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Stabilization of Expansive Clay Using Powdered Glass with Cement as Catalyst

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Abstract

Geotechnical properties of soil is targeted at providing stable and durable engineering structures. It becomes necessary to gain the knowledge of when materials intended for foundation and pavement construction will fail or pass in meeting the requirement in civil engineering practice. This study intended to investigate the potentials of using glass powder and cement at varying percentages to stabilize expansive clay. Soil samples obtained from Gombe State was used in this study which after some tests, the soil was found to have the following properties. Natural moisture content of the soil was found to be 10.47% and the specific gravity (Gs) of the clay was found to be 2.64, the natural soil has a liquid limit of 35.8% and a plastic limit of 27.8%. After compaction, the natural soil has a maximum dry density of 2.37Mg/m^3 and an optimum moisture content of 25%, after incorporating the additives, the peak values of MDD was obtained at 6% glass powder keeping cement constant at 3% which gave a value of 2.90 Mg/m^3 with an OMC of 44% also the maximum California bearing ratio value was also obtained at 6% glass powder with a value of 9.22% and the unconfined compressive strength of the soil also attains its highest values at 6% with values of 0.31 N/mm^2 and 0.33N/mm^2 at 3 and 7 days curing age respectively. The study reveals that cement and glass powder can significantly improve the engineering properties of expansive clays.

Keywords: Powdered glass, Cement, Expansive soil, Geotechnical Properties, Stabilization.

Introduction

Expensive clay is a clay soil that is prone to large volume changes (swelling & shrinkage) that an directly related to changes in water content. Clay soil can be stabilized by the addition of percentage by weight of lime and other materials. then by enhancing many of the soil and producing an improved construction material. Clay with high expansive mineral can form deep cracks in driver season or gears, such soil are called vertisols.

With the growing demand for space utilization there are also increasing number of incidence of structured damages which, can be accompanied by collateral losses, uncertainty associated with the design and planning of structures play a role in such failure. Design uncertainty related to unknown soil properties are among the most important. Soil humus as a result of agricultural activities on meth depreciated the soil properties. Water deposit as a result of rainfall and low penetration ability of the soil increased it moisture content well above water table causing waterlogging. Climate conditions have contributed to the soil strength deficiency such climatic factors are temperature, rainfall and cold. As temperature changes it influences the shear strength of the soil. After rainfall the stability of soil have been influence by an increase in water content, as water in soil freezes it expands, pushing soil particles apart. This opens pore spaces for air, as water thaws, pore spaces tend to remain temporarily.

Statement of Problem

The presence of the expansive clay also known as shrink-swell or swelling soils in Gombe State where semi and clay soils are predominant has caught many builders unawares.

Swelling or expansive clay are those that comprise swelling clay minerals such as montmorillonite (Smectite), which expand when the soil changes. In addition, expansive soil have high degree shrink-swell reversibility with change in moisture content.

A large number of structure especially light-weight structure found on these expansive soil have met with widespread problems associated with serviceability performance mainly in the form of cracks or permanent deformation.

The purpose of the study is to carry out laboratory studies on soil samples collected from the study area to determine the strength properties of the soil, and check the effect of broken Glass and cement on geotechnical properties of the soil.

LITERATURE REVIEW

SOIL STABILIZATION

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). Usually, the technology provides an alternative provision structural solution to a practical problem. The simplest stabilization

processes are compaction and drainage (if water drains out of wet soil it becomes stronger). The other process is by improving gradation of particle size and further improvement can be achieved by adding binders to the weak soils (Rogers et al, 1993). Soil stabilization can be accomplished by several methods. All these methods fall into two broad categories (FM 5-410) namely;

Mechanical stabilization

Under this category, soil stabilization can be achieved through physical process by altering the physical nature of native soil particles by either induced vibration or compaction or by incorporating other physical properties such as barriers and nailing. Mechanical stabilization is not the main subject of this review and will not be further discussed.

Chemical stabilization

Under this category, soil stabilization depends mainly on chemical reactions between stabilizer (cementitious material) and soil minerals (pozzolanic materials) to achieve the desired effect. A chemical stabilization method is the fundamental of this review and, therefore, throughout the rest of this report, the term soil stabilization will mean *chemical stabilization.*

Through soil stabilization, unbound materials can be stabilized with cementitious materials (cement, lime, fly ash, bitumen or combination of these). The stabilized soil materials have a higher strength, lower permeability and lower compressibility than the native soil (Keller bronchure 32-01E .

