Longitudinal Joint Repair Best Practices for the Ohio Department of Transportation

Keeping Ohio's Pavement Joints Zipped Up

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16. Abstract

The Ohio Department of Transportation (ODOT) has identified longitudinal joint (LJ) failure of existing hot-mix asphalt (HMA) paving as a systemic weakness in the structure of some asphalt surfaces. In the past, these joint failures were treated as if they were potholes, and maintenance staff used either hot or cold patching materials for their repair. Several improvements over this patching approach are now being used. Spray injection is a process in which a single piece of equipment is used to clean out the repair, blend aggregate chips and emulsified asphalt, and blow the aggregate-emulsified asphalt blend into the pavement failure. The process is a semi-automated substitute for traditional pothole patching. Slot paving includes milling a narrow section of deteriorated pavement around the longitudinal joint and repaving with HMA. Slot paving typically serves as a more durable repair than spray injection patching. A third approach, if the deterioration has only started and appears as a longitudinal crack, is to crack seal or fill using conventional sealing materials and techniques. Decision tools were developed to support ODOT staff in matching the proper longitudinal joint repair technique to a site's conditions. The guidance considers the severity of the longitudinal joint distress, the extent of the distress, and the recommended treatment or treatments.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

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

APPROXIMATE CONVERSIONS FROM SI UNITS

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

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

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EXECUTIVE SUMMARY

The Ohio Department of Transportation (ODOT) has identified longitudinal joint (LJ) failure of existing hot-mix asphalt (HMA) paving as a systemic weakness in the structure of some asphalt surfaces. In the past, these joint failures were treated as if they were potholes, and maintenance staff used either hot or cold patching materials for their repair. Several improvements over this patching approach are now being used. **Spray injection** is a process in which a single piece of equipment is used to clean out the repair, blend aggregate chips and emulsified asphalt, and blow the aggregate-emulsified asphalt blend into the pavement failure. The process is a semi-automated substitute for traditional pothole patching. **Slot paving** includes milling a narrow section of deteriorated pavement around the longitudinal joint and repaving with HMA. Slot paving typically serves as a more durable repair than spray injection patching. A third approach, if the deterioration has only started and appears as a longitudinal crack, is to **crack seal** or **fill** using conventional sealing materials and techniques.

A literature search and interviews with other agencies revealed that several additional techniques are in use. For example, Illinois and West Virginia use micro surface on their longitudinal joint deterioration. Indiana uses a joint adhesive material during construction and places a fog seal over the constructed joint, while Tennessee has used a variation of the slot joint repair on deteriorated joints. In short, a variety of preventive and restorative measures are being used across the country to address longitudinal joint performance problems.

While ODOT has started to apply improved techniques to construct longitudinal joints which will minimize this problem in the future, there will be many miles of longitudinal joints needing repair for years to come. Accordingly, ODOT has pursued the development of guidance on the optimum time to treat the joints, determining which longitudinal joint repair method should be used, and developing standard guidance for maintenance staff.

The basis for this project is the study of 15 longitudinal joint repair locations, located in District 6. The field performance of each location or project was evaluated, and available records were examined to determine the different labor, materials, equipment, and construction time required for the different types of repairs. Table ES-1 compares the typical life and total costs of the three ODOT techniques, including materials installation and attributable incidental costs i.e. pavement markings, maintenance of traffic (MOT), and mobilization.

Table ES-1. Cost effectiveness evaluation of LJ repair techniques.

Repair	Treatment Life, Years	Cost per mile, $	Cost per mile per year, $
Slot Paving	4.3	$104,464	$24,294
Spray Injection	2.2	$12,764	$5,802
Crack Sealing	4.5	$3,363	$747

When comparing these techniques, it is important to note that each is not applicable under the same conditions, and there are reasons to continue using all three of these repairs. Given the comparative costs of the different strategies, it is important to apply the right treatment for the given conditions. Accordingly, as part of this project a series of decision tools were developed to support ODOT staff in matching the proper longitudinal joint repair technique to a site's

conditions. The guidance considers the severity of the longitudinal joint distress, the extent of the distress, and the recommended treatment or treatments.

Recommendations are also provided to modify specifications for slot paving and implement a new specification for spray injection. Improved specifications will help ODOT by better defining what a high quality repair looks like and how to construct such a repair.

The project team has recommended the construction of test sections to evaluate the proposed decision tool and the recommended changes to the treatment specifications. It is also recommended that a "best practices" summary and training be provided to maintenance supervisors to help them to match up the best longitudinal joint repair method for the given conditions.

CHAPTER 1: INTRODUCTION

Problem Statement

The Ohio Department of Transportation (ODOT) manages 49,078 lane miles of highway. This system enables people and goods to access the markets, services, and production inputs that are essential to the economic vitality of the State of Ohio. When pavements fail, it is imperative that ODOT employ the best repair practices available to restore the pavement quickly and for the long-term. This requires proactive condition assessments, identification of systemic failure mechanisms, and well-timed, best practices for repair.

ODOT has identified longitudinal joint (LJ) failure of existing hot-mix asphalt (HMA) paving as a systemic weakness in the structure of affected pavements. In the past, the failures were repaired as if they were potholes opening on a joint, and maintenance staff were required to manually place either hot or cold patching materials in the localized failure and compact it. Improvements over the use of localized repairs have been in the form of either repairing the failures at the longitudinal joints using spray injection or slot paving. Spray injection is a process in which aggregate chips and emulsified asphalt are blended, the mixture is blown into a pavement opening using specialized equipment, and the placed materials are allowed to cure. The process is a mechanical substitute for traditional pothole patching. Slot paving is a process of milling a narrow section of pavement around the joint and repaving with HMA. Slot paving typically serves as a more durable repair than spray injection patching.

As LJ failures became better understood, ODOT developed enhanced construction practices to improve performance of the joint and mitigate the weakness. However, enhanced construction practices have only been implemented recently, and many miles of highway are still prone to experiencing LJ failure. Repairing LJs continues to be a significant maintenance concern for ODOT, and recognizing the optimum time to treat, determining which method should be employed, and developing standard guidance for maintenance staff is warranted.

ODOT is not alone in identifying longitudinal joints and their performance as key components to long-lasting pavements. Several other state highway agencies (SHAs) and research partners have identified more successful practices for constructing LJs. It is well documented in literature that pavement failures occur at LJs because of the advanced rate of weathering and the associated distresses that accompany them; e.g., cracking, raveling, stripping, potholes. HMA has been shown to have a higher permeability near joints, which allows water and air to more freely enter the pavement structure inducing weathering and advancing distresses. As shown in figure 1, as in-place density decreases, air voids and permeability increase, adversely affecting LJ performance.

As total air voids in the constructed pavement increase, the likelihood of the voids being interconnected also increases, increasing permeability dramatically. Research has generally shown that permeability of an in-place pavement is greatly reduced with an air void content of the compacted mixture lower than 7 to 11 percent, with general recommendations for compaction to achieve at least 90 percent density at the joint.

Figure 1. Relationship of the HMA properties of density, air voids, and permeability.

LJs on multilane highways are more susceptible to permeability than on two-lane highways because of multiple factors. A consistent cross-slope between adjacent lanes and the need to drain a larger surface area both contribute to a higher permeability. A consistent cross slope and a lack of sufficient material during compaction causes bridging of the rollers following laydown operations, as shown in figure 2. In places where the rollers bridge from the hot mat onto the cold, the hot material adjacent to the cold joint is not compacted with similar effort, yielding a mixture with lower in-place density and higher permeability. Furthermore, wider highway sections with consistent cross slope must drain surface water from multiple lanes across multiple LJs, providing increased opportunity and availability for water to infiltrate the pavement surface. Also contributing to increased permeability is the standard practice of milling and repaving along existing lanes, which continues a vertical joint stacking at the same location. Cox concludes that the likelihood to reform a longitudinal crack at the joint after resurfacing is largely influenced by underlying layers rather than LJ quality (Cox et al. 2015).

With permeable construction joints in place on many of ODOT highways, LJs fail or "unzip" prematurely. In the analogy shown in figure 3, the LJ performs the same function as a zipper would on a winter coat, securing the combination of two side-by-side barriers and making them impenetrable to wind and water. The remaining cross section of the highway remains functional and structurally adequate to carry traffic if appropriate repairs are implemented. ODOT has recognized the need to make timely repairs and has used at least three repair techniques: crack sealing, spray injection patching, and slot paving. Since these repairs are a significant expense to the Department, there is the need to determine which repair methods are best under certain circumstances, and to provide recommendations on the use of the most cost-effective treatment available.

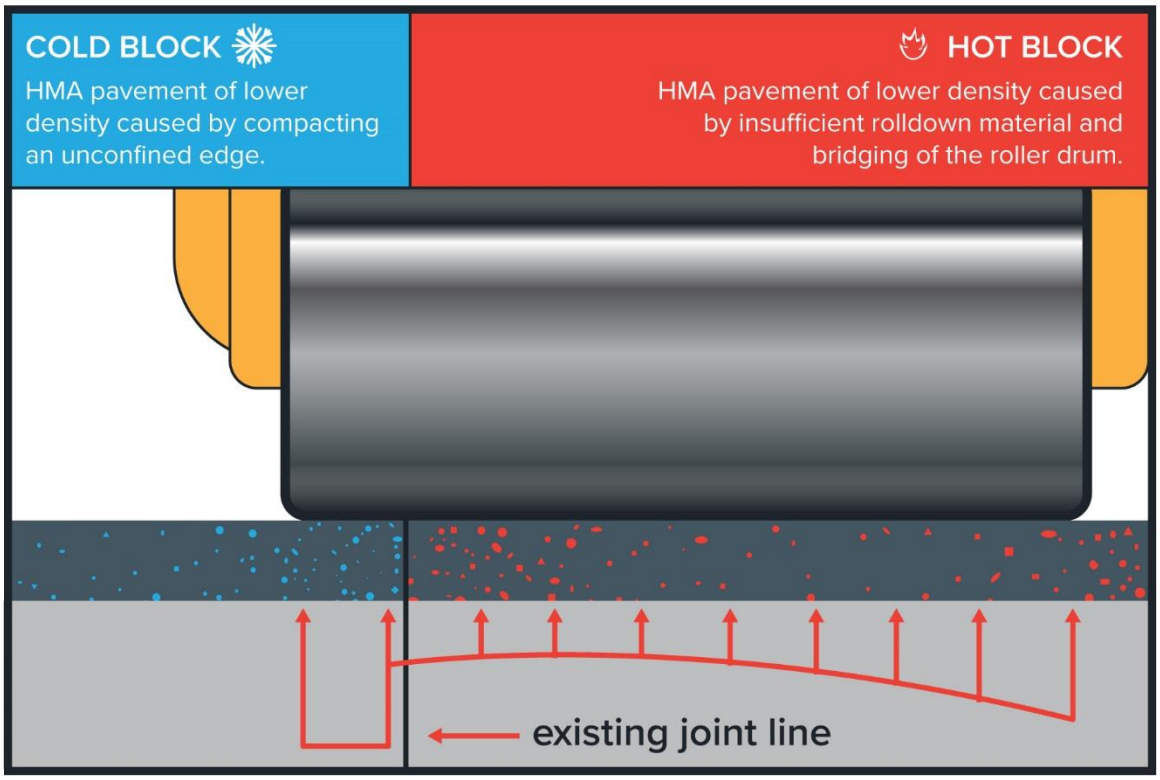

Figure 2. Illustration of bridging forces acting on a steel wheel roller and typical geometric alignment of HMA mixtures on a stacked LJ.

Figure 3. A LJ should zip-up as a waterproof union between two lanes of HMA.

Goals and Objectives

The goal of this research is to recommend improvements to ODOT's process of deciding the best repair method for LJs. The objective of this study is to provide ODOT with an empirically supported methodology to determine the most cost-effective LJ repair techniques for candidate roadways.

Recommendations are provided for implementation at the conclusion of the report.

Research Context

Several studies have been conducted to investigate LJ failures and propose ways to detect and mitigate construction defects. The relevant existing literature can be divided into three categories for discussion:

- Basics of LJ performance and failure modes.

- Evaluation of construction techniques to improve LJ performance.
- Evaluation of LJ repair techniques.

Williams concludes that measured permeability at the joint increases as density decreases (Williams 2011). Brown provides a summary of best practices for construction of superior LJs using laydown and compaction combinations (Brown 2006). Others provide assessments of how wedge joints perform compared with heated or conventional butt joints (Nener-Plante 2012; Zinke, Mahoney, and Shaffer 2008). ODOT has responded to this expanding experience by establishing joint construction specifications and testing protocols for verification of joint compaction.

This ODOT study is directly related to the third category and addresses the need to improve the standard of practice for LJ repair. The existing documentation to address repair techniques is deficient in addressing the short- and long-term repair alternatives outside of traditional joint filling and sealing practice. Most information about spray injection relates to patching potholes, but does not necessarily address LJ repairs. New repair and preservation techniques are emerging and may provide additional cost-effective benefits for nominal investment. For example, JointBond and other products have been applied in Tennessee and Maine to improve LJ performance and prevent weathering at the joint (Maine DOT 2013, Huang et. al. 2010). The Asphalt Institute lists various repair techniques, but stops short of providing a playbook approach based on condition and cost information as requested by ODOT (Buncher and Rosenberger 2012). These previously published studies provide examples of effective repairs of LJs to extend the useful life of existing pavements, in addition to best construction practices to reduce the failure of LJs in the future.

CHAPTER 2. CURRENT ODOT LJ REPAIR PRACTICES

The Ohio Department of Transportation has identified performance deficiencies with longitudinal HMA pavement joints, making finding a cost-effective repair solution a Department priority. Partial-depth slot paving, spray injection, and crack sealing have all been used in recent years as LJ failure repair methods. Field inspections were carried out between October 2016 and January 2017 to document and analyze the condition of each of these three types of repairs.

To analyze the current repair techniques on ODOT LJs, the following types of data were gathered from varied locations within ODOT:

- Location description of repairs, e.g., county, route, log mile, direction.
- Process descriptions and field observations.
- Pretreatment condition description and typical photographs.
- Cost and work quantity data from the maintenance management system (MMS) or construction management system (CMS).
- Performance data from the pavement management system (PMS).

From October 2016 to January 2017, the research team visited twelve locations of various repair treatments to identify the scope and scale of repairs. ODOT Districts provided moving work zone traffic control as needed to facilitate the site visits. During the visits, photographs were obtained to document the current visual condition of the repairs. Table 1 summarizes field inspection locations, average daily traffic (ADT), material types, repair descriptions, and repair performance observations, and figure 4 shows the site locations within ODOT District 6. Detailed site inspection records are included in appendix A.

Descriptions of the work processes were reviewed by the team to gather first-hand information regarding how the repairs were implemented along with observations of construction issues. Interviews were also conducted with the maintenance superintendent or crew supervisor responsible for implementing the project to collect additional information about the repair processes.

Where repairs were implemented with ODOT forces, MMS records were gathered to compile cost, effort, and production information. The labor, equipment, and material costs were summarized for each site available. Where treatments were implemented by both contract and internal forces, the in-house cost documentation was compared to estimates of contractor-performed services using the state average unit prices for let contracts. Section-specific pavement management data was requested to identify the pre- and post-treatment conditions of the pavement and the impact on pavement ratings of the LJ treatment. From these data sources, analysis was conducted to estimate the life span of each treatment, the likelihood of having repeated failures at the same location, and a PCR score increase in response to the treatment activity. Costs per year of treatment life for the treatments were calculated and used to produce a reliable, standardized decision-making process for statewide implementation.

Table 1. Description of LJ test sites and observed conditions.

Site No.	Location, Installation Crew, and Traffic	Date Repair Implemented	Material	Pavement Type	Repair Description	Condition of LJ Repair
Slot Paving						
1	I-70 (West Bound) MM: FRA 20.37 OH 106.41 Shelly Company 2014 24-hr ADT: 86,670	Spring 2015	Item 442-Aspahlt Concrete Surface Course, 12.5mm, Type A / Emulsion SS-1H	Full depth HMA	2-foot Partial Depth Slot Paving (2 inches deep) of the longitudinal joint within the middle lane. Between the wheel path of the middle travel lane. 4 feet from the nearest pavement markings	Repair HMA remains in good condition with only minor surface wearing and no visible cracking. Very minor wearing of the perimeter seal (PS) in which aggregate is beginning to show through. Sporadic low severity secondary cracking near pavement joint and only occurring in the original pavement. Little rutting and generally conforms to the roadway cross slope.
2	I-71 (South Bound) MM: FRA 17.48 OH 108.55 Kokosing Construction Company 2014 24-hr ADT	2014	Item 442-Aspahlt Concrete Surface Course, 12.5mm, Type A / Emulsion SS-1H	HMA overlay on concrete pavement	4-foot Partial Depth Slot Paving (3 inches deep). Repair centered on the pavement markings for both longitudinal joints within the travel lanes.	Repair HMA shows moderate wearing as aggregate is being exposed, but minimum deterioration. PS was placed but has worn off. 0.5 inch to 1 inch cracking occurring at the edges of the repair. 0.25 inch secondary cracking and deterioration on the non-repaired asphalt. Slight rutting at the edges of the repair (near the wheel path of adjacent travel lanes.

Table 1 (continued). Description of LJ test sites and observed conditions.

	Location, Installation Crew, and Traffic	Date Repair Implemented	Material	Pavement Type	Repair Description	Condition of LJ Repair
Slot Paving						
3	Collector/Distributor Road from I-270 South to Easton Way (South Bound) MM: FRA 31.51 OH 31.51 (From FRA I270) Shelly Company 2014 24-hr ADT: 157,070	Spring 2016	Item 442-Aspahlt Concrete Surface Course, 12.5mm, Type A / Emulsion SS-1H	Full depth HMA	3-foot Partial Depth Slot Paving (2 inches deep) of both longitudinal joints within the 3 travel lanes. Inside lane had one edge aligning with the pavement markings and the other edge extending into the wheel path of the inside lane.	Repair HMA remains in good condition with only minor surface wearing and no visible cracking. PS bands in fair condition, aggregate beginning to show as bands wear (especially in the edge within the wheel path). Minor localized cracking in the edge within the wheel path. Edge within the pavement markings has continuous low severity cracking through the PS. Minimal mounding or rutting and generally conforms to the roadway cross slope.
4	I-670 (West Bound) MM: FRA 8.1 OH 8.1 Kokosing Construction Company 2014 24-hr ADT: 107,260	2015	Item 442-Aspahlt Concrete Surface Course, 12.5mm, Type A / Emulsion SS-1H	HMA overlay on concrete pavement	4-ft Partial Depth Slot Paving (3 inches deep) centered on the pavement markings for both longitudinal joints within the travel lanes	Repair HMA showing moderate wear with 0.25 inch longitudinal cracking through the center of the repair (assumed to be original longitudinal joint). PS band has been worn completely away. Low to medium 0.25 inch to 0.5 inch secondary cracking near the north edge of the repair area within the original asphalt, areas have separated significantly to a point that the area required patching. Slight rutting at the edges of the repair within the wheel path of the adjacent traveling lanes.

Table 1 (continued). Description of LJ test sites and observed conditions.

	Location, Installation Crew, and Traffic	Date Repair Implemented	Material	Pavement Type	Repair Description	Condition of LJ Repair
Slot Paving						
5	I-77 (South Bound) OH 51.5 ODOT Personnel 2014 24-hr ADT: 23,860	Summer 2015	Item 448 Type "A" surface asphalt	-	2-ft Partial Depth Slot Paving (2 inches deep) between the two travel lanes.	Repair HMA intact, in some areas the original joint is beginning to reflect through the repair. PS band remains intact except in areas where the joint is beginning to show through as the PS band begins to slightly separate. Secondary cracking (0.25 inch wide) beginning to form perpendicular to the repair area mainly in the inside travel lane. Slight mounding in the repair area up to 0.25 inch over a 2-foot area; remaining is flush with existing pavement.
Spray Injection						
6	I-270 (North Bound) MM: FRA 13.0 OH 13.0 ODOT Personnel 2014 24-hr average ADT: 101,770	9/9/2015	Durapatch Liquid Asphalt, RS-2,	HMA overlay on concrete pavement	8 to 12 inch spray injection between lanes 2 and 3. Joint within the markings of the travel lanes but outside the wheel path.	Repair patch shows little to no distress. No areas of secondary cracking within the non-repaired pavement. Patching material exhibits a slight mounding of the material (0.25 inch to 0.5 inch) with respect to the original pavement.
7	I-270 (North Bound) MM: FRA 15.46 OH 15.46 ODOT Personnel 2014 24-hr ADT: 100,920	9/9/2015	Durapatch Liquid Asphalt, RS-2,	HMA overlay on concrete pavement	8 inch spray injection of the longitudinal joint within the markings of the travel lanes (outside the wheel path).	Repair patch is in overall good condition. Possible separation forming within the patching material itself. Repair area exhibits low severity secondary cracking within the non-repaired pavement (30-40 percent present.). Patching material exhibits mounding of the material (0.5 inch to 0.75 inch) with respect to the original pavement.

Table 1 (continued). Description of LJ test sites and observed conditions.

	Location, Installation Crew, and Traffic	Date Repair Implemented	Material	Pavement Type	Repair Description	Condition of LJ Repair
Spray Injection						
8	I-270 (East Bound) MM: FRA 22.0 OH 22.0 Premier Patching, Inc 2014 24-hr ADT: 174,180	Fall 2015	Limestone #9 Asphalt Emulsion HFRS-2	HMA overlay on concrete pavement	12 to 18 inch (some 24 inch) spray injection on the longitudinal joint within the markings of the travel lanes (outside of the wheel path).	Repair patch remains in good condition, exhibiting minimal infrequent distress. No signs of secondary cracking in the repair area. Some cracking perpendicular into the repair (perhaps due to inferior workmanship and application). These cracks are considered low severity. Patching material exhibits mounding of the material (0.5 inch to 0.75 inch, an extreme 1 inch) with respect to the original pavement.
9	US 23 (South Bound) MM: PIC 4.57 OH 59.73 ODOT Personnel 2014 24-hr ADT: 27,860	11/24/2015	Durapatch Liquid Asphalt, MWS 90	Full Depth Asphalt	8 inch spray injection within the pavement markings of the travel lanes (outside the wheel path).	Repair patch currently in poor condition. Patch breaking up in sections and exhibiting cracking within the patch. Areas of such high deterioration that little evidence of the patch remains. Secondary cracking (exceeding 0.5 inch) parallel to the spray patch. Slight mounding in some areas.
10	I-77 (Both Directions) MM: GUE 0.00 to 7.04 ODOT Personnel 2014 24-hr ADT: 22,580	March-May 2015	Durapatch Limestone #9, Liquid Asphalt, HFRS-2 Liquid Asphalt, MWS 90	HMA overlay on concrete pavement	Spray injection has been overlaid.	Repair patch did not perform as anticipated, it reportedly began to break apart over the course of the year and required maintenance.

Table 1 (continued). Description of LJ test sites and observed conditions.

	Location, Installation Crew, and Traffic	Date Repair Implemented	Material	Pavement Type	Repair Description	Condition of LJ Repair
Crack Sealing						
11	I-270 (East Bound) MM: FRA 19.16 OH 19.16 Scodeller Construction Company 2014 24-hrADT: 135,070	September, 2013	Performance Graded (PG) Asphalt (PG 64-22)	HMA overlay on concrete pavement	Typical width of the crack seal ranged from 3-4 inches. Longitudinal joints are outside of the wheel path aligned with lane markings.	Crack sealant shows deterioration in the center of the seal. Around 75 percent of the sealed cracks have reappeared through the sealant. Typical crack width is 0.25 inch; therefore, classified as low severity. No secondary cracking shown. Sporadic locations with slight mounding of the sealant material.
12	I-71 (North Bound) MM: MOR 18.0 OH 151.6 Kokosing Construction Company 2014 24-hr ADT: 44,110	2015	PG Asphalt (PG 64-22)	Full Depth Asphalt	Crack sealing in the joint between the inside and middle lane. Joint began separating shortly after construction, reason was never determined.	Crack sealant shows signs of wear, original HMA is appearing through overband. The majority of cracking has propagated through the sealant (small amount is still sealed). No routing of the joint prior to sealing. Secondary cracking (0.25 inch to 0.5 inch) occurring frequently and perpendicular to original cracking. No mounding of the crack sealant material.

