ACI 546R-14

Guide to Concrete Repair

Reported by ACI Committee 546

American Concrete Institute
Always advancing

First Printing
September 2014
ISBN: 978-0-87031-933-4

Guide to Concrete Repair

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. In spite of these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI via the errata website at http://concrete.org/Publications/DocumentErrata.aspx. Proper use of this document includes periodically checking for errata for the most up-to-date revisions.

ACI committee documents are intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided "as is" without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

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.

Participation by governmental representatives in the work of the American Concrete Institute and in the development of Institute standards does not constitute governmental endorsement of ACI or the standards that it develops.

Order information: ACI documents are available in print, by download, on CD-ROM, through electronic subscription, or reprint and may be obtained by contacting ACI.

Most ACI standards and committee reports are gathered together in the annually revised ACI Manual of Concrete Practice (MCP).

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
Phone: +1.248.848.3700
Fax: +1.248.848.3701

www.concrete.org

ACI 546R-14

Guide to Concrete Repair

Reported by ACI Committee 546

John S. Lund, Chair

David W. Whitmore, Secretary

James Peter Barlow
Michael M. Chehab
Marwan A. Daye
Michael J. Garlich
Paul E. Gaudette
Timothy R. W. Gillespie
Yelena S. Golod
Fred R. Goodwin
Harald G. Greve
Ron Heffron
Robert F. Joyce
Lawrence F. Kahn
Brian F. Keane
Benjamin Lavon
Kenneth M. Lozen
James E. McDonald
Myles A. Murray
Jay H. Paul
Richard C. Reed
Johan L. Silfwerbrand
Joe Solomon
Michael M. Sprinkel
Ronald R. Stankie
Joseph E. Tomes
David A. VanOcker
Alexander M. Vaysburd
Kurt Wagner
Patrick M. Watson
Mark [illegible] Ziegler

Consulting Members

Peter Emmons
Noel P. Mailvaganam
Kevin A. Michols
Richard Montani
Don T. Pyle

This guide presents recommendations for the selection and application of materials and methods for repairing, protecting, and strengthening concrete structures. An overview of materials and methods is presented as a guide for selecting a particular application. References are provided for obtaining in-depth information on the selected materials or methods.

Keywords: anchorage; coating; concrete repair; joint sealant; placement; polymer; protective systems; repair materials; structural strengthening.

CONTENTS

ACI 546R-14 supersedes 546R-04 and was adopted and published September 2014.

CHAPTER 1—INTRODUCTION

1.1—Guide use

This document provides guidance on removal and preparation, selecting material and application methods for repair, protection, and strengthening of concrete structures. The information is applicable to repairing deteriorated or damaged concrete structures; correcting design or construction deficiencies; and strengthening the structure for new use or to comply with current, more restrictive building codes.

Current practices in concrete repair are summarized and information provided for the initial planning of repair work and selecting repair materials and methods for various conditions.

1.2—Repair methodology

The methodology for repairing a concrete structure typically includes a condition assessment of the structure, designing repairs, developing construction documents, bidding and negotiation processes, and performing the repair work. Preparing a maintenance plan for the repaired structure is also recommended. A basic understanding of the causes of concrete distress, deterioration, or deficiencies is essential to performing meaningful evaluations and completing successful repairs (ACI 364.1R). Once the cause of deterioration or deficiency is determined, the appropriate repair program can be selected to address these conditions. Depending on the cause and extent of the damage, repair is not always warranted.

Assessment of the structure should determine the cause of the deterioration or deficiency and not focus only on the symptoms. For example, cracking can be a symptom of distress that may have a variety of causes, such as restraint of drying shrinkage, restraint of movement due to thermal cycling, overloading, corrosion of embedded metal, or inadequate design or construction. The cause of distress should be assessed for proper selection and implementation of an appropriate repair program (Fig. 1.2).

