Sudan University of Science and Technology
College of Petroleum Engineering and Technology
Petroleum Engineering Department

Evaluation of Local Bentonite for Utilization as Oil Well Drilling Mud
(Ed-Damazin Sample)
تقييم البنتونايت المحلي للإستخدام كسائل حفر للآبار النفطية (عينة الدمازين)

A dissertation Submitted In Partial Fulfillment for the Requirements of the Degree of Bachelor of Science In Petroleum Engineering

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الإستهلال

قال الله تعالى:

((أَمَّنْ هُوَ قَانِتٌ آنَاءَ اللَّيْلِ سَاجِداً وَقائِماً يَحْذَرُ الآخِرَةَ وَيَرْجُو رَحْمَةَ رَبِّهِ قُلْ هَلْ يَسْتَوِي الَّذِينَ يَعْلَمُونَ وَالَّذِينَ لا يَعْلَمُونَ إِنَّمَا يَتَذَكَّرُ أُوْلُوا الأَلْبَابِ)) (9)

صدق الله العظيم

الآيه (9):سورة الزمر.

DEDICATION

We dedicate this research to God Almighty our creator, our strong pillar, our source of inspiration, wisdom, knowledge and understanding. Also we dedicate this work to Sudan University of Science & Technology, College of Petroleum Engineering & Technology.

ACKNOWLEDGEMENT

ABSTRACT

This research focuses on the possibility of the utilization of local bentonitic clays as a basic material for drilling fluids application in order to increase the national income by adding natural resources and to decrease the cost and dependency on the imported bentonite from abroad. Thus, evaluation of local bentonitic clays should be imperative.

This study is the first one which is carried out to evaluate the local Bentonite in Ed-Damazin Area and to establish its suitability as drilling mud when compared with commercial Bentonite according to API specifications. A local bentonite sample was gathered from Ed-Damazin study area to determine it is physical, chemical properties, mineralogical composition and drilling fluids properties using series of experiments.

The sample was characterized by X-ray Diffraction and X-ray Fluoresence to determine mineralogical compositions and chemical properties respectively. Therefore, the physical properties were characterized using the Atterberg limits.

The rheological properties such as; Plastic Viscosity, Yield Point and Gel Strength were determined in accordance with the American Petroleum Institute (API) specifications in addition to the Filtrate Volume.
To have a better understanding of water base drilling fluids behavior, different percentages of flowzan and PAC-LV were used to increase the viscosity and to decrease filtration losses.

The results have shown that the local bentonite from Ed-Damazin study area can satisfy the American Petroleum Institute (API) specifications when we used 35% of PAC-LV.

التجريد

هذه الدراسة تسلط الضوء على إمكانية إستخدام طين البنتونايت المحلي كمادة أساسية في تطبيقات سوائل الحفر من أجل زيادة الدخل القومي بإضافة مصادر طبيعية وتقليل التكلفة الناتجة من إستيراد مادة البنتونايت من الخارج وبالتالي أصبح تقييم البنتونايت المحلي ضرورة لا بد منها.

تعتبر هذه الدراسة هي الأولى لتقييم البنتونايت المحلي في منطقة الدمازين لمعرفة إمكانية إستخدامه كسائل حفر مناسب عند مقارنته مع البنتونايت التجاري وفقا لمواصفات معهد البترول الأمريكي. عينة البنتونايت المحلي تم أخذها من منطقة الدمازين لتحديد الخواص الفيزيائية والكيميائية والتركيب المعدني وخواص سائل الحقر المحضر من البنتونايت المحلي.

أجريت إختبارات العينة بواسطة (X-ray Diffraction) و (X-ray Fluorosence) لتحديد التركيب المعدني والخواص الكيميائية أما الخواص الفيزيائية تم تحديدها بواسطة (Atterberg Limits).

الخواص التيارية مثل : اللزوجة البلاستيكية, نقطة المطاوعة ومقاومة الجل تم تحديدها وفقا لمواصفات معهد البترول الأمريكي بالإضافة إلى فاقد الرشح. لمعرفة سلوك سائل الحفر ذو الأساس المائي تم إستحدام نسب مختلفة من مادة Flowzan و PAC-LV لزيادة اللزوجة وتقليل فاقد الرشح.

أظهرت النتائج أن البنتونايت المحلي لمنطقة الدمازين يوافق مواصفات معهد البترول الأمريكي عند إستخدام تركيز 35% من مادة PAC-LV.

Contents

Chapter Four: Result and Discussion

Chapter Five: Conclusion and Recommendation

List of Figures

List of Tables

CHAPTER ONE

INTRODUCTION

CHAPTER ONE

INTRODUCTION

1.1. General:

Drilling fluids are also called drilling mud is a mixture of water, oil, clay and various chemicals. Within drilling it performs various functions and contributes with a large portion to the total well costs. In this way the mud system (or mud program) has to be carefully designed to ensure a successful drilling project.[1]

Bentonite is defined as consisting of fine-grained clays that contain not less than 85% Montmorillonite which belongs to the class of clay minerals known as smectites. Bentonite is classified as sodium bentonite or calcium bentonite, depending on the dominant exchangeable cation. In fresh water, sodium bentonite is more reactive than calcium bentonite and hence, in terms of performance, bentonite is classed as "high yield" (sodium bentonite) or "low yield" (calcium bentonite).

Bentonites are used worldwide as drilling fluid additives. Their main functions are the viscosities of the mud in order to reduce the fluid loss to the formation. A good quality bentonite should contain mainly montmorillonite. In practice, bentonites often contain other clay minerals such as elites, kaolinites, chlorites and non-clay components such as quartz and feldspar in appreciable amounts. Because montmorillonitic clays have the highest swelling capacity (which is responsible for viscosity build up and formation of low permeability filter cake), the presence of other materials will have an adverse effect on bentonite quality. The type of exchangeable ions has a great effect on the swelling capacity of the montmorillonite. By far the best performance is obtained with sodium montmorillonite. If the mineral composition of bentonite is such that its viscosifying power is insufficient, various additives can be added. The additive can be either a salt or a polymer and enhances of the fluid by slightly flocculating the bentonite was suspension.

In Sudan the local Bentonite was evaluated and studied for it is potential use as drilling mud such as; Umm Ali study area which is located in the northern Sudan. The ore deposit of local Bentonite is good in quantity and available with huge amounts. Drilling activities for the development of oil, gas and water resources usually require enormous amount of drilling mud which is usually imported into the country.

Bentonite is imported with high costs while it is exist in the country and needs an improvement to enhance the national industry rather than importing it from abroad. Thus, the need for local sourcing of bentonitic clays or close substitutes has become imperative. This study is conducted to evaluate Ed-Damazin Bentonite in the blue nile state that weathered from Ethiopian highlands for utilization as drilling mud.

1.2. Objectives:

1.2.1. General Objectives:

The aim of this research to evaluate local Bentonite properties from Ed-Damazin study area to meet the API specifications of drilling fluids and comparing it with the commercial Bentonite for usage as oil well drilling mud.

1.2.2. Specific Objectives:

1. Decrease the cost and dependency on the import of Bentonite from abroad.
2. To identify the chemical, physical properties and mineralogical composition of the Bentonite material in the study area.
3. To determine the rheological properties of the drilling fluids of the samples.

1.3. Problem Statement:

Bentonite is the main component in drilling fluids and cement additives. It is widely used in Sudan Oil Industry as a viscosifier additive in drilling fluids.
Bentonite is mainly Imported from abroad such as KSA, India, Libya, Egypt and USA. In order to reduce the cost and dependency of imported bentonite from abroad, the development and production of the local bentonite should be initiated due to a long way of transportation and storage.

1.4. Methodology:

Sample collection and preparation and the determination of the rheological properties of the drilling fluids prepared from local Bentonite (Ed-Damazin sample) should be initiated to meet the API specifications. The methodology as generally falling into: chemical test, physical test, mineralogical test and drilling fluids properties test of the samples.

1.5. Overview of Study Area:

The area of study lies in longitudes 11°48□45.50□ N and latitudes 34°26□23.6□ E in Blue Nile state. The sample was taken from the exposed surface of exploited quarry in Ed-Damazin area which is rich of local bentonites.
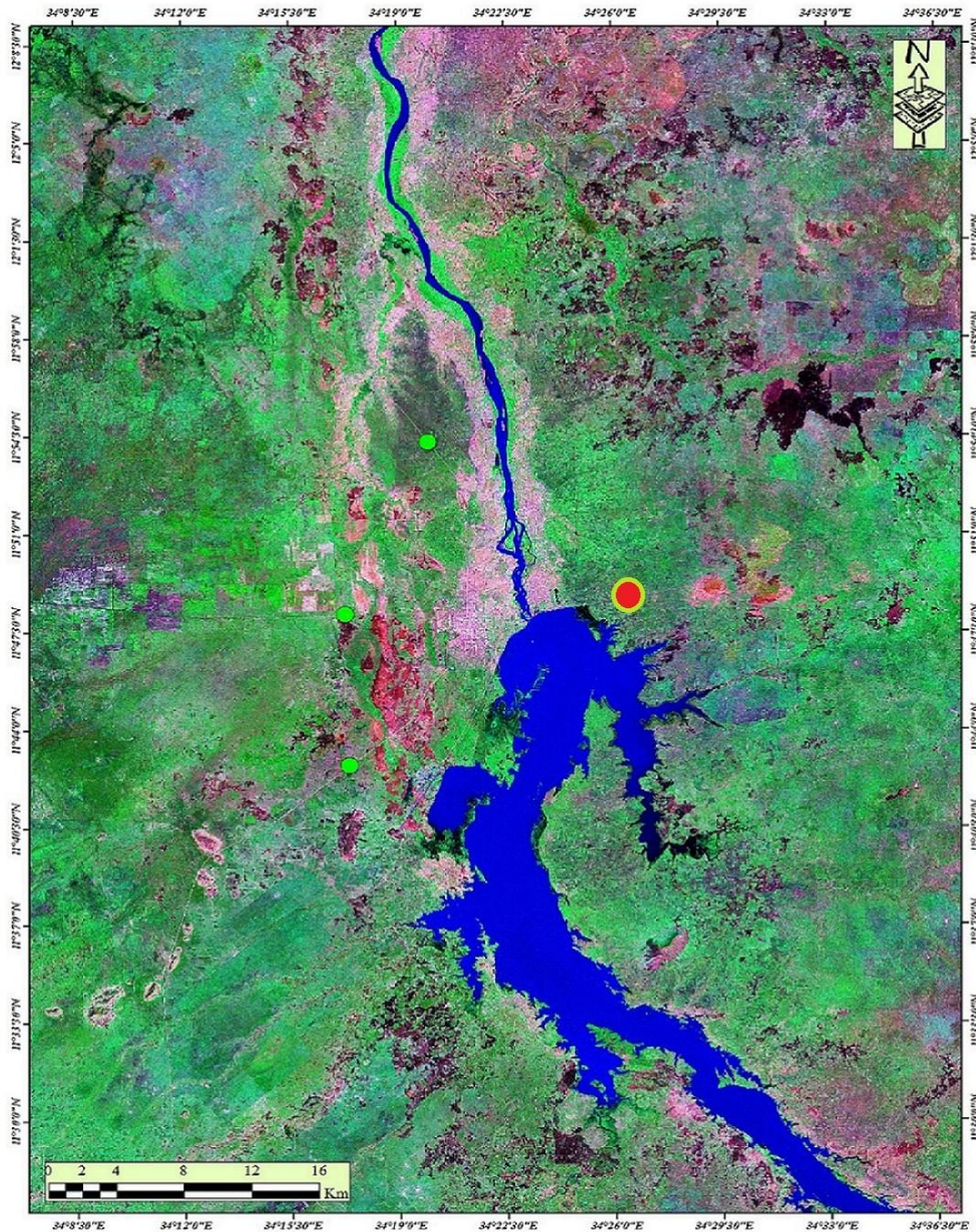
Figure (1.1): Map of the study area.

