ENHANCEMENT OF VISCOSITY AND FLUID LOSS IN DRILLING MUD BY USING POWDERS OF SEDGE AND WATER HYACINTH AS ADDITIVES

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การเพิ่มประสิทธิภาพความหนืดและลดการซึมผ่านของน้ำโคลนขุดเจาะโดยใช้ต้นกกและผักตบชวาเป็นสารเติมแต่ง

นางสาวมุกระวี โดนหมั้น

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
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Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for a Master's Degree.

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มุกระวี โดนหมั้น : การเพิ่มประสิทธิภาพความหนืดและลดการซึมผ่านของน้ำโคลนขุดเจาะโดยใช้ต้นกกและผักตบชวาเป็นสารเติมแต่ง (ENHANCEMENT OF VISCOSITY AND FLUID LOSS IN DRILLING MUD BY USING POWPDERS OF SEDGE AND WATER HYACINTH AS ADDITIVES) อาจารย์ที่ปรึกษา : ผู้ช่วยศาสตราจารย์ ดร.บัณฑิตา ธีระกุลสถิตย์, 140 หน้า.

วัตถุประสงค์ของการศึกษาเพื่อวิเคราะห์คุณสมบัติทางกายภาพและทางเคมีของผักตบชวา ต้นกก น้ำโคลนขุดเจาะผสมผักตบชวา และน้ำโคลนขุดเจาะผสมต้นกก ซึ่งทำการเติมผงผักตบชวาและผงต้นกกที่ความเข้มข้นร้อยละ 1, 3 และ 5 โดยมวล ที่อุณหภูมิ 30, 60 และ 80 องศาเซลเซียส โดยใช้วิธีการศึกษาผลกระทบของอุณหภูมิและอัตราส่วนผสมต่อคุณสมบัติด้านวิทยากระแสของน้ำโคลนขุดเจาะตามแบบจำลองบิงแฮมและเพาเวอร์ลอร์ ส่วนธาตุและแร่องค์ประกอบของน้ำโคลนขุดเจาะผสมผักตบชวาและต้นกก มีการเปลี่ยนแปลงตามอุณหภูมิเพียงเล็กน้อย การวิเคราะห์คุณสมบัติทางเคมีของน้ำโคลนขุดเจาะที่ผสมน้ำโคลนขุดเจาะผสมผงผักตบชวาและต้นกก ได้หาองค์ประกอบของธาตุและแร่โดยใช้เครื่องมือเอ็กเรย์ฟลูออเรสเซนต์ (XRF) และเครื่องมือเอ็กเรย์ดิฟแฟรคชั่น (XRD) ตามลำดับ ผลของปริมาณของธาตุและแร่เปลี่ยนแปลงตามอุณหภูมิและสัดส่วนของผักตบชวาและต้นกกในน้ำโคลนขุดเจาะ โดยประกอบด้วยธาตุ โพแทสเซียมออกไซด์ แคลเซียมออกไซด์ คลอไรด์ ซิลิกอนไดออกไซด์และแมกนีเซียมออกไซด์ ส่วนแร่ประกอบด้วยแบไรต์ เคโอลิไนต์ ควอตซ์ ยิปซัม แมกนีไซต์ แคลไซต์ ตามลำดับ การทดสอบคุณสมบัติทางกายภาพประกอบด้วยการซึมผ่าน ความหนืด ความหนาแน่น ความเป็นกรด-ด่าง ความต้านทานไฟฟ้า และปริมาณของแข็งของน้ำโคลนขุดเจาะที่ผสมผักตบชวาและต้นกก โดยทำการทดสอบตามขั้นตอนมาตรฐาน API RP 13B-1 ผลการเปรียบเทียบระหว่างน้ำโคลนขุดเจาะผสมผักตบชวาและต้นกก พบว่าน้ำโคลนขุดเจาะผสมผักตบชวาที่ความเข้มข้นร้อยละ 5 ที่อุณหภูมิ 80 องศาเซลเซียส มีความเหมาะสมสำหรับใช้เป็นน้ำโคลนขุดเจาะ ซึ่งแสดงค่าความหนืดเท่ากับ 48 เซนติพอยส์ การซึมผ่านน้ำโคลนเท่ากับ 15 มิลลิเมตร ความหนาแน่นเท่ากับ 1.09 กรัมต่อลูกบาศก์เซนติเมตร ความเป็นกรด-ด่างเท่ากับ 8 และความต้านทานไฟฟ้าเท่ากับ 4.42 โอห์ม-เมตร ผลการวิเคราะห์ด้วยกล้องจุลทรรศน์อิเล็กตรอนพบว่าผักตบชวามีการจับตัวและเชื่อมประสานกับน้ำโคลนขุดเจาะได้ดีกว่าต้นกก. ดังนั้นน้ำโคลนขุดเจาะผสมผักตบชวาจึงสามารถใช้เพื่อปรับปรุงคุณสมบัติด้านวิทยากระแสและควบคุมความซึมผ่านของน้ำโคลนขุดเจาะได้ดีกว่าน้ำโคลนผสมต้นกก จากผลการเปรียบเทียบราคาชี้ให้เห็นว่าไม่มีค่าใช้จ่ายของผักตบชวาและต้นกกแต่จะมีค่าขนส่ง ค่าแปรรูป และค่ากำจัดของเสีย โดยสรุปผักตบชวาสามารถใช้เป็นสารเติมแต่งสำหรับการเพิ่มประสิทธิภาพคุณสมบัติด้าน

วิทยากระแสและการป้องกันการสูญเสียน้ำในน้ำโคลนขุดเจาะและเป็นการเพิ่มมูลค่าให้กับผักตบชวาและต้นกกได้ แต่ควรมีการใช้สารเติมแต่งเหล่านี้ร่วมกับสารเติมแต่งอื่น เพื่อช่วยให้เพิ่มประสิทธิภาพมากขึ้น

สาขาวิชา เทคโนโลยีธรณี ลายมือชื่อนักศึกษา ____________________

ปีการศึกษา 2559 ลายมือชื่ออาจารย์ที่ปรึกษา________________

MOOKRAWEE DONMUN : ENHANCEMENT OF VISCOSITY AND FLUID LOSS IN DRILLING MUD BY USING POWDERS OF SEDGE AND WATER HYACINTH AS ADDITIVES. THESIS ADVISOR : ASST. PROF. BANTITA TERAKULSATIT, Ph.D., 140 PP.

WATER HYACINTH/ SEDGE/ RHEOLOGY/ FILTRATION

The objective of this study is to investigate the physical and chemical properties of water hyacinth, sedge, drilling mud mixed with water hyacinth and sedge powders by adding 1, 3 and 5 percentages by weight at 30, 60 and 80°C. The methodology investigates the effects of temperature and mixing ratio on rheological properties of drilling mud besed on Bingham and Power Law models. The chemical properties of drilling mud mixed with water hyacinth and sedge are determined the elemental and mineral composition by X-ray fluorescence and X-ray diffraction. Result of element and mineral contents slightly change along with temperature and mixing ratio of the water hyacinth and sedge powders in drilling mud. The elemental composition include K_2O, CaO, Cl, SiO_2, and MgO. The minerals comprise the barite, kaolinite, quartz, gypsum, magnesite and calcite, respectively. The physical properties analysis includes the filtration, viscosity, density, pH, resistivity and solid content according with API RP 13B-1 standard. The comparative results between drilling mud mixed with water hyacinth and drilling mud mixed with sedge demonstrate that the drilling mud mixed with 5 percentages of water hyacinth at 80°C is the appropriate for drilling mud. The viscosity is 48 cP, filtration is 15 ml, density is 1.09 g/cm^3, pH ranges from 7-8 and resistivity is 4.42 Ω.m. The results were analyzed by electron microscopy and found that the drilling mud mixed with water hyacinth there is a

catch, and the interface between the various components tightly over the drilling mud mixed with sedge. Therefore, the drilling mud mixed with water hyacinth could be used to improve the rheological properties and filtration loss of drilling mud better than that of drilling mud mixed with sedge. Comparison of cost and economic consideration, it clearly sees that the no cost of water hyacinth and sedge. It does not include a cost of the processing materials, materials handling and storage, packaging, transporting and other indirect materials. In conclusion, water hyacinth is suitable to be the additive in water based drilling mud to enhance the rheological properties and fluid loss control, and increase a value to these additives. However, it should be used with other additives for performance of rheology property.

School of Geotechnology Student's Signature____________________

Academic Year 2016 Advisor's Signature____________________

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Finally, I most gratefully acknowledge my parents and friends for all their supported throughout the period of this research.

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SYMBOLS AND ABBREVIATIONS

Gel_{in}	=	Initial gel strength
Gel_{10}	=	10 minutes gel strength
gm	=	gram
kg	=	Kilogram
ml	=	milliliter
N	=	range extension factor of the torque spring of the VG meter
rpm	=	Rotational speed
SD	=	Sedge
Temp.	=	Temperature
WH	=	Water Hyacinth
%w/w	=	Percentage of weight by weight

GREEK ABBREVIATIONS:

k	=	Fluid Consistency Index
n	=	Flow Behavior Index
τ	=	Shear Stress
τ_0	=	Yield Stress
γ	=	Shear Rate
γ_p	=	Yield point
μ_a	=	Apparent Viscosity
μ_p	=	Plastic Viscosity

SYMBOLS AND ABBREVIATIONS (Continued)

ϕ_i	=	Viscometer dial reading
ϕ_{300}	=	Viscometer dial reading at 300 rpm
ϕ_{600}	=	Viscometer dial reading at 600 rpm

CHAPTER I

INTRODUCTION

1.1 Background of problems and significance of the study

Drilling mud is important to petroleum production due to its use for protecting a lost circulation, controlling hydrostatic pressure in the well bore, minimizing fluid loss across permeable formations, and transporting rock cuttings to the surface. The drilling mud composition is a bentonite and barite with the base, and other additive such as cement, lime, starch, graphite, lignite, and carboxymethylcellulose (CMC). These are additives a high cost and could be imported from aboard. Petroleum industries have used drilling mud for (1) clean the rock fragment from beneath the bit and carry them to the surface, (2) exert sufficient hydrostatic pressure against subsurface formations to prevent formation fluids from flowing into the well, (3) keep the newly drilled borehole open until steel casing can be cemented in the hole, and (4) cool and lubricate the rotating drill string and bit. Thus, using water hyacinth and sedge are additive in drilling mud (Larry, 2006)

A weed is a plant considered undesirable in a particular situation, "a plant in the wrong place". Examples commonly are plants unwanted in human-controlled settings, such as farm fields, gardens, lawns, and parks. Taxonomically, the term "weed" has no botanical significance, because a plant that is a weed in one context is not a weed when growing in a situation where it is in fact wanted, and where one species of plant is a valuable crop plant, another species in the same genus might be a serious weed, such as a wild bramble growing among cultivated loganberries. Many plants that people widely regard as weeds also are intentionally grown in gardens and other cultivated settings. The term also is applied to any plant that grows or reproduces aggressively, or is invasive outside its native habitat. More broadly "weed" occasionally is applied pejoratively to species outside the plant kingdom, species that can survive in diverse environments and reproduce quickly; in this sense it has even been applied to humans. (Janick, Jules 1979)

In this study will bring weed such as water hyacinth and sedge. These weed are plants that have high fibers and it was natural materials that have too much in Thailand also. So this will be suitable to be brought to increase the effectiveness of mud in drilling petroleum industry to reduce cost of using chemicals and importing from overseas that are quite expensive.

1.2 Research objectives

The main aim of this research is to enhance the efficiency of drilling mud. Some more objectives are (1) to analyze properties of the drilling mud mixed with the sedge and water hyacinth based on the API RP 13B-1 1997 at the temperature ranging from 30, 60 and 80°C. And drilling mud mixed with sedge and water hyacinth powder by adding 1, 3 and 5 percentages by weight and particle morphologies by scanning electron microscope (SEM) to compare cost of additive between sedge, water hyacinth and other additive, (2) to analyze chemical properties to additives are both before and after mixed with mud for determine clay minerals by X-ray diffraction

(XRD), elemental composition by X-ray fluorescence (XRF), and the mineral crystals, components, (3) to study the effect of temperature and mixing ratio on the rheological properties of drilling mud mixed with additives, and (4) to compare the rheological properties of drilling mud mixed with different additives. The expected results will be presenting the potential for fluid loss and viscosity of sedge and water hyacinth powder for use additives in drilling mud.

1.3 Scope and limitation of the study

This research aims to study the chemical and physical properties of water-base drilling mud mixed with sedge and water hyacinth when the sedge and water hyacinth concentration and temperature were changed. The physical and chemical properties and rheological tests are determined at laboratory of Suranaree University of Technology following: The chemical properties of additives are analyzed both before and after mixed with drilling mud for determine mineral composition by using X-ray diffractometer (XRD). The element composition analyzes by X-ray fluorescence spectrometer (XRF). The physical properties test are including density, viscosity, API filtration, pH, resistivity and solid content of drilling mud. The drilling mud mixed with additives are determined by mud balance, direct-indicated Viscometers, Baroid standard filter press, analytical pH meter, Baroid resistivity meter, and Baroid oil - water retort kit, respectively which those properties affect to structure and properties of drilling mud should follow (API, 1997).and The mineral crystals, components and particle morphologies analyze by Scanning electron microscope (SEM).

1.4 Thesis contents

Chapter I introduces the thesis by briefly describing the background of problem and the significance of the study. The research objectives, scope and limitation are identified. **Chapter II** summarizes results of the literature review to improve an understanding of water-based drilling mud characteristics and the factor that affects to mud properties. **Chapter III** describes the sample preparation and the experimental procedure for laboratory tests. **Chapter IV** presents the results obtained from the laboratory tests and comparison of the results between each mud formula. **Chapter V** discusses and concludes the research results and provides recommendations for future research studies.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Relevant topics and previous research results are reviewed to improve understanding of water-based drilling mud and applications, using of additives in drilling mud, fly ash properties, and API stand practice. This chapter describes the drilling mud rheology that is shown to important roles for mud characteristic. The sources of information are from journals, researches, dissertation and books. The results of the review are summarized as follows.

2.2 Sedge (*Carex riparia*)

Ghorbani et al. (2013) explained that greater pond sedge is a clump-forming plant of ditches, ponds, canals, fens and riverbanks, particularly in lowland areas with clay and heavy soils. It is also a popular garden plant. It has a broad distribution over Europe and Western and Central Asia, with isolated occurrences in North Africa. In the UK, it is common in England, particularly the east, but rarer elsewhere. It can form large stands along slow-flowing rivers, canals, on the edges of lakes and in wet woodlands. It may be the dominant species in swamps, especially if there is standing water in the spring and it is also found in tall-herb fens, alongside Swamp Sedge

(Cacutiformis), Slender Tufted Sedge (Cacuta) and other closely-related species. This is the UK's largest species of Carex. The bright green leaves are up to 160 cm long by 6 to 20 mm wide, glaucous and narrowing at the tip to a trigonous point. The stems are 60 to 130 cm tall, rough and sharply triangular in section. The stems bear one to five female spikelets, each nearly cylindrical and generally overlapping with the next, and three to six more densely arranged male spikelets. All spikelets are dark brown. Each female spikelet is 3 to 10 cm long, often with some male flowers at the tip; while males are 2 to 6 cm long. Flowers are produced during May to June. Pollination is by the wind. The resultant fruit is a utricle, 5 to 8 mm long, with an inflated ovoid shape. It tapers to a distinct bifid beak, which bears three stigmas

2.2.1 Structural features of silica extracted from sedge ash.

Paya et al. (2001) studied the physical and chemical characterizations of fresh sedge were presented in Table 2.1. The unburned carbon (cellulose, hemicellulose, etc.) can be removed from the ash by further heating treatments at high temperatures, but this usually leads to the crystallization of the amorphous silica to cristobalite and/or tridymite.

Shinohara and Kohyama (2004) explained that the crystallization was a disadvantage toward preparing silicon based materials, because silica is rendered inactive in its crystalline form X-ray diffraction pattern of silica produced from sedge ash after burning at an uncontrolled temperature (ambient condition) is shown in Figure 2.1. Two peaks at [2u] = 258 and 318 illustrate the presence of the crystalline form of the silica. Therefore, similar to other studies, burning of sedge under uncontrolled conditions led to the crystallization of silica. Some studies have been performed to confirm an appropriate temperature for preparing the amorphous silica from the herbal materials. The temperature of 600–800 ºC has affect the silica extraction from rice husk. The results of the present study reveal that the structure of sedge ashes strongly depends on the burning temperature.

Ghorbani et al. (2013) use the X-ray diffraction pattern of silica powders at 500, 600, 700 and 800 °C for 6 hours, as shown in Figure 2.2. Sharp diffraction peaks at [2u] = 21.588, 25.568, 31.528 and 34.088 show the presence of crystalline cristobalite and tridymite forms of silica at 700 and 800 °C. But below 700 °C a typical amorphous structure, hill like peak in the range of [2u] = 158 to 308, indicated the absence of any ordered crystalline structure and highly disordered structure of silica. Therefore, sedge was heat-treated at 600 °C for 6 hours in order to retain amorphous phase of silica and also reduce unburned carbon.

Table 2.1 Physical and chemical properties of fresh sedge. (Ghorbani et al., 2013)

Contents	**Percentage (%)**
Moisture	70.03
Gray ash	5.41
Organic materials (cellulose, hemicellulose, etc.)	24.5
Silica content of gray ash	31.42

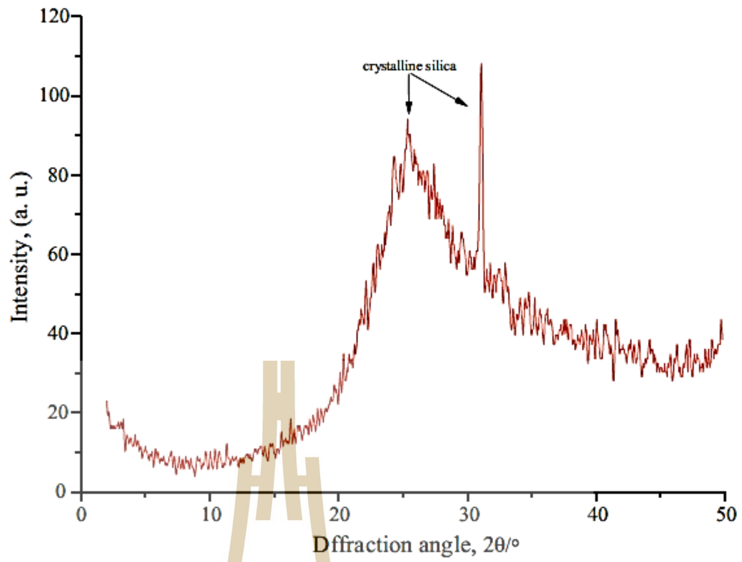


Figure 2.1 X-ray diffraction pattern of silica produced from sedge ash after burning at uncontrolled temperature. (Ghorbani et al., 2013)

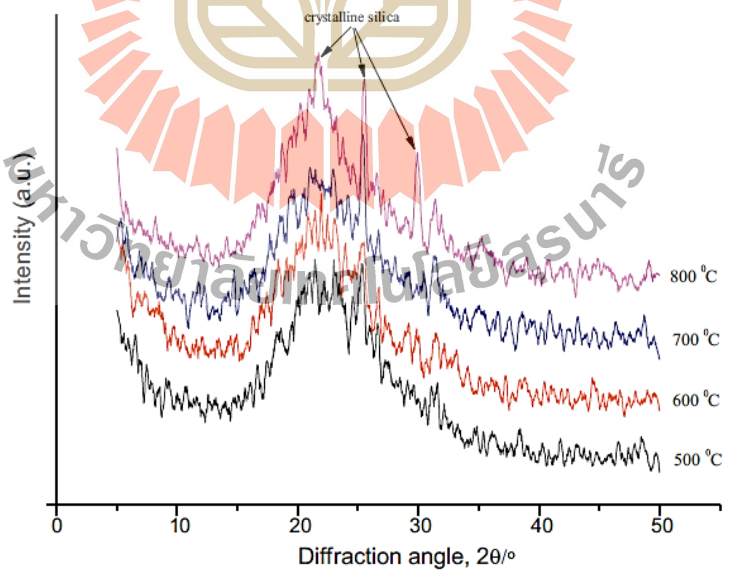


Figure 2.2 X-ray diffraction pattern of silica produced from sedge ash after burning at various temperatures of 500-800 ºC. (Ghorbani et al., 2013)

2.2.2 Chemical treatment of sedge ash

Ghorbani et al. (2013) investigate the elemental analysis of sedge ash under uncontrolled combustion, which is presented in Table 2.2. Evidently, the silica contents of the ash upon combustion are 31.42% and 33.14% under uncontrolled and 600 ºC conditions, respectively. Unburned organic matter as indicated by L.O.I and K_2O (Table 2.2) where the main impurities in the case of ash obtained under uncontrolled conditions. Also, we found that alkaline metal oxides like K_2O and CaO were the main impurities in the ash obtained at 600 ºC, which is in accord with the previous studies.

Zain et al. (2011) concluded that preliminary leaching of herbal material with a boiled solution of HCl, HNO_3, H_2SO_4, and NH_4OH before heat treatment proved an effective way in substantially removing most of the metallic impurities and producing silica completely white in color. In the present study, gray colors were observed in all of the untreated ash samples irrespective of the temperature and conditions of burning (Figure 2.3a). However, leaching of sedge with 1 mole of hydrochloric acid followed by heat treatment was found to give ash almost white in color (Figure 2.3b). Table 2.3 presents the chemical constituents of the ash samples upon leaching, refluxing and their combination at a combustion temperature of 600 °C. Therefore, the main effect of acid leaching is to remove metal oxides, especially potassium oxides.

Umeda and Kondoh (2010) show that the application of citric acid was remarkably effective in reducing the content of alkali metal oxides (Na_2O and K_2O) in the ash. The results show that the silica content of the ash samples after sedge leaching increased from 33.14% to 87.25%. It is evident from Table 2.3 that the main impurities in the leached sample are CaO and SO_3. The post-treatment process step of sedge ash performed by acid refluxing of white ash removed considerable amounts of metal ion impurities. Besides, acceptable silica purity of 93.82% was obtained by refluxing treatment of sedge ash with the main impurity being K_2O and Al_2O_3. However, the highest purity of 98% amorphous silica was obtained by applying a combination of pretreatment of sedge using leaching and post-treatment of sedge ash with refluxing.

Table 2.2 Mineral contents of sedge ash without acid treatment (some minerals with trace impurities are not included). (Ghorbani et al., 2013)

Temperature	**Minerals (%)**									
	SiO_2	**Fe_2O_3**	**CaO**	**K_2O**	**Cl**	**SO_3**	**P_2O_5**	**Al_2O_3**	**MgO**	**L.O.I[a]**
Uncontrolled	31.42	0.17	7.93	26.16	3.13	7.29	4.49	0.15	2.55	16.61
600 °C	33.14	0.39	11.21	33.39	5.33	6.33	6.49	0.47	2.91	0.40

Figure 2.3 Difference in color of the sedge ash produced at (a) 600 ºC – 6 hours without acid treatment and (b) 600 ºC – 6 hours with acid treatment. (Ghorbani et al., 2013)

Table 2.3 Mineral content of sedge ash with acid treatment (trace impurities are not given). (Ghorbani et al., 2013)

Temperature	**Minerals (%)**							
	SiO_2	**CaO**	**K_2O**	**SO_3**	**P_2O_5**	**Al_2O_3**	**MgO**	**Fe_2O_3**
Reflux	93.82	-	1.50	-	0.20	1.51	0.17	0.36
Leaching	87.25	6.23	0.60	3.07	0.77	0.38	0.92	-
Leaching and reflux	98.05	0.51	0.30	0.19	0.32	0.24	0.21	0.14

2.2.3 Ash morphology

Ghorbani et al. (2013) studied the morphology of the sedge ash by scanning electron micrograph (SEM). Figure 2.4 shows the SEM images of sedge ash under different treatment schemes. Figure 2.4a shows the structure of the ash before reflux treatment. Apparently, the ash retains the serrated structure of sedge and consists mainly of fragments of loose flakes with a skeleton like inner structure. This result is in agreement with a previous study conducted on rice husk. Figure 2.3a further reveals that sedge ash particles are not spherical in shape and exhibit irregularly fragmented particles Figure 2.4b, indicates that the ash particles after refluxing became much smaller and cellular structure disappeared.

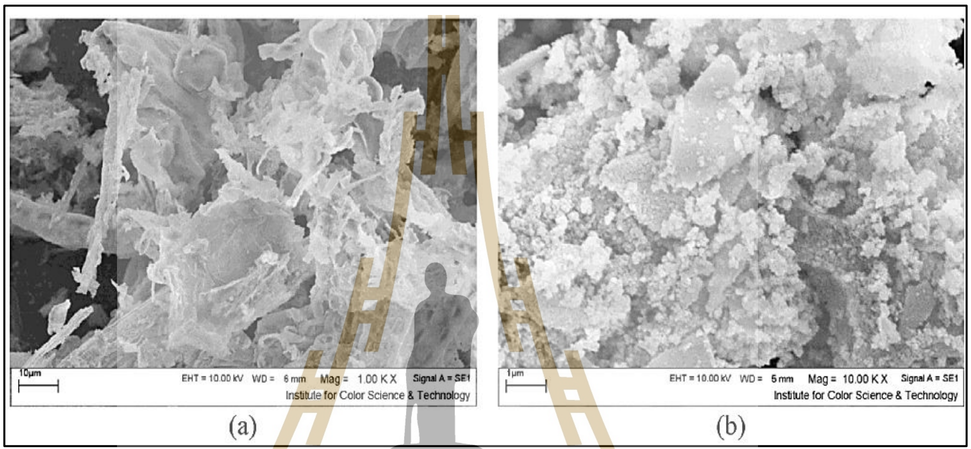


Figure 2.4 Scanning electron micrograph (SEM) sedge leaching + burning at 600 °C + ash refluxing. (Ghorbani et al., 2013)

2.3 Water hyacinth

Aboud et al. (2005) reported that Eichhornia crassipes also known as water hyacinth had gained significant attention as aquatic plant which has the ability to absorb pollutants from aquatic environments with rapid proliferation. As attempts for controlling, it has not been completely successful. The best management strategy is to find some use for them.

Patel (2012) concluded the most possible usage of water hyacinth includes making of animal fodder/fish feed. In addition, Indian scientists have suggested many formulations of medicines using water hyacinth for treating diseases.

Oudhia (1999) reported that natural water hyacinth be created serious challenges in the field of navigation, irrigation, and power generation. Therefore, in order to avoid these problems using of phytoremediation technology must be carried out along with the controlling of water hyacinth.

Mahamadi (2011) found that some of the aquatic plants like water hyacinth could be used for the production of biofuels. This technology to produce biofuels can overcome both environmental pollution and the depletion of energy sources worldwide.

Dixit et al. (2011) environmentally friendly technologies have been gaining attention among the researchers worldwide. Many researchers have reported the application of phytoremediation techniques for treating different types of wastewater. Water hyacinth, water lettuce and Vetiver grass or plants that have been used for the removal of a wide range of pollutants, which includes biochemical oxygen demand, heavy metals, total suspended solids, chemical oxygen demand. The different applications of water hyacinth have been illustrated in (Figure 2.5).

Recently, only few review papers related to wastewater treatment using water hyacinth have been published.

Mahamadi (2011), Patel (2012), and Gupta et al. (2012) reviewed that the most recently studies during the past five years for the uptake and removal of organic, inorganic and heavy metal present in wastewater using water hyacinth to make it as a suitable, inexpensive, effective and environmental friendly technology for treating wastewater. The main focus of this review is to compare how water hyacinth is effective in the removal of pollutants from wastewater in comparison to other aquatic plants and to provide insight for the development and new emerging technologies of phytoremediation.

Gopal (1987) reported that many centuries water hyacinth had been applied as an ornamental crop due to its attractive appearance by humans. Water hyacinth was also introduced as the invasive and free-floating aquatic macrophyte by many botanists.

Tellez et al. (2008) reported that the water hyacinth has a member of the family Pontederiaceae, which is indigenous to Brazil. There is a lot in the Amazon basin and Ecuador region. The growth of this plant on the surface of water can reduce the penetration of sunlight into the water.

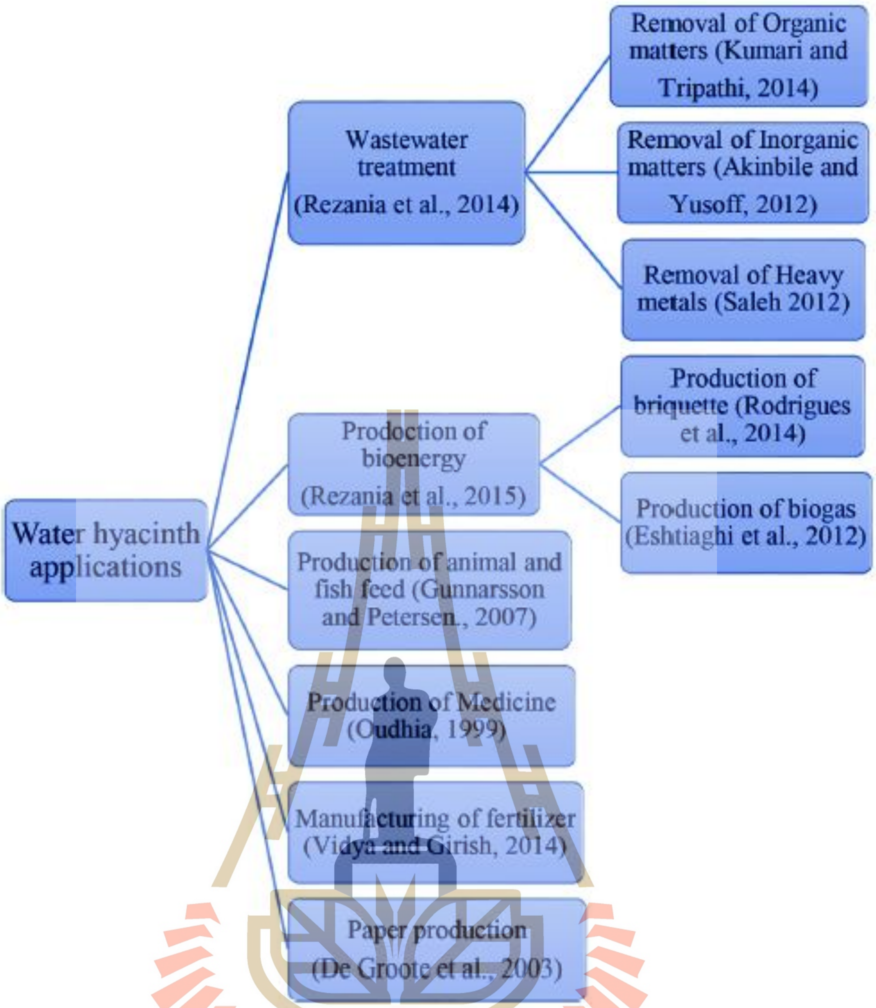


Figure 2.5 Different application of water hyacinth (Rezania et al., 2015)

Ganguly et al. (2012) described that the water hyacinth was frequently mentioned in literature as one of the most problematic plants in the world due to its uncontrollable growth in water bodies such as irrigation systems or open ponds. Water hyacinth can rapidly grow over 60 kg per each m^2 of water surface by which it can cause critical effects on sustainable development of economy.

2.3.1 Morphology and habitat

Center et al. (2002) reported that the mature water hyacinth comprises of stolons, leaves, fruit clusters, long pendant roots, leaves and rhizome. The average height of water hyacinth is 40 cm. Sometimes, it can grow up to 1 m height. Water hyacinth has 6 to 10 lily-like flowers, diameter of each one is 4 to 7 cm. Different parts of water hyacinth, such as the stems and leaves are made from air-filled tissues, which allows the plant to float on water (Figure 2.6). Water hyacinth has the ability to tolerate drought condition and can survive in the moist sediments for months.

Patel (2012) described that one of the problems to eradicate water hyacinth is because of its seed, which is known to survive up to 20 years. Although, sufficient research and efforts have been made to eradicate water hyacinth, this notorious weed continues to propagate worldwide successfully. Current geographical distribution of water hyacinth in the world is shown in (Figure 2.7).

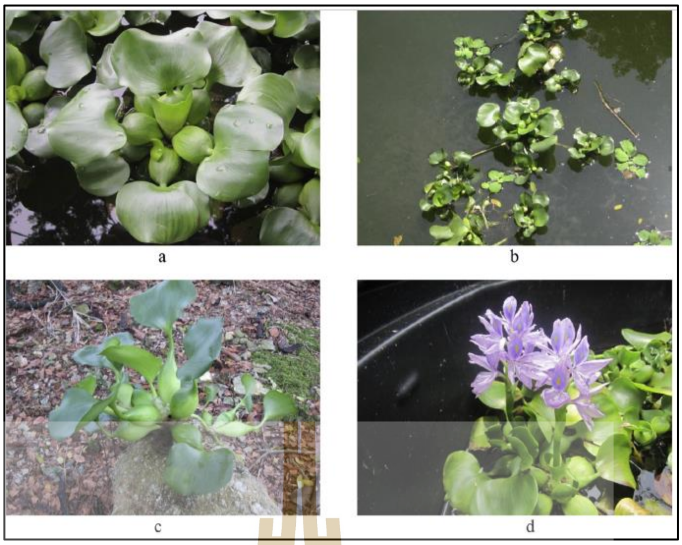


Figure 2.6 Different parts of water hyacinth. a) Leaves. b) Baby plant. c) Rhizome. d) Flower. (Rezania et al., 2015)

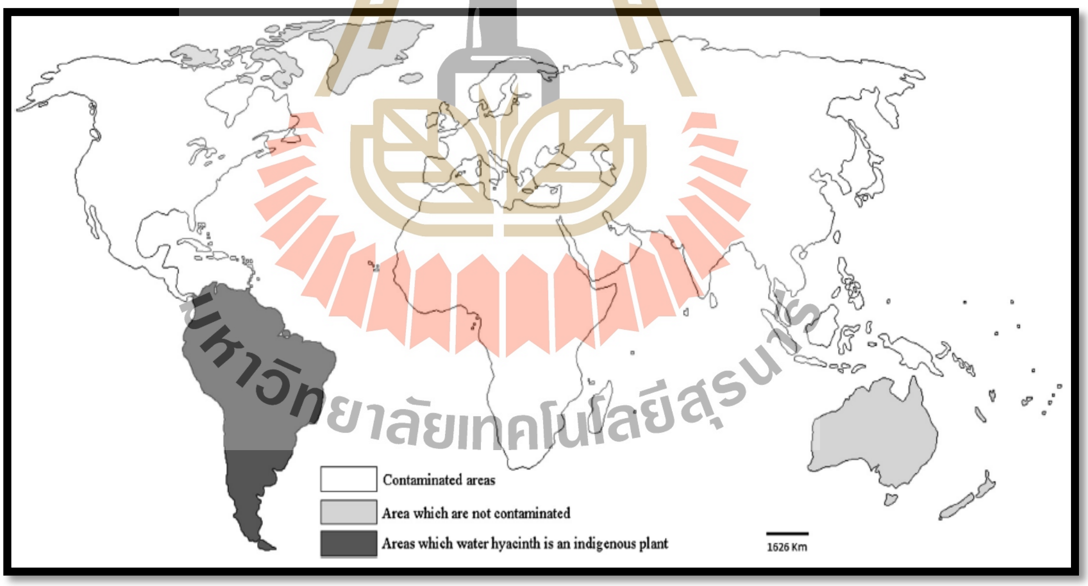


Figure 2.7 Current geographical distribution of water hyacinth in the world. (Rezania et al., 2015)

2.4 Drilling mud

Guichard et al. (2008) described the drilling mud. It was usually classified as either water base muds (WBMs) or oil base muds (OBMs), depending upon the continuous phase of the mud. However, WBMs may contain oil and OBMs may contain water. They generally use hydrocarbon oil as the main liquid component, with other materials such as clays or colloidal asphalts being added to provide the desired viscosity together with emulsifiers, polymers, and other additives including weighting agents. Water may also be present, but in an amount not usually greater than 50% by volume of the entire composition. If more than about 5% of water is present, the mud is often referred to as an invert emulsion, such as a water-in-oil emulsion. They conventionally contain viscosifiers, fluid loss control agents, weighting agents, lubricants, emulsifiers, corrosion inhibitors, salt, and pH control agents. Water makes up the continuous phase of the mud, and is usually present as at least 50 volume percent of the entire composition. Oil is also usually present in small amounts, but will typically not exceed the amount of the water, so that the mud will retain its character as a water- continuous-phase material.

