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Bentonite-Based Drilling Boyolali Mud Fabrication with Additive Carboxymethyl Cellulose, Na_2CO_3 and KOH

Adi Ilcham[1*], Muhammad Reza Adittyanto [1], Khairul Asrori[1], Wakhid Khoirul Umar [1]
[1]Department of Chemical Engineering, Faculty of Industrial Technology, Universitas Pembangunan Nasional "Veteran" Yogyakarta, Indonesia , Jl. SWK Jl. Ring Road Utara No.104, Ngropoh, Condongcatur, Kec. Depok, Kabupaten Sleman, Daerah Istimewa Yogyakarta 55283
*Corresponding Author: adi_ilcham@upnyk.ac.id

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Abstract

This study aims to examine the effect of adding KOH, Na2CO3, and Carboxymethyl Cellulose additives on the physical properties of the mud, as well as the optimal additive for sludge production. The preparation of the basal sludge involved the addition of 22.5 grams of bentonite, 350 millilitres of distilled water, and 10 grams of Barite as a constant variable. Then it stated 0.5 variations of the Na_2CO_3 additive; 1.5; 3 grams, KOH 0.5; 1.5; and 3 grams, and Carboxymethyl Cellulose 3; 6; and 9 grams. A physical property measurement involving density was conducted. Samples were evaluated for Plastic Viscosity and Yield Point at 300 and 600 rpm dial speeds. After 30 minutes of filter press compression, the filtration loss, mud cake, and pH were measured. The results indicate that the KOH additive decreases Yield Point by 8.6 lb/100ft2 and increases Filtrate Loss by 5.8 mL and sediment pH by 11.12 points. The additive Na2CO3 then causes a reduction in Filtrate Loss of 10.4, 8.8, and 7.6 mL and an increase in Plastic Viscosity. While Carboxymethyl Cellulose can increase Plastic Viscosity by 7; 13; 55 cP, Gel strength by 4; 6; 40 Lb/100 ft2, and Filtrate Loss by 10; 8; 7.6mL. Carboxymethyl Cellulose is the additive that has the most significant effect on the physical properties of the mud because it can affect Plastic Viscosity, Gel Strength, Yield Point, and Filtrate Loss so that the soil can approach API 13A Standards. The optimal amount of Carboxymethyl Cellulose should be added at a mass of 6 grams, or 13 cP.

INTRODUCTION

The search for oil and natural gas is part of drilling mud activities during exploration and development. (Wibowo, 2019) stated that one factor determining the success of a drilling operation is located in the drilling mud. Drilling can dash safely and economically, greatly influenced by the conditions and mud system. The condition in question is how the properties and rheology of the mud. At the same time, the mud system in question is a specific type of mud that is used with due regard to the state of the formation and drill holes.

According to the explanation (Zakky et al., 2015), so that drilling mud can function properly and prevent and overcome problems, the mud system used in a drilling operation must be adapted to the formation conditions and lithology of the rock penetrated. If there are obstacles in the drilling operation, this often happens, including clamping a series, lost circulation, illegal blockages, and enlargement of the drill hole. In the petroleum industry, this risk often occurs and becomes a lesson that must be faced(Amin, 2014). The mud often used and carried out in salt rock reservoirs (salt domes) is salt base mud. The salt dome is formed due to a very thick layer of salt formed by the mineral halite breaking through the rock above it to form like a dome. On a geological time scale, the rock salt that forms will be covered by sediment above it and buried in the earth (Pranajaya & Hamid, 2015).

Based on the geological scale, Indonesia is a meeting area of three plates; as a result of the meeting of these plates formed, mountain paths in almost all the islands. A basin is formed behind or in front of this mountain

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Journal of Earth Energy Engineering
Vol. 12 No. 2, October 2023, pp 76-84

path where sediment is deposited. The sediments that fill this basin come from the erosion of mountainous areas or other high places around the basin (Bintarto et al., 2020). Such sedimentary basins occur in Sumatra, Java, Kalimantan, Sulawesi, Timor-Seram, and Papua. Indicating the presence of salt domes is not yet possible because the depositional environment is not supportive. Still, it can be estimated that there are salt domes in the area due to the confluence of plates from the sedimentary basin (Wibowo, 2019).

