WJE

Improving Concrete Patching Practices on Iowa Roadways

IHRB TR-731

FINAL REPORT

July 8, 2022

WJE No. 2017.3375

SUBMITTED BY:

Todd Nelson, PE (PI)
Mohamed ElBatanouny, PhD (Co-PI)
Elizabeth Wagner, PhD (Co-PI)
Le Pham, PhD (Project Associate)
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16. Abstract

This research effort aims to improve pavement patching practices in Iowa by identifying best practices used for portland cement concrete (PCC) pavement repairs in the upper Midwestern United States and by developing guidelines and tools for improved materials selection, repair installation, and quality assurance and quality control (QA/QC) of full-depth and partial-depth PCC pavement repairs. This project included a literature review, survey of Midwestern DOTs, field trial repairs, and development of recommended repair procedures and drawings. The effort focused specifically on repairs to jointed plain concrete pavements (JPCPs) using long-term, durable materials such as portland cement concrete, polymer-based materials, and proprietary rapid setting patch materials. The outcome of this applied research includes practical recommendations to the Iowa DOT on both full-depth and partial-depth repair materials, procedures, and QA/QC procedures. In addition, a web-based application was developed to communicate the recommended materials, drawings, practices and QA/QC procedures to personnel designing, inspecting, and performing repairs on Iowa pavements. The goal of the web-based application is to provide guidance regarding the selection of patching materials, the definition and preparation of the patch area, the details of the repairs, the installation of the repairs, and the associated QA/QC procedures and reporting.

17. Key Words	**18. Distribution Statement**
Full-depth concrete patching, partial-depth concrete patching, pavement, concrete repair, concrete repair materials, jointed plain concrete pavements, and portland cement concrete.	No restrictions. This document is available to the public from the sponsoring agency.

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CONTENTS

1. INTRODUCTION

This final report details the applied research performed for IHRB TR-731, *Improving Concrete Patching Practices on Iowa Roadways*. This report includes a summary of the literature review, DOT survey, proposed changes to repair procedures and materials for partial- and full-depth repairs, and a summary of trial full-depth repairs. As part of this applied research, a web-based application was developed that includes repair procedures, drawings, and quality control/assurance procedures for both full- and partial-depth repairs to aid IDOT personnel and contractor.

1.1. Background

Portland cement concrete (PCC) pavements are subject to distress from a variety of sources, including traffic loads, thermal movement, wetting and drying, freezing and thawing, materials-related distress, and construction-related issues. This distress can manifest in the pavement as transverse cracking, longitudinal cracking, D-cracking, joint deterioration, corner breaks, spalls, blowups, or other forms of distress [1]. Depending on the type and severity of the distress, a partial-depth or full-depth repair of the concrete may be warranted.

Partial-depth repairs (PDRs) are typically specified for localized distress occurring near the surface of the concrete, such as surface spalling near a joint or surface scaling due to freezing and thawing [2]. PDRs are used to improve ride quality, to replace unsound concrete, and to restore structural integrity to pavements that may be otherwise compromised by these forms of distress [3]. PDR patches tend to be limited to the top one-third to one-half of the pavement thickness and are typically only a few square feet in area.

For distress occurring over larger areas or through the full thickness of the pavement, a full-depth repair (FDR) may be warranted. Like PDRs, FDRs are also used to improve ride quality and to restore structural integrity to the pavement [4]. They are commonly used to restore PCC pavements affected by blowups and corner breaks, moderate to severe levels of joint deterioration and transverse cracking, and severe levels of longitudinal cracking [5]. As the name suggests, FDRs extend through the full thickness of the pavement and may include large areas for severely deteriorated pavements.

Both full-depth and partial-depth PCC repairs have been performed using a variety of materials; including portland cement concrete, polymeric materials, and proprietary materials based on rapid setting cements. These repairs typically last between 5 and 15 years; however, longer service lives have been noted [5, 6, 7]. The most important performance characteristics for concrete patch materials include the rate of strength gain, workability, durability (i.e., service life of the repair), cost, and constructability [7, 8]. These aspects may not always agree with one another: for example, rapid strength gain of a patching material may reduce road closure time and minimize disruption to traffic but may also cause problems with respect to the workability, constructability, and durability of the patch, and improper installation or surface preparation may lead to reduced performance and durability, regardless of the materials used. Therefore, selection of a suitable repair material should be based on a balance of performance characteristics to achieve the overall best performance over the life of the PCC pavement repair.

Currently, the Iowa Department of Transportation (Iowa DOT) specifies the use of portland cement concrete mixtures with or without calcium chloride accelerators for full-depth and partial-depth patches of PCC pavements. Rapid-setting proprietary materials are also permitted for partial-depth patches only. The *Iowa*

DOT Standard Specifications include provisions for removal of the existing concrete; preparation of the surface to receive the repair material; and placement, consolidation, finishing, and curing of the repair concrete. A set of standard drawings also provides details regarding patch installation.

Despite the guidance provided in these specifications, patches on many of Iowa's pavements are reportedly not achieving the long-term performance desired. Failure of patches to achieve target performance over time is typically a consequence of poor materials performance and/or improper installation procedures. Although concrete pavement patching has been used for several decades by many state DOTs, including Iowa DOT, the emergence of alternative repair materials and improved installation practices require updating of existing specifications.

This research effort aims to improve pavement patching practices in Iowa by identifying best practices used for PCC pavement repairs in the upper Midwestern United States and by developing guidelines and tools for improved materials selection, repair installation, and quality assurance and quality control (QA/QC) of full-depth and partial-depth PCC pavement repairs. This research effort focuses specifically on repairs to jointed plain concrete pavements (JPCPs) using long-term, durable materials such as portland cement concrete, polymer-based materials, and proprietary rapid setting patch materials. Repairs to jointed reinforced concrete pavements (JRCPs) or continuously reinforced concrete pavements (CRCPs), and short-term repairs using asphaltic materials are not explicitly considered.

1.2. Research Objectives

The main objective of this study is to evaluate the performance of current and alternative patching materials and placement procedures for full-depth and partial-depth repairs of jointed plain concrete pavements in Iowa. Best practices for PCC pavement patching practices were identified based on a literature search and a survey of state department of transportation (DOT) representatives in the upper Midwest states with climates similar to that of Iowa. Performance of standard and alternative patching materials and placement procedures were evaluated, and guidelines and repair procedures were developed to facilitate future full- and partial-depth repairs of PCC pavements in Iowa. Finally, tools will be developed to communicate the guidelines and repair procedures to repair contractors throughout the state.

The project is divided into the following five tasks:

- Task 1: Literature Review
- Task 2: Survey of States in the Upper Midwest
- Task 3: Field Evaluation of Partial and Full Depth Repairs
- Task 4: Draft Guidelines and Associated QA/QC Procedures
- Task 5: Website and Mobile Application Development

2. LITERATURE REVIEW

A comprehensive literature review was performed to compare current patching materials and installation procedures specified by the Iowa DOT for full-depth and partial-depth repairs of PCC pavements to those specified by other state DOTs in the upper Midwest. Previous research by others was also reviewed to support the identification of "best practices" for PCC pavement patching. The key findings of the literature review are summarized in the following sections.

2.1. Current Iowa DOT Specifications

2.1.1. Full-Depth Repairs

Full-depth concrete pavement repairs are covered by Section 2529, "Full Depth Finish Patches," of the *Iowa DOT Standard Specifications* [9]. Approved repair materials for concrete pavements include Class M concrete mixtures using portland cement or blended cement, defined by Materials IM 529 [10]. The Class M concrete mixture is intended to obtain a high early strength for opening to traffic in either 5, 10, or 24 hours. High early strength is achieved through use of a high cementitious materials content (typically 790 to 850 pounds per cubic yard); a low water-cement ratio (typically 0.33 with a maximum of 0.40 for most aggregate types); and for 5- and 10-hour patches only, the addition of a calcium chloride accelerator (32 percent solution) at a rate of 3 gallons per cubic yard.

The required properties for full depth repair concrete mixtures are listed in Table 2.1. Section 2529 only lists requirements for fresh concrete. Requirements for mechanical performance (e.g., compressive or flexural strength) of the hardened concrete are not provided.

Table 2.1 Required Properties for Full-Depth Concrete Patch Material

Property	With Calcium Chloride[1]	Without Calcium Chloride
Slump[2]	1 to 2.5 inches (3 inch max.)	1 to 3 inches (4 inches max.)
Air content	5.0 ± 2.0%	6.5 ± 1.5%
Temperature[2]	5 hr patch: 75 °F min. for Type I or Type II cement; 80 °F min. for Type IS cement 10 hr patch: 65 °F min. for Type I or Type II cement; 70 °F min. for Type IS cement 24 hr patch: 50 °F min. for Type I, Type II, and Type IS cements	

Notes: [1] Properties are measured before the addition of calcium chloride solution.

[2] If using a Type A mid-range water reducer, slump requirement is 1 to 4 inches (5 inches max.) and temperature requirement is 75 °F min. for 5 hr patch, 65 °F min. for 10 hr patch, and 50 °F min. for 24 hr patch.

The Engineer is responsible for determining the size and location of the full-depth repair and for selecting the patch material. All patches are the full lane width, unless shown otherwise in the contract documents, and are not less than 6 feet in length for interstate pavements or 4 feet in length for other pavements. For patches with dowels, the existing concrete is removed by saw-cutting for the full depth of the pavement with a blade saw. For patches without dowels, the transverse edges of the patches are cut to a depth of 1-1/2 inches with a blade saw, then the pavement is severed by a full depth saw cut approximately 1-1/2 inches inside the original transverse saw cut. The pavement can be removed by break-up or lift-up method. The transverse edges are tapered and roughened using a 15-lb chipping hammer to promote interlock and bond of the repair concrete to the existing concrete.

Before placing the concrete patch, the subbase or subgrade is restored as needed, dowels are installed as required by the contract documents, and the subbase or subgrade is moistened or covered with a single layer of plastic film. The concrete is placed in a continuous pour, consolidated by vibration, and finished flush to the adjacent pavement. Level is checked with a 10-foot straightedge prior to the concrete setting. The concrete is cured by covering with an insulating blanket and cellulosic fiber sheathing for a minimum of 5, 10, or 24 hours before opening to traffic. Smoothness testing is performed after curing for patches 50 feet or greater in length.

2.1.2. Partial-Depth Repairs

Partial-depth concrete pavement repairs are covered by Section 2530, "Partial Depth Finish Patches," of the *Iowa DOT Standard Specifications* [9]. Approved repair materials for concrete pavements include rapid-setting patch materials, defined by Materials *IM 491.20* (Class A patch material) [11]; and high early strength Class M concrete mixtures with either 5-hour or 24-hour curing times (Class B and Class C patch materials, respectively), defined by Materials IM 529.

Class A patch materials are proprietary formulations meeting the minimum requirements listed in Table 2.2. The current Iowa DOT approved products list for Class A partial-depth patch materials includes mixtures based on rapid-setting alternative cements such as magnesium phosphate cement; polymer-modified cements; and polymer concretes and grouts.

Table 2.2 Minimum Requirements for Rapid Set Concrete Patch Materials (Class A Patch)

Property	Test Method	Requirement
Compressive Strength	AASHTO T22 or T106	1,000 psi, min. at 3 hours 3,000 psi, min. at 24 hours
Bond Strength	ASTM C882 (slant shear) **or**	1,000 psi, min. at 1 day
	ASTM C1583 (direct tension)	260 psi, min. at 28 days
Freeze-Thaw Resistance	AASHTO T161, Method A or B	Durability factor = 70 percent, min. after 300 cycles
Length Change	AASHTO T160 **or**	+0.15%, max. after 28 days in water -0.15%, max. after 28 days in air
	ASTM C531 for high polymer content mixes	-0.10%, max. after 14 days in air 5.0 microstrain/°F, min. thermal expansion coefficient
Chloride Penetration Resistance	AASHTO T358 (surface resistivity) **or**	29 kOhm-cm after 28 days moist curing
	AASHTO T277 (rapid chloride permeability)	1,500 coulombs after 28 days moist curing

Class B and Class C patching materials are based on Class M concrete mixtures (as defined for full-depth repairs above) with and without calcium chloride, respectively. The composition and fresh concrete property requirements for Class B and Class C patching materials are the same as those defined for the 5- and 24-hour full-depth repairs described above. In addition, Class B and Class C patching materials must use coarse aggregates meeting the requirements of Section 4115 and Gradation No. 5, Aggregate Gradation Table.

Partial-depth patches of PCC pavements include partial-depth PCC finish patches and partial-depth PCC joint and crack repair patches. The Engineer is responsible for determining the size and location of the repair and for selecting the patch material. The size, shape, and depth of the patch may depend on the extent of the pavement deterioration and is determined during the removal operation. Finish patches are less than 6 feet in length, while joint and crack repair patches are longer than 6 feet in length. In both repair types, concrete is removed by milling or cutting-and-chipping to a minimum width of 12 inches, and a minimum depth of 2 inches. The depth of the repair may not exceed one-half of the pavement thickness unless unsound concrete remains within the patch area. In this case, the Engineer may designate part of the patch area as an "overdepth patch," which extends to the full depth of the concrete. If an overdepth patch is

designated, the subgrade or subbase material must be compacted after removal of the concrete and No. 4 tie bars installed at mid-depth of the existing pavement.

Prior to placing the patch material, secondary spalling resulting from the concrete removal process is chipped out, and the patch area is cleaned, first by sandblasting, then with compressed air. A joint or crack is re-created in the patch area using a joint board extending the full depth of the patch. A cementitious grout mixture consisting of two-parts portland cement and one-part sand and water is applied to the surfaces of the patch area, then the patch material is placed, consolidated, and worked into place before the grout dries. The surface of the patch is leveled to the adjacent pavement and checked with a 10-foot straightedge before curing. Class A patching materials are cured according to the manufacturer's specifications; Class B mixtures are cured with insulating blankets for 5 hours, as specified in Section 2529; and Class C mixtures are cured with a white pigmented curing compound for a minimum of 36 hours, or as directed by the Engineer. Joints and cracks extending into the patch area are sealed and cleaned within 5 working days after the patch is placed.

2.2. Other Midwest DOT Specifications

2.2.1. Illinois

Concrete pavement repair in Illinois is specified under Section 442, "Pavement Patching", of the *Illinois DOT Standard Specifications for Road and Bridge Construction* [12], and additional information and guidance is provided in Chapter 53, "Pavement Rehabilitation" of the *Illinois Bureau of Design and Environment Manual* [13]. The Illinois DOT categorizes repairs by class and size, as described in Table 2.3. Class A patches are used for full-depth repairs of continuously reinforced concrete pavements. Class B repairs are preferred for full-depth repairs of jointed concrete pavements with sound concrete, while Class C repairs are recommended for full-depth repairs of jointed concrete pavements only if the concrete is unsound enough to preclude the use of a Class B repair. Class C and D (hot-mix asphalt) repairs are used for partial-depth patches. The minimum full-depth repair dimensions are 6 ft length and full lane width, and the minimum distance between patches is 6 ft. Partial depth repairs are a minimum of 1 ft by 1 ft in area.

Table 2.3. Illinois DOT Pavement Patch Classes and Types

Class	Description
A	Full-depth repair for continuously reinforced PCC pavement
B	Full-depth doweled patches for jointed concrete pavements
C	Full- and partial-depth undoweled PCC patches for jointed concrete pavements
D	Full- and partial-depth undoweled HMA patches for jointed concrete pavements

Type	Description
I	Less than 5 yd^2 (5 m^2)
II	5 yd^2 (5 m^2) or more, but less than 15 yd^2 (15 m^2)
III	15 yd^2 (15 m^2) or more, but less than 25 yd^2 (20 m^2)
IV	25 yd^2 (20 m^2) or more

The *Standard Specifications* list permissible materials for Class A, B, C, and D patches and detail procedures for concrete removal, reinforcement and dowel placement, form and bond breaker placement, placement and consolidation of the repair concrete, finishing and curing of the repair surfaces, and sealing of joints. Requirements for concrete patch materials, as defined in Article 1020, *Portland Cement Concrete*, are summarized in Table 2.4. High early-strength patching mixes based on either portland cement or calcium aluminate cement (Class PP-3, 4, or 5, as indicated in Table 2.4) are typically specified for Class A and Class B patches. Chloride-containing accelerators are not permitted for any mixtures. Opening to traffic is based on minimum flexural strength (600 psi, min. PP-1; 250 psi, min., all others) and compressive strength (3200 psi, min. PP-1; 1600 psi, min. all others). With approval of the Engineer, strength may be determined by the maturity method.

Table 2.4. Illinois DOT Pavement Repair Concrete Mixture Proportions and Properties

Class	Cement Type	Cement Factor, lb/yd^3	w/cm	Slump, inches	Air Content, %	Compressive Strength, psi	Flexural Strength, psi
PP-1	Type I, II, V Type III	650-750 620-720	0.32-0.44	2-4	4-7	3200 at 48 hr	600 at 48 hr
PP-2	Type I, II, III, V	735	0.32-0.38	2-6	4-6	3200 at 24 hr	600 at 24 hr
PP-3	Type III + 100 lb/yd^3 slag + 50 lb/yd^3 silica fume	735	0.32-0.35	2-4	4-6	3200 at 16 hr	600 at 16 hr
PP-4	Rapid hardening cement	600-625	0.32-0.50	2-6	4-6	3200 at 8 hr	600 at 8 hr
PP-5	Calcium aluminate cement	675	0.32-0.40	2-8	4-6	3200 at 4 hr	600 at 4 hr

2.2.2. Indiana

Concrete pavement repair in Indiana is specified in Section 506, "PCCP Patching," of the *Indiana DOT Standard Specifications* [14]. PCC pavement patches are produced with portland cement concrete having a minimum cement content of 658 lb/yd^3 and maximum w/c of 0.45. High early strength cement is recommended. Calcium chloride accelerators are also permitted at a dosage not exceeding 2% by weight of cement, unless the air temperature is greater than 80°F, in which case the calcium chloride may not exceed 1% by weight of cement.

The concrete patch material must have a minimum slump of 2 inches, an air content of 5 to 8%, and a minimum flexural strength of 300 psi at 24 hours and 500 psi at 3 days. Performance of concrete mixtures must be demonstrated through trial batching.

The *Standard Specifications* list requirements for concrete removal, mixing, placement, consolidation, curing, and sealing of joints. Limited guidance is provided regarding the size of the repair area: full-depth repairs are specified across the full width of the lane, while partial-depth repairs are specified to a depth of 1 to 3 inches. Opening to traffic is based on ambient temperature if calcium chloride accelerator is used and based on flexural strength (300 psi, min.) if calcium chloride is not used.

2.2.3. Kansas

Concrete pavement repair for Kansas is specified in the *Kansas DOT Standard Specifications* [15], Section 833 "Pavement Patching." Full-depth repairs are used for repair of full-depth deterioration at joints and cracks, honeycombed pavement edges, and full-depth deterioration of transverse and longitudinal joints. Partial-depth repairs are used for repair of longitudinal joints or pavement edges with shallow spalls or honeycombing in the upper half of the pavement, or for repair of joint spalls, mid-panel cracks, and interior surface spalls. Asphalt pavement patching is permitted as a temporary repair.

Permissible patching materials for long-term repairs include air-entrained concrete (as defined in Sections 401 and 403) and rapid-setting concrete patching material (as defined in Section 1716). Calcium chloride may be used to accelerate setting and early-age strength development. The concrete and repair material specifications are largely performance-based, with requirements related to freeze-thaw durability and chloride penetration resistance. Requirements for the air-entrained concrete and rapid-setting concrete patch materials are summarized in Table 2.5.

Table 2.5. Kansas DOT Pavement Repair Material Performance Requirement

Repair Material	Material Requirements	Performance Requirements
Air-Entrained Concrete	**Cement**: 517 lb/yd^3, min. Type IP, IS, IT, IL, or II Type III for high early strength **w/cm**: 0.45, max. **Admixtures**: Calcium chloride accelerator permissible	**Slump**: ≤ 5 inches **Air**: 5-8% + air void spacing factor ≤ 0.0100 in. **Compressive strength**: ≥ 4000 psi (28 days) **Volume of permeable voids**: ≤ 12.5% **Surface resistivity**: ≥ 9.0 kOhm-cm (28 days)* **Rapid chloride permeability**: ≤ 3000 Coulombs (28 or 56 days)*
Rapid-Set Concrete Patching Material	Complies with ASTM C928	**Freeze-thaw resistance**: < 0.10% expansion and ≥ 90.0% durability factor, ASTM C666, Method B

** Required only if existing pavement is less than 10 years old.*

The *Standard Specifications* detail requirements for pavement removal, surface preparation, concrete placement, consolidation, finishing, curing, and jointing for each type of full-depth or partial-depth repair. Guidance for determining the limits of pavement removal is provided for both full-depth and partial-depth repairs. Opening to traffic is based on flexural strength (380 psi, min.) or compressive strength (1800 psi, min.), with the option to base opening on Schmidt rebound hammer testing or concrete maturity. If rebound hammer or maturity testing is used to determine opening to traffic, previous correlations to concrete flexural and/or compressive strength from laboratory testing are required.

2.2.4. Michigan

Full-depth pavement repairs in Michigan are specified in *Michigan DOT Standard Specifications* [16], Section 603 "Concrete Pavement Restoration." Partial-depth repairs are not included in the standard specifications; however, repairs of spalls with an epoxy mortar or a cementitious mortar are included in Section 602.03.P, "Concrete Pavement Construction", and Section 603.03.B implies that hot mix asphalt is also used for partial-depth repairs. Additional partial-depth concrete repair specifications using non-cementitious patch materials and have been included in project-specific special provisions.

Materials for full-depth repairs include three different grades of portland cement concrete. Grades P1 and P1M concrete are used for pavement repairs that open to traffic three or more days after casting, while Grade P-NC concrete is used for pavement repairs that open to traffic within 72 hours of casting. Calcium chloride accelerators are not permitted, but other, non-chloride accelerators may be used for P-NC concretes. Grade P-NC concrete using a non-chloride set accelerator is preferred for patching. Requirements for the three grades of concrete are summarized in Table 2.6.

Table 2.6. Michigan DOT Full-Depth Repair Concrete Requirements

Concrete Grade	Cement Content, lb/yd³	Min. Flexural Strength, psi	Min. Compressive Strength, psi
P1	564 526 (with water reducing admixture)	550 psi at 7 days 600 psi at 14 days 650 psi at 28 days	2,600 psi at 7 days 3,000 psi at 14 days 3,500 psi at 28 days
P1M	470-564		
P-NC	658	550 psi at 3 days 600 psi at 7 days 650 psi at 28 days	2,600 psi at 3 days 3,000 psi at 7 days 3,500 psi at 28 days

The *Standard Specifications* include requirements for removing the existing pavement; preparing the base or subbase; constructing joints; placing, consolidating, and finishing the concrete repair; cleaning, sawing, and sealing joints; and opening to traffic. The electronic *Michigan DOT Construction Manual* [17] provides additional clarification and guidance on all procedures. Opening to traffic is based on flexural strength (300 psi for Grade P-NC concrete; 550 psi for Grades P1 and P1M concrete); compressive strength testing is not required for opening the repairs to traffic. Maturity methods may be used to determine the in-place flexural strength for opening the repairs to traffic.

2.2.5. Minnesota

Pavement repair is specified in Minnesota DOT (MnDOT) Special Provision 2302 "Concrete Pavement Rehabilitation" of the MnDOT *Standard Specifications* [18, 19]. Repairs are classified as Type A, joint or crack sealing; Type B, partial depth repairs; or Type C, full depth repairs. Each repair type is further subdivided based on the size and location of the repair and/or the anticipated traffic volume. Guidance regarding selection and installation of repairs is provided in Chapter 9 of the *Concrete Manual* [20]; however, this document is based on previous versions of the pavement rehabilitation specification and may not fully reflect current MnDOT practices.

All full-depth and partial-depth repairs are made with air-entrained portland cement concrete with optimized gradations of fine and coarse aggregates. Full-depth repairs are constructed with portland cement concrete meeting the requirements of Mix 3R52 or 3RHE52, as summarized in Table 2.7, while partial-depth repairs are constructed with portland cement concrete meeting the requirements of Mix 3U18. Mix 3U18 concrete is typically pre-bagged for on-site batching and has the proportions listed in Table 2.8. Air entraining admixtures are used with all three concrete mixtures to achieve a target air content of 5 to 8 percent. Accelerating or water reducing admixtures may be added to any of the mixtures to achieve 3,000 psi minimum compressive strength or 500 psi flexural strength at the time of opening; however, accelerating admixtures may only be used with the approval of the Engineer and may not be used if the ambient air temperature exceeds 80 °F. No concrete placement is allowed after October 15th without the Engineer's

approval, and further, partial-depth repairs may not be placed when the air temperature or in-place concrete temperatures are less than 50 °F.

Table 2.7. MnDOT Full-Depth Repair Mix Requirements

Mix	Max. w/c	Max. cementitious content, lb/yd^3	Slump, inches	Max. SCM content	Min. 28-day Compressive Strength
3R52	0.45	750	2-5	Fly ash: 30% Slag: 35% Combination: 40%	4000 psi
3RHE52	0.42	750	2-5	Fly ash: 30% Slag: 35% Combination: 40%	4000 psi

Table 2.8. MnDOT 3U18 Partial-Depth Repair Mixture Proportions, per 100 lb of cement

Mix	Type I Cement	Coarse Aggregate (#89 or CA-80)	Fine Aggregate	Water
3U18	100 lb	159 lb	162 lb	Sufficient to achieve slump of 1 inch after 5 min. of batching

The MnDOT Special Provisions include requirements for removing the existing concrete; preparing the surface(s) to receive the repair (including grade restoration and compaction for full-depth repairs); placement, finishing, and curing of the repair concrete (including re-establishing longitudinal and transverse joints and cracks); and opening to traffic. Failure to comply with the curing requirements results in a monetary deduction for the concrete in question. The age of opening is based on the concrete type, admixture types and dosages, ambient temperatures, and compressive and flexural strength. A minimum of 12 hours of curing is required for all pavement repairs. For full-depth repairs, strength must be verified with control specimens for any pavement opening within 7 days of placement, and for partial-depth repairs, strength must be verified for any pavement opening within 72 hours of placement. In both cases, control specimens must achieve a minimum compressive strength of 3,000 psi or 500 psi flexural strength prior to opening.

2.2.6. Missouri

Pavement repairs are specified in *Missouri DOT Standard Specifications* [21], Section 613 "Pavement Repair." An electronic *Engineering Policy Guide* [22] is also available through the Missouri DOT to provide interpretation of the specifications and recommendations for practice. The Missouri DOT pavement repair specification covers full-depth concrete repairs for locations where joints have failed; Class A partial-depth concrete repairs for locations where joints are structurally sound but spalled or locally delaminated at the surface or near joints, cracks, or edges; Class B partial-depth bituminous repairs for locations where joints are structurally sound but spalled or locally delaminated near the surface and where resurfacing in excess of 3 inches will be performed; and Class C partial depth repairs for asphalt pavements. Class B and C repairs are not considered to be within the scope of this document.

For full-depth repairs, air-entrained portland cement pavement concrete is specified. This mixture consists of a minimum 560 pounds per cubic yard of cementitious material, with a maximum water-cementitious materials ratio (w/cm) of 0.50. Type III cement, calcium chloride accelerator, and other chemical admixtures are permissible with approval of the Engineer. The *Engineering Policy Guide* recommends a 7-bag (658 pounds per cubic yard) mixture using Type I cement with 2% calcium chloride accelerator to enable opening to traffic within 6 hours of placement.

For partial-depth Class A repairs, portland cement concrete, elastomeric concrete, or epoxy mortars are permissible. Epoxy mortars are not permitted to repair spalls caused by reinforcing steel corrosion. The portland cement concrete is similar to that used for full-depth repairs, except that there are additional requirements for aggregate gradations.

The Pavement Repair specification and the *Engineering Policy Guide* include provisions for determining the repair area; removing existing concrete and preparing the concrete surface to receive the repair; re-establishing joints and cracks; placing the repair material (including application of a suitable bonding material for partial-depth repairs); finishing and texturing; sealing and curing of the repair area; and opening to traffic. Full-depth repairs may not be opened to traffic until the compressive strength of the concrete is at least 2,000 psi, as verified by compressive strength cylinders, the maturity method, or rebound hammer (minimum rebound ratio number of 60). Partial-depth repairs may be opened to traffic once the patch material has attained a minimum compressive strength of 1,600 psi but may not be opened until at least two hours after placement or as recommended by the manufacturer.

2.2.7. Nebraska

Concrete pavement repair is specified in Section 605 "Concrete Pavement Repair" of the *Nebraska DOT Standard Specifications for Highway Construction* [23]. Repairs are classified based on surface area, with Type A repairs having a surface area less than 5 square yards, Type B repairs having surface areas between 5 and 15 square yards, and Type C repairs having surface areas greater than 15 square yards. Requirements for both full-depth and partial-depth repairs are provided.

Portland cement concrete (Mix PR1-3500 or PR3-3500) and blended cement concrete (Mix 47B-3500 or 47B-HE-3500) are the only materials permitted for concrete pavement repairs. The proportions for these mixtures are summarized in Table 2.9. Mixes 47B-3500 and 47B-HE-3500 have extended curing periods and are only permitted if the contract allows for lane closures or detours to accommodate curing. Type III cement mixes (PR3-3500) are typically used when the pavement must be open to traffic within 24 hours.

Table 2.9. Nebraska DOT Concrete Pavement Repair Materials

Mix Designation	Cement Type	Total Cementitious (pcy)	Total Aggregate (pcy)	Max. w/cm	Air (%)	Accelerator
PR1-3500	I/II	752	2,500-2,950	0.36	6.0-8.5	Calcium chloride
PR3-3500	III	799	2,500-2,950	0.45	6.0-8.5	
47B-3500	IP/IT	564	2,850-3,150	0.45	6.0-8.5	Non-calcium chloride (only use if air temp. <70 °F)
47B-HE-3500	IP/IT	752	2,850-3,150	0.40	6.0-8.5	

The concrete pavement repair specification covers repair area determination; concrete removal and subgrade repair; surface preparation; mixing, placement, consolidation, and finishing of the concrete; curing; cleaning and sealing of joints; and opening to traffic. Repaired areas may be opened to traffic once the concrete has achieved a minimum compressive strength of 3,500 psi, as determined by maturity method or testing of concrete cylinders. Guidance provided in the specification indicates that Class PR1-3500 and PR3-3500 mixes may achieve minimum opening strengths in 4 to 8 hours, while Class 47B-3500 mixes may achieve minimum opening strengths in 48 to 72 hours.

2.2.8. North Dakota

Concrete pavement repair is specified in Section 570 of the *North Dakota DOT Standard Specifications for Road and Bridge Construction* [24]. For full-depth repairs, Class AAE portland cement concrete using Type I or IA cement[1] is specified. For partial-depth repairs (referred to in the specification as "spall repairs"), Class AE portland cement concrete using Type I or IA cement is used. Requirements for these mixtures are given in Table 2.10. Fly ash may be used in either class of concrete as a replacement of cement at up to 29 percent by weight.

Table 2.10. North Dakota DOT Repair Concrete Material Requirements

Class	Cement Type	Cement Content (pcy)	Max. w/cm	Slump (in.)	Air (%)
AAE	I or IA[1]	600-650[2]	0.44	1-4 for formed pavements 0-2 for slip-formed pavements	5-8
AE	I or IA[1]	550-600[2]	0.47	1-4 for formed pavements 0-2 for slip-formed pavements	5-8

Notes: [1] May substitute Type III or IIIA cement to achieve high early strength.

[2] May increase cement content to 650-750 pcy to achieve high early strength.

Construction requirements for concrete repairs are detailed in Section 570.04 in the *Standard Specifications*. Requirements include removal of deteriorated concrete, surface preparation (for partial-depth repairs), and joint sealing (for full-depth repairs). Provisions for placement, consolidation, finishing, and curing of the full-depth repairs and opening to traffic are found in the general "Concrete Pavement" specification, Section 550.04. Provisions for placement, consolidation, finishing, and curing of partial-depth repairs are explicitly referenced in the specification. Full-depth repairs may be opened to traffic after joints have been sealed and concrete has achieved a minimum compressive strength of 3,000 psi, or minimum flexural strength of 450 psi. Maturity method may be used to confirm that minimum strengths for opening are met.

2.2.9. Ohio

Concrete pavement repair is specified in Section 250 (Items 251 through 258) of the *Ohio DOT Construction and Materials Specifications (CMS)* [25]. Full- and partial-depth repairs of portland cement concrete pavements with rigid repair materials are covered in Items 255 and 256, respectively. Additional guidance regarding full- and partial-depth pavement repairs is provided in Section 504.3 of the *Pavement Design*

[1] Type IA cement is an air-entrained Type I cement.

Manual (PDM) [26]. Both full-depth and partial-depth asphalt concrete repairs are permitted in the *CMS* but are not recommended by the *PDM* in most cases and are not considered within the scope of this document.

Four classes of concrete are permitted for full-depth, rigid pavement repairs, as outlined in Table 2.11. These include three classes of portland cement concrete (QC 1, QC MS, and QC FS), and one class of rapid repair concrete mix (RRCM). Class QC FS concrete may be produced with calcium chloride accelerating admixtures. The *PDM* notes that use of Class QC MS and QC FS concrete often results in problems related to rapid and significant early-age shrinkage due to the high cementitious materials contents, and RRCM is the preferred alternative when early opening times are required. Approved RRCM materials listed in the CMS include the BASF 4x4 Concrete System, Sika Rapid-1 Concrete System, or other manufactured systems acceptable to the director. In addition to flexural strength testing, maturity testing is also required for RRCM mixtures.

Table 2.11. Ohio DOT Full-Depth Repair Concrete Material Requirements

Class	Design Strength	Opening Time	Max. Coulombs by AASHTO T277	Min. Cementititous (pcy)	Aggregates	Air (%)
QC 1	4000 psi comp. at 28 days	3 to 7 days	2000	520	Well-graded	5 to 9
QC MS	400 psi flex. in 24 hours	24 to 48 hours	N/A	800	1-inch nominal MSA	5 to 9
QC FS	400 psi flex. in 4 hours	4 to 8 hours	N/A	900	1-inch nominal MSA	5 to 9
RRCM	400 psi flex. in 4 to 6 hours	4 to 6 hours	N/A	Not specified	Not specified	4 to 8

Three types of materials are permitted for partial-depth repair:

- Type A patch material consists of high early strength portland cement, fine aggregate, and coarse aggregate at 1:1.5:1.5 ratio by volume; sufficient air entraining admixture to achieve 6 to 10% air; and sufficient water to achieve a maximum slump of 4 inches. Type A material is batched on site.
- Type B patch material consists of a quick setting, pre-packaged concrete mortar (Type 1 or 2, as specified by Section 705.21), with coarse aggregate as needed. Material is batched on site according to the manufacturer's instructions. Type 1 materials have a specified minimum compressive strength of 100 psi at 1 hour and 1,000 psi at 24 hours, and a minimum flexural strength of 650 psi at 3 days. Type 2 materials have a specified minimum compressive strength of 2,000 psi at 1 hour and 3,500 psi at 24 hours, and a minimum flexural strength of 200 psi at 4 hours and 500 psi at 3 days.
- Type C patch material consists of quick setting, pre-packaged concrete mortar (Type 2, as specified by Section 705.21), selected aggregates, and an activator. Material is batched on site according to the manufacturer's instructions and has a specified minimum compressive strength of 2,000 psi at 1 hour and 3,500 psi at 24 hours, and minimum flexural strength of 200 psi at 4 hours and 500 psi at 3 days.

Additional performance requirements for the Type B and C mortars are specified in Section 705.21 of the *CMC*; these include initial set time, bond strength, freeze-thaw resistance, and long-term performance after 3 years.

Details on construction of full-depth and partial-depth repairs are specified in Section 255 and 256, respectively, of the CMC. These include requirements for removal of unsound concrete; repairing subgrade

and subbase, or preparing the concrete surfaces, as applicable; placing, consolidating, finishing, and curing the repair materials; and opening to traffic. Opening to traffic for full-depth patches and Type A partial-depth patches is based on a minimum flexural strength (modulus of rupture) of 400 psi. Opening to traffic for Type B and C partial-depth patches is based on manufacturer recommendations.

2.2.10. South Dakota

The *South Dakota DOT Standard Specifications for Roads and Bridges* [27] only includes provisions for partial-depth pavement repairs. Partial-depth repairs are discussed in Section 390, "Concrete Spall Repair". Full-depth repairs are discussed in Chapter 9, "Pavement Repair," of the *South Dakota DOT Concrete Paving Manual (CPM)* [28], but are not included in the standard specifications.

Portland cement concrete repair materials, modified from the standard pavement mixtures defined in Section 380, are specified in the *CPM* for full-depth repairs. "Fast Track Concrete" is specified for two-lane roadway repair locations, where opening to traffic is required within 8 hours of concrete placement. General requirements for full-depth concrete repair materials are listed in Table 2.12. Chloride-containing admixtures, including calcium chloride accelerators, are not permitted.

Table 2.12. South Dakota DOT Full-Depth Repair Material Requirements

Mix	Cementitious Materials	Aggregates	Slump	Air	Compressive Strength
Portland cement concrete	Type I or II cement, 650 pcy, min. or Type III cement, 600 pcy, min.	Size No. 1 coarse aggregate, 50% by weight of concrete	3 in., max., after addition of water reducer	4.5-7.0%	4,000 psi at 28 days
Fast-track concrete	Type I or II cement, 700 pcy, min. or Type III cement, 650 pcy, min.	Size No. 1 coarse aggregate, 50% by weight of concrete	2 in., max., prior to addition of water reducer or set accelerator 8 in., max. after addition	4.5-7.5%	3,800 psi at 8 hr 4,000 psi at 28 days

Permissible materials for partial-depth pavement repairs are classified as Type I, Type II, and Type III materials. Type I and II materials are pre-packaged, dry, rapid-hardening mortars and concretes, respectively; and Type III materials are pre-packaged, dry, air-entrained concrete meeting the MnDOT 3U18 designation. Repair materials may not contain chloride ions. Magnesium or phosphate-based products are not permitted.

Construction procedures for full-depth repairs are specified in Chapter 9 of the *CPM* and for spall repairs in Section 390 of the Standard Specifications. Provisions for full-depth repairs include concrete removal; re-establishing of joints; finishing and curing of concrete surfaces; and opening to traffic. It is assumed that South Dakota DOT intends for concrete mixing, handling, placement, and consolidation; and joint sealing to be performed as specified in Section 380, "Portland Cement Concrete Pavement." Provisions for partial-depth spall repairs include removal of the deteriorated concrete, preparing the concrete surface, re-establishing joints, finishing and curing the repair material, sawing and sealing joints, and opening to traffic. Partial-depth repair materials are mixed and placed according to the manufacturer's instructions. Repaired

areas may be opened to traffic once the concrete has obtained 4,000 psi for full-depth repairs, 3,800 psi for fast-track full-depth repairs, and 3,000 psi for partial-depth repairs.

2.2.11. Wisconsin

Full-depth pavement repair is specified in the *Wisconsin DOT Standard Specifications for Highway and Structure Construction* [29] under Section 416, "Concrete Pavement - Appurtenant Construction." Partial-depth pavement repairs, including joint repair, crack repair, surface repair, and edge repair, are covered by a standard special provision, STP 416-015 [30].

Both full-depth and partial-depth pavement repairs are constructed using portland cement concrete. Seven grades of pavement concrete, and one grade of special high early strength (SHES) pavement concrete are permitted for full-depth repairs, and a single grade of concrete is permitted for partial-depth repairs. General mixture proportions are summarized in Table 2.13. The special high-early strength concrete is specified to be produced with calcium chloride accelerator; non-chloride accelerator is specified for the other grades of concrete.

Table 2.13. WisDOT Concrete Repair Materials

Grade	Cementitious Materials	Total Aggregate	Design w/cm
C	660 pcy Type I, II, or III cement	2980 pcy, 30-40% fine agg.	0.38
C-FA	560 pcy Type I, II, or III cement + 100 pcy Class C fly ash	2960 pcy, 30-40% fine agg.	0.38
C-S	560 pcy Type I, II, or III cement + 100 pcy Grade 120 slag	2970 pcy, 30-40% fine agg.	0.38
C-IL	660 pcy Type IL cement (max. 10% limestone)	2970 pcy, 30-40% fine agg.	0.38
C-IS	660 pcy Type IS cement (max. 30% slag)	2970 pcy, 30-40% fine agg.	0.38
C-IP	660 pcy Type IP cement (max. 30% pozzolan)	2950 pcy, 30-40% fine agg.	0.38
C-IT	660 pcy Type IT cement (max. 10% limestone, 30% pozzolan + slag)	2970 pcy, 30-40% fine agg.	0.38
SHES[1]	846 pcy total cementitious material	Not specified	Not specified
Partial-depth repair	850 pcy Type I or Type III cement	2676 pcy, 50% fine agg.	Not specified

Notes: [1]Must achieve 3,000 psi compressive strength within 8 hours of placement.

The *Standard Specifications* and *Special Provisions* detail repair procedures including concrete removal; repair area preparation; re-establishing cracks and joints (for partial-depth repairs only); concrete placement, finishing, and curing; and cleaning joints and cracks after sawing (for partial-depth repairs only). Minimum criteria for opening to traffic are not provided.

2.3. Summary of DOT Practices

Materials for full-depth and partial-depth repairs currently specified by Midwest DOTs are summarized in Table 2.14 and Table 2.15, respectively. For full depth repairs, all twelve state DOTs specify portland cement

concrete, and most allow or specify the use of calcium chloride accelerator (except for Illinois, Michigan, and South Dakota). Three states (Illinois, Kansas, and Ohio) permit the use of pre-packaged proprietary repair materials, and one state (Illinois) permits calcium aluminate cement concrete.

For partial-depth repairs, eleven state DOTs specify portland cement concrete, and most allow or specify the use of calcium chloride accelerator. Proprietary materials are permitted by six state DOTs including Iowa, Illinois, Kansas, Michigan, Ohio, and South Dakota, and polymeric materials (polymer concrete or epoxy) are permitted by Missouri and local jurisdictions in Nebraska (e.g., City of Lincoln). Asphalt is specified or permitted by six state DOTs, including Illinois, Indiana, Kansas, Michigan, Missouri, and Ohio.

Procedures for full-depth and partial-depth repairs currently specified by Midwest DOTs are summarized in Table 2.16 and Table 2.17, respectively. Most states specify placement, consolidation, and curing methods or both full- and partial-depth repairs; however, this guidance is sometimes found in the main portland cement concrete pavement (PCCP) specification, rather than in the repair specification. About half of the states define surface preparation methods and joint-sealing procedures, and one-third of the states include provisions for sealing cracks. Only four states provide guidance on defining the repair boundaries within their standard specifications (all for partial-depth repairs); in most states, defining the repair boundaries is typically left to the discretion of the Engineer.

Table 2.14. Specified Repair Materials - Full-Depth Repairs of PCC Pavements

State	Portland Cement Concrete	Calcium Aluminate Cement	Epoxy Mixtures	Polymer Concrete	Proprietary Materials	Bituminous Materials
Iowa	**x[1]**					
Illinois	x[2]	x			x	x
Indiana	x[1]					
Kansas	x[1]				x[4]	x
Michigan	x[2]					
Minnesota	x[3]					
Missouri	x[1]					
Nebraska	x[1]					
North Dakota	x[3]					
Ohio	x[1]				x[5]	x
South Dakota	x[2]					
Wisconsin	x[1]					
Total	**12**	**1**	**0**	**0**	**3**	**3**

*Notes: [1] Calcium chloride accelerator **permitted**.*

*[2] Calcium chloride accelerator **not permitted**.*

*[3] Restrictions on use of calcium chloride accelerator **not specified**.*

[4] Rapid Set

[5] Master Builders; SIKA

Table 2.15. Specified Repair Materials - Partial-Depth Repairs of PCC Pavements

State	Portland Cement Concrete	Calcium Aluminate Cement	Epoxy Mixtures	Polymer Concrete	Proprietary Materials	Bituminous Materials
Iowa	**x[1]**				**x**	
Illinois	x[2]	x			x	x
Indiana	x[1]					x
Kansas	x[1]				x	x
Michigan			x		x	x
Minnesota	x[3]					
Missouri	x[1]		x	x		x
Nebraska	x[1]			--[4]		
North Dakota	x[3]					
Ohio	x[2]				x	x
South Dakota	x[2,5]				x	
Wisconsin	x[2]					
Total	**11**	**1**	**2**	**2**	**6**	**6**

*Notes: [1] Calcium chloride accelerator **permitted**.*

*[2] Calcium chloride accelerator **not permitted**.*

*[3] Restrictions on use of calcium chloride accelerator **not specified**.*

[4] Flexible polymer modified concrete specified by local jurisdictions.

[5] 3U18 mixture.

Table 2.16. Specified Repair Procedures - Full-Depth Repairs of PCC Pavements

State	Boundary Determination	Surface Preparation	Placement	Consolidation	Curing	Sealing Cracks	Sealing Joints
Iowa		**x**	**x**	**x**	**x**		**x**
Illinois			x	x	x		x
Indiana			x	x	x	x[1]	x[1]
Kansas		x	x	x	x		x
Michigan		x	x	x	x	x	x
Minnesota		x	x	x	x	x	x
Missouri			x[1]	x[1]	x[1]		x
Nebraska		x	--[2]	x	x		
North Dakota			x[1]	x[1]	x[1]	x[1]	x
Ohio		x	x	x	x		
South Dakota		x[3]	x[3]	x[3]	x		x[3]
Wisconsin		x	x	x	x[1]		
Total	**0**	**8**	**12**	**12**	**12**	**4**	**9**

Notes: [1] References main PCCP specification.

[2] As directed by contractor.

[3] Assumed to follow main PCCP specification.

Table 2.17. Specified Repair Procedures - Partial-Depth Repairs of PCC Pavements

State	Boundary Determination	Surface Preparation	Placement	Consolidation	Curing	Sealing Cracks	Sealing Joints
Iowa		**x**	**x**	**x**	**x**	**x**	**x**
Illinois			x	x	x		x
Indiana		x	x	x	x	x[1]	x[1]
Kansas	x	x	x	x	x		x
Michigan	x[3]	x[3]	x[3]	x[3]	x[3]		x[3]
Minnesota		x	x	x	x	x	x
Missouri	x	x	x	x	x		
Nebraska	x	x	--[2]	x	x		x
North Dakota[3]		x					
Ohio		x	x	x	x		
South Dakota[3]		x	x	x	x		x
Wisconsin		x	x	x	x	x	x
Total	**4**	**11**	**11**	**11**	**11**	**4**	**9**

Notes: [1] References main PCCP specification.

[2] As directed by contractor.

[3] Partial-depth repair specification only considers spall repairs.

3. SURVEY OF STATE PRACTICES

The project team conducted a survey of Midwest state DOTs and road/highway agencies to gather information regarding currently used materials and procedures for partial and full depth repairs for concrete roadways. The survey was distributed to state and selected county/district engineers in the following states: Iowa, Illinois, Indiana, Wisconsin, Minnesota, Michigan, Ohio, Nebraska, Missouri, North Dakota, South Dakota, and Kansas. In total, thirty-four responses were received. This chapter provides a summary of the results. Detailed responses are provided in Appendix A.

