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Experimental analysis of Black cotton soil using lime stabilization technique

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Abstract - Improving the different type of engineering properties of black cotton soil and it is making for stable soil. It can be done by the use of controlled compaction, proportioning and the addition of suitable different types of admixtures and stabilizers. There are used in various infrastructure projects are also used in different highways, railways, water reservoirs reclamation etc. which are requires earth material in very large quantity. In many which are not suitable for due to black cotton soil, so we should stabilize soil by use of locally available materials like lime. Soil stabilization is very necessary for various construction works like road pavement and foundation because it improves the engineering properties of the black cotton soil. The experimental analysis evaluates the effect of the lime and on the some basic engineering properties of soil such as liquid limit, plastic limit and compaction of black cotton soil and California bearing ratio (CBR) of black cotton soil.

***Key Words*:** lime stabilisation, bearing capacity, soil test, black cotton soil, CBR test

1. INTRODUCTION

Black cotton soils of India are well known for their expansive nature. These expansive soils are called black cotton soils become of their predominant black color and the cotton crop that is grown abundantly on such soils. These soils cover about 520000 km^2 area which is more than one-fifth of the country and extend over the states of Maharashtra, Gujarat, southern part of Utter Pradesh, Eastern part of Rajasthan, Southern and western part of Madhya Pradesh, and few parts of Andhra Pradesh and Chennai.

The black cotton soils possess low strength and undergo excessive volume changes, making their use in the constructions very difficult. Because of its high swelling and shrinkage characteristics, the black cotton soil (BC soils) has been a challenge to the highway engineers. The black cotton soil is very hard when dry, but loses its strength completely when in wet condition. It is observed that on drying, the black cotton soil develops cracks of varying depth. As a result of wetting and drying process, vertical movement takes place in the soil mass. All these movements lead to failure of pavement, in the form of settlement, heavy depression, cracking and unevenness. The properties of the black cotton soils may be altered in many ways viz. mechanical, thermal, chemical and other means. Modification of black cotton soils by chemical admixture is a common stabilization method for such soils. Among various admixtures available lime, fly ash and cement are most widely and commonly used for the stabilization of the black cotton soils.

2. Body of the Paper

Lime in the form of quicklime (calcium oxide-Cao), hydrated lime (calcium hydroxide- $Ca(OH)_2$), or lime slurry can be used to treat soils. Quicklime is manufactured by chemically transforming calcium carbonate (limestone – $CaCO_3$) into calcium oxide. Hydrated lime is created when quicklime chemically reacts with water. It is hydrated lime the reacts with clay particles and permanently transforms then into a strong cementitious matrix. Most lime used for soil treatment is "high calcium" lime, which contains no more than 5% magnesium oxide or hydroxide. On some occasions, however, "dolomitic" lime is used. Dolomite lime contains 35 to 46% magnesium oxide or hydroxide. Dolomite lime can perform well in soil stabilization, although the magnesium fraction reacts more slowly than the calcium fraction. In present experimental analysis the performance of black cotton soil with lime for the improvement in strength is done. The experimental analysis is planned to study the following objectives.

1. To study physical properties of black cotton soil with varying percentage of lime from 0 to 10%.

2. To study the behavior of strength gain in Black cotton soil using process of lime stabilization.
3. To determine optimize proportion of lime to achieve maximum strength.

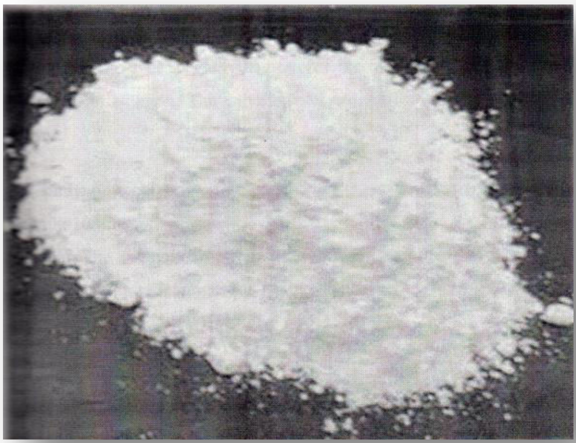


Fig-1 Hydrated Lime

The use of lime for stabilizing plastic montmorillonite clays has been increasing in favor during the last few decades because it lowers volume change characteristics. Generally the amount of lime required to stabilize expansive soils range from 2 to 10% by weight. The addition of lime to clay soil provides an abundance of calcium ions (Ca_{2+}) and magnesium ions (Mg_{2+}). These ions tend to displace other common cation such as sodium (Na+) and potassium (K+), in a process known as cation exchange. Replacement of sodium and potassium ions with calcium significantly reduces the plasticity index of the clay. A reduction in plasticity is usually accompanied by reduced potential for swelling. The addition of lime increases the soil pH, which also increase the cation exchange capacity. A change of soil texture takes place when lime is mixed with clays.

