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ORIGINAL RESEARCH ARTICLE

CEMENT STABILIZED STRUCTURAL FOUNDATION LATERITIC SOIL WITH BONE ASH POWDER AS ADDITIVE

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ABSTRACT
Investigation on the potentials of bone ash powder on cement stabilized structural foundation was carried out in this paper. The aim of the study was to discover local waste material as complement for cement to reduce construction cost. Three soil samples were collected from different borrow pits in Ile-Ife and Ibadan, Nigeria called sample A, B and C. Preliminary tests such as the natural moisture content, specific gravity, grain size analysis and Atterberg's limits were performed on the samples at their natural states and when stabilized at the condition of 8, 8 and 6% cement for samples A, B and C respectively. Engineering tests such as compaction, California bearing ratio (CBR) and undrained traixial were also performed on them at their natural states, when stabilized with optimum cement and when bone ash powder (BAP) was introduced at 2, 4, 6 and 8% to the samples. The results of the engineering tests showed that BAP increased the maximum dry density (MDD) of all the samples. With the optimum cement content kept at 8% for samples A and B and 6% for sample C, the values increased from 1687.89 to 2219.05 kg/m^3 and 1634.12 to 2174.71 kg/m^3 at 4% in samples A and B respectively and 1521.59 to 1620.70 kg/m^3 in sample C at 2% BAP content. The unsoaked CBR values of all the cement stabilized samples dropped with BAP contents. The values dropped from 4.79 to 1.79%, 3.88 to 2.31% and 4.84 to 2.43% respectively in samples A, B and C. However, the shear strengths of samples A and B increased from 604.77 to 740.09 kN/m^2 and 317.73 to 616.05 kN/m^2 respectively. It was therefore concluded that BAP is not an effective additive on cement stabilized structural foundation soil, except in the compaction and shear strength characteristics.

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1.0 Introduction

Structural foundation over the years had been faced with the problem of marginal residual soil for construction works (Handy, 1995). This problem had led to the failure of many structural foundation constructions built on lateritic soil which is the predominant residue soil available in Nigeria (Ayininuola and Agbede, 2009). In a quest to solve this problem, the concept of soil stabilization which is the treatment of soil to improve its engineering properties was introduced. This concept was targeted towards improving the quality of lateritic soils for sustainable structural foundation construction, both in the water proofing and strength properties. However, many modifications have been introduced to the concept with the use of conventional materials that help in reducing construction costs. This study was therefore focused on the potential of calcination bone ash powder as additive on cement stabilized lateritic soil for sustainable foundation construction with the aim of discovering a suitable complement for cement in soil stabilization, bone ash powder is a white material primarily composed of calcium phosphate, commonly used in fertilizers and in making ceramics, other products of bone such as animal glues have been used for soil stabilization (Stulz and Mukerji, 1993)

1.1 Soil - Cement Stabilization

This is the treatment of natural soil to improve its engineering properties. Stabilization is the alteration of foundation soils to the desired characteristics or the improvement of a less stable soil in both strength and durability. Many soils are subject to differential expansion and shrinkage when they undergo changes in moisture content. It is therefore usually necessary to stabilize them to reduce the volume changes and strengthen them to the point where they can carry the imposed loadings even when they are saturated. According to O'Flaherty (2002), there are three types of soil-and-cement mixtures; Plastic soil-cement is a hardened mixture of soil and cement that contains, at the time of placing, enough water to produce a consistency similar to plastering mortar. It is used to line or pave ditches, slopes, and other areas that are subject to erosion. Cement-modified soil is an unhardened or semi hardened mixture of soil and cement. When relatively small quantities of Portland cement are added to granular soil or silt-clay soil, the chemical and physical properties of that soil are changed. Cement reduces the plasticity and water-holding capacity of the soil and increases its bearing value. The degree of improvement depends upon the quantity of the cement used and the type of soil. In cement-modified soil, only enough cement is used to change the physical properties of the soil to the degree desired. Cement-modified soils may be used for structural foundation base, sub base, and as trench backfill material. Compacted soil-cement, often referred to as simply soil-cement, is a mixture of pulverized soil and calculated amounts of Portland cement and water that is compacted to a high density. The result is a rigid slab having moderate compressive strength and resistance to the disintegrating effects of wetting and drying and freezing and thawing.

