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SOIL STABILIZED WITH LIME AND SODIUM SILICATE

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Abstract: The development of infrastructure, such as highways, requires earthwork mainly for the construction of pavement. Expensive soils can induce damage to road founded on them as they exhibit volumetric changes with change of degree of saturation. Compacted soils are used in earthwork such as construction of embankments and road foundation. Unsaturated soils are often classified as expensive or non-expensive materials. Upon an increase of moisture, the former exhibits an irreversible volume increase, while the latter does not.

1.0 Introduction

Improving an on-site soil's engineering properties is called soil stabilization. Soils containing significant levels of silt or clay,have changing geotechnical characteristics: they swell and become plastic in the presence of water, shrink when dry, and expand when exposed to frost. Site traffic is always a delicate and difficult issue when projects are carried out on such soils. In other words, the re-use of these materials is often difficult, if not impossible. Once they have been treated with lime, such soil can be used to create embankments or subgrade of structures, thus avoiding expensive excavation works and transport. Use of lime significantly changes the characteristics of a soil to produce long-term permanent strength and stability, particularly with respect to the action of water and frost. The mineralogical properties of the soils will determine their degree of reactivity with lime and the ultimate strength that the stabilized layers will develop. In general, fine-grained clay soils.

2.0 Theoretical Background

2.1 General

2.1.1 Lime stabilization

Treatment with lime is especially effective in improving the engineering properties of heavy clays or of granular soils which, because of granular soils which, because of high water affinity in their silt-clay fraction fall short of having a dependable granular skeleton in accordance with U.S .Experience treatment with lime in most effective for;

Stabilization of clay gravel materials to serve as basis pavements stabilization of heavy clay soils to serve as basis or sub basis for pavements

Lime treatment is found is less effective for silt loam soils the physical changes effected by lime treatment of clay soils can be summarized as follows:

1. The plasticity index drops sharply by a factor of 3 or more in some instance
2. the plastic limit generally increases and liquid limit decreases
3. increase the optimum moisture content and reduce the dry density
4. the soil binder content decrease substantially
5. linear shrinkage and swell decrease markedly
6. lime and water accelerate disintegration of clay during pulverization soils become friable and can be worked easily
7. strength and load bearing values increases substantially.
8. Application of lime facilities drying of soil in swampy areas

9. lime stabilized bases or sub-bases from a water resistant barrier by stopping penetration pf gravity water and by rapid evaporation of resisting structures.

2.2 Review of Literature

2.2.1 Suitability and Applications : Lime treatment is especially effective for heavy clays or for silty and clayey granular soils, which are likely to lose strength because of high water affinity in their silt-clay fraction. Lime is less effective for silty soils and is not recommended for sandy soils except in combination with added clay or other pozzolanic material. Organic soils are not suitable for lime stabilization. Lime may be used as a stabilizer for soils in the sub-base and base course of pavements, under concrete foundations, on embankment slopes and canal lining. Lime treatment is also used as a preparatory measure for subsequent stabilization of clay with cement, bitumen and other water proofing agents. Quicklime treatment has been used for drying soils by the heat of hydration, which is generated. Lime piles and lime columns are used for treating deep layers.

Several types of limes are available, notably quicklime (CaO), slaked or hydrated lime [CA(OH)2] and dolomite lime (CaO+MgO). Quicklime is difficult to handle and is suitable especially for marshy lands where quick drying is also aimed at. Dolomite lime containing significant-proportions of magnesium oxide is not an effective stabilizer. Hydrated lime with a high percentage of calcium oxide is better for stabilization and also easy to handle.

2.2.2 Lime Stabilized Base Course

(Winterkorn 1975) Based on U.S experience lime requirements for stabilized base and sub base course of pavements are as follows:

I. Five to ten percent of lime by weight of oil, for heavy clay soils to serve as bases, or one to three percent in sub-bases.
II. Two to four percent of lime for clay-gravel materials to serve as bases

In India, the amount of lime needed for stabilization is recommended to be decided by the criteria of pH value, CBR and an unconfined compressive strength **(IRC 1983).** The s minimum percentage of lime is that which on mixing with soil in the rorm of slurry gives pH of 12.4. When lime and water are added to clayey soil, due to exchange of cations between lime and caly, the character of the clay soil altered immediately. The clay particles flock around one another form bigger particles of soil of the soil slit, the soil becoming less plastic with reduced Plasticity Index(PI) more friable and workable. The amount of lime required for immediate reaction is about 3% (TRC 180,1976) depending upon the clay mineral.

