Chapter 4
Effect of Metakaolin on Geopolymer Industry

ABSTRACT

This chapter discusses the effects of metakaolin (MK) on geopolymer mortar and concrete industries. The research topics of MK-based geopolymer cover reaction mechanisms and kinetics. This chapter aims at augmenting knowledge about enhancing mechanical properties of geopolymer mortars/concrete using MK. Specifically, this chapter presents literature studies as well as current experimental studies which delineate the effect of MK on fresh and hardened-state properties of geopolymer mortars (GPMs). Properties and characteristics of metakaolin are explained followed by properties of fresh MK mortars. Properties of hardened MK concrete and durability aspects of MK mortars are explained. Applications of MK-based geopolymers and metakaolin-based geopolymers as repair materials are also included in this chapter. The results of using MK-based GPMs revealed improved workability, enhanced setting time, increased density, higher compressive strength, flexural strength, and resistance against acid attack than conventional ordinary portland cement mortar/concrete.

INTRODUCTION

In late 1970s, Professor Joseph Davidovits carried out a research on fireproof polymers and introduced the concept of geopolymer, which was coined to describe a family of alkali activated alumina-silicate binders (Davidovits, 2008). The formation of geopolymer was based on the reaction between the two parts of materials: alkali activator and reactive alumina-silicate precursor.

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In this study, the precursor was mainly metakaolin (MK) and is at a very early stage of the research development. The geopolymer based on alkali activation of MK has gained worldwide interests in the past several years. It was not only because of its excellent thermal stability, which is much better compared with conventional polymer material, but also due to its comparable mechanical properties to cements, which is being considered as a green alternative to Portland cement (Duxson et al., 2007). In recent years, the rapid growth in research and development of geopolymer has shifted from the early interests of thermal resistant applications towards construction and building materials (Pacheco-Torgal et al., 2008). Because of this, the raw materials used for large volume geopolymer manufacture has been significantly broadened, including heated low quality clays and a variety of silica and aluminium-bearing (Si- and Al) waste materials and by-products sourced from different industries (Zhang et al., 2016).

Despite the fact that fly ash and slag became the two major waste materials used in today’s limited commercial geopolymer products, MK is probably still the most promising feedstock materials for geopolymer in the future. This is because MK has more consistent chemical compositions than fly ash and slag, and is expected to result in more consistent and predictable products. In fact, fly ash and slag are becoming less available in many countries because of their effective usage in the manufacture of blending cements and concrete (Malhotra and Mehta, 1996). Therefore, from a long-term point of view, the use of MK as raw material is becoming more attractive and realistic. MK is a thermally treated product from kaolin, which is one of the naturally occurring abundant minerals in the earth’s crust (Zhou and Keeling, 2013). Kaolin has been historically used in the production of Portland cement. To produce one tonne of clinker, the most important ingredient of cement, it requires about 0.3 tonnes of clay to mix with 1.5 tonnes of limestone and other iron-bearing minerals and calcination at 1450 °C (Zhang et al., 2014). Kaolin can also be used in another form as the supplementary cementing material in concrete mixing. This utilization requires a thermal treatment process, usually at temperatures ranging between 500 °C and 800 °C, to convert kaolin into metakaolin (MK). MK is a pozzolan, which in itself possesses little or no cementing property but will react chemically with calcium hydroxide (Ca(OH)_2) to form compounds in the presence of water to possess cementing properties. Theoretically, the replacement, usually 5–20% by mass of cement, contributes to a slight reduction in CO₂ emission due to the less
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