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Effect of Lime Treatment on California Bearing Ratio (CBR) of Expansive Soil

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Abstract:- Expansive clays are problematic deposits to civil engineering constructions as these deposits exhibit swelling and shrinkage during wet and dry seasons respectively. Therefore stabilization of expansive clay is of interest to engineers who deal with this soil. Among various stabilizing agents addition of lime with clay is considered more effective. The research work on California Bearing Ratio (CBR) of lime stabilized soil cured at various curing conditions are limited. Towards this, an attempt is made in this study, to bring out the effect of curing conditions and lime contents on CBR of lime stabilized clayey soil. In the present study, a black cotton soil, classified as clay of high plasticity (CH) is used. For the stabilization of soil, laboratory grade hydrated lime was used. The soil is stabilized with 3%, 5% and 7% lime contents and the specimens were cured at 30˚C and 40˚C for 7, 14 and 28 days prior to testing. The results of California Bearing Ratio test brought out the fact that the as the lime content, curing temperature and curing period increases, CBR value increased. The rate of improvement in CBR was higher upto CBR value of about 50% and beyond that the rate of gain was lesser.

Keywords:- *Expansive Clay, Lime Stabilization, California Bearing Ratio.*

I. INTRODUCTION

Many parts of soil present in arid and semi arid regions are expansive in nature. The plasticity of these soils are generally moderate to high, strength is moderate and swell-shrink behavior is high (Holtz and Gibbs 1956; Sherwood 1967; Nasrizar et al 2010). In order to make this clay soil suitable for construction activities, stabilizing this soil using lime has been adopted even since Roman periods McDowell (1959). Several researchers reported the stabilization of clay soil using lime and its use for civil engineering projects involving earth material (Clare and Cruchley 1957; Mc Caustland 1925; Bell, 1996).

Presently, stabilization of clay with lime is a popular technique practiced to improve its strength and settlement characteristics. In addition, lime stabilization is one of the most economical techniques to improve the strength and deformation behavior of expansive clay soils. To improve the strength of sub-bases and sub-grades for road ways lime stabilisation is used. Further, to make the clay soil suitable for the construction of embankments and to utilize this as backfill material, lime treatment of clay soil is mostly selected (Davidson and Handy, 1960; Ingles and Metcalf, 1973; Anon 1985, 1990).

It is essential for any road work project to have suitable subbase layer. If the subbase layer is not meeting the required specifications, improving the soil is required. For the design of pavement, California bearing ratio (CBR) is one of the important required design parameters. Lime stabilization is most preferred for improving the performance of clayey soil. However, not much work has been carried out on the CBR of lime treated clayey soil. Therefore, the present study aims to bring out the CBR of clay soil treated with different percentages of lime and cured for different period under various temperature.

In the following sections, the experimental results of CBR test conducted on thermally cured lime treated expansive soils are presented and discussed.

II. CBR OF UNTREATED SPECIMENS

The clayey soil used in the present study is collected from Siruseri, Tamil Nadu, India. The natural soil showed specific gravity of 2.72. The soil composed of 30% sand, 34% silt and 36% clay. The liquid limit and plastic limit of soil are 80% and 25% respectively. The plasticity index of the soil is 55% and its shrinkage limit is 12%. The soil is classified as Clay of High plasticity (CH) as per USCS soil classification system.

The natural soil has been compacted in the CBR mould at its standard Proctor maximum dry unit weight of 15.5 kN/m^3 and optimum moisture content of 23%. The specimens are tested after 2 hours to determine the unsoaked CBR value. Identical specimens were soaked in water for 96 hours to determine the soaked CBR value. The CBR value is calculated as per ASTM D 1883-05.

Stress versus Penetration response of the natural soil, is presented in Figure 1. CBR values for 2.5 mm penetration are 12.62% and 1.98% for unsoaked and soaked conditions respectively. CBR values ranging upto 5% are considered in poor category in subgrade soil. Further there is a large difference between unsoaked and soaked CBR value, that is unsoaked CBR is 6.4 times that of soaked CBR.

