

Chemical, Petroleum and Environmental Engineering

Study the Effect of Particle Sizes and Concentration on the Rheological Properties of Iraqi Bentonite for Using as Drilling Fluids

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ABSTRACT

The aim of this study is to identify the effect of particle size and to increase the concentration of Iraqi bentonite on rheological properties in order to evaluate its performance and to know if it can be used as drilling fluid without additives or not. In this study, Iraqi bentonite was carried out by mineral composition (XRD), chemical composition (XRF) and Particle size distribution (PSD), and its rheological properties were measured at different particle size and concentration. The results showed that when the particle size of Iraqi bentonite decreased, and the rheological properties were increased with increased concentration of Iraqi bentonite. Also, Iraqi bentonite was unable to use as drilling fluid without certain additives.

Keywords: Iraqi bentonite, Drilling fluids, Rheological properties, Particle Size.

دراسة تأثير الاحجام الحبيبية و التراكيز على الخواص الريولوجية للبتونايث العراقي لأستعمالة كسائل حفر

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الخلاصة

الهدف من البحث هو لمعرفة تأثير الحجم الحبيبي و زيادة التركيز البنتونايث العراقي على الخواص الريولوجية ، كذلك لتقييم ادائته و معرفة اذا كان بالامكان استعماله كسائل حفر او لا. في هذه ادراسة , تم تقييم البنتونايث العراقي من خلال التحليل المعدني (XRD) , التحليل الكيمائي (XRF) و تحليل التوزيع الحجمي الحبيبي. و خواصه الريولوجية حيث فحصت لمختلف الاحجام الحبيبية و مختلف التراكيز. النتائج اظهرت انه عندما يقل الحجم الحبيبي فان الخواص الريولوجية تزداد , و انه عندما يزيد تركيز البنتونايث العراقي فان الخواص الريولوجية تزداد, كذلك اظهرت النتائج ان البنتونايث العراقي لا يمكن استعماله كسائل حفر بدون اضافات .

الكلمات الرئيسية: البنتونايث العراقي ,سوائل الحفر ,الخواص الريولوجية ,الحجم الحبيبي

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1. INTRODUCTION

Drilling fluid plays major role in the drilling operations. It is very important to improve the properties of drilling fluid to satisfy the increasing demands. Drilling fluid is often described as shear thinning thixotropic fluid and yield stress. The rheological properties (plastic viscosity, yield point, and gel strength) are essential to transport drilling cuttings to the surface the drilling, improve the rate of penetration, and ensure downhole safety (**Meng, et al., 2012**). In the oil and gas industries, drilling fluid is classified into three types: water-based drilling fluid, nonaqueous-based drilling fluid, and pneumatic systems. The typical water-based drilling fluid is composed of base fluid (water), active and inactive solids, and chemical additives. Water-based drilling fluid has many advantages that made it the most suitable choice. These advantages involve low cost, availability, and ease of control (**Hussein, et al., 2013**). The selection of the most suitable mud type, mud properties, and the efficiency of engineering support in drilling operations, may help to assure the safety and the successful operations (**Omela, et al., 2013**). To achieve the optimum performance of any drilling mud during the drilling operations the physical and chemical properties of the mud should be controlled; rheology properties, gel strength, fluid loss are the important special parameters of the drilling fluids. Also, the surface chemistry of the clay and that of various drilling fluids should be controlled (**Dardir, et al., 2016**). The main functions of bentonite are the viscosities of drilling mud and to control the fluid loss to formation (**Abdou, et al., 2013**). Bentonite is the mineral silica and is expressed as the hydrated aluminosilicate. Bentonite consists mainly of montmorillonite, and other components such as beidellite, saponite, and other minerals, (**Naswir, et al., 2014**). API specifications for acceptable drilling mud were the standard for evaluating the local bentonite. Bentonite has a structure composed of one aluminum sheet of octahedral (O) placed between two silicate sheets of tetrahedral (T) with substitution of some silicate tetrahedral atoms by aluminum atoms and/or of octahedral atoms (Al^{3+} or Mg^{2+}) substituted by atoms with lower oxidation number. The net negative charge of the 2:1 (TOT) layers is balanced by the exchangeable cation such as Ca^{2+} and Na^{+} located between the layers and around the edges (**Zaidon, 2019**). There are two types of bentonite: sodium bentonite and calcium bentonite, depending on the predominant exchangeable cation. In the freshwater, sodium bentonite is reacted higher than calcium bentonite. In terms of the performance, bentonite is classified as "high yield" (sodium bentonite) or "low yield" (calcium bentonite), (**Rabia, 2001**).

