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Alternative Utilization of Sawdust for Oilfield Chemical Additive (Cement Retarder) Production: A Case Study of Local Cement

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Abstract-Sawdust is one of the major wastes and poses environmental challenges in this country. In order to address this environmental menace this study was carried out to source for an alternative use of sawdust in the oil and gas industry. The sawdust was hydrolyzed using sulphuric acid and the product was sulphonated by sodium bisulphite in a chemical reaction. Product formed was used to retard cement slurry at different concentrations. Results show that there was over 50% retardation of the cement slurry from 4hrs 31 minutes to 7hrs 25minutes at 2ml and to 8hrs 35 minutes at 3ml by volume of the sample produced.

Keywords- *Sawdust, Oilfield Chemical, Cement Retarder, Local Cement, Setting Time*

I. Introduction

Sawdust is one of the major wastes resulting from wood exploitation and processing, which if its storage is not in controlled conditions may be an important factor for environmental pollution. But at the same time, it is one of the main sources of biomass for the production of solid fuels for generating heat in centralized system, co-generation installations decentralized system for residential use, and classic boilers for thermal energy generation. The environmental challenges posed by sawdust waste have made our environment untidy and the lands where they are dumped are unfit for certain economic activities, those dumpsites have also become a breeding place for some disease causing agents and in a bid to reduce its effect. The common practice in Nigeria is to burn this sawdust and other agricultural waste or leave them to decompose (Olorunnisola 1998, Jekayinfa and Omisakin 1995). Some people have suggested that sawdust be burnt to generate energy for in-house use by the wood industry (Peter, etal 1988). This has been one of the methods of reducing the sawdust waste but these methods pose another environmental problem due to the poisonous gases being released to the environment such as: CO_2, SO_2, NOx. These gases that are released to the environment cause greenhouse effects that lead to global warming. Other viable and promising technologies by which sawdust can be converted to biomass energy is through the process of briquetting (Wilaipon, 2008). Briquetting is a process of producing a biofuel from agro waste for easy handling such as sawdust, groundnut shell, and paper, etc by binding the waste with a combustible binder to generate heat for home and industrial use. Though briquetting has some challenges in the process of its production and usage.

Converting biomass in general to biofuel for heat generation has beneficial effects on the environment. However, as with other sources of energy such as crude oil their use often pose an environmental challenges due to the emission of pollutants as the bye-products into the environment with negative impact on the environment and on the biological systems. Pollutants from sawdust briquettes conversion into heat energy are ash and air pollutants that results from the combustion gases such as carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NOx), sulfur oxides (SOx) and particulate emissions (PE). According to Annamalai k.and Puri, IK, 2006, NOx and SOx are dominant components in the emissions process. NOx has the most adverse impact on human health because it damages the human respiratory system. De Sjaak etal, 2012., and Grübler, 2004 show that NO> 3ppm leads to quantifiable measures of damage to the lungs, while a value of 0.1ppm can cause lung irritation and decrease in pulmonary operation causing the development of asthma. NO_2 high concentrations affect the production of hemoglobin, reducing the oxygen in human tissues. On the other hand, NOx emissions have negative impacts also on the ozone layer: such as creation produces ground-level ozone (photochemical smog) and destruction of naturally occurring ozone high in the atmosphere (Annamalai k.and Puri, IK, 2006, and Grübler,2004). The SOx emissions, by reacting with atmospheric oxygen, lead to the formation of acid rains and snowfalls. Due to the lower amount of sulfur in the chemical composition of solid biomass, it produces a small amount of sulfur oxide emissions (SOx) from the conversion into thermal energy. The CO_2 produced in the process of wood burning is considered part of the carbon cycle in nature, not being regarded as air pollutant. More than 80% of the particulate matter are in the form of ash driven by the combustion gases (fly ash) of which 40% have a diameter <10ppm. Of these, 20% lies on the ground and the rest is released into the atmosphere where it poses health problems. (De Sjaak et al., 2012). Hence, in this study locally sourced sawdust materials was used to formulate oilfield cement retarder with application on locally manufactured cement.

A. Cement Additives

The kinetics of the hydration that results immediately water and cement is in contact can be changed by applying chemical additives. The chemical additives which help to slow the reaction rate of the slurry are known as retarders. While the chemical additives which help to speed up the hydration rate of cement are known as accelerators. In using retarders precautionary measures must be taken as they may have an influence on the building of strength of the hardened cement. Cellulose, lignosulphonates, and sugar extracts, are predominantly used additives as cement retarder in the oil industries. These chemical additives slow down the speed of the reaction by undergoing chemical reactions that involve phases of cement that is not hydrated or by building a film layer on the cement that are not hydrated thereby hindering the cement coming into play with water (Joel, 2009). There are over one hundred (100) additives some come in solids or liquid form, the additive are in eight categories, the eight categories are given below.

