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Effects of Burnt Clay on Cement Stabilized Lateritic Soil Samples in Osun and Oyo States, Nigeria

Burnt clay as complement for cement stabilization

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***Abstract*—This research was carried out to determine the effects of burnt clay as a potential pozzolanic material on cement stabilized lateritic soil. This is with the view of adopting burnt clay as a partial replacement in cement stabilization to further reduce cost. Three soil samples named A,B and C were collected in Osun and Oyo States and were subjected to both the preliminary tests (natural moisture content, specific gravity, grain size analysis, Atterberg's limit) and engineering tests (California Bearing ratio, compaction and triaxial) following the standard procedures as stated in BS EN 1377, Part 1, 2 & 4 (1990). The results of the natural moisture contents for samples A, B and C were 19.34%, 15.95% and 18.19% respectively while that of the burnt clay was 1.49%. The specific gravity of samples A, B and C were 2.66 and 2.39 and 2.54 respectively which showed that all the soils samples are hollaysites. Sample A and B obtained maximum MDD at 8% cement and 4% burnt clay stabilization while for sample C, the maximum MDD was attained at 6% cement and 2% burnt clay stabilization. The CBR values of all the samples reduced consistently with increased percentages of burnt clay, the maximum values of 4.79, 3.88 and 4.84% were all obtained at 0% of burnt clay. The results showed that the initial shear stress value of 604.77 kN/m^{2}in sample A increased to 740.09 kN/m^2 after it has been stabilized with 8% cement and 4% burnt clay while sample C increased from 317.73 kN/m^2 to 616.68 kN/m^2 after stabilizing with 8% cement and 4% burnt clay. Therefore this confirms that burnt clay is an effective complement for cement in soil stabilization.**

Keywords—burnt clay; cement stabilization; lateritic soil

I. Introduction

Civil Engineers are in the midst of a construction revolution. The methods of constructing roads have changed a lot since the first roads were built around 4,000 BC – made of stone and timber [1]. Heavy structures are now being located in areas formerly considered unsuitable from the standpoint of the supporting power of the underlying soils. All structures eventually transmit their loads into the ground. In some cases this may be accomplished only after circuitous transfers involving many component parts of a building; in other cases, such as highway pavements, contact is generally direct. Load transfer may be between soil and soil or, as in retaining walls, from soil through masonry to soil [2]. Hence, the response of the soil to these imposed loadings is the point of concern in Geotechnical Engineering.

Burnt clay has been analyzed to contain reactive silica and alumina which on its own have little or no binding property, but when mixed in the presence of water, will set and harden like cement. This study is to discover the use of burnt clay as a form of partial replacement in chemical stabilization in order to further reduce the cost of stabilization.

A. Lateritic Soil

Laterites and lateritic soils form a group comprising a wide variety of red, brown, and yellow, fine-grained residual soils of light texture as well as nodular gravels and cemented oils. They may vary from a loose material to a massive rock. They are characterized by the presence of iron and aluminum oxides or hydroxides, particularly those of iron, which give the colors to the soils. For engineering purposes, the term "laterite" is confined to the coarse-grained vermicular concrete material, including massive laterite. The term "lateritic soils" refers to materials with lower concentrations of oxides. Laterization is the removal of silicone through hydrolysis and oxidation that results in the formation of laterites and lateritic soils. The degree of laterization is estimated by the silica-sesquioxide (S-S) ratio (SiO_2/ (Fe_2O_3 + Al_2O_3). Laterites are formed from the leaching of parent sedimentary rocks (sandstones, clays, limestones); metamorphic rocks (schists, gneisses, migmatites); igneous rocks (granites, basalts, gabbros, peridotites); and mineralised proto-ores [3]which leaves the more insoluble ions, predominantly iron and aluminium. The mechanism of leaching involves acid dissolving the host minerallattice, followed by hydrolysis and precipitation of insoluble oxides and sulfates of iron, aluminium and silica under the high temperature conditions[4] of a humid sub-tropical monsoonclimate [5]. An essential feature for the formation of laterite is the repetition of wet and dry seasons[6].

