BANANA TRUNK AS A LOST CIRCULATION MATERIAL IN HYDROCARBON DRILLING FLUID

by

Mohd Amirul Hakim Bin Sulaiman

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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Approved by,

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

DECEMBER 2008

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Mohd Amirul Hakim Bin Sulaiman

ABSTRACT

This project concerns on the investigation of the effect of banana trunk derive from plant waste as a lost circulation material in water-based drilling fluid. The objectives of this project are to determine the effect of banana trunk on density and rheological properties of drilling fluid, to compare the change in properties of drilling fluid between banana trunk, corn cobs and sugar cane and also to determine the suitable particle size of banana trunk between 63μm and 125μm as a lost circulation material in water-based drilling fluid for respective selected core sample through formation damage system test. For this project, water-based drilling fluid is used. The loss of drilling fluid is usually more costly for oil-based fluids because the base fluid is more expensive but the loss of fluid can be quite costly with water-based fluid because of the chemicals in the fluid. Banana trunk which contains a flattened, modified stem called pseudostem consisting layers of leaf sheath and crown of large leave contain of fibers which is potential to use as a loss circulation material. Tests have been conducted in accordance with the by API RP 13B-1 procedure and the related equipments used are mixer, mud balance, viscometer and formation damage system device. Properties measured through this experiment are density, plastic viscosity, yield point, 10 seconds and 10 minutes gel strength, pH and permeability for formation damage test. The pesudostem will undergo drying, dehumidifying, grinding and sieving process. The blend of pseudostem added in drilling fluid will be large enough to form bridge of material in the fracture or cavern formation. The results show that the rheological properties of drilling fluid increase in value as the amount of banana trunk added increase. Through formation damage system test, it shows that 63μm particle size of banana trunk was efficiently act as lost circulation material for this core sample as compared to 125μm particle size.

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INTRODUCTION

1.0 INTRODUCTION

1.1 Background of Study

According to American Petroleum Institute (API), drilling fluid is defined as a circulating fluid used in rotary drilling to perform any or all of the various functions required in drilling operations (J. L. Lummus and J. J. Azar 1986). To perform these functions, an efficient drilling fluid must exhibit numerous characteristics, such as desired rheological properties (plastic viscosity, yield value and low-end rheology, gel strengths), fluid loss prevention, stability under various temperatures and pressure operating conditions and also stability against contaminating fluids. A wide variety of additives are added to drilling fluid formulations to achieve the above performance properties.

Due to environment concerns, an extensive industrial research aiming at designing non toxic substitution and biodegradable of additives that have the same performance to deliver to same function has been done widely. An important factor in this research is to investigate the effect of banana trunk as a lost circulation material in water-based drilling fluid.

1.2 Problem Statement

The problems of reducing drilling fluid loss from drilling wells have been recognized and addressed for decades. The generic causes of drilling fluid loss from boreholes to the surrounding earth formations include natural fractures in the rocks drilled, induced fractures when pressure in drilling fluid exceeds fracturing stress of the earth, cavernous formations and highly permeable formations. Unfortunately, the cause of loss circulation in drilling a particular well is not always known.

The purpose of using lost circulation material is to reduce drilling fluid loss from borehole in a wide range of circumstances, which is compatible with the other functions desired in a drilling fluid and which is economical to use. Therefore it is a need to find out the suitable substance or material to act as an effective lost circulation material in drilling process.

Bananas are produced in large quantities in tropical and subtropical areas. After harvesting fruit, the pseudostem is traditionally wasted as it usually left in the soil plantation. This waste material creates great environmental problems when left on the plantation floor. Therefore, economic utilization of this plant waste fiber will be beneficial. The pseudostem of banana contains of fiber which is potentially to use as a lost circulation material in drilling fluid.

1.3 Significance of the Project

The main concern of this project is to study the effect of banana trunk derive from plant waste as a lost circulation in water-based drilling fluid. Through this project, effective solutions which enable to reduce cost and increase the drilling performance will be achieved.

1.4 Objectives

The objectives of this project are:

- To determine the effect of banana trunk on density and rheological properties of drilling fluid.
- To compare the change in properties of drilling fluid between banana trunk, corn cobs and sugar cane.
- To determine the suitable particle size of banana trunk between 63μm and 125μm as a lost circulation material in water-based drilling fluid for respective selected core sample through formation damage system test.

1.5 Scope of Work

The scope of work consists of the literature reviews which involve study on "Lost Circulation Definition and Classification", "Lost Circulation Material", "Banana Trunk (pseudostem) as a Lost Circulation Material", " Sugar Cane as Drilling Fluid Additive", " Corn Cobs as Drilling Fluid Additive", "Properties of Micronized Cellulose Fiber", "Drilling Fluid" and "Recommended Mud Properties" and also involve experimental work on preparing the lost circulation agents, preparing mud sample, conducting rheology test and formation damage test.

The laboratory experiments were conducted in order to formulate a blend of water-based drilling fluid with lost circulation material and to compare the properties with the base fluid and finally to test the efficacy of blend of banana trunk for the ability to reduce lost of drilling fluid through formation damage system test.

CHAPTER 2
LITERATURE REVIEW

2.0 LITERATURE REVIEW

2.1 Lost Circulation Definition and Classification

2.1.1 Definition

Lost circulation can be defined as the lost of drilling fluid or cement slurries into the formation. The problems of lost circulation encountered during drilling is caused by the differential pressure of the hydrostatic column which is generally greater than the formation pressure and is especially through the openings in the rock in low pressure or depleted zone.

2.1.2 Classification of losses

Losses can be classified as naturally occurring losses which is resulting from the formation being drilled and mechanically induced losses which is caused by the over pressuring and fracturing the formation during drilling operation.

There are four types of formations which are responsible for lost circulation such as:

- Natural formation fracture
- Vugular or cavernous formation
- Highly permeable formation
- Unconsolidated formation

The most common causes of mechanically induced losses are:

- High hydrostatic pressure resulting from an excessive mud weight.
- High hydrostatic pressure resulting from an excessive annular cutting load.
- High hydrostatic pressure resulting from an excessive Equivalent Circulation Density
- High downhole pressure resulting from a restricted annulus.

2.2 Lost Circulation Materials

According to Offshore Mineral Management Glossary, lost circulation material (LCM) is define as a substance added to cement slurries or drilling mud to prevent the loss of cement or mud to the formation. The substance may contain a blend of granular, fibrous and flake material with particle size distribution believed to be large enough to form bridge of material in the fracture or cavern. It is important that the bridge be within the formation and not on the surface of the wellbore where it can be dislodged by the drill pipe.

Industry has developed the following three basic types of agents depending on the operational phase of the well to combat lost circulation.

- Bridging agents
- Gelling agents
- Cementing agents

Bridging agents are found effective to handle lost circulation problems and are classified in respect to their morphology as fibrous, flake, granular and blended.

2.2.1 Banana Trunk (pseudostem) as a Lost Circulation Material

Bananas are produced in large quantities in tropical and subtropical areas. After harvesting fruit, the pseudostem is traditionally wasted as it usually left in the soil plantation. This waste material creates great environmental problems when left on the plantation floor. Therefore, economic utilization of this plant waste fiber will be beneficial. The pseudostem of banana contains of fiber which is potentially to use as a lost circulation material in drilling fluid.

Table 1 (Abdul Khalil al.2006) shows the percentage of various chemical components present in different types of plant waste fibers. Clearly, banana trunk (pseudostem) contains of high composition of cellulose fibers which is potentially to use as a lost circulation material in drilling fluid.

Table 1: Chemical composition of different lignocellulosic fibers

Composition (%)	Oil palm frond	Coconut	Pineapple leaf	Banana stem	Softwood
Extractive	6.4	6.4	5.5	10.6	0.2-8.5
Holocellulose	56.3	56.3	80.5	65.2	60-80
α-cellulose	44.2	44.2	73.4	63.9	30-60
Lignin	32.8	32.8	10.5	18.6	2-37
Ash	2.2	2.2	2.0	1.5	< 1

Lignin is a chemical compound (complex, highly cross-linked aromatic polymer) that is most commonly derived from wood and is an integral part of the cell walls of plants, especially in tracheids, xylem fibers and sclereids. Lignin fills the spaces in the cell wall between cellulose, hemicellulose and pectin components. It is covalently linked to hemicellulose. It also forms covalent bonds to polysaccharides and thereby crosslinks different plant polysaccharides. Lignin plays a crucial part in conducting water. The polysaccharide components of plant cell walls are highly hydrophilic and thus permeable to water, whereas lignin is more hydrophobic. The cross linking of polysaccharides by lignin is an obstacle for water absorption to the cell wall. Thus, lignin makes it possible for the plant's vascular tissue to conduct water efficiently.

In the other hand cellulose is a long chain of glucose molecules, linked to one another primarily with glycosidic bonds. The simplicity of the cellulosic structure, using repeated identical bonds, means that only a small number of enzymes are required to degrade this material.

