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The Positive Impact of Using High Concentration of Pre – Hydrated Bentonite As Hi-Viscosity Drilling Fluids Sweep While Drilling Wells with Lost Circulation

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ABSTRACT
Over the years, drilling wells with lost circulation has been of great challenge in the oil industry. This leads to the loss of liquids in the drilling fluid and in some cases, a huge amount of the drilling fluid is lost in circulation while drilling through formations of severe loss zones. Several methods to combat this issue of lost circulation has been developed, though not without its own challenges and short comings. The use of a Sweep to combat this issue of lost circulation, especially while drilling wells with total lost circulation or drilling without return, has also been developed. The use of Bentonite Sweeps has been prominent in this regard.
This study however considered the impact of concentration or increased concentration of pre – hydrated bentonite on the rheological properties, fluid loss and filter cake formation of the hi – vis sweep used in combating lost circulation, especially as regards to lifting of cuttings from the down hole in cases of total lost circulation.
The result of the study showed that Funnel Viscosity increased simultaneously with increase in the concentration of pre- hydrated bentonite used in preparing the hi – vis sweep samples, indicating that concentration plays a major role in the funnel viscosity of sweeps prepared with pre – hydrated bentonite.
Also, Yield Point and Gel Strength increased with increase in the concentration of pre- hydrated bentonite used. Hence, using a high concentration of pre – hydrated bentonite in sweep preparation would give a good result while drilling wells with lost circulation.
Lower filter cake thickness was formed by the hi – vis sweep samples, with higher concentration of pre – hydrated bentonite, also leading to a lower fluid loss or filtrate volume. Hence, formation of lower filter cake is more suitable to reduce the amount of filtrate passing through it in the course of drilling operations.
Generally, the study shows that concentration of pre- hydrated bentonite used in preparing the Hi – Vis sweep plays a major role in influencing the rheological and other properties of the Hi – Vis sweep. It is therefore advised that higher concentration of pre- hydrated bentonite should be used while preparing a Hi- Vis Bentonite Sweep to enable the lifting of drilled cuttings to the loss zone.

KEYWORDS: Drilling fluids, concentration, pre-hydrated bentonite, hi-vis sweep, oil and gas, drilling challenges, lost circulation, drilling practice, filter cake, viscosity, bentonite, down hole, hole instability, rheological properties, filter cake, fluid loss, gel strength, yield point, plastic viscosity, mud density.

I. INTRODUCTION

In the oil and gas industry, drilling of oil wells involves the use of drilling fluids, which play a major and vital role in the entire drilling operation. Some of these roles include cooling, lubricating and supporting the drill bits, suspending and release of cuttings, removing cuttings from the wellbore, control of formation pressures, sealing permeable formations, maintaining wellbore stability, minimizing formation damage, transmitting hydraulic energy to tools and bit, control of corrosion, facilitating cementing and completion, etc [1, 2, 3]. In the process of drilling, drilling fluids are usually circulated within the wellbore by means of pumps. Losses are usually recorded during circulation of drilling fluids in the course of operations [1]. These losses occur in different degrees and are caused by mainly two factors, which are drilling through naturally occurring faults, fractures, permeable or unconsolidated formation and losses induced due to drilling with high mud weight or ECD (Equivalent circulating density) [3]. The challenge of loss circulation can lead to several drilling problems such as loss of several barrels of drilling fluids, increase in the non – productive rig time, wellbore collapse, formation damage, stuck - pipe, blowout, etc. Also, it leads to higher costs in drilling operations, amounting to several millions of dollars annually [1, 4].

The loss circulation of drilling fluids which can be classified into three; total or complete, partial and seepage loss, shows the extent of losses being experienced in the process of drilling [1, 3]. Total or Complete Loss Circulation occurs when the rate of loss circulation is greater than 500 barrel per hour (bph) [3, 4, 6]. Long horizontal and vertical fractures, vertical fractures with large openings, big voids and other highly permeable zones usually cause this type of loss circulation [3, 5]. Figure 1 below describes the kind of voids involved in total loss circulation. Partial Loss Circulation occurs when the Loss circulation rates is between 10 to 500 bph [5, 6]. This basically occurs in small natural fractures, gravels and vertical fractures with small openings. Finally, the seepage loss category describes the light losses with the loss rate of between 1 and 10 bph [3, 5]. This type of loss circulation can be easily controlled by the reducing or stopping the pumping of mud and allowing the fractures to be filled by the solid phase of mud [7].

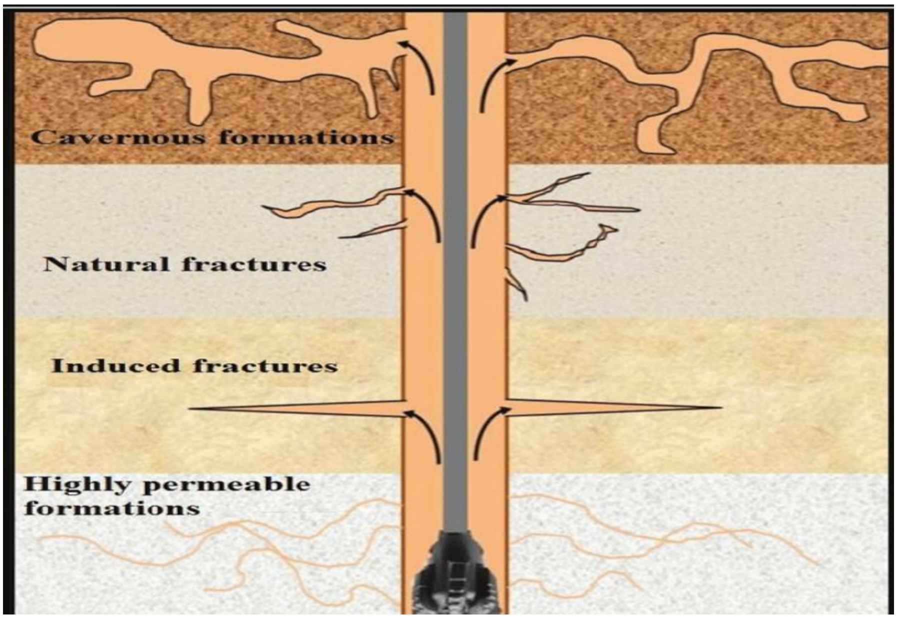

Figure 1 Schematic classification of Loss Circulation [8, 9].