One of the causes of changing the physical properties of the mud is unwanted materials entering the mud during drilling operations; one of the contaminations that often occurs is contamination from NaCl which occurs when drilling penetrates the salt dome due to high salt contamination or due to the formation of water. (Agnes et al., 2015). Which has a high salt content, enters the mud system, can change the viscosity, yield point, and filtration loss, and can lower the pH and create a thick mud cake in the mud, which will make the mud conditions unsafe and efficient (Amin, 2014).

In research conducted by (the International Association for Conservation of the Petroleum Industry for the Environment (IPLECA) and the International Association of Oil and Gas Producers (OGP), 2009), it was found that bentonite and CMC in sodium solution are the controllers for fluid loss in the drilling mud.

Based on the description above, the researcher is interested in knowing which substitute additive can reduce the loss circulation of drilling mud. The research covered the physical properties of the mud (Density, Viscosity, Gel Strength, Filtration Lost, PH Index, and Mud Cake). The additives used in this study were Na_2CO_3, KOH, and CMC. The use of Na_2CO_3 and KOH can reduce Filtrate Loss in drilling mud, while the use of CMC additives is because these additives are cheap, easy to obtain, and often used by researchers to overcome the problem of filtration loss in mud.

MATERIAL AND METHOD

Material

The materials used consist of samples Bentonite Tulungagung and Boyolali, Barite, Aquadest, Carboxymethyl Cellulose (CMC), Sodium Carbonate (Na_2CO_3), Potassium hydroxide (KOH).

Tools

The equipment used is Multimixer Model 9B, Mud Balance Model 140, Viscometer Fann VG Model 35, and Filter Press Series 300.

Work procedures

Sludge Making

Prepared the ingredients for making bottom mud, weighing 22.5 grams of Bentonite, 350 ml of distilled water, and 10 grams of barite. After that, put Bentonite and water into the mixer cup, then place the mixer cup on the Multimixer. Then add barite after 3 minutes; finally, add the additive (CMC, KOH, and Na_2CO_3) at 3-5minute intervals.

Measuring Density

Calibrate the Mud Balance equipment by cleaning it, filling the cup with water until it is complete, closing it and cleaning the outside, and drying it with tissue paper. Then, put the Mud Balance back in its original position with the Rider placed on a scale of 8.33 ppg, which can be checked on the Level Glass; if it is not balanced, adjust the Calibration Screw until it is balanced. After calibrating, measure 350 ml of distilled water and mix it with 22.5 grams of Bentonite. The trick is to put water into the vessel, then install the vessel on the Multimixer and add Bentonite little by little after the mixer is running; after a few minutes after mixing, take the vessel and pour the mud that has been made into the Mud Balance cup. Close the cup, clean the mud adhering to the outer wall, and cover the cup until clean. Then, put the balance arm in its original position until the Rider is balanced, then read the density shown on the scale. Repeat the steps above by adding CMC, Na_2CO_3 and KOH.

Measuring Mud Viscosity with a Fann VG Viscometer

First, fill the vessel with mud up to the specified level. Place the vessel, and adjust its position so that the rotor and bob are immersed in the mud according to predetermined limits. Move the rotor to the High position and place the rotor rotational speed at 600 RPM. Playback continues until the position of the scale (dial) reaches balance. Then record the price indicated by the scale. After reaching balance, the price recording indicated by the pointer scale is continued for the 300 RPM speed in the same way as above. After completing the shear stress measurement:

- Mix the mud with a Viscometer at 600 RPM for 10 seconds.
- Turn off the Viscometer.
- Let the mud rest for 10 seconds.

After 10 seconds, it drives the rotor at 3 RPM. Read the maximum deviation on the pointer scale. Stir the mud again with a Viscometer at a rotor speed of 600 RPM for 10 seconds. To determine the exact quantity of each specification, mathematical calculations are required; the number of these specifications can be calculated as follows:

γ : 1,074RPM. (1)

τ : 5.077 C. (2)

with : γ : *shear rates*, second -1

τ : *shear stress*, dyne/cm^2

C : dial reading, degrees

RPM : revolutions per minute of the rotor.

