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Long term durability properties of concrete modified with metakaolin and polymer admixture

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HIGHLIGHTS

- A review on the principles using metakaolin and polymer to improve concrete properties.
- Long-term mechanical and durable properties of concrete using both metakaolin and polymer.
- The optimum mix and the complement mechanisms using both metakaolin and polymer.
- A guidance for concrete design for the application in severe environmental conditions.

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ABSTRACT

Previous studies show that both metakaolin (MK) and polymer can respectively improve certain mechanical and durability properties of concrete. Also, recent studies show that a combination of MK and polymer further enhances the mechanical properties by complement of each other. However, the knowledge of the effect on durability, a critical governing factor of concrete for the applications in extreme environments such as sewage, off-shore and bridge structures, has not been well established yet. This paper reports on a comprehensive study of the effect of metakaolin as a supplementary cementitious material together with polymer as admixture on the durability of concrete at relatively old ages. The results confirm that replacing Portland cement with 15% metakaolin and an additional 5% polymer (by weight) provide the optimum improvement for Portland cement concrete on both mechanical properties and durability.

1. Introduction

Using mineral supplementary cementitious materials (SCM), such as fly ash (FA), silica fume (SF) and thermally activated kaolin (also known as metakaolin (MK)), as additives has already been proved effective to improve properties of concrete [26]. MK requires less energy to produce compared to cement [39,40], which, in recent years, has attracted more and more interest in the use for the SCM [2,41] because of the environmental concern and the decreasing supply capacity of fly ash and silica fume [40]. The MK product has predominant alumina (Al_2O_3) and silica (SiO_2) composition, which have an active pozzolanic nature [4]. The pozzolanic reaction of MK with portlandite ($Ca(OH)_2$) will result in significant compositional changes of calcium silicate hydrate (CSH) gel to give high Al uptake and low Ca content in a new gel formation known as CASH, which has a low Ca/(Al + Si) ratio but a high Al/Ca ratio [40].

Previous research showed that a 20% replacement of cement using MK resulted in a substantial 50% increase of the compressive strength of mortar [29], and the concrete using MK additive displayed a lower water sorptivity compared to that using silica fume [22]. Recently, Pouhet and Cyr [38] studied the pore solution carbonation of MK-based geopolymer and found that the pH decreased rapidly in the first few days when the normal concrete was exposed to natural CO_2 conditions. Moreover, a high CO_2 content or a relatively high environmental temperature led to durability issues when the pH was lower than 10. However, the pozzolanic nature of MK increased the pH and kept it above 12 even after one year, indicating a minimum carbonation inside the concrete. Another study [28] showed that self-compacting concrete (SCC) with a high MK content (up to 30%) exhibited a significant resistance to chloride ion penetration. For acid attack

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