Application of silane coupling agent in composite epoxy cement mortar

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This paper studies the performance influence of silane coupling agent on portland cement mortar, polymer modified cement mortar, steel fiber reinforced mortar and steel fiber polymer modified cement mortar, as well as its influence mechanism. The results show that solution of silane coupling agent with the concentration of 0.5%~1% can not only enhance obviously the flexural strength and tensile strength of various types of CMMR, but also improve the consistency of Portland cement mortar and polymer modified cement mortar, however, its delamination degree shall increase a little.

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Keywords: Silane coupling agent, Cement mortar, Polymer, Steel fiber

1. Introduction

Mortar is widely used in construction area, and gradual development of architecture technology leads to higher performance requirement for cement mortar, thus each country across the world has developed various CMMR materials in the past years. Since polymers have good bond force and higher tensile strength, further to this, the flexural degree, tensile strength and bond force of polymer cement-based composite materials have been obviously improved comparing with portland cement-based materials, meanwhile, the introduction of polymer also improves the microstructure of original Portland cement-based materials, thereby, excellent performance enables the widespread use of polymer cement mortar[1]; steel fiber reinforced cement-based composite material is also an engineering material with excellent performance. As far as current research and application over the world are concerned, though both polymer cement-based composite material and steel fiber cement-based composite material have displayed a variety of excellent performances, however, the enhancement of polymers and steel fiber toughening effect have not played their full role due to the invalidity of interfacial wettability and bond force resulting from thin interfacial [2].

Two different reactive groups, which lie in silane coupling agent molecule, enable to achieve chemical bonding between interface of inorganic materials and organic ones to significantly improve the strength and aging-resistant performance, thus physical and mechanical properties and durability of composite materials have been strikingly enhanced.

This paper uses silane coupling agent with different concentration in several types of CMMR to test their changer of various physical and mechanical properties to study the performance influence of silane coupling agent on various types of CMMR.

2. Experimental materials methods

2.1 Experimental materials

Cement: PC 32.5R composite Portland cement, produced by Jingyang Yaobai Cement Co.，Ltd.; Sand: standard sands; Steel fiber: length-diameter ratio: 39, equivalent diameter: 0.81 mm, density: 7.8g/cm^3, corrugated, Shangyu Huaxia Geosynthetic Material Co.，Ltd.; Polymer: elastic water-resistance styrene-acrylate emulsion, solid content: 56%，produced by Guangzhou Honsea Chemistry Co.，Ltd.; Silane coupling went: KH-550.

2.2 Experimental methods

Mortar-cube was molded in accordance with standard methods and conserved for 7 days and 28 days, after that strength test was carried out. Consistency and delamination degree of mortar were examined according to specifications.

Took out cement mortar powder after being baked at 100°C for 1h, immediately added 20mL silane coupling agent with the volume fraction of 1% while blending, after that dried them under the same condition; after being cooled, cement mortar powder should be repeatedly flushed with anhydrous alcohol, and then it was pressed into tablets together with KBr, and finally test would be carried out with Vector 33 Fourier transform infrared

spectrometer made of Bruker Company of Germany.

The sample was dried at 50°C and vacuum-pumping for 1h, and then it was placed in a storage. Natural and fresh fracture sample was used with gold-plated surface, and S-550 made by Japan Hitachi Ltd, was used to carry out scanning electron microscopy(SEM) analysis.

3. Experimental results and analysis

3.1 Performance influences of silane coupling agent on portland cement mortar

Used silane coupling agent solution with the concentration of 0.5%, 1% and 2% respectively mixing with Portland cement mortar to achieved the tested results on consistency and delamination degree which are shown as Table 1, and the tested variation curves of 7-day, 28-day flexural force and compression strength which as shown in Fig. 1 and Fig. 2.

Table 1. Consistency and delamination degree values.

Added silane Concentration	0%	0.5%	1%	2%
Consistency /cm	2.1	2.5	3.6	3.5
Delamination degree/cm	1.9	2.0	2.0	2.1

Observing Table 1, we know that with the increase of dosage in silane coupling agent, the consistency also grows, which is much more obvious when the dosage of silane coupling agent exceeds 1%. It is proved that the use of silane coupling went has improved fluidity of mortar an<l increased delamination degree a little.

