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Soil Stabilisation Using Pond Ash And Alcofine

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ABSTRACT- Need for locally produced building materials is developing in third-world nations as a result of the increased demand for new roads and apartment units brought on by a growing population.. Over the years, the availability of conventional material has not been sufficient to meet the demand of growing population. However, using conventional methods and procedures would require significant financial outlays in order to create a vast network of roadways. According to Road Note 31 (TRRI, 1977), the values of UCS for both BSL and WAS were insufficient to stabilise the commercial range of the OPC. For base courses of pavers, the UCS value of the BSH compaction, however, can be acceptable. The OPC/ALCCOFINE mix provides a long-term benefit in terms of strength increase, as seen by the 28-day curing period UCS values that were attained. The values of UCS significantly increased from their initial conditions.. The 28 days curing period UCS produced a peak value of 2616kN/m2 at 30% pond ash & 3% alccofine for BSH compaction, showing that the soil treated With this mixture, base school curriculum for paving can be utilised (during BSH compaction).. The unsoaked CBR values of 5, 7 and 11% (for the natural soil) compacted with BSL, WAS and BSH energy efforts, respectively, increased to 46, 77 and 83% at 30% pond ash & 3% alccofine. The 24 hours soaked CBR values recorded peak values of 42, 66 and 66% with BSL, WAS, BSH energies, respectively, which showed about 10-15% decrease from the unsoaked CBR values. The CBR values of 66% with BSH compaction at 30% pond ash & 3% alccofine blend can be used as sub base material because it meets the 29% recommended values specified in the Nigerian General Specification for Sub-Base (1997).resistance to loss in strength (Ola, 1983) based on 4 days soaking. The 6% OPC 6% ALCCOFINE treatment of the soil can be used, at BSH compaction, for sub-base material because the soil was subjected to a harsher condition (of 7 days soaking) and due to the time dependent gain in strength advantage of the pozzolana Also the 42% recorded with BSL compaction at 30% pond ash & 3% alccofine treatment meets the 15% recommended for subgrade material by the Nigerian.

KEYWORDS- Pond ash, Alcofine, Natural Soil, CBR

I. INTRODUCTION

The top layer of the ground, or soil, is made up of air, water, and solid particles and is often created when rocks break down. The need for locally produced building materials is developing in third world nations as a result of the increased demand for new roads and housing units brought on by a growing population. The demand of a burgeoning population has outpaced the supply of traditional material throughout the years. However, using conventional methods and procedures would require significant financial outlays in order to create a vast network of roadways. Finding alternatives materials, ideally locally accessible low grade ones, that result in substantial savings without affecting the technical performance of the building becomes imperative.The characteristics of the soil change from location to location [1]. Because of its weak strength, high compressibility, and low permeability, cohesive soil presents significant engineering challenges. It encompasses a huge and widely dispersed area of India as well as many other regions of the world. Large lengths of silty soil make it difficult to build on them for buildings like roads and other pavements. It is crucial to remediate these soils in order to solve these issues. These soils can be treated using a wide variety of techniques. Some of them are highly expensive, while others are very time-consuming. The use of pozzolanic materials has led to the development of several techniques for improving soil.

It is very easy, affordable, and pollution-controlling to treat soft clayey soils with flyash, rice husk ash, phasphogypsum, and a tiny amount of cement. It has been used in many different civil engineering projects, including the construction of base courses where high-quality materials are not economically feasible, lowering water infiltration and mechanical properties in hydraulic and foundation works, and stabilizing slopes, embankments, and underground structures. The literature has a sizable quantity of research on soil improvement using additions including cement, alumina, lime-fly ash and salt, bitumen, and polymers. Similarly, coal ash, which is regarded as an industrial waste, may be used successfully in the building sector. [2]

A. *Various Types of Stabilization Techniques*

a. ***Lime stabilization***
b. ***Chemical stabilization***
   - Stabilization with calcium chloride
   - Stabilization with sodium chloride
   - Stabilization with resins
   - Stabilization with lignin
   - Stabilization with sodium silicate
   - Stabilization with molasses.

c. ***Pond ash stabilization***
d. ***Cement stabilization***
e. ***Mechanical soil stabilization***
f. ***Soil-bitumen stabilization***
g. ***Complex stabilization***
h. ***Electrical stabilization***
i. ***Stabilization by grouting***
j. ***Stabilization by Geotextile & Fibers***
k. ***Reinforced Earth***

B. Pond Ash

The primary source of energy in emerging nations like India, where it accounts for over 75% of total energy output, is thermal power. Over 100 million tons of coal ash are produced annually by all thermal power plants currently in operation. Fly ash (70%) and pond ash (30%) are the two main ways that this coal ash is produced. Utilizing these waste products is crucial for environmental preservation. The fly ash, together with pond ash or bottom ash produced by the industry, is often dumped in a built ash pond, which is a few kilometre away from the power station [3]. The ash and water ratio in the slurry varies from 1 part ash to 6 to 10 parts water. It is called pond ash for this reason. Actually, fly ash and bottom ash are both present in the pond ash. The size of the particles distinguishes fly ash and pond ash the most. Pond ash as shown in Figure 1 is not recognized as pozzolana since it is coarse and less pozzolanic.

