RAP Bulletin 6

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Field Guide to Concrete Repair Application Procedures

Vertical and Overhead Spall Repair by Hand Application

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Field Guide to Concrete Repair Application Procedures

Vertical and Overhead Spall Repair by Hand Application

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Introduction

One of the most common application methods for repairing concrete is by hand troweling mortars to replace damaged concrete. This method can be used to repair spalled or deteriorated concrete (Fig. 1) or to resurface vertical, overhead, and horizontal concrete surfaces. Applying repair materials by hand does not require extensive or complicated equipment and is ideal for shallow surface repairs, especially in areas with limited or difficult access. While both portland cement-based and resin-based repair mortars have been used for trowel-applied vertical and overhead repairs, this field guide focuses on the application of portland cement-based repair materials.

Before any concrete repair is initiated, the root cause of the damage should be determined with a thorough condition survey of the structure. Typical causes of concrete damage can include corrosion of embedded metals from carbonation or exposure to chloride ions from deicing salts or sea spray in coastal areas; disintegration from freezing-and-thawing cycles when the concrete is saturated with water; expansion and cracking due to alkali-aggregate reaction; or deterioration from chemical attack. Where possible, if the cause of damage is determined and can be prevented, necessary steps should be taken to avoid need for future repair. Understanding the cause of the deterioration, the owner's repair objectives, and the in-service environment of the concrete structure will help in the proper selection of repair materials and application methods. To rehabilitate the overall structure, concrete repair may need to be augmented with other technologies such as coatings or electrochemical corrosion mitigation methods (refer to International Concrete Repair Institute (ICRI) Technical Guideline 510.1).

The technique of hand troweling repair mortars requires the selection of a sag-resistant mortar and attention to detail during application to achieve an adequately consolidated repair that is well-bonded to the concrete substrate. The successful installation is a function of good surface preparation, application techniques, curing procedures, and properties of the repair material selected.

What is the purpose of this repair?

Hand-applied repair mortars replace damaged concrete and are generally recommended for thin repairs that are cosmetic in nature. Thin overlays of mortar can also be applied to renovate deteriorated vertical and overhead concrete surfaces. This technique, when properly executed, improves the appearance of the deteriorated structure and provides additional protection to the concrete surface.

When do I use this method?

Hand application has been used to repair vertical and overhead surfaces including walls, columns, beams, soffits, and building façades. Experienced workers using wood floats, sponges, or steel trowels can achieve a variety of finishes with trowel-applied mortars.

Hand application of concrete repair materials are used to reinstate spalled or delaminated concrete. Larger and deeper repairs may be more conductive to the use of form-and-pump, form-and-pour, or spray application methods. Refer to the material manufacturer's recommendations for recommended repair material placement thickness. Placement thickness will vary depending on the type of materials selected and the size, depth, and orientation of the repair cavity and may range from 1/8 to 4 in. (3 to 100 mm) on vertical surfaces, and on overhead surfaces in a single layer. Deeper placements may require the repair material to be placed in additional layers. It is critical in applications where repair material is applied in multiple lifts that necessary care is taken to ensure bond between subsequent lifts. Failure to do so will result in interlayer adhesion problems and cause the repair to fail.

Fig. 1—Spalled concrete.

Fig. 2—Concrete removal.

How do I prepare the surface?

The recommended steps in properly preparing the surface to receive a hand-applied mortar are as follows:

1. *Concrete removal and edge conditioning*—Loose, delaminated concrete should be removed until the substrate consists of sound concrete (Fig. 2). Where corrosion of the reinforcement exists, continue concrete removal along the reinforcing steel and adjacent areas with evidence of corrosion-induced damage that would inhibit bonding of repair materials. Concrete removal should include

Fig. 3—Edge conditioning.

Fig. 4—Final surface cleaning after abrasive blasting.

undercutting the corroded reinforcing steel by approximately 3/4 in. (19 mm). The shape of the prepared cavity should be kept as simple as possible, generally square or rectangular in shape. Repair configurations with reentrant corners should be avoided to prevent stress concentration that could cause cracking of the repair material cracking. The edges of the patches should be sawcut perpendicular to the surface to a depth of 1/2 in. (13 mm) to avoid feather edging the repair material (Fig. 3). Avoid cutting into reinforcing steel when sawcutting.

