Investigation of the "Soil" of Alluvia Tin-Columbite Mineralization Deposit of Gada-Biu, Plateau State

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Abstract

This research focused on the engineering properties of the soil under investigation in order to enhance the reduction of artisanal mining risk of Gada-Biu, Jos Plateau State. Several measures had been taken to investigate the properties of the soil in the study area using some selected parameters such as Proctor Compaction Test, Liquid-limit Test, Plastic-limit Test, Shrinkage-limit Test and Plastic Index Test. The tests revealed the following results; Moisture content (24.26), Specific gravity (2.31), moisture content during compaction (10.92), Liquid-limit (38.10), Plastic-limit (26.02) and shrinkage-limit (7.90). The results showed that when comparing with the standard values, the properties of the soil were suitable for the design and construction of structural foundation, the placement and improvement of soil properties and the specification and quality control of soil compaction work. In conclusion, the investigation of the soil in the study area provides the information about the engineering properties of the soil that would help the artisanal miners to know the types of support to be used and precautionary measures during mining.

Keywords

Soil, Alluvia Tin-Columbite, Mineralization Deposit, Gada-Biu

1. Introduction

Several research works have been conducted on mining, its effects as well as contributions to economic development of nations. Some highlighted the benefit of mining to economic development while others focused on the negative impacts of mining on the overall development of such economies. Economic mineral deposits are located in the earth - sometimes on the surface, near surface or at considerable depths below the earth surface [1]. These mineral deposits are mined at a profit for man use either by employing Surface or Underground mining methods depending on their depths of occurrence, mechanical properties of overburden, host rock, and the mineral itself. Shallow Ore deposits are extracted or mined by surface mining methods (open pit, open cast etc). Economic mineral deposits occurring at considerable depths are mined by employing underground mining methods, where these ore deposits are mechanically extracted and hauled or transported by shuttle cars or conveyors to the surface through the underground mine roadways and shafts. This is mostly the practice in Nigeria until the introduction of the indigenization Degree of 1982 which sent many foreign companies and their expertise out of Nigeria. This resulted in many mine workers being laid off by the companies they were working at, making some of them to resort to artisanal mining till date.

Artisanal Lotto mining is commonly practice in the exploitation of cassiterite, columbite, lead-zinc, precious stones etc., on the Plateau and other state within the country and other developing economic due to poverty [2].

"Lotto" mining is an unscientific method of mineral exploitation and extraction of mineral deposits mostly carried out by artisanal miners. It involves digging a cylindrical pit with average diameter of 1 to 10 meters (shaft) on the natural overburden until the cylindrical pit hits the mineralized zone (pay zone). At this point, rectangular horizontal pits are dug along the pay zone in different directions with cross-cuts at various intervals. Moreover, the artisanal miner does not use the personal protective equipment (PPE) and they lack the adequate geo-technical knowledge of the alluvial tin deposit on which they mined thereby, exposing them to high safety risk.

In 2018, it was recorded that more than 55 artisanal miners lost their lives as a result of caving at Gada Biyu tin field. In addition, between 2017 and 2018 over 530 dead where recorded and over 3600 various degree of casualties were also recorded from various mining sites across the state. The number might be even being far greater than what was recorded because there is no proper documentation of the activities of artisanal mining by the regulation bodies within Nigeria.

1.1 Aim and Objectives

Aim

The aim of this research work is to determine the soil's engineering properties in order to affirm the competency of the soil in the study area for proper engineering purposes so that the risk of artisanal mining in the study would be minimized.

Objectives

1.To determine soil formation strength using Proctor Compaction Testing Machine.
2.To study the formation engineering properties using a liquid-limit test, Plastic-limit test, Shrinkage limit test and Plastic index.

1.2 Justification

In order to justify the purpose of this research, the type of supporting system requires, would depend on the results of the analyses in order for small scale (artisanal mining) to take proper measure so that, the problem of formation caving and subsidence, would be reduces and hence optimum recovery of ore deposits would be achieved.

1.3 Statement of the Problem

Subsidence and caving are common phenomenon in small scale/artisanal mining; this is as a result of the absence of proper knowledge of the formation engineering properties and lack of supporting system.

1.4 Location, Extent and Accessibility

Location

The area is located around Kuru-Jantar(Gada biyu) and it forms part of Jos-Bukuru Complex and form part of Naraguta Sheet 168S.E covering an area extent of about 16km^2, the area lies between latitude of N9^0 41'30", N09^0 43' 30" and longitude E 08^0 51' 30" and E08^0 53' 30"in Plateau State.

The area falls within 1: 50, 000 topographic map of and it forms part of Naraguta Sheet 168 SE covering an area extent of about 16km^2. The area is accessible through trunk A Maraba-jama'a,-Heipang-Barkin ladi express way. This trunk A road passes in between the study area.
According to figure 1, it is showing the location map of the selected research area.

