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VARIATIONS IN GEOTECHNICAL ENGINEERING PROPERTIES OF SOILS USING POZZOLANS

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ABSTRACT:

Study brings out the effect of Siliceous and Aluminous compounds available in amorphous form present in waste of thermal power plant after burning coal, when different doses are mixed with expansive and non-expansive soils, the two extreme end Geotechnical properties, for soil stabilization purpose. Fly ashes produced after burning coal exhibit different proportion of compounds which can produce cementitious products called pozzolans, interact with soils to attain stabilized status. The waste product Fly ash in thermal power plant, some of them are pozzolanic in nature and some may not have that property which depends on chemical composition. Use of Fly ash for soil stabilization attributes to the chemical composition and physical characteristics of Fly ash, which favour pozzolanic reactions. The major chemical compounds present in Fly ash contribute active role in chemical reactions with constituents of soil are calcium Ca^{+} and Silica Si^{-} ions. The optimum binder combination varies with type of soil and binder pozzolanic reactivity. The pozzolanic reactivity assessed on the rate at which the strength imparting phases are produced due to chemical reactions between soil ingredients and binder. In this work Geotechnical Engineering properties of two extreme types of soils, expansive one – Black cotton soil (BC Soil) and non-expansive type – Red Earth (RE) are stabilized using pozzolanic Fly ash – Nyveli Lignite Fly (NFA) ash and non-pozzolanic Fly ash – Raichur Fly ash (RFA) mixed at different doses along with supplementing additives like Lime and Cement. Addition of calcium component to soil and non-pozzolanic Fly ash mix in the form of cement is used to exploit chemical compounds formation due to silica component present in non-pozzolanic Fly ash. Similarly addition of Lime to pozzolanic Nyveli Fly ash to stabilize both soils is used. The Geotechnical engineering properties like stabilization, Compressive strength, Compaction character for both soils have been studied in this work. The maximum dry density of the BC soil increased from 13.6 to 15.2 kN/m^3 for addition of 40% NFA. For Red earth MDD changed from 14.6 to 17.8 kN/m^3 for NFA addition. Pozzolanic Fly ash has shown considerable improvement in compressive strength from 310kPa to 1393kPa for B C soil and from 590kPa to 2342kPa for Red Earth, for addition of 30% of Fly ash,

NFA. Addition of 3% cement to non-pozzolanic Fly ash, RFA (30%) in case of B C soil has shown strength increase in four folds reaching 1317 kPa for 28 days curing period.

KEY WORDS: *Pozzolanic Reactivity, Fly ash, Stabilization, Red Earth, Black Cotton Soil, pozzolana, Geotechnical Properties, calcium Ca $^{+}$ and Silica Si $^{-}$ ions.*

INTRODUCTION

Expansive soil deposits are problematic to engineering structures because of their swelling and shrinkage property. The deformations produced as a result of swelling or shrinking are significantly greater than elastic deformations and classical elastic or plastic theory cannot predict them. Structures on these soils experience large-scale damage due to heaving accompanied by loss of strength of these soils during rainy season and shrink during summer. The apparent effect of swelling is observed as considerable distress in the form of ground cracks, building cracks, canal lining slides, beds of canal heave, heaving and rutting of pavements etc. The soil engineer must choose the most efficient method considering the environment, type of structure and most important of all, establish the degree of treatment needed for the structure to survive under future moisture changes.

In chemical stabilization the use of pozzolanic materials such as cement, lime, and other waste materials are well established.

On the other hand, non expansive soils are abundantly available. If not they are as problematic as that of expansive soils, but require improvement in Geotechnical properties before utilizing it as construction material. In similar way non expansive soils can also be treated as in the case of expansive soils, depending on physical properties and chemical composition of this group of soil.

Fly ashes are finely divided residue resulting from the combustion of ground or powdered coal in thermal power plants. They are generally finer than cement and consist mainly of glassy-spherical particles as well as residues of hematite and magnetite, char and some crystalline phases formed during cooling.

Fly ash is a fine powder consisting of inorganic mineral constituents in the coal and the organic matter which is not fully burnt during the combustion of coal. The principle constituents in fly ash are silicon dioxide (SiO_2), aluminum oxide (Al_2O_3)' iron oxide (Fe_2O_3) calcium oxide (CaO) and carbon content. Ash also contains smaller amounts of MgO, TiO_2, Na_2O and K_2O; and very small quantities of 20 to 50 elements. Loss on ignition is generally equal to carbon content though some times it is about 0.5 to 1.0% more than carbon content. This may be due to presence of carbonates and combined water in residual minerals. Researchers reported that carbon is the most abundant in coarser fraction of fly ash.

