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Effect of Active Admixture and Air Entraining Agent on Frost Resistance of Volcanic Scoria Thermal Insulation Plastering Mortar

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Abstract. The effects of fly ash, slag powder, diatomite and air entraining agent on the mechanical properties and freeze-thaw resistance of volcanic scoria thermal insulation plastering mortar were studied by orthogonal test. The test results showed that the thermal insulation plastering mortar achieves the best performance when the replacement rate of fly ash was 20% , the substitution rate of slag micropowder and diatomite is 10%, and the amount of air entraining agent is 0.1% . Compared with the ordinary thermal insulation plastering mortar, the 28d compressive strength is increased by 17.8% , the strength loss rate was reduced by 34.5% and the quality loss rate was reduced by 43.3%. Observing the microstructure of the thermal insulation plastering mortar by SEM, active admixture is beneficial to improving the structure of the hydration product and improving the compactness of the thermal insulation mortar.

1. Introduction

Winter in northern China is very cold, often accompanied by snowstorms. After several years of construction of a large number of thermal insulation projects, a large area of freezing damage of external wall thermal insulation mortar occurs under the action of alternating wet-dry and freeze-thaw cycles, which affects the safe use of the project[1]. It is found that the mechanical properties and durability of thermal insulation mortar prepared with volcanic scoria as light aggregate have been greatly improved compared with the previous glazed hollow beads thermal insulation mortar[2]. Using various active admixtures such as fly ash, slag powder and diatomite[3] as building materials can not only reduce the amount of cement, but also improve the submicrostructure of cement-based materials, so as to improve the basic mechanical properties and freeze-thaw resistance of cement-based materials, which has become an important direction in the development of building science. At present, there are more studies on the application of admixtures in concrete, and less studies on the application of admixtures in thermal insulation mortar[4]. In this paper, the effects of fly ash, slag powder, diatomite and air entraining agent on the basic mechanical properties and freeze-thaw resistance of thermal insulation plastering mortar with volcanic scoria were studied by orthogonal test.

2. Experimental part

2.1. Raw materials



Cement is Dinglu P.O 42.5 grade cement produced by Yatai Group of Jilin Province; fly ash is grade II fly ash, used after grinding, and its chemical composition is shown in Table 1; chemical composition of slag powder is shown in Table 1; diatomite is the third-grade low-grade diatomite in Changbai County of Jilin Province, used after purification and activation, and its chemical composition is shown in Table 1; air-entraining agent: sodium dodecyl sulfonate; volcanic scoria: lightweight volcanic scoria, produced in Huinan County of Jilin Province. Other materials: Powdered polycarboxylic acid series superplasticizer, redispersible latex powder, hydroxypropyl methyl cellulose ether, tap water.

Table 1. Chemical composition of admixture/%

Name	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO+k ₂ O	Other ingredients
Fly ash	53.82	27.13	7.14	2.82	2.52	6.57
Slag powder	34.6	14.7	0.65	35.8	10.81	3.44
Diatomite	92.13	5.45	1.23	0.53	0.54	0.12

2.2. Test method

When preparing the test piece, first mix the cement, admixture, etc. in a certain proportion, then add the volcanic scoria and mix evenly to make the dry mixed heat preservation mortar, and add water and stir when using it. After the specimen was molded for 24 h, the specimens were demolished and cured for 28 days. The compressive strength of the mortar for 28 days and the frost resistance of the mortar under 25 freeze-thaw cycles were tested. According to the relevant requirements of JC/T 890 "autoclaved mortar for autoclaved aerated concrete wall" and JGJ/T 70 "Standards for Testing Basic Performance of Building Mortar", the performance of the thermal insulation plastering mortar is tested.

3. Experimental results and discussion

3.1. Orthogonal design

The purpose of this test is to study the influence of fly ash, slag powder, diatomite and air entraining agent on the 28d compressive strength and freeze-thaw resistance of volcanic scoria thermal insulation plastering mortar by orthogonal test, in order to obtain a mix ratio with suitable strength and resistance freeze-thaw durability. The relationship between orthogonal test factors and horizontal variables in Table 2, the orthogonal test plan and results in Table 3 (The fly ash and slag powders use over-substituted method [5], the supergeneration coefficient is 1.3; the diatomite is replaced by an equal amount, and the air entraining agent is based on the mass percentage of the cementitious material).