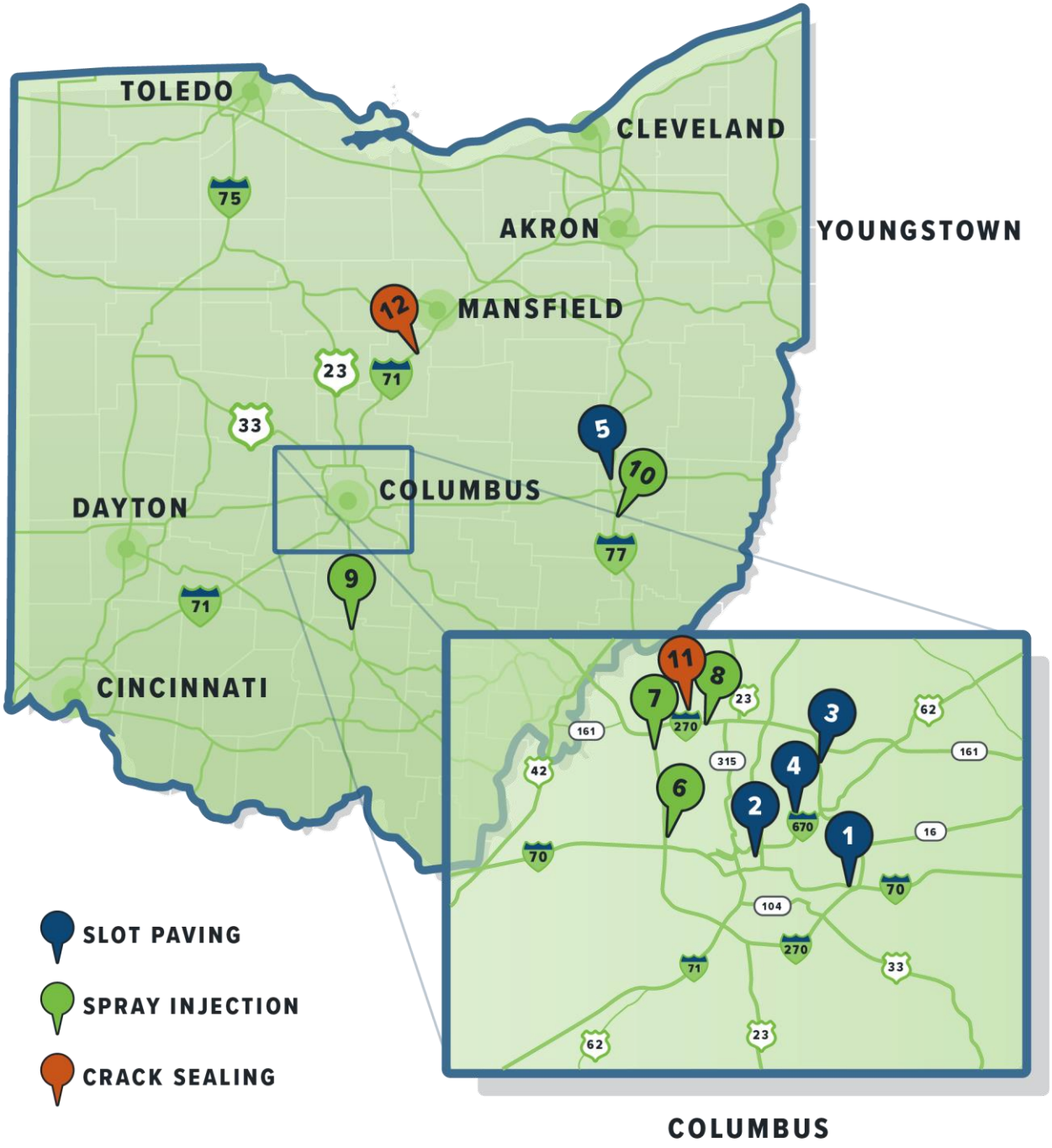

Figure 4. ODOT LJ Repair study locations.

Treatments

A summary of each current repair technique used by ODOT is prepared to compare the outcomes achieved over the multiple sites where the treatments were applied. The following topics are addressed for each of the treatments:

- Process description – equipment required, site preparation, material specifications.
- Cost – cost per foot of LJ repair, production rate capability.

- Performance – life cycle cost, cost-benefit ratio.
- Implementation issues – observations of maintenance managers, construction specifications.
- Traffic control requirements – work zone duration, number of lanes closed.
- Factors affecting treatment success – weather factors, pre-treatment condition, severity of LJ deterioration, joint loading effects.

Slot Paving

Slot paving is a process to repair longitudinally oriented failures. The first step is to cold-plane over a LJ to a fixed depth. The resultant void or slot is then filled with paver-placed HMA. In Ohio, the width of slot paving has varied from full lane removal, to a 2-, 3-, or 4- foot minimum. Table 2 shows the evolution in *Item 251 Partial Depth Repair* descriptions and nomenclature since 2012, along with the reference project identification numbers (PID).

Table 2. Partial Depth Repair items included in District 6 contracts

Type	Quantity Used	Minimum Width, ft	Depth, in	Low Bid, $/sq. yd.	Note
2012 PID 91621					
Type 1	38,143	4	2	$21.50	
Type 2	155,169	4	4.5	$35.00	
Type 3	2,066	4	6	$85.50	
2013 PID 94372					
Type 1	3,212	4	2	$27.00	
Type 2	42,799	4	4.5	$45.00	
2014 PID 91622					
Item 251	18,895	4	4.5	$58.00	
2015 PID 91623					
Type 1	9,770	2	2	$50.00	Varying width
Type 2	5,586	2	2	$50.00	Consistent width
Type 3	4,314	4	4.5	$74.00	Full depth HMA
Type 4	1,345	3	3	$60.00	HMA overlay on JPCP
2016 PID 101959					
Type A	1,501	4	6	$62.50	
Type B	5,453	4	2	$21.40	PG 64-22 HMA
Type C	106	2	2	$54.40	Consistent width
Type D	550	4	2	$26.30	PG 70-22 HMA (Superpave)
Type E	17	1-foot by 1-foot block	3	$545.00	Repair RPM void

ODOT staff report that the typical width for slot paving has generally been decreasing in recent years, and the contract payment records support that statement. This move may be the result of addressing the worst LJ repair locations in previous years, which required more repair width, and being able to address the less severe joint distress locations in later contracts.

Construction Details

A short-term work zone is established prior to initiating the work. Because the repairs are typically made between two functioning lanes of traffic, the traffic control zone closes those two lanes. For each repair, the milling width is specified to include the known distressed area as well as a uniform, but nominal, amount of sound pavement. Contractors have requested that the repair width be uniform for as long a distance as possible to minimize equipment idle time for grinding width adjustment or reversing field to clip irregular additional widths. Removing the distressed joint area to a sufficient depth requires preplanning by ODOT staff and the contractor to minimize removing sound material while ensuring that all the damaged pavement is removed and the slot sides remain vertical. Debris is swept and removed from the excavated slot to permit the repair materials to bond to the remaining pavement.

To complete surface preparation in the slot, generous tack (0.075 gal/sq. yd.) is applied to the sides and bottom of the excavation. For slot widths from 4 feet to 12 feet, a standard paver is used to place the HMA materials. Smaller slot widths are typically filled using a "berm" box paving attachment mounted on the side of a paving machine. In a similar application to paving with an extended screed, augers transport the HMA laterally to fill the slot to the required level. Typical slot paving applications are constructed with a 2- to 3-inch depth placed in a single lift using 0.75-inch maximum aggregate sized HMA. When the 4.5 inch deep slot is called for, a 3-inch binder lift is typically placed before a surface lift is placed. The berm box strikes off the material above the intended lift surface to allow for compaction to be achieved and maintain the appropriate vertical grade. Similarly, the surface lift is placed at a level above the intended profile of the adjacent pavement such that the material can be rolled to the appropriate level after compaction. Mark Brumenschenkel, ODOT District 6 New Albany Outpost supervisor, observed that slot construction is successful when each inch of slot depth is accompanied by at least one foot in slot width. This observation would suggest minimum slot widths as follows:

- 1-inch slot depth 1-foot minimum slot width.
- 2-inch slot depth 2-foot minimum slot width.
- 3-inch slot depth 3-foot minimum slot width.

HMA mixes meeting requirements for ODOT Standard sections 301 and 442 Type A are used for the binder and surface layers of the slot, respectively. Small-width drum rollers and plate compactors are used to densify the materials placed in the slot. Compaction inspection centers on verifying that the material is struck off at the appropriate height so that proper roll-down (approximately 0.25 inch per inch of depth) can occur, and achieving the desired density at the appropriate vertical grade. Quality control density measurement is typically not done, and not required by specifications, because of the small quantity waiver typical in state specifications. After compaction is completed, a hot-applied perimeter seal (PS) is placed over the joints of the repair. The 4-inch wide seal is applied by wand and distributed equally over the new patch material and the existing sound pavement. Figure 5 shows the slot paving treatment installed at site 1 on I 70 in Franklin County at mile marker 20.37.

Contractors reported at least 3 miles of production in an 8-hour work shift if the slot could be constructed in a continuous manner. This assumes one traffic control zone established in a single work shift and no changes in milling and paving width during the shift. Skipping linear sections

of joint repair was viewed as a risk taken into account by the contractors that increase bid prices for the work. Additional setups increase costs and affect construction quality because the pattern is interrupted and equipment cools during the transition.

Figure 5. Typical 2-ft slot paving placed on I-70 Westbound. (Site 1)

Treatment Life

All the LJ pavement repairs conducted prior to 2012 have been further treated with either a follow-up resurfacing or rehabilitation project and were not available for inspection under this project. This suggests that most slot paving repairs are implemented as a stopgap measure rather than as preservation, and are only intended to provide a solution until the next paving project can be completed.

Factors that affect the treatment life include the patch location and size, patch construction quality, the severity of the LJ deterioration prior to treatment, and the condition of the pavement adjacent to the patch. Distresses observed in the slot paving repairs include minor rutting, secondary cracks in the patch, and secondary cracking in the adjacent pavement near the patch. The rutting distress was observed in repairs that encompassed lane wheel paths, either with a joint occurring near the wheel path or a wider repair extending into the wheel path of a travel lane. Patches placed on composite pavement sections may deteriorate more rapidly than those on full-depth asphalt due to the existence of the formed joint in the underlying layer and the

likelihood that a distressed joint existed prior to the overlay. Reflection cracking could also exacerbate the deterioration at these locations. The photo in figure 6 shows distresses in the 4-foot slot paving including a reflection crack forming at the underlying LJ, secondary cracking and edge deterioration occurring around the perimeter of the patch, and slight rutting within the patch.

Figure 6. Reflection cracking, secondary cracking, and minor rutting occurring in 4-foot slot paving on I-670 in Franklin County. (Site 4)

District 6 pavement condition rating (PCR) data was reviewed in the log mile vicinity for each repair from 2014 and 2015, which covers most of the repair projects reviewed. In some cases, the improvement in condition was detected as a lower severity of distress or a lower distress extent after the treatment. Additionally, the 2014 installed repairs identified by the research panel are the earliest treatments considered in the project. Extrapolating performance greater than 2 years is assumed to follow a linear performance trend, and that ODOT would allow a patch to deteriorate to failure before replacement. Because the records of LJ conditions prior to the construction of the treatment were only available from the single-pass PCR condition rating, drawing further conclusions about the effect of pre-treatment conditions on treatment performance was not possible.

Treatment Cost

In estimating the treatment costs for slot paving, bid files and final pay estimates were reviewed. Incidental costs including pavement markings, maintenance of traffic (MOT), and mobilization were summed and included. Because the unit of measurement for the slot paving items was square yards, the total square yards paid were counted as the accomplishment for each contract. Cold planing, tack material, hot-applied sealant, and HMA materials were included within the bid price by the square yard for partial depth repair. In reviewing multiple repair items included in each contract varying based on either depth or width, no multiyear trends could be drawn from the cost data. Because no trend could be identified, the research team elected to use the arithmetic average for slot paving costs per square yard since 2014. This provides that all the slot paving work that has been previously done is included in the unit price estimate that is used to compare treatments types.

Spray Injection

As described by Abbas et al. (2016), the first step of the spray injection or spray patching procedure consists of blowing air into a pothole to remove water and debris. Next, an asphalt emulsion, which is heated to a working temperature of about 150°F or 65°C, is sprayed on the sides and bottom of the pothole. The aggregates are then mixed with the heated asphalt emulsion before being forced into the repair area using compressed air. Finally, the patched area is covered with a layer of aggregate, and the area is typically left open to traffic, either with or without compaction. The typical, in-service, spray injection LJ repair appearance is shown in figure 7.

Figure 7. Typical spray injection LJ repair site. (Site 6)

ODOT has additionally used this equipment and method to repair pavements with LJ deterioration. This repair method has been implemented by both ODOT crews and by contract or construction change order. In order for spray patching to be cost-effective and serve its purpose, surface preparations, weather conditions, material properties, and compaction must be ideal. Care must be taken by the installer to achieve a successful application, and if shortcuts are taken, the treatment may not perform as intended. The applicator plays a significant role in determining the quality of the work done, since he exercises more control of the equipment, is seeing the crack being filled, and is making modifications to adjust the application based on crack depth and thickness.

Spray injection is a stopgap, corrective repair that serves as a partial depth repair alternative treatment. But some contractors suggest that the application could be considered preventive maintenance through a planned, proactive approach. With a predicted service life, applying spray injection at a prescribed joint condition could retard additional deterioration and secondary cracking, preserving the pavement to serve its intended life.

There were four example locations where spray injection was used to repair LJ deterioration. General pre-treatment conditions were available from reviewing previous year pavement condition ratings. Table 3 presents observations of treatment construction, work orders, and specifications used to procure the materials or service.

Table 3. Spray Injection project details.

Type	Minimum Width, ft	Item Costs	Note
2015 PID 5536693			
Durapatch	0.75	$1.84/gal (RS-2) $1.90/gal (MWS 90) $15.43/ton (#9 stone)	Up to 1 foot width
2015 PID 150249			
Not Specified	1	$875/ton (#9 stone with 2,250 gal of emulsion)	Up to 1.75 feet wide (some 2 feet wide)
2015 PID 4306727			
Durapatch,	Not Specified	$2.25/gal (HFRS-2) $2.85/gal (MWS 90) $10.49/ton (#9 stone)	
2015 Work Order 4997960			
Not Specified	Not Specified	$2.48/gal (MWS 90) $10.49/ton (#9 stone)	

Installation Practices

The typical application ratio for spray injection is 20 to 25 gallons of emulsified asphalt per ton of aggregate (Abbas et. al. 2016). Contractors estimated emulsion usage as high as 35 gallons per ton of aggregate. This indicates a fairly broad range of application rates in practice. Further estimates were provided that approximately 15 tons of materials could be placed during one nighttime shift, and could cover roughly 1 mile of continuous LJ repair locations. Based on these estimates, a spray injection crew should consume 15 tons of aggregate and 525 gallons of emulsified asphalt during a shift, and should complete approximately 1 mile of LJ deterioration repair.

Estimated aggregate yield:

$$\frac{15\ tons/mile \times 2000\ lbs/ton}{5280\ feet/mile} = 5.68\ lbs/ft \tag{1}$$

Estimated emulsified asphalt yield:

$$\frac{15\ tons/mile \times 35\ gal/ton}{5280\ feet/mile} = 0.0994\ gal/ft \tag{2}$$

As a final repair dressing, contractors recommend sweeping loose chips from the repair surface with a hand broom and using a static steel wheel roller or vehicle tire to compact the repair area. The compacted, final surface should be in close conformity with the grade of the adjacent pavement. Excessive mounding could prohibit water draining from the pavement surface freely, and a depressed surface could hold water and develop damage under freezing conditions. An uneven surface, whether high or low, will also be disruptive to vehicles as they change lanes. Mounding was a typical observation of the in-service spray repairs, and typical mounding of 0.5 inch to 0.75 inch is illustrated in figure 8.

Figure 8. Slight mounding may occur with spray injection. (Site 8)

Traffic control

Spray injection may be considered a mobile operation or short-term lane closure depending on the repair length being completed. For the sections in this study, ODOT permitted multiple freeway lanes to be closed while the repair process was completed. ODOT costs to conduct MOT were reported as $6,000 per night and included multiple arrow boards, a mobile crash cushion, and the required installation of temporary signs and cones.

Surface Preparation

A significant factor contributing to spray injection repair success is surface preparation. The spray injection nozzle can direct high air volumes into the crevice, removing any dust, debris, or loose material that may have accumulated there. Larger debris may be removed by hand or using hand tools. It is advantageous to apply the repair adjacent to sound materials, so it may be necessary to dislodge failing crack walls or secondary cracking around the joint. After the distressed area has been cleared of debris, the operator should coat the joint surfaces with a generous application of emulsified asphalt to serve as an adhesive or tack between the existing pavement and the repair materials.

Weather Limitations

While winter repairs have been implemented, the temperature should be a minimum 40 degrees F and rising for planned permanent repairs. The pavement and repair areas should be dry to facilitate quick setting of the repair, and to minimize any free water from mixing with the application. Spray patching repairs are expected to cure more slowly in colder weather, but the delay may be mitigated by switching to a rapid set emulsion.

Materials

The most significant materials criteria for spray injection patch performance is the compatibility of the asphalt emulsion with the aggregate surface. The adhesion between the asphalt and the aggregate is formed by a chemical reaction at the stone surface as opposite charges attract each other. Typical aggregates used in Ohio are mined limestones from quarries or crushed gravels drawn from alluvial deposits or bank locations. The limestones typically have a positive charge on the surface and are most compatible with anionic emulsions, while gravels typically have a negative charge and bond best with cationic emulsions. Current materials selection and approval processes have relied predominantly on the experience of the contractor or State personnel overseeing the work to procure the best materials combination available.

Applicators agree that better tests for compatibility and material quality approval are required. Standard emulsion tests address the compatibility of materials, and were used during the Abbas et al. project completed in March 2016. The compatibility tests are often used to approve materials combinations for other applications such as chip seals or slurry seals. Materials typically used in chip seals are under similar application treatments and the emulsified asphalt is expected to rapidly bond to the aggregate applied. The researchers investigated compatibility of several combinations of asphalt emulsions and aggregates with different dust and moisture contents. The researchers used the AASHTO T-59 Coating Test to determine the relative coating achieved for each combination of materials. (AASHTO 2013) As an initial acceptance step, ODOT may utilize this procedure as a laboratory test to pre-approve the materials combination selected for a project. A field coating test should also be performed periodically to verify the aggregate coating achieved is sufficient for in situ conditions. Washed Number 9 limestone is the preferred aggregate called for with either RS-2 or HFRS-2 emulsion.

Asphalt Emulsion

Judgment of a practiced operator is required to control the application ratio of emulsion-to-aggregate using the spray injection repair process. The equipment requires regular maintenance to minimize clogging within the supply lines and applicator nozzle. Previous research has observed that using emulsions with lower demulsibility values results in fewer equipment disruptions or irregularities during application (Abbas 2016). Using lower demulsibility emulsions requires changing grades to a medium-set emulsion or a custom made rapid-set emulsion. Previous research recommended choosing an emulsion with a demulsibility value less than 70 (Abbas 2016); however, ODOT and AASHTO M 140 specifications require RS-2 and HFRS-2 emulsion to have a minimum demulsibility of 60 and 50, respectively (ASTM D 977-13). Table 4 lists relevant emulsified asphalt specifications that affect the stiffness, coating, and set time in a spray injection application. Emulsion suppliers indicated that producing an RS-2 with a demulsibility range of 10 percent would be exceedingly difficult to manufacture and control through the shipping process. The research findings that emulsions with higher demulsibility coated aggregate less effectively than those with lower demulsibility. As a result,

ODOT may consider using different products during different seasons to achieve a thorough aggregate coating, minimal set time, and minimal equipment irregularities.

Table 4. Asphalt emulsion properties relevant to spray injection.

Property	RS-2 Limit	HFRS-2 Limit	MWS-90 Limit
Viscosity, Saybolt Furol, 50 ºC, sec (AASHTO T59)	75-400	75-400	50 min
Demulsibility, 0.02 N CaCl2, % min. (AASHTO T59)	60 min.	50 min.	65 max
Sieve Test, % max. (AASHTO T59)	0.1 max.	0.1 max	0.1 max
Penetration, 100g, 5s (AASHTO T49)	100-200	100-200	90-150
Residue by Distillation, %, min. (AASHTO T59)	65 min.	65 min.	68 min.
Oil Distillate, Volume % max. (AASHTO T59)		4 max	7 max
Float test, 60 ºC, sec, min. (AASHTO T50)		1,200 min.	1,200 min.

Aggregate Properties

The most common aggregate type used in spray injection is limestone size #9. Abbas et. al. recommended that the aggregate be washed or processed to minimize the dust content and increase the coating efficiency (Abbas 2016). Table 5 summarizes the ODOT specification gradation band for size #9 aggregate. A high percentage of #9 aggregate is sized between the #4 and #8 sieves. The surface area for this aggregate size is relatively small compared to the same mass of particles passing the #200 sieve (or dust). Similarly, a smaller amount of asphalt emulsion is required to coat the material retained on the #8 sieve as compared to the same mass of material passing the #200 sieve. Therefore, reducing the percentage of fines in the source stockpile for spray injection increases the coating efficiency and produces a more cost effective repair.

Table 5. Recommended aggregate gradation for spray injection.

Sieve Size	Specification
3/8” (9.5 mm)	100
#4 (4.75 mm)	75-90
#8 (2.36 mm)	0-30
#16 (1.18 mm)	0-10
#50 (0.3 mm)	0-5
#200 (0.075 mm)	0-3[1]

1. P_{200} recommended by Abbas et. al. Sieve size not typically specified for a standard #9 aggregate.

Additionally, the aggregate is required to be sound and abrasion resistant so that the repair components are of similar, high quality to the paving materials adjacent to the repair.

Treatment Life

Factors that affect the treatment life include the patch location and size, patch construction quality, the joint severity prior to treatment, and the condition of the pavement adjacent to the patch. Distresses observed in the spray injection repairs include mounding of the material with respect to the original pavement, secondary cracks in the patch, and secondary cracking in the adjacent pavement near the patch. Patches placed on full-depth asphalt sections deteriorated

more rapidly than those on composite pavement with the exception of one area where the patch began to break apart over the course of the year after construction. Because the records of LJ conditions prior to the construction of the treatment were only available from the single-pass PCR condition rating, drawing further conclusions about the effect of pre-treatment conditions on treatment performance was not possible.

Treatment Cost

Bid files and final pay estimates were reviewed to derive the treatment costs for spray injection. Because the unit of measurement for the spray injection items were tons of aggregate and gallons of emulsion, several assumptions (overall project length and average patch dimensions) were made to convert these quantities to square yards. It should be noted that labor and equipment were included in the unit cost. Because all bid files and final pay estimates were from a single year (2015) and repair items included in each contract varied based on repair width, no multiyear trends could be drawn from the cost data. Because no trend could be identified, the research team elected to use the average for spray injection cost per square yard. This allows all the work that has been previously done to be included in the unit price estimate that is used to compare treatment types.

Warranty

Spray injection repair of LJ distress is more successful when the materials are installed by competent, experienced applicators. Application rates are controlled by the installer, and also contribute to the treatment success. To place the risk appropriately with the installing contractor, ODOT may consider a warranty for materials and workmanship extending for several months after installation. Signs that the repair is failing prematurely would require the contractor to reapply the treatment at no cost to ODOT. Suggested warranty language is included in the draft spray injection specification in appendix B.

Crack Filling

Crack sealing is a treatment that many agencies have used to address LJ distress. The practice is more appropriately considered crack filling, because most LJ distresses are considered to be non-working cracks. The term “non-working” relates to the characteristic that the crack is usually not as dynamic in its response to thermal stresses induced by temperature changes as a transverse crack. Figure 9 shows a typical crack filling treatment in an Ohio LJ after 1 year in service.

Figure 9. Section of crack sealing showing signs of wear (Site 12).

When filling the crack, bituminous materials are injected into the distressed area to bond to the crack face and fill the voids, preventing air, water, and incompressibles from entering into the pavement structure through the crack. This seal is a stopgap measure to slow down moisture infiltration. The most common material used to seal or fill cracks is a hot-applied asphalt modified with an elastomeric polymer to enhance the elasticity and adhesiveness of the material. ODOT specifies four types of crack sealants, each with its respective specifications defined in section 702.17 of ODOT's *Construction and Material Specifications*. These materials are used to fill cracks of increasing widths due to the increasing resilience of the sealants.

Sealant types

Type I - Hot Applied Joint Sealer: must conform with ASTM D 6690, Type II. This material is the typical hot-applied bituminous material used to seal cracks from 0.25 in to 0.75 inches wide or greater.

Type II – Mixture of PG 64-22 certified binder and polyester fibers (fiber and fiber manufacturer must be on the Department's QPL) that comply with the requirements listed in table 6.

Table 6. Type II fiber specifications.

Property	Limit
Denier, ASTM D1577	3.0 to 6.0
Length	0.25 ± 0.02 inch (6.5 ± 0.51 mm)
Crimps, ASTM D3937	None
Tensile str, min. ASTM D2256	70,000 psi (483 Mpa)
Specific gravity	1.32 to 1.40
Minimum melting temperature	475 ºF (256 ºC)
Ignition temperature	1000 ºF (538 ºC) min.

Materials should be combined so the fibers are a minimum of 5.0 percent by total weight of the asphalt binder and the combined materials have properties in accordance with the specifications listed in table 7.

Table 7. Type II mixture specifications.

Property	Limit
Strength (at break) at 72 ºF (22 ºC)	350 psi (2.4 Mpa) min.
at 0 ºF (-18 ºC)	500 psi (3.5 Mpa) min.
Elongation (at break) at 72 ºF (22 ºC)	50 percent min.
at 0 ºF (-18 ºC)	20 percent min.

Premixed and prepackaged Type II sealant is permitted provided (1) the fibers and fiber binder are according to the requirements as shown and, (2) the fiber binder is according to the manufacturer's specifications.

Type III – Mixture of PG 64-22 certified binder and polypropylene fibers (fiber and fiber manufacturer must be on the Department's QPL) that comply with the requirements listed in table 8.

Table 8. Type III fiber specifications.

Property	Limit
Denier, ASTM D1577	15 ± 3
Length	0.39 ± 0.08 inch (9.91 ± 2.0 mm)
Crimps, ASTM D3937	None
Tensile str, min. ASTM D2256	40,000 psi (276 Mpa)
Specific gravity	0.91 ± 0.04
Minimum melting point	320 ºF (160 ºC)

Materials should be combined so the fibers are a minimum of 7.0 percent by total weight of the asphalt binder, and the combined materials are according to the specifications listed in table 9.

Table 9. Type III mixture specifications.

Property	Limit
Strength (at break) at 72 ºF (22 ºC)	350 psi (2.4 Mpa) min.
at 0 ºF (-18 ºC)	500 psi (3.5 Mpa) min.
Elongation (at break) at 72 ºF (22 ºC)	50 percent min.
at 0 ºF (-18 ºC)	20 percent min.

