Stabilization of Expansive Subgrade Soil Derived from Ameki Formation in Ozuitem, Southeastern Nigeria, Using Calcium Carbide Residue

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Abstract
This research investigated the possibility of using Calcium carbide residue (CCR) as an additive in the modification of the geotechnical properties of clay soil from Ameki formation in Ozuitem so as to increase their strength bearing capacity and reduce their swelling potentials. The clay soil samples were collected from Ozuitem LGA of Abia State. Chemical analysis of the CCR shows that it contains 65.71%, 27.93% and 4.01% of CaO, Ag_2O and SiO_2 respectively. Preliminary tests to determine the geotechnical properties of the natural soil including Particle size distribution, Atterberg limits, Maximum Dry Density and California Bearing Ratio were determined in the laboratory to classify the soil. The soil samples were later stabilized with various percentages of CCR (2, 4, 6, 8 and 10). The geotechnical tests earlier performed on the soils were repeated (after stabilization) to evaluate the effects of CCR on the geotechnical properties of the clay soils. Results of the study indicate that CCR stabilization of clay soils in Ozuitem has the general effect of reducing the swelling indicators, thereby reducing the swelling potential of the soil. The liquid limit ranges between 31.51% to 43.18% and plasticity index extends from 12.14% to 23.005%. Optimum stabilization was achieved with 8% CHA stabilization. Stabilization with CCR acts like lime stabilization by increasing the CBR but reducing the MDD of the soils. Therefore, calcium carbide residue can be effectively used to reduce swelling indicators and to improve CBR values in clay soil and should be encouraged in the construction industry.

Keywords: *Expansive soils, geotechnical properties, liquid limit, plasticity index, calcium carbide residue and stabilization.*

1.0 INTRODUCTION

It is impossible to ignore the troublesome issue of expansive clays in road construction. This is because the soil volume is constantly changing, causing structures to shift unevenly and crack, potentially leading to failure. One of the factors causing the problem is the high cost of building materials, which are currently utilized in construction using traditional materials and techniques. One way to address the problem is to use affordable building materials that are easily accessible in the area. To achieve this, roads can be constructed using recycled or sustainable raw materials that are comparable to conventional building materials made of cement, sand, and aggregates to offer an appropriate level of comfort and quality.
Road failure is a physically flawed state that results from cracks, flaking off, surface or face defects, dissection, deformation, the development of potholes, subsidence, and/or complete collapse of the pavement, all of which impair traffic flow. The original purpose of the road is thus no longer possible. Prior to road construction, raw materials had to be stabilized due to the poor condition of Nigeria's roads, particularly those in the southeast, and their negative impacts

on the country's economy, agricultural output, transportation and communication networks, overall environmental degradation, and national development.

Since all roads are built on the earth's surface, which is composed of geological elements, geology plays a critical role in the functionality, stability, and/or failure of road pavements.

This study assesses the feasibility of stabilizing expansive clay with calcium carbide residue. Clay soil is readily available in Nigeria and was acquired from Ozuitem. The stabilized soil would take the place of the traditional soil typically used for home construction. The study is anticipated to have a major influence on the road construction industry in terms of design, strength, durability, and cost. It would also provide designers and contractors with more options regarding the market availability. Roads for transport would become stronger and more resilient as a result.

Expansive Soil

Expansive soils are thought to be among the most problematic soils, and their potential to swell and shrink when exposed to water can cause damage to a variety of civil engineering structures. Their behaviour differs from that of other soils, and as a result, expansive soils can cause the following issues in structures or construction projects (Patel, 2019): They have a significant tendency to swell and plasticity, which can cause foundation collapses, structural damage, and instability in the infrastructure (Al-Humairi et al, 2019). Their expansive nature can result in costly repairs and safety hazards when buildings collapse, roads deteriorate, and pipes burst.

The main problem with expansive soil is their propensity to experience volumetric changes in reaction to changes in moisture content (Wei et al, 2023). These alterations can potentially harm infrastructure, such as roads, retaining walls, buildings, and pipelines, posing a risk to public safety and causing large financial losses (Usta, 2023). Historically, methods for stabilizing the soil have been used to lessen the negative consequences of expansive soils by altering their characteristics and making them less vulnerable to volume fluctuations. Adding chemical agents like lime, cement, or fly ash (FA) is common in conventional stabilizing techniques (Zamin, 2024), (Subramanyam, 2024). This strategy may be advantageous, but it may also be expensive and harmful to the environment. Managing waste from various industrial processes restricts landfill space and hinders environmental sustainability.

These materials, which are leftovers from industrial operations, are a viable way to address waste management and soil stability issues, Mohamed, Yuan, Al-Ajamee, Dong, Ren & Hakuzweyezu, (2023). In addition to providing a long-term solution to soil engineering issues, using these industrial wastes in soil stabilization meets the urgent demand for waste management and environmental protection, Suiyi, Yanong, Yuxin, Minglin, Weilu, Xinfeng, Yang, Jiancong, Zhan, Jialin & Yu, (2024).

Identification of swelling soils

The swelling potential of a soil basically depends upon its mineral composition along with the in situ moisture content and density. Soil permeability also affects the rate of swelling on site. In general, clays with plasticity indices > 25, liquid limits > 40, and natural water content near the plastic limit or less are more likely to swell. Based upon the Atterberg limits, the degree of expansion of a soil can be classified as presented in Table 1. Similarly, as per the ASTM D4829-11, the degree of expansion may be very low (EI = 0–20), low (EI = 21–50), medium (EI = 51–90), high (EI = 91–130), and very high (EI > 130), where EI is the expansion index. (Patel, 2019).

Table 1: Prediction of the degree of expansion in fine-grained soils (Patel, 2019)

	Degree of expansion			
Soil properties	**Low**	**Medium**	**High**	**Very high**
Liquid limit	20–35	35–50	50–70	70–90
Plasticity index	< 12	12–23	23–32	> 32
Shrinkage index	< 15	15–30	30–60	> 60
Free swell percentage	< 50	50–100	100–200	> 200

Expansive clay

Clays are classified as soils containing colloidally sized particles and are found in sedimentary deposits. In essence, they are made up of hydrated alumino silicates, but because of differences in their composition and structure, over 30 different types of clay minerals have been identified, each with its own characteristics. Additionally, as the conditions in which they are found change, so do their properties. One of the most crucial factors is soil moisture, which has the power to swiftly and significantly alter clay's properties. Analyzing clays and their characteristics is therefore extremely important in geotechnical investigation and testing and enables the assessment of soil stability and the understanding of processes that can take place during and after engineering interventions. (Crowley, 2007).

Smectites are one of the groups of clays that are categorised based on shared characteristics. Smectites include expansive clays, which have the characteristic of significantly changing volume in response to variations in humidity. Among these minerals, bentonite, montmorillonite, beidellite, and nontronite are the most well-known.

The amount of water in the soil varies with precipitation and seasonal weather variations. Smectite clays can expand and see a volume increase of over 10% when wet. As clay's volume grows, it starts to put pressure on structures; eventually, this pressure gets so great that cracks start to show. Clays lose water and become less volumetric when the dry period returns. The compaction of the clay further causes cracks to appear, which enables deeper penetration of the next inflow of water, and thus greater expansion of the clay, Crowley (2007).

