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Effect of Methyl Silicone Oil to Moisture Resistance of Sodium Silicate Sands by Microwave Hardening

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Abstract

The sodium silicate sands hardened by microwave have the advantages of high strength, fast hardening speed and low residual strength with the lower addition of sodium silicate. However, the sodium ion in the sands will absorb moisture from the atmosphere, which would lead to lower storing strength, so the protection of a bonding bridge of sodium silicate between the sands is crucial. Methyl silicone oil is a cheap hydrophobic industrial raw material. The influence of the addition amount of methyl silicone oil modifier on compressive strength and moisture absorption of sodium silicate sands was studied in this work. The microscopic analysis of modified before and after sodium silicate sands has been carried on employing scanning electron microscopy(SEM) and energy spectrum analysis(EDS). The results showed that the strength of modified sodium silicate sands was significantly higher than that of unmodified sodium silicate sands, and the best addition of methyl silicone oil in the quantity of sodium silicate was 15%. It was also found that the bonding bridge of modified sodium silicate sands was the density and the adhesive film was smooth, and the methyl silicone oil was completely covered on the surface of the sodium silicate bonding bridge to protect it.

Keywords: Sodium silicate sands, Microwave hardening, Methyl silicone oil, Moisture absorption

1. Introduction

Microwave hardening with fast and uniform features is used to improve the efficiency of the sodium silicate sands[1]. The strength of moulding sands is enhanced on the premise of a significant decrease in the amount of sodium silicate. The microwave hardening process has the characteristics of strong dehydration and no reaction[2,3]. Although the strength of the product obtained is high, the strength fell rapidly due to the lack of the protection of silica gel so that it has strong moisture absorption after hardening [4]. Because of this reason, the use of the product is restricted greatly. Therefore, it is of great significance to popularize microwave hardened sodium silicate sands via improving the moisture resistance and storage strength[5].

Methyl silicone oil is a cheap hydrophobic industrial raw material[6]. Sodium silicate was modified by treating methyl silicone oil as a modifier to improve the moisture resistance of samples in this study. The macroscopic and microscopic analysis can be also performed to evaluate modified effect[7,8].

2. Materials, measurement methodology and measurement equipment

The experimental materials include the quartz sands with the grain size of 50/100 meshes, the sodium silicate with the modulus of 2.06, the density of 1.45g/cm^3 and modifier made up methyl silicone oil. The customized box microwave oven was used to harden the sands with a power of 1400W. The TESTO 610 temperature and humidity instrument were used to test the temperature and humidity. The ambient temperature was 23℃.SHY vane sands mixer was selected to mix binder, sands and others. Sands samples were prepared using a homemade columnar split wooden mold with a diameter and height of 30 mm(Φ30×30mm). The desiccator without desiccant was used as a constant humidity bottle by adding water (humidity of 98%~99%). The compressive strength was tested using an SWQ-A material high-temperature strength tester and the moisture absorbability (ψ) was tested by the electronic balance with the accuracy of 0.001g.

2.1. Experimental methods

Raw sands, sodium silicate and methyl silicone oil weighed were put in the sands mixer according to certain proportion and sequence. The mixture was pulled out to prepare mould sands after mixing for 2 minutes.

Secondary microwave hardening new methods used in the experiment were as followed: Sodium silicate sands together with the wooden mould were heated 20s in the microwave oven, then taken out and demoulded, the sodium silicate sands were heated 100s by microwave. The moisture absorption of sands samples was tested by 4h storage strength in a constant humidity bottle (humidity of 98%~99%), 4h storage strength in the air (humidity of 80%) and instant strength after pulling out from microwave oven for three minutes to cool, respectively[9].

The bonding bridge and fracture morphology of mould sands treated by fixing in the little box and spraying-gold were observed using environmental SEM and its EDS[10,11].

3. Results and discussion

3.1. Effect of adding an order of methyl silicone oil and sodium silicate on compressive strength of samples

Methyl silicone oil is a cheap hydrophobic industrial raw material, but it is difficult to dissolve in sodium silicate[12]. To study the effect of the addition sequence of methyl silicone oil and sodium silicate on the strength of mould sands, three kinds of schemes were designed in the experiments as Table 1, and the 1# was a comparison blank test.

Testing conditions were as follows: microwave hardening power of 1400W, hardening time of 120s (20s+100s), the addition amount of sodium silicate amounting to 1.5% of the mass of the raw sand and addition of methyl silicate oil making up 15% of sodium silicate mass. Two kinds of experiments were performed according to the design scheme. Blank tests referred to the strength of sodium silicate sands via secondary microwave hardening with no methyl sodium silicate. The relative humidity of sands for 4h storage strength was 98-99%.

