Developing a Green Lost Circulation Material (LCM)
Derived From Coconut Coir Waste

By

Izzuddin Bin Jamaludin
9686

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Petroleum Engineering)

JAN 2011

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CERTIFICATION OF APPROVAL

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(PETROLEUM ENGINEERING)

Approved by,

(Pn Mazlin Idress)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
January 2011

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.

IZZUDDIN BIN JAMALUDIN

ABSTRACT

This dissertation presents a project aims to avoid or significantly reduce lost circulation of drilling fluid during drilling operation by introducing coconut coir waste as a lost circulation material (LCM). The oil and gas industry spends millions of dollars a year to combat lost circulation and the detrimental effects it propagates, such as loss of rig time, stuck pipe, side-tracks, blowouts and, occasionally, the abandonment of expensive wells. It is estimated that lost circulation costs the industry about US $800 million per year, while the lost circulation products could represent as much as US $200 million.

The objectives of this research will be focusing on formulating and developing a composition of drilling fluid containing coconut (*Cocos Nucifera*) coir as a lost circulation material (LCM) to either prevent or mitigate loss of drilling fluid during drilling wells. Two cases were developed in order to examine coconut coir feasibility as LCM by comparing with industrial nut plug and corn cob and to study on the effect of coconut coir concentration and particle size towards mud rheology, filtration volume and filter cake thickness.

Coconut coir is being examined as it is among the easiest fruit peel waste that can be found in the country and based on its characteristics. Based on study, coconut palm is one of the most important crops in Malaysia. With the increased of total area planted from 117000 hectares in 1998 to 147000 hectares in 2004, it also indicates that the fruits' wastes are increasing annually. The high content of lignin in coconut coir made the fiber tougher and stiffer as compared to other fibrous wastes.

Overall, coconut coir has showed some potential in acting as LCM. Although nut plug illustrated convincing values of plastic viscosity, yield point and gel strength, coconut coir has the advantages over the amount of filtrate and mud cake thickness. For the effect of particle size and concentration, course particles demonstrated good plastic viscosity and yield point. Finer particles, on the other hand, managed to control fluid loss better than course particles with thinner mud cake formation.

ACKNOWLEDGEMENT

Alhamdulillah, praised to Allah for He has the power of letting me to complete this dissertation as a requirement for my study in Bachelor of Petroleum Engineering. First and foremost, I would like to express my appreciation to my Final Year Project (FYP) supervisor, Mrs. Mazlin Idress for her kindness in guiding me through this research project. I also would like to express my highest gratitude to all lab technicians in Block 14 and 15 especially in drilling fluid lab for assisting me while making the experiments.

Special thanks to SCOMI Oiltools Kemaman as they have provided me with most of the chemicals required in making this research successful.

I am also very thankful to all my friends who have shared their knowledge especially those who previously have their internship in a drilling mud company. Last but not least, thanks to my family who have supported me throughout the entire project.

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

A drilling fluid is any fluid that is used in a drilling operation in which that fluid is circulated or pumped from the surface, down the drill string, through the drill bit, and back to the surface via the annulus. Drilling fluid is important in drilling operations since it plays role in;

i. Suspends and removes material (cuttings) from the borehole
ii. Cools, lubricates and cleans the bit
iii. Maintains wellbore stability
iv. Prevents formation fluids from entering the wellbore
v. Stabilizes the borehole pressures

However, one situation that occurs during drilling operation is lost circulation where lack of drilling mud fluid returning to the surface after being pumped down a well. Lost circulation mainly occurs when the drilling fluid encounters natural fractures or caverns, and consequently flows into the newly available pore spaces.

Within this project, a new composition of lost circulation mud with the mixture of coconut (*Cocos Nucifera*) coir (Figure 1) as a lost circulation material (LCM) is going to be formulated and tested for its efficiency in preventing drilling mud loss.

Figure 1. Mature coconut coir

1.2 PROBLEM STATEMENT

i. Problem Identification

In a drilling operation, pipe is lowered from the surface to the bottom hole as carrying a drill bit. The drill bit is rotated and thus removes drill cuttings ahead to extend the well. During most drilling procedure, a drilling fluid is pumped through the pipe and the drill bit. It returns through the annulus of the drilled well. Among other properties, the drilling fluid or mud in the annulus exerts a pressure on the surrounding formation to prevent both, the formation from collapsing into the well and sudden potentially hazardous influx of formation fluids. However the pressure exerted by the drilling fluid, when greater than the strength of the surrounding formation, generates fractures. Other fractures or openings may be already existed in the formation and crossed by the trajectory of the well. Through such fractures, a huge amount of drilling fluid can be suddenly lost to the formation.

Lost circulation or lost return (Figure 2) leads to partial or complete loss of the drilling fluid to pores in the formation. Such losses occur under varied conditions and the reason can often be difficult to identify. The loss of fluid to the formation represents a financial loss that should be dealt with, and the impact of which is directly tied to the per barrel cost of the drilling fluid and the loss rate over time.

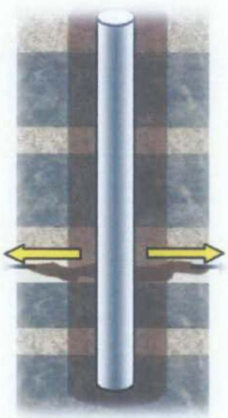


Figure 2. Lost circulation during drilling operation

In summary, subsurface conditions that lead to lost circulation are:

i. Induced or created fractures
ii. Cavernous formations (crevices and channels)
iii. Unconsolidated or highly porous formations (loose gravels)
iv. Natural fractures

To stop the loss of drilling fluids, the voids must be plugged so that a filter cake can be formed on the porous section. The plugging material must be of such reliability or contain particles of such sizes in order to offer greater resistance of the drilling fluid into the voids than the resistance to movement upward through the annulus. Thus, the so-called lost circulation materials (LCM) or agents are circulated in the well either as additives to the drilling fluid or as "pill" treatment.

ii. Significant of the Project

The problem of lost circulation became apparent in the early history of the drilling industry and was magnified considerably when operators began drilling deeper wells and through depleted formations. The industry pays millions of dollars a year to combat lost circulation and the detrimental effects it propagates, such as loss of rig time, stuck pipe, side-tracks, blowouts and, occasionally, the abandonment of expensive wells. It is estimated that lost circulation costs the industry more than US $800 million per year, while the lost circulation products could represent as much as US $200 million. Circulation losses can be prevented in zones known to be troublesome by simply adhering to good drilling practice.

1.3 OBJECTIVE AND SCOPE OF STUDY

The objective of this study is to formulate and develop a composition of drilling fluid containing coconut (*Cocos Nucifera*) coir as a green LCM to either prevent or mitigate loss of drilling fluid during drilling wells. This is done by analyzing the feasibility of coconut coir LCM in comparing with industrial nut plug and corn cob. Next, the effects of different particle sizes and concentrations towards its performance will be studied.

The scope of study will cover, but not limited to;

i. Literature review of coconut palm and coir – properties and characteristics.
ii. Fluid behavior – Newtonian and non-Newtonian fluids.
iii. Mud properties; mud formulation, density, plastic viscosity, yield point, gel strength filtrate volume performance test and mud cake thickness.
iv. Literature review of lost circulation materials – concepts and how it works theoretically.
v. Equipment to be used – equipment handling procedures and safety measures.

1.4 RELEVANCY OF THE PROJECT

Coconut coir is among the easiest fruit peel waste that can be found. In Malaysia, all parts of the country are using coconut mostly in cooking. The availability of this fruit peel waste freely in huge amount should not be a problem for LCM supply. Over 50 billion coconuts per year are produced by coconut trees (Walter L. Bradley and Howard Huang, 2006). In addition, coconut palm is not a seasonal fruit which means that it can supply coir continuously throughout the year.

Figure 3. Coconut coir processing in Malaysia

It is learnt that coconut coir can be extracted into long and short fibers. The long fibers are rigid and the short fibers are flexible. The long fibers form a tridimensional mat or net in the lost circulation pathway that traps the mixture of particles and short flexible fibers to form a mud cake (Jaleh Ghassemzadeh, 2010). The mixture of particles and blend of fibers may be added to water-based and oil-based drilling fluids. The composition, size, and concentration of each component of the mixture of particles and blend of fibers may be fine-tuned for various applications.

CHAPTER 2
LITERATURE REVIEW

2.1 UNDERSTANDING OF COCONUT (COCOS NUCIFERA L.)

Plant waste fibers can be described as lignocellulosics, i.e. resources comprised primarily of cellulose, hemicelluloses, and lignin. Lignocellulosics include timber, agricultural residues, water plants, grasses, and other plants substances (Rowell et al. 2000).

Plant waste fibers have the composition, properties, and structure that make them suitable for functions such as composite, textile, and pulp and paper manufacture. In addition, plant fibers can also be used to produce fuel, chemicals, enzymes, and food. Biomass, including agricultural crops and residues, forest resources, and residues, animal and municipal wastes, is the largest sources for cellulose in the world (Abdul Khalil et al, 2006).

Coconut fruit (*Cocos Nucifera L.*) (Figure 4) are an abundant renewable resource in coastal regions within 20° of the equator. Referring to Figure 5, in Zone 1 coconut trees are highly productive, in Zone 2 they are moderately productive, and in Zone 3 coconut trees grow but produce no fruit. Coconut palm is one of the most important crops in Malaysia. Statics showed that total area planted of coconut palm increased from 117000 (1998) to 147000 hectares in 2004 (Ministry of Agriculture, 2006).

Coconut fruit has approximately 1.6 kg of total mass, consisting of 35% husk, 28% copra, 12% shell, 5% milk, and 20% water in the husk. Coir fiber is obtained from coconut husk. Coir fiber is one of the hardest natural fibers, because it's high content of lignin. Coir is from the fibrous mass between the outer shell and the husk of the coconut – it comes from part of the seedpod of the coconut palm. Coir is stronger than cotton but because of its higher concentration of lignin, it is less flexible than cotton and doesn't dye very well. It is highly resistant to abrasion, water and weather. In fact, because it resists the effects of salt water so well, it is often used in fishing nets and ropes. Other uses for coir are indoor and outdoor mats, rugs, floor tiles, upholstery, and brushes. Mature coir fibers contain more lignin (a complex woody chemical) and less cellulose than fibers such as flax or cotton. Coir fiber is relatively water-proof.

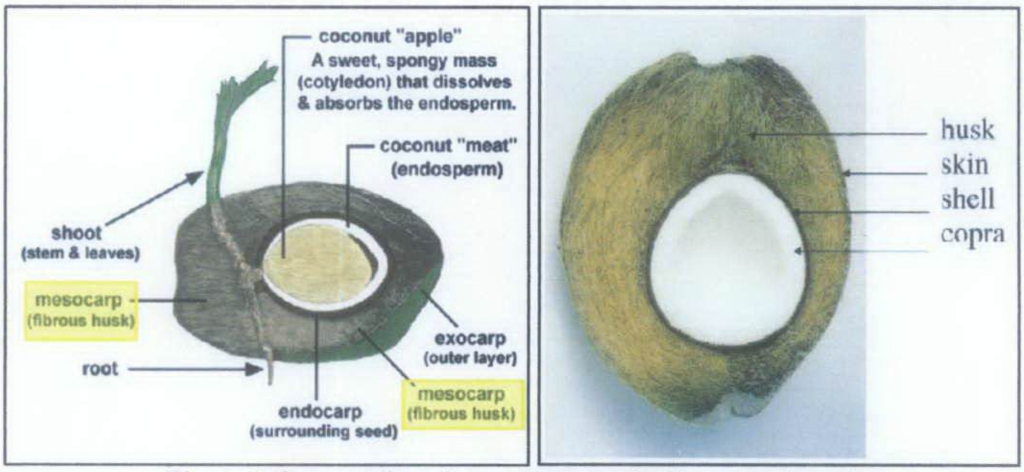


Figure 4. Cross section of coconut shows the fibrous husk part

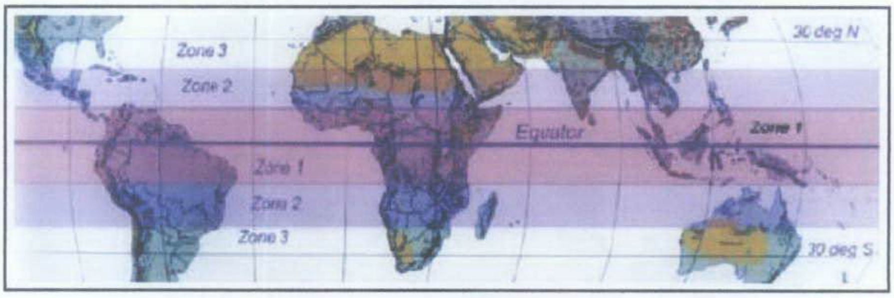


Figure 5. Coconut tree productivity around world

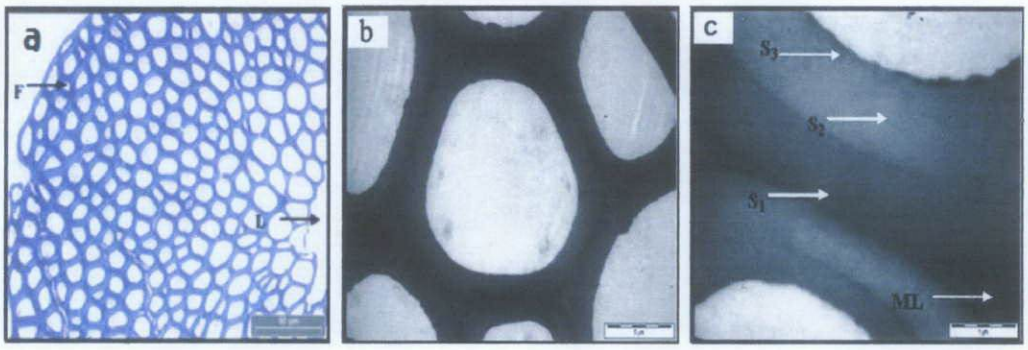


Figure 6. (a) Transverse section of coconut coir at (20x) magnification. F – fiber, L – lacuna. (b) Transmission electron micrograph of ultrathin section of coconut coir at (3400x) magnification. (c) Transverse section of a multi-layered structure of coconut coir at (17000x) magnification. S1, S2 – primary cell wall, S3 – secondary cell wall, ML – middle lamella.

