IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 21, Issue 4 Ser. 1 (July. – August. 2024), PP 27-32
www.iosrjournals.org

Characterization Of Clay Materials In Ekiti State For Siting A Locally Produced Ceramic Brick Production Plant

Afuye E.K[1], Akintunde M.A[2] & Akinola A.O[2]
Mechanical Engineering Department, Federal University Of Technology, Akure, Ondo State, Nigeria

Abstract
Brick making machines play a pivotal role in the construction industry. This is because of the indispensable role ceramic brick plays in the modern day building Construction, especially in the advanced cities and even the developing Nations like Nigeria. In order to enhance adequate supply to both urban and rural consumers, the production of a ceramic brick moulding machine is important. Though, availability of materials for the machine is more important. This paper presents the characterization of 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 machines. Bricks are produced in a very easy and faster rate. The brick making machine is available in different varieties. 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 three geopolitical zones in Ekiti State. The three zones are; Ekiti North, Ekiti South and Ekiti Central. Samples were taken from Ire Ekiti and Isan Ekiti to represent Ekiti North, Ikere Ekiti for Ekiti South and Ado Ekiti for Ekiti Central. 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 all the zones. 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 Isan clay remains the best material with highest Plasticity Index (PI) of 22.34, Linear Shrinkage (LS) of 7.14 % and Average moisture content (AMC) of 22.66.

Keywords: *Housing, cost, technologies, ceramic, clay, bricks, ekiti state, characterization*

Date of Submission: 13-07-2024 Date of Acceptance: 23-07-2024

I. Introduction

The development and performance evaluation of a ceramic brick production plant 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. The establishment of a ceramic brick production plant can contribute to the economic growth of a region by reducing dependency on imported bricks, cement blocks and creating employment opportunities. (Garcia, 2020). In recent years, there has been a growing emphasis on sustainable construction practices and the utilization of locally available resources. The development of a ceramic brick production plant aligns with these objectives by reducing transportation costs and carbon emissions associated with importing bricks from distant locations. Additionally, it promotes the use of indigenous raw materials, which can enhance regional economic development and reduce reliance on imported materials or plant. Several studies and research projects have been conducted to explore the development and performance evaluation of ceramic brick production plants. For instance, a study by Smith *et al.* (2019)

investigated the influence of different raw material compositions on the mechanical properties of ceramic bricks. They identified optimal mixtures that resulted in bricks with enhanced strength and durability.

Furthermore, the work of Zhang *et al*. (2020) focused on the optimization of the firing process in ceramic brick production plants. They proposed a novel firing technique that reduced energy consumption while maintaining the desired brick properties. The study demonstrated the potential for improving the efficiency and sustainability of brick manufacturing processes. The development and performance evaluation of a ceramic brick production plant hold significant importance in the construction industry. The utilization of indigenous resources, reduction of transportation costs, and promotion of sustainable practices are key drivers behind such initiatives. **(**Chen and Zhang, 2020)

Ceramics are solid compounds that are formed by the application of heat and sometimes heat and pressure, comprising at least two elements provided one of them is a non-metal and the other a metal (Richerson, 2018). Very few elements are used in their pure form; most often they are alloyed with other elements to form engineering materials. The latter can be broadly classified as metals, polymers, semi-conductors or ceramics with each class having distinctive properties that reflect the differences in the nature of their bonding, (Callister *et al*., 2018). The ceramic bond is either ionic or covalent bonding depending on the material characteristics or nature of the materials used for a typical ceramic product (Carter and Norton, 2022).

Ceramic materials are probably the most abundant findings in pre-historic and historic archaeological sites and represent after lithic artefacts, 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, non-metallic 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 (Smith, *et al*., 2019). 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. A ceramic is any of the various hard, brittle, heat- resistant and corrosion – resistant materials made by shaping and then firing an inorganic, non – metallic material, such as clay at a high temperature. Common examples are earthenware, porcelain and brick (Kishawy, *et al*., 2019).

Ceramics now include domestic, industrial and building products, as well as a wide range of materials developed for use in advanced ceramic engineering, such as in semiconductors (Richerson, et al., 2018)

Many early ceramics were hand-built using a simple coiling technique in which the clay was rolled into coils that were then check-punch and beaten together to form the body of a vessel. The artist had to turn the vessel around in order to wind the coils along the top of the piece, increasing its height with every complete turn. In the coiling method of construction, all of the energy required to form the piece is supplied directly by the hand of the potter (Afuye and Ejiko, 2017). This changed with the introduction of the potter's wheel. The heavy stone wheel was initially kicked or turned with a stick and then continued to turn based on its own momentum. In wheel-throwing, the bulk of the energy used does not come directly from the hands of the potter but from the turning wheel, (Rhodes, 2015).

The potter's wheel is a machine used in the shaping of round ceramic wares, occasionally it is also known as a "potter's lathe", however this is actually a different machine used for a shaping process or turning which is similar to shaping metal and wood pieces (Sutton, 2020). The potter's wheel may also be used during the process of trimming excess clay from dried wares and for applying incised decoration of the potter's wheel. In jiggering, a shaped tool is slowly brought down into plastic (semi-dried) clay body sits atop a rotating plaster mould. The jigger tool shapes the top face as it moulds the underneath one. The term is specific to shaping of flatware. A similar technique is jollying, that refers to the production of hollowware such as: cups or bowls having a symmetrical, hollow centre (Rhodes, 2015).

The introduction of the potter's wheel brought benefits in the form of speed, symmetrical shape, and efficiency, as a job that might have taken hours or even days to complete was reduced to one that could be done, in minutes. Early ceramics built by the coiling technique were often placed on mats or large leaves to allow them to be worked and turned more conveniently (Babalola and Ologunwa, 2017). This arrangement allowed the potter to turn the mat rather than walk around the vessel to add coils to the clay body. It has been theorized that the earliest forms of the potter's wheel were developed as an extension to this procedure. The earliest wheels were thus probably turned slowly by hand or by foot while coiling a pot, but later developments allowed energy in the momentum of a kick wheel to be used to speed up the process of throwing (Afuye and Ejiko, 2017)

Afuye and Ejiko, (2017), suggested that the potter's wheel first came into use, but dates between about 6,000 B.C. to about 2,400 B.C. John Spacey (2019); Evans (2019) and numerous scholars have reported that potter's wheel was first developed in Mesopotamia, although Egypt and China have also been claimed as possible places of origin. A stone potter's wheel found in Mesopotamian city of Ur, in modern-day Iraq, has been recovered in the same area. By the time of the early civilizations of the Bronze Age, the use of the potter's wheel has become widespread (Gorogianni, *et al*., 2016).

