Influence of chemical reagents and additives on the rheological properties of lightweight cement slurry with exfoliated vermiculite

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Abstract. The article is focused on the analysis of such rheological properties and parameters of lightweight cement slurry with exfoliated vermiculite as thickening time, gel strength and water loss.

1. Introduction
The problems caused by inappropriate cement slurry design that does not have required rheological properties occasionally occur during cementing operations. As a rule, inappropriately selected rheological properties of cement slurry result in cement density and strength variation (along hole), poor cement-pipe bond, open and closed pore channels (leading to behind-casing fluid movement), problems associated with cement slurry mixing (high viscosity, cement coagulation) or squeeze cementing (circulation loss, high working pressure, etc.). To avoid all of the above-mentioned challenges, it is required to design cement slurry for desired properties in compliance with nominative documents. Chemical reagents (polymers) or special additives (bentonite, starch, etc.) forming low-viscous structure for cement slurry are basically used to monitor rheological properties. When applying lightweight additives, the influence of polymer additives becomes an important factor which should not be neglected in order to avoid severe consequences.

2. Methodology
The experiments described in this paper are carried out with the application of lightweight additive - exfoliated vermiculite.

Vermiculite is a cleavage-structured mineral of the hydromica group. It is the secondary alteration product (hydrolysis and further weathering) of black phlogopite mica. Vermiculite typically consists of large tabular yellowish-brown crystals. After heat treatment, vermiculite increases 10-15 times in size as in figure 1 [1,3,4].
Figure 1. Appearance of exfoliated vermiculite

When heated, plates transform into worm-like cylinders or golden and/or silver “threads” where extremely fine flakes are observed in the cross-section (exfoliated vermiculite). Vermiculite parameters are listed in table 1.

| Parameters                        | Vermiculite | Exfoliated vermiculite |
|-----------------------------------|-------------|------------------------|
| Density, g/cm³                    | 2.4-2.7     | 0.065-0.130            |
| Vermiculite bulk density after    | 120-200     | 120-200                |
| burning, kg/m³                    |             |                        |
| Thermal conductivity, W(m,K)      | 0.05        | 0.05                   |
| Melting point, C                  | 1350        | 1350                   |
| Humidity, %                       | 5           | 3                      |

Vermiculite is divided into three primary grades based upon grain size:
- Coarse-grained – from 5 to 10 mm;
- Medium-grained – from 0.6 to 5 mm;
- Fine-grained – up to 0.6 mm;

The following vermiculite brands are distinguished:
- Vermiculite 100 – density 100 kg/m³;
- Vermiculite 150 – density 150 kg/m³;
- Vermiculite 200 – density 200 kg/m³;

Only the 0.9 to 0.1 vermiculite fraction was used in the experiments of this study [3].

The spreadability of the cement slurry grout mixed with chemical reagents and additives was measured by means of grout flow cone as in Figure 2 and measuring table. The horizontally leveled measuring table which is equipped with the reference scale basically consists of concentric circles, with minimum diameter being 70 mm and maximum – mot less than 250 mm. After filling the flow cone with grout, the cone was lifted for letting the grout flow out. After allowing the grout to spread over the table surface, the horizontal spread was measured at its widest. Water loss was measured by pouring the grout into the measuring cylinder where it was kept still for 120 minutes. Then, the amount of water accumulated on the grout surface was measured. Experimental results are listed in table 1-4 [1,3].
Cement slurry thickening time tests were made in atmospheric consistometer Offite 120-80 as given in figure 2. The consistometer stir blade rotated at a speed of 150 r/min ± 5 r/min. Thickening time was evaluated, with temperature ranging from 25°C to 30°C. The test involved mixing the cement slurry and pouring it into the slurry cup up to the inner mark. The test concluded when slurry reached a consistency of 30 Bearden Consistency (BC). The time to reach this consistency value was measured. The temperature which was set in terms of the mean value of moderate well temperatures (75°C) was considered. Test results are listed in table 2-5 [2-6].

