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A Study on Swelling Characteristics of Lime Stabilized Soils

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ABSTRACT: Soil is critical material that influences the successful completion of any construction project. Soils are expansive in state. Such problematic soils need to fix by stabilization technique. It is to modify the soil behavior by altering physical and chemical properties. So it is very important to determine the soil characteristics before undertaking any project. In India black cotton soil is one of the utmost deposits, covering 20% area of land. It is one of the major problematic soil comprises of montmorillonite as the principle clay mineral, which renders a high degree of swelling and shrinkage behavior. Owing to such poor soil its shear strength and high swelling and shrinkage properties through volumetric change of soil due to change in moisture content around environment. In this study, a novel approach has been made to understand the reaction and modification in liquid limit, compaction characteristics, swelling and shrinkage characteristics of stabilized soil composites comprising of different varying percentages of soil, lime and cement. The percentage of lime used is 3%, 6%, 9%, 12% and 15% with 3% of cement in each of the soil composites. On the soil sample basic tests such as grain size distribution, liquid limit, plastic limit, standard proctor test, unconfined compressive strength and free swell index test are carried out. The soil composites are prepared by substituting the soil with different percentages of lime and cement. On each of the stabilized soil composites liquid limit, plastic limit, standard proctor test are carried out and the soil composites are tested to evaluate the swelling and shrinkage characteristics. For each of stabilized soil composite relation between the liquid limit with lime content, optimum moisture content with lime content, swelling percent with no of curing days has been established. In the field these relations are helpful in evaluating the WL, WP, OMC, Swelling percent values for stabilized soil composites at different lime content

KEYWORDS: Soil sample, lime, Cement.

I. INTRODUCTION

Soil is critical material that influences the successful completion of any construction project. Soils are expansive in state. Such problematic soils need to fix by stabilization technique. It is to modify the soil behavior by altering physical and chemical properties. So it is very important to determine the soil characteristics before undertaking any project. In India black cotton soil is one of the utmost deposits, covering 20% area of land. It is one of the major problematic soil comprises of montmorillonite as the principle clay mineral, which renders a high degree of swelling and shrinkage behavior.

Owing to such poor soil its shear strength and high swelling and shrinkage properties through volumetric change of soil due to change in moisture content around environment. In this study, a novel approach has been made to understand the reaction and modification in liquid limit, compaction characteristics, swelling and shrinkage characteristics of stabilized soil composites comprising of different varying percentages of soil, lime and cement. The percentage of lime used is 3%, 6%, 9%, 12% and 15% with 3% of cement in each of the soil composites. On the soil sample basic tests such as grain size distribution, liquid limit, plastic limit, standard proctor test, unconfined compressive strength and free swell index test are carried out. The soil composites are prepared by substituting the soil with different percentages of lime and cement. On each of the stabilized soil composites liquid limit, plastic limit, standard proctor test are carried out and the soil composites are tested to evaluate the swelling and shrinkage characteristics. For each of stabilized soil composite relation between the liquid limit with lime content, optimum moisture content with lime content, swelling percent with no of curing days has been established. In the field these relations are helpful in evaluating the WL, WP, OMC, Swelling percent values for stabilized soil composites at different lime content and to the super structures exposed by heaving, cracking, swelling, unevenness, settlement and splitting-up of the pavements. The increase in the

volume of the expansive soil when soil comes in contact with water particles required to surface properties. The pressure which the expansive soils exhibits, if it's not allowed to swelling or change in the volume of soils is arrested is known as swelling pressure of the soil. It depends upon amount of clay particles in the soil and nature of a clay mineral, initial moisture/water content and weight of dry density and including confining pressure, finally swell-shrink cycles subjected to the soils. Swelling occurs in unsaturated soils during saturation process. The compacted unsaturated dry soil mass of optimum are more vulnerable to drastic change in volume upon saturation. The change in a volumetric swell -shrink behaviour on wet and dry process of soils is based on the osmotic pressure theory. Swelling of the soil occurs under low normal stress during saturation process. And other side, sudden decrease in volume followed by a gradual swell will be analyzed under high normal stresses. The sudden and consequential decrease in the volume is known as "Volumetric Collapse". This scant natural stability must be fix up to make them befitting for construction projects. Numerous stabilization techniques are implemented to intensify the swelling characteristics of the BC Soil.