Johannes (2011) described that important parameters for characterizing the properties of a drilling mud, which are viscosity, specific weight, gel strength, and filtration. The viscosity is measured by means of a Marsh funnel. The funnel is dimensioned so that the outflow time of 1 quart (926 ml) fresh water at 70°F (21°C) is 26 seconds. Viscosity is also measured with a rotational viscometer. The mud is placed between two concentric cylinders. One cylinder rotates with constant velocity, while the other is connected by springs. The torque on this cylinder results in a deviation of its position from the rest. Which may serve as a measure of viscosity. A filter press is used to determine the wall-building characteristics of a mud. This press consists of a cylindrical chamber, which is resistant to alkaline media. A filter paper is placed on the placed on the bottom of the chamber. The mud is placed into the chamber and a pressure of 0.7 MPa is applied. After 30 minutes the volume of filtrate is reported. The filter cake is inspected visually and the consistency is noted as hard, soft, tough, rubbery, or firm. Alkalinity is measured by acid-base titration, with methylorange or phenolphthalein as an indicator. Phenolphthalein changes color at pH 8.3, whereas methylorange changes color at pH 4.3. At pH 8, the neutralization of the strongly alkaline components such as NaOH is essentially complete. Further reduction of the pH to 4 will also be measured the levels of carbonates and bicarbonates that are present. Colorimetric tests and glass electrode systems are used to determine pH.

Schroeder (1987) described that the effects of temperature and various chemical additives on the rheological filtration, and chemical properties of fluids and muds under simulated circulating conditions could be elucidated in a roller over.

Johannes (2011) reported the drilling mud properties, which are developed after improvement by added additives. The bentonite is highly colloidal and swells in water to form thixotropic gels. This property results from their micaceous sheet structure. Because of these viscosity-building characteristics, bentonite is used as viscosity enhances or builders in such areas as drilling muds and fluids concrete and mortar additives foundry and molding sands and compacting agents for gravel and sand, as well as cosmetics. Most bentonites that are found in nature are in their sodium or calcium form API and Turkish Institute of Standards (TSE). Apparent viscosity of at least 15 cP is assumed to be an acceptable value which corresponds to 90 barrels per ton slurry yield.

Jarrett and Clapper (2010) described that filtration control is an important property of a drilling fluid particularly. When drilling through permeable formations, where the hydrostatic pressure exceeds the formation pressure. It is important for a drilling fluid to quickly form a filter cake to effectively minimize fluid loss but which also is thin and erodible enough to allow product to flow into wellbore during production to API and Turkish Institute of Standards (TSE) limited a fluid loss of 15 ml or less.

2.5 Drilling mud improvement

Petchote and Sikong (2005) studied the properties of drilling mud blended with dolomite powder and fly ash in order to improve the formula of drilling mud with low cost. Furthermore, the properties of dolomite and fly ash affected on the properties of drilling were also investigated such as particle size distribution, density, pH, viscosity and dispersion of drilling mud.

Xianghai et al. (2012) indicated the rheological properties of bentonite dispersion with carbon ash are improved markedly in yield point (YP), and especially for the low solid content of bentonite dispersion. The filtration and density test are also carried out using an API Filter Press and mud balancer respectively. From the results, it could be observed that the filtrate loss and filter cake thickness increase dramatically, whereas the density of bentonite dispersion decreases slightly as the addition of carbon ash increases. Furthermore, the stability of bentonite dispersion incorporated with carbon ash is evaluated. The experimental results indicate that carbon ash is better than RM in stability. Through this study, carbon ash is an excellent potential additive for improving the rheological properties of water-based drilling fluids.

2.6 Drilling mud rheology

Rheology described the drilling mud and models that used to explain fluid flow behavior. Rheology is the science of flow and deformation of matter. It describes the interrelation between force, deformation and time. The rheological model describes the flow behavior of a fluid by developing a mathematical relationship between shear stress and shear rate. In general, drilling mud rheology is described by two widely used models, namely: the Bingham plastic model and the Power law model. These two models are discussed in this study.

2.6.1 Bingham plastic model

Bingham plastic fluid that has a linear shear stress and strain rate relationship require a finite yield stress before they begin to flow. Several examples are clay suspensions, drilling mud etc. Once the yield stress has been exceeded, changes in shear stress are proportional to changes in shear rate and the constant of proportionality is called the plastic viscosity. The graphical representation of this model has shown in Figure 2.8. The plastic viscosity decreased with increased shear rate due to a phenomenon called "shear thinning".

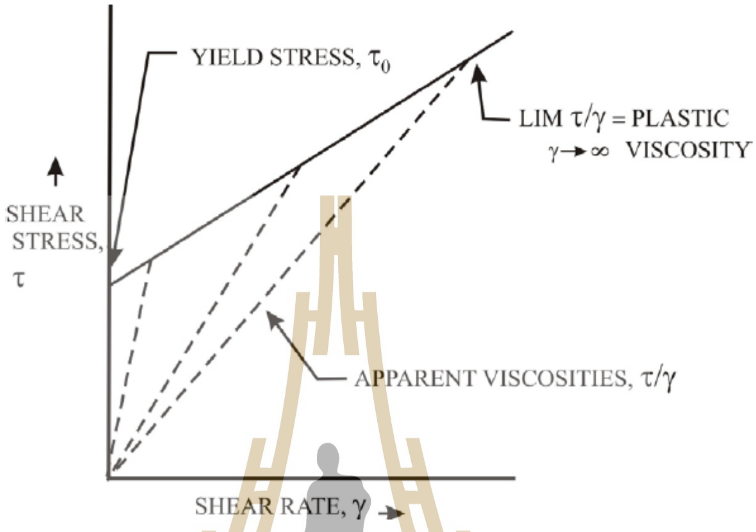


Figure 2.8 Flow curve for Bingham plastic model (after Riyapan. T., 2011)

2.6.2 Power law model

The log-log plot of shear stress versus shear rate when $n = 1$, the fluid behaves as a Newtonian fluid and the Power law equation is identical to the Newtonian fluid. For n greater than 1, the fluid is classified as dilatants. Dilatants fluids are shear rate dependent. Their apparent viscosities increase with increase in shear rate. If n is less than 1, then the fluid is referred as pseudoplastic. Pseudoplastic fluids are also shear rate dependent with their apparent viscosities decreasing as shear rate decreases. Figure 2.9 shows the graphical representation of Power law fluids.

This model also called the modified power law model and yield pseudoplastic model. The model is used to describe the flow of pseudoplastic drilling muds that require stress to initiate flow. A rheogram of shear stress minus yield stress versus shear rate is straight line on log-log coordinates. This model is widely used because it (1) describes the flow behavior of most drilling fluid, (2) includes a yield stress value that important for several hydraulic issues, and (3) includes the Bingham plastic and Power law model as special cases. The rheological parameters recorded in an API Drilling Fluid report are plastic viscosity and yield point from Bingham plastic model. These two terms can be used to calculate key parameters for other rheological models.

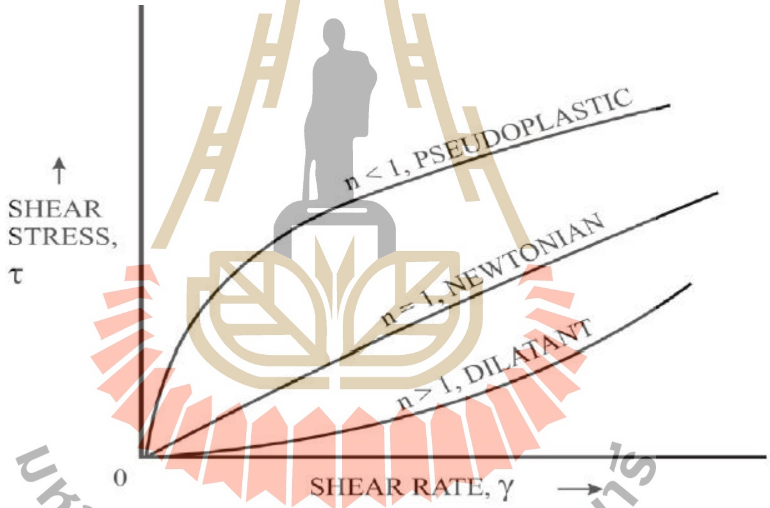


Figure 2.9 Flow curve of Power law model (after Riyapan. T., 2011)

CHAPTER III

METHODOLOGY

3.1 Introduction

The objective of this study is to investigate the physical and chemical properties of water hyacinth, sedge, drilling mud mixed with water hyacinth and sedge powders. This chapter includes the research methodology, sample collection, sample preparation, testing instruments and experimental methods. The tests divide into two groups; physical properties tests and chemical properties tests.

3.2 Research methodology

3.2.1 Literature review

A literature review was carried out to improve understanding of the drilling mud properties. It is composed of reviewing and studying water-based drilling mud powder in drilling mud, sedge and water hyacinth properties and testing procedure. The sources of information was from journals, researches, dissertation and books concerned.

3.2.2 Laboratory tests

The laboratory tests were divided into two groups; physical and chemical properties tests. The physical properties were determined under temperatures at 30, 60 and 80°C. The methods followed the relevant API standard practice.(API RP 13B-1, 1997)

3.2.2.1 Physical properties tests

The objective of physical properties are to measure rheological characteristics of drilling mud with various shear rates. The test procedures followed API standard practice (API RP 13B-1, 1997). The test performed by rotary Viscometer (Fann VG) which had geometry that gave the following expression for a fit of the data to Bingham Plastic Model (API RP 13D, 2010). The mineral crystals, components and particle morphologies analyze by Scanning electron microscope (SEM).

3.2.2.2 Chemical properties tests

The objective of chemical properties are to measure the compositions and elements of the additives by using X-ray Diffractometer (XRD) and X-ray fluorescence spectrometer (XRF), respectively.

3.2.3 Data analysis and comparisons

The research results are analyzed to optimize the drilling mud mix ratio in terms of the physical and chemical properties. The results from analysis of sedge, water hyacinth and drilling mud with mixing will be compared between before and after of additives.

3.2.4 Discussions and conclusions

The laboratory results of measurements in terms of plastic viscosity, yield point, gel strength, filtrate volume, mud cake thickness and pH, are compared with those results from water-based mud and water-based mud mixing additives. Similarity and discrepancy of results have been discussed. The effect of temperature on drilling mud properties was described and the feasibility of using water-based mud mixing additives in onshore and offshore well in Thailand was also considered.

3.2.5 Thesis writing

The research methodology comprised five steps as shown in Figure 3.1, including literature review, sample collection and preparation, laboratory tests (physical and chemical property's testing), gathering the result of discussions, conclusions, and thesis writing. Each step is described as follows:

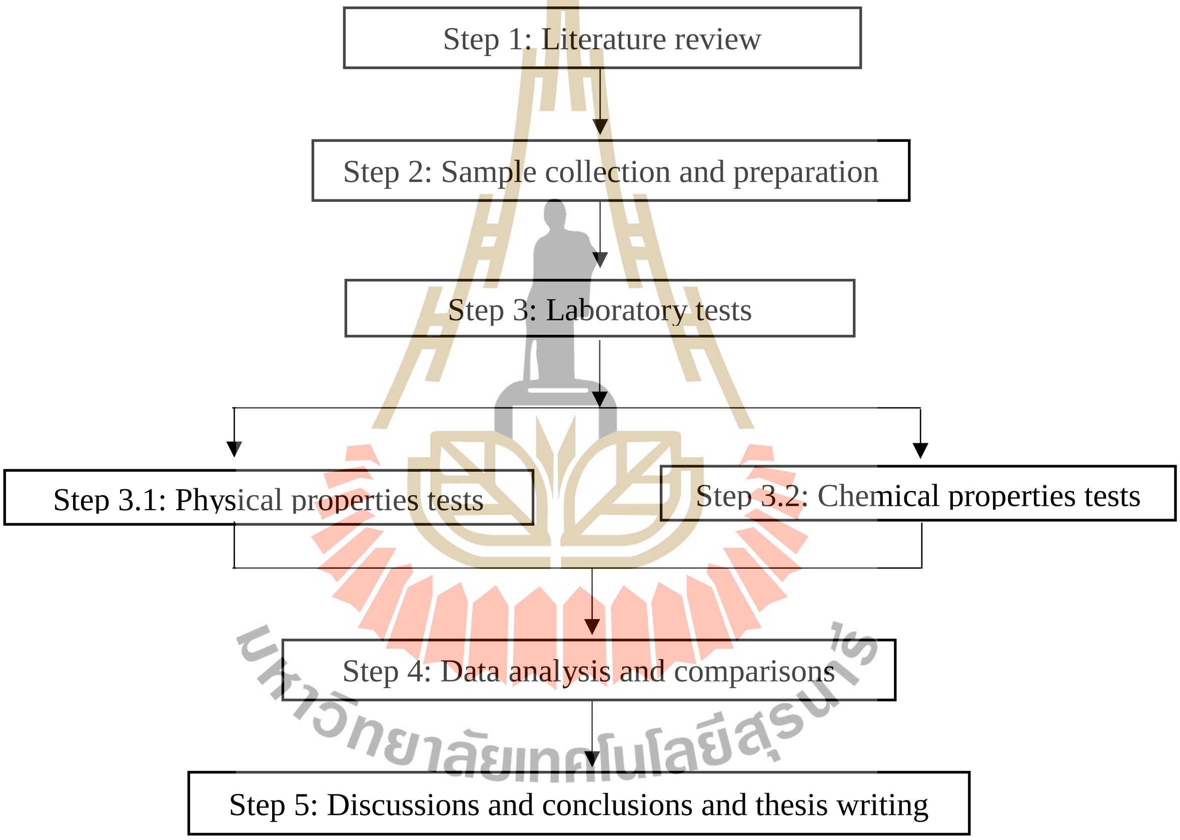


Figure 3.1 Research methodology.

3.3 Sample collection

The water hyacinth and sedge are from country at Nakhon Ratchasima province. Bentonite is supported from Thai Nippon Chemical Industry Co., Ltd. Barite was assisted from Weatherford International Thailand Company.

3.4 Sample preparation

The water hyacinth and sedge are prepared and tested at laboratory of Suranaree University of Technology. These additives divide into two parts for chemical property's tests by sieving size less than 75 micrometers (mesh No.200) before stored in zip lock bags for X-ray diffraction (XRD) and X-ray fluorescence (XRF) tests, respectively. Physical properties were determined by mixing with water-based drilling mud.

A water-based drilling mud suspension prepares to use 60 grams of bentonite per 1,000 grams of water and 100 grams of barite per 1,000 grams of water was added to control density.

3.5 Typical well drilling

The range of drilling mud density for typical well drilling are 1.5 to 8.5 percentages bentonite weight by volume. Mud weight varied around 8.85 to 18 pounds per gallon depends on graded bentonite and drilled formations (MI-Swaco, 1998). Figure 3.1 demonstrates the composition and nature of common drilling muds. The curves show the increasing of viscosity with percentage of bentonite solids.

Since the grade of bentonite clay that uses in the experiment are not Wyoming grade. It is necessary to find the appropriate amount of bentonite that meets the viscosity required for typical well drilling. Table 3.1 shows the bentonite water-based suspension at 2, 4, 6, and 8 percentages bentonite weight by volume meet a minimum required viscosity for typical well drilling. Therefore, the experiment has been selected 6 percentages of bentonite weight by weight as a base composition.

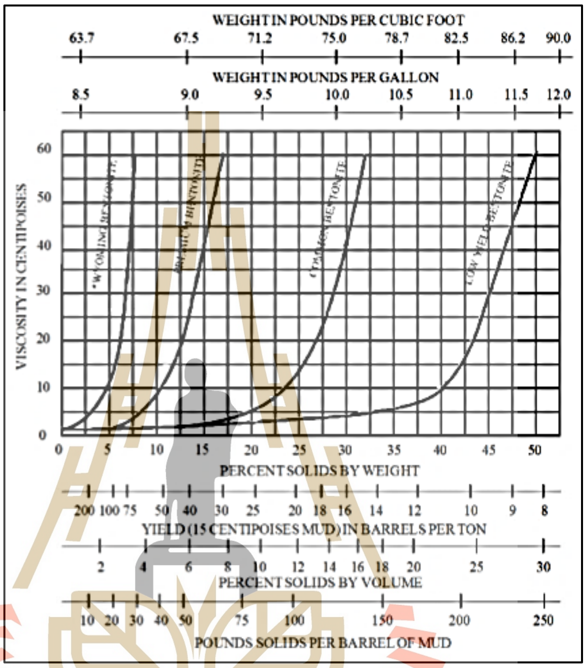


Figure 3.2 Yield curve for typical clays (modified from Gatlin, 1960).

Table 3.1 Bentonite water-based suspension.

Bentonite (%weight by volume)	Average apparent viscosity (cP)
2	6.0
4	12.5
6	21.5
8	39.0

A water-based bentonite suspension was prepared using 60 grams of bentonite per 1,000 grams of water and 100 grams of barite added to control density. The mud components are mixed for 15 minutes using a high-speed mixture. During mixing, the water hyacinth and sedge was slowly to agitated base fluid to avoid a lump occurring within the mud system. The testing mud samples are weighted of 1.10 grams per cubic-centimeter (9.20 pound per gallon) containing 6 percentages bentonite weight by volume as a based composition. The mud weights are measured by mud balance that is an API standard instrument for testing mud weight (Figure 3.2). Various concentrations of water hyacinth and sedge and the other additives are added to perform as a mud additive. These systems are prepared to compare the properties of the mud. The formulations of the mud are shown in Table 3.2 and Table 3.3.

Table 3.2 Compositions of drilling mud mixed with water hyacinth samples**.**

Composition of mud	**Bentonite mud**	**Bentonite +1%wh. mud**	**Bentonite +3%wh. mud**	**Bentonite +5%wh. mud**
Water (g)	1,000	1,000	1,000	1,000
Barite (g)	100	100	100	100
Bentonite (g)	60	60	60	60
Water hyacinth (g)	-	11.6	34.8	58.0

Table 3.3 Compositions of drilling mud mixed with sedge sample.

Composition of mud	**Bentonite mud**	**Bentonite +1%sd. mud**	**Bentonite +3%sd. mud**	**Bentonite +5%sd. mud**
Water (g)	1,000	1,000	1,000	1,000
Barite (g)	100	100	100	100
Bentonite (g)	60	60	60	60
Sedge (g)	-	11.6	34.8	58.0

Figure 3.3 Mud balance.

3.6 Chemical properties tests

The objective of chemical property testing is to determine the mineral crystals and components of samples by using X-ray fluorescence spectrometer (XRF) and X-ray diffractrometer (XRD). Sample preparations are sieved by the mesh No. 200 (0.075 mm) and was dried at 60 °C in the oven for 24 hours per sample.

3.6.1 X-ray fluorescence

Samples are prepared to use 0.5 to 1.0 gram. Samples are compacted and spread out to the holder. Sample holders are analyzed by X-ray fluorescence spectrometer (XRF), Holiba-XGT 5200 (Figure 3.4) and spent time to 200 seconds per sample. A typical X-ray generator passes an electric current through a filament, which cases an electron to be emitted. These electrons are then accelerated by high voltage (usually somewhere between 20 and 100 kV) towards an anode (target).

Results are analyzed in the spectrum, including Rayleigh and Compton scattered characteristic line from the X-ray generator, peak caused by X-ray diffraction, and sum/escape peak. A quantitative technique, the peak height of any element is directly related to the concentration of that element within the sampling volume. The XRF results are presented as the percentage of major elements.

Figure 3.4 Horiba (XGT-5200) X-ray fluorescence.

3.6.2 X-ray diffraction

Amount of 1.0 to 1.5 grams of samples are compacted and spread out to holder. Sample holder is analyzed by X-ray diffractrometer (XRD), Bruker-D2 Phaser (Figure 3.5) and spent time 15 minutes per sample. XRD performed on polycrystalline material, the incident X-ray beam is diffracted by innumerous crystallites in specific 2 Theta directions. Data is recorded the exact 2 Theta positions a narrow slit in front of a point detector is required. Conditions of analysis include a Cu standard ceramic sealed tube (0.4x12 mm), X-ray generation (30 kV, 10mA), angular range analysis (2^{0}, 5° to 80°) and accuracy. Results are calculated relative intensity, divide the absolute intensity of every peak by the absolute intensity of the most intense peak, and then convert to a percentage.

Figure 3.5 Bruker (D2 Phaser) X-ray diffractrometer.

3.7 Physical properties tests

The physical properties studied have include of density, rheology, filtration, hydrogen ion, resistivity, solid content and sand content. They are determined following API standard.

3.7.1 Rheological tests

In order to fully comprehend the rheology calculation, it is appropriate to discuss some basic drilling fluid flow properties, determination of rheological parameters which describe the flow behavior of a fluid.

Apparent viscosity is a rheological property calculated from rheometer readings. It measures the shear rate of drilling fluid specified by API. Apparent viscosity is expressed in centipoises (cP), it indicates the amount of force required to move one layer of fluid in relation to another. The apparent viscosity can calculate from equation 3.1.

Plastic viscosity is the shearing stress in excess of yield point that induce a unit rate of shear. It is that part of flow resistance caused by mechanical friction, which occurs: (1) between the solids in the mud, (2) between the solids and the liquid that surrounds them, and (3) with the shear of the liquid itself. Therefore, all practical viscosities can be calculated from equation 3.2 and its range value that used in well drilling is shown in Figure 3.5.

Yield point is the second component of resistance to flow in drilling fluid. It is a measurement of electro-chemical or attractive forces in a fluid underflow condition. These forces are a result of negative charges located on or near the particle surfaces and are dependent on: (1) the surface properties of mud solids, (2) volume concentration of solids, and (3) the electro-chemical environment of ions. The yield point could be regulated by the use of chemical additives. Therefore, it dictates the nature and degree of treatment necessary to maintain a desirable fluid viscosity. The yield point value can be calculated from equation 3.3 and its range value that used in drilling well is shown in Figure 3.5.

Gel strength is a measurement of the thixotropic properties of drilling fluid under static condition. Similar to the yield point, gel strength is a measure of the electro-chemical attractive forces between solid particles. Yield point and gel strength are the result of the flocculation forces of a thixotropic fluid. Gel strength is measured by rotational speed of 3 rpm. The drilling fluid is allowed to stand undisturbed for 10 seconds and 10 minutes that are referred to initial gel strengths and 10 minutes gel strength respectively, at which time of an outer cup is rotated at 3 rpm and the maximum deflection of the dial is recorded. The gel strength results are reported in lb/100ft.

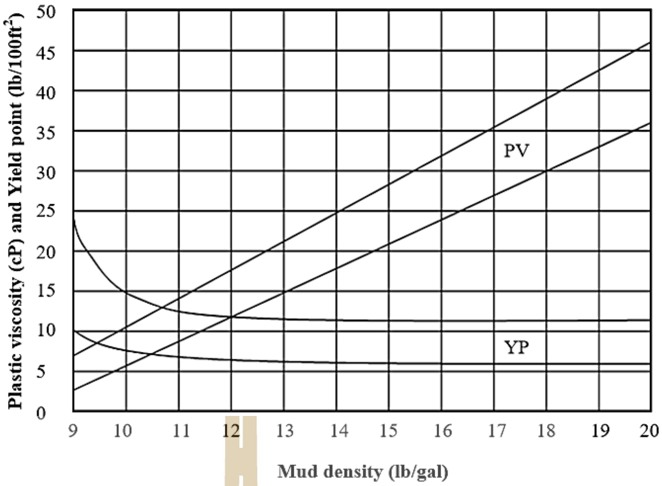


Figure 3.6 Plastic viscosity and yield point ranges for water-based mud (modified from MI-Swaco, 1998)

Drilling mud is tested for the rheological properties at 30, 60 and 80 °C. The Rheology testing is carried out by a Fann 35SA model Viscometer (Figure 3.6) and measured by using six rotational speeds (3, 6, 100, 200, 300 and 600 rpm) for the viscosity, yield point and gel strength that relate to flowing properties of drilling mud.

Figure 3.7 Fann (35SA.115 Volt) Viscometer.

The apparent viscosity, plastic viscosity and yield point are calculated from 300 and 600 rpm reading following formulas from API standard.

$\mu_a = \varphi600/2$ (3.1)

$\mu_p = \varphi600/\ \varphi300$ (3.2)

$\Upsilon_p = \varphi300/\ \mu_p$ (3.3)

where μ_a = apparent viscosity (cP), μ_p = plastic viscosity (cP), and Υ_p = Yield point (lbf/100 ft^2)

It is the rotational coaxial cylinder type used to measure the viscosity of the drilling mud. The shear stress is determined as a function of the shear rate. The drilling mud is calculated by the shear rate and shear stress relationships. The equations are as follows:

$\tau = 0.01066\phi_i N$ (3.4)

$\gamma = 1.703\rho\pi\mu$ (3.5)

where τ = shear stress (lb_f/ft^2), γ = shear rate (sec_{-1}), ϕ_i = viscometer dial reading, N = range extension factor of the torque spring of the VG meter, rpm = rotational speed.

The power law model parameters in the term of behavior index (*n*) and consistency (*k*) are calculated from viscometer reading using following equations.

$n = 3.322\log(\varphi_{600}/\ \varphi_{300})$ (3.6)

$k = 510\ \varphi_{300}/511_{n}$ (3.7)

where, n = flow behavior index, k = fluid consistency index, φ_{600} = viscosity dial reading at 600 rpm, φ_{300} = viscosity dial reading at 300 rpm.

3.7.2 Static filtration tests

Filtration is tested by using Fann filter press (Figure 3.7) which determines the API filtrate loss through standard filter paper and the filter cake thickness under static conditions. It consists of fluid cup support by a frame, a filtering medium and a pressurized nitrogen gas cylinder and regulator. A graduated cylinder is used to measure the discharged filtrate. The 100 psig is applied to a column of fluid for the 30 minutes period, which filtrate volume and filter cake thickness are measured and recorded.

Figure 3.8 Fann (series 300) filter press.

3.7.3 Hydrogen ion tests

The hydrogen ion (pH) measurements of the fluids are conducted by using the glass electrode pH meter (OAKTON pH 700 model) (Figure 3.8). The instrument determines the pH of an aqueous solution by measuring the electropotential generated between a glass electrode and a reference electrode. Measurement and adjustments of pH are fundament of drilling fluid control. Clay interactions, solubility of various components and effectiveness of additives are all dependent on pH, as in the control of acidic and sulfide corrosion processes.

Figure 3.9 OAKTON (pH 700 model) pH meter.

3.7.4 Resistivity tests

The drilling mud, filtrate and mud cakes are measured by the Fann 88C model resistivity meter (Figure 3.9). The resistivity meter provides a direct digital reading of resistivity in three ranges, including 2, 20, and 200 Ω/m^2 The direct measurement of the sample's resistivity and temperature is in the transparent cell. Instrument calibration is used salt solution and calculated the correction factor for accurate data.

Figure 3.10 Fann (88C model) resistivity meter.

3.7.5 Solid content tests

Fann oil and water retort kit (Figure 3.11) are used for determining the account of water and solid defined as the percentage by volume in the drilling mud The excessive sand makes a filter cake thickness with increasing due to abrasive wearof the pump parts, the bit and pipe and may settle when circulation stopped andinterfered with the pipe move-mentor the setting of the casing.

Figure 3.11 Fann retort kit

3.7.6 Scanning Electron Microscope

Scanning electron microscope (SEM), JEOL JSM-6010LV (Figure 3.12) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the sample's surface topography and composition. The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 nanometer. Specimens can be observed in a high vacuum, in low vacuum, in wet conditions (in environmental SEM), and at a wide range of cryogenic or elevated temperatures.

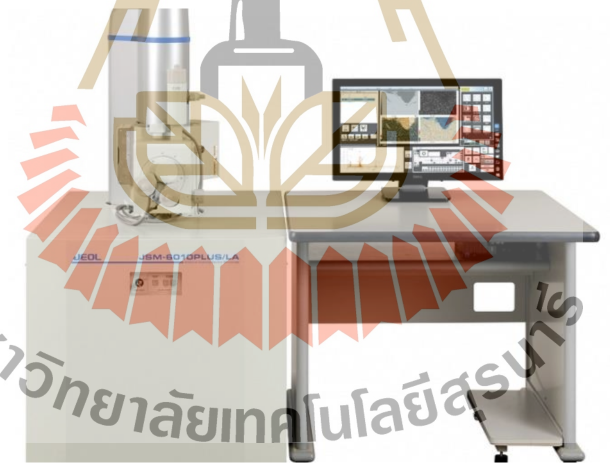


Figure 3.12 JEOL JSM-6010LV Scanning Electron Microscope.

CHAPTER IV

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter describes the data analysis and results of laboratory experiments used to determinate their chemical, physical, rheological properties and the cost of new invented mud are compared with a common mud system that used in well drilling. The results of the experiment and analysis are displayed below.

4.2 Chemical properties

The objectives of these tests are to determine the elements and minerals of drilling mud both before and after mixed with additives. The step of methods is the rheological and physical properties. These results lead to the determination that the most suitable mixing ratios and temperature of drilling mud mixed with additives.

4.2.1 Chemical properties before mixing of drilling mud.

The elements are determined by an X-ray fluorescence spectrometer. The minerals are measured by an X-ray diffractometer. Tables 4.1 and 4.2 show the major elements and minerals of materials before mixing.

Table 4.1 Major elemental composition of varying materials using X-ray fluorescence.

Major element	Materials (weight %)			
	Barite	Drilling mud	Water hyacinth	Sedge
SiO_2	38.339	50.527	9.016	24.942
SO_3	54.869	23.073	-	-
K_2O	0.536	0.56	33.282	31.853
CaO	0.201	2.752	31.425	13.8
Fe_2O_3	2.832	4.796	0.922	0.139
SrO	0.497	0.343	-	-
ZrO_2	0.019	-	-	-
BaO	2.631	2.073	0.146	-
OsO_4	0.048	-	-	-
Au_2O_3	0.019	-	-	-
Bi_2O_3	0.009	-	-	-
MgO	-	3.915	5.984	0.644
Al_2O_3	-	11.694	-	-
Rh_2O_3	-	0.267	0.575	0.353
Cl	-	-	15.716	27.435
MnO_2	-	-	2.742	0.324
PdO	-	-	0.192	0.115
TiO_2	-	-	-	0.386
Total	**100**	**100**	**100**	**100**

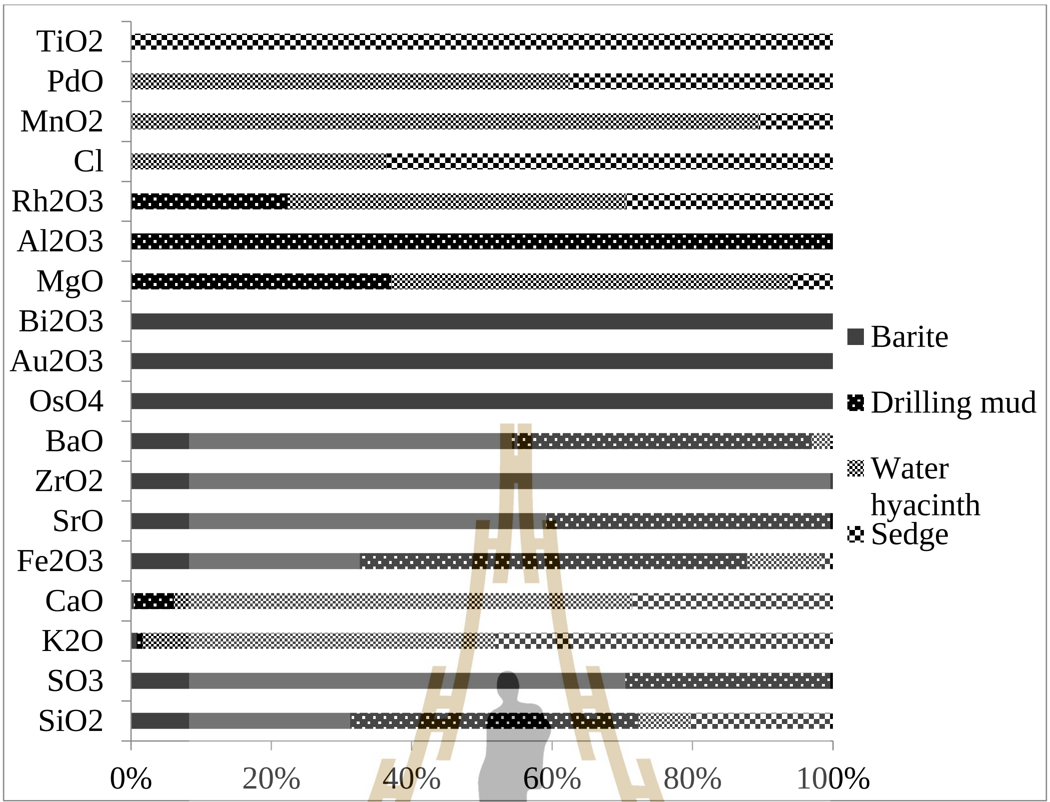


Figure 4.1 Major elemental compositions of varying materials using X-ray fluorescence

Table 4.2 Mineral contents of varying materials using X-ray diffraction.