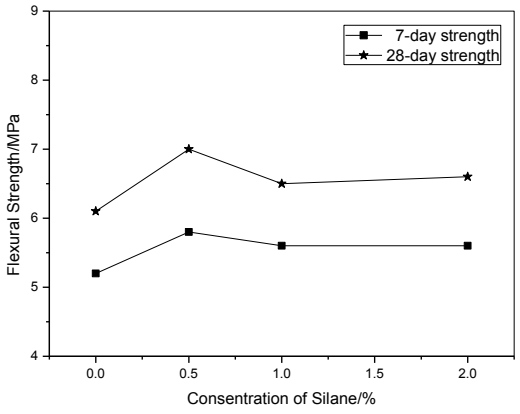


Fig. 1. 7-day and 28-day flexural strength of portland cement mortar processed with silane.

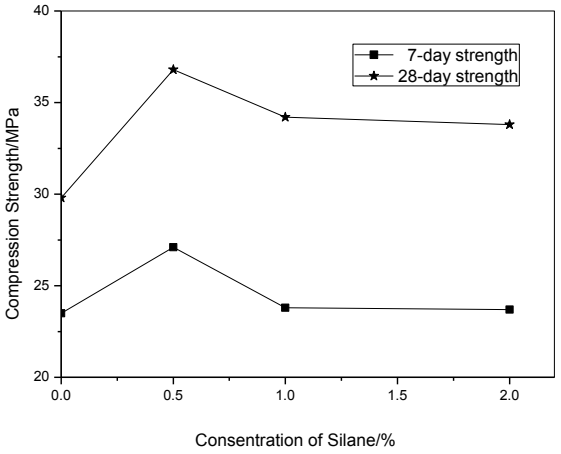


Fig. 2. 7-day and 28-day compression strength of portland cement mortar processed with Silane.

Observing Fig. 1 and Fig. 2, flexural strength and compression strength of the mortar-cubes with adding silane coupling agent have increased to differ agent. With the increase of the dosage, their flexural strength and compression force have decreasing trend after being enhanced to a certain degree. When the dosage of Silane coupling agent is 0.5%, the values of flexural strength and compression strength have increased significantly. It is indicated that appropriate dosage of silane coupling agent could play a role to modify cement mortar. Based on bonding mechanism of silane coupling agent on siliceous materials surface, cement mortar paste is abundant in-OH, which could be combined with free silane group in silane coupling agent and form hydrogen bond, thus two silane groups respectively combined with-OH and formed hydrogen bonds, with gradual hydration and drying, hydrogen bond has transferred into chemical bond[4] by dehydration. Under the special condition of strong chemical activity of cement mortar, silane coupling agent in cement mortar could form Si-O-Si chemical bond, to enable cement mortar to bind more firmly, thus the strength is increased. If too little silane coupling agent is used, not all mortar could be coated, and if less Si-O-Si bond in uncoated mortar formed with silane coupling agent, the strength will be lowered; when silane coupling agent has reached optimal dosage, it will form monomolecular layer on cement mortar surface, with the best effect; if too much silane coupling agent is used, it will form polymolecular layers, which is not only unnecessary but also brings negative effect [3-4]. As for portland cement mortar, the optimal dosage of silane coupling agent is 0.5%.

3.2 Performance influence of silane coupling agent on styrene-acrylic latex modified cement mortar

Added styrene-acrylic latex in cement mortar for

modification, then added 0.5%, 1%, 2% and 6% silane coupling agent respectively, the tested results on consistency and delamination degree were shown in Table 2, and the tested variation curves 7-day and 28-day flexural strength, compression strength were shown in following Fig. 3 and Fig. 4.

Observing Table 2, we know that silane coupling agent significantly has improved the consistency of styrene-acrylic modified mortar, i.e. has significantly improved fluidity of mortar, compared with Portland cement mortar, the improved extent is much greater; but silane coupling agent also enables delamination degree of the mortar to increase a little.

Table 2. Consistency and consistency number of styrene –acrylic mortar processed with different concentrations of silane coupling agent.

Added silane Concentration	0%	0.5%	1%	2%
Consistency /cm	3.3	3.9	4.6	4.9
Delamination degree/cm	1.9	2.1	2.4	2.4

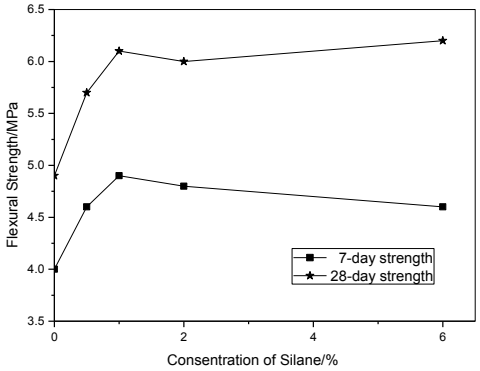


Fig. 3. 7-day and 28-day flexural strength of styrene-acrylic mortar processed with silane.

