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Warranty Utility Cut Repairs (QC/QA of Utility Cut Repairs)

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16. Abstract

Poor construction techniques in utility cut repairs often lead to settlement of the patches, increasing the roughness of the pavement and decreasing the rideability of the repaired pavement. Identifying the company responsible for faulty pavement repairs is difficult since multiple utilities may have performed repairs in the same section.

The objective of this study was to develop a set of guidelines to assist INDOT in addressing challenges with utility cut repairs. The key research tasks included: (1) a synthesis of utility cut repair guidelines among State Highway Agencies (SHAs), (2) interviews with INDOT engineers and utility contractors to identify the challenges faced in restoring utility cuts, (3) an evaluation of INDOT's Electronic Permitting System in the context of managing utility cut permit information, and (4) an investigation of automated methods to track/manage utility cut repairs.

INDOT specifications require utility cuts to be repaired using the T-section method, backfilled either, with soil compacted to 95% Standard Proctor density or with flowable fill, and edges treated with a tack coat for flexible pavements and dowel bars for rigid pavements. These specifications were found to be in alignment with a majority of the specifications of other State Highway Agencies. INDOT personnel recommended that flowable fill be made mandatory to circumvent the need for compaction, and suggested incorporating pre-qualification requirements for contractors who perform utility cut repairs.

INDOT's Electronic Permitting System lacks data fields to store information about contractors performing pavement cut repairs, record details of the work, such as dimensions of the cut, backfill materials, construction methods, etc., and list information about periodic inspections by INDOT. Including data fields to record such information will facilitate a more effective use of EPS for reviewing and managing permits and tracking the work done by permittees. Enhancements to the EPS System could also automated identification of repaired patches by correlating the global positioning system (GPS) location of INDOT's pavement monitoring vehicle with the location information of utility cut repairs from the EPS.

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EXECUTIVE SUMMARY

WARRANTY UTILITY CUT REPAIRS (QC/QA OF UTILITY CUT REPAIRS)

Introduction

Utility cuts are made to either install, maintain, repair, or replace utilities buried under the roadway. Upon completion of the work, the cuts are backfilled, compacted, and resurfaced, leaving behind a pavement patch. These utility cut repairs are expected to restore pavements to their original condition. However, poor construction techniques often lead to settlement of the patches, thus increasing the roughness of the pavement and decreasing the rideability of the repaired pavement. Identifying the company responsible for faulty pavement repairs requires a considerable amount of time and effort, with inspectors having to search for permit information in a database that has records of permits dating back to the 1990s. Information from the Indiana Department of Transportation's (INDOT's) electronic permitting system (EPS) indicates that in the 2012–2016 time frame, INDOT received 12,593 cut-road permit applications. Such a large number of cut-road permit applications is motivation to investigate strategies to reduce or prevent the resulting damage from utility cuts and to develop methods for automated monitoring of utility cut repairs.

In this study, five key tasks were undertaken to develop a set of recommendations and guidelines to assist INDOT in addressing their challenges with utility cut repairs. These tasks included (1) a synthesis of utility cut repair guidelines and practice among State Transportation Agencies (STAs) or Department of Transportations (DOTs), (2) interviews with INDOT engineers and utility contractors to identify the challenges faced in effectively restoring utility cuts, (3) an evaluation of INDOT's EPS in the context of managing utility cut permit information, and (4) an investigation of automated methods to track/manage utility cut repairs.

Findings

INDOT specifications require utility cuts to be repaired using the T-section utility patch, backfilled either with soil compacted to 95% Standard Proctor density or with flowable fill. In addition, the edges of the patch are to be treated with a tack coat for flexible pavements and dowel bars/tie bars for rigid pavements. These specifications were found to be in alignment with a majority of the specifications used by STAs who participated in this study, or whose documents were reviewed as part of the study. Interviews with INDOT personnel revealed that contractors do not always comply with INDOT specifications, and hence, repair jobs often result in improperly restored patches. They conjectured that the non-compliance is partly due to the contractor's lack of familiarity with INDOT specifications or due to difficulties in soil compaction arising out of the size constraints of typical utility cuts. INDOT personnel recommended that flowable fill be made mandatory (instead of soil backfill) to circumvent the need for compaction. They also suggested incorporating prequalification requirements for contractors who perform utility cut repairs. A common observation shared by the INDOT personnel was that utility cuts repaired with temporary patching materials in winter are often not permanently restored during the warmer months. However, determining which company is responsible for an improperly restored utility cut is challenging, given the large number of utility cuts and limited number of inspectors.

INDOT uses the EPS to assist permit managers and inspectors in reviewing, managing, and tracking permits. However, in the context of managing utility cut permits, the following five limitations were identified:

- A lack of distinction between utility cut permits and other "Cut-Road" permits, making the process of searching for utility cut permits overly tedious.
- The requirement for permittees to specify the location of a utility cut operation by means of a mouse click on a map. This method of data entry results in inaccurate locations being recorded in the EPS.
- An absence of data fields for permittees to provide information about the contractors hired to perform the work.
- A lack of data fields to record technical details of the work, such as dimensions of the cut, backfill materials, construction methods, and so forth.
- A lack of data fields to record information from periodic inspections by INDOT inspectors.

To address these limitations, the research team recommends the following modifications to the EPS:

- Addition of data fields to record the permit sub-type (i.e., utility cut), name and details of the contractor, and to store information from periodic inspections.
- Addition of data fields to record technical specifications of the work, such as length and width of the cut, depth of the excavation (if relevant), backfill material used, length of additional cutback to create the T-section, type of edge treatment, and type of surfacing material used (i.e., permanent or temporary patching materials). These additional fields could be incorporated into the EPS using a graphical user interface (GUI) (see Chapter 5).
- Discontinuing the current method of specifying permit locations using a mouse click on a map. Instead, the permittee should be required to measure the location of the repair with a global positioning system (GPS) device, equivalent triangulation method, or physically measure the distance from a known and noted physical location, and report the latitude and longitude of the location.

Two methods for automated condition monitoring of utility cut repairs were investigated during the course of this study. The first method involved the installation of radio frequency identification (RFID) tags in the repaired pavement and the use of RFID readers on pavement monitoring vehicles. The tags which were expected to be automatically identified by the readers would provide the location of the repair, as well as information about the company responsible for the repair. By correlating the location of the repaired patch with the roadway condition at or surrounding the patch, INDOT would be able to periodically monitor repairs for settlement, and also identify the utilities and contractors responsible for the pavement cut repairs. However, based on test results conducted by the RFID vendor on a pilot INDOT project, these tags could not be reliably detected by RFID readers mounted on the vans used by the Pathway roadway condition assessment system. Since further development and testing is being considered by the RFID vendor, the research team and the Study Advisory Committee of this study decided to evaluate a second method for automated monitoring.

The second method for automated condition monitoring involves correlating a pavement monitoring vehicle's global positioning system (GPS) location with the location information of utility cut repairs from the EPS, for automated identification of the repaired patches. After a patch is identified, the roadway condition at or surrounding the patch could be used as an indicator of the condition of the repair. To implement this method, accurate location information about each utility cut repair must be available in the EPS. The current EPS does not distinguish between utility cuts and "Cut-Road" permits. The second barrier to implementation is that INDOT's data collection vehicles currently report pavement condition at intervals of approximately 0.1 miles. Since an interval of 0.1 miles could contain several utility cuts, the research team recommends that the reporting interval be reduced to 0.01 miles for this method to work effectively.

Further Investigation

Degradation Fee/Billings for Defective Work

Utility cuts are known to reduce the service life of roadways. Thus, it is recommended that STAs impose a fee in addition to the permit fee to recover the cost associated with subsequent reduction in pavement service life due to utility cuts. The degradation fee also serves as an incentive to the utilities to coordinate their work with STAs' road construction projects, thereby minimizing the impact to roadways. The degradation fee charged must be fair to the utility contractors and should be technically justifiable. The fee should be reflective of the loss of serviceability of the pavement and could be determined based on the age and service life of the pavement, size of the cut, and so forth.

To alleviate issues related to poor utility cut repairs, STAs may choose to pursue the rework themselves, and later bill the cost of rework to the utility contractors. The outstanding balance for the cost of rework could be considered by STAs in the approval of future permits by a utility contractor. A topic for further investigation could be the implementation of degradation fees and billings for utility cut repairs.

Warranties

This study also recommends the implementation of warranties on utility cuts that failed to achieve the desired smoothness as required by INDOT. These warranties would ensure that adequate measures are taken to preserve the quality of the pavement. Moreover, the utility contractors would be liable for any rework that may be required to achieve the specified level of smoothness. In addition, the warranties would also serve as a motivation for the contractors to perform high-quality work, in order to avoid rework.

Prequalification

Utility contractors' failure to comply with INDOT specifications was one of the concerns that surfaced during the interviews with INDOT engineers. This failure to comply was attributed to the lack of familiarity of utility contractors with INDOT specifications. A common recommendation to address this concern is the implementation of prequalification for contractors performing utility cut repairs. By only permitting prequalified contractors, INDOT would be assured that its standards will be met. Effectively communicating the expectations by means of INDOT-led orientations and training programs could improve contractors' understanding of INDOT requirements.

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LIST OF ABBREVIATIONS

ACI	American Concrete Institute
ACPA	American Concrete Pavement Association
ADA	Americans with Disabilities Act
APWA	American Public Works Association
ASTM	American Society of Testing Materials
CATV	Cable Television
CA	California
Caltrans	California Department of Transportation
CO	Colorado
CDOT	Colorado Department of Transportation
CDF	Controlled Density Fill
CLSM	Controlled Low Strength Material
DOT	Department of Transportation
EPS	Electronic Permitting System
FHWA	Federal Highway Administration
FL	Florida
FDOT	Florida Department of Transportation
GPS	Global Positioning System
GUI	Graphical User Interface
HMA	Hot Mix Asphalt
ID	Idaho
ITD	Idaho Transportation Department
IL	Illinois
IDOT	Illinois Department of Transportation
IN	Indiana
INDOT	Indiana Department of Transportation
IRI	International Road Roughness Index
IA	Iowa
KS	Kansas
KDOT	Kansas Department of Transportation
MI	Michigan
MDOT	Michigan Department of Transportation
MT	Montana
MDT	Montana Department of Transportation
NE	Nebraska
NV	Nevada
NDOT	Nevada Department of Transportation
NJDOT	New Jersey Department of Transportation
NC	North Carolina
NCDOT	North Carolina Department of Transportation
OH	Ohio
ODOT	Ohio Department of Transportation
RFID	Radio Frequency Identification
ROW	Right of Way
RRP	Road Reference Post
SC	South Carolina
SCDOT	South Carolina Department of Transportation
SHA	State Highway Administration
STA	State Transportation Agency
SAC	Study Advisory Committee
TX	Texas
TxDOT	Texas Department of Transportation
UAM	Utility Accommodation Manual
UAP	Utility Accommodation Policy
VA	Virginia
VDOT	Virginia Department of Transportation
WA	Washington
WSDOT	Washington Department of Transportation

1. INTRODUCTION

Utility cuts are made to either install, maintain, repair, or replace buried utilities. Upon completion of the work, the cuts are backfilled, compacted, and resurfaced, resulting in a pavement patch (see Figure 1.1). These utility cut repairs are expected to restore pavements to their original condition. However, poor construction techniques often result in settlement of the patches, leading to a reduction in the life of the pavement.

State highway agencies (STAs) typically prohibit the use of open cutting on roads unless there are no reasonable alternate methods to accomplish the work. However, information from INDOTs electronic permitting system (EPS) indicates that between 2012 and 2016, INDOT received 12,593 cut-road permit applications. Such a large number of cut-road permit applications is motivation to investigate strategies to reduce or prevent the resulting damage from utility cuts. This motivation is also in line with INDOT's goal of managing the right of way by preserving the integrity, safe operation, and function of the state highway system (INDOT, 2014).

1.1 Background

Providing consistent roadway pavement conditions with minimal irregularities is of primary concern for highway agencies nationwide. However, maintaining consistently smooth pavements tends to be difficult due to the existence of buried utilities under the roadway, which often require access through open cutting. According to the Federal Highway Administration (FHWA) utility cuts increase pavement roughness, decrease pavement rideability, and often lead to a decrease in pavement life (FHWA, 2015). Utility cuts have the greatest damaging effect on newly paved streets, leading to a significant reduction in roadway life (Tarakji, 1995).

Pavement patches create a joint where they meet the existing pavement, thus making the pavement more permeable and vulnerable to moisture penetration. The manner in which the pavement fails depends on factors such as the quality and type of restoration adopted, backfill materials used and their compaction, and the age and condition of the existing pavement before restoration. A study by the Iowa Highway Research Board (IHRB) that included a survey of seven cities across Iowa, indicated that utility cut restorations often lasted less than two years (Schaefer, Suleiman, White, Swan, & Jensen, 2005). Typical pavement patch failures that occur within the first year or two after the repair include: settlement of the pavement patch, pavement patch rising to form a hump over the utility cut area, settlement of the pavement adjacent to the utility patch, and ultimately the failure of the patch" (Schaefer et al., 2005).

INDOT personnel have often observed utility cut patching operations similar to those shown in Figure 1.2, where upon completion of utility repairs, contractors 'patch the pavement cut' by merely 'dumping cold mixed asphalt" with no compaction process, and 'hoping that moving vehicles will consolidate the patching material." This mode of utility cut patching is a recurring theme that INDOT permit engineers encounter frequently. One of the major problems faced by INDOT is in determining which utility/company had performed the faulty work, since at times there are several utility companies performing work in the same area. In such situations, there is no clear method to identify who is responsible for each pavement cut. Another key challenge is monitoring the compaction procedure in the field. There are three options to ensure the delivery of high-quality utility cut repairs: (1) include the inspection of compaction of the patched surface as key component of the current specifications, and assign resources to undertake this task, (2) utilize a performance specification (for instance, include IRI and/or other measurements) before payment is made, and (3) utilize a warranty specification that requires the utility permittee to guarantee the restored/repaired utility cut meets specific requirements after a certain period of time. Currently, INDOT does not include any of these options in the assessment of pavement cut repairs.

1.2 Research Objectives

To improve the quality of pavements post utility cutting, a study is needed to standardize the QC/QA process of utility cuts and explore possible strategies to manage information related to utility cuts. This study aims to answer the following questions:

1. What are the current utility cut repair guidelines and practices adopted by other STAs in the United States?
2. What challenges does INDOT face in managing utility cut repairs?
3. What challenges do utility contractors face when performing utility cut repairs?
4. What can INDOT do to manage information/track the condition of different utility cut patches?

An outcome of this study will be suggested modifications to INDOT's utility cut repair guidelines and Electronic Permitting System (EPS).

1.3 Research Approach

A literature review was initially conducted to investigate typical utility cut repair operations. Four key tasks were then undertaken to develop a set of recommendations and guidelines to assist INDOT in addressing the challenges with utility cut repairs (see Figure 1.3):

1. A synthesis of utility cut repair guidelines and practices among STAs in the U.S. was developed. This task was achieved by: (a) reviewing the standard specifications and utility accommodation manuals of STAs in order to identify current utility cut repair guidelines, and (b) conducting a survey of US STAs in order to identify utility cut repair practices.
2. Phone interviews were conducted with INDOT engineers, engineers from the City of Indianapolis, and a utility

Figure 1.1 Example of a utility cut repair operation on a concrete pavement (Schaefer 2005).

Figure 1.2 Example of a poorly performing utility cut. (Courtesy of Dr. Tommy Nantung and Dr. Jusang Lee, August 2015.)

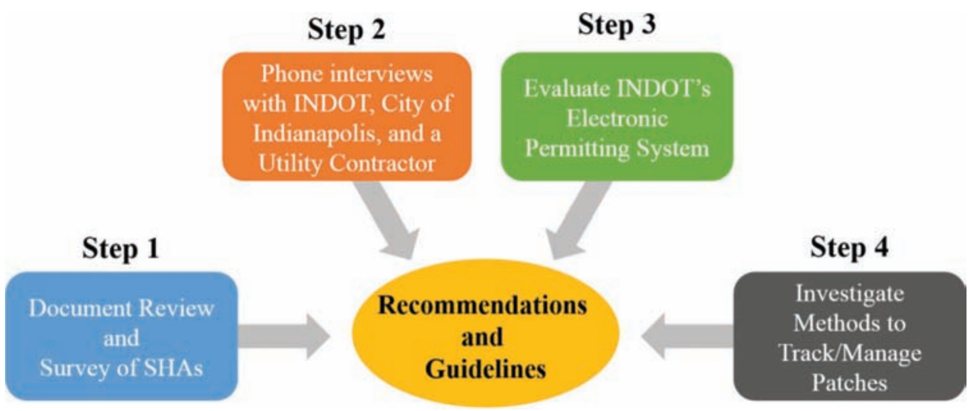


Figure 1.3 The four-step research approach adopted in this study.

contractor to identify the challenges faced with respect to repairing utility cuts.

3. A detailed evaluation of INDOT's EPS was performed within the context of managing of utility cut permit information.
4. An investigation of two methods to facilitate the automated tracking of utility cut repairs.

2. UTILITY CUT REPAIRS

This chapter discusses prior research in the domain of utility cut repairs and some of the common engineering practices adopted in the field. Further, the chapter describes the steps involved in utility cut repairs and the specifications provided by INDOT for pavement cutting and restoration.

2.1 Standard Methods of Utility Cut Repairs

Utility cut repairs typically consist of the following three basic steps in sequence: pavement removal, backfilling, and pavement restoration. However, the specifications provided for each of the three steps vary across STAs. The following section provides an overview of the procedures adopted across different STAs (including INDOT) for utility cut repairs.

2.1.1 Pavement Removal

A typical utility cut begins with the pavement being saw cut in straight lines separated enough to accommodate trenched construction (see Figure 2.1). In the case of small openings, jackhammering is more

Figure 2.1 *Left:* asphalt pavement removal (Schaefer et al., 2005); *right:* saw cutting of a concrete pavement (ACPA, 2009).

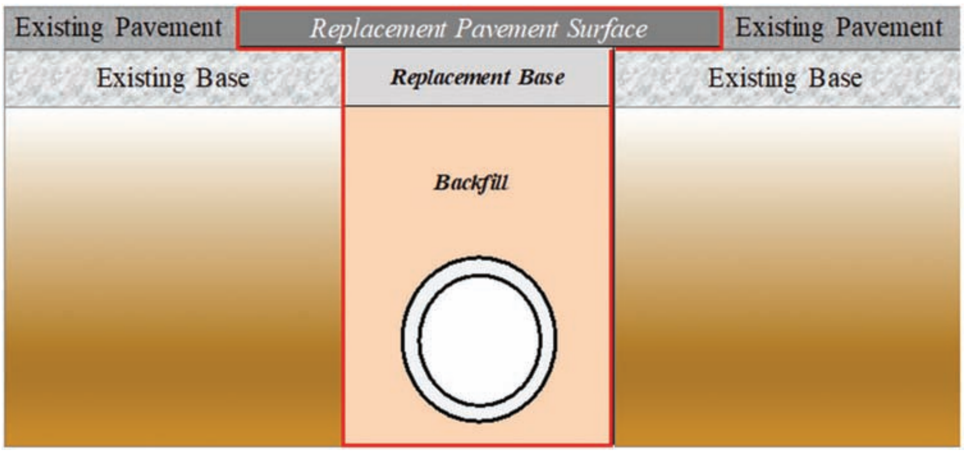


Figure 2.2 Typical T-section patch with additional section of pavement cut on either side of the trench.

appropriate and practical than saw cutting (Todres, 2011). The depth of saw cut varies across STAs, from a few inches to the entire depth of the pavement, depending on thickness of the pavement. For instance, the Department of Public Works and Transportation at Dallas allows breakout grooves to be sawed to a minimum depth of 1.5 inches instead of the full depth of the pavement (City of Dallas, 2003). The width of the initial saw cut is usually equal to the width of the trench.

INDOT's specification for bituminous pavements states that "*the trench or area to be removed shall be sawed to a minimum depth of 2 inches. Breakage shall be confined to required lines. The edge of the area after removal shall be such that the maximum variation from the vertical will not exceed 1½ inches. In trimming and straightening these edges it may be necessary to use hand methods. Methods and equipment used in cutting, breaking, and removal shall not cause undue breakage, excessive shattering or spalling of the bituminous pavement to be left in place*." (INDOT, n.d.).

INDOT's specification for concrete pavements states that "*the trench or area to be removed shall be sawed to the bottom of the steel mesh with a minimum depth of 2 inches. Breakage shall be confined to required lines. The edge of the area after removal shall be such that the maximum variation from the vertical will not exceed 1 ½ inches. In trimming and straightening these edges it may be necessary to use hand methods. Methods and equipment used in cutting, breaking, and removal shall not cause undue breakage, excessive shattering or spalling of the concrete to be left in place and shall be such that will prevent excessive vibration and shock from being transmitted along reinforcing steel to the adjacent pavement.*" (INDOT, n.d.).

After the trench has been backfilled and compacted, an additional section of pavement surface on either side of the trench is saw cut. The width of the second cut is usually 2 feet wider than the original cut (i.e., an overhang of 1 foot on either side of the trench), resulting in the formation of a T-section or bridge patch (see Figure 2.2). In a T-section the location of the patch joints is offset from the sides of the trench, preventing the creation of a plane of weakness directly under the patch joints. Once the pavement is restored, the patch bridges the utility trench and rests on the original base layer on either side of the trench. When examined in cross-section, the patch and trench appear to create a T-shape.

