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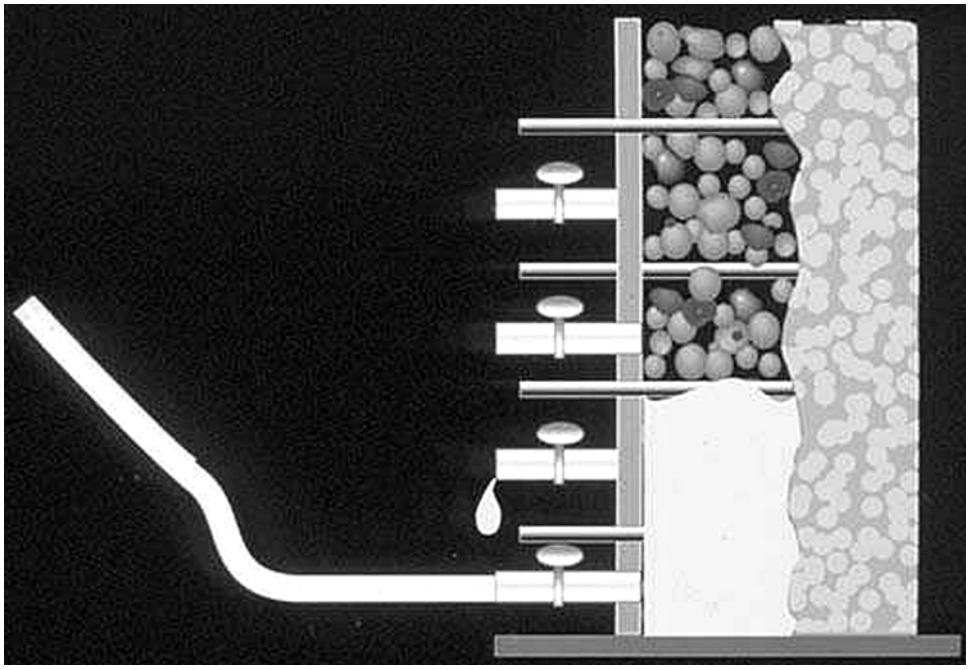
ACI RAP Bulletin 9

FIELD GUIDE TO
CONCRETE REPAIR
APPLICATION PROCEDURES

Spall Repair by the Preplaced Aggregate Method



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(Reapproved 2010)

Field Guide to Concrete Repair Application Procedures

Spall Repair by the Preplaced Aggregate Method

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ACI Repair Application Procedure 9.

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This document is intended as a voluntary field guide for the Owner, design professional, and concrete repair contractor. It is not intended to relieve the user of this guide of responsibility for a proper condition assessment and structural evaluation of existing conditions, and for the specification of concrete repair methods, materials, or practices by an experienced engineer/designer.

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Introduction

Preplaced-aggregate concrete (PPA) is defined as "Concrete produced by placing coarse aggregate in a form and later injecting portland cement-sand grout, usually with admixtures, to fill the voids." ACI 304.1R-92, "Guide for the Use of Preplaced Aggregate Concrete," provides information for job-site mixing of grout for PPA. There are also proprietary products available for grouting preplaced-aggregate concrete. Today, most preplaced-aggregate concrete is produced with prepackaged grouts made specifically for use with PPA.

Placing the aggregate first has several benefits:

- Point-to-point contact of large aggregate is optimized;
- Uniform aggregate distribution and density are achieved;
- The ratio of aggregate-to-cement paste is higher than in placeable concrete;
- Aggregate can be placed in hard-to-get-at locations such as around closely spaced reinforcing steel; and
- Shrinkage is reduced by 50 to 100% compared to typical cast-in-place concrete.

Before any concrete repair is carried out, assess the root cause of the damage so the objective of the repair is understood.

Typical causes of concrete damage include steel corrosion, sulfate attack, freezing-and-thawing damage, and alkali-aggregate reactions (AARs). Excessive shrinkage of the original concrete and/or settlement in the structure may be a cause of damage. Improper joint spacing and load imbalances also contribute to cracking and spalling.

What is the purpose of this repair?

Preplaced-aggregate concrete is used for repairs to restore structural integrity, provide extra cover, reduce the potential for shrinkage-related repair failures, and for underwater repair, particularly when cofferdams are impractical.

When do I use this method?

