Concrete Repair Manual

January 2019

Manual Notice 2019-1

From: Graham A. Bettis, P.E., Director, Bridge Division

Manual: *Concrete Repair Manual*

Effective Date: January 25, 2019

Purpose

This manual includes step-by-step repair procedures for use on new and existing concrete members cast for the Texas Department of Transportation (TxDOT).

Changes

Revisions to this manual include various editorial changes including reference to CST revised to MTD, reference to epoxy anchors revised to adhesive anchors, and patch revised to repair; revising Contractor's Responsibilities to include visual and non-destructive testing to ensure quality of repairs; incorporated procedure to address lifting strands on prestressed piling; added storage, temperature, humidity, and document controls to ensure material quality; added typical repair detail and photos showing steps for intermediate spall repairs; revised Gravity-Fed Epoxy to Gravity-Fed Sealant to include other acceptable sealants.

Contact

Please contact the Bridge Division with comments or questions.

Archives

Past Manual Notices are available in a PDF archive.

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Chapter 1 — Introduction

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Section 1 — Overview

This manual includes step-by-step repair procedures for use on new and existing concrete members cast for the Texas Department of Transportation (TxDOT). It includes a comprehensive list of common concrete distress and repair methods. The methods adhere to industry standards and the provisions from applicable documents by the American Concrete Institute and American Society for Testing and Materials. This manual was developed in collaboration with various repair material manufacturers to ensure that the procedures meet common proprietary requirements.

In general, repairs to TxDOT concrete structures should be implemented in accordance with the methods outlined in this manual. However, unusual circumstances occasionally arise. Engineers may determine that methods differing from those outlined here are more appropriate in some circumstances.

Updates to the manual are summarized in the following table.

Table 1-1: Manual Revision History

Version	Publication Date	Summary of Changes
2015-1	April 2015	New manual.
2017-1	January 2017	Revision adding manual revision history to Chapter 1; revision breaking Chapter 1 into seven sections with no changes to content; revision adding Section 8, discussing rail damage due to vehicular impact, to Chapter 2; revisions for consistency with current DMS-4655; revised maximum application for neat product to 2"; various revisions to Chapter 3, Section 4, “Bridge Deck Repair” and Section 6, “Crack Repair – Gravity-Fed Epoxy” for improved performance of repairs; minor formatting and editorial revisions in various sections.

Table 1-1: Manual Revision History

Version	Publication Date	Summary of Changes
2019-1	January 2019	Various editorial revisions including: ◆ Reference to CST revised to MTD ◆ Reference to epoxy anchors revised to adhesive anchors. ◆ Various references to patch revised to repair. Ch 1, Section 6: ◆ Incorporated visual and non-destructive evaluation of repair material as part of Contractor's Responsibilities (QC). Ch 2 Section 4: ◆ Added procedure to recess and coat lifting strands on pre-stressed piling after installation of piling. Ch 2, Section 8: ◆ Referenced Item 445, "Galvanizing" for repair material to galvanized rail components. ◆ Added language that tests on new railing adhesive anchorage may be required by the Engineer. Ch 3, Section 1 ◆ Incorporated storage, temperature, humidity controls, and document controls to ensure material quality. Ch 3, Section 2: ◆ Incorporated typical repair detail and photos showing steps for typical intermediate spall repair. ◆ Incorporated language for temperature controls for mixing and using chilled water. ◆ Added inspection prior to finishing Ch 3, Section 3: ◆ Added inspection prior to finishing Ch 3, Section 6: ◆ Gravity-Fed Epoxy revised to Gravity-Fed Sealant to include other acceptable sealants. ◆ Incorporated language to follow product specifications for maximum working time.

Section 2 — Using the Concrete Repair Manual

When developing repair or rehabilitation plans, the Engineer should specifically include which sections of this manual will be enforced. Chapter 2 includes information on assessing damage, distress limits, and common types of concrete repair. Chapter 3 includes information on various repair materials and procedures for implementation.

Typically concrete repair work will include categorizing the type of distress as outlined in Chapter 2 and selecting a type of repair material from Chapter 3. In some cases, the material section includes enough information that choosing a corresponding type of repair is not necessary. For instance, the sections on crack repair do not require that corresponding repair types be selected

Each section in this manual is written as a stand-alone document, and individual sections contain all necessary information on material selection and application. It is not necessary to read the manual from start to finish. Rather, the intention is that Inspectors and Contractors will need only to reference the applicable section or sections. The sections are kept as concise as possible since they are intended for field use.

This manual does not address post-tension strand, duct, or anchorage repairs. Repairs or defects associated with post-tension work should be addressed by the Bridge Division Construction & Maintenance Branch on a case-by-case basis.

Section 3 — Standard Specification References to the Concrete Repair Manual

The Concrete Repair Manual is referenced in several 2014 Standard Specification Items. This section includes a list of each of those references, along with the corresponding Section to reference within this Manual.

Standard Specification References

Spec Item	Item Title	Spec Reference	Repair Manual Reference
409	Prestressed Concrete Piling	3.1 (Defects and Breakage)	Refer to Section 2.4 for limits and repair procedures when assessing damage to prestressed concrete piling.
420	Concrete Substructures	4.13 (Ordinary Surface Finish)	Spalls are defined per Section 2.1, and repaired (based on severity) per Section 3.1, 3.2, or 3.3. Most spalls in this category will be defined as minor and repaired per Section 3.1.
424	Precast Concrete Structural Members (Fabrication)	4.3 (Workmanship)	Recess prestressed strands per Section 2.7.
		4.3.1 (Defects and Breakage)	This item covers damage or surface defects that occur during fabrication, handling, storage, hauling, or erection of precast concrete members. Any of the sections in this manual could apply depending on the situation.
429	Concrete Structure Repair	2 (Materials) 3 (Construction Methods)	Severity of the unsound, delaminated, or spalled concrete is defined per Section 2.1. After defining, select materials and implement repair per Section 3.1 (Minor), 3.2 (Intermediate), or 3.3 (Major).
780	Concrete Crack Repair	2 (Materials) 3 (Construction Methods)	Select materials and perform repair work in accordance with the applicable section in this manual. Section 3.5 covers pressure-injected epoxy, 3.6 covers gravity-fed sealant, and 3.7 covers both routing and sealing and surface sealing.
788	Concrete Beam Repair	2 (Work Methods)	Concrete Beam Repair is a plan-specific item. Provide materials and perform work in accordance with the applicable sections of this Manual and as defined in the project plans.

Section 4 — Repairs and Repair Manual

It is critical that repair crews use appropriate repair materials and installation methods. Even the best materials will not work effectively unless each aspect of the repair work is considered. Proper proportioning, mixing, surface preparation, application, and curing are all vital to the long-term success of a repair.

TxDOT maintains Departmental Material Specifications and corresponding preapproved Material Producer Lists for most of the materials outlined in the manual. It is vital that Engineers, Inspectors, and Contractors select and use only preapproved materials when applicable. The Engineer may select or Contractors may propose to use material not included on an MPL if it will provide for the best repair in a specific application. The Engineer will review such requests from the Contractor on a case-by-case basis, but in almost all cases a preapproved material should be selected.

Notify the Engineer before proceeding with the repairs if there are discrepancies between TxDOT's requirements and industry standards or manufacturers' instructions. Maintain up to date copies of the manufacturers' technical literature to ensure the proper procedures are followed.

Section 5 — Repair Procedure Submission and Approval

When the Engineer prepares repair or rehabilitation plans that include reference to this manual, the Contractor must prepare and submit formal procedures outlining repair plans and which proprietary materials they plan to utilize. The Engineer must approve in writing any procedures that differ from those in this manual or materials that are not included in one of TxDOT's MPLs.

For damage that occurs in precast concrete fabrication yards or on construction sites in which Contractor is required to prepare a Nonconformance Report or Request for Information, the Contractor should propose repair methods and materials outlined in this manual. Contractors may also propose to use a procedure that differs from those outlined in this manual, in which case TxDOT will consider on a case-by-case basis.

For cases in which the Engineer is not preparing repair documents and the Contractor is not issuing a Nonconformance Report or Request for Information, the Contractor and Inspectors should work collaboratively to determine an appropriate repair solution and then follow the applicable sections from this manual. Documentation of this communication should be retained in the project files.

Section 6 — Quality Control/Quality Assurance

In addition to providing step-by-step procedures for Contractors and Fabricators, this manual is also meant to provide Quality Control (Contractor) and Quality Assurance (Owner) inspectors with the knowledge needed to ensure that appropriate repair solutions are selected and implemented. Each procedure in Chapter 3 of this manual includes detailed instructions on each individual facet of the repair.

Proper attention to and implementation of each step in the repair process is critical to successful application. The first step is ensuring that the contractor is using approved materials. Correct proportioning and mixing is also critical. A common mistake is for Contractors to "eyeball" or guess at proper proportions when using multi-part mixes. Inspectors should verify that Contractors are measuring, either by volume or weight, all individual components prior to mixing. In almost all cases the Contractor should utilize an acceptable form of mechanical mixing; hand mixing is not acceptable. It is not possible to put a sufficient amount of energy into mixing when doing so using a shovel, trowel, or by hand. In small applications a small "jiffy" type paddle and mixer are often sufficient. When using larger quantities of cementitious repair material a mortar or volumetric mixer is more appropriate.

Application varies significantly with repair type and material. Refer to the applicable section in Chapter 3.

Another frequent problem leading to premature failure of repairs, especially cementitious materials, is inadequate curing. Improper curing often leads to cracking very early in the life of the repair. The best (and easiest) curing method is to leave the forms in place when using form-and-pour applications. In those cases only a small amount of moist curing is required in the small areas used to place the concrete. Ponding is also an excellent method of curing but is typically impractical in most repair scenarios. Many manufacturers include instructions for application of curing membranes. However, continuous moist curing is typically preferable to curing membranes. When using wet mats it is imperative that the mats be kept moist during the entire curing interval. In cases where membrane curing is approved, the Contractor must use material that is preapproved by TxDOT and is recommended for use by the repair material manufacturer.

Since curing requirements vary significantly depending on the type of material and the manufacturer, it is important that curing methods adhere to the technical product literature for the specific material being utilized. As noted above, moist curing is the preferred method for most cementitious patch materials. However, moist curing can actually harm some patch materials, such as those that contain magnesium phosphate. Again, the Contractor must adhere to the requirements for the specific material being applied.

Contractor's Responsibilities (QC):

- It is the Contractor's responsibility to use repair materials specified in the Contract Documents and this manual. For materials in which there are lists of materials available through TxDOT's DMS and MPL process, the Contractor should only use products that have been preapproved. Any deviation from the originally proposed and approved materials must be approved by the Engineer in writing. When in doubt, contact the Bridge Division or Materials and Tests Division for guidance on whether a proposed material is acceptable.
- Store materials on jobsite according to material manufacturer's requirements, preventing direct exposure to sunlight and moisture. Materials exceeding their shelf life shall not be used.
- When required by the Contract, perform a trial repair or mockup to demonstrate acceptable performance and installation methods.
- Ultimately, quality is the Contractor's responsibility. If the Contractor feels that any of the procedures outlined in this manual or in the contract plans could lead to unacceptable performance, they must inform the Engineer of those concerns in writing prior to commencing work. In such cases, the Engineer will work collaboratively with the Contractor to come to an agreeable solution.
- Confirm that repair material performance is acceptable through visual observations and nondestructive testing of all repaired locations. Patch material should not exhibit cracking. One of the easiest and most effective tests is to sound the repair material using firm (but not destructive) blows with a hammer. When repair material has debonded from the substrate there is generally a distinctive hollow sound when the material is struck. Defective repair material must be removed and replaced.