The ability of the drilling fluid to perform its base function depends on its viscosity. Without viscosity, all the weighting materials and the drill cuttings would be settled to the bottom of the hole as soon as the circulation is stopped. Viscosity in drilling fluid is a structure built within the water or oil phase suspends solid material (**Wilfred, and Akinada, 2016**). The properties of local drilling mud can be improved economically by shearing speed as an enhancement method to improve the dispersion rate of the clay suspensions, and hence increase viscosity and decrease filtration loss. But the use of shearing speed should be limited to feasible and economical speed (**Al-Homadhi, 2007**). The aims of this study were to identify the effect of particle size and an increase in the concentration of Iraqi bentonite on rheological properties, also to evaluate its performance and to know if it can be used as drilling fluid.



2. EXPERIMENTAL WORK

In the first part of this work, Iraqi bentonite taken from Trefawi formation/ Al-Anbar region/ Iraq and supplied from Iraqi Geological Survey was grinded in a special grinder and sieved into three particle sizes (53-75, 75-106, 106-150) μm . Then, it was dried in an electrical oven at 180 $^{\circ}\text{C}$ (not exceed 200 $^{\circ}\text{C}$) (Wedlp, 2010) for 12 hours to remove the interlayer water between molecules. After that, 22.5 g (6 wt. %) of Iraqi bentonite was mixed with 350 ml of distilled water, and the mixture was aged for 24 hr to ensure good hydration (Sallam, 2018). Finally, the rheological properties of the mixture were measured at room temperature using OFFITE Model 900 Viscometer.

In the second part of this work, Iraqi bentonite was characterized by X-Ray Diffraction (XRD) using XRD 6100/7000 X-Ray Diffractometer, X-Ray Fluorescence (XRF) using XRF-1800 Sequential X-Ray Fluorescence Spectrometer, and Particle Size Distribution (PSD) using Malvern Mastersizer 2000 Particle Size Analyzer.

In the third part of this work, different concentrations (6, 15, 17. 18 and 20) wt. % of Iraqi bentonite was mixed with 350 ml of distilled water to identify the quality of bentonite and maintain the value of yield.

3. RESULTS and DISCUSSIONS

3.1 Effect of Particle Size on Rheological Properties of Iraqi Bentonite

Iraqi Bentonite was grinded and sieved into three particle sizes range of (53-75) μm , (75-103) μm , and (106-150) μm to show the effect of particle size on the rheological properties. After 24 hr, the rheological properties of 22.5 g of the different particle sizes of Iraqi bentonite after mixed with 350 ml of distilled water were measured, as shown in **Table 1**.

Table 1. Rheological properties of different particle sizes of Iraqi bentonite.

Particle Size, μm	(53-75)	(75-106)	(106-150)
600 Reading, RPM	5.43	5	4.79
300 Reading, RPM	3.08	2.98	2.87
Apparent Viscosity(AV),cp	2.72	2.5	2.39
Plastic Viscosity(PV),cp	2.35	2.02	1.92
Yield Point(YP), lb/100ft²	0.73	0.96	0.95
Yield Point/Plastic Viscosity(YP/PV), lb/100ft²/cp	0.31	0.47	0.49
10 Sec Gel, lb/100ft²	0.8	0.5	0.7
10 min Gel, lb/100ft²	1.9	1.3	1.2

Table 1 shows that better results carried out from the minimum size (53-75) μm because as the particle size decreases, the surface area increases causes an increase in adsorption and swelling capacity. From the table above, all the results from the three sizes indicated that the Iraqi



bentonite did not satisfy the API specification. The rheological properties of Iraqi bentonite are very low because Iraqi bentonite is calcium type that has low adsorption and swelling capacity.

