Report on Alternative Cements

Reported by ACI Innovation Task Group 10

ACI ITG-10.1R-18

American Concrete Institute
Always advancing

First Printing
August 2018
ISBN: 978-1-64195-024-4

Report on Alternative Cements

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

www.concrete.org

Report on Alternative Cements

Reported by ACI Innovation Task Group 10

Lawrence L. Sutter, Chair

Mary U. Christiansen
Jonathan E. Dongell
James K. Hicks
R. Douglas Hooton
Kevin A. MacDonald
Claudio E. Manissero
Anol K. Mukhopadhyay
Deepak Ravikumar

This report addresses available and emerging alternative cements with the intent to facilitate the adoption of these new materials. Given the initiatives to address the sustainability of construction, owners, architects, and engineers are actively seeking alternatives to portland cement for concrete. An alternative cement is intended to be a replacement for portland cement in some applications. In some cases, alternative cements can also be used in combination with portland or blended hydraulic cements. In addition to a reduced environmental impact associated with their production and use, alternative cements offer improved performance over portland cement in some applications. Various alternative cement technologies are discussed, including their physical and compositional characteristics, methods of production, fresh and hardened properties, and example applications. Additionally, the applicability of existing tests methods for specifying alternative cements is discussed and new testing needs are identified.

Keywords: alkali-activated; alternative cementitious materials; alternative cements; calcium aluminate cement; calcium sulfoaluminate cement; carbonated calcium silicate cement; geopolymer; magnesium oxychloride cement; magnesium phosphate cement; supersulfated cement.

CONTENTS

CHAPTER 1—INTRODUCTION AND SCOPE

1.1 —Introduction

This report provides a summary of alternative cement technologies currently available or emerging for construction use. This report also identifies the need for development of test methods to facilitate the use of alternative cements with the same level of reliability expected from portland cement. The goal of this document is to introduce the concrete construction community to alternative cements and increase their knowledge base, experience, and confidence in their

ACI ITG-10.1R-18 was adopted and published August 2018.

use. Because of the long history of using portland cement as the exclusive or primary cement for concrete construction, concrete specifications and design codes have an inherent assumption, or in some cases a requirement, that portland cement is the primary cementitious binder material to be used. Supplementary cementitious materials are commonly used but very rarely as a complete replacement for portland cement. Because alternative cements are developing and their commercialization is increasing, it is important that engineers, architects, contractors, and owners become familiar with alternative cement properties and applications, and be knowledgeable of how to test these materials.

1.2—Scope

This report addresses available and emerging alternative cements, with the intent of introducing these materials and facilitating the development of test methods to address their safe and reliable use. The discussion herein includes material properties, production methods, and testing methodologies. References made to portland cement and portland cement production are for comparison purposes only. An in-depth discussion of portland cement is not within the scope of this report.

1.3—History

In its simplest conception, concrete consists of aggregates bonded together using a cohesive binder, or cement. More than 2000 years ago, concrete was produced with noteworthy cement technologies such as those used by the Romans in construction of the Pantheon and Colosseum (Kosmatka and Wilson 2011). These ancient concrete mixtures relied on lime or various natural cements and pozzolans for the cohesive binder. Since its introduction in 1824, portland cement has universally become the most common cement for concrete given its relatively low cost, uniformity, availability, and ease of use.

Portland-cement concrete (PCC) is the most widely used manmade material and is unrivaled for its versatility and durability. Because of these general characteristics, PCC is an indispensable ingredient of modern civilization, used in the construction of civil engineering and architectural structures, including roads, bridges, public water and sanitary systems, and buildings.

Like many manufacturing processes, portland cement production is not without detriment to the environment with respect to the energy-intensive nature of its production and the inherent release of greenhouse gas (GHG) emissions. Production of portland cement begins with a mixture of raw materials that includes limestone, which is primarily calcium carbonate ($CaCO_3$) and shale. These materials are heated in a rotary kiln to temperatures of approximately 2460 to 2640°F (1350 to 1450°C) to produce clinker. The conversion of calcium carbonate to calcium oxide by heating is called calcining. In this process, carbon dioxide (CO_2) and other GHG emissions are created. The primary source of CO_2 is the conversion of $CaCO_3$ to CaO. Additional CO_2 is released through burning fossil fuels to heat the kiln. The negative results of this process are a high energy demand due to the temperatures needed for producing portland-cement clinker and the identified GHG emissions. Although portland cement is a minor ingredient in PCC, it is the principal source of embodied energy and GHG emissions for the material. There are numerous papers and references discussing the environmental footprint of portland cement with a brief list referenced here (Hanle et al. 2009; Kosmatka and Wilson 2011; NRMCA 2012; EPA 2012). With respect to both embodied energy and GHG emissions, the state of the art for portland cement production is approaching the point where only minimal additional reductions can be expected using existing production technologies.

Given recent initiatives to address the sustainability of everything we do as a society, owners, architects, and engineers are actively seeking alternatives to portland cement to meet the demand for concrete. It is unlikely that portland cement will be completely replaced as the primary cement for producing concrete, but there are applications in which available alternative cements can be used. Adoption of alternative cements can result in numerous environmental advantages, including the beneficial and effective incorporation of recycled and residual materials, and reductions in the embodied energy and GHG emissions associated with PCC.

In addition to environmental advantages, alternative cement concrete can perform better in specific applications when compared to PCC. Examples of performance improvements include faster setting times, increased wear resistance, and improved chemical or fire resistance.

CHAPTER 2—DEFINITIONS

ACI provides a comprehensive list of definitions in "ACI Concrete Terminology." Definitions provided herein complement that source.

alkali activation—the process of using an alkali-based solution to cause the dissolution of an alumino-silicate precursor and to initiate the chemical reactions leading to the formation of reaction products.

alkali activator—an alkali-based solution that causes alkali activation, such as sodium hydroxide and sodium silicate solutions.

alternative cement—an inorganic cement that can be used as a complete replacement for portland or blended hydraulic cements, and that is not covered by applicable specifications for portland or blended hydraulic cements.

Note: An alternative cement or alternative cement blend could provide better performance than that of portland or blended hydraulic cement in some applications. An alternative cement, however, might not perform adequately as a replacement for portland or blended hydraulic cement in every application. In some cases, alternative cements can also be used in combination with portland or blended hydraulic cements.

ambient-cured—curing without the addition of heat above that available from room or the external environment.

calcined alternative cement—an alternative cement produced by calcining a raw material only, without further pyroprocessing, to produce additional mineral phases within the material.