Lime is a frequently used additive for modification and stabilization purpose. Upon addition of lime content to the soil mass in presence of water, a physiochemical reaction takes place. After immediate addition of lime, negatively charged soil surface gets neutralized by the positively charged calcium cations. The calcium ion of lime reacts with silica and alumina present in the clay particles of soil to form Table pozzolanic compounds calcium silicates and calcium aluminates. Both reactions are non-simultaneous. Neutralization of the charges takes place immediately although the pozzolanic reaction is time sensitive which might get prolonged for a longer duration. Lime is used to ameliorate strength and minimizeswell, shrink and compressibility characteristics of clay in case of shallow and deep stabilization. Initially, application of lime was widely adopted in road works and lately with apprehension, availability and handiness of techniques for deeper application of lime; its use has been broadened to many areas such as foundations, slopes, tunnels and embankment and stabilization of sensitive clays.

The modification in the mechanism of soil behaviour due to addition of lime is clearly acknowledged. Numerous factors such as soil gradation, nature of exchangeable ions, type and amount of lime, Ph, quantity of lime, organic matter, water content, curing periods and temperatures influence the reactions between soil and lime. Strength due to addition of lime enhances, depending upon the quantity of lime available is above/below the lime fixation point. Optimum level of lime content that brings down the negative charges present on the soil and thereby reduces the chemical activity of the clay is called as lime fixation point. Occurrence of clay flocculation due to substitution of exchangeable monovalent cations by positively charged divalent ions of calcium results in enhancing strength up to lime fixation stage. It was observed from the earlier works that as lime content increases, activity of the expansive soil decreases and results as stable mass. But the lime fixation point was a challenge because the optimum lime content depends very much on the quantity of lime used for stabilization as well as on the moisture available for the reaction to occur between soil and lime. Since two variables are to be handled simultaneously for fixing optimum lime content, researchers have used optimum moisture content of un-stabilized soil and added moisture content beyond that to fix up optimum lime content which has been very satisfactory. A novel approach was proposed for lime stabilized soil composites over the earlier methods of lime fixation point, each percentage of lime added results in new stabilized soil composite and properties like MDD, LL, corresponding OLC and strength properties of the stabilized soil composites are to be determined. Also in the present study it is proposed to analyze the swelling and permeability characteristics of lime stabilized soil composites

II. LITERATURE WORK

An made attempt to stabilize expansive soils using cementitious materials, industrial wastes, chemicals, agriculture waste etc. Tests have been carried out to stabilize expansive soils using bagasse ash, cement, lime and/or combination with some other materials. P V Sivapullaiah et al [] studied the significance of the lime fixation point of expansive Indian black cotton soil on the compaction characteristics. Lime percentage varied as 1%, 2% and 6%. Compaction tests were carried out after curing for 1 and 7 days. UCS test were conducted once the soil samples kept for curing period of 1, 6, 13 and 27 days, soaking for 1 day before testing, for various water contents. The influence of lime on compaction characteristics and strength characteristics was analyzed. It was concluded that, lime fixation below the point, MDD gradually decreased with lime and strength improved marginally. Time elapsed between moist blending and compaction below lime fixation was less critical. The Lime fixation above the point, there is no substantial change in compaction curve was observed whereas strength improved considerably. There was steep reduction in MDD and strength above the lime fixation point for compaction of soil. As elapsed, the effect was observed in between the extremes at about the lime fixation point.

P V Sivapullaiah et al []studied the significance of type and amount of lime and clay in the lime stabilization .Main objective was to understand the influence of time for curing (7days) and quantity of lime. BC soil having different percentages of clay content (40%, 35%, and 19%), commercially available kaolinite and chemically pure hydrated lime (1%, 2%, 3%, 6%, 9% and12%) has been used in the study. The Atterberg limits and swell index (FSI) tests were conducted on soil with varying percentages of lime. At 6% optimum percentage of lime was determined at varying percentage of clay, mixed with BC soil. Test results of addition of different percentage of lime on WL, WP, PI, SL and Swell Index of black cotton soil. Experimental results obtained for various curing time and clay contents and 6% lime has been plotted. Time period for curing on the WL and PI and WL and SL of soil in the presence and absence of lime treatment has also been plotted. Test results showed that, for natural BC soil optimum lime content is observed, with increased curing period WL decreases for any lime percentage. The shrinkage limit increases initially. Change in the shrinkage limit is much more in montmorillonite type of soil whereas for coarse and fine BC soils and kaolinite soil, it follows identical trend. No proper relationship exists between WL and Swell Index and the changes in Swell Index are higher than in WL.

