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Research Article

EXPERIMENTAL ANALYSIS OF WATER-BASED MUD SYSTEM: EVALUATION OF MUD RHEOLOGY AND FILTRATION PROPERTIES

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Key words: Mud weight, Fluid loss, Viscosity, Mud cake, Shear rate.

ABSTRACT

The characteristics of the mud are responsible for the success of drilling operations as the main purpose. Drilling fluids must have sufficient viscosity to control fluid loss into the formation and to suspend the rock cuttings when drilling operation is stopped, it is essential to consider the mud rheology and filtration characteristics. To produce high quality mud, bentonite is used as the base clay, Barium Sulphate, and compound A and B were used as additives in four mud samples in this study. Based on the findings, mud 3 has the highest density of 8.7 ppg, and mud 1 has the lowest density of 8.4 ppg. Mud 2 and mud 4 have densities of 8.5 ppg and 8.6 ppg, respectively. Theoretically, the density of the mud gradually increased from mud one to mud four. However, due to the addition of compound B to mud 4, the density decreased by 0.1 ppg. The Fann viscometer readings increased from mud 1 to mud 4 at 300 and 600 rpm and showed an increase in the shear stress. Increasing in shear stress indicated that the fluid is more viscous, and, thus, requires more effort to initiate the fluid movement. The Filter press experiment determined the water loss, mud one loses most of the fluid, 22 mL/30 minutes, and mud four loses the least fluid, 12 mL/30 minutes. Alternatively, mud four has the thickest mud cake with 0.5 mm and the least amount of fluid loss, whereas the higher the fluid loss, the thinner the mud cake with 0.2 mm. In this paper, different experiments related to mud weight, viscosity, gel strength, filtration and yield point were examined to determine the rheology of multiple mud samples, and data were collected to comprehend the effects of various additives on mud. Based on the findings, it is to conclude that the rheological and filtration capabilities improved at a high shear rate. From the perspective of practical side, drilling low-pressure, depleted, and fractured oil and gas reservoirs can benefit from this study's findings by providing environmentally friendly, stable, and inexpensive additives.

INTRODUCTION

Mud is a crucial part of any drilling activities. It has many positive functions; drilling mud may contain various additives depending on the application and desired property enhancement. Water-based mud may be segregated into functional groups. Due to their favorable effects on the environment, the use of Water-Based Muds (WBM) in drilling operations has significantly increased over the past few decades (Bayat, et al., 2021). Failure of the mud to perform as intended can be very costly in terms of time, jeopardize the well's completion, and may create major problems like stuck pipes, kicks, or blowouts, as seen in well-A in the Niger Delta Region, this leaded in decreased rate of penetration, increased torque, and drag, In addition, wellbore instability caused by a poorly designed mud system could result in Non-Productive Time, (NPT) (Aluola, et al., 2022). Drilling fluids, which account for up to 15% to 18% of the overall cost of a well and generally must satisfy three main criteria: Simple to use, affordable and environmentally safe. Consequently, it is crucial to properly plan and select the drilling fluid types to reduce the likelihood of wellbore issues, Water-Based Drilling Fluids (WBDFs), which are