Ash is one of the components in the proximate analysis of biological materials, consisting mainly of salty, non-organic constituents. It includes metal salts which are important for processes requiring ions such as Na_+ (Sodium), K_+ (Potassium), Ca_+ (Calcium). It also includes trace minerals which are required for unique molecules, such as chlorophyll and hemoglobin.

2.2.2 Properties of Micronized Cellulose Fibers

Cellulose fibers have demonstrated the unique characteristic of quickly forming a seal at the face preventing entrance of damaging fluids or solids into producing formations. Compared to the more rigid and brittle inorganic solids such as sized calcium carbonate, sized salts or fibrous calcium silicates, certain types of micronized cellulose fibers are flexible, highly compressible, slightly swellable and partially extrudable. As a result, properly selected cellulose fibers have the ability to form quick, surface seals and to minimize the penetration of solids or liquids into the formation.

Micronized cellulose fibers can effectively forms seals at much lower concentrations than the more commonly used acid or water soluble inorganic seepage loss additives. In spite of this, micronized cellulose fibers have been restricted to use in drilling operation. They have had limited use in payzone fluids because of their very low acid solubility.

It has been demonstrated that micronized cellulose fibers are highly soluble in concentrated alkaline solutions. Alkaline removal solutions are just as effective in removing these cellulose fibers as acids are in removing calcium carbonate or some types of calcium silicate fibers.

2.2.2.1 Advantages of Micronized Cellulose Fibers

There are many types of cellulose material and not all are fibrous. Fibrous cellulose has very distinct advantages over granular or flake materials, such as orientation, matting, compressibility, deformability and an almost infinite particle size distribution. One of the most important advantages of micronized cellulose fibers is orientation. As dynamic of flow, fibers gravitate toward the area of slowest flow. They tend to drag along the borehole or perforation tunnel, orienting end first as they enter the formation., then corkscrew or pig tail as they fill the pore throat, quickly forming protective seal. They will also enter the formation and lay flat against the borehole or perforation tunnel gripping the formation while creating a matting effect increasing wall cake strength and integrity.

Another distinct advantage of fibers over granular and flaked cellulose is their infinitely variable particle size distribution. Particle size analysis and distribution have become an integral part of drilling fluid design. Particles necessary for a quick seal and thin, tough wall cake must be compressible and deformable. Because fibers will lay in fractures, orient and fill very small pore throats, pig tail or corkscrew to fill larger pore spaces, their particle size distribution is almost infinity variable. This accounts for the quick sealing characteristic of cellulose fibers in a wide range of permeabilities and porosities.

Field experience has shown that for a drilling fluid to have adequate plugging characteristic the spurt loss must be below 5 cm^3 and made up entirely filtrate. This allows the formation to be plugged quickly, creating a thin impermeable wall cake. By quickly forming a near surface seal the cellulose fibers are easily accessible for removal. A highly alkaline pill can be spotted at the formation face and allowed to solubilize the fibers without the need for injection of large amounts of fluid into the formation, reducing the possibility of damage from potential precipitates.

2.2.2.2 Disadvantages of Micronized Cellulose Fibers

Although the cellulosic fibers themselves provided a positive seal in the mud sample in the laboratory, the seal appeared to be short lived and unstable when field tested. Any foreign material introduced into any formation will cause some degree of formation damage, especially if the foreign material enters the formation matrix. The specially formulated LCM blend is no exception. On the basis of the laboratory test results, formation damage caused by the specially formulated LCM blend can be minimized by perforating beyond the damage zone or HCI or NACIO treatment.

2.2.3 Sugar Cane as Drilling Fluid Additive

Sugar cane can be used in well working composition for filtration control, thus as an environmentally friendly drilling fluid. It provides an additive that is very effective as a filtration in both water-based and oil-based well-working fluids, that work as a filter and has no harmful environmental side effects. A filter forms when the drilling fluid contains particles of a size only slightly larger than the size of the pore openings of the formation. If an acceptable cake does not form, the mud will continue to invade (Watson R.B & Nelson A.C, 2003).A thin, low-permeability filter of some form is desired on the sides of the borehole to control the filtration characteristics of the drilling fluid since the pressure of the mud column in the borehole is greater than the formation pressure.

A study conducted by Sampey and James A, in their paper, 'Sugar Cane Additives for Filtration Control in Well Working Compositions', relates to a drilling fluid containing sugar cane for filtration control usable in a well-working fluid in contact with a permeable formation that comprises sugar cane, or a mixture of sugar cane and 50 to 90 wt % of another cellulose-like material such as oat hulls, cotton burrs, paper, bagasse, wood, peat, kenaf, rice hulls, rice bran, cottonseed hulls, soybean hulls, straw, peanut shells and nut shells. The permeability of the filter layer is directly related to the particle size distribution in the drilling fluid. Generally, the filter layer permeability decreases as the concentration of particles in the colloidal size range increases. The amount of potential filtration from a well depends on the nature of the formations being drilled and on the type of drilling fluid used. Thus, in water-sensitive formations, oil-based mud provides superior filter characteristics when the salinity of the aqueous phase of the mud is adjusted to prevent damage to the formation (James A. & Sampey, 2006).

Theoretically, by considering this as an additive, it does not increase the viscosity of the drilling fluid by more than 10% (James A. & Sampey, 2006). A need has long existed for an environmental-friendly additive for drilling fluids that does not cause the drilling fluid to become thick and viscous.

Sugar cane bagasse is a fibrous residue remaining after sugar cane stalk has crushed and the juice removed. Because of its fibrous in nature, the sugar cane bagasse has been most widely used as a fuel, paper and pulp, structural materials and agricultural activities (Han W.Y, 1983).

The simplest of sugars are strings of 3 to 7 carbon atoms. Carbon forms 4 bonds, and the two bonds remaining are used to bond with a hydrogen atom on one 'side' and a hydroxyl (OH) moiety on the other.

2.2.4 Corn Cobs as Drilling Fluid Additive

The problems of reducing fluid loss from drilling wells have been recognized and addressed for decades. The generic causes of fluid loss from boreholes to the surrounding earth formations are well-known. They include: natural fractures in the rocks drilled, induced fractures when pressure in the drilling fluid exceeds fracturing stress of the earth, cavernous formations, and highly permeable formations. Unfortunately, the cause of fluid loss in drilling a particular well is not always known. Therefore, a variety of responses are often employed in attempts to control loss of fluid from a well. A variety of naturally-occurring products have been used as lost circulation materials in the past.

Another material derived from plants and available in industry is corn cobs, which is the material supporting the kernels of corn, the kernels being the principal product of the corn plant. Few tests have been conducted by Boyce and Burts in their paper, 'Lost Circulation Material with Corn Cobs Outer'. This material serves more as a viscosifier than as a fluid loss agent, but actually serves both purposes (Boyce & Burts, 1994). In their invention, the plant materials are to be added to water based drilling fluid, which is mixed with a small ratio of oil. The oil wets the particle and adds to their lubricity while at the same time helping to control dust produced in the mixing operation. Boyce and Burts make use of ISOPAR V, which is the product of Exxon Corporation for this purpose. The oil which is in the range of 1% to 5% by weight of the total weight of the plant materials. Preferably, they add polyanionic cellulose type of polymer that is corboxymethylcellulose which enable to reduce fluid loss rate through a mat or cake of fine solid materials. Suitable concentration of the polymer is in a range from 0.1 to 0.5 % by weight.

2.3 Drilling Fluid

Drilling fluids are typically classified according to their base material. The drilling mud may be either a water-based mud having solid particles suspended therein or an oil-based mud with water or brine emulsified in the oil to form a discontinuous phase and solid particles suspended in the oil continuous phase. Water based drilling fluid which includes an aqueous fluid, at least one of a weighting agent and a gelling agent, and a lubricant, which includes at least one ester derivative. Water-based drilling fluids may be suitable for drilling in certain types of formations; however, for proper drilling in other formations, it is desirable to use an oil-based drilling fluid. During the drilling operations, the drilling fluid is injected into the well through the drill pipe and re-circulated to the surface in the annular area formed by the wellbore wall and the drill string. Once back at the surface, the drilling fluid is physically and chemically treated and conditioned before it is pumped back into the well.

2.3.1 Drilling Fluid Properties

2.3.1.1 Mud Density

Mud density is used to control subsurface pressures and stabilize wellbore and it is commonly measured with a mud balance capable of ± 0.1 lb/gal accuracy. A mud balance calibrated with fresh water at $70^0 \pm 5^0$ should give reading of 8.3 lb/gal. When we drill the wellbore we replace a cylinder of rock with a cylinder of mud. The first critical step towards designing a drilling fluid is to establish the mud weight required to provide the correct level of bore hole pressure support.