Figure 1: Pond Ash

The pond ash is a by-product of boilers, which are used in most coal-based energy sources to burn coal to hot water to create steam. The primary source of it is the moist disposal of fly ash. The wet procedure or the dry type of disposal are frequently used. The ashes and water are combined in the wet process, which creates ash ponds, which are then dumped into bodies of water. Ash contains soluble alkalis that are cleaned by water in the ponds. Fly ash is combined with bottom ash and dumped as slurry in large ponds or dykes. [4]
It also goes by the name "pond fly ash" and has rather big particles. Land deterioration close to the thermal power plants results from the enormous expanses of land being utilized to store this kind of combination of pond ash. Pond ash is being created at a startling rate, thus efforts are needed to safely dispose of it and, if feasible, find uses for it. Disposal of Pond Ash is shown in Figure 2.

Figure 2 : Disposal of Pond Ash

This issue is complicated by the fact that one of the biggest issues facing India's industrial industry is how to dispose of the garbage they create. Each year, India generates roughly 180 million metric tons of fly ash. Only around 38% of the nation's total fly ash output is used to make cement (about 10.42 million metric tons), land fills, bricks, mine fills, agriculture, and other things. Due to its continuous reliance on coal, India will have enormous amounts of fly ash in the years to come. By 2032, more than 1.8 million acres of ponds would be required to hold the anticipated 225 million metric tons of fly ash.[5].
Pond ash and fly ash are now sought-after building materials due to their self-hardening properties, which hinge on the presence of free lime in them. The engineers have always put forth the effort to use pool ash properly in the communities that are close to thermal power plants. for building local roads. Because pond ash is the byproduct of coal combustion in thermal power plants, its characteristics depend on the kind of coal used and might vary from one power station to another.

C. Alccofine

Many byproducts produced by factories and businesses are discarded in the open, where they damage the environment and spread illness. The environment can be protected by making use of these leftovers. Fly ash, silica fume, ground granulated blast furnace slag, and alccofine are examples of by-products or so-called waste materials that are currently being reused in the construction industry for soil stabilization or concrete production, primarily by making a few stabilized changes to these waste materials. Figure 3 shows Alccofine.

Figure 3: Alccofine

Counto Microfine Goods Pvt. Ltd. (CMPPL), an entered into an agreement comprising ACL and the Goa-based Alcon Group, released a line of products called Alccofine Micro Materials in 2013.

Alccofine 1203 (a supplemental cement ingredient that effectively substitutes the Silica fume used in high quality concrete) and Alccofine 1101 are the two products that have been introduced (a micro-fine cement-based substance used for soil stabilization, injection grout, and other purposes underground tunnels). Types of Alccofine is shown in Table 1.

Table 1: Types of Alccofine

Alccofine	Alccofine-1203	Low Calcium Silicate
	Alccofine-1101	High Calcium Silicate

It is an ultra-manufacture of a new generation whose primary raw material is regulated granulated slag with a high glass content and strong reactivity. Low calcium silicates make up the majority of the raw ingredients. Controlled particle size distribution is produced by processing with additional well-chosen components (PSD). ALCCOFINE 1203 offers reduced water demand for a given applicability because to its distinct chemistry and ultra-fine particle size. It may also be utilized as a high range water reducer to increase tensile properties or as a super buildability aid to plans for achieving.

II. OBJECTIVES

- To stabilize the poor subgrade that is already present in the area by utilizing 3% alccofine and variable amounts of pond ash as the major stabilizing ingredient
- To research the effects of pond ash content on the strength metrics, UCS, and CBR, OMC, and MDD (Soaked).
- To determine the ideal pond fibre content.
- To investigate how different pond ash blends influence the actions of soil under load.
- Results and interpretation

III. MATERIALS AND METHODS

A. Natural Soil

Preliminary tests conducted to determine the natural properties of the soil revealed that the soil has very high moisture content of 36%, due the period of its collection. The index properties are summarized in Table 2, while its oxide compositions are summarized in Table 3. The soil is grayish black in color (from wet to dry states) with a liquid limit of 62%, plastic limit of 28% and plasticity index of 37%. [6]

The soil has a free swell of about 75%, soaked CBR values of 5% and UCS values of 151 KN/m^2. For the majority of geotechnical construction operations, particularly for sub-base or base courses in highway building, the soil was found to be very plastic and below the standard guideline.

B. Pond Ash

Because pond ash is the by-product of coal combustion in thermal power plants, its

another. Particle sizes of the ash vary from around one micron to around 600 microns. The very fine particles (fly ash) collected from this ash generated by electrostatic precipitators are being used in the manufacture of blended pond ash. The chemical, geotechnical and mineralogical features of ash depend on various factors like:

- Type of coal used for fuel.
- Degree of combustion.
- Disposal system used.

