ASSESSMENT OF LOCAL CEMENTS FOR OIL WELL DRILLING IN THE NIGER DELTA

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ABSTRACT

The abundant local cements frequently used for construction purposes in Nigeria, have been found to possess the following operational issues: low thickening time, low setting time and high gel strength. Oil well cementing is one of the most critical operations required to put the wellbore into production stage. In the Niger Delta region of Nigeria, high pressure and temperature exist beneath the earth and the cements must withstand these conditions in order to prevent costly damage, which threatens lives and onshore or offshore facilities. In this study, we carried out performance evaluation of local cements against industry standard class-G cement (Dykerhoff cement). The evaluation included three (3) scale experiments, according to API specifications, to measure the thickening time, rheology and compressive strength of the commonly found local cements (Dangote and Unicem cements) in the Niger Delta region. The slurries were formulated for the three samples using 456.61 g of the cements, 159.89 g of silica flour, 200.91 g of distilled water and other additives. In addition, we used Excel data analysis to correlate between the properties of cement pairs. The study shows that the local cements samples may possess the capability of being used for drilling in the Niger Delta region; but, require optimization of the oxide contents in order to meet drilling specifications. The selection of the appropriate cement composition and additives responsive to the conditions in the basin are the major issues with the utilization of local cement for oil well drilling. The Dangote cement performed better in terms of the compressive strength and thickening time, while the unicem performed better in terms of the rheology and ease of being pumped, thus, we recommend a hybrid cement mixture of the local cements in order to meet the HPHT condition found in the Niger Delta region of Nigeria.

Keywords: Class-G cement, thickening time, cement rheology, compressive strength, set time

INTRODUCTION

A basic requirement for the successful drilling and completion of oil and gas well is a quality cement operation. By a quality cement operation, we imply a good design and execution, together with good cement slurry. Although it is known for use in the construction industry, cement has been applied in oil well drilling (Miska, Mitchell, 2011). The application of cement in oil well is the process of placing cement slurry in a wellbore by mixing cement, water and additives, and pumping them to the target location. In the drilling industry, cement is used to seal off the annular space between the wellbore and casing to obtain zonal isolation. Thus providing structural reinforcement for the casing and protecting it from corrosion. It is also used for sealing off an abandoned portion of the wellbore. Poor cementing job can negate oil production and result in oil loss at a global scale, like in the

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Macondo blowout of the Gulf Coast deepwater, which began on 20 April 2010, (Robertson C., Krauss C., 2010) (Boemre, 1929). The resulting oil spillage was devastating to environment, economy and aquatic life. In the world at large, the industry uses Portland cement for drilling operation, (Bourgoyne, 1991). The process of cementing follows the American Petroleum Institute (API), International Standard Organization (ISO) or the American Standard Testing Method (ASTM) standardizations.

After creating the wellbore and placing casing of steel pipes in place, cement slurry is pumped through the drill pipe to the annular space. During this process, the slurry exists under great condition of temperature and pressure and exhibits different rheological properties and strength, which must be favourable to the wellbore. The gel strength, thickening time and set time of cement slurry are very important property requirements for successful cementing operation. Quick gel strength is a requirement for the cement needed in order to prevent formation fluid influx into the wellbore. When formation fluids enter the wellbore, it could lead to kick and blow out, which are detrimental to life and property. At high temperature, the cement must remain in a pumpable state long enough to enable movement into the target location, (Miska, Mitchell, 2011). The compressive strength of the cement must be adequate to withstand downhole pressure.

Physical market survey indicates that the most dominant local cements in the Niger Delta region of Nigeria are Dangote cement and Unicern cement. While these cements are useable in project constructions of various kinds in the locality, they will face stiff competition from foreign cement, like the Dyckerhoff cement, should they be used for oil and gas well drilling. The major issue is whether they can perform well when exposed to the same condition of pressure and temperature as their foreign cement counterpart does. We are also interested in knowing how to optimize these cements in order to make them conform to the standard of safety required of drilling engineering. With the current dollar rate, only a few indigenous oil companies can venture into a drilling project because of the cost of obtaining foreign cement. Drilling operation will become less expensive if local cements, which abound in the locality, are employable for oil well drilling in the nation. The use of local cement for drilling in the country can be a source of revenue for government. It can help create job for the unemployed of the nation should the Nigerian government channel her resource into establishing a sustained local cement industry. Thus, the importance of assessing the suitability of local cement for well drilling in the Niger Delta cannot be overemphasized. The following issues have been identified when experimenting with the Nigerian local cement compared to class-G foreign cement (Oriji A.B., Dulu A., 2014): high gellation, low thickening time and setting time.

