Effect of Carbonates on Compaction Behaviour of Lime treated BC Soil treated, Fly ash mixtures

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***Abstract*—Black cotton soils are problematic to civil engineering structures they undergo large volume changes due to variation in water content. Montmorillonite is the major clay mineral present in the Black cotton soil. In order to improve their properties, different admixtures are used. Among them fly ash, which is the byproduct of combustion of pulverized coal in thermal power plants is being increasingly used. Industrial activity is necessary for the social-economic progress of a developing Country but at the same time it generates large amount of solid and liquid waste. These wastes contain different types of chemicals both in solid and liquid form. These chemicals consist of different chemical compositions which alter the geotechnical properties of soil by reacting with the chemical composition of soils. Soils when contaminated with chemicals, significant change in their volume is observed. This paper presents the experimental programme on compaction characteristics of black cotton soil treated with fly ash and lime in presence of varying percentages of alkalis. Alkalis used in the present study are calcium carbonate and magnesium carbonate, both ranging from 5% - 20%. On addition of calcium carbonate to BCS-FA-Lime mixture maximum dry density of BC soil increases from14.74kN/m^3 to 14.88kN/m3 and optimum moisture content of BC soil decreases from 31% to 25.4% respectively, on addition of magnesium carbonate maximum dry density of BC soil decreases from14.7kN/m^3 to 11.1kN/m3 and optimum moisture content of BC soil increases from 31% to 47.8% respectively. Based on the present study it can be concluded that compaction characteristics improves with calcium carbonate compared to magnesium carbonate.**

I. INTRODUCTION

Expansive soils due to high plastic nature are extremely difficult to compact properly. This can be overcome by adding additives with no or low plasticity lime, cement, fly ash, rice husk ash etc. Compaction is a mechanical process in which the densification is achieved through the expulsion of air voids at almost constant water content of the soil mass. The important factors which affect these characteristics are the compactive effort, admixtures and the type of soil. Peninsula and observed that with increasing phosphoric acid addition, there is clearly a reduction in optimum moisture
(Bowles,1984). With increasing compactive effort, the maximum dry density increases and the optimum moisture content decreases. The dry density and water content depends on the amount of silica and free lime content in the fly ash. Compaction increases the strength characteristics of soils, which in turn increases the bearing capacity of foundation over them. It also increases the stability of slopes of embankments and decreases the undesirable settlement of structures. This paper presents effect of carbonates on compaction characteristics of BC soil treated with fly ash and lime. The alkalization alters the index and engineering properties of soil, if present in excess quantity could be detrimental and acts as contaminant. Bell, (1980) studied the phosphoric stabilization for insitu loessial soils of Banks content, and a corresponding increase in maximum compacted dry density. Bell, (1987) studied the enhancement of the properties of clayey soils by addition of cement or lime. Tests were conducted for soil a, soil b and soil c and reported that the decrease in maximum dry density and corresponding increase in optimum moisture content in clayey soils treated with either lime or cement may be caused by flocculation. In addition, the increases in hydroxyl ions which are liberated, especially by lime, increase the affinity of the surfaces of clay particles with water. Mir, (2004) studied the effect of fly ash on geotechnical properties of soils and reported that addition of fly ash improves the workability of soil considerably and it can be used as an effective stabilizer.

II. MATERIALS

Black cotton soil used is a residual soil, collected at a depth of one meter below the natural ground surface in Davanagere, about 250 km from Bangalore. This pulverized soil passed through 425 micron BIS sieve has been used for the investigation.

The fly ash used is non-pozzolanic collected from Raylaseema thermal power plant (R.T.P.P) Muddanur, from Andhra Pradesh. The physical properties of oven dried black cotton soil and fly ash were analyzed as per the standard methods and have been presented in table 1.

Chemically pure hydrated lime and alkalis (calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) is obtained from Fisher Scientific chemicals private limited Mumbai, India. The physical and chemical properties of calcium carbonate are presented in table 2.

Calcium carbonate is a compound of calcium and carbon dioxide. It is a common substance found as rock in all parts of the world. It is the main component of shells of marine organisms, snails, and egg shells. It is the active ingredient in agricultural lime.

Magnesium carbonate occurs in the minerals, magnesite ($MgCO_3$) and dolomite ($MgCO_3$. $CaCO_3$). It can also be prepared by adding sodium carbonate solution to magnesium chloride solution.

