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Study on Application of Organosilicon Materials in Construction Industry

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This paper briefly introduces the organosilicon waterproofing agent at home and abroad, the research significance and the waterproof mechanism of several groups of experiments. Through the comparative analysis of silicone coated with mixing effect, cement mortar mixing silicone water in unit time was significantly lower than that of ordinary cement mortar, and with the increase of silicone content, water absorption of modified cement reduce the rate of mortar. The effects of different kinds of organosilicon on the mechanical properties of concrete are also studied. The mechanical strength of the mortar can be reduced by the machine silicon waterproof agent.

1. Introduction

Since the reform and opening up, the construction industry has witnessed rapid development. Infrastructure construction, residential building, urban construction, municipal construction and the implementation of the western development strategy of China have promoted and pushed forward the research on and development of cement-added polymer modification in the construction industry. In China, organosilicon materials have already been used in many important project at present, which has achieved good application results. (Li et al., 2017). The cement mortar used in the buildings belongs to porous and heterogeneous brittle materials, with such defects as large brittleness, low compressive strength, high dry shrinkage deformation, low elongation, poor crack resistance, poor waterproof and impermeability during hardening process, which greatly restrict its application and make it difficult to meet the demands of future engineering. It is a common method to modify common cement mortar by adding polymer. Organosilicon compounds are composed of Si-O bonds, which have the properties of both inorganic and organic materials, and excellent features such as low surface tension, high and low temperature resistance, electrical insulation, oxidation resistance, etc. (Liu et al., 2013). They have been widely used in aerospace, electronics and electrical, building waterproof and other fields. In this study, waterproof mortar is made by adding different types and contents of organosilicon into common cement mortar, and the influence of organosilicon on the impermeability and mechanical properties of waterproof mortar is studied, which provides some reference value for the subsequent preparation of waterproof mortar with excellent durability and waterproofness.

2. Silicone Impermeability Research

2.1 Harm of water leakage to buildings

The leakage of water will reduce the durability and safety of the structure of the building. There are gaps and cracks in cement products, also in brick masonry and mortar. If the water that sneaks in becomes ice when the temperature drops to below zero, the volume of the gap and cracks will expand by about 90%, which will directly squeeze the material, resulting in erosion of the surface material, and the remaining internal water will be squeezed, so that the compressive stress within the materials is also engendered, resulting in cracks, or causing the cracks to further expand. If the concrete protective layer is damaged, it will cause the corrosion of reinforcement, and the effective cross-section of the steel bar will also decrease. Besides, the volume expansion of the steel bar will be doubled, which will squeeze the concrete, thus causing gaps or cracks to expand further, or even the failure of the concrete protective layer (Zhang et al., 2014).

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2.2 Waterproofing principle of organosilicon

There are generally three ways to prevent water from penetrating into the concrete:

1. Adding waterproofing agent in the preparation of concrete to improve the permeability. However, this method is not applicable to structure maintenance or repair, and to mass concrete structure.
2. Sealing surface for waterproof protection with materials, such as epoxy coating. However, it will affect the concrete's permeability, which is not conducive to concrete wetting, and the film will easily bubble and even fall off.
3. Permeability protection, that is, by utilizing its special molecular structure, the material penetrates the surface layer into the interior of the concrete. They condense each other to form hydrophobic membrane permeability protection on the capillary wall of the substrate surface, which can greatly reduce the water absorption of capillary pores of concrete, reduce chloride ion erosion, prevent freeze-thaw damage and steel bar corrosion, and ensure long-term durability, alkali resistance and ultraviolet resistance, and can also maintain air permeability and natural appearance of concrete pores. Figure 1 shows permeability protection of organosilicon (Sun et al., 2014).

Figure 1: Coated with silicone building materials

Permeability protection is generally used to protect the surface of concrete by using organosilicon coating. Organosilicon has low surface energy and can penetrate into the concrete surface to a certain depth, so that the contact angle between the concrete surface and water increases, even up to above 105 ° (Hosoda et al., 2010). After the concrete surface is treated with organosilicon, the polymer will be firmly attached to the concrete surface, and its Si-O-Si long chain will form a netted membrane structure on the surface. Silicon and oxygen have large electronegativity differences, which are close to ionic bonds. Since the bonds are strong, they do not easily dissociate, giving them heat resistance, oxidation resistance, radiation resistance and other properties. The working principle is shown in Figure 2.