Under normal conditions, losses in drilling fluids circulation are being controlled by the use of loss circulation materials (LCMs) in the formulation of the drilling fluids, depending on the properties of the formation to be drilled [1, 8, 9]. This is however only applicable for the partial loss circulation and seepage loss as described above. But for the Total loss circulation cases, the mere use of only loss circulation materials in the formulation of the drilling fluid is not enough to arrest the problem of losses in circulation [10, 11]. This is due to the very large holes present in the formations which cause total loss circulation [8, 9, 12]. This has posed a very great challenge in drilling through formations with properties that present such problems of total loss circulation.

The negative impacts of total loss circulation are very enormous and of great safety concern, as well as cost increasing [9, 12, 13, 14]. Total loss circulation could result to the following problems;

1. Settling of cuttings at the down/ bottom hole (due to the inability of the drilling fluid to lift cuttings to the surface, caused by the loss of fluids to the large holes in the formation).
2. Low rate of penetration as the settled cuttings will make it more difficult for the drill bit to make fast progress in cutting through the formation and making more holes deeper into the formation.
3. Faster wear of drill bits.
4. Poor well cleaning.
5. Stuck pipe.
6. Longer/ extended time of project completion.
7. Higher cost of drilling operations due to the use of higher amount of drilling fluids as a result of total loss of circulation leading to no returns of drilling fluids sent into the wellbore.
8. Overall wellbore instability due to loss in hydrostatic pressure.

Total loss circulation which can also be referred to as "drilling without returns" therefore has become a very serious challenge in the oil and gas drilling operations [15]. This is because of the numerous drilling problems that it causes, as stated above.

In other to solve this problem of total loss circulation/ drilling without returns, a process called drilling with pre-hydrated hi-bentonite sweep has been developed to enable drillers lift up cuttings from the down hole. Sweep is a special drilling fluid formulated to transport cuttings from the wellbore in order to clean the hole effectively [16]. This is done most times by adjusting the density and viscosity of the drilling fluid being used in drilling in order to be suitable enough to lift cuttings from the down hole, the challenges of total loss not withstanding. The Hi-vis sweep drilling fluid is prepared by increasing only the concentration of the necessary additives that helps to increase the drilling fluid viscosity [15, 16, 17]. Some of the various weighting agents and viscosifying agents may be used for this purpose. There may be cases where only the drilling fluid density is adjusted and such sweep is referred to as "Weighted Sweep" [18]. While in some cases, only the viscosity of the fluid is adjusted and is called "High Viscosity (Hi – Vis) Sweep" [17, 18]. Bentonite is one of the generally used viscosifiers in drilling fluid formulations (spud drilling fluids) and also finds application in preparation of a Sweep.

However, the concept of using well "pre – hydrated bentonite" as sweep while drilling wells without returns has proved to be successful and effective in lifting cuttings from the down hole [9, 10, 11, 12 13, 19]. The sweep prepared with pre – hydrated bentonite as the viscosifier can be referred to as "Bentonite Sweep". Using a sweep with high viscosity can be very beneficial in drilling wells without returns (total loss circulation), in directional and horizontal wells, where cuttings tend to settle at the low side of the well due to gravity [19, 20]. Such characteristics as high viscosity, increased shear rate, which facilitates the maintenance of viscosity even under high flow rates, and higher mud weight, which may slightly exceed that of the base drilling fluid, which gives it more buoyancy, makes the Sweep suitable for drilling operations in wells without returns. Some of the importance of using Sweep include effective removal of cuttings and debris from the annulus, by moving them to the loss zone thereby preventing stuck pipe by avoiding the accumulation of cuttings in the down hole and reducing friction, and enhancing drilling efficiency by improving hole cleaning and reducing drilling time [21].

It is believed that the use of high concentration of well Pre – Hydrated Bentonite as Sweep in drilling such wells with loss circulation will be very effective in lifting cuttings and avoiding most of the problems associated with drilling such wells. This study therefore focuses on the positive impacts of using high concentration of Pre – Hydrated Bentonite as Sweep while drilling wells with loss circulation.

FIELD PROVEN PRACTICES THAT SUPPORT THE EFFECTIVENESS OF HI-BENTONITE SWEEP IN TOP HOLE DRILLING SECTIONS (22", 16" 12.25").

1. During active drilling activity, spotting high bentonite sweep at the bottom of the wellbore before making fresh connections helps in preventing cuttings from settling to the bottom of the wellbore, this is made possible because of the great suspension ability of the pre-hydrated bentonite [22].
2. Pumping 30 bbls of this sweep after each 45ft drilled helps to sweep and get the equivalent currings drilled out of the wellbore.
3. Spotting a high concentration pre-hydrated bentonite sweep, with slight increase in weight at the bottom, at section TD, helps suspend left-over cuttings to enable smooth casing run.

II. MATERIALS AND METHODS

2.1 EXPERIMENTAL DESIGN

In the course of this study, experiments were carried out using various drilling fluid samples prepared as sweep for the removal of cuttings from the down hole during drilling operations. The sweep samples were formulated with different concentrations of Pre – Hydrated Bentonite. The Bentonite used in all the sweep samples was added to the water to be used for preparing the sweep and allowed to soak for 16 hours in order to allow for proper Pre – Hydration.

A total of 6 sweep samples were prepared and used for experiment/ analysis. These sweep samples were prepared using different concentrations of pre hydrated bentonite, in order to ascertain the effect of concentration on the effectiveness of the sweep in lifting cuttings, evidenced by the weight, rheological, filtration and filter cake formation properties exhibited by the different sweep samples.

The concentrations of pre hydrated bentonite used in the preparation of the sweep samples are 20ppb, 25ppb, 30ppb, 35ppb, 40ppb and 45ppb. Based on the fact that 1lab barrel = 350cm^3, the following weights of bentonite was used for pre hydration and in the final sweep preparation. The first sweep sample was prepared using 20g of bentonite, while the second sweep sample was prepared using 25g of bentonite. The third sweep sample was prepared using 30g of bentonite, the fourth sweep sample used 35g of bentonite, the fifth sweep sample used 40g of bentonite and the sixth sweep sample used 45g of bentonite.

