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Fly Ash as a Weighting Agent: An Experimental Investigation on Fly Ash to use it as a Possible Replacement of Barite and Ilmenite

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Abstract: ***Barite (Barium Sulphate) is the most commonly used weighting agent during drilling operation. It is abundant in nature as well as in the market. Global Barite production is about 6 million tons and these all are traded worldwide. But it's been observe that prices have increased rapidly in the last few years due to the transportation issue. Ilmenite is another weighting agent currently used in drilling fluids, but due to its high abrasiveness and issues with the mud cake removal industry is looking for a more suitable alternative. Fly ash is a waster product from coal feed thermal plants. Million tons of Fly ash is produced every year from these thermal plants and due to the lack of proper disposal methods it spreads in the environment and causes pollution. In this work we are trying to use Fly ash as a weighting material in drilling fluid. Comparable results are obtained from the samples having Fly ash. This justifies that Fly ash can be a replacement for Barite and Ilmenite.***

Keyword: Barite, Fly ash, Ilmenite, Weighting agent

1. Introduction

Designing of the drilling fluids based on wellbore condition is most challenging. It is important to design a stable mud system as the wellbore condition can push the mud to its limit and make any contaminant to the system react very rapidly causing destabilization of the fluid. Thus we have to make sure that the drilling fluid will remain stable for maximum expected time under the most extreme conditions anticipated. One of the major properties of drilling fluid is to counter balance the formation pressure to avoid kick or blow out. This is only possible when we have a mud which gives a suitable hydrostatic head. The purpose of adding weighting agent is to provide density to the drilling fluid [1]. Barite (Barium Sulphate) is most commonly used weighting agent as it is abundant in nature as well as in the market [2]. Global Barite production is about 6 million tons and these all are traded worldwide. But it's been observed that prices have increased rapidly in the last few years due to the transportation issue. India produces around 12% of it but due to lack of proper transportation and depletion of Barite reserves there is a hike in its price [3]. Barite (SG 4.2-4.4) often contains components like lead, cadmium, mercury and arsenic [4]. These all are heavy material and very harmful to environment as well as to the human body. Along with these one more problem with Barite is its sagging tendency. Sagging is settlement of particles at the lower side of the well bore [5 & 6]. Because of this sagging tendency mud having Barite has high chances of loss circulation which may lead to serious well control situation, reduction in ROP, higher chances of pipe sticking etc [7 & 8]. On the other hand Ilmenite ($FeTiO_3$) is another weighting material used in drilling fluid for density enhancement [9]. It has a specific gravity range 4.7-4.9. Literature study shows that properties of drilling fluid having Ilmenite gives better results in drilling fluid as compared to Barite [10 & 11]. The major disadvantage of Ilmenite is its abrasiveness. Farid Ibrahim et. al. reported that there is a possibility of formation damage when Ilmenite is used in drilling fluid [12]. However this issue has been solved by using micronized Ilmenite yet this also increases the overall cost of the drilling fluid [13 & 14]. In another study a combination of Barite and Ilmenite is used in drilling but this also increases the price of drilling fluid. Fly ash is a waste product from thermal plants. It is also considered as the fifth-biggest raw material. 25% of Fly ash produced in India is utilized for the bricks and construction works. The rest is left without any consideration [15]. Fly ash possesses pozzolanic properties and its size is also fine [16 & 17]. That is why it is also used in cement industry. The amount of fly ash left unchecked causes many environmental issues. In humans, it causes diseases such as cancer, asthma, heart disease, respiratory illness, stroke, inflammation, and immunological reactions etc [18]. These effects can be reduced if the Fly ash is used in areas of interest for instance drilling operations. Fly ash can be used as a preparation agent for drilling fluid and in this way adequate waste management and efficient drilling implication can be carried out. In this study we have given an attempt to utilize these waste Fly ash as a weighting material in drilling fluid and compare it with Barite and Ilmenite.

2. Materials Used and Methodology

2.1 Materials used

For the experiments we have used API Grade Bentonite, industry grade Barite (SG 4.2), Fly ash (VM Blocks Ecological and Economical in Srirangapatna, Karnataka, India), Ilmenite(V V minerals Tamil Nadu), Carboxy Methyl Cellulose (CMC, Sigma Aldrich), Calcium Carbonate-Fine ($CaCO_3$, Karnataka Fine Chem.), Sodium Hydroxide (NaOH, Karnataka Fine Chem.), Potassium Chloride (KCl, Karnataka Fine Chem.) and Mica.

