

Rheological Properties Evaluation of Sudanese Bentonite with Different Additives

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ABSTRACT: This study was carried out to assess the rheological properties and filtration loss for a drilling fluid prepared from local bentonite. Required data and samples were carefully gathered from the study area (Al-fao area) in accord of approved sampling procedures. Mineralogical, physical, chemical tests were carried out to assess quality of local bentonite. Sodium carboxymethyl cellulose (CMC), polyanionic cellulose polymer (PAC-LV), and sodium carbonate (Na_2CO_3) were used to increase viscosity and to decrease filtration losses. The results have shown that the local bentonite can satisfy the American Petroleum Institute (API) specifications for different concentrations of CMC and PAC-LV. Addition of 10% CMC concentration for the selected local bentonite, enhances rheological properties, filter loss and yield point as related to plastic viscosity ratio became within the range of API specifications.

Keywords: Drilling Engineering, Rheological Properties, Sudanese Bentonite.

المستخلص: أجريت هذه الدراسة لتقييم الخواص الانسيابية وفقدان الرشح لسائل حفر محضر من بنتونايت محلي من منطقة الفاو. أجريت اختبارات التركيب المعدني والاختبارات الفيزيائية والكيميائية لتقييم جودة البنتونايت. استخدمت بعض المواد مثل CMC و PAC-LV وكربونات الصوديوم وذلك لزيادة اللزوجة وتقليل فواید الرشح. أظهرت النتائج أنه عند إضافة CMC و PAC-LV بنسب محددة فإنه يحقق مواصفات معهد البترول الأمريكي لقياس جودة البنتونايت. عند إضافة CMC بنسبة 10% فإن الخواص الريولوجية وفقدان الرشح ومعدل المطاوعة إلى اللزوجة البلاستيكية تكون ضمن حدود مواصفة معهد البترول الأمريكي.

INTRODUCTION

Drilling fluids are considered as the single most important earth excavation exercise, especially when drilling oil and gas wells and are often used for much simpler boreholes such as water wells using conventional rotary method.^[1] The importance of drilling fluids to drilling operations is almost the same as the importance of blood to human body^[1]. The main objective of drilling fluids is the successful completion of oil and gas wells^[2]. The drilling fluids must be selected and/or designed to fulfill the following functions^[3]

- Remove cuttings from wellbore.
- Prevent formation fluids flowing into the wellbore.
- Maintain wellbore stability.
- Cool and lubricate the bit.
- Transmit hydraulic horsepower to bit.

These functions are controlled by rheological and filtration properties of the mud^[4]. Rheological parameters are used to determine the following characteristics of the mud^[2].

- Ability to suspend and carry cuttings to the surface.
- To analyze the effect of drilled solids contaminant, chemical and temperature.
- To calculate swage and swab pressure.

Drilling fluids are commonly classified, according to their base fluid, into three main groups: (1) water- base drilling fluids, (2) oil – base drilling fluids, and (3) gaseous drilling fluids. (4)

The main component of water-base drilling fluids is clay (mostly bentonite)^[5]. Bentonite is a major additive, which gives the proper rheological (Non newtonian shear thinning) and

filtration control (low fluid loss under differential pressure) properties^[6]. Commercial bentonite rarely contains less than 60% smectite and usually more than 70%, associated minerals typically being quartz, cristobalite, feldspars, zeolite, calcite, volcanic glass and other clay minerals such as kaolinite.

Depending on the dominant exchangeable cations present, the clay may be referred to as either calcium or sodium bentonite, the two varieties exhibiting markedly different properties and thus uses^[7]. In the local oil and gas industry, bentonite is used as a drilling mud material and as an oil well cement additive. In Sudan, bentonite is mainly imported from abroad, from India, KSA, Egypt and Libya. In order to reduce the dependency of imported bentonite, the development and production of the local bentonite are sought to be initiated due to long way of transportation and storage. The objective of this study is to enhance Al-fao bentonite properties to meet American petroleum institute (API) and oil companies' material association (OCMA) specifications^[8].