Earlier, soil improvement has been in the qualitative sense only, but more recently it has also become associated with quantitative values of strength and durability which are related to performance. These quantitative values include compressive strength, shearing strength, load bearing quality, adsorption softening and reduction in strength and so on. Several studies have been made on soil stabilization using different stabilizing agents. (Shon et al, 2010), showed the effectiveness of addition of calcium chloride to soil treatment. (Lopez and Castano, 2001), used calcium oxide as a stabilization technique clay soils in order to inhibit its expansion contraction properties. (Ghafoori and Cai, 1997), used coal combustion by-products in roller compacted concrete, roadway and parking lots.

The investigation of soil condition on site will indicate whether stabilization is needed or not and tests may be necessary to determine which of the several techniques may be feasible and economical. There are two major types of stabilization, mechanical and chemical. Mechanical stabilization is the process of improving the gradation of a raw soil by adding a coarse and/or fine material (usually 10% to 50%) with the aim of achieving a dense homogeneous mass when compacted. Mechanical stabilization is also known as granular stabilization and soil-aggregate stabilization, in the latter context, the term 'aggregate' refers to the addition of non-fine materials greater than 0.06mm that contribute to the development of internal friction (O'Flaherty, 2002). Mechanical stabilization in widely used in road making. Chemical stabilization includes cement stabilization, bituminous stabilization and lime stabilization. Cement stabilization usually involves the addition of 5 to 14% Portland cement by volume of the compacted mixture being stabilized. This type of stabilization is mainly used to obtain the required geotechnical properties of soils intended as base course materials. Although, the best results have been obtained when well graded granular materials were stabilized with cement, Portland cement association has indicated that nearly all types of soils can be stabilized with cement.

1.2 Pozzolan

Pozzolan is a fine powdered material which is added to non-hydraulic lime mortars to accelerate the set. The material possesses little or no cementitious value, but in a finely divided form, it will react with calcium hydroxide in the presence of moisture to provide a chemical set (Traditional lime, 2010). The first pozzolans were used by eruptions. One of the compelling reasons for incorporating pozzolans in concrete today is to improve quality and to extend service life by enhancing the durability of this ubiquitous construction material. To function properly, pozzolans must be amorphous or glassy and generally finer than 325 mesh in particle size. Finer particle sizes generally have greater reactivity helping in the early strength development (Vitro minerals, 2005). Pozzolans can continue to react in concrete for many years, further strengthening the concrete and making it harder and more durable during its service life. Pozzolans also serve to increase density and reduce the permeability of concrete, which helps to make it more resistant to deterioration and swelling associated with various exposure conditions.

The two major types of pozzolans are; natural and artificial pozzolans. The natural pozzolans are present on earth's surface such as diatomaceous earth, opaline shale, volcanic ash, tuff and pumiced. These materials require further accessing such as calcining, grinding, and drying. The Aegean island of Santorini has volcanic ash, volcanic tuffs, pumicites and opaline shale are found in the west of River Mississippi in Oklahoma, Nevada, Arizona and California. Fly ash is an example of artificial pozzolan produced when pulverized coal is burnt in electric power plants. The glassy spherical particulars are the active pozzolani portion of the fly ash. Fly ash is 66 - 68% glass. Class F fly ash readily reacts with lime (produced when Portland cement hydrates) and alkalis to form cementitious compounds. Class C fly ash also may exhibit hydraulic (self-cementing) properties.

1.3 Bone Ash

The ash of animal bones consists primarily of calcium phosphate. For many years, bones were principal source of phosphorus and ground bones or bone meal is still used as fertilizer for its phosphorus and calcium contents. Mineral deposits of calcium phosphate are now exploited, but much of this was formed from the bones of prehistoric animals. The vertebrae, freed from soft tissue as nearly as possible and defatted with boiling alcohol can be ashed by a process with certain important modifications. This method consists in dissolving the entire organic matrix of bone by heating in a 3 per cent KOH solution in glycerol. However, a reagent previously freed from water by boiling was used and the ashing was done by heating the bone at about 250°C. The bone thus leached out with alkaline glycerol reagent retains its morphological form perfectly; only the organic matter was destroyed, leaving a compact white mass of bone salts. The procedure of washing the ashed bone is also an important departure. The leached bone is boiled briskly with distilled water once or twice, depending on how much of the reagent adheres

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to the surface; it is then extracted several times in boiling 95 per cent alcohol, to remove as nearly as possible the entire glycerol reagent, and is dried to a constant weight at 110°C.

