

A Review on Study of Properties of Black Cotton Soil & Its Stabilization Using Lime

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Abstract- Growth of population and urbanization leads to less availability of suitable land for construction of buildings and other civil engineering structures. For construction, there is only choice left to construct on soft and weak soil such as black cotton soil. Due to swelling and shrinkage properties of black cotton soil it is very difficult for civil engineers to construct any structure on it. Black cotton soil produces deformations in structures. This paper gives information about properties of black cotton soil and its stabilization by using lime.

Index Terms- Black Cotton Soil, Montmorillonite, Kaolinite, Stabilization, Lime, California Bearing Ratio.

1. INTRODUCTION

Black cotton soil is predominant in India. Black cotton soil has been found in large part of central India and some portion of south India. This soil is useful for growing cotton and it has dark brown colour hence it is termed as Black Cotton Soil. The basic needs of human life such as food, clothes and house are dependent on soil. Without soil, these needs can not be fulfilled. But in Civil Engineering, Black Cotton soil is very hazardous and problematic because it has properties of swelling and shrinkage. Black cotton soil swells when it is in contact with water and shrinks when it is dry. Every civil engineering structure is constructed over soil. All the loads of structure are transferred to the soil. So the soil should be capable of carrying all the loads. The soil swells due to Montmorillonite mineral present in it^[1]. This swelling and shrinkage properties of soil causes cracks without giving any warning. The properties of black cotton soil can be improved by stabilization.

The common types of stabilization are-

- Cement Stabilization
- Bitumen Stabilization
- Chemical Stabilization
- Lime Stabilization
- Salt Stabilization

2. FORMATION OF BLACK COTTON SOIL

2.1 Black cotton soil is formed by disintegration of Basalt rock. Black cotton soil is present upto a depth of 3.5m approximately. Black cotton soils are made of varying properties of minerals like Montmorillonite and Kaolinite, chemicals like Iron Oxide and Calcium Carbonate and organic matter like humus^[2].

2.2 Montmorillonite is the main content of Black Cotton soil. The swelling and shrinkage in black cotton soil are due to this mineral. Montmorillonite

contains alumina and silica sheets. An alumina sheet is present between two silica sheets. Water molecules are present in the space between two structural units. The structure of montmorillonite is shown in Fig 1.

2.3 Kaolinite contains alumina sheet and silica sheet. Alumina sheet and silica sheet are joined together by hydrogen bond. The mineral is stable due to presence of hydrogen bond. It has hexagonal shape in plan. The structure of kaolinite is shown in Fig 2.

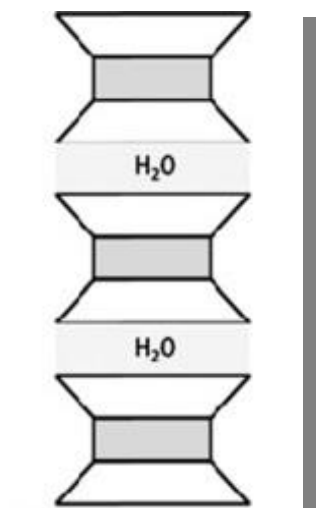


Fig 1: Montmorillonite Mineral

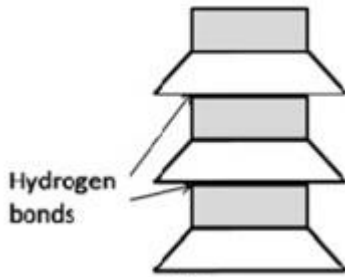


Fig 2: Kaolinite Mineral

3. BLACK COTTON SOIL IN INDIA

In India, 20% soil is black cotton soil. This soil occurs in states of Gujarat, Madhya Pradesh, Andhra Pradesh, Maharashtra, Karnataka, etc. They are black due to compounds of iron and Aluminium. These soils are deficient in nitrogen, phosphoric acid and organic matter but rich in calcium potash and magnesium^[3]. Fig. 3 shows the different soil types in India.



Fig 3: Soil Map of India

4. PROPERTIES OF BLACK COTTON SOIL

The physical and chemical properties of black cotton are explained below.