Type IV – Prepackaged, preapproved mixture of modified binder meeting the properties in table 10 and minimum 2.0 percent polyester fibers (must meet requirements for Type II polyester fibers and both fiber and manufacturer must be on the Department's QPL). Table 10 summarizes the properties of modified binder for Type IV sealant, and the material properties of the sealant materials after fiber addition.

Table 10. Type IV material specifications.

Property	Limit
Modified Binder	
Cone penetration, 77 ºF (25 ºC)	50-90
Flow, 140 ºF (60 ºC)	1.0 cm max
Resilience, 77 ºF (25 ºC)	25-60 percent
Ductility, 77 ºF (25 ºC)	40 cm min.
Bond, 0 ºF (-18 ºC), 100 percent ext. Pass	5 cycles
Impact, 0 ºF (-18 ºC)	Pass
Compression recovery	0.40 min.
Recommended pour temperature	380 ºF (193 ºC)
Safe heating temperature	410 ºF (210 ºC)
Fibers	
Safe heating temperature	400 ºF (204 ºC)
Softening point	190 ºF (88 ºC)
Viscosity, 400 ºF (225 0C)	3000 cp min.
Cone penetration, 77 ºF (25 ºC)	25-45
Workability	Workability - Capable of being melted and applied through a pressure feed, indirectly heated, and agitated melter
Flexibility – 1 in (25mm) sample at -20 ºF (-30 ºC), 90 degree bend, 10 sec	Pass

Treatment Life

Factors that affect the treatment life of joint sealing include the joint distress severity prior to treatment, construction quality, material selection, and the condition of the pavement adjacent to the longitudinal joint. Prior to sealant being applied, it is imperative that any incompressible material or dust be removed from the crevice. Debris or dust can inhibit the bond forming adequately between the sealant and the crack wall leading to the sealant being pulled away from one or both sides. In some cases, the wrong type of sealant material may have been called for. Fiber-modified Type II or III sealants, as defined in ODOT specifications, have very high viscosities and may be better suited for filling crack openings wider than 0.75 inches. Although they are flexible and exhibit elasticity, they may not thoroughly penetrate low to medium

severity cracks. Distress observed in the crack sealing repairs include deterioration of the sealant material, absence of the sealant material entirely, slight mounding of the sealant material, and secondary cracking in the adjacent pavement near the joint. Generally, crack sealant is expected to perform for 2 to 6 years assuming good quality installation, low percentage of crack deterioration, and low crack movement. Life expectancy for ODOT LJ treatment is discussed in more detail later in this chapter.

Treatment Cost

In deriving the treatment costs for crack sealing, bid files and final pay estimates were reviewed. One contract was bid with the understanding that the entire pavement area would define the area of acceptance, and the contractor was required to bid his estimate of what percentage of that area would actually be crack sealed. For Work Order 5558425, the entire length of the project was assumed to be exclusively LJ sealing. For PID 91831, only the LJ sealing item was included as the accomplishment of work. Incidental costs (or their pro rata share)—including pavement marking, MOT, labor, and mobilization—were summed and included as the cost of conducting the work. Assumptions were required to determine a reasonable treatment area within the work orders. Each contract included variations in crack sealing quantities, materials, and whether the materials were placed by in-house or contractor personnel. Using three evaluated cost records, the research team elected to use the arithmetic average for crack sealing cost per square yard for comparison with slot paving and spray injection.

Cost Analysis

Work order summaries were analyzed to obtain average costs per mile, per square yard, and per square foot for each of the repairs. Work orders from ODOT maintenance staff and construction contract summaries were both evaluated for each treatment. Table 11 presents project summary costs. In order to obtain comparable quantities for each treatment type, the following assumptions were made:

- Project lengths from work orders were assumed accurate and used in the calculations as the treatment length for slot repairs and spray injection.
- The cost per mile of slot paving are normalized to a 3-foot wide slot installed.
- Costs includes all work order costs including pavement markings, MOT, and applicable contract adjustments.
- The total area of spray injection work was calculated based on the average width of the patch (e.g. patches ranging in width from 8 to 12 inches throughout a section were calculated as 10 inches wide).
- The total area of work for crack sealing was calculated as 1 foot wide (band plus sealed crack). Project 91831 is the 2017 crack sealing project bid and separates the items for LJ sealing from other crack sealing work.
- In Work Order No. 130334 the entire pavement was quantified for crack sealing. The contractor was only required to seal the cracks that exceeded the minimum threshold of 0.25 inch wide. In order to estimate a quantity for crack sealing area, 8 percent of the pavement area (assuming 1-foot width) was assumed to be crack sealing. This value was used to compare the cost per square yard with slot paving and spray injection.

- Work Order No. 160179 included two pavement repair items with a higher cost and different units (cubic yards) than the partial depth repair items. These items were excluded from the cost analysis to avoid inclusion of treatments different than the unit of study.

Table 11. Project cost summaries for each treatment.

Project / Work Order No.	Total Project Cost $	Total Area of Work [ft^2]	Cost per Mile	Cost per Yd^2	Cost per Ft^2
Slot Paving					
140176	$1,511,100.58	24,395	$109,021.95	$61.94	$6.88
150171	$1,540,889.69	21,278	$127,453.98	$72.42	$8.05
160232	$2,334,788.57	20,975	$195,913.55	$111.31	$12.37
160179	$371,391.19	68,644	$85,700	$48.69	$5.41
130230	$2,418,817.20	46,011	$92,524.33	$52.57	$5.84
120407	$7,356,532.83	195,379	$66,268.77	$37.65	$4.18
140229	$669,388.85	21,670	$54,367.84	$30.89	$3.43
Average	**$2,314,701.27**	**56,907.43**	**$104,464.35**	**$59.35**	**$6.59**
Spray Injection					
I-270 (NB)	$8,183	11,440	$3,776.8	$6.44	$0.72
I-270 (EB)	$51,586	15,417	$17,666.6	$30.11	$3.35
US 23 (SB)	$8,349	7,040	$6,261.9	$10.67	$1.19
I-77	$7,611	16,685	$2,408	$4.11	$0.46
4953554	$4,232	810	$27,598.5	$47.04	$5.23
4997960	$3,774	1,056	$18,870.5	$32.17	$3.57
Average	**$13,955.83**	**8,741.33**	**$12,763.72**	**$21.76**	**$2.42**
Crack Sealing					
5558425	$25,259.88	25,872	$5,155.08	$8.79	$0.98
130334	$393,204.50	794,897	$2,611.81	$4.45	$0.49
91831	$295,812.39	672,939	$2,321.00	$3.96	$0.44
Average	**$238,092.26**	**497,902.67**	**$3,362.63**	**$5.73**	**$0.64**

The variation of costs per mile for evaluated projects and treatment type are shown in figure 10. Slot paving cost variations may reflect the adjustment over the years to decrease the width of typical slot paving treatments from greater than 4 feet to 2 feet.

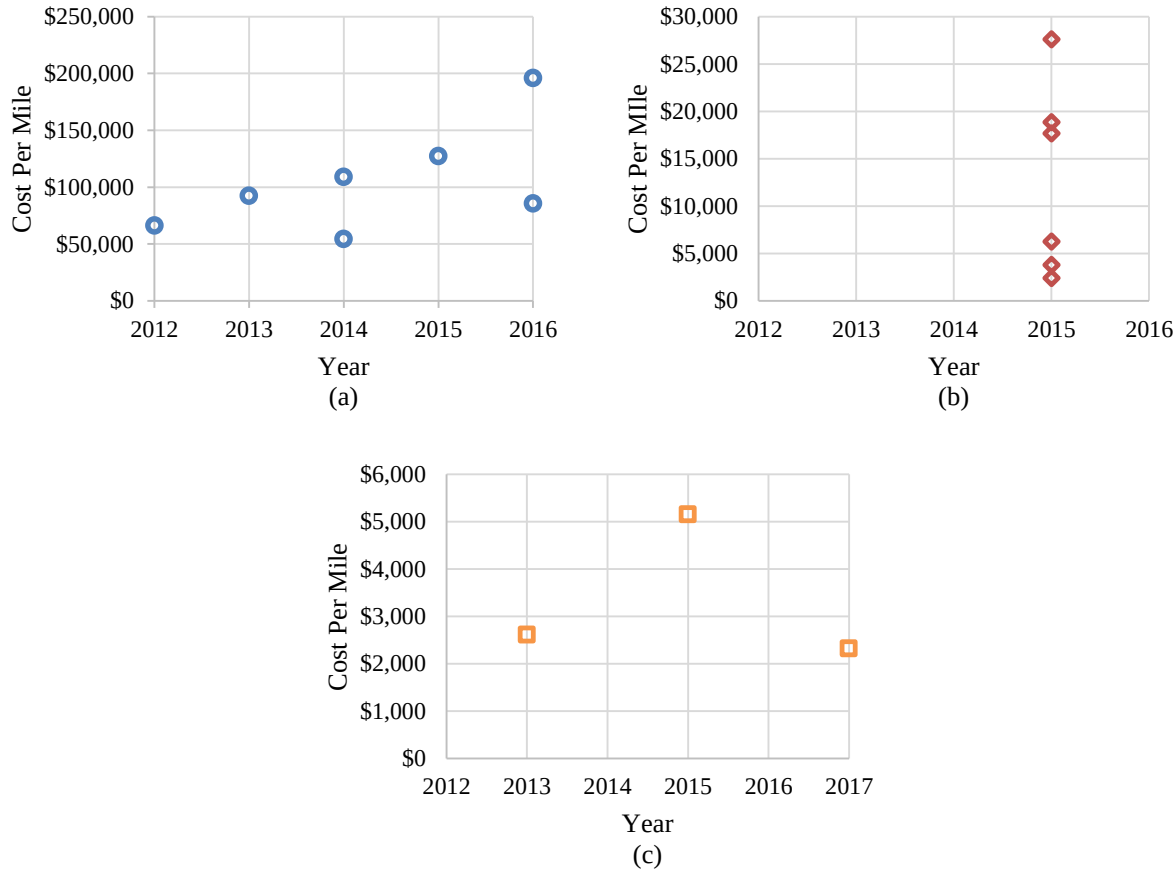

Figure 10. Variation in Cost per Mile for (a) slot paving, (b), spray injection, and (c), crack sealing.

Performance Modeling

Data modeling allows a visual perspective of each treatment's performance and allows comparison for a benefit-cost analysis. To compare treatment performance, it is necessary to evaluate all treatments under similar rating conditions. Although this is possible for slot paving and spray injection, crack sealing is a different treatment and required different rating conditions. To develop the rating system, terminology similar to that found in *ASTM D6433 Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys* (ASTM 2011) was used.

A 1-to-5 index was developed, combining distresses into one index value representative of the overall condition of the repair, with 5 being a repair in pristine condition and 1 identifying a treatment failure. As mentioned before, slot paving and spray injection have similar performance conditions so a single rating was used, while a separate rating was developed for crack sealing. Table 12 summarizes the rating scale.

Table 12. Rating scale used to evaluate field sections.

Rating	Description
Slot Paving / Spray Injection	
5	• New repair. • Repair is in good condition with only minor surface wear and no visible cracking. • Perimeter seal in excellent condition.
4	• Minor low severity secondary cracking near joint. • Minor amount of aggregate beginning to show through the AC band. • Minor rutting due to sloping of roadway.
3	• Cracking occurring at edge of repair. • Secondary cracking in the non-repaired area. • Low rutting or mounding of the repair. • Moderate wearing and exposed aggregate in the patched area. • Perimeter seal has worn off.
2	• Cracking occurring in the repair area. • Significant rutting of the repair. • Opening of the joint between the repaired and non-repaired area. • Reflection of the patched joint.
1	• Significant separation at the edges of the repair. • Highly deteriorated and distressed repair (rutting, cracking, weathering, raveling).
Crack Sealing	
5	• New crack sealant. • No loss of adhesion, cohesion, resilience, durability, or extensibility.
4	• Wearing of the sealant overband, but crack is still sealed. • Minor areas where crack has begun to show.
3	• Appearance of secondary cracking. • Crack has begun to show. • Some missing material.
2	• Significant cracking showing through the sealant. • Significant amount of sealant material missing. • Significant amounts of secondary cracking. • Mounding of the crack sealant material.
1	• Crack sealant no longer present. • 100 percent of the crack has reflected through the sealant.

Based on each field inspection a rating was given to every repair, each condition was plotted as a function of age, and a polynomial fit for these condition versus age curves was developed. The best fit models are illustrated in figure 11 with the treatment data points and the equations are listed in table 13.

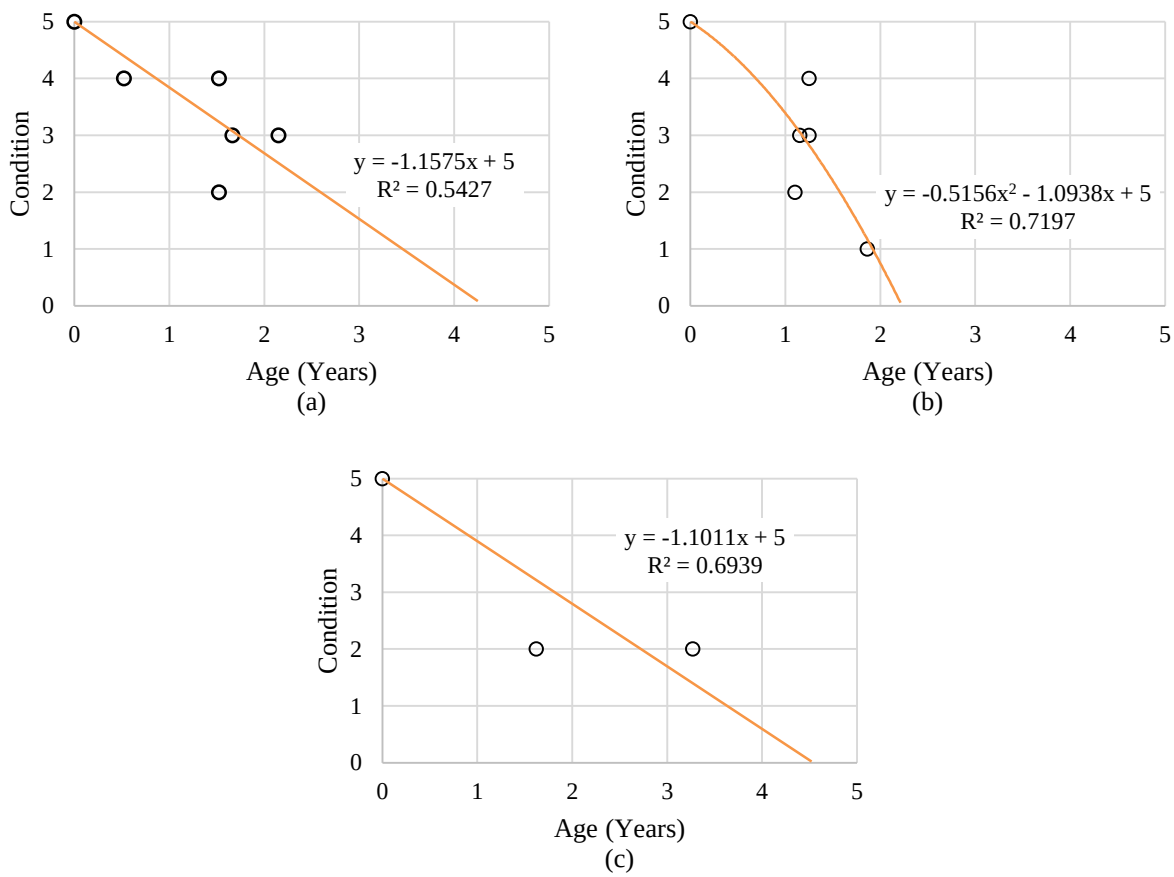

Figure 11. Performance models for (a) slot paving, (b) spray injection, and (c) crack sealing.

Table 13. Estimated LJ treatment life.

Repair	Model	Treatment Life in Years
Slot paving	Condition = -1.1575*(Age) + 5	4.3
Spray injection	Condition = -0.5156*$(Age)^2$ - 1.0938*(Age) + 5	2.2
Crack sealing	Condition = -1.1011x + 5	4.5

It is noteworthy that the pre-treatment condition has a direct effect on the performance of each individual treatment. ODOT has installed each treatment in areas believed suitable for the treatment. For instance, comparing crack sealing to spray injection, crack sealing has typically been installed where the severity of the LJ cracking is less. Similarly, comparing spray injection to slot paving, spray injection has been placed where there is lower severity deterioration. Performance measured under this study uses those pre-existing conditions as a base assumption for concluding the relative performance of each treatment. Going forward and selecting treatments, it is highly recommended that ODOT staff assess the condition of the joint and determine the proper treatment based on the treatment selection recommendations.

Life-cycle Cost Effectiveness

Based on the data provided by ODOT and the records retrieved to-date, the cost effectiveness of the treatments can be summarized in table 14.

Table 14. Cost effectiveness evaluation of LJ repair techniques.

Repair	Treatment Life, Years	Cost per mile, $	Cost per mile per year, $
Slot paving	4.3	$104,464.35	$24,294.03
Spray injection	2.2	$12,763.72	$5,801.69
Crack sealing	4.5	$3,362.63	$747.25

Based on this review, slot paving is four times more costly per year for treating LJs than spray injection and crack sealing is one-eighth the cost per year of spray injection. Reviewing the typical uses of each treatment previously, each treatment type has a place in the ODOT maintenance toolbox. Crack sealing should be used as a treatment until it is no longer appropriate or effective. This typically means that the crack is too wide and too deep for sealing to be effective, and there is secondary cracking and possibly breakdown of the crack. As deterioration of LJs continue, spray injection can be applied to the point where high severity joint deterioration has occurred. Slot paving remains the last resort treatment and with it comes the highest unit costs.

Additional Factors

The research team also considered how use of the treatments might be considered differently with respect to maintenance of traffic, pavement age, and traffic loading. MOT is completed similarly for each treatment. Because the repair area is between two adjacent travel lanes, installation occurs with both lanes closed. On major arterials and freeways, the treatments are most often performed at night or during off-peak hours. Production, defined as miles repaired during a nightly lane closure, may vary between the treatments, but the costs for MOT have been included in the production costs. Therefore, any differences in production rates for the treatments have been included in their related MOT costs and included in the average costs.

Pavement age is related to treatment timing in the same way that increasing severity and extent of distresses trigger treatments. In choosing the most appropriate treatment, the type and severity of distress and the treatment cost should be considered as well as the expected time that the treatment will remain in-service.

Strategies have long been considered during project design to place construction joints outside of wheelpaths. ODOT recommends staggering construction joints laterally for each subsequent HMA lift to not align them vertically. Inevitably, however, some construction joints fall in wheelpaths due to staged construction, shifting lanes, and roadway widening projects. Considering loading conditions along the repaired joint, it is undesirable for each treatment type. Traffic may assist in compacting the spray injection and slot paving materials, but any raveling the treatment may have exhibited will likely be accelerated by wheelpath loading. Some patch distress was noted in the slot paving section at site 4 where wheelpath loading was occurring, but the amount of additional distress could not be determined. Nonetheless, it is likely that the treatment life will be reduced as a result of wheel path loading.

CHAPTER 3. BEST PRACTICES IN LJ REPAIR IDENTIFIED THROUGH LITERATURE AND SHA SURVEY

Like Ohio, other states have adopted aggressive construction and repair strategies to improve longitudinal joint performance on HMA pavements. This section summarizes practices found either in specification review or in discussions with state DOT officials from the representative states.

Illinois

Micro surfacing has become an accepted repair technique for longitudinal joint repair in Illinois. As shown in figure 12, the micro surfacing is typically applied to the 18 inches centered on the joint. The repair technique requires removal of raised pavement markings and thermoplastic prior to application. If the joint has significant deterioration, a two-lift micro surfacing is used with the first layer of materials being applied only within the deteriorated joint, and the second layer extending 9 inches on each side. The treatment also requires re-installing striping and grooves for RPMs. The prices are typically higher for first projects, but the price is expected to fall as the required equipment is purchased by more contractors.

Figure 12. Micro surface seal applied over a LJ in Illinois (Illinois DOT).

As shown in figure 13, Illinois DOT has also implemented a “J-band” seal applied at the joint during a resurfacing project prior to overlay. The seal material is highly polymerized PG 64-22, which meets a PG 82-22 asphalt binder, and is sprayed directly over two adjacent paved lanes using a distributor truck. This material has experienced success in sealing longitudinal

construction joints by working up into the voids of a lower density joint. The material temperature near 350°F cools rapidly to prevent tracking the material in subsequent operations.

Figure 13. PG 82-22 used as LJ seal between paving lifts (Illinois DOT).

Washington

The Washington State DOT implemented the notched wedge joint construction practice in approximately 2007, in addition to applying bituminous sealing material to the vertical joint faces prior to placing the matching HMA lift. These practices have reportedly solved their longitudinal joint deterioration issues seen until the construction detail was changed. One measure leading to this application success is the HMA lift thickness typically applied in the surface course. WSDOT typically places a 0.5 inch nominal maximum aggregates size (NMAS) as a 1.8 inch layer, which is a 3.6:1 ratio. Thicker HMA lifts hold their compaction temperature longer, which helps to achieve a higher relative density and lower permeability.

West Virginia

Like Illinois, West Virginia DOT has used micro surface as a preventive maintenance treatment for LJ distress. Travis Walbeck, WVDOT State Pavement Engineer, plans further use of the treatment after having completed two successful applications since 2015. In one section, the treatment was placed on medium severity cracks with secondary cracking and some of the cracks reflected through within a year. However, when the distress severity is low, the treatment has shown promise. Figure 14 illustrates the WVDOT use of the product 4 months after placement on I 64 near Dunbar.

Figure 14. Micro surfacing placed over two adjacent LJs on I 64 near Dunbar (WVDOT).

Indiana

The Indiana DOT has not pursued a longitudinal joint density specification, but has instead opted for a prescriptive application of a joint adhesive material onto the unconfined edges of the surface course and onto the top lift of the intermediate course for bonding with the follow-on adjacent lane; this approach was intended to address durability of the longitudinal joint. The final process is to apply an emulsion as a joint sealant (fog seal) spanning 12 inches on either side of the longitudinal joint for only the surface course; this approach was intended to address permeability of the longitudinal joint.

Michael Prather was charged with improving the performance of HMA longitudinal joints in 2008 and by 2009 he had arranged for the first installation of the joint adhesive and joint sealant materials with full implementation occurring in 2012. Efforts to implement a longitudinal joint

density specification have been rebuffed because it was recognized that any failed attempts to achieve density constructed under a joint density specification would still leave a poor performing joint. Looking at a more reliable solution, Indiana took the approach of applying the maintenance solution while under initial construction.

Massachusetts

According to Akosua A. Yeboah, the Massachusetts DOT (MassDOT) requires all longitudinal joints of the surface course and all longitudinal joints in the Dense Binder Course under Open Graded Friction Course or Open Graded Friction Course-Modified be coated with a hot poured rubberized asphalt sealant prior to laying the next lane of hot mix asphalt. When using pavers in tandem, the use of the hot poured rubberized asphalt sealer may be omitted at the discretion of the Engineer, if the temperature of the mixture at the longitudinal joint does not fall below 200°F (95°C) prior to the placement of the adjacent mat. The nozzle of the applicator shall be set to deliver sufficient sealant to effectively bond and seal the longitudinal paving joint between two adjacent lanes of HMA. MassDOT specs require longitudinal and transverse joints be made in a careful manner, well bonded and sealed, and true to line and grade.

Connecticut

Connecticut DOT specifies longitudinal joint construction methods requiring the contractor use Method I- Notched Wedge Joint (see figure 15) when constructing longitudinal joints where lift thicknesses are between 1½ and 3 inches. Method II Butt Joint (see figure 16) is used for lifts less than 1½ inches or greater than or equal to 3 inches. During placement of multiple lifts, the longitudinal joint shall be constructed in such a manner that it is located at least 6 inches from the joint in the lift immediately below. The joint in the final lift is constructed at the centerline or at lane lines. Each longitudinal joint maintains a consistent offset from the centerline of the roadway along its entire length. The difference in elevation between the two faces of any completed longitudinal joint is not to exceed 0.25 inch in any location.

Method I - Notched Wedge Joint:

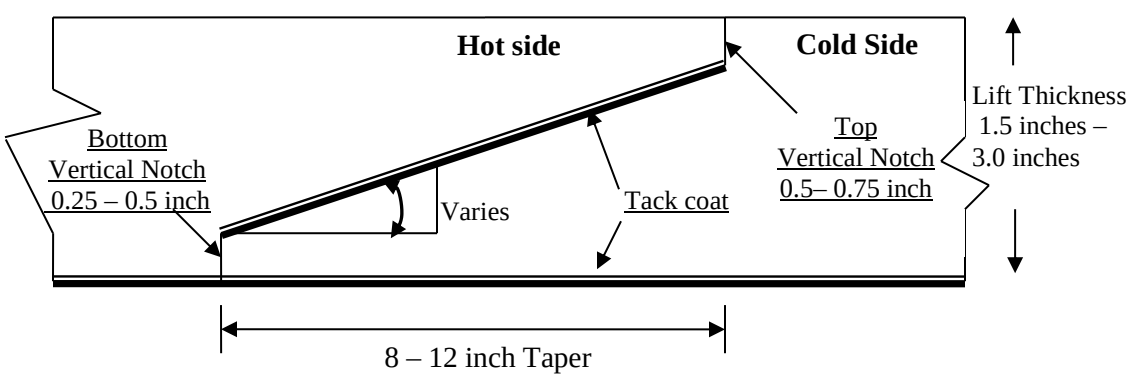

Figure 15. Notched wedge joint.