1.2.1 *Condition assessment*—The process of repairing a concrete structure starts with the evaluation of existing conditions. The evaluation can be divided into several steps:

a) Reviewing available design and construction documents, previous reports, repair/maintenance records, and test data, if available;

b) Visually examining the existing structure;

c) Performing structural analysis of members in question or the structure in its deteriorated condition;

d) Evaluating corrosion activity;

e) Performing invasive or nondestructive testing, or both;

f) Reviewing physical, chemical, and petrographic analysis results of laboratory-tested concrete samples.

Additional information on conducting condition surveys can be found in ACI 201.1R, 207.3R, 222R, 224.1R, 228.2R, 364.1R, 437R, and 562.

1.2.1.1 *Unsafe conditions*—During the condition assessment, conditions discovered that pose an immediate safety issue should be identified and reported to the owner for mitigation. Local building codes may require that the licensed design professional (LDP) report unsafe conditions to the authorities and typically require that the owner take measures to protect the public safety where hazardous conditions exist. For example, if loose concrete on overhead or vertical surfaces is discovered, access should be limited in the areas adjacent to and below until the hazards are removed or stabilized. If structural members exhibit compromised integrity, these members should be stabilized or the affected areas removed from service.

1.2.1.2 *Global issues*—The performance of a structure depends on maintaining the integrity of the structure and envelope of the building. If the LDP becomes aware of an item of concern outside the assigned scope of work that could compromise the integrity of the structure or jeopardize public safety, the appropriate parties should be notified for implementation of remedial action.

1.2.1.3 *Determination of cause and extent*—During the condition assessment of a structure, the cause of distress, deterioration, or deficiency should be determined. Because many deficiencies are caused by more than one mechanism, a basic understanding of the causes of concrete deterioration is essential to determine what has happened to a particular concrete structure. After completing the assessment, a suitable remedial action plan can be developed, repair applications and materials selected, and contract documents prepared. If a delay occurs between the condition survey and performing the repair work, additional deterioration and distress could occur and consideration should be given to updating the condition survey to minimize variations between estimated and actual quantities of repair work.

1.2.2 *Design considerations*—When designing a concrete repair, strengthening system, or protective system, the LDP should consider the safety and serviceability of the structure

