International Journal of Engineering & Technology, 7 (1) (2018) 100-105

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International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i1.8658
Research paper

Rheological evaluation of local clay samples in central region Ghana for oil well drilling fluid formulation

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Abstract

The superb rheological features of bentonites makes them an excellent candidate in drilling operations. Its capacity of bentonite to swell and extend to a few times its unique volume gives it the gelling and viscosity controlling quality. The execution of clay or specifical bentonite as a great consistency controlling operator in drilling fluids largely depends on the great extent of its rheological conduct. Ghana as of late found oil and it has tossed a test to research to explore the utilization of local materials in the oil and gas operations. A rheological study was conducted on local clay samples from Ajumako, Saltpond and Winneba in the Central district of Ghana as a viscosifier in drilling muds. This will help to improve the local content of Ghana's oil and gas industry. Drilling muds were prepared from the samples in addition to a control mud using imported non-treated bentonite. The local clay samples were subjected rheological test where the flow behavior of the muds was determined by measuring the gel strength, plastic viscosity, and the yield point. The experimental values were compared to the API standards. It was revealed that the local clay had some potential features of bentonite and could be utilized as controlling operators in drilling fluids provided the clays are beneficiated to enhance their rheological properties. This novel tend to improve the local content in oil and gas industry in Ghana through the deployment of the local materials in oil and gas operations in the nation.

Keywords: *Bentonite; Drilling Mud; Clay; Rheology; Temperature; Viscosity; Yield Point.*

1. Introduction

Drilling fluids are essential in any drilling operation in the oil and gas industry. The drilling fluid can be regarded as any type of circulation fluid with different functions to satisfy the requirements needed for drilling. Drilling fluids functions are the carrying and the suspending cuttings; stabilizing the wellbore and balancing the formation pressure, and cooling and lubrication the bits. Also, it serves as a means of hydropower transmission to the well. According to Skalle [1], the most important qualities of a drilling fluid is viscosity and the density. Viscosity is essential in designing the flow pattern of the drilling fluid during the fluid, whereas the density becomes relevant in evaluating the pressure required to counter the high pore pressure in the formation. Bentonites are very common in most drilling fluid formulations due to their volumetric yield, soluble impurities, abrasive content and their inherent filtration characteristics [2]. It also possesses unique rheological properties and is generally plastic at appropriate water contents. Due to these unique rheological properties, it has been applied in a various projects such as land protections against erosion, reclamation of infertile land or landfill, and some cases as an agent for purification of waste water and drinking water [3].

Nigeria is noted as the highest daily oil producer in Africa and also the oil industry is the matured stage. Nigeria has put in many efforts to increase their local content in their oil industry by employing local materials in the various oilfield application. A lot of work has been done by the various individual and co-operate bodies to investigate the suitability of local bentonite clay as a substitute for Wyoming bentonite, which is mainly used as a viscosifier for drilling mud in the upstream industry. Abdullahi and coworkers [4] performed a comparative study on commercial bentonite (Wyoming bentonite) and a local bentonite clay from a marine deposit in the upper part of Benue Basin, Nigeria. They observed that the local clay samples without beneficiation met the API standard. After, beneficiation with sodium bicarbonate, the local clay samples meet all the API standard required for viscosifier. Similar studies have been conducted by Joel and Nwokoye [5] and Apugo-Nwuso et al. [6] and it was observed that all local samples used in their studies can attain the API specification for viscosifier when they are appropriately beneficiated. These studies have helped the oil policy makers in achieving their goal of local content as well as gearing towards development in their petroleum industry.

Ghana in 2007 discovered oil in commercial quantities along the coast of the south-western part of Ghana. According to report, over 25 new other discoveries of oil and gas condensate have been made since the discovery of the first discovery. This shows the potential of the oil and gas industry in Ghana of achieving new heights. However, the deployment of local content in the oil and gas industry is quite low. This has directed the researchers and engineers in the country to discover ways in which local materials can be used in the oil industry. This study tends to investigate into the suitability of local clay samples from Ajumako, Saltpond, and Winneba (as shown in Fig.1- Kindly refer to the Figures and Table) for the formulation of drilling fluid in the oil and gas industry. More attention will be given to the rheological study of the local bentonite clays and the results obtained will be compared Wyoming Bentonite which used by the API as a standard for viscosifier.