A notched wedge joint is constructed as shown in figure 15 using a device that is attached to the paver screed and is capable of independently adjusting the top and bottom vertical notches. The device is required to have an integrated vibratory system. The taper portion of the wedge joint

must be placed over the longitudinal joint in the lift immediately below. The top vertical notch must be located at the centerline or lane line in the final lift. The taper portion of the wedge joint is required to be evenly compacted using equipment other than the paver or notch wedge joint device, and the taper portion of the wedge joint should not be exposed to traffic for more than 5 calendar days. If Method I, Notched Wedge Joint cannot be used on lifts between 1.5 and 3 inches, Method II Butt Joint may be substituted (see figure 16).

Method II - Butt Joint:

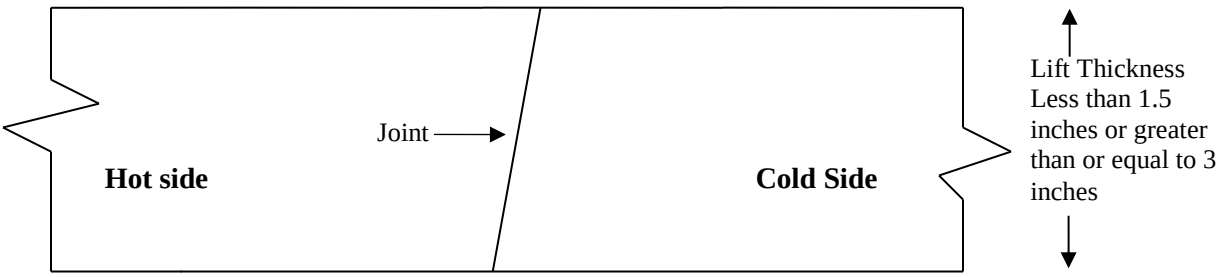

Figure 16: Butt joint.

When adjoining passes are placed, the contractor must utilize equipment that creates a near vertical edge (refer to Figure 16). The completing pass (hot side) must have sufficient mixture so that the compacted thickness is not less than the previous pass (cold side). The end gate on the paver should be set so there is an overlap onto the cold side of the joint.

Method III - Butt Joint with Hot Poured Rubberized Asphalt Treatment

If Method I Wedge Joint cannot be used due to physical constraints in certain limited locations; the contractor may submit a request to utilize Method III Butt Joint (see figure 17) as a substitution in those locations.

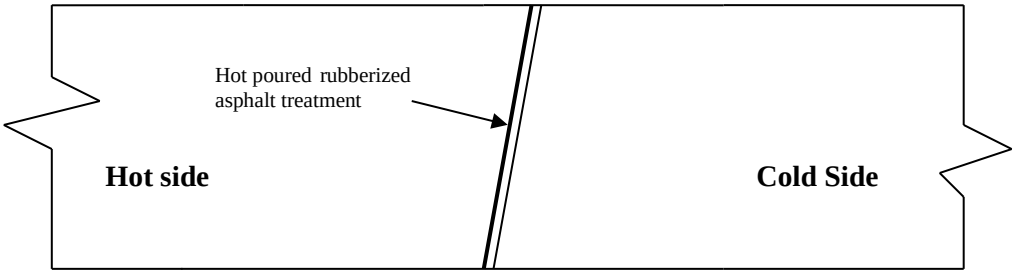

Figure 17. Butt joint with hot-poured rubberized asphalt treatment.

All of the requirements of Method II must be met with Method III. In addition, the longitudinal vertical edge must be treated with a rubberized joint seal material meeting the requirements of ASTM D 6690, Type 2. The joint sealant is placed on the face of the "cold side" of the butt joint as shown above prior to placing the "hot side" of the butt joint. The joint seal material shall be applied in accordance with the manufacturer's recommendation so as to provide a uniform coverage and avoid excess bleeding onto the newly placed pavement.

Tennessee

The Tennessee DOT implemented joint density specifications during construction to improve contractor efforts to obtain compaction there. Previously, standard specifications had exempted an area within 2 feet of a joint from normal nuclear density testing. The agency noticed a tendency for the areas around joints to fail prematurely, leading to measuring density at the joint for information purposes. As construction staff began to recognize joint density as an issue, joint densities improved. Contractors use practices such as assuring adequate materials were placed to achieve density within roll-down dimensions and optimizing roller combinations and patterns to achieve higher joint density. A pneumatic-tired roller has been effective in increasing joint density.

Tennessee has also used a type of slot paving in addressing LJ deterioration. Prior to resurfacing in Hickman County on I 40, an 8-foot slot centered on the previous LJ was milled 3.5 inches deep and replaced with structural HMA mix including Performance Graded (PG) 76-22 asphalt binder. The joint damage was viewed as high severity longitudinal cracking and had been patched with cold patch and HMA in numerous instances.

Minnesota

Jerry Geib from the Minnesota DOT reported that they prefer treating LJ with micro surface as a preventive maintenance and repair treatment. From a cost standpoint, it is much cheaper to place micro surface compared to slot paving, and the treatment can be repeated after deterioration and remain a cost effective repair. The work is typically performed during an off-peak closure of two lanes of traffic.

North Dakota

Stephanie Weigel from NDDOT reported not having an ideal solution for LJ distress; however, they have pursued using the Minimac (http://www.slurry.com/index.php/slurry-seal-and-microsurfacing-equipment/minimac), as depicted in figure 18, to place micro surface in transverse joints. The Minimac may provide an option for placing a narrow area seal on the distressed joint, using smaller equipment than required for high production typically used to apply the treatment on a full lane. The VSS Minimac is an example of a small slurry micro surfacing machine designed to operate effectively in confined areas like parking lots, garage structures, footpaths, walkways, and bicycle trails. It could likely place up to 0.5-mile sections of LJ repair without stopping to refill materials. (VSS 2017)

Figure 18. VSS Minimac slurry micro surface machine. (VSS 2017)

Alberta and British Columbia

Alberta uses vendors to implement their maintenance program. Their procedures provide for using spray injection as a LJ distress treatment, and provide a construction specification for implementing the treatment. Alberta requires a similar size stone be used as the aggregate with most of the material retained between the #4 and #8 sieve, and a high-float medium to rapid set emulsion. Alberta specifies a softer base asphalt since their climate is significantly colder than Ohio's. (Alberta, 2010)

Similarly, the British Columbia Ministry of Transportation and Infrastructure permits using spray injection for small potholes and for cracks larger than 25 mm wide. (MOTI 2016) Spray injection is listed as a possible treatment for longitudinal cracking associated with poor joint construction.

The findings of the literature review and SHA surveys for best practices in LJ construction, LJ distress prevention, and LJ repairs are summarized in table 15.

Table 15. Longitudinal joint best practices for construction, distress prevention, and repair.

State	LJ Best Practices
Illinois	• Micro surfacing: typically applied to the 18 inches centered on the joint. The repair technique requires removing or covering raised pavement markings and thermoplastic prior to application. If the joint has significant deterioration, a two-lift micro surfacing is used with the first layer of materials being applied only within the deteriorated joint, and the second layer extending 9 inches on each side. • Seal applied at the joint during resurfacing projects prior to overlays. The seal material is polymer modified PG 82-22 asphalt binder, and is sprayed directly over two adjacent paved lanes using a distributor truck.

State	LJ Best Practices
Washington	• Notched wedge joint construction practice in addition to applying bituminous sealing material to the vertical joint faces prior to placing the matching HMA lift. Typically, a 0.5-inch nominal maximum aggregates size is used in a 1.8-inch layer.
West Virginia	• Micro surfacing is used as a stop gap measure to slow the rate of LJ deterioration. It is typically placed as an 18-24 inch area seal centered on the LJ.
Indiana	• Application of a joint adhesive material onto the unconfined edges of the surface course and onto the top lift of the intermediate course for bonding with the follow-on adjacent lane. The final process is to apply an emulsion as a joint sealant (fog seal) spanning 12 inches on either side of the longitudinal joint for just the surface course.
Massachusetts	• All longitudinal joints must be coated with a hot poured rubberized asphalt sealant prior to laying the next lane of hot mix asphalt.
Connecticut	• Method I - Notched Wedge Joint • Method II - Butt Joint • Method III- Butt Joint with Hot Poured Rubberized Asphalt Treatment
Tennessee	• Joint density specifications during construction to improve contractor efforts to obtain compaction there. • Slot paving.
Minnesota	• Micro surfacing
North Dakota	• Minimac: placing a narrow area seal on the distressed joint. The VSS Minimac is a small slurry micro surfacing machine designed to operate effectively in confined areas.
Alberta and British Columbia	• Alberta uses spray injection as a LJ distress treatment, and provide a construction specification for implementing the treatment. A similar size stone is to be used as the aggregate with most of the material retained between the #4 and #8 sieve, and a high-float medium to rapid set emulsion. • British Columbia Ministry of Transportation and Infrastructure uses spray injection for small potholes, cracks larger than 25 mm wide, or longitudinal cracking associated with poor joint construction.

CHAPTER 4. CONSTRUCTION SPECIFICATIONS

In order to document longitudinal joint best practices, a review of applicable ODOT specifications and policies was conducted. The review covered requirements for longitudinal joint construction, slot paving, crack filling, and spray injection. Based on the review, suggested revisions to related specifications are considered in this chapter.

LJ Construction

As noted previously, for a long time the practice has been to not measure density on HMA paving jobs within 2 ft of the longitudinal paving joint. It is believed that practice has led to lower densities at these joints and many of the subsequent performance problems. ODOT has adopted a construction joint density specification that requires cores to be taken at the joint and density measured for project acceptance. Item 446 *Asphalt Concrete Core Density Acceptance*, as referenced within ODOT-specified items, refers to the requirement that cores for density acceptance should include 30 percent of the cores from the longitudinal joint. The specification also makes reference to testing conditions where the notched-wedge joint installation is used to construct less permeable pavement adjacent to joints. Although not required on every project, ODOT expects these practices to improve performance at construction joints in the future. Additionally, ODOT has begun to experiment with a sprayed sealer below the longitudinal joint that is believed to seal the pavement from the bottom up and minimize the amount of infiltration and oxidation that occurs at the pavement edges.

Slot Paving

The ODOT Construction and Material Specifications (ODOT 2016) *Item 251 Partial Depth Pavement Repair* has been used as the basis for slot paving repairs. *Item 251* provides requirements for material removal, surface preparation, HMA placement, and compaction with a pneumatic-tired roller. Special notes in the plan set have complemented the standard specifications to outline repair material requirements, dimensions, and bid quantities, and to provide for some contingencies which may be used by the contract administration staff during construction. The description for 2-foot width by 2-inch depth, the most commonly used slot paving treatment in 2015, is shown in figure 19. (ODOT 2015)

Item 442-Asphalt Concrete Surface Course, 12.5 mm Type A (448) is called for in the plans as the paving material to fill the slot. This denotes that a Superpave 12.5 mm dense graded HMA is required. The Type A mix design denotes that 100 percent of the coarse aggregate have 2 fractured faces. The asphalt binder used in this item is a Performance Graded (PG) 70-22M with polymer modification. The item denotes density acceptance by *Item 448-Asphalt Concrete Acceptance* which requires the contractor to conduct density gauge testing as a part of the quality control system. However, ODOT staff stated that the slot paving nightly production usually falls into the “low quantity” category exempting density measurement requirements.

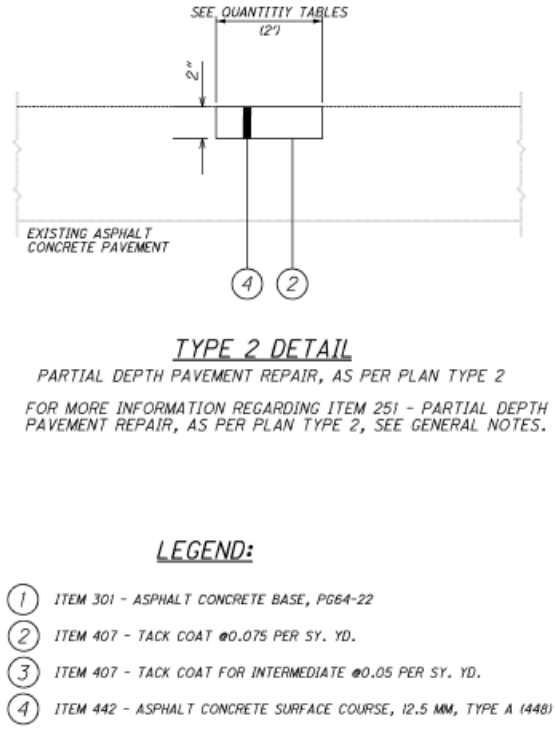

Figure 19. Typical profile description for slot paving types (ODOT 2015).

Figure 20 depicts the special notes that accompany the 2-foot width by 2-inch depth slot paving item. Drawings shown in figure 19 and notes in figure 20, along with standard specification language in Items 251, 442, 448, and 702, contain the requirements for slot paving.

ITEM 251 - PARTIAL DEPTH PAVEMENT REPAIR, A.P.P., TYPE 2:
ALL AREAS TO BE REPAIRED SHALL BE LOCATED BY THE ENGINEER. THE REPAIR AREAS SHALL BE OF VARYING LENGTH AND HAVE A CONSISTANT WIDTH OF 2 FEET. THE DEPTH OF REPAIRS SHALL BE 2 INCHES AS DETAILED ON SHEET 6. ALL AREAS SHALL BE REFILLED WITH 2 INCHES OF ITEM 442 - ASPHALT CONCRETE SURFACE COURSE, 12.5 MM, TYPE A (448). GREAT CARE SHALL BE TAKEN TO MAINTAIN THE EXISTING PAVEMENT CROSS-SLOPE (CROWN) AS WELL AS ALL LONGITUDINAL SLOPES. NO MORE PARTIAL DEPTH PAVEMENT REPAIR SHALL BE STARTED AND PERFORMED THAN CAN BE COMPLETED IN THE SAME WORKING DAY.

Figure 20. Slot paving general notes (ODOT 2015).

As outlined in Chapter 2, the dimensions for slot paving have varied through the years to address different levels of LJ distress. No documentation has been presented that summarizes the dimension selection process used by the slot paving project designers to assign the different types of slot paving to different highway sites. It is supposed that engineering judgment is exercised to apply the appropriate repair technique for each site. Sections of highway exhibiting more significant LJ distress including additional distresses and increasing severity within the paved lanes would have necessitated the removal and replacement of wider slots of material than sections with less severe LJ distress.

Designers have also attempted to develop different repair geometries based on the type of pavement being repaired. Plans identify a repair geometry for asphalt overlays on concrete pavements that includes a 3-feet wide by 3-inch deep slot. This repair technique implies that designers are trying to determine whether the LJ distress is being caused by a reflecting joint from the concrete pavement, a reflecting joint on a full depth HMA pavement, or a general LJ distress caused by density deficiencies around the pavement joint. Slot paving may be best suited to correcting LJ joint distress caused by construction density deficiencies and less suited to mitigating reflection cracking from joints beneath the slots. For instance, if a joint beneath the slot paving section continues to experience deflection or movement, the joint will naturally reflect through the overlaid slot and reappear within a few years. In these cases, it will likely be necessary to stabilize the underlying joint or reestablish load transfer across the joint to provide a long-term repair for the surface.

Future slot paving projects should also consider the locations of wheel paths when sizing slot dimensions and include density requirements for the slot repairs.

Slot Dimensions

Slot paving repairs eliminate a defective LJ, but also create two "new" LJs in the pavement. Placing slot paving repairs in wheel paths exposes the "new" LJ constructed between the patch and the existing pavement to traffic loads. Assuming LJs are on the edges of 12-ft lanes and the wheel paths are 100 inches apart equally centered on the lane, the dimension between the LJ and the wheel path edge would be a maximum of 22 inches. If each wheel path is 2 feet wide, slot paving repairs between 4- and 8-foot widths place the LJ of the patch in the wheel path.

Slot sizing may result in inefficiencies because proper patching requires the deficient materials be removed. If the deficient materials are not removed, the patch will be weak in that area, and will likely fail prematurely. ODOT has minimized the removal of sound material in the past by changing slot widths for each pavement section length and caused the contractors to modify their equipment setup and re-establish the milling, paving, and compaction routine.

Assuming slot paving is conducted to correct areas of poor LJ construction, it is recommended to remove and replace 18 inches on each side of the LJ. This recommendation results in cutting a 3-foot slot and allows for a 3-inch maximum depth while keeping the "new" LJs a few inches away from the wheel paths. The repairs should be triggered when deterioration from the LJ has extended not more than 12 inches from the joint. A 3-foot slot width should provide enough opening for small rollers to be used inside the slot to achieve compaction.

Density Requirements

Density requirements should be considered for slot paving repairs. Contractors have resisted density requirements due to the variability in the repair lengths and widths and the claim that the frequent equipment setup reduces the consistency of the process required to achieve consistent high density. ODOT may consider applying one of the following options to slot paving contracts.

1. Establish the project length and slot width and depth so that only one equipment mobilization is required to complete the slot paving. In essence, the milling and paving equipment could move into a traffic control zone and complete the LJ repair without a

required stop or adjustment. Contracts of this type could encourage lower bid prices because the contractor would know production could proceed in a uniform manner. The process could be established and density measured using typical density requirements at the joint.

2. A method specification could be used when placing material with a berm box to control the amount of material that is placed and leveled above the normal plane of the pavement. Typically 0.25 inches per inch of mix is considered the roll-down value, but the assumption should be checked and calibrated for the test mixture. Rather than requiring a certain value for density, a density measurement device could be used to establish the maximum density that can be achieved with the placement technique and a standard roller pattern.

Compaction will occur in the slot paved patch, either as it is constructed or once traffic is released. Therefore, the patch should be constructed to achieve a similar compacted density as new pavement is required to achieve. The adjacent material has likely achieved its terminal density, so any additional consolidation that occurs in the patch will result in a slight depression or rut. Repairs observed during this study exhibited minor rutting within the patch for three out of five patches. Compaction should also be considered when sizing the slot width. Steel wheel rollers as narrow as 34 inches wide could be used to compact inside a 3-foot wide slot. The use of rollers wider than the width of the slot shall not be permitted.

Spray Injection

Spray injection has been used as a partial depth pavement repair within ODOT performed by maintenance personnel without a standard or documented procedure. In cases where private contractors have performed the repair, the work has been negotiated under a construction change order with project-specific requirements. Under this research project, a draft specification was developed for the spray injection process. It includes several sections that cover the materials required for placement, surface preparation, weather limitations, and equipment requirements. The topics covered in the specification were largely described and reasoned in chapter 2 establishing the background for the treatment. Abbas et al. reported, after this project's initiation, pertinent descriptions of spray injection equipment typical within Ohio. (Abbas 2016) Each key sub-process is described to explore the various equipment types, equipment strengths, and applicability to local Ohio materials. The previous project report was used as background in developing the necessary requirements for a standard ODOT specification. The goal in writing the specification was not to be unnecessarily prescriptive, but to outline methods having shown success internally and by contractors during the recent past. To provide a wide range of acceptable equipment for use by ODOT, table 16 was developed to summarize available spray injection equipment capabilities and compare similarities.

Table 16. Spray injection equipment comparison.

Brand	Equipment Name	Type	Crew Size	Emulsion Tank Size, gal (L)	Emulsion Tank Working Pressure, psi, (MPa)	Aggregate Hopper Size, yd^3 (m^3)	Max Aggregate Size, inch (mm)	Air Flow Rate, ft^3/min (m^3/min)	Patching Material Rate, lbs/min (kg/min)
Cimline	DuraPatcher	Trailer Mounted	2	250 (946)	200 (1.4)	DTR	2.5 (62.5)	450 (12.7)	135 (61)
	DuraPatcher	Truck Mounted	2	250 (946)	200 (1.4)	7 (5.4)	2.5 (62.5)	450 (12.7)	135 (61)
	DuraMaxx	Man-Cab Operated	1	300 (1,100)	200 (1.4)	5 (3.8)	N/S	450 (12.7)	N/S
Vision Technologies Systems	Rosco RA-400	Trailer Mounted	2	300 (1,100)	N/S	DTR	N/S	876 (25.0)	N/S
	Rosco RA-400	Man-Cab Operated	1	300 (1,100)	N/S	5 (3.8)	0.75 (19)	850 (24.1)	N/S
Schwarze Industries	Spray Patcher Street Max	Trailer Mounted	2	300 (1,100)	70 (0.5)	0.07 (0.06)	0.375 (9.5)	670 (19)	125 (57)
	Spray Patcher Load King	Trailer Mounted	1	100 (380)	70 (0.5)	2.0 (1.5)	0.375 (9.5)	435 (12.3)	125 (57)
	Roadpatcher	Man-Cab Operated	1	300-400 (1,100)	70 (0.5)	6.5 (4.6)	N/S	435 (12.3)	N/S
Warren Power Attachments	Total Patcher T-7500	Trailer Mounted	2	250 (946)	200 (1.4)	DTR	2.5 (62.5)	450 (12.7)	125 (57)
Bergkamp, Inc	SPT Spray Injection Patcher	Trailer Mounted	2	260 (984)	N/S	DTR	N/S	N/S	N/S
	SP5-SP8	Man-Cab Operated	1	265-370 (1000-1400)	N/S	5–7.5 (3.8 – 5.7)	N/S	N/S	N/S
Patch Management, Inc.	Pothole Killer	Man-Cab Operated	1	N/S	N/S	N/S	N/S	N/S	N/S
Sherwin Industries, Inc. (Crafco)	Magnum	Trailer Mounted	2	250 (946)	N/S	DTR	N/S	486 (13.8)	N/S
	Airstream		1	250 (946)	N/S	4, 5 or 6.5 (3, 3.8, or 4.6)	N/S	546 (15.5)	175 (79)

Abbas et al. (2016) was also used as the primary information resource to specify spray injection materials. The asphalt emulsion and aggregate compatibility along with the ability of the asphalt emulsion to be applied without leading to equipment clogging seemed to be the most important material characteristics. Abbas et al. recommends using an emulsion with a maximum demulsibility of 70. ODOT should consider permitting or requiring that a medium or quick set emulsion be used in spray injection. The patch should cure quickly enough that traffic can be permitted on it within 20 minutes, but slow enough to allow patch construction without clogging the spray injection equipment. Desirable properties for a spray patch repair include the following:

- A durable patch capable of withstanding the pavement environment and traffic for 5 years or more.
- Cohesive bonds between the individual particles with minimal loose stones raveling from the patch after construction.
- Compacted, impermeable surface resistant to air and water.
- Stable material which adheres to the sides of the distressed LJ, but does not form bonds with vehicle tires.

CHAPTER 5. DECISION TREE FOR LJ REPAIR, PLAYBOOK, AND TREATMENT SELECTION TOOL

A process has been developed to assist in identifying LJ joint distressed pavement candidates that are best suited for each treatment type. ODOT distress definitions were reviewed, but revised definitions have been incorporated into the logic to reflect the specific needs for LJ distress. Table 17 contrasts the distress definitions for longitudinal cracking that were considered in developing distress severity statements for longitudinal joint distress.

Table 17. Comparison of longitudinal cracking distress definitions and severity levels.

Severity	FHWA Distress Identification Manual for the LTPP	ODOTs PCR Manual	ASTM D6433	ODOT Longitudinal Joint Repair Playbook
Low	A crack with a mean width ≤ 0.25 inch A sealed crack with sealant material in good condition and with a width that cannot be determined.	Single crack with width ≤ 0.25 inch and no spalling.	Non-filled longitudinal crack width ≤ 0.375 inch Filled crack of any width.	Non-filled longitudinal crack width ≤ 0.25 inch
Medium	Any crack with a mean width > 0.25 inch and ≤ 0.75 inch Any crack with a mean width ≤ 0.75 inch and adjacent to low severity random cracking.	Single or multiple cracking 0.25 inch – 1 inch wide with some spalling	Non-filled longitudinal crack width > 0.375 inch and ≤ 3 inch Non-filled longitudinal crack width is ≤ 3 inch surrounded by light random cracking. Filled crack is of any width surrounded by light random cracking.	Non-filled longitudinal crack width > 0.25 inch and ≤ 3 inches Non-filled longitudinal crack width is ≤ 3 inches surrounded by low severity random cracking. Filled crack where sealant is failed and surrounded by low severity random cracking.
High	Any crack with a mean width > 0.75 inch Any crack with a mean width ≤ 0.75 inch and adjacent to moderate to high severity random cracking.	Multiple cracking > 1 inch wide with much spalling.	Any crack filled or non-filled surrounded by medium or high severity random cracking. Non-filled crack > 3inches A crack of any width where approximately 4 inches of pavement around the crack is severely broken.	Non-filled or failed sealant longitudinal crack width is > 3 inches Filled or non-filled crack surrounded by medium or high severity random cracking. A crack of any width where approximately 4 inches of pavement around the crack is severely broken.

The following steps will assist in project selection:

- Identify that a LJ distress exists.
- Define the distress severity according to the crack width (L, M, or H).
- Identify other existing distress characteristics; i.e. failed crack filler, secondary cracks.
- Determine the distress extent within the section; i.e. occasional, frequent, and extensive.
- Select an economical treatment given the performance requirements and life expectation.

Table 18 identifies the severity levels describing LJ distress. Likewise, table 19 identifies the criteria to describe distress extent within a segment.

Table 18. LJ distress severity levels.

Severity Level	Letter Identifier	Description
Low	L	Non-filled longitudinal crack width is less than 0.25 inch
Medium	M	Non-filled longitudinal crack width is greater than 0.25 inch and less than 3 inches
		Non-filled longitudinal crack width is less than or equal to 3 inches surrounded by low severity random cracking (secondary cracking)
		Crack sealant is failed and surrounded by low severity random cracking (secondary cracking)
High	H	Non-filled longitudinal crack width is greater than 3 inches
		Filled or non-filled crack surrounded by medium or high severity random cracking (secondary cracking)
		A crack of any width where approximately 4 inches of pavement around the crack is severely broken.

