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# Experimental study of the effect of chemical additives on mechanical properties of foamed concrete

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This paper deals with the foaming of four commonly used anionic surfactants, such as sodium α-alkenyl sulfonate, fatty acid polyoxyethylene ether sodium sulfate, sodium dodecyl benzene sulfonate LAS and sodium dodecyl sulfate K12, which were used as the foaming agent mother liquor. And the new liquid silicone foam stabilizer and carboxymethyl cellulose sodium were used to modify the mother liquor. With the increase of fly ash content, the appearance of foam concrete in the air-cooled group has no obvious change, and the appearance can be kept intact. The appearance of the water-cooled group is obvious. With the increase of fly ash content, the appearance of foam defects are more serious.
**Keywords:** foam concrete, chemical additives, compressive strength.

Исследовано вспенивание четырех обычно используемых анионных поверхностно-активных веществ, таких как α-алкенилсульфонат натрия, полиоксиэтиленовый эфир жирной кислоты, сульфат натрия, додецилбензолсульфонат натрия LAS и додецилсульфат натрия K12, которые используются в качестве пенообразователя основного раствора. Новый жидкий силиконовый стабилизатор пены и карбоксиметилцеллюлоза натрия были использованы для модификации раствора.

**Експериментальне вивчення впливу хімічних добавок на механічні властивості пінобетону.** *L.Gao.*
Досліджено спінювання аніонних поверхнево-активних речовин, що часто використовуються, таких як сульфонат натрію α-алкенів, сульфату натрію поліоксиетиленового ефіру жирної кислоти, додецилбензолсульфонату LAS та додецилсульфату натрію K12, які використовувалися як піноутворювачі розчину. Новий рідкий стабілізатор силіконової піни та карбоксиметилцелюлоза натрію використані для модифікації розчину.

## *1. Introduction*

Foam concrete is a kind of porous concrete, because it contains a large number of closed pores, so that it shows light, high strength, energy saving, insulation and other excellent physical and mechanical properties [1, 2]. There are two kinds of foam concrete production and use. One is a kind of on-site preparation, in situ pouring, when the commercial concrete can be concentrated, and irrigated. And the other way is that a variety of foam concrete building components and products are prefabricated in the factory, and then used for construction [3].

Almost all of the early foam concrete used aluminum powder as a foaming agent. The aluminum powder and other components of water and concrete were put in the mixer simultaneously then the foam was finished in the process of static stop after the gradual completion [4, 5]. The chemical reaction between the aluminum powder and alkali is affected by various factors, such as alkali concentration and ambient temperature in the system. With the evolution of foaming agents from the aluminum powder to organic surfactants and to proteins, the technology and quality of foam concrete are also improved accordingly [6]. The effect of different additives, such as nonionic surfactants, cationic surfactants and water-soluble macromolecules on the concrete foams, was analyzed by using anionic surfactants [7,8]. Through the theoretical and experimental results of the analysis of the different performance of the foam, a suitable compound law for the concrete foam agent was found.

In this paper, by comparing the foam properties of different anionic surfactants, the optimal foaming substance and its dosage were determined, which was defined as the foaming agent mother liquor. The effects of temperature change on the foam properties were determined by single-factor and orthogonal tests. The optimal ratio of the foaming agent was determined by different factors. Based on the Griffith fracture mechanics and composite theory, the relationship between strength and the pore structure of foam concrete was quantitatively analyzed and modified. The related mathematical model was established to reveal the relationship between foam concrete porosity and pore size.

## 2. Experimental

*2.1 Raw materials*

The P · II42.5R grade Portland cement of Nanjing Cement Co., Ltd and grade I fly ash in Jiangsu were used. River sand was used, and according to building materials testing standards "Building sand" (GB/T14684-2007) [9], the sand was used; the test results are shown in Table 1. The monofilament polypropylene fibers which were surface pretreatment and produced by Nanjing Institute of Building Materials were used. Laboratory tap water, which was in line with the "concrete water standards" (JGJ63) requirements was used. The chemical raw materials are presented in Table 2.

