Effect of Lime Stabilization on the Alteration of Engineering Properties of Cohesive Soil

Sarah Tahsin Noor and Rokon Uddin

Abstract The scarcity of land is ever increasing all over the world. Thus, ground condition is often improved through different techniques (such as soil stabilization using admixtures, compaction sand drains, etc.) if the shear strength and bearing capacity of the subsoil is inadequate. Highway construction projects often demand soil stabilization at the construction site to attain the design specifications related to shear strength and CBR. In the present context, an experimental program was carried out to investigate the influence of two different admixtures (namely, cement and lime) on different geotechnical parameters (such as maximum dry density, optimum water content, liquid and plastic limits) of the original soil characteristics and also in improving the soil's shear strength and CBR. The admixtures are found to have significant influence in modifying the soil's properties. The lime (%) mixed with the soil does not influence optimum moisture content and maximum dry density but shows significant effects on shear strength and CBR. The outcome of this study will be useful in roads, highways and airfield pavement constructions.

Keywords Lime stabilization · Unconfined compressive strength
California bearing ratio

1 Introduction

Lime has a history of more than 2000 years for being used as construction material because the Romans used to apply lime in road construction, since the ancient time. Today, lime is widely applied in different construction projects of highways, railways, airports, embankments, etc. [1–3] for stabilizing, controlling erosion and improving the engineering properties of fine-grained soil. Due to the lack of good

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quality soil and the urge for reutilizing the poor quality excavated materials (e.g. clay), lime stabilization is now globally recognized as one of the most common soil stabilization methods because of its ease of construction and economy as well. Several researchers paid attention to investigate the influence of lime in improving the soil performance in terms of strength, stiffness and compressibility [4–10].

Addition of lime for soil stabilization can modify the properties of soil significantly, as four basic reactions (such as cation exchange, flocculation/agglomeration, carbonation and pozzolanic reaction) that take place in the soil–lime mixture [11, 12]. The alteration of long-term soil properties (e.g. improvement in strength and deformation behaviour of soils) is caused by pozzolanic reaction that might depend on the type and amount of clay minerals and duration of interaction [4].

Hence, in this study, the effects of the reactions, between clay minerals (present in the Dhaka clay) and lime, on the alteration of engineering properties of soil were investigated for different percentages of lime over a period of a month. The effect of additional pozzolanic agent (i.e. local fly ash) along with lime was also investigated.

2 Experimental Program

In this study, natural clay collected from Dhaka, Bangladesh was chosen. Different percentages of lime were added to Dhaka clay as stabilizing agent, and its effects were investigated on different engineering properties of soil. The untreated soil and the soil treated with lime were tested for the determination of liquid limit, plastic limit, optimum moisture content, maximum dry unit weight, unconfined compressive strength and CBR. While investigating unconfined compressive strength, the effect of fly ash that was added to the soil as an additional pozzolanic agent along with lime was also investigated.

In conducting liquid limit, plastic limit and standard Proctor tests, soil and lime (of predetermined quantity) were added with water and mixed thoroughly to form a mixture of uniform consistency and then waited for 1 h before conducting tests. Liquid limit test was conducted using Cassagrande's apparatus, and plastic limit test was conducted by thread rolling method.

The soil–lime mix was compacted at optimum moisture content in cylindrical metallic mould of 38 mm in diameter and 76 mm in length. Unconfined compressive strength test was conducted on the prepared samples after desired time periods (i.e. 3, 14 and 28 days). Soaked CBR tests were conducted for both untreated and treated soils.

3 Experimental Results and Discussions

When lime was added to Dhaka clay, improvement in workability was immediately observed. In literature, this immediate effect is believed to depend on the cation exchange capacity and the type of exchangeable ions present in the soil [3].

Liquid limit (LL), plastic limit (PL) and plasticity index (I_p) were determined for Dhaka clay with different percentages of lime varying from 0 to 12%, as shown in Fig. 1. According to Cassagrande's plasticity chart, the untreated Dhaka clay is classified as CL, while the soil with any percentage of lime changes the classification to ML. This implies that the natural clay soil is transformed to a silty soil due to lime stabilization. Similar observation was noted for black cotton soil studied by [3].