(Bell, 1988) The amount of lime is known as lime fixation. When the lime in excess of lime fixation is added to soil and water, silicones and aluminous material in clays enter into alumina silicate complexes having binding property that participate on the soil grains and holds the grain property that participate on the soil grains and holds the grains together. With passage of time, the lime soil transforms into a hardened mass having strength os sustain loads(Bell, 1988). Thus addition of lime in excess of modification optimum contributes to increase in strength. It is observed that if lime is 4 percent above the modification and resistant to frost provided soil activity is 0.75 or less.

(Mitchell and hooper 1961 ; Ingles and Metcalf 1972; Researchers have illustrated the impact of lime addition on the strength of clay soils depends on several factors. These include, soil type, curing time and method, moisture content, soil unit weight and time elapsed between mixing and compaction .

Al-Rawi 1981; Bell 1988; Rao and Venkataswamy 2002);

Comparatively fewer studies have focused on the impact of lime stabilization on the compressibility as much as by the shear strength. in addition, sodium silicate as a glass material can be used efficiently in soil stabilization because it is cheap and available. This work shows that the sodium silicate can improve the geotechnical properties by increasing strength of soil and reducing its volume change.

The aim of this work is to investigate the effect of lime and sodium silicate (Na2SiO3) powder on different geotechnical engineering properties of soil. In order to achieve, an experimental program was designed into three steps.

Firstly, to estimate the optimum amount of lime and sodium silicate that required to improve the soil properties. This optimum value (fixation point) can be estimated by short term reaction using different independent methods like plasticity index.

Secondly, to study the development and progressive of the pozzolanic reaction with curing time for various lime and sodium silicate mix percentage added below and above optimum value.

Thirdly, is to investigation the effect of lime and sodium silicate mix on the shear strength and CBR of clay soil.

3.0 Proposed Work

3.1 Properties of Materials Used

3.1.1 Soil

The soil selected for investigation was taken from Village baroosa Distt. Ganderbal. The soil was collected from the base of dried seasonal pond –bed.

According to Indian standard of soil classification, the soil is classified. :- inorganic clay of low compressibility.

The properties of soil are as under:

1.	Colour	Light Brown
2.	Liquid limit (%)	48.47
3.	Plastic limit (%)	26.67
4.	Plasticity index (%)	25.33
5.	Specific gravity (%)	2.66
6.	Maximum dry density (gm/cc)	1.7
7.	O.M. (%)	17.8
8.	I.S. Classification	CL (Clay of low compressibility)
9.	U.Confied compressive strength (kg/sq.cm)	3.86
10.	(a) CBR (%) Unsoaked (b) CBR (%) Soaked	6.2 3.2

3.1.2 LIME

Calcium hydroxide (slacked lime) purchase from local market was used through the study, it was purchased from new minerals and chemicals, Srinagar.

Various properties of lime provided by manufacture are:

1.	Minimum assay (Acidic – metric)	90%
2.	Maximum limit of impurities	
	(a) chlorides	0.04%
	(b) Sulphates	0.04%
	(c) At, Fe and insoluble matter	1%
	(d) Arsenic	0.0004%
	(e) Lend	0.0004%

3.1.3 WATER

Ordinary potable water from tap was used throughout the study. The water was neat, clean and without any suspension material.

3.1.4 Sodium Silicate

Sodium silicate used in experimental programme was bought from Amorphous Chemicals Srinagar. The price of sodium silicate was 30 rupees per kilogram. It is used in powder form in the experiments.