Table 2. Level table of orthogonal experimental factors

Factor Level	Fly ash substitution rate/%	Slag powder replacement rate/%	Diatomite substitution rate/%	Air entraining agent content/%
1	0	0	0	0
2	10	10	10	0.10
3	20	20	20	0.20

Table 3. Orthogonal experiment results

Column number Test No.	A	B	C	D	28d Compression Strength /MPa	Strength loss rate after 25 freeze-thaw cycles/%	Mass loss rate after 25 freeze-thaw cycles /%
1	1	1	1	1	7.3	14.8	3.58
2	1	2	2	2	6.8	11.4	2.34
3	1	3	3	3	5.2	15.6	3.66

4	2	1	2	3	5.9	16.8	2.97
5	2	2	3	1	7.7	10.6	2.72
6	2	3	1	2	6.4	12.7	2.99
7	3	1	3	2	6.3	13.5	2.35
8	3	2	1	3	6.6	14.7	3.02
9	3	3	2	1	8.1	10.5	2.53

3.2. compressive strength

The 28d compressive strength is an important parameter for evaluating the mechanical properties of the insulating mortar. The 28d compressive strength calculation results of the thermal insulation mortar are shown in Table 4. The relationship between the 28d compressive strength k value and the factors and levels of the thermal insulation mortar is shown in Fig. 1.

Table 4. 28d compressive strength calculation results

Factor	A	B	C	D
Calculated value				
k1	6.43	6.50	6.77	7.70
k2	6.67	7.03	6.93	6.50
k3	7.00	6.57	6.40	5.90
Δ R	0.57	0.53	0.53	1.80
Optimal result	7.00	7.03	6.93	7.70

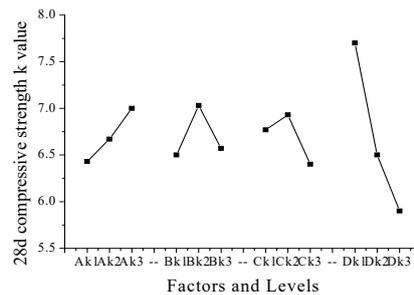


Fig. 1 28d compressive strength k value and its relationship with factors and levels

It can be seen from the extremely poor results of Table 4 that the main factors affecting the compressive strength of the volcanic scoria thermal insulation plastering mortar 28d are air entraining agent>fly ash>slag powder=diatomite. Analysis of Fig. 1 shows that the incorporation of air entraining agent will reduce the compressive strength of the thermal insulation mortar. In a certain range, fly ash, slag powder and diatomite are beneficial to enhance the 28d compressive strength of the thermal insulation mortar. When the substitution rate is in the range of 0%~20%, the compressive strength of thermal insulation plastering mortar increases with the increase of fly ash substitution rate. It's due to after the mechanical grinding, the spherical vitreous structure of the fly ash is destroyed, the chemical activity is greatly improved, and the secondary hydration reaction with the calcium hydroxide produced by the hydration of the cement can be generated in the hydration process, secondary hydrated calcium silicate and hydrated calcium aluminate with cementitious effect are produced, which improves the later strength of thermal insulation plastering mortar. The effect of slag powder and diatomite on the compressive strength of the thermal insulation plastering mortar is similar. When the substitution rate is 10%, both slag powder and diatomite can improve the 28d compressive strength of thermal insulation plastering mortar. Because of the high activity of slag powder, the strength of thermal insulation plastering mortar is improved more obviously.

3.3. Frost Resistance

The number of freeze-thaw cycles is 25, the strength loss rate is shown in Table 5, and the mass loss rate is shown in Table 6. The effects of factors and levels on the strength loss rate and the mass loss rate k are shown in Figures 2 and 3, respectively.

It can be seen from the extremely poor results of Table 5 that the air entraining agent is the most important factor affecting the strength loss rate after the freeze-thaw cycle of the thermal insulation mortar. The slag micropowder is second, the effects of fly ash and diatomite are relatively weak and the results are very close. From Table 6 we can see that the most important factor affecting the mass loss rate of the thermal insulation plastering mortar is the air entraining agent, followed by the fly ash and diatomite, and the effect of the slag micropowder is slightly weaker. Fig. 2 and Fig. 3 shows that with the increase of the amount of air entraining agent, the strength loss rate of the thermal insulation plastering mortar gradually increases, and the mass loss rate first decreases and then increases, which is due to the incorporation of the air entraining agent. The gas content of the thermal insulation plastering mortar is improved, but at the same time, the pore structure inside the thermal insulation plastering mortar is also improved. With the increase of the replacement rate of fly ash, the strength loss rate and mass loss rate of the thermal insulation plastering mortar after the freeze-thaw cycle show a decreasing trend, because the physically activated fly ash has a large specific surface area and high chemical activity, the micro-aggregate filling effect is good, and the internal structure of the thermal insulation plastering mortar is improved. With the increase of the amount of slag powder and diatomite, the strength loss rate and mass loss rate of the thermal insulation plastering mortar were firstly reduced and then increased.

