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# Moisture-Density Relationship of Selected Clay Soils in Ekiti State, Nigeria

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## ABSTRACT

This research work is aimed at accessing the moisture-density relationship of clay soils in Ekiti state. Soil samples were therefore collected from four locations (Ire-Ekiti, Ilawe-Ekiti, Ikere-Ekiti and Ado-Ekiti), with a target of one local government area per location. The samples were all subjected to various laboratory tests like specific gravity, particle size distribution, hydrometer test, Atterberg limits and compaction test in accordance with British standard (BS 1377: 1990) in other to ascertain their geotechnical properties, especially the relationship between the moisture contents and dry density of the samples. Detailed study of the particle size distribution, hydrometer and Atterberg limits tests on the soil samples shows that the samples are all A-7 soils. Two methods of compaction (Standard Proctor and Modified proctor) were used given the Maximum Dry density (MDD) of range 1554 to 2074 Kg/m$^3$ and Optimum Moisture Contents (OMC) ranges between 12.2 to 25.0% with samples A and D having the highest MDD and the lowest OMC. It was observed that the increase in compactive energy (Modified Proctor) increases the MDD and reduces the OMC of the samples.

KEYWORDS: hydrometer, clayey soil, maximum dry density, group index, plasticity index

## INTRODUCTION

Soil is considered by the engineer as a complex material produced by the weathering of solid rock, to form different materials like boulders, gravels, sands, silts, of which clays are not immune [12]. Clay soil is fine-grained unconsolidated material which has the characteristic property of being plastic when wet and which loses its plasticity and retains its shape upon drying or when heated. It is the smallest particles (with diameter less than 2 x 10$^{-3}$mm) in a soil mass and a very important engineering material. Though it is regarded as problematic soil by some people due to its adverse consolidation settlement and volumetric change characteristics, it's presence to some degree in soil's composition added a great value to engineering works because of its ability to bind grains together. Clays are alumino-silicates with a two-dimensional sheet lattice structure.

Clay soils are normally used as materials for construction of dams because of its relative low rate of permeability. Naturally, clay soils are deposited in most of the local government in the state. Some of this clay soils has been tapped by the state for the production of bricks (Ire clay products limited), pottery, etc as a means of generating revenue. While we have some of the clay materials used, some are still left untouched this may be due to their plasticity, and negligence.

Clay soils with high plasticity index are suitable for potteries, construction of the clay core in a high dam, and for the construction of a layer of low permeability covering a deposit of polluted material without much fear of changing phase [13]. In other to make clay soils suitable for engineering purposes, many scholars had critically looked into the effects of available materials like palm kernel nutshell, rice husk ash, anthill, lime, bagasse ash, and many other additives [4,6,7,8,11] to increase the workability of the available clay soils around.

Clay soils from different locations reacted in a different manners with water based on the mineral contents presents in them. Most engineering properties of soil, such as the strength, stiffness, resistance to shrinkage, and imperviousness of the soil, will improve by increasing the soil density. Hence, the need for study the relationship between the moisture contents of selected clay soil in Ekiti state and their dry density.

# MATERIAL AND METHODS

## MATERIAL

Clay soils used for this study were collected from four locations representing four local government areas in Ekiti state in its disturbed form. The samples were collected at an average depth of 1.2m below the ground level. The first sample was collected along Ire/Ilupeju road, Ire-Ekiti. The second sample was collected along Ado/Ilawe road, Ilawe Ekiti. The third sample was collected along Ise/Ikere Road, Ikere-Ekiti, while the fourth sample was collected at Falegan, Ado/Ilawe road in Ado Ekiti, Oye, Ekiti south-west, Ikere and Ado local government respectively [1]