High temperature cementing is a problem of its own, which can be encountered in oil and gas well, geothermal well and thermal recovery well (Guillot, 2006). High temperature affects cement rheological properties such that both plastic viscosity and yield point decrease with increase in temperature (Ravi, K.M., Sutton,D.L., 1990). It reduces thickening time, as the movement of the cement becomes faster (Prisca S., Mamood A., 2013). A high-density and high-compressive strength cement will be a better design model for oil well. The high density will help prevent influx of formation fluid into the wellbore. Loss circulation, varying temperatures and gas migration are experienced in HP/HT wells (Shadravan, A., Amani, M., 2012). The cement in use must withstand these severe conditions if success is to be achieved.

The aim of this study is to investigate the suitability of local cements for oil well drilling in Niger Delta region of Nigeria. The objectives include the following:

- To select the commonly used operational cements in the locality

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- To test for the thickening time, rheology and compressive strength of the cement slurries over a range of temperature simulating API limits
- To conduct regression modeling of the properties measured.

The major constituents of Portland cement are oxides, alumina and lime combined in a predesigned chamber. It is a blend of burnt limestone and clay (Miska, Mitchell, 2011). The oxides of aluminium, iron, calcium and silicon are reacted in a kiln operating at about 2,700^{o}F, which produces clinker upon cooling (Beaudoin, J.J., Ramachandren,V.S.,, 1992). The clinker is then passed into a grinding mill, where gypsum is added to retard set time and hardening of the cement. Additives are usually added to obtain certain desired results, but are capable of changing the chemo-physical properties of the cement. The relative amount of the oxides bears a significant effect on the properties of the cement (Bogue, 1929). **Table 1** shows the proportional limits of the oxides in a typical Portland cement (Halliburton, 2001). There are four (4) basic hydrating-crystalline compounds in the clinker, which aides the rigidity of the cement (Miska, Mitchell, 2011). They are the tricalcium silicate, C_3S , which is the major strength contributor, tricalcium aluminate, C_3A, which hydrates rapidly, dicalcium silicate, C_2S, which hydrates slowly to contribute to long-term strength, and tetracalcium aluminoferrite, C_4AF , which has minor effect on cement physical properties. The following expressions are applicable to obtain the crystalline compounds in cement (10A, 2002):

$$C_3S = 4.07C - 7.6S - 6.72A - 1.43F - 2.85SO_3 \tag{1}$$

$$C_2S = 2.87S - 0.7542.85C_3S \tag{2}$$

$$C_3A = 62.65A - 1.69F \tag{3}$$

$$C_4AF = 3.04F \tag{4}$$

Where $C = \%CaO$, $S = \%SiO_2$, $A = \%Al_2O_3$, $F = \%Fe_2O_3$ and $A/F > 0.628$

Table 1. Percentage of oxides in Portland cement (Halliburton 2001)

Oxides in cement	%
CaO	60-67
SiO_2	17-25
Al_2O_3	3-8
Fe_2O_3	0.5-6
MgO	0.1-4
SO_3	1.8-3
K_2O	0.4-1.3
Na_2O	0.4-1.3

MATERIALS AND METHOD

Two (2) local cements were sourced from retailers within the Niger Delta region, while the foreign cement was obtained from oil Service Company. The Dykerhoff cement was used as the control cement, while the experiments carried out included measurements for the thickening time, rheological and compressive strength of the cements.