Table 1. Chemical composition of different lignocellulosic fibers

	Oil palm frond	Coconut	Pineapple leaf	Banana stem	Softwood*	Hardwood*
Extractive (%)	4.5	6.4	5.5	10.6	0.2-8.5	0.1-7.7
Holocellulose (%)	83.5	56.3	80.5	65.2	60-80	71-89
α-cellulose (%)	49.8	44.2	73.4	63.9	30-60	31-64
Lignin (%)	20.5	32.8	10.5	18.6	21-37	14-34
Ash (%)	2.4	2.2	2.0	1.5	<1	<1

* Tsoumis 1996

Table 1 shows chemical composition of different lignocellulosic fibers which are oil palm frond, coconut, pineapple leaf and banana stem. Generally, coir fibers contained the highest percentage of lignin (32.8%), although there is probability that wood fiber percentage is higher (14-37%). The high content of lignin in coir fiber made the fiber tougher and stiffer, compared to the others. This is because lignin provides plant tissue and individual fibers with compressive strength and stiffens the cell wall of the fibers, to protect the carbohydrates from chemical and physical damage. Among the advantages of using coconut coirs are;

- High resistant towards decay (or expire) and wet condition
- Good insulation towards temperature
- Non-flammable
- Support water three times compared to its weight
- 15 times more resistant compared to cotton

Usually, coconut coir is sold in large quantity. The price for processed coconut coir in Malaysia can be estimated as (according to Mudah.my);

- 100 sacks = RM 550
- 200 sacks = RM 1000
- 300 sacks = RM 1450
- 400 sacks = RM 1880
- 500 sacks = RM 2300

2.2 UNDERSTANDING OF RHEOLOGY

The word rheology comes from the Greek - rheo, for flow, and –ology, meaning study of. In general, it means the study of how matter deforms and flows, including its plasticity and viscosity. Drilling fluids are expected to transport cuttings and control fluid loss. The rheology of drilling fluids plays an important role in both of these aspects of drilling fluid performance. A number of years ago the American Petroleum Institute (API) established a set of standards for evaluating the rheology of drilling fluids.

Two models were developed to discuss the rheology of fluid which are Newtonian and Non-Newtonian fluid. However, before going through the models, it is essential to understand the terms '*shear rate*' and '*shear stress*'. Figure 7 illustrates these two terms.

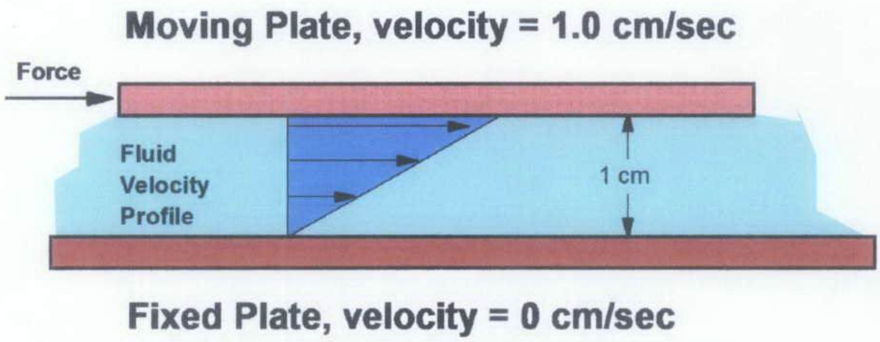


Figure 7. Illustration of shear stress and shear rate

i. **Shear rate**

- Defined as the relative velocity of the fluid layers, divided by their normal separation distance.
- Shear rate is expressed in reciprocal seconds (sec-1).
- Basic formula is:

$$\text{Shear Rate}, \gamma = V / H$$

Where: V = Velocity (cm/sec)

H = Distance (cm)

- The Shear Rate equivalent to the rpm's of a Rheometer (VG Meter) multiplied by 1.7033.

ii. **Shear Stress**

- Defined as the force required to overcome a fluid's resistance to flow, divided by the area that force is working on.
- Measured in dynes/cm^2.
- Shear Stress, lbs/100 ft^2 = Dial Reading X 1.0678
- Basic formula is:

Shear Stress, $\tau = F / A$

Where: F = Force applied (dynes)

A = Surface area under stress (cm^2)

2.2.1 Rheological Fluid Model

i. **Newtonian fluid**

A fluid that has a constant viscosity at all shear rates at a constant temperature and pressure. Sir Isaac Newton stated that "*For every action, there is an equal and opposite re-action*." Therefore, if a force is applied to a fluid layer, it should move. Every force increase should give a proportional velocity increase (Figure 8). Examples of Newtonian fluids are air, water and honey.

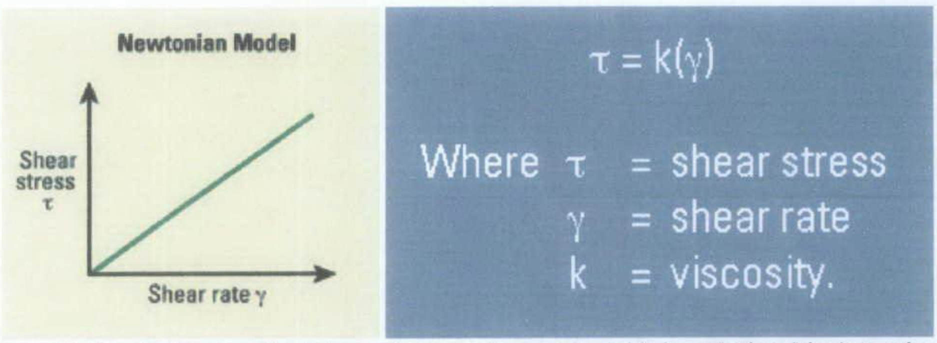


Figure 8. Newtonian graph of shear stress vs shear rate, with its relationship (equation)

ii. Non-Newtonian fluid

A fluid whose viscosity is not constant at all shear rates and does not behave like a Newtonian fluid. Most successful drilling fluids are non-Newtonian. Examples of non-Newtonian fluids are paint and molten plastics. Bingham Plastic and Power-Law are among Non-Newtonian fluid models.

The Bingham Plastic Model is the most widely used mathematical rheological model in the oil field. All data are generated from the 600 and 300 readings on a VG Meter. The model assumes that the fluid evaluated acts in a linear manner on the shear rate - shear stress curve, but has a positive yield stress (Figure 9).

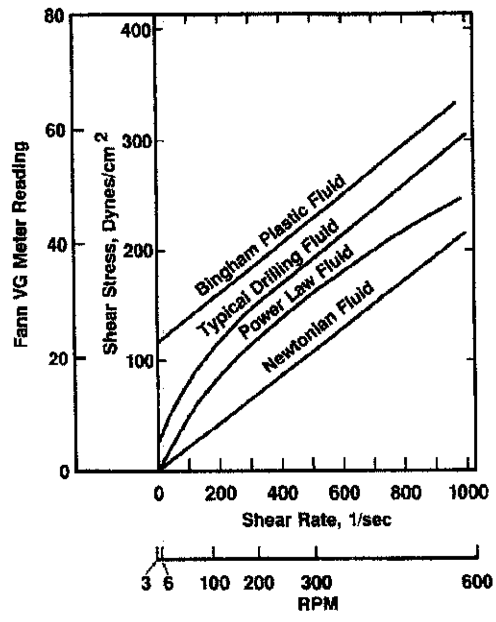


Figure 9. Non-Newtonian graphs of shear stress vs. shear rate for Bingham Plastic, typical drilling fluid, Power-Law and Newtonion models

The equation for the Bingham Plastic model is:

$$\tau = PV(\gamma/300) + YP$$

Where;

Plastic Viscosity (PV) = 600 reading – 300 reading

Yield Point (YP) = 300 reading – PV

Common terms associated with the Bingham Plastic Model are: plastic viscosity (PV), yield point (YP) and gel strengths. Most drilling fluids, as seen in Figure 9, do not match exactly to this model or to any universal model, but drilling fluid behavior can usually be approximated with acceptable accuracy. The Bingham Plastic Model assumes that the curve is approximated by a straight line. This is rarely true for drilling fluids, especially at low shear rates found in the annulus.

2.2.2 Type of Test to Be Conducted

Several tests will be conducted based on Bingham Plastic Model in order to evaluate the mud properties for all cases involved in this research. Based on the objectives of this study, two cases are expected to be initialized which are;

- **Case A: Coconut Coir Feasibility as LCM in Comparison with Industrial Nut Plug and Corn Cob.**
- **Case B: Identifying the Effects of Two Different Particle Sizes and Four Different Concentrations towards Coconut Coir Performance as LCM.**

Both cases will be evaluated based on the following:

i. Plastic Viscosity

Plastic Viscosity (PV) is the resistance of fluid to flow caused by mechanical friction. The friction is caused by several factors such as solids concentration, size and shape of solids, and viscosity of the fluid phase (Amoco Production Company Drilling Fluids Manual, 1994).

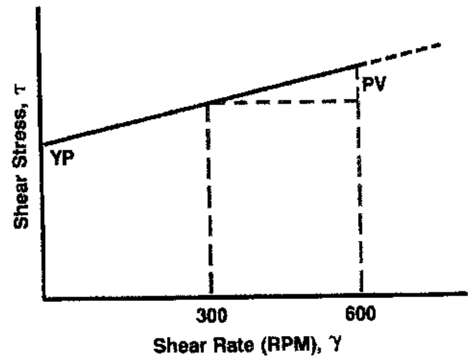


Figure 10. Bingham Plastic Model Parameters

According to the Bingham plastic model, the PV is the slope of shear stress and shear rate (Figure 10). Several impacts of PV on drilling operation (Rachain J, 2010) are as follows;

- Equivalent Circulating Density (ECD) – The higher the PV, the higher ECD will be.
- Surge and Swab Pressure – PV has the same effect as ECD. If the PV increases, surge and swab pressure will increase.
- Rate of Penetration (ROP) – High PV drilling mud results in slower ROP.
- Differential Sticking – Potential of differential sticking will increase, especially in water base mud, when the plastic viscosity increases because of increases in solid content.

ii Yield Point

Yield Point (YP) is resistance of initial flow of fluid or the stress required in order to move the fluid, caused by electrochemical forces between the particles. In other words, it simply means the attractive force among colloidal particles in drilling mud. This electrochemical force is due to charges on the surface of the particles dispersed in the fluid phase. Yield point is a measure of these forces under flow conditions and is dependent upon:

- The surface properties of the mud solids
- The volume concentration of the solids
- Ionic environment of the liquid surrounding the solids

Several impacts of YP on drilling operation (Rachain J, 2010) are as follows;

- Equivalent Circulating Density (ECD) - ECD normally increases when the YP increases
- Hole cleaning – Generally larger diameter hole requires higher YP value in order to increase hole cleaning efficiency

iii Gel Strength

Gel strength is the ability of the drilling mud to suspend drill solid and weighting material when circulation is ceased (static condition). It indicates the thixotropic (behavior exhibited by certain gels of becoming liquid when stirred or shaken) properties of a drilling fluid and are the measurements of the attractive forces under static conditions in relationship to time. Generally, gel strengths will increase with time, temperature, and increase in drill solids (Baker Hughes Drilling Fluids Reference Manual, 2006). Additionally, initial gel strength in a weighted fluid system must be sufficient to prevent settling of weight materials. Gels are described as progressive/strong or fragile/weak (Figure 11). For a drilling fluid, the fragile gel is more desirable since excessive gel strengths can cause problems such as:

- Swabbing, when pipe is retrieved
- Surging while pipe is lowered
- Difficulty in getting logging tools to bottom

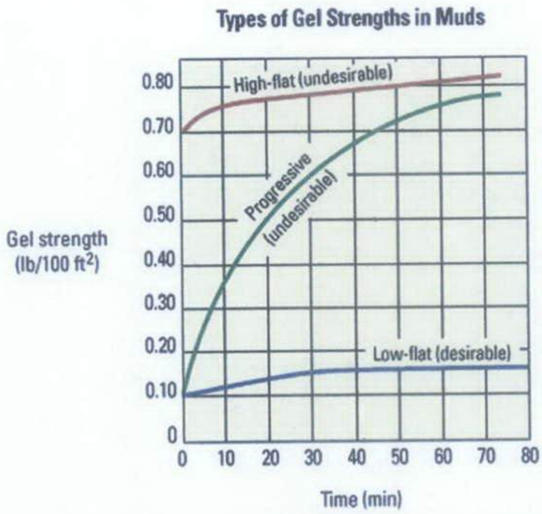


Figure 11. X-Y plot of gel strengths showing high-flat, progressive and low-flat gel

Gel strengths and yield point are both a measure of the attractive forces in a mud system. A decrease in one usually results in a decrease in the other; therefore, similar chemical treatments are used to modify them both. The 10-second gel reading more closely approximates the true yield stress in most drilling fluid systems (Amoco Production Company Drilling Fluids Manual, 1994). Water dilution can be effective in lowering gel strengths, especially when solids are high in the mud.

iv. Static Filtration Tests and Mud Cake Thickness

Filtration is a process of separating components of slurry by leaving the suspended solids as filter cake (Figure 12) on a filter medium, driven by differential pressure, while the liquid passes through it (Figure 14). This process can be divided into two types which are static and dynamic (Figure 13). Static filtration occurs when the fluid is not in motion (static) in the hole. Dynamic filtration occurs when the drilling fluid is being circulated. For this project, the test will only be focusing on the static filtration since the availability of the equipment in the lab. For static filtration, filter cake will continue to grow thicker as filtration continues. In theory, the filtrate volume increases as the square root of elapsed time. In the static filtration process, the filter cake continues to grow because no erosion occurs in the absence of shear. It is always desirable that the filter cake be thin due to several reasons such as to keep the amount and properties of the mud, reduce potential of differential sticking and prevent excessive drilling cost. This is the most important requirement placed on the filtration characteristics of a mud. The next characteristic which is important is that the cake has a low permeability. However, mud cake permeability will not be examined within this study.

