Academia Open
Vol 10 No 1 (2025): June (In Progress)
DOI: 10.21070/acopen.10.2025.10508 . Article type: (Engineering)

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ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

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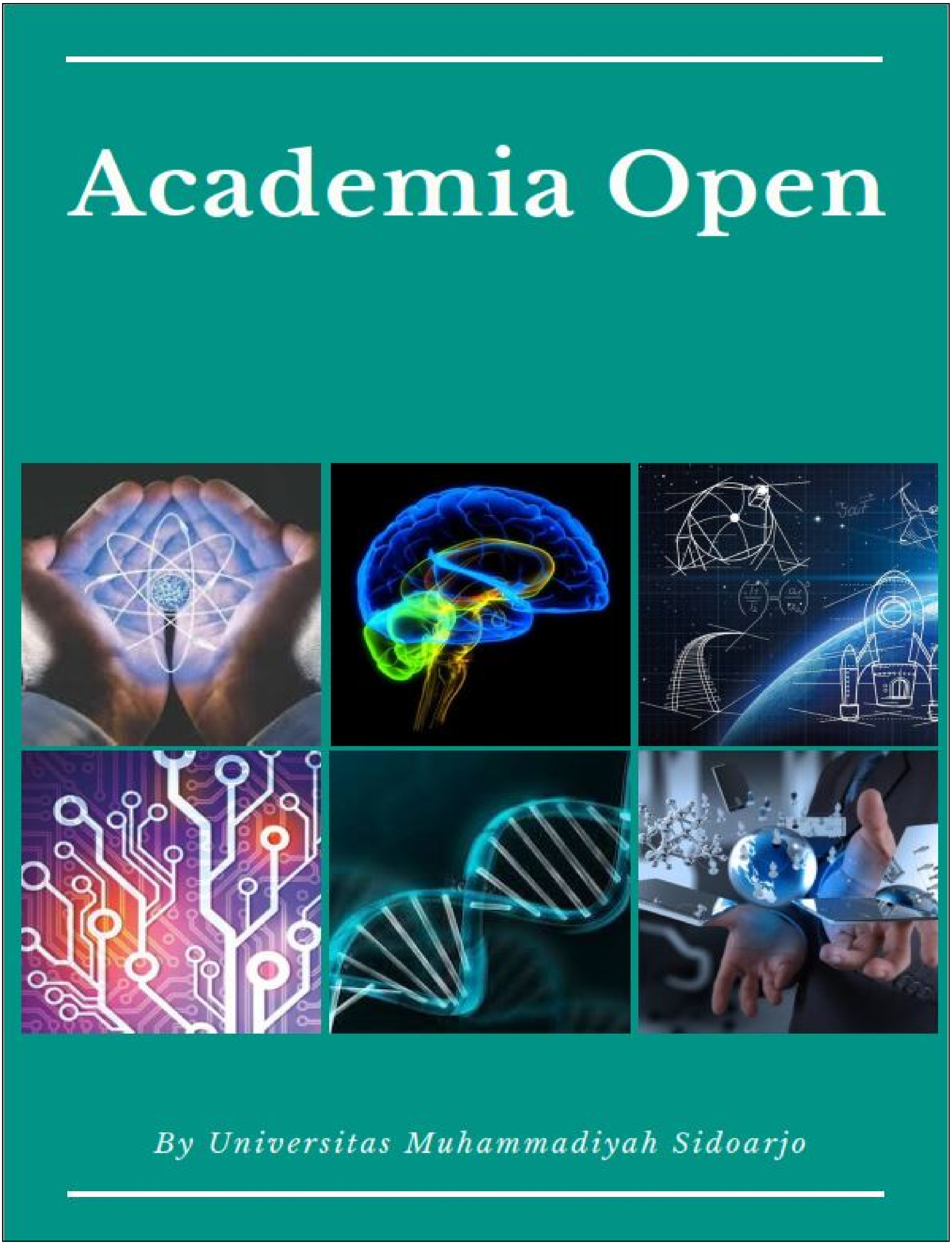

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Academia Open
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ISSN 2714-7444 (online), https://acopen.umsida.ac.id, published by Universitas Muhammadiyah Sidoarjo

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Study of the Properties of Foaming Agents Ufapore gp xp 75%, Omax ks100 and Frem Foam for Foam Concrete