Table 19. Distress extent definitions.

Extent	Letter Identifier	Description
Occasional	O	Less than 25 percent of the longitudinal joint* shows distress
Frequent	F	25-70 percent of the longitudinal joint* requires treatment
Extensive	E	Over 70 percent of the longitudinal joint* requires treatment

*Typically a 1-mile-long segment

Severity levels and distress extent definitions in tables 17 and 18 served as a basis for the development of the longitudinal joint repair decision trees. Based on the relative treatment cost discussed in chapter 2, crack filling and area sealing are the preferred treatments when low- to medium-severity LJ distress are present. Spray injection is recommended for medium to high-severity LJ distress, except where significant structural deterioration has occurred. The team evaluated the life expectancy for each treatment to determine to how to trigger treatments based

on when the next rehabilitation projects were expected to occur. Figures 21, 22, and 23 show the decision trees that were used to develop the agency's *LJ Repair Playbook* and LJ repair treatment selection tool. The Playbook is included as appendix C.

Given the increasing life cycle costs of crack sealing, spray injection, and slot paving respectively; crack sealing and spray patching should be used to treat low and medium severity LJ distress. Slot paving will be most beneficial on high severity LJ distress where at least 4 years of life remains in the adjacent pavement.

Based on documented success in other States, micro surfacing area seals are recommended for low- to medium-severity LJ distress where low-severity secondary cracking may have formed. The benefits for this type of area seal are the sealing capability with a minimal application thickness, and the limited width that should fall outside of the wheel paths of traffic. Micro surfacing can also be combined with crack filling for medium severity LJ distress to minimize reflective cracks forming in the micro surfacing. The resulting repair can be constructed to match the pavement surface elevation, creating a much smoother transition from one lane to the next. The construction joints for this treatment differ from slot paving because cold planing is not required prior to application of the seal and traditional longitudinal construction joints are not formed.

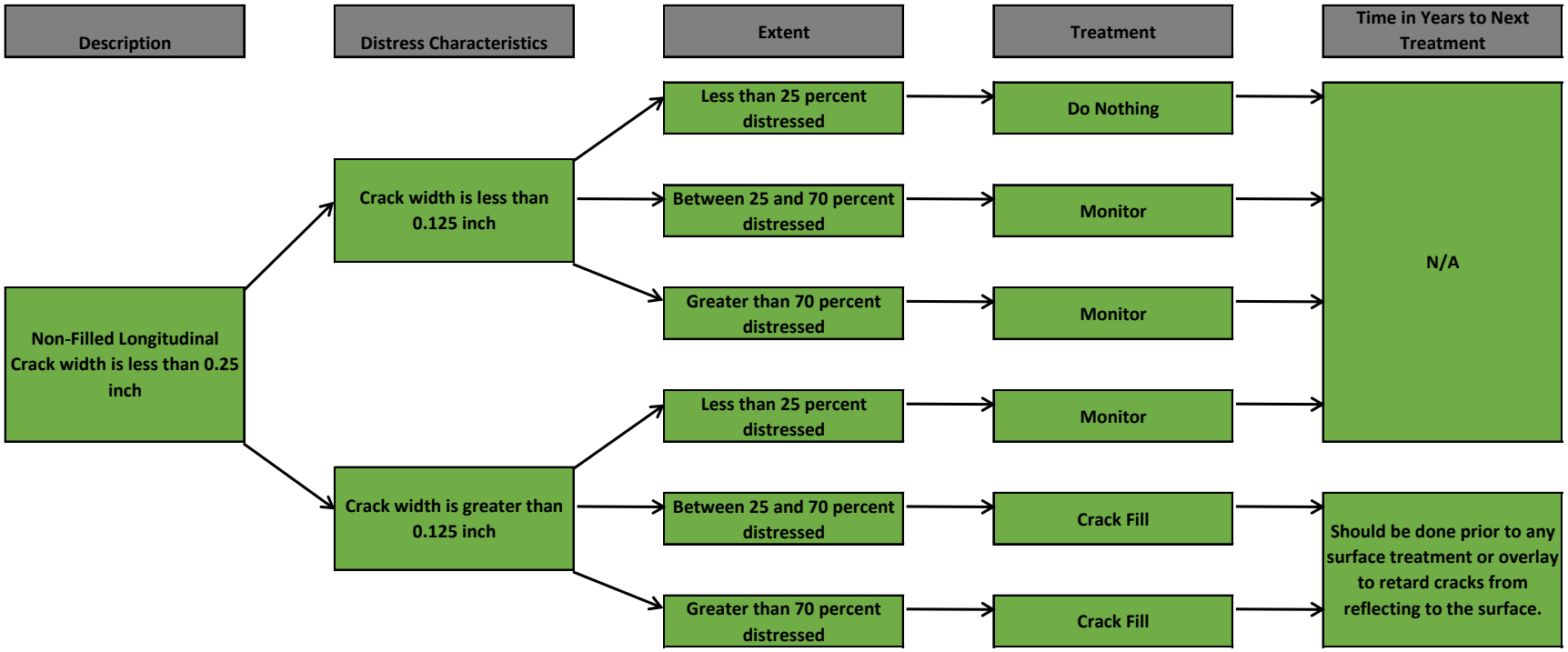

Figure 21. Recommended decision tree for low-severity longitudinal distress.

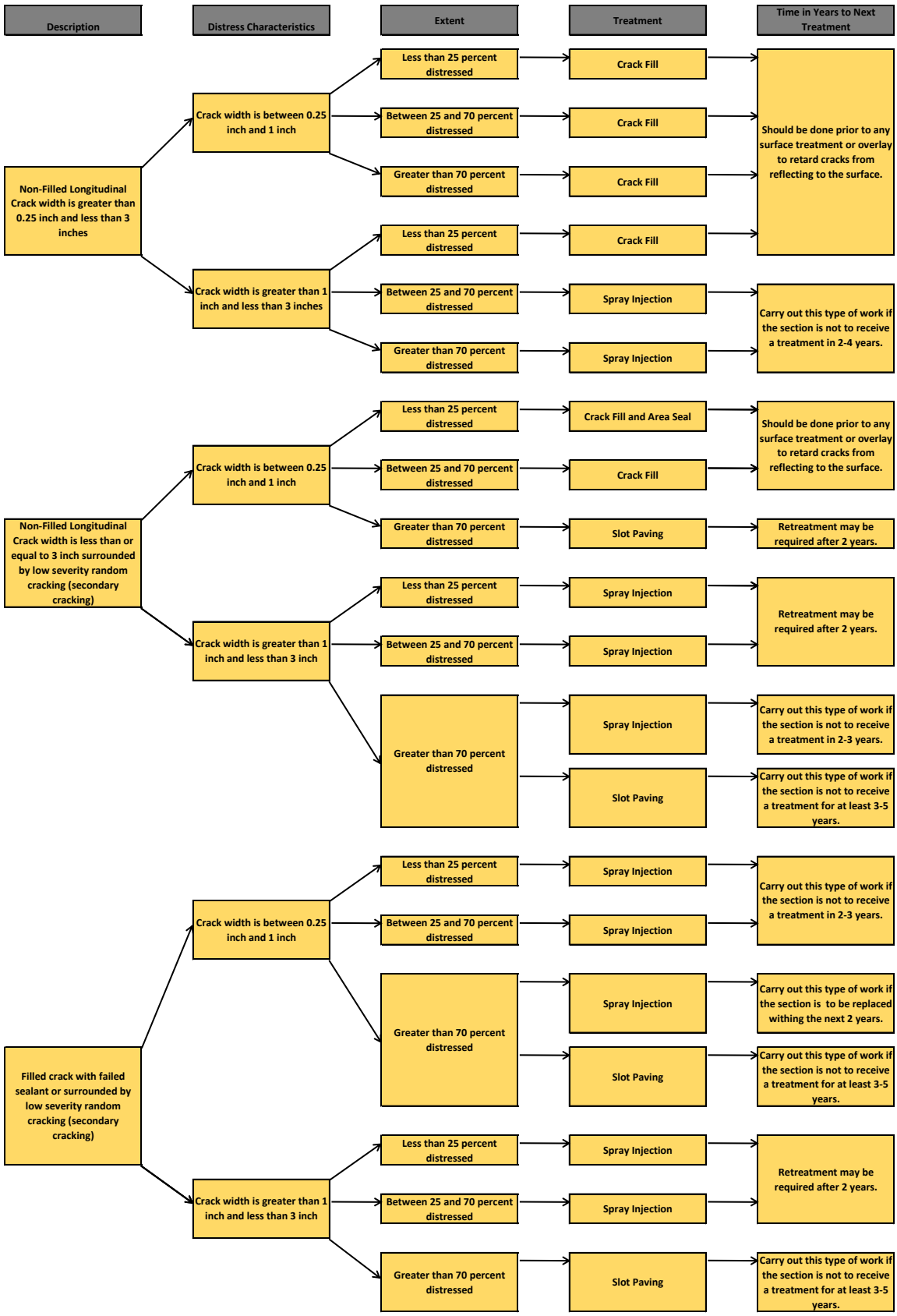

Figure 22. Recommended decision tree for medium-severity longitudinal distress.

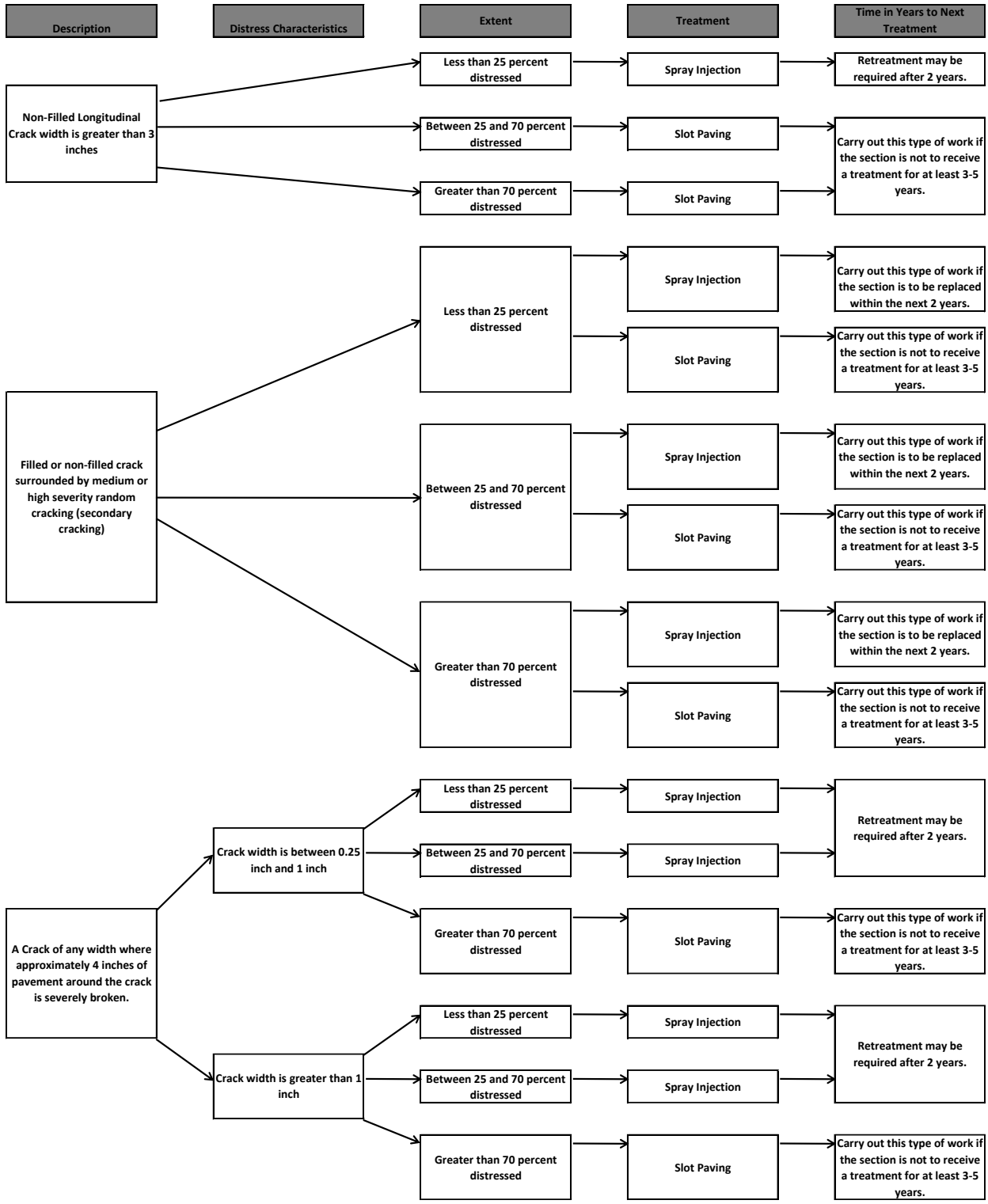

Figure 23. Recommended decision tree for high-severity longitudinal distress.

CHAPTER 6. RECOMMENDATIONS AND CONCLUSIONS

ODOT has constructed successful repairs for LJ distress using crack sealing, spray injection, and slot paving. Table 20 summarizes the annualized, life-cycle costs and the typical performance life achieved by each treatment. Based on the current ODOT use of these three techniques, crack sealing is most cost effective, but is only applicable to treat low to medium LJ distress. Spray injection and slot paving are suitable treatments for medium and high severity distress, with slot paving having a 4.3-year life expectancy compared to 2.2 years of treatment life for spray injection.

Table 20. Cost effectiveness evaluation of LJ repair techniques.

Repair	Treatment Life, Years	Cost per mile, $	Cost per mile per year, $
Slot Paving	4.3	$104,464.35	$24,294.03
Spray Injection	2.2	$12,763.72	$5,801.69
Crack Sealing	4.5	$3,362.63	$747.25

Treatment Application Recommendations

The primary recommendation is to use the most appropriate treatment based on the condition of the LJ, the age of the pavement, and the expected time until next overlay, while also considering the comparative cost effectiveness of the different strategies. Recommendations for improvements to the current ODOT processes include the following:

Slot Paving

- Slot paving is the most expensive treatment option studied under this research project, and should be reserved for longer-term solutions in high traffic areas. In addition, improvement to the construction process may result in longer performance.
- Construct uniform 3-foot width slots
- Require density specifications to achieve optimum compaction during patch construction.
- Develop projects of a length to facilitate continuous production for a single shift of work to minimize disruptions in the construction process.
- Consider uniform thickness slots to facilitate the construction process.

Spray Injection

- Develop mix design criteria for spray injection materials to ensure compatibility of the asphalt emulsion and the aggregate. Consider using the AASHTO T 59 Field Coating Test to field verify compatibility and appropriate proportions between the selected aggregate and asphalt emulsion.
- Implement spray injection specifications through a review by the appropriate ODOT specification approval committee. Require additional equipment such as a cold planer and broom to be onsite to remove cupped or bulging crack faces and to ensure debris is removed before application and loose stones are removed after application.

- Establish cure times for spray injection for warm and cold seasons considering the asphalt emulsion and the demulsibility. The goal is to use the most rapid setting emulsion to open the repair to traffic with minimal clogging of the equipment.

Crack Filling

- Type I or Type IV sealant is recommended for low- and medium- severity LJ distress to fill cracks up to 1 inch wide. The crack should be cleaned prior to treatment as required by ODOT Standard Specification 423.05.
- Type II or Type III sealant is recommended for sealing medium-severity, non-spalled LJ distress with 1- to 3-inch cracks that does not include secondary cracking around the LJ opening. This recommendation appears to be contrary to current ODOT standard specification 423.05. Due to the opening size and small secondary distress permitted, this option is believed to be seldom found in pavement settings.

Micro surfacing

- Based on results identified in Illinois, Minnesota, and West Virginia, consider developing an 18-inch micro surfacing preventive maintenance practice that seals the longitudinal construction joint in addition to the adjacent areas that may have higher permeability.
- Micro surfacing may be used in combination with crack filling applications.
- Micro surfacing area seals may be most appropriate on low- to medium- severity LJ distress where low severity secondary cracks have begun to form.

Place Test Sections

An opportunity exists to gain additional pre-treatment condition data and to gather production rate and cost information by continuing to place repair locations. Implementation activities should include the following:

- Verify construction costs and accomplishments to confirm the data produced from the projects reviewed for the research effort.
- Determine the output capacity for each repair technique to optimize lane closures and construction phasing.
- Track performance for 18 months.
- Evaluate the capacity to detect LJ distress with automated data collection equipment currently used by ODOT to collect pavement condition data for the pavement management system.

Conduct training for maintenance supervisors using the *Playbook* principles

Because most pavement condition data is collected and evaluated by a small group within ODOT, the maintenance managers and superintendents should be trained to identify key pavement distresses. Proper treatment selection depends on accurately identifying distress severity and extent. Key training outcomes should include:

- Knowledgeable supervisors that can identify low- to medium-severity joint distress to be treated with crack sealing.
- Identifying slot paving repairs for high severity joint distress on pavements that are expected to be in place for more than 4 years.

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APPENDIX A

LONGITUDINAL JOINT SITE REVIEW

2390 Advanced Business Center Drive
Columbus, Ohio 43228
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www.dhdcinc.com

Longitudinal Joint Repair Best Practices, ODOT

Site 1 Visit

Date: 12-8-16

Location:
Route: I-70
Direction: West Bound
County MM/State MM: FRA 20.37/ OH 106.41
Lanes: 3 travel lanes
Traffic: 86,670 (Based on ODOT 2014 24-hr average daily volume traffic study)

Longitudinal Joint Repair:
Treatment: 2' Partial Depth Slot Paving
ODOT Project Number: 150171
Installation Date: Spring 2015
Installed By: Shelly Company
Material Used: Item 442-Asphalt Concrete Surface Course, 12.5mm, Type A / Emulsion SS-1H
Cost: $50.00/Square Yard
Pavement Type: Full Depth Asphalt
M.O.T. Cost: $5,000 per night (nightly lane closure)

Site Observations:
This section consists of approx. 24" slot paving for the longitudinal joint within the middle lane for I-70 westbound (see Figure 1-1). The slot paving in this section lies within the wheel path of the middle travel lane. The repair is 4' from the nearest pavement markings. The condition of the repair asphalt remains in good condition with only minor surface wearing and no visible cracking. The AC bands were in good condition, however, very minor wearing of the AC band shows aggregate beginning to show through band (see Figure 1-2). There is only very minor secondary cracking near the repair joint. Secondary cracking is sporadic and only occurring in the original pavement. These cracks would be considered low severity per ODOT PCR Manual. Despite being in the wheel path, the repair overall is showing very little mounding or rutting and generally conforms to the sloping of the existing roadway. According to ODOT maintenance personnel, no compaction testing was done during placement of the asphalt.

Attachments:
Site Photos (4), Project Proposal line numbers, Site Map, Pavement Repair Detail

Figure 1-1. Typical section of the 2’ slot paving.

Figure 1-2. Typical distance from pavement markings.

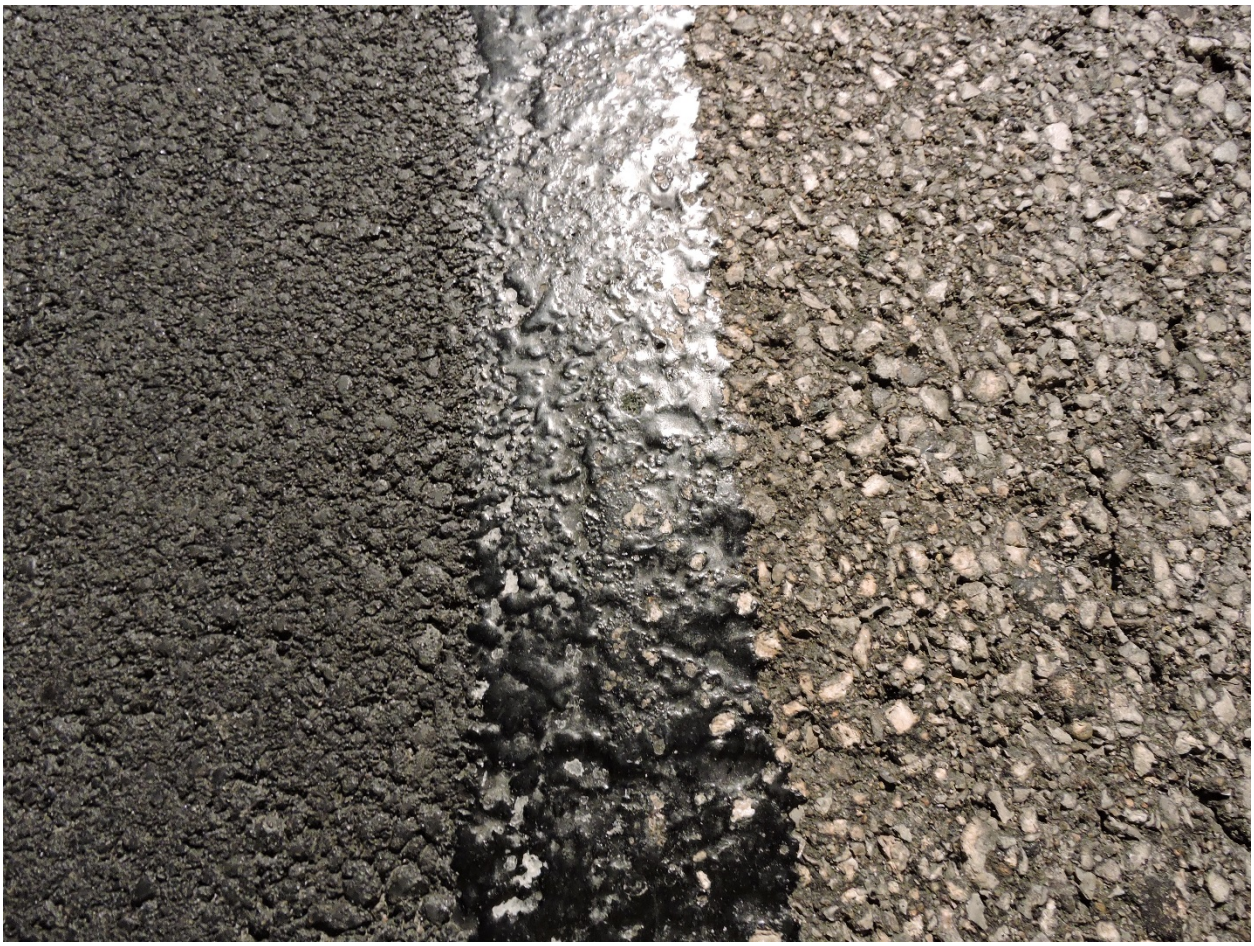

Figure 1-3. Typical AC band condition and the minor sporadic secondary cracking (repair on left).

Figure 1-4. Typical level of repair area.

Prop Line Nbr	Proj Nbr	Line Item Nbr	Item	Description	Unit Price	Unit	Bid Qty	Bid Amt
0001	D0691623-1	0001	832E30000	Erosion Control	$1.00	EACH	1,000.000	$1,000.00
0002	D0691623-1	0002	251E01001	Prtl Depth Pvmt Repair, App , TYPE 1	$50.00	SY	8,444.900	$422,245.00
0003	D0691623-1	0003	251E01001	Prtl Depth Pvmt Repair, App , TYPE 2	$50.00	SY	4,261.800	$213,090.00
0004	D0691623-1	0004	251E01001	Prtl Depth Pvmt Repair, App , TYPE 3	$74.00	SY	3,418.600	$252,976.40
0005	D0691623-1	0005	251E01001	Prtl Depth Pvmt Repair, App , TYPE 4	$60.00	SY	1,347.800	$80,868.00
0006	D0691623-1	0006	621E00100	Rpm	$39.50	EACH	738.000	$29,151.00
0007	D0691623-1	0007	621E54000	Raised Pavement Marker Removed	$3.00	EACH	738.000	$2,214.00
0008	D0691623-1	0008	642E00094	Edge Line, 6"	$485.00	MILE	36.880	$17,886.80
0009	D0691623-1	0009	642E00194	Lane Line, 6"	$375.00	MILE	15.820	$5,932.50
0010	D0691623-1	0010	642E00394	Channelizing Line, 12"	$0.45	FT	3,618.000	$1,628.10
0011	D0691623-1	0011	632E26500	Detector Loop	$1,400.00	EACH	5.000	$7,000.00
0012	D0691623-1	0012	632E27200	Loop Detector Tie In	$110.00	EACH	5.000	$550.00
0013	D0691623-1	0013	614E11110	Leo With Patrol Car	$72.00	HOUR	450.000	$32,400.00
0014	D0691623-1	0014	614E18601	Portable Chngbl Messg Sign, App	$1,000.00	SNMT	6.000	$6,000.00
0015	D0691623-1	0015	614E20100	Work Zone Lane Line, Cl I, 642 Pt	$225.00	MILE	15.820	$3,559.50
0016	D0691623-1	0016	614E22100	Work Zone Edge Line, Cl I, 642 Pt	$375.00	MILE	36.880	$13,830.00
0017	D0691623-1	0017	614E23200	Work Zone Ch Line, Cl I, 642 Pt	$0.25	FT	3,618.000	$904.50
0018	D0691623-1	0021	103E05000	Contract Performance Bond	$6,764.20	LS	1.000	$6,764.20
0019	D0691623-1	0018	614E11000	Maintaining Traffic	$162,000.00	LS	1.000	$162,000.00
0020	D0691623-1	0019	623E10001	Const Layout Stakes, App	$25,000.00	LS	1.000	$25,000.00
0021	D0691623-1	0020	624E10000	Mobilization	$40,000.00	LS	1.000	$40,000.00
8000	D0691623-1	8000	990E24700	104.02 Adjustment Calculations Attached	$9,453.48	LS	0.000	$0.00
9000	D0691623-1	9000	255E10111	Full Dpt Rmvl & Repl, Cl Qc Fs, App 270N @ 9.85MM, All Three Lanes	$641.46	SY	0.000	$0.00
9001	D0691623-1	9001	614E11000	Maintaining Traffic I-71EB@21.67-24.5MM MOT Conflicts	$10,961.04	LS	0.000	$0.00
9002	D0691623-1	9002	624E10000	Mobilization I-71EB@21.67-24.5MM MOB Conflicts	$2,706.09	LS	0.000	$0.00
9003	D0691623-1	9003	251E01001	Prtl Depth Pvmt Repair, App PLI#2: Partial Depth Pavement Repair, App, TYPE 1	$50.00	SY	0.000	$0.00
9004	D0691623-1	9004	251E01001	Prtl Depth Pvmt Repair, App PLI#4: Partial Depth Pavement Repair, App, TYPE 3	$74.00	SY	0.000	$0.00
								$1,325,000.00

Figure 1-5. Project proposal line numbers.

