Experimental Study of Silty Clay Stabilization With Cement and Lime in Multan, Pakistan

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Abstract-Stabilization is valuable substitute for advancing the soil characteristics. The engineering features gained after stabilization differs broadly owing to non-uniformity in constitutions of soil. This study describes an assessment of cement and lime additives for advancing soils ventures. The effectiveness of lime and cement stabilization on geotechnical characteristics of the in situ soil has also been described in the paper. The additives like cement and lime were added in different dosage rates to examine the change in properties of the in situ soil. Cement addition caused an increase in unconfined compression strength (UCS) throughout from 4% to 16% of cement. Moreover, it has been observed that by adding lime, the early strength of clay increases up to 6% of lime but for long term strength i.e. 28 days maximum strengths is achieved for 4% of lime. It also confirms that with more percentage of lime and longer duration of curing, it expands. In addition to the strength behavior of samples at various percentages of cement and lime, the deflection at failure point was also examined. In order to make a straight comparison, both cement and lime stabilized soils were also tested in laboratory. Generally, the performance of Portland cement-stabilized soils was advanced to lime in the experiments performed.

Keywords-Atterberg Limits, Portland Cement, Unconfined Compressive Strength, Hydrated Lime, Soil Stabilization, Deflection.

I. INTRODUCTION

It is an eminent verity that, every building structure must rest upon the soil or be made up of various soils. It would be ideal to hit upon a soil to be suitable for the proposed use as it exists in nature at a precise construction field but unluckily, such a thing is of rare occurrence.

Stabilization of soil is only one of the several techniques available to the geotechnical engineers and its preference for any circumstances should be made only after a comparison with other techniques in terms of technical and economical parameters. Scientific methods of stabilization of soil have been initiated in recent years [i]. The two techniques to augment the properties of sandy soils i) mechanical stabilization and ii) mixing of stabilization agents into un-disturbed soils were discussed in detail by Reference [ii]. "Soil Stabilization, in an extensive sense, refers to the techniques utilized with a view to alter one or more properties of a soil so as to recover its engineering performance" [ii].

Soils when at a construction field are not fit or when contain objectionable possessions composing them inapt for exercise in a geotechnical tasks, they may need to be stabilized [iii]. Chemical stabilization includes the variation of characteristics of a native accessible soil to recover its engineering properties. Two most frequently utilizing chemical stabilization techniques are cement and lime stabilization. There are many stabilization techniques and methods presently in application. In accordance with Reference [iv] the type of methods to be selected for a certain field relies on the kind of the stabilizing soil, the kind of construction to be executed, extend of needed stabilization, on the environmental impact sand the accessibility of construction materials. Stabilized soil increases shearing conflict of the soil, conflict against wear and tear, reduces the quantity of soil and water permeability of unsealed pavements.

1.1. Stabilization of Soil with Cement and Lime

Stabilized soil is usually a merged material that results from amalgamation and optimization of characteristics in individual component materials [v]. Regarding soil stabilization using various additives like cement and lime, broad studies have been conducted by [vi]. Soil stabilization using lime or cement has extensively been utilized to enhance the mechanical properties of various soils for civil engineering functions [vii].

1.1.1. Lime Stabilization

Lime stabilization results in reducing maximum dry density and enhancing optimum moisture content, Strength, fatigue intensity and elasticity modulus. Lime was initially utilized as a mean of soil stabilization in modern building construction in 1924 for little widening of road toughened by the accumulation of the hydrated. Laboratory testing shows that lime counters to average, modestly fine and fine sized soil particle sand increases workability, strength and reducing plasticity [viii]. Lime action augments optimum water content and reduces maximum dry density of soil. Many researchers have also exposed that optimum water content increase by advancing lime quantity [ix-x].

