EFFECT OF GRAIN SIZE ON SELECTED PHYSICO-CHEMICAL PROPERTIES OF LOCALLY AVAILABLE BENTONITE IN GEOTHERMAL DRILLING

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Abstract

Geothermal operations at Olkaria have been using imported Bentonite for drilling since the beginning of drilling operations in 1958. Mixture of the right proportion of expanding and non-expanding clay to improve plasticity (moldability) of locally available Bentonite which can be used in the drilling industry in Kenya has not been investigated. In addition, little is known on the choice of the right grain size to eliminate or reduce the content of undesirable compounds such as iron oxide (Fe_2O_3), and aluminium oxide (Al_2O_3) to improve the strength of mud cake in the drilling process. The objective of this study was to investigate how selected physico-chemical properties of drilling clay relate to grain size of Bentonite available in Kenya. Randomised and probability sampling was employed in the month of February, March, and May on Bentonite from Parminters and Krigers field within the Lewa Wildlife conservancy. Clay samples were refined into 25, 20, 63 µm using size grading method. The mineralogical composition of the samples was determined using X-Ray Diffraction (XRD). The chemical composition, liquid limit, plastic limit and plasticity index were also determined. Firing was done at 800°C in a muffle furnace and the cracks of the samples recorded. The study showed that clay particles with sizes 20 and 25 µm were higher in Loss On Ignition (LOI) and total Carbon (C) than that of 63 µm regardless of grain size, the clay investigated had Quartz (SiO_2), Illite-montmorillonite, Anatase (TiO_2) and Kaolinite. Grading affected the concentrations of Iron (Fe), Aluminium (Al) and Silicon (Si) as clays with particle sizes 20 and 25 µm had higher contents of the aforementioned elements compared with those of 63 µm. The clay with particles 63 µm had the best strength and this was so because the clay particles had the lowest amount of Fe, Al and Si. Proper grading of clay particles can improve the physico-chemical properties of locally available Bentonite and make it a better quality than imported Wyoming Bentonite.

Key words: Clay mineral, drilling, mud cake, x-ray, iron oxides, aluminum oxides

1.0 Introduction

Drilling for geothermal energy and related industries in the world have been in existence for many centuries. This has been possible because of the exploitation of important soil resources such as soil colloids and minerals. There are different types of soil colloids (crystalline silicate clays, noncrystalline silicate clays) and minerals (feldspars, micas and so on) with different composition, structure and properties, Brady, Tan (2002, 2005). Smectite (montmorillinite), an example of expanding crystalline silicate clay, is abundant in Kenya including soils of Lewa conservancy in Laikipia County. Due to its plasticity, it is commonly used in drilling and other geotechnical related industries as its expanding nature allows it to be dried in the process of drilling and cementing without cracking from shrinkage, Brady (2002). The drilling industry is not only lucrative in Kenya, China, Iceland and USA but also in the rest of the world because of the industry's close association with energy developments. The household and antique value of electric energy in both the developing and developed countries cannot be overemphasized. The socioeconomic aspect or contribution of the energy industry to the Kenyan economy does not deserve underestimation. For instance, a small to medium scale electric energy firm can employ 155 workers. Additionally, energy production from geothermal resource in Kenya is greater than those of Japan, Taiwan and the Philippines. The combined resource potential of over 7000 MW can supply energy needs for the whole East African states. This quantity is greater than the combined production of the region. This indicates that if local bentonite is used in the geothermal well drilling processes, we shall produce high quality green energy at reduced cost. Also the socio-economic contribution of the energy sector and production related industries to the economy of the East African Community can tremendously improve than it is at the moment. Despite the potential of Kenya to take a leading role in the energy market (being a country whose grounds are dominated by geothermal resources), among the pertinent problems in the use of Kenyan Bentonite for drilling is their fragility or unknown strength. This may be so because of their chemical and mineralogical compositions alterations during mining and other factors such as the size of clay grains Thiasem, (2002). As an example, a mixture of the right proportion of non-expanding (e.g., kaolinite) and expanding (e.g., montemorillonite) clays to improve plasticity (moldability) has not yet been well investigated in the country. In addition, the choice of the right clay size to eliminate or reduce the content of undesirable compounds such as Fe_2O_3 and Al_2O_3 not to mention the incorporation of some amount of feldspars to increase the strength of cake and roofing tiles have also not been dully researched in Kenya. To improve upon the strength of mud cake and Kenyan clays for a large scale commercial purpose in the country, there is need to have some sound and sufficient knowledge about soil clays. With this information the quality of the clays in Kenya can be improved to suit the drilling and other clay related industries. The objective of this study was to investigate how selected physico-chemical properties of Kenyan drilling mud clay relate to grain size.

2.0 Materials and Methods

The traditional method of producing pots and roofing materials is that the clay material is saturated with water, kneaded and moulded or thrown on a potter's wheel to obtain the desired shape. They are then hardened by drying or firing. When fired, the mass cohering clay platelets hardens irreversibly yet they are vulnerable to breakage, Brady (2002). To improve upon this problem, clay samples were refined into 63, 25 and 20 µm using size grading method, Thiansem (2002). This range of size grading was chosen so that any differences as a result of particle size in addition to drilling technological behaviour could be examined. This screen sieving is also necessary to significantly reduce Fe_2O_3, Al_2O_3 and SiO_2 which are undesirable constituent in raw clays. The ash and Carbon contents of the clay were determined by the combustion method. The Aqua Regia method was used to extract Potassium, Sodium, Calcium, Magnesium, Iron, Aluminium and Silcon. Their concentrations were determined using Inductively Coupled Plasma. The mineralogical composition of the clay was determined using X-Ray Diffraction (XRD). The clay samples were wetted (sticks between thumb and forefinger). Rings of the clay samples made were fired at 800°C using a muffle furnace at 800^oC for five hours to observe their cracking strength.