3.2 Methodology

3.2.1 Scarification and Initial Pulverization: After the soil has been brought to line and grade, the subgrade can be scarified to the specified depth and width and then partially pulverized. It is desirable to remove non-soil materials larger than 3 inches, such as stumps, roots, turf, and aggregates. Scarification is done because a scarified or pulverized subgrade offers more soil surface contact area for the lime and sodium silicate at the time of lime and sodium silicate application

ii) Lime and sodium silicate Spreading: the soil is generally scarified and the slurry is applied by distributor truck. Because lime in slurry form is much less concentrated than dry lime, often two or more passes are required to provide the specified amount of lime solids. To prevent runoff and consequent non-uniform lime distribution, the slurry is mixed into the soil immediately after each spreading pass.

iii) Preliminary Mixing and Watering: Preliminary mixing is required to distribute the lime and sodium silicate throughout the soil and to initially pulverize the soil to prepare for the addition of water to initiate the chemical reaction for stabilization. During this process or immediately after, water should be added to ensure the complete hydration and a quality stabilization project.

iv) Final mixing and pulverization: To accomplish complete stabilization, adequate final pulverization of the clay fraction and thorough distribution of the lime and sodium silicate throughout the soil are essential

v) Compaction: Initial compaction is usually performed as soon as possible after mixing, using a sheeps foot type roller or a vibratory pad foot roller. After the section is shaped, final compaction can be accomplished using a smooth drum roller. The equipment should be appropriate for the depth of the section being constructed.

vi) Final curing: Before placing the next layer of sub-base (or base course), the compacted subgrade (or sub base) should be allowed to harden until loaded dump trucks can operate without rutting the surface. During this time, the surface of the lime treated soil should be kept moist to aid in strength gain. This is called "curing" and can be done in two ways:

3.3 Scheme Of Experimentation

3.3.1 Experimental Programme

The various materials used, their properties, the details of testing equipment and the test procedures have been described in details in the following sections.

3.4 Standard Prrocter Test to Find Maximum Dry Density.

It was found by modified proctor test. The apparatus used for light compaction consists of a cylindrical mould having an internal diameter of 100 mm and height of mould 127.5 mm and volume of mould 1000 ml. A detachable collar of 60 mm height fits on the top of the mould and base is also detachable. The rammer used in the test weighs 2.6 kg with a drop of 310 mm and having face diameter of 50 mm.

The procedures were repeated for determining optimum moisture content and maximum dry density of soil-lime mix and soil-lime-jute mix. Dry density was calculated by the equation.

$$\gamma d = 1+W$$

where, γd = dry density (gm/cc)

γt = wet density

w = water content

Fig 4.3 Filling the mould

Fig 4.4 Compaction

3.5 Unconfined Compression Strength Test

The unconfined compression test is a special form of triaxial test, in which the confining pressure is zero. The test can be conducted only on clayey soils which can withstand load without confinement. The test is generally performed on intact saturated clay specimens.

3.5.1 Testing Procedure

I. **Specimen mould:** specimen is prepared in mould having diameter 52 mm and height 78mm.

II. **Specimen Extractor:** hydraulic jack is generally used to extract the sample from the mould. Samples may also be extracted by using wooden log of well seasoned wood having diameter same as that of mould.

III. **Testing Machine:** In this machine proving ring is used tp measure the compressive force. There are two plates. Specimen is placed on bottom plate, then raised gradually by turning handle to make its contact with upper plate.

The soil passing through 600µ sieve was used to prepare the sample in the mould. The weight of soil equal to the product of maximum dry density and the volume of mould (165.56cm³), was thoroughly mixed with quantity of water equal to O.M.C. the samples were made by compacting the soil mixes in the mould. The sample were extracted from the moulds and tested in unconfined compression testing machine. The handle was rotated gradually so as to produce axial strain equal to 0.50% to 2% per minute. The shearing was continued till failure or 20% of the axial strain, which occurred first.

Fig 4.5 Unconfined compression apparatus

3.6 California Bearing Ratio (Cbr) Test

This method was originally devised by porter in California State Highway Department, but it has since modified by various organizations for different conditions, CBR method as recommended by IRC 37-1970, is generally used for structurally evaluation of sub grade soil in India. The samples obtained from sub grade are compacted to maximum dry density at optimum moisture content and CBR values for these samples are determined. In place field CBR tests are sometimes performed, but base are expensive and time consuming. Some of important points recommended by IRC for performing CBR test are given below:

Some IRC recommendations for performing CBR test:

4.0 CBR Method

This is penetration test developed by the California Division of Highways, as a method for evaluating the stability of soil sub grade and other flexible pavements materials. The test result have been correlated with flexible pavement thickness requirements for highways and airfields. The CBR test may be conducted in the laboratory on a prepared specimen in a mould or in-situ in the field

The laboratory CBR apparatus consists of a mould 150 mm diameter with a base plate and a collar, a loading frame with the cylindrical plunger of 50 mm diameter and dial gauges for measuring the expansion on soaking and the penetration values.

