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Supplementary Notes	

Abstract

This project evaluated the use of precast concrete patches for repairing jointed concrete pavement. Six patches were placed: three had dowels cast into them during fabrication, and three had dowels inserted in place (dowel bar retrofit). Fabrication and placement were documented. The load transfer efficiency at the joints and the ride quality were determined approximately 2 weeks after construction.

After 1.5 years, the general condition of the patches was determined by a visual survey for cracks and spalls. In general, there were no distresses on the replaced slabs except for a few hairline cracks; however, there were failures in the joint area, mainly because of dowels, that were attributed to poor construction practices.

FINAL REPORT

EVALUATION OF PRECAST PATCHES ON U.S. 60 NEAR THE NEW KENT AND JAMES CITY COUNTY LINE

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DISCLAIMER

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INTRODUCTION

When an area of concrete pavement is in need of repair because of extensive cracking, faulting, or spalling, the deteriorated concrete section is replaced with a concrete patch. When full-depth patches are used, the distressed concrete must be removed and the patch placed and cured before the repair can be opened to traffic. The typical repair uses cast-in-place concrete. Such patches are efficiently and effectively used under very tight time constraints in heavily congested areas.

In order to construct full-depth patches during the limited lane closures allowed, high early strength concretes are used. The durability of the patches can be compromised to meet high early strength requirements.[1] The high cement contents in high early strength concrete patches increase the chance of cracking because of thermal effects and shrinkage. Precast patches are an alternative to cast-in-place patches. They may provide a higher quality product when strict time constraints are required. In some applications, they may also be more economical through the use of less cementitious products or less cement and possibly be placed faster than cast-in-place patches.

Because the precast slabs are cast off-site, the lane closure times could be reduced and a quality product achieved due to the controlled production environment. The reduced lane closure time was demonstrated in Michigan.[1] This study showed that one slab could be placed in approximately 3 hours, from the time the deteriorated concrete is removed to the time the joints are sealed and the lane is opened to traffic. Although traditional cast-in-place methods of patching are fast, they require additional time for setting and strength development before the lanes can be opened to traffic. However, precast concrete patches save time and money only when the final product is durable enough to outperform cast-in-place patches and when they can be placed in a short period of time. In full-depth precast patching, the selection of the bedding material is important because the material should enable proper leveling of the precast patch and provide sufficient support and drainage. Finally, the transfer of wheel loads from the patch to the existing concrete must be done properly to ensure an adequate performance of the patch.

PURPOSE AND SCOPE

The purpose of this study was to evaluate the use of precast concrete patches for repairing jointed concrete pavement. The precast patches were 12 ft wide (lane width) and 6 ft long. Bedding material was flowable fill. Six patches were placed; three had dowels cast into them during fabrication and the other three had dowels inserted in place (dowel bar retrofit) after placement of the patch. The project was located on U.S. 60 eastbound about 0.5 mile east of the New Kent and James City County line. Fabrication and placement were documented. The load transfer efficiency at the joints and the ride quality were determined approximately 2 weeks after construction. After 1.5 years, the general condition of the patches was determined by a visual survey for cracks and spalls.

METHODOLOGY

Overview

This study evaluated precast concrete patch installations with two types of jointing. In one type of jointing, patches were fabricated with dowel bars in place at transverse joints, the existing pavement was saw-cut (slotted) to receive the dowels, and the dowels were grouted into the existing pavement after installation of the patch. In the other type, dowels were retrofit after patch installation by cutting slots in the patch and existing pavement. Three dowels were placed in each of the right wheel and left wheel paths on both transverse joints of the patch.

The project consisted of three installations of each patch type. The patches were evaluated for ride quality and load transfer efficiency (LTE) using non-destructive testing (NDT) methods: high speed profiler and falling weight deflectometer (FWD). The condition of the patches was also determined by visual surveys for cracking, spalling, and jointing.

Site Selection

Five distressed joint locations and one mid-slab crack location were selected to receive the precast patches. The site was on U.S. 60 eastbound about 0.5 mile east of the New Kent and James City County line, starting 86 ft before the centerline of Route 603. The existing pavement consisted of 9-in-thick jointed reinforced concrete pavement with a joint spacing of 30 ft, as shown in Figure 1. The concrete pavement reportedly was supported by 6 in of soil cement. The pavement was initially constructed in 1948 using a six-bag concrete mix (564 lb of cement per cubic yard of concrete).

