BEHAVIOR OF BLACK COTTON SOIL WITH ADDITION OF SODIUM CARBONATE AND CALCIUM CARBONATE

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Abstract *The properties of Black Cotton Soil may be improved with Sand Cushions, CNS layers techniques, sand Columns, Stone Columns, Vibration Techniques and by adding Chemicals etc. Among these Chemical Stabilization is expansive than other types of stabilization methods. But the main advantage is setting time and curing time can be controlled. The effectiveness of Sodium Carbonate and Calcium Carbonate is stabilizing a Black Cotton Soil(BCS) is presented in this paper. The effectiveness of Calcium Carbonate is much better than Sodium Carbonate from Strength and stability point of View.*

The soil sample are prepared with chemical solution of varying percentages. Chemical solution is prepared by dissolving chemical powder in distilled water. The percentages of chemical are varied from 0%, 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, 3.0% by weight of the soil at 0, 3, 7 days curing. The Quantity of chemical computed corresponding to the above percentages is dissolved in distilled water and blended into soil thoroughly in order to obtain even distribution of the chemical and used for the tests

Key Words: Soil Stabilization, Sodium Carbonate, Calcium Carbonate, Black Cotton Soil, Compaction, UCS, Triaxial Shear Test, Scanning Electron Microscopy(SEM) Analysis.

1. INTRODUCTION

Expansive soils in India are appreciate to farmers but problematic to civil engineers. Civil engineering structures experience large scale or damage due to change in properties of soil. Expansive soils always pose challenges to foundation engineers in India, these soils occupy around 20% of the total area, it is mostly present in central part and western part of India.

Montmorillonite is the main compound in black cotton soil. BCS containing Montmorillonite absorb large amount of water molecules and high bulk density in dry condition.
The characteristics of expansive soils namely, swelling and shrinkage are due to presence of some expanding lattice type of clay minerals. The shear strength of the soil is very high in dry state and it reduces considerably in wet state. The variation in shear strength directly influences the bearing capacity. Seasonal changes cause large damage to structure built on these soils. Following damages are occurred in structures over BCS break up of pavements, railways lines, embankments, building foundations, reservoir lining, water tanks, sewer lines etc.,

The effectiveness of Sodium Carbonate and Calcium Carbonate in stabilizing a Black Cotton soil is presented in this paper.

Objectives of the Paper

1. Determination of the Index and Engineering Properties of the soil samples.
2. Determination of the Index, Strength and Triaxial Shear Strength of the Black Cotton soil blended with sodium Carbonate ($NaCO_3$) and Calcium Carbonate ($CaCO_3$) mixtures.
3. Determination of the optimum percentage of Stabilization for Sodium Carbonate ($NaCO_3$), and Calcium Carbonate($CaCO_3$) in the proposed mix.
4. To study he quantitative changes in Triaxial test values of soil treated with Sodium Carbonate($NaCO_3$) and Calcium Carbonate ($CaCO_3$) at 0, 3 , 7 days.

2. LITERATURE REVIEW

Uppal and Wason (1957) were investigated the effect of addition of some surface-active agents, namely soap and sulphonated castor oil to stabilize soil mixtures. They observed that the addition of these agents to the water to bring it to optimum moisture tends to increase the dry and bulk densities, resistance to the softening action of water, and the compressive strength and reduce volumetric shrinkage on drying of the compacted soil. As these agents are available at low cost and are simple to manufacture even at the site itself, they suggested that they can be employed as aids to soil stabilization.

Katti & Kulkarni (1966) were experimented on black cotton soils with and without inorganic additives. The studies revealed that most of the inorganic chemicals can make the black cotton soils non-plastic and greatly improve the volume change, permeability and bearing characteristics. Cement is found to be effective not only in improving the texture of the soil but also in improving the strength characteristics. The investigations also indicated that combinations of lime and cement distinctly increase the strength characteristics, considerably improved the bearing and shear properties. The soil-lime-cement mixes possess a certain amount of flexural strength. Hydroxides and chlorides of potassium, sodium, calcium, were found to be effective. They not only improve the texture of soil but also its strength characteristics.

