Role of Lime Content on Soil-Lime Reaction under Thermal Curing

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ABSTRACT

In this study to examine the role of lime content on strength a black cotton soil from Chennai was selected. After knowing the Initial Consumption of Lime (ICL) required for the soil selected four percentages of lime (i.e. 3%, 5%, 7% and 9%) were added with the soil and UCC specimens were prepared to study the effect of lime on strength. The specimens thus prepared were cured at three different temperatures of 5°C, 30°C and 50°C for curing periods of 7, 14, 28 and 90 days. The results show that increase in lime content increases the strength up to certain lime content and beyond that the strength reduces. The optimum lime content for strength gain depends on curing temperature. The lime addition equal to ICL is not very effective in increasing the strength irrespective of curing temperatures. From the tests conducted for various lime contents and curing temperatures, it was observed that the maximum portion of strength was obtained in initial curing period of 7 days.

1. INTRODUCTION

Expansive clays are considered as problematic deposits for civil engineering constructions since they are susceptible for volume change due to seasonal moisture variation and temperature. The drastic changes in the characteristics of expansive clays upon exposure to moisture and temperature changes are the main cause for the damage of facilities built in them. Therefore stabilization of expansive clay is of interest to any engineer who uses this soil for supporting foundation of structure. Stabilization techniques can be mechanical or chemical, or both, but the addition of a stabilizing agent is generally the favoured approach (Kennedy et al. 1987). Though different types of chemicals are in use for stabilization, lime is considered to be most suitable stabilizing agent particularly in clays. However, degree of improvement depends on other factors such as soil type, curing period, soil temperature and soil moisture at the time of curing apart from type and content of lime.

The lime content required for stabilization depends upon the role of lime. Short term function that it affects on the plasticity and long term function that it affects on strength.

When lime is added to a clay soil, it must first satisfy the affinity of the soil for lime, that is, ions are adsorbed by clay minerals and are not available for pozzolanic reactions until this affinity is satisfied. The content of lime, which is fixed in the soil and is not available for other reactions, has been referred to as lime fixation (Hilt and Davidson, 1960). The lime fixation point corresponds with the point where further addition of lime does not bring further changes in the plastic limit. However an optimum quantity of lime is needed for achieving maximum improvement on targeted properties of soil. Normally between 1% and 3% lime by weight of soil is required to modify plasticity. The content of lime more than the limit of fixation is available for other reactions and it increases the strength of the soil until an optimum lime content is reached beyond which the strength continues to increase at a reduced rate or begins to decline (Bell 1996).

In contrast to first stage (i.e. short term function) long term role of lime strongly depends upon curing conditions (i.e. temperature, duration and moisture content).

Extended curing times and elevated temperatures promote pozzolanic reactions. For instance, significant improvement in strength can be achieved with relatively small increases in temperature. Conversely, if the temperature falls close to 4°C, pozzolanic reactions are retarded and may cease to occur at lower temperatures (Bell 1996).

Several researchers (Thompson 1966, Ranganatham
A. A. Nasrizar, M. Muttharam and K. Ilamparuthi 1971, Wild et al. 1986, George et al. 1992, Bell 1996, Boardman et al. 2001, Rao & Shivananda 2005, Nasrizar et al. 2008) have worked on the effect of curing temperature on strength of lime stabilized expansive soils. Still there are several questions that are not well understood with respect to the relation between acceleration of soil-lime reactions due to temperature and lime content. Towards understanding this aspect an attempt is made in the present study to bring out the effect of lime content and curing temperature on accelerating the reactions between soil and lime.

2. TESTING MATERIAL
The black cotton soil used in this study was collected from Siruseri, Chennai, Tamil Nadu. Table 1 presents the properties of the soil used in the present study.

The laboratory grade hydrated lime was used for stabilization in the present study.

Table 1: Physical Properties of Soil

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Sand (%)</td>
<td>30</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>34</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>36</td>
</tr>
<tr>
<td>Specific gravity, $G_s$</td>
<td>2.72</td>
</tr>
<tr>
<td>Liquid limit, $LL$ (%)</td>
<td>80</td>
</tr>
<tr>
<td>Plastic limit, $PL$ (%)</td>
<td>25</td>
</tr>
<tr>
<td>Plasticity index, $PI$ (%)</td>
<td>55</td>
</tr>
<tr>
<td>Shrinkage limit, $SL$ (%)</td>
<td>12</td>
</tr>
<tr>
<td>Optimum moisture content (%)</td>
<td>23</td>
</tr>
<tr>
<td>Maximum dry unit weight (kN/m³)</td>
<td>15.50</td>
</tr>
<tr>
<td>Free Swell Index (%)</td>
<td>85</td>
</tr>
<tr>
<td>IS classification</td>
<td>CH</td>
</tr>
</tbody>
</table>

3. TESTING METHOD
The natural soil was dried in air and pulverized and passed through 425 µm sieve prior to use to determine Atterberg limits and Initial Consumption of Lime (ICL). For Proctor compaction test and UCC test the pulverized soil was passed through 4.75 mm sieve.

Two independent methods were used to determine the lime fixation point for the soil. First method is suggested by Eades & Grim (1966) (ASTM D 6276-99a, Reapproved 2006). As per this method the ICL of the soil is found to be 3%. Second method is based on plastic limit values (Nelson & Miller 1992). The minimum percentage of lime required to modify the plasticity characteristics of the soil used in the present study is also 3%. It is well documented in the literature that lime addition in excess of Initial Consumption of Lime is utilized for the pozzolanic reactions which leads to the increase in strength of lime treated soil (Thompson 1968, Rogers et al. 1997, Nasrizar et al. 2008). Hence lime contents of 3% (equal to ICL), 5%, 7% and 9% by weight (above ICL value) has been used to stabilize the soil selected. The compaction characteristics of soil and soil-lime mixtures were determined as per ASTM D 698 – 07.