2.1) Density, ρ = mass / volume (unit in ppg)

2.3.1.2 Rheology

Rhelogical properties measured with a rotational viscometer are commonly used to indicate solid buildup flocculation or deflocculation 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 Bingham Plastic parameters, plastic viscosity (PV) and yield point (YP) are calculated directly. The instrument 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.

2.2) Plastic Viscosity (PV), cP = [600 rpm reading] – [300 rpm reading]
2.3) Yield Point (YP), lb / 100 ft^2 = [300 rpm reading] – PV

2.3.2 Additive in Drilling Fluid

Additive in drilling fluid consist of weighting agent, deflocculation or dispersing agent, filtration control agent and viscosifying agent. Table 2 summarizes the types of additive used base on its function on drilling fluid.

Table 2: Types of additives base on its function in drilling fluid

Weighting agents	Deflocculation agent	Filtration control agent	Viscosifying agent
Barite	Lignosulfonate	Bentonite	Bentonite
Hematite	Polymers	Starch	Polymer
Calcium Carbonate	Phosphates	Modified cellulosic	
Salt	Modified tannis	Syntetic Polymer	

2.4 Recommended Mud Properties

The empirical correlations are used to compute the recommended upper and lower limits of the plastic viscosity and the yield point which is shown in the following figure. All the correlations below are based on the mud density and suitable for all types of fluids.

Acceptable Plastic Viscosity Range

	Plastic Viscosity (cP)	
Mud Weight (ppg) Range	High range	Low Range
$\rho_m < 14$	$3.40\ \rho_m - 18.6$	$2\ \rho_m - 14$
$14 \leq \rho_m < 17$	$5\ \rho_m - 40$	$4.33\ \rho_m - 46.95$
$17 \leq \rho_m < 18.4$	$8.57\ \rho_m - 100.25$	$8.57\ \rho_m - 118.25$
$\rho_m \geq 18.4$	$16.68\ \rho_m - 248.73$	$16.67\ \rho_m - 266.73$

Acceptable Yield Point Range

	Yield Point, (lb/ft^2)	
Mud Weight (ppg) Range	High Range	Low Range
$\rho_m < 11$	$-4\ \rho_m + 66$	$0.4\ \rho_m - 0.6$
$11 \leq \rho_m < 14$	$-1.67\ \rho_m + 40.04$	$0.4\ \rho_m - 0.6$
$\rho_m \geq 14$	$-0.6\ \rho_m + 25.4$	$0.4\ \rho_m - 0.6$

Figure 1: Empirical correlations to determine upper and lower limits of Plastic Viscosity and Yield Point. (Drilling Engineering Manual, Department of Petroleum Engineering, Curtin University of Technology)

CHAPTER 3

METHODOLOGY

3.0 METHODOLOGY

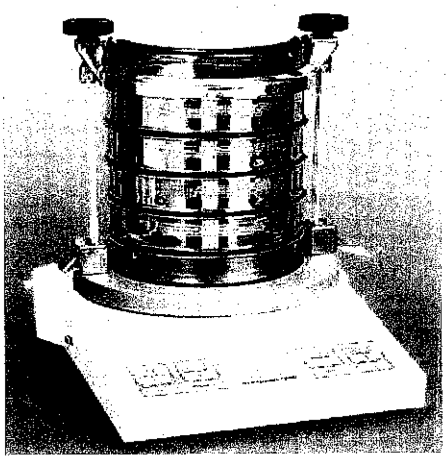
The experiments were conducted in accordance with the standard stipulated in API RP 13B-1; Recommended Practice Standard Procedure for Field Testing Water-Based Drilling Fluids. Water-based drilling fluid was used as the base fluid through out the study. The activities involve were preparation of lost circulation agent, preparation of mud sample and properties measure such as density (lb/gal), yield point, plastic viscosity (cP),gel strength (cP) and filtration loss (ml/30 min). Formation damage system test was also been conducted in order to determine the effect of banana trunk to the permeability of the core which simulates the permeability of the formation.

3.1 Preparation of Loss Circulation Agent

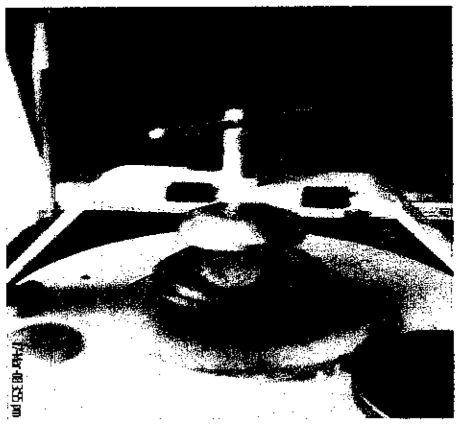
The pseudostem was firstly cut into small pieces. Then, the small pieces of pseudostem were dried directly to the sun in order to remove the presence of water inside it. Due to the wet condition, the small pieces of pseudostem were dehumidified for 3 hours at 105°C in a furnace to ensure it is totally free from water. A Mortar Grinder was used to grind the material into powder form. To obtain the desired particle size, a Sieve Shaker was used.

Process of cutting the banana trunk into small pieces

Process of drying the small pieces of pseudostem direct to the sun



Process of sieving the pesudostem by using sieve shaker



Process of grinding the small pieces of pseudostem by using motor grinder

Figure 2: Process of preparing lost circulation agent

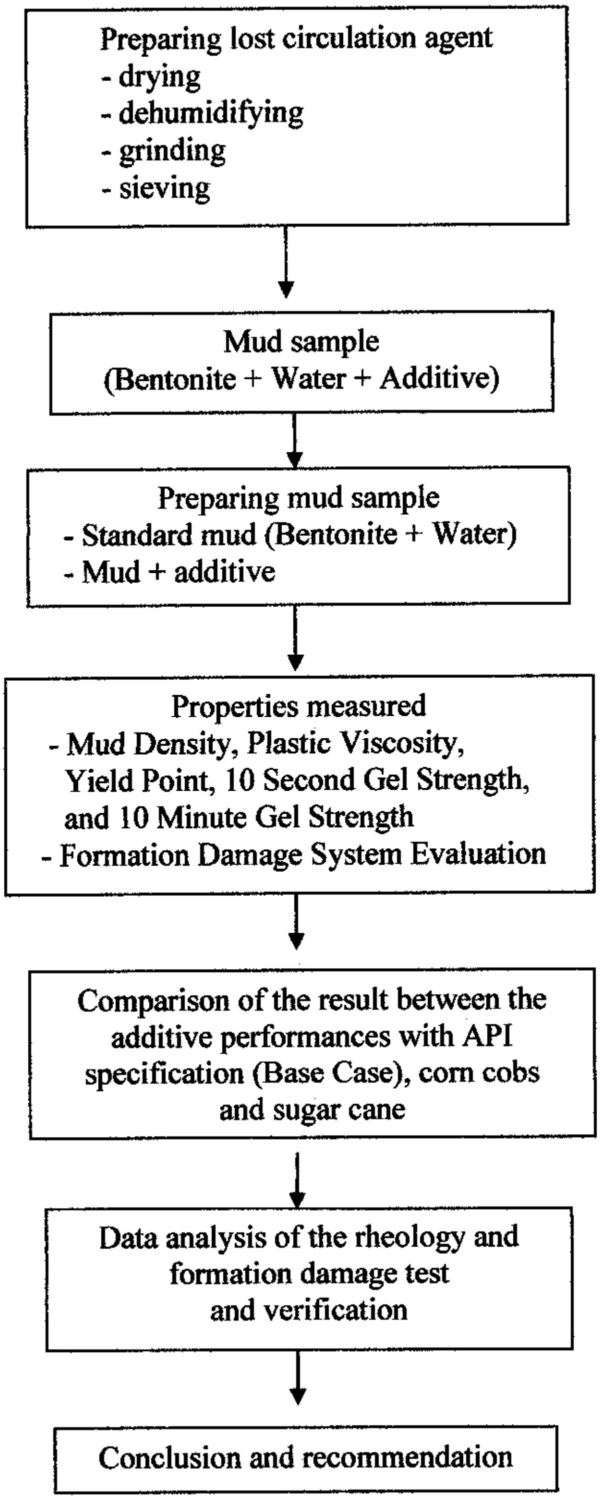


Figure 3: Project flowchart

3.2 Drilling Mud Preparation

A suspension of 75μm bentonite powder was prepared by adding 22.5 $\pm$ 0.01g of Indian bentonite to 350 $\pm$ 5 cm^3 deionized water while stirring by using Fann Multimixer. After stirring for 5 $\pm$ 0.5 minutes, the container was removed from the mixer and its sides were scraped with spatula to dislodge any bentonite adhere to the container walls. Then, the container was replaced and stirring process was continued. The total stirring time is approximately equal to 20 $\pm$ 1 minutes.

