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Comparative Study of the Rheological Properties of Local Clay (Afuze) As a Possible Replacement for Imported Bentonite in Drilling Fluids Formulation

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Abstract— Drilling fluids (muds) are complex fluids consisting of several additives. These additives are added to enhance/control the rheological properties (such as density, viscosity, yield point and gel strength) of the drilling mud. These properties are controlled for effective drilling of an oil or gas well. In this project work, the rheological properties of locally sourced Bentonite clay from Afuze in Edo state was investigated as a possible substitute for imported Bentonite clay. This was carried out by the comparative analysis of the parameters of the local clay mud with the imported bentonite mud to ascertain the level of compliance in drilling operation. This research work focused on three additives: barite, Pac R (Polyanionic Cellulose Regular grade), and sodium carbonate (Na2CO3) to compare the density, pH and rheological properties of local clay mud and bentonite mud. At the end of the laboratory analysis, the result obtained showed that there was a slight difference in the rheological properties of the formulated drilling mud and the pH values when compared to that of bentonite. Therefore it was concluded that the clay exhibits good rheological properties when compared to imported bentonite.

Index Terms— Drilling fluid, Rheological properties, Afuze, Bentonite.

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1 Introduction

The term drilling fluid or mud generally applies to fluids that are used in maintenance of well control and removal of drill cuttings (rock fragments from underground geological formations from holes drilled in the earth). The original use of the drilling fluids was to remove cuttings continuously. Progress in drilling engineering demanded more sophistication from the drilling mud. In order to enhance the usage of drilling fluids, numerous additives were introduced and a simple fluid became a complicated mixture of liquids, solids and chemicals (Moore, 1974).
As the drilling fluids evolved, their design changed to have common characteristic features that aid in safe, economic and satisfactory completion of a well. In addition, drilling fluids are also now required to perform following functions (Growcock & Harvey, 2005; Darley & Gray, 1988)

- Clean the rock formation beneath the bit for rock cuttings ;
- Transport these rock cuttings to surface through annulus ;
- Suspend cuttings in fluid if circulation is stopped;
- Cool and clean the bit;
- Manage formation pressure to maintain wellbore stability until the section of borehole has been cased;
- Assist in cementing and completion of well;
- Seal the formation pores by forming low permeability filter cake to prevent inflow of formation fluids into the well;
- Provide necessary hydraulic power to down hole equipment;
- Minimize reservoir damage;
- Aid in collection and interpretation of data available through drill cuttings , cores , and electrical logs;

Drilling engineers select specific drilling fluid with most favourable properties for the job. Most of the drilling fluid functions are controlled by its rheological properties. A “Mud Engineer” is often on site to maintain and revaluate these properties as drilling proceeds. The main factors governing the selection of drilling fluids are;

- The types of formation to be drilled;

ISSN 2229-5518

- The range of temperatures; and
- Strength, permeability and pore fluids pressure exhibited by the formation.

While in addition to the above, selection of the drilling fluid can be informed through consideration of other factors such as -production concerns, environmental impact, safety and logistics, the most important factor that governs selection of drilling fluid is the "overall well cost".

Rheology is the study of the deformation of fluids and flow of matter. Its importance is recognised in the analysis of fluid flow velocity profiles, fluid viscosity (marsh funnel viscosity, apparent viscosity and plastic viscosity), friction pressure losses and annular borehole cleaning.

Rheological properties are basis for all analysis of well bore hydraulics and to assess the functionality of the mud system. Rheological characteristics of drilling mud also include yield point and gel strength. Rheological properties (such as density, viscosity and gel strength) are tested throughout the drilling operations. It is critical to control and maintain rheological properties as a failure to do so can result in financial and loss of time, and in extreme cases, it could result in the abandonment of the well (Darley & Gray, 1988). Besides rheological other tests such as filtration tests, pH, hydrogen ion and swelling capacity of the mud are conducted throughout drilling process.