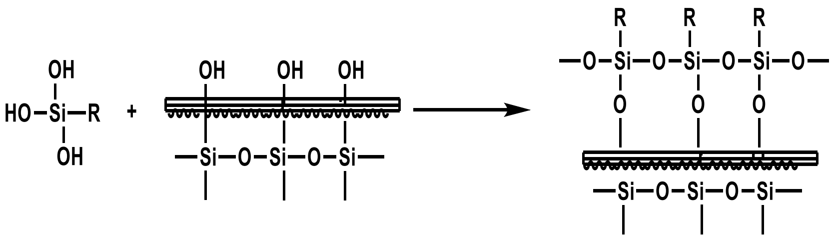

Figure 2: Silicone waterproof coatings on the surface of the coagulation structure formed by the protective structure

The organosilicon and the base material atom of concrete can form chemical bond. The organosilicon waterproofing agent can easily react chemically with the base material of cement-based material to form cross-linked network structure. In addition, since the organosilicon waterproofing agent adopted is water repellent, when the dehydration reaction between the organosilicon molecule and the silanol group is carried out, an ordered dense hydrophobic membrane is formed inside the material (Zhang et al., 2014). The hydrophobic membrane is usually several nanometers thick, which does not affect the surface characteristics of cement based materials, but drives the capillary of the base materials from the surface and inside to prevent water intrusion (Wu et al., 2001). The main composition of concrete is silicate, as shown in Figure 3 as follows:

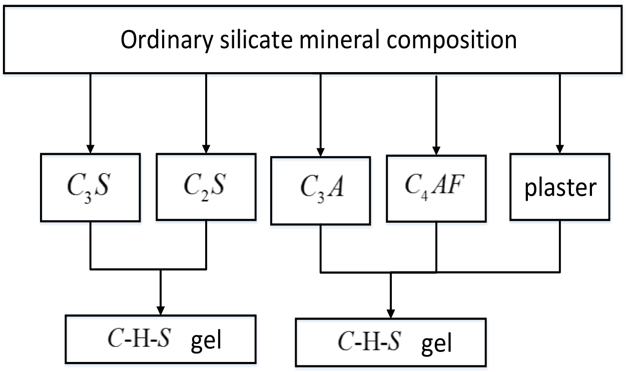

Figure 3: The composition of Silicate

2.3 Influences of different organosilicon content on the anti-seepage property of concrete

Concrete: ordinary portland cement; Sand: ISO standard sand; Organosilicon: KH560, produced by Hubei Huanyu Chemical Co., Ltd.

The mixing ratio of test cement mortar is cement: sand: water = 1: 2: 0.4; Contents of organosilicon: 0%, 1%, 2%, 3%, 4%, 5% (mass fraction, the same hereinafter); Serial numbers of the samples: S_0, S_1, S_2, S_3, S_4, S_5.

Waterproof performance: water absorption is used to characterize the waterproof performance of cement mortar; test is undertaken in accordance with DL/T5126—2001Test Code for Polymer Modified Cement Mortar (Guan et al., 2011);

Resistance to chloride ion permeability: The chloride ion diffusion coefficient is used to characterize the resistance to chloride ion permeation of cement mortar (Hu, 1994):

$$D = \frac{RT}{zFE} \frac{x_d - a x_d^b}{t} \tag{1}$$

Where, D refers to chloride ion diffusion coefficient, m2/s; R refers to the gas constant, 8.314J·K/mol; T refers to temperature, K; z is the charge number of chloride ion, -1; F is Faraday constant, 96480J / V; E is electric field strength, V / m; x_d is chloride ion penetration depth, mm; t refers to the time, s.

Figure 4 shows the results of water absorption test of silicone modified cement mortar.

