Acta Technica 62 No. 4A, 697–704

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

Lihua Gao[1]

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

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 (Aydin et al., 2007; Ayudhya et al., 2016). There are two kinds of foam concrete production and use. One is a kind of on-site preparation, in situ pouring, and can also be concentrated, and irrigated by the use of commercial concrete. And the other is that a variety of foam concrete building components and products are prefabricated in the factory, and then used for construction (Binici et al., 2007).

Almost all of the early foam concrete used aluminum powder as a foaming agent. Aluminum powder and other components of water and concrete were put in the mixer at the same time and then the foam was finisher in the process of static stop after the gradual completion (Mydin et al., 2015; Olusunle et al., 2015). The chemical reaction between aluminum powder and alkali is affected by various factors, such as alkali concentration and ambient temperature in the system. With the development of foaming agents from aluminum powder to organic surfactants and to proteins, the technology and quality of foam concrete are also improved accordingly (Roslan

[1] Workshop 1 - Department of Environmental Engineering, North China Institute of Science and Technology, Langfang, Hebei, China, 065201

et al., 2012). 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 (Tan et al., 2017). The different performance of the foam through the theoretical and experimental results of the analysis, were found a suitable compound law for the concrete foam agent.

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 test. The optimal ratio of foaming agent was determined by different factors. Based on Griffith fracture mechanics and composite theory, the relationship between strength and pore structure of foam concrete was quantitatively analyzed and modified. The related mathematical model was established to reveal the relationship between foam concrete and its porosity and pore size.

2. Experiment

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) (Uysal et al., 2012), the sand was used, and the results are shown in Table 1. Use the monofilament polypropylene fiber which were surface pretreatment and produced by Nanjing Institute of Building Materials. Use laboratory tap water, which was in line with the "concrete water standards" (JGJ63) requirement. The chemical raw materials are shown in Table 2.

Table 1. Physical properties of sand

Number	Detect content	standard indicators	Test result
1	performance density/ (kg/m3)	>2500	2550
2	bulk density/ (kg/m3)	>1350	1570
3	void content/%	<47	38
4	grain composition	Grading qualified	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	manufacture factory
SDS sodium dodecyl sulfate	blister	Nanjing chemical industry co. LTD
Sodium alpha-olefin sulfonate	blister	
SDBS sodium dodecyl benzene sulfonate	blister	
Fatty acid polyoxyethylene ether sulfate	blister	Beijing chemical industry co. LTD
Silicone stabilizer	foam stabilization	
hydroxymethyl cellulose	foam stabilization	Shanghai chemical industry co. LTD
n-butyl alcohol	hydrotropy	

2.2. Preparation and performance testing equipment for foaming agent

High pressure air foaming machine, as shown in Figure 1; cement paste fluidity tester; NDJ-1 type rotary viscometer; foam concrete special mixer; HN101-3A blast oven; DRY-300F thermal Coefficient tester.

Fig. 1. High pressure air blowing machine

2.3. Test methods

2.3.1 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 of three processes, the preparation of the base material, the stability of the foam prefabricated, and foam and base material mixture; another one known as the mixing bubble, which is characterized by the preparation of slurry and foam at the same time, and it includes three steps: the preparation of blowing agent base, prefabricated pouring and static stop foam. Take fiber reinforced high density foam concrete as an example, the preparation process is shown in Figure 2.

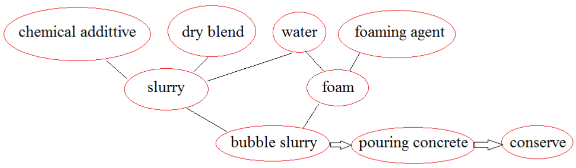

Fig. 2. The production process of foam concrete

2.3.2 Determination of thermal shock resistance

Thermal shock resistance, also known as resistance to rapid cooling hot, mainly refers to the capocity that the material withstand a certain degree of rapid changes in temperature and structure until it will be destroyed. The determination of 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 is adjusted according to the actual situation of this experiment: the standard curing changed to 28 d age, size of 40mm × 40mm × 160mm foam concrete was as specimens, 10 times acute and emergency heat were carrried out at 20 ℃ and 80 ℃ to observe the appearance of the specimen, and determine the quality and strength loss rate. In this test, there are three types of water cooling and air cooling. Three sets (one group of three) specimens, one of which is kept in the standard room until the test is completed for comparison; a group of it is water cooling.

3. Result 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 reference group 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 Figure 3.

Table 3. Mix proportion of the test on 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

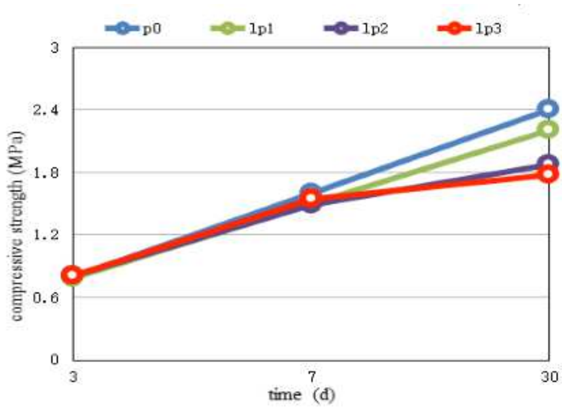

Fig. 3. The influence of chemical additive on the compressive strength of foam concrete

Figure 3 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 in 3 d mixed with limestone powder was larger than that of the baseline group. The p3 group was the largest, which was 0.83 MPa, and followed by p2 group. With the increase of time, the strength of each group of foam concrete which was mixed with limestone powder gradually increased, but were less than the age group. It is worth noting that the aerosol concrete with lp2 group of limestone powder has the highest strength intensity of 28 d, which is 2.35 MPa, which is larger than that of lp1 and lp3 limestone powder.