3.0 Results

The effect of grading on Loss On Ignition (LOI) and total carbon of the clay investigated in this study is shown in Table 1. The clay particles with sizes 20 and 25 µm were higher in Loss On Ignition and total Carbon than those of 63 µm. However, the sieve size difference of 5 µm between 20 and 25 µm particles had no significant effect on the quantity of Loss On Ignition and total Carbon (Table 1).

Qualitatively, regardless of particle size (sieve size), the clay investigated had quartz (SiO_2), illite, montmorillonite, Anatase ((TiO_2) and kaolinite. Quartz was dominant but kaolnite was prominent too.

Quantitatively, grading affected the concentrations of Iron, Aluminium and Silcon as clays with particle sizes 20 and 25 µm had higher contents of the aforementioned elements compared with those of 63 µm (Table 2). A similar observation was made for Potassium, Sodium, Calcium and Magnesium (Table 3). The effects of firing at 800°C for five hours on the strength of clay with particles with 20, 25 and 63 µm are shown in Table 1-3. The molded clay with particles 63 µm had no cracks but there were cracks for particles 20 and 25 µm.

Table 1: Effect of grading on Loss on ignition (LOI) and total carbon of clay

Sieve size (µm)	LOI %	Total C %
20	5.71	1.48
25	5.71	1.47
63	4.58	1.36

Table 2: Effect of grading on iron, aluminium and silicon concentration of clay

Sieve size (µm)	Fe (µg g-1)	Al (µg g-1)	Si (µg g-1)
20	14900	111650	288
25	15400	111350	405
63	13900	9436	261

Table 3: Effect of grading on potassium, sodium, calcium and magnesium concentrations o clay

Sieve Size (µm)	K (%)	Na (%)	Ca (%)	Mg (%)
20	0.10	4.21	0.24	0.13
25	0.44	2.70	0.31	0.16
63	0.20	2.76	0.38	0.14

Figure 1: Effect of grain size on the strength of clay particles at 20 µm and temperature of 800^{o}C after firing for five hours

Figure 2: Effect of grain size on the strength of clay particles at 25 µm and temperature (800°C) after firing for five hours

Figure 3: Effect of grain size on the strength of clay particles at 63 µm and temperature (800°C) after firing for five hours

4.0 Discussion

The clay particles with sizes 20 and 25 µm had higher contents Loss On Ignition and total Carbon than those of 63 µm because organic substances such carbon associates well with relatively finer clay particles. However, this association seems not obvious when the particle sizes are relatively close. Hence the insignificant difference in the contents of Loss on Ignition and total Carbon contents observed for clay particles 20 and 25 µm. Unlike K, Na, Ca and Mg whose contents were not significantly affected by grain size or grading, the contrary was true for Fe, Al and Si. Fine clay particles are known to effectively retain Fe, Al and Si compared with relatively coarse clay particles. A similar observation has been reported by Thiansem *et al*. (2002). The lower contents of Fe, Al and Si in the 63 µm clay particles may be one of the reasons why there were no pronounced cracks when they were moulded into rings and fired at 800°C. The reduction in the contents of the aforementioned elements may have improved the strength of the clay and hence the significant reduction in the breaking or cracking ability of 63 µm clay compared with those of 20 and 25 µm. Thiansem *et al.,* (2002) observed that significant reduction in the contents of Fe_2O_3, Al_2O_3 significantly improved the strength of white clays.

5.0 Conclusion

The clay with particles 63 µm had the best working quality and this was so because the clay particles had the lowest amounts of Fe, Al and Si_2. While better than natural clays, Bentonite does not readily break down its cohesive structure it can be difficult to remove from the well as required. Drilling mud is created by thoroughly mixing water with clay to a desired consistency. Pumping water through the by-pass hose on a 3 way valve and recirculation water back through the pits will help ensure that the clay and water are thoroughly mixed. After the fliud is mixed, sufficient time must be allowed to elapse to ensure complete hydration of the clay prior to its being circulated into the hole. If this is not done, the clays may swell in the well or in the reservoir itself. If this happens, it may be impossible to remove them after the casing is installed and the well may never reach its potential yield.

Drilling fluids must be mixed thick (viscous) enough to bring soil cuttings up from the bottom of the hole to the surface, yet not so viscous as to prevent their settling out in the mud pits. It is, therefore, very important to understand the properties of drilling muds and their proper use: The ability of a fluid to lift cuttings increases rapidly as viscosity (the degree to which a fluid resists flow under an applied force) and up-hole velocity are increased. After cuttings are brought to the surface, however, it is essential that they drop out as the fluid flows through the settling pit. The desired results are obtained by properly designing the mud pits, controlling the viscosity and weight of the drilling fluid and adjusting the pump speed Driscoll, (1986).

During the drilling process, solids accumulate in the drilling fluid - especially when drilling silt, clay or weakly consolidated shale Driscoll, (1986). The thickness of the drilling fluid often needs to be adjusted during drilling by adding more water and/or removing some of the accumulated cuttings from the settling pit. Fluid which is too thick will be difficult to pump and will cause unnecessary wear of the mud pump since cuttings will not have settled out of the mud before the mud is pumped back down the hole. It will also make it difficult to remove the mud from the hole walls and adjacent reseiviorr during well development. The rate of penetration is also potentially reduced Driscoll, (1986). If the mud is too thin, cuttings will not be brought to the surface and the drill bit and drill pipe may get stuck in the well by settling cuttings. In addition, thin mud can result in excessive migration of mud into the formation, thus decreasing the potential yield of the well. The quality of Kenyan Bentonite for drilling can be improved upon proper grading and mixing of the clay particles.

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