In this sense, expansive clays have an adverse effect on underground and mining operations, as well as foundations, basement walls, and roads. Determining the location and distribution of these clays, stabilizing the terrain, replacing materials, employing deeper foundations, and managing soil moisture can all lessen their impact.

Pozzolanas

Pozzolans are siliceous and aluminous materials that have little to no cementitious value on their own but will chemically react with calcium hydroxide at room temperature to create compounds with cementitious qualities when moisture is present. Robert (1993). The potential of using agricultural waste to produce cementitious compounds in addition to lime has been demonstrated by more recent developments. As they grow, many plants absorb silica from the soil and incorporate it into the structure of their leaves, stalks, and other parts (Akinmade, 2008). Accordingly, the majority of the organic materials in such agricultural products decompose and vanish as carbon dioxide and water vapour when they are burned (Akinmade, 2008). The inorganic residue, primarily silica, makes up the majority of the resulting ash.

Chemical principles of pozzolanic reactions

When large amounts of reactive CaO, Al2O3, and SiO2 are combined with water, pozzolanic reactions occur. Garcia, Prieto, Oroz, Urmeneta, Ramirez, Miqueleiz, and Seco (2012). While Al2O3 and SiO2 can be present in the material to create cementation gels that can be added as cement or, for instance, with a pozzolana, CaO is typically added as lime or cement. Pozzolanic

reactions take place in these circumstances, combining the Si and Al with the available Ca to form cementitious compounds known as Calcium Silicate Hydrates (CSH) and Calcium Aluminate Hydrates (CAH) (Nalbantoglu, 2004; Yong & Ouhadi, 2007).
Below is a summary of a basic qualitative representation of these reactions:

$$Ca(OH)_2 \rightarrow Ca^{2+} + 2OH^- \quad (2.11)$$

$$Ca^{2+} + 2OH^- + SiO_2 \rightarrow CSH \quad (2.12)$$

$$Ca^{2+} + 2OH^- + Al_2O_3 \rightarrow CAH \quad (2.13)$$

Because of the increasing development of pozzolanic reactions over time—some authors have suggested that this may occur over years—these compounds are in charge of enhancing the mechanical properties of the mix (Wild et al, 1998). These oxides must be added to the binder when they are not present in adequate amounts in the materials that need to be cemented (Seco et al., 2012). Stabilisers such as OPC, those rich in SiO2, Al2O3, and CaO (Wild et al., 1998), or the use of lime and pozzolana mixes, for example, are especially beneficial in these situations (Degirmenci et al., 2007). Adding these oxides as a binder is not required when they are present in a material that needs to be cemented; this is most common in the stabilisation of clay soils with oxides present in the matrix.

Fineness of pozzolanas

The fineness of a cementing material is a crucial physical characteristic that influences its affinity for water. The fine grinding of pozzolanas increases their activity.

Pozzolana's application in soil enhancement

To reduce the high cost of soil improvement when using traditional additives, geotechnical engineers have concentrated on using pozzolanas as a partial or complete replacement for the standard stabilizers (Cokca et al., 2004). These materials are mostly derived from agricultural waste. The largest constituents, organic materials, are broken down and vanish as carbon dioxide and water vapour when plant residues are burned. The remaining ash is primarily composed of inorganic residue, with silica in particular present in an amorphous form that can react with oxides in the soil and improve its properties.

Stabilisation of the Soil

According to Mekonnen, Kebede, Tafesse, and Tafesse (2020), soil stabilisation is the permanent physical and chemical modification of soils to improve their physical characteristics. It encompasses a wide range of processes, including drainage, preconsolidation, and compaction. However, according to Mekonnen, Kebede, and Tafesse (2020), the term stabilisation is typically limited to the process that modifies the soil material itself in order to improve its properties. According to Clough and Duncan (1991), it is the general term for any physical, chemical, biological, or combination of these techniques used to enhance specific qualities of natural oil so that it can be used for intended engineering purposes. According to Onyelowe and Okafor (2012), stabilizing soils can improve their strength and durability or stop erosion and dust production.
The process of stabilizing soil involves using physical, physico-chemical, and chemical techniques to ensure that the stabilized soil can be used as a component material for pavement. Koteswara (2011). Enhancing soil strength, reducing permeability and water absorption, and increasing bearing capacity and durability under cyclical conditions like fluctuating moisture content are the main goals of stabilization. Akinmade (2008).

2.0 Study Area Description

2.1 Location and Climate

The study area is situated between latitudes 3° and 6°N and longitudes 5° 8°E along the Umuahia-Bende road (Nwajide, 2013; Figure 2.1). Situated in the southeast region of Nigeria, the region experiences alternating dry and rainy seasons. From March to October, it receives more than 140 mm of rain on average each year. June is when the rainy season peaks the highest. November through February is considered the dry season. With an annual range of 23 to 32 degrees Celsius, the temperature is high all year long, with the dry season being the hottest time of year. Numerous species of tall forest trees, shrubs, and grasses make up the area's rainforest-type vegetation.

