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## IMPROVED PALM OIL FLY ASH IS A BETTER OILWELL CEMENT ADDITIVE

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### ABSTRACT

#### Oil well cement, palm oil fly ash, additive, fluid loss, free water, compressive strength

Oil well cementing is the process of mixing and placing cement slurry in an annular space between a casing string and drilled hole. Today, oil wells cover a wide range of depth and temperature conditions than any time in history. Therefore, the cement slurry compositions should be designed to encounter pressure to more than 30,000 psi and temperature up to 700°F. It has been possible to accommodate such a wide range of conditions only through the applications of additives to modify the available oil well cement for the individual well requirements; i.e., allowing successful slurry placement, rapid compressive strength development, and adequate zonal isolation. All additives are imported and, quality and economic problems have been observed, therefore it is the best time to highlight the potential of local natural and waste material to be used as additives to the oil well cement.

This paper presents the results of burning conditions effect to palm oil fly ash (POFA) performance as a class G cement additive. Laboratory experiments had been carried out by using the class G cement slurry with various amount of palm oil fly ash that was produced at different burning temperature and time, and BJ-Blue was used for the comparison purpose. The AAS was used for the chemical analysis and API Specification 10 for cement slurry performance test. With increase burning temperature and time, and amount added, the results show less fluid loss and free water, better compressive strength and thickening time. From these results, it can be concluded that better POFA can be produced from higher burning temperature and longer burning time. The class G cement with improved POFA performed well than with standard BJ-Blue. The total cement material cost can be reduced since POFA is a local agricultural waste product.

### INTRODUCTION

Oil well cementing is the process of mixing and placing cement slurry in the annulus between the casing string and the formation exposed to the drilled hole. Oil well cement used in wells must have the required properties that apply for special field conditions. By selecting the right cement slurry formulation with additives, performance of the cement slurry can be adjusted for the individual oil well requirement. Today, oil wells in the field cover a wider range of depth and temperature than at any other time in history. Therefore, cement slurry compositions have to maintain pumpability and be able to retain their properties under severe conditions. The cement slurry compositions regularly have to be designed for temperature up to 700°F in deep oil wells, steam injection and geothermal wells. Pressure encountered ranging from atmospheric to 30,000 psi in extremely deep wells. It has been possible to accommodate such a wide range of conditions through the development of additives used to modify the available oil well cements for individual well requirements (Nelson, 1990). The additives that are added to the cement to change their thickening time, density, volume or slurry viscosity. They

can also reduce fluid loss, free water, and improved compressive strength and prolong their thickening time. In general, additives modify the behavior of the cement system, ideally allowing successful slurry placement in the annulus, rapid compressive strength development, and adequate zonal isolation during the lifetime of the oil well. Now more than 100 additives are used with various API class of cement to provide optimum slurry characteristics for all down hole conditions, many of which can be supplied in solid or liquid forms. The available additives had been categorized into eight which are generally recognized as accelerator, retarder, extender, weighting agent, dispersant, fluid loss control agent, lost circulation control agent and specialty additives (Nelson, 1990).

In the local oil industry, the class G cement is being used during the cementing operation and this cement is imported from other countries, such as Australia, Thailand, Indonesia and Singapore. In addition, all additives used with the G cement were also imported. And, quality and economic problems have been observed, therefore affords have been made to improved the potential of local natural and waste material to be used as additives to the oil well cement, such as POFA. Initial study had shown that the local POFA can be used as an additive with less free water, less fluid loss, better compressive strength development but shorter thickening time than the Halad 322s, even though still within the API specification (Ariffin, 1997). In order to meet the individual oil well requirement, the additives must be used to control major cement slurry characteristics, such as fluid loss, free water, compressive strength and thickening time. Fluid loss is a loss of the aqueous phase of a cement slurry system to the formation, which may lead to cementing job failure. For most oil well primary cementing job, an API fluid loss rate between 50 to 100 ml/30 minutes is generally considered to be adequate (API, 1991). Free water is the amount of water that may be separated from the cement slurry when the slurry is allowed to stand for a period of time prior to the set. The API specification for free water content is not exceeding 3.5 ml or 1.4 % of column height (API, 1991).

