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EFFECT OF LIME ON CONSOLIDATION CHARACTERISTICS OF CLAY SOIL

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Abstract*-Consolidation characteristics are one of the prime considerations for any structure constructed above clay soil. This behavior of soil is mainly responsible for the settlement of a clay layer. Structure may be penetrated considerably in the soil; roadway may be undulated due to this settlement problem. Moreover differential settlement causes excessive damage to the structure. Therefore it is required to understand the process properly which will eventually help to mitigate the problems related to the settlement. For this purpose, a wide range of consolidation tests were performed in the laboratory to understand the settlement characteristics and to improve the condition by soil stabilization with different percentage of lime. Lime is a natural rock which can be used as an effective soil stabilizer to improve workability and load bearing capacity of soil. The study covers the improvement of consolidation characteristics to reduce the settlement of clay soil by using lime. In investigation 4% lime was found to be the optimum percentage for soil stabilization which improves the settlement behavior of the soil. This composition of lime and soil can be used to treat the foundation soil of any structure which may decreases the possibility or risk of differential settlement.*

Keywords: Compression index, Consolidation, Differential settlement, Settlement, Stabilization.

1. INTRODUCTION

Consolidation characteristics as well as settlement characteristics is the most burning topics in the field of geotechnical engineering. This property is directly related with the total settlement of any structure. Excess and ununiform settlement of foundation soil may cause a high amount of imbalance moment in the entire joint of the existing structure, which may cause failure of structure. So it is very important to make stable the structure against those uncertainties. Different methods are available to improve those characteristics, but most easy and reliable method is lime stabilization. By using different percentage of lime as a soil modifying agent the risk of settlement can be reduced. In this thesis the authors try to find the optimum percentage of lime which improves consolidation characteristics of silty clay soil which may show a significant impact in the field of foundation engineering. In these circumstances authors select 4% lime content for improving the lacking property of foundation soil.

2. CONSOLIDATION

Consolidation settlement is the vertical displacement of the surface corresponding to the volume change at any stage of the consolidation process. Consolidation settlement will result, for example, if a structure is built over a layer of saturated clay or if the water table is lowered permanently in a stratum overlying a clay layer. On the other hand, if an excavation is made in a saturated clay, heaving (the reverse of settlement) will result in the bottom of the excavation due to swelling of the clay. In cases in which significant lateral strain takes place, there will be an immediate settlement due to deformation of the soil under undrained conditions, in addition to consolidation settlement. Immediate settlement can be estimated using the results from elastic theory. This chapter is concerned with the prediction of both the magnitude and the rate of consolidation settlement (required to ensure that serviceability limit states are satisfied). The progress of consolidation in situ can be monitored by installing piezometers to record the change in pore water pressure with time. The magnitude of settlement can be measured by recording the levels of suitable reference points on a structure or in the ground: precise leveling is essential, working from a benchmark which is not subject to even the slightest settlement. Every opportunity should be taken of obtaining settlement data, as it is only through such measurements that the adequacy of theoretical methods can be assessed.

Fig.1: Soil specimen in consolidation cell

Fig.2: A consolidation cell during experiment

Normally consolidated and Over-consolidated clays: A normally consolidated soil is one which had not been subjected to a pressure greater than the present existing pressure. A soil is said to be over consolidated if it had been subjected in the past to a pressure in excess of the present pressure.

Under consolidated clays: If the clay deposit has not reached equilibrium under the applied overburden loads, it is said to be under consolidated. This normally occurs in areas of recent land fill.

There are three types of consolidation,[1]

a. Initial consolidation,

b. Primary consolidation

c. Secondary consolidation

Parameters of Consolidation:

a. Compressibility

b. The compression index (C_c)

c. Co-efficient of consolidation (c_v)

2.1 Compressibility (m_v)

This is defined as the volume change per unit volume per unit increase in effective stress. The units of m_v are the inverse of pressure (m^2/KN). The volume change may be expressed in terms of either void ratio or specimen thickness. If, for an increase in effective stress from σ_0' to σ_1' the void ratio decreases from e_0 to e_1, then

$$m_v=\frac{1}{1+e_0}\left(\frac{e_0-e_1}{\sigma_1'-\sigma_0'}\right)$$

$$m_v=\frac{1}{H_0}\left(\frac{H_0-H_1}{\sigma_1'-\sigma_0'}\right)$$

The value of m_v for a particular soil is not constant but depends on the stress range over which it is calculated. BS 1377 specifies the use of the coefficient m_v calculated for a stress increment of 100 kN/m² in excess of the effective overburden pressure of the in-situ soil at the depth of interest, although the coefficient may also be calculated, if required, for any other stress range.

2.2 Compression Index (C_c)

The compression index for the calculation of the field settlement caused by consolidation can be determined by graphic construction after one obtains the laboratory test results for void ratio and pressure. Skempton suggested the following empirical expression for the compression index for undisturbed clays.

C_c=0.009(LL - 10)

C_c=0.007(LL - 7) (for remolded soil)

Where LL=liquid limit.

