Structural Behaviour of Low Shear Strength Soil Stabilised by Bone Ash and Sodium Chloride

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Abstract- *Most failures of soil have been attributed to poor shear strength. Subsequently, the current paper inspected the suitability of cattle bone ash and sodium chloride as a possible stabilizer to improve the shear strength of soils. Soil sample was collected and stabilized with prepared bone ash and sodium chloride in proportions of 2%, 4%, 6%, 8%, 10%,12% and 1%, 2%, 3%, 4%, 5%, 6% respectively by weight. Chemical analyses of the bone ash; followed by classification, standard proctor, and direct shear tests of the treated soil samples were conducted. Results acquired indicated that bone ash contained high percentage of calcium oxide and phosphate. Addition of bone ash and sodium chloride to soil samples led to increase in soil shear strengths in the range of 7.52% to 51.07% over the strengths. Conversely, samples attained maximum shear strengths at 10% bone ash and sodium chloride stabilization. The use of bone ash and sodium chloride as a stabilizer will therefore improve the shear strength of soils; but, using bone ash and sodium chloride quantities in excess of 10% and 6% respectively may not yield ample results.*

I. INTRODUCTION

Practically every structure is supported by soil or rock. In civil engineering soil is acollection of discrete particles in the form of a deposit, usually of mineral composition but sometimes of organic origin, which can be separated by moderate mechanical means and which containsinconstant amounts of water and air, and occasionally other gases. The engineering behaviour of soil is very important because the foundations of all structures have to be positioned on or in soil. It is therefore needed to understand different soil types and to develop various techniques to improve their properties. Soil stabilizations are essential when a given soil does not have suitable engineering properties to support structures, roads, and foundations. One possibility is to adapt the foundation to the geotechnical conditions at the site. Another possibility is to try to stabilize or improve the engineering properties of the soils at the site. Depending on the circumstances, the latter approach may be the most economical solution to the problem [1]. Therefore, soil stabilization is the physical and chemical alteration of soils to enhance their physical properties. Stabilization can substantially increase the shear strength of a material such that it can be incorporated into structural design calculations. As a matter of fact, the magnitude of soil stabilization is usually measured by the increase in strength [2]. The shear strength of a soil sample is generally defined as its maximum resistance to shearing forces [3]. In as much as most soils can withstand only small tensile stresses or even none at all, significant tension rarely develops in masses of soil. Therefore, most failures of soil take place in shear. Hence, knowledge of the shear strength characteristics of soils is a prerequisite to the solution of many problems in foundation engineering [4].

Over time, various stabilization techniques and materials have been applied to improve the shear strength of soils. The primary methods for improving shear strength today are either mechanical or chemical forms of stabilization. Mechanical stabilization refers to either compaction or the introduction of fibrous and other non-biodegradable reinforcement to the soil. Chemical stabilization, on the other hand, involves the addition of chemicals or other materials to improve the existing soil. Some of these chemicals or materials used in present day include Portland cement, lime, fly ash, calcium chloride, bitumen, enzymes, cement kiln dust (CKD) and other naturally available materials. Majority of the commonly used soil stabilizing materials contain varying levels of calcium e.g. Portland cement, lime and coal fly ash. Studies have also shown the recent use of egg shells which are also rich in calcium, as soil stabilizers [5]. The present study focuses on the possibility of using bone ash - which is yet material containing calcium - as anadditive. Bone ash is the white material produced by the calcination of bones. It is primarily composed of calcium phosphate. It is commonly used in fertilizers, polishing compounds and in making tiles such as bone china. It also has ancient uses in the manufacture of baking powders and assay cupels [6]. A review of literature revealed that bone ash calcined at a temperature of 1100°C contains the following oxides: CaO (55.25%), P2O5 (41.65%), MgO (1.40%), CO2 (0.43%), SiO2 (0.09%), FeO (0.08%) and AlO (0.06%). Any application of bone ash in sand and clay stabilization will be governed by the physical and chemical composition of the ash. Although other products of bone such as animal glues have been used for soil stabilization [7], but important works have not been published to analyse the use of bone ash as a soil stabilizer which may improve shear strength which is the main focus of this work.

II. MATERIAL AND METHOD

For the purpose of determining the shear strength of the soil required for geotechnical design and assessing the behaviour of soil properties as affected by bone ash, the following laboratory tests were conducted on the samples: particle size analysis, Atterberg limits test, standard proctor and direct shear strength test. The first stage of thedirect shear strength tests involved mixing bone ash and sodium chloride with each of the three soil samples in the following percentage proportions: 0% (control test), 2%, 4%, 6%, 8%, 10%, 12% and 1%, 2%, 3%, 4%, 5%, 6% respectively by weight. This resulted to a total of twenty-one samples that were tested.

