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A Study on Stabilization of Black Cotton Soil by Use of Fly Ash, Ferric Chloride and Stone Dust

[1]Brajesh Mishra, [2]Ravi Shanker Mishra
[1]*M. Tech., Assistant Engineer, U.P. Cane Development Department, Lucknow, India*
[2]*(Professor &Head, Department of Civil Engineering, AIM T , Lucknow, India*

ABSTRACT - *Black cotton soil is susceptible to detrimental volume changes due to variation in moisture content. A clay mineral named Montomorillonite which has expanding lattice is responsible to such behavior of this soil. Because of its special structure and properties it is subjected to appreciable volume changes. These soils are covering a large area approximately around 20% of land in India. It is due to its extensive area sometimes it becomes impossible to alter the highway alignment to avoid this type of soil. In recent past years various methods of stabilizing these type of soils have been used with varied degree of results. Some of the common methods like lime stabilization, soil replacement, moisture control and, prewetting have been used. The research is still going on to find out suitable and perfect solution for the treatment of black cotton soil. According to recent research strong electrolytes can be used in place of lime due to their dissolving nature in water and readiness for adequate cation exchange .In the present research work experimental investigations were carried out by using fly ash, stone dust and ferric chloride to improve the properties of black cotton soil.*

Keywords- *Fly ash, stone dust, ferric chloride, maximum dry density(M.D.D.),California Bearing Ratio(C.B.R.).*

I. INTRODUCTION

Black cotton soils are one of the most challenging soils for engineers because of their swelling and shrinkage action due to variation in moisture content. When these soils come in contact with water volume increases and the volume decreases when water is removed. These soil cover approximately 20% area of land in India. Black cotton soil are found in extensive region of Deccan Trap in Indian. They are of variable thickness, underlain by black sticky material known as "black soil". Black cotton soil when comes in contact with water it either swells or shrinks and resulting in moments to the structure which are generally not related to direct effect of loading. On account of its high volumetric changes it is not suitable for construction. It swells and shrinks excessively due to present of fine clay particles. Alternate swelling and shrinking of soil is responsible for differential settlement of structure so black cotton soil must be treated by using suitable admixtures to stabilize it. In my research work stabilization of black cotton soil is done by using lime as an admixture. The most common type of stabilization are listed below-

- Lime stabilization
- Cement stabilization
- Chemical stabilization
- Bitumen stabilization
- Salt stabilization

Many researchers have performed various investigations on characteristics of black cotton soil. Some of the prominent names are Erdal Cokca (2001), Dr. K.V. Manoj Krishna (2012), D. Koteswara Rao(2012), K. Ramu (2012), Prasada D.S.V.(2010), Katti R.K.(1966) and P.P. Sivapulliation .