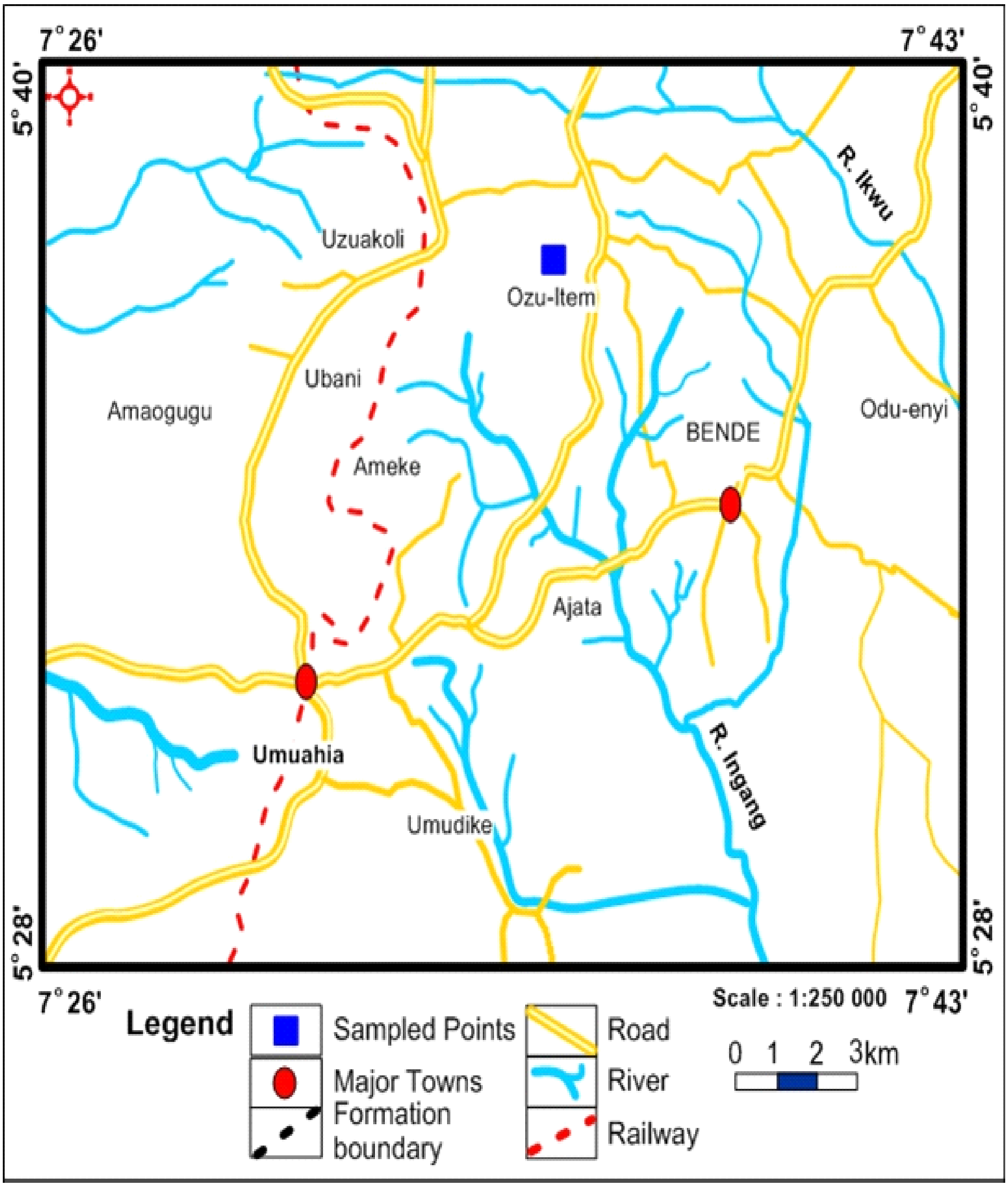

Figure 1: Location map of the study area (modified from Chiaghanam, Chiadikobi, Oguanya, Ikegwuonu & Nwokeabia, 2017).

2.2 Geology of the Study Area

The study area is located in southeast Nigeria's Northern Depo Belt, which is part of the Niger Delta Basin (Fig 1). Geographically located in the Gulf of Guinea, the Niger Delta Basin is defined by latitudes 30 and 60N and longitudes 50 and 80E (Nwajide, 2013; Figure 1). The Okitipupa Ridge forms the basin's western boundary, while an unconformity separates it from the Anambra Basin to the north. The Guinea Abyssal plain marks the southern boundary, while the Cameroun volcanic line marks the eastern boundary. After the southern portion of the Benue Trough subsided during the Danian due to thermal contraction of the lithosphere, the Niger Delta Basin was formed (Sleep, 1971; Nwajide, 2013). According to Nwajide (2013), this subsidence induced major marine transgression of the Early Paleocene that paved the way for the accumulation of the basal beds of the Niger Delta basin.

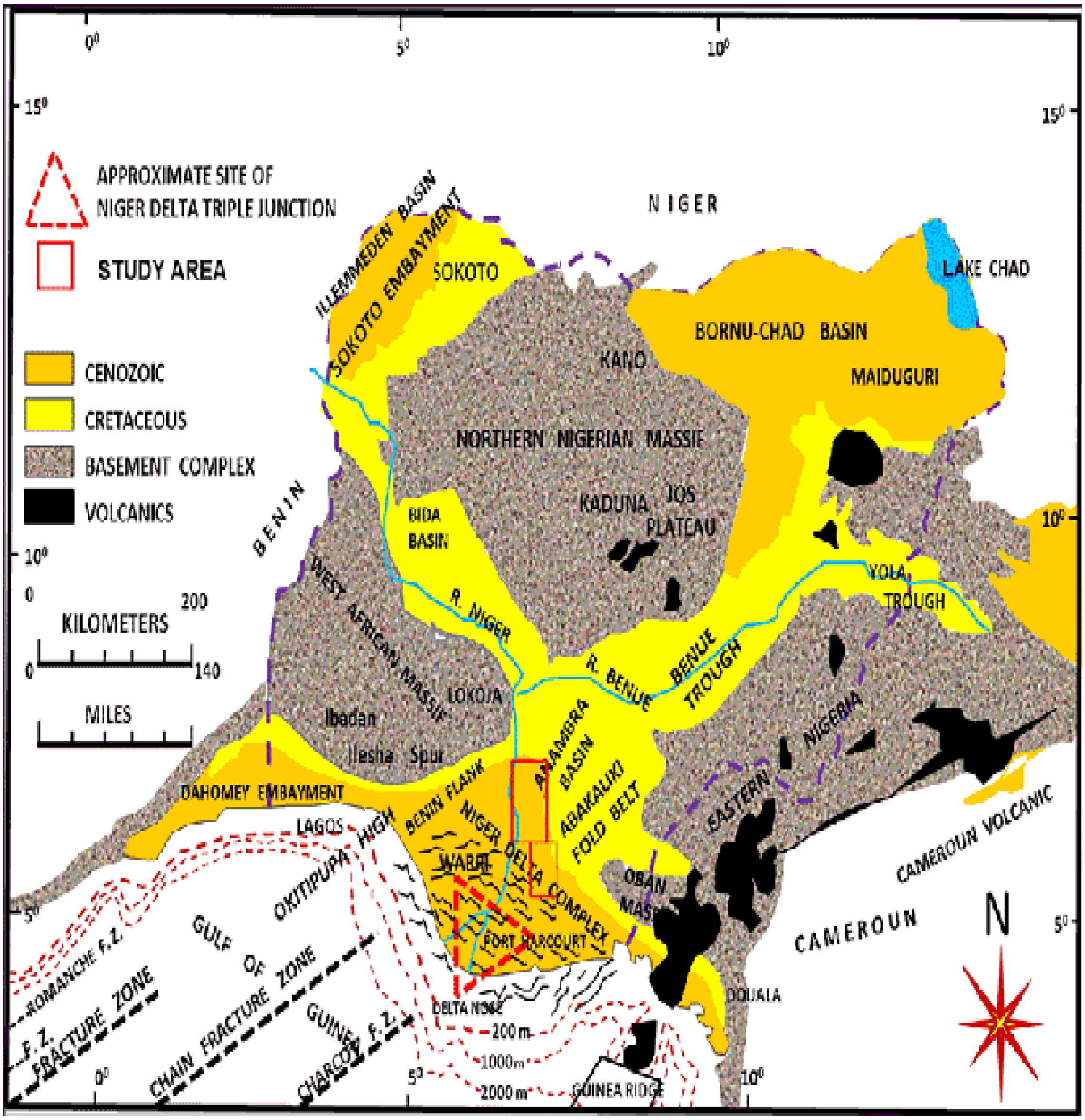

Figure 2. Structural map of the Nigerian Sedimentary Basin showing the chain and Charcot oceanic fracture zone (modified after Murat, 1972)

The Paleogene system, which comprises the Imo Formation, Ameki Group, and Ogwashi Formation (Figure 1), makes up the Niger Delta's succession. Its composite thickness is approximately 3,500 meters.

The Ameki Group's lateral equivalents are the Ameki, Nanka, and Nsugbe formations; they conformally cover the Imo Formation (Nwajide, 1980). Along the portion left over from the eastern railway construction at Ameki Town, Reyment (1965) described the type locality of the formation between miles 73 and 87. The Ameki Formation, which comprises fine-grained fossiliferous sandstone with thin limestone beds (Reyment, 1965), clayey sandstone, mudstone, rapidly alternating shale, and sandy shale (Adegoke et al., 1980; Arua, 1980), makes up the majority of the Eocene.