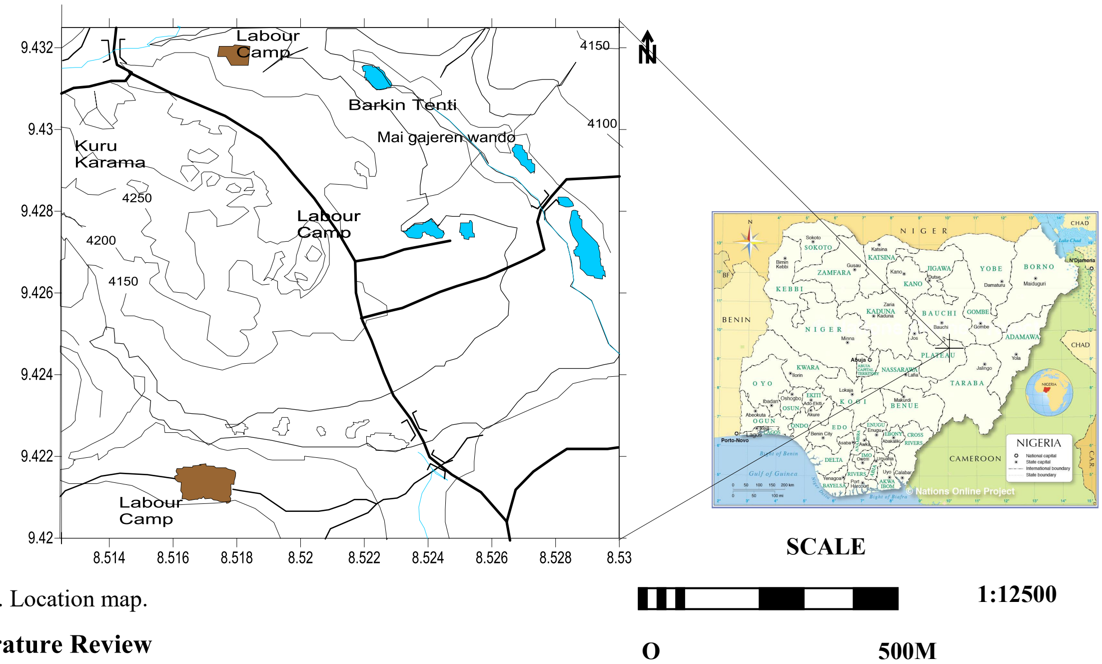

Figure1. Location map.

2. Literature Review
2.1 Introduction
Numerous studies on mining, its impacts, and its contributions to national economic development have been carried out. While some emphasized the positive effects of mining on economic growth, others concentrated on the detrimental effects of mining on these economies' overall development.

Soft clay soil can be classified as problematic soil, following a study conducted in Malaysia Pahang on the evaluation of basic soil parameters and shear strength of pekan soft clay [3]. The low strength and high compressibility characteristics the soil hard, are the major reasons why a careful design analysis could be taken for any structure built on it. These issues necessitate a soil analysis of the fundamental characteristics and shear strength of the soil.

The basic soil characteristics and shear strength of the Langgar and Pahang Tua soils, both of which are in Pekan, have been the subject of local engineering studies thanks to this soft clay study. Laboratory analysis of the soil samples was attempted. The soil at Langgar and Pahang Tua has a good chance of being classified as soft clay based on the results of the basic soil properties analysis. According to the American Association of State Highway and Transportation Officials' (AASTHO) standards, clay particles predominate in both the Langgar and Pahang Tua soil samples, with over 35% of them passing the No. 200 sieve-52 percent in Langgar and 57 percent in Pahang Tua.

The soil samples from Pahang Tua and Langgar had natural moisture contents of 48% and 57%, respectively, falling within the range of moisture content for soft clay soil. Langgar has a 51% liquid restriction and a 26% plastic limit for atterberg limit findings. For Pahang Tua, the liquid limit and plastic limit result are 58% and 27%. Both Langgar and Pahang Tua have been identified as clay with high plasticity based on the plasticity chart [4]. The findings of the shear strength test have unequivocally demonstrated the Langgar and Pahang Tua soils' weakness, which falls within the range of a soft clay's strength. The shear strengths of Pahang Tua and Langgar are 21.11kPa and 19.18kPa, respectively.

The findings of this study can provide engineers with additional dimensions and applications for any initial design in the Pekan area. A simple and affordable alternative for designing for construction on soft clay soil may also be made possible by the results of the fundamental soil characteristics and shear strength tests.

Particles in clay soil are less than 0.005 mm. Because the particles are too minute for a practical sieve with such tiny pores, soft clay soil cannot be separated using a sieve analysis test [5].

Alternatively, the settling velocities of the particles in a water combination can be used to evaluate and identify the soil. When the right amount of water is added to soft clay soil, it also has a high degree of flexibility. Settlement is a possibility for every building constructed on soil. However, the likelihood of settlement is higher in soft clay soil. Since excessive settlement frequently surpasses the allowable limitations, it is predicted to be a major issue. The stability of the structure will be impacted by settlement. Cracked foundations and structural columns are a couple of potential problems.