Liquid limit Test on soil:

Liquid limit is significant to know the stress history and general properties of the soil net with construction. From the results of liquid limit the compression index may be estimated. The compression index value will help us in settlement analysis. If the natural moisture content soil is closer to liquid limit, the soil can be considered as soft if the moisture content is lesser than liquids limit. The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. At this limit the soil possess low shear strength.

Fig-2 Liquid Limit Test

Plastic limit test on soil:

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 1/8 in (3 mm) in diameter using a ground glass plate or other acceptable surface.

Fig-3 Plastic Limit Test (thread before & after crumble)

Standard Proctor Test:

Compaction is the process of densification of soil mass by reducing air voids. This process should not be confused with consolidation which is also a process be confused with consolidation which is also a process of densification of soil mass but continuously acting static load over a long period. The degree of compaction of a soil is measured in terms of its dry density the degree type of soil. For given compaction mainly depends upon soil for a given compaction energy every soil attains the maximum dry density at a particular water content. In the dry side, water acts as a lubricant and helps in the closer packing of soil grains. On the wet side, water starts to occupy the space of soil grains and hinders in the closer packing of grains.

Fig-4 Standard Proctor Test

California Bearing Ratio (CBR) test

CBR test, an empirical test, has been used to determine the material properties for pavement design. Empirical tests measure the strength of the material and are not a true representation of the resilient modulus. It is a penetration test wherein a standard piston, having an area of 50mm diameter, is used to penetrate the soil at a standard rate of 1.25 mm/minute. The pressure up to a penetration of 12.5mm and its ratio to the bearing value of a standard crushed rock is termed as the CBR. In most cases, CBR decreases as the penetration increases. The ratio at 2.5mm penetration is used as the CBR. In some case, the ratio at 5mm may be greater than that at 2.5mm. If this occurs, the ratio at 5mm should be used. The CBR is a measure of resistance of a material to penetration of standard plunger under controlled density and moisture conditions.

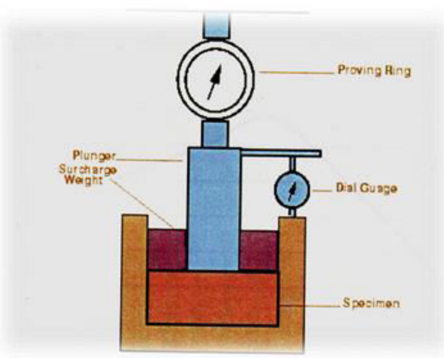


Fig-5 California Bearing Ratio Test

OBSERVATIONS

The mix proportion for soil specimen taken for analysis is as shown in table below.

Sr. No.	Mix No.	Soil	Lime
1	M00	100%	0%
2	M10	98%	2%
3	M20	96%	4%
4	M30	94%	6%
5	M40	92%	8%
6	M50	90%	10%

Observation of MDD & OMC for Mix M00

Determination No.	1	2	3	4	5
Dry Density g/ml	1.55	1.60	1.64	1.54	1.41
Water Content	6.85	11.76	15.55	20.00	25.01

Table -1

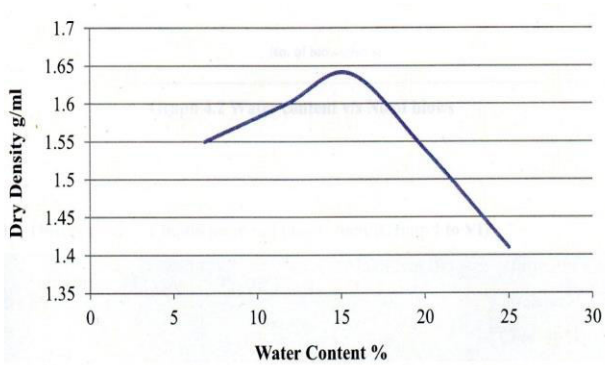
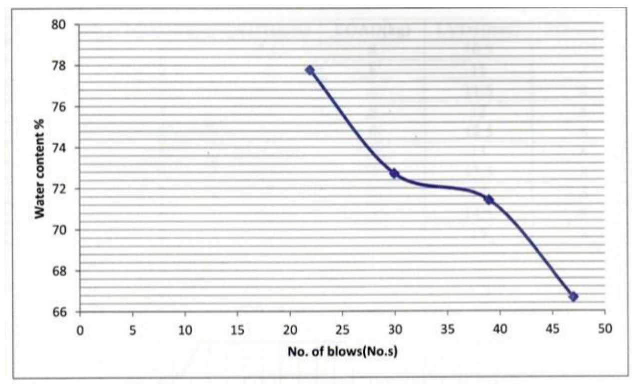


