Lightweight Cement Slurries based on vermiculite

K Minaev[1], V Gorbenko and O Ulyanova[2]
Tomsk Polytechnic University, Tomsk, Russia

E-mail: [1]minaevkm@bk.ru, [2]shamaim_7@mail.ru

Abstract. The main purpose of the research is to study the lightweight cement slurry based on vermiculite and its parameters in accordance with GOST 1581-96 requirements as well as improvement of its formulation by polymer additives. Analysis of vermiculite-containing mixture providing the lowest density while maintaining other required parameters was conducted. As a cement base, cement PTscT-I-G-CC-1, cement PTscT - 100 and vermiculite M200 and M150 were used. Vermiculite content varied from 10 to 15 %; and water-to-cement-ratio ranged from 0.65 to 0.8. To sum up, despite the fact that lightweight cement slurry based on vermiculite satisfies GOST 1581-96 requirements under laboratory conditions, field studies are necessary in order to make a conclusion about applicability of this slurry for well cementing.

1. Introduction

Well cementing is a hard technological process where proper selection of the cement slurries affects the successful realization. The main requirements for cement slurries used for casing cementing are to ensure sealing of annular space and to exclude cross-flows of fluids between casings. That is why cement slurries and cement stone must comply with necessary rheological and structural mechanical properties depending on hydrogeological conditions of well construction. Construction of wells in certain fields is complicated by high-permeability formations, and formations with low pore pressure. The most efficient process solution, which allows significant reducing of cost on casing cementing under these conditions, is the use of lightweight cement slurry with specified density. It can increase well productivity and enhance quality of plugging [1-4].

Often the reduction of cement slurry density is done by increasing. However, the increasing of cement-water ratio results in the necessity of adding water-retaining agents, otherwise cement slurry segregation could occur as well as the increasing of cement slurry filtration. Increasing of water content in Portland cement slurry, results in the decrease of sedimentation stability. When cement-water ratio is about 0.55, the dehydration is observed. If this parameter is 0.6, over-dehydration may occur. Filtration rate of fluid through the suspension could be reduced by increasing fluid viscosity and dispersity of solid phase, as well as air-entraining agents. Most of all, viscosity of cement is increased by clay, but in this case hydrated cement has lower compressive strength. As air-entraining agents potassium alumen hollow microspheres (PAHM) are used, which are waste products of heat electro power stations or other industries. This cement mixtures are well studied, have predictable and easily controlled properties. However, the PAHM is a scarce product as it is not produced in sufficient amounts which results in the increase of its cost. Foamed vermiculite might be used as an alternative to PAHM.

Vermiculite, a hydromica group mineral, is a product of secondary biotite conversion (figure 1). It has heat-and-sound-insulating properties and high absorbency. It absorbs to 500% of liquid from its self-weight. The mineral is not subjected to biological decomposition under acid and alkalis action. It should be noted that vermiculite is a non-toxic environmentally friendly material.

According to the opinion of different researchers [5 – 8], efficiency of lightweight cement slurry based on vermiculite is connected with vermiculite and cement physicochemical interaction. New hydrated phase formation reinforces composite material structure. In comparison with gel-cement slurry, vermiculite cement slurry has better plugging ability that increases the level of cement in fractured rocks. Moreover, this cement slurry has lower thermal conductivity providing better facilities for cement hardening, and increases frost resistance and fracture strength.

