HEATING OF LIME STABILIZED LOW COMPRESSIBILITY CLAY (CL) ON INDEX PROPERTIES, COMPACTION AND PERMEABILITY

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Abstract

The objective of the paper is to see the heating effect on lime stabilized low compressibility clay (CL) at two different temperatures of 35^{0}C and 90^{0}C on specific gravity, liquid limit, plastic limit, optimum moisture content, maximum dry density and coefficient of permeability. The percentage addition of lime to clay soil were taken as 4%, 6%, 8% and 12%. Generally, it is found from literature that lime between 5% and 10% provides the maximum benefit for stabilization of soil. We would like to probe the benefits of lime stabilization slightly below and above this range.

It is observed from the results, that liquid limit (LL) decreased from 15.4% for 0% lime to 13.5% for 12% lime at 35^{0}C and to 13.2% for 12% lime at90^{0}C. The plastic limit (PL) increased correspondingly and the values are 12%, 12.7%, 12.9% respectively. The optimum moisture content (OMC) values decreased and the values are 12.5%, 11.85%, 10.9% respectively.The maximum dry density (MDD) values increased and the values are 1.82 gm/cc, 1.90 gm/cc, 1.95 gm/cc respectively. Thecoefficient of permeability(k) values decreased and the values are 11×10^{-6} cm/sec, 8.3×10^{-6} cm/sec,7.6×10^{-6} cm/sec respectively.

Keywords: **heating of clays, lime-stabilization, compaction, permeability, index properties.**

1. INTRODUCTION

The influence of heating on clayey soils as a soil stabilization technique has been of significant interest in the last two decades. The applications include underground structures which are subjected to temperature changes like radioactive waste disposal, thermoactivegeostructures, oil recovery, petroleum drilling, high-voltage cables buried in soils etc.

The use of lime for improving soil properties was used by Romans and Chinese in the construction of pyramids of Shenshi and for massive bridge footings respectively. The lime-stabilized soil was used in India for making rough roads. In United Kingdom many kilometers of Banbury motorway were stabilized using lime.

The technique of lime stabilization is achieved by adding some measured quantities of hydrated lime or calcium hydroixide, quick lime or calcium oxide to clay soils.

The reaction between lime and soil can be explained in two ways – Cation exchange and flocculation-agglomeration. The addition of lime to fine grained soil in sufficient quantities adds an excess of Ca++ monovalent cations. The cation exchange will occur with Ca++ substituting dissimilar cations from the exchange complexity of the soil. This will cause a change in the electric-charge density around the clay particles. These electrically charged clay particles attract one another and cause flocculation and agglomeration. This will produce a change in texture and clay particles forming “large-sized” aggregates.

Though Carbonation and Pozzolanic reaction also take place when lime is added to clay soil, these are not aggressive reactions in the current case of study.

Effect of hydrated lime on permeability showed that coefficient of permeability of CL soil increased five fold with 2% addition of lime and and then decreased on further addition of lime (Ca´ ssia et al. 2004). The general tendency observed for CI soil is with increase in lime content the MDD decreases and OMC increases. (Al hassan 2008, Osinubi 1998, Marks and Harliburton 1970, Ladd et al. 1960.)

Amongst one of the earliest examinations of the effect of temperature on the AtterbergLimits was conducted by Youssef et al (1961). They observed that at increased temperatures the Liquid and Plastic Limits (LL and PL) reduced, for all three clays tested. A more detailed investigation was carried out by Laguros (1969). He examined the Atterberg Limits of four clay soils of different mineralogies over a temperature range of 2 to 41°C. He noted that the LL of all four soils followed the same trend discussed above.

Hogentogler and Willis (1936) were amongst the first to investigate compactioncharacteristics in conjunction with temperature. Ctori (1988) examined the compaction characteristics of brick clay at 8, 20 and 35°C. It was concluded that for an increase in temperature, a reduction in the optimum moisture content and an increase in themaximum dry density occurs.

2. MOTIVATION AND OBJECTIVE

The influence of heating of clay soils on shear strength, atterberg limits, compaction characteristics, consolidation etc have been done by several researchers in the past century. But the effect of heating on chemically stabilized soils has been done by few geotechnical engineers. In this paper, we would like to review the double-advantage of lime-stabilization and heating, together, of clay soil of low compressibility.