Kezdi etal (1979) were reported that the soil stabilization aspects of the chemicals including resins, calcium acrylate, aniline furfural, synthetic resins and RRP (Reynolds road packer 233), calcium chloride and sodium chloride. The main objective of this chemical stabilization is intended to modify the interaction between water and soil by surface reactions in such a manner to make the behavior most favorable for the given purpose.

Sudhendu saha and Prasanta saha (1991) were studied the improvement of silty clay soil by use of calcium chloride and ferric chloride contaminants. They reported that decrease of LL with increase in percentage of the chemicals, particularly predominant with ferric chloride. Further, there is little change in values of plastic limit and the plasticity index decreases showing the same trend as the liquid limit. The increases of cohesion with increase of chemical percentage are not very significant. The values of angle of internal friction reach peak values at 2% of the chemicals, with further addition of both the chemicals, the friction angle decreases.

3. MATERIAL AND METHODOLOGY

3.1 Material:

3.1.1 Black Cotton Soil:

The soil used for this investigation is obtained from Balupalli near Chinthakomma Dinne (Mandal), Kadapa. The soil is collected at 1.5m depth below the natural ground level. It is dried and pulverized and sieved through a sieve of 4.75mm size to eliminate gravel fraction, if any. This dried and sieved soil is stored in airtight bags ready for use for mixing. The soil is classified as 'CH' as per IS Classification (IS 1498:1978) that it is inorganic clay of High Plasticity. Its degree of expansiveness is very 'High' as the Differential Free Swell Index (DFSI) is 90%.

Table: 3.1 Properties of Black Cotton Soil

S.No.	Properties of the soil	Value
1.	Specific gravity	2.34
2.	Color of soil	Black
3.	**Grain size distribution**	
	Clay (%) Silt (%) Sand (%)	69% 13% 18%
4.	**Atterberg Limits**	
	a) Liquid Limit (%) b) Plastic Limit (%) c) Plasticity Index (%)	68.18 31.52 36.66
5.	Free Swell Index(DFSI), %	90
6.	Degree of expansion	High
7.	IS classification of soil	CH
8.	**Compaction Characteristics**	
	a) Optimum Moisture Content b) Maximum Dry Density, (gm/cc)	27.44% 1.44gm/cc
9.	Unconfined Compression Test	0.603Kg/cm^2
10.	**Tri-axial Compression Strength Test Results**	
	a) Cohesion(kg/cm^2) b) Angle of Internal Friction(φ), Degrees c) Shear Strength, (kg/cm^2)	0.3015 2.95° 0.34

3.1.2 Sodium Carbonate

Sodium carbonate ($NaCO_3$) is a chemical compound of sodium and carbon dioxide. Sodium carbonate is a white, crystalline compound soluble in water (absorbing moisture from air) but insoluble in alcohol. It forms a strongly alkaline water solution. Soda ash is the industrial name of anhydrous sodium carbonate. Sodium carbonate decahydrate, a colorless, transparent crystalline compound, is commercially called Sal soda or washing soda. Soda Ash is produced synthetically using the ammonia soda process (Solvay process treating sodium chloride with ammonia and carbon dioxide).

3.1.3 Calcium Carbonate

Calcium carbonate ($CaCO_3$) is a chemical compound of Calcium and carbon dioxide. It is a common substance found as rock in all parts of the world, and is main component of shells of marine organisms, snail, and egg shells. Calcium carbonate is active ingredient in agricultural lime, and is usually the principal cause of hard water. It is commonly used medicinally as a calcium supplement or as an antacid, but high consumption can be hazardous.

3.1.4 Scanning Electron Microscopy Analysis

Scanning Electron microscopy is the apparent ease with which SEM images of three-dimensional objects can be interpreted by any observer with no prior knowledge of the instrument. This is somewhat surprising in view of the unusual way in which image is formed, which seems to differ greatly from normal human experience with images formed by light and viewed by the eye.