3.1. Materials

3.1.1. Full-Depth Repairs

A summary of the survey results for materials used for full-depth repairs is shown in Figure 3.1. The results show that the most used materials for full-depth repairs are normal and high early strength portland cement concrete mixes. Unlike partial-depth repairs, asphalt materials are only used by thirteen agencies for full-depth repairs compared to the twenty-eight reported for partial-depth repairs. The use of other rapid setting concrete mixes, such as calcium aluminate and calcium sulfoaluminate cements, was reported by seven agencies while no agencies use epoxy or polymer materials for full-depth repairs.

Limited use of proprietary materials was reported for full-depth repairs where only **TechCrete™** by Crafco and **Rapid Set** by CTS are being used for this purpose. The use of precast concrete panels was also reported by Illinois DOT.

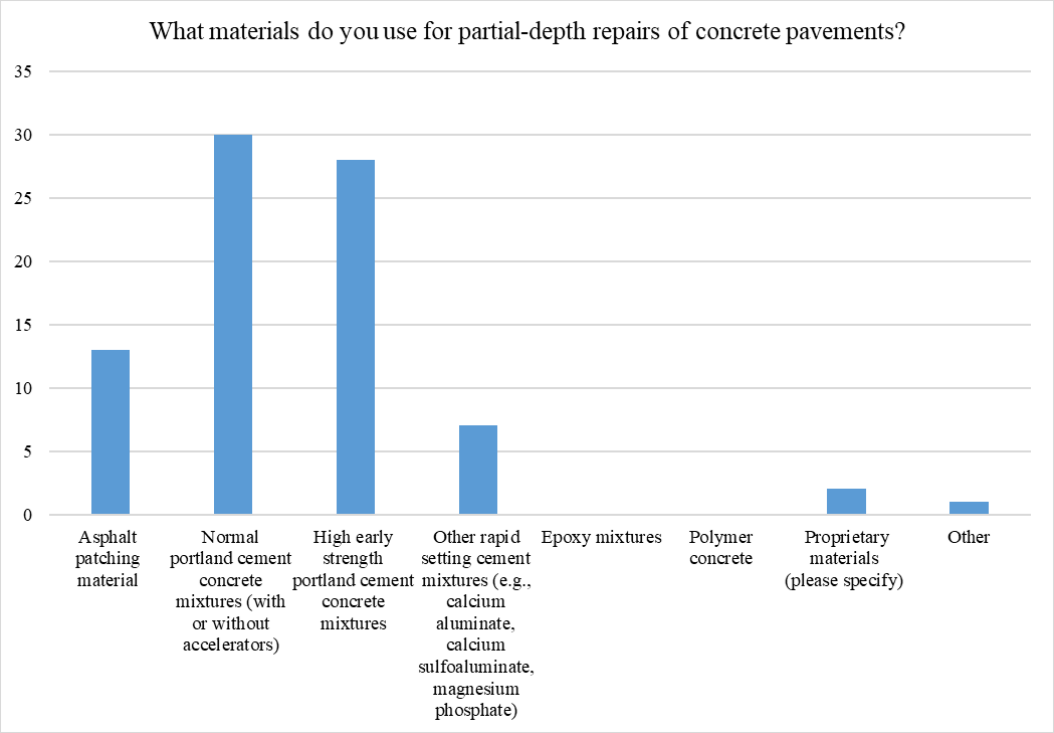

Figure 3.1. Summary of survey results for materials used for full-depth repairs.

3.1.2. Partial-Depth Repairs

The survey indicated that a wide variety of materials are used for partial-depth repairs across the states and counties/districts. One observation is that there is some variability in the used materials within the same state. A summary of the survey results for materials used for partial-depth repairs is shown in Figure 3.. The results show that the most used material for partial-depth repairs is asphalt, followed by normal and high early strength portland cement concrete mixes. Epoxy and polymer based concrete mixes were reported for use by less than five respondents each. It is noted that other rapid setting concrete mixes, such as calcium aluminate and calcium sulfoaluminate cements, are rarely used for partial-depth repairs.

Use of proprietary materials for partial-depth repairs was reported by twelve respondents (two of the other category indicated proprietary materials). The products used, as reported by agencies, are: **TechCreteTM** by Crafco, **Mastic One** by Crafco, **Fibrecrete** by Fibrecrete Preservation Tech., **Aqua Patch** by Tensar; **FlexKRETE** by FlexKRETE Technologies, **PolyPatch** by Crafco, **FUTURA-15** by W R Meadows, and **Rapid Set** by CTS.

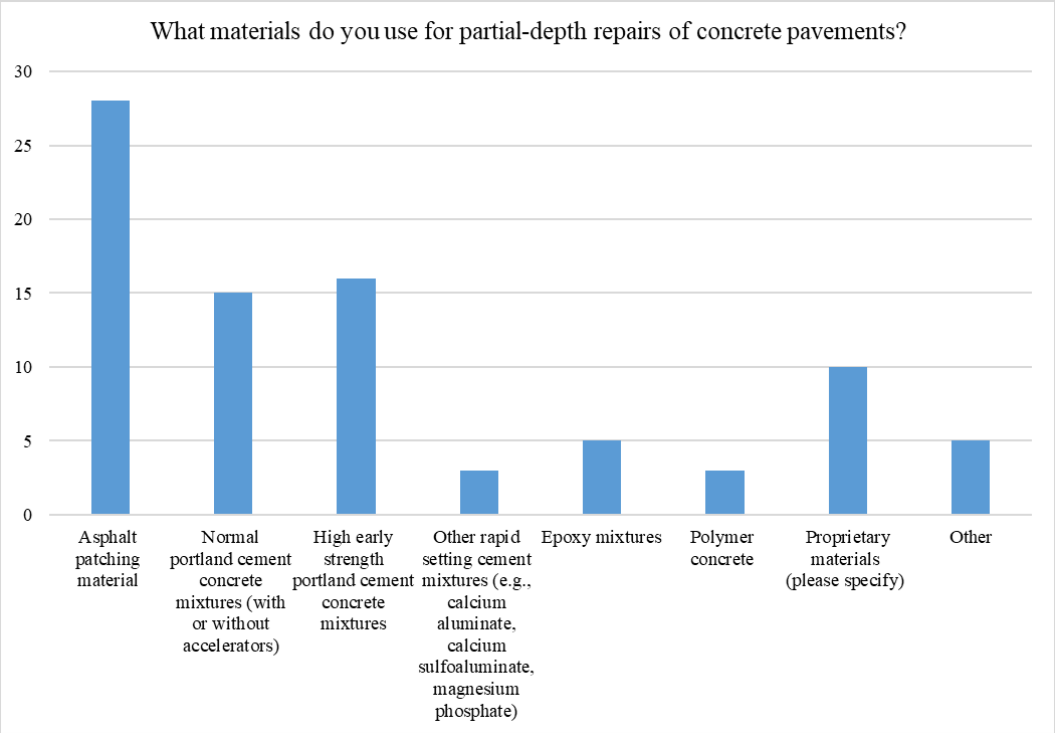

Figure 3.2. Summary of survey results for materials used for partial-depth repairs.

3.2. Agencies Experience with Proprietary Materials

The survey results indicated that for the majority of respondents (17 out of 34), the use of proprietary materials is allowed but they are not typically used, while 12 respondents indicated that they do not currently use these materials. Only three respondents indicated that proprietary materials are regularly used for pavement repairs.

In terms of the effectiveness of the repair materials in meeting the expectations of users, ten respondents indicated that they meet most of the expectations while one respondent indicated that they meet all expectations. Three respondents indicated that these materials exceeded their expectations. Most the respondents (15 out of 34) did not provide any comments as they do not have direct experience with the materials. Only three respondents indicated that proprietary materials only meet some of the expectations.

The results discussed above show that while the use of proprietary materials is limited, they do meet or exceed the expectations when used. Comments provided by the individual respondents varied in terms of the longevity of the repair, with one indicating these are typically used for short term repairs while another indicated they verge on permanent repairs. Responses also indicated that the type of product and workmanship is very important for the adequacy of the repairs.

Proprietary products that have performed well include **TechCrete**^{TM} by Crafco, **Mastic One** by Crafco, **Fibrecrete** by Fibrecrete Preservation Tech., **Master Builders 4X4q**; **FUTURA-15** by W R Meadows, and **Rapid Set** by CTS. The MnDOT mix (3U18) was also included.

3.3. Service Life Expectations

For full-depth repairs, a longer expected service life compared to partial depth repairs is expected by the respondents with the majority (19 out of the 32 answers to this question) targeting at least 10 to 15 years. Only few expected these repairs to last less than 10 years (2 out of 32) while the remaining respondents expected service life longer than 20 years and up to 40 years.

Most the respondents (12 out of 29 answers to this question) indicated that partial depth repairs are only expected to last between 2 and 5 years, making them a short term repair. This was followed by a split between respondent expecting such repairs to last about 10 years and respondents expecting them to remain intact to the extent of the remaining pavement life.

The responses presented above are consistent with the opinions of the authors in terms of the difference between expectations for partial- and full-depth repairs service life, where partial-depth repairs are viewed as short-term repairs while longer life is expected for a full-depth repair.

3.4. Specifications and Quality Control

The survey included four questions that focused on existing specifications, procedures and quality control tests that are available for partial and full-depth pavement repair projects. The first question focused on specification or procedures that are used during repair projects to complete the following tasks: determining boundaries of the repair area, preparing the concrete surface, placing and consolidating the patch material, curing the repair area, sealing cracks, and sealing joints. Figure 3.1 provides a summary of the results. As can be seen, almost all respondents indicated that they have procedures to placing and consolidating the patch material and curing the repair area. For the remaining tasks, more than 20 respondents in each category indicated that they do have standard procedures to quantify and prepare the repair area, and for sealing cracks and joints.

In terms of quality control and quality assurance procedures, 29 out of the 34 respondents indicated that they have such procedures established for repair projects. The provided comments show that typical quality control tests include air content, slump, quality verification cylinders collected at placement, compressive strength, sub-base preparations, thickness of patch, prep work for dowels, and ride profile. In terms of training materials, 20 out of the 24 respondents indicated that their agencies have training materials for the patching crews or the inspection staff that focuses on partial and full-depth repairs of concrete pavements.

For performance evaluation, the survey results showed that visual inspection is the most widely used method followed by ride quality and then sounding as shown in Figure 3.2. Physical testing, such as concrete cores, cylinders, or split tensile, is only used by eight respondents. Five respondents indicated that the performance of the patches is not evaluated after installation.

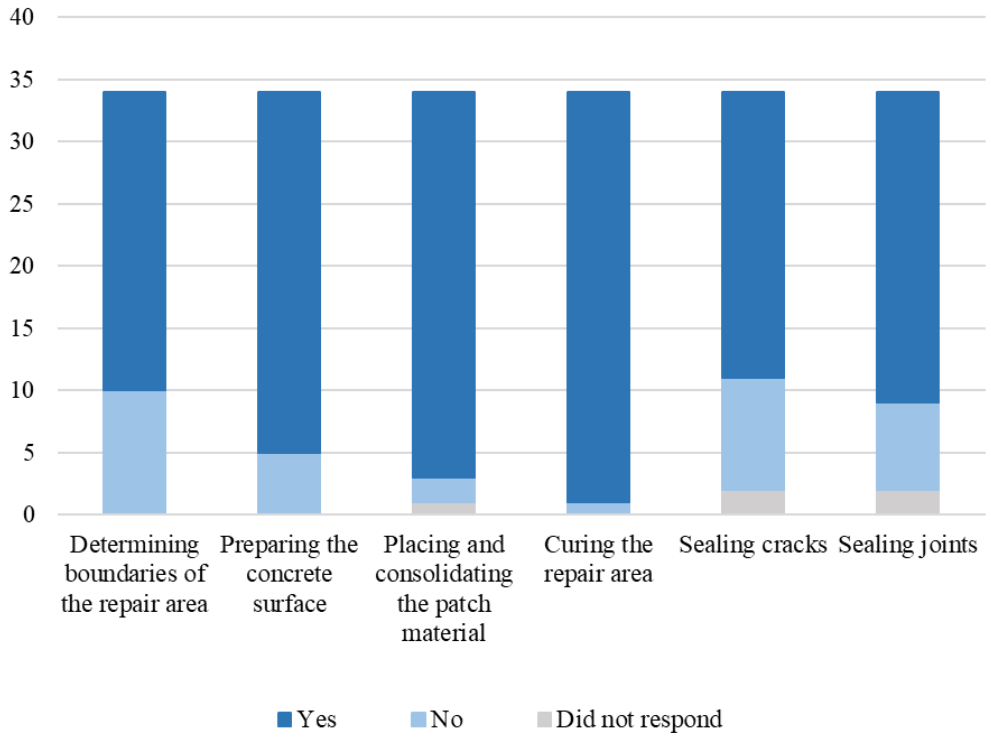

Figure 3.1. Summary of survey results for procedures for partial- and full-depth repairs.

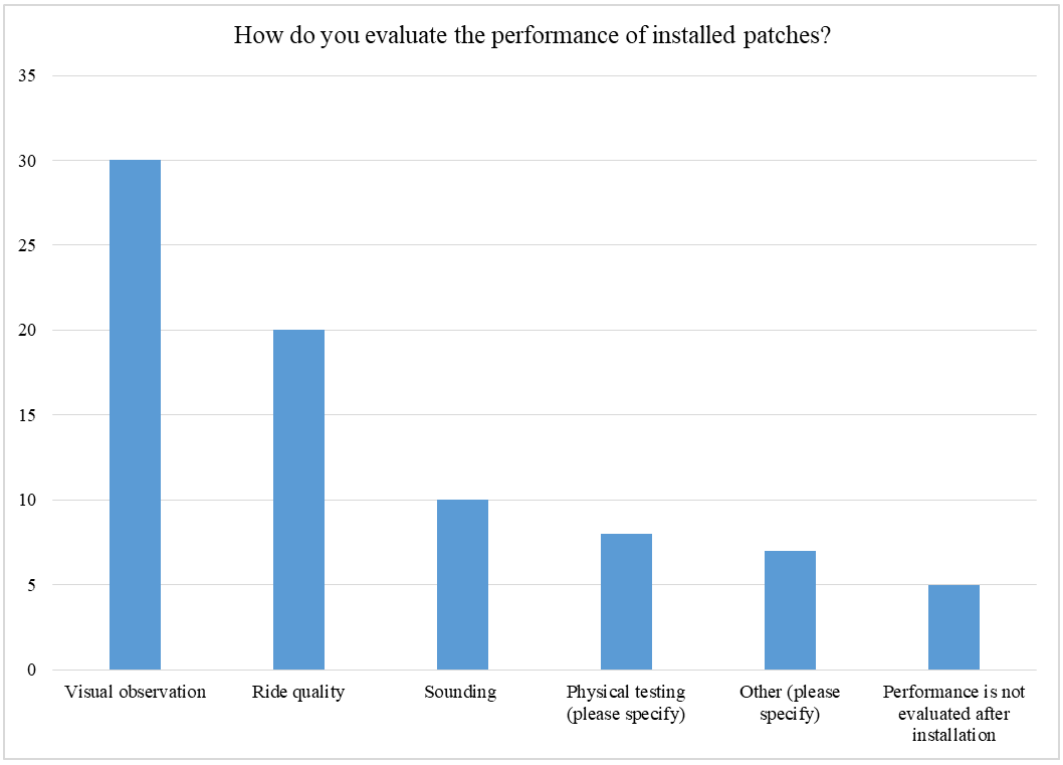

Figure 3.2. Summary of survey results for methods to evaluate performance of installed patches.

3.5. Performance Rating of Different Patching Materials

This section summarizes the survey results in terms of performance rating of different patching materials. Individual experiences for the most effective patching techniques as well as typical patch failures are provided in the individual survey responses in Appendix A. Figure 3.3 and Figure 3.4 provide summary of the performance rating results for the partial- and full-depth repair materials, respectively. The figures also gives an indication to which are the most used materials for each repair type.

For partial-depth repairs, asphalt patching materials have a wide variety of performance experience ranging from excellent to poor, with most the responses indicating fair experience with this repair material. Normal portland cement concrete materials has higher response rate in the good and excellent category. However, several respondents also indicted poor performance for this type of material. High early strength materials are also rated highly with the majority of the responses indicating at least an average performance and very limited number indicating poor performance. Epoxy, polymer, and proprietary materials are generally less used but achieved a rating of at least average with the majority of respondents indicating good or excellent performance. Proprietary materials used by respondents include **TechCreteTM** by Crafco, **Mastic One** by Crafco, **Fibrecrete** by Fibrecrete Preservation Tech., **FUTURA-15** by W R Meadows, and **Rapid Set** by CTS.

For full-depth repairs, the most widely used material is normal portland cement concrete which achieved a rating of at least average with the majority of the respondents indicating good or excellent performance. Similar results were collected for high early strength concrete; however, some respondents indicated poor performance. Asphalt materials are less used for full-depth repairs and have generally less favorable performance compared to the concrete options based on the survey results. Epoxy, polymer, and proprietary materials are seldom used for full-depth repairs but achieved a rating of at least average. Other

options for full-depth repairs include normal setting cement with calcium aluminate, the MnDOT high early strength ready mix, and precast panels used in IL Tollway.

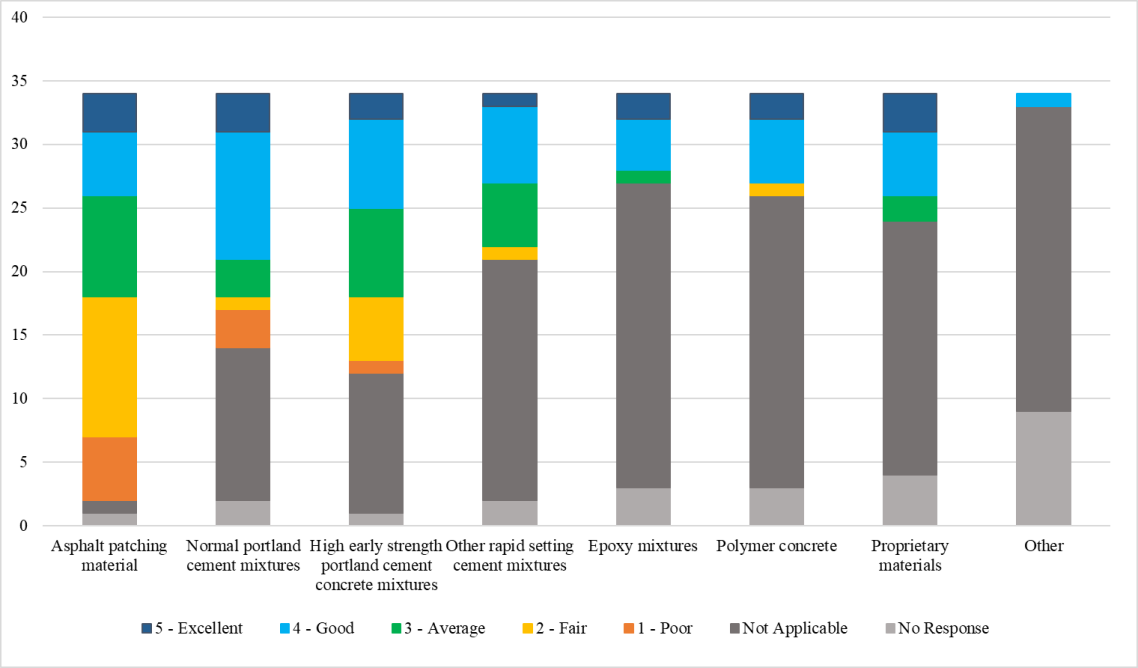

Figure 3.3. Summary of survey results for methods to evaluate performance of installed patches for partial-depth repairs.

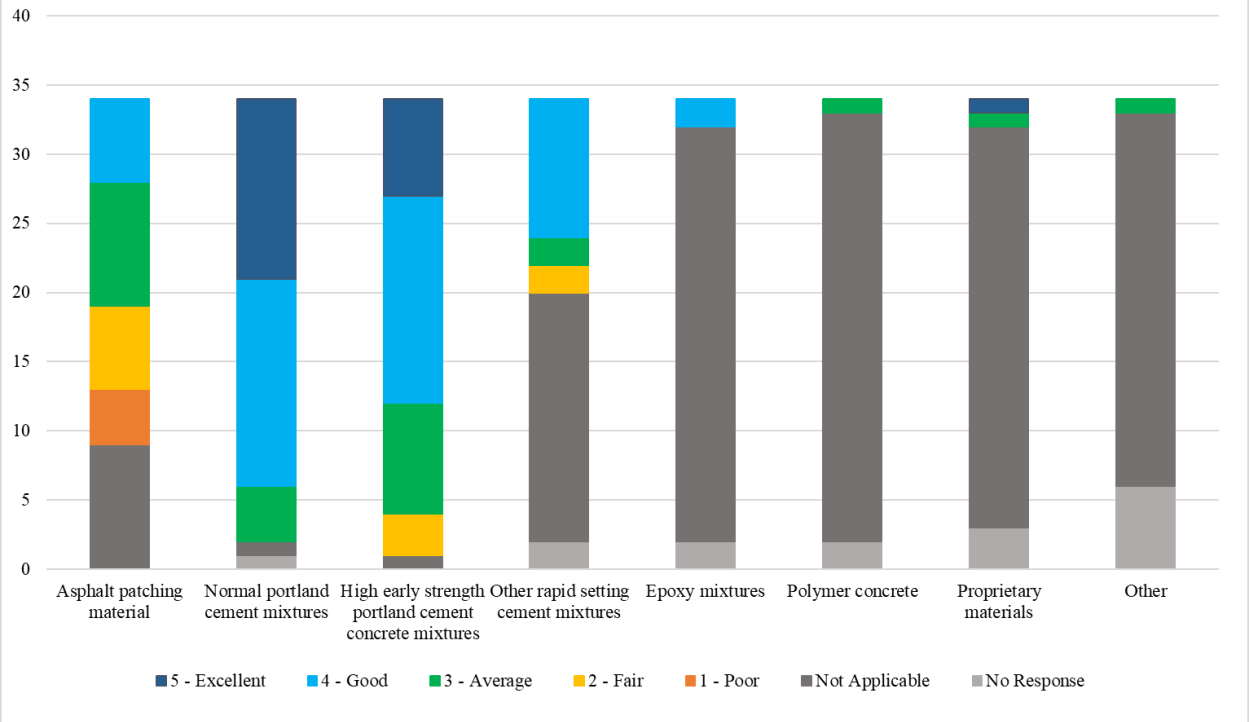

Figure 3.4. Summary of survey results for methods to evaluate performance of installed patches for full-depth repairs.

4. DRAFT REPAIR PROCEDURES AND MATERIALS

Based on WJE's review of various DOT practices, relevant research, feedback from the DOT survey, and WJE's experience, following are recommended repair procedures and materials for full- and partial-depth pavement repairs, and recommended quality control/quality assurance procedures. Recommended drawings with details and notes, and quality control checklists are presented in Appendix B.

4.1. Full-Depth Repairs

4.1.1. Current Iowa DOT Standard Practices

The following practices are currently specified by Iowa DOT for full-depth repairs:

4.1.1.1. Repair Boundaries

- The length of each patch, measured parallel to the center line, will not be less than 6 feet on Interstate pavements and 4 feet on other pavements except continuously reinforced full depth finish patches. Continuously reinforced patches will not be less than 8 feet in length.
- Typical minimum width of full depth repair is one lane, but partial lane width patches are permitted.

4.1.1.2. Joint Types

The following joint types used in concrete pavement repairs by Iowa DOT are referenced in this report:

- 'CD' joints: 'CD' joints are doweled transverse contraction joints that are entirely within the patch.
- 'CT' joints: 'CT' joints are tied transverse contraction joints that are entirely within the patch.
- 'RD' joints: 'RD' joints are doweled transverse contraction joints at the end of the patch where the dowels are embedded into the existing pavement.
- 'RT' joints: 'RT' joints are tied transverse contraction joints at the end of the patch where the tie bars are embedded into the existing pavement.
- 'BT-3' joints: 'BT-3' joints are tied longitudinal joints where the tie bars are embedded into the existing pavement.

4.1.1.3. Joint Spacing

- Transverse joint spacing is 10 ft minimum, 20 ft maximum, and 15 ft optimum. New 'CD' joints must be at least 5 feet from the ends of patch.
- Longitudinal joints will match existing.

4.1.1.4. Joint Details

- According to Iowa standard road plan drawings PV-101, for transverse joints adjacent to existing pavement ('RD' and 'RT' joints), the joints are saw cut to a depth of 1 to 1 1/2 inches with width of 3/16 to 5/16 inches. According to Article 2529.03.G, joints at lane edges and at ends of patches may be constructed by hand methods or sawed to a depth of approximately 1 1/8 inches, leaving an opening of at least 3/8 inch to provide a reservoir for joint sealer.

- For transverse joints in the interior of the repair, 'CD' and 'CT' joints, the joints are saw cut to a depth of T/3±1/4 inch with width of 3/16 to 5/16 inches.
- Longitudinal joints of full depth repairs are not required to be sawn and sealed.

4.1.1.5. Dowels and Tie Bars for Transverse Joints

- For transverse joints in the interior of the repair ('CD' and 'CT' joints), dowels or tie bars are placed 12 inches on center and from pavement edge. For transverse joints adjacent to existing pavement ('RD' and 'RT' joints), four dowels or tie bars are embedded into the existing pavement for each wheel path; dowel spacing in each wheel path is 12 inches on center and from pavement edge.
- Dowels and tie bars are placed at mid-depth of pavement.
- Dowel diameter varies from 3/4 to 1 1/4 inches, and tie bar diameter varies from #6 to #11 depending on pavement thickness.
- Minimum dowel length is 18 inches with at least 9-inch embedment. Minimum tie bar length is 24 inches with at least 9-inch embedment, except for 'CT' tied contraction joint placed at an existing crack in adjacent pavement where the tie bar length is 30 inches. Hole diameter is 1/8 inch greater than dowel or tie bar diameter.
- The portion of dowels extending into the patch area shall be coated with a bond breaker. Tie bars shall not be coated.
- Tie bars for longitudinal joints ('BT-3'):
  - #5 tie bars are placed at 30 inches on center. Minimum tie bar length is 24 inches with at least 9-inch embedment. Hole diameter is 3/4 inch.
  - Tie bars are placed at mid-depth of pavement

4.1.1.6. Concrete Strength for Opening to Traffic

Iowa DOT currently does not specify concrete strength for opening to traffic.

4.1.2. Recommended Practices

The following practices are recommended by the authors to supplement Iowa DOT standard practices:

4.1.2.1. Repair Boundaries

- Use a minimum repair length of 6 feet for all jointed plain concrete pavements to minimize rocking, pumping, and break-up.
- Avoid leaving a remaining slab panel less than 5 feet long. If a patch boundary is less than 5 feet from an existing transverse joint, extend the boundary to the joint.
- Combine two patches less than 8 feet apart into a single larger repair to be more cost effective by reducing the number of transverse joints.

4.1.2.2. Joint Spacing

- A maximum joint spacing of 10-ft is recommended for full-depth repairs.

4.1.2.3. Repair Materials

Based on the DOT survey and review of literature, repair materials were recommended for trial full depth repairs as part of IHRB TR-731. In general, materials with shorter curing time require more stringent installation procedures and tend to be more expensive. Thus, the full depth repair materials have been grouped into 5, 12, and 24-hour curing periods prior to opening of the pavement (Table 4.1). Installation procedures are also presented for the select repair materials.

Table 4.1. Full depth repair materials recommended for trial repairs

Curing Time	Mix Name	Supplier/Specifier	Material Description
5 hours	**Rapid Set DOT Concrete** Mix	CTS	Calcium sulfoaluminate cement-based concrete
	4x4 Concrete System	Master Builders	Portland-cement based concrete with BASF chemical admixtures
12 hours	MnDOT 3U18 Concrete Patch Mix	MnDOT	MnDOT 3U18 Type I Portland Cement Concrete Mix
24 hours	Class M concrete mixture	Iowa DOT	Portland/Blended cement concrete (Article 2529.02.B)

5-Hour Curing

Rapid Set DOT Concrete Mix

Rapid Set DOT Concrete Mix by CTS has been identified by Minnesota DOT during the DOT survey and is currently an approved repair material by Iowa DOT. This is a calcium sulfoaluminate cement-based proprietary concrete mixture, commercially available in 60-lb bags.

The following are general installation notes for this material:

1. The surface must be clean, sound, and free of any materials that may inhibit bond, such as oil, asphalt, curing compound, acid, dirt, or loose debris.
2. Saturate the subgrade surface with water before placement. Remove any standing water before material placement.
3. Mix Rapid Set DOT Concrete Mix in accordance with the manufacturer's instructions:
    a. Place the desired quantity of water into the mixing container (use 3.25 to 3.5 quarts of water per 60 lb bag).
    b. While mixing in a power-driven mechanical mixer (mortar mixer or drill-mounted mixer), add approximately 2/3 of the materials to the mixer. Continue mixing for 30 to 60 seconds.
    c. While mixing, add the remaining material. Mix for an additional 1 to 2 minutes to achieve a uniform, lump-free consistency.
    d. Do not re-temper.
4. The working time for this material is 15 to 20 minutes at 70 °F.
5. Place, consolidate, and screed the repair material using traditional methods for concrete.
6. Finish by trowel, float, or broom. Apply final finish as soon as possible; do not wait for bleed water.

7. Wet cure all exposed surfaces for a minimum of 1 hour. Begin wet curing as soon as the surface starts to lose its moist sheen.

4x4 Concrete System

The 4x4 Concrete System by Master Builders has been used by Ohio DOT and Caltrans. The 4x4 Concrete System is a custom ready-mixed concrete mixture using local materials with Master Builders' chemical admixtures. Master Builders' provides chemical admixtures and technical support to assist ready-mix producers with this development.

The 4x4 concrete mixtures generally have the following characteristics:

- Total cementitious materials content = 750 to 850 lb/yd^3
- w/cm = 0.28 to 0.32 for Type I cement; 0.32 to 0.36 for Type III cement
- Maximum aggregate size = 1 inch
- Slump = 5 to 9 inches
- Flexural strength = 400 psi in 4 hours

The 4x4 concrete mixtures typically include the following typical chemical admixtures:

- High-range water reducer (MasterGlenium product)
- Hydration controlling admixture (MasterSet Delvo)
- Non-chloride accelerating admixture (MasterSet AC 534)
- Other set-controlling admixtures may also be included.
- Some chemical admixtures may be added on-site.

12-Hour Curing

MnDOT 3U18 Concrete Patch Mix

The MnDOT 3U18 Bagged Portland Cement Concrete Patching Mix has been used by Minnesota and South Dakota DOTs. The 3U18 mix was developed by MnDOT for use in partial- and full-depth repairs and has shown good performance. This is a bagged portland cement concrete mixture proportioned in accordance with Minnesota Department of Transportation (MnDOT) Specification 3105 for Grade 3U18 concrete. This concrete mixture is commercially available in 50-lb bags with brand name ProSpec Concrete Patching Mix by TCC Materirals, but equivalent materials, including ready-mixed concrete, meeting the MnDOT specifications for Grade 3U18 concrete may be permitted with approval. The mix proportions for a 50-lb bag are as follows:

Material	Small Batch Proportions
Type I Cement	11.9 lb.
Coarse Aggregate (#89 or CA-80)	18.9 lb.
Fine Aggregate (MnDOT 3126)	19.3 lb.
Water	4.76 lb. (w/cm = 0.40)

The following are general installation notes of this material:

1. Condition all materials to 50 to 75 °F at least 24 hours prior to installation. Apply patch material only when air and substrate temperatures are between 50°F and 90°F within 24 hours of application and placement, and when rain is not forecast for 24 hours after placement.
2. All concrete surfaces receiving repairs must be fully cured, structurally sound, and non-flexing.
3. Saturate the subgrade surface with water before placement. Remove any standing water before material placement.
4. Mix the concrete patch mix on site, in paddle-type or drum mixer.
    a. Mix material in a clean mixer with wetted surfaces free of standing water.
    b. Add water and chemical admixtures into the mixer. Use an air entraining admixture (ASTM C260) and high range water reducing admixture (ASTM C494 Type F), dosed to obtain a 1 inch maximum slump and a 6.5% air content. Do not use more than 4.75 pints of water per 50 lb. bag.
    c. Place the desired number of bags of patching mix into the mixer. Always use full bags. Do not exceed the mixer capacity.
    d. Mix 3 to 5 minutes until a uniform, lump-free consistency is obtained.
    e. Maintain water content, admixture dosages, and mixing time from batch to batch to ensure product consistency.
    f. Do not re-temper.
5. Shovel or place mixture immediately onto repair area. Application should be full depth.
6. Compact and spread the mixture to completely fill the forms or patch.
7. Strike off the surfaces with a straight board or screed, moving the edge back and forth with a saw-like motion. Use a darby or bull float to level any ridges and fill voids left by the screed.
8. Place all concrete into final position within 1 hour of initial mixing. Discard any concrete that has not been placed after 1 hour. Warmer temperatures will accelerate setting time.
9. Allow the concrete to reach initial set, wait for all water to evaporate from the surface before finishing with a trowel or broom.

24-Hour C---uring

Iowa DOT Class M Mixture without Calcium Chloride

Iowa DOT Class M Mixture is a high early strength Portland/blended cement concrete that meets requirements of Iowa DOT Standard Specifications, Section 2529 - *Full Depth Finish Patches*, and Materials

I.M. 529 - *Portland Cement (PC) Concrete Proportions*. The basic and maximum w/c ratios are 0.328 and 0.400 respectively. Mix proportions with different fine/coarse aggregate ratios are in Table 4.2.

Table 4.2. Iowa DOT Class M Concrete Mixes by Absolute Volumes of Materials per Unit Volume of Concrete

Mix No.	Cement	Water	Air	Fine	Coarse	Fine/Coarse
M-3	0.149	0.153	0.060	0.287	0.351	45/55
M-4	0.156	0.161	0.060	0.311	0.312	50/50
M-5	0.160	0.165	0.060	0.338	0.277	55/45

General requirements of the Class M mixtures are as follows:

- Cementitious materials:
  - Type I or Type II cement
  - Type IS cement with a maximum substitution of 25% slag (in cement)
  - Do not use fly ash.
- Slump = 1 to 3 inches, max. 4 inches; if Type A mid-range water reducing admixture is used, slump = 1 to 4 inches, max. 5 inches.
- Air entrainment = 6.5 ± 1.5%.
- Minimum mix temperature, as delivered to job site = 50 °F
- Use a mix from a plant from which the concrete can be delivered and placed within 60 minutes from the start of mixing. The time may be extended to 90 minutes when a retarding admixture is added at the plant.

4.1.2.4. General Repair Procedures

The following describes the general full-depth repair procedures. For proprietary materials, the manufacturers' instructions should be followed.

1. Mark patch boundaries.
2. Make full-depth saw cuts along full perimeter of area to be repaired.
3. Remove concrete in repair area in accordance with Article 2510.03, B.
4. If longitudinal subdrain is not to be placed, or is not present, on the side of roadway to be patched, place patch subdrain in accordance with Article 2502.03, C.
5. Repair subbase and/or subgrade as planned or if disturbed during construction in accordance with Article 2529.03, C.
6. Place dowels and tie bars in predrilled holes using epoxy grout, according to Article 2301.03, E. Coat the dowels extending into the patch area with a bond breaker. Do not coat reinforcing bars/ties.
7. Place forms on all exposed edges.
8. Moisten the subbase or subgrade or cover with a single layer of plastic film meeting requirements of section 4107.
9. Mix, place, and consolidate repair material in accordance with manufacturer's recommendations or with Article 2529.03, G.

10. Strike off repair material flush with pavement surface at perimeter of repair area, and texture surface of repair to match the surrounding pavement.
11. Cure the patch in accordance with manufacturer's recommendations or Article 2529.03, G.
12. Saw and seal joints in accordance with Article 2301.03, P.

4.1.2.5. Quality Control/Quality Assurance Procedures

To ensure quality of the repairs, the following provides a list of documents and work to be reviewed at each stage of the pavement repair project (pre-construction, construction, and post-construction), with recommendations based on FHWA [31], ACPA [4] and WJE's experience. A list of common construction problems and suggested solutions for full depth repairs are provided in Table 4.3. A QC checklist for use during construction of the repair is also provided in Appendix B.

Pre-Construction

The following items should be reviewed prior to the start of construction:

1. Document Review

- Bid/project specifications and design
- Special provisions
- Traffic control plan
- Manufacturers' instructions
- Material safety data sheets
- Applicable Occupational Safety and Health Administration (OHSA) safety requirements

2. Project Review

- Verify that pavement conditions have not significantly changed since the project was designed.
- Verify the number of full depth repairs, but allow flexibility if additional deterioration is found below the surface.

3. Materials Check

All materials should be checked against specifications as required by contract documents, including the following:

- The mix design for the material being supplied meets the criteria of the contract documents.
- The concrete patch material has been sampled and tested prior to installation and is not contaminated.
- Dowels and tie bars meet specifications and that dowels are properly coated with epoxy (or other approved material) and free of any minor surface damage in accordance with contract documents.
- Dowel-hole cementing grout or epoxy meets specifications.
- Bond-breaking board meets specifications.
- Joint sealant material meets specifications.
- Curing compounds or curing blankets, as appropriate.
- Sufficient quantities of materials are on hand for completion of the project.
- All material certifications required by contract documents have been provided to the agency prior to construction.

4. Equipment Inspections

All equipment that will be utilized in the repair construction should be inspected to verify that it is available on site and in proper working condition, and meet specifications as required in the contract documents. Below is a list of typical equipment required for full-depth repairs:

- Concrete saws and blades
- Concrete removal equipment (front-end loader, forklift, crane, backhoe, skid steer, jackhammer, etc.)
- Subbase compactor
- Dowel drilling equipment
- Air compressor for cleaning dowel holes
- Material testing equipment
- Concrete vibrator
- Floats and screeds
- Plastic sheeting for rain protection of fresh concrete if required
- Sprayers with correct nozzles if membrane curing compound to be used for curing repair area.

5. Traffic Control

- The traffic control plan should be reviewed and verified that the setup complies with the Federal Manual on Uniform Traffic Control Devices or local agency traffic control procedures. Traffic control needs to be maintained until the concrete meets the strength requirement specified in the contract documents for opening to traffic. Unsafe conditions, if any, should be reported to a supervisor.

6. Weather Requirement

- The air and surface temperatures should be verified to meet manufacturer and contract requirements for concrete placement (typically 40°F minimum).

Construction

The following should be verified during construction:

1. Concrete Removal

- The boundaries of the removal areas are clearly marked on the pavement surface and the cumulative area of the pavement to be removed is consistent with quantity in the contract documents.
- The patch size is large enough to accommodate a gang-mounted dowel drilling rig, if one is being used. Note: The minimum longitudinal length of patch is usually 6 ft.
- Boundaries are sawed vertically the full thickness of the pavement.
- Concrete is removed using either the break-up or lift-out method and minimizing disturbance to the base or subbase as much as possible. Note: The sawcut and lift method is preferred to jackhammer removal.
- Inspect the perimeter of the repair areas after pavement removal is complete for damage to the edges of the pavement to remain in place.
  - If extent of damages so warrants, extend pavement removal area before proceeding, and re-inspect new edges.
  - For shallow edge spalls (up to maximum of 1/3 of pavement thickness) along repair area edges, repair in accordance with Iowa DOT standard repair procedures for Partial-Depth Repairs.

2. **Subgrade and Subbase Preparation**
   - Verify water, if present, has been drained out of the repair area.
   - Verify that disturbed base or subbase is re-compacted, and additional subbase material is added and compacted if necessary.
   - Verify that concrete adjoining the patch is not damaged or undercut by the concrete-removal operation.
   - Verify that removed concrete is disposed of in the manner described in the contract documents.
3. **Dowel and Tie bar Installation**
   - Verify that dowel holes are drilled perpendicular to the vertical edge of the remaining concrete pavement using a gang-mounted drill rig and that the hole diameter meets requirements.
   - Verify that holes are thoroughly cleaned using compressed air.
   - Verify that preparation and cleaning of holes is performed in accordance with the manufacturer's requirements.
   - Verify that approved cement grout or epoxy is placed in dowel holes, from back to front.
   - Verify that dowels are inserted with a twisting motion, spreading the grout along the bar inside the hole. A grout-retention disk can be used to keep the grout from seeping out of the hole.
   - Verify that dowels are installed in transverse joints to the proper depth of insertion and at the proper orientation (parallel to the centerline and perpendicular to the vertical face of the sawcut excavation) in accordance with contract specifications. Tolerances of 1/4 in. misalignment per 12 in. of dowel bar length measured perpendicularly to the sawed faced are recommended.
   - The protruding part of the dowel is coated with a thin bond-breaker such as form oil.
   - Verify that tie bars are installed at the proper location, to the proper depth of insertion, and to the proper orientation in accordance with contract documents.
4. **Concrete Placement**
   - Verify that the fresh concrete is properly consolidated using several vertical penetrations of the concrete surface with a handheld concrete vibrator.
5. **Finishing and Curing**
   - Verify that the surface of the concrete patch is level with the adjacent slab using a straightedge or vibratory screed in accordance with contract documents.
   - Verify that the surface of the fresh concrete patch is finished and textured to match adjacent surfaces.
   - Verify that adequate curing compound, if used, is applied to the surface of the fresh concrete properly.
   - Verify that wet-curing methods (burlap, burlene, insulation blankets, etc.) cover the entire patch and are secured to prevent movement.
6. **Joint Sealing**
   - Verify that patches have attained adequate strength to support concrete saws and that patch perimeters and other unsealed joints are sawed to specified joint reservoir dimensions.
   - Verify that joints are cleaned and resealed according to contract documents.

7. Cleanup

- Verify that all concrete pieces and loose debris are removed from the pavement surface and disposed of in accordance with contract documents.
- For patches that extend to the pavement edge, verify that all formwork, including stakes have been removed, proper backfill material was placed and compacted in the space used for the forms, and that the pavement shoulder has been properly re-established. Verify that mixing, placement, and finishing equipment is properly cleaned for the next use.
- Verify that all construction-related signs are removed when opening the pavement to normal traffic.

8. Opening to Traffic

- Before opening the pavement to traffic, verify that the required length of time has elapsed before opening to traffic.
- For patches constructed with proprietary repair concrete mixes, verify that the concrete meets the specified opening strength.

Table 4.3. Construction problems and suggested solutions (ACPA 2008)

Problems	Solutions
Saw binds when cutting full-depth exterior cuts	Shut down saw and remove blade from saw, wait for slab to cool, then release blade if possible, or make another full-depth angled cut inside the area to be removed to provide a small pie-shaped piece adjacent to the stuck saw blade. Make transverse saw cuts when the pavement is cool. Use a carbide-tipped wheel saw to make pressure-relief cuts 4 in. wide inside the area to be removed.
Slab disintegrates when attempts are made to lift it out	Complete removal of patch area with backhoe or shovels Angle the lift pins and position the cables so that fragmented pieces are bound together during lift-out Keep lift height to an absolute minimum on fragmented slabs
Undercut spalling (deterioration on bottom of slab) is evident after removal of concrete from patch area	Saw back into adjacent slab until sound concrete is encountered. Make double saw cuts, 6 in. apart, around patch area to reduce damage to adjacent slabs during concrete removal. Use a carbide-tipped wheel saw to make pressure-relief cuts 4 in. wide inside the area to be removed.
Adjacent slab is damaged during lift-out of the repair slab	Adjust lifting cables and re-position lifting device to assure a vertical pull. Use a forklift or crane instead of a front-end loader Re-saw and remove broken section of adjacent slab
Patches become filled with rainwater or groundwater seepage, saturating the subbase	Pump the water from the patch area or drain it through a trench cut into the shoulder. Re-compact subbase to a density consistent with contract documents, adding material as necessary. Allow small depressions in subbase to be filled with aggregate dust or fine sand before patch material is placed. Permit the use of aggregate dust or fine sand to level small surface irregularities (1/2 in. or less) in surface of subbase before concrete patch is placed.

Problems	Solutions
Grout around dowel bars flows back out of the holes after dowels are inserted	Pump grout to the back of the hole first. Use a twisting motion when inserting the dowel. Add a grout retention disk around the bar to prevent grout from leaking out.
Dowels appear to be misaligned once they are inserted into holes	If misalignment is less than 1/4 in. per 12 in. of dowel bar length, do nothing. If misalignment is greater than 1/4 in. per 12 in. of dowel bar length on more than three bars, re-saw patch boundaries beyond dowels and re-drill holes. Use a gang-mounted drill rig referenced off the slab surface to drill dowel holes.

4.2. Partial-Depth Repairs

4.2.1. Current Practices in Iowa

The following practices are currently specified for partial-depth repairs by Iowa DOT (Section 2530, Revised 4/20/2021):

4.2.1.1. Patch Types and Geometry

General:

- Minimum patch width will be at least 12 inches.
- Minimum patch depth shall be 2 inches. Maximum patch depth shall be one half of the pavement depth.
- Edges of patch shall be milled or chipped to a 30 to 60 degree angle. Alternatively, a 2-inch saw cut may be made along perimeter of the patch and the patch edges are chipped to a 30 to 60 degree angle.
- Partial Depth PCC Finish Patches and Partial Depth PCC Joint and Crack Repair Patches, as defined in Iowa DOT Specification Section 2530, are square or rectangular in shape.
- Over-depth patches, as defined in Iowa DOT Specification Section 2530, are irregular in shape. They are placed to the full depth of existing pavement in areas of unsound concrete as designated by the Engineer. Repair size and location will be determined at time of construction. No. 4 tie bars 10-inch long will be inserted at mid-depth of existing pavement with 6-inch embedment.

4.2.1.2. Concrete Strength for Opening to Traffic

Iowa DOT currently does not specify concrete strength for opening to traffic.

4.2.2. Recommended Practices

The following practices are recommended to supplement Iowa DOT standard practices:

4.2.2.1. Patch Geometry

General:

- The patches including overdepth patches shall be generally rectangular.
- Patch boundaries will extend at least 3 inches beyond deteriorated concrete boundary determined visually or by sounding techniques to ensure all unsound concrete is removed.

- Keep vertical edges along patch boundaries, as opposed to 30 to 60 degree edges as in current Iowa DOT practices, to minimize debonding of the patch from existing pavement. This can be accomplished by saw-cutting perpendicular to the surface of the pavement along the patch perimeter and removing the remaining unsound material by chipping.

Patches not at transverse or longitudinal joint or crack:

- The patch shall be at least 12 inches in each direction.
- Edges of patch shall be at least 12 inches from transverse and longitudinal joints. If an edge of patch must be less than 12 inches from the joints to remove all unsound concrete extends, extend the edge to the joint.

Patches at transverse or longitudinal joints or cracks:

- The patch shall be at least 12 inches long in the direction of the joint or crack, and at least 12 inches wide on the side of the joint or crack that needs repairing.

Over depth patches:

- When removal to one half of pavement thickness leaves unsound concrete within the patch area, remove the concrete for the full depth of the existing pavement and perform a full-depth patch. The patch shall be generally rectangular and at least 4 feet in each direction. 'BT-3' joints shall be used on edges of patch with No. 5 tie bars inserted into existing pavement with at least 9-inch embedment and extended 15 inches into the patch and spaced at 30 inches on centers.