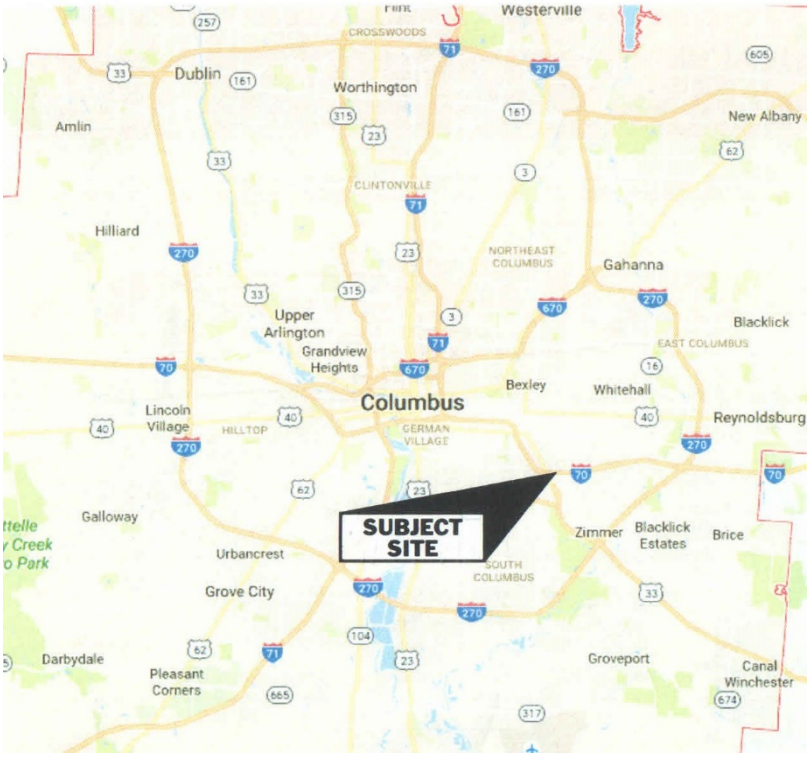

Figure 1-6. Site map

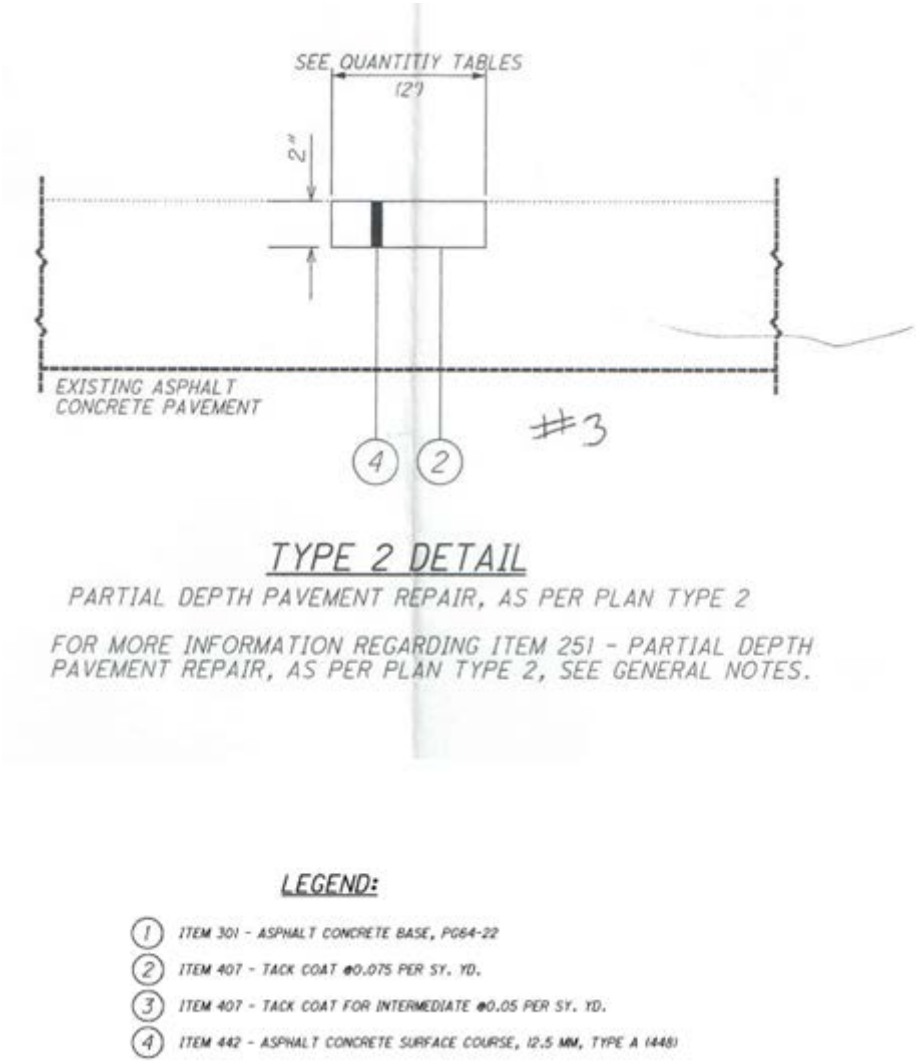

Figure 1-7. Pavement repair detail PID 91623.

2390 Advanced Business Center Drive
Columbus, Ohio 43228
o: 614.527.7656
f: 614.527.7489
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Longitudinal Joint Repair Best Practices, ODOT

Site 2 Visit

Date: 12-8-16

Location:
Route: I-71
Direction: South Bound
County MM/State MM: FRA 17.48/OH 108.55
Lanes: 3 travel lanes
Traffic: 117,520 (Based on ODOT 2014 24-hr average daily volume traffic study)

Longitudinal Joint Repair:
Treatment: 4' Partial Depth Slot Paving
ODOT Project Number: 140176
Installation Date: 2014
Installed By: Kokosing Construction Company
Material Used: Item 442-Asphalt Concrete Surface Course, 12.5mm, Type A / Emulsion SS-1H
Cost: $58.00/Square Yard
Pavement Type: Composite Asphalt with Concrete Base
M.O.T. Cost: $5,000 per night (nightly lane closure)

Site Observations:
This section consists of approx. 48" slot paving repair for longitudinal joints. The repair is centered on the pavement markings for both longitudinal joints within the traveling lanes (see Figure 2-1). The asphalt within the repair is consistently showing moderate wearing as aggregate is being to be exposed. Overall the asphalt in the repair area is showing minimal deterioration. The AC band has been nearly 100% removed. There is evidence that the band was in place at one time. Low- to medium-severity cracking (1/2" to 1") is occurring at the edge of the repair on both sides of the repair (see Figure 2-2). There are also low- to medium-severity secondary cracking (1/4") and deterioration on the original non-repaired asphalt (see Figure 2-3). There was no compaction testing performed onsite at time of placement according to ODOT maintenance personnel. The repair exhibited slight rutting at the edges of the repair. These areas are near the wheel path of the two adjacent traveling lanes.

Attachments:
Site Photos (3), Project Proposal line numbers, Site Map, Pavement Repair Detail

Figure 2-1. Typical section of the 4’ slot paving.

Figure 2-2. Cracking along edge of repair (repair pavement is left side).

Figure 2-3. Deterioration secondary cracking along repair area (repair pavement on right).

Project Proposal Line Number list (140176)
Ohio Department of Transportation

Prop Line Nbr	Proj Nbr	Line Item Nbr	Item	Description	Unit Price	Unit	Bid Qty	Bid Amt
0001	D0691622-1	0001	832E30000	Erosion Control	$1.00	EACH	970.000	$970.00
0001	D0691622-2	0001	832E30000	Erosion Control	$1.00	EACH	30.000	$30.00
0002	D0691622-1	0002	251E01001	Prtl Depth Pvmt Repair, App	$58.00	SY	18,303.000	$1,061,574.00
0002	D0691622-2	0002	251E01001	Prtl Depth Pvmt Repair, App	$58.00	SY	600.000	$34,800.00
0003	D0691622-1	0003	621E00100	Rpm	$24.00	EACH	1,858.000	$44,592.00
0003	D0691622-2	0003	621E00100	Rpm	$24.00	EACH	2.000	$48.00
0004	D0691622-1	0004	621E54000	Raised Pavement Marker Removed	$2.00	EACH	1,858.000	$3,716.00
0004	D0691622-2	0004	621E54000	Raised Pavement Marker Removed	$2.00	EACH	2.000	$4.00
0005	D0691622-1	0005	642E00094	Edge Line, 6"	$470.00	MILE	81.760	$38,427.20
0005	D0691622-2	0005	642E00094	Edge Line, 6"	$470.00	MILE	0.080	$37.60
0006	D0691622-1	0006	642E00194	Lane Line, 6"	$275.00	MILE	40.880	$11,242.00
0006	D0691622-2	0006	642E00194	Lane Line, 6"	$275.00	MILE	0.040	$11.00
0007	D0691622-1	0007	642E00394	Channelizing Line, 12"	$0.35	FT	4,310.000	$1,508.50
0008	D0691622-1	0008	632E26500	Detector Loop	$1,200.00	EACH	5.000	$6,000.00
0009	D0691622-1	0009	632E27200	Loop Detector Tie In	$75.00	EACH	5.000	$375.00
0010	D0691622-1	0010	614E11110	Leo With Patrol Car	$72.00	HOUR	434.000	$31,248.00
0010	D0691622-2	0010	614E11110	Leo With Patrol Car	$72.00	HOUR	16.000	$1,152.00
0011	D0691622-1	0011	614E18601	Portable Chngbl Messg Sign, App	$450.00	SNMT	6.000	$2,700.00
0012	D0691622-1	0012	614E20100	Work Zone Lane Line, Cl I, 642 Pt	$200.00	MILE	40.880	$8,176.00
0012	D0691622-2	0012	614E20100	Work Zone Lane Line, Cl I, 642 Pt	$200.00	MILE	0.040	$8.00
0013	D0691622-1	0013	614E22100	Work Zone Edge Line, Cl I, 642 Pt	$350.00	MILE	81.760	$28,616.00
0013	D0691622-2	0013	614E22100	Work Zone Edge Line, Cl I, 642 Pt	$350.00	MILE	0.080	$28.00
0014	D0691622-1	0014	614E23680	Work Zone Ch Line, Cl Iii, 642 Pt	$0.20	FT	4,310.000	$862.00
0015	D0691622-1	0018	103E05000	Contract Performance Bond	$7,773.57	LS	1.000	$7,773.57
0015	D0691622-2	0018	103E05000	Contract Performance Bond	$226.43	LS	1.000	$226.43
0016	D0691622-1	0015	614E11000	Maintaining Traffic	$179,890.20	LS	1.000	$179,890.20
0016	D0691622-2	0015	614E11000	Maintaining Traffic	$5,239.80	LS	1.000	$5,239.80
0017	D0691622-1	0016	623E10001	Const Layout Stakes, App	$97.17	LS	1.000	$97.17
0017	D0691622-2	0016	623E10001	Const Layout Stakes, App	$2.83	LS	1.000	$2.83
0018	D0691622-1	0017	624E10000	Mobilization	$38,867.87	LS	1.000	$38,867.87
0018	D0691622-2	0017	624E10000	Mobilization	$1,132.13	LS	1.000	$1,132.13
8000	D0691622-1	8000	990E25300	105.03 Non-Conformance Adjustment Binder Content @ 4.2% less than Allowable 5%	($500.00)	LS	0.000	$0.00
8001	D0691622-1	8001	990E24700	104.02 Adjustment Prpsl Ln Itm #'s 4, 5, 6, & 7	$11,788.39	LS	0.000	$0.00
8002	D0691622-1	8002	990E25400	Lump Sum Adjustment - General / Other Post Winter Mobilization for Owner	$4,591.83	LS	0.000	$0.00
9000	D0691622-1	9000	251E01000	Prtl Depth Pvmt Repair (type-1 surface, 2 inch deep)	$25.00	SY	0.000	$0.00
								$1,509,355.30

Project Line Item List Page 1 of 1 12/6/2016 8:59:08 AM

Figure 2-4. Project proposal line numbers.

Figure 2-5. Site map.

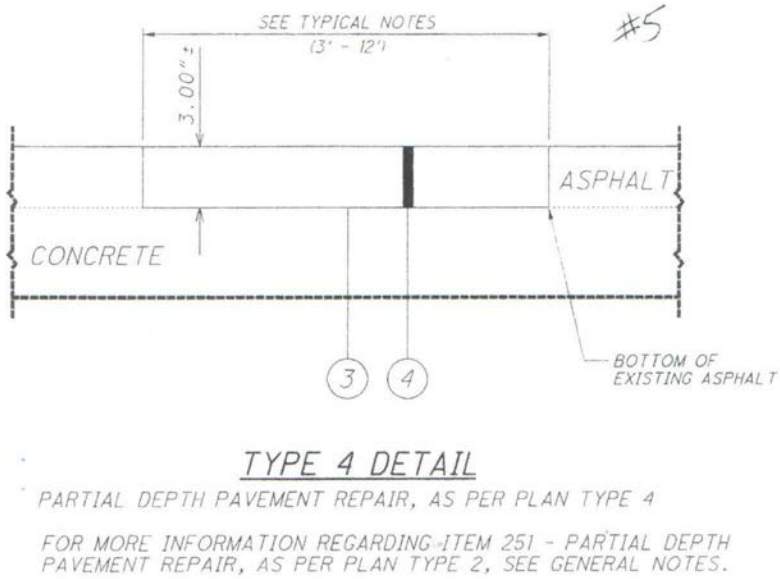

Figure 2-6. Pavement repair detail.

2390 Advanced Business Center Drive
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Longitudinal Joint Repair Best Practices, ODOT

Site 3 Visit

Date: 12-8-16

Location:
Route: CD Road from I270 South to Easton Way
Direction: South Bound
County MM/State MM: FRA 31.51/ OH 31.51 (From FRA I270)
Lanes: 3 travel lanes
Traffic: 157,070 (Based on ODOT 2014 24-hr average daily volume traffic study)

Longitudinal Joint Repair:
Treatment: 3' Partial Depth Slot Paving
ODOT Project Number: 150171
Installation Date: Spring 2016
Installed By: Shelly Company
Material Used: Item 442-Asphalt Concrete Surface Course, 12.5mm, Type A / Emulsion SS-1H
Cost: $50.00/Square Yard
Pavement Type: Full Depth Asphalt
M.O.T. Cost: $5,000 per night (nightly lane closure)

Site Observations:
This section consists of approx. 36" slot paving for both longitudinal joints within the 3 travel lanes for the Collector/Distributor Road from I270 south to Easton Way. The slot paving for the inside lane had one edge aligning with the pavement markings with the other edge extending into the wheel path of the inside lane (see Figure 3-1). The condition of the asphalt remains in good condition with only minor surface wearing and no visible cracking. The AC bands were in fair condition, though still present, aggregate is beginning to show as the band wears, more particularly on the edge within the wheel path (see Figure 3-2). The edge within the wheel path is showing minor cracking in periodic locations. However, the edge within the pavement markings generally has continuous cracking forming through the AC band to the surface (see Figure 3-3). These cracks would be considered low severity per ODOT PCR Manual. The repair overall is showing very little mounding or rutting and generally conforms to the sloping of the existing roadway. According to ODOT maintenance personnel no compaction testing was done during placement of the asphalt.

Attachments:
Site Photos (3), Project Proposal line numbers, Site Map, Pavement Repair Detail

Figure 3-1. Typical section of the 3’ slot paving.

Figure 3-2. Typical AC band within wheel path (band on left within wheel path).

Figure 3-3. Typical cracking along the slot paving edge located within pavement markings.

Prop Line Nbr	Proj Nbr	Line Item Nbr	Item	Description	Unit Price	Unit	Bid Qty	Bid Amt
0001	D0691623-1	0001	832E30000	Erosion Control	$1.00	EACH	1,000.000	$1,000.00
0002	D0691623-1	0002	251E01001	Prtl Depth Pvmt Repair, App TYPE 1	$50.00	SY	8,444.900	$422,245.00
0003	D0691623-1	0003	251E01001	Prtl Depth Pvmt Repair, App TYPE 2	$50.00	SY	4,261.800	$213,090.00
0004	D0691623-1	0004	251E01001	Prtl Depth Pvmt Repair, App TYPE 3	$74.00	SY	3,418.600	$252,978.40
0005	D0691623-1	0005	251E01001	Prtl Depth Pvmt Repair, App TYPE 4	$60.00	SY	1,347.800	$80,868.00
0006	D0691623-1	0006	621E00100	Rpm	$39.50	EACH	738.000	$29,151.00
0007	D0691623-1	0007	621E54000	Raised Pavement Marker Removed	$3.00	EACH	738.000	$2,214.00
0008	D0691623-1	0008	642E00094	Edge Line, 6"	$485.00	MILE	36.880	$17,886.80
0009	D0691623-1	0009	642E00194	Lane Line, 6"	$375.00	MILE	15.820	$5,932.50
0010	D0691623-1	0010	642E00394	Channelizing Line, 12"	$0.45	FT	3,618.000	$1,628.10
0011	D0691623-1	0011	632E26500	Detector Loop	$1,400.00	EACH	5.000	$7,000.00
0012	D0691623-1	0012	632E27200	Loop Detector Tie In	$110.00	EACH	5.000	$550.00
0013	D0691623-1	0013	614E11110	Leo With Patrol Car	$72.00	HOUR	450.000	$32,400.00
0014	D0691623-1	0014	614E18601	Portable Chngbl Messg Sign, App	$1,000.00	SNMT	6.000	$6,000.00
0015	D0691623-1	0015	614E20100	Work Zone Lane Line, Cl I, 642 Pt	$225.00	MILE	15.820	$3,559.50
0016	D0691623-1	0016	614E22100	Work Zone Edge Line, Cl I, 642 Pt	$375.00	MILE	36.880	$13,830.00
0017	D0691623-1	0017	614E23200	Work Zone Ch Line, Cl I, 642 Pt	$0.25	FT	3,618.000	$904.50
0018	D0691623-1	0021	103E05000	Contract Performance Bond	$6,764.20	LS	1.000	$6,764.20
0019	D0691623-1	0018	614E11000	Maintaining Traffic	$162,000.00	LS	1.000	$162,000.00
0020	D0691623-1	0019	623E10001	Const Layout Stakes, App	$25,000.00	LS	1.000	$25,000.00
0021	D0691623-1	0020	624E10000	Mobilization	$40,000.00	LS	1.000	$40,000.00
8000	D0691623-1	8000	990E24700	104.02 Adjustment Calculations Attached	$9,453.48	LS	0.000	$0.00
9000	D0691623-1	9000	255E10111	Full Dpt Rmvl & Repl, Cl Qc Fs, App 270N @ 9.85MM, All Three Lanes	$641.46	SY	0.000	$0.00
9001	D0691623-1	9001	614E11000	Maintaining Traffic I-71EB@21.67-24.5MM MOT Conflicts	$10,961.04	LS	0.000	$0.00
9002	D0691623-1	9002	624E10000	Mobilization I-71EB@21.67-24.5MM MOB Conflicts	$2,705.09	LS	0.000	$0.00
9003	D0691623-1	9003	251E01001	Prtl Depth Pvmt Repair, App PLI#2: Partial Depth Pavement Repair, App, TYPE 1	$50.00	SY	0.000	$0.00
9004	D0691623-1	9004	251E01001	Prtl Depth Pvmt Repair, App PLI#4: Partial Depth Pavement Repair, App, TYPE 3	$74.00	SY	0.000	$0.00
								$1,325,000.00

Figure 3-4. Project proposal line numbers.

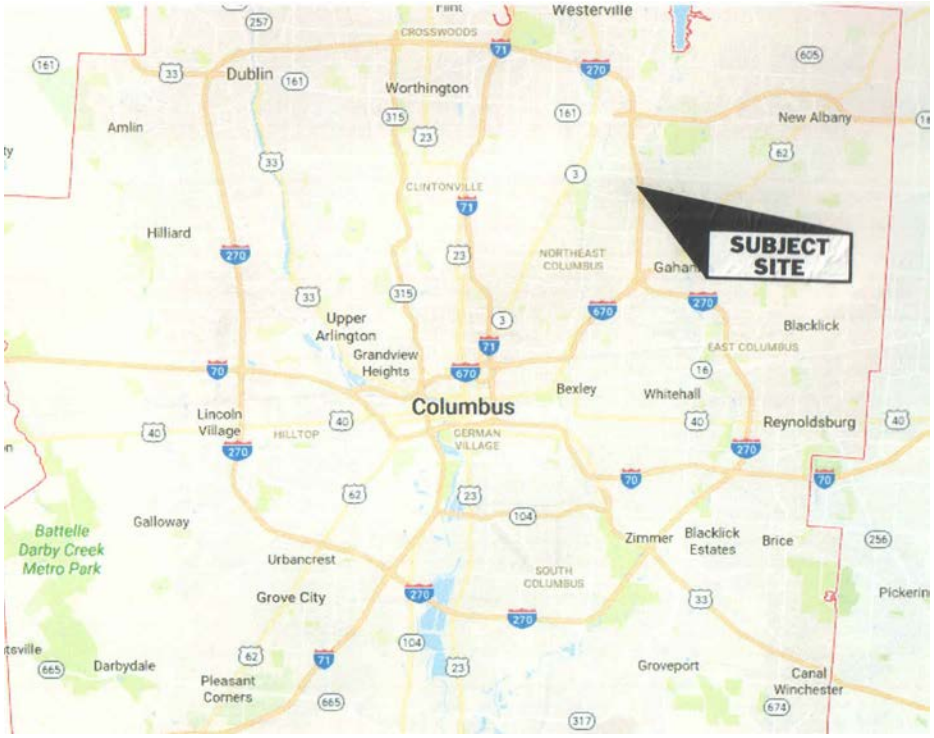

Figure 3-5. Site map.

PAVEMENT REPAIR DETAIL

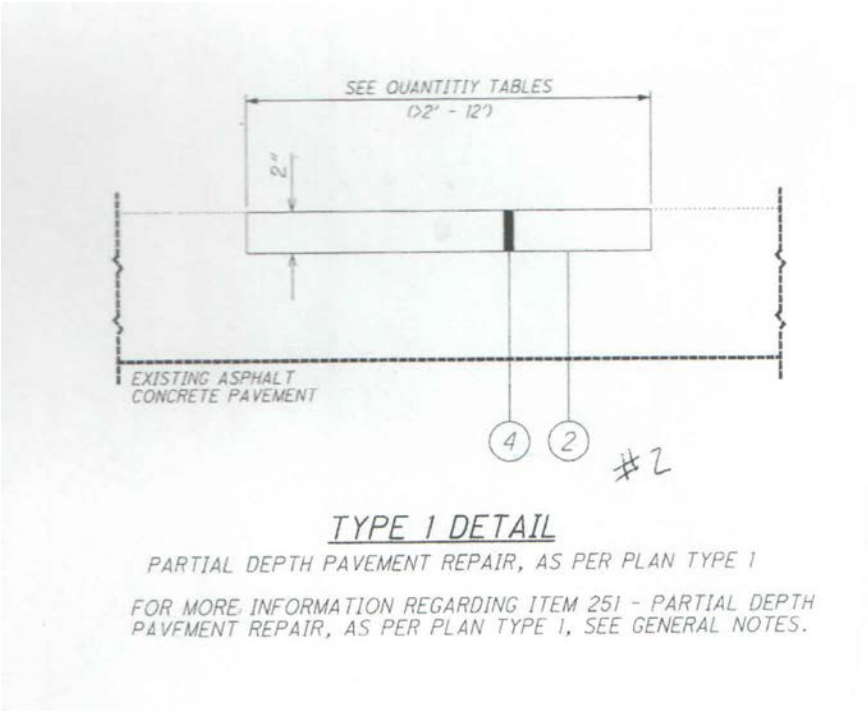

Figure 3-6. Pavement repair detail.

