2014

Installation and Field Testing of High Performance Repair Materials for Pavements and Bridge Decks

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INSTALLATION AND FIELD TESTING OF HIGH PERFORMANCE REPAIR MATERIALS FOR PAVEMENTS AND BRIDGE DECKS

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Bachelor of Science in Civil Engineering

Cleveland State University

May 2013

Submitted in partial fulfillment of requirements for the degree

MASTERS OF SCIENCE IN CIVIL ENGINEERING

at the

CLEVELAND STATE UNIVERSITY

November 2014

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ACKNOWLEDGEMENTS

This study was sponsored by the Ohio Department of Transportation (ODOT), under a research contract titled "Evaluation of High Performance Pavement and Bridge Deck Wearing Surface Repair Materials", State Job number 124816, Agreement number 25969. The research was also supported by Civil and Environmental Engineering Department, Washkewicz College of Engineering, and the College of Graduate Studies at Cleveland State University.

Completion of this study was assisted by a number of groups and individuals, without which this study could not have been completed. The research team would like to acknowledge and thank Jeff Jones, Jeff Darrah, Tony Gamiere, Eric Martin, Chris Robertson, Greg West, and Marcus Werner from the Great Lakes Construction Company, along with ODOT District 8 for their assistance, support, and coordination to make the field installation and testing possible. Special thanks to product representatives Chris Burford and Uriah Carpenter for coming out for the installation of their corresponding products, the University of Cincinnati's Dr. Richard Miller and Mohammad Asghar for their assistance, Cleveland State University graduate students Alice Sommerville and Kamran Amini for their input and support, and Dr. Norbert Delatte for his guidance, support, and knowledge of the subject.

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ABSTRACT

Pavement patching is a common maintenance activity in the state of Ohio, due to numerous freeze-thaw cycles. The Ohio Department of Transportation (ODOT) has a need for durable, more permanent high performing pavement and bridge deck materials that allow for a faster repair and for user safety. New or proprietary products were chosen, installed, and monitored in order to specify for use in future ODOT construction, based on the field performance of the products.

The objective of this study was to document the investigation, installation, and field testing of the previously chosen high performance patching materials. The investigation determined the proper field testing criteria used throughout this project. The installation of the patches was performed in both winter and summer weather conditions. Observations regarding the different products installed, and the installation process, were documented throughout the installations in order to determine which products are easier to install, and in order to document the potential problems that could arise throughout a future patching project. Field testing and visual inspections were performed throughout the project as well, in order to determine the overall performance of the products being tested. The proper installation and testing of these

new products will assist in determining the overall performance of these patching products.

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ACRONYMS

AASHTO	American Association of State and Highway Transportation Officials
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
ERDC	Engineer Research Development Center
NTPEP	National Transportation Product Evaluation Program
ODOT	Ohio Department of Transportation
PCC	Portland cement concrete

CHAPTER I

INTRODUCTION AND RESEARCH OBJECTIVES

1.1 Introduction

This thesis covers the installation and field testing of high performance repair materials for pavements and bridge decks, as part of a Cleveland State University research project for the Ohio Department of Transportation. During the installations of the repair materials, the product and patching process observations were also documented, as well as potential problems to look out for throughout the remainder of the project. This thesis follows Alice Sommerville's thesis covering the selection of the high performance repair materials (Sommerville, 2014).

1.2 ODOT Problem Statement

The Ohio Department of Transportation (ODOT) has identified the need to specify durable, more permanent high performing pavement and bridge deck patching materials that allow for expediting pavement and bridge deck wearing surface repair for worker and user safety. Currently, either temporary or generally specified in-kind or like materials are being used to perform pavement patching. Usually, the Department provides generically specified cementitious or cold mix asphalt materials for patching wearing surfaces with varied performance characteristics. Current products used for this purpose are generally those that have been used for many decades for which competition exists. However, new or proprietary products are difficult to specify unless incorporated into a construction project for research purposes, an approved equal is permitted, or procurement of the product complies with the Department's direct purchasing requirements. Consequently, this creates a situation in which the desired product is precluded from use.

1.3 Research Context

The failure of patches on highways and bridge decks is an issue that has been researched previously to determine the causes of failure, and to determine better practices to limit the potential for patch failures. This research is intended to identify more durable and permanent high performance pavement and bridge deck patching materials for future construction use. The ultimate goal of this research project is to evaluate the field performance of current proprietary or new pavement and bridge deck wearing surface repair products and develop a High Performance Pavement and Bridge Deck Wearing Surface Repair Specification for the inclusion of these High Performance Products in construction and purchasing contracts.

Currently, either temporary or generally specified in-kind or like materials are being used to perform pavement patching. Usually, the Department provides generically specified cementitious or cold mix asphalt materials for patching wearing surfaces with varied performance characteristics. Current products used for this purpose are generally those that have been used for many decades for which competition exists. With this new construction project, new or proprietary products will be specified and incorporated in order to research their potential benefits. Without a construction project for research purposes, new or proprietary products are difficult to specify due to limited prior use, and are therefore excluded from use.

The focus of this report is on the field performance investigation and installation for the aforementioned bridge deck and highway patching construction project. The field investigation methods that were used to investigate performance include visual inspection, nondestructive evaluation (NDE) for internal cracking and damage, and NDE for debonding.

In order to properly compare the different products installed throughout this project consistency was important. The same construction company, and most of the same construction crew, was used for all patch installations. Each product material installed had the same tests performed on them, along with the same information documented for each patch installed throughout this project. Having the same information and data for each patch and product, the performance of each product can be compared easily.

1.4 Study Objectives

The objectives of this thesis were to document the installation and field performance of the new bridge deck, asphalt, and concrete patches being constructed for this ODOT project, and to report the initial field performance of the patches, in order to determine acceptable field performance criteria for comparative analysis of selected products. The products will then be evaluated based on the field performance criteria. Other objectives include: determining the site locations for all patch installations, documenting the patch installation process, and performing preliminary patch inspections following the patch installations. This research aimed to determine more durable and permanent high performance pavement and bridge deck patching materials that can be specified for use in future bridge patching construction projects. A combination of an accelerated pavement repair with more durable and longer lasting materials will also help with worker and user safety of the bridge patches, along with lowering future repair and construction costs.

1.5 Organization of this Thesis

This thesis consists of 9 chapters, beginning with this introduction. The second chapter consists of a background and literature review of pavement repairs, focusing on the installation and field testing aspects of the repairs. The third chapter discusses the testing done throughout this project. The fourth chapter consists of the experimental plan. The fifth chapter contains the installation plan. The sixth chapter discusses the installation of the patches along with the patching process. The seventh chapter includes the results and observations. The eighth chapter consists of the patch inspection results. The ninth and final chapter discusses the summary and final conclusions of this thesis.

CHAPTER II

BACKGROUND AND LITERATURE REVIEW

This chapter reviews prior research projects that were similar to the research project currently being performed. These research projects provided helpful insight into the field testing criteria that were used to identify the proper field testing methods and investigations to be performed throughout this research, and was adapted to meet the requirements of this research. The Engineer Research Development Center (ERDC) (Priddy, 2010) and the National Transportation Product Evaluation Program (NTPEP) (NTPEP, 2009) literatures were focused on throughout Sommerville's thesis to determine which products were to be used for this project, and was therefore focused on for this thesis regarding the field testing and installation processes (Sommerville, 2014).

2.1 Engineer Research Development Center (ERDC)

ERDC performed a research project on rapid pavement repair technologies for airfield pavements, in order to minimize the out of service time of the airfield pavements. ERDC realized that “selecting the proper material reduces the likelihood of accidents, the potential for delays, the need for future maintenance efforts and accompanying service interruptions that could result from the selection of a poor-quality product” (Priddy, 2010, page 1). The ERDC report gives information meant to help in the selection of proper materials, repair techniques, and mixtures for the appropriate repair sizes. The ERDC research project primarily tested commercially available materials that were not yet accepted as potential repair materials. The main objectives of the ERDC project were to characterize material behavior from laboratory and field testing on materials that were commercially available, and to use these test results to develop a minimum acceptable criteria for material performance (Priddy, 2010).

The primary reasons for ERDC performing the field testing were to verify the laboratory test results and to provide handling and placement information of the repair materials for the cold patches. The field tests were performed on the materials that ended up having the best laboratory results (Priddy, 2010).

The ERDC report thoroughly documented the installation procedure of the new patches being constructed, which included (Priddy, 2010):

- Describing each step in the installation process.
- Discussing the equipment used during the installation, and discussing their uses.
- Documenting and commenting on the materials used, and the conditions at the times of the installations.

2.2 National Transportation Product Evaluation Program (NTPEP)

The American Association of State Highway and Transportation Officials' National Transportation Product Evaluation Program (AASHTO/NTPEP) performed a research project to determine an efficient and cost effective means of evaluating products used by member transportation departments in the construction and repair of transportation facilities. The NTPEP reported and documented results from testing different rapid setting patching materials for portland cement concrete. This NTPEP project consisted of similar field testing procedures and evaluations to those that will be performed for this ODOT project (NTPEP, 2009).

All of the patches for the NTPEP project were chosen to be located at the same test bridge location with the following site characteristics and installation recommendations (NTPEP, 2009):

- Full depth portland cement concrete bridge deck surface, no overlays or membranes.
- Wet freeze climate.
- Patches should be located away from expansion joints and end dams.
- Boundaries of the patch area will be original sound concrete.
- Patch areas will be similar of size (nominal 9ft x 3ft x 4 inches deep) (nominal 2.7m x 0.9m x 10cm deep).
- All patch edges will be saw cut.

For the installation process of the project, only one patch was installed for each material type being analyzed. Field observations (visual inspection) were performed on the patches during the installation, 12 month after installation, and 24 months after the installation. Once the installation of the patches was completed, the testing of the patches began (NTPEP, 2009).

During the field observations, some measurements and reporting requirements needed to be met (NTPEP, 2009):

- Material characteristics and installation procedures.
- Photos of the installation procedure, and at each evaluation.
- Patch dimensions.
- Site characteristics – Average daily traffic, percent trucks, and area weather data.
- Percent of delamination, edge/cross patch cracking width, and percent spalling.

In order to properly rate the performance of the patch materials installed, NTPEP created a subjective rating system, which can be seen below in Table 1. This system was used to subjectively determine the top performing patch materials NTPEP used for their project (NTPEP, 2009).

Rating	Cracking or Edge Debonding		Delamination or Hollow		Spalling
1	Over 1/8 inch	and	Over 90%	and	Over 90%
2	1/16 inch	or	Over 70%	and	Over 70%
3	1/32 inch	or	Over 50%	and	Over 50%
4	Hairline	or	Over 30%	or	Over 30%
5	None	and	None	or	Slight

Table 1: Patch material rating system (NTPEP, 2009).

2.3 PCC Pavement Patching Materials and Procedures

Researchers Frazier Parker Jr. and W. Lee Shoemaker, from the Civil Engineering Department at Auburn University in Alabama, performed laboratory and field studies on portland cement concrete (PCC) patch materials. Their field study focused on the effects of condition and location of the pavement, the air temperature during construction, and the sawing of the patch outline. The main objectives of their research were to "identify patch materials and construction techniques that would produce durable patches when constructed and cured in one working day; construct a series of patches under a variety of conditions and monitor their performance; and develop recommendations for PCC pavement patch construction" (Parker & Shoemaker, 1991).

The patches were constructed on Interstate-59 and Interstate-85 in Montgomery, Alabama. The materials used included rapid-settling PCC, rapid-settling fibrous PCC, and a Thoro Systems Products patching material named Roadpatch II. The patching installation took place during two separate seasons (hot and cold), both anchored and unanchored, and prepared with and without sawing (Parker & Shoemaker, 1991).

The field strength of the patching material was determined by molding 4 inch-diameter (100 mm), 8 inch-long (200 mm) compressive strength cylinders in the field and transporting those specimens directly to a laboratory for testing. The early 4 hour strength, along with longer curing times, were determined after the specimens were taken to the lab. Apart from visual inspection, no other field testing was performed on the newly constructed patches (Parker & Shoemaker, 1991).

The percent of patches in each distress category relative to each variable can be seen in Table 2, below. In order to evaluate the overall performance of the patches installed relative to each variable, an analysis of variance was performed. A statistical SAS linear model was used to obtain an F value to indicate the model's confidence level. The summary of the results from the analysis can be found in Table 3. For the Type I analysis, each source of variation was added sequentially. For the Type III analysis the effects of each variable were adjusted depending on the presence of other sources of variation to eliminate terms that interacted (Parker & Shoemaker, 1991).

Variable (1)	Percent Patches in Distress Category: No distress (2)	Moderate distress (3)	Severe distress (4)
Warm (46)	46	41	13
Cool (36)	25	28	47
Type III (29)	21	41	38
Roadpatch (27)	22	48	30
Fibrous (26)	70	15	15
Unanchored (42)	29	48	23
Anchored (40)	45	22	33
Not sawed (23)	22	39	39
Sawed (59)	42	34	24
All patches (82)	37	35	28

[a]Numbers in parentheses indicate number of patches.

