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Stabilization of Black Cotton Soil using Lime

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Abstract: ***The design foundation on black cotton soil (expansive soil) has always been a difficult task for the engineers as the structure resting on black cotton soil cracks without any warning. Black cotton soil is found in M.P., Karnataka, Maharashtra and Andhra Pradesh in our country. Soil proportion changes depending upon their constituents, i.e. water content, density, bulk density, angle of friction, shear strength etc. The properties of black cotton soil can be modified by stabilizing the soil can be modified by stabilizing the soil with the use of additives or by mechanical means. In this project an attempt has been made to stabilize the soil using lime. Experimental work has been carried out with 4 % and 6 % of lime content. The experimental work is based on different percentages of lime content in soil on tests for soil Liquid limit, Plastic limit, O.M.C., M.D.D, Bulk density and Dry density, C.B.R. test, Grain size analysis and Swelling pressure. The aim is to improve the engineering properties of the black cotton soil such that the structure built on this soil can be efficiently withstanding applied loads. It was found that the engineering properties of black cotton soil substantially improved by addition of lime.***

Keywords: Black Cotton Soil, Stabilization, Lime, CBR**.**

1. Introduction

In India Black Cotton soil also known as 'Regurs' are found in extensive regions of Deccan Trap. They have variable thickness and are underlain by sticky material locally known as "Kali Mitti". In terms of geotechnical Engineering, Black Cotton soil is one which when associated with as engineering structure and in presence of water will show a tendency to swell or shrink causing the structure to experience moments which are largely unrelated to the direct effect of loading by the structure. Black cotton soil is not suitable for the construction work on account of its volumetric changes. It swells and shrinks excessively with change of water content. Such tendency of soil is due to the presence of fine clay particles which swell, when they come in contact with water, resulting in alternate swelling and shrinking of soil due to which differential settlement of structure takes place, so the stabilization is being done for the Stabilization of black cotton soil has been done in this project work by using lime as an admixture.

The most common types of stabilization are described below
a) Cement stabilization
b) Bitumen stabilization
c) Chemical stabilization
d) Lime stabilization
e) Salt stabilization

2. Distribution in India

In India, an area about one-six is occupied by black cotton soil. The area covers mostly the Deccan Trap plateau, between 73°80' East longitude and 15° to 24° north, latitude. Thus, most of soil in and around Mumbai, Madras, Gwalior, Khandwa, Indore, Nagpur and even some on the river banks is Black cotton .That means these soils are predominant in Deccan trap plateau region, i.e., in states of Andhra Pradesh, Western Madhya Pradesh, Gujarat, Maharashtra, Northern Karnataka and Tamilnadu.

3. Characteristics of B.C. Soil

Black cotton soils are generally reddish brown to black in color and occur from 0.5m to 10m deep and have high compressibility. The generally observed characteristics of black cotton soils are recorded in table below -

Table 1: Characteristics of Black Cotton Soils

S. No.	*Property*	*Value*
1.	Dry Density (γ_d)	1300 to 1800 kg/m^3
2.	Fines (<75µ)	70 to 100%
3.	2µ Fraction	20 to 60 %
4.	Liquid Limit (L.L.)	40 to 120%
5.	Plastic Limit (P.L.)	20 to 60%
6.	Activity	0.8 to 18%
7.	Soil Classification	CH or MH
8.	Specific Gravity (G)	2.60 to 2.75
9.	Proctor Density	1350 to 1600 kg/m^3
10.	Max. Dry Density O.M.C.	20 to 35 %.
11.	Free Swell Index	40 to 180%
12.	Swelling Pressure	50 to 800 kN/m^2
13.	C.B.R. (Soaked)	1.2 to 4.0
14.	Compression Index	0.2 to 0.5