Table 2 shows Properties of the Natural Soil and Table 3 Shows Physical Properties of pond Ash

Table 2: Properties of the Natural Soil

S. No.	Property	Quantity
1	Percentage passing sieve (%)	71.0
2	Natural Moisture Content (%)	36.0
3	Liquid Limit (%)	62.0
4	Plastic Limit (%)	28.0
5	Plasticity Index (%)	37.0
6	Linear Shrinkage (%)	16.0
7	Free Swell (%)	75.0
8	Specific Gravity	1.93
9	Maximum Dry Density (Mg/m3)	1.35
10	Optimum Moisture Content (%)	25.0
11	Unconfined Compressive Strength (KN/m2)	221
12	California Bearing Ratio (%)	5
13	Colour	Greyish black
14	Dominant clay minerals	Montmorillonite

Table 3: Physical Properties of Pond Ash

S. No.	Properties	Value
1.	Lime Reactivity of Pond ash	0.66
2.	Specific Gravity	2.16
3.	Bulk density in Loose State	825 kg/m^3
4.	Bulk density in Compacted State	992 kg/m^3
5.	Atterberg's Limits Liquid Limits percentage	47.4
6.	Grain size distribution Sand % Silt % Clay %	73 27 NIL
7.	IS Classification	SP-SM

The coal obtained from mines can be categorized according to carbon content asa) Grade A (maximum carbon content)

b) Grade B

c) Grade C

d) Grade D (minimum carbon content)

The quantity of ash produced varies according to the grade of coal used for combustion. A coal having maximum carbon content will produce minimum ash and vice versa. The chemical compositions of fly ash & pond ash generally lie in same range except in their particles size as shown in Table.4 and 5 respectively. And Table 7 shows Chemical Composition of Alccofine 1203

Table 4: Chemical Compositions of Pond Ash

S. No.	Constituent	Pond ash (%)
1.	Silica (SiO_2)	67.42
2.	Alumina (Al_2O_3)	19.38
3.	Iron Oxide (Fe_2O_3)	8.7

4.	Calcium Oxide (CaO)	2.9
5.	Magnesium Oxide (MgO)	0.47
6.	Sulphur (SO_3)	0.32
7	Loss of Ignition	3.49

C. Alccofine

The Alccofine utilized in this investigation came from the ash discharge of Abuja Pond. Alcofine's physical and chemical characteristics are displayed in a table 5

Table 5: Physical Parameters of Alccofine 1203

Specific gravity	**Bulk Density (kg/m^3)**	**Particle size distribution (μ)**		
2.9	600-700	d 10	d 50	D 90
		1-2	4-5	8-9

Table 6: Chemical Composition of Alccofine 1203

CaO	**Al_2O_3**	**SiO_2**	**Glass content**
31-33%	23-25%	33-35%	>90%

IV. EXPERIMENTAL INVESTIGATION

A. Natural Moisture Content

The water content(w), also known as natural water content or natural moisture content, is the ratio of the weight of water to the weight of solids in a given mass of soil. The natural moisture content (as collected from the site) is calculated as the average as given below.

Moisture Content (w) = $[(W_2 – W_3) / (W_3 – W_1)] \times 100$

B. Specific Gravity

This test is done to determine the specific gravity of fine-grained soil by density bottle method as per IS: 2720 (Part III/Sec 1) – 1980. The weight in air of a certain volume of a substance at a reference temperature divided by the weight in air of a volume of distilled water at the same reference temperature is known as specific gravity.[7]

The specific gravity is calculated using equation.

Specific Gravity (G) = $(M_2 - M_1) / (M_4 - M_1) \times (M_3 - M_2)$

C. Particle Size Distribution

This test is done to determine the particle size distribution of soil as per IS: 2720 (Part 4) – 1985.Wet sieving was conducted by measuring 200g of the soil sample and soaking it for 24hours.. After that, the material was filtered via sieve No. 200.

The particles retained were then dried in the oven for 24 hours and a dry sieving was carried out on the dried sample to obtain the particle size distribution.

D. Atterberg's Limits

The test includes the determination of the liquid limits, plastic limits and the plasticity index for the natural soil and the stabilized soils. They were also conducted in accordance with Test IS: 2720 (Part 5) – 1985 for the natural soil a nd stabilized soils. [8]

E. Liquid Limits

The variation of liquid d limit of the soil/soil-pond ash mixtures with alccofine. The addition of alccofine and pond ash, especially, introduces calcium for its strength which caused a decrease in the re pulsive force of the soil mixture; thereby needing more to bring the soil's dynamic shear resistance through water.The value of the liquid limit of the soil increased from 61% of the natural soil to a peak value of 75% at 3% alccofine and 30% pond ash. It was observed that the liquid limit increased steadily from its natural state to 3% alccofine and 30% pond ash before the values reduced.

F. Plastic Limit

Rolling out a threads of the fine section of a soil on a flat, non-porous substrate yields the plastic limit (PL).The moisture content at which the thread separates at 3.2 mm (or 1/8 inch) in diameter is known as the plastic limit.[9]

G. Plasticity Index

The plasticity index of the soil/soil–pond ash- alccofine mixes is the difference between the liquid limits of the natural/various mixes of the soil and their corresponding plastic limits. Table shows the plasticity index of the samples which were calculated as:

PI = LL – PL

H. Maximum Dry Density

A stress applied to a soil results in urban growth as air, that is a common process as soil structure in geotechnical engineering. is displaced from the pores between the soil grains. It is an instantaneous process and always takes place in partially saturated soil (three phase system).[10].