Owner's Responsibilities (QA):

- Check materials to ensure that they are appropriate for the given application. Material should either be on one of TxDOT's preapproved lists or approved by the Engineer prior to use.
- Ensure that the Contractor is following the procedures outlined in this manual and as shown on the plans for material selection, preparation, implementation, curing, and any other steps crucial to the performance of the concrete repair. Procedures may need to be altered for varying weather conditions (excessive heat or cold, rain, high wind, etc.).
- Verify that all damaged material has been removed and that the remaining surface is clean and sound before the Contractor proceeds with repair material installation.
- Confirm that repair material performance is acceptable through visual observations and nondestructive testing. See Contractor's Responsibilities (QC) for acceptance criteria. QA may be performed jointly with the contractor's QC or separately at the discretion of the Engineer.

- In some cases, the Contractor may opt to perform nondestructive or destructive testing when there is a question about whether a repair is performing adequately. Often such testing will involve taking cores for petrographic analysis. Though a Contactor may use an independent consultant or lab for performing forensic or petrographic investigations, ultimately TxDOT will decide whether a repair is acceptable.

Section 7 — Definitions and Abbreviations

The terms “Engineer,” “Inspector,” “Contractor,” and “Fabricator” are used regularly throughout this manual. “Engineer” typically refers to the Engineer of Record that signed and sealed the repair plans, the Area Engineer or the Area Engineer’s authorized representative where the work is being performed, or in the case of precast fabrication one of the licensed Professional Engineers at TxDOT Materials and Tests Division Headquarters in Austin. “Inspector” refers to the person, usually a Department employee, assigned by the Engineer to check compliance with the Contract. “Contractor” refers to the entity responsible for implementing the repair work. “Fabricator” refers to a manufacturer that produces precast concrete structures for TxDOT. When not specifically stated, requirements for Contractors also apply to Fabricators.

The following abbreviations are used in the manual:

- CFRP: Carbon Fiber Reinforced Polymer
- MTD: TxDOT Materials and Test Division
- DMS: Departmental Material Specification
- MPL: Material Producer List
- NCR: Nonconformance Report (typically prepared by Precast Fabricators)
- QA: Quality Assurance
- QC: Quality Control
- RPM: Revolutions per Minute
- SSD: Saturated Surface-Dry

Chapter 2 — Damage Assessment and Repair Types

Contents:

Section 1 — Defining Concrete Spalls

Description

Spalls are categorized based on severity of damage per the definitions in this Section. Once a spall has been categorized, then an appropriate repair material and installation procedure can be selected.

Reference: TxDOT Standard Specification Item 429, "Concrete Structure Repair."

Notes

Based on severity, spalls can be categorized as minor, intermediate, or major. Appropriate repair materials and methods differ significantly depending on the spall depth, size (area), cause(s) and configuration (horizontal, vertical, or overhead). The guidelines in this section help define various spall types. These are general definitions; depending on the circumstances, the Engineer may define spall severity differently than these definitions, on a case-by-case basis.

This section does not apply to spalls in the riding surfaces of bridge decks. Refer to the Chapter 3 sections on Bridge Deck Repair when addressing such damage.

Spall Categories

- Minor Spall:
  - Damage is less than 1 inch deep and it covers an area less than 12 square inches. However, if the majority (more than 50%) of a reinforcing bar or strand circumference is exposed due to inadequate cover then the spall would be classified as Intermediate even if it is less than 1" deep.
  - The Inspector may elect to designate patches that cover areas larger than 12 square inches as minor depending on the location and extent of the damage.
  - A deeper spall (2" maximum) can be categorized as minor as long as it does not progress beyond the outer layer of reinforcement.
- Intermediate Spall:
  - The damage exposes a majority (more than 50%) of the outer cage of reinforcing bar or strand circumference, or the damage is greater than 2" deep.
  - The maximum depth of an intermediate spall is 6 inches.
  - No significant stresses are likely to develop in or immediately around the patch material due to service loads.
- Major Spall:
  - Damage extends well beyond the outer layer of reinforcement.

- Significant stresses are likely to develop in or immediately around the patch material due to service loads.

Selecting an Appropriate Repair Procedure

Beyond categorization of spalls, repair procedures depend on location to be repaired and volume of work. The following is only a brief overview of repairs. See Chapter 3 for detailed discussion on repair materials and procedure.

- Minor Spall:
  - Regardless of configuration (vertical, overhead, or horizontal), the best repair method for minor spalls is typically neat epoxy or epoxy mortar. Epoxy that is formulated for concrete repair has very tenacious bond and performs well in thin applications.
  - Excavating the concrete to expose all corroded sections of the bar is the only way to stop corrosion, but that typically requires the removal of sound material. Such measures are usually unnecessary unless the minor spalling is occurring over a large area.
  - Applying epoxy over thin spalls in which a small amount of steel is exposed will not typically stop corrosion. However, it provides an excellent waterproof barrier and can significantly slow down the rate of corrosion if properly applied.
  - Building up thin spalls with epoxy mortar is generally an aesthetic decision. Mortar should not be applied if the damage will occur over vehicular or pedestrian traffic. In those cases only neat epoxy should be applied.
- Intermediate Spall:
  - Proprietary, bagged concrete repair materials are typically used to patch intermediate spalls. Use only preapproved materials meeting the requirements of DMS 4655, "Concrete Repair Materials."
  - A common mistake when choosing bagged cementitious concrete repair materials is to select those with compressive strengths far higher than needed. Materials with lower compressive strengths typically perform better since they also have a lower modulus of elasticity, and therefore greater ductility. For intermediate spalls it is typically desirable not to redistribute loads into the patch material. Limiting compressive strength and modulus of elasticity are the best ways of achieving that.
  - Vertical and Overhead Repairs:
    - In most cases a Contractor will opt to use a trowel-applied repair material in vertical and overhead applications. The maximum lift thickness of trowel-applied materials is 2 inches or the maximum permitted by the repair material supplier, whichever is less.
    - In deeper applications the Contractor may propose to patch using pneumatically applied cementitious material, in which case they should follow the provisions set forth in Item 431. Pneumatically placed concrete is not addressed in this manual. The

Engineer must approve use of pneumatically placed concrete in lieu of the repair methods outlined in this manual.

  - The Contractor may opt to use form-and-poured bagged material or batched concrete, which is often a better option since it can be extended with coarse aggregate. Most trowel-applied materials do not include coarse aggregate, which can lead to drying shrinkage cracking if not applied or cured properly.

- Horizontal Repairs: Form-and-pour materials are typically the best option in horizontal applications because they can be extended with coarse aggregate, which significantly reduces the potential for shrinkage cracking.
- Precast Concrete Production Yards: Batched concrete is readily available in precast concrete plants. Therefore, fabricators should typically use batched concrete (same mix design) as that used to fabricate the damaged member, even when the spall is classified as intermediate.
- Major Spall:
  - Major spalls typically involve deep repairs to members in which capacity has been reduced as a result of the damage. The repair is meant to restore capacity of the damaged member. The best option in such applications is to use batched concrete with properties similar to the parent material.
  - When the mix design is unknown, the Engineer and Contractor should select an approved concrete mix that meets the requirements of the anticipated service loads.
  - In smaller applications it is often not practical to specify batched concrete when rehabilitating or repairing existing structures. The Engineer should determine when a preapproved bagged material is more appropriate and offer that as an alternative to batched concrete.

Section 2 — Voids Due to Honeycombing

Description

Honeycombing in concrete members can result from either of the following:

- Forms not being sufficiently secured or tight, allowing mortar to leak out during casting operations. The `mortar` leakage can lead to pockets of air voids between coarse aggregates.
- Lack of consolidation due to unworkable concrete mixes or inadequate vibration.

Investigating Honeycombed Regions

The biggest cause for concern when voids occur on the exterior portions of members is that additional, unseen defects could exist on the interior portions. Honeycombing due to lack of proper consolidation is of particular concern, especially in the portions of precast concrete members that are highly congested with prestressing strands and mild reinforcement.

Prior to considering repair options, explore the voids to check for additional damage. The areas around the voids should be chipped to sound, undamaged concrete. However, do not chip out concrete around prestressed strands before discussing with the Engineer.

Occasionally Contractors ask to use Nondestructive Evaluation (NDE) to investigate the severity of honeycombing when it appears to be severe and the Engineer is considering rejection. Most of the available technology (e.g. Impact Echo and Pulse Velocity) cannot effectively show whether small voids exist along congested prestressing strands or mild reinforcement. Although the Contractor may propose to use NDE, it is up to the Engineer to determine whether it is acceptable. Generally NDE requires destructive verification testing, which is oftentimes not an option in highly congested concrete, such as the bottom flanges of prestressed girders.

Repairing Honeycombed Regions

After the honeycombed regions have been removed, the damaged area should be evaluated and defined per Section 1 of Chapter 2 unless the damage is too severe to consider acceptance of the member. An appropriate repair material and method can be selected once the damage is categorized as minor, intermediate, or major.

At a minimum, remove defective material, patch, and finish as required in Section 420.4.13 of the Standard Specifications for Ordinary Surface Finish.

Section 3 — Damage over Traffic

Description

This section applies to damage that occurs or could occur over vehicular or pedestrian traffic. Damage consists of any spall, delamination, honeycombing, or other unintentional void. The Engineer will typically require additional measures to help ensure the repair material will not fall into traffic in the case of a patch failure.

The most frequent damage that occurs over roadways is overhead vehicular impact. In addition to whatever necessary structural and waterproofing repairs, the Engineer should typically also require confinement or other acceptable means to prevent spalling or to catch portions of the repair material that become detached. Wire netting often works as a temporary solution. More permanent solutions should be included when the member or members are repaired. In almost all cases the best option for preventing damaged concrete from falling onto traffic is to confine the patch material with Carbon Fiber Reinforced Polymer wraps. Perform the CFRP work in accordance with Item 786, "Carbon Fiber Reinforced Polymer."

In the case of precast concrete fabrication, damage that will occur over traffic may not be patched unless approved by the Engineer. When feasible, members should be reassigned or rotated to move the damage to an area where damage will not occur over traffic in its final configuration. Minor damage may be coated with neat Type VIII epoxy but should not be built up with repair mortar. When the Engineer does permit more extensive repair, the patch material must be confined using CFRP or other approved method.

There is no standard repair procedure for patching damage over traffic. Do not proceed with such repairs without authorization from the Engineer.

Section 4 — Prestressed Concrete Piling

Description

This section includes limits and repair procedures when assessing damage to prestressed concrete piling.

This section also includes a procedure to recess and coat lifting strands after installation of piling.

Reference

Standard Specification Item 409, “Prestressed Concrete Piling.”

Notes

Piling damage is divided into two categories: (1) damage that occurs prior to driving (during fabrication, handling, storing, or hauling), and (2) damage that occurs during driving operations (lifting or driving). When assessing damage to exposed portions of prestressed piling in an existing structure, treat it as a typical concrete substructure element. No special limits apply.

The acceptance and rejection criteria for prestressed piling are more severe than with most other structural elements because the consequences of a failure are also very severe. Foundation distress is typically very difficult to remedy and can lead to shortened service life of an entire bridge. Therefore, damage that could potentially hinder performance or reduce durability will typically lead to rejection of the piling.