Table 1. Physical properties of sand

| Number | Detect content | Standard indicators | Test result |
|---|---|---|---|
| 1 | Performance density, kg/m$^3$ | >2500 | 2550 |
| 2 | Bulk density, kg/m$^3$ | >1350 | 1570 |
| 3 | Void content, % | <47 | 38 |
| 4 | Grain composition | Grading qualified | $^o$C standard |
| 5 | Fineness modulus | >2.3 | 3.0 |
| 6 | Clay powder content, % | <3.0 | 1.0 |
| 7 | Clay lump content, % | <1.0 | 0 |
| 8 | Strong quality loss, % | <8 | 0.2 |
| 9 | Chloride, % | <0.02 | 0.0074 |

Table 2. Chemical raw materials

| Designation | Function |
|---|---|
| SDS sodium dodecyl sulfate | Blister |
| Sodium alpha-olefin sulfonate | Blister |
| SDBS sodium dodecyl benzene sulfonate | Blister |
| Fatty acid polyoxyethylene ether sulfate | Blister |
| Silicone stabilizer | Foam stabilization |
| Hydroxymethyl cellulose | Foam stabilization |
| *n*-butyl alcohol | Hydrotropy |

*2.2 Preparation and performance testing equipment for foaming agent*

A cement paste fluidity tester; a NDJ-1 type rotary viscometer; a foam concrete special mixer; an HN101-3A blast oven, and a DRY-300F thermal Coefficient tester were used.

*2.3 Test methods*

*Preparation of foam concrete and test block conservation*

At present, there are two kinds of foam concrete preparation methods: one is the pre-bubble mixing method, including three processes: the preparation of the base material, the stabilization of the foam prefabricated, and mixing the foam and base material. Another one is known as the mixing bubble, which is characterized by the preparation of slurry and foam simultaneously, and it includes three steps: the preparation of the blowing agent base, prefabricated pouring and static stop of the foam. Compared with the mixed foaming method, the

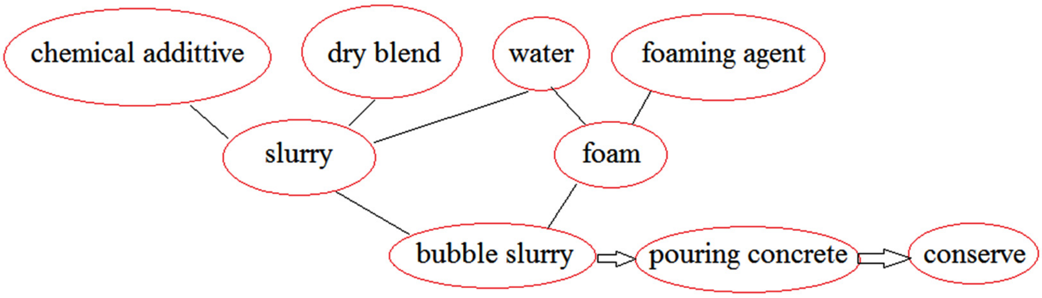


Fig. 1. The production process of foam concrete.

foam concrete slurry prepared by the pre-blister mixing method has good fluidity and can be pumped at a long distance, and the amount of the foaming agent is small. Therefore, the pre-foam mixing method is used to prepare high density foam concrete. Taking fiber reinforced high density foam concrete as an example the preparation process is shown in Fig. 1.

*Determination of thermal shock resistance*

Thermal shock resistance, also known as resistance to rapid cooling-heating, mainly refers to the capacity of the material to withstand a certain degree of rapid changes in temperature and structure until it will be destroyed. Determination of the thermal shock resistance of foam concrete is mainly based on GB/T 3298-2008 "Test method of thermal shock resistance of ceramics for daily use". The specific method was adjusted according to the actual situation of this experiment: the standard curing continued to 28 days aging, foam concrete specimens of 40 mm×40mm×160 mm size were used, acute and emergency heating at 20° and 80° was carried out 10 times in order to observe the appearance of the specimen and determine the quality and strength loss rate. In this test, there were three types of water cooling and air cooling. Three sets (one group of three) of specimens, one of which was kept in the standard room until the test was completed for comparison; two of the group were water cooled.

