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2D Resistivity Imaging and Geotechnical Investigation of Structural Collapsed Lecture Theatre in Adekunle Ajasin University, Akungba-Akoko, Southwestern, Nigeria

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Geotechnical and geophysical investigation involving electrical resistivity survey and laboratory test of the samples were conducted on the samples obtained at the three different locations in the area. The study is aimed at evaluating the competence of the near surface formation building construction materials. Geophysical and geotechnical methods of investigation were adopted. The Electrical Resistivity Tomography, using Dipole-Dipole configuration and soil analysis techniques were adopted. A total of four traverses and three soil samples from different location within the study area were used for the study.

The geophysical results revealed that the topsoil is within the depth of 0 to 5m and it is reflective of varying resistivity which indicates materials suspected to be composed of low resistive materials such as water and underlain with a basement complex and presence of a very low resistivity in which water accumulate and percolate which makes it inimical to foundation of engineering structures. There is an evident of geological feature such as fracture within the bedrock which might aid subsidence in the area. while geotechnical results of natural moisture content, specific gravity, liquid limits, plastic limit, plasticity index, linear shrinkage, compaction and permeability ranges from 5.3-9.2%, 2.620-2.730, 23.0-41.9%, not plastic to 21.4%, from not plastic to 22.4%, 1.4-9.3,1790-2114 kg/m^3, 9.1-9.9 and very low to medium respectively. Thus, the soil formation in the study area is therefore rated as relatively poor for foundation material.

Key words: *geotechnical, dipole-dipole, sub-grade, basement complex, engineering structures*

1. Introduction

Electrical resistivity tomography and geotechnical method have been important for environmental and engineering site delineation, and routinely applied for structural failures (Dahlin and Loke, 1998; Olayinka, 1999). The characterization of engineered structural geology, hydrogeology and geotectonics have greatly improved in recent times (Aizebeokhai et.al., 2010, Binley et.al, 2002).

Subsurface instabilities and foundation failures assessment is now a great concern to engineers and geoscientists all around the world. A well-constructed building on a good foundation may fail if subjected to an extraordinary load, for example, a building originally designed for residential purpose and converted to a factory, Mesida, (1987). They live load which is the sum of the weight of machines, furniture's, products and the effect of vibration of these machines will be greater than the initial live load before the conversion of the building to factory (Ranjan and Roa, 2000).

Instances of continuity or preponderance of mobile structures or structures or structural cracks, monitoring and repairs of building are routinely recommended (Donald and Cohen, 1998). Tomlingson et.al, 1978 classified the extent of wall cracking ranging from negligible hairline 0.1-1mm to the very sever cracks (>25mm) which demands partial, major or complete rebuilding.

Most importantly, the geophysicists, engineering geologists have placed the cause the foundation mobility on the competence of the soil which can support the loads of structures (Sands, 2006). Though some fractured rocks carry loads, most foundation-based structural failure are the weak zones of a

fracture rocks. In the same vein geological factors are also important causes of building failure. The geological structures (or near–surface linear features) lateral or lithological heterogeneity and incompetence of sub-surface or surface formation supporting super structure and thinning out of facies lead to collapse of building. If a building is found on any of these geological structures, it may not be able to resist shear failures. Similarly, construction of a building on a chemically active rock for example carbonate rocks (such as limestone and Marble) may cause a building to fail

Swelling and shrinkage of clays are due to climatic factors which alters the soil moisture. Shrinkage of clays leads to subsidence to ground surface, thus causing a colossal damage of superstructure. Biological factors like tree planting and subsequent removal around existing structure reduce soil water content especially when clays are removed.

Figure 1 shows a sample of lecture theatre where 2D dipole-dipole and geotechnical survey were carried at Adekunle Ajasin University, Akungba-akoko lecture theatre to investigate the geophysical, geotechnical and engineering characterization of the subsurface.

Fig. 1. Sample of affected building structure from the area

2. Site description and geology

The study area lies within latitude 7^0 28 85'N - $7^0$28 86'N and longitude 005 44 46'E - 005 44 48' E in Adekunle Ajasin University, Akungba-akoko. Figure 2 and three show both the geological map of Ondo state and Akungba-akoko respectively in the figure below. The study area is characterized by dendritic drainage pattern. It is observed that some of the rivers and their tributary streams in the study area trend east of North while other trend West of North. These trends are influenced by topography and the joint system. Its climate is predominantly rainforest characterized by two seasons-the wet season (between April-October) and the dry season (between October-March) with a mean annual rainfall of 1250 mm and a temperature range of 18 to 33°C. The topography is generally undulating with Eastward highlands of granitic origin. The study area lies within the basement complex of the South-Western Nigeria. The study area is characterized by Precambrian Basement rocks such as: grey gneiss, quartzo-feldspathic gneiss, charnockite; granite gneiss; and porphyritic gneiss and they are believed to have evolved in at least four orogenic events namely: the Pan African (600±150 My), The Kibaran (1100±200 My), The Eburnean (2000±My) and the Liberian (2800±200 My). The Migmatite- gneiss complex dominate the basement complex in the study area composed of fairly uniform biotite and biotite – hornblende-gneiss with locally intercalated bands of aplitic quartz veins (Ajibade et.al, 1989).

