Comparison of Isan and Ire Ekiti Clay Materials for Ceramic Brick Production

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Abstract- The evaluation of ceramic materials is a crucial area of research and innovation in the construction industry. Ceramic bricks are widely used as building materials due to their superior properties such as high strength, durability, thermal insulation, and fire resistance. This paper focuses on the comparison of Isan and Ire Ekiti clay materials for use of a ceramic brick manufacturing plant in Ekiti State, Nigeria. Originally mud bricks were used and they were made by human hands manually, today, the process of brick making has become much easier with emerging technologies and discoveries, using brick making plant. Bricks are produced in a very easy and faster rate. Providing adequate housing requires continuous research and investment especially in appropriate technologies that reduce the cost of construction and the cost to the environment. Ceramic brick production is one of such appropriate technologies. Soil samples were collected from the borrow pits within the two towns in Ekiti State. Preliminary geotechnical tests were conducted to determine the engineering properties of the soils so as to determine the best sample(s) or to know whether ceramic blocks can be produced in the communities. The soil samples were tested in order to know their performance characteristics, compressive strength, density and water absorption. The results from the study show that the soil samples consist of varying proportions of mineral compositions which form baseline data with regards to the characterization of clay samples. The study revealed that ceramic bricks manufacturing company can be sited in the two places since raw materials for the production are readily available in good quality.

Indexed Terms- Engineering properties, clay, bricks, housing ekiti state

I. INTRODUCTION

A ceramic is any of the various hard, brittle, heat-resistant and corrosion – resistant materials made by shaping and then firing an inorganic, nonmetallic material, such as clay, at a high temperature. Common examples are earthenware, porcelain and brick (Aeslina et al, 2010). Stone is a natural building material you can use the moment you dig it out of the ground. Bricks, on the other hand, have to be made from clay before we can build with them. Clay is a naturally occurring ceramic based on the chemical elements such as aluminum, silicon, and oxygen (Barsoum, 2003) If you have ever dug wet, clay-rich soil, you know it is very thick and sticky. To turn this gooey material into hard, durable bricks, we have to cut and mould it into rectangular chunks which are then fired in an industrial oven called a kiln at temperatures of over 1000°C (1800°F). Bricks are popular as building materials for several reasons. First, clay is available throughout the world in large quantities and brickmaking is a fairly simple process, so bricks themselves are relatively inexpensive (Alan, 2005) Building bricks are much lighter and easier to work with than stone and sometimes last longer. They're attractive to look at, weatherproof, and-like other ceramics-very good at resisting high temperatures. By using different clays, it's possible to make bricks in different colours. Traditional red bricks take their colour from iron in their clay, while yellow bricks have a greater quantity of lime or chalk. There are essentially two kinds of bricks: ordinary building bricks and refractory bricks, (David et al, 2012) & (J.E Oti et al, 2008)

Building bricks are made to a standard size (typically 20–22 cm long, 9–11 cm wide, and 5–7 cm high (approx. 8–8 5 in long, 3.5–4.5 in wide, and 2–3 in high), with the dimensions varying slightly from country to country). They're made from higher grades of clay and finished on at least one side (face) so they look attractive on houses and walls. Refractory bricks are made for high-temperature use for lining such things as industrial smokestacks (chimneys) and household fireplaces, so they tend to be made more crudely and less attractively finished. Unlike ordinary bricks, they're typically made using such raw minerals as fireclay, alumina (aluminum oxide), silica (silicon oxide), and dolomite (calcium magnesium carbonate). Some are designed to survive temperatures over 2000°C, (3600°F) (Gandon, 2013)

Ceramic materials are probably the most abundant findings in pre-historic and historic archaeological sites and represent after lithic artifacts, the most ancient form of production. Since technologically advanced ceramic materials developed in the last century, the term 'ceramic' has assumed a wide meaning, comprising all those inorganic, nonmetallic and solid materials obtained by heating and subsequent cooling, (Afuye and Ejiko, 2017). Pottery includes a series of different ceramic materials that can be distinguished, on the basis of their physical characteristics, especially porosity, verification grade, firing temperature and surface treatments. Pottery is the result of clay firing. Therefore, it can be distinguished from clay materials, such as argillaceous rock fragments and unfired bricks, on the basis of those mineral-physical changes produced during firing. Microscopically, a fragment of pottery appears as formed by different components: micro mass, inclusions, voids and eventually a coating. The features of each of these components can supply information on the production technology and/or provenance, (Maritan, 2017). The term ceramic comes from the Greek word keramikos, which means burnt substance"of pottery" or "for pottery", from κέραμος (keramos), "potter's clay, tile, pottery". The earliest known mention of the root "ceram-" is the Mycenaean Greek ke-ra-me-we, workers of ceramic written in Linear B syllabic script. The word ceramic can be used as an adjective to describe a material, product or process, or it may be used as a noun, either singular, or more commonly, as the plural noun "ceramics". The desirable properties of these materials are normally achieved through a high-temperature heat treatment called firing. Up until the past sixty years, the most important materials in this class were called traditional ceramics, for which the raw material is clay, e.g. china, bricks, tiles and in addition, glasses and high-temperature ceramics, (Afuye and Ejiko, 2017). Recently, significant progress has been made in understanding the fundamental character of these materials and of the phenomena that occur in them that are responsible for their unique properties. Consequently, a new generation of these materials has evolved, and the term ceramic has taken on a much broader meaning. These new materials are applied in, e.g. electronics, computers, communication technology, biomedical implants and aerospace. (Edward and Robbert, 2011)