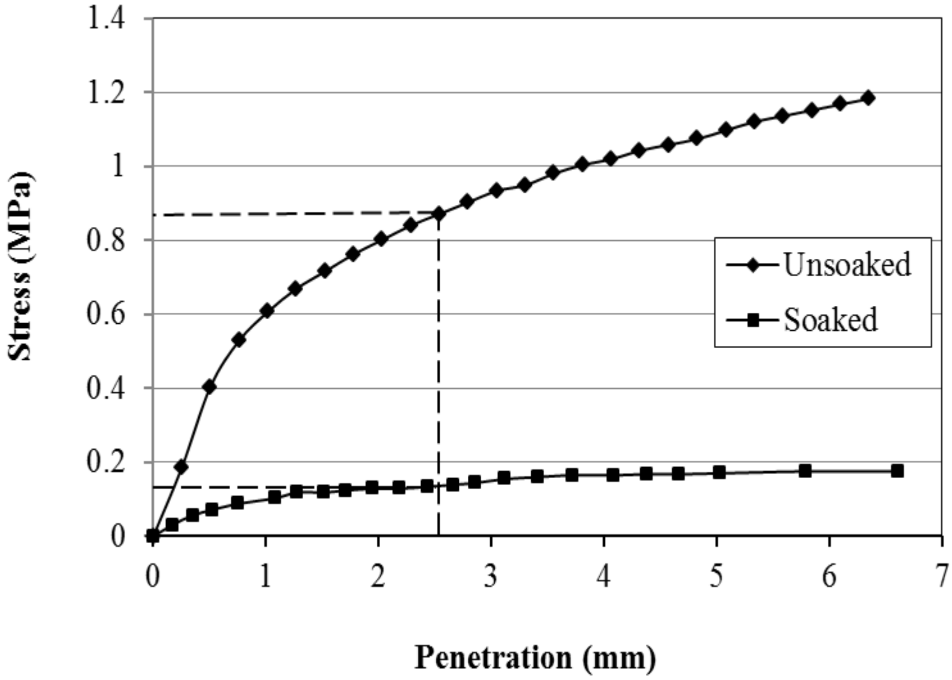

Fig 1:- Stress vs. Penetration for Natural Soil

III. CBR OF LIME TREATED SOILS

The lime stabilised specimens were compacted at dry unit weight of 14.5kN/m^3 and water content of 26%. The specimens were cured at 30°C and 40°C for the required curing period.

The CBR test results obtained for 3%, 5% and 7% soil-lime mix cured at 30°C and 40°C for a curing period of 7, 14 and 28 days are presented in Figures 2 to 7. By examining the stress on plunger vs penetration curves for all lime treated soil, it is inferred that the CBR value for 2.5 mm penetration is higher than the CBR value for 5.0 mm penetration for all cases irrespective of lime content, curing period and curing temperature. In addition, it is noticed that the failure of the specimen takes place at about 2.5 mm penetration for all the samples.

