Society of Petroleum Engineers

SPE 77216

CHEAPER CEMENT FORMULATION FOR LOST CIRCULATION CONTROL

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This paper was prepared for presentation at the Fourth biennial Asia Pacific Drilling Technology Conference (APDT 2002), jointly sponsored by the International Association of Drilling Contractors (IADC) and the Society of Petroleum Engineers (SPE), will be held 9-11 September 2002, in Jakarta, Indonesia.

Abstract

Laboratory experiments had been carried out by using G and special blended cement with various amount and types of standard cement additives, and various amount of local bentonite and sugar cane fiber. The ASTM-C 114 and AAS procedures were used for the chemical analysis and API Spec. 10 procedures under atmospheric and reservoir conditions for the cement performance.

One of the serious cementing problems is a lost circulation, which may occur in high permeability formation, vugs or naturally fractured formation. Therefore this study focused on development of a cement mixture to overcome lost circulation problem and also strong enough to hold casing with minimize damage to potential producing formation. The results shown that optimum size of local bentonite ranging from 150-250μm and sugar cane fiber ranging from 2000-2800μm. A suitable cement system formulation for optimum lost circulation control is 9% local bentonite, 2% calcium chloride, and 0.5 sugar cane fiber with adequate shear bonding strength and formation permeability reduction is about 10%.

Generally, special blended cement has less free water and fluid loss, better strength development but shorter thickening time than G cement. The cost of blended cement is cheap, bentonite is a local material and sugar cane fiber is a waste material, therefore there will be about 48% of the cement material cost saving if this cement formulation is used for an average oil well at 8,000 ft depth. This formulation also proves to be the cheaper choice for cementing job, particularly the shallow well due to the shorter thickening time.

Introduction

Cementing job is the process of placing cement slurry to the desired location in the annular between casing and well bore with general functions to bond the casing and formation, to protect producing strata, to prevent the migration of formation fluids between zones, and to control lost circulation. Lost circulation is a concerned problem for many years. Many previous works have used materials such as mica, cellophane, walnut hulls, foamed cement, and high strength micro sphere (HSMS) for lost circulation control. However, this type of material may result in permanent damage of producing formation. The target of this study is to develop a cement system that can control lost circulation and not inhibit productive formation.

Experimental work

All tests were performed in accordance with API Spec. 10 (1990) at room and simulated reservoir conditions in order to determine the effect of amount and grain size of local bentonite and sugar cane on suitable cement system performance for lost circulation control during fractured formation cementing job. The ASTM-C 114 and AAS procedure were used for chemical analysis of bentonite.

Local bentonite was graded in particle size from 75 μm to 850 μm with percentage ranging from 3 to 12 % by weight of cement (WOC). Sugar cane fiber was graded in particle size from 0.5 mm to 4.75 mm with percentage ranging from 0.5 to 2 % by WOC. Calcium chloride concentration used was 2 % to 4 % WOC.

Results and Discussions

Bentonite Composition

The XRD analysis results of local bentonite and Wyoming bentonite were shown in Table 1. From the results, it is found that local bentonite only consist of 45.5 % montmorilonite and 5 % hematite as compared of 86 % for Wyoming bentonite.

Sugar Cane Fiber Composition

The fiber compositions in sugar cane stalks contain cellulose, himecellulose and lignin. Therefore, a sugar cane fiber can act as the fluid loss and retarder additives (Shell & Wynn, 1958).

Cement slurry density

Table 2 show that cement slurry density is lighter with the presence of local bentonite and sugar cane fiber. The density of three optimum cement slurries is in the range of 13.7-12.8 lb/gal. From the results, it can be concluded that three optimum cement slurries are suitable to be used for controlling lost circulation in fractured formation cementing job. Since lightweight cement slurry will give a smaller hydrostatic column, therefore decreasing weak formation damage and the cement slurry can easily go up to the desired height as well as preventing cement slurry invades the formation fractures.

