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Experimental study on Variation of Unconfined Compressive Strength of a Lime Stabilized Solina, Soil Srinagar-J&K.

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ABSTRACT: The unconfined compression test is the most popular procedure to evaluate the strength of lime soil mixture .The addition of lime can generate immediate improvement in strength and stability because of cation exchange flocculation, and agglomeration. These immediate effects are beneficial when soft, highly plastic cohesive soils create mobility problems when the soil is used as foundation medium or construction material. This paper presents the detailed investigation on some physical and mechanical properties of soil samples collected from Solina Site Srinagar. In this study, high quality samples from construction site were tested in their undisturbed and reconstituted states. Laboratory tests involved determination of physical properties, compaction characteristics and shear strength parameters. The test results showed that the soil mainly consists of high plasticity silty clay/sandy silt. The test results indicatthat in-situ state of soil is not suitable for using construction site either as foundation medium or as a construction material. Therefore, effects of lime on unconfined compression strength of the soil was evaluated. The results showed that maximum value of unconfined compressive strength was obtained at 6.5% lime content and unconfined compressive increment of more than 250 kN/m2 after the addition of lime to the CH soil indicated that pozzolanic reaction has taken place..

Key Words: Soft soil, Physical properties, Mechanical properties, unconfined compressive strength, limes Stabilization.

INTRODUCTION

The Srinagar city is the summer capital of Jammu and Kashmir (J&K) – known as Kashmir, the "Paradise on Earth" and crown of India. It is the largest district of the state, which lies in the extreme North of the country and is located between 34°5′24″ North 8latitude and 74°47′24″ East longitude at 1585m above MSL. It is on both the sides of the Jhelum River a tributary of the Indus, known as *Vyath* in Kashmir. The river passes through the city and meanders through the valley, moving onward and deepening in the Dal Lake.. Over the last two decades, various infrastructural developments are in progress in the city, which involve major construction activities of roads and buildings. With tremendous increase in population and infrastructural activities, the availability of stable construction sites has become scarce.. In Srinagar city, in most of the cases, there exists a top layer of filled material comprising of soft to very soft clay/silty clay of varying depth along with alluvium deposits along river Jhelum.

In last few decades, world population has been increased rapidly especially in developing countries like India. To accommodate the huge number of population and to produce food, all unused lands are needed to use. But a large amount of land consists of soft clay in our country where any type of construction is risky due to uneven settlement or bearing capacity failure of the clay soil. Therefore, a suitable and cheap soil improvement/ stabilization technique is required to use these soft soils for industrializations as well as to improve the communication facilities (construction of roads). Improvements in engineering properties of soil such as increases in soil strength (shearing resistance), stiffness (resistance to deformation) and durability (wear resistance), reductions in swelling potential or dispersivity (tendency to deflocculate) of wet clay soils can be done by soil stabilization (McNally 1998). Soil stabilization involves the blending of natural soils with chemical agents such as lime, Portland cement and asphalt (Spangler & Handy 1973). These agents are generally potential binders which effectively bind together the soil aggregates to achieve the properties of binders and improve load carrying and stress distributing characteristics, and control shrinkage and swell of the soil. A very common and cheap technique to improve the soft clay soil is to add a certain percentage of lime with that soil (Petry and Glazier 2004). The unconfined compression test is the most popular procedure to evaluate the strength of lime soil mixture .The addition of lime can generate immediate improvement in strength and stability because of cation exchange flocculation, and agglomeration. These immediate effects are beneficial when soft, highly plastic cohesive soils create mobility problems when the soil is used as foundation medium or construction material. The aim of this study is to determine the engineering properties and unconfined compressive strength ofclayey soil of solina, Srinagar . Additionally, this study investigates the improvement of the unconfined compressive strength of soil by mixing different percentages of lime with soil.

