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ACI RAP Bulletin 3

FIELD GUIDE TO
CONCRETE REPAIR
APPLICATION PROCEDURES

Spall Repair by Low-Pressure Spraying

Field Guide to Concrete Repair Application Procedures

Spall Repair by Low-Pressure Spraying

Reported by ACI Committee E706

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ACI Repair Application Procedure 3.

Introduction

Similar to wet-mix shotcrete but sprayed at a much lower velocity, low-pressure spall repair spray comes in the form of prepackaged mortar. The spray is applied using small concrete pumps or heavy-duty grout pumps to force the low-slump mortar through a hose. Air is added at the nozzle to impel the mortar. Bond with the prepared substrate is achieved through a combination of proper surface preparation, low-velocity impact, and the material properties of the prepackaged mortar.

Compared with either wet- or dry-mix shotcreting, this method allows the spray nozzle to be much closer to the repair surface. This means it can be used in tight spaces. Due to the viscous, sticky nature of the mixture and the low pressures involved, there is considerably less rebound than with high-velocity shotcreting.

Before any concrete repair is carried out, the cause of the damage must be assessed and the objective of the repair must be understood.

Typical causes of concrete deterioration include steel corrosion, sulfate attack, alkali-aggregate reactions (AARs), excessive deflection, and freeze-thaw damage. Poor practices during the original construction can lead to premature deterioration. Improper joint spacing and load imbalances also contribute to cracking and spalling.

What is the purpose of this repair?

Depending on the mortar mixture selected, low-pressure spray is used for surface repairs, structural repairs, or cosmetic renovation. The spray can be formulated for freeze-thaw durability, sulfate resistance, low permeability, and other desired or specified characteristics.

When do I use this method?

Low-pressure spray is typically used for vertical and overhead repairs. Successful applications have included structural repairs to bridges, bridge and building piers, structural slab undersides, tank walls (interior and exterior), stadiums, tunnels, and retaining walls. Structural repairs utilizing low-pressure spray are best done under the guidance of a qualified engineer.

The placement thickness can be 1/2 to 4 in. (13 to 100 mm) in a single lift. Thicknesses greater than 6 in. (150 mm) are possible in multiple lifts. If the repair application requires more than a 4 in. (100 mm) thickness, other methods may be more economical (see ICRI Guideline No. 03731, "Guide for Selecting Application Methods for the Repair of Concrete Surfaces").

The ingredients that make up the mortar vary widely, and the ingredients selected will depend on the specific repair situation. Formulas may contain ingredients such as corrosion inhibitors, air-entraining agents, and bonding additives.

The initial material costs are generally higher with this method than for a typical shotcrete application, but in-place costs are often lower or comparable because this method produces less rebound and requires less cleanup. Certified nozzle operators are not required.

How do I prepare the surface?

Consult the recommendations of ICRI Guideline No. 03732, "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays," or ICRI Guideline No. 3730, "Surface Preparation for Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion."

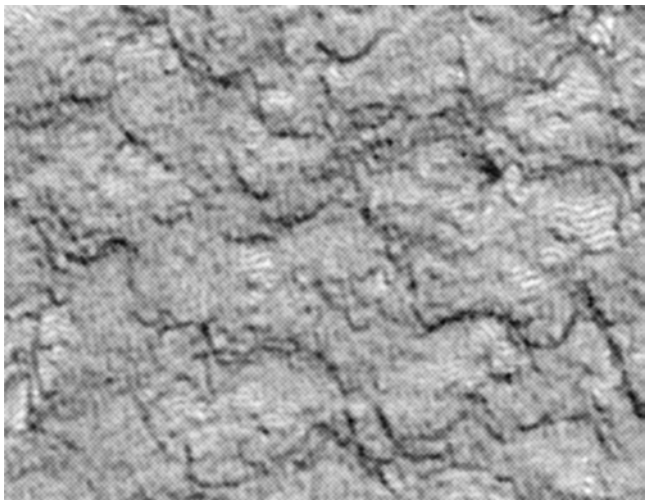


Fig. 1—Typical plus or minus 1/4 in. profile (From ICRI Guideline No. 03732 *Profile No. 7). This is standard recommended surface profile for low-pressure spray-applied mortars.*

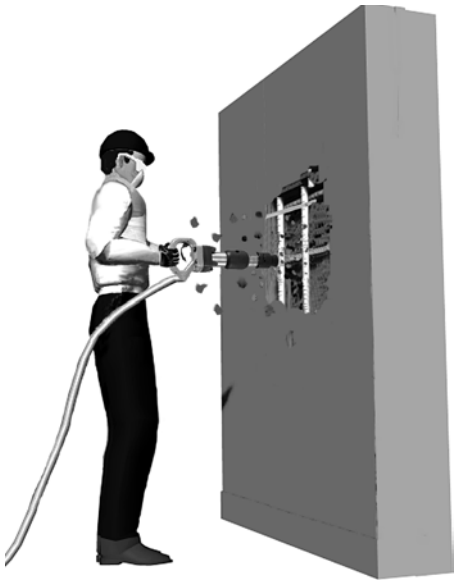


Fig. 2—Chipping surface.

