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THE INVESTIGATION OF SODIUM LAURYL SULPHATE AS FOAM STABILIZER IN CEMENT FOAMS

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Abstract: In this study, we investigated hydrogen-peroxide foamed cement foams to which we used sodium-lauryl-sulfate (SLS) as a foam stabilizing additive. The specimens were prepared cement, water, hydrogen peroxide, expanded perlite and the aforementioned foam stabilizer. The substances listed were applied in two series. In one the amount of foam stabilizer additive was 0.01 wt%, while in the other it was twice 0.02 wt% relative to the weight of the cement. The samples were foamed with a 30% hydrogen-peroxide solution in 4 wt%, 6 wt% and 8 wt%. As a result, we obtained specimens with a body density of 450–660 kg/m^3. The prepared samples had 0.89–2.24 MPa compressive strength on the 28th day. In addition, we examined the macro structure of the specimens.

Keywords: cement foam, body density, foam stabilizing, compressive strength, porosity

INTRODUCTION

Cement foam belongs within to the group of lightweight concretes, with a wide range of bulk densities from 300 to 2,000 kg/m^3. Research on this topic has been carried out since 1980 [1, 2]. Cement foam is a low density and high porosity building material, which we can prepare using by various methods. There are three common forms of making cement foams, which can be made by blowing air, using precursor foam or mixing a chemical foaming additive [3, 4, 5].

There are two types of chemical foaming additives: the most common one is aluminum paste and the other type is hydrogen-peroxide [6, 7, 8]. Hydrogen-peroxide is a strong oxidizing agent that is stable at low pH, however it decomposes in the presence of increasing alkalinity. As a result, the strong alkaline property of fresh cement slurry is a propitious condition for catalyzing the decomposition of hydrogen peroxide. Nevertheless, these are elements in the cement that further catalyze the decomposition process [9]. During the decomposition process bubbles are formed in the cement matrix which these promotes the production of high porosity cement foam. The degree of porosity and compressive strength are closely related. In this context it is not sufficient to determine only the percentage by the volume of the total

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air content, since the mechanical properties are also strongly influence by the shape, size, and distribution of the pores [10, 11].

Fresh cement foam ages through a number of interrelated processes, which reduces the stability of the foam. Such a destabilizing process is fluid flow. As fluid flows, the fluid layers become thinner, thus causing the collapse of the foam sample resulting. The simultaneous presence of bubbles of different sizes improves fluid drainage. However, the presence of smaller and larger size bubbles leads to the diffusion of gases due to different internal pressures [12, 13]. Larger size bubbles also reduce the stability of the foam as the size of the bubble is directly related to the buoyancy force. As a result, the larger the bubbles the faster leave the system, which in dangers the preservation of the foam structure [14]. The bulk density and stability of cement foam can be affected by the addition of appropriate additives, these substances are increased by the viscosity of the solution [15]. Significant in current cement foam production foaming agents are added to create pores in the cement slurry. This is supported by applying various foam stabilizing additives [16, 17, 18]. A number of foam stabilizers have been investigated, such as calcium stearate, sodium-lauryl-ether-sulfate and sodium-lauryl-sulfate [15, 19].

In this study, we used sodium-lauryl-sulfate (SLS) as a foam stabilizer for the preparation of hydrogen peroxide foamed cement foams. During the tests, we changed the amount of foaming agent from 4 to 8 wt% and the foam stabilizing additive, then we observed the effect of these on the bulk density as well as the compressive strength of the specimens.

1. Materials and specimen detail

1.1. Cement

CEM II / B-M (V-LL) 32.5 R composite Portland cement was used as raw material for the tests, which contains fly ash and limestone additives in an amount of 21–35 wt%. A quick-setting cement has a positive impact on the stability of the cement foam. Therefore, we chose rapid cement instead of conventional cement of normal setting time.

1.2. Foaming agent

Hydrogen peroxide is a strong oxidizing agent in which the oxygen atoms are peroxo-bonded to each other. The binding energy of the peroxo-bond is not high. Therefore hydrogen peroxide is thermodynamically unstable, thus quite decomposable, this decomposition process is used to produce cement foams. During the decomposition process water and oxygen are formed [9]. The rate of decomposition of H_2O_2 depends on the alkalinity of the solution: at pH = 10.3 the rate of decomposition is 4-5 times higher than in neutral water [20, 21]. This property is also preferential for the production of cement foams, as fresh cement sludges are strongly alkaline in nature. A 30 wt% hydrogen-peroxide solution was used to prepare the specimens.