Accordingly, if the structure develops cracks, it is presumed that the foundation moved and may have contributed to the cracking. Due to the rapid compression of the soil, settlement may occur when building loads are applied to the ground. However, in some circumstances, fine-grained soils will continue to compress for many years under continuous load. Consolidation settlement is the phrase for this long-term compression that results from water being squeezed out of the clay's pores. Nonetheless, there are steps that may be made to address the issue [6].

a) Deep foundations could be driven through the unsuitable soils thereby avoiding them altogether.

b) Excavate and replace the soft soils with suitable soils.

c) Stabilize the soft soils with injected additives.

Gogoi carry out a research on the comparative analysis of engineering properties of stone dust and river (sharp) sand for asphalt production in Rick-Rock Quarry in Shendam Local Government of Plateaus State. During her research, stone dust and river sand were both mixed with bitumen in order to determine which one will be suitable for Asphalt production [7]. In asphalt production, bitumen was mixed with ¼ inch, 3/8 inch and stone dust and bitumen and river sand in which both the two Asphalt products were tested using comparative strength test which shows that rock aggregate proved to be more suitable than river sand for road construction and more preferable for road construction. Analysis carried out where; sieve analysis (to determine the grain size of aggregate/sand) the materials are found to have irregular shape and has more cohesive to binder for both aggregates. Specific gravity test (to determine the ration of the weight of an equal volume of aggregate/sand to the weight of an equal volume in H_20) was found to be of standard with the NIGERIAN INDUSTRIAL STANDARD, NIS 87 (2004) of 2.0 upward, porosity (water absorption) test (to determine the rate of water absorbed of aggregate/sand was found to be within standard for Road Construction Industries base on the Federal Ministry of Industries Draft, pp31; Chemical analysis (to determine the chemical composition of the rock/sand was found to contain Fe_2O_3 of 7.35mg/l, MgO of 51.90mg/l and K_2O of 240.92mg/l for Granite and Fe_2O_3 of 6.72mg/l, MgO of 47.42mg/l and K_2O of 48.18 mg/l for River Sand as their higher element contains; Asphalt production using bitumen, rock aggregate and River sand was found out that the rock aggregate Asphalt is more suitable and have more stability better than the River Sand aggregate with the varying compressive strength of 28KN and 24KN respectively.

2.2 The Jos-Bukuru Complex

The form of the Jos-Bukuru complex has been determine by a major elliptical ring-fracture which extent around the Northern, Western and Southern margin of the massif embraces the separate Jarawa complex to the East. The Jos-Bukuru and Jarawa group of intrusion presents the best example in the presence of large scale cauldron subsidence and superposition of the ring-structures. The area bounded by the major peripherals fracture has been segmented by subsidiary internal polygonal fractures and remnants of the original fracture mosaic are preserve in Neil's valley and the basins of the Jarawa and Fusa rivers. Granite intrusion of a magnitude unrivalled in the province has occupied the internal segmented zone.

The complex exhibits an extremely intricate pattern of separate granite intrusions. Unfortunate the low topographic relief and poor exposures in many critical areas are serious handicap to structural interpretation.

2.3 Economic Geology of the Study Area

This Basement complex and Younger granites of Nigeria forms notable units and have contributed to the mineral resources of Nigeria, either by their insitu decomposition forming alluvial deposit or by erosion to form alluvial deposits. In the mapped area, the economic minerals are derived chiefly from the weathered and disintegrated Younger Granites. The decomposed mineralized rocks materials transported and deposited at the river valley by running streams.

Basically, the most predominant mineral found in the study area is

•Cassiterites
•Rock material of economic importance, which includes; Laterite clay materials, and sand which are quariable materials as classify by the Nigerian's Mining Regulations and Act 19, and are materials used for construction purposes.

2.4 Construction Materials

These are rock materials that can be use as bulk raw materials for the construction of structures like roads, bridges, buildings etc. these materials include:

•Sandy soil
•Sand
•Laterite and so on
Sand occurring in large quantities in rivers and streams beds is quarried; they occur in various sizes of grains and are used for constructions.

2.5 Hydro-Geology of the Study Rea

i.Surface Water: Surface Water in the study area includes water found in rivers, streams and run-off water drains in into the main streams. The surface water observed, is impure and not good for human consumption. It is only suitable for agriculture purposes.
ii.Underground Water: Water supply in the mapped area is rich. This is as a result of the presence of underground waters and adequate recharge of aquifer from sources mainly through precipitation.

2.6 Geology of the Study Area

Kuru is a village (district) in Jos Sound with a boundary with Barkin-ladi LGA of Plateau State North Central Nigeria. Geologically, it falls within the Jos-Bukuru Younger Granite Ring Complex of North Central Nigeria. Generally characterized by the abundant occurrence of the Younger Granite rocks which were emplaced during the Jurassic era. The formation of the Younger granite is associated with the hot spot magmatism. The rock bodies are massif occurring rings complexes which are known for hosting Tin and Columbite within the Jos-Bukuru and environs as shown in Figure 2 bellow.