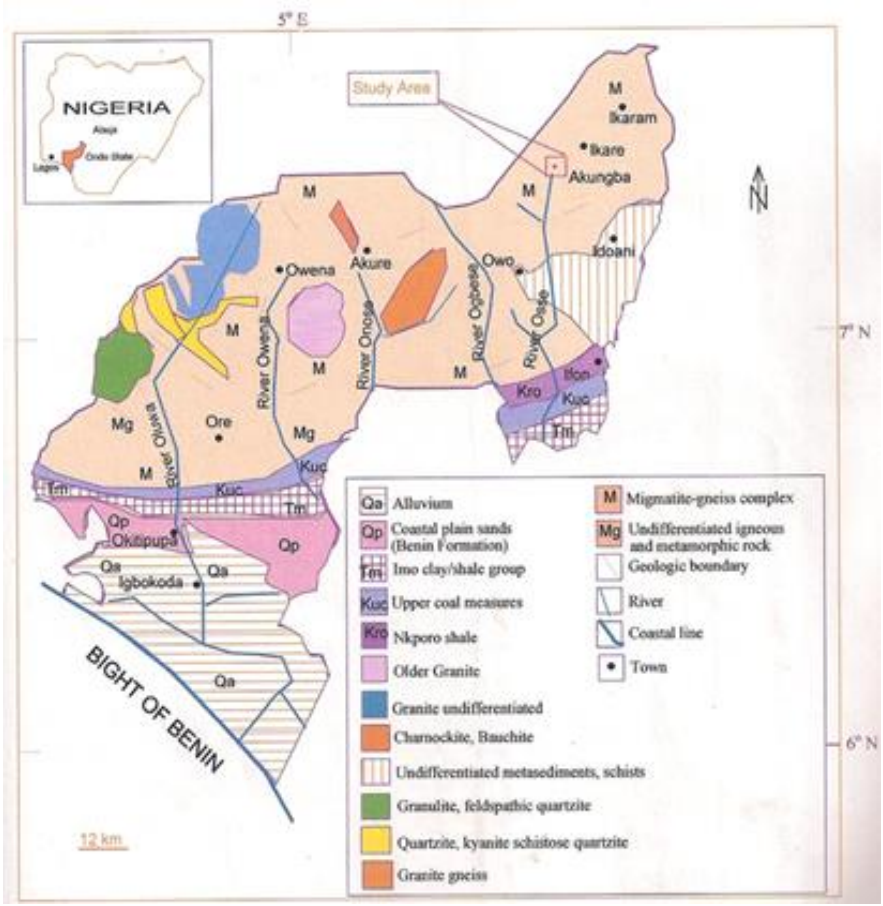

Fig. 2. Geological Map of Ondo State showing the study Area

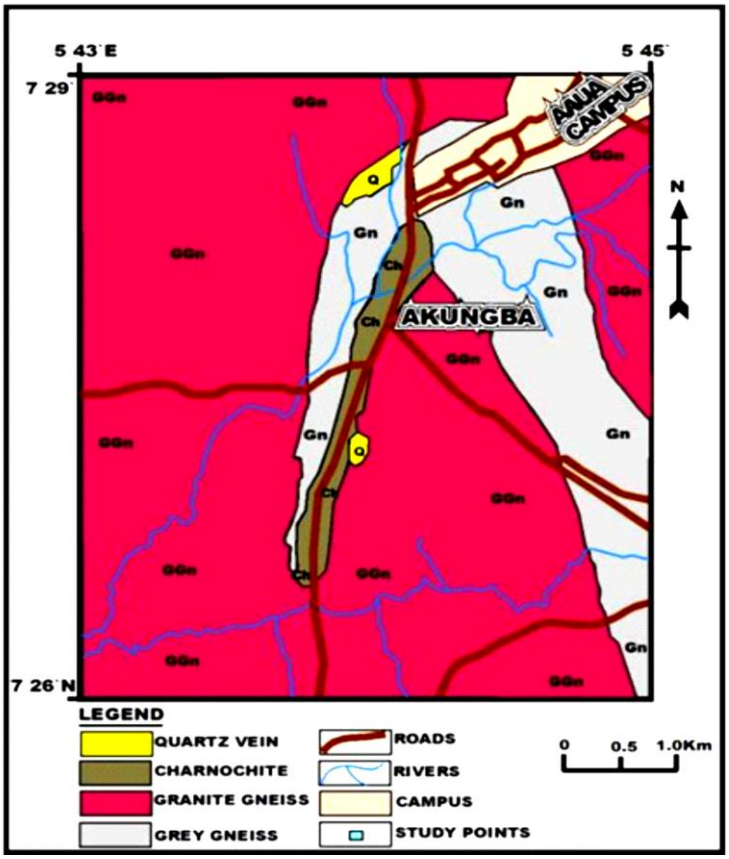

Fig. 3. Showing geological map of the study area. Modified after independent field mapping Akungba group, 2012

3. Material and methods

3.1. 2D Electrical resistivity imaging

The electrical resistivity (dipole-dipole array) method of geophysical survey was used in S – N and E-W direction in AAUA campus. Four traverses with inter- traverse separations of 50 m were mapped out The ABEM 1000 SAS Terameter Resistivity Meter was used in acquiring the electrical resistivity data using the dipole-dipole configuration. The equipment is capable of measuring apparent resistivity with induced polarization (IP) or self -potential (SP) at the same time, though with increase data acquisition time. The dipole-dipole data were acquired at an electrode spacing of 5 m on all the traverses with an expansion factor 'n' ranging from 1 – 5 and applying 2-D inversion software to generate current density sections and the dipole-dipole pseudosections. The data is inverted from apparent resistivity through "true" resistivity by Earth-Imager software "Diprowin software". The goal is to create an image of the ground in terms of electrical resistivity showing both the lateral and depth extent of area of investigation. The resistivities of the blocks were iterated and adjusted until the calculated and field apparent resistivities agreed to barest minimum differences (Loke et.al , 2003).

