Influence of Lime on Plasticity Behaviour of Soils

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ABSTRACT

This paper presents the influence of lime, in the range of 0-13%, on the plasticity behavior of soils with wide range of plasticity characteristics (i.e. liquid limit varying from 45% to 460% and plastic limit 26% to 53.7%). The test results indicate that, there is an immediate decrease in plasticity index with increase in the lime content. However, the plasticity index of the lime treated soil increases with increased duration of curing. The soils, which are high plastic clay (CH), just with 3% lime, have changed to silt (CM). However, 5% lime content can be considered as lime fixation point that can provide substantial increase in the workability of the soils.

1. INTRODUCTION

The workability of a soil is closely related to its plasticity characteristics that primarily depends on the water holding capacity of the soil and is quantified through index properties such as liquid limit, plastic limit and plasticity index. The expansive soils due to their large water holding capacity are highly difficult material to be handled in construction sites. This problem can be overcome by altering the soil through addition of non expansive soil and chemicals such as lime, cement etc. In the recent past several investigations have been reported highlighting the beneficial use of lime for improvement of workability of clay soils (Herrin and Mitchell 1961, Prakash et al. 1989, Bell 1996, Sivapullaiah et al. 1996, 2000). This paper presents the results of the experiments aimed at understanding the plasticity behaviour of a highly expansive soil (ES) modified through addition of a non expansive residual soil (RS) and lime. The influence of the time-dependent effects of pozzolanic reactions on the plasticity characteristics are brought out through a series of tests carried out at different curing periods.

2. MATERIALS AND METHODS

Primarily an expansive soil (ES) and a residual soil (RS) that represent the extreme types of soil are used in the present study. Expansive soil used in this study is a commercially available bentonite. This soil, a typical of highly expansive clay, has montmorillonite as chief clay mineral. The specific gravity, liquid limit, plastic limit and shrinkage limit of this soil are found to be 2.63, 459.94%, 53.7% and 7% respectively. As per ASTM D2487, the soil is classified as clay with high plasticity (CH). The residual soil used consists of 83% fines in which silt is predominant (71.74%). The specific gravity, liquid limit, plastic limit and shrinkage limit of this soil are found to be 2.67, 45.33%, 25.99% and 25.45% respectively. As per ASTM D 2487, the soil is classified as clay with medium compressibility (CI).

A laboratory reagent grade quick lime (CaO) is used in this investigation.

For the preparation of test samples required amount of oven dried residual soil and expansive soil were measured and dry mixed together thoroughly. Lime was mixed with these soil samples at 0%, 1%, 3%, 5%, 9% and 13% by weight of dry soil sample. A large amount of water (i.e. greater than liquid limit) was added to the soil/soil-lime mixture, and mixing was done frequently by hand. The soil samples thus prepared were kept in polythene bags and sealed. These sealed packets were kept in desiccator under 100% relative humidity and were cured for 0, 3, 7, 21 and 28 days at room temperature. After curing is done the samples were again mixed thoroughly before the tests were done.

3. RESULTS AND DISCUSSION

Variation of Liquid Limit

The variation of liquid limit with lime content and curing period for different soil mixes (i.e. 100%ES, 80%ES+20%RS, 60%ES+40%RS, and 100%RS) are depicted in Fig. 1 to Fig. 4 respectively. It could be observed that, in general, for all soils initially there is a decrease in liquid limit with increases in lime content. This reduction is maximum for expansive soil (100%ES) and gradually reduces with increased content...
of residual soil. For expansive soil the liquid limit continues to reduce till 3% lime content, beyond which the increased lime content has marginal effect on the liquid limit. However, at very high lime content (i.e. 13%) and long curing period (i.e. 28 days) the liquid limit of the expansive soil has shown an increasing trend. This increasing trend gradually grows more prominent with increased percentage of residual soil and curing period (Fig. 2 to Fig. 4). Addition of lime leads to increase in pH of soils. In an alkaline environment with pH value above 12, there occurs formation of Calcium Silicate Hydrate (C-S-H) gel, which consists of solid products of hydration and water that is held physically or adsorbed on surface of the hydrates. In addition to gel water there exists water which is combined chemically or physically with the hydrates. This large amount of water significantly marginalizes the influence of the double layer reduction induced decrease in water content and thereby the liquid limit. Indeed, the increase in liquid limit with increase in lime content is more incase of residual soil that has high silica content leading to formation of higher quantity of CSH gel thereby the increase in gel water content and hence the liquid limit. Hence it can be said that soil having high silica content are prone to have increased liquid limit, due to lime induced pozzolanic reactions. With increased duration of curing thereby increased duration of pozzolanic reaction produces increased quantity of the water holding gelatinous products leading to increased liquid limit.

Variation of Plasticity Index

The plasticity index variations for different soils are depicted in Figs. 5, 6, 7 and 8. It could be observed that, in general, soils have shown an immediate decrease in plasticity index upon addition of lime. However increasing the lime content beyond 5% had a marginal effect in further reducing the plasticity index. In general the plasticity index increases with increase in curing period however it is more prominent for the increased percentage of residual soil. This is attributed to the silica gel that enhances the water holding capacity of the soil.

Fig. 9 shows that in most of cases the lime treated soils have crossed the A-line to the silt (M) region indicating that the clay soil upon lime treatment has transformed itself to silt. Exceptions were for the specimens with 1% lime indicating that the low quantity of lime is not sufficient enough to convert the high plastic clays (CH) to silt.
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Fig. 6: Variations of Plasticity Index with Lime Content for Expansive Soil-Residual Soil Mix (80%ES+20%RS)

Fig. 7: Variations of Plasticity Index with Lime Content for Expansive Soil-Residual Soil Mix (60%ES+40%RS)

Fig. 8: Variations of Plasticity Index with Lime Content for Residual Soil (100%RS)

Fig. 9: Effect of Lime on Plasticity of Soils

4. CONCLUSIONS

Based on the results obtained, the following conclusions can be made on the behaviour of residual soil-lime treated expansive soils.

1. The liquid limit, irrespective of the clay soils, initially reduces with increase in lime content. Beyond about 3% of lime the liquid limit for expansive soils practically remains unchanged. But for soils having larger fraction of silica rich residual soils the liquid limit has once again shown increasing trend at higher lime content. This trend is more prominent at higher curing period. The initial reduction is attributed to the reduction in the thickness of double layer due to increased electrolyte concentration in the pore fluid. For silica rich soils with increased lime content there takes place pozzolanic reactions forming gelatinous materials. These gel materials hold a very large amount of water onto themselves leading to increased liquid limit.

2. 5% lime content can be considered as lime fixation point that can provide substantial increase in workability of the soil.

3. Even high plastic clay, just with 3% lime, changes to silt.

REFERENCES