4. Chemical Composition of B. C. Soil

The black cotton soils are found to have the following chemical composition –

Table 2: Chemical Composition of B. C. Soil

S. No.	*Property*	*Range*
1.	pH Value	>7(Alkaline)
2.	Organic Content	0.4 to 204 %
3.	$CaCO_3$	5 to 15 %
4.	SiO_2	50 to 55 %
5.	SiO_2 , Al_2O_3	3 to 5 %
6.	Montmorilonite Mineral	30 to 50 %

Black cotton soil are made of varying properties of clay minerals like Montmorrilonite, Illite and Kaolinite, chemicals like iron oxide and calcium carbonate (in the form of kankars), and organic matter like humus. Montmorrilonite is the predominant mineral of Black cotton soils. The swelling and shrinkage behavior of black cotton soil originate mainly from this mineral are hydrous silicates of aluminum and magnesium .They are made of sheets of silica (tetrahedral) and alumina (octahedral) stacked on above the other forming sheet like of flaky particle. Montmorrilonite has a three-sheeted structure with expanding lattices. The structure carries negative charge, due to isomorphic substitution of some aluminum ions by magnesium ions and minerals becomes chemically active.

5. Problem Associated with B. C. Soil

Black Cotton soils are problematic for engineers everywhere in the world, and more so in tropical countries like India because of wide temperature variations and because of distinct dry and wet seasons, leading to wide variations in moisture content of soils. The following problems generally occur in black cotton soil -

5.1. High Compressibility

Black Cotton soils are highly plastic and compressible, when they are saturated. Footing, resting on such soils under goes consolidation settlements of high magnitude.

5.2. Swelling

A structure built in a dry season, when the natural water content is low shows differential movement as result of soils during subsequent wet season. This causes structures supported by such swelling soils to lift up and crack. Restriction on having developed swelling pressures making the structure suitable.

5.3. Shrinkage

A structure built at the end of the wet season when the natural water content is high, shows settlement and shrinkage cracks during subsequent dry season.

6. Engineering Properties of B. C. Soil

The main engineering properties of soil are permeability, plasticity, compaction, compressibility and shear strength.

6.1. Permeability

The permeability is defined as the property of a porous material which permits the passage or seepage of water through its interconnecting voids

6.2. Plasticity

It is defined as the property of a soil which allows it to be deformed rapidly, without elastic rebound, without volume change.

6.3. Compaction

Compaction is a process by which the soil particles artificially rearrange and packed together into a closer state of contact by mechanical means in order to decrease the porosity of the soil and thus increase its dry density.

6.4. Compressibility

The property of soil mass pertaining to its susceptibility to decrease in volume under pressure is known as compressibility.

6.5. Shear Strength

This is the resistance to deformation by continuous shear displacement of soil particles or on masses upon the action of a shear stress.

7. Index Properties of B. C. Soil

The properties of soil, which are not of primary interest to the geotechnical engineering, but are indicative of the engineering properties are called index properties. This includes –

7.1. Particle Size Analysis

This is method of separation soils into different fraction bases on particles present into soils. It can be shown graphically on a particle size distribution curve. The coal ashes can be classified as sandy silt to silty sand as per this classification.

7.2. Specific Gravity

It can be classified as the ratio of the weights of a given volume of soil solid at a given temperatures of the weight of an equal volume of distilled water at that temperature both weight being taken in air.

$$G = \frac{\gamma_s}{\gamma_w}$$

The range of specific gravity of coal ashes varies from 1.46 to 2.66 the low values of specific gravity is because of hollow particles chemosphere the sp. Gr. Of soil solids is determined by –

1. 50 ml density bottle or
2. A 500 ml flask or
3. A pycnometer

The density bottle method is most accurate and is suitable for all types of soil the flask or pycnometer method is suitable for coarse grained soil.

7.3. Atterberg's Limit

The water content at which the soil changes from one state to other state are known as consistency limits or Atterberg's limit .The Atterberg's limit which are useful for engineering purposes are; Liquid limit, plastic limit and shrinkage limit. These limits are expressed as percent water content.