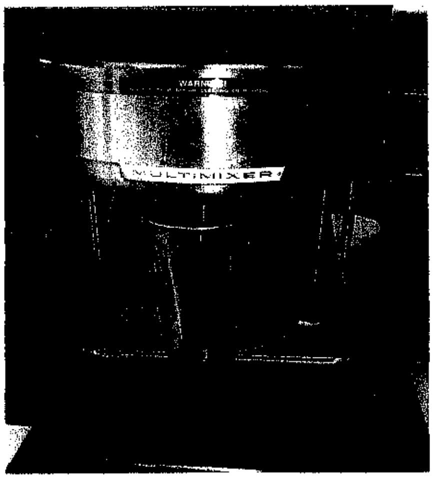


Figure 4: Fann Multimixer

Base on the standard stipulated in API RP 13B-1; Recommended Practice Standard Procedure for Field Testing Water-Based Drilling Fluids, sample 1 actually is the base case for this experiment. Other drilling mud samples were prepared in order to measure the change in properties such as density, plastic viscosity, gel strength and filtration loss as compared to the base case. Two different particles size of banana trunks which are 63 μm and 125 μm were used in this experiment. Table 1 below summarizes the quantity of banana trunk in grams that had been added with the respective quantity of the water and bentonite.

Table 3: Five mud samples with different quantity of banana trunk added

Substance, Quantity	Sample				
	1	2	3	4	5
Water, ml	350	350	350	350	350
Bentonite (Indian), g	22.5	22.5	22.5	22.5	22.5
Banana trunk fiber, g	0	5	10	15	20

3.3 Properties Measured

3.3.1 Density (Mud Weight)

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 counterweight at the other end with a sliding weight rider free to move along a graduated scale. Clean and dry cup was firstly filled with drilling fluid to be tested. Then the cap was put on the filled drilling fluid holding cup and the cap was rotated until it is firmly seated. The beam was placed on the base support and it was balanced by moving the rider along the graduated scale. Balanced is achieved when the bubble is under the centerline. The density at the edge of the rider toward the drilling fluid holding cup was recorded.

Figure 5: Mud Balance

3.3.2 Viscosity and Gel Strength

A prepared drilling mud sample was placed inside the cup and the rotor sleeve was immersed exactly to the scribed line of Fann VG Rheometer. The drilling mud was stirred for 5 minutes on the Hamilton mixer. The dial reading was recorded when it reach steady value with the sleeve rotating at 600 rpm. Then the speed was shifted to 300 rpm and dial reading is recorded when it reach a steady value. The drilling mud sample was stirred for 10 seconds at the high speed (600 rpm). The mud was allowed to still undisturbed for 10 seconds. Slowly and steadily the hand wheel was turned in the direction to produce a positive dial reading. The maximum reading is the initial gel strength. The initial gel strength (10 seconds gel) was recorded in lb / 100 ft^2 or Pa. Then, the drilling mud sample was re-stirred for measurement of 10 minutes gel strength.

Plastic viscosity (PV) and yield point (YP) can be calculated by using the following equation:

3.1) Plastic Viscosity (PV), cP = [600 rpm reading] – [300 rpm reading]

3.2) Yield Point (YP), lb / 100 ft^2 = [300 rpm reading] – PV

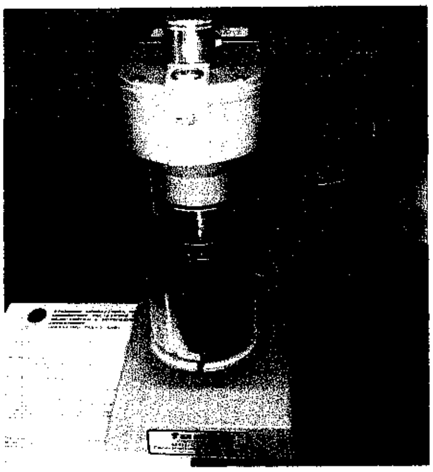


Figure 6: Fann Viscometer

3.4 Core Sample Preparation and Porosity Measurement

Three cores which have same diameter and length were used for this experiment. The cores were dried inside the oven at 100^0C overnight to ensure there is no water trapped inside the cores.

Table 4: Parameters of core used

	Core
Rock type	Sandstone
Diameter	3.790 cm
Length	2.593 cm
Absolute porosity	18.87 %
Effective permeability	124.819 mD

Vinci He Porosimeter was used to measure the porosity of the core samples. This instrument measures core grain volume, density, pore volume, porosity and void volume. The sample is evacuated prior to the injection of Helium gas. A measurement of equilibrated pressure determines the porosity.

Figure 7: Vinci He Porosimeter

The system is computer controlled and the porosity is automatically calculated, or manually acquired data can be loaded into spreadsheet program for calculation and parameter determination. This method is in high accuracy as helium is a light gas and will fill the very small pore spaces.

After the porosity of the cores was measured, the next step was preparing the brine solution. The description of brine formulations are as follow:

3.3) $$\frac{\text{Brine concentration (ppm)}}{10^6} \times \text{quantity of distilled water (liter)} = \text{quantity of salt (kg)}$$

For 15000 ppm in 1 liter of water, the calculations are as follow:

15000ppm = 15g/L

Therefore for 1 liter of water, 15 g of salt will be required to prepare the brine.

After preparing the brine, the plugs were saturated in TEMCO saturator at 2000psi applied pressure (typical wellbore pressure) to fill the pore spaces with brine. During the saturation process, the applied pressure will reduce showing that the brine is filling the empty pore spaces. Once the pressure is constant, the plugs are assumed to be fully saturated.

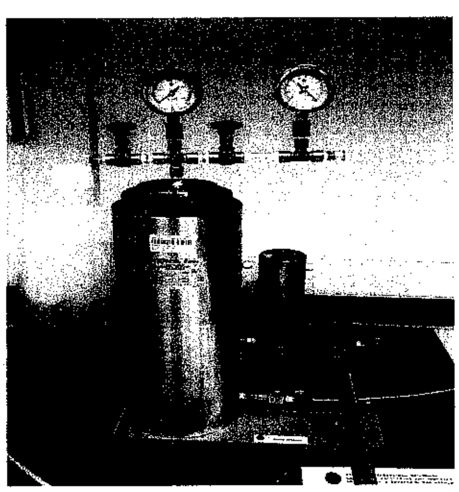


Figure 8: TEMCO saturator

3.5 Formation Damage System

Formation damage measurements were made with three different drilling fluids. Each permitted the determination of the core permeability before and after the exposure to the drilling fluids. The first mud sample was made with water and bentonite as the base case, the second mud sample was made with water, bentonite and banana trunk with the size of 63μm and the third sample was made with water, bentonite and banana trunk with the size of 125μm. Pressure taps along the core holder is maintained by constantly apply pump flow rate of 5mL/min intervals allow direct spatial resolution of the permeability impairment during and after filtration. Before use, cores were vacuum saturated with brine with concentration of 15000ppm simulating connate water saturation from the reservoir.

Table 5: Three different drilling fluids used in Formation Damage System Test

	First Sample (Base Case)	Second Sample	Third Sample
Water	1050 ml	1050 ml	1050 ml
Bentonite	67.5 g	67.5 g	67.5 g
Banana Trunk	0	15 g (63μm)	15 g (125μm)

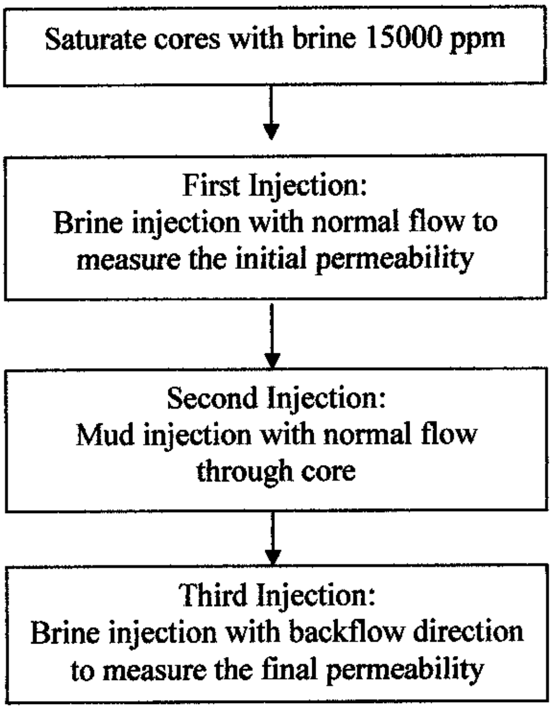


Figure 9: Experimental flowchart for Formation Damage System Test

The core sample prepared should be loaded into the core holder through the sleeve provided. The domes were attached at the ends after filling up the spaces within the sleeves with spacers which are hollowed cylindrical metal blocks. The spacers prevent the sleeve from rupture under the overburden pressure acting upon the sleeve. The core sample and holder were mounted horizontally for the analysis. The overburden pressure was gradually increased until it reaches the desired pressure, which in this experiment is 2000 psia. This represents the reservoir pressure also known as the confining pressure. When the overburden pressure was achieved the flow of the test fluid was started using ISCO Pump. The pump injects the test fluid at a specified rate in ml / min. Specific valves were opened manually to commence.