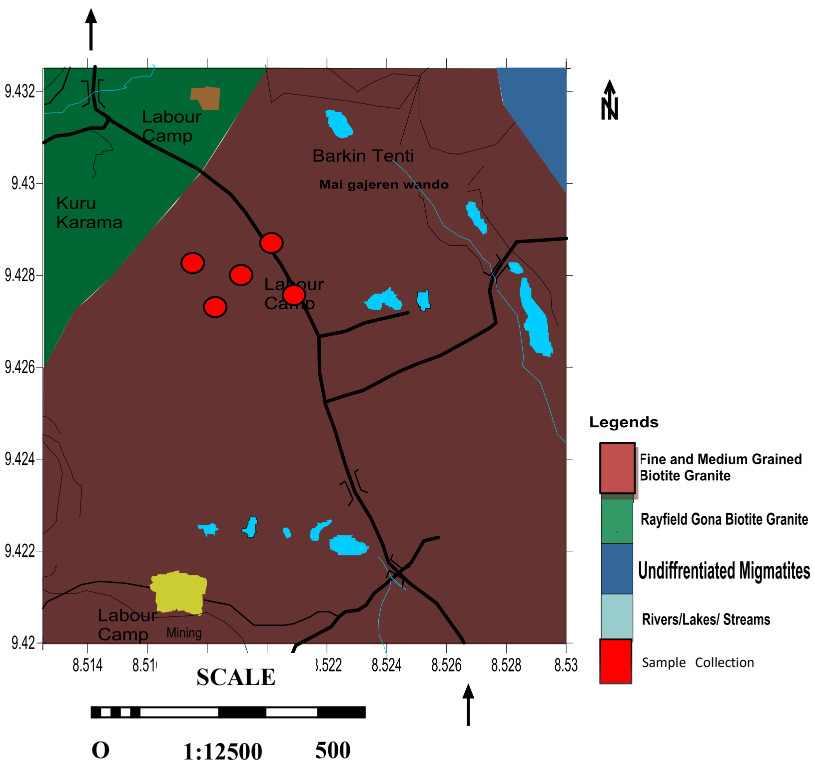

Figure 2. Geological Map of the Study Area

According to Figure 2, it was showing the study area that based on geological map form.

2.7 Economic Geology of the Study Area

This Basement complex and the alkaline granites of Nigeria forms notable units and have contributed to the mineral resources of Nigeria, either by their, in-situ decomposition forming eluvial deposit or by erosion to form alluvial deposits. In the case study area (Gada biyu), the economic minerals are derived chiefly from the weathered and disintegrated alkaline granites rocks. The decomposed mineralized rocks materials transported and deposited in ancient micro basins and the river valley by running streams to form the present day alluvial deposits. Basically, the most predominant minerals found in the study area are; Cassiterites, columbite, zicon sand, monazite, iron, etc. usually occurring in association with the tin mineralisation. Rock material of economic importance, which includes; Laterite clay materials (bauxite), and sand which are mineable materials as classify by the Nigerian's Mining Regulations and Act 19, and are materials used for construction purposes [8].

The purpose of this paper is to proffer solution that will mitigate this high risk such as caving in of overburden or hanging wall specially when lotto mining is evolve, therefore leading to loss of lives of miners and environmental degradation as a result of subsidence. This is achieved using soil compaction and consolidation of the study area. These will make mining operations carried out by artisanal miners to be carried out safely and efficiently at minimal cost.

The method involves in lotto mining is unscientific method of mineral exploitation and extraction mostly carried out by artisanal miners on the Jos-Plateau. All construction works are carried out on the natural overburden. Therefore, before the commencement of any engineering project, a sound Geo-technical knowledge of the overburden or rock is required which ascertain the type of construction to be embarked upon. Geo-technical investigation will include surface exploration and sub-surface exploration of the site.

3. Materials and Methods

3.1 Sample Collection

This is the process of obtaining samples of the overburden from the study area with the view of accessing the engineering property of the overburden in order to ensure proper design of the lotto mine support system. Five (5) samples were collected from different points. The laboratory test includes; Soil Compaction test, Soil Consolidation test, Samples was collected from trial pit of 9 meters,8.5 meters, 9.4 meters, 9 meters and 8 meters, five (5) samples.

The parameter of the mining activities is as follows:

i.Depth of lotto mine - between 8-10 meters.
ii.Average number of personnel working / mine pit-eight (8) workers.
iii.Support system use - one (1) natural support system.
iv.Average number of cylindrical pit dug in the study area as at the time of this research work is 58 pits.
v.The equipment use by artisanal miners for their operations is: diggers, shovels, timber wheels arrangement with mounted bucket, water pump (3 inches), ground sluicing etc.

The measure problems that are associated with mining operations are:

i.Over flow of water in the pits.
ii.Sudden collapse of the mine overburden due to overburden weight and negligence in carrying out some soil mechanics test on the overburden.
iii.Lack of support systems in the mine.