1) Accelerator

In shallow, low temperature wells, accelerators speed up the first period of hydration and cut the cements setting time. Accelerators also aid to obliterate the effect of delay in setting of the slurry because of other additives such as fluid loss agents and dispersant. The most abundantly used accelerator is Calcium Chloride ($CaCl_2$), why it accelerates reactions such as hydration is completely not understood, but evidence suggests that Calcium Chloride could cause an increase in the permeability of the C-S-H gel forming around each silicate particles and therefore, gives water ready access to the grains anhydrous surface. This would shorten the induction period. Calcium Chloride is normally added between 2% to 4% by weight of cement (BWOC). (Nelson et al., 1990)

2) Retarders

These are oil well cement additives applied to decrease the rate of cement hydration. Retarders prevent cement hydration and delay hardening process for the cement slurry for a given period of time, giving enough time for slurry placement in a high pressure and high temperature zone in an oil well (Michaux, et al, 1990). In actual sense, it increases the setting time for the cementing operation (Nguyen, 1996; Huwel et al, 2014). Retarders do not decrease the ultimate compressive strength of cement but do slow the rate of strength development (Joel, 2009; Bett, 2010). The most common retarders are natural lignosulfonates and sugars derivatives. Ligno sulphonates and hydroxyl carboxylic acids are retarders that are believed to perform well for oil well cements with low C3A contents. The newest retarders are made from various synthetic compounds such as: Maleic anhydride, 2-Acrylamido-2-methylpropanesulfonic acid (AMPS) copolymers and inorganic compound like borax. Michaux et al, 1990; Anon, 2014; Bentz et al, 1994 reported on the use of carbohydrates such as sucrose as a retarder. According to Bentz et al. (1994), the addition of carbohydrates such as sucrose can significantly extend thickening time or even prevent setting completely. However, they are not commonly used in oil and gas well cementing because of the sensitivity of the degree of retardation to small variations in concentration (Nelson et al., 1990; Bermudez, 2007). As a result of processing, three grades of lignosulphonate are available for the retardation of cement slurries. Each grade is available as calcium/sodium or sodium salts. According to Joel (2009), the three grades can be described as filtered, purified, and modified. Also, Adams et al, (1985) stated that the most common retarder among the three types may be calcium lignosulphonate.

Retarders do not promote hydration but prolong setting of cement slurry, providing enough time for cementing operation in both deep and hot wells. The technology of retarder is well developed and several types are used. Retarding mechanisms of these retarders is something mysterious and seems impossible to understand completely though many theories have been proposed.

The most abundant retarders are obtained from wood pulp. They comprise Calcium and sodium salts of lignosulphonic acids and contain some saccharides. They are believed to attach onto initial layer of C-S-H gel, causing it to be hydrophobic and prolonging the induction period. Added in concentrations 0.1 to 1.5 percent BWOC, they retard hydration at temperatures up to 122^{o}C (250^{o}F). When treated with other chemicals such as borax, lignosulphonates can be used up to 315^{o}C (600^{o}F). Hydroxycarboxylic acids, such as glucoheptonate and gluconate salts, also retard hydration but are not used when the bottom-hole temperature is below 93^{o}C (200^{o}F). Cellulose sources like carboxymethylhydroxyethyl cellulose (CMHEC) have been used for many years as cement retarder.

3) Extenders

Cement extenders reduces the density of the slurry and bring down the hydrostatic pressure in the course of cementing operations. They prevent the damage of weak and porous formations and also prevent circulation loss into the zone. They increase the yield of the slurry because they are cost effective than cement, they provide some savings. Three types of extenders are low-density aggregates, water extenders, and gas; usually more than one may be used in a slurry design.

4) Weighting agents

These help to add more weight to the cement and increase the slurry density. They are used in high pressure formations, which might become unstable if slurry density were too low.

5) Dispersants

This additive helps to thin down the viscosity of cement slurry and increases the mixability of other additives and ensures good mud removal during placement. It also helps to offset the tendency of the cement slurries to gel up. This additive is also called friction reducing additives because it is added in order to improve the rheology of the cement slurry (Adams et al, 1985). In a good concentration, this additive improves cement homogeneity and lowers its permeability. But if the concentration is higher than required may cause phase separation of the cement slurries causing cement settlement at the bottom and excess free fluid. The most common dispersant is the sodium salt of Polynapthalene Sulphonate (PNS) which is the most widely used materials for dispersing cement particles in slurries. PNS can also allow higher solids-to-water ratio slurries to be designed with improved properties. PNS materials are polymeric with molecular weights ranging between about 3,000 and 20,000 (Cowan et al, 1993).

6) Fluid Loss Control Agent (FLAC)

These additive help to prevent excessive loss of water from the slurry and prevent untimely setting known as ‘’flash setting’’

7) Lost Circulation Control Agents

These help to prevent slurry from being lost into unconsolidated formations Loss of cement may necessitate a costly, remedial cementing operation.

8) Special Additives

Such as antifoam agent and fibres are manufactured for specific cementing tasks, such as prevention of foaming that might cause loss in height and prevention of cavitation during cementing operation

Therefore, in order to address these issues there is the need to find an alternative use of sawdust for production of oil well cement retarder, which will help in curbing the environmental menace caused by sawdust waste.