The bone in this condition can easily be reduced to a fine powder; indeed, it crumbles when pressed between the fingers. The bone powder which may be snowy white or only slightly tinged dissolves in hydrochloric acid without leaving any insoluble residue. The elementary chemical composition of bone ash is presented in Table 1

Table 1: Elementary chemical composition of bone ash expressed in percent

Material	Composition of Bone Ash				
	Ca	Mg	K	P	CO
Dogfish	37.00	0.58	0.44	16.71	3.23
Goosefish	36.90	0.55	0.56	16.98	3.19
Mackerel	36.74	0.76	0.20	17.42	2.79
Squeteague	35.68	0.12	1.31	16.97	3.11
Frog (common)	36.09	0.72	0.44	16.45	4.67
Bull Frog	36.62	0.61	0.36	16.15	4.11
Amphiuma	36.86	0.51	0.76	15.96	5.34
Siren	36.96	0.57	1.05	16.00	5.73
Turtle	35.68	0.62	0.98	14.88	5.63
Hen	37.24	0.51	-	16.40	5.50
Rabbit	36.25	0.53	0.92	15.99	5.71
Cow	36.05	0.74	0.85	15.43	4.58
Dog	35.66	0.46	1.87	15.56	5.62
Guinea Pig	35.54	0.75	-	15.78	5.03

Source: Studies of the chemical composition of bone ash, Sergius Morgulis, 1931.

2.0 Materials and Method

2.1 Selection of Samples

The materials used for this study are lateritic soil samples, ordinary Portland cement, bone ash and water. The three lateritic soil samples were collected from three different sites, samples A and B were obtained from Obafemi Awolowo University, Ile-Ife, Osun state, Nigeria while C was collected from Ibadan, Oyo state, Nigeria. All the samples which were for foundation construction materials were kept clean in plastic bags and properly sealed with adhesive tape before they were deposited in the geotechnical laboratory of Obafemi Awolowo University Ile-Ife for the necessary experiments. Soil description and date of sampling were marked clearly on a paper and stapled to the plastic bags. Samples were kept in the shade to prevent loss of moisture. The required quantity of ordinary Portland cement for the study was obtained locally. The bone ash was obtained by burning cow bones which were collected from a slaughter's slab at a temperature of about 1200°C. This was kept in a properly sealed polyethylene bag to prevent absorption of moisture. Potable water was obtained from the laboratory.

2.2 Experimental Method

Preliminary tests such as the natural moisture content, specific gravity, grain size analysis and Atterberg's limits were performed on the samples at their natural states and when stabilized at optimum of 8, 8 and 6% cement for samples A, B and C respectively. Engineering tests such as compaction, California bearing ratio (CBR) and undrained traixial were also performed on them at their natural states, when stabilized with optimum cement and when bone ash powder (BAP) was introduced at 2, 4, 6 and 8% to the samples. The potential of Bone Ash Powder (BAP) as additive on the mixture was thereafter determined. The various tests were carried out with standard procedures stipulated in BS 1377- 4:1990.

3.0 Results and Discussion

The results of the preliminary tests (specific gravity, natural moisture contents, particle size distribution and Atterberg's Limits) and the engineering strength tests (Maximum dry density at optimum moisture content, California bearing ratio and shear strength) are presented and discussed below:

3.1 Preliminary Tests

The summary of the preliminary test results for soil samples A, B, C are shown in Table 2. The natural moisture contents of samples A, B and C are 17.15, 18.19 and 15.83% respectively while that of the bone ash was also found to be 1.5%. The result showed that sample B has the highest natural moisture content and sample C the lowest. The specific gravities of sample A, B and C are 2.40, 2.37 and 2.33 respectively. In his work, (Bwalya, 1998) he stated that the performance of lateritic soil may be influenced by many factors such as climatic condition, the hydrological regime and the topography of the area in which the structure is to be constructed. The results of the sieve analysis indicated that all the soil samples fall within the granular material group and range between A1 - A3 in the AASHTO classification system, suggesting that they are fairly good materials for foundation construction. Bwalya (1998) in his studies on the relationship between the natural moisture content and the plastic limit indicated generally that soils with natural moisture contents lower than the plastic limits are normal lateritic soils, therefore samples A and B are normal lateritic soils.

