

# IMPROVE THE HUMIDITY RESISTANCE OF SODIUM SILICATE SANDS BY ESTER-MICROWAVE COMPOSITE HARDENING

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An easy hardening method of sodium silicate sands, ester-microwave composite hardening, could decrease the sands mould absorbing moisture and the mould materials requirement. And it was performed by hardening the sodium silicate sands with a little ester, and then demoulding, finally hardening the non-mold sands with microwave energy. The results showed that the 4h storage strength of composite hardening increases by 29,4 % compared with the common one, when the addition amount of ester was wt. 1,5 % according to the weight of sodium silicate binder. The humidity resistance of the sodium silicate sands was improved after the production of hydrophobic materials, glycerol and sodium acetate trihydrate by the ester.

*Key word:* foundry, sodium silicate sands, ester-microwave composite hardening, humidity resistance, non-mold

## INTRODUCTION

Microwaves are broadly applied in such fields as telecommunications, meteorology or chemistry [1]. Microwave energy might also be used in foundry engineering and hardening process of molding sands, including sodium silicate molding sands. The microwave hardening of sodium silicate sands is low cost and energy saving because the energy is delivered directly to the objects to be heated [2].

However, the microwave heating of sodium silicate sands requires high-quality mould materials and strong moisture absorbability of the sodium silicate sands. Wood, plastic and metal can't be used as mould materials [3].

The most important is that the bonding bridges formed by dehydration between the sands grains were not protected from the humidity circumstance, so the strength would degrade quickly [4].

A simple and easy ester-microwave composite hardening method (EMCHM for short) was used to solve those two problems. The sodium silicate sands was hardened by a little ester to produce hydrophobic materials of glycerol and sodium acetate, and then hardened by microwave without mold, in which the latter was the main hardening step. So this new process could combine the advantages of the ester and microwave hardening method. It allowed using ordinary wood mould or plastic mold, which were not heated in the microwave oven because it had taken out. In this study, the performance characteristics of sodium silicate sands by ester-microwave composite hardening were tested systematically, and the mechanism was demonstrated.

## PREPARATION OF MOULDING SANDS

The experimental materials include the basic sands with the grain size of 50/100 meshes, the sodium silicate with the modulus of 2,06, density of 1,45g/L and the ester of ethylene glycol diacetate. Three heating powers of 700 W, 1 400 W and 2 000 W were used for microwave heating. The sands samples could be heated in the oven for 0 ~ 99 min. After hardening, the mechanical properties of sodium silicate sands were tested using the cylindrical sands samples with  $\Phi 30 \times 30$ mm. The compressive strength was tested on a lever-type universal strength testing machine and the moisture absorbability weight was tested by the electronic balance with the accuracy of 0,001g [5].

For ester-microwave composite hardening method (EMCHM), the sands mould samples were prepared by the following steps: 1. The ester was mixed with water by the weight proportion of 1:2 as a pretreatment process. 2. Every component was dosed in laboratory miller mixer in the following weight portions: silica sands about 98,5 %, sodium silicate about 1,5 %, ester 0,0015 % - 0,0075 %, so the ester addition was 0,5 % - 2 % by weight percent of sodium silicate binder. The silica sands was mixed with water and ester for 60 s to reduce dusting and improve wettability of grains, and then the sodium silicate binder was added and mixed for the next 120 s. 3. The samples were cured by ester to the stripping strength of 15 KPa after rammer and then demolded. 4. The samples were cured in a microwave oven until reaching service strength ( $\geq 0,7$  MPa), during which the dehumidification was also accomplished.

But for the common hardening method (CHM for short), the sodium silicate sands samples were hardened directly in microwave oven for about 80 - 120 s to the sands service strength.

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The samples were prepared on a laboratory rammer in identical way as for mechanical tests. From the samples, samples with good performance were taken for SEM observations.