*Determination of drying shrinkage*

The test method of dry shrinkage of foamed concrete is carried out according to the industry standard JGJ/T 70-2009 "Basic performance test method of building mortar". The foamed concrete is molded in the 40 mm×40 mm×160 mm mold, and then placed in the standard curing room. After three days conserving in the test block, the

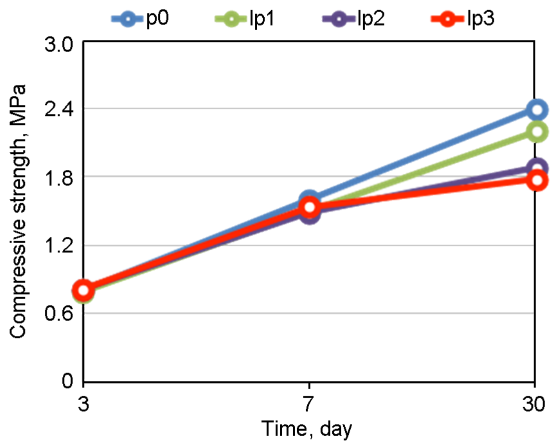


Fig. 2. The influence of chemical additive on the compressive strength of foam concrete.

specimens were placed in the drying shrink room at the temperature 20±2° and relative humidity is 60±5 % to determine the initial length. As the porosity of the foam concrete is large, the linear shrinkage value is relatively large. Therefore, the measurement time interval is short and the moving time is calculated as the aging zero point. The length change is measured according to the time interval of 1, 3, 7, 14, 21 and 28 days. The each time the length is measured, the mass is also weighed at a time.

## *3. Results and discussion*

### *3.1. Effect of chemical additive fineness on foam concrete strength*

In order to study the effect of the fineness of limestone powder on the strength of foam concrete, and to understand the influence of different fineness on the strength of foam concrete, three kinds of limestone lp1, lp2 and lp3 were selected. The specific surface area was 520 $m^2$/kg, 812 $m^2$/kg and 1280 $m^2$/kg, respectively. B05 grade foam concrete and a reference group of B05 grade foam concrete were prepared at 20 % dosage, as shown in Table 3. The compressive strength was tested after curing to the specified age, and the test results are shown in Fig. 2.

Figure 2 shows the effect of different fineness of chemical additive on the compressive strength of foamed concrete. It can be seen that there is a similar trend in each group as the time changes. Specifically, in the early stage, the strength of the foamed concrete mixed with limestone powder after 3 days was larger than that of the baseline group. The strength of the foamed concrete in the p3 group was the largest, 0.83 MPa, and followed by that of p2 group. With the increase of time, the strength of each group of the foam concrete mixed with limestone powder gradually increased, but it was less than in the age group. It is worth noting that the aerosol concrete with lp2 group of limestone powder has the highest strength intensity after 28 days, 2.35 MPa, which is larger than that of the concrete with lp1 and lp3 limestone powders.

*3.2. Effect of chemical additive on drying and shrinkage of foam concrete*

In this study, the B05 grade foam concrete was prepared by using the lp2 group of chemical additive and the A type foaming agent at different water/material ratios. The drying shrinkage value at different aging times was measured, and the test results of the corresponding period of the quality loss are shown below:

Fig. 3 reflects the relationship between the content of the limestone powder and the shrinkage and mass loss of the foam concrete at different water/material ratios. This relationship is not the same at different water/material ratios. Specifically, the drying shrinkage over the whole process is increasing at the ratio of water/material from 0.5 to 0.6, shown in Fig. 4a, and the growth rate of the first 7 days is slightly larger than that in the later stage.

The dry shrinkage of each group continued for 28 days, and for the L30I group with limestone powder content of 30 % it was the largest.

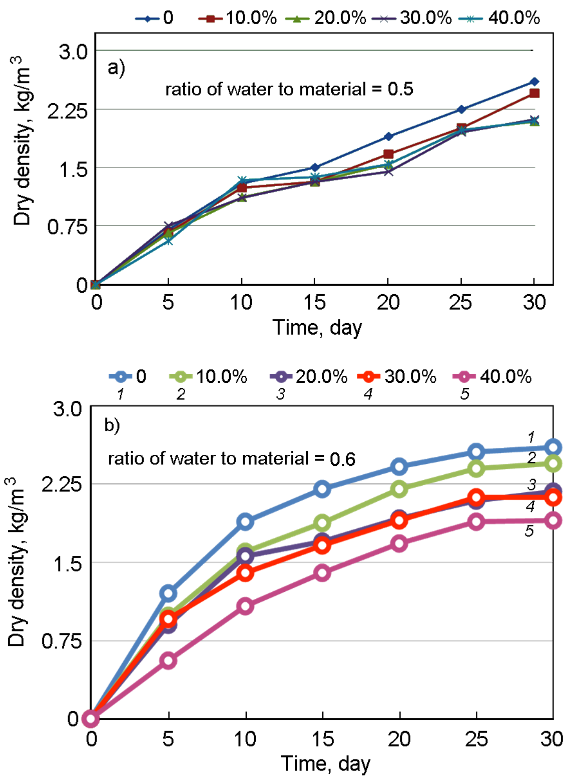


Fig. 3. The relationship between chemical additive and the dry shrinkage and quality loss of foam concrete.