Damage Prior to Driving (e.g. in the Fabrication Yard)

- Minor damage.
  - Only thin spalls may be repaired. The Engineer will determine what constitutes an acceptable spall, but in general the limits are 1-inch in depth and 6 square inches in area. If either of those limits is exceeded, or if the damage exposes any reinforcing steel or prestressing strand, the damage will render the piling unacceptable unless specifically deemed otherwise by the Engineer.
  - Smooth out the perimeter of the damaged area to eliminate jagged edges.
  - Minor spalls deemed acceptable for repair should be cleaned and coated with neat epoxy in accordance with Section 1 of Chapter 3 of this manual.
  - Do not build up the spalled areas with repair material other than neat epoxy since it is likely to debond during driving operations.

  - The Engineer may allow for repair when damage is deeper than 1 inch but does not progress beyond the outer layer of steel reinforcement. In those cases the damaged areas should be built up with epoxy mortar and confined by CFRP wrapped completely around the piling for a distance not less than six inches beyond the damaged area.
- Damage to one end.
  - If one end of a piling is damaged beyond the limits outlined above, but the damage extends less than 6 inches from the end, then the fabricator or contractor may remove (cut) up to 6 inches from the end to eliminate the damaged portion.
  - Clearly mark the altered side as the "Tip End."
  - After cutting, recess the prestressing strands 3/8-inch minimum and fill the voids with epoxy mortar (typical strand end treatment).
  - Re-form the chamfers after completing the cutting and patching operations.
- Damage to both ends.
  - There are no standard criteria for acceptance or rejection when both ends of a piling are damaged, but generally the member will be rejected since it would not be possible to avoid hammering a damaged end.
  - Engineer must approve any repairs when damage occurs on both ends of a piling.

Damage During Driving

- Horizontal cracks (transverse to longitudinal reinforcement or strand) greater than 1/16 inches wide.
  - Piling will be rejected if crack occurs in a portion that will be below ground or water level after driving.
  - If crack occurs in a portion that will be above grade or water level, the Contractor may opt to cut back beyond the crack and rebuild to required elevation.
- Horizontal cracks less than 1/16 inches wide.
  - Inject the cracks with epoxy in accordance with Section 3.7 of this manual.
  - If cracks develop that will be inaccessible in final configuration, cease driving operations and repair cracks before continuing.
- Vertical or diagonal cracks.
  - In most cases a piling member will be rejected if vertical or diagonal cracks form during driving operations.
  - If the Engineer approves repair of vertical or horizontal cracks, inject with epoxy in accordance with Section 3.7 of this manual.

- Fine hairline cracks (less than 0.006 inches) or surface checks that do not extend to the plane of the nearest reinforcing steel will not require repair and will not be cause for rejection.

Lifting Strands

- Recess lifting strands to help prevent corrosion due to exposure to the elements.
  - Recess the prestressing strands a minimum 3/4-inch using a torch, grinder, or other approved method. Do not overheat or damage the surrounding concrete.
  - Abrade the concrete and the end of the steel strand with a needle gun, steel brush, or other suitable means to ensure that no slag remains on the steel or concrete surfaces.
  - Coat the inside of the recessed area, including the strand, with 10 mils (minimum) of neat Type VIII epoxy and patch the recess with epoxy mortar.

Section 5 — Taking, Marking, and Patching Cores

Description

Cores may be taken from concrete members for a variety of reasons, including verification of compressive strength, investigation of potential concrete material problems (e.g. segregation or bleeding), or examination of specific defects (e.g. cracks or cold joints). This section covers proper taking and marking of cores, and patching of the core holes.

Selection Criteria

Select core locations and have them approved by the Engineer. Check fabrication sheets so, if possible, cores are taken with minimum impact to mild reinforcement. Check design sheets or shop drawings to ensure that cores are not taken through prestressing strands unless specifically approved by the Engineer.

Take four-inch outside diameter cores when feasible. When approved by the Engineer, take smaller cores in highly congested areas to avoid impact to mild reinforcement or prestressed strands.

When possible, take cores through the entire width of the concrete section.

Taking Cores to Check Compressive Strength

- Take at least two cores from a member if design cylinders reveal a potential deficiency in the required 28-day compressive strength.
- Evenly space the cores along the member(s) in question. Typically, take the cores through the webs or sidewalls of prestressed concrete girders.
- Ensure cores taken for testing compressive strength have lengths at least twice their diameter.
- There can be no mild reinforcement or prestressed strands in the cores if they will be used for testing compressive strength.

Taking Cores to Investigate Potential Concrete Material Problems

- To check questionable batches of concrete, take the cores through the worst section or sections. Also take a control core from the same member where the concrete was placed from a different batch and there are no apparent problems.
- If checking for bleeding or segregation, take one core through the problem area and another core through the top of the member directly above the first one. Again, take a control core from an unaffected section of the member.

Taking Cores to Investigate Specific Defects

- Take cores directly through the problem areas when investigating specific damage or defects. It typically will not be necessary to take control cores in these types of situations.
- If investigating a cold joint, take the sample such that approximately half the core is above the joint and half is below the joint.

Marking Cores

When cores are not taken from a horizontal surface, draw two arrows on the core locations BEFORE a core is taken. Point both arrows straight up, and draw them on each side (left and right) of the core. In most cases the petrographer will need to cut in the vertical orientation, so it is important that the core be marked such that both sides will indicate the "up" direction after cutting.

After a core has been taken, write additional information on each side (left and right) of the sample. Include the following information:

- Structure No. (existing structure) or CSJ (new construction).
- For new construction, name of Prime Contractor if at jobsite or Fabricator if in Precast Concrete Plant.
- Member ID and location.
- Core number. Also, take photographs and notes indicating from where in the member the core was taken and why.

Again, most cores are cut vertically. Write all of the above information on both sides of the core so each part of the sample can be properly identified if it is cut.

Include a standard TxDOT Form 202 for each set of cores taken from a member. Request that the TxDOT Inspectors fill out Form 202 as needed so hard copies of the completed forms can be sent directly with the samples. Also send copies of applicable concrete mix design worksheets and batch tickets with the cores when they are available.

Patching Cores

As with all large patches, utilize preapproved bagged cementitious repair material or batched concrete to patch core holes when feasible. Follow the requirements set forth in the section on Intermediate Spall Repair for implementing the work.

Section 6 — Trimming or Cutting Prestressed Concrete Girder Ends

Description

This section includes allowances and repair procedures for trimming or cutting the ends of prestressed concrete I-beams.

- Removal of more than 1 inch of a beam end is considered cutting.
- Removal of 1 inch or less from a beam end is considered trimming.

Cutting beam ends requires preparation of an NCR from the Fabricator. The TxDOT Inspector determines whether an NCR is required when a beam end will be trimmed.

NOTE: Standard provisions for cutting beam ends apply to Tx Girders (bulb tees) only. Cutting the ends of prestressed members other than Tx Girders requires a detailed analysis by a Professional Engineer and authorization from TxDOT MTD Headquarters or the Bridge Division. There is no standard repair for such alterations; proposals will be considered on a case-by-case basis.

Provisions for Acceptance

No more than 12 inches may be removed from either girder end.

If more than 6 inches is removed from a girder end, include in the modification proposal stamped calculations from a Professional Engineer indicating the viability of the proposed modification. Calculations must include:

- Required moment and shear capacity.
- Actual moment capacity of the modified member, obtained using PGSuper or another acceptable analysis program.
- Actual shear capacity.

In most cases equal amounts should be removed from each end if the total length to be cut exceeds 6 inches. However, that would not be a viable solution if a beam end is being cut in order to eliminate damage or when a beam end contains an anchor slot.

The Area Engineer and MTD Engineer must approve modifications. All parties, including the Fabricator, Contractor, and Engineer, must agree that trimming will not result in any unacceptable issues related to deck forming, slab or haunch thickness, camber, or plan profile deck geometry.

The girder must be modified as required for use in its new configuration, including but not limited to blockouts, inserts, hangers, and bevels.

When the strand pattern differs from the destination design, or if more than 6" is cut off one or both beam ends, a replacement shop plan for the permanent record must be provided that indicates all characteristics of the candidate girder that differ from the originally specified girder.

Include dual girder identification by permanently marking the inside face of the girder, clearly indicating which is the previous girder I.D. and which is the current I.D. Fabricator or Contractor must send written notification to the Area Engineer informing them of the circumstances of the dual marked girder for their information and records.

Repair Procedure

After the beam has been trimmed or cut, re-measure the member (length, skew, and batter) to ensure that the altered dimensions are acceptable.

Once the dimensions have been checked and found to be acceptable, remove all vertical reinforcement that has less than 3/4-inch concrete cover. Recess longitudinal reinforcing steel and prestressing strands approximately 3/8-inch.

- Locate the steel using shop drawings, exploratory drilling, and whatever other means is necessary to ensure that all reinforcement with inadequate concrete cover is identified.
- Remove the steel using a torch or other approved method. Do not overheat or damage the surrounding concrete and steel that will remain in place.
- If steel is removed using a torch, abrade the steel and concrete surfaces with a needle gun, steel brush, or other suitable means to ensure that no slag remains.

Apply a silane penetrating sealer and neat Type VIII epoxy to every portion of the member that was trimmed or cut. Wait at least 48 hours after applying the penetrating sealer before applying neat epoxy. Do not extend the neat epoxy material with sand except to fill in the voids where the steel has been recessed or removed.

Section 7 — Recessing Prestressed Strands

Description

Recess prestressed strands to help prevent corrosion due to exposure to the elements.

Repair Procedure

Recess the prestressing strands a minimum 3/8-inch using a torch or other approved method. Do not overheat or damage the surrounding concrete.

Abrade the concrete and the end of the steel strand with a needle gun, steel brush, or other suitable means to ensure that no slag remains on the steel or concrete surfaces.

Coat the inside of the recessed area, including the strand, with 10 mils (minimum) of neat Type VIII epoxy and patch the recess with epoxy mortar.

Do not coat the beam end away from the recessed strands with epoxy mortar.

Section 8 — Rail Damage Due to Vehicular Impact

Description

Traffic rails frequently sustain damage from vehicular impact, often resulting in reduced structural capacity. It is imperative to implement repairs to railing that restore capacity, in the event that the same section of rail is impacted again.

Many rail types include steel components mounted to concrete parapets. Although this manual addresses concrete repairs, damage to steel elements must also be considered when rail damage is assessed and repaired.

Assessment

Damage to railing can be categorized as minor, intermediate, or major. Damage should be assessed on a case-by-case basis.

Minor rail damage is defined as spalling or cracking that does not extend beyond the outer reinforcing steel cage, with no loss in structural capacity, and that covers an area of less than 12 square inches. Additionally, there is no deformation of any steel components.

Intermediate damage extends beyond the outer cage of reinforcement but based on the Engineer’s assessment hasn’t significantly reduced rail capacity. The maximum depth of an intermediate spall is 6 inches.

Major rail damage occurs from any impact that necessitates restoration of structural capacity. Damage is typically greater than 6 inches deep and results in plastic deformation of reinforcing steel, anchor bolts, or other steel elements.

The Engineer may evaluate slight deformations in steel elements or reinforcement to determine whether they can be reused.

Even slight deformations in galvanized steel can severely limit its long-term viability in preventing corrosion; therefore, damaged galvanized elements should typically be replaced rather than repaired or touched-up. In no case should damaged anchor bolts be reused.