The main components of a typical SEM consists of an electron gun and two or more electromagnetic lenses operating in vacuum. The electron gun generates free electrons and accelerates these electrons to energies in the range of 1-40 keV in the SEM. The purpose of the electron lenses is to create a small, focused electron probe on the specimen. Most SEMs can generate an electron beam at the specimen surface with spot size less than 10nm in diameter while still carrying sufficient current to form acceptable image. Typically the electron beam is defined by probe diameter (d) in the range of 1nm to 1μA, probe current (i_b) – pA to μA; and probe convergence (α) – 10^{-4} to 10^{-2} radians.

3.2 Methodology

The soil sample is kept ready and mixed with chemical solution of varying percentages. Chemical solution is prepared by dissolving chemical powder in distilled water. The percentages of chemical are varies from 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, and 3.0% percent by weight of the soil at 0, 3, 7 days Curing. The soil and chemical are mixed thoroughly and used to perform the tests.

4.1 Tests conducted

The following tests are conducted in this investigation as per Standard Specification:

1) Specific Gravity (IS: 2720 Part 3, Section 1-1981)

2) Grain Size Analysis Test (IS: 2720 Part 4 1985)

3) Liquid limit tests (IS: 2720 Part 5 1985)

4) Plastic limit tests (IS: 2720 Part 12 1985)

5) Differential Free Swell Index Tests (IS: 2720 Part 40 1977)

6) Standard proctor Compaction tests (IS: 2720 Part 7 1980/1987)

7) Unconfined compression strength tests (IS: 2720 Part 101991) and

8) Triaxial compression strength tests (IS: 2720 Part 12 1981)

Importance has been accorded to qualitative magnitude of impact of stabilization, rather than to study the mechanism due to which it happens.

4. RESULT AND DISCUSSION

4.1 Compaction Test

Table 4.1: Maximum Dry Density and Optimum Moisture Content of Soil Admixed with Na_2CO_3

Particulars	MDD (gm/cc)	OMC (%)
BCS Alone	1.44	27.54
BCS + 0.5% of $NaCO_3$	1.56	26.12
BCS + 1.0% of $NaCO_3$	1.59	24.56
BCS + 1.5% of $NaCO_3$	1.62	21.84
BCS + 2.0% of $NaCO_3$	1.58	19.78
BCS + 2.5% of $NaCO_3$	1.55	18.88
BCS + 3.0% of $NaCO_3$	1.53	18.24

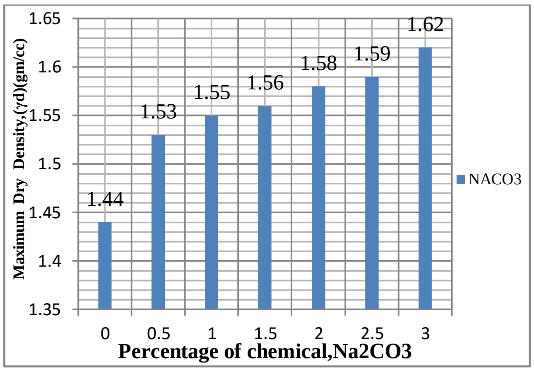

Fig.4.1 Variation of Maximum Dry Density and Optimum Moisture Content with per cent chemical

Table 4.2 Maximum Dry Density and Optimum Moisture Content of Soil Admixed with $CaCO_3$

Particulars	MDD (gm/cc)	OMC (%)
BCS Alone	1.44	27.54
BCS + 0.5% of $CaCO_3$	1.59	19.44
BCS + 1.0% of $CaCO_3$	1.67	18.53
BCS + 1.5% of $CaCO_3$	1.62	17.89
BCS + 2.0% of $CaCO_3$	1.56	17.18
BCS + 2.5% of $CaCO_3$	1.53	16.78
BCS + 3.0% of $CaCO_3$	1.52	16.07

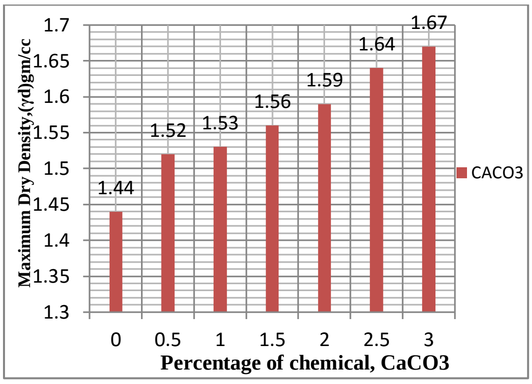

Fig.4.2 Variation of Maximum Dry Density and Optimum Moisture Content with per cent Chemical