To match the requirements of different depth intervals, the properties for drilling fluids are modified using various additives for the drilling process. Properties such as density, flow properties or rheology, filtration and solid content as well as chemical properties must be accurately measured, controlled and appropriately maintained at their pre-selected level throughout drilling process.

Additives commonly used in drilling muds are viscosifiers, viscosity reducers, weighting materials, fluid-loss reducers, lost circulation materials, corrosion control chemicals and pH control additives.

2.0 Methodology

This section outlines methodologies used in carrying out the experiment.

i. Mud formulation

ii. Acquisition and preparation of raw materials

iii. Mixing of drilling fluid according to procedure

iv. Decision on the sequence of experiment

v. Use of equipment

vi. Study of experimental procedure

2.1 Materials and Equipment Used

2.2.1 Materials

1. Distilled water

Distilled water is water that has many of its impurities removed through distillation. Distillation involves boiling the water and then condensing the steam to clean container. It should be free from salt. It is odourless and tasteless, it has a freezing point of $0^o C$ ($32^o F$) at standard atmospheric pressure; and boiling point of $100^o C$ ($212^o F$).

2. Bentonite

Wyoming bentonite is a naturally occurring bentonite which is mined in Wyoming. There are no other commercial sources of this mineral of comparable quality. It is predominately sodium montmorillonite, but contains some calcium bentonite and sand or silt; as a result, it is somewhat variable in performance.

3. Barite

Barites are compounds that are dissolved or suspended in drilling fluid to increase its density. They are used to control formation pressures and to help combat the effects of sloughing or heaving shales that may be encountered in stressed areas. Barite is a substance that is denser than water and that does not adversely affect other properties of the drilling fluid.

4. Pac R (Polyanionic Cellulose Regular grade)

This is a white powdered material used as viscosity enhancing agent in drilling mud and also work well as fluid-loss agent.

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ISSN 2229-5518

5. Sodium carbonate (Na_2CO_3)

A white material in powdered form used to add alkalinity to drilling fluid in other to decrease the acidity of the drilling mud.

3.0 RESULTS

3.1 Result of Analysis.

SAMPLE A: Local Clay
SAMPLE B: Bentonite

Table 3.1 Showing results obtained for the first experiment.

Mixing Procedure	Properties	Sample A	Sample B
Water 350ml	Density (ppg)	8.5	8.7
Clay 21g	Specific gravity	1.02	1.04
Barite 5g	Sand content (%)	1.25	2.2
Sodium carbonate 2g	pH	8.0	8.4
PacR 0.5g	Filtrate volume (ml)	12	11.4
Filter cake thickness (inch)		1/32	1/32
Funnel Viscosity (sec/quartz)		35	36
600 rpm		24	22
300 rpm		17	16
Plastic viscosity		7	6
Apparent viscosity		12	11
Yield point		10	10
6 rpm		5	8
3 rpm		3	6
Gel strength (10sec), lb/100ft2		1.00	4.00
Gel strength (10min) , lb/100ft2		2.00	8.00

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Table 3.2 Showing results obtained for the second experiment.

Mixing Procedure	Properties	Sample A	Sample B
Water 350ml	Density (ppg)	9.1	9.3
Clay 21g	Specific gravity	1.09	1.12
Barite 10g	Sand content (%)	1.5	2.5
Sodium carbonate 3g	pH	9.0	9.5
PacR 1.0g	Filtrate volume (ml)	13	12.4
Filter cake thickness (inch)		1/32	1/32
Funnel Viscosity (sec/quartz)		41	42
600 rpm		32	34
300 rpm		22	23
Plastic viscosity		10	11
Apparent viscosity		16	17
Yield point		12	12
6 rpm		7	10
3 rpm		5	8
Gel strength (10sec), lb/100ft2		3	6
Gel strength (10min), lb/100ft2		4	10

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Table 3.3 Showing results obtained for the third experiment.

