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Nigeria Local Clay as an Alternative for Imported Bentonite as Drilling Mud in oil Sector

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Abstract

Drilling mud is an important element of the drilling processes. Any drilling mud must possess common properties that facilitate safe and satisfactory completion of the well. However, the importation of bentonite is very expensive and the consumption is very high, there is need to further the research on the use of local clay as drilling mud. Clay samples were collected from three locations in Ekit-State, Nigeria. Atterberg limit (plastic, liquid and shrinkage limit) and pH of the samples were determined using laboratory approach and compared with the API standard. The liquid limit of the clay samples range between 28.0% and 50%, while the plastic limit range between 19.2% and 22.8% and the plasticity index ranges between 8.8% and 27.5%. The pH value of the clay samples range between 5.5 and 6.0. It decreases after addition of both Na_2CO_3 and KOH, ranges between 4.0 and 4.5. The pH value before and after enhancement did not meet the API specification for acceptable drilling mud of 9.0. However, the clay samples from Papa and Isan-Ekiti which consist of montmorillonite minerals can be used as bentonite if its pH is enhanced.

Key words: Drilling Mud, Bentonite, Atterberg limit, Plasticity, pH, Clay.

Introduction

Clays and clay mineral have been mined since the Stone Age and are among the most important, versatile and are indispensable raw materials needed by manufacturing and environmental industries. Clay is a general term including many combinations of one or more clay minerals with traces of metal oxides and organic matter. Geologic clay deposits are mostly composed of phyllosilicate minerals containing variable amounts of water trapped in mineral structure. Clay minerals are typically formed over long periods of time by the gradual chemical weathering of rock s, usually silicate bearing by low concentration of carbonic acid and other diluted solvents. These solvents usually acidic migrate through the weathering rock after leaching through upper weathered layers.

However, clay deposits can be found in several towns in Nigeria which include Ifon and Igbotako both in Ondo-State, Papa in Isan-Ekiti, Falegan road Ado-Ekiti, Ihiala and Jos (Plateau State). Others include Bui and Maiduguri in Borno-State, Nnewi in Anambra-State to mention but few. There is currently a strong demand for utilization of treated local clay in place of imported Bentonite in drilling operations[1]. Generally, the industrial utilization of treated local clay as drilling mud in place of Bentonite depends largely on its geologic disposition, chemical and physical properties. This research work is aimed at evaluating different types of local clay in Ekiti State, to determine their reserves and their quality by carrying out the laboratory test and the activation by polymer according to the world standard requirement of American Petroleum Institute and Oil Company Materials Association[2], to determine the chemical and physical characteristics in order to be used as well drilling mud.

Location and Climate :

The study area are clay deposits along Falegan road Ado-Ekiti, clay deposits at Papa in Isan-Ekiti, and the clay deposits at the back of Ekiti State House of Assembly complex, Ado-Ekiti. The location along Falegan road in Ado-Ekiti is characterized by a near temperature climate, and that of Papa in Isan-Ekiti has hot humidity climate below the one at the back of Ekiti State House of Assembly in Ado-Ekiti. Generally, weather conditions are normal (warmer) during rainy season (April-October) and much colder during the harmattan period (December-February).

General Geology of Clay :

Soil particles that come from rock and have diameter smaller than 0.0002 inch (0.005 millimeter) are collectively called clay. Particles of clay, when mixed with the proper amount of water, cling together in a soft, sticky mass. A lump of wet clay is said to be plastic because it can be squeezed or pressed into any deserved shape. The synthetic materials commonly called plastics take their name from the same property, but they are softened by heat rather than water. When dried, a molded clay object holds its form. If it is wetted it will soften again; however, if it is fired or baked at high temperature, the object becomes as hard as stone and will no longer soften in water. Thousands of years ago, during the Neolithic stage of civilization, people learned how to mold and bake clay to form bricks and pottery. Keller[3] reviewed the process of formation of clay minerals. In his work, he stated “clay minerals seem to form by alteration of some pre-existing mineral”. This is especially true of those formed in the soil profile. The clay deposits often occurred in a very wide geological area, broadly divided into two major groups, viz: The primary and secondary clay deposits.

Primary clay deposits are those that are formed as a result of endogenetic process under the conditions of high temperature and pressure and are usually formed in-situ by chemical breakdown of parent rocks. The weathering process, by which the clay minerals are formed from the parent minerals are complex but the main factors are climate, topography, vegetation, and time of exposure[4] which are product of metasomatic alteration of pre-existing volcanies, mostly granite and volcanic (igneous) rocks. They are otherwise called hydrothermal and volcanic clays. Hydrothermal clays are products of alteration of pre-existing crystalline rocks under the influence of hot fluids and gases emanating from igneous activities resulting into conversion of volcanic glass, ash and tuff into clay, mostly Bentonite (which finds its application as drilling mud in well site operation). While secondary clay deposit are usually formed by enxogenetic process under conditions of low temperature and pressure by weathering of pre-existing silicate rocks e.g Granite, Syenite, Gnesis e.t.c. These deposits composed of detrital materials, and the type of clay minerals formed depends on their parent rock, climate, topography, vegetation and time of formation[5]. They can occur as alluvial sedimentary or residual deposits.