Use of Stabilization

The primary use of stabilized soil mixture at the present time is in the basic and sub-base construction. A stabilized soil base or sub-base may provide the support for a relatively thin wearing surface that will be subject to light or moderate amounts of traffic or it may function as a base for a high type pavement that will be subjected to a very high volume of traffic. Stabilized soil mixtures also tend themselves to the process of stage constructions, which involves the gradual

Several studies have been carried out on soil stabilization using different stabilizing agents

Eberemu et al.(2012) had investigated the stabilizing effects of glass cullet on engineering properties of expansive soil. The glass cullets added were from 5-20% at an increment of 5%. With increase in percentage addition of glass cullet, there was continuous decrease in wL, wP, OMC, C, Ps and continuous increase in Ip, specific gravity (G), MDD, UCS, Ø, hydraulic conductivity and CBR.

Ene and Okagbue (2009) had examined the stabilizing effects of pyroclastic rock dust on expansive soil .The pyroclastic rock dusts added to soil were 4%, 8% and 12% by dry weight of the soil. A significant reduction in plasticity and Ls with increase in percentage of rock dust was found out. MDD, OMC, shear strength and CBR values were increased with increase in percentages of rock dusts. At 8 % of rock dust addition, the optimum value of CBR was obtained.

AI-Azzo (2009) had studied the stabilizing effect of crushed limestone on engineering properties of expansive clayey. Different percentages of crushed limestone dusts added were 2, 4, 6, 8 and 10%.It was found that there was reduction in the plasticity of the clay and significant decrease in expansion.
Ogbonnaaya and IIIoabachie (2011) had examined the stabilizing effect of granite dust on expansive soil. The percentages of granite dusts added were from 10 to 20% at an increment of 5%. It was found that with increase in percentage of addition granite dust, there was continuous decrease in wL, Ls, OMC, C, continuous increase in wP, MDD, unsoaked CBR and Ø.
Ijimdiya et al. (2012) had also studied the effect of groundnut shell ash on wL, wP, compaction properties, unsoaked CBR and UCS of expansive soil. The doses of groundnut shell ash were 0 to 10% at an increment of 2%. Though 10% addition of groundnutshell ash increased wL, decreased both wP and IP, the peaked CBR and UCS at 7 days curing were obtained at 8% of groundnut shell ash which was not a very significant increase.

MATERIALS AND METHOD

Materials

Broken glass (glass powder): The glass bottles used for this study were obtained from Cocacola's Bottling depot, Gombe State. They were washed, dried, broken down manually and passed into Loss Angels abrasion testing machine for further grinding.
Cement: Ordinary Port-land Cement was use for the research work.
Expansive clay: the expansive clay soil was collected from Gombe after removing the top soil and excavating to a depth of about 1.5m, for both disturbed and undisturbed samples.

METHODS

Sample preparation

The samples for testing were prepared according to American standard for Testing. The expansive soil sample was first sieved through the required sieve number (200) for the test. The required amount of soil was weighed out for the test. The broken glass material to be added was grinded using loss Angels abrasion testing machine and passed through sieve number (200), it was then added to the soil in different percentages of 2%, 4%, 6%, 8% and 10% while cement remains constant at 3%. The soil and the material were mixed together in dry conditions thoroughly before testing. The mixed samples were then used for performing the various tests.

Index properties tests

The various index properties test like Specific gravity, moisture content, Attergber limit (Liquid limit test, Plastic limit, shrinkage limit test) were conducted on the expansive soil.

Engineering properties tests

The various Engineering properties test like compaction test, unconfined compressive strength (UCS) and California Bearing Ratio tests were conducted on the expansive

soil without additives (control) and with additives at various percentages of 2%, 4%, 6%, 8% and 10%.

California Bearing Ratio (CBR)

It measures the shearing resistance, controlled density and moisture content.
The CBR value is the resistance to a penetration of 2.5mm of a standard cylindrical plunger of 50mm diameter, expressed as percentage of the known resistance of the plunger to 2.5mm in penetration in crushed aggregate, (taken as 13.2KN). The test was carried out based on BS 1337: part 4: 1990.

Compaction Test

The densification of soil with mechanical equipment thereby rearranging the soil particles which makes them more closely packed resulting in an increase of the ratio horizontal effective size to the vertical effective stress.. To obtain the relationship between compacted dry density and the soil moisture content of varying percentage. This test is to determine the maximum dry density (MDD) and the optimum moisture content (OMC) with a given compaction effort.