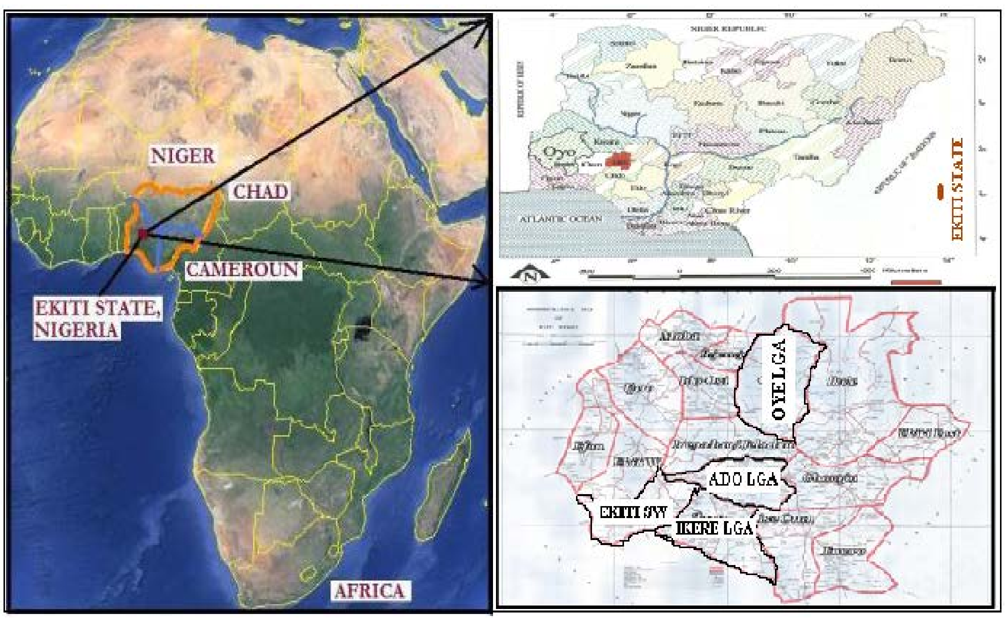


**Figure 1:** Geological Map of Ekiti Showing The Study Areas [5]

## Methods

The samples were air-dried at room temperature for about two weeks. All dried samples were then pulverized to remove deleterious materials such as roots of trees and stones. The following tests were then carried out in the laboratory in accordance with the British Standard [9], to ascertain the soils compaction characteristics and few of their geotechnical properties;

*Specific gravity*

The specific gravity was determined using small pyknometer method. The sample was oven-dried at 105$^{o}$C and the test was carried out in accordance with part 2 of British Standard [9].

*Particle size distribution and hydrometer test*

In accordance with [7,9], the samples were soaked for 24 hours and washed with 75µm sieve. The portion retaining on this sieve was dried and sieved through a set of sieves. The filtrate was therefore subjected to hydrometer test to ascertain the percentage of silt and clay contents present in the soil.

*Atterberg limits*

Plastic Limit and Liquid Limit (Casagrande method) tests were conducted on the soil samples passing 0.425mm (No 40) sieve in accordance with British Standard [9] in other to examine the reactions of the samples to water.

*Compaction test*

Standard proctor and modified proctor method of compaction was adopted for this study in other to evaluate the water-density relationship of the clay from each locations. The procedure was in accord with part 4 of British Standard [9] and classified according to [3]

# RESULTS AND DISCUSSION

## Specific gravity

The specific gravity values of the clay soils are shown in Table 1. The values derived from the specific gravity test of the soils ranges from 2.12 and 2.62. Generally, the specific gravity of inorganic clays range from 2.70 to 2.80 normally varies between 2.6 and 2.9. The values of 2.45 and 2.12 from sample A and C respectively, may indicate the presence of organic substances in the soil.

**Table 1:** Atterberg Limit and Specific Gravity Test Results of the Soil.

| LOCATION | SAMPLE CODE | LL (%) | PL (%) | PI (%) | $G_S$ | % PASSING #200 | GI | AASHO CLASSIFICATION |
|---|---|---|---|---|---|---|---|---|
| IRE-EKITI | A | 51.9 | 32.8 | 19.1 | 2.45 | 62.18 | 11.35 | A-7-5 |
| ILAWE-EKITI | B | 42.5 | 31.9 | 10.6 | 2.60 | 54.52 | 4.39 | A-7-5 |
| IKERE-EKITI | C | 48.8 | 30.7 | 18.1 | 2.12 | 94.48 | 20.95 | A-7-5 |
| ADO-EKITI | D | 40.6 | 24.8 | 15.8 | 2.62 | 36.54 | 1.56 | A-7-6 |

## Particle size distribution and hydrometer test

The soil samples were subjected to sieve analysis and hydrometer tests and the results are shown in Table 2 and 3 respectively. The graph of percentage soil passing was plotted against sieve size in Figure 2 which revealed that sample A and B are well graded while sample C and D are gap graded.

From the result on Table 2, the soils justifies silt-clay materials as percentage passing sieve No 200 (0.075mm) is greater than 36[2].

**Table 2:** Table showing results of the grain size analysis

| Sieve Size (mm) | PERCENTAGE WEIGHT PASSING | | | |
|---|---|---|---|---|
| | A | B | C | D |
| **16.00** | 100.00 | 95.38 | 100.00 | 100.00 |
| **9.50** | 98.16 | 94.10 | 100.00 | 100.00 |
| **4.75** | 97.26 | 92.34 | 99.60 | 99.14 |
| **2.36** | 95.04 | 89.96 | 98.70 | 97.26 |
| **1.18** | 90.52 | 85.22 | 97.68 | 89.90 |
| **0.60** | 81.56 | 78.26 | 96.70 | 50.56 |
| **0.30** | 73.58 | 69.28 | 95.66 | 37.50 |
| **0.15** | 66.42 | 59.32 | 94.92 | 36.74 |
| **0.075** | 62.18 | 54.52 | 94.48 | 36.54 |