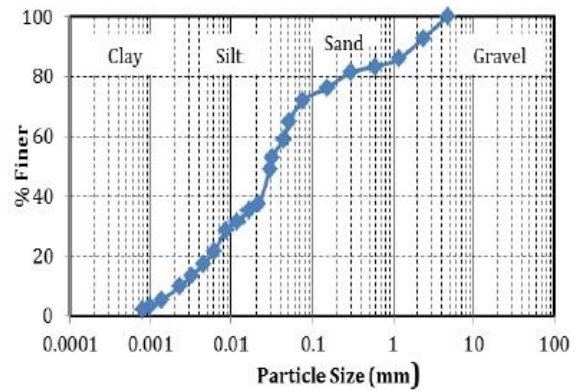


Fig 4: Grain Size Distribution Curve^[5]

4.1 Physical Properties

Physical properties of black cotton soil are listed in table 1.

Table 1: Physical Properties of Black Cotton Soil^[2]

Sr.	Property	Value
1.	Dry Density	1300-1800 Kg/m ³
2.	Liquid Limit(L.L)	40-120%
3.	Plastic Limit(P.L)	20-60%
4.	Specific Gravity(G)	2.60-2.75
5.	Proctor Density	1350-1600 Kg/m ³
6.	C.B.R(Soaked)	1.2-4.0
7.	Swelling Pressure	50-800 kN/m ²
8.	Free Swell Index	40-180%
9.	2 μ Fraction	20-60%
10.	Fines(<75μ)	70-100%

4.2 Chemical Properties

Chemical properties of black cotton soil are listed in table 2.

Table 2: Chemical Properties of Black Cotton Soil^[2]

Sr.	Property	Value
1.	pH Value	>7(Alkaline)
2.	Organic Content	0.4-2.4%
3.	CaCO ₃	1-15%
4.	SiO ₂	50-55%
5.	SiO ₂ , Al ₂ O ₃	3-5%
6.	Montmorillonite Mineral	30-50%

5. LIME STABILIZATION

Soil stabilization is a collective term for any physical, chemical, or biological method, or any combination of such methods that may be used to improve certain properties of a natural soil to make it serve adequately an intended engineering purpose. It is the process of blending and mixing materials with a soil to improve certain properties of the soil^[4]. Increased strength and improved workability are the main benefits of lime stabilization. The stabilization of black cotton soil with lime has been done in three different ratios of lime i.e. 0%, 3% and 5%. Following various tests are performed after stabilization of soil with lime-

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

California Bearing Ratio test is most widely used for testing stabilized soil. The apparatus used in this test is shown in fig. 5 and the results are shown in table 3.

California Bearing Ration = $(PT/PS) \times 100$

Where,

PT = Test Load, PS= Standard Load

Table 3: CBR Test Comparison Results^[3]

Sr.	Composition	CBR Value
1.	BC Soil + 0% Lime	2.0
2.	BC Soil + 3% Lime	6.5
3.	BC Soil + 5% Lime	9.52

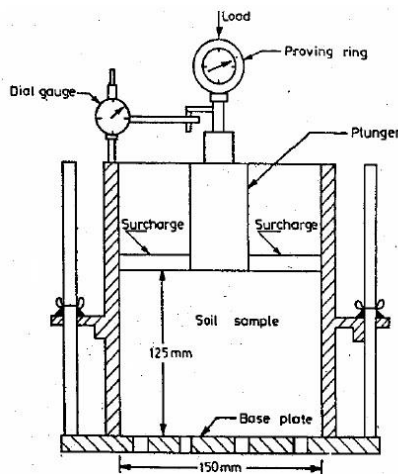


Fig 5: C.B.R. Apparatus

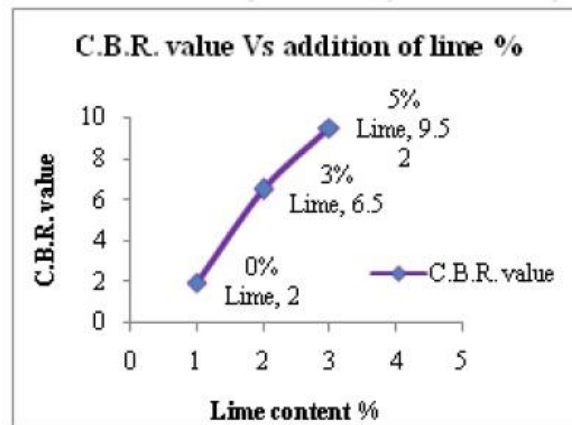


Fig 6: CBR Value For Different Lime Percentage^[3]

5.2 Liquid Limit Test

Liquid limit is the water content at which soil changes from liquid state to plastic state. At liquid limit, clay is like a liquid and have some shearing strength. The liquid limit test is carried out by Casagrande’s apparatus. Fig 7 shows Casagrande’s apparatus and test results are shown in table 4.