Figure 1. Pavement Condition Before Precast Patching Installation

Fabrication and Installation

As mentioned previously, the project consisted of three installations of each of the two patch types. The patches were fabricated off-site at the contractor's shop on February 10, 2004, as shown in Figure 2. Dowels were cast in three of the patches. During removal of the distressed concrete, the existing concrete was cut (slotted) to receive the pre-placed dowels. The spacing between the patches along the traffic flow was 209 ft; 158 ft 8 in; 253 ft 6 in; 208 ft 5 in; and 268 ft. After placement of the patches with dowels, the dowel bar slots were grouted. In the other three slabs, dowels were retrofitted after placement of the slabs. The patches were installed on March 2 and 3, 2004.

The air content of the plastic concrete was measured, and cylinders were made for compressive strength testing . The thickness of the precast slabs was 8.5 in, which is less than the thickness of the old pavement to accommodate the subbase preparations. The mixture proportions for the concrete used in the patches are given in Table 1. Concrete for the patches was Class A3 and was air entrained. The minimum compressive strength requirement was 2,000 psi prior to opening to traffic. The grout used in both methods of dowel installation was commercially available general purpose non-ferrous, non-shrink grout complying with VDOT's high-strength grout and mortar requirements.[2] The 7-day compressive strength was expected to exceed 4,000 psi, and the 7-day bond strength was expected to be greater than 1,000 psi when tested in accordance with Virginia Test Method 41.

Figure 2. Precast Patch Fabrication With Cast-In Dowels

Table 1. Mixture Proportions

Ingredients	**lb/yd^3**
Cement	496
Class F Fly Ash	124
Fine Aggregate	1072
Coarse Aggregate	1851
w/cm	0.46
Air (fl oz/yd^3)	6.4
Retarder (fl oz/yd^3)	12.5

After the removal of the old patch, the existing subbase was leveled with gravel as shown in Figure 3. Then, approximately 2 in of flowable fill was used to level the base, as shown in Figure 4. The precast slabs were lifted at four pre-selected points and placed in the location using an excavator, as shown in Figure 5.

The difficulty in placing the precast patches involved connecting the new patch to the existing concrete. The joints were sealed with silicone over the backer rod. Figure 6 shows the cutting of dowel slots for dowel retrofit. For the slabs with preinstalled dowels, the receiving end in the existing slab was slotted before the placement of the precast slab. After placement, some areas were not level. The elevation difference between the patch and existing pavement is shown in Figure 7.