Table 2: Summary of preliminary test for soil samples

Sample	Natural Moisture Content (%)	Specific Gravity	Liquid Limit (%)	Plastic Limit (%)	Plastic Index (%)
A	17.15	2.40	47.25	25.29	21.96
B	18.19	2.37	39.73	21.33	18.40
C	15.83	2.33	25.05	10.76	14.49

The variations in the liquid limits, plastic limits and plasticity indices for the samples at the natural state and when stabilized with 2-10% cement are shown in Figures 1 to 3. The optimum cement for samples A and B were obtained at 8% and at 6% for sample C.

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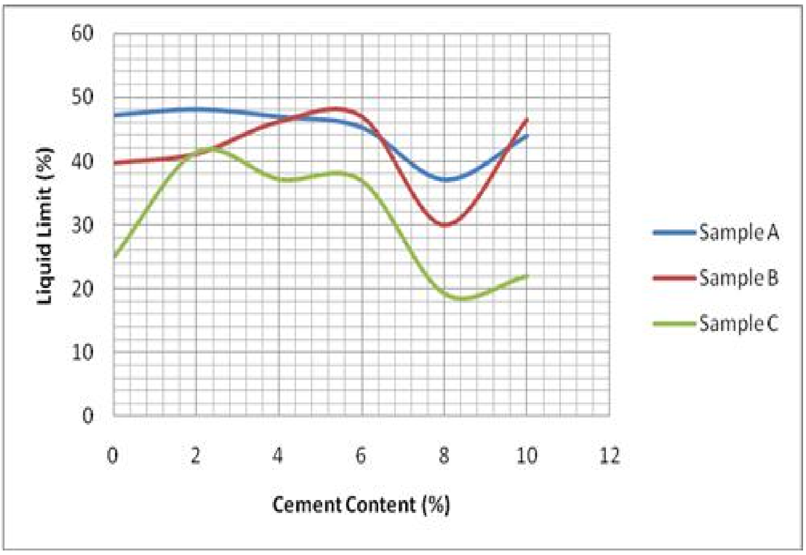