Mixing Procedure	Properties	Sample A	Sample B
Water 350ml	Density (ppg)	9.7	9.9
Clay 21g	Specific gravity	1.09	1.12
Barite 15g	Sand content (%)	2.5	3.5
Sodium carbonate 4g	pH	10.0	10.4
PacR 1.5g	Filtrate volume (ml)	14	13.4
Filter cake thickness (inch)		2/32	2/32
Funnel Viscosity (sec/quartz)		49	50
600 rpm		42	44
300 rpm		32	34
Plastic viscosity		10	10
Apparent viscosity		21	22
Yield point		22	24
6 rpm		9	12
3 rpm		7	10
Gel strength (10sec), lb/100ft2)		4	8
Gel strength (10min), lb/100ft2)		5	12

Table 3.4 Showing results obtained for the fourth experiment

Mixing Procedure	Properties	Sample A	Sample B
Water 350ml	Density (ppg)	10.2	10.5
Clay 21g	Specific gravity	1.23	1.26
Barite 20g	Sand content (%)	3.5	4.0
Sodium carbonate 5g	pH	11	11.5
PacR 2g	Filtrate volume (ml)	15	14
Filter cake thickness (inch)		2/32	2/32
Funnel Viscosity (sec/quartz)		61	62

ISSN 2229-5518

600 rpm	55	56
300 rpm	41	43
Plastic viscosity	14	13
Apparent viscosity	27.5	28
Yield point	27	30
6 rpm	11	14
3 rpm	9	12
Gel strength (10sec), lb/100ft2)	7	10
Gel strength (10min), lb/100ft2)	8	14

3.1.1 Density Test Results

The results gotten for the densities of the mud samples are shown in the table below.

Table 3.5 Showing the density results obtained from increasing mass of barite

S/N	Mass of Barite (g)	Density of Sample A (ppg)	Density of Sample B (ppg)
1	5	8.5	8.7
2	10	9.1	9.3
3	15	9.7	9.9
4	20	10.2	10.5

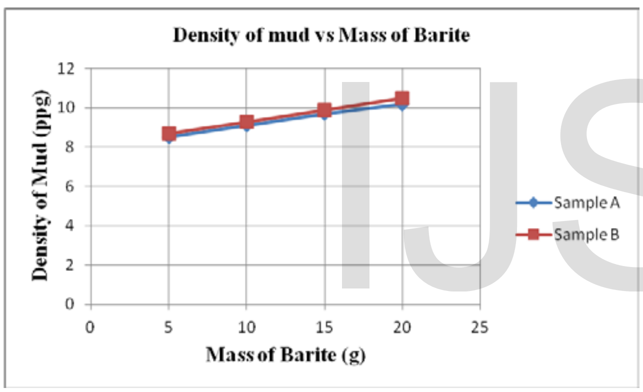

Figure 3.1 Showing the relationship between the density of Sample A and B

3.1.2 pH Test Results

The results gotten for the pH of the mud samples are shown in the table below.

Table 3.6 Showing the pH results obtained from increasing mass of Na_2CO_3

S/N	Mass of Na2CO3 (g)	pH of Sample A	pH of Sample B
1	2	8	8.4
2	3	9	9.5
3	4	10	10.4
4	5	11	11.5

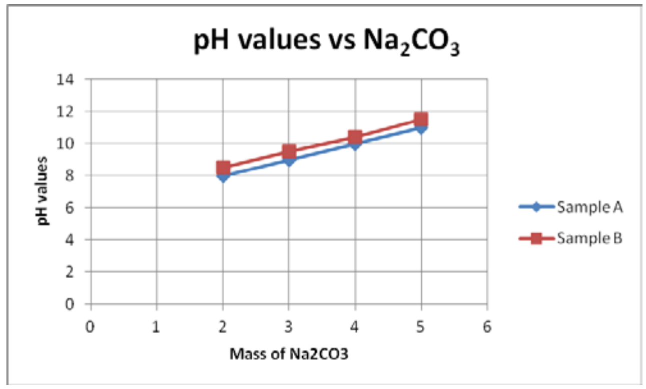

Figure 3.2 Showing the relationship between the pH of Sample A and B

3.1.3 Funnel Viscosity Test Results

The results gotten for the viscosities of the mud samples are shown in the table below.