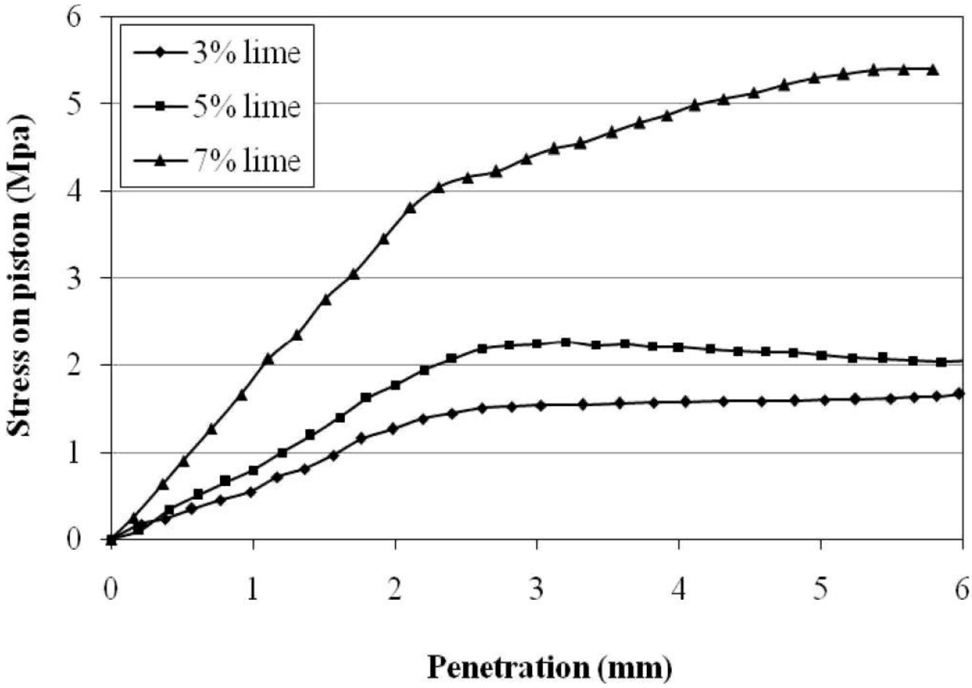

Fig 2:- Stress vs. Penetration for Lime Treated Soil Cured at 30°C for 7 Days

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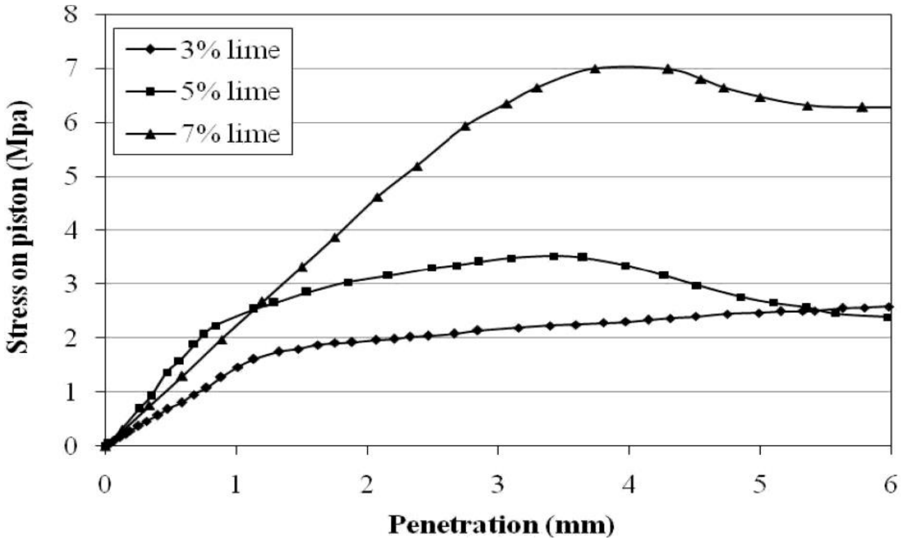

