

ACI 232.1R-12

**Report on the Use of Raw or
Processed Natural Pozzolans in
Concrete**

Reported by ACI Committee 232



American Concrete Institute®



American Concrete Institute®
Advancing concrete knowledge

First Printing
July 2012

Report on the Use of Raw or Processed Natural Pozzolans in 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 www.concrete.org/committees/errata.asp. 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
U.S.A.
Phone: 248-848-3700
Fax: 248-848-3701

www.concrete.org

ISBN 978-0-87031-773-6

Report on the Use of Raw or Processed Natural Pozzolans in Concrete

Reported by ACI Committee 232

Karthik H. Obla*, Chair
Robert E. Neal†, Vice Chair

Michael D. A. Thomas*, Vice Chair
Bruce W. Ramme*, Secretary

Thomas H. Adams
James C. Blankenship
Julie K. Buffenbarger
Ramon L. Carrasquillo
Barry A. Descheneaux
Jonathan E. Dongell*
Thomas M. Greene
Harvey H. Haynes
James K. Hicks
R. Doug Hooton*
Morris Huffman
James S. Jensen
Tilghman H. Keiper
Steven H. Kosmatka
William J. Lyons III
Adrian Marc Nacamuli
Tarun R. Naik
Gerald C. Plunk
Steve Ratchye
Michael D. Serra
Ava Shypula
Boris Y. Stein

Lawrence L. Sutter*
Oscar Tavares
Paul J. Tikalsky*
Orville R. Werner II*
Subcommittee Members
Gregory S. Barger*
Theodore W. Bremner*
Per Fidjestøl*
Ken S. McPhalen*
Stephen C. Morrical*
Prasad R. Rangaraju*
Caijun Shi*
Thomas J. Van Dam*
Consulting Members
Mark A. Bury
James E. Cook
Dean M. Golden
William Halczak
G. Terry Harris Sr.
Jan R. Prusinski
Harry C. Roof
Della M. Roy

*Subcommittee member for this report

†Subcommittee Chair for this report

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.

This report reviews the use of raw or processed natural pozzolans in concrete and provides an overview of the properties of natural pozzolans and their use in the production of hydraulic-cement concrete. Long before the invention of portland cement, natural pozzolans mixed with lime were used to strengthen concrete and mortar. Today, they can be used to enhance the properties of fresh and hardened concrete and may provide economic value in some cases.

Keywords: alkali-silica reaction; diatomaceous earth; lime; pozzolan; pozzolanic activity; strength; sulfate attack.

ACI 232.1R-12 supersedes ACI 232.1R-00(06) and was adopted and published July 2012.

Copyright © 2012, 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.

CONTENTS

Chapter 1—Introduction and scope, p. 2	
1.1—Introduction	
1.2—Scope	
Chapter 2—Definitions, p. 2	
Chapter 3—Historical use of natural pozzolans, p. 2	
3.1—Ancient history	
3.2—Modern history	
Chapter 4—Natural pozzolans: descriptions, p. 6	
4.1—Calcined clay	
4.2—Calcined shale	
4.3—Diatomaceous earth	
4.4—Metakaolin	
4.5—Opaline shales	
4.6—Volcanic materials	
4.7—Other materials	
Chapter 5—Reaction mechanisms, classification, and composition, p. 10	
5.1—General reaction mechanisms	
5.2—Classification systems	
5.3—Chemical and mineralogical composition	
5.4—Pozzolanic reactivity	
5.5—Factors affecting pozzolanic reactivity	
Chapter 6—Effects of natural pozzolans on concrete properties, p. 15	
6.1—Concrete mixture proportions	
6.2—Properties of fresh concrete	
6.3—Properties of hardened concrete	
Chapter 7—Specifications, test methods, quality control, and quality assurance, p. 20	
7.1—Introduction	
7.2—Chemical requirements	
7.3—Physical requirements	
7.4—General specification provisions	
7.5—Methods of sampling and testing	
7.6—Quality control and quality assurance	
Chapter 8—Concrete production: handling, storage, and batching, p. 22	
8.1—Storage and handling	
8.2—Batching	
Chapter 9—Uses of natural pozzolans in concrete and concrete products, p. 23	
9.1—Structural concrete	
9.2—Precast, prestressed concrete products	
9.3—Mass concrete	
9.4—Concrete pipes	
9.5—Concrete masonry units	
9.6—Controlled low-strength materials	
9.7—Grout and mortar	

Chapter 10—References, p. 25

CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Pozzolans are made up of siliceous or siliceous and aluminous materials that, in finely divided form, will react with calcium hydroxide to form cementitious materials. The term “pozzolan” evolved from the name given to a deposit of volcanic material located near Pozzuoli, Italy. This deposit, originally referred to as pozzolana, consisted of pumice ash, or tuff, comprised of trachyte found near Naples and Segni, Italy. Trachyte is a volcanic rock comprised primarily of feldspar crystals in a matrix of siliceous glass. Pozzolana was formed from an explosive volcanic eruption in 79 AD at Mount Vesuvius, which engulfed Herculaneum, Pompeii, and other towns along the bay of Naples. Chapter 3 provides historical information about the use of pozzolans.

The term “natural pozzolan” encompasses a broad range of materials. A few of these materials are pozzolanic in their natural state. However, most of the materials considered natural pozzolans require some type of processing to render the material pozzolanic. Some may require only drying and grinding/classifying, while others may require heat treatment and grinding to adequately activate the pozzolanic nature of the material. Chapter 4 provides a brief description of the various materials classified as natural pozzolans, which are the focus of this report.

1.2—Scope

This report contains information and recommendations concerning the selection and use of natural pozzolans generally conforming to the requirements of ASTM C618-08. Topics covered include the effect of natural pozzolans on concrete properties, a discussion of quality control and quality assurance practices, and guidance regarding handling and use of natural pozzolans in specific applications.

CHAPTER 2—DEFINITIONS

ACI provides a comprehensive list of definitions through an online resource, “ACI Concrete Terminology,” <http://terminology.concrete.org>.

CHAPTER 3—HISTORICAL USE OF NATURAL POZZOLANS

3.1—Ancient history

Many people associate the use of quarried building stones with the construction of structures by the Greeks, Romans, and other similar ancient civilizations. Concretes and mortars using various cementitious binders, however, were likewise used to some extent during these ancient times. These cementitious binders contained pozzolans of a natural origin, such as volcanic ash, pulverized pumice, and diatomaceous earth. When these pozzolans were combined with burned limestone and mixed with water, the combination would form a cementitious material. Therefore, pozzolans have been used in mortar and concrete for several millennia