MATERIAL AND METHODS

Sampling collection

The samples used in this study were obtained from Al -Fao (Lat: 14.150 – Long: 34.33 – Alt : 700 km) in Eastern part of the Sudan. Samples were obtained from the active zone of shrinkage and swelling (between 0.5 to 3.0 m). These clayey soils are estimated to have high to very high Smectite. The samples were collected during the dry season of the year.

Raw Samples Preparation

Raw samples were dried in an oven and then crushed using crusher type RS200 in accord with standard methods. The powder was sieved by using a 75 micron opening mesh.

Methodology of Tests

The laboratory testing program was divided into four types of testing: mineralogical test, physical tests, chemical tests and drilling fluid properties tests

Mineralogical Tests

The X-ray diffraction and scanning electronic microscope SEM were used to obtain mineralogical composition of the raw bentonite. The result of X-ray and SEM methods are shown in Figures 1, 2, 3 and Table1.

Physical Tests

The physical tests carried out on the samples are: Atterberg limits, liquid and plastic limits, particle size distribution.

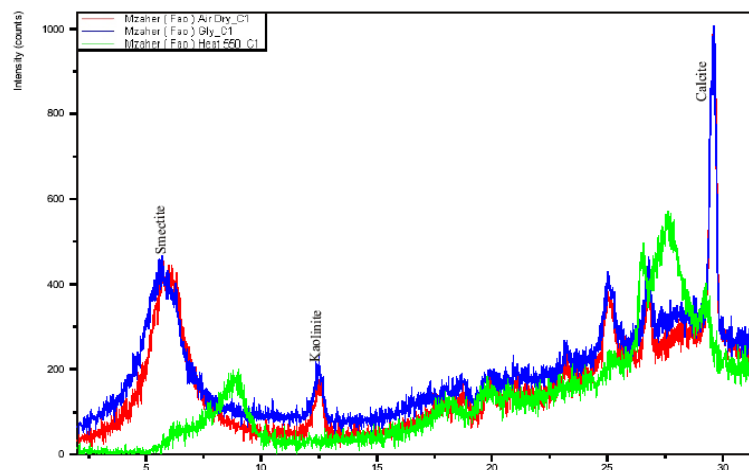


Figure 1: X-ray diffraction analysis.

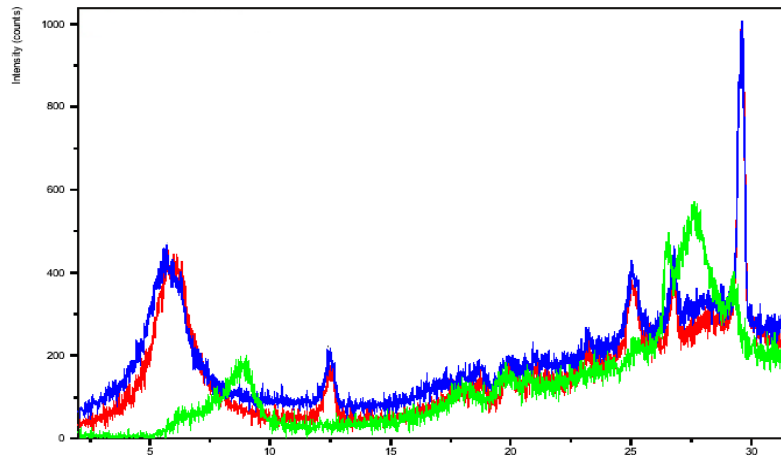


Figure 2: X-ray diffraction analysis.

