High Performance And Low Cost Compound Admixture Of Expanded Perlite Powder/Redispersible Polymer Powder For Dry-mixed Mortar

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Abstract. Since modern architectural technology has set a new standard for toughness of mortar, expensive polymer admixture has been used to modify dry-mixed mortar currently. But high cost critically restricted popularization of dry-mixed mortar. A new expanded Perlite powder-redispersible Polymer powder Compound dry-mixed mortar Admixture (PPCA) was researched in this paper. The research has indicated that PPCA showed synergistically optimized effect. There was the best modification effect when expanded perlite powder/redispersible polymer powder rate was 2 and admixture/cement rate was 0.15. The Ratio of Compressive strength to Flexural strength (RCF) declined to less than 3 when compressive strength of mortar staying above 10MPa. Moreover, cost of this compound admixture only was 1/3 of redispersible polymer powder admixture of the same performance. Meanwhile, this PPCA can improve water retention and increase softening coefficient of mortar to above 1.

Introduction

Nowadays, developing architectural technology and improving people's living standard require building mortars to demand for more higher performance [1], and one of key-issues is toughness of mortar. In many types of Chinese mortar standards, the way used to assess the cement mortar performance is measuring the ratio of compressive strength to flexural strength of mortar whether it is less than 3.

At the same time, the government is actively making dry-mixed mortar more widespread because of its advantages compared with traditional mortar. Hence, in order to obtain the dry-mixed mortar complying with stipulation about the Ratio of Compressive strength to Flexural strength (RCF), currently polymer admixture such as redispersible polymer powder (RPP) [2] was added to the traditional cement mortar to produce polymer modified dry-mixed mortar [3]. Though polymer modified dry-mixed mortar with excellent performance can be utilized in all aspects of construction field, the price of polymer admixture is too to accepte. What's more, the cost of polymer admixture occupies 60% to 80% of total cost of mortar due to the high ratio of polymer admixture in common industrial formulation (usually the polymer to cement ratio reaching 20%) [4]. Now the unacceptable cost is the key hindrance to popularize dry-mixed mortar in construction market.

In this contribution, expanded perlite powder (EPP) and redispersible polymer powder (RPP) were compounded to prepare a new dry-mixed mortar admixture. The research aimed to reduce the cost of dry-mixed mortar while meeting the requirement that the (RCF) was less than 3. A number of studies have been reported in the paper concerning the modification effect of expanded Perlite powder- redispersible Polymer powder Compound dry-mixed mortar Admixture (PPCA) on traditional cement mortar in inorganic-organic composite approach. The PPCA also was compared with pure redispersible polymer admixture in the strength modification behavior.

Experiment

Materials and basic formulation. The EPP used in experiment was the waste dust coming from bag-type dust collector in the expanded perlite production process, which belongs to industry solid waste. Polymer admixture compared was the RPP type 2350(AkzoNobel, Netherland). Before experiment the microstructure and the surface topography of EPP were observed by scanning electron microscope (SEM, Hitachi S4800). The basic formulation of mortar to be modified was shown in Table1.

Table1 Basic formulation of mortar to be modified

component	Component/cement mass ratio
Cement	1
Sand	3
Cellulose ether	≤0.003
Polypropylene fiber	≤0.003
Lignocelluloses	≤0.003

Measurement of water retention property of mortar. The water retention property measurement was carried out according to JGJ/T 70-2009 Standard for test method of basic properties of construction mortar. A set of EPP was added into dry-mixed mortar respectively, and the EPP/cement mass ratio was in a range from 0.1 to 0.5. After dry agitation to effectively mix the raw, a certain number of water was added with keeping consistency of grout staying in 80mm. Then the mortar samples were encased into the annular mould, and the water retention property was measured following standard procedure.

Measurement of the RCF. The experiment of measuring the RCF of mortar was carried out according to DB33/T1054-2008 The technical code for thermal insulating rendering systems based on mortar with mineral binder and using lightweight inorganic granule aggregate. In this try, the admixture added into the mortar was designed into four different series shown in Table 2. The raw materials were mixed with a certain number of water by agitation, following that the mixture was encased into triple 160mm×40mm×40mm rectangular mould to prepare test coupons for strength test. At last, the mortar samples were cured in the Standard Curing Box of Cement in condition of temperature of 20±2°C and relative humidity above 90% for a period of time before testing the compressive strength and flexural strength of mortar samples.

