



A physio-evaluation of bamboo stalk ash as a possible cement slurry modifier on local cement for oil field cementing

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Abstract

The oil and gas industry consumes large amount of cement and additives as cement slurry modifiers for its cementing operations. These cements and additives are not readily available and are therefore imported with high foreign exchange. This has necessitated the need to investigate into other alternative sustainable local materials that can perform similar purpose as the imported ones. This research evaluated the performance of Bamboo Stalk Ash (BSA) as possible additive for oil well cementing as a modifier using a local cement. The BSA was obtained from bamboo harvested in Tarkwa, charred and ash at 600 °C in an electric furnace opened to air. The cement slurry experiments were performed in line with API 10B requirement for materials and testing of oil well cement. The Diamond Portland cement was used. The cubes were cured for 8 hours at temperature of 140 °F. The use of the BSA as an additive has positive effect on the local cement slurry properties. All PV values obtained were below the 100 cP, which is desired to keep cement slurry pumpable. The YP values also exceeded 15 lb/100 ft² indicating prevention of solid settling. The BSA concentrations from 1% to 5% showed enhancement in compressive strength. A concentration of 5% BSA gave the optimal value for achieving the highest compressive strength of 2,205 psi using the local Portland cement. The higher the concentration of the BSA, the higher the slurry density, that is the BSA served as a weighting material. The percentage of free fluid of the slurry decreased as the percentage of BSA was increased, serving as a good free fluid loss agent for well integrity.

Keywords: bamboo stalk ash, cement, compressive strength, rheology, free water

Introduction

Well cementing plays a vital role in the long-term usefulness of a well. Successful cementing operations result in cement sheath that bond and support casings and provide good zonal isolations. Other applications of cementing operations include providing hydraulic seal, structural support for casing and isolating casing seat from subsequent drilling ^[1]. Generally, large amount of Portland cement and additives are used in the oil and gas industry to achieve a good cement job. These cement and additives are not readily available and are therefore imported affecting the overall cost of a well. This has necessitated the need to research into other alternative materials that are sustainably available locally rather than the popular Class G cement. Works on the use of Portland cement have prove to be very useful in most situations as a potential substitute for Class cements ^[2, 3]. However, these cements require some additives or slurry modifiers to enhance the properties of the cement for various conditions ^[2].

There has been increasing attention in recent times for the usage of agricultural by-products to achieve good cement job in many areas of engineering, especially in civil engineering ^[4]. Agro-waste materials such as corn stalk, wheat straw, sunflower stalk, saw dust, corn cob, bamboo leaves and rice straw contain cementitious materials that enhances cement properties ^[5]. The chemical analysis of the

Bamboo Leaf Ash (BLA) showed that the combined Silica Oxide (SiO₂), Aluminum Oxide (AlO₃) and Ferrous Oxide (Fe₂O₃) content was above the 70% minimum standard requirement specified by American Standard of Testing Materials (ASTM) for pozzolanic materials ^[6]. Bamboo Stalk Ash (BSA) on the other hand is reported to contain major compounds such as SiO₂, CaO, and MgO with minor traces of other oxides such as Fe₂O, Al₂O₃, K₂O, Na₂O ^[7]. Ghana is endowed with huge hydrocarbon potentials and also potential oilfield additives ^[8, 9]. In Ghana, there are about 400,000 hectares of bamboo plantation across the country, of which most is found in the Western region ^[10]. Most of the bamboo harvested are used for construction works and or as wood fuel. Due to the reported high cementitious content of bamboo, this work therefore evaluated the performance of bamboo stalk ash as a possible cement slurry modifier for oil well cementing operation.

Material Used

1. Bamboo Stalk Ash

The ash was obtained from bamboo harvested in Tarkwa. It was dried, charred and ash at 600°C in an electric furnace opened to air. The bamboo stalk ash was introduced to the slurry in a percentage of 1%, 2%, 3%, 4% and 5%. Figure 1 shows the dried bamboo stalk, charred bamboo and the bamboo stalk ash.



Fig 1

The cement slurry experiments were performed in line with API 10B requirement for materials and testing of oil well cement. The Diamond Portland cement was used. The ratio of water to cement was 0.46. the following properties were checked; rheological properties and density, free fluid at 80 °F, and compressive strength. The cement cubes were cured for 8 hours at a temperature of 140 °F. Table 1 shows the cement slurry formulations.