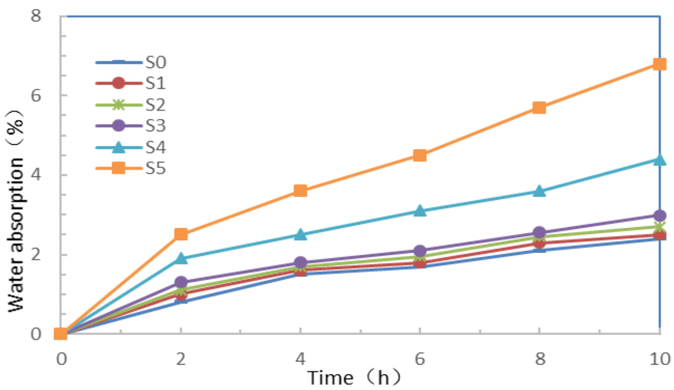

Figure 4: Waterproof performance test results

It can be seen from Figure 4, that the water absorption of cement mortar mixed with organosilicon per unit time is significantly lower than that of ordinary cement mortar, and with the increase of organosilicon content,

the water absorption of modified cement mortar decreases, which is mainly due to the hydrophobicity of the organosilicon and the changes of the pore structure of the mortar.
Compared with the ordinary cement mortar, the chloride ion diffusion coefficient of the organosilicon modified cement mortar decreases greatly, and decreases with the increase of the content of the organosilicon. The chloride ion diffusion coefficient of ordinary cement mortar specimen S0 is 5.2m2/s, while that of modified cement mortar with 1%, 2%, 3% and 4% of organosilicon is reduced by 25%, 39%, 44% and 58% respectively. When the content of organosilicon is 5%, the diffusion coefficient of chlorine ion is reduced by 58% and the decreasing trend is slowed down. When the content of organosilicon is 4%, the effect of increasing the content of organosilicon on the diffusion coefficient of chloride ion is not obvious, which indicates that 4% of organosilicon content has better protective effect on cement mortar.

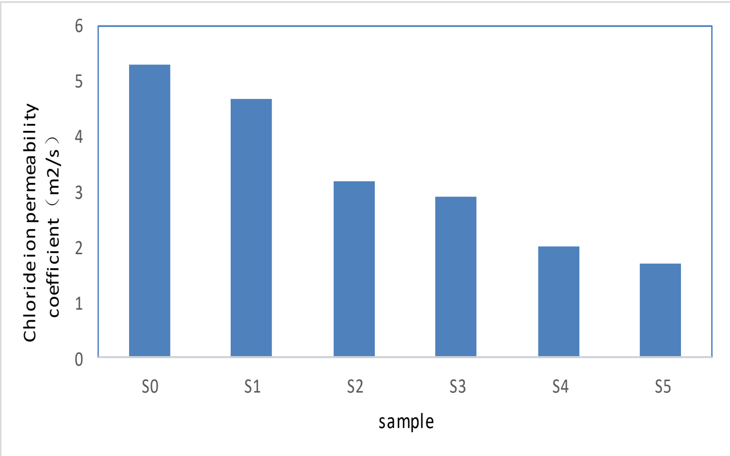

Figure 5: Resistance to chloride ion permeability test results

3. The type of silicone on the mechanical properties of concrete

3.1 Preparation of test materials

BS (silane / siloxane, 50% of active ingredient) and IE (siloxane, 40% of the active ingredient) were used as the emulsion-type organosilicon waterproofing agents, and SH-1 (silane) and SH-2 (silane / siloxane) as powder-type organosilicon waterproofing agents; The mixing ratio of waterproof mortar foundation was prepared according to the standard of Mortar and Concrete Waterproof Agent (JC474-2008), and the mixing ratio in the test is as shown in Table 1. When the emulsion-type organosilicon waterproofing agent was used, it was added into water and the mortar was prepared after stirring them uniformly. When the powder-type organosilicon waterproofing agent was used, it was added into the cement, and the mortar was prepared after stirring them uniformly (Yun et al., 2007).

