Report on Floating and Float-In Concrete Structures

Reported by ACI Committee 357
Report on Floating and Float-In Concrete Structures

Copyright by the American Concrete Institute, Farmington Hills, MI. All rights reserved. This material may not be reproduced or copied, in whole or part, in any printed, mechanical, electronic, film, or other distribution and storage media, without the written consent of ACI.

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. Proper use of this document includes periodically checking for errata at www.concrete.org/committees/errata.asp 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.

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
U.S.A.
Phone: 248-848-3700
Fax: 248-848-3701

www.concrete.org

ISBN 978-0-87031-384-4
Report on Floating and Float-In Concrete Structures
Reported by ACI Committee 357

This report addresses the practical experience and engineering considerations for the design and construction of floating concrete structures. Recommendations for design loads and design criteria are presented. Design procedures and methods of analysis are discussed to better acquaint the reader with the design considerations unique to floating marine structures. Methods used to construct floating concrete structures play a major role in the success of each application. Construction methods and materials used for recent applications are presented to demonstrate the importance of the construction process during the planning and design of marine concrete structures. Important aspects of delivery, from the construction site and installation at the deployment site, are presented. The durability and serviceability of floating structures at remote sites are important considerations to project planners and developers. Construction execution, materials selection and inspection, maintenance, and repair techniques are discussed. The materials, processes, quality control measures, and inspections described in this document should be tested, monitored, or performed as applicable only by individuals holding the appropriate ACI Certifications or equivalent.

Keywords: abrasion; accidents; admixtures; aggregates; concrete construction; concrete durability; detailing; dynamic loads; fatigue (materials); finite element method; floating structures; inspection; installing; lightweight concretes; limit design method; loads forces; maintenance moorings; permeability; post-tensioning; precast concrete; prestressed concrete; prestressing steels; quality control; reinforced concrete; reinforcing steels; repairs; serviceability; ships, stability; structural design surveys; towing.

CONTENTS
Chapter 1—Introduction and scope, p. 2
1.1—Introduction
1.2—Scope

Chapter 2—Notation, definitions, and acronyms, p. 2
2.1—Notation
2.2—Definitions
2.3—Acronyms

Chapter 3—Applications, p. 3
3.1—Introduction
3.2—Historical background
3.3—Ships and barges
3.4—Industrial plantships
3.5—Floating piers and docks
3.6—Floating bridges
3.7—Immersed tunnels
3.8—Navigation structures
3.9—Summary

Chapter 4—Materials and durability, p. 13
4.1—Introduction
4.2—Testing and quality control
4.3—Structural marine concrete
4.4—Reinforcement and concrete cover
4.5—Special considerations
4.6—Summary
Prestressed or reinforced concrete structures are used as either permanently floating structures or temporary float-in structures to facilitate marine construction. In this report, the definition of a floating structure is a structure that is temporarily, intermittently, or continuously afloat. For those floating structures that have a bow or stern, the bow or stern may be raked or shaped as required. Certain floating structures included within this definition are designed for towing and subsequent grounding, and afterward function as fixed structures. Later, these structures may be refloated and transported to a new location. Other structures are designed to remain continuously afloat, with or without permanent mooring.

Permanently floating structures serve a variety of uses such as industrial plantships, floating bridges, floating dry docks, offshore terminals, navigation structures, and parking and hotel structures. Applications of temporary float-in structures include the bridge pier foundations, offshore gravity-based structures, locks and dams, immersed concrete tunnels, and storm or tidal surge barriers.

In 1943, the first prestressed concrete barge was built by the U.S. Navy (U.S. Department of Transportation [USDOT] 1981). Today, the preferred construction approach for large structures is to use prestressed concrete instead of ordinary reinforced concrete. The ability of prestressed structures to control net tensile stresses and to close cracks that develop from temporary overload situations enhances water tightness and durability. Composite concrete-steel construction is also becoming popular. Concrete is used in the exterior bulkheads and base to provide durability, and steel is used for the internal framing and deck to provide weight savings (Gerwick 1975a, 1978).

