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Experimental Study on the Stabilization of Expansive Soils (Black Cotton Soils) by using Lime

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ABSTRACT

Black cotton soils are expansive in nature, when it comes in contact with moisture it swells and when it is dry it shrinks. To improve the soil properties it is necessary to stabilize the soil by different stabilizers. Soil stabilization is a process of treating the soil with additives. Additives are added to improve the engineering properties. In this paper an attempt has been made to stabilize the soil with lime. In this paper, the effect of lime used as a stabilizing additive to expansive soil is experimented for improving engineering properties of expansive soil. The basic properties of soil are evaluated by performing tests such as sieve analysis; liquid limit, plastic limit, and specific gravity are performed. The engineering properties of the soil are evaluated by various tests performed such as compaction, unconfined compression test in the laboratory. Shear strength of soil for varying percentages of lime are studied and optimum percentage of lime was obtained as 4 percent, strength of lime stabilized soil 2%,4%,6%,8% was studied. The soil with 4 percentage lime gives the maximum strength to the expansive soil.

KEYWORDS: ***Stabilization, Black Cotton Soil, Lime, Compaction, Unconfined compression test.***

INTRODUCTION

Generally, lands with black cotton soils are fertile and very good for agriculture, horticulture, sericulture and aquaculture. Good irrigation systems exist. Though black cotton soils are very good for agricultural purposes, they are not so good for construction purposes and for laying durable roads. These soils have the property of high swelling due to imbibing of water in monsoon and shrinkage due to evaporation of water in summer seasons. This swelling and shrinkage nature is attributed to the presence of mineral montmorillonite. Because of this high swelling and shrinkage nature, the structures constructed on these soils experience cracks, making it unsuitable for foundation. Hence there is a need for improving black cotton soil to suite as foundation material. Over the past few decades, stabilization is found to be the best technique for reducing the swelling and shrinkage nature of black cotton soil.

Various researchers had tried stabilizing black cotton soil using lime, cement, fly ash, rice husk ash, etc. Of these, lime stabilization is one of the techniques which is in use for stabilizing black cotton soil from the past few decades. Use of lime reduces the high plasticity of black cotton and makes it workable. Also reaction between lime and soil makes the soil-lime mixture more strength resistant. Brick powder, a waste material available in abundance at brick kilns, is rich in silica and is available free of cost can also be used.

Types of soils:

1. Sandy soil:

The first type of soil is the sand. It consists of small particles of weathered rock. Sandy soils are one of the poorest types of soil for growing plants because it has very low nutrients and poor in holding water, which makes it hard for the plant's roots to absorb water. This type of soil is very good for the drainage system. Sandy soil is usually formed by the breakdown or fragmentation of rocks like granite, limestone, and quartz.

Fig: Sandy soil

2. Silty Soil

Silt, which is known to have much smaller particles compared to the sandy soil and is made up of rock and other mineral particles which are smaller than sand and larger than clay. It is the smooth and quite fine quality of the soil that holds water better than sand. Silt is easily transported by moving currents and it is mainly found near the river, lake, and other water bodies. The slit soil is more fertile compared to the other three types of soil. Therefore it is also used in agricultural practices to improve soil fertility

Fig: Silty soil

3. Clay Soil

Clay is having the smallest particles among the other two types of soil. The particles in this soil are tightly packed together with each other with very little or no airspace. This soil has a very good water storage qualities and making hard for moisture and air to penetrate into it. It is very sticky to touch when wet, but smooth when dried. Clay is the densest and heaviest type of soil which will not drain well or provide space for plant roots to flourish.

Fig: Claysoil

4. Loamy Soil

Loam is the fourth type of soil. Even though it is a combination of sand, silt and clay. It is the gardener's favourite kind of soil. Among all these three types of soil, this loamy soil is more suitable for farming. This soil is also referred to as an agricultural soil as it includes equilibrium of all three types of soil materials being sandy, clay and silt and also happens to have humus. Apart from these, it also has a higher calcium and pH levels because of its previous organic material content.

Fig: Loamy soil.

