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Consolidation Stress Effect On Strength Of Lime Stabilized Soil

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ABSTRACT
Improvement of soft soils by deep mixing is gaining popularity in many countries. The strength of stabilized soils is generally estimated by conducting unconfined compression test, whereas triaxial compression tests are used very rarely. Further the undrained strength of the stabilized soil is considered for design. The strength of stabilized soil is treated as being independent of stress. Triaxial tests have shown that the drained strength of stabilized soils is stress dependent in a similar way to that of natural soils. Hence, the stress dependency of the strength of stabilized soils should be considered in the design process for most soil and loading conditions. Hence in the present study an attempt is made to bring out the effect of consolidation stress on the strength of lime stabilized soil. The various laboratory test such as vane shear test, unconfined compressive strength test and Triaxial test were conducxred. In general the undrained cohesion and the angle of internal friction increases with increase in lime content and curing periods. However for a given lime content and curing period, the undrained cohesion increases with increase in consolidation stress and angle of internal friction decreases with increase in consolidation stress. Hence, it is important to consider the consolidation stress effects to arrive at the design strength parameters for stabilized soils.
Keywords – Lime, Shear strength, Consolidation stress, Triaxial test, Unconfined compressive strength.

I.INTRODUCTION

Soil stabilization, in a broad sense, incorporates, the various methods employed for modifying the properties of a soil to improve its engineering performance. Stabilization is being used for a variety of engineering works, where the main objective is to increase the strength or stability of soil and to reduce the construction cost by making best use of the locally available materials. Methods of stabilization may be grouped under two main types: a) Modification or improvement of a soil property of the existing soil without any admixture. b) Modification of the properties with the help of admixtures. Compaction and drainage are the examples of the first type, which improve the inherent shear strength of soil. Examples of the second type are: Mechanical stabilization, stabilization with cement, lime, bitumen and chemicals etc. The properties of soft soils can be improved by either of the above mentioned methods.

1.1 Deep Stabilization of soil

The improvement of soft soils by deep mixing is now widely used in many countries. Lime has been used for several decades as stabilizing agents in deep stabilization of soft soil and it is used to improve the strength parameters (cohesion, angle of internal friction). An important factor for the design of deep mixing is the effect of lime on the strength achieved in the stabilized soils. Although a number of investigations have been performed, showing different aspects of the strength of lime stabilized soils (Helen Ahnberg 2003).there is a need for further studies, particularly concerning the effect of consolidation stress on soils stabilized with lime on undrained as well as drained strength. Clay generally shows a significant increase in strength when lime is used for stabilization (Bell 1988, Narasimha Rao et al; 1990). Lime has been found to be the most effective and economic of all additives. Addition of lime to clay reduces the swell potential and increase the strength (Sakr,Mohammed 2000) .Khelifa Harichane et al. (2011), presented the laboratory study of expansive soil stabilized with lime. They concluded that the addition of lime reduces the plasticity index, increases optimum moisture content (OMC) and decreases maximum dry density (MDD). Increasing the curing time increased the shear stress of soil stabilized with lime. There is a considerable increase in cohesion and angle of internal friction in samples containing lime with increasing curing period (Helen Ahnberg 2003).The strength of lime-soil mixture is influenced by several factors such as soil type, amount of lime added, curing period, moisture content and unit weight of soil and time elapsed between mixing and compaction (Ingles and Bell et al; 1993).Mir (2004) used lime stabilization technique to improve the properties of dredged material from dal lake in Srinagar. On addition of small amount of lime (2%), the immediate UCC strength of soil unaffected where as there is a significant increase in the UCC strength for 7 days curing period and a marginal increase for 21 days curing period. Lime stabilization improves the compressibility characteristics of clayey soil (Broms and Boman 1977; Maharan et al. 2004). Back pressure can greatly affect the strength of lime stabilized soil (Helen Ahenberg 2003). Though several researchers worked on lime stabilized soil, to study on the behaviour of lime stabilized soil subjected to consolidation stress is limited. Hence the present study aims to bring out the effect of consolidation stresses on the strength characteristics of lime stabilized soft clay.

II.Experimental study

2.1 Materials

Natural soils were collected from Velachery, Chennai, Tamil Nadu, India at 0.5-1.5 m depth from ground level by making open trench. The physical properties of natural soil are shown in table 1. Laboratory grade hydrated lime was used for the study.

