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Effect of slaked lime and aluminum sulfate on the properties of dry-mixed masonry mortar

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HIGHLIGHTS

- The optimal ratio of slaked lime and aluminum sulfate was determined.
- The compound admixture can better improve the performances of mortar.
- The compound admixture promotes the formation of AFt.
- Results provide new insights into potential ways to improve the performances of mortar.

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ABSTRACT

There are some drawbacks, such as bleeding, poor cohesiveness, etc, because the water to cement (W/C) ratio of dry-mixed masonry mortar is greater. Therefore, the influences of the slaked lime and aluminum sulfate on performances of masonry mortar were studied. The results show that the optimum ratio of slaked lime to aluminum sulfate by weight is 5–1, and the consistency, bleeding and strength of the mortar can be better improved by the two compounds. The consistency increases by 12.3%, the bleeding water decreases by 6.1% and 28d compressive strength of mortar increases by 27.3% when the content of compound admixture is 6 wt%. The results of SEM, XRD and TG-DTA show that the amount of AFt and C-S-H is changed by the slaked lime and aluminum sulfate, the hydration products and hardened structures are optimized by the compound admixture, and the performances of mortar are improved. This is a good reference value for the performance improvement of masonry mortar.

1. Introduction

Building mortar can be divided into ordinary mortar and special mortar, and masonry mortar is a kind of common mortar. According to the kind of cementitious material, masonry mortar can be divided into lime mortar, cement mortar and mixed mortar. Lime mortar has high water holding capacity, but it has lower strength [1], poorer water resistance and easier weathering compared with other kind of mortar; it is easy to deteriorate under freeze–thaw cycles and dry wet cycles, resulting in poorer durability [2,3], therefore, it is usually used in indoor construction. Cement mortar has better water resistance, and it can be used in outdoor construction. However, because of its greater water to cement (W/C) ratio and sand to cement (S/C) ratio, there are some shortcomings in the use of cement mortar, such as poorer water retention, greater bleeding, etc. The hydration of cement is not sufficient and the strength of mortar is decreased because of the reduction of water or the water absorption of the building matrix. To improve performances of mortar, the influences of different kind of additives or fiber materials on performances of mortar were studied.

Spychał [4] presented that the water retention of fresh mortar could be improved by 15% by the cellulose ether, the workability of the mortar was improved and the setting time of mortar was retarded, but at the same time, the compressive strength and adhesion strength decreased a little. The study gave the same regularity by Zhang [5] and Jumate [6]. Cellulose ether is adsorbed on the surface of cement particles, therefore, the early hydration of cement is retarded [7], and performances of mortar are affected with the relevant of the amount and viscosity of Cellulose ether [8,9]. Raupp-Pereira [10] reported the effect of Na-bentonite as a retarder on the performances of mortar, and the mortar had good workability and mechanical properties when its dosage was 0.25–0.5%. The effect of fiber materials on the performances of mortar was reported by Cao [11], the results showed that the surface roughness of the mortar was increased and its porosity was improved,

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and the compressive strength and thermal conductivity of the mortar were increased when the content of the fiber was 0.2–0.7%. Basaran [12] gave the effect of polypropylene fiber with different proportions on the performance of mortar under different wall angles, and the results showed that mortar had good strength, stiffness and ductility. The effect of gypsum on the performances of masonry mortar was studied when the water to gypsum ratio was 0.66 by Bemhoeft [13], and the results of hydration heat showed that hydration of cement was promoted when the content of gypsum was 5%, the performance of mortar was better, and the setting time of mortar was determined by the dosage of gypsum. The effect of air-entraining plasticizers on mortar performance was studied by Lenart [14], and the results showed that air-entraining agent could improve the performance of the fresh mortar, but the flexural strength of the hardened mortar decreased by 20% and the 28d compressive strength also decreased, meanwhile, the water absorption of mortar decreased by about 50%. The effect of adhesive on the properties of mortar was studied by Lanas [15], the proper amount of adhesive could significantly improve the strength of mortar at 28 days, and the pore structure of mortar was optimized and a space for carbonation of $Ca(OH)_2$ was provided. Yan [16] presented the effect of polymer modifier on the performance of mortar, and pointed out that strength at 91 days of mortar mixed with 2.5% and 10% polymer still attained to 91% and 52% strength of control mortar, and dry shrinkage rate decreased by 34% and 64%. Fiat [17] also pointed out that polymer modifiers could promote the anti-deterioration of mortar. New masonry mortar with good thermal conductivity and durability was achieved through adding PCM into mortar [18–20].