Table 6: Parameters setting of FDS-800-1000 device

Test Parameters	Core Samples		
	1	2	3
Overburden pressure (psia)	2000	2000	2000
ISCO pump flowrate (ml/min)	5	5	5
ISCO pump pressure (psia)	500	500	500
Inlet BPR pressure (psia)	500	500	500
Outlet BPR pressure (psia)	0	0	0

Figure 10: FDS-800-1000 device

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Properties of Drilling Fluid

The experiments were conducted in accordance with the standard stipulated in API RP 13B-1; Recommended Practice Standard Procedure for Field Testing Water-Based Drilling Fluids. Sample 1 actually is the base case for this experiment. Other drilling mud samples were prepared in order to measure the change in properties such as density, plastic viscosity, yield point, gel strength and filtration loss as compared to the base case (sample 1). Two different particles size of banana trunks which are 63 μm and 125 μm were used in this experiment.

Table 7: Five mud samples with different quantity of banana trunk added

Substance Quantity	**Sample**				
	1	**2**	**3**	**4**	**5**
Water, ml	350	350	350	350	350
Bentonite (Indian), g	22.5	22.5	22.5	22.5	22.5
Banana trunk fiber, g	0	5	10	15	20

Table 8: Properties measured for different mud samples with the size of 63μm banana trunk added

Properties Measured	**Sample**				
	1	**2**	**3**	**4**	**5**
Mud Density, ppg	8.60	8.65	8.70	8.75	8.80
VG 600 reading, lb / 100ft^2	13	19	26	29	33
VG 300 reading, lb / 100ft^2	9	13	19	22	25
Plastic viscosity, cP	4	5	7	8	9
Yield point, lb / 100ft^2	5	9	12	15	17
Gel strength, 10 sec	12	20	25	27	30
Gel strength, 10 min	22	25	28	30	32
pH	9	9	9	9	9

Table 9: Properties measured for different mud samples with the size of 125μm banana trunk added

Properties Measured	Sample				
	1	2	3	4	5
Mud Density, ppg	8.60	8.65	8.70	8.75	8.80
VG 600 reading, lb / 100ft^2	13	19	23	28	34
VG 300 reading, lb / 100ft^2	9	14	16	20	25
Plastic viscosity, cP	4	6	8	9	10
Yield point, lb / 100ft^2	5	7	9	12	16
Gel strength, 10 sec	12	25	28	30	32
Gel strength, 10 min	22	30	33	35	36
pH	9	9	9	9	9

4.1.1 Mud Density

Mud density is an important property in maintaining well control. Freshwater has a density of 8.34 ppg or pressure gradient of 0.433 psi/ft. Most formation has a pressure gradient of 0.466 psi/ft which exceed the freshwater property. Thus, weight material must be added to the freshwater and the most common is barite. In this experiment, the density is set to 8.6 ppg which obtained by adding 350 ml of water with 22.5 g of bentonite.

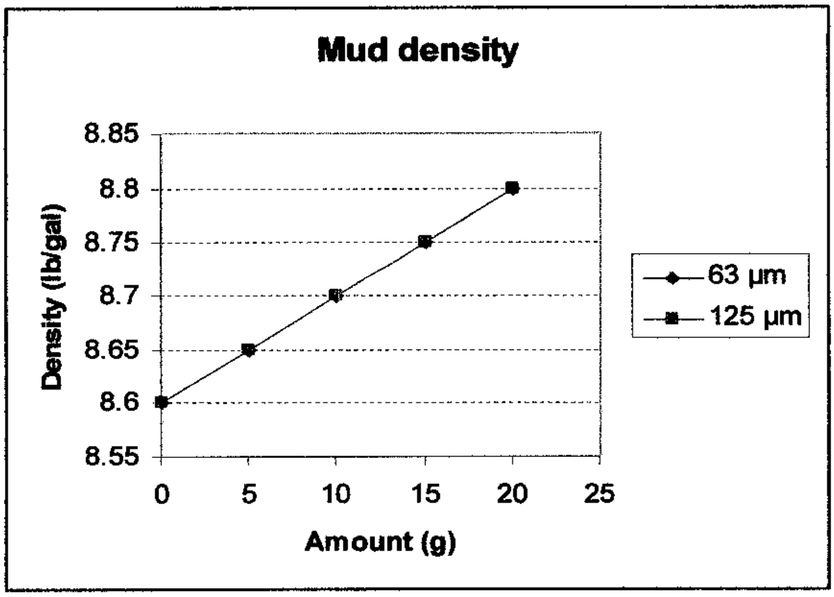


Figure 11: Graph of mud density for different mud samples

As shown in the figure 11, the mud density is proportionally increased with the amount of banana trunk added. For both sizes, the values of density are similar through out the addition of banana trunk. The pink line (125μm) in front of the blue line (63μm) therefore the blue line can not be seen. This indicates that the particle size has less effect on the changes of mud density.

4.1.2 Plastic Viscosity

Plastic viscosity depends on the friction between solids and liquids. It represents the shear rate viscosities encountered at the drill bit. A low plastic viscosity indicates that the mud is capable of drilling rapidly because of the low viscosity of mud exiting at the bit. High plastic viscosity can be caused by viscous base fluid and by excess colloidal solids. A reduction in solids content in order to lower plastic viscosity can be achieved by dilution.

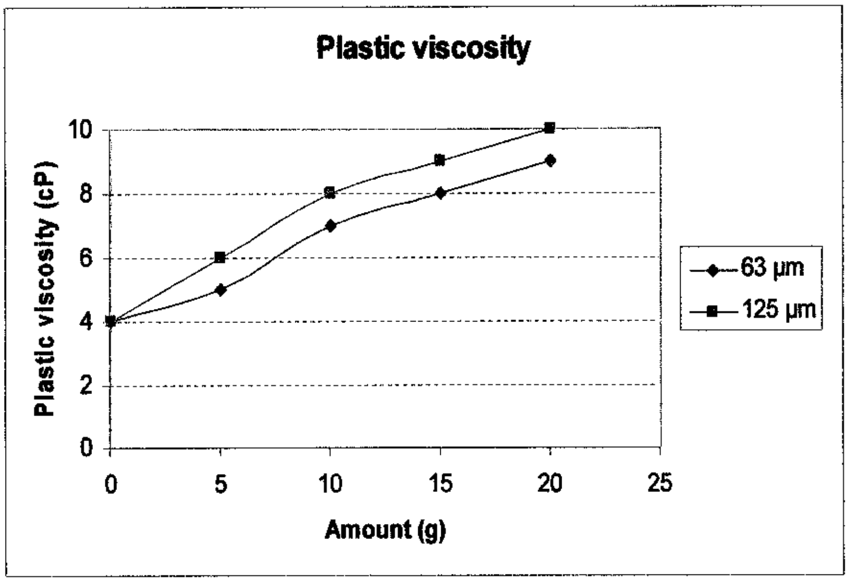


Figure 12: Graph of plastic viscosity for different mud samples

The figure 12 above shows the trend of plastic viscosity for drilling fluid when certain amount of banana trunk was added. Initially, 5g of banana trunk was added in drilling fluid and plastic viscosity increases compared with the base case which is 4 cP. Then, the values of plastic viscosity keep increasing as the amount of banana trunk added increase for the both sizes of 63μm and 125μm. However, the graph for 125μm gives slightly higher reading compare to 63μm due to its particle size. As expected, 125μm shows a slightly higher value of plastic viscosity compared to 63μm due to its particle size. The larger the particle, the more viscous of the fluid will be.

4.1.3 Yield Point

Yield point is a measure of the attractive forces between active clay particles in the mud under flowing condition. It is used to evaluate the ability of a mud to lift cutting out of annulus. A higher yield point implies that drilling fluid has ability to carry cuttings better than a fluid of similar density but lower yield point. Yield point can be lowered by adding deflocculant and increased by adding flocculant.

