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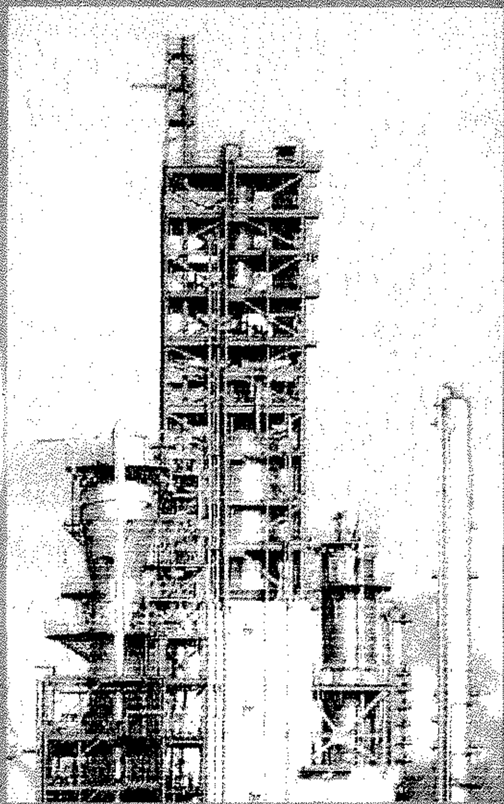

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THE APPLICATION OF PALM OIL FLY ASH IN IMPROVING A PETROLEUM WELL CEMENT CHARACTERISTICS

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ABSTRACT

The paper presents the results of the laboratory studies on G cement characteristics with respect to the free water, fluid loss, strength development and thickening time when palm oil fly ash (POFA) is added to the cement slurry. Laboratory experiments had been carried out by using G-cement slurry with various amount and types of standard petroleum well cement additives, and various amount of palm oil fly ash. The ASTM-C 114 procedures was used for the chemical analysis and API Spec. 10 procedures under atmospheric and reservoir conditions for the cement characteristics. The results show that less free water and fluid loss, and better strength development and thickening time when palm oil fly ash is added to the cement slurry. From these results, it can be concluded that palm oil fly ash can be used as an additive for petroleum well cement and G-cement characteristics can be improved when palm oil fly ash was added to the cement slurry. Palm oil fly ash is compatible to be used with others standard petroleum well cement additives. Therefore, the total cement material cost can be reduced since palm oil fly ash is a local product. In addition, the petroleum well cement formulation can be improved for better strength, fluid loss and free water content.

BACKGROUND

Cementing is the process of placing cement in the annulus between the casing and the formation exposed to the borehole. Since its inception in 1903, the major objectives of cementing has always been to provide zonal isolation in the petroleum wellbore, e.g., to exclude fluids such as water or gas in one zone from oil in another zone, to protect casing against aggressive wellbore fluids, and against collapse by rock creeping in on the wellbore. To achieve this objective, a hydraulic seal must be obtained between the casing and the cement, and between the cement and the formations, while at the same time preventing fluid channels in the cement sheath. This requirement makes cementing the most important operation performed on a petroleum well. Without complete zonal isolation in the wellbore, the well may never reach its full producing potential. Remedial work required to repair faulty cementing job may do irreparable harm to the

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producing formation. In addition to the possibility of lost reserves and lower producing rates, start-up of production is delayed. Other problems may arise, such as not being able to confine stimulation treatments to the producing zone, or confining secondary and tertiary fields to the pay zone.

The physical and chemical properties, and the performance of the cement slurry (cement plus water and additives) are crucial to every facet of well cementing operation. Cement systems must be designed to be pumped under downhole conditions. After placement, the cement systems must preserve their integrity and provide zonal isolation during the life of the well. It has only possible to accommodate such a wide range of conditions through the development and usage of additives which modify the available petroleum well cements for individual well requirements. Additives modify of the cement system, ideally allowing successful slurry placement between the casing and the formation, rapid compressive strength development, and adequate zonal isolation during the lifetime of the well. To properly use the available cements, additives were developed to control the major cement properties, i.e., thickening time, consistency, fluid-loss rate, free water, setting or thickening time, compressive strength, etc. Consequently, a wide variety of cement additives is now available to alter cement properties to meet most well conditions.