In the Iron Age, the potter's wheel in common use had a turning platform about a meter above the floor, connected by a long axle to a heavy wheel at ground level. This arrangement allowed the potter to keep the turning-wheel rotating by kicking the wheel with the foot, leaving both hands free for manipulating the vessel under construction (Taylor, 2020). The use of the potter's wheel became widespread throughout the Old World, but was unknown in the Pre-Columbian New World, where pottery was hand-made by methods that included coiling and beating (Evans, 2019). The use of the motor-driven wheel has become common in modern times, particularly with craft potters and educational institutions, although human-powered ones are still in use and are preferred by some potters (Yarbrough, 2021). The origin of pottery is associated with early period in life when man was trying to create domestic tools out of nature and since then, there has always been an improving method of production. All early pottery was baked in fire and blackened on the outside in order to strengthen the product source. Pot making was an essential part of life and thus women were the potters in early times and during this period when the potter's wheel for throwing or spinning was not in existence (Gardon, 2013; Palmer, 2020; Pulitani, *et al*., 2017). Throwing wheel is a kind of machine or device design to make throwing process easier in ceramic vessel making. The partly mechanized nature of throwing (using throwing wheel) allows the artist or craftsman to achieve an economic rate of production and survive much more successfully in affluent society (Afuye and Ejiko, 2017). The essential principle of design is based on the science of wheel and axle. The wheel and axle is a mechanism consisting of a wheel mounted rigidly upon the axle or drum of smaller diameter, both on the same axis (Valkov and Nikolov. 2019; Afuye and Ejiko, 2017). Otitoju *et al*. (2020) defines ceramics as solid compounds that are formed by the application of heat and sometimes heat and pressure, comprising at least two elements provided one of them is a non-metal or a non-metallic elemental solid. The other elements may be metal(s) or another non-metallic elemental solid(s). Kishawy *et al*. (2019) also defines ceramics as "the art and science of making and using solid articles, which serve as their essential components and are composed in large part of inorganic non-metallic material". In other words, what is a metal, a semi-conductor or a polymer is a ceramic. John (2019) defined ceramics as a category of hard material that is typically manufactured by heating minerals. Humans have produced ceramics since at least 24,000 BC. This predates the use of modern metal ceramics including some of the strongest known materials. Ceramics are commonly used in Construction works, Consumer Products, Vehicles, Scientific and Industrial Equipment. This study aims to provide an overview of the development of a ceramic brick production plant, highlighting key considerations and factors that need to be addressed during the setup process. The production of ceramic bricks involves several stages, including raw material preparation, moulding, drying, firing, and finishing. The raw materials typically include clay, sand, and other additives where necessary, which are mixed, formed into brick shapes, and then fired in kilns at high temperatures. The firing process imparts structural strength and durability to the bricks (Davis, 2022). The global construction industry is witnessing substantial growth, particularly in emerging economies. This growth is driving the demand for ceramic bricks, making it an attractive business opportunity for investors. Brick moulding machine has been widely used in construction, road, square, water conservancy project, landscape, etc. Till now, we have manufactured brick moulding machine with features of high quality, large production, stable performance and high automatic degree (Ding, *et al*., 2020). The bricks to be produced by the brick moulding machine will have the advantages of high intensity, good insulation performance, and good resistance of water, corrosion and weathering. The brick moulding machine could produce many kinds of bricks, such as exterior wall brick, inner wall brick, decorated wall brick, floor slab brick, reinforcing dam brick as well as interlock road brick and roadside brick (Pearson, 2016)

II. Aim Of The Research Work

The aim of this research is to assess clay materials for use in production of Ceramic Bricks, determine the best source of raw materials in Ekiti State suitable for the development of a locally produced Ceramic Brick production plant.

III. Objective Of The Research Work

The primary objective of this study is to ascertain the effect of mineralogical composition of the clay samples collected from the three geopolitical zones in the State as a case study. Ijero Ekiti and Ado to represent Ekiti central, Ikere Ekiti for Ekiti South, Isan and Ire Ekiti to represent Ekiti North. This study is expected to serve as the first stage in the compilation of characteristic behaviours of clay soils from different parts of Ekiti State with a view to proposing guidelines for the use of clay soil in the State. 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) Characterization of the soils

Statement Of Problem

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, source of adequate raw material and transportation. All these affect ceramic bricks production.

IV. Materials And Methods

The collected clay samples from borrowed pits were tested, these include: Atterberg limit; to determine the liquid and plasticity limit of the clay samples, Compaction test; to know the point at which the bricks will compact and the falling point after various trials during compaction. Figure 3 is the map of the location where the Samples were collected. The geotechnical properties of the samples were carried out to determine the Sample characteristics. The tests conducted are as follows: **Natural Moisture Content:** This test was performed in accordance with BS 1377: Part 2: 1990 using the oven-drying method. **Density:** the test was perform according to British Standards, this is to determine the Specific gravity, void ratio and for grain size distribution of the Samples. **Compaction Test**: This laboratory test was performed to determine the relationship between the moisture content, the dry density, Optimum Moisture Content (OMC), Maximum Dry Density (MDD) of the soil Samples. The OMC and MDD of the Samples, light compaction test was conducted in accordance with BS 1377: Part 4:1990 in order to establish the engineering properties, such as strength, stiffness, resistance to shrinkage, and imperviousness of the Samples.

V. Results And Discussion

The results showed each status of the 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 of it and were poured on a plain slab and not less or much water was added to it, thereafter with hands they were robed on the surface of the slab to ensure the it doesn't have any water in it again. The can at which the samples were placed was firstly weighed using weighing balance 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 weigh 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 Figure 3 to 8 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 Figure 10 to 14 explains the Compaction of the brick in relation to the Dry density and Moisture content and hence State the level and point at which the bricks will be dried and the water it will contain.

VI. Conclusion

The objective of the study was to investigate the effect of mineralogical compositions on the suitability of clay soils in Ekiti State as alternative building materials and also determine where a locally produced ceramic brick production plant can be sited. The study revealed that Ekiti State is highly rich with different clay samples. Samples were obtained from the three geopolitical zones in the State. Ijero Ekiti and Ado to represent Ekiti central, Ikere Ekiti for Ekiti South, Isan and Ire Ekiti to represent Ekiti North. Results showed that clays are available in almost all parts of the state. Various tests such as, moisture contents, density, atterberg limits, and compaction tests were conducted. 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 test) Production and testing of compressed stabilized ceramic bricks (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 Ikere with PI = 19.39 %, LS = 12.86 and AMC = 2341 though in smaller quantity, followed by Ire 2 with PI = 10.72 %, LS = 23.28 and AMC = 23.28 but in large quantity, the next is Ire with PI = 8.65 %, LS = 12.86 and AMC = 32.45 in large quantity as well. Ado clay has PI of 7.5 %, LS = 5.71 and AMC =21.5. Ijero clay is the least with Zero Plasticity Index (PI), LS =3.50 and AMC = 31.63. It implies that except Ijero clay all other materials from other sources can be used for bricks production but Isan clay remains the best material which is also readily available in large quantity for siting a locally produced bricks production plant.