An attempt has been made in this work to improve physical and strength properties of black cotton (BC) soil a highly expansive one and other red earth (RE) a non expansive soil. Two verities of fly ashes have been incorporated to black cotton soil and red earth to test improved properties. In cases where ash stabilization alone is not sufficient to meet the requirement of particular task, the ash stabilization can be improved by adding suitable chemicals. Cement is also used to improve further strength of soils.

The present paper describes the effect of pozzolanic and non pozzolanic fly ashes along with cement on strength behavior and improvement in physical properties of black cotton soil and red earth.

MATERIALS:

Naturally occurring black cotton soil (BC Soil) containing montmorillonite as principal clay mineral has been used. This is a residual soil and was collected from an open excavation, at a depth of one meter below the natural ground surface. The soil was dried and passed through IS sieve size of 425 microns before being used in this investigation. The soil has got unconfined compressive strength of 310 kPa and maximum dry density 13.6 kN/m^3. The chemical properties reveal that BC Soil has 52.85% Silica (Sio_2) and 6.01% Calcium Oxide (CaO). The other soil is Red Earth is collected same way and it soil has got unconfined compressive strength of 590 kPa and maximum dry density 14.6 kN/m^3. The chemical properties reveal that Red earth has 60.4% Silica (Sio_2) and 6.9% Calcium Oxide (CaO).

Raichur Fly Ash (RFA) is non plastic with specific gravity of 2.02. Chemical analysis reveals that the soluble silica and free lime content in fly ash are very less. Neyveli Fly Ash (NFA) is collected from Neyveli Thermal Power station, Chennai, Tamilnadu. NFA is non plastic with a specific gravity of 2.0. Chemical analysis shows that there is base soluble silica content of 5.61% and free lime content of 3.92%. Ordinary Portland cement is collected from authorized supplier. Chemically pure hydrated lime Ca $(OH)_2$ is procured commercially.

METHODS OF TESTING:

COMPACTION

According to I.S.10074-1982 Compaction was done for soil and trail mixes chosen to immediate mixing using Proctors apparatus and the value of maximum dry density and corresponding optimum moisture content inferred from compaction curves. About 300 grams of soil mixed with water thoroughly and stored in polythene bag for moisture equilibrium and remixed as per ASTM D 698-91 (1995). The soil and additives are compacted in the mould in three layers by giving 45 blows to each layer. Rest as per light compaction test according to I S 2720(part VII) (1980) is followed.

UNCONFINED COMPRESSIVE STRENGTH:

SPECIMEN PREPARATION:

The samples were prepared by static compaction method to achieve maximum dry density at optimum water content. The mould consists of steel device with an internal diameter of 38 mm and height of 77 mm. The volume of steel tube was calculated as equal to the volume of the sample knowing the volume and the density required, the weight of the sample of trial mixes whose combination percentages were chosen are determined and the water content corresponding to the optimum moisture content was added. This was transferred to the steel-tubing device. It was then compressed by rotating or pushing the pistons simultaneously from both the ends, which resulted in a sample of 38-mm diameter and 77 mm height. These samples were extracted with the help of a sample extruder. The ends of each specimen were trimmed flat perpendicular to its axes of specimen.

CURING:

Three identical samples were prepared for their maximum density at optimum water content based on compaction curves obtained. The sample for various curing periods of testing that is immediate, 3, 7, 14, 21 and 28 days testing. All the samples prepared were labeled according to the trial combination chosen. Samples were cured in desiccator's and covered with moist cloth to maintain 100 % humidity and prevent loss of any moisture from the samples. All the samples intended for immediate testing were tested immediately.

TEST PROCEDURE:

The test was conducted using unconfined compression test apparatus at a strain rate of 1.2 mm/min. The specimen to be tested was placed centrally in between the lower and upper platform of the testing machine. The proving ring readings were noted for each 50 divisions on a deformation dial gauge. The loading was continued until three or more consecutive reading of the load dial showed a decreasing or a constant load or a strain of 20 % had been reached.

RESULTS AND DISCUSSIONS:

EFFECT OF ASHES ON PROCTOR'S MAXIMUM DRY DENSITY OF SOILS:

Figure 1 shows the compaction values of both soils and ashes mixtures. For every addition of ash (10% every time) the maximum dry density goes on decreasing. The maximum dry density from 13.6 kN/m3 reduces to 12.9 kN/m3 for B C+ RFA mixtures. Moisture content of the mixtures continuously decreases for addition of RFA. Optimum water content decreases from 34% to 23.3%. The decrease in maximum dry density is due to domination of low specific gravity of ash. Further the soil gradation may be adversely affected the dry density at higher content of ash in the mixture. However above factors decreases the water holding capacity of the mixture and hence optimum moisture content decreases continuously with every increment in ash. Fig 1 also shows similar changes in other three combinations like BC+NFA; RE+RFA & RE+NFA. At 40% addition of both ashes to both soils separately, have reached maximum density as seen in graph. The MDD for four combinations of soil-ash mixtures BC+RFA, BC+NFA, RE+RFA and RF+NFA at 40% addition of ash has reached to14.2, 15.2, 17.4 and 17.8 kN/m^3 respectively.

