

ACI 213R-14

Guide for Structural Lightweight-Aggregate Concrete

Reported by ACI Committee 213



American Concrete Institute
Always advancing



Guide for Structural Lightweight-Aggregate Concrete

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 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 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.

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.

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
Phone: +1.248.848.3700
Fax: +1.248.848.3701

Guide for Structural Lightweight-Aggregate Concrete

Reported by ACI Committee 213

Jiri G. Grygar*, Chair

Mauricio Lopez*, Secretary

David J. Akers
Theodore W. Bremner
Michael A. Caldarone
David A. Crocker
Per Fidjestol
Dean M. Golden
Ralph D. Gruber
Thomas A. Holm*

Bruce W. Jones
Edward S. Kluckowski
Mervyn J. Kowalsky
Ronald L. Kozikowski
Michael L. Leming
Keith A. McCabe
Fred Meyer*
Avi A. Mor

Dipak T. Parekh
Bruce W. Ramme
John. P. Ries*
G. Michael Robinson*
Jeffrey F. Speck
Jody R. Wall
William H. Wolfe
Shelley Wright

Min-Hong Zhang

Consulting Members

Tor Arne Hammer
W. Calvin McCall
William X. Sypher†
Alexander M. Vaysburd

*Members of the Task group who prepared the update of this guide.

†Deceased.

Special thanks to the following associate members for their contribution to the revision of this document: Reid W. Castrodale, and W. Jason Weiss. The committee would also like to thank the late William X. Sypher for his contribution to revision of the guide.

SYNOPSIS

The guide summarizes the present state of technology, presents and interprets the data on lightweight-aggregate concrete from many laboratory studies and the accumulated experience resulting from its successful use, and reviews performance of structural lightweight aggregate concrete in service.

This guide includes a definition of lightweight-aggregate concrete for structural purposes and discusses, in a condensed fashion, the production methods for and inherent properties of structural lightweight aggregates. Current practices for proportioning, mixing, transporting, and placing; properties of hardened concrete; and the design of structural concrete with reference to ACI 318 are all discussed.

Keywords: abrasion resistance; aggregate; bond; contact zone; durability; fire resistance; internal curing; lightweight aggregate; lightweight concrete; mixture proportion; shear; shrinkage; specified density concrete; strength; thermal conductivity.

CONTENTS

CHAPTER 1—INTRODUCTION AND SCOPE, p. 2

- 1.1—Introduction, p. 2
- 1.2—Scope, p. 2

CHAPTER 2—NOTATION AND DEFINITIONS, p. 3

- 2.1—Notation, p. 3
- 2.2—Definitions, p. 4

CHAPTER 3—STRUCTURAL LIGHTWEIGHT AGGREGATES, p. 4

- 3.1—Internal structure of lightweight aggregates, p. 4
- 3.2—Production of lightweight aggregates, p. 4
- 3.3—Aggregate properties, p. 5

CHAPTER 4—SPECIFYING, PROPORTIONING, MIXING, AND HANDLING, p. 7

- 4.1—Scope, p. 7
- 4.2—Specifying lightweight concrete, p. 7
- 4.3—Materials, p. 7
- 4.4—Mixture proportioning criteria, p. 8
- 4.5—Proportioning and adjusting mixtures, p. 9
- 4.6—Aggregate preparation for mixing, p. 10
- 4.7—Placing and finishing, p. 10
- 4.8—Curing, p. 11
- 4.9—Laboratory and field control, p. 11

ACI 213R-14 supersedes ACI 213R-03 and was adopted and published in June 2014..

Copyright © 2014, American Concrete Institute.

All rights reserved including rights of reproduction and use in any form or by any means, including the making of copies by any photo process, or by electronic or mechanical device, printed, written, or oral, or recording for sound or visual reproduction or for use in any knowledge or retrieval system or device, unless permission in writing is obtained from the copyright proprietors.

ACI Committee Reports, Guides, and Commentaries are intended for guidance in planning, designing, executing, and inspecting construction. This document is 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. The American Concrete Institute disclaims any and all responsibility for the stated principles. The Institute shall not be liable for any loss or damage arising therefrom.

Reference to this document shall not be made in contract documents. If items found in this document are desired by the Architect/Engineer to be a part of the contract documents, they shall be restated in mandatory language for incorporation by the Architect/Engineer.