Preplaced-aggregate concrete is most often used for vertical, overhead, and underwater repairs. It can be used for horizontal repairs. PPA is often chosen when repairs require getting concrete into tight or hard-to-reach areas. The applications can be structural or cosmetic. Successful applications have included dam faces, spillways, bullnoses, and bridge columns and footings. Many of these applications have required that repairs be completed under water and sometimes in moving water.

This method has been particularly successful for jacketing columns.

The preplaced aggregate method can be used for most repair applications that call for a thickness or depth greater than 2 in. (50 mm). An experienced contractor working under the guidance of a qualified engineer is the best choice for repairs using this method.

Forming is very similar to that used for cast-in-place concrete. The forms must be watertight. The selection and preparation of materials also require careful attention to detail (see the "Repair procedure" and "How do I select the correct materials?" sections).

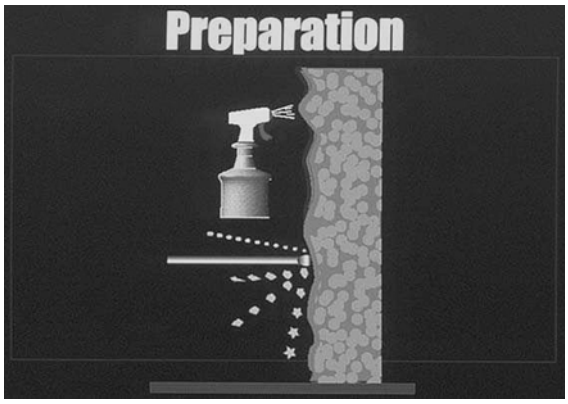

Fig. 1—Preparation

This method of repair can have higher labor costs than cast-in-place concrete but has proven to be effective where shrinkage of the repair cannot be allowed.

How do I prepare the surface?

Consult the recommendations of International Concrete Repair Institute (ICRI) Guideline No. 310.2-1997, "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays," or No. 310.1R-2008, "Guide to Surface Preparation for Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion." Also, consult the manufacturer of any prepackaged grout to be used.

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

- Desired roughness profile of the prepared surface;
- The method of preparation, such as: hydrodemolition, sandblasting, use of pneumatic hammers, and shot-blasting;
- Possible contamination of the surface by oils or soaps, or surface carbonation—both of which require additional preparatory steps. These may include pressure washing, hot-water pressure washing, cleaning with degreasing detergents, and chemical extraction methods;
- Requirements for saturation of concrete in the area to be repaired;
- Reinforcing requirements by the engineer or owner;
- Treatment of existing cracks and joints in the substrate; and
- Repair the cracks? How? Fill the joints? If so, how and with what?

Surface preparation is similar to that for most concrete repairs. With the above considerations in mind, concrete is removed until acceptable-quality concrete is located and revealed. Reinforcing steel, if exposed, is undercut, and all exposed surfaces are cleaned with high-pressure water (minimum 3000 psi) or are abrasively blasted. With PPA repairs, consideration should be given to how the grout will be pumped into the forms and through the aggregate from the bottom up (refer to ACI 304.1R).

How do I select the right materials?

Use sound, tested, properly graded aggregate. Test aggregate for reactivity in accordance with ASTM C 1260. Grade

the aggregate in accordance with the recommendations of Table 1 of ACI 304.1R. Rewash the aggregate.

Considerations in grout selection include:

- The traditional material used for PPA grout has been site-mixed sand-cement with the addition of grout fluidifiers and aluminum powder. These materials can be difficult to control and keep consistent under field conditions. Control of expansion and bleeding are very difficult. Prepackaged products made specifically for use in preplaced-aggregate concrete should provide greater consistency and control;
- Grouts with pretested freezing-and-thawing resistance should be used where repairs will be exposed to freezing-and-thawing cycles;
- Grouts with corrosion-inhibiting admixtures should be considered where corrosion of reinforcing steel is a factor;
- Very low or no bleeding of the fluid grout is necessary to ensure quality repair with PPA; Bond characteristics for grout should be tested in accordance with ACI 503R Appendix A; see ICRI Technical Guideline 03739, "Guide to Using In-Situ Tensile Pull-Off Test to Evaluate Bond of Concrete Surface Materials."
- Test compressive strength of grouts in accordance with ASTM C 942;
- Make all tests on grout mixed to flow consistency to be used in repair; and
- Test compressive strength of the grout and aggregate combination in accordance with ASTM C 943. This is a special method of testing. Be sure to consult with the testing laboratory and engineer to ensure that proper test equipment is on-site and technicians are trained in the procedure.