2.2 Equipments used

The equipments used in this work are Hot Air Oven, Muffle Furnace, Hamilton Beach Mixer, Mud balance (OFITE), Fann VG Meter (Model 35, Fann Instrument Company), API Filter press (Model 300).

2.3. Methodology

2.3.1 Preparation of weighting materials

First of all Barite, Ilmenite and Fly ash all three materials were allowed to pass through a sieve of mesh size 75 micron. Particle size larger than 75 micron will remain on the top of the mesh. These will be removed and those who pass through the mesh will be collected from the bottom. Then the Fly ash was kept in a muffle furnace at temperature 800°C for two hours. This is done to remove any unburnt carbon present in it. Then all three materials were kept in a Hot air oven at 90°C for three hours for the removal of moisture.

2.3.2 Preparation of Drilling fluid samples

For this experiment we prepare four samples of Drilling fluid using Hamilton Beach Mixer following the American Petroleum Institute (API) standards to investigate the properties of the fluids. The composition of each sample has been mentioned in Table 1

Table 1: Composition of different samples

Component	Unit	Sample 1	Sample 2	Sample 3	Sample 4
Water	mL	1000	1000	1000	1000
Bentonite	gm	30	30	30	30
Barite	gm	-	15	-	-
Ilmenite	gm	-	-	15	-
Fly ash	gm	-	-	-	15
CMC	gm	4	4	4	4
CaCO3 (Fine)	gm	13	13	13	13
KCl	gm	8	8	8	8
NaOH	gm	10	10	10	10
Mica	gm	5	5	5	5
Nut plug	gm	5	5	5	5

2.3.3 Mud weight, Rheological and Filtrate Loss test

OFITE Mud Balance was used to measure the mud weight of the samples. Both lb./gal (ppg) and lb./cf. (pcf) readings were taken from the balance scale. Fann VG meter (Model 35, Fann) was used to determine rheological properties like Apparent Viscosity (AV), Plastic Viscosity (PV), Yield Point (YP) and Gel strength of all the samples. After getting reading at 600, 300 and 3 rpm, equations 1, 2 and 3 were used to calculate the properties. Filtrate loss and Filter-cake thickness were determined using Fann API Filter Press (Model 300, Fann). All these experiments were performed as per the guidelines from API.

$$PV = \theta_{600} - \theta_{300} \quad \ldots\ldots(1)$$
$$YP = \theta_{300} - PV \quad \ldots\ldots(2)$$
$$AV = \theta_{600}/2 \quad \ldots\ldots(3)$$

3. Results and Discussion

3.1 Mud Balance Results

Mud weight of all samples were taken using mud balance. Recorded results are shown in Table 2. It was observed that there was a very negligible change in the mud weight values for Sample 2, 3 and 4. It is a clear indication that Fly ash added mud can exert almost same amount of hydrostatic head if it is used as a weighting agent.

Table 2: Mud weight for all four samples

SAMPLE	ppg	pcf
Sample 1	13	97.24
Sample 2	19	142.12
Sample 3	18.5	138.38
Sample 4	17.5	130.9

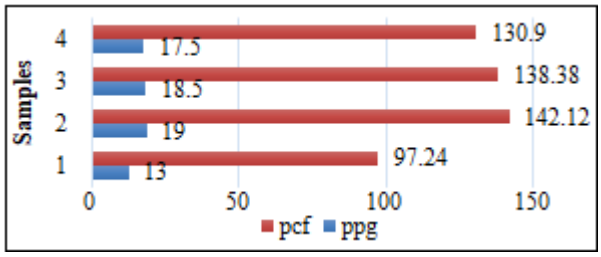

Figure 1: Comparison of Mud weight

3.2 Fann VG Meter results

From the Figure 2 we can interpret that sample with Fly ash has comparable results for PV and AV. AV values are ranging from 15.5, 16 and 15 cP for samples having Barite, Ilmenite and Fly ash respectively. For PV, the values are same for all three samples i.e. Sample with Barite, Ilmenite and Fly ash. From Figure 3 it is observed that YP values are ranging from 11, 12 and 10 lb./100 ft^2 for samples with Barite, Ilmenite and Fly ash respectively. It is an indication that the cutting carrying capacity of the fluid may get affected if we use fly ash as a weighting agent. YP/PV ratio of all four samples were also measured. It was observed that this ratio varies from 2, 1.1, 1.2 and 1 for Sample 1, 2, 3 and 4 respectively. It means that the sample with Fly has a higher degree of stabilization [19].

