer for approval at least 2 weeks before starting grouting operations. Grouting shall be completed within 7 days after stressing of the post-tensioning tendons, unless otherwise approved by the Engineer. Grouting shall not be performed until the anchor access pockets (Panel Type A) have been patched. Compressible foam shall be injected into the bottom of each expansion joint to seal the bottom of the joint from grout intrusion. The sides of the pavement slab shall be backfilled (or shoulders constructed) to prevent grout leakage from beneath the slab.

The grout fluidity shall be checked according the provisions of ASTM C 939. Efflux time for fluidity shall be between 11 and 30 seconds after mixing, but no more or less than recommended by the manufacturer. Fluidity shall be adjusted to achieve the necessary flow requirements to achieve fully grouted tendons. If excessive bleeding of the grout is observed, the Engineer may require the Contractor to adjust the grout mixture to reduce bleed. The fluidity of the grout shall be checked at the beginning of each grouting operation and after each time the grout pump and hose is flushed.

Samples for grout compressive strength determination will be collected by the Department at least once per day during grouting operations. A minimum of three strength cubes shall be made by the Department during each sampling. The average compressive strength of three cubes shall be a minimum of 3000 psi at 7 days and 5,000 psi at 28 days.

Grout shall be pumped into the lowest end of each tendon if an elevation difference exists between the ends. Grouting pressure shall not exceed the bursting pressure of the duct/port connection or 145 psi, whichever is less. If grout does not flow from the nearest intermediate port after the maximum grouting pressure has been reached, grout may be pumped into an intermediate port. A diagram of grout flow shall be produced by the Contractor and supplied to the Engineer to demonstrate full grouting of the tendons.

D. Grouting Problems

If grout is observed leaking into an expansion joint, from the end of a joint between panels, from beneath the slab, or out of an adjacent duct, pumping shall be stopped and grout shall be pumped into the nearest intermediate port. Any grout that flows into an expansion joint shall be flushed from the expansion joint immediately. Any grout that hardens in an expansion joint shall be removed at the Contractor's expense.

E. Cleanup

Upon completion of grouting, recesses in the surface of the panels at the grout ports shall be filled with an approved mortar and finished flush with the surface of the pavement. Any grout that flows onto the finished surface of the pavement during the grouting operation shall be immediately flushed from the surface. Any residual grout which hardens on the pavement surface shall be removed by the Contractor using an approved technique to the satisfaction of the Engineer at the expense of the Contractor.

VIII. UNDERSLAB SEALING

Underslab grouting shall be used to fill any voids beneath the precast panels that may be present after placing the panels over the prepared base. Underslab grouting shall utilize the underslab grout ports cast into each of the panels, as shown in the plans. The Contractor shall attempt to pump grout at each grout port location.

A. Materials

Grout materials shall consist of a mixture of Type I, II or III Portland cement, a fluidifier, fly ash and water. All materials shall be furnished by the Contractor.

The fluidifier shall be a cement dispersing agent possessing such characteristics that will inhibit early stiffening of the pumpable mortar, tend to hold the solid constituents of the fluid mortar in suspension and prevent completely all setting shrinkage of the grout.

Class C fly ash shall be selected from the Department's list of approved Fly Ash sources.

B. Equipment

Equipment for underslab grouting shall consist of the same equipment listed in VIII.B.

C. Proportioning Grout Mixture

The mixture used in underslab grouting shall consist of proportions of Portland cement, fly ash, fluidifier and water. The Contractor shall furnish the Engineer the proposed mixture design meeting the following requirements:

The grout slurry shall remain fluid and not exhibit a resistance to flow for a minimum of one hour after placement

The time of efflux from the flow cone shall be between 11 and 20 seconds. The flow test shall be performed in accordance with ASTM C 939, "Standard Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method),"

The grout slurry shall achieve initial set in less than 4 hours. The grout slurry shall not be allowed to carry traffic until which time it has set to the satisfaction of the Engineer; or until which set time, as determined by ASTM C266, "Time of Setting of Hydraulic Cement Paste by Gillmore Needles," has been reached, and

The 7 day compressive strength of the grout slurry shall not be less than 200 psi.

