IN-LB	Inch-Pound Units
SI	International System of Units

Concrete Repair—Guide

Reported by ACI Committee 546

ACI PRC-546-23

American Concrete Institute
Always advancing

First Printing: December 2023
ISBN: 978-1-64195-238-5

Concrete Repair—Guide

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. Despite 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 regarding 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.

ACI documents are written via a consensus-based process. The characteristics of ACI technical committee operations include:
(a) Open committee membership
(b) Balance/lack of dominance
(c) Coordination and harmonization of information
(d) Transparency of committee activities to public
(e) Consideration of views and objections
(f) Resolution through consensus process

The technical committee documents of the American Concrete Institute represent the consensus of the committee and ACI. Technical committee members are individuals who volunteer their services to ACI and specific technical committees.

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 PRC-546-23

Concrete Repair—Guide

Reported by ACI Committee 546

Peter Barlow‡, Chair

Chris White‡, Secretary

Michael M. Chehab‡
Kevin Conroy‡
Marwan A. Daye
John D. Fauth
Michael J. Garlich
Paul E. Gaudette‡
Timothy R. W. Gillespie‡
Matthew R. Hansen‡
Susan Isble‡
Lawrence F. Kahn
Brian F. Keane‡
Kenneth M. Lozen‡
John S. Lund‡
Johan L. Silfwerbrand
Michael M. Sprinkel
Peter Tarara*
Joseph E. Tomes‡
David A. VanOcker†
Kurt Wagner
David W. Whitmore‡

Consulting Members

Peter Emmons‡
Etien Frett‡
Fred R. Goodwin‡
Harald G. Greve‡
Noel P. Mailvaganam
James E. McDonald
Kevin A. Michols
Richard Montani
Jay H. Paul
Don T. Pyle
Aamer H. Syed
Nicholas R. Triandafilou‡
Patrick M. Watson

*Chair of ACI Subcommittee 546-C.
†Vice Chair of ACI Subcommittee 546-C.
‡Member of ACI Subcommittee 546-C.
§Deceased.
Note: Additional ACI Subcommittee 546-C members: R. C. Arnold, J. Costa, A. Harrer, A. Hossack, M. Knapp, L. Lau, L. Lou, E. Marshall, M. R. Nelson, C. Porter Jr., D. Romero, G. E. Schaefer, C. Shimon, and G. I. Taylor.

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 PRC-546-23 supersedes ACI 546R-14 and was published December 2023. This guide was first published in 1996 and revised in 2004 and 2014.

CHAPTER 1—INTRODUCTION

1.1—Summary

The successful repair of concrete structures depends on many factors, including proper design, material selection, and application methods. The information provided in this guide is intended to assist the reader with repairing deteriorated and damaged concrete structures (Fig. 1.1), correcting design and construction deficiencies, and strengthening existing structures for new uses and to comply with current building codes. Current practices in concrete repair and strengthening are summarized and information is provided for the planning, design, and execution of repair and strengthening work for various conditions.

Fig. 1.1—Deteriorated concrete column on building façade.

Fig. 1.2—Concrete removal at underside slab repair in progress.

1.2—Scope

This document provides guidance on concrete removal, substrate and reinforcement preparation, material selection, material application methods, and protective systems for concrete structures (Fig. 1.2). An overview of concrete repair methodology is included with references to ACI 562 and ACI 563.

In addition to concrete repair, this document provides guidance for the strengthening of concrete structures. Many of the same techniques are used to both repair and strengthen concrete members and structures, including demolition, bonding new material to existing substrate, and installation of new reinforcing steel.

CHAPTER 2—DEFINITIONS

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology." Additional concrete repair definitions are found in the International Concrete Repair Institute (ICRI) terminology database, https://www.icri.org/page/terminology_A.