According to different theories, the formation is Early Eocene (Reyment, 1965) or Early Middle Eocene (Lutetian) (Adegoke, 1969). Based on the faunal content, the depositional environment has been classified as open marine, lagoonal, and estuarine. Because some fish species have a known affinity for estuaries, White (1926) interpreted the formation as occurring in an estuarine environment. However, according to Adegoke (1969), the fish favoured an open marine depositional environment and were most likely washed into the Ameki Sea from inland waters. The environments proposed by Nwajide (1980) and Arua (1986) included intertidal and subtidal zones of the shelf environments as well as nearshore (barrier ridge-lagoonal complex). However, according to Fayose and Ola (1990), the sediments were deposited in marine waters that ranged in depth from 10 to 100 meters. Ekwenye et al. (2017) proposed a tide-dominated estuarine system for the Ameki Group using the concepts of sequence stratigraphy and facies analysis.

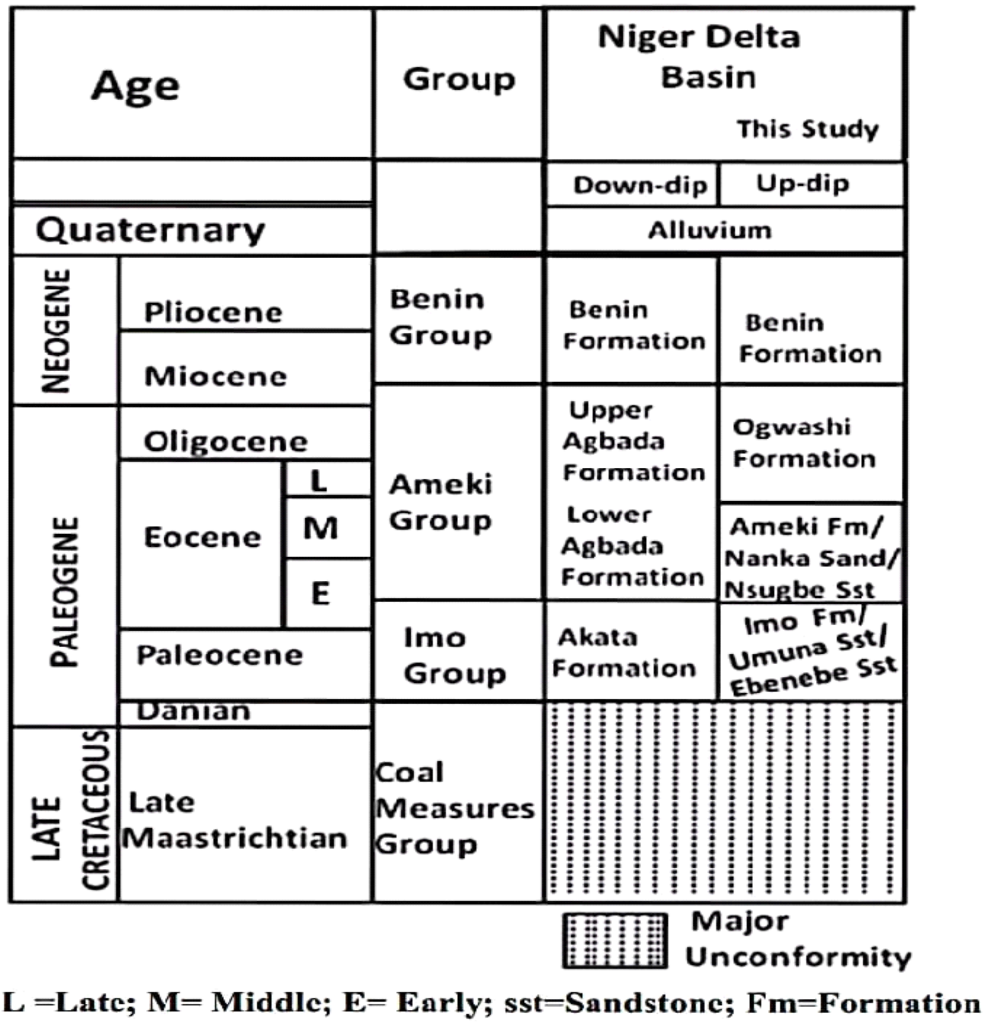

Figure 3: Stratigraphic column of Niger Delta Basin (modified after Frankyl and Cordry, 1967)

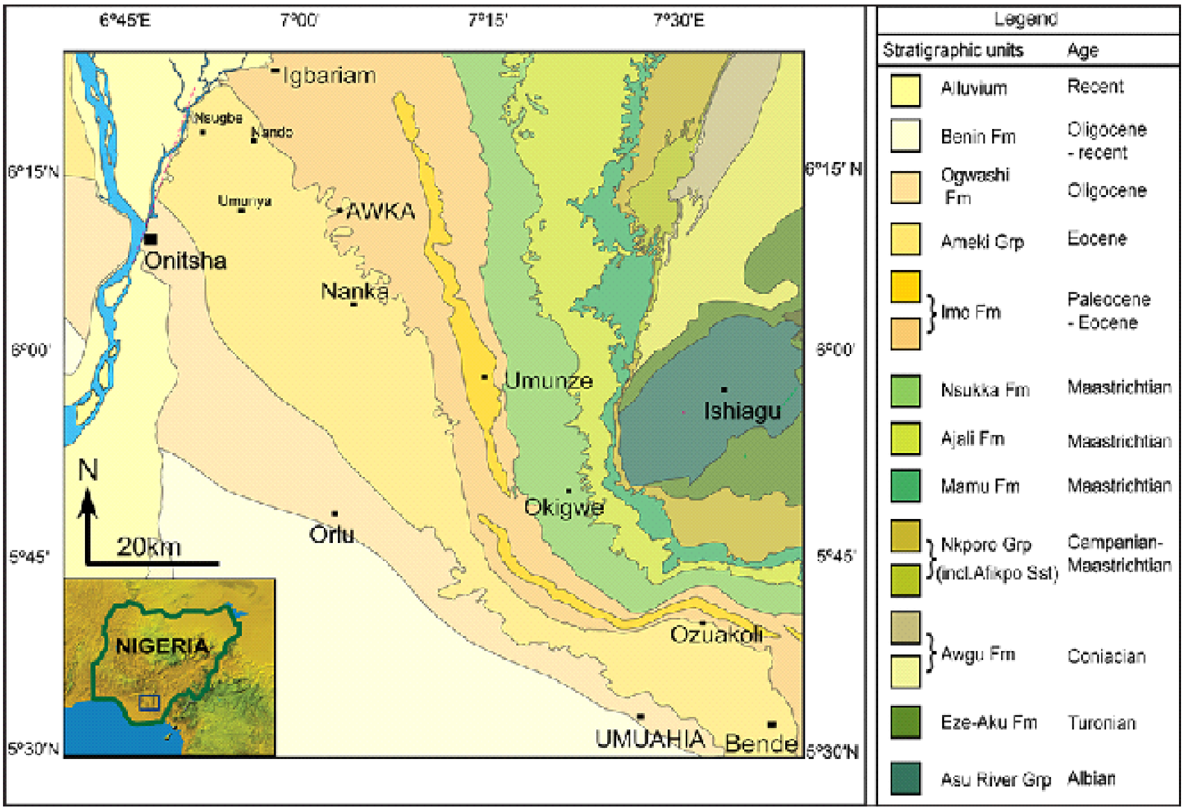

Fig 4: Geologic map of South-eastern Nigeria showing the Paleogene formation (modified from Ekwenye, 2014).

