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Stability Analysis of Cement and Residue from Spent Calcium-Carbide Stabilized Cohesive Soil.

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ABSTRACT
The stability characteristics of cohesive soil blended with Portland Limestone Cement (PLC) and Residue from Spent Calcium-carbide (RSCC) was investigated in Amalem Community, Abua, Rivers State, Nigeria. Remolded soil samples obtained at depth of 1-2 meters were mixed with PLC and RSCC and subsequently subjected to Unconfined Compressive Strength (UCS). The cohesive soil was mixed with 3%, 4%, 5% and 6% PLC content by weight of the soil and for each percentage of PLC content, 7%, 9%, 11%, 13% and 15% RSCC by weight of the soil was subsequently added. Results showed that stabilization of the soil with PLC and RSCC increased its Unconfined Compressive Strength (UCS) and bearing capacity. However, addition of more than 5% PLC and 13% RSCC caused a decrease in the UCS and bearing capacity of the sample. From the above results, the most suitable mixed proportion of PLC and RSCC with cohesive soils was 3% PLC and 15% RSCC to satisfy Stability requirements. Based on the test results, PLC and RSCC blended binds suitably for the stabilization of cohesive soils.

KEYWORDS: Cohesive soils**,** Portland Limestone Cement, Residue from Spent Calcium-carbide, Soil Stabilization, Stability.

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1. INTRODUCTION
Cohesive soils with deficient engineering properties present a great challenge to numerous construction and geotechnical engineering applications because of its high shrinkage, high compressibility, and low strength potentials (Latifi *et al.*, 2017; Rosa *et al.*, 2017; Chen *et al.*, 2017; Disfani*et al.*, 2017). In Rivers State, there is abundance of low load bearing cohesive soils, which has a substantial impact on the stability of structural foundations. Soil stabilization is one of the most effective ways to treat low-load-bearing cohesive soils to achieve the desired engineering properties while reducing construction constraints.

Portland Limestone Cement (PLC) has been used to improve the engineering properties of cohesive soil for a long time. Nonetheless, its production demands high-capital plants and expertise, resulting in high costs (Chang *et al.*, 2015; Awarri & Otto, 2022). Recently, the market price of PLC has been rising at an uncontrollable rate, making it difficult for many people to develop their properties. This has made many research efforts to focus towards utilizing cheaper and readily available local materials that are less polluting to bring the cost of soil stabilization down to an affordable rate while also alleviating the negative environmental pollution effects. These are mostly industrial by-products that are utilized as a soil stabilizing alternative binder (Yilmaz & Civelekoglu, 2009; Arulrajah *et al.*, 2017a; Bazne *et al.*, 2017; Choi *et al.*, 2017; Rosa *et al.*, 2017; Awarri & Otto, 2022).

Residue from Spent Calcium-carbide (RSCC) is a by-product of the acetylene gas production, and it has its prime element as $Ca(OH)_2$. It can be blended with siliceous materials in the process of pozzolanic reaction to give results which are comparable to that of cement hydration process. It is at little or no cost

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because it is usually discarded on landfills. One of the disposal outlets would be the use of Residue from Spent Calcium-carbide (RSCC) to improve the engineering properties of soil (Horpibulsuk*et al.*, 2012; Somna *et al.*, 2011).
This research work is intended to examine the stability (Bearing capacity) response of different blended proportions of PLC and RSCC on cohesive soil. Besides, the most suitable mix proportion of PLC and RSCC in relation to stability response to loading is eminently desirable.

2. MATERIALS AND METHODS

2.1 Materials

In this study, the clayey soil samples were obtained from Amalem Community, Abua in Rivers State, Nigeria. The Portland Limestone Cement was purchased from roadside sellers of building materials at Mile 3 market, Diobu Port Harcourt. The Residue from Spent Calcium-carbide was gotten from different vehicle mechanic workshops within Port Harcourt.

2.2 Methods

The disturbed soil samples were collected at 1.0 m - 2.0 m depth below the ground surface. These material samples were then taken to a Geotechnical and Chemical Engineering Laboratory for laboratory experiments/tests. The RSCC was first oven-dried at 100°C for 24 hrs and afterward ground in a Los Angeles abrasion machine. To remove bigger particles, the RSCC powder was passed through a 425-μm sieve. All Laboratory tests and data analysis were done in accordance with British Standard (BS 1377: 1990) and American Society for Testing and Materials (ASTM D2166-16, 2016) for soil testing.