Mineral	Samples (weight %)			
	Barite	Drilling Mud	Water hyacinth	Sedge
Quartz	12.35	25.8	12.3	1.150
Kaolinite	3.35	14.18	21.97	94.799
Hematite	0.15	0.79	-	-
Gypsum	-	0.95	3.67	3.117
Anhydrite	-	-	-	-
Calcite	0.16	6.44	-	-
Barite	82.32	51.84	60.32	0.934
Magnesite	1.67	-	1.74	-
Total	**100**	**100**	**100**	**100**

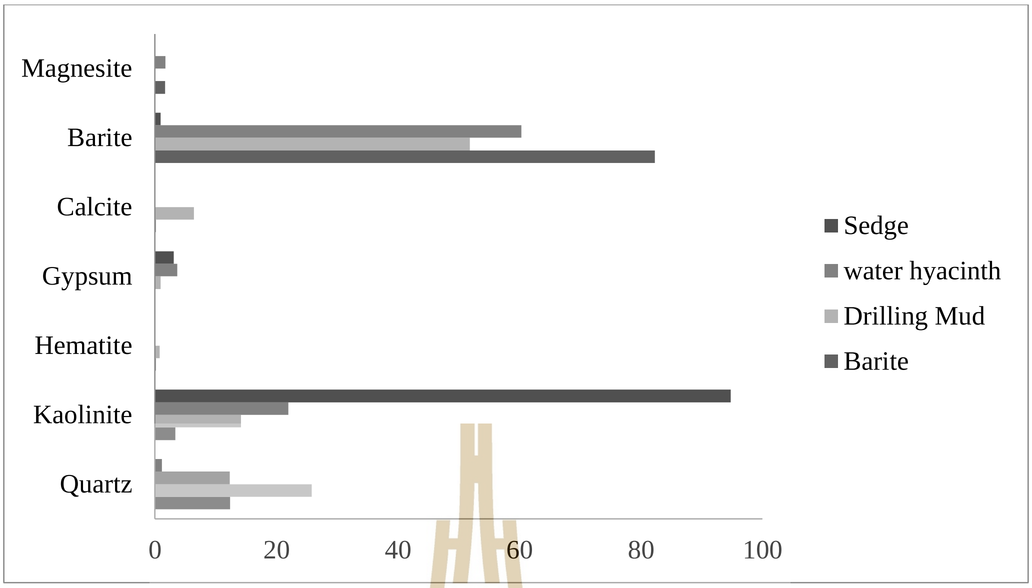


Figure 4.2 Mineral contents of varying materials using X-ray diffraction.

4.2.2 Chemical properties after mixing of drilling mud.

Drilling mud mixed with additives by varied mixing ratios and temperatures are measured by the X-ray fluorescence and X-ray diffraction to determine the compositions of the element and mineral. Tables 4.3 and 4.4 show the X-ray fluorescence and X-ray diffraction of drilling mud mixed with various additives.

Tables 4.3 Major elemental composition of drilling mud mixed with additives by varies mixing ratio and temperature are measured by the X-ray fluorescence.

Samples	Major element (weight %)											
	MgO	**Al_2O_3**	**SiO_2**	**SO_3**	**K_2O**	**CaO**	**Fe_2O_3**	**ZnO**	**SrO**	**Rh_2O_3**	**BaO**	**Total**
Base 30 °C	3.915	11.694	50.527	23.073	0.561	2.752	4.796	-	0.343	0.267	2.073	100
Base 60 °C	4.651	15.578	65.999	-	-	3.740	5.951	-	0.457	0.370	3.253	100
Base 80 °C	5.249	14.992	67.560	-	0.514	3.064	5.931	-	0.370	0.292	2.029	100
Hyacinth 1% 30°C	3.132	11.889	50.048	24.553	-	1.076	5.365	0.006	0.355	0.314	3.263	100
Hyacinth 3% 30°C	2.925	11.443	49.595	20.475	-	1.917	7.007	0.014	0.481	0.468	5.676	100
Hyacinth 5% 30°C	4.607	11.090	48.328	17.438	2.031	2.860	7.971	0.015	0.518	-	5.142	100
Hyacinth 1% 60°C	3.758	11.913	49.230	23.212	-	1.104	6.249	0.01	0.407	-	4.028	100
Hyacinth 3% 60°C	4.452	11.087	51.00	19.093	1.336	1.953	6.449	0.011	0.397	0.384	3.793	100
Hyacinth 5% 60°C	5.364	13.644	59.624	-	-	2.743	10.048	0.018	0.693	-	7.734	100
Hyacinth 1% 80°C	3.948	11.621	47.954	22.089	-	1.100	6.848	0.049	0.415	0.408	5.567	100
Hyacinth 3% 80°C	5.693	11.018	49.828	19.816	1.164	1.920	5.639	0.010	0.453	-	4.460	100
Hyacinth 5% 80°C	5.023	14.308	61.132	-	-	3.274	9.745	0.026	0.622	-	5.808	100

Tables 4.3 Major elemental composition of Drilling mud mixed with additives by varies mixing ratio and temperature are measured by the X-ray fluorescence (continued).

Samples	Major element (weight %)										
	MgO	**Al_2O_3**	**SiO_2**	**SO_3**	**K_2O**	**CaO**	**Fe_2O_3**	**ZnO**	**SrO**	**Rh_2O_3**	**BaO**	**Total**
Sedge 1% 30°C	3.132	11.889	50.048	24.553	-	1.076	5.365	0.006	0.355	0.314	3.263	100
Sedge 3% 30°C	3.827	11.676	49.215	20.975	1.149	1.339	6.487	0.009	0.427	0.405	4.451	100
Sedge 5% 30°C	-	15.587	63.483	-	1.779	1.603	8.036	0.011	0.632	0.635	8.235	100
Sedge 1% 60°C	-	13.032	48.441	21.420	-	1.265	6.754	0.010	0.545	-	8.502	100
Sedge 3% 60°C	4.691	11.267	48.405	18.702	0.941	1.367	6.079	0.009	0.526	0.539	7.473	100
Sedge 5% 60°C	-	12.678	51.515	19.143	1.536	1.704	6.968	0.009	0.499	0.495	5.404	100
Sedge 1% 80°C	3.869	11.953	48.226	21.479	-	1.049	5.922	0.007	0.472	0.492	6.498	100
Sedge 3% 80°C	-	12.351	47.688	19.839	0.839	1.221	6.469	-	0.564	0.591	10.439	100
Sedge 5% 80°C	-	13.530	51.753	19.427	1.763	1.761	7.596	0.011	0.437	0.403	3.318	100

Tables 4.4 Drilling mud mixed with additives by varies mixing ratio and temperature are measured by the X-ray fluorescence and X-ray diffraction.

Samples	Major element (weight %)							
	Quartz	Kaolinte	Hematite	Gypsum	Calcite	Barite	Magnesite	Total
Base 30 °C	25.8	14.18	0.79	0.95	6.44	51.84	-	100
Base 60 °C	20.08	18.03	0.7	1.74	1.72	57.73	-	100
Base 80 °C	18.59	18.7	0.94	0.93	6.14	54.7	-	100
Hyacinth 1% 30°C	5.18	26.61	0.47	1.57	0.41	63.51	2.25	100
Hyacinth 3% 30°C	8.05	28.48	0.51	0.88	-	62.08	0.88	100
Hyacinth 5% 30°C	4.25	28.61	0.11	1.76	0.27	64.1	0.9	100
Hyacinth 1% 60°C	5.99	22.6	0.45	0.97	0.35	67.27	2.37	100
Hyacinth 3% 60°C	7.63	20	-	1.49	0.22	68.11	2.55	100
Hyacinth 5% 60°C	12.3	21.97	-	3.67	-	59.32	2.74	100
Hyacinth 1% 80°C	8.29	21.12	0.09	1.04	0.01	66.01	3.44	100
Hyacinth 3% 80°C	8.11	20.28	-	1.13	0.84	67.7	1.94	100
Hyacinth 5% 80°C	5.16	25.34	-	1.56	0.27	67.67	-	100
Sedge 1% 30°C	9.45	28.65	0.57	0.57	0.35	57.83	2.58	100

Tables 4.4 Drilling mud mixed with additives by varies mixing ratio and temperature are measured by the X-ray fluorescence and X-ray diffraction (continued).

Samples	Major element (weight %)							
	Quartz	Kaolinte	Hematite	Gypsum	Calcite	Barite	Magnesite	Total
Sedge 3% 30°C	10.24	35.43	0.39	0.01	0.18	53.75	-	100
Sedge 5% 30°C	8.01	37.73	0.07	0.99	0.34	52.04	0.82	100
Sedge 1% 60°C	9.99	22.23	0.62	1.52	0.77	64.82	0.05	100
Sedge 3% 60°C	13.98	18.26	1.08	1.28	1.42	59.93	4.06	100
Sedge 5% 60°C	9.39	29.46	0.23	0.46	0.48	56.86	3.13	100
Sedge 1% 80°C	16.66	23.12	0.46	0.65	0.01	59.07	0.03	100
Sedge 3% 80°C	4.54	22.02	0.45	3.14	0.02	67.07	2.76	100
Sedge 5% 80°C	15.97	24.61	0.92	-	-	57.1	1.4	100

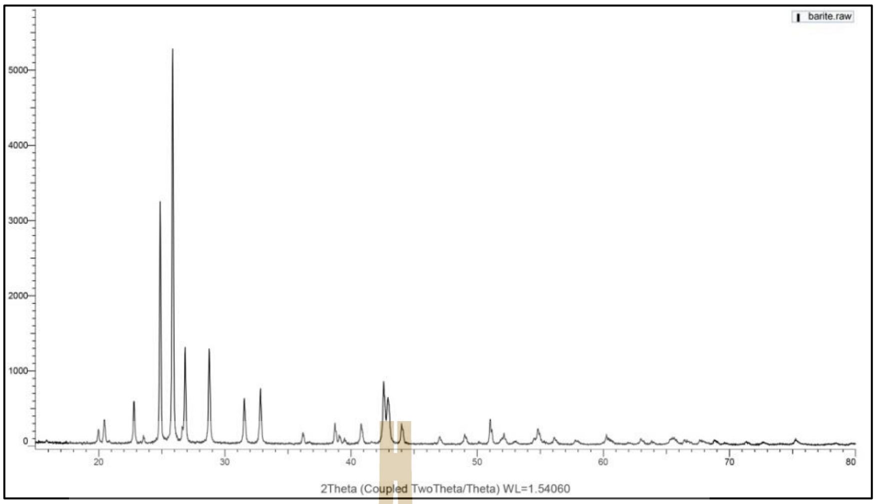


Figure 4.3 XRD of barite

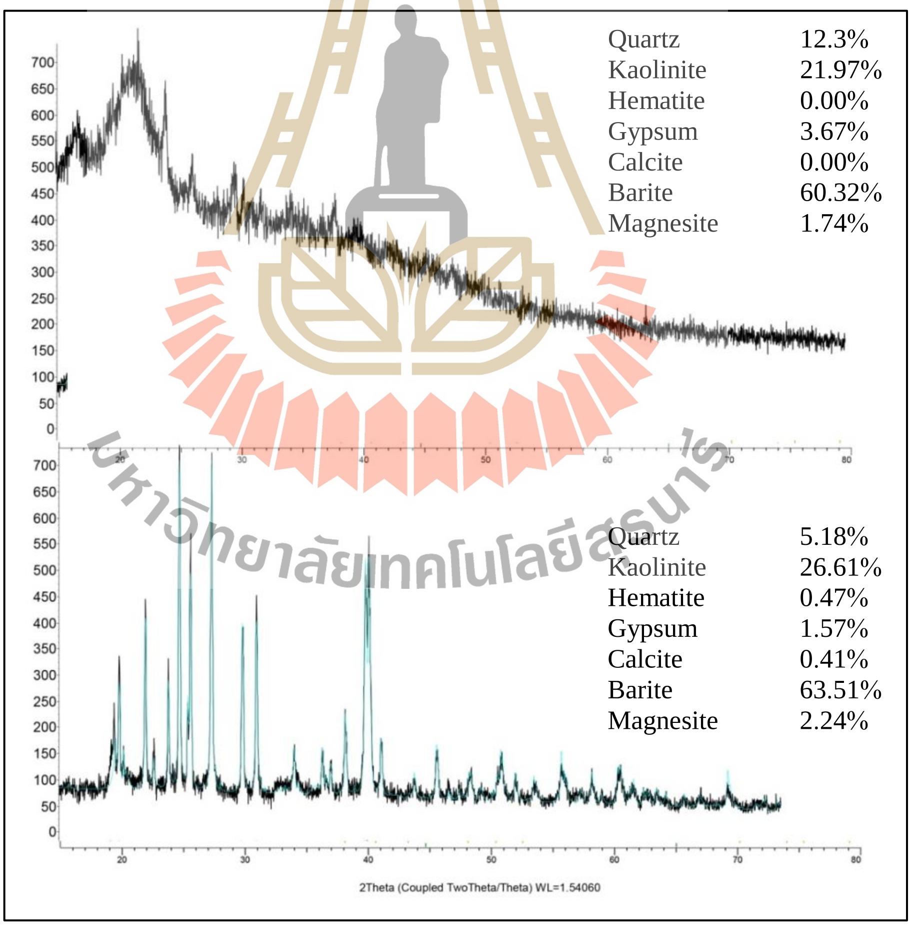


Figure 4.4 XRD of water hyacinth and drilling mud mixed with 1% of water hyacinth at 30°C.

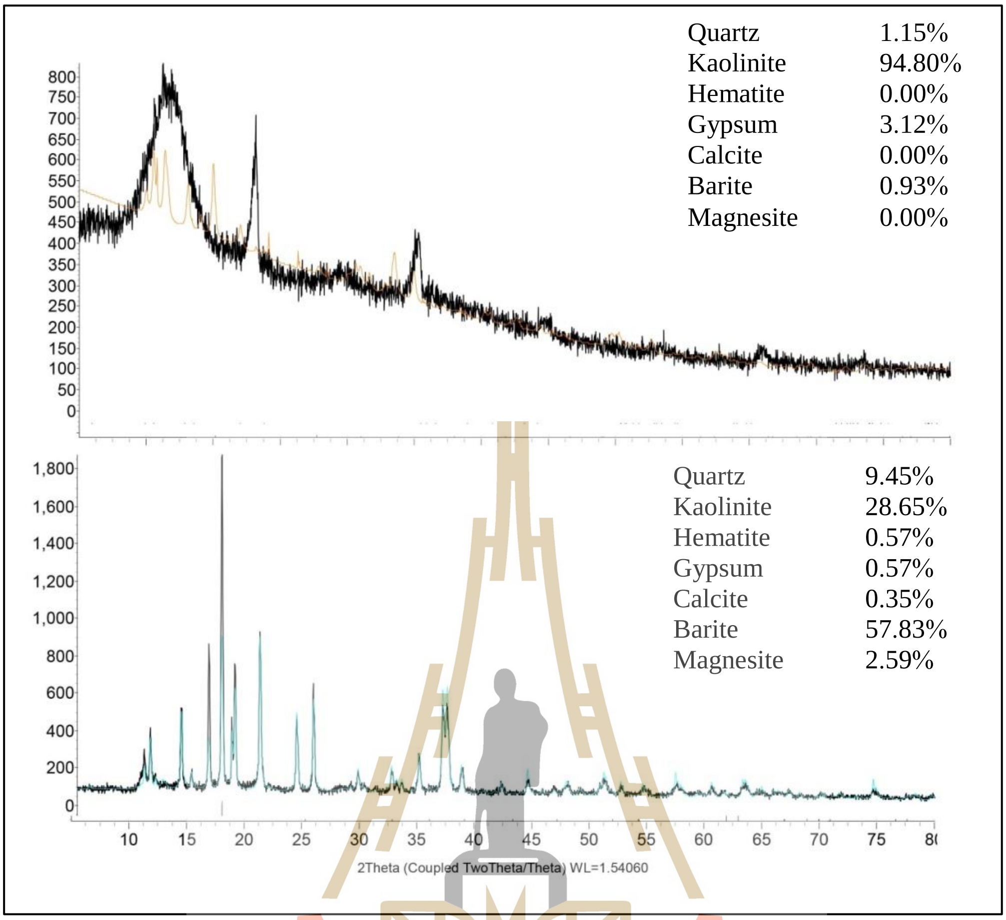


Figure 4.5 XRD of Pure sedge and drilling mud mixed with 1% of sedge at 30°C.

4.3 Physical properties

The varied compositions of drilling mud mixed with additives Table 4.5. Base-composition consists of 1,000 grams of water, 100 grams of barite, and 60 grams of bentonite. Additives include a water hyacinth and sedge powders.

Table 4.5 Compositions of drilling mud mixed with additives.

No.	**Temperature (^oC)**	**Base**	**Water hyacinth (%)**	**Sedge (%)**
1	30	100 g of barite and 60 g of bentonite	-	-
2	60	100 g of barite and 60 g of bentonite	-	-
3	80	100 g of barite and 60 g of bentonite	-	-
4	30	100 g of barite and 60 g of bentonite	1	-
5	30	100 g of barite and 60 g of bentonite	3	-
6	30	100 g of barite and 60 g of bentonite	5	-
7	60	100 g of barite and 60 g of bentonite	1	-
8	60	100 g of barite and 60 g of bentonite	3	-
9	60	100 g of barite and 60 g of bentonite	5	-
10	80	100 g of barite and 60 g of bentonite	1	-
11	80	100 g of barite and 60 g of bentonite	3	-
12	80	100 g of barite and 60 g of bentonite	5	-
13	30	100 g of barite and 60 g of bentonite	-	1
14	30	100 g of barite and 60 g of bentonite	-	3
15	30	100 g of barite and 60 g of bentonite	-	5
16	60	100 g of barite and 60 g of bentonite	-	1
17	60	100 g of barite and 60 g of bentonite	-	3
18	60	100 g of barite and 60 g of bentonite	-	5
19	80	100 g of barite and 60 g of bentonite	-	1
20	80	100 g of barite and 60 g of bentonite	-	3

4.3.1 Rheological properties and parameters.

The shear stress and shear rate values for all six viscometer readings of water-based drilling mud are shown in Table 4.6. The average viscometer reading is used to calculate the shear stress and shear rates by following equations (3.4) and (3.5) in previous chapter. The calculated shear stresses are plotted against shear rates in order to choose the best-fit curve for Bingham Plastic model or Power-law models, which they were fitted with a linear correction representing in Figure 4.6 and the Power Law fluid show the flow behavior in line with the power trend line in Figure 4.7.

The result of a graph can be inferred that the fluid tends to be a Bingham Plastic fluid more than Power-law showing the consistency plots for based bentonite mud under 30^{o}C.

Table 4.6 Shear stress and shear rates resulted from the base-bentonite mud calculation

RPM	Average reading	τ	γ
600	30	0.064565217	1021.8
300	21.25	0.045855263	510.9
200	18	0.039176471	340.6
100	14.25	0.030798387	170.3
6	10.5	0.022810345	10.218
3	8.75	0.01875	5.109

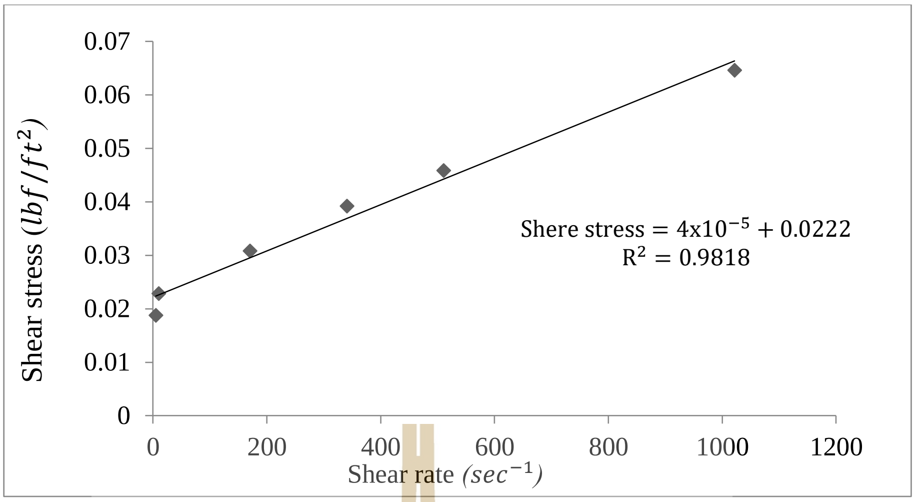


Figure 4.6 Consistency plot of base bentonite mud with a linear correlation.

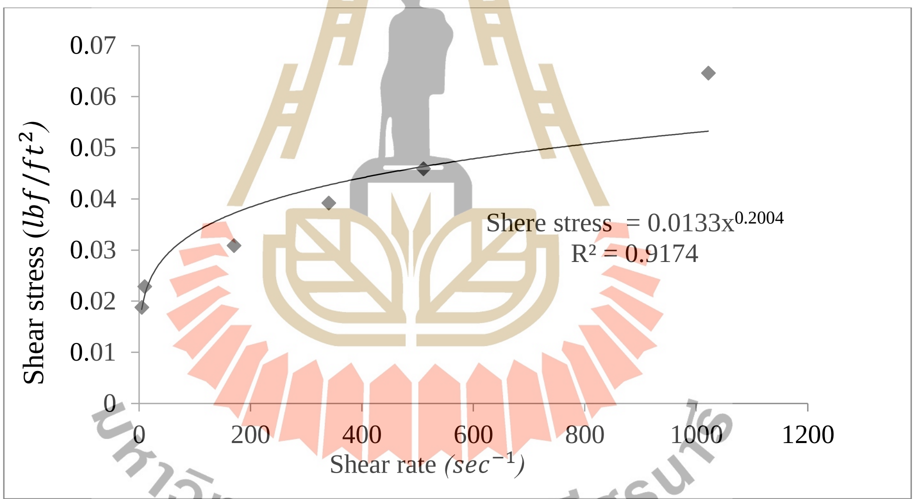


Figure 4.7 Consistency plot of base bentonite mud with a power correlation.

The Bingham Plastic model demonstrates the appropriate rheological model for other drilling mud samples. The water-based drilling mud samples are categorized into ten different groups of testing temperature (30, 60 and 80°C) and mixing ratios. Their consistency curves are plotted in Figures 4.8 to 4.13. For all tested temperatures, the results indicate that a significant increase viscosity as the water hyacinth and sedge concentration increase. Elevation of temperature reduce the viscosity of mud mixing with water hyacinth and sedge. The drilling mud mixed with the water hyacinth and sedge increases gradually as the addition of water hyacinth and enlarge, which illustrate that the drilling mud mixed with water hyacinth and sedge has the better flowability and can prevent the borehole problem such as surge, swab pressure, differential stick and slow rate of penetration, nevertheless, the effect of temperatures are increased with viscosity.

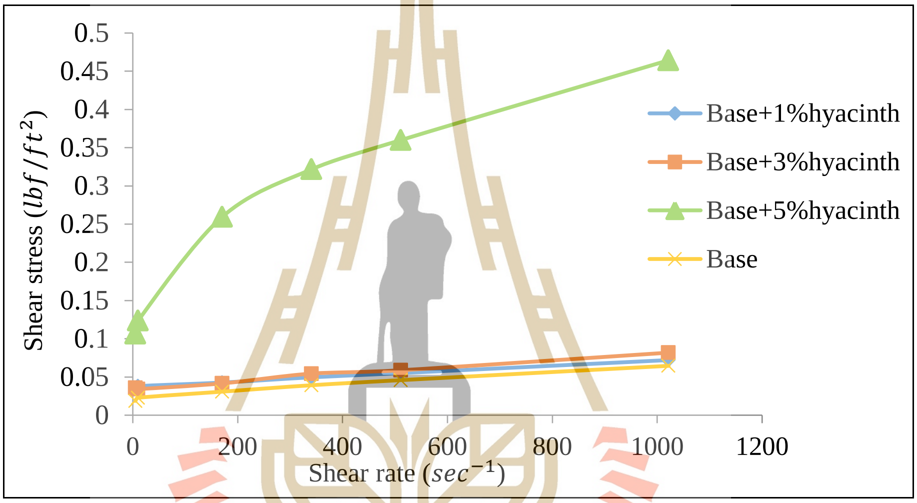


Figure 4.8 Consistency plot of drilling mixed with water hyacinth at 30°C.

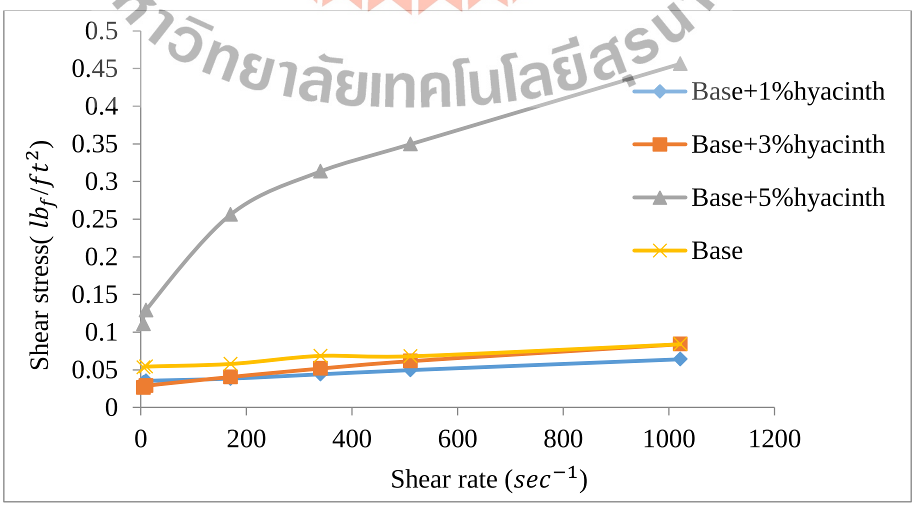


Figure 4.9 Consistency plot of drilling mixed with water hyacinth at 60°C.

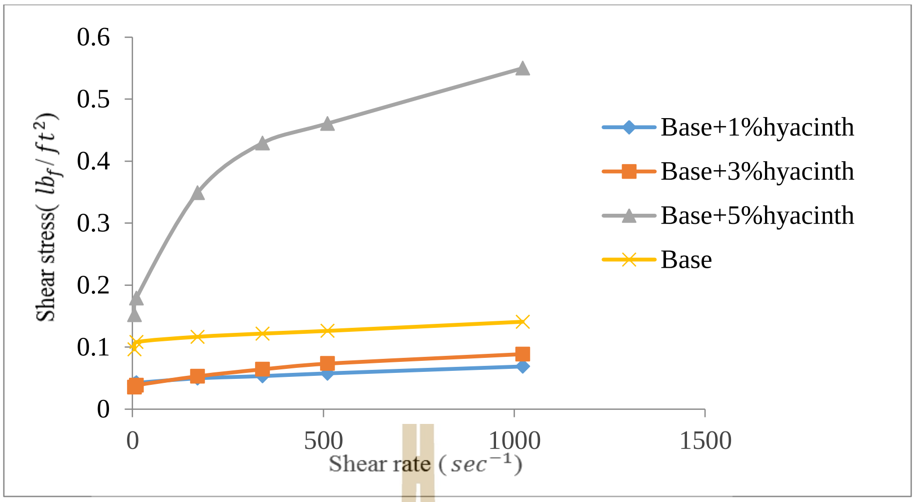


Figure 4.10 Consistency plot of drilling mixed with water hyacinth at 80°C.

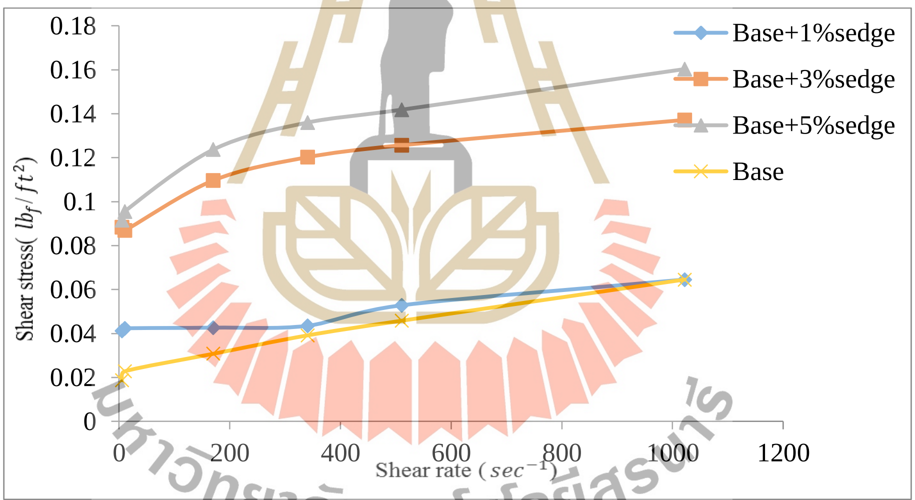


Figure 4.11 Consistency plot of drilling mixed with sedge at 30°C.

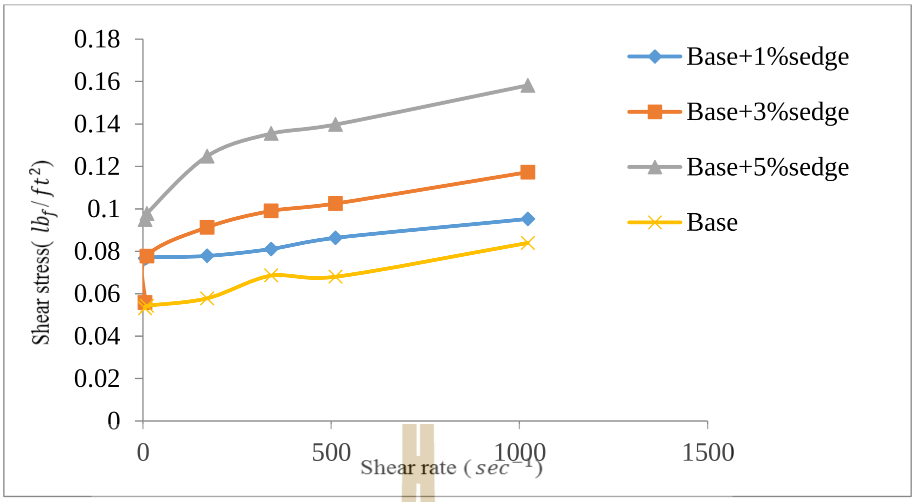


Figure 4.12 Consistency plot of drilling mixed with sedge at 60°C.

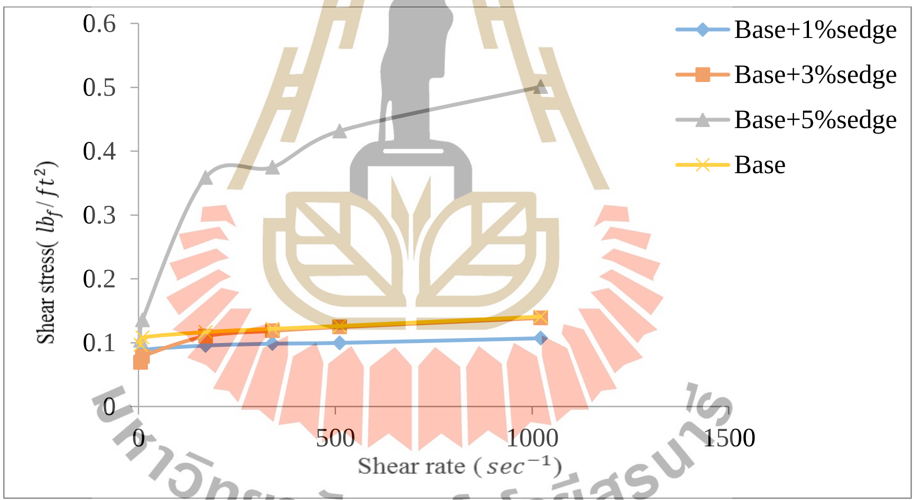


Figure 4.13 Consistency plot of drilling mixed with sedge at 80°C.

Table 4.7 Rheological parameters of mud samples.

Temperature. (°C)	Mud Composition	No.	$\phi 600$	$\phi 300$	Apparent viscosity (cP)	Bingham Plastic model		Power Law model		Gelin (lbf/ 100 ft^2)	Gel10 (lbf/ 100 ft^2)
						Plastic viscosity (cP)	Yield point (lbf/ 100 ft^2)	n	K ($lbs^n/100ft^2$)		
30	Based	1	27	19	13.5	8	11	0.50	16.34	8	12
	Based	2	39	32	19.5	7	25	0.28	49.08	25	27
	Based	3	64	56	32	8	48	0.19	21.46	45	53
	(1%) Water Hyacinth	4	32	24	16	8	16	0.41	10.95	24	18
		5	34	26	17	8	18	0.38	9.14	19	19
		6	35	26	17.5	9	17	0.43	10.26	19	20
		AVG	33.67	25.30	16.83	8.33	17	0.41	5.96	20.67	19
	(3%) Water Hyacinth	7	38	27	19	11	16	0.49	6.36	18	19
		8	38	27	19	11	16	0.49	6.36	20	20
		9	38	27	19	11	16	0.49	6.36	19	19
		AVG	38	27	19	11	16	0.49	11.21	19	19.33
	(5%) Water Hyacinth	10	185	140	92.50	45	95	0.40	70	48	48
		11	211	163	105.50	48	115	0.37	250.02	49	49
		12	192	168	96	24	144	0.19	114.74	45	48
		AVG	196	157	98	39	118	0.32	288.82	47.33	48.33

Table 4.7 Rheological parameters of mud samples (continued).

Temperature. (°C)	Mud Composition	No.	ϕ600	ϕ300	Apparent viscosity (cP)	Bingham Plastic model		Power Law model		Gelin (lbf/ 100 ft^2)	Gel10 (lbf/ 100 ft^2)
						Plastic viscosity (cP)	Yield point (lbf/ 100 ft^2)	n	K (lbs^n/100ft^2)		
30	(1%)Sedge	13	28	25	14	3	22	0.16	47.73	20	20
		14	29	26	18.5	3	23	0.15	36.59	20	20
		15	30	26	15	4	22	0.20	44.29	20	20
	(3%) Sedge	16	65	60	37.5	5	55	0.11	147.18	44	27
		17	64	59	37	5	54	0.11	122.27	41	28
		18	63	57	31.5	6	51	0.14	132.70	41	28
		AVG	64	58.6	35.33	5.333	53.33	0.12	105.29	42	27.67
	(5%) Sedge	19	73	65	36.5	8	57	0.16	89.78	37	35
		20	74	64	37	10	54	0.20	99.91	39	37
		21	73	64	36.5	9	55	0.19	100.48	38	39
		AVG	73.33	64.3	36.67	9	55.33	0.19	17.97	38	37
60	(1%) Water Hyacinth	22	29	21	14.5	8	13	0.46	8.04	18	19
		23	32	24	16	8	16	0.41	12.75	19	15
		24	36	28	18	8	20	0.36	10.77	22	20
		AVG	32.33	24.3	16.17	8	16.33	0.41	9.32	19.667	18

Table 4.7 Rheological parameters of mud samples (continued).

Temperature. (°C)	Mud Composition	No.	ϕ600	ϕ300	Apparent viscosity (cP)	Bingham Plastic model		Power Law model		Gelin (lbf/ 100 ft^2)	Gel10 (lbf/ 100 ft^2)
						Plastic viscosity (cP)	Yield point (lbf/ 100 ft^2)	n	K (lbs^n/100ft^2)		
60	(3%) Water Hyacinth	25	32	24	16	8	16	0.41	9.97	17	18
		26	37	28	18.5	9	21	0.40	8.38	17	19
		27	37	27	16.5	10	17	0.45	9.79	18	18
		AVG	35.33	26.3	17	9	18	0.42	13.16	17.33	18.33
	(5%) Water Hyacinth	28	211	163	105.5	48	115	0.37	89.39	52	51
		29	205	160	102.5	45	115	0.35	72.10	53	54
		30	220	168	110	52	116	0.38	83.68	53	54
		AVG	212	163	106	48.33	115.33	0.37	230.33	52.67	53
	(1%) Sedge	31	45	39	22.5	6	33	0.20	68.92	38	35
		32	45	40	22.5	5	35	0.16	68.90	37	38
		33	44	39	22	5	34	0.17	63.34	37	36
		AVG	44.6	39.3	22.33	5.33	34	0.18	57.52	37.33	36.33
	(3%) Sedge	34	54	47	27	7	40	0.20	84.78	28	30
		35	55	49	27.5	6	43	0.16	118.01	30	39
		36	50	46	25	4	42	0.12	85.19	30	32
		AVG	53	47.3	26.5	5.667	41.667	0.16	114	29.33	33.67

Table 4.7 Rheological parameters of mud samples (continued).