3.2 Laboratory Analysis

3.2.1 Determination of Water Content of Soils

A. Equipment

1.Moisture can(s): Moisture cans available in various sizes as in 2-in.(50.8mm) diameter and 7/8in.(22.2mm) high, 3.5-in. (88.9mm) diameter and 2 -in. (50.8mm) high.
2.Oven with temperature control: For drying, the temperature of oven is generally kept between 105^0C to 110^0C. A higher temperature should be avoided to prevent the burning of organic matter in the soil.
3.Balance: The balance should have a readability of 0.01g for specimens having a mass 200g or less. If the specimen has a mass of over 200g, the readability should be 0.1g.

B. Procedure

1.Determine the mass in gram (g) of the empty moisture can plus its cap (W_1), and also record the number.
2.Place a sample of representative moist in the can. Close the can with its cap to avoid loss of moisture.
3.Determine the combined mass in gram (g) of the close can and moist soil (W_2).
4.Remove the cap from the top of the can and place it on the bottom (of the can).
5.Put the can in the oven to dry the soil to constant weight. In most cases, 24 hours of drying is enough.
6.Determine the combined mass (g) of the dry soil sample plus the can and its cap (W_3).

C. Calculation

1.Calculate the mass of moisture=W_2-W_3.

2.Calculate the mass of dry soil=W_3-W_1.
3.Calculate the water content.
W(%)=W_2-W_3/W_2-W_3X100

Report the water content to the nearest 1% or 0.1% as appropriate based on the size of the specimen.

3.2.2 Determination of Water Content of Soil During Compaction Test

Soil compaction is the determination of the weight of dry soil per unit volume when the soil is compared in a specific manner over a range of moisture contents including that giving the maximum weight of dry soil per unit volume. In the test a 2.5kg rammer falling through a height of 12 inch (305mm) is used.

For construction highways, and other structures like underground structure, it is necessary to compact to improve its strength. Proctor (1933) developed a laboratory compaction test procedure to determine the maximum dry unit weight of compaction of soils which can be used for specification of field compaction. This is referred as the standard Proctor compaction test and is based on the compaction of the soil fraction passing No.4 U.S.sieve.

A. Equipment
1.Compaction Mold
2.No.U.S.sieve
3.Standard Proctor hammer(5.5Ib)
4.Balance sensitive up to 0.01 Ib
5.Balance up to 0.1g
6.Jack
7.Steel straight edge
8.Moisture can
9.Dry oven
10.Plastic squeeze battle with water
B. Procedure

1. Acquire approximately 10 Ib (4.5 kg) of air-dry soil to perform the compaction test on. Break up any lumps of earth.

2. Use a No. 4 U.S. sieve to filter the soil. Fill a big pan with all of the minus -4 material. This should weigh at least 6 Ib (2.7 kg).

3. To raise the moisture level to around 5%, add enough water to the minus -4 material and carefully mix it in.

4. Calculate the Proctor mold + base plate weight, W1. (Ib)

5. Next, fasten the extension to the mold's top.

6. Fill the mold with three equal layers of damp soil. The usual Proctor hammer should be used to compact each layer consistently. The next layer of loose dirt is placed into the mold after 25 iterations.

7. Take off the mold's top attachment. When removing the top attachment, take care not to break off any of the compacted soil inside the mold.

8. Trim the extra dirt above the mold using a straight edge. The top of the mold and the top of the compacted dirt will now be level.

9. Calculate W2 (Ib), the weight of the mold plus base plate plus compacted wet soil inside the mold.

10. Take the mold's base plate out. Extrude the compressed dirt cylinder out of the mold with a jack.

11. Calculate the mass of a damp can, W3 (g).

12. Take a moisture sample in the moisture can (step 11) from the moist soil that was extruded in step 10 and calculate the mass of the can plus the moist, W4 (g).

13. To dry to a consistent weight, put the moisture container with the damp in the oven.

14. Hand-break the remaining compacted soil and combine it with the pan's remaining damp soil. To increase the moisture level by roughly 2%, add more water and stir.

C. Calculation
The compaction maximum content w(%) is expressed as

W(%)=(W_4-W_5)/W_3 - W_1X100, where,

w=moisture content

3.3 Determination of Dry Density/Moisture Content 2.5kg Rammer Method

The specific gravity of a given soil can be expressed as the ratio of the weight of a given volume of the soil to the weight to the weight of equal volume of distilled water.

Therefore, G_s=unit weight (or density) of ssoil solids only/unit weight (or density) of water.

$G_s=W_s/V_sP_w$

Where, W_s=mass of soil solids (g)

$V_{s=}$volume of soil solids (cm^3)

P_w=density of water (g/cm^3).

Aim: The aim of the test is to determine the optimum moisture content and the maximum dry density of a given sample.

According to Table 1, below are the all apparatus for the research purposes.

Table 1. Apparatus Use for Compaction Test.

