The effect of lightweight agents on the density of cement slurry applied during oil and gas well drilling

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Abstract. The article highlights the principles of cement slurry density changing by adding new lightweight agents (exfoliated vermiculite, aluminosilicate hollow microspheres, tripolite).

1. Introduction
At present, a large number of wells are intensively drilled in hard geological conditions. The regular challenges during well construction process are the cement slurry underlift in a borehole annulus, lost of cement circulation in highly permeable horizons and low cement bond.

All these challenges are somehow connected with inappropriate choice of cement slurry compounds not satisfying geological requirements. For instance, one of the solutions to solve the problem of cement slurry underlift is to use lightweight cement. The most common lightweight agents and their basic characteristics are given below:

Vermiculite – micaceous hydrated silicate mineral with bedded structure; large, golden-yellow or brownish platy minerals. Under high temperature (at heating up to 400-1000°C) vermiculite is split to the worm-like particles, exfoliated and expanded in volume in 15-25 times. Added to cement slurry has a tendency of floating up. At high concentrations loses its spreadability, leads to coagulation and blocks cement squeeze.

Tripolite – soft or low cemented, light, fine-pored opaline sedimentary rock. Colored from white or grayish to dark gray, brownish, red and black. Specific gravity varies from 1.2 to 2.5 g/cm³. Low water absorbing capacity. Added to cement slurry has a tendency of floating up. Subjected to implosion under high pressure influence.

Aluminosilicate hollow microspheres (AHM) – glassceramic aluminosilicate balls originated at coal combustion. Hollow silicate smooth balls with the diameter varying from 10 to in average 100 micrometers. Particles wall density - 2.5g/cm3. AHM has low density, high mechanical resistance, chemical and heat stability, low thermal conductivity. Added to cement slurry has a tendency of floating up and exfoliating.

2. Methodology
Density of cement slurry samples was measured by picnometer (bottle method). The device is shown in figure 1. The method is approved by GOST (State Standard) 26798.1-96 [2-5,]
Preparation and testing was realized as follows:

- Preparation of experimental cement grout with lightweight agents of definite concentration;
- Picnometer net weight defining;
- Filling in of picnometer with cement slurry. The slurry should fill the channel in picnometer cap;
- Picnometer full weight defining;

Density of cement slurry $\rho_c$ g/cm$^3$, was calculated according to formula 1

$$\rho_c = \frac{m_1 - m_2}{V}$$  (1)

were $m_1$ - picnometer net weight, g;
$m_2$ - picnometer full weight, g;
$V$ - picnometer volume, cm$^3$.

The results were rounded to 0.01 g/cm$^3$. The influence of lightweight agents on the density of cement slurry, at different concentrations, is shown in tables 1-3.

Defining of cement stone stress characteristics was realized in accordance with GOST 26798.1-96. Cement stone bars with different lightweight agents concentration were made for this purpose. Before breaking, the bars were kept in water curing camera during 48 hours at temperature of 75°C. Breaking was realized with the help of special unit “Matest” E160. Unit external view and the scheme of bar placement are illustrated in figure 2.
3. Results and discussions
Viscosity of slurry was measured by grout flow cone and measuring table. Measuring table – horizontally leveled unit with measuring scale presented in concentric circles having the diameter of min. 70mm and max. 250mm. The volume of slurry was poured into the grout flow cone and raised until the surface of measuring table was covered with slurry. After that, the extreme values of slurry spread boarders were measured. Defining of water loss was realized by pouring the slurry into the measuring cup and keeping it steady for 120 min., than the volume of segregated water was measured. The results of experiments are shown in table 1. [1,3-6]
It is obvious from the table that adding of exfoliated vermiculite positively influences density decrease of prepared cement slurry. Dispersion and bulk density of vermiculite, added during the experiment, also contribute to the change of cement slurry density. Adding of exfoliated mixed-fraction vermiculite results in density decrease, at this, serious density decline is not observed. Sometimes exfoliated coarse-fraction vermiculite particles emerge. This leads to the decline of cement slurry density at the increase of exfoliated vermiculite concentration in the cement slurry.

If compared with exfoliated vermiculite experiments, the application of AHM agent results in density as well as water loss and spreadability values decrease.

Results of tripolite experiments show good spread ability and water loss characteristics, but stress characteristics are lower than that of vermiculite and AHM.

For clarity, the results of experiments are given in figure 4.
Figure 4. Cement slurry density change from raising of lightweight agents concentration.

4. Conclusion

The results of the experiment allow to make the following conclusions:
- Application of described lightweight agents effectively decreases slurry density from 1.83 g/cm$^3$ (PCT*-I-100 agent free density) to 1.50-1.54 g/cm$^3$. This allows to mark our cement slurry composition as OTM**-5.
- During application of all the above mentioned lightweight agents it is necessary to use polymer agents to decrease the viscosity as the emerging of interface between cement and lightweight agent is constantly observed.
- For all lightweight agents it is necessary to consider particle-size distribution and bulk density as it greatly influences the density index of cement slurry.
- When concentration of lightweight agents exceeds 10% (for all types mentioned in the article) it leads to the formation of cement grout with low spreadability and stress indexes.

* PCT – oil-well portland cement
** OTM - Lightweight cement

References

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