$\mu a = \frac{\tau}{\gamma} x\ 100$ (3)

$\mu a = \frac{300 \text{ x C}}{\text{RPM}}$ (4)

Real viscosity (μa) for each price the shear rate is calculated based on:

$\mu a = \frac{\tau 600 - \tau 300}{\gamma 600 - \gamma 300}$ (5)

By plugging equations (1) and (2) into equation (5) we get:

μp.s = C600– C300 (6)

Yb = C300- μp.s (7)

Where : μp.s = Plastic Viscosity, cp

Yb = Yield Point Bingham, lb/100 ft2

C600 = dial reading at 600 RPM, degrees

C300 = dial reading at 300 RPM, degrees

Measurement of Filtrate Loss, Mud cake, and pH

First, place the rubber gasket over the base cup. Install the filter paper, set it as tightly as possible, place the screen next to it, attach the filter paper, and set it as tightly as possible. Then, place the rubber gasket on top of the filter paper, install the mud cup, place the rubber gasket on top of the cylinder, install the top cap, pour the mud into the cylinder, and then close it tightly. After closing tightly, install the cylinder on the filter press, then place the beaker just below the cylinder and circulate air with a pressure of 100 psi. Stop pressing after 30 minutes, and then record the filtrate volume. Pour the remaining mud into a measuring cup, take filter paper, and determine the thickness. To remove the tool assembly on the cylinder, wash and dry it with clean water. Then, measure the mud cake with a vernier caliper, the filtrate volume with a measuring cup, and the pH with pH paper.

RESULTS AND DISCUSSION

Bentonite including a type of mineral that contains a lot of montmorillonite (Adi Tama & Priadi, 2013). Bentonite has the form of light yellow, white, and gray fine granular particles. The bentonite used in this modification of the drilling mud is Tulungagung Bentonite and Boyolali Bentonite (Yuliyanti et al., 2018). The drilling mud is modified to improve the mud's physical properties to comply with API 13A standards.

This research begins with surface area analysis using the BET method, which is a method that uses the Brunauer-Emmet- Technology equation with the NOVAe series 1200e tool to calculate the surface area of solid materials. The BET method applies to multilayer adsorption systems and uses adsorbates that do not react chemically with the material's surface to be analyzed. In the Bentonite surface area analysis, nitrogen adsorbate was used and carried out at a boiling temperature of N_2, 77 K. The surface area test obtained the following results:

Journal of Earth Energy Engineering
Vol. 12 No. 2, October 2023, pp 76-84

Bentonite Boyolali

1. MBET

slopes	=	115,788
Intercepts	=	6.153 e-01
Correlation coefficient (r)	=	0.9999 19
Constanta (C)	=	189,171
Surface Area	=	29,918 m2/g

2. Single Point Surface Area

Relative Pressure (P/P0)	=	3.04507 e-01
STP volumes (cc/g)	=	9.6943
1/[W((P/P0)-1)]	=	3,6136 e+01
slopes	=	118.6701
surface areas	=	29.3462m2/g

Bentonite Tulung Agung

1. MBET

slopes	=	38,979
Intercepts	=	1,596 e-01
Correlation coefficient (r)	=	0.999903
Constanta (C)	=	245,160
Surface Area	=	88.979 m2/g

2. Single Point Surface Area

Relative Pressure (P/P0)	=	2.04039 e-01
@STP volumes (cc/g)	=	25.1460
1/[W((P/P0)-1)]	=	8.1565
slopes	=	39.9750
surface areas	=	87.1173 m2/g

Based on the results of BET analysis, the surface area of Bentonite Boyolali was 29.3462 m2/g, and Bentonite Tuluangagung was 88.979 m2/g. In practice, the smaller the surface area, the more spending time for drilling will increase. Spending time itself is the time used to reduce the initial concentration of acid to a concentration level that is reactive to formations by injecting acid into the productive formation, which is damaged, so that it is expected that a chemical reaction will occur between the acid and the formation, from this reaction it will cavities are formed in the formation rock around the wellbore to recover the optimum production rate (Kriswiyanti Artati & Irvina H).

Sludge Comparison with API 13A Standards

The physical properties of the drilling mud determine the success of the drilling operation because the physical properties play a role as a function of the drilling mud (Pranajaya & Hamid, 2015).

From the experiments that have been carried out, bottom mud is made from a mixture of 350 ml of water with 22.5 grams of Boyolali Bentonite and Tulungagung Bentonite and Barite, additional additive material of 10 grams which results in comparison with the results of the physical properties of API 13A standard Bentonite, can be seen in Table 1.