The provision of adequate housing has continued to remain a daunting task around the world, especially in developing countries. This challenge has been attributed to the exponential growth of population, low Gross National Product and apparent lack of purchasing power of the middle/low income earners in these countries (Arumala and Gondal, 2007). The scarcity and /or high cost of conventional building materials have further exacerbated the situation. This has resulted in the need to explore alternative building construction materials with a view to improving housing delivery. Providing adequate housing requires continuous research and investment especially inappropriate technologies that reduce the cost of construction and the cost to the environment (UN-HABITAT, 2009). Appropriate technologies is a concept that refers to the use of locally available materials, methods and/or practices which are in tandem with the cultural values and practices in a particular environment. This approach helps to preserve the natural environment as well as contribute to local economic development. The use of earth for construction is an old technology that is being revisited in recent times as a result of the obvious environmental challenges that have resulted from the use of conventional building materials. Compared with alternatives such as fired brick and sandcrete blocks, it offers lower construction costs at comparable quality, is suitable for a wide range of environments, and dramatically reduces the impact on the environment (Riza, Rahman, and Zaidi, 2011). Several studies have established the fact that earth construction has the potentials to address the urban housing challenges that are especially prevalent in the developing countries (Didel Matawal, and Ojo, 2014; Zami and Lee, 2011).

The use of clay as a construction material dates as far back as prehistoric times. It has been reported that a third of the world's population live in houses made of earth (Marton, 2008) and (Martin, 2009). Due to the growing environmental concerns, there has been a resurgence of construction with earth over the last decade. In comparison with other masonry units, earth materials offer a number of advantages: it ensures the use of locally available construction materials thereby reducing transportation costs; ensures the availability of quality affordable housing for a wider population, creates job opportunities as the technology requires semi skills which are easily transferable to locals; it generates local revenue as the materials and labour are sourced locally; and it is more energy efficient. Clay soils have very good insulation and thermal properties and also possess the ability to absorb atmospheric moisture resulting in a healthier environment for the occupants (Riza et al., 2011). Despite its obvious advantages, the use of ceramic brick as a walling material is still very low in Nigeria as most citizens still associate the use in construction with poverty (James et al, 2016). The first and most important step in ceramic technology is the identification of suitable soil for brick production and the availability in the required quantity (Ismail, 2008). Soil suitability is best ascertained by laboratory techniques but field identification techniques can be very useful in the absence of a laboratory (Quintilio, et al, 2011). In Nigeria, clay soils are typically used for the production of ceramic bricks as a result of its abundance in most parts of the country. Since the geotechnical composition of tropical residual soils appear to be largely controlled by their mineral composition, it would seem logical that the first level of any classification system should take account of the factors giving rise to their development (Raheem, Falola, and Adeyeye, 2012). Hence, there is the need for extensive data on the nature of soils from different parts of the country and their suitability for use as Ceramic bricks (Malhotra and Tehri, 1996)

II. STATEMENT OF PROBLEM

Nigerians are versed in traditional vocations before it attained independence in 1960. Such vocations include farming, cloth weaving, traditional bead making, soap making, basket weaving and local fish farming. Most of these vocations have disappeared or are performing at their lowest capacity due to foreign alternatives or modern method of production (Stuart, 2007). However, producing ceramic products in the traditional way has survived and remained unaffected despite modernization of the production process and diffusion of substitutes such as plastics, porcelain and metallic products. Makers of ceramic products are faced with mirage of challenges some of which are; lack of standard laboratories for soil characterizations, modern equipment and machineries, modern handling methods, lack of funds to meet the increasing demands of their consumers. Others are bad roads, electricity, water shortage, inadequate knowledge about the mineralogical compositions and availability of the raw materials. All these constituted to increase the cost of ceramic bricks production. The aim of this research is to assess clay materials for use in production of ceramic bricks, compare and contrast the characterization of the clay samples for brick production at the selected locations and determine which location is suitable for the development of a locally produced ceramic brick production plant. The primary objective of this study is to ascertain the effect of geotechnical composition of the clay samples collected from Ire Ekiti and Isan Ekiti. This study is expected to serve as the first stage in the compilation of characteristic behaviours of clay soils from different locations with a view to proposing guidelines for the use of clay soil. In order to achieve this, the following objectives were outlined:

(a) Determination of index/engineering properties of samples collected from the locations
(b) Determination of engineering classification of these soils
(c) Determination of mineralogical composition of the soils

III. MATERIALS AND METHODS

- Sample collection

Representative soils were extracted from identified borrow pits of the selected locations within Ekiti State. Figure 1 presents map showing the areas where the soil samples were collected. Figure 2 is the Map of Nigeria showing areas where clay soil can be found within the country. Figure 3 shows how the samples were collected in one of the borrow pits. Atterberg limit test which is done to determine the liquid limit and plasticity limit of the clay samples and also Compaction tests to know the point at which the bricks will compact and the falling point after various trials during compaction. This will enable the ceramic engineer to determine the best clay soil suitable for the brick production.

The geotechnical properties of the samples were carried out to determine its characteristics. The samples obtained were first tested to determine their basic geotechnical properties for the purpose of identifying and classifying the soils. The tests conducted are as follows:

a. Natural Moisture Content
For many soils, the water content may be an extremely important index used for establishing the relationship between the way a soil behaves and its properties. The consistency of a fine-grained soil depends largely on its water content. The water content is also used in expressing the phase relationships of air, water, and solids in a given volume of soil. Moisture content and density tests are the most commonly conducted experiments in geotechnical laboratories. This test was performed using the oven-drying method. This is shown in Plates 1 and 2.

b. Density
According to the British Standards, particle density of soil particles is a term which has been used to replace specific gravity which is basically the ratio of the mass of a unit volume of dry soil at a given temperature to the mass of the same volume of de-aired water at the same temperature. In soil testing, the Specific gravity of a soil is required to determine the void ratio and for grain size distribution using the sedimentation method. The test was conducted using the small pycnometer method. Weighing balance is used to determine the mass of the samples. See Plates 1, 2, 3, and 4

c. Atterberg Limits
The Atterberg limits are based on the moisture content of the soil. Atterberg limit test simply means Plasticity test and liquid limit of any soil sample carried out in the Soil mechanics laboratory. The liquid limit (LL) is defined as the water content, in percent, at which the soil changes from a semi-solid to liquid state. The plastic limit is the moisture content that defines where the soil changes from a semi-solid to a plastic (flexible) state. The shrinkage limit is the moisture content that defines where the soil volume will not reduce further if the moisture content is reduced. A wide variety of soil engineering properties have been correlated to the liquid and plastic limits, and these Atterberg limits are also used to classify a fine-grained soil according to the Unified Soil Classification System (USCS) or AASHTO system. The cone penetrometer test was used instead of the Casagrande apparatus as the former is capable of giving more reproducible results: The linear shrinkage test was used to quantify the shrinkage limit of the soil. See Plates 5 and 6.

d. Compaction Test
Compaction of soil is the process by which the solid particles within a soil are packed more closely together, usually by mechanical means, thereby increasing the dry density of the soil. This laboratory test is performed to determine the relationship between the moisture content and the dry density of a soil for a specified compaction effort. For a given degree of compaction of a soil there is an Optimum Moisture Content (OMC) at which a Maximum Dry Density (MDD) is obtained. In general, most engineering properties, such as the strength, stiffness, resistance to shrinkage, and imperviousness of the soil, will improve by increasing the soil density. Furthermore, the MDD of a soil will increase and the OMC decrease with increased compaction effort (Matawal, 2012). To determine the OMC and MDD of the soils, the light compaction test was conducted in accordance with BS 1377: Part 4:1990. To carry out a compaction test, two various methods can be put into action which are West African method (WAM) and Protor method but preferably West African method was used to carry out the test on various samples of the clay soils.

IV. RESULTS AND DISCUSSION

The results showed each status of those Clays in Plates 2-4. Pictures of the clay samples were shown in Plates 3 and 4. The result of Liquid limit, plastic limit and compaction test were shown in the Tables 1 to 5. So also the graphs for each of those clay samples were plotted. For the Atterberg plastic limit test the process involves the sieving of the clay samples and 200 g was measured out in each and were poured on a plain slab and not less or much water was added to it. The can at which the samples were placed was firstly weighed using weighing balance as shown and after putting the samples it was ensured that the initial results must be higher than the first readings by 10 g and the process has to be done with 2 trials. In this same sequence of operation the test was run on all the four clay samples given.