Table 2 Four admixture series

Series number	RPP/cement mass ratio	EPP/cement mass ratio
1	0	0.10~0.30
2	0.05	0.05~0.20
3	0.10	0~0.20
4	0.1~0.25	0

Measurement of softening coefficient of mortar modified by PPCA in optimal formulation. The experiment of measuring softening coefficient of mortar modified by PPCA in optimal formulation was carried out according JG158-2004 External thermal insulating rendering systems made of mortar with bonding powder and using expanded polystyrene granule as aggregate. The mortar samples were mould into 100mm×100mm×100mm cube specimens, then were immersed in water at temperature of 20±5°C for 48h and placed in air at the same temperature for 24h. The bond tensile strength of samples was tested before and after preparing procedures.

Results and discussion

Characterization of the microstructure and the surface topography of EPP. The main chemical composition of EPP was SiO_2, Al_2O_3, Fe_2O_3, FeO, CaO, MgO, K_2O, Na_2O, MnO, which was exactly the same as normal expanded perlite particle. SEM photograph of EPP was shown in Fig.1. Fig.1 illustrated that the most of EPP was the broken cell wall fragment of foramens generated at high temperature when the perlite particle expanded rapidly. Also the figure showed clearly that the shape of powder was irregular and piecemeal, and diameter of majority of powder was between 20 to 40μm while some particles with patchy foramens were between 60 to 80μm. In addition, it could be observed that through the broken cell wall there were plenty of connected or disconnected holes in patchy particles.

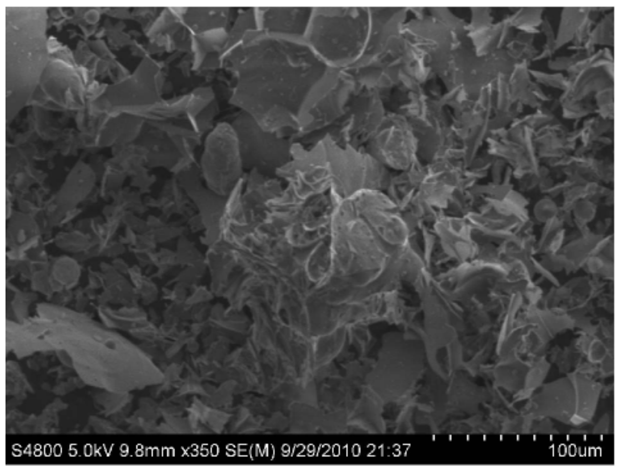
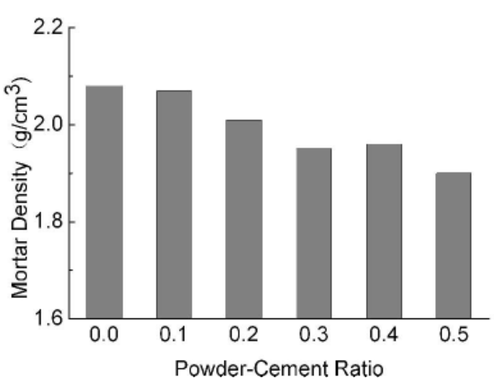


Fig.1. SEM photograph of EPP

Influence of EPP to the water retention property of mortar. The effect to the bulk density of fresh mortar brought into by EPP was diagrammatic in Fig.2. It's indicated that the bulk density continually declined with increasing amount of EPP blended in, which elucidated that not only the water demand increased but also air entraining was caused by EPP in the mortar. So that EPP was beneficial to enhanced water retention property of mortar. What's more, the air entraining also could improve the crack resistance of mortar.



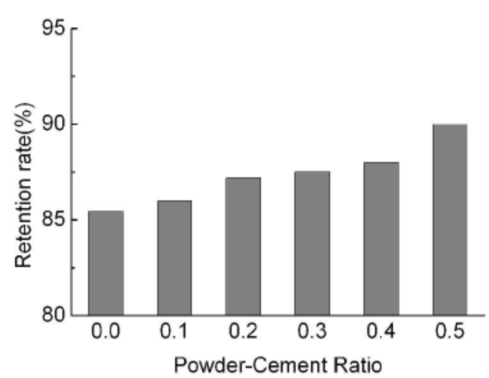


Fig.2. Influence of powder to mortar density Fig.3. Influence of powder to water retention

The Fig.3 diagramed the influence of EPP to water retention property. In the figure, water retention property increased with increasing amount of EPP blended in, which explained the role of EPP in improving water retention property of mortar. When the EPP was added into mortar system, the degree of bending of water floe channels was increased, and the free movement of water in the mortar was restricted. Hence, the bleeding of mortar was reduced. Moreover, fixing and making free water to distribute more uniformly had contribution to hydration reaction of mortar.

Comparison between the influence of PPCA and RPP on the mechanical property of mortar. Fig.4 shows the influence of four admixture series to the compressive strength of mortar. With increasing amount of four admixture series, the compressive strength of all mortar samples kept continuously declining. When adding mass of admixture was ranging from 0.1 to 0.25 of cement mass, the compressive strength of mortar samples modified by admixture series 2 and 3 in which EPP and RPP were compound were lower than mortar samples modified by pure RPP, but higher than 8MPa, both. The compressive strength of mortar samples modified by pure EPP declined too fast so that the EPP could not be used as admixture alone.