The compaction tests were carried out for the natural soil and the stabilized soils (in different percentages); all according to IS 2720-PART VII-1980) Reaffirmed -2011. [11].

The bulk density in Mg/m^3 was later calculated for each compacted layers using:

$(M_2 - M_1)/1000$.

The following equation was used to compute the dry density:

D = 100 / (100 + W)

I. Optimum Moisture Content

According to the graph of dry density, the matching moisture contents at maximum dry densities (MDD) density against moisture contents, gives the optimum moisture contents (OMC). The results are given in Table below for each compactive effort.

V. RESULTS & DISCUSSION

A. Particle Size Distribution of Soil

The sieve analysis results have been given in table 7 and figure 4 provides the particle size distribution curve of the natural soil.

Table 7: Results of specific gravity, Atterberg limits, (LL, PL, PI) SPT(MDD, OMC),pond ash-alccofine

Pond Ash Content (%)	Specific gravity		Liquid Limit Test		Plastic Limits Test		Plasticity Index Tests		MDD (mg/m^3)		OMC (%)	
	Alccofine(%)		Alccofine(%)		Alccofine (%)		Alccofine(%)		Alccofine(%)		Alccofine(%)	
	0	3	0	3	0	3	0	3	0	3	0	3
0	1.92	1.93	62	68	26.8	21.4	34.3	47.4	1.43	1.56	29	37
15	1.91	1.91	65	70	30.6	22.7	32.5	47.3	1.45	1.58	32	42
20	1.94	1.92	66	73	32.3	21.3	24.6	52.4	1.49	1.62	34	44
30	1.91	1.90	64	76	29.6	22.7	35.3	52.2	1.53	1.66	38	49
50	1.90	1.89	63	72	30.7	24.7	32.2	46.3	1.54	1.63	31	42