Compressive strength is the strength indication of the ability of set cement to provide zonal isolation, and to protect and support the casing string. The most widely used minimum strength required for any well bore operation is 500 psi in 24 hours at down-hole static temperature. API specification requirement is a minimum of 500 psi for 8 hours curing and 1000 psi for 24 hours curing period. In addition, thickening time is a length of time which a cement slurry remains in a pumpable fluid state under simulated well bore conditions of temperature and pressure or the elapsed time from initial mixing of the cement with water to achievement of a final consistency of 100 Bc. The API Spec 10 requirement is in the range of 90 to 176 minutes (API, 1991).

## **LABORATORY WORK**

### **Palm Oil Fly Ash Preparation**

After palm oil fibre had been dried and cleaned from impurities, they were burn in a furnace under control burning time ranging from 1 to 5 hours and temperature of 300 to 800 °C. After cooling, the collected ash undergo the sieving process by using sieves in order to get the size of 150 micron meter before added to the cement slurry. The POFA' also undergo the chemical analysis through the wet test method, as described in ASTM C-114.

### **Cement Slurry Preparation**

While the G-cement, POFA or BJ-Blue and water are added into the mixer, the mixer is operated at 4,000 RPM for 15 seconds, followed by 35 seconds at 12,000 RPM. Details equipment specification and operational procedures for the slurry preparation are contained in Section 5 and Appendix A of API Spec.10 (API, 1991).

### **Fluid Loss Test**

After being subjected to the simulated wellbore conditions in a consistometer, the prepared cement slurry is placed in a heated filter press cell and the filtrate loss at 100 psi differential pressure is measured across a standard filtration medium (325 mesh screen supported on a 60 mesh screen). The duration of the test is 30 minutes, and the filtrate volume is noted. Details operational test procedure for the fluid loss determination can be referred from Appendix F of API Spec. 10 (API, 1991).

### **Free Water Test**

After two hours of prepared cement slurry had been in the 250 ml graduated cylinder at ambient and reservoir simulated conditions, the separated volume of water is measured. The detail specification and operational test procedures are contained in the API Spec. 10, Section 6, and Appendix M (API, 1991).

### **Compressive Strength Test**

The prepared cement slurry is poured into two-inch cube molds, and cured for 8 and 24 hours at ambient and simulated reservoir conditions. The set cement cube is removed from the mold, and placed in a Compression Strength Tester where increasing uniaxial pressure is exerted on the cube until failure. The compressive strength is then calculated by dividing the pressure at failure by the cross-sectional area of the specimen. Details API specifications and procedures for the determination of compressive strength are described in Section 7 and Appendix D of API Spec. 10 (API, 1991).

### **Thickening Time Test**

The prepared cement slurry is tested in a high temperature and pressurized consistometer. The time required for the slurry to reach a consistency of 100 Bc is noted. The detail specification and operational procedures for determining slurry-thickening time are contained in Section 8 and Appendix E of API Spec. 10 (API, 1991).

## **RESULTS AND DISCUSSION**

### **Chemical Analysis**

From Table 1, it can be seen that the silica oxide, aluminium oxide, potassium oxide and magnesium oxide increase as the burning temperature increases with the dominant oxide being the silica oxide. In contrast the oxide of ferrous and calcium is decreasing as the burning temperature increasing. The same phenomenon occurred when the burning time is increasing, as shown in Table 1. In general, the higher the burning temperature and time, the more oxide of silica, aluminium, potassium and magnesium, and lesser oxide of ferrous and calcium, due to complete burning of palm oil fly ash.

### **Fluid Loss Characteristic**

Table 2 shows that lesser fluid loss volume produced from slurry with more POFA, which had been produced at higher burning temperature and longer burning time. This is due to better quality of POFA had been produced with more silica oxide content, as previously discussed. Table 2 also shows that fluid loss decreases as more BJ Blue was added to the cement slurry. At room temperature, BJ Blue performed better than POFA if less than 1.5 % of volume had been added, but if volume added is more than 2 %, POFA produced less fluid loss than BJ Blue. At reservoir temperature, POFA generally performed better than BJ Blue.

Silica compound in POFA will occupied the pore space between cement particles and hold water, which in turn will reduce the fluid loss volume. In addition, the amorphous of POFA with higher silica content will also reduced permeability of a filter cake which will reduced the fluid loss. Generally, with more POFA added to the cement slurry, then more water particle will be hold and more specific area of impermeable filter cake. As a

result, less fluid loss with more POFA added. POFA produced from high burning temperature and longer burning time will have more silica content which in return more amorphous. Therefore, when added to the cement slurry, less fluid loss volume will be produced.