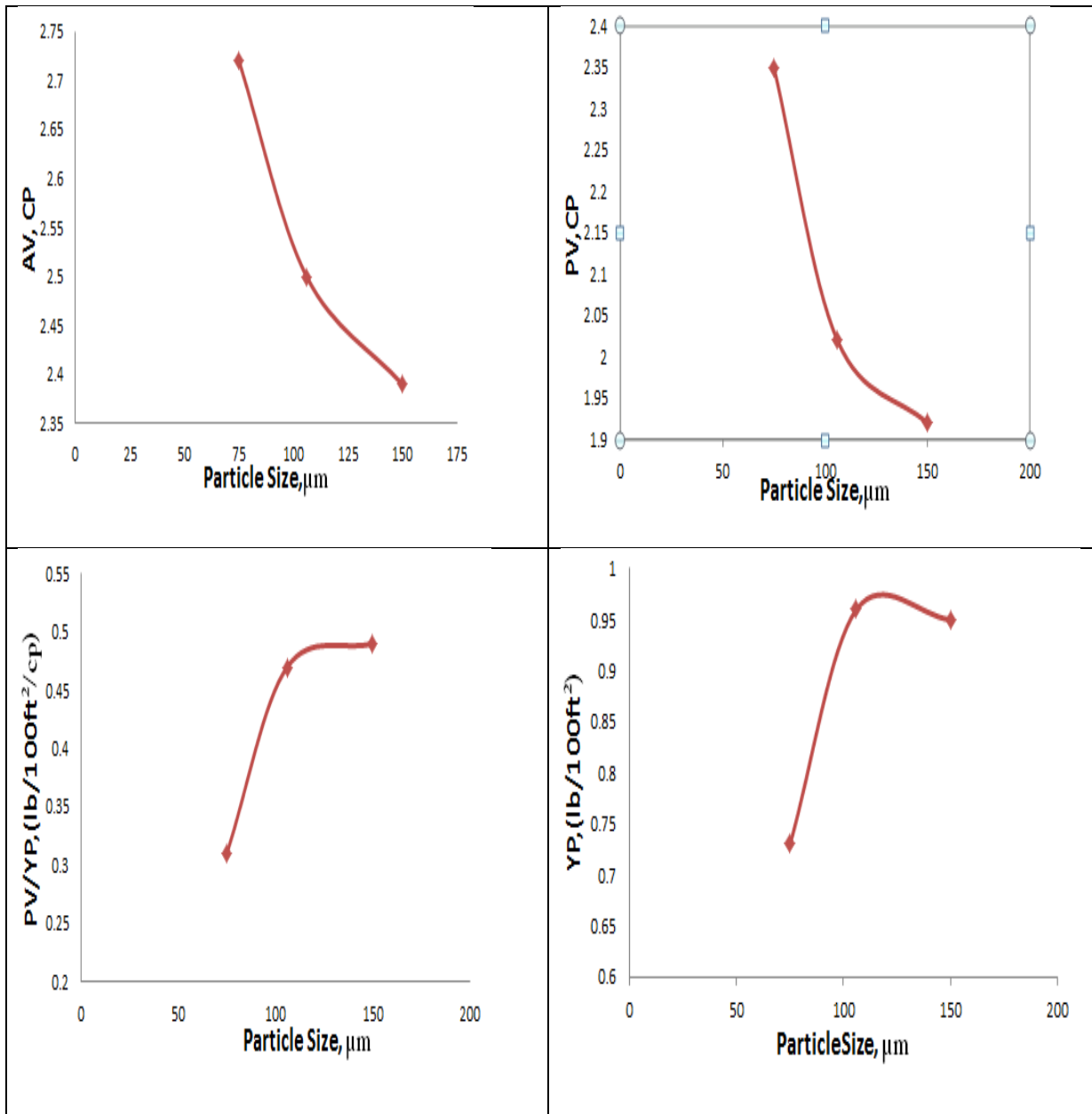


Figure 1. Effect of Iraqi bentonite particle sizes on the rheological properties.

It is clear from **Fig. 1** that the apparent viscosity and plastic viscosity was increased when the particle size was decreased, and the minimum size has better 10-sec gel strength and 10 min gel strength. From figure above, all results indicate that the best size of Iraqi bentonite was (53-75) mμ.