On the basis of observation on several natural clays Rendon-Herrero (1983) gave the relationship for the compression index in the form

$C_c=0.141G_s^{1.2}\left(\frac{1+e_0}{G_s}\right)^{2.38}$

Table 1: Soil classification based of compression index,[4]

Compression index (Cc)	Soil type
0.3	High plastic clay
0.3-0.075	Medium plastic clay
0.075	Low plastic clay

2.3 Co-efficient of Consolidation(c_v)

The co-efficient of consolidation C_v generally decreases as the liquid limit of soil increases. The range of variation of C_v for a given liquid limit of soil is wide. For a given load increment on a specimen, two graphical methods are commonly used for determining C_v from laboratory one-dimensional consolidation tests. The first is the logarithm-of-time method proposed by Casagrande and Fadum (1940), and the other is the square-root-of-time method given by Taylor(1942).

3. 1 LIME STABILIZATION ,[5]

Lime stabilisation may be defined as soil modification or soil stabilisation (Little, 1995). Researchers now believe that with the addition of low amounts of lime, the calcium present causes an initial ionic exchange, which results in flocculation (or edge to face reorientation of the clay plate-like particles). This flocculation has a dramatic effect on the soil, in terms of a reduction in PI, improved workability and shear strength.

3.2 METHODOLOGY, [6]

A. **Scarification and Initial Pulverization**: After the soil has been brought to line and grade, the soil can be scarified to the specified depth and width and then partially pulverized. It is desirable to remove non-soil materials larger than 3 inches, such as stumps, roots, turf, and aggregates. Scarification is done because a scarified or pulverized subgrade offers more soil surface contact area for the lime at the time of lime application.

B. **Lime Spreading**: the soil is generally scarified and the slurry is applied by distributor truck. Because lime in slurry form is much less concentrated than dry lime, often two or more passes are required to provide the specified amount of lime solids. To prevent runoff and consequent non-uniform lime distribution, the slurry is mixed into the soil immediately after each spreading pass.

C. **Preliminary Mixing and Watering**: Preliminary mixing is required to distribute the lime throughout the soil and to initially pulverize the soil to prepare for the addition of water to initiate the chemical reaction for stabilization. During this process or immediately after, water should be added to ensure the complete hydration and a quality stabilization project.

D. **Final mixing and pulverization**: To accomplish complete stabilization, adequate final pulverization of the clay fraction and thorough distribution of the lime throughout the soil are essential.

E. **Compaction**: Initial compaction is usually performed as soon as possible after mixing, using a sheeps foot type roller or a vibratory padfoot roller. After the section is shaped, final compaction can be accomplished using a smooth drum roller. The equipment should be appropriate for the depth of the section being constructed.

4. EXPERIMENTAL RESULT

Table 2: Soil properties before stabilization with lime

Moisture content (w)	17.95%
Specific gravity (g)	2.68
Liquid limit (L.L)	50%
Plastic limit (P.L)	18.7%
Plasticity index (P.I)	31.1%
Shrinkage limit (S.L)	10.96%
Soil type (USCS) [2]	CH (high plastic clay)

Table 3: variation of consolidation properties due to lime stabilization

% of lime	Co –efficient of compressibility (c_v)	Compression Index (c_c)	Co-efficient of volume change (m_v)	Swell index (c_s)	Void ratio (e)
0%	.00016	.120	.000113	.033	41.6 %
2%	.00015	.072	.0001	.0173	61.4 %
4%	.0001	.066	.00008	.0110	28.1 %
6%	.00012	.102	.000072	.0170	66.4 %

Table 4: comparison between graphical and theoretical value

% of lime content	From graph (C_c)	C_c =.007(L.L-7)
0%	0.120	0.29
2%	0.072	0.04
4%	0.066	0.03
6%	0.102	0.04