1.6. Thesis Outline:

This research consists of five chapters, an introduction, literature review and history background, methodology, results and discussion and conclusion & recommendation.

Chapter One The introduction includes a simple definition of drilling fluids and the research orientation towards bentonite material, objectives of the project, a problem statement, Methodology as general and thesis outline.

Chapter Two contains some basic concepts of drilling fluids and the concept of bentonite for potential use as drilling mud.

Chapter Three is conducted to sample collection and preparation, chemical, physical and mineralogical analysis of the clays mainly bentonite. The rheological determination of the prepared drilling fluids of the samples.

Chapter Four provide the results and discussion of work. The results of this research is based on chapter three.

Chapter Five presents a general conclusion of the whole work in this research. Recommendations are included for further studies and probabilities.

CHAPTER TWO

LITERATURE REVIEW & HISTORY BACKGROUND

CHAPTER TWO

LITERATURE REVIEW & HISTORY BACKGROUND

2.1. Literature Review:

(Shakhatreh K. Saleh, **Mehaysen A. Mahasneh 2015)** discussed the investigation and activation of Ain Al-Baida bentonite by Na_2CO_3. The products were investigated by chemical analysis, X-ray diffraction, rheological properties and free swelling index with clay fraction. It was observed that the activities clay ranged between 0.98 to 1.48 medium to high content of clay minerals. In addition, it was determined the Atterberg limits, the results of plasticity chart and relation between index and clay fraction. This means that the amount of the attracted water will be suitable influenced by the clay that is present in Ore Ain Al-Baida bentonite. The liquid limit was ranged between 83% to 140% and plastic limit ranged between 39% to 48%. Also, the rheological properties (apparent viscosity, plastic viscosity), gel strength, yield point, filtrate loss. These properties have been compared with those standard specifications properties required for the drilling fluid in order to know the appropriate circumstances to activate the bentonite ore of Ain Al-Baida at Azraq basin to become close to the standard specifications required for the drilling fluids, the ratio between YP/PV was ranged 0.88 to 1.21, it is meant that the behaviour of drilling fluids confirms the Bingham plastic and power-law rheological models using fine grinding of bentonite mixture with 3% - 6% concentration of sodium carbonate powder.[2]

(Nweke, O.M.* et al., 2015) discussed the evaluation of clays from Abakaliki formation, southern Nigeria to establish its suitability as drilling mud when compared with commercial bentonite such as Wyoming bentonite. The clays were all characterized as dominantly Illite as well as montmorillonite with low percantages of kaolinite. The chemical composition of the clays indicates low percantages of Na_2O when compared with that of Wyoming bentonite with fairly higher percentages of CaO and K_2O than are required for drilling mud clays. The clays are plastic; with

liquid limit(LL) of 58.8% to 72.8% , plastic limit (PL) of 25% to 30% and plasticity index (API) of 26% to 45.8%.

Sodium carbonate and carboxymetheyl cellulose were used to improve the rheological properties for Abakaliki clays. The clays exhibited presence of high concentration of exchangeable Ca^{+2}. The weak swelling properties are thought to buttress the presence of low expansive montmorillonite, most probably the calcium variety. The viscosity values of the clays are also low but with additives such as sodium carbonate and carboxymetheyl cellulose the rheological properties for Abakaliki clays will remarkably improve.[3]

(Dardir M.M et al.,2014) discussed the improvement of the bentonite from (south Hammam) by using low molecular weight polyvinyl alcohol (PVA) as a viscosifier additive. The evaluation involved the study of the rheological properties (apparent viscosity, plastic viscosity, yield point, gel strength and thixotropy), filtration properties before and after treatment with PVA as a viscosifier additive. The results were compared with the commercial grade bentonite according to American Petroleum Institute specification (API) and OCMA specification.

Most of the studied samples were of bentonite clay, was mainly Na-montmorillonite. The studied non-activated samples cannot be used as a drilling mud without activation. The studied clay sample L1 can be used after activation with PVA as a drilling fluid for its rheological properties satisfied the API standard and OCMA specification while clay samples L2, L3 cannot be used as drilling fluid even after the activation with PVA.

The obtained results revealed that the activated samples may be expressed as medium grade bentonite clays and these grades of clays can be used as drilling fluids for shallow depth wells.[4]

(Solomon Omale Obaje.,2013) discussed the industrial suitability of Borno bentonites as drilling mud. The oxide geochemical investigation indicated that the samples have high montmorillonite content. The qualitative laboratory suitability studies showed that Borno bentonites are suitable for drilling mud production. Bentonitic clays occur in Dikwa,Ngala,New Marte and Mafa areas of Borno State,Nigeria.

The result of the analysis of these samples agreed with local and international standard for industrial drilling mud.[5]

(Rashid.A.M.Hussein.,2013) studied the rheological properties and filtration loss for a drilling fluid prepared from local bentonite. Required data and samples were carefully gathered from the study area (Al-fao area) in accord of approved sampling procedures. Mineralogical, physical and chemical tests were carried out to access quality of local bentonite. Carboxymetheyl Cellulose(CMC), polyanionic cellulose polymer(PAC-LV) and sodium carbonate (Na_2CO_3) were used to increase viscosity and to decrease filtration losses. The results have shown that the local bentonite can satisfy the American Petroleum Institute (API) specifications for different concentrations of CMC and PAC-LV.

CEC of Al-fao untreated bentonite amounted to 83meq/100g. This finding implies a positive impact of hydration and swelling. Rheological properties and filter loss enhanced with addition of CMC and PAC-LV.

Addition of about 10% CMC concentration lead the Al-fao bentonite meet API specifications.[6]

(Arabi Suleiman Abdullahi et al.,2011) studied the evaluation of rheological properties of standard commercial bentonite and a locally beneficiated bentonitic clay from a marine deposit in upper benue basin, Nigeria. The study has beneficiated local bentonitic clay using Na_2CO_3 as the beneficiating agent and ion exchange as the procedure. The rheological properties of the beneficiated clay were determined together with that of a standard commercial bentonite and compared with the United State API grade and European OCMA standard for complience. The result shown that bentonitic clay from fika member of the pindiga formation in upper benue trough in north-eastern Nigeria are Ca-based, therefore, it can only be used as drilling mud when effectively beneficiated to a Na-based. It was discovered that the rheological properties of the locally beneficiated bentonitic clay compared very well with the standard and presented some rheological properties that are a little better than the studied standard commercial bentonite. The studied clay had some properties that met standard even before beneficiation, these are loss on ignition, Al/Si ratio, moisture content for example whereas other clays from other parts of Nigeria e.g. Obakala bentonitic clay has no property on their own for use as drilling mud.[7]

2.2. Drilling Fluid Background:

The main objective of drilling fluids is the successful completion of oil & gas wells. The selection of right type of fluid is essential to perform the following functions: [8]

1. To transport the drilled solids from the bottom of the hole to the surface.

2. To suspend the drilled solids and weighting materials when the mud is under static condition.

3. To provide a thin impermeable cake to seal pore and other openings in the formation and thereby restricting the movement of fluids.

4. To contain formation pressure.

5. To support the weight of casing and drill string.

6. To transmit hydraulic horse power to the bit.

7. To assist in evaluation of the formation.

2.2.1. Drilling Fluids Additives:

There are many drilling fluid additives which are used to develop the key properties of the mud.

The variety of fluid additives reflect the complexity of mud systems currently in use. The complexity is also increasing daily as more difficult and challenging drilling conditions are encountered.

We shall limit ourselves to the most common types of additives used in water-based and oil-based muds. These are [1]:

1. Weighting Materials.

2. Viscosifiers.

3. Filtration Control Materials.

4. Rheology Control Materials.

5. Alkalinity and pH Control Materials.

6. Lost Circulation Control Materials.

7. Lubricating Materials.

8. Shale Stabilizing Materials.

2.2.1.1. Weighting Materials:

Weighting materials or densifers are solids material which when suspended or dissolved in water will increase the mud weight. Most weighting materials are

insoluble and require viscosifers to enable them to be suspended in a fluid. Clay is the most common viscosifier.

2.2.1.2. Viscosifier:

The ability of drilling mud to suspend drill cuttings and weighting materials depends entirely on its viscosity. Without viscosity, all the weighting material and drill cuttings would settle to the bottom of the hole as soon as circulation is stopped. One can think of viscosity as a structure built within the water or oil phase which suspends solid material. In practice, there are many solids which can be used to increase the viscosity of water or oil. The effects of increased viscosity can be felt by the increased resistance to fluid flow; in drilling this would manifest itself by increased pressure losses in the circulating system.

Materials are used as viscosifier:
1. Bentonite.
2. CMC.
3. PAC.
4. Xanthan gum.
5. HEC.
6. Guar.
7. Resins.
8. Silicates.
9. Synthetic polymers.

2.2.1.3. Filtration Control Materials:

Filtration control materials are compounds which reduce the amount of fluid that will be lost from the drilling fluid into a subsurface formation caused by the differential pressure between the hydrostatic pressure of the fluid and the formation pressure. Bentonite, polymers, starches and thinners or deflocculants all function as filtration control agents.

Bentonite imparts viscosity and suspension as well as filtration control. The flat, "plate like" structure of bentonite packs tightly together under pressure and forms a firm compressible filter cake, preventing fluid from entering the formation Polymers such as Polyanionic cellulose (PAC) and Sodium Carboxymethylcellulose (CMC) reduce filtrate mainly when the hydrated polymer chains absorb onto the clay solids

and plug the pore spaces of the filter cake preventing fluid seeping through the filter cake and formation. Filtration is also reduced as the polymer viscosifies the mud thereby creating a viscosified structure to the filtrate making it difficult for the filtrate to seep through.

Starches function in a similar way to polymers. The free water is absorbed by the sponge like material which aids in the reduction of fluid loss. Starches form very compressible particles that plug the small openings in the filter cake.

Thinners and deflocculants function as filtrate reducers by separating the clay flock's or groups enabling them to pack tightly to form a thin, flat filter cake.