It can be seen from Fig.1 that the strength of samples obtained is relatively high. Compared with unmodified sodium silicate sands samples, the strength of samples in two options has increased, indicating that methyl silicone oil can improve the moisture resistance of microwave hardened sodium silicate sands. Based on the above study, The 2# sequence was chosen to study the effect of the amount of methyl silicone oil on the properties of sodium silicate-bonded sands.

Table 1.
Addition sequence of raw materials

	1	2	3
1#	raw sands	sodium silicate	—
2#	raw sands	methyl silicone oil	sodium silicate
3#	raw sands	sodium silicate	methyl silicone oil

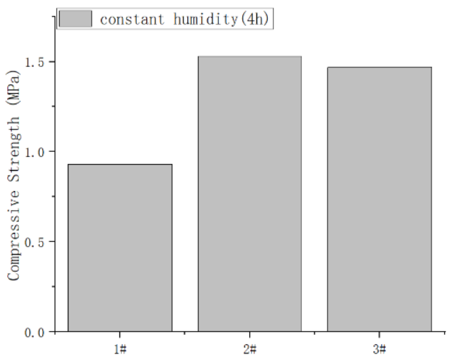


Fig. 1. Effect of addition sequence of methyl silicone oil and sodium silicate on compressive strength

3.2. Influence of amount of methyl silicone oil on the compressive strength of samples

Testing conditions were as follows: microwave hardening power of 1400W, hardening time of 120s (twice the hardening time, the 20s and 100s, respectively), the addition amount of sodium silicate amounting for 1.5% of the mass of the raw sand and an additional amount of methyl silicate oil making up 5%, 10%, 15%, 20% and 25% of sodium silicate mass, separately. The samples were stored in a constant humidity bottle (humidity of 98%~99%) and air (humidity of 80%), respectively. It can be displayed from Fig.2 the influence of the amount of methyl silicone oil on the compressive strength of samples.

As shown in Fig.2, the compressive strength of sodium silicate sands firstly increased with the increase of the amount of methyl silicone oil and then showed a trend of decrease. It was up to its peak when the addition amount of methyl silicone oil accounted for

15% of sodium silicate mass. Compared with unmodified sodium silicate sands, after 15% of methyl silicone oil was added, the strength of sodium silicate samples at room temperature, in air and the constant humidity bottle was improved by about 48%, 138% and 130%, respectively.

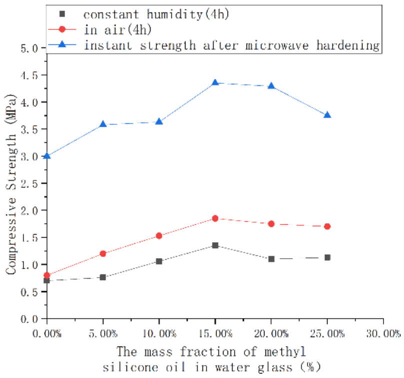


Fig. 2. Influence of amount of methyl silicone oil on the compressive strength

The addition of methyl silicone oil can not only significantly improve the moisture resistance of microwave hardened sodium silicate sands in a high humidity environment, but also enhance the storage strength. In addition, the strength of itself can be boosted so that the strength at room temperature was higher than that of unmodified sodium silicate samples.

3.3. Modified moisture absorption of microwave hardened sodium silicate sands using methyl silicone oil

The strength of samples with characterization hardening of moisture absorption declined in certain humidity environment because of absorbing moisture. This characterization can be expressed by water absorption percentage (ψ) as following calculation formula.

$$\psi = 100\% * (M_a - M_b)/M_b$$

M_a is the weight after absorbing moisture, and M_b is the weight before absorbing moisture.

Test conditions were as followed: microwave hardening power of 1400W, hardening time of 120s (twice the hardening time, the 20s and 100s, respectively), the addition amount of sodium silicate amounting for 1.5% of the mass of the raw sand and an additional amount of methyl silicate oil making up 15% of sodium silicate mass. The samples were stored in a constant humidity bottle (humidity of 98%~99%). The hygroscopicity of before and after modified sodium silicate sands samples was shown in Fig. 3, and the 4 absorbing moisture at high humidity of modified sodium silicate sands was reduced by about 14%.