Table 2: Performance evaluation of all patches (Parker & Shoemaker, 1991).

Dependent variable (1)	*DF* (2)	Sum of *SQS* (3)	Mean *SQ* (4)	*F* Value (5)	Probability > *F* (6)
			(*a*) Overall Model		
Model	6	48,066.62	8,011.10	7.24	0.0001
Error	75	82,939.48	1,105.86		
Corrected	81	131,006.10			
			(*b*) Type I Analysis		
Site	1	4,896.97	4,896.97	4.43	0.0387
Temperature	1	18,376.87	18,376.87	16.62	0.0001
Material	2	20,051.32	10,025.66	9.07	0.0003
Anchor	1	157.39	157.39	0.14	0.7070
Saw	1	4,584.06	4,584.06	4.15	0.0453
			(*c*) Type III Analysis		
Site	1	6,401.30	6,401.30	5.79	0.0186
Temperature	1	19,126.12	19,126.12	17.30	0.0001
Material	2	19,951.30	9,975.65	9.02	0.0003
Anchor	1	375.82	375.82	0.34	0.5617
Saw	1	4,584.06	4,584.06	4.15	0.0453

Table 3: Patch performance analysis of variance-SAS general linear model procedure (Parker & Shoemaker, 1991).

From this research, many performance observations were made concerning PCC patch material and construction techniques. It was found that including anchors in the patches did not improve the performance of the patches significantly. It was also found that the patches that were placed during weather greater than 70 degrees Fahrenheit (21 degrees Celsius) performed better than those that were constructed in cooler weather. A saw cut outlining the patch was also found to improve patch performance (Parker & Shoemaker, 1991).

2.4 Pothole Patching in Tennessee

Researchers Qiao Dong and Baoshan Huang from the University of Tennessee conducted a study to evaluate the performance of four different patching materials used for pothole repair in the winter season throughout Tennessee. They investigated these materials through both field survey and laboratory tests (Dong & Huang, n.d.).

During this project, 65 pothole patches were installed using 4 different materials, at 6 different locations. Important information that was measured and recorded:

- Length, width, and depth of the patches,
- The latitude and longitude coordinates of the field spots using a GPS, and
- Photos of each patch.

A 6 month field survey on these pothole patches was performed, and the overall ratings of the materials in the field and in the laboratory were determined. The performance of the patches was said to be dependent on the following factors: traffic level, speed of vehicular traffic, size and depth of patches, material, and freeze condition. Thin patches with large areas were said to deteriorate faster due to the increased abrasion (Dong & Huang, n.d.).

CHAPTER III

FIELD TESTING METHODS

Multiple field tests were performed on the new patches over the course of the project to investigate the performance of each patch after installation. The methods of investigation included visual inspection, nondestructive evaluation (NDE) for internal cracking and damage, and NDE for debonding. In this section the field tests that were used for this project are described in detail, along with why and how the tests were performed.

3.1 Visual Inspection

Visual inspections were performed numerous times throughout the research project. ACI 201.1R-08, Guide for Conducting a Visual Inspection of Concrete in Service, states: “a visual inspection is an examination of concrete to identify and define many of the various conditions concrete may exhibit during its service life” (ACI 201.1R-08, 2008, 2). It is an important test to determine whether or not the pavement has signs of distress or failure, done without causing destruction to the pavement and without the use of test equipment. The level of distress that the pavements show may be observed visually, and can be measured using the Distress Identification Manual for the Long-Term Pavement Performance Program FHWA PUBLICATION NO. FHWA-RD-03-031, JUNE 2003, for asphalt and concrete pavements. This manual, along with ACI 201.1R-08 can be followed regarding the visual inspection process.

For this research project, each repair was visually inspected and evaluated with respect to pavement or bridge deck related distresses for each patching material and each substrate type, with consideration given to pavement section or bridge deck composition and seasonal limitations. One key element of this observation was documenting the baseline condition of all patches before and immediately after installation, through visual observations, photographic documentation, and nondestructive evaluation. An infrared camera was on hand during the installation to monitor surface temperatures of all of the patches.

The FHWA Distress Manual was used throughout the visual inspection process to document the types of distress that may be found. Some of the possible types of distress include spalling, scaling, and patch deterioration. Figure 1 shows scaling on concrete, in which the surface of the concrete is deteriorating. Spalling, similar to scaling, is the chipping or breaking of the surface of the concrete (Miller & William, 2003).

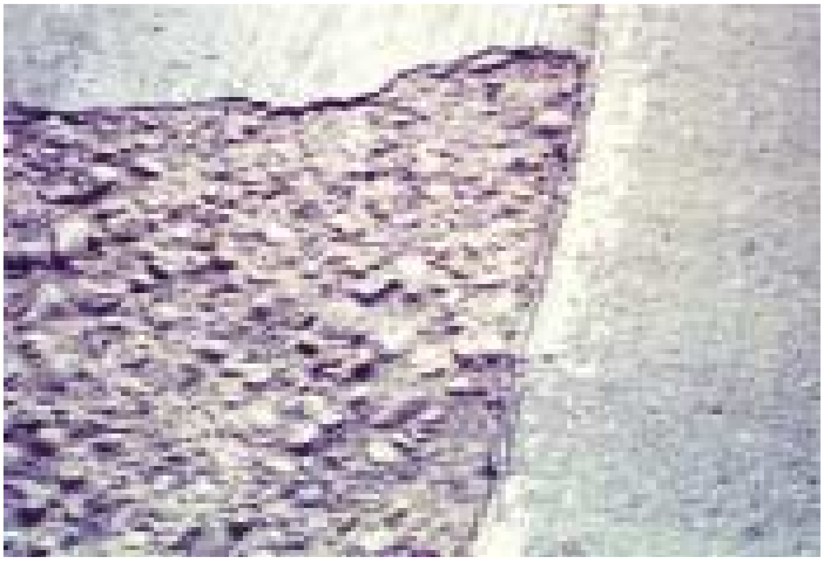
Figure 1: Scaling on concrete (Miller & William, 2003).

3.2 Delamination Testing

Each patch installed during this research project was tested for delamination and debonding by one of two different methods, described below. This testing took place mostly during the patch inspections throughout this project.

3.2.1 Rebar Test

The first method was the rebar test (ASTM D4580), where a 4 to 5 foot long piece of rebar is used to tap the patch to check for delamination and potential debonding. The rebar makes a distinct ping when hitting the patch that is sound and bonded well to the pavement. If the patch is not sound, or is not bonded well to the pavement, the rebar does not make a pinging noise, but makes more of a thudding noise.

3.2.2 Rotary Percussion

The second method is similar to the rebar test, but uses a rotating and multi-toothed apparatus in place of the piece of rebar (ASTM D4580). For this project, a Delam 2000, shown in Figure 2, was used. The Delam 2000 was rolled over the patches, making a consistent ringing sound if the patch was sound. It also makes a hollow sound, or drum-like sound, over a section of patch or pavement that has delaminated.

This test method was also used in determining where the patches would be located, and what size the patches needed to be. This was done by testing the area around a section which needed to be repaired, to check for delamination near and around the section. If delamination was detected, the area of the pavement that had the delamination was included as part of the section to be repaired. This is because a delaminated area of pavement will likely fail sometime in the near future, and this could cause patch failure if a patch is installed next to an area of pavement that has delamination.

Throughout this project it was found that using the Delam 2000 was easier and faster than when using a piece of rebar for the delamination testing. The Delam 2000 gave off a distinct hollow sound over debonded sections, while it was difficult to differentiate accurately between the noises coming from the rebar test. The rebar test was used for the first patch inspection performed one month after the March installations; however, the Delam 2000 was used for the second patch inspection performed one month after the June installations, and will be used for all future patch inspections.

Figure 2: The Delam 2000, which detects delamination in concrete, and comes with an extension pole (soundingtech.com).

3.3 NDE for Internal Cracking and Damage

Laboratory tests for freeze-thaw damage to concrete may be performed following ASTM C215 and ASTM C666, but these procedures are not suitable for use in the field. However, ASTM C215 measures the compression wave speed through concrete, and that is directly related to the dynamic modulus of elasticity, which can be measured in the field. The ultrasonic pulse velocity (UPV) method can measure the compression wave velocity in the field in indirect transmission mode (ASTM C597), the impact-echo method (ASTM C1383), or the spectral analysis of surface wave (SASW) method.

The ultrasonic pulse velocity (UPV) method, or the ultrasonic through transmission method, measures the amount of time that a pulse of ultrasonic waves takes to travel through a path of a known length. This testing method determines the uniformity or general condition of the concrete tested from the pulse velocity measured. The speed of the ultrasonic waves through the concrete is dependent on the density and the elastic constants of the concrete. Variations of the density in the concrete could come from uneven consolidation, and variations in the elastic constants of the concrete could come from the different materials used, or different proportions of mixture materials used. From this known relationship between these factors and the speed of the ultrasonic waves, the uniformity of the concrete at different locations can be estimated (ACI Committee 228, 2013).

The impact-echo testing method uses a mechanical impact to generate a transient stress pulse into the test object, on its surface. P-waves and S-waves are produced by the stress pulse, and these waves are reflected by internal interfaces. The receiving transducer that picks up the waves measures the displacement of the waves by the internal interfaces (ACI Committee 228, 2013).

The spectral analysis of surface waves (SASW) testing method applies an impact on the surface of the specimen to generate a surface or R-wave. Two receivers are used to monitor the R-wave as it moves along the surface. The stiffness of the underlying layer can be determined by the output of this method, due to the longer-wavelength components penetrating deeper into the specimen (ACI Committee 228, 2013).

3.4 NDE for Debonding

Several methods are available for investigating whether a patch has become debonded from a pavement or bridge deck. Simple acoustic sounding (hammer tap) methods (ASTM D4580) may be used, but they are prone to operator error and fatigue. The impact-echo method (ASTM C1383) is probably the best for locating a debonded surface, because the frequency return provides a clear numerical signal of a gap between layers. Research also showed that impulse-response methods and spectral analysis of surface wave methods are also useful (Delatte et al., 1998). In the event that moisture becomes trapped between layers, ground penetrating radar is likely to be able to detect it. These procedures are described in detail in ACI 228.2R (ACI Committee 228, 2013).

3.5 Coring and Pull-Off Testing

In the future, some of the patches may be cored with respect to patch and pavement type, and data and data analysis may be provided for all applicable measurable physical and/or chemical material performance characteristics and physical substrate bond properties. The pull-off test can be performed on the cores to evaluate the tension bond strength between the two materials. These tests will likely not be done on patches in the field, but will be performed in the laboratory with the different patching products. Another possible test to be performed on the cores would be the shear test, if an intact core with two layers is extracted, where the core would be tested in shear across the bond plane (ACI Committee 228, 2013).

CHAPTER IV

EXPERIMENTAL PLAN

The sites selected for the installation of the patches depended on several factors. First, the project needed to be performed with all partial depth patching, which means that areas with deep concrete cracking should be avoided, since concrete pavement with deep cracks needs full depth patches. With this in mind, areas that needed repair due to spalling were focused on in the selection process of the construction sites throughout this entire project. Another major factor to be considered was that the patches should be placed fairly close together and along a maximum of 3 to 4 different stretches of road, so that the construction could be performed with minimal lane closures. This will also benefit the research team for monitoring performance, so that the testing and inspection of the patches can be performed with minimal traveling between patches or between sites.

4.1 Weather Conditions

Acceptable conditions for construction of the patches primarily depend on the specific patch materials used, and their specific condition requirements. Wet or snow/ice covered pavement conditions would be unsatisfactory for all patch materials. Dry pavement conditions that allow for adequate surface preparation of the patch area, along with temperatures that meet the patch material manufacturer's surface or ambient temperature requirements, are acceptable patch installation conditions.

Out of the 6 different patching material products that were installed during this project, only two of them could be installed in subfreezing temperatures. These material mixtures were used for the first phase of patch installations in March of 2014, which tested these materials in winter installation conditions. A key objective of this project was to be able to test the installation of patch materials in conditions that are representative of a typical winter day in Ohio. The rest of the patching products that could not be installed in low temperatures were installed in June of 2014.

The winter phase of the installations for this project was chosen to happen in early March in hopes that the ambient temperature would be below 40 degrees Fahrenheit (4.4 degrees Celsius). One of the primary objectives of this project was to install products throughout the year, in order to determine seasonal installation acceptability. The two chosen patching materials for the first phase of the patch installation were the only two materials that were recommended for use in temperatures below 40 degrees Fahrenheit (4.4 degrees Celsius). The ambient temperature also needed to be above 14 degrees Fahrenheit (-10 degrees Celsius) for one of these materials. With this information, an installation date after the bulk of the harsh winter season, and before the warmer spring weather came in, seemed to be suitable to have some of the first patches installed in temperatures ranging from 14 to 40 degrees Fahrenheit (-10 to 4.4 degrees Celsius).