For the liquid limit, the test was run using a Penetrometer apparatus and the moisture contents determined by penetration for all the used clay soil samples. But in determining the Average Moisture Content the plastic limit was subtracted from the liquid limit and the graphs from Figures 3 to 7 were all derived from all the results gotten for each sample. For the Compaction test, West African method (WAM) was implemented in the process of carrying out the test and in considering that method, the apparatus used were; Measuring cylinder, Weighing scale, Hammer, Head Pan, Temperature cooling oven, Can of different sizes, 3000 g of Clay was weighed from each sample and pour into the head pan, also the initial weight of the mould was measured with a weighing scale which gives 4000 g without the extension collar of the mould. Various trials were performed until the clay sample falls back from its previous trials.

According to the specification of the West African Method of the Compaction test, each clay sample was divided into 5 layers with 25 blows per layer. The water content of each sample was determined at different trials. The mould with wet soil was weighed again to determine the weight on each trial until it falls in between fourth and fifth trials. The graphs in Figures 3-5 shows the relationship between Actual penetration and moisture content which helps in determining the plasticity limit and required liquid limit of the bricks to be produced with the clay samples. The graphs in Figures 6 - 8 explain the compaction strength of the soils in relation to the dry density and moisture content.

CONCLUSION

The objective of the study was to assess clay materials for use in production of ceramic bricks, compare and contrast the characterization of the clay samples for brick production. Samples were obtained from Ire Ekiti and Isan Ekiti respectively all in Oye local government. The study revealed that the samples from Ire and Isan Ekiti locations are good for brick production. Various tests such as, moisture contents, density, atterberg limits, and compaction tests were conducted on the three samples: Ire 1, Ire 2 and Isan. The tests were carried out in Soil mechanics workshop and they include; Determination of geotechnical properties of samples of clay soil, (Plasticity and Liquid limit tests) Production and testing of compressed stabilized ceramic bricks, CSCB (Compaction Test). The results showed that; Isan clay is the best material for making ceramic bricks with highest Plasticity Index (PI) of 22.34, Linear Shrinkage (LS) of 7.14 % and Average moisture content (AMC) of 22.66, followed by Ire 2 with PI = 10.72 %, LS = 23.28 and AMC = 23.28 but in large quantity, the next is Ire 1 with PI = 8.65 %, LS = 12.86 and AMC = 32.45 in large quantity as well. The three sources from the two communities can be used for bricks production and are readily available in large quantity for siting a locally produced bricks production plant.

RECOMMENDATIONS

From the investigation conducted, the following conclusions can be drawn:

1. It is suggested that more samples from other areas of Ekiti State be obtained for laboratory tests on geotechnical properties of samples of clay soil in order to get more realistic test values.
2. The mineral resources sector should promote this research work to solve the problem of unemployment rate in Ekiti State and in the country at large for poverty alleviation.
3. The government should allow investors to harness the soils and use for mass production of bricks in the state so as to reduce housing problems.
4. It is recommended that individuals should use clay soils in building houses. Clay soils have very good insulation and thermal properties and also possess the ability to absorb atmospheric moisture resulting in a healthier environment for the occupants.
5. In selecting suitable clay soils for use in the production of bricks for buildings and siting of brick production plant, it is imperative to conduct preliminary tests on soils prior to brick production to ascertain the optimum plasticity and stabilization of the soil for durability.
6. The government should fund this kind of research for manufacturing purposes and socio – economic development.
7. Individuals should tap into ceramic bricks production to serve as a means of earning a living.
8. Design and fabrication of machines for turning the clay raw materials into bricks as finished products

becomes the responsibility of the Mechanical Engineers.

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Figure 1: A section of Ekiti Map showing the location of clay samples

Figure 2: availability of Clay soil materials in Nigeria


Plate 1: 425MIC sieving apparatus


Plate 2: Measuring Sieved Clay samples


Plate 3: Sieved Clay samples


Plate 4: Prepared Sieved Clay samples for test


Plate 5: Dried Clay Samples after undergoing


Plate 6: Clay Samples after undergoing Shrinkage limit

Plasticity Test

Plate 7: Temperature cooling oven

Plate 8: Clay samples loaded in the oven

Table 1: Atterberg limit test for clay sample IRE-EKITI CLAY SOIL 1)

IRE- EKITI CLAY SOIL 1							
TEST	Liquid Limit				Plastic Limit		Linear Shrinkage
Initial Penetration (mm)	6.2	6.3	6.8	7.4			12.86%
Final Penetration (mm)	20.1	21.8	27.2	32.6			
Actual Penetration (mm)	13.9	15.5	20.4	25.2			
Can Weight (g)	9.5	12.0	8.0	13.0	8.9	9.3	
Can + Wet Soil (g)	28.5	30.8	22.5	37.6	20.7	22.4	
Can + Dry Soil (g)	24.5	26.0	18.2	29.3	17.8	19.2	
Moisture Content (%)	26.67	34.29	42.16	50.92	32.58	32.32	
Average M.C. (%)					32.45		