The design of concrete floating structures requires knowledge of many disciplines. The designer should have a thorough understanding of concrete design principles, concrete as a material, and construction practice. Also, the designer should have an understanding of environmental loadings, marine operations, requirements for vessel certification, and the importance of structure inspection, maintenance, and repair. All of these aspects have been addressed in this report to provide the reader with a background in the subject of concrete floating structures.

1.2 Scope

This report is intended to further the development of floating concrete structures by presenting relevant design, materials, construction, installation, maintenance, and repair. Application of available technology is demonstrated for a range of floating concrete structures to show that technological risks are at a known and acceptable level.

The report starts with a historical presentation of floating structures and design concepts to establish both the versatility and technical viability of concrete floating marine structures. The durability and serviceability of floating structures at remote sites are important considerations to project planners and developers. Recommendations for design loads and design criteria are presented. Design procedures and methods of analysis are discussed to better acquaint the reader with the design considerations unique to floating marine structures.

**CHAPTER 1—INTRODUCTION AND SCOPE**

1.1 Introduction

Prestressed or reinforced concrete structures are used as either permanently floating structures or temporary float-in structures to facilitate marine construction. In this report, the definition of a floating structure is a structure that is temporarily, intermittently, or continuously afloat. For those floating structures that have a bow or stern, the bow or stern may be raked or shaped as required. Certain floating structures included within this definition are designed for towing and subsequent grounding, and afterward function as fixed structures. Later, these structures may be refloated and transported to a new location. Other structures are designed to remain continuously afloat, with or without permanent mooring.

Permanently floating structures serve a variety of uses such as industrial plantships, floating bridges, floating dry docks, offshore terminals, navigation structures, and parking and hotel structures. Applications of temporary float-in structures include the bridge pier foundations, offshore gravity-based structures, locks and dams, immersed concrete tunnels, and storm or tidal surge barriers.

In 1943, the first prestressed concrete barge was built by the U.S. Navy (U.S. Department of Transportation [USDOT] 1981). Today, the preferred construction approach for large structures is to use prestressed concrete instead of ordinary reinforced concrete. The ability of prestressed structures to control net tensile stresses and to close cracks that develop from temporary overload situations enhances water tightness and durability. Composite concrete-steel construction is also becoming popular. Concrete is used in the exterior bulkheads and base to provide durability, and steel is used for the internal framing and deck to provide weight savings (Gerwick 1975a, 1978).

The design of concrete floating structures requires knowledge of many disciplines. The designer should have a thorough understanding of concrete design principles, concrete as a material, and construction practice. Also, the designer should have an understanding of environmental loadings, marine operations, requirements for vessel certification, and the importance of structure inspection, maintenance, and repair. All of these aspects have been addressed in this report to provide the reader with a background in the subject of concrete floating structures.

1.2 Scope

This report is intended to further the development of floating concrete structures by presenting relevant design, materials, construction, installation, maintenance, and repair. Application of available technology is demonstrated for a range of floating concrete structures to show that technological risks are at a known and acceptable level.

The report starts with a historical presentation of floating structures and design concepts to establish both the versatility and technical viability of concrete floating marine structures. The durability and serviceability of floating structures at remote sites are important considerations to project planners and developers. Recommendations for design loads and design criteria are presented. Design procedures and methods of analysis are discussed to better acquaint the reader with the design considerations unique to floating marine structures.

**CHAPTER 2—NOTATION, DEFINITIONS, AND ACRONYMS**

2.1 Notation

\( A_i \) = free surface in partially filled compartment, \( \text{ft}^2 \) (\( \text{m}^2 \))

\( B \) = beam (width) of a floating structure, in. (m)

\( BM \) = distance from center of buoyancy to metacentric point, in., (m)

\( D \) = draft, in. (m)

\( F(t) \) = external force due to waves, lb (kN)

\( j \) = total number of load blocks considered

\( KB \) = distance from keel to center of buoyancy, in. (m)

\( KG \) = distance from keel to center of gravity, in. (m)

\( l \) = length, in. (m)

\( M_{sw} \) = still-water bending moment, in.-lb (m-kN)

\( M_t \) = total bending moment, in.-lb (m-kN)