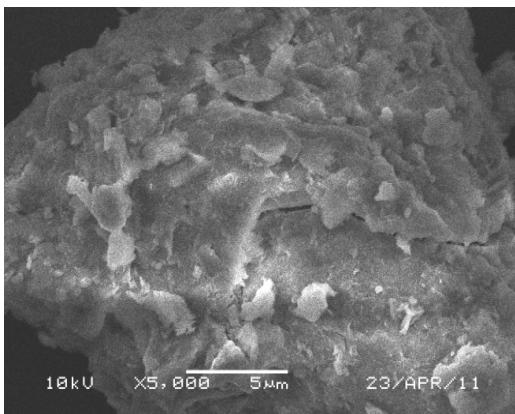
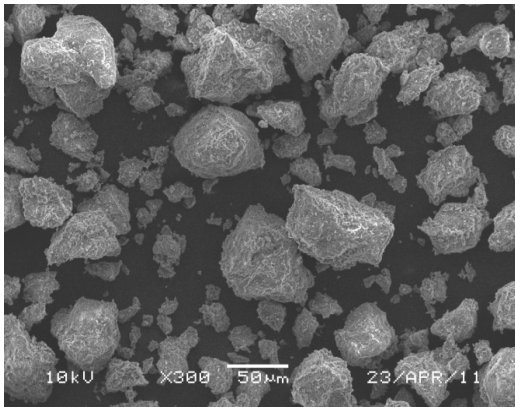


Figure 3: SEM photograph of Alfaocentonite.

The determination of the Atterberg Limit values was carried out according to the cone penetration method in BS 1377: Part 2:1990 CL 4.3. Particle size distribution by sieve analysis was carried out for quantitative determination

for particle size greater than 0.063mm (sand and gravel), and by hydrometer analysis method, for particle size smaller than 0.063 mm (clay and silt). The results of Atterberg Limit values and particle size distribution are shown in Table 2.

Chemical Test

The Sodium Absorption Ratio (SAR) test was carried out to determine the amounts of main metallic cations (calcium, magnesium and sodium). All the results of chemical testing were reported in Table 3.

Drilling fluids Tests

These tests were carried out to determine rheology and filtration loss properties for treated bentonite. All tests depend on API specification 13A and 13B-1. The results of Drilling fluids Tests are shown in Figure 5 to 18.

RESULTS AND DISCUSSIONS

From Table 1 it can be seen that the amount of fines is 89% and L.L value is 66 which is very low for non treated bentonites compared with Na and Ca bentonites.

Table 2 lists chemical composition of non treated bentonite and the CEC value was found to be 83 meq/100g. This indicates a positive impact on hydration and swelling. Figure 1,2 and 3 and Table 3 show that the clay mineral composition is smectite group with few amounts of impurities such as kaolinite and illite.

The increase of PAC-LV concentration decreases the filtration loss values as shown in Figure 4. This is associated with the increase of

plastic viscosity and viscometer dial reading at 600 r/min Figure 5 and 6. These results show that the treated bentonite reaches the API specification for filter loss at 20% PAC-LV concentration, while viscometer dial reading at 600r/min reaches the API specification at concentration of 30% PAC-LV. Nevertheless the local bentonite reaches the API specification of YP/PV ratio at low values of PAC-LV concentration as presented in Figure 7.

Figure 8 illustrates that the filter loss decreases with an increase of CMC concentration. This situation causes an increase of plastic viscosity and viscometer dial reading at 600 r/min as shown in Figures 9 and 10. According to the above mentioned results it is demonstrated that the local bentonite satisfies the API specification at 10% CMC concentration for filter loss, viscometer dial reading at 600r/min and YP/PV ratio.

No change occurred when 5% and 10% Na₂CO₃ concentration were added in viscometer dial reading at 600r/min Figure 11, plastic viscosity Figure 12 and YP/PV ratio Figure 13. The viscometer dial reading at 600 r/min and plastic viscosity showed an increase in addition of 15% concentration of Na₂CO₃ and no change took place regardless of the amount of Na₂CO₃ added. Nonetheless, the YP/PV ratio decreased preserving the same reading at different concentration ratios. Figure 14 show that an increase of Na₂CO₃ concentration increases pH values up to 14.

Modeling

The filter loss (F) and viscometer dial reading 600r/min were related to the CMC concentration in the sample (C). Figures 15 and 16 show the best trend lines which represent the above relationship for Al-fao bentonite. The measured data was used to develop an empirical model that would predict the effect of increasing CMC

concentration on filter loss and viscometer dial reading 600r/min.