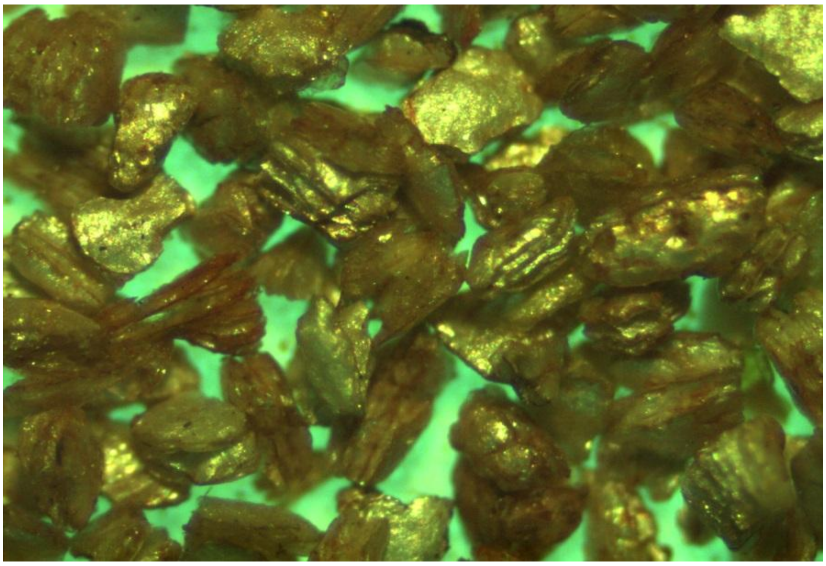

Figure 1. Vermiculite brand M200, 0.5mm fraction (Zooming is 40 times)

Despite the first application of vermiculite as an air-entraining additive was studied in early 1980s [6, 9] vermiculite is rarely used in well construction. It is connected with lack of vermiculite production in oil extraction regions, besides the transportation of vermiculite at a distance more than 400 km is unprofitable.

The purposes of the article - developing of lightweight vermiculite-cement slurry in accordance with GOST 1581-96 “Oil-well Portland cement. TS”; as well as improvement of cement slurry by polymers.

2. Research methodology

Distilled water with necessary water-solid ratio is used for cement gauging. Density and flowability of cement slurry have been measured. Water separation and thickening of cement were measured by consistometer OFITE 80 and graduated cylinder. Flexural strength tests of cement were carried out by hydraulic press MATEST E160. Volumetric shrinkage of experimental cement, cement PTscT-I-G-CC-1 and expansive backfill materials PTM-75 was carried out by OFITE 120-54 under constant pressure equals to 0.7MPa.

3. Discussion

At the first stage, lightweight cement slurry with the lowest density has been chosen. It keeps flowability of cement slurry in accordance with GOST 1581-96 “Oil-well Portland cement. TS”. Vermiculites M200 with bulk density about 200 kg/m^3 (0.5 mm fraction) and PTscT-I-G-CC-1 are used as additives. Experimental results are shown in table 1.

Table 1. Density and flowability of cement slurry

Parameters	Cement I 90% cement, 10% vermiculite			Cement II 87.5% cement, 12.5% vermiculite			Cement III 85% cement, 15% vermiculite			GOST 1581-96
	Water-solid ratio									
	0.65	0.75	0.80	0.65	0.75	0.80	0.65	0.75	0.80	
Density, g/cm^3	1.60	1.55	1.50	1.57	1.53	1.48	-	1.46	1.44	-
Flowability, mm	145	170	250	120	150	210	-	<90	165	>180

Decrease in water-solid ratio and increase of vermiculite content in cement, lead to the decrease in density and flowability of cement slurry. Thus, for further experiments cements I and II were chosen (water-solid ratio 0.8).

Experimental results are shown in table 2.

Table 2. Test results of cements with water-solid ratio 0.8

Parameters	Cement I 90% cement, 10% vermiculite	Cement II 87.5% cement, 12.5% vermiculite	GOST 1581-96
Density, g/cm^3	1.5	1.48	-
Flowability, mm	250	210	> 180
Thickening time, min - 30Bc (75ºC)	110	75	> 90
Thickening time, min (room temperature)	>430	155	Uncontrolled
Flexural strength after two days, MPa (30ºC)	1.7	1.45	1.0
Flexural strength after two days, MPa (60ºC)	1.65	1.50	Uncontrolled
Dehydration, cm^3	3.5	4.2	<7.5

Table 2 shows that both cements comply with GOST 1581-96 requirements. It should be noted that the greater vermiculite content is, the lesser is the time of cement slurry thickening. At the second stage physical-mechanical properties of experimental lightweight vermiculite cement slurries were tested in accordance with GOST 1581-96 requirements to III-type cements.

During flexural strength tests cement stone expansion has been observed. Figure 2 shows the comparison of vermiculite cement stone and cement PTscT-I-G.

Volumetric shrinkage of experimental cement, cement PTscT-I-G-CC-1 and expansive backfill materials PTM-75 was carried out under constant pressure equals to 0.7MPa. Results are given in figure 3.