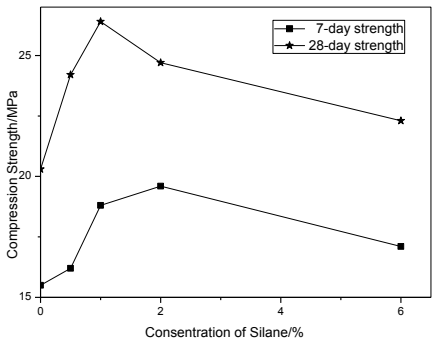


Fig. 4. Play and 28-day compression strength of styrene-acrylic mortar processed with silane.

Observing Fig. 3 and Fig. 4, we know that silane coupling agent an enhance flexural strength and compression strength values of this kind of mortar, and when silane coupling agent is 1%，its play and 28-day strength have enhanced strikingly, an<l strength values are approximately 20% higher than those without being processed with silane coupling agent. Compared with mortar above, the extent of strength increase for styrene-acrylic modified mortar is obviously higher than that for Portland cement mortar.

When concentration of silane coupling agent exceeds 1%， its flexural strength changer little while its compression strength shows a downward trend.

Since chemical reaction between polymer and inorganic cementing material is the assumption to form ionic bond or covalent bond(or forming ionic bond and covalent bond at the same time). Basing on analysis of inorganic cementing material polymer science, we can assert that it is impossible for organic polymer and inorganic cementing material for covalent bond under hydraulicity condition. Only when there is the presence of polyelectrolyte, chemical interaction can be formed through ionic bond[5].Two groups in silane coupling agent molecules can respectively form firm covalent bond with inorganic cementing material and polymer, thus the two materials combined with each other closely, and plays a role of improving the structure, thus its flexural strength and compression strength have been increased.

3.3 Performance influence of silane coupling agent on steel fiber cement mortar

Added 0.5%, 1%, 2% and 6% silane coupling agent respectively to process steel fiber, then added in volume ratio of 1.5% into portland cement mortar, and the tested 7-day and 28-day flexural strength, compression strength were shown in following Fig. 5 and Fig. 6.

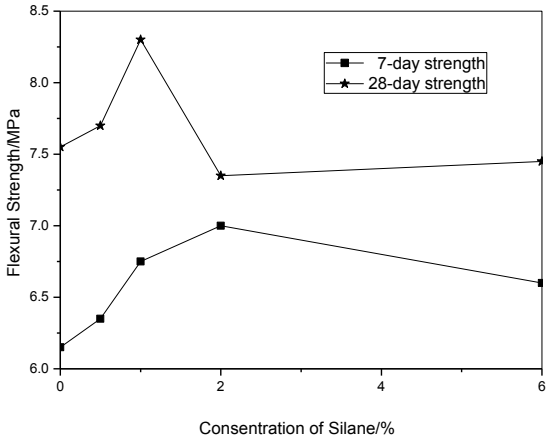


Fig. 5. 7-day and 28-day flexural strength of steel fiber mortar processed with silane.

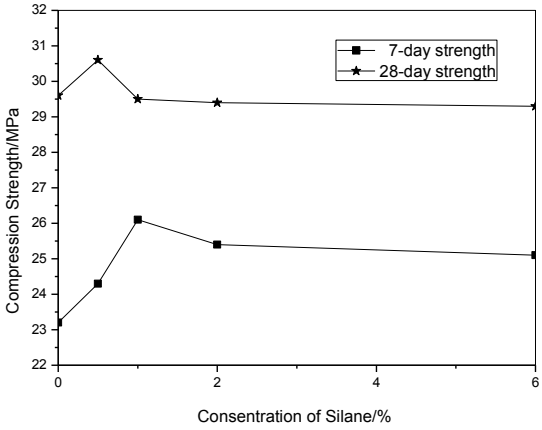


Fig. 6. 7-day and 28-day compression strength of steel fiber mortar processed with silane.

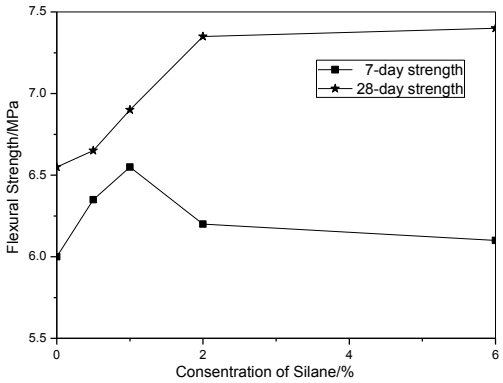


Fig. 7. 7-day and 28-day flexural strength of steel fiber styrene-acrylic latex mortar processed with silane.