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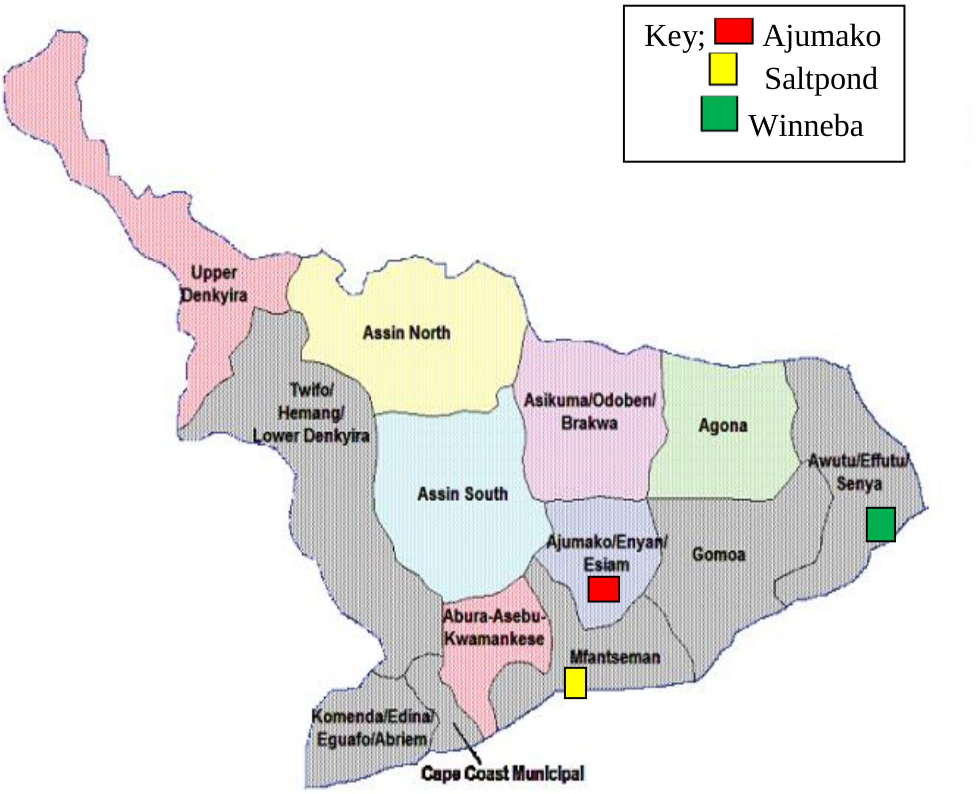

Fig. 1: A Map of the Central Region, Showing the Places Where the Samples Were Picked for Our Study.

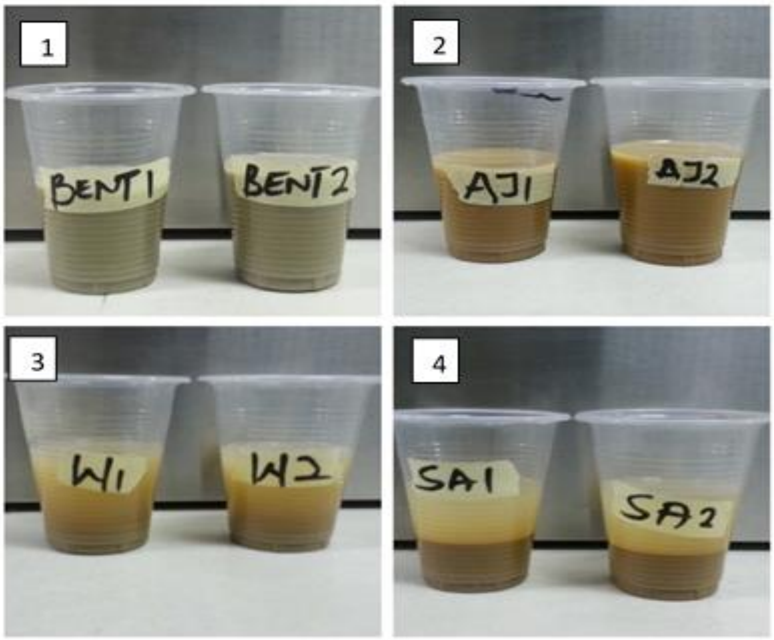

Fig. 2: Prepared Samples; 1). Bentonite Mud. 2) Mud Prepared from Clay Samples from Ajumako. 3) Mud Prepared from Clay Samples From Winneba & 4) Mud Prepared from Clay Samples from Saltpond.