5. Peat Soil:

Peat soils are high in organic matter and retain a large amount of moisture. This type of soil is very rarely found in a garden and often imported into a garden to provide an optimum soil base for planting.

Fig: Peatsoil

6 .Chalk soil:

Chalk soil can be either light or heavy but always highly alkaline due to the calcium carbonate or lime within its structure. As these soils are alkaline they will not support the growth of ericaceous plants that require acidic soils to grow. If a chalky soil shows signs of visible white lumps then they can't be acidified and gardeners should be resigned to only choose plants that prefer an alkaline soil.

Fig: Chalk soil.

SOIL STABILIZATION

Stabilization can increase the shear strength of a soil or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support foundations. The most common improvements achieved through stabilization include better soil gradation, reduction of plasticity index or swelling potential and increases in durability and strength. In wet weather, stabilization may also be used to provide a working platform for construction operations. These types of soil quality improvement are referred to as soil modification. Benefits of soil stabilization are higher resistance values, reduction in plasticity, lower permeability, reduction of pavement thickness, elimination of excavation, material hauling and handling and base importation, aids compaction, provides all weather access on to and within project sites. The determining factors associated with soil stabilization may be the existing moisture content, the end use of the soil structure and ultimately the cost benefits provided. As good soil becomes scarcer and their location becomes more difficult and costly, the need to improve quality of soil stabilization is becoming more important.

Soil stabilization using raw plastic bottles is an alternative method for the improvement of sub grade soil of pavement. It can significantly enhance the properties of the soil used in the constructions of road infrastructure.

1) Stabilization of soil with lime:

Slaked lime is very effective in treating heavy plastic clayey soils. Lime may be used alone or in combination with cement, bitumen or fly ash. Sandy soils can also be stabilized with these combinations. Lime has been mainly used for stabilizing the embankments and the sub grade. Lime changes the nature of the adsorbed layer and provides pozzolanic action. Plasticity index of highly plastic soils are reduced by the addition of lime with soil. There is an increase in the optimum water content and a decrease in the maximum dry density and the strength of soil increases. Normally 2 to 8% of lime may be required for coarse grained soils and 5 to 8% of lime may be required for plastic soils. The amount of fly ash as admixture may vary from 8 to 20% of the weight of the soil.

Types of Stabilization

1.In situ stabilization:

The method involves on site soil improvement by applying stabilizing agents without removing the soil. This can be used for deep foundation, shallow foundation, and contaminated sites. This is done by using techniques like grouting and injecting. Grouting is a process in which stabilizers either in the form of a solution or suspension are injected into soil. The choice to either use dry or wet mix depends on in situ soil conditions, in situ moisture content, effectiveness of binders, and nature of construction. Depending on depth of stabilization it may be deep mixing or mass stabilization.

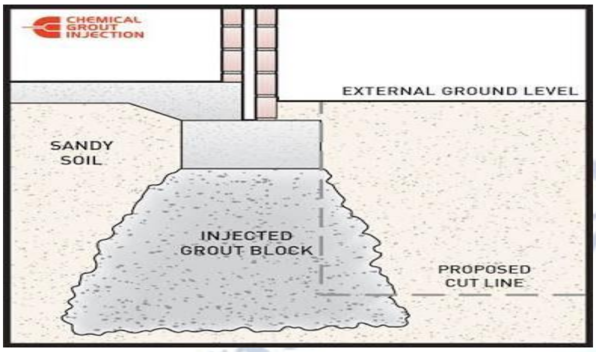

Fig:Grout Stabilization.

2.Ex-situ stabilization:

It involves removing of the soil or sediments from the original position and moved to other places. These can be encountered during dredging of river channel and ports. It is normally not done for common structures.

Stabilization of soil is very important as ultimately, it is soil which bears the complete load (dead, live, seismic, wind). A structure is finally safe if its foundation is safe. Stabilization of soil may cost you, though it's beneficial to improve the quality of soil if required, rather than to play with the safety of structure and feel guilty for the settlement of structure in near future.