D. Procedures

Underslab grouting shall be completed after stressing of the post-tensioning tendons, but not more than 7 days after placement of the precast panels. The Engineer may require grouting to be completed prior to opening the pavement to traffic if significant voids are observed during panel placement. Underslab grouting may be completed prior to tendon grouting only if underslab grouting will not interfere with tendon grouting.

Slab edges shall be backfilled or sealed to prevent grout leakage from beneath the slab during underslab grouting. The bottom of all expansion joints shall be sealed prior to underslab grouting to prevent grout leakage into the joints. The sealant material shall be compressible such that it will not inhibit free movement of the expansion joints.

Underslab grouting shall require minimal pressure to force the grout beneath the pavement slab. Under no circumstances shall underslab grouting cause the pavement slab to lift. Grout shall be pumped into each underslab grout port of each panel. Grout shall be pumped until it flows out of an adjacent grout port or until the line pressure on the grout pump reaches 5 psi. Grouting pressure of 5 psi may be exceeded if the Contractor can demonstrate that slab lift is not occurring at higher pressures.

The fluidity of the grout shall be checked at the beginning of each grouting operation and after each time the grout pump is flushed. Grout fluidity shall be checked in accordance with ASTM C 939, "Standard Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)." Fluidity shall be adjusted to achieve the necessary flow requirements to achieve full undersealing. If excessive bleeding of the grout is observed, the Engineer may require the Contractor to adjust the grout mixture.

E. Grouting Problems

If grout is observed leaking into an expansion joint, from beneath the slab, or out of an adjacent port, grouting shall be stopped and grout will be pumped into the nearest intermediate port. Any grout that flows into an expansion joint shall be flushed from the expansion joint immediately. Any grout that sets up in an expansion joint shall be removed at the Contractor's expense.

F. Cleanup

Upon completion of grouting, recesses in the surface of the panels at the grout ports shall be filled with an approved mortar and finished flush with the surface of the surrounding pavement. Any grout that flows onto the finished surface of the pavement during the grouting operation shall be immediately flushed from the surface. Any residual grout which hardens on the pavement surface shall be removed using an approved technique to the satisfaction of the Engineer at the expense of the Contractor.

IX. FINISHED SURFACE

The finished pavement surface (after installation of all precast panels) shall have an average IRI less than 70 inches per mile with no individual 0.01 mile section having an IRI greater than 80 inches per mile when tested for rideability in accordance with the Special Provision for Section 316 Rideability for Hydraulic Cement Concrete Pavement included with the contract documents. Corrective action to improve the rideability and any necessary re-texturing shall be completed in accordance with the Special Provision for Section 316 Rideability for Hydraulic Cement Concrete Pavement. The pavement may be opened to traffic prior to meeting the final surface smoothness requirements unless the surface conditions are deemed to be hazardous by the Engineer.

X. MEASUREMENT AND PAYMENT

Pre-cast pre-stressed concrete pavement will be measured in square yards of pavement surface area, complete-in-place, and will be paid for at the contract unit price per square yard for the depth specified, which price shall be full compensation for transportation, saw cutting existing pavement to the required depth, removing and disposing of existing concrete, furnishing and placing Aggregate No. 10 leveling material, preparation of sub-layer, furnishing and installing reinforcing steel, furnishing and installing pre-stressing steel, furnishing and installing post-tensioning steel and gaskets for post-tensioning ducts, preformed expansion material, furnishing and installing steel dowels, furnishing and installing reinforcing steel, furnishing, placing, finishing, and curing pre-cast concrete, furnishing and installing concrete patching material, furnishing and installing under slab and other grout, designing, furnishing and installing expansion joints, furnishing and installing mechanical couplers, furnishing and installing epoxy, furnishing and joint sealants, cleaning and sealing joints, furnishing and installing/removing temporary covers for post-tensioning block-outs and for all materials, labor, tools, equipment, and incidentals necessary to fully complete the work as well as allowing on-site visitors and representatives of FHWA.