CHAPTER 3—REPAIR METHODOLOGY

3.1—Introduction

The methodology for repairing a concrete structure typically includes:

(a) Condition assessment (Section 3.2)
(b) Design considerations (Section 3.3)
(c) Selection of repair methods and materials (Section 3.4)
(d) Temporary shoring (Section 3.5)
(e) Construction documents (Section 3.6)
(f) Bid or contract negotiation process (Section 3.7)
(g) Execution of work (Section 3.8)
(h) Maintenance after completion of repairs (Section 3.9)
(i) Sustainability considerations (Section 3.10)

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 and the residual structural capacity is assessed, the appropriate repair program can be selected to effectively address these conditions. Figure 3.1 presents a detailed overview of the process for effecting successful concrete repairs.

3.2—Condition assessment

The process of repairing a concrete structure starts with the assessment of existing conditions. The assessment can include the following steps:

(a) Reviewing available design and construction documents, previous reports, repair/maintenance records, and test data, if available
(b) Performing a visual condition survey of the existing structure and surrounding environment and documenting deterioration and distress
(c) Evaluating corrosion activity
(d) Performing invasive or nondestructive testing, or both
(e) Reviewing physical, chemical, and petrographic analysis results of laboratory-tested concrete samples
(f) Performing structural analysis of members in question, or the structure overall, in its deteriorated condition

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

3.2.1 *Potentially dangerous conditions*—During the assessment, conditions may be discovered that pose an immediate safety issue; these should be reported to the owner for mitigation upon discovery. Local building codes may require that the licensed design professional (LDP) report unsafe conditions to the authorities and may require that the owner take measures to protect the public safety. 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 signs of behavior suggesting an inability to support required loads, these members should be stabilized, shored, or the affected areas removed from service.

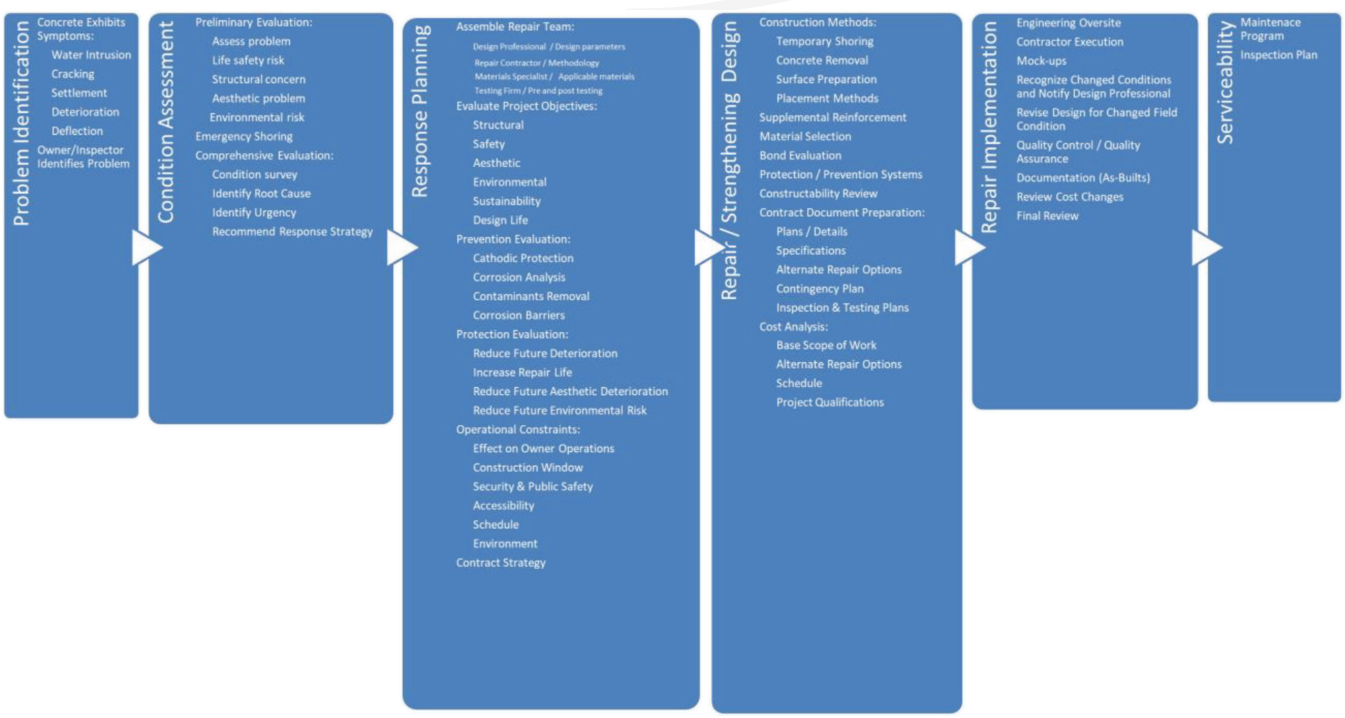

Fig. 3.1—Concrete repair/strengthening process.

