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Improving the Efficiency of Well Cementing in Permafrost Regions by Using Gas-Liquid Cement Mixtures

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Abstract
The result of the experimental investigation on the technological properties of the cement containing silica-alumina hollow microsphere are observed to increase the quality of well casing. It was defined that increased content of hollow microspheres in the composition of the cement will increase the strength of the set cement.

Keywords: cementing, permafrost, silica-alumina hollow microsphere, microsphere, gas-liquid cement mixture, cement stone

INTRODUCTION

In connection with the growth of drilling operations in areas with complex geological and hydrogeological conditions and harsh climate there is a need to develop efficient technologies of wells construction. Poor sealing of the annular space entails increasing labor intensity, material consumption, and accidents. Changes in temperature in the borehole may contribute to violations in the integrity of the cement stone with the surrounding rocks and boreholes [1] and stone [2]. Therefore, for cementing casing columns of wells in the areas of distribution of permafrost (ADP) is required to use special grout mixes.

From this point of view the optimal solution for creating high-quality thermal insulation and tightness the annular space of wells in the intervals of ADP is the use of ultra-light cement slurries, which are presented as gas-liquid cement mixtures (GLCM), which have low thermal conductivity (0,25-0,7 W/(m·°C)) [3]. Their properties allow to avoid the main complications associated with casing in ADP.

Cement blend involving the gas phase are characterized by a number of specific properties that makes them unique. For example, the density of these mixtures can vary in wide range, their minimum value can reach up to 360 kg/m3 [3], which is impossible for other cement slurries. Owing to the low density values and the presence of hollow cells filled with gas, GLGM and get them on the basis of cement stone have lower thermal conductivity than conventional cement slurries. In addition, GLSM have the best bridging (bridging) capability [4]; provide in the annular space of optimal hydrostatic pressure, on the one hand prevents flow in the borehole formation water, and with another – warning hydraulic fracturing; have a low water and gas permeability [3]. The ability of these solutions to expand contributes to better isolate areas of acquisitions [5]. The resulting cement stone has good enough strength and durability in the annulus [6], and able to efficiently communicate with rocks and the casing [7]. With the elimination of zones acquisitions using GLSM great importance is their low density [3, 6, 8].

Results of researches of technological properties of gas-liquid cement mixtures with silica-alumina hollow microspheres

To give greater strength of the formed cement stone was proposed for GLSM to enter the silica-alumina hollow microsphere (SAHM). In addition, the choice of this additive was caused by the low density and low thermal conductivity and low cost [9]. In the result of experimental researches it was identified that GLSM entered in them, SAHM also have low density [10].

Based on the analysis of experience of the wells, were identified the main indicators of the cement slurry, allowing to provide high-quality grouting the annulus. Due to the different geological conditions and possible complications some of the parameters used cement compositions can vary.

The technology of preparation and methods of research of properties of liquid cement mixes with the inclusion of SAHM conventional aerated cement slurries. This paper studied the following technological properties GLSM: the water and gas content, flow, density, sedimentation stability, setting time, strength of cement stone.

Mounting holes in the areas of ADP imposes on the applied cement compositions and formed by them the cement stone special requirements (table 1).

Table 1. Requirements for properties GLGM and get the stone in the cementing of wells in areas of ADP [11]

Indicators	Units	Normalized rate of cement
The ratio of dehydration at the temperature of 0°C no more	%	2,0
Water-cement ratio, not more	-	0,6
Spreadability* at a temperature of 0°C, no more not less than	см см	19 16
Setting time* when the temperature 0±5°C: start no earlier completed	ч ч	2 10
Shrinkage of the cement stone	%	0
Tensile strength at bending up to 48 h of hardening at a temperature of 0±5°C , not less than	МПа	0,7

* - these figures relate to parisvendome grouting solution

Based on previously conducted experiments for determining the start and end of setting of cement mixes at a temperature of 0±5°C was chosen cement from gypsum and alumina as a binder. In addition, in order to reduce the setting time of the mortars, they were introduced CaCl2 and Ca(NO3)2. It should also be noted that these additives prevented the freezing of cement mixes in the process of setting and hardening at low temperatures (0 to -5°C).

Setting time developed GLSM containing SAHM was determined using Vicat apparatus prior to the aeration of the mixtures, but with the inclusion of all components. Experiments indicate that air bubbles do not have a significant effect on the setting time of cement slurry [12].

After mixing of grouting mixture at room temperature, it was poured into the cone tool, placed in the refrigerating chamber and the passage of time was measured in terms of its setting. Initial setting time of the plugging mixture should occur no earlier than 2 hours at a temperature of 0±5°C and end no later than 10 hours [11, 13, 14, 15].

The results of experiments to determine the setting time of the cement mixtures developed from different content of hollow microspheres and temperature is shown in Figure 1.