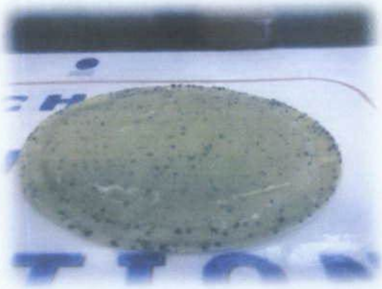


Figure 12. Mud cake formation during filtration test

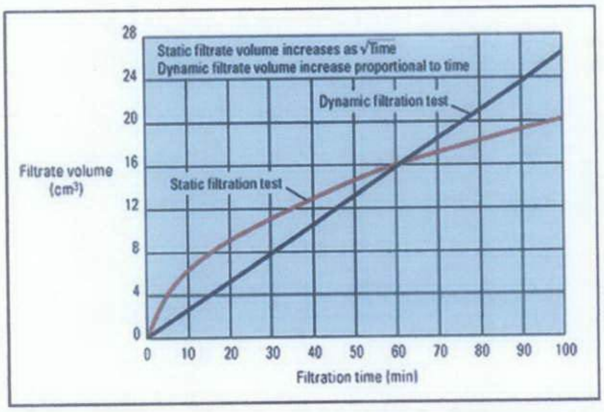


Figure 13. Relations between static and dynamic filtration volume over time

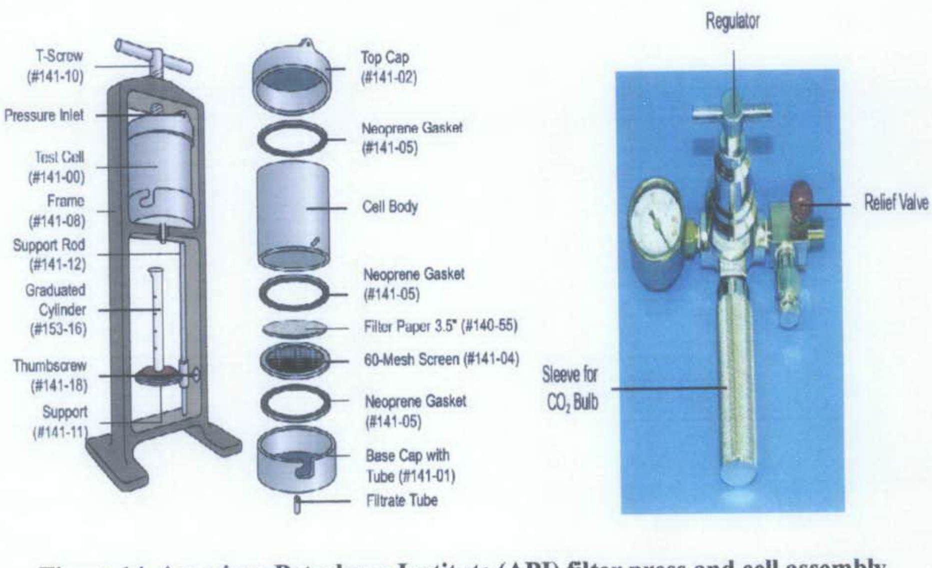


Figure 14. American Petroleum Institute (API) filter press and cell assembly

2.3 UNDERSTANDING OF LOST CIRCULATION MATERIAL (LCM)

Lost circulation materials (LCM) are substances added to drilling fluids when drilling fluids are being lost to the formations downhole. The main objective is to create filter cake (as thin as possible) thus prevent further loss of drilling fluid into the formation. Basically LCM can be divided into few types which are;

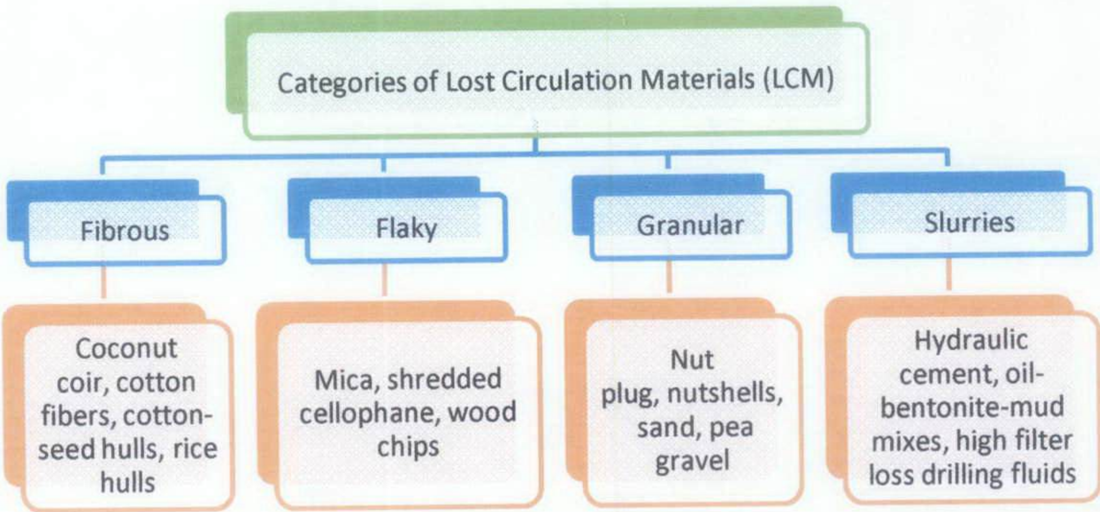


Figure 15. Categories of lost circulation materials (LCM)

Based on my findings, four key steps are available for 'Lost Circulation Assessment and Planning Program' (Catalin Ivan and James Bruton, 2003) which are:

i. Gather and process all the available project-related and problem-specific data (i.e., well team input, offset well data including logs, recaps etc.)
ii. Identify the most probable thief zones
iii. Develop project, specify lost circulation prevention and mitigation measures and guidelines
iv. Identify the best conventional lost circulation prevention, and recommending the contingency specialized treatments (i.e., cross-linking pills, gunk squeezes) including detailed operational procedures.

As planning and creating a strategy prior to drilling a potential lost circulation zone is critical for preventing and minimizing mud loss, it is very important that the right process in decision making takes place. The decision tree presented in Figure 16 can be employed successfully in selecting the appropriate techniques for curing the lost circulation in a specific case.

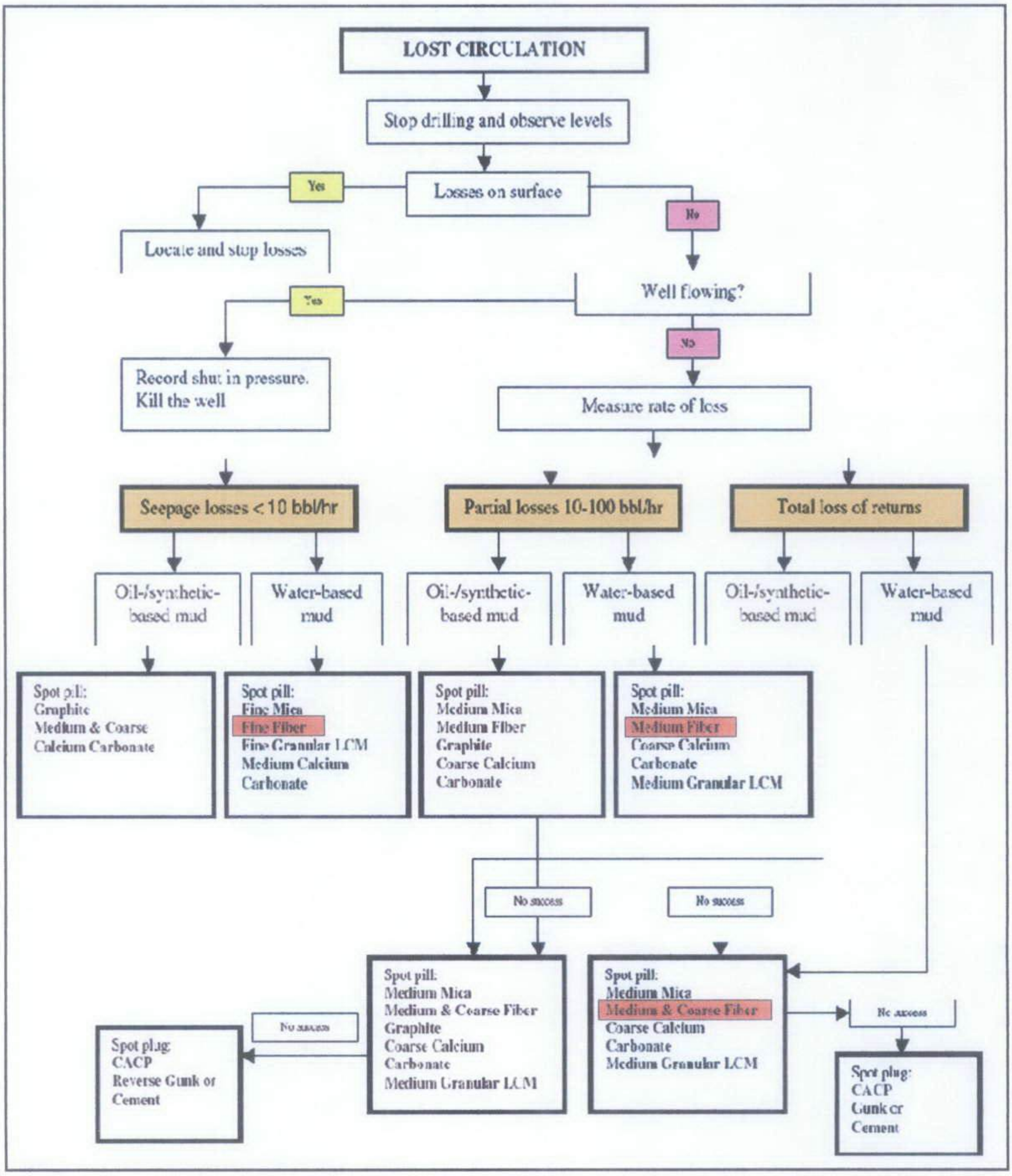


Figure 16. Lost circulation treatment decision tree. Figure also shows the usages of fiber type LCM in water-based mud and three type of loss severity (James R. Bruton, 2001)

2.3.1 Coconut Coir as a Lost Circulation Material (LCM)

Figure 17 shows a cross section of fractures in a typical rock formation surrounding the bore hole. The drill pipe extends through the well annulus. The fractures in the rock formation create openings in the well bore face through which drilling fluid can flow. Larger fractures as well as smaller fractures can cause excessive loss of drilling fluid.

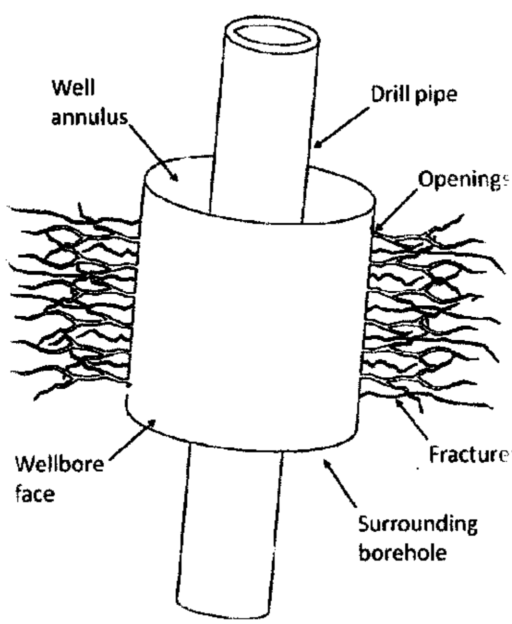


Figure 17. Scenario in well bore while drilling

Drilling fluid flows out of the borehole through the openings. Depending on the size and number of the openings, and the characteristics of the soil/rock formation, a considerable amount (or even all) of the drilling fluid can be lost.