## TESTS OF SAMPLES STRENGTH AND MOISTURE ABSORBABILITY OF SANDS MOULD

The compressive strengths of 24 h indoor and 4 h humidistat storage strength of the samples were tested on a lever-type universal strength testing machine. The former was the strength of samples stored in air for 24 h, and the latter was in humidistat with the related humidity of 98 ~ 100 % for 4 h.

The moisture absorbability of the sands samples, in the humidistat with the related humidity of 98 %, were tested by the electronic balance. Firstly the original weight ( $M_0$ ) of the cured sands samples was measured, then the samples were placed in the above condition to get the final weight ( $M_1$ ), so the moisture absorbability of sands samples  $\psi$  was obtained by  $\psi$  [5]:

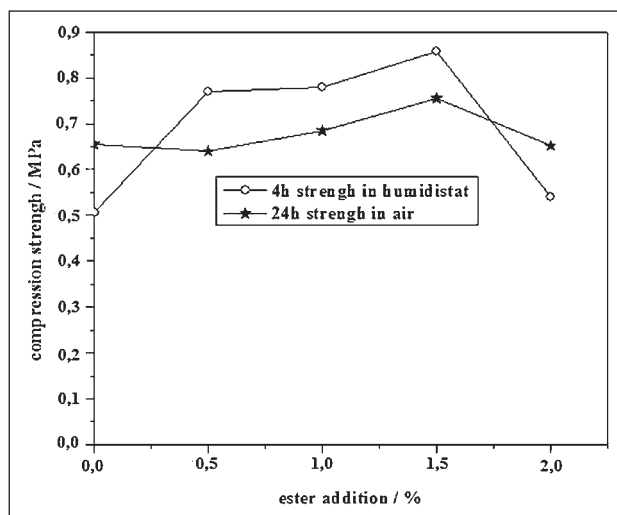
$$\psi = 100 \% \times \frac{M_1 - M_0}{M_0}$$

## RESULTS AND DISCUSSION

The literature results showed that the sodium silicate binder addition was 1,5 % - 1,8 % according to the weight of the sands, and there was an optimal addition amount between the peak strength and material cost [6]. So the addition amount of 1,5 % was used.

When microwave power was 1 400 W and the hardening time was 100 s, the influence curves of ester addition amount on the 24 h indoor and 4 h humidistat storage strength were shown in Figure 1. The ester addition amount was 0 %, 0,5 %, 1 %, 1,5 % and 2 % by weight percent of sodium silicate binder, respectively.

From Figure 1, it was noted that the 24 h indoor and 4 h humidistat storage strength increased with increasing ester at first, and then decreased, and the peak strengths of 1,5 % ester addition were improved by