Payment will be made under:

Pay Item	**Pay Unit**
Pre-cast Pre-stressed Concrete Pavement (8" Depth)	Square Yard

In areas where the Engineer deems the sublayer insufficient to support the PPCP, the sublayer shall be excavated to sound material and replaced with Aggregate Base Material, Type I, Size No. 21B at a predetermined price of $30 per ton. This price shall be full compensation for excavation and disposal of unsuitable sublayer, and for furnishing, placing, and compacting aggregate material.

APPENDIX D

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS FOR PRE-CAST CONCRETE PAVEMENT SYSTEM APPROVAL

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS FOR
PRE-CAST CONCRETE PAVEMENT SYSTEM APPROVAL

December 1, 2008

I. Description

This specification covers requirements for approval of pre-cast concrete pavement slab systems.

II. Requirements for system approval

The system approval process consists of two phases:

- Submittal and review of Fabricator Standard Drawings and Standard Installation Procedures.
- Construction and evaluation of a Trial Installation.

Each of these phases is described below.

A. Submittal of Pre-Cast Concrete Pavement System Standard Drawings and Standard Installation Procedures

1. Pre-Cast Concrete Pavement System Standard Drawings

The manufacturer shall provide the Pre-Cast Concrete System Standard Drawings (developed or approved by the system designer) to the Department for review. These drawings shall include the following details:

- Transverse joint type, locations and spacing, and the mechanism used to transfer loads across transverse joints after slabs are placed.
- Longitudinal joint type, locations and spacing, and the mechanism used to tie adjacent slabs together (if appropriate).
- Calculations to demonstrate load transfer for transverse and longitudinal joints equivalent to Standard PR-2.
- Lifting insert type, location, positions, and grout capping method.
- Grout port type, location, positioning, and capping method.
- These drawings shall include the tolerance, texturing, curing, sampling and testing requirements listed in the Fabrication and Construction Specification for Pre-cast Concrete Pavement Slab Systems.

2. Installation Instructions

The manufacturer shall provide Standard Installation Instructions (developed or approved by the system designer) to the Department a minimum of 7 days prior to the Trial Installation. After the completion of the Trial Installation, the instructions shall be evaluated by the Agency and revised by the manufacturer as required prior to final approval.

These instructions will include the need for any special equipment and will address the following:

Sub-base Preparation (if appropriate)
Include complete instructions for required sub-base preparation procedures.

Pre-overlay Preparation (if appropriate)
Include complete instructions for preparing the existing pavement surface (either asphalt or concrete) to receive a pre-cast concrete pavement overlay.

Slab Installation
Include complete instructions for lifting, moving, protecting, lowering and adjusting the positions of the slabs.

Bed and Level Slabs
Include complete instructions for ensuring that the slabs are fully supported by underlying layers at the correct line, grade, and cross-slope while meeting contract smoothness requirements. Slabs may be placed by one of the following means:

- Grade-supported: Placed on a precisely graded bedding layer and stabilized in place using cementitious grout to fill any small, isolated voids between the slabs and bedding layer.

- Grout- or Urethane Polymer-Supported: Placed or held near final position and anchored/supported in place using cementitious grout (grout-supported), urethane polymer foam (urethane polymer-supported) or another accepted material.

- Placed by other methods approved by the Department.

For grade-supported slabs, include all pertinent bedding and leveling instructions, including:

- Bedding material composition and gradation.

- Method used to place the bedding material.

- Stabilizing grout mix design and anticipated strength gain. (Note: Stabilizing grout must develop a minimum compressive strength 200 psi within 24 hours.)

- Method used to place stabilizing grout beneath the slab.

- Method(s) used to ensure complete support after placement, as described for the Trial Installation below.