What equipment do I need?

- Test equipment, if not provided by an independent laboratory: Flow cone in accordance with ASTM C 939 and PPA test cylinders in accordance with ASTM C 943;
- Placement equipment: Water meter or water measuring device;
- pH indicator such as phenolphthalein;
- Concrete or grout pump (not ball valve type): Short-stroke, swing-type piston pumps or heavy-duty rotor-stator pumps perform well. If using a rotor-stator or "moyno"-type pump, have a backup rotor on hand at the job site;
- Grout mixers, if not built into pump: Use tub-type vertical shaft mixers or horizontal shaft mortar mixers with rubber blade wipers. (Do not use portable concrete mixers with a rotary drum.) Have a backup mixer available in case of breakdown. Some specialty concrete/grout pumps come equipped with mixers and water meters;
- For large projects, grout can be batched into ready-mix concrete transit mixer trucks, or prepackaged grout is available in bulk bags up to 3300 lb (1500 kg) each;
- A sieve of adequate size for on-site grading of aggregate if a pre-graded supply is not available;
- A method of rewashing sieved-graded aggregate. This may be a second sieve with washout hoses and agitator;
- Connector valves or shutoffs for grout inlet pipes; and
- A sprayer, rollers, or brushes if a curing compound is required.

What are the safety considerations?

Safety considerations include but are not limited to:

Portland cement-based materials are alkaline and abrasive, and should be treated as such. Job-site safety practices should include:

- Having Material Safety Data Sheets for products on site and reviewing them before startup;
- Having correct safety guards, maintenance, and warnings in place for all machinery and equipment to be used;
- Having all workers wearing protective eyewear, safety glasses, or face shields;
- Having all workers in contact with wet cementitious material wearing protective gloves (rubber- or neoprene-coated) and clothing;
- Having eyewash facilities available on site;
- Providing dust masks for workers operating material mixers;
- Confirming that adequate ventilation is available in closed spaces before operating equipment or using products that emit dangerous exhaust, fumes, or dust;
- Having secured storage available for all hazardous or flammable materials; and
- Holding a safety meeting for all involved parties, lead by the prime contractor's safety manager, prior to beginning repair operations.

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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.

Include the owner's representative, the specifier, the project manager, the repair grout manufacturer, and the construction team foreman. See ICRI Guideline No. 03733, "Guide to Selecting and Specifying Materials for Repair of Concrete Surfaces," for additional agenda items.

The preconstruction meeting list or agenda might include:

- On-site availability of power;
- On-site availability of mixing water;
- Site accessibility;
- Debris removal and disposal;
- Dust, odor, and emissions control;
- Control of water runoff;

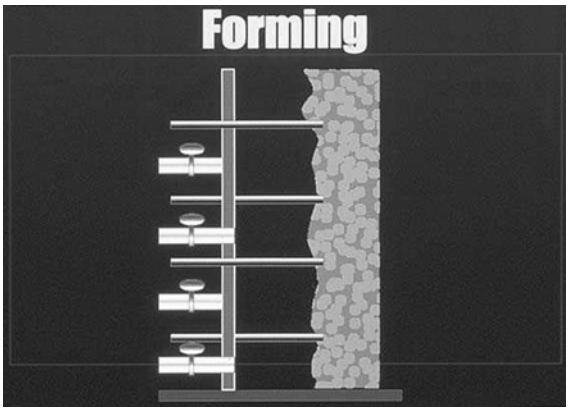

Fig. 2—Forming

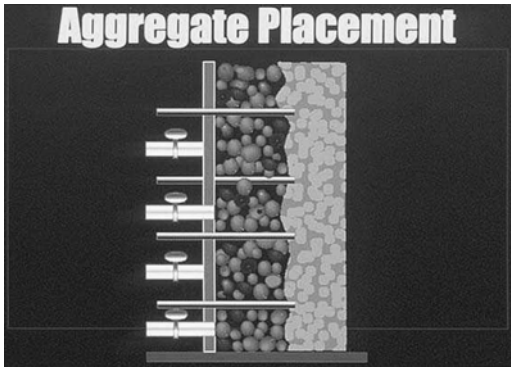

Fig. 3—Aggregate placement

- Confirmation that all materials and equipment are available. Pay particular attention to required quantities of grout and graded, washed aggregate;
- Confirmation that all material documentation is on site; for example, MSDS information;
- Noise control;
- Methods of curing and time required for curing;
- Responsibility for quality control and final acceptance;
- Possible emergencies and breakdowns—what to do if they occur; and
- All other concerns that could affect the progress of the repair.