Observing above-mentioned two figures, we know that with the increase dosage of silane coupling agent for the processing of steel fiber, flexural strength and compression strength have the increasing trend at the beginning, then decrease a little or keep unchanged, when the concentration is 1%, both strengths will be enhanced. After load-carrying of steel fiber and substratecs interface, the thinnest position would be destroyed first. After being processed with silane coupling agent, steel fiber will form a chemical reaction film [6] which closely combined with ferrous material through chemical bonding. The film can not only prevent metal surface from corroding, besides hydrogen bonding between groups of easy hydrolysis and hydration products of mortar play a role of bridging, which enables the interfacial structure to become more compact, and increase interfacial bonding force, thus mechanical properties of steel fiber enforced mortar have been increased to a certain degree.

In comparison with portland cement mortar, we know that after adding steel fiber processed with silane coupling agent, its flexural strength will be much higher than that of mortar without adding steel fiber, and its peak value will be approximately 20% higher. Compression strength has been increased unobviously.

3.4 Performance influence of silane coupling agent on steel fiber polymer modified cement mortar

Added steel fiber (volume ratio of 1.5%) processed with silane coupling agent solution with the concentration of 0.5%, 1%, 2% and 6% respectively, into styrene-acrylic latex modified mortar to test flexural strength, compression strength which are shown as Fig. 7 and Fig. 8.

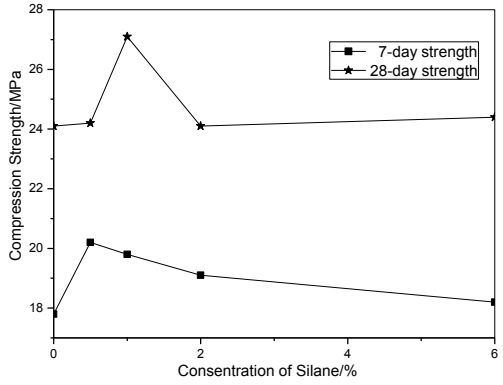


Fig. 8. 7-day and 28-day comperession strength of steel fiber styrene-acrylic latex mortar processed with silane.

Observing above-mentioned Fig. 7 and Fig. 8, we know that as shown in previous types of mortar, flexural strength and compression strength have increased at the beginning in styrene-acrylic latex modified steel fiber mortar, then decrease, and have been significantly enhanced when the concentration of silane coupling agent is 1%.

In this type of mortar, silane coupling agent formed film on metal surface, and enhanced interfacial bonding by preventing corrosion on metal surface and forming hydrogen bonding with mortar, which is similar to previous type of steel fiber mortar. Furthermore, since polymers have modification effect on mortar and polymer molecules filled in mortar pores can combine with organic groups of silane coupling agent on metal surfaces, thus bonding force between steel fiber and mortar has been enhanced.

3.5 SEM analysis

After various cementing materials are maintained up to 28 days, cut internal representative small sample to conduct electron microscope(SEM) scanning, and analyze the scanning results. It is found through observing that internal structures are diverse after hydrating different cementing materials.

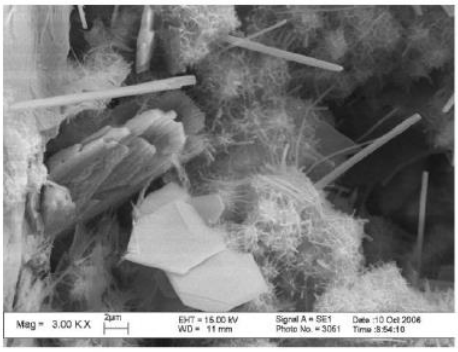


Fig. 9. SEM photograph of pure cement mortar.