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When efficient control of viscosity and gel development cannot be achieved by control of viscosifier concentration, materials called "thinners", "dispersants", and/or "deflocculants" are added. These materials cause a change in the physical and chemical interactions between solids and/or dissolved salts such that the viscous and structure forming properties of the drilling fluid are reduced.

Thinners are also used to reduce filtration and cake thickness, to counteract the effects of salts, to minimize the effect of water on the formations drilled, to emulsify oil in water, and to stabilize mud properties at elevated temperatures.

Materials commonly used as thinners in clay- based drilling fluids are classified as: (1) plant tannins, (2) lignitic materials, (3) lignosulfonates, and (4) low molecular weight, synthetic, water soluble polymers.

2.2.1.5. Alkalinity and PH Control Materials:

The pH affects several mud properties including:

• detection and treatment of contaminants such as cement and soluble carbonates

• solubility of many thinners and divalent metal ions such as calcium and magnesium

Alkalinity and pH control additives include: NaOH, KOH, $Ca(OH)_2$, $NaHCO_3$ and $Mg(OH)_2$. These are compounds used to attain a specific pH and to maintain optimum pH and alkalinity in water base fluids.

2.2.1.6. Lost Circulation Materials:

There are numerous types of lost circulation material (LCM) available which can be used according to the type of losses experience.

a. Conventional LCM:

These include:

1. Flakes: includes mica and cellophane.

2. Granular: includes nutshells, calcium carbonate and salt.

3. Fibrous: includes glass fibre, wood fibre and animal fibre.

b. Reinforcing Plugs and Cement:

These are specialised plugs and are only used as a last resort if everything else fails.

Two types of reinforcing plugs are in common use:

• Oil bentonite plug (water based muds).

• Water organophilic clay plug (oil based muds).

• **Oil/Bentonite Plug:**

The use of this plug is based on the fact that bentonite does not hydrate in oil but when spotted downhole it will contact water, hydrate and with oil forms a strong plug. The pill is pumped to the loss zone with spacers ahead and behind to prevent it from contacting the water based mud en route to the loss zone. When the pill is finally spotted, it will contact water and will hydrate and seal the loss zone.

- **Water/Organophilic Clay Plug:**

For oil based mud, the reverse of the above is used. An organophilic clay, which yields (disperse) in oil based mud but not in water, is mixed with water and is pumped as a pill to the loss zone .On contact with the oil mud downhole it will form a strong solid material. The pill must be pumped with a spacer ahead and behind to prevent it from contacting the oil based mud en route to the loss zone.

2.2.1.7. Lubricating Materials:

Lubricating materials are used mainly to reduce friction between the wellbore and the drillstring. This will in turn reduce torque and drag which is essential in highly deviated and horizontal wells. Lubricating materials include: oil (diesel, mineral, animal, or vegetable , oils), surfactants, graphite, asphalt, gilsonite, polymer and glass beads.

2.2.1.8. Shale Stabilizing Materials:

There are many shale problems which may be encountered while drilling sensitive highly hydratable shale sections.

Essentially, shale stabilization is achieved by the prevention of water contacting the open shale section. This can occur when the additive encapsulates the shale or when a specific ion such as potassium actually enters the exposed shale section and neutralises the charge on it.

Shale stablisers include: high molecular weight polymers, hydrocarbons, potassium and calcium salts (e.g. KCl) and glycols.

Field experience indicates that complete shale stabilisation cannot be obtained from polymers only and that soluble salts must also be present in the aqueous phase to stabilize hydratable shales.

2.2.2. Drilling Fluids Types:

A drilling fluid can be classified by the nature of its continuous fluid phase. There are three Types of drilling fluids:

1. Water Based Muds.

2. Oil Based Muds.

3. Gas Based Muds.

2.2.2.1. Water based mud:

These are fluids where water is the continuous phase. The water may be fresh, brackish or seawater, whichever is most convenient and suitable to the system or is available.

The following designations are normally used to define the classifications of water based drilling fluids:

1. Non-dispersed-Non – inhibited.

2. Non-dispersed – Inhibited.

3. Dispersed - Non-inhibited.

4. Dispersed – Inhibited.

Non-Inhibited: means that the fluid contains no additives to inhibit hole problems.

Inhibited: means that the fluid contains inhibiting ions such as chloride, potassium or calcium or a polymer which suppresses the breakdown of the clays by charge association and or encapsulation.

Dispersed: means that thinners have been added to scatter chemically the bentonite (clay) and reactive drilled solids to prevent them from building viscosity.

Non-Dispersed: means that the clay particles are free to find their own dispersed equilibrium in the water phase.

Non-dispersed-non-inhibited: fluids do not contain inhibiting ions such as chloride (Cl^-), calcium (Ca^{+2}) or potassium (K^+) in the continuous phase and do not utilize chemical thinners or dispersants to affect control of rheological properties.

Non-dispersed- inhibited: fluids contain inhibiting ions in the continuous phase, however they do not utilize chemical thinners or dispersants.

Dispersed-non-inhibited: fluids do not contain inhibiting ions in the continuous phase, but they do rely on thinners or dispersants such as phosphates, lignosulfonate or lignite to achieve control of the fluids' rheological properties.

Inhibited dispersed: contain inhibiting ions such as calcium (Ca^{+2}) or potassium (K+) in the continuous phase and rely on chemical thinners or dispersants to control the fluids rheological properties.

2.2.2.2. Oil Based Muds:

An oil based mud system is one in which the continuous phase of a drilling fluid is oil. When water is added as the discontinuous phase then it is called an invert emulsion. These fluids are particularly useful in drilling production zones, shales and

other water sensitive formations, as clays do not hydrate or swell in oil. They are also useful in drilling high angle/horizontal wells because of their superior lubricating properties and low friction values

between the steel and formation which result in reduced torque and drag.

Invert emulsion fluids (IEFs) are more cost-effective than water muds in the following situations:

1. Shale stability.
2. Temperature stability.
3. Lubricity.
4. Corrosion resistance.
5. Stuck pipe prevention.
6. Contamination.
7. Production protection.

2.2.2.3. Gas based fluids:

There are four main types of gas based fluids:

1. Air.
2. Mist.
3. Foam.
4. Aerated Drilling Fluid**.**

These are not common systems as they have limited applications such as the drilling of depleted reservoirs or aquifers where normal mud weights would cause severe loss circulation. In the case of air the maximum depth drillable is currently about 6-8,000 ft because of the capabilities of the available compressors. Water if present in the formation is very detrimental to the use of gas-based muds as their properties tends to break down in the presence of water.

