REPAIR APPLICATION PROCEDURES

ICRI's mission is "to be a leading resource for education and information to improve the quality of repair, restoration, and protection of concrete and other structures." One aspect of being the leading resource is searching out material on concrete repair and making this information, or at least a path to the information, available to our members.

In the spirit of our mission, ICRI has published several Repair Application Procedures (RAP) Bulletins developed by Committee E706 of the American Concrete Institute (ACI). Most of the members of this committee are active ICRI members as well. These bulletins are "how-to" documents for commonly used concrete repairs. ACI is allowing us to publish them in the *CRB*, as we feel that they are of great benefit to our members. These documents are also available free of charge on ACI's website at **www.concrete.org/members/freedownloads.asp#E706**.

Each bulletin gives a concise description of the repair method, including the purpose of the repair, when it should be used, needed surface preparation, material and equipment selection, and safety considerations. The bulletins are useful reference documents for facility owners, design professionals, concrete repair contractors, and others involved in the concrete repair industry.

Readers are encouraged to tear out these pages for handy reference or, if they prefer, download these documents from ACI's website, make copies for distribution to field personnel, and file them for future reference.

CONCRETE REMOVAL USING HYDRODEMOLITION

Reported by ACI Committee E706

David W. Whitmore, Chair

J. Christopher Ball	Paul E. Gaudette	Kenneth M. Lozen	David A. VanOcker*
Gerald Churry	Fred R. Goodwin	John S. Lund	Patrick M. Watson
H. Peter Golter	Bob Joyce	Kelly M. Page	Patrick M. Winkler*
Timothy R. W. Gillespie	Brian F. Keane	George I. Taylor	

**Primary author.*

ACI Repair Application Procedure 14.

American Concrete Institute®
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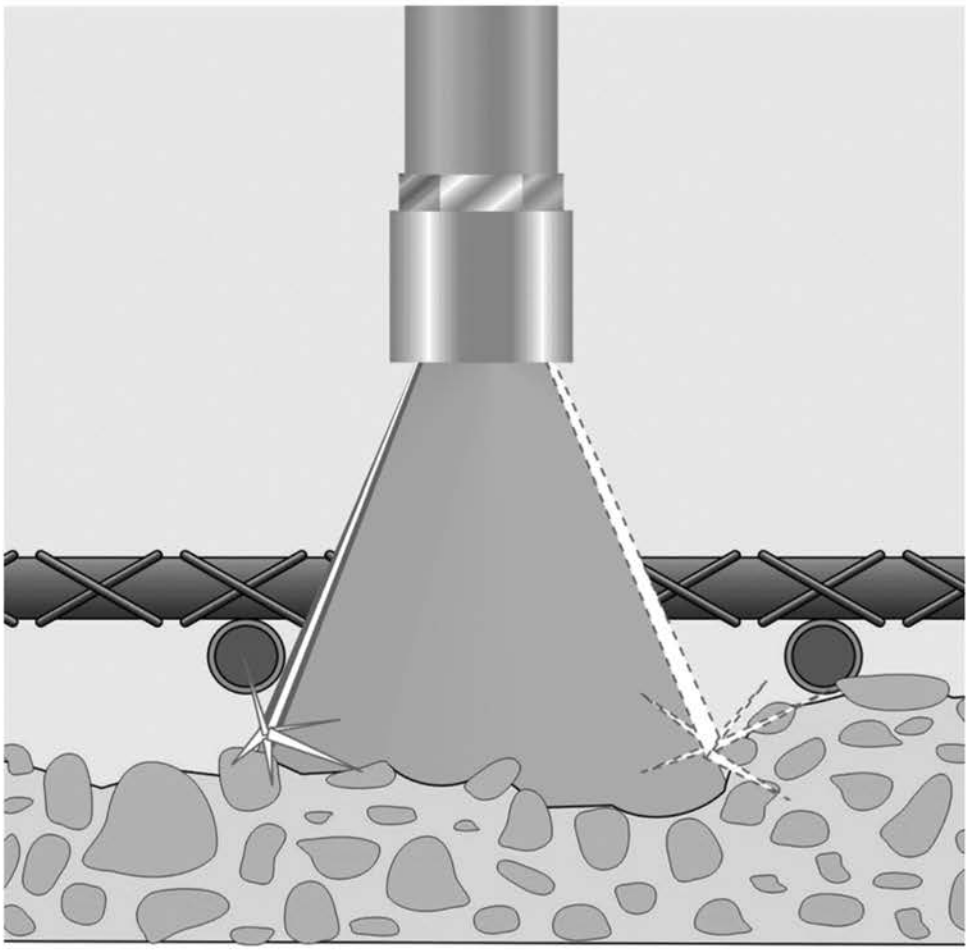
ACI RAP Bulletin 14

FIELD GUIDE TO CONCRETE REPAIR APPLICATION PROCEDURES

Concrete Removal Using Hydrodemolition



Introduction

Concrete repair and restoration will typically require removal of deteriorated concrete, preparation of the repair surface, and cleaning of the reinforcing steel and embedded items. Hydrodemolition is a method of concrete removal and surface preparation using high-pressure water jets. When used to remove concrete, the remaining surface is roughened sufficiently to enhance bond and help ensure composite action between the base concrete and the repair material (Fig. 1). Unlike impact methods of demolition, hydrodemolition does not induce microcracking, a condition that can be detrimental to the longevity of a repair. Concrete removal using hydrodemolition can be fast and efficient, expediting the repair project. Removal using robotic hydrodemolition equipment can eliminate fatigue and potential injury to employees. Using water during concrete removal can suppress dust and provide a healthier work environment.