Dry pavement conditions were also necessary, and ultimately cannot be predicted too far in advance. For this condition, early March is typically before the more rainy spring season that mostly happens during the months of April and early May for Ohio. Ultimately, the weather forecast was checked for temperatures and precipitation a week or two prior to the installation dates in order to avoid unwanted weather scenarios. With all of the weather conditions considered, the first installation phase of this project was chosen for the beginning of March.

4.2 Locations

Working with ODOT District 8, a number of potential sites were proposed for patching repair through the course of this project. ODOT District 8 personnel were able to specify which locations needed patching repair and would fit our project within their District. The sites proposed for repair were located near and around Xenia, Ohio, located within Greene County. The sites proposed by ODOT District 8, before the first phase of construction for this project had begun, are shown in Figure 4, on the following page. The entire proposed area of State Route 35 spans approximately 20 miles (32 km) of 4 lane divided highway, both eastbound and westbound. State Route 35 has a high amount of truck traffic through it, leading to and from Interstate 71. All of the locations considered on State Route 35 have a speed limit of 70 mph (110 km/h).

For the majority of the sections proposed for repair, shallow spalling failures of the concrete pavement are present. Where present, this failure was primarily in the right lane. At the bottom of the spalls, reinforcement can be seen in the concrete pavement. These shallow spalls were caused due to an error in placing the reinforcement too high, and not leaving sufficient cover between the reinforcement and the top of the pavement. A bridge deck was proposed to be repaired as well, due to the failure of a previously installed patch, seen in Figure 3.

Figure 3: Failing patch on bridge deck, before installation of new patches.

The first section of State Route 35 that was proposed for patching construction was between coordinates A and C in Figure 4. This section of freeway has numerous failures along it that primarily consist of potholes. The surface pavement along this stretch of State Route 35 is primarily bituminous concrete with a base pavement of concrete as well. This section stretches a length of 4.6 miles (7.4 km) along State Route 35.

The sections proposed between coordinates C and D and coordinates E and F, as seen in Figure 4, also have a surface pavement of bituminous concrete. The section between coordinates C and D has a base pavement type of concrete and stretches a length of 2.6 miles (4.2 km) along State Route 35, while the section between coordinates E and F has a base pavement type of bituminous concrete and stretches a length of 6.3 miles (10.1 km) along State Route 35.

The proposed section for patching construction between coordinates D and E, as seen on Figure 4, has a reinforced concrete surface pavement type. This section also stretches a length of 6.5 miles (10.5 km) along State Route 35.

The last section proposed by ODOT District 8 can be seen in Figure 4 as coordinate B. Coordinate B consists of a bridge deck, as seen in Figure 3, that spans over Little Miami Bikepath and Creek, and is located between State Route 42 and Lower Bellbrook Road.

These sections were chosen by ODOT District 8 due to their need for patching repair based on previously specified failure conditions that avoid full depth cracking of concrete that would require full depth patching. The failures of the pavements at these sites were primarily due to spalling, previous patch deterioration, and potholes.

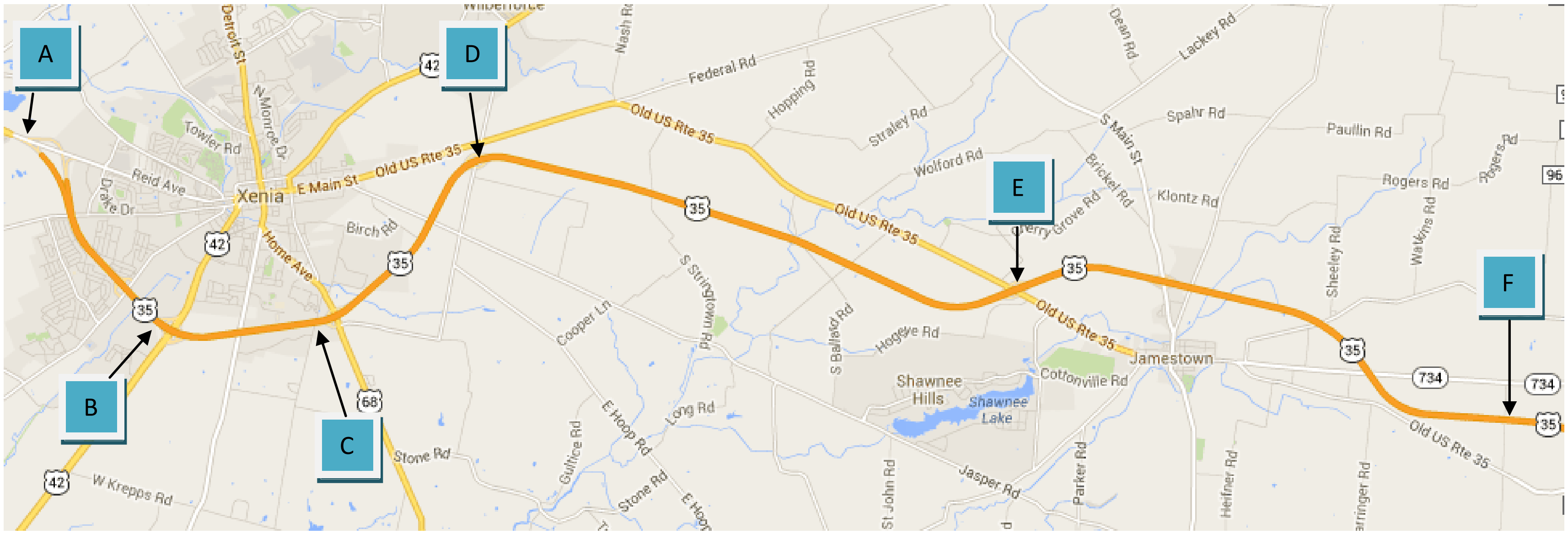

Figure 4: Map with proposed patching construction sites along section of SR 35 (Google Maps).

CHAPTER V

INSTALLATION PLAN

This section documents the installation plan for this project and addresses which materials were chosen, why they were chosen, and the proper installation procedures for these materials. This section also gives the locations that were chosen, and the reasoning behind selecting these locations.

5.1 Chosen Materials

This section discusses the materials chosen for both the winter installation and the summer installation in detail. All of the materials chosen for this project were chosen based on research done by Alice Sommerville, a member of the research team for this project. These materials were chosen based on numerous factors that included some, or all, of the following criteria:

- initial recommendation from ODOT District 8,
- previous research with these materials, primarily from NTPEP or ERDC studies,
- approval in other DOTs with similar climates to that of Ohio, and

- outside temperature range at time of installation, for either winter or summer patching.

5.1.1 Roklin Systems Inc. – FlexSet

FlexSet is a two part polymer concrete that can be used in both asphalt and concrete patch repairs. It was originally developed as a rapid runway concrete repair system for the military. The material has a 9 to 12 minute working time at 75°F (24°C). The resulting repair can be put back into service in as little as 30 minutes. It has a temperature range of -10°F to 140°F (-23°C to 60°C), making it one of only a few materials that can be placed at extreme hot and cold temperatures. This product was chosen for the winter installation because it could be installed in extreme cold conditions. This product costs $235 per cubic foot (0.028 m^3) (Roklin, 2013).

FlexSet is packaged in 5 gallon (20 L) sealed plastic buckets. Each kit contains ½ gallon (2 L) each of specially formulated A and B polymers, 30 pounds (14 kg) of polymer coated sand, and 12 pounds (6 kg) of uniformly graded polymer coated topping sand which will deliver 0.4 ft^3 (0.01 m^3) and cover approximately 50 ft^2 at a thickness of 1/8 inch (3 mm). A 25 pound (11 kg) bag of 3/8 inch (10 mm) polymer coated basalt aggregate can be used to extend the material. The aggregate is bought separately (Roklin, 2013).

When mixing the materials, the A and B polymers are poured into the bucket that the product came in with the 30 pounds (14 kg) of polymer coated sand. Polymer A should be added first and fully mixed with the sand before B is added. Adding polymer coated aggregate or some of the topping sand into the mix is optional, and depends on whether a thicker or more flowable material is required. If an accelerant is needed, due to cold weather, it should be included with the B polymer before it goes in the main mixture. The bucket is placed in a specialized mixer, the Motor Mix Machine, and can be seen in Figure 5. This mixer uses an electric motor to spin the bucket and has an arm attachment to stir the materials in the bucket. The topping sand should be added a few minutes after the holes are filled, for skid resistance and to make the patches look more aesthetically pleasing (Roklin, 2013).

Figure 5: The Motor Mix Machine in use, which is a specialized mixer for the FlexSet product.

5.1.2 IMCO Technologies Inc. – MG Krete

MG Krete is a two component, magnesium phosphate based, high early strength repair material that is suitable to cure in all weather and temperatures higher than 14°F (-10°C). This product was also chosen for the winter installation since it could be installed in colder temperatures. It has a set time of 15 minutes at 68°F (20°C) and a 2 hour compressive strength greater than 3000psi (20.7 MPa), which surpasses the requirements set by ODOT and ASTM C928. This product costs $122.22 per cubic foot (0.028 m^3) (IMCO, 2012).

MG Krete is packaged as a 50 pound (23 kg) bag of dry compound and 1 gallon (3.8 L) of liquid activator. By maintaining the mix ratio supplied of one container of liquid to one bag of compound, it will give a trowellable consistency, however, the ratio may be adjusted to suit the needed application by increasing either of the two components. There is no critical mix formula. If adding accelerant, it goes into the mixture last. It is not needed when the temperatures exceed 40°F (5°C). The surface of the patches should be tined shortly after placement (IMCO, 2012).

This material requires no special equipment and no primer. Pea gravel can be used to extend the product, but the gravel needs to be clean and dry; otherwise the product will most likely fail due to poor bond. The hole must be clean, dry and free of loose material. Water will ruin the integrity of the mixture, so the patch location must be completely dry as well. The more aggregate used, the more heat is absorbed by the aggregate, therefore slowing down the setting process. Also, the deeper the patch, the hotter the repair will become when setting, due to the heat from the hydration reaction taking place. A green ammonia smelling slime and gas will be produced on the surface from this reaction (IMCO, 2012).

5.1.3 Southeast Resins – SR-2000

SR-2000 is a polymer concrete composed of a two part polyester resin that can be used to restore both damaged concrete and asphalt. It can be re-opened to traffic within two hours after the repair is complete. It can be installed in temperatures ranging from 35°F to 120°F (2°C to 50°C). One of the reasons this product was chosen was because it can be used for both asphalt and concrete patch repairs. This product costs $175 per cubic foot (0.028 m^3) (Southeast Resins Inc., 2012).

The SR-2000 kit comes with liquid resin and a bag of #30 grit aggregate, which is clean and dry. Before this product is placed, the hole needs to be clean of loose materials, have no dust or oil, and be primed with the resin from the kit. Pea gravel can be added to extend this product. A non-slip top coat can be added if required (Southeast Resins Inc., 2012).

5.1.4 D.S. Brown – Delpatch

Delpatch is a two-part polyurethane elastomeric concrete that can accept traffic one hour after the final pour. The typical Delpatch application is in concrete spall repair patching or bridge expansion joint work. It is not to be used in asphalt repair. This product costs \$232.43 per cubic foot (0.028 m^3) (Delpatch Elastomeric Concrete, 2013).

Delpatch comes as a bag of sand and fiberglass, part A and B polyurethane liquid in separate barrels, and primer. The primer can be sprayed or brushed into the hole before the hole is filled. The primer must be cured for approximately 20 to 30 minutes before the hole is filled with the product. The mixing of the material asks for 100 ounces (3000ml) of Part A and 50 ounces (1500ml) of Part B. These liquids are added to the mixing bowl and the mixer is started at a slow speed. Immediately, the sand/fiberglass mixture is added at a gradual rate. The mixer is then increased to a medium speed until the product turns an even grey color, indicating an even mixture. The product should be mixed for about 3 minutes, and has around a 10 minute set time. It is specified that a Hobart, drill, or pail mixer be used when mixing the material. A 1 inch (25 mm) minimum application thickness is required and it must be installed at 45°F (7°C) or higher. There cannot be even slight rain when it is poured, and on hot, sunny days, the kit must be kept under cover or in the shade (Delpatch Elastomeric Concrete, 2013).

5.1.5 Quikrete – FastSet DOT Mix

FastSet DOT Mix is a fiber reinforced, portland cement, rapid setting repair material specifically designed to meet ASTM C928 Category R3 specifications. FastSet DOT Mix has a 20-30 minute working time and can accept traffic 1.5 hours after the patch has been poured. This product does not have an ambient temperature range during application, but it is specified that cold water should be used during extreme hot or dry conditions to keep the mixed product at a moderate temperature at the time of placement. Hot water is also specified for use during extreme cold weather. The cost of this product is \$11.32 per cubic foot (0.028 m^3). This product has already been approved by ODOT for use. This testing will serve as a baseline for the other materials (Quikrete, 2012).

