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

Guide to Underwater Repair of Concrete

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

www.concrete.org

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Peter Barlow,* Chair

Chris White, Secretary

Michael M. Chehab
Kevin Conroy
Marwan A. Daye
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
James E. McDonald
Terrence McDonald
Jay H. Paul
Johan L. Silfwerbrand
Michael M. Sprinkel
Aamer H. Syed
George I. Taylor
Joseph E. Tomes
David A. VanOcker
Kurt Wagner
David W. Whitmore*

*Subcommittee members who prepared this guide.

Consulting Members

Peter Emmons
Fred R. Goodwin
Harald G. Greve
Noel P. Mailvaganam
Kevin A. Michols
Richard Monti
Don T. Pyle
Nicholas R. Triandafilou
Patrick M. Watson

This document provides guidance on the selection and application of materials and methods for the repair and strengthening of concrete structures under water. An overview of materials and methods for underwater repair is presented as a guide for making a selection for a particular application.

Keywords: anti-washout; cathodic protection; concrete removal; deterioration; diver; formwork; marine placement; pile jackets; polymer(s); repair; surface preparation; tremie; underwater.

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ACI 546.2R-20 supercedes ACI 546.2R-10, was adopted August 20, 2020, and was published December 2020.

CHAPTER 1—GENERAL

1.1—Introduction

The repair of concrete structures under water presents many complex problems. Although the applicable basic repair procedures and materials are similar to those required in typical concrete repair, the harsh environmental conditions and specific problems associated with working under water or in the splash zone area (Fig. 1.1a) create many differences. The repair of concrete under water is usually difficult, requiring specialized products and systems, and the services of highly qualified and experienced design professionals and contractors.

Proper evaluation of existing structural condition is the essential first step in designing long-term repairs. To be most effective, the evaluation procedure should begin with a review of historical information on the structure and its envi-

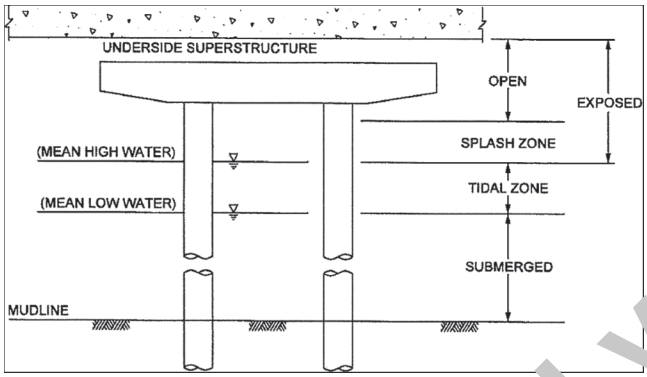

Fig. 1.1a—Repair zones: submerged, tidal, and exposed

Fig. 1.1b—Deteriorated pile in tidal and exposed zones (image courtesy of M. J. Garlich).