A study on the impact of excavation on the streets of San Francisco, recommended that the contractor make two cuts in the pavement, an initial cut prior to excavating the trench, and a wider cut after backfilling and compaction (Tarakji, 1995). Opting for a single wider cut prior to excavating the trench could lead to the top of the excavation sloughing off (see Figure 2.3), because excavation for utility repairs creates a weak zone of soil adjacent to the utility patch, which in time, leads to the failure of the patch (Schaefer et al., 2005). A T-section decreases the stresses imposed on the pavement as it incorporates the undisturbed soil surrounding the excavation and provides additional support to the pavement patch (APWA, 1997). This method of patching prevents sloughing off of the material adjacent to the utility excavation. INDOT's specification requires a T-section patch on flexible as well as rigid pavements (INDOT, n.d.).

In addition to creating a T-section utility patch, an additional section of the pavement base layer can be cut in such a manner that the extents of the pavement surface, base layer, and trench do not lie in the same vertical plane with either of the other two areas of the utility cut repair. This practice results in the creation of staggered T-section patch and prevents the formation of a single vertical plane of weakness through the different pavement layers and excavated trench (see Figure 2.4). The width of the cut in the base layer is typically 1 foot wider than the trench (6 inches on either side of the trench).

Figure 2.3 Material sloughing off the edges of a trench (Schaefer et al., 2005).

2.1.2 Backfilling

Following the completion of utility work, the trench must be filled with an appropriate backfill or flowable fill. According to the APWA (1997) cohesionless granular native materials compacted to high densities are suitable to backfill the trench. INDOT's specification states that *"The backfill shall be Compacted Aggregate Base or "B" Borrow. The compacted aggregate base or "B" Borrow shall extend beyond the shoulder line at a slope of 1 to 1. This backfill shall meet Department of Transportation Standard Specifications."* (INDOT, n.d.). The Standard Specification defines B borrow as *"The material used for special filling shall be of acceptable quality, free from large or 20 frozen lumps, wood, or other extraneous matter and shall be known as B borrow. It shall consist of suitable sand, gravel, crushed stone, ACBF, GBF, or other approved material. The material shall contain no more than 10% passing the No. 200 (75 μm) sieve and shall be otherwise suitably graded. The use of an essentially one-size material will not be allowed unless approved."* (INDOT, n.d.). A common practice among SHAs including INDOT, is to place the backfill in lifts no larger than 8 to 10 inches, and compact each layer to 95% of the Standard Proctor Density. However, achieving this amount of compaction tends to be challenging due to difficulties in performing mechanical compaction in a constrained space.

Flowable fill—also known as soil-cement slurry, controlled low strength material (CLSM), soil-cement grout, unshrinkable fill, flowable mortar, controlled density fill (CDF), plastic soil-cement, and K-Krete—can be used as a backfill material in place of compacted soil. ASTM D4382 (2002) defines CLSM as *"A mixture of soil, cementitious materials, water, and sometimes admixtures that hardens into a material with a higher strength than the soil but less than 8400 kPa (1200 psi). Used as a replacement for compacted backfill, CLSM can be placed as a slurry, a mortar, or a compacted*

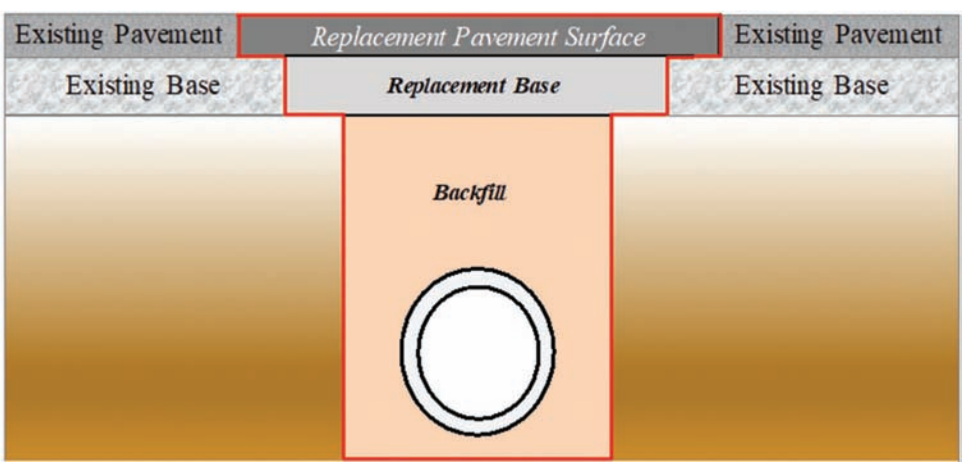


Figure 2.4 Variation in the T-section patch, with the replacement base layer extending beyond the edges of the trench.

material and typically has strengths of 350 to 700 kPa (50 to 100 psi) for most applications." (INDOT, n.d.). While flowable fill tends to require a larger upfront cost than traditional backfilling, the use of this material circumvents the need for compaction. A study by Meade, Hunsucker, and Stone (1993) concluded that in cases where the volume of trench backfill is sufficiently small, the cost of using flowable fill is comparable with the cost of using conventional backfill. The immediate costs of using CLSM backfill and conventional backfill (manufactured sand) for a 28-foot-long, 6-foot-deep, and 4.5-foot-wide trench was found to be $669.88 and $672.44, respectively (Meade et al., 1993). The advantages of flowable fill over traditional backfill materials include (1) better strength and durability, (2) little required field inspection, and (3) elimination of settlement once the mix has cured (ACI Committee 229, 2013).

2.1.3 Pavement Restoration

After backfilling and compaction, the cut should be restored to match or exceed the original pavement. Base and surfacing for asphalt pavements typically consist of a specified depth of stabilized aggregate base course and a bituminous surface course. For bituminous pavements INDOT's specification states that "*pavement replacement shall not be less than 12 inches of bituminous base mixture, thoroughly compacted in lifts of not more than 3 inches and a top lift of 1 inch shall be bituminous surface mixture properly compacted. All exposed bituminous edges shall be treated with bituminous tack. A "Wacker Rammer" compactor or equivalent shall be used for compacting the bituminous mixtures. The surface course shall meet Department of Transportation specifications for smoothness*" (INDOT, n.d.). For asphalt pavements, a tack coat is usually applied to all vertical edges (i.e., surfaces where the trench has been cut) to assure a good bond and seal between old and new pavements. In certain situations, the entire affected area of asphalt pavements should be resurfaced or overlaid, after a specified amount of time once the repair has been completed. SCDOT for example, requires asphalt roadways to be overlaid one year after initial restoration of the pavement.

The American Concrete Pavement Association (ACPA) recommends repairing cuts in concrete pavements with concrete (ACPA, 2009). Such repairs consist of a concrete slab over a stabilized subbase. INDOT's specification states that *"The depth of the concrete pavement shall be the same as the removed pavement except it shall be a minimum of 9 inches. Anchor bolts shall be placed along all sides of the removed area. The spacing shall be 3 feet center to center on the transverse side and 5 feet center to center on the longitudinal side with a minimum of 2 anchor bolts on a side. The anchor bolts and steel reinforcing shall be the same type (of steel reinforcing bars) and shall be placed as specified in the Department of Transportation's Standard Sheets. The concrete used shall be high early strength as set out in the Indiana Standard Specifications, except test beams will not be required"* (INDOT, n.d.). For utility cut repairs in concrete pavements that are 7 inches (175 mm) or thicker, dowel bars are used to achieve load transfer (i.e., the ability of the repaired section to transfer its load to the adjacent concrete) (ACPA, 2009).

2.2 Related Studies on Utility Cut Repairs

The increase in infrastructure requirements to meet the needs of growing cities has led to an increase in the number of utility cuts on urban streets (Todres, 2011). Excavation is often required for installation of pipes or cables for utilities such as water, gas, telecommunications, and wastewater (Schaefer et al., 2005). A direct consequence of these cut repairs is the loss in aesthetics due to appearance of repair patches. In certain situations, it may be possible for utilities and agencies to coordinate pavement rehabilitation with major utility work. However, such coordination cannot be undertaken in case of emergencies such as gas pipe leaks or water main breaks (Todres, 2011).

The Utility Accommodation Policy of certain states and counties, such as IDOT and Nashville, Tennessee require that the roadway be restored to a condition which is at least as good, if not better than the condition prior to the utility cut (Metro Nashville, 2008). The real issue is not the cutting of the pavement but the manner in which pavement restoration is carried out after the utility work is completed. A typical utility cut repair process involves (a) marking the location of the cut, (b) cutting the pavement at the required location (with or without additional cutbacks), (c) excavation of a trench, (d) repair/installation of the utility, (e) backfilling and compaction, and (f) repaving of the surface (FHWA, 2015). Schaefer et al. (2005) attribute the poor performance of pavements around utility trenches to improper backfilling i.e., inadequate compaction, improper backfilling, and improper moisture control of the trenches. Peters (2002) reported that deterioration of the pavement can be caused by water seeping into the base course through the cracks which may be formed by distress in the pavement. Such events influence the integrity of the pavement, pavement life, aesthetic value, and safety of the driver (Arudi, Pickering, & Flading, 2000). Tiewater (1997) observed that a utility cut on a pavement can reduce the functional life of the repaired portion by up to 50% of its design life. Repairs often fail to restore pavements to their original condition (Schaefer et al., 2005). This has led to several cities pursuing projects to assess the damage caused by utility cuts and evaluate a suitable fee schedule to reclaim the damages (Metro Nashville, 2008).

During an investigation of improved utility cut repair techniques by Videkovich (2008), the types of failures documented were (a) settlement of the utility cut restoration, (b) a "bump" forming over the restoration, and (c) weakening of the surrounding soils. Further, the study identified that settlement was caused by a combination of poor compaction of natural soil, exposure of backfill material to wet or frozen conditions, or the use of unsuitable backfill material (Videkovich, 2008). The formation of the "bump" is due to differential frost heave, and subsequently leads to the settlement of the patch (Maher, 2013). A region of weak soil, commonly referred to as the "zone of influence," is created adjacent to the excavated trench or pit. This weakened zone of natural soil which lacks adequate lateral support, triggers cracking in the surrounding pavement (Videkovich, 2008). According to the FHWA, one of the primary causes of failure is poor or improper compaction of the backfill material (FHWA, 2015). Other causes of failure of repaired cut pavements identified were insufficient thickness of materials, poor quality of materials, and damage to the side of the cut (Macy, 2002). In addition to these causes of failure, field and laboratory investigations by Jensen, Schaefer, Suleiman, and White (2005) attribute the poor performance of cut repairs to inadequate minimal moisture content control and the use of large construction equipment, leading to uneven compaction, weakening of soil around the edges of the trench, and differential settlement.

Lee and Lauter (1999), Jensen et al. (2005), Videkovich (2008), and Todres (2011) have developed guidelines to improve current practices of utility cut repairs. A special report published by American Public Works Association (APWA, 1997) states that, "*The issues surrounding the management of utility cuts are as varied as the cuts are numerous. As the demand for greater access to the right of way increases, so will the need for better coordination of multi-agency schedules and a higher level of accountability for employing less intrusive, more durable and cost-efficient methods for making utility cuts.*" Trenchless methods have been explored and adopted for the installation of new utilities. These methods, which include boring and tunneling, are being mandated by State Highway Agencies such as those of Fort Wayne, Greenfield, and Vincennes Districts in Indiana, during installation of new utilities, unless proven infeasible. Likewise, MDOT, ODOT, and KYTC do not permit open cutting of pavements, unless no other reasonable alternative is available. Under circumstances where open utility cuts are unavoidable, careful execution of cutting and repairing tasks, in accordance to established specifications, quality assurance and quality control procedures becomes imperative. The advantages associated with the use of trenchless technology are minimal disturbance to traffic, smaller construction crew requirement, reduced impact on businesses, lower noise and air pollution, and lesser haul materials (Iseley & Gokhale, 1997). However, a survey conducted by Iseley and Gokhale (1997), also pointed out that trenchless methods had the potential to form sinkholes due to errors in construction (improper use of trenchless methods).

The most commonly implemented practices to preserve the quality of pavements after utility cuts, are the use of flowable fill material in trenches, adequate compaction of trench soil, and the use of additional cutback or T-sections. However, these practices are also known to result in poorly performing repairs. Todres (2011) noted that the use of flowable fill material leads to differential frost penetration caused by differential thermal conductivity. The differential frost heave may in turn lead to the formation of bumps, which affect rideability (Baker, 1998). Other issues with using flowable fill include high environmental cost, especially if the excavated material is no longer being re-used as backfill (Baker & Goodrich, 1994). Additionally, a cutback or T-section does not always mitigate the settlement of soil as they cannot account for poor compaction, and pavement surfaces are often made of visco-elastic materials that cannot provide the bridge effect (Todres, 2011).

Advanced technologies have evolved over the years to mitigate issues related to utility cut repairs. The Keyhole Technology developed in the early 1990s, for instance, is now widely used throughout North America by gas utility companies (Maher, 2013). Maher (2013) also reported that National Grid (a gas and electricity company in the United States) estimated savings of $4.5 million for cutting and restoring 4,516 keyholes compared to conventional methods in the year 2010 (Maher, 2013). The keyhole technology includes the following steps: (a) extraction of the pavement core using a truck mounted coring machine; (b) removal of loose material and excess moisture from the core hole; (c) repair/maintenance of the utility using a long handle tool; and (d) insertion of the core and grouting (see Figure 2.5). The Keyhole Technology allows reopening of the road to traffic in about two hours after beginning of reinstatement procedures (Maher, 2013). In addition to lower traffic disruption, there is a significant reduction in the amount of materials needed and equipment time associated with this technology (Maher, 2013) as this technology eliminates the requirement of flowable fill and problems related to disposal of excavated soil material.

A measure taken by the City of Dayton (Ohio) to ensure the quality of workmanship while carrying out utility cut repairs is the mandatory placement of radio frequency identification (RFID) tags during restoration. Typically, these RFID tags are placed in the middle of the cut, at a depth specified by the Engineer as per the pavement class (City of Dayton, 2016). A single RFID tag issued to the permittee by the Engineer is placed in each cut. The City of Dayton *Rules and Regulations for Making Openings in a Public Way* specifies that for pavement cuts exceeding fifty feet, one RFID tag is placed at each end, or at fifty-foot intervals, or as determined by the Engineer (City of Dayton, 2016). Further, for concrete pavements, e one RFID tag is placed in the middle of both transverse construction joints prior to sealing (City of Dayton, 2016) as shown in Figure 2.6. While for asphalt pavements overlaid on a concrete base, a RFID tag is placed in the middle of restoration in between the intermediate and surface lift of the asphalt (City of Dayton, 2016) as shown in Figure 2.7.

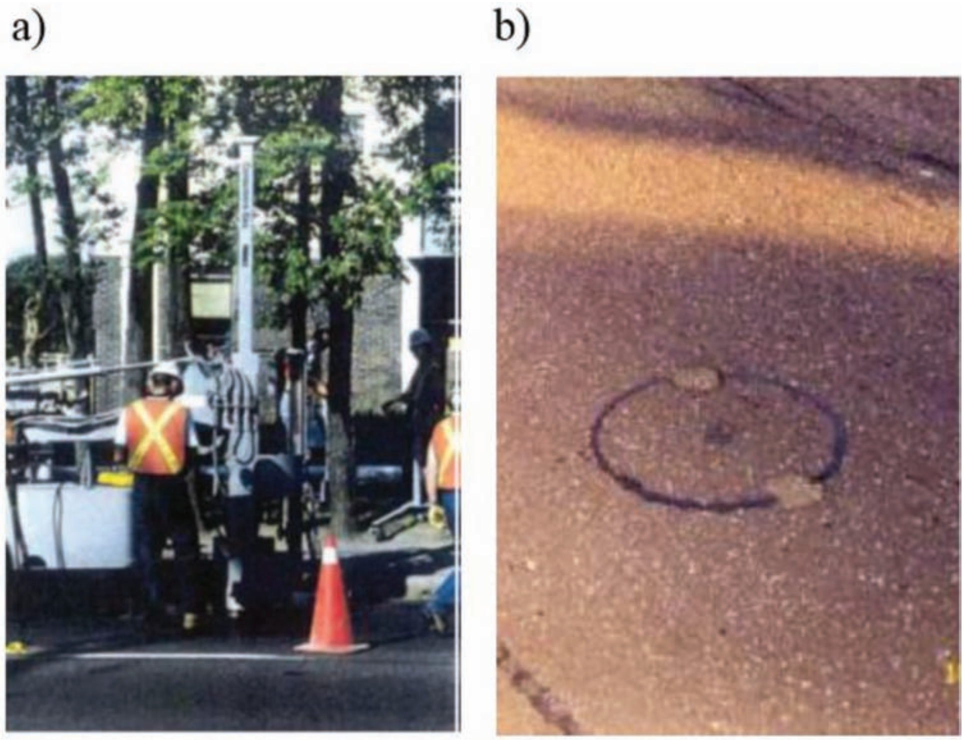


Figure 2.5 (a) Extraction of a core (Maher, 2013); (b) appearance of pavement after reinstating the core (Maher, 2013).

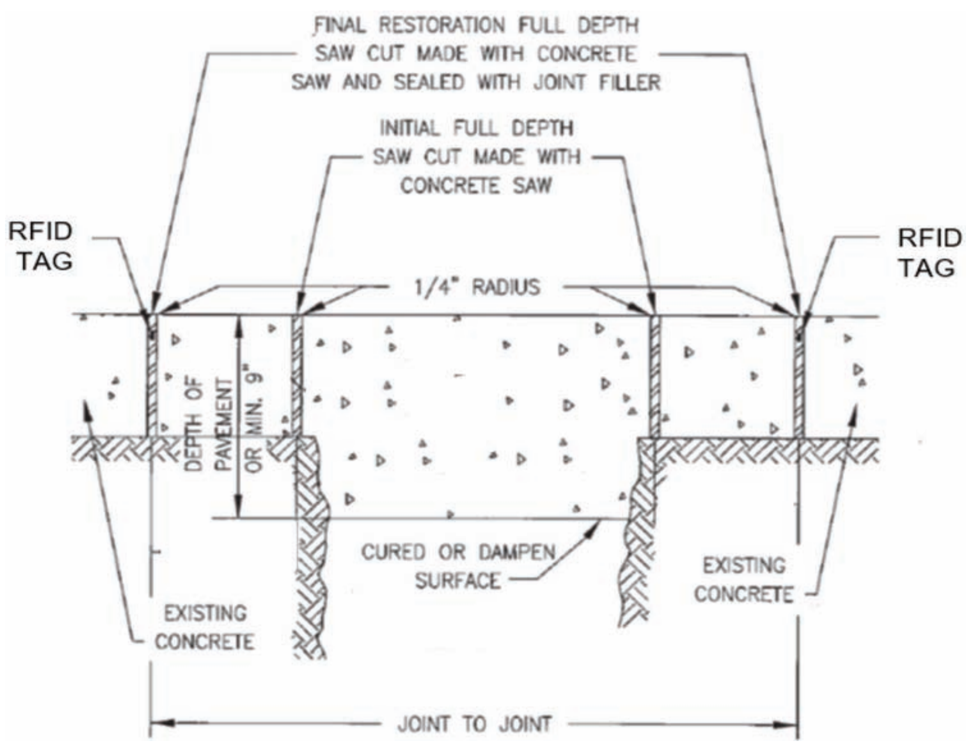


Figure 2.6 Placement of RFID tags in concrete pavement (City of Dayton, 2016).

This sandwiching of RFID tags also ensures at least two lifts of compaction. In the case where the RFID tag cannot be detected within the cut by the Engineer, the Utility must replace the cut with a RFID tag within thirty calendar days of this discovery (City of Dayton, 2016).

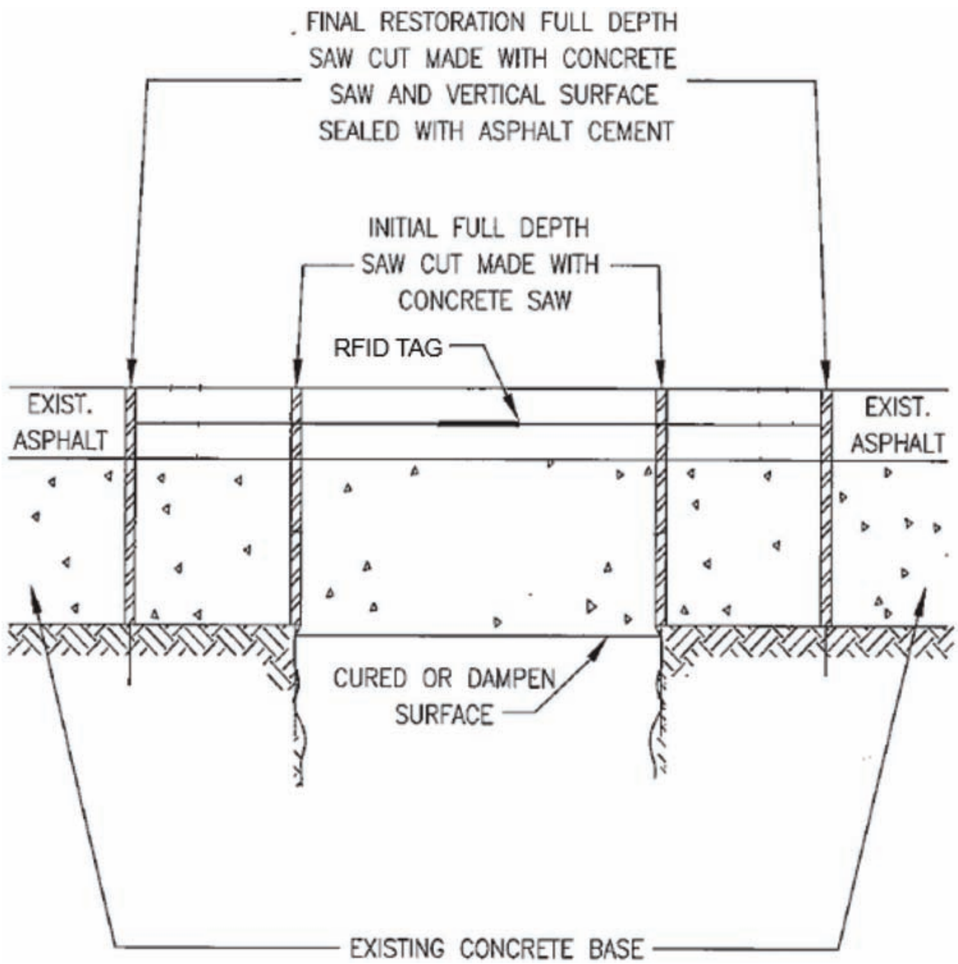


Figure 2.7 Placement of RFID tags when asphalt is laid on concrete base (City of Dayton, 2016).