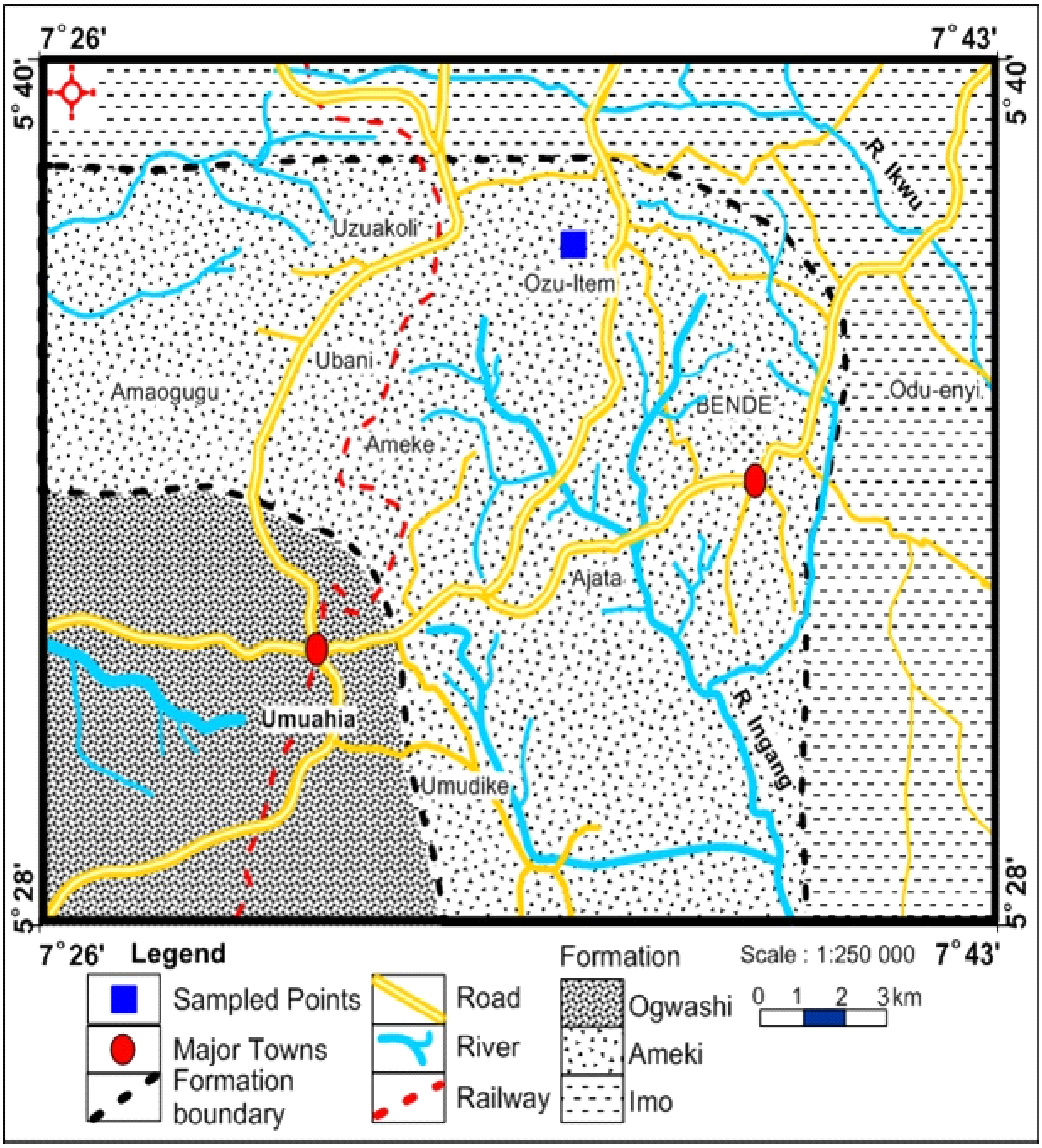

Fig 5: Geologic map of the study area (modified from Chiaghanam et al, 2017).

3.0 Materials and Methods

3.1. Field studies and sample collection

Desk work: The literature review on expansive soil, which serves as the study's desk work, is used to conduct this research. In order to comprehend the local geology and to help with the area where samples would be collected for this study, various literatures and maps of the study area were thoroughly examined.

Reconnaissance survey: This provides firsthand information about what to expect and is one of the first steps in any research project. Several geological formations that are essential to this study were found during a reconnaissance survey visit, and the difficulties presented by the study area's soils were also noted.

Soil Samples Collection:

The equipments used for samples collection in the field include:

Global Positioning System (GPS): To obtain the coordinates of sampled points and direct location on the map, GPS was used.
Nylon Bags: These were used to collect, seal and label samples and also preserve the natural moisture content and thereafter taken to the various laboratories for laboratory analysis.
Camera: It was used to take pictures of the exposures, samples and the locations of samples.
Shovel: It was used to dig and shovel out the soil.
Field notebook: it was used to record all geologic data and observation.
Maps: Where used for easy location of villages and towns, and sample locations.
Computer: Excel application was used to plot graphs for determining atterberg limits and other plots.
Other field equipment used consists of hammer, tapes.
Soil Sample: Clay Soil: Ameki Formation. Clay Soil was collected from Ozuitem
Collection of Calcium carbide residue: CCR used in the investigation was collected from panel beaters within the vicinity of MCC road, Owerri, Imo State. It was placed in containers, dried, pulverized, sieved-tagged for laboratory analysis.

3.2 Laboratory Tests

The tests carried out in the laboratory include:

3.2.1 Determination of Major Oxide Composition of Calcium Carbide Residue

The CCR samples were subjected to geochemical analyses in the lab. Atomic Absorption Spectrophotometry (AAS), Loring & Ramtala (1992), was used to perform geochemical tests. At Asemabot Analytical Services in Kaduna, Nigeria, a quantitative analysis of the calcium carbide residue's percentage composition of silica oxide and other chemical compounds, including Cao, Al_2O_3, Fe_2O_3, and others, was conducted. To confirm the precise amount of oxides, each of these tests was conducted twice.

3.2.2 Soil Stabilization Tests

3.2.2.1 Atterberg Limit Tests

The main method for determining the critical water content of fine-grained soil is the Atterberg limit test. It is employed to ascertain the liquid limit, plastic limit, and linear shrinkage. Depending on the amount of water absorbed, dry expansive/lateritic soils behave differently as they absorb more water. It may exhibit liquid, plastic, semi-solid, or solid behaviour. The behaviour or consistency of the soil varies in each instance, and so do the engineering characteristics. These behavioural variations are used to assess which soils are suitable for building structures or which ones should be avoided or treated before any construction is done. When wet, expansive soils absorb water and expand in volume; this expansion is correlated with the soil's water-taking capacity as well as its structural and mineralogical composition. The test is primarily conducted on clay and silt soils, which can expand or contract in response to the addition or removal of water.