2. Experimental

2.1. Clay samples preparation

Clay samples from our study were taken, dried and crushed down into smaller particles in a cone crusher. Afterwards, 1 kg of each sample was weighed and transferred into a ball mill, where it is then ground. Each sample was ground for 45 minutes to obtain a uniform grinding. The product obtained was then sieved with a 75 μm sieve to obtained reduced particle size.

2.2. Rheological characterization of the clay samples

22.5 g of bentonite was added slowly in 350ml of water while stirring. The stirring was done for 5 minutes and the sides of the cup were scraped to ensure that all the mixture enters the suspension. It was then stirred for an extra 15 minutes to ensure homogeneity. A Fann viscometer was used to pick the reading, dial readings at 600 and 300 rpm, and also the 10 seconds and 10 minutes gel strength respectively. The same process was repeated for clay samples from Ajumako, Winneba, and Saltpond.

3. Results and discussion

3.1. Results

The American Petroleum Institute (API), requires that the ϴ600 rpm reading should be a minimum of 30 and the Yield Point/ Plastic Viscosity ratio should not exceed 3 for an untreated bentonite sample (Table 1).

Table 2 presents a total account of results from the rheological tests conducted on both the control bentonite and the local samples of clay giving details of the rpm readings, gel strength, plastic viscosity, yield point and YP/PV ratio ranging from room temperature of 25 °C to 80 °C, whereas Table 3 provides that of the samples aged at 90 °C. From the tables, BENT stands for Bentonite, AJU for Ajumako, SALT for Saltpond, and WIN for WINNEBA. Table 4 is basically a comparison of the rheological properties of the bentonite and the other clay samples used in this study.

3.2. Discussion

Table 1 indicates the standard API specification for a good quality bentonite. It is important that before any sample is used, quality assurance and quality control must be determined to ensure the results are within acceptable range as specified by API. Table 2 indicates the rheological properties of the unaged samples at varying temperatures. The local samples did not meet some of the API requirements such as the gel strength, plastic viscosity, and the ϴ600 rpm reading. Samples from Saltpond and Winneba which had a value of 4 did not meet the requirement for the YP/PV ratio but the only sample from Ajumako met the API requirement which was 0.5 at room temperature. Considering the ɵ600 reading for all of the local samples, they could not meet the API specification as they all ranged from 4 to 6. Similar work was conducted in Nigeria by Joel and Nwokoye in 2010 and their results are as tabulated in Table 4. From the table, it is seen that the local clay samples recorded higher values of 5, 6 and 6 for Ajumako, Saltpond, and Winneba respectively in terms of the 600 rpm reading than the samples used by Joel and Nwokoye at room temperature (25 °C). Only the sample from Ajumako which recorded a value of 0.5 at room temperature met the API Specification whiles that of Saltpond and Winneba which values of 4 could not meet the API Specification.

Practically, the gel strength is the ability of the fluid to suspend the cuttings at static conditions. It is evident that the local samples cannot suspend cuttings at static conditions because of the values they recorded for the 10 seconds and 10 minutes gel strength. Once again, the control bentonite sample exhibited superiority in terms of its gel strength indicating that when it is used in drilling mud formulation, it can suspend cuttings under static conditions. Fig. 4 shows the 10 seconds and 10 minutes gel strengths for both the control bentonite sample and the local samples at various temperatures and Fig.5 shows the 10 seconds and 10minutes gels strength of the aged samples. The API specifications for gel strength are, 3 - 20 lb/100ft^2 and 8 - 30 lb/100ft^2 for 10 seconds and 10 minutes gel strength respectively. It is also clear that none of the local samples met the API specification for gel strength.The local clay samples from Ajumako and Saltpond had10 minutes gel strength value of 3 Ib/100ft2 with only Winneba having a value of 4 Ib/100ft2 at 60 ^{0}C and 80 ^{0}C Whiles that of control sample (bentonite) at 80 ^{0}C had 10 minutes gel strength value of 16 Ib/100ft2 indicating that the bentonite gels three times more than the local clay. Figure 3 shows the gel strength of the unaged samples.