1.1.2. Cement Stabilization

Cement is a versatile material that has both adhesive and cohesive characteristics, facilitating it to bond mineral splinters into a firm mass. Soil stabilization with cement method has been in survival over a long period of time. Cement treatment affects chemical response parallel to lime and may be utilized for both soil stabilization and modification functions. Cement stabilization is more exclusive than lime. Reference [xi] presented that Portland cement has been deemed as one of the most flourishing soil stabilizers, due to its easy worth control and easy handling properties. Reference [xii] discovered that the larger will be the strength of the cement stabilized clayey soil, if the cement quantity increases. Several researches have revealed cement treatment is found to be more suitable for the grainy soils and also for clayey materials having low plasticity index [xiii].

The accumulation of cement also augments the optimum water content. However, it reduces the maximum dry density [x]. On the other hand, by ACI committee 230 (1990), a report describes that the intention of cement action affects the variation of optimum water content and maximum dry density. In supplement, cement dealing affects instantaneous reduces water content [xiv]. Consequences of a specific investigation revealed that, decreases in unconfined compressive strength were 10% to 20% and reaches up to 40% for four and 24 hours deferrals, respectively [xv].

1.2. Curing Time

The shear strength of lime-treated and cement treated soils enhances with the passage of time. In the starting periods of the curing time, the tempo of increase in strength is usually quick after that, as the time increases, the tempo of increase in strength declines. However, in the early stages, the rate of increase in strength for cement stabilized soil is more as compared to that of the lime stabilized soils. In both, the concrete and lime stabilized soils; the shear strength of cement stabilized clay augments with the passage of time [v].

II. Methodology and Data Collection

The soil sample used in the project was acquired from Bahadurpur Chowk near Bahauddin Zakariya University, Multan, where construction of road was in progress. Hydrated lime and Portland cement were exercised as the stabilizing agents at various dosage levels. The collected samples were treated with lime and cement at different mix ratios. The cement and lime were treated to the natural in situ soil by loose volume and dry mass of the soil respectively. Consequently, the treated soil samples were investigated for unconfined compression strength UCS values. Curing, without adjusting the temperature, was carried out in the laboratory.

2.1. DosageRate

The dosage rate is the amount of stabilizer mixed to the soil for stabilization purpose. Dosage values may be enumerated in various modes, but we utilized the dosage rates to be depended on the dry weight of soil to be stabilized.

The following dosages (%) of cement and lime were utilized in our study:

- 4, 6, 8, 10, 12, 14 and 16 percent cement by the dry weight of soil
- 4, 5, 6, 7 and 8 percent lime by the dry weight of soil

III. Environmental Investigations

3.1. Soil Characterization

Soil characterization tests, as a preliminary step, were carried out to appraise key soil characteristics to ascertain either it is appropriate for stabilization. Soil categorization tests were executed on soil specimen in agreement with approved ASTM standard methods. The brief explanation of each testing is as follows:

3.2. Soil Classification

Soil classification was done by employing the Unified Soil Classification System (USCS). Utilizing the Atterberg limits and the grain size distribution, the USCS appoints a dual letter indication and a group name for soil reorganization. A visual physical inspection method could also be employed to classify soil simply at the site; but, classification offered in this study was supported on laboratory testing depended method.

3.3. Specific Gravity

Specific gravity values of the soils were decided by inserting known weight of oven-dried soil in a flask and then adding water to fill the flask. The displaced water weight was then computed by contrasting the weight of the soil and water in the flask with the weight of flask having water in it, only. The specific gravity was then computed by dividing the dry weight of the soil by the weight of the displaced water.

3.4. Particle Size Distribution

The mixture of particle sizes and the distribution of these sizes provide very useful knowledge about the engineering performances of the soil. The particle size distribution was determined by using the process of sieving analysis in the laboratory.

3.5. Atterberg Limit

For the determination of the plasticity of the soils, the liquid limit and plastic limit values were estimated. The Atterberg limits apparatus was employed to find the liquid limit, while the plastic limit was found by rolling 3 mm diameter threads of soil till they started to fracture.