The Pseudo section obtained from DIPROWIN SOFTWARE using Jacobian iteration is presented below. The differences of the eight iterations done; were expressed in percentage as root-mean-square error (RMS error), which ranges from 5.43 to 7.87 for the present work.

3.2. Engineering Laboratory Characterization

3.2.1. Index properties (classification) test

Classification tests were carried out on all the representative soil samples includes; grain size distribution analysis, wet sieving, drying sieving and the experimental procedure.

The natural moisture content was performed to determine the water (moisture) content of soils and is expressed in percentage. The apparatus are: drying oven, balance, Moisture can, Gloves, Spatula.

About 100 g of each of the soil sample was preserved in a cellophene bag immediately after collection and then transfer to the laboratory to be weighed in the weighing balance in order to minimize loss of moisture through evaporation. The weighed sample was placed in a thermostatically controlled oven at a constant temperature of 105 ^{0}C for 24 hours. This was removed and allowed to cool. It is necessary for the dried soil sample to cool before weighing to accuracy of 0.1 because the hot container can impair the sensitivity of the balance by irregular expansion.

The natural moisture content of the soil sample was calculated using the formula:

$$\mathrm{Mc} = \frac{W_2 - W_3}{(W_3 - W_1)} \mathrm{x}100 \qquad (1)$$

Where: W_1 - Weight of empty container, g;
W_2 - Weight of container with moist soil, g;
W_3 - Weight of container dried soil, g;
M_c - Water moisture content, %.

3.2.2. Grain size analysis

I classified the soil sample by size of the individual particles. This test is important in order to determine the percentage of the various grain sizes contained in the soil.

The stages involved in grain size determination are:

(a) Sieve analysis (Mechanical) coarse grain soil.
(b) Hydrometer analysis of fine soil.

Coarse-grained soils behave in nature as individual particles. They are subdivided into gravel and sand. Gravel soils have particles sizes coarser (larger) than about the no 4 or no 10 mesh sieve opening, depending upon which particular classification system is used. Sand have particle sizes finer than gravel (no 4 or no 10 mesh) and coarser than no 200 mesh sieve, Coarser sand particles pass through the no 4 sieve and are retained on the no 10 mesh sieve. Medium sand has a particle size that is smaller than the no 10mesh sieve and larger than the no 40 mesh. Fine sand has particle in the no. 40 to the no. 200 mesh size.

Fine grained soils largely behave as a mass and not as individual particles. Their particles sizes can be divided, however, into silt and clay. Silt is smaller than the no 200 mesh (75 μm) but larger than 2 μm. The mechanical weathering of rocks derives silts. Clay particles are smaller than 2 μm in size. Chemical weathering of rock minerals (Stephension, 2004) develop them. For the purpose of this geotechnical "investigation, wet sieve analysis and sedimentation analysis were carried out.

The apparatus used are: set of sieves, weighing balance, a thermometer, sieve shakers, control cylinder, Beaker, cleaning brush, mixer (blender), 152H Hydrometer sedimentary cylinder, Timing device.

About 500 g of each air-dried soil was soaked in distilled water for about 24hours. The soil sample was thoroughly washed in a tap of water, a little at a time through 2mm sieve nested in a 63 um sieve until the water passing through the sieve was nearly clear. The soil material passing through the sieve was collected in a container and left undisturbed for about 20minutes for the silt and clay particles to settle down. The cleared water was drained.

Finally, fractions coarse than 63 um and fractions finer than the 63 um were oven dried for about 24 hours in over maintained at 105^{0}C and later subjected to sieve analysis and hydrometer analysis respectively.

3.2.3. Hydrometer analysis

The fine soil from the bottom pan of the sieve was placed into a beaker, 125 ml of dispersing agent (sodium hexametaphosphate (40 g/L)) solution. The

mixture was stirred until the soil became thoroughly wet and soaked for at least 10minutes.While soaking 125 mL of dispersing agent were added into the control cylinder and filled with distilled water to the mark. The reading at the top of the meniscus formed by the hydrometer stem and the control solution were recorded, a reading less than zero was recorded as a negative (-) correction and a reading between zero and sixty were recorded as a positive (+) correction. This reading is called the zero correction. The control cylinder was shaked in such a way that the contents are mixed thoroughly. The hydrometer and thermometer were inserted into the control cylinder, the zero correction and temperature were noted.

The soil slurry was transferred into a mixer by adding more distilled water, until the mixing cup is half filled and the solution was mixed for a period of 2minutes, the open end of the cylinder was covered with a stopper and secured with the palm, the cylinder was turned upside down and back upright for a period of one minute. The cylinder was set and the times taken were recorded, the stopper was removed from the cylinder. After an elapsed time of one minute and forty seconds, the hydrometer was inserted slowly and carefully for the first reading. The reading was taken by observing the top of the meniscus formed by the suspension and the hydrometer stem, the hydrometer was removed slowly and placed back into the control cylinder. The hydrometer readings were taking after an elapsed time of 2 and 5, 8, 15, 30, 60 minutes and 24hours.