Since improper reinstatement of the pavement patches leads to deterioration of roads, it is essential to carry out the cutting and restoration operations in a way that will eliminate or reduce damage to the pavement. The restoration plan should be designed such that the performance of the restored patch is comparable with the surrounding undisturbed pavement (Todres, 2011). Generally, a service life of 15 to 20 years can be expected if the pavement restoration and trench backfill are constructed in a proper manner (Jensen et al., 2005). According to Mahar (2013), the enforcement of appropriate standards and specifications and implementation of quality control can reduce the negative impact of utility cuts.

3. UTILITY CUT REPAIR PRACTICES AND GUIDELINES AMONG STATE TRANSPORTATION AGENCIES (STAs) IN THE US

To investigate the current utility cut repair practices and guidelines, the research team conducted a survey of STAs in the U.S., followed by a review of the states' published utility cut repair guidelines (e.g., standard specifications, utility accommodation manuals, right-of-way permit applications, etc.). The survey aimed to gauge whether the current utility cut repair practices adopted by STAs yielded satisfactory results, whether the respondents used any special methods/techniques to extend the life of the repairs, and to explore if STAs had warranty requirements for the repaired pavement patches (see Appendix A for a copy of the survey questionnaire). Twenty-five (25) respondents from 19 STAs completed the survey.

The project team also conducted a detailed review of the utility cut repair specifications of the 19 STAs that responded to the survey. The goal of this task was to synthesize the utility cut repair specifications of STAs in the US and provide a comparison between INDOT's specifications and those of the other 19 STAs. Information sought from the review of these documents pertained to standard pavement cut specifications, pavement repair specifications, QC/QA practices, warranties, and performance bonds. Figure 3.1 shows the 19 states whose STAs participated in the survey.

3.1 Current Utility Cut Practices at STAs

The survey participants were asked whether they had a standard method of utility cut repair and whether the

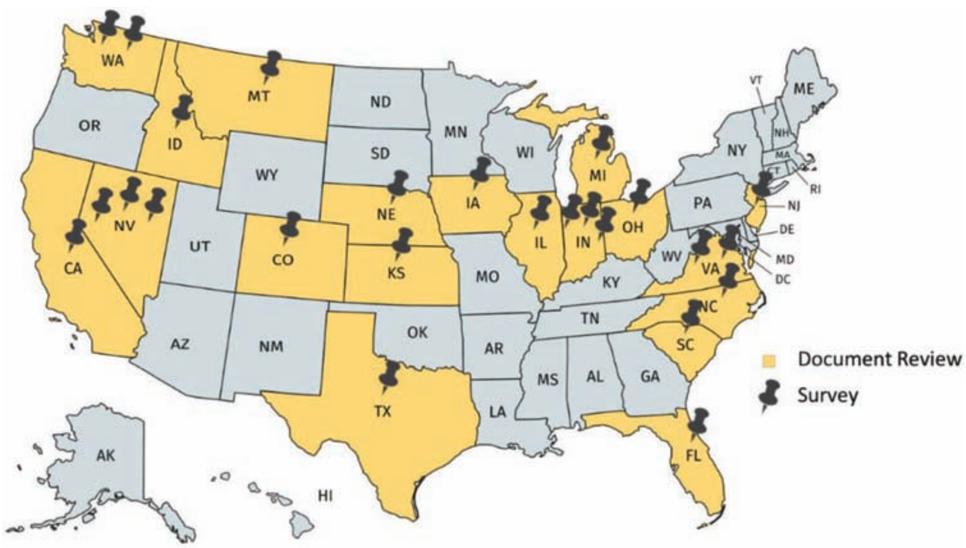


Figure 3.1 STAs whose standards and practices were evaluated in this study, through a survey and review of documents.

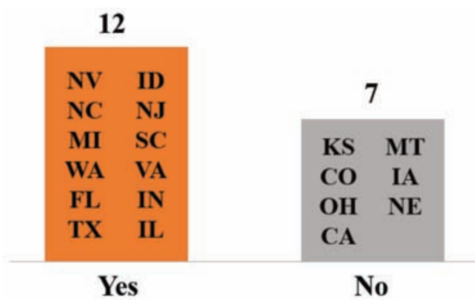


Figure 3.2 Responses to the question: "Does your agency have a standard method of repair of utility cuts in the pavement?"

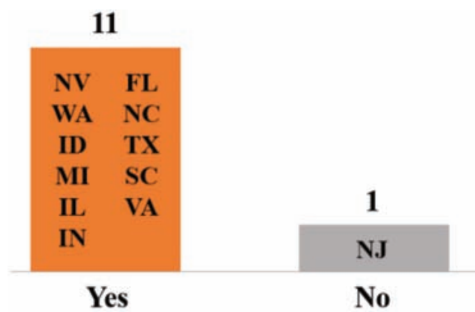


Figure 3.3 Responses to the question: "Does your standard method of repair produce satisfactory results?"

standard method yielded satisfactory results. As shown in Figure 3.2, respondents from 12 STAs indicated that they did have a standard method of utility cut repair, while respondents from 7 STAs indicated that their STA did not have used a standard method of utility cut repair. A majority of the respondents (i.e., 12 respondents representing 11 STAs) shared the perception that their standard method of utility cut repair provided satisfactory results (see Figure 3.3).

The participants were also asked to provide details about how their STAs measured satisfactory results, and their performance expectations of utility cut repairs. Respondents from NDOT indicated that meeting or exceeding minimum compaction requirements was the criteria to gauge success of the repair. The extent of compaction was tested using nuclear gauge in-place density testing. One respondent from the NDOT indicated that the contractor is required to use a third-party testing agency to measure the compaction parameters. The STA respondents also indicated that the repaired patch was expected to match the design life and ride smoothness of the existing pavement. WSDOT respondents indicated that density measurements are conducted when possible to test the success of the repair, and the expectation is that the repair should perform as well or better than the surrounding pavement and last until the next resurfacing of the pavement. IDOT respondents indicated that the smoothness and durability were the two indicators of a successful repair. Furthermore, they stated that they held the utility responsible for the patch for its lifetime, and mandated that any faults in the patch must be repaired by the utility.

MDOT respondents indicated that repairs are tested during the repair and after completion of the work. The repair is expected to match the existing pavement's design and life, and should provide a smooth ride. NCDOT respondents indicated that there is no specific measure of success when it comes to pavement repair; instead they rely on the perception of performance over time. NCDOTs expectation is that the repair matches the existing pavement in performance. TxDOT indicated varying expectations of utility cut repairs. The acceptance level for the smoothness of the patch typically depends on the judgement of the inspector from the maintenance office. Furthermore, they expect the repair to last until the roadway is resurfaced in the future.

TABLE 3.1
Perception of satisfactory utility cut repairs

STA	Measure of satisfactory utility cut repairs
Idaho Transportation Department (ITD)	Material and compaction testing is performed during the repair
	The repair should have similar design life and smoothness as the existing pavement
Illinois DOT (IDOT)	Smoothness and durability of the repair are the basis for measuring satisfactory repairs
Indiana DOT (INDOT)	Settlement in the repairs are measured after 1 year
Michigan DOT (MDOT)	Inspection during and after repair
	Patch should match design life and provide a smooth riding surface
Nevada DOT (NDOT)	Density measurements during repair, third-party testing through contractor
	Patch should match design life and smoothness of existing pavement
North Carolina DOT (NCDOT)	Perception of performance over time
	Similar performance to existing pavement
Texas DOT (TxDOT)	Smoothness to the satisfaction of the inspector
	Expect the repair to last until further construction on the roadway
Virginia DOT (VDOT)	Settlement is checked within 2 years of repair
	The repair should match existing pavement in ride and durability
Washington DOT (WSDOT)	Density measurements during repair
	Perform as well or better than the surrounding

TABLE 3.2
Duration of time before performance issues appear

STA	How long do repairs last before they have performance problems?
Indiana DOT (INDOT)	1 winter cycle is enough to gauge whether the patch will fail
Nevada DOT (NDOT)	Generally, last the lifetime of the pavement
	8–10 years depending upon freeze-thaw cycles of winter and spring months
New Jersey DOT (NJDOT)	2 years
Texas DOT (TxDOT)	Between 1–2 years and 10–12 years

VDOT's representatives indicated that they typically wait one year and check the condition of the repair. While they do not have any formal design life calculations for the pavement patch, they expect the design life to match the existing pavement and the transition from patch to roadway to be smooth for the travelling public. The practices across INDOT districts vary. The respondent from the INDOT district of Fort Wayne indicated that repairs are tracked for one year to monitor settlements. A respondent from the INDOT district of Greenfield indicated that repairs are only tested once after completion, and as a result the performance of repairs is not monitored. Table 3.1 summarizes the results of the 19 STAs with respect to their expectations of pavement patches and method of measuring successful repairs.

The survey also included questions pertaining to failures in utility cut repairs. The participants were asked how long typical repairs last before they exhibit performance problems such as settlement (see Table 3.2). NJDOT's representative indicated that most repairs typically lasted two years, whereas representatives from NDOT indicated that repairs typically lasted through the lifetime of the pavement or 8–10 years depending upon freeze and thaw cycles. A respondent from TxDOT stated that repairs could last anywhere between 1–2 years or 10–12 years, while a respondent from the INDOT district of Greenfield indicated that one winter cycle after the repair is usually a good indicator of whether the repair will eventually fail or not. Inadequate compaction of the backfill leading to settlement was perceived as the primary cause of failure by a majority of the respondents (see Table 3.3).

The respondents were also asked what percentage of utility cut repairs had experienced settlement. A representative from NDOT stated that none of their repairs had performance issues, whereas the other representative indicated that approximately 5% of repairs faced performance issues. A TxDOT representative indicated that between 1% and 50% of their repairs experienced performance issues, whereas the respondent from the INDOT district of Greenfield indicated that up to 65% of repairs in their district had faced performance issues. A representative of NDOT indicated that the permittee is held accountable for the quality of the repair for the entire duration of the permit, whereas VDOT and CDOT respondents stated that they have a fixed warranty period of one year for all pavement cut repairs.

3.2 Review of Utility Cut Repair Specifications among STAs

Five categories of documents pertaining to utility cut repair specifications were reviewed. They include (1) Standard Specifications, (2) Utility Accommodation Manuals, (3) Standard Drawings, (4) Special Provisions

TABLE 3.3
Perception about the causes of failure

STA	Primary cause of failure
Colorado DOT (CDOT)	Settlement
Indiana DOT (INDOT)	Poor compaction and not complying with T patch detail The use of temporary surface patches (with cold-mix asphalt) during winter months
Michigan DOT (MDOT)	Poor compaction of backfill
Nevada DOT (NDOT)	Freeze thaw cycle
Nebraska DOT	Poor subgrade compaction leading to settlement
New Jersey DOT (NJDOT)	Poor compaction of backfill material
Texas DOT (TxDOT)	Differential settlement between the repair and surrounding pavement Inadequate density of the repair leading to water infiltration
Virginia DOT (VDOT)	Poor backfill material and/or lack of compaction Not following the T-patch method resulting in the patch not structurally integrating into the surrounding pavement
Washington DOT (WSDOT)	Poor compaction of backfill Low quality asphalt and backfill material

TABLE 3.4
Documents that were reviewed

	Documents reviewed				
STA	**Standard specification**	**Utility accommodation manual**	**Standard drawings**	**Special provisions for utility cut repairs**	**Permit regulations**
California DOT (Caltrans)	(Caltrans, 2015)	(Caltrans, 2016)			(Caltrans, 2017)
Colorado DOT (CDOT)	(CDOT, 2017)	(CDOT, 2011b)	(CDOT, 2011a)		
Florida DOT (FDOT)	(FDOT, 2016b)	(FDOT, 2016c)	(FDOT, 2016a)		
Idaho Transportation Department (ITD)	(ITD, 2017)	(ITD, 2016b)	(ITD, 2016a)		
Illinois DOT (IDOT)	(IDOT, 2012)	(IDOT, n.d.)		(IDOT, 2002)	
Indiana DOT (INDOT)	(INDOT, 2016)	(INDOT, 2014)	(INDOT, 2008)	(INDOT, n.d.)	
Iowa DOT	(Iowa DOT, 2012b)	(Iowa DOT, 2012a)			
Kansas DOT (KDOT)	(KDOT, 2015)	(KDOT, 2007)	(KDOT, 2010)		
Michigan DOT (MDOT)	(MDOT, 2012)		(MDOT, 2017)		
Montana DOT (MDT)	(MDT, 2014b)	(MDT, 2008)	(MDT, 2014a)		
Nebraska DOT	(Nebraska DOT, 2017)	(Nebraska DOT, 2008)			
Nevada DOT (NDOT)	(NDOT, 2014)	(NDOT, 2016)	(NDOT, 2017)		
New Jersey DOT (NJDOT)	(NJDOT, 2007)		(NJDOT, 2016)		
North Carolina DOT (NCDOT)	(NCDOT, 2018)	(NCDOT, 2014)	(NCDOT, 2012)		
Ohio DOT (ODOT)	(ODOT, 2016)	(ODOT, 2015)			
South Carolina DOT (SCDOT)	(SCDOT, 2007)	(SCDOT, 2011)	(SCDOT, 2017)		
Texas DOT (TxDOT)	(TxDOT, 2017)				
Virginia DOT (VDOT)	(VDOT, 2016b)	(VDOT, 2016c)		(VDOT, 2012)	(VDOT, 2016a)
Washington DOT (WSDOT)	(WSDOT, 2018)	(WSDOT, 2016)			

for Utility Cut Repairs, and (5) Permit Regulations. In total, 51 documents pertaining to the 19 STAs were reviewed. Table 3.4 lists the documents which were reviewed for each STA. Based on the review of documents, the project team identified five key attributes pertaining to utility cut repairs. They include:

1. Pavement surface removal,
2. Base course/layer removal,
3. Backfill materials and compaction,
4. Pavement restoration, and
5. Warranties and performance bonds.

3.2.1 Pavement Surface Removal

A majority of the reviewed STAs (14 out of 19) required an additional cutback of the pavement surface, in order to create a T-section patch (refer to Section 2.2). The extent of the cutback varied from 1 foot to 4 feet on either side of the trench. The reviewed STAs were grouped into five categories based on the specified extent of the additional cutback (see Figure 3.4). In general, the extent of the additional cutback was the same for flexible and rigid pavements. VDOT and SCDOT had different

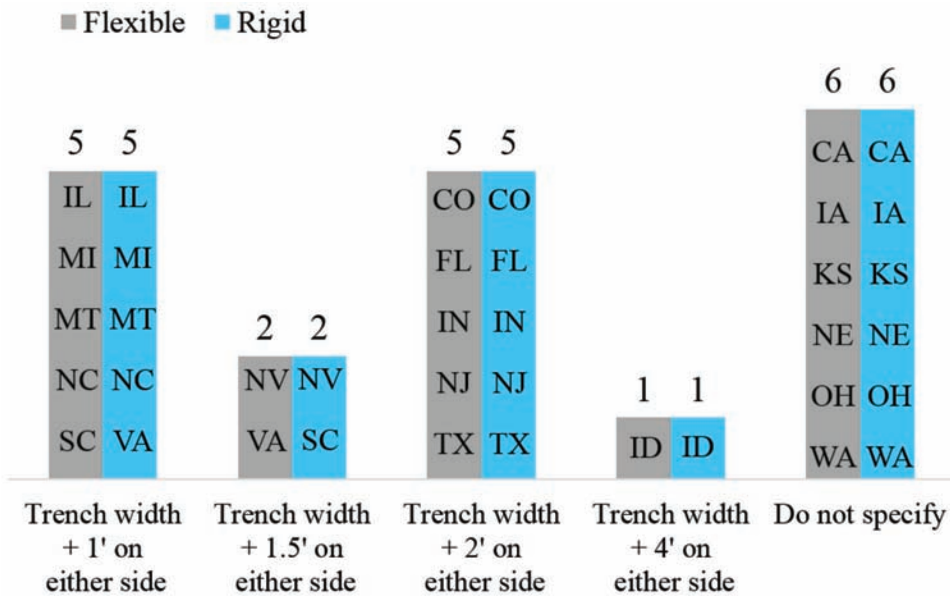


Figure 3.4 Width of pavement surface removal for the reviewed STAs.

pavement removal widths for flexible and rigid pavements. A majority of the STAs require between 1′ and 2′ of additional cutback, on either side of the trench. ITD's minimum required additional cutback was 4′ on either side of the trench. IDOT and MDOT require the additional cutback to be 1′, whereas INDOT's specification requires an additional cutback of 2′ on either side of the trench. Information about T-sections could not be found for Caltrans, Iowa DOT, Nebraska DOT, ODOT, KDOT, or WSDOT.

Seven STAs included in this study also specified a minimum width of the pavement surface that should be removed and replaced during utility cuts. NDOT for example requires the entire width of pavement surface to be removed if the saw-cut edge is within 2′ of the pavement edge, an existing pavement patch, or falls within the wheel path. Iowa DOT requires the minimum width of pavement removal to be 6′. However, if the distance from the specified cut to any adjacent longitudinal or transverse joint or crack is less than four feet, the pavement should be removed to that joint or crack. VDOT specifies that if a concrete pavement is removed within two feet of an existing transverse joint, pavement removal should be extended two feet beyond the joint. Caltrans, similar to VDOT specifies that if the edge of the cut is within 2′ of curb, the pavement should be removed till the edge. CDOT requires PCCP pavements to be cut to the full lane width. WSDOT requires PCCP to be replaced to the next panel joint. INDOT's specification is similar to CDOT in that PCCP pavements should be cut to the full lane width. (INDOT, 2016).

3.2.2 Base Course/Layer Removal

Seven of the 19 reviewed STAs also specify an additional cutback in the base course/layer, resulting in the formation of a staggered cut. Figure 3.5 summarizes the specifications for additional cutback of the base course/layer for the reviewed STAs. In general, the specifications for additional cutback in base course/layer varies from 0.5′ (feet) on either side to 2′ (feet) on either side of the trench. INDOT recommends an additional cutback of 2′ (feet) on either side of the trench. Information for additional cutback of base course/layer could not be found for IDOT, MDOT, ODOT, Iowa DOT, Nebraska DOT, MDT, KDOT, TxDOT, WSDOT or Caltrans.

3.2.3 Backfill Materials and Compaction

Sixteen (16) of the reviewed STAs permitted the use of either granular materials/structural backfill or flowable fill (see Figure 3.6). KDOT and MDOT only permit the use of granular materials, whereas ODOT and NDOT only permit the use of flowable fill.

Upon completion of the utility work, the granular backfill is compacted in layers typically not exceeding 10″ (inches) in depth. IDOT specifies that the backfill must be compacted in lifts not exceeding 6″ (inches) in thickness.

Seventeen of the 19 STAs (included in this study) specified a minimum backfill compaction density of 95% of the Standard Proctor Density. ODOT and NDOT only allow flowable fill in trenches and as a result do not specify a minimum backfill compaction density.