Asmaa Al-Taie et al []analyzed the characteristics of soils, mixed with lime less than OLC. The soil mass compacted at moisture contents less than the optimum moisture content (OMC) or lime content which is less than the optimum lime content (OLC). The study investigated effect of not reaching the target OMC or OLC under the volumetric swelling phenomenon under swell-shrink cycles. Series of swell-shrink test cycles were carried out under different initial amount of lime content, moisture content and stress levels. Relation between swell-shrink cycle and vertical deformation were obtained and analysed. At the third cycle, the tested specimens attained equilibrium. Results indicate maximum swelling in second cycle, degree of expansion changed from moderately swelling to high swelling clay. Obtained result recommended in reviewing current pavement design procedure in considering cyclic potential of contraction and expansion to simulate long-term conditions in the field. Where the maximum swelling occurs at first cycle suggests the non-dependence on long term stability. The study also shows under the condition of constant moisture content, the swelling pressure decreases with decrease of compaction stress. Also under the constant compaction stress, the expansion pressure decreases with decrease in moisture content. Sridharan et al [] determined the swelling pressure of clays by three methods upon which conventional consolidation test gives an encouraging value, this paper gives a concept on characteristics of swelling pressure with respect to time which predict the utmost swelling percent and swelling pressure respectively. Experimental program is conducted with various initial conditions of moisture content and mass. There exists a relationship between swelling pressure and initial dry mass of expansive soil. This is the line with osmotic pressure theory. The moisture content has marginal effect on swelling pressure.

III. MATERIALS & METHODOLOGY

Since ancient times using lime for stabilization of soil has been considered very encouraging and effective. From literature review it has been observed that, optimum lime content has been fixed by considering OMC of an un-stabilized native soil and addition of moisture content beyond OMC for the completion of pozzolanic reactions. Since lime content and moisture content are two variables which decide the optimum lime content, the approach adopted by different researchers are found to be ambiguous and mostly empirical. Since addition of varying lime percentages and cement to the soil results in formation of a composite material, a comprehensive study and approach is necessary for understanding the stabilization technique. Hence, a new approach is contemplated using lime and cement as additives for stabilization.

MATERIALS

Four different types of soil, lime and cement are used in the present work. Detailed characterizations of these materials are mentioned in the following steps.

Soil

The prime intention of the work is to analyze the stabilization of expansive soil. The four different types of soils are Yellow soil, Red soil & Black cotton soil.



Table 1. PROPERTIES OF FOUR DIFFERENT SOILS

Sl. No	Property of Soil		Red Soil(Bgk)	BC soil (BGK)	Yellow Soil (BGK)	HungundS oil(BGK)
1.	Grain size analysis (%)					
	a.	Gravel	0	0	0	0
	b.	Sand	33.33	26.92	30	8
	c.	Silt and clay fractions	66.66	73.08	70	92
2.	IS Soil Classification		CH	CH	CH	CH
3.	Atterberg Limit (%)					
	a.	Liquid Limit	53	56.6	63.5	84.7
	b.	Plastic Limit	24.03	24.5	32.2	41.3
	c.	Plasticity Index	28.97	32.1	34.6	43.4
4.	Compaction characteristics					
	a.	OMC (%)	22.3	23.7	26.7	33.4
	b.	MDD (KN/m3)	16.5	16.2	15.4	14.3
5.	Free Swell Index (%)		13.5	42	24	82

IV. EXPERIMENTAL WORK

Liquid limit values obtained for four different soil composites with different proportions of lime content with cement are plotted as shown in figure 1. The relation between lime content and liquid limit is obtained and it appears to be linear.

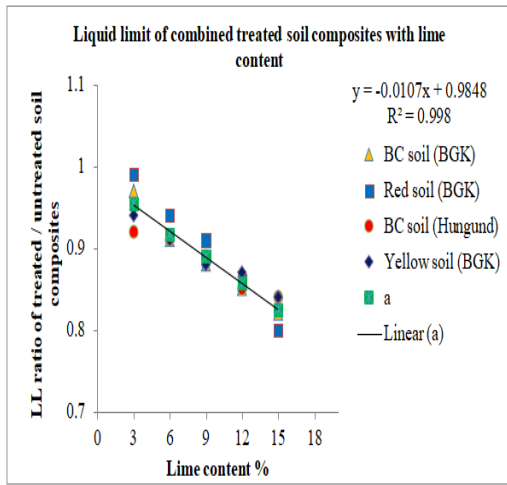


Fig 1.

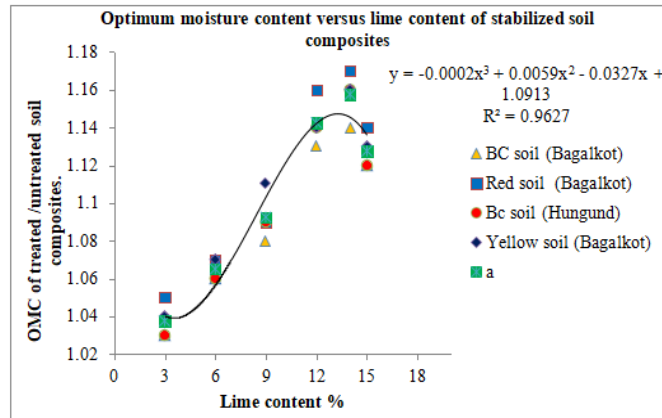


Fig 2.