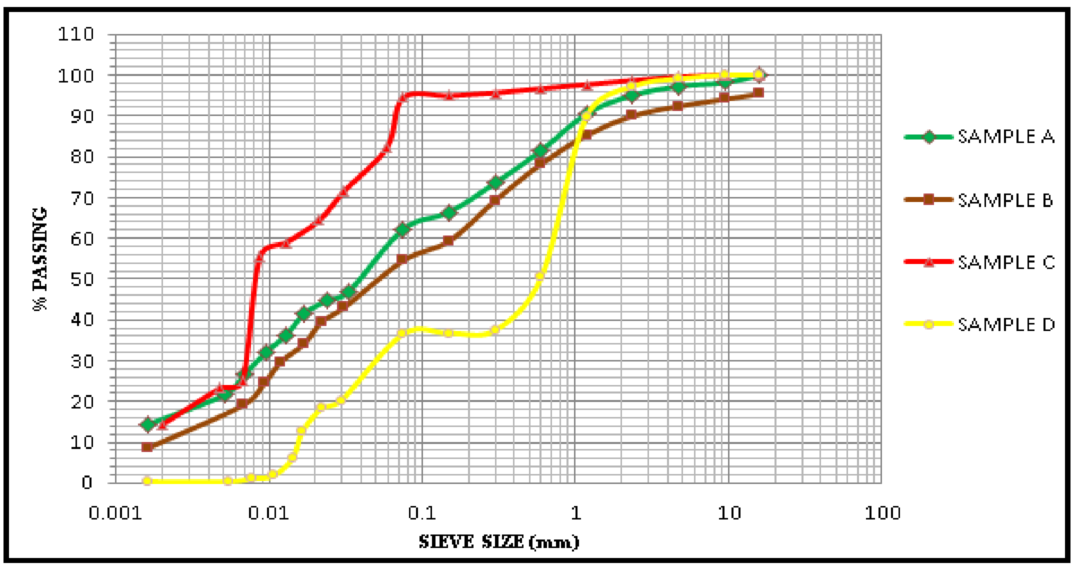


**Figure 2:** Particle Size Distribution curve of the samples

## Atterberg limits

The results of the Atterberg limits test (liquid and plastic limits) of the samples are shown in Table 1. The result shown that sample A is clay of high plasticity (LL>50%) while others shown to be clay of low plasticity (LL<50%). According to AASTHO classification [9] using the results gotten from the Atterberg limits test, the soils fall within the range A-2-7 and A-7 soils. Further classification on the soil reveals that the samples are A-7-5 soils except sample D which proves to be A-7-6 soil.

**Table 3:** Summary of Hydrometer test

*D* is the equivalent particle diameter and *K* is the percentage by mass of particles less than *D*

| D (mm) | K (%) | D (mm) | K (%) | D (mm) | K (%) | D (mm) | K (%) |
|---|---|---|---|---|---|---|---|
| A | | B | | C | | D | |
| 0.033 | 46.86 | 0.031 | 43.06 | 0.0588 | 82.26 | 0.0296 | 20.28 |
| 0.024 | 44.76 | 0.022 | 39.52 | 0.0309 | 71.53 | 0.0220 | 18.31 |
| 0.017 | 41.61 | 0.017 | 34.20 | 0.0212 | 64.38 | 0.0165 | 12.67 |
| 0.013 | 36.35 | 0.012 | 29.77 | 0.0130 | 59.01 | 0.0143 | 6.22 |
| 0.0096 | 32.15 | 0.0093 | 24.45 | 0.0087 | 55.44 | 0.0107 | 1.83 |
| 0.0070 | 26.90 | 0.0068 | 19.14 | 0.0067 | 25.04 | 0.0077 | 1.10 |
| 0.0051 | 21.65 | 0.0016 | 8.51 | 0.0048 | 23.25 | 0.0055 | 0.37 |
| 0.0016 | 14.29 | | | 0.0020 | 14.30 | 0.0016 | 0.36 |

## Compaction test

Two method of compaction (Standard proctor and Modified Proctor) was used for the study and the results are shown in Table 4 and 5 respectively. In other to determine the optimum moisture content (OMC) and the soils MDD, the graph of dry density against moisture contents of the soils was plotted as shown in Figure 3. From the graph, it was deduced that the soils' MDD ranges between 1554 to 2074 Kg/m$^3$ and its OMC ranges between 12.2 to 25.0%. The increase in the values of MDD is due to closer packing of the clay soil with increase in compactive energy. The results established the facts that as the compactive energy increase, the MDD increases and vice versa for the OMC as proved by [14].