This document focuses on the concrete removal and surface preparation required for the installation of cementitious repair materials or bonded overlays having a material thickness of 12 mm (0.5 in.) or greater.

Terms

bruised surface—a surface layer weakened by interconnected microcracks in concrete substrates caused by use of high-impact, mechanical methods for surface preparation.

hydrodemolition—a method for removal of concrete by means of water under high pressure directed against a surface.

microcracks—small, numerous cracks that develop in hardened concrete.

surface preparation—the process of removing deteriorated or contaminated concrete and roughening and cleaning a substrate to enhance bond of a repair material or protective coating.

When do I use hydrodemolition?

This method may be used in a broad range of applications requiring concrete removal and surface preparation prior to installation of a repair material. Removal of deteriorated concrete may include concrete that is spalled, cracked, delaminated, chloride contaminated, carbonated, or damaged by fire or cycles of freezing and thawing. It may also include removal of sound concrete to provide proper clearance under the reinforcing steel or to provide a minimum thickness of repair material. The process may be used when vibration of the structure from the use of impact removal methods may lead to further damage or where vibration and sound is easily transmitted and will interfere with the simultaneous occupancy and use of the structure.

Hydrodemolition is particularly effective in removing concrete from around embedded metal elements such as reinforcing steel, anchors, and pipe conduits (Fig. 2). Embedded metal elements may block the water jet from removing the concrete directly beneath the element, leaving a concrete shadow. If the concrete removal depth is sufficient, however, the angle of the water jet will undercut the metal element and remove the shadow. Otherwise, the shadow may be removed using a hydrodemolition hand lance or chipping hammers.

Fig. 1—Surface profile after hydrodemolition.

Fig. 2—Reinforcing steel exposed using hydrodemolition.

Impact removal techniques can bruise the surface, creating a fractured layer typically extending 1/8 to 3/8 in. (3 to 10 mm) deep and frequently results in lower bond strengths compared to surfaces prepared with nonimpact methods. Where impact removal techniques such as jack-hammers, rotomilling, or similar methods are used, hydrodemolition may be used to perform final concrete removal and surface preparation to remove resulting microcracking. High-pressure water jetting may also be used to remove corrosion products from reinforcing steel (Fig. 3).

What should I consider when using hydrodemolition?

The process should not be used in areas where the wastewater cannot be controlled and water leakage into adjacent areas can cause damage.

Because there is the possibility that the water may enter the post-tensioned tendon sheathing and cause long-term durability issues, hydrodemolition may not be suitable and is not recommended for removing concrete from around post-tensioned tendons. In addition, caution should be exercised with post-tensioned structures, as hydrodemolition may remove concrete around the tendon anchorages, resulting in

Fig. 3—Reinforcing steel and bar joist top chords exposed using hydrodemolition.

Fig. 4—Hydrodemolition pump trailer.

movement or de-tensioning of the tendons. Sudden release of anchorages or removal of support for the tendon profile could lead to equipment damage, personal injury, or structural integrity loss. Refer to International Concrete Repair Institute's (ICRI's) *ICRI Technical Guideline* No. 310.3, "Guide for the Preparation of Concrete Surfaces Using Hydrodemolition Methods," for additional information regarding considerations for hydrodemolition use.

Removal of concrete can reduce structural capacity. A qualified engineer should verify the integrity of the structure and determine whether shoring is required. The weight of the robotic tractor, if used, should be included in the shoring calculations. Shoring should be installed prior to the start of removal, and the shoring layout should accommodate debris removal because it will remain until after replacement occurs.

What equipment do I need?

Hydrodemolition equipment consists of high-pressure pumps (Fig. 4); self-propelled robotic units to hold and maneuver the water jet (Fig. 5); small push or self-propelled units (mowers) used for small removal areas (Fig. 6); and hand lances (Fig. 7). The robotic units move the water jet uniformly over the surface. Where the concrete quality is consistent, the removal will be uniform and result in a finished surface profile amplitude approximately the size of the coarse aggregate. Travel speed of the unit can be adjusted to control the overall amount and depth of removal. The

Fig. 5—Hydrodemolition robot.

Fig. 6—Hydrodemolition mower.

Fig. 7—Hand lance for hand-held hydrodemolition

removal units may or may not be connected to vacuum systems to collect the water and debris during the removal and surface preparation operation.