Table 1: Cement Slurry Formulation

Samples	BSA (%)	BSA (g)	Cement (g)	Fresh Water (g)
A	0	0	700	322
B	1	7	700	322
C	2	14	700	322
D	3	21	700	322
E	4	28	700	322
F	5	35	700	322

The compressive strength was calculated using Equation 1 [11];

$$\text{Compressive strength (psi)} = \frac{\text{Force(pounds)}}{\text{Area(sqare inch)}} \quad (1)$$

The plastic viscosity, yield point and free water were estimated using Equations 2, 3 and 4 respectively [11, 12];

$$\text{Plastic Viscosity (PV)} = 1.5(\theta_{300} - \theta_{100}) \text{ dial readings} \quad (2)$$

$$\text{Yield Point (YP)} = \theta_{300} - \text{PV} \quad (3)$$

$$\text{Free Water } \phi = \frac{V_{ff} \times \rho \times 100}{m_s} \quad (4)$$

Where; θ_{300} is the dial reading at 300 rpm and θ_{100} is the dial reading at 100 rpm; rpm is revolution per minute. ϕ is the percentage of free fluid; V_{ff} is the volume of free fluid collected in ml; ρ is density of slurry in g/cm³; and m_s is the mass of cement.

Results

1. Rheological Properties

The rheological properties were tested at Bottom Hole Circulating Temperature (BHCT) of 125 °F. The rpm and the corresponding dial readings are recorded in Table 1.

Table 1: Results for Rheology Test at 125 °F

RPM	Concentration of Bamboo Stalk Ash (BSA) % BWOC					
	0	1	2	3	4	5
600	106	135	155	160	162	131
300	73	94	102	105	106	89
200	58	66	77	81	83	72
100	39	51	59	61	61	53
6	14	16	18	20	21	18
3	11	12	13	14	15	14
PV	51	64.5	64.5	66	67.5	54
YP	22	29.5	37.5	39	38.5	35

It is recommended that the PV of cement slurries are less than 100 cP to endure good pumpability of the slurry [12]. All the samples met the satisfied the threshold value (Figure 1). It is recommended that cement slurry yield point should exceed 15 lb/100 ft² to prevent settling [13]. The YP recorded values above this threshold. The addition of the BSA caused a relatively marginal increase in the PV and YP values up to a concentration of 4% and experienced a marginal drop at 5%. Generally, this may be due to n increase in solid concentration.

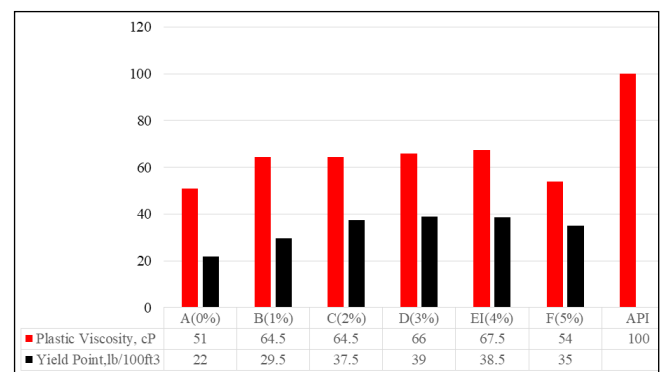


Fig 1: Effect of BSA Concentration on Plastic Viscosity and Yield Point

2. Density

The density of the slurry helps in maintaining well integrity by not fracturing the formation or wellbore. The slurry is generally designed to obtain a density not lower than the hydrostatic head and also not exceeding the fracture gradient of the formation. Generally, cement slurry density varies between 11 – 18.5 ppg [8]. From Figure 2, it was observed that the values of density of the slurry samples were increasing as the quantity of BSA was increased at a temperature of 80 °F hence serving as an extender

(weighting material). The density of the various slurry concentrations is shown in Table 2.

Table 2: Slurry Density

BSA on BWOC (%)	A (0)	B (1)	C (2)	D (3)	E (4)	F (5)
Slurry Density	16.4	16.6	16.7	16.8	16.8	16.9

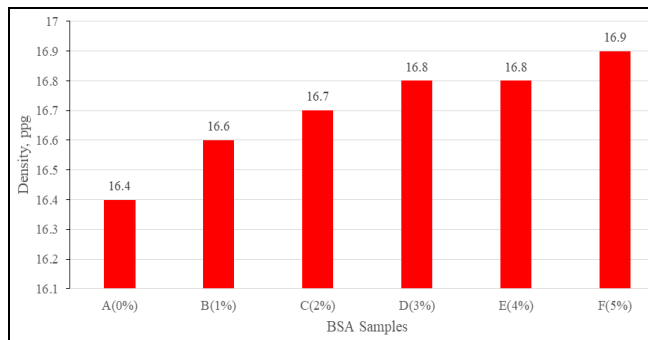


Fig 2: Effect of BSA on Slurry Density on Local Cement

3. Compressive Strength

Results on compressive strength were obtained by curing the cubes at a temperature of 140 °F for 8 hours (Table 3). The cubes were then crushed to obtain the compressive strengths.

