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Stabilization of Expansive Soil by Lime and Reinforcement

Neha Sen
Aryan Institute of Engineering & Technology, Bhubaneswar

ABSTRACT: This paper manages the review on strength improvement of expansive soil by the joined use of lime and geosynthetic support. A progression of unconfined pressure tests have been led on soil blended in with various rates of lime (2, 4, 8, 12 and 16%) and for various relieving periods (3, 7, 14 and 28 days). Huge upgrades in strength with expansion in lime-content have been noticed. At 2, 4, 8, 12 and 16% of lime content the strength enhancements were observed to be 2.5, 3.5, 8.4, 8.7 and 8.5 occasions individually than that of untreated soil. Expecting better strength and malleability attributes, geosynthetic support have been brought into lime balanced out soil tests in three equivalent layers. With the geosynthetic support the soil lime blends have shown improved strength that kept on expanding with expansion in lime content. With 2, 4, 8, 12 and 16% of lime, the geosynthetic support actuated strength upgrades were observed to be 2.6, 3.8, 8.6, 9.5 and 11.3 occasions separately. In this manner these outcomes set up that the geosynthetic support can additionally upgrade the exhibition of lime treated expansive soils.

INTRODUCTION

Expansive soil is a problematic soil and one of the prevalent causes of damage of infrastructures. It swells when the water content increases, and shrinks as it dries out. Therefore, during rainy season, such a soil increases in volume by absorbing water, and in dry season it reduces in volume by evaporation of water. In the process it exerts severe force of expansion mainly on the lightly loaded structures such as pavements, canal beds and linings, residential buildings etc. and causes damage to them. In countries like United States it has been reported that damages caused by expansive soil has exceeded the average annual damage caused by natural disasters like floods, hurricanes, earthquakes and tornados [1]. In India expansive soil covers almost one fifth of its area. They mostly are found in Maharashtra, Gujarat, Uttar Pradesh, Rajasthan, Madhya Pradesh, Andhra Pradesh and Tamilnadu [2].

Expansive soil is characterised by small particle size, a large specific surface area (SSA), a high cation exchange capacity (CEC) and a high liquid limit and plasticity index [3]. It also shows very poor strength behaviour and thus need to be improved before any construction on it. There are many methods e.g. mechanical stabilization, chemical stabilization, stabilization with additives, thermal stabilization etc. for improvement of expansive soil. At present, chemical stabilization is the most effective and cheap method where the soil properties are altered and made less plastic, less expansive, more workable and of high strength by using different chemicals mostly lime, cement, magnesium oxide, calcium chloride, gypsum etc. [1, 3, 4]. Though it has been observed from most of the investigations that lime treatment is the most effective method in performance improvement of expansive soil out of all chemical treatment methods [1, 3, 4].

Stabilization of expansive soil by lime is now a well-established method. It satisfies both from the point of meeting the desired engineering properties of soil and also from the cost aspects. When lime is added to clay soil in presence of water, a number of reactions take place leading to the improvement of soil properties. These reactions are mainly cation exchange, flocculation and pozzolanic reaction [5, 6, 7]. Cation exchange takes place by the substitution of the monovalent cations (sodium or potassium ions) associated with the surfaces of the clay particles by the divalent calcium cation (Ca^{2+}) from lime (CaO). This balances the electrostatic charges of the layers of clay and reduces the electrochemical forces of repulsion between them. In this condition, adhesion between the soil particles occurs and yields a flocculated structure. This structure is relatively a granular structure of low plasticity, low swelling potential and better permeability. This process is termed as flocculation [3]. Flocculation is primarily responsible for the modification of the engineering properties of clay when treated with lime. These reactions are very swift and occur within a few minutes of mixing. Secondly, lime addition to soil causes pozzolanic reaction to occur which is mainly responsible for its enhanced strength. When lime is added to soil, there forms an abundance of OH^- ions, which increases the pH (approximately upto12.4) of the soil solution. At such high pH, the Silica and Alumina constituents of clay sheets gets dissolved and combine with Ca^{2+} ions from lime yielding cementing compounds such as Calcium Silicate Hydrates (CSH) and Calcium Aluminate Hydrates (CAH). These compounds are mainly responsible for improving the strength and durability of soil. These compounds also reduce expansivity of the soil by their cementing action [3].

