Oil & Gas Research
ISSN: 2472-0518

Broni-Bediako and Amorin, Oil Gas Res 2017, 3:3
DOI: 10.4172/2472-0518.1000148

Research Article Open Access

Advances in the Possibility of Utilising Construction Grade Cements (CGCs) for Oil Well Cementing

Eric Broni-Bediako* and Richard Amorin

Department of Petroleum Engineering, University of Mines and Technology, Tarkwa, Ghana

Abstract

Cement is used as the primary sealant in oil and gas wells throughout the world and is manufactured to meet specific chemical and physical standards set up by the American Petroleum Institute (API). As a result, oil companies purchase cement manufactured according to specification of API for its oil well cementing. These special classes of cements are called Oil Well Cements (OWCs). In oil well cementing, less error is tolerated in the performance of the cement used as compared to conventional cementing work. This has resulted in more attention being placed on the usage of high grade API special class of cements as against any ordinary type of cement. However, there are some cementing operations that Construction Grade Cements (CGCs) have been used without resulting in any cementing challenges. This paper presents the progressions in experimental investigations and field applications of CGCs in oil well cementing. The experimental investigations on the physical properties such as thickening time and rheological properties revealed that local cements in its natural state lack sufficient technical properties for oil well cementing. However, with the right addition of oil well additives, local cements have proven to have the required technical properties for oil well cementing. Countries like Vietnam and Thailand have demonstrated the field applications potentials of CGC. Comparing the cost of CGCs and OWCs (imported), it is realised that more savings are made when CGCs are used in cementing operations.

Keywords: Additives; Universal cement system (UCS); Gelation; Construction grade cement (CGC); Oil well cements (OWCs)

Introduction

Oil Well Cement (OWC) is used primarily as an impermeable seal material in oil and gas wells throughout the world. It is manufactured to meet specific chemical and physical standards set up by the American Petroleum Institute (API) [1,2]. In the process of well cementing, various types of cement systems are placed into the space between the casing and the formation, called annular space. The cement seals to secure and structurally support casing strings inside the well as well as prevent fluid communication between the various underground fluid-containing layers which can lead to casing corrosion [3-5]. Cement is also used for remedial or repair works such as to seal off perforated casing when a producing zone starts to produce large amounts of water and/or to repair casing leaks.

The first recorded oilfield cementing operation took place in 1903 when Frank F. Hill with Union Oil Company mixed and dumped 50 sacks of cement by bailer to shut off water flow in a California oil well. After 28 days, the cement was drilled out and the well completed successfully. However, it was not until 1910 when Perkins and Double introduced 2-plug cementing technique that modern oil well cementing was born. Since then, major improvements have been made in both technique and equipment. The introduction of bulk cement in 1940 and the use of special additives to control the slurry properties highlight some of these improvements [6]. In oil well cementing, less error is tolerated as compared to conventional cementing works. As a result, oil companies purchase cement manufactured according to specification of API for its oil well cementing. These special classes of cements are called Oil Well Cements (OWCs). However, there are some operations that Construction Grade Cements (CGCs) or Local Cements (LCs) have been used without resulting any cementing challenges. For example, Griffin [7] reported that 37 cement jobs had been done with the local cement as at 2005 at depths from 250 ft to 8,400 ft (76.2 m to 2560.3 m) and at temperatures from 100°F (37.8°C) to 165°F (73.8°C). In spite of this successes, there is still less attention placed on the use of CGCs. This paper presents some progressions in experimental investigations and field applications of Construction Grade Cements (CGCs).

Challenges with the Use of Construction Grade Cement for Oil Well Cementing

CGCs are commonly available from variety of manufacturers throughout the world. They are inexpensive as compared to the higher grades of cement used in oil and gas cementing operations. The composition of construction grade cements varies from manufacturer to manufacturer and this makes it difficult to predict the properties of cements slurries containing such cements (Tables 1 and 2) [8].