Table 5. 25 calculation results of strength loss rate after freeze-thaw cycles

Factor	A	B	C	D
Calculated value				
k1	13.93	15.03	14.07	11.97
k2	13.37	12.23	12.90	12.53
k3	12.90	12.93	13.23	15.70
Δ R	1.03	2.80	1.17	3.73
Optimal result	12.90	12.23	12.90	11.97

Table 6. 25 Calculation results of mass loss rate after freeze-thaw cycles

Factor	A	B	C	D
Calculated value				
k1	3.19	2.97	3.20	2.94
k2	2.89	2.69	2.61	2.56
k3	2.63	3.06	2.91	3.22
Δ R	0.56	0.37	0.59	0.66
Optimal result	2.63	2.69	2.61	2.56

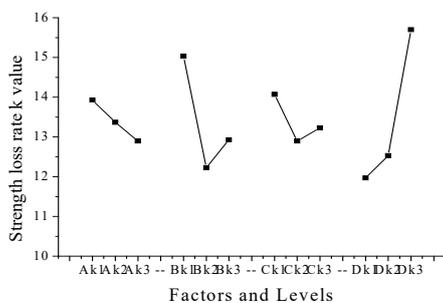


Fig. 2 Strength loss rate K value and its relationship with factors and levels

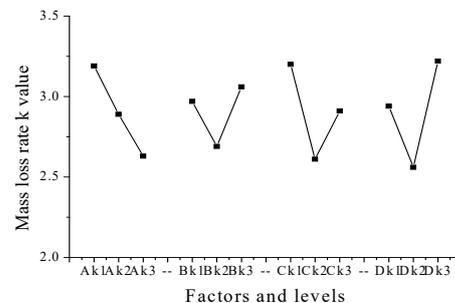


Fig. 3 Mass loss rate K value and its relationship with factors and levels

Considering the influence of admixture and air entraining agent on the 28d compressive strength, strength loss rate and mass loss rate after freeze-thaw cycle, the optimal mix ratio should be $A_3B_2C_2D_2$. Compared with $A_1B_1C_1D_1$, the compressive strength of volcanic scoria thermal insulation plastering mortar increased by 17.8%, the strength loss rate decreased by 34.5% and the mass loss rate decreased by 43.3%.

Table 7. Performance of volcanic scoria thermal insulation plastering mortar under optimal mix ratio

28d compressive strength /MPa	strength loss rate after 25 freeze-thaw cycle/%	mass loss rate after 25 freeze-thaw cycle/%
8.6	9.7	2.03

3.4. SEM analysis

Comparing (a) and (b) of Fig. 4, when the admixture is not blended, the cement hydration produces a large amount of calcium hydroxide, and the structure of the hydrated product is not dense, shows that the thermal insulation plastering mortar has low compressive strength and poor durability against freezing and thawing. Under the optimal mix ratio, the calcium hydroxide produced by cement hydration and the active component in the admixture undergo secondary hydration reaction, which is completely consumed, and the generated secondary hydration product and cement hydration product are intertwined, and the structure is dense, shows that the thermal insulation plastering mortar has high compressive strength and good durability against freezing and thawing.

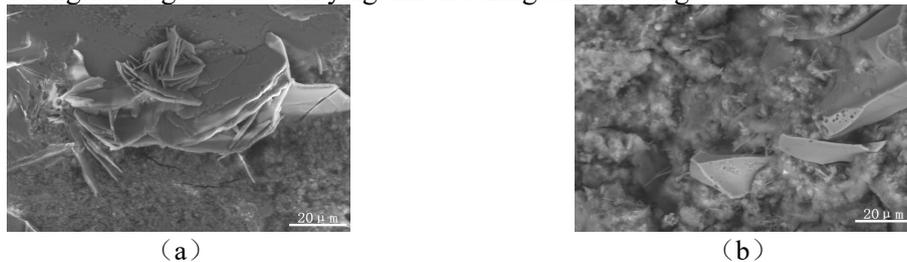


Fig.4 Partial SEM image of volcanic slag insulation mortar (a) $A_1B_1C_1D_1$ (b) $A_3B_2C_2D_2$

4. Conclusion

(1) Incorporation of fly ash, slag powder and diatomite is beneficial to enhancing the 28d compressive strength of volcanic scoria thermal insulation plastering mortar and improving its resistance to freeze-thaw durability.

(2) The incorporation of air entraining agent is beneficial to improving the internal pore structure of the thermal insulation plastering mortar and reducing the mass loss rate of the freeze-thaw cycle.

(3) The replacement rate of fly ash is 20%, the substitution rate of slag powder and diatomite is 10%, and the performance of thermal insulation plastering mortar is the best when the amount of air entraining agent is 0.1%. Compared with ordinary insulation mortar, the 28d compressive strength increased by 17.8%, the freeze-thaw cycle strength loss rate decreased by 34.5%, and the mass loss rate decreased by 43.3%.

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