Table 2 shows the gravimetric compositions of the materials sourced for laboratory tests. The convention for identifying the cement samples are the following: D1 is the Dyckerhoff class-G cement, D2 is the Dangote cement while D3 is the unicem cement. The specific gravities of the various cements show that D1 is the densest of the samples, while D2 is denser than D3. The D1, been a class-G cement, was chosen for this study because it is applicable in deep wells having high pressure and high temperature conditions as found in the Niger Delta basin.

The dispersant added to form the slurry is Calcium Chloride while the retarder is Calcium Lignosulfonate.

Table 2. Gravimetric details of materials used for laboratory test

S/N	Specimen	Specific Gravity	Mass (gram)
1.	Dyckerhoff	3.18	456.61
2.	Dangote	2.74	456.51
3.	Unicem	2.61	456.61
4.	Silica Flour	2.64	159.81
5.	Barite	4.23	228.31
6.	Dispersant	1.28	0.91
7.	Retarder	1.16	0.91
8.	Distilled water	1.00	200.91

Table 3 shows the composition of the oxides and crystalline compounds used in this study (Haliburton 2001, Oriji and Dulu 2014**)**. The limits are within API specifications for cement composition. Eqns. (1)-(4) were used to obtain the crystalline compounds from the oxides analysis.

Table 3. Composition of D1, D2 and D3 cement samples

Oxides in cement	% in D1	% in D2	% in D3
CaO	62.9	59.6	62.2
SiO_2	21.7	20.62	20.77
Al_2O_3	3.2	6.01	5.63
Fe_2O_3	3.7	3.22	3.59
MgO	4.3	3.65	1.21
SO_3	2.2	2.46	2.19
K_2O	0.54	0.71	0.22
Na_2O	0.74	-	-
C3S	58.018	38.1132	45.279
C2S	18.5	28.8348	25.469
C3A	2.227	10.4847	8.8524
C4AF	11.248	9.7888	10.9136

Researchers determined sample weights using an electronic weigh balance, and formulated the slurries using the Hamilton beach mixer. The 12-Speed viscometer (model 800), with speeds of 600, 300, 200, 100, 60, 30, 6 and 3, was used to obtain the rheology of the samples at bottom hole circulating temperature (BCHT) of 80 deg F (26.67^{o}C). This test was aided by proper conditioning of the samples using the atmospheric consistometer; while the pressurized consistometer was used to get the slurry viscosity. In order to get the compressive strength of the samples, the ultrasonic cement analyser was the equipment employed.

Using the electronic balance, we measured approximately 456.61 gram of D1, D2 and D3 into three different cups. We then added the 159.81 gram of silica flour, 228.3 gram of barite, 0.91 gram of dispersant, 0.91 gram of retarders and 200.91 gram of distilled water to obtain the slurries. Rheological test for cements were conducted with respect to standard API temperature limit of 190^{o}F (87.78^{o}C (API 1990). The rotational viscometer was used to obtain the rheological properties of the samples. The compressive strength test was carried out to determine how long the cement remains static, before resumption of drilling activity. This was aided by the use of cement HP/HT curing and strength-testing machine. The standard for the compressive test is the ((10A, 2002) (10426-1, 2002)). In order to finish experimentation, the thickening time of the samples were obtained using a HP/HT consistometer at BHCT of 190, 210 and 230^{o}F in accordance with API recommendations. The test for compressive strength was a non-destructive method using the ultrasonic cement analyser at bottom hole static temperatures of 190, 210 and 230^{o}F and pressure of 7000Psi (482.63Bar) for 24 hrs run.

We carried out correlation analysis, using Microsoft Excel, in order to determine the association between the compressive strength of D1, D2 and D3, and that of the thickening time. We obtained good correlation between the cements.

RESULTS PRESENTATION AND DISCUSSION

Table 4 shows result for the rheological data of the samples at bottom hole circulating temperature (BHCT) of 80^{o}F (26.67^{o}C). The rheology data shows that value for the plastic viscosity of D1 is the greatest of the three, followed by that of D2, which indicates that there will be higher friction pressure added to get the circulating density for D1. That is, it is more difficult to pump D1 than the local cements are, and D3 appears to be easiest to pump.