Table 3: Compressive Strength Results

Samples	A (0%)	B (1%)	C (2%)	D (3%)	E (4%)	F (5%)	API
Compressive Strength (psi)	1506	1625	1745	1852	1967	2205	1500

After a curing period of 8 hours at a temperature of 140 °F, all the cement samples met the API minimum compressive strength requirement of 1,500 psi. It was observed that, the values for compressive strength were increasing as the amount of BSA increased. This may be as a result of the SiO₂ present in the BSA. silica reacts with cement in the presence of water to produce xonotlite or tobermorite at higher temperatures. They are both responsible for the enhancement of cement strength. Again, after aging the cement for 8 hours, its anhydrous metallic oxides contain is responsible for liberating heat when it comes into contact with water [11]. The higher the concentration of the ash addition, the better the compressive strength.

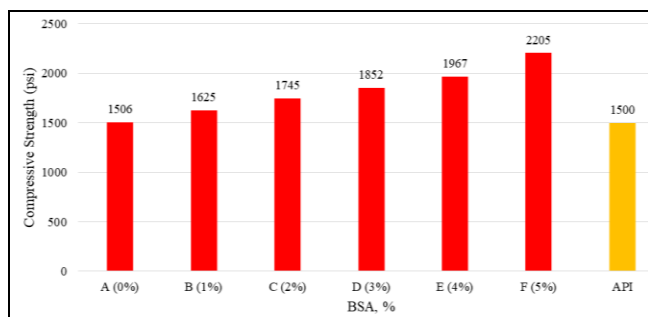


Fig 3: Effect of BSA Concentration on the Compressive Strength on Local Cement

4. Free Fluid

Results on volume of free fluid (V_{ff}) were obtained at a temperature of 80 °F. The free fluid results of the various samples after 2 hours are shown in the Table 4 and Figure 4. From Figure 4, it was observed that as the amount of the

BSA was increasing the percentage free fluid of the slurry decreased. The addition of SiO₂ (Siliceous materials) may have react chemically with Calcium Hydroxide (Ca(OH)₂) in the presence of moisture resulting in hydration of Portland cement to form Calcium Silicate Hydrate (C-S-H). this increases the absorbing rate of free water [11]. Therefore, as the ash concentration increases, the free water decreases which is a positive indication of a good cement slurry.

Table 4: Free Fluid

Slurry Sample	A	B	C	D	E	F	API
Free Fluid (%)	5.82	5.23	4.95	4.92	3.39	2.98	5.9

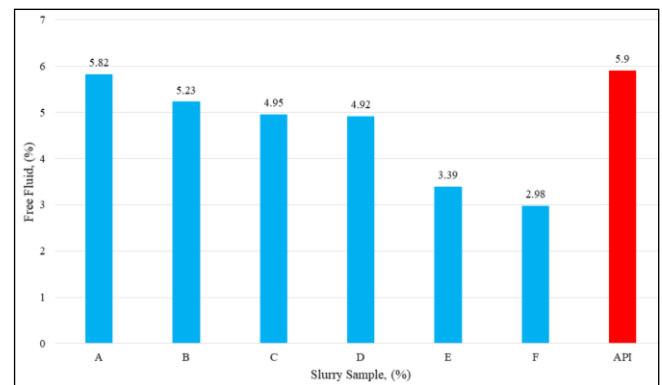


Fig 4: Effect of BSA Concentration on Free Fluid Loss on Local Cement

Conclusions

The research investigated the effect of Bamboo Stalk Ash (BSA) concentrations on cement slurry properties as a cement slurry modifier on local Portland cement. Conclusions drawn from the research were that:

1. The use of BSA as an additive has positive effect on local cement slurry properties;
2. All PV values obtained were below the 100 cP, which is desired to keep cement slurry pumpable. The YP values also exceeded 15 lb/100 ft² indicating prevention of solid settling;
3. Concentrations from 1% to 5% showed enhancement in compressive strength. A concentration of 5% BSA gave the optimal value for achieving the highest compressive strength of 2,205 psi using the local Portland cement when cured at 140 °F for 8 hours.
4. The higher the concentration of the BSA, the higher the slurry density, that is the BSA served as a weighting material.
5. Percentage free fluid of the slurry decreased as the percentage of BSA was increased, serving as a good free fluid loss agent for well integrity.

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