Performance and Improvement Measures of Concrete with Internal Addition of Water-based Organic Silicon

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Abstract: In this paper, the change laws of compressive strength, water absorption and chloride diffusion coefficient of concrete mixed with different dosages of water-based organic silicon was studied. Meanwhile, the influence of modified meta kaolin on concrete mixed with water-based organic silicon was studied. The results show that the water-based organic silicon can significantly reduce water absorption of concrete, nevertheless, it will reduce the compressive strength of concrete. The higher the dosage, the greater decrease in strength. The mixing of meta kaolin can effectively improve the mechanical properties of the concrete mixed with water-based organic silicon and its waterproof performance and chloride resistance.

1 INTRODUCTION

Concrete durability has become a hot spot in the field of international concrete research, especially the concrete structure in the marine environment and chemical corrosion environment. It is noteworthy that, in the pass century, a large number of constructions had collapsed or demolished because of poor durability performance[1-4]. Undesirable ions penetrate into the concrete structure with water, causing physically and chemically damage of it. In order to improve the durability of the concrete structure and ensure the structure meets the design life requirements, when adopting the corrosion-resistant high-performance concrete, the necessary additional anti-corrosion technology measures should also be taken in view of the corrosive environment characteristics of different structure. For the additional anti-corrosion technology, pieces of research have been carried out in these years. At present, it mainly includes two kinds of technical method: external coating and internal addition. External coating materials are easily affected by the surface layer concrete properties and the anti-aging properties of the materials. Once the surface concrete occurs cracking, abrasion, or the anti-corrosion materials are aging because exposed to the outdoor environment for a long time, the protective effect will be greatly reduced [5]. By mixing anti-corrosion material in fresh concrete to produce concrete with integral waterproof properties, the above drawbacks of traditional surface anti-corrosion materials can be effectively improved. However, mixing the anti-corrosion materials by internal addition generally has the problem of reducing the compressive strength of the concrete[6,7].

Metakaolin sakind of mineral admixture with superpozzolanactivity, when modified by acid，the thermal and mechanical activation, Activities of $SiO_2$and Al_2O_3 will be stimulated and give full play to itspozzolanic effect and filling effect, and also significantly improve strength and resistance permeability of concrete[8-11]. In order to reduce the side effect to the strength of concrete and greatly improve the resistance permeability of concrete, based on the study of the influence of the water-based organic silicon on concrete, the modified metakaolin and water-based organic silicon will be mixed to explore the influence of the modified metakaolin on water-based organic silicon concrete.

2RAW MATERIALS AND TEST METHODS

2.1 Cement

The cement uses Yuexiu PII 42.5R portl and cement. The main chemical composition of cement is shown in Table 2.1, and the physical properties are shown in Table 2.2.

Table2.1：Cement Chemical Composition(%).

composition	SiO_2	Al_2O_3	CaO	SO_3	MgO	Fe_2O_3	LOI
cement	19.76	4.52	62.42	4.26	1.13	4.42	3.49

Table 2.2 :Cement Physical Properties.

Specificsurf ace area（ m^2/kg）	Standard consistency water demand P（%）	Setting time（min ）		Flexural strength（MPa）		Compressive strength（MPa）	
360	25.5	Initial time	Final time	3d	28d	3d	28d
		121	197	6.82	8.86	32.43	52.09

2.2 Aggregate

Granite gravel (5~20mm) produced by Zhuhai Jianbang Stone Field, apparent density is 2.70 g/cm 3, close bulk density is 1.63 g/cm 3, needle content is 2.3%,crush value is 3.0%; fine aggregate with Guangdong Xijiang sand, apparent density is 2.64g/cm 3, fineness modulus is 2.7, mud content is 0.4%, mud mass content is 0.2%.

2.3 Water-based Organic Silicon

The alkyl siloxane water-based organic silicon with a long-chain molecular structure was used, and the active ingredient was 40%.

The metakaolin made by calcining kaolin from Guangdong Maoming was used. The main chemical composition and specific surface area of metakaolin are shown in Table 2.3. The metakaolin becomes modified metakaolin when activated by acid, thermal and mechanical activation methods.

