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

Design and Construction of Waterfront and Coastal Concrete Marine Structures—Guide

Reported by ACI Committee 357

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Waterfront and coastal concrete marine structures are exposed to severe environmental conditions for which concrete is ideally suited. These conditions include wind; waves, including seiches and tsunamis; ice and ship impact; abrasion and impact from floating debris; passing vessel effects; and seismic events. As many of these structures are pile-supported, the seismic loading can be critical and, therefore, a discussion of piles and their installation is included in this guide. Also provided are the measures that can be taken to minimize the undesirable effects of these environmental factors and reduce the potential for serious problems.

This guide also defines waterfront and coastal concrete marine structures, discusses materials that can be used to construct them, describes potential durability issues and how to mitigate them, and presents sustainability and serviceability requirements. Design loads, analysis techniques, design methodology, and construction considerations are also presented. Other topics include quality control (QC), above-water and below-water inspection of these structures, and repair of damaged structures. The materials, processes, QC measures, and inspections described in this guide should be tested, monitored, or performed as applicable only by qualified individuals holding the appropriate ACI certifications or equivalent.

Keywords: construction procedures; durability; inspection; marine structures; materials; quality control; serviceability; structural analysis; structural design; sustainability.

CONTENTS

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CHAPTER 1—GENERAL

1.1—Introduction

The use of properly designed, durable, and sustainable concrete is an economical approach to the design and construction of marine structures. Concrete exposed to the marine environment requires considerations related to the design, construction, and maintenance that likely extend beyond those described in ACI PRC-357 and ACI CODE-318. Current building codes and ACI standards do not address the requirements unique to the design of these structures, with the exception of special applications or requirements for piles and concrete durability. This guide provides design guidance for the use of concrete for coastal marine structures and is intended to complement other design manuals and guides used for this purpose.

1.2—Scope

This guide primarily covers marine structures used for berthing marine vessels in protected harbors, and for supporting the associated loads. Structures covered by this guide include pile-supported platforms, bulkheads, and gravity structures. Although other marine structures such as gravity block walls, tunnels, breakwaters, floating structures, or offshore platforms are not explicitly covered, this guide may provide helpful information related to the construction of such structures. Emphasis is placed on special considerations for marine concrete and guidance for the design and construction of marine structures. Because of the severe nature of the marine environment and associated loading conditions, certain recommendations in this report are intended to complement the requirements of ACI CODE-318.

Existing design guides are used for basic concepts, loadings, marine hardware, and other criteria that affect the use of concrete in marine structures. There are some comprehensive manuals that cover functional and structural guidelines for the design of coastal marine structures (MIL-HDBK-1025 [2006]; BS 6349-1 to 8; Goda et al. 2009; EAU 2004; Ports, Customs and Free Zone Corporation 2007; Werner 1998; FEMA P-55 [FEMA 2011]).

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

EI = flexural stiffness, lb-in.^{2} (N-m^2)

2.2—Definitions

Please refer to the latest version of ACI Concrete Terminology for a comprehensive list of definitions. Definitions provided herein complement that resource.

air gap—distance from the underside of the structures deck to the datum high water level.

arctic structures—floating or fixed structures for exploration and production of oil and gas in ice-containing waters above the Arctic Circle and Antarctic Circle.

barge-like structures—a floating vessel with vertical walls and a near-rectangular plan; the bow and stern may be raked or shaped as required.

batter action—the phenomenon that occurs if a horizontal load is applied to a pair of piles connected in an A-frame configuration; one that causes an axial compressive load in the batter pile and a vertical tension load in the vertical pile of the A-frame.

batter piles—piles with a receding upward slope of the outer surface of the pile.

berm—a narrow shelf or ledge typically at the bottom of a slope.

coastal structure—any facility built in close proximity to the sea or ocean.

fixed offshore structures—structures that are founded on the seabed and obtain their stability from the vertical forces of gravity.

floating structures—structures that are temporally, intermittently, or continuously afloat.

graving dock—another term for dry dock, which is a relatively narrow, long basin, into which a vessel can be floated and the water pumped out, leaving the vessel supported on blocks; used for building or repairing a vessel below the waterline.

gravity structures—see **fixed offshore structures**.

liquefaction—loss of capacity by loosely packed, waterlogged sediments or soil near the ground in response to shaking or vibrations.

marine growth—biofouling organisms that attach themselves to marine structures.

marine structure—any facility built to function in contact with a body of brackish or salt water.

mudline—the top of the soil surface underlying a body of water.

offshore concrete structures—reinforced or prestressed concrete structures for service in deeper waters far from the shoreline.

offshore terminal—facility built far from the shoreline but connected to the shore by roadways or bridges.

***p*-Δ analysis**—analysis to quantify the changes in ground shear or overturning moment, or through axial force distribution at the base of a structural component, or all of the above, due to a lateral displacement.

***p-y* analysis**—analysis to characterize the lateral load behavior of a single embedded pile.

pier—a platform structure extending from the shore into the sea for use as a landing place or promenade or to protect or form a harbor.

pucher influence field charts—a series of contour plots of influence surfaces for various plate and loading geometries that can be used for deck design. For example, local moments in the deck slab due to wheel loads can be determined.

rip-rap—a loose assemblage of stones erected in water to prevent erosion of a shoreline or foundation.

scour—erosive action of moving water that removes material, creates holes, or lowers the sea floor adjacent to structures.

slipway—a sloping surface leading down to water on which ships are built or repaired. Marine structures can be moved to and from the water. Also called a marine railway, on which ships or vessels can be moved to and from the water.

tidal fluctuations—the rise and fall of the water surface from low-tide to high-tide levels.

waterfront structure—any facility built along the edge of a shoreline.

wharf—a structure built along, or at an angle from, the shore for berthing ships to receive and discharge cargo and passengers.

CHAPTER 3—GENERAL TYPES AND STRUCTURAL CONFIGURATIONS OF CONCRETE MARINE STRUCTURES

3.1—General definition

The term "waterfront and coastal concrete marine structure" is used in this guide to specifically refer to facilities constructed at or near a river or seashore to perform the functions associated with activities such as transportation of cargo or people, shore protection, shipbuilding, fishing, recreation, and military and research installations. This guide primarily covers maritime structures used for berthing ships and supporting uniform and transit loads. It is not intended to cover all types of marine structures, such as gravity block walls, jetties, breakwaters, and other shore protection structures. Refer to the *Coastal Engineering Manual* of the Engineer Research and Development Department (ERDC 2002) of the U.S. Army Corps of Engineers for shore protection structures.

The term "marine structure" is usually applied to both onshore and offshore structures. Offshore structures, while physically not connected to the shore, retain close association with the shore in their basic functions. An example would be detached breakwaters. Consequently, detached structures are usually treated in the same way as shore-located or shore-connected facilities. With the growth and expansion of oil exploration and production on the continental shelf, structures erected in the sea for these purposes acquired the name "offshore structures". A true offshore structure is a facility structurally detached from the shore (a pipeline is not a structural connection) and built to function indepen-