The FastSet DOT Mix comes in 55lb (25 kg) bags, and the extended version in 80lb (36 kg) bags. The bag is added to 1 gallon (3.8 L) of water and mixed for three minutes. The water can be adjusted as necessary to achieve the required consistency, but without exceeding the recommended slump range. The 55lb (25 kg) bag can be extended with 25lb (11 kg) of high quality ASTM C33 size number 8 aggregate. All surfaces should be clean of foreign substances, and water added to the hole to leave the surface damp for the new patch. No primer is required for this product (Quikrete, 2012).

5.1.6 SpecChem – RepCon 928

RepCon 928 is a single component, polymer modified, fiber reinforced, rapid setting concrete repair mortar with corrosion inhibitor for use on concrete floors, highway pavements, bridge decks and other applications requiring early resumption of traffic or use. Testing data showed a 3 hour compressive strength of 3000 psi (20.7 MPa), which is more than required by ODOT and ASTM C928. The optimum ambient temperature range for installing the patch is 65°F to 85°F (18 to 29°C) but can be installed in temperatures as low as 45°F (7°C). In temperatures higher than 85°F (29°C), cold water should be used to keep the mixed product at a moderate temperature at the time of placement. This product costs $57.36 per cubic foot (0.028 m^3) (SpecChem, 2010).

RepCon 928 comes as a 50lb (23 kg) bag of material. Mixing the materials calls for 4.75 to 5.0 pints (2.2 to 2.4 L) of water per 50lb (23 kg) bag and a mortar mixer or drill. Surface preparation for the hole involves removing all foreign objects including oil, grease and dust. Best results will be obtained by abrasive blasting the area to be repaired. All surfaces to be repaired should be in a saturated-surface-dry (SSD) condition with no standing water on the surface (SpecChem, 2010).

Product	Application	Cost per ft^3 (0.028 m^3)	Primer
FlexSet	Asphalt/Concrete	$235.00	no
MG Krete	Concrete	$122.22	no
SR-2000	Asphalt/Concrete	$175.00	yes
Delpatch	Concrete	$232.43	yes
FastSet DOT Mix	Concrete	$11.32	no
RepCon 928	Concrete	$57.36	no

Table 4: Details for products used during this project.

Product	Set Time Before Traffic, hr	Temperature Range, °F (°C)
FlexSet	0.5	-10 to 140 (-23 to 60)
MG Krete	2	14 to no max (-10 to no max)
SR-2000	2	35 to 120 (2 to 50)
Delpatch	1	45 to no max (7 to no max)
FastSet DOT Mix	1.5	no range*
RepCon 928	3	45 to 85* (7 to 29*)

Table 5: The set time before traffic can be opened, and the ambient temperature ranges for installation, for each product used during this project. *Cold water is suggested when the ambient temperature is high.

Table 4 shows the pavement application, cost per ft^3 (0.028 m^3), and whether a primer is needed before installation, for each product used during this project. Table 5 shows the amount of time needed before the lane can be opened to traffic, and the ambient temperature range in which a patch can be installed, for each product used during this project.

5.2 Test Locations

The locations that were chosen for the winter and summer patch installations for this project were chosen based on the recommendations from ODOT District 8, documented in the previous chapter.

5.2.1 Winter Installation Locations

The first location for the winter patch installation was a bridge deck, heading westbound along State Route 35, over the Little Miami Bikepath and Creek. An approximately 9 foot by 12 foot (2.7m by 3.6m) area, which included a previously installed patch, was located on this bridge deck and was experiencing high severity patch deterioration, which can be seen in Figure 6. Additionally, two spalling and pothole failures on asphalt pavement within 0.1 miles (0.16 km) of the bridge deck were also chosen as patch repair sites.


Figure 6: Previous patch deterioration, at location of patches #2 and #3.

The other locations for the first phase of patching construction were along an approximate 2.5 mile (4 km) stretch of State Route 35, heading eastbound, between mile marker locations 15.9 and 18.3. All of the failures along this stretch of State Route 35 consisted of spalling, delamination, and potholes. Some of these failures can be seen on the next page in Figure 7 and Figure 8.

Figure 7: Spalling, at location of patch #6.

Figure 8: Spalling and potholes at location of patches #9 and #10.

5.2.2 Summer Installation Locations

On June 23rd, 2014, two days before the summer patch installations began, the locations for the patches were determined. With the help of ODOT traffic control, 71 different locations that needed repair were marked with spray paint. These locations varied in size, in order to test out each material in both smaller and larger patches. Since the plan was to install approximately 80 yd^2 (67 m^2) of patching material for this summer installation, a stretch of State Route 35 eastbound was chosen due to the high frequency and closely spaced locations of road failures in need of repair.

The first area chosen for summer patching was located at mile marker location 14.3, under the Bickett Road Bridge. Along with the need for repair due to failure, this section was chosen because the adjacent pavement was asphalt. This area of asphalt was also close to the concrete pavement sections chosen for the rest of the summer installations. A total of 6 patch locations were chosen in this area, and were all within a 100 foot (30 m) stretch of road.

The second area chosen for the summer patch installation was located at mile marker location 16.1, starting a few feet past patches #7 and #8 from the winter patch installation. This section stretched from approximately mile marker location 16.1 to 16.2, with most of the patch locations located within a few strides of each other. A total of 37 patch locations were chosen in this area for the summer installation.

The third, and last, area chosen for the summer patch installation was located at mile marker location 18.3, starting a few feet past patches #13 and #14 from the winter patch installation. These patch locations were located close to each other and did not span much past mile marker location 18.3. A total of 28 patch locations were chosen in this area for the summer installation.

During the construction of the second area, at the 16.1 mile marker location, the planned patch locations that were not yet started were tested with the Delam 2000 for delamination. This was done to ensure that the future patches would not be installed next to a section of pavement that has delamination, and to adjust the sizes of the patch locations to include the delamination portion of the pavement if delamination was present.

CHAPTER VI

INSTALLATION

The winter patch installation for this ODOT research project was performed on March 6^{th} and 7^{th} of 2014, on State Route 35 in and near Xenia, Ohio. During this installation 14 patches of varying sizes were installed during these two days, with two different products. This installation phase consisted of approximately twenty percent of the total number of patches installed over the course of this research project. Twenty percent was based on the amount of patching material that was used during the first installation, and not based on the number of patches installed.

The summer patch installation was performed on June 25^{th}, 26^{th}, 30^{th}, and July 1^{st} of 2014, on State Route 35 just east of Xenia, Ohio. 71 patches were installed throughout these 4 days, with 4 different products. A different product was installed during each day, with each product consisting of approximately twenty percent of the entire number of patches installed over the course of the project. The summer patch installation accounted for around eighty percent of the total patches installed for the project.

6.1 Patching Process

To begin the patching process, the proposed patch areas were first outlined with spray paint, as seen below in Figure 9. The outlining was done well before the patch installation started.

Figure 9: Outlining the proposed patch areas with spray paint.

The patch perimeter was then cut with a concrete saw. The pavement was then removed with jackhammers, as seen in Figure 10, below. An air compressor was used to blow out all of the loose debris, dust, and dirt from the hole in order for the patching material to have a clean surface to bond with. While the holes were being cleared of debris, a torch was occasionally used for the holes that had moisture in them, in order to make sure that the holes were dry upon installation. The torch was primarily used for the bridge deck, as seen in Figure 11 on the following page, due to the amount of moisture trapped within the bridge deck. The locations that were not on a bridge deck did not have much moisture present in the holes, if at all. The torch was not used at all during the summer patch installation, since the holes did not have any standing water in them.

Figure 10: Removing the pavement with jackhammers.

Figure 11: Drying the hole with a torch.

Once the hole for the patch had been cleaned and dried (if necessary), the patching material was then mixed and added to the hole, as seen in Figure 12 and Figure 13, respectively. The proper installation procedures of the 6 different patching materials used throughout this project were described in the previous chapter.

Figure 12: Mixing Flex Set patching material.

Figure 13: Filling hole with Flex Set patching material.

The holes were then completely filled with the patching material. Lastly, since the new patches have smooth surfaces, in order to avoid potential slipping surfaces for vehicles, the surface was either tined or had topping sand added to it, according to the patching material specifications. This was done to add skid resistance for traffic over the patches.

6.2 Winter Installation

The process of the first installation phase of the project was completed with the Great Lakes Construction Co. and ODOT District 8, in which a total of 14 patches were installed along State Route 35, near Xenia, Ohio. From the research performed before the installation, primarily from ERDC and NTPEP reports, two products were chosen for use during the winter installation, Flex Set and MG Krete. These materials were discussed in Chapter V.

The bridge deck was patched first, with two side by side patches installed simultaneously, with one patch consisting of Flex Set and the other patch consisting of MG Krete. The patch that used the MG Krete material was placed in the right side of the lane, and the Flex Set patch was placed directly to the left of the MG Krete patch. These two patches span completely across the right lane of State Route 35, heading Westbound. The dimensions of these patches can be found in Table 6. The thickness of each patch was roughly the same for all the patches installed, except for the bridge deck patches. The bridge deck patches had a range of thickness between 3 to 8 inches (75 to 200 mm), while the other patches were between 2 to 5.5 inches (50 to 140 mm) deep.

Along with the two bridge deck patches, two more patches were installed near the bridge deck on March 6th, 2014. These two patches were smaller, and were installed on asphalt. Since MG Krete is only meant for concrete pavement patching, Flex Set was used for these two patches.

The final 10 patches were installed on March 7th, 2014, within a 2.5 mile (4 km) stretch of State Route 35 Eastbound. All of these patches were installed in concrete pavement, with five of the patches consisting of Flex Set, and the other five patches consisting of MG Krete. The dimensions and depths of all of the patches installed in the first phase of this project can be seen in Table 6.

				Dimensions					
Patch #	Date	Pavement Type	Material	feet			meters		
1	3/6/2014	Bridge deck	MG Krete	8.33	x	6.25	2.53	x	1.90
2	3/6/2014	Bridge deck	Flex Set	9.08	x	6.25	2.76	x	1.90
3	3/6/2014	Asphalt	Flex Set	3.50	x	2.00	1.06	x	0.61
4	3/6/2014	Asphalt	Flex Set	3.00	x	2.00	0.91	x	0.61
5	3/7/2014	Concrete	Flex Set	4.25	x	2.58	1.29	x	0.79
6	3/7/2014	Concrete	MG Krete	2.17	x	1.50	0.66	x	0.46
7	3/7/2014	Concrete	MG Krete	2.42	x	2.17	0.73	x	0.66
8	3/7/2014	Concrete	Flex Set	2.83	x	2.17	0.86	x	0.66
9	3/7/2014	Concrete	Flex Set	3.58	x	2.83	1.09	x	0.86
10	3/7/2014	Concrete	MG Krete	3.58	x	3.08	1.09	x	0.94
11	3/7/2014	Concrete	Flex Set	3.33	x	2.50	1.01	x	0.76
12	3/7/2014	Concrete	MG Krete	2.50	x	2.50	0.76	x	0.76
13	3/7/2014	Concrete	MG Krete	2.33	x	2.25	0.71	x	0.68
14	3/7/2014	Concrete	Flex Set	2.58	x	2.17	0.79	x	0.66

Table 6: Phase one installation of patches, with dates of installation, road type installed on, material used for patch, length, and width of each patch.

For the winter patch installation, three different locations were installed with MG Krete in one half of the patch, and FlexSet in the other half. This included patches #1 and #2 on the bridge deck, patches #9 and #10, and patches #11 and #12 together. Patches #9 and #10, side-by-side, can be seen in Figure 14. For all of the side-by-side patches, the MG Krete was installed first, since the MG Krete had significantly lower slump. A thin piece of wood was placed temporarily at the halfway point of the hole, to help keep the MG Krete in its half of the hole. Once the MG Krete was solid enough, the FlexSet was then installed. The FlexSet was installed last because it is self-leveling.

Figure 14: Patches #9 (left) and #10 (right), containing FlexSet and MG Krete, respectively.

6.3 Summer Installation

A total of 71 patches were installed along State Route 35 Eastbound, near Xenia, Ohio, by the Great Lakes Construction Company. From the research performed before the installation, primarily from ERDC and NTPEP reports, four products were chosen for use during the summer installation, which were SR-2000, Delpatch, FastSet DOT Mix, and RepCon 928. Originally, Watson Bowman's Wabo Elastopatch was chosen to be used during the summer installation, but Watson Bowman could not provide the product on time due to an aggregate shortage. Quikrete's FastSet DOT Mix was then chosen to replace the Wabo Elastopatch material.

All of the locations that were chosen for the summer patch installations were along State Route 35 Eastbound, between mile markers 14 and 19. The first location along this stretch consisted of asphalt pavement, with all of the following locations consisting of concrete pavement.