Thirteen of the reviewed STAs have specific requirements for the compressive strength or air content of flowable fill to be used in trenches (see Table 3.5). In general, the required 28-day compressive strength varies from 30 psi to 200 psi, whereas the air content is less than 40%. INDOT's flowable fill specification is based on flow consistency, lightweight dynamic cone

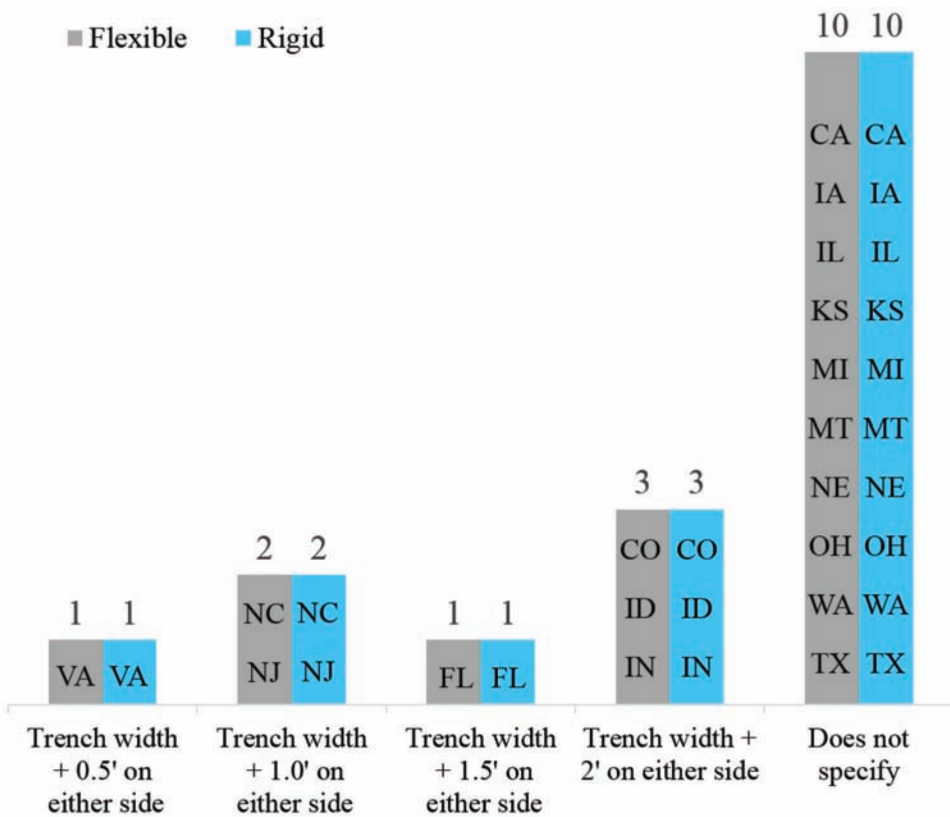


Figure 3.5 Width of base course/layer removal.

penetrometer blow count number, and removability modulus (see Figure 3.7). INDOT specifies that the lightweight dynamic cone penetration test should be performed after the fill has cured for 3 days. The average penetration resistance blow count number should be between 12 and 30. The removability modulus shall be less than or equal to one.

3.2.4 Pavement Restoration

Pavement restoration practices vary significantly across STAs. Pavement restoration for bituminous pavements were found to have the following four specifications: replacement depth, edge treatment, method of compaction, and lift thickness. Pavement restoration for concrete pavements were found to have the following three specifications: replacement depth, edge treatment, and type of concrete used. INDOT requires the restored pavement surface to be either 12 inches in depth or equal to the original pavement depth for asphalt pavements, whereas for concrete pavements the replacement depth should match that of the existing pavement. VDOT specifies that the pavement base layer be a minimum of 6 inches in depth with the surface layer having a minimum thickness of 1.5 inches. INDOT specifies compaction using a Wacker rammer or an equivalent method. NDOT specifies compaction with a standard rolling pattern, whereas VDOT specifies rolling or mechanical tamping. Concrete pavements are typically required to be repaired with high early-strength concrete.

Prior to restoration, the edges of the cut are typically treated with a tack coat for asphalt pavements and dowel bars for concrete pavements (see Figure 3.8). INDOT requires anchor bolts @ 3′ c/c transverse side & 5′ c/c longitudinal for all concrete repairs.

3.2.5 Warranties and Performance Bonds

A common practice among STAs is to specify a warranty period for the repair, and require a performance bond. Through warranties, the utility guarantees to repair, replace and restore a portion of the pavement, if the pavement or portion thereof degrades (usually due to settlement of backfill or pavement) within the warranty period. Should the utility fail to repair, replace or restore the degraded patch, the STA could cause the repair to be made and charge the amount of the repair to the utility. The warranty period on pavement utility cuts for the reviewed STAs varies between 1 and 2 years (see Table 3.6). Caltrans and MDT specify a warranty period of 1 year, whereas VDOT, SCDOT and CDOT have a warranty period of 2 years on pavement utility cuts.

Performance bonds ensure that the repair work will be completed in accordance with the standards and specifications of the agency, and should typically be in an amount sufficient to cover all work within the right of way. Table 3.7 lists the performance bond amounts

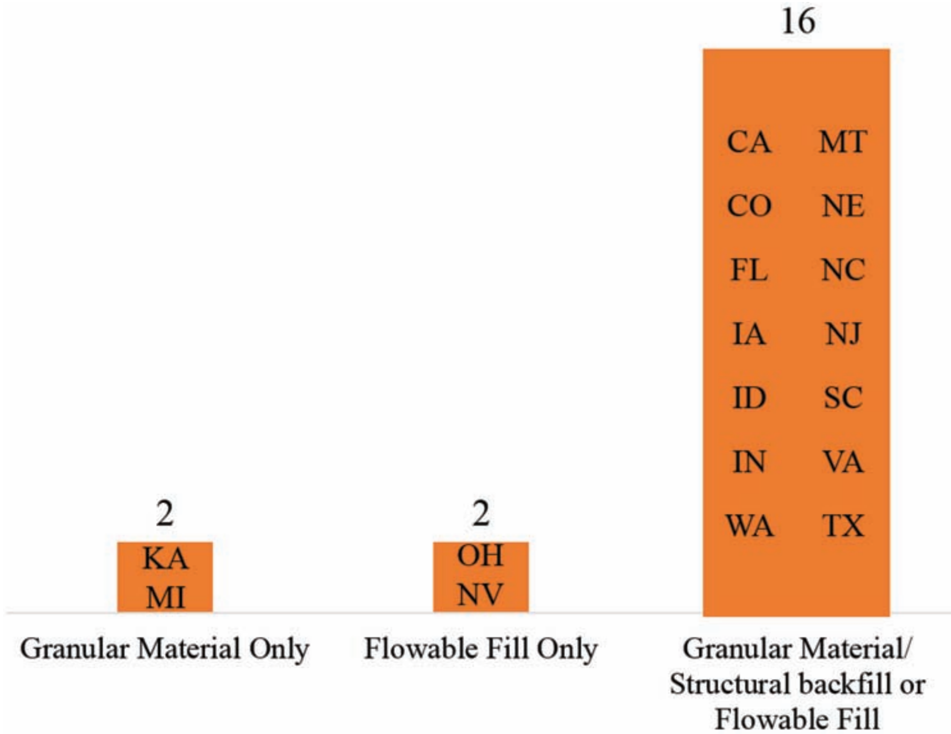


Figure 3.6 Allowable backfill materials.

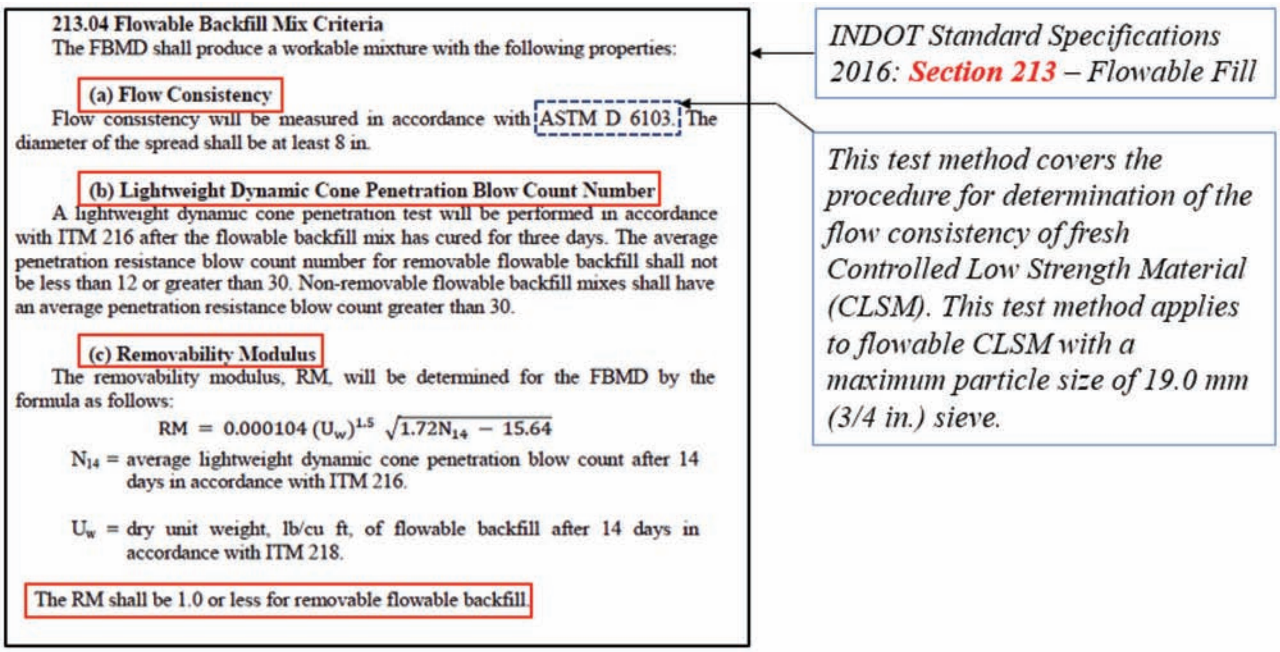
TABLE 3.5
Flowable fill specifications

Highway authority	Compressive strength (28 day)	Air content
California DOT (Caltrans)	50–100 psi	
Florida DOT (FDOT)	<100 psi	5–35%
Illinois DOT (IDOT)	30–150 psi	<25%
Montana DOT (MDT)	35–150 psi	5–40%
Nebraska DOT	85–125 psi	10%
Nevada DOT (NDOT)	50–200 psi	5%
New Jersey DOT (NJDOT)	50–150 psi	
North Carolina DOT (NCDOT)	<150 psi (56 day)	
Ohio DOT (ODOT)	50–100 psi	
South Carolina DOT (SCDOT)	<150 psi	15–35%
Texas DOT (TxDOT)	80–200 psi	10–30%
Virginia DOT (VDOT)	30–200 psi	

required by different STAs for utility cut repairs. Although warranties and performance bonds are intended to protect STAs from poor/failed repairs, STAs face several difficulties in enforcing them, as discussed in Chapter 4. In this regard, one of INDOT's primary concerns is in identifying which utility contractor is responsible for a failed repair. Methods to monitor and track information related to each utility cut repair will be discussed in Chapter 5.

3.3 Billings and Degradation Fees

Cities in Canada including Toronto, Calgary, Vancouver, and Ottawa impose a pavement degradation fee for utility cuts made on pavements. This fee is determined from a "Pavement Degradation Fee Schedule" and is charged in addition to the permit fee (Lakkavalli, Eng, Eng, & Dhanoa, 2015; Mouaket, Eng, & Capano, 2013). The pavement degradation fees allow the City to recover costs incurred for rehabilitation and additional maintenance needs of pavements after utility cuts are made. The fee charged is typically estimated based on the cost of loss in serviceability and additional maintenance cost. An example of the fee schedule implemented by the City of Toronto is shown in Table 3.8. The loss in serviceability is based on factors such as the age of the road, size of the cut made, and type of the road. Mouaket et al.'s (2013) study estimates


213.04 Flowable Backfill Mix Criteria
The FBMD shall produce a workable mixture with the following properties:

(a) Flow Consistency
Flow consistency will be measured in accordance with ASTM D 6103. The diameter of the spread shall be at least 8 in.

(b) Lightweight Dynamic Cone Penetration Blow Count Number
A lightweight dynamic cone penetration test will be performed in accordance with ITM 216 after the flowable backfill mix has cured for three days. The average penetration resistance blow count number for removable flowable backfill shall not be less than 12 or greater than 30. Non-removable flowable backfill mixes shall have an average penetration resistance blow count greater than 30.

(c) Removability Modulus
The removability modulus, RM, will be determined for the FBMD by the formula as follows:

$$RM = 0.000104\,(U_w)^{1.5}\,\sqrt{1.72N_{14} - 15.64}$$

N_{14} = average lightweight dynamic cone penetration blow count after 14 days in accordance with ITM 216.

U_w = dry unit weight, lb/cu ft, of flowable backfill after 14 days in accordance with ITM 218.

The RM shall be 1.0 or less for removable flowable backfill.

Figure 3.7 INDOT's flowable fill specifications (INDOT Standard Specifications 2016).

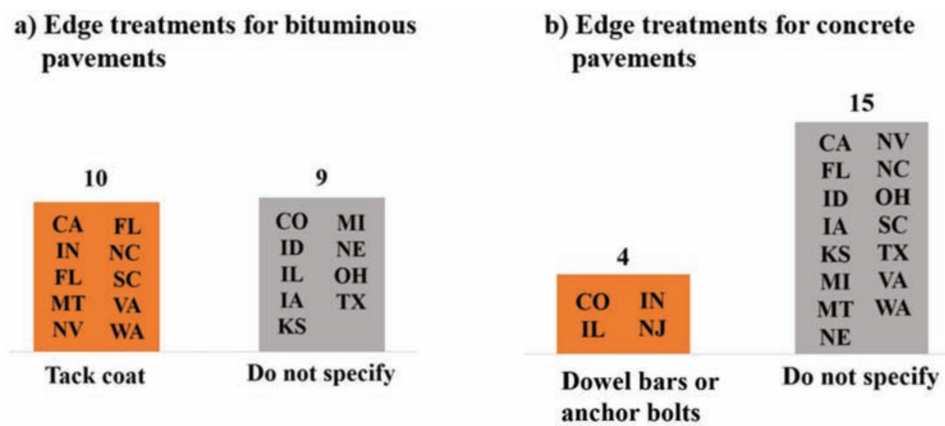


Figure 3.8 Edge treatment requirements for (a) bituminous pavements and (b) concrete pavements.

TABLE 3.6
Warranty requirements on utility cut repairs

STA	Warranty requirement
California DOT (Caltrans)	Guarantee that work remains free from substantial defects for 1 year after contract acceptance
Colorado DOT (CDOT)	The utility must maintain any finished work for a 24-month period after completion of the work
Montana DOT (MDT)	The permittee will be responsible for maintaining the patch for 1 year from the installation date
South Carolina DOT (SCDOT)	Where the pavement cut is not to be resurfaced, it will be maintained for 2 years or until the cut is satisfactorily restored.
Virginia DOT (VDOT)	The permittee shall be responsible for any settlement in the backfill or pavement for a period of 2 years after the completion date of permit and for the continuing maintenance of the facilities placed within the highway right-of-way

that the additional maintenance cost can be estimated to be 30% of the cost of loss in serviceability. Implementation of pavement degradation fees is an incentive for the utilities to schedule and coordinate their work with construction projects, or to pursue trenchless alternatives.

TABLE 3.7
Performance bond amounts

STA	Performance bond amount
California DOT (Caltrans)	At least 50% of total bid
Idaho Transportation Department (ITD)	Should be large enough to cover costs to correct potential damage
Illinois DOT (IDOT)	Based on the potential for highway facility damages
Indiana DOT (INDOT)	Depends on the scope of work; typically, between $5,000 and $10,000
Iowa DOT	Minimum $5,000
Nevada DOT (NDOT)	110% of the engineer's estimate
Ohio DOT (ODOT)	Amount decided based on the scope of work
South Carolina DOT (SCDOT)	Full amount of the contract and not less than $10,000
Virginia DOT (VDOT)	Depends on the estimate cost of work
Washington DOT (WSDOT)	Minimum $1000, typically increased for open cuts

TABLE 3.8
Example of pavement degradation fee schedule implemented by the City of Toronto (adapted from Mouaket et al., 2013)

Fee type	Roadway classification	Utility cut (<100 m^2)	Utility cut (>100 m^2)
Pavement Degradation	Arterial	$1,900	$49/$m^2$
	Collector	$1,900	$44/$m^2$
	Local	$1,900	$40/$m^2$

4. EXPERIENCES WITH UTLITY CUT REPAIRS

The research team conducted phone interviews with utility engineers and permit managers from INDOT districts and the City of Indianapolis, as well as utility service providers, in order to assess how utility cut and repair practices were administered within the INDOT districts and to investigate reasons for failed pavement patches. In addition, the interviews aimed to seek recommendations from INDOT personnel about improving the current utility cut and repair practices.

4.1 Experiences of INDOT Engineers

Four out of the six INDOT districts responded to the project team's request for a phone interview. A total of five interviews were conducted—one interview each with respondents from the districts of Crawfordsville, Fort Wayne, and Vincennes, and two interviews with respondents from the district of Greenfield. Figure 4.1 shows the INDOT districts that were interviewed in this study.

The interview questions were structured along the following themes: (1) preparation, scheduling and coordination activities performed by INDOT prior to a utility cut operation; (2) effectiveness of current repair methods in the interviewees' district; and (3) insights for improving the overall process of utility cut repairs. The interview questions and the list of respondents are provided in Appendix B. The following sections summarize and compares the responses from the four INDOT districts.

4.1.1 Preparation Taken by INDOT Prior to Approving a Utility Cut Permit

The respondents were asked about the preparation by INDOT prior to approving a utility cut permit. Respondents from INDOT's Greenfield district indicated that open cutting of pavements is the last resort in the case of utility repairs, and that permittee may apply for an open cut only after justifying that alternative methods have been exhausted. Boring is given preference over open cutting of the pavement. Once an open cut permit application is received, the district utility engineer verifies the details to ensure that the work does not impact the structural integrity of the pavement. The response from Greenfield was in consensus with the responses received from the Vincennes and Fort Wayne district respondents. That if open cutting is justifiable, the INDOT engineers provide the necessary designs, specifications, and drawings to the permittee. The permit is not approved unless the designs, specifications, and traffic control plans, submitted by the permittee, comply with INDOT standards. Depending on the complexity of the work, the requirement for having a bond may be waived. In situations that call for emergency repairs, or when the extent of the open cut is relatively small, requirements for bonds may be waived. The permit application must include a detailed plan of the construction process, including the dimensions of the cut, location of repair, and method of repairing the cut. In the Crawfordsville District, a permit manager and investigator review the permit application and make modifications if needed. Typically, the district takes six to eight days to approve or deny the permit. The permittee is required to provide a surety bond; however, for utility relocation, a surety bond was not required.

4.1.2 Typical Work Practices Associated with Performing Utility Cut Repairs

The interviewees were asked about the typical work practices in their district. Crawfordsville personnel

Figure 4.1 INDOT districts that participated in interviews with the research team. (Source: http://www.in.gov/indot/3167.htm.)

typically make field visits to utility cut repair locations to ensure that the work performed complied with the plans submitted in the EPS. However, such site inspections are not always feasible due to the limited number of permit investigators in the Crawfordsville district. Respondents from the Greenfield district stated that the permittee was required to follow the precautions set by INDOT pertaining to the repairs including saw cutting and excavating the pavement surface in neat lines, backfilling with flowable fill, paving of the surface with hot mix asphalt (HMA), and sealing of the edges of the patch. Similar to the response from Crawfordsville, the Greenfield respondents noted that given the limited number of field investigators, site inspections were not always possible. Site visits are typically performed for large utility cut repair operations, such as repair of large water main breaks. However, in case of smaller utility cuts, inspection is performed after the repair has been completed. The respondent from Fort Wayne explained that the utilities are required to provide drawings indicating the location(s) and the extent of pavement removal while applying for the permit. Further, if the cities or towns do not provide their separate pavement section drawings, INDOT provides standard details for the utility cut. At this stage, INDOT engineers may specify the use of flowable fill rather than structural backfill, if the former is found more suitable for the utility cut. The respondent from Fort Wayne noted that he considered flowable fill to be better than structural backfill since it reduced challenges arising from poor backfill compaction.

4.1.3 Scheduling and Coordination Activities Performed by INDOT

The respondents were asked about the type of scheduling and coordination when performing utility cuts. The respondent from Crawfordsville indicated that the permit applicant has one year to complete the work from the date of permit approval. Furthermore, the utility contractor is expected to notify INDOT at least five days prior to the commencement of work, based on which the permit investigator schedules a visit to the site. In addition, the respondent stated that the utility contractor must notify INDOT, within a maximum of seven days of completion of the work. The patch is observed for settlement (by INDOT inspectors) for a period of one year from the date of completion. The respondent added that if settlement occurred within the first year, then the utility is expected to take corrective actions. This practice is similar to the type of scheduling and coordination reported by the Vincennes district respondents. The respondents further elaborated that INDOT investigators travel to the site to check whether the contractor possesses the required permit and appropriate standards, and whether appropriate work procedures are being followed. The respondents from Vincennes district stated that often permittees do not always follow the five-day rule, especially during emergencies, and hence scheduling inspections, may be a challenge. The Fort Wayne INDOT district respondent noted, that often times, up to 10 utility cut repairs could occur simultaneously, especially during winter months, due to a high frequency of water main breaks. The respondent also stated that in situations where multiple locations have simultaneous repair activities, it may not be feasible for inspectors to be present while the repairs are being performed. Greenfield district attempts to schedule utility cuts concurrently with the road repair activities schedule in order to reduce the number of pavement cuts.

4.1.4 Selection of Contractors for Performing Utility Cut Repairs

The respondent from the Fort Wayne district conveyed that contractors/subcontractors were typically hired by the utility company, and INDOT 'did not have a say on which contractor could work on a utility cut'. The respondent from Crawfordsville noted that there is no prequalification of contractors undertaking utility cut and repair jobs and suggested that the research team contact the utility companies to check if they have prequalification requirements for contractors. A discussion with a utility provider is provided in Section 4.2. Hence, some of the contractors may be unfamiliar with INDOT standards. The respondents from Greenfield district also noted that the absence of contractor prequalification was an issue impacting the quality of pavement cuts/repairs. Respondents from the Vincennes district elaborated on the classification of entities working on INDOT's right of way. The first category consisted of the contracting companies hired by the utility, which typically performed the best work since they are reimbursed for the job. The second category were the utilities themselves. The respondents stated that cities having their own utilities typically performed repairs to the best of their ability to maintain the integrity of their roads. The third category consisted of small communities. The respondents pointed out that, since the third category typically faces challenges in procuring funds and equipment for repairs, INDOT could provide resources and assist such communities in completing the work satisfactorily.