CHAPTER 5—PHYSICAL AND MECHANICAL PROPERTIES OF STRUCTURAL LIGHTWEIGHT AGGREGATE CONCRETE, p. 11

- 5.1—Scope, p. 11
- 5.2—Compressive strength, p. 11
- 5.3—Density of lightweight concrete, p. 12
- 5.4—Tensile strength, p. 12
- 5.5—Modulus of elasticity, p. 14
- 5.6—Poisson's ratio, p. 14
- 5.7—Ultimate strain, p. 14
- 5.8—Creep, p. 15
- 5.9—Shrinkage, p. 15
- 5.10—Bond strength, p. 16
- 5.11—Thermal expansion, p. 16
- 5.12—Heat flow properties, p. 17
- 5.13—Fire endurance, p. 18
- 5.14—Energy absorption and blast resistance, p. 19

CHAPTER 6—DURABILITY OF STRUCTURAL LIGHTWEIGHT-AGGREGATE CONCRETE, p. 20

- 6.1—General, p. 20
- 6.2—Absorption, p. 20
- 6.3—Contact zone / interface, p. 20
- 6.4—Resistance to corrosion, p. 22
- 6.5—Alkali-aggregate reaction, p. 24
- 6.6—Abrasion resistance, p. 24

CHAPTER 7—DESIGN OF STRUCTURAL LIGHTWEIGHT-AGGREGATE CONCRETE, p. 24

- 7.1—Scope, p. 24
- 7.2—General considerations, p. 24
- 7.3—Modulus of elasticity, p. 25
- 7.4—Tensile strength, p. 25
- 7.5—Shear and diagonal tension, p. 25
- 7.6—Development length, p. 26
- 7.7—Deflection, p. 27
- 7.8—Columns, p. 27
- 7.9—Prestressed lightweight concrete, p. 27
- 7.10—Thermal design considerations, p. 28
- 7.11—Seismic design, p. 28
- 7.12—Fatigue, p. 28

CHAPTER 8—PERFORMANCE AND APPLICATIONS OF LIGHTWEIGHT-AGGREGATE CONCRETE, p. 30

- 8.1—Scope and historical development, p. 30
- 8.2—Structural efficiency of lightweight concrete, p. 30
- 8.3—Applications of high-performance lightweight concrete, p. 30
- 8.4—Self-consolidating lightweight concrete, p. 34
- 8.5—Advantages of lightweight concrete, p. 35
- 8.6—Sustainability of lightweight concrete, p. 36

CHAPTER 9—ENHANCED PERFORMANCE DUE TO INTERNALLY STORED WATER (INTERNAL CURING), p. 36

- 9.1—Concept of internal curing, p. 36
- 9.2—Mixture proportioning for internal curing, p. 37

- 9.3—Properties of the aggregate for internal curing, p. 38
- 9.4—Influence of internal curing on concrete properties and behavior, p. 39
- 9.5—Field experience, p. 44
- 9.6—Internal curing summary and potential impact on sustainability, p. 45

CHAPTER 10—REFERENCES, p. 45

CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

The objectives of this guide are to provide information and guidelines for designing and using lightweight concrete. By using such guidelines and construction practices, the structures can be designed and performance predicted with the same confidence and reliability as normalweight concrete and other building materials.

This guide covers the unique characteristics and performance of structural lightweight-aggregate (LWA) concrete. General historical information is provided along with detailed information on LWA and proportioning, mixing, and placing of concrete containing these aggregates. The physical properties of the structural LWA, along with design information and applications, are also included.

Structural lightweight concrete has many and varied applications, including multistory building frames and floors, curtain walls, shell roofs, folded plates, bridge decks and girders, prestressed or precast elements of all types, and marine structures. In many cases, the architectural expression of form, combined with functional design, is achieved more readily with structural lightweight concrete than with any other medium. Many architects, engineers, and contractors recognize the inherent economies and advantages offered by this material, as evidenced by the many impressive lightweight concrete structures found throughout the world.

Because much of the properties and performance of lightweight concrete are dependent on the type of LWA used, the ready mix supplier, LWA producer, or both, might be an important source of specific information for attaining the project objectives.

1.2—Scope

1.2.1 Historical background—The first known use of lightweight concrete dates back over 2000 years. There are several lightweight concrete structures in the Mediterranean region, but the three most notable structures were built during the early Roman Empire and include the Port of Cosa, the Pantheon Dome, and the Coliseum.

Built in approximately 273 BC, the Port of Cosa used lightweight concrete made from natural volcanic materials. These early builders learned that expanded aggregates were better suited for marine facilities than the locally available beach sand and gravel. They traveled 25 mi. (40 km) to the northeast to quarry volcanic aggregates at the Volcine complex for use in the harbor at Cosa (Bremner et al. 1994). This harbor on the west coast of Italy consists of a series of