Table 1: waterproof mortar test mix

number	Silicone waterproofing agent		cement（g）	Standard sand（g）	water（g）
	species	Quality Score（%）			
1	None	/	536	960	115
2	BS	0.75	536	960	115
3	IE	0.75	536	960	115
4	SH-1	0.75	536	960	115
5	SH-2	0.75	536	960	115
6	SH-2	0.9	536	960	115
7	SH-2	2.4	536	960	115
8	SH-2	3.2	536	960	115

In order to prevent significant changes in humidity and temperature inside the specimen, the test shall be started immediately after the specimen is removed from the maintenance site. This test operation was performed using a compressive strength tester to test half of the parallelepiped facade. The error between the pressure center of the bearing plate of the test machine and the weight center of half parallelepiped shall not exceed ± 0.6mm. The size of the parallelepiped outside the press machine shall be about 8mm. The loading rate was maintained at 3000N/s±150N/s until the test component was broken. The formula for calculating the compressive strength of mortar is as follows:

$$R_c = \frac{F_c}{A} \tag{2}$$

In the formula: A —area of the compressed part, mm
F_c, compressive strength of cubic mortar, MPa
In accordance with the national standard in China, the numerical accuracy of all compressive strength was set to 0.1MPa. The final test data are the mean values of the compressive strength of all parallelepiped in the experimental group. If the test data exceed ± 12% of the mean value, the variation data will be removed and the remaining data will be recalculated as the final test result. If more than one set of test data exceeds the mean value by ± 12%, the test fails and the compressive strength test will be repeated (Wu et al., 2009).

3.2 Test results

The effects of different types and content of organosilicon waterproofing agents on the mechanical properties of mortar are studied. The test results are as shown in Figure 5.

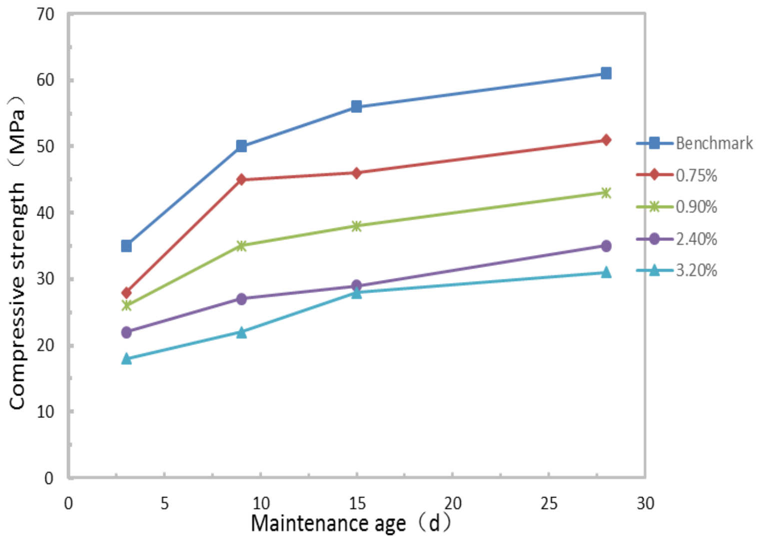

Figure 6: Different silicone content on the tensile strength

It can be seen from Figure 6 that the flexural strength and compressive strength of the mortar decrease after the addition of the organosilicon waterproofing agent, and the emulsion-type organosilicon waterproofing agent and the powder-type organosilicon waterproofing agent have substantially the same influence on the mechanical strength of the mortar under the case of the same dosage. With the addition of 0.9% of silicone waterproofing agent, the flexural strength and compressive strength of mortar 7d decrease by about 11% ~ 13% and 10% ~ 18% respectively, and those of the mortar 28d decrease about 5% ~ 18% and 16% ~ 24% respectively.
As can be seen from Figure 6, the flexural strength and compressive strength of the mortar decrease with the increasing content of the powder-type organosilicon waterproofing agent SH-2, in which the compressive strength of mortar decreases more significantly. When the content of SH-2 increases from 0.75% to 3.2%, the flexural strength of mortar 7d is reduced by 7%, and that of mortar 28d remains unchanged, while the compressive strength of mortar7d and mortar 28d decline by 11% and 21% respectively.

4. Conclusion

In this paper, organosilicon-modified cement mortar was prepared by the method of incorporation of organic silicon. The water resistance and resistance to chloride ion permeation of ordinary cement mortar and silicone modified cement mortar were compared. The water absorption rate of silicone cement in unit time is obviously lower than ordinary cement mortar, and with the increase of silicone content, the water absorption of modified cement mortar decreases, the main reason is that with the hydrophobicity of silicone and Mortar pore structure changes related. This paper also compared the different types of silicone mechanical properties of concrete, silicone waterproofing agent will reduce the mechanical strength of mortar, and with the dosage increased, the degree of decline increased.

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