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Analysis of Engineering Properties of Black Cotton Soil & Stabilization Using By Lime.

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ABSTRACT
With the increasing of population and the reduction of available land, more and more construction of buildings and other civil engineering structures have to be carried out on weak or soft soil. Owing to such soil of poor shear strength and high swelling & shrinkage, a great diversity of ground improvement techniques such as soil stabilization and reinforcement are employed to improve mechanical behavior of soil, thereby enhancing the reliability of construction. Black cotton soil is one of the major soil deposits of India. They exhibit high swelling and shrinking when exposed to changes in moisture content and hence have been found to be most troublesome from engineering considerations. Stabilization occurs when lime is added to black cotton soil and a pozzolanic reaction takes place. The hydrated lime reacts with the clay particles and permanently transforms them into a strong cementations matrix. Black cotton soil showing low to medium swelling potential from Rajkot Gujarat was used for determining the basic properties of the soil. Changes in various soil properties such as Liquid limit, Plastic Limit, Maximum Dry Density, Optimum Moisture Content, and California Bearing Ratio were studied.
Keywords– Black cotton soil, density, lime , soil, and stabilization

I. INTRODUCTION

1.1Soil

Soil is the indispensable element of this nature. It is attached to everyone in one or another way. All the basic amenities of life, whether it is concerned with food, clothes and house, have been fulfilled by the soil .Without the soil it is just next to impossible to think about life on this earth. The word ‘soil’ is derived from the Latin word solium which according to Webster’s dictionary means the upper layer of the earth that may be dug or plowed; specifically, the loose surface material of earth in which plant grows.The term soil in soil engineering is defined as an unconsolidated material, composed of solid particles produced by disintegration of rocks. The voids space between particles may contain air, water or both. The solid particles may contain organic matter. The soil particles maybe separated by such mechanical means as agitation and water. Soil deposits in nature exist in an extremely erratic manner *producing* thereby an infinite variety of possible combination which will affect the strength of the soil and the procedures to make it purposeful. So is the particular case of black cotton soil with a wide range of challenges associated with the construction at sites with black cotton soil. In case of *coarse* grained soil, the mineralogical composition of the grain hardly affects the engineering properties of the soils perhaps the grain to grain friction is influenced to a degree. Is such soils, inter particle forces other than those due to gravity are of no consequence, but the finer particles, the more significant becomes the forces associated with the surface area of the grains. The soil structure means the mode of arrangement of soil particles related to each other and the forces that are acting between soil particles to hold them together in their positions. The concept is further extended to include the mineralogical composition of the grains, the electrical properties of the particle surface, the physical characteristics, ionic composition of pore water, the interactions among the soil particles, pore water and the adsorption complex. The formation of soil structures is governed by several factors in coarse grained soils, the force of gravity is the main factor, while in fine grained soils, and the surface bonding becomes predominant. The specific surface (the ratio of the surface area of a mineral to its mass or volume) is a parameter which is often used to decide the importance of surface bonding forces relative to forces of gravity. Smaller particles have much larger surface area than the larger particles .for the same void ratio water content are more for fine grained soil than for the coarse grained. ‘Clay’ is understood to mean a clay soil whose grains are predominantly composed of clay minerals and which has plasticity and cohesion. Though the clay soils are fine grained but, not all fine grained soil possess plasticity and cohesion. The presence of water, its content plays a decisive role in the engineering behavior of a clay soil. On the other hand, grain –size distribution and grain shape influence the engineering properties of granular soils and hardly affect the behavior of clays. The expansive soils occur all over the world. India has large tracks of expansive soil known as Black Cotton soil (BC soil), covering an area of 0.8 million square kilometre, which is about 20% of total land area. The major areas of their occurrence are states of Maharashtra, Gujarat, southern parts of Uttar Pradesh, eastern parts of Madhya Pradesh, parts of Andhra Pradesh and Karnataka. This type of soil is available up to a depth of 3.7 meters on an average in the above parts of India. Expansive soils occurring above water table undergo volumetric changes with change in moisture content. Increase in water content causes the swelling of the soils and loss of strength and decrease in moisture content brings about soil shrinkage. Swelling and shrinkage of expansive soil cause differential settlements resulting in severe damage to the foundations, buildings, roads, retaining structures, canal linings, etc. The construction of foundation for structure on black cotton soils poses a challenge to the civil engineers. Chemical stabilization is one of the oldest methods of stabilization of problematic soil. In general, all lime treated fine-grained soils exhibit decreased plasticity, improved workability and reduced volume change characteristics. However, not all soils exhibit improved strength characteristics. It should be emphasized that the properties of soil-lime mixtures are dependent on many variables. Soil type, lime type, lime percentage and curing conditions (time, temperature, and moisture) are the most.