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better for the environment and perform better than oil-(OBDFs), investigated extensively in the last decade in response to growing pressure on the environment. However, environmental protection is difficult to achieve (Li, et al., 2022). Bentonite (1%) and Barite (7%), which make up the total percentage of solids by volume of the Water Based Mud and yield a final weight of 12.5 ppg (pounds per gallon). Prehydrated bentonite was introduced by mixing bentonite with water and waited for approximately 16 hours to hydrate. A High-Pressure High-Temperature (HPHT) viscometer (Chandler Viscometer 7600) is utilized for rheological examination. In addition, the viscometer is intended for rheological investigations for drilling fluids while exposed to changing the well drilling conditions (Biwott, et al., 2019). Mud additives are chosen based on the lithologies, cost, and drilling operations; the focus in the oil sector is on developing environmentally friendly fluids that perform like oil-based muds because of strict environmental legislation, therefore, it is important to investigate naturally based mud to improve drilling mud's rheological properties while also being inexpensive and environmentally friendly, in addition, the study conducted by (Kanjirakat, et al., 2018). looked into how Terminalia mantaly leaves improved the properties of drilling mud when added to water-based mud, moreover, the American Petroleum Institute (API) standard procedures were used to formulate the test and control muds and determine their properties. The achieved results presented that the consistency of the mud test worked on by 18% and 29% for the mud with 1% and 2% T. mantaly leaves were adopted by the temperature and were inside the suggested values at standard temperature of 49°C. However, temperature had an impact on the PV values of the mud containing T. mantaly leaves; a plant sample with a concentration of 4% at 70°C revealed a value of 37 Cp. For plant concentrations of 3 and 4, the formulated mud's yield point increased by 21 percent. For a drilling operation to be efficient, drilling fluid is recognized as a crucial element, and, consequently, extra precautions should be taken in the selection of the application for drilling fluids. In addition, adding various concentrations of Banana Peel Powder (BPP) to water-based mud could be an alternative for an environmentally friendly and biodegradable addition. Using a variety of BPP groups, three distinct studies were conducted to examine the effects of BPP in water-based mud. The readings were effectively recorded using Low-Temperature and Low-Pressure (LTLP) API standard tests for drilling fluid to comprehend the effects of BPP added materials on the characteristics of the mud. Rheometer/viscometer, LTLP filtration, mud balance, chemical titration, resistivity device, and pH and temperature tests were the seven testing methods used (Al-Hameedi, et al., 2020). The pounds per gallon (ppg) is the most frequently used measurement unit for drilling mud density, and the density of water used to produce most of the drilling fluid is approximately 8.3 ppg, where the mud man must be able to efficiently control the mud weight to regulate the formation pressure during drilling operations. Hence, it is vital to continuously monitor, evaluate, and investigate the properties of drilling fluids throughout the drilling operation.

Furthermore, the amount and types of suspended solids, together with time, temperature, and chemical environment, influence the strength of the structure formed. Thus, the tendency of mud to gel is negatively impacted by any circumstance that causes the particles to flocculate or deflocculates (Ali, et al., 2022). The two major types of mud that have been extensively used are water and oil-based, however, most drilling operators worldwide recommended using Water-Based Muds (WBM) due to less environmental impact, and reduced cost compared to Oil-Based Muds (OBM). Fig. 1 presents the summary chart of water-based mud, which is classified into three primary groups, non-inhibitive, Inhibitive and Polymer (Fang, et al., 2022). The term "mud cake" or "filter cake" refers to the deposit of solids on the wellbore walls during the filtration process, which is the partial loss of water phase from drilling fluid into a permeable formation and the primary benefits of the filter cake are protecting the rocks from further filtration and stabilization and preventing issues such as hole carve-in or sloughing, in addition, the properties of a filter cake are influenced by three main types of variable quantity: formulations of drilling fluid, characteristics of the substrate, and operating the parameters. Within static and dynamic filtration tests, the effect of these variable quantities on the properties of the filter cake was assessed. According to the findings of this investigation, the filtration profile that was derived from filtration tests using a substrate, moreover, the process first phase is governed by depth invasion of the grains into the substrate, which results in rocks and a gradual decrease in the substrate's rock properties. Furthermore, since pores were no longer accessible, surface filtration was characteristic of the second regime. As a result, an external filter cake was formed, and the abrupt change in the slope of the filtration profile cake's formation, additionally, substrate means that the pore size did not play any significant impact on the properties of the external filter cake once it had formed, whereas filtration pressure did (Sorrentino, et al., 2022). Numerous considerations must be considered when selecting a drilling mud for a certain drilling operation. Besides the cost, other considerations include well design, predicted formation pressure, rock mechanics, formation chemistry, mud performance, limit formation damage, temperature, environmental consequences, and logistics, therefore, measuring the mud qualities that determine the ability to carry out its function to build and maintain mud is essential (Giambastiani, et al., 2022). The properties of drilling fluids can be physical or chemical and are assessed based on the mud and its filtrate and some of these properties are density, viscosity, gel strength, filter cake thickness and pH. in addition, drilling fluids are often designed to have a higher density than the cuttings for easier and quicker wellbore cleaning, therefore the primary cause of frictional losses during circulation is that typical drilling fluids have lower rheological properties at higher temperatures or higher gel properties, thus one of the difficulties in managing Equivalent Circulating Density ECD and its effects is maintaining constant rheological properties because primary objective as per Taraghikhah is to introduce a water-based flat rheology mud with the intention of enhancing fluid stability, preventing loss circulation(Taraghikhah, et al., 2020). The Rate of Penetration (ROP) can be slow even if there is no fracture in the formation due to excessive mud weight; a sudden decrease in mud weight and an increase in the volume of mud in the tanks are the two clear indications that the well may have kicked and viscous mud may carry heavier cuttings, and frequently contain materials that enhance the viscosity; however, viscosity must be controlled since an overly viscous mud applies an excessive strain on mud pump and may interfere with other necessary well-drilling mud features (Abdelaal, et al., 2022). The viscosity of the liquid can be significantly increased by adding small amount of substance in suspension or in solution due to the closer packing of liquid molecules than gas molecules, which increases the cohesive forces between liquids and gases; as a result, liquids have a higher viscosity than gases, and that viscosity varies inversely with the temperature and pressure (Fritoli, et al., 2021).