4.2 Triaxial Test for Sodium Carbonate (Na_2CO_3)

Table 4.2.1 Shear parameters (C, φ, τ) of Soil Admixed with Sodium Carbonate at 0 day Curing

Shear parameters	Cohesion (C) kg/cm²	Angle of internal friction, degrees	Shear Strength (τ)
0% of Na_2CO_3	0.3015	2.95	0.34
0.5% of Na_2CO_3	0.344	3.0	0.38
1.0 % of Na_2CO_3	0.38	4.4	0.45
1.5 % of Na_2CO_3	0.395	6.5	0.50
2.0 % of Na_2CO_3	0.38	4.4	0.45
2.5 % of Na_2CO_3	0.29	2.85	0.33
3.0 % of Na_2CO_3	0.24	2.5	0.31

Table 4.2.2 Shear parameters (C, φ, τ) of Soil Admixed with Sodium Carbonate at 3 days Curing

Shear parameters	Cohesion(C) kg/cm²	Angle of internal friction, degrees	Shear Strength (τ)
0 % of Na_2CO_3	0.3015	2.95	0.34
0.5% of Na_2CO_3	0.38	3.5	0.42
1.0 % of Na_2CO_3	0.40	5.45	0.49
1.5% of Na_2CO_3	0.44	8.25	0.58
2.0 % of Na_2CO_3	0.41	6.6	0.52
2.5 % of Na_2CO_3	0.39	4.2	0.45
3.0 % of Na_2CO_3	0.37	3.3	0.40

Table 4.2.3 Shear parameters (C, φ, τ) of Soil Admixed with Sodium Carbonate at 7 days Curing

Shear parameters	Cohesion(C) kg/cm²	Angle of internal friction, degrees	Shear Strength (τ)
0 % of Na_2CO_3	0.3015	2.95	0.34
0.5% of Na_2CO_3	0.40	3.9	0.44
1.0 % of Na_2CO_3	0.43	6.0	0.53
1.5% of Na_2CO_3	0.51	8.9	0.66
2.0 % of Na_2CO_3	0.45	6.4	0.55
2.5 % of Na_2CO_3	0.42	5.9	0.51
3.0 % of Na_2CO_3	0.38	5.5	0.49

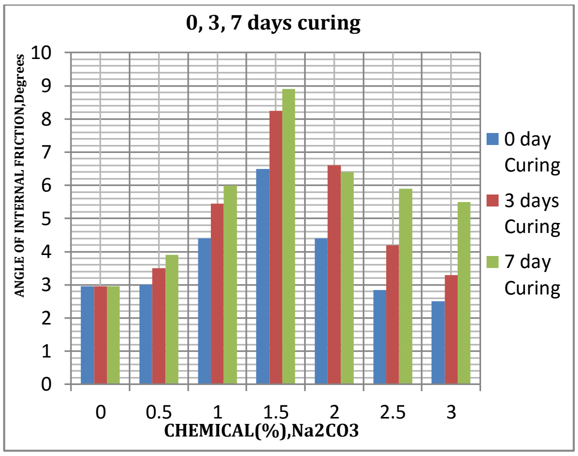

Fig. 4.2.2 Variation of Angle of Internal Friction with % of Na_2CO_3 for different Curing Period

4.3 Triaxial Test for Calcium Carbonate ($CaCO_3$)

Table 4.3.1 Shear parameters (C, φ, τ) of Soil admixed with Calcium Carbonate at '0' day Curing

Shear parameters	Cohesion(C) kg/cm²	Angle of internal friction, degrees	Shear Strength (τ)
0% of Na_2CO_3	0.3015	2.95	0.34
0.5% of $CaCO_3$	0.64	4.5	0.71
1.0 % of $CaCO_3$	0.74	9.4	0.86
1.5 % of $CaCO_3$	0.68	8.5	0.85
2.0 % of $CaCO_3$	0.65	6.95	0.72
2.5 % of $CaCO_3$	0.62	4.0	0.68
3.0 % of $CaCO_3$	0.59	3.1	0.62