PROBLEM SUMMARY

2.1 Problems of Construction in Black Cotton Soil Areas

1.2.1. Problems Arising out of Water Saturation

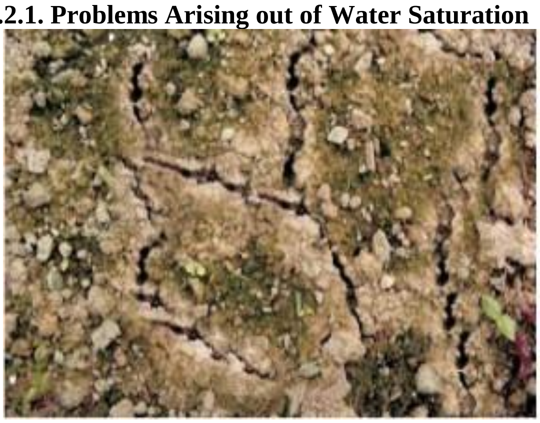


Fig. 1.1 Typical Cracks in Black Cotton Soil in Dried State

It is a well-known fact that water is the worst enemy of all structures, particularly in expansive soil areas. Water penetrates into the foundation from three sides viz. top surface, and from bottom layers due to capillary action. Therefore, specifications in expansive soil areas must take these factors into consideration. The surfacing must be impervious, sides paved and soil beneath well treated to check capillary rise of water.

It has been found during handling of various investigation project assignments for assessing causes of structural failures that water has got easy access into the foundations. It saturates the soil and thus lowers its bearing capacity, ultimately resulting in heavy depressions and settlement. Water lubricates the soil particles and makes the mechanical interlock unstable. In the top surface, raveling, stripping and cracking develop due to water stagnation and its seepage into the bottom layers. Generally, construction agencies do not pay sufficient attention to the aspects of construction and maintenance of sides. In expansive soil areas, unpaved offsets pose the maximum problem as they become slushy during rains, as they are most neglected lot. Fig. 3.2 and Fig. 3.3 show development of alligator cracks and extensive depression as well as upheavals respectively in bituminous surfacing in Black cotton soil (BC soil) areas.

1.2.2 Design Problems in Black Cotton Soils

Fig. 1.2 Construction of Road Embankment with Cohesive Non Swelling Soil (Moorum)

In India, CBR method developed in USA is generally used for the design of crust thickness. This method stipulates that while determining the CBR values in the laboratory and in the field, a surcharge weight of 15 kg and 5 kg per 62 mm and 25 mm thickness respectively should be used to counteract the swelling pressure of Black cotton soils (BC soils). BC soils produce swelling pressure in the range of 20-80 tons/m^2 and swelling in the range of 10-20%.Therefore, CBR values obtained are not rational and scientific modification is required for determining CBR values of expansive soil. For the study of the soil we have used the CBR test as a prime indicator to the strength of the soil.