When dry, soil becomes crumbly and friable; when a specific amount is added, it becomes semi-solid; if the soil is expansive, it starts to expand in volume as the moisture content rises. The soil will become a malleable plastic mass if the water content is raised above the soil plastic limit which causes additional swelling. The soil in this plastic state until its liquid limit is exceeded which transforms it into a viscous liquid that can flow.

3.2.2.2 Bulk Density and Dry Density test

Bulk density is the weight of the soil for a particular given volume. It is used to measure compaction. Generally, the greater the density of soil, the less pore space for water movement and penetration.

Procedure
The empty ring is weighed and recorded, and then the ring was filled with the soil sample and leveled with a flat blade knife and then it is weighed and recorded. The known volume is also recorded.

3.2.2.3. West African compaction test
This test is done to determine the maximum dry density and the optimum moisture content of soil. There three (3) methods used for compaction which include:
i. Standard proctor test.
ii. Modified AASHTO method.
iii. West Africa method.

3.3 Calcium Carbide Residue Background and Composition
Calcium Carbide Residue is a by-product from acetylene gas production**,** Neeraj & Ahirwar, (2014). This gas is used around the world for welding, lighting, metal cutting and to ripen fruit**,** Neeraj & Ahirwar, (2014). Calcium carbide residue is obtained from a reaction between calcium carbide and water to form acetylene gas and calcium hydroxide in a slurry form, which mainly consists of calcium hydroxide $Ca(OH)_2$, along with silicon dioxide SiO_2, $CaCO_3$ and other metal oxides**,** Gurugubelli, (2017). For high content of natural pozzolanic materials in clayey soil, calcium hydroxide [$Ca(OH)_2$] is a rich material that can be used to produce high strength material. For environmental and economic impact such rich waste materials can be utilized collectively with natural pozzolanic material to form a cementitious material.
Calcium carbide residue production is described in the following equation:
$$CaC_2 + 2H_2O \rightarrow C_2H_2 + Ca(OH)_2 \qquad (3.4)$$
(Calcium Carbide) (Acetylene) (Calcium Hydroxide or CCR)
From the equation above, if 64g of calcium carbide (CaC_2) is used, it will provide 26g of acetylene gas (C_2H_2) and 74g of CCR in terms of Ca(OH)2**,** Kumrawat & Ahirwar, (2014).

4.0 Results and Discussion
4.1. Results
4.1.1 Chemical Composition of Calcium Carbide Residue
Table 2 shows the chemical composition of Calcium Carbide Residue (CCR). The cementing characteristics of CCR are dependent on its oxide composition. This reveals that the calcium carbide residue contains large percentage of CaO (65.71%) followed by Ag_2O (27.93%), which corroborate the fact that calcium carbide residue is a good pozzolana.

Table 2: Chemical composition of calcium carbide residue

Oxide	Percentage Composition CCR (%)
SiO_2	4.01
TiO_2	0.03
Al_2O_3	1.68
Fe_2O_3	0.15
CaO	65.71
MgO	0.06
Na_2O	0.01
K_2O	<0.001
P_2O_5	0.32
MnO	<0.001
Ag_2O	27.93
SO3	0.32
Rb_2O	-
Cl	-
ZnO	-
L.O.I	27.93

Table 3: Summary of the geotechnical properties of the clay soil

As seen below, the natural clay soil with LL of 63.8 %), PI of 30.55 (%) has a high degree of expansion based on ASTM D2487-17, 2011 and Nigerian Standard FMWH, 2010 classification of soils.

Experiments	Clay Soil	Unit
Liquid Limit	63.80	%
Plastic Limit	33.25	%
Plasticity Index	30.55	%
Linear Shrinkage	17.20	%
MDD	1.55	g/cc
OMC	22.50	%
CBR Soaked	5.00	%
CBR Unsoaked	15.00	%

4.1.3. Variation of Liquid Limit for Ozuitem Clay with Increased Percentage of CCR

When the clay soil sample derived from Ozuitem was treated with CCR at different percentages, the minimum values of liquid limits were obtained at 6% (Fig 6). The maximum amount of additive to achieve hardening was obtained at 6 %. The Liquid limit for the stabilized soil ranges from 31.51% to 43.18% with an inconsistent pattern of reduction and later increase. Federal Ministry of Works and Housing (1972) for road works recommend liquid limits of 50% (35%) maximum for sub-base and base materials. All the values at 2-10% fall under the values recommended by Federal Ministry of Works and Housing therefore renders the soil suitable for use as sub-base and base materials.

Table 4: Atterberg limits of Ozuitem Clay with CCR

Liquid Limit (%)		**Plastic Limit (%)**		**Plasticity Index (%)**
Moisture Content	No of blows	%	Moisture Content (%)	Moisture Content (%)
63.8	26	0	33.25	30.55
43.18	28	2	20.175	23.005
39.44	35	4	25.05	14.39
31.51	40	6	19.37	12.14
37.72	42	8	23.45	14.27
41.00	45	10	25.83	15.17

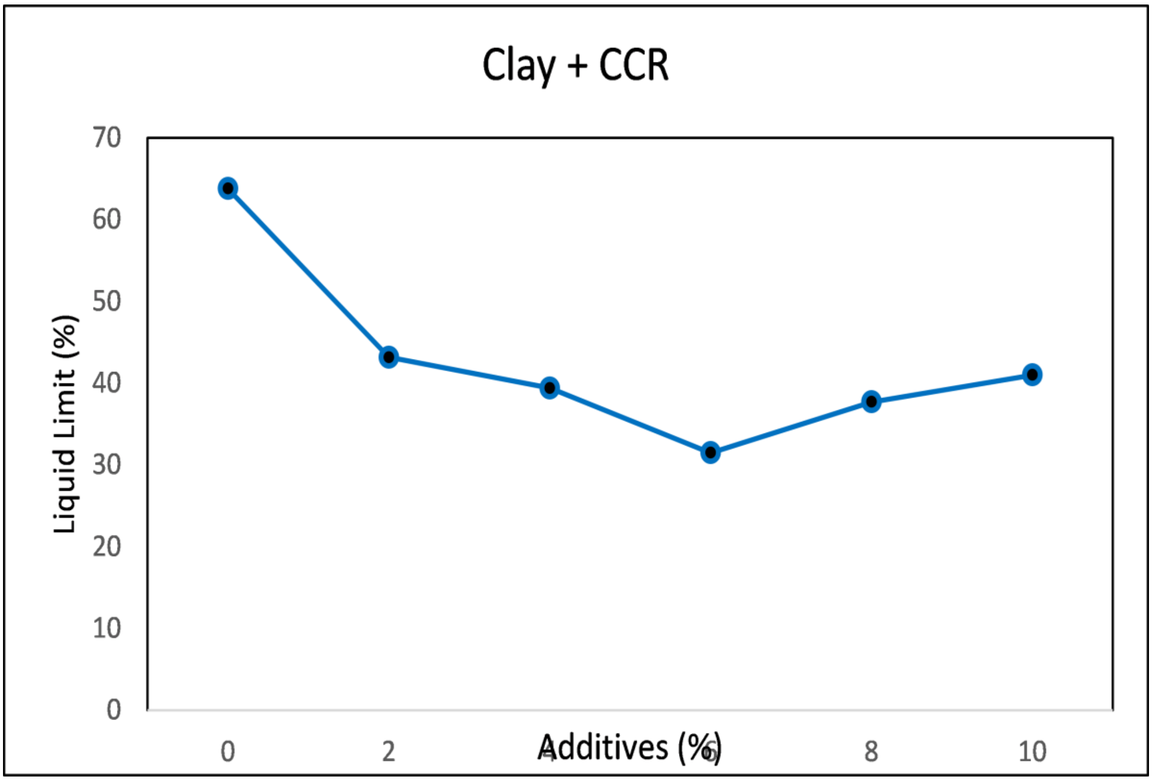

Figure 6: Variation of Liquid limit for Ozuitem Clay with increase in dosage of CCR

