GEOGRAPHICAL INFORMATION SYSTEM (GIS) AS A SEARCH TOOL FOR GEOTECHNICAL INFORMATION OF SOIL

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Abstract— The research on Geographic Information System (GIS) as a search tool for geotechnical information of soils was informed by the need to develop a GIS based geotechnical map for the Federal University of Technology, Akure, Ondo State, Nigeria (FUTA) and to allow easy access to information on the geotechnical properties of soils within the University. Different soil samples were collected at different locations within the University and their coordinates obtained with the aid of Global Positioning System (GPS). The test results of the engineering properties of the soil got were analysed, stored and manipulated using GIS (ArcMap 10.2)to display graphical information. Maps with the descriptions of the properties of soil in contour form or colour pattern at different locations in the University were obtained and a database was produced. These facts can be accessed in the future to obtain information that could help in making informed engineering decisions when needed.

Index Terms—*Information System (GIS), Global Positioning System (GPS), Maps*

1 INTRODUCTION

A Geographic Information System (GIS) or Geospatial Information System is a system designed to capture, store, manipulate, analyze, manage and present all types of spatial or geographical data. In a general sense, the term describes any information system that integrates, stores, edits, analyzes, shares, and displays geographic information. GIS applications are tools that allow users to create interactive queries (user-created searches), analyze spatial information, edit data in maps, and present the results of all these operations **[7].** A GIS consists of three broad components which are- computer hardware and software, spatial data from real world and trained personnel.

A Global Positioning System (GPS) is a tool used to collect data for a GIS. The terms GIS and GPS are often confused; GPS stands for Global Positioning System, which is a system of satellites, ground stations and receivers that allow the user to find an exact location on earth. By collecting location points, datasets can be compiled that can be used to map whatever data that are being collected. GPS systems generate geographic reference points in the form of latitude, longitude and elevation coordinates. Once the data is collected, it can be put into a GIS and displayed digitally as it is in the real world.

1.1 Soil And Infrastructural Development

Soil is an essential component in civil engineering infrastructural development. It often controls the design and cost of construction projects, predominantly lightweight and shallow foundation structures [6]. Therefore collecting appropriate soil and geotechnical information is a crucial aspect in infrastructure planning and development. Soil geotechnical investigation is usually tailored towards determination of soil types, estimating their geotechnical characteristics and performance [8]. With government and investors conducting numerous construction projects at one time, the amount of documentation needed to be stored quickly becomes overwhelming. Much of this data is generated from geotechnical investigations and contains soil information as well as its location on the earth. The engineering profession quickly identified a need to improve document storage techniques. With the increase in computing power in the recent years, most organizations have begun storing past engineering data on computers [9]. Storing engineering data using an electronic management system has many advantages to storing physical document. Electronic management systems can handle large quantities of engineering data with a high level of efficiency. According to [9], data is safe from the elements and access can be limited to provide a much more secure storage environment. Most of civil engineering data has spatial attributes. In these cases a GIS is ideal to represent the information on a map.

A geographic information system is a very powerful tool that is becoming increasingly popular for managing geotechnical data [2]. The use of GIS is a good solution for data management due to the fact that GIS has the ability to store, manipulate, analyse and display graphical information that has been referenced to a location on the earth [3]. A point of strength in a GIS is the ability to perform spatial and non-spatial analysis on data. Spatial analysis is a very powerful tool when used in a system for storing construction documentation. In particular, the storage of geotechnical documents is ideally suited for a GIS. Roadway projects, soil borings, bridges and building foundations and other features can be represented on a map and all data associated with those features can be stored in a database.

1.2 Aim and Objectives

The aim of this study is to develop a GIS-based geotechnical map of Federal University of Technology, Akure (FUTA) for easy access to the geotechnical properties of soils within the University.

The objectives are to:

i. compile and archive geo-referenced soil test reports;
ii. store all test data for a particular sample in a central database and prepare GIS-based maps of soil properties that make such test data available for other users and
iii. make recommendations as appropriate.

1.3 Scope of Study

The study area is Federal University of Technology, Akure, in Akure South Local Government Area of Ondo State. It is as shown in plate 1 and it is located in the South-Western Region of Nigeria. It lies between latitudes 7o16′03′′N – 7o18′06′′N and Longitudes 5o8′02′′E – 5o08′05′′E. The site has a low lying topography and it is located within the sub-equatorial climatic belt with tropical rain-forest vegetation. The mean annual temperature is 24oC-27oC, while the annual rainfall varies between1500mm and 3500mm [1].

2 MATERIALS AND METHOD

2.1 Materials

The materials for this research were obtained from two major sources. They were from Geotechnical field investigation and public domain and information research

2.2 Geotechnical field investigation

Disturbed soil samples were collected at different locations at a depth exceeding 1m within the study area together with the co-ordinates of each samples location with the aid of "GPS Coordinates'' a mobile application developed by woozillo, inc. These samples were preserved in airtight bags and transported to the laboratory. Methods of testing soils for engineering parameters were conducted in accordance with B.S. 1377 for all the soil samples collected. The tests include natural moisture content, grain size analysis, Atterberg limit test, compaction test, unconfined compression test, and specific gravity test.