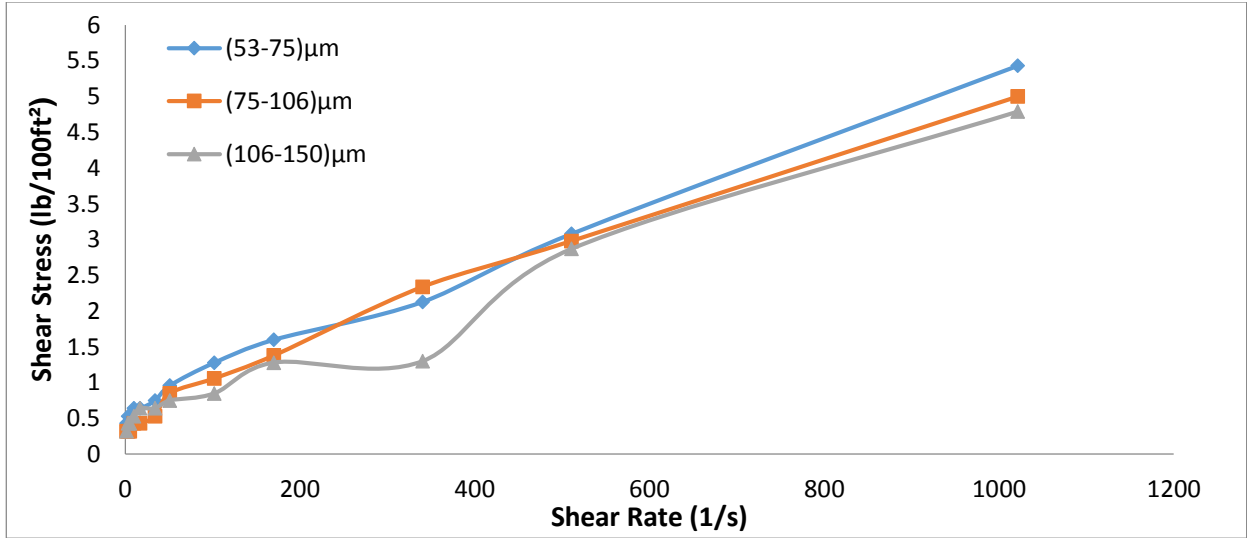


Figure 2. Consistency curve of different particle sizes of Iraqi bentonite.

Fig. 2 shows the consistency curve of the three particle sizes of Iraqi bentonite, where drilling fluid with less particle sizes has the highest shear stress with different shear rates. The figure above presents that less size has the highest shear stress.

3.2 Mineral Composition (XRD), Chemical Composition (XRF) and Particle Size Distribution Analyses of Iraqi Bentonite

The analyses were carried out in the Geological Survey/ Central Laboratories Department using instruments that illustrated in Fig. 3.



XRD 6100/7000 X-Ray Diffractometer



XRF-1800 Sequential X- Ray Fluorescence Spectrometer



Malvern Mastersizer 2000 Particle Size Analyzer

Figure 3. XRD, XRF, and particle size analyzer.