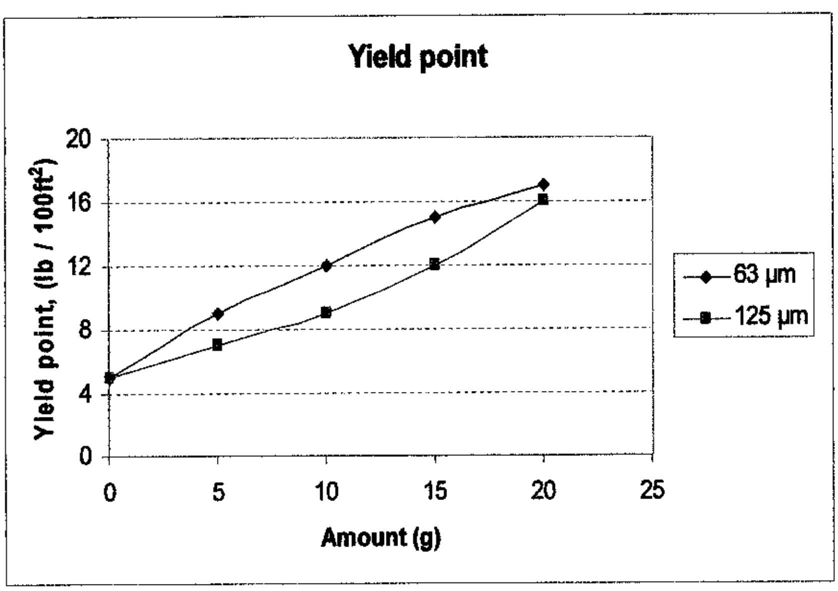


Figure 13: Graph of yield point for different mud samples

As shown in the figure 13 above, the value of yield point keep increasing as the amount of banana trunk added increase which is similar to the trend of plastic viscosity graph.

The particle size 125μm has the lower value of yield point compare to 63μm. This is due to solid content in mud sample of 63μm which is higher with consequent decrease in inter particle distances.

4.1.4 Gel strength

Gel strength denotes the thixotropic properties of the mud. It indicates the pressure required to initiate flow after the mud has been static for sometime and also the suspension properties of the mud hence its ability to suspend cuttings when the mud is stationary. Gels are described as progressive (strong) or fragile (weak). Excessive gelation is caused by high solid concentration leading to flocculation. For a drilling fluid, the fragile gel is more desirable. Rogers (1978) stated that the 10 minutes gel strength will cause the higher gel strength as the particles have more time to arrange themselves in a proper manner in which the repulsive and attractive forces best satisfied.

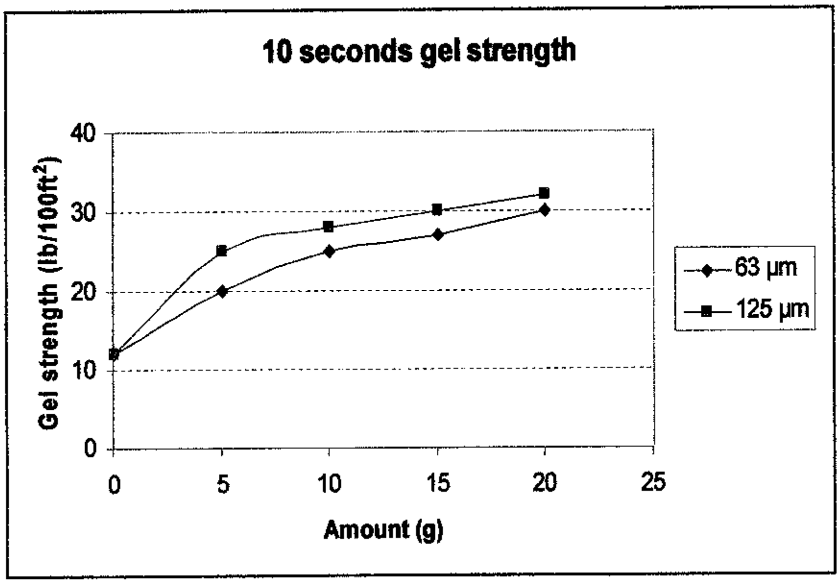


Figure 14: Graph of 10 seconds gel strength for different mud samples

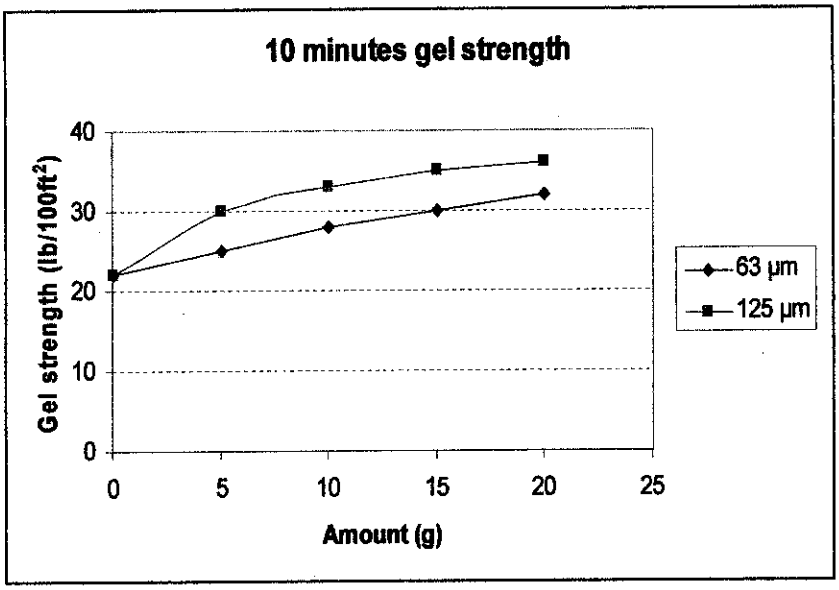


Figure 15: Graph of 10 minutes gel strength for different mud samples

From the both graphs of 10 seconds and 10 minutes gel strength, the values obtained tend to increase as the amount of banana trunk added increase. The particle size of 125µm shows a slightly higher value compare to 63µm. The trends of the graph for gel strength are almost similar with the yield point graph. An increase in one usually results in increase in another which is due to attractive forces in a mud system.

4.2 Comparison of Properties between Banana Trunk, Sugar Cane and Corn Cobs

The experiment was conducted by Ahmad Zakuan (2006) to evaluate the effect of additives on the density and the rheological properties of drilling fluid by using sugar cane and corn cobs. The change of drilling fluid properties caused by different particle size and different amount of additives added were measured as similar to the experiment conducted on banana trunk. The only difference is the base fluid used is oil (SARAPAR 147) while for the banana trunk the base fluid used is water.

4.2.1 Mud Density

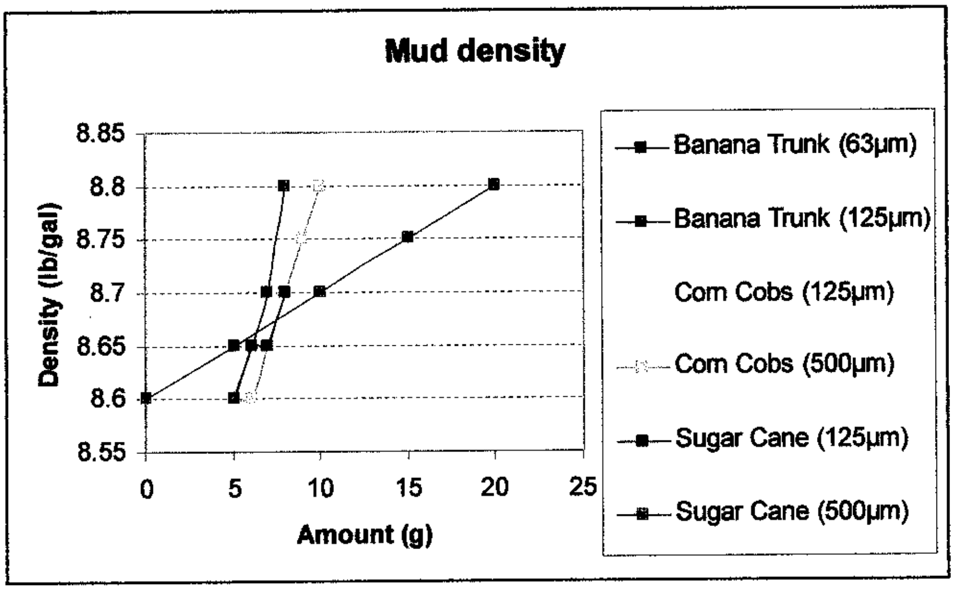


Figure 16: Mud weight for banana trunk, corn cobs and sugar cane

As shown in figure 16, the amount of corn cobs and sugar cane has a direct relationship with the density. However, the particle size has less effect. Observe that, the density is almost similar through out the addition of the additives and starts to increase when the amount exceeds 6g and above. For banana trunk, the mud density is proportionally increased and the values are similar through out the addition of banana trunk for both sizes. The blue line behind the pink line and the yellow line behind the light green line. Thus, these two lines can not be seen.