2.3 Public Domain and Information Research

Geotechnical and Geology laboratory on campus were consulted to obtain geotechnical site information of recent work pertaining to this research. Furthermore, works of other researchers were also obtained and included so as to accumulate large volume of data to make the research a robust work. Currently, there are various classification systems commonly used by soil engineers, but for the purpose of this study, the American Association of State Highway and Transportation Officials (AASHTO) classification system was used as the basis for soil sample classification.

3 METHODOLOGY

3.1 Modelling and Visualization using ARC GIS

The process of data compilation and editing data involves the collection and integration of the soil geotechnical reports containing soil attribute data, drawing files (dwg), shape files (shp), Google satellite imagery and also the coordinates of each sample. Creating database was a critical part of the project and the completeness and accuracy of the data used, determines the accuracy of results.

3.1.2 Data modelling with Software

Modelling data with ArcMap 10.2 Desktop software was done. Beyond showing data as points on a map, ArcMap 10.2 Software gives the power to manage and integrate data, perform advanced analysis, model and automate operational processes, and displayed results on professional-quality maps.

3.1.3 Data Presentation

Geographic Information System (GIS) allowed two and three-dimensional representation of the Earth's surface, subsurface or atmosphere from geospatial data. Most data contouring were accomplished using sub-routines that utilized either linear interpolation or the mathematical principles of Inverse Distance Weighting Method. Inverse Distance Weighting (IDW) predicts cell values by averaging the values of sample data points in the neighborhood of each processing cell. The closer a point is to the centre of the cell being predicted, the more weight it has in the averaging process. Inverse Distance weighting method, generally yields much smoother curves than the other interpolation method. The modelling technique used in analysis for the purpose of this study is contouring and colour pattern. This data model can then be combined with other types of information layers in the GIS.

4 RESULTS AND DISCUSSION

4.1 Natural Moisture Content

The Natural Moisture Content (NMC) of samples of soils tested within the study area is shown as contour lines in Plate 2. The NMC ranges between 22 and 26 as can be seen around theCentre for Continuing Education (CCE) office, Centre for Space Research and Administration (CESRA), Education Trust Fund (ETF) Lecture Theatre, Academic Building. This NMC value also spread across to Big Lecture Theatre area. The Lower values of NMC having contour lines within the range of 1 to 8% can be seen around Abiola hostels 1,2 and 3, Jibowu hostels 1 and 2, School of Earth and Mineral Sciences (SEMS) Annex,. From the Plate, it is seen that the highest NMC value of 28% occurs around Postgraduate (PG) laboratory and CCE office

