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

Materials Selection for Concrete Repair—Guide

Reported by ACI Committee 546

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This document provides guidance on the selection of materials for concrete repair. An overview of the important properties of repair materials is presented as a guide for making an informed selection of the appropriate repair materials for specific applications and service conditions.

Keywords: cementitious; cracks; epoxy; materials; methacrylate; polymer; polyurethane; repair; surface sealer; silica fume; test methods; waterproofing.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Concrete is inherently a durable material. However, its durability under any given set of exposure conditions varies with concrete mixture proportions; the presence and positioning of reinforcement; and the detailing, placing, finishing, curing, and protection it receives. In service, it may be exposed to adverse environmental conditions resulting in deterioration, reduction of its service life, and the need for concrete repair. With the increasing number and age of concrete structures, frequent deferral of maintenance, and increased public awareness of deterioration and maintenance needs, concrete repair is becoming a priority in design and construction activities.

Due to an expanding concrete repair industry, new materials and repair methods are continuously being introduced to the construction market. At the same time, due to changing environmental building codes and other regulations, many existing, well-proven products are being reformulated into essentially new products that may have limited track records. The user might not always be informed of these changes.

It is often difficult for a specifier to find the appropriate data to systematically evaluate a product for a given repair situation. Often, test data are unavailable or, if available, are either not presented in useful or appropriate terms, making comparison with other competing materials difficult. One example is the use of nonstandard or modified test methods.

ACI Committee 546 is devoted entirely to the subject of concrete repair. Its principal emphasis is on techniques for concrete repair with limited information on selecting repair materials. Although there are many competent repair materials available commercially, even the highest-quality materials do not perform as expected if they are used inappropriately. The physical properties of repair materials are also important to the performance of a concrete repair. This guide is prepared by Committee 546 to aid the user in specifying and executing typical concrete repairs. ACI 515.2R provides additional information on protection treatments.

The objective of this guide is to provide guidance for the materials selection for concrete repair, including:

(a) Identification of common repair materials
(b) Discussion of relevant material properties
(c) Lists and discussion of test procedures for measuring these properties

(d) Recommendations of minimum test values or performance levels (where appropriate)
(e) Discussion of the importance of specific material properties for various repair applications and service environments

1.2—Scope

This guide discusses material selection for several types of concrete repairs, including the following:

(a) Concrete repairs
(b) Overlays
(c) Crack repairs
(d) Surface-applied sealers and traffic-bearing elastomeric membrane systems
(e) Anti-carbonation coatings
(f) Steel corrosion mitigation including reinforcing steel coatings, embedded galvanic anodes, and corrosion inhibitors
(g) Concrete bonding agents and procedure
(h) Crystalline pore blockers

1.2.1 *Summary tables of test methods and test values*—Tables 4.7a and 4.7b present summaries of available test methods and typical test values, and summaries of material properties for these materials. Table 5.19 presents a selection guide for crack repair material. Tables 6.5a, 6.5b, and 6.5c present summaries of available test methods and typical test values for these materials. Tables 8.5a, 8.5b, and 8.5c present summaries of available test methods and typical test values for surface sealers, anti-carbonation coatings, and traffic-bearing elastomeric coatings.

1.2.2 *Special repair and service environments*—This guide covers concrete repair materials for common types of concrete repair. Special repair and service environments may require concrete repair materials with enhancement of specific properties. For the repair of environmental or mass-concrete structures, underwater repairs, and other special repair and service environments, refer to the recommendations of other ACI publications (including those of ACI Committees 207, 350, and 546). Refer to industry organizations and material manufacturers for specific guidance in repair material selection.

1.2.3 Appendix A includes a discussion of numerous current industry issues and concerns, including:

(a) Material test methods and reporting of test data
(b) Curing of repair materials and manufacturers' reported test results
(c) Product limitations and warnings
(d) Standardized industry acceptance
(e) Repair material bond
(f) Corrosion reduction
(g) Structural repairs
(h) Ongoing developments

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

There are no notations used in this guide.

2.2—Definitions

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology". Definitions provided herein complement that source.

concrete repair—the removal and restoration of damaged or deteriorated concrete.

electrical resistivity—the resistance of a material to the flow of electrical charge in the presence of a voltage potential between two points.

permeability—the ability of a material to transmit or resist the penetration of water and waterborne chemicals. This definition differs from that in "ACI Concrete Terminology" in that the ability to transmit or resist the penetration of gases is not included.

portland-cement concrete (PCC)—a composition of portland cement, fine and coarse aggregates, and water.

surface sealer—a material applied to the concrete surface to reduce moisture and chemical penetration into the concrete member. Surface sealers may achieve limited penetration into uncracked concrete but are either too brittle (or applied in a coating too thin) to bridge moving cracks or cracks that may form in the concrete after the material application. Surface sealers are differentiated from **sealers**, as defined in "ACI Concrete Terminology," in that surface sealers may or may not prevent the penetration of gaseous media, be colorless, or be absorbed by the concrete, and commonly are visible on the concrete surface.

traffic-bearing elastomeric coating—a material applied to the concrete surface to greatly reduce moisture and chemical penetration to the concrete member and that is suited for exposure to pedestrian and/or vehicular traffic. Elastomeric coatings have some flexibility, so they are capable of bridging narrow cracks that experience some movement and some cracks that might form in the concrete after the elastomeric coating application.

volume stability—the initial and long-term changes in the linear dimensions or volume of a material after placement.

working time—the elapsed time from completion of mixing until the material becomes too stiff or otherwise unusable.