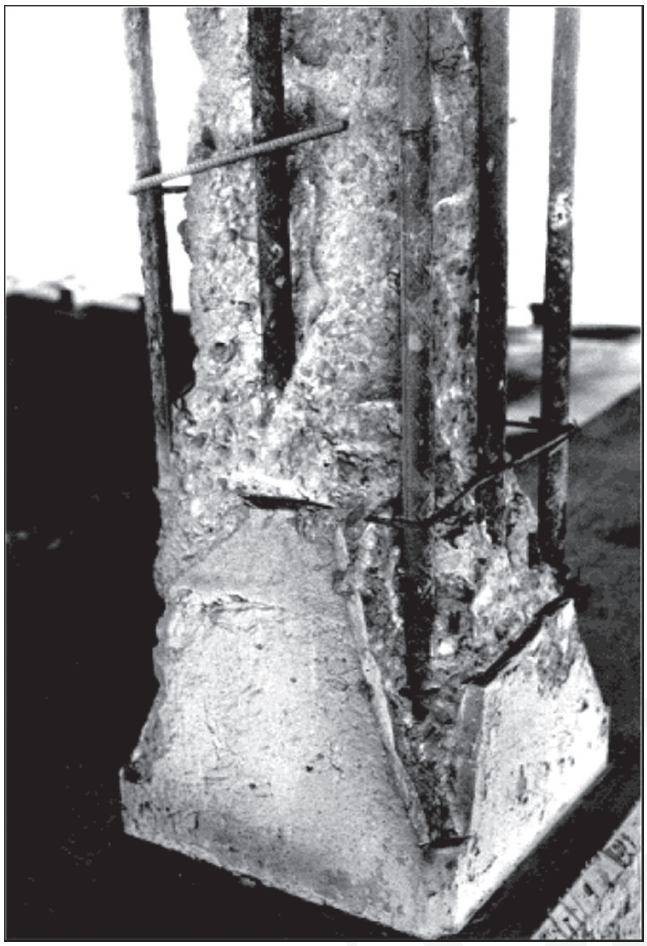

Fig. 1.1c—Advanced deterioration; pile has been cleaned (image courtesy of M. J. Garlich).

ronment, including any changes made to the structure over time and the records of prior on-site inspections or repairs. Accurate repairs can be designed only after the extent of deterioration is documented and the failure mechanism is determined. In addition, proper repair techniques and installation procedures should be followed to produce an optimum repair system.

Water containing oxygen and contaminants can aggressively attack concrete (Fig. 1.1b and 1.1c). Selecting appropriate repair materials and methods, and maintaining quality control not normally associated with repair above water are critical when working in a marine environment. As such, underwater repair of concrete is a specialized and highly technical part of concrete repair technology. Successful repairs can be achieved when these factors are carefully implemented. This guide provides an overview of underwater repair technology to assist the design professional, contractor, and owner in making repair decisions.

1.2—Scope

This guide covers the repair of concrete structures in the splash zone and underwater portions of structures located in lakes, rivers, seas, oceans, and groundwater. Concrete deterioration, investigation and testing procedures, preparation, materials and methodology, and inspection procedures are described. Design considerations and references for underwater repair of concrete bridges, wharves, pipelines, piers, outfalls, bulkheads, and offshore structures are identified. Scour repair, however, is not included in this guide.

One option for repairing underwater structures is to construct a cofferdam around the structure and remove the water inside the cofferdam. Concrete repairs can then be installed in the dry, as discussed in ACI 546R.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Definitions

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

anti-washout admixture—chemical admixture that reduces the loss of fine materials from cement-based materials when placed in water.

tremie—a pipe extending below water, generally with a funnel-shaped top, through which concrete can be deposited.

CHAPTER 3—CAUSES OF DETERIORATION

3.1—Introduction

Concrete structures located in water are susceptible to various types of deterioration. The type and rate of deterioration depends on various factors including concrete properties, reinforcing type, construction practices, and environmental conditions. Generally, structures located in warm marine (salt water) environments experience more rapid deterioration. In many cases, observed deterioration is the result of several deterioration mechanisms acting concurrently (Holland et al. 2014).

3.2—Deficient construction practices

Underwater placement of concrete and other materials is often susceptible to deficient construction practices due to the difficult working conditions and the inability to provide adequate inspection during construction. Failure to follow specified procedures and good practice or outright carelessness may lead to construction errors. Typically, most of these errors do not lead directly to failure or deterioration of concrete. Instead, they enhance the adverse impacts of other mechanisms.

Deficient practices include:

(a) Exceeding the target water-cementitious material ratio (*w*/*cm*)
(b) Inadequate surface preparation
(c) Improper alignment of formwork
(d) Improper concrete placement and consolidation
(e) Improper location of reinforcing steel
(f) Movement of formwork during placement
(g) Premature removal of forms or shores
(h) Settlement of the concrete during hardening

Each of these construction errors is discussed in USACE (1995).

One deficiency observed in marine structures is tension cracking of precast concrete piling, resulting from improper