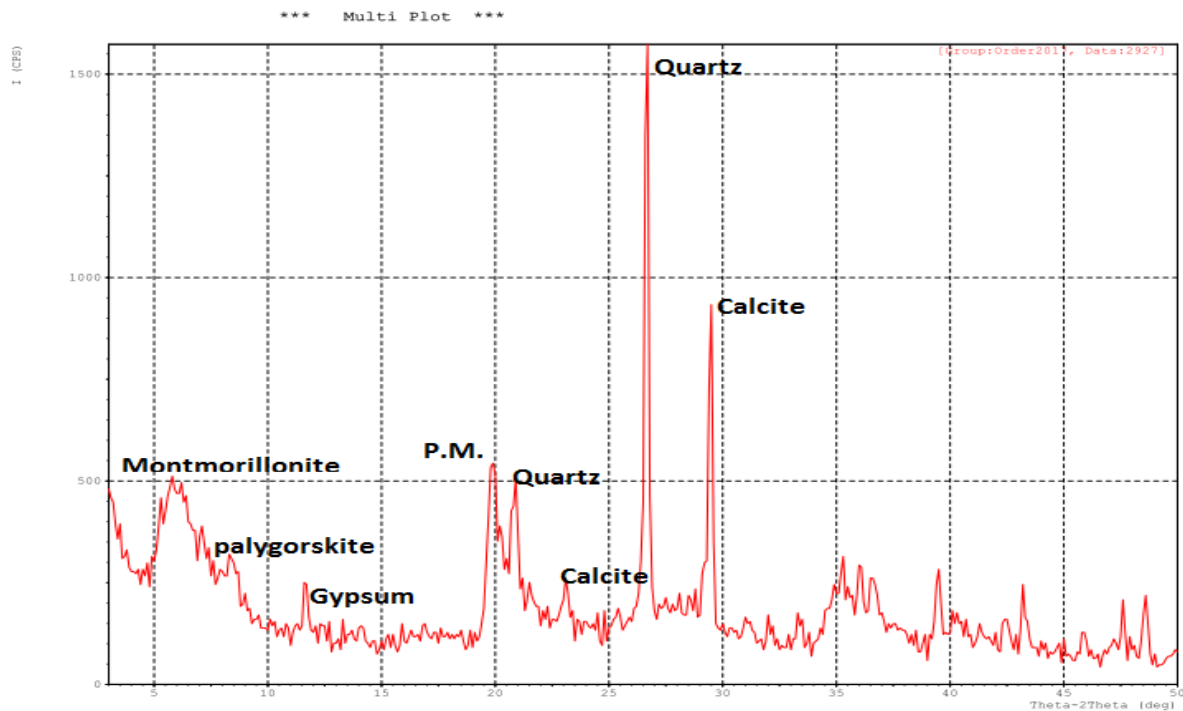


Figure 4. X-ray diffraction of Iraqi bentonite.

X-ray diffraction was carried out to investigate the mineral composition of bentonite. XRD of Iraqi bentonite contains montmorillonite and palygorskite as clay minerals with high concentration of impurities (quartz and calcite). Therefore, special process of grinding was used to remove quartz to increase the concentration of montmorillonite.

Table 2. XRF analysis of Iraqi bentonite.

SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	CaO	MgO	SO ₃	LOI	Na ₂ O	K ₂ O	Mn
%	%	%	%	%	%	%	%	%	p.p.m
52.1	5.71	15.91	7.06	1.79	0.99	13.68	0.60	0.67	133.00

X-ray fluorescence was used to show the chemical composition of Iraqi bentonite. Table 2 shows that the ratio of Al₂O₃/SiO₂ was 1/3 as expected for montmorillonite, which is the main component of bentonite. The ratio of [(Na₂O+K₂O)/ (CaO+MgO)] for Iraqi bentonite was 0.143 confirming that Iraqi bentonite was Ca-bentonite (Abdow, 2013).