Alluvial clays are product of transportation by rivers and subsequent deposition along flood plains. This group of clay is usually characterized by their irregular shape, size and thickness, and their mode of occurrence as isolated pockets, which may be unrelated to other parts of the same area. Sedimentary clays are usually formed and transported from their places of origin by natural agencies, deposited and consolidated in sedimentary environments, forming strata. Residual clays minerals formed in place by chemical weathering of rocks, without further transportation *i.e.* in-situ. They are products of weathering of mostly granite and gnesis rocks with high Al_2O_3 content and variable iron (Fe) impurities.

Materials and Method

Samples Collection :

Samples were collected from the clay deposits along Falegan raod, Ado-Ekiti. Local miners have exposed profiles of about 200m. Other samples were collected from Papa, Isan-Ekiti. Outcrops are found exposed to the side of the location by excavation, likewise the sample collected from the back of Ekiti State House of Assembly complex in Ado-Ekiti. Before the samples were collected on the field, erosional surfaces were removed and statistically representative fresh samples were collected at considerable depths (2.0-3.0 meters).

Samples Preparation :

Representative samples collected from the three locations were disaggregated, carefully sun-dried and closely monitored to avoid contaminations of any form. The samples were crushed using agate mortar and pestle and ready for the various laboratory analyses.

Physical Tests

(i) Grain size analysis

The dry-sieving (mechanical sieve shaker) method was used for the grain size distribution determination.

$$Percent\ retained = \left(\frac{weight\ retained}{original\ weight}\right) x\ 100 \quad (1)$$

$$Percent\ passing\ = \%\ (arriving\ a\ particular\ sieve) - \%\ (retained\ on\ the\ sieve) \quad (2)$$

Then the graph of % passing was plotted against the sieve size.

(ii) Moisture content (MC) test :

The percentage of water lost when the sample was at around 20^{o}C is dried at 105^{o}C were determined using electric weighing balance and electric oven.

$$\% MC = \frac{A-B}{B-C} x100 \quad (3)$$

Where A, B and C are weight of sample at 20^{o}C, 105^{o}C and of can respectively.

(iii) Atterbergs limits test :

Consistency (or Atterberg) limit test were carried out on the representative clay samples. The three most popular of the five “limits” proposed by A. Atterberg, a Swedish scientist’ which are the liquid, plastic and shrinkage limit test were carried out[6]. Liquid limit (cassangrande) device and plastic limit plate with soil mixing equipment’s (porcelain dish, spatula, plastic squeeze bottle to add controlled amount of water) and weighing balance (electrical) sensitive to 0.01g, 0.425mm sieve were used to determine the plastic and liquid limit while the shrinkage limit were determined using equation below.

$$Linear\ shrinkage = \frac{Lo - Lf}{Lo} x\ 100 \quad (4)$$

Where L_o and L_f is the initial and final length of the linear shrinkage

Chemical Analysis :

The hydrogen potential (pH) of the samples without and with additives was determined using Kent EIL7045/46 pH meter. Buffer solutions (pH4 and pH9) standardized. The chemical added are Sodium II tri oxo carbonate (Na_2CO_3) and Potassium Hydroxide (KOH).

Results

Grain size analysis is a very expedient and important step for the evaluation of clays for industrial use. This is owing to the fact that grain size of clay particles affects the quality of finished products. The sieve analysis was used to determine the relative proportions of the different grain sizes (particle sizes) contained in the samples. We observe that the samples constitute high percentage of sand ranging between 0 and 13.0%, and the weight retained ranging between 0 and 67.9g respectively.

Table 1. Summary of results for Grain size distributions.

Sieve Diameter(mm)	Percentage passing		
	Falegan Sample	EKHA secretariat Sample	Papa, Isan-Ekiti Sample
9.50	98.7	100	100
4.75	91.1	98.7	99.8
2.36	83.7	97.6	99.1
1.18	78.3	92.4	95.1
0.600	69.8	79.0	83.0
0.425	65.1	68.8	76.5
0.300	60.8	57.7	70.4
0.15	58.7	44.5	57.4
0.075	53.2	40.8	49.6

Table 2. Results for Moisture Content Test

Sample	Profile Depth (m)	%MC
EKHA secretariat	2.0	16.5
Along Falegan	2.5	18.0
Papa, Isan-Ekiti	3.0	14.4

Table 3. Atterberg limit results.