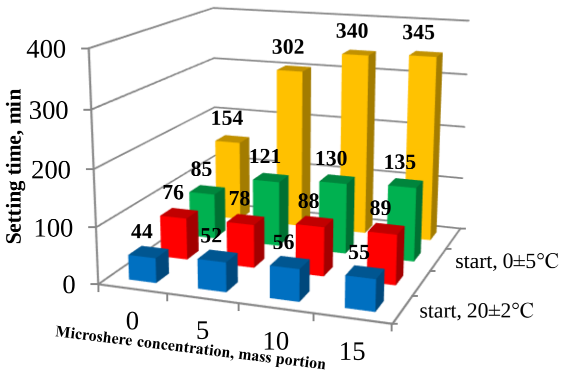

Figure 1. Dependence of setting time of backfill mixes content in their composition, and SAHM ambient temperature

The setting time of cement mixes increases with increase in the concentration of the hollow microspheres. This phenomenon can be explained by the fact that with increasing the content of SAHM in the mixture decreases the amount of the binder component. Almost all solutions (except the first) setting time complies with the requirements related to permafrost.

The setting time of the mixtures is affected by many factors which include the type of binders and their concentration, introduce additives that can speed up or slow down the process of setting, the amount of the contained water, temperature, pressure, and many others.

Long setting time of cement mixture can lead to poor sedimentation stability in which the cement ring will lose its continuity, and formed the cement stone will have a loose structure with the inclusion of water-filled cracks and channels that have a variety of shapes and sizes [16].

Determination of the density of the developed mixtures on the scale Mud Balance Model 140, depending on the amount of entrained air and the concentration of the hollow microspheres was carried out under conditions of room temperature and atmospheric pressure is close to normal. In Figure 2 presents the results of experimental studies.

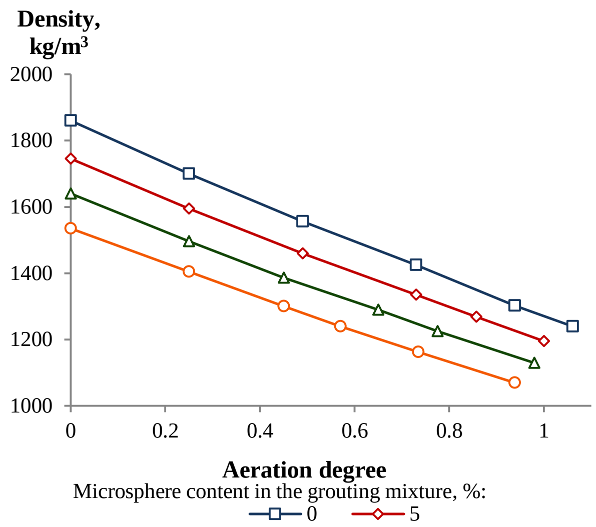

Figure 2. Dependence of the density of the mixtures to the degree of the aeration and the content of HASM

The air involved in the mixture by mechanical aeration using a special stirrer, which is equipped with two blades, located at a distance of 32 mm from each other (the axes), and has a rotational speed equal to 1000 rpm.

As air-entraining additives used wood saponified resin (WSR). Based on the studies of thin sections of the cement stone been found that the use of WSR allows to obtain cement stone with pore sizes less than 250 mm (Figure 3).

The density of the cement mixtures decreases with increasing content of hollow microspheres. This is due to the fact that the input of SAHM are characterized by a significantly lower density than the cement. It should also be noted that increasing the concentration of hollow microspheres reduces formation in mixtures of air bubbles, as SAHM delay a part of the free water contained in the mixture and is essential for formation of air cells. Despite this, the entry of this Supplement, does not rule out the possibility of obtaining a sufficient low density mixture at low value of the ratio.

The increase in the number of air bubbles in the structure grouting mixture leads to a decrease in its density and thermal conductivity, but, at the same time, degrades the strength of the formed cement stone. On the other hand, the growth in the size of pores in the cement stone frame and their coupling contributes to gas and water permeability of the cementing.

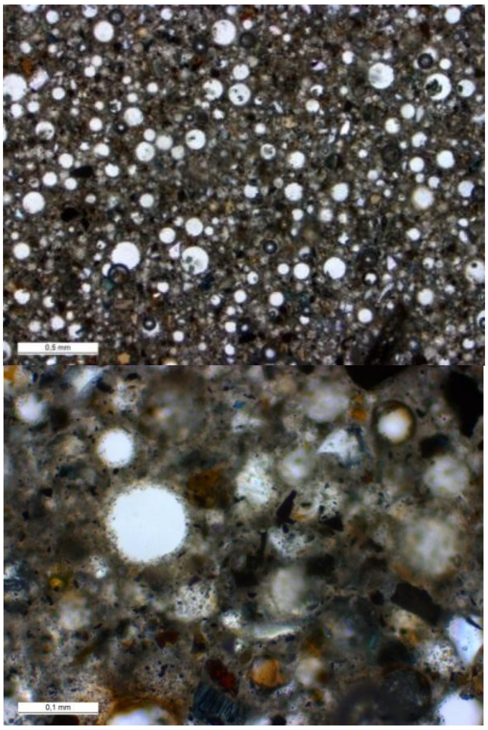

Figure 3. Structure of cement stone

A high value on the strength of the stone formed GLSM has a compression ratio of the gas phase. In addition, a significant effect for strength of cement stone have a water content in the backfill mixture, included in its composition additives, chemical reagents, temperature of curing and other factors [3, 12].