Chart -1

Dry density v/s Water content



Water content v/s no. of blows
Chart -2

Observation for liquid limit and plastic limit

Mix No.	Liquid Limit (%)	Plastic Limit (%)	Maximum Dry Density (g/cc)	Optimum Moisture Content (%)
M00	55	32.1	1.64	23
M10	54	29.8	1.61	22
M20	52	28.6	1.56	23
M30	48	27.9	1.54	23
M40	42	27.7	1.49	24
M50	40	27.2	1.42	24

Table -2

California Bearing Ratio for M00

LVDT(mm)	LOAD(kg)	LVDT(mm)	LOAD(kg)	LVDT(mm)	LOAD(kg)
0.5	1	5.5	8	10.5	8
1	3	6	8	11	8
1.5	4	6.5	8	11.5	8
2	4	7	8	12	8
2.5	5	7.5	8	12.5	8
3	6	8	8	13	8
3.5	7	8.5	8	13.5	8
4	7	9	8	14	8
4.5	8	9.5	8	14.5	8
5	8	10	8	15	8

Table -3

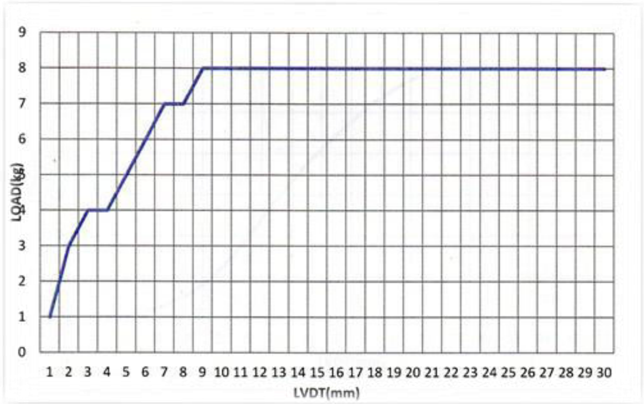


Chart -3

California Bearing Ratio for M10

LVDT (mm)	LOAD (kg)	LVDT (mm)	LOAD (kg)	LVDT (mm)	LOAD (kg)
0.5	1	5.5	298	10.5	298
1	4	6	298	11	298
1.5	13	6.5	298	11.5	298
2	29	7	298	12	298
2.5	56	7.5	298	12.5	298
3	97	8	298	13	298
3.5	145	8.5	298	13.5	298
4	188	9	298	14	298
4.5	223	9.5	298	14.5	298

5	255	10	298	15	298

Table -4

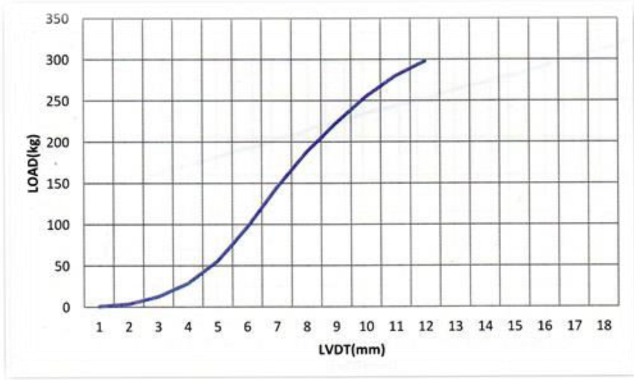


Chart -4

California Bearing ratio for M20

LVDT (mm)	LOAD (kg)	LVDT (mm)	LOAD (kg)	LVDT (mm)	LOAD (kg)
0.5	29	5.5	100	10.5	127
1	56	6	102	11	129
1.5	72	6.5	106	11.5	132
2	80	7	108	12	134
2.5	83	7.5	111	12.5	137
3	85	8	114	13	140
3.5	88	8.5	116	13.5	143
4	91	9	119	14	146
4.5	94	9.5	121	14.5	148
5	96	10	124	15	152