4.1.5 INDOT's Role in Assisting Contractors with Utility Cut Repairs

The respondent from Crawfordsville district indicated that INDOT engineers provided suggestions to assist the contractors with the utility cut repairs. Similarly, the respondent from Fort Wayne noted that INDOT engineers vetted the utility cut repair detail which was submitted by the utility. If the detail did not comply with INDOT's specification, then the utility would have to use the cut repair detail provided by INDOT. Respondents from Vincennes district explained that there were typically three types of applications for utility cuts: (1) new installations, (2) maintenance and repair, and (3) emergencies. The respondents elaborated that while open cuts were prohibited for new installations, they could be approved for maintenance and repair. In case of emergencies, such as a pressurized pipe blowing out over the weekend, INDOT engineers are often notified of the repairs only after the work has been completed. In such situations, INDOT would not be able to make field visits to the repair site, let alone provide the contractor with assistance in performing the repairs.

When asked if it was possible to identify the contractor/subcontractor that performed the utility cut repair work at a particular location, the respondent from Crawfordsville informed that INDOT's Electronic Permitting System (EPS) gives the approximate location of the permit. However, it was typically not possible to identify the contractor/subcontractor responsible for the work, since this information is not maintained in the EPS.

4.1.6 Construction Practices That Lead to Rework

The respondent from Crawfordsville identified improper compaction of backfill as the major concern in utility cut repairs, and improper backfilling of trenches or improper asphalting of the surface led to the most rework. The respondent from Fort Wayne reported that poor compaction of aggregate while using structural backfill often leads to settlement. However, he reported that settlement in utility cut repairs have seldom been observed in Fort Wayne district. The respondents from Greenfield stated that the settlement of backfill material due to improper choice of backfill and inadequate compaction caused most instances of rework. The respondents further explained that due to the small size of typical utility cuts, compacting the backfill material to the appropriate density was a challenge. Respondents from the Vincennes district indicated that temporary cold mix patching was the cause for most rework. Since most asphalt plants seldom operate during the colder months, contractors fill the trench with flowable mortar or stone and temporarily repair the surface using cold mix. These temporary cold mix patches are expected to be replaced with permanent asphalt patches during the warmer months. However, such temporary cold mix patches are not always replaced with hot-mix patches (in the warmer months), leading to faster deterioration of those pavement sections. The respondents further added that patches repaired in the summer (using asphalt) have fewer problems. The respondent from Crawfordsville reported that sometimes contractors cut corners and do not comply with INDOT specifications, and often subcontractors, performing the utility cut and repairs, do not have the actual permit copy (for reference) while performing the work on site.

4.1.7 Situations Where Multiple Repairs Have Been Performed at the Same Location

The respondents were asked if they had observed multiple repairs on the same utility cut, and were requested to provide details about the typical locations of the multiple repairs and the reasons for multiple repairs. A common response from all of the respondents was that information about poorly performing utility cut repairs, was not actively tracked by INDOT. The respondent from Crawfordsville reportedly observed multiple repairs on the same utility cut, and attributed these repairs to poor compaction, failure to tack the joints, and the use of temporary cold mix patches on repairs during the winter, without permanent repairs using hot-mix patches in summer. The respondents from Vincennes noted that Washington St (off Old US 40), and Petersburg St. were known to have several patches between the year 2016 and 2017. They attributed the reason for recurrent utility cuts in these areas to the presence of old (i.e., over 80 years old) water lines and drainage tiles. In contrast, the respondent from Fort Wayne district stated that they had not observed multiple repairs on the same utility cuts. Further, the respondent explained that out of 20 to 30 open cuts performed during 2017, they had experienced settlement in just one open cut. Similarly, the respondents from Greenfield stated that they did not observe multiple repairs on the same utility cuts. However, they added that smaller cuts typically undergo greater settlement due to the size restrictions imposed on compaction equipment.

4.1.8 Effectiveness of the Backfilling Process

The respondents were asked for their opinions on the effectiveness of the backfilling process used by contractors. The respondent from Crawfordsville reported that the backfilling process had been effective in their district. The respondents from Greenfield stated that smaller cuts typically undergo greater settlement due to the size restriction on compaction equipment. The respondents suggested that using rollers or jumping jacks instead of plate compactors may be effective in achieving desired compaction. They also suggested using flowable fill in pavement cut repairs since it does not require compaction. However, they added that flowable fill may need to be ordered in advance, and may not always be readily available immediately for emergency utility cut repairs. They also noted that backfilling with structural backfill was typically difficult due to size limitations of the cut.

INDOT inspectors from the Greenfield district periodically checked the utility cut repair work for compliance with specifications. The respondent from Vincennes noted that most of the problems with pavement cut repairs occur in smaller towns, especially during the winter. They recognized that although contractors performing these repairs were experts at repairing utilities, these contractors were not experts at repairing the road surfaces and asphalt patching.

4.1.9 Effectiveness of the T-Section Utility Patch

The respondents from Vincennes indicated that the T-section utility patch was an effective method of repair. Respondents from the Crawfordsville district noted that the T-section method was effective provided that the cuts were not in the wheel paths (which is prohibited in Crawfordsville), while the respondent from Fort Wayne commented that although they did not use the latest version of the INDOT T-section detail (i.e., at the time of the interview), the method was found to be effective.

Respondents from the districts of Fort Wayne and Greenfield stated that the contractors did not face difficulties conforming to the current INDOT specifications, specifically the T-section detail, if qualified contractors perform the job. However, the respondents from Vincennes expressed their concern that in smaller communities, contractors performing the work may not be experts in utility cut repairs. In certain situations, the repairs may be performed using a backhoe by untrained volunteers with inadequate expertise to comply with INDOT specifications.

The respondents from Greenfield stated that the utility contractors often seek clarification during the permitting stage. They recommended that the contractors contact INDOT regarding any queries on utility cut repair specifications as very little guidance is provided by INDOT once the permit is approved.

4.1.10 Suggested Modifications to Current Utility Cut Repair Practices

Respondents from Crawfordsville and Vincennes suggested that prequalification requirements of contractors may help improve compliance with INDOT specifications for utility cut repairs, although they recognized that prequalification of contractors could be a significant challenge to implement, especially in emergency repair situations or in smaller communities. The respondents from Greenfield suggested mandatory use of flowable fill in INDOT's utility cut repair specifications. They also suggested that open cuts should be prohibited and that the use of trenchless options should be made mandatory.

The respondents from Vincennes district noted that the district has a maintenance crew that performed repairs in situations where contractors did not complete the job. However, INDOT does not have a dedicated crew solely for open-cut repairs.

All respondents were unanimous in their opinion that the contractor/utility should be held responsible for damages if a patch failed within the warranty period. However, identifying the responsible contractor is often challenging since this information is not provided in the EPS. Furthermore, if the cost of repairing the failed patch is low, INDOT would bear the cost, as litigation charges may be higher than the cost to repair the failed patch. All respondents suggested making it mandatory for the permittees to

TABLE 4.1
Summary of challenges and recommendations pertaining to utility cut repairs by INDOT district representatives

INDOT district	Challenges	Recommendations
Vincennes	Non-adherence to the five-day rule (i.e., failing to inform INDOT at least 5 days prior to the start of the repair activity) Failure to replace temporary cold-mix patches	Discourage open cuts unless it is absolutely necessary Prequalify contractors as a means to ensuring their familiarity with INDOT specifications Require the permittee to provide INDOT with information about the subcontractors performing utility cut repairs.
Greenfield	Settlement of patches due to improper backfill material being used Failure to achieve desired amount of compaction in small cuts due to size restrictions on the compaction equipment	Discourage open cuts Make it mandatory to use flowable fill in trenches Schedule utility cut repair operations with road repair activities, to ensure minimal impact to road surfaces
Fort Wayne	Poor compaction of aggregate backfill leading to settlement Insufficient number of inspectors for cut repair inspections (especially during winter months)	Use trenchless construction methods only
Crawfordsville	Utility contractors are not familiar with INDOT standards Improper backfilling methods Temporary cold mix patches in winter are not replaced with permanent patches in the summer	Prequalification requirements for contractors should be instated

provide information about the subcontractors who perform utility cut jobs, in order to enable INDOT to directly contact the responsible subcontractors in the event of a failed patch. Table 4.1 summarizes the challenges faced by each district and the recommendations for addressing the challenges.

None of the interviewees mentioned the "mismatch" of pavement during restoration as a cause for concern during utility cut restoration. Pavement "mismatch" occurs when the resurfaced portion of a pavement is not identical in section with the surrounding pavement section. This mismatch was identified as a major concern during utility cut repairs. For instance, when a utility cut is made on a composite pavement, and later resurfaced with asphalt only, there is a pavement "mismatch." Further it was pointed out that the "mismatch" of pavements was often observed when temporary cold mix patches during the winter are not appropriately replaced during the warmer months.

4.2 Experience of the City of Indianapolis

Three representatives from the City of Indianapolis responded to the project team's request for an interview. The discussion questions were similar to those with the INDOT engineers and were structured along the following themes: (1) preparation, scheduling and coordination activities performed by INDOT prior to a utility cut operation; (2) effectiveness of current repair methods in the interviewees' district; and (3) insights for improving the overall process of utility cut repairs.

4.2.1 Preparation Taken by INDOT Prior to Approving a Utility Cut Permit

Similar to the practices adopted by INDOT, the City of Indianapolis requires utilities to apply for a right of way permit through a one-page application. Only certificated licensed contractors are allowed to excavate on the right of way. However, there is no pre-qualification requirement for the contractors.

4.2.2 Typical Work Practices Associated with Performing Utility Cut Repairs

The contractors are required to perform traffic control activities and provide secure work zones during the repair. The City of Indianapolis also requires the entire width of an affected lane to be replaced, regardless of the size of the cut. This practice reduces the number of joints on the roadway. Furthermore, an additional cutback of one foot on either side of the repair is required in order to form a T-section utility patch.

4.2.3 Scheduling and Coordination Activities Performed by INDOT

The repair work is typically coordinated so as not to conflict with special events and other ongoing projects, which may increase the traffic flow in that region. The repairs are also coordinated to ensure that two private contractors do not work in the same area at the same time. Once a repair is completed, the right-of-way inspector is notified of the repair and inspects the repair for compliance.

4.2.4 Practices That Lead to Rework

According to the respondents, poor compaction of the backfill and a failure to achieve ADA compliance are the leading causes of violations. The respondent also indicated that the failure to replace temporary cold mix patching as another leading cause for rework. They believe that their specifications are not difficult to achieve. However, effectively communicating the expectations with contractors is challenging. Furthermore, the City of Indianapolis faces a shortage of staff to enforce that repairs be properly executed. At present, four inspectors are assigned to 8,000 lane miles of roadway.

4.3 Experiences of Utilities

A representative from Indiana American Water, a utility service provider, responded to the project team's request for an interview. The discussion during the interview was aimed at obtaining the utility's experiences with pavement cut and repair project on INDOT's roadway assets, and identifying challenges and effectiveness of specifications related to utility cut repairs.

4.3.1 Typical Work Practices When Performing Utility Cuts

The main contractor hired by the utility service provider is notified upon receiving the permit for a utility cut. The main contractor then schedules the work and performs work. On completion of the job, the main contractor submits a bill to the utility service provider along with an attachment describing the activities performed. However, the utility service provider does not inspect the pavement restoration work performed by their contractor. Apart from during emergency situations, the utility provider does not participate in the scheduling and coordination of utility cuts.

4.3.2 Repairs During Emergencies

In addition to pipe breakages during winter, the utility has also occasionally encountered emergency situations during the summer. In case of emergencies during regular work hours, the utility first obtains an emergency permit for the main contractor, and later applies for a utility repair permit online. In case of an emergency during weekends or non-working hours, the main contractor takes the necessary actions required to repair the utility. The utility service provider then applies for the utility cut permit within two days of the repair.

4.3.3 Prequalification

The contractors have to meet certain requirements and be prequalified by Indiana American Water. Only approved contractors can be used to provide any new connections for the Indiana American Water lines.

4.3.4 Rework on Utility Cuts

In case of poorly repaired patches, INDOT contacts utility providers if INDOT personnel/inspectors are able to identify the responsible utility. Typically, the settlement of backfill is observed on pavement sections which have temporary patches, and which have not been replaced by permanent patches.

4.3.5 Difficulties in Conforming to INDOT Specifications with Regard to Utility Cut

Neither the utility service provider nor its contractors have experienced any difficulties in conforming to the INDOT specifications related to utility cut.

4.3.6 Effectiveness of Backfilling Process and "Pipe Backfill" Section

The respondent from Indiana American Water stated that the use of 100% flowable fill for backfilling has been very effective. Additionally, the contractors have not reported any difficulties with the use of flowable fill during the winter. Further, no issues were observed with the use of the T-section utility patch or "pipe backfill" section by the utility provider.

4.3.7 Extension of Work Permit and Guarantee of Work

Except for one instance in the past year, when the utility service provider had to seek an extension of six months on a permit, extension on permits was usually not required. Generally, Indiana American Water provides a guarantee for a year within which faulty work is repaired.

4.3.8 Use of Flowable Fill for Backfilling

The interviews with the INDOT engineers and the representative from the utility provider indicated that the primary cause leading to rework was settlement of backfill material. A majority of the interviewees from INDOT recommended the use of flowable fill to eliminate the issue of settlement. Moreover, the use of flowable fill for backfilling utility cuts has been found to be effective by the utility contractors.

A study by Griffin and Brown (2011) indicates that the use of flowable fill for utility cut repairs can provide a cost saving ranging from 5% to 40% when compared to backfilling with granular base. The comparison in cost takes into consideration the costs related to material, skilled labor requirement, transportation, equipment, and placement (Lin, Luo, Wang, & Hung, 2007). Further, the use of rapid setting blends of flowable fill also reduces construction time which in turn reduces the exposure of workmen to moving traffic, hence increasing workmen safety (Griffin & Brown, 2011). Albright and Nantung (1993) noted that as flowable fill could be placed quickly, without the requirement of compaction and inspection, paving of the surface could be completed in a few hours. The self-leveling and self-compacting properties, in addition to other desirable properties like rapid hardening capability, flowability, material uniformity, strength selection, and reduced construction requirements, make it more favorable to use flowable fill for backfilling (Griffin & Brown, 2011). Due to its high early bearing capacity development, low shrinkage and compression, low economic impact, low construction labor intensity, ability to excavate, and resistance to damaging effects of moisture, Pons, Landwermeyer, and Kerns (1998) found flowable fill to be an effective material for backfilling. Griffin and Brown (2011) recommend the use of properly designed flowable fill in conditions where problems related to site access, equipment and material availability, and natural soil exist.

The views of a representative from the City of Dayton (Ohio), on the effectiveness of flowable fill as a backfill material, were in alignment with the interview responses. Prior to 2016, the City of Dayton (Ohio) allowed the use of gravel to backfill the subgrade during restoration. However, the contractors faced difficulties in compaction of gravel with specified lifts in the case of small street cuts. Hence a modification was made in the pavement restoration specification of the City of Dayton (Ohio) in 2016, requiring all utility street cuts within thoroughfare streets to be backfilled to the top of the existing subgrade with controlled density fill (CDF). The flowability characteristics of CDF eliminated the requirement of compaction and filled all the voids within the excavation. In addition, CDF reduced the probability of sinking of the street cut repairs. The City of Dayton (Ohio) was considering making CDF backfill mandatory on all city streets.

In addition to CDF backfill, the City of Dayton (Ohio) also implements warranties and use of radio-frequency identification (RFID) tags to ensure the quality of utility cut repairs (Discussion about the use of RFID tags by the City of Dayton, is provided in Section 5.2). An increase in level of workmanship has been observed since the use of RFID tags. Consequently, a decrease in number of street cut complaints has been reported. As a result, the utilization of RFID tags has reduced the quality control inspection requirement. Furthermore, embedding the RFID tag in between two lifts of asphalt ensures that the compaction of asphalt is done in two layers.

5. MANAGING INFORMATION ABOUT UTILITY CUT REPAIRS

The interviews with INDOT personnel highlighted that there are key challenges faced by INDOT in managing information about utility cut repairs. These challenges include inspecting and monitoring patches for settlement, ensuring that temporary cold-patches are permanently restored in the summer months, and determining which utilities/contractors are responsible for failed patches.

In order to enforce warranties for failed repair patches, INDOT must first be able to identify which utility is responsible for a particular repair. INDOT uses an online database called the Electronic Permitting System (EPS), to collect, process, and track utility cut permits. This chapter begins with a review of INDOT's EPS from the context of managing utility cut repair permits, and provides a discussion of two methods to assist in the automated monitoring of utility cuts.

5.1 Review of INDOT's EPS

Any utility company that wishes to apply for a utility cut permit on INDOT's roadway assets, must fill out an application form on the EPS. Applying for a utility cut repair permit consists of the following four steps: (1) specifying the type of permit; (2) specifying the location of the work; (3) providing applicant details and bond information; and (4) providing technical details (e.g., scope of work, construction drawings, and traffic control plans). The permit application is reviewed by an INDOT permit manager and either approved or denied. Once work has been completed on an approved utility cut job, INDOT inspectors travel to the location of the work to evaluate whether the repair has met INDOT's standards. The following subsections describe the steps required to apply for a permit, identify limitations within the current permitting system, and provide recommendations to facilitate effective management of utility cut repair permits.

5.1.1 Specifying the Type of Permit

Upon logging into the EPS, a permit applicant is presented with a drop-down menu and the option to select from seven permit types (see Figure 5.1). The permit types include:

1. *Pole Line*—For the installation of a utility pole line or attachments to an existing pole line in the right-of-way (ROW) controlled by INDOT.
2. *Cut Road*—For any excavation in the ROW controlled by INDOT that creates a permanent change other than a pole line or driveway installation.
3. *Driveway*—Required for the permits involving the construction of driveways or public road approaches that connect to a highway.
4. *Outdoor Sign*—Required for work related to billboard signs.
5. *Miscellaneous*—For activities on INDOT controlled ROW that do not permanently alter the roadway, right-of-way, or supporting appurtenances.
6. *Railroad*—To close a road and perform work on the railroad.
7. *Broadband Access*—To install improvements on, below, or above State Property for the purposes of data transmission and related services.

Since utility cut repair operations involve excavation on the roadway, which is a part of the ROW, an applicant requesting for a utility cut permit must select the "Cut Road" option. However, since "Cut Road" permits are required for all activities that involve excavation on the ROW, many operations that do not involve roadway excavation are also classified under this permit type. For example, the trenchless installation of cable television (CATV) cables under the INDOT ROW, which does not involve excavating the roadway, also requires a "Cut Road" permit. This system of classifying permits in the EPS hinders the query process (i.e., search for and retrieval of information about) of utility cuts that impact the roadway. For instance, review of data from EPS, indicated that between 2016 and 2017, INDOT received 12,593 cut-road applications. However, the actual number of utility cuts on roadways cannot be determined using the current system. To retrieve information about utility cuts on a particular highway, one must manually read through the "scope of work" described in each "Cut Road"

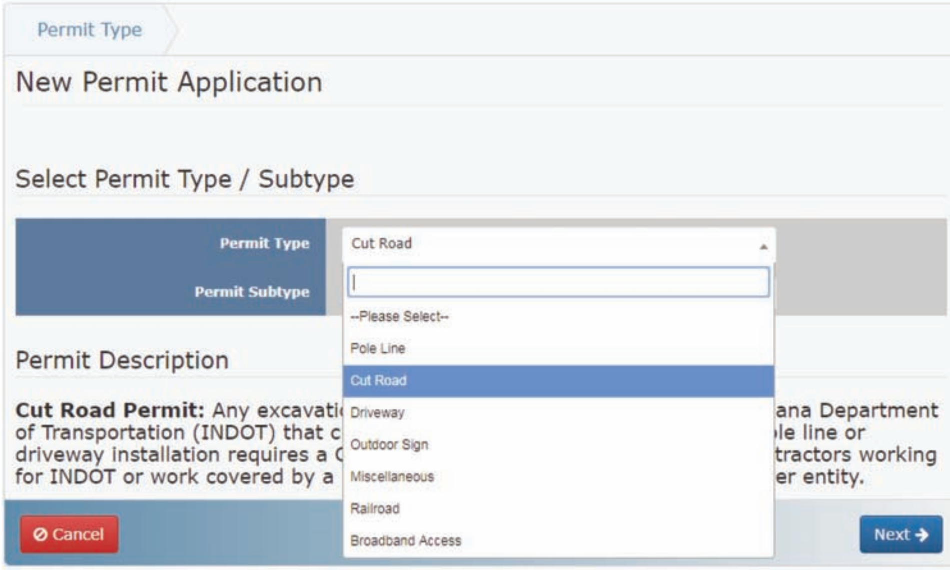


Figure 5.1 EPS interface for specifying the type of permit.