EFFECT ASHES ON UNCONFINED

COMPRESSIVE STRENGTH OF SOILS:

The effect of addition of ash on unconfined strength of soil samples compacted to their respective maximum dry density at corresponding moisture content has been examined. Figure 2 and Table 1 shows the unconfined compressive strength of soil and ash mixtures for all combinations cured for 28 days. The combination of RE+NFA mixtures has shown good strength. This has reached strength of 2306 kPa for addition of 40% NFA after 28 days curing from as low as 590 kPa of red earth. The effect of pozzolanic reaction dominates strength gain at higher curing periods where as the effect of density dominates strength gain at lower curing periods. Graph reveals that for all combinations an addition of 30 to 40% of ash has shown high strength gain by both soils.

EFFECT OF STRENGTH BY SECONDARY

ADDITIVE ON 28 DAYS CURED SAMPLES:

To observe possibility of further improvement of strength of 28 days cured samples, addition of cement for RFA and addition of lime for NFA has been considered. The chemical analysis reveals that RFA has less reactive silica and free lime, which are responsible for early impart of strength to mixtures. But NFA has got base soluble silica of 5.61% and free lime content of 3.92%. Experiments reveal that there is considerable increase in strength of mixtures.

The cement treated RFA + BC soil mixtures have reached strength upto 1387 kPa for 40% ash and 3% cement cured for 28 days. Similarly cement treated RFA+RE mixtures have reached strength upto 1697 kPa for 40% ash and 3% cement cured for 28 days. The lime treated NFA+BC soil mixtures have shown strength reaching upto 2073 kPa for 40% ash and 5% lime cured for 28 days. Similarly lime treated NFA+RE mixtures have reached strength upto 2842 kPa for 40% ash and 5% lime cured for 28 days. The figure 3 & 4 shows the effect of cement on strength behavior of both soils and figures 5 & 6 shows the effect of lime on strength of both the soils after curing samples upto 28 days.

CONCLUSIONS:

- The following are the conclusions of the study carried out.
- On addition of any ash decreases the diffused double layer thickness of mixture and hence water holding capacity of soil mixtures decreases.

- On addition of any ash the gradation of mixture is adversely affected which leads in reduction of dry density for higher content of ash. But at 40% of any ash addition shows high density of mixtures.
- Both ashes can be used as a good stabilizer along with secondary additives. RFA ash needs cement as secondary additive and NFA ash needs lime as secondary additive.
- Cement and lime imparts considerable strength in both the soils.

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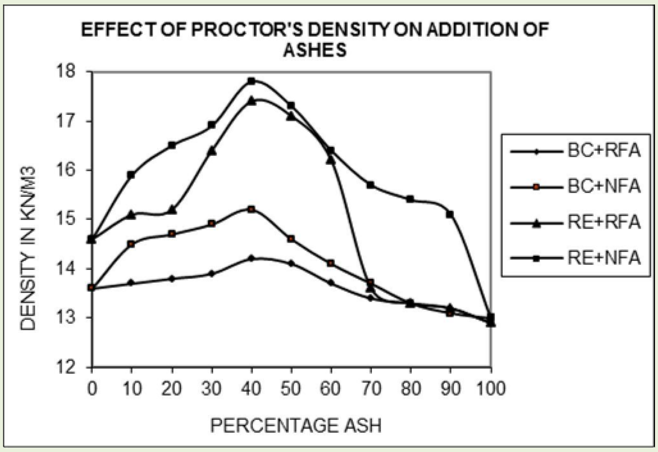