Table 1. Comparison of Tulungagung and Boyolali Bentonite Samples with API 13A Standards

Parameter	Tulungagung Mud	Boyolali Mud	API 13A
Density	8.7	8.8	-
C600	7	10	Min 30
C300	5	6	-
PV(cp)	2	4	Min 8
Yp (Lb/100 ft2)	3	2	Max 3 × PV
GS (10')	6	7	-
GS (10”)	4	6	-
Filtrate loss(ml)	350	84.8	Max 15 ml
*Mudcakes (*cm)	0.31	0.16	Max 0.28cm
pH	5	9	-

Information :

C300 : Reading Dial when 300RPM
C600 : Reading Dial when 600RPM
PV : Plastic Viscosity
Y.P : Yield Points
GS (10') : Shows the value of gel strength at 10 second (100 lb/ft2)
GS (10”): Shows the value of gel strength at 10 minutes (100 lb/ft2)

The results of the comparison of the results of the physical properties obtained from Bentonite in the Tulungagung area, Bentonite Boyolali, and API 13A show that the physical properties of the Bentonite in the Boyolali area are closer to the API 13A standard specifications, so Bentonite Boyolali was chosen to improve its physical properties by adding additives so that Bentonite Boyolali complies with API 13A standards.

Testing the addition of several additives was carried out to increase the performance of Bentonite in the Boyolali area and to find out how much additive was needed for Bentonite Boyolali to achieve expected results from API 13A mud and to determine the effect of adding additives on the physical properties of Bentonite Boyolali. Sludge modification with the addition of several chemicals, such as CMC, KOH, and Na_2CO_3, results in comparison with the results of the physical properties of Bentonite API 13A standard.

Effect of CMC Mass on Mud Properties

In order to determine the effect of adding CMC additive on the properties of the drilling mud, this experiment was conducted by adding 3 grams, 6 grams, and 9 grams of CMC additive as shown in Table 2. Based on the analysis performed, it has been determined that each additional mass of CMC will increase the Plastic Viscosity, Yield Point, and Gel strength, while decreasing the Filtrate loss of the drilling mud. Adding 9 grammes of CMC resulted in a Yield Point of 40, the maximum possible value. The addition of 9 grams of CMC resulted in the lowest filtrate loss of 7.6 ml. In addition, as shown in Figure 1.A., the inclusion of CMC increased the gel strength in a number of treatments, with the highest and most significant increase occurring when 9 grams were added. CMC can increase gel strength because it is an emulsifier that helps bond water and oil together. This creates a sturdier and more resilient structure, and CMC can also prevent gel from breaking. This is because CMC can form a protective layer around the gel, preventing it from being damaged (Arancibia et al., 2016).

Table 2. Data on the Effect of CMC Mass on Mud Properties compare with API 13A Standards

Parameter	Mass CMC (grams)			API 13A
	3	6	9	
Density	8,9	9	9	
C600	18	36	150	Min 30
C300	11	19	95	
PV(C600-C300)	7	13	55	Min 8
YP (C300-PV)	4	6	40	Max 3×PV
GS (10')	19	35	145	
GS (10”)	15	30	130	
Filtrate Loss	10	8	7,6	Max 15 ml
mudcakes	0.1	0.1	0.1	Max 0.28cm
pH	11	11	11	