Figure 3. Recompaction of Existing Base

Figure 4. Flowable Fill for Leveling

Figure 5. Placement of Precast Slabs

Figure 6. Dowel Bar Retrofit

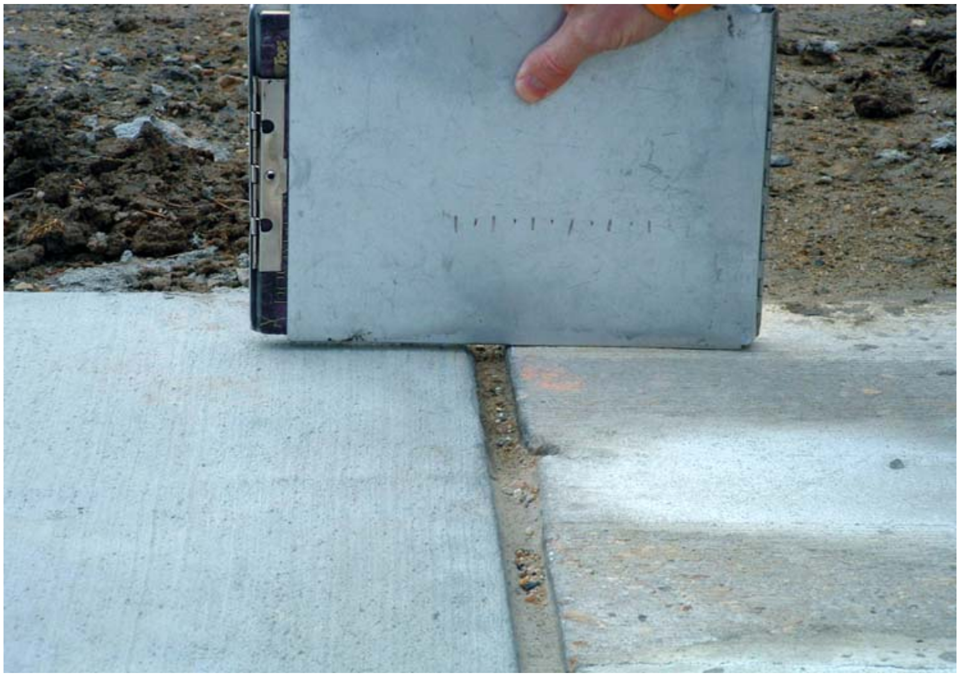

Figure 7. Checking Elevation Difference After Placement of Precast Slab

Load Transfer Efficiency and Ride Quality

On March 24, 2004, approximately 2 weeks after construction, the LTE and the ride quality were measured. The LTE tests were performed using an FWD on the right wheel path. The testing protocol described in the VDOT Materials Division's *Manual of Instructions* [3] was followed for the FWD tests. A series of four load levels was used for each of the six patch locations. There were three replicate measurements for each load level. Ride quality was measured with a high speed profiler at the same time FWD testing was performed. One of the measured properties from the profiler is the International Roughness Index (IRI) which indicates the smoothness of the pavement.

Condition Survey

The condition of the pavement was determined through a visual survey of the cracks in the patches and grouted areas and spalls in the grouted areas on September 21, 2005, about 1.5 years after placement.

RESULTS AND DISCUSSION

Fabrication and Installation

Concrete slabs with satisfactory strengths were cast. The cylinder strengths at 27 days were 4,720 psi and 4,706 psi. Although flowable fill was used to level the slabs, the patches had a differential height difference up to one-fourth inch in limited areas, necessitating greater attention to leveling. This difference in height greatly affected the IRI data collected when the patches were completed.

In the September 2005 survey, the contractor indicated that during installation of the slabs with pre-fabricated dowels difficulties were encountered in aligning and centering the dowels. There is also some evidence of misalignment as indicated by cracks initiating at the corners of the dowel slots. The construction practices for securing dowel bars with grout and forming joints in the dowel retrofit area were less than desirable. Specifically, in the first two patches, the grouted area was continuous between the new slab and the old pavement. The joint was not cut at that location, as shown in Figure 8. Thus, the joints at the slots were filled with grout instead of silicone. Three of the dowels in Slab 1 and all 12 in Slab 2 were reset or reinstalled within 2 months of initial construction. In addition, the slots were not well cleaned before dowels and grout were placed during initial construction.

Figure 8. Discontinuous Joint at Dowel Retrofit

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Load Transfer Efficiency and the Ride Quality

Table 2 summarizes the 12 measurements of LTE for each patch. The LTE varied from 12 to 70 percent, with five of six patches scoring below 50 percent. According to the 1993 *AASHTO Guide for Design of Pavement Structures,*[4] LTE is divided into three categories. Anything below 50 is the lowest category, and anything above 70 is the highest category assumed to provide satisfactory performance. The LTE values for the patches were obtained within 2 weeks of construction and deemed inadequate for such construction. Therefore, the dowel bars were probably not secured properly from the beginning and were not providing

Table 2. FWD Data for Load Transfer Efficiencies at Precast Patch Joints

Test Date: 03/24/2004 and Average Temperature: 54ºF (range 42ºF to 67ºF)					
			Load Transfer Efficiency (%)		Relative
Patch Type	Patch No	Distance[a]	Average	S.D.	Ranking
Retrofitted Dowel Bar	1	0.495	38.8	0.99	4
	2	0.534	12.8	1.35	6
	3	0.565	25.2	2.27	5
Pre-installed Dowels	4	0.613	48.9	2.93	2
	5	0.653	44.7	2.05	3
	6	0.704	69.6	4.69	1

[a]Distance in miles to the east of the New Kent and James City County line on U.S. 60.

adequate LTE. Improper construction techniques may have contributed to these poor LTEs and may have resulted in the early deterioration of the grout used in securing the dowel bars. The grout may also have been a problem by not attaining the specified early strength.

A recent field survey of the patches supports the lack of proper jointing. According to the field survey, Patches 2 and 3 exhibited the worst grout conditions with more cracking as shown in Table 4. Patches 4, 5, and 6 (pre-installed dowels) were in relatively better condition than Patches 1, 2, and 3 (retrofitted dowels). The relative rankings based on the LTEs given in Table 2 correspond to these observations. Although the profiler was run for the entire 0.85-mile section of the road, the IRI values presented in Table 3 are only for the patch locations as identified by the operator at the time of the test. Although patches are only 6 ft long, the IRI values are an average for 15 to 20 ft around the patch area. The IRI values were higher than 110, which is the limit for the non-interstate roadways above which a $2 per square yard pay adjustment or a corrective action is needed.[5] In most cases, the patch locations showed higher IRI (rougher pavement) relative to the overall average for the entire section. The recent field observations also revealed rougher joints at the patches.