CGCs typically contain high quantities of metal sulphates while the cements used in oil well cementing must have relatively low metal sulphate contents. While cement slurries formed from inexpensive construction grade cements are suitable for a large number of surface applications, they do not have the properties required for subterranean oil and gas well cementing such as consistent viscosities, suitable thickening times and high compressive strength after setting, and good fluid loss control, etc. [9-11]. A research conducted by a service company in the north eastern US, for wells as deep as 20,000 ft and with temperatures higher than 200°F revealed the major challenges of the local cement as predictability and reproducibility of results [7].

***Corresponding author:** Eric Broni-Bediako, Department of Petroleum Engineering, University of Mines and Technology, Tarkwa, Ghana, Tel +233 20 151 1690; E-mail: bronibediako2005@yahoo.com

Received November 03, 2017; **Accepted** November 08, 2017; **Published** November 15, 2017

Citation: Broni-Bediako E, Amorin R (2017) Advances in the Possibility of Utilising Construction Grade Cements (CGCs) for Oil Well Cementing. Oil Gas Res 3: 148. doi: 10.4172/2472-0518.1000148

Copyright: © 2017 Broni-Bediako E, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Chemical Name	Mineral Name	Chemical Formula	% Weight
Calcium Oxide	Lime	CaO	0.729
Calcium Carbonate	Calcite	$CaCO_3$	0.725
Silicon Oxide	Quartz	SiO_2	0.626
Calcium Sulphate Hydrate	Gypsum	$CaSO_4.2H_2O$	0.693
Potassium Sodium Aluminium Silicate	Sanidine	$(Na,K)\ (Si_3Al)O_8$	0.693
Calcium Sulphate	Anhydrite	$CaSO_4$	0.676
Potassium Aluminium Silicate Hydroxide	Muscovite	$KAl_2(Si_3Al)O_{10}\ (OH,F)_2$	0.701

Table 1: Chemical and mineralogical composition of CEM A.

Chemical Name	Mineral Name	Chemical Formula	% Weight
Silicon Oxide	Quartz	SiO_2	0.803
Magnesium Oxide	Periclase	MgO	0.745
Calcium Magnesium Carbonate	Dolomite	$CaMg(CO_3)_2$	0.732
Calcium Sulphate Hydrate	Gypsum	$CaSO_4.2H_2O$	0.749
Calcium Carbonate	Calcite	$CaCO_3$	0.719

Table 2: Chemical and mineralogical composition of CEM B.

Another research conducted by Oriji and Appah [12] on four types of Nigerian construction grade (local) cements at Bottom Hole Static Temperatures (BHST) of 100°F showed that the Nigerian local cements in its original state have low setting time, low thickening time, very high fluid loss and high gelation compared to class G cement or OWC. These are some of the major challenges revealed by other researchers.

Universal Cement System (UCS) Additive

For several years, a service company has identified the value that could be created for its customers by the use of locally manufactured cements, particularly in areas remote from locations where oil well cements are manufactured. To overcome the problems associated with local cements, the service company developed and tested a product that allows non-API specification (local cements) to be used in oil well cementing designs and application and also manages problems associated with the local cements. This product is commonly referred to as Universal Cement System (UCS) additive. In the majority of cements tested worldwide, UCS additive has allowed the formulation of consistent slurry recipes with locally manufactured cements at concentrations that make it economically desirable [13,14]. The physical properties that a UCS additive can provide include enhances compressive strength, controls fluid loss, controls rheology, imparts chemical resistance, controls premature gelation, and allows use in freshwater and seawater [14,15]. UCS additive can be added to cement that might not normally be usable in oil well cementing, such as those often produced in developing countries, those with high alkali sulphate and high free-lime content, and ASTM Type I/II construction-grade cements. UCS additive may be available in liquid or powder form (Figure 1) [15].