B. Laterite in Road Building

The French surfaced roads in the Cambodia, Thailand and Viet Nam area with crushed laterite, stone or gravel. Kenya, during the mid-1970s, and Malawi, during the mid-1980s, constructed trial sections of bituminous-surfaced low-volume roads using laterite in place of stone as a base course. The laterite did not conform to any accepted specifications but performed equally well when compared with adjoining sections of road using stone or other stabilized material as a base. The lateritic soils behave more like fine grained sands, gravels, and soft rocks. The laterite typically has a porous or vesicular appearance. Some particles of laterite tend to crush easily under impact, disintegrating into a soil material that may be plastic. Lateritic soils may be self-hardening when exposed to drying; or if they are not self-hardening, they may contain appreciable amounts of hardened laterite rock or laterite gravel.

C. Soil Stabilization

Stabilization is the process of blending and mixing materials with a soil to improve certain properties of the soil. The process may include the blending of soils to achieve a desired gradation or the mixing of commercially available additives that may alter the gradation, texture or plasticity, or act as a binder for cementation of the soil. According to [7]; [8], can also be defined as any process which improves the physical properties of a soil, such as increasing the shear strength, bearing capacity and the resistance to erosion, dust formation, or frost heaving. Soil stabilization, in terms of pavement construction, is the process of (usually in-situ) pulverizing and moisture conditioning by mixing various binders with soil, compaction and trimming as necessary. This improves soil characteristics preferred for construction in terms of moisture content, density, strength (California Bearing Ratio, CBR), permeability, plasticity index and shrink swell characteristics.

Portland cement can be used either to modify and improve the quality of soil or to transform the soil into a cemented mass with increased strength and durability. The amount of cement used will depend upon whether the soil is to be modified or stabilized.

Pozzolans can be defined as a siliceous and alumineous material, which in itself possesses little or no cementation value but will in a finely divided form, such as a powder or liquid and in the presence of moisture, chemically rich with calcium hydroxide at ordinary room temperature to form permanent, insoluble compound possessing cemetitious properties. Pozzolan is a fine powdered material which is added to non hydraulic lime mortars to accelerate the set and it must be amorphous or glassy and generally finer than 325 mesh particle size. Finer particles sizes generally have greater reactivity, helping in the early strength development. It can continue to react in concrete for many years, further strengthening the concrete and making it harder and more durable during its service life. 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 [9]

D. Burnt Clay

Burnt clay pozzolanas are produced by burning suitable clays at temperatures between 600-900 ºC, depending on the nature of the clay and the conditions of burning. The product is milled usually to cement fineness before it fully develops pozzolanic activity. Burnt clay pozzolana has been used to execute several construction projects such as the Bonville dam in the USA and the Vanivilas Sagar and Krishnarajar Sagar dams among many others in India, where the clay pozzolana was used under the name “Surkhi”. An important criterion for a good burnt clay pozzolana as well as most other pozzolanas in terms of constituents is that the sum of SiO_2, $Al_2O_3$and Fe_2O_3 contents should exceed 70%.When heated, the clay minerals lose most of their surface adsorbed water in the 100-120 ºC temperature range.

Research done with various Ghanaian clay deposits has shown that when milled to cement fineness, clay pozzolanas can replace up to 30% of ordinary Portland cement in structural applications. These clay pozzolana-cement mixes have been successfully used for various housing construction projects in Ghana [10].

II. MATERIALS AND METHODS

The materials used for this research include: burnt clay, lateritic soil, ordinary Portland cement and water.The burnt clay samples were obtained from clay potters in Ipetumodu, Osun State and burnt to about 100^0C. Three lateritic soil samples A, B and C were obtained from different existing borrow pits in Osun and Oyo States, Nigeria. Sample A was obtained from Obafemi Awolowo University Teaching Hospital Complex, sample B from Alakia Area, Ibadan, Oyo State and sample C from Obafemi Awolowo University, Ile-Ife, Osun State. Ordinary Portland cement was purchased locally while water supply from the laboratory of Civil Engineering Department was used for the experiments.