Unlike the residual soil studied in [2], both LL and PL of Dhaka clay increase with the increase of lime content. However, plasticity index (I_p) decreases for both the soils due to the increase in lime content. According to [3], index properties indicate that lime treatment will be favourable for Dhaka clay.

Standard Proctor compaction tests were carried out to determine the optimum moisture content of Dhaka clay in untreated natural composition and also that with different percentages of lime. The compaction curves obtained from this investigation are presented in Fig. 2.

It can be noted that percentage of lime added to the natural Dhaka clay does not show any significant influence on the maximum dry unit weight $\gamma_{d(max)}$ obtained from standard Proctor test. For addition of 8% or more lime, almost the same value of $\gamma_{d(max)}$ was obtained. The experimental results also show that the optimum moisture content increases from 15.5 to 21% due to the increase in lime content from 4 to 16%, respectively. Similarly, increase in optimum moisture content was also obtained even for silt soil [8], as lime changes the soil characteristics significantly. However, silt soil showed decrease in $\gamma_{d(max)}$ due to lime treatment.

In natural composition, the unconfined compressive strength of Dhaka clay as compacted at optimum moisture content was determined about 300 kPa. This chapter presents the unconfined compressive strength of Dhaka clay when

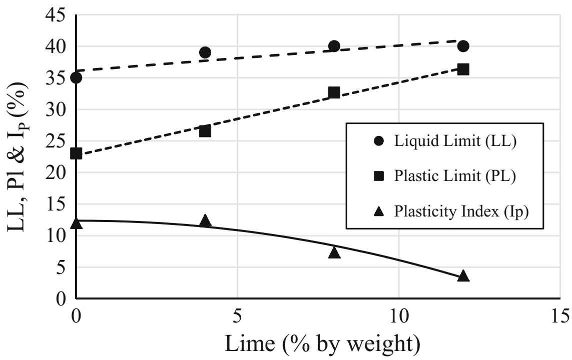

Fig. 1 Effect of different percentages of lime on the consistencies of Dhaka clay

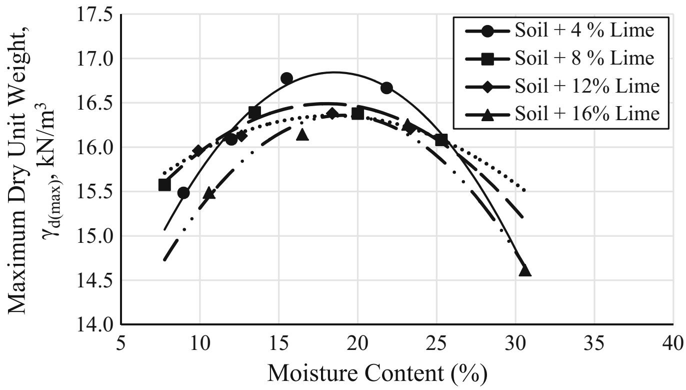

Fig. 2 Effect of different percentages of lime on compaction characteristics of Dhaka clay

stabilized with different percentages of lime and fly ash. The effect of ageing upon stabilization and compaction was also investigated at the same moisture content.

Figure 3 presents the stress–strain behaviour of the Dhaka clay stabilized with 4% lime at three different ages (3, 14 and 28 days) from unconfined compressive strength test results. It can be noted that the stabilized and compacted soil takes about a month to attain significant increase in undrained shear strength. At the age of 3 and 14 days, similar stress–strain behaviour was observed. The soil showed brittle behaviour at the age of 3 days but exhibit ductile type behaviour at the age of 14 or 28 days. Similar increase in unconfined compressive strength was observed in previous studies [6]. In addition, strain at failure had reduced below 1% after lime treatment in both cases.