Journal of Earth Energy Engineering
Vol. 12 No. 2, October 2023, pp 76-84

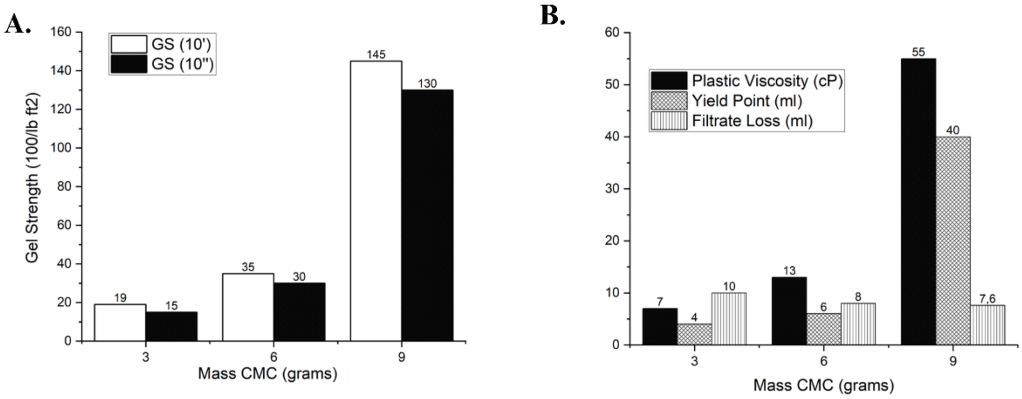

Figure 1. **A.** Displays the effect of adding CMC mass on Gell Strength, with GS'10 indicating that the test was conducted in 10 seconds and GS''10 in 10 minutes, **B.** Displays the effect of adding CMC mass, with the black bar chart displaying the effect of CMC on Plastic Viscosity, Matrixs bar charts displaying the effect of CMC on Yield Point, and Vertical diagrams displaying the effect of CMC on Filtrate Loss.

In addition, Figure 1.B. depicts the impact of CMC addition on plastic viscosity, yield point, and filtration loss. It can be seen that the addition of CMC can increase the Yield Point and Plastic Viscosity, and that 9 grams of CMC can substantially increase the Plastic Viscosity and Yield Point. CMC can increase the plastic viscosity and yield point of drilling mud because it creates a hydrophilic network that can bind mud and water particles. This hydrophilic network will impede the mud's passage, thereby increasing the viscosity of the plastic. Additionally, this hydrophilic network will provide attractive forces between clay particles, thereby elevating the yield point (Syawaluddin, 2020).

CMC is an excellent viscosifier substance, so it can increase viscosity and minimize filtrate loss (Hamid, 2017). CMC is a long-chain polymer molecule whose characteristics depend on the chain length or degree of polymerization (DP) (Kamal, 2010). The molecular weight of the polymer determines the DS value and DP value; with an increase in the molecular weight of CMC, its properties as a thickening agent also increase (Kamal, 2010).

The Effect of KOH Mass on Mud Properties

Experiments involving the addition of KOH with varying treatment of 0.5 grams, 1.5 grams, and 3 grams are detailed in Table 3. This experiment was designed to ascertain the impact of KOH additives on the properties of drilling mud. According to the results of the analysis, each addition of KOH mass decreases the Yield Point and increases the Filtrate loss of the drilling fluid. Any addition of KOH can reduce Gell Strength, as KOH can hydrolyze bentonite, the primary component of drilling mud, as depicted in Figure 2.A. Bentonite is a clay that is capable of gelling when combined with water. KOH reacts with bentonite to produce hydrated bentonite ions when applied to drilling mud. This hydrated bentonite ion is more dilute than its dehydrated counterpart. This will diminish the gel strength of the drilling sludge (Dong et al., 2019). Figuring 2.B. Adding 3 grams resulted in the lowest yield point, which was 1. Then, adding 3 grams of KOH resulted in the greatest filtrate loss, which is 11.6 ml. KOH can reduce filtrate loss and yield point because it aids in mud cake formation. The addition of KOH mass raises the pH, as shown in Table 3, because KOH is a potent base. In practise, if the drilling mud is too acidic or alkaline, it will have a negative impact on the drilling apparatus, but the characteristics of the mud can fluctuate even though the acidity level is fixed. This is due to variations in the type and concentration of ions in the drilling fluid. Adjusting the pH is used to modulate the rate of reaction and to prevent overreaction with metal well equipment. (Buntoro, 2016).

Mass Effect of Na_2CO_3 On the Nature of Mud

In order to determine the effect of adding additive Na_2CO_3 on the properties of the drilling fluid, this experiment was conducted by adding 0.5 grams, 1.5 grams, and 3 grams of Na_2CO_3. Table 4 compares the Mass Effect Data of Na_2CO_3 on the Characteristics of Mud to API 13A Standards. Figure 3.A. depicts the effect of adding Na_2CO_3 on variations of 0.5 grams, 1.5 grams, and 3 grams. Because Na_2CO_3 is an alkali capable of breaking down polymer bonds in the drilling fluid, the Gell Strength decreases with each addition. These polymer bonds are accountable for the gel's strength (Mahmud et al., 2020).