Because many of the materials applied using low-pressure spray are prepackaged, the manufacturer's recommendations should also be consulted.

A typical roughness or profile recommendation for this repair method is ICRI Concrete Surface Profile (CSP) No. 7 or higher, as per ICRI Guideline No. 03730. A CSP No. 7 is equivalent to an amplitude of approximately 1/4 in. (7 mm) (see Fig. 1).

Factors that will influence the specific surface preparation include, but are not limited to:

- Desired roughness profile of the prepared surface (CSP);
- Method of preparation. These may include, but are not limited to, hydrodemolition, sandblasting, and use of pneumatic hammers (see Fig. 2);

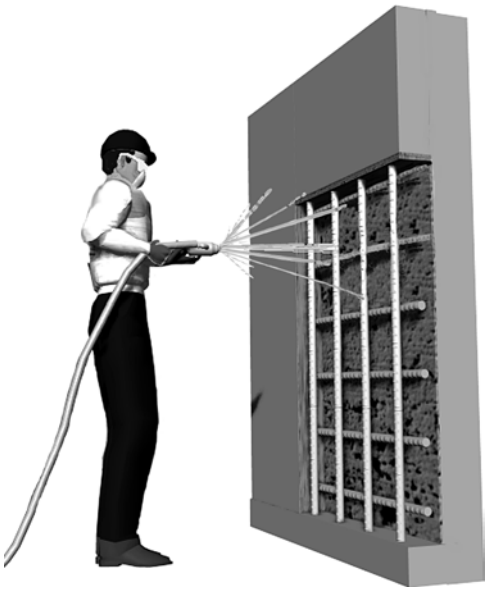


Fig. 3—Presaturate prepared surface with water.

- Possible contamination of the surface by chemicals, oils, soaps, or carbonation. Test for carbonation with a pH indicator. The pH should be 11.5 or higher;
- Methods of treatment for contaminated surfaces;
- Required substrate saturation (see Fig. 3);
- Reinforcing requirements from the mortar manufacturer, the engineer, or the owner; and
- Treatment of existing cracks and joints: Repair the cracks? How? Fill the joints? If so, how and with what?

How do I select the right material?

Low-pressure spray-applied repair materials are proprietary, prepackaged cementitious products. Specifiers, applicators, and owners should consult *ICRI Guideline No. 03733*, "A Guide for Selecting and Specifying Materials for Repair of Concrete Surfaces." Consult the American Concrete Institute publications on concrete repair by ACI Committee 546, Repair of Concrete. Refer to manufacturers' data sheets for material properties.