**Table 4:** Results of Standard Proctor Compaction

| Dry density (Kg/m$^3$) | MC (%) | Dry Density (Kg/m$^3$) | MC (%) | Dry density (Kg/m$^3$) | MC (%) | Dry Density (Kg/m$^3$) | MC (%) |
|---|---|---|---|---|---|---|---|
| A | | B | | C | | D | |
| 1746 | 11.32 | 1449 | 6.96 | 1372 | 21.51 | 1493 | 7.14 |
| 1860 | 13.50 | 1467 | 9.09 | 1482 | 23.67 | 1547 | 9.89 |
| 1960 | 16.25 | 1532 | 10.95 | 1552 | 25.29 | 1618 | 11.24 |
| 1930 | 20.91 | 1579 | 13.98 | 1401 | 30.82 | 1672 | 13.62 |
| 1743 | 24.33 | 1661 | 17.39 | | | 1738 | 17.95 |
| | | 1759 | 19.43 | | | 1655 | 20.86 |
| | | 1600 | 21.91 | | | | |

**Table 5:** Results of Modified Proctor Compaction

| Dry density (Kg/m$^3$) | MC (%) | Dry Density (Kg/m$^3$) | MC (%) | Dry density (Kg/m$^3$) | MC (%) | Dry Density (Kg/m$^3$) | MC (%) |
|---|---|---|---|---|---|---|---|
| A | | B | | C | | D | |
| 2042 | 11.58 | 1616 | 8.27 | 1406 | 14.27 | 1749 | 8.64 |
| 2071 | 12.63 | 1844 | 11.16 | 1489 | 16.08 | 1806 | 10.73 |
| 1957 | 19.22 | 1847 | 13.78 | 1547 | 18.97 | 1858 | 13.02 |
| 1822 | 21.96 | 1803 | 16.54 | 1632 | 21.32 | 1835 | 17.18 |
| | | 1649 | 21.32 | 1568 | 26.14 | 1680 | 22.04 |

# CONCLUSION AND RECOMMENDATION

From the results of tests conducted on the samples, it was concluded that the water holding capacity of clay soils from the selected locations is of the average since the maximum value of the soil's OMC is 25.0%. The soil as classified by AASHTO are A-7 soils. As classified by [3], the soils are generally rated as not suitable for base course, fair to poor for subgrade materials and of good stability for embankment.

It was concluded from the results that modified proctor method of compaction requires lower optimum moisture content to achieve its maximum dry density which makes it more desirable for construction purposes. It was also discovered that the MDD gotten from Modified Proctor method of compaction is greater than that of the standard Proctor at the average of 5.7%

Blended clay is therefore recommended for engineering purposes where appreciable strength is needed. The available clay soils within the state and the country at large could be worked upon to suit the purpose of liner in landfill. Further research work could be done to access more of the hidden geotechnical properties of the soils.

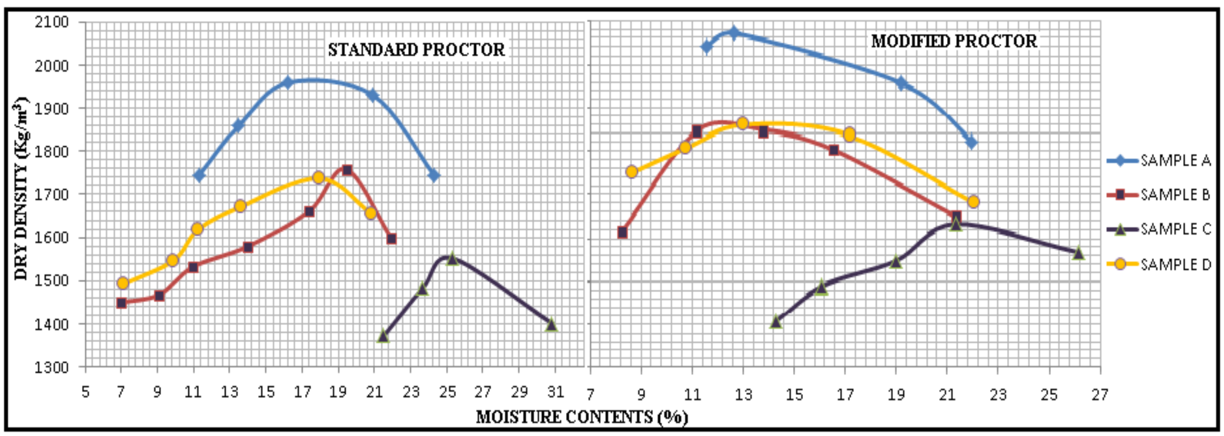


**Figure 3:** Compaction curves for the soil samples

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| ***Editor's note.*** This paper may be referred to, in other articles, as: |
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