Fig 3:- Stress vs. Penetration for Lime Treated Soil Cured at 30°C for 14 Days

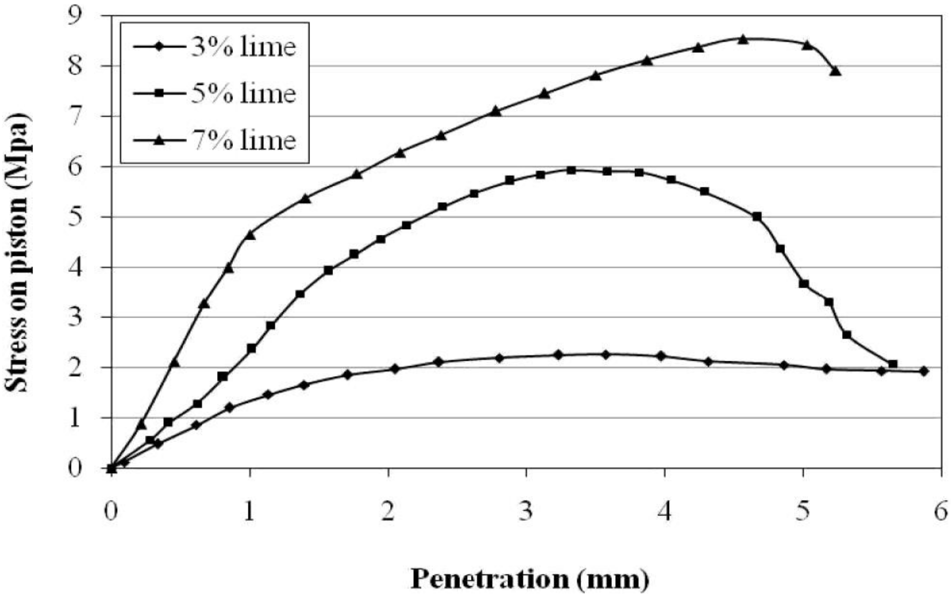

Fig 4:- Stress vs. Penetration for Lime Treated Soil Cured at 30°C for 28 Days

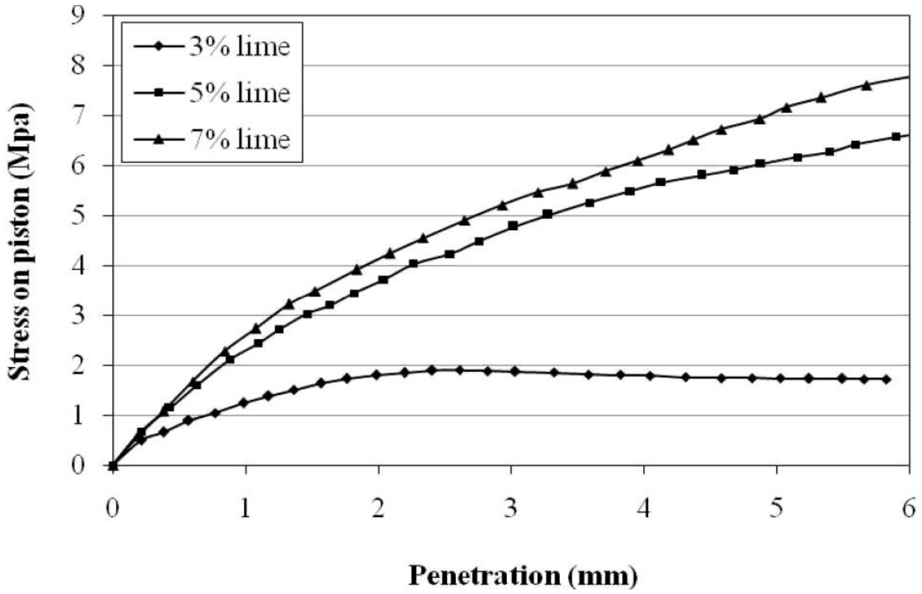

Fig 5:- Stress vs. penetration for lime treated soil cured at 40°C for 7 days

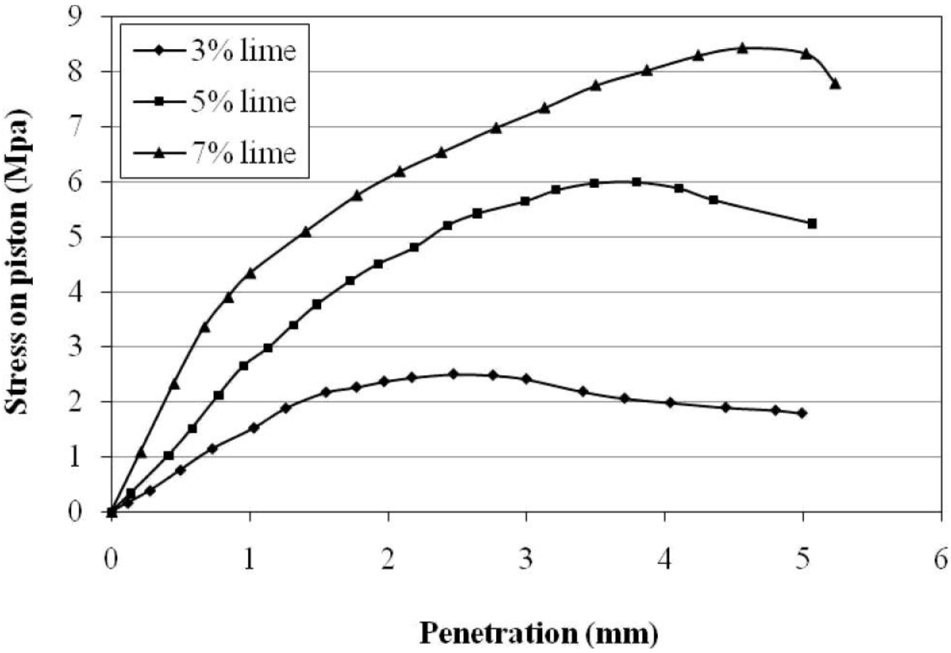

Fig 6:- Stress vs. Penetration for Lime Treated Soil Cured at 40°C for 14 Days

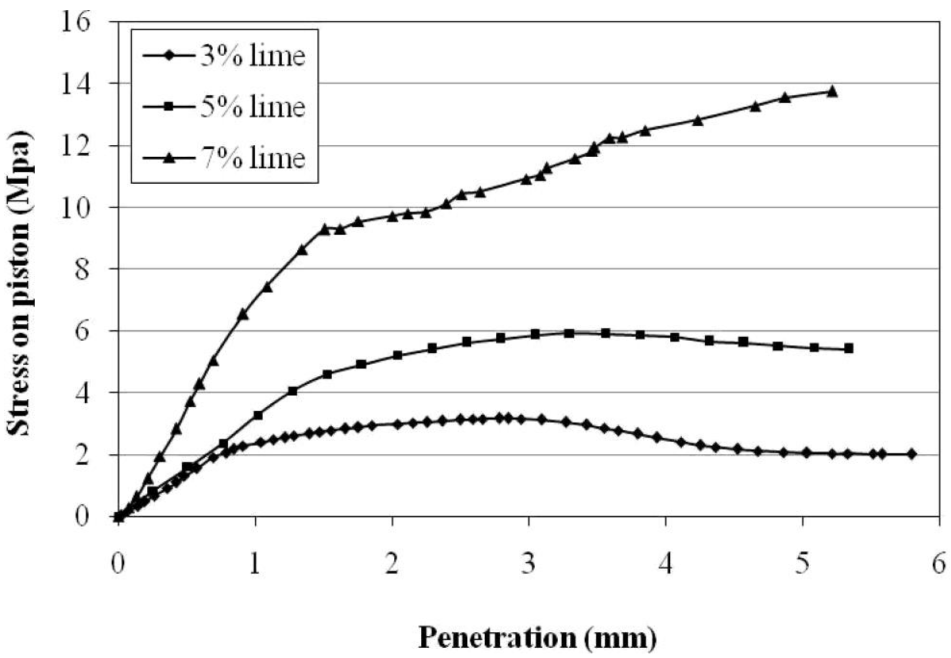

Fig 7:- Stress vs. Penetration for Lime Treated Soil Cured at 40°C for 28 Days

Table 1 summarizes the CBR value of soil treated with 3%, 5% and 7% lime contents cured for 7, 14 and 28 days at 30°C and 40°C. From the Table 1, it is observed that the CBR value of soil is very much improved by lime treatment. Even lime addition as less as 3% is able to improve the CBR by 10.9 times as that of untreated soil. Further, for 7% lime treated soil cured at 40°C for 28 days the CBR value is 115%, which is more than 100%. According to NAPA the CBR of natural soil (1.98%) falls under poor category, whereas, the CBR of 3% lime treated soil cured for 7 days (21.57%) falls under excellent category. This indicates the improvement of CBR of clayey soil by the addition of lime. Further the CBR value increases rapidly upto 60% at 7% lime treated soil. The CBR value is further increased by higher curing periods and elevated curing temperatures as evidenced from Table 1. The ratio of CBR value of lime treated soil to the soaked CBR value of untreated soil is known as CBR gain factor. It is noticed that CBR gain factor varied from 10.9 to 22.95 by addition of 3% lime, the variation in the gain factor for a constant lime content implies the effect of curing conditions on CBR value.