Figure 18 shows a condition when the drilling fluid containing coconut coir being inserted in the bore hole. The drilling fluid containing coconut coir migrates through the openings in the wellbore face. As the coconut coir migrates through the openings, the smaller particles tend to lodge across the smaller openings, while the larger particles tend to lodge across the larger openings. As coconut coir continues to lodge in the fractures, it blocks the further migration of the drilling fluid into the fractures. Thus, the coconut coir eventually prevents further loss through the fractures. As particles of coir continue to absorb water and swell, they will more tightly seal (bridge) the openings and more completely block the flow of the drilling fluid. Depending on the amount (density) of processed coconut coir in the drilling mud, the coir may continue to swell (MacQuoid et al., 2004).

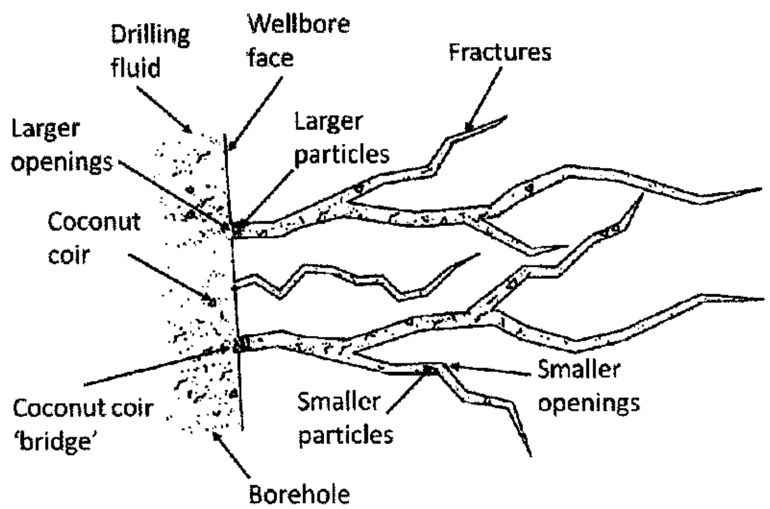


Figure 18. Scenario of drilling fluid together with coconut coir as LCM in the well bore

Figure 19 shows a close-up view of a fracture, with the opening through the well bore face. The drilling fluid containing coconut coir has migrated through the openings, lodge into the fractures thus impeding the further flow of drilling fluid.

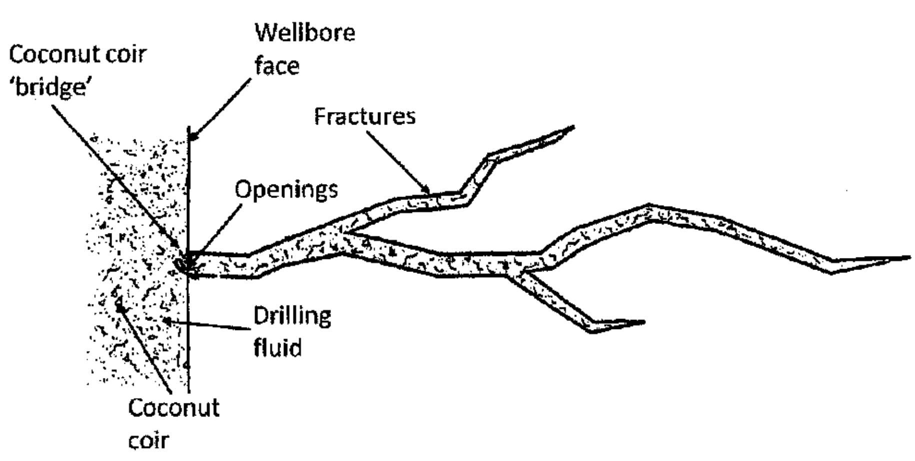


Figure 19. Close-up view of a fracture

Coconut coir can be used as the only lost circulation medium in that particular water-based mud, or can be used in combination (mix) with materials from fibrous, flaky or granular categories. By swelling to fill cracks in the rocks, the coir helps to improve the functioning of other materials. Coir then can be mixed (further researches) with slurries whose strength generally increases after placement such as hydraulic cement, oil-bentonite-mud mixes, and high filter loss drilling fluid.

On the other hand, the characteristic of absorbing water is advantageous as coir particles that lodge into the pores and holes of a region where drilling fluid is loss can continue to absorb water and swell. Continuously this will lodge the coir tighter into the openings and effectively sealing the hole. It will better prevent loss of drilling fluid than common LCMs.

I also found that several considerations should be studied first in order to get high performance LCM (James R. Bruton, 2001). This, however, might be an additional study since it requires higher level of research and continuous commitment;

i. A lost circulation material should be highly effective in sealing unconsolidated formations and fractures in hard formations.
ii. It should form an effective seal under both low and high differential pressure conditions.
iii. Final plug shear strength should be high enough to support fluid column, but low enough to ensure removal by washing or jetting (low sidetrack risk).
iv. The plugging seal has to withstand both negative (swab) and positive (surge) pressures applied during drilling, drill pipe trips and casing runs.
v. It should have workable/controllable set time and should be functional in oil-, synthetic- or water-based systems.
vi. It must resist from being blown around when added through the mud hopper.

2.3.2 Theoretical Outcomes

After preparing the LCM with the drilling fluid, the mixture will be tested for its rheology using viscometer followed by filtration test using the API filter press and cell assembly (Figure 14). When added to drilling fluid, the fibrous coconut coir moves towards the fractures and forms a mat-like bridge over porous formations. These mats effect a reduction in size of the openings to the formations, permitting the colloidal particles in the mud to rapidly deposit a filter cake thus effectively sealing the formation. Consequently this will produce results as shown in Figure 20. At the early stage, the LCM is creating its mat before successfully prevent the lost circulation. After a period of time, it is predicted that pores or fractures are sealed and there will be no significant lost circulation afterward. The figure also shows volume of mud that successfully being prevented from entering the well bore fractures (orange-shaded area) after LCM treatment.

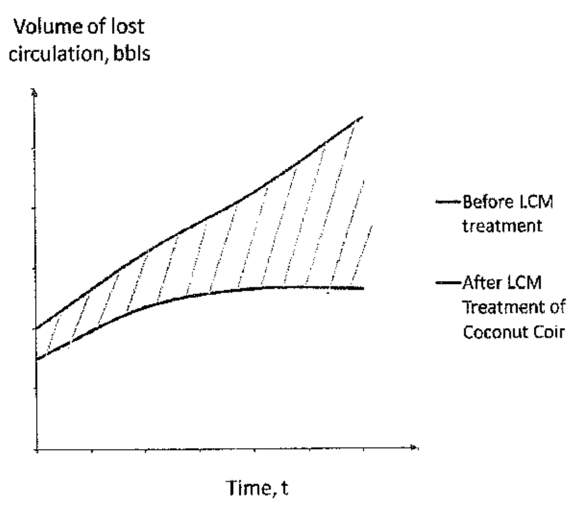


Figure 20. Estimated volume of lost circulation before and after the LCM treatment. The orange area between the two graphs indicates volume of mud that successfully being 'saved' from entering the well bore fractures

After additional studies, I also found out that the lost circulation can be further improved by increasing the LCM's concentration. Referring to the next Figure 21, we can observe the differences when the concentration of LCM is increased from 5 lb/bbl to 25 lb/bbl (based on research conducted by using synthetic rubber as LCM).

This means that larger quantity or concentration of LCM will increase the quality and effectiveness thus reduces failure of sealing built.

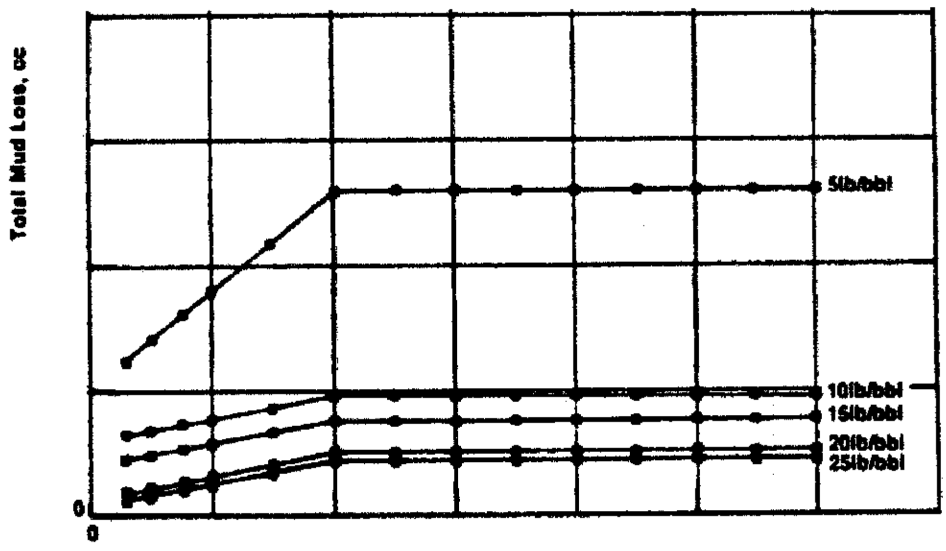


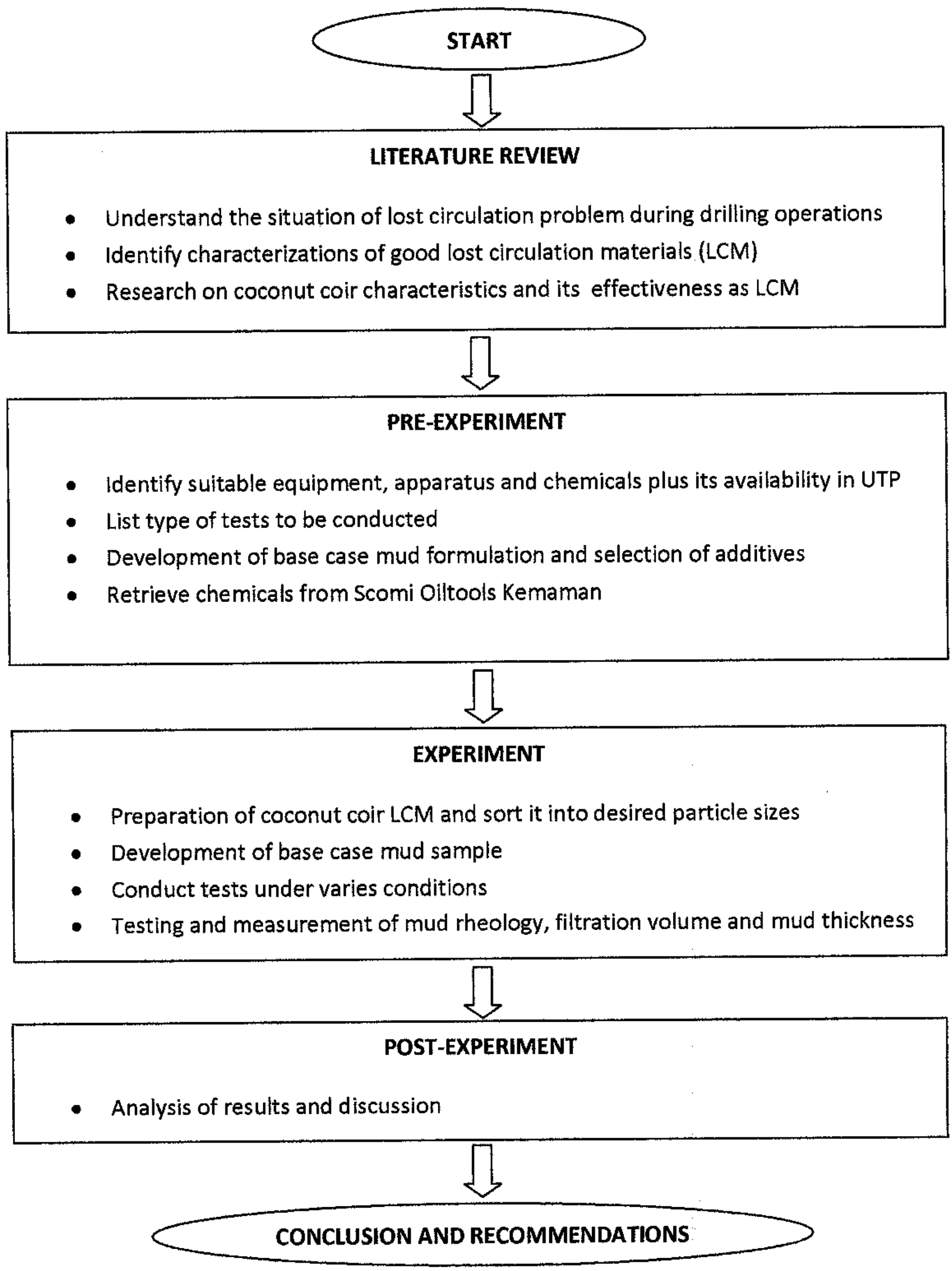
Figure 21. Change in volume of lost circulation (total mud loss) as concentration of LCM increased

Briefly, the actual experiment will give me further chance to improve my understanding about the project I am running. From there, I will further analyze the effectiveness of using coconut coir as LCM based on the type of tests that were discussed earlier. This will be achieved by using water-based mud and laboratory equipment that will be discussed in the upcoming chapters. Outcomes and results will be taken, calculated, analyzed and presented for evaluation.