Improvement of clayey soils for construction purposes can be easily achieved by admixtures. Among various admixtures, the most commonly used stabilizer for clayey soils is lime. For engineering soil modification, lime is used in the form of quicklime (CaO), or hydrated lime ($Ca(OH)_2$). The principal use of the addition of lime to soil is for subgrade and sub-base stabilization and as a construction expedient on wet sites where lime is used to dry out the soil. The addition of lime to soils to improve their use for construction purposes has a very long history. For instance, McDowell (1959) mentioned that stabilized earth roads were used in ancient Mesopotamia and Egypt, and that the Greeks and Romans used soil-lime mixtures. Clay minerals are natural pozzolanas and have the ability to react with lime added to the soil to produce cementitious products. The lime added to the soils results in an increase in pH to a value in excess of 12 witha resultant increase in the solubility of siliceous and aluminous compounds which react with calcium to form calcium silica hydrates and calcium alumina hydrates which occur initially in gel form to coat the soil particles (Bell 1989). Strength is enhanced because of the increase in cohesion. This makes it possible to improve soils prone to movement by settlement or swelling so that they can be utilized in structural applications. Generally, the plasticity index is used as a measure of the clay content and Perry et al (1995) indicated that a lower limit of 10% should ensure the suitability of the soil for the reaction to take place. Many researchers have reported that a reactive soil exhibits higher unconfined strength after lime treatment (e.g. Dunlop 1977, Bell 1996). The stabilizing effect depends on the reaction between lime and the clay minerals (Bell 1996). Thus, lime can be potentially used to improve clayey soils before construction for heavy structures such as bridges, flyovers, multi-storey buildings is undertaken on or above them. Therefore, this paper presents the detailed investigation of some physical and mechanical properties of soil samples collected from Solina Site Srinagar. The physical properties of clay are of extreme importance in soil engineering and are largely controlled by reactions in which clay plays a leading part. Mechanical properties are normally measured as resistance to shear in terms of the internal friction and cohesion of the soil .

In this paper, high quality samples were tested in their undisturbed and reconstituted states to study the properties of soil samples procured from construction site. Laboratory tests involved determination of physical properties, compaction characteristics, and shear strength parameters. The test results showed that the soil mainly consists of high plasticity clay-silt. The test results indicate that in-situ state of soil is not suitable for using construction site either as foundation medium or as a construction material. Therefore, effects of lime on unconfined compression strength were evaluated. Test mixtures were prepared at optimum water content and $0.95\gamma_d$ obtained from standard Proctor compaction test. Test results indicate that maximum value of unconfined compressive strength was obtained at 6.5% lime content and unconfined compressive increment of more than 250 kN/m2 after the addition of lime to the CH soil indicated that pozzolanic reaction has taken place..

MATERIALS USED

For the present study, clayey soil from Solina Srinagar was collected at different depths (1.5m to 4.5m). Disturbed and undisturbed soil samples were also collected from the site for conduct of various field and lab. tests. Naturally available commercial quick lime CaOwas used as an additive to stabilize the clayey soil. All the tests were carried out as per the relevant Standards (ASTM). The physical properties of the soil used in this investigation are listed in Table 1. The particle size distributions curves of these materials are shown in Fig. 1.

Table 1 – Physical properties of materials used

Property	Locations		
	S-1 (1.5m)	S-2 (3m)	S-3 (4.5m)
Fine Sand Size (%)	22	08	11
Silt Size (%)	47	59	63
Clay Size (%)	31	33	26
Specific gravity, G	2.67	2.68	2.65
Liquid Limit (%)	53.6	55.3	47.1
Moisture content(%)	35.6	37.8	39.2
Plastic Limit (%)	29.4	30.5	27.6
Plasticity Index (%)	24.2	24.8	19.5
Shrinkage limit (%)	15.2	13.1	16.2

Classification	MH	MH	MI
Free Swell Index (%)	0.8	1.2	0
Optimum Moisture Content (%)	17.8	15.6	16.7
Max^{m}. Dry Density (kN/m^3)	17.5	18.1	18.2 `

Particle size distribution analysis revealed that the Solina soil contained about 47%, 59% and 63% highly plastic silt at 1.5m, 3m and 4.5m depth along with 31%, 33% and 26% clay content respectively (Table 1 above). The particle size distribution curves gives, at a glance, the nature of size gradation, range of particle sizes, and a comparison of different soils. The particle size curve is used to know the susceptibility of a soil to frost action, required for the design of drainage filters, an index to the coefficient of permeability and the shear strength of the soil. The suitability of a backfill material also depends on the gradation. As per test results, the soil is classified poorly graded high plastic clayey silt with clean fine sand content.