OBJECTIVE OF STUDY

The basic objectives of study of black cotton soil are as following:

- **Improvement of bearing capacity of Black Cotton Soil on addition of lime.**
- **Variation of Strength of soil at different water content.**
- **Effect of lime on CBR value of the soil.**
- **Effect of lime on Compressive strength of soil.**

In order to achieve the above objective, the black cotton soil has been arbitrarily reinforced with lime. So the suitability of lime is considered to enhance the properties of black cotton soil. A cycle of experiments such as Liquid limit test, Plastic Limit Test, Permeability test, California bearing ratio test (CBR) test, unconfined compressive strength and Hydrometer test is carried out on black cotton soil sample with different percentages of lime. They are performed to study the variation in bearing capacity and other properties like liquidity and plasticity behaviour, and compaction behaviour are also studied. The CBR test is carried out to access the suitability of this composite for a road sub grade material.

As a reference test for making evaluation, the above mentioned tests are also carried out for raw soil sample.

Fig. 1.3: Extreme example of pavement failure from unstable soils

II. REVIEW OF LITERATURE

2.1 Soil Stabilization

Soil stabilization with lime can be done by mixing dosage of unsoaked lime into damp soil creates both immediate and medium – term effects. Some of immediate effects are:

Drying*:* On mixing, there is immediate exothermic hydration reaction. It reduces water content with further reduced by aeration of soil. Water – fall percentage varies by 2 to 3 % of added lime.

Flocculation*:* Mixing affects the ultrasonic field between clay particles which changes to granular structure.

Reduction in Plasticity Index (PI): It switches from being plastic to stiff and grainy.

Improvement in bearing capacity: After two hours of mixing, CBR of a treated soil is between 4 and 10 times higher than that of an untreated soil. The reaction greatly relieves on –site transportation difficulties.

2.2 Soil Lime Stabilization

2.2.1 Basic Properties of Soil Lime Mix

Soil – lime has been widely used as a modifier or as a binder.
Soil – lime is used as modifier in high plasticity soils.
Soil – lime also imparts some binding action even in granular soils.
It is effectively used in expansive soils with high plasticity index.

2.2.2 Factors Affecting the Properties of Soil with Lime

Lime Content*:* Generally increase in lime content causes slight change in liquid limit and considerable increase in plasticity index. The rate of increase is first rapid and then decreases beyond a certain limit upto lime fixation point.

Types of Lime*:* After long curing periods all types of limes produce some effects. However the quick lime has been found more effective than hydrated lime. Calcium carbonate must be treated at higher temperature to form quick lime calcium oxide. Calcium oxide must be slaked to form hydrated lime.

Curing: The strength of soil – lime increases with curing period upto several years. The rate of increase is rapid during initial period. The humidity of the surroundings also affects the strength.

Additives: Sodium metasilicate, sodium hydroxide and sodium sulphate are found to be very much useful.

Lime Meets the Construction Challenge: Using lime can substantially increase the stability, impermeability and load bearing capacity of the subsurface.

Facts: One million metric tons of lime used annually in the US for soil modification and stabilization.

III. MATERIALS TO STUDY THE BLACK COTTTON SOIL

3.1 Black Cotton Soil

Black cotton soil (BC soil) is a highly clayey soil. The black colour in Black cotton soil (BC soil) is due to the presence of titanium oxide in small concentration. The Black cotton soil (BC soil) has a high percentage of clay, which is predominantly montmorillonite in structure and black or blackish grey in colour. Expansive soils are the soils which expand when the moisture content of the soils is increased. The clay mineral montmorillonite is mainly responsible for expansive characteristics of the soil. The expansive soils are also called swelling soils or black cotton soils.