Advantages of soil stabilization:

Soil properties vary a great deal and construction of structures depends a lot on the bearing capacity of the soil. Hence, we need to stabilize the soil which makes it easier to predict the local bearing capacity of the soil and even improve the load bearing capacity. The gradation of the soil is also a very important property to keep in mind while working with soils may be well- graded which is desirable as it has less number of voids or uniformly graded with though sound stable but has more voids. Thus, it is better to mix different types of soils together to improve the soil strength properties. It is very expensive to replace the inferior soil entire soil and hence, soil stabilization is important.

- It improves the strength of the soil, thus, increasing the soil bearing capacity
- It is more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation.
- It is also used to provide more stability to the soil in slope or other such places.
- Sometimes soil stabilization is also used to prevent soil erosion or entering into the soil and hence helps the soil from losing its strength
- It helps in reducing the soil volume change due to change in temperature or moisture content
- Stabilization improves the workability and the durability of the soil.

Materials:

To study the performance of lime on expansive soil, which is obtained from farm lands of Govindhapally village, Rangareddy, Telangana, India and Lime was collected from G.K Industries, Hyderabad, Telangana, India .

The soil used in this study is a Black Cotton Soil (dark grey in colour) .The black cotton soil was collected by method of disturbed sampling after removing the top soil at 500mm depth and transported in sacks to the laboratory. Little amount of the sample was sealed in polythene bag for determining its natural moisture content. The soil was air dried, pulverized and sieved with Indian Standard Sieve N0. 4 (4.75mm) as required for laboratory test.

LIME:

Lime is a calcium-containing inorganic mineral composed primarily of oxides, and hydroxide, usually calcium oxide and/ or calcium hydroxide.

Types of limes:

Quick Lime

It is also known as caustic lime. It is obtained by calcination (i.e. heating to redness) of comparatively pure lime stone. It is amorphous in nature, highly caustic and possesses great affinity to moisture.

Slaked Lime

It is also known as hydrate of lime. It is obtained by slaking (i.e. chemical combination of quick lime with water) of quick lime. It is ordinary pure lime, in white powder form, available in market. It has got the tendency of absorbing carbonic acid from the atmosphere in presence of water.

Fat Lime

It is also known as high calcium lime or pure lime or rich lime or white lime. It is popularly known as fat lime as it slakes vigorously and its volume is increased to about 2 to 2.5 times that of quick lime. This lime is used for various purposes as white washing, plastering of walls, as lime mortar with sand for pointing in masonry work, as a lime mortar with surkhi for thick masonry walls, foundations, etc.

Hydraulic Lime

It is also known as water lime. This lime contains clay and some amount of ferrous oxide. It sets under water and hence also known as water lime. Depending upon the percentage of clay IS has divided hydraulic lime in three classes namely

CLASS A – EMINENTLY HYDRAULIC

This lime contains about 25% clay content and sets readily under water within a day or so. This lime slakes with difficulty. The mortar and lime concrete prepared from this lime is very useful for construction under water or in damp places.

CLASS B – SEMI HYDRAULIC

Semi-hydraulic lime contains about 15% clay content and sets under water at a slower rate within a week or so. The mortar and concrete prepared from this lime is strong and used for superior type of masonry work.

CLASS C – NON-HYDRAULIC (OR FAT LIME)

This lime contains about 7.5% of clay content and is prepared from pure lime stone. This slakes vigorously within few minutes but does not set under water. This is used for white washing and colour washing.

Uses of lime:

Lime provides benefits to mortar and plaster in both the plastic and hardened state. In the plastic state, lime can enhance workability and water retention. In the hardened state, lime products react with carbon dioxide to regenerate calcium carbonate or limestone. This is a slow, gradual process that increases the hardness of the finished surface and allows for the closing of hairline cracks by a process called autogenous healing. Since initial strength is needed in most applications, additives such as gypsum, cement or pozzollans are mixed with lime in construction applications. Lime can react with pozzolanic materials in the mortar or plaster to produce a cement-like product. The strength of lime-based mixes can be modified according to the needs of the particular application. This is beneficial in restoration applications where low strength and high vapor permeability are needed.