Table 3. Data on the Effect of KOH Mass on Mud Properties compare to API 13A Standards

Parameter	Mass KOH (grams)			API 13A
	0.5	1.5	3	
Density	8,9	9	9	
C600	36	30	25	Min 30
C300	22	18	13	
PV(C600-C300)	14	12	12	Min 8
YP (C300-PV)	8	6	1	Max 3×PV
GS (10')	35	31	23	
GS (10”)	30	25	20	
Filtrate Loss	5,6	8	11,6	Max 15 ml
mudcakes	0.1	0.17	0.17	Max 0.28cm
pH	11	12	13	

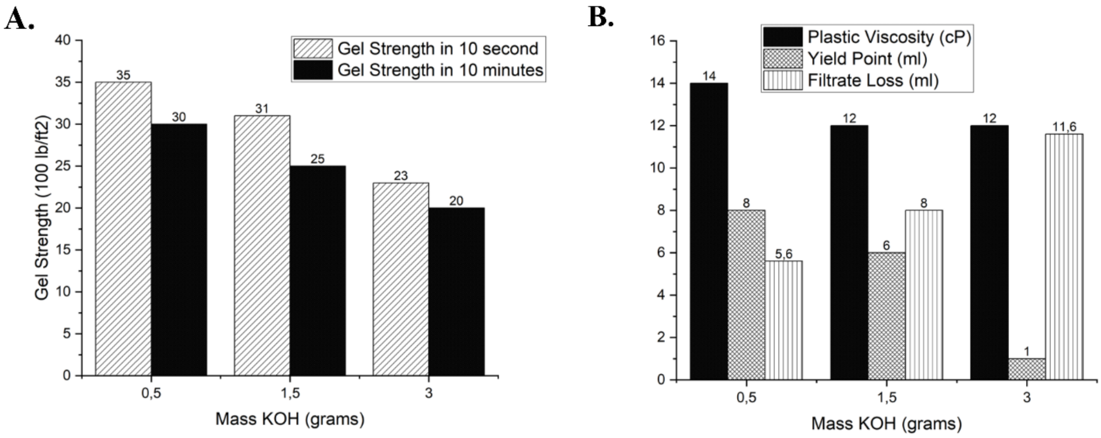

Figure 2. **A.** The effect of adding mass of KOH on Gel Strength, **B.** the effect of adding mass of KOH on plastic viscosity, yield point, and filtration loss.

Table 4. Mass Effect Data of Na_2CO_3 On the Nature of Mud compare to API 13A Standards.

Parameter	Mass Na_2CO_3 (grams)			API 13A
	0.5	1.5	3	
Density	8,9	9	9	
C600	35	35	35	Min 30
C300	18	19	21.5	
PV(C600-C300)	17	16	14.5	Min 8
YP (C300-PV)	8	3	7	Max 3×PV
GS (10')	40	35	35	
GS (10”)	35	30	30	
Filtrate Loss	10,4	8,8	7,6	Max 15 ml
mudcakes	0.12	0.12	0.14	Max 0.28cm
pH	11	11	11	

The addition of Na_2CO_3 mass decreases the Plastic Viscosity and Filtrate loss of the drilling fluid, as determined by the analysis shown in Figure 3.B. The lowest Plastic Viscosity, 14.5 cP, was attained by adding 3 grammes. Adding 3 grammes of Na_2CO_3 resulted in the lowest filtrate loss, which was 7.6 ml. This is due to the fact that Na_2CO_3 is a fluid loss control agent that minimises filtrate loss to ensure compliance with API 13A standards. Na_2CO_3 is a salt that functions as an absorbent for water in shales and clays (water absorption) and its dispersion so that it has the ability to absorb water. The greater the addition of additive mass Na_2CO_3, the greater the Na content in the drilling mud, which causes the mud to bind or absorb water more easily. quite satisfactory, and the resulting filtrate loss is modest. (Sirait, 2018).