On June 25th, 2014, the first day of patching for the summer phase of the project, Southeast Resins' SR-2000 product was used for 19 patches. The SR-2000 was the only product of the four chosen for the summer installation that could be used on asphalt pavement, which is why this product was chosen to be used first. At the mile marker location of 14.3, six patches were installed on asphalt pavement. At the mile marker location of 16.1, 13 more patches were installed on concrete pavement. The dimensions and depths of these patches, along with the patch numbers corresponding to these patches, can be seen in Table 7.

				Dimensions	
Patch #	Date	Pavement Type	Material	feet	meters
15	6/25/2014	Asphalt	SR2000	5.42 x 3.00	1.65 x 0.91
16	6/25/2014	Asphalt	SR2000	3.83 x 3.00	1.17 x 0.91
17	6/25/2014	Asphalt	SR2000	8.50 x 3.08	2.58 x 0.94
18	6/25/2014	Asphalt	SR2000	3.00 x 1.17	0.91 x 0.35
19	6/25/2014	Asphalt	SR2000	3.00 x 2.00	0.91 x 0.61
20	6/25/2014	Asphalt	SR2000	2.67 x 1.17	0.81 x 0.35
21	6/25/2014	Concrete	SR2000	2.42 x 2.42	0.73 x 0.73
22	6/25/2014	Concrete	SR2000	4.83 x 2.67	1.47 x 0.81
23	6/25/2014	Concrete	SR2000	2.58 x 2.67	0.79 x 0.81
24	6/25/2014	Concrete	SR2000	5.00 x 3.42	1.52 x 1.04
25	6/25/2014	Concrete	SR2000	3.67 x 3.17	1.11 x 0.96
26	6/25/2014	Concrete	SR2000	3.08 x 1.67	0.94 x 0.51
27	6/25/2014	Concrete	SR2000	1.67 x 3.92	0.51 x 1.19
28	6/25/2014	Concrete	SR2000	1.50 x 1.92	0.46 x 0.58
29	6/25/2014	Concrete	SR2000	3.50 x 3.42	1.06 x 1.04
30	6/25/2014	Concrete	SR2000	2.83 x 2.67	0.86 x 0.81
31	6/25/2014	Concrete	SR2000	3.00 x 4.33	0.91 x 1.32
32	6/25/2014	Concrete	SR2000	2.83 x 2.33	0.86 x 0.71
33	6/25/2014	Concrete	SR2000	5.58 x 3.42	1.70 x 1.04

Table 7: SR-2000 patch dimensions.

On June 26th, 2014, D.S. Brown's Delpatch product was used for 18 patches. All of these patches were installed on concrete pavement at the mile marker location of 16.1, directly following the SR-2000 patches. A representative for D.S. Brown was present throughout all of the Delpatch installations to ensure that the product was being installed properly. The dimensions and depths of these patches, along with the patch numbers corresponding to these patches, can be seen in Table 8.

				Dimensions					
Patch #	Date	Pavement Type	Material	feet			meters		
34	6/26/2014	Concrete	Delpatch	6.58	x	2.67	2.00	x	0.81
35	6/26/2014	Concrete	Delpatch	2.25	x	2.50	0.68	x	0.76
36	6/26/2014	Concrete	Delpatch	2.75	x	4.67	0.84	x	1.42
37	6/26/2014	Concrete	Delpatch	2.08	x	2.33	0.63	x	0.71
38	6/26/2014	Concrete	Delpatch	1.92	x	1.92	0.58	x	0.58
39	6/26/2014	Concrete	Delpatch	3.25	x	1.33	0.99	x	0.41
40	6/26/2014	Concrete	Delpatch	2.67	x	1.67	0.81	x	0.51
41	6/26/2014	Concrete	Delpatch	1.67	x	2.83	0.51	x	0.86
42	6/26/2014	Concrete	Delpatch	4.83	x	2.83	1.47	x	0.86
43	6/26/2014	Concrete	Delpatch	2.83	x	3.17	0.86	x	0.96
44	6/26/2014	Concrete	Delpatch	1.17	x	4.50	0.35	x	1.37
45	6/26/2014	Concrete	Delpatch	1.33	x	3.92	0.41	x	1.19
46	6/26/2014	Concrete	Delpatch	2.00	x	3.50	0.61	x	1.06
47	6/26/2014	Concrete	Delpatch	3.25	x	2.25	0.99	x	0.68
48	6/26/2014	Concrete	Delpatch	2.17	x	1.67	0.66	x	0.51
49	6/26/2014	Concrete	Delpatch	2.50	x	1.33	0.76	x	0.41
50	6/26/2014	Concrete	Delpatch	1.83	x	3.33	0.56	x	1.01
51	6/26/2014	Concrete	Delpatch	2.83	x	1.50	0.86	x	0.46

Table 8: Delpatch dimensions.

On June 30th, 2014, Quikrete's FastSet DOT Mix product was used for 18 patches. All of these patches were installed on concrete pavement, with 6 of them located at the mile marker location of 16.1, directly to the east of the Delpatch patches, and the other 12 located at the mile marker location of 18.3, directly to the east of the patches numbered 13 and 14 from the winter installations. The dimensions and depths of these patches, along with the patch numbers corresponding to these patches, can be seen in Table 9.

				Dimensions					
Patch #	Date	Pavement Type	Material	feet			meters		
52	6/30/2014	Concrete	FastSet DOT Mix	2.42	x	2.42	0.73	x	0.73
53	6/30/2014	Concrete	FastSet DOT Mix	3.75	x	2.50	1.14	x	0.76
54	6/30/2014	Concrete	FastSet DOT Mix	2.17	x	1.92	0.66	x	0.58
55	6/30/2014	Concrete	FastSet DOT Mix	3.08	x	1.67	0.94	x	0.51
56	6/30/2014	Concrete	FastSet DOT Mix	3.83	x	1.25	1.17	x	0.38
57	6/30/2014	Concrete	FastSet DOT Mix	6.75	x	2.67	2.05	x	0.81
58	6/30/2014	Concrete	FastSet DOT Mix	3.08	x	1.50	0.94	x	0.46
59	6/30/2014	Concrete	FastSet DOT Mix	3.83	x	2.75	1.17	x	0.84
60	6/30/2014	Concrete	FastSet DOT Mix	2.08	x	2.83	0.63	x	0.86
61	6/30/2014	Concrete	FastSet DOT Mix	7.75	x	4.08	2.36	x	1.24
62	6/30/2014	Concrete	FastSet DOT Mix	2.92	x	3.17	0.89	x	0.96
63	6/30/2014	Concrete	FastSet DOT Mix	2.42	x	2.17	0.73	x	0.66
64	6/30/2014	Concrete	FastSet DOT Mix	5.42	x	2.92	1.65	x	0.89
65	6/30/2014	Concrete	FastSet DOT Mix	3.67	x	2.33	1.11	x	0.71
66	6/30/2014	Concrete	FastSet DOT Mix	4.50	x	3.08	1.37	x	0.94
67	6/30/2014	Concrete	FastSet DOT Mix	1.92	x	2.67	0.58	x	0.81
68	6/30/2014	Concrete	FastSet DOT Mix	4.92	x	1.83	1.49	x	0.56
69	6/30/2014	Concrete	FastSet DOT Mix	4.08	x	2.83	1.24	x	0.86

Table 9: FastSet DOT Mix dimensions.

On July 1st, 2014, SpecChem's RepCon 928 product was used for the last 16 patches. All of these patches were installed on concrete pavement at the mile marker location of 18.3, directly to the east of the FastSet DOT Mix patches. The dimensions and depths of these patches, along with the patch numbers corresponding to these patches, can be seen in Table 10.

				Dimensions					
Patch #	Date	Pavement Type	Material	feet			meters		
70	7/1/2014	Concrete	RepCon 928	3.75	x	1.92	1.14	x	0.58
71	7/1/2014	Concrete	RepCon 928	5.83	x	2.92	1.77	x	0.89
72	7/1/2014	Concrete	RepCon 928	1.33	x	2.42	0.41	x	0.73
73	7/1/2014	Concrete	RepCon 928	3.75	x	2.25	1.14	x	0.68
74	7/1/2014	Concrete	RepCon 928	2.67	x	2.50	0.81	x	0.76
75	7/1/2014	Concrete	RepCon 928	1.75	x	1.92	0.53	x	0.58
76	7/1/2014	Concrete	RepCon 928	1.33	x	3.08	0.41	x	0.94
77	7/1/2014	Concrete	RepCon 928	3.83	x	2.50	1.17	x	0.76
78	7/1/2014	Concrete	RepCon 928	2.92	x	3.00	0.89	x	0.91
79	7/1/2014	Concrete	RepCon 928	3.83	x	1.42	1.17	x	0.43
80	7/1/2014	Concrete	RepCon 928	2.25	x	1.42	0.68	x	0.43
81	7/1/2014	Concrete	RepCon 928	1.58	x	1.75	0.48	x	0.53
82	7/1/2014	Concrete	RepCon 928	5.83	x	2.67	1.77	x	0.81
83	7/1/2014	Concrete	RepCon 928	2.83	x	1.25	0.86	x	0.38
84	7/1/2014	Concrete	RepCon 928	5.50	x	2.33	1.67	x	0.71
85	7/1/2014	Concrete	RepCon 928	6.08	x	3.25	1.85	x	0.99

Table 10: RepCon 928 patch dimensions.

CHAPTER VII

RESULTS AND OBSERVATIONS

7.1 Patch Locations

During the winter installation, at each individual location patched, a handheld Garmin GPS 72H GPS was used in order to mark down the exact coordinate location of the patches. This was performed in order to better locate the specific patches for future observation and testing. The device is accurate up to within 10 feet (3 m) to the true coordinate. The coordinates recorded for each patch can be seen in Table 11.

The specific spot between the mile markers, where the eastbound heading patches were located, was also recorded, and can also be seen in Table 11. For example, the mile marker for patches #9 and #10, as seen on the following page in Figure 15, represents a location that is approximately one-fifth of the way between mile marker 16 and 17. This specification, along with the exact GPS coordinates, will make the future location of the patches installed in the winter fairly simple. These steps needed to be taken because the patches were installed on a state route, in which the speed limit is set at 70 miles per hour (110 km/h), and knowing the precise location of the patches is necessary in order to safely locate each patch.

Patch #	GPS Marked Location	Direction	Mile Marker
1	N39°40.023' W083°57.315'	SR35 Westbound	N/A
2	N39°40.023' W083°57.315'	SR35 Westbound	N/A
3	N39°40.023' W083°57.315'	SR35 Westbound	N/A
4	N39°40.165' W083°57.491'	SR35 Westbound	N/A
5	N39°41.222' W083°51.372'	SR35 Eastbound	15.9
6	N39°41.222' W083°51.372'	SR35 Eastbound	15.9
7	N39°41.191' W083°51.200'	SR35 Eastbound	16.1
8	N39°41.188' W083°51.184'	SR35 Eastbound	16.1
9	N39°41.169' W083°51.076'	SR35 Eastbound	16.2
10	N39°41.169' W083°51.076'	SR35 Eastbound	16.2
11	N39°41.032' W083°50.515'	SR35 Eastbound	16.7
12	N39°41.032' W083°50.515'	SR35 Eastbound	16.7
13	N39°40.623' W083°48.882'	SR35 Eastbound	18.3
14	N39°40.623' W083°48.882'	SR35 Eastbound	18.3

Table 11: Locations of each patch during phase one of installation.

The exact coordinate locations were not obtained for the patches constructed during the summer installation, because the patches were installed close together, and near the patches installed in the winter. Thus, they will be easy to locate in the future. Patches #15 through #20 were located on State Route 35 Eastbound at mile marker 14.3 directly under the Bickett road bridge. Patches #21 through #58 were located on State Route 35 Eastbound at mile marker 16.1, with patch #21 located a few feet past patches #7 and #8 from the winter installation. Patches #59 through #85 were located on State Route 35 Eastbound at mile marker 18.3, with patch #59 located a few feet past patches #13 and #14 from the winter installation. All of the patches at these three locations (mile markers 14.3, 16.1, and 18.3) were located very close together, which made the need for an exact GPS coordinate for each of the summer patches unnecessary.

Figure 15: Mile marker location for patches #9 and #10.

7.2 Weather during Construction

The outside temperatures, percent humidity, wind speed, and weather conditions were recorded at the start of the installation of each of the patches. Table 12 shows the weather data recorded during the winter installation. It can be seen in the table that the first 8 patches were installed within 14 and 40 degrees Fahrenheit (-10 to 4.4 degrees Celsius). For both Flex Set and MG Krete, there were at least two patches installed at or below freezing temperatures, and some patches installed above freezing temperatures as well as above the standard minimum temperature of 40 degrees Fahrenheit (4.4 degrees Celsius) for most patching materials. With this range of outside temperatures at installation, these patching products can be properly tested for performance and durability regarding both winter and in-season installations.