III. RESULT AND DISCUSSION

Results of the conducted chemical analysis are as summarized as: calcium oxide (CaO) 45.53% phosphate (P2O5) 38.66% magnesium oxide (MgO) 1.18% silicon oxide (SiO2) 0.09% iron oxide (Fe2O3) 0.1% aluminum oxide (Al2O3) 0.06% moisture 0.11% loss on ignition 0.29%.The results of the chemical analysis revealed that the major oxides present in the prepared bone ash samples were CaO (43.53%) and P2O5 (38.66%). The result justified the earlier works and gives authenticity to the methodology adopted in preparing the bone ash [8]. The CaO present in the bone ash is capable of reacting with the fine particles of soils to aid stabilization. The P2O5 has the potential to act as a binding agent to cement particles of soil together and increase its stability. The results of the particle size analysis are summarized and presented (Fig. 1).

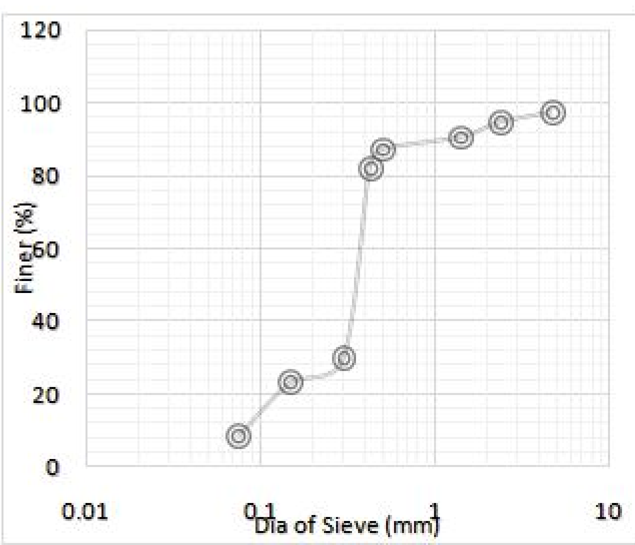

Fig.1 Particle size distribution of soil sample.

The results of the particle size analysis suggested that soil Samples were sandy in nature. The soil classification was carried out according to the Unified Soil Classification System (USCS).

Soil shear strength is considered to be a unique function of cohesion and friction. The values of cohesion and angle of friction were obtained from normal stress and shear stress plots. These values, which were used in computing shear stresses, are fully analytic of the influence of bone ash on shear strength. The cohesion (c) values for all samples were observed to increase from 0% bone ash stabilization to a maximum at between 8% and 10% stabilization, followed by a decline at 12% stabilization (see Fig. 2).