VII. Recommendations

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

1. 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.
2. 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.
3. The government should fund this kind of research for manufacturing purposes and socio – economic development.
4. Individuals should tap into ceramic bricks production to serve as a means of earning a living.
5. Design and fabrication of machines for the turning the clay raw materials into bricks as finished products becomes the responsibility of the engineers.
6. It is suggested that more samples be obtained for laboratory tests on geotechnical properties of samples of clay soil in order to get more realistic test values.
7. 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.
8. 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.

References

[1] Adeloye, E. K. (2017). Development Of Brick Making Machine (Doctoral Dissertation, Department Of Mechanical Engineering, Faculty Of Technology, Obafemi Awolowo University, Ile-Ife).
[2] Afuye, E. K., And Ejiko, S. O. (2017). Development Of An Interchangeable Throwing Wheel. Scholarly Journal Of Engineering Research, 3(1), 11-21
[3] Barsoum, M. W, (2003). Fundamentals Of Ceramics" Published In Great Britain By Tailor And Francis Groul, 3, 6, 7, 8 And 13
[4] Alan, G. K, (2021). Ceramic Technology And Processing Published By A. K Jain, Standard Publishers, Printed By Meenaksly Printers, Delhi Isbn: 81 – 8014 – 0490. 2, 3
[5] Babalola, A. B., And Ologunwa, T. P. (2017). Reinventing The Wheel: Design And Fabrication Of Electric Throwing Wheel Using Locally Available Materials In Nigeria. Ceramics Art And Perception, (106), 143-146.
[6] Callister, W. D., Rethwisch, D. G., Blicblau, A., Bruggeman, K., Cortie, M., Long, J., And Mitchell, R. (2007). Materials Science And Engineering: An Introduction (7) 665-715). New York: John Wiley And Sons.
[7] Carter, C. B., And Norton, M. G. (2007). Ceramic Materials: Science And Engineering, 716, 712. New York: Springer.
[8] Charlotte S. And John T.(2012). Hands On Clay: An Introduction To Ceramics, Goshen College: Publication, 1-4.
[9] Chen, L., And Zhang, H. (2019). Technological Innovations In Ceramic Brick Production: A Comprehensive Review. Construction Materials And Structures, 42(4), 327-345.
[10] Chen, L., And Zhang, H. (2020). Technological Innovations In Ceramic Brick Production: A Review.
[11] Journal Of Manufacturing Engineering, 35(4), 256-269.
[12] Davis, R. (2022). Market Analysis Of The Ceramic Brick Industry: Trends And Forecasts. Construction Research Journal, 45(2), 112-125.
[13] Ding, L., Wang, X., Zhang, M., Meng, J., And Hu, T. (2020). Construction Quality Control Study Of Double-Layer Continuous Paving For Large-Thickness Cement-Stabilized Base. Advances In Civil Engineering, 2020, 1-13.
[14] Enea-Giurgiu, A., Ionescu, C., Hoeck, V. Tămaş, T. And Roman, C. (2019). An Archaeometric Study Of Early Copper Age Pottery From A Cave In Romania. Clay Minerals, 54(3), 255-268.
[15] Evans, E. (2019). How To Make Pottery, Retrieved 13 January 2021 Http://Www.Art-Craft-Create-Show.Com/How To Make Pottery.Html
[16] Garcia, M., (2020). Life Cycle Assessment Of Ceramic Brick Production: A Comparative Study.Sustainable Materials And Technologies, 15, 76-92.
[17] Gorogianni, E., Abell, N., And Hilditch, J. (2016). Reconsidering Technological Transmission: The Introduction Of The Potter's Wheel At Ayia Irini, Kea, Greece. American Journal Of Archaeology, 120(2), 195-220.
[18] James, W., Campbell, P. And Will Pryce. (2016). Thames & Hudson, Brick: A World History. 2003-2016.
[19] John Spacey, (2019). Types Of Ceramics" Simplicable.Com/New/Ceramics, Retrieved 15th May, 2021.
[20] Kevin Petrie And Andrew Livingstone, (2017): "The Ceramics Reader" Bloomsbury (Eds) A Wide-Ranging Series Of Essays That Explores The History And Cultural Significance Of Ceramics".
[21] Kishawy, H. A., Hosseini, A., And Hosseini, A. (2019). Ceramics. Machining Difficult-To-Cut Materials: Basic Principles And Challenges, 179-204.
[22] Otitoju, T. A., Okoye, P. U., Chen, G., Li, Y., Okoye, M. O., And Li, S. (2020). Advanced Ceramic Components: Materials, Fabrication, And Applications. Journal Of Industrial And Engineering Chemistry, 85, 34-65.
[23] Palmer, G. (2020). Pot Throwing: An Investigation Into The Real-Time Cognitive And Physical Processes Involved In A Craft Performance (Doctoral Dissertation, Loughborough University).
[24] Pearson, L. (2016). Victorian And Edwardian British Industrial Architecture. The Crowood Press.
[25] Pulitani, G., Caldana, I., Conti, G., Schiavon, F., And Busato, R. (2017). Performances Of (And On) The Greek Potter's Wheels: An Experimental Project. Eidola: International Journal Of Ancient Art History: 14, 35-56.
[26] Rahman, A., (2021). Optimization Of Ceramic Brick Manufacturing Process, Using Artificial Intelligence Techniques. Construction Engineering And Management, 48(3), 215-231.
[27] Rhodes, D. (2015). Clay And Glazes For The Potter (3rd Ed.). Seattle, Wa: Ravenio Books.
[28] Richerson, D. W. (2018). Modern Ceramic Engineering: Properties, Processing, And Use In Design. Boca Raton, Fl: Crc Press.
[29] Richerson David W., And William E. Lee. (2018). Modern Ceramic Engineering: Properties, Processing, And Use In Design. Crc Press,
[30] Smith J., Johnson, A., And Brown, L. (2019). Influence Of Raw Material Composition On The Mechanical Properties Of Ceramic Bricks. Construction Materials Journal, 25(2), 123-138.
[31] Stuart T. (2007). Wheel Performance At Any Speed Http://Pottery.About.Com/Od/Potterswheels/Tp/Hbwheel.Htm, Retrieved 24 January, 2022.
[32] Sutton, A. (2020). Revolutions: The Introduction Of The Potter's Wheel To Southern Britain, And Its Implications For Understanding Late Iron Age Societies. Archaeological Journal, 177(2), 214-255.
[33] Taylor, L. (2020). Ceramics Master Class: Creative Techniques Of 100 Great Artists. White Lion Publishing.
[34] Valkov, G. And Nikolov, V. (2019). Analysis Of The Power Drives Of Terrain Forklifts In Environment. Technologies Resources. Proceedings Of The International Scientific And Practical Conference (Vol. 3, 241-248).
[35] Yarbrough, N. H. (2021). The Geoarchaeology Of The Wakulla River Drainage Basin. The Florida State University.