Engineering properties of Black cotton soil:

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

A. Permeability

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

B. Plasticity

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

C. 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.

D. Compressibility

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

E. 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.

EXPERIMENTAL WORK

Index tests on the natural and stabilized BC soils were carried out in accordance with the procedures outlined in BS 1377 (1990) and BS 1924 (1990) respectively, for the stabilized soil specimens, step percentages of lime by dry weight of soil (2%, 4%, 6%, 8%) was introduced into the soil. The following test were carried out on the natural and stabilized soils

- Free swell
- Sieve analysis
- Atterberg's limits (Liquid limit, Plastic limit)
- Specific gravity
- Standard proctor's compaction test
- Unconfined compression test

Free swell Index test (As per IS: 2720 part (40)-1997):

Free Swell Index is the increase in volume of a soil, without any external constraints, on submergence in water. It determines free swell index of soil.

Sample	Measuring cylinder		Reading after 24 hours		Free swellindex (%)
	Kerosene (ml)	Distilled Water(ml)	Kerosene (ml)	Distilled Water(ml)	
1.	10	10	10	21	110

There is a10% increase in volume of soil.

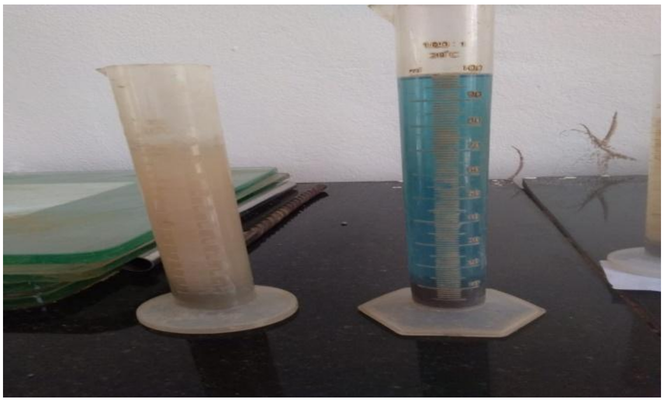

Fig: Free Swell Indextest.

Sieve Analysis (As per IS 2720 part (iv)-1975):

Soil is compared of soil grains of different shapes and sizes in varying propositions. In order to determine the percentage of various sizes of soil grains present in a given soil sample, mechanical analysis of soil is carried out. Soils are broadly classified as follows based on size of soil grains.

Sieve size (mm)	Mass of sieve (gm)	Mass of soil retained (gm)	Mass of sieve + soil retained (gm)	Cumulative mass retained (gm)	Cumulative % retained	Cumulative % passing
4.75	432.76	141.94	574.7	141.94	47.31	52.69
2.0	264.01	87.31	351.32	229.25	76.41	23.59
1.0	212.41	28.76	241.17	258.01	86.00	14
0.600	381.52	18.10	399.62	276.11	92.03	7.97
0.425	311.07	4.36	315.43	280.47	93.49	6.51
0.300	314.26	5.52	319.78	285.99	95.33	4.67
0.150	325.92	7.65	333.57	293.64	97.88	2.12
0.075	411.17	1.54	411.71	295.18	98.06	1.94
Pan	239.05	4.82	244.83	300	100	0

Cumulative percentage shows the % of fines of different sizes.

Specific Gravity [As per IS: 2720(Part 3) -1980]:

Specific gravity G is defined as the ratio of the weight of an equal volume of distilled water at that temperature both weights taken in air.

S:No	Observations	Weight 0f soil with out lime	Weight with 2% lime	Weight with 4%lime	Weight with 6%lime
1	Weight of (W_1)	652	652	652	652
2	Weight +Dry soil (W_2)	852	852	858	862
3	Weigh of pycnometer bottle + soil + water (W_3)	1610	1610	1608	1612
4	Weigh of pycnometer bottle + water (W_4)	1500	1504	1496	1498
5	Specific gravity $\frac{w2-w1}{(w2-w1)-(w3-w4)}$	2.22	2.12	2.36	2.18

Specific Gravity (G) with and without lime are known

Atterberg limits:

The Atterberg limits are a basic measure of the nature of a fine-grained soil. Depending on the water content of the soil, it may appear in four states: solid, semi-solid, plastic and liquid In each state, the consistency and behavior of a soil is different and thus so are its engineering properties. Thus, the boundary between each state can be defined based on a change in the soil's behavior. The Atterberg limits can be used to distinguish between silt and clay, and it can distinguish between different types of silts and clays. These limits were created by Albert Atterberg, and later refined by Arthur Casagrande.