### **Free Water Characteristic**

From Table 3, it is clearly shows that POFA which was produced from higher temperature and longer burning time, when added to the cement slurry will produced less free water content. The effect become more significant if the POFA added is more than 0.5 % BWOC. With more POFA added, less free water content will be produced. Table 3 also shows that less free water content from slurry with POFA than with BJ-Blue. As previously mentioned, more silica content in POFA, which had been produced from higher burning temperature and longer burning time. POFA performed better as an additive for free water control in higher reservoir temperature. More SiO in the slurry will improve reaction with calcium hydroxide, which will produce more C-S-H gel. In turn, more C-S-H gel formation in the slurry will reduce the amount of free water. In general, free water content in the cement slurry with POFA, as an additive is less then the API minimum requirement, i.e. 3.50 ml.

### **Compressive Strength Development**

Table 4 shows that POFA which was produced from higher burning temperature and longer burning time, when added into the cement slurry will produced higher compressive strength of the set cement which also higher than when BJ-Blue was used. When more POFA was added to the cement slurry, the compressive strength of the set cement will increase. In contrast, the compressive strength of set cement will decreased when more BJ-Blue was added to the slurry. In general, the compressive strength is higher when tested at the higher reservoir temperature. It is understandable that POFA, which was produced at higher burning temperature and longer burning time, content more SiO. When added into the slurry, more pozzolanic reaction will occurred and more C-S-H gel will be produced. More C-S-H gel will increased the compressive strength of the set cement. In general, the compressive strength of the set cement with POFA as an additive is higher and more than the API minimum requirement, i.e. 500 psi.

### **Thickening Time Characteristic**

As shown in Table 5, the thickening time of cement slurry increases when POFA, which was produced at higher burning temperature and longer burning time, was added. The thickening time also increased as more POFA was added into the cement slurry. As previously mentioned, higher SiO content in the POFA will able to hold water molecule from cement particles in the pre-hydration phase. Therefore, the reaction between SiO and  $\text{Ca}(\text{OH})_2$  in the pre-hydration phase will be reduced which in turn will prolong the thickening time of the slurry. But, in general, the thickening time of cement slurry with POFA as an additive still shorter than with BJ-Blue, even though it improved with POFA produced from higher burning temperature and longer burning time.

## **CONCLUSION**

From the study, it can be concluded that :

1. POFA produced at higher burning temperature and longer burning time performed better as an additive of an oilwell cement.
2. POFA performed better than BJ-Blue in fluid loss control, free water content and compressive strength but still shorter in thickening time.

3. Shorter thickening time of POFA can be improved by producing POFA at higher burning temperature and longer burning time.

### REFERENCES

API Specification 10, "Specification for Materials and Testing for Well Cements," American Petroleum Institute, USA, July 1, 1991.

Ariffin Samsuri: "The Application of Palm Oil Fly Ash in Improving a Petroleum Well Cement Characteristics", paper presented at the Regional Symposium on Chemical Engineering 1997, Johor Bahru, Malaysia, 1997.

Nelson, E. B.: "Well Cementing," 2<sup>nd</sup> edition, Schlumberger Educational Services, Houston, Texas, 1990.

**TABLE I. Effects of Burning Temperature and Time to a Chemical Composition.**

Compound	Composition @ t=3 hrs (%)					Composition @ T=800°C (%)		BJ-Blue (%)
	400°C	500°C	600°C	700°C	800°C	3 hrs	5 hrs	
SiO	55.90	56.84	56.94	57.75	61.31	61.31	62.73	0.10
Al <sub>2</sub> O <sub>3</sub>	9.09	12.58	12.83	12.86	13.05	13.05	13.76	0.11
K <sub>2</sub> O	5.79	10.42	10.55	10.83	11.47	11.47	11.72	0.08
MgO	5.53	6.25	7.25	7.69	7.93	7.93	8.05	0.00
Fe <sub>2</sub> O <sub>3</sub>	3.50	2.71	2.32	2.20	1.82	1.82	1.61	0.01
CaO	1.86	1.68	1.66	1.49	1.32	1.32	1.23	0.00
Lain-lain	18.33	9.53	8.45	7.19	3.10	3.10	0.91	99.69