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			
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	12.86%
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		

Table 4: Atterberg limit test for clay sample (IJERO-EKITI CLAY SOIL)

IJERO SAMPLE						
TEST	Liquid Limit				Plastic Limit	Line Shrink e
Initial Penetration (mm)	1.6	1.5	1.6	1.7	NON PLASTIC	3.50
Final Penetration (mm)	17	19.3	23.5	26.3		
Actual Penetration (mm)	15.4	17.8	21.9	24.6		
Can Weight (g)	10.9	15.5	21.0	19.3		
Can + Wet Soil (g)	30.2	32.5	37.8	33.3		
Can + Dry Soil (g)	26.5	28.6	33.5	29.4		
Moisture Content (%)	23.72	29.77	34.40	38.61		
Average M.C. (%)				31.63		

Table 5: Atterberg limit test for clay sample (IKERE-EKITI CLAY SOIL)

IKERE-EKITI CLAY SOIL							
TEST	Liquid Limit				Plastic Limit		Linear Shrinkage
Initial Penetration (mm)	9	8.5	8.4	8.5			12.86%
Final Penetration (mm)	22	25	28.4	34.2			
Actual Penetration (mm)	13	16.5	20	25.7			
Can Weight (g)	8.6	8.0	6.6	8.2	5.0	13.7	
Can + Wet Soil (g)	23.8	30.5	33.4	32.6	15.6	25.3	
Can + Dry Soil (g)	19.8	24.3	25.2	24.6	13.5	23.2	
Moisture Content (%)	35.71	38.04	44.09	48.78	24.71	22.11	
Average M.C. (%)					23.41		

Table 6: Atterberg limit test for clay sample (ADO-EKITI CLAY SOIL)

ADO-EKITI CLAY SOIL							
TEST	Liquid Limit				Plastic Limit		Linear Shrinkage
Initial Penetration (mm)	7.6	8.1	7.6	8.7			5.71%
Final Penetration (mm)	21.4	24.4	28.1	33			
Actual Penetration (mm)	13.8	16.3	20.5	24.3			
Can Weight (g)	11.5	10.8	13.6	12.5	7.6	11.1	
Can + Wet Soil (g)	31.4	26.7	38.0	34.3	17.7	33.7	
Can + Dry Soil (g)	28.3	23.8	32.4	28.4	16.1	29.3	
Moisture Content (%)	18.45	22.31	29.79	37.11	18.82	24.18	
Average M.C. (%)					21.50		

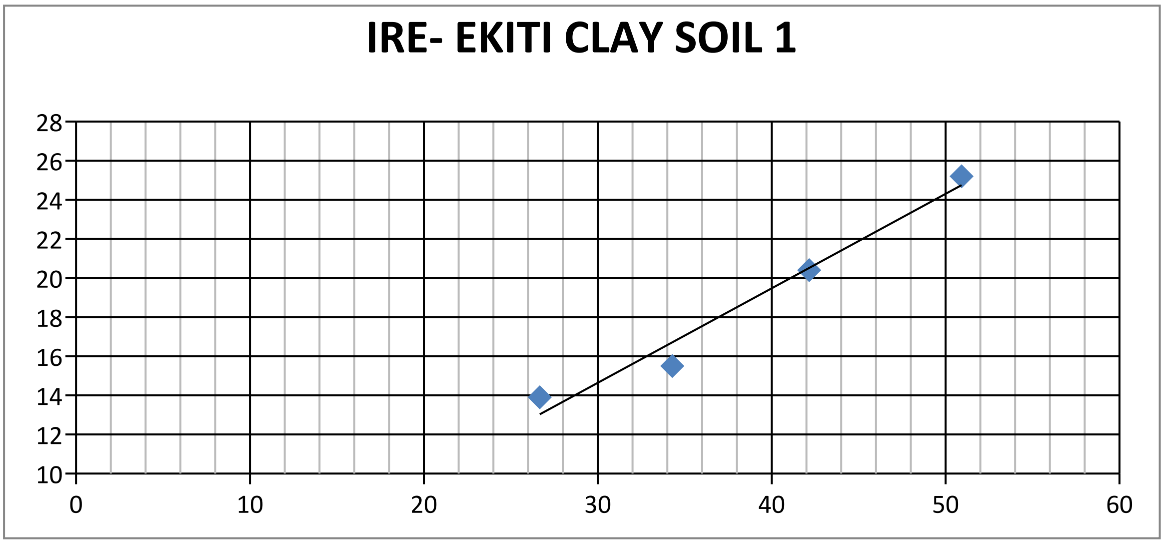

Figure 3: Graph of Actual Penetration against Moisture Content of the Ire 1
At 20 mm Penetration point, the Plasticity index is determined given as;