For grout- or urethane polymer-supported slabs, include all pertinent support and leveling instructions, including:

- Material properties, composition, mix design (if appropriate), and required strength gain of any slab-supporting material. (Note: Cementitious support grouts must develop a minimum compressive strength of 200 psi before opening to construction or service traffic. Urethane polymer materials must be fully cured before opening to construction or service traffic.)

- Method used to place the slab-supporting material (i.e., urethane polymer or cementitious grout) beneath the slab.

- Equipment and experience required to successfully install the slab-supporting material.

- Method(s) used to ensure complete slab contact with the slab-supporting material after placement, as described for the Trial Installation below.

<u>Encasing Pavement Hardware and Filling Block-outs</u>
Include instructions for completely encasing load transfer devices and longitudinal joint ties, as well as for filling grout ports, and lifting insert holes . Include all pertinent information, including:

- Material properties, composition, mix design and required strength gain of any encasement and/or grout fill materials that are not named in the Standard Specifications or Special Provisions.

- Revised instructions for those materials for which the manufacturer's instructions are not to be followed exactly.

- Methods used to place encasement and/or grout fill materials.

- Method(s) used to ensure complete hardware encasement, as described for the Trial Installation below.

After the standard drawings and installation instructions have been approved, any subsequent changes must be submitted to and approved by the Department to maintain product status on the Approved List. The Department reserves the right to require additional trial installations if the changes are deemed significant.

3. **Trial Installation**
Arrange for a trial installation, on-site or at a facility agreeable to the Agency, such that Agency personnel, particularly those directly involved with the approval process and those involved with any projects, will be present during the installation. Place a ***minimum*** of six (6) slabs in a manner that simulates the construction of pavement over a minimum length of 24 ft. Provide a drill rig, with operator, capable of retrieving 4-in diameter cores from any portion of the slab, and a technician capable of fabricating test specimens in accordance with ASTM C31. As a minimum, the following will be evaluated:

<u>Stabilizing Grout Properties and Completeness of Placement (for grade-supported applications)</u>
Fabricate and test 24 cube specimens meeting the requirements of the Special Provision for Pre-cast Concrete Pavement and demonstrate completeness of placement. Completeness of placement must be demonstrated by retrieving and inspecting at least three cores (6-inch diameter) from random locations within the trial installation area.

Supporting Material Properties and Completeness of Placement (for grout- and urethane polymer-supported systems)
For grout-supported systems, fabricate and test 24 cube specimens according to the requirements of the Special Provision for Pre-cast Concrete Pavement. For urethane polymer-supported systems, the urethane polymer material must be pre-approved and used according to the manufacturer's recommendations; no further testing of the material is required. Completeness of placement of either material must be demonstrated by retrieving and inspecting at least three cores (6-inch diameter) from random locations within the trial installation area.

Encasement, Grout Fill and Capping Material Properties and Completeness of Placement
If a material identified in the Fabrication and Construction Specifications (under Material Requirements) as Encasement Material for Pavement Hardware is used in accordance with the manufacturer's written instructions, no further material testing is required. If a different material is used or if a material is not used in accordance with the manufacturer's instructions, fabricate a sufficient number of test specimens of appropriate sizes to determine the properties identified in the special provision for Pre-Cast Concrete Pavement. Completeness of placement must be demonstrated through encasement areas by drilling, retrieving and inspecting at least 2 cores (6-inch diameter) from randomly selected hardware encasement locations (e.g. through dowel bars).

Panel Fit
For systems utilizing keyed joints between panels, ensure proper contact between the vertical faces of adjacent panels and proper fit of mating keyways, and ensure uniform joint width between adjacent panels.

Dimensions and Tolerance
Slabs must conform to the Fabricator Standard Drawings and be capable of being placed to meet the specified joint width and vertical deviation tolerances. Provide allowable tolerances for length, width, thickness, squareness, horizontal alignment, vertical alignment, deviation of ends (horizontal and vertical batter), keyway dimensional tolerance, vertical and horizontal dowel alignment, dowel location, dowel embedment, position of lifting anchors and location of reinforcing steel.