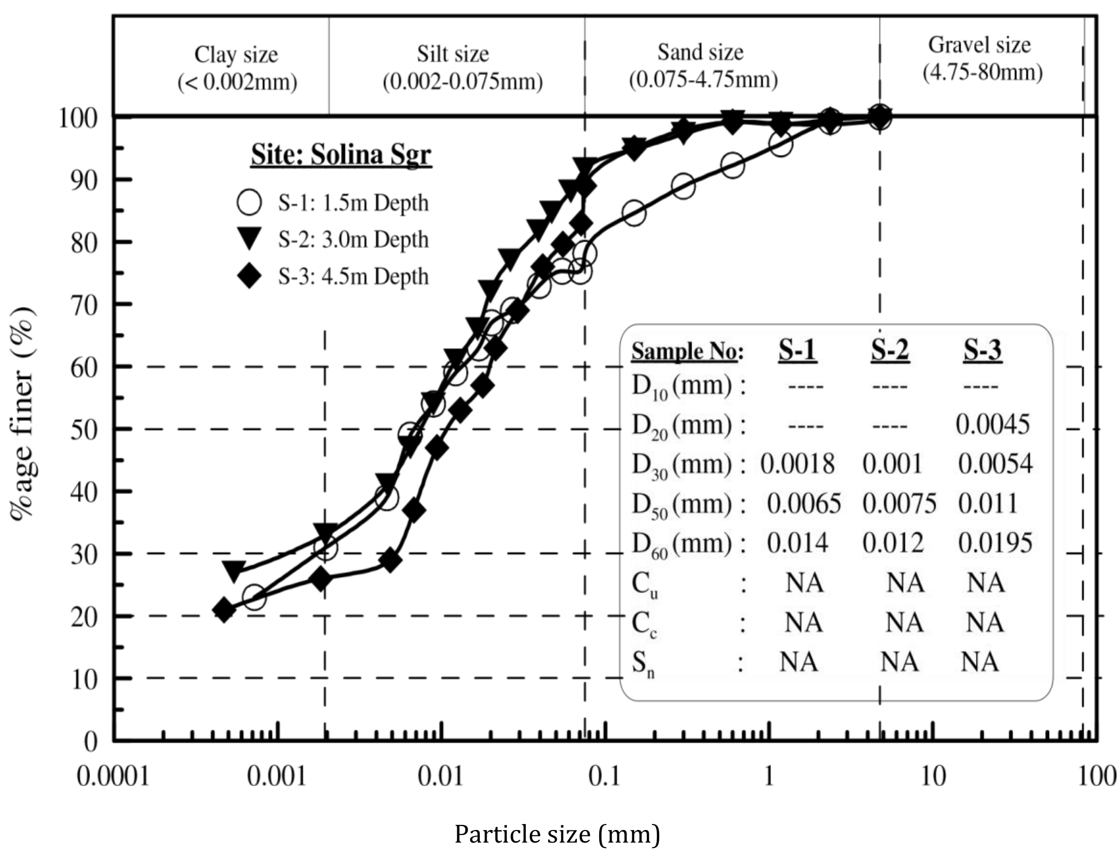

Fig. 1. Particle size distribution curves for Solina soils

EXPERIMENTAL PROGRAMME

The soil samples from site location and Lime were mixed in the dry state and the percentage of lime varies from 0 to 9% with 3% increments. The soil was dried and passed through ASTM sieve No. 40 (425 micron IS sieve) before being used in this investigation. Index properties, Standard Proctor Compaction tests and strength tests were carried out on the so obtained soil specimens. All the samples were prepared as per ASTM codal procedures and compacted at 0.95 $\gamma_{dmax}$and corresponding water content on the dry side of optimum.

RESULTS AND DISCUSSIONS

Mechanisms of Lime Stabilization

A number of explanations have been proposed as mechanisms of lime stabilization. They include:

(a). Drying out by absorption and evaporation. The reduction in the moisture content of the soil can be substantial and occurs immediately the lime and soil are mixed.

(b). Rapid physio-chemical reactions between the lime and clay minerals produce immediate changes in soil plasticity and workability. This is known as soil improvement or modification.

(c). Long term soil-lime pozzolanic reactions result in the formation of cementing agents, which increase strength and durability. This is known as lime stabilization.