Table 2: Atterberg limit test for clay sample (IRE-EKITI CLAY SOIL 2)

IRE- EKITI CLAY SOIL 2							
TEST	Liquid Limit				Plastic Limit		Linear Shrinkage
Initial Penetration (mm)	7.5	8.5	8	8.5			11.43%
Final Penetration (mm)	20.2	25.5	28.7	33.5			
Actual Penetration (mm)	12.7	17	20.7	25			
Can Weight (g)	9.8	14.4	18.6	19.9	12.9	10.3	
Can + Wet Soil (g)	29.8	39.1	39.0	36.4	29.7	29.0	
Can + Dry Soil (g)	26.9	34.6	33.2	31.3	26.5	25.5	
Moisture Content (%)	16.96	22.28	39.73	44.74	23.53	23.03	
Average M.C. (%)					23.28		

Table 3: Atterberg limit test for clay sample (ISAN-EKITI CLAY SOIL)

ISAN SAMPLE							
TEST	Liquid Limit				Plastic Limit		Linear Shrinkage
Initial Penetration (mm)	0.6	1.2	0.6	0.7			7.14%
Final Penetration (mm)	13.3	16.8	22.5	23			
Actual Penetration (mm)	12.7	15.6	21.9	22.3			
Can Weight (g)	18.8	10.0	7.8	20.2	9.8	13.8	
Can + Wet Soil (g)	35.8	28.9	23.9	31.7	17.4	27.2	
Can + Dry Soil (g)	32.1	24.0	18.9	27.5	15.9	24.9	
Moisture Content	27.82	35.00	45.05	57.53	24.59	20.72	
Average M.C. (%)					22.66		

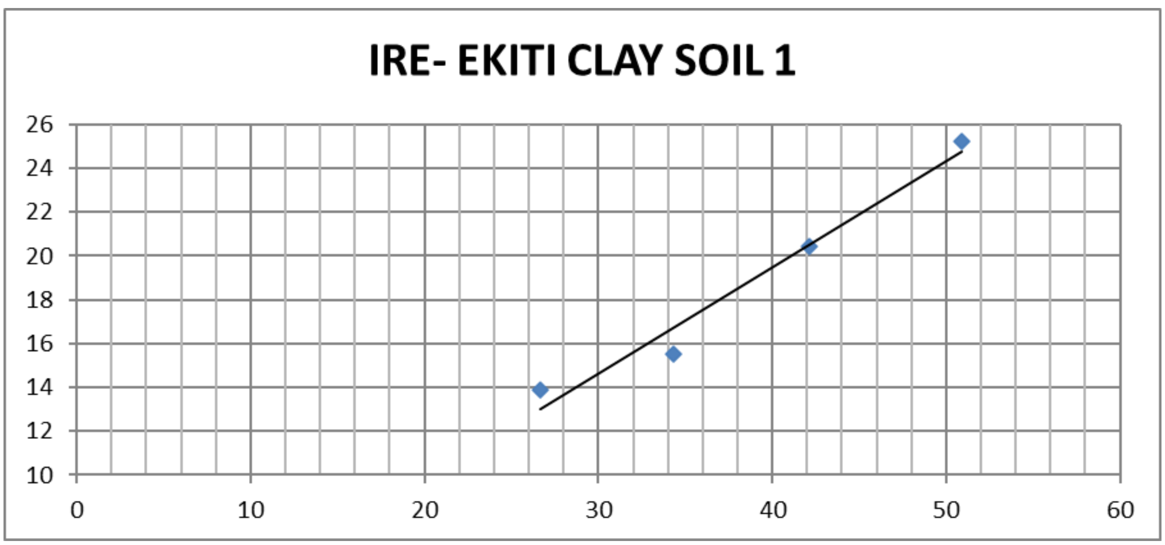

Figure 3: Graph of Actual Penetration against Moisture Content of the Clay sample in Table 1

At 20 mm Penetration Point, the Plasticity index is determined given as;
$Plastic\ Index = Liquid\ Limit - Plastic\ Limit$
P.I = 41.1 – 32.45
P.I = 8.65%