Consequently, if coconut coir failed to act effectively in preventing further lost circulation, the reasons will be figured out and discussed. This is important as it shows why coconut coir characteristics are not suitable for LCM. It also can assist in future improvement if the potential of using it as LCM is still there.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 PROJECT ACTIVITIES



3.2 KEY MILESTONE & GANTT CHART

Final Year Project 2 Gantt Chart															
Project Schedule	**Week**														
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Briefing & update on students progress															
Project work commences															
Submission of Progress Report															
Pre-EDX combined with seminar/ Poster exhibition/ Submission of Final Report (CD Softcopy & Softbound)															
EDX															
Final oral presentation															
Delivery of Final Report to external examiner / marking by external examiner															
Submission of hardbound copies															

3.3 EQUIPMENT AND PREPARATION OF DRILLING MUD

Before preparing the drilling mud, it is important to understand the equipment to be used during the experiment, their functions and handling procedures.

1. **Sieve Shaker** - shakes stacks of sieves for a certain amount of time when doing sediment analysis. It sorts different sizes of grains (processed coconut coir) to fall into the correct sieves containers.

Figure 22. Sieve shaker (left) and sample of 150 micron coconut coir (right)

Table 2: Particle sizes and classifications

Particle Size	Particle Classification
> 200 microns	Coarse
200 - 150 microns	Intermediate
150 - 74 microns	Medium
74 - 44 microns	Fine

2. **Electronic Balance** – measures mass in gram (g).

Figure 23. Electronic balance

3. **Multi-Mixer** – mixes all ingredients needed to develop drilling fluid.

Figure 24. Multi-Mixer

4. **Mud Balance** – also known as a mud scale, use to measure the density (weight) of drilling fluid, cement or any type of liquid. The mud balance consists of a graduated beam with a bubble level and a weight slider along its length and a cup with a lid on one end. The cup is used to hold a fixed amount of fluid so it can be weighed.

Figure 25. Mud Balance

Determining mud weight using the mud balance:

i. Instrument base must be set on a flat level surface.
ii. Measure and record the mud temperature.
iii. Fill the mud cup with the mud to be tested.
iv. Replace cap and rotate until it is firmly seated, ensuring some of the mud is expelled through the hole on top, to free any trapped gas.

v. Place the beam on the base support and balance it by using the rider along the graduated scale. Balance is achieved when the bubble is directly under the centre line.

vi. Take the mud weight reading

5. **Fann VG Rheometer** - measures the way in which a liquid, suspension or slurry flows in response to applied forces. It is used for those fluids which cannot be defined by a single value of viscosity and therefore require more parameters to be set and measured than is the case for a viscometer.

Figure 26. Fann VG Rheometer

It is important to regularly monitor the mud rheology as to make sure that the mud is always within the specification as stated in the mud program:

i. Place the sample in the rheometer thermo cup and adjust the cup until the mud surface level is equal height to the scribed line on the rotor surface.

ii. Turn on the rheometer, first taking dial measurements at the top most speed (600rpm), then gradually switch to lower gear and to obtain all readings (600, 300, 200, 100, 6,3 rpms).

a. Determining Plastic Viscosity

Indicate the amount of solids (sands, silts) in mud. High PV means that the mud is not clean and there is a problem with the solids control equipment.

PV = 600 rpm reading - 300 rpm reading

b. Determining Yield Point

Indicate the carrying capacity of cuttings (usually the case is that the higher the viscosity is, the higher the YP).

YP = 300 rpm reading – PV

c. Determining Gel Value of the mud using Rheometer:

i. Stir the sample in 600rpm speed for 15 seconds. Just before the motor stops, slowly shift the moving gear to the lowest speed.
ii. Wait for 10 seconds. After 10 seconds has finished, turn on the 3rpm speed and record the maximum deflection of the dial. This is the 10 seconds gel reading.
iii. Repeat step one and step two, but this time, wait for 10 minutes before turning on the 3rpm speed. The maximum deflection of this reading shall give us the 10-minute gel reading.

6. **Low Pressure Low Temperature Filtration Test** - measures static filtration behavior of water mud at ambient (room) temperature and 100-psi differential pressure, usually performed according to specifications set by API, using a static filter press. Knowing the fluid loss is important since it is undesirable to have mud that has a high filtrate loss because this contribute to high fluid invasion and also thick mud cakes.

There are two important parameters to be measured using this equipment:

i. The filtrate volume that passed through (cc/30 min)
ii. The thickness of the cake on the filter paper (mm)

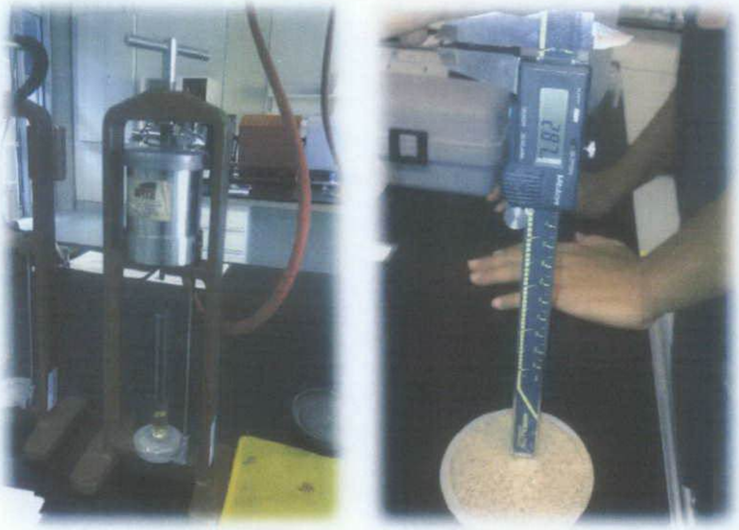


Figure 27. Low pressure low temperature filtration test (left) and mud cake thickness measurement (right)

3.4 DRILLING MUD COMPOSITION

For this project, water-based mud is being used as the drilling fluid. General composition of water-based mud is shown in the figure below;

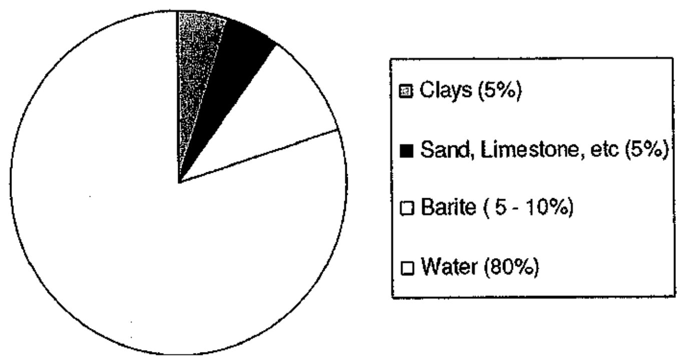


Figure 28. General composition of water-based mud

The selection of water-based mud in the project is driven by several advantages (over oil-based mud (OBM)) such as;

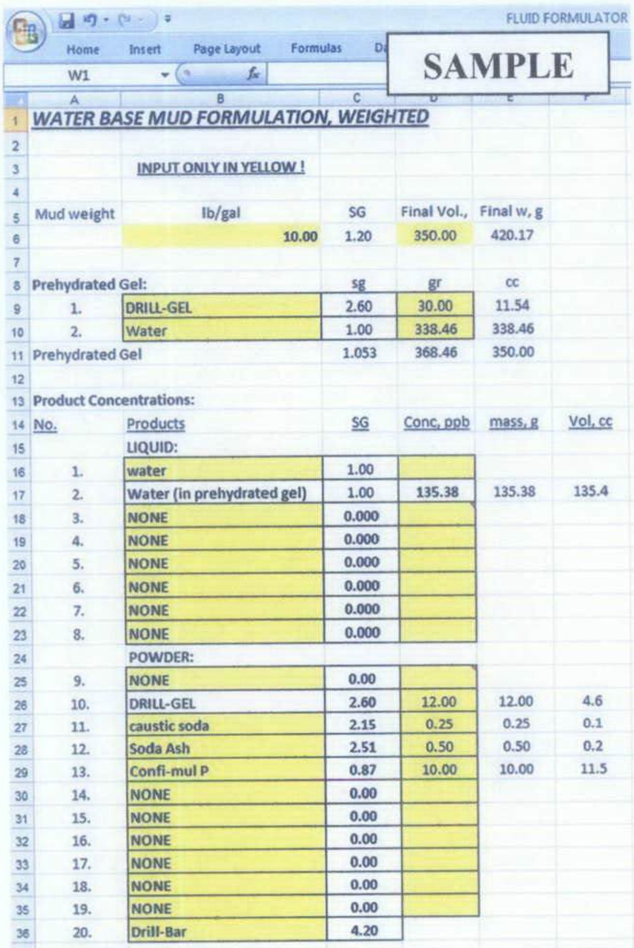
i. Cheaper
ii. More environmental friendly
iii. Less handling complexity
iv. Easier to prepare / less time consuming
v. Can be formulated to overcome most drilling problems (Amoco Production Company Drilling Fluids Manual, 1994)

Basically the mud (as shown in Figure 28) contains:

i. Fluid phase – water as continuous phase.
ii. Solids (to give desired mud properties):
   - Inactive solids – do not react within mud (e.g. barite as weighting agent).
   - Active solids – clays that react with chemicals (e.g. bentonite as viscosifier).

iii. Other additives (e.g. soda ash and caustic soda) – aid in controlling viscosity, yield point, gel strength, fluid loss, pH value, filtration behavior.

For more accurate composition of drilling fluid, I choose to use the Fluid Formulator Excel Spreadsheet generated by Scomi Company. This file was obtained from a colleague who was an intern in that company previously. By using the excel file, I can simply key-in the desired mud weight and final volume that I wish to add inside the yellow columns as shown in Figure 29(a). The output from the data inserted will be shown in Figure 29(b).



	A	B	C	D	E	F
1	WATER BASE MUD FORMULATION, WEIGHTED					
2						
3		INPUT ONLY IN YELLOW !				
4						
5	Mud weight	lb/gal	SG	Final Vol.,	Final w, g	
6		10.00	1.20	350.00	420.17	
7						
8	Prehydrated Gel:		sg	gr	cc	
9	1.	DRILL-GEL	2.60	30.00	11.54	
10	2.	Water	1.00	338.46	338.46	
11	Prehydrated Gel		1.053	368.46	350.00	
12						
13	Product Concentrations:					
14	No.	Products	SG	Conc, ppb	mass, g	Vol, cc
15		LIQUID:				
16	1.	water	1.00			
17	2.	Water (in prehydrated gel)	1.00	135.38	135.38	135.4
18	3.	NONE	0.000			
19	4.	NONE	0.000			
20	5.	NONE	0.000			
21	6.	NONE	0.000			
22	7.	NONE	0.000			
23	8.	NONE	0.000			
24		POWDER:				
25	9.	NONE	0.00			
26	10.	DRILL-GEL	2.60	12.00	12.00	4.6
27	11.	caustic soda	2.15	0.25	0.25	0.1
28	12.	Soda Ash	2.51	0.50	0.50	0.2
29	13.	Confi-mul P	0.87	10.00	10.00	11.5
30	14.	NONE	0.00			
31	15.	NONE	0.00			
32	16.	NONE	0.00			
33	17.	NONE	0.00			
34	18.	NONE	0.00			
35	19.	NONE	0.00			
36	20.	Drill-Bar	4.20			

Figure 29(a). Excel spreadsheet of Scomi's Fluid Formulator used to determine drilling fluid composition for experiment. The above figure shows the input section

OUTPUT:

No.	Products	SG	Conc, ppb	mass, gr	Vol, cc	bbl/bbl	GPB	l/l	kg/l	kg/m³				%V
	LIQUID:													
1.	water	1.00	178.24	178.24	178.24	0.51	21.39	0.51	0.51	509.25	0.42	0.00		
2.	Water (In prehydrated gel)	1.00	135.38	135.38	135.38	0.39	16.25	0.39	0.39	386.81	0.32	0.00		
3.	NONE	0.00												
4.	NONE	0.00												
5.	NONE	0.00												
6.	NONE	0.00												
7.	NONE	0.00												
8.	NONE	0.00												
	POWDER:													
9.	NONE	0.00												
10.	DRILL-GEL	2.60	12.00	12.00	4.62	0.01	0.55	0.01	0.03	34.29	0.03	0.00	0.03	
11.	caustic soda	2.15	0.25	0.25	0.12	0.00	0.01	0.00	0.00	0.71	0.00	0.00	0.00	
12.	Soda Ash	2.51	0.50	0.50	0.20	0.00	0.02	0.00	0.00	1.43	0.00	0.00	0.00	
13.	Confi-mul P	0.87	10.00	10.00	11.49	0.03	1.38	0.03	0.03	28.57	0.02	0.00	0.02	
14.	NONE	0.00												
15.	NONE	0.00												
16.	NONE	0.00												
17.	NONE	0.00												
18.	NONE	0.00												
19.	NONE	0.00												
20.	Drill-Bar	4.20	83.79	83.79	19.95	0.06	2.39	0.06	0.24	239.41	0.20	0.00		0.20
FINAL MUD														
	10.00 ppg	1.200	420.168	420.17	350.00	1.00	42.00	1.00	1.20	1200.48	100%	0%	5.4%	20%

SAMPLE

Figure 29(b). Excel spreadsheet section which displays the output of drilling mud composition

Table 3. Base Case mud formulation

Chemicals	Composition (g)
Water	318.93
Soda Ash	0.5
Drill Gel	12
Drill Bar	109.19
Duovis	0.3
Caustic Soda	0.25

During this research, the mud weight will be kept constant as at 10.5 lb/gal. The final volume also has been set to 350 cm³. By taking into consideration advices from supervisor and colleagues, I have come to a formulation for my drilling mud as shown in Table 3. After mixing all of the chemicals step by step, the LCM will be added into the 10.5 ppg mud for 10 minutes (Figure 30).