Figure1. Effect of ashes on density of soil

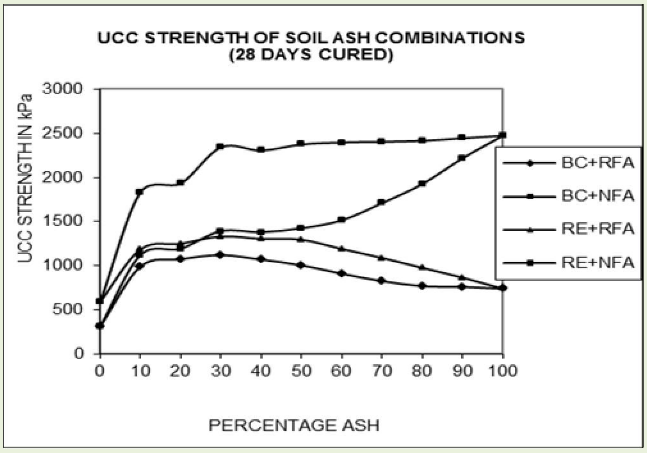


Figure 2 Effect of ashes on strength of both the soils

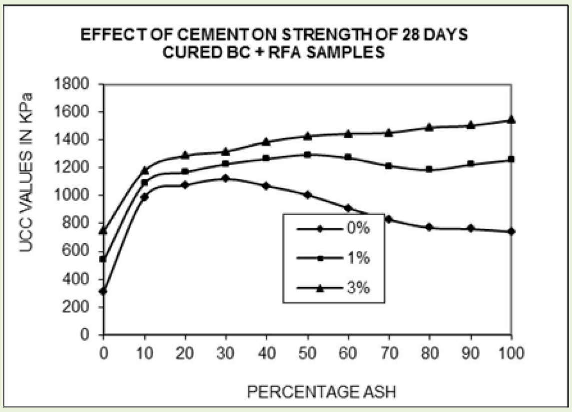


Figure 3. Effect of cement on strength of BC soil

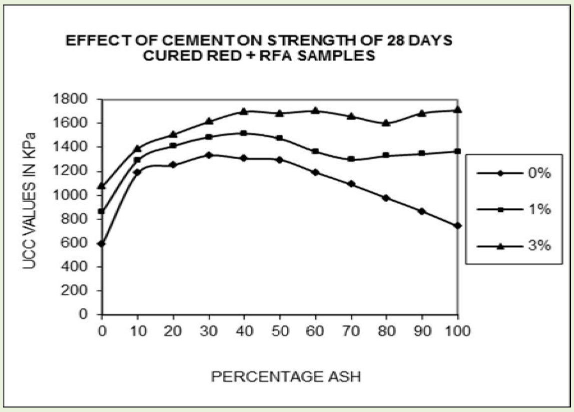
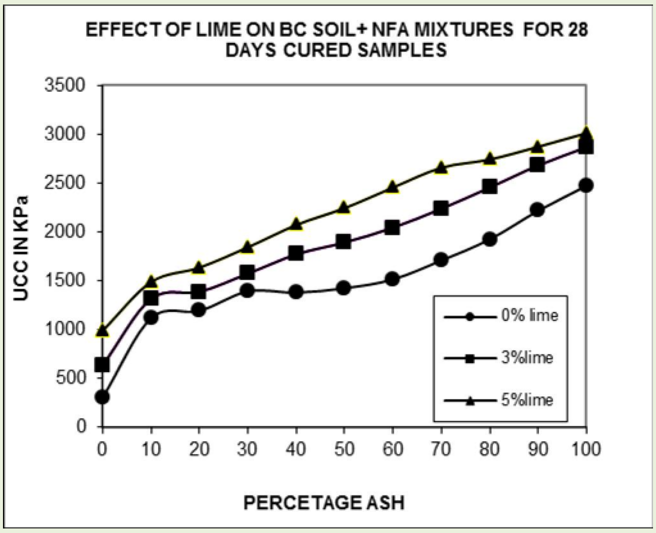


Figure 4 Effect of cement on strength of Red soil



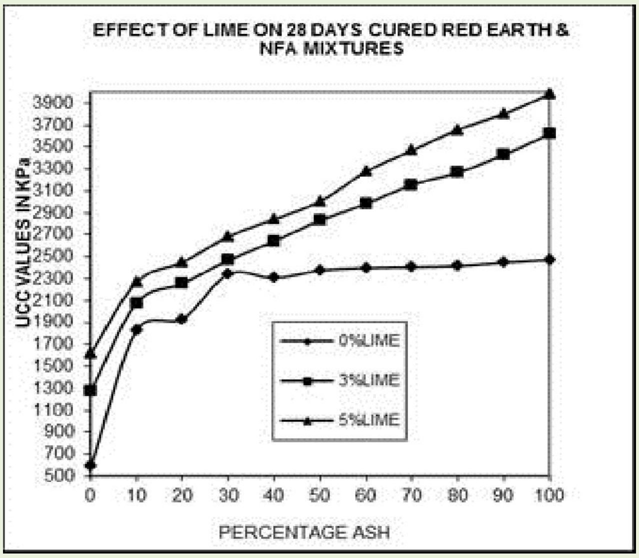


Figure 5 Effect of lime on strength of BC soil Figure 6. Effect of lime on strength of red soil

Table 1 Comparison of the strength of soils with fly ashes after curing for 28 days

Fly Ash (%)	UCC Strength, kPa			
	BC+RFA	BC+NFA	RE+RFA	RE+NFA
0	310	310	590	590
10	990	1120	1185	1831
20	1075	1194	1250	1932
30	1120	1393	1332	2342
40	1070	1381	1305	2306
50	1005	1425	1295	2375
60	910	1516	1190	2397
70	826	1710	1089	2405
80	769	1926	976	2415
90	760	2218	865	2446
100	740	2473	740	2473