Unconfined Compressive Strength Test

Unconfined Compression Test (UCS) is a simple laboratory testing method to assess the mechanical properties of rocks and fine-grained soils. the unconfined compressive strength test may be defined as the compressive strength at which an unconfined cylindrical specimen will fail in a simple compression test. The test was conducted according to BS 1924: Part Section4.

RESULTS AND DISCUSSION

General Classifications of the soil

The geotechnical index properties of the tropical soil before addition of stabilizers are shown in Table 1. The overall geotechnical properties of the soil classified as A-7-6 in the AASHTO (1986) classification system, shows that it falls below the standards recommended for most geotechnical construction works and would therefore require stabilization.

Table 1: Properties of the soil before stabilization.

Characteristics	Description
Natural moisture content (%)	10.47
Percent passing B.S sieve. NO. 200 (%)	59.8
Liquid limit (%)	35.8
Plastic limit (%)	27.8
Plasticity index (%)	8.0
AASHTO classification	A-7-6
Maximum Dry Density kg/m^3	2.37
Optimum Moisture Content (%)	25
Unconfined Compressive strength 3 days (N/mm^2)	0.12
Unconfined Compressive strength 7 days (N/mm^2)	0.16

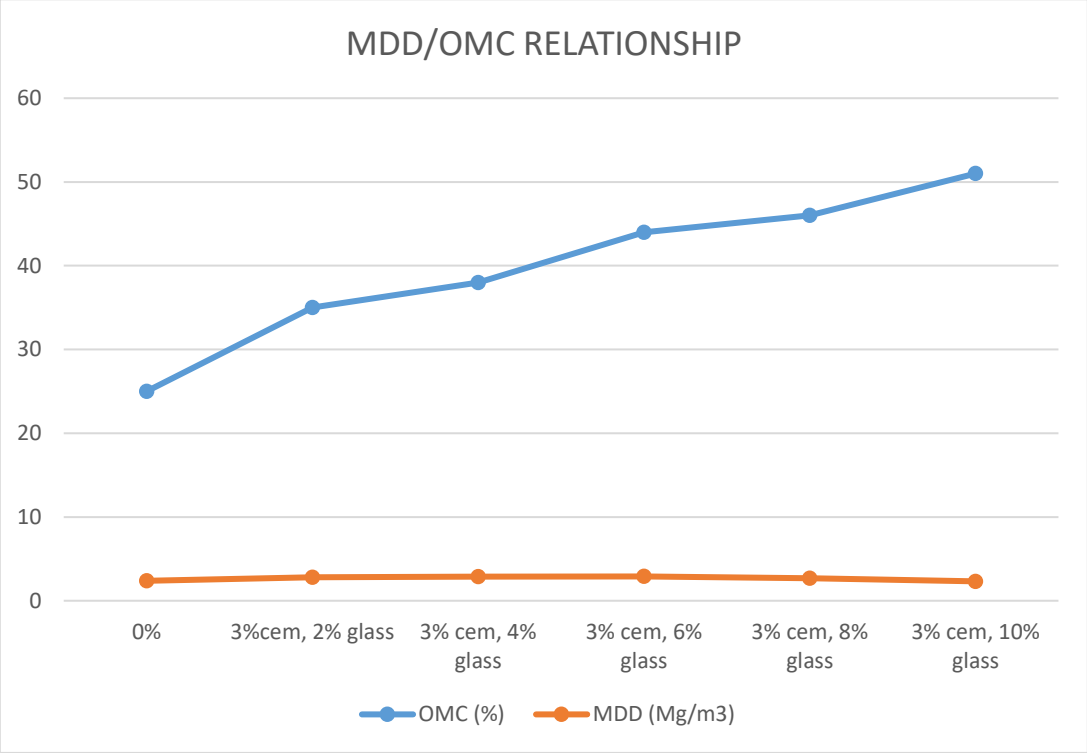
California Bearing Ratio (%)	2.88
Specific gravity	2.64

Compaction Test

Table below summarizes the compaction test results for the expansive soil with and without the powdered glass as well as cement base.

Table 2. Summary of MDD and OMC Values at Different Additives Proportions.