**TABLE II. Effect of Burning Temperature and Time to a Fluid Loss Characteristic.**

Additives (%)	Fluid Loss @ t=3 hrs (ml)										Fluid Loss @ T=800°C (ml)				BJ-Blue	
	Room T=27°C					Simulated T=52°C					27°C		52°C		Fluid Loss (ml)	
	400°C	500°C	600°C	700°C	800°C	400°C	500°C	600°C	700°C	800°C	3 hrs	5 hrs	3 hrs	5 hrs	27°C	52°C
0.0	230.0	230.0	230.0	230.0	230.0	270.2	270.2	270.2	270.2	270.2	230.0	230.0	270.2	270.2	230.0	270.2
0.5	199.0	180.0	160.0	137.0	121.0	256.0	213.0	173.0	136.0	117.6	121.0	118.0	117.6	110.0	95.0	15.0
1.0	183.0	150.0	120.0	101.0	99.0	237.0	188.0	144.0	111.0	106.0	99.0	84.2	106.0	89.0	66.0	96.0
1.5	173.0	134.0	104.0	87.0	82.0	206.8	163.0	127.0	93.0	87.0	82.0	65.0	87.0	77.8	58.0	86.0
2.0	145.0	108.0	81.0	62.0	57.0	170.0	142.0	109.0	76.0	64.0	57.0	44.6	64.0	56.0	47.0	80.0

**TABLE III. Effect of Burning Temperature and Time to a Free Water Characteristic.**

Additives (%)	Free Water @ t=3 hrs (ml)										Free Water @ T=800°C (ml)				BJ-Blue	
	Room T=27°C					Simulated T=52°C					27°C		52°C		Free Water (ml)	
	400°C	500°C	600°C	700°C	800°C	400°C	500°C	600°C	700°C	800°C	3 hrs	5 hrs	3 hrs	5 hrs	27°C	52°C
0.0	2.90	2.90	2.90	2.90	2.90	2.60	2.60	2.60	2.60	2.60	2.90	2.90	2.60	2.60	2.90	2.60
0.5	2.80	2.50	2.40	2.20	2.00	2.50	2.40	2.20	1.90	1.65	2.00	1.80	1.65	1.40	2.00	2.10
1.0	2.65	2.30	2.15	2.00	1.85	2.20	2.20	1.90	1.60	1.30	1.85	1.60	1.30	1.00	1.80	1.60
1.5	2.35	2.15	1.80	1.70	1.60	2.05	2.00	1.65	1.25	1.00	1.60	1.45	1.00	0.80	1.55	1.25
2.0	2.10	1.85	1.65	1.50	1.40	1.85	1.80	1.40	1.00	0.80	1.40	1.25	0.80	0.50	1.30	1.00

**TABLE IV. Effect of Burning Temperature and Time to a Compressive Strength.**

Additives (%)	Compressive Strength @ t=3 hrs (psi)										Compressive Strength @ T=800°C (psi)				BJ-Blue	
	Room T=27°C					Simulated T=52°C					27°C		52°C		Compressive Strength (psi)	
	400°C	500°C	600°C	700°C	800°C	400°C	500°C	600°C	700°C	800°C	3 hrs	5 hrs	3 hrs	5 hrs	27°C	52°C
0.0	1000	1000	1000	1000	1000	1950	1950	1950	1950	1950	1000	1950	1000	1950	1000	1950
0.5	1050	1100	1100	1175	1375	2100	2175	2250	2275	2400	1375	2400	1400	2450	1000	1950
1.0	1125	1150	1200	1275	1425	2250	2350	2475	2525	2650	1425	2650	1550	2700	975	1900
1.5	1250	1375	1450	1500	1650	2450	2500	2625	2750	2925	1650	2925	1700	3000	950	1850
2.0	1375	1475	1625	1750	1825	2475	2650	2800	2925	3125	1825	3125	1900	3200	900	1825

**TABLE V. Effect of Burning Temperature and Time to a Thickening Time.**

Additives (%)	Thickening Time @ t=3 hrs					Thickening Time @ T=800°C		BJ-Blue Thickening Time (min)
	Simulated T=52°C					52°C		
	400°C	500°C	600°C	700°C	800°C	3 hrs	5 hrs	52°C
0.0	117	117	117	117	117	117	117	117.0
0.5	130	133	140	149	151	151	152	146.0
1.0	133	140	149	154	155	155	157	162.0
1.5	136	143	153	157	160	160	162	187.0
2.0	141	150	156	160	163	163	166	203.0