The purpose of this paper is to experimentally assess the rheological properties to understand how the rheology of drilling fluids changes, such as plastic viscosity, gel strength, and yield point, and to examine how various additives affect drilling fluid. The experiments were conducted in accordance with sample preparations, which is the most significant step and the materials used to obtain a reasonable result.

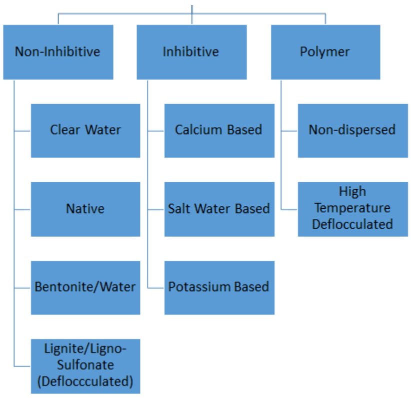

Fig. 1 Schematic for water-based mud.

MATERIALS AND METHODS

Properties of Water-Based Mud

Throughout the whole study, WBM was considered the base fluid. Activities included preparing to evaluate drilling fluid parameters such as density (ppg), plastic viscosity (cp), yield point (lb./100 ft2), gel strength (cp), and filtration loss (ml/30 min). It presents the tool utilized to determine the parameters for mud, in addition, mud used complies with industry standards, consisting of 350 ml of water, 12 g of bentonite, and additional additives that must be mixed well to form a homogenous mud. pH, the hydrogen ion concentration in a solution, can be determined by its pH value. There is an equilibrium hydroxyl (OH^-) ion concentration at each hydrogen ion (H^+) concentration. There is no discernible difference in the concentration of H^+ and OH^- at the neutral point, distilled water with a pH of 7. The pH of the acidic solution varies from 0 to 7, whereas a basic solution has a pH of 7 to 14 (Ignatenko, et al., 2021). Maintaining a pH around and above 9 is preferred in drilling operations because it is desired for all clay and shale particles to be negatively charged. Moreover, most of the used polymers solubilize more readily in alkaline settings, and for the chemicals in the mud to operate properly and to reduce corrosion, the mud must be alkaline, with a pH of 8 to 13. Acids speed up corrosion but are minimized between a pH of 10 and 12 in Fig. 2.

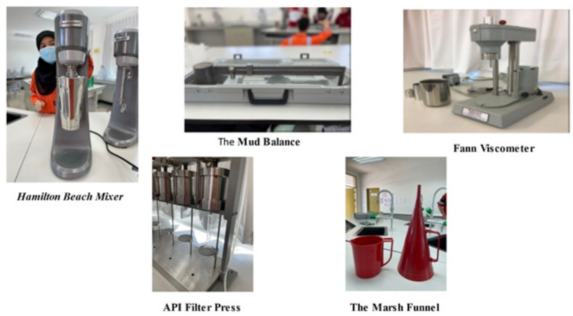

Fig. 2 Mud rheology equipments.