Figure 30. Coconut coir before mixing (left) and after mixed with drilling fluid (right)

Before continuing with the experiment, a request has been sent to Scomi Oiltools Kemaman to provide most of chemicals needed. After the permission has been granted, collection of the chemicals was done sometimes in December 2010 (Figure 31). The chemicals then were being relocated to UTP's lab and labeled.

Figure 31. Retrieve chemicals from Scomi Oiltools Kemaman

CHAPTER 4

RESULTS AND DISCUSSION

As were discussed earlier in the introduction part, the objectives of this study can be divided into two. The first purpose is to determine the effectiveness and feasibility of coconut coir as LCM by comparing it with industrial LCM which are nut plug and corn cob. Then the second objective is to determine the effects of particle sizes and concentration towards the coconut coir performance.

4.1 CASE A: COCONUT COIR FEASIBILITY AS A LCM IN COMPARISON WITH INDUSTRIAL NUT PLUG AND CORN COB

Table 4. Experimental results for comparison between base case, fine particles of nut plug, coconut coir and corn cob

Mud weight	10.5 ppg						
Rheology at	120° Fahrenheit						
Case	Base Case	Fine nut plug 5 grams	Fine nut plug 10 grams	**Fine coconut coir 5 grams**	**Fine coconut coir 10 grams**	Fine corn cob 5 grams	Fine corn cob 10 grams
600 rpm	45	49	50	62	54	41	42
300 rpm	32	36	35	44	35	31	30
200 rpm	26	29	25	40	30	26	25
100 rpm	20	23	20	31	24	21	20
6 rpm	9	11	8	16	10	15	13
3 rpm	8	10	7	14	9	15	12
PV,cp	13	13	15	18	19	10	12
YP, lb/100ft^2	19	23	20	26	16	21	18
Gel 10 sec	7	10	10	13	10	17	13
Gel 10 min	13	18	12	20	14	25	19
Mud thickness, mm	1.00	2.00	2.20	2.00	1.85	2.02	2.17
API , cc/30min	13.8	13.8	15.0	14.0	13.2	19.0	19.5

Table 4 presents the results of seven cases which were done to analyze the effectiveness of coconut coir as LCM which include the comparisons of rheology and API filtration test between the base case, industrial nut plug, proposed coconut coir and industrial corn cob. All cases are subjected to temperatures of 120°

Fahrenheit. The analysis starts by observing the plastic viscosity behaviors followed by other measurements.

4.1.1 Plastic Viscosity and Yield Point

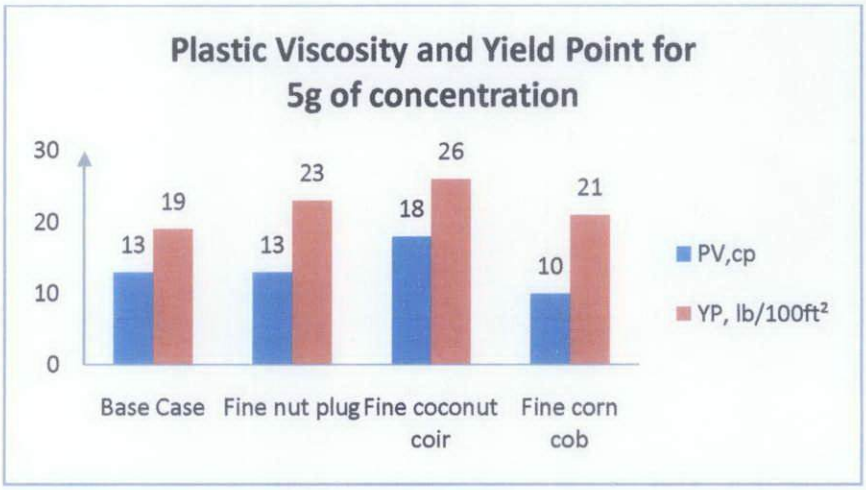


Figure 32. Plastic viscosity and yield point results for four cases of base case and 5 grams of LCM concentration

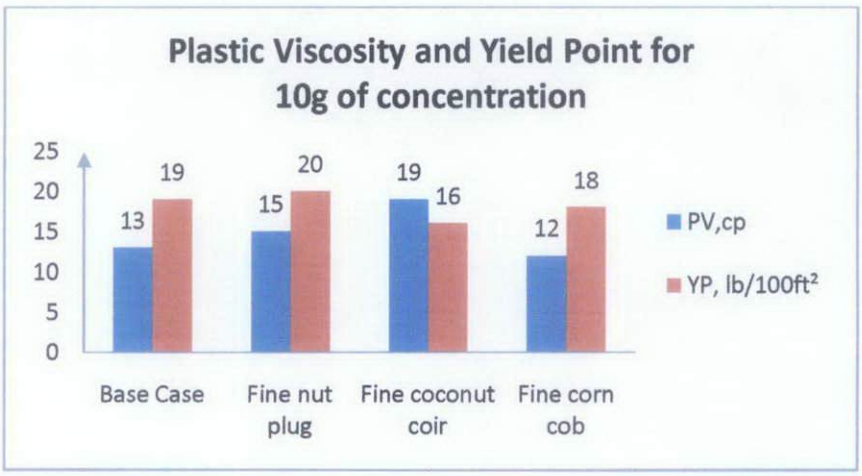


Figure 33. Plastic viscosity and yield point results for four cases of base case and 10 grams of LCM concentration

Based on Figure 32 and 33, the plastic viscosity (PV) trend shows increment as the concentrations of LCMs were increased. Obviously we can observe that the coconut coir produced greater PV compared with industrial LCMs and base case. This may cause by the specific gravity of the coconut coir of approximately 0.87 (M. Sivaraja,

2010) compared with the specific gravity of nut plug which is 1.2-1.4 (Champion Drilling Fluid, 1999) and corn cob 1.0-1.2 (OptaMinerals Inc, 2011). Since the SG of coconut coir is the lowest, more coir particles must be added to reach the same weight (5 grams) as nut plug and corn cob. This consequently resulted in more solid build-up or excess colloidal solids inside the drilling fluid which then leads to higher plastic viscosity values. Increasing PV values is actually a good indicator of a solids build-up (Scomi Oiltools Drilling Fluid Engineering Handbook, 2008). Even though the PV of coconut coir blend values is higher, a reduction in solids content can be achieved by reducing solid content i.e. by diluting drilling mud with base fluid. For plastic viscosity, I can conclude that corn cob and nut plug are better than coconut coir for both 5 and 10 grams concentrations since they have lower PV (and within acceptable range – Figure 34) thus indicates that the mud is capable of drilling rapidly with higher ROP because of the low viscosity of mud exiting at the bit.

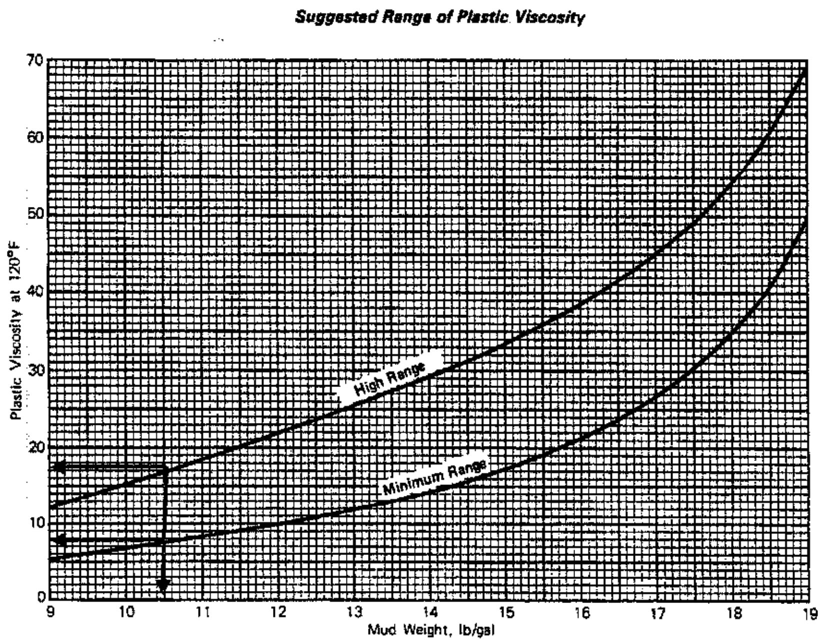


Figure 34. Suggested range of plastic viscosity

As for yield point results, we can observe that the yield point (YP) increased after the addition of 5 grams of nut plug, coconut coir and corn cob. However, the trend went downward after the concentrations of all LCMs were increased to 10 grams. In theory, the increase of LCM amount inside the drilling fluid will increase the amount of fine solids, rising the attractive forces among the colloidal particles. This resulted in increase carrying capacity which means that the yield point should be increased rather than going down. However the inconsistent readings of all LCMs (which contain lignin) can be explained by the following phrase;

'*Charges on the positive edges of particles can be neutralized by adsorption of large negative ions on the edge of the clay particles. These residual charges are satisfied by chemicals such as: lignins, complex phosphates, lignosulfonates, etc. The attractive forces that previously existed are satisfied by the chemicals, and the negative charge of the clay particles predominates, so that the solids now repel (force back) each other*'.

(Amoco Production Company Drilling Fluids Manual, 1994)

In this case, all LCMs showed the same pattern. However, from this point of view, industrial LCMs showed more consistent results with higher YP and smaller decrement of 3 lb/ 100 ft^2 after addition of 10 grams of concentration. Coconut coir on the other hand, produced higher YP for 5 grams of concentration. Note that coconut coir's YP also fall within acceptable range (Figure 35).

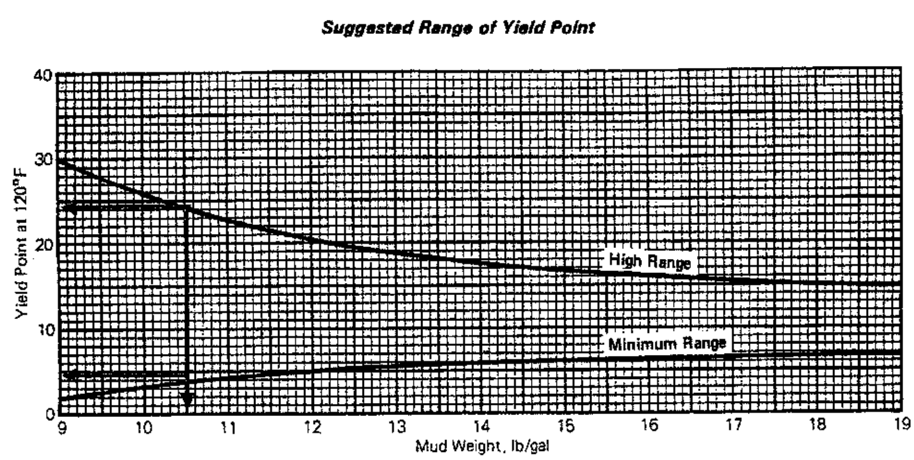


Figure 35. Suggested range of yield point

4.1.2 Gel Strength

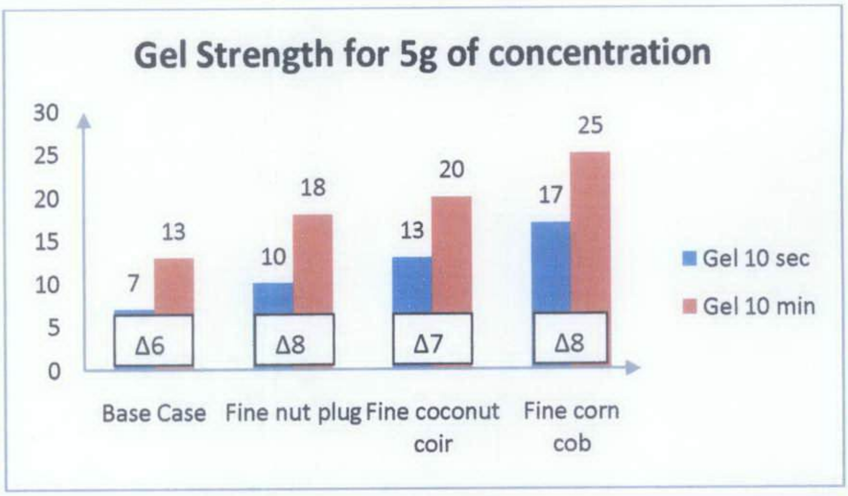


Figure 36. Gel strength results for four cases of base case and 5 grams of LCM concentration

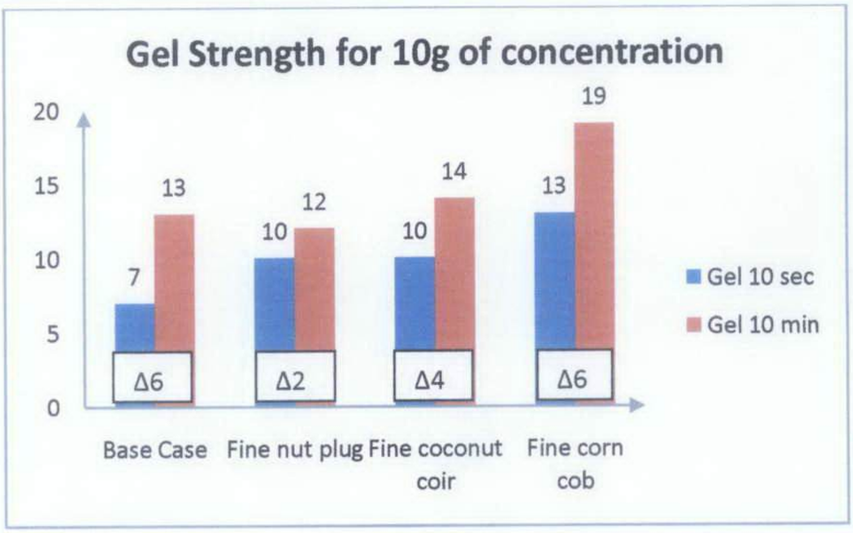


Figure 37. Gel strength results for four cases of base case and 10 grams of LCM concentration

Based on Figure 36, we can observe that for 5 grams concentration of coconut coir, the gel strengths values recorded are higher than nut plug. The trend is the same in the case of 10 grams of concentration. It is understood that increase in low-gravity solids (LGS) will increase the gel strength values (Scomi Oiltools Drilling Fluid Engineering Handbook, 2008). Since coconut coir has lower SG value (thus more amount of particles) compared with nut plug, it will illustrate higher gel strength values. However, due to some reason which might be higher tendency for flocculation due to higher attractive forces, corn cob is showing high readings of gel strength for both concentrations although the amount of solid is lesser than coconut coir.