Table 3.7 Showing the funnel viscosity results obtained from increasing mass of PacR

S/N	Mass of PacR (g)	Funnel viscosity of Sample A (sec)	Funnel viscosity of Sample B (sec)
1	0.5	35	36
2	1.0	41	42
3	1.5	49	50
4	2.0	55	56

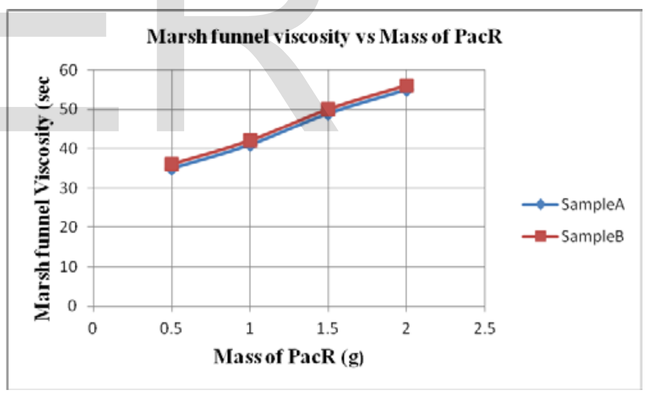

Figure 3.3 Showing the relationship between the funnel viscosities of Sample A and B

3.1.5 Filtrate Volume Test Results

The results gotten for the filtrate volume of the mud samples are shown in the table below.

Table 3.8 Showing the filtrate volume results obtained from increasing mass of PacR

S/N	Mass of PacR (g)	Filtrate volume of Sample A (ml)	Filtrate volume of Sample B (ml)
1	0.5	11.4	12
2	1.0	12.4	13
3	1.5	13.4	14
4	2.0	14	15

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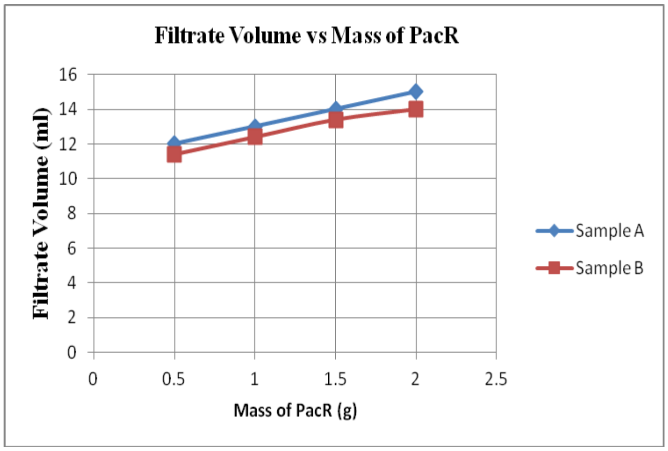

Figure 3.4 Showing the relationship between the filtrate volume of Sample A and B

3.1.6 Test Results at 600 rpm

The results gotten for the dial reading at 600 rpm of mud samples are shown in the table below.

