To the Question about Cements for Deep Wells

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Abstract. The article considers the question about cements for deep wells. Various classifications of cement mortars are considered. The time of setting for cement slurry, specific gravity of cement slurry, strength of set-cement, permeability of set-cement and waterloss of cement slurry are described. The cementing job may be recommended to be done on the deep well El Dosuky in two ways are shown.

1. Introduction
Cementation of wells is a highly responsible stage of well completion. Special importance and significance of cementing operations lie in the fact that it is the closing stage of operations and therefore all failures during their executions can minimize the successes achieved in preceding stages of well completion.

The next stage in a well's life is production, which depends upon successful cementation. Inferior quality of cementation in exploratory regions may lead to erroneous estimation of pay zones. With a view to improve technological process of well cementation, it is necessary, primarily, to have cement slurry with appropriate properties essential for cementing operations.

There cannot be talk of improving the quality of cement bond in wells, particularly in gas and deep wells with high temperatures and pressures unless we have suitable cements for cementation which can subsequently form into set cement with necessary physical and mechanical properties.

2. Actuality and scientific value
Owing to relatively low cost of and availability, of the Portland cement so far has been serving as the main material even though in certain cases its use leads to damage in the well.

Generally speaking, there is only a vague idea about cement and its properties. Many specialists say that they should have cement which should not require any chemical treatment and that the treatment of cement by accelerators or retarders points out to inferior quality of cement and so forth. I must say with all my responsibility, that these specialists are greatly mistaken.
Does it mean to say that at the present time serious attention is not being paid to the treatment of drilling mud? Or is it that treatment of drilling mud during mud loss, blow outs, high temperature or the presence of salt formations is not an important business?

Cement slurry has an important role. Its presence in well creates substantial pressure on formations. Its presence makes drilling fluid and case coagulate. It sucks water from residues of drilling mud and, finally, it remains for ever in sharply different technical and geological conditions. But it is, of course, impossible to use only cement alone to get rid, of all troubles without treating it, to isolate formations and ensure reliable conservation of mineral resources.

In the view of increased bottom hole temperatures and pressures, appearance of new cementing materials, active additives and chemicals which have started to play a definite role, there has arisen a need for more careful study of compositions of mixtures, assignment and regulation of properties of fluids and set cements. These complex operations demand training of specialists possessing good knowledge of allied sciences and capable of conducting detailed analyses of the conditions pertaining to the well. Quick solution is necessary for a number of problems connected with establishment of laboratory equipped with consistometers, thick wall autoclaves with Vocat needless, chemicals, new types of cements, etc.

Highly diversified conditions exist in oil and gas wells, particularly, in deep wells with high bottom temperatures and pressures, which act differently on cement slurry and the resultant set cement. There is no universal cement, which could serve the purpose under all diversified conditions. We have got to select the most suitable composition after conducting different treatments.

3. Tasks
The world cements industry mainly produces Portland cement, which with certain changes in its phased chemical compositions, is suggested for use in pit and gas industry.

The ultimate aim of cementation is to ensure long-term production from wells and dependable conservation of mineral resources. Therefore, technical requirements for cement slurry and set cement must primarily proceed from the object of achieving the final aim. Thus, firstly, the cement slurry should be pumped into the annulus to a definite height. Secondly, it should form into set cement, which is impermeable, free from shrinkage and possesses a definite mechanical strength.

Depending upon base, the cementing material can be classified as follows:
- a) oil well cement based on Portland cement;
- b) oil well cement based on blast furnace slag;
- c) belite sand cement;
- d) lime-sand cement;
- e) other forms of oil well cement (gypsum, based on natural minerals and rocks, based on organic materials).

Depending upon temperatures of testing and use of oil well cement it is expedient to classify it in the following categories:
- a) cement with a temperature of testing at 25 °C;
- b) cement with a temperature of testing at 75 °C;
- c) cement with a temperature of testing at 100 °C;
- d) cement with a temperature of testing at 125 °C;
- e) cement with a temperature of testing at 150 °C;
- f) cement with a temperature of testing at 200 °C.

Depending upon the fluid used for mixing, cement slurries can be divided as follows:
- a) water based;
- b) water emulsion based;
- c) oil based cement.