4.1.4. Variation of Plasticity Index for Ozuitem Clay with Increased Percentage of CCR

Plasticity index ranges from 12.14% to 23.005%. Federal Ministry of Works and Housing (1972) for road works recommend plasticity index of 10% maximum for sub-base and base materials. All the percentages of clay soil stabilized at 2-10% values are more than the maximum values recommended by Federal Ministry of Works and Housing therefore renders the soil unsuitable for use as sub-base and base materials. The minimum plasticity index was obtained at 4% CHA as shown in Figure 7.

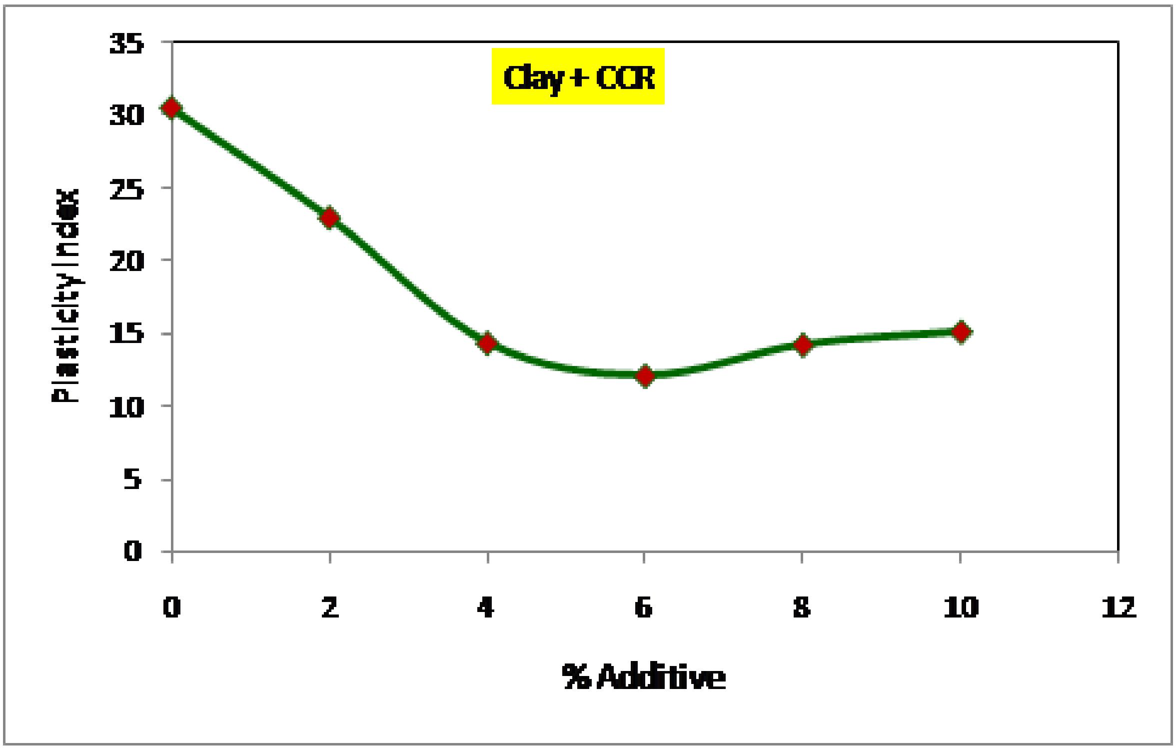

Figure 7: Variation of Plasticity Index for Ozuitem Clay with increase in dosage of CCR

4.1.5. Maximum Dry Density (MDD) for Ozuitem Clay at various percentages of CCR

Variation of Maximum Dry Density (MDD) for Clay at various percentages of CCR is presented in Figure 8. From the Figure, it can be observed that the MDD of the virgin soil is greater than that of the stabilized soil, only MDDs at 2% CCR come close to that of the virgin soil. At constant dosage of CCR, MDD of the stabilized clay soil generally decreased with increase in percentage of CCR from 1.55 g/cm3at 0% CCR to a minimum value of 1.16 g/cm3 at 4% CCR. This represents 25% decrease in MDD of the soil. The reduction in MDD of the treated soil may also be due to flocculated and agglomerated clay particles occupying larger spaces leading to corresponding decrease in dry density (Akinmade, 2008; Oyediran and Fadamoro, 2015). This observed trend of MDD variation is similar to that of lime reported by Ogbuchukwu & Okeke, 2021).

Table 5: Results of maximum dry density (g/cm3) for Ozuitem Clay with various dosages of CCR

Maximum Dry Density (g/cm3)	
Percentage	**CCR**
0	1.55
2	1.44
4	1.16
6	1.21
8	1.38
10	1.43