1.3. Foam stabilizer

Foam stabilizing additives to play an important role in the production of cement foam, whereas it greatly effects the foam structure formed and the stability of the fresh cement foam produced by the foaming additive. The stabilizers used are generally surfactants which reduce the surface tension of the water. Synthetic surfactants can be further divided into anionic, cationic, amphoteric and non-ionic tensides. Anionic surfactants are the most common due to their low cost [22]. For this reason, sodium-lauryl-sulfate (SLS) was chosen, which belongs to the group of anionic surfactants with a molecular weight of 288.38 g/mol.

1.4. Other additives

As a further, expanded perlite (ANZO P2) was added, which is one of the most popular admixtures in lightweight concrete due to its low body density and excellent thermal insulation. During production, the crude mined perlite is heated to 760–1,100 °C at this temperature, the substance becomes pyroplastic and the water inside it becomes water vapor and increases 4–20 times the original volume of the substance [23, 24]. The energy properties of the expanded perlite are excellent. Due to its high water absorption capacity, it facilitates the post-treatment of concrete. As water-saturated expanded perlite provides water for the later hydration of the cement [25]. In our previous studies, we found that applying expanded perlite during the preparation of cement foams resulted in a more stable fresh cement foam. For this reason, we included in the formula for cement foams. A superplasticizer additive (Mapei Dynamon NG 1012) was also for production of cement foams. This ensured that the cement slurry had sufficient consistency to be field moulds.

1.5. Cement foam preparation

Cement foams were prepared from cement, expanded perlite, water, superplasticizer, foaming agent and foam stabilizer additives. Two series were prepared with different amounts of foam stabilizer. In the first series, the amount of foam stabilizer – relative to the weight of the cement – blended in the mixture was 0.01 wt% while in the other series this amount of double (0.02 wt%). For both series, we made specimens by mixing different volumes of hydrogen peroxide, which we adjusted to 4, 6, and 8 wt%. The w/c ratio was 0.6 in all mixtures, which includes the amount of water introduced with hydrogen peroxide.

The first step in sample preparation was to mix about 30% of the mixing water with the expanded perlite in order to reduced its dusting *(Figure 1)*. The perlite was then added to the weighed out cement. The amount of mixing water remaining was divided in to two parts. The superplasticizer was added to one part, and we dissolved the foam stabilizing additive in the other part *(Figure 2)*.

Figure 1
Expanded perlite mixed with water

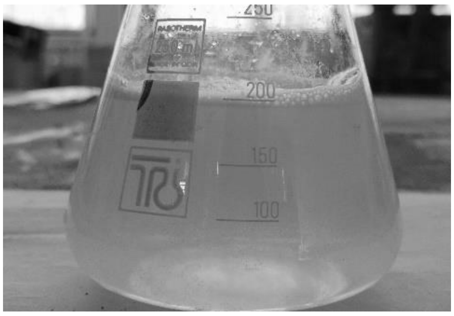

Figure 2
SLS dissolved in water

The moistened expanded perlite and cement were mixed with each other by an electric mixer *(Figure 3)*. After we obtained a homogeneous mixture we added the superplasticizer and the water containing the foam stabilizing additive. The cement slurry was further mixed with intensive mixing, the mixing time was 2 minutes, during which time the superplasticizer made the cement paste reasonably fluid *(Figure 4)*. Finally, diluted (30 wt%) H_2O_2 as the foaming agent was added to the cement slurry. The incorporation of hydrogen-peroxide was carried out by intense mechanical stirring for 10 seconds.