3.3 API Filter Press results

Filtrate loss and Filter cake thickness were calculated using API Filter Press equipment. Obtained results are listed in the Table 3.

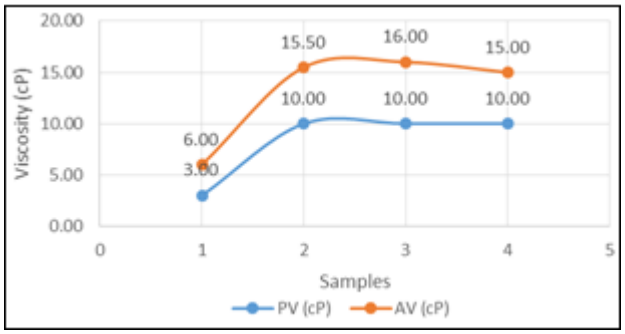

Figure 2: Comparison of AV and PV

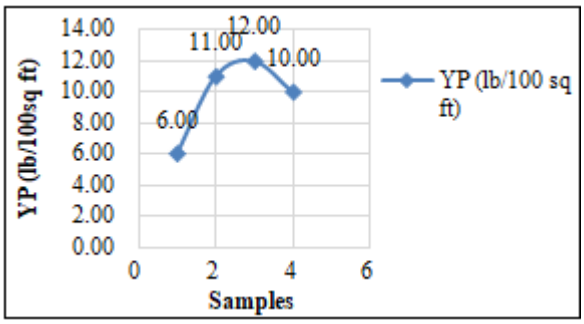

Figure 3: Comparison of YP

Graphs were plotted and it was observed that filtrate loss value for Ilmenite and Fly ash added mud is almost similar. Whereas we observe a slight increment in the filtrate loss value for mud having Barite. Regarding mud cake thickness, Fly ash added mud has the similar mud cake thickness as Barite added mud whereas we observe a thicker mud cake in case of Ilmenite added mud. This can be interpreted as mud having Fly ash gives almost comparable results in terms of filtrate loss and mud cake thickness (Figure 4&5)

Table 3: Filtrate loss and Mud Cake thickness values for all four samples

Sample	Mud Filtrate (mL)	Mud Cake thickness (1/32")
Sample 1	19	3
Sample 2	14	4
Sample 3	13	5
Sample 4	13	4

Figure 4: Comparison of Filtrate loss

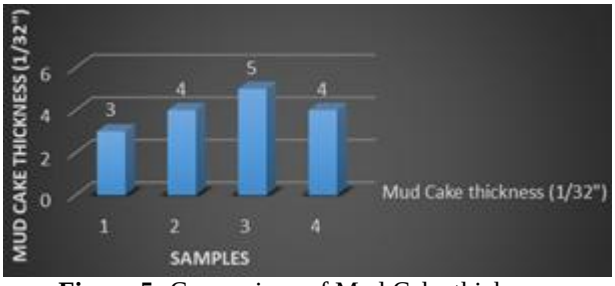

Figure 5: Comparison of Mud Cake thickness

4. Conclusion

Based on our investigation we can draw the following conclusions-

1) Fly ash as a weighting agent can give us good amount of density which is comparable with Barite and Ilmenite.
2) PV and AV results indicated that they are almost identical for the fluid samples with Barite, Ilmenite and Fly ash.
3) However there is a slight reduction in YP values which may affect the cutting carrying capacity of mud.
4) YP/PV ratio of Fly ash added mud is the least, which indicates that this mud is more stable as compared to Barite and Ilmenite
5) Filtrate loss properties are also satisfactory for mud with Fly ash. These values are almost same with mud having Barite and Ilmenite.
6) Overall we can conclude that Fly ash can be used as a replacement of Barite and Ilmenite. By doing so we are not only utilizing industry waste but also reducing environmental pollution.

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Nomenclature:
AV: Apparent viscosity (cP)
PV: Plastic viscosity (cP)
YP: Yield point (lb./100 ft^2)
θ: Bob dial reading
CMC: Carboxy Methyl Cellulose

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