The Cylindrical samples of diameter 51 mm and height 102 mm for unconfined compressive strength test were prepared at maximum dry unit weight and optimum moisture content as per ASTM D 5102-04. All these samples were prepared at room temperature of 25°C to 27°C. The samples were sealed in plastic bags to minimize moisture loss and carbonation and cured for 2 hours, 7, 14, 28 and 90 days at 5°C, 30°C and 50°C.

4. RESULTS AND DISCUSSIONS
Relationship Between Lime Content and Curing Time in Strength Gain
From Figures 1 to 3 it is noticed that the 3% lime treated specimens exhibited almost comparable strength irrespective of curing period and curing temperatures. This confirms the fact that lime addition in excess of ICL is required for improvement in strength.
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Further Figures 1 to 3 reveal that increase in lime content increases the strength significantly at elevated curing temperature. The gain in strength is marginal with increase in lime content for specimens cured at 5°C. The strength increased from 534 kPa to 963 kPa for the lime addition of 3% to 9% after 90 days of curing when cured at 5°C. However, the specimens cured at 50°C showed increase in strength of 839 kPa to 4965 kPa when the lime content increased from 3% to 9% after 90 days. For the given lime content and curing period specimens cured at 50°C exhibited higher strength compared to the same cured at 30°C. It is interesting to note that at curing temperature of 30°C, 7% lime treated specimens showed slightly higher strength compared to 9% lime treated specimens. Similar specimens when cured at 50°C, 9% lime treated specimens showed strength higher than that of 7% lime treated specimens. This shows that not only the lime content, the curing temperature also plays a major role in accelerating the soil-lime reactions.

The results clearly show that for 3% lime treated specimens curing time and temperature are not very effective in strength gain. In contrast maximum rate of increase in strength has been obtained at 9% lime content in 50°C curing temperature whereas for 30°C curing temperature the rate of increase in strength for 7% lime content is higher than 9%.

Further the figures show that the rate of strength is not constant and maximum rate has been happened within first 7 days then gradually decreases. The reduction in the rate of strength gain depends on curing temperature and lime content. In 50°C the rate of reduction is higher than 30°C and the rate of reduction for low lime content is more than that for high lime content.

The rate of strength gain for the first 7 days and 7 to 28 days curing at 5°C is 18.8& 4.0, 13.0& 7.6, 18.3& 5.6 and 35.8& 6.5 kPa per day for 3%, 5%, 7% and 9% lime contents respectively. At curing temperature of 30°C, the strength gain for the first 7 days and 7 to 28 days curing is 41.6& 2.8, 106.0& 24.2, 147.7& 37.3 and 125.6& 31.2 kPa/day respectively for 3%, 5%, 7% and 9% lime contents. The same for 50°C curing is 43.4 & 1.7, 195.4 & 11.9, 337.8 & 37.9 and 470.9 & 32.5 kPa/day for 3%, 5%, 7% and 9% lime contents respectively.

The results clearly show that the first 7 days curing is more important for strength gain irrespective of curing temperature and lime content and when the curing period increased the rate of strength gain gradually decreases. This depends on lime content and curing temperature.

For 5°C, ratios of strength at 7 days to 90 days are 0.74, 0.64, 0.57 and 0.64 and these values at 30°C found to be 0.85, 0.53, 0.46 and 0.44 whereas at 50°C the ratios are 0.94, 0.73, 0.70 and 0.80 for 3%, 5%, 7% and 9% of lime content respectively. This shows that specimens treated with higher percentage of lime offers maximum benefit with in seven days curing, if cured at elevated temperature.

**Effect of Curing Temperature on Optimum Lime Content**

Figures 4 and 5 show the variation of strength of lime treated specimens after 7 and 28 days of curing respectively at various curing temperatures. It is noticed that samples cured at 5°C showed marginal increase in strength with lime content. Whereas the specimens cured at 30°C showed increase in strength with increase in lime content until 7%. Reduction in the strength is noticed when lime content is increased to 9%. From this it can be inferred that 7% lime content is the optimum lime content to get maximum strength at 30°C. In contrast the specimens cured at 50°C showed a linear increase in strength with increase in lime content. It may be said that elevated temperature increases the bond strength for the given percentage of lime.

Fig. 4: Effect of Curing Temperature on Optimum Lime Content after 7 Days Curing
5. CONCLUSIONS

The effect of lime content and curing temperature on strength of expansive clay is studied by conducting UCC test on lime stabilized specimens. From the results obtained the following conclusions are drawn:

1. Strength of lime treated specimens cured at low temperatures shows marginal improvement in strength with curing period. However prolonged curing at low temperatures is beneficial than curing at elevated temperatures.

2. Curing of stabilized specimens at elevated temperatures accelerated the strength gain. The maximum gain in strength is achieved with in 14 days of curing irrespective of the lime content.

3. The optimum lime content required to produce maximum strength depends on curing temperature and curing period. Among these two parameters, curing temperature produces more beneficial effect if the temperature is higher than ambient whereas for the curing temperature lower than ambient, the curing period offers beneficial effect.

REFERENCES