The application of the powdery UCS is always pre-blended with the dry cement and not added directly to the mixing water for maximum results. The UCS additives can counteract the difference of the physical properties often seen between different batches of locally manufactured cement, reducing the high gelation effects, imparting chemical resistance, allowing their use at temperatures up to 250°F (121°C) [15]. The application of Gelation Control Additive (GCA) or UCS-additive of 1% by weight of cement (bwoc) has showed resistance to sulphate attack similar to that of a class G oil well cement [14,16]. The sulphate resistance testing was based on ASTM C102. The untreated, non-resistant cement used in the study expanded and showed sulphate attack during a 90 day test period.

Figure 1: UCS additive in powder and liquid form.

Experimental Investigations

Shahrudin et al. [17] investigated the possibility of using local Portland cements and pulverised fly ash cements in Malaysia for oil well cementing operations. Test was also run on class G cement for comparison to be made. Compressive strength, thickening time, fluid loss and free fluid tests at BHCT of 125°F (52°C) and a depth of 8,000 ft (2,438 m) were examined by closely using API Specification 10. Different additives were used based on percentage by weight of cement but the specific types of additives were not mentioned in their research. They concluded that, in terms of fluid loss, thickening time, compressive strength and free fluid tested at atmospheric temperature and pressure, and simulated reservoir condition, locally produced cement, especially the pulverised fly ash cement, proved to have the properties suitable for application in oilwell cementing operations.

Samsuri and Subbiah [18] also studied the use of locally produced blended cement as oil well cement for cementing operations in Malaysia. Laboratory experiments were carried out on dry cement powders, cement slurry and hard cement. The chemical analysis was done by wet test method as described by the ASTM C-114. The cement slurry, specimen preparation and the physical properties were conducted by closely following the API Specification 10. The physical properties test such as compressive strength, fluid loss, thickening time and free fluid loss were tested at BHCT of 125°F (52°C) and a depth of 8,000 ft (2,438 m). A retarder, fluid loss control agent and palm oil fly ash were used as additives for the study. An economic analysis was also carried out to understand the market need. The results of the chemical test revealed that the percentages of oxides minerals and chemical compounds for the locally produced blended cement and class G cement were very different. The locally produced blended cement has less free fluid, less fluid loss, better compressive strength development but shorter thickening time than class G cement. The thickening time measured at 100Bc for the blended cement was within API 10A Specification. The results also showed that blended cement is compatible with existing retarder and fluid loss agent. The palm oil fly ash used improved the blended cement compressive strength with the highest strength achieved when 15% of the ash was added to the neat cement. According to them, the strength would be decreased if 20% or more fly ash was added to the cement and about 48% of the cement material cost would be saved if the blended cement was used to cement oil well at 8,000 ft (2438 m) depth. In general, the locally produced blended cement has properties which are within the range of API 10A Specification, and therefore suitable for application in oil well cementing operations particularly for five hours or less cementing operations.

Mfonnom et al. [14] presented a paper on experimental study of the use of locally produced cement, normally referred to as ASTM-type cement, for cementing oil and gas wells. Their experiment was conducted on two types of Nigerian cements (Dangote and Elephant) and the results were evaluated to determine whether local construction cements could be used for cementing oilwells in onshore and offshore Nigeria. A comparison of local and imported class G cement was conducted and evaluated at different experimental conditions. A series of tests were performed to evaluate the performance, physical, and chemical properties. Slurry performance tests, including fluid loss, thickening time, compressive strength, free fluid, sedimentation, and gelation tests, were conducted. All tests were conducted according to API recommended practice 10B at BHCT ranges of 100°F (37.8°C) to 216°F (102.1°C), pressure ranges of 2,300 psi to 13,090 psi and depth ranges of 11,100 ft (3383.3 m) to 15, 092 ft (4,600 m). Cement microscopy was also conducted to determine the quality and sulphate resistance of the local cements. To prevent the problem of premature gelation associated with local construction cements, Universal Cement Systems (UCS) additive was used. Other cement additives such as WG-17™ agent, D-AIR 3000L™ anti-foaming agent, bentonite, HR®-5 retarder, HALAD®-322™ fluid loss additive, LAP-1 additive, and CFR-3™ cement dispersant, were used in the research. They concluded that locally produced cements, especially Dangote cement, proved to have properties suitable for application in oilwell cementing operations. In terms of fluids loss and free fluid test, their results showed that the local cements have desirable control of fluid loss and free fluid. In terms of compressive strength, they reported that lead and tail slurries at slurry weights of 12.5lbm/gal and 15.8 lbm/gal respectively showed good strengths as compared to class G cement. The thickening time and rheological properties of the local cements also showed comparable results. All the tested lead slurries of weight 12.5 lbm/gal showed longer setting times than the imported class G cement and at 15.8 lbm/gal the local cements pumped shorter than class G cement. But the addition of UCS additive enhanced the chemical properties, eliminated gelation problems, imparted sulphate resistance, and improved bulk-flow characteristics of the locally manufactured cement.