Instruction Completeness
Manufacturer's instructions must accurately reflect the processes used in the trial installation.

Load Transfer
Load transfer for transverse and longitudinal points shall equal, or exceed, the load transfer provided in Standard PR-2. The Department reserves the right to conduct falling weight deflectometer (FWD) tests to determine the LTE at the joints. Inadequate load transfer (i.e., LTE $\leq$ 80% when differential deflection (d_{loaded} - $d_{unloaded}$) exceeds 0.005 in for a load of 9000 lb applied in the wheel path) may be cause for rejection.

Instruction Completeness
Manufacturer's instructions must accurately reflect the processes used in the trial installation.

No payment will be made for trial installations except when the trial installation is performed as part of a specific contract and the contract includes provision for payment of the trial installation.

III. BASIS FOR APPROVAL

Approval will be based upon successful demonstration that the proposed system meets the requirements of the Special Provision for Pre-cast Concrete Pavement based upon a) submitted documents and b) field testing performed by the Department and the Contractor at the Trial Installation. Field testing shall include the items listed above (e.g. FWD, cores, etc.). Partial approval may be granted contingent upon successful completion of field testing at the Trial Installation. Approved systems will be placed on the Materials Division's List No. 67 "Approved Pre-cast Concrete Pavement Systems". Rejection may be based upon unsuccessful past performance.

APPENDIX E

VIRGINIA DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISION FOR GRINDING HYDRAULIC CEMENT CONCRETE PAVMENT

ORDER NO.: C03
CONTRACT ID. NO.: C00089579M01

VIRGINIA DEAPRTMENT OF TRANSPORTATION
SPECIAL PROVISION FOR
GRINDING HYDRAULIC CEMENT CONCRETE PAVMENT
0066-029-767, N501

November 7, 2008

I. DESCRIPTION

This work shall consist of diamond grinding of hydraulic cement concrete pavement to remove irregularities and pavement high spots, in conformity with the lines, grades and profiles established by the Engineer. The ground surface shall be free from gouges, grooves, oil film and other imperfections of workmanship, and shall have a textured surface suitable as a riding surface.

II. EQUIPMENT

Grinding shall be accomplished with a self-propelled diamond grinding machine having a leveling sensor, a self-contained water system for control of dust and fines, and be of a type that has operated successfully on work comparable to that proposed under this contract. The equipment shall be capable of grinding the surface at a minimum width of 3 feet per pass without causing spalls at joints and cracks or fracture of aggregates in the surface.

III. CONSTRUCTION METHODS

Grinding shall be performed in a longitudinal direction, and shall begin and end at lines normal to the pavement centerline in any ground section.

Sufficient passes shall be made so that irregularities and pavement high spots are removed and the remaining surface is ground to a depth of 1/8 inch to ¼ inch as necessary to achieve a smooth surface. Regardless of the number of passes, only 1 payment will be made for each area ground.

Unless otherwise permitted, all equipment and vehicles in use under traffic shall be equipped with and shall operate flashing or rotating amber warning lights.

Grinding shall provide a surface texture with skid number (SN) greater than 25 when tested in accordance with ASTM E274 and ASTM E524 using a bald tire. Corrective measures the Contractor uses to achieve skid resistance shall be submitted to the Engineer and shall be at no additional cost to the Department.

Grinding of concrete pavement shall not be performed when ambient or pavement surface temperatures are less than 35 degrees or when ambient temperatures are forecast to fall below 35 degrees within 12 hours of completion of grinding operations

IV. MEASUREMENT AND PAYMENT

Grinding of concrete pavement will be measured in square yards of pavement surface and will be paid for at the contract unit price per square yard, which price shall be full compensation for grinding pavement, removal and disposal of residue, and for all materials, labor, tools, equipment and incidentals necessary to complete the work.

Payment will be made under:

Pay Item	**Pay Unit**
Grinding Concrete Pavement	Square Yard