Rheological Mud Models

Rheology studies matters deformation and flows in water-based mud when circulated. The Herschel-Buckley model was used to describe the rheology of the drilling fluid, therefore, the Reynolds number was around 1000, where the flow behaviour changed along with drill pipe revolution per minute, RPM, and the assessment covered the flow regime design, the transport velocity related to the chips according to the drill pipe and ROP. In addition, most of the rock cuttings in the laminar flow were localized in the quasi-solid region, where the rotation for the drill pipe RPM increased and had negligible effect on the integral parameters (Jondahl, et al., 2019). The rheological models that drilling engineers employ to describe the drilling fluids are the Newtonian model and the non-Newtonian model. The viscosity of the Newtonian fluid is independent of the shear rate, whereas the viscosity of a non-Newtonian fluid is shear-rate dependent. Non-Newtonian fluids are prevalent in drilling mud, where acoustic attenuation and rheological properties of Newtonian fluids have been shown to have a non-linear relationship. Additionally, three distinct fluid systems were studied and the fluid systems were weakened by water to give a sum of 33 liquid sets, afterwards, ultrasonic, and rheological properties are estimated, moreover, soft sensors that can estimate rheological properties based on ultrasonic measurements are developed using machine learning models. The difference between Newtonian fluids and non-Newtonian fluids. Bingham plastic fluids are one of the non-Newtonian fluids shown in Fig. 3.

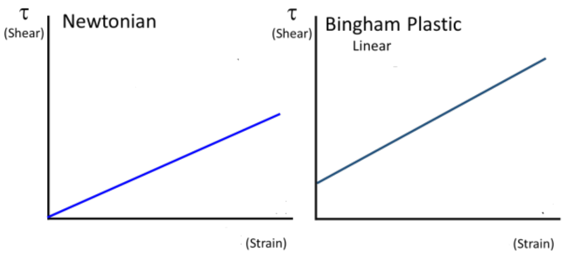

Fig. 3 The rheological models of Newtonian fluids and non-Newtonian fluids.

Newtonian Model

This model is the simplest of all the flow behaviours and the fluids move more freely as the shear stress rises because of a higher shear rate. Alcohol, water, oil, and gasoline are a few examples however Sun conducted an experimental work related to the cuttings accumulation to begin with, the viscosity and differential pressure on the cuttings during their settlement in power-law flow regime are connected with the particle Reynolds number, yet to the flow regime and consistency file (Sun, et al., 2018). when the particle Reynolds number is less than 2.9446, the viscosity becomes higher than the differential pressure during cuttings settlement in Newtonian fluids, but when the particles Reynolds number is greater than 2.9446, the differential pressure becomes greater than the viscosity, eventually if the particle Reynolds number is lower than 1.11, the viscosity assumes a prevailing part in the cuttings settlement in addition, the rock cuttings settlement is caused by the combination of viscosity and differential pressure between the numbers 1.11 and 500, furthermore, the differential pressure takes precedence when the number is greater than 500. Thus, the presence of contaminants may cause these fluids to alter in rheology. Hence it is crucial to emphasize that they should be free of all impurities (Table 1). Also, the shear stress is directly proportional to the shear rate and is mathematically expressed in Equation 1.

$$\mu=\tau/\gamma \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where

μ=viscosity (cP)

τ=Shear stress

γ=shear rate

Non-Newtonian Model

These fluids deviate from Newton's law because there is no direct relationship between shear rate and shear stress. It has been observed that there is a change in shear stress as the shear rate changes Lucky AP rheologists and researchers have consistently demonstrated that the Bingham plastic rheological model does not accurately represent the behaviour of the drilling fluid at very low shear rates in the annulus and very high shear rates at the bit (Lucky, et al., 2018). To correct these anomalies, a dimensionless stress correction factor is required in (Table 2).