On the basis of the additives they can be classified as sand cement, gel cement, fibrous, pozzuolanic, perlite, hematite-magnetite bentonite, etc.

On the basis of specific gravity the oil well cement slurries are classified as follows:
a) light cement with sp. gr. up to 1.30 g/cm$^3$;
b) lightened cement – // – 1.30-1.75 g/cm$^3$;
c) normal cement – // – 1.75-1.95 g/cm$^3$;
d) loaded cement – // – 1.75-2.20 g/cm$^3$;
e) heavy cement – // – 2.20 g/cm$^3$ and more.

Based upon setting time suitable for a given tor temperature, cement slurries can be divided into fast setting slurry with initial setting time of less than 40 min, the accelerated setting time with IST of 40 min to one hour 20 min; normal setting slurry with IST of one hour 20 min to two hours and slow setting slurry with IST of more than two hours.

4. Theoretical part

Oil well cements can be divided according to the categories of corrosion resistivity purpose of use, etc.

In a wider sense of the worth, oil well cement slurry means a product consisting of a mixture composed of binding materials (Portland cement, slag, lime, belite or other materials), minerals (quartzite sand, asbestos, clay, perlite, etc.) or organic materials (cotton, cellulose products waste, gelsonite, plastics, etc.) and additives which make slurry after water is mixed, followed by set cement of a particular quality.

Now we have come to the questions of technical requirements that cements should meet and the properties that need to be checked.

I. It is essential to check and ensure the following under all circumstances:

1. Time for setting or thickening of cement slurry – it is essential that this time is more than time necessary for cementation by 20-25 %.
2. Specific gravity of cement slurry, especially in the case of formations which have high pressure, or those which are amenable to hydro-fracturing or mud loss.
3. Strength of set cement, especially, when cement plug is to be put in the well.
4. Permeability of set cement, particularly, when there is fear of high temperatures and pressure and we use pure Portland cement.
5. Water loss of cement slurry, especially, during cementation of formation with high permeability.

II. The following is desirable:

1. The cement should be checked that it is finely grinded.
2. Viscosity and dynamics shear stress should be checked and regulated.
3. Possible foaming of cement slurry, especially, during the use of chemicals, should be checked up.
4. Contraction effect of cement slurry should be measured and regulated. In case of cementation of gas wells this property should be determined.
5. Pump ability of cement slurry and drilling fluid blend (piston) especially in case of cementation of deep wells with small bore, should be checked because blend of the above-mentioned, fluids usually have high viscosity and shear stress.

Of course, none of the cements normally produced in the world can meet such a wide range of requirements.

It is necessary to change the properties of cements in desirable direction by chemical treatment and addition of additives based on one or two basic cements. World practice, especially Russian and American besides others, shows that only a limited quantity of these cements is produced by cement industry in each country, e.g., in the USA 7 types of cements are produced which are classified only on the basis of temperature conditions of use. In the USSR slag cement is also produced which is heat resistant, not to say about Portland cements.

But for specific conditions of use, particularly when they are unusual, it becomes entirely essential to improve the properties of cement.

The main factors, which can have substantial influence on cement primarily on cement slurry, are temperature and pressure. They tend to change the properties of cements.
5. Practical value and results

5.1. The time of setting for cement slurry

With an increase in temperature, the setting time considerably reduces. For an increase in setting time of cement slurries it is necessary to treat cements with chemicals. For this purpose retarders should be used.

It is the Russian practice to use lignosulfonate (SSB), CMC, boric acid, gipan, tartaric acid, chromates along with SSB, gipan or CMC.

Depending upon temperature conditions different quantities of the above-mentioned materials are taken. It should also be noted that, sometimes, depending upon chemical and mineralogical compositions of cement which is not at all uniform, it requires a lot of effort to ensure the required setting time of cement slurry. In certain cases we have to take two or three retarders so as to obtain necessary results, and, sometimes, cement has to be condemned, when it does not yield to chemical treatment, it is the task of the field personnel to see that the given composition is obtained.

CMC and tartaric acid can be recommended up to 0.5% of the weight of cement. As practice has shown, good results are obtained by the mixture of tartaric acid and boric acid in the ratio of 4:1 under temperature of 200 °C and pressure of 1500 kg/cm².

