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Geotechnical Properties of Expansive Soil Stabilized with Periwinkle Shells Powder

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Abstract: This research investigates the effect of stabilizing with Perinwinkle Shell Powder (PSP) on the geotechnical properties of expansive soil. A comparison of the stabilization effect of PSP to that of commonly use Ordinary Portland Cement (OPC) on the expansive soil sample was also carried out. Preliminary test was carried out on the un-stabilized soil samples for the purposes of identification and classification, i.e, natural moisture content, specific gravity, liquid limits, plastic limits, plastic index after which engineering tests such as compaction and California Bearing Ratio (CBR) tests on the expansive soil at its natural un-stabilized state. The engineering tests was repeated on the soil samples stabilized with 2-10% PSP and OPC, respectively. Cement as expected shows a progressive increase in the Maximum Dry Density (MDD) of the soil sample from 1875-2294 kg/m^3 from 2-10%, respectively. This represent 22% increase in the MDD from the un-stabilized state. For PSP, the Maximum MDD was recorded at 6% PSP addition with a value of 1974 kg/m^3, representing a mere 5.3% increase in MDD of the soil from the un-stabilized state. For both stabilizing agent the Optimum Moisture Content (OMC) increases from 13.65-13.83% and from 11.72-14.41% for cement and Periwinkle Shell powder, respectively. For PSP CBR from 5.8-19.7%. Periwinkle Shell powder is therefore a fairly good stabilizer for expansive soil.

Key words: Periwinkle shell powder, geotechnical property, expansive soil, stabilization un-stabilized state, expansive soil

INTRODUCTION

Soil can be defined as the solid material on the Earth's surface that results from the interaction of weathering and biological activity on the parent material or underlying hard rock (Braja, 2010). Soil is used as a construction material in various civil engineering projects and it supports structural foundation. It is note-worthy to state that not all soil are suitable for construction in their natural states.

Soils with properties that make them unsuitable for construction of engineering structures in their natural state are generally known as problematic soil (Ola, 1978). problematic soils could either be expansive soil or collapsible soil.

Expansive soil as a problematic soil is characterized by clayey materials and when used for engineering purposes without treatment could result into structural cracks in building foundations heaving and cracking of floor slabs, walls, sidewalks, driveways and patios. Heaving and cracking of paved surfaces, jammed doors, sticky or hard to open windows, ruptured pipe lines and other underground infrastructure.

In Nigeria, clay minerals is predominantly present in most sub grade materials, making expansive soils problems very common. Clays exhibit generally undesirable engineering properties characterized by low shear strengths which is further lost upon wetting or other physical disturbances.

Clay can be plastic and compressible and they expand when wetted and shrink when dried. Some types expand and shrink greatly upon wetting and drying, this is a very undesirable feature. Cohesive soils can creep over time under constant load, especially when the shear stress is approaching its shear strength making them prone to sliding.

The above accounts for the need for problematic soil geotechnical properties to be improved before they are used for engineering purposes otherwise they are bound to cause damages when used in their natural state. This improvement is usually done by stabilization. There are three purposes for soil stabilization which includes; strength improvement, dust control and soil water proofing (Amu and Adetuberu, 2010).

Soil stabilization: is the alteration of soils to enhance their physical properties and increase the shear strength of a soil, control its shrink-swell properties and improve its load bearing capacity. Oyediran and Kalejaiye (2011)

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defines soil stabilization as a means through which soil properties are enhanced and made more apt for construction purpose, the process can either be mechanical, chemical and sometimes biological.

Stabilising a soil implies the modification of the properties of a soil, this means that the three phases present in the soil are modified, i.e., the solid phase which is the mineral particles, the liquid phase which denotes the moisture content of the soil and the gaseous phases which is the void or air present in the soil are all modified in the process of soil stabilization to obtain desirable lasting properties which are compatible with a particular application.

Soil stabilization aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together, water proofing the particles or combination of the two (Sherwood, 1993). The commonly used stabilizing agents are cement, lime, fly ash, bitumen or combination of these, application of these application of these stabilizing agents to a usually results in a stabilized soil whose materials have a higher strength, lower permeability and lower permeability and lower compressibility than the native un-stabilized soil.

For expansive soils chemical stabilization for soil property improvement consists of changing the physicochemical environment around and inside clay particles, changing the nature of the water that alternately moves into and out of the voids, thus, effecting behavioural changes in the soil mass as a whole. Chemical stabilization aims at making the clay require less water to satisfy the charge imbalance, making it difficult for water to move into and out of the system, flocculating the clay to cause aggromulation and perhaps, cementing particles together to reduce volume change.