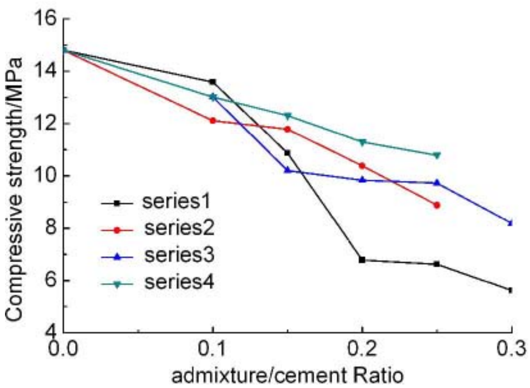


Fig.4. Influence of 4 of admixture series to compressive strength of mortar (28d)

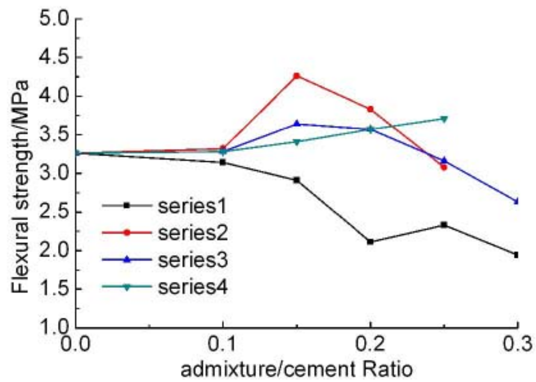


Fig.5. Influence of 4 admixture series to flexural strength of mortar (28d)

Fig.5 shows the influence of four admixture series to the flexural strength of mortar. The result indicated that flexural strength of mortar samples added EPP only continued to decline; on the contrary, mortar samples added RPP only of which flexural strength continued to increase. It's unpredictable but reasonable that the mortar samples modified by two PPCA series of which flexural strength illustrated increase at first and then decline. When the admixture mass was 0.15 of cement mass, mortar samples modified by PPCA, in which the rate of EPP to RPP was 1:2 or contrary, showed higher flexural strength than mortar samples modified by RPP alone. The same result occurred when the admixture mass was 0.2 of cement mass and the rate of EPP to RPP was 3:1 in admixture.

It's easy to get RCF of mortar, and Fig.6 shows the result. Both of admixture series 2 and 3 could make RCF of mortar fell below 3. Though RPP could make the RCF of mortar decline continuously, the ratio was not lower than 3 until the admixture was added more than 0.2 of cement mass. EPP also could be used to bring the RCF of mortar down, but considering strength results discussed in above paragraphs there was no meaning in practical application.

Considering the data of compressive strength, flexural strength and the RCF of mortar, when the admixture mass was 0.15 of cement mass and admixture was composed of EPP and RPP in rate 2 to 1, the mortar samples attained the most satisfactory comprehensive performance: the RCF was below 3 with compressive strength not declining too much. Even compared with RPP, this kind of admixture still had an advantage in performance. Furthermore, EPP was a kind of industrial solid waste, the cost was no more than 1000￥/t, on the contrast, RPP cost 20000￥/t at least. So the cost of this PPCA could achieve a minimum of one-third of pure RPP admixture.

The influence of PPCA to the strength before and after immersion of mortar compared with RPP was illustrated in Fig.7. It is surprising that the calculative soften coefficient of mortar modified by compound admixture was above 1.0 while the other only was 0.84. This result also shows an advantage of PPCA.

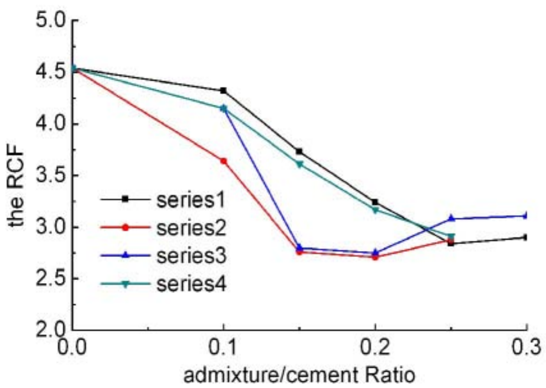


Fig.6. Influence of 4 admixture series to the RCF of mortar (28d)