It should be noted that the use of SSB or CMS with chromates in ratio of 2:1 is expedient. Chromates give high heat resistivity to retarders.

But for every particular case the composition of cement slurry must be selected in the laboratory, if the conditions in the deep well are difficult.

It is necessary to raise the responsibility of chemists in the selection of composition for cement slurries and they should be emphatically told to take active participation in cementing operations.

All wells with bottom hole temperatures of more than 100 °C and of high pressure must be cemented only after getting recommendations from the laboratory. For this purpose the average sample of cement (approximately from 15 sacks) should be given to the laboratory for testing a week before the operations. In case water with high salt content is used for mixing cement, it is necessary to send water samples for analysis. Only this practice of preparing cement slurry will completely eliminate chances of complications of early setting of cement slurry. This is especially important when putting cement plugs in deep high temperature wells.

It is this practice of preparatory jobs that is followed in the Russia. In the USA, for highly important wells, the composition of slurry is selected by two analogical laboratories with a view to eliminate chances of mistakes.

5.2. Specific gravity of cement slurry

Specific gravity of cement slurry must be specified by the geological and technical conditions of the project based upon actual conditions of the well.

As the practice in the Russia and USA has shown, a difference of 0.2 g/cm³ in the specific gravity of cement slurry and drilling fluid is quite sufficient. Specific gravity of cement slurry should be determined on the basis of the geological and technical peculiarities of the region. It is necessary to have in mind that the greater the difference, the higher is the pressure created on the formations.

Thus, with a view to ward off the possibility of hydro-fracturing the formations, it is necessary to lighten the cement slurry. For this purpose the following methods can be recommended at the present moment:

1. Cement should be mixed with clay (or bentonite) and the slurry should be prepared by the usual method of adding water, treated with chemicals, as given by the laboratory.
2. Cement should be mixed with drilling mud of 1.10-1.12 g/cm³ sp. gr. prepared and treated with chemicals with preliminary analysis of the composition in the laboratory.

The cement-bentonite (or clay) slurries must be used only in the interval where temperature does not exceed 100 °C.
There are other ways to decrease specific gravity of cement slurry by adding perlite, organic materials and so on.

When there is drilling fluid of high specific gravity in the well, it is necessary to increase the specific gravity of cement slurry. This can be obtained by the following means:

1. Reduce water cement ratio of cement slurry while simultaneously adding chemicals meant for reducing viscosity. Sp. gr. of cement slurry at this time may go maximum up to 20 g/cm$^3$.

2. Sp. gr. of cement slurries can be increased approximately to 2.05-2.10 g/cm$^3$ by adding into them 30% of quartzite sand which have a small quantity of fine fractions. The increase it specific gravity is ensured by reduction in the total volume of water.

3. The most effective increase in specific gravity of cement slurry is obtained by adding rough, heavy quartzite-magnetite sand by lowering water-cement ratio and by treatment by thinning chemicals.

5.3. Strength of set-cement

It is necessary to distinguish between two types of strengths of set-cement:

There is the strength which must be ensured by cement factories and the strength which is considered to be sufficient for ensuring high grade cementing of well. The former should not be below the above-mentioned standard where as the latter is permissible even when it is less. Theoretical calculations which are based on the use of the theory of flexibility and softness, as well as laboratory and practical experience show that in order to ensure qualitative bondage in the well in the initial cementation, it is sufficient to have 50-60 kg/cm$^2$ of compression.

However, in special cases of putting cement plugs it should be substantially higher. While increasing hardening time of oil well cements in temperatures of 20-30 °C the strength of set-cement increases very much. The increase in temperature up to 70-80 °C causes a sharp increase in strength followed by a decrease in it. In temperatures of 100-120 °C, during first 24 hours strength increases very fast, but thereafter, towards the end of hardening it decreases approximately by 50-60 %. With higher temperatures strength of set-cement, after 48 hours already, becomes 50 % of the strength of set-cement, which set during the same period of time at 70-80 °C.