For the gel strength of the aged samples, it could be observed for the bentonite which is the control experiment has a similar value of 16 Ib/100 ft^2. Comparatively, the bentonite had better gel strength than the local clay samples. All the local clays had gel strength at 10 seconds and 10 minutes of 1 Ib/100 ft^2 and 3 Ib/100ft^2 respectively. Figure 4 shows gel strength of aged samples. The viscosity of a fluid is defined as its resistance to flow. Comparatively, the plastic viscosities of the control bentonite sample ranged from 8 cp to 11 cp are higher than the samples of the local clay which was around 2 cp at different temperatures of 25 ^{0}C, 40 ^{0}C, 60 ^{0}C and 80 ^{0}C. The higher mud weight, the higher PV will be. It can, therefore, be said that the poor viscous nature of the clays from Ajumako, Saltpond, and Winneba is not viscous compared to the control bentonite sample to bring cuttings to the surface. The bentonite also recorded higher plastic viscosity values for the aged samples as well. Figure 5 and 6 shows the plastic viscosity of the unaged samples at varied temperatures and aged samples for 8 hours at 90 ^{0}C respectively.

Comparing, the yield point of the control bentonite sample and the local clay samples at different temperatures of 25 ^{0}C, 40 ^{0}C, 60 ^{0}C and 80 ^{0}C, it is observed that the bentonite recorded higher yield point values which were ranging from 6 Ib/100ft^2 to 15 Ib/100ft^2. The values of the yield points increased as the temperature was increased steadily. This also occurred for the aged samples as well. The yield point is an indication of the drilling mud to carry cuttings out of the hole. The lower readings obtained from Ajumako, Saltpond and Winneba clays show that they cannot carry drilling cuttings out of the wellbore since they possess very low inertia to lift the cuttings. Figure 9 and 10 show the yield point graphs of the unaged samples at varied temperatures and aged samples for 8 hours at 90 ^{0}C respectively.

A graph of shear stress was plotted against shear rate to show the flow behaviour of the local clay sample and the control sample which is the bentonite. It is clearly seen that the bentonite had a higher value of shear stress than the local clay samples. It can be concluded that the bentonite which is the control sample together with the local clay had a flow behavior which can be described a non-Newtonian fluid since they both had a value of shear stress other than being zero and starting from the origin. Also, the shear stress to shear rate relationship was not constant. Figure 7 and 8 show a graphical representation of the shear stress to shear rate relationship of aged samples at and unaged samples respectively.

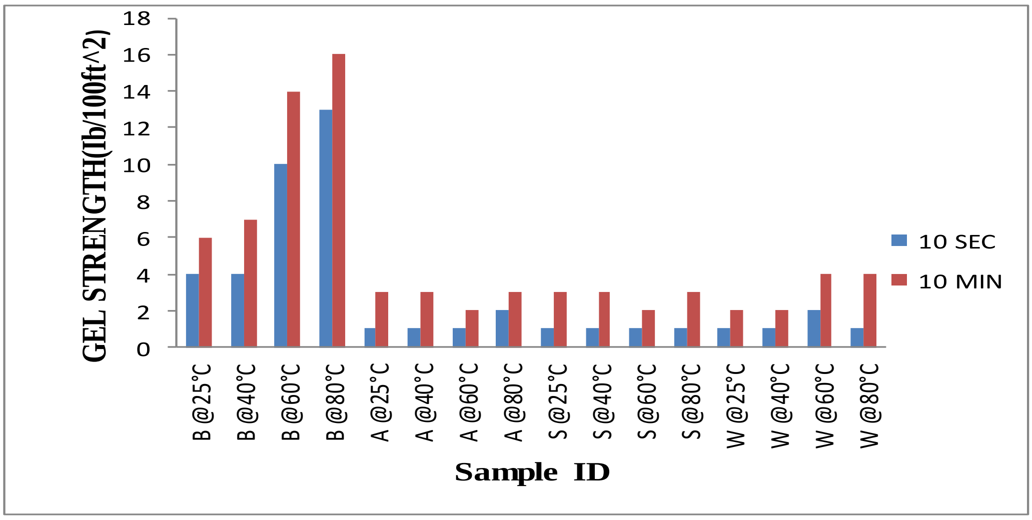

Fig. 3: Gel Strength against Samples at Different Temperatures.