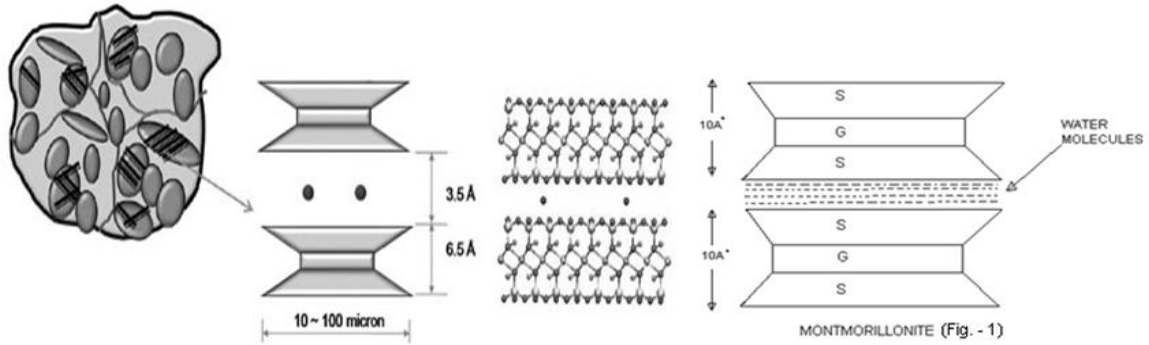

Fig-1: Structure of Montomorillonite mineral

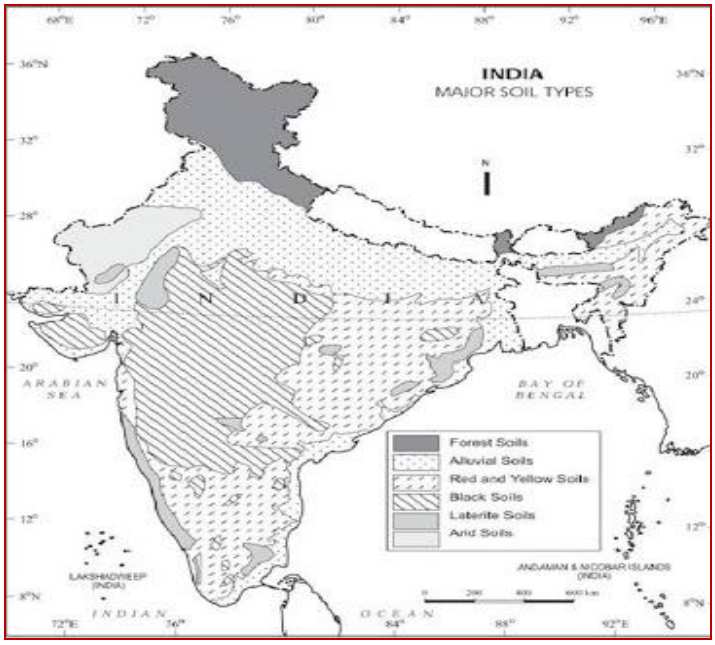

Fig-2: Map of India showing Black Cotton & other soils

II. MATERIALS USED

2.1. Samples Collection: To study the effect of fly ash, stone dust and ferric chloride on black cotton soil the samples of black cotton soil were collected from some parts of Jhansi, a district in state of Uttar Pradesh in India, samples of stone dust were collected from a Lalkuwan quarry near Haldwani district of Uttarakhand state in India and ferric chloride ($FeCl_3$) of laboratory grade from local area of Lucknow in India. Fly ash from thermal power in Uttar Pradesh in India.

2.1.1. Properties of Black Cotton Soil: The properties of black cotton soil are listed below-

Table-1 Chemical Composition of Black Cotton soil

S. No.	Description	Range
1	Silica (SiO_2)	48- 58(%)
2	Alumina (Al_2O_3)	13- 22(%)
3	Lime (CaO)	1- 8(%)
4	Magnesium Oxide (MgO)	1.8- 5(%)
5	Ferric Oxide (Fe_2O_3)	7.5- 15(%)
6	Sulphates (SO_4)	0.9- 2.0(%)
7	Carbonates (CO_3)	0.5- 6.6(%)
8	Organic Matter	0.54 3.6(%)
9	Loss on Ignition	4.8- 16.5(%)
10	pH	6.7- 8.9

Table-2 Other properties of Black Cotton soil

S. No.	Description of Properties	Value
1	Liquid Limit (%)	58
2	Plastic Limit (%)	24
3	Plasticity Index (%)	34
4	Specific Gravity	2.51
5	I.S. Classification	CH
6	Optimum Moisture Content(OMC)	23%
7	Maximum Dry Density(MDD) g/cm³	1.624
8	California Bearing Ratio(CBR)	1.92%
9	Free Swell Index	85

Intended percentage of addition of various materials are shown below-

2.1.2. Fly ash: Fly ash content was varied from 0 to 15% by dry weight of soil with a increment of 3%.

Table-3 Engineering properties of Fly ash

Parameter	Range
Specific Gravity	1.90 – 2.55
Plasticity	Non plastic
Maximum dry density (gm/cc)	0.9 – 1.6
Optimum moisture content (%)	38.0 – 18.0
Cohesion (KN/m^2)	Negligible
Angle of internal friction (¢)	$30^0 – 40^0$
Coefficient of consolidation C_v (cm^2/sec)	$1.75 \times 10^{-5} – 2.01 \times 10^{-3}$
Compression index C_c	0.05 – 0.4
Permeability (cm/sec)	$8 \times 10^{-6} – 7 \times 10^{-4}$
Particle size distribution (% of materials) Clay size fraction Silt size fraction Sand size fraction Gravel size fraction	 1 – 10 8 – 85 7 – 90 0 – 10
Coefficient of uniformity	3.1 – 10.7

2.2.3. Ferric chloride ($FeCl_3$): Ferric chloride (laboratory grade) content was varied from 0 to 2.5% by dry weight of soil with a increment of 0.50%.