The cohesive soil (clay) was first tested for specific gravity, Moisture content, Atterberg limit, Particle size distribution and UCS. The PLC and RSCC were tested for their specific gravity as well as their physical and chemical properties. To ascertain the various mix ratios to employ, PLC and RSCC were separately mixed with the cohesive soil. For PLC, 5%, 10%, 15% and 20% by weight of the soil were tested to obtain the most ideal and optimum PLC content needed for stabilization. Consequently 10% PLC was gotten as the optimum value to achieve stability with the cohesive soil. Similarly, RSCC was tested with 5%, 10%, 15% and 20% by weight of the soil and the optimum RSCC content obtained was 15%. However, the optimum value was not large enough to meet the requirements for stability. Upon achieving the optimum content for the PLC and RSCC for the modified cohesive soil, various percentages of cement content (3% - 6%) were used and each percentage of cement content was mixed with 7%, 9%, 11%, 13% and 15% RSCC content.

2.2.1 Unconfined Compressive Strength Test for PLC and RSCC Modified Soil

The soil sample was blended with PLC (3% - 6%) and for every percentage of the soil cement mixture, 7%, 9%, 11%, 13% and 15% RSCC was added and subjected to UCS test.

The split mould was oiled carefully from inside and samples were set in the mould with 76 mm height and 38 mm diameter as per the standard requirements. The sample was then removed from the mould and put on the bottom plate of the loading device after which the upper plate was adjusted to connect with the sample. The load dial gauge and strain dial gauge were then set to zero. Then, the sample was compressed until cracks started developing. The load readings were taken at every 20 mm deformation of the specimen. Then, the sample was loaded by bringing down the bottom plate and removed from between the two loading plates. The failure height and weight of the deformed sample was noted then a free-hand sketch of the sample after failure was drawn. Finally, the sample was placed in a porcelain evaporating dish and the moisture content was determined.

Plates 1 to 3 shows the sample preparations for UCS test of the modified soil sample, sample

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undergoing UCS test and the sample depicting a point of UCS test failure.

Plate 1: Preparation of the Modified Soil Sample for UCS Test

Plate 2: Sample Undergoing UCS Test

Plate 3: Sample Depicting a Point of UCS Test Failure

Table 1 shows that 60 samples (3 per percentage) of PLC and RSCC of varying mix proportions were prepared for UCS test.

Table 1: Number of PLC and RSCC Stabilized Soil Samples

PLC (%)	RSCC (%)	No. of Samples	Total No. of Samples
6	7,9,11,13, and 15	3	15
5	7,9,11,13, and 15	3	15
4	7,9,11,13, and 15	3	15
3	7,9,11,13, and 15	3	15
Total Samples			**60**

After obtaining the UCS values from the test, Terzaghi's bearing capacity formula as shown in Equations (2.1) to (2.4) was applied and hence the bearing capacity for each mix ratio was obtained.

Cohesion, $c_u = \frac{q_u}{2}$

UCS, $(q_u) = 2c_u$ (2.1)

The ultimate bearing capacity of any soil is given as

$Q_u = cN_c + qN_q + \frac{1}{2}B\gamma N_\gamma$ (2.2)

For cohesive soils: $\Phi = 0$, $N_\gamma = 0$, $N_c = 5.7$, $N_q = 1$

Therefore, $Q_u = cN_C + q$ (2.3)

Where.

Surcharge, $q = \gamma D_f$ (2.4)

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D_f = depth of foundation
N_c, N_q, N_γ = dimensionless numbers called bearing capacity factors.

3. RESULTS AND DISCUSSION

3.1 Index Properties of Amalem Cohesive Soil

Table 2 shows the index properties of Amalem cohesive soil which helps in the identification and classification of the soil for general engineering purposes. Table 3 shows the physical and chemical properties of PLC and RSCC.

Table 2: Index Properties of Amalem Cohesive Soil

Property	Values
Moisture content (%)	23.65
Bulk density (kN/m^3)	20.59
Specific gravity	2.4
Liquid Limit (%)	33.2
Plastic Limit (%)	9.36
Plasticity index (%)	23.84
UCS (kN/m^2)	65.32
Bearing Capacity (kN/m^2)	68.05
USCS	CL
AASHTO Classification	A-6

Table 3: Physical and Chemical Properties of PLC and RSCC

Property	PLC	RSCC
Specific gravity	3.05	2.02
pH	11	12.20
CaO (%)	64	61.41
SiO_2 (%)	20.40	2.69
Al_2O_3 (%)	5.75	1.78
Fe_2O_3 (%)	2.50	0.17
MgO (%)	1.94	0.80
SO_2 (%)	2.75	0.36
LOI (%)	1.20	32.51

Amalem cohesive soil was viewed as A-6 and CL soil by the AASHTO and Unified soil classification systems respectively (USCS). The UCS and bearing capacity properties of Amalem cohesive soil shows that it is a soft clay/silt since it is less than 75kN/m^2. Hence, there is need for stabilization of the soil to make it suitable for developments.