2390 Advanced Business Center Drive
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Longitudinal Joint Repair Best Practices, ODOT

Site 4 Visit

Date: 12-8-16

Location:
Route: I-670
Direction: West Bound
County MM/State MM: FRA 8.1/ OH 8.1
Lanes: 3 travel lanes
Traffic: 107,260 (Based on ODOT 2014 24-hr average daily volume traffic study)

Longitudinal Joint Repair:
Treatment: 4' Partial Depth Slot Paving
ODOT Project Number: 150171
Installation Date: 2015
Installed By: Kokosing Construction Company
Material Used: Item 442-Asphalt Concrete Surface Course, 12.5mm, Type A / Emulsion SS-1H
Cost: $60.00/Square Yard
Pavement Type: Composite Asphalt with Concrete Base
M.O.T. Cost: $5,000 per night (nightly lane closure)

Site Observations:
This section consists of approx. 48" slot paving repair for longitudinal joints. The repair is centered on the pavement markings for both longitudinal joints within the traveling lanes (see Figure 4-1). The asphalt within the repair is consistently showing moderate wearing with approx. ¼" longitudinal cracking through the center of the repair, presumably where the original longitudinal joint existed (see Figure 4-2). The AC band has been nearly 100% removed. There is evidence that the band was in place at one time. Low- to medium-severity cracking (1/2" to 1") is occurring at the edge of the repair on both sides (see Figure 3-3). There are also low- to medium-severity secondary cracking (1/4" to 1/2") particularly to the north edge of the repair area within the original asphalt (see Figure 3-4). Some areas have separated significantly enough that the area required patching. There was no compaction testing performed onsite at time of placement according to ODOT maintenance personnel. The repair exhibited slight rutting at the edges of the repair. These areas are within the wheel path of the two adjacent traveling lanes.

Attachments:
Site Photos (4), Project Proposal line numbers, Site Map, Pavement Repair Detail

Figure 4-1. Typical section of the 4’ slot paving.

Figure 4-2. ¼ cracking through center of slot repair.

Figure 4-3. Typical north edge of slot paving (upper right portion of photo is repair asphalt).

Figure 4-4. Secondary cracking on north edge of repair (left portion of photo is repair asphalt).

Prop Line Nbr	Proj Nbr	Line Item Nbr	Item	Description	Unit Price	Unit	Bid Qty	Bid Amt
0001	D0691623-1	0001	832E30000	Erosion Control	$1.00	EACH	1,000.000	$1,000.00
0002	D0691623-1	0002	251E01001	Prtl Depth Pvmt Repair, App TYPE 1	$50.00	SY	8,444.900	$422,245.00
0003	D0691623-1	0003	251E01001	Prtl Depth Pvmt Repair, App TYPE 2	$50.00	SY	4,261.800	$213,090.00
0004	D0691623-1	0004	251E01001	Prtl Depth Pvmt Repair, App TYPE 3	$74.00	SY	3,418.600	$252,978.40
0005	D0691623-1	0005	251E01001	Prtl Depth Pvmt Repair, App TYPE 4	$60.00	SY	1,347.800	$80,868.00
0006	D0691623-1	0006	621E00100	Rpm	$39.50	EACH	738.000	$29,151.00
0007	D0691623-1	0007	621E54000	Raised Pavement Marker Removed	$3.00	EACH	738.000	$2,214.00
0008	D0691623-1	0008	642E00094	Edge Line, 6"	$485.00	MILE	36.880	$17,886.80
0009	D0691623-1	0009	642E00194	Lane Line, 6"	$375.00	MILE	15.820	$5,932.50
0010	D0691623-1	0010	642E00394	Channelizing Line, 12"	$0.45	FT	3,618.000	$1,628.10
0011	D0691623-1	0011	632E26500	Detector Loop	$1,400.00	EACH	5.000	$7,000.00
0012	D0691623-1	0012	632E27200	Loop Detector Tie In	$110.00	EACH	5.000	$550.00
0013	D0691623-1	0013	614E11110	Leo With Patrol Car	$72.00	HOUR	450.000	$32,400.00
0014	D0691623-1	0014	614E18601	Portable Chngbl Messg Sign, App	$1,000.00	SNMT	6.000	$6,000.00
0015	D0691623-1	0015	614E20100	Work Zone Lane Line, Cl I, 642 Pt	$225.00	MILE	15.820	$3,559.50
0016	D0691623-1	0016	614E22100	Work Zone Edge Line, Cl I, 642 Pt	$375.00	MILE	36.880	$13,830.00
0017	D0691623-1	0017	614E23200	Work Zone Ch Line, Cl I, 642 Pt	$0.25	FT	3,618.000	$904.50
0018	D0691623-1	0021	103E05000	Contract Performance Bond	$6,764.20	LS	1.000	$6,764.20
0019	D0691623-1	0018	614E11000	Maintaining Traffic	$162,000.00	LS	1.000	$162,000.00
0020	D0691623-1	0019	623E10001	Const Layout Stakes, App	$25,000.00	LS	1.000	$25,000.00
0021	D0691623-1	0020	624E10000	Mobilization	$40,000.00	LS	1.000	$40,000.00
8000	D0691623-1	8000	990E24700	104.02 Adjustment Calculations Attached	$9,453.48	LS	0.000	$0.00
9000	D0691623-1	9000	255E10111	Full Dpt Rmvl & Repl, Cl Qc Fs, App 270N @ 9.85MM, All Three Lanes	$641.46	SY	0.000	$0.00
9001	D0691623-1	9001	614E11000	Maintaining Traffic I-71EB@21.67-24.5MM MOT Conflicts	$10,961.04	LS	0.000	$0.00
9002	D0691623-1	9002	624E10000	Mobilization I-71EB@21.67-24.5MM MOB Conflicts	$2,705.09	LS	0.000	$0.00
9003	D0691623-1	9003	251E01001	Prtl Depth Pvmt Repair, App PLI#2: Partial Depth Pavement Repair, App, TYPE 1	$50.00	SY	0.000	$0.00
9004	D0691623-1	9004	251E01001	Prtl Depth Pvmt Repair, App PLI#4: Partial Depth Pavement Repair, App, TYPE 3	$74.00	SY	0.000	$0.00
								$1,325,000.00

Figure 4-5. Project proposal line numbers.

Figure 4-6. Site map.

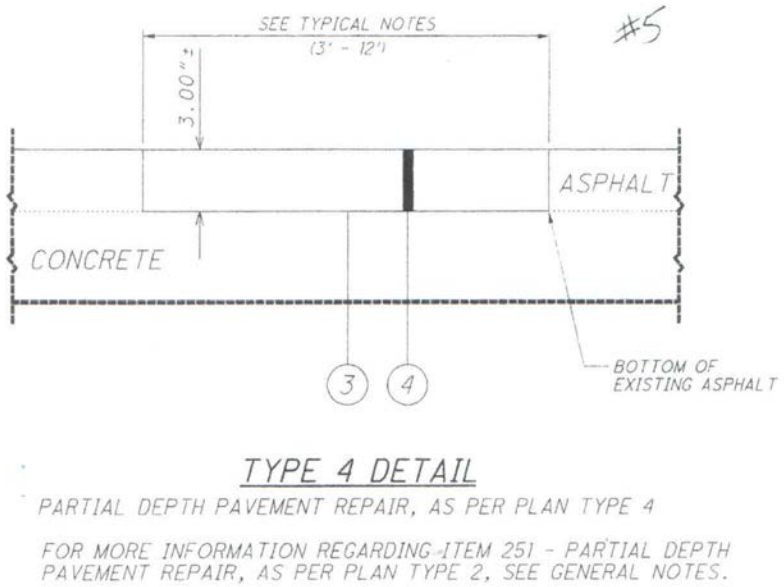

Figure 4-7. Pavement repair detail.

2390 Advanced Business Center Drive
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Longitudinal Joint Repair Best Practices, ODOT

Site 5 Visit

Date: 1-28-2017

Location:
Route: Interstate I-77
Direction: South Bound
State MM: OH 51.5
Lanes: 2 travel lanes
Traffic: 23,860 (Based on ODOT 2014 24-hr average daily volume traffic study)

Longitudinal Joint Repair:
Treatment: 2' slot paving
ODOT Project Number:
Installation Date: Summer 2015
Installed By: ODOT Personnel
Material Used: Item 448 Type "A" surface asphalt
Cost:
Pavement Type:
M.O.T. Cost: $6,000 per night (based on conversation with ODOT)

Site Observations:
This section has longitudinal joint repair between the two travel lanes on I-77 in Guernsey County. The repair is 2 inch depth, 2 foot width, slot paving for the longitudinal joint between the two travel lanes (see Figure 5-1). Overall the asphalt within the repair area remains in tack however in some areas the original joint is beginning to form on the repair area itself. These areas were evident from rain event the previous day as they remain saturated as the majority of the remaining pavement has dried. The AC band remains intact in appropriate condition; however the joint between the original pavement and the repair area is beginning to show through as the AC band begins to separate slightly (see Figure 5-2). Secondary cracking is beginning to form, more so on the inside travel lane. The cracking is running perpendicular to the repair area, and is roughly ¼" in width. Generally speaking, the repair area is flush with the existing pavement area; however, there are sections that exhibit slight mounding up to ¼" over a two foot area.

Attachments:
Site Photos (3), Site Map, Pavement Section Detail

Figure 5-1. Typical slot paving repair area, secondary cracking on inside lane, and cracking through slot pave from original joint.

Figure 5-2. Typical slot pave section inside lane to the left.

Figure 5-3. Section of 2’ slot paving.

Figure 5-4. Site map.

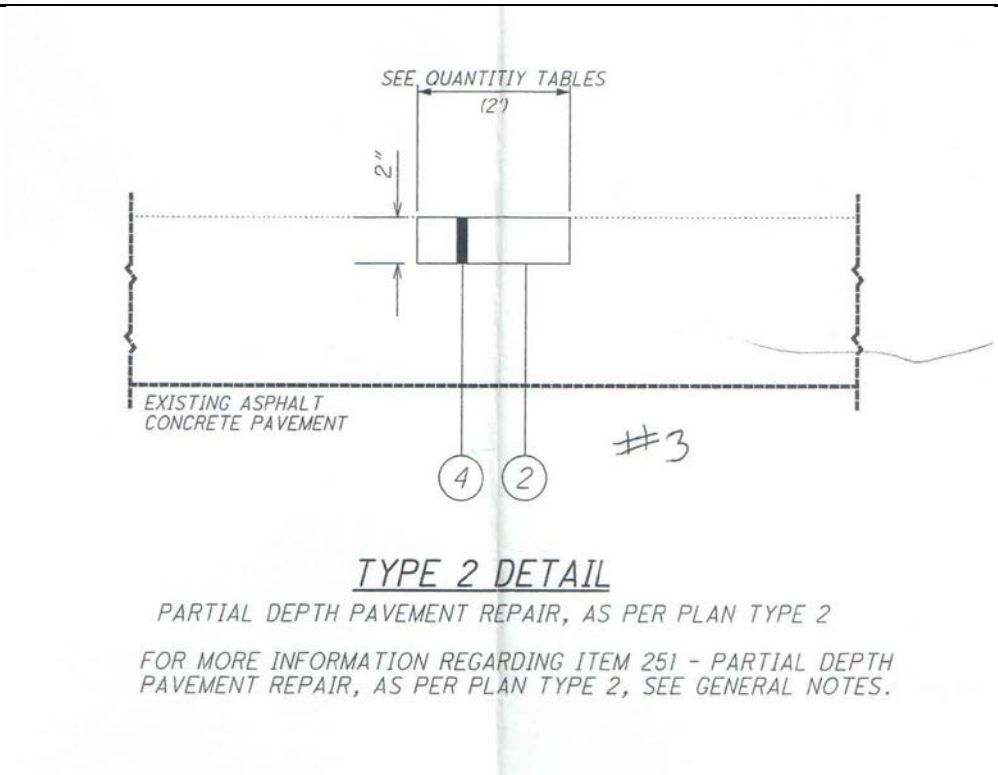

Figure 5-5. Pavement repair detail.

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Longitudinal Joint Repair Best Practices, ODOT

Site 6 Visit

Date: 12-8-16

Location:
Route: I-270
Direction: North Bound
County MM/State MM: FRA 13.0/ OH 13.0
Lanes: 4 travel lanes
Traffic: 101,770 (Based on ODOT 2014 24-hr average daily volume traffic study)

Longitudinal Joint Repair:
Treatment: Spray Patch
ODOT Work Order #: 5536693
Installation Date: 9-9-15
Installed By: ODOT Personnel
Material Used: Durapatch Liquid Asphalt, RS-2, Anionic
Cost: $1.84/Gal
Pavement Type: Composite Asphalt with Concrete Base
M.O.T. Cost: $5,000 per night (nightly lane closure based on conversation with ODOT personnel)

Site Observations:
This section consists of approx. 8”to 12” spray patching of longitudinal joint within the pavement markings for I-270. The patching was done outside of the wheel path but within the pavement markings of the travel lanes (see Figure 6-1). The patched area was between lanes 2 and 3. The longitudinal joint between lanes 1 and 2 was patch with asphalt (see Figure 6-3). The condition of the repair patch remains in good condition, with the patch showing little to no distress (see Figure 6-2). The repair area did not show areas that exhibited secondary cracking within the non repaired pavement. This was consistent throughout the patching areas. The patching material did consistently exhibit a slight mounding of the material throughout, roughly ¼” to ½” over the original pavement. This spray patch section was installed by ODOT personnel.

Attachments:
Site Photos (3), Site Map, Project Work Order Summary

Figure 6-1. Typical section with spray patching.

Figure 6-2. Typical spray patch condition.

Figure 6-3. Longitudinal joint treated with asphalt patching.

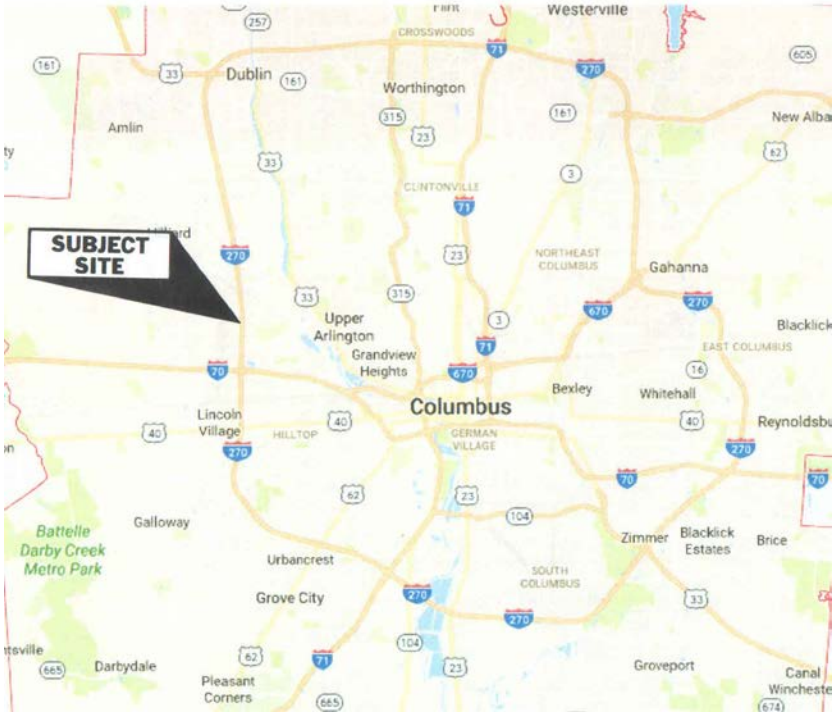

Figure 6-4. Site map.

Work Order Summary

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Longitudinal Joint Repair Best Practices, ODOT

Site 7 Visit

Date: 12-8-16

Location:
Route: I-270
Direction: North Bound
County MM/State MM: FRA 15.46/ OH 15.46
Lanes: 3 travel lanes
Traffic: 100,920 (Based on ODOT 2014 24-hr average daily volume traffic study)

Longitudinal Joint Repair:
Treatment: Spray Patch
ODOT Work Order #: 5536693
Installation Date: 9-8-15 & 9-9-15
Installed By: ODOT Personnel
Material Used: Durapatch Liquid Asphalt, RS-2, Anionic
Cost: $1.84/Gal
Pavement Type: Composite Asphalt with Concrete Base
M.O.T. Cost: $5,000 per night (nightly lane closure)

Site Observations:
This section consists of approx. 8” spray patching of longitudinal joint within the pavement markings for I-270. The patching was done outside of the wheel path but within the pavement markings of the travel lanes (see Figure 7-1). The condition of the repair patch remains in good condition, however, the patch is beginning to show signs of distress with possible separation forming within the patching material itself (see Figure 7-2). The repair area did show areas that exhibited secondary cracking within the non repaired pavement. These cracks would be considered low severity per ODOT PCR Manual. The secondary cracking was not consistent throughout the patching areas. An estimate of 30% to 40% linear feet of patching exhibited the secondary cracking (see Figure 7-3). The patching material did consistently exhibit a mounding of the material throughout, roughly ½” to ¾” over the original pavement. This spray patch section was installed by ODOT personnel.

Attachments:
Site Photos (3), Site Map, Project Work Order Summary

Figure 7-1. Typical section with spray patching.

Figure 7-2. Typical spray patch with material beginning to show signs of distress.

Figure 7-3. Typical secondary cracking forming outside of the patching material.

Figure 7-4. Site map.

Work Order Summary

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Longitudinal Joint Repair Best Practices, ODOT

Site 8 Visit

Date: 12-8-16

Location:
Route: I-270
Direction: East Bound
County MM/State MM: FRA 22.0/ OH 22.0
Lanes: 4 travel lanes (Area under construction at time of visit, number of lanes could change)
Traffic: 174180 (Based on ODOT 2014 24-hr average daily volume traffic study)

Longitudinal Joint Repair:
Treatment: Spray Patch
ODOT Project: 150249
Installation Date: Fall 2015
Installed By: Premier Patching, Inc.
Material Used: Asphalt Emulsion - HFRS-2
Cost: Not Available, bid as lump sum on change order. See attached proposal
Pavement Type: Composite Asphalt with Concrete Base
M.O.T. Cost: $6,399 per night (nightly lane closure)

Site Observations:
This section consists of approx. 12” to 18” wide with extremes 24” wide of spray patching of longitudinal joint within the pavement markings for I-270. The patching was done outside of the wheel path but within the pavement markings of the travel lanes (see Figure 8-1). The condition of the repair patch remains in good condition, exhibiting very minimal distress in infrequent areas (see Figure 8-2). The repair area generally did not show signs of secondary cracking. There is some cracking running perpendicular into the repair, however this cracking pattern is not limited to occurring in just the repair area, they exist in areas where spray patching was not done as well (see Figure 8-3). These cracks would be considered low severity per ODOT PCR Manual. The patching material did consistently exhibit a mounding of the material throughout, roughly ½” to ¾” with an extreme of 1” over the original pavement (see Figure 8-4). This spray patch section was installed by Premier Patching, Inc., which was a subcontractor to Igel Construction.

Attachments:
Site Photos (4), Site Map, Project Proposal Line Number, Force Account Proposal

Figure 8-1. Typical section with spray patching.

Figure 8-2. Typical spray patch condition.

Figure 8-3. Spray patch area with perpendicular cracking running into repair area.

Figure 8-4. Typical mounding of spray patch material.

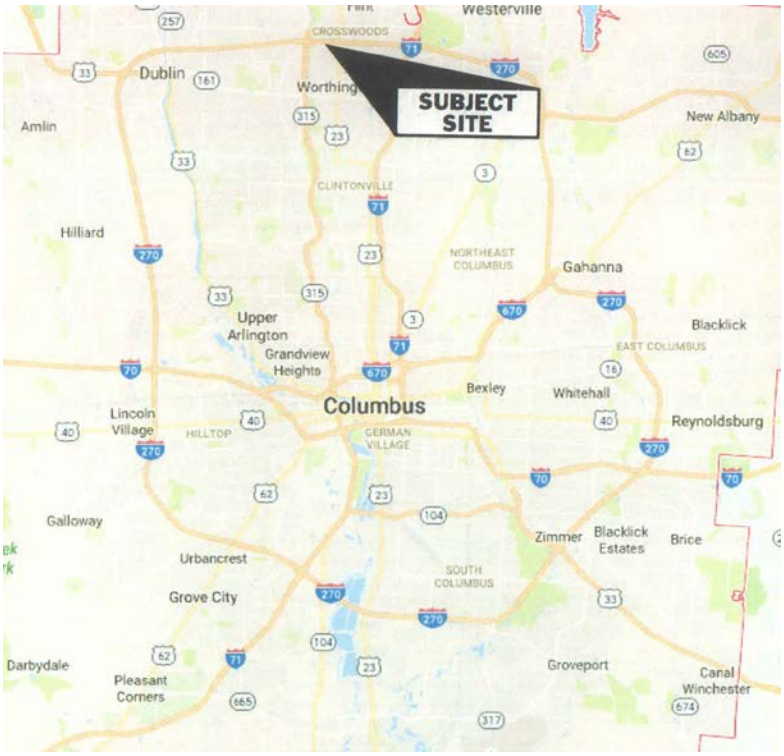

Figure 8-5. Site map

PROJECT PROPOSAL AND FORCE ACCOUNT PROPOSAL

2390 Advanced Business Center Drive
Columbus, Ohio 43228
o: 614.527.7656
f: 614.527.7489
www.dhdcinc.com

Longitudinal Joint Repair Best Practices, ODOT

Site 9 Visit

Date: 12-30-16

Location:
Route: US 23
Direction: South Bound
County MM/State MM: PIC 4.57/ OH 59.73
Lanes: 2 travel lanes
Traffic: 27,860 (Based on ODOT 2014 24-hr average daily volume traffic study)

Longitudinal Joint Repair:
Treatment: Spray Patch
ODOT Work Order #: 5536693
Installation Date: 11-24-15
Installed By: ODOT Personnel
Material Used: Durapatch Liquid Asphalt, MWS 90
Cost: $1.90/Gal
Pavement Type: Full Depth Asphalt
M.O.T. Cost: $5,000 per night (nightly lane closure based on conversation with ODOT personnel)

Site Observations:
This section consists of approx. 8" wide spray patching of longitudinal joint within the pavement markings for US 23. The patching was done outside of the wheel path but within the pavement markings of the travel lanes (see Figure 9-1). The area has also been heavily crack sealed. The spray patch is currently in poor condition. The spray patch is breaking up in sections and exhibiting cracking within the patch itself (see Figure 9-3). There are areas that the spray patch has degraded a significant amount, some much so that little evidence of the patch remains. There are distinct signs of secondary cracking running parallel to the spray patch. Cracks can exceed ½" width in some sections. Many of these areas have been crack sealed. Generally speaking, the repair area is flush with the existing pavement however there are sections the exhibit slight "mounding" of the patch work. This spray patch section was installed by ODOT personnel.

Attachments:
Site Photos (3), Site Map, Project Work Order Summary

Figure 9-1. Section of roadway with spray patch and misc. crack sealing.

Figure 9-2. Typical spray patch condition.

Figure 9-3. Section of spray patching that has broken down with secondary cracking.

Figure 9-4. Site map.

Work Order Summary

2390 Advanced Business Center Drive
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Longitudinal Joint Repair Best Practices, ODOT

Site 10 Visit

Date: 1-28-2017

Location:
Route: Interstate I-77
Direction: Both Directions
County MM: GUE 0.00 to 7.04
Lanes: 2 travel lanes
Traffic: 22,580 (Based on ODOT 2014 24-hr average daily volume traffic study)

Longitudinal Joint Repair:
Treatment: Spray Patching
ODOT Project Number: 4306727
Installation Date: From March 2015 to May 2015
Installed By: ODOT Personnel
Material Used: Durapatch, Limestone #9, Liquid asphalt HFRS-2 and Liquid Asphalt MWS 90
Cost: $13.11/ton for #9 Limestone, $3.56/Gal for MWS 90, $2.96/Gal for HFRS-2
Pavement Type: Concrete base with Asphalt Surface
M.O.T. Cost: $5,000 per night (based on conversation with ODOT)

Site Observations:
This section of I-77 in Guernsey County (county mile marker 0.00 to 7.04) had longitudinal joint repairs done in the spring of 2015. ODOT maintenance workers applied the Durapatch to the needed repair areas in this section. Today this section of highway has been overlaid and thus observations of the patch cannot be done. However, based on conversations with ODOT personnel from Guernsey County, the Durapatch did not perform as they had anticipated. The patch began to break apart over the course of the year and a fix was needed. Given the overall condition of the pavement, along with the status of the longitudinal joints, it was determined to overlay this section of highway.

Attachments:
Work Order Summary

Work Order Summary

2390 Advanced Business Center Drive
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Longitudinal Joint Repair Best Practices, ODOT

Site 11 Visit

Date: 12-8-2016

Location:
Route: Interstate I-270
Direction: East Bound
County MM/State MM: FRA 19.16/ OH 19.16
Lanes: 4 travel lanes
Traffic: 135,070 (Based on ODOT 2014 24-hr average daily volume traffic study)

Longitudinal Joint Repair:
Treatment: Crack Seal
ODOT Project Number: 130344
Installation Date: September 2013
Installed By: Scodeller Construction Company
Material Used: PG Asphalt (PG 64-22)
Cost: $0.25/Square Yard
Pavement Type: Composite asphalt with concrete base
M.O.T. Cost: $5,000 per night (nightly lane closure)

Site Observations:
100% crack seal on longitudinal joints from section 17.10 to 23.00 in 2013. The typical width of the crack seal ranged from 3” to 4”. The longitudinal joints are outside of the wheel path aligned with lane markings. Typical crack seal in this section shows deterioration in the center of the seal (see Figure 11-1). Approx. 75% of the sealed cracks are experiencing cracking through the crack seal material (see Figure 11-2). Typical crack width is ¼” which would classify the crack as low severity per ODOT PCR Manual. Majority of the area is showing little to no signs of secondary cracking. There are a few spot areas however that the crack significantly opened up and also exhibiting secondary cracking. These areas were patched in place (see Figure 11-3). Generally speaking, the majority of the crack seal was flush with the existing pavement. A few sporadic locations did have slight mounding of the material causing the crack seal to not be flush with the existing pavement (see Figure 11-4). These areas did not exhibit signs of more negative impact on the performance of the crack seal than those without mounding.

Attachments:
Site Photos (4), Project Proposal line numbers, Site Map

Figure 11-1. Typical crack sealing section with deterioration in center of seal

Figure 11-2. Typical cracking through the crack seal material.