Further, the effectiveness of lime admixture with/without additional pozzolanic agent, fly ash, was studied in terms of stress–strain behaviour in unconfined

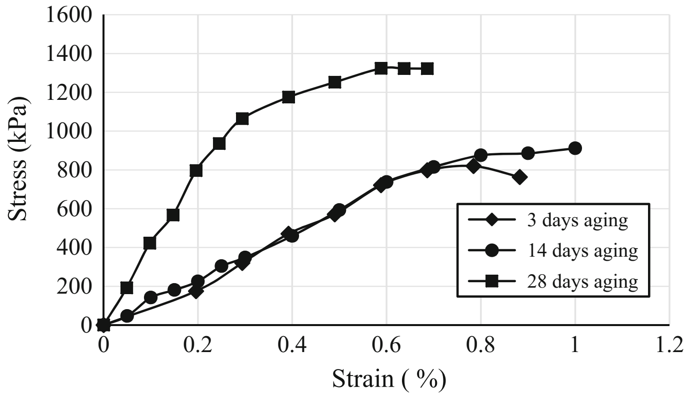

Fig. 3 Effect of ageing on unconfined compressive strength of Dhaka clay with 4% lime

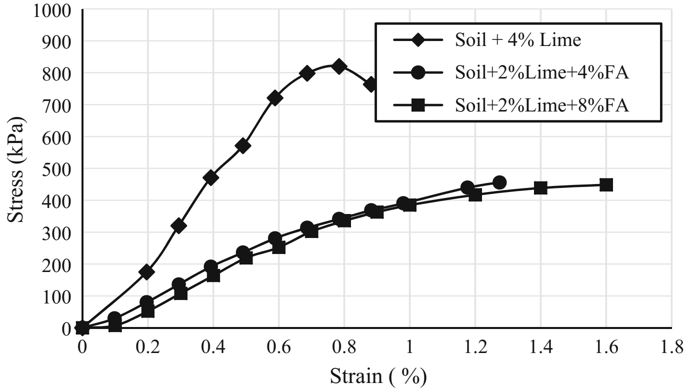

Fig. 4 Effect of different admixtures on unconfined compressive strengths of Dhaka clay at the age of 3 days

condition at the age of 3, 14 and 28 days, as shown in Figs. 4, 5 and 6. For this comparison, three different combinations of lime and fly ash admixtures, such as only 4% lime, 2% lime & 4% fly ash and 2% lime and 8% fly ash, were considered.

For all cases of stabilized soil, strain was observed below 1.5% at failure. At the age of 3 days, the percentages (4 or 8%) of fly ash with 2% lime did not show significant influence on the stress–strain behaviour.

Ultimately, soil stabilized with 2% lime with 8% fly ash showed greater undrained shear strength than that stabilized with 2% lime and 4% fly ash. In any case, soil stabilized with 4% lime gave significantly higher undrained shear strength than other two cases. Inclusion of additional pozzolanic agent was not found significant in increasing strength over a period of a month.

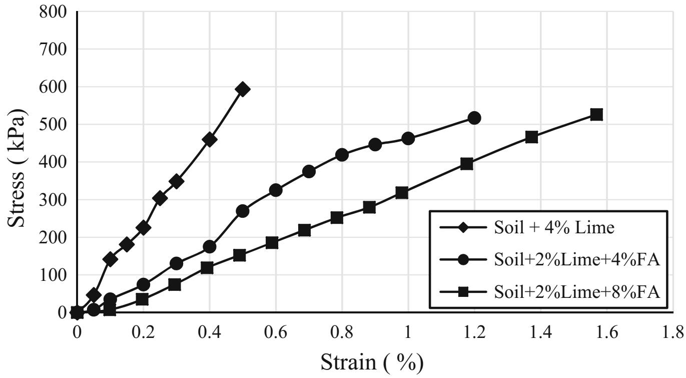

Fig. 5 Effect of different admixtures on unconfined compressive strengths of Dhaka clay at the age of 14 days