3.2.2 *Global issues*—The satisfactory performance of a structure depends on maintaining the integrity of the structure, including the exterior envelope of the building. In situations where an LDP is performing an assessment of a limited portion of a structure and 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 LDP should inform the owner of such conditions and advise that an expanded evaluation be conducted to confirm whether implementation of remedial action is warranted (ACI 132R).

3.2.3 *Determination of cause, severity, and extent*—During the condition assessment of a structure, the cause of distress, deterioration, or deficiency should be determined. For example, cracking is a symptom of distress that results from one of several possible causes, such as drying shrinkage, thermal cycling, overloading, corrosion of embedded metal, or inadequate design or construction. As deficiencies may be caused by more than one mechanism, a basic understanding of the causes of concrete distress and deterioration is essential to determine an appropriate repair option. After completing the assessment, a suitable remedial action plan can be developed, repair methods and materials selected, and construction documents prepared. If a considerable 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 variation between estimated and actual quantities of repair work.

3.3—Design considerations

In designing a concrete repair, strengthening system, or protective system, the LDP should consider the safety and serviceability of the structure during construction and its performance after 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 of the existing structure, as the ACI 562 code requirements were developed specifically for existing concrete structures and may prove more applicable to assessment, repair, and strengthening conditions. The LDP should apply basic principles of structural mechanics and understand material behavior to evaluate and design a structural repair, a strengthening procedure, or a protective system. Several design considerations are discussed in 3.3.1 through 3.3.6.

3.3.1 *Current load distribution*—In a deteriorated condition, a structural member or system may distribute dead and live loads differently than it did in its undamaged condition. Cracks, deteriorated concrete, and corroded reinforcement can alter the behavior of members, leading to redistribution of shear and moment forces, and changes in axial load. As concrete and reinforcement are removed as part of the repair process, these redistributed forces may be further altered. To understand the final behavior of the structural system, the LDP 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 alter the load path differently than was assumed in the original design of the structure. Furthermore, the LDP should consider the loss of structural capacity due to the reduced concrete section and effectiveness of reinforcement during demolition in determining shoring and repair phasing requirements.

3.3.2 *Compatibility of materials*—If a repair material 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 material characteristics further exacerbates the effects of thermal change, vibration, long-term creep, and shrinkage. Concrete coring and petrographic analysis may be performed to determine properties of existing concrete. Refer to ACI 546.3R and ACI 364.5T for additional information on material selection and compatibility.

3.3.3 *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. Creep and shrinkage of concrete tends to diminish over time, so newly placed cementitious repair materials may exhibit a higher rate of creep and shrinkage than the older underlying original concrete, resulting in differential movements between the two materials. This differential movement can cause cracks to occur between the repair and the surrounding original concrete, and to even cause the repairs to delaminate, resulting in a loss of stiffness of the repaired structure creating a redistribution of forces in, and increased deformations of, the structure. Controlled-shrinkage cementitious repair materials and systems can contribute to the reduction of the volume change effects.

3.3.4 *Vibration*—When the installed repair material is in a plastic state or prior to the development of adequate strength, vibration of a structure can damage the bond between the repair material and surrounding concrete. Isolating the repairs or eliminating the vibration may be a design consideration. Examples of potential vibration sources include live traffic on bridge decks adjacent to repair areas, rotating equipment in process units, and concrete demolition and surface preparation in adjacent areas.

3.3.5 *Water and vapor migration*—Water or vapor migration through a concrete structure can degrade the bond strength and durability of a repair. Understanding repair material properties and their susceptibility to moisture damage and controlling the cause and degree of moisture migration should be a repair design consideration.