Table -5

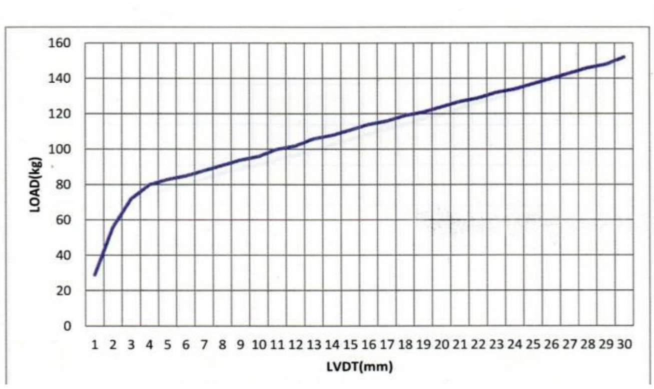


Chart -5

California Bearing Ratio for M30

LVDT (mm)	LOAD (kg)	LVDT (mm)	LOAD (kg)	LVDT (mm)	LOAD (kg)
0.5	136	5.5	208	10.5	272
1	152	6	213	11	278
1.5	159	6.5	220	11.5	284
2	164	7	227	12	292
2.5	171	7.5	233	12.5	296
3	177	8	240	13	304
3.5	184	8.5	246	13.5	311
4	191	9	252	14	316
4.5	196	9.5	259	14.5	322
5	201	10	264	15	328

Table -6

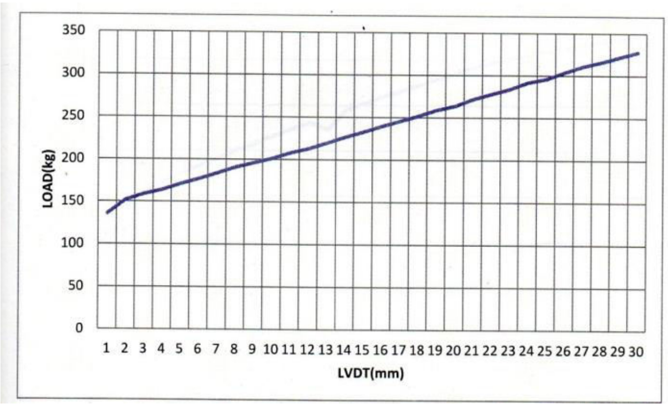


Chart -6

California Bearing Ratio for M40

LVDT(mm)	LOAD(kg)	LVDT(mm)	LOAD(kg)	LVDT(mm)	LOAD(kg)
0.5	192	5.5	448	10.5	584
1	282	6	462	11	593
1.5	312	6.5	447	11.5	604
2	332	7	489	12	612
2.5	349	7.5	504	12.5	620
3	367	8	520	13	626
3.5	384	8.5	531	13.5	634
4	400	9	545	14	640
4.5	415	9.5	557	14.5	648
5	432	10	571	15	652

Table-7

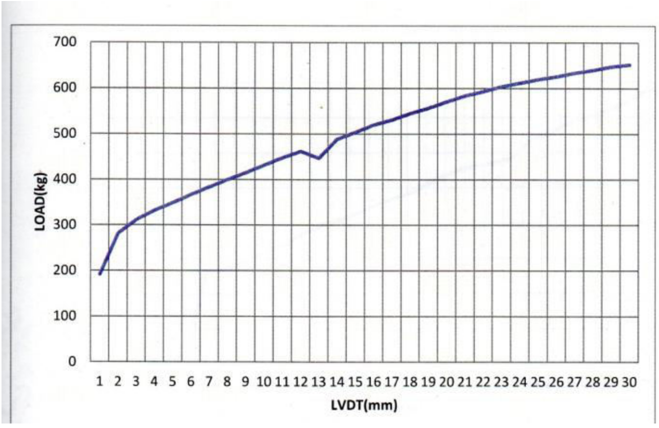


Chart -7

California Bearing Ratio for M50

LVDT(mm)	LOAD(kg)	LVDT(mm)	LOAD(kg)	LVDT(mm)	LOAD(kg)
0.5	50	6	1965	11	2935
1	68	6.5	2055	11.5	3205
1.5	84	7	2161	12	3305
2	98	7.5	2277	12.5	3418
2.5	112	8	2377	13	3515
3	1325	8.5	2455	13.5	3605
3.5	1355	9	2631	14	3722
4	1475	9.5	2741	14.5	3888
4.5	1575	10	2823	15	3874
5	1695	10.5	2855	11	2935