Temperature. (°C)	Mud Composition	No.	ϕ600	ϕ300	Apparent viscosity (cP)	Bingham Plastic model		Power Law model		Gelin (lbf/ 100 ft^2)	Gel10 (lbf/ 100 ft^2)
						Plastic viscosity (cP)	Yield point (lbf/ 100 ft^2)	n	K (lbs^n/100ft^2)		
60	(3%) Water Hyacinth	25	32	24	16	8	16	0.41	9.97	17	18
		26	37	28	18.5	9	21	0.40	8.38	17	19
		27	37	27	16.5	10	17	0.45	9.79	18	18
		AVG	35.33	26.3	17	9	18	0.42	13.16	17.33	18.33
	(5%) Water Hyacinth	28	211	163	105.5	48	115	0.37	89.39	52	51
		29	205	160	102.5	45	115	0.35	72.10	53	54
		30	220	168	110	52	116	0.38	83.68	53	54
		AVG	212	163	106	48.33	115.33	0.37	230.33	52.67	53
	(1%) Sedge	31	45	39	22.5	6	33	0.20	68.92	38	35
		32	45	40	22.5	5	35	0.16	68.90	37	38
		33	44	39	22	5	34	0.17	63.34	37	36
		AVG	44.6	39.3	22.33	5.33	34	0.18	57.52	37.33	36.33
	(3%) Sedge	34	54	47	27	7	40	0.20	84.78	28	30
		35	55	49	27.5	6	43	0.16	118.01	30	39
		36	50	46	25	4	42	0.12	85.19	30	32
		AVG	53	47.3	26.5	5.67	41.67	0.16	114	29.33	33.67

Table 4.7 Rheological parameters of mud samples (continued).

Temperature. (°C)	Mud Composition	No.	ϕ600	ϕ300	Apparent viscosity (cP)	Bingham Plastic model		Power Law model		Gelin (lbf/ 100 ft^2)	Gel10 (lbf/ 100 ft^2)
						Plastic viscosity (cP)	Yield point (lbf/ 100 ft^2)	n	K (lbs^n/100ft^2)		
60	(5%) Sedge	37	125	115	62.5	10	105	0.12	223.75	40	47
		38	128	115	64	13	102	0.15	313.75	45	46
		39	134	125	67	9	116	0.10	292.29	45	47
		AVG	129	118	64.5	10.67	107.667	0.12	130.85	43.333	46.67
80	(1%) Water Hyacinth	40	32	27	16	5	22	0.24	22.63	20	20
		41	33	27	16.5	6	21	0.28	22.63	20	19
		42	33	27	16.5	6	21	0.28	24.82	20	19
		AVG	32.67	27	16.33	5.67	21.333	0.27	11.92	20	19.33
	(3%) Water Hyacinth	43	42	32	21	10	22	0.39	30.28	17	17
		44	41	34	20.5	7	27	0.27	23.28	17	17
		45	40	32	20	8	26	0.32	21.08	18	17
		AVG	41	32.67	20.5	8.33	25	0.32	31.08	17.33	17
	(5%) Water Hyacinth	46	235	195	117.5	40	155	0.26	191.42	75	78
		47	245	204	122.5	41	163	0.26	259.92	75	77
		48	238	204	118	34	170	0.22	216.19	74	78
		AVG	239.3	201	119.33	38.33	162.667	0.25	3604.85	74.667	77.66

Table 4.7 Rheological parameters of mud samples (continued).

Temperature. (°C)	Mud Composition	No.	ϕ600	ϕ300	Apparent viscosity (cP)	Bingham Plastic model		Power Law model		Gelin (lbf/ 100 ft^2)	Gel10 (lbf/ 100 ft^2)
						Plastic viscosity (cP)	Yield point (lbf/ 100 ft^2)	n	K (lbs^n/100ft^2)		
80	(1%) Sedge	49	40	46	25	4	42	0.20	89.07	43	41
		50	49	44	24.5	5	41	0.15	105.97	40	40
		51	50	46	25	4	42	0.12	201.17	41	39
		AVG	46.33	45.3	24.833	4.333	41.667	0.02	96.72	41.333	40
	(3%) Sedge	52	65	59	32.5	6	53	0.14	168.35	29	43
		53	64	60	30	4	56	0.09	128.02	30	44
		54	65	59	32.5	6	53	0.14	138.69	32	42
		AVG	64.67	59.3	31.667	5.333	54	0.12	198.39	30.333	43
	(5%) Sedge	55	240	229	120	11	198	0.06	765.73	48	44
		56	240	229	120	11	198	0.06	514.23	46	52
		57	241	220	120.5	11	199	0.13	644.20	48	54
		AVG	240.3	226	120.167	11	198.333	0.089	1152.6	47.333	50

***Gel$_{in}$** is initial gel strength and ****Gel$_{10}$** is 10 minutes gel strength of drilling mud

4.3.2 Rheological behavior of drilling mud.

The rheological parameters of water-based drilling mud and drilling mud mixed with additive samples are summarized in Table 4.7. The additives are divided into two parts, consisting of water hyacinth and sedge. The theological data of total test are shown in Appendix A. The Power Law model parameter in the term of flow behavior index (*n*) and consistency (*k*) is calculated by equation 3.6 and 3.7 as shown in the previous chapter. The index *n* indicated that all drilling mud samples exhibited pseudoplastic flow with *n* less than 1. As mentioned above, the flow behavior of typical drilling mud usually acted between the Bingham Plastic and Power Law model. It is called pseudoplastic fluid. The trendy consistency factor of drilling mud sample increases as the increasing of water hyacinth and sedge. The constant is similar to the apparent viscosity of the fluid that described the thickness of the fluid. The Power Law model did not describe the behavior of drilling fluids exactly, but the constant *n* and *k* normally describe in the interest of hydraulic utilization that is used in hydraulic calculations.

Figures 4.14 to 4.23 are the plots of the theological parameters obtained from the calculation with various water hyacinth and sedge concentrations. The apparent viscosity was plotted as a function of water hyacinth and sedge concentration as showed in Figure 4.14. For all tested temperature, the results indicate a significant increase in the apparent viscosity as the water hyacinth concentration increase. This is due to greater colloidal fraction of bentonite and sedge in mud sample that result of increasing flow resistance. The influence of temperature on the apparent viscosity is shown in Figure 4.14. It clearly shows that for all of water hyacinth and sedge compositions, the apparent viscosity increase with increasing temperature. The consequence of temperature increase interaction energy of mud system (Luckham and Rossi, 1999). It induces more inter-particle attractive force between solid particles and so the clay particles come into contact with another and agglomerate which is known as flocculation.

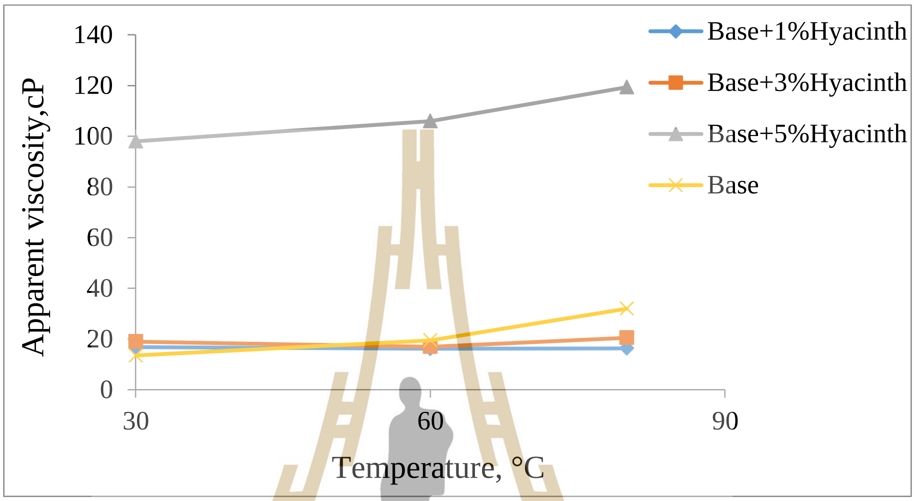


Figure 4.14 Apparent viscosity of mud samples versus water hyacinth concentration.

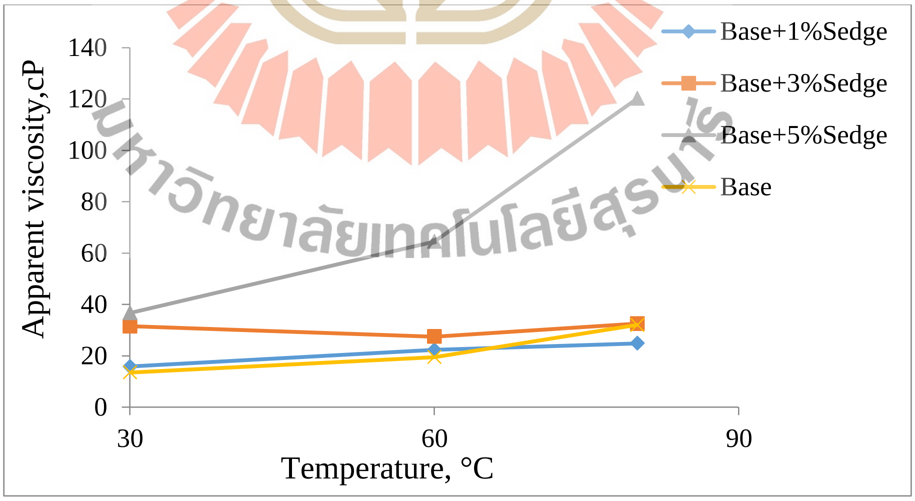


Figure 4.15 Apparent viscosity of mud samples versus sedge concentration.

The Bingham plastic model in the term of plastic viscosity was plotted versus water hyacinth and sedge concentrations and temperature and showed in Figures 4.14 and 4.15. The results viscosity property of drilling mud mixed with the water hyacinth and sedge are the flow behavior index less than 1, which represent to the pseudo-plastic flow and shear thinning fluid.

After drilling mud mixed with the water hyacinth concentration from 1, 3 and 5 percent has the apparent viscosity increases 82.82% at 30°C, 84.84% at 60°C and 83.31% at 80°C. The plastic viscosity increases 78.64% at 30°C, 83.44% at 60°C and 85.21% at 80°C .The drilling mud mixed with the sedge concentration from 1, 3 and 5 percentage has the apparent viscosity increases 56.89% at 30°C, 65.37% at 60°C and 79.33 % at 80°C. The plastic viscosity increases 62.97% at 30°C, 50% at 60°C and 60.60% at 80°C. The result indicated that the apparent and plastic viscosities of water hyacinth and sedge containing mud slightly increased with increasing water hyacinth and sedge concentration from 1, 3 and 5 percent for all tested temperature and water hyacinth containing mud indicated a better the rheological properties at 5 percent water hyacinth concentration compared to the rheological properties of sedge concentration.

Considering effect of elevated temperature, the influence of elevated temperature treatment was shown slightly decreased of plastic viscosity after elevating temperature from 30 to 80 ^{o}C. The trend of line indicated that the mud behaved non-Newtonian and shear-thinning as temperature increased (up to 80 ^{o}C), and displayed lower plastic viscosities and higher yield stress. The effect of temperature on bentonite suspension could be described as follows: heating up the bentonite suspension increased the conductivity of the system. This was indicated that more cations (Na^+) were dissolved from the surface of the particles. It was also suggested that this effect was responsible for the reduction of the normalized plastic viscosity and the observed of the yield stress increasing, the latter also due to thermal induced swelling (Luckham and Rossi 1999).

The yield point of water hyacinth and sedge containing mud was plotted as function of water hyacinth and sedge concentrations and temperature as showed in Figures 4.18 and 4.19. For all tested temperature, The drilling mud mixed with 1, 3 and 5 percentage of water hyacinth has the yield point increases 85.60%, 86.08%, and 86.88% at 30, 60 and 80°C, respectively. The drilling mud mixed with 1, 3 and 5 percentage of sedge has the yield point increases 59.63%, 68.42%, and 79.15% at 30, 60 and 80°C, respectively. The result indicated that the yield stress clearly increased with water hyacinth and sedge containing mud increasing. This is because large amount of solid in mud sample tend to agglomerate and result in increasing yield stress. For all water hyacinth and sedge containing mud, the yield stress increased with elevated temperature. Rising of temperature increases interaction energy of clay system that leads bentonite suspension become thickened. From the experiment, it can be concluded that the presence of water hyacinth and sedge increase yield strength of mud which enhance carrying capacity of drilling fluid while drilling circulation periods.

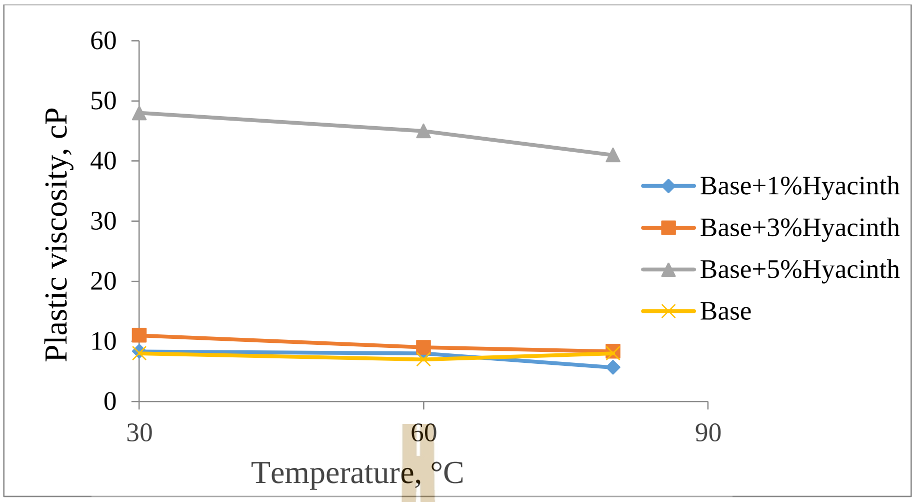


Figure 4.16 Plastic viscosity of mud samples versus water hyacinth concentration.

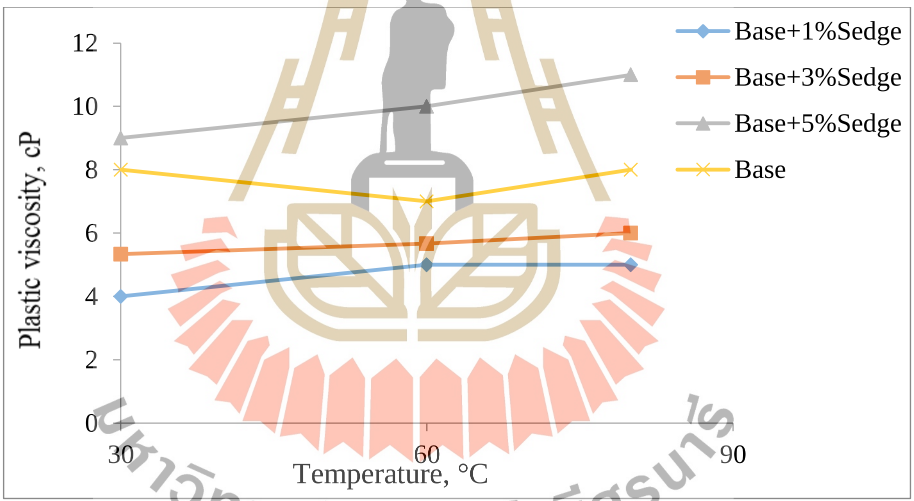


Figure 4.17 Plastic viscosity of mud samples versus sedge concentration.

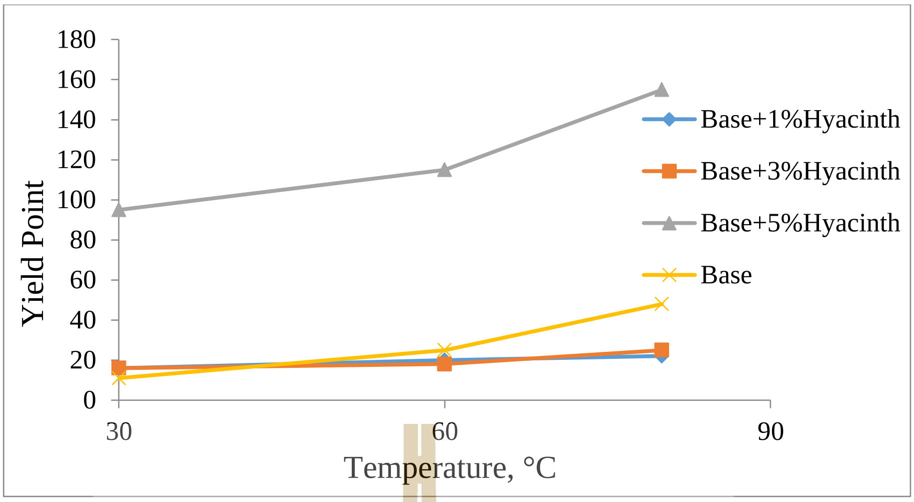


Figure 4.18 Yield point of mud samples versus water hyacinth concentration.

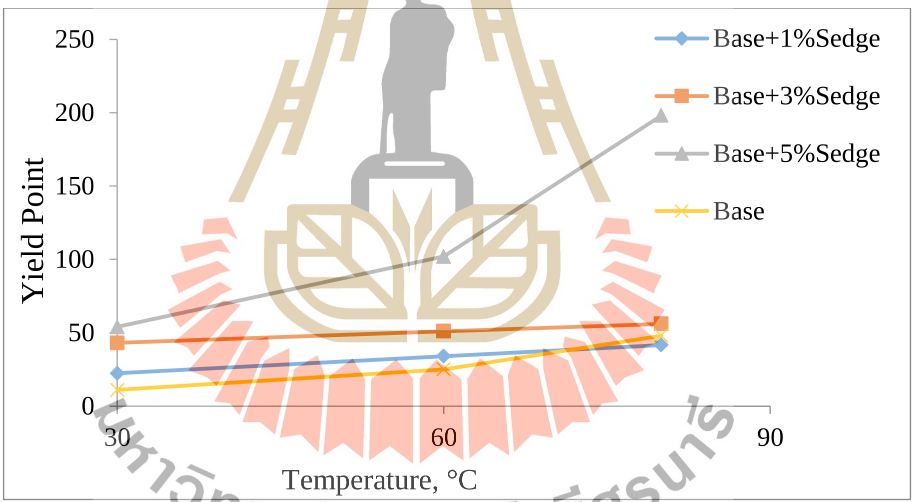


Figure 4.19 Yield point of mud samples versus sedge concentration.

The initial and 10 minutes gel strength of water hyacinth and sedge containing mud were investigated and their result was plotted as function of water hyacinth and sedge concentration and temperature as showed in Figures 4.20 to 4.23. The result showed insignificant improvement of gel strength with an increasing water hyacinth and sedge concentration and temperature. Considering water hyacinth and sedge containing mud at 30, 60 and 80 °C show in Table 4.7, the 10 minutes gel strength was greater than initial gel strength. This is because of more undisturbed mud standing time would lead mud to form stronger gel structure compared to less undisturbed time. Considering water hyacinth and sedge containing mud at 60 and 80 °C, the 10 minutes gel strength tended to became less than initial gel strength. The result indicated that the great temperature drop occurred while 10 minutes standing time period, which in turn, led to the lower of 10 minutes gel strength. This can be noted that gel strength is strongly influenced by time and temperature. From the experiment, it can be concluded that the presence of water hyacinth and sedge increase gel strength of mud which enhance hole cleaning efficiency of drilling fluid by suspend cutting and weighting material when circulation is ceased.

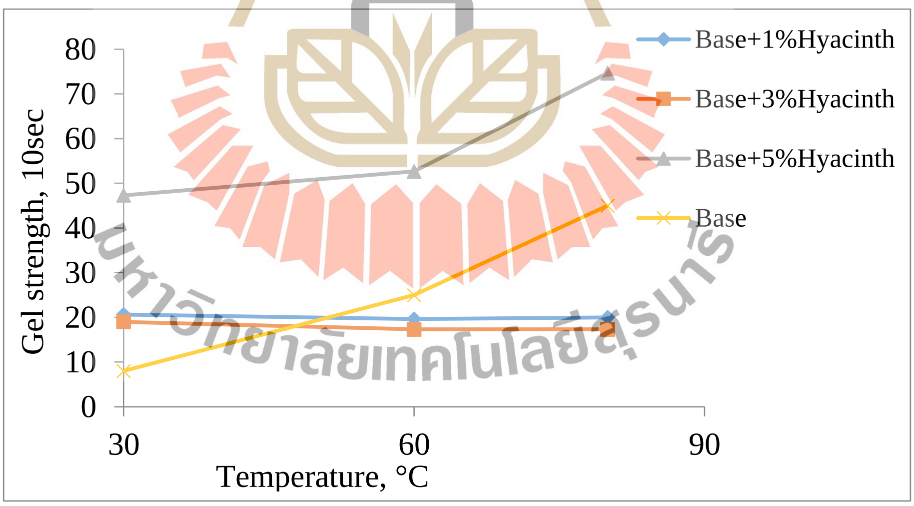


Figure 4.20 Gel strength 10 seconds of mud samples versus water hyacinth concentration.

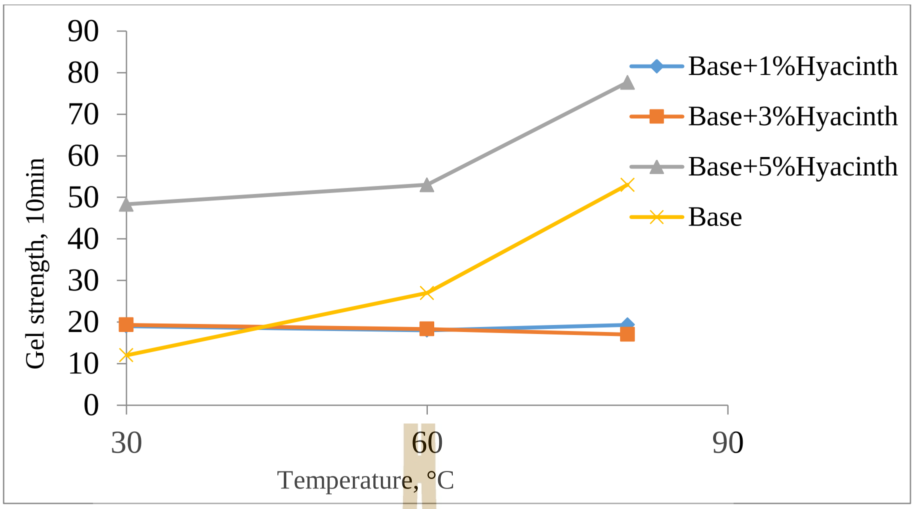


Figure 4.21 Gel strength 10 minutes of mud samples versus water hyacinth concentration.

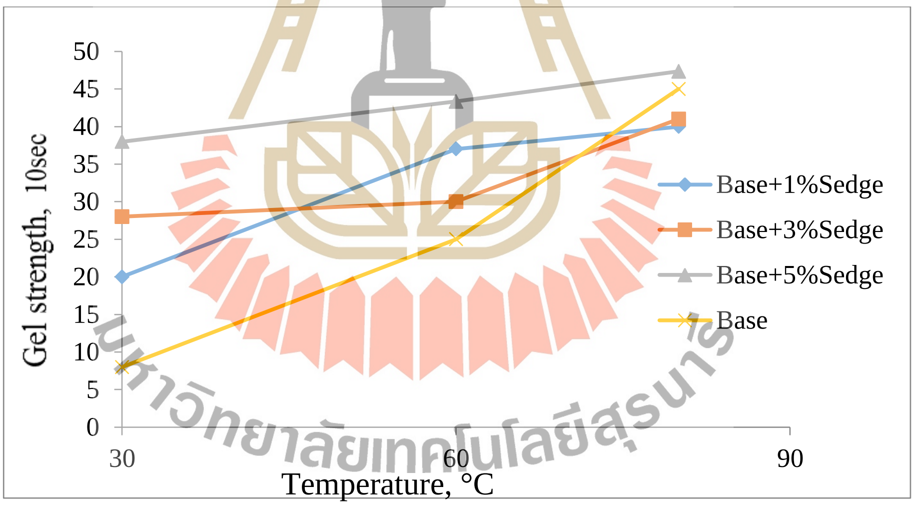


Figure 4.22 Gel strength 10 seconds of mud samples versus sedge concentration.

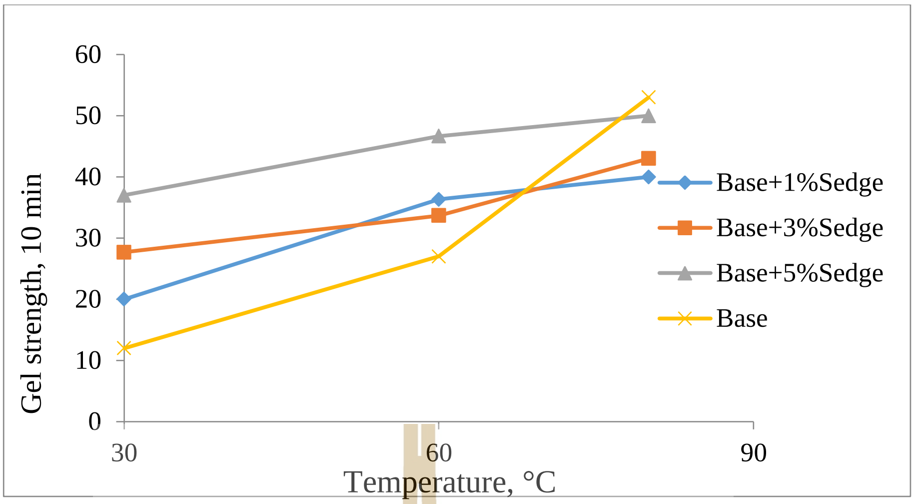


Figure 4.23 Gel strength 10 minutes of mud samples versus sedge concentration.

4.3.3 Filtration properties of drilling mud

The aim of filtration is to create a low-permeability mud cake to seal between the wellbore and the formation. Control of fluid loss restricts the invasion of the formation by filtrate and minimizes the thickness of mud cake. The average API static filtration loss within 30 minutes of drilling mud mixed with additives and total data testing of filtration properties and mud cake thickness are displayed in Appendix A.

The plot of filtration properties of water-based drilling mud is measured at 30 60 and 80 °C (Figure 4.24). The filtration properties of drilling mud mixed with water hyacinth and sedge are shown in Figures 4.25 to 4.30. These graphs show time-dependent filtration behavior of water-based drilling mud and indicate that the fluid loss exponentially increases as the time increase. The decreasing of filtrate volume is resulted from continuous mudcake deposition and compactions until the formation of a constant thickness and stable mud cakes have been formed completely.

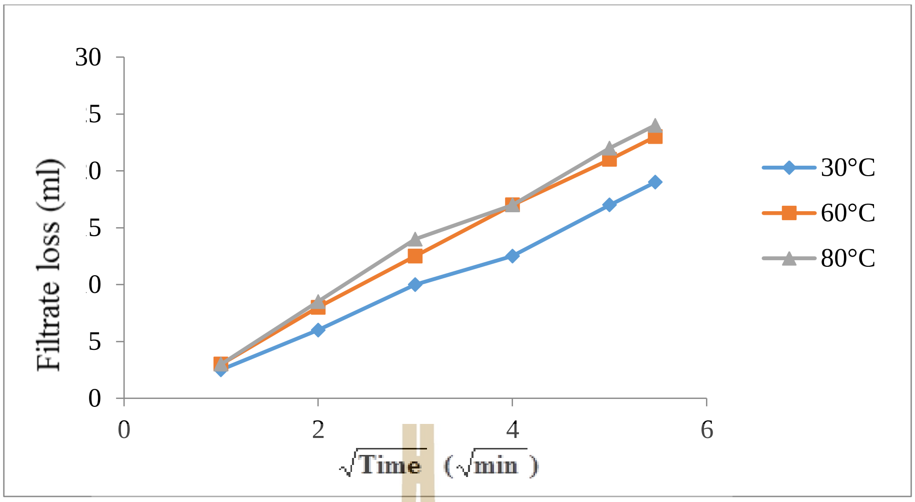


Figure 4.24 Static filtration and time of water-based drilling mud.

The drilling mud mixed with additives on filtration properties at 30 °C has shown in Figures 4.25 to 4.26. The static filtration curves indicate that at water-based drilling mud compares the drilling mud mixed with 1, 3 and 5 percentages of additives at 30 °C. They are tested for determine the appropriate amount of additives for control filtration loss of drilling mud after mixing with water hyacinth and sedge.

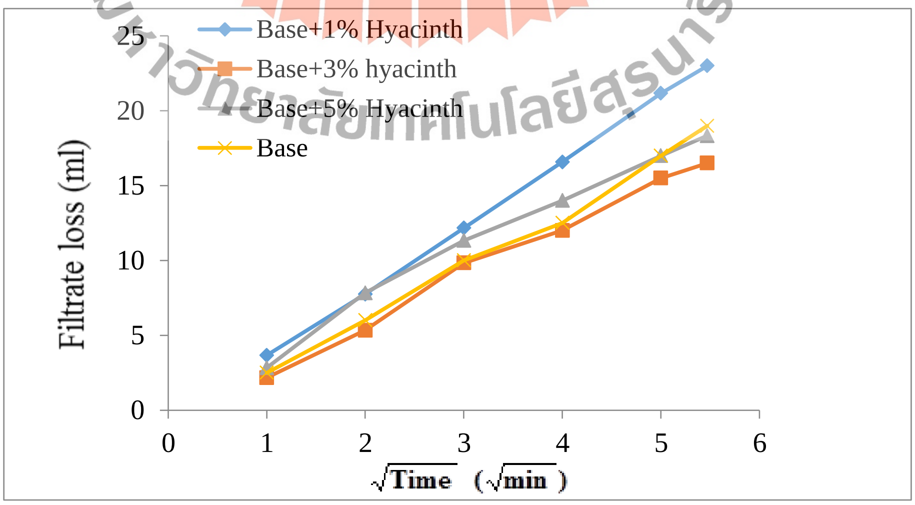


Figure 4.25 Static filtration of water hyacinth versus time at 30 °C.

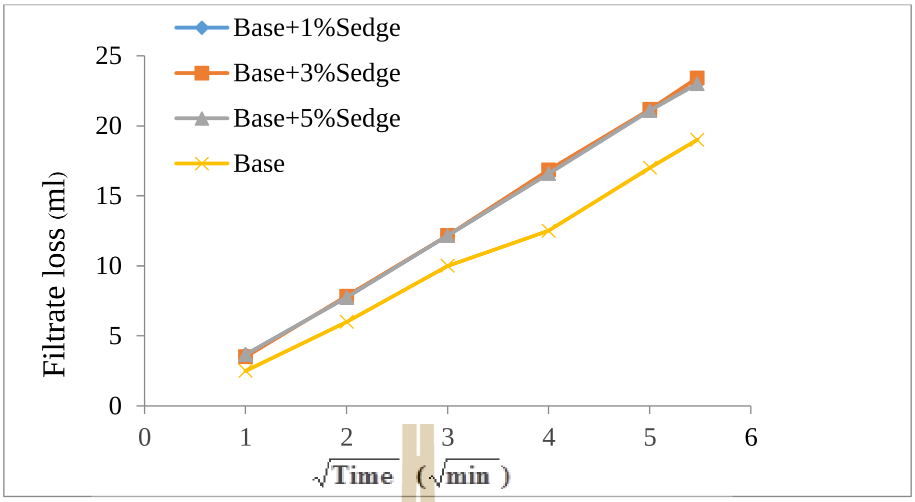


Figure 4.26 Static filtration of sedge versus time at 30 °C.

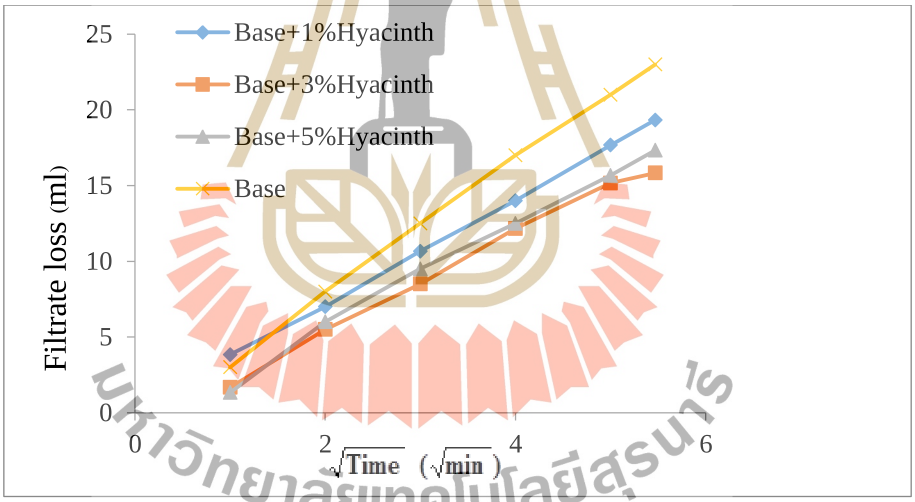


Figure 4.27 Static filtration of water hyacinth versus time at 60 °C.

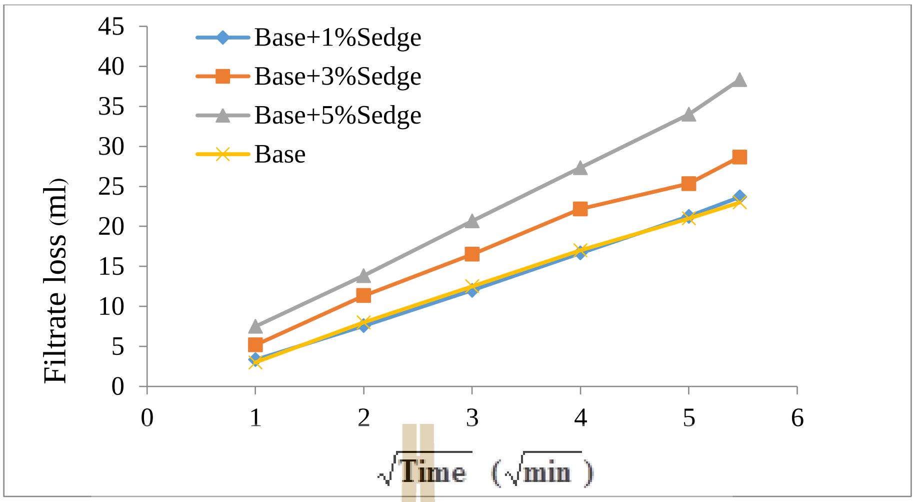


Figure 4..28 Static filtration of sedge versus time at 60 ◦C.