3. TEST MATERIALS AND SAMPLE PREPARATION

The clay soil sample is collected near the vicinity of SONTYAM area of Visakhapatnam and various tests on soil have been performed on clay soil.

Initially the specifications of lime were obtained from the vendor.

Table 1. Chemical Properties of lime

Chemical formula	Ca(OH)2
Molar mass	74.093 g/mol
Appearance	white powder
Odour	odourless
Density	2.211 g/cm^3, solid
Melting point	580 °C (1,076 °F; 853 K) (loses water, decomposes)
Solubility in water	1.89 g/L (0 °C)
	1.73 g/L (20 °C)
	0.66 g/L (100 °C)
Solubility product (Ksp)	5.5×10^{-6}
Solubility	Soluble in glycerol and acids. Insoluble in alcohol.
Basicity (pKb)	1.37 (first OH–), 2.43 (second OH–)[1][2]
Magnetic susceptibility (χ)	$-22.0\cdot10^{-6}$ cm^3/mol
Refractive index (nD)	1.574

Then the preliminary index tests, optimum moisture content (OMC), maximum dry density (MDD), coefficient of permeability (k) using variable head method are found for the soil sample obtained.

The soil was initially air-dried in the sun and then kept in the oven at around 80^{0}C for 24 hours to dry further. Then lime was added in different proportions of 4%, 6%, 8% and 12% of dry weight of the soil and was left open to atmosphere for 4 hours. Then the stabilized soil is kept in an oven at two different temperatures of 35^{0}C and 90^{0}C for 24 hours. No water was added during the preparation of the sample.

Then tests to determine the specific gravity (G), liquid limit (w_L), plastic limit (w_P), standard proctor test to determine optmimum moisture content (OMC), maximum dry density (MDD), coefficient of permeability (k) were conducted.

Table 2. Properties of Remoulded Soil without Lime Addition or Heating

SOIL TEST	RESULTS OF REMOULDED SOIL SAMPLE
SPECIFIC GRAVITY	2.56
LIQUID LIMIT (%)	15.4
PLASTIC LIMIT (%)	12
PLASTICITY INDEX (%)	3.4
OPTIMUM MOISTURE CONTENT (%)	12.5
MAXIMUM DRY DENSITY (GM/C.C)	1.82
COEFFICIENT OF PERMEABILITY (CM/SEC)	11×10^{-6}

Based on the test reports various discussions have been present as per the strength variations criteria. The various physical properties of soil were assessed using methods below given in different parts of Indian standards (IS 2720).

4. Tests and Result Analysis

Variation of Specific Gravity (G)

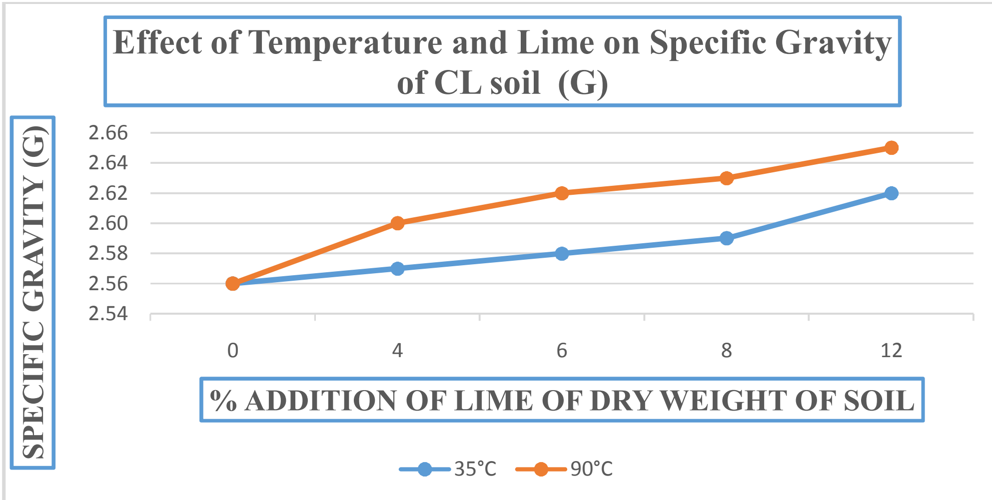

Fig 1. Effect of Heating on Lime Stabilizied CL Clay - Specific Gravity

Using IS 2720 Part (3) Section (1) for fine grained soils the specific gravity test was performed using density bottle method. The following figures will show the variation of G, with different proportions of lime at 35^0C and 90^0C.

