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The Water Impermeability and Self-repairing Performance of the Rapid Setting Polymer-modified Waterproof Mortar

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Abstract. The water impermeability of the rapid setting conventional and polymer-modified waterproof mortars is systematically compared in this paper. Additionally, the self-repairing performance of the rapid setting polymer-modified waterproof mortar is highlighted. Compared with the rapid setting conventional waterproof mortar, the rapid setting polymer-modified waterproof mortar possesses better water impermeability. Furthermore, the presence of the specific reactive chemical compound is justified to improve the secondary water impermeability and thus the self-repairing property of the rapid setting polymer-modified waterproof mortar.

1. Introduction

Concrete, one of the most commonly used construction materials, is intrinsically a porous material [1-5]. Therefore, micro-pores, micro-voids and micro-cracks are inevitably present in its surface and interior [1-2, 5-6]. Furthermore, shrinkage crack may be created because of the water evaporation during the plastic stage of concrete. In addition, temperature crack can be generated during the hardening stage of concrete. All of these structural defects can provide the easy path way for water and aggressive water-soluble agents to penetrate into the interior of the concrete [5], leading to the deterioration of reinforced structures of the concrete [7-9] and reducing the life span of buildings. Consequently, it is of particular significance to prevent water from penetrating into the reinforced concrete structures.

Among them the most commonly used waterproof materials are waterproof mortars, particularly the polymer-modified waterproof mortars (PMMs). Of the waterproof mortars, rapid setting waterproof mortars are commonly used in the situations where the rapid repair materials are needed. Although rapid setting waterproof mortars are particularly attractive in locations where the rapid repair of deteriorated concrete structures is of great urgency, the literature on the studies of this type of waterproof materials is quite limited [10-16]. In these studies, the mechanical properties of sulphoaluminate cement based rapid setting mortars [11-12] and magnesium phosphate cement based rapid setting mortars [13-15] were fully investigated. However, the self-repairing ability for rapid setting waterproof mortars were not highlighted in these studies.

To gain more insights into this research area, the preparation and self-repairing ability of rapid

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setting waterproof mortars are presented in this paper.

2. Materials and methods

2.1. Selection of materials

To prepare the different rapid setting waterproof mortars, a rapid-hardening sulphoaluminate cement (cement grade can reach the levels of 1/42.5 R) was selected because sulphoaluminate cement based mortars have been found to possess a quick set, high early strength and slightly expansion [11-12]. Additionally, the following commercially available main materials were also selected: vinyl acetate–ethylene (VAE) copolymer re-dispersible powders; a specific reactive chemical compound for cementitious capillary crystalline waterproof materials, grade DMC-S-WS-720; and a hydroxyethyl methyl cellulose ether.

In addition, a commercially available coagulant (lithium carbonate), a hemi-hydrated gypsum, a ground limestone, a silica fume, a quartz sand and a naphthalene water-reducing agent (super plasticizer) were also selected.

2.2. Preparation of rapid setting waterproof mortars

The following three types of rapid setting waterproof mortars were prepared in this work: the rapid setting conventional waterproof mortar without addition of any VAE powders (denoted as sample-1), the rapid setting waterproof mortar with the addition of prescribed amounts of VAE powders (designated as sample-2) and the rapid setting polymer-modified waterproof mortar without the addition of the reactive chemical (denoted as sample-R). The compositions of the three samples are listed in Table 1.

Table 1. The compositions of the three samples.

Materials	Weight contents (%)		
	sample-1	sample-2	sample-R
Sulphoaluminate cement	43	40.2	40.2
Specific reactive chemical compound	5	5	0
Quartz sand	50	45	50
Ground limestone	1.8	1.8	1.8
Hemi-hydrated gypsum	1.2	1.2	1.2
VAE	0	3	3
Silica fume	2.2	2.2	2.2
Water-reducing agent	1.2	1.2	1.2
Coagulant	0.6	0.4	0.4

The preparation process: all of the materials were weighed and mixed in a planetary type mortar mixer for 90 s, followed by the addition of the water. Subsequently, the mixture was stirred for additional 90 s and the final mortars were manufactured. The prescribed amounts of mortars were used to prepare the specimens for measurements.

The specimens demoulded within 1 h and then were allowed to cure. All of the specimens were cured at the room temperature in air under standard curing conditions (20 ± 2 °C, relative humidity 50 ± 5%) unless otherwise indicated.

2.3. Measurements of water impermeability

Water impermeability of the rapid setting waterproof mortars were tested according to Chinese national standard JB/T 23440-2009 (inorganic waterproof and leakage-preventing materials) using six truncated-cone-shaped specimens on a model SS-15 permeability tester (Hebei Jugao Instruments co., Ltd).

3. Results and discussion

3.1. The water impermeability

Figure 1 shows the comparison of the mean penetration height at the maximum hydraulic pressure of 4.5 MPa between the rapid setting conventional and the polymer-modified waterproof mortars. It should be mentioned that the impermeability pressure of a qualified rapid setting waterproof mortar should be higher than or equal to 1.5 MPa according to Chinese national standard GB/T 23440-2009. However, the measured impermeability pressure values of two types of rapid setting waterproof mortars developed are higher than 4.5 MPa. Because 4.5 MPa is the maximum hydraulic pressure that the testing device can reach, we compare the water penetration height of the specimens at this pressure. As observed in Figure 1, at the maximum hydraulic pressure of 4.5 MPa, the average penetration height of the rapid setting polymer-modified waterproof mortars (0.6 mm) is lower than that of the rapid setting conventional waterproof mortars (1.13 mm). It is well established that polymer particles which are much smaller than the sand and cement particles can fill the smaller voids and eventually form a hydrophobic layer. Furthermore, the presence of polymer particles reduces the formation of micro cracks during the curing process [10, 17-20]. Therefore, the rapid setting polymer-modified waterproof mortars have lower water permeability.