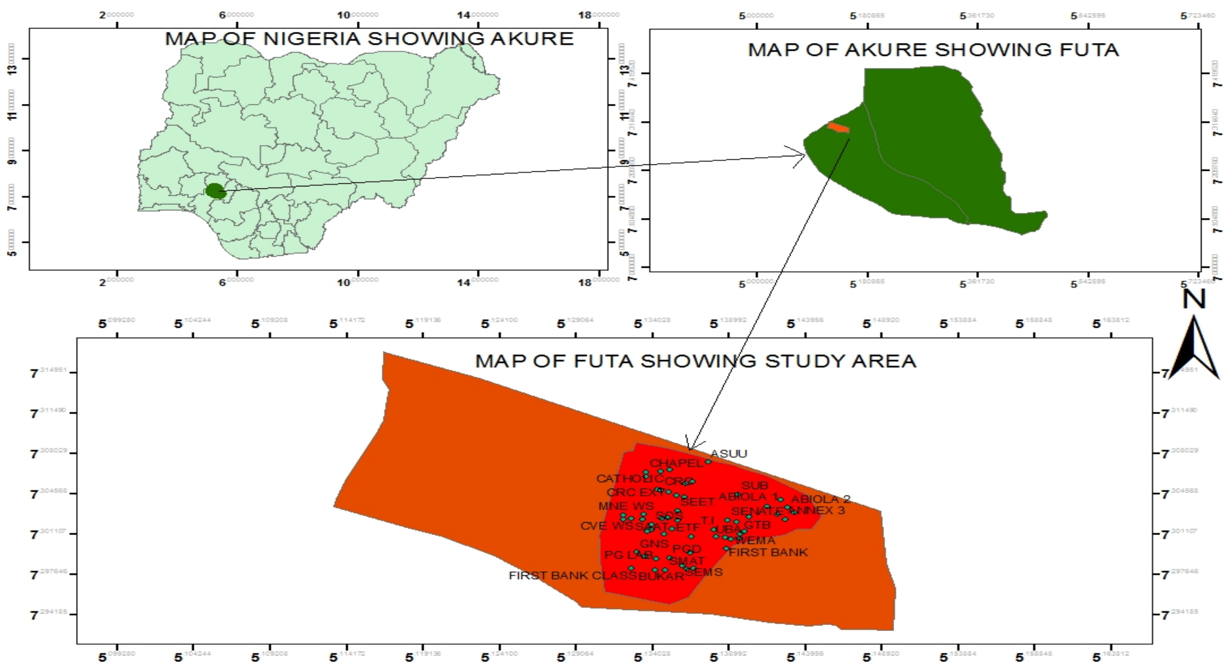

Plate : Location Map of the Study Area

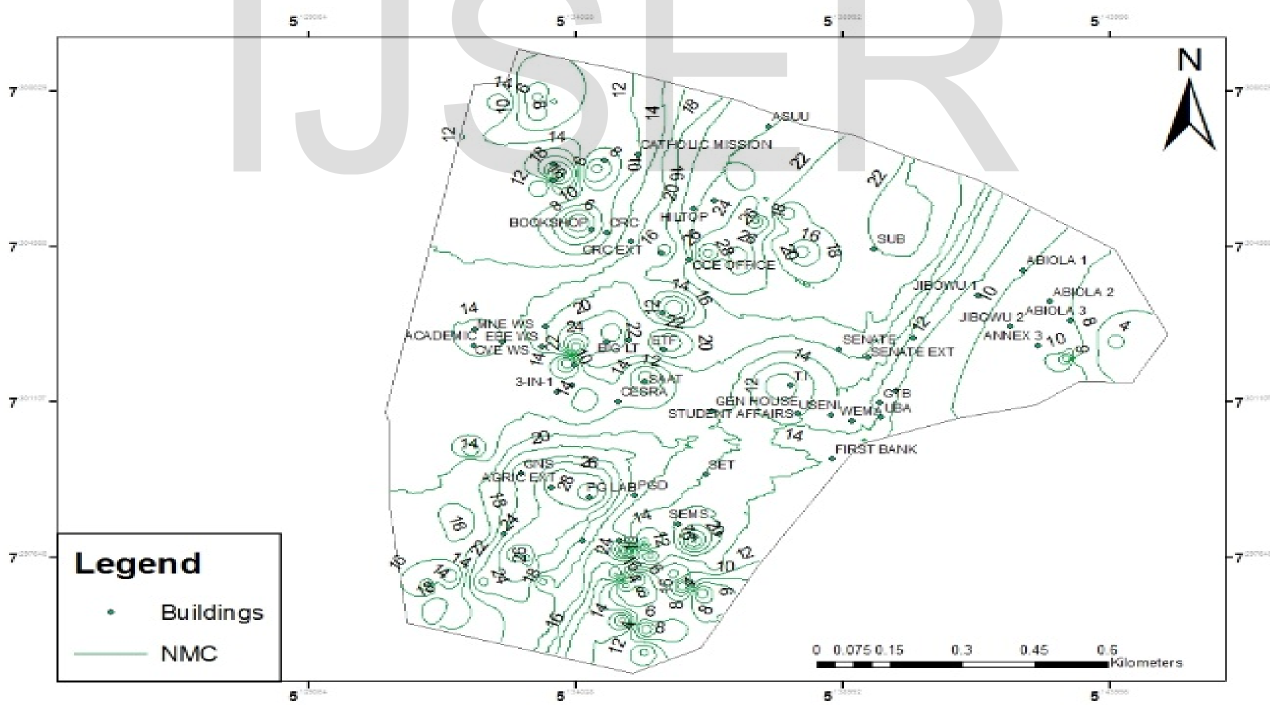

Plate2: Natural Moisture Map

4.2 Liquid Limit

Plate 3 shows the liquid limit (LL) of soil samples tested within FUTA. The contour lines in the plate show the range of 23 to 38% LL around the Chapel area, Bookshop area, Computer Resource Centre (CRC) area, 3 in 1 Lecture Theatre area, ETF Lecture Theatre area, Electrical and Electronic Engineering (EEE) workshop area, Big Lecture Theatre area, Mining Engineering (MNE) workshop area, Civil Engineering (CVE) workshop area, Academic Building, Abiola, Jibowu , First Bank areas, and some portion behind the SEMS building. Liquid limit within the range of 38 to 43% can be seen around the Academic Staff Union of University (ASUU) building, Hilltop, CCE office, School of Environmental Technology (SET) building, and FUTA Alumni building. Liquid limit within the range of 46-51% is shown around the Senate building and Centre for Research and Development (CERAD) building. Liquid limit within the range of 51 to 56% is shown around the PG laboratory, Buka Hall, TI Auditorium, Useni and Student Affairs areas. The most predominant liquid limit range is from 23-38%, and it indicates soil with relatively low clay content and high load carrying capacity while the highest LL range is from 51 to 56%, indicating soil with high clay content and low load carrying capacity. From this, a civil engineer working around FUTA could easily locate where good soil could be found.

4.3 Plastic Limit

The Plastic Limit (PL) of the soil samples tested are as shown in Plate 4. From the Plate, Soils with PL range from 13 to 21% can be seen around Abiola Jibowu, Annex 1, 2and 3, behind SEMS building, Chapel, Catholic Church, CRC, and EEE workshop. Plastic limit within the range of 21to 25 % can be seen around Big LT, FUTA alumni building, Senate extension building, First Bank, WEMA buildings, Student Affairs building, 3 in 1 Lecture Theatre and CRC extension building. Plastic limit within the range of 25 to 26% can be seen around the SET building, SMAT building, SUB, SEET building and those within the range of 26 to 30% is around CCE office, Hilltop, ASUU building, First Bank area, PGD and some parts of SEMS building. Plastic limit within the range of 30 to 39% is around PGD, Buka hall, and Hill Top. The commonest range is within 13 to 21%, and it is indicative of a low clay content, while the least occurring range is within 30 to 39%, and it is indicative of high clay content.