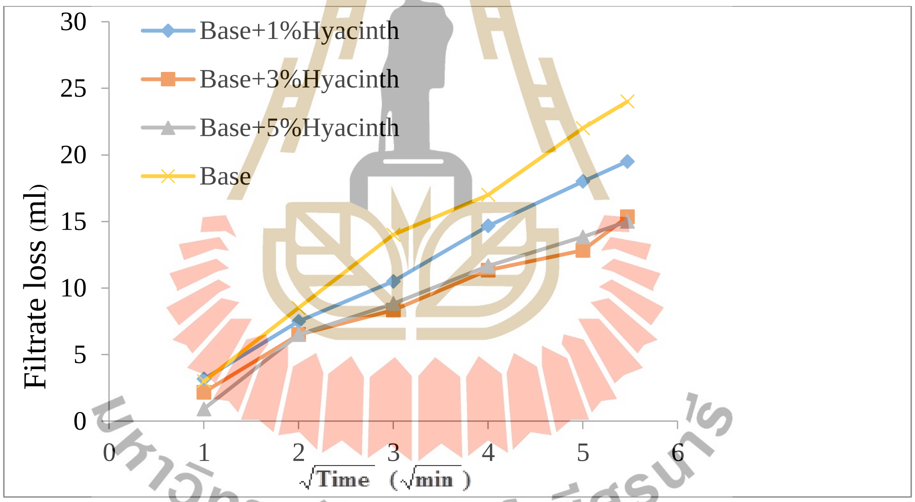


Figure 4.29 Static filtration of water hyacinth versus time at 80 °C.

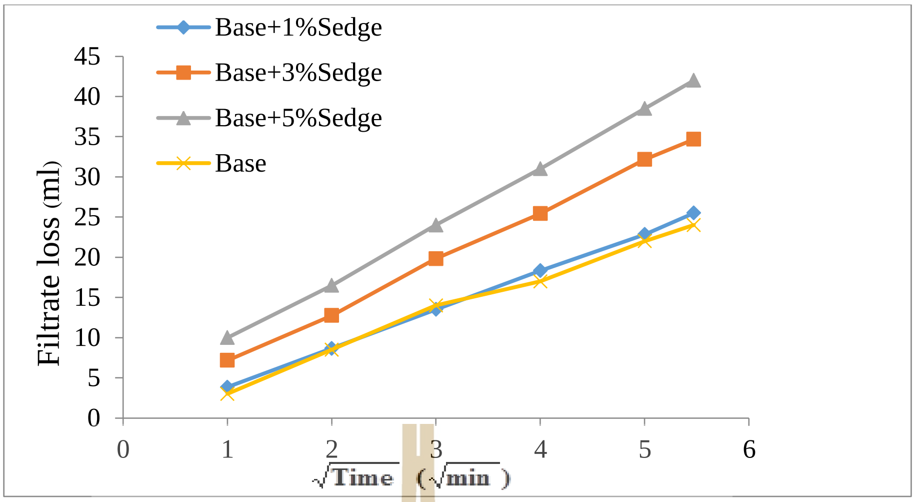


Figure 4.30 Static filtration of sedge versus time at 80 °C.

Figures 4.25 to 4.30 show the effect of water hyacinth concentration and sedge concentration with water-based mud on filtration properties at 30, 60 and 80˚C. The static filtration curves indicate that at 1, 3 and 5 percentages of additives.

Analyses of filtration behavior of the mud after respectively thermal treatment at 30, 60, and 80 ˚C are demonstrated in Figures 4.25 to 4.30. The experimental result represents 30 minutes static fluid loss values indicates that the presence of 1, 3 and 5 percentages of water hyacinth in bentonite can reduce fluid loss more than drilling mud with sedge concentration.

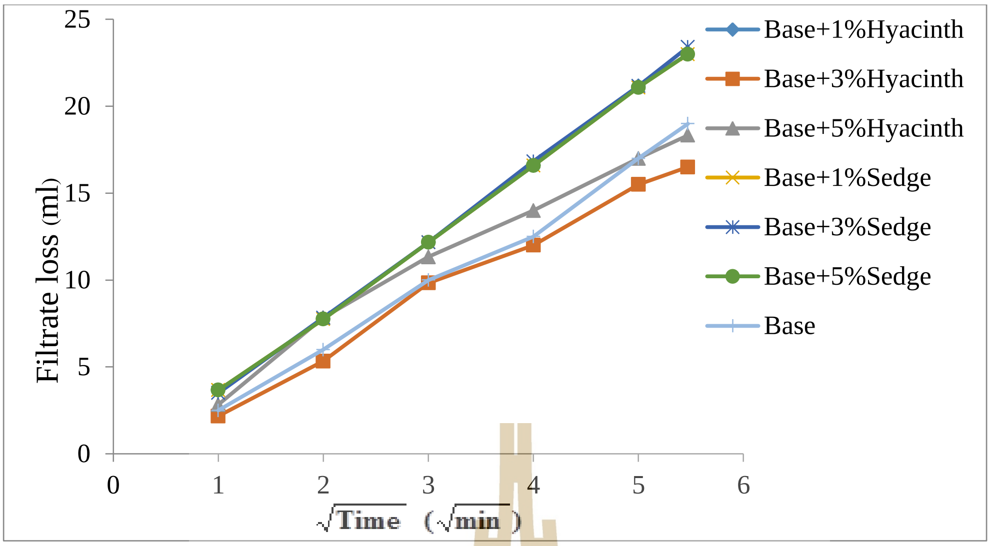


Figure 4.31 Static filtration of water hyacinth and sedge versus time at 30 °C.

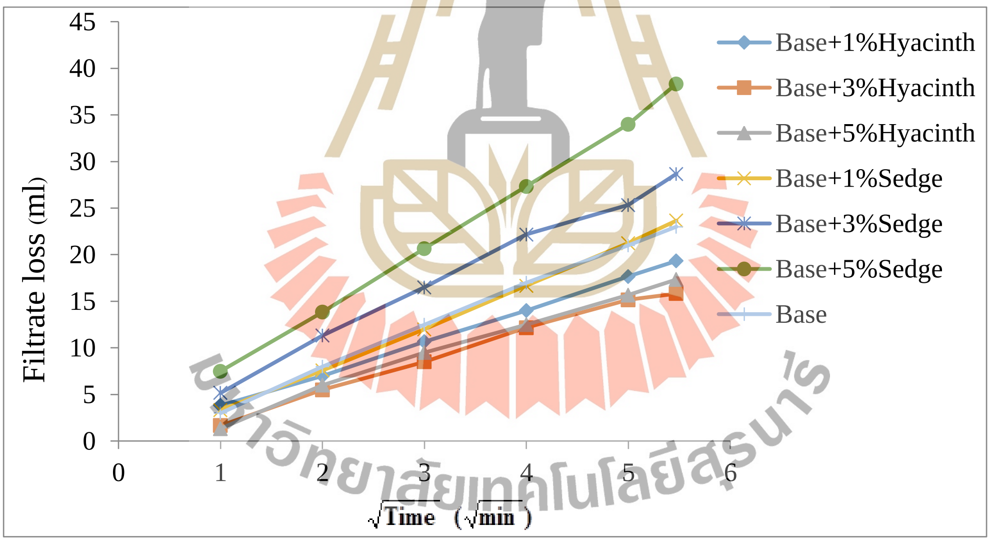


Figure 4.32 Static filtration of water hyacinth and sedge versus time at 60 °C.

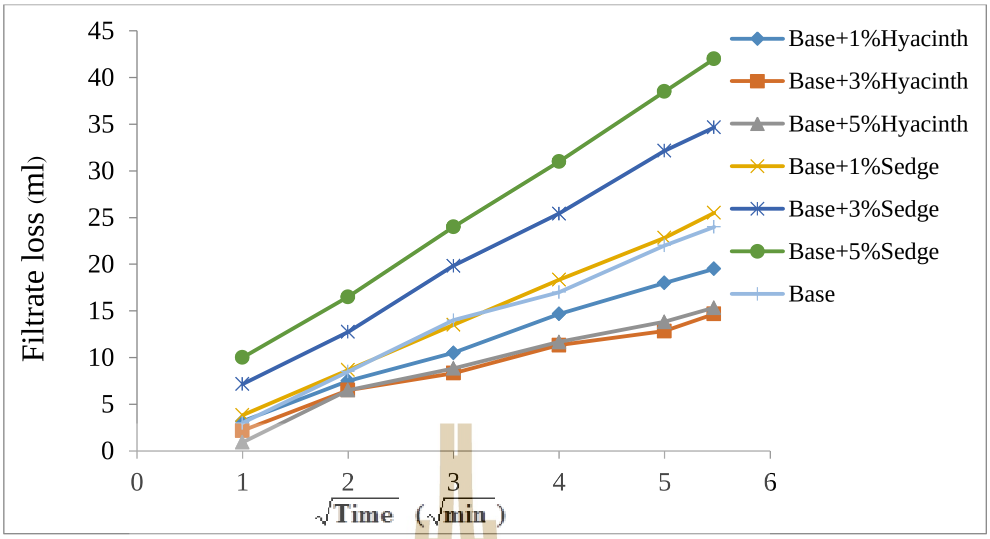


Figure 4.33 Static filtration of water hyacinth and sedge versus time at 80 °C.

Figures 4.31 to 4.33 show the compared effect of water hyacinth and sedge concentrations with water-based mud on filtration properties at 30, 60 and 80˚C

The appropriate additive is 3 and 5 percentages of water hyacinth. They can control fluid loss both low and high temperatures. In the other hand, concentration 1, 3 and 5 percentages of sedge decreasing the fluid loss but it is not significant for drilling mud. Filtration behavior analyses of the drilling mud at 60 and 80 °C demonstrated in Figures 4.24 to 4.33. The static fluid loss values of drilling mud mixed with 1, 3 and 5 percentages of water hyacinth and sedge indicate to the increasing of filtration.

Mud cake thickness of the drilling mud mixed with additives is shown in Figures 4.34 and 4.35. The histograms show that the mud cake thickness is depending on the additives concentration and temperature increasing. The mud cake qualities deposited by the additive containing drilling mud are measured. The slickness and toughness of sedge in drilling mud are more than water hyacinth in drilling mud. The quality of mud cake that referred to build up on the borehole wall, helping for reduces the formation damage and the chance of differential sticking of drill pipe.

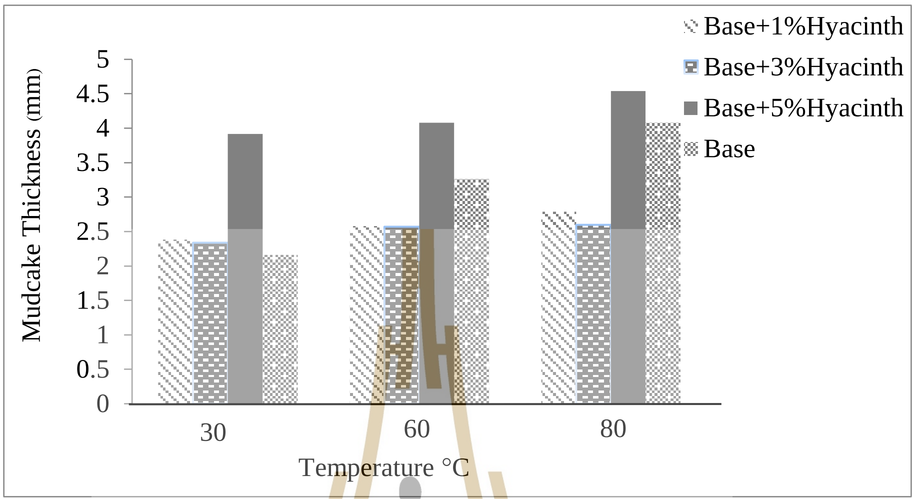


Figure 4.34 Mud cake thickness of water hyacinth containing drilling mud at 30, 60 and 80 °C.

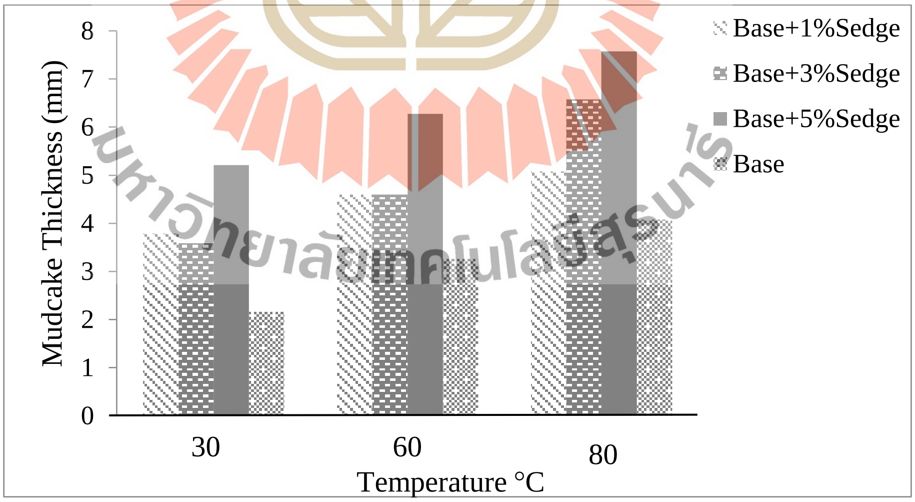


Figure 4.35 Mud cake thickness of sedge containing drilling mud at 30, 60 and 80°C.

4.3.4 Density of drilling mud.

Hydrostatic pressure is required to prevent the borehole wall from caving in and to keep formation fluid from entering the wellbore. The results of density of drilling mud after mixing additives describe by Figures 4.36 through 4.37. The result demonstrates the ability of additives to provide weight to drilling mud. The range of drilling mud mixed with additives is 1.10 to 1.14 g/cm^3 or 9.16 to 9.50 lb/gal. The density slightly decreases as the temperature increase, however, the concentration of additives increased as the density increased.

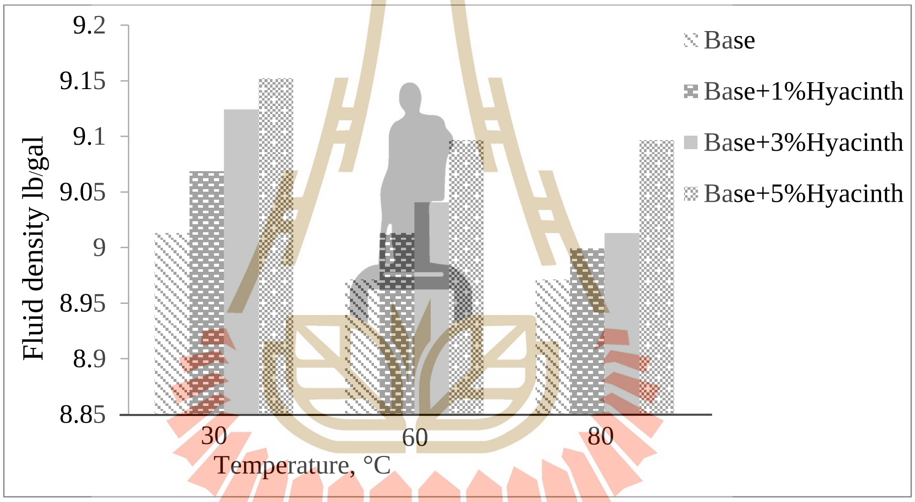


Figure 4.36 Density of water hyacinth containing mud at 30, 60 and 80 °C.

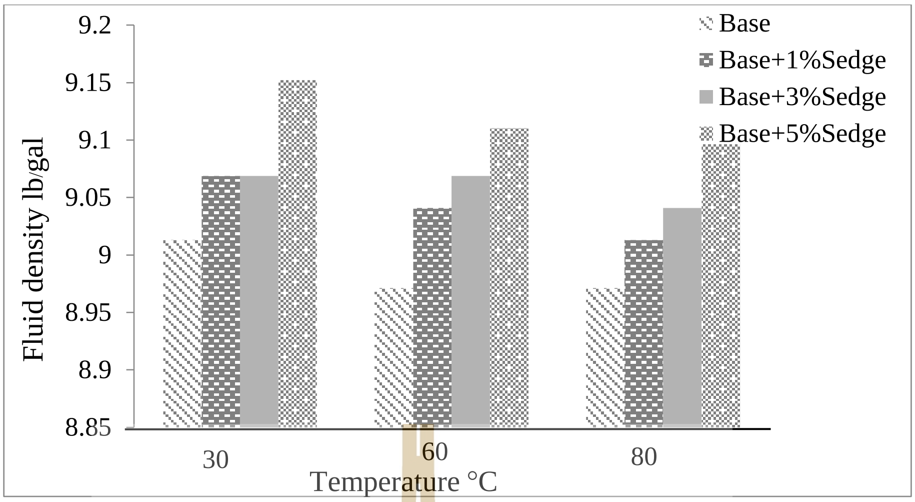


Figure 4.37 Density of sedge containing mud at 30, 60 and 80 °C.

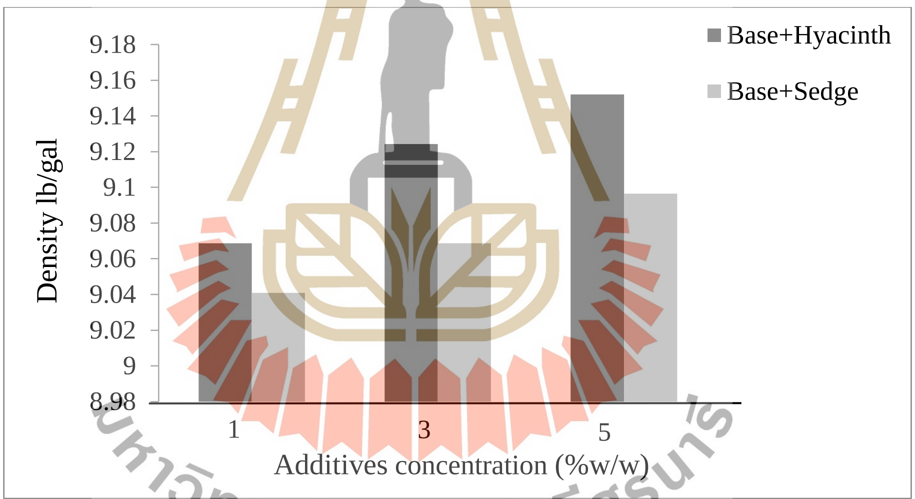


Figure 4.38 Density of additives containing mud at 30 °C.

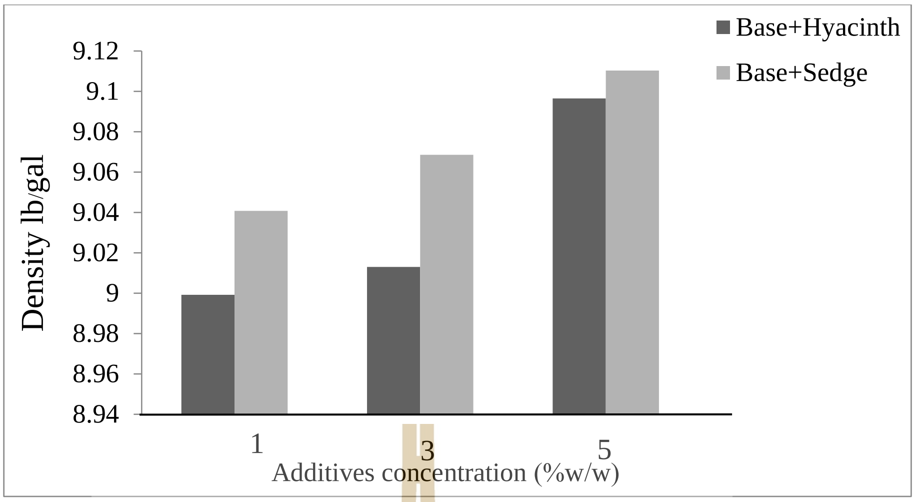


Figure 4.39 Density of additives containing mud at 60 ◦C.

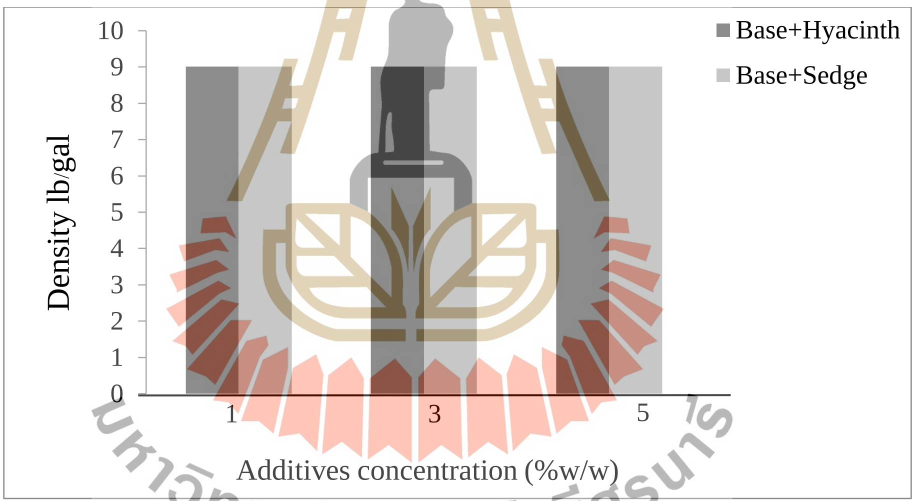


Figure 4.40 Density of additives containing mud at 80 ◦C.

Figures 4.38 to 4.40 show the compared effect of water hyacinth and sedge concentrations with water-based mud on filtration properties at 30, 60 and 80˚C. The result demonstrates the ability of additives to provide weight to drilling mud. The sedge concentration as the density increased more than water hyacinth concentration in drilling mud

4.3.5 pH of drilling mud.

The total data testing of pH tests are display in Appendix A. Figures 4.41 to 4.46 summarize the test results on the pH of drilling mud before and after mixing additives at 30, 60 and 80 °C. They describe the pH of mud and mud filtrates for filtration test.

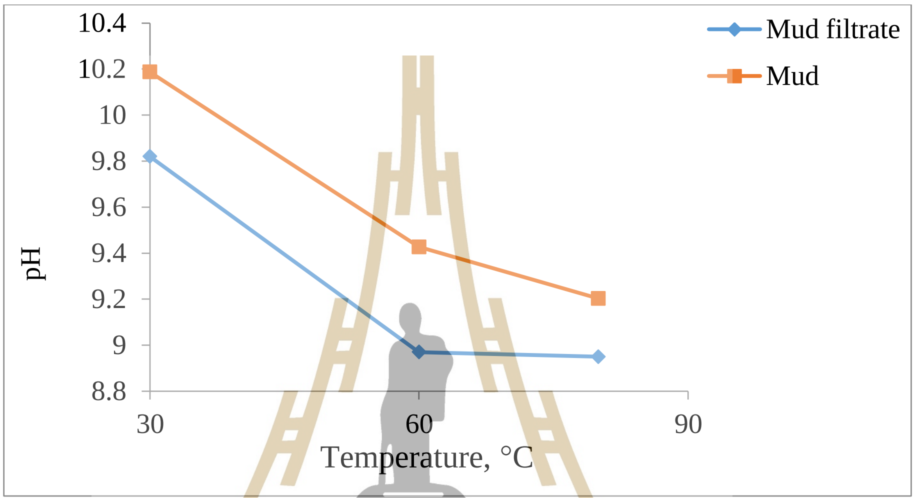


Figure 4.41 pH value of based drilling mud and mud filtrate at various temperature.

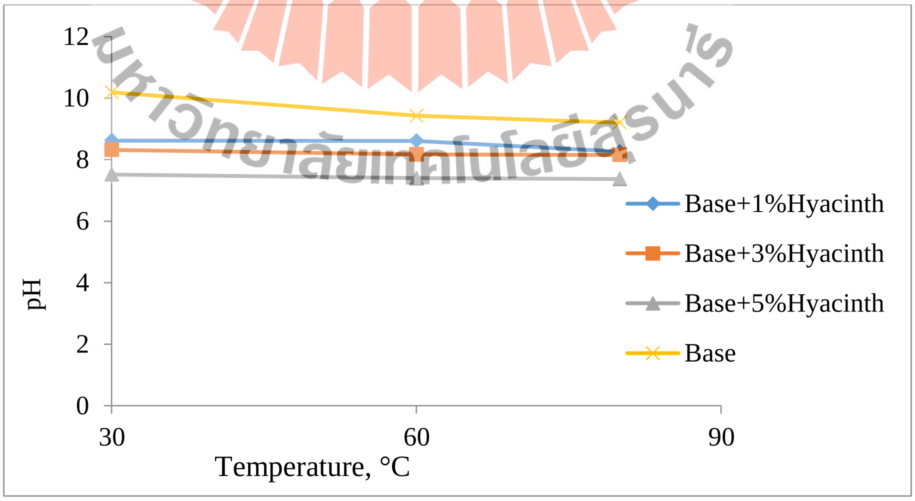


Figure 4.42 pH value of drilling mud mixed with 1, 3 and 5% of water hyacinth concentration at various temperature.

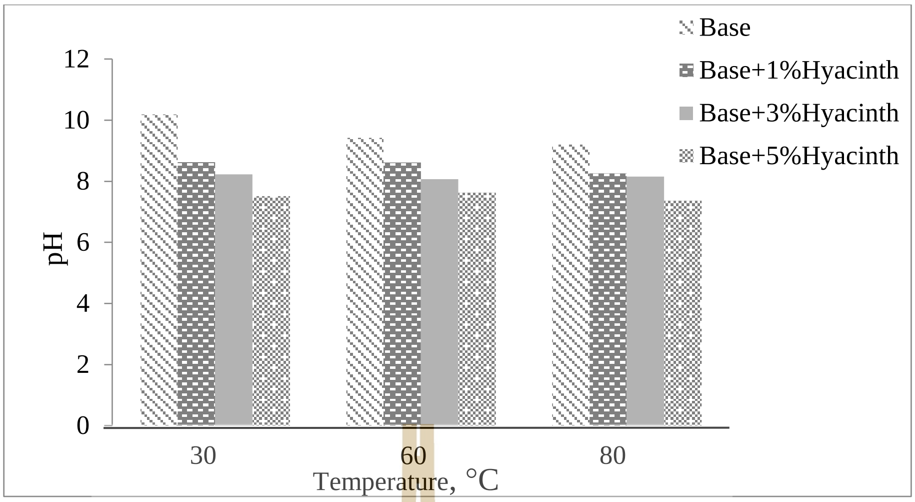


Figure 4.43 pH value comparison of drilling mu mixed with 1, 3 and 5% of water hyacinth concentration at various temperature.

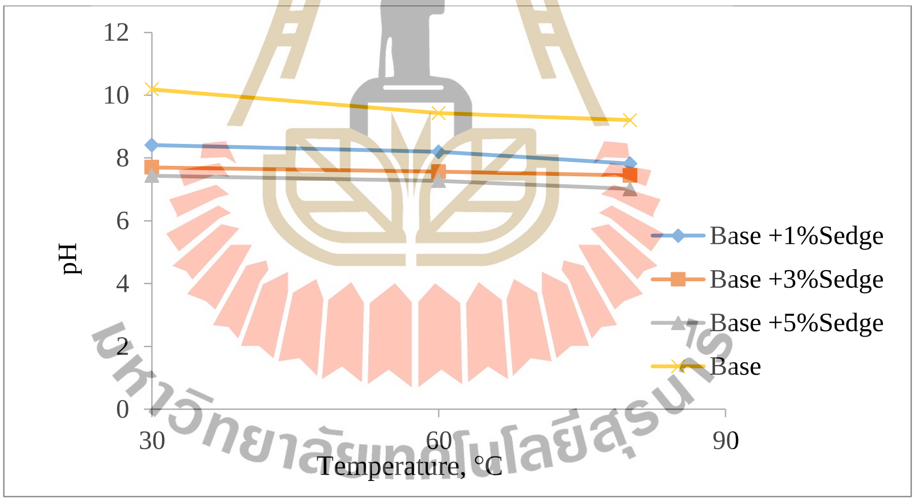


Figure 4.44 pH value versus temperature of drilling mud mixed with sedge concentration at various temperature

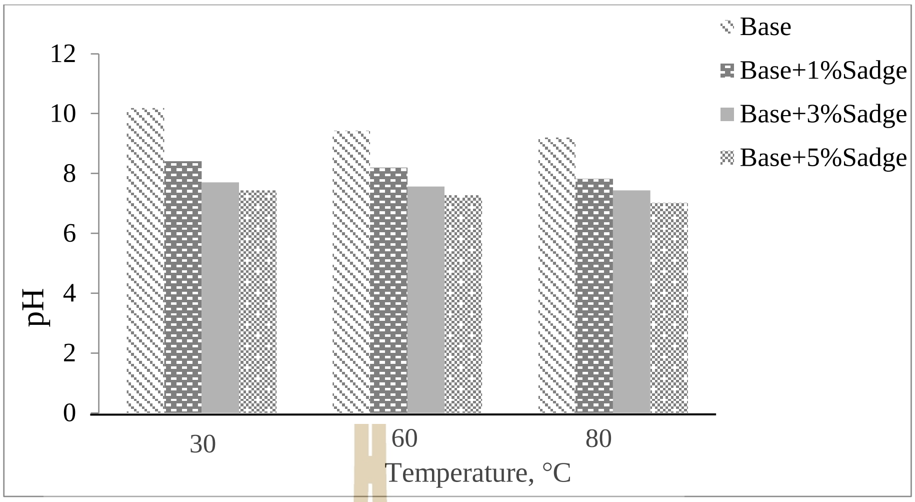


Figure 4.45 pH value comparison of drilling mu mixed with 1, 3 and 5% of sedge concentration at various temperature.

The result indicates that the pH decreased as the increasing concentration of water hyacinth and sedge. Temperature effect to the pH value by the slightly decreased of temperature increased causes the pH decreasing. The pH of drilling mud is more than the pH of the filtrate for filtration test.

Figure 4.46 shows the compared effect of water hyacinth concentration and sedge concentration with water-based mud at 30, 60 and 80˚C. The result demonstrates the ability of additives to provide weight to drilling mud. The pH values of drilling mud mixed with sedge and water hyacinth are similar.

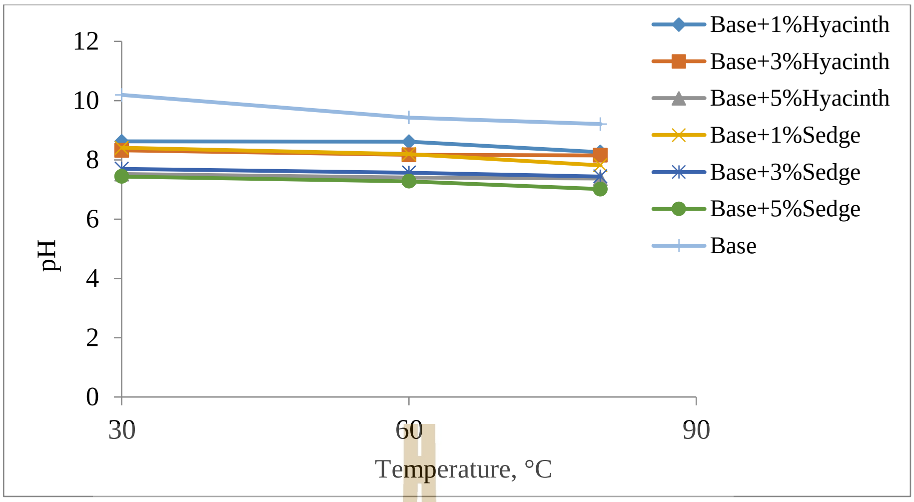
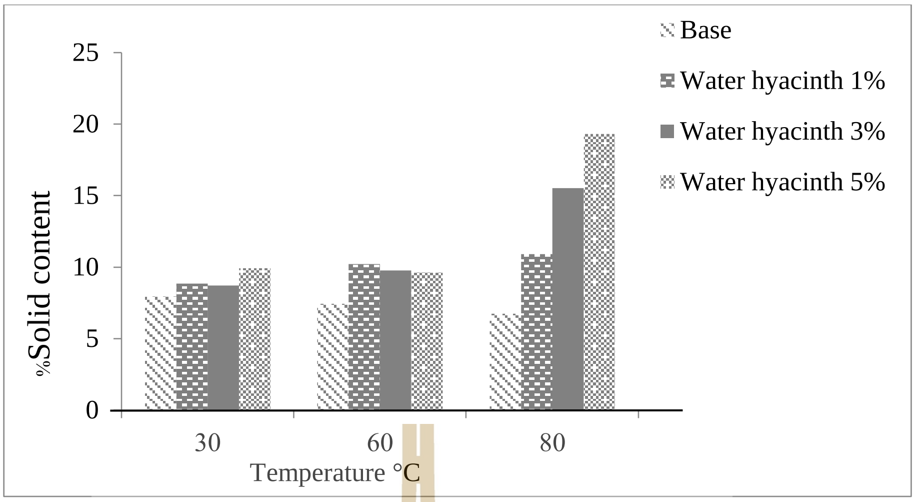


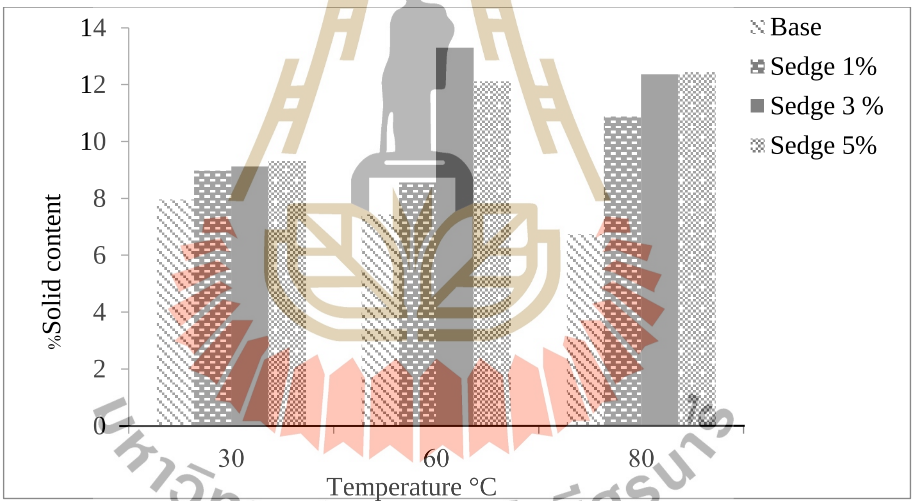
Figure 4.46 pH value versus temperature of drilling mud mixed with 1, 3 and 5% of water hyacinth and sedge concentration at various temperature.

4.3.6 Solid content in drilling mud.

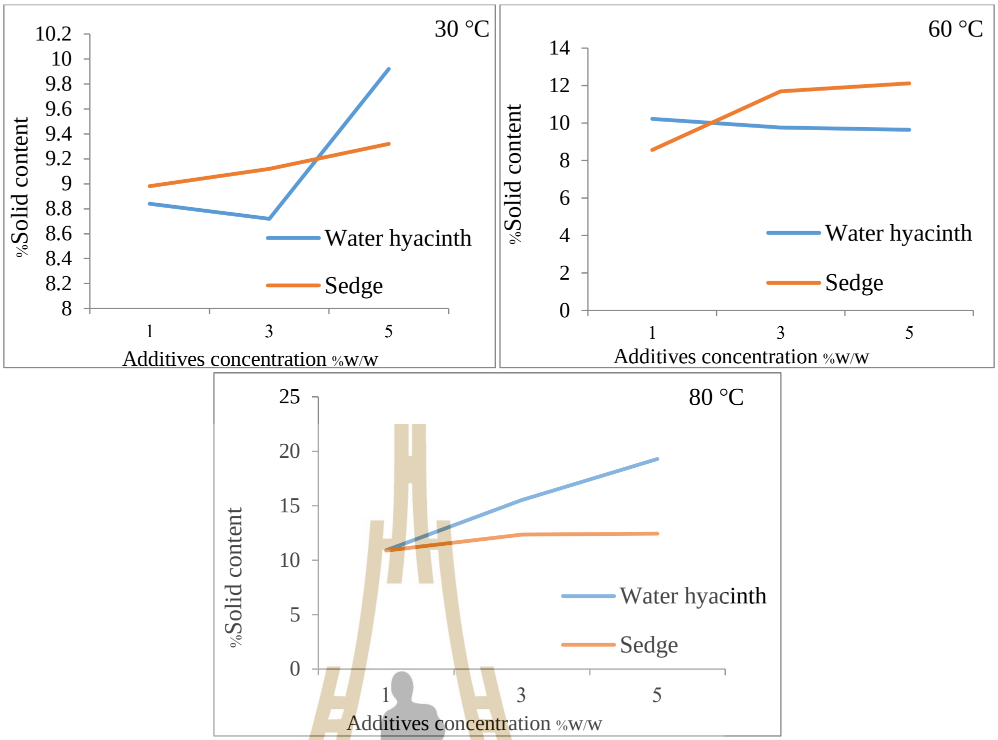
Solids are usually classified as high gravity solid (HGS) that referred to barite and other weighting agents. Low gravity solid (LGS) consists of clays, polymers and bridging materials deliberately put in the mud, plus drilled solids from dispersed cuttings and ground rock. The amount and type of solids in the mud affect a number of drilling mud properties. The results of solid content describe in Figures 4.49 to 4.51.