Free Water Performance

Table 3 shows the test result of free water content of cement slurry. Free water content of cement slurry will increase with higher local bentonite concentration. This finding can be explained by the fact that the presence of hematite in local bentonite composition. Since hematite does not absorb water, therefore it will reduce the water absorption ability of local bentonite. From the results, it can be seen that the free water content will be decreased with higher percentage of calcium chloride. This is due to calcium chloride increases the permeability of C-S-H gel building around silicate grain, giving water ready access to the anhydrous grain surface, and reducing the free water content (Nelson, *et.al.* 1990). The free water content of cement slurry also will decrease with the presence of sugar cane fiber. This finding is in agreement with Shell & Wynn (1958) that cellulose in sugar cane fiber will reduce the free water content, since cellulose absorbs onto the initial layer of C-S-H gel and render its hydrophobic. From the results, it can be seen that the free water content of cement slurry ranges from 2.6 ml to 3.0 ml. This is in agreement with the free water specification requirement of API Spec.10 (1990) that the free water content of cement slurry does not exceed 1.4% by column height.

Fluid Loss Performance

Fluid loss content of cement slurry will increase with higher percentage of local bentonite, as shown in Table 4. This finding can be explained by the fact that the presence of hematite in local bentonite tends to reduce the water absorption ability and cause exceed free water content as well as fluid loss content. However, the fluid loss content of cement slurry will decrease with the presence of calcium chloride and sugar cane fiber. This finding can be explained by the fact that calcium chloride accelerates the hydration of the C_3S and aluminate phase. This results in the stability of the water-in-cement suspension and reduces fluid loss content in cement slurry. Respectively, sugar cane fiber consists of cellulose that can act as a fluid loss additive, as discussed before. These cement slurry systems have fluid loss content ranging from 100 ml to 103 ml. This value is considered a good control and produce cement slurry with a fairly acceptable fluid loss and a short thickening time which is accepted for fractured formation cementing job.

Compressive Strength Performance

As shown in Table 5, the compressive strength of set cement will decrease with higher percentage of local bentonite and sugar cane fiber. However, the compressive strength of set cement will increase with the presence of calcium chloride in cement slurry.

The compressive strength value of three optimum cement systems is in a range of 575 psi to 625 psi (at room condition). Based on the compressive strength requirement for cementing job, these three optimum cement systems are accepted for any cementing operation as well as for fractured formation cementing job.

Thickening Time Performance

The effect of local bentonite on the thickening time of cement slurry is shown in Table 6. The thickening time of cement slurry will be longer with higher percentage of local bentonite. This is understandable since the cement slurry density decreases, the thickening time will be increased (Nelson, 1990). However, the thickening time of cement slurry will be shorter with the presence of calcium chloride. This finding is in agreement with Nelson (1990) that calcium chloride may tend to increase the permeability of the C-S-H gel building around each silicate grain and provide water ready access to the anhydrous surface of silicate grain, which will shorten the introduction period. The cement systems have thickening time ranging from 90 minutes to 137 minutes. This setting time range is accepted for fractured formation cementing job, since fractured formation job has a fairly short thickening time requirement, i.e.; 2 hours (Harrison & Blount, 1986). This is understandable since if the cement slurry set faster, lost circulation can be reduced.

Bonding Performance

The shear bonding between cement-formation of these cement systems reach a quarter of their compressive strength, as shown in Table 7. According to Smith (1976), the shear bonding strength of cement slurry will be accepted for cementing performance, if its value is about 1/8-1/10 times of compressive strength. Therefore, the shear bonding of these cement systems fulfilled the requirement for oil well cement as well as for fractured formation, since it is strong enough to hold the casing.

Formation Damage Performance

The permeability damage of core samples caused by these cement systems is in the range of 10 %-20 %, as shown in Table 8. In general, permeability damage degree caused by drilling fluid or cement slurry is about 40 %-75 % and some serious damage can be 80 %-90 % (Rahman and Marx, 1991). Therefore, these cement systems had minimized formation damage.