Today, over 100 additives for petroleum well cements are available, many of which can be supplied in solid or liquid forms. Eight categories of additives are generally recognised, i.e., accelators, retarder, extenders, weighting agents, dispersants, fluid-loss control agents, lost circulation control agents and speciality additives, such as antifoam agents, fibers, etc. Most additives are strongly influenced by the chemical and physical properties of the cement, which are highly variable. Consequently, a wide spectrum of results can be obtained with the same slurry design. The important cement parameters including; particle size distribution, distribution of silicate and aluminate phases, reactivity of hydrating phases, gypsum/hemihydrate ratio, and total sulfate content, free alkali content, and chemical nature, quantity, and specific surface area of initial hydration products. Other important parameters include temperature, pressure, additive concentration, mixing energy and order, and water-to-cement ratio. One of the routine additive used in the industry is a pozzolans. Pozzolans are the most important group of extenders and are defined as a silicous or siliceous and aluminous material, which in itself posses little or no cementitious value, but will, in finely divided form and in the presence of moisture, chemically react with calcium hydroxide at ordinary temperature to form compounds possesing cementitious properties.[1] Thus, pozollans not only act as extender, but also react and contribute to the compressive strength of the set cement product. There are two types of pozzolans: (1) natural pozzolans which include volcanic ashes and diatomaceous earth, and (2) artificial pozzolans such as certain fly ashes. According to ASTM specifications, three types of fly ash are recognized: Types N, F and C, the distinction is made on chemical grounds. Type F fly ashes are most frequently used in well cementing. They are normally produced from burning anthractite or bituminous coals. Type C fly ashes, made from lignite or subbituminous colas, are less siliceous, and some contain more than 10% lime, as a result, many of them are themselves cementitious therefore are sufficiently cementitious to be used as the principal component of a well cement. Compressive strength development is often more rapid than observed with conventional Portland cement systems.[2]

Fly ashes are heterogenous fine powder consisting mostly of rounded or spherical particles of variable silica (SiO_2), alumina (Al_2O_3) and iron (Fe_2O_3) content. The structures, composition and properties of the particles depend on the raw material and the combustion processes by which they are formed.[3] As mentioned before, only coal fly ash has been used as a pozzolanic material that is added to the blended cement. With the same charateristics and chemical composition, palm oil fly ash has been chosen to be studied as an additive to the class G cement for its suitability as a pozzolanic material.

EXPERIMENTAL WORK

Local palm oil fly ash and imported class G cement were studied. Laboratory experiments were carried out on dry palm oil fly ash, dry cement powders, cement slurry and hard set cement. The chemical analysis was done by wet test method, as described by the ASTM C-114. The cement slurry and specimen preparation, and the physical properties were conducted by closely followed the API Specification 10.[4] The physical properties test include the compressive strength, fluid loss, thickening time and free water.

RESULTS AND DISCUSSION

CHEMICAL ANALYSIS

Table 1 shows the percentages of the oxides minerals and other chemical compounds for ASTM fly ashes and palm oil fly ash. It can be seen that local palm oil fly ash fit into the ASTM category. Based on the content of silicon dioxide, aluminum oxide and iron oxide, the local palm oil fly ash is between Type F and C. In general, local palm oil fly ash fulfilled the ASTM mineral admixture content for the fly ash used as an additive in petroleum well cementing, even though there are slight different in the percentages of the mineral content. The differences involved between them were due to the composition and percentage of raw materials used, and combustion process during the manufacturing. These differences will have an effect to the performance of the cement.