Since it was low compressible clay, the variation of G was not so profound. At 35^0C, the percentage variation of G for no-lime to 12% addition of lime was found to be 2.35%. For each increment of lime percentage, the amount of variation to the previous proportion was between 0.39% to 1.16%. The minimum value of G was found to be 2.56 and the maximum value for 12% lime and 35^0C heating was 2.62.

At 90^0C also, the change was not too much. The percentage variation between no-lime admixture to 12% admixture was found to be 3.52%. The amount of variation with each increment of lime proportion also did not vary much. The maximum value was found to be 2.65 at 12% addition of lime.

In generally, it can be seen that there was a slight increasing tendency in the value of G with the variation of lime and temperature. Also after 8% of lime addition, the influence of temperature seemed to decrease.

Variation of Liquid Limit (LL - %)

Using IS 2720 – 5, the liquid limit and plastic limit tests were performed. The LL test was done using Cassagrande liquid test apparatus. Since it was a low compressible clay, the LL values were below 35%. The following figures show the variation of liquid limit with heating of lime stabilized clay.

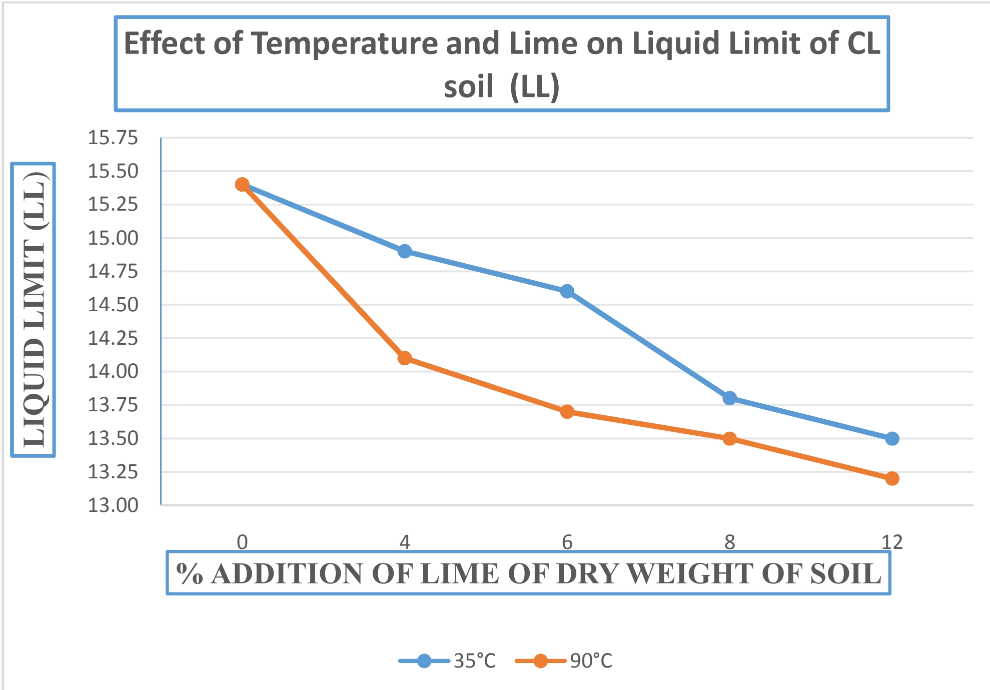

Fig 2. Effect of Heating on Lime Stabilizied CL Clay -Liquid Limit

At 35^0C, the liquid limit percentage variation from no-lime percentage to 12% lime addition was seen as -12.34%. The LL values decreased as lime percentage was increased, but not much variation was found from 0% to 12% variation of lime. At 90^0C, the changes were also similar with decreasing values of LL with increase in percentage of lime. The percentage variation between 0% and 12% variation was found to be -14.29%.

Variation of Plastic Limit (PL - %)

The PL values also followed a small increasing trend, just like LL values. At 35^0C, the percentage variation between 0% and 12% addition of lime was 5.83% and at 90^0C, the percentage change was 7.5%. It was observed that in comparison with 35^0C, the LL and PL values were slightly higher.