Plastic limit:

Plastic limit is the water content at which a soil sample begins to crumble when rolled under the palm of the hand, into threads of diameter 3mm.

Observations	Soil without admixtures	Soil with 4% lime	Soil with 6% lime
Container no	2	4	6
Wt of container(W_1) (grams)	31.71	33.230	34
Wt of container + soil (W_2) (grams)	39.52	42.130	42.72
Wt of container + oven dry soil(W_3) (grams)	36	39.81	40.970
wt of water(W_2-W_3) (grams)	3.52	2.32	1.75
Wt of oven dry soil(W_3-W_1) (grams)	4.29	6.58	6.97
Water content$\frac{w2-w3}{w3-w1}$×100 (%)	82.05	35.25	25.107

Result:

Plastic limit of soil without admixtures is 82.05%

Plastic limit of soil with 4% lime is 35.25

Plastic limit of soil with 6% lime is 25.107%

Liquid limit:

Liquid limit is the minimum water content at which, the soil cut by a groove of standard dimensions, flows together by 12mm, when jarred twenty five times

Casagrande grooving tool is used for cohesive soils and ASTM tool is used for sandy soil. Casagrande tool cuts a groove of 2 mm wide at the bottom, 11 mm wide at the top and 8 mm high. ASTM tool cuts a grove of 2 mm wide at the bottom, 13.6 mm at the top and 10 mm high.

At the liquid limit, the soil has low shear strength to resist the flow, though it is in a fluid state.

Observations	Soil without lime	Soil with 4%lime	Soil with 6%lime
No. of blows	25	9	13
Container no	3	6	9
Wt of container(W_1)	36	33	32
Wt of container + soil (W_2)	90	78	65
Wt of container + oven dry soil(W_3)	80	72	62
wt of water(W_2-W_3)	10	6	3
Wt of oven dry soil(W_3-W_1)	44	39	30
Water content$\frac{w2-w3}{w3-w1}$× 100	22.72	15.38	10

RESULT: The liquid limit has decreased with increasing percentage of lime

Standard proctors compaction test [as per IS: 2720 (PART 7)-1980]

Determines the maximum dry density and optimum moisture content of a given soil.

Fig: standard proctors compaction mould.

Observations of standard proctor compaction test:

S. NO	Proportion	Value
1	Soil with no admixtures	O.M.C=19.43% M.D.D=1.70g/cc
2	Soil with 2% lime	O.M.C=15.92% M.D.D=1.824g/cc
3	Soil with 4% lime	O.M.C=19.23% M.D.D=1.787g/cc
4	Soil with 6% lime	O.M.C=20.52% M.D.D=1.72g/cc
5	Soil with 8 % lime	O.M.C=10.71% M.D.D=1.70g/cc

BLACK COTTON SOIL WITHOUT ADMIXTURES

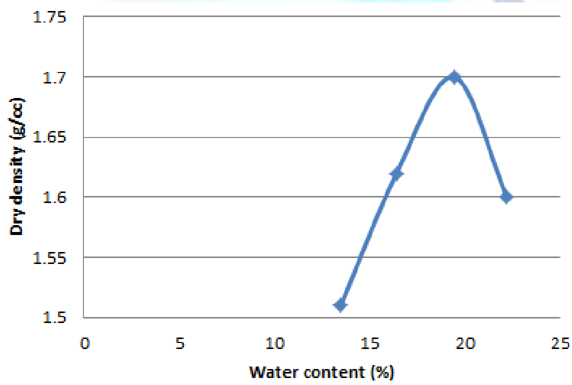

Fig: Graph between water content and Dry density.