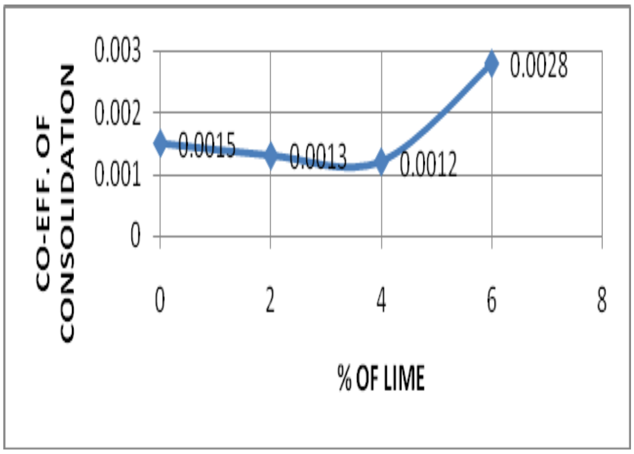

Fig.3: Variation of co-efficient of consolidation

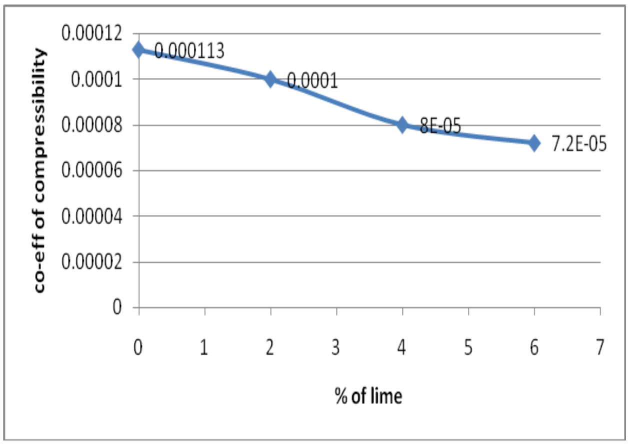

Fig.4: Variation of co-efficient of compressibility

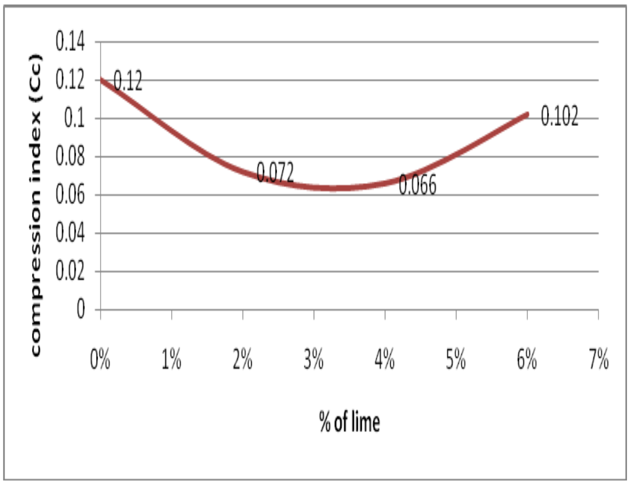

Fig.5: Variation of compression index (c_c) with % of lime

5. NUMEROUS ADVANTAGES IN BROAD RANGE OF APPLICATION

• In the time of a few hours, an unconditional soil is transformed by lime into a stabilized soil which can carry the traffic load sufficiently. An added bonus is that the soil becomes less sensitive to moisture. This immediate and spectacular effect makes it possible to build job site roads that can be used regardless of weather condition.

• The technique makes it possible to retain high quality raw materials for quality applications. The building of embankments using moist plastic soils treated with lime can result in considerable savings on materials brought in from elsewhere, often at great cost, and the inevitably high costs of waste soil disposal.

• Lime treatment makes it possible to construct good quality capping layers and beds for roads, railway tracks, and runways. The stiffening/curing of the structure means that the slopes of the structure have greater stability.

• Because it is such a simple process, lime-stabilization of soil is easy to apply to "small" works, such as foundations for car parks, industrial platforms, and agricultural and forestry roads. The greatest benefits of this procedure, namely the savings on aggregate and disposal charges, are indeed the same as for all major earth moving works.

6. ECONOMIC BENEFITS OF LIME STABILISATION

• Limitation of the need for embankment materials brought in from outside and the elimination of their transporting costs.

• Reduction of transport movements in the immediate vicinity of the construction site.

• Machines can move about with far greater ease. Delays due to weather conditions are reduced, leading to Improved productivity. As a result, the overall construction duration and costs can be dramatically reduced.

• Structures have a longer service life (embankments, capping layers) and are cheaper to maintain.

7. CONCLUSION

In reality, clay soil may undergo a large amount of settlement gradually with time. As a result structure may experience considerable settlement after some period of time. Therefore it is required in every geotechnical project to keep the total settlement within the allowable limits described previously; addition of lime may be a promising method to reduce the total settlement substantially. The soil was stabilized with 0%, 2%, 4% and 6% lime content. After improvement, the physical as well as engineering properties were evaluated. The compression index decreased from 0% to 4% lime content and then it showed increasing tendency for higher percentage of lime. The compression index (C_c) varies 0.120 to 0.066 for 0% to 4% lime addition. But for 4% to 6% of lime content it varies 0.066 to 0.102. Again for co-efficient of compressibility (a_v) varies 0.00016 to 0.0001 for 0% to 4% lime content. But for lime content 4% to 6% it varies 0.0001 to 0.00012. Finally it is observed from the study, the value of compression index decrease with addition of lime up to 4% then it increase with higher percentage of lime. With the compression index value the settlement of soil also decreases.

Finally this investigation showed that 4% lime is that proportion which yield minimum settlement and minimum cost. Therefore, this study recommends to use this optimum proportion of lime to get economical solution of the settlement problem.

8. ACKOWLEDGEMENT

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9. NOMENCLATURE

Symbol	Meaning	Unit
C_c	compression index	(K)
c_v	Co-efficient of consolidation	Unit less
c_s	Swell index	Unit less
m_v	Co-efficient of volume change	Unit less
e	Void ratio	Unit less