The structures on Black cotton soil (BC soil) bases develop undulations at the road surface due to loss of strength of the sub-grade through softening during monsoon. The physical properties of Black cotton soil (BC soil) vary from place to place 40 % to 60 % of the Black cotton soil (BC soil) has a size less than 0.001 mm. At the liquid limit, the volume change is of the order of 200 % to 300% and results in swelling pressure as high as 8 kg/cm^2/ to 10 kg/cm^2. As such Black cotton soil (BC soil) has very low bearing capacity and high swelling and shrinkage characteristics. Due to its peculiar characteristics, it forms a very poor foundation material for road construction. Soaked laboratory CBR values of Black Cotton soils are generally found in the range of 2 to 4%. Due to very low CBR values of Black cotton soil (BC soil) excessive pavement thickness is required for designing for flexible pavement. Research & Development (R&D) efforts have been made to improve the strength characteristics of Black cotton soil (BC soil) with new technologies. The construction of foundation for structure on black cotton soils poses challenge to civil engineers.

3.2 Lime

In general, all lime treated fine-grained soils exhibit decreased plasticity, improved workability and reduced volume change characteristics. However, not all soils exhibit improved strength characteristics. It should be emphasized that the properties of soil-lime mixtures are dependent on many variables. Soil type, lime type, lime percentage and curing conditions (time, temperature, and moisture) are the most important.

3.2.1 Types of Lime

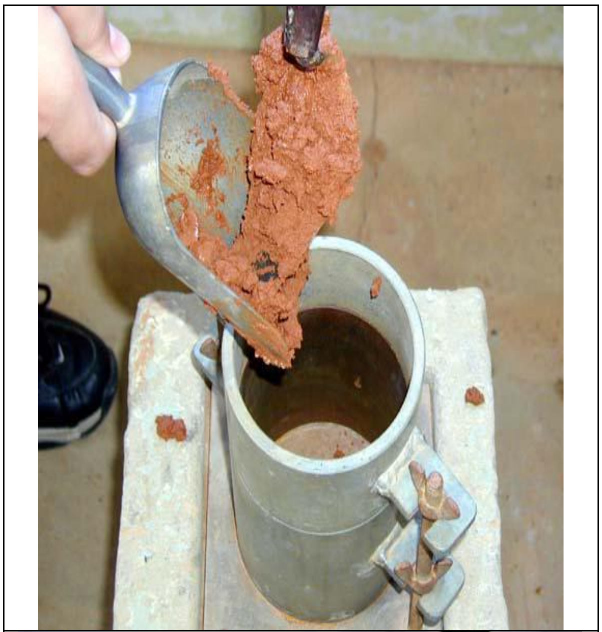
Various forms of lime have been successfully used as soil stabilizing agents for many years. However, the most commonly used products are hydrated high-calcium lime, monohydrated dolomite lime, calcite quicklime, and dolomite quicklime. Hydrated lime is used most often because it is much less caustic than quicklime; however, the use of quicklime for soil stabilization has increased in recent years mainly with slurry-type applications. The design lime contents determined from the criteria presented herein are for hydrated lime. If quicklime is used, the design lime contents determined herein for hydrated lime should be reduced by 25 percent. Specifications for quicklime and hydrated lime may be found in ASTM C 977.

3.2.2 Gradation Requirements

Graduation requirements for lime stabilized base and sub-base courses are presented as:

Type Course	*Sieve Size*	*Percent Passing*
Base	1½ in.	100
	¾ in.	70-100
	No. 4	45-70
	No. 40	10-40
	No. 200	0-20
Subbase	1½ in.	100
	No. 4	45-100
	No. 40	10-50
	No. 200	0-20

Table 3.2 Gradation Requirements



IV. RESULTS & DISCUSSION

4.1 Particle Size Analysis

4.1.1 Dry Sieve Analysis with 0 % lime content

4.1.1.1 Observation Table

RESULT OF TEST-1

S.N.	IS Sieve	Particle size D (mm)	Mass retained (g)	% retained	Cumulative % retained	Cumulative % finer (N)
1	4.75 mm	4.750 mm	41.70	10.43	10.43	89.58
2	2.36 mm	2.360 mm	55.61	13.90	24.33	75.67
3	1.78 mm	1.780 mm	53.30	13.33	37.65	62.35
4	1.18 mm	1.180 mm	51.60	12.90	50.55	49.45
5	600 micron	0.600 mm	68.60	17.15	67.70	32.30
6	300 micron	0.300 mm	61.60	15.40	83.10	16.90
7	150 micron	0.150 mm	41.80	10.45	93.55	6.45
8	90 micron	0.090 mm	3.00	0.75	94.30	5.70
9	75 micron	0.075 mm	4.40	1.10	95.40	4.60
10	pan		18.39	4.60	100.00	0.00