The API bentonite powder samples were obtained from a certified vendor. The samples were further manually cleaned during inspection to remove traces of foreign materials. Then the samples were placed in an oven at 105 ^{o}C for 3-4 hours. This was done to remove their moisture content and thus obtain dry samples. The experiments were conducted in accordance with the standard stipulated in API RP13B-1; recommended Practice Standard Procedure for Field Testing of Water-Based Drilling Fluids/mud [1, 3]. Being a Water based drilling fluid, water was used as the base fluid throughout the study. The experimental analysis of this study, which includes; Density, Rheology, MBT, Filter cake formation and filtration test was conducted. All experiment was done in triplicates and the average value reported.

2.2 PREPARATION OF SWEEP SAMPLES

The test was carried out on drilling fluids of appropriately measured samples. It was based on the fact that 1gm/350cm³ of the sample is equivalent to 1lb/bbl (42gal) of the actual mud system [3]. Also 8.33cm³/350 is equivalent to 1gal/bbl (42gal) of the actual mud system. 1lab barrel = 350cm³ (final volume 1gm=1b, 1gallon = 8.33cm³) [1, 3]. The water-based drilling fluid (sweep) was formulated by adding appropriate concentrations of the materials into the base fluid (water) to obtain 1bbl (350ml) with measured mass. A Hamilton beach mixer was used to obtain a homogenous mixture. Bentonite takes some time to properly hydrate and subdivide to make a thoroughly dispersed clay in water [23,24]. For this reason, before preparing the sweep samples, bentonite was dispersed in water, (already treated for hardness with soda ash and PH adjusted with caustic soda) using a Hamilton beach mixer and left for 16 hours to allow complete hydration. Bentonite was added slowly into the water while mixing to avoid the formation of clusters which may take longer than usual time to disperse. After the mud has been mixed and kept overnight for the desired duration (16 hours) for pre – hydration, it was mixed again for 2 minutes before the addition of other additives. Polymers are one of the key additives used in WBM. It is very important that polymeric additives are properly mixed into the mud system to obtain uniform consistency in mud [25, 26, 27]. Due to this fact, the Xanthan Gum polymer was added in pre – hydrated bentonite slurry with a very slow rate in stepwise manner (0.05 – 0.10 g at a time). This ensured that the polymer (Xanthan Gum) did not make lumps in which solid material is covered by wet film of polymeric membrane preventing dissolution of inner dry polymer. After the addition and proper mixing of the Xanthan Gum, other additives to the sweep were added and mixed accordingly. Below is the formula for mud samples developed for the study.

Table 1 BENTONITE SWEEP FORMULATION

S/N	MATERIAL	SWEEP 1	SWEEP 2	SWEEP 3	SWEEP 4	SWEEP 5	SWEEP 6	MIXING TIME
1	Water	350g	350g	350g	350g	350g	350g	1
2	Soda Ash	0.5g	0.5g	0.5g	0.5g	0.5g	0.5g	4
3	Caustic Soda	0.5g	0.5g	0.5g	0.5g	0.5g	0.5g	4
4	Bentonite	20g	25g	30g	35g	40g	45g	20
5	Xanthan Gum	4g	3g	2g	1.5g	1g	0.5g	10

PROCEDURE: The sweep samples were prepared using the formula stated in table 1 above. The mixing order was according to the numbering and the mixing time stated above. The Hamilton Beach mixer was used for efficient mixing.

2.3 DETERMINATION OF BENTONITE SWEEP DENSITY

Drilling fluid density is used to control subsurface pressures and stabilize wellbore and it is commonly measured with a mud balance capable of +0.1lb/gal accuracy. A mud balance calibrated with fresh water at 700 + 50 should give reading of 8.3 lb/gal [3]. When drilling through the wellbore, a cylinder of rock is replaced with a cylinder of drilling fluid. The first critical step towards designing a drilling fluid is to establish the mud weight required to provide the correct level of borehole pressure support. Mud balance is the instrument used for drilling fluid density determination. The mud balance is designed such that the drilling fluid holding cup at one end of the beam is balanced by a fixed counter weight at the other end with a sliding weight rider free to move along a graduated scale.

PROCEDURE:

1. The cup of the mud balance was filled to the brim.
2. The filled mud cup was covered with the cap to allow excess mud and air out of the cup.
3. The mud balance was cleaned of any excess mud while holding the cap tightly to the cup.

4. The mud balance was made to balance on the provided knife edge using the rider.
5. When balanced, the reading on the scale as indicated by the arrow was recorded.

2.4 DETERMINATION OF RHEOLOGY

The Mash Funnel and the Graduated mud Cup was used to determine the Funnel Viscosity. The FANN 33 viscometer was used to measure the plastic viscosity (PV), yield point (YP), and gel strength. Rheological properties measured with a rotational viscometer are commonly used to indicate solid buildup flocculation or de-flocculation of solids, lifting and suspension capabilities, and to calculate hydraulics of drilling fluid. A rotational viscometer is used to measure shear rate or shear stress of drilling fluid from which the Birmingham Plastic parameters; plastic viscosity (PV) and yield point (YP) are calculated directly. The instrument was also used to measure gel strengths. The plastic viscosity is due to the physical size and presence of any solids or emulsified droplets in the fluid. The PV should be as low as possible and to reduce the PV we need to reduce the solids as well. The yield point is the viscosity due to the chemical attraction between the particles and to increase the YP, we need to add products with attractive forces. The Gel strengths refer to the increase in viscosity at zero shear rates. It is a measure of the attractive forces under static conditions. The equations to calculate the rheological properties, plastic viscosity and yield point are stated in equations below. The gel strength was read directly from the viscometer.

Plastic viscosity (PV) = $\Theta600 - \Theta300$ (1)

Yield point (YP) = $\Theta300 – PV$ (2).

PROCEDURE:

Place the VG Meter cup containing the sample on the VG Meter platform and raise the platform until the mud level reaches the scribed line around the VG Meter sleeve.

1. Tighten the screw to hold the platform in place while using the VG Meter.
2. Pull the red knob up or push it down only with the meter running.
3. Toggle the switch in the high-speed position, the sleeve will be turning at 600rpm. The first reading will be taken at 600rpm. Record the reading.
4. Toggle the switch to the low-speed position with the red knob still all the way down. This will shift the sleeve to 300 rpm where the second reading is taken. Record the reading.
5. Push the toggle switch off for 10 seconds. After 10seconds push the switch back on to the low-speed position while watching the dial. The dial turned to a high number and then fell back to a lower value. The highest dial value is taken before it dropped back as the 10sec Gel strength.
6. The VG meter cup is turned off again without changing the position of the red knob for 10mins. After 10mins the toggle switch is pushed low while watching the dial. The highest value reached before the dial falls back is the taken as the 10mins Gel strength.
7. The procedure is repeated for with all the LCM mud samples.