Studi Sifat Bahan Pembusa Ufapore gp xp 75%, Omax ks100 dan Frem Foam untuk Beton Busa

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Abstract

The article examines the main properties of foaming agents UFAPORE GP XP 75%, OMAX KS100 and FREM FOAM such as - high expansion and durability, sufficient foam durability in solution, durability of the mixture over time. The results of the analysis of the stability, expansion rate and mechanical strength of the foam made it possible to determine the optimal concentrations of the FREM FOAM foaming agent, at which the foam demonstrates the best technological characteristics. To assess the effect of binders and fillers on the foam volume, the foam utilization factor (FUF) was calculated, which is the ratio of the volume of the foam-cement mixture to the initial volume of foam. It is believed that high-quality foam should have a FUF in the range of 0.8–0.85. Initial experiments showed that at surfactant concentrations of up to 0.5%, the foam mass is insufficient to obtain foam-cement masses with constant properties. At the same time, at concentrations over 2.5%, there is excessive consumption of foaming agent, which leads to a violation of the homogeneity of the foam structure. As a result, the optimal range of foaming agent concentrations from 0.5 to 2.5% was selected.

Highlights:

1. Examines properties of foaming agents: expansion, durability, and stability.
2. Determines optimal FREM FOAM concentrations for best foam characteristics.
3. Identifies optimal foam utilization factor range (0.8–0.85) for quality foam.

Keywords - foaming agent, non-autoclave, foam, porous , foam mass , foaming agent multiplicity.

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Academia Open
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Published date: 2025-01-29 00:00:00

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Introduction

The growth of prices for fuel and energy resources requires improvement of thermal insulation of buildings. To solve the problem of reducing heat loss in building structures, several effective thermal insulation materials have been developed, among which non-autoclaved cellular concretes are promising. These materials have such advantages as fire resistance, biological stability and low thermal conductivity.

In recent years, there has been a steady increase in the use of non-autoclaved foam concrete with an average density of 400 to 600 kg/m³, which is actively used for external wall structures. Foam concrete is one of the most effective materials for thermal insulation, especially in regions with extreme climatic conditions.

However, despite its positive properties, such as low thermal conductivity, medium density and cost-effectiveness, as well as the possibility of recycling industrial waste, non-autoclaved foam concrete has significant limitations, the main one being low strength. This complicates its use as a wall material or insulation for interfloor ceilings, where it is necessary to ensure strength in the range from 0.5 to 2.0 MPa. The use of plasticizers and ultrafine fillers can significantly improve the physical and mechanical properties of non-autoclaved foam concrete, bringing them closer to the properties of autoclaved concrete at a similar density. Today, many new plasticizers appear on the market, but their use in the production of foam concrete has not yet been studied much.

Foam concrete is an artificial porous building material that is obtained by mixing specially prepared foam with a mortar mixture (including a binder, filler and water), or by quickly mixing the mortar mixture with a foaming agent. The latter is a surface-active substance (SAS) that reduces the surface tension of water and retains air in the mixture. Depending on its density, foam concrete can contain up to 85% or more air, which gives it excellent heat and sound insulation properties.

This article examines foam concretes with an average density of 400 to 500 kg/m³, which are classified as thermal insulation materials. Synthetic substances such as UFAPORE GP XP 75%, OMAX KS100 and FREM FOAM were studied as foaming agents.

The foaming agent has a dual effect on the quality of foam concrete: on the one hand, it helps form a porous structure and achieve the required density, on the other hand, it slows down the process of setting and hardening of the binder, which can lead to a decrease in the strength of the final product. Therefore, the choice of the type of foaming agent and its optimal concentration is of crucial importance. For each foaming agent, key parameters were determined, such as multiplicity, stability and foam utilization coefficient at different concentrations of aqueous solutions.

Methods

Study Of Foam Stability In Cement Mortar

One of the main indicators that characterizes the stability of foam in solution is the coefficient of stability of foam in solution (α). To determine it, the same volumes of foam and solution were used in the experiments. The mixing process continued for one minute. After that, the final volume of the foam mass was measured , and based on the data obtained, the coefficient of stability was calculated using the appropriate formula.

$$\alpha = \frac{(V_п + V_р)}{V_{пм}} \cdot 100\%,$$

Figure 1.

where V_p is the volume of foam, l;

V_p – volume of solution, l;

V_{pm} – volume of foam mass , l.

