Analysis of Nigerian Local Cement for Slurry Design in Oil and Gas Well Cementation

Oriji Aleruchi Boniface [1], Dulu Appah[2],

Department of Petroleum and Gas Engineering,
University of Port-Harcourt, NIGERIA.

ABSTRACT

During oil and gas well cementation, fluid migration behind the cased holes is a major problem in drilling and completion both short terms and long terms after cementing operations. High formation pressures, high shrinkage rate of cement slurry, lack of mechanical seal and channeling due to poor cement slurry design leads to expensive drilling and completion operations and sometimes well abandonment. This research is a comparative analysis based on experimental study on the effectiveness of accelerators and retarders on local Nigerian cement using foreign cement as a control. The accelerators and the retarders were used for the cement slurry design to achieve better setting time, thickening time and compressive strength. The local Nigerian cement samples used were; the Eagle cement, Bua cement, Dangote cement and Ibeto cement while sample of class- G industrial foreign cement was used as a control standard. The cements were analysed to determine the percentage chemical composition (SiO_2, CaO, Fe_2O_3, Al_2O_3, MgO, SO_3,),the Particle size composition ,Compressive strength, Soundness of the cement and the consistency . The results obtained from the experiments showed that the Nigerian local cements in its original state have low setting time, low thickening time and very high fluid loss compared to class –G foreign cement. Also, high gelation was observed on the local cement and therefore could not be considered effective on its natural state for slurry design in the oil and gas well cementation. However, further analysis showed that with the additions of some accelerators and retarders the local cement could compare favorably with the foreign cement and could be recommended for shallow oil well cementation.

Keywords: Cement Slurry, retarders, accelerators, setting time and thickening time

INTRODUCTION

Well cementing is primarily the process of placing cement slurry in the annulus between the well casing and the geological formations surrounding the well bore to provide zonal isolation in order to prevent fluids such as water or gas moving from one zone to another zone in the well. Incomplete zonal isolation or a weak hydraulic seal between the casing and the formation due to poor cement slurry design, may cause fluid channels and probable collapse of the wellbore . Appropriate cement slurry design for well cementing is a function of various parameters like; the well bore geometry, casing hardware, formation integrity, drilling mud characteristics, presence of spacers, mixing and pumping conditions. Therefore the rheological behavior, setting time and the thickening time of the cement slurries must be optimized with appropriate retarders and accelerators to achieve an effective wellbore cementing operation.

The choice of a particular cement for zonal isolation centers largely on down hole and formation conditions and also on the cement integrity in terms of durability and being free from strength retrogression during the operational life of a well. The optimal setting time of the cement slurry is also a major factor because too reactive slurry will result in a short setting time while an insufficiently reactive slurry takes too long to set. Other qualities are; low viscosity to make the slurries pumpable, high sulphate resistant and low permeability .

ISSN: 2223-9944, e ISSN: 2223-9553
www.journals.savap.org.pk

Oil well cementing is generally less tolerant to errors than conventional cementing work. Thus, the oil well cement slurry must be carefully designed to meet demanding requirements such as a predictable thickening time, setting time, fluid loss control, consistency, low viscosity, low free fluid, adequate strength, high sulphate resistance and overall high durability. The slurries must have a particularly low viscosity to be pumped into great depths. The down-hole temperatures and pressures also compel severe requirements on the setting behavior of the cement. The cement slurries are formulated to provide the required physical properties at the conditions of pressure and temperature of the hole as well as the nature of the geological formations. However, they often have to contend with weak formation, corrosive fluids and over pressured formation fluids. A wide variety of cement admixtures are currently available to enhance oil well cement slurry properties to achieve successful placement and rapid compressive strength development for adequate zonal isolation during the lifetime of the well. The effect of these admixtures depends on a number of parameters, such as; the particle size distribution ,chemical composition of the cement, distribution of silicate and aluminate phases, reactivity of hydrating phases, gypsum/hemihydrate ratio, total sulphate content, free alkali content, and the quantity and specific surface area of the initial hydration products. The temperature, pressure, admixture dosage, mixing energy, mixing sequence, and water/cement ratio also have a significant effect on the behavior of admixtures in oil well cement slurries.

There are several types of cement slurry chemical admixtures such as ; super plasticizers, retarders, accelerators and viscosity modifiers that are used to optimize the flow properties of cement-based products. Early age and hardened properties of cement based systems are highly depended on the type and dosage of chemical admixtures used. The proper selection of chemical admixtures is mainly based on a trial and error procedure based on Marsh cone flow, Mini slump test and the rheological tests. The performance of the chemical admixtures is strongly influenced by the chemical and physical properties of the cement. Most of the commercial chemical admixtures have been used with Ordinary Portland cement and for general purpose. Hence, the technical data sheets provided by the manufacturers are not generally applicable for oil well cementing. In order to contend with bottom hole conditions a special class of cements called OWCs, specified by;(API Specification 10A, 2002) are usually used in the slurry composition. The interactions of OWC with different types of admixtures and the associated cement-admixture compatibility at high temperature/high pressure are still largely unexplored.