Figures 4.47 Solid content of water hyacinth containing mud at 30, 60 and 80 °C



Figures 4.48 Solid content of sedge containing mud at 30, 60 and 80 °C



Figures 4.49 Comparison of solid content between water hyacinth with sedge containing mud

High solids content (HGS) increase plastic viscosity and gel strength. High solids muds have much thicker filter cakes and slower drilling rates The result indicates that the solid content increase as the increasing concentration of water hyacinth and sedge. The temperature effect to the solid content value by the slightly increase of temperature increased causes the solid content increasing. Comparison of result found that the drilling mud after mixed sedge more than drilling mud after mixed water hyacinth.

4.3.7 Resistivity of drilling mud.

The results of resistivity are illustrated in Figures 4.50 to 4.55. Resistivity of drilling mud decreased as additives concentration and temperature increased. The resistivity compared to the effect of water hyacinth more than sedge. The resistivity of mud filtrate is more than drilling mud and mud cake thickness, respectively.

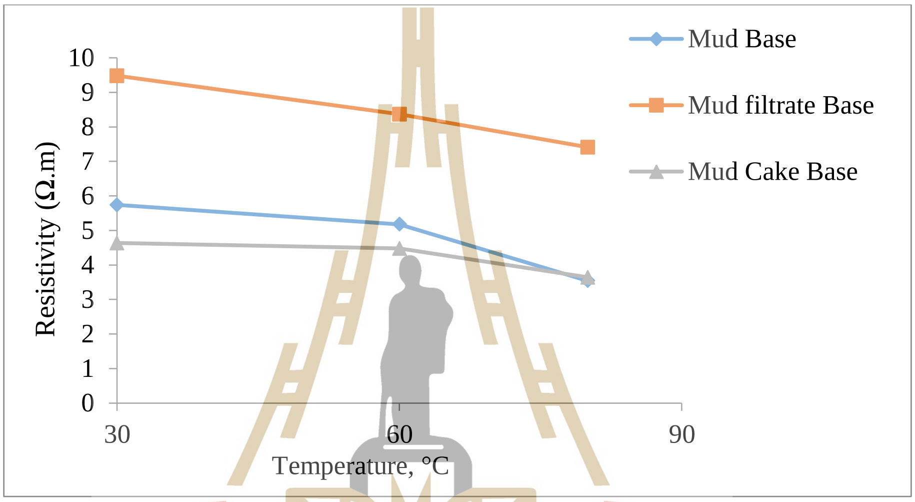


Figure 4.50 Resistivity of drilling mud at 30, 60 and 80 °C.

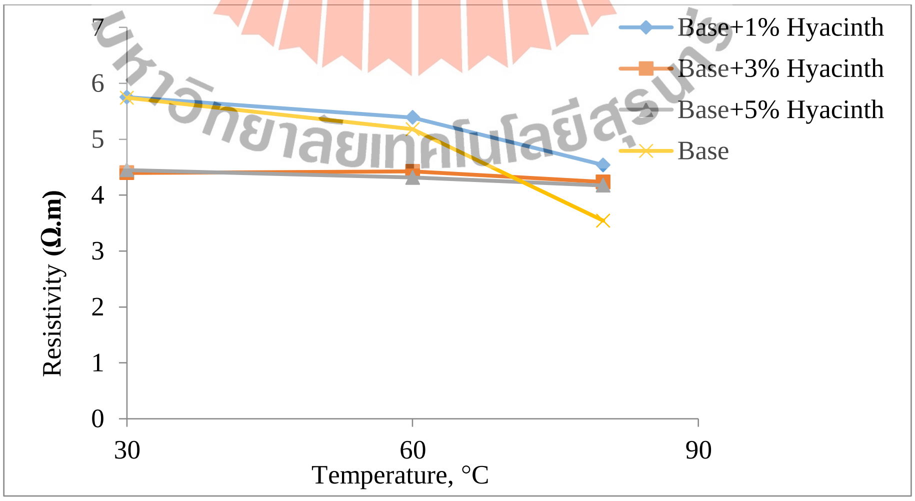


Figure 4.51 Resistivity of drilling mud mixed with water hyacinth at 30, 60 and 80°C.

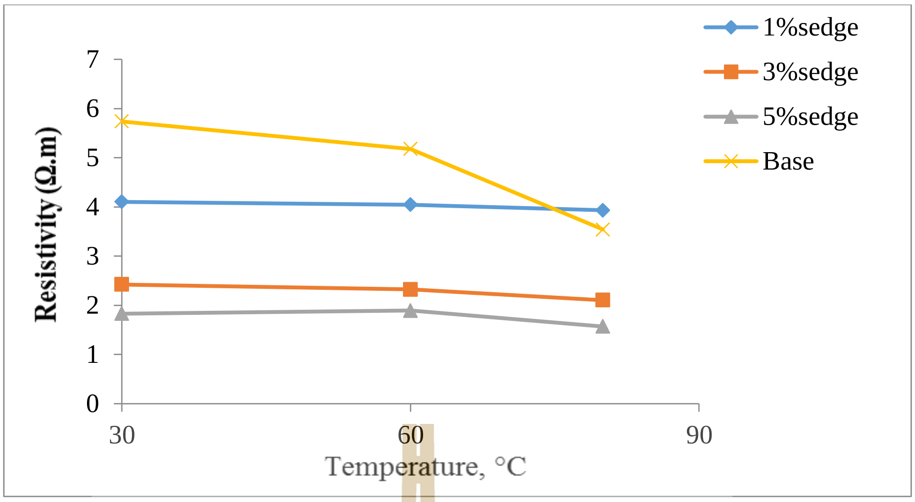


Figure 4.52 Resistivity of drilling mud mixed with sedge at 30, 60 and 80 °C.

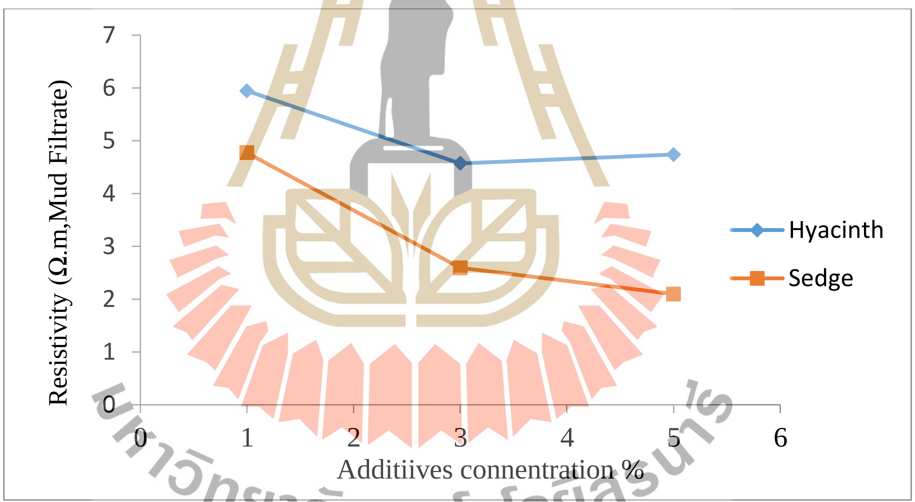


Figure 4.53 Resistivity of additives containing drilling mud at 30 °C.

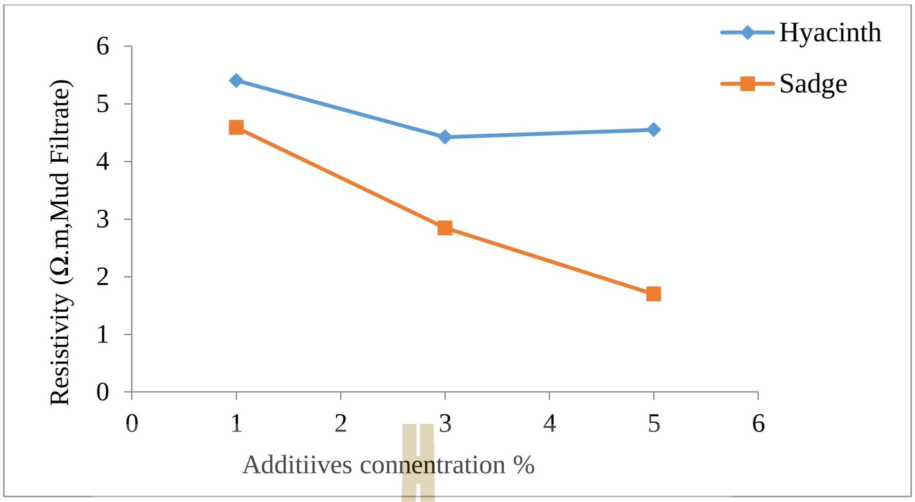


Figure 4.54 Resistivity of additives containing drilling mud at 60 °C.

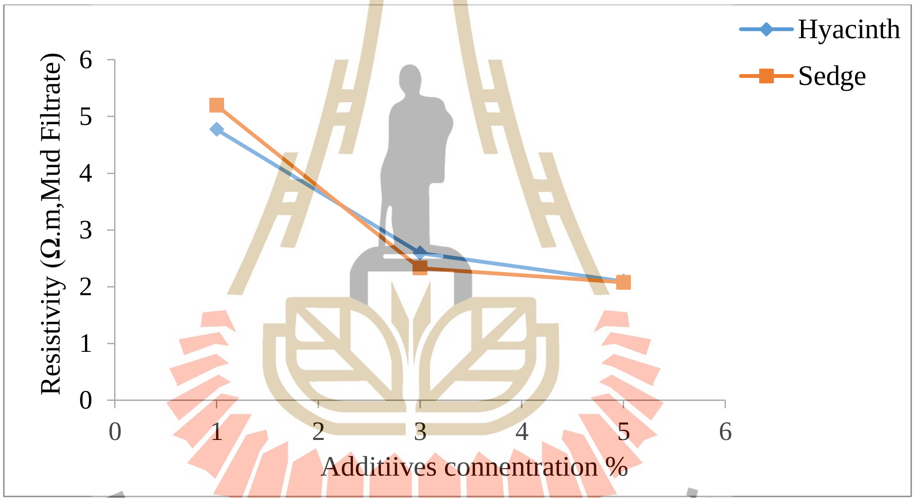


Figure 4.55 Resistivity of additives containing drilling mud at 80 °C.

4.3.8 Scanning Electron Microscope (SEM) analysis.

Morphology and texture of materials are analyzed by JEOL (model JSM-6010LV) to determine the value of the energy used in photography, which use the system at 20 kV and a vacuum (High Vacuum Mode). The result of characteristic, distribution and size of the surface of the drilling mud before mixed with additives is shown in Figure 4.56.

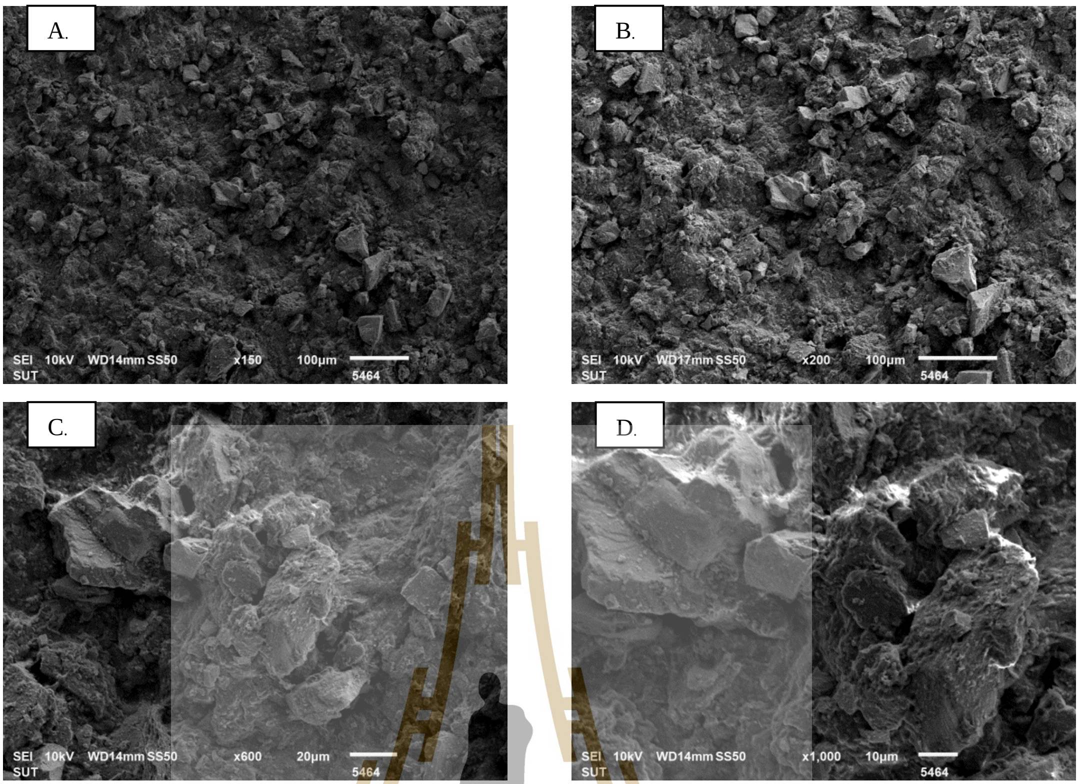


Figure 4.56 Characteristics, distribution and size of the surface of the drilling mud before mixing as additives (A)-(B). The surface characteristics of the barite square (C)-(D).

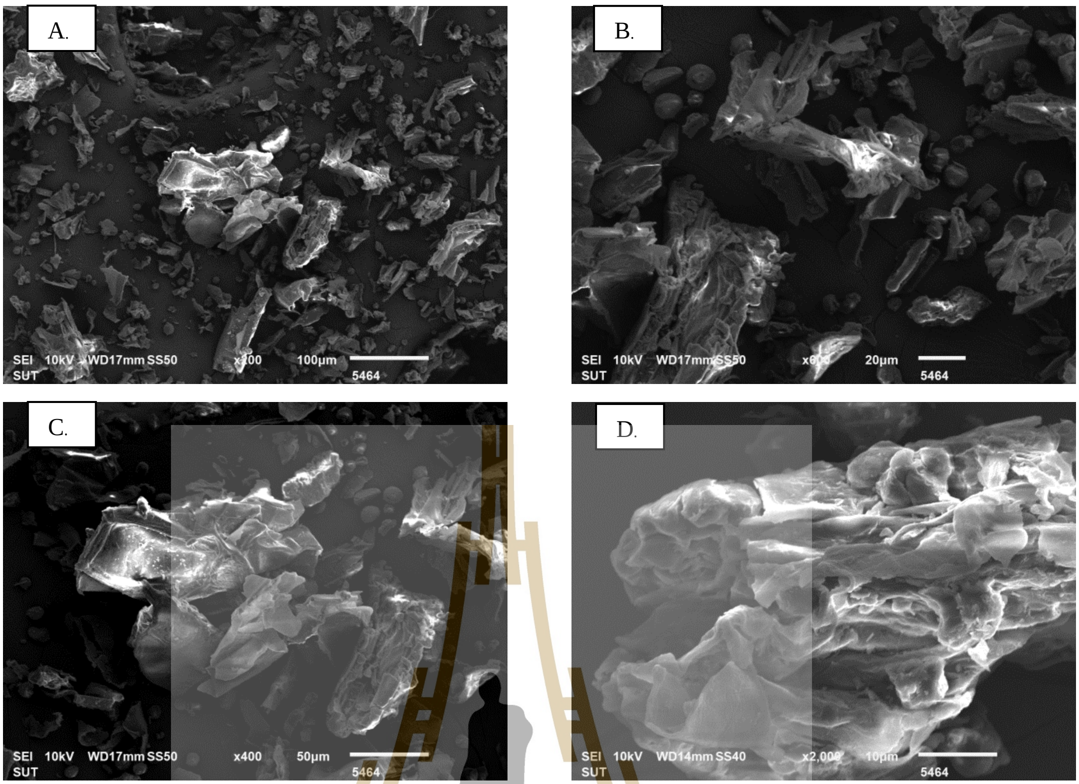


Figure 4.57 Characteristics, distribution and size of the surface of the water hyacinth powders (A)-(B). The surface characteristics of the water hyacinth powders angular length. (C)-(D).

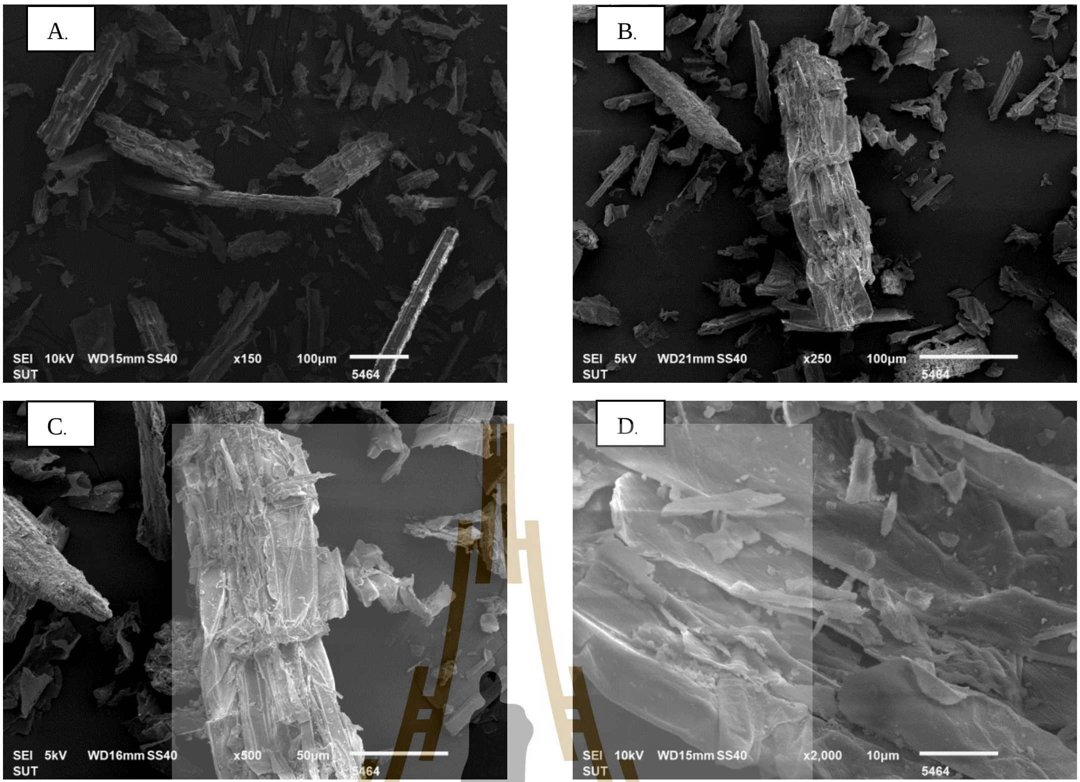


Figure 4.58 Characteristics, distribution and size of the surface of the sedge powders (A)-(B). The surface characteristics of the sedge powders cylindrical rod and angular length. (C)-(D).

The results are analyzed by electron microscopy image of barite water hyacinth and sedge before mixing with drilling mud was expanded from 100 to 2000 found that the skin surface into barite the angular and sharp debris (Figure 4.56 and Figure 4.58). The surface characteristics of the water hyacinth powders angular length and the surface characteristics of the sedge powders cylindrical rod and angular length.

Figure 4.59 shows the characteristics, distribution and size of the surface of the drilling mud mixed water hyacinth powders. It represents homogeneous and found only a small part of water hyacinth.

Figure 4.60 shows the characteristics, distribution and size of the surface of the drilling mud mixed sedge powders. It represents mixed with mud poorly. Some parts still find cylindrical parts of sedge.

The results were analyzed by electron microscopy found that the rough surface of the sample with tightly packed components and remains of particle substances that through heating at a temperature of 30, 60 and 80 °C. The drilling mud mixed with water hyacinth there is a catch, and the interface between the various components tightly over the drilling mud mixed with sedge.

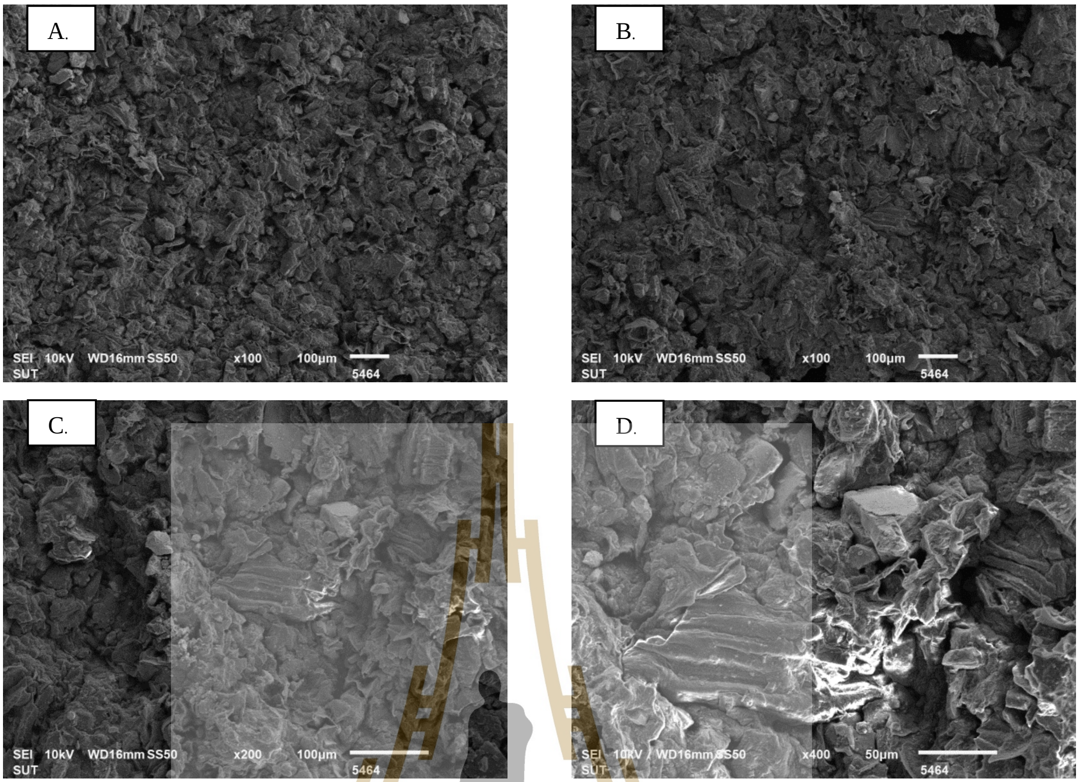


Figure 4.59 Characteristics, distribution and size of the surface of the drilling mud mixed water hyacinth powders (A)-(D).

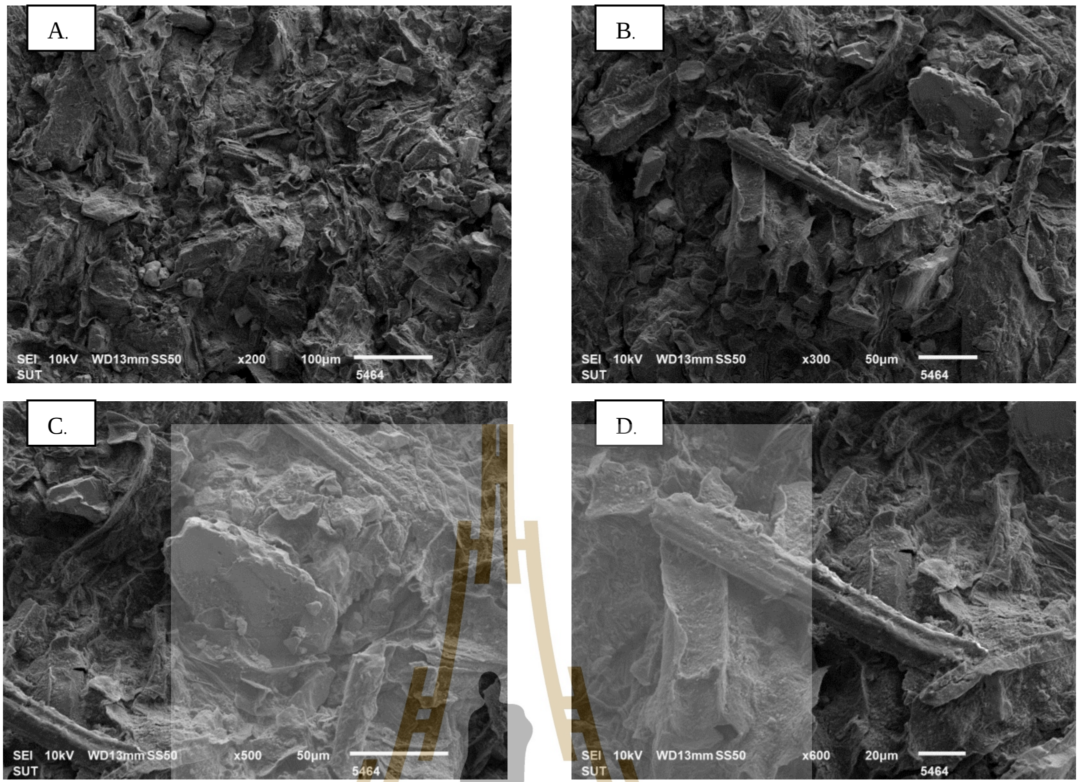


Figure 4.60 Characteristics, distribution and size of the surface of the drilling mud mixed sedge powders (A)-(D).

4.4 Cost comparison

It is very important to improve the properties of drilling fluids in order to satisfy the increasing demands and need to cut drilling costs, no least of which in economics. In general, drilling mud may represent about one-fifth (15%-18%) of the total cost of petroleum well drilling, but many causes 100% of drilling problems.

Table 4.8 shows the cost of the water hyacinth and sedge, which compared with other additives for viscosifier and fluid loss control agent. The cost of two additives are cheaper than fluid loss control agent, but not commercial. Because of the cost of the water hyacinth and sedge, it does not include a cost of process materials and other indirect materials. However, it can be conclude that the cost for the water hyacinth and sedge cost effective and environmentally friendly.

Table 4.8 Cost of drilling fluid chemicals.

Chemicals	Cost (Bath)	Unit (Kg)	Cost/Kg (Bath/Kg)
API Bentonite	11,400	1,000	11.4
Barite	5,000	1,000	5
PAC Polymer	72,000	25	2,880
CMC Gabrosa HV TECH	200,000	1,000	200
Sugarcanes bagasse	500	1,000	0.5
Corn cob	650	1,000	0.65
Rice straw	1,400	1,000	1.4
Water hyacinth*	-	-	-
Sedge*	-	-	-

**Water hyacinth and sedge were waste materials. Cost does not include the cost of process materials, materials handling and storage, packaging, transport and other indirect materials.*

4.5 Summary of chemical and physical properties of drilling mud mixed with water hyacinth and sedge

Analysis result of drilling mud mixed with of water hyacinth and sedge powders can be summarized the chemical and physical properties in Table 4.9.

An analysis of the physical experiment, found that the water hyacinth improves efficiency the viscosity, rheology and API filtration loss of water bentonite mud better than sedge. Water hyacinth is relatively effective at concentration of 5 percent by weight, where the temperature does not affect the performance of drilling mud. The physical properties associated with the chemical properties related to the same direction with the effect of analysis XRD, XRF and SEM.

Table 4.9 Summarized comparison of the chemical and physical properties of drilling mud mixed with WH and SD additives

Samples	Temperature (°C)	Chemical property			Physical property										Cost analysis	Remarks
		XRF	XRD	SEM	Density	Viscosity					Filtrate loss	pH	Resistivity	Solid content		
						AV	PV	YP	n	K						
Based	30	SiO_2 = 66.53 Al_2O_3 = 11.694 Fe_2O_3 = 4.796 MgO = 3.915 BaO = 2.073	Bar = 51.84 Kao = 14.18 Qua = 25.8 Cal = 6.44	surface mud filter cake of the based mud shows uneven, thin sheet of bentonite clay larger and smaller particles of barite with compactness of individual grains and remains of the grains of the material is even though heating at 60 and 80°C	1.08	13.5	8	11	0.50	16.34	19	10.18	5.74	7.96	Bentonite price are 11.4 baht/kg. Barite price are 5 baht/kg.	API Standard
	60	SiO_2 = 65.999 Al_2O_3 = 15.578 Fe_2O_3 = 5.951 MgO = 4.651 BaO = 3.253	Bar = 57.73 Kao = 18.03 Qua = 20.08 Cal = 1.72		1.075	19.5	7	25	0.28	49.08	23	9.4	5.18	7.44		
	80	SiO_2 = 67.560 Al_2O_3 = 14.992 Fe_2O_3 = 5.931 MgO = 5.249 BaO = 2.029	Bar = 54.7 Kao = 18.7 Qua = 18.59 Cal = 6.14		1.075	32	8	48	0.19	21.46	24	9.2	3.45	6.74		

↑ = *Better*, ↓ = *Worse*, - = *Unaltered*

Table 4.9 Summarized comparison of the chemical and physical properties of drilling mud mixed with WH and SD additives (continued)

Samples	Temperature (°C)	Chemical property			Physical property										Cost analysis	Remarks
		XRF	XRD	SEM	Density	Viscosity					Filtrate loss	pH	Resistivity	Solid content		
						AV	PV	YP	n	K						
Water hyacinth (1%)	30	SiO_2 = 50.048 Al_2O_3 = 11.889 BaO = 3.263 MgO = 3.132 Fe_2O_3 = 5.365	Bar = 63.51 Kao = 26.61 Qua = 5.18 Cal = 0.41 Mag = 2.25	Mud filter cakes are dense on their surfaces and distributed of particles water hyacinth into pores of mud filter cakes in tight connection, with no big pores and filtrate loss is less.	↑	↑	-	↑	↓	↓	↑	↓	↑	↑	Prices of water hyacinth is cheaper than fluid loss control agent. They are cost effective and environmentally friendly.	Addition of 1% water hyacinth to the water based drilling mud samples improved the properties of density (at 30,60 and 80˚C), apparent viscosoty, plastic vicsosity (at 60 and 80˚C), yield point, n (at 60 and 80˚C), K, pH, and solid content.
	60	SiO_2 = 49.230 Al_2O_3 = 11.913 BaO = 4.028 MgO = 3.758 Fe_2O_3 = 6.249	Bar = 67.27 Kao = 22.6 Qua = 5.99 Cal = 0.35 Mag = 2.37		↑	↓	↑	↑	↑	↓	-	↑	↑	↑		
	80	SiO_2 = 47.954 Al_2O_3 = 11.621 BaO = 5.567 MgO = 3.948 Fe_2O_3 = 6.848	Bar = 66.01 Kao = 21.12 Qua = 8.29 Cal = 0.01 Mag = 3.44		↑	↓	↓	↓	↑	↓	↑	↓	↑	↑		

↑ = *Better*, ↓ = *Worse*, - = *Unaltered*

Table 4.9 Summarized comparison of the chemical and physical properties of drilling mud mixed with WH and SD additives (continued)

Samples	Temperature (°C)	Chemical property			Physical property										Cost analysis	Remarks
		XRF	XRD	SEM	Density	Viscosity					Filtrate loss	pH	Resistivity	Solid content		
						AV	PV	YP	n	K						
Water hyacinth (3%)	30	SiO_2 = 49.595 Al_2O_3 = 11.889 BaO = 3.263 MgO = 3.132 Fe_2O_3 = 5.365	Bar = 62.08 Kao = 28.48 Qua = 8.05 Mag = 0.88	Mud filter cakes are dense on their surfaces and distributed of particles water hyacinth into pores of mud filter cakes in tight connection, with no big pores and filtrate loss is less.	↑	↑	↑	↑	-	↓	↓	↓	↓	↑	Prices of water hyacinth is cheaper than fluid loss control agent. They are cost effective and environmentally friendly.	Addition of 3% Water hyacinth to the water based drilling mud samples improved the properties of density, apparent viscosity, plastic vicsosity, yield point, n, K, pH, and solid content.
	60	SiO_2 = 49.230 Al_2O_3 = 11.913 BaO = 4.028 MgO = 3.758 Fe_2O_3 = 6.249	Bar = 68.11 Kao = 20 Qua = 7.63 Cal = 0.22 Mag = 2.55		↑	↓	↑	↑	↑	↓	↓	↓	↓	↑		
	80	SiO_2 = 47.954Al_2O_3 = 11.621 BaO = 5.567 MgO = 3.948 Fe_2O_3 = 6.848	Bar = 67.7 Kao = 20.28 Qua = 8.11 Cal = 0.84 Mag = 1.94		↑	↑	↑	↓	↑	↑	↓	↓	↑	↑		

↑ = Better, ↓ = Worse, - = Unaltered

Table 4.9 Summarized comparison of the chemical and physical properties of drilling mud mixed with WH and SD additives (continued)

Samples	Temperature (°C)	Chemical property			Physical property										Cost analysis	Remarks
		XRF	XRD	SEM	Density	Viscosity					Filtrate loss	pH	Resistivity	Solid content		
						AV	PV	YP	n	K						
Water hyacinth (5%)	30	SiO_2 = 48.328 Al_2O_3 = 11.090 BaO = 5.142 MgO = 4.607 Fe_2O_3 = 7.971	Bar = 64.1 Kao = 28.61 Qua = 4.25 Cal = 0.27 Mag = 0.9	Mud filter cakes are dense on their surfaces and distributed of particles water hyacinth into pores of mud filter cakes in tight connection, with no big pores and filtrate loss is less.	↑	↑	↑	↑	↓	↑	↓	↓	↓	↑	Prices of water hyacinth is cheaper than fluid loss control agent. They are cost effective and environment ally friendly.	Addition of 5% Water hyacinth to the water based drilling mud samples improved the properties of density, apparent viscosity, plastic vicsosity, yield point, n, K, pH, and solid content.
	60	SiO_2 = 59.624 Al_2O_3 = 13.644 BaO = 7.734 MgO = 5.364 Fe_2O_3 = 10.048	Bar = 59.32 Kao = 21.97 Qua = 12.3 Mag = 2.74		↑	↑	↑	↑	↓	↑	↓	↓	↓	↑		
	80	SiO_2 = 50.048 Al_2O_3 = 14.308 BaO = 5.808 MgO = 5.023 Fe_2O_3 = 9.745	Bar = 67.67 Kao = 25.34 Qua = 5.16 Cal = 0.27		↑	↑	↑	↑	↑	↑	↓	↓	↑	↑		