COMPRESSIVE STRENGTH

Table 2 shows the results of class G and blended cements compressive strength when the palm oil fly ash was added to the neat cement. As shown in Figure 1, the cement compressive strength increases as the amount of palm oil fly ash added to the cement increases up to 15 %. The pozzolanic reactivity provided by the ash has helped in developing the extra gel of tricalcium hydrate which contribute to the strength development. A reduction in cement strength can be noticed when 20 % or more of the palm oil fly ash is added but the strength is still higher then the neat cement strength. Further increase in the amount of fly ash content to 25 % will results in a further reduction of the cement strength, i.e. below the strength of the neat cement. This is due to the fact that too much pozzolanic activities which does not contribute further to enhance the cement strength but to reduce the strength.

As shown in Table 3 and Fig. 2, the compressive strength of class G cement cured at 8 hours increases as the amount of the palm oil fly ash added to the slurry increases, but the strength decreases as the amount of retarder and fluid loss agent increase in the cement slurry. Besides the delaying effect of cement to set cause by an additive, the slow pozzolanic activities which took place between the calcium hydroxide that is the product of cement hydration process has helped in developing the extra gel of tricalcium silicate hydrate which occupied the pores and contribute to the strength development of the cement.

FLUID LOSS

Results of fluid loss tested at 52 °C circulating temperature and 1000 psi differential pressure with different percentage of the additives are shown in Table 4. From the table, it can be seen that when the amount of additive added to the cement slurry increases, the slurry released less fluid loss, depending on the additive used. As clearly seen in Fig. 3, type C fly ash produced less fluid loss than palm oil fly ash and Halad 322s. In other words, palm oil fly ash performed better in term of fluid loss control than the Halad 322s, but still below the performance of the type C fly ash, since it content more silicon, aluminum and iron oxides than type C, but less than the content in the Halad 322s. This is due to the additive presents in the cement slurry and also due to the part played by the fine fly ash in occupying the micro pores and it's pozzolanic reactivity in reducing the permeability of the cement, therefore reduced the amount of fluid loss.[3,5]

Table 5 shows the effect of POFA particle size to the fluid loss performance. It can be seen that fluid loss decreases as the POFA particle size decreases. For example, for 1 % BWOC of POFA with 38 micron particle size produced 255 ml fluid loss, which is less than the fluid loss produced by particle size of 75 and 106 micron, which are 306 ml and 333 ml, respectively. The same phenomenon occurred when the POFA concentration increases to 3 and 5 % BWOC. This is due to the surface area - volume ratio for the smaller particle size is higher than the bigger particle, therefore the faster chemical reaction rate. When the smaller POFA is added to the cement slurry, the formation of calcium silicate hydrate gel is faster, therefore faster permeability reduction and less fluid loss is produced. In addition, smaller particles had the better sorting, therefore bigger surface area for the chemical reaction to take place, which resulting in higher chemical reaction rate. Fig. 4 shows the relationship between the POFA particle size and fluid loss for various concentration.

THICKENING TIME

Table 6 shows the results of the thickening time of the cement slurry with various concentration of POFA and Halad 322s. It was found that the cement slurry with POFA will set at a shorter time then the cement with Halad 322s. Fig. 5 shows that the thickening time of the cement slurry increases as the amount of POFA increases since the pozzolanic reaction between the POFA and cement decreases as the amount of POFA increases, therefore the formation of calcium silicate hydrate gel a bit slower. The thickening time produced by the POFA is lower than produced by the cement with Halad 322s. This is due to the Halad 322s is a synthetic polymer which can hold the cement particles and preventing them from react with water, therefore more time is needed by the water to break the polymer bonding and react with the cement particle.

FREE WATER CONTENT

The results of free water test is shown in Table 7. From the table, it is clear that the cement slurry with POFA gives less free water then the cement with Halad 322s, both below API Standard for free water content of 3.50 ml maximum. The different in tricalcium aluminate content in each cement will result in different rate of reaction and consumption of water, and will effect the amount of free water produced by the cement, respectively.