Table 3. IRI Values for Precast Patch Locations

Test Date: 03/24/2004 and Average Speed: 40.6 mph					
	Patch	Average Distance	IRI values on the Wheel Path (in/mi)		
Patch Type	No.	(mi)	Left	Right	Average
Retrofitted Dowel Bar	1	0.004	137	386	261
	2	0.003	103	157	130
	3	0.003	223	216	220
Pre-installed Dowels	4	0.003	116	179	147
	5	0.004	289	251	270
	6	0.002	155	175	165
Overall Project Average			134	156	145

Condition Survey

Table 4 provides the number of cracked or spalled grout areas. In all three slabs cast with dowels, cracks were observed propagating into the patch because of the presence of dowel, as shown in Figure 9. In all the patches, there were grouted areas with cracks. All except one of the slabs also had spalled joint areas; in one area, the dowel was visible, as shown in Figure 10. In two of the patches cast with dowels, cracks were also noticed propagating between the wheel

Table 4. Condition Survey Results

Patch Type	Patch No.	Condition of Slab	Condition of Grouted Area (no. of dowels of total 12)	
			Crack	Spall
Retrofitted Dowel Bar	1	No distress	9	6
	2	Minor edge break	12	0
	3	No distress	12	9
Pre-installed Dowels	4	Cracks from dowels	3	2
	5	Cracks from dowels and at mid-width	2	1
	6	Cracks from dowels and at mid-width	7	1

Figure 9. Cracks Propagating into Patch Cast With Dowel

paths in a region without dowels, as shown in Figure 11. In limited areas, the silicone joint material was missing or its surface was depressed up to an inch below the top of the slab as shown in Figure 12. This also indicates the need for better construction practices.

Figure 10. Exposed Dowel

Figure 11. Crack Propagating Between Wheel Paths in Patch with Cast-In Dowel

Figure 12. Missing Silicone Joint Sealer

CONCLUSIONS

- *Precast patches with quality concrete can be placed in a short period of time.*[1]
- *Particular construction issues related to jointing, leveling the slabs, and sealing the joints require special attention.* In this limited study, the problems with aligning the dowels, consolidating grout around the dowels, and achieving good jointing were evident. Construction practices related to leveling the slabs and sealing the joints also need attention. The LTE tests support the poor condition of the jointing, which was evident in the condition surveys.
- *Any VDOT approved grout material can be used provided that the specified strength prior to opening to traffic is achieved.* The Kansas Department of Transportation uses 2,000 psi as the minimum strength, but no sooner than 2 hours after grouting.[6]
- *The LTE and ride quality were poor.*
- *Precast patches may provide contractors another option for limited lane closures if construction problems are resolved.*

RECOMMENDATIONS

1. *VDOT's Asset Management Division and Materials Division should place more precast patches incorporating improved construction techniques to determine the feasibility of the system.*

2. *The Virginia Transportation Research Council and VDOT's Materials Division should evaluate leveling options including flowable fill and diamond grinding to achieve acceptable IRI values.*

3. *Asset Management Division should try using both the dowel retrofit and dowel cast in slab.* However, better construction practices in aligning and better consolidating around the dowel should be accomplished. The movement of the dowels vertically reduces the load transfer efficiency.

4. *VDOT should ensure that the contractor cuts or forms the grouted area for a continuous joint and places the joint material at the proper depth.*

5. *The Virginia Transportation Research Council and VDOT's Materials Division should evaluate the cost-effectiveness of precast slabs since the construction and placement cost may be higher than the cast-in place patches.* However, the lane closure times and user delays might be reduced, leading to savings that could offset the cost of construction.

BENEFITS AND COSTS ASSESSMENT

The purpose of this project was to evaluate the use of precast concrete patches for repairing jointed concrete pavement. The benefit to the traveling public is to have an alternative to cast-in-place concrete that will allow the work to be done with short lane closures at night.

Material and labor costs are comparable for cast-in-place and precast patches. The life cycle cost savings will be a function of durability. However, the sample size of six patches was too small to provide information on cost. In addition, the duration of the project was too short and the quality of the construction too poor to provide a good indication of durability.

ACKNOWLEDGMENTS

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