S/N	Apparatus
1	Mould of 150cm x 30cm
2	Trays and scoopers
3	Standard compaction hammer
4	2.5kg Rammer
5	Weighing balance
6	Strength edge

Procedure of Soil Compaction Test

i.The mould was weighed empty and floured to be 300g and volume was 1000m3. The sample which was dried was passed through sieve 20mm and was thoroughly mixed with some amount of water. 7% by weigh.
ii.The sample was poured into the mould of 105mm in diameter, head falling freely from 300mm above the top of the soil.
iii.Compaction was affected in three layers each being given 25 blows. The third layer was filled and compacted so that not more than 6mm of overburden in the mould stick above the top of the soil.
iv.The top of the compacted sample was then trimmed and level with the mould using a straight edge.
v.The base was moved and the mould with the soil was weighed.
vi.The test was repeated five (5) times varying the moisture continent by adding 2% for each test, the moisture continent of each was determined using the previous procedures discussed above.

3.4 Atterberg Limit Test

This test was carried out to determine the liquid limit, the plastic limit and plastic index.

A. Equipment

1.Casagrande liquid limit device
2.Grooving tool
3.Moisture can
4.Porcelain evaporating dish
5.Spatula
6.Oven
7.Balance sensitive up to 0.01g
8.Plastic squeeze botte
9.Paper towel

B. Procedure

1.Determine the mass of five moisture cans (W_1).
2.Put about 250g of air-dry soil passed through No.40 sieve, into an evaporating dish. Add water from the plastic squeeze bottle and mix soil to the form of uniform past.
3.Place a portion of the past in the brass cup of the liquid limit device. Using the spatula, smooth the surface of the soil in the cup such that the maximum depth of the soil is about 8mm.
4.Sing the grooving tool, cut a groove along the Centre line of the soil put in the cup.
5.Turn the crank of the liquid device at the rate of about 2 revolutions per second. By this, the liquid limit cup will rise and drop through a vertical distance of 10mm once for each revolution. The soil from the sides of the cup will begin to flow toward the center. Count the number of blows, N, for the groove in the soil to close through a distance of ½ in. (12.7mm).
6.Add more water to the soil in the evaporating dish and mix thoroughly. Repeat Steps 3, 4, and 5 to get the groove closure of ½ in. (12.7mm) in the liquid limit device at a blow count N=20 to 25. Take a moisture sample from the cup. Remove the rest of the soil past to the evaporating. Clean the cup with the paper towels.

7.Add more water to the soil past in the evaporating dish and mix well. Repeat steps 3, 4, and 5 to get blow count N between 15 and 20 for a groove closure of 1/2in. (12 7mm) in the liquid limit device. Take a moisture sample from the cup.
8.Put the three moisture cans in the oven to dry constant mases (W_3). The caps of the moisture cans should be removed from the top and placed at the bottom of the respective cans in the oven.

C. Calculation

The moisture content w(%) is expressed as

$W(\%)=(W_2 - W_3)/W_3 - W_1 X100$, where,

w=moisture content

i. Liquid Limit (LL)

The liquid limit was determined and the position of sample of the soil that pass through the sieve No. 36. 100 grams of the soil sample was obtained and thoroughly mixed with distilled water to form a homogeneous portion of plaster and was then placed in the cup of the liquid limits device, the surface was smoothened to the maximum depth of 12.5mm and grooving tool was drawn through the paste along the symmetrical axis of the cup holding the tool perpendicular to the cup at the constant point. The handle of the device was used to rise and drop the cup on the rubber based at the rate of 2 revolutions per second unit. The bottom of the ground paste was observed to close. The number of blows which the grooved closed was recorded. A small portion of the sample (overburden) from the top was taken moisture content determination. The water content of the soil was altered and the procedure stated above was repeated and more addition moisture content was determined between the ranges of 10-40 blows.

The moisture content valves were obtained and their corresponding number of blows was plotted on the semi-logarithm scale. The liquid limit was reduced at the moisture content corresponding to 25 blows.

iii. Plastic Limit (PL)

The plastic limit was determined on a sample soil used for liquid limit test. Plastic limit is the water content at which the soil begins to break apart and crumble when rolled by hand into thread of 3mm in diameter.

iv. Plastic Index (PI)

The aim of plastic index determination is to determine the range if moisture content over which a soil is plastic. The plastic index was calculated from the liquid limit (LL) and plastic limit (PL) as; PI=LL-PL.

4. Presentation of Result

Different samples were taken from different points in Gada Biu alluvial Tin-columbite mineralization and the samples were analyzed using Proctor compaction testing parameter to determine the water content of the soil and its specific gravity as well as other tests such as liquid limit, plastic limit, shrinkage limit and plastic limit and the results were presented in Table 2, 3, 4, 5, 6, 7, and 8 below.

4.1 Interpretation of Data

Several tests such as water content and specific gravity during Compaction test, Liquid-limit Test, Plastic-limit, Shrinkage test and Plastic index were used to analyze the engineering significant of the study area in order to ascertain whether the area is good for engineering work such as construction of building or highways as well as underground structures such as underground mining.

Determination of Water Content of Soil

Water content of soil can be determined in the laboratory for the purpose of engineering work. Water content of a material can be express as the weight of water in a given soil mass to the weight of dry soil and is express in percentage.

Generally, most natural soils, which are sandy and gravelly in nature. May have water contents up to about 15 to 20%. In natural fine-grained (silty or clayey) soils, water contents up to about 50 to 80% can be found.