3.2 Unconfined Compressive Strength of PLC and RSCC Modified Cohesive Soil

The typical UCS test results from the different blends of PLC (3% - 6%) and RSCC (7% - 15%) stabilized cohesive soil is introduced in Table 4. Nonetheless, Figure 1 shows the behaviour of the cohesive soil for every percentage of PLC and its varying RSCC content, while Figure 2 is a bar chart showing the pictorial view of the behaviour.
The UCS of 65.32kN/m^2 shows that the soil is a medium soft clay. Upon the addition of PLC and RSCC content, the UCS increased and was improved to stiff and very stiff clay.
Addition of over 5% PLC and 13% RSCC caused a reduction in the UCS. This is because increased content of PLC and RSCC formed a gel-like material which made the soil structure to be more porous which counteracts the strength acquired by cementation and hence reduced the bond in the cohesive soil and the modifiers.

Table 4: UCS and Bearing Capacity Values for Unmodified and Modified Soil Samples

PLC Content (%)	RSCC Content (%)	UCS (kN/m^2)	Bearing Capacity (kN/m^2)
0	0	65.32	68.05
	7	84.78	87.22
	9	92.13	94.31
3	11	104.42	106.08
	13	119.45	120.44
	15	128.79	129.33
	7	140.53	140.27
	9	154.40	153.58
4	11	165.29	163.97
	13	174.49	172.48
	15	184.19	181.62

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	7	191.29	188.59
	9	205.77	202.50
5	11	213.99	210.42
	13	219.00	214.73
	15	208.38	204.75
	7	199.86	196.62
	9	193.00	190.22
6	11	178.18	175.89
	13	155.54	154.33
	15	118.79	118.69