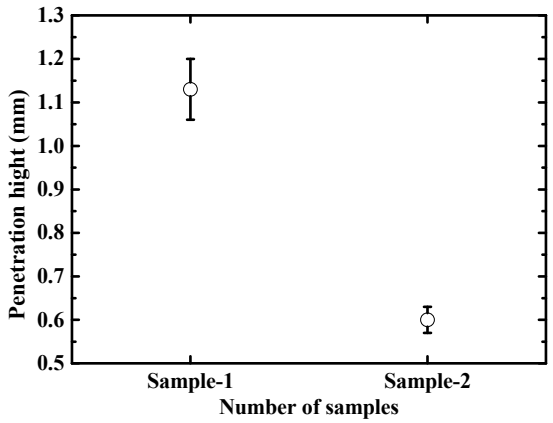

Figure 1. Measured water impermeability for the primary water impermeability tests.

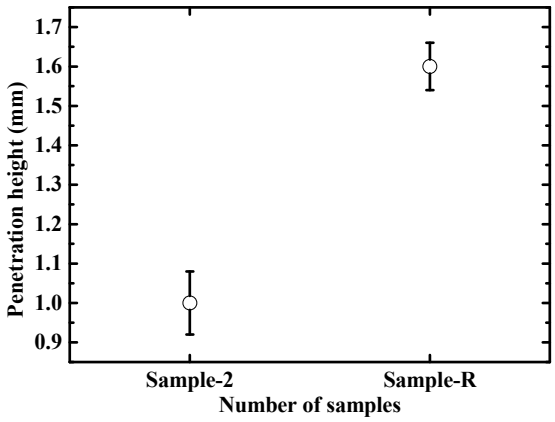

Figure 2. Measured water impermeability for the secondary water impermeability tests.

3.2. Self-repairing properties

Ideally speaking, the secondary water impermeability measurements for sample-2 and sample-R should have been conducted after the high pressure water had percolated through all of the six test specimens. However, as mentioned above, at the maximum hydraulic pressure of 4.5 MPa that the testing device can reach, the high pressure water did not seep through all of the specimens for the sample-2 and sample-R. Therefore, after the hydraulic pressure of the testing device for the primary water impermeability measurements had reached 4.5 MPa for identical 8 hours, the specimens with the moulds cured under standard curing conditions for additional 7 days and subsequently the secondary water impermeability measurements were conducted over these specimens.

Figure 2 compares the measured secondary water impermeability results obtained for the rapid setting polymer-modified waterproof mortar sample-2 and the reference rapid setting waterproof mortar sample-R. As indicated in Figure 2, at the maximum hydraulic pressure of 4.5 MPa, the average penetration height of the secondary impermeability tests for the rapid setting polymer-modified waterproof mortar sample-2 (2 mm) is lower than that of the reference rapid setting polymer-modified waterproof mortar sample-R (1.6 mm), implying that the rapid setting polymer-modified waterproof mortar sample-2 has better self-repairing properties because of the

presence of the specific reactive chemical compounds.

By causing a catalytic reaction, the specific reactive chemical compounds contained in the rapid setting polymer-modified waterproof mortar combine with the moisture present in the capillary tract and the by-products of cement hydration to form insoluble crystalline complexes. These crystals fill the pores, capillary tracts and minor shrinkage cracks in the mortar to prevent any further water ingress (even under pressure) [21-22].

In the absence of water and/or moisture, the reactive chemical compounds remain dormant, yet, they can still activate the by-products of cement hydration upon meeting with water and/or moisture. Subsequently, the chemical reaction and sealing process repeats itself automatically, completing self-repair process.

In the water impermeability measurements, the high pressure water imposed to the mortar specimens may cause recoverable and irrecoverable damages to the specimens [23]. The former damage can be self-repaired via the hydration of cement. As the curing time increases, the strength of cement mortars increases and the mortars gradually lose the thixotropic recoverability [23]. Consequently, the recoverable damages decrease whereas the irrecoverable damages increase. For rapid setting waterproof mortars, after 7 d of curing period, the structural defects caused by the high pressure water of the primary impermeability tests lose the thixotropic recoverability. However, the specific reactive chemical compounds contained in the sample-2 use water as a migrating medium to enter and travel down the structural defects caused by the high pressure water of the primary impermeability tests. Subsequently, the chemical reaction and sealing process repeats itself automatically, completing self-repair process. Therefore, the presence of the specific reactive chemical compounds in the sample-2 improves the self-repairing of the waterproof mortars.

4. Conclusions

The water impermeability and the self-repairing performance of the rapid setting polymer-modified waterproof mortars developed in our laboratory are systematically presented. The experimental results presented above lead us to draw the following conclusions:

1) The modification of rapid setting waterproof mortars with polymer improves the water impermeability of the mortars.

2) The addition of Vandex reactive chemical compound to the rapid setting polymer-modified waterproof mortar improves its self-repairing performance.

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