2.5 DETERMINATION OF FILTRATE VOLUME AND FILTER CAKE THICKNESS

This test determines the rate at which fluid is forced through the filter paper under specified conditions of time, temperature and pressure. The test is conducted at 100psi and the filtrate volume is read and recorded after 5mins, 10mins, 15mins, 20mins 25mins and 30mins. The thickness of the solid filter cake deposited 32nd of an inch is measured after the test.

PROCEDURE:

1. Mount the API filter press apparatus on the work table.
2. Remove the cell from the rack if not already removed disassemble the cell.
3. Fill the cell with mud sample to 3-4cm to the brim of the cell.
4. Cover the cell body with the regulator cap and place the assembly into the filter press stand.
5. Back off the T screw on the regulator fully but without removing the t-screw. Place the CO_2 cartridge in the cartridge barrel and fasten to puncture the cartridge (ensure no leakage of CO_2).
6. Place a 25ml graduated measuring cylinder under the cell to collect the filtrate.
7. Pressurize the cell to 100psi by turning the T-screw clockwise and pushing the red knob in.
8. Start the timer and run the test for 30mins. Values of mud filtrate were taken at 0-5 th mins, 5 th – 10th mins, 10th - 15th mins, 15th – 20th mins, 20th – 25th mins and 25th – 30th mins.
9. The filtrate volumes were recorded and the filter cake thickness observed.

2.6 METHYLENE BLUE TEST

Methylene blue test is an API-approved standard of knowing the exact quantity or concentration of bentonite in the drilling fluid. The higher the concentration, the more the bentonite yields during the pre – hydration process, this helps to form a good filter cake downhole, it's a very crucial test to be carried out on the field, as test results can show if more bentonite are picked from the formation while drilling.

PROCEDURE:

1. Place 10ml of distilled water in a 250ml Erlenmeyer flask.
2. With the aid of syringe, add 2ml of properly stirred mud to the flask.
3. Add 15ml of 3% hydrogen peroxide (H_2O_2) to the flask.
4. Add 0.5 (10 drops) of 5N sulphuric acid (H_2SO_4) to the flask.

Note: the peroxide and sulphuric acid are oxidizers which are added to destroy the polymers and organic compounds that will also absorb methylene blue.

5. Mix by swirling, then place the Erlenmeyer flask on a hot plate and gently boil it for 10 minutes (to speed up the reaction of the oxidizers). After 10 minutes remove the flask from the hot plate and add distilled water to bring the volume to 50ml.
6. Use the 5ml disposable pipette to add methylene blue to the flask, 0.5ml at a time.
7. After each addition, stir it gently for about a minute and then dip a stirring rod in the sample and put the drop of sample on the stirring rod on a large piece of filter paper, keeping track of how much methylene blue has been added for each drop. Initially each drop on the filter paper will have a clump of dark blue solids in the center surrounded by water. The dark blue is the clay solids and they are blue because they have absorbed the blue dye of Methylene Blue. At some concentration of the methylene blue, the clays will not be able to absorb any additional dye. At that point, there will be a clear light blue halo, without mud solids, surrounding the dark blue solids. Stir very well without adding additional methylene blue and test the sample again with another drop of sample, if the halo persists without the addition of more methylene blue, this is the end point. If the halo disappears after stirring, add another half millilitre ($^1/_2$ml) of methylene blue and check again until the halo persists.
8. The MBT is reported on the mud check as equivalent pounds per barrel of bentonite.

MBT (Bentonite eq lbs/bbl) = (vol. Methylene Blue, ml x 5)/ ml of mud. Record the calculated value.

9. Clean and replace all materials used for the MBT test.

III RESULTS AND DISCUSION

The results of the experiments for the measurement of the already stated properties of the six formulated sweep samples are presented here. All the experiments were done in triplicates and the average values reported. These results are hereby presented and discussed.

3.1 ANALYSIS OF PREHYDRATED BENTONITE SWEEP

Drilling fluid samples were formulated according to standard API procedure.

The results of the analyses carried out on the prepared mud samples are presented and discussed below. They include mud density/ weight, funnel viscosity, plastic viscosity, yield point, gel strength, fluid loss or filtrate test and mud/ filter cake thickness and methylene blue test.

3.2 DRILLING FLUID DENSITY

Drilling fluid density is a very important property of the drilling mud because it is important in controlling the formation pressure while drilling and very important in maintaining the wellbore stability.

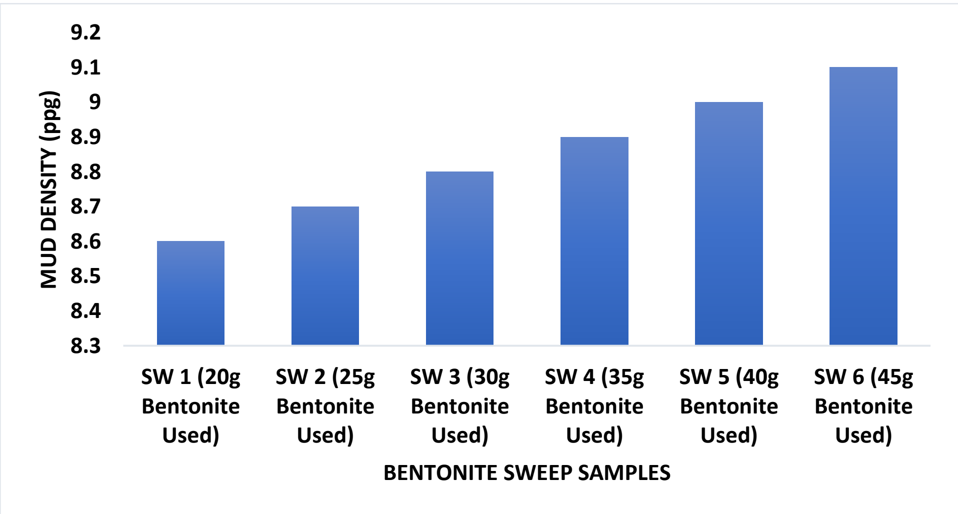

Figure 1 Mud Density

From the result in figure 1 above, it can be seen that SW 6 (45g Bentonite Used) had the highest weight of 9.1 ppg, followed by SW 5 (40g Bentonite Used) and SW 4 (35g Bentonite Used) with 9.0 ppg and 8.9 ppg respectively. Also, the SW 1 (20g Bentonite Used) had the least weight of 8.6 ppg, followed by SW 2 (25g Bentonite Used) with 8.7ppg.