2. *Final surface cleaning*—Use abrasive blasting where possible or other mechanical means (Fig. 4) to remove residual dust, debris, fractured concrete, and other contaminants that prevent proper bonding. If abrasive blasting is not feasible, low-pressure water cleaning using a minimum 3000 psi (20 MPa) may be acceptable depending on the bond strength required. If removal of microcracking or bruising caused by concrete removal is necessary, abrasive blasting or high-pressure water blasting (minimum 5000 psi [35 MPa] is required. Blowing with oil-free compressed air or, alternately, the use of a vacuum, may be appropriate if dust is still present after the blasting. The final surface texture should be rough, with a 1/8 to 1/4 in. (3 to 6 mm) amplitude (Fig. 5) (Concrete Surface Profile No. 6 to 10 per ICRI Technical Guideline No. 310.1R); also refer to ACI 364.7T-02. It is highly recommended to follow manufacturer's guidelines for surface profile and preparation prior to the installation of the material.

3. *Treatment of exposed reinforcement*—All cement, scale, and bond-inhibiting corrosion should be removed from the reinforcing steel by abrasive blasting or high-pressure water blasting. If the cross-sectional area of the reinforcing steel has been significantly reduced, a structural engineer should be consulted (refer to ACI 364.10T). If a reinforcing steel coating, such as an epoxy or zinc-rich coating, and/or Type 1 embedded galvanic anodes are specified, install the protective systems according to manufacturer instructions after the reinforcing steel has been cleaned (Fig. 6).

4. *Substrate saturation*—Most portland cement-based materials require the base concrete to be in a saturated surface-dry (SSD) condition prior to application to prevent

Fig. 5—Properly prepared surface.

Fig. 6—Treatment of exposed reinforcement.

a rapid loss of moisture from the repair material into the substrate. An SSD condition is achieved when the body of the concrete is saturated and free surface water and puddles have been removed from the surface of the concrete. An SSD surface is not recommended if a polymer bonding agent is to be used. When using polymer bonding agents, follow the manufacturer's recommended surface preparation requirements. The general recommendations previously given may be influenced by several factors, including:

- Desired roughness profile of the prepared surface (this may be specified by the manufacturer of the repair product);
- Method of surface preparation, including chipping hammers, abrasive blasting, high-pressure water-blasting, or hydrodemolition;
- Possible contamination of the surface by chemicals, oils, or grease; possible carbonation; and methods of removing contaminants or carbonated concrete;
- Repair material manufacturer's recommendations (ask for technical data sheets and installation bulletins and read the printed instructions on the packaging); and
- Treatment of existing cracks and joints.

For additional information, consult the recommendations of ICRI Guidelines No. 310.2 and 310.1R, and U.S. Bureau of Reclamation (USBR) ST-2016-2886-01 (Vaysburd et al. 2016).

How do I select the right material?

Hand- or trowel-applied repair materials are generally proprietary, prepackaged, cementitious products. Portland cement-based materials designed for hand application may also include polymers, silica fume, shrinkage-compensating materials, and other additives for enhanced physical properties and improved handling.

Specifiers, applicators, and owners can consult ACI 546.3R or ICRI Guideline No. 320.2R for a useful checklist for prioritizing desired material properties. Manufacturers' technical data sheets should be consulted for material properties.

The physical property requirements such as drying shrinkage, permeability, freezing-and-thawing resistance, and mechanical properties vary from project to project, depending on the expected service conditions. The properties critical to the long-term success of the repair should be deter-mined during the evaluation phase and be specified.

Other factors that may influence the selection of repair materials include desired application thickness, rate of strength gain, ease of application, color, and in-place cost.

For some hand-applied repairs, sealers, or decorative or protective coatings may be used to provide additional protection to the base concrete, to enhance aesthetics, or both. When this is the case, confirm the required curing and drying time (or maximum moisture content) with the sealer or coating manufacturer before application commences. For more information, consult ACI 515.2R.

What equipment do I need?

Typical equipment needed for hand-applied repair mortars includes:

Fig. 7—Typical equipment to mix materials.

- A suitable mixer unit such as a drill/paddle/pail combination for small repairs (Fig. 7), or paddle-type mortar mixers for larger applications. Follow repair material manufacturer's guidelines on mixing equipment, mixing paddle, and mixing time;
- Oil-free air compressor, sawcutting equipment, blades, and abrasive blast equipment;
- Water-measuring device to ensure that proper amounts of mixing water are used; and
- Finishing, handling, and testing tools required by the specification or good concreting practice.