Table 4. Rheology data @ BHCT of 80^{O}F

	D1	D2	D3
300 RPM	96	59	33
200 RPM	81	42	27
100 RPM	50	32	20
6 RPM	28	21	13
3 RPM	19	15	10
PV (CP)	69	40.5	19.5
YP lb/ft^2	27	18.5	13.5

Table 5, Table 6 and table **7** show the thickening time of the samples at various temperatures. The tables show that the local cements possess low thickening times compared to the foreign cement. Thus, indicating that the time in which the local cements remain pumpable is lower than that of the foreign cement. The major reason for this may be due to the amount of gypsum added in forming the cements. Gypsum reduces the speed at which C_3S molecules bind with water in order to set (Miska, Mitchell, 2011). When set, it becomes difficult to pump the cement. Thickening time is bound to be low if there is rapid binding with water. D1 probably has lesser quantity of gypsum added to it than the corresponding local cements, thus to optimize the thickening and setting time of the local cements, lesser quantity of gypsum is the requirement. The molecule C_3A hydrates rapidly. The local cements have more of this molecule than the foreign one, thus their setting times are lower. In order to optimise local cement set time, a reduction in the amount of aluminium oxide and/or increase in iron oxide is required. This will help reduce the amount of C_3A in the slurry based on eqn. (3). Ramachandran achieved an increase in setting time of up to 6 hours for significant reduction in C_3A molecule (Ramachandran, 1984). The thickening time relatively decreases with increase in temperature. The increase in temperature causes an increase in the speed at which C_3S molecules binds with water, thus reducing the thickening time. At higher temperatures, in order to allow cements to set a target location retarders like sugars and lignosulfonates are added to the slurry (Miska, Mitchell, 2011).

Table 5. Thickening Time FOR D1, D2, AND D3 @ 190°F

Consistency (B_c)	Thickening time (min)		
	D1	**D2**	**D3**
30	90	70	58
50	120	94	68
70	160	115	105
100	178	130	125

Table 6. Thickening Time FOR D1, D2, AND D3 @ 210°F

Consistency (B_c)	Thickening time (min) 210°F		
	D1	**D2**	**D3**
30	87	40	20
50	120	65	58
70	150	73	73
100	165	138	130

Table 7. Thickening Time FOR D1, D2, AND D3 @ 230°F

Consistency (B_c)	Thickening time (min) @ 230°F		
	D1	**D2**	**D3**
30	84	25	5
50	120	50	43
70	150	58	58
100	165	130	142

The trend for the thickening time follows more of a power law model than a linear one. Power law regression between the samples shows that D2 has a thickening time that correlates better with the foreign cement than D3. Nevertheless, both cement types can function as oil well cement for drilling in the locality when appropriate measures are taken. Figure 1 is a display of the correlation analysis showing the association of thickening time between local cements and the foreign one.