Generally, all the bentonite sweeps samples had a good mud weight, which is good enough for surface – hole drilling purpose, and has the capacity to lift suspend and lift cuttings form the wellbore, while drilling without returns.

The results of the mud density or mud weight obtained from this study shows that mud weight increases uniformly as the amount of bentonite used in preparing the sweep sample increases.

3.3 RHEOLOGY PARAMETERS

The FANN 35 viscometer was used for the experiment and the result of the VG meter readings were used for calculations to generate the values for the Plastic Viscosity, Yield Point and gel strength, while the funnel viscosity was determined using the Marsh funnel and graduated mud cup. The results are presented in figure 2 to 5 below.

3.3.1 FUNNEL VISCOSITY

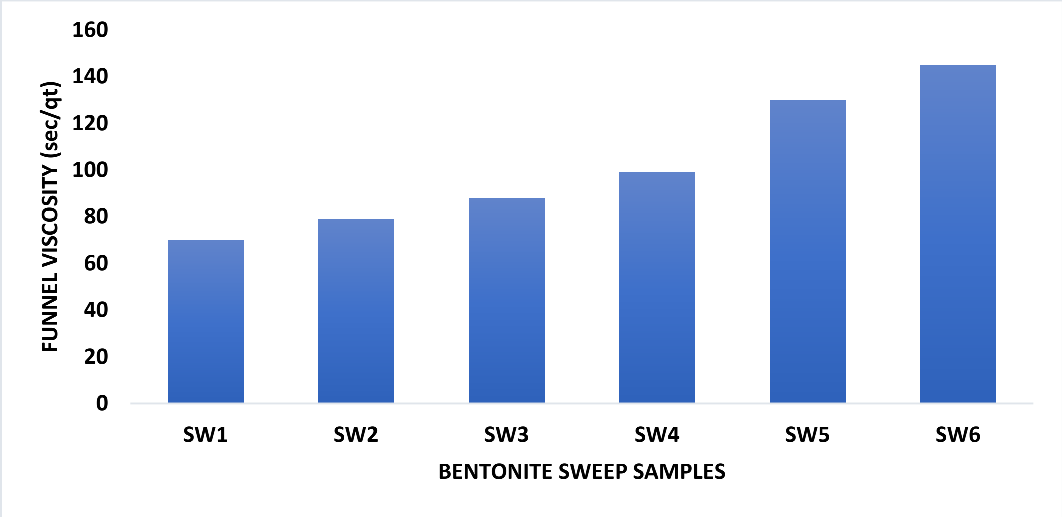

Figure 2 Funnel Viscosity

Funnel viscosity is defined as seconds for one quart of mud to flow through a Marsh funnel. It is a measure of the resistance of flow observed in a suspension, without considering the underlying interactions. Funnel viscosity quantifies the flowability of the drilling fluids. It is not a true viscosity but serves as a qualitative measure of how thick the mud is. The unit is sec/qt.

The study reveals that SW6 had the highest Funnel Viscosity (145 sec/qt), followed by SW5 with 130 sec/qt, while SW1, had the lowest (70 sec/qt), followed by SW2 with 79 sec/qt. SW3 and SW4 had 88 sec/qt and 99 sec/qt respectively.

The result shows a high funnel viscosity for all the sweep samples. This is necessary as what was intended is a Hi- Vis Bentonite Sweep. The verry high viscosity exhibited by the sweep samples is necessary to enable them lift cuttings from the wellbore down hole.

It can also be seen that the higher the concentration of pre- hydrated bentonite used in preparing the sweep, the higher the funnel viscosity. This shows that concentration of pre- hydrated bentonite used in the sweep plays a major role in influencing the viscosity of the sweep. It is therefore advised that the use of higher concentration of pre- hydrated bentonite should be used while preparing a Hi- Vis Bentonite Sweep.

3.3.2 PLASTIC VISCOSITY

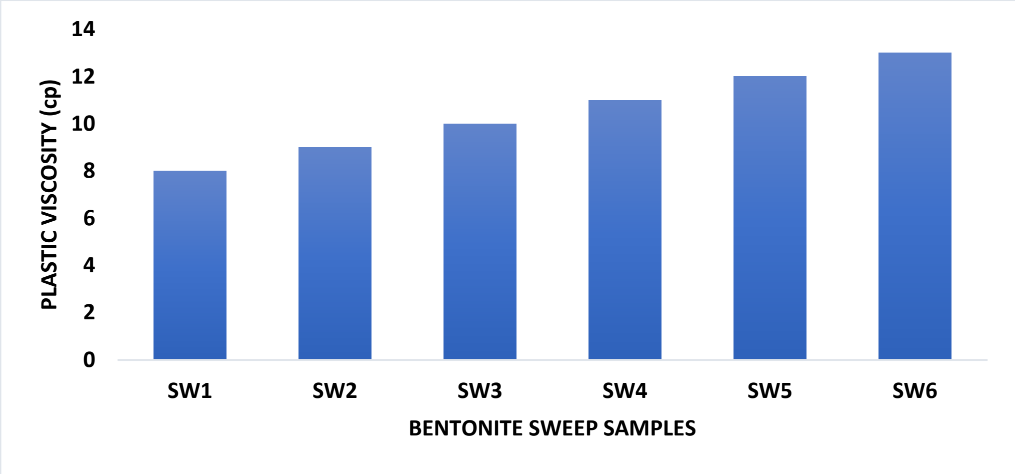

Figure 3 Plastic Viscosity

Plastic viscosity PV is a combination of resistance to flow caused by the friction between the suspended solids and the based fluid in the drilling fluid. A high PV may be caused by viscous base fluid and excess solids. A high plastic viscosity is associated with wellbore problems, while the low plastic viscosities at high temperature indicate that the mud formulations are lubricious and are capable of a fast rate of penetration (ROP). Mud formulations that retain their rheological properties and have low PV at high temperatures are suitable for use as drilling fluids.

The result of the study showed that SW6 with 13cp had the highest PV, followed by SW5 with 12cp, while SW1 with 8cp had the lowest PV followed by SW2 with 9cp. SW3 and SW4 had a PV of 10cp and 11cp respectively. The result showed that the PV increased simultaneously with increase in the concentration of pre-hydrated bentonite used in preparing the sweep samples.