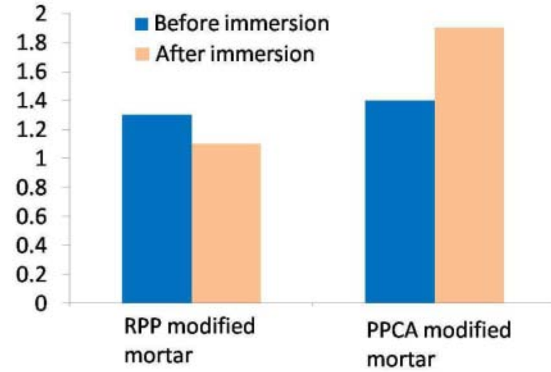
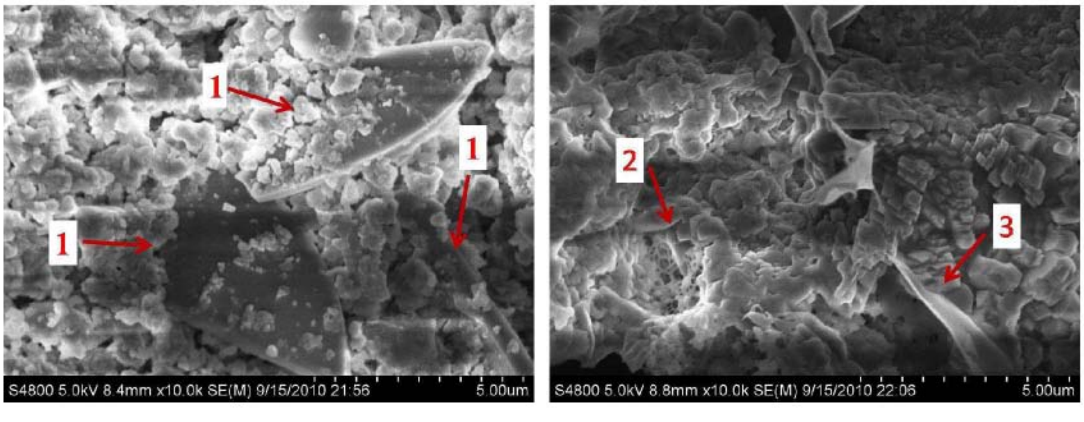


Fig.7. Bond tensile strength of two admixture modified mortar

In Fig.8 (a), it could be found there was plenty of hydration product adhering on surface of EPP (mark 1), which proved the right reaction place where cement hydration process was carried out. Most of hydrated aluminium silicates first generated covered the surface leading to restriction of diffusion of $Ca(OH)_2$ crystal, which caused enhancement of interface boundary [5] and improved cracking resistance of cement mortar [6]. On the other hand, EPP in cement mortar could reduce the elastic modulus of the local area, which could reduce the stress intensity factor in the crack tip of mortar to improve toughness of cement mortar [7]. Adding EPP alone was no positive effect on the flexural strength of mortar, because at the same time, the water demand had sharp increase under the condition of same mortar fluidity resulting that water-cement ratio increased substantially, making no use to increasing mortar strength.

After EPP and RPP was compound, the RPP filling the gaps and pores in the cement [8] and EPP enhancing mortar interface boundary could be implemented simultaneously. After hydration reaction the RPP turned into continuous glutinous elastic films (Fig.8 (b) mark 3) which the hydrate and RPP agglutinate to, and polymer-EPP- hydrated cement interpenetrating matrix was formed(Fig.8 (b) mark 2), improving toughness of mortar, increasing fracture energy to restrict crack propagation, and ultimately enhancing flexural strength of mortar. In addition, when the mortar was immersed form several hours, if there was organic film only, the mortar would be soft, but EPP was inorganic so that it could become supporting point to maintain strength of mortar. Also it may be the secondary activity reaction of EPP why the strength of mortar was enhanced after long time immersion.



(a) (b)

Fig.8. SEM photographs of microstructure of PPCA modified mortar
(1- Expanded perlite powder; 2- Polymer-Powder-Cement hydration mixture; 3- Polymer film)

Conclusion

1. Compared with admixture prepared by EPP or RPP alone, the PPCA had an advantage in modifying mortar, which had shown the modification effect of collaborative optimization.
2. When the PPCA was composed by EPP and RPP of rate 2 to 1, and the adding mass was 0.15 of cement mass, the RCF of the modified mortar declined below 3 with compressive strength meeting 10MPa. What's more, the minimum cost of admixture was only one-third of RPP admixture with same performance.
3. PPCA can increase the softening coefficient of mortar, maintain or even enhance the bond tensile strength after immersion of mortar.
4. PPCA can increase water retention of mortar, so that work ability is greatly improved.EPP is a kind of industrial solid waste, making it useful in the production of inorganic-organic compound admixture will produce economic and environmental benefits, and there is a broad application prospect in the construction industry.

Acknowledgements

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