4.4 Specific Gravity

Plate 5, shows the specific gravity (G) of soils in the study area and the plate also changes from contour line representation to colour pattern. From the Plate, the range of specific gravity of soil within the range of 2.5 to 2.7 can be seen around Abiola 1,2 and 3, Jibowu 1and 2, Senate, Chapel, Catholic, Computer Resource Centre (CRC), Hilltop, First Bank Class, Mining Engineering workshop, Civil and Environmental Engineering workshop, SUB, WEMA, Student Affairs, Useni buildings. Specific gravity within the range of 2.7 to 2.9 can be seen around, SEET, ETF, CESRA, SEMS, SET, PGD, PG laboratory, Buka hall, 2 in 1, CCE, CCE office, Bookshop.

4.5 Optimum Moisture Content (OMC)

Plate 6 does not also show the information in contour line form but in colour pattern. It shows the Optimum Moisture Content (OMC) range of 8 to 12% around the SOS, some part of CCE class and CCE office buildings. The OMC within the range of 12 to 15% could be found around the Academic building, MNE workshop, MEE workshop, Generator house, Student Affairs, CESRA, SAAT, ETF, SEET, CCE class, and north east corner around Abiola hostel 3. The OMC within the range of 15 to 18% is found around SET, First Bank, Senate, Senate extension, FUTA alumni, Jibowu 1,2 and 3, Abiola 1,2 and 3, Catholic Mission, CRC, Bookshop, Big LT buildings. The OMC within the range of 18 to 24 % can be seen around SUB, Annex 3, ASUU, Hilltop, SEMS, Buka hall, Research laboratory, PG laboratory, PGD, Agric extension, GNS, First Bank Class buildings. OMC within the range of 24 to 32% can be seen at Chapel, Chapel extension buildings.

The OMC predominant range lies in-between the range of 15 to 18%, and the least range is from 24 to 32% meaning that the soils in these areas are fairly good.

4.6 Maximum Dry Density (MDD)

Plate 7 shows the MDD (in colour pattern) within the range of 1373 to 1747 Kg/m^3 and 1531 to 1627 Kg/m^3 around SUB, Annex 3, First Bank Class and Chapel buildings.

The MDD within the range of 1725 to 1745 Kg/m^3 and 1748 to 1770 Kg/m^3, can be seen around ASUU, Abiola 1 and 2, Jibowu 1and 2, FUTA alumni, Senate extension buildings. The MDD in the range of 1771 to 1808 Kg/m^3 is found around Abiola 3, UBA, GTB, Senate, SET, SEMS and Hilltop buildings and the MDD within the range of 1809 to 1868 Kg/m^3 can be seen around T.I. auditorium, Useni, First Bank, Catholic mission buildings. The MDD in the range of 1966 to 2122Kg/m^3 can be seen around 3 in 1, SOS, CCE class, CCE office, EEE workshop buildings.The implications of this is that the soil around T.I. auditorium, Useni, First Bank, Catholic mission , 3 in 1, SOS, CCE Class, CCE office, EEE workshop buildings are fairly good soil materials for engineering use.The most predominant MDD is within the range of 1869 to 1965 Kg/m^3, while the least range is 1373 to 1530 Kg/m^3.

4.7 Soil Classification

The result obtained under the AASHTO Classification system is as shown in Plate 8. The Plate shows the spatial distribution of various soil classes in the study area. The categories of soil in study region are: A-2-4, A-2-6, A-2-7, A-2-5, A-1-b, A-1-a, and A-6. The A-2-7 can be seen around First bank, Catholic mission , Chapel, Bookshop, CESRA, SAAT, SEET, MEE workshop, 3 in 1, Big LT, CVE workshop, Student affairs and Gen house. The A-2-5 group can be seen around Abiola 1, 2 &3, Jibowu 1&2, Annex 3, GTB, UBA, T.I. auditorium, ASUU, SET, SEMS, Buka hall.

A-7-6 group can be seen around SUB, Chapel extension, Agric extension and First bank The most widespread group is the A-2-7 group, and can either be a silty or clayey gravel and sand, and is regarded as a good sub base material, while the least soil class is the A-6 group.

4.8 Unconfined Compressive Strength

For soils, the unconfined compressive strength (qu) is necessary for the determination of the bearing capacity of foundations, dams, etc. The undrained shear strength (Cu) of clays is commonly determined from an unconfined compression test. A typical preview of the test results is shown in appendix II. The undrained shear strength (Cu) of a cohesive soil is equal to one-half the unconfined compressive strength (qu) when the soil is under the f = 0 condition (f = the angle of internal friction).

From Plate 9, the Unconfined Compressive Strength (UCS) within the range 0 to 40 kN/m² can be seen around Chapel, Catholic extension, Annex 3, south-west of the First bank class. The UCS within the range of 40 to 70 kN/m² can be seen around Abiola 1, 2 &3, Jibowu 1 &2. The UCS within the range of 140 to 170 kN/m² and 180 to 230 kN/m2 can be seen around UBA, GTB, First bank, CVE workshop, SUB. The UCS within the range of 230 to 280KN/m² and 280 to 300 kN/m² can be seen around GNS, CESRA, SAAT, CRC extension, ASUU, Senate, extension, MEE workshop. The UCS within the range of 320 to 342KN/m² can be seen around Hilltop, CCE class, CCE office, Buka hall, 2 in 1, PG laboratory, Agric extension. The most predominant range of UCS is from 320 to 341 kN/m², while the least range is from 100 to 140 kN/m².