3.6. Modified Proctor Compaction Test

Optimum moisture content (OMC) at maximum dry density (MDD) for the as-received soil without any stabilizers was established by testing. The test was carried out to calculate the degree of compaction in concern of its dry unit weight. The optimum moisture content then was measured. At least four density values were taken by which the optimum moisture content was obtained. The dry density of the soil specimen was calculated and plotted versus moisture content.

3.7. Unconfined Compression Strength (UCS)

Effect on stabilization was inspected by varying the dosage rates of Portland cement and lime on UCS of the soil sample. UCS tests were carried out on the same day, after 7, 14, 21 and 28 days. Unconfined compressive test uses a cylindrical soil sample with no lateral confinement. An axial compressive load was gradually employed on the soil until it started to fail. The load was applied quite rapidly (typically 1 minute to failure), thus produced an un-drained condition.

IV. Results and Discussions

4.1. Soil Classification

The soil classification and grain size analysis of the as-received soil are presented in Table I. Soil characteristics i.e. Atterberg limits, optimum moisture content (OMC) and maximum dry density (MDD) are shown in Table II. The OMC and MDD of the soil samples were determined using modified compactive effort.

TABLE I
CLASSIFICATION AND GRAIN SIZE ANALYSIS OF AS-RECEIVED SOIL

Sieve No.	Sieve Size (mm)	Retained Weight (gm)	% Retained Weight	Cumulative Retained On Each Sieve	% Finer
4	4.75	209	13.93	13.93	86.07
8	2.36	157	10.47	24.4	75.6
40	0.425	310	20.67	45.07	54.93
100	0.15	542	36.13	81.2	18.8
200	0.075	107	7.13	88.33	11.67
Pan	0.0	175	11.67	100	0

TABLE II
CLASSIFICATION OF AS-RECEIVED SOIL

Basic Characteristics	Soil	Test Standards
USCS Classification	CL-ML	ASTM D 2487
Liquid Limit (%)	24	ASTM D 4318
Plastic Limit (%)	18	ASTM D 4318
Plasticity Index (%)	6	ASTM D 4318
Specific Gravity	2.62	ASTM D 854
Optimum Moisture Content (%)	12.64	ASTM D1557
Maximum Dry Unit Weight (KN/m^3)	19.13	ASTM D1557

4.2. Unconfined Compressive Strength (UCS)

The UCS tests of stabilized/treated soils were then executed on various dosages of stabilizers to appraise the dosage of stabilizer, the technique (% dosage of stabilizer) required to gain the aimed strength rates and the aptness of the specific stabilizer for certain soils. Following results of USC were revealed when soil was treated with cement and lime at various dosage rates.

4.2.1. Results for Cement

The Fig. 1 exhibits the performance of soil (CL-ML) at various percentage dosages of cement. It shows the ultimate strength achieved at various percentage dosages of cement as a stabilizer. It has been observed that the ultimate strength of soil enhances by increasing the percentage dosage of cement. This increase in strength is monitored throughout from 4% of cement to 16%. In addition to the strength behavior of samples at different percentage dosages of cement the deflection at failure point have been examined. The failure deflections along with their respective percentage dosages of cement are given in Fig. 2. It may be seen from the figure that pattern of deflection cannot be easily examined and cannot be related accurately to any other factor like percentage dosage of cement and curing dates as it can be seen that while coming down from 4 to 8% dosage, deflection is first decreasing and then rising up again. In the same way for the sample of all percentage dosages magnitude of deflection is first decreasing by increase of curing period and then increasing again. The decrease in deflections with the passage of time was observed (up to 15 days of adding cement) but after that deflections were increased (at 25 days). Increase in the deflection may be pointed towards the partial breakage of bond between the soil and stabilizer due to high increase in unconfined compressive strength. Also increase in deflection may be attributed to either environmental effects or due to mishandling of sample during compression test.

