

IN-LB

Inch-Pound Units

SI

International System of Units

Alkali-Activated Cements— Report

Reported by ACI Committee 242

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Alkali-Activated Cements—Report

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Alkali-Activated Cements—Report

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This report provides a technical overview of alkali-activated cement (AAC) history; chemistry; and mechanical, physical, and durability properties. It also highlights successful case study applications and current technical challenges.

Keywords: alkali-activated cements (AACs); alternative cements; geopolymers.

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CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Concrete has traditionally been made with portland cement (PC) binders and PC binders with supplementary cementitious materials, but several emerging alternative cements offer distinctive properties that may be beneficial for some applications (ACI ITG-10.1R). Alkali-activated cements (AACs) are a distinct class of cements that react using alkali activation to form a cement paste solid. This activation consists of using an alkali- or alkali-salt-based activator to promote the dissolution of an aluminosilicate precursor and subsequent precipitation of cementitious reaction products. Depending on the aluminosilicate precursor (for example, fly ash, ground-granulated blast-furnace slag, calcined clays), alkali activation can initiate a series of either polycondensation reactions, in which water is produced as a result of reaction product formation, or hydration reactions similar to PC, in which water is consumed (Pacheco-Torgal et al. 2014).

AACs are sustainable, low-to-zero-clinker cement alternatives to PC due to their achievable mechanical and durability properties. They also have lower manufacturing carbon dioxide (CO₂) emissions, which are largely due to the use of industrial by-product materials as precursors (McLellan et al. 2011; Habert and Ouellet-Plamondon 2016). In general, successful precursors used for AACs should contain significant amounts of reactive silica (SiO₂) and alumina (Al₂O₃), whereas the presence of additional oxides, such as calcium oxide (CaO), can result in changes to the resultant phase assemblages (Provis et al. 2014). The most common precursors include fly ash, ground-granulated blast-furnace slag, and natural or calcined clays (for example, metakaolin). The most widely used alkaline solutions include alkali silicates (for example, sodium silicate) and alkali hydroxides (for example, sodium hydroxide). Other activators include alkali carbonate and sulfate salts, which have been demonstrated to have better compatibility with conventional chemical admixtures and are less caustic (that is, lower pH) when implemented in cast-in-place field applications (Bernal 2016). However, the strength development of AACs activated with alkali carbonate and sulfate salts often depends more on the physical (for example, fineness) or chemical (for example, reactive glass) characteristics of the chosen precursor (Wang et al. 1994). Alkali aluminates—especially the by-products of alumina refining—are also capable of activating AAC precursors (van Riessen et al. 2013) and may offer a potentially cost-

effective alternative to other activators produced from virgin materials.

This report provides a technical overview of AAC history, chemistry, mechanical and physical properties, and durability. It also highlights successful case study applications and current technical challenges. The results from extensive research in the field have revealed that the engineering properties of specific formulations of AACs can be comparable to PC or blended hydraulic cements. In some applications, AACs can provide better durability and mechanical performance. Nonetheless, AACs constitute a class of materials that is suitable to use as part of a toolkit of various concrete technologies. Thus, while AACs may not be considered a direct replacement to PC or blended hydraulic cementitious materials for every application, AACs may meet or exceed economic and technical performance requirements in some applications.

1.2—Scope

This report defines relevant AAC terminology and a brief history of AACs. The fundamental materials science and engineering of AAC technology is discussed, along with the definitions of important parameters required for proper mixture proportioning. This report summarizes the fresh- and hardened-state properties of AAC concrete, with a specific focus on reaction kinetics, mechanical properties, and durability. Finally, this report summarizes challenges and opportunities for the AAC field and presents an overview of full-scale industrial applications and safety considerations of AAC concrete.

CHAPTER 2—DEFINITIONS

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

alkali—a chemical compound containing one or more elements belonging to Group 1 or Group 2 of the periodic table of elements.

alkali activating powder—an alkali powder that can be mixed with a precursor to form one-part alkali-activated cements.

alkali activating solution—an alkali-based solution that causes the dissolution of the precursor(s).

alkali activation—the process of using an alkali-based solution or powder to promote the dissolution of an aluminosilicate precursor and the precipitation reactions leading to the formation of reaction products.

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

geopolymer cements—a subset of AACs comprising low-calcium (or calcium-free) alkali-activated precursors, such as metakaolin, that produce amorphous inorganic three-dimensional (3-D) aluminosilicate structures that resemble natural mineral systems.

one-part alkali-activated cement—a “just add water” AAC in which the precursor is premixed with an alkali