II. MATERIALS AND METHODOLOGY

40grams of sawdust which was sourced from Igwuruta timber market in Ikwerre local government area of Rivers state was measured using electronic weighing balance, the weighed sample was transferred into 500ml heating flask, and sodium Hydroxide was poured into the flask and the sawdust was completely covered with the alkaline solution to achieve delignification of the sawdust. The solution was allowed to boil for 5 hours at a regulated temperature of 100^0C to increase the yield of lignin. The sample was filtered to remove the cellulose and hemicellulose component and the filtrate was neutralized with Sulphuric acid until the P^H reached value of 2 according to Heradewi, 2007.

1g of yeast was then added to the mixture to enhance fermentation of the sugar content of the sawdust which dissolved with the lignin content of the sawdust for 24hours, the fermented solution was filtered further to separate the alcohol and water content from the lignin solution, after that the filtrate was oven dried at 70^oC for 3hours to remove the remaining water content in the lignin. The lignin solution was subjected to sulphonation reaction with sodium bisulphite for 5hours to form the Product.

A. Testing the Thickening time effect of the product on local cement at surface Temperature of 80^oF

The laboratory quantities of cement, fresh water, deformer for neat cement slurry by weight and volume is presented in Table 1 while the compositions of cement slurries with the formulated sample as an additive are shown in Tables 2 and 3.

1) Cement Slurry Preparation

The above quantities of cement, fresh water, deformer and the samples were measured, and blended according to API recommended practice 13B-2 standard using a warring blender as shown in Figure 1.

Figure 1. Warring blender for blending the cement slurry

2) Setting of the surface Sample

The blending cups presented in Figure 2 were used to carry out blending of the cement slurries while the blended samples were poured into plastic bottles as shown in Figure 3.

Figure 2. Blending Cup used to blend the cement slurry

Figure 3. Surface Samples at 80^{o}Ffor the setting time experiment

TABLE I. SHOWING THE LABORATORY QUANTITY OF THE ADDITIVE FOR NEAT SLURRY

Components	Weight (gram)	Volume (ml)
Local-Cement	770.2	242.81
Fresh Water	364.12	355.23
Deformer	0.87	0.96
Total	1136.69	600
Mix Fluid		357.19

TABLE II. SHOWING THE LABORATORY QUANTITY OF THE ADDITIVE @SAMPLE VOLUME OF 2ML

Components	Weight (gram)	Volume (ml)
Local-Cement	769.47	242.58
Fresh Water	363.32	354.46
Sample	3.03	2
Deformer	0.87	0.96
Total	1136.69	600
Mix Fluid		357.42

TABLE III. SHOWING THE LABORATORY QUANTITY OF THE ADDITIVE @SAMPLE VOLUME OF 3ML

Components	Weight (gram)	Volume (ml)
Local-Cement	768.75	242.35
Fresh Water	362.53	353.69
Sample	4.54	3.00
Deformer	0.87	0.96
Total	1136.69	600
Mix Fluid		357.65

III. RESULTS AND DISCUSSION

The setting time of the formulated slurries shows that the neat slurry setting (slurry with zero (0) concentration of formulated sample) approximates the setting time proposed by the America Concrete Institute for neat slurry at 80^{o}F to be around 4hrs. See Table 5 for setting time of concrete. For this experiment, the obtained setting time for the neat slurry is 4hrs 31mins. Also, other slurry samples shows that at 2ml concentration addition of the formulated sample; the setting time is 7hrs 25mins while 3ml concentration addition of the same formulated sample shows a setting time of 8hrs 35mins as presented in Table 4.

TABLE IV. THE THICKENING TIME OF THE CEMENT SLURRY

Samples Concentration (ml)	0	2	3
Set Time (hrs:mins)	04:31	07:25	08:35
Set Time (mins)	271	445	515

TABLE V. SETTING TIME OF CONCRETE AT VARIOUS TEMPERATURE

Temperature	Approximate Setting Time (hours)
100^{o}F (38^{o}C)	1-2/3
90^{o}F (32^{o}C)	2-2/3
80^{o}F (27^{o}C)	4
70^{o}F (21^{o}C)	6
60^{o}F (16^{o}C)	8
50^{o}F (10^{o}C)	11
40^{o}F (4^{o}C)	14
30^{o}F (-1^{o}C)	19
20^{o}F (-7^{o}C)	Set will not occur

Source: ACI 116R (America concrete institute)

From Table 4, it can be clearly seen that the sample produced has the capacity to retard the cement slurry by over 50% of its neat slurry.

IV. CONCLUSION

The results obtained from the experiment shows that sawdust can be converted to a useful oilfield chemical with the capacity to cause retardation in setting time of cement slurries as demonstrated here with local cement. This emphasizes how sawdust a waste material from the pulp industry can be converted to a use resource for wealth creation and alternative source to imported oilfield cement chemical.

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