While yield point are considered as dynamic properties, gel strengths and yield point are somewhat related in that gel strengths will typically decrease as the yield point decreases (Baker Hughes Drilling Fluids Reference Manual, 2006). This is proved as we compare Figure 37 and 36 with previous observation of yield point in Figure 33 and 32. The 10 minutes gel strength will cause 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 (Rogers, 1978). All three LCMs illustrated that the values obtained tend to decrease as the concentration is increased. In general, the results are good since high gel strengths are not desirable and can even be dangerous.

Based on gel strength results, nut plug continues to illustrate good LCM characteristics as it has lower 10-seconds and 10-minutes gel strength compared with coconut coir and corn cob. Nut plug and coconut coir showed slight differences in the amount of incremental while corn cob yielded even higher incremental value as more concentration of it is added into the mud.

4.1.3 API Filtration Volume and Mud Cake Thickness

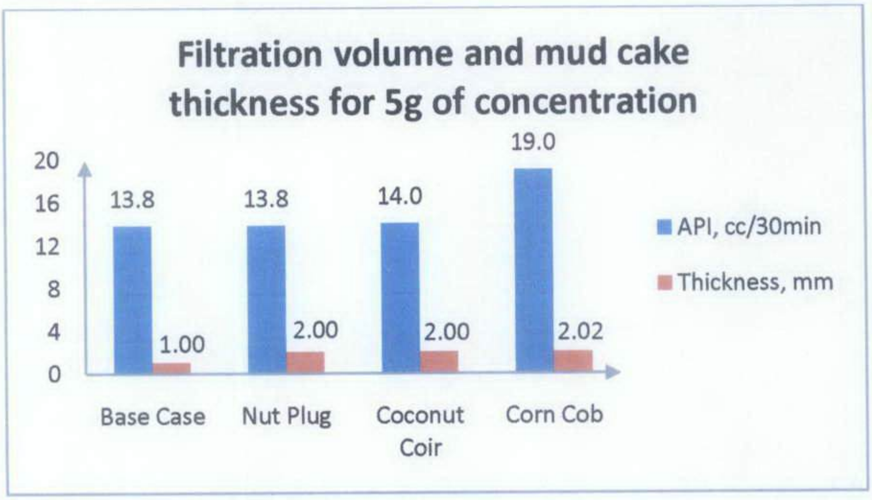


Figure 38. Filtration volume and mud cake thickness results for four cases of 5 grams of LCM concentration

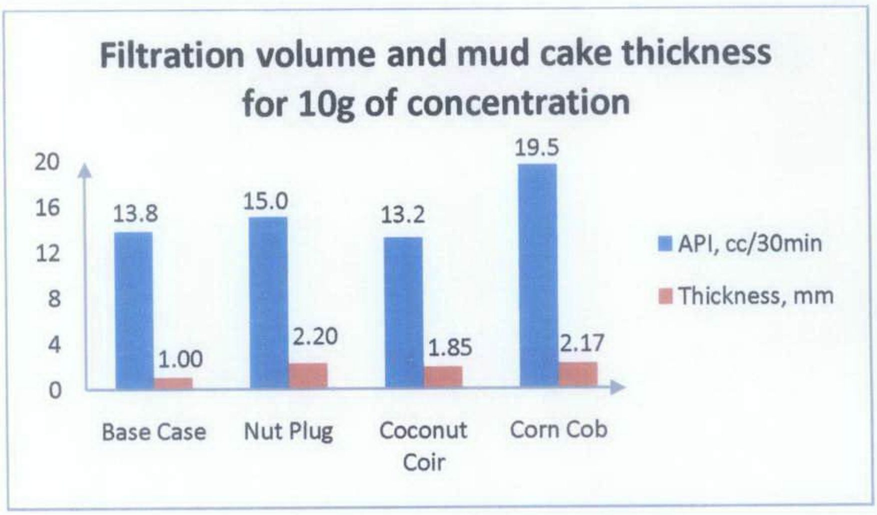


Figure 39. Filtration volume and mud cake thickness results for four cases of 10 grams of LCM concentration

Figure 38 and 39 illustrate the results obtained for API fluid loss and filter cake thickness for five cases after 30 minutes of filtration test under differential pressure of 100 psi. For nut plug case, the fluid loss increased as much as 1.2 cm^3 as higher concentration of nut plug is added. Corn cob also showed increased in filtrate volume of 0.5 cm^3 compared to 5 grams of concentration. However, in the case of coconut coir, the filtrate volume decreased as much as 0.8 cm^3 for 10 grams concentration. Theoretically, the amount of fluid loss should decrease as higher LCM concentration is added. But, depending on type of LCM used, the optimum concentration of LCM that minimizes the fluid loss amount might be different (Ali A. Pilehvari, 2002) as shown in Figure 40. For this experiment, nut plug and corn cob might already trespassed their optimum concentrations thus the reading for 10 grams concentration got higher than 5 grams. On the other hand, coconut coir is still moving towards its optimum concentration thus the results show decreasing volume. Based on this observation, coconut coir shows convincing fluid loss volume in reference with the base case, industrial nut plug and corn cob. This might be related to coconut coir characteristic as fibrous material which is best used for controlling losses to porous and highly permeable formations (Middle East Technical University, 2011), because they are able to form a mat-like bridge over the pore openings. The mat reduces the size of the openings to the formation, allowing the colloidal particles in the mud to rapidly deposit a filter cake. Nut plug and corn cob, in contrast, are categories as granular particles.

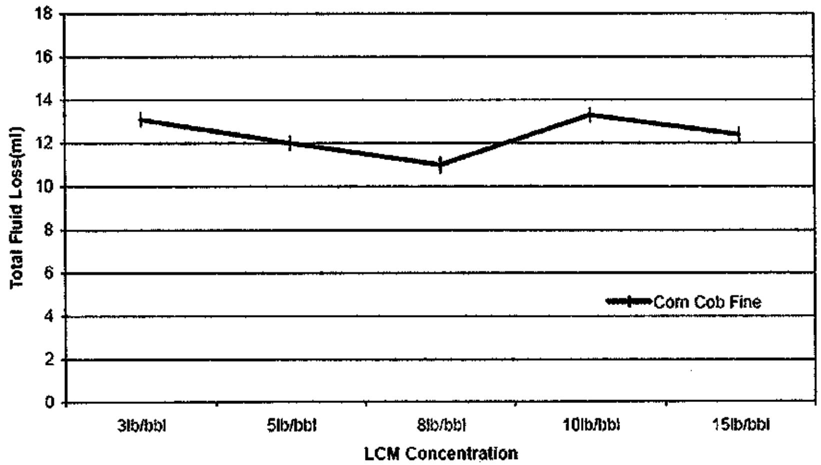


Figure 40. Optimum concentration of fine Corn Cob LCM that produce minimum fluid loss of 11 ml at 8 ppg concentration

As for filter cake, practically, the thickness should be less than or equal to 1/16 inch (1.6 mm) (Rachain J, 2010). Bad drilling fluid will result in a thick filter cake in the wellbore, thus might lead to stuck pipe situation and high torque/drag. Referring to Figure 38 and 39, the mud cake thickness for industrial LCMs slightly increased as more LCMs are added into drilling fluid. All values are greater than 1.6 mm except for base case. The inconsistent results of mud thickness might be due to parallax error during reading. However, in general, the results should obey the concept of as more amount of the LCM is added gradually, the weight of the mud is increased causing the density and plastic viscosity to increase while the yield point and gel strength to decrease. This affects the rate of the water filtered to decrease, causing the thickness of the mud cake to increase too as well. As discussed earlier under API fluid loss section with the aid of Figure 40, nut plug and corn cob might already cross their optimum concentration, thus the mud cake formation got thicker again with higher fluid loss. Thus, based on the mud cake thickness and filtration volume, coconut coir has shown good characteristics in both measurements.

4.2 CASE B: IDENTIFYING THE EFFECTS OF TWO DIFFERENT PARTICLE SIZES AND FOUR DIFFERENT CONCENTRATIONS TOWARDS COCONUT COIR PERFORMANCE AS A LCM

Table 5. Experimental results for course coconut coir with four concentrations at 80° Fahrenheit

Mud Weight	10.5 ppg				
Rheology	80° Fahrenheit				
Case	Course coconut coir 3 g	Course coconut coir 5 g	Course coconut coir 8 g	Course coconut coir 10 g	Base case
600 rpm	45	55	73	80	36
300 rpm	33	41	56	58	26
200 rpm	26	35	45	49	22
100 rpm	19	25	32	39	18
6 rpm	11	14	19	27	12
3 rpm	11	13	18	26	11
PV, cp	12	14	17	22	10
YP, lb/100ft^2	21	27	39	36	16
Gel 10 sec	10	10	12	11	13
Gel 10 min	22	23	27	25	23
API, cc/30min	13.5	14.5	17.0	15.5	19
Mud thickness, mm	2.40	2.90	3.60	3.35	2.2

Table 6. Experimental results for fine coconut coir with four concentrations at 80° Fahrenheit

Mud Weight	10.5 ppg				
Rheology	80° Fahrenheit				
Case	Fine coconut coir 3 g	Fine coconut coir 5 g	Fine coconut coir 8 g	Fine coconut coir 10 g	Base case
600 rpm	46	62	78	95	36
300 rpm	32	44	54	64	26
200 rpm	24	34	43	52	22
100 rpm	18	25	30	38	18
6 rpm	12	17	22	27	12
3 rpm	12	17	22	26	11
PV, cp	14	18	24	31	10
YP, lb/100ft^2	18	26	30	33	16

Gel 10 sec	11	12	14	15	13
Gel 10 min	20	22	24	27	23
API, cc/30min	13.0	14.0	15.5	12.5	19
Mud thickness, mm	1.95	2.35	2.80	2.45	2.2

4.2.1 Plastic Viscosity

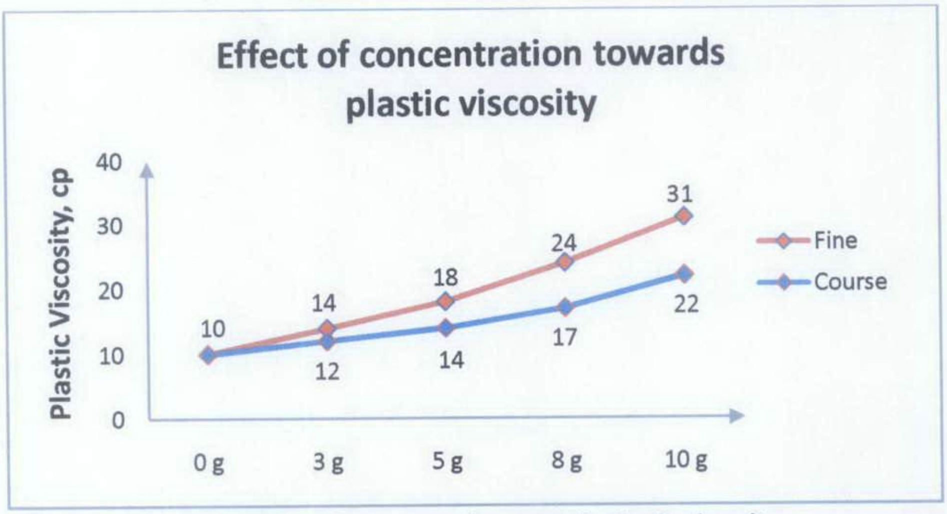


Figure 41. Effect of concentration towards plastic viscosity

The effect of concentration towards plastic viscosity can be described as the same as what we have seen earlier in Case A. As higher concentration of coconut coir is added into the mud, the plastic viscosity values also were increased. Plastic viscosity increases if the volume percent of solids increases or if the volume percent remains constant, and the size of the particle decreases. Decreasing particle size increases surface area, which increases frictional drag (Scomi Oiltools Drilling Fluid Engineering Handbook, 2008). Here, course coconut coir is better since it has lower resistance for the fluid to flow.