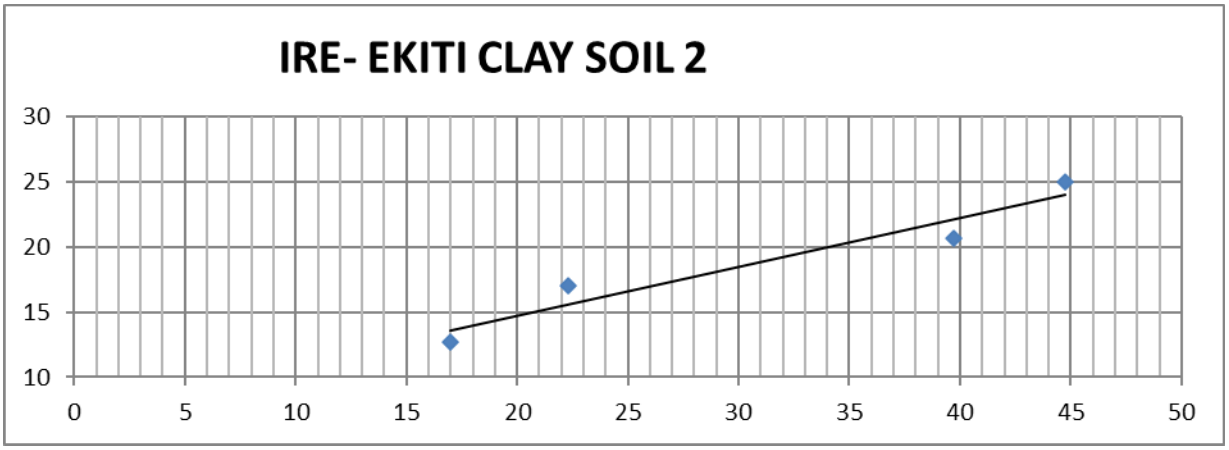

Figure 4: Graph of Actual Penetration against Moisture Content of the Clay sample in Table 2

At 20 mm Penetration point, the Plasticity index is determined given as;
$Plastic\ Index = Liquid\ Limit - Plastic\ Limit$
P.I = 34.00 – 23.28
P.I = 10.72%

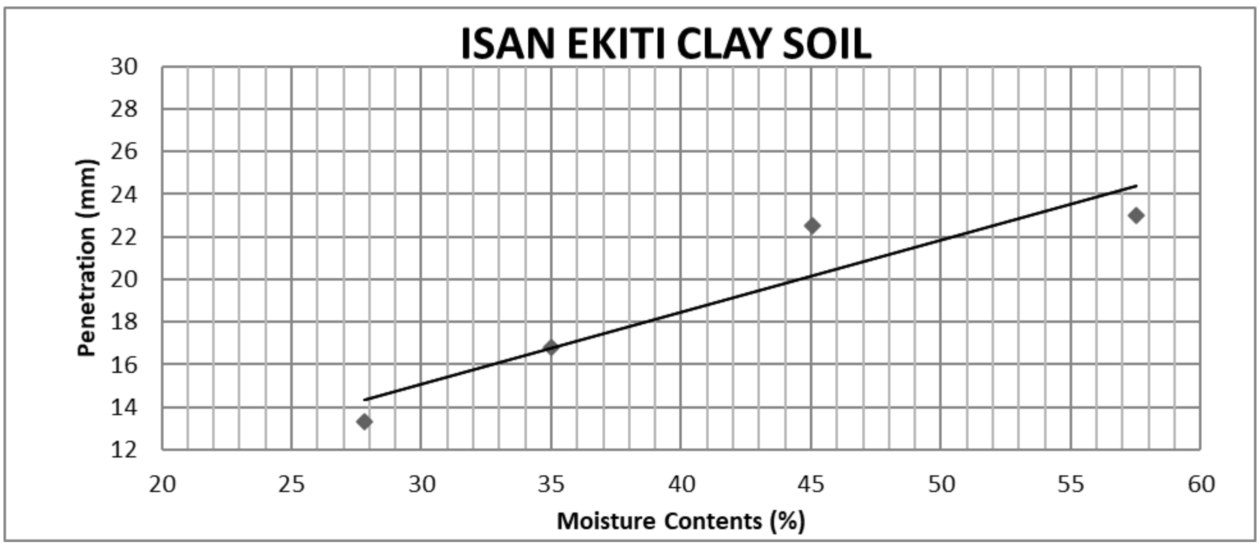

Figure 5: Graph of Actual Penetration against Moisture Content of the Clay sample in Table 3

At 20mm Penetration point, the Plasticity index is determined given as;
$Plastic\ Index = Liquid\ Limit - Plastic\ Limit$
PI=LL-PL
PI=45-22.66
PI=22.34

Table 4: Compaction Test for clay sample (IRE-EKITI CLAY SOIL 1)

IRE-EKITI (1)					
Trial	1	2	3	4	5
Weight of Mould (g)	4000	4000	4000	4000	
Mould + Wet Soil (g)	5600	5700	5800	5700	
Weight of Wet Soil (g)	1600	1700	1800	1700	
Volume of Mould (m^3)	0.001	0.001	0.001	0.001	
Bulk Density (Kg/m^3)	1600	1700	1800	1700	
Weight of empty can (g)	13.2	8.4	17.4	21.0	
Can + wet sample (g)	34.9	32.0	51.3	53.2	
Can + dry sample (g)	31.2	27.3	42.9	43.7	
Moisture Content (%)	20.56	24.87	32.94	41.85	
Dry Density (Kg/m^3)	1327	1361	1354	1198	