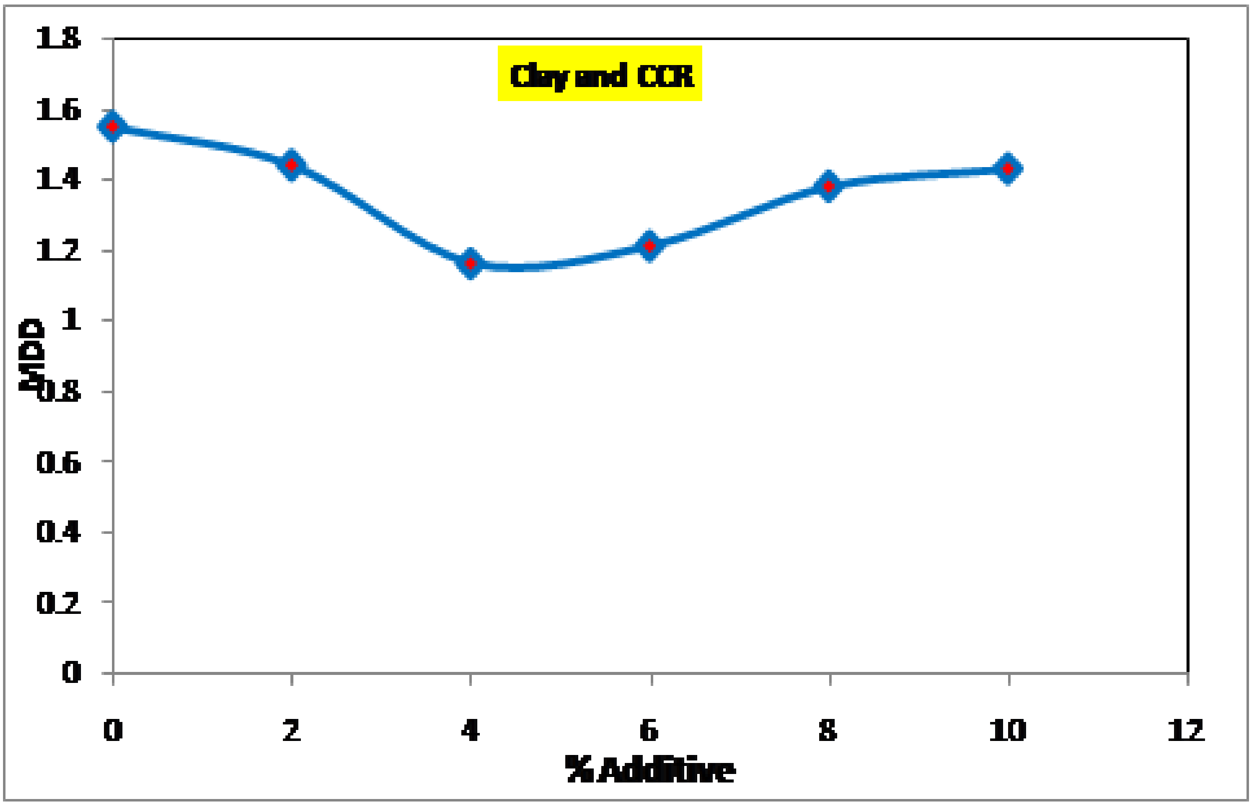

Figure 8: Variation of Maximum Dry Density for Ozuitem Clay with increase in dosage of CCR

4.1.6. California Bearing ratio (CBR) Variations for Ozuitem Clay with Higher Dosage of CCR

Additives Variations of California Bearing ratio (CBR) of the clay soil with varying dosages of CCR are shown in Figures 9. From Figure 4.16, the results of CBR (Soaked) of the stabilized soil, at 2% increased from 11.48kN/m^2 to a maximum value of 63.53 kN/m2 at 10% and CBR (Unsoaked) increased from 19.93kN/m^2 at 2% to 91.31 kN/m^2 at 10%.

The maximum strength was achieved at 10% CCR contents. It was observed that as the percentage composition of CCR increased, CBR (soaked and unsoaked) of the treated soil increased.

Table 6: Results of California Bearing Ratio test of Ozuitem Clay samples

California bearing ratio (m)		
Clay + CCR		
Percentage	Soaked	Unsoaked
0	5.0	15.0
2	7.36	19.93
4	11.48	21.27
6	24.48	41.27
8	41.05	68.46
10	63.53	91.31

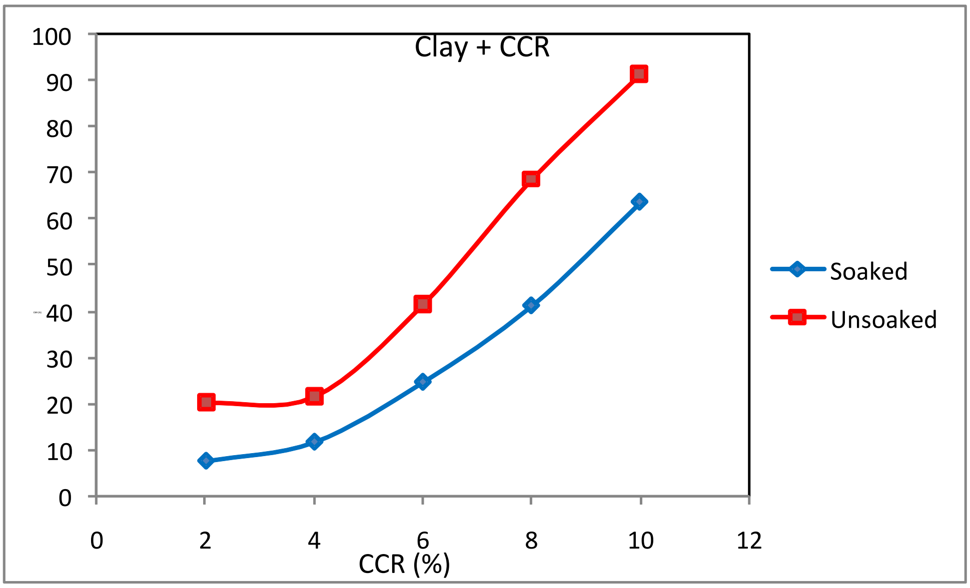

Figure 9: Variations of California Bearing ratio (CBR) values of clay with varying dosages of CCR soaked and unsoaked

4.2. Discussion

The chemical compounds that were significantly present in the CCR included Calcium oxide (65.71%), Silver oxide (27.93%), silicon dioxide (4.01%), Aluminium (III) oxide (1.68%), phosphorus pentoxide (0.32%), which together total 71.97%.

The results of the Atterberg limits tests indicate that the natural clay soil has a liquid limit of 63.8%, plastic limit of 33.25% and plasticity index of 30.55%; a high degree of expansion based on ASTM D2487-17, 2011 and Nigerian Standard FMWH, 2010 classification of soils. All the values at 2-10% except that of 6% fall under the values recommended by Federal Ministry of Works and Housing therefore renders the soil suitable for use as sub-base and base materials. All the percentages of clay soil stabilized at 2-10% values are more than the maximum values recommended by Federal Ministry of Works and Housing therefore renders the soil unsuitable for use as sub-base and base materials.

For all combinations of the clay soil and CCR, MDD decreased with increasing CCR content, as shown in Figure 8. This represents 25% decrease in MDD of the soil. This observed trend of MDD variation is similar to that of lime reported by Ogbuchukwu & Okeke, 2021).

The reduction in MDD of the treated soil may also be due to flocculated and agglomerated clay particles occupying larger spaces leading to corresponding decrease in dry density (Akinmade, 2008; Oyediran and Fadamoro, 2015).
CBR values (soaked and unsoaked) for Clay with CCR increased from 11.48kN/m^2 to 63.53 kN/m2 (soaked) and 19.93kN/m^2 to 91.31 kN/m^2 (unsoaked) respectively. The maximum Strength was achieved at 10% CCR contents. It was observed that as the percentage composition of CCR increased, CBR (soaked and unsoaked) of the treated soil increased.

5.0 Conclusion

In the laboratory, natural clay and laterite soils from Bende and Ozuitem were geotechnically analysed to assess the strength characteristics and degree of swelling behaviour. A variety of tests, such as liquid limit, plastic limit, plasticity index, optimum moisture content, maximum dry density, and California bearing ratio, were performed. The natural geotechnical properties of both soils show that, according to the ASDM classification of soils, the clay soil has a high degree of expansion.
In order to decrease the swelling behaviour and improve the soils' strength characteristics, stabilisation was carried out using calcium carbide residue at percentages of 2,4,6,8, and 10.
In Umuahia-Bende, the analysis's findings show that CCR stabilisation of expansive soils has the general effect of lowering swelling indicators (liquid limits, plasticity index), which in turn lowers the soil's swelling potential or propensity to swell when water is present. Through an increase in CBR and a decrease in MDD, CCR stabilisation functions similarly to lime stabilisation. With 6% CCR stabilisation, the lowest values of swelling indicators were attained, indicating optimal stabilisation.

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