4.2.2 Yield Point

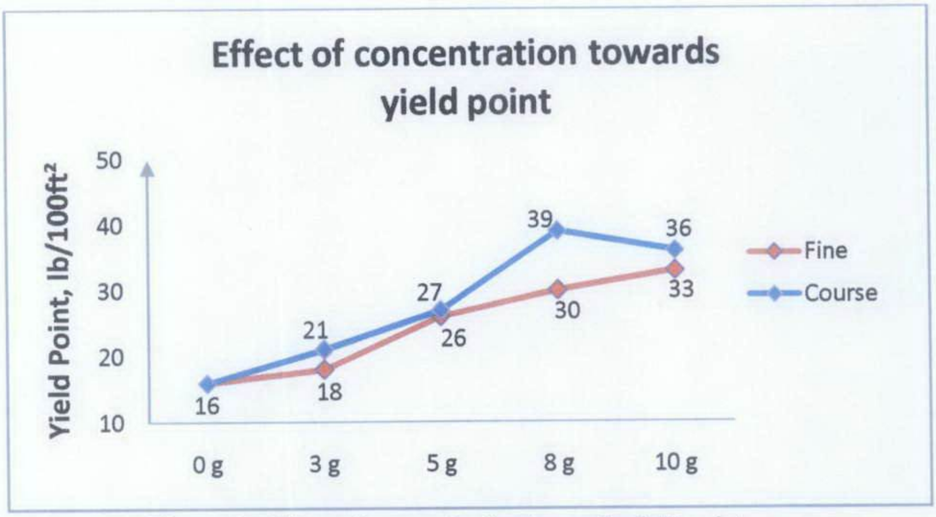


Figure 42. Effect of concentration towards yield point

Shortly, based on Figure 42, the trend of both particle sizes roughly can be said as increasing. However, fine particle size resulted in lower yield point. This means that courser particles have higher ability in transporting cuttings as the electrochemical forces between particles are greater.

4.2.3 Gel Strength

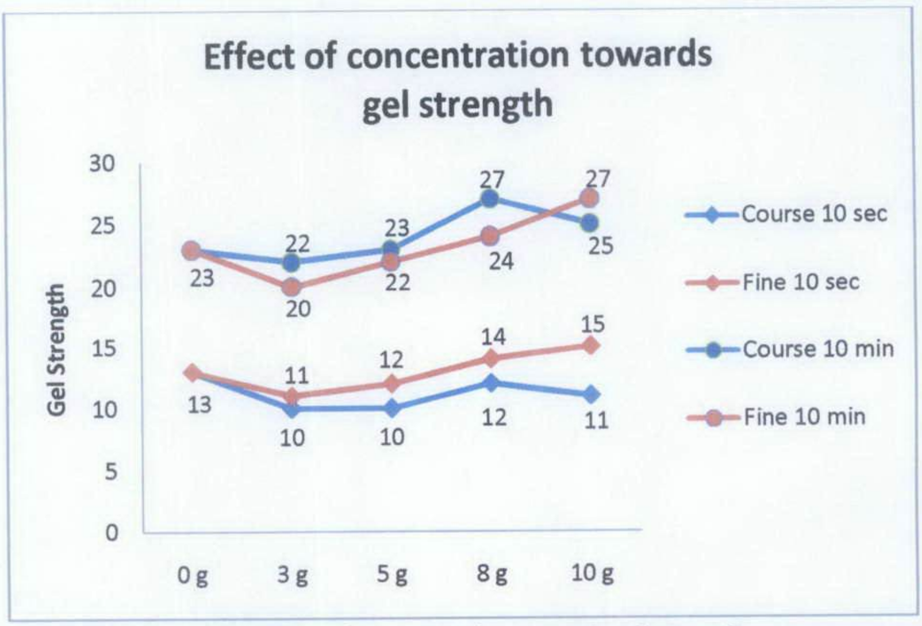


Figure 43. Effect of concentration towards gel strength

Generally, based on Figure 43, increase in concentration has resulted in increase in gel strength. In term of particle size, initial 10-seconds readings showed that fine coconut coir produced higher values. However, after 10-minutes in static condition, course coconut coir yielded higher values of gel strength. This consequently produced smaller range between initial and 10-minute gel readings for fine coconut coir which are more desirable in designing drilling fluid (more fragile). In contrast, larger particles require higher pressure to break circulation after shutdown (more progressive). Excessive strength of attractive forces (gelation) in a drilling fluid under static conditions might be experienced by courser particles. In water-base muds, flocculation increases gel strength and deflocculation decreases gel strength (Exxon Company Drilling Fluid Technology, 1996).

4.2.4 API Fluid Loss

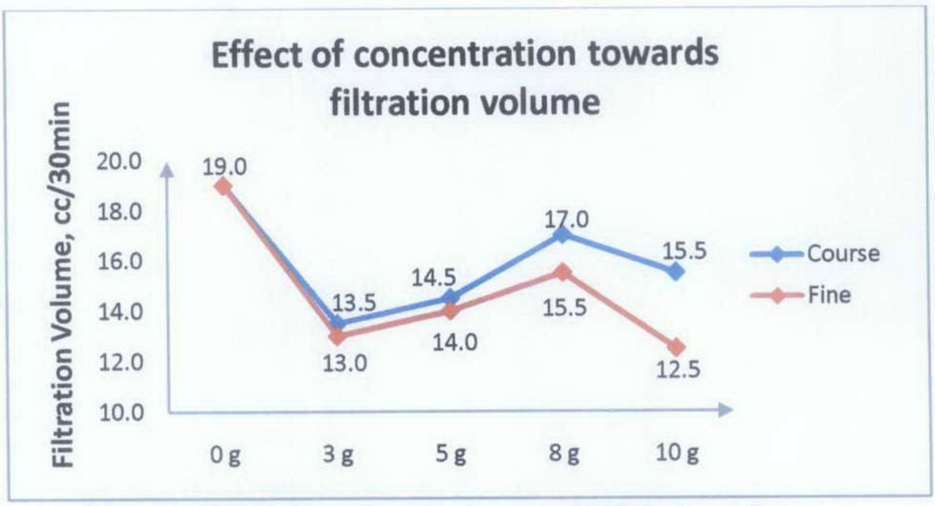


Figure 44. Effect of concentration towards API filtration volume

Figure 44 demonstrates the observations for concentration effect towards filtration volume. As higher LCM concentration being introduced to the mud, filtration volume moved down-up-down, yet still having lesser amount of filtration compared with base case. Although in many cases that I have studied showed that the amount of filtration should be lesser as the concentration of LCM is increased (as shown in Figure 40), coconut coir has produced opposite results. The consistency of these results is proved by both particle sizes. Shift in particle size may be related to the increase of fluid loss volume (Scomi Oiltools Drilling Fluid Engineering Handbook, 2008). However, both graphs show decreased amount again when concentration was at 10 grams. In this case, we can observe that fine particles are more effective in preventing lost circulation.

4.2.5 Mud Cake Thickness

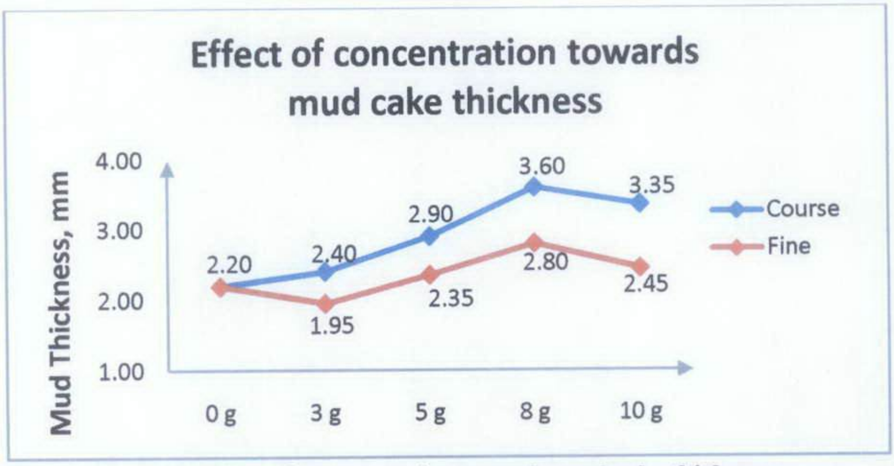


Figure 45. Effect of concentration towards mud cake thickness

For mud cake thickness, the results are consistent with the amount of filtrate produced as discussed earlier in Part 4.1.4. As higher filtrate volume was recorded (Figure 44), the thicker the mud cake formed (Figure 45). On the other hand, coarser particles resulted in greater thickness as the size is larger than fine particles. Thus, fine coconut coir is better since thinner filter cake can reduce the potential of differential sticking during drilling operations.

CHAPTER 5
CONCLUSION

Coconut coir is among mass fruit peel waste that can be found in Malaysia. It is not a seasonal fruit thus the resource is always available throughout the year. In addition, the price is very cheap and will be getting cheaper if being bought in large quantity. Coconut coir is categorized under fibrous material which tells us how it may works as a LCM. Briefly, after coconut coir is added to drilling fluid, the fibrous particles moves towards the fractures and forms a mat-like bridge over porous formations. These mats help to reduce the size of the openings into the formations, permitting the colloidal particles in the mud to rapidly deposit a filter cake thus effectively sealing the formation.

For Case A, the overall performance of coconut coir is slightly just fair with industrial nut plug and better than corn cob. In terms of plastic viscosity and yield point, nut plug and corn cob show convincing performance compared to proposed coconut coir. Mixture of coconut coir with drilling mud yielded higher value of plastic viscosity thus indicated that the rate of penetration (ROP) will be slower compared to nut plug. Other effects such as higher equivalent mud density will be encountered and increase in swab and surge pressure. In case of yield point, nut plug and corn cob showed higher values for 10 grams of concentration which exposed their ability of transporting cuttings more effective in comparison with coconut coir. However, coconut coir has the advantage with 5 grams concentration since the yield point is higher. Nut plug also recorded low 10-seconds and 10-minutes gel strength with slightly lower increment which is more desirable. However, corn cob performance is not very good in term of gel strength. From API filtration volume aspect, coconut coir managed to overcome nut plug and corn cob by producing slightly less filtrate volume, meaning that it can restrict the amount of fluid escaped into porous formation. Mud cake thickness readings for coconut coir also showed good results when being related to amount of API fluid loss. However, it is not clear whether nut plug has already exceeded its optimum concentration. If it is proved that such situation is happening, thus the nut plug will have slightly more advantages in all five measurements over coconut coir. The reason is that nut plug just required lesser amount of concentration to reduce the fluid loss. Although this situation might happen, coconut coir has shown good ability in acting as LCM and additional studies can be done to improve its characteristics.

In addition, nut plug that has been used during the experiment were coming from a drilling fluid company. Thus the characteristics or properties might be tailored physically or chemically to meet the requirements as high performance industrial LCM. There is also a probability that only selected grade of nut plug is being processed as LCM. On the other hand, coconut coir sample is just coming from local nursery and probably as natural as it was originally found. This assumption might counter-back the reasons behind the performance of coconut coir during the experiment.

As for Case B, overall, fine coconut coir particles showed better performance than course particles. However, for the first two tests, course coconut coir performed better by showing lower plastic viscosity and higher yield point. This means that the fluid has lower resistant to flow and higher ability in suspending drill cuttings. As for gel strength, fine particles are preferable because the incremental values recorded for 10-seconds and 10-minutes are lesser than course particles. This indicates that the shear stress necessary to break the gel structure is lower than the course case. Fine coconut coir also managed to illustrate lower filtration volume and thinner filter cake compared with courser particles. These observations show that fine particles can seal permeable zone more effective and reducing other potential problems resulted from mud losses thus minimizing drilling cost. As a whole, finer particles of coconut coir are proved to perform better than courser particles in preventing lost circulation.

CHAPTER 6
RECOMMENDATIONS

In order to improve the results that have been recorded, several improvements must be done. This also may help in obtaining more accurate data in the future. Firstly, the temperature of which the experiments are done can be increased to 120° Fahrenheit. This is a good practice since it reflects the flow line temperature which is more accurate to actual conditions. For this research, only Case A is tested under temperature of 120° Fahrenheit since I only have limited time in using the heated cup. For Case B, the operating temperature is only at 80° Fahrenheit which is room temperature.

Second, all equipment such as thermometer and viscometer should be frequently calibrated in order to prevent errors in readings. Minor error sometimes can lead to huge miscalculation later. Thirdly, testing of coconut coir as a LCM can be further expanded by using oil-based mud. The reason is that, the properties of mud (rheology), filtration volume and mud cake thickness will not be the same as testing using water-based mud. Here, I may have the chance to compare coconut coir performance in different type of mud. In addition, oil-based is also being widely use in the industry, thus testing of LCM with this mud is preferable.

Next is to use the high pressure high temperature (HPHT) filter press which operates at 300° Fahrenheit and 500 Psi. Together with low pressure low temperature (LPLT) filter press, both tests will cover wide range of temperatures from surface to bottom for most wells drilled. Lastly, the experiments can be continued using other particle sizes (or mixture of different particle sizes) and various other concentrations in order to get clearer picture of the performance of coconut coir as a green LCM. By applying all of these improvements, I may come out with the most effective particle size with optimum concentration that suits various operating temperature and pressure for specific type of mud with minimum error.

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