2.1 Methods

Unconfined compressive strength, Triaxial test and Vane shear tests were conducted on natural and lime stabilized soil at a consistency of 0.2. The soil was stabilized with lime contents of 3%, 5%, 7% and 9% and cured for 7, 14 and 28 days.

2.2 Preparation of soil sample

Samples are prepared by mixing a required amount of water to the soil passing through 425μm to reach the required consistency. Then required amount of stabilizers are mixed to the soil at the soft consistency to get a uniform paste of soil-stabilizer mix. Then the soil stabilizer mix is placed in spilt mould of 38mm inner diameter and length of 80mm by kneading compaction technique. The samples were sealed with rubber lids at the ends and stored in humidity chamber at ambient temperature for the required curing period. After the required curing period, tests are conducted by extracting the samples from spilt mould. The sample prepared in the split mould with required percentage of lime stabilizer cured for the required time is taken out from the mould, and set in the triaxial apparatus by conventional way. Then the sample is subjected to a consolidation stress of 50 kPa, after ensuring the consolidation, the sample was subjected a cell pressure of 50 kPa and sheared. Next an identical sample is taken and consolidated for 50 kPa then the cell pressure is increases to 150kPa. Mohr's circle is drawn for the set of data, from the strength envelope cohesion intercept and angle of internal friction are obtained. This is "c' and "φ" for consolidation stress of 50 kPa. The above said procedure is repeated with identical specimens with the only difference that, this time the consolidation stress is 150 kPa. The same procedure is repeated with identical specimens subjected to a consolidation stress of 150 kPa. For each lime content and curing periods at least nine identical specimens are tested.

TABLE 1 Physical Properties of Soils

Parameter	Symbol or Percentage	Values
Specific Gravity	G_s	2.43
Clay	%	76
Silt	%	18
Sand	%	6
Liquid Limit	%	86
Plastic Limit	%	29
Plasticity Index	%	57
IS Classification	CH	Clay of High Plasticity

2.3 Experimental Procedure

2.3.1 Unconfined compressive strength test

Strength is an important engineering behavior based on which foundations are designed. In order to determine the strength, unconfined compressive test was performed. Unconfined compression test is simple test, which is useful for the evaluation of suitable quantities and compositions of stabilizers. However, they do not provide information on the influence of stress and pore water pressures. Unconfined compression test are extensively used to estimate the undrained strength of stabilized soils.

2.3.2 Triaxial compression test

Triaxial tests are used to enable the assessment of undrained strength under varying loading conditions. In the current design models, the undrained strength is the main property considered, and this is treated as being independent of stress. However, it is believed that both undrained and drained strength is dependent on stress and this stress dependence should be considered in the design process for most soil and loading conditions. Triaxial tests have shown that the undrained strength of stabilized soil is dependent in a similar way to that of natural soils.

2.3.3 Vane shear test

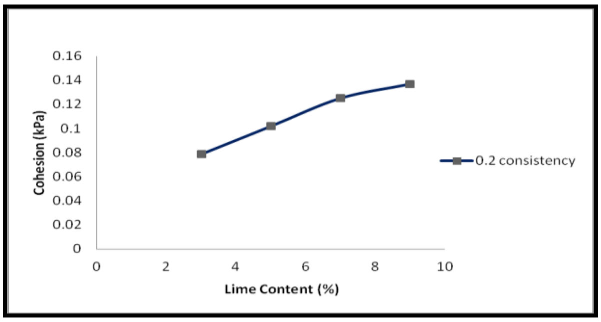
Vane shear test is used to get the undrained strength parameters of soft clay.

III.Result and Discussion

3.1 Vane Shear test

Vane shear test was conducted for clay consistency of 0.2, mixed with 3%, 5%, 7% and 9% lime content immediately after preparation. The undrained cohesion varies from 0.05 to 0.13 kPa for various lime contents. Figure 3.1 brings out the variation of undrained cohesion with various percentage of lime content at a consistency of 0.2. From figure 3.1, it was observed that the cohesion marginally increases with the increase in lime content. Though lime stabilization would increase the strength, since the test was conducted immediately after preparation of lime treated specimens, there was no scope for soil-lime reactions. Hence there is no appropriate improvement in undrained cohesion.