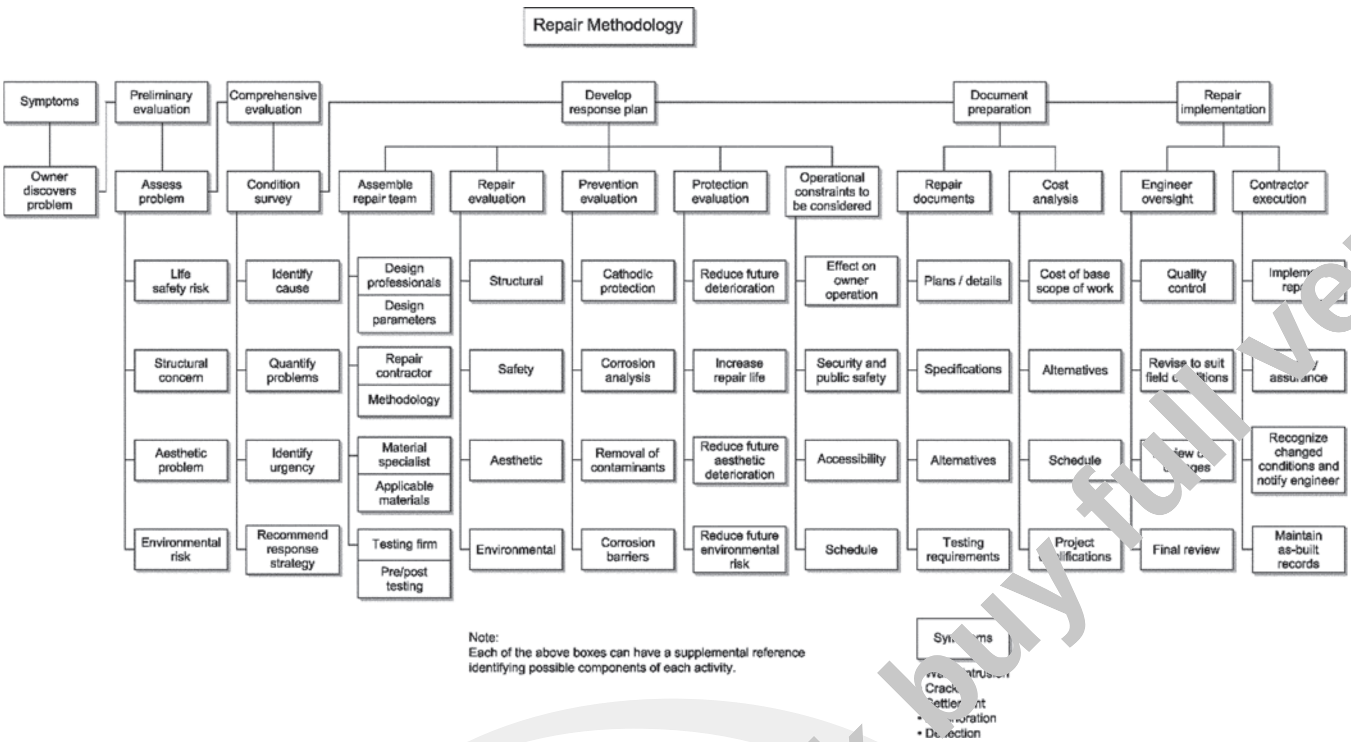

Fig. 1.2—Repair methodology.

during construction and its performance at completion. At a minimum, the repaired structure should satisfy the building code requirements for which it was designed. If required by the governing agency, the repaired structure may have to satisfy current building code requirements and be repaired and strengthened to meet these criteria. In any case, it is the LDP's responsibility to satisfy applicable code requirements for all structural components within the LDP's scope of work. Structural code provisions such as those contained in ACI 318 may not be directly applicable to the current situation. In such cases, ACI 562 requirements should be followed. The LDP should apply basic principles of structural mechanics and have an understanding of material behavior to evaluate and design a structural repair or strengthening procedure, or a protective system. Several design considerations are discussed 1.2.2.1 through 1.2.2.6.

1.2.2.1 *Current load distribution*—In a deteriorated condition, a structural member or system may distribute dead and live loads differently than when the structure was undamaged. Cracking, deteriorated concrete, and corroded reinforcement can alter the behavior of members, leading to changes in shear, moment, and axial load distribution. As concrete and reinforcement are removed and replaced during the repair operation, these redistributed forces may be further modified. To understand the final behavior of the structural system, the engineer should evaluate the redistribution of the forces. To reestablish the original load distribution, a member can be relieved of the load by jacking or other means before repair implementation. If the structure is not jacked and the dead load is not relieved, the repaired and adjacent members may support loads differently than was assumed in the original design of the structure.

1.2.2.2 *Compatibility of materials*—If a repair and the existing substrate materials have the same stiffness or modulus of elasticity, the behavior of the repaired member may be assumed to be the same as the original member before deterioration or damage. Conversely, if the stiffnesses differ, then the composite nature of the repaired system should be considered. A mismatch of other material characteristics further exacerbates the effects of thermal change, vibration, long-term creep, and shrinkage. If the coefficient of thermal expansion of the repair material differs from that of the original material, stresses will be generated in both the repair and original material by temperature changes.

1.2.2.3 *Creep and shrinkage*—Reduction in length, area, or volume of both the repair and original materials due to creep, shrinkage, or both, affect the structure's serviceability and durability. As an example, compared with the original material, high creep or shrinkage of repair materials results in loss of stiffness of the repair, redistributed forces, and increased deformations. Controlled-shrinkage cementitious repair materials and systems can contribute to the reduction of the volume change effects.

1.2.2.4 *Vibration*—When the installed repair material is in a plastic state or until adequate strength has been developed, vibration of a structure can result in reduced bonding of the repair material. Isolating the repairs or eliminating the vibration may be a design consideration.

1.2.2.5 *Water and vapor migration*—Water or vapor migration through a concrete structure can degrade a repair. Understanding the cause of the migration and controlling it should be a repair design consideration.

1.2.2.6 *Material behavior characteristics*—After a repair is executed, the structural behavior of the repaired section