Table 7 and Figure 6 also show that the amount of free water produced by both cements decreases as the amount of additives increases, but the cement slurry with POFA still produced less free water as compared to the cement with Halad 322s. The fly ash content in the first delayed the reaction of cement with water by filling the pores between the cement grains and calcium silicate hydrate, and thus traps some of the water. In addition, some of the water is consumed by the fly ash to disintergrade and react with the calcium hydroxide to produced cementitious material, therefore the cement set with less free water.

CONCLUSION

The results of the study had shown that the local palm oil fly ash 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. The thickening time for the cement with palm oil fly ash is still within the API specification. The results also proved that the palm oil fly ash performance as an additive depend on the particle size and amount used. The palm oil fly ash can be used to improve the cement compressive strength, with the highest strength can be achieved when 15 % of the ash is added to the neat cement. The strength will be decreased if 20 % or more fly ash was added to the cement. In addition, palm oil fly ash also can be used to improved the cement fluid loss and free water content. In general, the local palm oil fly ash has the properties which are within the range of API Specification and therefore is suitable for the application as an additive in the petroleum well cementing operations, particularly for the five hours or less cementing operation.

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4. API Specification 10, *Specification For Materials and Testing For Well Cements,* American Petroleum Institute, USA, July 1, 1991.

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Table 1. Chemical Composition of Several Additives

Mineral Admixture	Type N (%)	Type F (%)	Type C (%)	POFA (%)	Halad (%)
Silicon dioxide, aluminum oxide & iron oxide (max.)	70	70	50	62	93
Sulfur trioxide (max.)	4	5	5	2.4	0.14
Moisture content (max.)	3	3	3	1.5	0.02
Loss on ignition (max.)	10	12	6	4.3	3.77
Others	13	10	36	29.8	3.07

Table 2. Compressive Strength with various Palm Oil Fly Ash Amount

POFA	Compressive Strength (psi)							
(%)	8 hours		1 day		3 days		7 days	
	Class G Cement	Blended Cement	Class G Cement	Blended Cement	Class G Cement	Blended Cement	Class G Cement	Blended Cement
0	1700	1850	2900	2980	3200	3930	3250	4700
5	1750	1910	3100	3190	3300	4060	3350	4910
10	1900	2070	3300	3460	3600	4440	3650	5350
15	2100	2240	3600	3730	3900	4820	3950	5800
20	2000	2130	2800	2870	3600	4440	3400	4970
25	1600	1680	2700	2820	3100	3800	3050	4440

Table 3. Compressive Strength of Class G Cement with Various Additives

Additives (%)	Compressive Strength at 8 hours curing time (psi)		
	Retarder	Fluid Loss	Palm Oil Fly Ash
0.00	1700	1700	1700
0.50	1550	1650	1704
1.00	900	1540	1706
1.50	500	1420	1710
2.00	300	1310	1715

Table 4. Fluid Loss Tested for Various Additives

Additive (% BWOC)	Fluid Loss Volume (ml)		
	Type C	Palm Oil Fly Ash	Halad 322s
1.00	125	220	260
1.50	60	205	255
2.00	45	190	250
2.50	40	170	195
3.00	35	150	140

Table 5. The Effect of POFA Particle Size to the Fluid Loss

Additive (% BWOC)	Fluid Loss (ml)		
	38 u - POFA	75 u - POFA	106 u - POFA
0.00	438	438	438
1.00	255	306	333
3.00	233	277	311
5.00	194	228	262

Table 6. Effect of the Palm Oil Fly Ash to the Thickening Time

Additive (% BWOC)	Thickening Time (minutes)	
	Palm Oil Fly Ash	Halad 322s
0.00	126	126
0.50	133	207
1.00	148	251
1.50	155	276
2.00	169	297