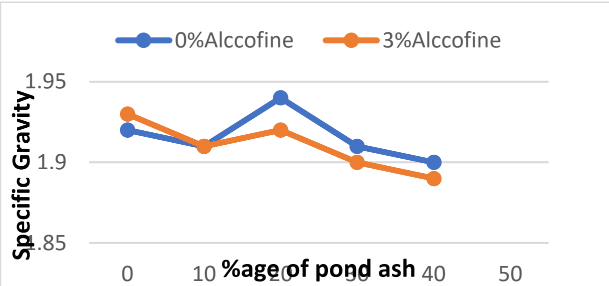

Figure 4: Specific Gravity for Soil / Soil-Pond Ash–Alccofine Mixes

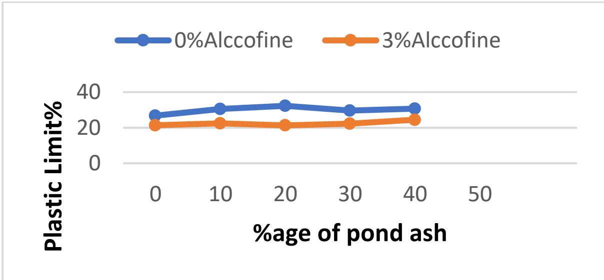

Figure 6: Plastic Limits for Soil / Soil-Pond Ash–Alccofine Mixes

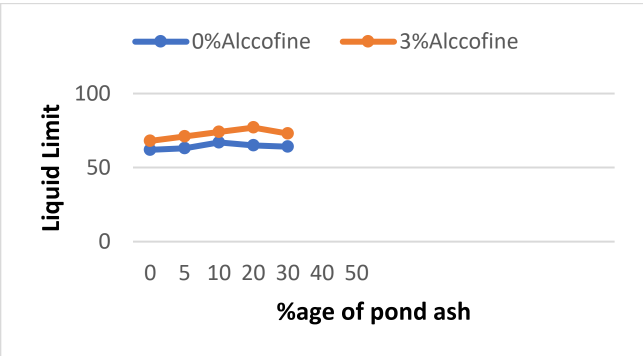

Figure 5: Liquid Limit Test for Soil / Soil-Pond Ash–Alccofine Mixes

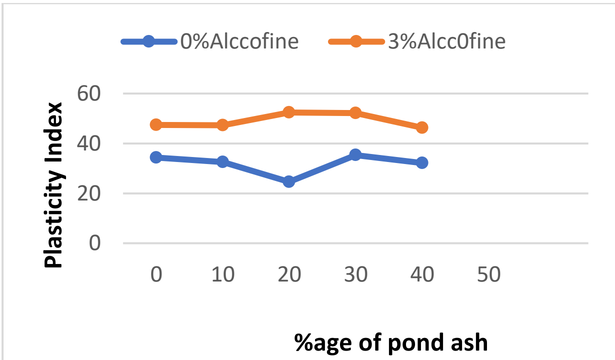

Figure 7: Plasticity Index Tests for Soil-Pond Ash-Alccofine Mixes

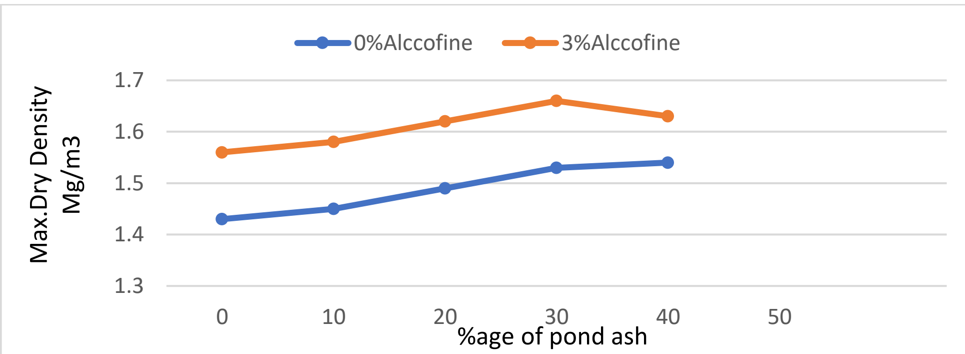

Figure 8: Maximum Dry Density Test for Soil–Pond Ash–Alccofine

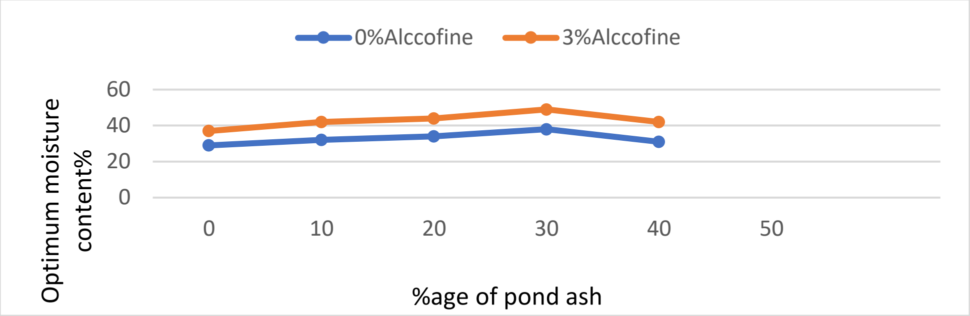

Figure 9: Optimum Moisture Content Tests Results for Soil–Pond Ash– Alccofine Mixer

Figure 4, 5, 6, 7, 8, 9 show the results for Specific Gravity for Soil / Soil-Pond Ash–Alccofine Mixes, Liquid Limit Test for Soil / Soil-Pond Ash–Alccofine Mixes , Plastic Limits for Soil / Soil-Pond Ash–Alccofine Mixes, Plasticity Index Tests for Soil-Pond Ash-Alccofine Mixes, Maximum Dry Density Test for Soil–Pond Ash–Alccofine and Optimum Moisture Content Tests Results for Soil–Pond Ash– Alccofine Mixer respectively

Table 8: Unconfined Compressive Strength (7 Days Curing) Test Results for Soil Pond Ash–Alccofine Mixes

Pond Ash content (%)	Alccofine (%)	Alccofine (%)
	0	3
0	176.58	583.35
15	287.37	567.24
20	452.15	733.78
30	695.27	984.56
50	538.317	821.88

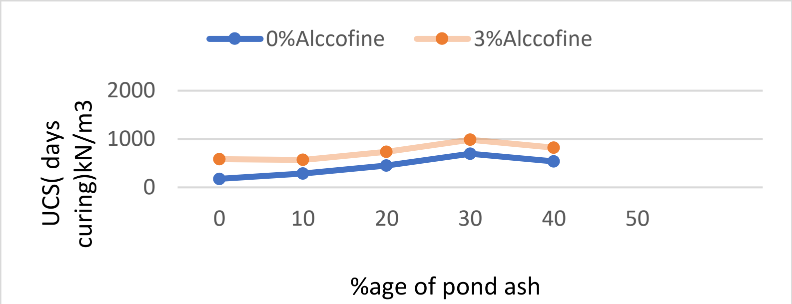

Figure 10: Unconfined Compressive Strength (7 Days Curing) Test for Soil Pond Ash-Alccofine Mixes

Table 9: Unconfined compressive strength (14 days curing) test results for soil pond ash-alccofine mixes

Pond Ash content (%)	Alccofine (%)	
	0	3
0	182.87	876.63
15	356.45	924.87
20	475.53	908.47
30	507.21	1018.31
50	627.43	1325.57

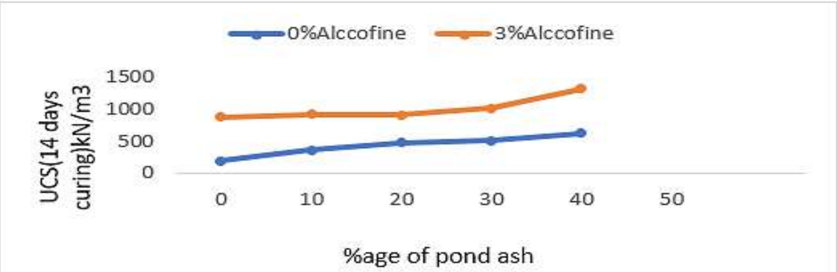

Figure 11: Unconfined compressive strength (14 days curing) for soil-pond ash-alccofine mixes