4.2.2.2. Repair Material Recommendations

Based on the DOT survey and review of literature, select repair materials were identified for trial partial depth repairs as part of IHRB TR-731. Options have been presented for the contractor, Iowa DOT, and WJE to discuss on each selected repair project. In general, materials with shorter curing time require more stringent installation procedures and tend to be more expensive. Thus, the partial depth repair materials have been divided in to 1, 5 and 24-hour curing procedures prior to opening to traffic (Table 4.4). Installation procedures are also presented for the select repair materials.

Table 4.4. Partial depth repair materials recommended for trial repairs

Curing Time	Mix Name	Supplier/Specifier	Material Description
1 hours	TechCrete - TBR	Crafco	Hot-applied Mastic
	FUTURA-15	W.R. Meadows	Very rapid-setting cementitious mortar
5 hours	Rapid Set DOT Concrete Mix	CTS	Calcium sulfoaluminate cement-based concrete
	Pave Patch 3000	Dayton Superior	Portland-cement based mortar
	4x4 Concrete System	BASF	Portland-cement based concrete with BASF chemical admixtures
24 hours	Class C patching material	Iowa DOT	Portland/blended cement concrete (Article 2530.02.B)
	MnDOT 3U18 Concrete Patch Mix	MnDOT	MnDOT 3U18 Type I Portland Cement Concrete Mix

1-Hour Curing

Techcrete - TBR (Crafco)

Techcrete has been identified by five states during the DOT survey (Illinois, Indiana, Missouri, South Dakota, and Wisconsin). This product consists of a hot-applied repair mastic that can be used for partial depth repairs. Repair materials come in 35-lb bags containing all ingredients, including aggregates, and can be shipped to site. Primer comes in 5 gal. pails. Materials will be heated using a mastic melter. Equipment can be rented from Crafco or dealers in Iowa.

The following are general installation notes for this material:

1. Ensure that any new concrete has cured at least 7 days and that the pavement surface is sound.
2. Remove loose debris from the area. Clean and dry the area using a hot air lance capable of producing a continuous stream of clean, dry compressed air, free of oil and moisture at a minimum of 90 psi.
3. Immediately prime the entire repair area, including sides and bottom surfaces, with TechCrete Primer. Use a brush or spray applicator and allow the primer to dry before applying the TechCrete.
    a. Primer should not be applied below 40 °F.
    b. Puddled or pooled primer in the repair area should be brushed out to speed drying and prevent bubbling.
    c. Do not use open flame to dry the primer.
    d. Drying time varies, typically from 15 minutes in warm, dry conditions to several hours in cooler, damper conditions. Primer is dry when lightly touched with a finger and there is no transference or pick up of primer residue.
4. Heat and mix TechCrete as per the directions in the TechCrete Installation Instructions.
    a. Melt the TechCrete-TBR in an appropriate indirectly heated melter with sufficient agitation to uniformly mix the product, such as the Crafco Patcher II. Contact Crafco for suitability of other melters.
    b. Ensure the melter is in good working order and clean and free of any residual material or contamination.
    c. Place the bag containing the TechCrete-TBR into the melter. Do not remove the material from the bag.
    d. Heat the TechCrete-TBR to between the minimum application temperature of 375 °F and the maximum heating temperature of 400 °F. It is recommended that temperature be monitored using a secondary device such as an infrared thermometer or hand-held thermometer.
    e. Do not continuously heat TechCrete-TBR for longer than 6 hours.
5. Pour melted TechCrete into the repair as per the TechCrete Installation Instructions.
    a. Gravity feed the heated TechCrete-TBR directly into the repair area or into an appropriate transfer container and then immediately pour into the repair area.
    b. Any TechCrete-TBR that has cooled to below the minimum application temperature shall be emptied back into the melter to re-heat.

c. Apply the TechCrete-TBR in multiple layers not exceeding 2 inches. The final (top) layer should not be greater than 3/4 inch deep. Overfill the top layer by about 1/8 inch.

d. Allow material to cool to 200 °F or less before between successive layers. Allow material to cool to 120 °F or less before installing the final layer.

6. Apply surfacing aggregate to the top layer of TechCrete after it has cooled to 225 ± 25 °F. Where practical, the surfacing aggregate should be applied around the perimeter first and then applied to the center, after the temperature falls into the appropriate range.
7. Surfacing aggregate should completely cover the patch surface. The usage rate is approximately 2 pounds of aggregate per square foot.
8. After the material has cooled to the surrounding pavement temperature, clean with a sweeper or vacuum to remove any surplus surfacing aggregate prior to opening to traffic.

Futura-15 (W.R. Meadows)

FUTURA-15 has been used by Minnesota DOT according to the DOT survey and is currently an Iowa DOT approved product. This is a very rapid hardening, one component structural repair mortar and comes pre-bagged.

The following are general installation notes of this material:

1. Prepare concrete substrate by mechanical roughening or high-pressure water jet to a minimum concrete surface profile (CSP) of CSP-6 or higher in accordance with ICRI Technical Guideline 310.2, depending on substrate condition. Sanding, grinding, wire-abrading, or similar are not approved surface preparation methods.
2. Remove all unsound concrete and provide a profiled, porous surface, free of dust, grease, oil, dirt, curing compounds, release agents, or any other surface or penetrated contaminants that will adversely affect bond.
3. Prepare the substrate to a saturated surface-dry (SSD) condition, free of standing water.
4. For repairs greater than 2 inches in depth, extend FUTURA-15 with aggregate as per the Installation Instructions. For repairs greater than 2 inches in depth, extend with 12.5 lbs of aggregate. For repairs greater than 4 inches in depth, extend with 25 lb of aggregate. Extension will decrease the mechanical performance of the material relative to the performance indicated in the product data sheet. The aggregate must be 3/8-inch pea gravel, at SSD. Always add the aggregate to the mixing water prior to the addition of FUTURA-15.
5. Mix FUTURA-15 as per the directions in the FUTURA-15 Installation Instructions.
   a. Using a suitable sized mortar mixer, add 4.75 to 5.25 pints of clean water to the mixer per bag of FUTURA-15. Only use complete bags.
   b. If extension is required, add the appropriate amount of aggregate to the mixer prior to the addition of FUTURA-15.
   c. Mix for 3 to 5 minutes until homogenous and lump-free.

d. Do not mix more product than can be mixed, placed, and finished in 15 minutes at 70 °F. Do not over-mix.
e. Do not re-temper or over-work.

6. Apply FUTURA-15 by trowel or screed. Ensure complete encapsulation of the dowel and tie bars.
7. The working time of this material is 7 to 9 minutes at 75 °F. Initial setting occurs within 14 to 18 minutes, and final setting occurs within 20 to 25 minutes.
8. Finish surfaces by screeding to a level surface.
9. Cure immediately after application using a suitable water-based curing compound. On large patches, cure repaired area as work proceeds. Wet curing for at least one day, followed by application of a suitable curing compound, helps minimize shrinkage.

5-Hour Curing

Rapid Set DOT Concrete Mix

Rapid Set DOT Concrete Mix by CTS has been identified by Minnesota DOT during the DOT survey and is currently an approved repair material by Iowa DOT. This is a calcium sulfoaluminate cement-based proprietary concrete mixture, commercially available in 60-lb bags.

The following are general installation notes of this material:

1. The surface must be clean, sound, and free of any materials that may inhibit bond, such as oil, asphalt, curing compound, acid, dirt, or loose debris.
2. Saturate the surface with water before placement. Remove any standing water before material placement.
3. Mix Rapid Set DOT Concrete Mix in accordance with the manufacturer's instructions:
   a. Place the desired quantity of water into the mixing container (use 3.25 to 3.5 quarts of water per 60 lb bag).
   b. While mixing in a power-driven mechanical mixer (mortar mixer or drill-mounted mixer), add approximately 2/3 of the materials to the mixer. Continue mixing for 30 to 60 seconds.
   c. While mixing, add the remaining material. Mix for an additional 1 to 2 minutes to achieve a uniform, lump-free consistency.
   d. Do not re-temper.
4. The working time for this material is 15 to 20 minutes at 70 °F.
5. Place, consolidate, and screed the repair material using traditional methods for concrete.
6. Finish by trowel, float, or broom. Apply final finish as soon as possible; do not wait for bleed water.
7. Wet cure all exposed surfaces for a minimum of 1 hour. Begin wet curing as soon as the surface starts to lose its moist sheen.

4x4 Concrete System

The 4x4 Concrete System by Master Builders has been used by Ohio DOT and Caltrans. The 4x4 Concrete System is a custom ready-mixed concrete mixture using local materials with Master Builders (MB) chemical admixtures. MB provides chemical admixtures and technical support to assist ready-mix producers with selection of their materials and development of their mix proportions for this system.

The 4x4 concrete mixtures generally have the following characteristics:

- Total cementitious materials content = 750 to 850 lb/yd^3
- w/cm = 0.28 to 0.32 for Type I cement; 0.32 to 0.36 for Type III cement
- Maximum aggregate size = 1 inch
- Slump = 5 to 9 inches
- Flexural strength = 400 psi in 4 hours

4x4 concrete mixtures typically include the following typical chemical admixtures:

- High-range water reducer (MasterGlenium product)
- Hydration controlling admixture (MasterSet Delvo)
- Non-chloride accelerating admixture (MasterSet AC 534)
- Other set-controlling admixtures may also be included.
- Some chemical admixtures may be added on-site.

Pave Patch 3000 (Dayton Superior)

Pave Patch 3000 is currently an Iowa DOT approved product. This is a fast setting, one component cementitious concrete repair material requiring only water to be added and comes pre-bagged.

The following are general installation notes of this material:

1. Prepare the concrete surface according to ICRI guidelines.
2. The surface must be sound and free of all foreign material, including oil, grease, laitance, or other contaminants.
3. All surfaces to be repaired should be in a saturated surface-dry (SSD) condition with no standing water.
4. Mix Pave Patch 3000 in accordance with the manufacturer's Installation Instructions.
    a. Mix with a low-speed drill or mortar mixer with rubber tipped blades.
    b. Add water to the mixer first, then the powder. Use 6 pints of water per 50 lb bag of powder. Only use full bags of powder.
    c. For repairs 2 to 6 inches in depth, extend the mix with 30 lb. of 3/8-inch pea gravel per 50 lb. bag of powder. Pea gravel should be clean, SSD, and conforming to ASTM C33.
    d. Mix for 2 to 3 minutes until uniform.
    e. Place within 15 minutes of mixing.
    f. Do not re-temper or use admixtures.

5. The working time of this material is 7 to 10 minutes at 72 °F. Initial setting occurs within 15 to 20 minutes, and final setting occurs within 25 to 30 minutes.
6. Scrub a thin layer of freshly mixed material onto the substrate using a stiff fiber brush. Place repair mortar before the scrub coat dries. Trowel the repair material into the surface to a minimum thickness of 2 inches and a maximum thickness of 6 inches.
7. Wet cure for at least 1 hour or apply a water-based curing compound to the repaired area. Apply curing immediately after placement.

24-Hour Curing

Iowa DOT Class C Patching Material

Class C patching materials are defined in the Iowa DOT Standard Specifications, Section 2530, *Partial Depth Finish Patches*. Class C patching materials utilize Class M concrete mixtures meeting the requirements of the current Materials I.M. 529, *Portland Cement (PC) Concrete Proportions*, without the addition of calcium chloride. The basic and maximum w/c ratios are 0.328 and 0.400 respectively. Mix proportions with different fine/coarse aggregate ratios are in Table 4.2.

General requirements of the Class C patching material are as follows:

- Cementitious materials:
  - Type I or Type II cement with a maximum substitution of 10% fly ash
  - Type IS cement with a maximum substitution of 25% slag (in cement)
- Slump = 1 to 3 inches, max. 4 inches; if Type A mid-range water reducing admixture is used, slump = 1 to 4 inches, max. 5 inches.
- Air entrainment = 6.5 ± 1.5%.
- Minimum mix temperature, as delivered to job site = 65 °F for Type I or Type II cement, 70 °F for Type IS cement. If Type A mid-range water reducing admixture is used, minimum mix temperature = 65 °F.
- Use a mix from a plant from which the concrete can be delivered and placed within 60 minutes from the start of mixing. The time may be extended to 90 minutes when a retarding admixture is added at the plant.

MnDOT 3U18 Concrete Patch Mix

The MnDOT 3U18 Bagged Portland Cement Concrete Patching Mix has been used by Minnesota and South Dakota DOTs. The 3U18 mix was developed by MnDOT for use in partial and full depth repairs and has shown good performance. This is a bagged portland cement concrete mixture proportioned in accordance with Minnesota Department of Transportation (MnDOT) Specification 3105 for Grade 3U18 concrete. This concrete mixture is commercially available in 50-lb bags with brand name ProSpec Concrete Patching Mix by TCC Materirals, but equivalent materials, including ready-mixed concrete, meeting the MnDOT specifications for Grade 3U18 concrete may be permitted with approval.

The mix proportions for a 50-lb bag are as follows:

- Type I cement: 11.9 lb
- Coarse Aggregate (#89 or CA-80): 18.9 lb
- Fine aggregate (MnDOT 3126): 19.3 lb

The following are general installation notes of this material:

1. Condition all materials to 50 to 75 °F at least 24 hours prior to installation. Apply patch material only when air and substrate temperatures are between 50°F and 90°F within 24 hours of application and placement, and when rain is not forecast for 24 hours after placement.
2. Roughen the surface and remove all unsound concrete. Clean the area to remove grease, oil, paint, and any other foreign materials that may inhibit performance.
3. All concrete surfaces receiving repairs must be fully cured, structurally sound, and non-flexing.
4. Saturate the surface with water before placement. Remove any standing water before material placement.
5. Mix the concrete patch mix on site, in paddle-type or drum mixer.
    a. Mix material in a clean mixer with wetted surfaces free of standing water.
    b. Add water and chemical admixtures into the mixer. Avoid direct contact between different admixtures before they are added to the concrete mixture or mix water. Use an air entraining admixture (ASTM C260) and high range water reducing admixture (ASTM C494 Type F), dosed to obtain a 1-inch maximum slump and a 6.5% air content. Do not use more than 4.75 pints of water per 50 lb. bag.
    c. Place the desired number of bags of patching mix into the mixer. Always use full bags. Do not exceed the mixer capacity.
    d. Mix 3 to 5 minutes until a uniform, lump-free consistency is obtained.
    e. Maintain water content, admixture dosages, and mixing time from batch to batch to ensure product consistency.
    f. Do not re-temper.
6. Apply a scrub coat to the repair surfaces with the repair material. Place repair material within 15 minutes of scrub coat application.
7. Shovel or place mixture immediately onto repair area. Application should be between 1-1/2 inch to full depth.
8. Compact and spread the mixture to completely fill the forms or patch.
9. Strike off the surfaces with a straight board or screed, moving the edge back and forth with a saw-like motion. Use a darby or bull float to level any ridges and fill voids left by the screed.
10. Place all concrete into final position within 1 hour of initial mixing. Discard any concrete that has not been placed after 1 hour. Warmer temperatures will accelerate setting time.
11. Allow the concrete to reach initial set, wait for all water to evaporate from the surface before finishing with a trowel or broom.

4.2.2.3. General Repair Procedure Recommendations

The following provides WJE's recommendations to the general partial depth repair procedures. For proprietary materials, any additional manufacturers' instructions should be followed.

1. Determine extent of deteriorated areas:
   a. Identify deteriorated concrete visually and by sounding techniques, such as hammer tapping and/or chain dragging.
   b. Mark boundaries of deteriorated concrete on pavement surface.
2. Determine repair boundaries:
   a. Extend repair boundaries at least 3 inches beyond deteriorated concrete.
   b. Combine two patches less than 1 foot apart into a single, larger repair area.
   c. If edge of patch is less than 1 foot from longitudinal joints/shoulder, extend patch to joints/shoulder.
3. Make saw cuts:
   a. Make vertical saw cuts to depth of 1/2 to 1 inch along perimeter of area to be repaired.
   b. Saw cuts to be generally parallel to pavement panel edges, to maintain approximately rectangular repair area.
4. Remove all concrete in repair area:
   a. Use maximum 15-lb. chipping hammer.
   b. Keep vertical edges along repair boundaries.
   c. Use care to prevent damage to sound concrete to remain at perimeter of repair area and at bottom of repair area.
   d. Rotary milling can be utilized if size of repair area is sufficient and the perimeter edges can be squared up.
   e. If deteriorated concrete extends over mid-depth of slab, perform full-depth repair.
5. Prepare repair surface:
   a. Clean all surfaces of repair area by sand blasting, jet blast, and followed by blowing with compressed air.
   b. If proprietary repair material to be used, additional surface preparation and conditioning to be in accordance with manufacturer's recommendations.
   c. If Iowa DOT Class C patching materials to be used, moisten repair area surface, but no free water should be present in repair area cavity. Remove all excess moisture with compressed air just prior to placing repair material.
   d. Do not use a bond agent.
6. Joint board installation:
   a. Place a joint board at joint or crack in accordance with Article 2530.02, C.
   b. Use a board made of compressible material of a width approximately equal to joint/crack.
   c. Extend joint board approximately 3 inches beyond patch boundaries to prevent repair material from getting into the joint/crack.

7. Mix, place, consolidate, and finish repair material:
    a. Thoroughly mix repair material in accordance with manufacturer's recommendations or Section 2530.03.
    b. If scrub coat is required, immediately prior to placing repair material, use stiff brushes or brooms to aggressively apply scrub coat of repair material onto vertical edges and bottom surface of repair area.
    c. Place repair material within 15 minutes of scrub coat application.
    d. Consolidate repair material.
    e. Strike off repair material flush with pavement surface at perimeter of repair area, and
    f. Texture surface of repair to match the surrounding pavement.
8. Cure the patch:
    a. If Iowa DOT Class C patching materials to be used, cure the patch in accordance with Article 2529.03, G.
    b. If proprietary repair material to be used, follow manufacturer's recommendations for curing.
9. Seal joints and saw-cut runoffs:
    a. Remove joint board in a manner that does not damage the patch.
    b. Prior to application of sealant, remove all curing compound, and other contaminants from surface to receive sealant
    c. Clean and seal joints and runoffs with an appropriate material described in Section 4136.
    d. Recess sealant 1/4 inch from pavement surface.

In the above procedures, the following changes from Iowa DOT specifications have been recommended:

Table 4.5. Recommended changes for Iowa DOT specifications

Iowa DOT Article	Description	Recommended Change	Reason for recommendation
2530.03, B.3.a.1	Remove concrete in designated repair area to a minimum width of 12 inches using either of the following methods: a) Mill transversely or longitudinally matching general alignment of patch. Use a mill that produces patch edges with a 30 to 60 degree angle or chip back patch edges to a 30 to 60 degree angle. Chip out secondary spalling resulting from milling at no additional cost to the Contracting Authority. b) Place 2 inch saw cuts along perimeter of patch area and chip back patch edges to a 30 to 60 degree angle.	Mill or chip back patch edges to obtain vertical edges along patch boundaries.	Use of vertical edges would help better confine the repair concrete and minimize debonding of patch.

Iowa DOT Article	Description	Recommended Change	Reason for recommendation
2530.03, B.3.b.1	Scrub a cement-sand-water grout of creamy consistency onto the patch surfaces, including the edges. Grout shall consist of two parts of Type I or Type I/II Portland cement and one part sand mixed with water. Mix grout by mechanical means. Place the patch material before the grout dries. If grout dries before placement of patch material, clean patch area again by sandblasting and air blasting, then reapply grout.	Apply a scrub coat to the repair surfaces with the repair material instead of the cement-sand-water grout. Place repair material within 15 minutes of scrub coat application. For proprietary repair materials, follow the manufacturers' instructions on the use of a bonding agent.	It is more convenient for the contractor to scrub coat using repair material, minimizing potential errors associated with dried grout. The 15-minute limit was to minimize loss of bond between patch and existing pavement

4.2.2.4. Quality Control/Quality Assurance Procedures

The QA/QC procedures recommended for full-depth repairs is generally applicable to partial-depth repairs. Additional recommendations are as follows:

- Cleanliness of the existing concrete surface must be verified, and a bonding agent (as needed for proprietary materials) or a scrub coat of the repair material (for non-proprietary materials) be applied immediately before placement of repair material. This is important to ensure bonding between the existing slab and the patch.
- Placement of joint board before casting repair materials and joint sealing after curing are important to avoid point bearing and blow-up failure of the patch.
- The perimeter of the patch (patch-slab interface) and saw-cut runouts need to be filled, typically using the grout material, to avoid delamination of the patch.
- Double application rate of curing compound may be desired because the large surface-area-to-volume ratio of PDRs makes them susceptible to quick moisture loss.

A list of common construction problems and suggested solutions for partial depth repairs are provided in Table 4.6. A QC checklist for use during construction of the repair is also provided in Appendix B.

Table 4.6. Construction problems and suggested solutions (ACPA 2008)

Problems	Solutions
More deterioration found below surface than is evident above	Extend limits of repair area into sound concrete. If deterioration extends below one-half the depth, perform a full-depth repair.
Dowel bar or reinforcing steel exposed during concrete removal	If the steel is in the upper third of the slab, remove steel to edges of the patch and continue. If removal extends to the mid-depth of the slab, perform a full-depth repair.
Patch material flows into joint or crack	Ensure joint insert extends far enough into adjacent joint/crack and into portions of joints and cracks that are at bottom of patch area. Ensure insert is correct size for joint/crack width.

Problems	Solutions
Patch cracking or debonding	Check that joint insert was used properly. Ensure insert is correct size for joint/crack width and inserted correctly. Check that patch area was cleaned immediately prior to grout and/or concrete placement. Check that grout material did not dry out before concrete placement. Ensure curing compound was applied adequately. Check that patch material is not susceptible to shrinkage or durability problems.

5. IMPLEMENTATION OF TRIAL REPAIRS IN 2020

As discussed in Sections 4.1.2.3 and 4.2.2.2, several concrete mixtures were recommended by WJE for trial full-depth and partial-depth pavement repairs to evaluate performance and applicability of these materials for use in Iowa. WJE, in coordination with Iowa DOT and Iowa district engineers, identified a project in Hardin County for trial full-depth repairs. Trial batching was first performed to evaluate two Portland cement concrete mixtures, and based on the results, one of the mixtures was selected for the trial full-depth pavement repairs. Unfortunately, WJE was unable to identify any projects for trial partial-depth repairs. Thus, the discussion in this section is limited to trial full-depth repairs.

5.1. Trial Batching for Full-Depth Pavement Repair Mixes

WJE in conjunction with Concrete Inc., Brett Admixtures, and Terracon completed trial batching of two high early strength concrete mixtures in August 2020. The purpose of the trial batching was to evaluate applicability and reasonability of the two proposed mixtures for use in full-depth pavement repairs in Iowa. The two concrete mixtures were developed by WJE based on previous literature search, which identified these mixtures to have the performance and characteristics desired to achieve the project goals. Generally, the two concrete mixtures were designed to mimic the Minnesota DOT mix identification "3U18" and the 4x4 Concrete System (Master Builders) discussed in Sections 4.1.2.3, both utilizing a non-calcium chloride accelerating admixture. The focus of the trial batching was to assess the slump and air retention, early age strength gain, time of setting of concrete, and to develop maturity curves (flexural strength and compressive strength) for the two mixtures. Details of the mix designs and test results were presented in a memo dated August 17, 2020 which was submitted to the Iowa DOT. The memo was later updated and is attached in Appendix C. Based on findings of the trial batching, the Alternative M-Mix, which is based on the 4x4 Concrete System, was selected for the trial full depth pavement repairs.

5.2. Trial Full Depth Pavement Repairs

WJE was on site to assist the Hardin County to perform trial repairs of five full-depth pavement patches in September 2020. The purpose of the trial repairs was to evaluate applicability, reasonability, and performance of the Alternative M-Mix and pavement repair details developed by WJE based on best practices in Iowa and other Midwest states for use in full-depth pavement repairs in Iowa. The Alternative M-Mix is a high early strength concrete mixture using non-chloride accelerator that was developed based on literature search and the trial batching performed in August 2020. Strength development of the Alternative M-Mix was compared with the Iowa DOT standard M-Mix with calcium chloride accelerator. Comments on the performance of the patches constructed with the two mixes will also be provided in a subsequent report (Appendix C).

5.2.1. Concrete Mixtures and Pavement Locations

Two concrete mixtures were used for the trial full depth repairs in Hardin County: Iowa Standard M-Mix and WJE's proposed Alternative M-Mix. The mix proportions are shown in Table 5., which were designed based on the aggregates and admixtures available at the plants that provided concrete for the trial repairs. Five full depth repairs/patches were included in this trial: two patches on County Highway D65 and three patches on County Highway D41. Locations, dimensions, and concrete mixtures of each patch are shown in Table 5.2. The patches were 11 feet wide (one lane) and 26 to 172 feet long. Pavement thickness was 6 to

6-1/2 inches thick. There appeared to be plastic slip sheet underneath the existing concrete slabs in Patch Nos. 1 and 2 on County Highway D65, which was removed during surface preparation process. It was unclear if there was plastic slip sheet underneath the existing slabs in the other patches; at the time of concrete placement; however, no plastic sheet was present in any of the patches.

Table 5.1. Concrete Mixtures for Trial Pavement Full Depth Repairs

Materials	Materials Characteristics		Quantity per cu. yd.	
			Standard M-Mix	Alternative M-Mix
Cement	Source:	PC0102-Ash Grove - Chanute	825 lb	870 lb
	Type:	Type I/II		
	Specific Gravity:	3.15		
Fine Aggregate	Source:	A42512-Hardin Aggregates	1399 lb	1490 lb
	Specific Gravity:	2.67		
Coarse Aggregate	Source:	A42002-Alden	1346 lb	1190 lb
	Specific Gravity:	2.606		
Air Entraining Admixture [1]	Product Name:	Euclid Eucon AEA-92	3.8 - 4.5 oz	2.0 oz
High-Range Water Reducer [2]	Product Name:	Euclid Plastol 6420	-	77 - 90 oz (8.8 - 10.0 oz/cwt)
Chloride Accelerator [3]	Product Name:	Calcium Chloride, 2%	1.9 - 2.1 gal	-
Non-Chloride Accelerator [3]	Product Name:	Euclid Accelguard NCA	-	2.0 - 3.0 gal
Water	Source:	Local Source	w/c = 0.32 - 0.39 (0.37 - 0.42)[4]	w/c = 0.32 (0.31 - 0.34)[4]

Notes:

[1] Added at plant

[2] Added at plant and on site

[3] Added on site

[4] Actual w/c in parentheses

Table 5.2. Repair Locations and Concrete Mixtures

Patch No.	Concrete Placement Date	Road	Location	Length x Width (ft x ft)	Concrete Mixture
1	9/21/2020	D65	D Avenue	41 x 11	Standard M-Mix
2	9/22/2020	D65	E Avenue	172 x 11	Alternative M-Mix
3	9/23/2020	D41	M Avenue	54 x 11	Standard M-Mix
4	9/24/2020	D41	O Avenue	26 x 11	Alternative M-Mix
5	9/24/2020	D41	O Avenue	29 x 11	Alternative M-Mix

Notes: Pavement thickness is 6 to 6-1/2 inches.

5.2.2. Pavement Repair Details

The pavement repair details generally followed drawings FDR-02 or FDR-03 in Appendix A. Particularly, the following details were implemented:

- When a transverse joint at the end of patch was in line with an existing transverse joint or crack in adjacent pavement, epoxy-coated dowels, 3/4 inches diameter and 18 inches long, were installed into the existing pavement along the transverse joint with an epoxy adhesive at spacing of 12 inches on centers; the protruding ends of the dowels were coated with form oil, which functioned as a bond breaker.
- When transverse joints at the ends of patch were not in line with an existing transverse joint in adjacent pavement, No. 6 epoxy-coated tie bars, 18 inches long, were installed into the existing pavement in the same manner as the dowels, except that the protruding ends of the tie bars were not coated with a bond breaker.
- At intermediate transverse joints, dowel baskets were used; dowels in the basket were spaced at 12 inches on centers and were fully coated with a bond breaker.
- At longitudinal joints, No. 6 epoxy-coated tie bars, 24 inches long, were installed into the existing adjacent lane at spacing of 30 inches. Tie bars were not to be coated with a bond breaker.

5.2.3. Pavement Repair Procedures

The repair generally followed procedures in drawings FDR-02 or FDR-03 in Appendix A with the following steps:

- After the existing patch boundary was saw-cut to full depth, the concrete was broken and removed using a backhoe (Figure 5.1).
- The subbase was filled with granular materials and compacted using mechanical tampers (Figure 5.2).
- Tie bar holes were drilled into adjacent pavement and cleaned using compressed air. Holes were filled with epoxy and dowels and tie bars were inserted (Figure 5.3 through Figure 5.6).
- Dowel baskets were placed at interior transverse joints and secured to the ground (Figure 5.7).
- Concrete was dry batched at a transit mix plant and mixed in the delivery truck drums. Air-entraining admixture was added at the plant while accelerator, either calcium chloride or NCA, was added to the truck mixer drum on site. For the first truck of Alternative M-Mix, the entire HRWR was added at the plant. However, for later batches part of HRWR was added at the plant while the remaining was added at the site to improve workability of the concrete.
- Concrete was leveled and consolidated using vibrating screed (Figure 5.8).
- Concrete was finished using a bull float, then textured with a broom (Figure 5.9) and cured using insulation blankets (Figure 5.10). No curing compound was used because equipment and materials were not available to the repair crew.
- Transverse and longitudinal joints were saw cut the same day of or the following morning after placement (between 4 and 24 hours after placement), and the joints were cleaned and filled with sealant before opening to traffic (Figure 5.11 and Figure 5.12).

Figure 5.1. Concrete breaking and removal (Patch 1).

Figure 5.2. Subbase preparation (Patch 1).

Figure 5.3. Tie bar hole drilling (Patch 2).

Figure 5.4. Hole cleaning using compressed air (Patch 1).

Figure 5.5. Filling hole with epoxy (Patch 1)

Figure 5.6. Inserted dowel

Figure 5.7. Tie bars, dowels and dowel baskets installed (Patch 1)

Figure 5.8. Concrete placement and screeding (Patch 2)

Figure 5.9. Concrete finishing (Patch 1)

Figure 5.10. Concrete curing with insulation blanket (Patch 1)

Figure 5.11. Cut and sealed transverse joint (Patch 1)

Figure 5.12. Crack formed at transverse joint as expected (Patch 1)

5.2.4. Concrete Testing

5.2.4.1. Test Methods

The following tests were performed for the trial pavement full depth repairs.

1. Plastic concrete testing:
   a. Air content - ASTM C 231
   b. Slump - ASTM C 143
   c. Concrete temperature - ASTM C 1064
2. Compressive strength testing - ASTM C 39
   a. (8) 4x8-inch cylinders were cast for each mix
   b. Compressive tests were performed at 8 hours, 12 hours, and 28 days (two cylinders per age)
   c. Cylinders were initially cured adjacent to the pavement using wet burlap and plastic sheeting for approximately 7 hours, after which they were transported to the Terracon laboratory in Des Moines, Iowa.
   d. At the Terracon laboratory, the cylinders were stripped, marked and placed in a moist curing environment until time of test.
3. Maturity testing on pavement - ASTM C1074
   a. Two Giatec SmartRock wireless probes were installed in Patch No. 2 and one probe installed in each of the Patch Nos. 4 and 5, where the Alternate M-Mix was used. Additionally, two probes were installed in Patch no. 3 where the Standard M-Mix was used. The probes were installed in accordance with the instructions in Iowa DOT Materials I.M. 383.

5.2.4.2. Plastic Concrete Test Results

Concrete was sampled and tested at discharge location. Results are presented in Table 5.3.

Table 5.3. Plastic Concrete Test Results

Concrete Placement Date	Concrete Mixture	Patch No.	Truck No.	Timing of Test	Air Content (%)	Slump (in.)	Concrete Temperature (°F)
9/21/2020	Standard M-Mix	1	1	Before CaCl2	6.8	6 1/4	70
				After NCA	6.2	7	78
9/22/2020	Alternative M-Mix	2	2	Before NCA	6.6	6 3/4	78
				After NCA	5.2	6 1/4	78
9/23/2020	Standard M-Mix	3	1	Before CaCl2	6.8	4 1/4	78
				After CaCl2	7.7	7	78
9/24/2020	Alternative M-Mix	4	1	After NCA	6.6	10	88
9/24/2020	Alternative M-Mix	5	1	After NCA	7.0	9 1/4	83

5.2.4.3. Estimated In-place Strengths of Concrete Pavements Using Field Maturity Testing

Maturity curves for the Alternative M-Mix were established during the Trial Batching in August 2020 as follows (See Appendix C for details):

- For flexural strength (psi), the following maturity function was developed: $f_b = 807*\log_{10}(TTF) - 1{,}728$
- For compressive strength (psi), the following maturity function was developed: $f'_c = 6{,}227*\log_{10}(TTF) - 13{,}536$

Where TTF is time temperature factor (Celsius degree-Hours).

Temperature data for each field probe was downloaded via a smartphone; the data was processed to calculate the time temperature factor as a function of time. Based on the maturity curves and field TTF data, the in-place flexural and compressive strengths of pavement were determined, and times to reach given target strengths were estimated. The estimated time to reach a flexural strength of 400, 500, or 600 psi in each day is presented in Table 5.4. The estimated time to reach a compressive strength of 2000, 3000, or 4000 psi is presented in Table 5.5. On average, the times to reach a flexural strength of 500 psi and a compressive strength of 3,000 psi are approximately 11 to 13 hours and 9 to 10 hours, respectively.

Table 5.4. Estimated Time for In-place Pavements to Reach a Target Flexural Strength - Alternative M-Mix

Target Flexural Strength (psi)	Time (hours) [1]	
	Patch No. 2 (9/22/2020)	Patch Nos. 4 & 5 (9/24/2020)
400	10	9
500	13	11
600	17	15

[1] Average of two probes for each day, rounded up to the nearest hour.

Table 5.5. Estimated Time for In-place Pavements to Reach a Target Compressive Strength - Alternative M-Mix

Target Compressive Strength (psi)	Time (hours) [1]	
	Patch No. 2 (9/22/2020)	Patch Nos. 4 & 5 (9/24/2020)
2000	8	7
3000	10	9
4000	14	13

[1] Average of two probes for each day, rounded up to the nearest hour.

5.2.4.4. Compressive Strength Test Results

The compressive strengths at different ages for the Standard M-Mix and Alternative M-Mix are presented and compared in Table 5.6. The strength development curves are shown in Figure 5.13. On average, the compressive strength of the Alternative M-Mix was approximately 50 to 100% higher than that of the Standard M-Mix. This was likely the result of the lower w/c and higher cement factor used in the Alternate M-Mix (see Table 5.2).

Table 5.6. Concrete Compressive Strengths (psi) [1]

Concrete Age	Standard M-Mix	Alternate M-Mix	Alternate/Standard
8 hours	1,440	2,925	2.03
12 hours	2,390	3,890	1.63
3 days	4,820	8,380	1.74
28 days	6,580	9,695	1.47

[1] Average of two cylinders for each age.

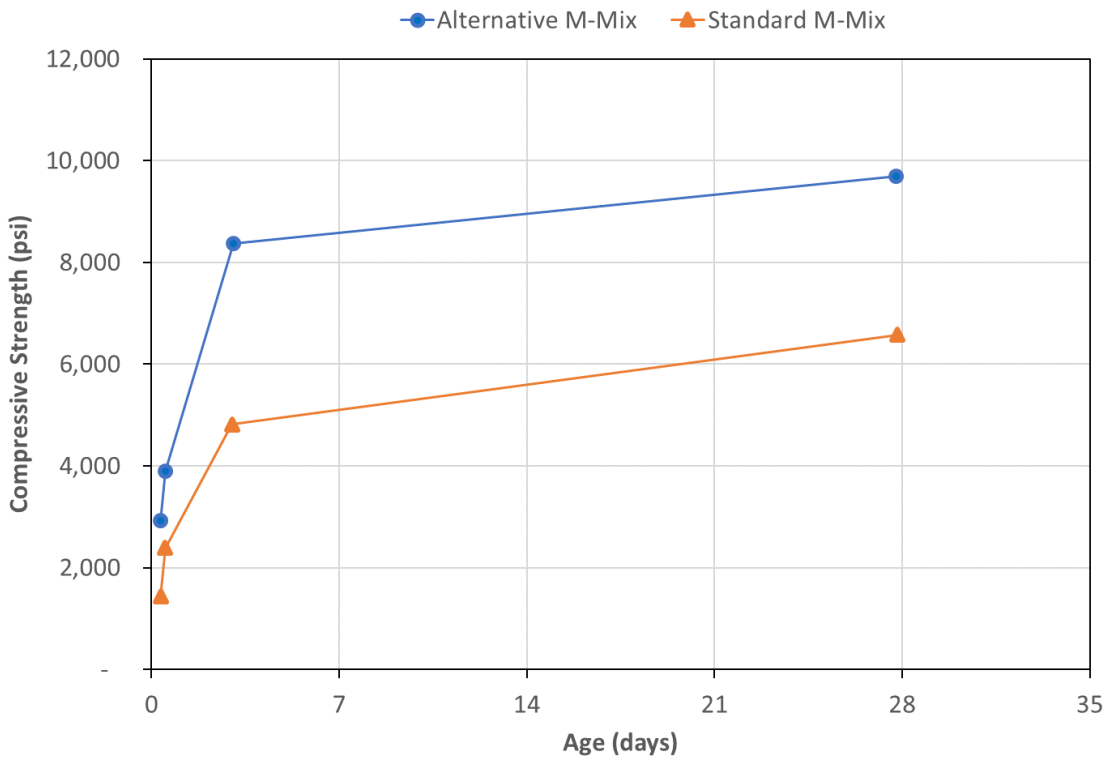

Figure 5.13. Trial Full Depth Pavement Repairs - Compressive Strength Versus Age

5.2.5. Initial Field Evaluation

An initial visual evaluation of each of the patches was performed the day after concrete was cast. Cracks and other visible distress in the patches were documented on pavement plan views, and are provided in Appendix D. The main findings are as follows:

- Patch 1 placed with Standard M-Mix on September 21, 2020: No cracks.
- Patch 2 placed with Alternate M-Mix on September 22, 2020: Due to equipment issues and miscommunication, the patch was not saw-cut until late the next morning. For this reason, a transverse crack occurred in two pavement panels before joint cutting was performed; the crack widths were

approximately 50 to 75 mils (0.05 to 0.075 inch). An additional crack occurred in another panel after the joints were cut; the crack width was 20 to 25 mils. These cracks were likely caused by thermal contraction of the concrete due to the cooling from peak hydration temperature and temperature drop overnight. Joints were not cut until late the morning after placement and saw-cut depths were 1/2 inch (depth of saw-cut was correct on subsequent patches), measured at the edge of the pavement, much smaller than the recommended one third of the slab thickness. Depth of saw-cutting was corrected on subsequent patches.

- Patch 3 placed with Standard M-Mix on September 23, 2020:
  - A transverse crack occurred in a pavement panel after joint cutting was performed, with a crack width of 20 mils. This crack was possibly due to excessive thermal contraction and concrete shrinkage and the long joint spacing.
  - There were several cracks around the shoulder edge and a corner of the pavement, which appeared to be caused by impact from heavy equipment. Reportedly, the contractor had impacted this panel with the excavator operator impacted the edge of the panel shortly after removal of the curing blankets.
- Patch 4 placed with Alternate M-Mix on September 24: No cracks. This patch was saw-cut within 5 hours after concrete placement.
- Patch 5 placed with Alternate M-Mix on September 24: No cracks. This patch was saw-cut within 5 hours after concrete placement.

Table 5.7. Patch Information

Patch No.	Concrete Mixture	Timing of Saw-Cut	Transverse Joint Spacing
1	Standard M-Mix	~ 18 hours	14 ft.
2	Alternative M-Mix	~ 22 hours	20 ft.
3	Standard M-Mix	~ 5 hours	21 ft.
4	Alternative M-Mix	~ 5 hours	10 ft.
5	Alternative M-Mix	~ 5 hours	11 ft.

5.3. Discussion/Recommendations

The Alternative M-Mix exhibited faster strength development than the Standard M-Mix used. The maturity testing suggest that the in-place flexural strength of the Alternative M-Mix concrete reached 500 psi at an age of 11 to 13 hours. The faster strength development of the Alternative M-Mix was likely a result of the lower w/c, higher cement content and possibly, the effect of the NCA.

A disadvantage of the Alternative M Mix was the quick loss of workability after the addition of HRWR and NCA. It was observed that the slump dropped from 6 to 10 inches to zero after 15 to 20 minutes, and the crew experienced difficulties in finishing the pavement. Additional research on this mix is recommended, with the use of slump extending admixtures being a high priority for Iowa DOT.

Based on the early age transverse cracks on Patch 2 (Alternative M Mix) but not present in Patch 4 and 5 (both Alternative M Mixes), transverse joints spacing is recommended at a maximum of 10 feet with saw-

cutting performed within the first 5 hours after concrete placement. The current IDOT specifications would allow for a maximum joint spacing of 20 feet in PCC patching. WJE feels this is too long for PCC patching, especially for Class M mixes. The more stringent requirements for joint spacing and timing are associated with the rapid strength and heat gain and associated cooling effect resulting in higher early age stresses due to restraint of the volumetric movement, as opposed to standard PCC pavement concrete mixes which would have a slower strength gain and less cooling effect. In addition, ensuring pavement joints are cut to the proper depth at one third of the slab thickness.

Finally, the concrete mix proportions reported in this section were designed for the aggregates and admixtures available at the plants that provided concrete for the trial repairs. At other plants in Iowa or other states, aggregates from other sources and cement and admixtures from other manufacturers that have comparable properties to those used in this study may be used to develop concrete mixtures with similar characteristics. However, recommended dosage rates and performance may vary from those obtained with the particular combinations of cement and admixtures used in these trial repairs. For these reasons, it will be necessary to perform tests of proposed materials and mix designs prior to repair construction.

6. FOLLOW-UP EVALUATIONS IN 2021

WJE performed a follow-up evaluation of the trial full-depth repairs on August 31 and September 1, 2021. Evaluation methods include visual inspection, elevation measurements using a D-Meter Floor Profiler, and ground penetrating radar (GPR). This section summarizes the methods and findings of the evaluation.

6.1. Methods

6.1.1. Visual Inspection

During the visual inspection, WJE mapped crack locations, measured crack widths, and documented condition of control joints and other notable distress. Crack mapping was performed in WJE's Plannotate software and exported into PDF files (provided in Appendix D).

6.1.2. Elevation Measurements

WJE utilized a D-Meter Floor Profiler (by Allen Face) to survey the relative elevations of the concrete surface in the repaired patches. In each patch, measurements were first performed along a longitudinal line along the edge of the patch to locate reference points for transverse measurement lines. Subsequent measurements were performed for transverse lines spaced at 2 or 4 feet. Data was then used to generate elevation profile for the patch.

Figure 6.1. Elevation measurements using a floor profiler.

6.1.3. Ground Penetrating Radar

WJE utilized a handheld GPR unit (StructureScan Mini XT by GSSI) to locate dowels/tie bars at select transverse contraction joints to verify their layout. GPR scanning was also performed at selected areas of the patches to detect potential voids underneath the concrete slab.

Figure 6.2. Locating dowels at transverse joints using GPR.

6.2. Findings

6.2.1. Patch No. 1 (Standard M-Mix)

New transverse and longitudinal cracks occurred in all three pavement panels in the patch. A crack map with notes on crack widths is presented in Appendix D. The spacing of transverse cracks within a panel is approximately 3 to 7 feet, and the distance from transverse cracks to an adjacent transverse joint is approximately 3 to 9 feet. Transverse crack width varies from 5 to 40 mils. The longitudinal cracks are generally along the centerline of the lane with crack widths varying from 5 to 35 mils. Examples of cracks in Patch No. 1 are shown in Figure 6.3 and Figure 6.4. Potential causes for the transverse and longitudinal cracks include excessive shrinkage, transverse joint lockup due to inadequate dowel coating or dowel misalignment, too much longitudinal joint restraint, inadequate subgrade support, and excessive joint spacing.

Transverse and longitudinal joints are generally in satisfactory conditions with minor spalling or raveling along the joint. An example of transverse joint in Patch No. 1 is shown in Figure 6.5. GPR scanning performed at representative transverse dowelled joints indicates that locations of the dowels are generally consistent with the design.

No voiding underneath the concrete slab was indicated in the GPR scanning.

Figure 6.3. Examples of transverse cracks (yellow arrows) and longitudinal cracks (red arrows) in the middle panel in Patch No. 1.

Figure 6.4. Close-up photo of a transverse crack exhibiting spalling (Yellow arrow). Crack width = 40 mils. (Middle panel in Patch 1).

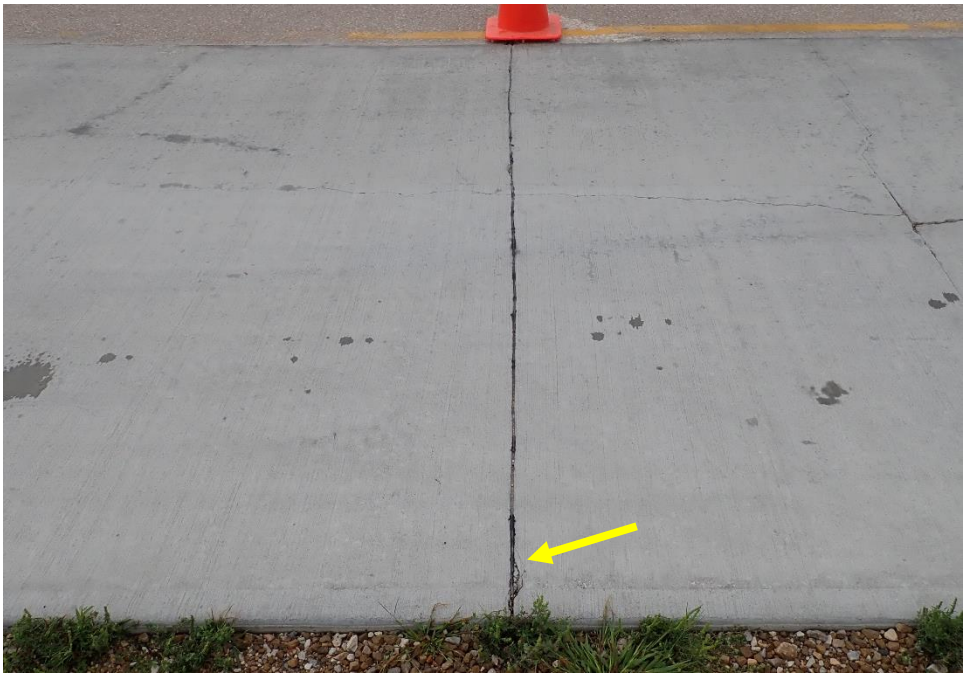

Figure 6.5. Transverse joint exhibiting minor spalling (Yellow arrow). (Patch No. 1).