Table 3.9 Showing the 600 rpm dial reading results obtained from increasing mass of PacR

S/N	Mass of PacR (g)	600 for Sample A (cp)	600 for Sample B (cp)
1	0.5	27	29
2	1.0	32	34
3	1.5	42	44
4	2.0	55	56

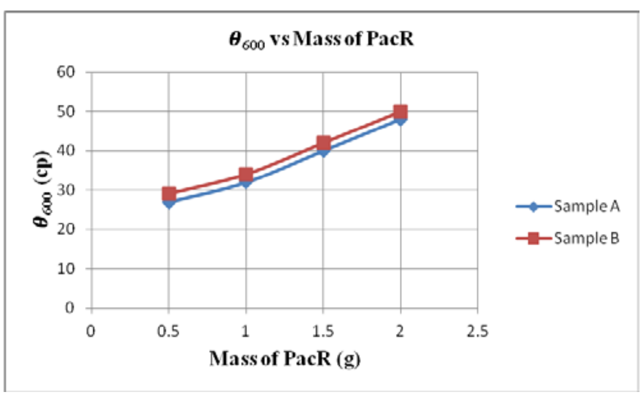

Figure 3.5 Showing the relationship between the dial reading at 600 rpm of Sample A and B

3.1.7 Test Results at 300 rpm

The results gotten for the dial reading at 300 rpm of mud samples are shown in the table below.

Table 3.10 Showing the filtrate volume results obtained from increasing mass of PacR

S/N	Mass of PacR (g)	300 for Sample A (cp)	300 for Sample B (cp)
1	0.5	20	19
2	1.0	22	23
3	1.5	32	34
4	2.0	41	43

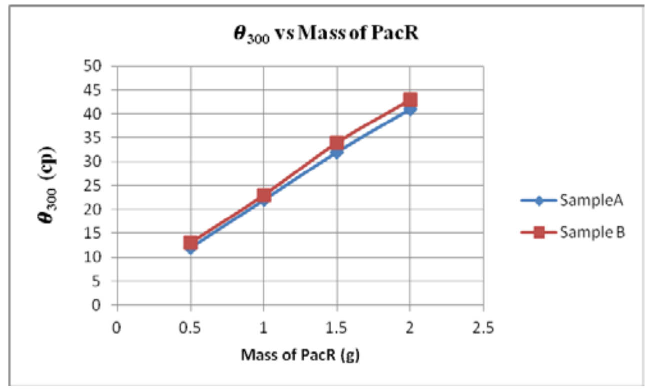

Figure 3.6 Showing the relationship between the dial reading at 300 rpm of Sample A and B

4.0 DISCUSSION OF RESULT

The results obtained from the properties of the local clay and bentonite are presented in tables 3.1 through 3.9. The difference in the density, sand content, filtrate volume, rheological properties as well as their pH values between the local clay and Bentonite at increasing addition of additives are close considering the results of the analysis carried out.

Mud weight analysis from table 3.5 shows the Bentonite mud weight as 8.7ppg, 9.3ppg 9.9ppg and 10.5ppg and that of local clay mud weight as 8.5g, 9.1g, 9.7g and 10.2g at increasing concentration barite. The results between the local clay mud and Bentonite mud are close. This shows that the local clay can serve as a substitute for foreign clay in term of mud weight

For pH analysis, table 3.6 shows that the local clay mud pH value as 8.0, 9.0, 10.0 and 11.0 and bentonite mud pH values as 8.4, 9.5, 10.4 and 11.5 at increasing concentration of Sodium carbonate. The closeness of the result implies that the local clay can also serve as substitute for foreign clay in term of drilling mud pH.

From table 3.7, table 3.8, table 3.9, and table 3.10 the local clay muds funnel viscosity, filtrate volume, viscometer reading at 600

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rpm, viscometer reading at 300 and also the mud plastic viscosity and apparent viscosity at increasing concentration Polyanionic Cellulose Regular grade shows that the local mud rheological properties were close except for the gel strength which needs a little beneficiation to improve it property.

5.0 Conclusion

At the end of the comparative study of the local clay (Afuze) with the foreign bentonite based on their mud densities and rheological properties, the following conclusions are arrived at;

1. The local clay has good density as compare with the foreign bentonite.
2. Addition of concentrated Polyanionic Cellulose Regular grade increases the local mud rheological properties.

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Figure 3.7: Raw clay in solid form

Figure 3.8: Pulverized clay

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