Repair Procedure

Minor rail damage: Repair spalls in accordance with Section 1 (epoxy mortar) or Section 2 (proprietary, bagged concrete repair materials) of Chapter 3 in this manual. Seal cracks in accordance with Section 6 (gravity-fed `sealant`) or Section 7 (surface seal) of Chapter 3. Touch up any scrapes or other minor damage to steel elements in accordance with standard District maintenance practices. If any galvanized elements are impacted, then the Engineer should evaluate to determine appropriate repair procedures, such as touch-up using zinc-rich paint or other process. See Item 445, “Galvanizing” and the Department Material Producer List for Galvanizing Repair Paints for more information.

Intermediate rail damage: Repair spalls in accordance with Section 2 (proprietary, bagged concrete repair materials) or Section 3 (batched concrete) of Chapter 3. Ensure there is a mechanical bond by completely excavating around exposed reinforcing steel.

Major rail damage: When damage is severe enough to reduce the structural capacity of a rail, the best option for full restoration is to remove the rail to the level of the concrete deck and retrofit in accordance with the TxDOT Bridge Standards Retrofit Guide for concrete rails or curbed structures. All damaged components should be replaced or supplemented, and structural class batched concrete should be used to cast the new section of concrete railing.

If the Engineer determines that major rail damage can be repaired rather than retrofitted to sufficiently restore capacity, perform work in accordance with Standard Specification Item 778, “Concrete Rail Repair.” When feasible, utilize batched concrete rather than proprietary, bagged material to repair the damaged rail.

Installation of new anchors and reinforcement is critical to ensuring adequate capacity of the concrete railing and steel-mounted components. When using an adhesive to anchor steel bars, install in accordance with Standard Specification Item 450, “Railing.” Note that anchorage testing of installed adhesive anchorages may be required as directed by the Engineer.

Chapter 3 — Repair Materials and Procedures

Contents:

Section 1 — Minor Spall Repair

Description

Most minor concrete spalls are repaired using neat Type VIII epoxy (no sand) to help protect against deterioration caused by exposure to the water, chlorides, and other contaminants. Minor spalls are defined in Section 2.1 of this Manual.

Minor spalls can be built up using Type VIII epoxy mortar. Generally building up minor spalls with mortar provides no additional corrosion protection or capacity vs. neat epoxy only. Filling the voids removes the appearance of spalling and is typically done based on aesthetic concerns.

Material

TxDOT Type VIII neat epoxy compound (ASTM C 881 Type I or IV) is produced by mixing two proprietary liquid components in the ratio required by the manufacturer.

- Refer to DMS 6100, DMS 6110, and the MPL for *Epoxies and Adhesives* for additional information.
- Use materials from TxDOT's preapproved list for Type VIII epoxy. Contractor may use other materials only if specifically authorized by the Engineer in writing.
- Follow manufacturer's published recommendations for storage including temperature and humidity controls. Retain manufacturer lot tags with packaged date and shelf life for inspection prior to product use.

TxDOT Type VIII epoxy mortar is produced by combining the neat epoxy compound and an aggregate (usually silica sand) approved by the epoxy producer and TxDOT.

- Ratio by Volume:
  - Adhere to the requirements from the manufacturers' technical data sheets when proportioning the sand to add to the neat epoxy.
  - If using Industrial Coatings as the supplier for Type VIII epoxy, proportion the mortar at 1 part neat epoxy to 5 parts sand. The epoxy-to-sand ratios are typically lower for the other approved suppliers, in the range of 1 part epoxy to 1.5 to 2 parts sand.
- Silica Sand:
  - Most manufacturers recommend that 20/40 mesh sand be used to produce epoxy mortar. It is acceptable to use sand that passes a No. 16 sieve but is retained by a No. 50 sieve (16/50 mesh).

- Use sand other than 16/50 mesh or 20/40 mesh only if authorized by the epoxy manufacturer and the Engineer.
- If the patch will remain visible after a member has been erected, the Engineer may require use of a combination of gray and white sand to make the epoxy mortar material closely resemble the surrounding concrete.

Do not exceed 130°F if heating any of the epoxy liquid components to ease mixing or application.

If using sand from a stockpile, ensure that it has been properly dried and graded before mixing. Sand should not stay clumped together after being bunched up in a fist.

NOTE: Keep a separate container that is protected from rain and other water for storing sand used to mix Type VIII epoxy mortar. Sand from a stockpile is typically far too wet to be used for mixing epoxy mortar.

Do not exceed 230°F when heating sand to dry it. Allow sand to cool to a maximum temperature of 130°F before mixing with the neat epoxy.

Repair Procedure

- ◆ Surface preparation.
  - Remove any damaged or loose concrete.
  - Avoid damage to sound concrete that is to remain in place by saw cutting the perimeter of the patch area or taking other appropriate measures acceptable to the Engineer.
  - Unless otherwise approved by the Engineer, use only hand tools or power-driven chipping hammers (15-lb. class maximum) to remove concrete.
  - If the damage occurs at the end of a member and prestressing strand is exposed, recess the strands a minimum 3/8-inch using a torch or other approved method. Do not overheat or damage the surrounding concrete.

NOTE: In the past some Contractors and Fabricators opted not to recess prestressing strands in spalled areas so the protruding sections could serve as dowels for the patch material. While the strands would serve well as dowels in those circumstances, they could be exposed to moisture and chlorides if the patch fails over the life of the structure. For that reason it is more important that the strand be completely recessed.

  - Ensure substrates are clean and sound. Remove any contaminants, including laitance, oil, dust, debris, or other foreign particles.
  - Just prior to coating or patching, blast the repair area using a high-pressure air compressor equipped with filters to remove all oil from the compressed air.
  - For minor spalls in which a short longitudinal section (less than 4 inches) of mild reinforcement or prestressing strand is exposed, the steel should NOT be removed. Nor should

sound material behind the steel be excavated unless more than half the bar circumference is exposed, in which case the spall should be classified as Intermediate.

- It is not necessary to install dowels or provide other mechanical anchorage in applications less than 1 ½ inch thick. The Engineer may require dowels, typically stainless steel expansion anchors, in thicker applications to help tie the patch to the parent material in case of a delamination.

◆ Mixing.

Measure the proper quantity of each component per the manufacturer's requirements, then dispense into a clean container. Do not estimate the proper amounts while adding the different components.

Mix the liquid components thoroughly using a low-speed electric drill (400 – 600 rpm) and a clean "Jiffy" type mixing paddle. Do not mix Type VIII neat epoxy or epoxy mortar by hand.

- If utilizing whole batches, mix the liquid components for a minimum of 3 minutes or in accordance with the manufacturer's instructions.
- If using partial batches, mix for at least 1 minute or until the material is well-blended and uniform, whichever is longer.

Slowly add the sand or other approved aggregate to the epoxy compound while mixing with an electric drill and paddle. Mix the material until the epoxy mortar is well-blended and all sand particles are coated (1 minute minimum after the sand is added).

Mix an adequate amount of additional neat epoxy compound for use as a waterproofing and bonding layer.

Set times vary significantly depending on type of epoxy and ambient conditions (temperature, wind, humidity). In hot weather (greater than 90°F) place a partial batch in a cup to determine set-up time, and adjust production volumes accordingly.

◆ Neat Epoxy Application.

- Surface must be dry and clean prior to application of the repair material.
- Brush, roll, or scrub the material into the prepared substrate to ensure that all small voids are filled.
- Cover the entire damaged area, including exposed steel reinforcement and dowels when applicable, with at least 10 mils of the neat epoxy compound.

NOTE: Members of the repair crew should have a wet-film thickness gauge to periodically check that neat epoxy is being installed in adequate application depth. Inspectors should also carry wet-film thickness gauges so they can verify adequate minimum thickness.

◆ Epoxy Mortar Application.

- Apply a layer of neat epoxy compound to the substrate as outlined above to serve as a bond coat layer for the repair mortar.

- Trowel-apply the epoxy mortar into the repair area while the bonding layer is still tacky. If the bonding layer loses its tackiness prior to patching, clean the epoxy surface and apply additional neat epoxy before proceeding.
- Limit repair depth to 1 inch when using epoxy mortar unless otherwise approved by the Engineer. In multiple lift applications wait until previous lift has cured sufficiently to prevent sagging prior to applying the next lift. Apply a bonding layer of neat epoxy between each lift.

◆ Finishing.

The Contractor should consult the Engineer before patching minor spalls in which an aesthetic treatment will later be applied.

As noted above, the Engineer may require that white or gray sand be used to produce epoxy mortar if a patch will remain visible in its final configuration. Such patches should not be easily discernible if viewed from more than 25 feet away. The Engineer will review other methods proposed for blending patches.

◆ Curing.

The required time for the material to cure properly can increase significantly when the ambient temperature is below approximately 50°F. If artificial means are used to heat the in-situ neat epoxy or epoxy mortar, ensure that the air around the repair material does not exceed 130°F.

Moist curing is not required.

Commentary

The high bond strength of properly mixed and applied Type VIII epoxy mortar makes it a good option for use in thin applications where inclusion of dowels is not practical and excavation behind partially exposed steel would unnecessarily necessitate removal of sound material.

Do not use Type VIII epoxy mortar for structural patches or in other areas where significant movement from loading or temperature variations are anticipated. Stress caused by differential movement at the bond line can develop because the coefficient of thermal expansion of Type VIII epoxy mortar varies significantly from the concrete substrate. This can apply even in thin applications if the damage covers a large area.

Section 2 — Intermediate Spall Repair

Description

Most intermediate spalls, as defined in Section 1 of Chapter 2, are patched using proprietary, bagged concrete repair materials.

Extending bagged cementitious repair material with coarse aggregate can significantly reduce the potential for shrinkage and cracking. When feasible, the Contractor should either use a pre-extended repair material or add coarse aggregate (typically pea gravel). Using extended material is often not practical when using trowel-applied materials in vertical and overhead applications.

It is a common misconception that higher compressive strength equals a better patch. In reality, excessively high compressive strength can lead to early failure as a result of excessive loads being transferred into the patch material. Engineers and Contractors should typically select materials that have only enough strength for the intended use. In most cases intermediate spall repairs will be non-structural in nature, and therefore compatible or lower compressive strengths are beneficial.

In general, slower strength development means better long term performance. Often, Contractors select rapid strength-gaining repair materials even when it is not necessary to do so. When it is practical, standard (non-rapid) strength-gaining materials should be selected.

Batched concrete should generally be used when patching intermediate spalls in precast fabricator yards since it is readily available. Likewise, batched concrete should be used on construction sites when practical. Although bagged mixes can work well when applied correctly, batched concrete is typically a better alternative since the material properties will very closely match those of the parent concrete. Follow the provisions in Section 3 of Chapter 3 when using batched concrete to patch intermediate spalls. In highly congested areas, the largest of the coarse aggregate can be removed using a sieve to allow the material to flow adequately in the confined patch spaces.

Material

Proprietary, cementitious repair mortars and concretes (pre-extended with coarse aggregate) typically consists of a mixture of the following:

- Prepackaged powder, and
- Either water or a proprietary liquid component supplied by the manufacturer.

Only preapproved materials listed on the MPL for DMS 4655, *Concrete Repair Materials*, should be used on TxDOT projects. The MPL includes several repair categories. The Engineer should specify on the plans which category or categories are acceptable in specific applications.

Use neat materials for applications up to 2 inches thick. Use extended materials for repairs exceeding 2 inches.