Joel [19] also conducted a research to establish the possibility of utilising local cement as an alternative for oil well cementing in Nigeria. Series of tests were carried out to evaluate the performance on thickening time, compressive strength, free fluid, fluid loss and rheological properties. All the tests were conducted in line with the API Specification for Materials and Testing for Well Cements (API Recommended Practice 10B) at BHCT ranges of 84°F (28.8°C) to 192°F (88.9°C) and at pressure ranges of 1,150 psi to 10,367 psi. Cement additives such as retarders, accelerators, fluid loss additives, dispersants, light weight and gas control additives were employed for the research. His findings were not different from the findings of Mfonnom et al. [14] except that premature gelation and non- reproducibility of test results were phenomenal at higher temperatures. However, it was concluded that locally manufactured cement could be used as a substitute for imported cements in cementing of gas and oil wells. This was because the test results obtained using construction grade (local) cements were in conformance with API Specifications and also compared favourably with the imported cement sample. Joel [19] in his work did not use UCS which according Mfonnom et al. [14] is capable of eliminating premature gelation and improving bulk flow characteristics of the local cement slurries.

In addition to the progress of the utilisation of local construction cement for oil and gas cementing operations, Oriji and Appah [12] again analyse four Nigeria cements and also concluded the same as the earlier research works in Nigeria. To Oriji and Appah [12], Nigerian local cements in its original state have low setting time, low thickening time very high fluid loss and high gelation compared to class G foreign cement. Further analysis showed that with the additions of some accelerators and retarders, the local cement compared favourably with the foreign cement and recommended local cement slurries for shallow oil well cementation. Their experiment was conducted following API Specifications at a BHST and pressure of 100°F and 800 psi respectively.

Another research work by Broni-Bediako et al. [11], to evaluate the performance of local cements with imported class G cement for oil well cementing operations in Ghana also contributed to the progress in the area of using construction grade cement which is readily available and cheap. The test was conducted based on the API Specification 10A and API Recommended Practice 10B in terms of compressive strength, thickening time, free water and rheological properties. The results indicated that some local cement in their natural state have the potential to be used for cementing oil and gas wells at a BHCT of 125°F and pressure of 5,160 psi. However, they recommended further tests should be conducted to ascertain their stability under High Pressure and High Temperature (HPHT) conditions.

Further test conducted by Broni-Bediako et al. [20] to determine the suitability of local cements as an alternative to imported class G cement at different temperatures for oil well cementing operations in Ghana proved to be an alternative to class G cement at BHCTs of 80°F (27°C) and 150°F (66°C).The local cements appeared to pump shorter at low 80°F (27°C) and high temperature 150°F (66°C). Nonetheless, at 80°F (27°C) and 150°F (66°C) local cements proved to be good for cementing operations if operating time is less or equal to the thickening time of the local cements. The local cements proved to be better than the imported class G in terms of free fluid and fluid loss at these temperature conditions. In terms of compressive strength, the entire local cements proved to have the required compressive strength after 24 hour curing periods to structurally hold casings at 80°F (27°C) and 150°F (66°C). The results of the local cements also compared very well with imported class G in terms of the plastic viscosity and yield point at low temperature (80°F). However, premature gelations of test results were phenomenal at 66°C (150°F) for the entire local cements. All tests were conducted according to API recommended practice 10B on both local and imported cements using oil well additives such accelerator, retarder, defoamer and fluid loss additive. The results of their test also indicated that local construction grades are compatible with all the oil well cement additives used at 80°F and 150°F.