Patch #	Material	Outside Temperature (°F)	(°C)	% Humidity	Wind Speed (mph)	(km/h)	Weather Conditions
1	MG Krete	30	-1	56	9	14	clear
2	Flex Set	37	3	56	9	14	clear
3	Flex Set	27	-3	56	9	14	clear
4	Flex Set	45	7	41	6	10	partly cloudy
5	Flex Set	32	0	81	2	3	clear
6	MG Krete	32	0	81	2	3	clear
7	MG Krete	34	1	69	0	0	clear
8	Flex Set	34	1	69	0	0	clear
9	Flex Set	45	7	59	4	6	clear
10	MG Krete	45	7	59	4	6	clear
11	Flex Set	48	9	44	2	3	clear
12	MG Krete	48	9	44	2	3	clear
13	MG Krete	48	9	40	5	8	clear
14	Flex Set	48	9	40	5	8	clear

Table 12: Table listing the outside temperatures corresponding to the start of each of the winter patches installed.

The weather data collected on June 25th, 2014, during the SR-2000 patch installations can be seen in Table 13. Since the SR-2000 product is a polymer concrete that uses a polymer resin, and not water like cementitious concrete would use, the higher temperatures would not affect the setting time as much as some of the other products used during this project. The temperature and the other weather conditions did not noticeably affect the installation of the SR-2000 patches.

Patch #	Material	Outside Temperature (°F)	(°C)	% Humidity	Wind Speed (mph)	(km/h)	Weather conditions
15	SR2000	71	22	97	8	13	cloudy
16	SR2000	70	21	96	9	14	cloudy
17	SR2000	70	21	96	9	14	cloudy
18	SR2000	72	22	90	7	11	partly cloudy
19	SR2000	72	22	90	7	11	partly cloudy
20	SR2000	72	22	90	7	11	partly cloudy
21	SR2000	75	24	75	7	11	partly cloudy
22	SR2000	75	24	75	7	11	partly cloudy
23	SR2000	75	24	75	7	11	partly cloudy
24	SR2000	76	24	81	12	19	partly cloudy
25	SR2000	80	27	70	10	16	partly cloudy
26	SR2000	80	27	70	11	18	partly cloudy
27	SR2000	81	27	67	10	16	partly cloudy
28	SR2000	83	28	57	6	10	partly cloudy
29	SR2000	83	28	57	6	10	partly cloudy
30	SR2000	83	28	58	8	13	partly cloudy
31	SR2000	83	28	58	8	13	partly cloudy
32	SR2000	83	28	59	9	14	partly cloudy
33	SR2000	83	28	59	9	14	partly cloudy

Table 13: Weather data collected on June 25th, 2014, during the SR-2000 patch installations.

The weather data collected on June 26th, 2014, during the Delpatch patch installations can be seen in Table 14. The Delpatch product is a polyurethane elastomeric concrete, and can be installed in high temperatures. This product set quickly during the construction, but the specifications for the product state that the product will set in 10 minutes at room temperature. The product did not seem to set faster than that during installation.

Patch #	Material	Outside Temperature (°F)	Outside Temperature (°C)	% Humidity	Wind Speed (mph)	Wind Speed (km/h)	Weather conditions
34	Delpatch	73	23	83	0	0	sunny
35	Delpatch	74	23	78	1	2	sunny
36	Delpatch	74	23	78	1	2	sunny
37	Delpatch	79	26	65	3	5	sunny/slightly overcast
38	Delpatch	79	26	65	3	5	sunny/slightly overcast
39	Delpatch	79	26	65	3	5	sunny/slightly overcast
40	Delpatch	79	26	65	3	5	sunny/slightly overcast
41	Delpatch	79	26	65	3	5	sunny/slightly overcast
42	Delpatch	79	26	65	3	5	sunny/slightly overcast
43	Delpatch	79	26	65	3	5	sunny/slightly overcast
44	Delpatch	80	27	61	2	3	partly cloudy
45	Delpatch	80	27	61	2	3	partly cloudy
46	Delpatch	80	27	61	2	3	partly cloudy
47	Delpatch	80	27	56	8	13	sunny/slightly overcast
48	Delpatch	81	27	56	8	13	sunny/slightly overcast
49	Delpatch	81	27	56	8	13	sunny/slightly overcast
50	Delpatch	81	27	56	8	13	sunny/slightly overcast
51	Delpatch	81	27	56	8	13	sunny/slightly overcast

Table 14: Weather data collected on June 26th, 2014, during the Delpatch patch installations.

The weather data collected on June 30th, 2014, during the FastSet DOT Mix patch installations can be seen in Table 15. The FastSet DOT Mix product is a portland cement. This product, unlike the SR-2000 and Delpatch, mixes with water. Higher ambient temperatures can cause the hydration reaction to speed up. If the reaction is accelerated, the setting time of the product will decrease, making it harder to install. In order to reduce the possibility of the early set, ice was added to the water used. There were no issues with the setting time during the installation of the FastSet DOT Mix.

Patch #	Material	Outside Temperature (°F)	(°C)	% Humidity	Wind Speed (mph)	(km/h)	Weather conditions
52	FastSet DOT Mix	73	23	96	7	11	cloudy
53	FastSet DOT Mix	73	23	96	7	11	cloudy
54	FastSet DOT Mix	74	23	91	7	11	partly cloudy
55	FastSet DOT Mix	74	23	91	7	11	partly cloudy
56	FastSet DOT Mix	74	23	91	7	11	partly cloudy
57	FastSet DOT Mix	75	24	87	8	13	partly cloudy
58	FastSet DOT Mix	82	28	70	11	18	sunny/slightly overcast
59	FastSet DOT Mix	82	28	70	11	18	sunny/slightly overcast
60	FastSet DOT Mix	82	28	70	11	18	sunny/slightly overcast
61	FastSet DOT Mix	82	28	69	15	24	sunny/slightly overcast
62	FastSet DOT Mix	83	28	66	13	21	partly cloudy
63	FastSet DOT Mix	84	29	61	15	24	partly cloudy
64	FastSet DOT Mix	84	29	61	15	24	partly cloudy
65	FastSet DOT Mix	84	29	61	15	24	partly cloudy
66	FastSet DOT Mix	84	29	61	15	24	partly cloudy
67	FastSet DOT Mix	84	29	66	14	23	partly cloudy
68	FastSet DOT Mix	84	29	66	14	23	partly cloudy
69	FastSet DOT Mix	84	29	66	14	23	partly cloudy

Table 15: Weather data collected on June 30th, 2014, during the FastSet DOT Mix patch installations.

The weather data collected on July 1st, 2014, during the RepCon 928 patch installations can be seen in Table 16. The RepCon 928 product is a polymer modified mortar, with a maximum ambient temperature of 85 degrees Fahrenheit (29.4 degrees Celsius) recommended for installation. This product, like the FastSet DOT Mix, mixes with water, which is why the maximum recommended temperature at installation is at 85 degrees Fahrenheit (29.4 degrees Celsius), so that early set will not be a problem. Due to the warm temperatures, ice was added to the water to reduce the setting time of the product. There were no issues with the early setting time during the installation of the RepCon 928.

Patch #	Material	Outside Temperature (°F)	(°C)	% Humidity	Wind Speed (mph)	(km/h)	Weather conditions
70	RepCon 928	79	26	83	16	26	partly cloudy
71	RepCon 928	79	26	83	16	26	partly cloudy
72	RepCon 928	79	26	83	16	26	partly cloudy
73	RepCon 928	80	27	79	14	23	partly cloudy
74	RepCon 928	80	27	79	14	23	partly cloudy
75	RepCon 928	80	27	79	14	23	partly cloudy
76	RepCon 928	80	27	79	14	23	partly cloudy
77	RepCon 928	80	27	79	14	23	partly cloudy
78	RepCon 928	82	28	76	13	21	partly cloudy/mostly sunny
79	RepCon 928	82	28	76	13	21	partly cloudy/mostly sunny
80	RepCon 928	82	28	76	13	21	partly cloudy/mostly sunny
81	RepCon 928	85	29	67	17	27	partly cloudy/mostly sunny
82	RepCon 928	85	29	67	17	27	partly cloudy/mostly sunny
83	RepCon 928	85	29	67	17	27	partly cloudy/mostly sunny
84	RepCon 928	85	29	67	17	27	partly cloudy/mostly sunny
85	RepCon 928	85	29	67	17	27	partly cloudy/mostly sunny

Table 16: Weather data collected on July 1st, 2014, during the RepCon 928 patch installations.

7.3 Patch Temperatures Recorded With the Infrared Camera

For each product installed during this project, the temperatures of the hole before and after installation were recorded with an infrared camera. During the winter installation, temperatures were taken of each patch that was installed. Since there was little cloud cover during the construction of these patches, and the infrared camera's accuracy is subject to the amount of sunlight present, a range of temperatures was recorded for each patch. The temperature recordings were taken about 20 minutes after the patch construction was finished. The infrared camera readings from the winter patching can be seen in Table 17.

		Infrared Camera Temperatures			
		Hole (before)		Patch (after)	
Patch #	Material	(°F)	(°C)	(°F)	(°C)
5	Flex Set	22.8	-5.1	37	2.8
6	MG Krete	22.9	-5.1	36	2.2
7	MG Krete	36	2.2	44	6.7
8	Flex Set	38	3.3	49	9.4
9	Flex Set	-	-	62	16.7
10	MG Krete	-	-	62	16.7
11	Flex Set	47	8.3	86	30.0
12	MG Krete	47	8.3	75	23.9
13	MG Krete	55	12.8	90	32.2
14	Flex Set	55	12.8	88	31.1

Table 17: Infrared camera temperature readings.

As seen in Table 17, the patches that were installed earlier in the day, with a lower air temperature during the construction, ended up producing less heat. The increase and difference in the documented temperatures between patch #5 and patch #14 could be attributed to any or all of the following:

- the air temperature and ground temperature increasing throughout the day,
- error in the infrared recording due to sunlight, and
- accelerator added to some of the later installed patches

For both the summer and winter patch installation, infrared camera temperatures were recorded for each patching product used. The maximum temperature recorded for each patching product can be seen in Table 18. The higher the temperature of the patch, the faster the patch will set. With the ambient temperature for the summer installation being in the low 80’s in degrees Fahrenheit (around 27 degrees Celsius), it was expected that the patching material would reach a fairly high temperature, especially with the temperature of the pavement reaching temperature of over 100 degrees Fahrenheit (38 degrees Celsius). If there were too big of a difference in the temperature of the hole before the patching material was added and the patching material at its highest temperature, the material might not bond properly to the pavement. In Table 18, the max temperatures recorded with the infrared camera can be seen for each product used during this project.

	Infrared Camera Max Patch Temperatures	
Material	**(°F)**	**(°C)**
FlexSet	88	31
MG Krete	90	32
SR-2000	160	71
Delpatch	124	51
FastSet DOT Mix	114	46
RepCon 928	130	54

Table 18: Max patch temperatures recorded with the infrared camera for each patching product used during this research project.

Out of the six materials used for this project, the FlexSet and MG Krete were installed in the winter patch installation. The maximum temperatures of these products did not get as high as the other materials due to the low ambient temperatures during installation. These max temperatures were likely not high enough to cause concern.

The FastSet DOT Mix and RepCon 928 were both cementitious materials, and were not expected to reach high temperatures during curing. SR-2000 was a polymer concrete material, and was expected to reach high temperatures during the curing process. When the SR-2000 material reached 160 degrees Fahrenheit (71 degrees Celsius), the temperature of the pavement was recorded to be between 115 and 120 degrees Fahrenheit (46 and 49 degrees Celsius). The difference between these temperatures does not appear to be high enough to cause any issue with the product bonding to the pavement. From this table, it can be seen that the temperature difference was minimal and likely did not have a negative effect on the bonding of the patching materials and the pavement.

A picture from the infrared camera of patch #11, containing FlexSet, can be seen in Figure 16. The heat distribution of the FlexSet tended to be even throughout the patch, as can be seen in the figure. The top half of the patch shows slightly more heat, likely because it was installed before the bottom half of the patch, thus having more curing time. The differences of the temperature noticed in the figure throughout the patch are minimal.

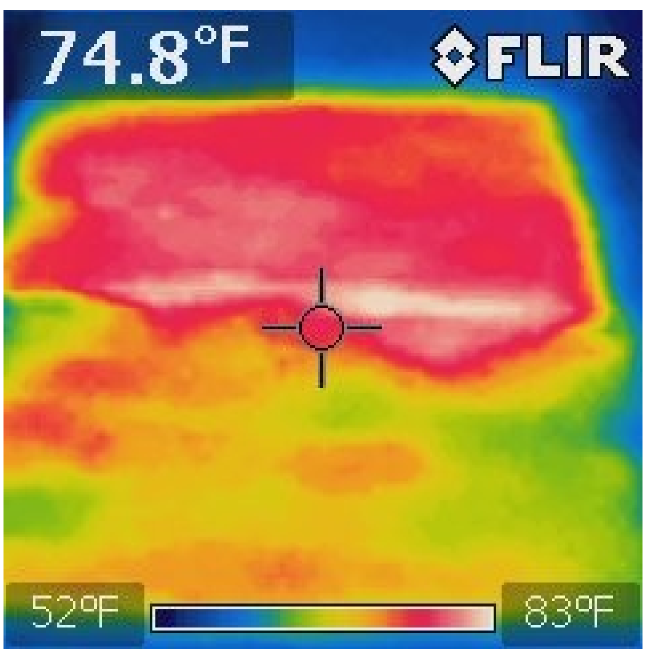

Figure 16: Infrared camera picture of patch #11, containing FlexSet, showing the temperature variation throughout the patch.