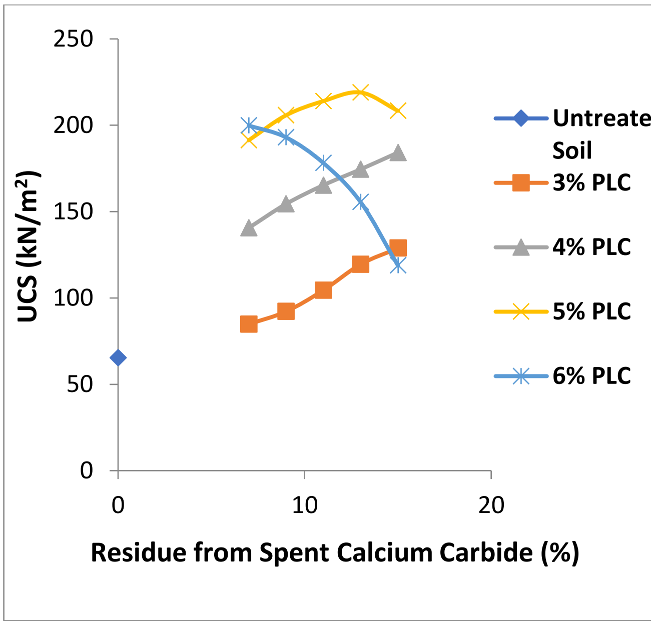

Fig 1 UCS of PLC and RSCC Modified Cohesive Soil

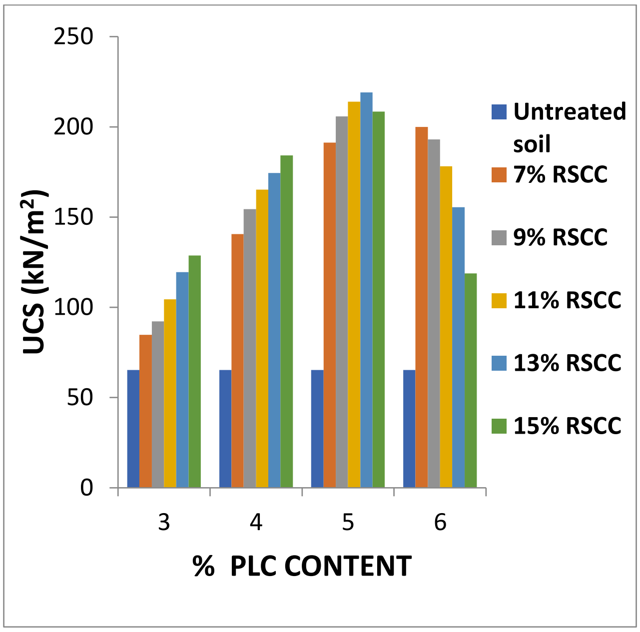

Fig 2 Bar Chart showing UCS of PLC and RSCC Modified Cohesive Soil

3.3 Bearing Capacity of PLC and RSCC Modified Cohesive Soil

The Bearing capacity results from the UCS test on different combination of PLC (3% - 6%) and RSCC (7% - 15%) stabilized cohesive soil and with the utilization of equations (2.0) – (2.4) is shown in table 4 above. Figure 3 and 4 below shows behaviour of the cohesive soil for each percentage of PLC and its varying RSCC content. The bearing capacity results followed the same trend with that of the USC result as it was seen that it increased with increase in PLC and RSCC content.

This suggests that the addition of RSCC improved on the stability/bearing capacity of the cohesive soil from a condition of soft clays and silts (68.05kN/m^2) to firm clay and stiff clays (87.22kN/m^2 - 214.73kN/m^2). Further addition of over 5% PLC and 13% RSCC caused a reduction in the bearing capacity, and this is because of the same reason as that of UCS above.

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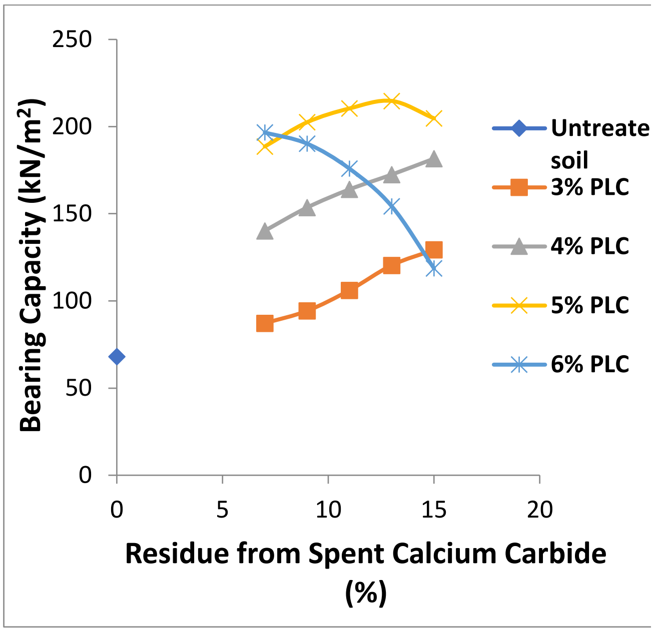

Fig 3 Bearing Capacity of PLC and RSCC Modified Cohesive Soil

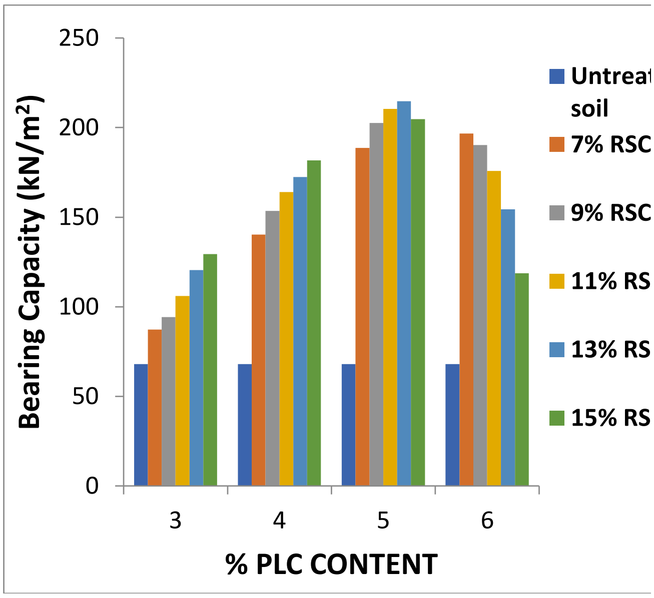

Fig 4 Bar Chart showing Bearing Capacity of PLC and RSCC Modified Cohesive Soil

The results show that the most suitable blended proportion of PLC and RSCC in relation to Stability (Bearing capacity) considering minimal expense and decrease in environmental pollution is 3% PLC and 15% RSCC.

4. CONCLUSION

In the light of this research, the accompanying conclusions were made

i. The modified cohesive soil in relation to UCS and Bearing Capacity performed better compared to the unmodified soil sample. Thus, RSCC and PLC blend improved the cohesive soil.

ii. The most suitable blended proportion of PLC and RSCC on cohesive soils in terms of UCS and Bearing capacity is 3% PLC and 15% RSCC.

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