2.2.4. Stone Dust: Stone dust content was varied from 0 to 25% by dry weight of soil with a increment of 5%.

Table-4 Physical properties of Stone dust

S. No.	Description of Properties	Value
1	Liquid Limit (%)	Non Plastic
2	Plastic Limit (%)	Non Plastic
3	Specific Gravity	2.57
4	Optimum Moisture Content(OMC)	7.3%
5	Maximum Dry Density(MDD) g/cm^3	1.90
6	Color	Grey

III. EXPERIMENTAL INVESTIGATIONS

Test on virgin soil sample were carried out. Samples were prepared with addition of fly ash, ferric chloride and stone dust in various portions and sufficient time was given for its stabilization and again various tests like Atterberg's limits, compaction parameters and C.B.R. were carried out. The various composition are as below-

Table-5 Showing different compositions of samples

Samples	Composition
BC1	B.C. soil+0% $FeCl_3$+0% Fly ash+ 0% Stone dust
BC2	B.C. soil+0.5% $FeCl_3$+3% Fly ash+ 5% Stone dust
BC3	B.C. soil+1% $FeCl_3$+6% Fly ash+ 10% Stone dust
BC4	B.C. soil+1.5% $FeCl_3$+9% Fly ash+ 15% Stone dust
BC5	B.C. soil+2.0% $FeCl_3$+12% Fly ash+ 20% Stone dust
BC6	B.C. soil+2.5% $FeCl_3$+15% Fly ash+ 25% Stone dust

- **Liquid Limit (L.L.):** The liquid limit test was conducted as per guidelines of IS:2720-:IV-1970 on treated and untreated black cotton soil samples.
- **Plastic Limit (P.L.):** The plastic limit test was conducted as per guidelines of IS:2720-:IV-1970 on treated and untreated black cotton soil samples.
- **O.M.C. and Maximum dry density:** This test was conducted as per guidelines of IS:2720-:VI-1974 on treated and untreated black cotton soil samples.

- **California Bearing Ratio (CBR):** This test was conducted as per guidelines of IS:2720:XVI-1979 on treated and untreated black cotton soil samples.

IV. RESULTS AND DISCUSSIONS

The effect of addition of fly ash, ferric chloride and stone dust in various portions on properties of black cotton soil is tabled below-

Table-6 The effect of addition of fly ash, $FeCl_3$ and stone dust on properties B. C. soil

Samples as per Table-5	L.L. (%)	P.L. (%)	M.D.D. (g/cm³)	O.M.C. (%)	C.B.R. (%)
BC1	58	24	1.624	23	1.92
BC2	56	23.95	1.638	22.82	2.32
BC3	54	25.50	1.723	22.52	2.78
BC4	51	26.50	1.813	21.48	3.82
BC5	46	26.80	1.852	20.85	4.95
BC6	45	26.30	1.915	20.12	5.20

Effect of addition of fly ash, $FeCl_3$ and stone dust on Atterberg's limit: It was observed that when percentage of addition of fly ash, $FeCl_3$ and stone dust increased there was considerable decrease in liquid limit of black cotton soil and it goes down to 22.41% on sample BC5 (B.C. soil+2.5% $FeCl_3$+15% Fly ash+ 25% Stone dust). The figure below shows the variation in liquid limit and plastic limit with different compositions of fly ash, $FeCl_3$ and stone dust. The increase in plastic limit and decrease in liquid limit causes a net reduction in plasticity index (P.I.). It was observed that reduction in plasticity index was 45 for sample BC6 (B.C. soil+2.5% $FeCl_3$+15% Fly ash+ 25% Stone dust). The improvement in the properties of B.C. soil could be the presence of ferric chloride in the composition of the mix which is responsible for depression of double layer thickness due to readiness of cation exchange and increase in electrolyte concentration as the chemical fully dissolves in water.