Recently, performance improvement of expansive soil using geosynthetics such as geotextiles, fibers etc. with or without additives have been investigated with significant success [8, 9, 10]. Studies conducted on clay soil reinforced with different layers of non-woven geotextile or geomesh etc. have shown enhanced strength attributed to the increase in internal friction angle of reinforced soil [10].

In spite of all these available methods for the treatment of expansive soil, it still has been felt for the importance to study the effect of combined treatment of such methods so as to obtain a more improved technique to deal with this problematic soil. So in this research wok an attempt has been made to study the effect of combined treatment of lime and geosynthetic reinforcement on strength behavior of expansive soil.

Materials and Methods

Expansive soil used in this study is a commercially available bentonite. The detailed properties are presented in table 1.

Table 1 Properties of the expansive soil

Property	Quantity
Specific gravity	2.64
Liquid limit (%)	450.4
Plastic limit (%)	48.2
Plasticity index	402.2

Lime used in the study is a commercially available laboratory reagent grade quick lime (CaO) obtained from S. D. Fine Chem. Ltd. Mumbai, India. Properties of lime are listed below in table 2.

Table 2 Properties of lime

Property	Quantity
Physical appearance	Dry powder
Colour	White
Molecular weight	56.08
Specific gravity	3.1
Minimum assay (%)	95

The geosynthetic reinforcement that was used in this study has the following properties mentioned in table 3.

Table3 Properties of the geosynthetic reinforcement

Property	Quantity
Thickness (mm)	0.4
gm/cm^2	9.76× 10-3
Tensile strength (kN/m)	5.7
Secant modulus at 5% strain (kN/m)	5.5

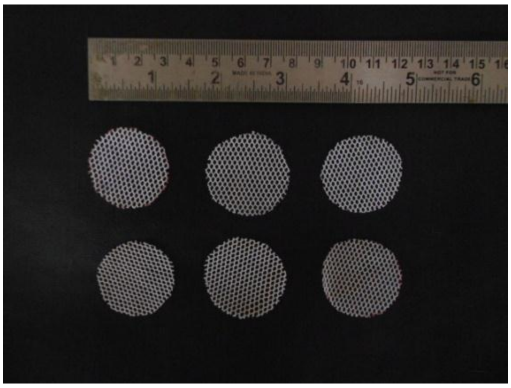

Fig. 1 Geosynthetic reinforcement

Planning of Experiments

In the 1st phase of the investigation, a series of compaction tests have been performed on the expansive soil and expansive soil mixed with different percentages of lime (2%, 4%, 8%, 12% and 16%). This was to study the effect of lime addition on dry density-moisture content responses. From the response curves the optimum moisture contents (OMC) for all the combinations of soil lime mixes were obtained with respect to the corresponding maximum dry density (MDD) conditions. For all the compaction tests, a mini compaction apparatus has been used [11]. This apparatus was developed by Sridharan and Sivapullaiah and is suited for fine grain soils. The mini compaction apparatus requires only 1/10th of the volume (approximately 200gm) of the soil compared to standard proctor test and consumes very less time and effort. The apparatus mainly consists of a brass mould, a base plate, a removable collar and a steel drop hammer with guide frame (Fig. 2). The mould is of 38.1mm internal diameter, 46.1mm external diameter and height of 100mm. Soil samples required for all the unconfined compression tests in this study have also been prepared in this mould.

Fig. 2 Mini compaction apparatus [11].

In the 2nd phase, samples for unconfined compression tests have been prepared by mixing expansive soil with the mentioned percentages of lime, and compacting at their respective OMC and MDD conditions. These samples were then kept for different curing periods (i.e. 3, 7, 14 and 28 days). After attaining required curing periods, samples have been checked for any change in their weight and length parameters and finally tested in the unconfined compression testing machine. All soil

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samples have been tested maintaining a strain rate of 1.25 mm/min throughout the investigation program.