Gel strength and yield point were measured by viscometer OFFITE 900 given in figure 3. Experimental results are illustrated in table 1-4.
3. Results and discussions
The concentration of the chemical reagent which was added to the sample was defined before the experiment. GOST (State Standards) and visible binding of vermiculite and cement (i.e. the absence of vermiculite floating effect) were the main criteria to select the concentration values.

| Table 2. Influence of chemical reagents on spreadability, mm |
|-------------------------------------------------------------|
| Composition | HEC, 0.3% | Bentonite 3% | Servei 1% | Krep, 2% | Starch 0.5% |
| oil-well portland cement+vermiculite 95/5 | 180 | 245 | 250 | 245 | more than 250 |
| oil-well portland cement+vermiculite 92/8 | 195 | 250 | 250 | 250 | more than 250 |
| oil-well portland cement+vermiculite 93/7 | 205 | more than 250 | more than 250 | 250 | more than 250 |
| oil-well portland cement+vermiculite 95/5 | 215 | more than 250 | more than 250 | more than 250 | more than 250 |

| Table 3. Influence of chemical reagents on water loss, ml |
|----------------------------------------------------------|
| Composition | HEC, 0.3% | Bentonite, 3% | Servei, 1% | Krep, 2% | Starch 0.5% |
| oil-well portland cement+vermiculite 95/5 | 0 | 5 | 3 | 4.5 | 2 |
| oil-well portland cement+vermiculite 92/8 | 0 | 5.5 | 4 | 5.5 | 2.5 |
| oil-well portland cement+vermiculite 95/5 | 0 | 6 | 4 | 5.0 | 2.8 |
cement + vermiculite
93/7
oil-well portland cement + vermiculite
95/5

Table 4. Influence of chemical reagents on gel strength 10sec/10min

| Composition                               | HEC, 0.3% | Bentonite 3% | Servei 1% | Krep, 2% | Starch, 0.5% |
|-------------------------------------------|-----------|--------------|-----------|----------|--------------|
| oil-well portland cement + vermiculite    | 17.5/26.5 | 10/13.9      | 4.5/328.8 | 12/15.9  | 7.0/19.3     |
| 95/5                                      |           |              |           |          |              |
| oil-well portland cement + vermiculite    | 9/18.5    | 9.3/12.9     | 4.8/328.8 | 11.3/13.5| 6.8/16.8     |
| 92/8                                      |           |              |           |          |              |
| oil-well portland cement + vermiculite    | 8/16.8    | 9.1/11.7     | 5.1/328.8 | 11.1/14.0| 6.6/12.2     |
| 93/7                                      |           |              |           |          |              |
| oil-well portland cement + vermiculite    | 5/10.3    | 8.5/10.8     | 5.5/328.85| 10.5/13.0| 6.3/10.6     |
| 95/5                                      |           |              |           |          |              |

Table 5. Influence of chemical reagents on thickening time, hr.

| Composition                               | HEC, 0.3% | Bentonite 3% | Servei 1% | Krep, 2% | Starch 0.5% |
|-------------------------------------------|-----------|--------------|-----------|----------|-------------|
| oil-well portland cement + vermiculite    | 3:20      | 2:45         | 0:08      | 2:35     | 0:59        |
| 95/5                                      |           |              |           |          |             |
| oil-well portland cement + vermiculite    | 3:15      | 2:40         | 0:06      | 2:30     | 0:45        |
| 92/8                                      |           |              |           |          |             |
| oil-well portland cement + vermiculite    | 3:15      | 2:40         | 0:06      | 2:25     | 0:41        |
| 93/7                                      |           |              |           |          |             |
| oil-well portland cement + vermiculite    | 3:05      | 2:32         | 0:05      | 2:20     | 0:39        |
| 95/5                                      |           |              |           |          |             |

4. Conclusion

Based on the results, the following conclusions can be drawn:

Application of hydroxyethylcellulose (HEC) as a chemical reagent to monitor rheological properties and water loss significantly decreases water loss value, as well as cement slurry spreadability.

Such chemical additives as Servei and Starch considerably decrease the thickening time. This can be explained by the fact that these reagents are considered to be fluid-loss additives which fix free fluid and, by doing so, reduce cement slurry thickening time.

Introducing such chemical reagents as Bentonite and Krep into cement slurry composition is not effective enough to maintain low water loss values.
References

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