The temperature at each interval was also noted.

Based on the total weight of sample taken and the weight of soil retained on each sieve, the percentage of the total weight of soil passing through each sieve (termed percent finer than) can be calculated shown below.

$$\% \text{ Retained on Sieve} = \frac{\text{weight of soil reatained on that sieve}}{\text{Total weight of soil taken}} \text{ x } 100 \quad (2)$$

Cumulative percentage retained = Sum of percentage retained on all sieves of larger sizes and the percentage retained on that particular sieves.

Percentage finer than sieve under reference = 100 % - cumulative percentage retained.

3.2.4. Specific gravity determination

To determine the specific gravity of soil, I used a pycnometer, vacuum pump, weighting balance, mortar and pestle, funnel, stirrer and spoon.

The weight of an empty and dry pycnometer, W_1 was determine and recorded. About 100 g of an air-dried soil sample was put in the pycnometer.

The weight of pycnometer containing the dry soil, W_2 was determined and recorded. Distilled water was added to fill about half of the pycnometer, and then the pyncometer was shaked properly and stirred before cover to make the soil sample reach saturation thereby dislaysing the entrapped air. The pyncometer was filled with distilled water to make covers and re-filled again. The exterior surface of the pyncometer was clean with a dry cloth. The weight of the pyncometer and the contained distilled water, W_4 was determined and recorded; finally, the pyncometer was emptied and clean.

The specific gravity of the soil sample can be calculated by using the formula below.

$$\text{Specific Gravity Gs} = \frac{(W_2 - W_1)}{(W_4 - W_1) - (W_3 - W_2)} \quad (3)$$

Where: W_0 - weight of sample of oven-dry soil, g;
W_1 - weight of empty pyncometer, g;
W_2 - weight of pycnometer + air dried, g;
W_3 - weight of the pycnometer filled + air dried soil + water, g;
W_4 - weight of pycnometer + water, g;
G_s - Specific gravity, g.

3.2.5. Liquid limit determination

Liquid limit device, porcelain dish, six moisture cans, balance, glass plate, spatula, drying oven set at 105 ^{0}C.

I took a sample of soil of sufficient size to give a test specimen weighing at least 300 g that passes 425 μm test sieve. Afterwards, the sample was thoroughly mixed on the glass using two spatulas, and if necessary, add distilled water to form a plastic material.

Place the paste into an airtight container, and leave it standing for a curing period of a 24 hours or overnight to allow water to permeate through the solid mass. For soil of low content, such as very silty soils, the curing period may be omitted.

Remove the soil from the container and remix with spatulas for at least 10 minutes. Some soils (heavy clay) up to 40 minutes. Fill the sample cup with the soil and trim off excess materials with the spatula to form a smooth oven surface being careful not to trap any air bubbles. Bring the point of the cone to the surface of the sample lower the dial gauge to the top of the cone and set the gauge on zero. Release the cone, pressing the release button for 5 seconds. Lower the pointer to the new position of the cone. Take a reading to the nearest 0.1 mm; it should be approximately 15 mm for the first test.

Lift out the cone and clear it carefully, add a little- more wet soil to the cup and take a second reading. If the second cone penetration differs from the first by less than 0.05 mm. The average is recorded, and moisture content is measured, if the second penetration is between 0.5 mm and 1 mm different from the first, a third test is carried out, and provided the oven drying range does not exceed 1mm, the average of the three penetrations was recorded and the moisture content is measured. If the overall range exceeds 1mm, the soil is removed from the cup and remixed and the test is repeated. Take a

sample of approximately 10g from the cup and determine its moisture content.

To the remainder of the material, add some distilled water and repeat the above procedure. This is done at least three more time to get a range of penetration value for about 15 mm to 25 mm.

The moisture contents determined one plotted against the respective penetration depth, both on a linear scale the liquid limit is defined as the moisture content where the cone penetrate 20 mm into the sample. The value is interpolated from a graph.

3.2.6. Plastic limit determination

Weighing balance, moisture content cans that are labeled, corrosion resistant suitable for repeated heating and cooling, having closed fitting lids to prevent the lost of moisture. One container is needed for each moisture content determination, glass plate, spatulas, wash bottle filled with distilled water and thermostically controlled dry oven, capable of maintaining temperature of 110 ± 5°C.

About 15g of air-dried soil passing through BS sieve 42 μm (no. 40) is taken for plastic limit determination and is mixed with a sufficient quantity of water which would enable the soil mass to become plastics enough to be easily shaped into a ball.

A portion of the ball is taken and rolled on a glass plate with the plain of the palm of the hand into a thread of uniform diameter throughout its length. The process of making the thread and remolding is continued until the thread at the diameter of 3 mm, just start crumbling. Some of the crumbed portion of the thread is kept in the oven for water content determination.

The test is repeated twice with fresh samples. The average of the three values of water content is taking as the plastic limits.

3.2.7. Linear shrinkage determination

The apparatus used are: Spatula, a flat glass plate, a mould made of brass, silica grease or petroleum jelly (Vaseline), a drying oven capable of maintaining temperature 105 ± 5^{O}c and a means of measuring a length, such as an engineer's steel rule.