As the lime content, curing period and curing temperature increases, CBR gain factor increases. The improvement in the CBR value of lime- treated soil is due to cation exchange, flocculation, and agglomeration produced by the lime added. Though the CBR of 3% lime treated soil are much higher than untreated soil, they are comparatively lesser than 5% and 7% lime treated soil. The increase in CBR of 3% lime treated soil compared to natural soil shows the benefits that can be obtained from cation exchange and not with extensive cementing action. The higher CBR of 5% and 7% lime treated soil indicates the extensive development of cementing agents. The soil-lime mix with 7% lime content cured for 28 days at 40°C, the CBR value is more than 100%. This indicates that the bearing stress of lime-treated specimens is comparable with that of crushed stone. The CBR value exceeding 100 have little practical significance and are not meaningful as a measure of strength or stability. In spite of this fact, the test results are presented to understand that lime addition can bring enormous improvement in CBR value, which could be comparable with that of bearing stress of crushed stone.

Experimental results revealed that lime treatment of clayey soil produces increased CBR irrespective of the amount of lime, curing period and curing temperature. However the magnitude of improvement depends on the amount of lime, curing period and curing temperature.

Lime content (%)	**Curing period (day)**	**Curing temperature (°C)**	**CBR (%)**	**CBR gain factor**
0	0,7, 14, 28	30, 40	1.98 ± 0.14	
3	7	30	**21.57**	10.90
		40	27.54	13.91
	14	30	29.79	15.05
		40	36.11	18.24
	28	30	31.02	15.66
		40	45.40	22.93
5	7	30	31.14	15.73
		40	61.43	31.02
	14	30	48.05	24.27
		40	77.06	38.92
	28	30	77.93	39.36
		40	81.17	41.00
7	7	30	60.43	30.52
		40	69.04	35.07
	14	30	79.95	40.38
		40	97.27	49.12
	28	30	98.91	49.96
		40	115.55	58.31

Table 1:- CBR Value of Lime Treated Soil

IV. CBR VALUE OF LIME STABILISED SOIL

Figures 8 and 9 plot the variation of CBR value with lime content. The rate of increasing CBR value for specimens cured at 40°C is higher than the specimens cured at 30°C. CBR value for specimens cured at 40°C for 14 days are 36.11%, 77.06% and 97.27% for 3%, 5% and 7% respectively and these values are almost comparable with specimens cured at 30°C for 28 days which are 31.02%, 77.93% and 98.91% for 3%, 5% and 7% respectively. This results reveal that elevated temperature accelerate the rate of gain in bearing stress.

It is evidenced from Figures 8 and 9 that the CBR value increases with lime content, curing period and curing temperature. However, the rate of increase in CBR is not uniform. It depends on percentage of lime addition, curing period and curing temperature.

For curing temperature of 30°C, the rate of gain in CBR for lime addition from 3% to 5% is lesser than the same for lime addition from 5% to 7%. However, for curing temperature of 40°C, this behavior is reversed. That is for lime addition from 3% to 5% the rate of gain is higher than the same for lime addition from 5% to 7%. The reason for this behavior could be atributed to following: Higher curing temperature promotes the soil-lime reaction at faster rate and almost 80% of maximum benefits are attained with 5% lime itself as evidenced from CBR values of lime treated soil given in Table 1. Since, only remaining about 20% of benefit need to be attained, addition of another 2% lime beyond 5% lime (=7% lime) is not enhancing the value of CBR at a higher rate.

Further, it is interesting to note from Figures 8 and 9 that upto CBR value of 50%, the addition of lime gives higher rate of gain of CBR, but beyond CBR of 50%, the rate of gain in CBR is lesser irrespective of the curing temperatures.