Cost Saving

From a simple economic analysis shown in Table 9, it is cheaper to use locally produced blended cement for the cementing operation of an average oil well of 8,000 ft depth. Based on the current selling price of the cement, there will be a saving of RM5.70 per foot or 48% of the total cost for cement material if the locally produced blended cement is used for the oil well cementing operation.

Conclusions

A suitable cement system for fractured formation is the mixed cement including local bentonite as lightweight material, sugar cane fiber as bridging agent, and calcium chloride as an accelerator. In order to overcome the lost circulation, a cement system must fulfill several physical property requirements. These requirements are light density, minimum free water and fluid loss content, compressive strength and bonding strength are strong enough to support the casing, and shorter thickening time to prevent lost circulation.

The physical properties of cement slurry such as density, free water, fluid loss, compressive strength, thickening time, and bonding strength are affected by the amount of local bentonite, sugar cane fiber, and calcium chloride. The presence of local bentonite in a cement formation will reduce the cement slurry density, cause less formation breakdown, and minimize lost circulation. Sugar cane fiber can reduce cement slurry density, free water and fluid loss content, and prevent lost circulation problem. Calcium chloride increases compressive strength and shorten thickening time.

The used of local bentonite and sugar cane fiber can reduce cement slurry density, increase slurry yield and therefore reduce the cost of cementing job.

References

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TABLE 1- WHOLE ROCK COMPOSITION OF WYOMING AND LOCAL BENTONITE

Mineral	Wyoming bentonite (%)	Local bentonite (%)
Montmorilonite	86	45.5
Montmorilonite -Chloride	4.0	-
Kaolinite -Chloride	-	7.5
Quartz	5.0	35.0
K-feldspar	2.0	Trace
Plagioclase	3.0	5.5
Illite	-	4.0
Hematite	-	2.5

TABLE 2- CEMENT SLURRY DENSITY RESULT

Cement slurry	Density (lb/gal)
3 % local bentonite	15.1
6 % local bentonite	14.6
9 % local bentonite	13.9
12 % local bentonite	13.2
3 % local bentonite and 2 % calcium chloride	15.1
3 % local bentonite and 4 % calcium chloride	15.1
3 % local bentonite and 2 % calcium chloride and 0.5 % sugar cane fiber	14.8
3 % local bentonite and 2 % calcium chloride and 1.0 % sugar cane fiber	14.4
3 % local bentonite and 2 % calcium chloride and 2.0 % sugar cane fiber	14.1
9 % local bentonite (grain size is 150 μm-250 μm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	13.7
9 % local bentonite (grain size is 150 μm -250 μm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 1.0 mm-2.0 mm)	13.7
12 % local bentonite (grain size is 150 μm -250 μm) and 4 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	12.8

TABLE 3- FREE WATER TEST RESULT

Cement slurry	Free water, ml
3 % locel bentonite	4.2
6 % local bentonite	6.5
9 % local bentonite	7.6
12 % local bentonite	8.8
3 % local bentonite and 2 % calcium chloride	1.6
3 % local bentonite and 4 % calcium chloride	No
3 % local bentonite and 2 % calcium chloride and 0.5 % sugar cane fiber	0.9
3 % local bentonite and 2 % calcium chloride and 1.0 % sugar cane fiber	0.7
3 % local bentonite and 2 % calcium chloride and 2.0 % sugar cane fiber	0.4
9 % local bentonite (grain size is 150 μm-250 μm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	2.5
9 % local bentonite (grain size is 150 μm -250 μm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 1.0 mm-2.0 mm)	2.6
12 % local bentonite (grain size is 150 μm -250 μm) and 4 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	3.0

TABLE 4-FLUID LOSS CONTENT RESULT (AT ROOM CONDITION)