Sample	W_L %	W_P %	I_P %	S. L %
EKHA secretariat	40.2	22.8	17.4	10.0
Along Falegan	28.0	19.2	8.8	8.6
Papa, Isan-Ekiti	50.0	22.5	27.5	6.4

Where: W_L (%) = Liquid limit, W_p(%) = Plastic limit, I_P (%) = Plasticity Index and S. L (%) = Shrinkage limit

Plasticity Index (PI) and their meaning

(i) 0- Non plasticity
(ii) 1-5 Slightly plasticity
(iii) 5-10 Low plasticity
(iv) 10-20 Medium plasticity
(v) 20-40 High plasticity
(vi) >40 Very high plasticity[7].

Result of the liquid limit and the plastic limit analysis revealed that the clay samples have W_L values ranging between 28.0 and 50.0% and W_P between 19.2 and 22.5%. The plastic indices (difference between W_L and W_P) ranges between 9 and 28% while the shrinkage limit values ranges between 6 and 10% respectively. (Table 3).

The plasticity index indicates that the sample from EKHA secretariat Ado-Ekiti has medium plasticity, while the sample from Falegan road, Ado-Ekiti has low plasticity and the sample from Papa, Isan-Ekiti has high plasticity.

Table 4. pH test result of the samples before and after adding additives (1g of Na_2CO_3 and KOH).

Sample Name	Colour	pH value (Before)	pH value (After)
EKHA secretariat	Deep brown clay	5.5	4.0
Along Falegan	Light brown clay	5.5	4.0
Papa, Isan.	Dark brown clay	6.0	4.5

pH variation: (i) 0-6 Acidic, (ii) 7.0 Neutral, (iii) 7-14 Alkaline/Basic.

Drilling fluids performs better in a pH range between 8.0 and 10.5 for Water-base mud. If the pH of the mud is low, below 7.0, it becomes acidic and can corrode the drilling equipment and also pollute the environment. Imported chemicals such as Soda ash [Na_2CO_3], Potash Soda [KOH] and Calcium hydroxide [Ca (OH_2)] are usually added to the mud to raise the mud pH to 8.0 or 10.5

Before the addition of 1.0g of both Na_2CO_3 and KOH to the clay sample, the pH value of the sample ranges between 5.5 to 6.0 (Table 4) which falls under acidic, this indicates that the samples themselves are acidic. After the sample are being treated with 1.0g 0f both Na_2C0_3 and KOH to each sample, the pH value decreases slightly ranges between 4.0 and 4.5 which falls acidic range.

Discussion

Table 3 revealed that the three clay samples are moderately plastic, with the plastic limit ranges between 19.2 to 22.5%. But the plasticity index shows that the sample collected behind House of Assembly chamber, Ado-Ekiti with plasticity index(PI) of 17.4% has medium plasticity, while the sample collected along Falegan road, Ado-Ekiti with plasticity index (PI) of 8.8% has low plasticity, and the sample from Papa, Isan-Ekiti with plasticity index (PI) of 27.5% has high plasticity.

Plasticity index of clay is an expression of its mineralogy to a considerable extent. If clay consists of predominantly of Kaolinite, the plasticity index would be low; the low plasticity exhibited by the local clays may result in failure to control the magnitude of shear stress of fluids and this may lead to fluid failure during an operation[8]. Also the presence of kaolinite in the local clay could lead to poor rheological properties which has a remarkable influence on its use as drilling fluids[9]. The low yield point may also cause the failure of the local but with the predominance of Montmorillonite, the plasticity index would be high.

Table 4: shows the pH value of the soil samples ranges between 5.5 and 6.0 which is acidic. The attempt to increase the pH value (from acidic to alkaline/basic) to at least 9.0 (API standard) an acceptable pH value of clay to be used as drilling mud was futile as the pH value reduced slightly to 4.0 and 5.5 which is still acidic. After the sample are being treated with 1.0g 0f both Na_2C0_3 and KOH to each sample, the pH value decreases slightly ranges between 4.0 and 4.5 which falls acidic range.

Conclusion

The pH value of the clay samples could not meet the API standard, they are less than 9.0. The pH values of the samples before and after treatment are acidic. A high degree of acidity can cause corrosion of metals, and excess of the acidity can have detrimental effect on concrete buried in the ground.

The plasticity index indicates that the sample from Papa, Isan-Ekiti consist of Montmorillonite, while the sample from Falegan road consist mostly of Kaolinite. Hence, the clay samples from Papa, Isan-Ekiti can be used as bentonite it consists of montmorillonite minerals and its pH value must be influenced to meet the API standard of 9.0[2].

Recommendation :

Based on the experimental result and in order to produce a product which can compete with the imported bentonite and to meet the API standard, more research and experimental work should be done. Another way of extending the local clay by different additives should be discovered, because the imported bentonite is not a raw bentonite.

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