Although these measures have good effects on performances of mortar, there are also some shortcomings. For example, cellulose can easily lead to the decrease of the compressive strength and the bond strength, and the air entraining agent makes the strength decrease, etc. At the same time, the addition amount of the admixtures such as cellulose and air entraining agent is small, it is hard to mix well and the agitation of quality is easy to occur, which leads to the greater quality volatility of the mortar, easy bleeding water and the susceptibility. Therefore, the research on the modification of mortar with slaked lime and aluminum sulfate was carried out. On the one hand, the ettringite produced by the reaction of slaked lime with aluminum sulfate can constrain a large amount of water, and sulphoaluminate cement can prepare high water materials because of the main hydration product of AFt [21]. On the other hand, the slaked lime particles have a large specific surface area, and the surface of the particles can absorb a thick layer of water film, so that the particles of the fresh mortar mixture are liable to slip, thereby increasing the water-holding capacity and plasticity of the mortar, and the mechanisms were done.

2. Raw materials and test methods

2.1. Raw materials

Ordinary Portland cement with Grade of 42.5(P.O 42.5) is used, its main property indexes are shown in Table 1, and its main chemical compositions are shown in Table 2. Limestone manufactured fine aggregate (MFA) was used, its fineness modulus is 2.90 and some performances are shown in Table 3. Slaked lime is used, and the effective dosage of calcium hydroxide is 95 wt%. The chemical reagent of aluminum sulfate is used, its chemical formula is $Al_2(SO_4)_3{\cdot}18H_2O$, and its effective dosage is 99 wt%. Clean tap water is used.

2.2. Test methods

Consistency of mortar was measured by mortar consistency meter. Test the bleeding rate of mortar with 500 ml container, put fresh mortar into the container, take the bleeding water out every 10 min interval until no bleeding, and weigh the total amount of bleeding water. Flexural strength and compressive strength were measured with 40 mm × 40 mm × 160 mm cubic samples at the ages of 7 and 28 days.

The XRD was tested with D8 ADVANCE X-ray diffraction produced in the German Brooke company, with an angle of 5°–70° and the scanning speed of 10°/min. Scanning electron micrographs(SEM) was tested with Merlin Compact field emission scanning electron microscope. TG-DTA was tested with HCT-3 type microcomputer differential thermal balance, and the test temperature was from 25 to 650 °C with heating rate of 10 °C/min.

3. Results and analysis

3.1. Slaked lime and aluminum sulfate on the performance of mortar

3.1.1. Effect of aluminum sulfate on the properties of mortar

The amount of cement was fixed at 360 g, the water to cement (W/C) ratio was 1.0, and the sand to cement (S/C) ratio was 5–1. The influences of aluminum sulfate on consistency, bleeding rate and strength of mortar were studied when the slaked lime was fixed at 10 wt% of the cement by weight, and the content of aluminum sulfate is 0 wt%, 1 wt%, 2 wt%, 3 wt%, 4 wt%, and 5 wt% of cement by weight, respectively.

The effect of aluminum sulfate on the workability of mortar is shown in Fig. 1. From Fig. 1, it can be seen that the consistency of mortar firstly increases and then decreases. The consistency increases from 65 mm to 72 mm when the content of aluminum

Table 1
Physical properties of P.O42.5.

Fineness/%	Specific surface area/(m^2/kg)	Stability	Setting time/min		Flexural strength/MPa		Compressive strength/MPa	
			Initial	Final	3d	28d	3d	28d
0.8	366	Qualified	156	225	5.6	9.1	25.1	51.5

Table 2
Chemical composition of P.O42.5/%.

CaO	SiO_2	Al_2O_3	Fe_2O_3	MgO	Na_2O	K_2O	Loss
61.91	21.65	5.32	3.22	2.51	0.21	0.16	0.62

Table 3
Main physical properties of MFA.

Project	Fineness modulus	Apparent density/(kg/m^3)	Loose density/(kg/m^3)	Void ratio/%	Stone powder content/%
MFA	2.90	2681	1541	42	11.5