

COOLING TECHNOLOGY INSTITUTE

Recommended Guidelines for Concrete Restoration and Repairs to Natural and Mechanical Draft Cooling Towers



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This guideline document summarizes the best current state of knowledge regarding the specific subject. This document represents a consensus of those individual members who have reviewed this document, its scope and provisions. It is intended to aid all users or potential users of cooling towers.

Approved by the CTI Executive Board.



This document has been reviewed and approved as part of CTI's Five Year Review Cycle. This document is again subject to review in 2017.

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Recommended Guidelines for Concrete Restoration and Repairs to Natural and Mechanical Draft Cooling Towers

Reinforced Concrete Cooling Towers and Basins are significant civil structures placed in intimate contact with, in many cases, “aggressive” cooling fluids and potentially harsh environmental exposure conditions. These cooling fluids can include freshwater, saltwater, wastewater or a combination thereof with ambient service conditions ranging from tropical to arctic climates. As such, prior to initiating reinforced concrete repairs at a Cooling Tower, it’s important to understand the deterioration mechanisms operating and how best to mitigate the damaging effects, prior to performing repairs and placing them into service.

Although outside the scope of this document, many different strategies are available to protect reinforced concrete from chloride penetration, embedded metal corrosion, chemical attack and erosion while the structure is in service. A recommended Reference exists that outlines reinforced concrete deterioration mechanisms, various protective strategies as well as additional cited references for specific site conditions. The Reference is available from the American Concrete Institute (ACI) in their “*Guide to Durable Concrete*” as Reported by ACI Committee 201.

Chapter No. 1: Concrete Surface Preparation for Concrete Repairs

1.1 Scope of Work

1.1.1 This section serves as a general guide to surface preparation for repairs.

1.1.2 This section discusses removal of concrete, preparation of concrete surfaces for repair, preparation and replacement (if necessary) of reinforcing steel that has been exposed during concrete removal and anchorage systems.

1.1.3 For detailed information needed to select and specify the methods for preparing concrete surfaces for application of sealers, coatings and polymer overlay systems, follow the recommendations of ICRI Guideline No. 310.2. For information regarding surface preparation for repair of deteriorated concrete resulting from reinforcing steel corrosion, follow the recommendations presented in ICRI Guideline No. 310.1R.

1.1.4 This section serves as a general guide to surface preparation for concrete repairs; specific information regarding the surface preparation requirements for a particular repair material shall be obtained from the repair material supplier.

1.2 General

1.2.1 The importance of surface preparation cannot be overstated. Proper attention to surface preparation is essential for a durable repair. Regardless of the cost, complexity and quality of the repair material and application method selected, the care with which deteriorated concrete is removed and concrete and reinforcement surface are prepared will often determine whether a repair project will be successful.

1.2.2 Any concrete repair project shall be preceded by an evaluation of the existing structure condition. The evaluation shall identify the cause of observed distress. The evaluation shall also identify the extent of

deteriorated and damaged concrete that shall be removed and replaced.

1.2.3 The process of concrete surface preparation for repair is the process by which sound, clean and suitably roughened surfaces are produced on concrete substrates. The process includes the removal of unsound concrete and bond inhibiting foreign materials from the concrete and reinforcement surfaces, opening the concrete pore structure, concrete strength verification and reinforcement damage verification and repair, if necessary.

1.2.4 Structural Safety. Before starting repair projects involving the removal of existing concrete, the effect of the removal on the structural integrity shall be reviewed and approved by the Structural Engineer of Record (SEOR) prior to commencing concrete removal activities.

1.2.5 Removal of existing deteriorated concrete and surface preparation of concrete and reinforcing steel shall conform to the recommendations of ACI 546 R, applicable recommendations of ICRI Guideline Nos. 310.1R and 310.2 and this guideline.

1.2.6 The methods used to remove the deteriorated or damaged concrete and prepare the concrete and reinforcement to receive the repair material shall not weaken or crack the surrounding sound concrete.

1.2.7 All deteriorated or damaged material shall be removed to the extent described in Section 1.2.3. Continue to remove material until aggregate particles are broken rather than simply removed.

1.2.8 Concrete removal is usually concerned with deteriorated and otherwise unsound material. However, some sound concrete is also removed to permit for adequate repair geometry, to prepare the embedded reinforcement and to permit structural modifications. The effectiveness of various concrete removal techniques may

differ for unsound and sound concrete and a combination of techniques may be necessary.