BLACK COTTON SOIL WITH 2% LIME

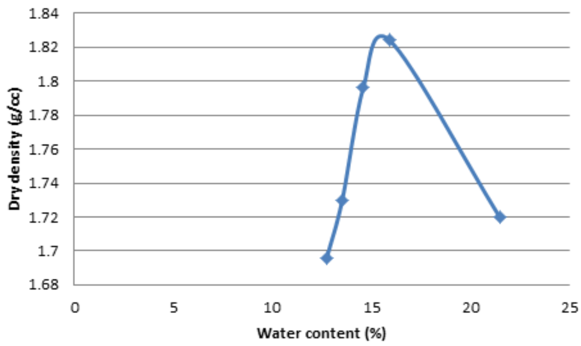

Fig: Graph Between water content and Dry density.

BLACK COTTON SOIL WITH 4% LIME

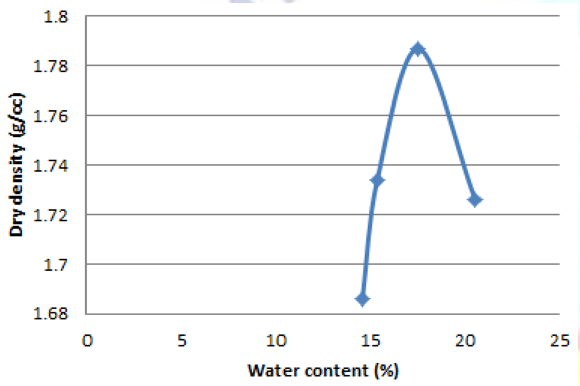

Fig: Graph between water content and Dry density.

BLACK COTTON SOIL WITH 8% LIME

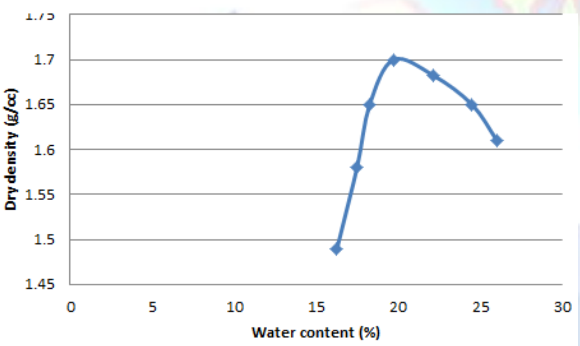

Fig: Graph between water content and Dry density.

From the above Graphs it is concluded that with the increasing water content the Maximum dry density increases till attainment of maximum dry density with further increasing in water content the maximum dry density decreases.

Unconfined compressive strength [As per IS: 2720 (Part 10)-1991]

The unconfined compression strength (qu) is the load per unit area at which the cylindrical specimen of cohesive soils fails in compaction.

Observations for unconfined compressive strength

S. NO	Proportion	Value
1	Black cotton soil Without admixtures	Cu=0.86 Qu=1.72
2	Black cotton soil with 2% lime	Cu=0.925 qu=1.85
3	Black cotton soil with 4% lime	Cu=1.26 qu=2.52
4	Black cotton soil with 6% lime	Cu=0.66 qu=1.32
5	Black cotton soil with 8% lime	Cu=0.565 qu=1.13

CONCLUSIONS:

From the study carried out on lime-stabilized black cotton soil mixture, the following conclusions can be drawn:

1. Lime stabilization of black cotton soil under study improved the strength characteristics of the soil.
2. Lime is used as a excellent soil stabilizing material for highly active soils which undergo through frequent expansion and shrinkage.
3. Optimum percentage of lime was observed at 4% for improving the properties of soil and Strength.
4. Lime acts immediately and improves various properties of soil such as carrying capacity of soil, Resistance to shrinkage during moist conditions, reduction in plasticity index and subsequent increase in compression resistance with increasing in time.
5. The liquid limit and plastic limit is decreased with addition of lime.
6. The reaction is very quick and reaction starts within few hours.
7. The graphs presented above give a clear idea about the improvement in the properties of soil after adding lime.

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Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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