The power trend line and polynomial trend line were the best empirical models to predict the filter loss and viscometer dial reading at 600r/min as a function of CMC concentration of Al-fao bentonite, respectively. The proposed empirical models were depicted in equations 1 and 2 .

$$F = 35.84 \times C^{-0.40} \dots \dots \dots (1)$$

$$\theta_{600} = 0.265C^2 + 1.408C + 12.2 \dots \dots (2)$$

where: F = filter loss, ml, θ_{600} = viscometer dial reading 600, r/min, C = CMC concentration, %
The empirical models equations 1 and 2 were validated by comparing predicted and measured data. The models were in good fit with measured data. Figures 17 and 18 show the measured and predicted data, respectively.

CONCLUSIONS

Combining the experimental results with conducted discussion, the following conclusions emerged: Clay minerals group (Smectite) of Al-fao bentonite revealed few amounts of impurities.

- CEC of Al-fao untreated bentonite amounted to 83 meq/100g. This finding implies a positive impact of hydration and swelling. Rheological properties and filter loss enhanced with addition of PAC-LV and CMC
- Addition of about 10% CMC concentration lead the Al-fao bentonite to meet API specifications.
- Equation 1 and 2 can be used to predict filter loss and viscometer dial reading at 600 r/min for Al-fao treated bentonite at various concentrations of CMC. Based on the above conclusions 10% CMC concentration is recommended as an additive more than PAC-LV.

Table 1: XRD results of the analyzed samples using bulk method.

Clay minerals					
LOCATION	SMECTITE, %	KAOLINITE, %	ILLITE, %	CHLORITE, %	SME/ILLI, %
Alfao	94	05	0.21	00	0.79

Table2: Index properties of testing bentonite.

AtterbergLimits			Particle Size, mm				Class
LL	PL	PI	Clay	Silt	Sand	Gravel	USCS
66	29	37	24	65	9	2	CH

Table3: Chemical analysis of the Bentonite samples.