P.I = 41.1 – 32.45, P.I = 8.65%

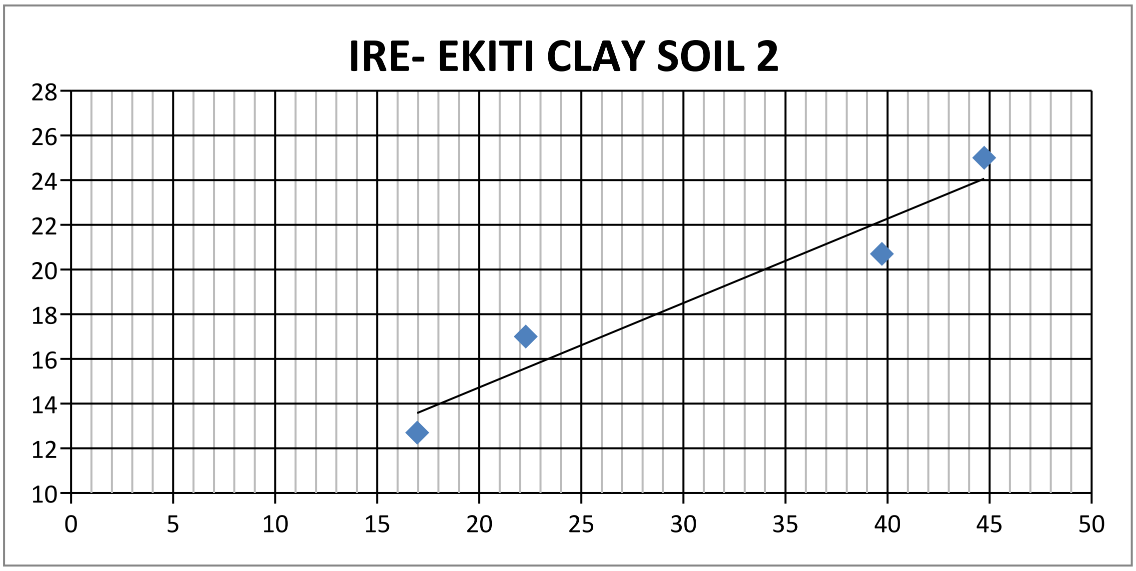

Figure 4: Graph of Actual Penetration against Moisture Content of the Ire Clay 2
At 20 mm Penetration point, the Plasticity index is determined given as;

P.I = 34.00 – 23.28
P.I = 10.72%

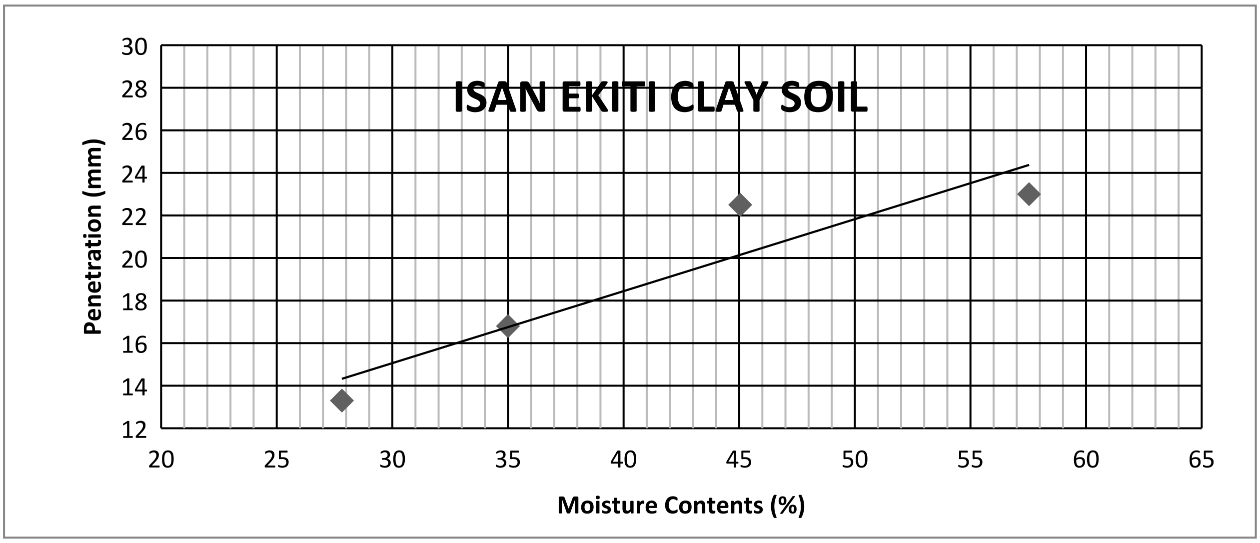

Figure 5: Graph of Actual Penetration against Moisture Content of Isan Clay sample
At 20mm Penetration point, the Plasticity index is determined given as;

PI=LL-PL
PI=45-22.66
PI=22.34

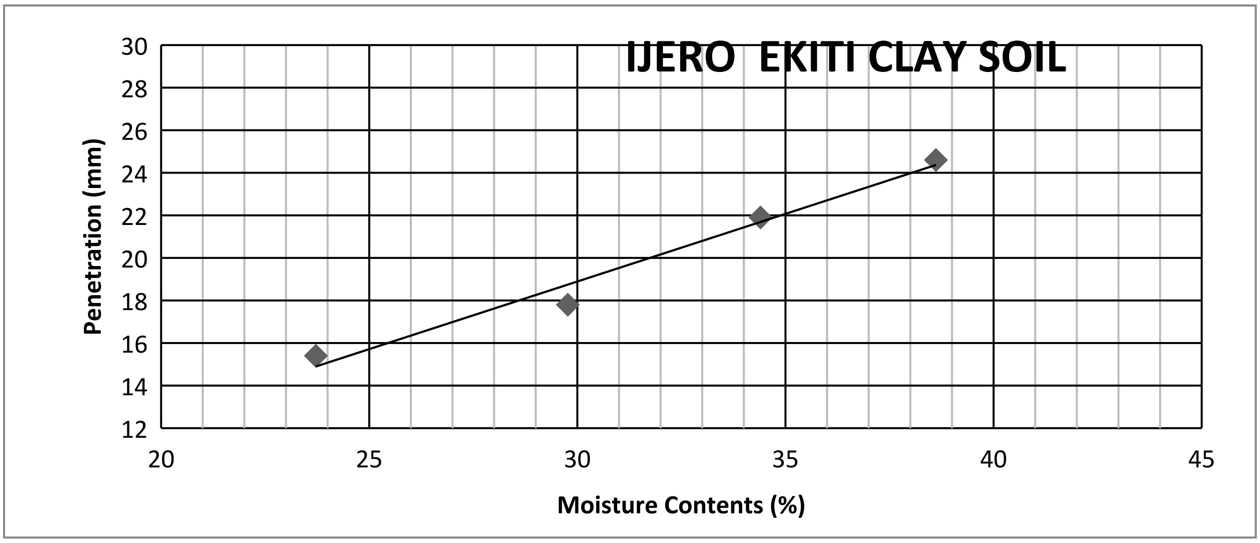

Figure 6: Graph of Actual Penetration against Moisture Content of Ijero Clay sample

At 20mm Penetration point, the Plasticity index is determined given as;