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┌──────────────┐                              ┌──────────────┐
│   Liquids    │                              │    Gases     │
└──────┬───────┘                              └──────┬───────┘
       │          ┌─────────────────────────┐        │
       │          │   Gas-liquid Mixtures   │        │
       │          └─────────────────────────┘        │
```

| Water-Base Muds | Oil-Base Muds | Foam (mostly Gas) | Aerated Water (mostly Water) | Air | Natural Gas |
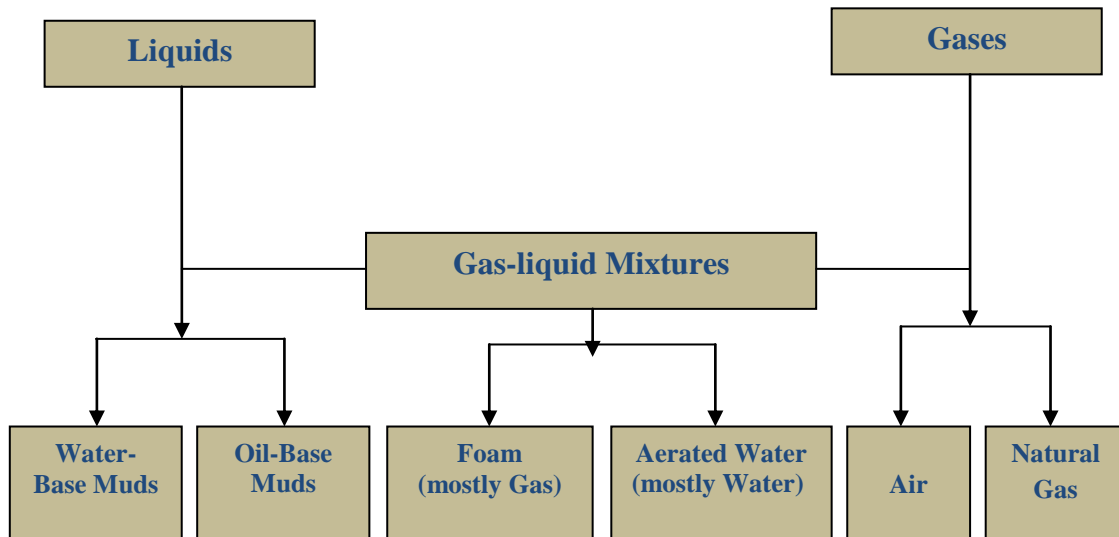
Figure (2.1): Classification of drilling fluids.

2.3. Bentonite Background:

2.3.1. Introduction:

Bentonite, which consist essentially of clay minerals of the smectite group, have a wide range of industrial uses. A particular feature of this group of minerals is the substitution of Si^{+4} and Al^{+3} in the crystal structure by lower valency cations.

Depending on the dominant exchangeable cations present the clay may be referred to as either calcium bentonite or sodium bentonite, the two varieties exhibiting markedly different properties and thus uses.

The terms nonswelling bentonite and swelling bentonite are synonymous with calcium bentonite and sodium bentonite respectively.

When mixed with water, swelling bentonites exhibit greater degree of dispersion and better plastic and rheological properties than nonswelling bentonites. Natural sodium bentonites, such as those in Wyoming, USA (Wyoming or Western bentonite), are comparatively rare although the cation-exchange properties of smectite enable the more widespread calcium form to be easily converted to high-swelling sodium bentonite by a simple sodium-exchange process. In some countries, notably Britain, calcium bentonite is referred to as fuller's earth, although elsewhere, and particularly in the USA, this term is applied to any clay that has the capacity to decolourise oil and may consist of smectite or attapulgite. The latter is mineralogically distinct but has

similar properties of adsorption to calcium bentonite and can substitute in certain applications.

The physical and chemical properties of bentonites typically vary both within and between deposits due to differences in the degree of chemical substitution within the smectite structure and the nature of the exchangeable cations present, and also due to the type and amount of impurities present. No bentonite is universally acceptable for every applications. In this context a distinction can be made between the grade and whilst its quality is related to the inherent physic-chemical properties of the clay, either in its natural or modified form, and is measure of likely industrial performance. However, there is no recognized minimum grade or smectite content below which a clay is no longer considered to be a bentonite. Commercial bentonites rarely contain less than 60% smectite and usually more than 70% , associated minerals typically being quartz, cristobalite, feldspars, zeolites, calcite, volcanic glass, and other clay minerals such as kaolinite. Amount and type of associated minerals are related to the origin of the bentonite.

The aim of this manual is to show how data gathered during initial mineralogical and chemical examination of a bentonite may be used to indicate the suitability of the clay for different applications.
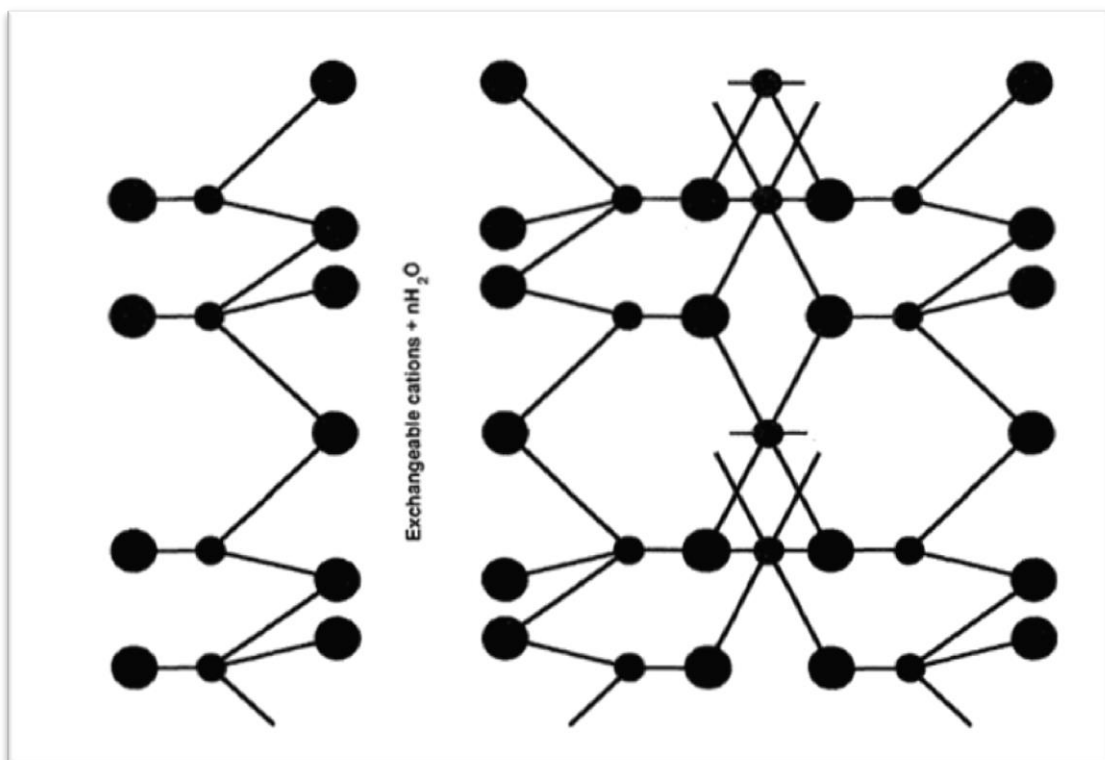

Figure (2.2): Crystal structure and chemistry of smectite clay minerals.

2.3.2. Geological Occurrence:

Most bentonites have formed by alteration of igneous material. Such deposits are of two markedly different types: (i) those resulting from sub-aqueous alteration of fine-grained volcanic ash and (ii) those resulting from in situ hydrothermal alteration of acid volcanic rocks (Grim & Guven, 1978).[8]

2.3.2.1 Sedimentary Bentonites:

These bentonites are formed by the alteration of volcanic ash deposited in the sedimentary environment. This material may have been subsequently reworked and concentrated by sedimentary processes.

As sedimentary bentonite are not usually associated with volcanic rocks, the ultimate source of the volcanic ash may be several hundred kilometers away and no longer exposed.

This type of commercial bentonite deposits are complex. Moorlock & Highley (1991) recognized five genetic stage in their formation :

1. Eruption of ash and it airborne transport.
2. Water sorting and concentration of volcanic ash in shallow-marine environment to give thick accumulations.
3. Conversion of the volcanic ash to smectite.
4. Protection of the bentonite beds from subsequent erosion.
5. No subsequent thermal alteration of the smectite to other clay mineral phases.

2.3.2.2. Hydrothermal Bentonites:

Some bentonite deposits have formed by the in situ hydrothermal alteration of volcanic rocks, normally of acidic composition.

2.3.2.3. Field Characteristics:

Bentonites range in colour from black through to white but most frequently are bluish-green when fresh, weathering to a yellowish-brown colour at or near outcrop due to the oxidation of ferrous iron.

2.3.3. Industrial Applications:

Bentonites have a wide range of industrial application. Based on production data for the USA, by far the largest producer, the major uses of bentonite have always been considered to be in bonding foundry sands, drilling fluids, and iron ore pelletising

(Vista, 1990). These uses accounted for 75% of total US production (3.5 Mt) in 1988, athough total usage is at much lower levels than in the late 1970s and early 1980s due to a downturn in oil drilling activity, as well as in the steel and foundry industries. Demand for bentonite varies significantly from country to country. In western Europe, the largest market for bentonite is currently pet litter. It is also used as a clarifying agent for oils and fats, in agriculture (as a carrier for pesticides and fertilizers and as a coating for seeds), in civil engineering, in papermaking, and in paints, pharmaceuticals and cosmetics. Descriptions of these and many other applications have been given by Ross (1965), Grim & Guven (1978) and Odom (1984) .[8]

CHAPTER THREE

METHODOLOGY

CHAPTER THREE

METHODOLOGY

3.1. Sample collection and preparation:

One of the available bentonite out crop in sudan is in Ed-Damazin study area which is located in the blue nile state. Bentonite was dried in an oven at 100°C, then crushed into fine particles by using Retsch Crusher (RS 200) and after that the sample was grinded. The powder was sieved with shaker by using a 75 micron opening mesh to suit the API 13 A specification for bentonite sample.

Figure (3.1): Retsch Crusher (RS 200). (GRAS)