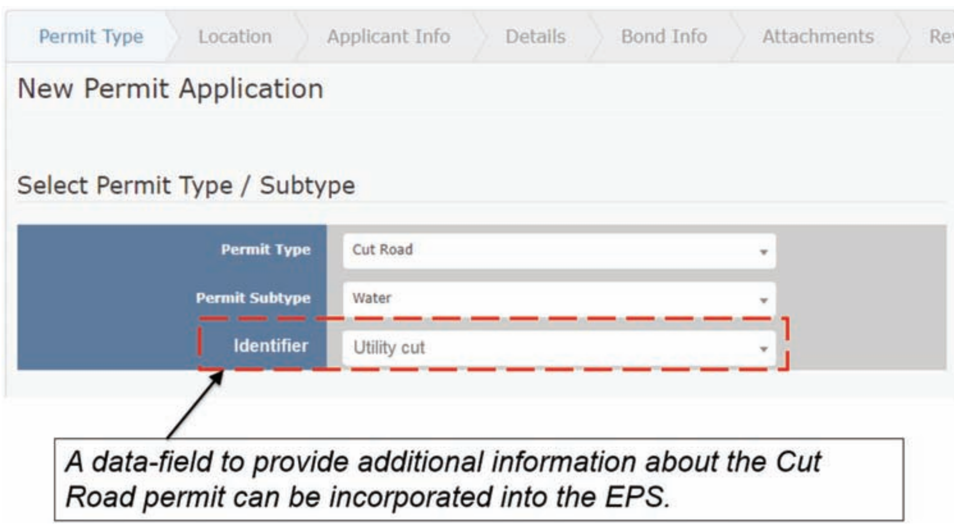


Figure 5.2 Example GUI of EPS after the addition of data fields to record permit sub-types.

permit to identify which cuts led to the excavation of roadways.

In order to identify permits that involved excavation of the roadway the research team searched through all of the "Cut Road" permit applications in the year 2016, on four major INDOT roads: US52, US36, US136, and SR26. Out of 86 "Cut Road" permits in the EPS (in the Crawfordsville and Greenfield districts), only four permits involved excavation of the roadway (see Appendix C for the list of Cut Road permit applications). The reasons for pavement excavation included: the installation of a valve on a water line, renewal of a gas service line, repair of an emergency water leak, and the repair of a gas main. A majority of the Cut Road permits, which did not result in roadway excavation, involved trenchless methods, such as boring or directional drilling for fiber services.

Recommendations. To facilitate the monitoring of utility cut permits on INDOT's ROW, a clear distinction should be made between permits that involve excavation of the roadway and permits that do not involve excavation of the roadway. The research team recommends the addition of a new permit sub-type for operations that lead to the excavation and repair of the roadway. The permit sub-type could be added as an option to the current permitting application in the EPS, as shown in Figure 5.2.

5.1.2 Specifying the Location of the Work

After specifying the type of permit, the applicant is required to provide information about the location of the work. In this step, the EPS provides the applicant with an aerial map of INDOT roads, and requires the

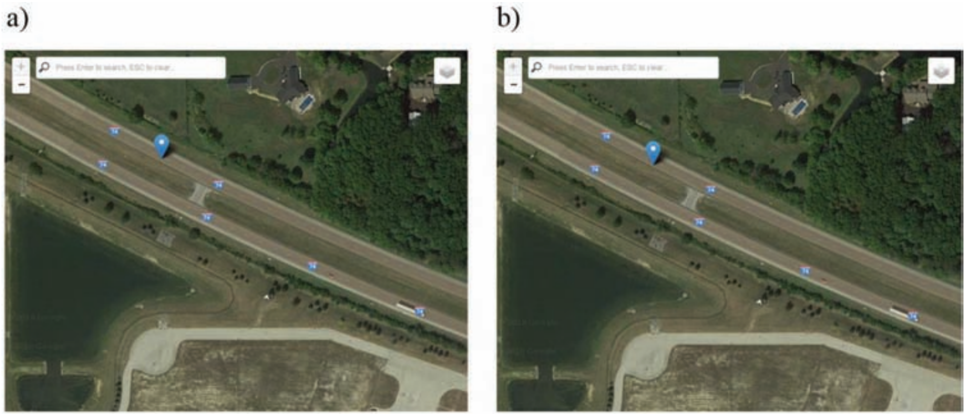


Figure 5.3 INDOT's EPS interface to enter the location of the permit by means of a mouse click on a map: (a) location with latitude: 39.863552512161576 and longitude: -86.4097836893052, and (b) location with latitude: 39.8635731000718 and longitude: -86.40977296046914.

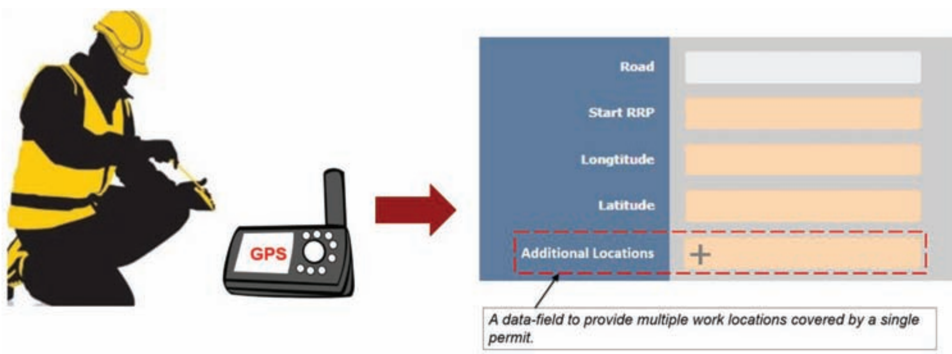


Figure 5.4 Example GUI of EPS for entering location(s) of utility cuts.

location of the work to be specified by means of a mouse click on the map (see Figure 5.3). The EPS then generates the latitude and longitude based on the location of the mouse click. However, this method of specifying the location does not report the work location accurately. Two seemingly similar locations on the map (that were generated by mouse clicks) could be a few feet apart. For instance, the location in Figure 5.3 (a) resulted in the EPS generating the following coordinates: latitude: 39.863552512161576 and longitude: -86.4097836893052, whereas the location in Figure 5.3; and (b) had the coordinates: latitude: 39.8635731000718 and longitude: -86.40977296046914. The research team calculated the Euclidean distance between the two coordinates as 3.93 feet (1.2 m), which is comparable to the dimensions of a typical utility cut.

Furthermore, the map provided in the EPS also displays traffic (i.e., cars, trucks, etc.) on the roads, further affecting the accuracy in pinpointing the location of the work. Accurate information about the location of utility cut repairs is essential to identify which utility/contractor is responsible for a particular patch, since certain sections of roads have multiple patches in close proximity. Due to the inconsistency in reporting the location using the current version of the EPS, discerning between nearby utility cut repairs could require a significant amount of time and effort. The EPS also lacks the provision to link multiple locations with a single permit—as in the case where a utility applies for a single permit for multiple road cuts.

Recommendations. The current method of specifying the location using a mouse click does not provide INDOT with accurate information about the actual location of the work. The research team recommends measuring the location of the work using an accurate GPS device and/or other triangulation methods (see Figure 5.4). The permittee could be required to provide the location information either while applying for the permit or after the permit has been approved. During inspection, INDOT inspectors could use a separate GPS/location device to validate the location of the repaired patch. The permittee could also provide INDOT with an aerial photograph of the repaired patch to help determine its exact location. Possessing accurate location information about utility cut repair patches could enhance the current permitting process in the following ways: (1) INDOT inspectors could coordinate periodic inspection activities to monitor the repaired patches for settlement/deterioration; (2) INDOT could use the location information to determine which utility is responsible for a particular utility cut repair, which would be useful in enforcing warranties; and (3) INDOT engineers could monitor if certain areas/roadway sections experience a larger number of cuts than others, and evaluate the impact of those cuts on the pavement life.

5.1.3 Providing Applicant Details and Bond Information

In this step, the permit applicant is required to provide their name, contact information, and details about the performance bond, although the need for a performance bond can be waived in certain situations. Although this step provides INDOT with information about the utility that is responsible for the permit, the EPS does not provide a data-field for recording information about the contractors/subcontractors performing the work. As discussed in Chapter 4, INDOT engineers would benefit from the knowledge of which contractors/subcontractors performed the work, since this would enable INDOT to contact the responsible contractors/subcontractors, should the repair perform poorly. Information about the contractors/subcontractors would also facilitate the checking of prequalification requirements, if prequalification were to be implemented for utility cut repairs.

Recommendations. The research team suggests adding a data-field in the EPS to record the name and details of the contractor (see Figure 5.5). INDOT could make it mandatory for the permit applicant to provide this information either while applying for the permit or once the permit has been approved.

5.1.4 Providing Technical Details about the Work

In this step, the applicant is required to describe the technical details of the work. The EPS provides the applicant with a text-box to describe the work in a few sentences, and an option to upload file attachments to supplement the description of the work. Typical attachments include traffic control plans, construction details, and performance bonds. Upon completion of this step, the applicant would submit the permit for review by an INDOT permit manager. Unfortunately, this step does not include a specific field for the applicant to provide technical details. As a result, the manner in which construction details are typically provided varies across applicants. For instance, it was observed that certain applicants chose to describe the dimensions (i.e., length, width, and depth) of the cut using written text (i.e., in the form of a paragraph) whereas other applicants communicated these details in the form of plan and section drawings. In addition, the EPS does not provide guidelines as to what information the applicant must provide, leading to inconsistencies in the type of information reported by the applicants. Hence, the data collection during the permit application results in the collection of 'disorganized' data, which are difficult to query from the EPS database. As a result, in the EPS system it is not possible to distinguish

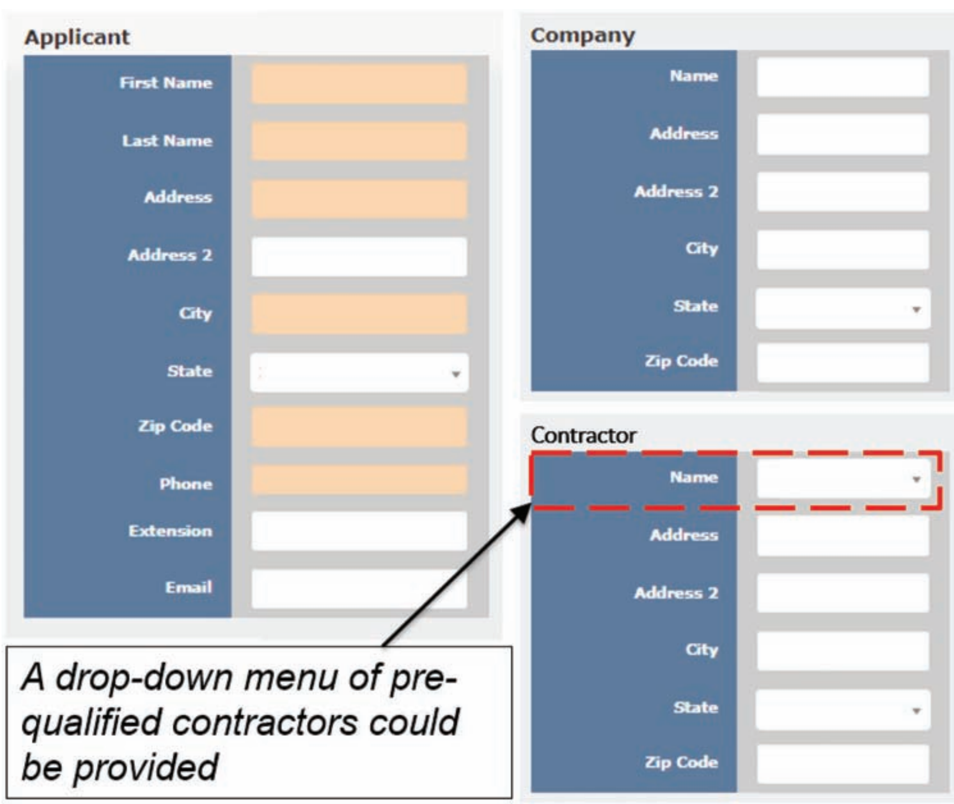


Figure 5.5 Example GUI for recording information about contractors hired to perform the utility cut repair.

between utility cuts based on their size (i.e., small, medium, and large), depth, or type of materials used. Furthermore, there is an absence of a data-field to indicate whether the repair is temporary or permanent.

Recommendations. In the current method of requesting permits, the applicants submit construction drawings which may or may not list the backfill materials used, T-section widths, dimensions of the cut, or type of surfacing material used. The research team recommends incorporating additional fields into the EPS, and mandating that permittees provide such information in the specified format. The additional fields recommended are (1) length and width of the cut, (2) depth of the excavation (if relevant), (3) backfill material used, (4) length of additional cutback to create the T-section utility patch, (5) type of edge treatment, and (5) type of surfacing material used (i.e., permanent or temporary patching materials). These additional fields could be incorporated into the EPS using a graphical user interface (GUI) similar to that shown in Figure 5.6.

5.1.5 Inspection by INDOT Inspectors After the Work Has Been Completed

After approval of the permit, the utility may provide additional information as PDF attachments. The permit manager provides the applicant with INDOT specifications for utility cuts, such as T-section details, Title VI assurances, ROW special provisions, general provisions, and traffic control plans. After the work has been completed, an INDOT investigator visits the location of the repair and creates a permit inspection report.

The following limitations were identified in this step of the permit process:

1. Not all permit applicants provided the plan and cross-sectional drawings of the repair work. As a result, information about the backfill materials used, length of additional cutback in the T-section, and depth of the cut are not always communicated to the INDOT permit manager.
2. Upon inspection of the patch, the INDOT inspector creates a report. However, these reports only state whether the work complies or does not comply with INDOT's standards. There are no provisions for the inspector to specify whether the repair shows signs of deterioration.
3. There are no data fields in the EPS to record information about the condition of patches once the work has been completed (i.e., data from periodic inspections).

Recommendations. The research team suggests adding data fields in the EPS to capture information from periodic inspections of repaired patches. The additional data fields should allow INDOT inspectors to report observations from periodic inspections, such as settlements, increased roughness, photographs, etc., and upload that information into the EPS (see Figure 5.7). If the patch is temporary then the expected date of the permanent repair should also be provided by the permittee. Such information would allow INDOT engineers to monitor the condition of utility cut repairs. The information could also be used by INDOT engineers to identify particular areas with a history of poor patches, utilities/contractors that are responsible for multiple failed repairs, and temporary patches which have not been resurfaced.

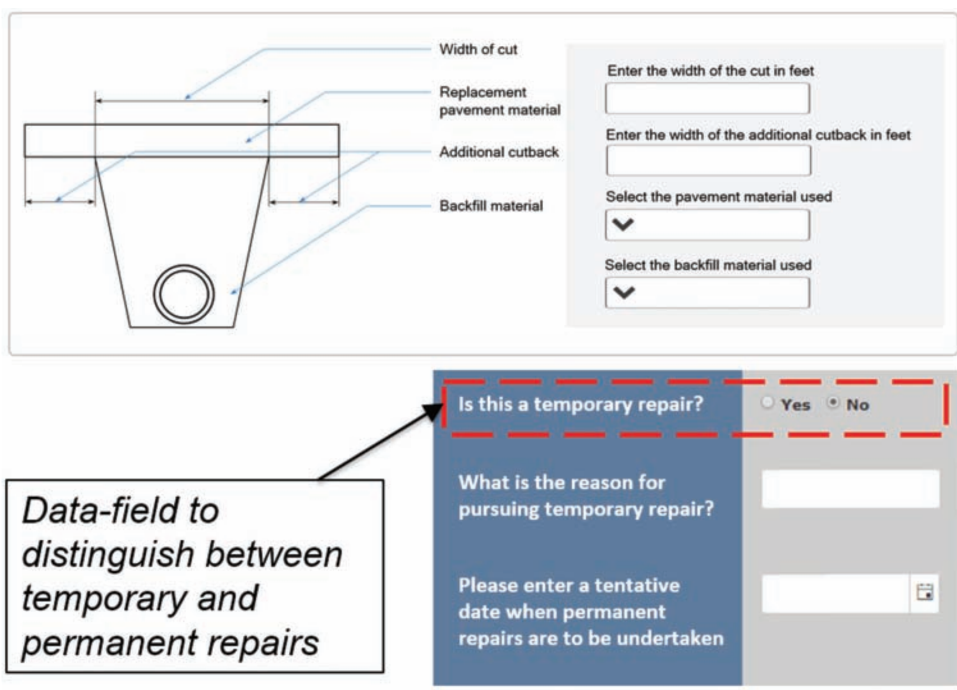


Figure 5.6 Example data entry GUI for recording technical details about a repair and to record details about temporary repairs.

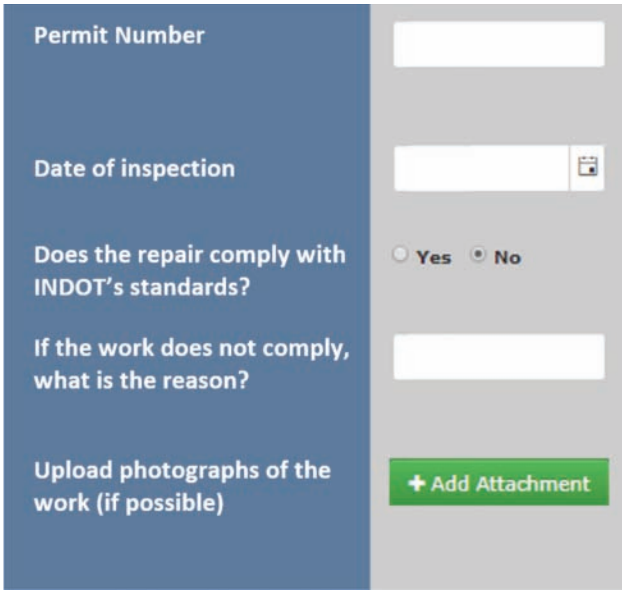


Figure 5.7 Example data entry GUI for recording information from inspections.

5.2 Methods to Monitor/Track the Condition of Utility Cut Repairs

Between January 1, 2012, and December 31, 2016, INDOT received 12,593 cut road permit applications, many of which involved utility cut repairs. While utility cut repairs are expected to restore the pavement to a condition equal to or better than the original condition, INDOT engineers have often observed patches being improperly restored (i.e., patches which show signs of settlement and/or other degradation). As discussed in Chapter 4, INDOT faces the problem of not being able to monitor whether temporary cold patches are permanently restored during the warmer months. This problem is compounded by INDOT's shortage of inspectors, leading to difficulties in discerning which utility is responsible for a failed patch. An automated method to identify failed patches and determine which utilities are responsible for those patches would enable INDOT to enforce corrective measures despite having a limited number of inspectors.

INDOT employs Pathway Services, Inc. for network-level data collection on its roadway assets. Pathway's automated road and pavement condition surveying system (which is housed in a van), measures road condition indicators such as the international roughness index (IRI), transverse profile, rutting, faulting, etc., and geo-references this information using the road reference point (RRP) system as well as the stage-log system. The measurement of pavement condition is achieved using five lasers mounted across the front bumper, one in each wheel path, one in the center, and two outside each wheel path of the van (see Figure 5.8). The lasers measure the longitudinal and transverse profile of pavement surfaces.

Based on discussions with the SAC, the research team hypothesized that correlating the road surface

Figure 5.8 Proposed method to install RFID readers on data collection vans.

information collected by Pathway, with the locations of utility cut repair patches, could facilitate the automated condition monitoring of patches. This section discusses two approaches of correlating such information. The first approach uses radio frequency identification (RFID) chips embedded in the pavement to identify which utility is responsible for the repair, whereas the second approach relies on correlating the global positioning system (GPS) coordinates of patches, with the location information collected by Pathway.

5.2.1 Evaluating the RFID Chip Embedded in the Pavement

In 2013, the City of Dayton implemented a new system of inserting RFID tags into utility cut repair patches (City of Dayton, 2016). The RFID tags along with handheld RFID readers were intended to assist inspectors in identifying which company is responsible for a utility cut repair patch. This method required RFID tags to be placed two inches below the surface in the center of utility cut. The RFID tags could then be detected by a handheld RFID reader held approximately at a distance of five feet from the tags (see Figure 5.9). An in designing and implementing this solution. In 2013, the City of Dayton issued 2,500 such RFID tags to contractors, at a cost of approximately \$2 per tag, which was factored into the contract (Sarkar, 2014).

Based on the success of this method in the City of Dayton, INDOT contacted CDO Technologies to evaluate the feasibility of implementing the RFID technology on a pilot project. RFID tags were installed in selected pavement sections on this pilot project, and the RFID readers were installed on Pathway data collection vans to facilitate the automated tracking of patches. Since Pathway collected road condition information and the RFID tag could be used to identify which company was responsible for the patch, this method was expected to facilitate automated assessment of utility cut patches. Field tests were conducted to determine whether the tags could be identified by the RFID reader, since the reader was to be mounted on a travelling vehicle. However, based on information provided by the SAC members involved with the pilot project, the RFID reader mounted on the vehicle was not able to consistently identify RFID tags in the pavement. Due to these poor initial results, and the limited duration of this project, the research team and SAC agreed to pivot from the original plan of assessing the Pathway-CDO integration—to focus instead on assessing the suitability of correlating GPS locations of pavement patches with location information obtained from Pathway.