Repair procedure

1. Install the repair.

A. Inspect and approve the surface preparation.

Check surface for contamination.

B. Saturate the prepared surface if required.

C. Set forms grout-tight.

Commonly used grout-head pressure number is 10 psi (70 kPa).

When form joints do not match perfectly, seal them from the inside with adhesive tape.

Where forms fit against original concrete, seal with thick mortar, strong compressible material, or caulking rope. Avoid the use of caulks as they may yield under head pressure from the grout.

D. Grade the aggregate.

PPA requires gap-graded aggregate. This can be provided as specified in ACI 304.1R, by a supplier, or sieved on site.

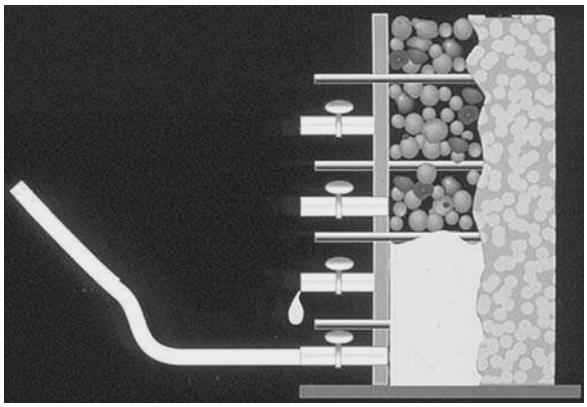

Fig. 4—Pumping grout

E. Saturate the aggregate

Saturate the aggregate to prevent rapid absorption of water from the grout and thickening of the grout as it flows.

F. Place clean/saturated aggregate as the forms are erected.

Do not drop aggregate more than 5 ft (1.5 m) except where repairs are under water and aggregate will fall through water.

Place grout pipes and observation tubes if required (see ACI 304.1R for suggestions concerning placement of grout pipes and observation tubes).

Inlet pipe placement will vary depending on the repair configuration.

G. Batch the grout.

Typical mixing equipment for mixing grout is a two-tub mixer equipped with a rotor-stator pump and a water meter. These pumps are commercially available from several grout pump manufacturers. Do not use ball-valve pumps.

Have adequate mixing and pumping equipment on hand. This usually means at least one backup unit.

If using prepackaged grout, consult the manufacturer for mixing recommendations.

Check the grout consistency. Grout should be tested in accordance with ASTM C 939. This is the flow cone test for consistency. A flow of 10 to 30 s is typical for site-made grouts; prepackaged grouts should have flow values as recommended by the manufacturer.

H. Pump and place the grout.

Provide a means of communication between mixer/ pump operator and placement crew.

Connect pump hose to grout inlet openings or pipes.

Start placement at bottom of aggregate placement.

External form vibration will aid in grout consolidation. It is not always necessary with well-graded aggregates and good quality grout.

When forms appear full, keep light pressure on from pump for several minutes to prevent sagging and displace water/air from forms. Stop if grout is spilling out of forms.

2. Finish the repair.

Confirm what the final finished appearance of the repair is to be at the open areas of the forms.

If vertical formed repairs with open tops are used, work small aggregate (3/8 or 3/4 in. [10 or 20 mm]) into the surface. Finish as required.

Cure PPA in the same manner as conventional concrete, per ACI 308R.

How do I check the repair?

Typical procedures could include:

- Document the project before, during, and after with photos;
- Pre-confirm the acceptability of the prepared surface, including any pH requirements, and the specified surface profile;
- Have all materials pre-tested by a qualified test laboratory for compliance with manufacturers' stated properties;
- Perform in-place tensile pulloff tests of the prepared substrate surface; Confirm the quality of bond of the completed repair by direct tensile bond test (ACI 503R Appendix A, see "ICRI Technical Guideline 03739, Guide to Using In-Situ Tensile Pull-Off Test to Evaluate Bond of Concrete Surface Materials."); and
- Confirm that all materials used were as specified, cross check material purchase orders with quantities estimated and with actual quantities billed.

Sources for additional information

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