PI=LL-PL
PI=31.9-31.9
PI=0

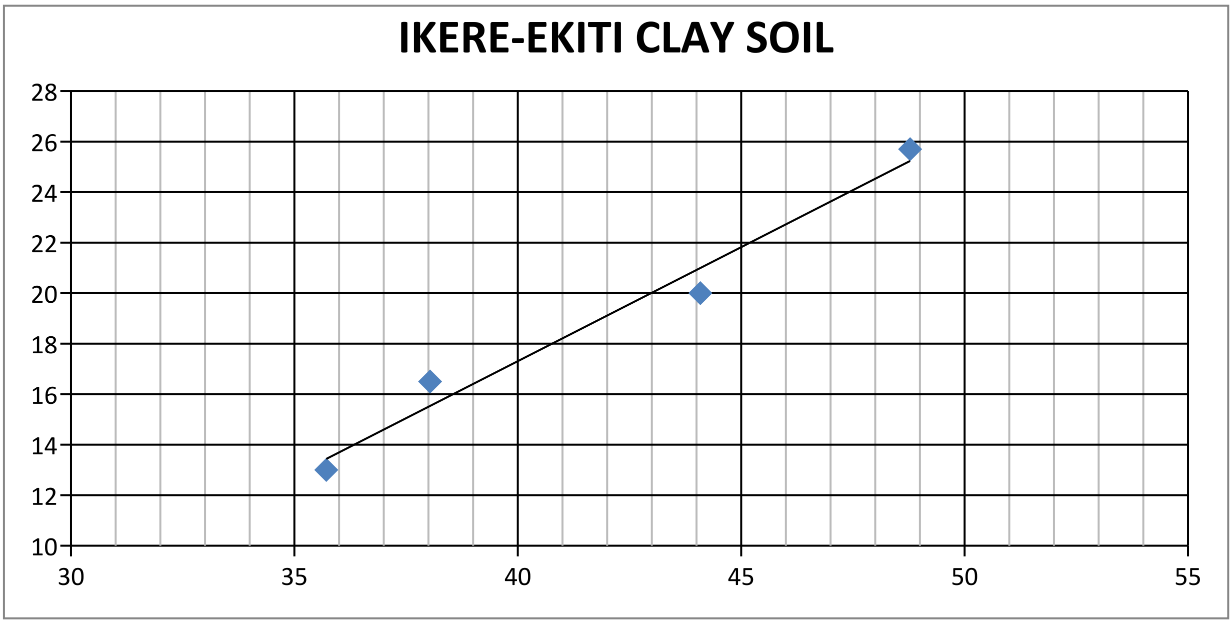

Figure 7: Graph of Actual Penetration against Moisture Content of Ikere Clay

At 20mm Penetration point, the Plasticity index is determined given as;

P.I = 42.8 – 23.41
P.I = 19.39%

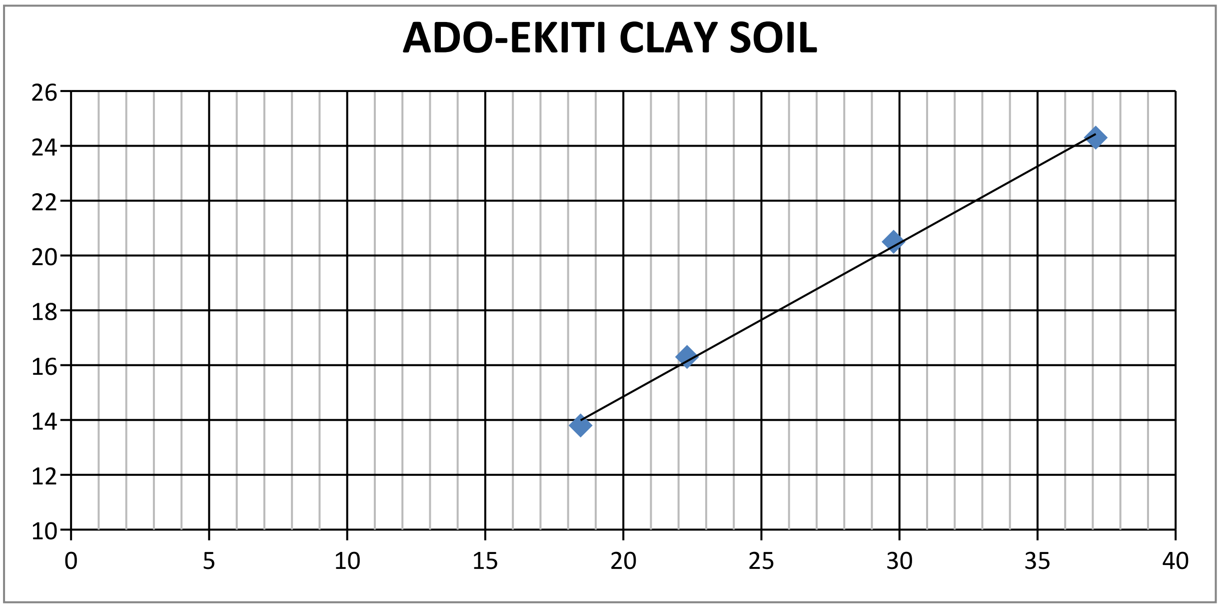

Figure 8: Graph of Actual Penetration against Moisture Content of Ado Clay sample

At 20 mm Penetration point the Plasticity index is determined given as;

P.I =29.0 – 21.50
P.I = 7.5%

Table 7: Compaction Test for clay sample (IKERE-EKITI CLAY SOIL)

IKERE-EKITI				
Trial	1	2	3	4
Weight of Mould (g)	4000	4000	4000	4000
Mould + Wet Soil (g)	5800	5900	6000	5900
Weight of Wet Soil (g)	1800	1900	2000	1900
	0.00	0.00	0.00	0.00
Volume of Mould (m^3)	1	1	1	1
Bulk Density (Kg/m^3)	1800	1900	2000	1900
Weight of empty can (g)	11.1	8.0	13.2	8.9
Can + wet sample (g)	40.2	25.8	42.4	35.5
Can + dry sample (g)	36.6	22.8	37.2	30.2
Moisture Content (%)	**14.12**	**20.27**	**21.67**	**24.88**

Dry Density (Kg/m³)	**1577**	**1580**	**1644**	**1521**

Table 8: Compaction Test for clay sample (ADO-EKITI CLAY SOIL)