% addition	Control	2% glass 3% cem.	4% glass 3% cem.	6% glass 3% cem.	8% glass 3% cem.	10%glass 3% cem.
OMC (%)	25.02	35.3	38.05	44.0	46.01	51.1
MDD (kg/m^3)	2.37	2.79	2.87	2.90	2.67	2.32



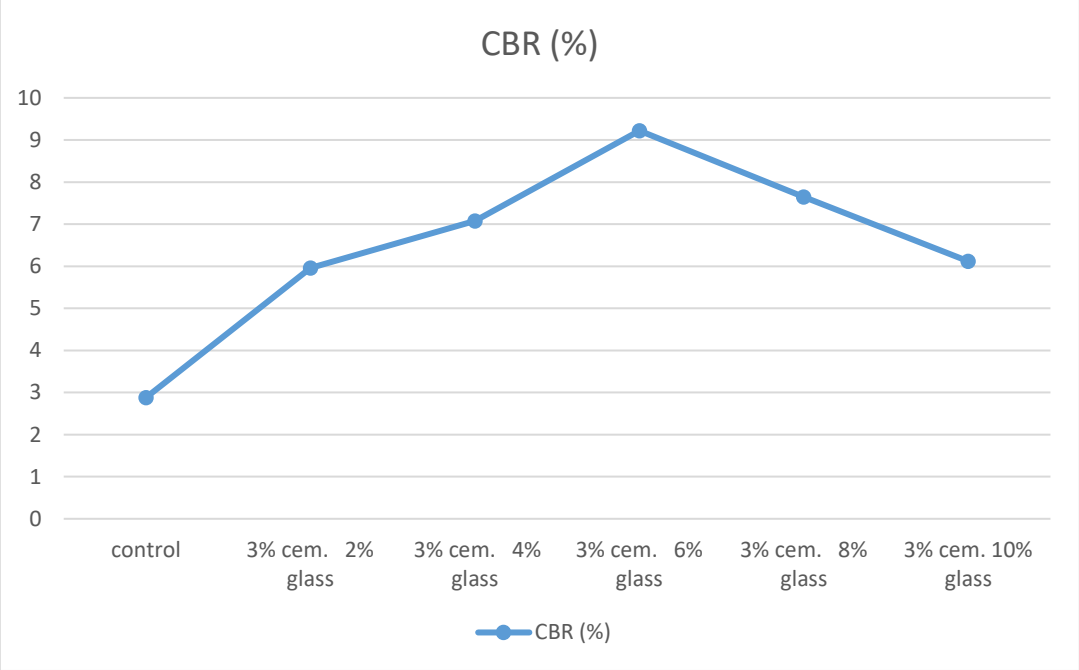
Graph of OMC/MDD relationship with 3% constant cement and varying proportions of glass powder.

From the above graph, its clearly shown that cement is kept constant at 3% and the glass powder varies. The compaction result indicates that the maximum dry density increases with increase in glass powder content up to 6% which gives a value of 2.90Mg/m^3 then from there it continue to decrease with increase in the glass powder content, while the optimum moisture content increases with increase in the glass and constant cement powder content.

California bearing ratio test

Tables 2 give a summary of the CBR values for the control and treated samples at 2.5 mm and 5 mm penetrations.

% glass and cement added	Control	2% glass 3% cem.	4% glass 3% cem.	6% glass 3% cem.	8% glass 3% cem.	10%glass 3% cem.
CBR Value(%)	2.88	5.96	7.08	9.22	7.65	6.12