6.2.2. Patch No. 2 (Alternate M-Mix)

New transverse cracks occurred in eight of the ten pavement panels in the patch in addition to the three transverse cracks observed in the initial field evaluation in September 2020. A crack map with notes on crack widths is presented in Appendix D. Most of the panels have a new transverse crack near mid-length of the panel, except for two panels (fourth and fifth from the east end) which have two new transverse cracks. In these two panels, the spacing of transverse cracks within a panel is approximately 4 to 9 feet, and the distance from transverse cracks to an adjacent transverse joint is approximately 5 to 7 feet. Transverse crack width varies from 10 to 35 mils. No longitudinal cracks were observed. Examples of transverse crack in Patch No. 2 is shown in Figure 6.6 and Figure 6.7. Potential causes for the transverse cracks include excessive shrinkage, transverse joint lockup due to inadequate dowel coating or dowel misalignment, and/or excessive transverse joint spacing.

Transverse and longitudinal joints are generally in satisfactory conditions with minor spalling or cracking along the joint. An example of transverse joint in Patch No. 1 is shown in Figure 6.8. GPR scanning performed at representative transverse dowelled joints indicates that locations of the dowels are generally consistent with the design.

Corner breaks, up to 12 inches by 12 inches, were present in two panels; an example is shown in Figure 6.9.

No voiding underneath the concrete slab was indicated in the GPR scanning.

Figure 6.6. Example of transverse crack (yellow arrow) in Patch No. 2, second panel from the east end).

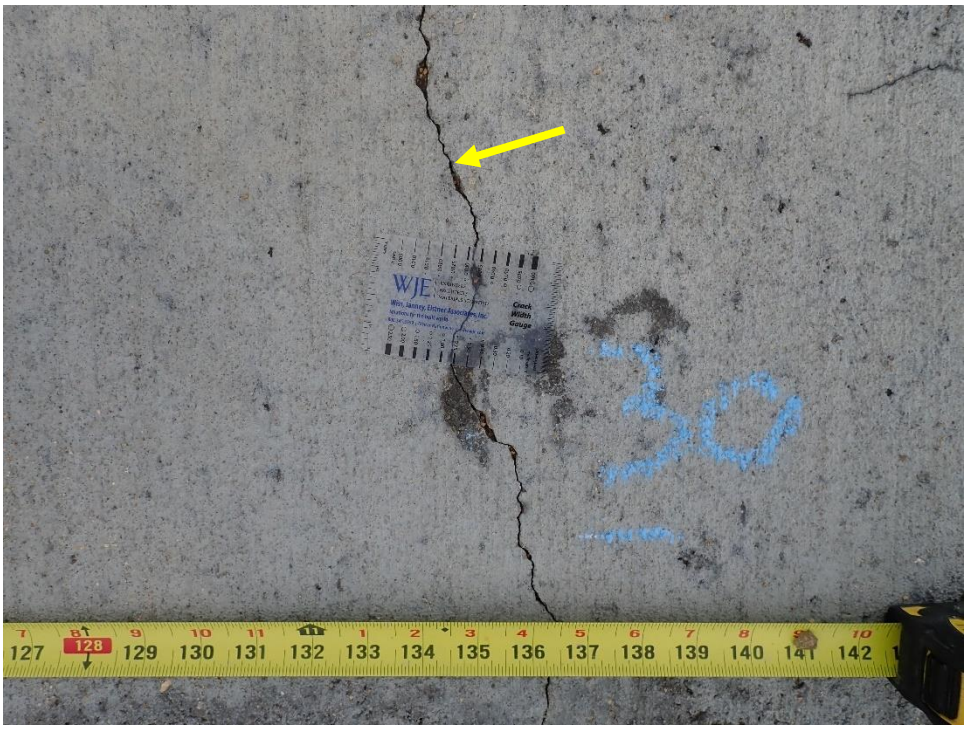

Figure 6.7. Close-up photo of a transverse crack in Patch No. 1 (Yellow arrow). Crack width = 30 mils.

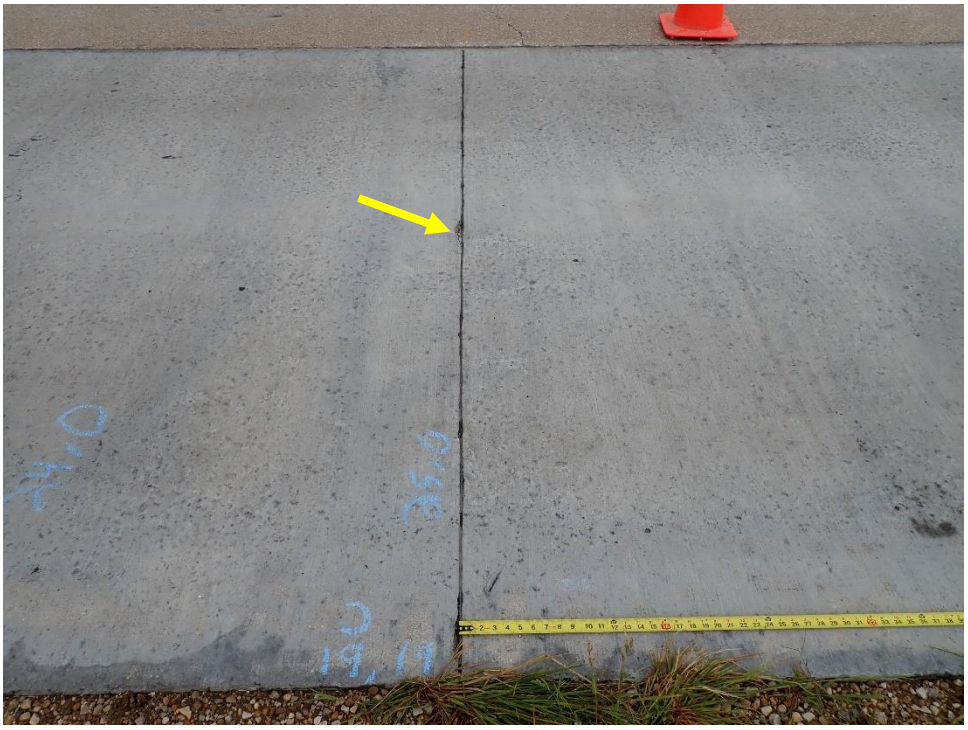

Figure 6.8. Transverse joint exhibiting minor raveling (Yellow arrow). (Patch No. 2)

Figure 6.9. Corner break in Patch No. 2, fourth transverse joint from east end.

6.2.3. Patch No. 3 (Standard M-Mix)

This patch is in poor condition. The shoulder edge break in the middle panel observed in 2020 has deteriorated and shattered, and two new corner breaks occurred in this panel and an adjacent panel to the west. These edge and corner breaks are located in the wheel paths of vehicles going in/out of M Avenue (unpaved road) from/to the west of Highway D41 (Figure 6.10). Fill materials in the unpaved road in M Avenue have loosened and eroded. The deterioration and development of these edge breaks appear to be caused by a lack of edge support combined with excessive edge loadings (see Figure 6.10 and Figure 6.11). It should be noted this patch receives frequent and heavy loading from the sanitization trucks the travel along M avenue.

New transverse cracks occurred in all three pavement panels, and new longitudinal cracks occurred in two of the panels. The spacing of transverse cracks within a panel is approximately 8 to 9 feet, and the distance from transverse cracks to an adjacent transverse joint is approximately 5 to 11 feet. Transverse crack width varies from 20 to 50 mils. The longitudinal cracks are generally along the centerline of the lane with crack widths varying from 5 to 35 mils. Examples of cracks in Patch No. 3 are shown in Figure 6.12 and Figure 6.13. A crack map with notes on crack widths is presented in Appendix D. Potential causes for the transverse and longitudinal cracks include excessive shrinkage, transverse/longitudinal joint lockup due to inadequate dowel coating or dowel misalignment, overloading, inadequate subgrade support, and inadequate slab thickness.

Transverse and longitudinal joints are generally in satisfactory conditions with minor raveling. An example of transverse joint in Patch No. 3 is shown in Figure 6.14. GPR scanning performed at representative transverse dowelled joints indicates that locations of the dowels are generally consistent with the design.

No voiding underneath the concrete slab was indicated in the GPR scanning.

Figure 6.10. Edge and corner breaks (yellow arrows) in wheel paths of vehicles going in/out of M Avenue. Fill materials have loosened and eroded (red arrows).

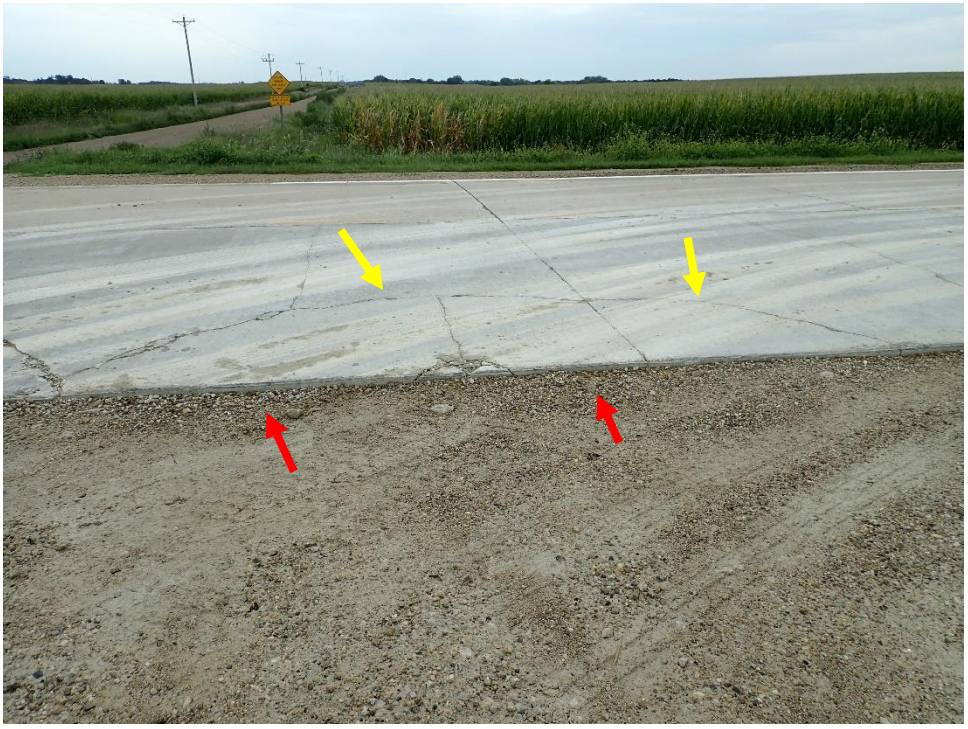

Figure 6.11. Corner breaks (yellow arrows) on the edge of the patch facing the unpaved road on M Avenue. Fill materials have loosened and eroded (red arrows).

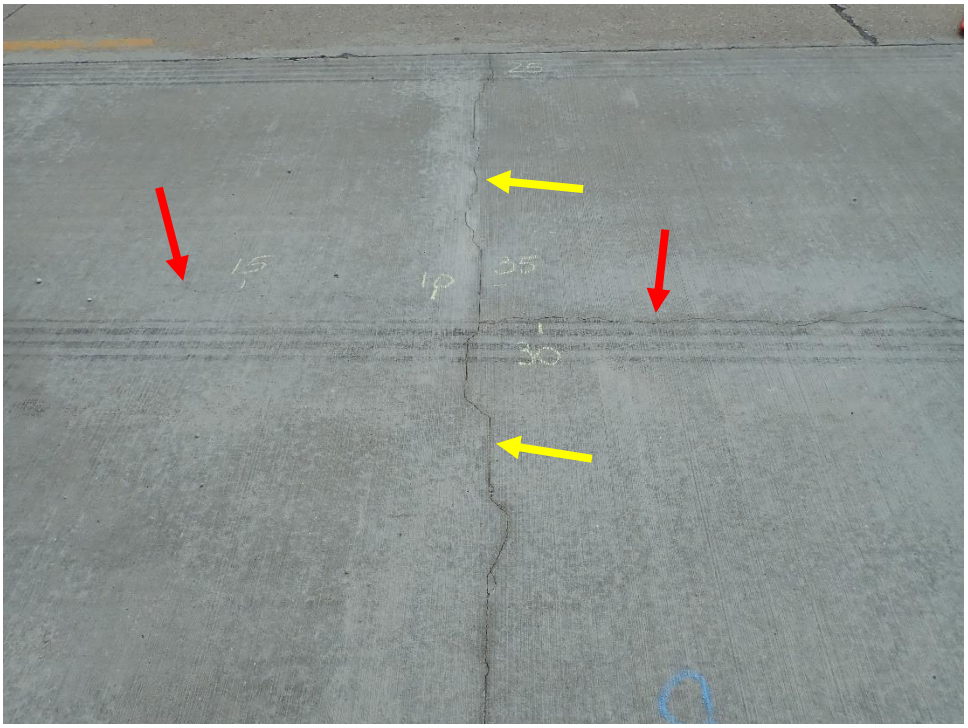

Figure 6.12. Transverse cracks (yellow arrows) and longitudinal cracks (red arrows) in the middle panel in Patch No. 3.

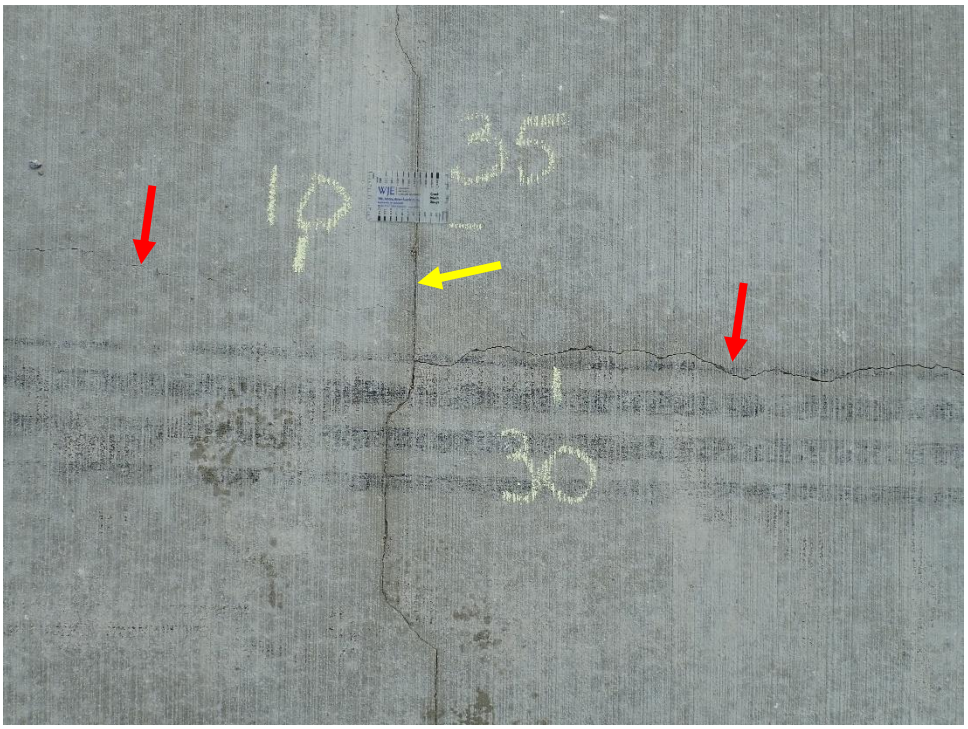

Figure 6.13. Close-up photo of a transverse crack (yellow arrow) and longitudinal cracks (red arrows). Numbers in yellow chalk indicate crack widths. (Middle panel in Patch No. 3).

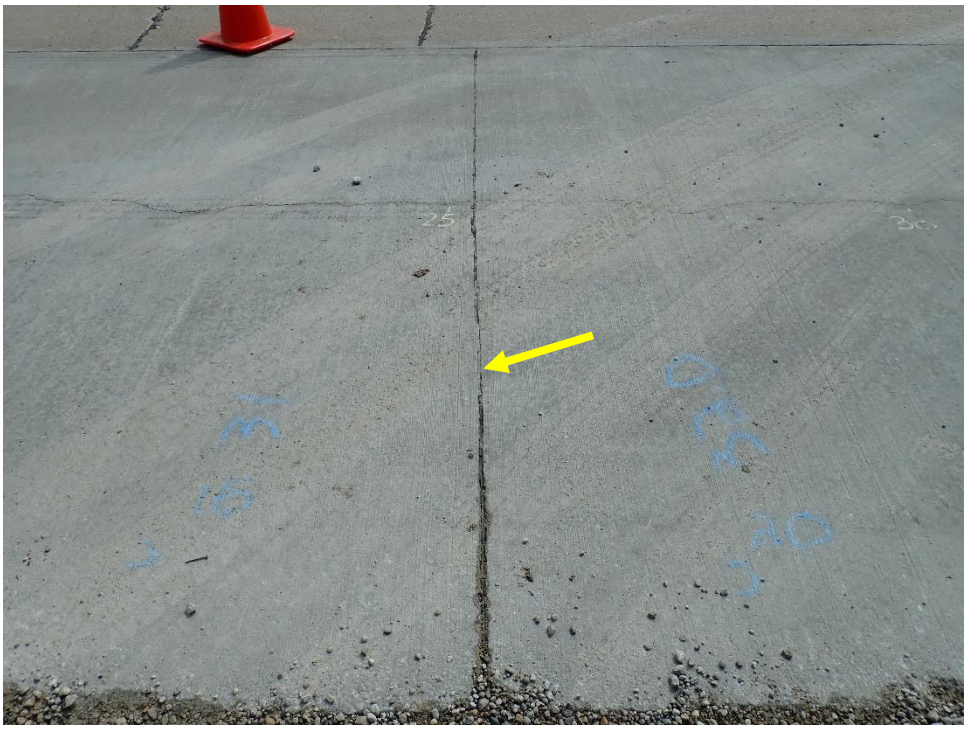

Figure 6.14. Transverse joint exhibiting minor raveling (Yellow arrow). (Patch No. 3)

6.2.4. Patch No. 4 (Alternate M-Mix)

This patch is in good condition with no cracks observed. A photo showing typical condition of Patch No. 4 is provided in Figure 6.15. A plan of the patch is presented in Appendix D.

Transverse and longitudinal joints are generally in satisfactory conditions with very minor raveling. An example of transverse joint in Patch No. 4 is shown in Figure 6.15. GPR scanning performed at representative transverse dowelled joints indicates that locations of the dowels are generally consistent with the design.

No void underneath the concrete slab was indicated in the GPR scanning.

Figure 6.15. Patch No. 4 typical condition. No cracks observed. Transverse joint in good condition with very minor raveling (Yellow arrow).

6.2.5. Patch No. 5 (Alternate M-Mix)

This patch is in similar condition to Patch No. 4 with no cracks observed. A photo showing typical condition of Patch No. 5 is provided in Figure 6.16. A plan of the patch is presented in Appendix D.

Transverse and longitudinal joints are generally in satisfactory conditions with very minor raveling. An example of transverse joint in Patch No. 5 is shown in Figure 6.16. GPR scanning performed at representative transverse dowelled joints indicates that locations of the dowels are generally consistent with the design.

No voiding underneath the concrete slab was indicated in the GPR scanning.

Figure 6.16. Patch No. 5 typical condition. No cracks observed. Transverse joint in good condition with very minor raveling (Yellow arrow).

6.3. Discussion/Recommendations

6.3.1. Causes of Cracking

Both Patch Nos. 1 and 3 using Standard M-Mix exhibited similar new transverse and longitudinal cracks occurring after the initial evaluation in 2020. It appears that both the transverse and longitudinal cracking may be related to restraint of volumetric movement. It has been known that high early strength concrete mixtures with calcium chloride accelerator have significantly higher early-age as well as final drying shrinkage than similar mixtures without an accelerator [35]. The high cement contents in Standard M-Mix also contribute to the increased drying shrinkage compared with conventional pavement concrete mixtures.

Performance of the patches using Alternative M-Mix vary. Patch No. 2 exhibited transverse cracks but no longitudinal cracks while Patch Nos. 4 and 5 did not have any cracks. It appears that the new transverse cracks in Patch No. 2, which occurred after the initial evaluation in 2020, are also related to dry shrinkage. Although high early strength concrete mixtures using non-chloride accelerator; such as the Alternate M-Mix, may have less drying shrinkage than mixtures using calcium chloride [35], they still have higher shrinkage than conventional concrete mixtures for pavement due to the high cement content. The better performance of Patch Nos. 4 and 5 could be attributed to the smaller transverse joint spacing, which helps reduce tensile stresses caused by concrete drying shrinkage.

In addition to concrete drying shrinkage, other potential causes for the cracks observed in the trial full depth repairs include transverse joint lockup due to inadequate dowel coating or dowel misalignment, overloading, inadequate support, and inadequate slab thickness.

6.3.2. Recommendations

Based on results of the trial repairs, the following are recommended by the authors for full depth pavement repairs in Iowa, in addition to the recommendations discussed in Section 5.3:

- The Alternative M-Mix is preferred over the Standard M-Mix due to the potentially higher drying shrinkage of the Standard M-Mix.
- For repairs using high early strength concrete mixtures such as the Alternate M-Mix and Standard M-Mix, a reduced maximum transverse joint spacing should be considered. The current 20-foot transverse joint spacing limit by Iowa DOT seems too long, and pavement patches with such joint spacing would likely result in transverse cracks similar to those observed in Patch Nos, 1, 2, and 3 in the trial repairs. For pavements with thickness and subbase conditions similar to those in the trial repairs, the maximum transverse joint spacing should be limited to about 10 to 12 feet to minimize cracking caused by the increased drying shrinkage of the high early strength concrete. For pavements with thickness and subbase conditions different from those in the trial repairs, additional research is needed to determine an appropriate maximum transverse joint spacing.
- A tied transverse contraction joint at the end of the patch where the tie bars are embedded into the existing pavement ('RT' joint) should only be used if the distance from the end of the patch to an adjacent doweled transverse joint in the patch does not exceed 5 feet. If this distance exceeds 5 feet, a doweled transverse joint ('RD' joint) should be used at the end of the patch. This is to minimize the potential transverse cracking in the end panel like those observed in the west end panel at Patch No. 1 and the east end panel at Patch No. 2.
- Increasing spacing and/or decreasing size of the tie bars at longitudinal joints between new and existing concrete should be considered to minimize restraint to longitudinal movement of the new concrete, which could help reduce transverse cracking.
- Adequate coating and proper installation of dowels at transverse joints should be checked during construction to avoid joint lock-up.

7. WEB-BASED APPLICATION

WJE developed of a user-friendly, web-based application to communicate the recommended materials, drawings, practices and QA/QC procedures to personnel designing, inspecting, and performing repairs on Iowa DOT pavements. The goal of the application is to provide guidance regarding the selection of patching materials, the definition and preparation of the patch area, the details of the repairs, the installation of the repair, and the associated QA/QC procedures and reporting. A link to this application is here.

8. SUMMARY OF RECOMMENDATIONS

8.1. Full-Depth Repairs

Based on the literature review and trial repairs performed during this applied research project, the following practices are recommended by the authors to supplement Iowa DOT standard practices in full depth concrete pavement repairs.

8.1.1. Materials

- It is recommended that Iowa DOT use non-chloride accelerators as opposed to calcium chloride (or other chloride containing accelerators) for enhanced yearly strength gain.
- It is recommended that the non-chloride accelerating admixture be added once the ready mix truck reaches the job site. The working time associated with the use of non-chloride accelerating admixtures and these high cement content mixes is less than 30 minutes, so addition on site will be needed. Future research on the site addition of hydration stabilizers alongside the NCAs is recommended (see below).
- Use an Alternative M-Mix in lieu of the Standard M-Mix because of its higher early strengths, use of non-chloride accelerators, and lower shrinkage potential. The Alternative M-Mix used in the trial repairs had a cement content of 870 lbs., fine aggregate content of 45% (by weight of total aggregate), and w/c of 0.32, and utilized a high range water reducer, non-chloride accelerating admixture, and air entraining admixture.
- Based on the field trial of full-depth repair mixes, it is feasible to have an off-the-shelf mix that can be specified in Iowa DOT specifications for 10 and 24 hour traffic openings. For the 5-hour opening time to traffic, mix designs will likely have to be developed specifically project-to-project and/or supplier-to-supplier.

8.1.2. Design

- Reduce the maximum transverse joint spacing for pavement repairs using high early strength concrete mixtures; such as the Alternate M-Mix and Standard M-Mix. For pavements with thickness and subbase conditions similar to those in the trial repairs, a maximum transverse joint spacing of 10 feet is recommended to minimize cracking caused by the increased drying shrinkage of the high early strength concrete compared with conventional PCC. The current 20-foot transverse joint spacing limit by Iowa DOT seems too long, and pavement patches with such joint spacing would likely result in significant transverse cracking.
- Use a doweled transverse joint ('RD' joint), instead of a tied transverse contraction joint, at the end of the patch unless the distance from the end of the patch to an adjacent doweled transverse joint in the patch is equal to or less than 5 feet in which a tied transverse contraction joint may be used with the tie bars embedded into the existing pavement ('RT' joint). This is to minimize the potential for transverse cracking in the end panel.
- Reduce the amount of tie bars at longitudinal joints between new and existing concrete by increasing spacing and/or decreasing size to minimize restraint to longitudinal movement of the new concrete, which could help reduce transverse cracking.

- Use a minimum repair length of 6 feet for jointed plain concrete pavements to minimize rocking, pumping, and break-up.
- Avoid leaving a remaining slab panel less than 5 feet long. If a patch boundary is less than 5 feet from an existing transverse joint, extend the boundary to the joint.
- Combine two patches less than 8 feet apart into a single larger repair to be more cost effective by reducing the number of transverse joints.

8.1.3. Construction

- Use sufficient bond-inhibiting materials on dowels and check dowel alignment at transverse joints during construction to avoid additional restraint at joints. Dowel suppliers typically coat dowel bar baskets with a bond inhibiting agent, ensure this practice is done on dowels supplier to full-depth repair projects.
- When high early strength concrete mixes are used, saw-cut transverse joints within 5 hours after finishing operations are complete to minimize the potential for transverse cracking caused by the increased thermal contraction and shrinkage during the early ages of these mixes as compared with conventional concrete mixes. Based on the full-depth trial repairs, early age saw cutting could be done as early as 1-hour for the mixes used and ambient conditions.
- Saw-cut transverse joints to a depth of one third of the slab thickness while avoiding cutting into dowels or tie bars. A sufficient saw-cut depth is important for the joint to be activated, which will minimize the potential for transverse cracking.

8.2. Partial Depth Repairs

Based on the literature review and DOT survey performed in this project, the following practices are recommended by the authors to supplement Iowa DOT standard practices in partial depth concrete pavement repairs.

8.2.1. Materials

- Customized PCC mixes and proprietary concrete mixes are available for partial depth repairs with some positive results as reported in the DOT survey. Several promising materials are presented in Section 4 of the report for Iowa DOT consideration; however, additional research that includes trial repairs should be performed to demonstrate performance of these materials.

8.2.2. Patch Geometry

General recommendations on geometry of all patches and specific recommendations for different types of patches are presented below, including patches at transverse/longitudinal joint or crack, patches not at joint or crack, and over-depth patches.

General recommendations:

- Use rectangular patches including over-depth patches.
- Extend patch boundaries at least 3 inches beyond deteriorated concrete boundary determined visually or by sounding techniques to ensure all unsound concrete is removed.

- Keep vertical edges along patch boundaries, as opposed to 30-to-60-degree edges as in current Iowa DOT practices, to minimize debonding of the patch from existing pavement. This can be accomplished by saw-cutting perpendicular to the surface of the pavement along the patch perimeter and removing the remaining unsound material by chipping.

Patches not at transverse or longitudinal joint or crack:

- Use patches of at least 12 inches in each direction.
- Locate edges of patch at least 12 inches from transverse and longitudinal joints. If an edge of patch must be less than 12 inches from the joints to remove all unsound concrete extends, extend the edge to the joint.

Patches at transverse or longitudinal joints or cracks:

- Use a patch length of at least 12 inches in the direction of the joint or crack, and a patch width of at least 12 inches on the side of the joint or crack that needs repairing.

Over-depth patches:

- When removal to one half of pavement thickness leaves unsound concrete within the patch area, remove the concrete for the full depth of the existing pavement and perform a full-depth patch. The patch shall be generally rectangular and at least 4 feet in each direction. 'BT-3' joints shall be used on edges of patch with No. 5 tie bars inserted into existing pavement with at least 9-inch embedment and extended 15 inches into the patch and spaced at 30 inches on centers.

8.3. Summary of Recommendations for Future Research for Iowa DOT

Additional research for full-depth pavement repairs is recommended for Iowa DOT, including the following:

- A disadvantage of the Alternative M Mix used in the trial full-depth repairs was the quick loss of workability (slump) after the addition of high range water reducers and non-chloride accelerators on-site. Additional research on the use of hydration stabilizers for these mixes is recommended, with the use of hydration stabilizers being added on-site as well. WJE's experience with hydration stabilizers at appropriate dosages is associated with extending the slump life (workability) without negatively impacting the early age strength development.
- As mentioned above, a maximum transverse joint spacing of 10 feet is recommended for pavements with thickness and subbase conditions similar to those in the trial repairs. For pavements with different thickness and subbase conditions, further research is recommended to determine an appropriate maximum transverse joint spacing.
- Additional research is recommended to evaluate potential benefits of reducing the amount and size of tie bars at longitudinal joints between new and existing concrete in reducing transverse cracking.

In the current project, several PCC and proprietary materials and changes to current practice by Iowa DOT were suggested for partial depth repairs; however, trial repairs were not performed to demonstrate performance of these materials due to lack availability of trial projects. Additional research that includes a trial repair program similar to that performed for full depth repairs in the current project is recommended.

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APPENDIX A. DOT SURVEY REPORTS

Survey: Concrete Pavement Full- and Partial-Depth Repair Procedures

Distributed to Midwest DOTs

This survey is part of an ongoing research plan funded by the Iowa Highway Research Board (IHRB), "Improving Concrete Patching Procedures in Iowa Roadways" (TR-731). The survey is expected to take no more than 10 minutes of your time. We appreciate your time and feedback in completing the following Form. The final results of this research program will be made available to all parties.

1. What materials do you use for partial depth repairs of concrete pavements? (Check all that apply)
   - ☐ Asphalt patching material
   - ☐ Normal portland cement mixtures (with or without accelerators)
   - ☐ High early strength portland cement concrete mixtures
   - ☐ Other rapid setting cement mixtures (e.g., calcium aluminate, calcium sulfoaluminate, magnesium phosphate)
   - ☐ Epoxy mixtures
   - ☐ Polymer concrete
   - ☐ Proprietary materials (please specify) _____
   - ☐ Other (please specify) _____

2. What materials do you use for full-depth repairs of concrete pavements? (Check all that apply)
   - ☐ Asphalt patching material
   - ☐ Normal portland cement mixtures (with or without accelerators)
   - ☐ High early strength portland cement concrete mixtures
   - ☐ Other rapid setting cement mixtures (e.g., calcium aluminate, calcium sulfoaluminate, magnesium phosphate)
   - ☐ Epoxy mixtures
   - ☐ Polymer concrete
   - ☐ Proprietary materials (please specify) _____
   - ☐ Other (please specify) _____

3. What is your experience with proprietary patching materials for concrete pavement repairs?
   - ○ My organization regularly uses these materials for concrete pavement repairs.
   - ○ My organization allows these materials to be used for concrete pavement repairs, but they are not typically used.
   - ○ My organization does not currently allow these materials to be used for concrete pavement repairs, but is considering using them.
   - ○ My organization does not currently use these materials.

4. How effective have proprietary materials been in meeting your expectations?

1	2	3	4	5	N/A
Does not meet expectations	Meets some expectations	Meets most expectations	Meets all expectations	Exceeds expectations	No direct experience
○	○	○	○	○	○

a) Comments:
_____
_____

b) Please identify any products that have performed particularly well and/or rather poorly:

Preformed well: _____

Preformed poorly: _____

5. What is your anticipated service life for partial depth patches? _____

6. What is your anticipated service life for full depth patches? _____

7. Does your organization have established procedures for the following:

a. Determining boundaries of the repair area	○ Yes	○ No
b. Preparing the concrete surface	○ Yes	○ No
c. Placing and consolidating the patch material	○ Yes	○ No
d. Curing the repair area	○ Yes	○ No
e. Sealing cracks	○ Yes	○ No
f. Sealing joints	○ Yes	○ No

Comments: _____

8. Does your organization have any quality control and quality assurance procedures for contract patching projects?

○ No.
○ Yes.
If yes, what activities do you closely monitor and document and what properties do you measure?
_____
_____

9. Does your organization have any training materials or aides for the patching crews and/or for your inspection staff?

○ No.
○ Yes.
If it is on your web site, please provide a link.
_____
_____

10. How do you evaluate the performance of installed patches? (Check all that apply)
    - ☐ Visual observation
    - ☐ Ride quality
    - ☐ Sounding
    - ☐ Physical testing (please specify) _____
    - ☐ Other (please specify) _____
    - ☐ Performance is not evaluated after installation

11. What has been the most effective patching material and technique for your common pavement distresses?

    _____

    _____

12. Based on your experience, please rate the performance of partial depth patches in your area that are made using the following materials:

	1 Poor	2 Fair	3 Average	4 Good	5 Excellent	N/A Not applicable
a. Asphalt patching material	○	○	○	○	○	○
b. Normal portland cement mixtures	○	○	○	○	○	○
c. High early strength portland cement concrete mixtures	○	○	○	○	○	○
d. Other rapid setting cement mixtures	○	○	○	○	○	○
e. Epoxy mixtures	○	○	○	○	○	○
f. Polymer concrete	○	○	○	○	○	○
g. Proprietary materials (please specify) _____	○	○	○	○	○	○
h. Other (please specify) _____	○	○	○	○	○	○

13. Based on your experience, please rate the performance of full-depth patches in your area that are made using the following materials:

	1 Poor	2 Fair	3 Average	4 Good	5 Excellent	N/A Not applicable
a. Asphalt patching material	○	○	○	○	○	○
b. Normal portland cement mixtures	○	○	○	○	○	○
c. High early strength portland cement concrete mixtures	○	○	○	○	○	○
d. Other rapid setting cement mixtures	○	○	○	○	○	○
e. Epoxy mixtures	○	○	○	○	○	○
f. Polymer concrete	○	○	○	○	○	○
g. Proprietary materials (please specify)_____	○	○	○	○	○	○
h. Other (please specify) _____	○	○	○	○	○	○

14. Based on your experience, what types of patch failures are typically encountered in your area? Please provide as much detail as possible (e.g., partial depth vs. full depth repair, installation problem vs. material durability problem, proximity to joints, type of materials used, type of distress observed, etc.).

15. Please provide your name, agency and department below.

☐ Name - _____

☐ Agency - _____

☐ Department -_____

As a follow-up to this survey, would you be interested in additional email correspondence and/or a follow-up phone conversations to further assist the investigators in this research? If yes, please provide a phone number and/or email address where we may contact you.

☐ Email correspondence - _____

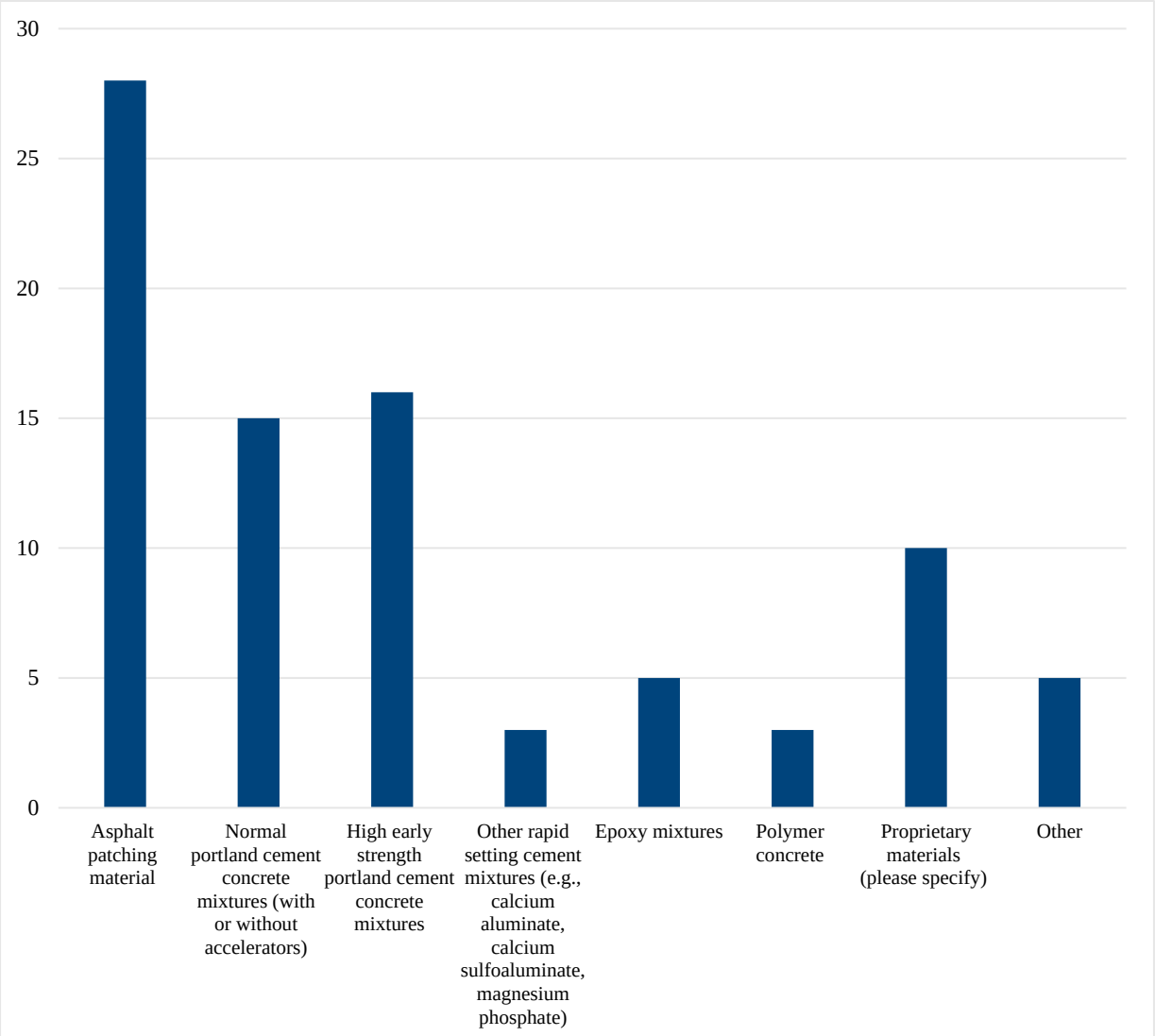
☐ Phone - _____

Thank you very much for your time and input!

Response to Survey Question 1: What materials do you use for partial depth repairs of concrete pavements? (Check all that apply)

Possible Answers:

- Asphalt patching material
- Normal portland cement mixtures (with or without accelerators)
- High early strength portland cement concrete mixtures
- Other rapid setting cement mixtures (e.g., calcium aluminate, calcium sulfoaluminate, magnesium phosphate)
- Epoxy mixtures
- Polymer concrete
- Proprietary materials (please specify)
- Other (please specify)



Response to Survey Question 1: Continued - Proprietary Materials

Response		
CTS & Futura 15		
Hot applied-thermal set		
TechCrete and Mastic One by Crafco; Fiber Crete; Aqua Patch by Tensar; FlexKRETE		
Quick setting concrete mortar extended with aggregates.		
Techcrete		
TechCrete and PolyPatch		
Techcrete a Crafto Product, Mastic1 a Crafto Product		
Crafco Techcrete		
Fibrecrete		
Techcrete		
	Valid Responses	10
	Total Responses	34

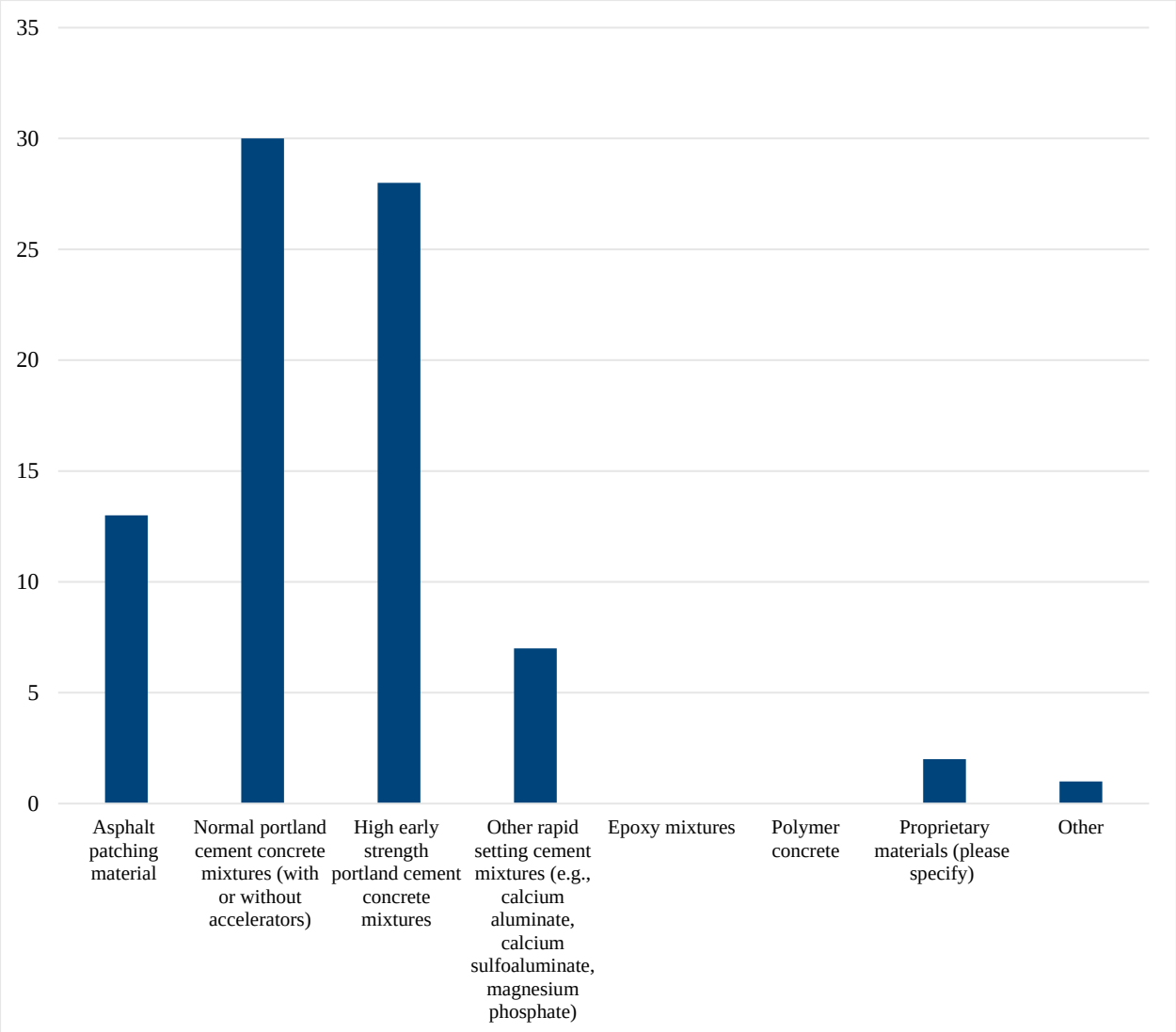
Response to Survey Question 1: Continued - Other

Response		
Mastic from CRAFCO		
Cold Patch		
District 2 doesn't do partial depth repair of concrete pavement		
Recessed mastic type materials		
Asphalt and other related materials are only used in short term instances. Epoxy is used for very small repairs due to cost and application		
	Valid Responses	5
	Total Responses	34

Response to Survey Question 2: What materials do you use for full-depth repairs of concrete pavements? (Check all that apply)

Possible Answers:

- Asphalt patching material
- Normal portland cement mixtures (with or without accelerators)
- High early strength portland cement concrete mixtures
- Other rapid setting cement mixtures (e.g., calcium aluminate, calcium sulfoaluminate, magnesium phosphate)
- Epoxy mixtures
- Polymer concrete
- Proprietary materials (please specify)
- Other (please specify)



Response to Survey Question 2: Continued - Proprietary Materials

Response		
Quick setting concrete mortar extended with aggregates.		
Techcrete a Crafto Product, Mastic1 a Crafto Product, Mastico Maxwell		
	Valid Responses	2
	Total Responses	34

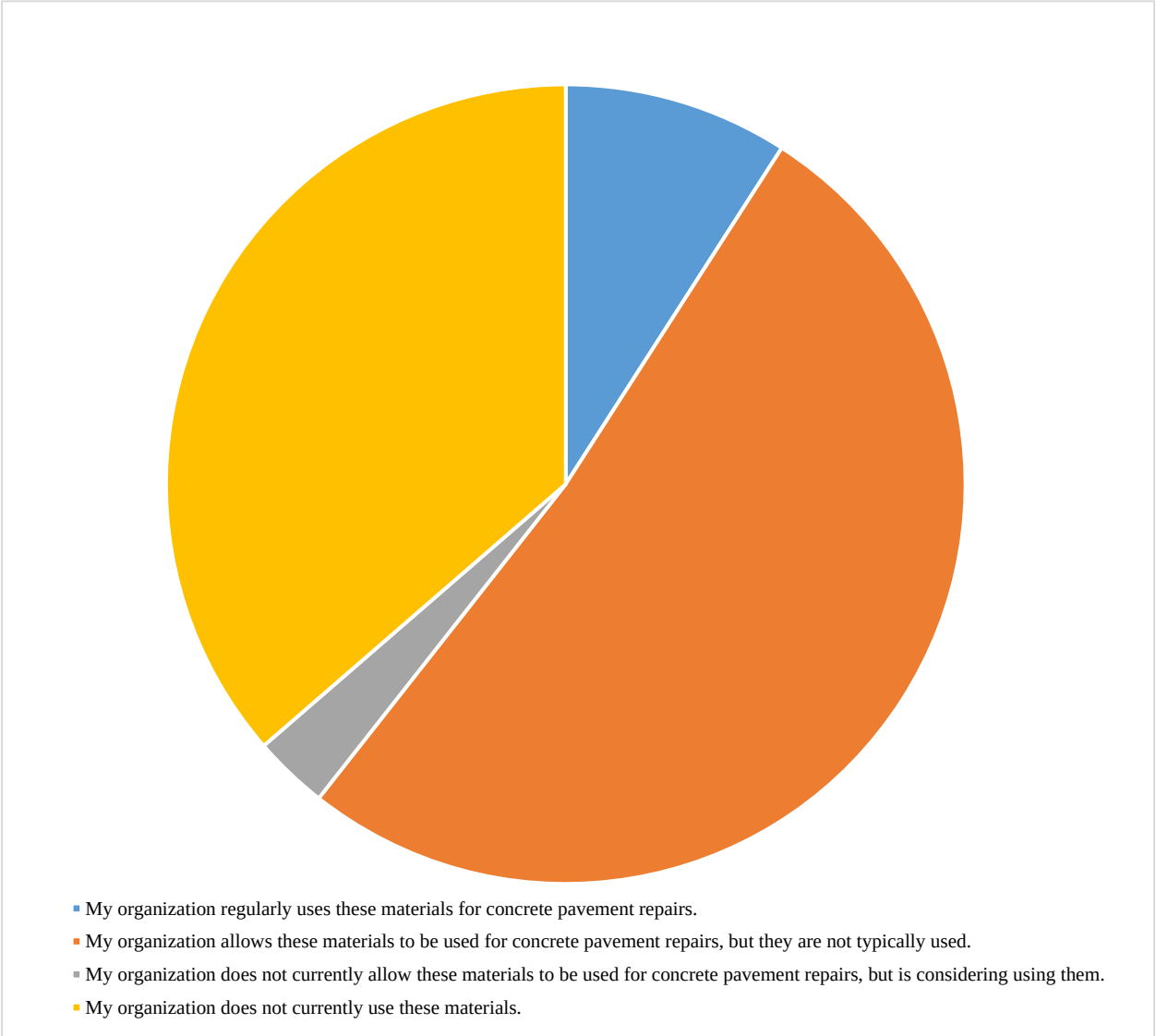
Response to Survey Question 2: Continued - Other

Response		
Precast panels		
	Valid Responses	1
	Total Responses	34

Response to Survey Question 3: What is your experience with proprietary patching materials for concrete pavement repairs?