MATERIALS AND METHODS

The API Specifications for Materials and Testing for Well Cements (API.2002) was used for the classification of A through H classes of cement. The Cements were classified into grades based upon their C3A (Tricalcium Aluminate) content.. The classes are applicable for certain range of well depth, temperature, pressure and sulphate environments. Class A, Class G and Class H are the three most commonly used in oil well cementing. Class A is used in milder and less demanding well conditions, while Class G and H cements are usually specified for deeper higher pressure/high temperature well conditions.. Local types of cement incorporating suitable additives have also been used. The chemical composition of the cement was what distinguished one type of cement from another and then determines the suitability of the cement for specific uses. The chemical compositions of the local cement were slightly different from one another. Oil well cement usually have lower C3A contents and are coarsely grounded with some amount of friction-reducing additives. The chemical composition of class H and G cement were similar to that of local cement though with basic difference in their surface areas. Class H is coarser than Class G cement and thus has a lower water requirement.

ISSN: 2223-9944, e ISSN: 2223-9553

RESULTS

Table 1: Composition of the locally made cements

SAMPLE	*CaO*	*Fe_2O_3*	*SiO_2*	*Al_2O_3*	*MgO*	*SO_3*	*K_2O*
Eagle	61.4	3.23	20.55	5.56	2.22	2.38	0.42
Bua	62.2	3.59	20.77	5.63	1.21	2.19	0.22
Dangote	59.6	3.22	20.62	6.01	3.65	2.46	0.71
Ibeto	62.6	3.20	20.34	5.09	1.74	2.19	0.29

Table 2: Result of the cement slurry design (slurry only)

Cement Samples	*Slurry Only*			
	Setting time (mins)	*Free water (%)*	*Thickening time (mins)*	*Compressive strength @ 100^0F & 800 Psi*
Eagle	11.48	2.10	96	290
Bua	13.11	1.20	91	260
Dangote	13.07	4.40	94	295
Ibeto	13.44	0.00	90	240
Class G	19.46	16.40	110	300

Table 3: Result of the cement slurry design (Slurry + $Cacl_2$

CEMENT SAMPLES	*Slurry + $Cacl_2$*			
	Setting time (mins)	*Free water (%)*	*Thickening time (mins)*	*Compressive strength @ 100^0F & 800 Psi*
Eagle	10.33	13.60	94	290
Bua	13.07	0.00	90	260
Dangote	12.30	0.00	92	300
Ibeto	12.09	0.40	90	245
Class G	14.20	12.80	108	310

Table 4: Result of cement slurry design (Slurry + NaoH)

Cement Samples	*Slurry + NaoH*			
	Setting time (mins)	*Free water (%)*	*Thickening time (mins)*	*Compressive strength @ 100^0F & 800 Psi*
Eagle	9.13	0.00	92	292
Bua	10.01	0.00	91	272
Dangote	7.14	2.16	94	290
Ibeto	8.52	0.00	88	250
Class G	12.33	10.40	105	300

Table 5 : Result of cement slurry design (Slurry + Sugar)

CEMENT SAMPLES	*Slurry + Sugar*			
	Setting time (mins)	*Free water (%)*	*Thickening time (mins)*	*Compressive strength @ 100^0F & 800 Psi*
Eagle	19.50	5.00	98	32
Bua	21.00	3.56	100	28
Dangote	19.00	8.50	96	54
Ibeto	17.80	7.50	99	30
Class G	18.50	6.50	120	69

Table 6 : Result of cement slurry design (Slurry + Lignosulfonate)

CEMENT SAMPLES	*Slurry + Lignosulfonate*			
	Setting time (mins)	*Free water (%)*	*Thickening time (mins)*	*Compressive strength @ 100^0F & 800 Psi*
Eagle	17.54	3.30	92	392
Bua	17.07	0.00	96	370
Dangote	15.53	12.00	90	400
Ibeto	16.45	0.00	94	360
Class G	21.27	19.20	110	322

DISCUSSIONS

The cement slurries in their natural state showed that Eagle cement has the least setting time when compared with the rest cements and therefore maybe preferred based on setting time, but for proper cement bonding, it is expected that after setting of the cement, the set cement should have zero free water, thus Ibeto cement was preferred in terms of free water.

The test inferred that the setting time was controlled by accelerators and retarders. The addition of sugar significantly extended the setting time ,though sugar are not commonly used in well cementing because of the sensitivity on the degree of retardation to small variations in concentrations. The sugar acted as a retarder to the cement slurries when added in small concentrations and as an accelerator when added in high concentration. The retarders also increased the thickening time of the cement slurries.