RESULT OF TEST-2

S.N.	IS Sieve	Particle size D (mm)	Mass retained (g)	% retained	Cumulative % retained	Cumulative % finer (N)
1	4.75 mm	4.750 mm	43.00	10.75	10.75	89.25
2	2.36 mm	2.360 mm	49.70	12.43	23.18	76.83
3	1.78 mm	1.780 mm	59.60	14.90	38.08	61.93
4	1.18 mm	1.180 mm	53.70	13.43	51.50	48.50
5	600 micron	0.600 mm	67.00	16.75	68.25	31.75
6	300 micron	0.300 mm	60.80	15.20	83.45	16.55
7	150 micron	0.150 mm	41.00	10.25	93.70	6.30
8	90 micron	0.090 mm	3.40	0.85	94.55	5.45
9	75 micron	0.075 mm	5.30	1.33	95.88	4.13
10	pan		16.50	4.13	100.00	0.00

RESULT OF TEST-3

S.N.	IS Sieve	Particle size D (mm)	Mass retained (g)	% retained	Cumulative % retained	Cumulative % finer (N)
1	4.75 mm	4.750 mm	40.20	10.05	10.05	89.95
2	2.36 mm	2.360 mm	60.40	15.10	25.15	74.85
3	1.78 mm	1.780 mm	54.70	13.68	38.83	61.18
4	1.18 mm	1.180 mm	50.40	12.60	51.43	48.58
5	600 micron	0.600 mm	65.20	16.30	67.73	32.28
6	300 micron	0.300 mm	57.30	14.33	82.05	17.95
7	150 micron	0.150 mm	40.30	10.08	92.13	7.87
8	90 micron	0.090 mm	3.10	0.78	92.90	7.10
9	75 micron	0.075 mm	7.90	1.98	94.88	5.12
10	pan		20.50	5.13	100.00	0.00

AVERAGE OF TEST

TEST -1	TEST-2	TEST-3	AVERAGE
Cumulative % finer (N)	Cumulative % finer (N)	Cumulative % finer (N)	Cumulative % finer (N)
89.58	89.25	89.95	89.59
75.67	76.83	74.85	75.78
62.35	61.93	61.18	61.82
49.45	48.50	48.58	48.84
32.30	31.75	32.28	32.11
16.90	16.55	17.95	17.13
6.45	6.30	7.87	6.87
5.70	5.45	7.10	6.08
4.60	4.13	5.12	4.62
0.00	0.00	0.00	0.00

Table 5.1 Dry Sieve Analysis

RESULT:-

From the curve calculate uniformity coefficient (Cu) and coefficient of curvature (Cc).

Uniformity coefficient (Cu):-

$$Cu = \frac{D60}{D10} = \frac{1.8}{0.2} = 9 \ (5\text{-}15)$$

From the graph and IS code soil is Medium graded soil

Coefficient of curvature (Cc):-

$$Cc = \frac{(D30)2}{D10 * D60} = \frac{(0.55)2}{0.2 * 1.8} = 0.84$$

From the graph and IS code soil is poorly graded soil5.1.2 Hydrometer Test
4.1.2.1 With 0% lime content
4.1.2.1.1 Observation table

Size of particles (in mm)	% Finer
0.043	80.3
0.0313	77.08
0.0227	73.876
0.0169	64.24
0.0119	54.604
0.0089	49.786
0.0063	44.968
0.0043	38.54
0.0033	32.12
0.0025	28.12
0.0012	25.03
0	0.00