Figure (3.2): Grinding Machine. (GRAS)

Figure (3.3): Local Bentonite sample after crushing. (GRAS)

Figure (3.4): Local Bentonite sample after crushing and grinding. (GRAS)

Figure (3.5): Local Bentonite sample sieving by using 75 micron opening mesh. (SUST Lab)

3.2. Physical Tests:

The physical tests carried out on the Ed-Damazin sample are:

-Atterberg Limits (Liquid and plastic limits).

-Particle size distribution of the sample.

3.2.1. Atterberg Limits:

3.2.1.1. Liquid Limit Test procedure:

The determination of the liquid limit value for the sample was carried out in accordance to the cone penetration method in BS 1377: Part 2:1990 CL 4.3. The tested sample was sieved through a BS No 40 (0.425 µm). After sieving the sample about 300g is mixed with distilled water using two palette knives for at least 10 minutes to make a homogenous paste. A portion of paste pushed into the cup, the penetration of the cone in (mm) was recorded from the dial gauge reading, and the corresponding moisture content of the sample then obtained. The relationship between the moisture content and the penetration was plotted as the best straight line fitting the plotted points. The results are shown in Table (4.1).

3.2.2.2. Plastic limit Test procedure:

The plastic limit is taken as the moisture content at which a sample of soil begins to crumble when rolled into a thread (about 3mm or 1/8 inch dia.) under the palm of the hand. The method of testing is specified in BS 1377: Part 2:1990 CL 5.3. A sample of soil (passing sieve No 40 BS sieves) was taken and rolled with the palm of the hand on a glass plate into a thread of about 3mm in diameter. The moisture content of the crumbled sample is then determined and the average moisture content of two samples is taken as the plastic limit. The difference between liquid and plastic limits is called Plasticity Index. The values of Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) are shown in Table (4.1).

3.2.2. Particle size distribution of the sample:

Particle size distribution by sieve analysis was carried out for the sample for quantitative determination for particle size greater than 0.063mm (clay and silt), and by the hydrometer analysis, for particle size smaller than 0.063mm is (sand and gravel). The results are summarized in Table (4.1).
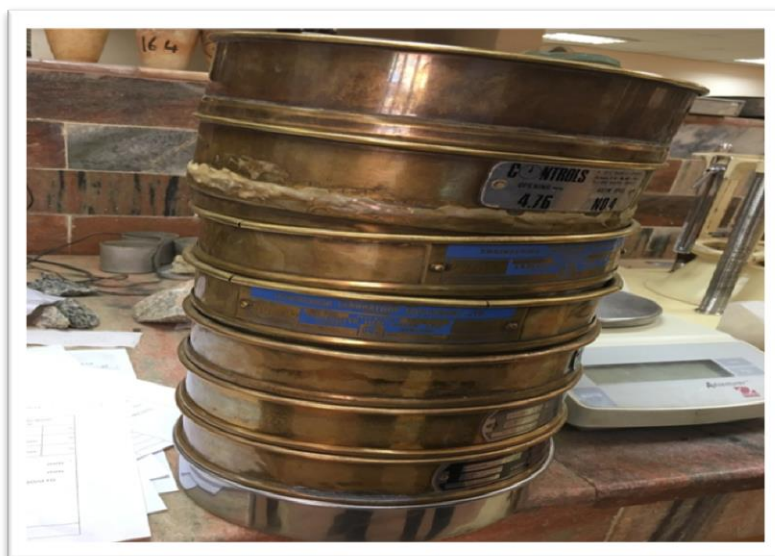
Figure (3.6): Shakers for particle size distribution of local Bentonite sample.

(GRAS)

3.2. Chemical Tests:

There are performed to know the chemical requirement and mud chemistry. This tests including:

3.2.1. Loss on Ignition:

The loss on ignition is defined as weight loss when dried bentonite at 105°C fired to 1000°C. The percentage loss in weight of each sample was determined by the difference between the weight before firing and the weight thereafter until the difference reach to two equal values, this value is loss on ignition for specified sample. Calculated from this equation:

L.O.I = ((m1 − m2) / m1)* 100%

Where

L.O.I = Loss on Ignition.

 m1= weight of sample before firing.

 m2= weight of sample after firing.

3.2.2. Moisture Content:

The moisture content defined as the percent of water removed when the bentonite is dried from ambient temperature to 105°C in oven.

3.2.3. Chemical Elements:

Chemical composition of bentonite was determined by X-ray spectrometer method (XRF). The sample was mixed with distilled water until the consistency is approximated that the liquid limit, then allowed to stay for hours until equilibrium took place between the salt in the pore water and on the cation exchange complex. Subsequently, a small quantity of the pore water was extracted from the saturated soil paste (10-25 ml) using vacuum of filters. The extracted water was applied to XRF test procedures to determine the chemical element.

3.2.4. Cation Exchange Capacity (CEC):

CEC measurements are based on determination of the quantity of a particular exchangeable cation by a variety of means , expressed per 100 g of dry clay. The CEC of studied sample was measured by methylene blue adsorption method as followed:

1- 0,01 N methylene blue dye solution was prepared by dissolving 3,74 g basic blue methylene dry powder per litter of distilled water.

2- bentonite sample was dried at 105°C for two hour.

3- a weight quantity (0.57 g) of clay was dispersed into 10 cm^3 water in the Erlenmeyer flask followed by addition of 0.5 ml of 5 N sulphuric acids.

4- this mixture was boiled gently for 10 minute and then diluted to about 50 cm^3 distilled water.

5- methylene blue solution was added in 0.5 ml increments from burette to the flask. After each addition, the contents of the flask were swirled for about 30 second. While the solid were still suspended in the liquid, one drop of the suspension was removed with a stirring rod and placed the drop on a piece of filter paper.

6- the end point of the titration was reached when dye appears as a blue ring surrounding the dyed solids.

7- when the blue tint spreading from the spot was detected, the flask was shaked an additional 2 minutes and placed another drop on the filter paper. If the blue ring was again evident, the end point had been reached.

8- the cation exchange of the clay was reported as the methylene blue capacity calculated as follow :

MBI = (E x V / W) x 100

Where :

MBI = meythylene blue index for the clay in meq/100 g clay.

E = milliequivalents of meythlene blue per milliliter.

V = milliliters of meythlene blue solution required for the titrations.

W = grams of dry material.

3.3. Mineralogical Test:

Mineralogical analysis for local bentonite showed that they are essentially montmorillonite as expected.

XRD patterns of the samples in air dried state indicated that the main constituents are montmorillonite, Quartz and Kaolinite in decreasing order of their abundance as shown in Table (4.3).

X-ray diffraction (XRD) using a philips X-ray diffraction equipment model Pw 710 with mono chromator, cu radiation (h= 1.542 Å) at 40 kV, 35 mA and scanning speed 0.02°/s. The reflection peaks between 2θ =2° - 70°, corresponding spacing (d, Å) and the relative intensities (I/I°) were obtained.

3.4. Drilling Fluids Tests:

The rheological and fluid loss properties were determined over multiple experiments according to API standard procedures through the laboratory work. This tests include :

3.4.1. Plastic Viscosity and Yield Point:

Plastic viscosity (PV) is a measure of the viscosity of the dispersed phase (base liquid) and friction between the insoluble solid particles in the mud.

Yield point (YP) is a measure of the resistance to initial flow, or represent the stress required to start fluid movement. This is due to electrical charges located on or near the surfaces of the particles.