In the 3rd and final phase of the investigation, lime stabilized soil samples reinforced with 3 layer of geosynthetic reinforcement or geomesh have been prepared and tested for its unconfined compressive strength. The reinforcement layers were cut circular at a diameter of 34 mm and are placed at equal intervals in a soil sample in every case.

RESULTS AND DISCUSSION

Compaction Characteristics

Expansive soils are normally highly plastic. The bentonite used in this study has a plasticity index of 402.2. Because of such high plasticity, it becomes difficult to compact it properly in compaction mould. But when lime has been added to expansive soil, some significant changes in their compaction characteristics have been observed. Figure 3 shows compaction curves for expansive soil with different percentages of lime content (0, 2, 4, 8, 12 and16%).

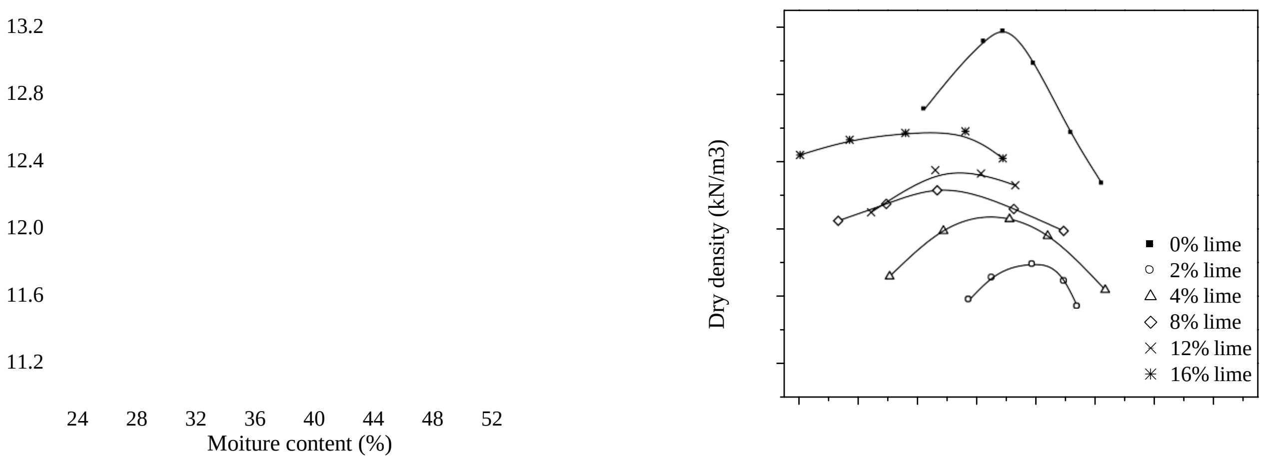

Fig. 3 Moisture content v/s dry density relationship for expansive soil at different percentage of lime.

It has been observed that, when 2% lime by dry weight of soil is added to expansive soil, the maximum dry density (MDD) of the mix reduces and optimum moisture content (OMC) of the soil increases than to soil with 0% lime. This is similar to the result obtained from many studies [12, 13]. It is attributed to the flocculation process that is initiated due to addition of lime which results a card house type of clay structure that resist the compaction effort giving lower density and higher moisture content [12]. With further increase in lime content, MDD starts to increase and continue to increase upto 8% lime, while it's OMC starts decreasing. This is because, when lime content is further increased beyond 2%, this results a relatively dispersed soil structure, thereby allows the soil particles to slide over each other and give a denser structure [12]. At lime content beyond 8%, the MDD of the soil continue to increase but OMC of the soil-lime mix again slightly increases, though the mechanism for this increase is not much clear and needs a further investigation.

From fig.3, another important observation is that-lime treatment has made the compaction curves flatter. This indicates that the desired density can be achieved over a relatively wider range of moisture content. This in other way manifests its improved workability due to addition of lime [12].