Table 7. Effect of the Palm Oil Fly Ash to the Free Water Content

Additive (% BWOC)	Free Water Content (ml)	
	Palm Oil Fly Ash	Halad 322s
0.00	1.95	1.95
0.25	1.34	1.45
0.50	1.11	1.22
1.00	0.75	0.86
1.50	0.60	0.65

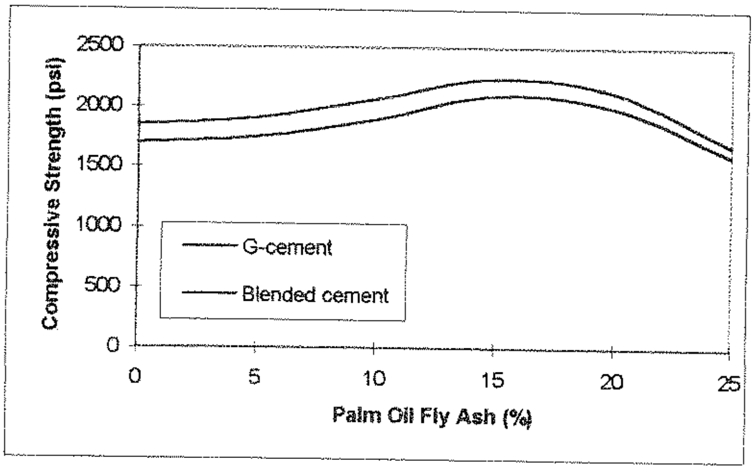

Fig. 1. Effect of Palm Oil Fly Ash to the Cement Compressive Strength

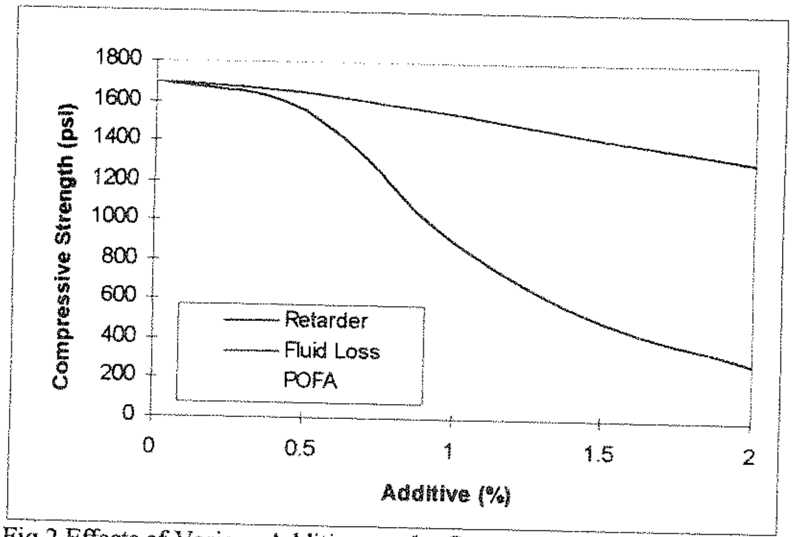

Fig.2 Effects of Various Additives to the Compressive Strength (8 hour)