EC	Na+	Ca+	Mg+	SAR	SAT%	CEC	ESP	TP
0.50	3.10	1.5	0.5	3	67	83	4	0.94

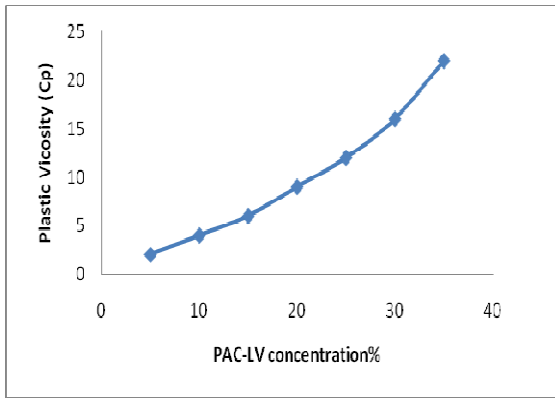


Figure 5: PAC-LV concentration vs.plastic viscosity

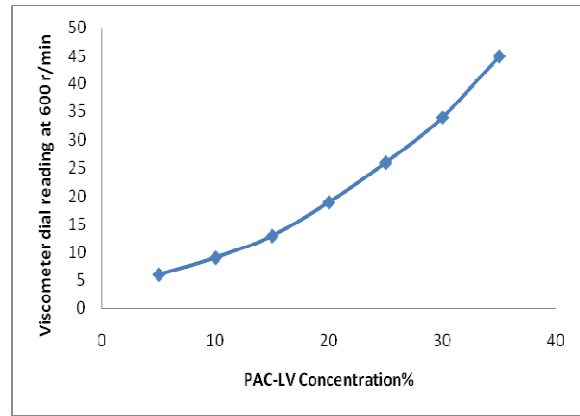


Figure 6: PAC-LV concentration vs.vicometer dial reading at 600

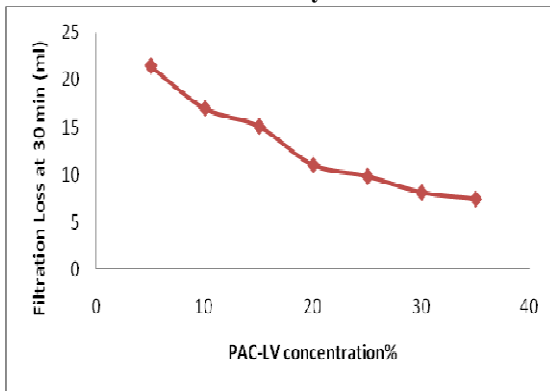


Figure 4: PAC-LV concentration vs. filtration loss

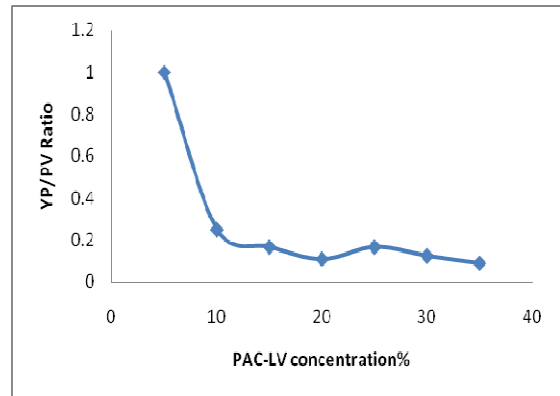


Figure 7: PAC-LV concentration vs. YP/PV ratio

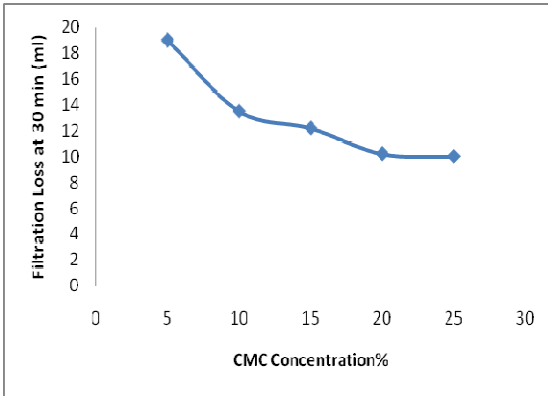


Figure 8: CMC concentration vs.filtration loss

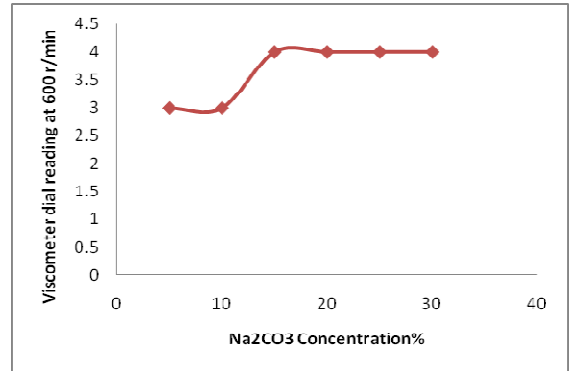