2.4 Modified Metakaolin

Table 2.3：Metakaolin chemical composition (%) and specific surface area(m^2/kg).

	SiO_2	Al_2O_3	CaO	SO_3	MgO	Fe_2O_3	LOI	Specific surface
metakaolin	53.00	42.67	0.04	0.14	0.08	0.73	1.35	15238

2.5 Concrete Mix Proportion

The mix proportion of the concrete specimens is shown in Table 2.4. The 2%, 4% and 6% dosage of water-based organic silicon was used to instead of the total amount of cementitious materials, and the same amount of mixing water was replaced at the same time. Modified metakaolin replaces the total amount of cementitious material with a 6% doping amount.

Table 2.4: Mix proportion(kg/m³).

Mumber	Cement	Modifiemeta kaolin	Water	Water-based organic silicon	Sand	Gravel	Superplasticizer
OPC	420	—	147	—	771.6	1065.6	2.58
SL2	420	—	142	8.4	771.6	1065.6	2.70
SL4	420	—	136.9	16.8	771.6	1065.6	2.66
SL6	420	—	121.8	25.2	771.6	1065.6	2.67
MK	394.8	25.2	147	—	771.6	1065.6	2.98
MKSL2	394.8	25.2	142	8.4	771.6	1065.6	3.07

2.6 Test Methods

2.6.1 Water Absorption Test

The water absorption test was conducted according to the method in "Mortar, Concrete Waterproof Agent"(JC474-2008).

2.6.2 Compressive Strength Test

According to the method in "Standard Test Method for Mechanical Performance of Ordinary Concrete"(GB/T50081-2002), the compressive strengths on 3d, 7d and 28d ages of the concrete were measured.

2.6.3 Rapid Chloride Migration Factor Test(RCM Method)

Referring to "Standard Test Method for Long-term Properties and Durability of Normal Concrete"(GB/T50082-2009) to test the chloride diffusion coefficient of concrete on 28d.

3. RESULTS AND DISCUSSION

3.1 Compressive Strength

Figure 1 shows the effect of different dosage water-based organic silicon on concrete for 3d, 7d and 28d. It can be seen from the figure that the compressive

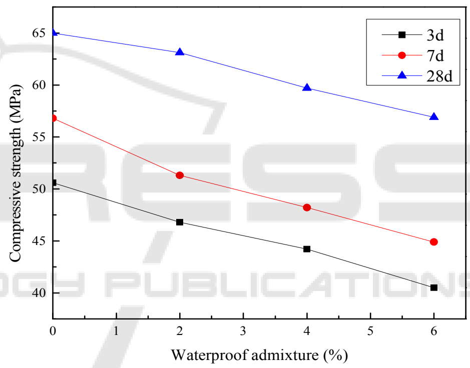

Fig 1: Effect of water-based organic silicon on compressive strength of concrete.

strength of concrete at the three ages are reduced because of add with water-based organic silicon, the greater the dosage is, the more the compressive strength decreases. Compared with the OPC which without water-based organic silicon, the compressive strength of SL2, SL4 and SL6 on 28d were reduced by 2.9%, 8.1% and 12.5% respectively. When the Water-based organic silicon mixed in concrete, it will adsorb on the surface of the cement particles. The greater the content of the water-based organic silicon, the greater the surface area of the adsorbed cement particles, the smaller effective contact area between the cement particles and water, the slower hydration rate and lower hydration degree of the concrete, and finally lead to a lower compressive strength of concrete.

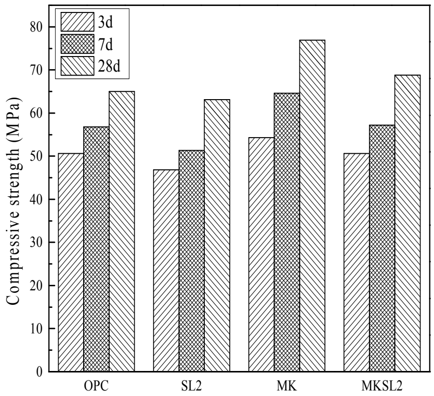

Fig2: Effect of modified metakaolin on compressive strength of concrete with water-based organic silicon.

