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Effects of Hydrated Lime in Stabilization of Black Cotton Soil

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Abstract: ***Worldwide, in arid and semi-arid areas expansive soils to be found. India has large tracks of expansive soil known as Black Cotton soil. Low bearing capacity, high compressibility, and high potential of shrinkage and swelling characteristics of soil with respect to moisture content, results heavy damage of structures laid above. Stabilization of expansive soil has been one of the viable techniques with a variety of stabilizers for remedying the problems. Lime can alter the properties of almost all soils, but the most remarkable enhancement, occurs in high plasticity clay soils. In this work attempt has been made to understand the effects on parameters like plasticity, compaction, strength and swelling potential of black cotton soil with addition of 2,4,6,8 and 10 % of hydrated lime by dry weight of soil sample. Experimental results shows, lime can alter properties of the soil by reducing the plasticity characterstics and enhance the strength of soil. Experimentl results indicate that hydrared lime is very effective in stabilization of black cotton soil.***

Index Terms: Atterbergs Limit, California bearing ratio, expansive soil, Hydrated lime, Lime stabilization, Unconfined compressive strength.

I. INTRODUCTION

In India, black cotton soil covers area of 0.8 million square kilometer. BC soil in natural state do not present adequate geotechnical properties to be used as road service layers, foundation layers and as a construction material, due to its high plasticity, causes the cracking Black Cotton soil have high clay content. The clay minerals have a high adsorptive capacity for water, which leads to the problem of swelling (Al-Rawas et al. 1992) . The adsorbed water or double layer gives clay particles their plasticity (Faisal Ali et al. 2012). Due to the addition of various stabilizers in expansive soils decrease the problematic behavior was stated by Little et al. (2002). In construction aspect, soil stabilization of low bearing capacity is an economical way (Nalawade et al. 2015). Clayey soil has easiest to stabilize because of a large surface area due to flat and elongated particle shapes. Soil stabilization involves the use of stabilizing agents in weak soils to improve its geotechnical properties; Stabilization of expansive clays consists of altering the environment around and inside of clay particles and an effective method to enhance soil properties (Wong et al. 2008). In order to adjust the geotechnical parameters to meet the requirements of technical specifications of, Construction industry stabilization of soil with low bearing capacity is an economical way and stabilized soils can be extremely useful construction material. Recently lime is widely used in construction site for stabilization of soil throughout the world, due to modern construction equipment particularly the availability of high power rotary mixers, spreading equipment and efficient lime delivery. Some of the advantages of lime stabilization are substantial increases in soil properties, strength gain with time, rapidly improve the load carrying capacity of the on- site soil, reduction of volume changes, durability and most important is economical as compare to other stabilization agent. Hydrated lime is produced by chemically combining a controlled amount of quicklime and water together. Hydrators produce hydrated lime as a fine, dry powder, with most particles less than 75 microns in size.

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II. LIME STABILIZATION

Hydrated lime is very effective in stabilizing highly plastic clayey soils. Clay surface having negative charge and attracts positive charge cations supplied by different chemical compound, attains very strong bond occurs at the surface of clay and accomplish the necessity requirements and hence additional cation of water (H+) do not interact with soil and elimination of extra water molecules (Faisal Ali et al. 2012) . Lime changes plasticity behavior of soil by reduction in diffuse double layer of clay particle**.** Stabilization process occurs due to pozzolanic reaction in which lime reacts with soil in presence of water to produce cementitious compounds. Due to lime addition, soils turn drier and less susceptible to water content changes.

When the pH value of the stabilizer -soil mixture reaches above 12, alumina, silica radicals of clay particle dissolve due to alkaline nature (Eades and Grim 1960). Soil stabilization process requires a more alkaline environment, slight changes of pH of soil show drastic change in soil properties. Curing period is an important aspect for lime-stabilized soils. When lime is mix in expansive soil rapid cation exchange and flocculation/agglomeration reactions occurs (Croft 1967). The flocculation and agglomeration phase converts the soil to more eagerly mixable, workable, and, eventually compactable (NLA Report 2004).

III. MATERIALS AND METHODOLOGY

The soil sample extracted at 1meter depth from the site. Location of the site is area near to, Pune city, Maharashtra State in India. Hydrated Lime procured from industry. Hydrated lime in the form of, fine dry powder, particles less than 75 microns in size.