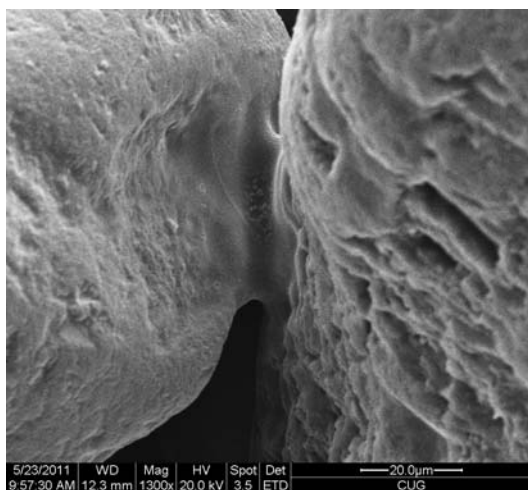


**Figure 1** The effect of ester addition on the compression strength

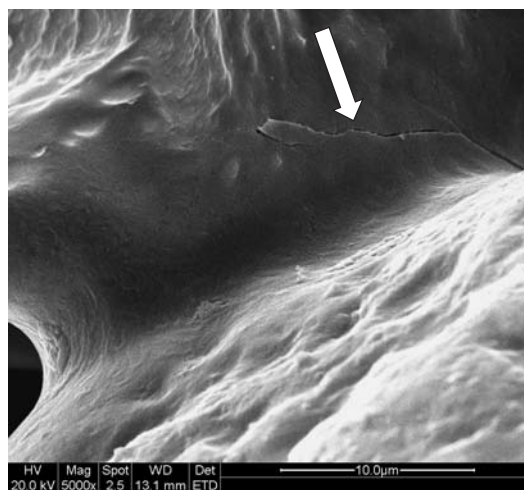
13,5 % (24 h indoor storage strength) and 29,4 % (4 h humidistat storage strength) compared with common microwave hardening. And it can be seen that the composite method can reduce the moisture absorbability by 14,4 %, but storage strengths of the indoor for 24 h and the humidistat for 4h were improved by 29,4 % and 13,5 %, respectively.

Sodium silicate would turn into unstable solution and gel in the  $\text{Na}_2\text{O}-\text{SiO}_2-\text{H}_2\text{O}$  phase diagram, when the modulus rose to 4,12 [7]. And the strength of sodium silicate sands samples reduced when the modulus raised from 2,5 to 4,12 according to our research [6]. The more ester addition to the sodium silicate would produce much higher modulus sodium silicate in the bonding bridge. The strength, however, would begin to decrease when the modulus is over 2,5. But less ester could not produce more sodium acetate crystal and glycerol to protect the bonding bridge. So there was an optimal ester addition, which was related to the solid content and modulus of the sodium silicate.

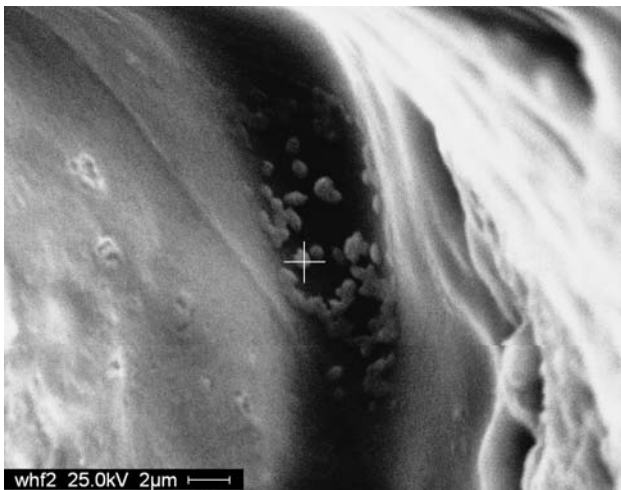
Figure 2 showed the bonding bridge of EMCHM and CHM of the sands samples stored in air for 24h. Figure 2a showed that the bonding bridge forms after