The PV and YP of studied sample were determined according to API specification with the following procedures :

1-Prepare a suspension of the bentonite. Add 22.5 g ± 0.01 g of clay (as received) to 350 cm^3 of deionized water while stirring on the mixer.

2-After stirring 5 min ± 0.5 min, remove the container from mixer and scrape its sides with the spatula to dislodge any bentonite adhering to container walls. Be sure all bentonite clinging to the spatula is incorporated into the suspension.

3-Replace the container on the mixer and continue to stir. The container may need to be removed from the mixer and the sides scraped to dislodge any clay clinging to container walls after another 5 min and after 10 min. Total stirring time shall equal 20 min ± 1 min.

4-Age the bentonite suspension up to 16 h in a sealed or covered container at room temperature or in a constant temperature device. Record storage temperature and storage duration.

5-After ageing bentonite suspension, shake well and then pour the suspension into the mixer container. Stir the suspension on the mixer for 5 min ± 0.5 min.

6-Pour the suspension into the viscometer cup provided with the direct-indicating viscometer. The dial readings at 600 r/min and 300 r/min rotor speed settings of the viscometer shall be recorded when a constant value for each r/min is reached. Readings shall be taken at a suspension test temperature of 25 °C ± 1 °C.

7- The plastic viscosity, yield point and Yield point / plastic viscosity ratio can be calculated by using following formulas :

$$PV = R600 - R300$$
$$YP = R300 - PV$$
$$b = YP / PV$$

where :

PV = plastic viscosity in (centipoises) .

YP = yield point in ($Ib/100\ ft^2$) .

b = yield point / plastic viscosity ratio .

$R600$ = the viscometer dial reading at 600 rpm/min.

$R300$ = the viscometer dial reading at 300 rpm/min.
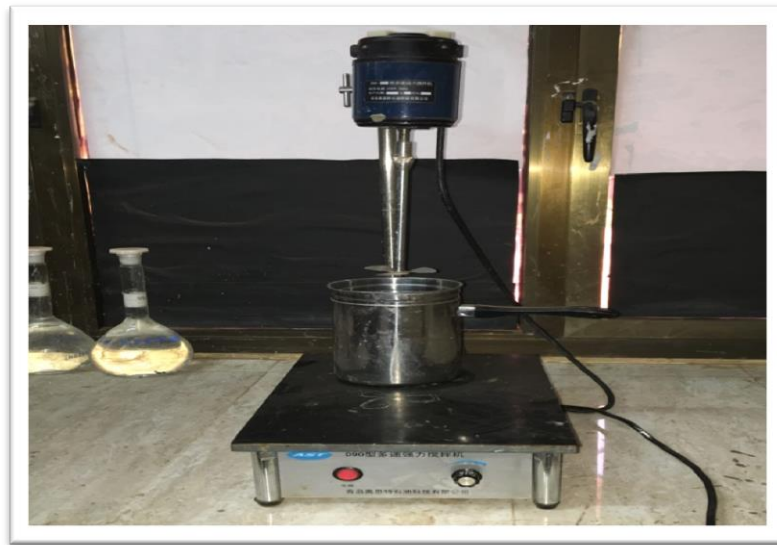
Figure (3.7): Mixer. (SUST Lab)

3.4.2. Gel Strength:

Gel strength is a measure of the ability of a colloid to form gels and is related to inter particle forces of the mud. It is determined by ZNN-D6 viscometer at 3 RPM. Mud is allowed to stagnate for 10 seconds, and then the container cup is rotated at 3 RPM by observing the dial on the viscometer the maximum deflection is recorded. The same procedure is repeated after allowing the mud to stand for 10 minutes. It is reported in $Ib/100ft^2$. The following procedures are employed :

1-A sample stirred at 600 RPM for about 5 seconds.

2-The RPM knob turned to the stop position.

3-Wait the desired rest time (normally 10 seconds or 10 minutes).

4-switch the RPM knob to the gel position.

5-Record the maximum deflection of the dial before the gel breaks, as the gel strength in Ib/100 ft^2.

Figure (3.8): Six Speed Viscometer. (SUST Lab)

3.4.3. Filtrate Volume:

The filter press instrument type (ZNS-4) was used to investigate of filtrate volume of drilling fluids.

filtrate volume of studied sample were determined according to API specification with the following procedures :

1- Recombine all of the suspension, as prepared and tested in 9.3, and stir in container for 1 min ± 0.5 min on the mixer. Adjust suspension temperature to 25 °C ± 1 °C.

2- Pour the suspension into the filter press cell. Before adding the suspension, be sure each part of the filter cell is dry and that all gaskets are not distorted or worn. Pour the suspension to within about 13 mm of the top of the cell. Complete assembly of the filter press cell. Place filter cell in frame and close relief valve. Place a container under the drain tube.

3- Set one timer for 7.5 min ± 0.1 min and the second timer for 30 min ± 0.1 min. Start both timers and adjust pressure on cell to 690 kPa ± 35 kPa. Both of these steps shall be completed in less than 15 s. Pressure shall be supplied by compressed air, nitrogen or helium.

4- At 7.5 min ± 0.1 min on the first timer, remove the container and any adhering liquid on the drain tube and discard. Place the dry 10 cm^3 graduated cylinder under

the drain tube and continue collecting filtrate until the end of the second timer set at 30 min. Remove the graduated cylinder and record the volume of filtrate collected.

5-The dispersed filtrate volume of clay suspension was calculated from :

$$V = 2 \times Vc$$

Where :

V = filtrate volume in cm3

Vc = filtrate volume, in cubic centimetres, collected between 7.5 min and 30 min.

Figure (3.9): API Filtration Press. (SUST Lab)

3.4.4. Density:

Density is defined as the ratio of the mass of the fluid to its volume. The unit of density in SI unit is Kg/m^3.

Density = mass of fluid / volume of fluid

Density of the mud can be determined by mud balance device. The device must be calibration as follow:

1- Remove the lid from the cup, and completely fill the cup with water.

2- Replace the lid and wipe dry.

3- Replace the balance arm on the base with knife-edge resting on the fulcrum.

4- The level vial should be centered when the rider is set on 8.33. if not, add to or remove shot from the well in the end of the bream.

Density test procedures:

1- Remove the lid from the cup, and completely fill the cup with the mud to be tested.

2- Replace the lid and rotate until firmly seated, making sure some mud is expelled through the hole in the cup.

3- Wash or wipe the mud from the outside of the cup.

4- Place the balance arm on the base, with the knife-edge resting on the fulcrum.

5- Move the rider until the graduated arm is level, as indicated by the level vial on the beam.

6- At the left hand edge of the rider, read the density on either side of the lever in all desired unit without disturbing the rider.

7- Note down mud temperature corresponding to density.

Figure (3.10): Mud Balance. (SUST Lab)

3.4.5. PH value:

The pH value is defined as negative logarithm of the hydrogen ion content of a solution (pH = log [H+]). In this way, an increase of the concentration of H^+ ions decreases the pH value and a decrease of H^+ ions increases the pH value. The pH value of the mud performed by pH paper which changes color according to the pH value determined.The results are shown in table (4.4) and (4.5).

CHAPTER FOUR

RESULT & DISCUSSION

CHAPTER FOUR

RESULT & DISCUSSION

4.1. Physical Analysis:

As shown in table (4.1) the plastic limit value is 47.8%, this proved that the montmorillonite mineral plays an important role that influences the plasticity of a sample. The liquid limit value is 83.63% however, the transition from plastic to liquid behavior is gradual over a range of water contents. This high value means there is no cohesive strength of soil to retain its shape under its own weight.