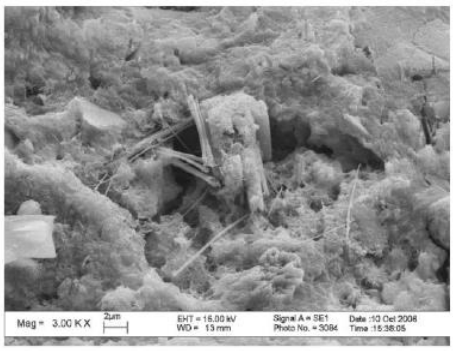
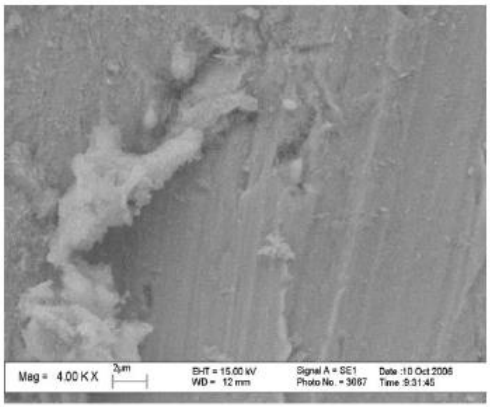


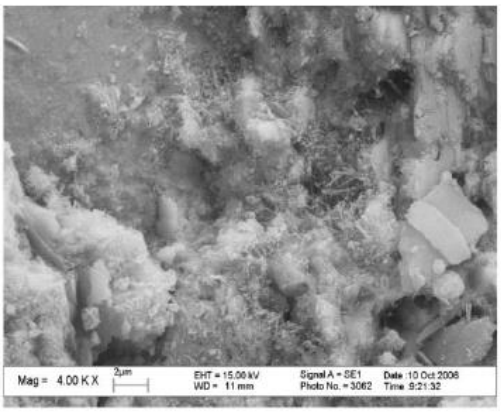
Fig. 10. SEM photograph of cement mortar modified with styrene-acrylic latex.

Fig. 9 is SEM photograph of pure cement mortar with the magnification of 3000 times, in which mutually interweaved netted fibrous type C-S-H gel particle can be clearly seen, with dotted long strips of ettringite crystal. Fibrous C-S-H and needle shape ettringite crystal interlinked, and form discontinuous and larger porosity of netted skeleton system. Fig. 10 is SEM photograph of styrene-acrylic latex modified cement mortar with the magnification of 3000 times, in which flocculation-like styrene-acrylic latex modified cement hydration products, exposing part of long strips of ettringite crystal. Modified cement mortar is improved bonding condition of cement paste and aggregate, and polymer is wrapped and filled in aggregate particles for the addition of styrene-acrylic latex. Polymer film can better fill in pores of cement mortar to form continuous polymer film layer, after bonding hydration products and wrapping unhydrated cement particles, polymer film and cement substrate have formed interfingering and continuous three-dimensional network structure.

After being maintained up to 28 days, samples of steel fiber cement mortar and silane coupling agent modified steel fiber mortar were respectively carried out electron microscope (SEM) scanning, which is shown as the following figures.



(a) high-magnification SEM photograph of steel fiber cement mortar before processed



(b) high-magnification SEM photograph of steel fiber cement mortar after processed

Fig. 11. SEM photograph of steel fiber cement mortar modified with silane coupling agent.

Fig. 11-a is bonding topography of steel fiber with portland cement mortar, in which we can clearly find that on steel fiber surface, there is part of cement hydration products, the remaining part is more smooth. This shows that unmodified steel fiber cannot bond with cement hydration products ideally.

Fig. 11-b is bonding micro-topography of steel fiber with cement paste, after steel fiber is modified with 1% silane coupling agent. Its surface is covered with fine layered material after modifying process of silane coupling agent, but not so bright and clean state as before. The bonding is closer than that before being processed. Through analyzing, we consider that there are reactions

between part of groups in silane coupling agent and steel fiber surface, and another part of groups will react with cement hydration products in cement paste to promote the 〔lose bonding of steel fiber and cement mortar.

4. Conclusions

(1) Silane coupling agent can increase flexural strength and compression strength of Portland cement mortar, especially when the dosage is 0.5%，it will increase up to approximately 10%. Silane coupling agent could also increase consistency of cement mortar, but delamination degree has increased a little.

(2) Silane coupling agent can significantly enhance flexural strength and compression strength of styrene-acrylic latex modified cement mortar, especially when the dosage is 1%, its strength is higher than that styrene-acrylic latex modified cement mortar without silane coupling agent by about 20%. The increase extent is higher than that of Portland cement mortar. Silane coupling agent could increase consistency of styrene-acrylic latex modified mortar, but layering degree is increased a little, which is similar to the function of Portland cement mortar.

(3) Silane coupling agent can improve flexural strength and compression strength of steel fiber cement mortar and steel fiber styrene-acrylic latex modified cement mortar. When the dosage of silane coupling agent is 1%, flexural strength and compression strength have significant increased. As for the two types of mortar, flexural strength s increase extent is higher than that of compression strength.

Acknowledgement

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