Table 5: Compaction Test for clay sample (IRE-EKITI CLAY SOIL 2)

IRE-EKITI (2)				
Trial	1	2	3	4
Weight of Mould (g)	4000	4000	4000	4000
Mould + Wet Soil (g)	5500	5600	5800	5700
Weight of Wet Soil (g)	1500	1600	1800	1700
Volume of Mould (m^3)	0.001	0.001	0.001	0.001
Bulk Density (Kg/m^3)	1500	1600	1800	1700
Weight of empty can (g)	13.8	13.8	8.2	8.0
Can + wet sample (g)	32.0	37.4	28.3	22.4
Can + dry sample (g)	29.8	33.8	24.5	19.3
Moisture Content (%)	13.75	18.00	23.31	27.43
Dry Density (Kg/m^3)	1319	1356	1460	1334

Table 6: Compaction Test for Clay Sample (ISAN-EKITI CLAY SOIL)

ISAN-EKITI					
Trials	1	2	3	4	5
Weight of Mould (g)	3292	3292	3292	3292	3292
Mould + Wet Soil (g)	4960	5130	5270	5400	5250
Weight of Wet Soil (g)	1668	1838	1978	2108	1958
Bulk Density (Kg/m^3)	1668	1838	1978	2108	1958
Weight of empty can (g)	12.2	11.86	15.27	13.95	13.38
Can + wet sample (g)	38.2	40.28	44.96	51.09	45.9
Can + dry sample (g)	35.11	36.24	40	43.95	39.15
Moisture Content (%)	13.49	16.57	20.06	23.80	26.19
Dry Density (Kg/m^3)	1470	1577	1648	1703	1552

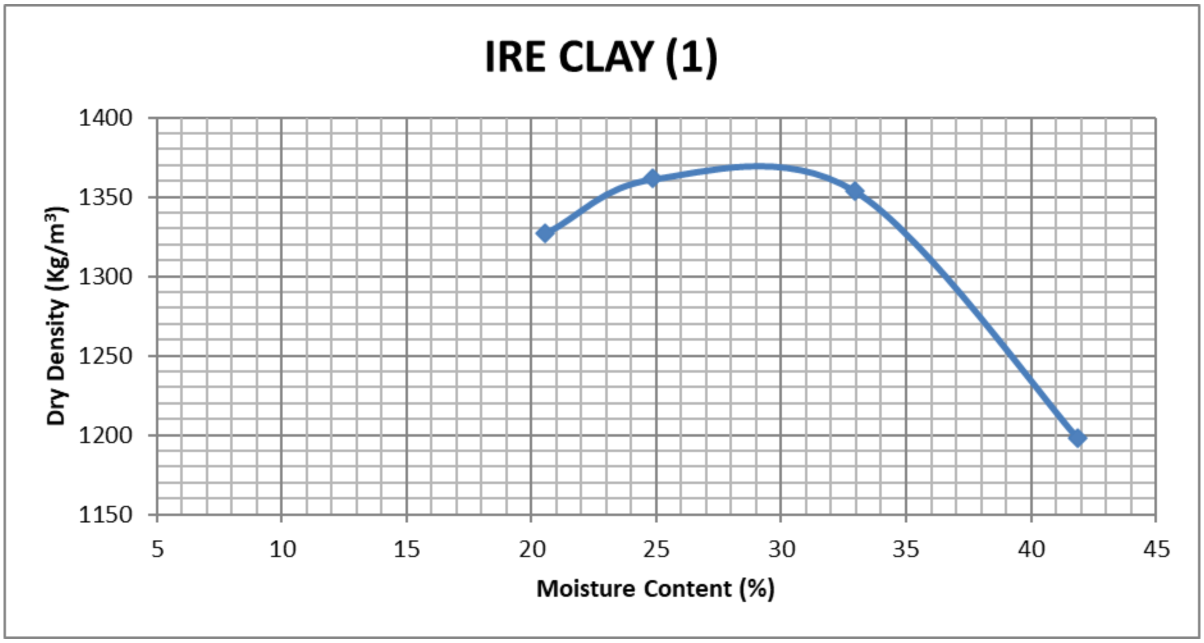

Figure 6: Graph of Dry Density against Moisture Content of the Clay sample in Table 4