Cement slurry	Fluid loss (ml)
3 % local bentonite	110
6 % local bentonite	133
9 % local bentonite	154
12 % local bentonite	175
3 % local bentonite and 2 % calcium chloride	93
3 % local bentonite and 4 % calcium chloride	76
3 % local bentonite and 2 % calcium chloride and 0.5 % sugar cane fiber	75
3 % local bentonite and 2 % calcium chloride and 1.0 % sugar cane fiber	69
3 % local bentonite and 2 % calcium chloride and 2.0 % sugar cane fiber	58
9 % local bentonite (grain size is 150 µm-250 µm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	100
9 % local bentonite (grain size is 150 um –250 µm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 1.0 mm-2.0 mm)	103
12 % local bentonite (grain size is 150 µm –250 µm) and 4 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	103

TABLE 5- COMPRESSIVE STRENGTH RESULT (AT ROOM CONDITION)

Cement slurry	Co (psi)
3 % local bentonite	980
6 % local bentonite	580
9 % local bentonite	380
12 % local bentonite	270
3 % local bentonite and 2 % calcium chloride	1450
3 % local bentonite and 4 % calcium chloride	1650
3 % local bentonite and 2 % calcium chloride and 0.5 % sugar cane fiber	1175
3 % local bentonite and 2 % calcium chloride and 1.0 % sugar cane fiber	1075
3 % local bentonite and 2 % calcium chloride and 2.0 % sugar cane fiber	970
9 % local bentonite (grain size is 150 µm-250 µm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	625
9 % local bentonite (grain size is 150 µm –250 µm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 1.0 mm-2.0 mm)	610
12 % local bentonite (grain size is 150 µm –250 µm) and 4 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	575

TABLE 6- THICKENING TIME RESULT (AT 120 ^{O}F, 5200 PSI)

Cement slurry	To (min)
3 % local bentonite	115
6 % local bentonite	140
9 % local bentonite	180
12 % local bentonite	240
3 % local bentonite and 2 % calcium chloride	74
3 % local bentonite and 4 % calcium chloride	55
6 % local bentonite and 2 % calcium chloride and 0.5 % sugar cane fiber (2.0mm-2.8mm)	96
6 % local bentonite and 2 % calcium chloride and 1.0 % sugar cane fiber (2.0mm-2.8mm)	97
6 % local bentonite and 2 % calcium chloride and 2.0 % sugar cane fiber (2.0mm-2.8mm)	99
9 % local bentonite (grain size is 150 µm-250 µm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	90
9 % local bentonite (grain size is 150 µm –250 µm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 1.0 mm-2.0 mm)	90
12 % local bentonite (grain size is 150 µm –250 µm) and 4 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	137

TABLE 7- BONDING STRENGTH RESULT (AT ROOM CONDITION)

Cement slurry	Bonding strength (psi)
9 % local bentonite (grain size is 150 µm-250 µm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	298
9 % local bentonite (grain size is 150 µm –250 µm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 1.0 mm-2.0 mm)	285
12 % local bentonite (grain size is 150 µm –250 µm) and 4 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	240

TABLE 8- FORMATION DAMAGE DEGREE RESULT

Cement slurry	%
9 % local bentonite (grain size is 150 µm-250 µm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	9.40
9 % local bentonite (grain size is 150 µm –250 µm) and 2 % calcium chloride and 0.5 % sugar cane fiber (grain size is 1.0 mm-2.0 mm)	14.80
12 % local bentonite (grain size is 150 µm –250 µm) and 4 % calcium chloride and 0.5 % sugar cane fiber (grain size is 2.0 mm-2.8 mm)	20.60

TABLE 9- SIMPLE ECONOMIC ANALYSIS FOR CEMENT REQUIREMENT

Cement Type	Well Depth (ft)	Average Cement Required (sack)	Average Cement Price (RM/sack)	Total Cement Cost (RM)
Class G	8,000	4267	22.30	95,154.10
Blended	8,000	4267	11.60	49,497.20