Sample No.	Liquid Limit LL%	Plastic Limit PL%	Plasticity Index PI %	Gravel %	Sand %	Silt %	Clay %
1	83.63	47.8	35.81	0.0	3	19	78

Table (4.1): illustrates the physical analysis for local Bentonite. (GRAS)

4.2. Chemical Analysis:

4.2.1. X-Ray Fluoresence Analysis:

XRF Values obtained in XRF analysis showed that the Al_2O_3/SiO_2 ratio was 0.387 which is typical to the Wyoming bentonite as expected for montmorillonite is the main component of bentonite under study. The ratio of $\{(Na_2O+K_2O)/(CaO + MgO)\}$ was found to be 0.11% confirming that the sample was Ca-bentonite. The results are shown in table (4.2).

Elements	Local bentonite %
Na_2O	0.316
MgO	1.908
Al_2O_3	17.986
SiO_2	46.437
P_2O_5	0.029
SO_3	0.051
K_2O	0.127
CaO	2.091
TiO_2	1.801
Cr_2O_3	0.037
Fe_2O_3	12.465
NiO	0.023
ZnO	0.008
CuO	0.009
Ga_2O_3	0.005
Cl	0.013
SrO	0.029
ZrO_2	0.089
Y_2O_3	0.007
Nb_2O_5	0.007
BaO	0.072
CeO_2	0.025
PbO	0.012

Table (4.2): illustrates the chemical composition for local Bentonite. (GRAS)

4.3. Mineralogical Analysis:

Mineralogical analysis for local bentonite showed that they are essentially montmorillonite.

X-ray Diffraction was used to determine the clay mineral types. The dominant clay mineral was found to be montmorillonite with minor amount of kaolinite and illite.

Constituent	Kaolinite	Smectite	Illite	Chlorite	Smec/Illite
Percentage %	21.51	77.19	1.30	0.00	0.00

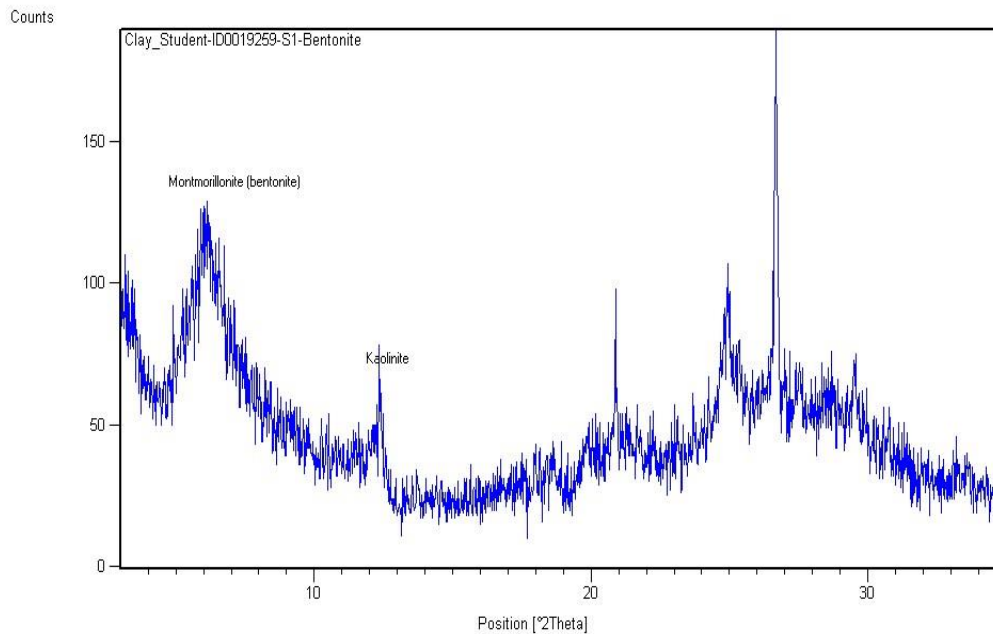**Table (4.3): illustrates the mineralogical composition for local Bentonite. (CPL)**

Figure (4.1): X-ray diffraction analysis. (CPL)

4.4. Drilling fluid Analysis:

Rheological properties of water-based mud formulated with local-bentonite samples were studied before and after treatment with (PAC-LV) and Flowzan compared with water-based mud formulated with commercial grade bentonite illustrated in table (4.4) and (4.5). Testing results of rheology indicated the following**:**
- Plastic viscosity (PV) for local and commercial bentonite before treatment are 2 and 6 cp respectively which are lower than API specification however the (PV) for local bentonite increased from 4 to 10 cp after treatment with different concentration of flowzan and from 2 to 18 cp after treatment with PAC-LV which is satisfying the API standard but the (PV) for commercial bentonite increased from 8 to 16 cp after

treatment with different concentration of flowzan and from 12 to 76 cp after treatment with PAC-LV which is compatible with the API standard.

-Yield point (YP) for local and commercial bentonite before treatment are 2 and 7 lb/100ft^2 respectively which are lower than API specification however the (YP) for local bentonite varies from 5 to 10 lb/100ft^2 after treatment with different concentration of flowzan and from 1 to 0 lb/100ft^2 after treatment with PAC-LV which is lower than the API standard but the (YP) for commercial bentonite varies from 10 to 26 lb/100ft^2 after treatment with different concentration of flowzan and from 10 to 79 lb/100ft^2 after treatment with PAC-LV which is compatible with the API standard.

-yield point/plastic viscosity ratio for local and commercial bentonite before treatment are 0 and 1.17 respectively which are satisfying API specification however the (YP/PV) for local bentonite varies from 1.25 to 1 after treatment with different concentration of flowzan and from 0.33 to 0.11 after treatment with PAC-LV which is meet the API standard but the (YP /PV) for commercial bentonite varies from 1.25 to 1.63 after treatment with different concentration of flowzan and from 0.83 to 1.04 after treatment with PAC-LV which is compatible with the API standard.

-Gel strength at 10 sec for local and commercial bentonite before treatment are 1 and 4 lb/100ft^2 respectively which are lower than API specification however for the local bentonite varies from 1 to 2 lb/100ft^2 after treatment with different concentration of flowzan and and still constant at one after treatment with PAC-LV which is lower than the API requirements but for commercial bentonite varies from 4 to 15 lb/100ft^2 after treatment with different concentration of flowzan and from 3 to 17 lb/100ft^2 after treatment with PAC-LV which is compatible with the API standard.

-Gel strength at 10 min for local and commercial bentonite before treatment are 1 and 7 lb/100ft^2 respectively which are lower than API specification however for the local bentonite varies from 1 to 5 lb/100ft^2 after treatment with different concentration of flowzan and and from 1 to 2 lb/100ft^2 after treatment with PAC-LV which is lower than the API requirements but for commercial bentonite varies from 7 to 21 lb/100ft^2 after treatment with different concentration of flowzan and from 6 to 30 lb/100ft^2 after treatment with PAC-LV which is compatible with the API standard.

-The filter loss of non-treated local bentonite, non-treated commercial Bentonite , treated local Bentonite with flowzan (5%) and treated commercial Bentonite with

flowzan (5%) all of them more than the maximum acceptable filter loss of the API Bentonite which is 15 ml.

But for the treated local Bentonite with PAC-LV (35%) and treated commercial Bentonite with PAC-LV (35%) both of them meet the API specifications. The results are shown in table (4.6).

-The obtained value of PH for local bentonite before treatment of caustic soda was 6. In order to increase the PH value the local bentonite was treated by adding 0.1 g and 0.01g caustic soda to meet the API specifications for bentonite sample.

Test parameter	Specification
Suspension properties:	
Viscometer dial reading at 600 r/min	minimum 30
Yield point/plastic viscosity ratio	maximum 3
Filtrate volume	maximum, 15.0 cm^3
Residue of diameter greater than 75 μm	maximum mass fraction 4.0%

Table (4.4): API 13A Specifications for Bentonite.

a. Local Bentonite:

Sample type		Viscometer dial reading		Gel strength (Ib/100ft^2)		PV(cp)	YP (Ib/100ft^2)	YP/PV	PH
		Θ_{300}	Θ_{600}	10 sec	10 min				
LB (non-treated)		2	4	1	1	2	0	0.00	6
LB with flowzan concentra-tion%	2.00%	9	13	1	1	4	5	1.25	12
	3.00%	14	20	2	3	6	8	1.30	12
	5.00%	20	30	2	5	10	10	1.00	12
LB with PAC-LV concentra-tion%	2.00%	2	4	1	1	2	0	0.00	12
	5.00%	4	7	1	1	3	1	0.33	12
	10.00 %	6	11	1	1	5	1	0.20	12
	15.00%	5	9	1	1	4	1	0.25	8
	20.00%	7	13	1	1	6	1	0.17	8
	30.00%	14	28	1	1	14	0	0.00	8
	35.00%	20	38	1	2	18	2	0.11	8

Table (4.5): illustrates the rheological analysis of local Bentonite.

(SUST Lab)

b. Commercial Bentonite:

Sample Type		Viscometer dial reading		Gel strength (Ib/100ft^2)		PV (cp)	YP (Ib/100ft^2)	YP/PV	PH
		Θ_{300}	Θ_{600}	10 Sec	10 Min				
CB (non-treated)		13	19	4	7	6	7	1.17	8