The most radical method to avoid drop in strength of set-cement under high temperature and pressure is in the addition of quartzite sand. Strength increases with this sand. The optimum ratio of cement and the sand is approximately 3:1. When putting cement plug in deep high temperature wells, the use of sand is absolutely necessary.

5.4. Permeability of set-cement

Impervious set-cement is necessary for separation of formations, but this property is not specified as standard.

At temperatures of 25-30°C permeability of set-cement goes down. The increase in permeability of set-cement in temperatures at 70-80 °C is unnoticeable. In temperatures at 100-120 °C permeability of set-cement increases noticeably. In temperatures at 140 °C and higher it often comes to 30-70 millidarcy. The most radical measure for lowering permeability of set-cement is the adding of quartzite sand in ratio of 3:1.

5.5. Waterloss of cement slurry

Water loss in pure cement slurry is very high. In the first minute under very small pressure more than 90 % of water can filter out of the cement slurry. With such water loss in cement slurry in the annulus the pressure increases sharply due to formation of unpumpable substance. Water loss in cement slurry through mud cake occurring in the well decreases sharply.

High water loss of cement slurry is particularly dangerous when there is no mud cake (when it is scratched). For reducing water loss in cement slurry, bentonite and chemicals such as CMC, should be added, but with that the viscosity of the slurry will increase.

Likewise, for reducing it, the slurry should be treated with thinning chemicals.
When cement is received by laboratory, it should be saved through screens and fineness of its grind should be checked up whether it conforms to the standard.

6. Conclusions
While making hydrodynamic calculations with a view to determine optimum speed, it is necessary to know the viscosity and dynamic shear stress of cement slurries. It is a known fact that the above-mentioned parameters of slurry increase with temperature, the latter one especially. Drop in viscosity and dynamic shear stress can be ensured only by chemical treatment or by adding excess quantity of water along with some chemicals. However in each concrete case it is necessary to select chemicals that may be suitable for the given cement and the conditions as existing in the wall. In case of difficulties in ensuring the required viscosity, some other consignment of cement ought to be used.

The contraction effect of cement should be considered as its highly important property. It was shown that it is one of the main reasons for channelling which occurs as a result of dehydration of mud cake and non-displaced drilling mud. Then higher the temperature of surrounding environment, the faster is the contraction effect in cement slurries and more intensive is its flow. For reducing it, stuffing material such as sand, clay, bentonite, tripoli, tuff, etc. Should be added to slurry. They reduce the quantity of cement in the unit of volume of slurry as a result of which the overall quantity of water sucked by cement comes down.

In case of cement slurry, after knowing geological and technical conditions, we should pay attention to those parameters which are vital under actual conditions, just as we do in case of drilling mud where we decide as to when we should increase specific gravity or reduce viscosity, or waterloss of mud, or we can allow deviation in theses parameters from the ideal ones.

We should also like to deep well upon the question of a now Russian cement meant for cementation of deep and supper deep wells with high temperatures, that is slag cement.

Slag is the waste material of metallurgical industry, and it is used for preparation of construction materials. Its chemical composition is quite similar to the cement composition. After coming out of blast furnace it is poured into water in a fluids state. As a result of difference in temperature in presence of water, the slag changes into granules.

After it is dried up and grinded, it forms into a cement material without Portland cement, for use under temperatures of more than 100 °C and under high pressures. Addition of quartzite sand increases strength of set-cement and setting time. Addition of day or of loading materials ensures the getting of suitably higher or heavier slag slurries. At high temperatures and pressures strength is also high. This cement is cheap.

Now deep well El Dosuky is under drilling. The project depth of the well is 4800 m. Tentative temperature is approximately 150-160 °C, pressure – 600-700 atm. The cementing job may be recommended to be done in two ways:

The first one: Use of slag cement which is manufactured in the Russia. The slurry, which is obtained by mixing it with water, should have 2.0-2.5 hours of initial setting time, or 1.5 hours of thickening time under bottom hole conditions.

The second one: Use of Egyptian Portland cement, mixed with 50 % of water, treated by some reagents (chemicals). For this purpose it is possible to use CMC (0.5 % by weight), calcium lignosulfonate (0.7 %), etc. But the actual composition of slurry must be checked up in the laboratory under the actual bottom hole temperature and pressure.

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