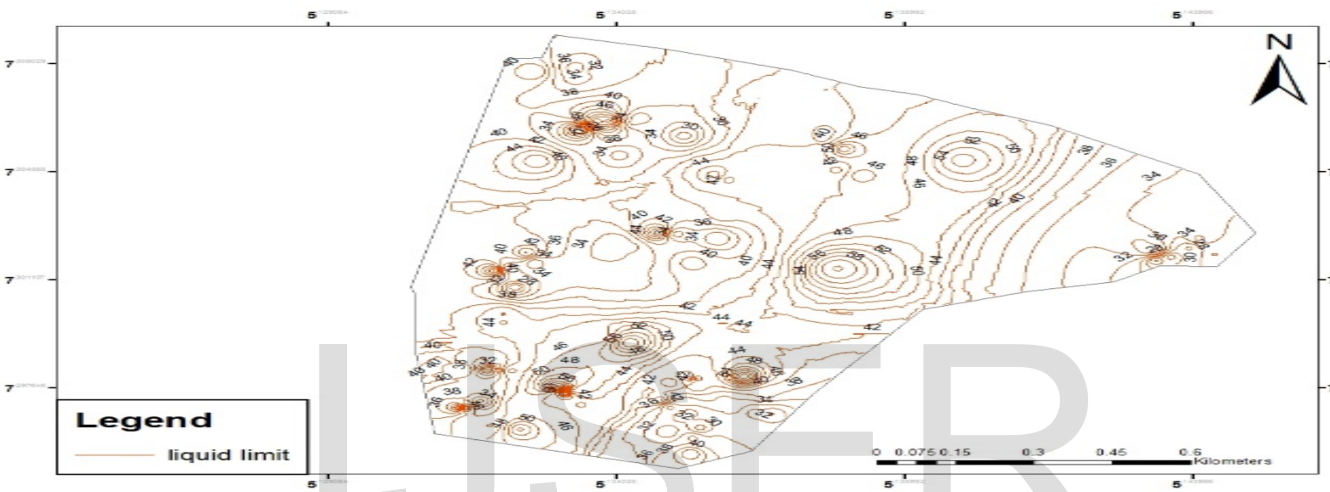

Plate 3: Liquid Limit Map

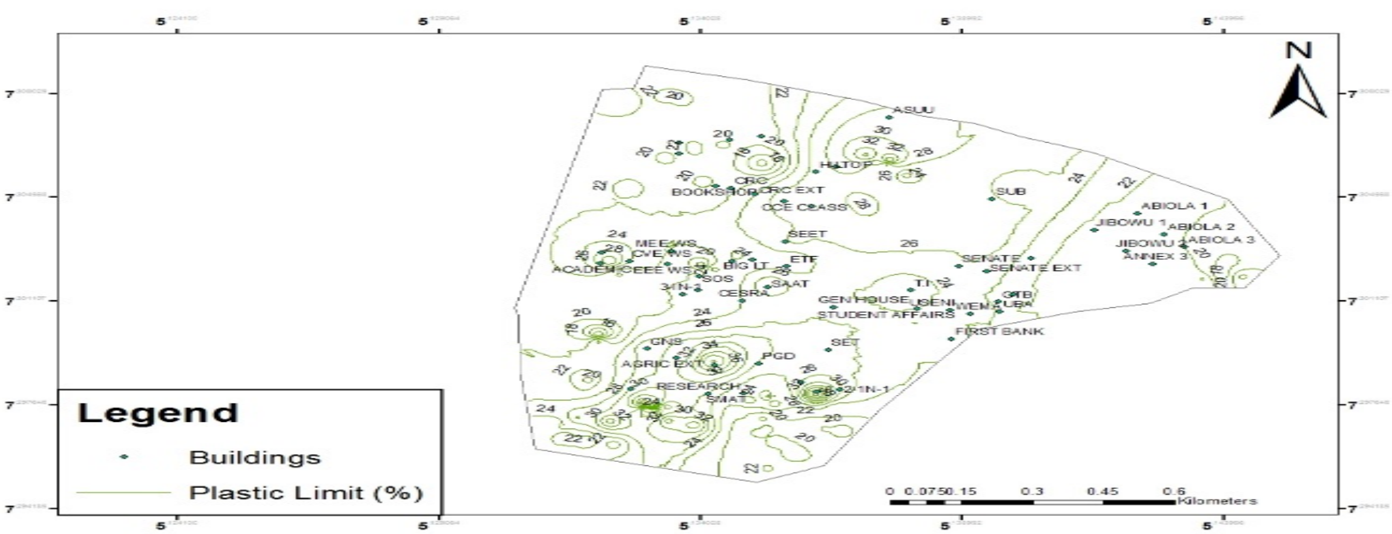

Plate 4: Plastic Limit Map

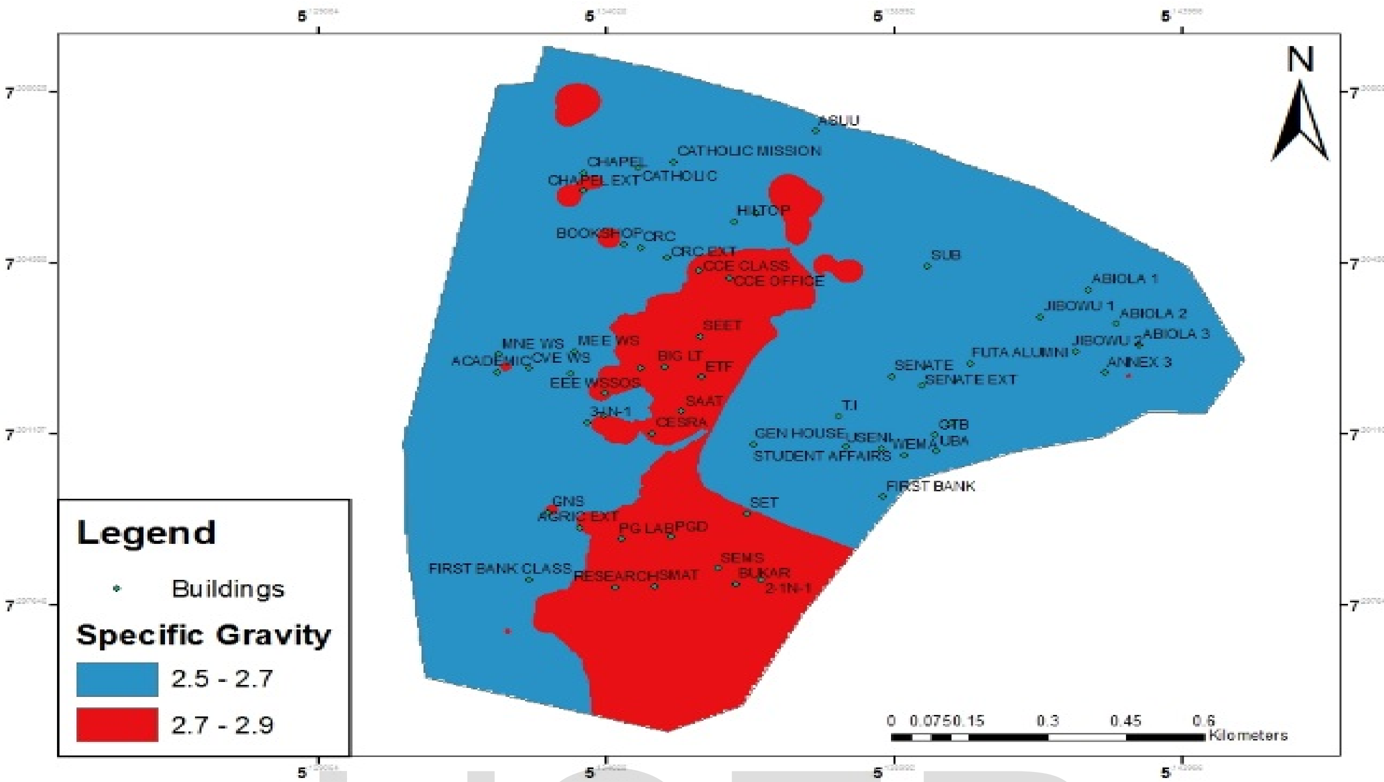

Plate 5: Specific Gravity Map

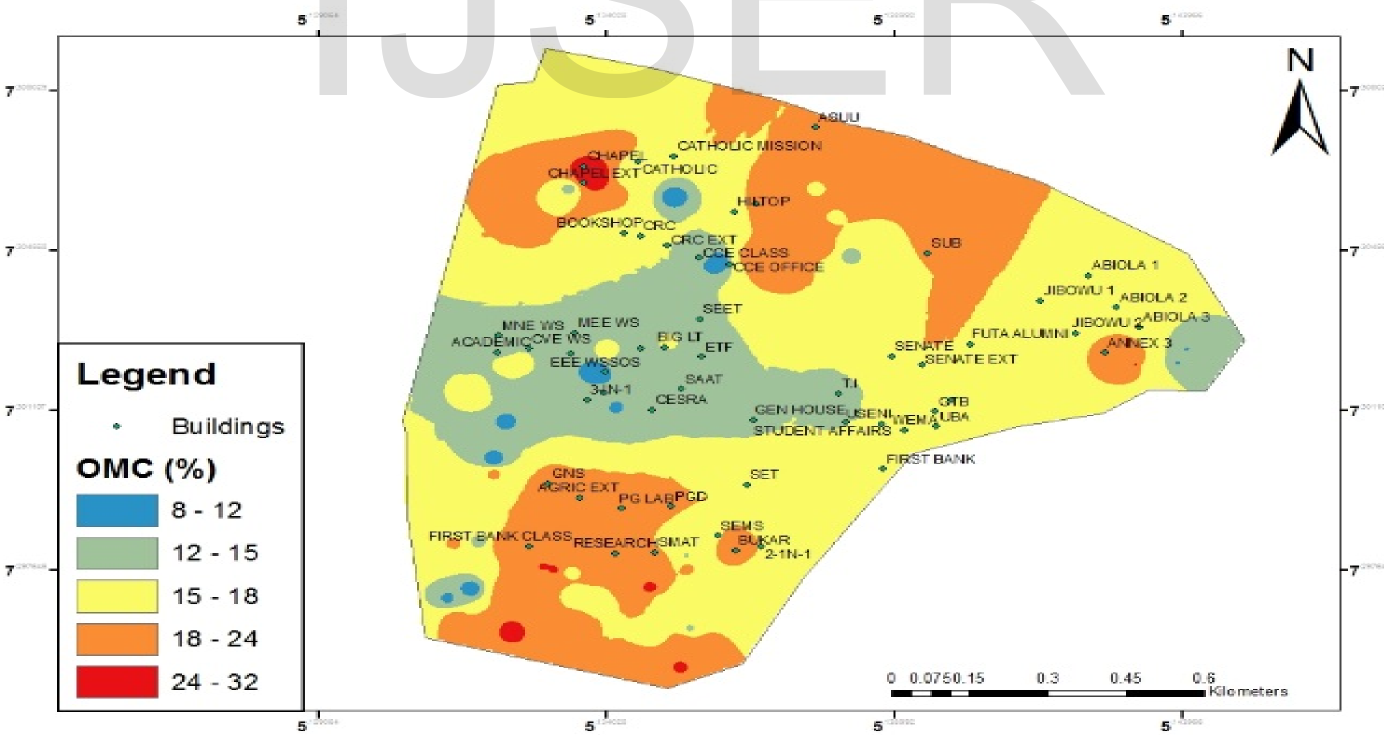

Plate 6: Optimum Moisture Content Map

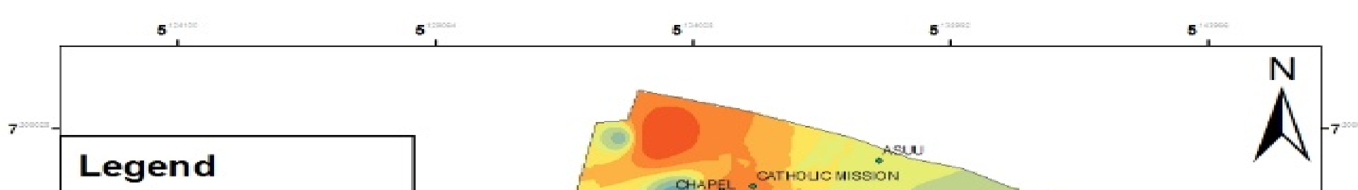

Plate 7: Maximum Dry Density Map

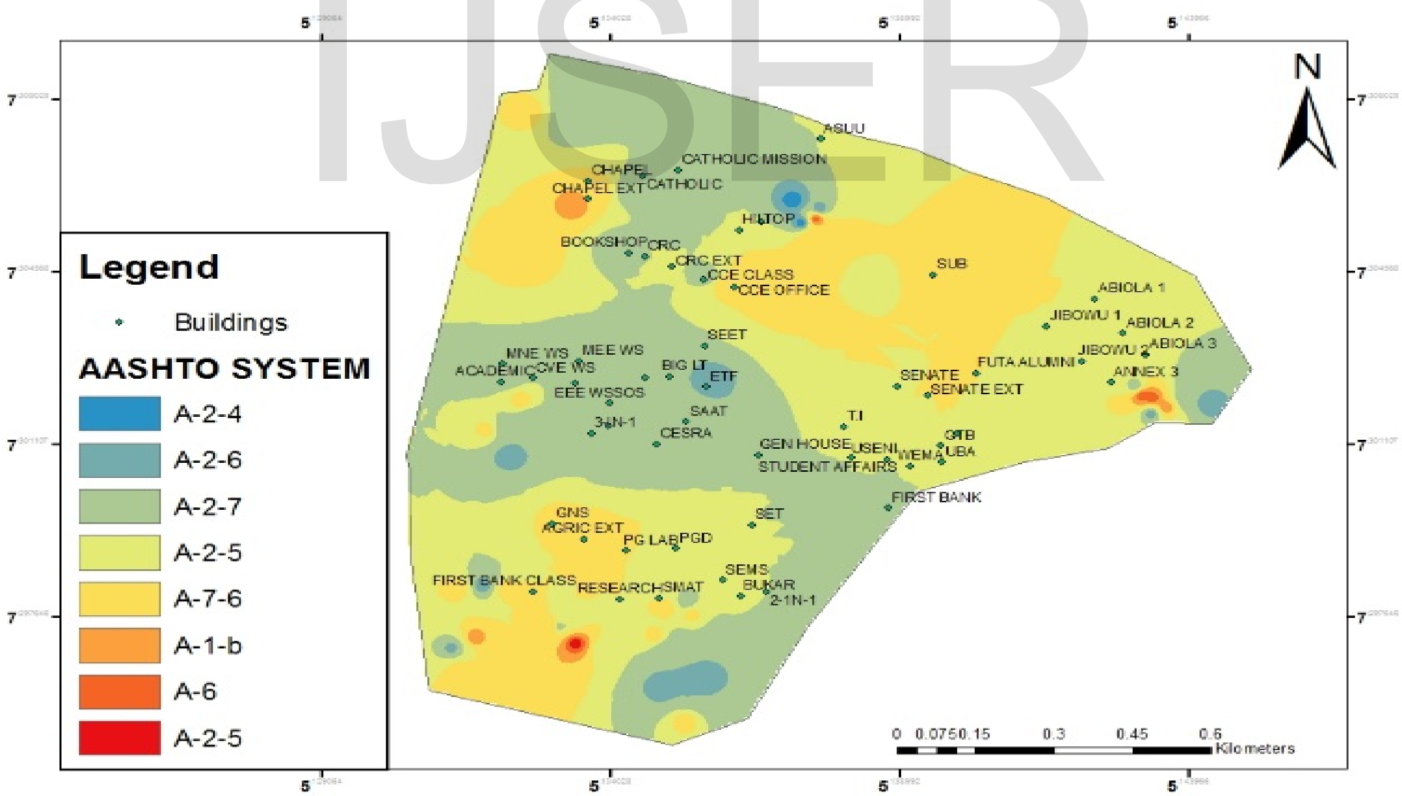

Plate 8: AASHTO Classification Map

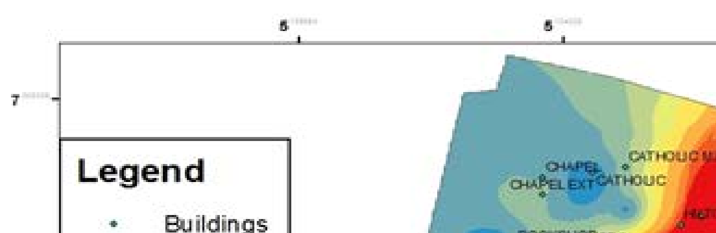

Plate 9: Unconfined Compressive Strength Map

5. CONCLUSION

From the study, the following conclusions were drawn:

i. The natural moisture content of soil with contour lines between 22 to 26% can be seen around ETF,CCE, CESRA, Academic building. Range between 1 to 16% can be seen around SEMS, Abiola 1, 2 and 3, Jibowu 1 and 2, while the highest natural moisture contour value, 28%, cut across PG laboratory, and CCE office.

ii. The liquid limit within the range of 23 to 38%, which is the most predominant, can be seen around Chapel, Bookshop, CRC, 3 in 1, EEE workshop, ETF, Big LT, MNE workshop,CVE workshop, Academic