These preliminary tests, moisture content determination, specific gravity determination, particle size distribution and Atterberg’s limit were conducted to classify the soil samples. The Atterberg’s limit test was used to determine the plasticity index of the soil samples in their natural states and after stabilization with cement. The main engineering tests carried out were, compaction test and the California bearing ratio

(CBR) at the optimum cement and also when stabilized with various percentages of burnt clay to determine the optimum level.

III. Results and Discussion

A. Preliminary Tests

Table 1 shows the summary of properties of soil samples. The natural moisture contents for samples A, B and C are 19.34%, 15.95% and 18.19% respectively. The moisture content for the burnt clay was equally determined to be 1.49%. It can be observed sample A has the highest natural moisture content and sample B the least.
From the results of the liquid limit, plastic limit and plasticity index of the soil samples, it is shown that for all the soil samples the liquid limits fall between 35% and 50% which indicates that they have intermediate plasticity according to [11]. The relationship between the natural moisture content and plastic limit showed that generally, the natural moisture content less than the plastic limits indicates normal lateritic soils [11]. Therefore, only soil samples A and C are normal soils.

The specific gravity is the measure of the weight of the aggregate to the weight of equal volume of water. This is an indication of natural surface condition of the soil sample. The specific gravity of samples A, B and C are 2.66 and 2.39 and 2.54 respectively, which range within that given in [12] for clay minerals, a Halloysite (1.60-2.55) and Biotite (2.8-3.2) which shows that all the soils samples are hollaysites. It was finally stated that most clay minerals have specific gravities within a general range of 1.6-2.9 [12].

The result of the particle size analysis is shown in Table 2, less that 35% of the three samples passed the sieve number 200 (0.0075mm). From this observation it can be said the all the soil samples fall within the granular material family. As implied in the AASHTO classification system, they fall within the range of A1 to A3, suggesting that they are fairly good for road construction.

The summary of the Atterberg's limit test is shown in Table 3. The results showed that soil samples A and B attained their lowest PIs both at 8% while that of sample C occurred at 6%. This indicates that the optimum cement stabilization will occur at 8% for both samples A and B and at 6% for sample C.

B. Engineering Test

Compaction test is usually used to determine the Maximum Dry Density (MDD) and the Optimum Moisture Content (OMC) of soil samples. The test was therefore performed at the optimum percentage of the Ordinary Portland Cement (OPC), which were obtained at 8% for samples A and B and 6% for sample C and varying quantities of burnt clay at 2, 4, 6 and 8% by weight of sample. Table 4 shows the summary of these results. From the results, MDD of samples A and C improved up till 4% level of stabilization with burnt clay after which it began to fall, while sample B obtained maximum MDD at 2% stabilization with burnt clay. This indicates that for sample A and B, maximum MDD is attained at 8% cement and 4% burnt clay stabilization while for sample C, the maximum MDD is attained at 6% cement and 2% burnt clay stabilization.

TABLE 1. SUMMARY OF PROPERTIES OF SOIL SAMPLES

Property	Sample A	Sample B	Sample C
Percentage passing BS No 200 sieve	2.1	3.9	2.3
Natural moisture content,%	19.34	15.95	18.19
Specific Gravity	2.66	2.39	2.54
AASHTO Classification	A-2-7	A-2-7	A-2-7
Liquid Limit, %	47.25	25.05	39.73
Plastic Limit, %	25.29	10.76	21.33
Plasticity Index, %	21.96	14.29	18.40
Maximum Dry Density	2219.05	1620.70	2174.71
Optimum Moisture Content	33.65	29.50	17.44
California Bearing Ratio %	4	3	23
Triaxial Shear Strength	20.14	30.62	60.57

TABLE II: SUMMARY OF PARTICLE ANALYSIS FOR SOIL SAMPLES

Sieve size (mm)	***Sample A***	**Percentage Passing (%)*Sample B***	***Sample C***
4.750	82.86	84.06	84.36
2.00	64.39	55.37	65.41
1.00	52.72	44.08	55.21
0.850	52.72	43.81	49.63
0.425	42.24	37.68	41.94
0.212	35.27	37.03	40.02
0.150	27.14	31.17	33.29
0.075	23.61	29.97	32.68
0.063	21.05	29.64	31.38

