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Cementitious Materials for Concrete

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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

CEMENTITIOUS MATERIALS FOR CONCRETE

Prepared under the direction and supervision of ACI Committee E-701, Materials for Concrete Construction

Thomas M. Greene, Chair
Corina-Maria Aldea
Richard P. Bohan*
David A. Burg
Darrell F. Elliot
Darmawan Ludirdja
Mark R. Lukkarila
Clifford N. MacDonald
Charles K. Nmai
David M. Suchorski
Lawrence L. Sutter
Joseph E. Thomas
Kari L. Yuers
Robert C. Zellers
*Chair of document subcommittee.

This document discusses commonly used cementitious materials for concrete and describes the basic use of these materials. It is targeted at those in the concrete industry not involved in determining the specific mixture proportions of concrete or in measuring the properties of the concrete. Students, craftsmen, inspectors, and contractors may find this a valuable introduction to a complex topic. The document is not intended to be a state-of-the-art report, user's guide, or a technical discussion of past and present research findings. More detailed information is available in ACI 225R-99, "Guide to the Selection and Use of Hydraulic Cements," ACI 232.2R-03, "Use of Fly Ash in Concrete," ACI 233R-03, "Slag Cement in Concrete and Mortar," and ACI 234R-06, "Guide for the Use of Silica Fume in Concrete."

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CHAPTER 1—INTRODUCTION

Concrete is made from a properly proportioned mixture of hydraulic cement, water, fine and coarse aggregates and, often, chemical admixtures and supplementary cementitious materials (SCMs). The most common hydraulic cement used in construction today is portland cement. Although other types exist, portland cement is the most widely manufactured and the focus of this document. Exceptions are noted otherwise. The successful use of concrete in construction depends on the correct selection of the appropriate materials necessary and the proper proportioning of those materials. This requires knowledge of the material properties and the tests used to measure those properties.

The selection and characterization of hydraulic cement and SCMs are the subjects of this bulletin, while aggregates, admixtures, and concrete characteristics are discussed in companion volumes. There are several varieties of hydraulic portland cement, as recognized by ASTM International, which vary in their properties. Hydraulic cement is defined as cement that sets and hardens by chemical reaction with water and is capable of doing so underwater. The following chapters review the composition and properties of the various portland cements and SCMs, discuss the tests used to evaluate a cement, and consider how cement properties influence the performance of the concrete.

1.1—History of portland cement

The name "portland" originates from a trade name used by Joseph Aspdin in 1824 to describe the new cement he patented that year in England. He claimed that the artificial stone (concrete) made with his cement was similar in appearance to portland stone, a high-quality limestone used in construction during that time period. Although the term "portland cement" dates from Aspdin's patent in 1824, hydraulic cement as a material can be traced back to ancient times, where several famous landmarks of the Roman era owe their survival to the cementitious qualities of the forerunner to portland cement.

The portland cement industry quickly spread in England. By 1890, there was a flourishing export business to the United States. The fledging U.S. industry founded by David Saylor at Coplay, PA, in 1871, soon captured the domestic market. U.S. production rose from 54,000 metric tons (60,000 tons) per year in 1890 to 1.5 million metric tons (1.7 million tons) in 1900, and by 1915 had increased to 14.1 million metric tons (15.5 million tons). Early cement production was measured on the basis of a barrel. One barrel of cement was equivalent to 374 lb (170 kg) of cement. One-quarter barrel of cement was then equivalent to 94 lb (43 kg), which quickly became the accepted basis for the quantity of cement in a bag or sack. Today, more than 121 million metric tons (133 million tons) of portland cement are used each year in the United States. The worldwide consumption of cement is more than 2160 million metric tons (2376 million tons). In the past, cement production was measured in tons (2000 lb) and now it is measured in metric tons (1000 kg). A metric ton, or megagram (Mg), is equal to 1 million grams and is approximately 10% more than a U.S. ton.

1.2—Sustainability

The sustainable attributes of concrete are strongly tied to the service life and performance of the cementitious binder system used. Conventional systems based on portland cement have an unparalleled record of performance under a wide range of conditions. However, as is the case with manufacturing processes used in the production of other building materials, production of portland cement requires a significant amount of energy and inherently produces greenhouse gases. Given this fact, engineers have developed approaches to improving the sustainability of concrete by an increased use of cementitious materials that rely less on portland cement and more on alternative materials (for example, coal fly ash, silica fume, slag cement, and natural pozzolans). Through the use of alternative materials, the ability to accomplish significant reductions in the embodied energy and greenhouse gas emissions associated with portland cement production has served to significantly improve the overall sustainability of concrete. In the future, the use of alternatives to portland cement will only increase. However, any changes in the binder system used in concrete must be accomplished without sacrificing the service life and performance attributes that have made concrete the most widely used construction material on the planet.

When examining the sustainability of concrete, and specifically the role of the hydraulic cement binder system in achieving sustainability goals, it is important to consider those areas where portland cement contributes. Portland cement provides a low-cost, effective binder system, whether used alone or in combination with alternative materials. As a result, society has reaped the benefits, enabling the construction of bridges, roads, dams, and buildings that simply cannot be constructed with other materials. Importantly, the most critical infrastructure systems of our society are built with concrete that uses a portland-cement-based binder system. The societal benefits of concrete, and indirectly the societal benefits of portland cement, cannot be overstated