Determination Of Multiplicity And Durability Over Time

The determination of the multiplicity and stability over time of foam of different concentrations of an aqueous solution of foaming agent was carried out in accordance with GOST R 50588-93, clause 5.2.

Foam multiplicity Kp is the ratio $_{of}$ the volume of foam obtained after foaming V_n , to the volume of the aqueous solution of the foaming agent V_n^p, spent on obtaining it.

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$$Kr_n = \frac{V_n}{V_n^P} , (1)$$

Figure 2.

Foam stability, or durability over time, is defined as the duration of its existence without losing its initial properties. This characteristic is assessed by the time required to destroy 50% of the foam volume or to lose 50% of the liquid.

The foam utilization coefficient allows one to evaluate its compatibility with the hardening solution and helps to determine the required volume of foam to obtain a foam concrete mixture.

To calculate the foam utilization factor, one liter of cement mortar with a water-cement ratio of 0.4 and one liter of foam with a given concentration of an aqueous solution of foaming agent should be mixed for one minute. After that, the volume of the resulting mixture is measured. foam mass and divide it by two. The resulting value will be the foam utilization factor (FUF).

Foam is considered satisfactory if the utilization factor is between 0.8 and 0.85, and high-quality if its value is equal to or greater than 0.95.

The higher the multiplicity and stability coefficient of the foam in the solution, the less amount of foam and foaming agent is required to achieve the required density of foam concrete.

Result and Discussion

The choice of foaming agent has a significant impact on both the technological process of foam concrete production and the technical and operational characteristics of the final product. The properties of the foam have a variety of effects on the process of formation and hardening of the foam concrete mass, which in turn affects the operational qualities of buildings and structures erected from this material. The quality of foaming solutions and the foams obtained from them is assessed using various criteria depending on the industry. These may be parameters such as the volume of foam obtained from a unit of foaming agent (for example, for cleaning boiler water), the time of maintaining foam activity (for cooking), biocidal properties (in pharmacology), bearing capacity (for flotation), viscosity (for dust suppression), resistance to thermal effects (for fire extinguishing), wetting ability (for cleaning surfaces), the time of maintaining effective foaming (in aerosol foams), and others.

At present, there is no universal approach to assessing the efficiency of a foaming agent, since each specific case requires the use of specific criteria. For the production of foam concrete, the following foam parameters are most significant: multiplicity (the ratio of the foam volume before its formation to the volume of the foaming agent solution), stability (the time of foam volume decay per unit of time), dispersion (the average size of bubbles and their distribution by the foam volume), density (the ratio of liquid and gas phases), structural and mechanical properties (the ability to retain their shape for a certain time), bearing capacity (the ability of bubbles to hold substances on their surface without destruction), the effect on the plastic viscosity of the cellular concrete mixture, hydrophobization or hydrophilization of the pore space of concrete, as well as the effect of foaming agent components on the cement hydration process. It is also important to consider the compatibility of foam with other additives used in the production of foam concrete, such as plasticizers, accelerators, gas-releasing and hydrophobic substances, etc.

To study the properties of foaming agents, three types of foaming agents were used : UFAPORE GP XP 75%, OMAX KS100 and FREM FOAM.

The foaming agent used in the production of foam concrete must meet several key requirements:

1. high multiplicity and durability;

2. compliance with sanitary and hygienic standards;

3. sufficient stability of foam in solution;

4. stability of the mixture over time.

High Multiplicity And Durability

The expansion ratio of the foaming agent and its stability are the main physical characteristics of technical foam, which determine the quality of the foaming agent. These indicators depend on the type of foaming agent and the process of its preparation, which, in turn, affects the physical and mechanical properties of porous concrete. The expansion ratio of the foaming agent should be at least 10, which is important to minimize the negative impact of

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the foaming agent on the hydration of the binder component. In most cases, foaming agents are supplied in concentrated form and require dilution with water. For the experiments, aqueous solutions of the foaming agent with concentrations of 1%, 2.5%, 5% and 10% were used. The expansion ratio of the foaming agent is defined as the ratio of the volume of the resulting foam to the volume of the original foaming agent solution in water.

The foaming agent multiplicity is calculated using the following formula: the volume of the resulting foam is divided by the volume of the original foaming agent solution, as shown in Figure 1.