Figure 11-3. Area repaired due to large separation in longitudinal joint.

Figure 11-4. Slight mound in the crack seal

Project Proposal Line Number list (130344)
Ohio Department of Transportation

Prop Line Nbr	Proj Nbr	Line Item Nbr	Item	Description	Unit Price	Unit	Bid Qty	Bid Amt
0015	D0683883-3/4	0015	614E11000	Maintaining Traffic	$2,542.59	LS	1.000	$2,542.59
0015	D0683883-4/4	0015	614E11000	Maintaining Traffic	$219.97	LS	1.000	$219.97
0016	D0683883-1/4	0016	624E10000	Mobilization	$27,525.17	LS	1.000	$27,525.17
0016	D0683883-2/4	0016	624E10000	Mobilization	$3,616.14	LS	1.000	$3,616.14
0016	D0683883-3/4	0016	624E10000	Mobilization	$4,011.64	LS	1.000	$4,011.64
0016	D0683883-4/4	0016	624E10000	Mobilization	$347.05	LS	1.000	$347.05
8000	D0683883-1/4	8000	990E24700	104.02 Adjustment	$1,621.49	LS	0.000	$0.00
								$479,562.61

Project Line Item List Page 2 of 2 12/6/2016 8:50:05 AM

Figure 11-5. Project proposal line numbers

Figure 11-6. Site map

2390 Advanced Business Center Drive
Columbus, Ohio 43228
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Longitudinal Joint Repair Best Practices, ODOT

Site 12 Visit

Date: 1-13-2017

Location:
Route: Interstate I-71
Direction: North Bound
County MM/State MM: MOR 18.0/ OH 151.6
Lanes: 3 travel lanes
Traffic: 44,110 (Based on ODOT 2012 24-hr average daily volume traffic study)

Longitudinal Joint Repair:
Treatment: Crack Seal
ODOT Project Number: 113011
Installation Date: 2015
Installed By: Kokosing Construction Company
Material Used: PG Asphalt (PG 64-22)
Cost: N/A (see site observations)
Pavement Type: Full depth asphalt
M.O.T. Cost: $5,000 per night (based on conversation with ODOT)

Site Observations:
100% crack seal on longitudinal joints from section of I-71 north bound from roughly mile marker 150 to the Richland County line. Only the joint between the inside and middle lane received crack sealing. This work was done by Kokosing Construction as extra work at no charge to ODOT as part of the original paving contract. This longitudinal joint began separating shortly after construction. According to ODOT, the reason for the separation was never determined. There was no routing of the joint prior to crack sealing. In many sections, secondary cracking is occurring frequently. Secondary cracks are running perpendicular to original cracking and are roughly ¼” to ½” wide. Crack sealing is showing signs of wear, as the original asphalt is beginning to show through. In a majority of the area, the cracking has come through the crack sealing to the surface again, while a minority of the area the cracks are still sealed. Generally speaking, the crack seal is flush with the existing pavement.

Attachments:
Site Photos (3), Site Map

Figure 12-1. Typical crack sealing section.

Figure 12-2. Perpendicular secondary cracking.

Figure 12-3. Section of crack sealing showing signs of wear.

Figure 12-4. Site map.

APPENDIX B

SPRAY INJECTION CONSTRUTION SPECIFICATION

250 PAVEMENT REPAIRS

ITEM 25X PARTIAL DEPTH PAVEMENT REPAIR BY SPRAY INJECTION

25X.1 Description. This work consists of partial depth patching of existing pavement in areas exhibiting deterioration at the surface or along a joint, using either a truck-mounted or self-contained device The spray injection procedure consists of blowing air into the distressed area to remove water and debris, applying a heated asphalt emulsion to the sides and bottom of the distressed area to be repaired, mixing aggregates with the heated asphalt emulsion, and spraying the repair material into the distressed area, applying a layer of aggregate to the patch surface, and finally, using additional equipment to compact the patch surface and sweep away loose stones prior to opening to traffic.

25X.2 Materials.

A. Aggregate: Use CCS sized to #8, #9, or a combination thereof in accordance with 703.05. The Engineer may permit crushed gravel aggregate to be substituted for CCS. The aggregate gradation shall contain less than 3 percent of material passing the #200 sieve, and have a maximum moisture content of 2 percent.

B. Emulsified Asphalt: Use either RS-2, MWS-90, or another asphalt emulsion approved by the Engineer in accordance with 702.04. If the use of gravel aggregate is approved by the Engineer, then use a similar cationic asphalt emulsion in accordance with 702.04.

Emulsified asphalt and aggregate shall be compatible with each other and suitable for blending with spray injection equipment. Demonstrate that the emulsion coats the aggregate when vigorously stirred at a rate of approximately 30 gallons per ton of aggregate (125 mL of emulsion per 1 kg of aggregate). At least 95 percent coating of the aggregate must be achieved.

25X.3 Equipment. Use spray injection equipment for material application consisting of one of three main types:

Trailer unit: In this configuration, the spray-injection unit is mounted on a trailer, which is pulled behind a dump truck loaded with aggregates. The aggregate is fed into the spray injection unit through a tailgate. This equipment requires a two-person crew consisting of a truck driver and a person to operate the patching spray injector hose and nozzle. The operator works on the road behind the trailer and controls a delivery hose suspended from a boom on the rear of the unit.

Modified truck unit: This equipment consists of a spray-injection unit that is mounted on the chassis of a maintenance truck, eliminating the need for a trailer. The spray injection hose and boom are operated from the rear of the truck.

Self-contained truck unit: The self-contained truck unit includes all of the spray injection equipment, asphalt emulsion storage tank, and aggregate storage bin on a single vehicle. This unit requires only a single operator, who drives the unit and operates the spray injection equipment from a controller in the cab.

The spray injection system includes four main lines: one for bringing air into the system, two separate lines to move asphalt emulsion and aggregates through the system, and a flush line to clean out the asphalt emulsion line

once road repairs have been completed. The air line includes an air cleaner (to remove dust from air drawn into the system) and a high volume/low pressure blower. The emulsion line includes a 250-gallon (946-liter) or larger asphalt emulsion storage tank with its own heating element and an air relief valve. The asphalt emulsion valve, located along the emulsion supply line, regulates the emulsion flow to the spraying/mixing nozzle. Aggregates, approximately 7 yd^3 (5.4 m^3), are stored either in the self-contained spray injection unit or in a tow vehicle that pulls the trailer unit. Aggregates are moved either along a conveyor or by gravity feed from the tow vehicle into the hopper on the trailer unit. From the hopper, the aggregates move through an air lock to the spraying/mixing nozzle via an aggregate hose. A boom provides support for all of the supply lines, and a nozzle permits the air, asphalt emulsion/aggregate mixture, or aggregates to be sprayed into the repair area. The operator of the spray injection unit controls the appropriate quantity of mix to apply to the repair area. The production capacity of the spray injection unit is determined by the pressure of air used to force the asphalt emulsion as well as the application rate for the aggregates. The latter is controlled either by the aggregate conveyor speed or by the aggregate suction air pressure. Following use, the unit is cleaned to prevent clogging of the asphalt emulsion line. To clean the unit, a cleaning fluid stored in the flush tank is forced through the flush valve to clean out any asphalt emulsion remaining in the emulsion line.

Air is used to feed and propel the aggregates and the asphalt emulsion to the nozzle at up to 135 lbs per minute (61 kg/min). Compressed air is blown from the nozzle at a rate of approximately 450 ft^3/min (12.7 m^3/min) with a 10 psi (0.07 MPa) pressure to remove water, dirt, or debris from the repair area.

Spray injection equipment shall be used only after receiving approval from the Engineer that the equipment meets the requirements set forth in this section.

25X.4 Repair Demarcation. The Engineer shall identify the location and limits of all areas to be repaired by making boundary marks on the pavement surface using aerosol spray paint. The boundaries of the repair area shall extend a minimum of 4 inches (100 mm) beyond the limits of the observed distressed.

25X.5 Weather Limitations. Unless written approval is provided by the Engineer, work shall only be performed when:

a. The pavement and air temperatures are 55 degrees F (13 degrees C) and rising.

b. The air temperature is below 100°F (38°C).

c. There is no danger of imminent precipitation.

d. There is no danger that the finished product will freeze before 24 hours has passed.

25X.6 Surface Preparation. Remove roadway dirt and debris from the area of the roadway to be repaired. A manual or power broom sweeper and a compressed air blower shall be used to ensure that the surfaces in the repair areas are dry and free of dust and dirt. Compressed air equipment with a minimum pressure of 100 psi (0.7 MPa) shall be used to blow all loose material from any visible cracks. Use a cold planing milling head to remove bulging or cupping of the joint faces prior to application of repair materials.

25X.7 Application. Emulsified asphalt tack material shall be applied to thoroughly coat the repair area, any cracks and joint openings, plus a 4-inch (100 mm) border around the repair area.

Asphalt and aggregate shall be blown into the repair area and onto the tacked border until a level, smooth surface of the patch is achieved. Afterwards, the repair area shall be covered with a layer of uncoated aggregate to serve as blotter and prevent adhesion to tires after maintenance of traffic is removed.

25X.8 Compaction. The repair area shall be thoroughly compacted using a Type I pneumatic tire roller conforming to 401.13 or another means as approved by the Engineer. As the compaction progresses, additional repair material may be applied, as necessary, to produce a smooth pavement surface.

25X.9 Finished Surface. The elevation of the completed repair patch shall vary by less than 0.5-inch and be in reasonably close conformance of the adjacent pavement. Use a mechanical broom to remove any loose stones from the repair area.

25X.10 Opening to Traffic. Unless otherwise approved by the Engineer, the roadway shall not be reopened to traffic until the last of the completed repair areas has been allowed to cure for a minimum of 20 minutes.

25X.11 Warranty. Contractor shall warrant the repairs against defects in materials and workmanship for a

period of 6 months after construction. Evidence of defects in materials and workmanship shall include the loss or disintegration of 10 percent or more of the repair material (by volume) at any given repair location. Any area that fails to meet the warranty shall be completely removed and re-repaired by the Contractor at no additional cost. This warranty shall be null and void if the Engineer provided written approval for the original work to be done outside of the specified weather limitations (section 25X.5).

25X.12 Method of Measurement. The Department will measure the quantity of Partial Depth Pavement Repair by Spray Injection by the number of square yards (square meters) or linear feet (linear meters) of pavement repaired in the complete and accepted work, calculated using the dimensions established by the Engineer.

25X.13 Basis of Payment. Payment is full compensation for furnishing all materials, including aerosol spray paint, tack coat, asphalt concrete, and perimeter seal.

The Department will pay for accepted quantities at the contract price as follows:

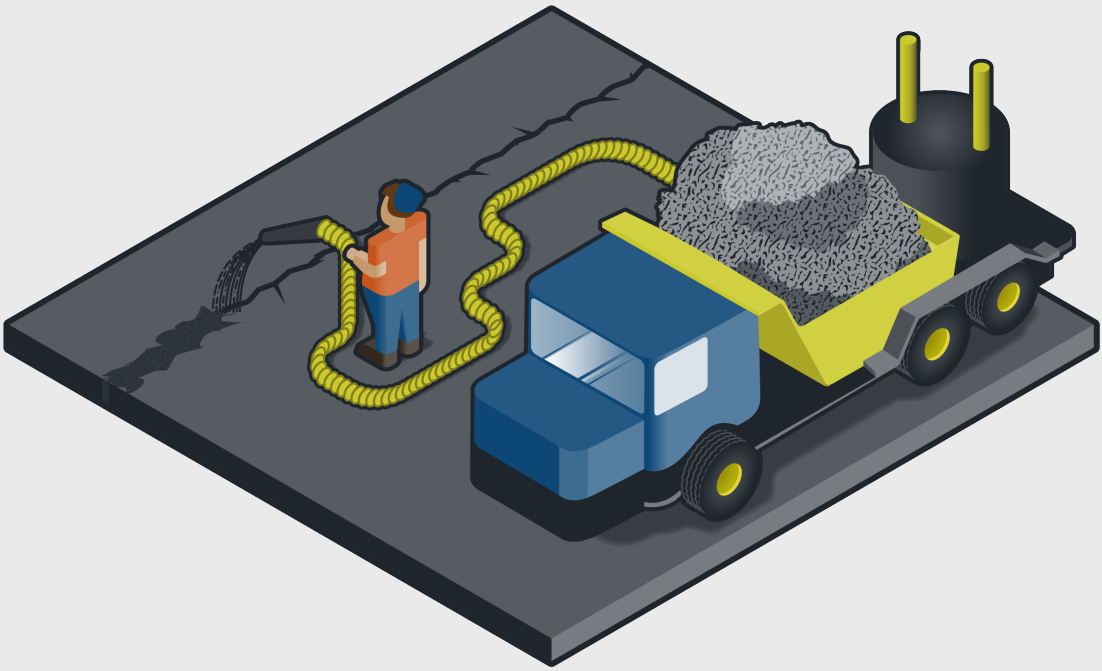
Item	Unit	Description
25X	Square Yard (Square Meter)	Partial Depth Pavement Repair (Spray Injection)
25X	Linear Foot (Linear Meter)	Partial Depth Pavement Repair (Spray Injection)

APPENDIX C

LJ REPAIR PLAYBOOK

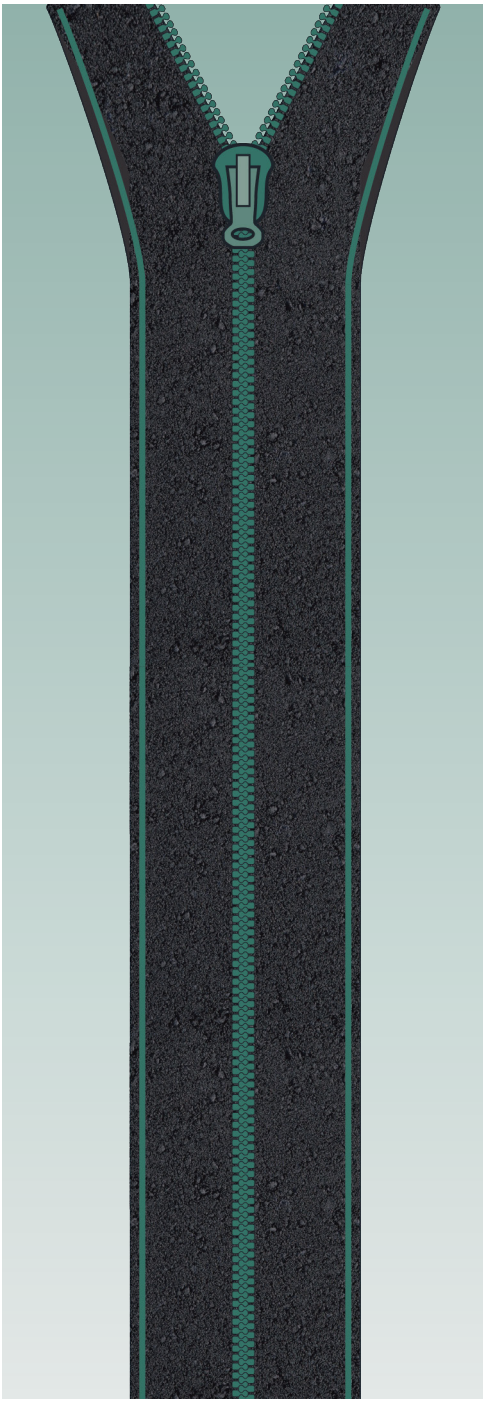
OHIO DEPARTMENT OF TRANSPORTATION

Longitudinal Joint Repair Playbook



Ohio Department of Transportation

applied pavement technology



INTRODUCTION

This *Longitudinal Joint Repair Playbook* (*Playbook*) is provided to assist Ohio Department of Transportation (ODOT) personnel in selecting the optimum treatment to repair a distressed longitudinal joint. The type, severity, and extent of distress will be determined by trained inspectors through a field assessment and used to select the optimum treatment and provide inputs to treatment selection. Optimum treatments are recommended based on the cost effectiveness of the treatments and the longevity of the repair required. The *Playbook* is based on research conducted by Applied Pavement Technology, Inc. for the ODOT in 2017 under State Job Number 135315.

The definitions for longitudinal cracking severity levels provided in the *FHWA Distress Identification Manual for the LTPP*, ODOT's *PCR Manual*, and ASTM D6433 were considered, and new definitions were developed for longitudinal joint distress to simplify the treatment selection process (see following table). The definitions were designed to aid inspectors to identify pavement conditions that have a direct impact on the recommended repair, its corresponding service life, and the agency's budget.

For this document, the terms "joint" and "crack" are sometimes used interchangeably.

Severity	Longitudinal Joint Distress Severity Characteristics
Low	Non-filled longitudinal crack width ≤ 0.25 inch.
Medium	Non-filled longitudinal crack width >0.25 inch and ≤ 3 inches. Non-filled longitudinal crack width is ≤ 3 inches surrounded by low severity random cracking. Filled crack where sealant is failed and surrounded by low severity random cracking.
High	Non-filled or failed sealant longitudinal crack where width is > 3 inches. Filled or non-filled crack surrounded by medium or high severity random cracking. A crack of any width where approximately 4 inches of pavement around the crack is severely broken.

The distress extent for the section should be identified as occasional, frequent, or extensive.

Extent	Letter Identifier	Description
Occasional	O	Less than 25 percent of the longitudinal joint shows distress
Frequent	F	25-70 percent of the longitudinal joint requires treatment
Extensive	E	Over 70 percent of the longitudinal joint requires treatment

Based on these new definitions, the observed distress characteristics, extent, and expected time in years to the next treatment, a corrective repair for the existing distress is recommended.

LOW SEVERITY LONGITUDINAL JOINT DISTRESS

Description

Non-filled longitudinal joint width is less than 0.25 inch

Distress Characteristics

JOINT WIDTH IS LESS THAN 0.125 INCH

JOINT WIDTH IS GREATER THAN 0.125 INCH

Extent

LESS THAN 25% | **25–70%** | **MORE THAN 70%** | **LESS THAN 25%** | **25–70%** | **MORE THAN 70%**

Treatment

DO NOTHING | **MONITOR** | **MONITOR** | **CRACK FILL**

Considerations

Joint has not yet opened to a width in which crack filling would be effective.

Joint has not yet opened to a width in which crack filling would be effective.

Monitor the development of secondary cracking and joint width expansion.

Not cost effective to crack fill due to low quantities. Monitor the develop-ment of secondary cracking and joint width expansion.

Joint must be cleaned prior to sealing to ensure a proper bond between the existing asphalt and the sealant.

Expected Treatment Life

N/A | N/A | N/A | 2–6 years

MEDIUM SEVERITY LONGITUDINAL JOINT DISTRESS

Non-filled longitudinal joint width is greater than 0.25 inch and less than 3 inches

Description

Distress Characteristics

JOINT WIDTH IS BETWEEN 0.25 INCH AND 1 INCH

- **LESS THAN 25%** → **CRACK FILL**
- **25–70%** → **CRACK FILL**
- **MORE THAN 70%** → **CRACK FILL**

JOINT WIDTH IS GREATER THAN 1 INCH AND LESS THAN 3 INCHES

- **LESS THAN 25%** → **CRACK FILL**
- **25–70%** → **SPRAY INJECTION**
- **MORE THAN 70%** → **SPRAY INJECTION**

Extent

Treatment

Considerations

Joint must be cleaned prior to filling to ensure a proper bond between the existing asphalt and the sealant. Crack filling at this point will still be cost-effective and will extend pavement service life.

Due to the low extent of the distress, it would not be cost-effective to carry out any other treatment.

Due to the high crack fill quantity and severity of the distress, crack filling would not be the optimum treatment. Spray injection will introduce aggregate and emulsion into the existing crack and fill it for a longer period of time.

Expected Treatment Life

2–6 years

2 years

MEDIUM SEVERITY LONGITUDINAL JOINT DISTRESS

Description

Non-filled longitudinal joint width is less than or equal to 3 inches surrounded by low severity random cracking (secondary cracking)

Distress Characteristics

JOINT WIDTH IS BETWEEN 0.25 INCH AND 1 INCH

JOINT WIDTH IS GREATER THAN 1 INCH AND LESS THAN 3 INCHES

Extent

LESS THAN 25% | **25–70%** | **MORE THAN 70%**

LESS THAN 25% | **25–70%** | **MORE THAN 70%**

Treatment

CRACK FILL

CRACK FILL AND AREA SEAL

SPRAY INJECTION

SPRAY INJECTION

SLOT PAVING

Considerations

Joint must be cleaned prior to filling to ensure a proper bond between the existing asphalt and the sealant. Sealant at this point will still be cost-effective and will extend pavement service life. Seal secondary cracking greater than 0.125 inch.

Extensive secondary cracking is an indication of load-related distress. Spray injection can effectively seal this area, but may require repeat applications after 2 years.

Longitudinal joint along with secondary cracking should be filled by spray injection.

Extensive secondary cracking is an indication of a load-related distress. Only slot paving would be able to temporarily correct this issue.

Expected Treatment Life

2–6 years

2 years

2 years

4 years

MEDIUM SEVERITY LONGITUDINAL JOINT DISTRESS

Sealed joint where sealant is failed and surrounded by low severity random cracking (secondary cracking)

Description

Distress Characteristics

JOINT WIDTH IS BETWEEN 0.25 INCH AND 1 INCH			JOINT WIDTH IS GREATER THAN 1 INCH AND LESS THAN 3 INCHES		
LESS THAN 25%	25–70%	MORE THAN 70%	LESS THAN 25%	25–70%	MORE THAN 70%
SPRAY INJECTION		SLOT PAVING	SPRAY INJECTION		SLOT PAVING
Longitudinal joint along with secondary cracking should be filled by spray injection to avoid water infiltration. Removing damaged crack sealant is preferred.		Extensive secondary cracking is an indication of a load-related distress. Only slot paving would be able to temporarily correct this issue.	Longitudinal joint along with secondary cracking should be filled by spray injection to avoid water infiltration.		Extensive secondary cracking is an indication of a load-related distress. Only slot paving would be able to temporarily correct this issue.
2 years		4 years	2 years		4 years

Extent

Treatment

Considerations

Expected Treatment Life

HIGH SEVERITY LONGITUDINAL JOINT DISTRESS

Description

Non-filled or failed sealant longitudinal joint width is greater than 3 inches

Distress Characteristics

JOINT WIDTH IS GREATER THAN 3 INCHES

Extent

LESS THAN 25% | **25–70%** | **MORE THAN 70%**

Treatment

SPRAY INJECTION

SLOT PAVING

Considerations

Not cost-effective to slot pave due to small quantities. Spray injection is the most cost-effective treatment, but re-treatment may be required after 2 years.

A crack that is over 3 inches wide means that the pavement is highly susceptible to tensile stresses. Cracks this wide may be experiencing some load-related deflection. Spray injection would not perform well and therefore a more extensive technique is necessary.

Expected Treatment Life

2 years

4 years

HIGH SEVERITY LONGITUDINAL JOINT DISTRESS

Filled or non-filled joint surrounded by medium or high severity random cracking (secondary cracking)

Description

SECONDARY CRACKING IS MEDIUM OR HIGH

Distress Characteristics

ANY	LESS THAN 25%	25–70%	MORE THAN 70%

Extent

SPRAY INJECTION	SLOT PAVING

Treatment

Spray injection is the most cost-effective treatment for temporary repairs	Medium or high severity secondary cracking is an indication of a load-related distress. Slot paving would be able to temporarily correct this issue.

Considerations

2 years	4 years

Expected Treatment Life

HIGH SEVERITY LONGITUDINAL JOINT DISTRESS

Description

A joint of any width where approximately 4 inches of pavement around the crack is severely broken.

Distress Characteristics

JOINT WIDTH IS BETWEEN 0.25 INCH AND 1 INCH

JOINT WIDTH IS GREATER THAN 1 INCH

Extent

LESS THAN 25% | **25–70%** | **MORE THAN 70%** | **LESS THAN 25%** | **25–70%** | **MORE THAN 70%**

Treatment

SPRAY INJECTION | **SLOT PAVING** | **SPRAY INJECTION** | **SLOT PAVING**

Considerations

Spray injection filling the joint and sealing the surrounded broken asphalt.

Crack filling and spray injection would not be cost-effective over the long term. The extensiveness of significant distresses requires a more extensive technique.

Longitudinal joint along with severely broken surrounding pavement should be filled by spray injection.

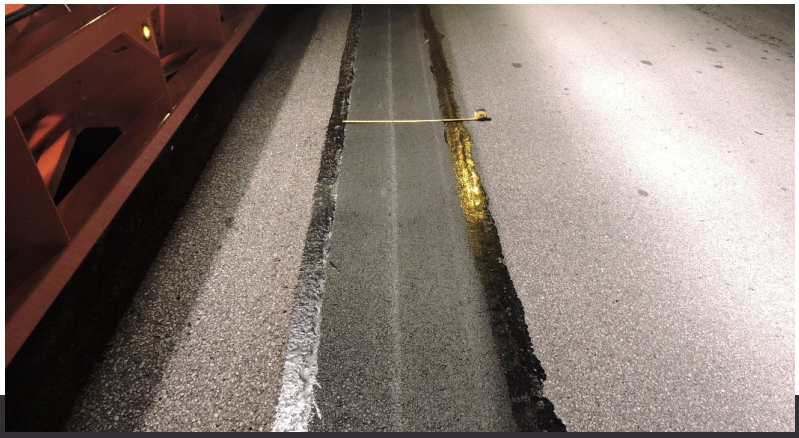
Spray injection would not be cost-effective. Because the distresses are widespread, a more extensive technique is required.

Expected Treatment Life

2 years | 4 years | 2 years | 4 years

Crack Filling

Spray Injection



Slot Paving