Figure 2 shows the effect of modified metakaolinon compressive strength of concrete with water-based organic silicon. The addition of modified metakaolin can effectively improve the compressive strength of concrete with water-based organic silicon.

Comparing with the OPC, the compressive strength of MK increased by 7.3%, 13.7% and 18.3% respectively on 3d, 7d and 28d. Compared with the SL2, the compressive strength of MKSL increased by 8.1%, 11.5% and 9% respectively on 3d, 7d and 28d, and 28d compressive strength increased 5.9% compared to OPC. After the acid treatment to metakaolin， thermal and mechanical activation can effectively stimulate the activity of SiO2 、 Al2O3 and other active substances, and significantly improve the strength of concrete[11]. When mixing the modified metakaolin with the water-based organic silicon, the strength promotion effect of modified metakaolin effectively compensates for the side effect of reducing the strength of the concrete with water-based organic silicon.

3.2 Water Absorption

Figure 3 shows the effect of different dosage water-based organic silicon on water absorption of concrete and the water-based organic silicon can significantly reduce the water absorption of concrete. Compared with the OPC , the water absorption of SL2, SL4 and SL6 on 28d were decreased by 64.4%, 69.9% and 65.8% respectively. With the increase of the amount of water-based organic silicon, there is little difference in reducing water absorption of concrete. When the content of water-based organic silicon increase to 6%, the water absorption of concrete will also increase, meaning the decrease of the waterproof ability. This is because the water-based organic silicon has a low surface tension and the surface energy promote a fine hydrophobic performance, which can react with cement in concrete and forms the interwoven hydrophobic layer, preventing water molecules from penetrating into the concrete, as well as reducing the water absorption of concrete [6]. However, as the content of water-based organic silicon increases, the more cement particles adsorbed by water-based organic silicon, the greater the influence on the hydration of cement in concrete, which will reduce its waterproof ability to a certain extent.

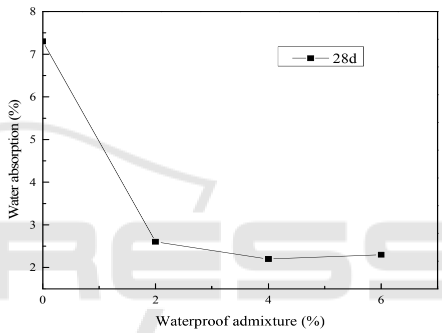

Fig 3:Effect of water-based organic silicon On water absorption of concrete.

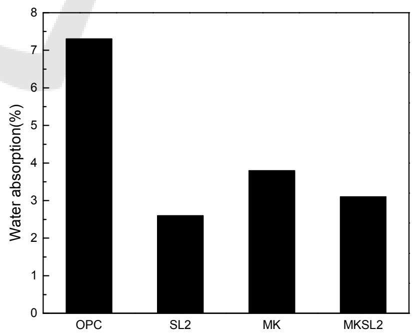

Fig4: Effect of modified metakaolin on water absorption of concrete with water-based organic silicon.

Figure 4 shows the effect of modified metakaolin on water absorption of concrete with water-based organic silicon ,the modified metakaolin and water-based organic silicon both can significantly reduce the water absorption of concrete. Compared with the OPC , the water absorption of MK and MKSL were decreased by 47.9% and 60.3% respectively. However, when comparing with the SL2,the water absorption of MK and MKSL was increased by49.2% and 19.2%. With the increasing content of SiO_2 and Al_2O_3 modified within the metakaolin, their secondary react with the cement hydration product—$Ca(OH)_2$ will be generated and padding the concrete pore, resulting in the increasing compactness of the concrete structure and the reducing of the water absorption performance of concrete[12].