building, Abiola, Jibowu, First bank classes, and some portion behind SEMS building. On the other hand, the least range, 51 to 66%, can be seen around PG laboratory, Buka hall, T.I. auditorium, Useni, and student affairs.

iii. Plastic limit within the range of 13 to 21%, is the most predominant, and can be seen around the Abiola, Jibowu, Annex 1, 2 and 3, SEMS building, Chapel, Catholic, Bookshop, CRC, EEE workshop. While the least occurring range from 30 to 39% can be seen around PGD, Buka hall and Hilltop.Plasticity index within the range of 1 to 16 % is the most dominating range, and it can be seen around Abiola, Jibowu, Annex 1 & 2, 3 in 1, CESRA, SAAT, SEET, EEE workshop, SEMS, Catholic, Chapel, Bookshop, CCE hall. While the least plasticity index ranges between 29 to 43%, can be seen around.

iv. The most predominant specific gravity range of soil is within 2.5 to 2.7. And this can be seen around Abiola 1,2&3, Jibowu 1&2, Senate, Chapel, Catholic, CRC, Hilltop, First bank class, MNE workshop, CVE workshop, SUB, WEMA, Student Affairs, Useni. Whereas, Specific gravity within the range of 2.7 to 2.9 can be seen around, SEET, ETF, CESRA, SEMS, SET, PGD, PG laboratory, Buka hall, 2 in 1, CCE, CCE office, Bookshop.