Table 8 , Figure 10, Table 9 , Figure 11 show the Unconfined Compressive Strength (7 Days Curing) Test Results for Soil Pond Ash–Alccofine, , Unconfined Compressive Strength (7 Days Curing) Test for Soil Pond Ash-Alccofine Mixes , Unconfined Compressive Strength (14 Days Curing) Test Results For soil Pond ash-alccofine Mixes, Unconfined Compressive Strength (14 Days Curing) For Soil-Pond Ash-Alccofine Mixes

B. California Bearing Ratio

An essential factor in determining if a soil or stabilized soil is suitable for engineering application is the California bearing ratio (CBR) rating. It provides a clue as to the soil's durability and bearing capacity.

C. Unsoaked CBR

Figure 1 illustrates the change in the CBR (unsoaked) of soil-pond ash mixes with alccofine concentrations. From a value of 4% for the natural soil, the unsoaked CBR produced a high value of 45% at 30% pond ash and 3% alccofine. [12]

Although larger additive contents and higher compactive efforts enhanced the value of the CBR, it was found that these factors had little to no impact on the CBR values.Table 10 show the California Bearing Ratio (Unsoaked) for Soil-Pond Ash-Alccofine Mixes.

Table 10: California Bearing Ratio (Unsoaked) for Soil-Pond Ash-Alccofine Mixes

Pond Ash content (%)	Alccofine (%)	
	0	**3**
0	4.17	17.27
15	10.78	21.54
20	17.65	26.3
30	21.79	45.1
50	22.67	36.42

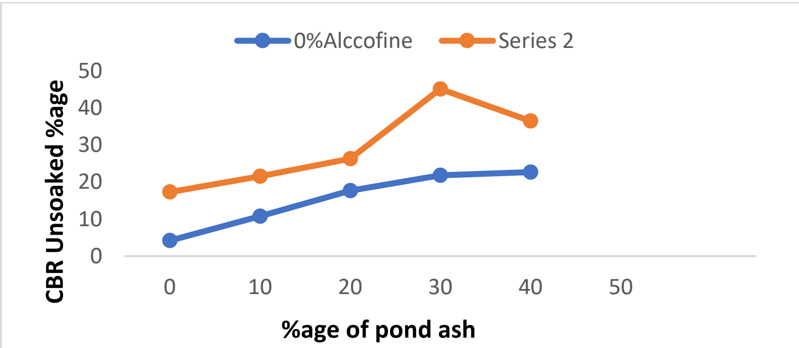

Figure 12: California Bearing Ratio (Unsoaked) for Soil-Pond Ash-Alccofine Mixes

D. Soaked CBR

Figure 12 illustrates the fluctuation in CBR of soil-pond ash mixes with alccofine concentrations after being soaked for 24 hours.

Higher additive levels and more compactive efforts resulted in increases in CBR values, with a peak value of 43% obtained at 30% pond ash and 3% alccofine. [13] The specimen was exposed to water when it was soaked for 24 hours, weakening it and decreasing their strength, which caused the drop in comparison to the unsoaked CBR values. All values were below in table 11 the minimum standards needed for foundation courses. Figure 12 show California Bearing Ratio (Soaked) for Soil-Pond Ash-Alccofine Mixes

Table 11: California Bearing Ratio (Soaked) for Soil-Pond Ash-Alccofine Mixes

Pond Ash content (%)	Alccofine (%)	
	0	3
0	4.59	17
15	9.65	19.69
20	15.83	35.87
30	19.6	42.5
50	20.4	32.43

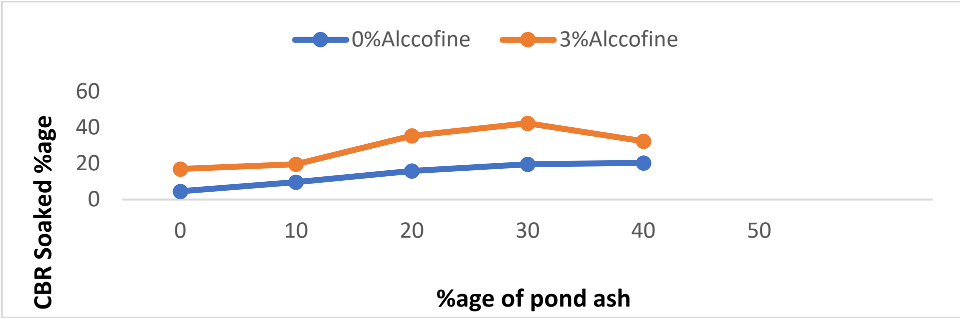

Figure 13: California Bearing Ratio (Soaked) for Soil-Pond Ash-Alccofine Mixes

E. Direct Shear Test

This test is used to understand the concept of shearing of soil. The resistance to shear for cohesion less soil is derived from friction b/w grain and interlocking of grains. The direct shear test is generally conducted on cohesion less soil as C-D test. It is convenient to perform, and it gives good result for the strength parameter. As shown in table 13 and table 14 .