7.3.1. Liquid limit: - It is defined as the minimum water content at which the soil is still in liquid state but has a small strength against flowing which can be measured by standard available means.

7.3.2. Plastic limit:- It is defined as minimum water content at which soil will just begin to crumble water rolled into a thread approximately 3mm in diameter, Plasticity index is determined as difference of L.L. and P.L.

7.3.3. Shrinkage limit: - It is defined as the maximum water content at which a reduction in water content will not cause a decrease in the volume of soil mass.

8. Stabilization

Lime stabilization helps in increasing the strength, durability and also minimizes the moisture variations in the soil and lime must be well compacted for obtaining sufficient strength and durability by maintaining OMC and the same assumption is made in the experimental determination of the required lime proportion. Quality of lime to be added depends upon the specific surface area of soil particles and it is more for fine grained soils even up to 15 % by weight of soil. The stabilization of black cotton soil with lime has been done in three different ratios of lime i.e. 0%, 4% and 6%. After the stabilization of soil with lime in above percentage the various tests have been performed –

8.1. Liquid Limit Tests

The liquid limit of a soil is the moisture content, expressed as a percentage of the weight of the oven-dried soil, at the boundary between the liquid and plastic states of consistency. The moisture content at this boundary is arbitrarily defined as the water content at which two halves of a soil cake will flow together, for a distance of ½ in. (12.7 mm) along the bottom of a groove of standard dimensions separating the two halves, when the cup of a standard liquid limit apparatus is dropped 25 times from a height of 0.3937 in. (10 mm) at the rate of two drops/second.

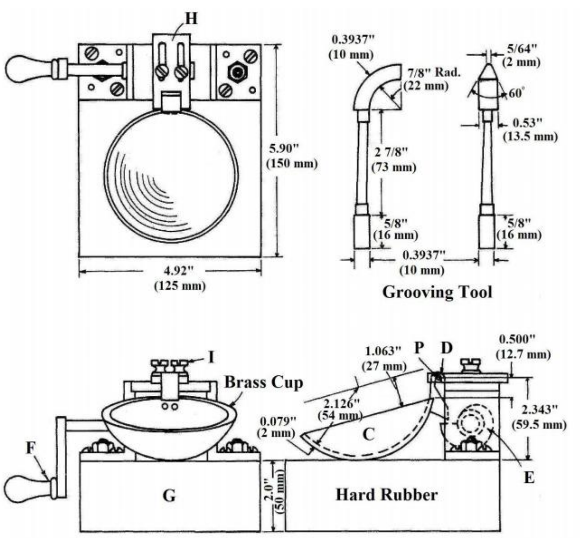

Figure 1: Mechanical Liquid Limit Device

8.2. Plastic Limit Tests

The plastic limit of a soil is the moisture content, expressed as a percentage of the weight of the oven-dry soil, at the boundary between the plastic and semisolid states of consistency. It is the moisture content at which a soil will just begin to crumble when rolled into a thread ⅛ in. (3 mm) in diameter using a ground glass plate or other acceptable surface.

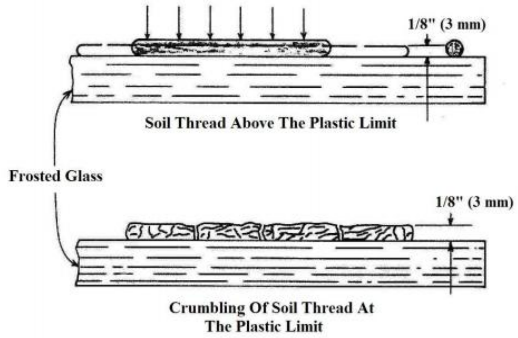

Figure 2: Diagrams Illustrating Plastic Limit Test

8.3. Plasticity Index

The plasticity index of a soil is the numerical difference between its liquid limit and its plastic limit, and is a dimensionless number. Both the liquid and plastic limits are moisture contents.