Briefly the penetration test consists of causing a cylindrical plunger of 50 mm diameter to penetrate a pavement component material at 1.25 mm/minute. The load values to cause 2.5 mm and 5 mm penetration are recorded. These loads are expressed as percentages of standard load values at respective deformation levels to obtain CBR values. The standard load values obtained from the average of a large number of tests on crushed stones are 1370 and 2055 kg respectively at 2.5 mm and 5.0 mm penetration.

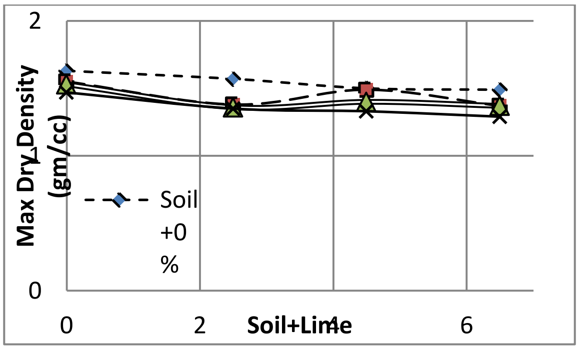
The required quantity of soil was mixed with water

4.0 Observations, Results and Discussions

4.1 Results and Observation Table for Proctor Test (Light Compaction)

Table 5.1.1 Maximum Dry Density And Optimum Moisture Content Of Various Soil Samples

Sample No	Soil+Lime	Sodium Silicate (%)	Max Dry Density (gm/cc)	O.M.C.(%)
1	Soil+0%	0	1.63	17.51
2	Soil+2.5%	0	1.55	19.22
3	Soil+4.5%	0	1.53	21.39
4	Soil+6.5%	0	1.47	23.47
5	Soil+0%	1.5	1.57	18.13
6	Soil+0%	2.5	1.50	18.73
7	Soil+0%	3.5	1.49	18.87
8	Soil+2.5%	1.5	1.38	19.03
9	Soil+2.5%	2.5	1.49	19.64
10	Soil+2.5%	3.5	1.37	19.76
11	Soil+4.5%	1.5	1.36	20.23
12	Soil+4.5%	2.5	1.40	20.61
13	Soil+4.5%	3.5	1.37	21.63
14	Soil+6.5%	1.5	1.35	22.12
15	Soil+6.5%	2.5	1.33	23.34
16	Soil+6.5%	3.5	1.29	24.21



Graph: 5.1.1 Maximum dry density variation of soil having different percentages of lime with various percentages of sodium silicate

Table 5.1.2 Variation Of Max Dry Density Of Soil Samples Having Different Percentages Of Lime [Sodium Silicate=0%]

Sr. No.	Lime%	Max Dry Density (gm/cc)
1	0	1.63
2	2.5	1.55
3	4.5	1.53
4	6.5	1.47

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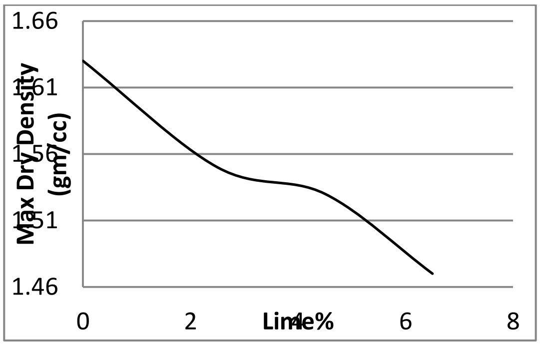
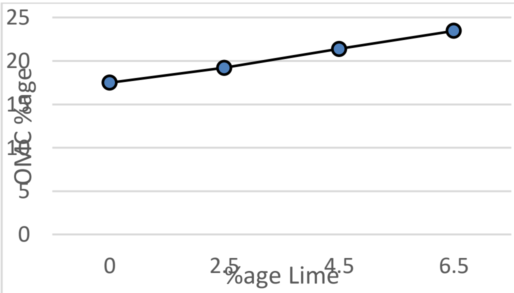