Figure 11: Na₂CO₃ Concentration vs.Viscometer dial reading at 600

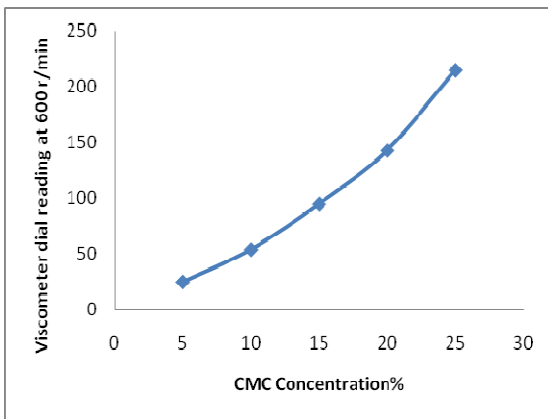


Figure 10: CMC Concentration vs.Viscometer dial reading at 600

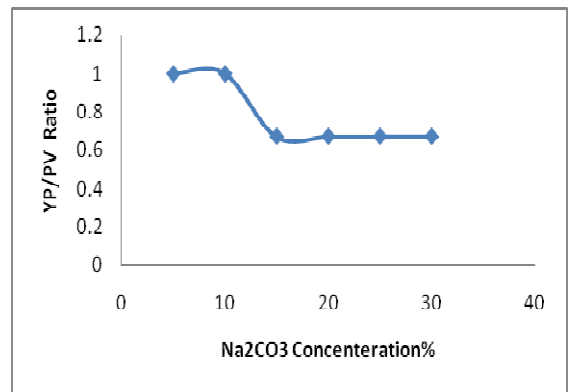


Figure 13: Na₂CO₃Concentration vs. YP/PV Ratio

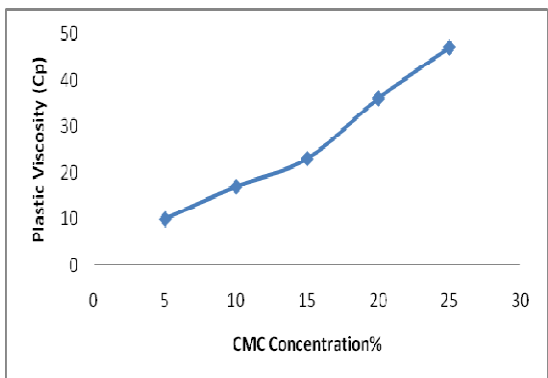


Figure 9: CMC Concentration vs Plastic Viscosity

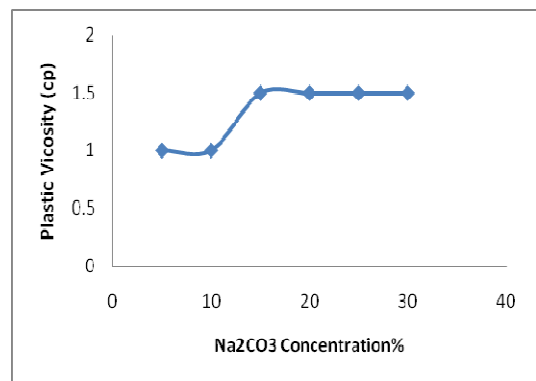


Figure 12: Na₂CO₃ Concentration vs. Plastic Viscosity

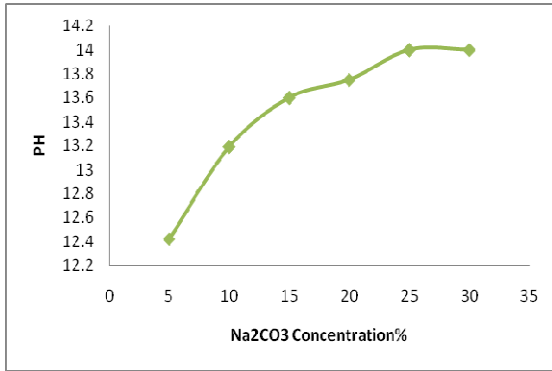


Figure 14: Na₂CO₃ concentration vs. pH.

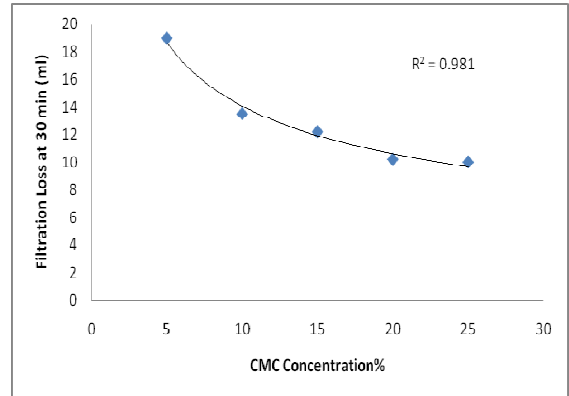


Figure 15: Change in filter loss as a function of CMC concentration.