Results obtained:

UFAPORE GP XP 75%

1. 1% 1.6/0.14=11.4
2. 2.5% 1.6/0.11=14.5
3. 5% 1.6/0.1=16
4. 10% 1.6/0.08=20

FREM FOAM

1. 1% 1.7/0.13=13.0
2. 2.5% 1.7/0.11=15.4
3. 5% 1.7/0.09=18.8
4. 10% 1.7/0.07=24.2

OMAX KS100

1. 1% 1.65/0.16=10.3
2. 2.5% 1.65/0.12=13.7
3. 5% 1.65/0.11=15.0
4. 10% 1.65/0.09=18.3

Foam with a multiplicity of 15–35 is used for the production of foam concrete.

The strength of foam concrete depends on the volume of water added to the foamed mixture, which promotes additional formation of capillary pores. A decrease in the water-solid ratio (W/S) in the foamed solution affects the value of C , which in turn leads to an increase in the density of the resulting foam concrete. In this regard, in the production process of foam concrete, some technologists prefer to use higher values of W /S. This approach allows, by increasing the value of C, to obtain foam concrete with a lower density, while reducing the negative impact of the foaming agent on the hydration of the binder.

The use of high expansion foam (the so-called "dry foam") leads to the redistribution of water from the hardening solution into the interfilm layers of foam bubbles. This effect is typical when using certain types of foaming agents and foams with increased viscosity.

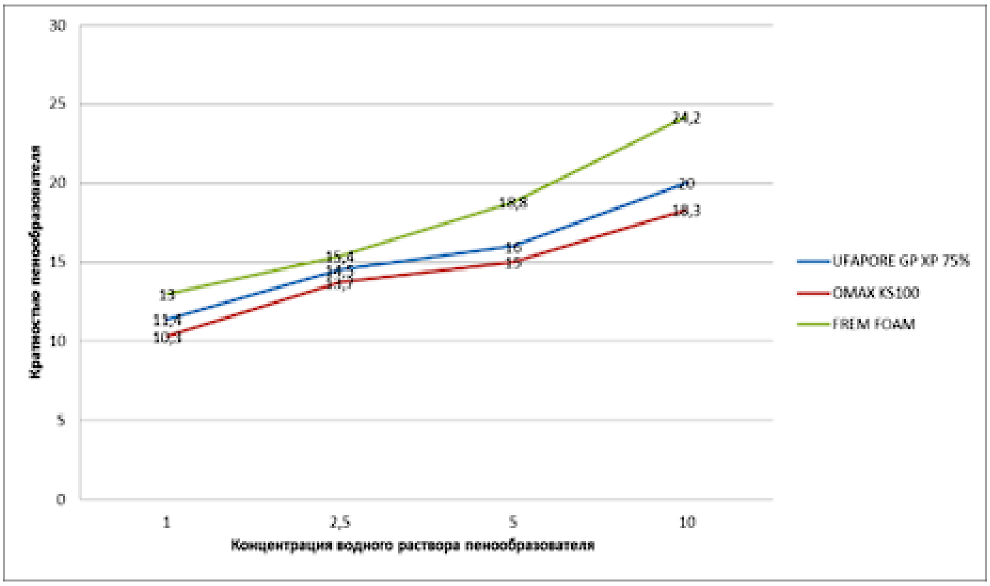

Figure 3. *Effect of concentration of aqueous solution on foaming agent multiplicity*

- compliance with sanitary and hygienic standards

Foaming agents must be non-toxic, non-explosive and, according to the classification according to GOST 12.1.007-76, belong to the 3rd, 4th class of low-hazard substances, and meet sanitary and radiation-hygienic requirements. The biodegradability of the foaming agents being developed must meet the requirements for the use of surfactants (surface-active substances) in the production of building materials.

- sufficient stability of foam in solution

This parameter is one of the key indicators of the quality of technical foam. It is determined by the coefficient of foam resistance in cement paste during laboratory tests, and in production conditions - by the coefficient of foam use. These coefficients reflect not only the compatibility of the foam with the hardening solution, but also show what part of the foam volume can be effectively used in the preparation of a porous solution.

In laboratory conditions, the foam stability coefficient was determined manually by mixing equal volumes (1 liter each) of cement mortar (with W/ C = 0.4) and foam for one minute. After mixing, the volume of the resulting porous mass was measured. The foam stability coefficient in the cement mortar was calculated as the average value of three measurements. For this, 1 liter of foam and 1 liter of cement were mixed for one minute, then the volume of the resulting foam mass was measured . After that, the result was divided by two, and the foam utilization coefficient was obtained, designated as C.

foam mass obtained with foaming agents UFAPORE GP XP 75%, -1.6:2 and received C - 0.8, OMAX KS100 – 1.65:2=0.82, FREM FOAM – 1.7:2=0.85.