Table. 1 Properties of hydrated lime

Sr. No.	Parameter	Results	Unit
1	Calcium Hydroxide as $Ca(OH)_2$	≥ 96	%
2	Moisture	1.50	%
3	Specific Surface(BET)	15-22	M^2/g
4	Bulk Density	500-650	Kg/m^3
5	Minimum Top Cut	10	µm
6	LOD	Nil	-
7	Acid Insoluble Matter	Nil	-

Black Cotton Soil sample collected was first pulverized, then drying of soil in oven, to perform the different laboratory tests to be conducted to observe the properties of natural state like gradation, plasticity, compaction and swelling behavior as well as strength aspect with the use of relevant IS code. Afterwards same tests were performed on addition various percentage of hydrated lime in soil sample.

- Gradation by Sieve Analysis.

Classification of soil was done based on particle size distribution by using different sieve size as per IS 2720 Part (IV).

- Plasticity behaviour by Atterberg limit.

Volume change behaviour of samples were determined by liquid, plastic as per IS 2720 part (V) and shrinkage limit by part(VI). Firmness of soil with respect to moisture content. . Water content of the soil in which converts from plastic state to the liquid state is liquid limit. soil transitions phase between brittle and plastic behavior indicated by plastic limit. A thread of soil when it begins to crumble when rolled to a diameter of 3 mm shows this limit. Maximum reduction in water content does not shows reduction in volume of the soil mass but keeps the constant volume indicates shrinkage limit.

- Compaction behaviour by proctor test.

As per IS 2720 part (VII) light compaction test were done to identify the relationship of corresponding water content and density achieved. Compaction curve was plotted to observe apex point which indicates MDD and OMC of particular sample

- Strength properties by Unconfined Compression Test.

To determine strength behaviour of samples were done as per IS 2720 part 10 (1991) with the help of UCS test. Samples were prepared with known moisture content which is Optimum moisture content obtained from compaction test of each case in mould of standard dimensions.

- Penetration resistance by California Bearing Ratio.

The Strength and stability aspect of soil samples were measured with the help of penetration resistance offered by sample against standard load applied were determine with the help of CBR tests were observed as per procedure laid down IS: 2720 part (16) . Soil samples were compacted with known Optimum moisture content and then evaluated at time interval of curing for 4 days. In soaked condition.

- Swelling potential with Free swell index.

Swelling of soil when comes in contact with water is important aspect, Swelling potential of treated and untreated soil samples were determined by free swell index test as per IS 2720 part (XL).

RESULTS AND DISCUSSION

Particle size distribution of a soil was determined by sieve analysis. The results of testing will reflect the condition and characteristics of the aggregate from which the sample is obtained. As per IS, Classification of soil is CH.

Figure. 1 Grain sizes

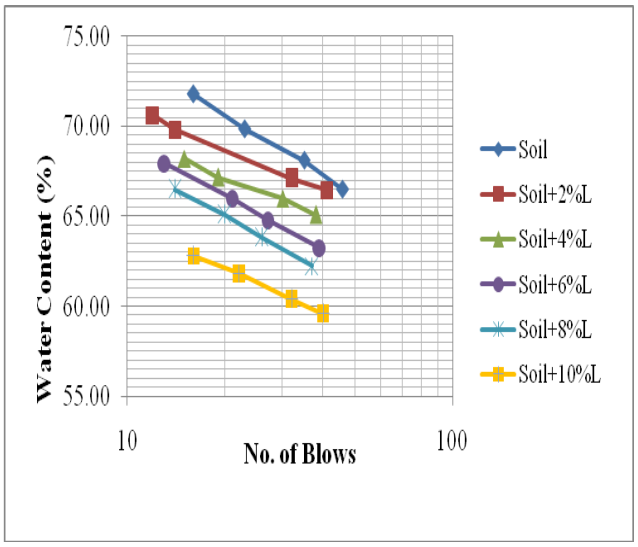

Figure. 2 variation of liquid limt value

As shown in figure 2, relationship between water content and corresponding number of blows plotted with the liquid limit test results conducted, it was found that addition of lime percentage, the liquid limit decrease but at the same that it was also observed that only lime is not sufficient to decrease liquid limit value with higher variations.