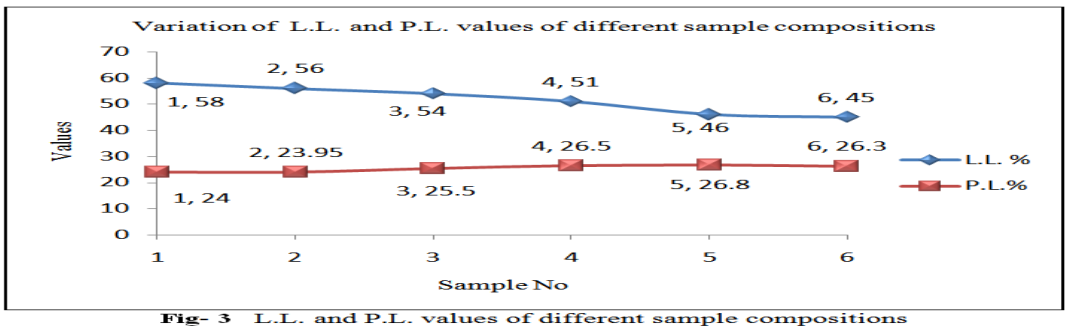

Fig- 3 L.L. and P.L. values of different sample compositions

Effect of addition of fly ash, $FeCl_3$ and stone dust on maximum dry density and O.M.C.- It can be seen from the figure-4 that when percentage of ferric chloride, fly ash and stone dust increases the M.D.D. increases from 1.624 g/cm³ to 1.915 g/cm³ for $FeCl_3$ 2.5%, fly ash 15% and stone dust 25% composition. The increase in maximum dry density implies that the strength of soil has increased. This may be explained due to formation of Silicacious material and cation exchange reaction.

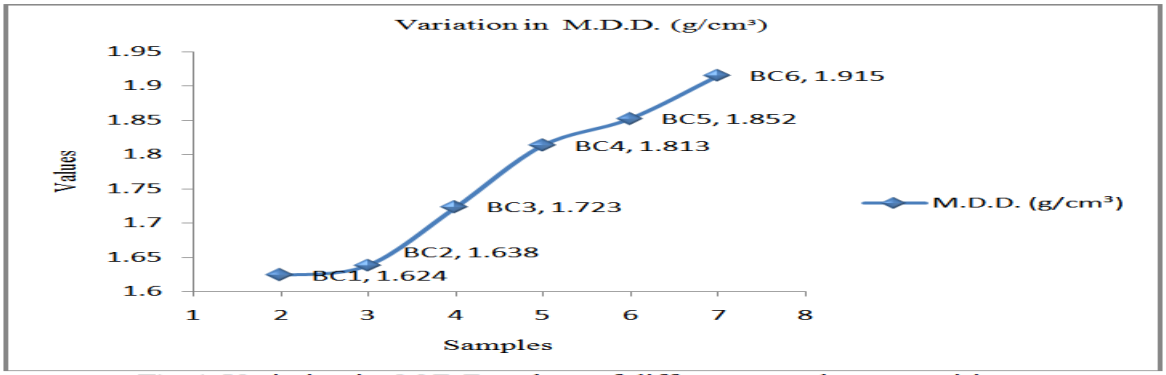

Fig-4 Variation in M.D.D. values of different sample compositions

It was also observed by the figure-5 that there is a decrease in O.M.C. as the percentage of ferric chloride, fly ash and stone dust increases.