The results as presented in Table 2 and 3, show that the optimum moisture content and the maximum dry density fall within the required standard values and are good for engineering purposes. It indicates that, the average moisture content ranges from 4.0 to 15.0 as required standard, therefore recommended for good engineering purposes.

Table 2 shows each of the number test that water content of soil.

Table 2. Determination of water content of soil.

Number of Test	1	2	3	4	5
Mass of can=W_1g	27.50	25.50	25.14	25.75	25.14
Mass of can+wet soil=W_2g	43.50	41.20	40.50	41.22	40.50
Mass of can+dry soil=W_3g	39.86	37.95	38.00	37.95	38.00
Mass of moisture=$W_2 - W_3$g	3.66	3.25	2.50	3.27	2.50
Mass of dry soil=$W_3 - W_1$g	12.37	12.45	12.86	12.20	12.86
Moisture content, W,=$(W_1 - W_2)/W_3 - W_1 X100$	29.59	26.10	19.40	26.80	19.40
Mean Value	24.26				

Table 3 shows the specific gravity of the soil.

Table 3. Determination of specific gravity the soil.

Number of Test	1	2	3	4	5
Mass of flask+water filled to mark=W_1g	559.58	550.0	546.35	661.21	546.35
Mass of flask+soil+water filled to mark=W_2g	622.0	600.0	600	622.0	600.0
Mass dry soil=W_S(g)	100.0	100.0	99.50	100.0	99.50
Mass of equal volume of water as the soil solids, W_w(g)=(W_1+W_S)-W_2	37.58	50.00	45.85	39.21	45.85
$G_{s(T1}{}^0C)=W_s/W_w$	2.66	2.00	2.17	2.55	2.17
$G_{s(20}{}^0C)=G_{s(T1}{}^0C)\times A$	2.66	2.00	2.17	2.55	2.17
Mean Value	2.31				

Table 4 shows the moisture content of soil during compaction of each trial.

Table 4. Determination of moisture content of soil during compaction.

Number of Trials	1	2	3	4	5
Mass of moisture can, W_3(g)	54.00	108.0	114.5	47.00	45.00
Mass of can+moist, W_4(g)	253.0	350.0	350.0	354.0	354.0
Mass of can+dry soil, W_5(g)	238.2	322.0	322	326	326.0
Moisture content, w(%)=W_4-W_5/W_5-W_3×100	8.10	13.10	13.5	10.00	9.90
Mean Value	10.92				

Table 5 shows the liquid limit by each mass.

Table 5. Liquid limit.

	1	2	3	4	5
Mass of moisture can, W_1(g)	19.42	13.17	24.40	26.41	17.01
Mass of can+moist, W_2(g)	29.40	27.91	40.45	40.45	31.58
Mass of can+dry soil, W_3(g)	25.89	24.50	35.70	35.91	27.72
Moisture content, w(%)=W_2-W_3/W_3-W_1×100	35.00	29.30	42.40	47.80	36.00
Number of blows	35	23	17		
Mean Value	38.10				

Table 6 shows the plastic limit test of each part.

Table 6. Plastic limit test.

	1	2	3	4	5
Mass of moisture can, W_1(g)	13.16	16.11	23.57	33.76	27.34
Mass of can+moist, W_2(g)	23.86	25.86	30.65	40.55	34.55
Mass of can+dry soil, W_3(g)	222.36	24.31	29.00	38.75	33.00
Plastic Limit (PL)=W_2-W_3/W_3-W_1×100	16.30	18.90	30.40	37.10	27.40
Mean Value	26.02				

Table 7 shows the plastic index of soil during compaction in each trial.

Table 7. Determination of Plastic index of soil during compaction.

Number of Trials	**Liquid Limit (LL)**	**Plastic Limit (PL)**	**Plastic Index=Liquid Limit-Plastic Limit PI=LL-PL**
1	35.00	16.3	18.70
2	29.30	18.90	10.40
3	42.40	30.40	12.00
4	47.80	37.10	10.70
5	36.00	27.40	8.60
Mean Value	38.10	26.02	12.08

Table 8 shows that the shrinkage limit test.

Table 8. Shrinkage limit test.

	1
Mass of coated shrinkage limit dish, W_1(g)	12.34
Mass of dish+wet soil, W_2(g)	40.43
Mass of dish+dry soil, W_3(g)	33.68
Moisture content, $W_i(\%)=W_2-W_3/W_3-W_1\times100$	25.53
Mass of mercury to fill the dish=W_4(g)	190.20
Mass of mercury displaced by soil part=W_5(g)	140.00
$\Delta W_i(\%)=W_4-W_5/(13.6)W_3-W_1\times100$	17.63
$SL=W_i-W_4-W_5/(13.6)W_3-W_1\times100$	7.90
Mean Value	

4.2 Discussion of Results

Generally, the competency of soil and rock to withstand engineering structures such as building, highways and underground structure such as underground mining, depends on the properties of rock and soil such as the density, plasticity, moisture content of the soil and rock. Various tests conducted in Alluvial Tin - Columbite deposit Mineralization of Gada Biu in Jos Plateau state indicate that, the study area, meets the standard for engineering construction. Despite the number of deaths recording during the cause of local mining activities in the study area, the soils tested have been found worthy for engineering purposes as shown in Table 2, 3, 4, 5, 6, 7 and 8 etc., therefore other measures such as core drilling test which is beyond the scope of this reach and the depth of the overburden from the surface to the ore deposit should be carried out and compared to the standard depth requires for underground mining. The average depths of the overburden to the ore deposit measured in the study area were 8 to 10 meters.