Results obtained from the standard compaction test for four different stabilized soil composites are plotted in form of optimum moisture content versus lime content as shown in figure 2.

A generalized equation is developed for a relation between swelling pressures for combined soil composites with voids ratio at liquid limit of stabilized soil composites as shown in figure 3.

$$SP = -13.655 x(e)^2 + 66.167 x(e) - 51.883$$

Where, SP = percentage of swelling for combined soil composites (%), x = Voids ratio at liquid limit of stabilized soil composites.

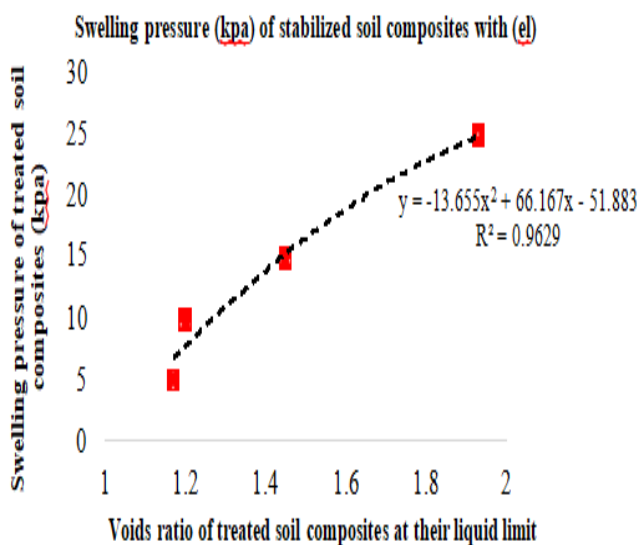


Fig 3.

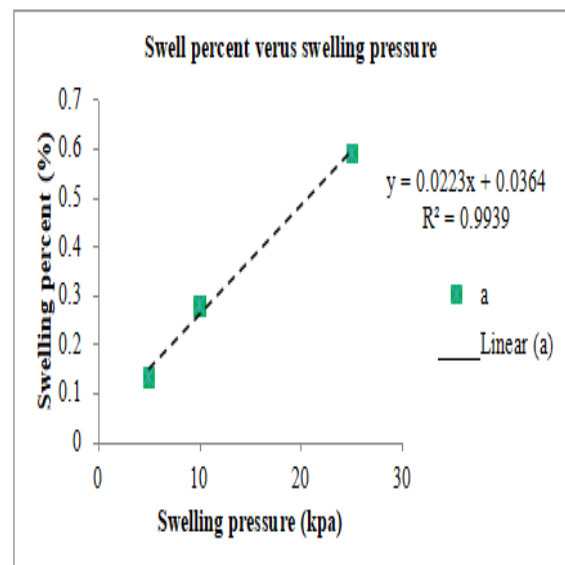


Fig 4.



Untreated Soil Samples	Swelling pressure for untreated soils (kpa)	Swelling pressure for treated soil composites (kpa)	% Reduction in swelling pressure
Red soil (BGK)	62	05	91.94
Yellow soil (BGK)	78	10	85.71
BC Soil (Hungund)	87	25	71.26
BC soil (BGK)	70	15	80.77

Increase in lime content the swelling of the composite decrease with number of curing periods. The addition of lime to the soil results in the reduction of liquid limit as well as swelling which indicates in the water holding capacity of the soil and thus a decrease in the volume change and swelling potential of the composite is observed.

A generalized equation is developed for a relation between swelling percentages for combined soil composites with swelling pressure of stabilized soil composites as shown in figure 4.

$$SP = 0.022 \times (\text{swell pressure}) + 0.036$$

Where, SP = percentage of swelling for combined soil composites (%), x = Swelling pressure (kpa)

V. CONCLUSION

From the experimental investigation which carried out for stabilized soil composites following conclusions can be drawn,

1. Mixing of soil, lime and cement in different proportions results in a new composite and each composite will have different characteristics. Hence, it is very important to determine the engineering properties for each composite.
2. For each four different soil composites liquid limit is determined separately and a generalized equation is established between liquid limit and lime content.
3. For each stabilized soil composites optimum moisture content and maximum dry density is evaluated. A generalized equation is established for optimum moisture content with optimum lime content.
4. Liquid limit of four different soil composites has decreased with increase in lime content. This is in line with the established diffused double layer theory.
5. The percentage of swelling soil composites has increases marginally with increase in lime content.
6. The percentages of swelling of soil composites increases substantially with number of curing days
7. Permeability substantially decreases with increase in lime content.

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