Be sure that necessary equipment and tools are on site and in proper working order. Have backup equipment or alternate methods planned and available.

What are the safety considerations?

Installing and handling concrete repair mortars is hazardous and should be treated as such, and workers should use appropriate personal protective equipment (PPE). Jobsite safety practices should include the following where applicable:

- Applicable printed safety data sheets (SDS) should be on hand;
- Machinery and equipment used must have the correct safety guards and warnings in place;
- Workers are required to wear protective gloves and other clothing needed to prevent skin contact with wet, highly alkaline cementitious materials;
- A face shield or safety glasses are needed to provide eye protection;
- Eye wash facilities should be available on the jobsite;
- Concrete demolition, surface preparation, and handling of repair materials can create a respirable crystalline silica hazard. Use dust controls and safe work methods to protect workers from silica exposures. Use respirators when dust controls and safe work methods cannot limit exposures above permissible levels. For more information, refer to the appropriate health and safety regulation such as United States Occupational Safety and Health Administration (OSHA) 29 CFR 1926.1153 in the United States;
- Hearing protection must reduce sound levels reaching the inner ear to limits that are specified by the appropriate regulatory body such as OSHA; and
- Confirm that adequate ventilation is available in closed spaces before operating equipment that emits dangerous exhaust fumes.

Refer to ICRI Technical Guideline 120.1. It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any recommendations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, OSHA health and safety standards.

Preconstruction meeting

Prior to proceeding with the repair, a preconstruction meeting is recommended. The meeting should include representatives for the owner, engineer, contractor, materials manufacturer, and any other parties needed to explain the means, methods, and materials necessary to achieve the repair objectives. A typical preconstruction meeting would include topics such as safety precautions, protection of workers, the public and surrounding structures, inspection and quality control requirements, curing and return to service. Refer to ACI 546.R for additional information on preconstruction meetings.

Repair procedure

1. *Apply the repair material:*

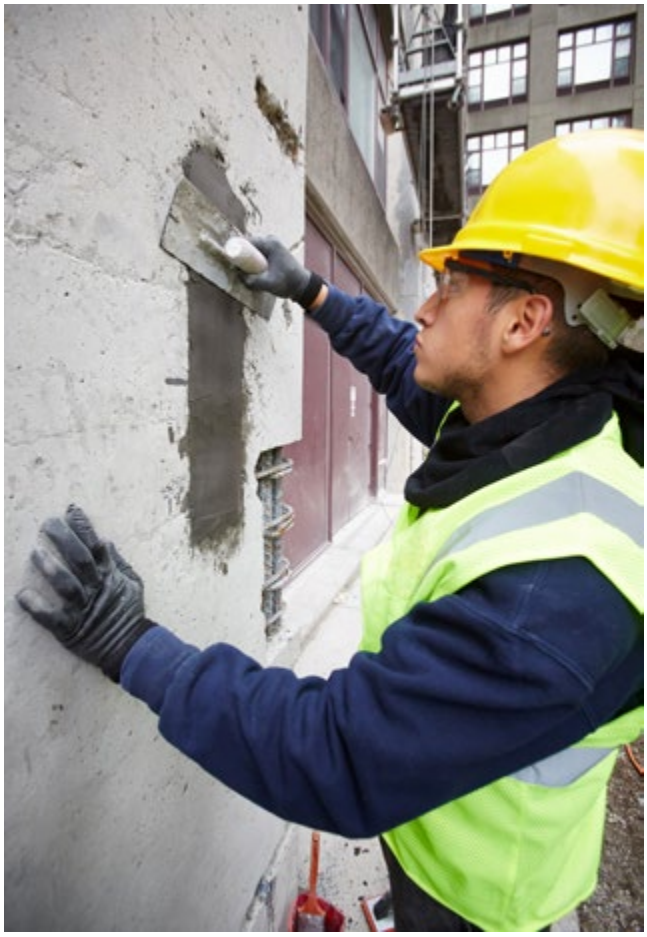

Fig. 8—Hand application of repair material.