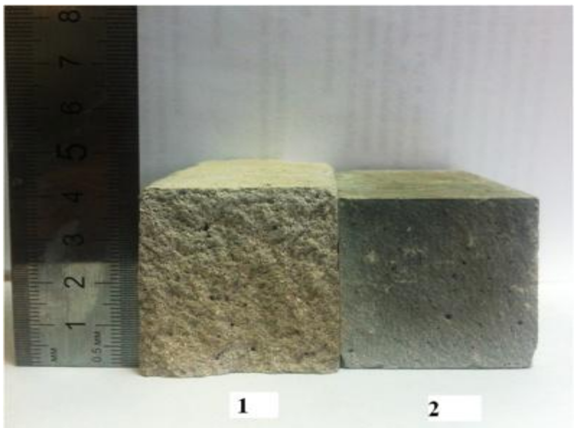

Figure 2. Cement stone surface during tests:
1 – Vermiculite cement stone
2 – Cement PTscT-I-G.

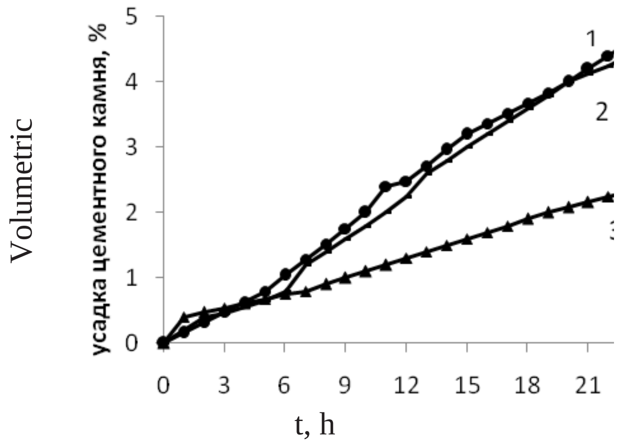

Figure 3. Volumetric shrinkage vs time:
1 – cement PTscT-I-G-CC-1;
2 – backfill materials PTM-75;
3 – experimental cement I

It is obvious, that experimental cement I has the smallest volumetric shrinkage. As this effect can be observed under low pressures and low temperatures, it could be assumed that the expansion of vermiculite cement stone is caused by replacement of air contained in vermiculite pores by water and its further expansion in cement slurry.

Recently, TyumenNIIgiprogaz did well cementing with vermiculite cement slurry using direct and reverse cementing of production wells. This type of cement slurry is patented by authors [10]. Calcium chloride was used as a setting rate regulator. It should be noted that only systems with water-solid ratio from 0.8 to 0.9 and density about 1500 kg/m^3 have optimal technological parameters. Nowadays cement slurry with density equals to 1350-1450 kg/m^3 is required to be used for single-stage cementing of well production. Thus, vermiculate cement slurry using has been reduced; it is used only for collar string cementing in permafrost rocks [11].

At present, vermiculite cement slurry with density ranges from 1350 to 1400 kg/m^3 is researched by us for single-stage well cementing. Moreover, to cut cementation cost, cement PTscT-I-G-CC-1 was replaced by cheap cement PTscT-I-100. In order to reduce cement slurry density, in comparison with previous ones, vermiculite with average bulk density (about 150 kg/m^3) and 1.0 mm fraction is used. This vermiculite provides greater air-entrainment that leads to major reduction of cement slurry density with the same proportions as in previous ones. However, such cements are unstable. Low stability as well as high filtration rate results in cross-flows and oil and gas casing blowouts during cement-slurry thickening time and formation of permeable cement stone. It decreases formation isolation quality and reduces workover period. Therefore, additional research was done to study the influence of bentonite clay and polymer additives on viscosity of vermiculite cement slurry and cement stone. Experimental results are shown in table 3.

In all cases polymer additives (such as carboxymethylcellulose, methylcellulose and starch) decrease cement slurry dehydration, stabilize cement slurry density, and reduce the probability of vermiculite formations. Moreover, it increases thickening of cement time, while cement stone flexural strength remains approximately at the same level. For commercial application methylcellulose could be recommended. This chemical agent provides the lowest density of cement slurry, dissolves well, and increases thickening time greatly, as well as reduces water separation.