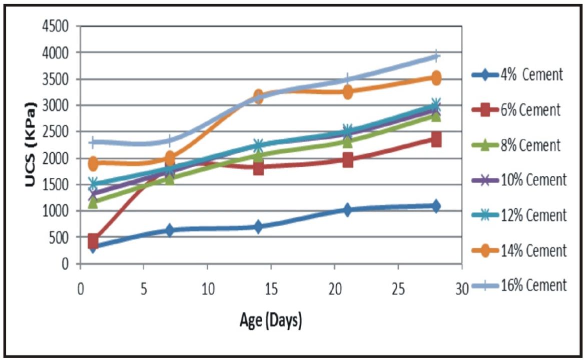

Fig. 1. Graph between UCS of Soil and Age at Different % of Cement

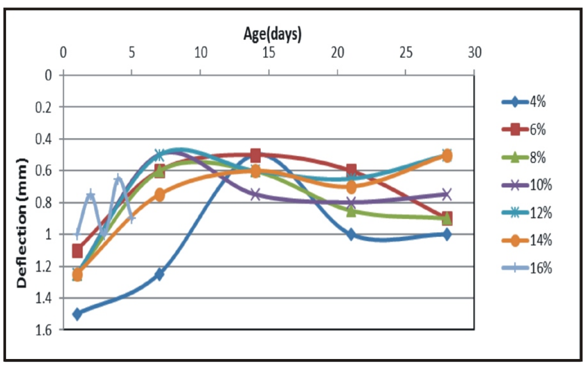

Fig. 2. Graph between Deflection of Soil and Age (Days) at Different %age of Cement

4.2.2. By Adding Lime

By adding lime following results from unconfined compression test were achieved:

From Fig. 3 it can be observed that early strength of soil increases up to 6% of lime but for longer term strength i.e. 28 days maximum strength is achieved for 4% of lime.

This is due to the reason that with more percentage of lime and longer duration of curing lime expands. Also, it can be perceived that for curing period up to 14 days 6% lime samples has the maximum value of strength. This was actually owing to fact that it was the optimum combination of percentage dosages of lime and curing period, as later this curing period of 14 days lime started to expand up to the point that its expansion affected the stability and consistency of soil samples and hence resulting in the loss of ultimate strength of soil. On the other hand, for percentage dosages more than 6% of lime sample started expansion in the premature days of the curing period and hence, showed less strength than 6% of lime and 14 days of appropriate curing the expansion became so much that sample were not able to stand stable enough for testing. In addition to the strength behavior of samples at different percentage dosages of lime the deflection at failure point have also been examined and shown in the Fig. 4. The deflection pattern determined from the figure with respect to curing periods for 4%, 5% and 6% of lime addition show decreasing trend. However, for 7% and 8% samples, there is a sudden increase of deflection from 7 to further days. The 14 and 28 days soil samples were found highly unstable and therefore, shown a sudden increase in deflection.

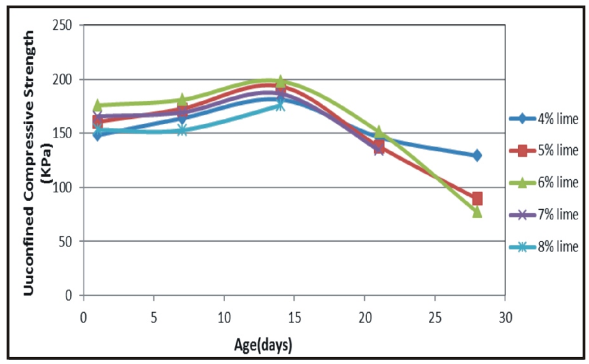

Fig. 3. Graph Between Unconfined Compressive Strength (UCS) of Soil (KPa) and Age (Days) at Different %age of Lime