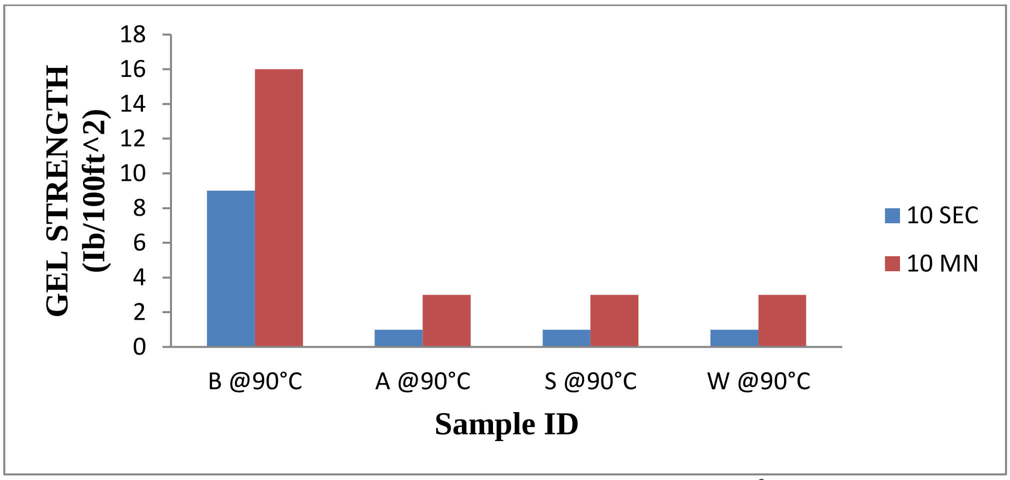

Fig. 4: Gel Strength against Samples at Aged for 8hours at 90^0C.

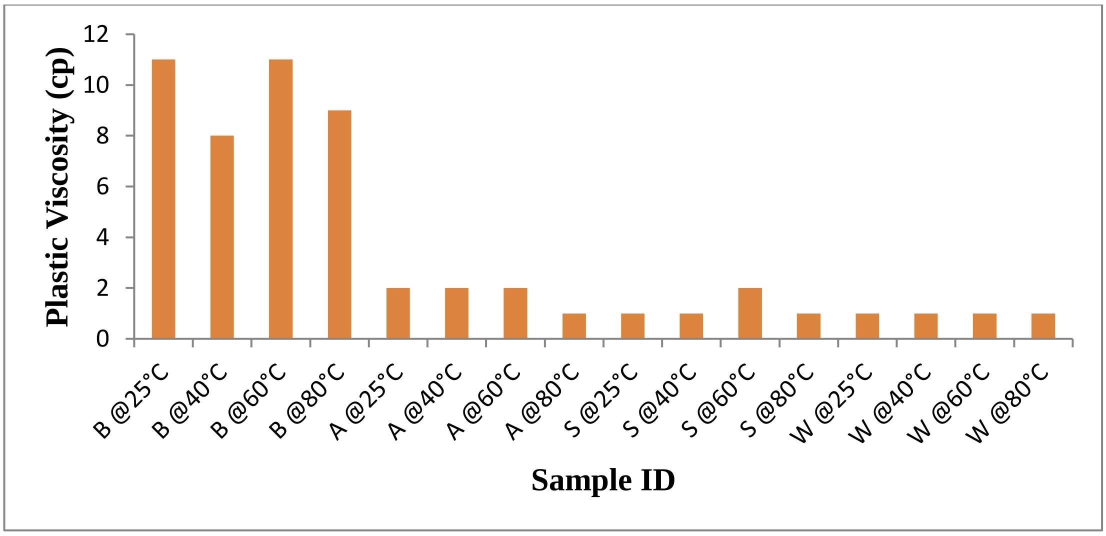

Fig. 5: Plastic Viscosities of Unaged Samples.