Strength Characteristics

In fig. 4, the variation of unconfined compressive strength of the expansive soil and expansive soil treated with different percentages of lime, at varied curing period has been shown. It should be mentioned here that the peak compressive stress (average of the peak stress of three soil samples) at which failure takes place is reported as the unconfined compressive strength of the soil sample.

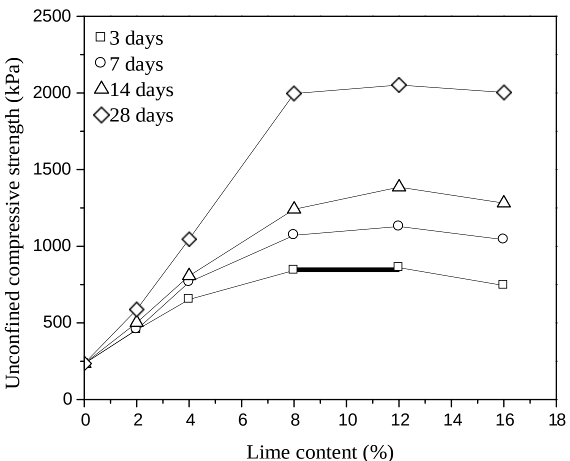

Fig. 4 Unconfined compressive strength v/s lime content for expansive soil-lime mixes

It has been observed that at 2% lime content,

kPa to 456 kPa, 457 kPa, 503 kPa and 588 kPa at 3, 7, 14 and 28 days of curing periods respectively. Thus the fig. clearly shows the significant effect of curing on strength behaviour of soil-lime mixes. With further increase in lime content, the increase in strength continues. At 4, 8, 12 and 16% lime content, strength achieved at 28 days are 827 kPa, 1996 kPa, 2051 kPa and 2003 kPa respectively.

Therefore it is clear from the results that addition of lime beyond 8%, rate of strength gain reduces. Further addition of lime content beyond 12% (i.e. at 16% lime content), some reduction in strength has been observed. It may be because of the fact that lime in itself does neither has appreciable friction nor cohesion, and a high lime content serve as a lubricant within the soil particles leading to lesser strength [12].

In the next phase, it has been observed that using geosynthetic reinforcement or geomesh the strength of lime treated soil can be further enhanced. Figure 7 shows unconfined compressive strength of reinforced expansive soil- lime mixes vs. lime content at different curing periods. It has been observed that reinforced expansive soil with 2, 4, 8, 12 and 16% lime strength achieved at 28 days curing are 628 kPa, 902 kPa, 2035 kPa, 2245 kPa and 2667 kPa respectively.

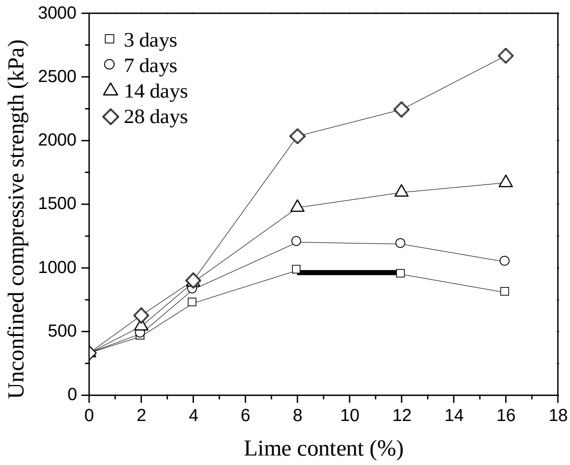

Fig. 5 Unconfined compressive strength vs. lime content for reinforced expansive soil-lime mixes.

Improvement Factor

strength of the expansive soil increases from 235

In this research work this term "Improvement Factor" has been used to clearly define the magnitudes of improvement ratio of expansive soil upon treatment of lime and reinforcement. It can be defined as the ratio of unconfined compressive strength of treated soil to the unconfined compressive strength of untreated expansive soil (IF).