3.3.3 YIELD POINT

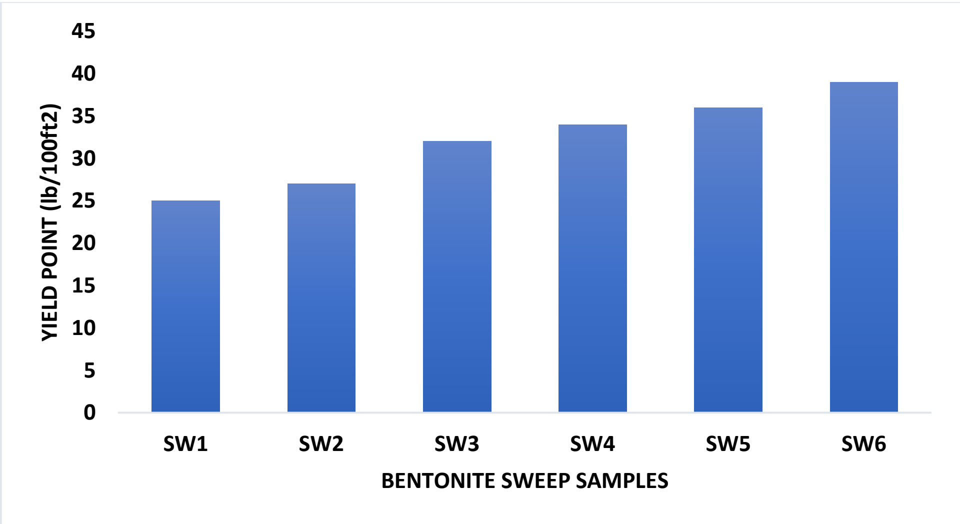

Figure 4 Yield Point

Yield Point YP shows an indication of the drilling mud to suspend weight materials and remove cuttings from the wellbore. It reflects the resistance to initial flow or the stress required to initiate fluid movement. A mud with higher yield point will carry cuttings better than the one with lower yield point, even if both have the same mud density.

The result of the study shows that SW1 had the least YP of 25 $lb/100ft^2$, SW6 had the highest YP of 39 $lb/100ft^2$, followed by SW5 with 36 $lb/100ft^2$. SW2 had YP of 27 $lb/100ft^2$, SW3 had 32 $lb/100ft^2$, while SW4 had 34 $lb/100ft^2$.

This result as can be seen in figure 4, shows that SW6 with SW5 has the highest capacity to suspend and release cuttings from the wellbore.

3.3.4 LOW SHEAR RATE YIELD POINT

Low shear rate yield point is a measure of the viscosity and rheological properties of a fluid, particularly drilling fluids, at low shear rates. It represents the minimum stress required to initiate flow in a fluid at low shear rates. It is a critical parameter in evaluating a fluid's flowability, pumpability, and settling characteristics. It helps to predict fluid behaviour during static conditions e.g in the annulus. It also helps to optimize drilling fluid formulations and ensures effective hole cleaning and suspension of solids. A good LSRYP value indicates reduced settling ability and improved suspension ability. While a higher value indicates increased viscosity, greater settling tendency and reduced flowability.

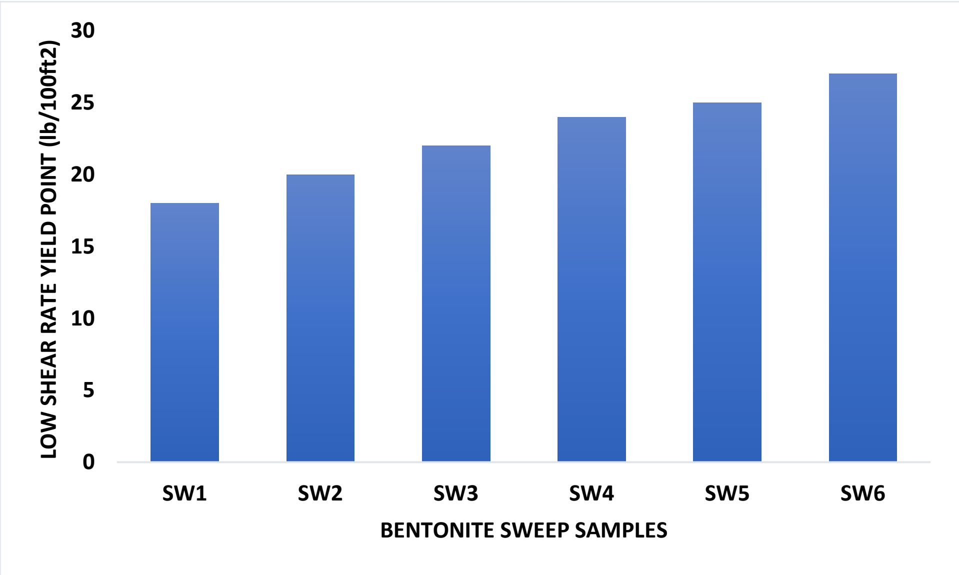

Figure 5 Low Shear Rate Yield Point

The result shows that SW1 had the least value of LSRYP with 18 lb/100ft^2, followed by SW2 of 20 lb/100ft^2. While SW6 had the highest value of 27 lb/100ft^2. Generally, the results shows that the LSRYP increases with increase in the concentration of the pre – hydrated bentonite used in preparing the sweep samples. Also, the values of the various sweep samples show a good ability to suspend solids and ensure proper hole cleaning.