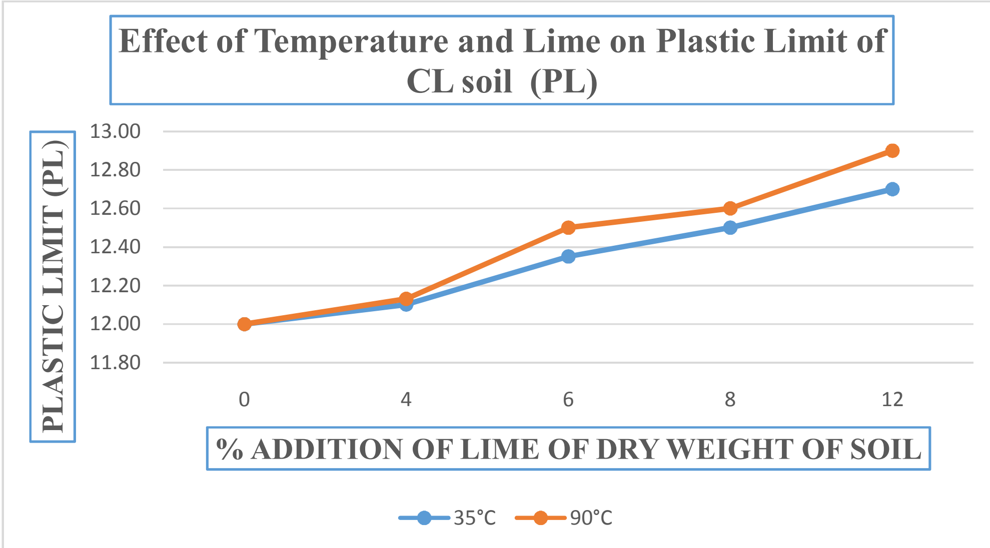

Fig 3. Effect of Heating on Lime Stabilizied CL Clay -Plastic Limit

Variation of Optimum Moisture Content (OMC - %) and Maximum Dry Density (MDD – gm/cc)

Using IS-2720-PART-7-1980, the standard proctor compaction test was performed at different lime proportions and temperatures as mentioned before.

Fig 4. Compaction test performed in laboratory

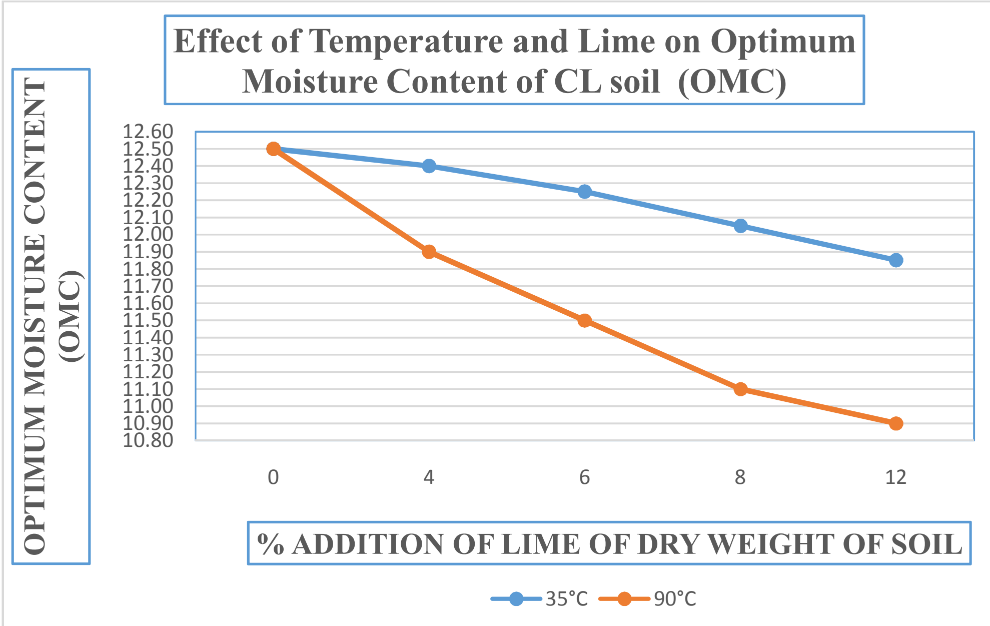

Fig 5. Effect of Heating on Lime Stabilizied CL Clay -Optimum Moisture Content (OMC)