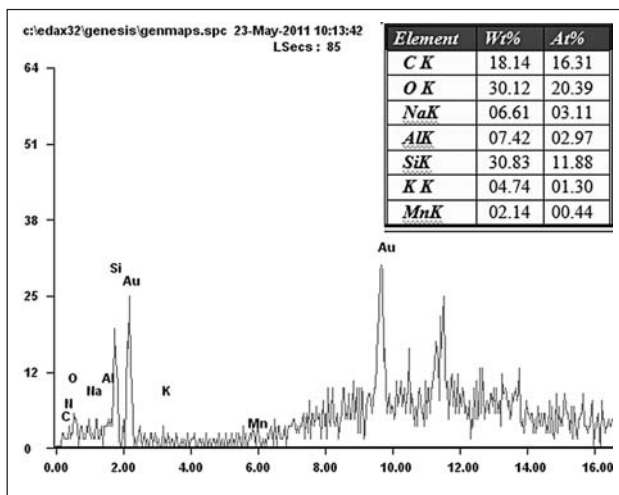
**Figure 2a** Bonding bridge of EMCHM



**Figure 2b** Bonding bridge of CHM

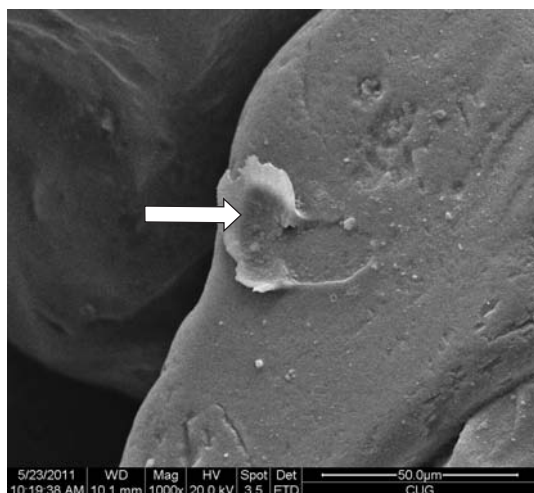


**Figure 3** Sodium acetate trihydrate in the bonding bridge



**Figure 4** EDS of sodium acetate trihydrate

EMCHM, and the bridge was smooth and free from defects. But some visible cracks were in the bonding bridge after CHM (Figure 2b), which reduced the strength. And the cracks in the sodium silicate bonding bridge were caused by the absorption of moisture.



**Figure 5a** Fracture of EMCHM

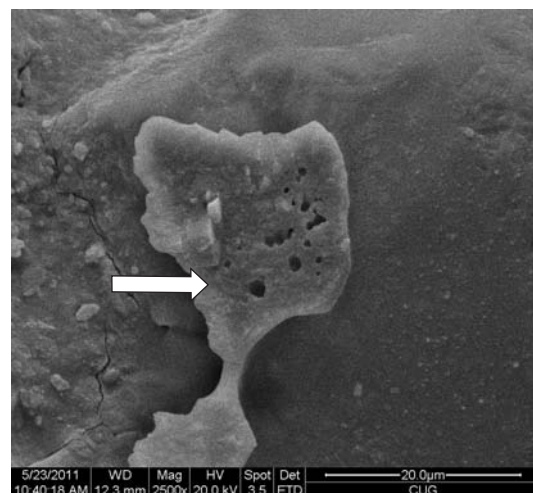
When the bonding bridge of EMCHM was amplified as Figure 3, it can be seen much crystal in the surface of bonding bridge. Figure 4 showed the element of the crystal, it can be seen that the carbon element was quite high, and as we know, there no other materials containing carbon element except for sodium acetate and ethylene glycol, which were produced simultaneously. So the crystal was sodium acetate trihydrate. As the experiments showed, the temperature of sand samples was below 130°C, which was the temperature that sodium acetate crystal could dehydrate the crystal water.

Figure 5 showed the bonding bridge fracture surfaces of EMCHM and CHM. The cohesive fracture mode between the salt particles and the binder was found to be predominant in the samples by EMCHM (Figure 5a), but the composite fracture, including adhesive fracture and cohesive fracture, in the samples by CHM was predominant (Figure 5b). And the visible holes were in the bonding bridge.

### CONCLUSIONS

The ester-microwave composite hardening included two steps: Firstly, the sodium silicate was solution, and it reacted with ester of ethylene glycol diacetate, so the silicon dioxide, sodium acetate and glycerol were produced in the bonding bridges between the sands grains, where there were relatively more reactants of ester and sodium silicate. At the same time, the most silica gel was dissolved to the nearby residual sodium silicate to produce higher modulus sodium silicate, thus the bonding bridges were built when the water was transformed into crystal water of sodium acetate and solvent water of ethylene glycol, so the stripping strength of 15Kpa was established. And locally, only the modulus of sodium silicate in the bonding bridge was improved.

Secondly, the sands samples were heated by microwave, so the bonding bridge formed by ester was reinforced to working strength. Such hydrophobic materials, as glycerol and sodium acetate trihydrate, were



**Figure 5b** Fracture of CHM

fixed in the bonding bridge to protect the bridge, so humidity resistance of the sands was improved.

The ester-microwave composite hardening method had some advantages, such as, simple process, good humidity resistant and no influence on mould. And there was an optimal ester addition amount, which was related to the solid content and modulus of the sodium silicate.

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**Note:** For English language is responsible the lecturer from Wuhan Textile University, China