Figure 17 shows a picture from the infrared camera of patch #7, containing MG Krete. The heat distribution for this product tended to be uneven, with the focus of the heat towards the middle of the patch. The Quikrete and RepCon 928 products had similar heat distributions, likely due to all three of these products being similar cementitious materials. The difference in the heat from the middle to the outside of the patches for all three products was small, and likely will not affect the durability of the patches.

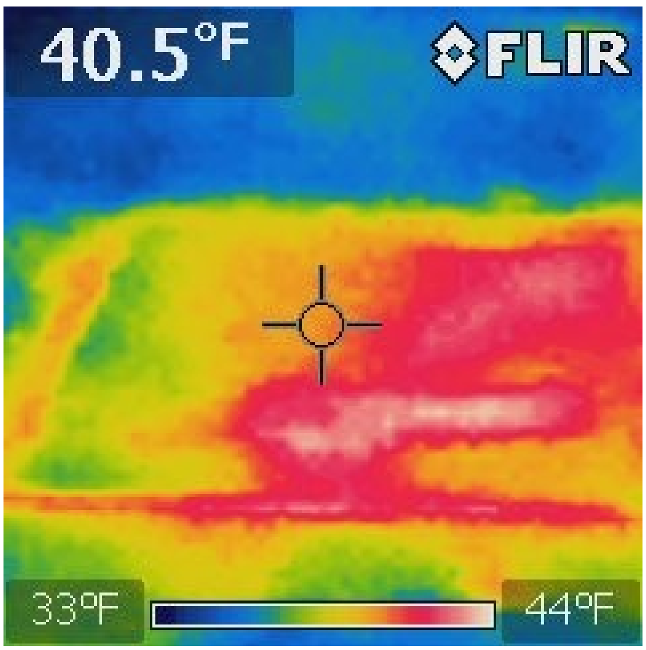

Figure 17: Infrared camera picture of patch #7, containing MG Krete, showing the temperature variation throughout the patch.

Similar to the FlexSet patches, the SR-2000 product had an even heat distribution throughout the patches, as seen in Figure 18. Figure 19 shows patch #34, containing the Delpatch product, with a fairly even heat distribution throughout the patch. This patch was nearly 7 feet (2.1 m) long, which would make the installation of the product take longer than the smaller patches, which is likely why half of the patch shows higher heat than the other half.

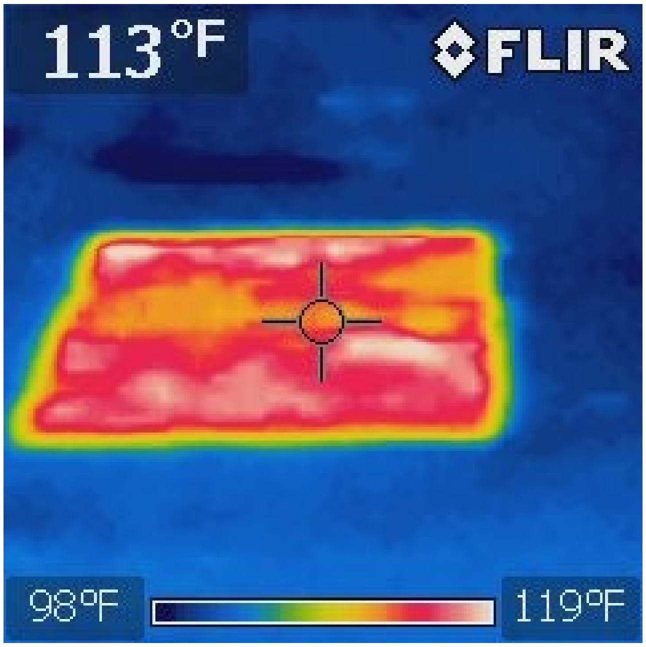

Figure 18: Infrared camera picture of patch #22, containing SR-2000, showing the temperature variation throughout the patch.

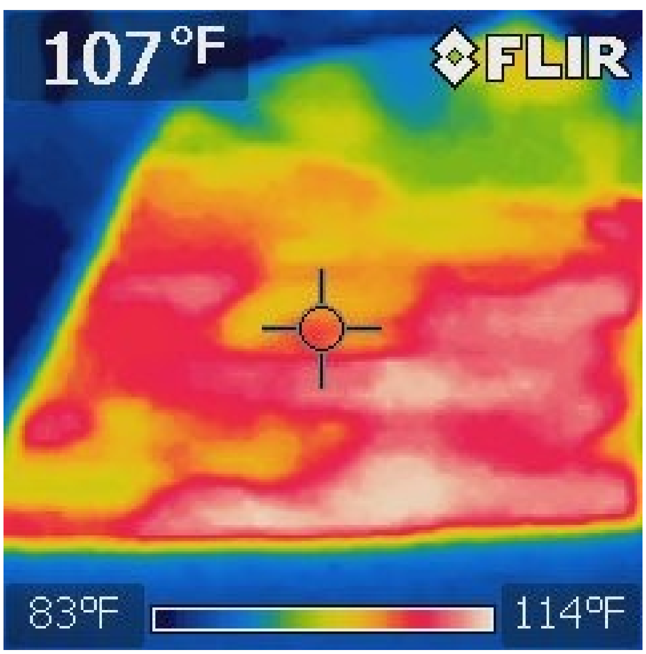

Figure 19: Infrared camera picture of patch #34, containing Delpatch, showing the temperature variation throughout the patch.

7.4 Ultrasonic Pulse Velocity (UPV)

The ultrasonic pulse velocity (UPV) method, or the ultrasonic through transmission method, was used on a number of patches, at different times, to try and estimate the strength of the patches relative to the concrete pavement around it. Some of the products did not give good readings, and others were not able to be tested. However, the data and information that was recorded will be discussed in this section.

First, the concrete pavement surrounding the majority of the patches for this project was tested, and gave a consistent pulse velocity reading of around 11,000 ft/s (3400 m/s), with the transducers at a distance of 12 inches (300 mm) apart. This wave velocity is indicative of generally good quality concrete. This reading shows that the concrete area that was tested was strong and intact (ACI Committee 228, 2013).

The RepCon 928 was tested at one hour after installation, and at two hours after installation. The transducers were spaced at a distance of 6 inches (150 mm) apart for both tests. One hour after the patch was installed the pulse velocity was measured at about 4700 ft/s (1400 m/s). Two hours after the patch was installed the pulse velocity was measured at around 7300 ft/s (2200 m/s). These readings show that the strengths of the RepCon 928 patches were increasing at a good rate after they were installed, and were probably strong enough for vehicular traffic after around two to three hours, consistent with the manufacturer’s recommendations.

The FastSet DOT Mix was tested one day after installation, at two different patches. These patches were also tested with the UPV transducers at a distance of 6 inches (150 mm) apart. Patch #68 gave a pulse velocity reading of around 6000 ft/s (1800 m/s), while patch #69 gave a reading of around 6500 ft/s (2000 m/s). These pulse velocities are lower than the pulse velocity for the concrete pavement; however, the pulse velocity for the FastSet DOT Mix patches should continue to increase.

The FlexSet, SR-2000 and Delpatch patches were also tested, but a signal could not be found due to their polymer classification. It is likely that these products are too flexible to transmit an ultrasonic wave, having a low Young's modulus and high damping. These materials also do not resemble concrete, and the UPV test is meant for use on concrete specimens.

The MG Krete patches were tested with the UPV method as well, but the results were inconclusive. This was likely due to a limited amount of petroleum jelly, for coupling, available at the time of the winter installation.

7.5 Wheel Path

One potentially important factor that was observed during the installation of the patches was whether or not a patch was in a wheel path. The majority of the patches constructed were located in a wheel path. The patches that were constructed in a wheel path will have a lot more vehicle traffic driving directly on the patch compared to the others. This will better test the durability and longevity of the patching materials being tested for this project, and should be considered when observing the patches throughout the duration of this project. The patches that are not directly in a wheel path will still get driven over, and can still be negatively affected by this, but this factor should still be considered as the project moves forward since these will have much less traffic.

7.6 Added Aggregate

For the Flex Set and SR-2000 products, trap rock (polymer-coated aggregate) could be added into the product mixture before pouring if desired. All except two of the Flex Set patches, and eight of the SR-2000 patches, had trap rock added to their mixtures. This difference is noted in case there is a noticeable difference between the strength and longevity of a product with or without added trap rock throughout the duration of the project.

7.7 Expansion Joints

Five of the patches for this project were installed on original expansion joints. Two of these patches were at the corner of concrete pavement slabs, as seen in Figure 20 and Figure 21. The material used for patch #5, on the first expansion joint, was chosen to be Flex Set due to its promoted flexibility. The material used for patch #75 was RepCon 928, which is a polymer modified material. Patch #75 is on an expansion joint, in Figure 21, and it can be seen that there is a tie-bar and dowel that seems to be located too close together to the expansion joint. With the obvious future expansion of the expansion joints, it will be interesting to see the performance of these patches over the course of this project. It can also be seen in Figure 20 that the upper left corner of the patch hole, at the expansion joint, is visibly damp. This was not flame dried, and should be monitored throughout the project.

Figure 20: Patch #5, placed at an expansion joint, visibly damp at upper-left corner.

Figure 21: Patch #75, placed at an expansion joint.

The other three patches installed over expansion joints were installed on asphalt pavement, with the SR-2000 product. These patches were placed over the joints, as seen in Figure 22, rather than along them. These patches will need to be closely monitored, especially throughout the winter.

Figure 22: Patch #16, containing SR-2000, placed over an expansion joint.

7.8 Product Observations

The observations that correspond to a specific product are discussed in this section.

7.8.1 MG Krete

During the mixture procedure of the MG Krete, only half of the bag and half of the bottle of the material could be mixed at a time. This differed from the instructions for installing the material (explained in the previous chapter). The construction workers estimated half of a bag and half of a bottle into a 5 gallon (19 liter) bucket that was used to mix the material, which caused consistency differences throughout the installation of the MG Krete patches. Due to this, some of the mixes ended up being denser than others, and some ended up being 'watery.' For some of the smaller patches, this ended up causing an issue with tining the patch after the installation, because part of the patch had too much liquid in it and caused the patch to flow into the tines. This can be seen below in Figure 23, where the left half of patch #6 was wet due to improper mixture proportions. The material had to be left to sit for a while before the left half of the patch was tined. Whether or not this affects the strength, durability, or longevity of the MG Krete patches is unknown at this point, but will be determined throughout the course of this project.

Figure 23: Patch #6, constructed with MG Krete, showing bleeding in the left half of the patch due to improper mixture proportions.

7.8.2 SR-2000

The product literature for SR-2000 did not clearly document the proper mixture proportions. After a phone call to the company, the proper proportions for this product's materials were determined. The first batch mixed of this product that was prepared had to be discarded due to the addition of too much activator liquid.

For the majority of the patches that were installed with SR-2000, the surface after the patch was installed was difficult to finish. The patches tended to float a liquid to the top of the patch, so the patch could not be tined effectively. The topping sand was mostly absorbed by the liquid and sank below the top of the patches. Most of the patches that were installed with the SR-2000 ended up being aesthetically ugly, smooth, shiny, and wet looking, even after being traffic ready. Patch #26 can be seen in Figure 24, which shows these issues.


Figure 24: Patch #26, containing SR-2000, bleeding liquid.

Patch #21, constructed with SR-2000, did not set after it was filled. Over 5 hours after the patch was installed only a thin layer on the top of the material was partially hard. Taking a stick, a hole was easily poked through the top layer of the material. Patch #21 with the material that did not set, before it was refilled, can be seen in Figure 25. The hole was then cleaned out with a shovel and refilled. Likely, the material that was put into the hole the first time did not have enough of the activator liquid added, so the material did not cure. The remnants of the bad batch were difficult to remove.

Figure 25: Patch #21, containing SR-2000, in which the entire patch did not set. The patch was cleared and refilled after the patch did not set over the course of 5 hours.

After patch #29 was installed, a spot of delamination was detected in the concrete pavement next to the middle right of the patch. This is a sign of potential spalling occurring next to this patch, which could cause damage to the patch. Patch #24 had what was observed as two loose batches of the SR-2000 product when it was installed. Also, patch #30 had an extension (ear) added onto the originally marked out rectangle, which may in the future lead to a cracking failure. Figure 26 shows the extension to the patch.