Specialized equipment is available for a variety of applications including overhead, vertical, tunnel, and underwater removal.

How do I dispose of the wastewater?

Wastewater disposal requirements for the local area must be determined and followed. The wastewater contains cement fines with a pH ranging from 11 to 13. Where the wastewater will be discharged to the local sanitary systems, a permit may be required, and the water may have to be treated to meet the sanitary system's discharge requirements. Commonly encountered sanitary discharge requirements may range from 300 to 400 mg/L (0.0025 to 0.0033 lb/gal.) total suspended solids (TSS), and a pH between 5 and 10. Discharge requirements vary, and the local governing authority should be contacted prior to discharging water.

In some areas, wastewater may be discharged on the ground and allowed to evaporate or be absorbed into the ground. Wastewater may not be discharged into lakes, streams or wetlands.

How do I clean up after hydrodemolition?

Following hydrodemolition, the surface must be cleaned to remove all debris, slurry, and wastewater. This may be done using vacuum equipment, water blasters operating at up to 70 MPa (10,000 psi), pressure washers, air lances, and other equipment that will remove waste from the repair substrate. Cleanup operations should follow immediately behind the hydrodemolition removal to prevent re-solidification of the debris, which can occur if the debris is allowed to dry. The surface should be thoroughly rinsed to remove all cement fines (slurry).

How do I check the surface following concrete removal?

The surface should be visually inspected to verify that it is free from dirt, dust, debris, oils, slurry, and other bond-inhibiting materials. Aggregate protruding from the surface should not be fractured or damaged. Clean, crisp aggregate protruding from the repair surface will enhance the mechanical bond between the existing surface and the repair material (Fig. 1). The surface can be sounded using a chain drag or hammer to locate any delaminations.

The bonding capacity of the prepared surface can be randomly checked using a direct tensile pull-off test (Fig. 8) as described in *ICRI Technical Guideline* No. 210.3, "Guide for Using In-Situ Tensile Pull-Off Tests to Evaluate Bond of Concrete Surface Materials," and ASTM C1583/C1583M, "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)."

How do I operate the equipment safely?

All high-pressure equipment should be operated by individuals experienced in the use and maintenance of this specialized equipment. Hydrodemolition uses high-pressure water jets; the water jet is very dangerous and can cause serious injury or death. Water jets can propel debris at high velocity, resulting in injury or death as well as damage to property. The water jet should be shielded to minimize the possibility of flying debris.

Fig. 8—Tensile bond test on prepared substrate.

Items in the work area that may be damaged should be protected. Electrical conduits and equipment should be de-energized. The area both around and below the removal area should be closed to prevent access. Anyone entering the work area should wear Personal Protective Equipment (PPE) including safety glasses (face shield if necessary), hearing protection, hard hat, long pants, long-sleeved shirt, and steel toed boots. Additional protective clothing may be necessary when operating hand-held tools.

Preconstruction meeting

Prior to proceeding with concrete removal using hydrodemolition, a preconstruction meeting is recommended. The meeting should include representatives from all participating parties (including the owner, engineer, contractor, and materials manufacturer), and should specifically address the following:

1. Location and schedule of the work;
2. Location and layout of shoring, if required;
3. Location and layout of the hydrodemolition equipment;
4. Location and layout of the temporary water supply, including materials to be used, and any permits required to secure the use of the water;
5. Location and layout of exhaust system to avoid exhaust intake into adjacent buildings;
6. Location and layout of fuel system required for the equipment, including method of fuel delivery;
7. Location and layout of the system to be used to contain the waste water, including methods of reducing the suspended particles to acceptable levels, adjusting the pH, if required, and discharging the waste water; any water tests that will be required and who will perform the tests; and any permits required to properly discharge the wastewater;
8. The impact tools (jackhammers) required to perform the work, whether the vibration noise will affect the structure or the occupants, and any additional surface preparation required in areas in which impact tools were used;

9. Equipment and method of removal for the debris from concrete demolition, including proposed active drive lanes to move debris off the structure such that the removal does not impact the ongoing operations; and

10. Methods to insure the safety of all personnel, property, and equipment.

References

ASTM C1583/C1583M-04^{e1}, 2004, "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)," ASTM International, West Conshohocken, PA, 5 pp.

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ICRI, 2004b, "Guide to Using In-Situ Tensile Pull-Off Test to Evaluate Bond of Concrete Surface Materials," 2004, *ICRI Technical Guideline* No. 210.3, International Concrete Repair Institute, Des Plaines, IL, 12 pp.

Sources for additional information

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ACI Committee 546, 2004, "Concrete Repair Guide (ACI 546R-04)," American Concrete Institute, Farmington Hills, MI, 53 pp.

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ICRI, 2009, "Guide for Selecting and Specifying Materials for Repair of Concrete Surfaces," *ICRI Technical Guideline* No. 320.2R, International Concrete Repair Institute, Rosemont, IL, 34 pp.