3.3.5 GEL STRENGTH

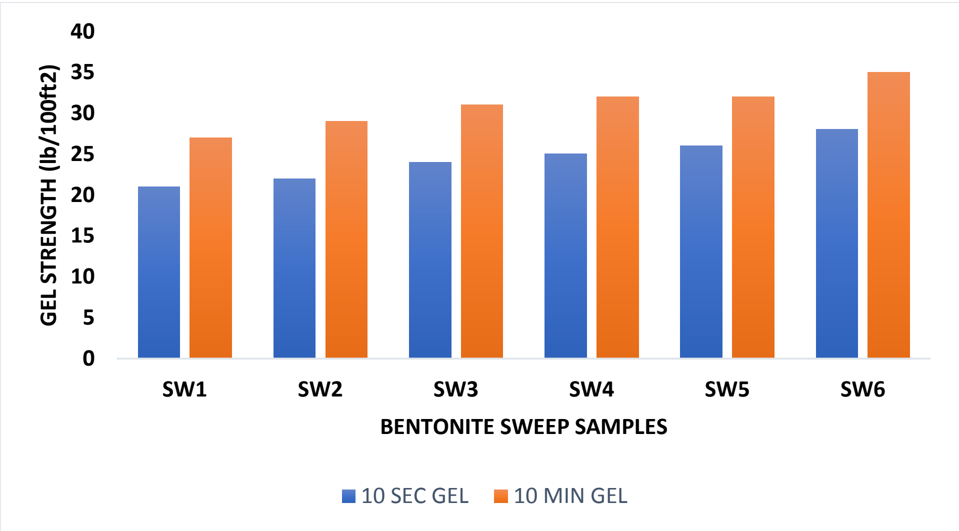

Figure 6 Gel Strength

Gel Strength is a property of mud that enables it suspend cuttings when pumping or circulation has been stopped. It measures the attractive forces of mud particles under static conditions for 10 seconds and 10 minutes. It also helps to determine if cuttings would settle in the wellbore under static conditions. The ability to

maintain the proper value of gel strength depends on effective solids control. A reasonable gel strength is vital to prevent immediate settling of solids when circulation has stopped.
From the result of the study, SW1 had the least Gel Strength (21 lb/100ft^2 and 27 lb/100ft^2 for 10sec and 10min gel respectively), while SW6 had the highest Gel Strength (28 lb/100ft^2 and 35 lb/100ft^2 for 10sec and 10min gel respectively) as shown in figure 6.
Generally, it can be seen that most of the bentonite sweep samples that showed a high yield point also had a high gel strength. Also, we notice that for all the sweep samples used in the study, Gel Strength increased with increase in the concentration of pre- hydrated bentonite used.

3.4 FILTRATION TEST

3.4.1 FLUID LOSS WITH RESPECT TO TIME

The term Fluid Loss or mud filtrate is used to refer to the fluid of drilling mud that filters into the formation in the process of drilling. It is the liquid part of mud which passes through a medium and become separated from the mud cake or filter cake. Reducing the volume of filtrate in drilling operations can reduce several problems associated with drilling.

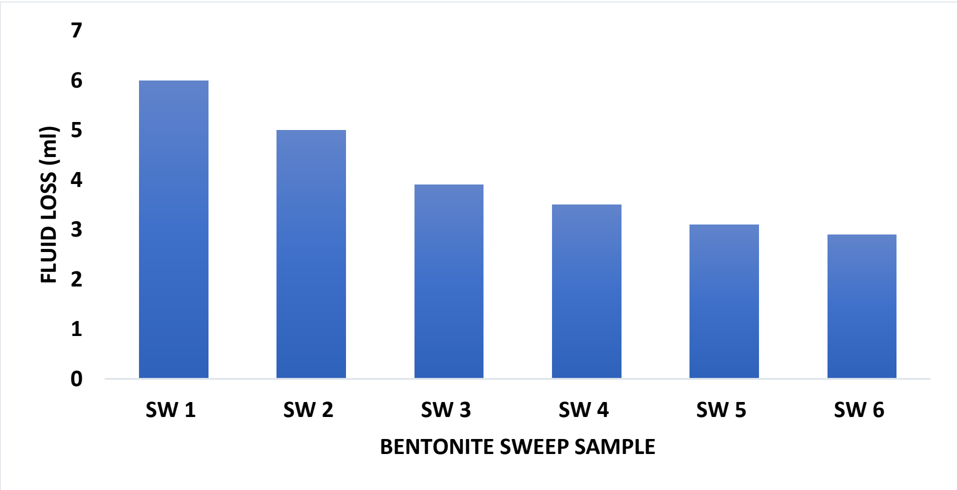

Figure 7 Fluid Loss

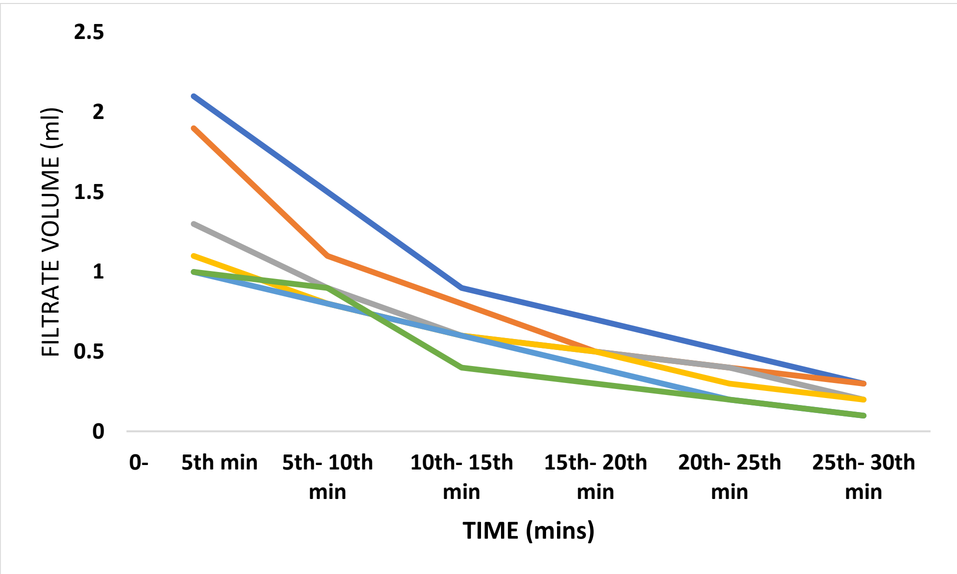

Figure 8 Filtrate Volume with Respect to Time

The result in figure 7 shows that SW1 had the highest filtrate volume of 6ml, followed by SW2 with filtrate volume of 5ml, while SW6 had the least filtrate volume of 2.9ml, followed by SW5 which had 3.1ml, over a period of 30 minutes, when the API Filter press was used to determine the filtrate volume of the sweep samples at 100psi.

Figure 7 shows that the sweep samples prepared with higher concentration of pre- hydrated bentonite (SW4, SW5 and SW6) had much better filtrate control ability as they recorded moderate to low filtrate volumes. It therefore advisable to use higher concentration of pre- hydrated bentonite while preparing a sweep when drilling formations with total loss zone or drilling without returns.
Figure 8 shows a relationship between fluid loss or filtrate volume of the various sweep samples under review and time. This shows that the amount of fluid being lost from the sweep reduces with respect to time in the course of drilling operation. This could be understood, as more filter cake is formed with time, plugging of the porous formation and thereby reducing the amount of filtrate seeping into the formation.
However, the rate at which the volume of fluid lost from the mud with time varied for different sweep samples, as shown in figure 8.