Minimum application thickness can vary depending on the material and size of coarse aggregate (if applicable). Consult the manufacturer's technical data to determine minimum thicknesses when determining minimum acceptable thickness, especially when working with extended materials.

For vertical and overhead repairs, limit lift thickness to 2 inches or the maximum permitted by the repair material supplier, whichever is less. Roughen the surface of materials that will receive subsequent lifts, and ensure substrate is clean and saturated surface dry prior to placing additional repair material.

Follow manufacturer's published recommendations for storage including temperature and humidity controls. Do not expose material to the environment for extended periods of time. For projects with greater than 1000 square feet of concrete repair, store material off-site. For short durations, not to exceed three days, prepackaged material may be stored on-site but must be raised off the ground and covered in waterproof tarps. Material exposed to the environment and showing signs of packaging wear should not be used until tested and approved by Materials and Tests Division. Retain manufacturer lot tags with packaged date and shelf life for inspection prior to product use.

Repair Procedure

- Surface preparation.
  - Remove any damaged or loose concrete.
    - Avoid damage to sound concrete that is to remain in place.
    - Unless otherwise approved by the Engineer, use only hand tools or power-driven chipping hammers (15-lb. class maximum) to remove concrete.
  - If more than 1/2 the perimeter of any mild reinforcement is exposed or if the exposed bar exhibits significant corrosion, remove the concrete from around the entire bar.
    - Provide ¾-inch clearance or 1.5 times the largest sized aggregate in the repair material, whichever is greater, between the steel and surrounding concrete to permit adequate flow of the repair material.

NOTE: A good rule of thumb is that adequate clearance is attained when you are able to wrap your fingers around the bar. Ensuring that you can grab the bar is a simple but highly effective method of ensuring there is adequate clearance to permit the repair material to flow around the exposed bar.

  - Do not chip around prestressing strand that is exposed anywhere away from the immediate end of the member. Consult the Engineer when patching an area in which prestressing strands have been exposed. When repair dictates that chipping occur around exposed strands, the Contractor must avoid striking the strands directly or otherwise causing damage that could lead to wire or strand breaks.
  - Use abrasive blasting or other approved technique to remove rust from exposed steel surfaces.
- Saw-cut the patch perimeters to eliminate feathered edges and to ensure that the repair material will be applied in depths no less than 1/2 inch.
  - Handheld grinders or saws may be used to square the patch perimeters.
  - Do not over-cut the patch perimeters at the corners of the repair areas.
  - When practical, undercut the patch perimeter at an approximate angle of 30 degrees such that the profile will help hold the patch material in place.
- Roughen the substrate to ensure that there will be a mechanical bond between the patch material and the parent concrete. Though difficult to quantify and measure, Contractor should attempt to attain a minimum surface roughness profile of 1/8 inch or CSP (Concrete Surface Profile) 6 per ICRI.
- If the damage occurs at the end of a member and prestressing strand is exposed, recess the strands a minimum 3/8 inch using a torch or other approved method. Do not overheat or damage the surrounding concrete.

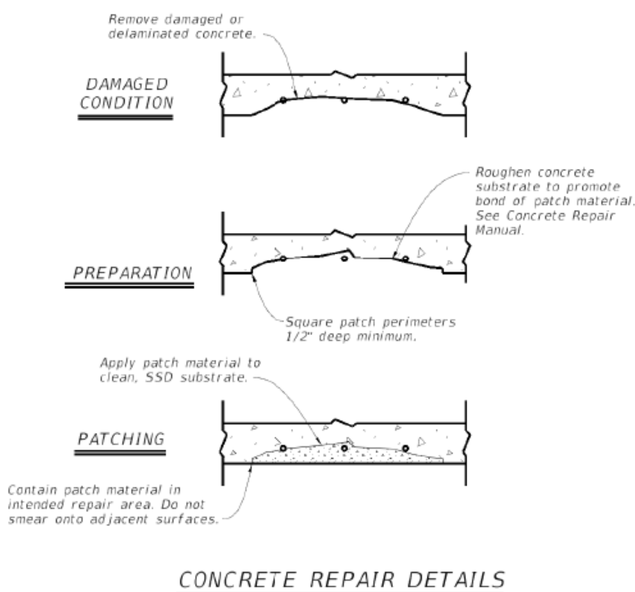

Figure 3-1. Typical Repair Details

Figure 3-2. Preparation (saw-cutting) straight and squared edges to contain patch material.

Figure 3-3. Chipping hammer used to remove unsound concrete.

Figure 3-4. Verifying adequate clearance around reinforcing.

Figure 3-5. Abrasive blasting to clean reinforcing of rust/active corrosion.

Figure 3-6. Reinforcing cleaned and free of rust.

Figure 3-7. Pressurized water to clean and prepare surface (saturated surface dry).

NOTE: In the past some Contractors and Fabricators opted not to recess prestressing strands in spalled areas so the protruding sections could serve as dowels for the patch material. While the strands would serve well as dowels in those circumstances, they could be exposed to moisture and chlorides if the patch fails over the life of the structure. For that reason it is more important that the strand be completely recessed. Install anchors to hold the patch material in place.

- Mechanical ties that bind repair material to the substrate can greatly decrease the risk of future delamination and spalling. For most intermediate repairs, exposed steel serves that purpose. However, there are scenarios in which no reinforcement is exposed and thickness of the spall dictates that cementitious repair material be utilized. In such cases it is necessary to install anchors to help mechanically tie the patch material to the parent concrete. When no mild reinforcement is exposed, install anchors at no more than 4 inches on center each way or as required by the Engineer. The anchors must consist of one of the following:
  - Stainless steel expansion anchors. The Contractor may propose to use other anchors, such as galvanized or zinc-painted metal. The Engineer will review on a case-by-case basis.
  - Rebar or threaded stainless steel pins (1/2-inch diameter minimum) anchored in place using TxDOT Type III `anchoring adhesive`. Remove any epoxy that leaks onto the patch substrate after the anchor is placed.
- If installing expansion anchors:
  - Drill and clean the holes as required by the anchor manufacturer. Do not use a drill bit that has a larger diameter than that required.
  - Embed the anchor the minimum amount required by the manufacturer. However, the anchor should not be driven further than necessary. In order to function as intended the head of the anchor must protrude into the repair material.
- If installing dowels using `anchoring adhesive`:

- Drill a hole 1/8 to 1/4 inch greater than the dowel diameter. Make the hole deep enough to permit a minimum 4-inch embedment of the dowel.
- Remove any contaminants from the hole using a brush or other mechanical cleaner.
- Just prior to installing the anchor, clean the hole using a high-pressure air compressor equipped with filters to remove all oil from the compressed air.
- Dry the concrete surface inside the hole prior to installing the dowel.
- Fill the hole approximately 1/3 full with the adhesive. Twist the dowel as it is inserted. Ensure that the space between the dowel and the concrete is completely filled with the adhesive. Remove all adhesive from the concrete surface that leaks from the hole after the dowel is inserted.

NOTE: When using anchoring adhesives it is critical to properly drill and clean the anchor holes and to place a proper amount of material to keep the anchors in place. The drilled holes must be thoroughly cleaned which should include the use of clean high pressure air and mechanical brushing. Also, if there is too little adhesive, the anchor will not have enough pullout resistance. If there is too much adhesive, the material can leak out of the anchor hole and create a bond breaker on the patch substrate. It is imperative that the Contractor follow the manufacturer's instructions and the above guidelines.

- Where anchors are installed, ensure that there will be a minimum cover of 1/2 inch for stainless steel and 1 inch for non-stainless steel after the patch material is applied. Often-times anchors or dowels do not protrude far enough from the concrete substrate, leaving large depths of patch material unanchored to the parent concrete. Contractor should install anchors with the exposed edge of the patch in mind, not the outside surface of the parent material.
- Substrates must be clean and sound. Remove any contaminants, including laitance, oil, dust, debris, or other foreign particles.
- Just prior to patching, blast the repair area using a high-pressure air compressor equipped with filters to remove all oil from the compressed air.

◆ Mixing.

For small applications (less than 1 cubic yard total) use measuring cups or containers to determine the proper quantity of each component per the manufacturer's requirements, then dispense into a clean container. Mix the components thoroughly until they are well-blended (3 minutes minimum) using a low-speed electric drill (400 – 600 rpm) and a clean "Jiffy" type mixing paddle. Do not mix repair mortar or concrete by hand.

- Do not estimate the proper amounts while adding the different components.
- For vertical and overhead applications Contractors often need to limit the amount of water or liquid component in order to achieve a stiff mix. Consult the manufacturer's literature for minimum requirements.

- If extending the mortar to produce concrete, add aggregate and mix in accordance with the manufacturer's requirements.

When mixing more than 1 cubic yard use a mortar mixer, volumetric mixer, or other method approved by the engineer. Contractor must submit detailed procedures on equipment type, proportioning methods, minimum mixing time, and placement.

Many cementitious repair materials have relatively short working times (15 to 30 minutes).

- Do not mix materials until the surface preparation is complete and the substrate is ready for application of the repair material.
- Mix only the amount of material necessary for immediate application.
- Review water requirements and temperatures. If the dry materials are left out in the environment, they can easily reach 90°F or higher. In cases where dry materials have elevated temperature, use cooled mix water to ensure workability. When performing repairs between the months of April and September, having ice to add to the mix water or using chilled water should be normal. It is much easier to use cooler patch repair material. Note that all the material set time and workability time shown on the material's product datasheet is based on a laboratory room temperature of 70°F.
- Do not attempt to make the material workable by over-mixing or adding additional liquid after it has begun to set. Over-mixing material that has begun to set can reduce the compressive strength and increase the permeability of the material. Exceeding maximum water content is bad for long term performance of patch material.
- The beneficial properties of bagged mixes are often lost when the repair material is retempered. Retempering of bagged mixes will not be permitted.

◆ Application.

Hot and cold weather application.

- The temperature of the patch material and the concrete substrate at the time of application must be between 40°F and 95°F. Contractor must also adhere to manufacturer limits if they are more stringent.
- Do not apply patch material when the ambient temperature in the shade is below 40°F and falling. Patch material may be placed when the ambient temperature in the shade is 35°F and rising or above 40°F.
- Shade the repair material components and the patch substrate if the ambient temperature is above 100°F.

In almost all cases, the repair material should be applied over an SSD substrate. Obtain an SSD condition using one of the following methods:

- Pond water over the substrate for a minimum of 24 hours.
- Several minutes before patching, apply high-pressure water blast to the surface for a brief period (1 or 2 minutes depending on the porosity of the concrete). An SSD condition is achieved if the surface remains damp until the patch material is applied.

Surface may be damp, but must be free of standing water.

Do not use a proprietary epoxy bonding layer in lieu of an SSD substrate unless approved by the Engineer. If use of a proprietary bonding agent is authorized, mix it in accordance with the manufacturer's requirements. Use only TxDOT approved Type V or Type VII material (refer to DMS 6100 – *Epoxies and Adhesives*).

If trowel-applying the repair material:

- Apply over a bonding layer, which typically consists of a scrub coat brushed into the SSD substrate.
- The scrub coat consists of a thin layer of repair mortar that is pushed into the surface using a stiff brush, completely covering the substrate and filling all voids. Ensure that there is not an excess amount of water on the brush used to apply the scrub coat.
- Do not dilute the scrub coat material with additional liquid.
- Apply the repair material while the bonding layer is still wet (scrub coat) or tacky (proprietary bonding layer).
- Apply in minimum 1/2-inch and maximum 1 1/2–inch lifts unless otherwise approved by the Engineer.
- For multiple lift applications, roughen the surface of the preceding lift before it has reached initial set.
- Wait until the preceding lift has reached initial set (30 minutes minimum) to prevent sagging prior to applying the next lift.
- Wet the surface just prior to applying the subsequent lift.