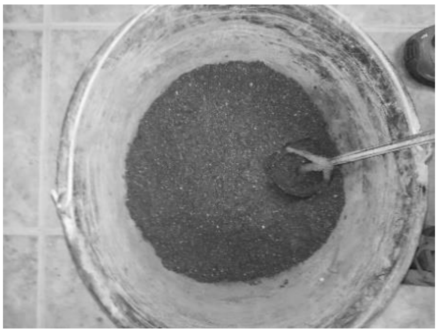

Figure 3
Mixing cement and perlite

Figure 4
Fresh cement slurry after mixing

The cement paste was filled into 70 × 70 × 70 mm moulds after mixing the hydrogen-peroxide. Then the moulds were vibrated with a vibrating table so that the slurry would fill the template evenly. Two hours after casting, top of the samples were removed with a wire. After 24 hours, the moulds decomposition was also performed *(Figure 5)*. The samples had been cured for 28 days at 22 °C under water.

Figure 5
Specimens after template disassembly

2. TESTING OF SPECIMEN

2.1. Compressive strength

The samples were fractured at 28 days of age for compressive strength testing. Three specimens were tested for all mixtures. The compressive strength test was performed with an INSTRON electromechanical tensile-pressure device. The results of compressive strength are included in Table 1 and graphically illustrated in *Figure 6*.

Table 1
Compressive strength and body density of specimen

	Compressive strength [MPa]			**Body Density [kg/m^3]**		
Content of H_2O_2	4 wt%	6 wt%	8 wt%	4 wt%	6 wt%	8 wt%
SLS 0.01wt%	2.24	1.85	1.37	662	557	472
SLS 0.02wt%	1.48	1.20	0.84	615	533	456

As it is shown in *Figure 6* the compressive strength of the samples with 0.02 wt% SLS was lower that of samples made with 0.01 wt% foam stabilizer. The compressive strength of specimens prepared with 4 wt% hydrogen peroxide decreased from 2.24 MPa to 1.48 MPa by doubling the amount of SLS. Numerical values are summarized in *Table 1*.

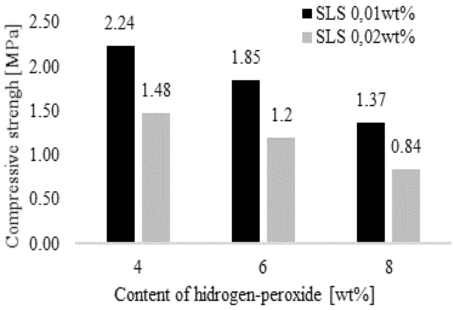

Figure 6
Compressive strength

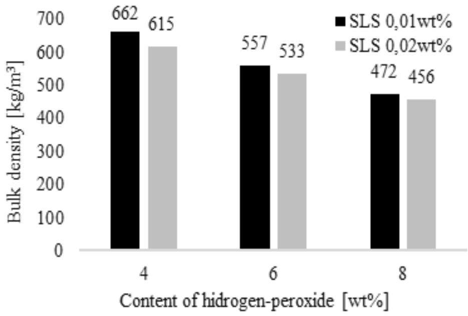

Figure 7
Bulk density

2.2. Bulk density of specimens

The samples were dried at 105 °C to constant weight. Bulk density was calculated for three samples per mixtures. After drying, lengths and weight of the specimens were measured and bulk density was calculated as mass per unit volume. According to *Table 1* that doubling of foam stabilizing additive did not have significant impact on the value of bulk density. Analyzing *Figure 7* it can be seen that, the bulk density of the cubes made with 4 wt% H_2O_2 foaming additive showed a 7% decrease while the amount of foam stabilizer was doubling. For specimens containing 6 wt% and 8 wt% H_2O_2, this reduction was 4.5% in both cases.

2.3. Distribution of average pore size

Macro images were taken of the fracture surface of the specimens. Macrographs of the samples are shown in *Figure 8*. In the captured images, the diameters of the pores were measured using software called ImageJ, then the values were averaged for each specimen. From the pore size measurements *(Table 2)*, it can be concluded that as the amount of hydrogen-peroxide was boosted the pore diameters were increased. In this case the 0.01 wt% SLS mixing was clearly visible, larger pores were formed than when the 0.02 wt% mixing was used.