Technical foam is considered satisfactory if its resistance coefficient (C) is in the range from 0.8 to 0.85, and high-quality if C = 0.95. For example, when using the foaming agent "imported foaming agent", it is possible to obtain foam with a resistance coefficient of C = 0.98. This foam resistance indicator is directly related to the density and strength of the resulting foam concrete. The higher the foam resistance coefficient, the less its volume is required to obtain foam concrete with the required density, which, in turn, reduces the consumption of the foaming agent.

Like any additive, a foaming agent introduced in excessive quantities can slow down or even completely stop the binder hardening process at the initial stage. The amount of foaming agent that passes into the liquid phase during the binder hardening process depends on the C value . Thus, it is possible to reduce the volume of foaming agent in the concrete mix by using foam with a higher expansion ratio, while maintaining high C values.

The technological parameters of foam are interrelated and can sometimes be contradictory. Therefore, for each foaming agent composition and type of technical foam, it is necessary to carefully determine the priority of their influence on the technological and physical-mechanical properties of foam concrete.

- stability of the mixture over time

The stability of the porous mixture over time is determined by the precipitation of the foam concrete mixture. It can be assumed that the precipitation process is affected by changes in the pH of the hardening concrete environment, as well as the redistribution of the surfactant (surface-active substance of the foaming agent) in the dispersed system. If the interpore partitions (formed under the influence of the surfactant) are not strong enough, they can break through and merge. Such changes in the porous mixture over time are recorded by measuring the height of the mixture's precipitation in relation to its initial height. The smaller the precipitation, the higher the quality of the foaming agent and technical foam.

The main criteria for assessing the properties of foaming agents include the concentration of the foaming agent at which stable foam is obtained, the foam multiplicity and the coefficient of its stability in the binder solution. These parameters are necessary for the preliminary assessment of the quality of the foaming agent.

When analyzing the foaming agents UFAPORE GP XP 75%, OMAX KS100 and FREM FOAM taking into account these criteria, it turns out that they are suitable for use under normal conditions. The results of these studies are presented in Table 1.

Foaming agent performance	UFAPORE GP XP 75%				FREM FOAM				OMAX KS100			
1	Concentration of aqueous solution, %	1	2.5	5	10	1	2.5	5	10	1	2.5	5

2	Foam multiplicity	11.4	14.5	16	20	13	15.4	18.8	24.2	10.3	13.7	15
3	Foam stability over time , min .	6	10	16	15	15	19	16	16	10	13	14
4	Foam utilization rate	0.8				0.85				0.82		

Table 1. *Characteristics of foams depending on the concentration of aqueous solution*

According to [1], high-quality foam should have a foam utilization factor (FUF) in the range from 0.8 to 0.85. The results of preliminary experiments showed that at surfactant concentrations of up to 0.5% by weight . the resulting foam does not ensure the creation of a stable foam-cement mass with constant properties. At the same time, at concentrations above 2.5% by weight . There is an overconsumption of foaming agent, which leads to a violation of the homogeneity of the foam structure. In this regard, the optimal range of foaming agent concentrations from 0.1 to 2.5% was selected.

Conclusion

1. It was found that the foaming agents UFAPORE GP XP –75%, FREM FOAM and OMAX KS100 have a high expansion factor, which for them is respectively: 11.4, 14.5, 16, 20 for UFAPORE GP XP –75%, 13.0, 15.4, 18.8, 24.2 for FREM FOAM, and 10.3, 13.7, 15.0, 18.3 for OMAX KS100 at a concentration of the aqueous solution of the foaming agent of 1%, 2.5%, 5% and 10%.

2. For all three foaming agents, their sufficient stability in solution was determined, measured using the foam utilization coefficient (C), which was: for UFAPORE GP XP –75% - 0.8, for FREM FOAM - 0.85, and for OMAX KS100 - 0.82.

3. The optimum stability of foaming mixtures over time was determined, which was assessed by measuring the height of the sedimentation of the porous mixture relative to its initial height. For foaming agents UFAPORE GP XP –75%, FREM FOAM and OMAX KS100 the results were 12, 18 and 15, respectively.

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