The tables showed the variation in the setting time for the local cements and class G cement with different cement admixtures. Class G had the highest value for all the cement admixtures.

Compressive loads were applied to the slurry samples using consistometer. The stress was increased linearly with strain until small micro cracks in the sample began to grow. As the cracks coalesce and reached a critical size, the samples fractured, which was determined by the boundary stress conditions and the geometry of the samples. The results showed that the compressive strength for slurry and sugar decreased rapidly for all the cement samples.

ISSN: 2223-9944, e ISSN: 2223-9553

CONCLUSION

A wide variety of cement admixtures are currently available to enhance the oil well cement slurry properties and achieve successful cementation. For the local cements to be effectively used for oil well cementation, it is desirable to optimize the setting time and the thickening time of the cement slurry. Accurate control of the thickening time and setting time is very important because a premature setting can have disastrous consequences due to loss of circulation in the well. Also, too long setting time can cause possible segregation of the slurry. A setting and thickening behavior can be achieved by adjusting the composition of the retarders and the accelerators. The Sodium chloride shortened the setting time though the accelerating effect depended on the chemical nature and the concentration of other constituents of the cement slurry.

ISSN: 2223-9944, e ISSN: 2223-9553
www.journals.savap.org.pk

REFERENCES

[1] American Petroleum Institute (API). 2002. Specification 10A: Specification for Cements and Materials for Well Cementing. API/ANSI/ISO 10426-1-2001. Washington, DC: American Petroleum Institute.

[2] Bouras, H., Doumaz, N., Sonatrach, Bellabarba, M., Caceres, E., Mananga, S., Leroy-Delage, S., Aziz, M. G. A., & Benberner, M. R. (2008).“*Responsive Cementing Material Prevents annular Leaks in Gas Wells”* paper SPE 116757 presented at 2008 SPE Annual Technical Conference and Exhibition held in Denver, Colorado, U.S.A., 21- 24 September.

[3] Coker, O. D., Harris, K. L., & Williams, T. A. (1992). *“Preventing Shallow Gas Migration in Offshore Wells: The Performance of Lead Cements*” paper SPE 24978 presented at European Petroleum Conference held in Cannes, France, 16-18 November.

[4] Dean, G. D., & Brennen, M. A. (1992). “*A Unique Laboratory Gas Flow Model Reveals Insight to Predict Gas Migration in Cement*” paper SPE 24049 presented at Western Region Meeting held in Bakersfield, California, March 30-April 1,.

[5] Harris, K. L., Ravi, K. M., King, D. S., Wilkonson J. G., & Faul, R. R. (1990). “*Verification of Slurry Response Number Evaluation Method for Gas Migration Control*” paper SPE 20450 presented at 65th Annual Technical Conference and Exhibition of the SPE held in New Orleans, LA, September 23-26,.

[6] Jennings, S. S., Al-Ansari, A. A., & Al-Yami, A. S. (2003). “*Gas Migration after Cementing Greatly Reduced”* paper SPE 81414 presented at 13th Middle East Oil Show & Conference held in Bahrain, 5-8 April,.

[7] Krusche, K., Johnson, C. R., Braud, N. Y., & Ghazi, H .B. (2006). “*Application of Cement Engineered Solutions to Solve Long Term Cement Integrity Issues in Tunisia,*” paper SPE 100390, SPE Annual Technical Conference, San Antonio, Texas, September.

[8] Ravi, K., Bosma, M., & Gastebled, O. (2002.). “*Improve the Economics of Oil and Gas Wells by Reducing the Risk of Cement Failure,”* paper SPE 74497, IADC/SPE Drilling Conference, Dallas, Texas, February.

[9] Reddy, B. R., Xu, Y., Ravi, K., Grey, D., & Pattillo, P. D. (2007). *“Cement Shrinkage Measurement in Oil Well Cementing- a Comparative Study of Laboratory Measurements and Procedures”* paper SPE 103610 presented at SPE Rocky

[10] Rogers, M. J., Dillenbeck, R. L., & Eid, R. N. (2004). “*Transition Time of Cement Slurries, Definitions and Misconceptions, Related to Annular Fluid Migration*” paper SPE 90829 presented at SPE Annual Technical Conference and Exhibition held in Houston, Texas, U.S.A., 26-29 September

[11] Santra, A., Reddy B. R., & Antia, M. (2007). “*Designing Cement Slurries for Preventing Formation Fluid Influx after Placement”* paper SPE 106006 presented at the 2007 SPE International Symposium on Oilfield Chemistry held in Houston, Texas, U.S.A., 28 February-2 March.

ISSN: 2223-9944, e ISSN: 2223-9553