Figure 1: Liquid limit variations for soil samples A, B and C

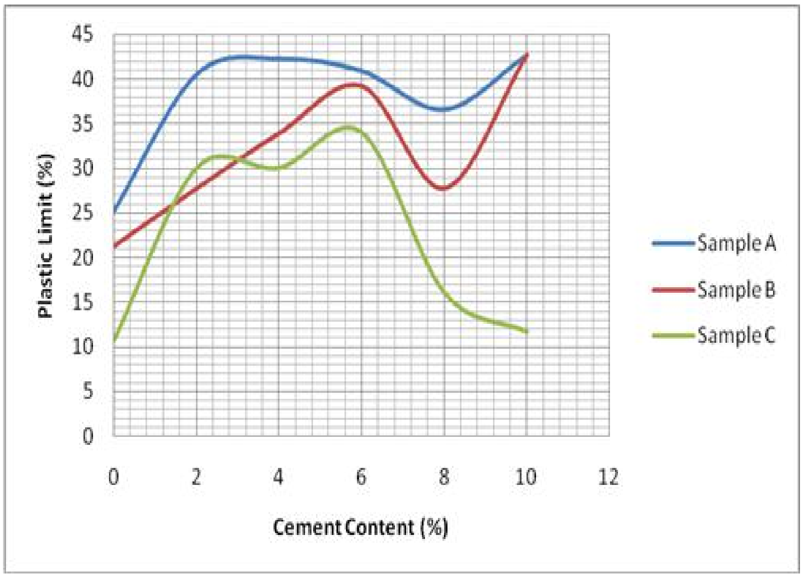

Figure 2: Plastic limit variations for soil samples A, B and C

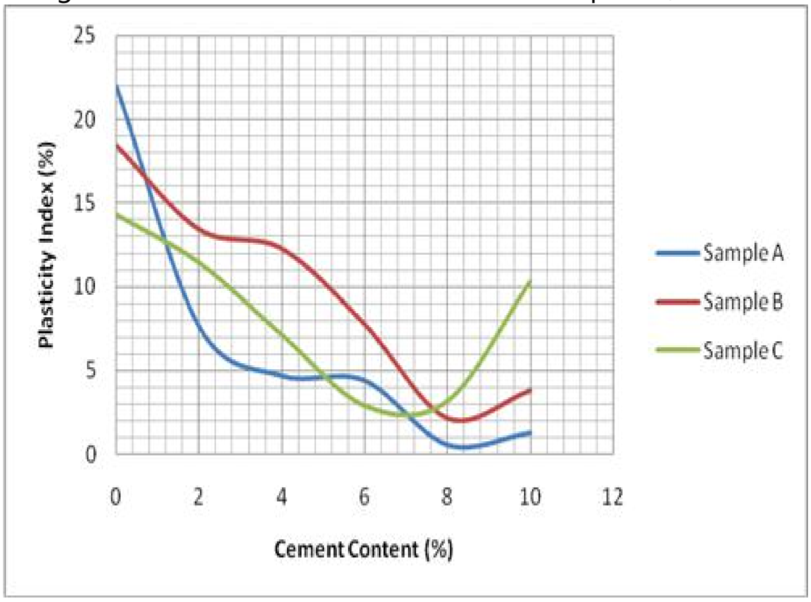

Figure 3: Variation in plasticity indices for soil samples A, B and C

3.2 Engineering Strength Tests

Table 3 shows the summary of the compaction test results at optimum cement stabilization. The Maximum Dry Densities (MDD) of samples A and B attained maximum values at 4% bone ash stabilization before dropping, while sample C showed improvement up to 2% bone ash stabilization. This indicates that the optimum MDD potential for samples A and B is at 8% cement and 4% bone ash stabilization while that of sample C is at 6% cement and 2% bone ash stabilization. (Lambe and Whiteman, 1979) stated that, for good soil, the lower the OMC, the better its workability and an increase in dry density is an indicator of soil improvement. The result of the CBR test on samples A, B and C at optimum cement is summarized in Table 4. The addition of bone ash lowered the unsoaked CBR of all the samples. The CBR value of sample A reduced from 4.79% to a minimum of 1.79% at 4% bone ash stabilization, while those of samples B and C reduced from 3.88 and 4.84% to 2.31 and 2.43% respectively at 2% bone ash stabilization. According to Ashworth (1966) the minimum unsoaked CBR value for sub grade in highway construction is 10%. Therefore, since all the samples fall short of this standard, they are inadequate as sub grade materials in highway construction.

Table 3: Summary of compaction test results for samples A, B and C at optimum cement

Sample	Percentage Stabilization with Bone Ash	Optimum Moisture Content (OMC) (%)	Maximum Dry Density (kg/m^3)
A	0%	19.79	1687.89
	2%	16.35	1998.57
	4%	14.17	2219.05
	6%	16.17	2107.93
	8%	16.16	1808.08
B	0%	21.30	1634.12
	2%	19.35	1994.79
	4%	16.06	2174.71
	6%	19.13	1900.97
	8%	21.29	1726.57
C	0%	23.39	1521.59
	2%	23.73	1620.70
	4%	21.35	1545.56
	6%	16.70	1379.44
	8%	17.39	1273.32

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Table 4: Summary of CBR test results

Sample	Percentage stabilization (%)	Unsoaked CBR (%)
A	0% Bone ash	4.79
	2% Bone ash	2.30
	4% Bone ash	1.79
	6% Bone ash	2.23
	8% Bone ash	2.38
B	0% Bone ash	3.88
	2% Bone ash	2.31
	4% Bone ash	2.73
	6% Bone ash	2.41
	8% Bone ash	2.38
C	0% Bone ash	4.84
	2% Bone ash	2.43
	4% Bone ash	2.73
	6% Bone ash	2.50
	8% Bone ash	2.86

The Undrained Triaxial tests were only performed on samples A and B due to some laboratory challenges. The summary of the results is presented in Table 5. The shear stresses of the two samples increased when stabilized with bone ash at optimum cement contents. Sample A with a natural shear stress value of 604.77 kN/m^2 increased to 740.09 kN/m^2 after stabilization with optimum 8% cement and 4% bone ash contents while sample B increased from 317.73 kN/m^2 to 616.68 kN/m^2 after stabilization with optimum 8% cement and 4% bone ash contents.

Table 5: Summary of undrained triaxial test results

Sample	Cement, Bone-ash ratio (%)	Deviator stress (kN/m^2)	Cohesion (kN/m^2)	Angle of internal friction (Ø)	Shear stress(τ) (kN/m^2)
Sample A	0	493.34	48.2	53	604.77
Sample B	0	348.82	64.3	36	317.73
Sample A	8 : 4	594.32	31.8	50	740.09
Sample B	8 : 4	618.05	133.8	38	616.68

4.0 Conclusion

Based on the results of this study which showed that the addition of bone ash lowered the unsoaked CBR of all the samples. It was therefore concluded that BAP is not an effective additive on cement stabilized lateritic soil, except only in the compaction and shear strength characteristics

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