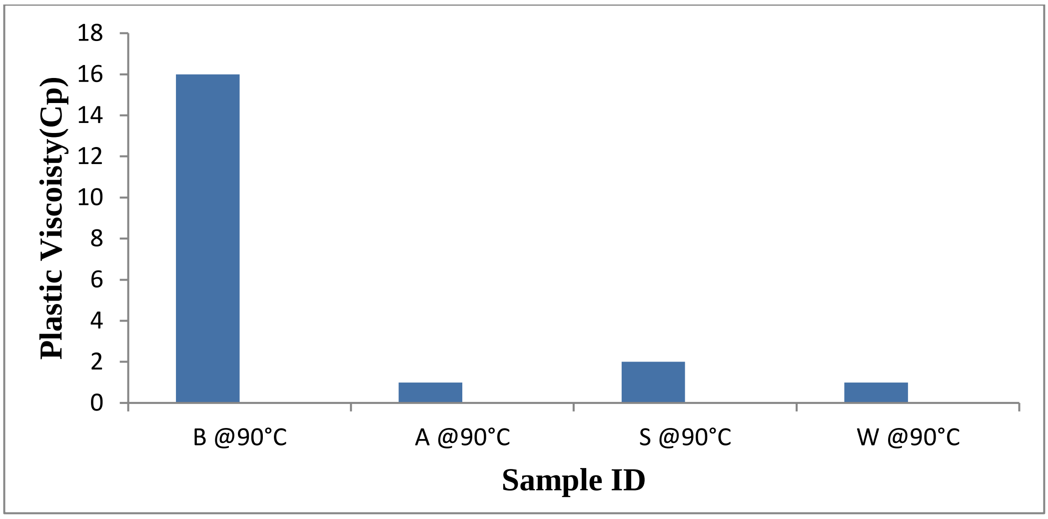

Fig. 6: Plastic Viscosities of Aged Samples.

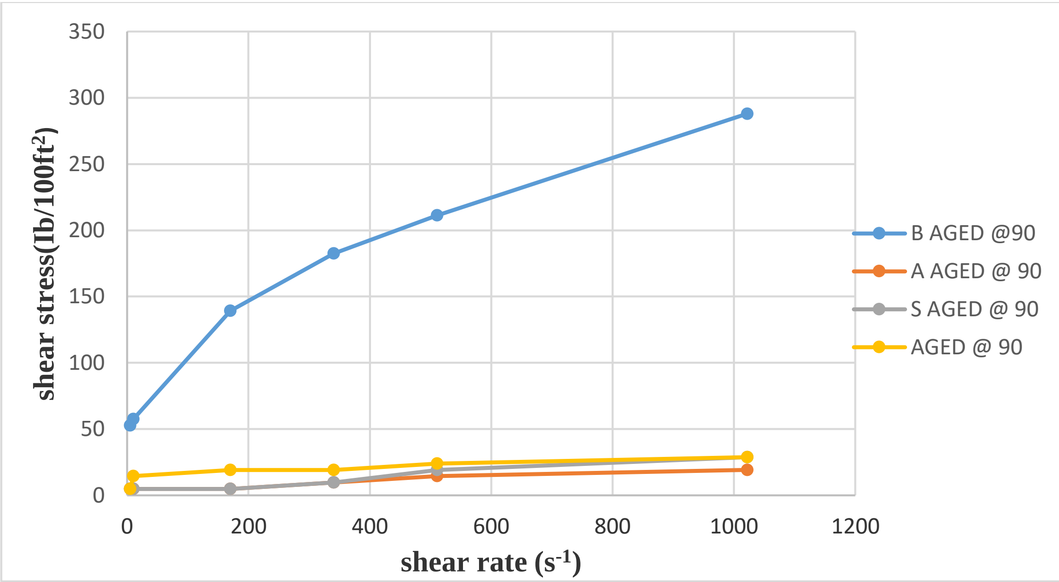

Fig. 7: Shear Stress-Shear Rate Relationship of Aged Samples.