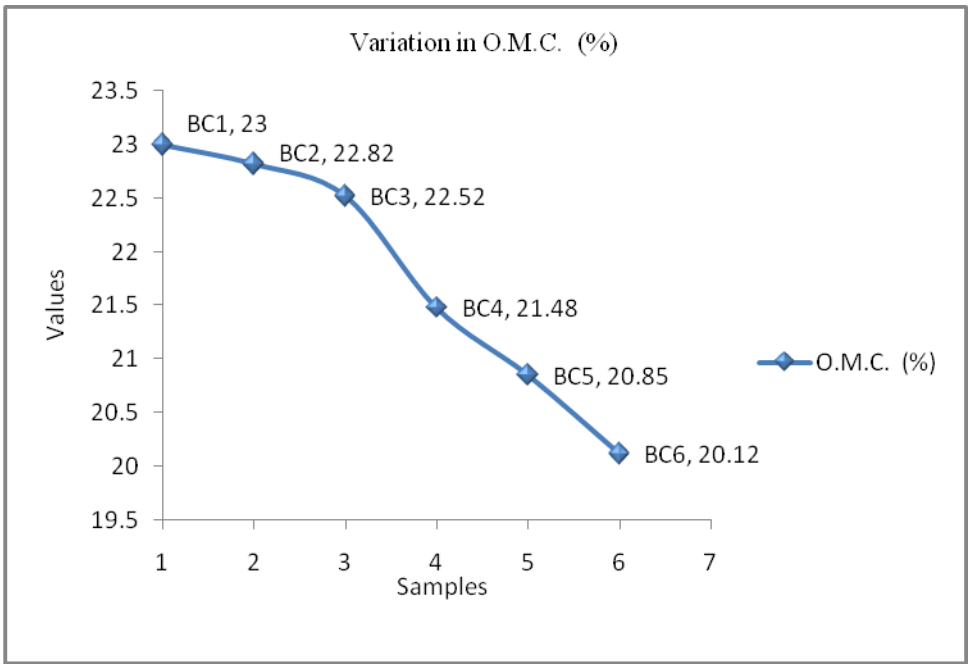

Fig -5 Variation in O.M.C. values of different sample compositions

Effect of addition of fly ash, $FeCl_3$ and stone dust on C.B.R. value: It can be seen from the figure-6 that when percentage of ferric chloride, fly ash and stone dust increases the C.B.R. value. increases from 1.92% to 5.2% for $FeCl_3$ 2.5%, fly ash 15% and stone dust 25% composition. Therefore the maximum increase in C.B.R. value is 170.83%. The increase in C.B.R. value is an indication of improvement of soil properties and its strength to counter the resistance to penetration resulting in a decrease in pavement thickness and reduction in cost of construction of pavement.

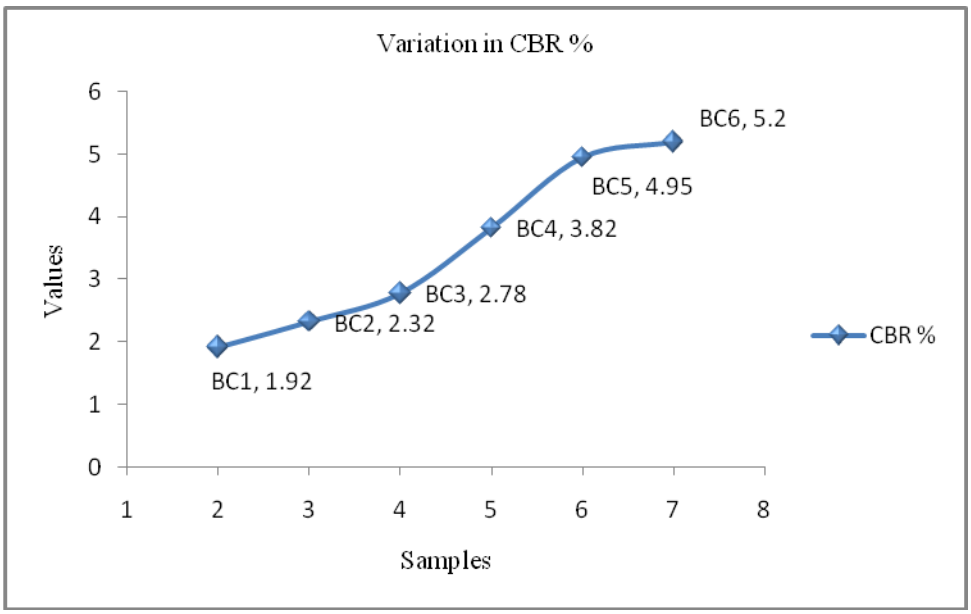

Fig- 6 Variation in C.B.R.. values of different sample compositions

V. CONCLUSION

On the basis of study, experimental investigations and results obtained by using ferric chloride, fly ash and stone dust to stabilize the black cotton soil, following conclusion can be drawn-

1. It was observed that the liquid limit was decreased by 22.41% with addition of 2.5%, $FeCl_3$, 15% fly ash and 25% stone dust.

2. Plastic limit of black cotton soil was increased by 9.58% for 2.5%, $FeCl_3$, 15% fly ash and 25% stone dust addition to black cotton soil.
3. The results show that there was a increase in maximum dry density of black cotton soil from 1.624 g/cm^3 to 1.915 g/cm^3 for 2.5%, $FeCl_3$, 15% fly ash and 25% stone dust addition to black cotton soil.
4. It was observed that C.B.R. value was increase by 170.83% for 2.5%, $FeCl_3$, 15% fly ash and 25% stone dust addition to black cotton soil. The increase in C.B.R. value is an indication of improvement of soil properties and its strength to counter the resistance to penetration resulting in a decrease in pavement thickness and reduction in cost of construction of pavement.

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