ADO-EKITI				
Trial	1	2	3	4
Weight of Mould (g)	4000	4000	4000	4000
Mould + Wet Soil (g)	5600	5700	5800	5600
Weight of Wet Soil (g)	1600	1700	1800	1600
	0.00	0.00	0.00	0.00
Volume of Mould (m³)	1	1	1	1
Bulk Density (Kg/m³)	1600	1700	1800	1600
Weight of empty can (g)	10.5	6.5	9.2	8.4
Can + wet sample (g)	27.5	30.8	35.6	28.6
Can + dry sample (g)	24.6	25.8	29.1	23.3
	20.5	**25.9**	**32.6**	**35.5**
Moisture Content (%)	**7**	**1**	**6**	**7**
Dry Density (Kg/m³)	**1327**	**1350**	**1357**	**1180**

Table 9: Compaction Test for clay sample (IRE-EKITI CLAY SOIL 1)

Trial	1	2	3	4
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 (m³)	0.001	0.001	0.001	0.001
Bulk Density (Kg/m³)	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/m³)	**1327**	**1361**	**1354**	**1198**

Table 10: 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 11: 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**

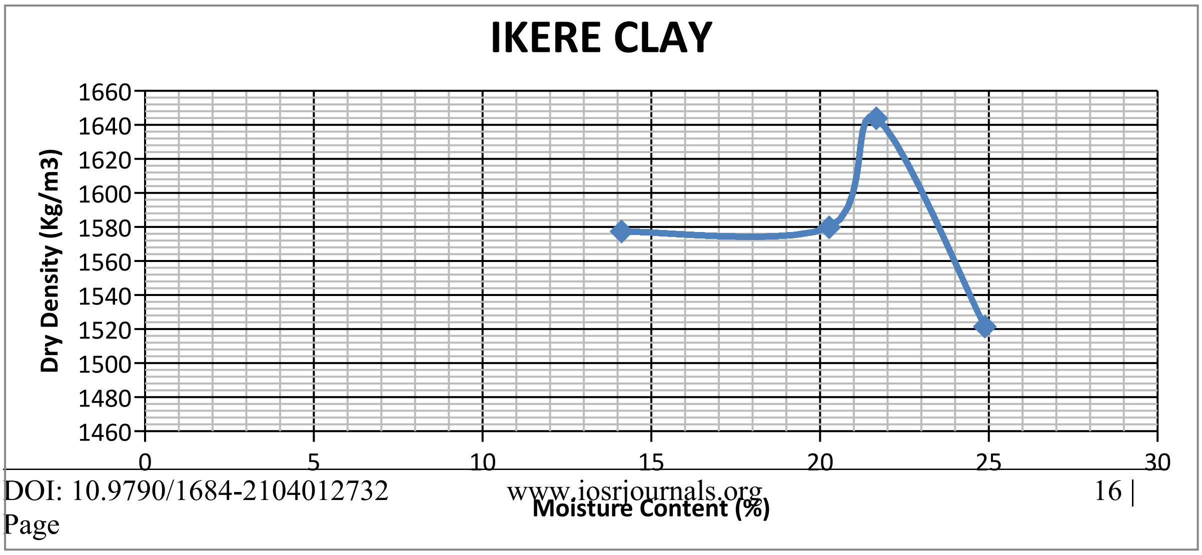

Figure 10: Graph of Dry Density against Moisture Content of Ikere Clay sample

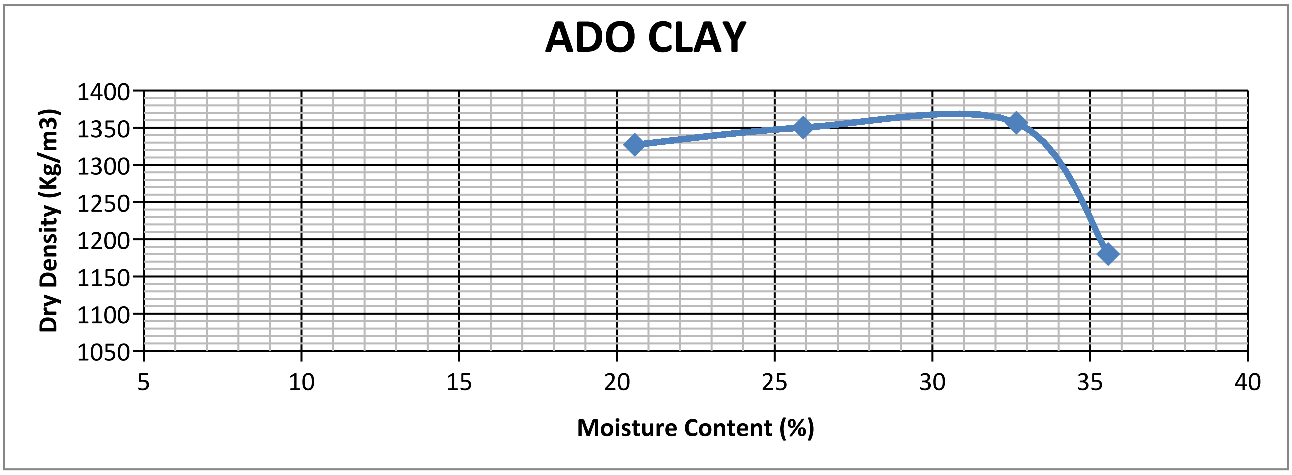

Figure 11: Graph of Dry Density against Moisture Content of Ado Clay sample

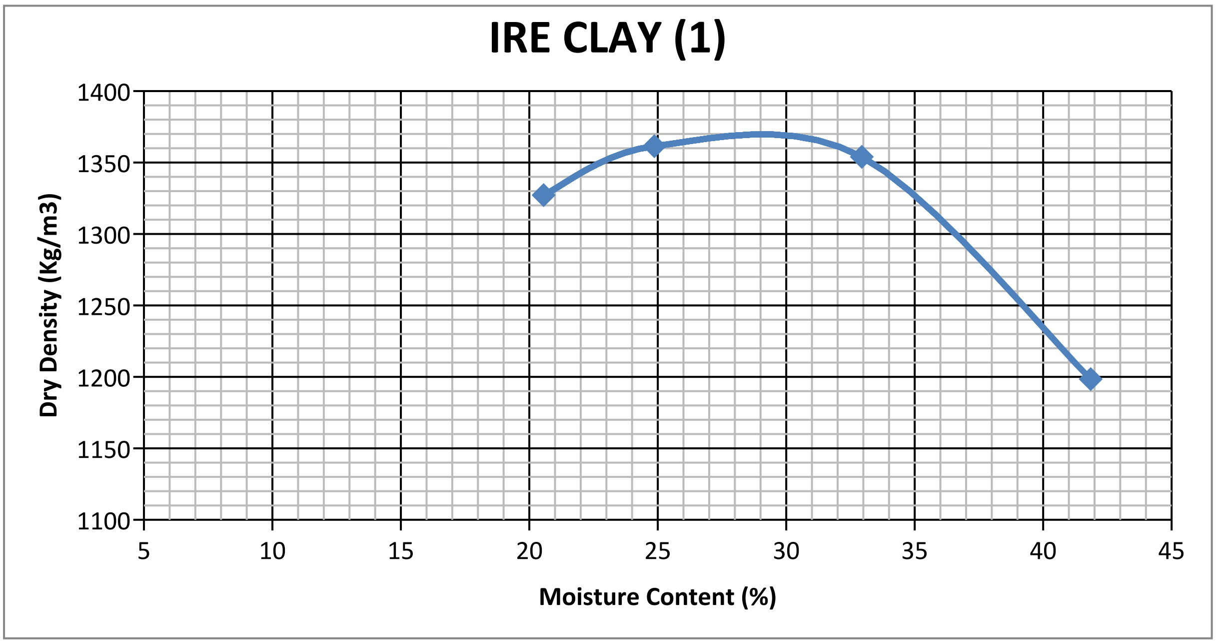

Figure 12: Graph of Dry Density against Moisture Content of Ire Clay sample 1

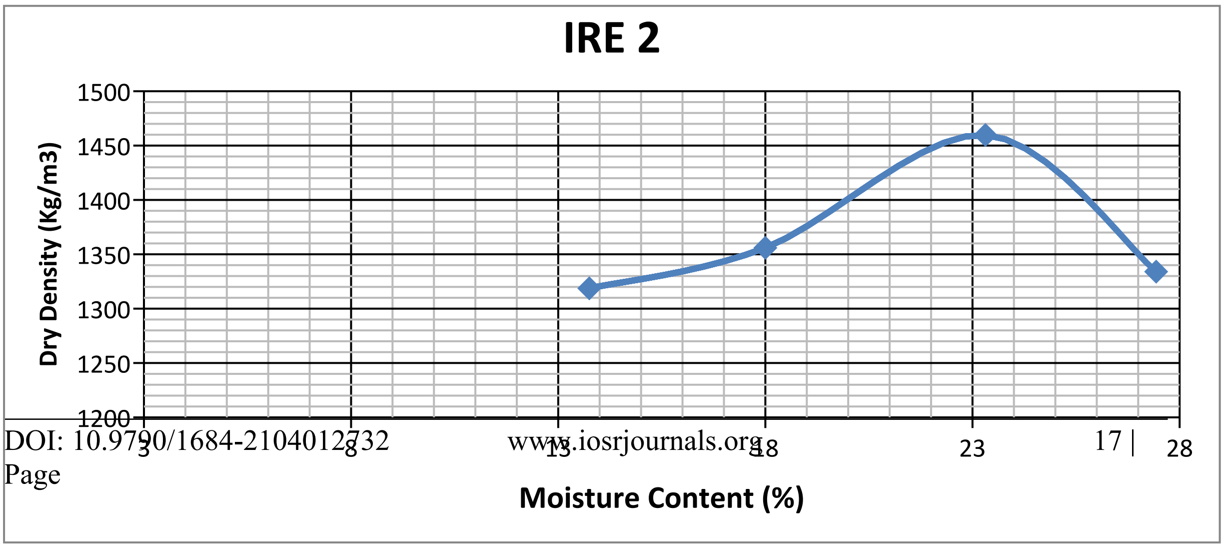

Figure 13: Graph of Dry Density against Moisture Content of Ire Clay sample 2

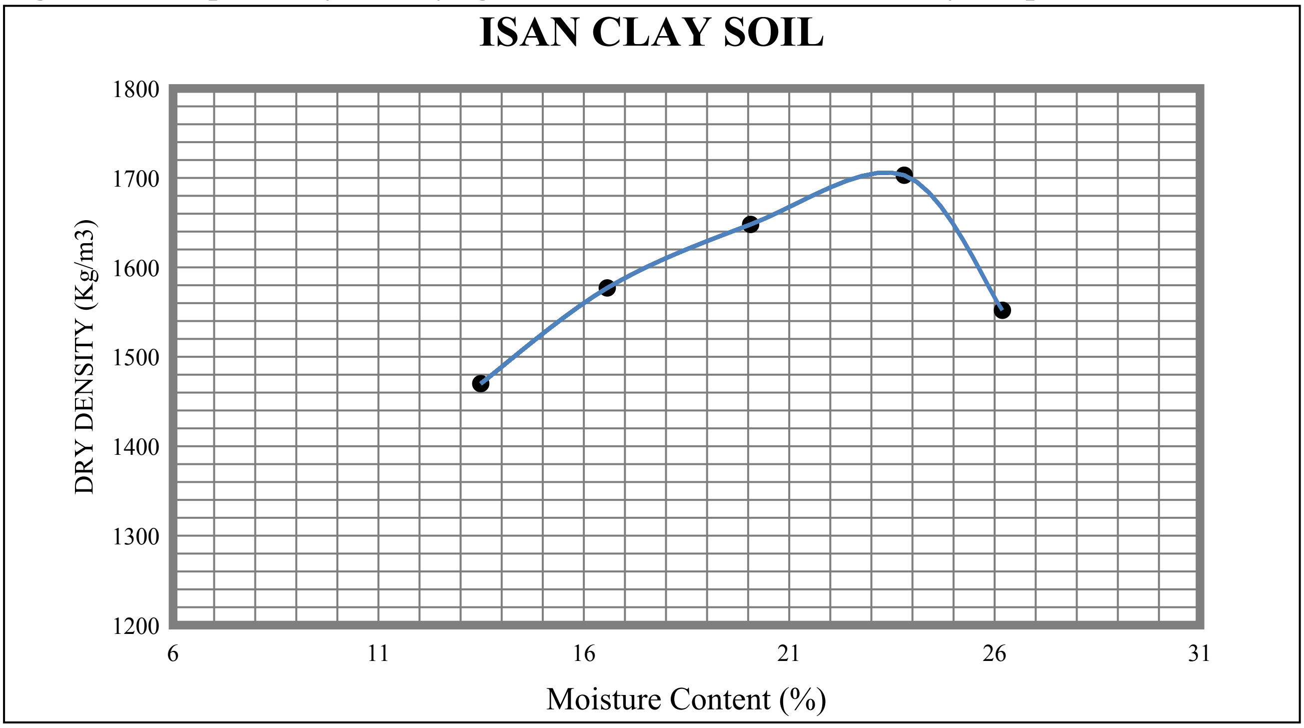

Figure 14: Graph of Dry Density against Moisture Content of Isan Clay sample