5.2.2 Correlating the Location of Patches with Road Condition Information Collected by Data-Collection Vans

The feasibility of correlating GPS coordinates of patches, with the road condition data collected by Pathway vans, was explored to determine if INDOT's existing EPS database with modifications could be used to store information about the condition of utility cuts and retrieve information about their location. The following steps describe a possible implementation of this method (see Figure 5.10 for the overall schematic):

1. Upon completion of the repair, the utility/contractor is required to record the location of the patch, either using GPS or an equivalent triangulation method. A consistent method of reporting a patch's location must be adopted, e.g., all measurements should be made at the centroid of the patch. This location information could then be uploaded into INDOT's EPS, and may be validated by an INDOT inspector during post-repair inspection.
2. The coordinates of the patch should then be converted into equivalent RRP measurements, since RRP is the referencing system used by Pathway to report the condition of INDOT roads.
3. When a data collection van assesses a particular section of a road, the location coordinates of that section (measured by the data collection van) can be compared with the location coordinates of patches (from the EPS), to determine whether that section contains a patch or not.
4. If the section contains a patch, then the measured IRI serves an indirect indicator of the amount of settlement that the patch has undergone.
5. If the amount of settlement exceeds a threshold value, the location is flagged in the EPS database and a notification sent to INDOT.

To facilitate accurate monitoring of pavement patches, this method relies on the granularity of the location data

Figure 5.9 RFID tag being installed in a utility cut patch.

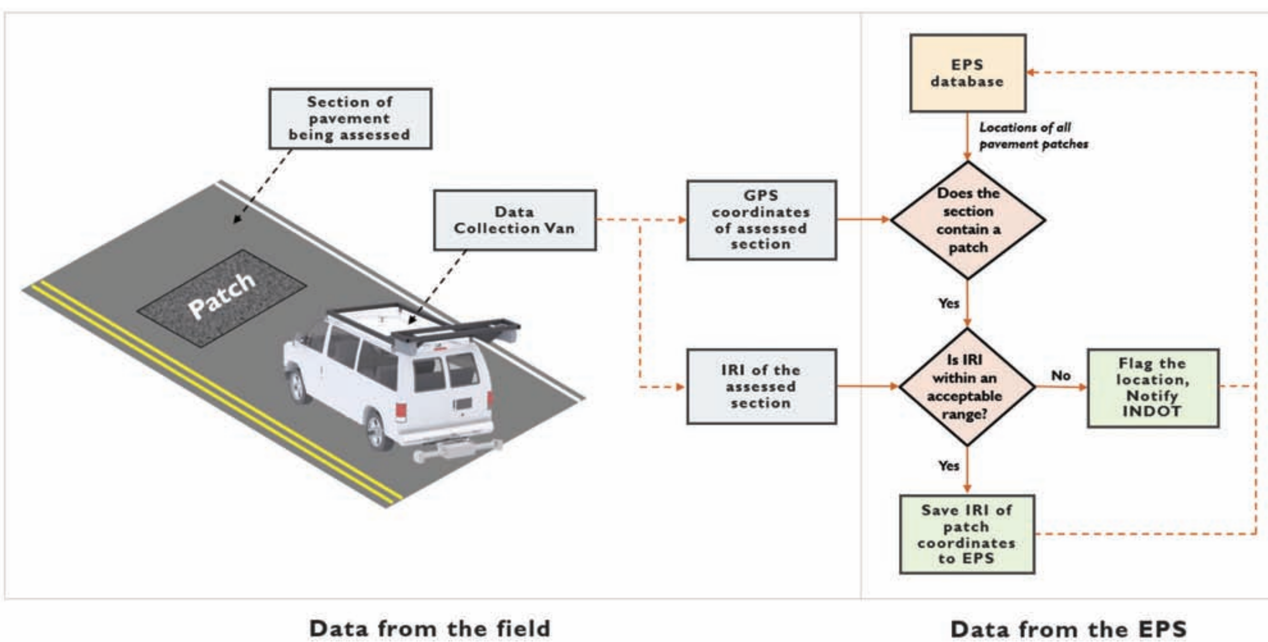


Figure 5.10 Schematic diagram of automated utility cut repair tracking by correlating patch location information with pavement condition data.

collected by the data collection vans. Pathway currently reports IRI measurements at intervals of approximately 0.1 miles. The opinion of the research team is that this interval is too large for the proposed method to accurately monitor patches, since several patches could exist in a 0.1 mile stretch of roadway. A shorter interval of 0.01 miles would likely contain fewer patches, and would enable a more precise identification of patches. The proposed method also method assumes that the EPS contains accurate location coordinates of every utility cut repair permit. Furthermore, it relies on the accuracy of the location information being measured by the data collection vans. Finally, IRI is the only indicator used to measure whether a utility cut repair is in good or bad condition.

Further discussions with Pathway are needed to assess whether this method can be implemented using the data collection vans currently in use. If implementation is feasible, then this method could either be used stand-alone or in conjunction with the RFID tags for automated utility cut tracking.

During a study advisory committee (SAC) meeting, the Principal Administrator suggested that the research team explore the possibility of measuring the IRI of the roadway section using a smartphone based application. Smartphone-based IRI measurement tools could present INDOT inspectors with a quick and economical method of measuring the pavement roughness, to check whether the repair complies with INDOT's standards. According to Islam, Buttlar, Aldunate, and Vavrik (2014), since pavement surface irregularities lead to vertical accelerations in moving vehicles, any moving vehicle equipped with a 3-axis accelerometer containing smartphone, can measure the IRI of a pavement section. TotalPave IRI (Android and iOS) and RoadBump (Android) are two such commercially available applications that INDOT inspectors could use to measure the IRI of the roadway section containing the repaired patch. IRI can be measured using these applications by securely mounting a smartphone inside a car (for e.g., on the dashboard) and driving at a predetermined speed (typically between 20mph and 70mph). The smartphone applications use accelerometer and GPS data to estimate IRI and provide graphs that show individual bumps, dips and waves.

6. CONCLUSIONS AND RECOMMENDATIONS

INDOT specifications for utility cut repairs were found to be in alignment with the specifications of a majority of the reviewed/surveyed STAs. However, a key concern raised during interviews with INDOT personnel, was contractors' failure to follow these specifications. Suggestions to address these concerns included making the use of flowable fill mandatory and establishing pre-qualification requirements of contractors. A common observation cited by the interviewees was that utility cuts which are repaired with temporary patches in winter, are often not permanently restored during the warmer months. Improper repairs lead to failed pavement sections. However, determining which company is responsible for an improperly restored utility cut is challenging given the large number of utility cuts (often within close proximity of each other) and limited number of inspectors available to monitor the pavement repair operations.

INDOT uses the EPS, which is an online database designed to facilitate the review, management, and tracking of permits. However, the EPS has several limitations in the context of managing utility cut repair permits, most notably a lack of distinction between utility cut permits and other "Cut-Road" permits, making the process of searching for utility cut permits overly tedious. The EPS also requires permit applicants to specify the location of work by means of a mouse click on a map, resulting in inaccurate locations being recorded. Furthermore, there is an absence of data fields to record the identity of the contractors that performed the work, technical details about the work (such as dimensions of the cut, backfill materials, construction methods, etc.), or information from periodic inspections.

The following sections describe the recommendations of the study.

6.1 Require Prequalification of Contractors Engaged in Utility Cut Repairs

The failure of utility contractors to comply with INDOT specifications was one of the concerns that surfaced during the interviews with INDOT engineers. This failure to comply was attributed to the lack of familiarity of utility contractors with INDOT specifications. A common recommendation from the INDOT engineers and SAC members was the implementation of prequalification for contractors performing utility cut repairs. By only permitting prequalified contractors INDOT would be assured that the work meets its standards, reducing the instances of failed repairs. Effectively communicating the expectations by means of INDOT-led orientations and training programs could improve contractors' understanding of INDOT requirements.

6.2 Implement Warranties

This study recommends that INDOT require warranties on all utility cuts. These warranties would ensure that adequate measures are taken to preserve the quality of the pavement. Moreover, the utility contractors would be liable for any rework that may be required to achieve the specified level of smoothness. In addition, the warranties would also serve as a motivation for the contractors to perform high quality work in order to avoid rework.

6.3 Evaluate the Viability of Degradation Fee/Billings for Defective Work

Utility cuts are known to reduce the service life of roadway. Thus, it is recommended that INDOT impose a fee in addition to the permit fee to recover the cost associated with subsequent reduction in pavement service life due to utility cuts. The degradation fee also serves as an incentive to the utilities to coordinate their work with INDOT's road construction projects thereby minimizing the impact to roadways. The degradation fee charged must be fair to the utility contractors and should be technically justifiable. The fee should be reflective of the loss of serviceability of the pavement and could be determined based on the age and service life of the pavement, size of the cut, etc.

To alleviate issues related with poor utility cut repairs, INDOT may choose to pursue the rework themselves, and later bill the cost of rework to the utility contractors. The outstanding balance for the cost of rework could be considered by INDOT in the approval of future permits by a utility contractor. A topic for further investigation could be to explore the viability of implementing degradation fees and billings for utility cut repairs.

6.4 Incorporate Enhancements to the Electronic Permitting System (EPS)

The research team suggested the following modifications to INDOT's EPS to facilitate the effective management of utility cut permits:

- Addition of data fields to record the permit sub-type (i.e., utility cut), in order to distinguish utility cuts from Cut Road permits.
- Addition of data fields to record information about the utility contractor.
- Addition of data fields to record technical specifications of the work, such as length and width of the cut, depth of the excavation (if relevant), backfill material used, length of additional cutback to create the T-section utility patch, type of edge treatment, and type of surfacing material used (i.e., permanent or temporary patching materials).
- Addition of a data field to specify whether a repair uses temporary patching material, and the anticipated date of permanent repairs. This data-field would enable INDOT to identify temporary patches that have not been permanently resurfaced.
- Discontinuing the current method of specifying permit locations using a mouse click on a map. Instead, the permittee should be required to measure the location of the repair with a global positioning system (GPS) device or equivalent triangulation method, and report the latitude and longitude of the location. The EPS interface should also allow the permittee to enter multiple work locations covered under a single permit.

Two methods for automated condition monitoring of utility cut repairs were investigated during the course of this study. The first method involved the installation of radio frequency identification (RFID) tags in the repaired pavement and RFID readers on the Pathway pavement monitoring vans. The tags which were expected to be automatically identified by the RFID readers would provide the location of the repair, as well as information about the company responsible for the repair. By correlating the location of the repaired patch with the roadway condition at or surrounding the patch, INDOT would be able to periodically monitor repairs for settlement, and hence identify parties responsible for the pavement repairs. However, based on tests conducted by the RFID vendor on a pilot INDOT project, as of September 2016, these tags could not be reliably detected by the RFID readers mounted on the Pathway pavement monitoring vans. Since further development and testing was being considered by the vendor of these RFID tags, the research team and study advisory committee decided to evaluate a second method for automated monitoring.

The second method for automated condition monitoring involves correlating Pathway's global positioning system (GPS) location with the location information of utility cut repairs from the EPS, for automated identification of the repaired patches. After a patch is identified, the roadway condition at or surrounding the patch could be used as an indicator about the condition of a repair. This first barrier to implementing this method is that it requires the EPS to contain accurate location information about each utility cut repair. The current EPS used by INDOT however cannot support this method, since it does not distinguish between utility cuts and "Cut-Road" permits. The second barrier to implementation is that INDOT's data collection vehicles currently report pavement condition at intervals of approximately 0.1 miles. Since an interval of 0.1 miles could contain several utility cuts, the research team recommends that the reporting interval be reduced to 0.01 miles for this method to work effectively.

REFERENCES

Albright, R. O., & Nantung, T. (1993). Flowable fill for street and highway applications. *Purdue Road School 1993 Proceedings*. West Lafayette, IN: Purdue University. Retrieved March 3, 2018, from https://docs.lib.purdue.edu/roadschool/1993/presentations/10/

ACI Committee 229. (2013). *Controlled low strength materials* (Report No. ACI 229R-13). Farmington Hills, MI: American Concrete Institute. Retrieved from November 1, 2017, from https://www.concrete.org/store/productdetail.aspx?ItemID=22913&Format=DOWNLOAD&Language=English

ACPA. (2009). Utility cuts in concrete pavements. *Concrete paving technology*. Skokie, IL: American Concrete Pavement Association. Retrieved November 1, 2016, from http://cncement.org/wp-content/uploads/2014/05/Utility-Cuts-for-Concrete.pdf

APWA. (1997). *Subsurface utility engineering: Applications in public works*. Kansas City, MO: American Public Works Association.

ASTM D4832. (2002). Standard test method for preparation and testing of controlled low strength material (CLSM) test cylinders. West Conshohocken, PA: ASTM International.

Arudi, R., Pickering, B., & Flading, J. (2000). Planning and implementation of a management system for utility cuts. *Transportation Research Record*, *169*, 42–48. https://doi.org/10.3141/1699-06

Baker, H., & Goodrich, L. (1994). *Trench backfill and reinstatement*. Paper presented at the 46th Annual Conference of the Western Canada Water and Wastewater Association, Winnipeg.

Baker, T. H. W. (1998). Frost penetration in flowable fill used in pipe trench backfill. In A. Howrd & J. Hitch (Eds.), *The design and application of controlled low-strength materials (flowable fill)* (STP1331-EB, pp. 275–282). West Conshohocken, PA: ASTM International. https://doi.org/10.1520/STP13080S

Caltrans. (2015). *Standard Specifications 2015*. Sacramento, CA: California Department of Transportation. Retrieved November 1, 2017, from http://www.dot.ca.gov/hq/esc/oe/construction_contract_standards/std_specs/2015_StdSpecs/2015_StdSpecs.pdf

Caltrans. (2016). Encroachment and utilities. Chapter 17 in *Project development procedures manual*. Sacramento, CA: California Department of Transportation. Retrieved November 1, 2017, from http://www.dot.ca.gov/design/manuals/pdpm/chapter/chapt17.pdf

Caltrans. (2017). *Encroachment permit application guide*. Sacramento, CA: California Department of Transportation. Retrieved November 1, 2017, from http://www.dot.ca.gov/trafficops/ep/docs/EP_Application_Guide_Booklet.pdf

CDOT. (2011a). *M standard plans and M standard project special details*. Denver, CO: Colorado Department of Transportation. Retrieved from November 1, 2017, from https://www.codot.gov/business/designsupport/standard-plans/2012-m-standards-plans

CDOT. (2011b). *Utility manual*. Denver, CO: Colorado Department of Transportation. Retrieved from November 1, 2017, from https://www.codot.gov/business/designsupport/bulletins_manuals/utility-manual

CDOT. (2017). *2017 Standard specifications*. Denver, CO: Colorado Department of Transportation. Retrieved from November 1, 2017, from https://www.codot.gov/business/designsupport/cdot-construction-specifications/2017-construction-standard-specs/2017-specs-book

City of Dallas. (2003). *Pavement cut and repair standards manual*. Dallas, TX: City of Dallas Department of Public Works and Transportation. Retrieved March 23, 2015, from http://dallascityhall.com/departments/sustainabledevelopment/DCH%20documents/pdf/CutManualOct2003.pdf

City of Dayton. (2016). *Rules and regulations for making public openings in a public way*. Dayton, OH: City of Dayton Department of Public Works. Retrieved from January 1, 2017, from https://www.daytonohio.gov/DocumentCenter/View/705

FHWA. (2015). *Pavement utility cuts*. Washington, DC: Federal Highway Administration, U.S. Department of Transportation. Retrieved March 23, 2015, from http://www.fhwa.dot.gov/utilities/utilitycuts/man03.cfm

FDOT. (2016a). Miscellaneous utility details. Section 307 in *FDOT design standards*. Tallahassee, FL: Florida Department of Transportation. Retrieved November 1, 2017, from http://www.fdot.gov/roadway/training/webinar12/designstandards.pdf

FDOT. (2016b). *Standard specifications for bridge and road construction*. Tallahassee, FL: Florida Department of Transportation. Retrieved November 1, 2017, from http://www.fdot.gov/programmanagement/Implemented/SpecBooks/July2016/Files/716eBook.pdf

FDOT. (2016c). *Utility accommodation manual*. Tallahassee, FL: Florida Department of Transportation. Retrieved November 1, 2017, from http://www.fdot.gov/programmanagement/utilities/Docs/UAM/UAMRuleDev/2016UAM-Nov-23-2015.pdf

Griffin, J., & Brown, E. (2011). Flowable fill for rapid pavement repair. *Transportation Research Record*, *2235*, 88–94. https://doi.org/10.3141%2F2235-10

ITD. (2016a). *Standard drawings*. Boise, ID: Idaho Department of Transportation. Retrieved November 1, 2017, from http://apps.itd.idaho.gov/apps/StandardDrawings/All_Standards_2016-06.pdf

ITD. (2016b). Utilities. Section 2.5.2.5 in *ITD bridge manual*. Boise, ID: Idaho Department of Transportation. Retrieved November 1, 2017, from http://apps.itd.idaho.gov/apps/bridge/manual/02%20General%20Design%20and%20Location%20Features/2.5.2.5%20Utilities.pdf

ITD. (2017). *Standard specifications for highway construction*. Boise, ID: Idaho Department of Transportation. Retrieved November 1, 2017, from http://apps.itd.idaho.gov/apps/manuals/SpecBook.pdf

IDOT. (n.d.). *Part 530: Accommodation of utilities on right-of-way*. Springfield, IL: Illinois Department of Transportation. Retrieved November 1, 2017, from http://www.ilga.gov/commission/jcar/admincode/092/09200530sections.html

IDOT. (2002). *Special provisions for open cutting*. Springfield, IL: Illinois Department of Transportation.

IDOT. (2012). *Standard specifications for road and bridge construction*. Springfield, IL: Illinois Department of Transportation. Retrieved November 1, 2017, from http://www.idot.illinois.gov/assets/uploads/files/doing-business/manuals-guides-&-handbooks/highways/construction/standard-specifications/12specbook.pdf

INDOT. (n.d.). *Right-of-way permit special provisions*. Indianapolis, IN: Indiana Department of Transportation. Retrieved November 1, 2017, from https://forms.in.gov/download.aspx?id=9483

INDOT. (2014). *Utility accommodation policy*. Indianapolis, IN: Indiana Department of Transportation. Retrieved November 1, 2017, from https://www.in.gov/indot/files/UC_UtilityAccommodationPolicy_061214.pdf

INDOT. (2016). *Standard specifications 2016*. Indianapolis, IN: Indiana Department of Transportation. Retrieved November 1, 2017, from http://www.in.gov/dot/div/contracts/standards/book/sep15/2016Master.pdf

Iowa DOT. (2012a). *Policy for accommodating and adjustment of utilities on the primary road system*. Ames, IA: Iowa Department of Transportation. Retrieved November 1, 2017, from https://iowadot.gov/traffic/pdfs/UtilityPolicy.pdf

Iowa DOT. (2012b). *Standard specifications for highway and bridge construction*. Ames, IA: Iowa Department of Transportation. Retrieved November 1, 2017, from https://www.iowadot.gov/specifications/Specificationsseries2012.pdf

Iseley, T., & Gokhale, S. (1997). *Trenchless installation of conduits beneath roadways* (NCHRP Synthesis 242). Washington, DC: Transportation Research Board.

Islam, S., Buttlar, W. G., Aldunate, R. G., & Vavrik, W. R. (2014). Measurement of pavement roughness using Android-based smartphone application. *Transportation Research Record*, *2457*, 30–38. https://doi.org/10.3141/2457-04

Jensen, K. A., Schaefer, V. R., Suleiman, M. T., & White, D. J. (2005). Characterization of utility cut pavement settlement and repair techniques. In *Proceedings of the 2005 Mid-Continent Transportation Research Symposium, Iowa State University, Ames, Iowa*.

KDOT. (2007). *Utility accommodation policy*. Topeka, KS: Kansas Department of Transportation. Retrieved from https://www.ksdot.org/Assets/wwwksdotorg/bureaus/burConsMain/Connections/UAP2007_2016_aug.pdf

KDOT. (2010). *Engineering standard drawings, manuals, software, and resources*. Topeka, KS: Kansas Department of Transportation. Retrieved November 1, 2017, from https://www.ksdot.org/descons.asp

KDOT. (2015). *Standard specifications for state road and bridge construction*. Topeka, KS: Kansas Department of Transportation. Retrieved November 1, 2017, from https://www.ksdot.org/bureaus/burConsMain/specprov/2015specprov.asp

Lakkavalli, V., Eng, P., Eng, B. P. P., & Dhanoa, S. (2015). *Challenges in utility coordination and implementation of pavement degradation fees*. Paper presented at TAC 2015: Getting You There Safely—2015 Conference and Exhibition of the Transportation Association of Canada.

Lee, S., & Lauter, K. (1999). *Impact of utility trenching and appurtenances on pavement performance in Ottawa-Carleton*. Ottawa, ON, Canada: Environment and Transportation Department, Regional Municipality of Ottawa-Carleton. Retrieved November 1, 2017, from http://www2.apwa.net/documents/organization/Lee_Lauter2_Apr00.pdf

Lin, D. F., Luo, H. L., Wang, H. Y., & Hung, M. J. (2007). Successful application of CLSM on a weak pavement base/subgrade for heavy truck traffic. *Journal of Performance of Constructed Facilities*, *21*(1), 70–77. https://doi.org/10.1061/(ASCE)0887-3828(2007)21:1(70)

Macy, M. (2002). Pavement degradation: How other cities are dealing with it. *APWA Reporter*, *69*(9). Retrieved March 10, 2018, from http://www3.apwa.net/Resources/Reporter/Articles/2002/9/Pavement-Degradation-How-other-cities-are-dealing-with-it

Maher, M. L. (2013). *Road utility cuts and repairs—Applying keyhole technology*. Paper presented at the 2013 Conference and Exhibition of The Transportation Association of Canada-Transportation: Better–Faster–Safer, Winnipeg, Manitoba.