Table 4.3.2 Shear parameters (C, φ, τ) of Soil Admixed with Calcium Carbonate at 3 days Curing

Shear parameters	Cohesion(C) kg/cm²	Angle of internal friction, degrees	Shear Strength (τ)
0% of Na_2CO_3	0.3015	2.95	0.34
0.5% of $CaCO_3$	0.87	6.30	0.97
1.0 % of $CaCO_3$	1.34	11	1.48
1.5 % of $CaCO_3$	1.10	10	1.31
2.0 % of $CaCO_3$	0.94	9.5	1.04
2.5 % of $CaCO_3$	0.86	6	0.95
3.0 % of $CaCO_3$	0.81	5.6	0.89

Table 4.3.3 Shear parameters (C, φ, τ) of Soil Admixed with Calcium Carbonate at 7 days Curing

Shear parameters	Cohesion(C) kg/cm²	Angle of internal friction, degrees	Shear Strength (τ)
0% of Na_2CO_3	0.3015	2.95	0.34
0.5% of $CaCO_3$	1.08	7.0	1.19
1.0 % of $CaCO_3$	1.58	12.5	1.75
1.5 % of $CaCO_3$	1.42	11.2	1.65
2.0 % of $CaCO_3$	1.39	10.6	1.50
2.5 % of $CaCO_3$	1.35	9.4	1.49
3.0 % of $CaCO_3$	1.26	8.5	1.44

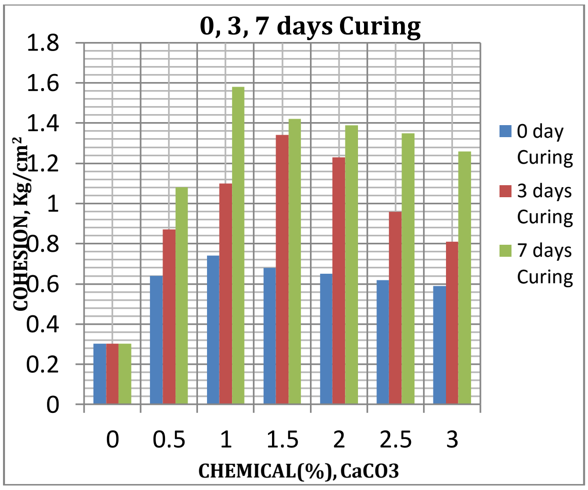

Fig. 4.3.1 Variation of Cohesion with % of $CaCO_3$ for different Curing Period

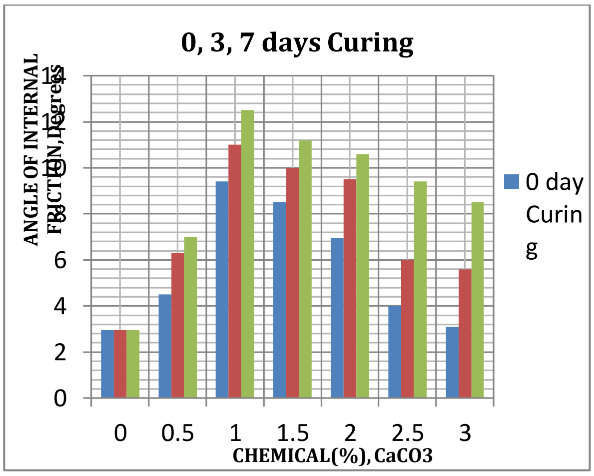

Fig.4.3.2 Variation of Angle of Internal Friction with % of $CaCO_3$ for different Curing Period