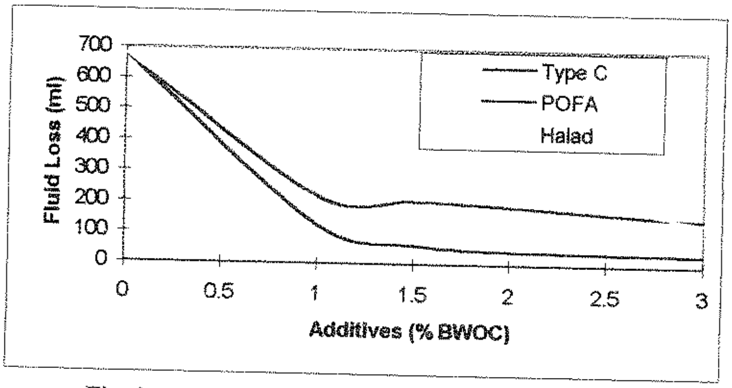

Fig. 3. Effect of Various Additives to the Fluid Loss

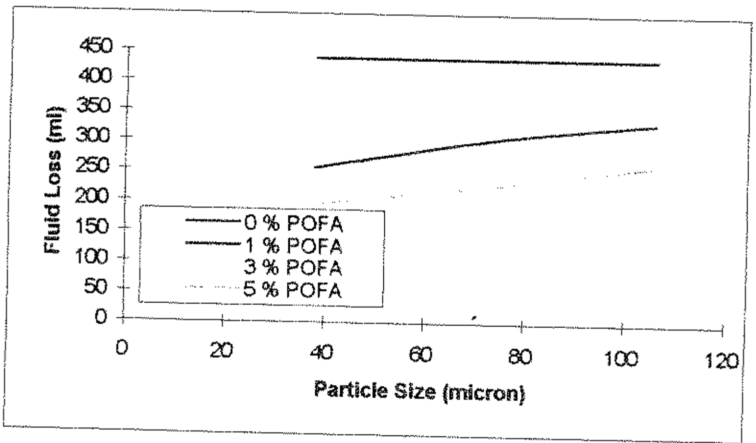

Fig. 4. Effect of POFA Particle Size to the Fluid Loss Volume

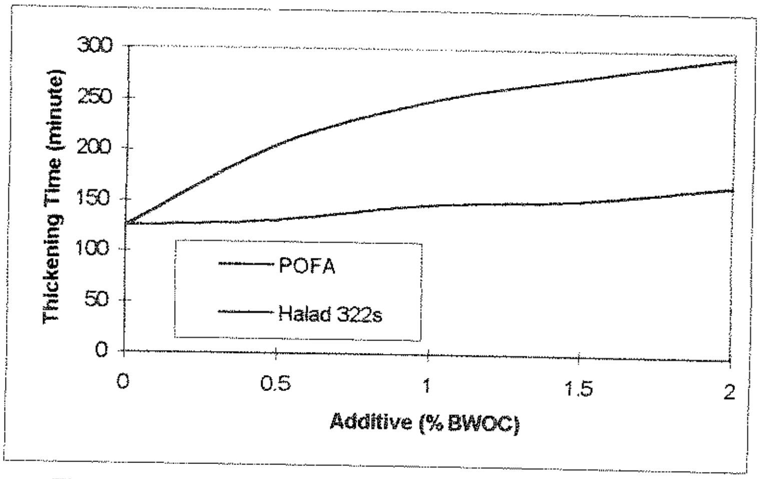

Fig. 5 Effect of Additives to the Thickening Time

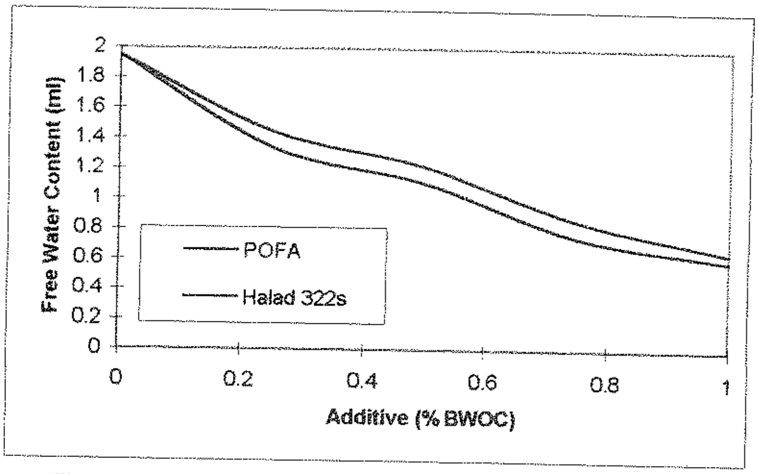

Fig. 6. Effect of Additives to the Free Water Content