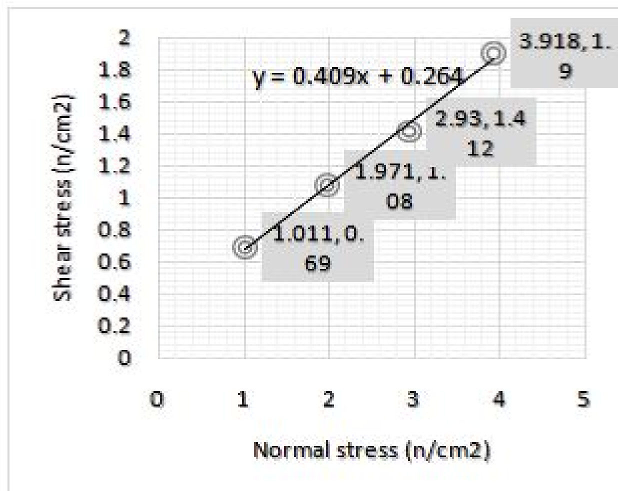

Fig. 2.1 Direct Shear Curve for 0% bone ash and 0% Sodium Chloride

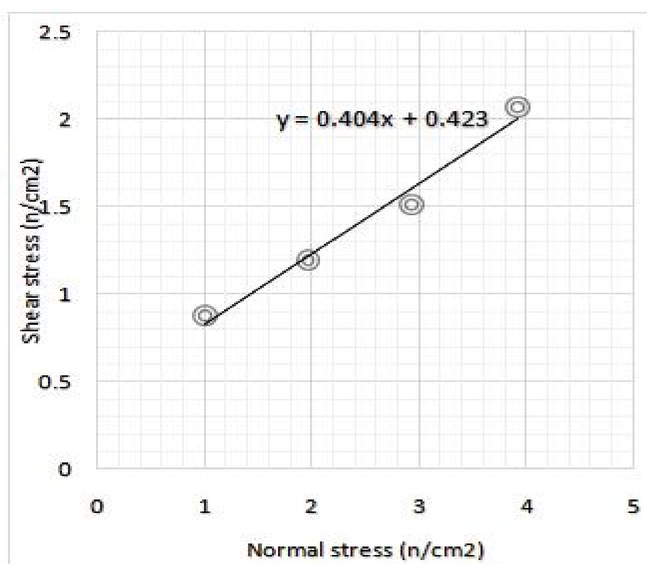

Fig. 2.2 Direct Shear Curve for 2% bone ash and 1% Sodium Chloride

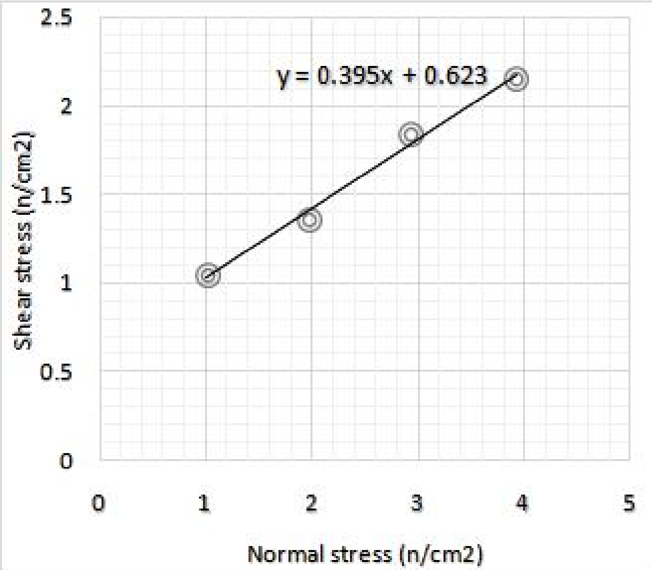

Fig. 2.3 Direct Shear Curve for 4% bone ash and 2% Sodium Chloride

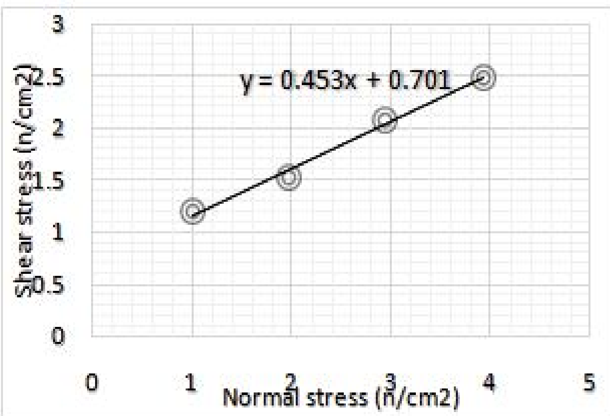

Fig. 2.4 Direct Shear Curve for 6% bone ash and 3% Sodium Chloride

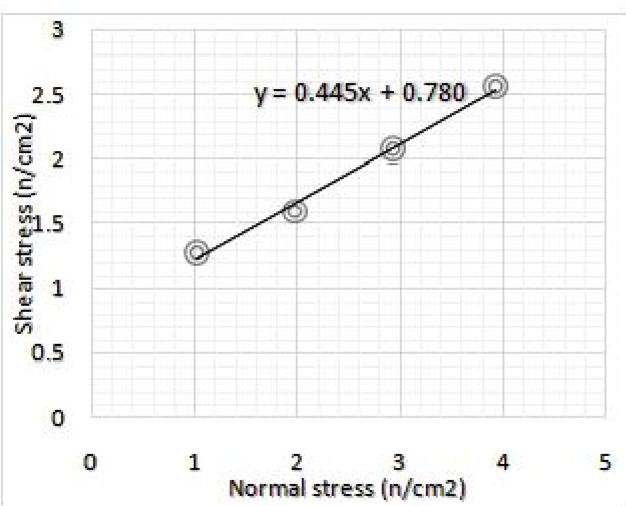

Fig. 2.5 Direct Shear Curve for 8% bone ash and 4% Sodium Chloride

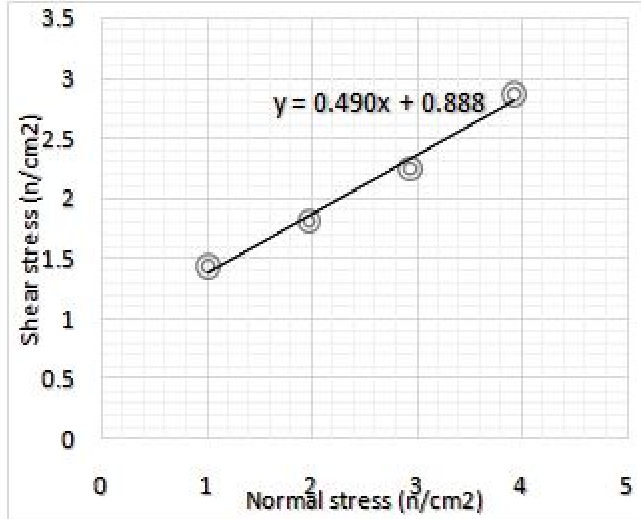

Fig. 2.6 Direct Shear Curve for 10% bone ash and 5% Sodium Chloride

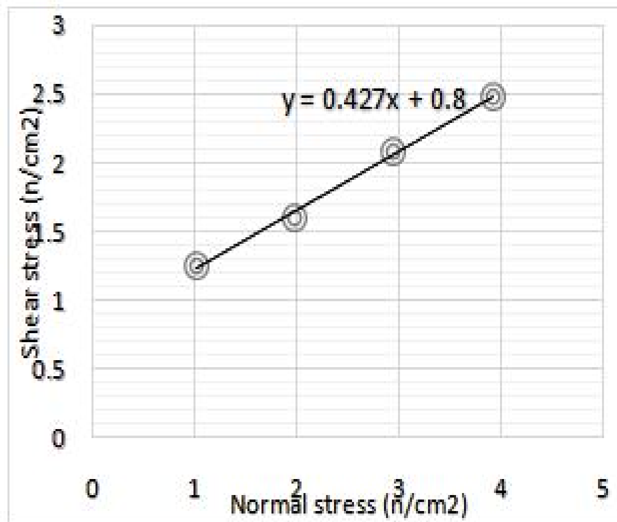

Fig. 2.7 Direct Shear Curve for 12% bone ash and 6% Sodium Chloride.

The angle of friction also shows nearly a uniform trend as the percentage content of bone ash and sodium chloride increases as shown in Fig.2. However, the plot of computed shear stresses against varying bone ash and sodium chloride proportions (Fig. 3) shows that the shear strength of the treated soil samples increased with increase in bone ash and sodium chloride content until a peak at 10% and 6% respectively was attained and an eventual drop thereafter.

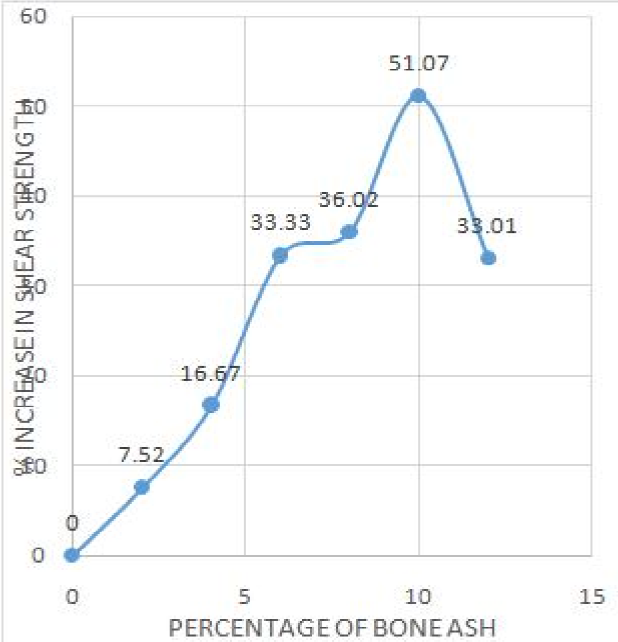

Fig. 3 % increase in shear strength vs % of bone ash and % of Sodium Chloride

The initial increase in the shear strength is expected because of the gradual formation of cementitious compounds between the calcium hydroxide present in the soil and the pozzolan present in the bone ash [9]. The decrease in the shear strength values after the addition of 10% bone ash and 6% sodium chloride is attributable to excess bone ash and sodium chloride that occupies spaces within the soil to form weak bonds between the soil and the cementitious compounds formed by reaction, thus having a negative effect on the cohesive nature of the soil.

IV. CONCLUSION

From the interpretation of results obtained from the implementation of the chemical analysis of bone ash, as well as the particle size analysis, Atterberg limits, standard proctor and direct shear tests on soils, the following facts emerged. Soil sampleswere identified to be sands (SP), according to the Unified Soil Classification System (USCS). Treatment with bone ash showed that lowest values of OMC were recorded within the range of 8% and 10% stabilization and that optimum MDD values were attained at 10% stabilization with bone ash and sodium chloride for soil samples. The shear strengths of all the soil samples increased with addition of bone ash and sodium chloride (within the range of 7.52% - 51.07% over the strengths of the respective control tests). Conversely, with all samples, it was observed that the addition of bone ash and sodium chloride in quantities above 10% and 6% of the soil specific gravity led to a decline in the shear strength values.

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