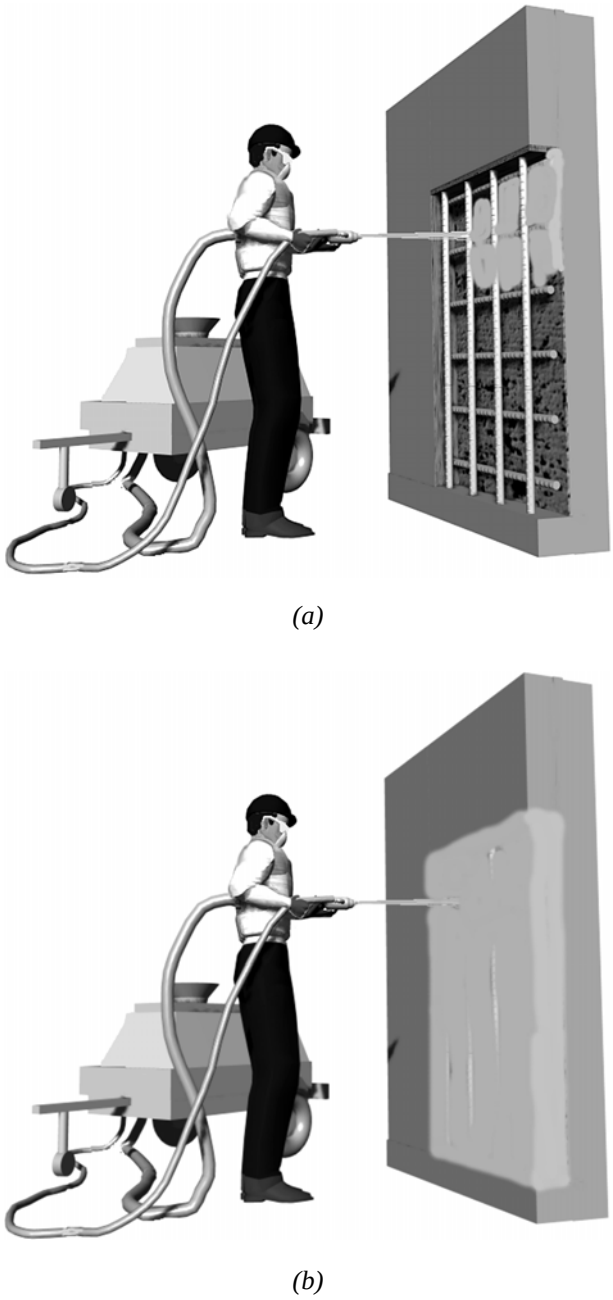
Physical property requirements such as bond strength, freeze-thaw durability, permeability, and flexural strength will vary from project to project.

When low-pressure spray-applied materials are used, some repair applications may require that the material be coated with a protective barrier system. When this is the case, confirm the required curing and drying time before installing the coating.

What equipment do I need?

Be sure that all necessary equipment and tools are on site and in proper working order. Have backup equipment or alternate methods planned and available. Typical equipment needed for low-pressure spray application of repair mortars includes, but is not limited to:

- Concrete or grout pumps suitable for low-pressure spray. Field experience has shown that ball valve pumps are not suitable. Short stroke, swing-type piston pumps or heavy-duty rotor-stator pumps perform well;



(a)

(b)

Fig. 4(a) and (b)—Application of mortar with pressure equipment and nozzle.

- If using a rotor-stator or "moyno" type pump, have a backup rotor on hand at the job site;
- Air compressor with pressure gages and controls. (Some pumps come equipped with built-in air compressors and controls.);
- A suitable mixer for mixing the mortar is needed. A backup mixer is recommended in case of breakdown. (Some repair type pumps come equipped with mortar mixers.);
- A water measuring device, preferably a meter. (Many repair-type pumps equipped with mixers include built-in water meters.); and
- A means of communication between the pump and mixer operators and the nozzleman;

Fig. 5—Skilled worker applying final finish to surface.

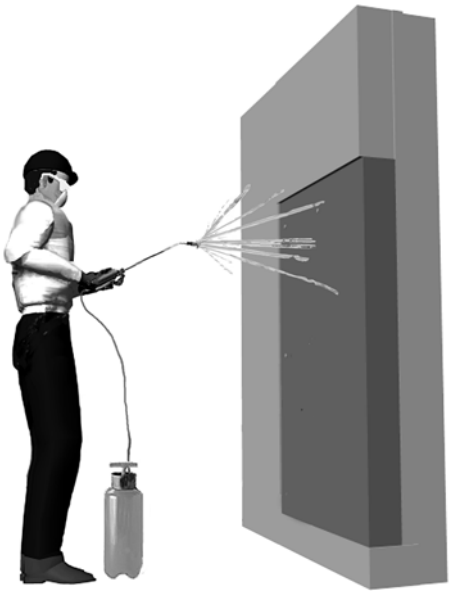


Fig. 6—Application of curing compound.

- All finishing, handling, and testing tools required by specification or good concreting practices.

What are the safety considerations?

Prepackaged mortars are hazardous materials and should be treated as such. Job-site safety practices should include, but are not limited to, the following where applicable:

- Material Safety Data Sheets (MSDS) should be on hand;
- Safety equipment: all machinery and equipment being used must have the correct safety equipment, guards, and warnings in place;
- Protective clothing: protective gloves for workers in contact with wet, cementitious material;
- Protective eyewear: safety glasses or face shields will be needed for all workers;
- Eyewash facilities should be provided;
- Respirators: dust masks will be needed for workers operating the material mixer;
- Ventilation of closed spaces: confirm that adequate ventilation is available before operating equipment that emits dangerous exhaust;
- Secured storage should be available for all hazardous materials;
- Fuel for equipment operation needs a safe storage area, well marked and visible; and
- A safety meeting with all involved should be held and led by the prime contractor's safety manager prior to beginning repair operations.