Areas of Construction Grade Cement Application

The substitution of construction grade cements for oil well cement is becoming more common and widespread throughout the oilfield community. They are used to supplement the supply of oil well cement. In north western New Mexico, an oil company and a service company found that the use of Type III construction grade cement was even better alternative than API class B or class H cement for cementing wells in the San Juan basin of north western New Mexico [7]. Griffin [7] reported that 37 cement jobs had been done with the local cement as at 2005 at depths from 250 ft (76.2m) to 8,400 ft (2560.3 m) and at temperatures from 100°F (37.8°C) to 165°F (73.8°C).

In 1999, after eight months of planning and research, a local cement factory in Vietnam was selected to produce cement for use in the oil and gas industry due to lack of API producer of class G cement. The Institute of Building Materials and Petro Vietnam's DMC branch were engaged in the process of making local oilwell cement a reality.

The new local oilwell cement was first used for an onshore project in the Hanoi Basin in North Eastern Vietnam. The cement was to prevent annular gas flow and provide satisfactory isolation and strength for frac treatments. Several wells were cemented using the new cement and no problems were reported. Extensive laboratory tests prior to and during the project revealed that the local cement performance was nearly identical to that of the imported class G cement [6]. This shows that with stringent quality control during the manufacturing process of local cement, it could be used in oil well cementing operations. According to Hibbeler et al. [6], drilling on land in Vietnam is relatively expensive due to the remote nature of the work, thus operators put high premium on cost savings. The cost savings realised from the use of local cement was about 35% of cost as compared to imported class G. In addition, because the drilling locations were remote, local cement from a factory just three hours from the rig made planning and logistics much easier. This also saved time and costs by allowing for less investment in inventory.

Another application of local cements instead of imported class G cement done in Thailand [6]. A Non-API Monogrammed cement was manufactured and used on 4 wells to date with an even split between offshore and onshore wells. Both physical laboratory testing and chemical analysis indicated that the new local cement performed like API class G and meet the criteria set for this class. During the development phase of this cement, six different batches were made and tests performed to determine the physical performance and the chemical composition. The data was evaluated with the manufacturer and the process reviewed. A new batch was made and placed under evaluation in a laboratory environment. This cement passed all API criteria and was selected for use in the field. The Non-API Monogrammed Cement has been used on both exploration and production wells. The production wells were land oil producers and the exploration wells were offshore in the Gulf of Thailand. The offshore wells utilised the cement for surface casing strings and the plug and abandonment programme after formation evaluation was performed [6].

Conclusion

The experimental investigations on the physical properties of local cements have demonstrated significant potential in the possibility of using construction grade (local) cement for oil and gas cementing. In terms of thickening time, free fluid, fluid loss, compressive strength and rheological properties, local cements showed comparable results with imported cement samples. However, premature gelation's were paramount at temperatures greater or equal to a BHCT of 66°C (150°F) for cement slurries without gelation control additive. With the advent of Universal Cement System (UCS), the major challenges such as poor thickening time and premature gelation's with construction grade (local) cement at high temperatures have been overcome. Field applications of local cements in countries like Vietnam and Thailand further demonstrated the potential of local cement when compared to commercial oil well cement (class G cement). To use local cement require stringent quality control during the manufacturing process as was evident in the case of Vietnam.