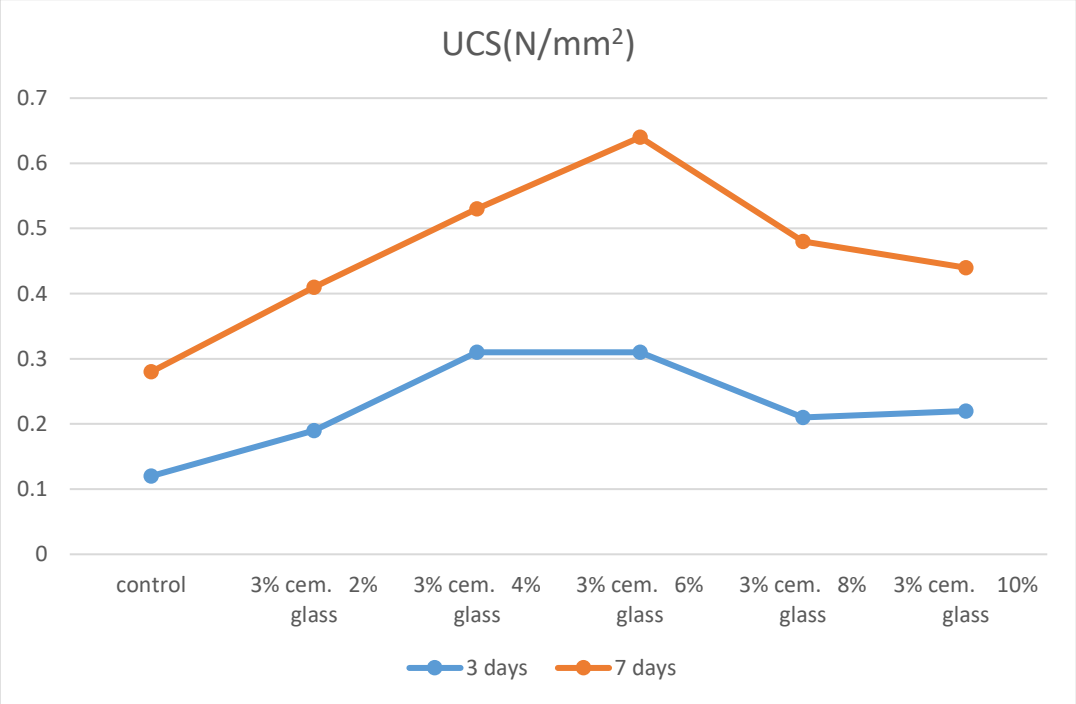
Graph of CBR against varying percentages of glass with constant additives

It can be observed that the powdered glass treated samples have greater CBR values than the untreated (control) samples. In addition, the CBR values increase with increasing powdered glass (cement kept at 3% constant) content up to 6% by mass of the soil after which the values began to drop. Consequently, the highest CBR values for the treated sample of 9.22% were obtained at 6% glass powder content, 3% cement (base) content and at 5 mm penetration.

Unconfined Compressive Strength (U.C.S)

Unconfined compressive strength test was also conducted on the natural soil and also the soil treated with glass and constant 3% cement at different curing ages of 3 and 7 days and the result obtained is as follows:

Percentage Additive Added	U.C.S Values (N/mm^2)	
	3 Days	**7 Days**
0%	0.12	0.16
2%	0.19	0.22
4%	0.31	0.22
6%	0.31	0.33
8%	0.21	0.27
10%	0.22	0.22



Graph showing variation in UCS values with varying percentages of additives for 3 and seven days respectively.

From the graph above, it's clearly indicated that the UCS increases with increase in the additive content up to 6% where a UCS values of $0.31N/mm^2$ and $0.33N/mm^2$ at 3 and 7 days respectively before it started decreasing.

CONCLUTION AND RECOMMENATION

Conclusion

This study has shown that the improvements in the properties of the expansive soil obtained herein are more significant with the addition of the powdered glass and cement. The percentage quantity of the powdered glass and cement required achieving the best results in terms of the expansive soil properties lies can be found at 6% by

mass of the soil and additives. This is because the corresponding maximum values from both the compaction and CBR tests were obtained at 6% glass and cement powder contents.

Furthermore, it can be concluded based on the results obtained that powdered glass with 3% can be effectively be used as a soil stabilizer since it was able to produce considerable improvements in the properties. Such improvements include an increase in the MDD value from 1.74 kN/m3 for the control sample up to 2.90 kN/m3 for the sample containing 6% powdered glass and cement by mass, achievement of the highest CBR values of 9.22% obtained at 6% powdered glass and cement content for the treated samples respectively as well as achievement of the maximum values of unconfined comprehensive strength of 3 and 7 days respectively obtained at 6% powdered glass an cement content.

Recommendation

This study reveals that 3% cement and 6% glass powder can significantly improve the engineering properties of expansive clays as seen from the driven conclusions.

The compaction result indicates significant improvement from 2.3774kg/m^3 to 2.90kg/m^3, califonia bearing ratio from 2.88% to 9.22% and the UCS from 0.12N/mm^2 to 0.31N/mm^2 and 0.16N/mm^2 to 0.33N/mm^2 for 3 and 7 days respectively all at 6% of the additives.

It is recommended that further research should be carried out to determine the optimum amount of this additive for effective clay soil stabilization. The effect of the powdered glass with cement on other kinds of soils such as laterites should also be investigated to determine whether similar results will be obtained which will help to establish it as an all-round or general soil stabilizer.

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