Clean the mould thoroughly and apply a thin film of silica or petroleum jelly to its inner faces to prevent the soil adhering to the mould. Place a sample of about 150 g from the material passing through the 425 μm test sieve on the flat glass or in the evaporating dish. Alternatively, take a sample of natural soil from which coarse particle have been removed and thoroughly mix it with distilled water in the dish to make a readily workable paste.

Add distilled water and mix thoroughly using the spatula until mass becomes a smooth homogeneous paste with a moisture content at about the liquid limit of the soil, Place the soil/water mixture in the mould such that it is slightly proud of the slide of the mould. Gently jar the mould to remove any air pocked in the mixture.

Level the soil along the top mud with the spatula and remove all soil adhering to the rim of the mould by wiping with a damp cloth. The original length of the specimen is taken.

Place the mould where the soil/water can air dry slowly in a position free from draught until the soil had shrink away from the wall of the mould. Then complete the drying, first at the temperature not exceeding 65^{o}C until shrinkage has largely ceased and then at 105^{o}C to 110^{o}C to complete the drying. Cool the mould and soil and measure the mean length of the soil bar. If the specimen has become cured during drying, remove it carefully from the mould, measure the length at the top, and bottom surface. The mean of the two lengths shall be taken as the length of the oven- dried specimen

The linear shrinkage of a soil can be expressed as the percentage of the original length of the specimen Lo (in mm), from the equation.

$$\text{Percentage of linear shrinkage} = \frac{(1-\text{Lf})}{\text{Lo}}\text{x}100\% \qquad (4)$$

Where Lf is the length of the oven dry specimen in mm.

3.2.8. Compaction test

I stabilized the soil sample by following the standard protocols with this apparatus: Standard sieve,a cylindrical metal mould, an authomatic compactor, a steel rod spatula, a weighing balance, dial gauge, metal stem and perforated plate.

Depending on the type of mold you are using obtain a sufficient quantity of air-dried soil in large mixing pan. For the 4-inch mold take approximately 10 lbs, and for the 6-inch mold take roughly 15lbs. pulverize the soil and run it through the # 4 sieve.

Determine the weight of the soil sample as well as the weight of the compactions mold with its base (without the collar) by using the balance and record the weights. Compute the amount of initial water to add by the following method:

(a) Assume water content for the first test to be 8%.
(b) Compute water to add from the following equation:

Water to add (in ml) = soil massing grams 8

Where "water to add" and the "soil mass" are in grams. Remember that a gram of water is equal to approximately one millilitre of water.

Measure out the water, add it to the soil, and then mix it thoroughly into the soil using the trowel until the soil gets a uniform colour. Assemble the compaction mold to the base, place some soil in the mold and compact the soil in the number of equal layers specified by the type of compaction method employed. The number of drops of the rammer per layer is also dependent upon the type of mold used.

3.2.9. Permeability Test

I used the following apparatus in determining the permeability of the sandy soil: Permeameter, Tamper, Balance, Scoop, 1000 mL Graduated cylinders, Watch (or Stopwatch), Thermometer, Filter paper.

The standard procedure adopted were the measurement of the initial mass of the pan along with the dry soil (M1), then I removed the cap and upper chamber of the permeameter by unscrewing the knurled cap nuts and lifting them off the tie rods.

Measure the inside diameter of upper and lower chambers. Calculate the average inside diameter of the permeameter (D). Place one porous stone on the inner support ring in the base of the chamber then place a filter paper on top of the porous stone. Mix the soil with a sufficient quantity of distilled water to prevent the Segregation of particle sizes during placement into the permeameter. Enough water should be added so that the mixture may flow freely. Using a scoop, pour the prepared soil into the lower chamber using a circular motion to fill it to a depth of 1.5 cm. A uniform layer should be formed.

Use the tamping device to compact the layer of soil. Use approximately ten rams of the tamper per layer and provide uniform coverage of the soil surface. Repeat the compaction procedure until the soil is within 2cm of the top of the lower chamber section. Replace the upper chamber section, and don't forget the rubber gasket that goes between the chamber sections. Be careful not to disturb the soil that has already been compacted. Continue the placement operation until the level of the soil is about 2cm below the rim of the upper chamber. Level the top surface of the soil and place a filter paper and then the upper porous stone on it. Place the compression spring on the porous stone and replace the chamber cap and its sealing gasket. Secure the cap firmly with the Cap nuts.

Measure the sample length at four locations around the circumference of the permeameter and compute the average length. Record it as the sample length. Keep the pan with remaining soil in the drying oven.

Adjust the level of the funnel to allow the constant water level in it to remain a few inches above the top of the soil.Connect the flexible tube from the tail of the funnel to the bottom outlet of the permeameter and keep the valves on the top of the permeameter open. Place tubing from the top outlet to the sink to collect any water that may come out. Open the bottom valve and allow the water to flow into the permeameter. As soon as the water begins to flow out of the top control valve, close the control valve, letting water flow out of the outlet for some time.

Close the bottom outlet valve and disconnect the tubing at the bottom. Connect the funnel tubing to the top side port open the bottom outlet valve and raise the funnel to a convenient height to get a reasonable steady flow of water.

Allow adequate time for the flow pattern to stabilize. Measure the time it takes to fill a volume of 750-1000 mL using the graduated cylinder, and then measure the temperature of the water.