Table 1. Functional categories of materials used in WBM

Functional Category	Function	Typical Chemicals
Alkalinity, pH Control	Optimize the mud's pH and alkalinity. Avoid corrosion and hydrogen embrittlement.	Soda Ash Na_2Co_3 Sodium Bicarbonate $NaHCO_3$ pH 9.5 to 10.5
Bactericides	Prevent biodegradation of natural organic additives.	CMC, Xanthan Gum, Glutaraldehyde
Calcium Reducers	Reduce the impact of gypsum, cement, formation anhydrites, and saltwater calcium on mud properties.	Caustic soda (NaOH),Polyphosphates, Soda Ash Na_2Co_3 Sodium Bicarbonate $NaHCO_3$
Corrosion Inhibitors	Prevent corrosion of drill string by forming acids and acid gases.	Amines, Phosphates
Defoamers	Reduce mud foaming	Alcohols, Silicones, Alkyl Phosphates, Aluminum Stearate ($C_{54}H_{105}AALO_6$)
Emulsifiers and Surfactants	Assist formation of stable dispersion of insoluble liquids in the water phase of mud.	Anionic, Cationic, or Non-ionic detergents, Soaps, Organic acids, Water-based detergents
Filtrate Reducers	Reduce fluid loss through the filter cake on the wellbore wall into the formation.	Bentonite clay, Lignite, Sodium Carboxymethyl, Cellulose, Polyacrylate, Pregelatinized Starch
Flocculants	Enhance the viscosity and gel strength of clays.	Inorganic salts, Hydrated, lime, Gypsum, Soda Ash Na_2co_3, Sodium Bicarbonate $NaHC0_3$, Sodium-tetraphosphate. Acrylamide-based Polymers

Lost Circulation Materials	Plug leaks in the wellbore wall. Avoid mud loss to the formation.	Nut shells, Natural fibrous materials, Inorganic solids, Other inert insoluble solids
Lubricants	Minimize torque and drag on the drill string.	Oils, Synthetic liquids, Graphite, Surfactants, Glycols, Glycerin
Pipe-freeing Agents	Prevent the wellbore wall from the pipe sticking	Detergents, Soaps, Oils, Surfactants
Shale-controlling Materials	Control the hydration of shale that results in swelling and shale dispersion.	Soluble Calcium and Potassium Salts, Glycols, Other inorganic salts
Temperature Stability Agents	Increased stability of mud emulsions, rheological characteristics, and dispersions at high temperatures	Acrylic or sulfonated polymers or copolymers, Lignite, Lignosulfonate, Tannins
Thinners	Deflocculates the clays to enhance the viscosity and gel strength of the mud. Reduce viscosity by attaching the clay plates to break plate attachment through the edge or face	Tannins, Polyphosphates, Lignite, Lignosulfonates
Viscofiers	Increase viscosity of mud to suspend cuttings and weighting agent in mud	Lime or cement, Sodium Carboxymethyl Cellulose, (CMC), Xanthan Gum
Weighting Materials	Increase in density (weight) of mud. Balancing formation pressure. Preventing a blowout.	Barite, Hematite Fe_2O_3, Calcite, Ilmenite, Lead Sulfide (PbS)

Table 2. Types of chemical additives for mud

Chemical	Uses
Bentonite (Clay)	A basic component was added, which acts as a viscosifier to get a good filter cake.
Barite	To increase density
Mil Pac	Filtration control agents improve filter cake by reducing permeability.
Xan pleed	To increase/adjust the viscosity

In addition, to determine the consistency of mud along the YP, a Fann rotational Viscometer was utilized initially, the cup was filled with a desired drilling mud to the scribed line, and the two dots on the rotor sleeve entirely submerged in the mixture. The rotation began at various RPMs at 300 and 600; however, 100, 200 existed, but there is no use of such rpms. When the rotor rotated at 300 and 600 rpms, as the dial speed, the readings were recorded once reached to a constant value. Furthermore, gel strength was measured using the same rotational viscometer and recorded, after the Fann Viscometer was adjusted to 3 RPM, and the readings were obtained for 10 seconds and 10 minutes. Using the dial reading obtained from each RPM, the parameters measurements, like the PV, YP and apparent viscosity, have been calculated using Eqs. (2), (3) and (4).

PV = N600 – N300 ………………… (2)

YP (Unit in lb./100ft2) = N300 –…… (3)

Apparent Viscosity (Unit in cp) = (Reading at 600 rp)/2 ….. (4)

The Standard API filter press was used to measure the water loss, and the thickness of the mud cake was evaluated as the device appears Fig. 4. Referring to the drilling fluids practical manual for a detailed step-by-step procedure to experimentally determine the filtration of the mud. Initially, the device was set, and then the data was recorded after 30 min. Besides the data with an interval of 5 min was recorded by a supply of nitrogen gas pressure at 100 psi, which is a low-pressure experiment.