TABLE III: SUMMARY OF ATTERBERG'S LIMIT RESULTS

Sample	% Stabiliz-ation	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
A	0% Cement	47.25	25.29	21.96
	2% Cement	48.17	40.55	7.62
	4% Cement	47.00	42.29	4.71
	6% Cement	45.33	40.91	4.42
	8% Cement	37.17	36.58	0.58
	10% Cement	43.99	42.69	1.30
B	0% Cement	25.05	10.76	14.29
	2% Cement	41.47	30.05	11.42
	4% Cement	37.18	30.05	7.13
	6% Cement	36.92	34.01	2.91
	8% Cement	19.21	16.01	3.20
	10% Cement	21.94	11.62	10.32
C	0% Cement	39.73	21.33	18.40
	2% Cement	41.18	27.78	13.40
	4% Cement	46.20	33.95	12.25
	6% Cement	46.99	39.23	7.76
	8% Cement	29.96	27.78	2.18
	10% Cement	46.52	42.69	3.83

Table 5 shows the summary of the triaxial test results of the samples. The results show that sample A which has an initial shear stress value of 604.77 kN/m^2 increased to 740.09 kN/m^2 after it has been stabilized with 8% cement and 4% burnt clay, while sample C increased from 317.73 kN/m^{2}to 616.68 kN/m^2 after stabilizing with 8% cement and 4% burnt clay. The traixial test is one of the most reliable methods now available for the determination of shear parameters. An increase in the shear strength of a soil indicates an improvement in the strength of the soil and also improved workability for construction works (Das, 2000). Therefore this confirms that the addition of burnt clay at optimum levels has the capacity to improve the geotechnical properties of lateritic soil.

Fig. 1 shows the summary of CBR test at optimum cement with varying percentages of burnt clay. From the result, the CBR values of all the samples reduced consistently with increased percentages of burnt clay. The maximum CBR values of 4.79, 3.88 and 4.84% were all obtained at 0% level addition of burnt clay.

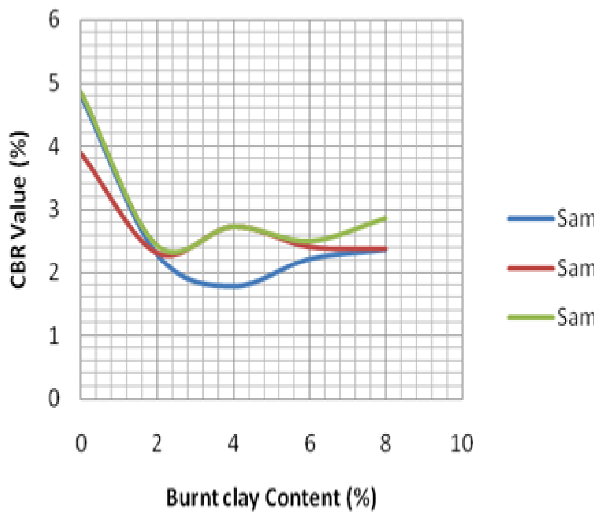

Fig. 1:Variation in CBR values for different percentages of burnt clay for the three soil samples

TABLE IV: SUMMARY OF COMPACTION TEST RESULTS AT OPTIMUM STABILIZATION WITH CEMENT

Sample	Percentage Stabilization with Burnt Clay	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%	23.39	1521.59
	2%	23.73	1620.70
	4%	21.35	1545.56
	6%	16.70	1379.44
	8%	17.39	1273.32
C	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

TABLE V: SUMMARY OF UNDRAINED TRIAXIAL TEST RESULTS

Sample	Cement-Burnt clay content (%)	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 C	0	348.82	64.3	36	317.73
Sample A	8% + 4%	594.32	31.8	50	740.09
Sample C	8% + 4%	618.05	133.8	38	616.68

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