Table 5.2 Hydrometer Analysis with 0% lime content
4.1.2.1.2 Gradation Curve

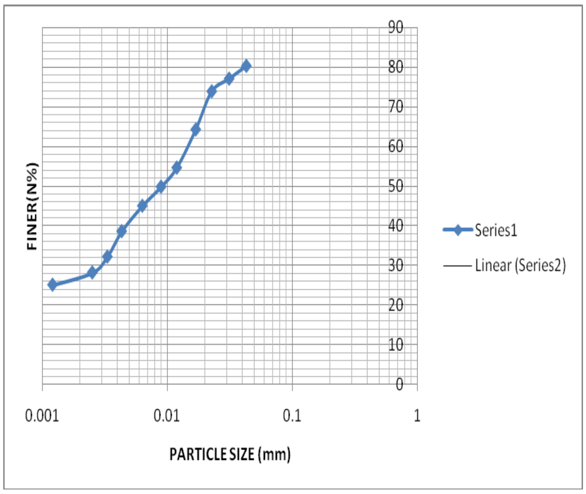


Fig 5.2 Hydrometer Analysis with 0% lime content

4.2 Liquid Limit
4.2.1 with 0% lime content

NO OF BLOWS	WATER CONTENT (%)
28	53.80
33	51
24	59.88

Table 5.3 liquid limit with 0% lime content

5.2.1.2 Flow Curve

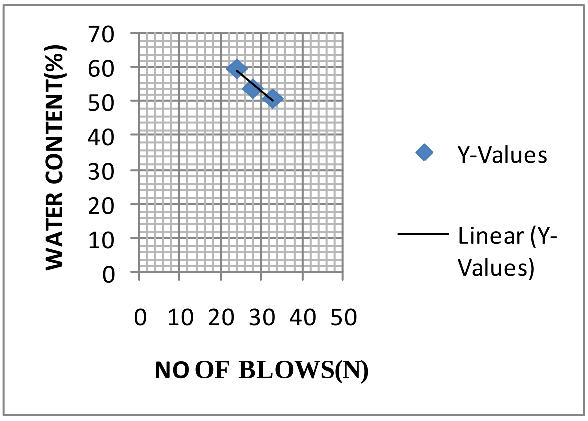


Figure 5.3 Graph for Liquid Limit with 0% lime content

RESULT:- from the graph we obtained the liquid limit corresponding to 25 blows.
Liquid limit is = 58%

4.3 Plastic Limit
4.3.1 With 0% lime content
4.3.1.1 Observation Table

Container No.	1	2	3
Wt. of container , W1 (gm)	8.8	8.5	8.2
Wt. of container+ wet soil sample,W2(gm)	15.3	14.4	15.5
Wt. of container+ dry soil sample,W3(gm)	13.5	12.7	13.1
Water content (%)={(W2-W3)/(W3-W1)}*100	28.2	23.61	32
PLASTIC LIMIT (MEAN VALUE, %) = 28%			

Table 5.4 Plastic limit with 0% lime content

4.3.2 Plasticity index (Ip) :
$I_P = W_L - W_P = 58 - 28 = 30$
So soil is a high plasticity clay.
It is also determine from the IS plasticity chart
As per the plasticity chart we obtained that the soil is above A- line and CH or OH group.
So soil is highly clay or high plasticity
Liquid limit is = 58%
PLASTIC LIMIT = 28%
Plasticity index= 30

4.3.2.1 Liquidity index (I_L):-
LI = (W-PL)/(LL-PL) = (35-28)/(58-28)
= 24%
4.3.2.2 Activity of soil (A):-
A=Ip/F =28/6
= 4.66 >4
So it means soil is highly active clay soil.