Variation in liquid limit and plastic limit value indicated by PI. As shown in fig.3 decrease trend of PI with addition of lime content.

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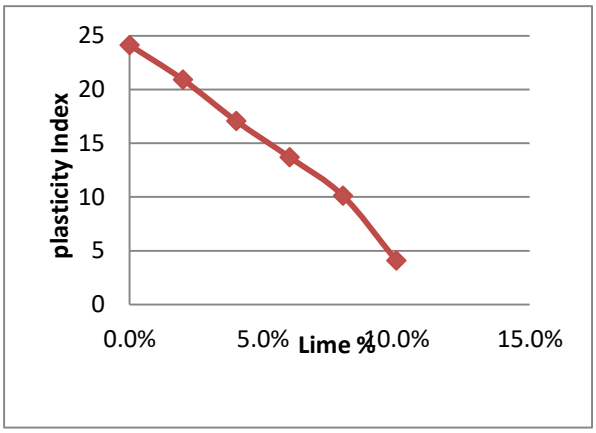

Figure. 3 variation Plasticity index value

Test results present that with addition quantity of lime, increase trend of plastic limit value, Shrinkage Limit decreases and Plasticity index also decreases.

Results of compaction test represented in table 2.

Table.2 Compaction test results

Sr. No.	Soil sample with Lime	MDD (gm/cm3)	OMC (%)
1	0 %	1.34	31.05
2	2%	1.32	33
3	4%	1.31	33
4	6 %	1.31	36.36
5	8 %	1.29	37.5
6	10 %	1.28	38.3

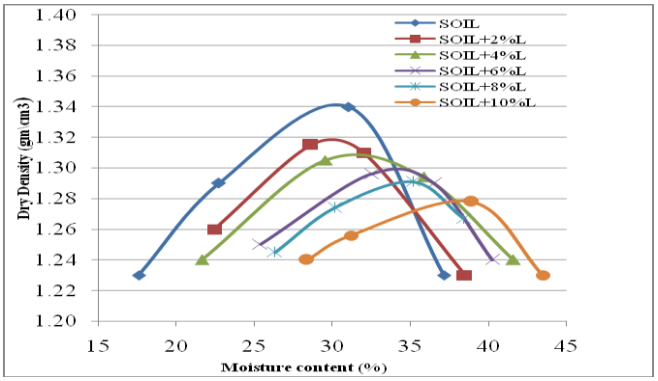

Figure. 4 Compaction curve

Results revealed that with addition on lime percentage, MDD decreases from 1.34 gm/cm3 of untreated soil to 1.28 gm/cm3 for 10% lime treated soil and where OMC value from 31.05|% to 38.3% .

Maximum dry density decrease while the optimum moisture content increased but result shows effect is less

Stress strain behavior of untreated soil and treated soil with various percentage of lime for 3 days curing period presented in the following figure,

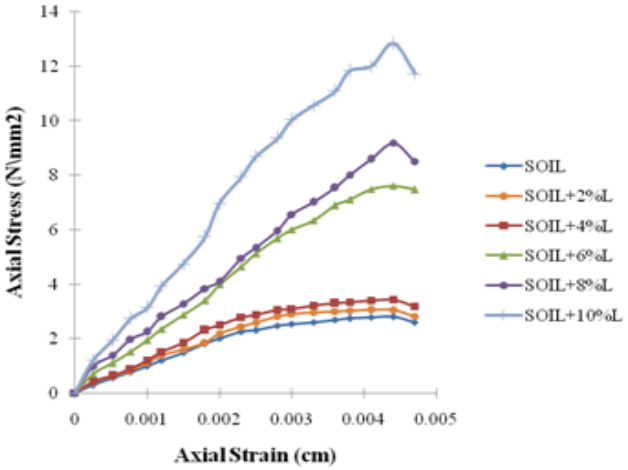

Figure. 5 Stress-Strain curve for 3 days curing Period.

Experimental investigation shows that with increase in lime percentages the strength of treated soil is increasing trend.

California bearing ratio tests, samples were tested in after 4 days curing period.