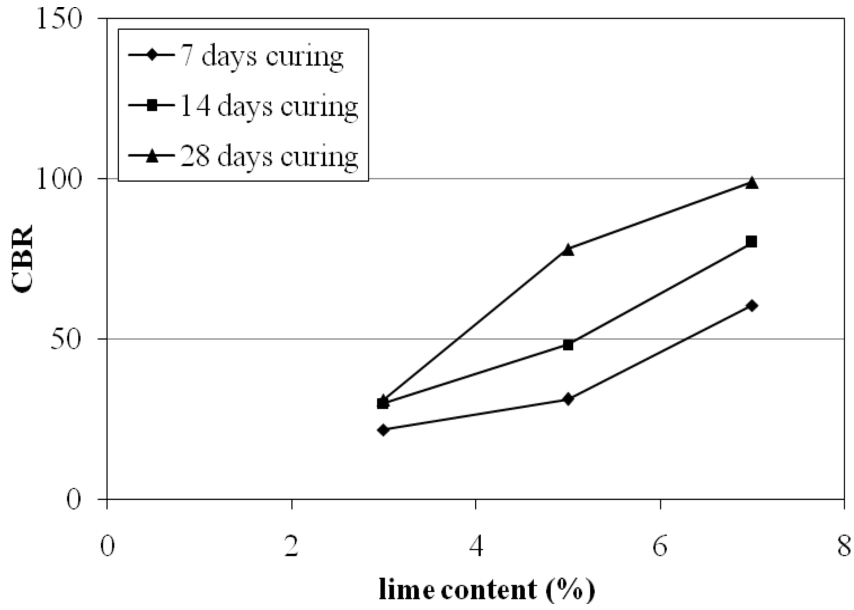

Fig 8:- Effect of Lime Content on CBR Value of Lime Treated Soil Cured at 30°C

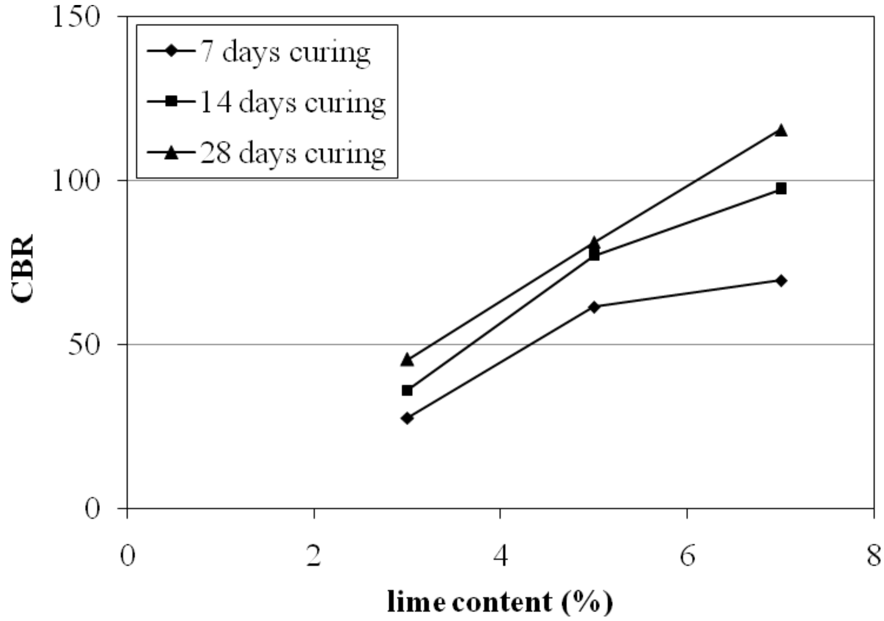

Fig 9:- Effect of Lime Content on CBR Value of Lime Treated Soil Cured at 40°C

V. SUMMARY AND CONCLUSION

Based on the laboratory experiments, it is understood that CBR of clayey soil is enhanced considerably by the lime-treatment. Even lesser lime addition which could alter only the plasticity characteristics of the soil is able to enhance the CBR value considerably. Further, the gain in CBR is at a faster rate upto the CBR value of 50% by increasing either of factors influencing CBR value, i.e. lime content, curing period and curing temperature. Beyond the CBR value of 50%, the rate of improvement in CBR is lesser irrespective of amount of lime, period of curing and temperature of curing.

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