The comparison between the sample result analyses and standard values of American Society for Testing and Material and the America Association of State highway Transportation officials (AASHTO) as sown in Table 9 indicate all values obtained during testing fall within the standard values.

Table 9. Comparison between Sample Analysis Results and Standard.

S/N	Test	Sample Analysis Results					Standard Values
		P_1S	P_2S	P_3S	P_4S	P_5S	
1	Consolidation ❖Moisture Content ❖Specific Gravity	29.59% 2.66	26.1% 2.00	19.45% 2.17	26.8% 2.55	19.45% 2.17	15 - 30% 9.81
2	Compaction ❖Optimum moisture content ❖Maximum dry density	8.1 2.065	13.1 1.820	13.5 1.350	10.0 1.930	9.9 1.880	4.0-15.0 1.502-2.03
3	Atterberg Limit ❖Liquid Limit ❖Plastic Limit ❖Linear Shrinkage ❖Plasticity Index	35.0 16.3 7.9 18.7	29.3 18.9 8.6 10.5	42.4 30.4 11.4 12.0	47.8 37.1 2.9 10.7	36.4 27.4 8.6 9.0	25.5-52.6 14.8-40.2 2.0-15.0 5.6-12.8

Table 9 shows that the comparison between sample analysis results and standard.

5. Summary, Conclusion and Recommendation

5.1 Summary

The study area is endowed with mineral potential such as cassiterite, presence of columbite and other associate minerals and that prompted the activities of Lotto/ Artisanal miners. Therefore, for successful exploitation of the mineral deposit, sound Geo-technical engineering properties of the study area must be conducted.

Even some of the reclaimed mine lands in most of the former mining areas are being reworked using Lotto mining techniques, making small-scale mining a continuous process on the Plateau. The abandoned Lotto mines now pose even greater environmental hazards, and artisanal miners are less likely to have adequate safety gear and may be forced to operate dangerous or malfunctioning machinery [9]. The possibility of miners suffering personal injuries and the collapse of the overburden are the two main risks associated with artisanal mining. These projects might not meet regulatory requirements for the caliber of tools and equipment or safety procedures because artisanal mining usually takes place illegally.

History has shown that miners may be carried away by large "find" of mineral deposits and as a result to excavate without due consideration of danger posed by excavation of large room without support system of any kind. Engineering properties analysis must be carried out before mining begins and where the load of the overburden leads to collapse of the large room, support system like sand packed bags and treated wood must be use as support following the factors of safety gotten from the engineering analysis. For compaction test the moisture contents were (29.59%, 26.1%, 19.45%, 26.8%, 19.45%), Specific Gravity (2.66, 2.00, 2.17, 2.55, 2.17), Atterberg Limit test; liquid limit test (35.0, 29.3, 42.4, 47.8, 36.4) Plastic limit (16.3, 18.9, 30.4, 37.1, 27.4), Linear Shrinkage (7.9, 8.6, 11.4, 2.9, 8.6), plasticity index (18.7, 10.0, 9.9), maximum dry density (2.065, 1.820, 1.350, 1.730, 1.880) [10].

5.2 Conclusion

The laboratory overburden analysis carried out has been used as a guide on the overburden collected from the trial pit shows that the overburden in the study areas is laterite. Such overburdens are normally fairly good in construction design. The engineering properties analysis carried out will guard the mining engineer in basic fundamental principles so as to avoid failures that might affect the lotto mine during operation and also help in improving the knowledge of miners on how to improve the overburden structural properties.

Since the study area has been found worthy for engineering construction purposes, despite the number of deaths being recorded during local mining (lotto mining), it is concluded that, the casualties recorded were not as a result of the competency of the soil, that it could be other factors such as the depth of the overburden to the ore deposit or the mining is carried out on a loose soil which requires core drilling to know the soil quality designation.

5.3 Recommendation

Base on the result of the engineering properties conducted on the study are, I would therefore wish to make the following recommendations.

1.For optimum and safe extraction of the mineral deposit in the study area, sand packed bags should be adopted as support system to reduce overburden failures and aids optimum extraction of ores.
2.The distance between the hanging wall and the ground should be increase for erection of support system.
3.For effective and profitable exploitation, detailed engineering properties examination must be carried out on the area.
4.For stability of mine, timber should be use as support and casing of the shaft in order to prevent the formation from caving.
5.For maximum control of surface underground water, high horse power hydraulic machines should be used for the dewatering.
6.For observation of the formation cracks, illumination should be provided in the mine during operation.

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