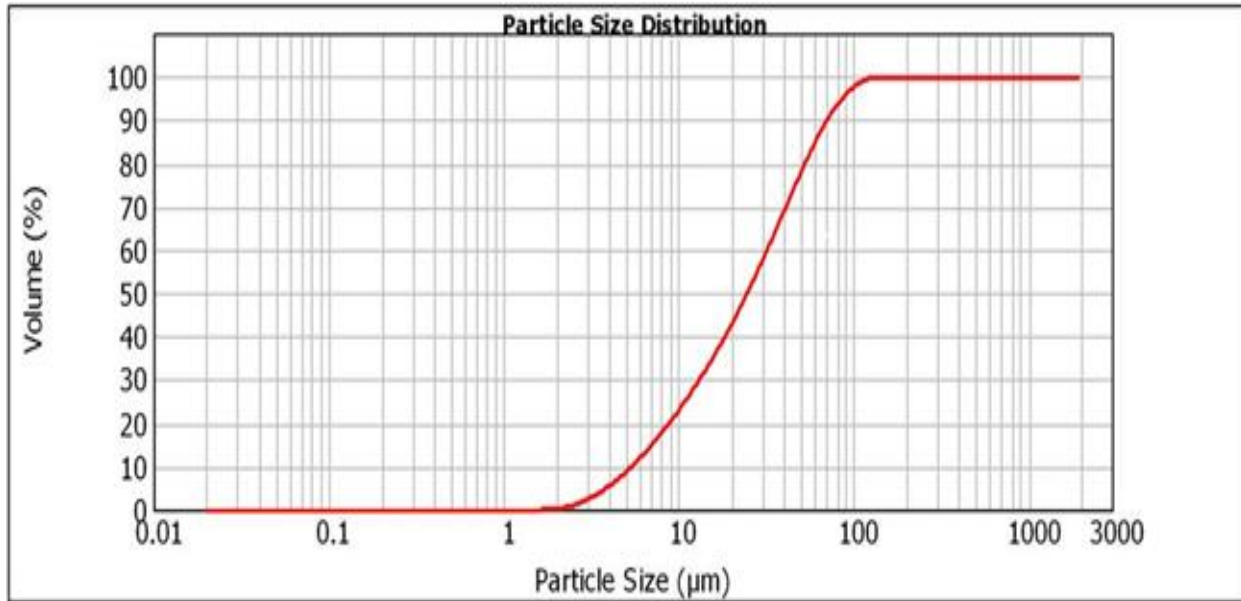


Figure 5. Particle size distribution of Iraqi bentonite.

Fig. 5 shows the particle size distribution of Iraqi bentonite after grinding with sieve less than 75 µm. The figure above shows that 10% of the particle size was smaller than 5.354µm, 50% of the particle size was smaller than 24.512µm, and 90% of the particle size was smaller than the 69.96µm. The average particle size of Iraqi bentonite after grinding was 36.0825µm.

3.3 Effect of Increasing Concentration of Iraqi Bentonite

The purpose of the testing yield of clay is to show the performance of bentonite. When clay production ≥ 85 barrels/ton (bbls of drilling fluid/ton of clay), it is classified as good clay yield, when clay produced (50-85) barrels/ton, it is classified as high clay yield, clay with (30-50) barrels/ton production, it is classified as medium clay yield, and when clay produced ≤ 30 barrels/ton, is classified as low clay yield. Good bentonite (for drilling purposes) should have a fan apparent viscosity of at least 15 cP (which is viscometer dial reading at 600/2 rpm) according to API and OCMA standards. Apparent viscosity with 15 cP is assumed to be an acceptable value, which corresponds to 90 bbl/ton clay yield. Clay concentration of suspension and its yield value are related by the equation below, (**Erdoğan and Demirci, 1996**):

$$Y = \frac{570.5}{\left(\frac{C}{3.5}\right)} \quad (1)$$

Where Y= Yield value C= concentration of clay in g clay per 350 ml water.



Table 3. Rheological properties of Iraqi bentonite with different concentrations.

Wt. g	S % By wt.	AV cP	PV cP	YP (lb/100ft ²)	YP/PV (lb/100ft ² /cp)	Gel Strength(lb/100ft ²)	
						10 sec	10 min
22.5	6	2.88	1.8	1.17	0.65	0.8	1.9
61.76	15	10.54	3.4	14.28	4.2	14.1	10.9
71.68	17	13.1	4.68	16.83	3.59	14.6	13.2
76.83	18	18.1	5	26.2	5.24	23.1	24
87.5	20	23.21	7.56	31.31	4.14	21.6	24.3

Plastic viscosity (PV) is that part of the resistance of flow caused by mechanical friction. An increase in the concentration of solids, a reduction of the size of solids particles, led to increase in the total surface area of solids exposed will increase the plastic viscosity. Yield point (YP) is the measurement of the attractive forces (resulting from the negative and positive charges located on or near the particle surfaces). Gel strength is caused because of electrostatic forces between different mid particles (**Salam, 2019**). **Table 3** shows that the apparent viscosity of Iraqi bentonite drilling fluid was achieved more than 15 cp at the concentrations of 18%. Bentonite concentration of (16.8 wt. %) yields gave the apparent viscosity of 15 cp, using **Eq. 1**, the value of yield of bentonite is 28. Therefore, Iraqi bentonite has low yield clay because it is Ca-type. Ca-bentonite has low rheological properties because it has low dispersion and low swelling capacity^[4]. Therefore, it cannot be used as drilling fluid without activation or adding additives to improve the rheological properties.