Periwinkle shell powder as a pozzollan: Pozollan in itself possess little or no cementitious value but when finely grounded in a powdery form or processed into liquid will chemically react with calcium hydroxide in the presence of moisture at room temperature to form permanent insoluble compounds possessing cementitious properties. Pozzolans generally are siliceous or/and aluminous materials which could either exist naturally like volcanic ash, opaline shale, tuff pumicite. Pozzollans can also be created artificially like the one used in this research work Periwinkle Shell Powder (PSP) obtained by the processing of empty Periwinkle shells into powder. Other artificial pozollans are Pulverised coal Fly Ash (PFA), Metakaolin (calcined clay), Ground Granulated Blast furnace Slag (GGBS) and silica fume.

Periwinkle shell powder is obtained by processing Periwinkle shells which is a waste product generated from the consumption of a small greenish-blue marine snail (periwinkle). The periwinkle snail is housed in a V shaped spiral shell, found in Lagos, Badagry, Port Harcourt, Calabar, Ikot Abasi and many other coastal communities in Nigeria. The periwinkle shell is a very strong, hard and brittle material (Fig. 1).

Fig. 1: Periwinkle shells

The people in the coastal areas mainly consume the edible part as sea food while disposing the shell as a waste, though few people utilize the shell as coarse aggregate in concrete in areas where there are neither stones not granite for purposes such as paving of water logged areas, etc. but a large amount of these shells are still disposed as waste and with disposal already constituting a problem in areas where they cannot find any use for it and large deposits have accumulated in many places over the years. It is with this view that this research seeks to investigate its use as a stabilizing materials for expansive soil. The crave for an alternative (either partially or wholly) to expensive ordinary Portland cement that would be cheaper, suitable and readily available is another thrust upon which the research work is based.

MATERIALS AND METHODS

The materials used for this study were:

- Periwinkle shells
- Ordinary Portland cement
- Expansive soils
- Water

Periwinkle shells was obtained from market women at the Sunday market Ogba. The shells were thoroughly washed in warmed water to removed traces of the periwinkle oysters from the shells, the washed periwinkle shells was sun dried and oven dried to ensure complete dryness after which it was milled to powder. The resulting powder was sieved through 75 μm to obtain fine powder. It was ensure that the Periwinkle shell powder is kept air tight before and after use to prevent contaminations through moisture and others materials in the atmosphere.

Expansive soil was obtained from mesan village along Oko-Omi at Iju-Ota of Ogun state and stored in jute bags and taken to the Geotechnical Laboratory of Covenant University. The expansive soil was collected at a depth not <1 m below the natural ground level indicating the sampling depth and date of sampling.

Water was obtained from the taps in the geotechnical laboratory of Covenant University. The expansive soil sample was air dried for 5 days to allow for partial elimination of its natural water which may affect the analysis, the sample was then sieved using sieve size 4.75 mm to obtain Table 1. The final soil sample for the tests. Preliminary tests like natural moisture content, specific gravity and Atterberg's limits were performed on the expansive soil samples for classification and identification purposes (Fig. 2).

Fig. 2: Sample preparation

Table 1: Preliminary test summary

Preliminary test summary of expansive soil sample	Values
Natural moisture content	28.0
Specific gravity	2.70
Liquid limit (%)	28.0
Plastic limit (%)	20.4
Plasticity index (%)	7.60
AASHTO classification	A-4-5
UCS (Unified Classification System)	Silt-Clay (SC)

Ordinary Portland Cement (OPC) was then added to the soil samples in 2-10% by weight of the soil sample. Atterberg's limits, compaction and California Bearing Ratio (CBR) was carried out on the stabilized samples. This stabilization process was repeated using Periwinkle Shell Powder (PSP) on the soil samples in 2-10% by weight of the soil. Atterberg's limits test, compaction, California Bearing Ratio (CBR), tests were also repeated while the result obtained using PSP as a stabilization agent was compared with that obtained using OPC as the stabilization agent.

RESULTS AND DISCUSSION

Table 1 shows the results of the initial tests on the soil sample without any stabilization agent added, the soil has a plasticity index of 7.6 and is classified as an A-4-5 from the AASHTO table of classification while it falls within the silt clay soil classification in the unified classification system.

The chemical composition of Periwinkle Shell Powder (PSP) and ordinary Portland cement is presented in Table 2, the table shows that PSP is a pozzollan since, it has constituent's elements that can react with CaO to form permanent compounds in the presence of moisture.

Table 2 aslo shows a remarkable similarities in the constituent's elements of OPC and PSP though the percentages composition differs, this accounts for the cementitious characteristics of PSP.