Table 2
Distribution of average pore size

	0.01 wt% SLS			0.02 wt% SLS		
Content of H_2O_2	4 wt%	6 wt%	8 wt%	4 wt%	6 wt%	8 wt%
Pore size [mm]	1.607	2.741	3.775	1.386	2.019	2.378

Figure 8 shows that as the ratio of hydrogen-peroxide increased, the pores which were differed more and more from the spherical shape. The sample was prepared with 0.01 wt% SLS and 8 wt% foaming additive showed the most distorted pore structure.

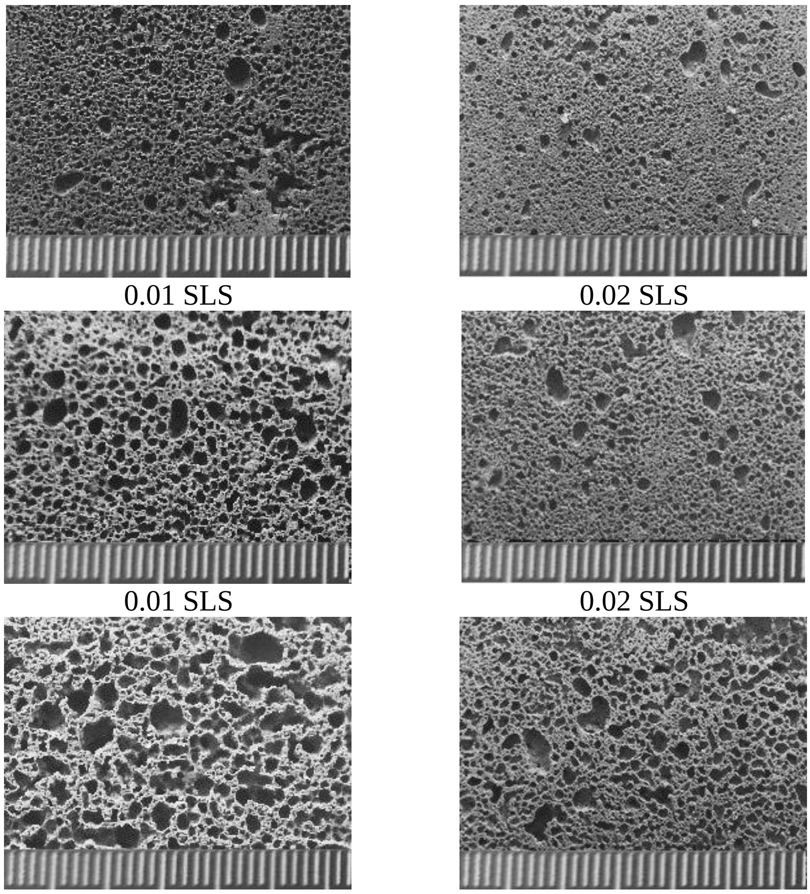

Figure 8
Macro structure of samples

CONCLUSIONS

Foam stabilizer additives promote the formation of an appropriate cement foam structure. It is most optimal for the foams to form spherical pores in an even distribution, which results in a stable fresh cement foam. For this purpose, we need to optimize a number of things, such as the w/c ratio, the amount of foaming and stabilizing additives, because the best combination of these materials gives the best results.

Investigations have revealed, that doubling the amount of SLS showed lower compressive strength values in all cases. Samples made with 0.02 wt% SLS had ~35% lower compressive strength than the series containing 0.01 wt% foam stabilizer. For instance, the compressive strength of cubes prepared with 4 wt% hydrogen-peroxide decreased from 2.24 MPa to 1.48 MPa.

The bulk density of specimens did not change significantly by doubling the amount of foam stabilizer. The bulk density of the specimens made with 4 wt% H_2O_2 foaming additive showed a 7% decrease while in the case of specimens containing 6 wt% and 8 wt% hydrogen-peroxide respectively this reduction was 4.5%.

The macro structure of specimens prepared with two different amounts of SLS differed from each other significantly. The largest divergences were in the case of the cubes prepared with 8 wt% H_2O_2 content. The samples with a foam stabilizer content of 0.01 wt% showed a rather deformed picture at this foaming additive content. In addition, the average pore size of the cement foam was larger than in the case of the 0.02 wt% foam stabilizer.

According to these results based on, it can be said that, increasing the amount of foam stabilizing additive resulted in a uniform pore distribution and pore size. In contrast, the results of the compressive strength test showed a significant decrease.

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