Figure 3.1 Variation of undrained cohesion with various percentage of lime content at 0.2 consistency



3.2 Unconfined Compressive Strength

Fig 3.2 plots the variation of UCC strength with curing periods for samples treated with various lime contents. The strength increase is almost linear with curing period for all the lime contents except for 9% lime, where there is a higher rate of increase in strength for curing from 7 days to 14 days compared to the strength gain for further curing up to 28 days. When the lime content is increased from 3% to 9%, the UCC strength increased from 6.09kPa to 18.5 kPa for 7 days curing. For the curing period of 14 days, the UCC strength increased to 65.24 kPa upon lime addition of 9% and the same is 78.88 kPa after 28 days curing.

Data presented in the table 3.2 brings out that the UCC strength of soil increased with increase in lime content and as well as increase in curing period. This is due to the beneficial effects derived from soil- lime reactions. However, it can be further observed that addition of 3% lime is not much effective in improving the strength, as this is less than lime fixation point. The lime fixation point for the soil considered in the present study is 4%. According to the theory, addition of lime up to lime fixation point is utilized for modifying the plasticity characteristics and the lime addition in excess of lime fixation is used for improving the strength. However, as soon as lime is added to the soil both modification and stabilization process starts together and it cannot be said that only after modifying the plasticity characteristics the strength should be improved. Hence, in the present investigation even 3% lime addition showed a marginal increase in UCC strength. The soil at 0.2 consistency treated with lime contents of 3%, 5%, 7% and 9% lime contents the strength increase after 14 days is nearly 2 to 4 times as that of 7 days strength. Further after 28 days curing the strength is increased to nearly 3 to 6 times the 7 days strength for all lime contents.

Fig 3.2 UCC Strength of soil at a consistency of 0.2 stabilized with 3%, 5%,7% and 9% lime

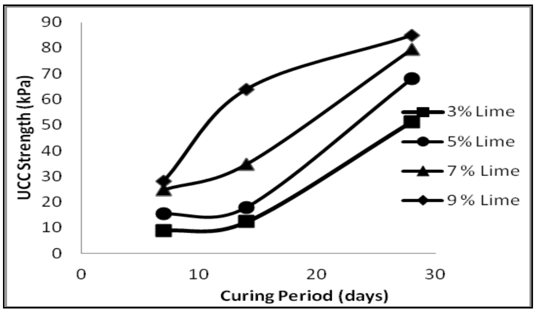


Table 3.2 UCC Strength of Cured Lime Stabilized Soil.

During periods (days)	UCC strength (kPa)			
	3% lime	5% lime	7% lime	9% lime
7	6.09	9.57	15.08	18.50
14	12.76	30.74	38.28	65.54
28	30.16	50.17	48.08	78.88

3.3 TRIAXIAL COMPRESSION TEST RESULTS

3.3.1 CONSOLIDATED UNDRAINED STRENGTH PARAMETERS

3.3.1.1 UNDRAINED COHESION

Consolidated undrained tests were conducted on soil at consistency of 0.2 treated with 3%,7% and 9% lime content cured for 7,14 and 28 days. A set of samples were consolidated for a constant pressure and the cell pressure was increased and tested, to get the strength parameters. The consolidation stress considered are 50kPa, 100kPa and 150kPa.

Fig 3.3.1 plot the variation of undrained cohesion with consolidation stress for soil at 0.2 consistency treated with 3%,7% and 9% lime respectively and cured for 7,14 and 28 days. From Figure 3.3.1, it is noticed that the consolidation stress increases the undrained cohesion value considerably. Further, the rate of increase in strength for consolidation stress from 50kPa to 100 kPa is slightly higher than that for increases in consolidation stress from 100 kPa to 150 kPa.

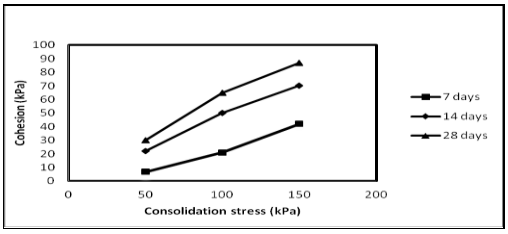


Fig 3.3.1 Variation of Cohesion of Soil at 0.2 Consistency Stabilized with 3% Lime

Table 3.3.1 summarizes the cohesion obtained for soil at 0.2 consistency treated with 3%,7% and 9% lime content cured for 7,14 and 28 days subjected to the consolidation stress of 50 kPa,100 kPa and 150 kPa.