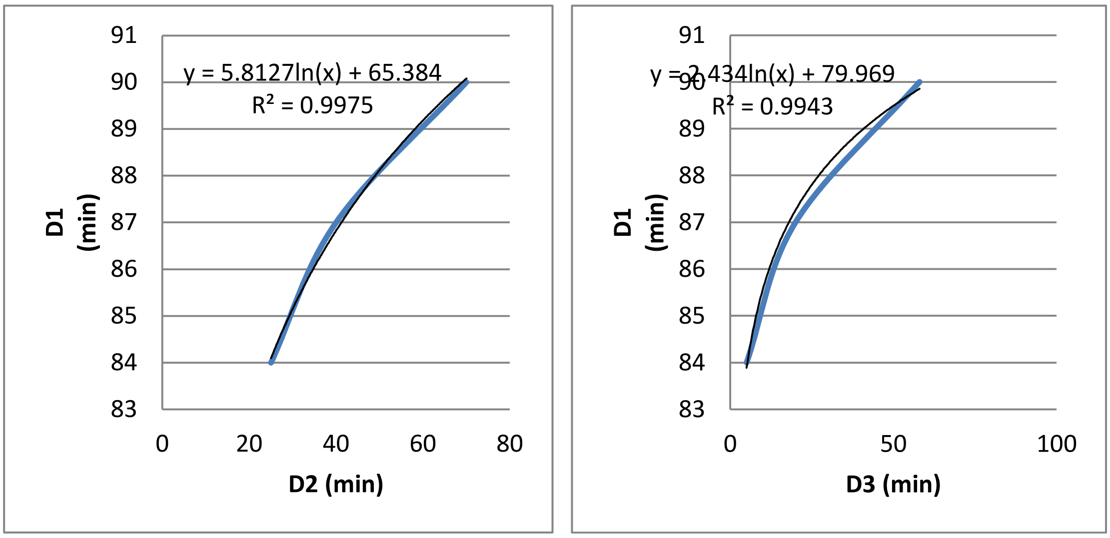

Figure 1: Results using power law correlation associating the thickening time of cements samples.

The molecule C_3S is indicative of short time rapid cement strength, (Beaudoin and Ramachandran, 1992; Mitchell and Miska, 2011). Table 3 shows that D1 has more C_3S molecules than the others do, thus the former possesses higher compressive strength as shown in **table 8**. The major factor for this is the relative magnitude of CaO compared to SiO_2, Al_2O_3 and Fe_2O_3 in the samples. The best way to optimize local cement compressive strength is to maximize eqn. (1).

Table 8. Compressive strength at varying for 24 HRS

D1		D2		D3	
Compressive Strength (Psi)	**Temperature (^oF)**	**Compressive Strength (Psi)**	**Temperature (230^{O}F)**	**Compressive Strength (Psi)**	**Temperature (^oF)**
983	230	975	230	970	230
969	210	958	210	947	210
955	190	942	190	935	190

The correlation analysis indicates that the Dangote cement possesses better compressive strength that the Unicem when associated with the foreign cement. Figure 2 shows the trend line analysis for the compressive strength of the samples. The plot indicates that the linear regression between the data of each of the cement is highly significant.

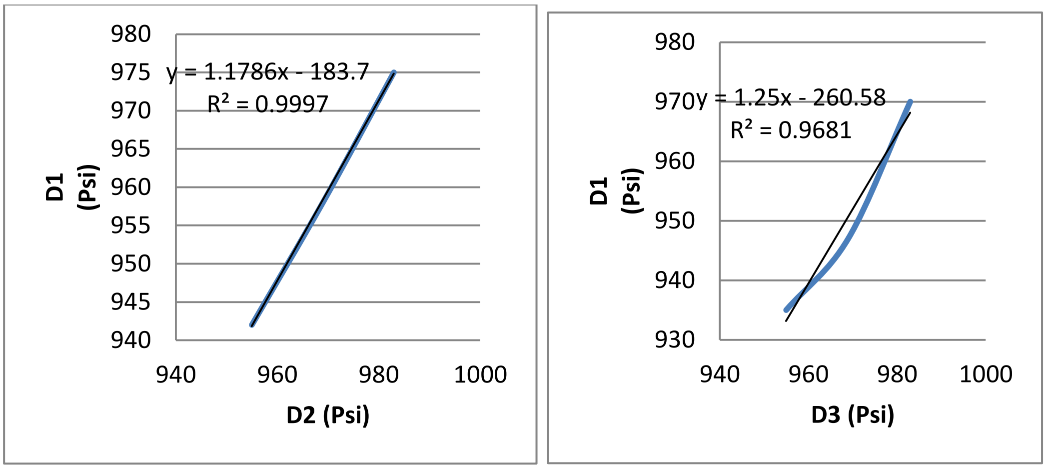

Figure 2. Results using linear regression to compare the compressive strength of the cement samples