Possible Answers:

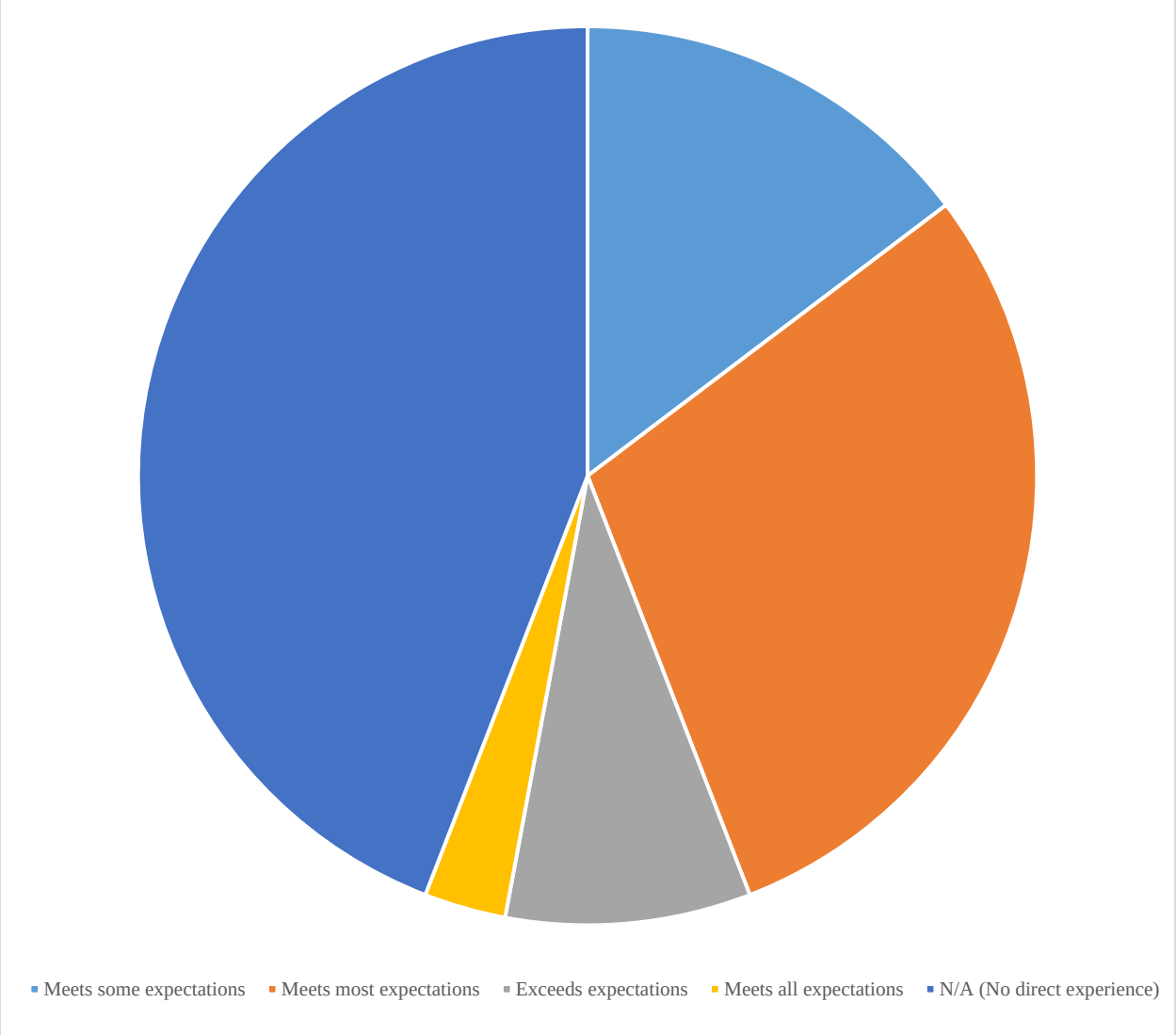
- My organization regularly uses these materials for concrete pavement repairs.
- My organization allows these materials to be used for concrete pavement repairs, but they are not typically used.
- My organization does not currently allow these materials to be used for concrete pavement repairs, but is considering using them.
- My organization does not currently use these materials.



Response to Survey Question 4: How effective have proprietary materials been in meeting your expectations?

Possible Answers:

- Does not meet expectations
- Meets some expectations
- Meets most expectations
- Meets all expectations
- Exceeds expectations
- No direct experience



Response to Survey Question 4: Continued - Comments

Response		
Most patch material we have used is a short term fix. They do not perform well enough for long term repair.		
We have had some previous issues, but now have a prequalification (testing) protocol. Seems to have improved performance. Although, we are only 6 years into the prequalification program. So, the verdict is still under review.		
Have experienced concrete deterioration around the perimeter of repair that results in loss of repair material.		
Our Product Evaluations/Technical Studies unit has an Experimental Features process to look at proprietary materials.		
It depends on the type and brand of the specialty materials. Some are good, some are not meeting the expectations		
The longevity of the Techcrete verges on permanent repairs. Mastic also.		
Performance can vary based on the product, the workmanship, the condition of the substrate, the weather, etc.		
We mainly patch subdivision roads and when culverts do not cover, concrete backfill with the ride surface being concrete.		
This response is only referring to TechCrete		
Proprietary materials are used for specialized repairs (damaged concrete girders) but not typically used for large scale pavement repairs.		
Some minor bonding issues if prep area is not large enough		
Have used some polymer modified that works well. In a low bid environment, they are seldom used over traditional methods.		
I have seen some that have a "secrete" material. It also had around 1,000 lbs of cement/cu yrd. Long term durability is of course an issue.		
	Valid Responses	13
	Total Responses	34

Response to Survey Question 4: Continued - Please identify any products that have performed well

Response		
Mastic by Crafco has worked well for pothole or joint deterioration repairs. Any failures we've had is due to the surrounding concrete that it is bounded to failed.		
With the type of sub-base, salt usage and very heavy axle loads from liquid manure wagon and other very heavy implements of husbandry, no material works very well and many pavements have no drainage or sub-grade.		
Magnesuim Phosphate Concrete		
MnDOT's own mix design "3U18", CTS's "DOT Repair Mix" & WR Meadow's "Futura 15"		
Fiber Crete has exceeded expectations.		
Patches typically perform well.		
Techcrete		
Duracal, FastTrack, and special mixes from some contractors (probably 4 x 4)		
Hot mix asphalt, better is mastic, and better yet is Techcrete		
Mastic 1 Deery Recessed Mastic Techrete Fibracrete		
TechCrete		
Fibrecrete Tekcrete		
NDOT has an approved products list that you can refer to.		
Techcrete		
Fibercrete, Tekcrete		
Most Type III cement with CaCl perform well, best is to use conventional and give adequate time to achieve strength.		
	Valid Responses	16
	Total Responses	34

Response to Survey Question 4: Continued - Please identify any products that have performed poorly

Response		
Tech Crete material has had bonding issues. Also, we do not use accelerated (Calcium) concrete unless absolutely necessary. Repairs have short life due to cracking within the repair.		
Five Star		
Aqua Patch did not perform well in one instance.		
For confidentiality, we cannot answer the question		
cold mix gets you through to the next storm		
Most prepackaged fast-set concrete products		
N/A		
Operator errors on proportioning typically causes these issues.		
	Valid Responses	8
	Total Responses	34

Response to Survey Question 5: What is your anticipated service life for partial depth patches?

Possible Answers: Comments

Response		
Mastic 2-3 years,		
2 to 5 years if lucky		
2 yrs		
1 - 2 years		
5+ years		
7-10 years on HV roadways		
Until the next rehabilitation		
10 years		
Short term, say 3-years		
5 years		
10 to 15 years		
To the extent of the remaining pavement life		
5-8 years		
3-5 years		
5 to 10 years		
10+ years		
3+ years		
None used		
5+ years		
30		
10		
3-5		
10yrs/poly 2yrs/aph		
Varies: 5 years +		
10yrs		
2 years		
10+ years polyconcrete, 2 years asphalt		
Same as full if concrete does not have D-cracking/Chemical issues		
5 years		
	Valid Responses	29
	Total Responses	34

Response to Survey Question 6: What is your anticipated service life for full depth patches?

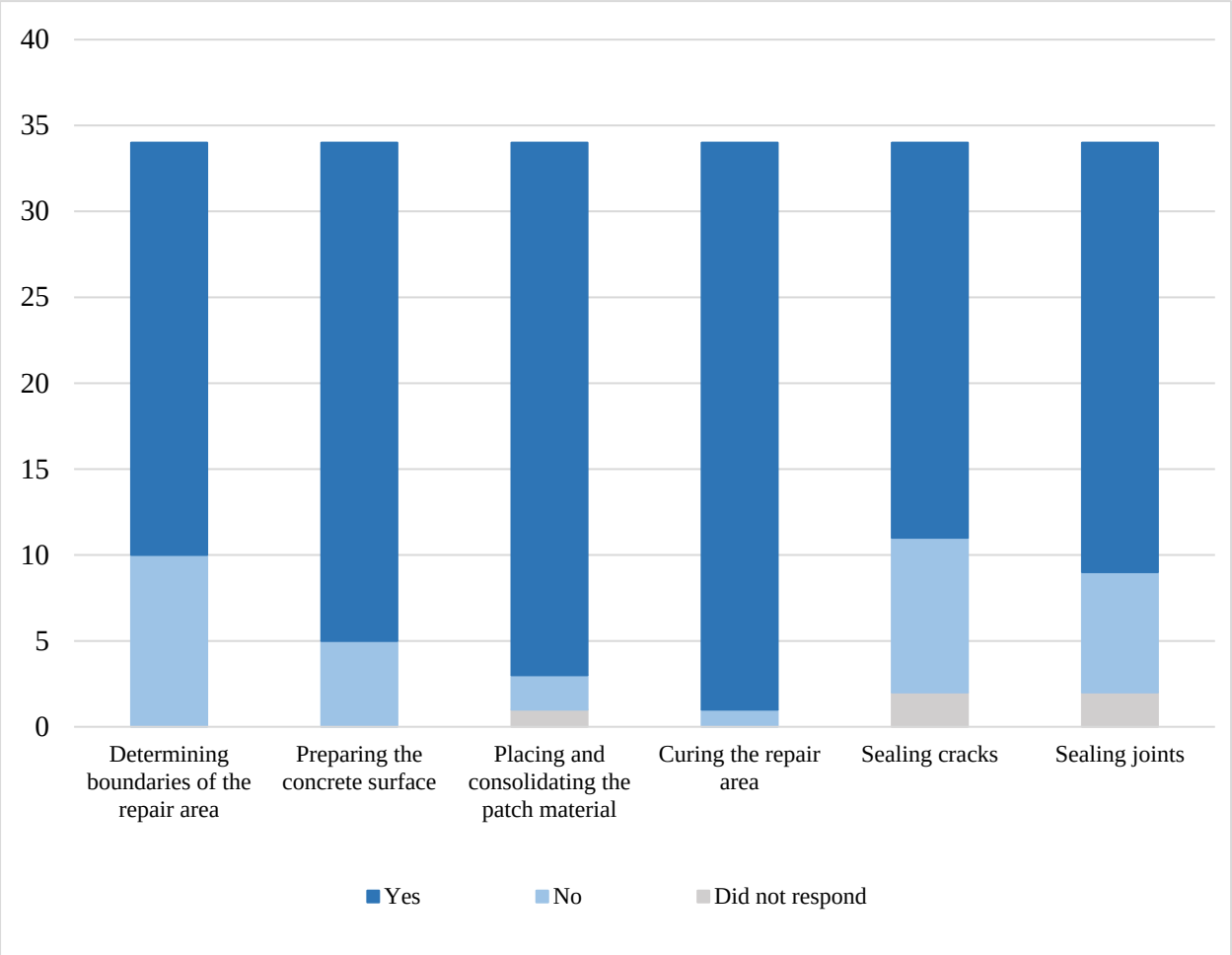
Possible Answers: Comments

Response		
15 years with 10% failure		
10 to 15 years		
20 years		
20 - 40 years		
With proper doweling should last as long as the pavement		
15 yrs		
15 years on HV roadways		
A minimum of 12 years		
12-15 years		
Match remaining life, +10-years		
15 years		
10 + years		
5 to 10 years		
To the extent of the remaining pavement life		
10-15 years		
15+		
7 to 12 years		
20+ years		
5+ years		
10-15 years		
10+ years		
30		
15		
7-10		
15yrs		
Varies: 5 years +		
25yrs		
10 years		
25 yr		
15+ years		
15 to 20 years		
20+ years		
	Valid Responses	32
	Total Responses	34

Response to Survey Question 7: Does your organization have established procedures for the following:

Possible Answers:

a. Determining boundaries of the repair area	Yes	No
b. Preparing the concrete surface	Yes	No
c. Placing and consolidating the patch material	Yes	No
d. Curing the repair area	Yes	No
e. Sealing cracks	Yes	No
f. Sealing joints	Yes	No

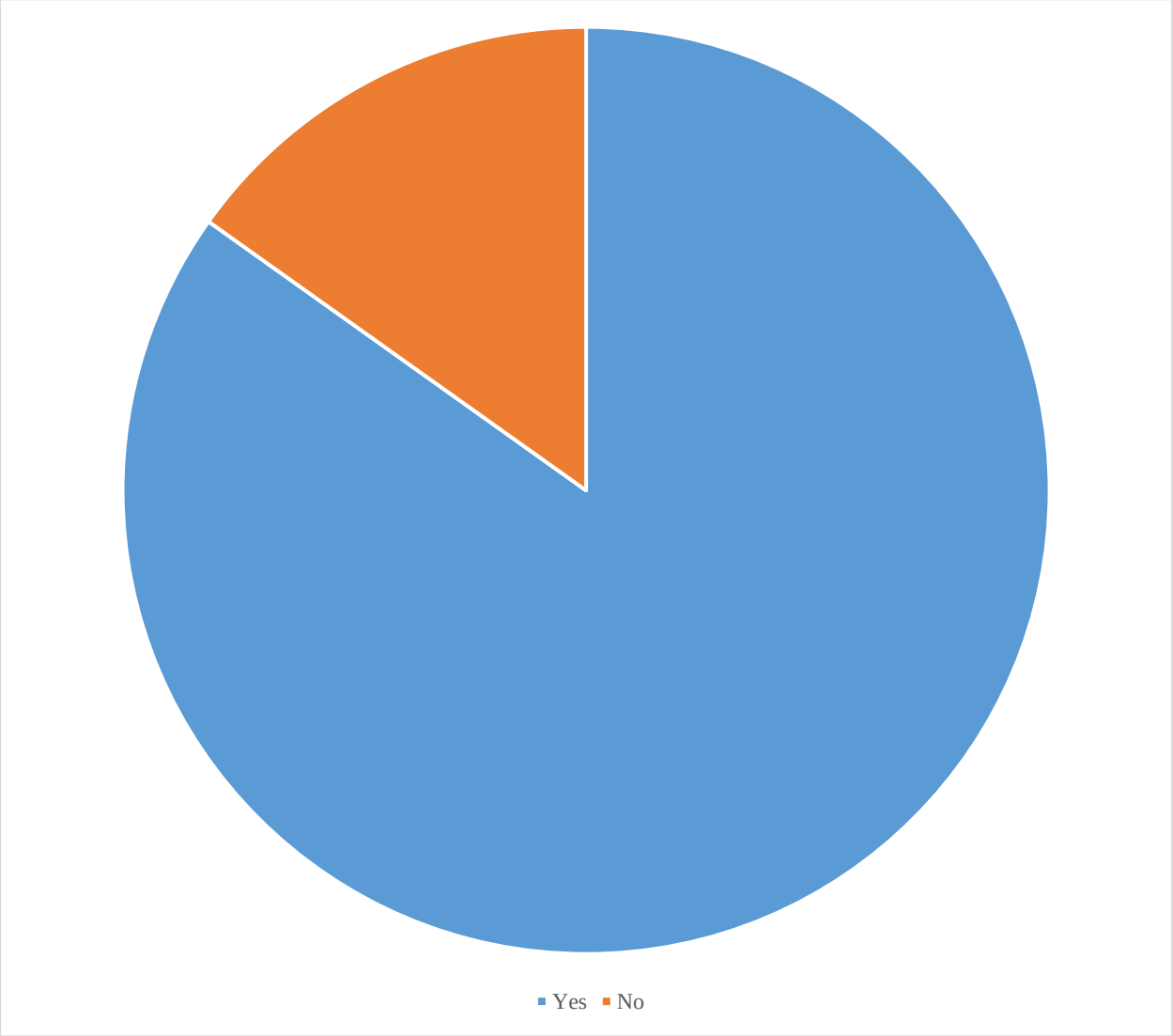


Response to Survey Question 7: Continued - Comments

Response		
We do not seal joints on our concrete pavement or joint replacement. Maintenance repairs have been completed concrete joint replacement due to buckles and installed felt with plastic caps on the drilled dowel bars to provide future relief. These joints are sealed. These are also standard in improvement projects at concrete bridge approaches.		
Not much consistent treatments or procedures were used in the past.		
Follow NCPTC 'Concrete Pavement Preservation Guide' & 'Partial Depth Repair Guide' for training and reference. Normally require compliance with 'IDOT Standard Specifications for Highway & Bridge Constr.' with modifications.		
Construction and material specifications: Partial Depth: Item 251, 256 Full Depth: Item 252 and 255 Link below to current version of specifications http://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Specifications/2016CMS/2016_CMS_01192018_for_web_letter_size_with_SS800_Included.pdf		
Full depth PCC patches only District 2 doesn't seal PCC patch cracks or joints		
Boundaries can vary based on the experience of the inspector.		
	Valid Responses	6
	Total Responses	34

Response to Survey Question 8: Does your organization have any quality control and quality assurance procedures for contract patching projects?

Possible Answers: Yes | No

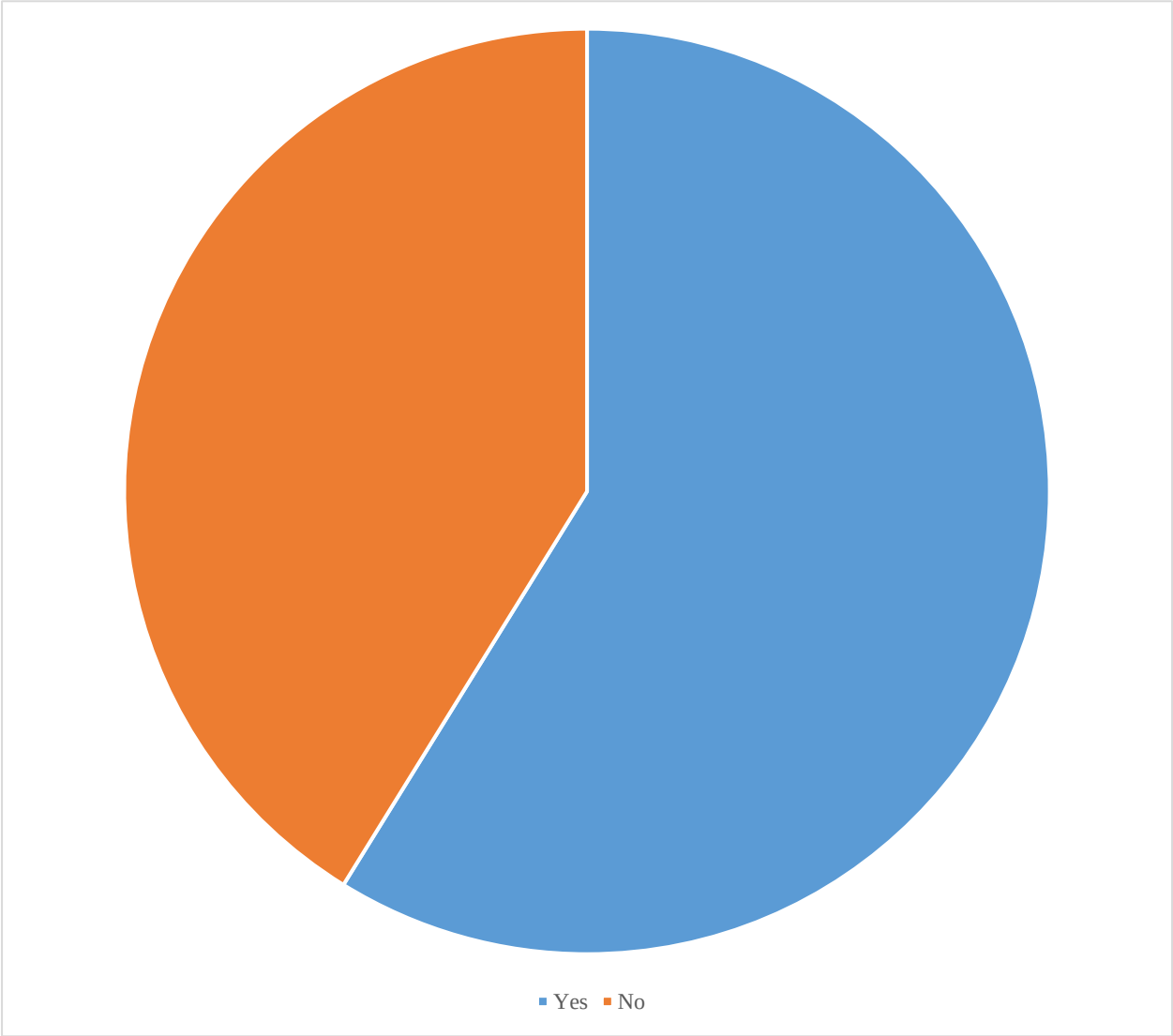


Response to Survey Question 8: Continued - If yes, what activities do you closely monitor and document and what properties do you measure?

Response		
Require state approved mix design including approved admixtures. Require air content, slump, opening cylinders, and quality verification cylinders at the time of placement.		
Sub-base preparations, thickness of patch, type of patch material used.		
Slump & air tests to meet IDOT specs.		
Concrete properties and placement methods.		
Document prep work, test concrete delivered to the site, follow IDOT specs.		
Sawing & removal, subgrade preparation, dowel drilling/placement, concrete placement & consolidatioin, cure and protection, sawing & sealing. Measure slump and air.		
Check all PDR's prior to backfilling and air and slump tests on MnDOT's repair mix.		
Repair area, material testing.		
Air content, strength, temperature and slump.		
Concrete - air, slump, compression.		
Strength (often flexural), air content, slump.		
We will typically measure air content, slump, and temperature for full depth concrete patches. If it is high early strength concrete we may waive the strength and slump requirements.		
Standard specs.		
Mixture Control is primary focus of the QC/QA. Documentation includes weather conditions, admixture dosages, etc. Measured properties include air, slump, mix temperature and strength.		
Air, slump, strength.		
Air, Opening time, prep work for dowels.		
Placing materials, temperature control, saw cutting times, maturity meter monitoring.		
On site inspection of repair, concrete testing (air, strength, etc.).		
Dowel bar placement, concrete strength, ride profile.		
Concrete air, slump, and compressive strength.		
All contract patching has QC/QA. from field inspection to lab testing of materials.		
Air content.		
Placing the materials, temperature, sawcutting times, maturity meter.		
We perform normal plastic concrete testing. We also test opening to traffic strength.		
Air, slump, compressive strength, coarse and fine aggregate gradations, moisture, absorption and mix designs.		
	Valid Response	25
	Total Responses	34

Response to Survey Question 9: Does your organization have any training materials or aides for the patching crews and/or for your inspection staff?

Possible Answers: Yes | No



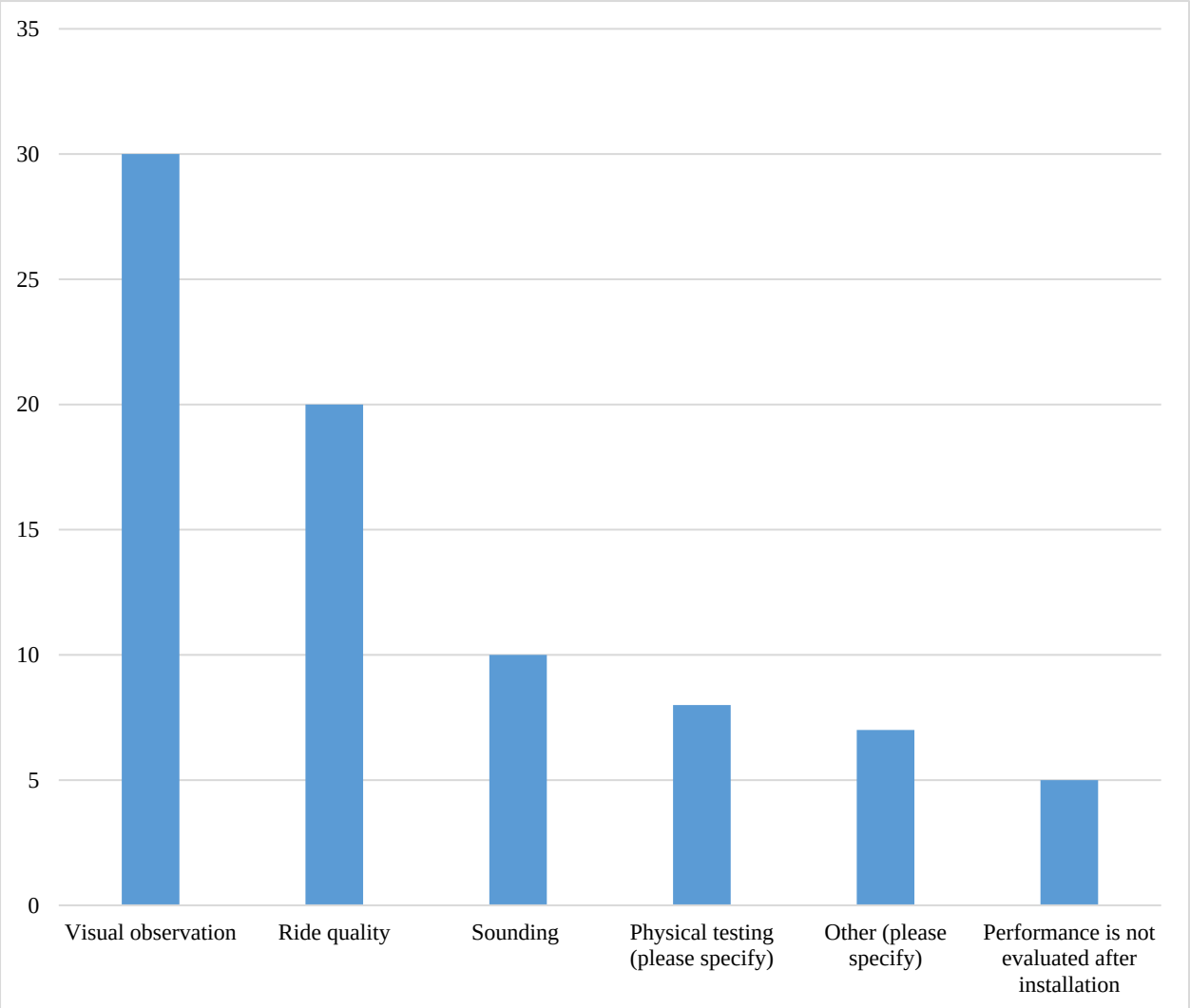
Response to Survey Question 9: Continued - If it is on your web site, please provide link:

Response		
We require certification for testing equipment and personnel.		
http://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Specifications/2017MOP/2017_MOP_Final_01202017_Letter_size_for_web.pdf		
Inspector Check List: http://www.idot.illinois.gov/Assets/uploads/files/Doing-Business/Specialty-Lists/Highways/Construction/Inspector-Checklists/Pavement%20Patching.		
OJT		
S18-Pavement Patching, Construction Inspectors Checklist for Pavement Patching, www.idot.illinois.gov/Assets/uploads/files		
Internal training in person		
ACI certifications		
N/A		
https://www.modot.org/missouri-standard-plans-highway-construction http://epg.modot.org/index.php/Category:613_Pavement_Repair		
Internal training sessions in person		
http://sharepoint/districts/d4/constructionandmaterials/kccmtt/sitepages/home.aspx		
	Valid Responses	11
	Total Responses	34

Response to Survey Question 10: How do you evaluate the performance of installed patches? (Check all that apply)

Possible Answers:

- Visual observation
- Ride quality
- Sounding
- Physical testing (please specify)
- Other (please specify)
- Performance is not evaluated after installation



Response to Survey Question 10: Continued - Physical testing (please specify)

Response		
Occasional cores if PDR's are found to be debonded		
In addition to opening to traffic strength, our standard patch concrete mixes (PP-1, PP-2, PP-3, PP-4, and PP-5) have to meet 600 psi flex or 3200 psi comp at 48, 24, 16, 8, and 4 hrs, respectively.		
Beams		
Shear and split tensile		
Strength specimens		
Straight Edge		
Cylinders/cores		
Compressive strength, air, slump		
	Valid Responses	8
	Total Responses	34

Response to Survey Question 10: Continued - Other (please specify)

Response		
Date stamp in new patch concrete		
Scanning electron microscope (for materials approval)		
Longevity of patches is watched		
Straight edge		
	Valid Responses	4
	Total Responses	34

Response to Survey Question 11: What has been the most effective patching material and technique for your common pavement distresses?

Possible Answers: Comments

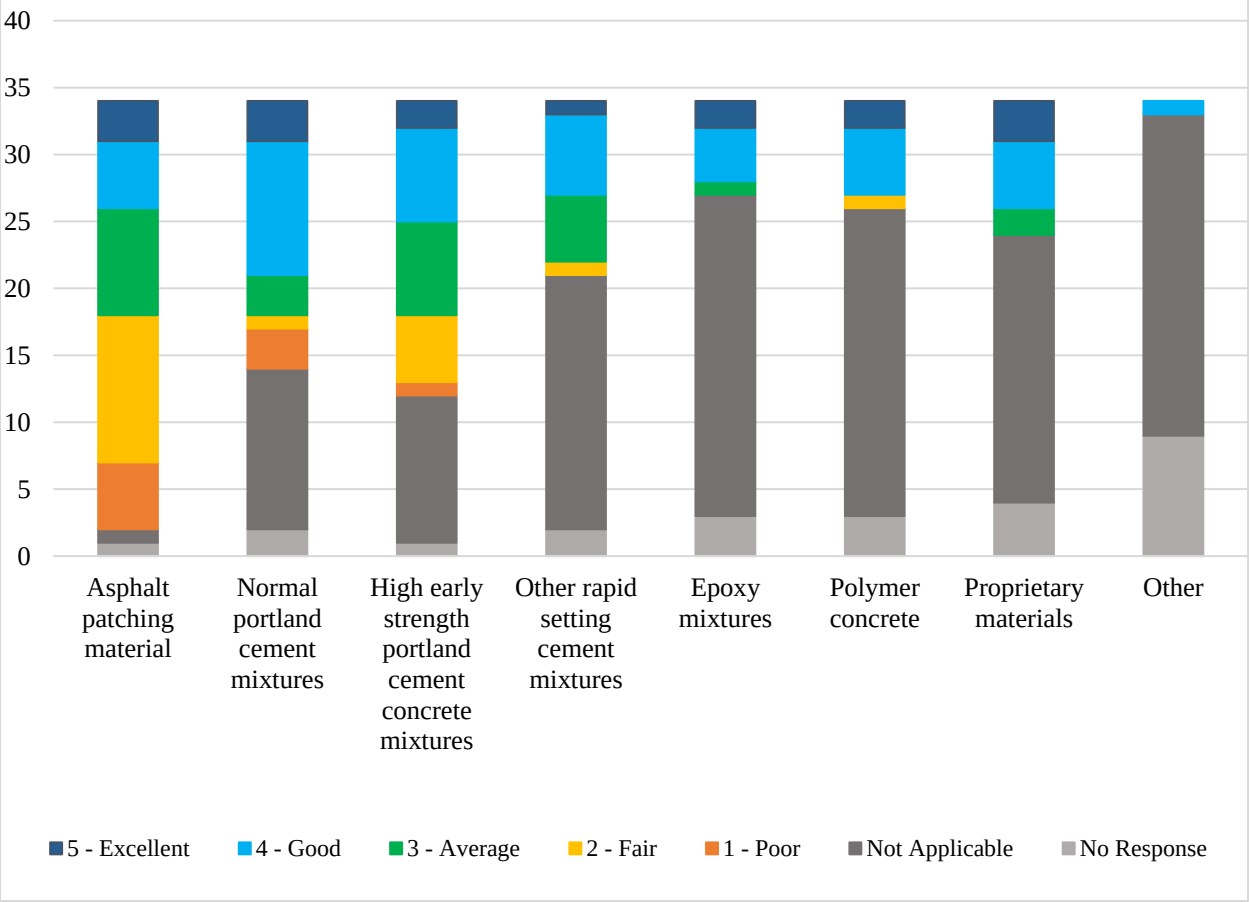
Response
Mastic for temporary repairs and partial depth. Portland cement without accelerators on full depth repairs.
M-mix concrete and HMA material
Full depth patching with 12 hr cure
Full depth concrete patches have been the most effective.
Full depth PCCP replacement
Full depth PCC normal Type 1 Portland cement mix, dowels if t>7", core out & place granular subgrade if needed. Training & construction inspection is a key to success.
MnDOT's own mix design for PDR's & High early ready mix for FDR's
Replace with like concrete
Full depth rigid repair (Item 255) is typically the best, but it depends on the pavement and situation being repaired
Full depth concrete
Most Districts use our standard PP-1 or PP-2 mixes.
PCC
Full depth patching with early strength mixtures
Concrete pavement should be patched with concrete
F.D. PCC, F.D. HMA, P.D. HMA
Most effective - Techcrete Most cost effective - Mastic
Normal PCC mixtures with or without accelerator
Non-cementitious repairs with sawcut edges and removal of ALL poor quality concrete prior to repair
Remove bad area, compact, place 6" of PCC.
Full Depth Repair with 48 Hour concrete mix
Concrete
Partial Depth Asphalt repairs Full Depth Concrete repairs
Concete
High early concrete for full depth repairs and asphalt for partial depths
Midpanel cracking - hot polymer patching materials High steel - hot polymer concrete patching materials Other - high early strength roadway repair mix
Conventional ready mix and full depth. Partials depth - again conventional mix and sounding the area similar to a bridge deck patch by chaining.
Using a pavement repair concrete mix where the hole is cutout, dowdrt tie bars inserted and allowed over 4 hours to cure

Response		
	Valid Responses	27
	Total Responses	34

Response to Survey Question 12: Based on your experience, please rate the performance of partial depth patches in your area that are made using the following materials:

Possible Answers:

	1 Poor	2 Fair	3 Average	4 Good	5 Excellent	N/A Not applicable
a. Asphalt patching material						
b. Normal portland cement mixtures						
c. High early strength portland cement concrete mixtures						
d. Other rapid setting cement mixtures						
e. Epoxy mixtures						
f. Polymer concrete						
g. Proprietary materials (please specify)						
h. Other (please specify)						



Response to Survey Question 12: Continued - Proprietary Materials (please specify)

Response		
CTS DOT repair mix & Futura 15		
Do not have a long term experience. Current problems appear to be existing pavement related not necessarily repair material properties.		
TechCrete and Mastic One by Crafco; Fiber Crete		
Techcrete		
TechCrete		
Mastic, Techcrete		
fibrecrete		
Techcrete		
A product that looked like peanut butter 10 years ago. Still holding up strong.		
Fibercrete		
	Valid Responses	10
	Total Responses	34

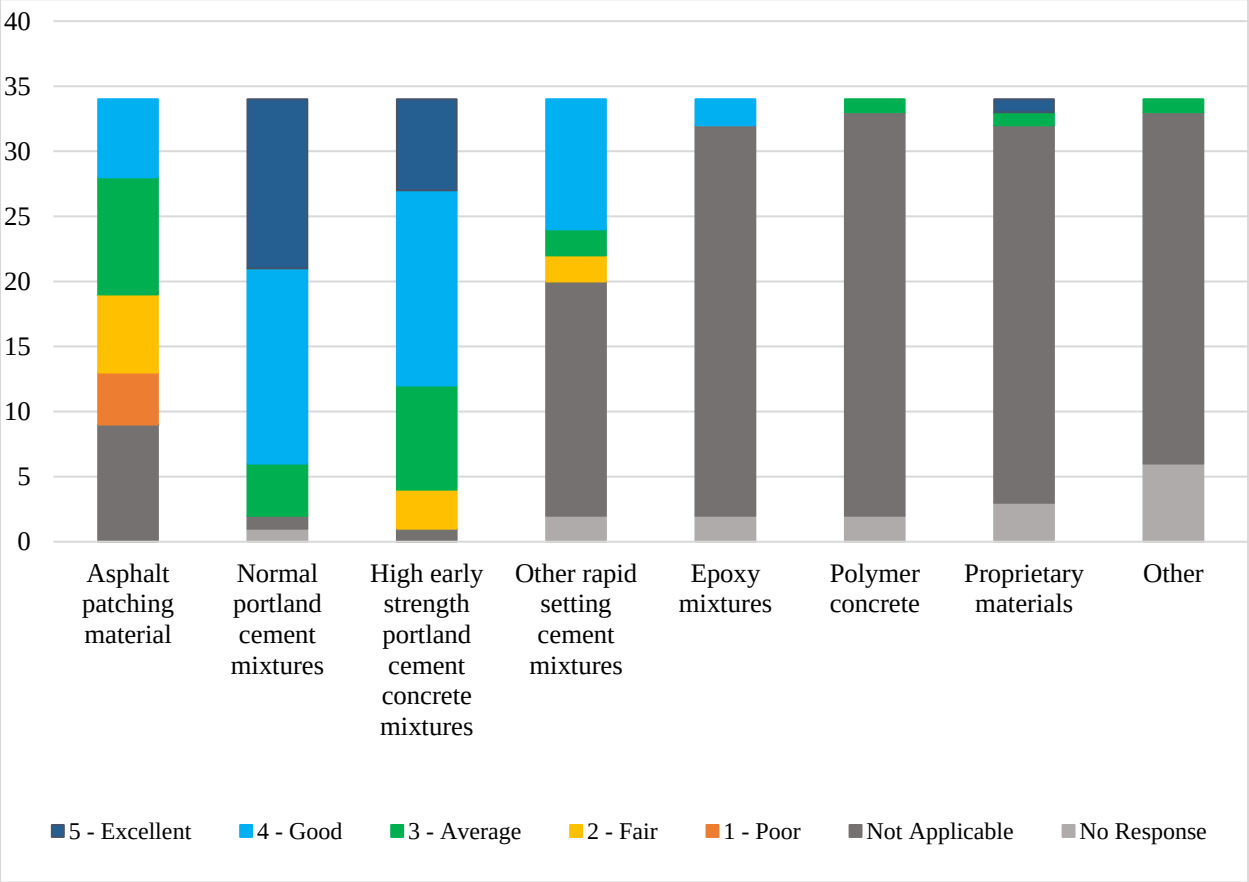
Response to Survey Question 12: Continued - Other (please specify)

Response		
No partial-depth patches		
Non-cementitious		
	Valid Responses	2
	Total Responses	34

Response to Survey Question 13: Based on your experience, please rate the performance of full-depth patches in your area that are made using the following materials:

Possible Answers:

	1 Poor	2 Fair	3 Average	4 Good	5 Excellent	N/A Not applicable
a. Asphalt patching material						
b. Normal portland cement mixtures						
c. High early strength portland cement concrete mixtures						
d. Other rapid setting cement mixtures						
e. Epoxy mixtures						
f. Polymer concrete						
g. Proprietary materials (please specify)						
h. Other (please specify)						



Response to Survey Question 13: Continued - Proprietary Materials (please specify)

Response		
Mastic by CRAFCO		
Mastic, Techcrete		
	Valid Responses	2
	Total Responses	34

Response to Survey Question 13: Continued - Other (please specify)

Response		
I am classifying normal-setting 7-bag mix with calcium as Other		
MnDOT has used Ultra-High Early ready mix		
It is too early to tell how our precast panel patching projects are fairing; though anecdotally they appear to work well for the IL Tollway.		
	Valid Responses	3
	Total Responses	34

Response to Survey Question 14: Based on your experience, what types of patch failures are typically encountered in your area? Please provide as much detail as possible (e.g., partial depth vs. full depth repair, installation problem vs. material durability problem, proximity to joints, type of materials used, type of distress observed, etc.).

Possible Answers: Comments

Response
Partial depth repairs have not performed well. Bonding and continued original concrete deterioration have been the source of the repair "Popping out". Partial depth with Mastic has required good preparation work. Cleaning surrounding concrete with compressed air. Also Deep repairs require asphalt pothole patch to minimize the depth to 2". Most partial or full depth repairs have failed at the joint because the original concrete continued to deteriorate next to the repair.
Its about even when looking at the total number of patches put in during any given year. Most of the problems with partial or full depth patches, deals with poor sub-grade and base conditions, very heavy axle loads, amount of heavy load traffic, with of these implements are wider than lanes and causes much edge cracking or tipping.
Soft limestone and subgrade prep
The most common patching failures we observe are joint deterioration and cracking. The cracking is typically seen where poor subgrade material has been used or where a joint should have been installed but was not.
Proximity to Joints, and not replacing a large enough patch area initially.
FULL DEPTH - failure of surrounding concrete due to bore holes for dowels, shrinkage cracks, subgrade failures, flexural & propagated cracks, poorly planned shape or location, failure to saw proper contraction joints. PARTIAL DEPTH - delamination/debonding, shrinkage cracks,
We have had material durability issues on dowel retrofit backfills. The Ultra High early proprietary mixtures seem predisposed to shrinkage cracks every 18'' (plus or minus) and very sensitive too over watering.
material durability problems with the old concrete around the patch area
Partial depth repairs are typically asphalt material placed in a spall, the failure is typically a pop out with freeze/thaw cycles due to being placed in varying conditions which results in varied performance. Full depth repairs using fast set concrete have shrinkage cracking.
mid panel crack repair full depth, some joint repair
Partial depth - material adhesion Full depth - cracking, poor ride, quick set related concrete pavement issues
While our standard PP-5 mix (which uses a calcium aluminate cement and is installed using mobile volumetric mixing trucks) appears to serve its purpose in very high traffic areas in the Chicagoland area, it also is only serviceable for 3-5 years according to the District. These patches suffer from durability-related distresses, possibly Table 20 – Cont'd.
initiated by shrinkage-related stresses exacerbated by heavy traffic/loads
We have both types of patch failures. Cracking is the most common failure with full depth concrete patches. When possible we try to avoid high early strength full depth patches because we have had mixed results. Some of the high early strength patches seem to deteriorate faster then a standard concrete patch. We assume it has to due with the rapid setting of the concrete and the heat that is generated. For partial depth asphalt patching the biggest problem is trying to keep the asphalt in the patch. We try to overlay the asphalt patched areas to help hold the material in place.
shrinkage cracking (both); delamination (partial depth)

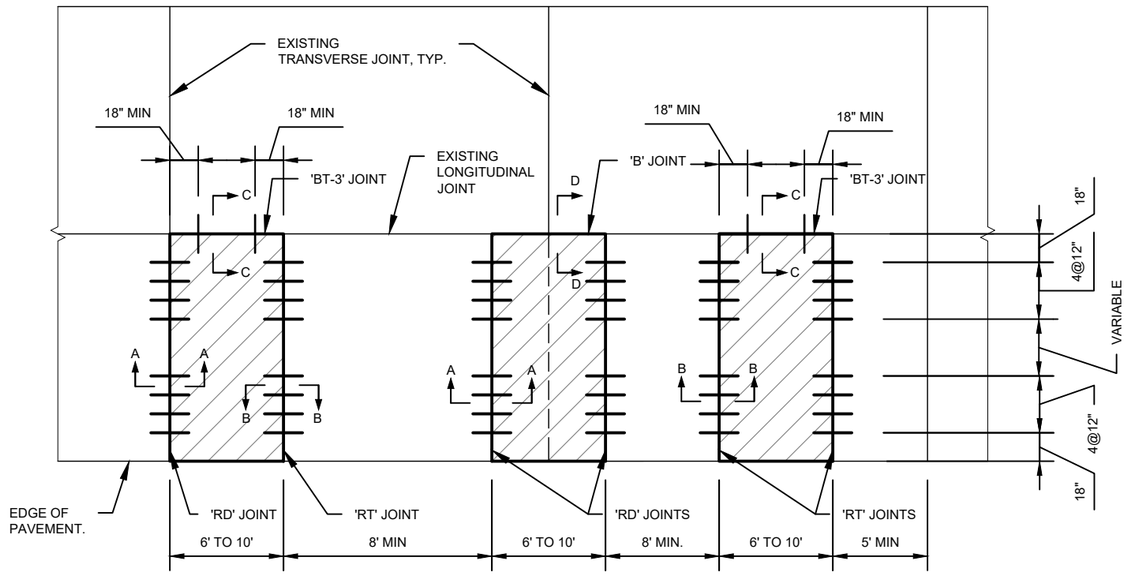
Response
Partial depth with asphalt tends to need to be patched again, Techcrete has been used and seems to stay well, but we don't have a lot of history with this product. Full depth repairs are typically done with high-early concrete and performs well, a 8 or 24 hour concrete is used, but typically doesn't hold up as well as our 3-day concrete.
Full Depth: Installation problem (installing dowel in older concrete), High heat of hydration (causing sulfate imbalance in hydration), Opening to traffic (maturity), Shrinkage, subgrade preparation, conversion of certain type of cements, and not achieving desired strength. All of them have either random cracks or longitudinal cracks in the middle of the patch. Partial-depth patching: Coefficient of thermal expansion compatibility, adhesion to existing concrete, bad preparation of the old surface, extending limitation of patching area, shrinkage. All of them with debonding results.
Damage to adjacent concrete with F.D. repairs when attempting to dowel in PCC patches.
The only kind of failure we have experienced with Techcrete or Mastic is when the surrounding area gives way. This has not been the case with asphalt or concrete patches where the patches have broken apart. Side benefit Mastic and Techcrete both seal (no seams) and do not crack.
Full depth PCC - no typical failures HMA - failure at the edge of patch - too small; rutting of the patch after placement - too hot when traffic allowed to drive over
Partial depth repairs commonly fail due to workmanship, particularly with rigid repair material. Challenges include properly removing poor material; re-establishing joints and cracks, repairs up against a free edge (joint); getting minimum repair thicknesses. Poor prep and workmanship can quickly lead to lack of bond and failure of the repair. Most failures here of full depth repairs come from the use of accelerated mixes. The concrete itself breaks down and the ride becomes unacceptable. Poor repairs may last 5 years, good repairs may last 20+ years.
Failure is on top and cracking. We did not cure top, over worked it, and didn't saw cut. That was fixed last year with training on proper procedure.
Full depth repair - Bar alignment and anchoring plus durability of concrete. Partial depth repair - not reestablishing the joint to current width, and cracking of type R3 bagged patch materials.
Full Depth patches typically crack mid panel eventually no matter the length of patch. We typically will saw at 12' panels
Partial Depth: Mid-panel cracking and faulting and high steel issues are the problem. Hot polymer concrete patching material is the long term repair when applicable. The repairs are milled out with a attachment to a skid steer and no more than 4" deep. Full Depth: A majority of the repairs done full depth are performed during large construction projects. As such, there are strict guidelines to the plant produced mix with accelerant added at the site. Repairs are between 10-12" deep and have a 6-8 hour time window for completion.
If a patch fails, it is usually due to either not fully addressing the cause of the initial failure, or expecting too much of a patch when the solution is a more involved fix.
Full Depth - Dowel bar failure / Joint failure Partial Depth Asphalt - debonding, cold compaction, bad profile, pushing Partial Depth Concrete - debonding, cracking
In my opinion, there tends to be more full depth than partial depth.
The district experiences mostly midpanel cracking and faulting due to panel length selection during installation. High steel is common in materials placed in 1980-1995. Partial depth repairs are used to a depth of no greater than 4" and are for the above referenced occasions. Installation problems are mainly during preparation and removal of

Response		
loose material. The District has had major issues with scaling in the concrete placed with calcium and may be related to temperature of mix. Full depth repairs are used during large projects and generally are large in volume. Concrete durability is good. Joint location and the placement of the bars and dowel bars is a focus when dealing with composite pavement. Most full depth repairs are 12" or 10" depending on the location.		
Most typical are partial depth patches failing. They need to have the area they are placed upon sounded and the establishment back of the joint/crack is crucial.		
1. There are some partial depth failures which is believed to be installation problems, 2. Our biggest full depth failures are on asphalt roadways where the material expands with the heat causing "push up" the width of the roadway		
	Valid Responses	30
	Total Responses	34

Response to Survey Question 15: Please provide your name, agency and department below.