RESULTS AND DISCUSSION

Rheological experiments were performed to determine the parameters of interest in this paper. The test was conducted on four mud samples with different additives (Table 3). Bentonite is used as the base clay, and barium sulfate or barite, compound A and compound B as the additives. Both compounds (A and B) are the products from Baker Hughes. The off-white powder-like substance Compound A is a filtration control additive utilized to regulate the filtration parameters for WBM. Contrarily, compound B appears as a white to brown powder and acts as a viscosifier to improve the viscosity and decrease the water loss. The information acquired during the experiment is presented below in Fig. 4. Based on the data as shown in Table 3, mud 3 has the highest density value, 8.7 ppg, and mud 1 has the lowest density value, 8.4 ppg. Mud 2 and mud 4 have densities of 8.5 ppg and 8.6 ppg, respectively. Theoretically, the density of the mud gradually increases from mud 1 to mud 4. However, due to the addition of compound B to mud 4, the density decreases by 0.1 ppg shown in Fig. 5.

Fig. 4 Bentonite as base clay and additives.

Tab. 3. Four mud samples with different additives

Substance Quantity	Mud Sample			
	1	**2**	**3**	**4**
H2O, ml	350	350	350	350
Montmorillonite, g	12	12	12	12
Barium Sulfate, g	10	10	10	10
Compound A, g	0	2	0	2
Compound B, g	0	0	1.5	1.5

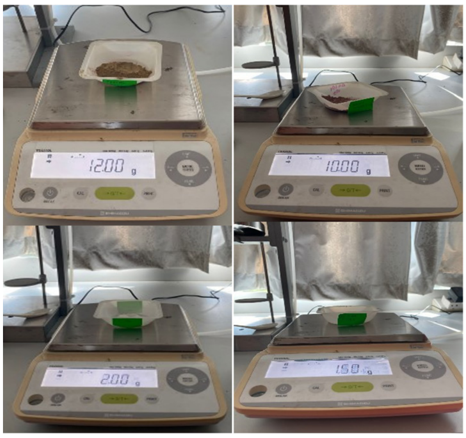

Fig. 5 The mass of bentonite with the additives.

Rheological models, like Newtonian and Non-Newtonian models, were typically used to describe fluid flow and the key measure for such models is the viscosity, to determine the flow rate of the drilling mud under a variety of different conditions (Table 4). According to the results as depicted in shown in Table 4, the Fann viscometer reading increased from mud one to mud four at 300 and 600 rpm, and that shows an increase in shear stress. Increasing shear stress indicates that the fluid is more viscous, and, thus, requires more effort to initiate the fluid movement. There is a meaningful change, as presented in Fig. 6, between mud 2 and mud 3 when compound B was added to the sample, so it is proven that the four different muds show a non-Newtonian fluid behavior because the viscosity does not start from zero.

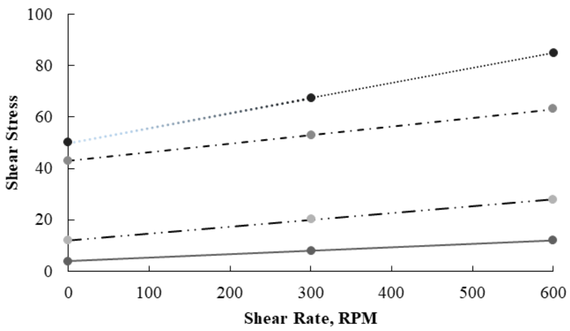

Fig. 6 Shear stress against shear rate for different mud samples. **Note:** ( ) Mud 1; ( ) Mud 2; ( ) Mud 3; ( ) Mud 4.

Tab. 4. Properties measured for different mud samples

Measured Properties	Samples			
	1	**2**	**3**	**4**
Mud weight, lb./gal	8.4	8.5	8.7	8.6
VG 600 reading, lb./100ft^2	12	28	63	85
VG 300 reading, lb./100ft^3	8	20	53	67.5
PV, cP	4	8	10	17.5
YP, lb./100ft^2	4	12	43	50
Gel strength, 10 sec	1	10	4	0.5
Gel strength, 10 min	2	12	1.5	1.5
pH	7	10	10	8
Filter Cake, mm	0.2	0.3	0.4	0.5