Lime stabilization and its effect on soil

Lime is widely used as a stabilizer to expedite construction on weak subgrade soils and to improve the engineering properties especially the strength and durability of fine grained soils. National Lime Association (NLA) reported in 2001 that lime is an unparallel aid in the modification and stabilization of soil beneath road and similar construction projects. The most commonlyutilized limes are slaked lime (Ca (OH)2) and calcitic quicklime (CaO). When lime is added to a fine grained soil, a number of complex reactions take place. Lime which is a source of free calcium reacts with all fine-grained soils in the presence of water. The reactions are rapid cation-exchange and flocculation-agglomeration. Tuncer and Basma (1991) reported that reactions between lime and soils within a few minutes to an hour are colloidal in nature which involves cation exchange and agglomeration-flocculation reactions because of varying double layer characteristics of individual clay particles. A cation exchange reaction causes a change in the relationship between clay particles, from state of mutual repulsion to one of mutual attraction; this results from the excess Ca2+ replacing dissimilar Cations from the exchange complex of the soils.

A soil-lime pozzolanic reaction can occur to form various cementing agents that increase compacted mixture strength and durability.Lime, water, soil silica, and alumina react to form various cementatious compounds. When a large amount of lime is added to a soil, the pH of the soil-lime mixture is increased to about 12.4, which is the pH of saturated lime water. At high pH levels, the solubility of silica and alumina are enhanced, which in turn, promotes the soil-lime reaction. Eades (1962) quoted from TRB (1987) postulated that the high pH causes silica from the clay minerals to dissolve and in combination with Ca2+ to form calcium silicate. This reaction continues as long as Ca (OH)2exists in the soil and there is available silica. It is also possible for the lime to react directly with clay crystal edges, producing accumulation of cementitious materials. These reactions cause a decrease in plasticity, dispersion, compressibility, volume change potential, and increase in particle size, permeability and strength.

The properties of lime-soils mixtures are dependent on the following:

- Soil type
- Lime type and lime percentage
- Curing conditions, which include time, temperature and moisture.

In general, strength increases as the lime content is increased, but for a given curing period, O'Flaherty (1988) pointed out there might be an optimum lime content. The exact optimum lime content is influenced by the amount and type of clay minerals present. Quick lime are more effective than hydrated lime in producing strength increases due to the greater amount of Ca^{2+} available from a given mass of quicklime as compared with the mass of hydrated lime.

Effect of Lime stabilization on strength characteristics

For any engineering application of soil, its strength characteristics are essential. In some special cases, as for checking the short-term stability of foundations and slopes where the rate of loading is fast but drainage is very slow, one of the most common shear tests is the unconfined compression test (UCT). The test samples were tested in an unconfined compression testing machine (ASTM D 2166 – 91:1995). Clays generally show a significant increase in strength when lime is used for stabilization. The effect of lime on unconfined compression strength (ucs) of Solina soil is shown in Fig. 2. The strength of lime-soil mixtures is influenced by several factors such as soil type, curing time and method, unit weight, moisture, mixing and compaction. The strength of lime stabilized soils is also proportional to the reduction in the pH value of the soil which occurs during curing. On addition of lime (6%), the ucs strength ofsoil is tremendously increased. For higher increments of lime, there is not significant increase in the ucc strength indicating that about 6.5% lime content is the optimum quantity to enhance the strength characteristics of clayey soil. Hence this is of vital importance for field engineers from time and economical point of view. The variation of maximum strength and failure strain with lime content is shown in Fig. 3.