CB with flowzan concentration%	2.00%	18	26	4	7	8	10	1.25	9
	3.00%	26	40	7	11	14	12	0.86	9
	5.00%	42	58	15	21	16	26	1.63	9
CB with PAC-LV concentration%	5.00%	22	34	3	6	12	10	0.83	8
	15.00%	51	79	7	13	28	23	0.82	8
	30.00%	126	180	15	25	54	72	1.33	9
	35.00%	155	231	17	30	76	79	1.04	9

Table (4.6): illustrates the rheological analysis of commercial Bentonite.

(SUST Lab)

Sample Type			Filtrate volume (ml)
LB	Non-treated		> 15
	Flowzan	5.00%	> 15
	PAC-LV	35.00%	0.8
CB	Non-treated		> 15
	Flowzan	5.00%	> 15
	PAC-LV	35.00%	8

Table (4.7): illustrates the filter volume of local and commercial Bentonite.
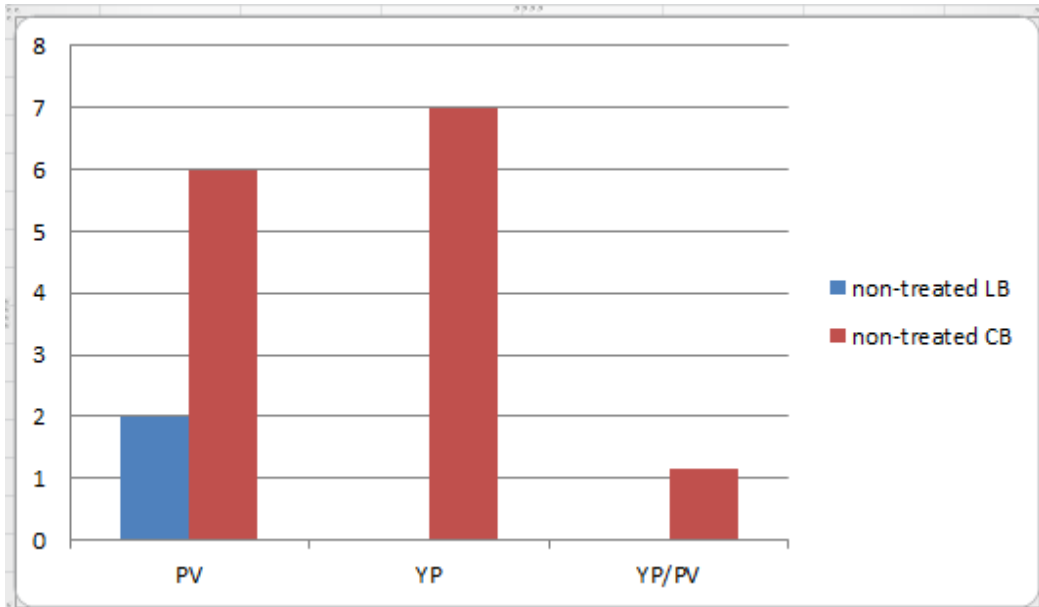
(SUST Lab)

Figure (4.2): PV, YP and YP/PV ratio for non-treated local and commercial Bentonite.

The plastic viscosity value for non-treated local and commercial bentonite is 2 and 6 respectively. The yield point value for non-treated local and commercial bentonite is 0 and 7. The yield point to plastic viscosity ratio for non-treated local and commercial bentonite is 0 and 1.17. The PV and YP are not satisfied the API specifications, while the YP/PV ratio for both local and commercial bentonite meet the API specifications.
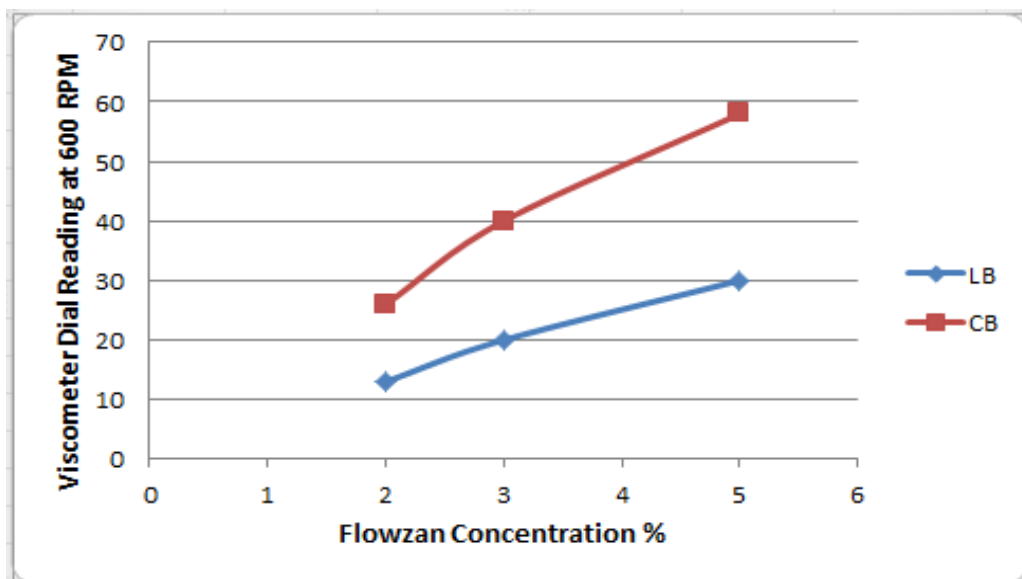

Figure (4.3): Viscometer dial reading at 600rpm vs flowzan concentration

The viscometer dial reading at 600 RPM for treated local bentonite with flowzan at concentration 2% to 5% range from 13 to 30. In addition to treated commercial bentonite with flowzan at concentration 2% to 5% range from 28 to 50. At concentration 5% with flowzan for both local and commercial bentonite meet the API specifications.
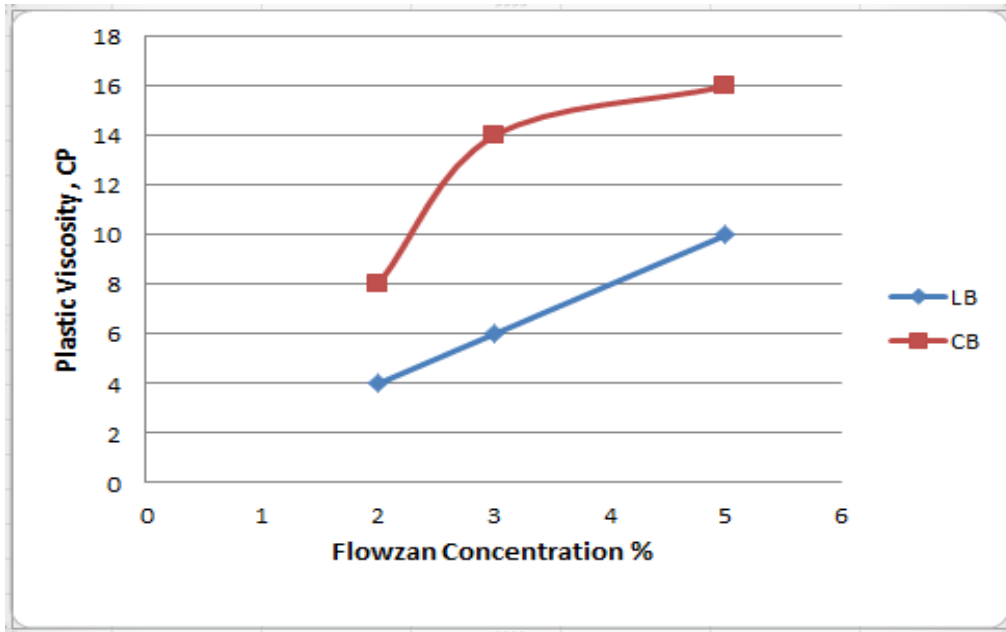

Figure (4.4): Plastic Viscosity vs flowzan concentration.

The Plastic viscosity for treated local bentonite with flowzan at concentration 2% to 5% range from 4 to 10 cp. In addition to treated commercial bentonite with flowzan at concentration 2% to 5% range from 8 to 16 cp. At concentration 5% with flowzan for both local and commercial bentonite meet the API specifications.
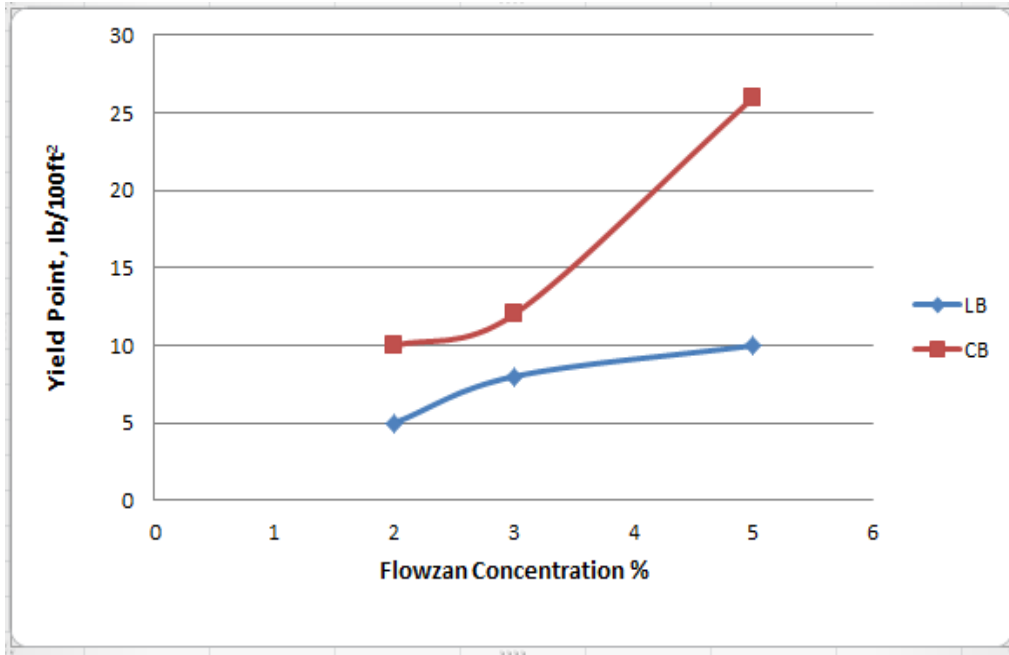
Figure (4.5): Yield Point vs flowzan concentration.

The Yield point for treated local bentonite with flowzan at concentration 2% to 5% range from 5 to 10 Ib/100ft^2. For treated commercial bentonite with flowzan at concentration 2% to 5% range from 10 to 26 Ib/100ft^2. At concentration 5% with flowzan for both local and commercial bentonite meet the API specifications.
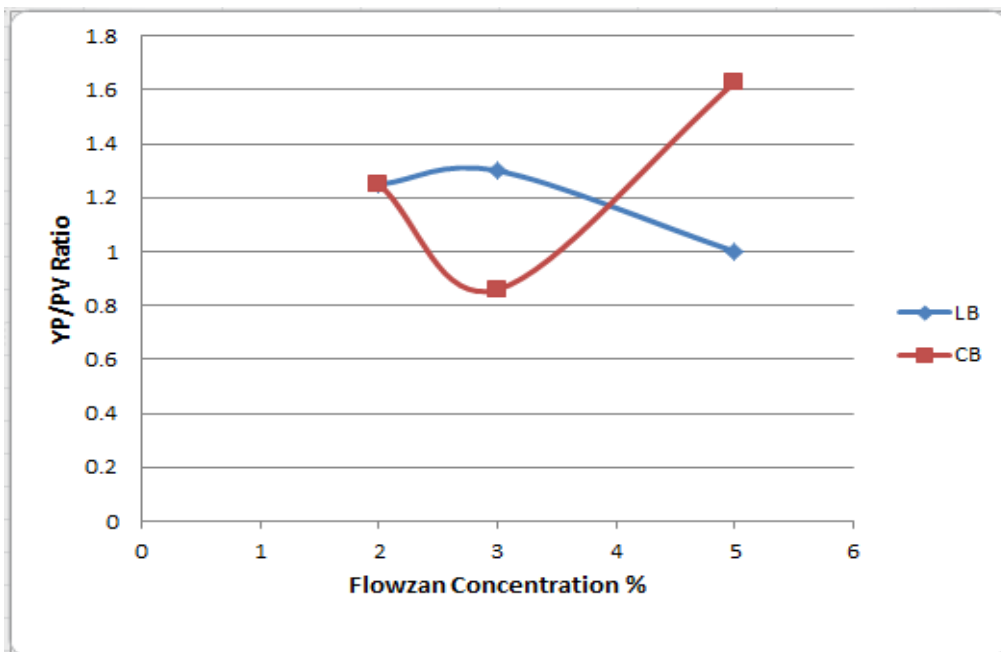

Figure (4.6): YP/PV ratio vs flowzan concentration.

The YP/PV Ratio for treated local bentonite with flowzan at concentration 2% to 5% range from 1.25 to 1. And for treated commercial bentonite with flowzan at

concentration 2% to 5% range from 1.25 to 1.63. At the concentration 5% with flowzan for both local and commercial bentonite meet the API specifications.
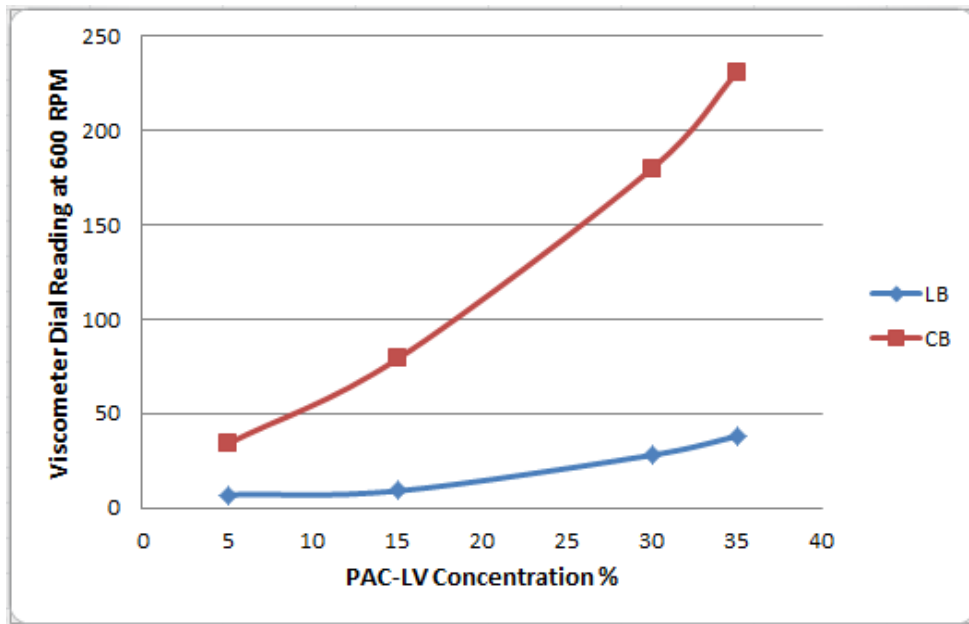

Figure (4.7): Viscometer dial reading at 600rpm vs PAC-LV concentration.

The viscometer dial reading at 600 RPM for treated local bentonite with PAC-LV at concentration 5% to 35% range from 7 to 38. In addition to treated commercial bentonite with PAC-LV at concentration 5% to 35% range from 34 to 231. At concentration 35% with PAC-LV for both local and commercial bentonite meet the API specifications.
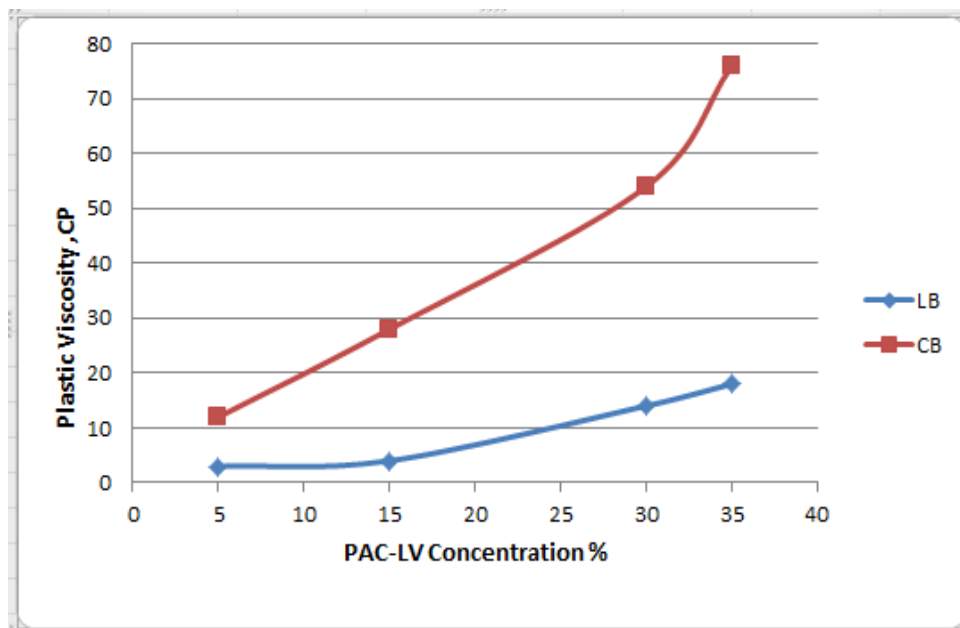

Figure (4.8): Plastic Viscosity vs PAC-LC concentration.

43

The Plastic viscosity for treated local bentonite with PAC-LV at concentration 5% to 35% range from 3 to 18 cp. In addition to treated commercial bentonite with PAC-LV at concentration 5% to35% range from 12 to 76 cp. At concentration 35% with PAC-LV for both local and commercial bentonite meet the API specifications.
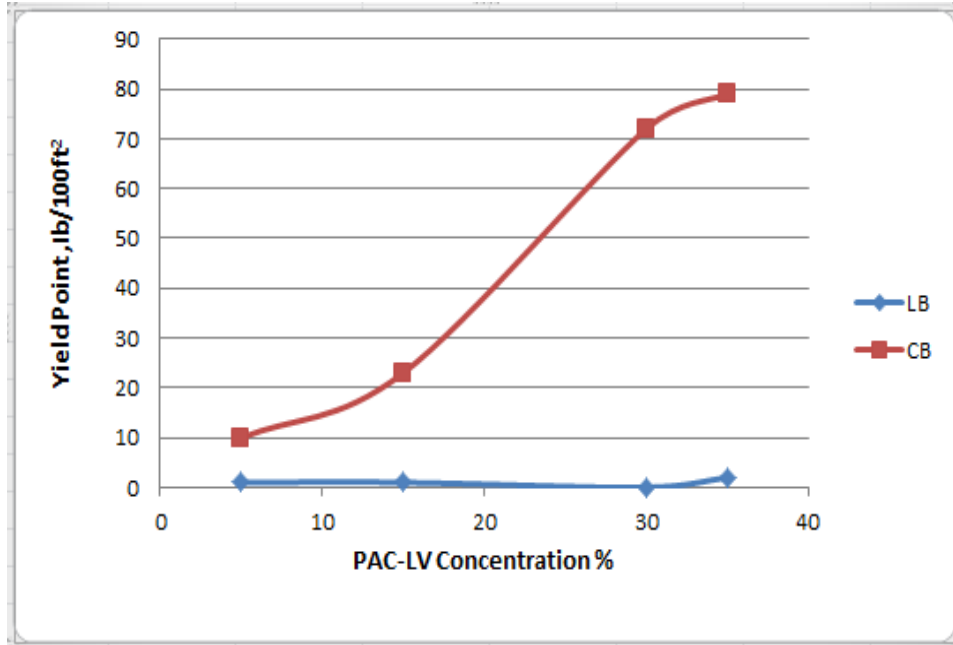

Figure (4.9): Yield Point vs PAC-LV concentration.

The Yield point for treated local bentonite with PAC-LV at concentration 5% to 35% range from 1 to 2 Ib/100ft^2. For treated commercial bentonite with PAC-LV at concentration 5% to 35% range from 10 to 79 Ib/100ft^2. At concentration 35% with PAC-LV for both local and commercial bentonite meet the API specifications.
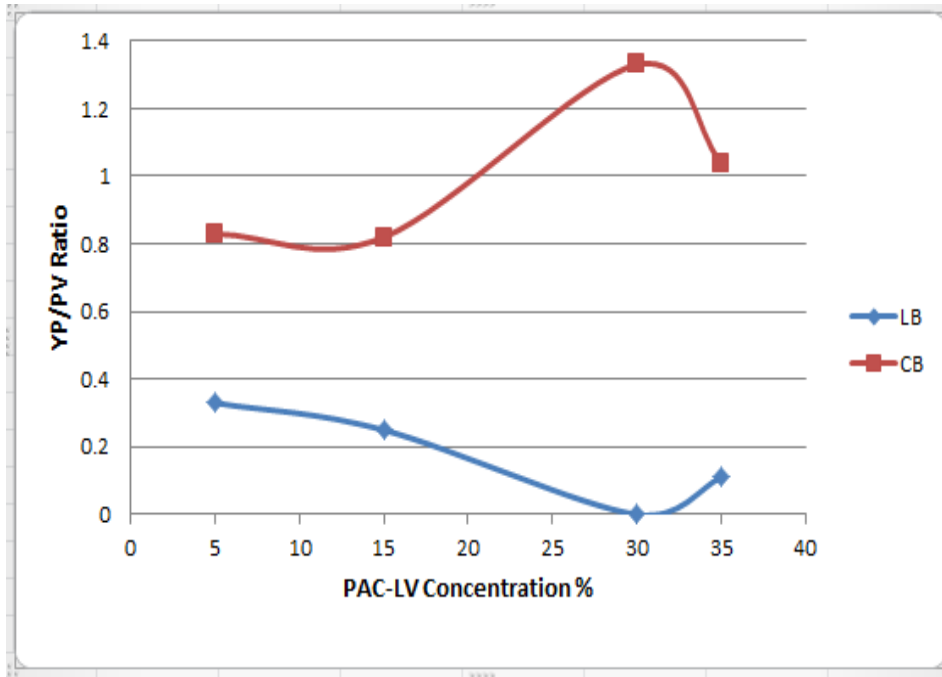
Figure (4.10):YP/PV ratio vs PAC-LV concentration.

The YP/PV Ratio for treated local bentonite with PAC-LV at concentration 5% to 35% range from 0.33 to 0.11. And for treated commercial bentonite with PAC-LV at concentration 5% to 35% range from 0.83 to 1.04 . At the concentration 35% with PAC-LV for both local and commercial bentonite meet the API specifications.

CHAPTER FIVE

CONCLUSION & RECOMMENDATION

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5.1. Conclusion:

Based on the results of the tests performed, the following conclusions were obtained:

- The ratio of $\{(Na_2O+K_2O)/(CaO + MgO)\}$ was found to be 0.11% confirming that the sample was Ca-bentonite according to the XRF analysis.
- The dominant clay mineral for Ed-Damazin sample was found to be montmorillonite with minor amount of kaolinite and illite.
- The non-treated local bentonite failed to meet the API specifications.
- Adding 35% concentration of PAC-LV enhanced Ed-Damazin sample within the API specifications.
- The treated local Bentonite with 5% concentration of Flowzan increases the yield point , plastic viscosity and gel strength within the API specifications however, The filter volume of treated local bentonite with flowzan failed to meet the API specifications.
- Addition of caustic soda for Ed-Damazin sample enhances the PH value.
- The YP/PV ratio for non-treated local bentonite is compatible with the API specifications.

5.2. Recommendation:

- Based on the above conclusion, Ed-Damazin sample requires an activation of sodium carbonate (Na_2CO_3) to convert the calcium base bentonite into sodium base bentonite.

- To study the effects of adding local bentonite on cement slurry properties.

- To study the economical aspect of Ed-Damazin sample.

- Test the treated local bentonite on a near well environment of pressure and temperature to see if it meets the specifications..

- This is the first study conducted in Ed-Damazin area and it is recommended as a benchmark for the next researchers to improve and enhance the local bentonite since the area is rich of local bentonite clays.

- In this research, only one local bentonite sample is evaluated for potential use as drilling mud. We recommend to evaluate several samples of local bentonite in Ed-Damazin area and compare them with the commercial bentonite according to American Petroleum Institute (API) and Oil Companies Materials Association (OCMA) specifications.

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