Journal of Earth Energy Engineering
Vol. 12 No. 2, October 2023, pp 76-84

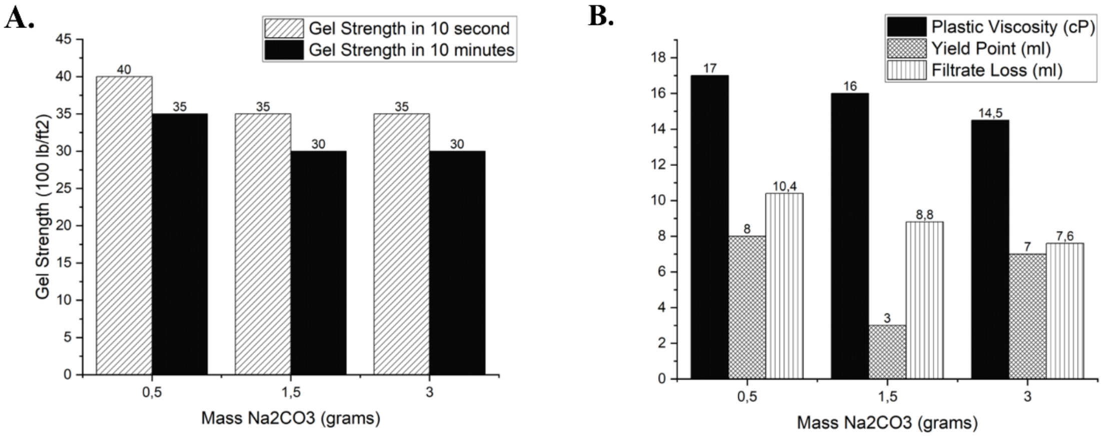

Figure 3. **A.** The effect of adding Na_2CO_3 mass on Gel Strength, **B.** The effect of adding Na_2CO_3 mass on plastic viscosity, the yield point, and filtration loss.

Compliance with API Standard 13A

Based on the experimental data 2 out of 9 samples did not meet the API 13A Plastic Viscosity standard, as determined by the experimental data: the CMC sample with a mass of 3 grams because it was unable to increase the Plastic Viscosity to 8 cP and the dial reading at 600 rpm was still below 30, including 18, and the KOH sample with a mass of 3 grams because the dial reading at 600 rpm was still below 30.

The CMC additive is the most significant variable in this experiment because it satisfies the majority of API 13A specifications, including Plastic Viscosity, Yield Point, Gel Strength, Dial reading at 600 rpm, Filtrate Loss, and Mudcake. Lifting fragments to the surface is a measurement of Plastic Viscosity field application. Using a high viscosity will result in heavy pump labor, while a low viscosity will result in poor cuttings removal. When the mud begins to circulate once more, the Yield Point attempts to raise the cutting to the surface. Gel strength is used here to maintain cutting when there is no blood flow, typically during a round voyage. If the strength of Gel is not optimal, the cutting will settle back to the bottom of the drill cavity. So that drilling is repeated (Nur Suhascaryo et al., 2021). Measurement of mud filtrate loss and mud cake thickness, i.e., if the water volume of mud and mud cake filtrate is not regulated, it will result in drilling issues. One of these is the issue of pipe sticking, particularly differential pipe sticking. Pipe sticking can occur if the volume of filtrate water produced is large enough for the mud cake to be sufficiently viscous and exceed the API Bentonite safe limits. In order to maintain the stability of the borehole, the mud we design must generate an ideal mud cake that adheres to the Bentonite API, namely mud with the criteria of a water Filtrate (Filtration Loss) volume that is not too large so that the mud cake formed is not too thick. The optimal amount of CMC additive is added at a mass of 6 grams, or 13 cP. Because using a high viscosity, such as when adding 9 grams of CMC, results in heavy pump work, while using a low viscosity, such as when adding 3 grams of CMC, results in poor cutting removal (Nur Suhascaryo et al., 2021).

This experiment shows that the density of the drilling mud has not changed significantly; this is because adding the additive KOH, Na_2CO_3 and CMC, does not affect the density of the drilling mud. Mud density measurement here is to prevent kick and lost circulation. The density of the drilling mud we make must meet the appropriate requirements to withstand pressure from within to neutralize kick and lost circulation (Ginting, 2018).

CONCLUSION

This study has addresseda Bentonite Boyolali as the closest to the AP1 13A specifications, so a composition modification was made to approach the API 13A standard. The effect of the KOH additive causes a decrease in Yield Point (8; 6; 1 lb/100 ft2) and increases Filtrate Loss (5.6; 8; 11.6 mL) and sludge pH (11; 12; 13). Then the additive Na_2CO_3 causes a decrease in Filtrate Loss (10.4, 8.8, 7.6; mL) and increases Plastic Viscosity. While CMC can increase Plastic Viscosity (7; 13; 55 cP), Gel strength, and Yield Point (4; 6; 40 Lb/100 ft2) and reduce Filtrate Loss (10; 8; 7.6 mL), the physical properties of the mud here are CMC additives because they can affect Plastic Viscosity, Gel strength, and Yield Point and Filtrate Loss so that they can approach API 13A Standards.

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