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Effect of seawater for mixing on properties of potassium magnesium phosphate cement paste

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HIGHLIGHTS

- Effect of seawater for mixing on properties of potassium magnesium phosphate cement paste was studied.
- The compressive strength, and hydration temperature of MKPC paste samples were investigated.
- The seawater corrosion resistance of MKPC paste was evaluated.
- Sea water corrosion resistance mechanism of MKPC paste was characterized by microstructure observation.

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ABSTRACT

This paper aims to study the effect of seawater mixing on the properties of potassium magnesium phosphate cement (MKPC) paste. Fresh water and seawater were used to prepare MKPC pastes, respectively. Then, the compressive strength, residual ratio of compressive strength, hydration temperature, phase composition and microstructure of the MKPCs prepared with seawater and fresh water were compared. Results showed that the MKPC pastes prepared with seawater had higher fluidity, longer initial setting time and lower compressive strength than those prepared with fresh water. Adding silica fume and limestone powders to MKPC pastes prepared with seawater can accelerate the early-stage hydration and make the pastes more compact, leading to significantly less loss of compressive strength. Thus, adding some mineral admixtures into MKPC paste prepared with seawater could lessen the negative effect of seawater for mixing on the properties of hardened body. This study might provide useful information for application of seawater in mixing MKPC for marine construction.

1. Introduction

With the fierce competition for marine resources, marine construction is expanding. However, because of a lack of fresh water and traffic inconvenience on islands away from the mainland, it is difficult to carry out construction on them. If seawater can replace the fresh water used for mixing concrete, it would bring great convenience and reduce the cost for marine construction. In fact, seawater has been used for mixing the ordinary Portland cement concrete, but the hardened body has a porous structure, poor durability and weak ability to resist chloride ion diffusion and seawater erosion. Thus, seawater used for mixing Portland cement concrete cannot meet the requirement of marine construction.

Magnesium phosphate cement (MPC) is a kind of inorganic cementitious material, formed via neutralization reaction and using phosphate as its binder phase. The neutralization reaction occurs at room temperature, followed by setting and hardening, which is similar to that of ordinary Portland cement, and the final hydration product has ceramic characteristics [1]. Compared with Portland cement, MPC has a more rapid hardening process, higher early strength, enhanced adaptability to environmental temperature, better adhesion, higher resistance to abrasion and frost, etc. [1–5]. Thus, at the end of last century, MPC was widely used for repairing the airport runway and municipal road, and its excellent durability has been verified [2]. Over the next two decades, MPC has been used in civil engineering (concrete structure repair, corrosion resistant, fireproof coatings, etc.), solidification of toxic waste and biological field. In fact, some MPC products have entered the market [6].

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MPCs can be classified into many groups according to the phosphate used for preparing them. Currently, ammonium magnesium phosphate cement (MAPC) prepared with ammonium hydrogen phosphate (ADP) and potassium magnesium phosphate cement preparation (MKPC) prepared with potassium dihydrogen phosphate (KDP) are mostly studied and applied. However, harmful ammonia is released during the mixing process of MAPC, so MKPC is preferable for research. The hydration process of MPC involves the dissolution of overburning MgO in acidic phosphate and the formation of $MgNH_4{\cdot}(K)PO_4{\cdot}6H_2O$ [1,7]:

$$MgO(s) + NH_4(K)H_2PO_4(s) + 5H2O(l) \rightarrow MgNH_4(K)PO_4 \cdot 6H_2O(s)$$

$MgNH_4(K)PO_4{\cdot}6H_2O$ (MKP, congeners of struvite), the main hydration product of MPC, gives cementitious properties to MPC and remains stable over a large pH range from 7.0 to 10.0 [8]. The hardened MPC paste consists of unreacted magnesium oxide particles and phosphate hydrates which form a network structure via ionic bonding among particles and the structure is as dense as ceramic [7,8]. Compared with porous Portland cement hardenite containing much $Ca(OH)_2$, whose main hydration product (C-S-H) depends on alkaline atmosphere and particles are combined via Van Edward force, MPC hardenite has obvious advantages in resisting chloride ion diffusion and salt corrosion [9–11]. Zhen et al. [12] investigated the erosion behavior of NaCl solution on MPC mortar and proved that MPC-based mortar's resistance to chloride ion penetration of was significantly better than that of Portland cement mortar. Jiang et al. [13] used sea sand and seawater to prepare MPC mortar and studied the development of its early strength and resistance to seawater erosion. Their results indicated that MPC mortar had almost no loss of strength after immersion in seawater for 180 days, meaning high resistance to seawater erosion over a certain period.