Table 3. Test results of cements with polymer additives (water-solid ratio 0.8)

Parameters	Additive				
	-	carboxymethylcellulose 0.12%	methylcellulose 0.15 %	methylcellulose 0.075% bentonite 1.5%	0.06% starch
Density, g/cm^3	1.35-1.40	1.37	1.35	1.40	1.40
Flowability, mm	>250	250	220	215	205-210
thickening time, min - 30Bc (75ºC)	110	148	145	105	152
Flexural strength after two days, MPa (30ºC)	1.35	1.40	1.35	1.30	1.46
Dehydration, cm^3	40	2.4	0	0	1.0

5. Summary and conclusions

To sum up, despite the fact that lightweight cement slurry based on vermiculite satisfies GOST 1581-96 requirements under laboratory conditions, field studies are necessary in order to make a conclusion about applicability of this slurry for well cementing. Some researchers [12] note the difficulty during vermiculite cement slurry use. For example, it’s impossible to pump it into the annular space after short break.

Conducted experiments showed that reason for this is water separation, vermiculite formations and water belt formations, as well as uncontrolled cement setting time. The researchers draw a conclusion that it is impossible to use vermiculite cement slurry for well cementing.

There are main advantages of vermiculite as lightening additives are its unlimited quantity, possibility to control bulk density and fraction. In case of correct cement slurry usage, in accordance with the operating conditions it is possible to eliminate the drawbacks.

This work was financially supported by Foundation for Assistance to Small Innovative Enterprises in Science and Technology (Program "Participant of youth scientific innovation contest").

6. References

[1] Sharafutdinov Z Z, Chegodaev F A, Sharafutdinova R Z 2007 *Burovyye i tamponazhnyye rastvory. Teoriya i praktika: spravochnik* (SPb: Professional) p 416 [in Russian]

[2] Melekhin A A, Dorovskikh I V and Devyatkova N V and other authors 2012 Modelling of lost circulation formation isolating using expansive cement blend *Oil Industry* 8 114-116

[3] Ustkachkintsev E N, Husaenov R Ya, Makarov N V and other authors 2013 Effect of cementing mounting quality on selection of wells for sidetrack construction *Oil Industry* (2) 78-81

[4] Nguyen D, Kagan M and Rahman S 1992 Evaluation of drilling fluid removal by cement slurry from horizontal wells with the use of an accurate mathematical model *Journal of Petroleum Science and Engineering* **8** (3) 191-204

[5] Klusov A A 1993 Razrabotka i issledovaniye tsementnykh tamponazhnykh kompozitsiy, tverdeyushchikh pri ponizhennykh temperaturakh *PhD Thesis* 560 [in Russian]

[6] Patent 884367 USSR, MKIZ E 21 B 33/138 Lightweight cement slurry for low useable temperature wells / A.A. Klusov (USSR) - № 2977437/ 22-03

[7] Patent 1339233 USSR, MKIZ E 21 B 33/138 *Cement slurry* (A A Klusov, T V Kuznesova, M M Shalyapin, N A Danukin, E M Nanivsky and Yu F Zakharov)(USSR) - № 4056952/22-03. Received 16.04.86.

[8] Klusov A A 1985 K effektivnosti ispolzovaniya tamponazhnykh rastvorov ponizhennoy plotnosti *EI Geologiya, bureniye i razrabotka gazovykh i morskikh neftyanykh mestorozhdeniy* 10 9-11 [in Russian]

[9] Gorskiy A T, Batalov D M and Shvezov V D 1983 Primeneniye vermikulitotsementnykh rastvorov dlya tsementirovaniya skvazhin *Tr. in-ta ZapSibNIGNI* 66 54-59 [in Russian]

[10 Oblegchennaya tamponazhnaya smes'. Ippolitov V V, Podshibyakin V V, Belej I I, Konovalov V S and Vyalov V V № RU2243358C1. Received 29.04.2003 [in Russian]

[11] Beley I I, Shtol V F and Sherbich N E 2005 Tipy primenyayemykh oblegchennykh tamponazhnykh rastvorov dlya krepleniya skvazhin na gazokondensatnykh mestorozhdeniyakh severa Tyumenskoy oblasti *Stroitelstvovo neftyanykh i gazovykh skvazhin na sushe i na more* 3 30-32 [in Russian]

[12] Danushevsky V S, Aliev R M and Tolstykh I F 1987 *Spravochnoye rukovodstvo po tamponazhnym materiala* (Moscow: Nedra) p 327