References

1. Arina S, Irawan S (2003) Effects of Pressure and Temperature on Well Cement Degradation by Supercritical CO_2. International Journal of Engineering and Technology 10: 55-61.
2. Salam KK, Arinkoola AO, Ajagbe B, Sanni O (2013) Evaluation of Thickening Time of Oil Field Class G Cement Slurry at High Temperature and Pressure using Experimental Design. International Journal of Engineering Sciences 2: 361-367.
3. Heinold T, Dilenbeck, R, Rogers J (2002) The Effect of Key Cement Additives on the Mechanical Properties of Normal Density Oil and Gas Well Cement Systems. Society of Petroleum Engineers, pp: 1-12.
4. Sauki A, Irawan S (2010) Effects of Pressure and Temperature on Well Cement Degradation by Supercritical CO_2. International Journal of Engineering and Technology 10: 47-55.
5. Zhang J, Weissinger EA, Peethamparan S, Scherer GW (2010) Early Hydration and Setting of Oil Well Cement. Cement and Concrete Research 40: 1023-1033.
6. Hibbeler J, Rae P, Gilmore T, Weber L (2000) Using Alternative Sources of Oilwell Cement. International Association of Drilling Contractors/Society of Petroleum Engineers (IADC/SPE) Asia Pacific Drilling Technology Conference, pp: 1-10.
7. Griffin TJ (2005) US Market Responds to Oil Well Cement Shortages. Oil and Gas Journal 103: 62-68.
8. Broni-Bediako E (2015) Experimental Evaluation of Locally Manufactured Cement for Oil and Gas Well Cementing Operations in Ghana, PhD ThesisUniversity of Mines and Technology, Tarkwa Ghana, pp: 95-96.
9. Di Lullo GFA (1996) Method of Using Construction Grade Cement in Oil and Gas Wells. United State Patent 1-8.
10. Joel OF (2010) Design and Field Application of Drilling, Cementing and Stimulation Fluids, Amethyst and Colleague Publishers, pp: 188.
11. Broni-Bediako E, Joel OF, Ofori-Sarpong G (2015) Evaluation of the Performance of Local Cements with Imported Class 'G' Cement for Oil Well Cementing Operations in Ghana. Ghana Mining Journal 1: 78 -84.
12. Oriji AB, Appah D (2014) Analysis of Nigerian Local Cement for Slurry Design in Oil and Gas WellCementation. Academic Research International 4: 176-181.
13. Hunter B, Ampuero HW, Faul R, Caveny B, McLoone J (2002) Oil Well Cementing Offshore West Africa with Local Cement. Sixth Annual Offshore West Africa Conference Abuja, Nigeria 1-8.
14. Mfonnom GA, Puyete TY, Joel FO (2009) Utilization of Local Cement as an Alternative Source of Oil and Gas Well Cement - A Case Study on Dangote and Elephant Cements. Technical Papers of Offshore West Africa (OWA) Conference, Nigeria, pp: 1-22.
15. Anon (2014) Universal Cement Systems Additive.
16. Carole F (2000) Chemical Admixture for Sulphate Resistance of Hydrated Oil Well Cement. Paper Presented at the 22nd International Conference on Cement Microscopy Montreal Canada, pp: 1-8.
17. Shahrudin S, Samsuri A, Suhiami A, Nasir AS, Ahmad Z (1993) Possibility Studies of Using Local Cement in Oil and Gas Well Cementing Operations in Malaysia.
18. Samsuri A, Subbiah SK (1997) Improvement of Blended Cement Characteristics as Possible Alternative for Oil Well Cement. Malaysian Science and Technology Congress 97, pp: 1-10.
19. Joel OF (2009) Comparative Study of Local Cement with Imported Class "G" Cement for Cementing of Oil Well in Nigeria- A Case Study. International Journal of Engineering 3: 1-10.
20. Broni Bediako E, Joel OF, Ofori Sarpong G (2016) Comparative Study of Local Cements with Imported Class 'G' Cement at Different Temperatures for Oil Well Cementing Operations in Ghana. Journal of Petroleum and Environmental Biotechnology. pp: 1-7.