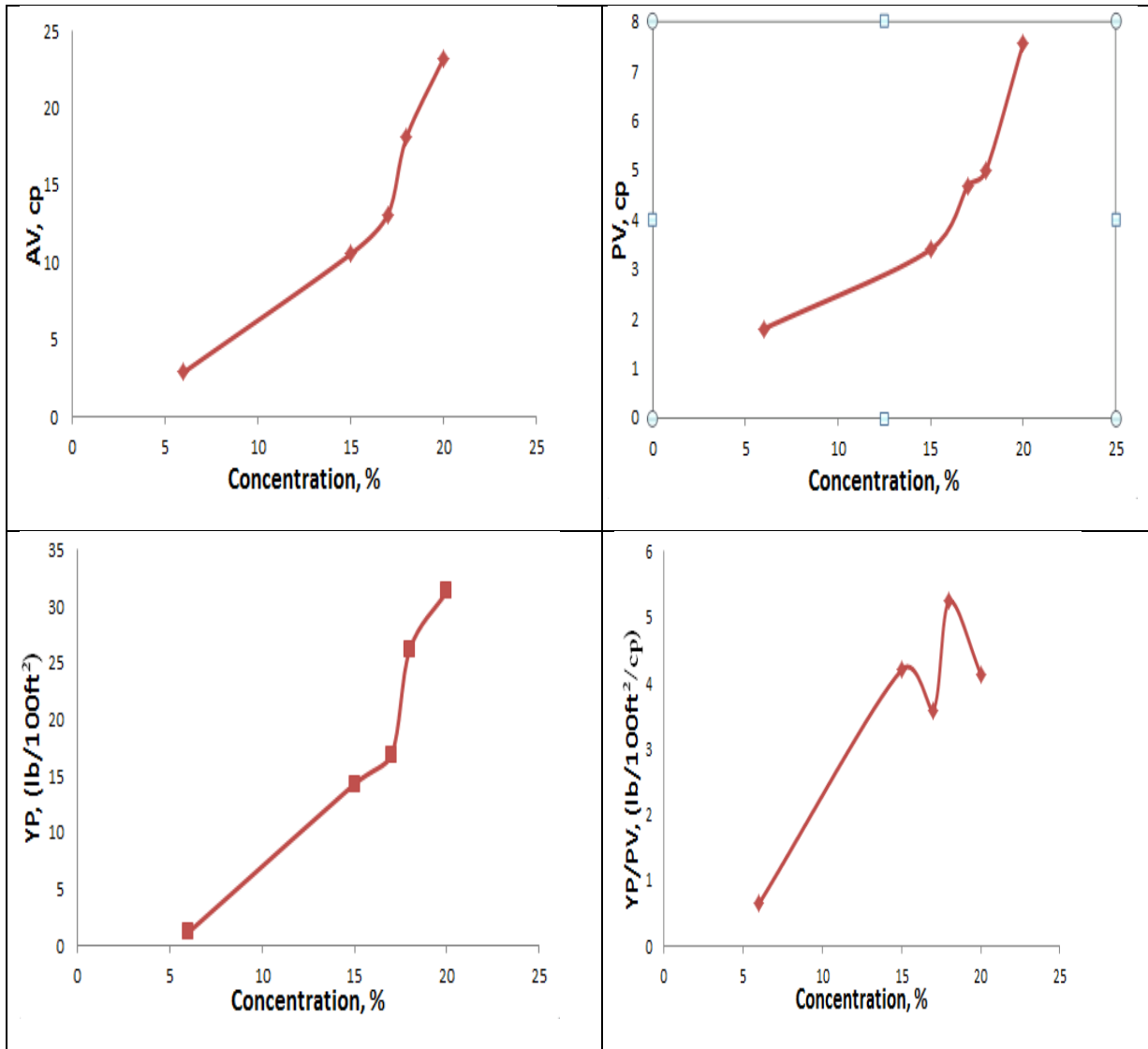


Figure. 6 Rheological properties of Iraqi bentonite with different concentrations.

Fig. 6 shows that the rheological properties of Iraqi bentonite with different concentrations added to 350 ml distilled water. The figure above shows that apparent viscosity, plastic viscosity, and yield point were increased when the concentration of Iraqi bentonite was increased. Increasing the concentration of bentonite caused an increase in the attractive forces between clay plates.