Table-8

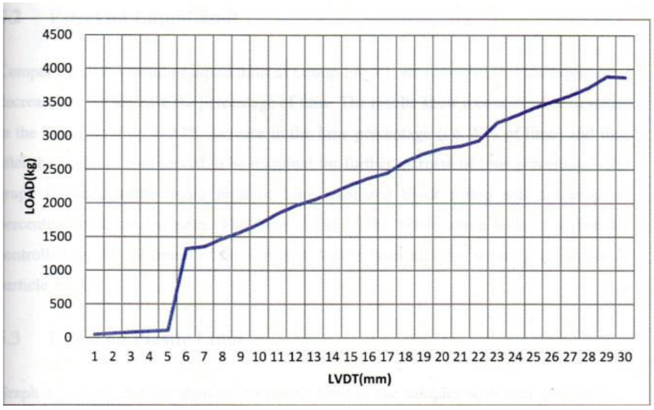


Chart -8

RESULTS AND DISCUSSIONS:

Effects on Liquid limit:

Comparing all the result of liquid limit of group I to VI, we observed that the liquid limit decreases as we increase the percentage of lime. The results show a considerable decrease in the liquid limit up to 33% increase in the lime percentage and then after the decrease is observed to be marginal for further increase of lime percentage. The graph shows that the liquid limit of lime stabilized black cotton soil decreases as percentage of lime decreases. The liquid limit of the black cotton soils is essentially controlled by the thickness of the diffused double layer and the shearing resistance at particle level.

Effect on Plastic limit:

The graph shows the variations of the plastic limit of the samples with lime percentages. As can be seen from the graph, the addition of lime results in a steady decline in the plastic limit of the soils on addition lime, the plastic limit of the soil may increase due to flocculation owing to the presence of free lime. Further increase in the addition of lime results in the increase of plastic limit. This is because of the fact that as the quantity of lime in the mix increases, the amount of soil to be flocculated decreases and also the finer particles of lime may be incorporated in the voids of flocculated soil.

Effect on Maximum Dry Density:

With the increase in lime content, the maximum dry density of soil-lime mixes decreases and optimum moisture content increases. The fall in density is more significance at lower percentage of lime. When lime is added to soil, maximum dry density decreases further and optimum moisture content increases. The results of compaction tests showed that a considerable decrease in the maximum dry density up to 20% with 25% increase in optimum moisture content.

Effects of CBR value:

The addition of the optimum lime content led to an increase in the CBR-values for black cotton soils. The lime-tertiary clay mixtures have the highest CBR-values, whereas the lime-weathered soil mixtures have the lowest values.

The Variation of CBR of the black cotton soil samples with the addition of lime in increasing percentage is shown in graph.The CBR value of the soil increases with the addition of lime up to a certain percentage of (8%) lime up to 3.4 times and thereafter it starts decreasing for further addition of lime. Addition of lime to the black cotton soil increases gradually the CBR of the mix up to a peak value. This is due to frictional resistance contributed from the lime in addition to the cohesion from the black cotton soil. Further increase in the lime percentage causes a reduction in the CBR due to the reduction in the cohesion because of the decreasing black cotton soil content in spite of increase in strength due to increase in lime content. It is hence observed that, a suitable mix optimizes the frictional contribution of lime and the cohesive contribution from black cotton soils; leading to the maximum of the CBR.

3. CONCLUSIONS

Through this experimentation it is observed that the lime is good stabilizing compound. The main engineering properties of the black cotton soil can be improved by using lime. The following conclusions can be derived from the present investigation:

1. Lime is beneficial in combination with OMC in improving of soil. With the increase in the percentage of lime, strength tends to increase and reaches a certain maximum value and thereafter it starts decreasing.
2. Utilization of lime in this manner has the advantage of reusing an industrial waste by-product without adversely affecting the environment or potential land use.
3. The results show a considerable decrease in the liquid limit. Decrease in liquid limit means there is decrease in permeability & increase in dry strength of black cotton soil.
4. With the increase in lime content, the maximum dry density of soil-lime mixes decreases and optimum moisture content increases. The fall in density is more significant at lower percentage of lime.
5. The CBR value of the soil increases with the addition of lime.
6. The optimum value of lime content in soil mixtures may be taken as 10%

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BIOGRAPHIES (Optional not mandatory)

Prof. Gaurav Ravindra Desai has completed his Bachelor's Degree in Civil Engineering and Master's Degree in Civil Engineering (Construction Management) from Shivaji University, Kolhapur. He has 6 years of teaching experience and 2 years of industry experience. He is currently working as Dean of Student Affairs and Assistant Professor in Civil Engineering Department of Dr. D. Y. Patil Pratishthan's College of Engineering, Salokhenagar, Kolhapur. He has worked as a Head of Civil Engineering Department for 4 years. He has published various research papers at National and International Level.