CONCLUSION:-

As per the Atterberg's limit we determined the liquid limit , plastic limit , plasticity index , activity of soil.We get the value of that by the experiments and which is prosperity of the black cotton soil. Due to those properties soil is highly clay and highly plasticity. So we cannot construct any structure or pavement design and need to stabilization. So we stabilized that soil by lime, sisal fibre or sand. So we need to improve the black cotton soil by various methods.

4.4 CBR Test

4.4.1 with 0% lime content

4.4.1.1 Observation Table

Penetration (in mm)	Load (in kg)
0	0
0.5	30
1	60
1.5	110
2	140
2.5	160
3	195
3.5	205
4	225
4.5	245
5	265
5.5	270
6	273

Table 5.4 CBR with 0% lime content

4.4.1.2 CBR Graph

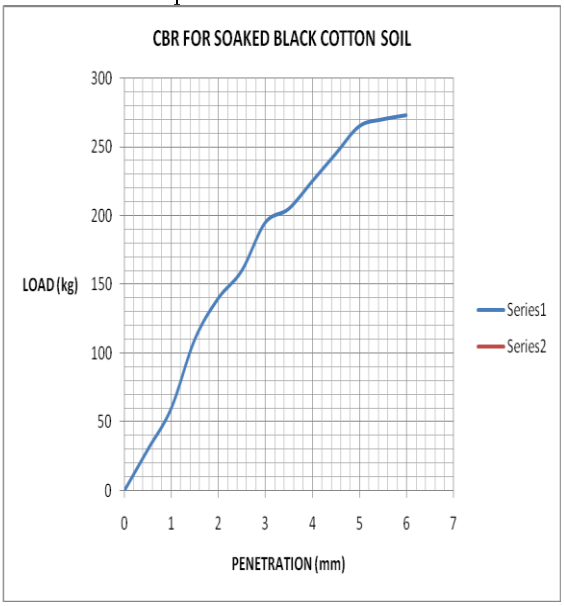


Fig 5.4 CBR with 0% lime content

RESULT:-

From laboratory test results we get value of C.B.R at different readings. for design of flexible pavement as per I.R.C 37-2001,value of C.B.R is very poor is less than 4%.

And the swelling pressure is 9 kg/cm2.

V. CONCLUSION

Some clayey sand mixes with determined gradations, abundant in northern India, was stabilized with different lime contents and then subjected to Bearing strength, Shrinkage property, and CBR tests. Materials were reconstituted in the laboratory and the fine content of mixes was provided from Kaolinite clay to reach a constant plastic characterization for all specimens. Results of this investigation are as below:

At finally we perform the all properties of the soil which we taken.

And after the all laboratory test we found that our soil is a highly clay content and sat that black cotton soil.

We found the value of liquid limit and plastic limit and which is very high and high content of water so we cannot use directly for the construction or highway pavement purpose.

In the test of proctor of soil we found that their is high value of optimum moisture content and as well as low dry density of soil. And more air voids in the soil. Sosoil loose their strength.

In the test of C.B.R. we found the value of the C.B.R. is less and high value of the swelling pressure and due to low C.B.R. value soil has no high strength and no stabilization.

So we require the stabilise the black cotton soil and increase the strength of soil and decrease the swelling pressure and decrease the liquid limit and plastic limit.

Lime-stabilization of geo-materials by producing cohesive materials in the soil increases the strength and decreases materials plastic properties. This is why these materials can be used for projects where high strength and high performance materials are desirable. The increase in strength of lime-stabilized materials in compression as well as in tension is attributed to the reactions between clay particles and lime. The clay content of lime-stabilized materials can affect the strength of the materials. The clay–lime compound provides the cemented material in soil.

Some mechanical properties of clayey sands were investigated and the behaviour of these materials was expressed in simple mathematical equations based on test results on soil samples provided from the Northern areas of India. These functions are applicable for materials that have the same or close gradations to those, which were used in this investigation. According to the results, it is noticeable that lime-stabilized materials with high clay contents are more brittle that others.Though addition of lime gives good result and can be used for large projects.

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