Repeat this process three times and compute the average time, average volume and average temperature. Record the values, measure the vertical distance between the funnel head level and the Chamber outflow level, and record the distance.

Calculate the permeability, using the following equation:

$$KT = \frac{QL}{Ath} \quad (5)$$

Where: KT - coefficient of permeability at temperature T, cm/sec;
L - length of specimen in centimeters;
t - time for discharge in seconds, sec;
Q - volume of discharge in cm^3 (assume 1 mL = 1 cm^3);
A - cross-sectional area of permeameter ($\pi/4D^2$);
D - inside diameter of the permeameter;
h - hydraulic head difference across length L, in between the constant funnel head level and the chamber overflow level.

4. Results and discussion

4.1. Geotechnical Results

The results of the laboratory tests includes: natural moisture content, specific gravity, grain size analysis, permeability, compression test, Atterberg limits and compaction test are presented in the tables below.

Table 1. Result of natural moisture content analysis, specific gravity, index properties and linear shrinkage of the soil samples

Parameter	Location 1	Location 2	Location 3
Natural moisture content (%)	5.3	9.2	6.2
Specific gravity	2.62	2.73	2.64
Liquid limit (%)	27.8	41.9	23.0
Plastic limit (%)	21.4	19.5	NP
Plastic index	6.4	22.4	NP
Original length, Lo, mm	140	140	140
Final length, Lf (mm)	136	127	138
Linear shrinkage $(1 - (L_f\text{-}L_o)) \times 100)$	2.9	9.3	1.4
Shrinkage limit	13.4	9.1	14.4

NP = non-plastic

The Natural Moisture Content: of the tested soil ranges from 5.3% to 9.2%. This shows that the natural moisture content of the soil in the study area is relatively low at its natural state. Due to poor drainage system detected, the soil can be generally rated as fair to poor sub-grade foundation materials.

Specific Gravity: Results show that the values of specific gravity of the soil samples ranges from

2.620 and 2.730. Therefore, the failed building in the study area is due to poor drainage network.

Atterberg Limits: As shown in Table1, the Liquid Limit of the soil samples ranges from 23.0-41.7%. The Plastic Limit ranges from not plastic-21.4%, and the corresponding Plasticity Index ranges from not- plastic 22.4%. The tested soil samples are of medium consistency limits indicating low percentage of clay content in the soil. Generally, soils having high values of liquid and plastic limits are considered poor as foundation materials. The plasticity index of sample no 1 & 3 is lower than 20% maximum which Federal Ministry of Works and Housing (FMWH) (1972) recommended, hence it shows a poor engineering property since the higher the plastic index of a soil, the lesser the competency of the soil as a foundation material. While that of sample no 2 is higher than the maximum value, therefore it is less competence as a good foundation material. Table 1: The index properties of the soil samples

The linear shrinkage: value of the tested soils ranges from 1.4-9.3% (Table 1). Brink, (1992) suggested that soils with linear shrinkage less or higher than 8% would not be good as foundation material. The linear shrinkage of sample no 1 & 3 is less than 8% recommended, hence not good as foundation materials. While the linear shrinkage of sample no 2 is greater than 8%, hence the soils is likely to be subjective to swelling and shrinkage during alternate dry and wet seasons of the humid tropical climatic condition of the south western Nigeria. This must be taken into cognizance in the design of the foundation.

The maximum dry density (MDD) and optimum moisture content (OMC) of the soils ranges between 1790-2124kg/m3 and 9.1-18.2% respectively. These values show that, the soils respond gradually to compaction. The importance of compaction is to improve the desirable load bearing properties of soil as a foundation material.

Table 2. Showing compaction test results

Sample Number	Compaction MDD (Kg/m^3)	Parameter OMC (%)
Location 1	2114	9.9
Location 2	1790	18.2
Location 3	2124	9.1

The degree of permeability of location one is low, this signifies that the drainage condition of the area is fair, while the degree of permeability of location two is very low, this signifies that the drainage condition is poor, and the degree of permeability of location three is medium, signifying fair drainage system in the area.

Table 3. Showing results for permeability test

Sample number	Permeability test	Degree of permeability
Location 1	8.0×10^{-5}	Low
Location 2	8.1×10^{-7}	Very low
Location 3	1.0×10^{-4}	Medium

Dipole-dipole pseudo-sections.