If patching, using a form-and-pour method:

- Prepare and install the forms prior to mixing the repair material.
- Ensure that forms are tight enough to prevent grout leakage.
- Place the repair material in the forms while the bonding layer is still wet (scrub coat) or tacky (epoxy).
- Consolidate the material by rodding, vibrating, and/or hammering the forms. Do not over-vibrate the mix.

If required by the Engineer, determine the compressive strength of the patch material by making concrete test cylinders or mortar cubes.

- Curing.

  Failures often occur in cement-based repair materials due to inadequate curing.

  - Large plastic shrinkage cracks can develop if rapid moisture loss occurs before the patch has the capacity to resist tensile loads that develop as a result of the shrinkage.
  - Drying shrinkage can lead to elevated stress levels that cause cracking within the repair material or at the bond line between the patch and the parent concrete.
  - It is paramount to the long-term success of the repair that proper moist curing commence as soon as possible after application of the repair material, and that it continue for a sufficient amount of time thereafter.

After placing repair material, moist cure exposed patch material surfaces for a minimum of 72 hours using wet mats, water spray, or ponding. Do not use a curing compound in lieu of moist curing unless approved by the Engineer. Curing compound will only be considered for use when water curing will be unnecessarily burdensome and when allowed by manufacturer literature. If use of a curing compound is authorized, any remaining residue must be completely removed after the required curing period.

In form-and-pour applications, leave forms in place for a minimum of 72 hours after placing the repair material. Place wet mats on exposed sections and over the openings used to place the material.

The Engineer may reduce required curing time in some cases, such as when there is a need to return the member to service quickly or when CFRP will be placed over the patch material.

Do not allow concrete surfaces to become dry during the specified moist curing period. Ensure that wet mats are kept wet during the entire cycle.

Insulate the patch material to ensure that there is adequate heat for curing if ambient temperature is expected to fall below 50°F. If using artificial heating methods, do not heat the air around the repair material to above 130°F.

After curing, the repair area will be inspected visually for cracking and sounded by the inspector with firm hammer blows to ensure the repair has adequate bond without cracking and is free of soft or other unsound material. Acceptance of the repair will be based on the findings of this inspection.

- Finish.

  Ensure that the patches closely resemble the surrounding concrete. Finish patch work as outlined in Item 427, Section 4.3.4 for Off-the-Form Finish.

- Blend in the repair area if after completing the work the patch material does not closely resemble the surrounding concrete. The Contractor may use a slurry coat finish in accordance with Item 427 to blend in the patch. The Engineer will review other methods proposed for blending patches.
- Patches should not be easily discernible if viewed from more than 25 feet away.

Commentary

When feasible, batched concrete is typically the best option for repairing intermediate spalls. However, it is often not practical to use batched concrete when working on existing structures or, in some cases, on construction sites. Using bagged mixes is also necessary when either trowel-applied or flowable form-and-pour mortar is needed in highly congested or thin applications. Proprietary cementitious repair materials can work effectively if applied correctly.

Each step in the repair process (preparation, proportioning, mixing, application, and curing) is critical in the overall performance of the patch material. The requirements set forth in DMS 4655, *Concrete Repair Materials*, ensure that only high quality materials will be added to TxDOT's preapproved list. It is imperative that Contractors only use concrete repair materials that have been preapproved for the given application.

Section 3 — Major Spall Repair and Concrete Replacement

Description

Use batched concrete for patching large spalls and defects in concrete members, or when removing and replacing large concrete components. Using batched concrete ensures that the `repair` material properties will be the same or similar to the parent concrete.

Batched concrete is required in structural applications because it becomes more critical that the `repair` material have similar material properties as the parent concrete. Proprietary bagged mixes may only be used in structural applications if specifically authorized by the Engineer.

Material

For new construction, make the repair material using the same concrete mix design that was utilized when the damaged member was originally cast. This applies to precast fabrication yards and construction sites where new structures are being built.

In remedial applications, the Engineer will specify which class of concrete should be utilized per Item 421. For repairs, the Engineer should select concrete mixes that closely match the parent material when such information is available via design documents or construction records.

Repair Procedure

- Surface preparation.
  - Remove any damaged or loose concrete prior to proceeding.
    - Avoid damage to sound concrete that is to remain in place.
    - Unless otherwise approved by the Engineer, use only hand tools or power-driven chipping hammers (15-lb. class maximum) to remove concrete.
- If more than 1/2 the perimeter of any mild reinforcement is exposed or if the exposed bar exhibits significant corrosion, remove the concrete from around the entire bar.
  - Provide ¾-inch clearance or 1.5 times the largest sized aggregate in the repair material, whichever is greater, between the steel and surrounding concrete to permit adequate flow of the repair material.

NOTE: A good rule of thumb is that adequate clearance is attained when you are able to wrap your fingers around the bar. Ensuring that you can grab the bar is a simple but highly effective method of ensuring there is adequate clearance to permit the repair material to flow around the exposed bar.

- The Engineer may require that the steel be coated or that corrosion inhibitor be added to the repair material when reinforcing steel has been exposed.
- Do not chip around prestressing strand that is exposed anywhere away from the immediate end of the member. Consult the Engineer when patching an area in which prestressing strands have been exposed. When repair dictates that chipping occur around exposed strands, the Contractor must avoid striking the strands directly or otherwise causing damage that could lead to wire or strand breaks.
- Use abrasive blasting or other approved technique to remove rust from exposed steel surfaces.

◆ Square the patch perimeters to eliminate feathered edges and to ensure that the repair material will be applied in depths no less than 1/2 inch.

- Handheld grinders or saws may be used to square the patch perimeters.
- Do not over-cut the patch perimeters at the corners of the repair areas.
- When practical, undercut the patch perimeter at an approximate angle of 30 degrees such that the profile will help hold the patch material in place.

◆ Roughen the substrate to ensure that there will be a mechanical bond between the patch material and the parent concrete. Though difficult to quantify and measure, Contractor should attempt to attain a minimum surface roughness profile of 1/8 inch or CSP (Concrete Surface Profile) 6 per ICRI.

◆ If the damage occurs at the end of a member and prestressing strand has been exposed, recess the strands a minimum 3/8 inch using a torch or other approved method. Do not overheat or damage the surrounding concrete.

NOTE: In the past some Fabricators have opted not to recess prestressing strands in spalled areas so they can serve as dowels for the patch material. While the strands would serve well as dowels in those circumstances, they could be exposed to moisture and chlorides if the repair fails over the life of the structure. For that reason it is more important that the strand be completely recessed. Anchors should be installed to hold the repair material in place.

◆ For practically all batched concrete repairs there will be an adequate amount of exposed steel to provide sufficient mechanical anchorage to the parent material. If the Engineer requires that Contractor install additional ties or dowels, select material and install in accordance with the requirements in Section 3.2 for Intermediate Spall Repair.

◆ Adhesive Anchors.

- The Engineer will identify anchor or reinforcing steel type in plans.
- Anchor the bars using a preapproved Type III anchoring adhesive.
- Drill a hole 1/8 to 1/4 inch greater than the bar diameter. Make the hole deep enough to permit a minimum 6-inch embedment of the bar.

- Remove any contaminants from the hole, including laitance, oil, dust, debris, or other foreign particles.
- Just prior to installing the anchor, clean the hole using a high-pressure air compressor equipped with filters to remove all oil from the compressed air.
- Dry the concrete surface inside the hole prior to installing the dowel.
- Fill the hole approximately 1/3 full with `anchoring adhesive`. Twist the bar as it is inserted. For u-shaped bars that cannot be twisted fill the holes approximately ½ full with `adhesive` prior to insertion.
  - Ensure that the space between the dowel and the concrete is completely filled with `adhesive`.
  - Remove all `adhesive` from the concrete surface that leaks from the hole after the dowel is inserted.
- Where supplemental reinforcement is installed, ensure minimum cover of 1 ½ inch.
- Substrates must be clean and sound. Remove any contaminants, including laitance, oil, dust, debris, or other foreign particles.
- Just prior to patching, blast the repair area using a high-pressure air compressor equipped with filters to remove all oil from the compressed air.

◆ Mixing.

Produce repair material in accordance with the approved methods for batching concrete. In order to ensure an adequate mix, batch a minimum of one cubic yard of concrete to `repair` the damaged area even if less volume is required to complete the repair.

Ensure that concrete is `workable` enough when it is placed that it can be adequately consolidated around reinforcing steel, anchors, and other tight places inside the forms.

Remove the largest coarse aggregate from the material if the `repair` depth will be less than 3 inches over a significant portion of the damaged area, the spall occurs in an area that is highly congested with prestressing strands or mild reinforcement, or there is any other reason for concern regarding adequate consolidation. Remove the large aggregate using a 3/4-inch sieve or another method approved by the Engineer.

◆ Application.

Hot and cold weather application.

- The temperature of the `repair` material and the concrete substrate at the time of application must be between 40°F and 95°F.
- Do not apply `repair` material when the ambient temperature in the shade is below 40°F and falling. `Repair` material may be placed when the ambient temperature in the shade is 35°F and rising or above 40°F.
- Shade the repair material components and the `repair` substrate if the ambient temperature is above 100°F.

Convey the material to the repair area using approved concrete delivery equipment.

Apply the repair material over an SSD substrate.

Obtain an SSD condition using one of the following methods:

- Pond water over the substrate for a minimum of 24 hours.
- Several minutes before repairing, apply high-pressure water blast to the surface for a brief period (1 or 2 minutes depending on the porosity of the concrete). An SSD condition is achieved when the surface remains damp after being exposed for 15 minutes.

Surface may be damp, but must be free of standing water. Remove all free (ponded) water just before placing repair material.

Do not use a proprietary epoxy bonding layer in lieu of an SSD substrate unless approved by the Engineer. If use of a proprietary bonding agent is authorized, mix it in accordance with the manufacturer's requirements. Use only TxDOT approved Type V or Type VII material (refer to DMS 6100 – *Epoxies and Adhesives*).

- Forms.

Prepare and install the forms prior to mixing the repair material.

Ensure that forms are tight enough to prevent grout leakage.

Place the repair material in the forms while the concrete substrate is still SSD. If the parent concrete is no longer SSD, remove the forms and re-spray the surface with a high-pressure water blast.

Consolidate the material by rodding, vibrating, and/or hammering the forms. Do not over-vibrate the mix.

If required by the Engineer, make concrete test cylinders to determine the compressive strength of the repair material. If the same concrete mix is being used for production work in another location, the results of compressive strength testing for that work may be used.

- Curing.

Cure batched concrete repairs for a minimum of 72 hours. For most batched concrete applications, the material should be cured by leaving the forms in place during the entire curing period. Place wet mats on exposed sections and over the openings used to place the material.

Do not allow concrete surfaces to become dry during the specified moist curing period. Ensure that wet mats are kept wet during the entire cycle.

Insulate the repair material to ensure that there is adequate heat for curing if ambient temperature is expected to fall below 50°F. If using artificial heating methods, do not heat the repair material to above 130°F.