Table 1. Physical properties of black cotton soil and fly ash

Physical properties	Black cotton soil	Fly ash
Colour	Black	Light Grey
Specific gravity	2.65	2.31
GRAIN SIZE DISTRIBUTION		
Fine sand (%)	7.78	0
Silt (%)	33.37	79.19
Clay (%)	58.85	20.81
ATTERBERG'S LIMITS		
Liquid limit (%)	74.32	27.50
Plastic limit (%)	40.20	NP
Shrinkage limit (%)	8.20	23.42
Unconfined Compressive Strength (kpa)	247.83	156.14
COMPACTION CHARACTERISTICS:		
Maximum dry density (kN/m^3)	14.74	15.34
Optimum moisture content (%)	31.00	20.30

*NP : Non-plastic

Table 2. Physical and chemical properties of alkalis

Physical and Chemical parameter	Calcium Carbonate (CaCO3)	Magnesium Carbonate ($MgCO_3$)
Color and appearance	White Powder	White Powder
Molecular weight	100.1	84.3
Density	2.71	2.05
Solubility in 100 parts solvent	0.013g/100ml@ 20°C,soluble in acids	0.01g/100ml @20°C,soluble in acids
Assay (%)	Min 98.5	Min 95
Substance insoluble in Hydrochloric acid (%)	Max 0.05	Max0.05
Chloride (Cl) (%)	Max 0.05	Max 0.075
Sulphate (SO4) (%)	Max 0.5	Max 1.2
Lead (Pb) (%)	Max 0.005	Max 0.001
Iron (Fe) (%)	Max 0.05	Max 0.04
Arsenic (As) (%)	…………	Max 0.0002
Calcium (Ca) (%)	98.5	Max 2

III. EXPERIMENTAL PROGRAM

Compaction test conducted to study the effect of calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$) on black cotton soil treated with optimum percentage of fly ash and lime. Compaction tests were conducted on black cotton soil with varying proportion of fly ash as 10, 20, 30, 40, 50, 60 and 70%. By conducting unconfined compression strength test on BC soil and fly ash mixtures, optimum percentage of fly ash was obtained with and without curing. For soil and optimum content of fly ash lime is varied as 1, 2, 3, 4 and 5% and optimum percentage of lime was obtained by strength test. Similarly carbonates were added to soil-fly ash-lime mixture as 5, 10, 15 and 20%. Optimum content of carbonates were determined by strength test. All the chemicals were thoroughly mixed with water to form a fine paste before adding to soil to obtain uniform mixture.

The compaction test was conducted using specially made apparatus (mini compaction test apparatus) (Sridharan et.al., 2005)., according to IS: 10074-1982 having a mould of internal diameter 38.1 mm and external diameter 46.1 mm and 100 mm in height. The mould has a detachable base plate and a removable collar of 35 mm height. The hammer guide is of mass 13 N and has 3 rods. The bottom steel rod is 80 mm long and 36.5 mm in diameter acts as an energy transferring foot and the top rod is 30 mm long and 36.5 mm in diameter. The compaction tests were done for the black cotton soils and other trial mixes chosen on immediate mixing using proctor's apparatus and the value of maximum dry density and corresponding optimum moisture content inferred from the compaction curves were calculated. The hammer are 35mm in height with a central bore of 19 mm, fall freely through a height of 160 mm (height of fall) over the energy transferring foot. About 300 grams of soil is used for each trial in the mini compaction test. Required amount of water is added to the soil and mixed thoroughly. The mould is cleaned, dried and greased lightly. This was done to reduce the side wall friction and for easy extrusion of compacted sample. The mould was fixed to the base plate and the soil is then compacted in the mould in three layers by giving 36 blows to each layer. Then the remaining procedure is same as that of light compaction test as per IS: 2720 (part VII) (1980).

The unconfined compression mould consists of steel device with an internal diameter of 38 mm and height of 76 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 76 mm in 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

Compaction test and unconfined compression strength tests were conducted for black cotton soil with various percentages of fly ash, lime and alkalis. With the test results it was observed that strength of BC soil increased till 50% fly ash, 3% lime, 10% calcium carbonate and 15% magnesium carbonate, further addition of additives caused decrease in strength.

IV. RESULT AND DISCUSSION

The effects of alkalis on compaction characteristics of black cotton soil treated with various percentages of fly ash and lime have been studied. Optimization of fly ash, lime and alkalis to be added to black cotton soil is done by unconfined compression strength test. Table 3 represents compaction characteristics of black cotton soil treated with optimum percentage of fly ash and lime in presence of varying percentages of alkalis ranging from 5% to 20%.