Graph 5.1.2: Maximum dry density variation with different percentages of lime [sodium silicate]

Table 5.1.3 Variation Of Omc Of Soil Samples Having 0% Sodium Silicate, With Different Percentages Of Lime [Sodium Silicate=0%]

Sr. No.	Lime%	O.M.C.%
1	0	17.51
2	2.5	19.22
3	4.5	21.39
4	6.5	23.47



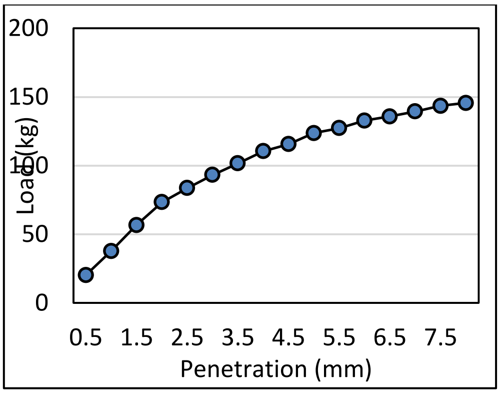
Graph 5.1.3: Variation of OMC of soil samples having 0% Sodium Silicate with different percentages of lime

5.0 Result And Observation Of Unconfined Test For Sample Cured (Curing Time 7 Days)

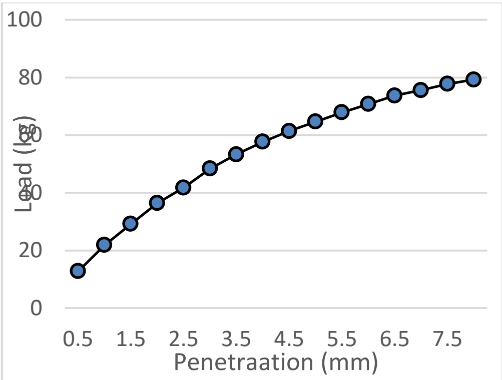
The confined compressive strength of virgin soil is 4.03 kg/cm². It increases to 6.23 kg/cm² at 2.5% lime addition, 7.37 kg/cm² at 4.5% lime addition and 8.09 kg/cm² at 6.5% lime addition. It is observed that relative increase in unconfined compressive strength with previous maximum value decreases at 6.5% lime addition. Hence, it was decided that U.C.S. test be conducted after adding 2.5% lime and 4.5% to the soil. Hence, the following samples were prepared and cured for 7 days before being tested for the most critical value of unconfined compressive strength.

5.4 Observation For California Bearing Ratio Test

The California bearing ratio test was carried out as explained in the article. Six samples were prepared. Out of these six samples two samples were prepared from virgin soil, two from soil +4% lime and two from soil + 4% lime + 2% sodium silicate. One each of these two samples was tested unsoaked whereas second samples was soaked for 96 hours and then tested. The load take n by the soil sample at different penetrations was noted. Graphs were plotted between penetration and load for various samples



Graph 5.4.1: Showing CBR values of unsoaked virgin soil



Graph 5.4.2: Showing CBR values of unsoaked virgin soil and soaked for 96 hours

6.0 Conclusion and Scope

6.1 Conclusion

1. The maximum dry density decreased by the addition of lime and sodium silicate to the soil.
2. The optimum moisture content increased by the addition of lime and sodium silicate to the soil.
3. The unconfined compression strength increased by 129% for uncured sample of soil + 4.5% lime + 2.5% sodium silicate mix as compared to virgin soil. The increased in unconfined compression strength for cured sample of soil + 4.5% lime + 2.5% sodium silicate was 162% as compared to virgin soil.
4. The California bearing ratio of soil + 4.5% lime + 2.5% sodium silicate mix increased by 219% and 197% for unsoaked and Soaked conditions respectively as compared to virgin soil.
5. Hence, there is an overall gain in strength parameters of clayey soil due to the addition of lime and sodium silicate.

6.2 Scope For Further Study

1. Effect of change in temperature on the rate of strength gain of lime and sodium silicate soil can be studied.
2. Effect of soil constituents on the biodegradability of sodium silicate can be investigated.
3. Effect of age on the strength of sodium silicate soil can be studied.
4. Bearing capacity improvement of soil- sodium silicate mix under saturation can be studied.

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