Let us denote the improvement factor for only lime treated soil as IF_1. From the fig. 6 the ratio of strength improvement (or the trend of strength improvement) upon lime treatment can be directly obtained. For example at 2, 4, 8, 12 and 16% lime content and at 28 days curing period improvement factors i.e. strength improvements are 2.5, 3.5, 8.4, 8.7 and 8.5 times than to untreated expansive soil.

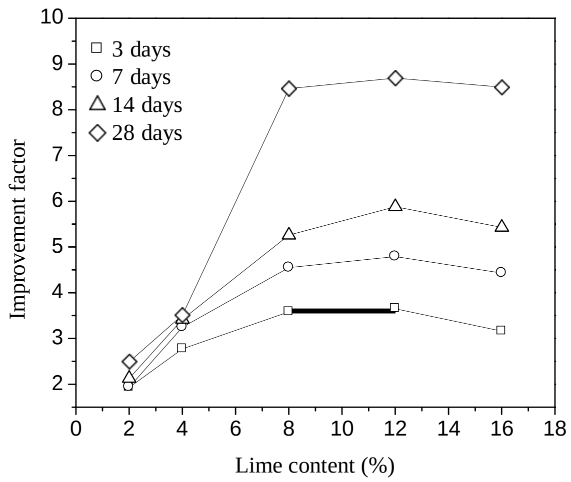

Fig. 6 Improvement factor vs. lime content for expansive soil-lime mixes.

In a similar way, let us denote the improvement factor for lime treated reinforced expansive soil as IF_2. The improvement factor IF_2 is defined as the ratio of unconfined compressive strength of lime treated reinforced soil to the unconfined compressive strength of expansive soil alone. From fig. 7 we can obtain the improvement factor (IF_2) of lime treated reinforced soil to the untreated soil. As for example, at a curing period of 28 days 2, 4, 8, 12 and 16% lime treated reinforced soil shows improvement factor i. e. strength improvements of 2.6, 3.8, 8.6, 9.5 and 11.3 times respectively than to untreated soil.

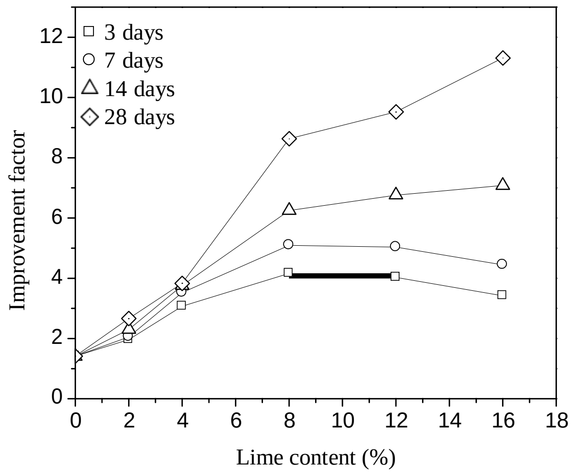

Fig. 7 Improvement factor vs. lime content for reinforced expansive soil-lime mixes.

CONCLUSIONS

This paper has studied the effect of combined application of lime and geosynthetic reinforcement on expansive soil. Addition of lime to expansive soil brings significant changes in compaction and strength behaviour of expansive soil. Also, reinforcing the lime stabilized soil samples with geosynthetic reinforcement showed further improvement in strength behaviour of expansive soil. For better comparison of the data, a term improvement factor (IF) has been introduced. It is the ratio between unconfined compressive strength of treated soil to the unconfined compressive strength of untreated soil. From the tests conducted on different expansive soil-lime and reinforced expansive soil- lime- mixed samples, the following main conclusions can be drawn,

1. At 28 days curing expansive soil with 2, 4, 8, 12 and 16% lime shows improvement in strength by 2.5, 3.5, 8.4, 8.7 and 8.5 times than to only expansive soil.
2. Geosynthetic reinforcement further enhances the strength of lime treated expansive soil. At 28 days curing, reinforced expansive soil with 2, 4, 8, 12 and 16 % lime shows improvement by 2.6, 3.8, 8.6, 9.5 and 11.3 times respectively.

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