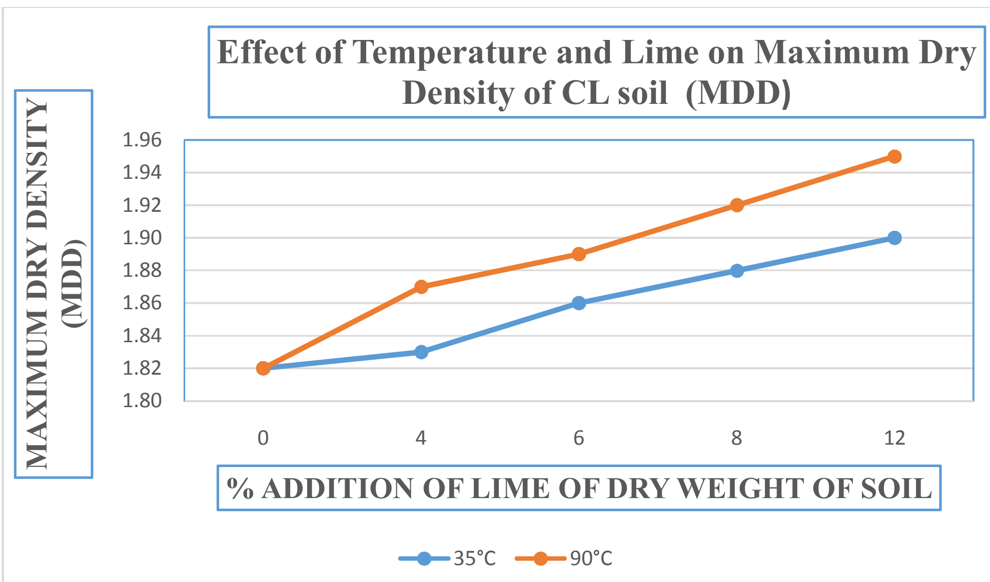

Fig 6. Effect of Heating on Lime Stabilizied CL Clay -Maximum Dry Density (MDD)

As a general trend it was observed for both 35^0C and 90^0C, that the OMC values decreased and MDD increasedwith increase in addition of lime. For the same percentage of lime, the same trend can be seen with increase in temperature. The percentage variation of OMC at35^0C between 0% to 12% additions of lime was found to be -5.2% and MDD was 4.4% respectively. At 90^0C the same results were found to be -12.8% and -7.14%.

Variation of coefficient of permeability using falling head method (k – cm/sec)

Using IS : 2720 (Part 15H), the falling head method of permeability test was performed to find out the changes in the k values for the earlier said criterion and see if there is any appreciable changes in the low compressible clays.