3.2. Effect of chemical additive on drying and shrinkage of foam Concrete

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

Figure 4 reflects the relationship between the content of limestone powder and the shrinkage and mass loss of foam concrete at different water/material ratios. In the different water ratio, the relationship between the two is not the same. Specifically,

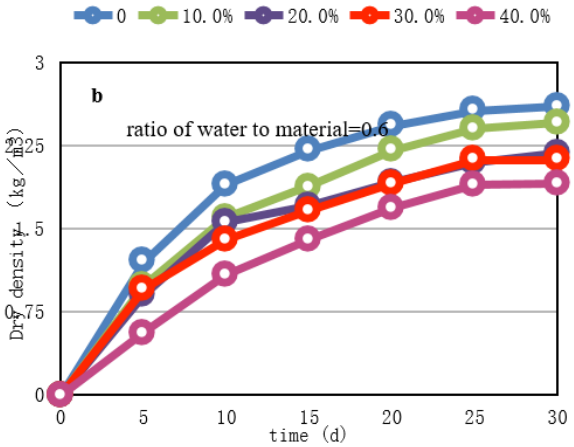

Fig. 4. The relationship between chemical additive and the dry shrinkage and quality loss of foam concrete

the drying shrinkage of the whole process is increasing at the ratio of water/material from 0.5 to 0.6, shown in Figure4 (a), and the growth rate of the first 7 d is slightly larger than that of the later stage. The dry shrinkage of each group was 28 d, and the L30I group with limestone powder content of 30% was the largest.

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

The thermal shock resistance performance of different chemical additive content of foam concrete is different. It is noteworthy that the use of water treatment when the limestone powder content of more than 20% will appear more obvious loss of quality.

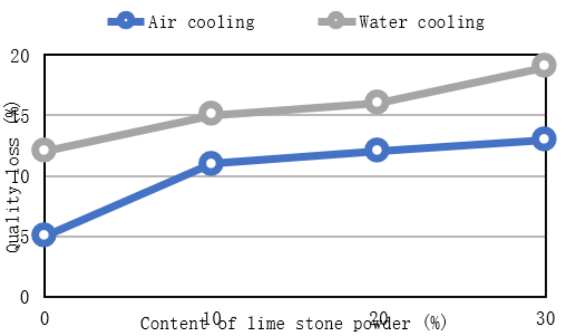

Fig. 5. The influence of chemical additive on the quality loss of foam concrete

Figure 5 and Figure 6 show that the different chemical additive content are, there aredifferent cooling methods after quenching and emergency treatment.. It can be seen from figure 5 that the mass loss rate and the strength loss rate of the foamed

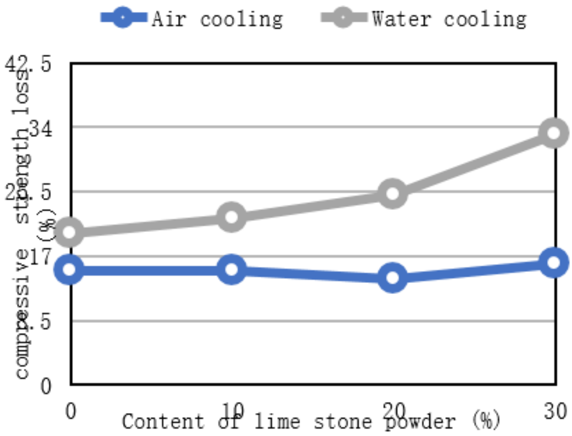

Fig. 6. The influence of chemical additive on the compressive strength loss of foam concrete

concrete treated by the water cooling method are higher than those of the air-cooled method under the respective chemical additive content. In addition, it can be seen from figure 6 that no matter what kind of cooling treatment is, foam concrete quality and strength loss rate increase with the increase in chemical additive content, but it is worth noting that the quality loss and strength loss rate of air-cooled treatment of chemical additive foam concrete is slow than the use of water.

4. Conclusion

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

References

[1] A. C. Aydin, R. Gül: *Influence of volcanic originated natural materials as additives on the setting time and some mechanical properties of concrete.* Construction & Building Materials *21* (2007), No. 6, 1277–1281.

[2] B. I. .N. Ayudhya: *Comparison of compressive and splitting tensile strength of autoclaved aerated concrete (AAC) containing water hyacinth and polypropylene fibre subjected to elevated temperatures.* Materials & Structures *49* (2016), No. 4, 1455–1468.

[3] S H. Binici, H. Kaplan, S. Yilmaz: *Influence of marble and limestone dusts as additives on some mechanical properties of concrete.* Scientific Research & Essays *2* (2007), No. 9, 372–379.

[4] M. A. O. Mydin: *Compressive, flexural and splitting tensile strengths of lightweight foamed concrete with inclusion of steel fibre.* *75* (2015), No. 5.

[5] S. O. O. Olusunle: *Effect of Organic Waste on Crystal Structure and Mechanical Properties of Concrete.* Journal of Minerals & Materials Characterization & Engineering *03* (2015), No. 5, 427–434.

[6] A. F. Roslan, H. Awang, M. A. O. Mydin: *Effects of Various Additives on Drying Shrinkage, Compressive and Flexural Strength of Lightweight Foamed Concrete (LFC).* Advanced Materials Research *626* (2012), No. 587, 594–604.

[7] X. Tan: *Influence of high temperature on the residual physical and mechanical properties of foamed concrete.* Construction & Building Materials *135* (2017), 203–211.

[8] M. Uysal: *The influence of coarse aggregate type on mechanical properties of fly ash additive self-compacting concrete.* Construction & Building Materials *37* (2012), 533–540.

Received October 31, 2017