3.4.2 FILTER CAKE THICKNESS

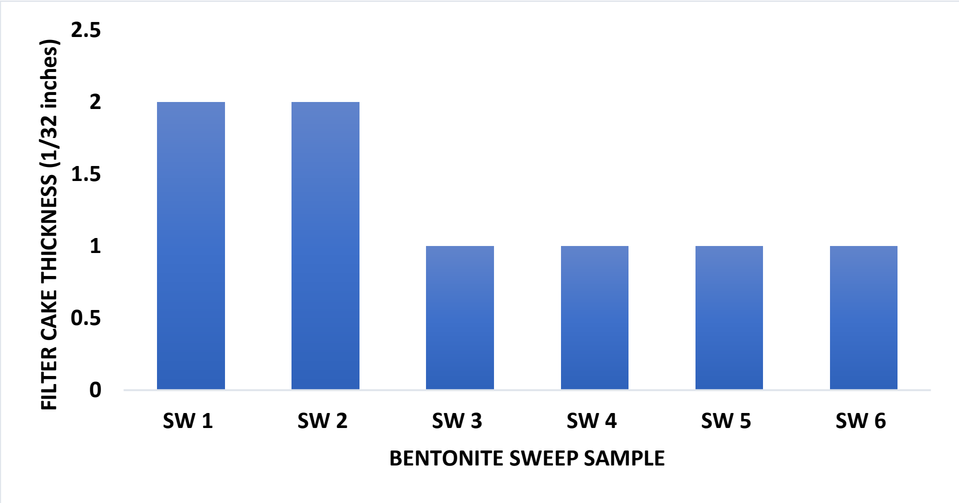

Figure 9 Filter Cake Thickness

Filter or mud cake is a very thin layer of solid particles deposited from the drilling fluid onto the surface of the drilled formation. This is very important during drilling process because it helps to reduce fluid filtrate invasion, thereby contributing to the wellbore stability. In drilling operations, it is better to have a filter cake that is impermeable and thin. Thin mud cake is always desired because thick mud cake would lead to increase in torque, drag while tripping out of the hole or logging, and can cause differential sticking.
From the results shown in figure 9 above, SW1 and SW2 had the highest filter cake thickness of $^{2}/_{32}$ inch each, while the rest had a filter cake thickness of $^{1}/_{32}$ inch each.
From the results, there is an indication that the higher the filter cake thickness, the higher the filtrate volume. The lower filter cake thickness of SW6, SW5, SW4 and SW3 makes it more suitable to reduce the amount of filtrate passing through it in the course of drilling operations.

3.5 METHYLENE BLUE TEST

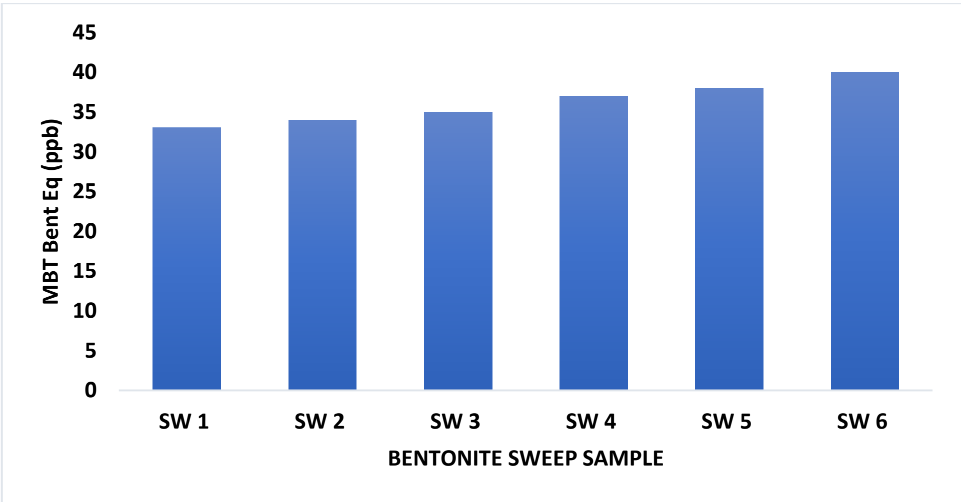

Figure 10 Methylene Blue Test

The result shows that SW1 had the lowest value of 33ppb, followed by SW2 of 34ppb, while SW6 had the highest value of 40ppb. This shows exactly that the actual concentration of active clay in the entire samples was highest in SW6, being the sample with the highest concentration of bentonite in the preparation of the sweep samples. Hence, the higher the actual active bentonite in the sweep, the higher the value of the MBT result and vice versa.

IV. CONCLUSION

After a careful consideration and study of the results obtained in the course of this study, the study hereby concludes thus;

The higher the concentration of pre- hydrated bentonite used in preparing the sweep, the higher the funnel viscosity. This shows that concentration of pre- hydrated bentonite used in the sweep plays a major role in influencing the viscosity of the sweep. It is therefore advised that higher concentration of pre- hydrated bentonite should be used while preparing a Hi- Vis Bentonite Sweep.

Most of the bentonite sweep samples that showed a high Yield Point also had a high Gel Strength.

Yield Point and Gel Strength increased with increase in the concentration of pre- hydrated bentonite used in preparing the sweep samples, indicating that concentration plays a major role in the yield point and gel strength of Hi – Vis sweeps prepared with pre – hydrated bentonite. Hence, using a high concentration of Pre – Hydrated Bentonite in Hi – Vis sweep preparation would give a good result while drilling wells with loss circulation.

The lower filter cake thickness formed by the sweep samples, the lower the fluid loss or filtrate volume. Hence, formation of lower filter cake is more suitable to reduce the amount of filtrate passing through it in the course of drilling operations.

The study therefore concludes that concentration of **Pre- Hydrated Bentonite** used in the **Hi – Vis Sweep** plays a major role in influencing the rheological and other properties of the sweep. It is therefore advised that higher concentration of **Pre- Hydrated Bentonite** should be used while preparing a **Hi- Vis Bentonite Sweep**.

V. RECOMENDATIONS

It is recommended that further studies be carried out to compare the effectiveness of using pre – hydrated bentonite as a sweep and using non pre – hydrated bentonite as sweep when drilling through loss circulation zones.

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