In addition, the filter press experiment determines the amount of drilling mud floss, due to its filtering and the thickness of the mud cakes was produced when the mud was pressurized. Furthermore, Table 5 shows mud 1 loses the most fluid, 22 mL/30 minutes, and mud 4 loses the least fluid, 12 mL/30 minutes. The best mud among the four mud samples is Mud 4 because less fluid flow means less fluid would be lost into the formation when subjected to high pressure. It presents the fluid loss for all four mud samples, having the volume of fluid loss in mud 4 being the least and mud 1 being the most is shown in Fig. 7. Alternatively, it is suggested that the formation of the mud cakes is inversely proportional to the filtrate. Mud 4 has the thickest mud cake with 0.5 mm and the least amount of fluid loss, whereas the higher the fluid loss volume, the thinner the mud cake, which is 0.2 mm. Additionally, as the concentration of particles added rises, so does mud cake(Table 5). Identification of the filter cake is crucial since it impacts on the wellbore whole problem like differential sticking, well completion, and wellbore clean-out. The thickness for different mud samples is shown in Fig. 8.

Tab. 5. The fluid loss for different mud samples in ml/min

Fluid Loss Time (min)	Mud Sample			
	1	**2**	**3**	**4**
5	8.5	7	6	4
10	12.7	9	8	6
15	16	11	10	8
20	18.5	13	12	10
25	20.5	15	13	11
30	22	16	14	12

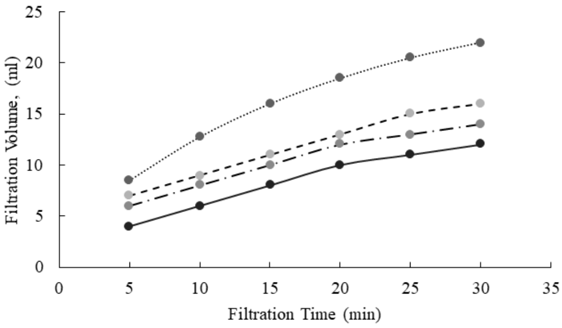

Fig. 7 Location of sawmill in Akure South Local Government Area. **Note:** (——) Mud 1; (— - -) Mud 2; (- - -) Mud 3; (——) Mud 4..

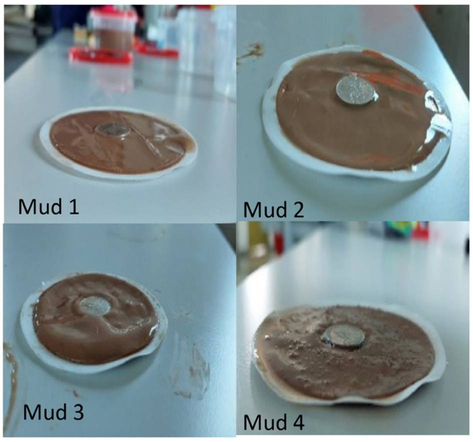

Fig. 8 The thickness of different mud samples.

CONCLUSIONS

The rheological and filtration properties of (Na, Ca) 0.3(Al, Mg)2Si4O10(OH)2•nH2O-BaSo4, Compound A, B were examined to see how concentration affected them. To better comprehend the rheological properties, four distinct rheological models were utilized. Viscosity and gel strength research provided the basis for the proposal of the filtering mechanism. The results of this study can be used to draw the following conclusions:

- From the laboratory experiments, ideal drilling mud can be produced using different tools. The compatibility of the drilling mud depends on the formation that needs to be drilled, and various additives or compounds were added to the mixture to produce the proper type of mud.
- These additives are Barium Sulphate, compound A, and compound B in the experimental work. These additions have various parameters like PV, YP and gel strength that influence the change in behaviour of the resulting mud.
- As more solid concentrations exist in the mud, the volume of fluid loss decreases, and the thickness of the mud cake increases. Because it affects the wellbore operations, including differential sticking, well completion, and wellbore clean-out, therefore,
- It is essential to comprehend the mud cake. All four samples of mud used in this study demonstrated and exhibited a non-Newtonian fluid behaviour.
- The limitation of utilizing the standard mud balance is that it needs to be performed on a flat surface and the balancing scale requires stop flocculating to produce an accurate result. Pressurizing the mud with the small piston-type hand pump will release all trapped gas or bubbles, enabling precise density measurement without the interference of any air.
- The OFITE model 1100 viscometer can be used instead of the standard Fann Viscometer to improve data collection, its speed accuracy (RPM) is 0.001, and while a standard Fann viscometer's is 0.1.

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