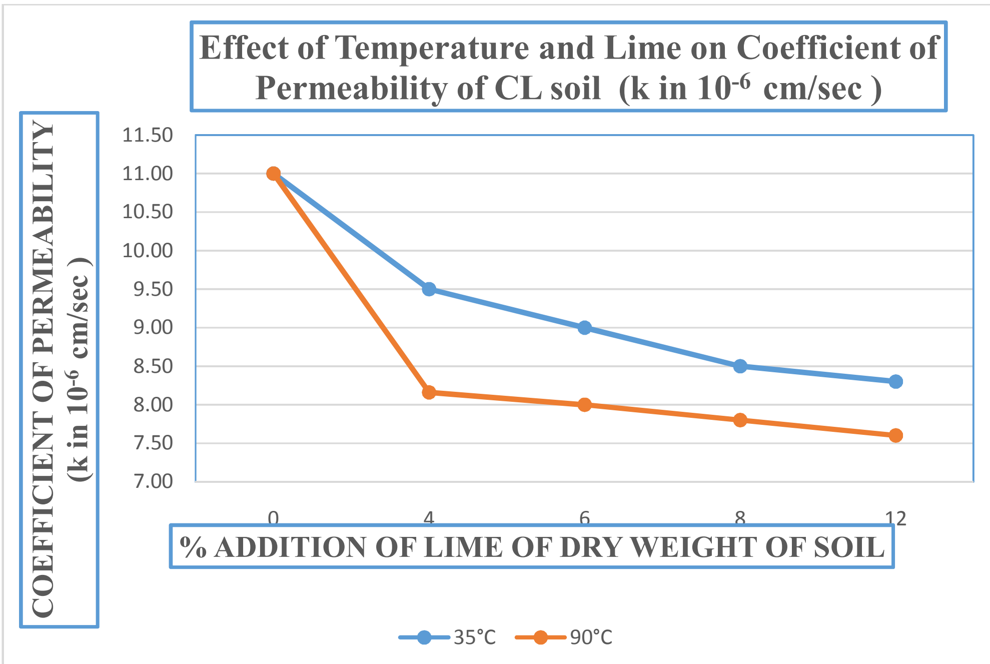

Fig 7. Effect of Heating on Lime Stabilizied CL Clay -Permeability

As a general trend in both the case of temperature, the k values decreased with the increase in lime percentage. The variation for 35^0C was found to be 24.5% between the minimum and maximum values of addition of lime and the same for 90^0C was calculated to be 30.9%. The lowest values of k for 35^0C and 90^0C were observed to be 8.3×10^{-6} cm/sec and 7.6×10^{-6} cm/sec which are typical of clay soils.

5. DISCUSSION

The decrease in liquid limit and increase in plastic limit with the addition of lime with both the temperature were in contradiction with the findings of George et al (1992). But the plasticity index decreased which was agreement to the results of George et al (1992).

Generally the MDD decreases with the increase in lime content. This has been observed by earlier findings of Osinubi (1998), Marks and Harliburton (1970) and Ladd et al. (1960). But on heating of lime stabilized soil, it was in contrast to the above findings. The decrease in OMC with increasing lime content was in line with the findings of Ladd et al. (1960), Marks and Harliburton (1970) and Osinubi (1998). But it contradicts the findings of Ola (1983) and Osula (1991).

Several researchers have conducted tests on permeability of lime-treated soils. While some researchers (e.g Forsberg 1969) reported that of coefficient of permeability values of as much as two orders with increasing lime content. But some others (e.g., Townsend and Klym 1966) reported a substantial increase in the coefficient of permeability values of high compressible soils. These results indicate that effect of lime on permeability of soils depends on the nature and chemical composition of the clay soil.

6. CONCLUSIONS

1. The plasticity index of the soil decreased with increase in percentage of lime and temperature. This decrease was associated due to the decrease in liquid limit and rather than the increase in plastic limit. It almost became zero, with 12% of lime.
2. Increase in lime causes an increase in the specific gravity values, due to soil-clay particles may be of less weight than the lime particles. Also with an increase in temperature, a small increase in the specific gravity is found which indicates there may change in the grain size due to bonding of lime-clay particles.This may add weight to the sample as a whole.
3. Addition of lime caused a substantialdecrease in the optimum moisture content and increase in the maximum dry density due to flocculation of the soil-clay particles. The change with the temperature is also not profound.
4. In the case of coefficient of permeability values there was linear decreasing trend for both the temperatures with the addition of lime which may due to the voids of the clay being filled by the lime particles. But the percentage change between without addition of lime and 12% lime, showed considerable percentage decrease in the k values.

7. Scope of future study

1. The current study of temperature variation on lime stabilization was done only on CL soils. It can be extended to CI and CH soils also. Mainly this may have an impact on high plastic and swelling soils, as with heating of clay, the grain size changes.
2. Only two temperatures were selected based on the time constraint. But even higher temperatures and higher percentage of lime can be selected and tested for the same properties.
3. Other properties like unconfined compressive strength, CBR and the variation in the cohesion and internal frictional angle of the soil can also be studies based upon the results.
4. Different other admixtures like bitumen, cement, flyash could also be added and effect of temperature on these soil-stabilization techniques can be studied.
5. The cost-estimation analysis can also be done compared to the normal stabilization techniques in relevance to thermal stabilization.

Acknowledgements

The experimental work that was conducted for this research paper was conducted in the Civil Engineering Department of VITAM college of Engineering of JNTUK University, as a B.Tech project with the help of G.Sai Kumar and their batch mates.

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