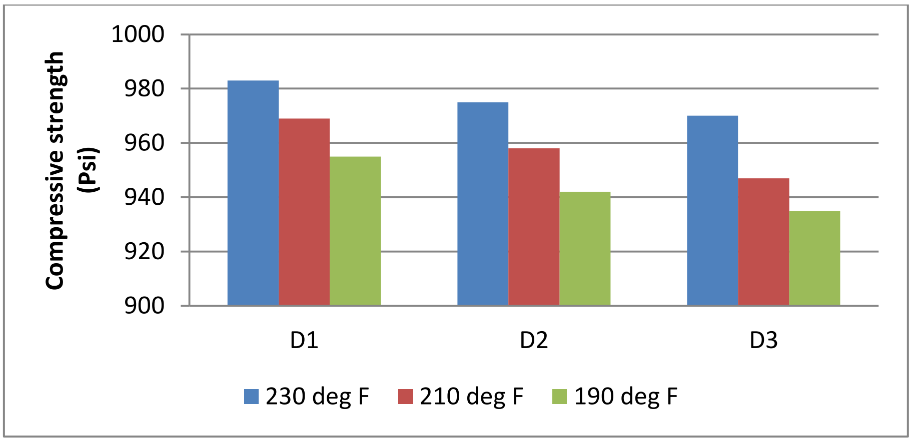

Figure 3. Histogram showing cement compressive strength at BHCT

The compressive strength of the cement slurries increased steadily with temperature. The Dykerhoff cement has the most steepness of the three samples, with correlation coefficient of unity. Above figure 3 is a display of the compressive strength variation with temperatures.

CONCLUSION

The authors of this study evaluated local cements found in the Niger Delta for the suitability of been used in drilling oil wells in the locality. In order to achieve this, standard API tests were carried out for the rheological behaviour of the slurries, the thickening time and the compressive strength. Regression analysis from the study showed that D2 is the favourable local cement in terms of compressive strength and thickening time, while D3 is the favourable cement in terms of the ease of being pumped downhole. Significant improvements in the performance of local cement are possible by using critical measures to step up slurry characteristics. Thus, there is the possibility of using local cement to comfortably complete oil wells in the Niger Delta region of Nigeria; although, optimization of the compositions of these oxides is required.

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REFERENCES

[1] API Spec, 10A. (2002). *Specifications for cementing and materials for well cementing*. Washinton DC: API.

[2] API TR 10TR3. (1999). *Temperature for API cement operating thickening time tests*. Washinton DC: API.

[3] Beaudoin, J.J., & Ramachandran, V.S. (1992). A new perspective on the hydration characteristics of cement phases. *Cement and Concrete Research*, *22* (4), 689-694.

[4] BOEMRE. (2011). *Deepwater horizon joint investigation team releases final report*. Retrieved from *www.boemre.gov.*

[5] Bourgoyne, A.T., Millheim, K.K., Chenevert, M.E., & Young, F.S. (1991). *Applied drilling engineering.* Texas: Textbook Series, SPE.

[6] Guillot, D. (2006). *Well cementing.* Texas: Schlumberger.

[7] Halliburton, H. (2001). *The red book: Halliburton cementing tables.* Oklahoma: Duncan.

[8] Kosmatka, S.H., & Wilson, M.L. (2011). *Design and control of concrete mixtures*. Skokie, Illinois: Portland Cement Association.

[9] Mitchell, R.F., & Miska, S.Z. (2011). *Fundamentals of drilling engineering*, Texas: SPE Text Book Series.

[10] Oriji, A.B., & Dulu A. (2014). Analysis of Nigerian local cement for slurry design in oil and gas well cementing. *Academic Research International*, *5*(4), 176-181.

[11] Prisca, S., & Mamood A. (2013). Special consideration in cementing high pressure high temperature wells. *Int. Jour. Of Engr. and Applied Science, 1* (4), 1-24.

[12] Ravi, K.M., & Sutton, D.L. (1990). *New rheological correlation for cement slurries as a function of temperature*. New Orleans: SPE 20499, Procd. 65th Annual Technical Conference and Exhibition of the Society of Petroleum Engineers.

[13] Robertson, C., & Krauss, C. (2010). Gulf spill is the largest of its kind, scientists say. *The New York Times*.

[14] Shadravan, A., & Amani, M. (2012). *HPHT 101: What every engineer or geoscientist should know about high pressure high temperature wells*. Kuwait: SPE Kuwait International Petroleum Conference and Exhibition.

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