Mix the material following the manufacturers' recommendations:

- Scrub a thin bond coat of the repair mortar into the SSD substrate, thus filling pores to ensure intimate contact and to help prevent sloughing or sagging of repair materials on vertical and overhead surfaces. The bond coat should be a thin layer of the same repair material; adding additional liquid to make a slurry can negatively affect the bond strength. Alternatively, the contractor may apply a bonding agent if it is required by the manufacturer or required by the repair specification.
- Before the bond coat dries, apply the repair material with adequate pressure to achieve intimate contact with the prepared substrate (Fig. 8). Thoroughly consolidate the repair material into the corners of the patch and around any exposed reinforcement in the repair zone. Full encapsulation of the reinforcement is important for long-term durability.
- If a second lift is required, thoroughly roughen the surface of the first lift by scoring the soft mortar to achieve an aggressive finish, similar in profile to the prepared concrete substrate to promote mechanical bond between lifts. If the second lift will not be immediately applied, keep the first lift moist until application of the second lift. After the first lift has reached final set, moisten the surface of the first lift, scrub in a thin layer of fresh mortar, and apply the second lift of

Fig. 9—Spray application of curing compound.

material. Once the desired thickness has been achieved, strike off level with the adjacent concrete.

2. *Finish and cure the repair:*

- Finish the repair material to produce a final finished appearance as required by the project specifications. Because of the nonbleeding, sticky nature of many of these materials, the use of an evaporation reducer for intermediate curing may be helpful.
- As with all portland cement-based materials, proper curing will provide enhanced physical properties. Good curing procedures prevent rapid moisture loss at early ages. Consult the product manufacturer for curing instructions. Curing will generally be conducted in accordance with ACI 308R. The use of curing compounds (Fig. 9) that comply with the moisture retention requirements of ASTM C309 or ASTM C1315, or moist curing are common curing methods.

How do I check the repair?

Requirements may include:

- Measuring the area or volume of repair;
- Documentation with before and after photos;
- Confirmation of acceptable surface preparation. This may include observing the surface amplitude profile. Alternatively, direct tension testing of the prepared surface will provide quantitative data regarding the level of surface preparation achieved;
- Material testing performed by a qualified testing agency;
- Sounding the cured repair for lack of bonding; and
- In-place direct tensile bond testing of the hardened, cured repair to the base concrete using methods similar to those described in ICRI Technical Guideline No. 210.3 or ASTM C1583/C1583M. Important observations include maximum stress, expressed in psi or MPa, and failure mode (base concrete, bond line, or cohesive failure of the mortar).

References

Committee documents are listed first by document number and year of publication followed by authored documents listed alphabetically.

American Concrete Institute (ACI)

ACI 201.1R-08—Guide for Conducting a Visual Inspection of Concrete in Service

ACI 308R-16—Guide to Curing Concrete

ACI 364.1R-07—Guide for Evaluation of Concrete Structures before Rehabilitation

ACI 364.7T-02(11)—Evaluation and Minimization of Bruising (Microcracking) in Concrete Repair

ACI 364.10T-14—Rehabilitation of Structure with Reinforcement Section Loss

ACI 515.2R-13—Guide to Selecting Protective Treatments for Concrete

ACI 546R-14—Concrete Repair Guide

ACI 546.3R-14—Guide to Materials Selection for Concrete Repair

ACI RAP 8—Installation of Embedded Galvanic Anodes

ASTM International

ASTM C309-19—Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete

ASTM C1315-19—Standard Specification for Liquid Membrane-Forming Compounds Having Special Properties for Curing and Sealing Concrete

ASTM C1583/C1583M-13—Standard Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-Off Method)

International Concrete Repair Institute

ICRI No. 120.1-2009—Guidelines and Recommendations for Safety in the Concrete Repair Industry

ICRI No. 210.3-2013—Guide for Using In-Situ Tensile Pull-Off Tests to Evaluate Bond of Concrete Surface Materials

ICRI No. 310.1R-2008—Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion

ICRI No. 310.2-2013—Guide for Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, Polymer Overlays, and Concrete Repair

ICRI No. 320.5R-2014—Pictorial Atlas of Concrete Repair Equipment

ICRI No. 510.1-2013—Guide for Electrochemical Techniques to Mitigate the Corrosion of Steel for Reinforced Concrete Structures

Occupational Safety and Health Administration (OSHA)

29 CFR 1926.1153—Respirable Crystalline Silica

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Vaysburd, A. M.; Bissonnette, B.; Thomassin, M. M.; von Fay, K. F.; Harrell, S. J.; and Robertson, B., 2016, "Concrete Substrate Moisture Requirements for Effective Concrete Repairs," *Report ST-2016-2886-01*, Research and Development Office, Science and Technology Program, U.S. Bureau of Reclamation, Research and Development Office, Denver, CO, 65 pp.