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 representations 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, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Preconstruction meeting

Prior to proceeding with the repair, a preconstruction meeting is recommended. The meeting should include representatives from all participating parties (owner, engineer, contractor, materials manufacturer, etc.), and specifically address the parameters, means, methods, and materials necessary to achieve the repair objectives.

Repair procedure

1. The prejob (preconstruction) meeting agenda might include:

- On-site availability of power;
- On-site availability of water;
- Site accessibility;
- Debris removal and disposal;
- Dust, odor, and emissions control;
- Confirmation that all materials documentation is on hand—for example, MSDS sheets;
- Methods of curing and time required for curing;
- Possible emergencies and breakdowns—what to do if they occur;
- Finish requirements;
- Testing required; and
- All other concerns that could affect the progress of the repair.

2. Apply the repair.

- Inspect and approve the surface preparation. (See ICRI and ACI references);
- Presaturate the prepared substrate. Twenty-four hours is standard. Prepared saturated surface should be saturated surface-dry when the repair mortar is sprayed;
- Install the specified reinforcement;
- Install/apply bonding agents, corrosion inhibitor sacrificial anodes, if called for;
- Mix the repair mortar and load it into pump hopper.
- Begin spray operations with pump, compressor, and suitable spray nozzle; and

- Apply the mortar at the thickness recommended by the material manufacturer. Most low-pressure spray materials require application in lifts when the thickness of the total application layer exceeds 3 in. (76 mm).

3. Finish the repair.

Confirm the final finished appearance of the repair with the owner. This may vary from rough as-sprayed to smooth troweled. If smooth troweling is specified, production may be reduced and additional labor may be required. One nozzle operator may require multiple finishers to keep pace. This will be influenced by such factors as:

- The installed thickness of the material being applied;
- The drying conditions caused by ambient and substrate temperatures;
- The setting characteristics of the repair mortar; and
- Whether the repair is vertical or overhead.

Because of the non-bleeding, sticky nature of these materials, use of an evaporation control film when finishing is recommended.

Proper curing is important and should be conducted in accordance with ACI 308.1-98, "Standard Specification for Curing Concrete." Additional curing information is available from ACI 308R-01, "Guide to Curing Concrete."

For most cementitious low-pressure spray-applied mortars, application of a curing compound that complies with the moisture retention requirements ASTM C 309 is satisfactory. As an alternate, moist cure for 7 days.

Always refer to the mortar manufacturer's instructions for specific curing methods and materials recommenced for the product selected.

How do I check the repair?

Requirements may include:

- Before and after photos;
- Confirmation of acceptable surface preparation. This can include the prepared surface profile and the pH of the prepared surface. A pH of 11.5 or greater is recommended;
- Confirm repair depth;
- Material property tests performed by a qualified testing agency. This is usually done to confirm the material manufacturers' published material properties;
- In-place direct tensile strength tests of the prepared surface;
- In-place bond direct tensile tests of the hardened, cured repair; and
- Confirmation that all materials used were as specified, cross checking material purchase orders with quantities estimated and with actual quantities billed.

Sources for additional information

ACI Committee 308, 1998, "Standard Specification for Curing Concrete (ACI 308.1-98)," American Concrete Institute, Farmington Hills, Mich., 1998, 9 pp.

ACI Committee 308, 2001, "Guide to Curing Concrete (ACI 308R-01)," American Concrete Institute, Farmington Hills, Mich., 2001, 31 pp.

ACI Committee 503, 1993, "Use of Epoxy Compounds with Concrete (ACI 503R-93)," Appendix A, Farmington Hills, Mich., 28 pp.

ACI Committee 506, 1995, "Guide to Shotcrete (506R-90 (Reapproved 1995))," American Concrete Institute, Farmington Hills, Mich., 41 pp.

ACI Committee 546, 1996, "Concrete Repair Guide (ACI 546R-96)," American Concrete Institute, Farmington Hills, Mich., 1996, 41 pp.

"Guide for Selecting Application Methods for the Repair of Concrete Surfaces," *ICRI Guideline* No. 03731, 1996, 8 pp.

"Guide for Selecting and Specifying Materials for Repair of Concrete Surfaces," *ICRI Guideline* No. 03733, 1997, 34 pp.

"Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Membranes," *ICRI Guideline* No. 03732, 1997, 41 pp.

"Surface Preparation for Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion," *ICRI Guideline* No. 03730, 1995, 8 pp.