Meade, B. W., Hunsucker, D. Q., & Stone, M. D. (1993). *Evaluation of CLSM (flowable fill) for trench backfill* (Kentucky Transportation Center Report No. KTC-93-5). Lexington, KY: University of Kentucky. https://doi.org/10.13023/KTC.RR.1993.05

Metro Nashville. (2008). Resurfacing and pavement preservation treatments. Appendix D in *Long range paving plan*. Nashville, TN: Metropolitan Government of Nashville and Davidson County, Tennessee.

MDOT. (2012). *Standard specifications for construction*. Lansing, MI: Michigan Department of Transportation. Retrieved November 1, 2017, from https://mdotcf.state.mi.us/public/specbook/2012

MDOT. (2017). *Standard drawings*. Lansing, MI: Michigan Department of Transportation. Retrieved November 1, 2017, from http://sp.mdot.ms.gov/RoadwayDesign/Pages/Standard-Drawings.aspx

MDT. (2008). *Right of way and utilities*. Helena, MT: Montana Department of Transportation. Retrieved November 1, 2017, from http://www.mdt.mt.gov/publications/manuals.shtml

MDT. (2014a). *Detailed drawings*. Helena, MT: Montana Department of Transportation. Retrieved November 1, 2017, from http://www.mdt.mt.gov/other/webdata/external/const/detailed_drawings/2018_Jan/_DETAILED_DRAWINGS.PDF

MDT. (2014b). *Standard specifications for road and bridge construction*. Helena, MT: Montana Department of Transportation. Retrieved November 1, 2017, from https://www.mdt.mt.gov/other/webdata/external/const/specifications/2014/2014_stand_specs.pdf

Mouaket, A., Eng, P., & Capano, N. A. (2013). *Development of a pavement degradation fee structure for the City of Toronto*. Paper presented at the 2013 Conference and Exhibition of The Transportation Association of Canada-Transportation: Better–Faster–Safer, Winnipeg, Manitoba

NCDOT. (2012). *Roadway standard drawings*. Raleigh, NC: North Carolina Department of Transportation. Retrieved November 1, 2017, from https://connect.ncdot.gov/resources/Specifications/pages/2012-roadway-drawings.aspx

NCDOT. (2014). *Utility policy manual*. Raleigh, NC: North Carolina Department of Transportation. Retrieved November 1, 2017, from https://connect.ncdot.gov/municipalities/Utilities/UtilitiesDocuments/Utilities%20Policy%20Manual.pdf

NCDOT. (2018). *Standard specifications for roads and structures*. Raleigh, NC: North Carolina Department of Transportation. Retrieved November 1, 2017, from https://connect.ncdot.gov/resources/Specifications/StandSpecLibrary/2018%20Standard%20Specifications%20for%20Roads%20and%20Structures.pdf

NDOT. (2014). *Standard specifications for road and bridge construction*. Retrieved November 1, 2017, from https://www.nevadadot.com/home/showdocument?id=6916

NDOT. (2016). *Right of way manual*. Carson City, NE: Nevada Department of Transportation Retrieved November 1, 2017, from https://www.nevadadot.com/home/showdocument?id=4492

NDOT. (2017). *Standard plans for road and bridge construction*. Carson City, NE: Nevada Department of Transportation. Retrieved November 1, 2017, from https://www.nevadadot.com/home/showdocument?id=6926

Nebraska DOT. (2008). Bedding and backfill requirements for concrete pipes. In *Standard Plans*. Lincoln, NE: Nebraska Department of Transportation. Retrieved November 1, 2017, from http://dot.nebraska.gov/media/6645/standard.pdf

Nebraska DOT. (2017). *Standard specifications for highway construction*. Lincoln, NE: Nebraska Department of Transportation. Retrieved November 1, 2017, http://dot.nebraska.gov/media/10343/2017-specbook.pdf

NJDOT. (2007). *Standard specifications for road and bridge construction*. Trenton, NJ: New Jersey Department of Transportation. Retrieved November 1, 2017, from http://www.state.nj.us/transportation/eng/documents/BDC/pdf/attachmentbdc07s03.pdf

NJDOT. (2016). *Standard construction details*. Trenton, NJ: New Jersey Department of Transportation. Retrieved November 1, 2017, from http://www.state.nj.us/transportation/eng/CADD/v8/pdf/StandConstDetails.pdf

ODOT. (2015). *Permitting process for utility accommodation of highway right of way*. Columbus, OH: Ohio Department of Transportation. Retrieved November 1, 2017, from https://www.dot.state.oh.us/districts/D10/d10planning/Right_of_Way_Permits/Documents/Manuals/Utilities%20Manual.pdf

ODOT. (2016). *Construction and material specifications*. Columbus, OH: Ohio Department of Transportation. Retrieved November 1, 2017, from https://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Pages/2016-Online-Spec-Book.aspx

Peters, T. (2002). City combats damage to city streets caused by utility cuts. *Public Works*, *133*(4), 54–56.

Pons, F., Landwermeyer, J. S., & Kerns, L. (1998). Development of engineering properties for regular and quick-set flowable fill. In A. Howard & J. Hitch (Eds.), *The design and application of controlled low-strength materials (flowable* *fill)* (STP1331-EB, pp. 67–86). West Conshohocken, PA: ASTM International. https://doi.org/10.1520/STP13063S

Sarkar D. (2014). RFID tags curb street repair time. *GCN*. Retrieved November 1, 2016, from https://gcn.com/articles/2014/03/25/dayton-rfid.aspx

Schaefer, V., Suleiman, M., White, D., Swan, C., & Jensen, K. (2005). *Utility cut repair techniques—Investigation of improved cut repair techniques to reduce settlement in repaired areas* (Iowa Highway Research Board Project TR-503). Ames, IA: Iowa Centre for Transportation Research and Education, Iowa State University. Retrieved March 23, 2015, from http://www.intrans.iastate.edu/reports/utility_cut.pdf

SCDOT. (2007). *Standard specifications for highway construction*. Columbia, SC: South Carolina Department of Transportation. Retrieved November 1, 2017, from http://www.scdot.org/business/pdf/2007_full_specbook.pdf

SCDOT. (2011). *Utilities accommodation manual*. Columbia, SC: South Carolina Department of Transportation. Retrieved November 1, 2017, from http://www.scdot.org/business/pdf/rightofway/ua_policy.pdf

SCDOT. (2017). *Standard drawings*. Columbia, SC: South Carolina Department of Transportation. Accessed November 1, 2017, at http://206.74.144.33/falconwebv3/default.aspx?cmd=logon&hiddenLogon=1

Tarakji, G. (1995). *The effect of utility cuts on the service life of pavements in San Francisco, Volume I: Study procedure and findings*. San Francisco, CA: Department of Public Works, City of San Francisco.

TxDOT. (2017). *Standard specifications for construction and maintenance of highways, streets, and bridges*. Austin, TX: Texas Department of Transportation. Retrieved November 1, 2017, from https://ftp.txdot.gov/pub/txdot-info/cmd/cserve/specs/2014/standard/specbook-2014.pdf

Tiewater, P. (1997). How to reduce utility trenching costs. *Better Roads*, 18–20.

Todres, H. A. (2011). *Utility cuts in asphalt pavements: Best engineering practices*. Paper presented at the APWA International Public Works Congress, NRCC/CPWA Seminar Series, Innovations in Urban Infrastructure.

Videkovich, K. A. (2008). *Utility cut repair techniques: Investigation of improved utility cut repair techniques to reduce settlement in repaired areas, Phase II* (Master's thesis). Iowa State University, Ames, IA. Retrieved from http://lib.dr.iastate.edu/rtd/15459

VDOT. (2012). *Special provisions for pavement open cuts*. Fairfax, VA: Virginia Department of Transportation. Retrieved November 1, 2017, from http://www.virginiadot.org/business/resources/nova_fairfaxpermits/lup-oc_nova_open_cut_request.pdf

VDOT. (2016a). *Land use permit open-cut pavement restoration requirements*. Fairfax, VA: Virginia Department of Transportation. Retrieved November 1, 2017, from http://www.virginiadot.org/business/resources/land_use_regs/LUP-OC_Open-Cut_Pavement_Restoration_Requirements.doc

VDOT. (2016b). *Road and bridge specifications*. Fairfax, VA: Virginia Department of Transportation. Retrieved November 1, 2017, from http://www.virginiadot.org/business/resources/const/VDOT_2016_RB_Specs.pdf

VDOT. (2016c). *Utility manual of instructions* (11th ed.). Fairfax, VA: Virginia Department of Transportation. Retrieved November 1, 2017, from http://www.virginiadot.org/business/resources/Right_of_way/Utility_Manual10012014.pdf

WSDOT. (2016). *Utilities accommodation manual*. Olympia, WA: Washington State Department of Transportation. Retrieved November 1, 2017, from https://www.wsdot.wa.gov/publications/manuals/fulltext/M22-86/UtilitiesAccommodationPolicy.pdf

WSDOT. (2018). *Standard specifications for road, bridge, and municipal construction*. Olympia, WA: Washington State Department of Transportation. Retrieved February 1, 2018, from http://www.virginiadot.org/business/resources/land_use_regs/LUP-OC_Open-Cut_Pavement_Restoration_Requirements.doc

APPENDIX A. SURVEY QUESTIONNAIRE SENT TO US STATE TRANSPORTATION AGENCIES

1. Does your agency have a standard method of repair of utility cuts in the pavement? Yes ___ No___
2. If you answered Yes to question 1, does your method provide satisfactory results? Yes___ No__
3. If you answered Yes to question 2, please describe the standard method of repair. Please be as detailed as possible or attach written standards, if available. If you answered no, proceed to question 4.
   Specifically, with your standard method of repair, please answer the following questions:

   a. What types of backfill materials do you allow (i.e., native materials, imported materials, special materials)?
   b. What type of compaction do you require of the backfill materials?
   c. How does your agency measure satisfactory results?
   d. What is the expectation of the utility cut repair (patch) with respect to the design life, smoothness, etc.?
   e. Are repairs surfaced with a temporary pavement? Yes ___ No____
   f. How are the patches inspected to ensure compliance?
      If you answered Yes to question 3(e), please identify the temporary pavement material and how long the temporary patch is left in place. If you have answered No to question 3, please indicate the type of permanent repair.

4. Do you have any quality control or quality assurance (QC/QA) requirements for utility cut repairs? Yes ___ No ___

   a. If yes to question 4, please identify (or attach) the QC/QA requirements.

5. Does your agency use in-house crew to repair utility cuts? Yes ____ No ___
6. If known, what do the failures and repairs cost your agency annually?
7. What is the predominant time of failures that require repair (i.e., winter, spring, summer, fall)?
8. How many failures do you have annually?
9. Has your agency/city you changed repair practices recently? Yes ___ No ___
10. If you have answered Yes to question 9, please identify the old practice and why you changed the practices.
11. If you have answered Yes to question 9, what is the new practice for utility cut repair? How is the new practice performing?
12. What percentage of repairs have experienced pavement performance problems?
13. How long do the typical repairs last before they have performance problems?
14. What, in your opinion, is causing the problems?
15. Does your agency have a fee system linked to each utility cut permit to address the effects of utility cuts on pavement performance? Yes ____ No ____
16. If you answered Yes to question 15, please list the fee structure and the factors used in structuring the fees.
17. Does your agency have warranty requirements for pavement cuts? Yes ____ No ____
18. If you answered Yes to question 17, please describe these warranty requirements or attach a copy of the requirements.

APPENDIX B. INTERVIEWS WITH INDOT ENGINEERS

TABLE B.1
Respondents and their affiliations

District	Name of respondent and role
Greenfield	Aschalew Aberra (Scoping manager)
	Chris Moore (Pavement Engineer)
	Peter White (Asset Manager)
Crawfordsville	Carla Sheets (Railroad & Utility Technician)
Fort Wayne	Jason Hanaway (District Permit Manager)
Vincennes	Randy Archer (Permit Consultant/Manager)
	Randy Carie (Acting Permit Manager)

List of Questions

1. What kind of preparation is taken by INDOT prior to approving a utility cut permit?
2. What are typical work practices when performing utility cuts?
3. What type of scheduling and coordination is done when performing utility cuts?
4. Who performs the work on these utility cuts?
5. Do you provide guidance to the utility contractors or do you let them decide how the work is going to be done?
6. What causes the most rework with regard to utility cuts?
7. Have you performed multiple repairs on the same utility cut? Where? When? What?
8. Do you think contractors would have difficulties conforming to INDOT specifications with regard to utility cuts? In what respects?
9. Based on your experience, how effective is the backfilling process? Explain.
10. Based on your experience, how effective is the T-section method? Explain.
11. Based on your experience, would you suggest any changes in the specifications for ensuring the integrity of pavement cut repairs?
12. Have you seen more cuts from one particular utility?
13. What recommendations do you have for contractors performing utility cut repairs?

APPENDIX C. NUMBER OF CUT-ROAD PERMITS ON INDOT ROADS IN 2016

TABLE C.1
Cut Road Permits on US 52 in Crawfordsville and Greenfield

Does the work require roadway excavation?	Submit date	Issue date	Project description	District
No	12/22/2016	12/27/2016	Test bores for pavement evaluation	Crawfordsville
No	12/22/2016	12/27/2016	Boring to provide fiber services	Crawfordsville
No	11/3/2016	11/3/2016	Installation of storm sewer	Crawfordsville
No	10/26/2016	10/27/2016	Boring to provide fiber services	Crawfordsville
No	10/12/2016	10/18/2016	Boring to provide fiber services	Crawfordsville
No	10/7/2016	10/7/2016	Test bores for pavement evaluation	Crawfordsville
No	9/29/2016	10/4/2016	Installation of communication lines	Crawfordsville
No	9/19/2016	10/4/2016	Boring to provide fiber services	Crawfordsville
No	9/15/2016	9/18/2016	Boring to provide fiber services	Crawfordsville
No	9/15/2016	9/15/2016	Directional drilling to relocate existing fiber services	Crawfordsville
No	9/14/2016	9/15/2016	Retiring service lines	Crawfordsville
No	9/8/2016	9/15/2016	Relocating cables	Crawfordsville
No	8/24/2016	9/1/2016	Landscape cut back	Crawfordsville
No	8/22/2016	8/23/2016	Replacing valve in grass	Crawfordsville
No	8/16/2016	8/16/2016	Removing contaminated spill	Crawfordsville
No	7/12/2016	7/26/2016	Place fiber optic cable	Crawfordsville
No	6/28/2016	6/28/2016	Install gas line	Crawfordsville
No	6/27/2016	6/28/2016	Install gas line	Crawfordsville
No	6/24/2016	6/28/2016	Boring to provide fiber services	Crawfordsville
No	6/20/2016	6/21/2016	Directional drilling to place fiber services	Crawfordsville
No	12/15/2016	1/24/2017	Connection to drainage outlet	Greenfield
No	12/1/2016	12/2/2016	Boring to provide fiber services	Greenfield
No	11/23/2016	12/30/2016	Replacement of existing storm sewer drain	Greenfield
No	11/8/2016	3/15/2017	Install stormwater drain through boring	Greenfield
No	9/30/2016	10/4/2016	Extending sewer service to buildings	Greenfield
No	9/22/2016	9/27/2016	Install fiber services	Greenfield
No	9/16/2016	9/22/2016	Boring to provide fiber services	Greenfield
No	9/15/2016	9/22/2016	Installation of an environmental monitoring well	Greenfield
No	8/17/2016	10/19/2016	Placing of flange for drainage	Greenfield
No	8/10/2016	8/15/2016	Boring to provide services	Greenfield

TABLE C.2
Cut Road Permits on SR-26 in Crawfordsville and Greenfield

Does the work require roadway excavation?	Submit date	Issue date	Project description	District
No	11/30/2016	12/1/2016	Tree trimming	Crawfordsville
No	11/16/2016	11/20/2016	Providing gas line to new building	Crawfordsville
No	7/15/2016	8/23/2016	Replacement of lift station	Crawfordsville
No	12/22/2016	1/6/2017	Excavation in grass	Greenfield
No	11/30/2016	12/1/2016	Tree trimming	Greenfield
No	10/25/2016	10/26/2016	Replace underground emergency gas valve	Greenfield
No	9/24/2016	10/3/2016	Boring to provide fiber services	Greenfield
No	8/30/2016	9/6/2016	Installation of gas line	Greenfield
No	8/2/2016	8/10/2016	Boring to provide fiber services	Greenfield
No	7/28/2016	7/28/2016	Excavation in grass	Greenfield
No	7/22/2016	7/25/2016	Repair gas leak	Greenfield
No	7/7/2016	7/7/2016	Install service tap on gas line	Greenfield
No	7/6/2016	7/7/2016	Placing buried fiber services	Greenfield
No	6/22/2016	6/22/2016	Placing buried telecom cable	Greenfield
No	6/22/2016	7/8/2016	Placing buried fiber services	Greenfield

TABLE C.3
Cut Road Permits on US 136 in Crawfordsville and Greenfield

Does the work require roadway excavation?	Submit date	Issue date	Project description	District
No	7/18/2016	7/20/2016	Excavation in grass	Crawfordsville
No	7/14/2016	7/26/2016	Excavation to expose water line	Crawfordsville
No	7/8/2016	7/12/2016	Directional boring for installation of water line	Crawfordsville
No	11/29/2016	12/1/2016	Installation of tap on water line	Crawfordsville
No	11/28/2016	11/28/2016	Directional boring for placement of fiber services	Crawfordsville
No	11/28/2016	11/29/2016	Directional boring for placement of fiber services	Crawfordsville
No	11/11/2016	11/15/2016	Directional boring for placement of fiber services	Crawfordsville
No	11/10/2016	12/13/2017	Sidewalk replacement	Crawfordsville
No	11/4/2016	11/9/2016	Directional boring for placement of fiber services	Crawfordsville
No	10/31/2016	10/31/2016	Sidewalk replacement	Crawfordsville
No	10/28/2016	11/1/2016	Installation of meter pit for water line	Crawfordsville
No	10/26/2016	10/27/2016	Directional boring for placement of fiber services	Crawfordsville
No	10/12/2016	10/12/2016	Directional boring for installation of water line	Crawfordsville
No	9/1/2016	9/1/2016	Directional boring for installation of water line	Crawfordsville
No	9/1/2016	9/20/2016	Installation of sanitary force main	Crawfordsville
No	8/23/2016	8/23/2016	Repair or replace water service line due to leak	Crawfordsville
Yes	10/12/2016	10/14/2016	Install valve on water line	Crawfordsville
Yes	7/19/2016	7/22/2016	Renew gas service line	Greenfield

TABLE C.4
Cut Road Permits on US 36 in Crawfordsville and Greenfield

Does the work require roadway excavation?	Submit date	Issue date	Project description	District
Yes	12/22/2016	12/22/2016	Repair emergency water leak	Crawfordsville
No	12/21/2016	1/6/2017	Directional boring to install fiber services	Greenfield
No	12/21/2016	1/6/2017	Directional boring to install fiber services	Greenfield
No	12/20/2016	12/21/2016	Directional boring for placement of fiber services	Crawfordsville
No	12/6/2016	12/9/2016	Excavation in grass	Crawfordsville
No	12/1/2016	12/5/2016	Directional boring for placement of fiber services	Greenfield
No	12/1/2016	12/5/2016	Directional boring for placement of fiber services	Greenfield
No	11/15/2016	11/16/2016	Boring to install gas line	Crawfordsville
No	11/10/2016	11/10/2016	Directional boring for placement of fiber services	Crawfordsville
No	10/31/2016	11/1/2016	Directional boring for placement of fiber services	Crawfordsville
No	10/31/2016	11/18/2016	Connecting pipe to a drain	Greenfield
No	9/27/2016	9/27/2016	Gas service installation	Crawfordsville
No	9/13/2016	9/19/2016	Directional boring for placement of fiber services	Crawfordsville
No	9/2/2016	9/8/2016	Directional boring for placement of fiber services	Crawfordsville
No	8/29/2016	9/6/2016	Installation of sanitary sewer	Greenfield
No	8/26/2016	8/29/2016	Directional boring for placement of fiber services	Crawfordsville
No	8/18/2016	8/22/2016	Clearing vegetation	Crawfordsville
No	8/15/2016	8/31/2016	Directional boring for placement of fiber services	Greenfield
No	8/10/2016	8/17/2016	Excavate existing fiber route to install access point	Greenfield
No	8/5/2016	8/8/2016	Directional boring for placement of fiber services	Crawfordsville
No	8/5/2016	8/8/2016	Directional boring for placement of fiber services	Crawfordsville
Yes	7/22/2016	7/25/2016	Gas main repair	Greenfield
No	7/19/2016	8/8/2016	Sewer line installation	Greenfield

About the Joint Transportation Research Program (JTRP)

On March 11, 1937, the Indiana Legislature passed an act which authorized the Indiana State Highway Commission to cooperate with and assist Purdue University in developing the best methods of improving and maintaining the highways of the state and the respective counties thereof. That collaborative effort was called the Joint Highway Research Project (JHRP). In 1997 the collaborative venture was renamed as the Joint Transportation Research Program (JTRP) to reflect the state and national efforts to integrate the management and operation of various transportation modes.

The first studies of JHRP were concerned with Test Road No. 1—evaluation of the weathering characteristics of stabilized materials. After World War II, the JHRP program grew substantially and was regularly producing technical reports. Over 1,600 technical reports are now available, published as part of the JHRP and subsequently JTRP collaborative venture between Purdue University and what is now the Indiana Department of Transportation.

Free online access to all reports is provided through a unique collaboration between JTRP and Purdue Libraries. These are available at: http://docs.lib.purdue.edu/jtrp

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