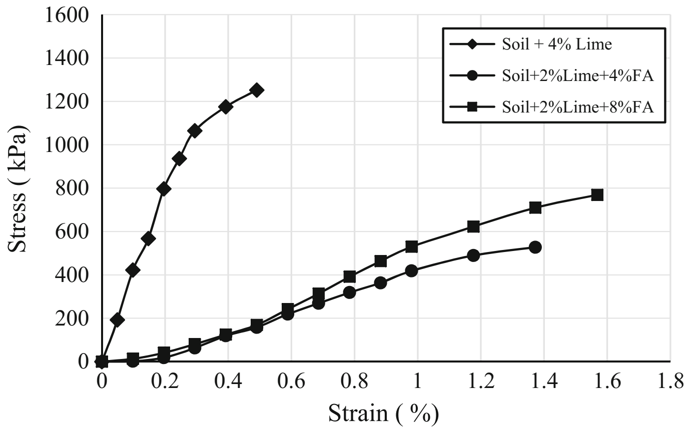

Fig. 6 Effect of different admixtures on unconfined compressive strengths of Dhaka clay at the age of 28 days

CBR tests were conducted on the soil samples in natural composition and also with different percentage of lime admixture. The stress versus penetration results are presented in Fig. 7. The CBR values are presented in Fig. 8.

It can be noted that though CBR of Dhaka clay (in natural composition) was obtained 4.5%, CBR values are greatly increased after stabilization with both 2% lime and 4% lime. CBR is found to vary linearly with the percentage of lime added to the soil for stabilization.

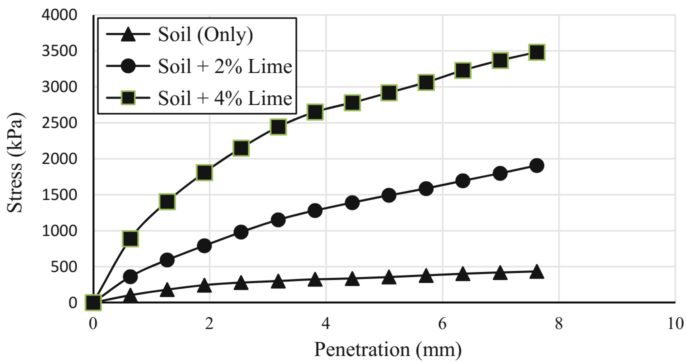

Fig. 7 Stress versus penetration curves from CBR tests

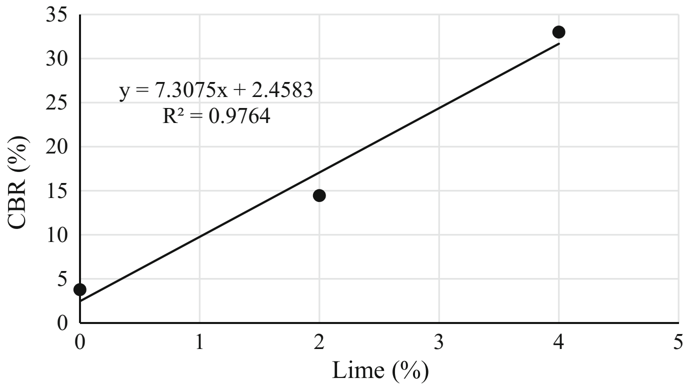

Fig. 8 Effect of lime admixture on CBR

4 Conclusions

Based on the experimental results and analysis, the following conclusions are drawn:

1. Addition of lime with Dhaka clay (i.e. CL) can significantly change the type of soil to low plastic silt according to unified soil classification system.
2. The optimum moisture content increases with the percentage of lime added to Dhaka clay for stabilization. The lime content has not shown any significant improvement in terms of γd(max).
3. When the Dhaka clay is stabilized with 4% lime, the undrained shear strength can be obtained about four times higher than that in natural composition.
4. When fly ash is added in combination with lime, the rate of gaining undrained shear strength was observed slow.
5. CBR values were found to vary linearly with the lime content for Dhaka clay. Lime stabilization can be considered advantageous for improving the ground proposed for roads and highways.

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