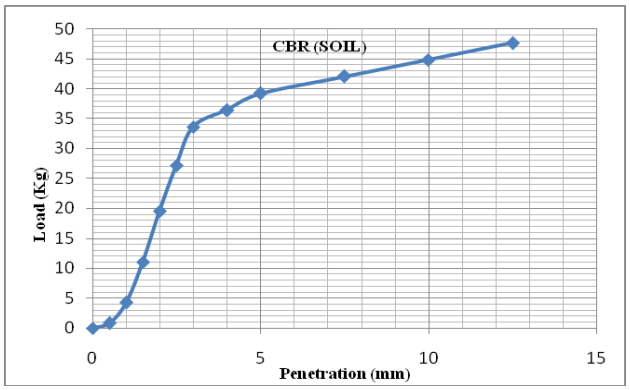

Figure. 6 Load penetration curve of black cotton soil

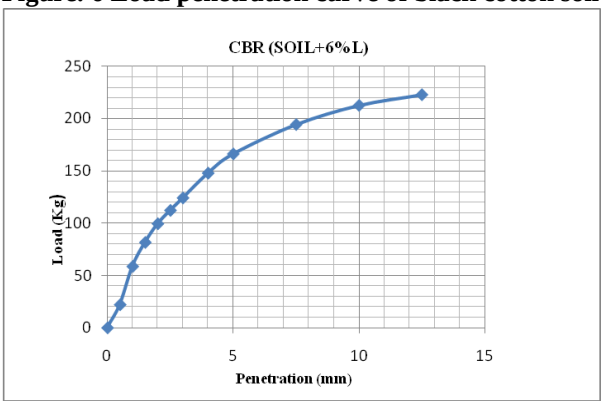

Figure 7. Load penetration curve with 6% lime.

Penetration resistance of natural soil shows CBR value is less, but after addition of lime values were increasing trend for all percentage of lime. Swelling behavior of stabilized soil was observed through, free swell test, following results are obtained. A result of FSI for natural soil was 80%, but lime decreases the swelling potential up to 33% for 10% content.

Table 3 . Results of free swell index

Sr. No	Lime %	Volume (V_1)	Volume (V_2)	FSI %
1	0	10	18.0	80
2	2	10	16.2	62
3	4	10	15.0	50
4	6	10	14.5	45
5	8	10	14.2	42
6	10	10	13.3	33

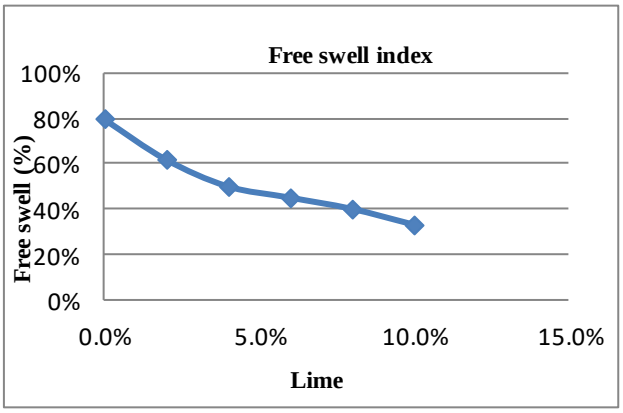

Figure. 8 Free sewll index with % lime.

IV. CONCLUSION

With the help of lab experiments and analysis of results following points to be concluded.

- Adding up lime percentage the liquid limit decreases. Result indicates that only lime is not sufficient for large variation of value.
- PL increases, Shrinkage and PI also decreases indicates that for 0 to 10% lime can alter properties of the BC soil by reducing the plasticity characteristics.
- After addition of lime, 0% to 10%, OMC slightly increases by 31.05|% to 38.3%, MDD decreases from 1.34 gm/cm^3 of untreated soil to 1.28 gm/cm^3, but result shows effect was small amount.
- Stress-strain behavior of stabilized samples reveals that strength value increases significantly with curing age.
- Penetration resistance of natural soil shows less CBR value but after addition of lime values were increasing trend for all percentage of lime.
- Swelling behavior of stabilized soil was observed through FSI test, reveals that FSI of natural soil was 80%, but lime decreases the swelling potential up to 33%.
- Comparing all lab test results shows that hydrated lime is very effective in stabilization of black cotton soil.

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