From Table 3 and 4, it shows that the maximum dry densities of the expansive soil increases as the percentages of the stabilization agent increases, however,

Table 2: The remarkable similarities

Elemental oxides	Cement (OPC) (%)	PSP (%)
SiO_2	21.40	33.84
Al_2O_3	5.03	10.20
Fe_2O_3	4.40	6.02
CaO	61.14	40.48
MgO	1.35	0.48
K_2O	0.48	0.14
Na_2O	0.24	0.24
TiO_2	0.37	0.03
$P2O_5$	0.00	0.01
SO_3	2.53	0.26
LOI	1.29	7.60

Table 3: Summary of the atterberg limit tests

Cement stabilization (%)	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	PSP Stabilization (%)	Liquid Limit (LL)	Plastic Limit (LL)	Plasticity Index (PI)
2	28	8.77	19.23	2	28	17.34	10.26
4	28	18.88	9.12	4	25	15.54	9.46
6	28.5	20.58	7.92	6	25	20.52	4.48
8	29	16.03	12.97	8	27	15.92	11.08
10	28	20.01	7.99	10	26	17.08	8.92

Table 4: Summary of the compaction test

Cement stabilization (%)	Cement optimum moisture content (%)	Cement max. dry densities (kg/m^3)	Stabilization PSP (%)	PSP optimum moisture content (%)	PSP max.dry densities (kg/m^3)
2	12.65	1895.95	2	11.72	1883.63
4	13.08	1957.17	4	12.62	1908.40
6	13.71	1994.41	6	13.58	1994.96
8	14.68	2170.15	8	13.74	1892.46
10	15.83	2294.48	10	14.41	1867.80

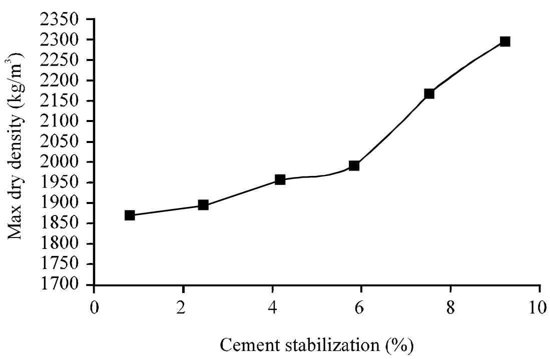

Fig. 3: Max dry densities vs. % cement stabilization

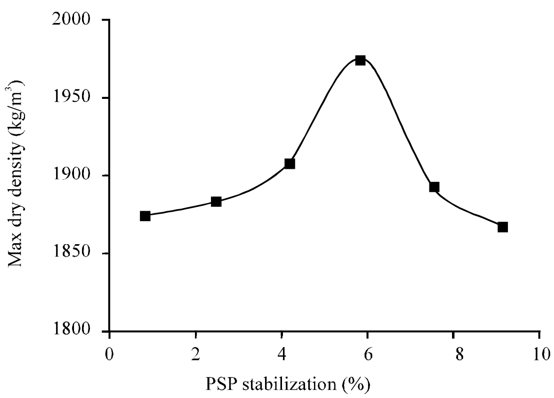

Fig. 4: Max dry densities vs. % PSP stabilization

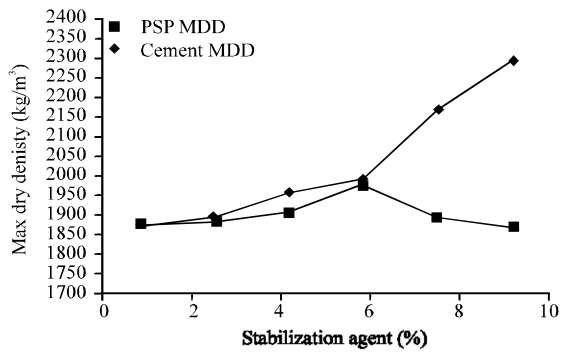

Fig. 5: Cement max dry densities vs. % PSP max dry densities

at 6% the peak MDD was reached for PSP as further increase to 8 and 10% leads to a reduction in the soil MDD to 1892.46 and 1867.80 kg/m^3, respectively.

The trend is however, different in OPC as the expansive soil MDD kept increasing from 1895 kg/m^3 at 2% to 2294 kg/m^3 at 10%, respectively, showing that it is a better stabilizing agent than the PSP (Fig. 3-5).

CONCLUSION

From the analysis and results discussion above, it was concluded that Periwinkle shell powder is a fairly good stabilizer for the enhancement of the geotechnical properties of expansive soils.

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