4.2.2 Plastic Viscosity

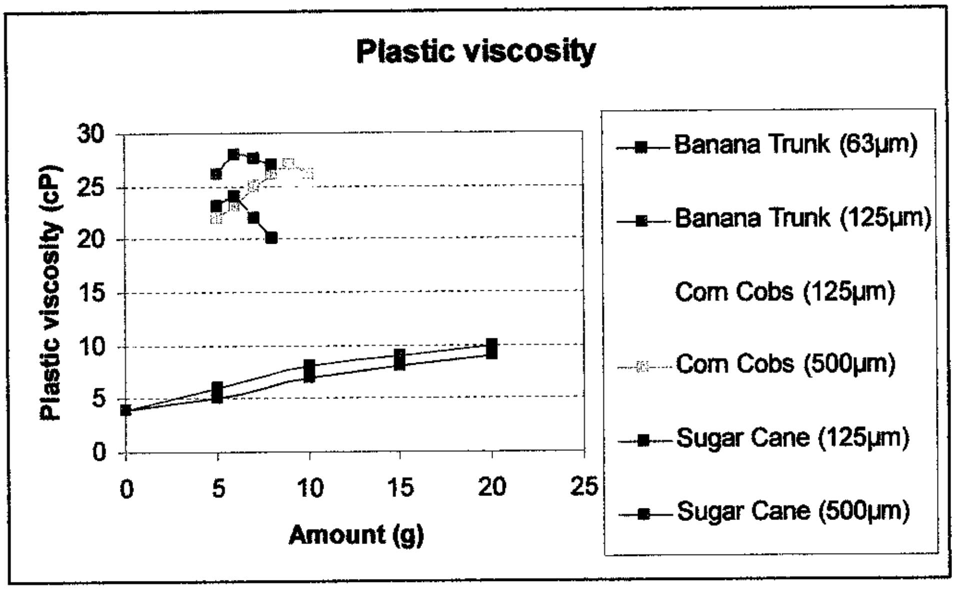


Figure 17: Plastic viscosity for banana trunk, corn cobs and sugar cane

From figure 17, the plastic viscosity of corn cobs keeps on increasing and the trend is valid from 5g to 9g which has the value of 25 cP for 125μm and 27 cP for 150μm. As the amount continually added the curves start to decrease. Unlike corn cobs, sugar cane additives experience its optimum value in the earlier amount of the addition. It started to decrease after the amount 6g. For banana trunk, the values of plastic viscosity keep increasing as the amount of banana trunk added increase for the both sizes of 63μm and 125μm. Upon observation, from both of the figures above, in adding the additives, there will be the optimum value. The optimum value can be found when there is a change in the trend of the curve from the graph but for the banana trunk, the optimum value is still unreachable.

4.2.3 Yield Point

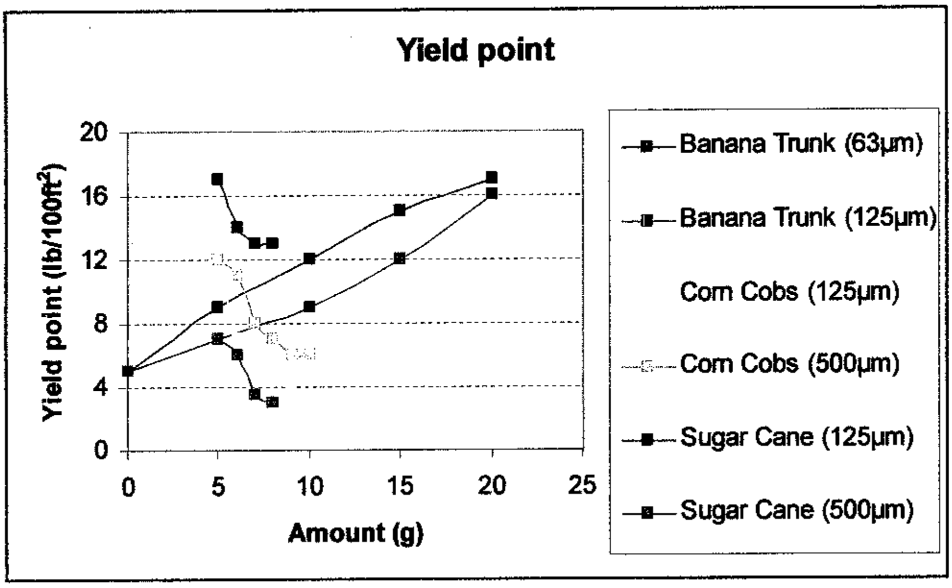


Figure 18: Yield point for banana trunk, corn cobs and sugar cane

From figure 18, for both sizes of corn cobs and sugar cane, the value of yield point decreases as the amount increases. Unlike corn cobs and sugar cane, for banana trunk, the value of yield point keep increasing as the amount of banana trunk added increase which is similar to the trend of its plastic viscosity graph. The difference trend of the result obtained was due to chemical additives used in oil base fluid for corn cobs and sugar cane. Yield point is sensitive to the electrochemical environment; hence indicate the need for chemical treatment. The yield point may be reduced by the addition of substances neutralizing the electric charges such as thinning agent and by addition of chemicals to precipitate the contaminants (Growcock, 2006).High viscosity resulting from high yield point is caused by introduction of soluble contaminant which interacts with negative charges on the clay particle, breaking of clay particles through mechanical grinding action creating new surface area of the particles and the addition of inert solids (Drilling Fluid Manual, Amoco Company).

4.2.4 Gel Strength

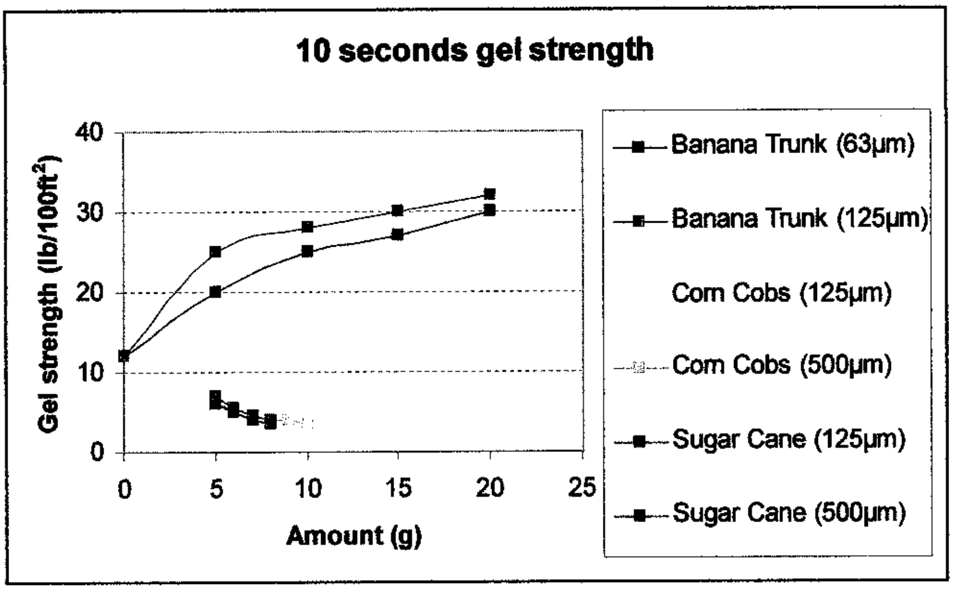


Figure 19: 10 seconds gel strength for banana trunk, corn cobs and sugar cane

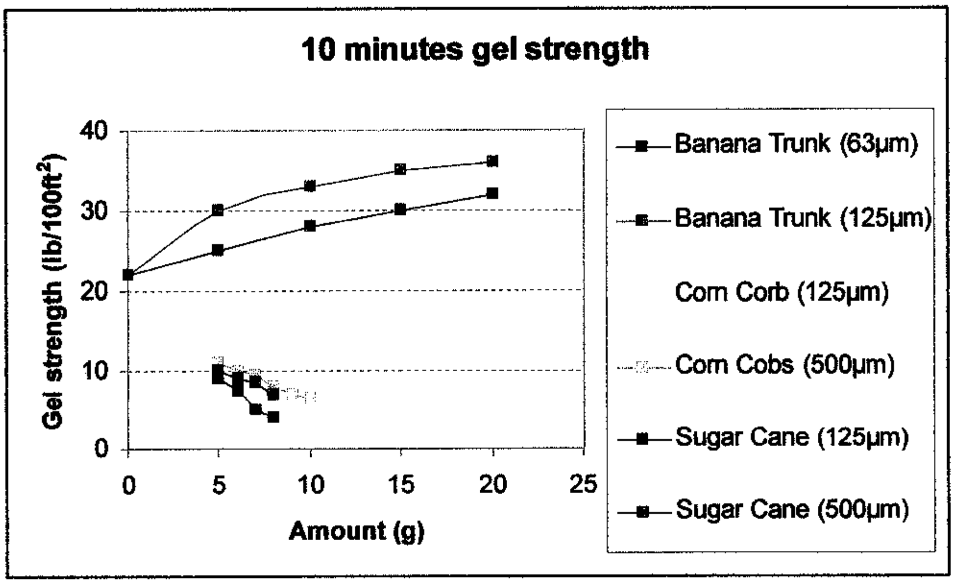


Figure 20: 10 minutes gel strength for banana trunk, corn cobs and sugar cane

The trends of the graph for gel strength for both corn cobs and sugar cane are almost similar with the yield point graph. This can be explained due to the attractive forces in a mud system. A decrease in one usually results in a decrease in another (Drilling Fluid Manual, Amoco Company). For banana trunk case, since the yield point increase as the amount of banana trunk added increase, the trend for both 10 seconds and 10 minutes gel strength increase as well.

