Materials Today: Proceedings 66 (2022) 2811–2817

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

The effect of the addition of metakaolin on the fresh and hardened properties of blended cement products: A review

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ARTICLE INFO

Article history:
Available online 9 July 2022

Keywords:
Calcined clays
Metakaolin
Supplementary cementitious material
Pozzolanic Materials
Blended Cement
Concrete

ABSTRACT

Globally, cement is only second to water as the most consumed material with over 6 billion tons being produced every year. However, it is the most energy-intensive and expensive component of concrete. This study reviews the research carried out on the use of metakaolin as a Supplementary Cementitious Material (SCM) in paste, mortar, or concrete. The characteristics of metakaolin and its influence on the fresh and hardened properties of blended cement mixtures are demonstrated based on the recent literature. The review reported three main aspects of metakaolin-cement blends which are: physical (workability and setting times), mechanical (compressive strength and shrinkage), and long-term durability properties (chloride ion diffusion, sulfate attack resistance, and Alkali-Silica/-Carbonate Reaction (ASR/ACR). According to the literature, metakaolin is demonstrated as an effective pozzolan that improves the pore structure significantly. It can greatly enhance early age strength in blended cement products with no degradation, and potentially some improvement too, in long-term strength, all while improving permeability and resistance against ASR/ACR and the intrusion of harmful solutions.

Selection and peer-review under responsibility of the 14th AUN/SEED-Net Regional Conference on Materials and 4th International Postgraduate Conference on Materials, Minerals and Polymer (RCM & MAMIP 2021).

1. Introduction

The use of Supplementary Cementitious Materials (SCMs) has emerged in the mid-1900s as a practical solution to face the environmental problems and the economic challenges in the cement industry [1]. Since then, a lot of work has been spent on the treatment of industrial wastes and processing of raw clays to produce SCMs, with the intention of substituting larger amounts of clinker, which is used in Portland Cement (PC) manufacture [2]. Several studies showed that thermal activation of raw clays is an effective method for SCMs production [3–6]. The utilization of SCMs, such as calcined clays (metakaolin), [3] and natural pozzolans [7], has become a rational approach to minimize the use of PC in concrete. The amounts of PC in the concrete mixture can be reduced through partial substitution with pozzolans. Nowadays, this has become a very common practice in concrete production [8]. Furthermore, it is expected that the utilization of these materials will increase with increasing global awareness on the environmental protection [9]. This will contribute to the requirements sustainability in the construction industry in terms of energy reservation and overall carbon footprint reduction while cutting down the costs.

Despite the fact that extensive research has been carried out, resulting in the development in specification standards in a number of countries, there are few scientific summaries on the progress of metakaolin-related application techniques in cementitious systems based on more recent investigations [10]. The objective of this study is to review the work carried out on the use of metakaolin as SCMs. In addition, the fresh and hardened properties of cementitious systems with metakaolin are comprehensively reviewed in terms of workability, setting time, mechanical properties, and long-term durability in applications with severe environments or in containment of hazardous wastes, e.g., chloride diffusion, sulfate attack, alkali silica and alkali carbonate reactions.

2. Characterization of Metakaolin

The characterization of Metakaolin (MK) has been a research topic since the late 19th century [11]. MK is a pozzolanic material of N type [12] with a small particle size (~1–2 μm) and high

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https://doi.org/10.1016/j.matpr.2022.06.521

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