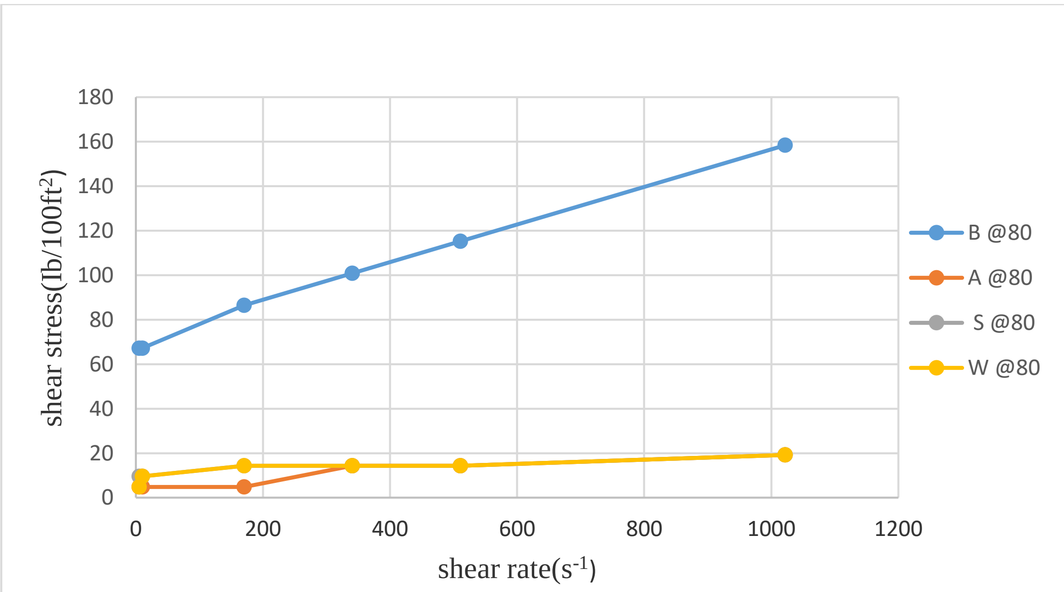

Fig. 8: Shear Stress-Shear Rate Relationship of Unaged Samples at 80^0C.

Table 1: Api Spec 13 A

S/N	Rheological properties	
1.	Θ_{600} rpm	30 Min.
2.	Yield Point/Plastic Viscosity	3 Max.

(Source: API Spec 13 A, 2010).

Table 2: Rheological Properties of Unaged Samples at Varying Temperatures

S/N	TEM (°C)	DIAL READINGS, RPM						GEL STRENGTH (lb/100ft^2)		PV (cp)	YP (lb/100ft^2)	YP/PV
		600	300	200	100	6	3	10'	10"			
BENT	25	28	17	14	10	4	4	4	6	11	6	0.5
	40	24	16	13	10	4	4	4	7	8	8	1
	60	34	23	19	14	13	8	10	14	11	12	1.1
	80	33	24	21	18	14	14	13	16	9	15	1.7
AJU	25	5	3	2	1	1	1	1	3	2	1	0.5
	40	5	3	2	2	2	1	1	3	2	1	0.5
	60	6	4	2	1	1	1	1	2	2	2	1
	80	4	3	3	1	1	1	2	3	1	2	2
SALT	25	6	5	3	2	2	1	1	3	1	4	4
	40	5	4	3	2	2	1	1	3	1	3	3
	60	6	4	4	3	1	1	1	2	2	2	1
	80	4	3	3	3	2	2	1	3	1	2	2
WIN	25	6	5	4	4	3	2	1	2	1	4	4
	40	5	4	3	2	1	1	1	2	1	3	3
	60	4	3	3	3	2	1	2	4	1	2	2
	80	4	3	3	3	2	1	1	4	1	2	2

Table 3: Rheological Properties of Aged Samples at 90 °C

S/N	TEM(°C)	DIAL READINGS, RPM						GEL STRENGTH (lb/100ft^2)		PV (cp)	YP lb/100ft^2)	YP/PV
		600	300	200	100	6	3	10'	10"			
BENT	90	60	44	38	29	12	11	9	16	16	28	1.8
AJU	90	4	3	2	1	1	1	1	3	1	2	2
SALT	90	6	4	2	1	1	1	1	3	2	2	1
WIN	90	6	5	4	4	3	1	1	3	1	4	4

Table 4: Rheological Properties of Clay Samples Compared

Name		Θ600	Yp/Pv
Api Spec 13a For Bentonite		Minimum 30	Maximum 3
Work On Bentonite By Joel And Nwokoye, 2010	Lb 1	3	0
	Lb 2	5	0.5
Control Bentonite	B @ 25 °C	28	0.5
Ajumako	I @ 25 °C	5	0.5
Saltpond	S @ 25 °C	6	4
Winneba	W @ 25 °C	6	4

4. Conclusion

From the results obtained it can be concluded that the yield points to plastic viscosities of the local clay samples are within the API specific value which requires a maximum of 3. However, from the studies, it can also be seen the local clay did not meet the API specification for the 600 rpm reading and it can, therefore, be concluded that local clay samples from Ajumako, Saltpond, and Winneba cannot be used as a viscosifier in their natural state. The performance of the clay samples can approach the API specification if properly beneficiated with a dosage of chemicals like Na_2CO_3, Carboxyl Methyl Cellulose (CMC) and Poly Anionic Cellulose-Regular.

Acknowledgement

The authors acknowledge the support from Dr Solomon Adjei Marfo, University of Mines and Technology, Tarkwa, Ghana and Professor Dr. Wang Yanling, China University of Petroleum, Qingdao.

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