Table 4: Liquid Limit Test Results^[3]

Sr.	Black Cotton Soil+0% Lime		Black Cotton Soil+3%Lime		Black Cotton Soil+5%Lime	
	% of Water	No. of Blows	% of Water	No. of Blows	% of Water	No. of Blows
1.	42	58	41	28	34	38
2.	44	28	43	17	36	32
3.	46	16	45	11	38	16
4.	L.L. = 44.40		L.L. = 43.20		L.L. = 36.40	

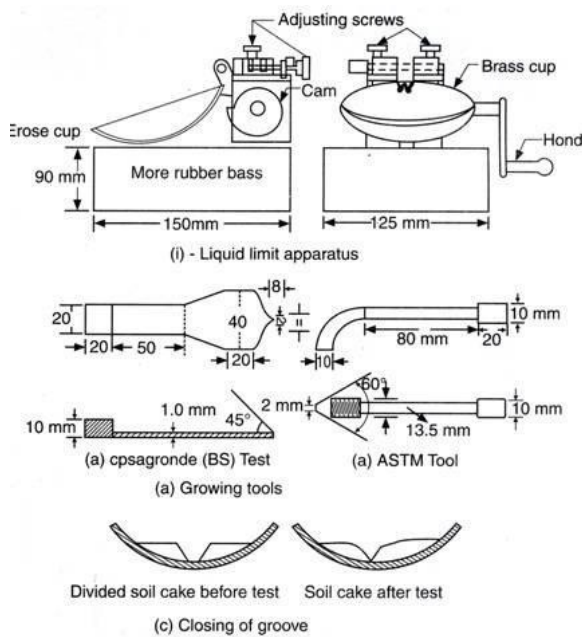


Fig 7: Liquid Limit Apparatus

5.3 Plastic Limit Test

The water content at which the soil stops behaving like plastic material is known as plastic limit. At this water content, soil starts to crumble when it is rolled into a thread of 3 mm diameter. Air dried soil sample is taken in this test. While rolling if the diameter of thread becomes less than 3 mm it shows that water content is more than plastic limit. Fig 8 shows plastic limit test procedure and table 5 shows test results.

Table 5: Plastic Limit Test Results^[3]

Sr.	Composition of Soil	Plastic Limit
1.	BC Soil + 0% Lime	30%
2.	BC Soil + 3% Lime	Non-Plastic
3.	BC Soil + 5% Lime	Non-Plastic

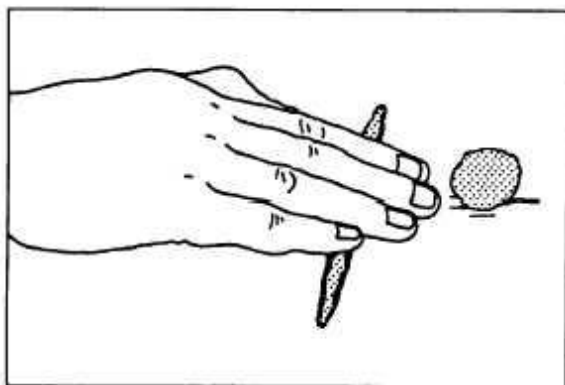


Fig 8: Plastic Limit Test

6. CONCLUSION

On the basis of review of different papers, it is found that the use of different percentages of lime content improves the properties of black cotton soil. After stabilization of black cotton soil construction becomes easier. Barren lands can be used for the construction of civil engineering structures. The points which are observed are given below-

- 1) It is observed that by adding 3% lime in black cotton soil, CBR value increases by 4.50 and with 5% lime it increases by 7.52.
- 2) Liquid limit decreases by 1.2 and 8 with lime content 3% and 5% respectively.

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