Table 12: Result of direct shear test for Soil-Pond Ash-Alccofine

S. No.	**Properties**	**Range OF ALCCOFINE (3%)**	**Range OF ALCCOFINE (5%)**	**Range OF ALCCOFINE (7%)**	**Range OF ALCCOFINE (9%)**
1	Volume of shear Box	90 cm^3	90 cm^3	90 cm^3	90 cm^3
2	Maximum dry density of soil	1.986 gm/cc	2.032 gm/cc	2.147 gm/cc	2.083 gm/cc
3	Optimum moisture content of soil	12.15 %	12.45 %	13.00 %	13.70 %
4	Weight of the soil to be filled in the shear box	178.84 gm	182.47 gm	191.63 gm	184.91 gm
5	Weight of water to be added	21.62698 gm	22.78217 gm	24.8797 gm	25.5123 gm

Table 13: Calculations for Direct shear test of the soil Admixed with 3%,5%,7%,9% with pond ash

S. No	**Normal Stress(kg/cm^2)**	**Shear Stress (kg/cm^2) (3%)**	**Shear Stress (kg/cm^2) (5%)**	**Shear Stress (kg/cm^2) (7%)**	**Shear Stress (kg/cm^2)(9%)**
1	0.5	0.667	0.69	0.763	0.74
2	1	0.87	0.8	0.97	0.97
3	1.5	1.107	1.12	1.4	1.17

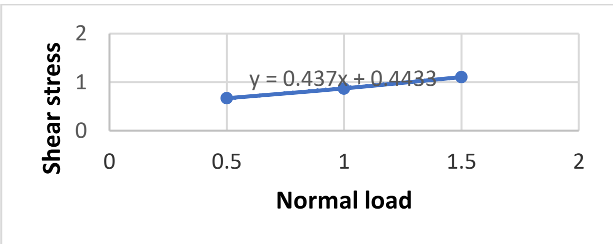

Figure 14: Normal load and shear stress graph for the soil admixed with 3% of pond ash computing from graph

Cohesion (C) = 0.443 kg/cm^2; Angle of internal friction (φ) = $23^0 50$’

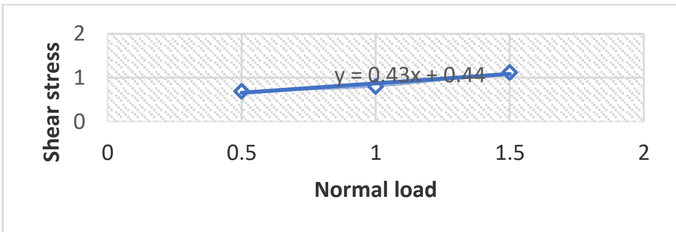

Figure 15: Normal load and shear stress graph for the soil admixed with 5% of pond ash' computing from graph

Cohesion (C) = 0.44 kg/cm^2; Angle of internal friction (φ) = $24^0 70$’

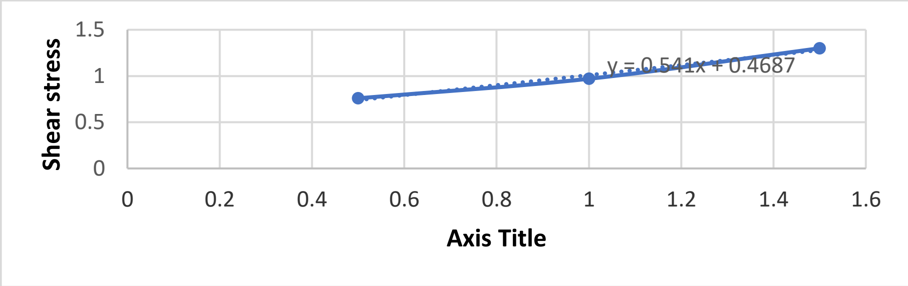

Figure 16: Normal Load and Shear Stress graph for the soil Admixed with 7% of Pond Ash computing from graph

Cohesion (C) = 0.468 kg/cm^2; Angle of internal friction (φ) = 23^{0}50'

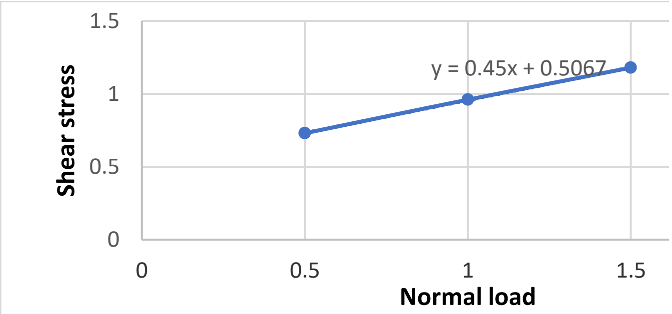

Figure 17: Normal Load and Shear Stress graph for the soil Admixed with 9% of Pond Ash Computing from graph,