1.2.9 The removal techniques selected for the particular project shall minimize damage to the concrete and reinforcement left in place, shall be effective, safe and economical. Field tests of various removal techniques may be appropriate to specify. When bond between rebar and concrete is weakened by the removal process, the reinforcement areas of weakened bond shall be undercut a minimum of $\frac{3}{4}$ -inches (3/4-19mm) inches to allow mechanical bonding with new repair materials forming a composite repair product.

1.2.10 The perimeters of repairs that involve concrete removal shall provide right angle cuts to the concrete surface by saw-cutting, chipping or hydro demolition. Saw-cuts shall avoid cutting the reinforcement.

1.2.11 Areas requiring repair shall be modified to provide for simple layouts. The layouts shall be designed to reduce boundary edge length and eliminate acute angles. Excessive or complex edge conditions are usually produced by trying to closely following the shape of the deteriorated concrete. Such edge conditions often result in shrinkage stress concentrations and cracking.

1.2.12 It is essential to monitor and evaluate the removal operations to limit the extent of damage to the concrete that remains. Near surface evaluation is usually accomplished by microscopic examination or bond testing as described in ASTM C 1583.

1.3 Concrete Demolition/Removal Methods

1.3.1 A saw-cut around the area to be removed shall be provided to reduce edge spalling and provide a sound surface against which to place the repair material.

1.3.2 During concrete removal, care shall be taken to avoid damage of embedded items such as electrical conduits, special anchorages, etc.

1.3.3 Concrete removal methods are categorized by the way which the process acts on the concrete. The general categories as outlined in ACI 546 R include blasting, cutting, impacting, milling, pre-splitting and abrading. In cases of special requirements for surface roughness, follow the recommendations of ICRI Guideline No. 310.2.

1.3.4 Cutting Methods – Cutting methods are used for full depth repairs and employ full depth perimeter cuts to disjoint concrete for removal as a unit(s). The cutting methods include diamond saw-cutting and high-pressure water jets.

1.3.4.1 Saw. Diamond or carbide saws are available in sizes ranging from very small (capable of being hand-held) to very large. A diamond saw can be used with other methods to improve crack control by making a cut through an area in which a crack plane is to be propagated.

1.3.4.2 High-pressure Water Jet (Without Abrasives). A high-pressure water jet uses a small jet of water driven at high velocities commonly producing pressures of 10,000 to 45,000 psi (69 to 310 MPa) psi and above.

1.3.5 Impacting Methods – Impacting methods are the most commonly used concrete removal systems. They generally employ the repeated striking of a concrete surface with a high energy tool or a large mass to fracture and spall the concrete. The use of these methods in partial depth removal may produce microcracking in the surface of the concrete left in place. Extensive microcracking may produce a weakened plane below the bond line. Additional treatment techniques may be required to remove microcracking. When adequacy of load transfer is critical to the repair, bond testing is required as outlined in ASTM C 1583. Impacting methods include hand-held breakers and scabblers.

1.3.5.1 Hand-held Breakers. The hand-held or chipping hammer is probably the best known of all concrete removal devices. Hand-held breakers are available in various sizes with different levels of energy and efficiency. The smaller hand-held breakers 15 to 30 lb class (7 to 14 kg) are commonly specified for use in partial removal of unsound concrete around reinforcing steel because they do little damage to surrounding concrete. The larger hand-held breakers 60 to 90 lb class (27 to 41 kg) are used for complete removal of large volumes of concrete. Care shall be exercised when selecting the size of breakers to minimize the damage to existing concrete and its bond to embedded reinforcing steel.

1.3.5.1.1 Remove the deteriorated or damaged concrete, working from inside the marked area toward the outside until sound, acceptable concrete is reached. Work forces shall remove deteriorated concrete until sound concrete is reached regardless of location of paint marks previously applied to define the repair areas.

1.3.5.1.2 If corrosion is evident, the generally accepted practice is to remove concrete surrounding the bar which is corroded. Concrete removal shall extend along the length of the bar to the extent that the bar is free of bond inhibiting corrosion products.