Figure 26: Patch #30, containing SR-2000, showing an extension (ear) on the middle left of the patch.

7.8.3 Delpatch

In the Delpatch product description in Chapter V, it is stated that the part A and part B polyurethane liquids need to be measured out to exactly 100 ounces (3000ml) of Part A and 50 ounces (1500ml) of Part B using beakers. However, parts A and B liquids arrive in drums of each liquid, and measuring beakers are not included with the product. The product representative for D.S. Brown's Delpatch went to the store to buy two beakers before the construction began, eliminating the issue for this project. If the product were to be installed without the proper means of accurately measuring the liquids, a problem in consistency might arise. It does not only call for using twice as much of part A as part

B, but there needs to be exactly 100 ounces (3000ml) of Part A and 50 ounces (1500ml) of Part B for each bag of sand and fiberglass. Although, with the beakers, there is no guessing on the proper proportioning, and the product ends up being consistent for every patch installed.

A batch of Delpatch that was mixed for patch #36 came out darker than normal, and it set faster than the average batch of Delpatch. This indicates that either too much of patch B was added to this batch mixture, or too little of part A was added. This was suggested by the fact that part A is a clear liquid, while part B is a black and darker liquid, and that the set time for the project would decrease with a higher than usual part B to part A ratio. The integrity of this patch is likely still strong; however, it is less aesthetically pleasing. A picture of the darker section on patch #36 can be seen in Figure 27.

Figure 27: Patch #36, containing Delpatch, showing a dark spot due to batch completed with improper material measurements.

7.8.4 FastSet DOT Mix

Patches #66 and #67 were installed with soupy batches, relative to the rest of the patches installed. The area between a pothole and Patch #68 detected delamination, and might cause a problem at the front of the patch if the area spalls. This section of delamination can be seen in Figure 28.

Figure 28: Patch #68, containing FastSet DOT Mix, with a pothole in front of it. Delamination was detected between the patch and the pothole after installation.

A small crack, as seen in Figure 29, ran through the pavement at the location of patch #64. Whether or not this causes a crack in the patch in the future is unknown. The crack can be seen running from the top right of the slab in the figure, down under the patch and to the left of the green ‘X’ on the right. Also, the last batch of FastSet DOT Mix that was added to this hole was loose.

Figure 29: Patch #64, containing FastSet DOT Mix, with a crack running through the concrete slab and under the patch.

7.8.5 RepCon 928

The RepCon 928 mixture bag that had the product details on it did not provide information about the time until it would be ready for vehicular traffic. Four of the RepCon 928 patches have small existing pavement cracks that either run to them or through them. Patch #70 had a crack running through the middle of the hole that measured at 0.025 inches (0.635 mm)) wide, while patch #71 had a small crack coming from the right side of the hole that measured at 0.013 inches (0.33 mm) wide. There were also two small cracks that span from patch #71 to patch #72. These two patches have around one foot (0.3 m) of pavement between them. Lastly, patch #76 had a large crack running through the middle of the hole, spanning the entire width of the slab. This crack can be seen in Figure 30.

Figure 30: Patch #76, containing RepCon 928, with a large slab crack running through the middle of the patch.

7.8.6 Construction Team Product Observations

The observations from the Great Lakes Construction team about the different products can show insight into which materials are easier or harder to use during patch construction, and which materials they would prefer to use again. On top of the cost of the materials, the ease of application and time needed for installation are important in the choosing of patching materials, which is why the installer's preference of product should be a big factor in the future rating of the products that were tested for this project.

Before the last material was installed (RepCon 928), MG Krete was stated as being “the most user-friendly, so far,” by Tony Gamiere, the head of the Great Lakes Construction team. He also stated that he did not like working with the Delpatch material, and that it was too difficult to work within the holes.

Marcus Werner, an intern for the Great Lakes Construction Co., rated the RepCon 928 product higher than the FastSet DOT Mix due to the following reasons:

- The mixed product cleaned out of the mixer easier.
- The RepCon 928 product had lighter material bags.
- RepCon 928 was more workable when forming the patches in the holes.

CHAPTER VIII

PATCH INSPECTIONS

As of August of 2014, two patch inspections have been completed for this project. On May 29th, 2014, a preliminary inspection was performed on the 14 winter patches installed in March of 2014. A month after the summer patch installation, on July 30th, 2014, another inspection was performed on all of the 85 installed patches for this project. With the help of ODOT traffic control, a visual inspection, and delamination testing was performed during both inspections. The delamination test was performed with the use of a piece of rebar for the first inspection, and the Delam 2000 for the second inspection. The results and observations from this inspection will be discussed in this chapter.

8.1 FlexSet

Overall, the Flex Set patches appeared sound and intact after both inspections. The only visible sign of distress was that 3 of the 8 FlexSet patches had small surface spalling. These patches were #8, #9, and #11. This spalling can be seen in Figure 31, where a small section at the bottom left of patch #8 shows part of the surface of the patch missing. Figure 31 consists of a picture of patch #8 from the first inspection. The second inspection did not show the spalling area increase much, compared to the first inspection, for all three of the patches that showed spalling. None of the new patches showed spalling during the second inspection.

Figure 31: Patch #8, constructed with Flex Set, showing slight surface spalling on the bottom left of the patch.

The rebar test, which was performed on the FlexSet patches during the first inspection, gave primarily good results on all of the patches. However, on patches #11 and #14, an inconsistent noise was produced from the rebar test on a small area of both of the patches. Near the middle of patch #11, and at the bottom left of patch #14, the dropped bar did not produce the distinct ping that was produced everywhere else on the other Flex Set patches. Figure 32 shows the rebar test being performed on patch #14, with the rebar pointing to the area that failed the rebar test. During the summer installations, in June, the delamination test was performed on patch #14 with the Delam 2000, and no delamination was detected anywhere on the patch. These areas of patches #11 and #14 should be monitored throughout the project; however, delamination, or debonding, does not seem to be present, as of the July inspection, at any of the FlexSet patches. The Delam 2000 was used on all of the Flex Set patches during the second inspection, and all of the patches passed this test.

Figure 32: Performing the rebar test on patch #11, containing Flex Set, with the rebar placed over the area that failed the rebar test.

8.2 MG Krete

The MG Krete installed patches, like the FlexSet patches, appeared from visual inspection to be sound and intact. A few of the patches showed small surface pitting, but that was expected due to the release of the ammonia during the curing process of the patches, and because a retarder was not used on the patches at the time of installation. These cracks are likely not deep, and are not likely to be an issue moving forward.

Patch #1, on the bridge deck, had the most of the small surface cracks, which was also expected due to the large size and depth of the patch. Figure 33 shows patch #1 two and a half months after the winter installation, where multiple cracks can be seen on the surface of the patch. Figure 34 shows a crack on patch #1 being measured at 1/32 inches (0.79 mm) wide. The entire patch passed the delamination test.

Figure 33: Patch #1, containing MG Krete, and showing cracking 2.5 months after installation.

Figure 34: Patch #1, containing MG Krete, and showing a crack that is approximately 1/32 inches (0.79 mm) wide, 2.5 months after installation.

Patch #6, which had improper mixture proportioning at the time of the winter installation, was solid and showed no signs of failure. The west half of patch #6, seen on the left of the patch pictured in Figure 35, shows that the improper proportioning is still visible, but there is no noticeable difference in strength and durability between the two halves of the patch. The delamination test produced the same positive results for both halves of the patch, indicating it was well bonded.


Figure 35: Patch #6, containing MG Krete, with the improper mixture proportioning still visible.

8.3 SR-2000

The SR-2000 installed patches did not have any visual cracks or deformities as of the July inspection. However, four of the patches did not pass the delamination test. Sections of patches #15, #16, #17, and #27 gave off a hollow sound upon the delamination test during the July inspection. Patches #15 through #17 were installed on asphalt pavement, and were the first three patches installed of this product. These four patches should be monitored closely over the course of this project, especially throughout the winter freeze-thaw cycles.

8.4 Delpatch

The Delpatch installed patches did not have any visual cracks or distress as of the July inspection. These patches also passed the delamination test, and showed no signs of concern for possible failure.

8.5 FastSet DOT Mix

The FastSet DOT Mix installed patches had two patches that had cracks form through them, patches #64 and #65. These cracks were small and expected, and were formed by cracks already present in the concrete pavement in which the patches were placed on. The crack in the pavement around patch #64 can be seen on the right side of the patch in Figure 36, but the crack through the patch following the crack through the pavement is difficult to see as it is not very wide. The FastSet DOT Mix patches also passed the delamination test, and showed no signs that would suggest concern for possible failure.

Figure 36: Patch #64, consisting of FastSet DOT Mix, with a small crack through the patch.

8.6 RepCon 928

The RepCon 928 installed patches had one patch that had a crack form through it, patch #77. This crack was also small and expected, and was formed by a crack already present in the concrete pavement in which the patch was placed on. The RepCon 928 patches also passed the delamination test, and showed no signs of concern for possible failure.

CHAPTER IX

SUMMARY AND CONCLUSIONS

9.1 Observations

In order for the installation of the patches to go smoothly, and for the products installed to have the best chance to succeed, there were a few factors regarding the patching process that should be noted. It is important to know that the cutting, jackhammer drilling, and properly cleaning the holes will be more time consuming than the time spent installing any of the products used during this project. It is essential to the longevity of the patch being installed that the hole is made in a rectangular shape with smooth-cut edges, and that the hole is cleaned of all dirt and debris before installation of a patching product. Figure 37 shows the hole where patch #14 was installed, properly prepared before installation. Simply placing a product in a pothole with loose debris in it and tapered edges will lead to early patch failure.

Figure 37: An example of a clean, smooth-cut hole, where patch #14 was installed.

The SR-2000 and Delpatch products required the holes be primed prior to installation, which can delay the installation of the products up to an additional half an hour. Also, some of the products had a wide range of acceptable ambient temperatures to install the product in, while others had smaller ranges that can limit the time at which the product can be installed.

9.1.1 Potential Problems

This section documents the potential problems that were observed throughout the installations, which should be considered when choosing a product for future installations.

Every product used during this project had the potential for early set during higher installation temperatures. The Delpatch product was also sticky, which made it tough to finish in the hole. This problem, along with the early setting issue, made the installation of the Delpatch product difficult. The FlexSet is also a sticky product; however, it is self-leveling, which eliminates the need for forming the product in the hole. The cementitious products (FastSet DOT Mix and RepCon 928) can use cold water to slow down the setting process, which requires the addition of ice to the water being used.

The SR-2000 product does not have a specific guideline for mixture proportions. This left the majority of the patches installed with inconsistent proportions, and a few of the patches with soupy batches of the product. The patches installed with more resin than the others ended up with a resin liquid bleeding to the top of the patches. Without knowing the proper proportions of the product, the presumed proper proportions were not figured out until after a few patches were already installed with the product.

The FastSet allow for freeze thaw cycles to take place and adequate time for surface wearing of the repairs. DOT Mix also did not specify a specific amount of water to mix with the product, which led to a few soupy batches being produced throughout the installation. These patches did not bleed like the SR-2000 patches, and there is no evidence as of yet that these patches are any less strong than the less soupy batches of this product.

9.2 Final Conclusions

Background research from ERDC and NTPEP provided helpful insight into the field testing criteria that was used to identify the proper field testing methods and investigation to be performed throughout this research. The study of similar literature to that of this research also showed what type of research has been already completed, and methods that were taken to get to the end result. The information found was used to determine the proper approach throughout this research project, and was adapted to meet the requirements of this research.

This research accomplished all of the objectives set out in this thesis, which consisted of:

- Determining the field testing criteria for comparative analysis of all of the selected products.
- Determining the site locations for the installation of the patches
- Documenting the installation and field testing of the bridge deck, asphalt pavement, and concrete pavement patches.
- Reporting the initial field performance of the patches.
- Perform preliminary patch inspections following patch installations.

The field testing that was performed for all of the products throughout this research was extensive and should provide enough data to analyze if any types of patch failure were to occur during the remainder of this project. The main reason for future patch failure will likely be due to the location of the patches, which include: patches placed on, or at, control joints; patches installed directly next to other patches; cracks or failure near the installed patches.

9.3 Follow on Research

All of the patches installed for this project will be monitored and studied through two winters to allow for freeze thaw cycles to take place, and to allow adequate time for surface wearing of the repairs. A visual inspection will be performed on the installed patches approximately every two months throughout the course of the project. If deterioration of any of the patches is observed, more frequent inspections will be performed to monitor the rate of deterioration. Laboratory testing on all of the products used for this project will also be conducted while these patches are being monitored. Additional products or materials may be tested in the laboratory to extend the scope of the research.

The complete performance and results recorded throughout this research will be analyzed, and a comprehensive standard material and performance based generic specifications in Standard ODOT Construction Material Specifications or Supplemental Specifications format will be produced based on desired ASTM or equivalent material properties and field performance analysis.

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