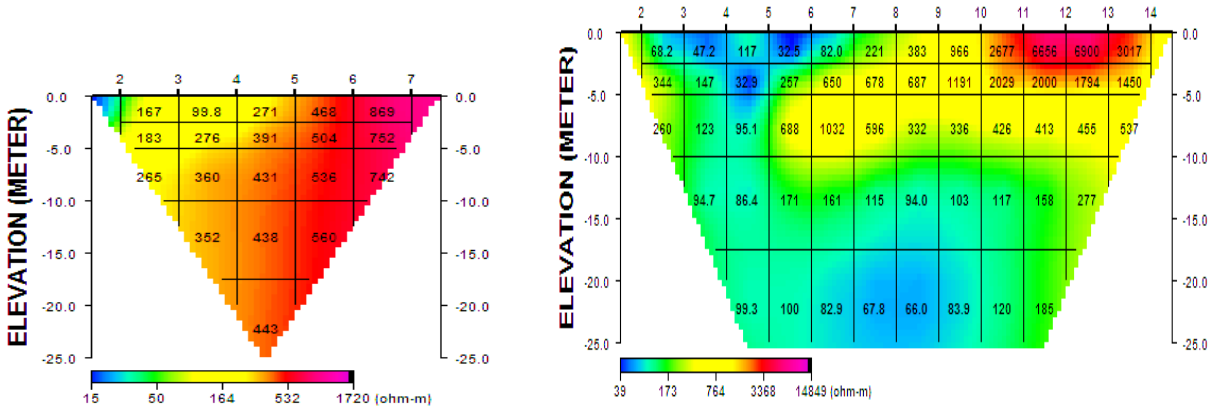

Fig. 3. Showing the Pseudosections of Traverse 1-2 in the study area

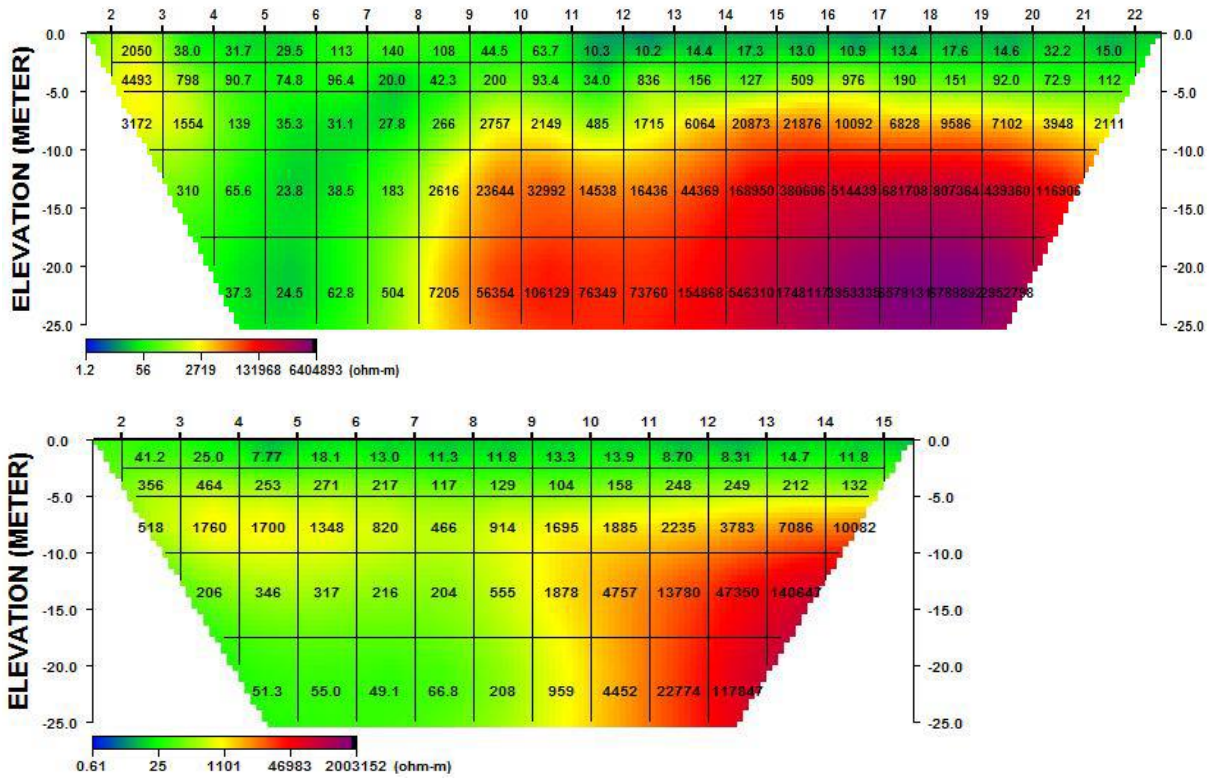

Fig. 4. Showing the Pseudosections of Traverse 2-4 in the study area

Traverse 1: The 2-D electrical resistivity section along traverse 1 is reflective of subsurface resistivity within the study area. From station 0 to 2 at a depth of 3m indicating very low resistivity, and between station 2 and 3 is of low to medium resistivity indicating a presence of a boulder and from station 5 to 7 to a depth of 25m is signifying a basement complex (hard rock). This layer is unfavourable for foundation of engineering structures.

Traverse 2: In the 2D electrical resistivity section along traverse 2, from station 0 to 8 at depth of 5m is signifying the presence of very low to low resistivity, between station 3 and station 5 is indicating the low resistivity area symbolizing the presence of water, there is a presence of a fracture creating a pathway for the water to percolate to the depot where Adekunle Ajasin spring water is extracted. While from station 10 to 14, to a depth of 3m is signifying the presence of a very hard rock (basement), between station 5 to 10 m along station 5 to 7 m is indicating a presence of a boulder and at the depth of 10 to 25 m along the stations, is indicating low resistive materials and finally at the depth of 17 to 25m along station 5 to 9 is indicating accumulation of water.