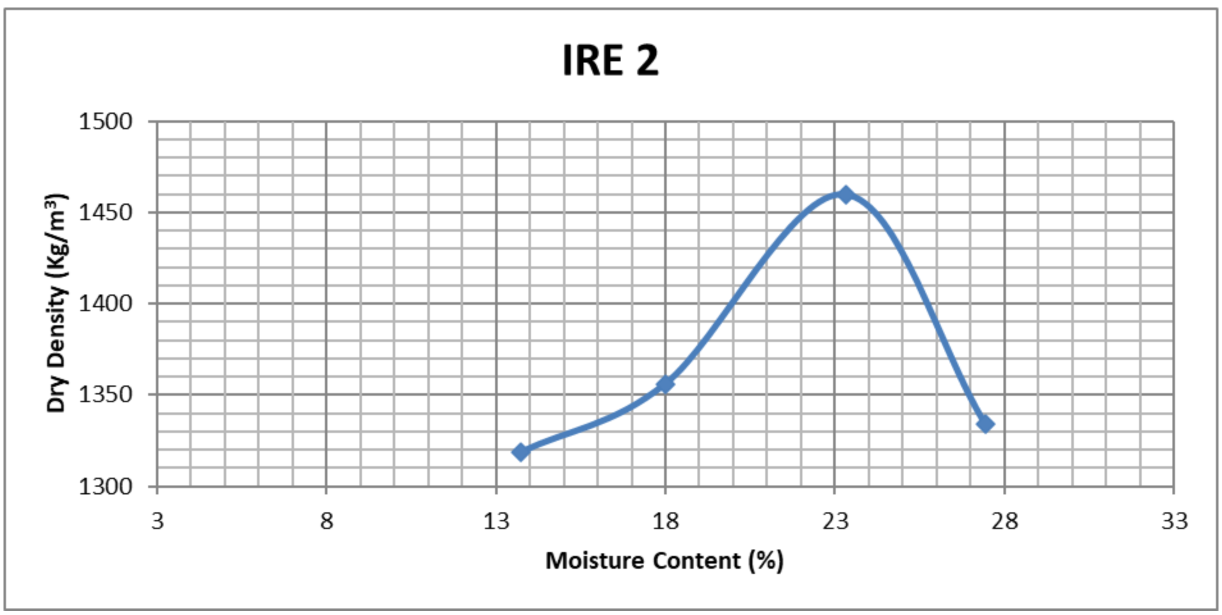

Figure 7: Graph of Dry Density against Moisture Content of the Clay sample in Table 5

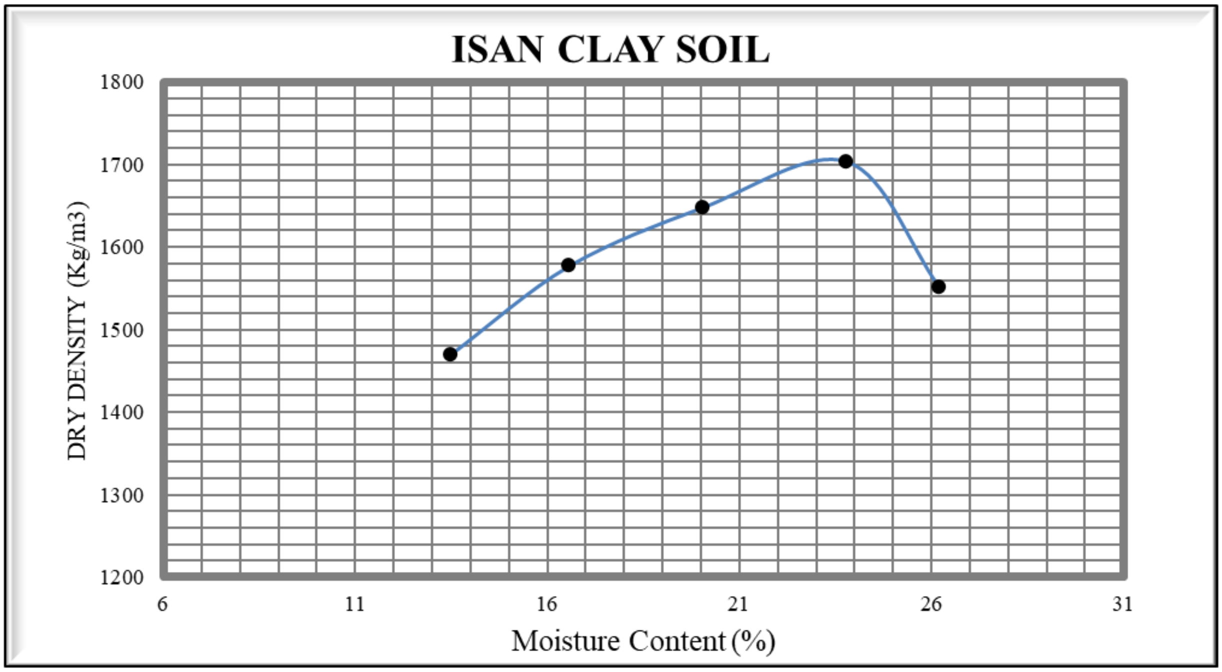

Figure 8: Graph of Dry Density against Moisture Content of Isan Clay sample in Table 6