Cohesion (C) = 0.506 kg/cm^2; Angle of internal friction (φ) = 25^{0}10'

Figure 14, Figure 15, Figure 16, Figure 16 and Figure 17 show Normal Load and Shear Stress graph for the soil Admixed with 3% of Pond Ash Computing from graph, Normal Load and Shear Stress graph for the soil Admixed with 5% of Pond Ash' Computing from graph Normal Load and Shear Stress graph for the soil Admixed with 7% of Pond Ash computing from graph, Normal Load and Shear Stress graph for the soil Admixed with 9% of Pond Ash Computing from graph,

VI. CONCLUSION

Exploratory research on the naturally occurring sand stabilized using pond ash and alfocine. Since the natural soil was gathered during a rainy season, it has a high moisture content of 36%. It has a 62% liquid limit, a 28% plastic limit, a 37% plasticity index, a 16% linear shrinkage, a 75% free swell, a specific gravity of 1.93, and a high swell potential NBRRI classification. With around 71% of the soil particles going through the B. S. No 200 sieve, all these numbers point to the soil being extremely plastic. The soil is unsuitable for sub-base or road base courses due to its relatively poor strength qualities..

The air dried samples were treated with OPC/ALCCOFINE in stepwise concentrations of 0, 2, 4, 6, and 8% by dry weights of the soil in an effort to improve the soil's suitability for engineering usage. The results of the experiments revealed that at 30% pond ash and 3% alccofine, the natural soil's liquid limit rose from 62% to 78%. However, with 6% OPC/4% ALCCOFINE, the plastic limit dropped from 27.6% for the natural soil to 22.3%. The plasticity index readings for all additive concentrations were higher than the Nigeria General Specification's 30% threshold for substandard materials (1997).

Higher additive mixes and compactive efforts led to a rise in the MDD, which is consistent with a tendency described by Osinubi (1999a), Osinubi et al. (2007b), Staphen (2005), and Akinmade (2008). At 30% pond ash & 3% alcofine treatment, the highest MDD values for BSL, WAS, and BSH compactive efforts are 1.4Mg/m3, 1.5Mg/m3, and 1.6Mg/m3, respectively. On the other hand, the OMC increased with increasing ALCCOFINE concentrations but dropped with higher compactive efforts. When larger compactive energies were applied, the aggregates that flocculated and big pores may have been eliminated, which may have caused the drop. When compacted employing BSL, WAS, and BSH energies at 8% OPC/6% ALCCOFINE, 50% pond ash & 3% alccofine, and 30% pond ash & 3% alccofine, respectfully, the optimal moisture saturation values at the natural states went from 24, 21, and 19% to 40, 38, and 33%.

Undrained shear strength (UCS) values for naturally occurring soil compaction with BSL, WAS, and BSH values at a 7-day curing tank are 177, 382, and 751, etc, and they rise to 984, 1435, and 1651kN/m2 with treating with 30% pond ash and 3% alocofine.

According to Road Note 31 (TRRI, 1977), the values of UCS for both BSL and WAS were insufficient to stabilize the economic range of the OPC. For base courses of pavements, the UCS value of the BSH compaction, however, can be acceptable. The OPC/ALCCOFINE blend provides a long-term benefit in terms of strength increase, as seen by the 28-day curing period UCS values that were attained. The values of UCS have increased significantly since they were in their original states. The soil treated with this composition can be employed (at BSH compaction) as the base course of pavement material, as demonstrated by the 28-day curing period UCS's peak value of 2617kN/m2 at 30% pond ash & 3% alccofine..

The unsoaked CBR values of 5, 7, and 11% (for the natural soil) climbed to 46, 77, and 83% at 30% pond ash and 3% alccofine when compacted with BSL, WAS, and BSH energy efforts, respectively. The highest BSL, WAS, and BSH energies for the 24 hours soaked CBR values were 42, 66, and 66%, respectively; this represented a 10-15% decrease from the unsoaked CBR values. Because the CBR values of 66% with BSH compaction at 30% pond ash & 3% alccofine blend meet the 29% recommended values for sub-base by the Nigerian General Specification, it can be used as sub-base material (1997). The 42% recorded with BSL compaction at 30% pond ash & 3% alccofine treatment also satisfies the Nigerian government's 15% recommendation for subgrade material.

When exposed to BSL, WAS, and BSH energies at concentrations of 50% pond ash and 3% alccofine, 8% OPC/0% ALCCOFINE, and 30% pond ash & 3% alccofine, respectively, the resistance of the soil to decline in strength improved from 13, 7, and 15% for the natural soil to peak values of 42, 13 and 71%. The limiting value of 80% barrier to loss in strength (Ola, 1983) based on 4 days of soaking is not reached until only 71% resistance to loss in strength (29% loss in strength) with 30% pond ash & 3% alccofine with BSH crushed. Due to the soil's tougher treatment (a 7-day drying period) and the duration of the 6% OPC 6% ALCCOFINE application, sub-base material can be employed at BSH compactor.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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