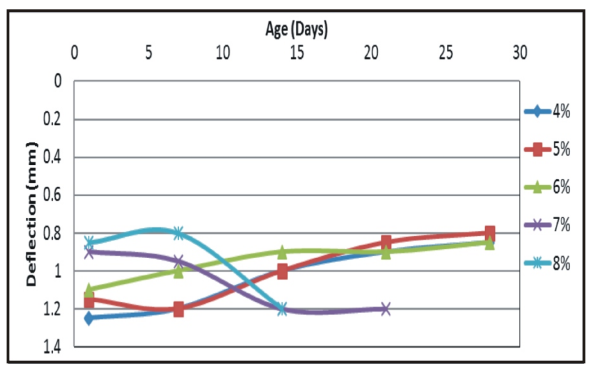

Fig. 4. Graph between deflection of soil and age (Days) at Different %age of Lime

V. CONCLUSIONS

This investigation was executed to appraise the performance of Portland cement and lime in stabilizing advanced engineering properties of particular soils by probing unconfined compressive strength. The following usual terminations can be drawn based upon the investigation executed. The unconfined compressive strength (UCS) of soil stabilized with cement is always higher than that of lime-stabilized soil at all stages.

Results acquired from UCS test of Portland cement indicate that with the addition of Portland cement to soil, the UCS values increases. The UCS values also increase as the curing time for the stabilized soil samples increases. Values of UCS increase considerably after 7, 14, 21 and 28 days curing period. The strength gained continued throughout 28 days curing period. The maximum strength that can be achieved on 28 days of curing is 3928.6 Kpa.

Lime-stabilized soil begins weaker but attains strength with time. The increase in UCS of lime-stabilized soil is more reliant on curing time rather than dosage. The increase in performance with higher dosages of cement is clearly manifested. This proposed the dependence of pozzolani reaction for strength obtain in the soils with lime stabilization.

The strength gained continued upto 14 days curing period and then it starts decreasing. The maximum strength that can be achieved is 198.44 KPa for 6% addition of lime at 14 days.

VI. Recommendations

The following recommendations have been drawn from the study:

The additive assortment must depends on the efficiency of provided stabilizer/additive to enhance the physio-chemical characteristics of the exclusive soils. The initial assortment of the suitable stabilizer(s)/additive(s) for the stabilization of soil must ponder:

Soil uniformity, consistency and gradation

Soil constituents and its mineralogy

Required geotechnical engineering and soil mechanics characteristics

Functions of soil treatment

Methods of stabilization

Ecological situations and engineering finances

The selection of using lime or cement mixing depend upon; in situ moisture content, in-situ soil state, effectual of stabilizer to be used and the kind of execution to be required. Moreover, lime should not be spread dry during the windy weather because it will cause dusting problems. A sprinkling with water with lime will diminish dusting.

The recommended procedure of soil stabilization with cement at site is: i) Grade the area, ii) Scarify, pulverize and pre - wet soil as needed, iii) Re-grade the area, iv) Spread Portland cement and mix it with soil, v) Apply water and mix it, vi) Compact the soil, vii) Final grade the area, viii) Cure the area.

The recommended procedure of soil stabilization with lime at site is: i) Grade the area first, ii) Scarify and pulverize the soil, iii) Spread lime on the soil, iv) Add water during preliminary mixing, v) Rough grade with light compaction, vi) Preliminary cure, vii) Final rotary mix and pulverize the soil viii) Compact the soil, ix) Finally cure all area.

Some practical application of the study includes: Soil stabilization is applicable to diminish compressibility and permeability of soil strata in existing earthen structures and to augment the unit weight of soil. It is applicable to augment bearing capacity of foundation soil materials and to prevent seepage (through cracks, joints and porous zones) from foundation, basements, slopes and ditches. It is utilized to advance the natural soils for execution of airfields and highways. In a short interval of time it is utilized to make an area trafficable for emergency needs. Soil stabilization expands the shear strength of soil.

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