Agency:	Department:
Wisconsin DOT	Maintenance Engineer
Mahaska County	Secondary roads
Montgomery County	Secondary Roads
Wayne County Iowa	Secondary Roads
Appanoose County	Secondary Roads
Ringgold County	Secondary Roads
Harrison County, IA	Secondary Roads
MnDOT	Concrete Engineering Unit
North Dakota DOT	Materials & Research
Ohio DOT	Department of Transportation; Division of Engineering; Office of Pavement Engineering
IDOT	Materials D1
Wisconsin DOT	Southwest Region Office
Illinois Department of Transportation	Central Bureau of Materials
WisDOT	Technical Services / Pavements
Ohio DOT	Office of Materials Management
IL DOT	Materials
INDOT	Research Division
IDOT D-5	Materials Bureau
WisDOT NE Region	Maintenance Section
Illinois DOT	Mixtures, Maintenance Specialist, Materials Concrete Supervisor
Michigan	Transportation
Johnson County, Indiana	Highway Dept.
South Dakota DOT	Materials and Surfacing
Henry County	Secondary Roads
MoDOT	Maintenance
Nebraska DOT	------
MoDOT	Construction & Materials
MoDOT	Construction
MoDOT	Construction Materials
Missouri Department of Transportation	Construction
KDOT	------
MoDOT	Materials

APPENDIX B. FDR AND PDR DRAWINGS



NOTE:
'RD' JOINT = TRANSVERSE JOINT WITH EPOXY EMBEDDED DOWELS
'RT' JOINT = TRANSVERSE JOINT WITH EPOXY EMBEDDED TIE BARS
'BT-3' JOINT = LONGITUDINAL JOINT WITH EPOXY EMBEDDED TIE BARS
'B' JOINT = UNTIED LONGITUDINAL JOINT

ONE LANE WIDTH PATCH
LENGTH = 6' TO 10'

A. REPAIR PROCEDURE NOTES:

1. DETERMINE PATCH BOUNDARIES.
   a. PATCH WIDTH SHALL BE ONE LANE.
   b. IF A PATCH BOUNDARY IS LESS THAN 5 FEET FROM AN EXISTING TRANSVERSE JOINT, EXTEND THE BOUNDARY TO THE JOINT.
   c. COMBINE TWO PATCHES LESS THAN 8 FEET APART INTO A SINGLE LARGER REPAIR.
   d. IF PATCH LENGTH AFTER ADJUSTED IS GREATER THAN 10 FEET, USE FDR-02 OR FDR-03 DRAWING AS APPROPRIATE.
2. MAKE FULL-DEPTH SAW CUTS ALONG FULL PERIMETER OF AREA TO BE REPAIRED.
3. REMOVE CONCRETE IN REPAIR AREA IN ACCORDANCE WITH ARTICLE 2510.03.A.
4. IF LONGITUDINAL SUBDRAIN IS NOT TO BE PLACED, OR IS NOT PRESENT, ON THE SIDE OF ROADWAY TO BE PATCHED, PLACE PATCH SUBDRAIN IN ACCORDANCE WITH ARTICLE 2502.03.C.
5. REPAIR SUBBASE AND/OR SUBGRADE AS PLANNED OR IF DISTURBED DURING CONSTRUCTION IN ACCORDANCE WITH ARTICLE 2529.03.C.
6. PLACE DOWELS AND TIE BARS IN PREDRILLED HOLES USING EPOXY GROUT, ACCORDING TO ARTICLE 2301.03,E. ALIGN DOWELS AND TIE BARS TO $\frac{1}{8}$ INCH OF PAVEMENT PROFILE AND CENTER LINE. COAT THE PORTION OF DOWELS EXTENDING INTO THE PATCH AREA WITH A BOND BREAKER. DO NOT COAT TIE BARS.
7. PLACE FORMS ON ALL EXPOSED EDGES.
8. MOISTEN THE SUBBASE OR SUBGRADE OR COVER WITH A SINGLE LAYER OF PLASTIC FILM MEETING REQUIREMENTS OF SECTION 4107.
9. SEE LIST OF APPROVED REPAIR MATERIALS - ITEM B BELOW.
10. MIX, PLACE, AND CONSOLIDATE REPAIR MATERIAL IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR WITH ARTICLE 2529.03.G.
11. STRIKE OFF REPAIR MATERIAL FLUSH WITH PAVEMENT SURFACE AT PERIMETER OF REPAIR AREA, AND TEXTURE SURFACE OF REPAIR TO MATCH THE SURROUNDING PAVEMENT.
12. CURE THE PATCH IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR ARTICLE 2529.03.G.
13. SAW AND SEAL JOINTS IN ACCORDANCE WITH ARTICLE 2301.03.P.

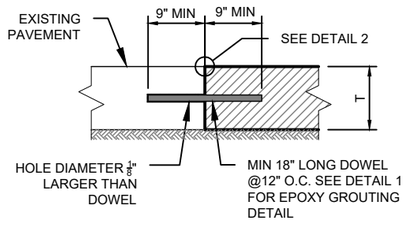
B. REPAIR MATERIALS:

REPAIR MATERIALS SHALL BE IN ACCORDANCE WITH ARTICLE 2529.02.B.

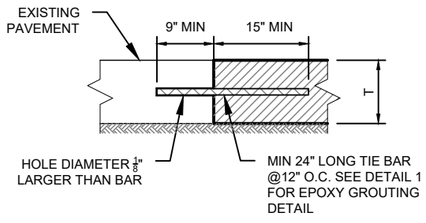
C. QUALITY CONTROL:

SEE CHECKLIST.

NOTE: ALL ARTICLES AND SECTIONS REFERENCED ON THIS DRAWING REFER TO THE IOWA DOT STANDARD SPECIFICATIONS UNLESS OTHERWISE INDICATED.

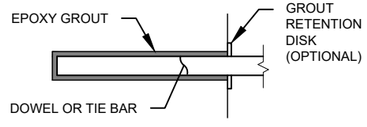


SECTION A-A
'RD' TRANSVERSE JOINT

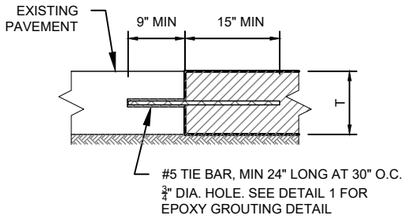


NOTE: SAWING OR SEALING JOINT IS NOT REQUIRED.

SECTION B-B
'RT' TRANSVERSE JOINT

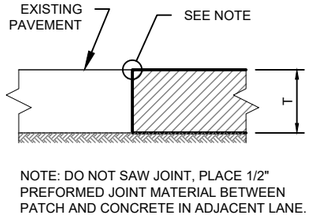


DETAIL 1
EPOXY GROUTING



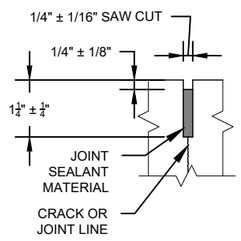
NOTE: SAWING OR SEALING JOINT IS NOT REQUIRED.

SECTION C-C
'BT-3' LONGITUDINAL JOINT



NOTE: DO NOT SAW JOINT, PLACE 1/2" PREFORMED JOINT MATERIAL BETWEEN PATCH AND CONCRETE IN ADJACENT LANE.

SECTION D-D
'B' LONGITUDINAL JOINT



DETAIL 2
'RD' JOINT SEAL

DOWEL AND TIE BAR SIZES FOR TRANSVERSE JOINTS		
PAVEMENT THICKNESS	DOWEL DIAMETER	TIE BAR SIZE
T < 8"	$\frac{3}{4}$"	#6
8" ≤ T < 10"	$1\frac{1}{4}$"	#10
T ≥ 10"	$1\frac{1}{2}$"	#11

NOTE: DOWELS AND TIE BARS SHALL BE EPOXY COATED

IOWA DOT
SMARTER I SIMPLER I CUSTOMER DRIVEN

Seal

Consultant

Project

Client
Iowa Department of Transportation

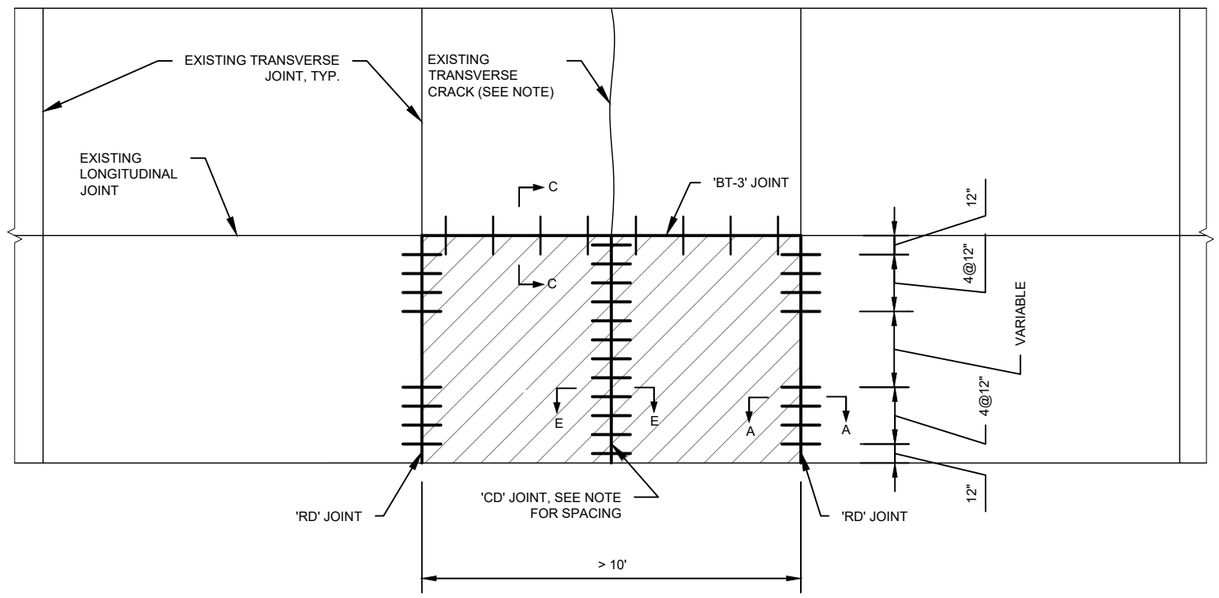
Mark	Date	Description

0 1/2" 1"
THIS SHEET PLOTS FULL SIZE AT 11x17 (INCHES)

Project No.
Date MAY 01, 2022
Drawn
Checked
Scale NTS

FULL DEPTH REPAIR
ONE LANE WIDTH
LENGTH = 6' TO 10'
Sheet Title

Sheet No. **FDR-01**



ONE LANE WIDTH PATCH
LENGTH > 10'
(ONE PAVEMENT PANEL REPLACEMENT)

NOTE:
'RD' JOINT = TRANSVERSE JOINT WITH EPOXY EMBEDDED DOWELS
'CD' JOINT = TRANSVERSE JOINT WITH DOWEL BASKET
'BT-3' JOINT = LONGITUDINAL JOINT WITH EPOXY EMBEDDED TIE BARS

A. REPAIR PROCEDURE NOTES:

1. DETERMINE NEW TRANSVERSE JOINT LOCATIONS AS FOLLOWS:
   a. JOINT SPACING 10 FEET MINIMUM, 20 FEET MAXIMUM, 15 FEET OPTIMUM
   b. NEW JOINTS TO MATCH EXISTING JOINTS IN ADJACENT PAVEMENT WHERE POSSIBLE
   c. IF THERE IS AN EXISTING TRANSVERSE CRACK NEAR MIDDLE OF ADJACENT PAVEMENT, PLACE A "CD" JOINT AT THE SAME TRANSVERSE LOCATION IN THE PATCH.
   d. 'CD' JOINT SHALL BE AT LEAST 5 FEET FROM THE PATCH END.
2. MAKE FULL-DEPTH SAW CUTS ALONG FULL PERIMETER OF AREA TO BE REPAIRED.
3. REMOVE CONCRETE IN REPAIR AREA IN ACCORDANCE WITH ARTICLE 2510.03.A.
4. IF LONGITUDINAL SUBDRAIN IS NOT TO BE PLACED, OR IS NOT PRESENT, ON THE SIDE OF ROADWAY TO BE PATCHED, PLACE PATCH SUBDRAIN IN ACCORDANCE WITH ARTICLE 2502.03.C.
5. REPAIR SUBBASE AND/OR SUBGRADE AS PLANNED OR IF DISTURBED DURING CONSTRUCTION IN ACCORDANCE WITH ARTICLE 2529.03.C.
6. PLACE DOWELS AND TIE BARS IN PREDRILLED HOLES USING EPOXY GROUT, ACCORDING TO ARTICLE 2301.03,E. ALIGN DOWELS AND TIE BARS TO $\frac{1}{8}$ INCH OF PAVEMENT PROFILE AND CENTER LINE. COAT THE PORTION OF DOWELS EXTENDING INTO THE PATCH AREA WITH A BOND BREAKER. DO NOT COAT TIE BARS.
7. PLACE FORMS ON ALL EXPOSED EDGES.
8. MOISTEN THE SUBBASE OR SUBGRADE OR COVER WITH A SINGLE LAYER OF PLASTIC FILM MEETING REQUIREMENTS OF SECTION 4107.
9. SEE LIST OF APPROVED REPAIR MATERIALS - ITEM B BELOW.
10. MIX, PLACE, AND CONSOLIDATE REPAIR MATERIAL IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR WITH ARTICLE 2529.03.G.
11. STRIKE OFF REPAIR MATERIAL FLUSH WITH PAVEMENT SURFACE AT PERIMETER OF REPAIR AREA, AND TEXTURE SURFACE OF REPAIR TO MATCH THE SURROUNDING PAVEMENT.
12. CURE THE PATCH IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR ARTICLE 2529.03.G.
13. SAW AND SEAL JOINTS IN ACCORDANCE WITH ARTICLE 2301.03.P.

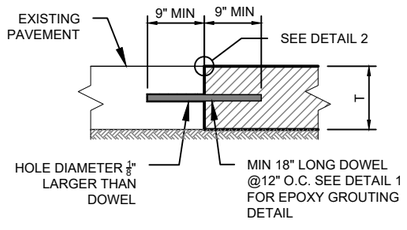
B. REPAIR MATERIALS:

REPAIR MATERIALS SHALL BE IN ACCORDANCE WITH ARTICLE 2529.02.B.

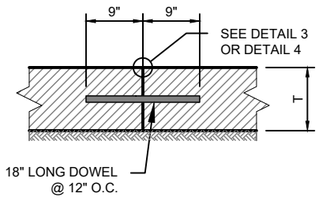
C. QUALITY CONTROL:

SEE CHECKLIST.

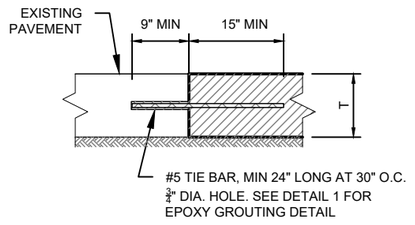
NOTE: ALL ARTICLES AND SECTIONS REFERENCED ON THIS DRAWING REFER TO THE IOWA DOT STANDARD SPECIFICATIONS UNLESS OTHERWISE INDICATED.



SECTION A-A
'RD' TRANSVERSE JOINT

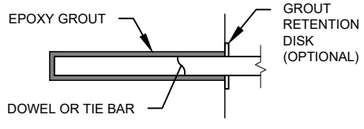


SECTION E-E
'CD' TRANSVERSE JOINT

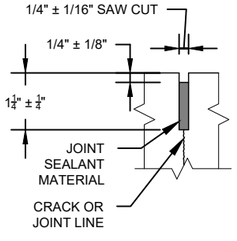


NOTE: SAWING OR SEALING JOINT IS NOT REQUIRED.

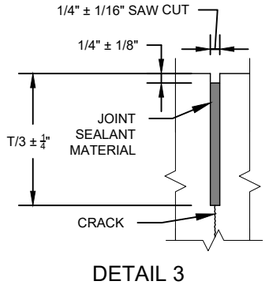
SECTION C-C
'BT-3' LONGITUDINAL JOINT



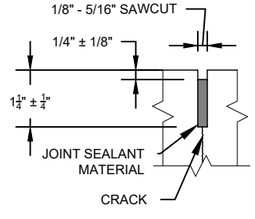
DETAIL 1
EPOXY GROUTING



DETAIL 2
'RD' JOINT SEAL



DETAIL 3
(SAW CUT FORMED BY CONVENTIONAL CONCRETE SAWING EQUIPMENT)



DETAIL 4
(SAW CUT FORMED BY APPROVED EARLY CONCRETE SAWING EQUIPMENT)

DOWEL AND TIE BAR SIZES FOR TRANSVERSE JOINTS		
PAVEMENT THICKNESS	DOWEL DIAMETER	TIE BAR SIZE
T < 8"	$\frac{3}{4}$"	#6
8" ≤ T < 10"	1 $\frac{1}{4}$"	#10
T ≥ 10"	1 $\frac{1}{2}$"	#11

NOTE: DOWELS AND TIE BARS SHALL BE EPOXY COATED

IOWA DOT
SMARTER | SIMPLER | CUSTOMER DRIVEN

Seal

Consultant

Project

Client
Iowa Department of Transportation

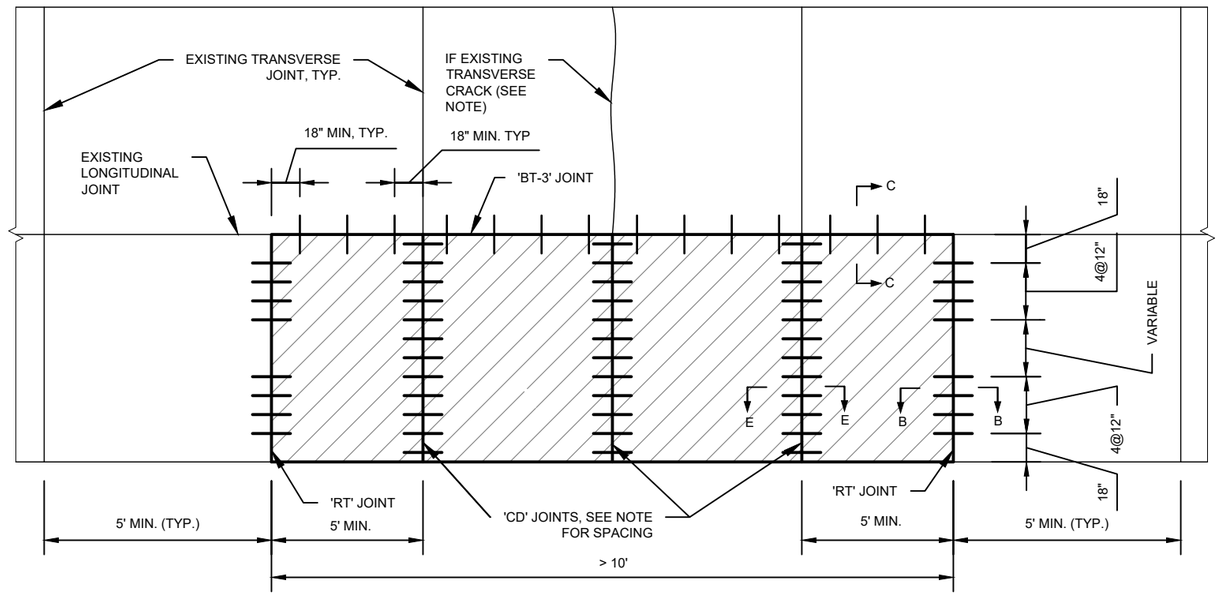
Mark	Date	Description

0 1/2" 1"
THIS SHEET PLOTS FULL SIZE AT 11x17 (INCHES)

Project No.
Date MAY 01, 2022
Drawn
Checked
Scale NTS

FULL DEPTH REPAIR
ONE LANE WIDTH
LENGTH > 10'
Sheet Title

Sheet No. **FDR-02**



NOTE:
'CD' JOINT = TRANSVERSE JOINT WITH DOWEL BASKET
'RT' JOINT = TRANSVERSE JOINT WITH EPOXY EMBEDDED TIE BARS
'BT-3' JOINT = LONGITUDINAL JOINT WITH EPOXY EMBEDDED TIE BARS

ONE LANE WIDTH PATCH
LENGTH > 10'

A. REPAIR PROCEDURE NOTES:

1. DETERMINE NEW TRANSVERSE JOINT LOCATIONS AS FOLLOWS:
   a. JOINT SPACING 10 FEET MINIMUM, 20 FEET MAXIMUM, 15 FEET OPTIMUM
   b. NEW JOINTS TO MATCH EXISTING JOINTS IN ADJACENT PAVEMENT WHERE POSSIBLE
   c. IF THERE IS AN EXISTING TRANSVERSE CRACK NEAR MIDDLE OF ADJACENT PAVEMENT, PLACE A "CD" JOINT AT THE SAME TRANSVERSE LOCATION IN THE PATCH.
   d. 'CD' JOINT SHALL BE AT LEAST 5 FEET FROM THE PATCH END.
2. MAKE FULL-DEPTH SAW CUTS ALONG FULL PERIMETER OF AREA TO BE REPAIRED.
3. REMOVE CONCRETE IN REPAIR AREA IN ACCORDANCE WITH ARTICLE 2510.03.A .
4. IF LONGITUDINAL SUBDRAIN IS NOT TO BE PLACED, OR IS NOT PRESENT, ON THE SIDE OF ROADWAY TO BE PATCHED, PLACE PATCH SUBDRAIN IN ACCORDANCE WITH ARTICLE 2502.03.C.
5. REPAIR SUBBASE AND/OR SUBGRADE AS PLANNED OR IF DISTURBED DURING CONSTRUCTION IN ACCORDANCE WITH ARTICLE 2529.03.C.
6. PLACE DOWELS AND TIE BARS IN PREDRILLED HOLES USING EPOXY GROUT, ACCORDING TO ARTICLE 2301.03,E. ALIGN DOWELS AND TIE BARS TO $\frac{1}{8}$ INCH OF PAVEMENT PROFILE AND CENTER LINE. COAT THE PORTION OF DOWELS EXTENDING INTO THE PATCH AREA WITH A BOND BREAKER. DO NOT COAT TIE BARS.
7. PLACE FORMS ON ALL EXPOSED EDGES.
8. MOISTEN THE SUBBASE OR SUBGRADE OR COVER WITH A SINGLE LAYER OF PLASTIC FILM MEETING REQUIREMENTS OF SECTION 4107.
9. SEE LIST OF APPROVED REPAIR MATERIALS - ITEM B BELOW.
10. MIX, PLACE, AND CONSOLIDATE REPAIR MATERIAL IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR WITH ARTICLE 2529.03.G.
11. STRIKE OFF REPAIR MATERIAL FLUSH WITH PAVEMENT SURFACE AT PERIMETER OF REPAIR AREA, AND TEXTURE SURFACE OF REPAIR TO MATCH THE SURROUNDING PAVEMENT.
12. CURE THE PATCH IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR ARTICLE 2529.03.G.
13. SAW AND SEAL JOINTS IN ACCORDANCE WITH ARTICLE 2301.03.P.

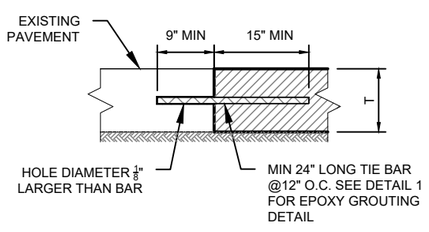
B. REPAIR MATERIALS:

REPAIR MATERIALS SHALL BE IN ACCORDANCE WITH ARTICLE 2529.02.B.

C. QUALITY CONTROL:

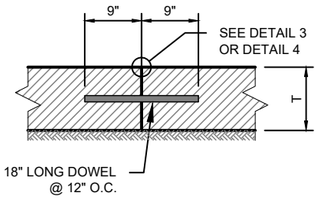
SEE CHECKLIST.

NOTE: ALL ARTICLES AND SECTIONS REFERENCED ON THIS DRAWING REFER TO THE IOWA DOT STANDARD SPECIFICATIONS UNLESS OTHERWISE INDICATED.

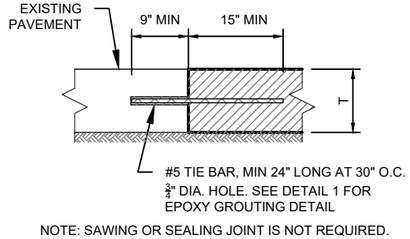


NOTE: SAWING OR SEALING JOINT IS NOT REQUIRED.

SECTION B-B
'RT' TRANSVERSE JOINT

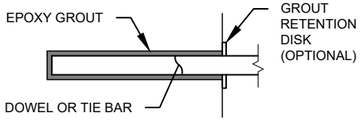


SECTION E-E
'CD' TRANSVERSE JOINT

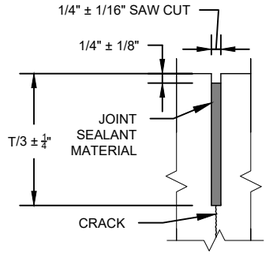


NOTE: SAWING OR SEALING JOINT IS NOT REQUIRED.

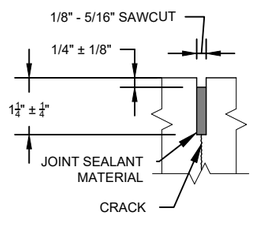
SECTION C-C
'BT-3' LONGITUDINAL JOINT



DETAIL 1
EPOXY GROUTING



DETAIL 3
(SAW CUT FORMED BY CONVENTIONAL CONCRETE SAWING EQUIPMENT)



DETAIL 4
(SAW CUT FORMED BY APPROVED EARLY CONCRETE SAWING EQUIPMENT)

DOWEL AND TIE BAR SIZES FOR TRANSVERSE JOINTS		
PAVEMENT THICKNESS	DOWEL DIAMETER	TIE BAR SIZE
T < 8"	$\frac{3}{4}$"	#6
8" ≤ T < 10"	1 $\frac{1}{4}$"	#10
T ≥ 10"	1 $\frac{1}{2}$"	#11

NOTE: DOWELS AND TIE BARS SHALL BE EPOXY COATED

IOWA DOT
SMARTER I SIMPLER I CUSTOMER DRIVEN

Seal

Consultant

Project

Client
Iowa Department of Transportation

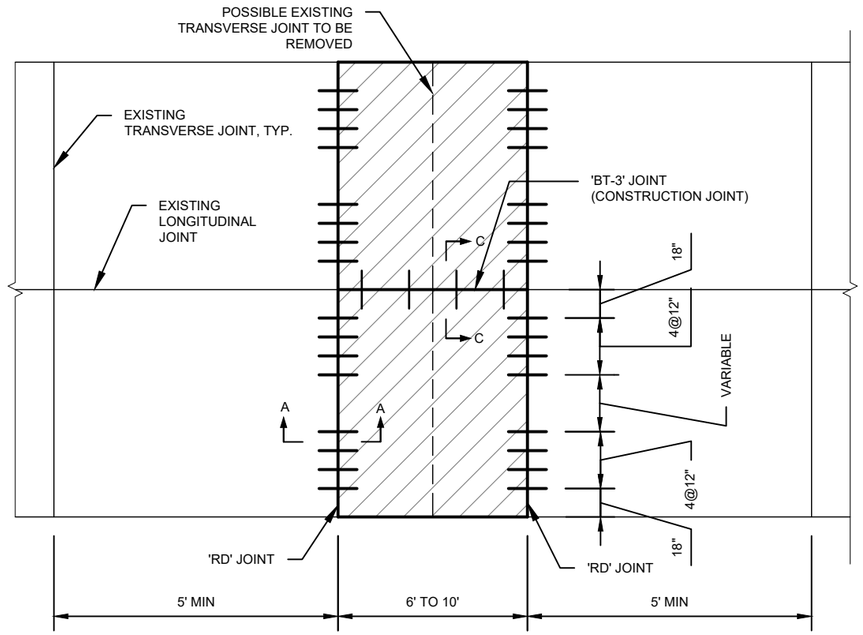
Mark	Date	Description

0 1/2" 1"
THIS SHEET PLOTS FULL SIZE AT 11x17 (INCHES)

Project No.
Date MAY 01, 2022
Drawn
Checked
Scale NTS

FULL DEPTH REPAIR
ONE LANE WIDTH
LENGTH >10'
Sheet Title

Sheet No. **FDR-03**



NOTE:
'RD' JOINT = TRANSVERSE JOINT WITH EPOXY EMBEDDED TIE BARS
'BT-3' JOINT = LONGITUDINAL JOINT WITH EPOXY EMBEDDED TIE BARS

FULL ROADWAY WIDTH PATCH
LENGTH = 6' TO 10'
(ASSUMING ONE LANE TO BE REPAIRED AT A TIME)

A. REPAIR PROCEDURE NOTES:

(IT IS ASSUMED THAT ONE LANE IS TO BE REPAIRED AND OPENED TO TRAFFIC BEFORE THE NEXT LANE IS REPAIRED.)

1. DETERMINE PATCH BOUNDARIES.
   a. PATCH WIDTH SHALL BE FULL LANES.
   b. IF A PATCH BOUNDARY IS LESS THAN 5 FEET FROM AN EXISTING TRANSVERSE JOINT, EXTEND THE BOUNDARY TO THE JOINT.
   c. COMBINE TWO PATCHES LESS THAN 8 FEET APART INTO A SINGLE LARGER REPAIR.
   d. IF PATCH LENGTH AFTER ADJUSTED IS GREATER THAN 10 FEET, USE FDR-05 DRAWING AS APPROPRIATE.
2. MAKE FULL-DEPTH SAW CUTS ALONG FULL PERIMETER OF AREA TO BE REPAIRED.
3. REMOVE CONCRETE IN REPAIR AREA IN ACCORDANCE WITH ARTICLE 2510.03.A.
4. IF LONGITUDINAL SUBDRAIN IS NOT TO BE PLACED, OR IS NOT PRESENT, ON THE SIDE OF ROADWAY TO BE PATCHED, PLACE PATCH SUBDRAIN IN ACCORDANCE WITH ARTICLE 2502.03.C.
5. REPAIR SUBBASE AND/OR SUBGRADE AS PLANNED OR IF DISTURBED DURING CONSTRUCTION IN ACCORDANCE WITH ARTICLE 2529.03.C.
6. PLACE DOWELS AND TIE BARS IN PREDRILLED HOLES USING EPOXY GROUT, ACCORDING TO ARTICLE 2301.03,E. ALIGN DOWELS AND TIE BARS TO $\frac{1}{8}$ INCH OF PAVEMENT PROFILE AND CENTER LINE. COAT THE PORTION OF DOWELS EXTENDING INTO THE PATCH AREA WITH A BOND BREAKER. DO NOT COAT TIE BARS.
7. PLACE FORMS ON ALL EXPOSED EDGES.
8. MOISTEN THE SUBBASE OR SUBGRADE OR COVER WITH A SINGLE LAYER OF PLASTIC FILM MEETING REQUIREMENTS OF SECTION 4107.
9. SEE LIST OF APPROVED REPAIR MATERIALS - ITEM B BELOW.
10. MIX, PLACE, AND CONSOLIDATE REPAIR MATERIAL IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR WITH ARTICLE 2529.03.G.
11. STRIKE OFF REPAIR MATERIAL FLUSH WITH PAVEMENT SURFACE AT PERIMETER OF REPAIR AREA, AND TEXTURE SURFACE OF REPAIR TO MATCH THE SURROUNDING PAVEMENT.
12. CURE THE PATCH IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR ARTICLE 2529.03.G.
13. SAW AND SEAL JOINTS IN ACCORDANCE WITH ARTICLE 2301.03.P.

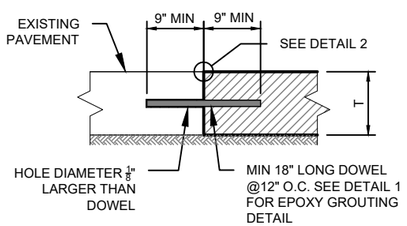
B. REPAIR MATERIALS:

REPAIR MATERIALS SHALL BE IN ACCORDANCE WITH ARTICLE 2529.02.B.

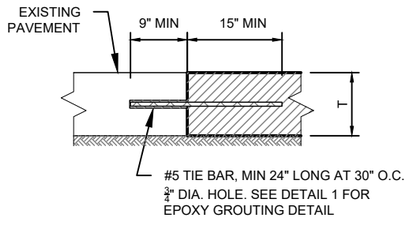
C. QUALITY CONTROL:

SEE CHECKLIST.

NOTE: ALL ARTICLES AND SECTIONS REFERENCED ON THIS DRAWING REFER TO THE IOWA DOT STANDARD SPECIFICATIONS UNLESS OTHERWISE INDICATED.

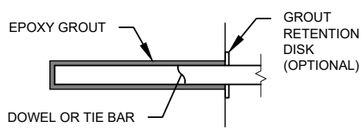


SECTION A-A
'RD' TRANSVERSE JOINT

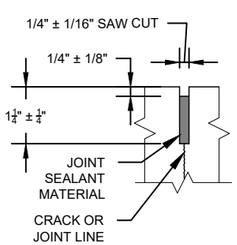


NOTE: SAWING OR SEALING JOINT IS NOT REQUIRED.

SECTION C-C'
BT-3' LONGITUDINAL JOINT



DETAIL 1
EPOXY GROUTING



DETAIL 2
'RD' JOINT SEAL

DOWEL AND TIE BAR SIZES FOR TRANSVERSE JOINTS		
PAVEMENT THICKNESS	DOWEL DIAMETER	TIE BAR SIZE
T < 8"	$\frac{3}{4}$"	#6
8" ≤ T < 10"	1 $\frac{1}{4}$"	#10
T ≥ 10"	1 $\frac{1}{2}$"	#11

NOTE: DOWELS AND TIE BARS SHALL BE EPOXY COATED

IOWA DOT
SMARTER | SIMPLER | CUSTOMER DRIVEN

Seal

Consultant

Project

Client
Iowa Department of Transportation

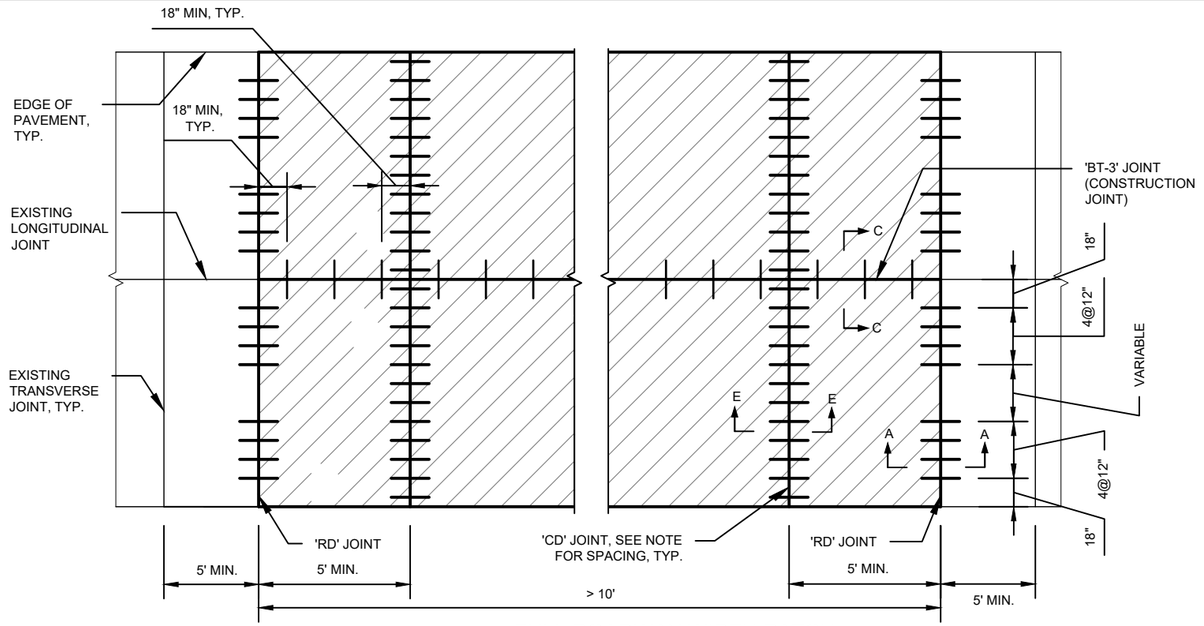
Mark	Date	Description

0 1/2" 1"
THIS SHEET PLOTS FULL SIZE AT 11x17 (INCHES)

Project No.
Date MAY 01, 2022
Drawn
Checked
Scale NTS

FULL DEPTH REPAIR
FULL ROADWAY WIDTH
LENGTH 6' TO 10'
Sheet Title

Sheet No. **FDR-04**



NOTE:
'RD' JOINT = TRANSVERSE JOINT WITH EPOXY EMBEDDED DOWELS
'CD' JOINT = TRANSVERSE JOINT WITH DOWEL BASKET
'BT-3' JOINT = LONGITUDINAL JOINT WITH EPOXY EMBEDDED TIE BARS

FULL ROADWAY WIDTH PATCH
LENGTH > 10'
(ASSUMING ONE LANE TO BE REPAIRED AT A TIME)

A. REPAIR PROCEDURE NOTES:

(IT IS ASSUMED THAT ONE LANE IS TO BE REPAIRED AND OPENED TO TRAFFIC BEFORE THE NEXT LANE IS REPAIRED.)

1. DETERMINE NEW TRANSVERSE JOINT LOCATIONS AS FOLLOWS:
   a. JOINT SPACING 10 FEET MINIMUM, 20 FEET MAXIMUM, 15 FEET OPTIMUM
   b. 'CD' JOINT SHALL BE AT LEAST 5 FEET FROM THE PATCH END.
2. MAKE FULL-DEPTH SAW CUTS ALONG FULL PERIMETER OF AREA TO BE REPAIRED.
3. REMOVE CONCRETE IN REPAIR AREA IN ACCORDANCE WITH ARTICLE 2510.03.A .
4. IF LONGITUDINAL SUBDRAIN IS NOT TO BE PLACED, OR IS NOT PRESENT, ON THE SIDE OF ROADWAY TO BE PATCHED, PLACE PATCH SUBDRAIN IN ACCORDANCE WITH ARTICLE 2502.03.C.
5. REPAIR SUBBASE AND/OR SUBGRADE AS PLANNED OR IF DISTURBED DURING CONSTRUCTION IN ACCORDANCE WITH ARTICLE 2529.03.C.
6. PLACE DOWELS AND TIE BARS IN PREDRILLED HOLES USING EPOXY GROUT, ACCORDING TO ARTICLE 2301.03,E. ALIGN DOWELS AND TIE BARS TO $\frac{1}{8}$ INCH OF PAVEMENT PROFILE AND CENTER LINE. COAT THE PORTION OF DOWELS EXTENDING INTO THE PATCH AREA WITH A BOND BREAKER. DO NOT COAT TIE BARS.
7. PLACE FORMS ON ALL EXPOSED EDGES.
8. MOISTEN THE SUBBASE OR SUBGRADE OR COVER WITH A SINGLE LAYER OF PLASTIC FILM MEETING REQUIREMENTS OF SECTION 4107.
9. SEE LIST OF APPROVED REPAIR MATERIALS - ITEM B BELOW.
10. MIX, PLACE, AND CONSOLIDATE REPAIR MATERIAL IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR WITH ARTICLE 2529.03.G.
11. STRIKE OFF REPAIR MATERIAL FLUSH WITH PAVEMENT SURFACE AT PERIMETER OF REPAIR AREA, AND TEXTURE SURFACE OF REPAIR TO MATCH THE SURROUNDING PAVEMENT.
12. CURE THE PATCH IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR ARTICLE 2529.03.G.
13. SAW AND SEAL JOINTS IN ACCORDANCE WITH ARTICLE 2301.03.P.

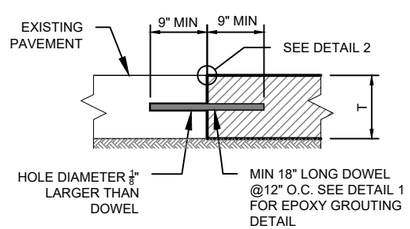
B. REPAIR MATERIALS:

REPAIR MATERIALS SHALL BE IN ACCORDANCE WITH ARTICLE 2529.02.B.

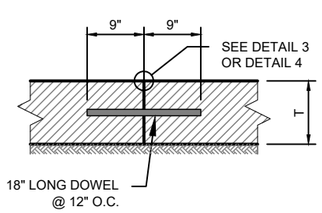
C. QUALITY CONTROL:

SEE CHECKLIST.

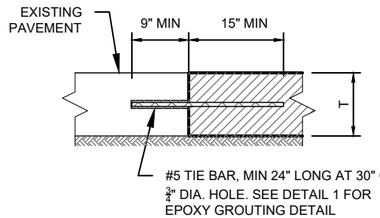
NOTE: ALL ARTICLES AND SECTIONS REFERENCED ON THIS DRAWING REFER TO THE IOWA DOT STANDARD SPECIFICATIONS UNLESS OTHERWISE INDICATED.



SECTION A-A
'RD' TRANSVERSE JOINT

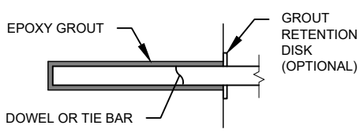


SECTION E-E
'CD' TRANSVERSE JOINT

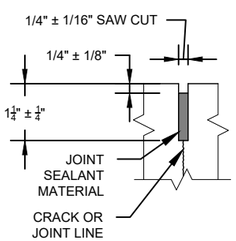


NOTE: SAWING OR SEALING JOINT IS NOT REQUIRED.

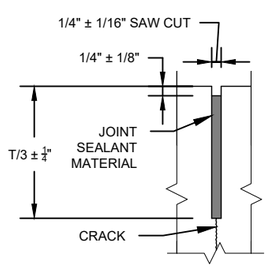
SECTION C-C
'BT-3' LONGITUDINAL JOINT



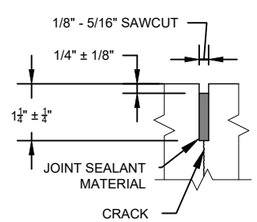
DETAIL 1
EPOXY GROUTING



DETAIL 2
'RD' JOINT SEAL



DETAIL 3
(SAW CUT FORMED BY CONVENTIONAL CONCRETE SAWING EQUIPMENT)



DETAIL 4
(SAW CUT FORMED BY APPROVED EARLY CONCRETE SAWING EQUIPMENT)

DOWEL AND TIE BAR SIZES FOR TRANSVERSE JOINTS		
PAVEMENT THICKNESS	DOWEL DIAMETER	TIE BAR SIZE
T < 8"	$\frac{3}{4}$"	#6
8" ≤ T < 10"	1 $\frac{1}{4}$"	#10
T ≥ 10"	1 $\frac{1}{2}$"	#11

NOTE: DOWELS AND TIE BARS SHALL BE EPOXY COATED

IOWA DOT
SMARTER I SIMPLER I CUSTOMER DRIVEN

Seal

Consultant

Project

Client
Iowa Department of Transportation

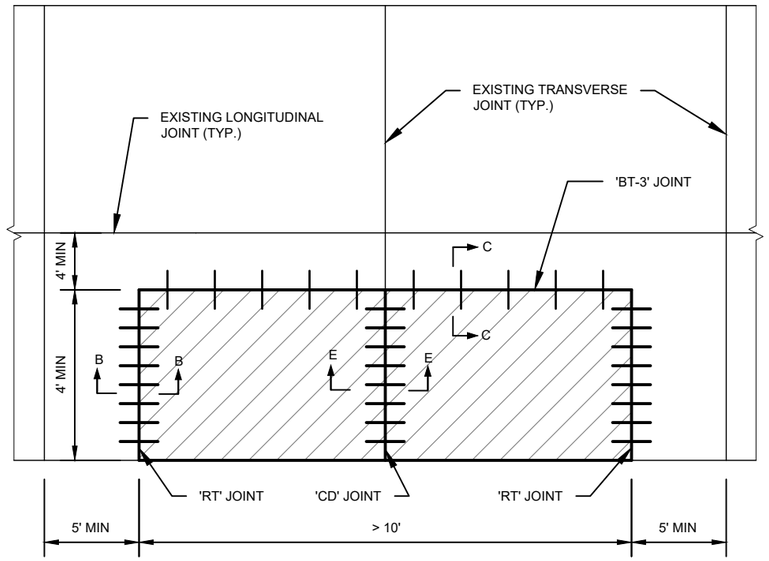
Mark	Date	Description

0 1/2" 1"
THIS SHEET PLOTS FULL SIZE AT 11x17 (INCHES)

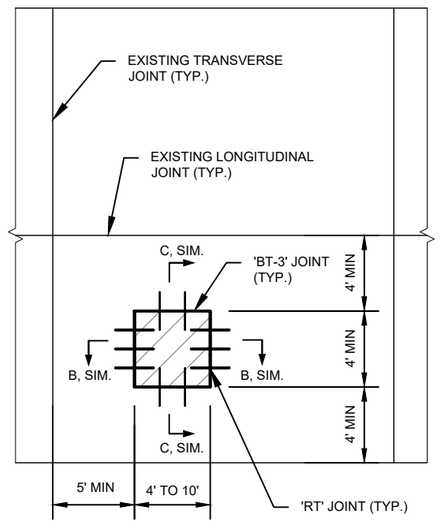
Project No.
Date MAY 01, 2022
Drawn
Checked
Scale NTS

FULL DEPTH REPAIR
FULL ROADWAY WIDTH
LENGTH >10'
Sheet Title

Sheet No. **FDR-05**



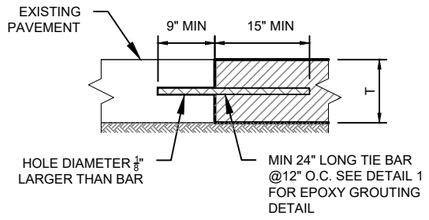
PARTIAL LANE WIDTH PATCH
LENGTH L>10'



NOTE: PROVIDE AT LEAST 2 TIE BARS PER JOINT.