4.4 Scanning Electron Microscopy (SEM) Analysis on chemical treated Black cotton soil

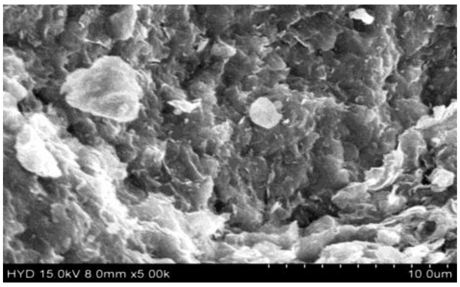

Fig.4.4.1 SEM Image for 1.5% of Na_2CO_3 Treated Soil

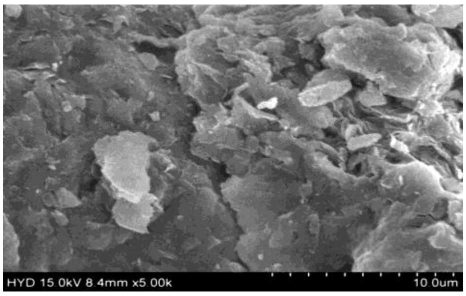

Fig.4.4.2 SEM Image for 3.0% of Na_2CO_3 Treated Soil

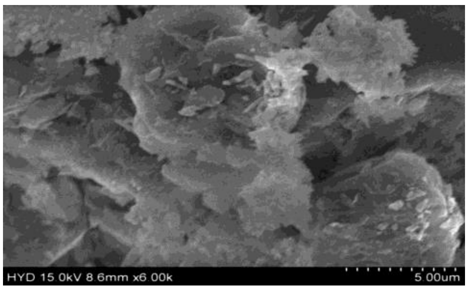

Fig.4.4.3 SEM Image for 1.0% of $CaCO_3$ Treated Soil

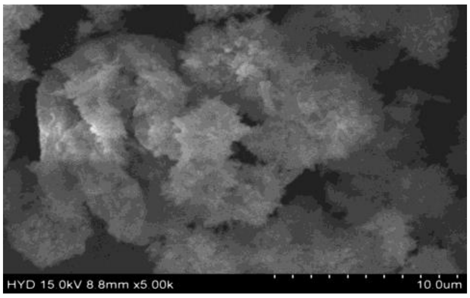

Fig.4.4.4 SEM Image for 3.0% of $CaCO_3$ Treated Soil

The treated specimens clearly indicated the crystalline format with faces and edges visible, in the photographs.

The fabrics seen in case of Na_2CO_3-treated specimen clearly demonstrate that the structure is not properly arranged, in between the cation-to-cation and cation-to-anion, whereas $CaCO_3$-treated sample clearly indicates that the texture orientation is arranged in order, after the treatment.

The results of fabric studies, have indicated that calcium carbonate($NaCO_3$) is the best alternative for treating the expansive soil when compared with sodium carbonate($CaCO_3$)

5. CONCLUSIONS

1) Calcium Carbonate is more effective than Sodium Carbonate in reducing the Optimum Moisture Content.

2) Calcium Carbonate is slightly more effective than Sodium Carbonate in increasing the Maximum Dry Density.

3) More value of Maximum Dry Density of Soil can be achieved with less amount of Optimum Moisture Content for constant Compactive effort, when the soil is admixed with a small percentage of Chemicals Sodium Carbonate and Calcium Carbonate.

4) Three percent of Chemical either Sodium Carbonate or Calcium Carbonate is effective in reducing the plasticity characteristics to certain extent in the tested range.

5) Both Chemicals are Equally Effective at Optimum Percentage of the Chemical in reducing the Plasticity Characteristics where as Sodium Carbonate is better than Calcium Carbonate in reducing the swelling characteristics at optimum percentages of the chemical in the tested range.

6) Three percent of Chemicals either Sodium Carbonate or Calcium Carbonate is effective in reducing the Differential Free Swell index.

7) The marginal amount of Improvement observed in angle of Internal Friction of 96.07%, 125.72% and 134.7% at 0, 3 & 7 days of curing with 1.5% of Na2CO3. Similarly, same type of observations witnessed in angle of Internal Friction of 161.42%, 188.15% and 215.85% at 0, 3 and 7 days of curing with 1.5% of CaCO3.

8) The marginal amount of improvement observed in cohesion of 28.49%, 41.29% and 134.7% at 0, 3 & 7 days of curing with 1.5% of Na2CO3. Similarly, same type of observations witnessed in cohesion of 126.33%, 242.57% and 304.99% at 0, 3 and 7 days of curing with 1.5% of CaCO3.

9) The effectiveness of Calcium Carbonate is much better than Sodium Carbonate from Strength and Stability point of view.

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