Calculation:

Plasticity Index = Liquid Limit – Plastic Limit

PI = LL – PL

8.4. Compaction Test

Compaction is one kind of densification that is realized by rearrangement of soil particles without outflow of water. It is realized by application of mechanic energy. It does not involve fluid flow, but with moisture changing altering.

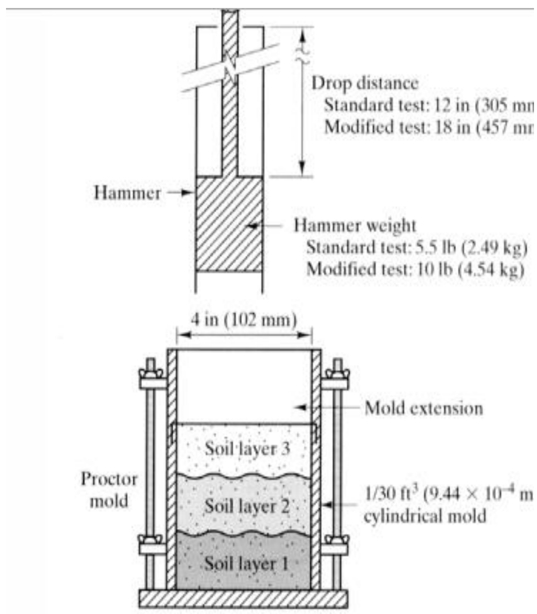

Figure 3: Standard Proctor Apparatus for Compaction Test

8.5. California Bearing Ratio (C.B.R.) Test

California bearing ratio is the ratio of force per unit area required to penetrate in to a soil mass with a circular plunger of 50mm diameter at the rate of 1.25mm/min.

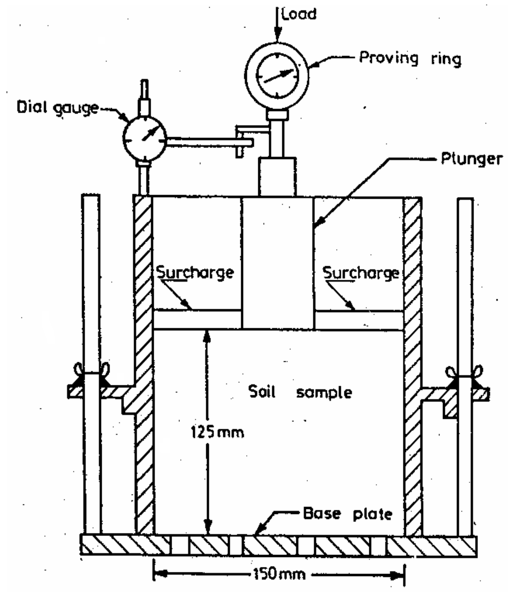

Figure 4: California Bearing Ratio Apparatus

9. Results

The results of the following tests are as follows –

9.1. Liquid limit test -

Calculation of liquid limit of black cotton soil -
Weight of sample = 100gms

Table 3: Liquid Limit Comparison

S. No	*B.C. Soil + 0% Lime*		*B. C. Soil + 4% Lime*		*B. C. Soil + 6% Soil*	
	Water (%)	*No. of Blows*	*Water (%)*	*No. of Blows*	*Water (%)*	*No. of Blows*
1.	44	60	40	30	35	40
2.	46	27	42	18	37	35
3.	48	15	44	12	40	17
4.	L. L. is 46.3%		L. L. is 40.7 %		L. L. is 38.1%	

Figure 5: Liquid Limit Comparison

9.2. Plastic limit test

Calculation of plastic limit of black cotton soil -
Sample taken = 100gms

Table 4: Plastic Limit Comparison

S. No.	*Composition*	*Plastic Limit*
1.	B. C. Soil + 0% Lime	31%
2.	B. C. Soil + 4% Lime	Non-Plastic
3.	B. C. Soil + 6% Lime	Non-Plastic

9.3. Plasticity Index-

Table 5: Plasticity Index

S. No.	*Composition*	*Plasticity Index PI = LL - PL*
1.	B. C. Soil + 0% Lime	15.3%
2.	B. C. Soil + 4% Lime	-
3.	B. C. Soil + 6% Lime	-

9.4. Compaction Test

Determination of compaction parameters of B. C. Soil:-
Sample weight = 3kg
Mass of mould + base plate (W_1) = 5520gms
Volume of mould (V) = 1000c.c.