Resistance GLSM describes their ability in the process of expectations setting not flake and does not allocate the gas phase. For conditions of well cementing in permafrost it is necessary to apply non-shrink, sedimentation stable cement blend.

Prepared cement mixture is poured into a special glass tube with a measuring scale (or graduated cylinders). Next, we measured the height of a column of cement slurry in the cylinder. After 2-4 hours on the graduated scale noted a drop in the level of the solution, and determined resistance GLSM. Experimental studies have shown that the developed mixes had 100 % stability.

The mobility of the cement mixes were measured using the cone of spreadability. The results of the measurements of the spreadability of the compounds is presented in Figure 4.

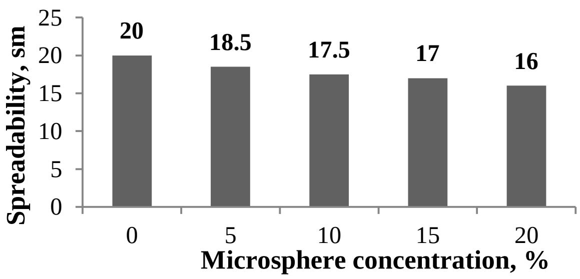

Figure 4. Graph of spreadability of content in a mixture of HASM

The mobility of the solution is reduced due to the fact that the input lightweight additive (SAHM) is characterized by a sufficiently high specific surface to allow for greater binding of the free water contained in the structure of cement blend. In this respect water (0,35), it is not advisable to enter into the cement blend of SAHM more than 15 %, since the spreadability of the mixture becomes lower than required (flow should be between 16 to 19 cm).

RESULTS OF CEMENT STONE STRENGTH RESEARCHES

To determine the Flexural strength of samples of cement stone were used semi-automatic device Controls 65-L11G2/C. After preparation of grouting mixture and aeration, it was poured into special forms which are then placed in a cooling chamber at a temperature of 0±5°C. samples of the stone was 40*40*160 mm.

Figure 5 depicts the results of experiments to determine the strength of the formed cement stone, hardened at a temperature of 0±5°C from the overall impact of the degree of aeration of the cement mixture and the content of hollow microspheres.

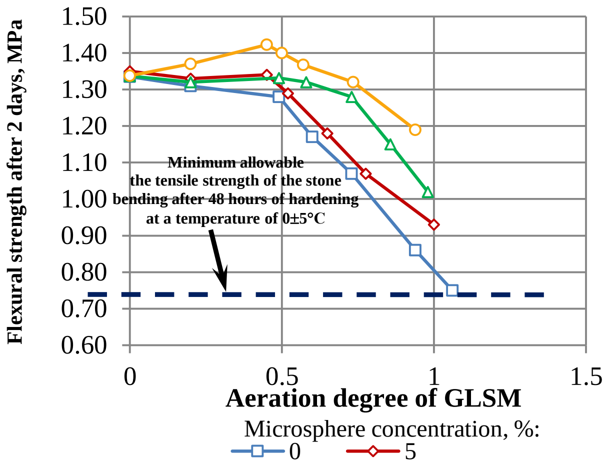

Figure 5. Dependence of the strength of cement the degree of aeration of the cement mixture and the content of hollow microspheres

Cement stone, which includes in its composition of 15% hollow microspheres, has the greatest strength. Further increase of SAHM in the composition GLSM leads to a deterioration of mobility of the solution and hinders the involvement of new portions of air, which requires an increase in the volume of mixing liquid. Of the cement stone samples with the lowest strength values were those samples in which there was no hollow microspheres. Despite this, the strength of all samples exceeded the minimum allowable value, which for low temperatures is 0.7 MPa [13].

CONCLUSIONS

On the basis of theoretical analysis and experimental studies on the properties of liquid cement mixtures, containing in its composition of HASM, have identified the main directions of technical and economic effect, which consists in the following:

- increasing the strength of the resulting cement stone bending and increase its adhesion with the casing [10];
- reduced the multiplicity of grouting mixture while maintaining its low density;
- improving the thermal insulation properties of the mixture compared with ordinary cement mortar [17];
- low water requirement and sufficient stability of the mixture.
- the ability to cement the well in a strong absorption of cement slurry;
- increased frost resistance of the formed cement stone [16];
- reduction of the consumption of grouting materials due to the presence in the structure GLSM with SAHM gas bubbles, a corresponding reduction in aggregatability, saving of energy and labor resources;
- prevention of complications associated with cementing the annulus of wells in cryolithozone;
- providing the reliable protection of the environment and the Earth.

Thus, to create high-quality cementing, designed for the permafrost, we can recommend grouting mixture on the basis of GLSM with the inclusion of SAHM. The application of these mixtures is capable of providing a reliable sealing of the annulus of the borehole and protect the permafrost from the thawing possible.

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