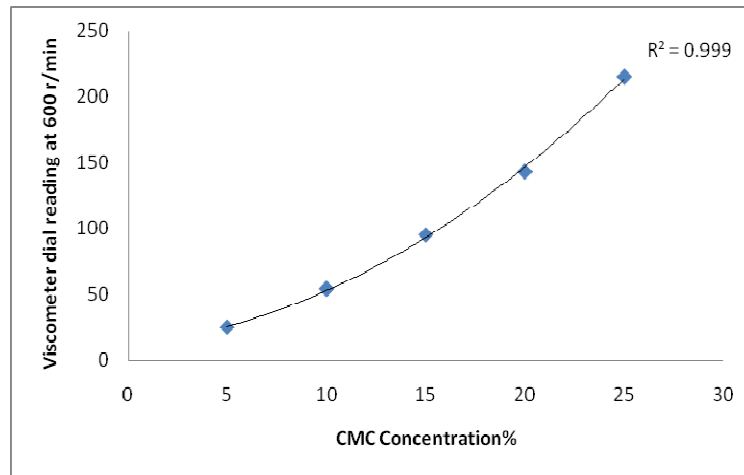


Figure 16: Change in viscometer dial reading at 600 r/min as a function of CMC concentration.

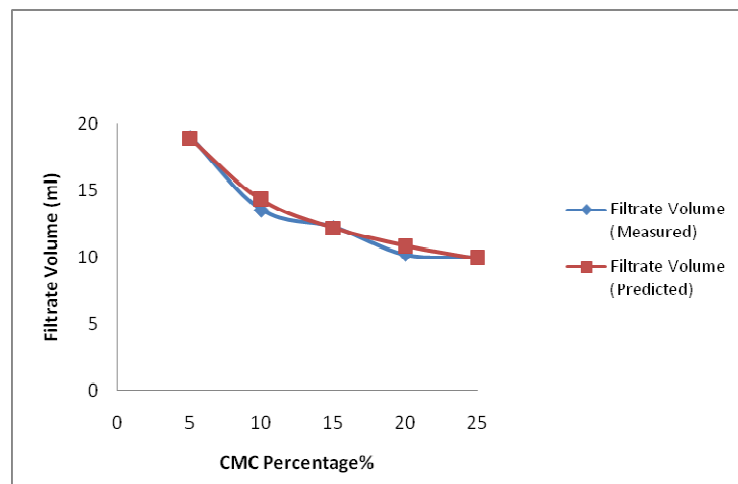


Figure 17: Predicted and measured values filter loss vs CMC concentration.

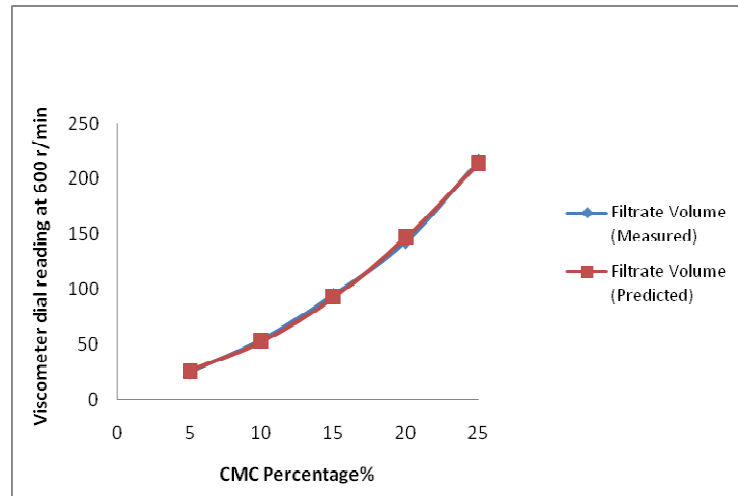


Figure 18: Predicted and measured values viscometer dial reading 600 r/min vs CMC concentration

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