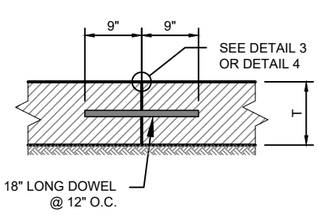
PARTIAL LANE WIDTH PATCH
LENGTH = 4' TO 10'

NOTE:
'CD' JOINT = TRANSVERSE JOINT WITH DOWEL BASKET
'RT' JOINT = TRANSVERSE JOINT WITH EPOXY EMBEDDED TIE BARS
'BT-3' JOINT = LONGITUDINAL JOINT WITH EPOXY EMBEDDED TIE BARS

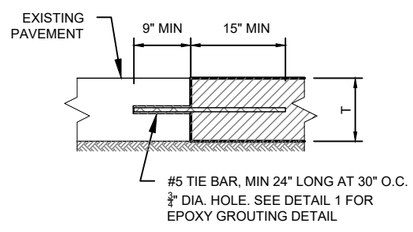


NOTE: SAWING OR SEALING JOINT IS NOT REQUIRED.

SECTION B-B
'RT' TRANSVERSE JOINT

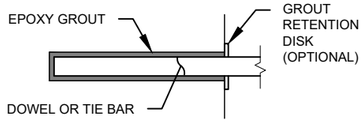


SECTION E-E
'CD' TRANSVERSE JOINT

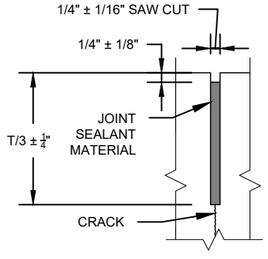


NOTE: SAWING OR SEALING JOINT IS NOT REQUIRED.

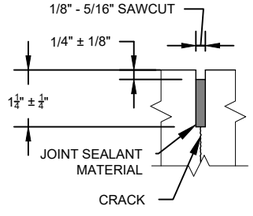
SECTION C-C
'BT-3' LONGITUDINAL JOINT



DETAIL 1
EPOXY GROUTING



DETAIL 3
(SAW CUT FORMED BY
CONVENTIONAL CONCRETE
SAWING EQUIPMENT)



DETAIL 4
(SAW CUT FORMED BY
APPROVED EARLY CONCRETE
SAWING EQUIPMENT)

A. REPAIR PROCEDURE NOTES:

1. DETERMINE PATCH BOUNDARIES.
   a. PARTIAL LANE FULL DEPTH PATCH SHALL BE USED ONLY WHEN A PATCH PLANNED TO BE PARTIAL DEPTH NEEDS TO BE CONVERTED TO FULL DEPTH BECAUSE THE REPAIR DEPTH EXCEEDS LIMITS FOR PARTIAL DEPTH REPAIRS.
   b. FOLLOW INSTRUCTIONS IN PARTIAL DEPTH REPAIR DRAWINGS TO DETERMINE DETERIORATED CONCRETE AND REPAIR BOUNDARIES UNLESS INDICATED OTHERWISE ON THIS DRAWING.
   c. PATCH WIDTH AND LENGTH IS 4 FEET MINIMUM.
   d. IF A PATCH BOUNDARY IS LESS THAN 5 FEET FROM AN EXISTING TRANSVERSE JOINT, OR LESS THAN 4 FEET FROM AN EXISTING LONGITUDINAL JOINT, EXTEND THE BOUNDARY TO THE JOINT.
   e. COMBINE TWO PATCHES LESS THAN 5 FEET APART INTO A SINGLE LARGER REPAIR.
2. MAKE FULL-DEPTH SAW CUTS ALONG PERIMETER OF AREA TO BE REPAIRED.
3. REMOVE CONCRETE IN REPAIR AREA IN ACCORDANCE WITH ARTICLE 2510.03.A.
4. REPAIR SUBBASE AND/OR SUBGRADE AS PLANNED OR IF DISTURBED DURING CONSTRUCTION IN ACCORDANCE WITH ARTICLE 2529.03.C.
5. PLACE DOWELS AND TIE BARS IN PREDRILLED HOLES USING EPOXY GROUT, ACCORDING TO ARTICLE 2301.03,E. ALIGN DOWELS AND TIE BARS TO $\frac{1}{8}$ INCH OF PAVEMENT PROFILE AND CENTER LINE. COAT THE PORTION OF DOWELS EXTENDING INTO THE PATCH AREA WITH A BOND BREAKER. DO NOT COAT TIE BARS.
6. PLACE FORMS ON ALL EXPOSED EDGES.
7. MOISTEN THE SUBBASE OR SUBGRADE OR COVER WITH A SINGLE LAYER OF PLASTIC FILM MEETING REQUIREMENTS OF SECTION 4107.
8. SEE LIST OF APPROVED REPAIR MATERIALS - ITEM B BELOW.
9. MIX, PLACE, AND CONSOLIDATE REPAIR MATERIAL IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR WITH ARTICLE 2529.03.G.
10. STRIKE OFF REPAIR MATERIAL FLUSH WITH PAVEMENT SURFACE AT PERIMETER OF REPAIR AREA, AND TEXTURE SURFACE OF REPAIR TO MATCH THE SURROUNDING PAVEMENT.
11. CURE THE PATCH IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR ARTICLE 2529.03.G.
12. SAW AND SEAL JOINTS IN ACCORDANCE WITH ARTICLE 2301.03.P.

B. REPAIR MATERIALS:

REPAIR MATERIALS SHALL BE IN ACCORDANCE WITH ARTICLE 2529.02.B.

C. QUALITY CONTROL:

SEE CHECKLIST.

NOTE: ALL ARTICLES AND SECTIONS REFERENCED ON THIS DRAWING REFER TO THE IOWA DOT STANDARD SPECIFICATIONS UNLESS OTHERWISE INDICATED.

DOWEL AND TIE BAR SIZES FOR TRANSVERSE JOINTS		
PAVEMENT THICKNESS	DOWEL DIAMETER	TIE BAR SIZE
T < 8"	$\frac{3}{4}$"	#6
8" ≤ T < 10"	1 $\frac{1}{4}$"	#10
T ≥ 10"	1 $\frac{1}{2}$"	#11

NOTE: DOWELS AND TIE BARS SHALL BE EPOXY COATED

IOWA DOT
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Seal

Consultant

Project

Client
Iowa Department of Transportation

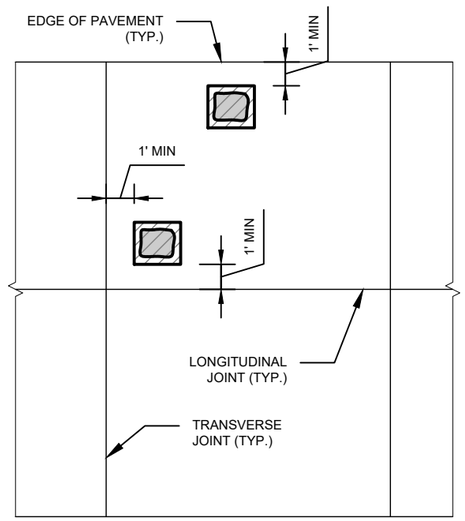
Mark	Date	Description

0 1/2" 1"
THIS SHEET PLOTS FULL SIZE AT 11x17 (INCHES)

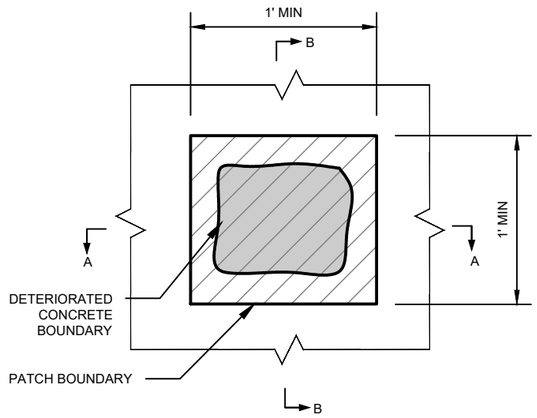
Project No.
Date MAY 01, 2022
Drawn
Checked
Scale NTS

FULL DEPTH REPAIR
PARTIAL LANE WIDTH
Sheet Title

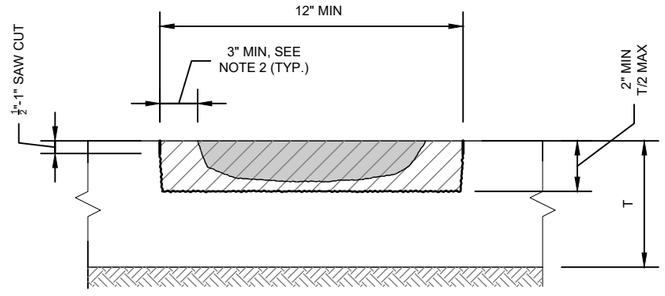
Sheet No. **FDR-06**



PLAN VIEW



PARTIAL PLAN VIEW



SECTION A-A
(SECTION B-B SIMILAR)

LEGEND:

DETERIORATED AREA

REPAIR AREA

A. REPAIR PROCEDURE NOTES:

1. DETERMINE EXTENT OF DETERIORATED AREAS:
- a. IDENTIFY DETERIORATED CONCRETE VISUALLY AND BY SOUNDING TECHNIQUES, SUCH AS HAMMER TAPPING AND/OR CHAIN DRAGGING.
- b. MARK BOUNDARIES OF DETERIORATED CONCRETE ON PAVEMENT SURFACE.

2. DETERMINE REPAIR BOUNDARIES:
- a. EXTEND REPAIR BOUNDARIES AT LEAST 3 INCHES BEYOND DETERIORATED CONCRETE.
- b. COMBINE TWO PATCHES LESS THAN 1 FOOT APART INTO A SINGLE LARGER REPAIR AREA.
- c. IF EDGE OF PATCH IS LESS THAN 1 FOOT FROM JOINTS/SHOULDER, EXTEND PATCH TO JOINTS/SHOULDER, AND PERFORM A REPAIR SHOWN IN PDR-02, PDR-03, OR PDR-04 AS APPROPRIATE.
- d. MARK REPAIR BOUNDARIES ON PAVEMENT SURFACE.

3. MAKE SAW CUTS:
- a. MAKE VERTICAL SAW CUTS TO DEPTH OF 1/2 TO 1 INCH ALONG PERIMETER OF AREA TO BE REPAIRED.
- b. SAW CUTS TO BE GENERALLY PARALLEL TO PAVEMENT PANEL EDGES, SO AS TO MAINTAIN APPROXIMATELY RECTANGULAR REPAIR AREA.

4. REMOVE ALL CONCRETE IN REPAIR AREA:
- a. USE MAXIMUM 15-LB. CHIPPING HAMMER.
- b. KEEP VERTICAL EDGES ALONG REPAIR BOUNDARIES.
- c. USE CARE TO PREVENT DAMAGE TO SOUND CONCRETE TO REMAIN AT PERIMETER OF REPAIR AREA AND AT BOTTOM OF REPAIR AREA.
- d. ROTARY MILLING CAN BE UTILIZED IF SIZE OF REPAIR AREA IS SUFFICIENT.
- e. IF DETERIORATED CONCRETE EXTENDS OVER MID-DEPTH OF SLAB, PERFORM FULL-DEPTH REPAIR PER FDR-06.

5. PREPARE REPAIR SURFACE:
- a. CLEAN ALL SURFACES OF REPAIR AREA BY SAND-BLASTING, FOLLOWED BY BLOWING WITH COMPRESSED AIR.
- b. IF PROPRIETARY REPAIR MATERIAL TO BE USED, ADDITIONAL SURFACE PREPARATION AND CONDITIONING TO BE IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.
- c. IF IOWA DOT CLASS C PATCHING MATERIALS TO BE USED, MOISTEN REPAIR AREA SURFACE, BUT NO FREE WATER SHOULD BE PRESENT IN REPAIR AREA CAVITY. REMOVE ALL EXCESS MOISTURE WITH COMPRESSED AIR JUST PRIOR TO PLACING REPAIR MATERIAL.

6. MIX, PLACE, CONSOLIDATE, AND FINISH REPAIR MATERIAL:
- a. THOROUGHLY MIX REPAIR MATERIAL IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR SECTION 2530.03.
- b. IMMEDIATELY PRIOR TO PLACING REPAIR MATERIAL, USE STIFF BRUSHES OR BROOMS TO AGGRESIVELY APPLY SCRUB COAT OF REPAIR MATERIAL ONTO VERTICAL EDGES AND BOTTOM SURFACE OF REPAIR AREA.
- c. PLACE REPAIR MATERIAL WITHIN 15 MINUTES OF SCRUB COAT APPLICATION.
- d. CONSOLIDATE REPAIR MATERIAL.
- e. STRIKE OFF REPAIR MATERIAL FLUSH WITH PAVEMENT SURFACE AT PERIMETER OF REPAIR AREA, AND TEXTURE SURFACE OF REPAIR TO MATCH THE SURROUNDING PAVEMENT.

7. CURE THE PATCH:
- a. IF IOWA DOT CLASS C PATCHING MATERIALS TO BE USED, CURE THE PATCH IN ACCORDANCE WITH ARTICLE 2529.03.G.
- b. IF PROPRIETARY REPAIR MATERIAL TO BE USED, FOLLOW MANUFACTURER'S RECOMMENDATIONS FOR CURING.

8. SEAL SAW CUT RUNOFFS:
- a. PRIOR TO APPLICATION OF SEALANT, REMOVE ALL CURING COMPOUND, AND OTHER COMTAMINANTS FROM SURFACE TO RECEIVE SEALANT.
- b. CLEAN AND SEAL RUNOFFS WITH AN APPROPRIATE MATERIAL DESCRIBED IN SECTION 4136.
- c. RECESS SEALANT 1/4 INCH FROM PAVEMENT SURFACE.

B. REPAIR MATERIALS:

REPAIR MATERIALS SHALL BE IN ACCORDANCE WITH ARTICLE 2530.02.B.

C. QUALITY CONTROL:

SEE CHECKLIST.

NOTE: ALL ARTICLES AND SECTIONS REFERENCED ON THIS DRAWING REFER TO THE IOWA DOT STANDARD SPECIFICATIONS UNLESS OTHERWISE INDICATED.

IOWA DOT
SMARTER | SIMPLER | CUSTOMER DRIVEN

Seal

Consultant

Project

Client
Iowa Department of Transportation

Mark	Date	Description

0 1/2" 1"
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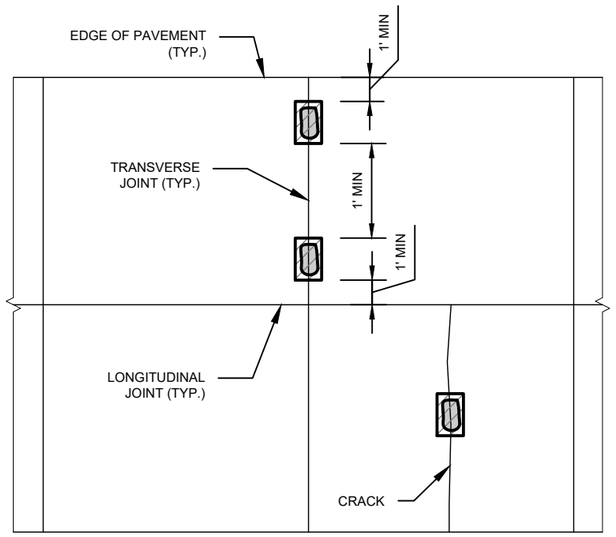
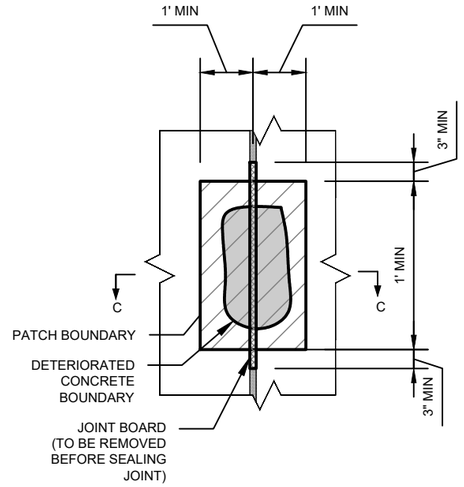
Project No.
Date MAY 01, 2022
Drawn
Checked
Scale NTS

PARTIAL DEPTH REPAIR NOT AT TRANSVERSE OR LONGITUDINAL JOINT
Sheet Title

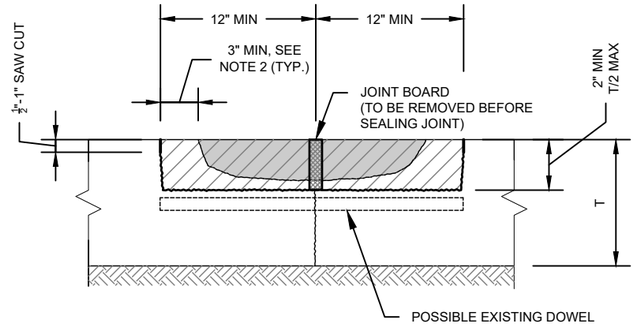
Sheet No. **PDR-01**



PLAN VIEW



PARTIAL PLAN VIEW



SECTION C-C

LEGEND:

DETERIORATED AREA

REPAIR AREA

A. REPAIR PROCEDURE NOTES:

1. DETERMINE EXTENT OF DETERIORATED AREAS:
- a. IDENTIFY DETERIORATED CONCRETE VISUALLY AND BY SOUNDING TECHNIQUES, SUCH AS HAMMER TAPPING AND/OR CHAIN DRAGGING.
- b. MARK BOUNDARIES OF DETERIORATED CONCRETE ON PAVEMENT SURFACE.

2. DETERMINE REPAIR BOUNDARIES:
- a. EXTEND REPAIR BOUNDARIES AT LEAST 3 INCHES BEYOND DETERIORATED CONCRETE.
- b. COMBINE TWO PATCHES LESS THAN 1 FOOT APART INTO A SINGLE LARGER REPAIR AREA.
- c. IF EDGE OF PATCH IS LESS THAN 1 FOOT FROM LONGITUDINAL JOINTS/SHOULDER, EXTEND PATCH TO JOINTS/SHOULDER, AND PERFORM A REPAIR SHOWN IN PDR-04.
- d. MARK REPAIR BOUNDARIES ON PAVEMENT SURFACE.

3. MAKE SAW CUTS:
- a. MAKE VERTICAL SAW CUTS TO DEPTH OF 1/2 TO 1 INCH ALONG PERIMETER OF AREA TO BE REPAIRED.
- b. SAW CUTS TO BE GENERALLY PARALLEL TO PAVEMENT PANEL EDGES, SO AS TO MAINTAIN APPROXIMATELY RECTANGULAR REPAIR AREA.

4. REMOVE ALL CONCRETE IN REPAIR AREA:
- a. USE MAXIMUM 15-LB. CHIPPING HAMMER.
- b. KEEP VERTICAL EDGES ALONG REPAIR BOUNDARIES.
- c. USE CARE TO PREVENT DAMAGE TO SOUND CONCRETE TO REMAIN AT PERIMETER OF REPAIR AREA AND AT BOTTOM OF REPAIR AREA.
- d. ROTARY MILLING CAN BE UTILIZED IF SIZE OF REPAIR AREA IS SUFFICIENT.
- e. IF DETERIORATED CONCRETE EXTENDS OVER MID-DEPTH OF SLAB, PERFORM FULL-DEPTH REPAIR PER FDR-06.

5. PREPARE REPAIR SURFACE:
- a. CLEAN ALL SURFACES OF REPAIR AREA BY SAND-BLASTING, FOLLOWED BY BLOWING WITH COMPRESSED AIR.
- b. IF PROPRIETARY REPAIR MATERIAL TO BE USED, ADDITIONAL SURFACE PREPARATION AND CONDITIONING TO BE IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.
- c. IF IOWA DOT CLASS C PATCHING MATERIALS TO BE USED, MOISTEN REPAIR AREA SURFACE, BUT NO FREE WATER SHOULD BE PRESENT IN REPAIR AREA CAVITY. REMOVE ALL EXCESS MOISTURE WITH COMPRESSED AIR JUST PRIOR TO PLACING REPAIR MATERIAL.

6. JOINT BOARD INSTALLATION:
- a. PLACE A JOINT BOARD AT JOINT OR CRACK IN ACCORDANCE WITH ARTICLE 2530.02.C.
- b. USE A BOARD MADE OF COMPRESSIBLE MATERIAL OF A WIDTH APPROXIMATELY EQUAL TO JOINT/CRACK.
- c. EXTEND JOINT BOARD APPROXIMATELY 3 INCHES BEYOND PATCH BOUNDARIES TO PREVENT REPAIR MATERIAL FROM GETTING INTO THE JOINT/CRACK.

7. MIX, PLACE, CONSOLIDATE, AND FINISH REPAIR MATERIAL:
- a. THOROUGHLY MIX REPAIR MATERIAL IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR SECTION 2530.03.
- b. IMMEDIATELY PRIOR TO PLACING REPAIR MATERIAL, USE STIFF BRUSHES OR BROOMS TO AGGRESIVELY APPLY SCRUB COAT OF REPAIR MATERIAL ONTO VERTICAL EDGES AND BOTTOM SURFACE OF REPAIR AREA.
- c. PLACE REPAIR MATERIAL WITHIN 15 MINUTES OF SCRUB COAT APPLICATION.
- d. CONSOLIDATE REPAIR MATERIAL.
- e. STRIKE OFF REPAIR MATERIAL FLUSH WITH PAVEMENT SURFACE AT PERIMETER OF REPAIR AREA, AND TEXTURE SURFACE OF REPAIR TO MATCH THE SURROUNDING PAVEMENT.

8. CURE THE PATCH:
- a. IF IOWA DOT CLASS C PATCHING MATERIALS TO BE USED, CURE THE PATCH IN ACCORDANCE WITH ARTICLE 2529.03.G.
- b. IF PROPRIETARY REPAIR MATERIAL TO BE USED, FOLLOW MANUFACTURER'S RECOMMENDATIONS FOR CURING.

9. SEAL JOINTS AND SAW-CUT RUNOFFS:
- a. REMOVE JOINT BOARD IN A MANNER THAT DOES NOT DAMAGE THE PATCH.
- b. PRIOR TO APPLICATION OF SEALANT, REMOVE ALL CURING COMPOUND, AND OTHER COMTAMINANTS FROM SURFACE TO RECEIVE SEALANT.
- b. CLEAN AND SEAL JOINTS AND RUNOFFS WITH AN APPROPRIATE MATERIAL DESCRIBED IN SECTION 4136.
- c. RECESS SEALANT 1/4 INCH FROM PAVEMENT SURFACE.

B. REPAIR MATERIALS:

REPAIR MATERIALS SHALL BE IN ACCORDANCE WITH ARTICLE 2530.02.B.

C. QUALITY CONTROL:

SEE CHECKLIST.

NOTE: ALL ARTICLES AND SECTIONS REFERENCED ON THIS DRAWING REFER TO THE IOWA DOT STANDARD SPECIFICATIONS UNLESS OTHERWISE INDICATED.

IOWA DOT
SMARTER I SIMPLER I CUSTOMER DRIVEN

Seal

Consultant

Project

Client
Iowa Department of Transportation

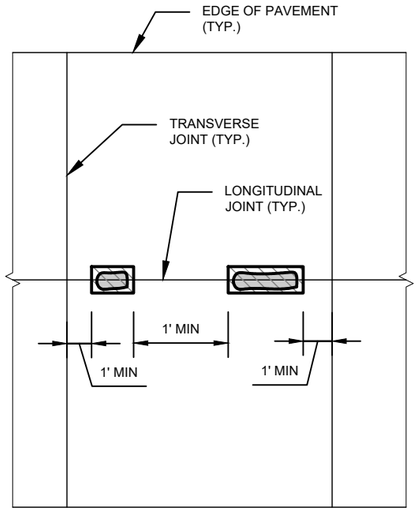
Mark	Date	Description

0 1/2" 1"
THIS SHEET PLOTS FULL SIZE AT 11x17 (INCHES)

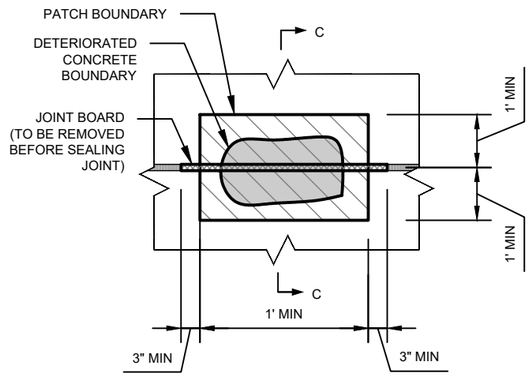
Project No.	
Date	MAY 01, 2022
Drawn	
Checked	
Scale	NTS

PARTIAL DEPTH REPAIR AT TRANSVERSE JOINT
Sheet Title

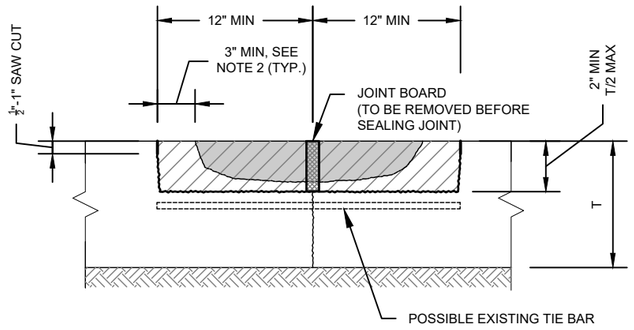
Sheet No. **PDR-02**



PLAN VIEW



PARTIAL PLAN VIEW



SECTION C-C

LEGEND:

DETERIORATED AREA

REPAIR AREA

A. REPAIR PROCEDURE NOTES:

1. DETERMINE EXTENT OF DETERIORATED AREAS:
- a. IDENTIFY DETERIORATED CONCRETE VISUALLY AND BY SOUNDING TECHNIQUES, SUCH AS HAMMER TAPPING AND/OR CHAIN DRAGGING.
- b. MARK BOUNDARIES OF DETERIORATED CONCRETE ON PAVEMENT SURFACE.

2. DETERMINE REPAIR BOUNDARIES:
- a. EXTEND REPAIR BOUNDARIES AT LEAST 3 INCHES BEYOND DETERIORATED CONCRETE.
- b. COMBINE TWO PATCHES LESS THAN 1 FOOT APART INTO A SINGLE LARGER REPAIR AREA.
- c. IF EDGE OF PATCH IS LESS THAN 1 FOOT FROM TRANSVERSE JOINTS, EXTEND PATCH TO JOINTS, AND PERFORM A REPAIR SHOWN IN PDR-04.
- d. MARK REPAIR BOUNDARIES ON PAVEMENT SURFACE.

3. MAKE SAW CUTS:
- a. MAKE VERTICAL SAW CUTS TO DEPTH OF 1/2 TO 1 INCH ALONG PERIMETER OF AREA TO BE REPAIRED.
- b. SAW CUTS TO BE GENERALLY PARALLEL TO PAVEMENT PANEL EDGES, SO AS TO MAINTAIN APPROXIMATELY RECTANGULAR REPAIR AREA.

4. REMOVE ALL CONCRETE IN REPAIR AREA:
- a. USE MAXIMUM 15-LB. CHIPPING HAMMER.
- b. KEEP VERTICAL EDGES ALONG REPAIR BOUNDARIES.
- c. USE CARE TO PREVENT DAMAGE TO SOUND CONCRETE TO REMAIN AT PERIMETER OF REPAIR AREA AND AT BOTTOM OF REPAIR AREA.
- d. ROTARY MILLING CAN BE UTILIZED IF SIZE OF REPAIR AREA IS SUFFICIENT.
- e. IF DETERIORATED CONCRETE EXTENDS OVER MID-DEPTH OF SLAB, PERFORM FULL-DEPTH REPAIR PER FDR-06.

5. PREPARE REPAIR SURFACE:
- a. CLEAN ALL SURFACES OF REPAIR AREA BY SAND-BLASTING, FOLLOWED BY BLOWING WITH COMPRESSED AIR.
- b. IF PROPRIETARY REPAIR MATERIAL TO BE USED, ADDITIONAL SURFACE PREPARATION AND CONDITIONING TO BE IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.
- c. IF IOWA DOT CLASS C PATCHING MATERIALS TO BE USED, MOISTEN REPAIR AREA SURFACE, BUT NO FREE WATER SHOULD BE PRESENT IN REPAIR AREA CAVITY. REMOVE ALL EXCESS MOISTURE WITH COMPRESSED AIR JUST PRIOR TO PLACING REPAIR MATERIAL.

6. JOINT BOARD INSTALLATION:
- a. PLACE A JOINT BOARD AT JOINT OR CRACK IN ACCORDANCE WITH ARTICLE 2530.02.C.
- b. USE A BOARD MADE OF COMPRESSIBLE MATERIAL OF A WIDTH APPROXIMATELY EQUAL TO JOINT/CRACK.
- c. EXTEND JOINT BOARD APPROXIMATELY 3 INCHES BEYOND PATCH BOUNDARIES TO PREVENT REPAIR MATERIAL FROM GETTING INTO THE JOINT/CRACK.

7. MIX, PLACE, CONSOLIDATE, AND FINISH REPAIR MATERIAL:
- a. THOROUGHLY MIX REPAIR MATERIAL IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR SECTION 2530.03.
- b. IMMEDIATELY PRIOR TO PLACING REPAIR MATERIAL, USE STIFF BRUSHES OR BROOMS TO AGGRESIVELY APPLY SCRUB COAT OF REPAIR MATERIAL ONTO VERTICAL EDGES AND BOTTOM SURFACE OF REPAIR AREA.
- c. PLACE REPAIR MATERIAL WITHIN 15 MINUTES OF SCRUB COAT APPLICATION.
- d. CONSOLIDATE REPAIR MATERIAL.
- e. STRIKE OFF REPAIR MATERIAL FLUSH WITH PAVEMENT SURFACE AT PERIMETER OF REPAIR AREA, AND TEXTURE SURFACE OF REPAIR TO MATCH THE SURROUNDING PAVEMENT.

8. CURE THE PATCH:
- a. IF IOWA DOT CLASS C PATCHING MATERIALS TO BE USED, CURE THE PATCH IN ACCORDANCE WITH ARTICLE 2529.03.G.
- b. IF PROPRIETARY REPAIR MATERIAL TO BE USED, FOLLOW MANUFACTURER'S RECOMMENDATIONS FOR CURING.

9. SEAL JOINTS AND SAW-CUT RUNOFFS:
- a. REMOVE JOINT BOARD IN A MANNER THAT DOES NOT DAMAGE THE PATCH.
- b. PRIOR TO APPLICATION OF SEALANT, REMOVE ALL CURING COMPOUND, AND OTHER COMTAMINANTS FROM SURFACE TO RECEIVE SEALANT.
- b. CLEAN AND SEAL JOINTS AND RUNOFFS WITH AN APPROPRIATE MATERIAL DESCRIBED IN SECTION 4136.
- c. RECESS SEALANT 1/4 INCH FROM PAVEMENT SURFACE.

B. REPAIR MATERIALS:

REPAIR MATERIALS SHALL BE IN ACCORDANCE WITH ARTICLE 2530.02.B.

C. QUALITY CONTROL:

SEE CHECKLIST.

NOTE: ALL ARTICLES AND SECTIONS REFERENCED ON THIS DRAWING REFER TO THE IOWA DOT STANDARD SPECIFICATIONS UNLESS OTHERWISE INDICATED.

IOWA DOT
SMARTER | SIMPLER | CUSTOMER DRIVEN

Seal

Consultant

Project

Client
Iowa Department of Transportation

Mark	Date	Description

0 1/2" 1"

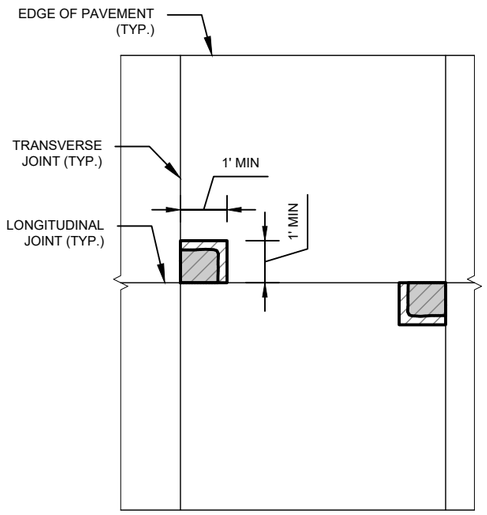
THIS SHEET PLOTS FULL SIZE AT 11x17 (INCHES)

Project No.	
Date	MAY 01, 2022
Drawn	
Checked	
Scale	NTS

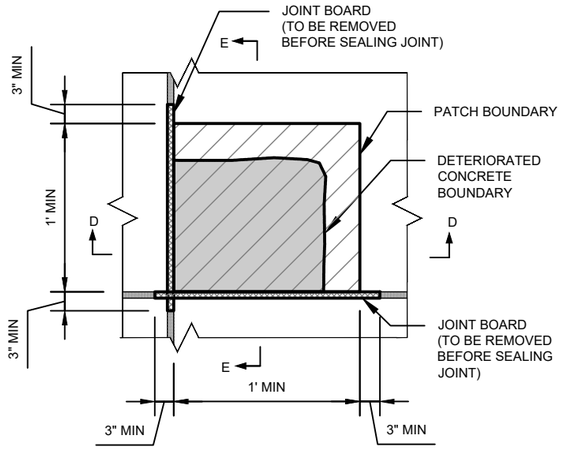
PARTIAL DEPTH REPAIR AT LONGITUDINAL JOINT

Sheet Title

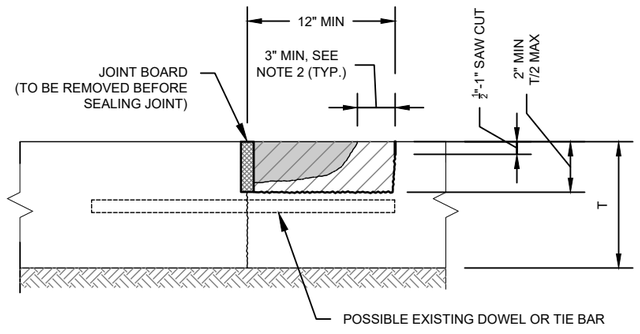
Sheet No. **PDR-03**



PLAN VIEW



PARTIAL PLAN VIEW



SECTION D-D
(SECTION E-E SIMILAR)

LEGEND:

DETERIORATED AREA

REPAIR AREA

A. REPAIR PROCEDURE NOTES:

1. DETERMINE EXTENT OF DETERIORATED AREAS:
- a. IDENTIFY DETERIORATED CONCRETE VISUALLY AND BY SOUNDING TECHNIQUES, SUCH AS HAMMER TAPPING AND/OR CHAIN DRAGGING.
- b. MARK BOUNDARIES OF DETERIORATED CONCRETE ON PAVEMENT SURFACE.

2. DETERMINE REPAIR BOUNDARIES:
- a. EXTEND REPAIR BOUNDARIES AT LEAST 3 INCHES BEYOND DETERIORATED CONCRETE.
- b. COMBINE TWO PATCHES LESS THAN 1 FOOT APART INTO A SINGLE LARGER REPAIR AREA.
- c. MARK REPAIR BOUNDARIES ON PAVEMENT SURFACE.

3. MAKE SAW CUTS:
- a. MAKE VERTICAL SAW CUTS TO DEPTH OF 1/2 TO 1 INCH ALONG PERIMETER OF AREA TO BE REPAIRED.
- b. SAW CUTS TO BE GENERALLY PARALLEL TO PAVEMENT PANEL EDGES, SO AS TO MAINTAIN APPROXIMATELY RECTANGULAR REPAIR AREA.

4. REMOVE ALL CONCRETE IN REPAIR AREA:
- a. USE MAXIMUM 15-LB. CHIPPING HAMMER.
- b. KEEP VERTICAL EDGES ALONG REPAIR BOUNDARIES.
- c. USE CARE TO PREVENT DAMAGE TO SOUND CONCRETE TO REMAIN AT PERIMETER OF REPAIR AREA AND AT BOTTOM OF REPAIR AREA.
- d. ROTARY MILLING CAN BE UTILIZED IF SIZE OF REPAIR AREA IS SUFFICIENT.
- e. IF DETERIORATED CONCRETE EXTENDS OVER MID-DEPTH OF SLAB, PERFORM FULL-DEPTH REPAIR PER FDR-06.

5. PREPARE REPAIR SURFACE:
- a. CLEAN ALL SURFACES OF REPAIR AREA BY SAND-BLASTING, FOLLOWED BY BLOWING WITH COMPRESSED AIR.
- b. IF PROPRIETARY REPAIR MATERIAL TO BE USED, ADDITIONAL SURFACE PREPARATION AND CONDITIONING TO BE IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.
- c. IF IOWA DOT CLASS C PATCHING MATERIALS TO BE USED, MOISTEN REPAIR AREA SURFACE, BUT NO FREE WATER SHOULD BE PRESENT IN REPAIR AREA CAVITY. REMOVE ALL EXCESS MOISTURE WITH COMPRESSED AIR JUST PRIOR TO PLACING REPAIR MATERIAL.

6. JOINT BOARD INSTALLATION:
- a. PLACE A JOINT BOARD AT JOINT OR CRACK IN ACCORDANCE WITH ARTICLE 2530.02.C.
- b. USE A BOARD MADE OF COMPRESSIBLE MATERIAL OF A WIDTH APPROXIMATELY EQUAL TO JOINT/CRACK.
- c. EXTEND JOINT BOARD APPROXIMATELY 3 INCHES BEYOND PATCH BOUNDARIES TO PREVENT REPAIR MATERIAL FROM GETTING INTO THE JOINT/CRACK.

7. MIX, PLACE, CONSOLIDATE, AND FINISH REPAIR MATERIAL:
- a. THOROUGHLY MIX REPAIR MATERIAL IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS OR SECTION 2530.03.
- b. IMMEDIATELY PRIOR TO PLACING REPAIR MATERIAL, USE STIFF BRUSHES OR BROOMS TO AGGRESIVELY APPLY SCRUB COAT OF REPAIR MATERIAL ONTO VERTICAL EDGES AND BOTTOM SURFACE OF REPAIR AREA.
- c. PLACE REPAIR MATERIAL WITHIN 15 MINUTES OF SCRUB COAT APPLICATION.
- d. CONSOLIDATE REPAIR MATERIAL.
- e. STRIKE OFF REPAIR MATERIAL FLUSH WITH PAVEMENT SURFACE AT PERIMETER OF REPAIR AREA, AND TEXTURE SURFACE OF REPAIR TO MATCH THE SURROUNDING PAVEMENT.

8. CURE THE PATCH:
- a. IF IOWA DOT CLASS C PATCHING MATERIALS TO BE USED, CURE THE PATCH IN ACCORDANCE WITH ARTICLE 2529.03.G.
- b. IF PROPRIETARY REPAIR MATERIAL TO BE USED, FOLLOW MANUFACTURER'S RECOMMENDATIONS FOR CURING.

9. SEAL JOINTS AND SAW-CUT RUNOFFS:
- a. REMOVE JOINT BOARD IN A MANNER THAT DOES NOT DAMAGE THE PATCH.
- b. PRIOR TO APPLICATION OF SEALANT, REMOVE ALL CURING COMPOUND, AND OTHER COMTAMINANTS FROM SURFACE TO RECEIVE SEALANT.
- b. CLEAN AND SEAL JOINTS AND RUNOFFS WITH AN APPROPRIATE MATERIAL DESCRIBED IN SECTION 4136.
- c. RECESS SEALANT 1/4 INCH FROM PAVEMENT SURFACE.

B. REPAIR MATERIALS:

REPAIR MATERIALS SHALL BE IN ACCORDANCE WITH ARTICLE 2530.02.B.

C. QUALITY CONTROL:

SEE CHECKLIST.

NOTE: ALL ARTICLES AND SECTIONS REFERENCED ON THIS DRAWING REFER TO THE IOWA DOT STANDARD SPECIFICATIONS UNLESS OTHERWISE INDICATED.

IOWA DOT
SMARTER | SIMPLER | CUSTOMER DRIVEN

Seal

Consultant

Project

Client
Iowa Department of Transportation

Mark	Date	Description

0 1/2" 1"
THIS SHEET PLOTS FULL SIZE AT 11x17 (INCHES)

Project No.	
Date	MAY 01, 2022
Drawn	
Checked	
Scale	NTS

PARTIAL DEPTH REPAIR AT SLAB CORNERS

Sheet Title

Sheet No. **PDR-04**

FULL DEPTH REPAIR - FIELD QUALITY CONTROL CHECKLIST

	Inspection Items	Checked	N.A.
A	**Materials**		
1	Concrete materials meet Iowa DOT specifications.	☐	☐
2	Proprietary repair materials, if being used, meet the manufacturer's requirements.	☐	☐
3	Dowels and tie bars are of proper sizes in accordance with Iowa DOT's specifications.	☐	☐
4	Dowel bars are epoxy coated without damage in the epoxy coating.	☐	☐
5	Joint boards are of proper material and sizes in accordance with Iowa DOT's specifications.	☐	☐
6	Joint sealant materials meet Iowa DOT specifications.	☐	☐
7	Insulation blanket and insulation board for concrete curing meet Iowa DOT specifications.	☐	☐
B	**Environmental conditions**		
1	Ambient and pavement temperatures are within Iowa DOT's specifications.	☐	☐
2	If proprietary repair materials are being used, ambient and pavement temperatures meet the manufacturer's requirements.	☐	☐
C	**Concrete Removal**		
1	Boundaries of removed concrete are in accordance with design drawings.	☐	☐
2	There is no damage to adjacent pavement during concrete removal.	☐	☐
3	Subbase/subgrade is undisturbed, or has been repaired if disturbed during concrete removal.	☐	☐
4	Subbase/subgrade is moistened, but there is no standing water in the repair area.	☐	☐
D	**Dowel and Tiebar Installation**		
1	Holes have been drilled into adjacent pavement to specified depth and cleaned.	☐	☐
2	Dowels and/or tie bars have been installed into the holes properly with cement grout or epoxy to specified depths.	☐	☐
3	Protruding part of the dowel is coated with a bond breaker.	☐	☐
4	Dowel baskets (if used) are constructed with proper dowel spacing and elevation and properly secured to grade at transverse joint locations.	☐	☐
E	**Concrete Mixing and Placement**		
1	Repair concrete has been thoroughly mixed, placed, and consolidated properly in accordance with Iowa DOT's specifications.	☐	☐
2	Proprietary repair materials, if being used, are mixed and placed in accordance with manufacturer's instructions.	☐	☐
3	Patch surface is level with adjacent pavement, and textured to match surrounding surfaces.	☐	☐
F	**Curing**		
1	Repair concrete has been cured properly in accordance with Iowa DOT's specifications.	☐	☐
2	Proprietary repair materials, if being used, have been cured in accordance with manufacturer's instructions.	☐	☐
G	**Joint Sealing**	☐	☐
1	Joints have been cut, cleaned, and sealed in accordance with Iowa DOT's specifications.	☐	☐

Comments:

PARTIAL DEPTH REPAIR - FIELD QUALITY CONTROL CHECKLIST			
	Inspection Items	**Checked**	**N.A.**
A	**Materials**		
1	Concrete materials meet Iowa DOT specifications.	☐	☐
2	Proprietary repair materials, if being used, meet the manufacturer's requirements.	☐	☐
3	Joint boards are made of compressible material and have proper sizes.	☐	☐
4	Joint sealant materials meet specifications.	☐	☐
5	Insulation blanket and insulation board for concrete curing meets specifications.	☐	☐
B	**Environmental conditions**		
1	Ambient and pavement temperatures are within Iowa DOT's specifications.	☐	☐
2	If proprietary repair materials are being used, ambient and pavement temperatures meet the manufacturer's requirements.	☐	☐
C	**Concrete Removal**		
1	Extent of deteriorated concrete has been determined with visual and sounding methods, and marked on the surface.	☐	☐
2	Repair area is generally rectangular, and has boundaries at least 3 inches beyond deteriorated concrete.	☐	☐
3	Repair boundaries are saw cut to a depth of 1/2 to 1 inch. Edge of repair is generally vertical without feathered edges.	☐	☐
4	Concrete to remain at bottom of the repair area is sound.	☐	☐
4	Patch depth is between 2 inches and half of pavement depth.	☐	☐
5	No dowels are exposed in repair area at transverse joint.	☐	☐
D	**Repair Surface**	☐	☐
1	Joint boards are properly placed for patches at transverse and/or longitudinal joints.	☐	☐
2	All surfaces in the repair area are properly prepared and clean.	☐	☐
E	**Concrete Mixing and Placement**	☐	☐
1	A scrub coat or bonding agent is applied to repair area before placing repair material.	☐	☐
2	Repair concrete has been thoroughly mixed, placed, and consolidated properly in accordance with Iowa DOT's specifications.	☐	☐
3	Proprietary repair materials, if being used, are mixed and placed in accordance with manufacturer's instructions.	☐	☐
4	Patch surface is level with adjacent pavement, and textured to match surrounding surfaces.	☐	☐
F	**Curing**		
1	Repair concrete has been cured properly in accordance with Iowa DOT's specifications.	☐	☐
2	Proprietary repair materials, if being used, have been cured in accordance with manufacturer's instructions.	☐	☐
G	**Joint Sealing**		
1	Joint boards have been removed, and joint resevoirs have been cleaned, and sealed in accordance with Iowa DOT's specifications.	☐	☐

Comments:

APPENDIX C. TRIAL BATCH MEMO - FULL DEPTH REPAIRS

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MEMORANDUM | Updated August 20, 2020

IHRB-TR-731: Improving Concrete Patching Practices on Iowa Roadways

Trial Batching for Full-Depth Pavement Repair Mixes

WJE PROJECT NO. 2017.3375

TO	Iowa DOT
FROM	Todd Nelson, Le Pham, and Elizabeth Wagner (all of WJE)

Introduction

As part of the IHRB-TR-731 research project, Wiss, Janney, Elstner Inc. (WJE) in conjunction with Concrete Inc., Brett Admixtures, and Terracon completed trial batching of two high early strength concrete mixtures. The purpose of the trial batching was to evaluate applicability, reasonability, and performance of the two proposed mixtures for use in full-depth pavement repairs in Iowa. The two concrete mixtures were developed by WJE based on previous literature search, which identified these mixtures to have the performance and characteristics desired to achieve the project goals. Generally, the two concrete mixtures were designed to mimic Minnesota DOT mix identification "3U18" and to a lesser extent BASF "4x4", both utilizing a non-calcium chloride accelerating admixture. The focus of the trial batching was to assess the slump and air retention, early age strength gain, time of setting of concrete, and to develop maturity curves (flexural strength and compressive strength) for the two mixtures.