Variables	Cohesion (kPa)								
Lime Content (%)	3%			7%			9%		
Consolidation stress(kPa)	50	100	150	50	100	150	50	100	150
Curing Periods (days) 7	7	22	30	12	40	60	24	60	84
14	21	50	65	34	63	88	50	80	105
28	42	70	87	50	89	105	79	102	130

Data presented in the table shows that for a given curing period and lime content the cohesion increases with increases in consolidation stress. For example 7% lime treated soil cured for 28 days showed cohesion of 50 kPa when consolidated for a stress of 50 kPa. The similar sample when subjected to 150 kPa exhibited undrained cohesion of 105 kPa. This is nearly double the cohesion value at consolidation stress of 50 kPa.

3.3.2 ANGLE OF INTERNAL FRICTION

Fig 3.3.2 plots the variation of angle of internal friction obtained for soil at 0.2 consistency treated with 3%, 7% and 9% lime respectively and subjected to consolidation stress of 50 kPa, 100 kPa and 150 kPa. The variation of angle of internal friction with curing periods is also plotted in figure 3.3.2. The angle of shearing resistance reduces with increase in consolidation stress for all the lime contents and curing periods.

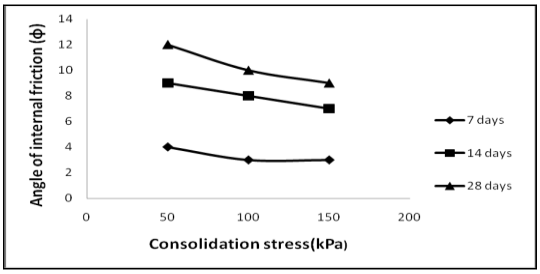


Fig 3.3.2 Variation of Angle of Internal Friction of Soil at 0.2 Consistency Stabilized with 3% Lime

Table 3.32 summarizes the angle of internal friction for soil at 0.2 consistency stabilized with various lime contents subjected to different consolidation stresses. The angle of internal friction increases with increase in lime content and increase in curing periods. However, for a given lime content and for a given curing period the angle of internal friction decreases with increase in consolidation stresses. This may be due to the fact that the consolidation stress might have broken the bonds developed due to soil-lime reactions which in turn reduced the angle of internal friction.

TABLE 3.3.2 Angle of Internal Friction of Lime Stabilized Specimens at Various Consolidation Stresses at 0.2 Consistency

VARIABLES		Angle of internal Friction (degrees)								
Curing period (days)		3% Lime			7% Lime			9% Lime		
Consolidation stress (kPa)		50	100	150	50	100	150	50	100	150
curing periods (days)	7	4	3	3	7	5	4	9	7	5
	14	9	8	7	12	10	15	15	12	10
	28	12	10	9	15	13	10	18	15	12

IV.CONCLUSION

Soft clay deposits are geologically recent deposits which are found in several parts of the world especially along the coast in narrow tidal plane and swamp areas. In Tamilnadu also these deposits occur in many parts like backwater areas of Kovalam, Vedaranyam as well as Chennai. The basic problems associated with these type of deposits were low shear strength and high compressibility. Chemical stabilization using various admixtures is a suitable solution to improve the strength of soft clay.

Based on the detailed experimental investigation and analyzing the data the following conclusions are arrived at

1. Soil at soft consistency exhibits very low strength when tested immediately after mixing the stabilizer lime with soil. Hence curing period plays a major role in improving the strength.
2. Unconfined compressive strength of soil at 0.2 consistency treated with various percentages of lime, showed increase in strength with increase in percentage of lime stabilizer and curing period.
3. Consolidated undrained test conducted on lime stabilized soil at 0.2 consistency showed increase in undrained cohesion and angle of internal friction with increase in lime content and curing periods.
4. For a given lime content and curing period, the undrained cohesion increases with increase in consolidation stress.
5. For a given lime content and curing period the angle of internal friction decreases with increase in consolidation stress.

The strength of lime stabilized soil is dependent on consolidation stress and thus this need to be considered for the design.

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