Table 6: Compaction Test Comparison

S. No.	*Determination No.*	*B.C. Soil + 0% Lime*	*B.C. Soil + 4% Lime*	*B.C. Soil + 6% Lime*
1.	Mass of mould + compacted soil 'W'(gms)	6993	7263	7202
2.	Mass of compacted soil $W_3 = W_2\text{-}W_1$ (gms)	1807	1743	1682
3.	Wet density $\gamma_t = \frac{w_t}{v}$	1.81	1.74	1.68
4.	Moisture content (%)	14	14	12
5.	Dry density $\rho_d = \frac{\rho}{1+W}$ (gm/cm^3)	1.58	1.53	1.50

9.5. California Bearing Ratio (C. B. R.) Test

Comparative table for California Bearing Ratio is given below -

Table 7: C. B. R. Test Comparison

S. No.	*Samples*	*C. B. R. Values*
1.	B. C. Soil + 0% Lime	1.9
2.	B. C. Soil + 4% Lime	11.2
3.	B. C. Soil + 6% Lime	15.2

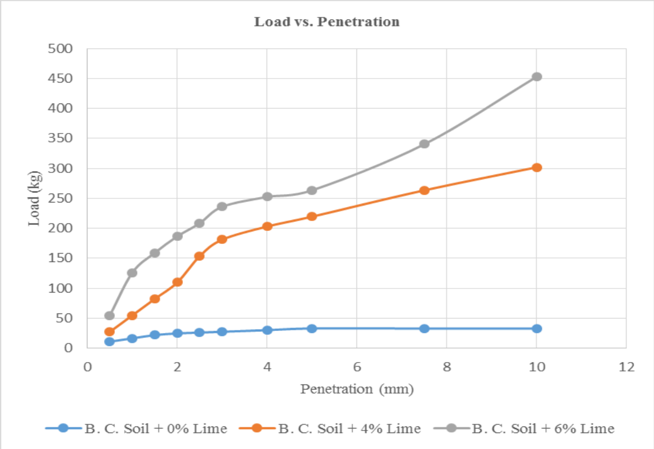

Figure 6: Load vs. Penetration Chart

9.6. Swelling Pressure

Table 8: Swelling Pressure Comparison

S. No.	*Samples*	*Swelling Pressure*
1.	B. C. Soil + 0% Lime	0.56
2.	B. C. Soil + 4% Lime	0.386
3.	B. C. Soil + 6% Lime	0.1

10. Conclusions

In this project work, it has been found that the properties of black cotton soil get effectively modified by varying proportions of lime. In this experimental program stabilization of soil has been carried out by mixing lime in varying percentages (4% and 6%). The following conclusions are drawn from this experimental study:-

1) It has been found that an addition of 4% lime decreases the liquid limit by 12.1 %, while 6% addition of lime shows a decrease of only 17.7%.
2) M.D.D. is found to decrease by 2.4% and 5.6% at 4% and 6% lime content respectively.
3) It was found that O.M.C. does not change with a decrease of 14.3% in O.M.C. was observed at 6% lime content.
4) The C.B.R. value of black cotton soil mixed with 4% and 6% lime at 2.5 mm penetration showed an increase of six folds and eight folds respectively. At 5.0 mm penetration the increase in C.B.R value were also found six folds and eight folds respectively.
5) The swelling pressure of Black cotton soil mixed with 4% and 6% lime decreased by 40% and 80% respectively.

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