The most basic problems limiting the application of MPC-based materials are their rapid hardening process, concentrated release of hydration heat and poor water stability. Compound retarder can solve the problem of rapid hardening and concentrated release

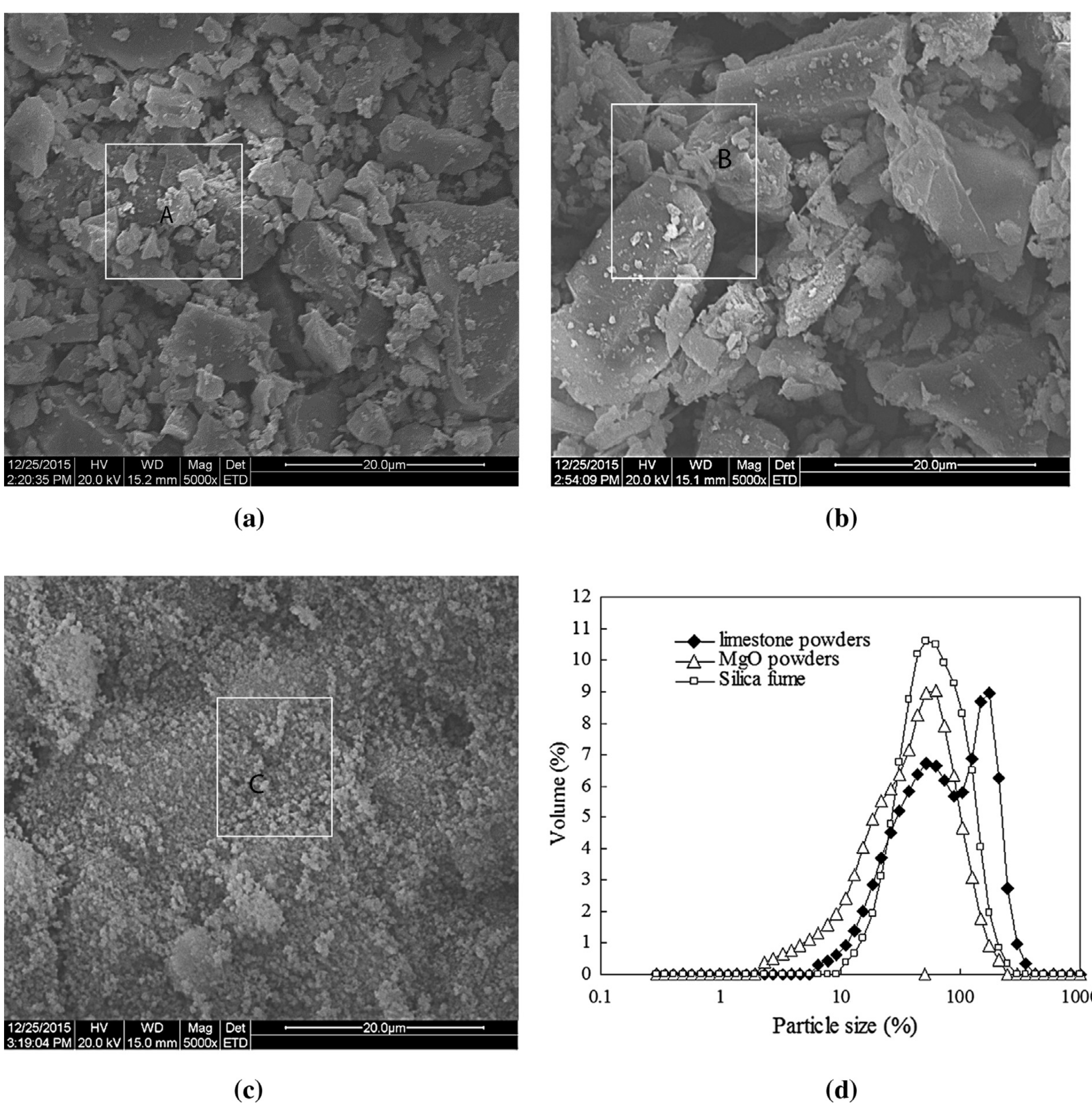

Fig. 1. SEM images of MgO powders (a), limestone powders (b) and silica fume (c); The particle size distribution of the overburning MgO powder, limestone powders and silica fume. (d).