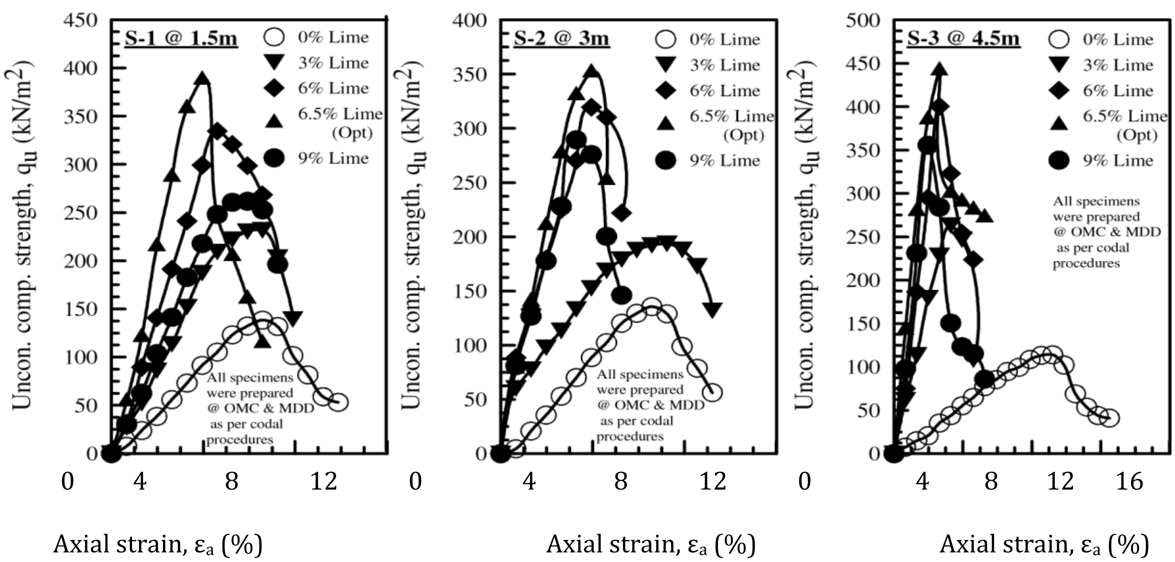

Fig. 2. Stress-strain behavior of Solina soil with & without lime content

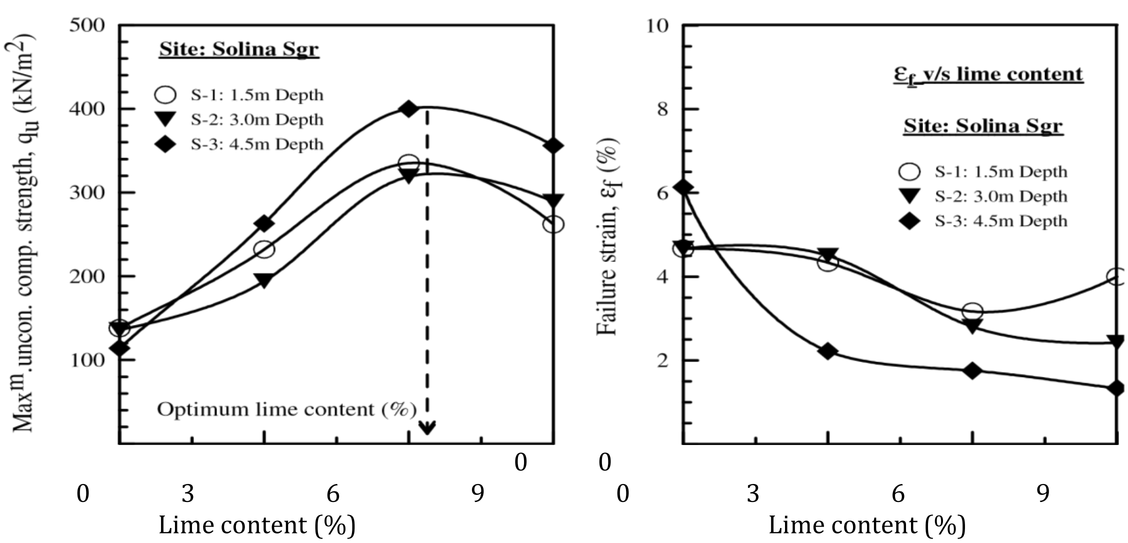

Fig. 3. Influence of the addition of lime on maximum strength and failure strain

CONCLUSIONS

On the basis of this investigation, it has been observed that Solina soil is composed of clayey silt of high plasticity. The index and engineering properties of this soil are significantly altered by addition of lime. It has been observed that 6.5% of lime is the optimum amount required to be used for stabilization of this material. Finally the study shows that only 6.5% addition of lime with solina soil increases 3 to 4 times the unconfined compressive strength of the soil used in this study. This study provides useful information about the optimum lime content and capability of unconfined compressive strength gain for selected solina soil which is very important to stabilize the soil for any necessary development work.

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