3.3 Resistance of Chloride Ion Penetration

Corrosion of steel reinforcement in concrete is considered to be one of the most significant reasons for durability damage of marine concrete structures. Cl- transmission from the concrete surface to the internal surface of steel, when its accumulated to a certain value of the concentration of the rebar depassivation and rust occurs, the expansive corrosion product make the concrete cover falls off, and lead to the failure of the structure eventually. Therefore, it is an important means to evaluate the durability of concrete to test the Cl- permeability of concrete. In addition, the transmission performance of concrete reflected by the resistance to chloride permeability of concrete is a fundamental problem directly influencing the durability of concrete.

Figure 5 shows the chloride diffusion coefficient of concrete with different dosage water-based organic silicon by RCM method and the chloride diffusion coefficient observably reduced with the water-based organic silicon. Compared with the OPC , the chloride diffusion coefficient of SL2, SL4 and SL6 on 28d were decreased by 23.6%, 30.6% and 32.3% respectively. The effect of water-based organic silicon on the diffusion coefficient of chloride ions in concrete is similar to that of water absorption, meaning that with the increase of water-based organic silicon, the diffusion coefficient of chloride ion is slightly changed. Water-based organic silicon hydrophobicity changed the surface tension of concrete and its internal pore, resulting in a hydrophobic surface and scatter within the concrete to block the connectivity of capillary pore at the same time, which can effectively reduce the chloride ion diffusion coefficient of concrete.

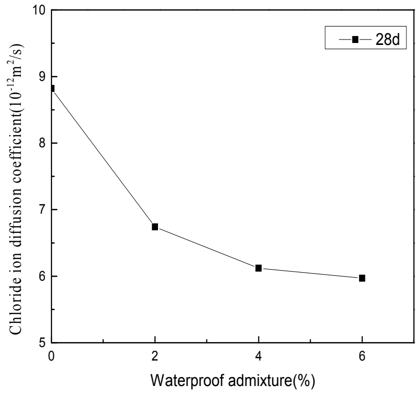

Fig 5:Effect of water-based organic silicon on chloride diffusion coefficient of concrete.

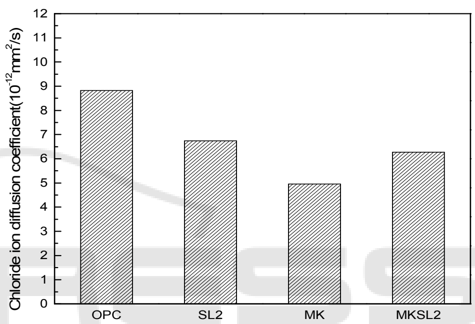

Fig6: Effect of modified metakaolin on chloride diffusion coefficient of concrete with water-based organic silicon.

Figure 6 shows the chloride diffusion coefficient of water-based organic silicon concrete with modified metakaolin. Compared with the OPC , the chloride diffusion coefficient of MK was decreased by 43.8% and compared with the SL2, the chloride diffusion coefficient of MK and MKSL were decreased by 43.8% and 7%, the results show that the effect modified metakaolin on the chloride diffusion coefficient on concrete is much more serious than that of water-based organic silicon. The modified metakaolin can improve the compactness of the pore structure, reducing the content of capillary pore in concrete, improving the gel content, and promoting the formation of F salt in the concrete under the chloride environment. It can not only reduce the transmission channel of Cl- in concrete but also improve the curing capacity of Cl-.In this way, the resistance of chloride permeation of concrete with water-based silicone concrete is improved[10].

4. CONCLUSIONS

1.Water absorption of concrete can be significantly reduced by adding with water-based organic silicon in concrete, when the dosage of water-based organic silicon between 2%-6% , the water absorption of concrete can be reduced by over 65%.

2.Adding water-based organic silicon in concrete will reduce the compressive strength of concrete, and it will be more distinct with the increase of the concentration. Considering the water absorption and compressive strength of concrete, the optimum dosage of water-based organic silicon can be refined as2%.

3.Mixing with modified metakaolin and water-based organic silicon is able to improve the compressive strength and waterproof ability at the same time. Compared with OPC, the compressive strength on 28d of MKSL was increased by 5.9%, and the water absorption and the chloride diffusion coefficient were decreased by 60.3% and 28.9%respectively.

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