↑ = *Better*, ↓ = *Worse*, - = *Unaltered*

Table 4.9 Summarized comparison of the chemical and physical properties of drilling mud mixed with WH and SD additives (continued)

Samples	Temperature (˚C)	Chemical property			Physical property										Cost analysis	Remarks
						Viscosity										
		XRF	XRD	SEM	Density	AV	PV	YP	n	K	Filtrate loss	pH	Resistivity	Solid content		
Sedge (1%)	30	SiO_2 = 50.048 Al_2O_3 = 11.889 Fe_2O_3 = 5.365 MgO = 3.132 BaO = 3.263	Bar = 57.83 Kao = 28.65 Qua = 9.45 Cal = 0.35 Mag = 2.58	fine particle of Sedge into the gap between bentonite and barite, but rough particle distributed on the surfaces of mud filter cakes, affect and engender to small pores between particle. However Sedge particle not even have a porous texture, thus can not absorb fluid, reduce filtration loss.	↑	↑	↓	↑	↓	↑	↑	↓	↓	↑	Prices of sedge is cheaper than fluid loss control agent. They are cost effective and environmentally friendly.	Addition of 1% Sedge to the water based drilling mud samples improved the properties of density (at 30 and 80˚C), apparent viscosity (at 30 and 60˚C), yield point (at 30 and 60˚C), K (at 30, 60 and 80˚C), filtrate loss and solid content.
	60	SiO_2 = 48.441 Al_2O_3 = 13.032 Fe_2O_3 = 6.754 BaO = 8.502	Bar = 64.82 Kao = 22.23 Qua = 9.99 Cal = 0.77 Mag = 0.05		↓	↑	↓	↑	↓	↑	↑	↓	↓	↑		
	80	SiO_2 = 48.226 Al_2O_3 = 11.953 Fe_2O_3 = 5.922 MgO = 3.869 BaO = 6.498	Bar =59.07 Kao = 23.12 Qua = 16.66 Cal = 0.01 Mag = 0.03		↑	↓	↓	↓	↓	↑	↑	↓	↑	↑		

↑ = *Better*, ↓ = *Worse*, - = *Unaltered*

Table 4.9 Summarized comparison of the chemical and physical properties of drilling mud mixed with WH and SD additives (continued)

Samples	Temperature (°C)	Chemical property			Physical property										Cost analysis	Remarks
		XRF	XRD	SEM	Density	Viscosity					Filtrate loss	pH	Resistivity	Solid content		
						AV	PV	YP	n	K						
Sedge (3%)	30	SiO_2 = 49.215 Al_2O_3 = 11.676 Fe_2O_3 = 6.487 MgO = 3.827 BaO = 4.451	Bar = 53.75 Kao = 35.43 Qua = 10.24 Cal = 0.18	fine particle of Sedge into the gap between bentonite and barite, but rough particle distributed on the surfaces of mud filter cakes, affect and engender to small pores between particle. However Sedge particle not even have a porous texture, thus can not absorb fluid, reduce filtration loss.	↑	↑	↓	↑	↓	↑	↑	↓	↓	↓	Prices of sedge is cheaper than fluid loss control agent. They are cost effective and environmentally friendly	Addition of 3% Sedge to the water based drilling mud samples improved the properties of density (at 30, 60 and 80˚C), apparent viscosity (at 30, 60 and 80˚C), yield point (at 30, 60 and 80˚C), K (at 30, 60 and 80˚C), filtrate loss (at 30, 60 and 80˚C).
	60	SiO_2 = 48.405 Al_2O_3 = 11.267 Fe_2O_3 = 6.079 MgO =4.691 BaO = 7.473	Bar = 59.93 Kao = 18.26 Qua = 13.98Cal = 1.42 Mag = 4.06		↑	↑	↓	↑	↓	↑	↑	↓	↓	↓		
	80	SiO_2 = 47.688 Al_2O_3 = 12.351 Fe_2O_3 = 6.469 BaO = 10.439	Bar = 67.07 Kao = 22.02 Qua = 4.54 Cal = 0.02 Mag = 2.76		↑	↑	↓	↑	↓	↑	↑	↓	↓	↓		

↑ = Better, ↓ = Worse, - = Unaltered

Table 4.9 Summarized comparison of the chemical and physical properties of drilling mud mixed with WH and SD additives (continued)

Samples	Temperature (°C)	Chemical property			Physical property										Cost analysis	Remarks
						Viscosity										
		XRF	XRD	SEM	Density	AV	PV	YP	n	K	Filtrate loss	pH	Resistivity	Solid content		
Sedge (5%)	30	SiO_2 = 63.483 Al_2O_3 = 15.587 Fe_2O_3 = 8.036 BaO = 8.235	Bar = 52.04 Kao = 37.73 Qua = 8.01 Cal = 0.34 Mag = 0.82	fine particle of Sedge into the gap between bentonite and barite, but rough particle distributed on the surfaces of mud filter cakes, affect and engender to small pores between particle. However Sedge particle not even have a porous texture, thus can not absorb fluid, reduce filtration loss.	↑	↑	↑	↑	↓	↑	↑	↓	↓	↓	Prices of sedge is cheaper than fluid loss control agent. They are cost effective and environmentally friendly	Addition of 5% Sedge to the water based drilling mud samples improved the properties of density, apparent viscosity, plastic viscosity, yield point (at 30, 60 and 80˚C), K (at 25 and 50˚C) and filtrate loss
	60	SiO_2 = 51.515 Al_2O_3 = 12.678 Fe_2O_3 = 6.968 BaO = 5.404	Bar = 56.86 Kao = 29.46 Qua = 9.39 Cal = 0.48 Mag = 3.13		↑	↑	↑	↑	↓	↑	↑	↓	↓	↓		
	80	SiO_2 = 51.753 Al_2O_3 = 13.530 Fe_2O_3 = 7.596 BaO = 3.318	Bar = 57.1Kao = 24.61 Qua = 15.97 Mag = 1.4		↑	↑	↑	↑	↓	↑	↑	↓	↓	↓		

↑ = *Better*, ↓ = *Worse*, - = *Unaltered*)

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter is divide into two parts, which are conclusions and recommendations. In conclusion part, it present the conclusion from two main sections (I) chemical property of drilling mud mixed with various additives, and (II) physical property of drilling mud mixed with water hyacinth and sedge, respectively. In recommendation part, it consist of some recommendations for the future study.

5.2 Conclusions

Based on the results of water hyacinth and sedge containing mud properties testing obtained from the study, some conclusions were reached as below.

5.2.1 Chemical properties

The chemical properties of drilling mud mixed with water hyacinth and sedge can be concluded the result as following:

1) Elemental composition and minerals

Result of elemental composition of drilling mud (base) mainly consist of SiO_2, SO_3, Fe_2O_3, MgO, BaO, and CaO. These change of mineral content can use by the variation of elemental composition in water hyacinth and sedge including K_2O, CaO, Cl, SiO_2, and MgO

Mineral result of drilling mud includes the barite, quartz, kaolinite, calcite, gypsum, magnesite and hematite.The content of barite, kaolinite, quartz, gypsum has increase after mixing with water hyacinth and sedge in the drilling mud.

Increasing of MgO and magnesite ($MgCO_3$) could be caused the improvement of rheology of drilling mud, due to the magnesium is the major element of bentonite $[(Na, Ca)_x (Al, Mg)_2 Si_4O_{10} (OH)_2.4H_2O]$ making the expansion property of drilling mud.

The results of element and mineral analysis found that the variation of temperature as 30, 60 and 80 °C, which is not affect to the content and structure of element and mineral of drilling mud. Hence, the drilling mud after mixed with additives is changed the content of elements and minerals that depended on the mixing ratio.

2) Characteristic and texture of materials

The results were analyzed by electron microscopy found that the rough surface of the sample with tightly packed components and remains of particle substances that through heating at a temperature of 30, 60 and 80 °C. The drilling mud mixed with water hyacinth there is a catch, and the interface between the various components tightly over the drilling mud mixed with sedge.

5.2.2 Physical properties

The physical properties of drilling mud mixed with water hyacinth and sedge can be summarized in each property follows:

1) Rheological properties

Viscosity properties of drilling mud mixed with the water hyacinth and sedge are the flow behavior index less than 1, which represent to the pseudo-plastic flow and shear thinning fluid.

The plastic viscosity of both drilling mud are slightly increased, which the drilling mud mixed with the water hyacinth more increased the plastic viscosity than drilling mud mixed with sedge. Therefore, the sedge could be the plastic viscosity property in drilling mud is better than the water hyacinth, due to the lower of plastic viscosity can prevents hole problems such as surge and swab pressure, differential stick and slow rate of penetration.

The apparent viscosity, plastic viscosity, yield point and gel strength of water hyacinth and sedge containing mud increase with increasing temperature while the plastic viscosity slightly increased with increasing temperature.

Drilling mud mixed with 5% weight by volume of water hyacinth powders concentration give appropriate rheological properties.

The result shows insignificant improvement of gel strength with an increasing water hyacinth and sedge concentration and temperature. the 10 minutes gel strength was greater than initial gel strength. This is because of more undisturbed mud standing time would lead mud to form stronger gel structure compared to less undisturbed time. From the experiment, it can be concluded that the presence of water hyacinth and sedge increase gel strength of mud which enhance hole cleaning efficiency of drilling fluid by suspend cutting and weighting material when circulation is ceased

1) Filtration properties

The API fluid loss values of water hyacinth containing mud indicate that better fluid loss control properties at 3 and 5 percent water hyacinth concentration compared to The API fluid loss values of sedge concentration.

Mud cake thickness of the drilling mud mixed with water hyacinth ranges from 2.33 to 3.92 mm. and the drilling mud mixed with sedge ranges from 3.58 to 7.67 mm. The slickness and toughness of sedge in drilling mud are more than water hyacinth in drilling mud. The presence of slickness and lubricity of mud cake that deposited by water hyacinth and sedge containing mud can lubricate drilling string while drilling

2) Other properties

Density: the increasing density depends on the amount of weighting materials. The density slightly decreases as the temperature increase; however, the concentration of additives increased as the density increased.

The pH value of drilling mud before mixing additives ranges from 9.16 to 10.31 at 30, 60 and 80 °C. The pH slightly decreases as the temperature increase. The pH value comparison showed that the pH of drilling mud mixed with the water hyacinth ranges to 7.37 to 8.62 and the drilling mud after mixed with the sedge rages to 7.0 to 8.4. These result represented that the water hyacinth making the pH value, which is slightly better than the sedge. However, the pH value of both additives is according in API standard (8-10 of pH value) of drilling fluid, indicating to it can minimize corrosion problems of steel in drilling mud circulation process.

Solid contents of drilling mud mixed with water hyacinth and sedge have increased as the increasing concentration. The temperature has affect to the solid content by the slightly increase of temperature increased resulting the solid content increase. The solid content comparison showed that the drilling mud mixed with sedge is more than drilling mud mixed with water hyacinth. However, the increasing of temperature effect to the solid content decreased. The increasing solid content has the effect as differential sticking, slower drilling rates, circulation and surge and swab pressure.

Resistivity of drilling mud before mixing additives rages from 3.42 to 5.80 Ω.m at 30, 60 and 80 °C. The temperature has affect to the resistivity value by the slightly decreased when. These result found that the resistivity of drilling mud after mixed with the water hyacinth and sedge range from 3.97 to 5.89 Ω.m. and 1.81 to 4.11Ω.m, respectively. The resistivity compared to the effect of water hyacinth more than sedge. The resistivity of mud filtrate is more than drilling mud and mud cake thickness, respectively.

5.2.3 Cost comparison

Comparison of cost and economic consideration, it clearly sees that the no cost of water hyacinth and sedge due to they were waste materials. The cost of two additives are cheaper than fluid loss control agent, but not commercial. Because of the cost does not include the cost of process materials, materials handling and storage, packaging, transport and other indirect materials. There is a processing fee shipping costs and environment costs only. Therefore, water hyacinth was suitable to be additive in water based drilling mud for rheological properties and fluid loss control properties and increases value to these additives.

5.3 Recommendations

The research, experimental and results lead to recommendation area for further studies including:

- It should be directed to study the thermal behavior of water hyacinth and sedge containing bentonite mud at elevated temperature more than 80 °C to limited range of usable temperature without serious thermal degradation of water hyacinth and sedge.
- The additive should be added at more than 5 percentages of additive concentration for test the property of drilling mud.
- To assess future performance of filtration loss or other properties in drilling mud, the lignin and cellulose of water hyacinth and sedge should be extracted before mixing.

- It should be tested all of sample in real conditions to know the characteristics of the actual borehole conditions.

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APPENDIX A

EXPERIMENTAL DATA

Filtration properties

Table A1 API static filtrate loss of drilling mud mixed with additives.

Temp. (°C)	No.	Filtrate loss (ml)					
		1 min	4 min	9 min	16 min	25 min	30 min
30 (Base)	1	2.5	6	10	12.5	17	19
60 (Base)	2	3	8	12.5	17	21	23
80 (Base)	3	3	8.5	14	17	22	24
30 (1%) Water Hyacinth	4	4	8	12.5	17	21.5	23.5
	5	3.5	7.75	12	16.25	20.5	22.5
	6	3.5	7.5	12	16.5	21.5	23
	AVG	3.67	7.75	12.17	16.58	21.17	23
30 (3%) Water Hyacinth	7	2.5	5.5	10.5	12	15	16.5
	8	2	5.5	9	12	16	16.5
	9	2	5	10	12	15.5	16.5
	AVG	2.17	5.33	9.83	12	15.5	16.5
30 (5%) Water Hyacinth	10	3	7.5	12	14.5	18	19
	11	3	8	12	14	16.5	18
	12	2.5	8	10	13.5	16.5	18
	AVG	2.83	7.83	11.33	14	17	18.33
30 (1%) Sedge	13	4	8	12.5	17	21.25	23.5
	14	3.5	7.75	12	16.25	20.5	22.5
	15	3.5	7.5	12	16.5	21.5	23
	AVG	3.67	7.75	12.17	16.58	21.08	23
30 (3%) Sedge	16	3.5	8	12.5	17	21.5	23.75
	17	3.5	7.5	12	16.5	21	23
	18	3.5	8	12	17	21	23.5
	AVG	3.5	7.83	12.17	16.83	21.17	23.42
30 (5%)Sedge	19	4	8	12.5	17	21.25	23.5
	20	3.5	7.75	12	16.25	20.5	22.5
	21	3.5	7.5	12	16.5	21.5	23
	AVG	3.67	7.75	12.17	16.58	21.08	23
60 (1%) Water Hyacinth	22	5	7.5	11	15	18.5	21
	23	3.5	7	11	14	18	19
	24	3	6.5	10	13	16.5	18
	AVG	3.83	7	10.67	14	17.67	19.33

Table A1 API static filtrate loss of drilling mud mixed with additives (continued).

Temp. (°C)	No.	Filtrate loss (ml)					
		1 min	4 min	9 min	16 min	25 min	30 min
60 (3%) Water Hyacinth	25	1.5	6	9	12	15	16
	26	1.5	5.5	8.5	12	15	15.5
	27	2	5	8	12.5	15.5	16
	AVG	1.67	5.5	8.5	12.17	15.17	15.83
60 (5%) Water Hyacinth	28	1	5.5	9.5	12.5	16.5	17.5
	29	1.5	6.5	9.5	12.5	15	16.5
	30	1.5	6	9.5	12.5	15.5	18
	AVG	1.3	6	9.5	12.5	15.6	17.3
60 (1%)Sedge	31	3	7.25	11.5	16	20	22
	32	3.5	8	12.5	17	21.75	24
	33	3.5	7.5	12	17	22	25
	AVG	3.333	7.583	12	16.67	21.25	23.67
60 (3%) Sedge	34	4.5	11	15	21	25	28
	35	6	12	17	22.5	25	29
	36	5	11	17.5	23	26	29
	AVG	5.167	11.33	16.5	22.16	25.33	28.67
60 (5%) Sedge	37	7	13.5	20.5	27.5	34.5	38
	38	8	14	20.5	27	33.5	38
	39	7.5	14	21	27.5	34	39
	AVG	7.5	13.83	20.66	27.33	34	38.33
80 (1%) Water Hyacinth	40	4	7.5	11	15.5	18	20
	41	2.5	7.5	10.5	14	18	19
	42	3	7.5	10	14.5	18	19.5
	AVG	3.17	7.5	10.5	14.67	18	19.5
80 (3%) Water Hyacinth	43	2.5	6.5	8	11	13	15
	44	2	6.5	8.5	11	12.5	14
	45	2	6.5	8.5	12	13	15
	AVG	2.167	6.5	8.33	11.33	12.83	14.67
80 (5%) Water Hyacinth	46	0.75	7	9	12	14	15
	47	1	6	8	11	13	15
	48	1	6.5	9.5	12	14.5	16
	AVG	0.917	6.5	8.83	11.67	13.83	15.33

Table A1 API static filtrate loss of drilling mud mixed with additives (continued).

Temp. (°C)	No.	Filtrate loss					
		1 min	**4 min**	**9 min**	**16 min**	**25 min**	**30 min**
80 (1%) Sedge	49	4	9.25	14.5	19.5	24.5	27
	50	3.5	8.25	12.5	17.5	22	24.5
	51	4	8.5	13.5	18	22	25
	AVG	3.83	8.67	13.5	18.33	22.83	25.5
80 (3%) Sedge	52	6.75	12.25	18.5	24	30.5	33.5
	53	7.5	13	20	26.75	33.5	36.75
	54	7.25	13	21	25.5	32.5	33.75
	AVG	7.17	12.75	19.83	25.42	32.17	34.67
80 (5%) Sedge	55	9.5	16	23	30	37.5	41
	56	10	18	25	32	39.5	43
	57	10.5	15.5	24	31	38.5	42
	AVG	10	16.5	24	31	38.5	42

Mudcake thickness data for all fluids tested.

Table A2 Mud cake thickness of the drilling mud mixed with additives

Temp. (°C)	No.	Mud cake thickness (mm.)			Average (mm.)
		#1	#2	#3	
30 (base)	1	2	2.4	2.08	2.16
60 (base)	2	3.24	3	3.56	3.26
80 (base)	3	4.2	4.06	4	4.08
30 (1%hyacinth)	4	2.54	2.5	2.4	2.48
	5	2	2.5	2.5	2.333
	6	2.5	2.5	2	2.333
	AVG				2.382
30 (3%hyacinth)	7	2	3	2.26	2.42
	8	3.28	3.02	2.48	2.927
	9	2.04	2.08	3.22	2.447
	AVG				2.337
30 (5%hyacinth)	10	4.2	4	3.5	3.9
	11	3.28	4.08	4.5	3.953
	12	3	4.5	4.2	3.9
	AVG				3.918
30 (1%sedge)	13	3.9	3.62	3.82	3.78
	14	3.82	3.9	3.72	3.813
	15	3.7	3.82	3.78	3.767
	AVG				3.786
30 (3%sedge)	16	3.7	3.52	3.54	3.587
	17	3.7	3.56	3.48	3.58
	18	3.65	3.58	3.56	3.597
	AVG				3.588
30 (5%sedge)	19	3.7	5.26	4.52	4.493
	20	6.38	4.76	5.46	5.533
	21	5.64	6.48	4.68	5.6
	AVG				5.209
60 (1%hyacinth)	22	2.24	2.5	3	2.58
	23	2.5	3.2	2.46	2.72
	24	2.32	3	2	2.44
	AVG				2.58

Table A2 Mud cake thickness of the drilling mud mixed with additives (continued).

Temp. (°C)	No.	Mud cake thickness (mm.)			Average (mm.)
		#1	#2	#3	
60 (3%hyacinth)	25	2	3.02	2.42	2.48
	26	2.04	2.46	3.02	2.507
	27	2.68	2.5	3	2.727
	AVG				2.571
60 (5%hyacinth)	28	4.02	4.14	4.04	4.067
	29	3.86	3.74	4.26	3.953
	30	4.54	4.68	3.44	4.22
	AVG				4.08
60 (1%sedge)	31	4.5	4.4	4.5	4.467
	32	5	4.5	4.5	4.667
	33	4.5	5	4.5	4.667
	AVG				4.6
60 (3%sedge)	34	4.82	4.72	4.58	4.7
	35	4.22	4.45	4.62	4.43
	36	4.56	4.84	4.62	4.67
	AVG				4.6
60 (5%sedge)	37	3.74	6.22	4.24	4.733
	38	6.3	6.36	8.92	7.193
	39	6.5	6.65	7.54	6.897
	AVG				6.274
80 (1%hyacinth)	40	3	2.58	2.45	2.67
	41	3.24	2.6	3	2.94
	42	3.22	3.04	2	2.75
	AVG				2.787
80 (3%hyacinth)	43	2.4	2.2	2	2.2
	44	2.24	2	3	2.41
	45	2	3.2	2	2.4
	AVG				2.597
80 (5%hyacinth)	46	4	4.42	4.48	4.3
	47	4	5	5.28	4.76
	48	5.25	4	4.42	4.56
	AVG				4.539

Table A2 Mud cake thickness of the drilling mud mixed with additives (continued).

Temp. (°C)	No.	Mud cake thickness (mm.)			Average (mm.)
		#1	#2	#3	
80 (1%sedge)	49	4.28	4.4	4.7	4.46
	50	5.08	6.14	5.38	5.533
	51	5.1	5.42	5.22	5.247
	AVG				5.08
80 (3%sedge)	52	6.28	6.8	6.6	6.56
	53	6	6.2	7.98	6.727
	54	6.5	6.42	6.39	6.437
	AVG				6.574
80(5%)Sd	55	8	6.98	8.04	7.673
	56	8.4	7.2	6.6	7.4
	57	7.62	7.54	7.82	7.66
	AVG				7.578

Density for all tested.

Table A3 Density of the drilling mud mixed with additives.

Temperature,°C	No.	Fluid density		
		g/cm^3	lb/gal	lb/ft^3
30 (base)	1	1.08	9.013037	67.422199
60 (base)	2	1.075	8.97131	67.422199
80 (base)	3	1.075	8.97131	67.422199
30 (1%)hy	4	1.09	9.096491	68.046479
	5	1.08	9.013037	67.422199
	6	1.09	9.096491	68.046479
AVG		1.0866667	9.068673	67.838386
30 (3%)hy	7	1.1	9.179945	68.670758
	8	1.08	9.013037	67.422199
	9	1.1	9.179945	68.670758
AVG		1.0933333	9.124309	68.254572
30 (5%)hy	10	1.09	9.096491	68.046479
	11	1.1	9.179945	68.670758
	12	1.1	9.179945	68.670758
AVG		1.096667	9.152127	68.46267
30 (1%)Sd	13	1.08	9.096491	67.422199
	14	1.08	9.013037	67.422199
	15	1.1	9.013037	68.670758
AVG		1.0866667	9.040855	67.838385
30 (3%)Sd	16	1.09	9.013037	68.046479
	17	1.08	9.013037	67.422199
	18	1.08	9.179945	67.422199
AVG		1.0833333	9.068673	67.630292
30 (5%)Sd	19	1.09	9.096491	68.046479
	20	1.09	9.096491	68.046479
	21	1.09	9.096491	68.046479
AVG		1.09	9.096491	68.04648
60 (1%)hy	22	1.075	8.97131	67.422199
	23	1.07	8.929583	66.797919
	24	1.09	9.096491	68.046479
AVG		1.0783333	8.999128	67.422199

Table A3 Density of the drilling mud mixed with additives (continued).

Temperature,°C	No.	Fluid density		
		g/cm^3	lb/gal	lb/ft^3
60 (3%)hy	25	1.08	9.013037	67.422199
	26	1.08	9.013037	67.422199
	27	1.08	9.013037	67.422199
AVG		1.08	9.013037	67.422199
60 (5%)hy	28	1.1	9.096491	68.670758
	29	1.09	9.096491	68.046479
	30	1.1	9.096491	68.670758
AVG		1.096667	9.096491	68.46267
60 (1%)Sd	31	1.09	9.096491	68.046479
	32	1.08	9.013037	67.422199
	33	1.08	9.013037	67.422199
AVG		1.0833333	9.040855	67.630292
60 (3%)Sd	34	1.09	9.096491	68.046479
	35	1.09	9.096491	68.046479
	36	1.08	9.013037	67.422199
AVG		1.0866667	9.068673	67.838386
60 (5%)Sd	37	1.09	9.096491	68.046479
	38	1.085	9.054764	67.734339
	39	1.1	9.179945	68.670758
AVG		1.0917	9.1104	68.151
80 (1%)hy	40	1.08	9.013037	67.422199
	41	1.07	8.929583	66.797919
	42	1.09	9.096491	68.046479
AVG		1.08	9.013037	67.422199
80 (3%)hy	43	1.08	9.013037	67.422199
	44	1.09	8.929583	68.046479
	45	1.08	9.096491	67.422199
AVG		1.0833333	9.013037	67.630292
80 (5%)hy	46	1.1	9.013037	68.670758
	47	1.09	8.929583	68.046479
	48	1.1	9.096491	68.670758
AVG		1.096667	9.013037	68.46267

Table A3 Density of the drilling mud mixed with additives (continued).

Temperature,°C	No.	Fluid density		
		g/cm^3	lb/gal	lb/ft^3
80 (1%)Sd	49	1.08	9.013037	67.422199
	50	1.09	8.929583	68.046479
	51	1.07	9.096491	66.797919
AVG		1.08	9.013037	67.422199
80 (3%)Sd	52	1.08	9.013037	67.422199
	53	1.09	8.929583	68.046479
	54	1.09	9.096491	68.046479
AVG		1.0866667	9.013037	67.838386
80 (5%)Sd	55	1.1	9.013037	68.670758
	56	1.09	8.929583	68.046479
	57	1.1	9.096491	68.670758
AVG		1.096667	9.013037	68.46267

The pH data for all tested

Table A4 The pH of drilling mud.

Temperature,°C	No.	Sample	(pH)			Average
			#1	#2	#3	
30 (base)	1	Mud	10.31	10.23	10.02	10.19
		Mud filtrate	9.78	9.96	9.72	9.82
60 (base)	2	Mud	9.37	9.49	9.42	9.43
		Mud filtrate	8.78	9.21	8.92	8.97
80 (base)	3	Mud	9.16	9.23	9.22	9.20
		Mud filtrate	8.97	8.86	9.04	8.96

Table A5 The temperature effect of water hyacinth and sedge concentration

Temperature,°C	No.	Sample	(pH)			Average
			#1	#2	#3	
30 (1%hyacinth)	4	Mud	8.86	8.47	8.55	8.6266667
		Mud filtrate	8.57	8.68	8.54	8.5966667
	5	Mud	8.45	8.87	8.65	8.6566667
		Mud filtrate	8.56	5.47	8.84	7.6233333
	6	Mud	8.74	8.57	8.48	8.5966667
		Mud filtrate	8.52	8.59	8.46	8.5233333
30 (3%hyacinth)	7	Mud	8.04	8.14	8.27	8.15
		Mud filtrate	8.12	8.18	8.19	8.1633333
	8	Mud	8.34	8.27	8.36	8.3233333
		Mud filtrate	8.25	8.34	8.26	8.2833333
	9	Mud	8.25	8.12	8.29	8.22
		Mud filtrate	8.09	8.02	8.1	8.07
30 (5%hyacinth)	10	Mud	7.47	7.42	7.53	7.4733333
		Mud filtrate	7.52	7.55	7.59	7.5533333
	11	Mud	7.56	7.62	7.58	7.5866667
		Mud filtrate	7.46	7.42	7.57	7.4833333
	12	Mud	7.46	7.49	7.52	7.49
		Mud filtrate	7.46	7.54	7.43	7.4766667
30 (1%sedge)	13	Mud	8.45	8.47	8.52	8.48
		Mud filtrate	8.21	8.23	8.32	8.2533333
	14	Mud	8.27	8.24	8.35	8.2866667
		Mud filtrate	8.32	8.47	8.27	8.3533333
	15	Mud	8.46	8.49	8.42	8.4566667
		Mud filtrate	8.47	8.53	8.49	8.4966667
30 (3%sedge)	16	Mud	7.74	7.68	7.7	7.7066667
		Mud filtrate	7.71	7.84	7.75	7.7666667
	17	Mud	7.6	7.57	7.62	7.5966667
		Mud filtrate	7.8	7.86	7.83	7.83
	18	Mud	7.76	7.84	7.79	7.7966667
		Mud filtrate	7.96	7.85	7.93	7.9133333

Table A5 The temperature effect of water hyacinth and sedge concentration (continued)

Temperature,°C	No.	Sample	(pH) #1	#2	#3	Average
30 (5%sedge)	19	Mud	7.21	7.27	7.23	7.2366667
		Mud filtrate	7.56	7.67	7.43	7.5533333
	20	Mud	7.62	7.57	7.49	7.56
		Mud filtrate	8.12	7.98	8.03	8.0433333
	21	Mud	7.52	7.56	7.45	7.51
		Mud filtrate	7.64	7.53	7.72	7.63
60 (1%hyacinth)	22	Mud	8.86	8.78	8.67	8.77
		Mud filtrate	8.86	8.74	8.92	8.84
	23	Mud	8.47	8.62	8.43	8.5066667
		Mud filtrate	8.47	8.53	8.49	8.4966667
	24	Mud	8.55	8.63	8.52	8.5666667
		Mud filtrate	8.54	8.65	8.51	8.5666667
60 (3%hyacinth)	25	Mud	8.12	8.17	8.21	8.1666667
		Mud filtrate	8.31	8.28	8.32	8.3033333
	26	Mud	7.97	7.86	8.02	7.95
		Mud filtrate	8.24	8.29	8.23	8.2533333
	27	Mud	8.09	8.12	8.1	8.1033333
		Mud filtrate	8.21	8.27	8.25	8.2433333
60 (5%hyacinth)	28	Mud	7.37	7.42	7.39	7.3933333
		Mud filtrate	7.57	7.63	7.47	7.5566667
	29	Mud	7.67	7.53	7.59	7.5966667
		Mud filtrate	7.46	7.35	7.52	7.4433333
	30	Mud	7.89	7.87	7.94	7.9
		Mud filtrate	7.79	7.87	7.65	7.77
60 (1%sedge)	31	Mud	8.35	8.37	8.29	8.3366667
		Mud filtrate	8.53	8.42	8.61	8.52
	32	Mud	8.23	8.21	8.19	8.21
		Mud filtrate	8.6	8.54	8.62	8.5866667
	33	Mud	7.98	8.12	8.02	8.04
		Mud filtrate	8.45	8.47	8.42	8.4466667

Table A5 The temperature effect of water hyacinth and sedge concentration (continued)

Temperature,°C	No.	Sample	(pH) #1	#2	#3	Average
60 (3%sedge)	34	Mud	7.53	7.67	7.49	7.5633333
		Mud filtrate	7.52	7.53	7.48	7.51
	35	Mud	7.67	7.69	7.58	7.6466667
		Mud filtrate	7.59	7.56	7.63	7.5933333
	36	Mud	7.46	7.52	7.49	7.49
		Mud filtrate	7.68	7.59	7.72	7.6633333
60 (5%sedge)	37	Mud	7.23	7.21	7.35	7.2633333
		Mud filtrate	7.09	7.06	7.28	7.1433333
	38	Mud	7.23	7.27	7.18	7.2266667
		Mud filtrate	7.12	7.21	7.09	7.14
	39	Mud	7.34	7.28	7.4	7.34
		Mud filtrate	7.17	7.14	7.23	7.18
80 (1%hyacinth)	40	Mud	8.1	8.21	8.12	8.1433333
		Mud filtrate	8.12	8.08	8.1	8.1
	41	Mud	8.37	8.29	8.32	8.3266667
		Mud filtrate	8.34	8.36	8.27	8.3233333
	42	Mud	8.39	8.32	8.25	8.32
		Mud filtrate	8.37	8.38	8.26	8.3366667
80 (3%hyacinth)	43	Mud	8.26	8.28	8.21	8.25
		Mud filtrate	8.07	8.16	8.04	8.09
	44	Mud	8.12	8.17	8.07	8.12
		Mud filtrate	8.14	8.19	8.08	8.1366667
	45	Mud	8.06	8.15	8.02	8.0766667
		Mud filtrate	8.12	8.19	8.1	8.1366667
80 (5%hyacinth)	46	Mud	7.64	7.67	7.63	7.6466667
		Mud filtrate	7.12	7.16	7.1	7.1266667
	47	Mud	7.24	7.27	7.23	7.2466667
		Mud filtrate	7.25	7.28	7.17	7.2333333
	48	Mud	7.22	7.28	7.15	7.2166667
		Mud filtrate	7.34	7.38	7.29	7.3366667

Table A5 The temperature effect of water hyacinth and sedge concentration (continued)

Temperature,°C	No.	Sample	(pH)			Average
			#1	#2	#3	
80 (1%sedge)	49	Mud	8.33	8.36	8.31	8.3333333
		Mud filtrate	8.32	8.29	8.3	8.3033333
	50	Mud	8.4	8.42	3.38	6.7333333
		Mud filtrate	8.37	8.29	8.35	8.3366667
	51	Mud	8.39	8.37	8.4	8.3866667
		Mud filtrate	8.37	8.34	8.36	8.3566667
80 (3%sedge)	52	Mud	7.63	7.72	7.6	7.65
		Mud filtrate	7.23	7.27	7.16	7.22
	53	Mud	7.28	7.19	7.24	7.2366667
		Mud filtrate	7.21	7.25	7.2	7.22
	54	Mud	7.48	7.37	7.45	7.4333333
		Mud filtrate	7.35	7.29	7.34	7.3266667
80 (5%sedge)	55	6.98	7.04	7.03	7.0166667	7.2633333
		7.12	7.16	7.08	7.12	7.1433333
	56	6.8	6.98	7.03	6.9366667	7.2266667
		7.36	7.29	7.34	7.33	7.14
	57	7.05	7.12	7.09	7.0866667	7.34
		7.37	7.29	7.32	7.3266667	7.18

Resistivity data for all tested.

Table A6 Resistivity of drilling mud

Sample		Temp. (oF)	#1	#2	#3	Average (Ω.m)
			Ω.m			
30 °C (Base)	Mud	75.4	5.8	5.78	5.64	5.74
	Mud filtrate	74.7	9.77	9.25	9.42	9.48
	Mud cake	75.4	4.89	4.28	4.74	4.64
60 °C (Base)	Mud	80	5.1	5.23	5.21	5.18
	Mud filtrate	88	8.37	8.45	8.28	8.37
	Mud cake	78.3	4.68	4.52	4.23	4.48
80 °C (Base)	Mud	80.2	3.53	3.68	3.42	3.54
	Mud filtrate	79.8	7.27	7.42	7.54	7.41
	Mud cake	77.4	3.81	3.49	3.63	3.64
30 °C (1% water hyacinth)	Mud	76.2	5.89	5.74	5.63	5.75
	Mud filtrate	77.8	6.03	5.95	5.86	5.94
	Mud cake	76.8	4.37	4.65	4.21	4.41
30 °C (3% water hyacinth)	Mud	77.3	4.56	4.69	3.95	4.4
	Mud filtrate	74.7	4.84	4.53	4.35	4.57
	Mud cake	77	3.78	3.67	3.87	3.77
30 °C (5% water hyacinth)	Mud	76	4.43	4.92	4	4.45
	Mud filtrate	77.3	4.87	4.57	4.78	4.74
	Mud cake	75.5	3.78	3.76	3.64	3.73
30 °C (1% sedge)	Mud	75.4	4.1	4.13	4.09	4.11
	Mud filtrate	76	4.77	4.8	4.75	4.77
	Mud cake	74.7	3.4	3.5	3.64	3.51

Table A6 Resistivity of drilling mud (continued).