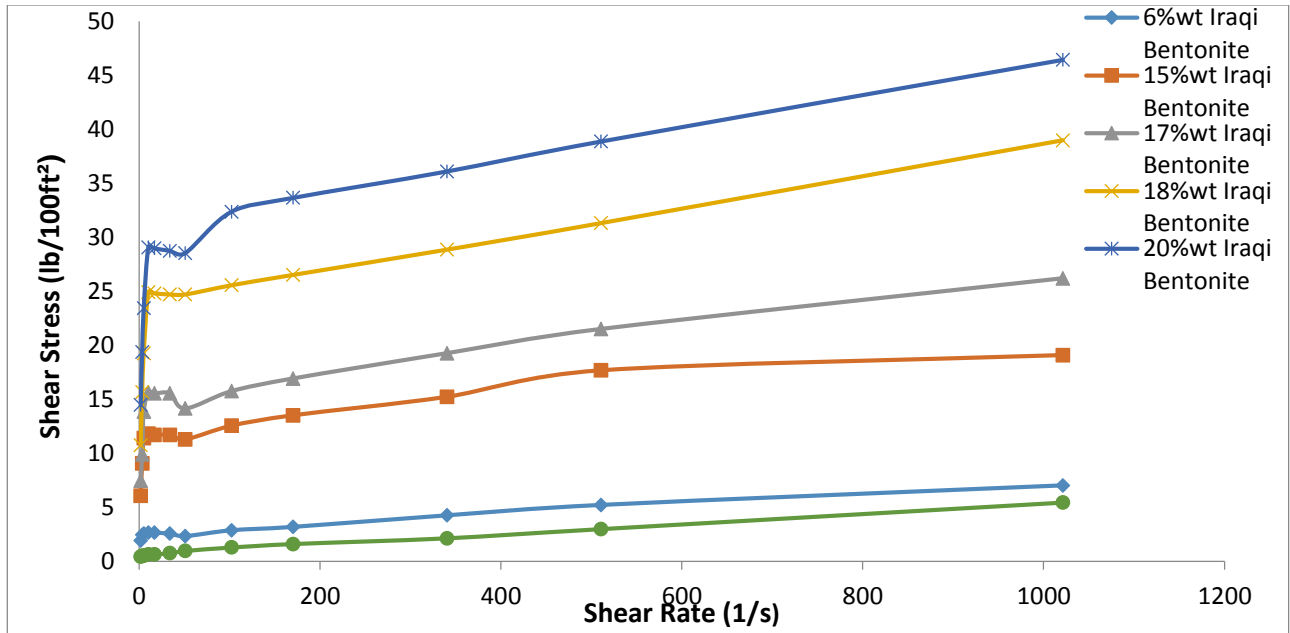


Figure 7. Consistency curve of Iraqi bentonite with different concentrations.

Fig. 7 shows the shear stress versus the shear rate of different concentrations of Iraqi bentonite in 350 ml of distilled water. Shear stress applied to static fluid, layers are slide past one another and frictional drag that occurs between layers (which are offering the flow resistance). The magnitude of the shear between layers represents by shear rate, which defines a difference in velocities between layers divides by the distant of separations. The relationship between the shear rate and shear stress is defined as fluid behavior (Throne, 2006). From the figure above, it is clear that the shear stress increased as the concentration of Iraqi bentonite increased because the colloidal particles or clays of the fluid increased, these particles tend to increase shear stress or force necessary to maintain a given rate. This is due to the attractive forces between particles and to then physically bumping into each other.

4. CONCLUSION

The rheological properties of Iraqi bentonite of different particle sizes and different concentrations were tested to evaluate the performance of Iraqi bentonite if it can be used as drilling fluid or not. The result illustrated that, as particle sizes decreased, the rheological properties were increased, and as the concentration of Iraqi bentonite was increased, the rheological properties of Iraqi bentonite were increased. Also, results showed that the theological properties of Iraqi bentonite of three different particle sizes were very low and did not satisfy API specifications, and the yield of Iraqi bentonite was very low. Therefore Iraqi bentonite cannot be used as drilling fluid without activation or adding additives to improve its performance.

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