v. Optimum moisture content within the range of 15 to 18 % is the most predominant and it can be seen around SET, First Bank, Senate, Senate extension, FUTA alumni, Jibowu 1, 2 and 3, Catholic mission, CRC, Bookshop, Big LT. on the other hand, the least occurring range is 24 to 32%, and can be seen at Chapel , Chapel extension.Maximum dry density within the range of 1869 to 1965 kg/m3 is the most predominant and can be seen around CESRA, SAAT, ETF, SEET, Academic building, MEE workshop, and Gen house. However, places around Annex 3, Chapel, First bank, and SUB have the least occurring range within 1373 to 1530 kg/m3.

vi. The categories of soil available in study region are: A-2-4, A-2-6, A-2-7, A-2-5, A-1-b, A-1-a, and A-6. The A-2-7 which is most widely spread class can be seen around First bank, Catholic Mission , Chapel, Bookshop, CESRA, SAAT, SEET, MEE workshop, 3 in 1, Big LT, CVE workshop, Student Affairs and Gen house.

vii. The most predominant range of UCS is from 320 to 341 kN/m2,and can be seen around Hilltop, CCE class, CCE office, Buka hall, 2 in 1, PG laboratory, Agric extension, while the least range is between 100 to

140KN/m2, and it covers areas which lies along FUTA alumni building.

6. RECOMMENDATION

On the basis of this research, the following essential points are recommended for future implementations:

Database containing all geotechnical data from soil laboratories should be established within the school.

Global Positioning Systems (GPS) should be used in taking coordinates of samples, as this would help in properly locating the points where samples has been taken.

I. GIS technology should be implemented in all ministries, Institutions, and Companies which deal with a huge quantity of geotechnical data.
II. GIS training should be integrated into the syllabus of undergraduate students especially the engineering and environmental students as this will help the public to have easy access to data.
III. Government should join hands with professional bodies, so as to enhance research which will make geotechnical data readily available and accessible.

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