Table 3. Compaction characteristics of black cotton soil with additives

Mixture	Maximum dry density (kN/m^3)	Optimum moisture content (%)
BCS alone	14.7	31.0
FA alone	15.3	20.3
BCS + 50% FA	16.8	18.2
BCS + 50% FA + 3% Lime	15.2	25.5
BCS + 50% FA + 3% Lime + 5% $CaCO_3$	14.7	28.0
BCS + 50% FA + 3% Lime + 10% $CaCO_3$	14.9	27.4
BCS + 50% FA + 3% Lime + 15% $CaCO_3$	14.7	26.4
BCS + 50% FA + 3% Lime + 20% $CaCO_3$	14.8	25.4
BCS + 50% FA + 3% Lime + 5% $MgCO_3$	13.2	33.2
BCS + 50% FA + 3% Lime + 10% $MgCO_3$	11.8	40.8
BCS + 50% FA + 3% Lime + 15% $MgCO_3$	12.1	40.2
BCS + 50% FA + 3% Lime + 20% $MgCO_3$	11.1	47.8

* BCS : Black cotton soil FA : Fly ash

Effect of Fly ash on Compaction Characteristics

The dry density and water content depends on the amount of silica and free lime content in the fly ash, it was found that 50% Muddanur fly ash is optimum for expansive black cotton soil. On addition of various percentages of fly ash to the black cotton soil the maximum dry density increases optimum moisture content decreases. With 50% flya ash content maximum dry density and optimum moisture content was observed to be 16.8kN/m^3 and 18.2% respectively as shown in figure 1. The addition of fly ash to BC soil decreases the optimum moisture content and increases the maximum dry density (Leonards and Bailey, 1982). This may be due to decrease in repulsive pressure of soil, which resists compactive effort, consequently better packing of soil particles achieved by improved gradation, and less water absorption capacity of fly ash.

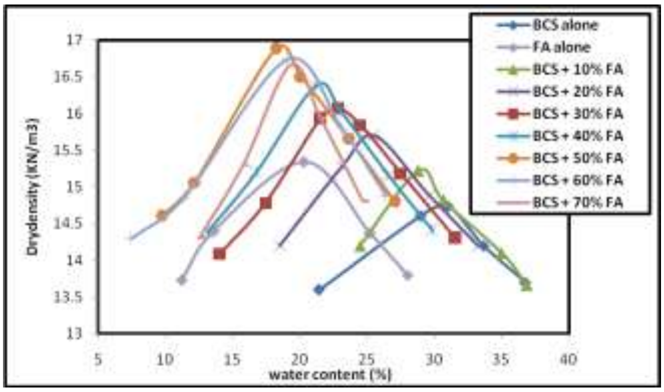

Fig 1 Variation of dry density-water content relationship of black cotton soil treated with various percentage of fly ash

Effect of Lime on Compaction Characteristics

On addition of 1% to 5% lime content to BC soil and fly ash mixture, the maximum dry density increases upto 3% of lime with decrease in optimum moisture content as shown in figure 2. This is due to the increased flocculation and agglomeration of soil particles having large void spaces occupied by lime (Ola, 1978 and Lees et al, 1982) with increase in availability of lime content. The increase in OMC of expansive clays treated with lime may be caused by flocculation so that when compacted the soil each have an increased volume of voids compared with untreated soil, in addition the increase in hydroxyl ions liberated by lime, increases the affinity of the surfaces of clay particles for water (Bell, 1987).

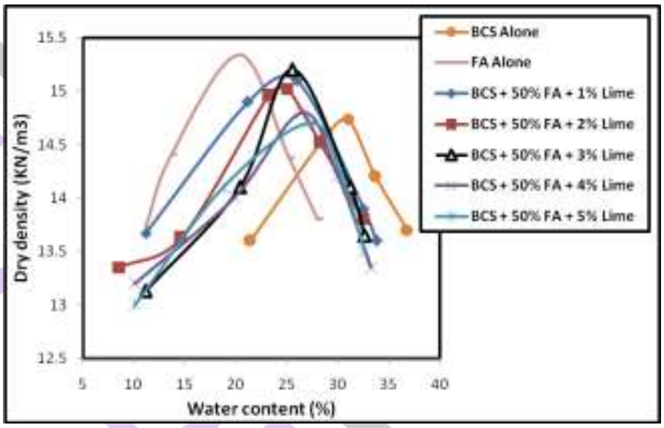

Fig. 2 Variation of dry density-water content relationship of black cotton soil and fly ash mixture treated with various percentages of lime

Effect of Calcium Carbonate on Compaction Characteristics

On addition of various percentages of calcium carbonate to the BCS-FA-Lime mixture, maximum dry density increases and optimum moisture content decreases upto 10% which is an optimum percentage for calcium carbonate as shown in figure 3. This may be due to the density and Specific gravity of calcium carbonate used is higher than that of BC soil decrease in moisture content is attributed to reduction in diffused double layer by cation exchange.