Sample		Temp.	#1	#2	#3	Average
		(°F)	Ω.m			(Ω.m)
30 °C (3% sedge)	Mud	79	2.32	2.28	2.67	2.42
	Mud filtrate	78.8	2.59	2.67	2.52	2.59
	Mud cake	78.6	2.02	2.08	2.1	2.07
30 °C (5% sedge)	Mud	78.6	1.9	1.65	1.95	1.83
	Mud filtrate	77.5	2.1	1.98	2.21	2.10
	Mud cake	77.2	1.88	1.85	1.75	1.83
60 °C (1% water hyacinth)	Mud	77.5	5.5	5.47	5.2	5.39
	Mud filtrate	76.9	5.77	5.27	5.17	5.40
	Mud cake	74.2	5.34	5.12	5.02	5.16
60 °C (3% water hyacinth)	Mud	78.4	4.46	4.57	4.24	4.42
	Mud filtrate	77.6	4.42	4.45	4.39	4.42
	Mud cake	77.4	4.34	4.47	4.23	4.35
60 °C (5% water hyacinth)	Mud	77.6	4.08	4.19	4.68	4.32
	Mud filtrate	78.2	4.38	4.85	4.42	4.55
	Mud cake	74.3	4.27	4.21	4.52	4.33
60 °C (1% sedge)	Mud	77.6	4.08	4.03	4.03	4.05
	Mud filtrate	78.2	4.52	4.47	4.77	4.59
	Mud cake	77.8	2.79	2.75	2.79	2.78
60 °C (3% sedge)	Mud	77.2	2.3	2.29	2.38	2.32
	Mud filtrate	76.8	3.41	2.83	2.3	2.85
	Mud cake	75.7	2.08	2.11	2.15	2.11

Table A6 Resistivity of drilling mud (continued).

Sample		Temp.	#1	#2	#3	Average
		(°F)	Ω.m			(Ω.m)
60 °C (5% sedge)	Mud	778.8	1.45	1.62	1.64	1.57
	Mud filtrate	80.9	1.68	1.7	1.72	1.7
	Mud cake	81	1.6	1.65	1.57	1.61
80 °C (1% water hyacinth)	Mud	87.6	4.7	4.45	4.47	4.54
	Mud filtrate	86.2	5.12	5.27	5.17	5.19
	Mud cake	86.4	5.06	5.04	5.21	5.10
80 °C (3% water hyacinth)	Mud	84.6	4.15	4.35	4.21	4.24
	Mud filtrate	84.2	4.77	4.15	4.17	4.36
	Mud cake	83.2	4.67	4.21	4.32	4.4
80 °C (5% water hyacinth)	Mud	97.4	4.25	4.34	3.94	4.18
	Mud filtrate	97.6	4.42	4.45	4.17	4.35
	Mud cake	98	4.47	4.52	4.12	4.37
80 °C (1% sedge)	Mud	79.8	3.98	3.87	3.95	3.93
	Mud filtrate	87.8	5.21	5.19	5.19	5.20
	Mud cake	77.7	3.57	3.63	3.48	3.56
80 °C (3% sedge)	Mud	*79*	2.28	1.99	2.05	2.11
	Mud filtrate	85.2	2.44	2.2	2.34	2.33
	Mud cake	75.3	2.06	2.08	2.03	2.056
80 °C (5% sedge)	Mud	79.8	1.97	1.9	1.81	1.89
	Mud filtrate	89.3	2.38	1.87	1.98	2.08
	Mud cake	78.2	1.63	1.58	1.57	1.59

Solid contents data for all fluids tested.

Table A7 Solid contents all drilling mud.

Samples	No.	Mud	Weight	Weight	Weight	Weight	% Solid	100%
Base	1	1.08	54	1541.28	1595.28	1549.26	0.0796	7.96
Base	2	1.075	53.75	1538.24	1591.99	1545.71	0.0744	7.44
Base	3	1.075	53.75	1538.58	1592.33	1545.70	0.0674	6.74
30 (1%)hy	4	1.09	54.5	1537.28	1591.78	1546.2	0.0884	8.84
	5	1.08	54	1541.23	1595.23	1549.62	0.0878	8.78
	6	1.09	54.5	1540.2	1594.7	1549.3	0.092	9.2
30 (3%)hy	7	1.1	55	1542.6	1597.6	1551.64	0.0808	8.08
	8	1.08	54	1541.86	1595.86	1550.22	0.0872	8.72
	9	1.1	55	1537.29	1592.29	1546.51	0.0844	8.44
30 (5%)hy	10	1.09	54.5	1539.74	1594.24	1549.24	0.1	10
	11	1.1	55	1542.36	1597.36	1552.32	0.0992	9.92
	12	1.1	55	1537.21	1592.21	1547.2	0.0998	9.98
30 (1%)Sd	13	1.08	54	1542.67	1596.67	1552.6	0.1186	11.86
	14	1.08	54	1540.39	1594.39	1549.23	0.0968	9.68
	15	1.1	55	1539.25	1594.25	1548.74	0.0898	8.98
30 (3%)Sd	16	1.08	54	1538.96	1592.96	1547.52	0.0912	9.12
	17	1.09	54.5	1539.82	1594.32	1547.28	0.0592	5.92
	18	1.09	54.5	1542.32	1596.82	1548.36	0.0308	3.08
30 (5%)Sd	19	1.1	55	1541.58	1596.58	1551.24	0.0932	9.32
	20	1.09	54.5	1540.39	1594.89	1548.42	0.0706	7.06
	21	1.1	55	1542.47	1597.47	1551.27	0.076	7.6
60 (1%)hy	22	1.075	53.75	1541.22	1594.97	1550.08	0.1022	10.22
	23	1.07	53.5	1537.84	1591.34	1547.26	0.1184	11.84
	24	1.09	54.5	1539.34	1593.84	1548.34	0.09	9
60 (3%)hy	25	1.08	54	1538.28	1592.28	1547.04	0.0952	9.52
	26	1.08	54	1540.74	1594.74	1549.62	0.0976	9.76
	27	1.08	54	1542.04	1596.04	1547.14	0.022	2.2
60 (5%)hy	28	1.1	55	1541.65	1596.65	1549.29	0.0528	5.28
	29	1.09	54.5	1538.92	1593.42	1548.24	0.0964	9.64
	30	1.1	55	1537.26	1592.26	1547.28	0.1004	10.04

Table A7 Solid contents all drilling mud (continued)

	No	Mud	Weight	Weight	Weight	Weight	% Solid	100%
60 (1%)Sd	31	1.09	54.5	1539.78	1594.28	1547.36	0.0616	6.16
	32	1.08	54	1537.98	1591.98	1547.94	0.1192	11.92
	33	1.08	54	1541.58	1595.58	1549.86	0.0856	8.56
60 (3%)Sd	34	1.09	54.5	1541.36	1595.86	1551.02	0.1032	10.32
	35	1.09	54.5	1539.21	1593.71	1550.36	0.133	13.3
	36	1.08	54	1541.64	1595.64	1551.48	0.1168	11.68
60 (5%)Sd	37	1.09	54.5	1542.17	1596.67	1549.09	0.0484	4.84
	38	1.085	54.25	1541.26	1595.51	1548.54	0.0606	6.06
	39	1.1	55	1538.57	1593.57	1549.63	0.1212	12.12
80 (1%)hy	40	1.08	54	1539.76	1593.76	1547.76	0.08	8
	41	1.07	53.5	1542.29	1595.79	1551.24	0.109	10.9
	42	1.09	54.5	1542.32	1596.82	1548.05	0.0246	2.46
80 (3%)hy	43	1.08	54	1541.21	1595.21	1552.07	0.1372	13.72
	44	1.09	54.5	1541.96	1596.46	1551.52	0.1012	10.12
	45	1.08	54	1539.48	1593.48	1551.24	0.1552	15.52
80 (5%)hy	46	1.1	55	1537.29	1592.29	1551.94	0.193	19.3
	47	1.09	54.5	1542.41	1596.91	1550.21	0.066	6.6
	48	1.1	55	1542.28	1597.28	1551.35	0.0814	8.14
80 (1%)Sd	49	1.08	54	1541.64	1595.64	1551.08	0.1088	10.88
	50	1.09	54.5	1539.29	1593.79	1549.58	0.1158	11.58
	51	1.07	53.5	1537.56	1591.06	1548.14	0.1416	14.16
80 (3%)Sd	52	1.09	54.5	1539.25	1593.75	1549.28	0.1106	11.06
	53	1.08	54	1542.32	1596.32	1551.04	0.0944	9.44
	54	1.08	54	1541.14	1595.14	1551.32	0.1236	12.36
80 (5%)Sd	55	1.09	54.5	1539.24	1593.74	1549.24	0.11	11
	56	1.09	54.5	1538.79	1593.29	1549.51	0.1244	12.44
	57	1.09	54.5	1539.29	1593.79	1548.04	0.085	8.5

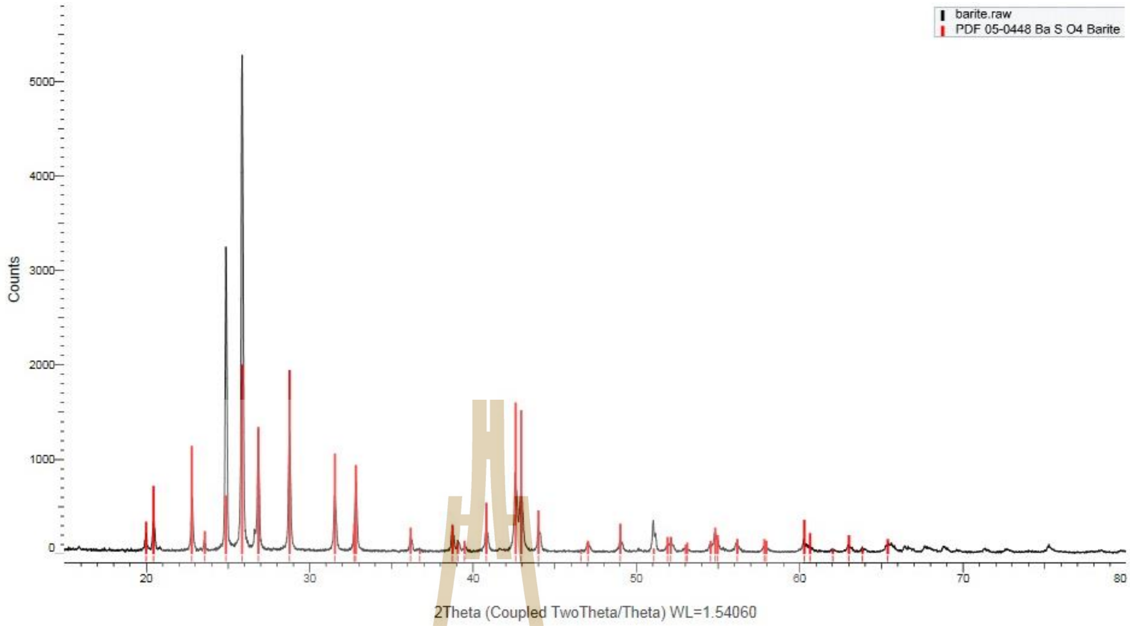

Figure A1. XRD of Barite.

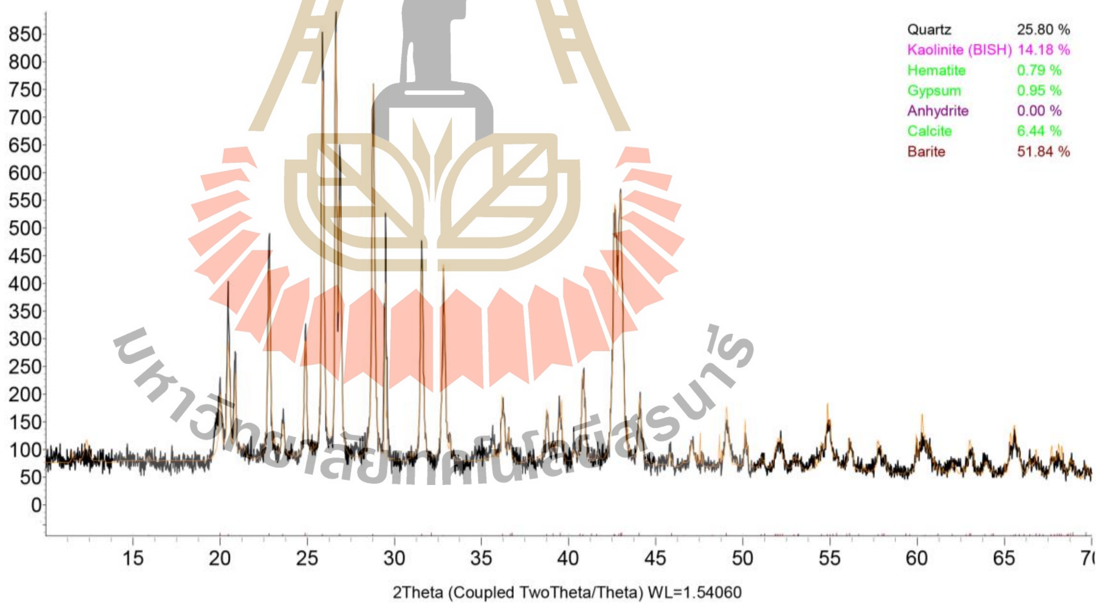

Figure A2. XRD of water-based drilling mud at 30°C.

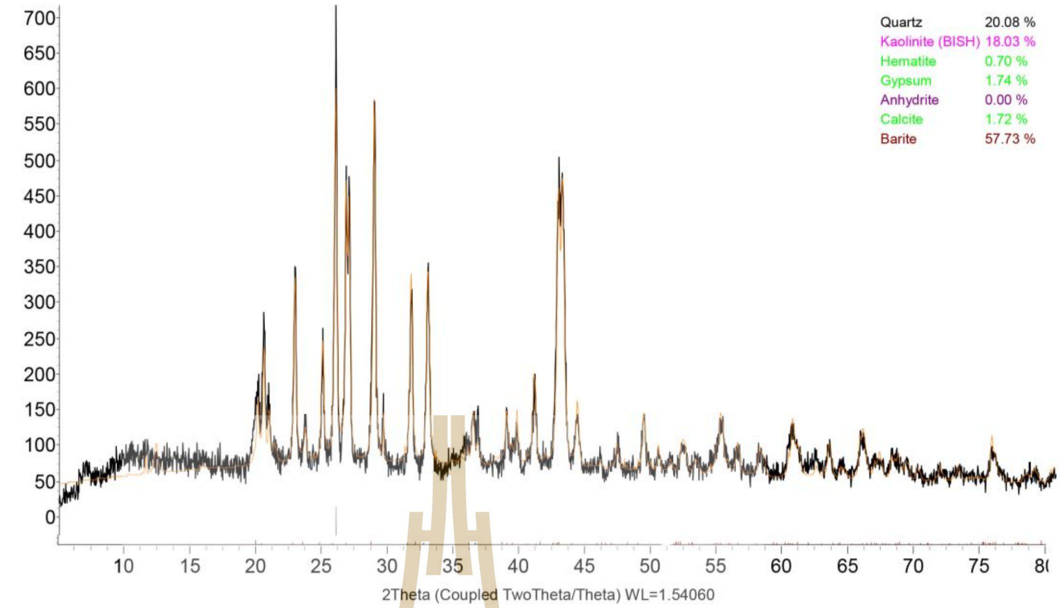

Figure A3. XRD of water-based drilling mud at 60°C .

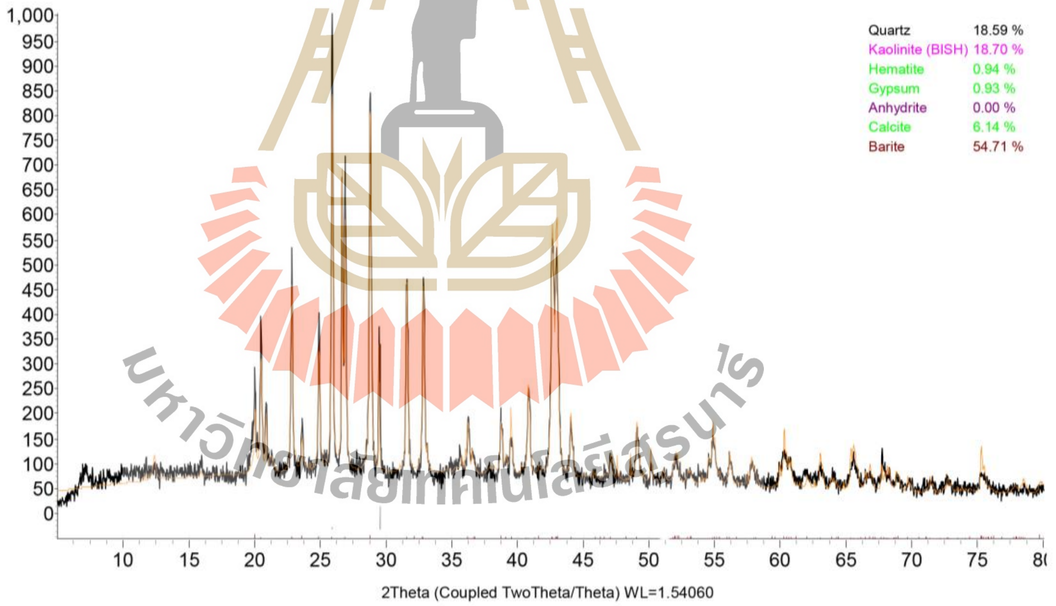

Figure A4. XRD of water-based drilling mud at 80°C.

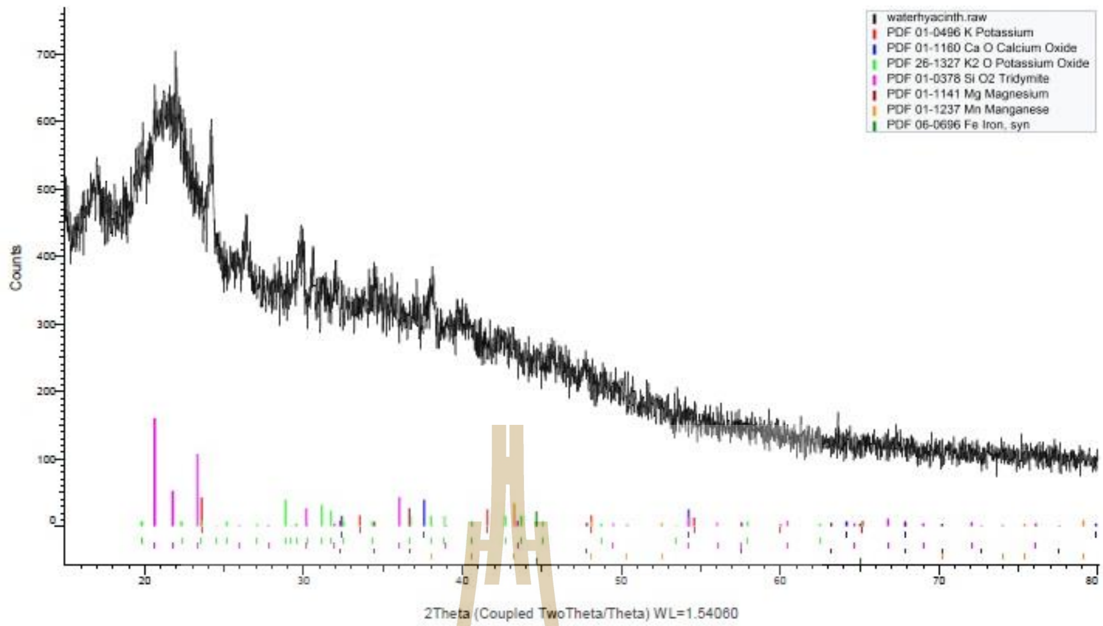

Figure A5. XRD of water hyacinth powder.

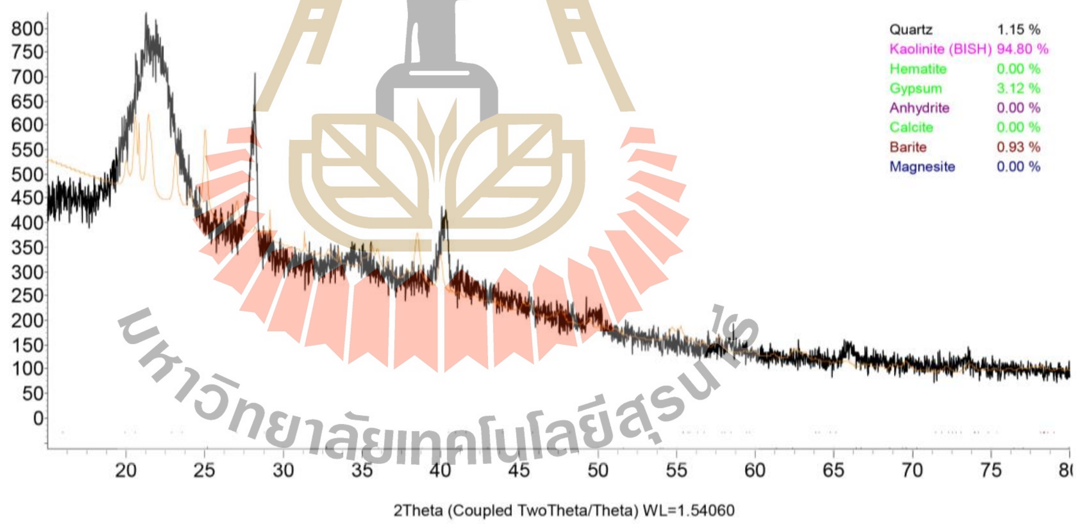

Figure A6. XRD of sedge powder**.**

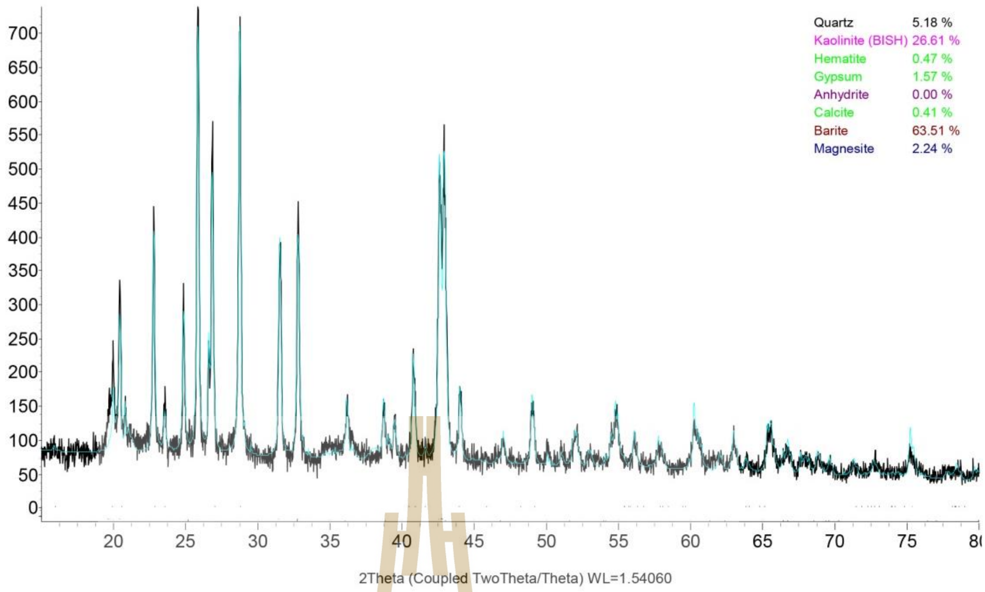

Figure A7. XRD of water-based drilling mud mixed 1 percentage of water hyacinth powder at 30°C.

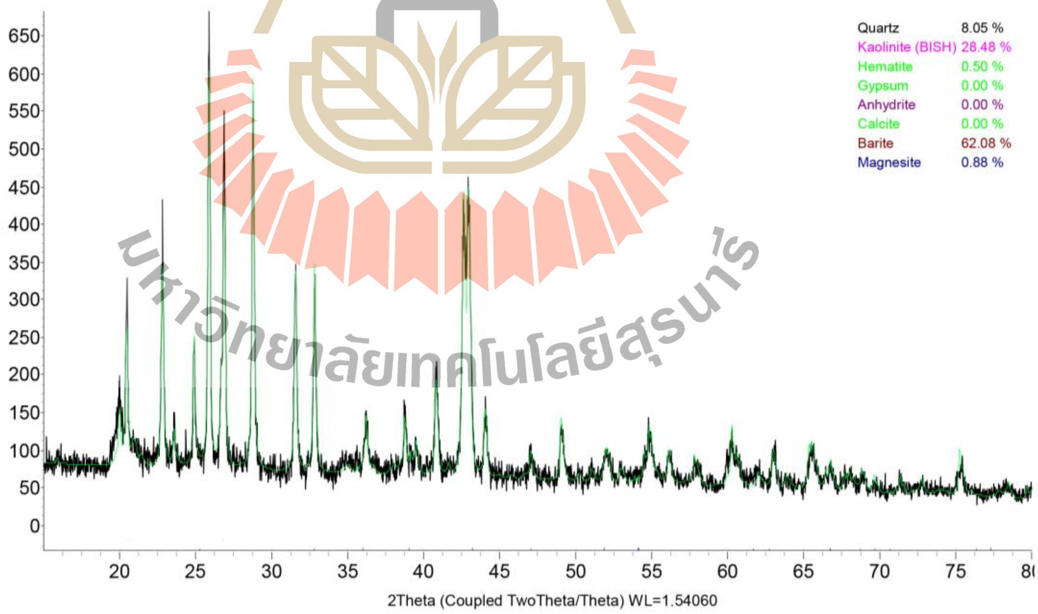

Figure A8. XRD of water-based drilling mud mixed 3 percentage of water hyacinth powder at 30°C.

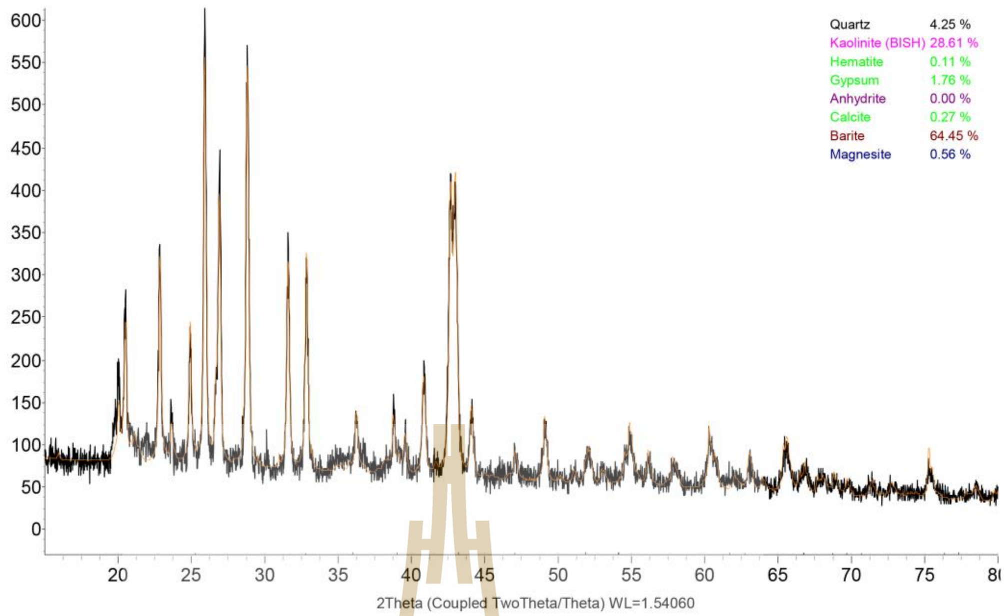

Figure A9. XRD of water-based drilling mud mixed 5 percentage of water hyacinth powder at 30°C.

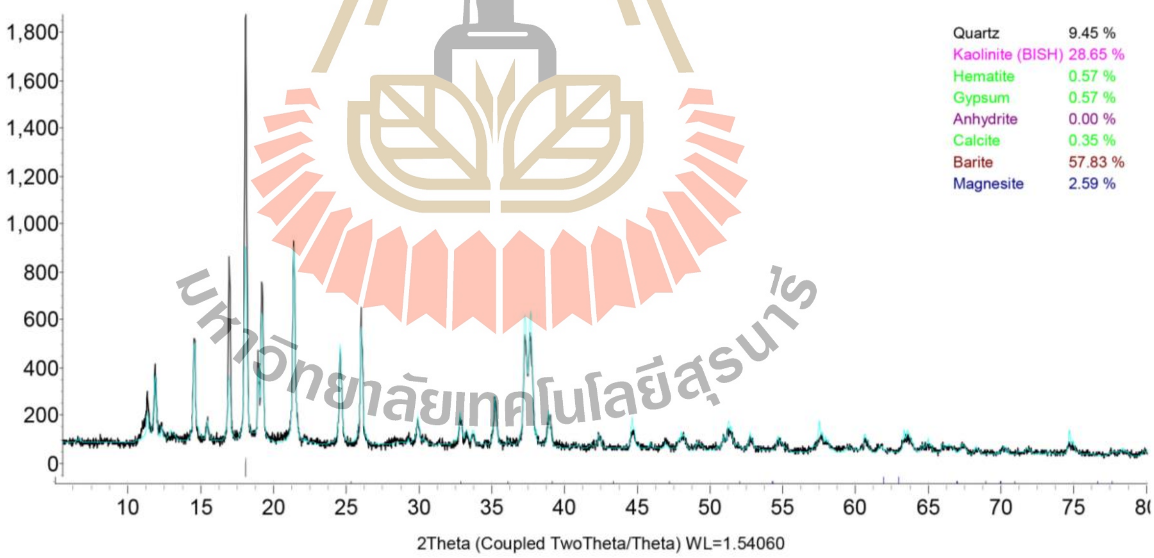

Figure A10. XRD of water-based drilling mud mixed 1 percentage of sedge powder at 30°C.

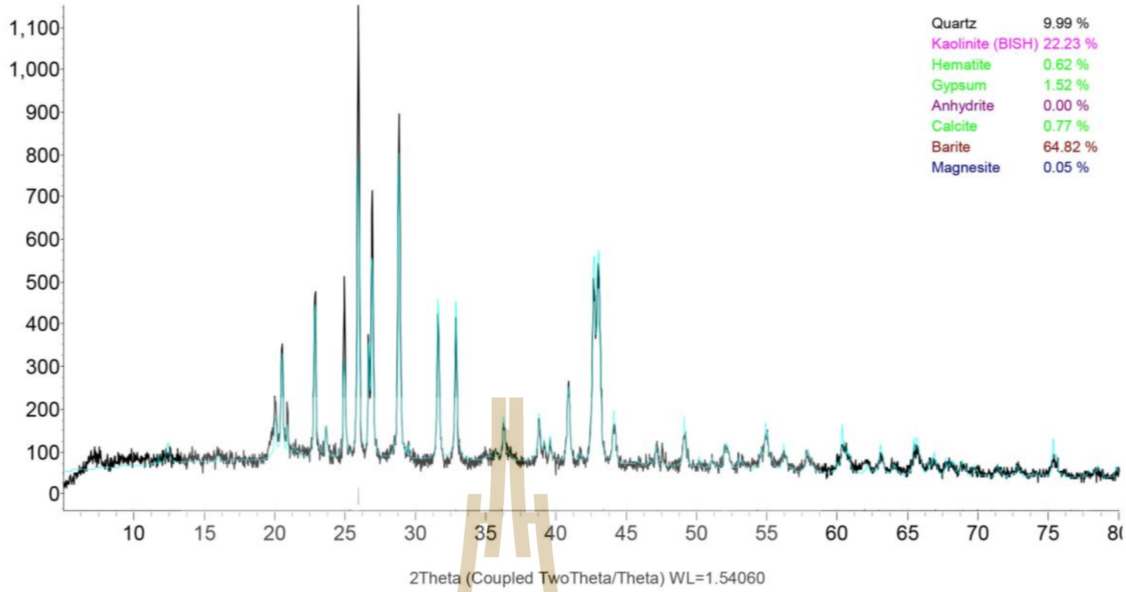

Figure A11. XRD of water-based drilling mud mixed 3 percentage of sedge powder at 30°C**.**

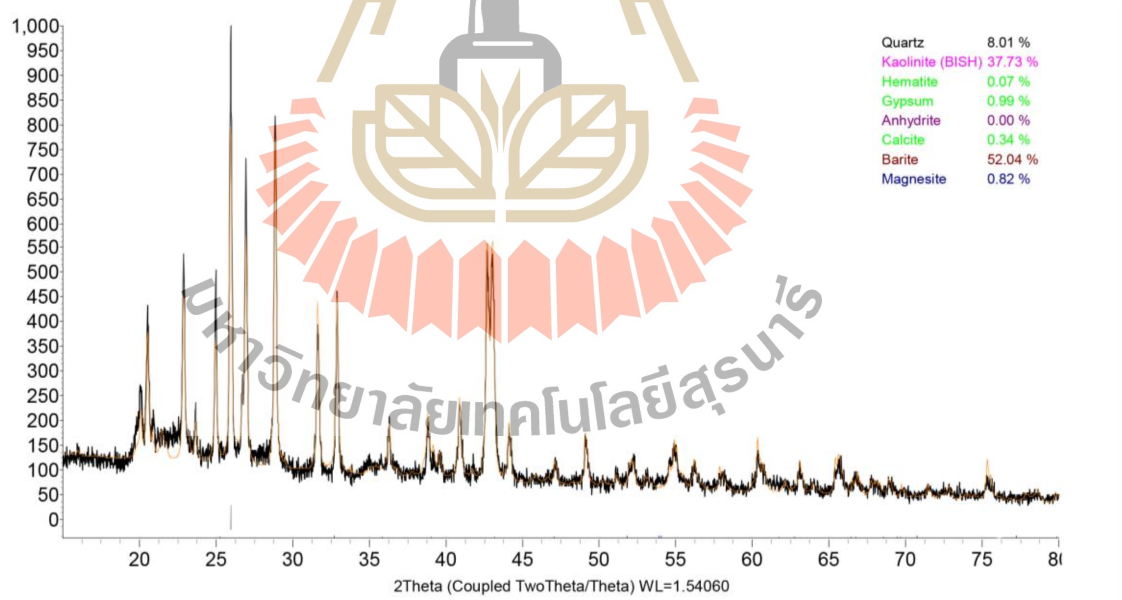

Figure A12. XRD of water-based drilling mud mixed 5 percentage of sedge powder at 30°C.

BIOGRAPHY

Miss. Mookrawee Donmun was born on September 11, 1991 in Nakhon Ratchasima province, Thailand. She received her Bachelor’s Degree in Engineering (Geotechnology) from Suranaree University of Technology in 2013. For her post graduate, her continued to study with a Master’s degree in the Geothecnology Program, Institute of Engineering, Suranaree university of Technology. During graduation, 2014-2016, she served in position of teacher and research assistant at SUT. Since 2014, she has a part-time teacher laboratory at SUT. She has a good knowledge in areas of oil field chemicals and drilling fluids processing.