After curing, the repair area will be inspected visually for cracking and sounded by the inspector with firm hammer blows to `ensure the repair has adequate bond without cracking and is free of soft or other unsound material. Acceptance of the repair will be based on the findings of this inspection.`

Commentary

Batched concrete is typically the best choice when `repairing` deep spalls and in structural applications. Particularly in new construction, mix designs can be selected to ensure that the material properties will closely match the substrate.

Failures at the bond line between the `repair` material and parent concrete are a common problem due to stresses that develop as a result of loading or differential thermal expansion and contraction between the `repair` and parent material.

To that end, using repair material that has a comparable coefficient of thermal expansion and a comparable or lower modulus of elasticity is critical for the long-term success of a repair when significant stresses are likely to develop.

Typically, it is not feasible to determine the modulus of elasticity and coefficient of thermal expansion in a member that has already been cast. The best solution is to use the same mix design for the repair material as that used when the damaged member was originally cast, ensuring that the material properties will be similar.

Section 4 — Bridge Deck Repair

Description

This section covers bridge deck repairs over relatively small areas. Large-scale deck repair or replacement work should typically include project-specific plans and be in accordance with Item 422, "Concrete Superstructures." The primary use of this section is to address unanticipated localized bridge deck damage that typically must be repaired quickly.

Whenever feasible, full-depth bridge deck repairs should extend such that two sides are bearing on supporting (e.g. girder) elements. Typically this means extending the repair along the entire width of a bay or bays such that they bear on girders or beams.

The work covered here can be categorized in two ways. First, by depth: (1) partial depth deck repairs, (2) deck repair over precast deck panels (PCP), and (3) full-depth bridge deck repair. Second, by speed: (1) ultra-rapid, (2) rapid, (3) accelerated, and (4) normal.

- Defining Bridge Deck Repairs by Depth:
  - Partial-depth bridge deck repairs are typically performed on full-depth cast-in-place bridge decks. Damage in the top of the deck only (not progressing full depth) is due to initial slab defects such as improper consolidation or insufficient concrete clear cover over the reinforcing steel; abrasion; wear; or top reinforcing mat steel corrosion.
  - Distress can also occur in the cast-in-place sections of deck above precast concrete panels (PCP's). Regardless of the severity, when performing deck repairs in such cases the cast-in-place portion should be removed to expose the top of the PCP, which then becomes the bonding interface for the patch material. When spalling is occurring above a precast panel, the underside of the panel should be checked for distress. If there is substantial staining on the girder side faces indicating roadway drainage passing through the haunch concrete, panels likely should be replaced with a full depth repair.
  - When damage extends into the PCP portion of the deck, exhibited by visible cracking on the panel soffit, then it should be treated as a full-depth deck repair.
  - Full depth repairs are typically performed when partial depth distress has gone untreated and has progressed to full depth distress as discussed in the commentary of this section and when required to perform expansion joint replacement.
- Defining Bridge Deck Repairs by Speed (Required Return to Service):
  - Often, the factor that trumps all others in bridge deck repair work is the need to return a structure to service quickly. Bridge deck failures and consequent lane closures can have hugely detrimental impacts on traffic, particularly in urban environments. Over the years, repair material suppliers and contractors have become accustomed to the need for extraordinarily quick turnaround, and have catered their services around that need. However, it

has been observed that re-repair of previously repaired decks occurs frequently when the rapid strength gaining materials are used. This is further expanded upon in the commentary of this section.

- In this section there are four categories of repair material based on the needed return to service time. Ultra-rapid repair material can attain sufficient compressive strength for return to service in 2 to 4 hours. Rapid repair materials can generally be returned to service in 6 to 8 hours. Class K material is batched concrete designed specifically in deck repair applications for accelerated strength gain and return to service, usually in less than 12 hours (not including moist curing time). Class S concrete is the best long term solution but can take several days to achieve sufficient strength. Follow the plan requirements related to required strength prior to opening to traffic. If no guidance is provided, provide concrete able to obtain a minimum of 3,600 psi compressive strength prior to opening to traffic.

Selecting an Appropriate Repair Material

An appropriate repair material can be selected once a project has been categorized based on the needed return to service. For depths exceeding 3 inches use material extended with coarse aggregate.

- 3 hours: Use a preapproved Type B Ultra-Rapid Repair Material meeting the requirements of DMS 4655, *Concrete Repair Materials*.
- 6 hours: Use a preapproved Type A Rapid Repair Material meeting the requirements of DMS 4655, *Concrete Repair Materials*.
- 24 hours: Use Class K concrete. These are typically specialty mix designs supplied by a Ready-Mix plant. Mix design requires review and approval from the Engineer. Depending on the capabilities of local Ready-Mix plants this option may or may not be available.
- 2 to 4 days: Class S concrete mixes, which are used to cast new bridge decks, offer the best likelihood of long term serviceability. However, it can take several days before the concrete has sufficient strength for return to service. Engineer should review the history of the proposed Class S mix to ensure that relatively fast strength gain (less than 4 days) is likely to occur. Even with rapid strength gain, Class S mixes should be moist cured for 72 hours (absolute minimum 48 hours).

For batched concrete, provide mixes meeting the requirements of Item 421, Hydraulic Cement Concrete. Note that typical Class HES mixes may not be classified as structural concrete, and should not be used, unless otherwise approved.

Repair Procedure

- Mixing.

- Except in very small applications (less than 1 cubic yard), use a mortar or volumetric mixer. Ready-Mix suppliers and trucks should typically provide batched concrete (Class K or Class S), though the Engineer may approve volumetric mixers on a case-by-case basis.
- For small applications (less than 1 cubic yard total), mix the components thoroughly until they are well blended (3 minutes minimum) using a low-speed electric drill (400 – 600 rpm) and a clean "Jiffy" type mixing paddle. Do not mix repair material by hand.
- Regardless of the mixer type, carefully proportion the water to ensure water-to-cement ratio falls within manufacturer limits. Do not guess at proper quantities or add water to attain a desired consistency.

NOTE: Contractors often use "5-gallon" buckets to proportion water. The actual volumes of these buckets can vary significantly. The Contractor and Inspector should verify actual volumes rather than assuming the buckets actually hold exactly 5 gallons.

- Do not mix material until surface preparation is complete. Ensure that there are sufficient amounts of material, mixing equipment, and labor to provide a continuous supply of mixed concrete until the placement is complete. Take sufficient steps to prevent cold joints between lifts, keeping in mind that many proprietary materials set up very rapidly (less than 15 minutes) in hot weather.

◆ Removal of Concrete.

- Saw-cut the perimeter of the proposed repair approximately 1/2 to 3/4 inches but do not cut existing reinforcing steel. Adjust depth as necessary to avoid damaging deck steel.
- Use power-driven chipping tools or hydro-demolition equipment to remove concrete. Avoid damage to sound concrete to remain. Contractor may use up to 30-lb. hammers for the bulk of the work. However, 15-lb. hammers or smaller must be used at the base and perimeter of the repair area to avoid damaging the surrounding concrete.
- Remove additional concrete as necessary to keep the repair area to a reasonably uniform depth.
- Partial-Depth Deck Repair
  - Remove a sufficient amount of damaged concrete to ensure that the remaining deck is sound. Provide a uniformly rough surface with a chipped appearance (1/4 inch minimum surface profile or ICRI Concrete Surface Profile 9).
  - Even if defective material does not extend beyond top layer of reinforcement, remove enough concrete to ensure there is minimum ¾ inch clearance below the top layer of steel in order to provide mechanical bond for new patch material.
- Repairs over PCPs: Completely remove cast-in-place concrete to expose roughened PCP surface. Ensure that demolition operations do not damage the PCPs.
- Full-Depth Deck Repair: Square or slightly undercut the repair perimeter.

- The Engineer or the Inspector may sound the perimeter of the `repair` area to determine whether demolition operations caused damage beyond the intended perimeter. If that is the case the repair area must be extended to include the unintentionally damaged area.
- For full-depth repairs, remove the concrete and place forms in accordance with Item 422, Concrete Superstructures, or as approved by the Engineer.
- Obtain approval from the Engineer of the completed concrete removal before proceeding with surface preparation.

◆ Reinforcing Steel.

- Remove all rust and other deleterious material from reinforcing steel.
- For non-epoxy coated reinforcing and for epoxy coated steel bars with coating failure, abrasive blast clean steel. Inspect cleaned steel for damage. Replace bars when cross-section is reduced greater than 25 percent.
- Apply an approved epoxy coating to repair minor damage to existing epoxy coated bars.
- When the original epoxy coating on the bars was removed by abrasive blasting, apply an epoxy coat around the entire circumference of the bars extending a minimum of 3 inches from the repair perimeter into the repair area.
- Install reinforcing steel as indicated on the plans or as directed by the Engineer. Place reinforcement parallel to the finished surface. Lap adjacent sheets or bars at least 6 inches and tie them together securely at a spacing of at most 18 inches.
- Pre-bend reinforcing steel fabric to fit around corners and into re-entrant angles before installing it. Place and secure reinforcement to prevent displacement due to repair material application.

◆ Surface Preparation.

- Just prior to patching, thoroughly clean the concrete surfaces (bottom and sides).
- Clean the area to be repaired by high-pressure water blasting, or other approved methods. Remove all loose particles, dirt, deteriorated concrete, or other substances that would impair the bond of the repair material. Follow this with a high-pressure air blast for final cleaning.
- Ensure the surface of the existing concrete is in a saturated surface-dry (SSD) condition but remove all free (ponded) water just before placing repair material. Achieve an SSD condition by high-pressure water blasting 15 to 30 minutes before placing the repair material. An SSD condition is achieved when the surface remains damp after being exposed for 15 minutes.

◆ Placement.

- Place the repair material onto the prepared surfaces. Consolidate using immersion-type vibrators or other methods acceptable to the Engineer.

◆ Curing.

Moist curing is often neglected in deck repairs due to the need to return the bridge to service quickly. However, lack of adequate curing leads to problems on deck repair materials just as it does on any other cementitious repair. Bridge deck repairs should be moist cured for as long as possible. Although 72 hours of curing time is ideal, that is seldom practical in deck repair applications. Even a few hours of moist curing can be beneficial.

Commentary

Shallow deck repairs are notorious for exhibiting poor performance. One common cause of early failure is debonding between the patch material and the substrate. Repair material applied over large areas but in thin applications tend to build up very high stresses at the bond line, leading to premature failure. To remedy this the Contractor should excavate below the top layer of steel, which serves two purposes. First, the reinforcing cage provides a mechanical tie for the patch material to the rest of the deck. Second, it helps to prevent overly thin applications that have little chance of performing well.

Another common cause of premature failure is that partial-depth repairs are often implemented when full-depth would have been more appropriate. The deck soffit should be inspected at partial depth repair locations looking for areas of distress that could be weak and fail when the upper surface is being removed. Partial-depth repairs are typically easier to perform because they do not require installation of formwork or road closures under the bridge. Bridge deck distress oftentimes progresses full depth, as evidenced by cracking in the deck soffit. If map pattern cracking is visible, or if there is widespread cracking with efflorescence and rust staining, then full depth repairs should usually be implemented in lieu of partial-depth.

Intended partial-depth deck repairs can unintentionally become full-depth repairs if the Contractor utilizes equipment too heavy for the application. Contractors should not use equipment larger than necessary to perform the required demolition work, and must stay within the applicable limits outlined in the “Surface Preparation” item below, unless specifically allowed otherwise by the Engineer. No additional compensation for full depth repairs caused by contractors operations will be made.

