

COOLING TECHNOLOGY INSTITUTE

Recommended Guidelines for Concrete Restoration and Repairs to Wet and Dry Cooling Tower Systems



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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.



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CTI - Guideline

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Recommended Guidelines for Concrete Restoration and Repairs to Wet and Dry Cooling Tower Systems

1.0 Scope

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, brackish/seawater, 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 is 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 201.2R. Whereas this document focuses on the use of cast-in-place and shotcrete repair methods, alternate methods such as bonded fiber-reinforced polymer (FRP) wrap systems are also available. These repair and strengthening systems use FRP composite materials as supplemental externally bonded reinforcement. Use of FRP is beyond the scope of this document. However, ACI440.2R is available for recommendations in engineering and construction of FRP systems for strengthening concrete structures.

2.0 Applicable Documents

2.1 This guideline is not intended to replace any design codes in effect in any jurisdiction. Applicable local building codes in force should govern design and construction.

2.2 Codes and standards referenced in this document are those in common usage in the United States of America. If the work is to be performed in a location outside the United States, the guidelines in this document should be used as a minimum to assure that the necessary procedures are followed for durable repairs.

2.3 Unless otherwise noted, the latest edition of the following standards, specifications and guides are intended for usage:

ACI – American Concrete Institute

ACI 121R – Quality Assurance Systems for Concrete Construction

ACI 211.1 – Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete

ACI 301 – Standard Specifications for Structural Concrete

ACI 304.2 – Placing Concrete by Pumping Methods

ACI 305 R – Hot Weather Concreting

ACI 306 R – Cold Weather Concreting

ACI 308 R – Guide to Curing Concrete

ACI 318 – Building Code Requirements for Structural Concrete

ACI 347 R – Guide to Formwork for Concrete

ACI 355.1R – State-of-the-Art Report on Anchorage to Concrete

ACI 364.1 R – Guide for the Evaluation of Concrete Structures Prior to Rehabilitation

ACI 440.2 R – Guide for the Design and construction of Externally Bonded FRP Systems for Strengthening Concrete Structures

ACI 506 R – Guide to Shotcrete

ACI 506.1 R – Guide to Fiber Reinforced Shotcrete

ACI 506.2 – Specification for Shotcrete

ACI 506.3 R – Guide to Certification of Shotcrete Nozzlemen

ACI 506.4 R – Guide to the Evaluation of Shotcrete

ACI 546 R – Concrete Repair Guide

ACI 546.3 R – Guide for the Selection of Materials for the Repair of Concrete

ASTM – American Society for Testing and Materials

ASTM A 615 – Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

ASTM A 1064 – Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete

ASTM C 31 – Standard Practice for Making and Curing Concrete Test Specimens in the Field

ASTM C 33 – Specification for Concrete Aggregates

ASTM C 39 – Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

ASTM C 42 – Test Methods for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

ASTM C 94 – Specification for Ready-Mixed Concrete

ASTM C 150 – Standard Specification for Portland Cement

ASTM C 157 – Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete

ASTM C 171 – Specification for Sheet Materials for Curing Concrete

ASTM C 172 – Standard Practice for Sampling Freshly Mixed Concrete

ASTM C 260 – Standard Specification for Air-Entraining Admixtures for Concrete

ASTM C 309 – Specifications for Liquid Membrane-Forming Compounds for Curing Concrete

ASTM C 330 – Specification for Lightweight Aggregates for Structural Concrete

ASTM C 494 – Standard Specification for Chemical Admixtures for Concrete

ASTM C 595 – Specification for Blended Hydraulic Cement

ASTM C 618 – Specification for Fly Ash and Raw or Calcined Natural Pozzolan for use as a Mineral Admixture in Portland Cement Concrete

ASTM C 685 – Specification for Concrete Made by Volumetric Batching and Continuous Mixing

ASTM C 989 – Specification for Ground Granulated Blast-Furnace Slag for use in Concrete and Mortars

ASTM C 1116 – Specification for Fiber-Reinforced Concrete and Shotcrete

ASTM C 1140 – Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels

ASTM C 1141 – Standard Specification for Admixtures for Shotcrete

ASTM C 1583 – 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 D 4580 – Standard Practice for Measuring Delaminations in Concrete Bridge Decks by Sounding

ICRI – International Concrete Repair Institute

ICRI Guideline No. 310.1R – Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion

ICRI Guideline No. 310.2R – Guide for Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays

ICRI Guideline No. 310.3 – Guide for the Preparation of Concrete Surfaces for Repair Using Hydrodemolition Methods

ICRI Guideline No. 320.2R – Guide for Selecting and Specifying Materials for Repair of Concrete Surfaces

AWS – American Welding Society

AWS D 1.4 – Structural Welding Code – Reinforcing Steel

Other Reference

Concrete Repair and Maintenance Illustrated by Peter H. Emmons, published by R.S. Means Company, Inc. dated 1994.

3.0 Concrete Surface Preparation for Concrete Repairs

3.1 Scope of Work

3.1.1 This section serves as a general guide to surface preparation for repairs. Specific information regarding the surface preparation requirements for a particular repair material needs to be obtained from the registered design professional.

3.1.2 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 embedded steel anchorage systems.

3.1.3 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. 310.2R. 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.

3.2 General

3.2.1 Proper attention to surface preparation is essential for a durable repair. This will often determine whether a repair project will be successful.

3.2.2 Any concrete repair project should preferably be preceded by an evaluation of the existing structure condition. The purpose of the evaluation should be to identify the cause of observed distress. The evaluation needs to identify the extent of deteriorated and damaged concrete that needs to be removed and replaced.

3.2.3 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.

3.2.4 Structural Safety. Before starting repair projects involving the removal of existing concrete, the effect of the removal on the structural integrity should be reviewed and approved by the registered design professional prior to commencing concrete removal activities.

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

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

3.2.7 All deteriorated or damaged material should be removed to the extent described in Section 3.2.3. Continue to remove deteriorated material until the coarse aggregates are broken rather than removed manually.

3.2.8 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