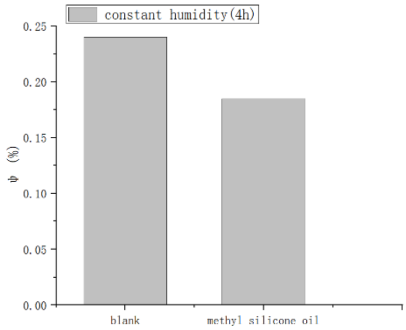
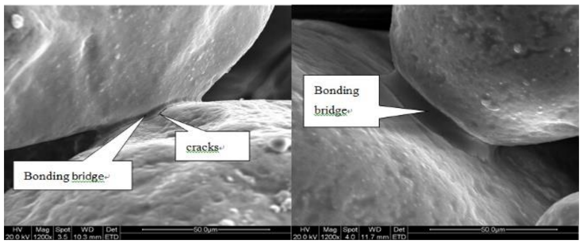


Fig. 3. Effect of methyl silicone oil on the hygroscopicity of mould sands

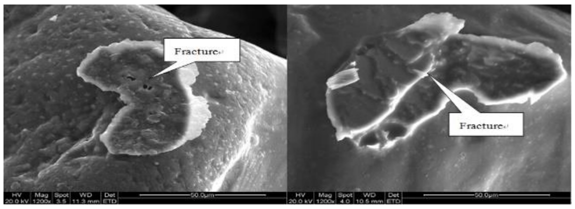
3.4. Microstructure analysis (SEM analysis)

Microwave hardening power was 1400W, the hardening time was 120s (twice hardening time, the 20s and 100s, respectively), and the amount of sodium silicate was 1.5%. The bonding bridge and fracture morphology of samples stored for 4h in a constant humidity bottle were shown in Fig.4 and Fig.5, respectively.



(a) Unmodified sodium silicate sands (b) Modified sodium silicate sands

Fig. 4. Bonding bridge microstructure of the microwave hardened sodium silicate sands



(a) Unmodified sodium silicate sands (b) Modified sodium silicate sands

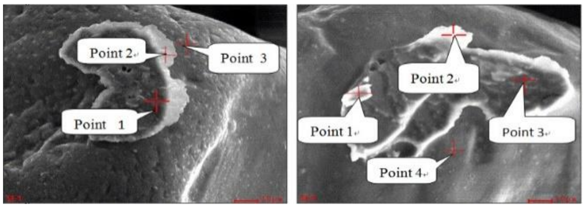
Fig. 5. The fracture morphology the microwave hardened sodium silicate sands

As displayed in Fig.4a, it can be observed that cracks appeared almost throughout the entire bonding bridge in the unmodified sodium silicate samples. It can be also found that more holes and cracks were formed in the fracture section in Fig.5a. The occurrence of cracks and holes resulted mainly from that during the storage process of samples, the sodium silicate absorbed water to cause the bonding bridge to be eroded and dissolved, which resulted in the decline of cohesive force among sands grains and that the sand the strength of samples were significantly reduced.

It can be seen from Fig.4b and Fig.5b that the bonding bridge of modified sodium silicate sands was very slippery and pyknotic, the surface of sands grains was covered by sodium silicate coating, and no cracks, holes and other defects appeared, and the shape of the bonding bridge is concave on both sides, which was caused by the cohesion of bonding bridge. It indicated that the addition of methyl silicone oil slowed the hydration and dissolving speed of sodium silicate binder, which significantly improve the moisture resistance of microwave hardened sodium silicate sands samples. The bonding bridge of modified sodium silicate was more closely connected than that of unmodified sodium silicate, so the strength of modified sodium silicate was higher.

3.5. Microstructure analysis (EDS analysis)

To further explore the existing state of the methyl silicone oil in the bonding bridge (film), the composition analysis was carried out on microwave hardening sodium silicate samples, as shown in Fig6a and b, Table 2 and Table 3.



(a) Unmodified sodium silicate sands (b) Modified sodium silicate sands

Fig. 6. The fracture composition analysis

It can be seen from the figure and table that there was obvious carbon content in the modified sodium silicate sands, which represents methyl silicone oil. It can be seen that point 1 in Fig.6b was an impurity, and point 2 the carbon content is the highest. Therefore, it can be concluded that there is a large amount of methyl silicone oil at the surface of the bonding bridge to protect it.

Table 2.
Unmodified fracture composition analysis

Wt %	O	Na	Si	Al	Ca
Point 1	15.15	6.13	72.58	2.36	3.78
Point 2	26.64	7.47	63.78	1.17	2.95
Point 3	9.53		90.49		

Table 3.
Modified fracture composition analysis

Wt %	O	Na	Si	Al	C
Point 1	18.47	2.69	66.48	0.57	11.79
Point 2	24.16	8.78	37.82	1.45	27.79
Point 3	19.21	0.76	52.01	12.52	15.50
Point 4	25.02	6.76	51.77	0.98	15.46

4. Conclusions

The results showed that the strength of modified sodium silicate sands was significantly higher than that of unmodified sodium silicate sands, and the moisture absorption of modified sodium silicate sands was worse than that of unmodified sodium silicate sands, and the effect was best when the addition of methyl silicone oil in the quantity of sodium silicate was 15%. It was also found that the bonding bridge of modified sodium silicate sands was the density and the adhesive film was smooth, and the methyl silicone oil was completely covered on the surface of the sodium silicate bonding bridge to protect it.

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