While rapid strength gain is beneficial for returning a bridge to service, it typically has detrimental effects for the repair material. Rapid curing of the cementitious material can prevent even distribution of the hydration products. Also, early return of service induces stresses into concrete that can create microcracking and other defects even when the compressive strength is high.

Because deck repairs must usually be performed quickly, Engineers and Contractors often select rapid methods even when they are not necessary. It is imperative that, when feasible, slower-hydrating materials and longer curing cycles be utilized. The faster the return to service, the shorter the anticipated service life of the patch.

Section 5 — Crack Repair – Pressure-Injected Epoxy

Description

Pressure-inject TxDOT Type IX low-viscosity epoxy resin into concrete cracks to restore structural integrity of damaged members or to prevent water and chloride infiltration.

Depending on the epoxy resin material, cracks as narrow as 0.002 inches can be injected with epoxy resin. However, it is often difficult to effectively fill cracks that are narrower than 0.005 inches. It is important to use a crack gauge to get accurate readings on crack widths.

Material

Crack Injection Material: TxDOT Type IX low-viscosity epoxy resin (ASTM C 881 Type IV, Grade 1) typically consists of two liquid components that are combined automatically during the pressure injection process.

Epoxy for Sealing the Surface of Cracks: TxDOT Type V or VII concrete epoxy adhesive. Use only material that is approved by TxDOT and the crack injection material manufacturer.

Refer to DMS 6110 and MPL for *Epoxies and Adhesives* for additional information. Also refer to approved manufacturers and products list.

Use material not included in the approved MPL only if authorized by the Engineer.

Repair Procedure

- Surface Preparation.
  - Drill holes to permit installation of the injection ports or mount the ports on the surface as required by the manufacturer. Space the ports at appropriate intervals as outlined in the Application section that follows.
  - Clean the interior of the cracks using either compressed air or vacuum systems to remove all loose materials entrapped in the cracks.
    - In some cases, it may be difficult or impossible to sufficiently remove dust or debris from inside the cracks.
    - If the debris is only near the surface, drill holes for the injection ports away from the exposed portion of the crack. Drill the holes at an angle so the injection ports intersect the crack beneath the surface away from the dust and debris.
    - When using compressed air ensure that the debris is not being forced deeper into the crack.

    - Consult the Engineer if it appears that debris in the crack could hinder proper injection of the epoxy resin.
  - Remove contaminants where the surface seal will be applied, including laitance, oil, dust, debris, or other foreign particles.
  - Unless the manufacturer or the Engineer specifically requires otherwise, do not grind the concrete around the crack to remove contaminants or provide a V-shaped groove along the crack.
    - Grinding can force dust into the crack and consequently hinder proper flow of the epoxy resin.
    - If a V-shaped groove is cut into place along the crack, carefully remove the dust using compressed air and/or high-pressure water blasting. Do not commence the surface sealer application or injection work until the crack and concrete surface have dried.

- ◆ Mixing.

  Mix the epoxy surface seal as required in the manufacturer's technical literature.

  Epoxy Injection Resin: Use portable injection equipment capable of automatically mixing the liquid components at the proper proportion during the pressure injection operation.

- ◆ Application.

  Install the injection ports.

  - Place the ports directly on the crack or in drilled holes that intersect the crack.
  - Install the injection ports at appropriate intervals along the crack.
    - The port spacing should not exceed the depth of the crack. If the depth of the crack is not known, space the ports as recommended by the resin manufacturer.
    - If the crack projects through the entire concrete section, the intervals between ports should not exceed the section depth.
  - Ensure that the ports are placed in locations where the crack is not too narrow or clogged with debris to permit adequate flow of the epoxy resin.
  - Anchor the injection ports and seal the surface of the crack between ports using a sealer as required by the resin manufacturer.
  - Allow sufficient time for the sealer to cure before commencing the resin injection.
  - The sealer must have adequate strength to hold the injection ports in place and withstand the pressure along the crack during the injection operations.
  - Apply sealer over the surface of the crack on the backside if the crack extends completely through the concrete section.
  - Pressure-inject the epoxy resin into the crack through the ports.
  - Use a positive displacement pump, air- or hand-actuated caulking gun, or paint pressure pot as recommended by the epoxy resin manufacturer and approved by the Engineer.

- If working on a vertical surface, start injecting at the lowest port and work upwards.
- Maintain the pressure until resin emerges from the adjacent port.
  - If resin does not emerge from the adjacent port, stop the work and reevaluate the crack.
  - Ports may need to be placed more closely together or debris cleared from under the existing ports.
  - As noted above, ports should be installed at an angle so they intersect the crack at a deeper point if debris is clogging the crack near the concrete surface.
  - Inadequate flow of the epoxy resin may be a sign that the crack is either too shallow or too narrow for pressure injection to serve its purpose.
- If the epoxy begins to flow out of a nonadjacent port, temporarily plug that port until the epoxy begins to flow out of the adjacent port.
- Once the resin appears in an adjacent port, remove the injection nozzle, seal the port, and begin injecting in the adjacent port.
- Move the equipment to the adjacent port and proceed with the epoxy resin pressure injection.
- Remove the injection ports and surface sealer after the epoxy resin has been given adequate time to cure. Resin material should not flow from the crack after the surface sealer is removed.

◆ Finishing.

- Grind away any epoxy resin or surface sealer residue that is left on the concrete surface after the injected material has had sufficient time to cure.

Commentary

Injection of concrete cracks with epoxy resin takes a great deal of skill and expertise. The repair crew should receive hands-on training from a technical representative from the resin manufacturer before proceeding with the work, or the Contractor should retain a specialty firm to perform the work.

Section 6 — Crack Repair – Gravity-Fed Sealant

Description

Use TxDOT Type IV low-viscosity, gravity-fed sealant to fill cracks to help prevent water and chloride infiltration into concrete.

Depending on the type of sealant used, cracks with widths as narrow as 0.004 inches can be filled using gravity-fed material. Use a crack gauge to get accurate readings on crack widths.

Material

TxDOT Type IV low-viscosity, gravity-fed sealant typically is made by combining two proprietary liquid components in the ratio required by the manufacturer.

Refer to DMS 6110 and MPL for *Epoxies and Adhesives* for additional information. Also refer to approved manufacturers and products list.

Use material not included in the approved MPL when specified on the plans or if authorized by the Engineer.

Provide dry, coarse sand to apply to deck surface when flood coating with sealant is specified.

Repair Procedure

- Surface Preparation.
  - Remove contaminants where the epoxy will be pooled around the crack, including laitance, oil, dust, debris, or other foreign particles.
  - The epoxy will not work effectively in cracks that are filled with contaminants. Use compressed air to remove debris and other foreign particles from inside the crack.
  - Ensure that concrete is sufficiently dry prior to applying the epoxy.
  - For cracks that extend completely through the concrete section, seal the crack on the back or underside of the concrete to prevent the epoxy material from flowing out. Remove the surface sealer after the gravity-fed epoxy has had adequate time to cure.
- Mixing.
  - Measure the quantity of each component per the manufacturer's requirements, then dispense into a clean container. Do not estimate the proper amounts while adding the different components. Follow the product specifications for maximum time allowed for use after mixing. These materials have

short pot life when left in a container and if left too long they will flash set.

- Mix the components thoroughly for 3 minutes using a low-speed electric drill (400 – 600 rpm) and a clean "Jiffy" type mixing paddle. Ensure that the material is well-blended after mixing.
- Do not mix gravity-fed epoxy material by hand.

◆ Application.

- Pour sealant directly on cracks within the treatment area. Distribute the sealant over the surface to be treated within the lot size that can be accommodated for the particular sealant being sealed. Brush grooved cracks with heavy nap roller. Pull additional sealant material onto crack using squeegee or broom and then re-brush crack with heavy nap roller.
- If applying on grooved surface, remove excess sealant from deck surface and brush or broom out epoxy from texture grooves. Do not allow the ponded sealant to stiffen, and do not allow sealant to remain in the grooves on the bridge deck.
- Broadcast or spread sand onto the still tacky sealant within 10 to 20 minutes of the last application of sealant. Apply the sand at a rate of 15 to 20 lb. per 100 sq. ft. of area.
- Contractor may propose alternate application techniques that meet manufacturer requirements.
- When sealing isolated cracks and flooding the surface will not be done, install temporary dams around the crack so the pressure head of the gravity-fed epoxy will build up. Install the dams using a material that will prevent the epoxy from spreading over the concrete surface, and that can be removed after the repairs have been completed. Leave the pooled epoxy in place for at least one hour. Refill the dammed area as necessary if the epoxy drains completely into the crack.

NOTE: Although a wide variety of materials will work for constructing temporary dams for pooling gravity-filled epoxy, plumbers putty is a good option because it does not require any curing time and it can be very easily removed after use.

Commentary

Gravity-feeding epoxy is an effective method for filling the tops of cracks. However, the depth of penetration can be variable. Limit its use to shallow cracks or locations where deeper cracks are acceptable, but protection from water and chloride infiltration is necessary.

Gravity-feeding sealant is an effective method for filling the tops of cracks. However, the depth of penetration can be variable and often times it will not penetrate the cracks more than ¼". The primary use of gravity-fed sealants is to address bridge deck cracking, which when used correctly, will provide a barrier keeping water and chloride from reaching the reinforcing steel.

Section 7 — Crack Repair – Surface Sealing

Description

Occasionally there is a need to seal cracks to prevent infiltration of water, chlorides, and other contaminants. While other crack sealing techniques can restore capacity or provide for complete filling of a crack, the methods outlined in this section only cover sealing the cracks at the outer surface of the concrete.

Method 1: Rout-and-Seal Cracks

- Routing and sealing cracks can be an effective way to prevent water infiltration in cracks in which a small amount of movement is anticipated due to service loads, thermal effects, or other causes.
- When routing a crack, the Contractor should use a grinder to create a V-shaped groove, with the crack centered in the groove. Though it can vary depending on the application, the grooves should typically be about 3/8 inch deep.
- For cracks in which a significant amount of movement is anticipated, bond breaker tape should be placed at the bottom of the groove prior to sealing. The tape must stay at the bottom of the groove in order to be effective. The bond breaker allows for 2-sided rather than 3-sided adhesion, which permits much greater elasticity of the sealant.

NOTE: Although good in principle, it is difficult to place bond breaker tape in the bottoms of the grooves such that the tape will not move during application of the sealant. If the bond breaker moves up it can reduce or eliminate the bonding surface on one side of the joint, eliminating their effectiveness. When used, the Contractor must take great care to ensure that tape stays in its intended location.

- After grooving, ensure substrates are clean and sound. Remove any contaminants, including laitance, oil, dust, debris, or other foreign particles.
- Fill the groove using a preapproved Class 4 low-modulus silicone meeting the requirements of DMS 6310, *Joint Sealants and Fillers* or Type V adhesive meeting the requirements of DMS 6100, Epoxies and Adhesives as specified on the plans.

Method 2: Surface Sealing

- Sealing the surfaces of cracks simply involves applying an adhesive directly over the crack to prevent infiltration of water, chlorides, and other contaminants.

- Sealing the surfaces of cracks should only be employed when no significant crack movement is anticipated. This can apply to minor cracks in compression members, or in cracks that occur in prestressed members as a result of fabrication, detensioning, or handling issues.
- For sealing cracks at the outer concrete surface, apply a preapproved Type VIII or Type X epoxy that meet the requirements of DMS 6100, *Epoxies and Adhesives*. Work the epoxy into the crack, then remove any excess epoxy from the surface before it sets.