1.3.5.2 Scabblers. Scabblers are best known for their ability to remove shallow depths of concrete from the surface. The scabbler heads are of various sizes and geometrical shapes and varying numbers may be mounted on the cylinders. The size of the equipment depends on the number of cylinders. The equipment is normally operated by compressed air. The scabbler is designed to remove deteriorated/damaged or sound concrete from a surface to a predetermined depth.

This method requires additional cleaning to remove microcracking.

1.3.6 Milling Methods – Milling methods are commonly employed to remove a specified amount of concrete from large areas of horizontal and vertical surfaces. The removal depth may vary from 1/8-inch (3 mm) to several inches. Milling operations usually leave a sound surface free of microcracks.

1.3.6.1 Scarifier. A scarifier is a concrete cutting tool that employs the rotary action and mass of its cutter bits to rout cuts into the concrete surfaces. Scarifiers are available in a range of sizes. The scarifier is a very effective tool for removing deteriorated or damaged concrete on vertical and horizontal surfaces. Other advantages include well defined limits of concrete removal, relatively small and easily-handled concrete debris and simplicity of operation.

1.3.6.2 Hydrodemolition. High-pressure water jetting (hydrodemolition) may be used as a primary means for removal of concrete when it is desired to preserve and clean the steel reinforcement for reuse and to minimize damage to the concrete remaining in place. Hydrodemolition disintegrates concrete, returning it to sand and gravel-sized pieces. This process works preferentially on unsound (deteriorated/damaged) concrete and leaves a rough profile. Care must be taken not to “punch” through thin slabs or walls if unsound concrete exists in an area to be repaired. ICRI Guideline No. 310.3 provides additional information and considerations when employing hydrodemolition methods.

1.3.6.2.1 Hydrodemolition and hydroblasting techniques have the advantage of removing concrete without leaving microfractured surfaces on the existing concrete. A disadvantage of the high-pressure water blasting techniques is that the waste water and debris must be handled in an environmentally acceptable manner as prescribed by local regulations.

1.3.6.2.2 A trial demonstration shall be required for the machinery and its operator at the start of the repair project to demonstrate that the equipment, personnel and methods of operation are capable of producing and meeting the specified requirements. An experimental demonstration shall consist of two areas of approximately 20 ft² (m²) each, one area of sound concrete and one area of deteriorated/damaged concrete. In the sound area, consistent concrete removal depth of ¾-inch (19 mm) behind the reinforcing bar shall be obtained. After successful cutting of the above test area, with specified depth control, the operation shall be moved to the

deteriorated/damaged concrete, and using the same parameters for sound concrete, remove all deteriorated concrete. If the result is obtained which meets the specified requirements, these parameters shall be used as a basis for the production removal. If not, the work forces shall repeat the trial process and recalibrate the equipment or replace the equipment until a result which meets the specified requirements is obtained.

1.4 Surface Cleaning

1.4.1 General

1.4.1.1 This section addresses the final concrete and reinforcement surface preparation steps taken after the removal of deteriorated or damaged concrete necessary to receive the repair materials. The appropriate preparation of the concrete surface depends on the preceding operations and on the type of repair being undertaken.

1.4.1.2 Some of the concrete removal methods described in Section 1.4 can also be used for surface cleaning. However, an effective method for concrete removal may not be appropriate for required surface cleaning. Concrete removal methods may leave the surface to receive the repair material too smooth, too rough, too irregular and without open pores. In these cases, procedures specifically intended for final surface cleaning are necessary. Also, microcracking of the concrete surface is common when impact tools are used which may weaken the bond between the existing concrete and the repair. In this case, a less aggressive method of surface preparation such as abrasive grit or waterblasting is necessary.

1.4.2 Abrading Methods

1.4.2.1 These techniques consist of removing thin layers of surface concrete using abrasive equipment such as blasters, shotblasters, or high-pressure waterblasters.

1.4.2.2 Abrading methods remove concrete by propelling an abrasive medium at high velocity against the concrete surface to abrade it as a final step in surface preparation. The process uses common abrasive medium as a primary abrading tool. The process may be executed in one of three following methods.

1.4.2.2.1 Abrasive Blasting. Abrasive blasting is the most commonly used method of cleaning concrete and reinforcing steel in the construction industry. The process uses common sand, metallic sand or granulated slag as the primary abrading tool. ***Although once a common blast media, silica sand is no longer allowed as it has been shown that prolonged inhalation of tiny, free silica particles which become permanently***