4.3 Formation Damage System Test

The mud was prepared by adding water and bentonite (Indian) as suggested by API 13B-1. Lost circulation material which is banana trunk will be mixed and the effects to the formation damage in term of permeability reduction to the cores were observed. Below is the three different drilling fluids used for formation damage system test.

Table 10: Three different drilling fluids used in Formation Damage System Test

	First Sample (Base Case)	Second Sample	Third Sample
Water	1050 ml	1050 ml	1050 ml
Bentonite	67.5 g	67.5 g	67.5 g
Banana Trunk	0	15 g (63μm)	15 g (125μm)

The base case which is the first sample is set for the purpose of comparison before the usage of lost circulation material which is banana trunk in drilling mud. The first sample was injected through the first core to analyze the formation damage caused by the mud in term of permeability reduction. Then, the second test which mud sample made by water, bentonite and banana trunk with the size of 63 μm was injected through the second core. The final formation damage test was conducted by injecting the third mud sample made by water, bentonite and banana trunk with the size of 125 μm to the third core. In this formation damage test, the liquid permeability for the core was calculated by the system by using leak-off flow rate. This means the volume of fluid that was injected and flow through the core will be collected as leak-off flow rate. The formation damage of these three cores was further analyzed base on the data collected.

Table 11: Initial permeability of the three cores with normal flow brine injection

Elapsed Time (minutes)	Inlet Pressure (psi)	Outlet Pressure (psi)	Overburden Pressure (psi)	Leak-off Flow Rate ml / min	Isco Pump Flow Rate ml / min	Calculated Liquid Permeability
28.02	84.74	0.95	2050.64	4.998	5	107.739
29.02	84.74	0.95	2051.28	4.982	5	107.697
30.02	85.38	1.59	2051.28	4.938	5	107.571
31.02	86.01	0.95	2051.91	4.804	5	106.564
32.02	86.01	0.95	2052.55	4.752	5	106.439
33.02	86.01	0.95	2053.18	4.795	5	106.231
34.02	86.01	0.95	2055.08	4.673	5	105.055
35.02	86.01	0.95	2056.35	4.591	5	104.168
36.02	86.65	1.59	2056.99	4.589	5	104.005
37.02	87.28	1.59	2056.99	4.479	5	103.272
Average Liquid Permeability						105.8741

Table 12: Final permeability of the first core with backflow brine injection

Elapsed Time (minutes)	Inlet Pressure (psi)	Outlet Pressure (psi)	Overburden Pressure (psi)	Leak-off Flow Rate ml / min	Isco Pump Flow Rate ml / min	Calculated Liquid Permeability
50.02	48.56	0.95	2249.96	4.572	5	104.245
51.02	47.29	1.59	2252.5	4.479	5	102.921
52.02	56.81	1.59	2255.67	4.432	5	102.634
53.55	73.32	0.95	2254.4	4.372	5	102.619
54.85	99.98	1.59	2254.4	4.325	5	102.273
55.15	141.87	1.59	2254.4	4.365	5	101.937
56.45	254.86	6.03	2255.67	4.339	5	101.644
57.75	256.77	7.3	2256.31	4.305	5	100.358
58.05	273.91	7.3	2256.94	4.238	5	99.367
59.35	291.68	9.2	2257.58	4.177	5	98.448
Average Liquid Permeability						101.6446

Table 13: Final permeability of second core with backflow brine injection

Elapsed Time (minutes)	Inlet Pressure (psi)	Outlet Pressure (psi)	Overburden Pressure (psi)	Leak-off Flow Rate ml / min	Isco Pump Flow Rate ml / min	Calculated Liquid Permeability
47.01	22.53	2.22	2128.72	4.196	5	97.435
48.01	22.53	2.22	2128.72	4.122	5	97.349
49.01	22.53	2.22	2129.35	4.163	5	97.394
50.01	22.53	2.22	2129.99	4.138	5	96.812
51.01	22.53	2.22	2131.26	4.085	5	95.628
52.01	22.53	2.22	2131.89	4.071	5	95.396
53.01	22.53	2.22	2132.53	4.077	5	94.716
54.01	22.53	2.22	2133.8	3.974	5	94.024
55.01	22.53	2.22	2135.07	3.989	5	93.682
56.01	21.9	2.22	2133.8	3.977	5	93.113
Average Liquid Permeability						95.5549

Table 14: Final permeability of third core with backflow brine injection

Elapsed Time (minutes)	Inlet Pressure (psi)	Outlet Pressure (psi)	Overburden Pressure (psi)	Leak-off Flow Rate ml / min	Isco Pump Flow Rate ml / min	Calculated Liquid Permeability
62.48	53.64	1.59	1952.89	4.363	5	101.969
62.79	53.64	1.59	1952.89	4.319	5	100.573
63.11	54.27	2.22	1952.89	4.205	5	100.135
63.43	54.27	1.59	1952.89	4.273	5	99.266
63.74	54.27	2.22	1952.25	4.231	5	99.23
64.06	54.91	1.59	1952.25	4.204	5	99.149
64.38	54.91	2.22	1952.25	4.155	5	97.577
64.69	54.91	2.22	1952.25	4.175	5	97.295
65.01	54.91	1.59	1952.25	4.195	5	96.655
65.33	54.91	2.22	1952.25	4.043	5	95.745
Average Liquid Permeability						98.7594

Table 15: Percentage reduction in permeability of the cores caused by the drilling fluid

	Initial Permeability	Final Permeability	Percentage Reduction
First mud sample (Water + Bentonite)	105.8741 mD	101.6446 mD	3.995%
Second mud sample (Water + Bentonite + 63 μm Banana Trunk)	105.8741 mD	95.5549 mD	9.747 %
Third mud sample (Water + Bentonite + 125 μm Banana Trunk)	105.8741 mD	98.7594 mD	6.719 %

The formation damage test is divided into three main phases; first injection by using brine with normal flow to measure initial permeability, second injection by using drilling fluid with normal flow and the final injection by using brine with the same concentration to measure final permeability with the backflow direction. These three phases of injection simulate the condition before and after the drilling fluid introduced into the formation during drilling operation.

From the table 15, for the base case with no presence of lost circulation material will result small percentage reduction in permeability which indicates small formation damage to the first core as expected. There is no lost circulation material introduce to the core therefore during the backflow of the brine, the fluid will flow smoothly without any interruption of pores plugged. Second core has slightly higher reduction in permeability compared to third core. This means that the higher formation damage occurred to the second core than third core is due to the particle size of lost circulation material used. The size of 63 μm of banana trunk was efficiently plugged the pores inside the core thus reducing the permeability of the core. There is no necessary relation between porosity and permeability. A rock may be highly porous and yet impermeable if there is no communication between pores but a highly porous sandstone is usually highly permeable. At this stage, the result shows that the size of 63 μm of banana trunk was efficiently act as a lost circulation material in drilling fluid for this selected core sample in order to prevent the loss of mud to the formation.

CHAPTER 5

CONCLUSION

5.1 Conclusion

The density and rheological properties of drilling fluid such as plastic viscosity, yield point, 10 seconds and 10 minutes gel strength increase in value as the amount of banana trunk added increase for both sizes of 63μm and 125μm.

For sugar cane additives, particle size has slight effect on the density, where it increases when the amount is increased. The plastic viscosity has a direct relationship with the added amount. The yield point and gel strength shows a reverse relationship with the added amount.

For corn cobs additives, as the amount of additives is increased, the density and plastic viscosity increase as well. The yield point and gel strength show a reverse relationship with the added amount. The particle size of corn cobs does affect and has direct relationship with properties measured.

For both sugar cane and corn cobs, no formation damage system (FDS) test has been conducted to test the efficacy for both additives as lost circulation material. The results obtained were more on rheological properties and composition of additives itself.

Through formation damage system (FDS) test, size of 63μm of banana trunk was efficiently act as a lost circulation material for this selected core sample in drilling fluid in order to prevent the loss of mud to the formation.

CHAPTER 6

RECOMMENDATION

6.1 Recommendation

1) The usage of oil as the base fluid maybe an option to cope with different types of drilling fluids programs, and to compare the effectiveness between the water-based and the oil-based drilling fluids.

2) Formation damage system (FDS) test should be further analyze by varying more particle size of lost circulation material used and quantity of lost circulation material added in drilling fluid.

3) Laboratory tests should be designed to demonstrate the real conditions during drilling operation especially on the temperature and pressure of certain selected reservoir to show the real effects of the fluids to the specific reservoir.

4) Economic evaluation shall be conducted to compare the effectiveness of the formulation to be used in the industry.

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