CHAPTER 3—SELECTION OF CONCRETE REPAIR AND OVERLAY MATERIALS

The success of concrete repairs depends on determining the cause and extent of concrete distress or deterioration and developing a repair strategy to address those problems. Typical steps in a systematic concrete repair operation are as follows:

1. Conduct an assessment to evaluate existing conditions. The scope should be consistent with the perceived condition of the structure and the owner's repair objectives. The assessment should be performed by qualified individuals, documenting and evaluating visible and concealed deterioration, distress, defects, and damage, as well as conditions with potential to cause future deterioration and distress.

2. Determine cause of damage or deterioration necessitating the repair. Examples might be: mechanical damage such as impact or abrasion; design, detailing, or construction

deficiencies; chemical reaction damage such as alkali-aggregate reaction; physical damage related to cycles of freezing and thawing or thermal movements; and corrosion of the reinforcing steel caused by improper placement or carbonation of the concrete or chloride ingress into the concrete to the reinforcing steel.

3. Assess the application and service conditions to which the concrete repair material will be exposed.

4. Determine the repair objectives, including desired service life.

5. Select a repair strategy, including consideration of an appropriate protection system in conjunction with future maintenance, in terms of what is required to preserve or protect the structure and repairs, and what actual maintenance is likely to be available.

6. Assess the loading before, during, and after the proposed repair procedures.

Once the concrete to be repaired is evaluated and the cause of distress established, details of the proposed repair are developed. This includes evaluating and determining the required physical properties of repair materials, followed by the appropriate selection of available repair materials. Selection is usually based on the ability of the material to conform to repair constraints and objectives as defined in this guide, including consideration of cost and availability.

The repair is then implemented, including protective systems if designed as part of the repair. Refer to ACI 546R, where these steps are discussed in further detail.

Every repair application places different demands on repair materials such as required strength, durability, permeability, depth, and orientation of application and desired appearance. It is essential to follow the assessment steps in Section 1.2 to achieve satisfactory results. As overlays have many similar demands to concrete repairs, selection of overlay materials is also included in this chapter.

Repair materials should have suitable properties to meet the demands of the repair application throughout the intended life of the repair. All repair materials have limitations, and the material specifier and user should select the materials with the highest likelihood of long-term performance. Of particular concern can be substrate, ambient, material, and curing temperatures at time of installation, as there are minimum and maximum temperatures for different types of materials, which can vary by application. The reader is also directed to ACI 318-19(22), Table 19.3.1.1, for exposure categories and classes.

Many of the proprietary products for concrete repair that are available commercially are blends of several types of materials. Because these materials are proprietary, a list of their ingredients is usually unavailable to the specifier, except possibly in terms of generic materials. Prior experience with specific products and the results of independent testing of products are useful in evaluating such products. In this regard, many State and Canadian Provincial Departments of Transportation (DOTs) maintain lists of approved proprietary concrete repair materials. These lists provide useful input from the specifier and user of products that have been found satisfactory by those agencies. Because repair products may be reformulated and their physical properties altered over time, some DOTs periodically update their approval lists based on regular retesting. The American Association of State Highway and Transportation Officials (AASHTO) maintains a Product Evaluation List Management System, APEL (https://apel.transportation.org), where the findings of evaluations of new, proprietary, or both new and proprietary engineered transportation products are voluntarily posted.

Compatibility between the properties of concrete repair and overlay materials and those of the intended substrate is an important consideration. For example, in many concrete repair applications, the properties of repair materials, such as the coefficient of thermal expansion and creep, should be similar to those of the substrate. In contrast, the success of many crack repair applications depends on repair materials that have significantly different properties, such as high elasticity and low modulus of elasticity, from that of the substrate, and which will perform better than the base concrete in the service environment. Regardless, it is necessary to identify the repair material properties and the substrate properties before an approach to the repair is determined (McDonald et al. 2002). Further discussion on material properties is provided in Chapter 4.

3.1—Types of concrete repair and overlays

Based on typical repair thicknesses and common methods for applying these materials, the following sections on concrete repairs and overlays are divided into three categories: 1) deep concrete repairs (including full depth) and overlays; 2) shallow concrete repairs and overlays; and 3) thin overlays. For the purposes of distinguishing repair materials in this guide, deep concrete repairs and overlays are thicker than 1.0 in. (25 mm) and the repair materials include coarse aggregate; shallow concrete repairs and overlays are at least 1/16 (0.06) in. (1.6 mm) thick and less than 1.0 in. (25 mm) thick, and the repair materials include fine aggregate only; and thin overlays are essentially thick coatings less than 1/16 (0.06) in. (1.6 mm) thick.

3.2—Deep concrete repairs and overlays

Deep concrete repairs and overlays, defined for the purposes of this guide as thicker than 1 in. (25 mm), are commonly constructed with repair materials that include fine and coarse aggregates.

3.2.1 *Top surface (horizontal) applications*—Materials used for deep concrete repairs and overlays in top surface applications include portland-cement concrete (PCC), silica-fume concrete, polymer-modified concrete (PMC), magnesium ammonium-phosphate cement concrete (MAPCC), and polymer concrete.

PCC is the most commonly used material, primarily because of low cost, ease of construction, and adequate compatibility with the substrate concrete. Silica-fume concrete is only moderately more expensive than conventional concrete and is used for protective overlays and concrete repairs in applications where its enhanced properties, such as increased density and decreased permeability,