Concrete batching and mixing were performed at the Concrete Inc. plant in Jewell, IA under the supervision of WJE. This plant is a transit mix plant, and as such the batching occurs at the plant while the mixing occurs in the ready mix trucks. This plant is anticipated to provide concrete for the two upcoming full-depth trial repair projects as part of this research. Mr. Jeff Brett of Brett Admixtures was present at the plant to assist with appropriate admixture dosages, and Terracon was present to assist WJE with concrete plastic and hardened concrete testing, which included the following:

1. Concrete slump (ASTM C143) and air content (ASTM C231) over time (every ~ 30 minutes) until initial set.
2. Time of set (ASTM C403).
3. Early-age compressive strength (ASTM C39) of 4x8-inch cylinders.
    a. 12 cylinders per mix for compressive strength testing.
    b. Testing performed at approximately 5, 8, 12, and 24 hours and 7 and 28 days (two cylinders per age).
4. Early-age flexural strength (ASTM C78) of 4x4x14-inch beams.
    a. 12 beams per mix for flexural strength testing.
    b. Testing performed at approximately 5, 12 and 24 hours and 28 days (three beams per age).
5. Concrete maturity (ASTM C1074) versus both compressive and flexural strengths.
    a. Two cylinders and two beams instrumented with Giatec SmartRock 2 temperature sensors per mix.
6. Hardened air void analysis (ASTM C457, Procedure B - Modified point-count method).

a. One cylinder per mix.

Compressive and flexural strength testing was conducted at Terracon's laboratory in Des Moines, IA.

This memo summarizes results of the trial batching of the two mixtures and recommendations for their use in trial pavement full-depth repairs in Fall 2020.

Trial Batching Mixtures and Procedures

Concrete Mixture Designs

The two concrete mixtures developed by WJE and used in the trial batching were designated "Modified 3U18 Mix" and "Alternative M Mix", which mimicked the Minnesota DOT's 3U18 and BASF 4x4 mixes, respectively. The mix designs are presented in Table 1. The cement contents of the two mixtures were 818 and 870 lb per cu. yd, and the w/c were 0.36 and 0.32 for the Modified 3U18 Mix and Alternative M Mix, respectively. The fine and coarse aggregate contents were the same for the two mixtures and were optimized for concrete pavement, utilizing the Tarantula Curve, as shown in the attached combined gradation. Dosages of admixtures were adjusted to achieve the design slump and air content in Table 2.

Mixing Procedures

Concrete was mixed in a ready mix truck using the following general batching sequence: first, 80% of the mix water and air entraining admixture was added to the truck, followed by coarse aggregate, fine aggregate, and cement. Then, accelerator and the remaining water were added, and the concrete was mixed for about 5 to 10 minutes. Finally, the retarder and high-range water reducer (HRWR) were added to the concrete in the truck, and the concrete was mixed for an additional 5 minutes.

Trial Batching Results and Discussion

Plastic Concrete Tests

Slump, air content, concrete temperature and unit weight of the two mixes over time are provided in Table 3 and Table 4. For the Modified 3U18 Mix, air content was first measured approximately 20 minutes after the cement was added to the water (Table 3). Since the air content (9.0%) was higher than designed, the concrete was allowed to sit in the truck for about 20 minutes and then tested again. An estimated slump loss of about 6 to 7 inches and a reduction in the air content of 4.5 percentage points were observed between the two times of testing (33 minutes). After this test, concrete cylinders and beams were made. It was noted that concrete workability dropped very quickly about 1 hour after hydration started.

For the Alternative M Mix, tests were first performed approximately 26 minutes after adding cement to the water (Table 4). Since the air content (8.7%) was higher than designed, the concrete was also allowed to sit in the truck for about 5 to 10 minutes and then tested again. A slump loss of about 3 to 4 inches and a reduction in the air content of 2.8 percentage points were observed between the two times of testing (12 minutes). As the slump (3-1/4 inches) was lower than designed, high-range water reducer (HRWR) was added to the truck and the concrete was mixed for 5 minutes. Testing was performed again at approximately 52 and 56 minutes and the results were determined to be acceptable. After this test, concrete cylinders and beams were cast and a mortar sample was obtained for time of set measurement.

Table 1. Concrete Mixtures for Trial Batching

Materials	Materials Characteristics		Quantity per cu. yd.	
			Modified 3U18 Mix	Alternative M Mix
Cement	Source:	PC0102-Ash Grove - Chanute	818 lb	870 lb
	Type:	Type I/II		
	Specific Gravity:	3.15		
Fine Aggregate	Source:	A42512-Hardin Aggregates	1490 lb	1490 lb
	Specific Gravity:	2.67		
Coarse Aggregate	Source:	A42002-Alden	1190 lb	1190 lb
	Specific Gravity:	2.606		
Air Entraining Admixture	Product Name:	Euclid Eucon AEA-92	3.25 oz	3.75 oz
High-Range Water Reducer	Product Name:	Euclid Plastol 6420	82 oz (10 oz/cwt)	65 oz (8 oz/cwt)
Retarder	Product Name:	Euclid Stasis	25 oz (3 oz/cwt)	41 oz (5 oz/cwt)
Non-Chloride Accelerator	Product Name:	Euclid Accelguard NCA	3 gal	3 gal
Water	Source:	Local Source	298 lb (w/c = 0.36)	282 lb (w/c = 0.32)

Table 2. Design Concrete Properties

Concrete Properties	Modified 3U18 Mix	Alternative M Mix
Target slump	2 to 5 in.	5 to 9 in.
Target air content	5 to 8%	5 to 8%

Table 3. Plastic Concrete Test Results - Modified 3U18 Mix

Time of Testing (After cement added to water)	Slump	Air Content	Concrete Temperature	Unit Weight
20 min.	Not tested (Visually estimated 9 in. or higher)	9.0%	81°F	-
53 min. (*)	2-1/4 in.	5.5%	81°F	144.8 pcf

**Cylinders and beams were cast after this test. It was unable to obtain mortar samples for time of setting due to the low slump of the material at the time of sampling*

Table 4. Plastic Concrete Test Results - Alternative M Mix

Time of Testing (After cement added to water)	Slump	Air Content	Concrete Temperature	Unit Weight
26 min.	Not tested (Visually estimated 7 to 8 in.)	8.7%	-	139.6 pcf
38 min.	3-1/4 in.	5.9%	80°F	144.8 pcf
52 min. (*)	9 in.	9.4%	84°F	138.0 pcf
56 min. (**)	Not tested (Visually estimated 7 to 9 in.)	8.5%	-	-

** HRWR added and concrete mixed for additional 5 minutes before this test*

***Cylinders, beams, and samples for time of setting were cast after this test*

Time of Setting

Time of setting of concrete for the Modified 3U18 Mix was not determined because it was not possible to obtain sufficient mortar sample due to the low slump of the concrete mixture at the time of sampling. The setting characteristics are assumed to be similar to the Alternative M Mix. Results of time of setting for the Alternative M Mix are presented in Table 5. The average times of initial and final setting were 2 hours 5 minutes and 2 hours 55 minutes, respectively.

Table 5. Times of Setting of Concrete - Alternative M Mix

Properties	Results
Time of initial setting (h:mm)	2:05
Time of final setting (h:mm)	2:55
Mortar temperature after sieving	83°F
Ambient temperature at start of test	74°F
Ambient temperature at end of test	79°F

Concrete Compressive and Flexural Strength Tests

The compressive strength results of the two mixes are presented in Table 6 and Table 7. Compressive strengths of the Modified 3U18 Mix were slightly lower than those of the Alternative M Mix at all ages. The average compressive strength of the Modified 3U18 Mix reached 3,000 psi, a strength typically required for opening to traffic, between 12 and 24 hours. The average compressive strength of the Alternative M Mix reached 3,000 psi within 12 hours.

Table 6. Concrete Compressive Strength Development (psi) - Modified 3U18 Mix

Concrete Age (hours)	Sample 1	Sample 2	Average
5	580	670	**625**
8	1,300	1,430	**1,365**
12	2,750	2,790	**2,770**
24	5,040	5,120	**5,080**
169 (7 days)	8,030	8,440	**8,235**

Table 7. Concrete Compressive Strength Development (psi) - Alternative M Mix

Concrete Age (hours)	Sample 1	Sample 2	Average
6	660	690	**675**
9	2,040	2,260	**2,150**
12	3,200	3,170	**3,185**
25	6,160	5,840	**6,000**
171 (7 days)	9,180	9,640	**9,410**

The flexural strength results of the two mixes are presented in Table 8 and Table 9. The flexural strengths of the two mixes were similar at all ages. For the Modified 3U18 Mix, the average flexural strength reached the minimum requirement for opening to traffic of 500 psi (Iowa DOT Specifications, Article 2301.03.U) between 12 and 24 hours. For the Alternative M Mix, the average flexural strength reached 500 psi within 12 hours. In pavement full-depth repairs, depending on the ambient temperature and curing method, the temperatures in the concrete pavement will likely be higher than represented by the small flexural strength samples, which will likely result in higher in-place strengths (at early ages) than reported in this memo.

Table 8. Concrete Flexural Strength Development (psi) - Modified 3U18 Mix

Concrete Age (hours)	Sample 1	Sample 2	Sample 3	Average
6	145	185	175	**168**
12	450	470	450	**457**
24	680	645	705	**677**

Table 9. Concrete Flexural Strength Development (psi) - Alternative M Mix

Concrete Age (hours)	Sample 1	Sample 2	Sample 3	Average
6	155	190	185	**177**
12	465	515	535	**505**
24	645	665	700	**670**

Concrete Maturity Testing

Maturity wireless sensors (SmartRock 2, Giatec Scientific Inc.) were embedded in two cylinders and two beams for each mix, one sensor for each cylinder/beam. Temperature data was downloaded by Terracon via the SmartRock smartphone app and processed by WJE to develop maturity curves of flexural strengths

and compressive strengths for each mix. A datum temperature of -10 C° was used for the analysis in accordance with Iowa DOT Materials I.M. 383. Maturity curves of flexural strength for the Modified 3U18 Mix and Alternative M Mix are presented in Figure 1 and Figure 2, respectively. Maturity curves of compressive strengths for the Modified 3U18 Mix and Alternative M Mix are presented in Figure 3 and Figure 4, respectively.

The temperature-time factors (TTF) required for typical strengths for opening to traffic were determined based on the maturity curves and summarized in Table 10. The TTFs required for a flexural strength of 500 psi were 568 and 597 C°-hours for the Modified 3U18 Mix and the Alternative M Mix, respectively. The TTFs required for a compressive strength of 3,000 psi were 537 and 452 C°-hours for the Modified 3U18 Mix and the Alternative M Mix, respectively.

Table 10. Required Temperature-Time Factors for Typical Concrete Strengths for Opening to Traffic

Target Strengths	Required TTF (°C-hours)	
	Modified 3U18 Mix	Alternative M Mix
Flexural Strength of 500 psi	558	575
Compressive Strength of 3,000 psi	537	452

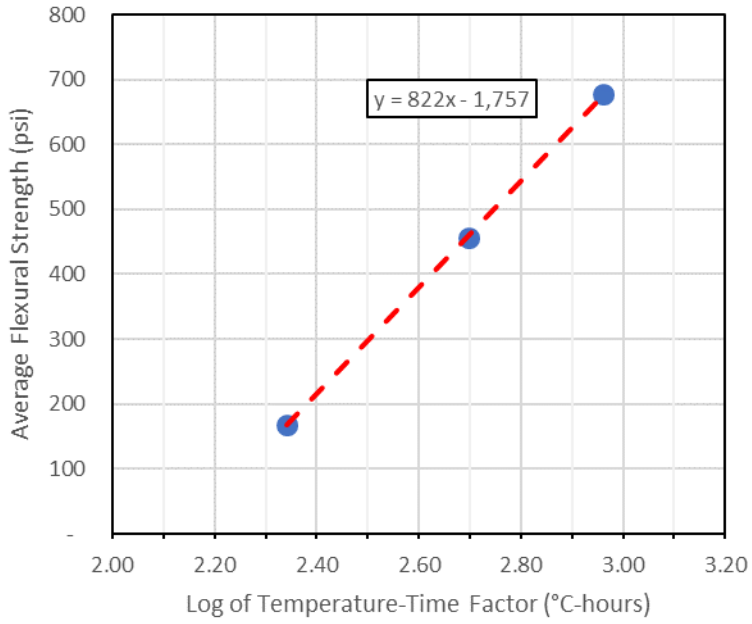

Figure 1. Maturity Curve of Flexural Strength - Modified 3U18 Mix

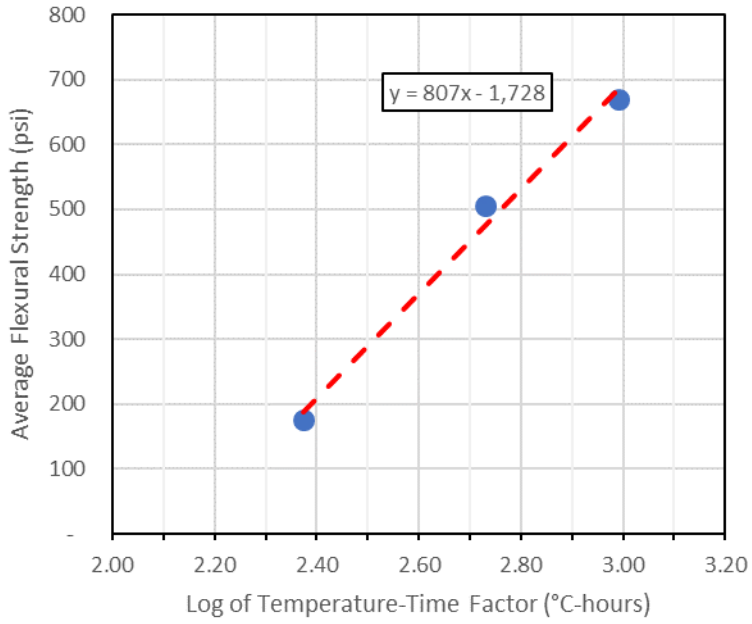

Figure 2. Maturity Curve of Flexural Strength - Alternative M Mix

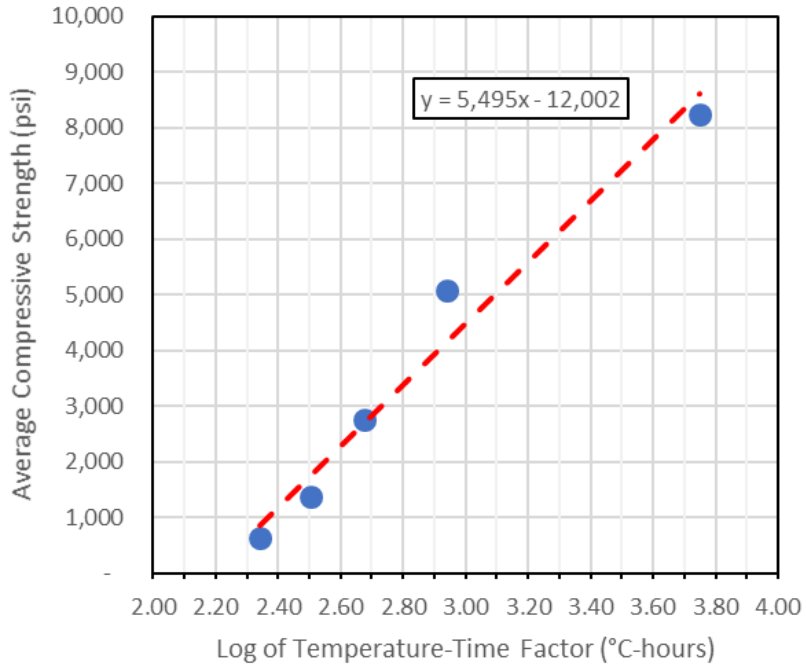

Figure 3. Maturity Curve of Compressive Strength - Modified 3U18 Mix

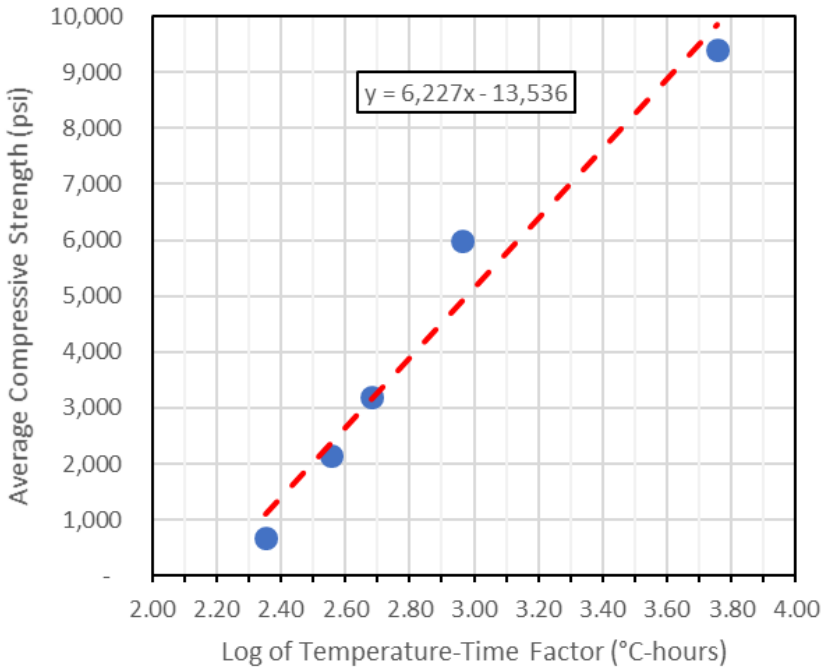

Figure 4. Maturity Curve of Compressive Strength - Alternative M Mix

Hardened Air Void Analysis

Hardened air void analysis was performed for two cylinders, one from each mix in accordance with ASTM C457, Procedure B - Modified point-count method. The results are presented in Table 11. The air content of the Modified 3U18 Mix was 5.7%, which was consistent with the final plastic air content of 5.5% (Table 3). The air content of the Alternative M Mix was 4.4%, which was significantly smaller than the final plastic air content of 8.5% (Table 4). The spacing factors were 0.014 and 0.011 inch for the Modified 3U18 Mix and Alternative M Mix, respectively; both were greater than the generally accepted maximum spacing factor value for concrete with good resistance to freezing and thawing of 0.008 in. (ACI 201.2R-16, *Guide to Durable Concrete*).

Table 11. Hardened Air Void Analysis Results

Air Void System and Test Parameters	Modified 3U18 Mix	Alternative M Mix
Air Content (A), %	5.7	4.4
Spacing Factor, in.	0.014	0.011
Paste Content (p), %	30.3	32.5
Fine Aggregate Content, %	29.7	30.4
Coarse Aggregate Content, %	34.3	32.8
Void Frequency (n), voids per in.	4.8	5.4
Paste-Air Ratio (p/A)	5.3	7.5
Average Chord Length, in.	0.012	0.008
Specific Surface, $in.^2/in.^3$	337	493
Total Traverse Length, in.	97.5	91.7
Total Points Counted	1463	1377
Total Traversed Area, $in.^2$	97.5	91.7
Aggregate Top Size on Lapped Surface, in.	1	¾

Recommendations

Based on the trial batching results, the two concrete mixes tested are suitable for the trial full-depth pavement repairs with a target opening-to-traffic time of 12 to 24 hours after batching. The following modifications are recommended for the upcoming trial full-depth pavement repairs:

- Because the performances of the two trialed mixes were similar, we recommend utilizing only one of the mixes, Alternative M Mix, for the upcoming trial repairs and comparing the performance of the full-depth patches to that of the traditional Iowa DOT M Mix.
- A target slump of 5 to 9 inches, measured after all admixtures are added, is recommended based on the slump retention characteristics of the concrete and admixtures used.
- It is recommended that the non-chloride accelerator be added to the mixing truck at the job site. Based on physical performance and visual observations of the mixes, WJE and Brett Admixtures feel that the rapid slump loss was associated with adding the accelerator at the plant. Even with the addition of the retarder, the slump retention was minimal. By adding the accelerator on site, the slump

and air retention will be longer and allow for unexpected travel and/or delays and a more suitable in-place consistency.

- Since the accelerator is being added on-site, the retarder dosage rate can be reduced, which can be helpful for early strength development of the concrete. It is recommended by Brett Admixtures that the retarder dosage be reduced to approximately 1 to 1.5 oz/cwt.
- High-range water reducer can be added at the plant but should also be available at the site to adjust slump as needed.
- Future research is recommended on the use of slump extending admixtures; such as Euclid AMP-X3. For full- and partial-depth repairs, the use of these admixtures would have desirable benefits of extended the slump life without retarding the concrete.
- When chemical admixtures are added at the site, the concrete in the truck should be mixed for at least 5 minutes on high revolutions to ensure that the admixtures are mixed uniformly with the concrete.
- For the upcoming trial full-depth repairs, it is recommended that both the Alternative M Mix and the typical Iowa DOT M Mix be used for pavement sections in similar conditions to allow for comparison of performance between the two mixes.

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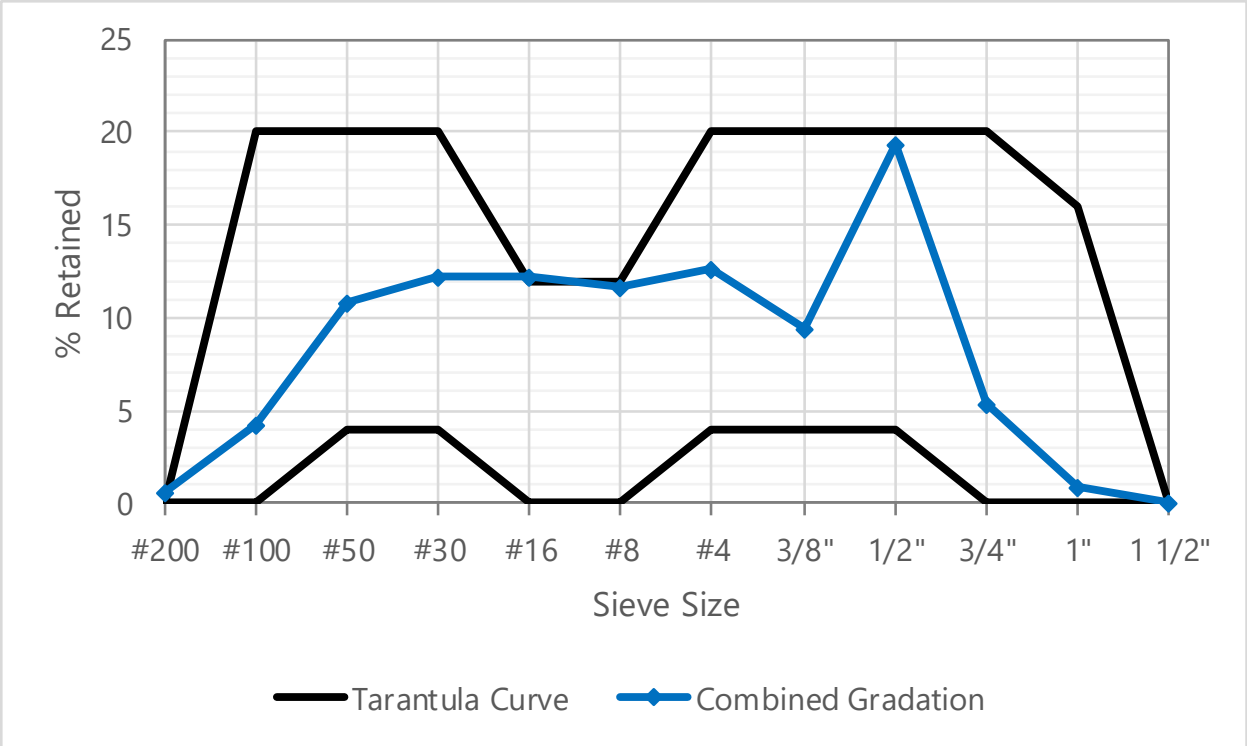
ATTACHMENT

Combined Aggregate Gradation for Trial Batches

Wiss, Janney, Elstner Associates, Inc.
330 Pfingsten Road
Northbrook, Illinois 60062
847.272.7400 tel
www.wje.com

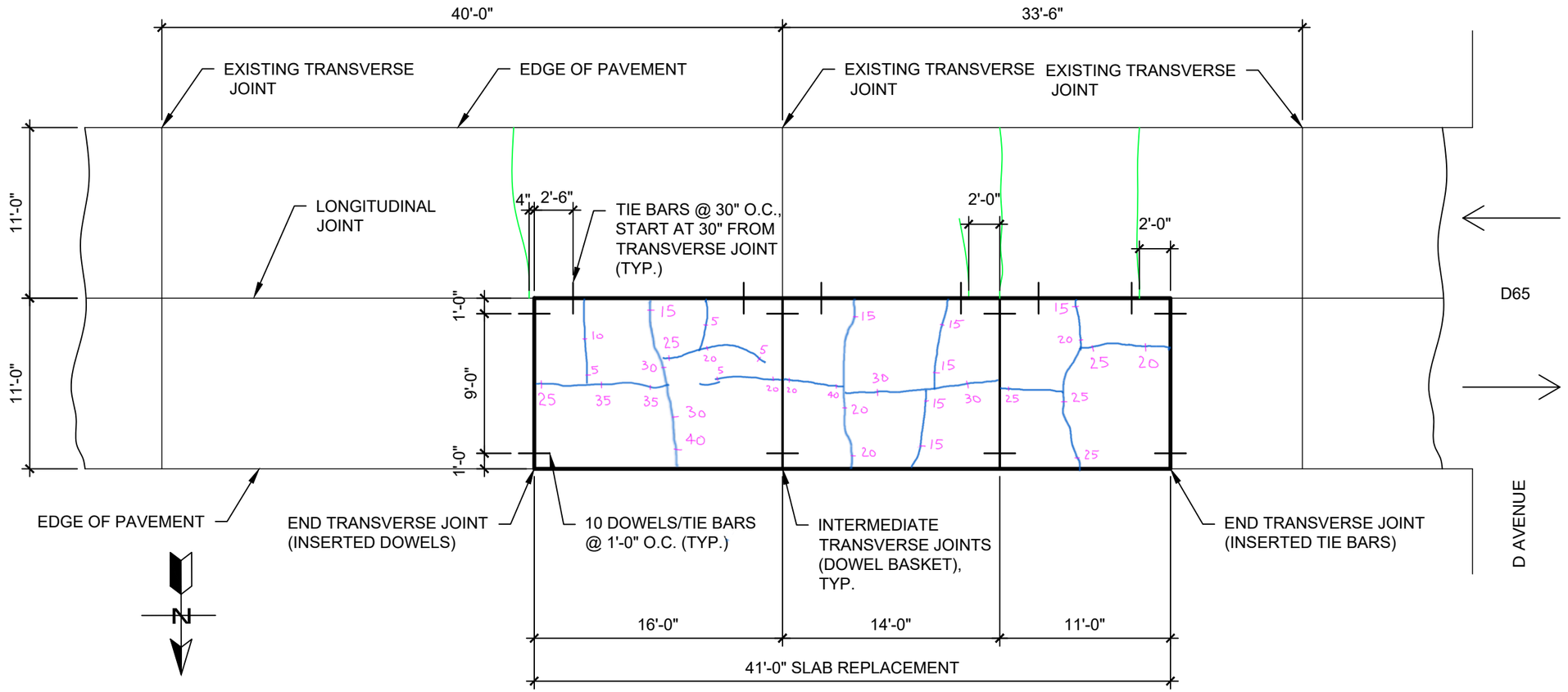
Combined Aggregate Gradation for Trial Batches - 45% Coarse / 55% Fine

Sieve	% Passing			% Retained			Tarantula Curve	
	Coarse	Fine	Combined	Coarse	Fine	Combined	Lower Bound	Upper Bound
1 1/2"	100	100	100.0	0	0	0	0	0
1"	98	100	99.1	2	0	1	0	16
3/4"	86	100	93.7	12	0	5	0	20
1/2"	43	100	74.4	43	0	19	4	20
3/8"	22	100	64.9	21	0	9	4	20
#4	1.4	94	52.3	21	6	13	4	20
#8	1.2	73	40.7	0	21	12	0	12
#16	1.1	51	28.5	0	22	12	0	12
#30	1	29	16.4	0	22	12	4	20
#50	0.8	9.5	5.6	0	20	11	4	20
#100	0.7	1.9	1.4	0	8	4	0	20
#200	0.6	0.8	0.7	0	1	1	0	0



Combined Aggregate Gradation for Trial Batches (45% Coarse / 55% Fine) Compared to Tarantula Curve

APPENDIX D. TRIAL FULL DEPTH REPAIRS - INSPECTION SHEETS



TRIAL PAVEMENT FULL DEPTH REPAIR - PATCH 1 (D65 NEAR D AVENUE)

NOT TO SCALE

(STANDARD M MIX)

NOTES:

DOWELS ARE ¾" DIAMETER, 18" LONG, EPOXY COATED.
TIE BARS ARE #6, 24" LONG, EPOXY COATED.

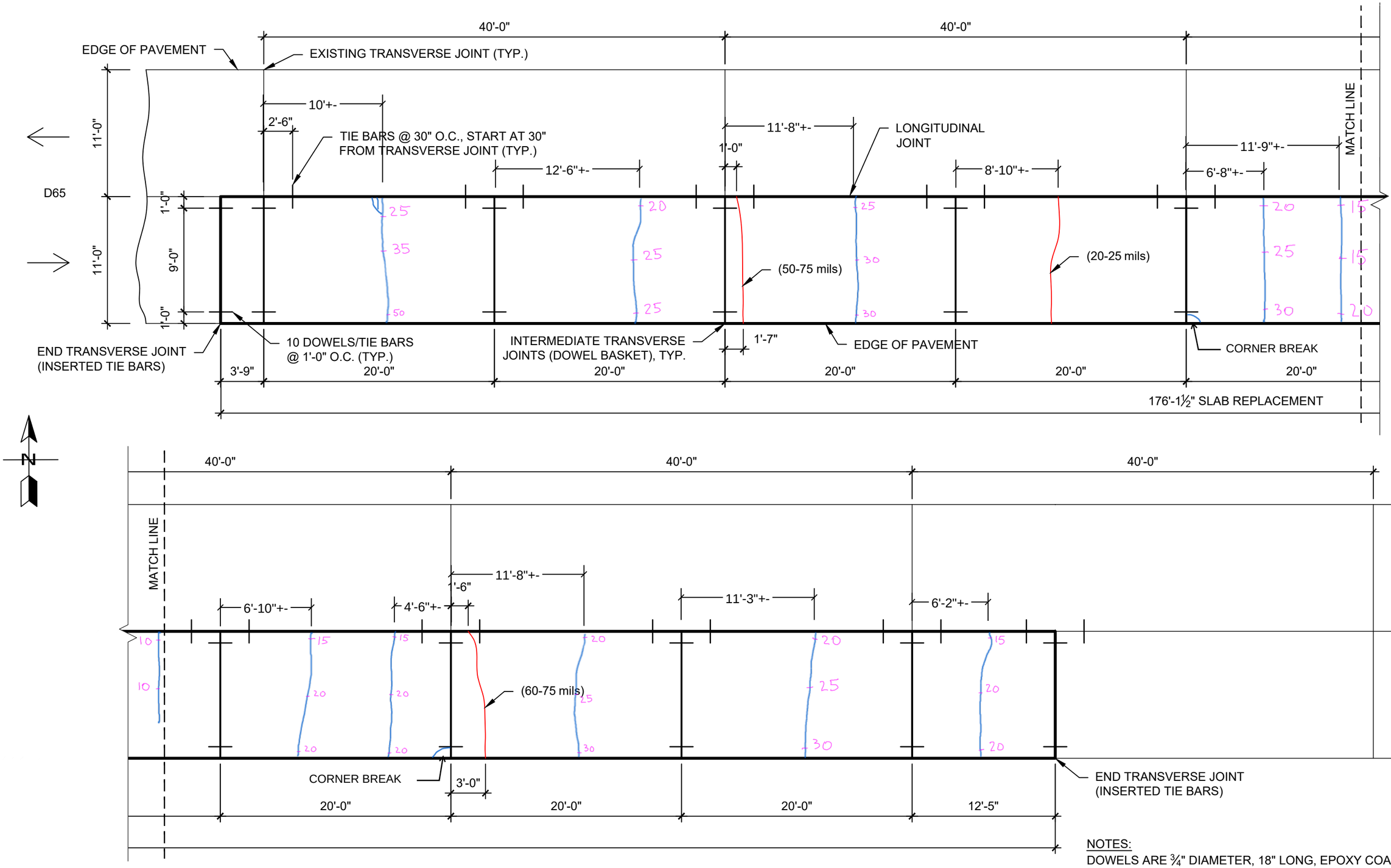
WJE ENGINEERS ARCHITECTS MATERIAL SCIENTISTS
Wiss, Janney, Elstner Associates, Inc.

TRIAL PAVEMENT FULL DEPTH REPAIR - HARDIN COUNTY
WJE No. 2017.3375.1
Construction date: September 21, 2020
SCALE: AS NOTED

PRE-EXISTING CRACKS IN ADJACENT SLAB

CRACKS IN REPAIRED SLAB, SURVEYED SEPTEMBER 22 TO 25, 2020

XX CRACKS WITH CRACK WIDTH (MILS) IN REPAIRED SLAB, SURVEYED AUGUST 31, 2021



NOTES:
DOWELS ARE ¾" DIAMETER, 18" LONG, EPOXY COATED.
TIE BARS ARE #6, 24" LONG, EPOXY COATED.

TRIAL PAVEMENT FULL DEPTH REPAIR - PATCH 2 (D65 NEAR E AVENUE)

NOT TO SCALE

(ALTERNATE M MIX)

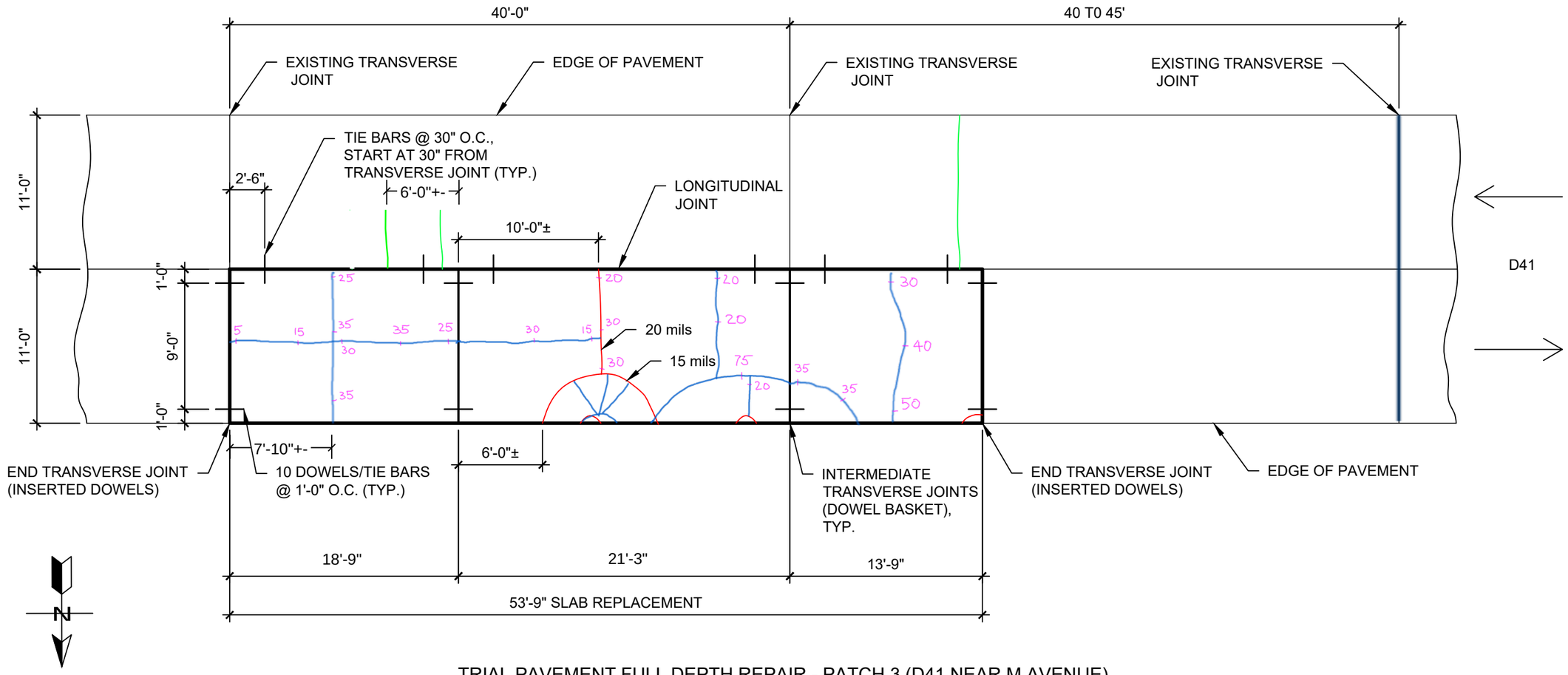
WJE ENGINEERS ARCHITECTS MATERIAL SCIENTISTS
Wiss, Janney, Elstner Associates, Inc.

TRIAL PAVEMENT FULL DEPTH REPAIR - HARDIN COUNTY
WJE No. 2017.3375.1
Construction date: September 22, 2020
SCALE: AS NOTED

PRE-EXISTING CRACKS IN ADJACENT SLAB

CRACKS IN REPAIRED SLAB, SURVEYED SEPTEMBER 23 TO 25, 2020

XX CRACKS WITH CRACK WIDTH (MILS) IN REPAIRED SLAB, SURVEYED AUGUST 31, 2021



TRIAL PAVEMENT FULL DEPTH REPAIR - PATCH 3 (D41 NEAR M AVENUE)

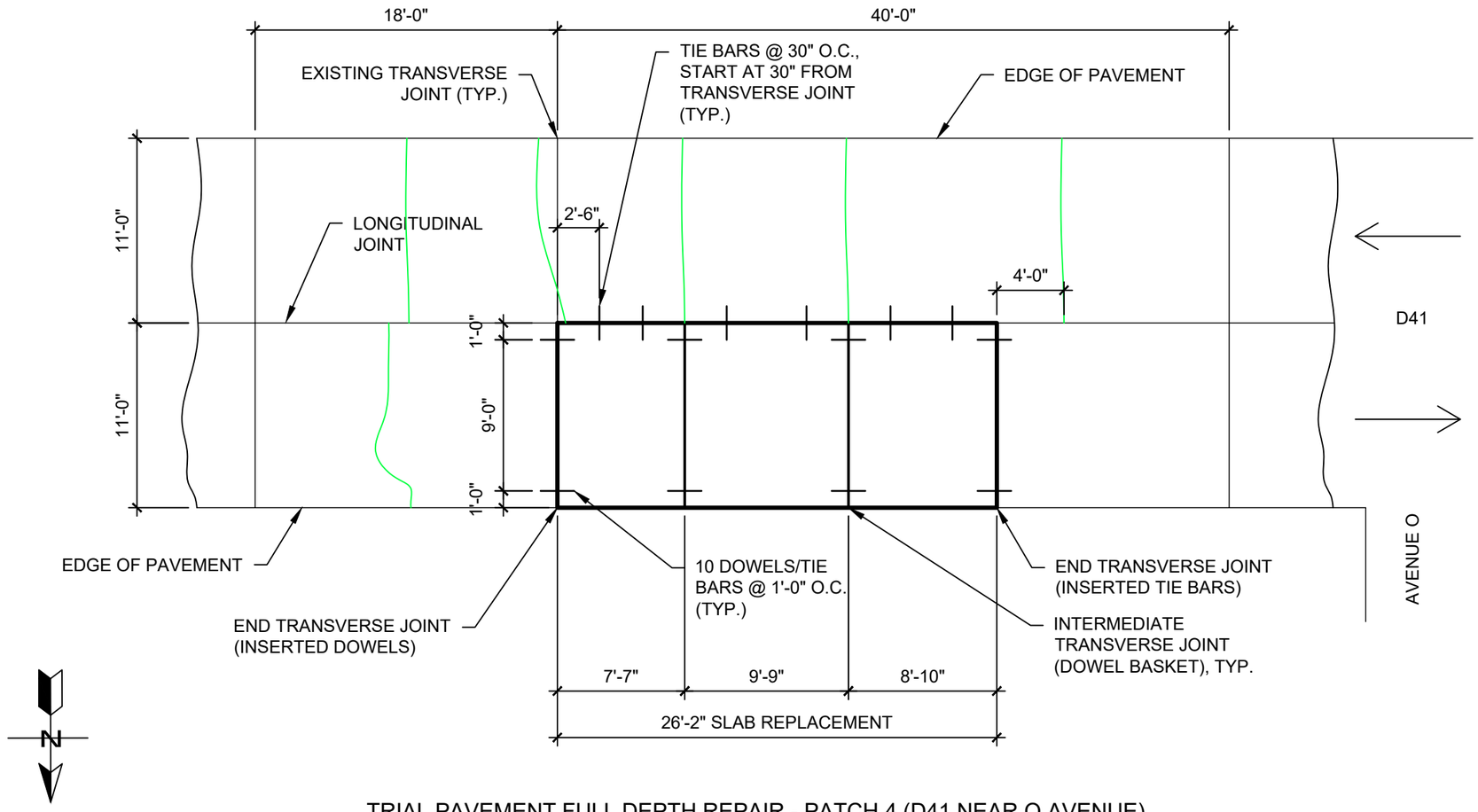
NOT TO SCALE

(STANDARD M MIX)

NOTES:

DOWELS ARE ¾" DIAMETER, 18" LONG, EPOXY COATED.

TIE BARS ARE #6, 24" LONG, EPOXY COATED.



TRIAL PAVEMENT FULL DEPTH REPAIR - PATCH 4 (D41 NEAR O AVENUE)

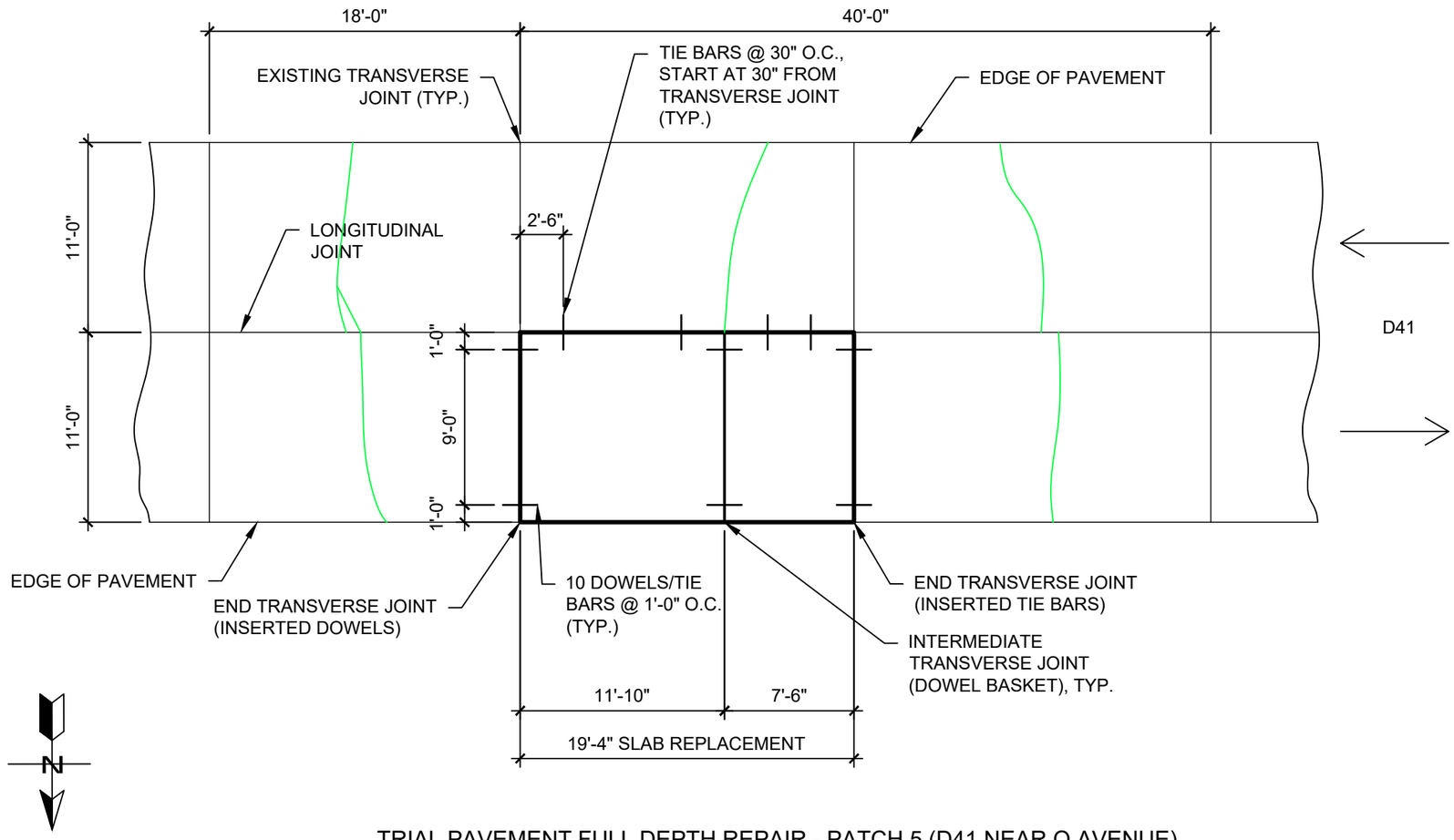
NOT TO SCALE

(ALTERNATE M MIX)

NOTES:

DOWELS ARE ¾" DIAMETER, 18" LONG, EPOXY COATED.

TIE BARS ARE #6, 24" LONG, EPOXY COATED.



TRIAL PAVEMENT FULL DEPTH REPAIR - PATCH 5 (D41 NEAR O AVENUE)

NOT TO SCALE

(ALTERNATE M MIX)

NOTES:

DOWELS ARE ¾" DIAMETER, 18" LONG, EPOXY COATED.

TIE BARS ARE #6, 24" LONG, EPOXY COATED.

WJE ENGINEERS ARCHITECTS MATERIAL SCIENTISTS
Wiss, Janney, Elstner Associates, Inc.

TRIAL PAVEMENT FULL DEPTH REPAIR - HARDIN COUNTY
WJE No. 2017.3375.1
Construction date: September 24, 2020
SCALE: AS NOTED

PRE-EXISTING CRACKS IN ADJACENT SLAB

CRACKS IN REPAIRED SLAB, SURVEYED SEPTEMBER 25, 2020

XX CRACKS WITH CRACK WIDTH (MILS) IN REPAIRED SLAB, SURVEYED AUGUST 31, 2021