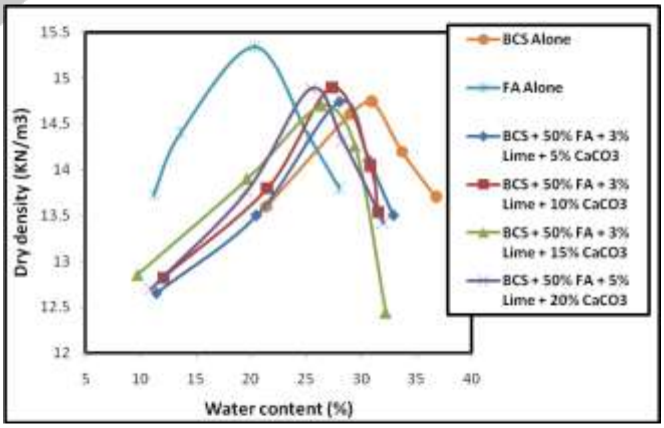

Fig. 3 Variation of dry density-water content relationship of lime treated black cotton soil and fly ash mixture treated with various percentages of calcium carbonate ($CaCO_3$)

Effect of Magnesium Carbonate on Compaction Characteristics

On addition of various percentages of magnesium carbonate to the BCS-FA-Lime mixture maximum dry density decreases to 12.1kN/m^3 and optimum moisture content is increases to 40.2% on 15% addition of magnesium carbonate. This is due to flocculation and hydration between soil and magnesium carbonate particles. This may be due to the light weight of magnesium carbonate and more water holding capacity of the rearranged particles as shown in figure 4.

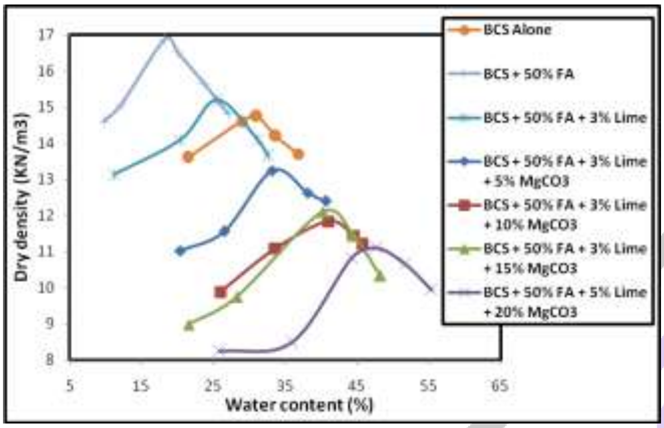

Fig. 4 Variation of dry density-water content relationship of lime treated black cotton soil and fly ash mixture treated with various percentages of magnesium carbonate ($MgCO_3$)

The effect of carbonates on compaction characteristics of lime treated black cotton soil, fly ash mixture is as shown in figure 5.

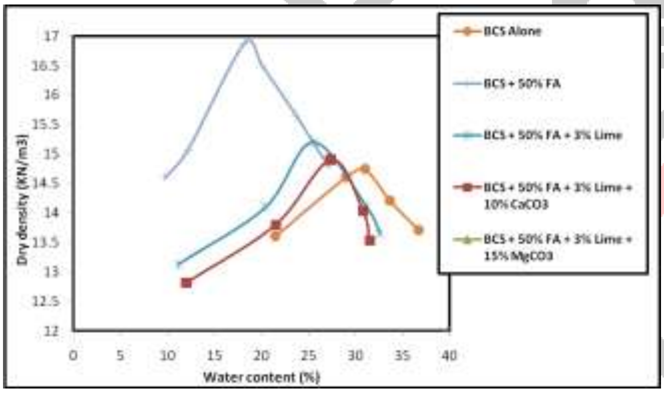

Fig. 5 Variation of dry density-water content relationship of lime treated black cotton soil and fly ash mixture treated with optimum percentage of carbonates

V. CONCLUSION

Addition of various percentages of fly ash to black cotton soil, the maximum dry density increases with decreasing in optimum moisture content upto 50% fly ash addition, due to decrease in repulsive pressure of soil, which resists compactive effort, consequently soil particles become closer with lower water absorption capacity.

Addition of 1 to 5% lime to optimum fly ash treated black cotton soil, the maximum dry density increases upto 3% lime addition, thereafter maximum dry density decreases with increase in optimum moisture content due to the increasing demand for water by various cations and the clay mineral particles to undergo hydration reaction.

On addition of various percentages of calcium carbonate to BCS-FA-Lime mixture maximum dry density increases and optimum moisture content decreases upto 10% which is an optimum percentage for calcium carbonate, beyond 10%.

This is due to the density and specific gravity of calcium carbonate used is higher than that of BC soil and decrease in moisture content is attributed to reduction in diffused double layer by cation exchange.

On addition of various percentages of magnesium carbonate to BCS-FA-Lime mixture maximum dry density increases and optimum moisture content is decreases upto 15% which is an optimum percentage for magnesium carbonate, beyond 15%, maximum dry density decreases with increase in optimum moisture content.

Maximum dry density achieved is less and optimum moisture content is more than that of black cotton soil alone. This is due to the light weight of magnesium carbonate and more water holding capacity of the rearranged particles. Index properties were improved for expansive BC soil, in which the liquid limit and shrinkage limit improves with $CaCO_3$.

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