*3.3. Effect of chemical additives content on thermal shock resistance of foamed concrete*

The thermal shock resistance performance is different for foam concrete with different contents of chemical additives. It is noteworthy that the use of water treatment when the limestone powder content is more than 20 % results in more obvious loss of quality.

Fig. 4 and Fig. 5 show the effects of different chemical additive contents, different cooling methods after quenching and emergency treatment. It can be seen from Fig. 4 that the mass loss rate and the strength loss rate of the foamed concrete treated by the water cooling method are higher than these characteristics at the air-cooled method

Table 3. Mixture proportion of the test for the influence of limestone powder on the strength of foam concrete

| Number | Ratio of water to material | Cement, % | Limestone flour, % | Water reducer, % | Early strength agent, % | Foam, L/kg |
|---|---|---|---|---|---|---|
| P0 | 0.5 | 100 | 0 | 1 | 1.5 | 1.5 |
| P1 | 0.5 | 80 | 20 (lp1) | 1 | 1.5 | 1.5 |
| P2 | 0.5 | 80 | 20 (lp2) | 1 | 1.5 | 1.5 |
| P3 | 0.5 | 80 | 20 (lp3) | 1 | 1.5 | 1.5 |

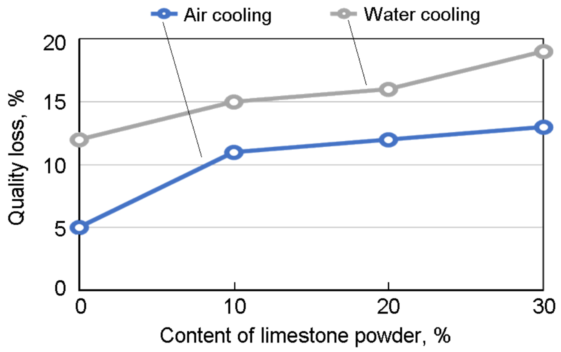


Fig. 4. The influence of chemical additive on the quality loss of foam concrete.

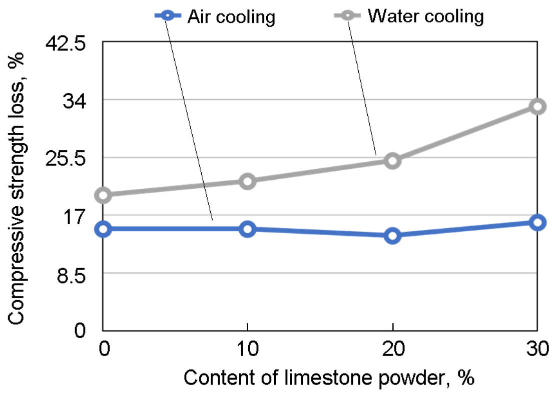


Fig. 5. The influence of chemical additive on the compressive strength loss of foam concrete.

with the respective chemical additive content. In addition, it can be seen from Fig. 5 that independently on the kind of cooling treatment, the foam concrete quality and strength loss rates increase with the increase in the chemical additive content. But it is worth noting that the quality loss and strength loss rates at the air-cooling treatment of the chemical added foamed concrete is slower than under the water-cooling.

## 4. Conclusions

In this paper, the durability of foam concrete with chemical additives is discussed in detail. It mainly deals with the compressive strength, dry shrinkage, thermal shock resistance and so on of the foam concrete added with limestone powder. The optimum content of each material was determined by the orthogonal test. The composite foaming agent was named as a GL-1 type foaming agent, and the effect of temperature change on its foam performance was studied. In the process of preparation of the low-density foam concrete, the use of chemical additives and slag complexes can stimulate the contribution of strength of the foam concrete. This allows the maximum degree of cement hydration while to ensure strength. In addition, an animal protein foaming agent should not be used in low density foam concrete.

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