Traverse 3: there is a high resistivity value indicating the presence of a boulder between stations 2 and 3, and depth of 0.1 m to 10.5 m [yellow]. There is a relatively low resistivity value from stations 3 to 10 at the depth of 0.1 m to 5.0 m. From stations 11 to 22 where the collapsed fence is located at a depth of 0.1 m to 2.0 m, the resistivity value is very low, [blue], which indicates the presence of an anomaly, which is water, which passes through the fault path occurring between stations 7 to 8 at depth 4.5m through stations 6 and 7 at a depth of 5.0m and through stations 5 and 6 at depth of 5.5m to 25.0m. There is a fault occurring from stations 8 to 9 at depth of 5.5m through stations 7 to 5 down the depth. Resistivity values in station 6 to station 21 is very high and it occurs between the depth of 5.1 to and beyond 40.0m [purple section] with the resistivity values ranging from 1.748.117 to 6.404.893 ohm-m, indicating the presence of very hard rocks. And the [red section] indicates zones of high resistivity values ranging from 56.354 to 131.968 ohm m.

Traverse 4: There is a relatively low resistivity values from stations 1 to 16 at a depth of 0.1 m to 2.5 m also at depth 2.5 m to 5.0 m. The resistivity value between stations 4 and 5 is relatively low [blue] showing the presence of water, and also between stations 11 and 13. There is a slight increase in the resistivity values from stations 1 to 16 indicating the presence of rocks and a contact between the first layer and the second layer. There is a fault passing through stations 7 and 8 at a depth of 5.0m downwards due to the low resistivity values. There is an increase in the resistivity value indicating the presence of a hard rock [orange]. At stations 12 and 13 there is also an increase in the resistivity values indicating the presence of a harder rock occurring at a depth 10.5m to 15.6m [Red]. And in stations 12 to 16 the resistivity values there are the highest indicating the presence of very hard rocks [purple] the very hard rocks occurs between the depth of 20.0m to 25.0m at stations 12 and 13. In this traverse, station 1 to 5, is occupied with soils from the surface to a depth of 40.0m.It is observed between station 11 to 12, the compression of the soils present there which could

also be as a result of faulting of the hard rock present beneath.

5. Conclusion

The geotechnical investigation and the Geophysical surveying involving 2-D dipole-dipole imaging, was carried out at the study area. The 2-D dipole-dipole imaging, it was discovered that the top soil is within the depth of 0 to 5m, it was also discovered that resistivity values varies, with low resistivity values characterizing the presence of anomalies such as water and weathered layers. From these results it could also be presumed that the failed segments of the building under investigation are presumably underlined by very hard rock which is jointed/ faulted. This zone is characterized by very high resistivity values, which is typical of very hard rocks. The soils samples are generally of relatively low natural moisture content. It has relatively low clay content, which are generally less than 35% recommended. Plasticity characteristics of the soil samples reveal that the soil samples can be considered as poor, based on the comparison of their plasticity values with values specified by the Federal Ministry of Works and Housing [1974]. The linear shrinkage of the soil samples indicates poor, thereby has every tendency to exhibit compaction problem. Grain size distribution characteristics of the soil showed that the soil is poorly sorted. This property limits the aptness of the soil as building construction material. The compaction classification after Wood's system shows that the soil samples present in location two is poor for any engineering construction. Hence, the structural collapse of the Lecture Theatre is due to: excessive settlement of the soil materials on which it was founded and jointing/faulting of hard rocks leading to percolation and accumulation of water present in the subsurface upon which the structure was founded.

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Varža 2D formatu ir geotechniniai struktūrinių trūkių tyrimai Adekunlo Ajasin universitete, Nigerijoje

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Geotechniniai ir geofiziniai tyrimai, apimantys elektros varžos matavimus ir laboratorinius tyrimus, buvo atlikti su mėginiais, surinktais trijose skirtingose tiriamosios vietovės dalyse. Studijos pagrindinis tikslas buvo įvertinti paviršinių dirvožemio medžiagų savybes. Tyrimui buvo pritaikyta elektros varžos tomografija, naudojant „dipolis-dipolis“ konfigūraciją bei dirvožemio analizių technikas. Iš viso tyrime buvo naudojami keturi traverso ir trys dirvožemio mėginiai.

Geofizinių tyrimų metu buvo nustatyta, kad viršutiniame dirvos sluoksnyje (nuo 0 iki 5 m gylyje) yra kintanti varža, tai, tikėtina, rodo, kad šioje vietoje dirvožemį sudaro mažos varžos medžiagos, tokios kaip vanduo, kartu su labai nedidės varžos pamatiniu kompleksu, kuriame vanduo akumuliuojasi ir per kurį filtruojasi. Dėl to tokio tipo dirvožemio sluoksniai tampa pavojingi inžinerinių statinių pamatams. Kaip akivaizdus neigiamas bruožas, įtakojantis susiformavusį dirvožemio įdubimą, buvo pasirinktas geologinis reiškinys – lūžis pamatinėje uolienoje. Geotechniniai rezultatai parodė, kad natūralaus drėgmės kiekio, savitojo sunkio, skystumo ribų, plastiškumo ribų, plastiškumo rodiklio, linijinio išsėdimo, sutankinimo ir pralaidumo vertės kito intervaluose 5.3-9.2%, 2.620-2.730%, 23.0-41.9%, ne plastinis iki 21.4%, nuo ne plastinio iki 22.4%, 1.4-9.3,1790-2114 kg/m^3, 9.1-9.9 bei nuo labai nedidelės iki vidutinio dydžio varžos. Dėl to dirvožemį formuojančios medžiagos buvo nustatytos kaip santykinai prastos pamatinės medžiagos tiriamojoje teritorijoje.