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An Experimental Study of Strengthening of Sub Grade Soil At Different OMC (Using Calcium Oxide And Sodium Silicate)

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ABSTRACT- The process of compaction is not enough to improve the properties of soil particularly in arid and semi arid regions. To enhance the strength and reduce the sensitivity to water change of weak clay deposits, lime and sodium silicate stabilization can be used. The soil stabilization process first involves adding suitable additive to the soil which first changes its properties and then compacting soil admixture suitably. The soil stabilization method is used only for the soils in shallow foundations or the base course of roads, airfield pavements etc. The properties of a soil changes with the usage of lime to give long term permanent strength and stability especially when exposed with water and frost. The degree of reactivity with lime and the ultimate strength that the stabilized layers will develop can be determined by the mineralogical properties of the soils. Recommended percentage of lime for Soil stabilization varies from 2% to 10%. For coarse soils such as clay gravels, sandy soils with less than 50% silt- clay fraction, the recommended percentage of lime varies from 2% to 5%, whereas for soils with more than 50% silt clay fraction, the recommended percentage of lime lies between 5% to 10%.

KEYWORDS- Sub Grade Soil, Compaction, Stabilization, Lime And Calcium Oxides, Silicates Of Sodium, Optimum Moisture Content.

I. INTRODUCTION

Construction works are facing problems in Due to expanding soil, cotton soil, or black soil in many places of the world. Damage to the road pavement and structure has been documented on a regular basis, resulting in fatalities and financial loss [1]. Soil replacement is possible, but it is a costly and complex process in underdeveloped countries like India. Furthermore, paving on clayey soil necessitates a lot of effort. the base's thickness and sub base course as a result of which The project's construction cost rises [2]. As a result, it is required to improve soil strength, which will aid in the reduction of pavement layer thickness and project cost. In the present thesis, the researcher has taken the soil sample for stabilization study from area of District Anantnag of Kashmir [3]. So, one of the best and readily available methods for improvisation of soil properties is the soil stabilization or study of stabilization [4]. The stabilizers which are used to improve the soil properties include gypsum tyres fly ash, lime, sodium silicate, jute, rice husk ash, etc. Most widely used and highly priced stabilizers include cement and fly ash which directly increases the cost of project [5]. The stabilizers used by the researcher in present study were the Increase the engineering qualities of clayey soil with lime and sodium silicate. Soil that is clayey has been taken from District Anantnag of Kashmir for present study [6]. The main focus of this study is to increase the clayey soil strength by making use of Lime and Sodium Silicate (Stabilizers). For the present study, the researcher has executed tests on collected soil sample and determined its properties and nature as well [7]. Firstly, the properties and characteristics of stabilizing material were determined in order to make the usage of quantity and quality of stabilizers easy [8]. Secondly, tests were conducted in order to acquire the best moisture content (OMC) and dry density (MDD) and the unconfined compressive strength of soil samples by adding constant content of lime as 3, 5, 7% and sodium silicate as 2, 3, 4%. The tests were executed for achieving the soil's optimal moisture content (OMC) and maximum dry density (MDD) the unconfined compressive strength of soil samples [9]. The tests were carried out on multiple soil samples one by one by parent soil with lime and sodium silicate (stabilizers) to provide the bearing capacity of soil little bit but as the percentage of lime and sodium silicate is increased 3 and 2% the weight of soil [10]. The mixture of clay soil and lime, sodium silicate as the dosage 3% and 2% and conduct the tests standard proctor test and unconfined compression test. The researcher gets the new bearing capacity, strength & durability of soil samples [11]. As the similarly, the percentage of lime and sodium silicate increases in 5 %, 7% and 3%, 4%. So that we get the bearing capacity of soil to improve the shear strength and durability hardness and increase the life of structure as the lime and sodium silicate possess the good engineering properties to hold the soil particles together and the permeability of soil decreases which in turn enhances the bearing capacity and stability of soil [12]. At present, this is the most approved method in India to stabilize many engineering work like the sub grade, highway drainage, embankment, airways etc. It is evident from the results that the unconfined compressive strength of the reference mix with lime and sodium silicate can be increased by treatment with calcium chloride [13]. The unconfined compression strength inflation was highest with calcium chloride. Moreover, the results indicated that unconfined compression strength was highest when cured in water filled container [14]. The effects on the shear strength of varying confining pressure and sand matrix relative density was assessed.

Among the recent developments, the reinforcement has been introduced in many forms and An attempt is being made to improve the soil's behaviour. Reinforcement forms such as sheets, strips, bars, and fabric grids have been placed into the soil mass in such a way that the tensile strength has been suppressed. This material is known as “macro scale”. The use of admixtures can often improve the physical properties of soils economically. The most widely used admixtures include Portland cement, lime and asphalt.

The soil stabilization process first involves adding suitable additive to the soil which first changes its properties and then compacting soil admixture suitably. The soil stabilization method is only utilised for soils in shallow foundations or the base course of highways, airport pavements, and other similar structures.

II. OBJECTIVES

- The main objective of this research is to access the response of soils through the application of the chemical additives at numerous curing durations.[CaO and Na2SiO3].
- The aim and objective of this research work is to investigate the feasibility of sodium silicates [Na2SiO3] for expanding Sub-grade soil strengthening, which are not suited for pavement sub-grades, by enhancing their carrying capacity and decreasing the swelling pressure and heave.
- This study aims to investigate the suitability of the chemical to decrease pavement thickness by increasing the bearing capacity of sub standard sub base materials.
- In this thesis The goal of this study is to see if mixing lime with sodium silicate can improve soil strength and minimise plasticity.
- Calcium oxide has the capability to decrease the shrinkage and expansive properties of sub grade soil and hence, help in providing the cracks and failures of the roads and highway construction becomes safe for easy passage of heavy vehicles.
- Variation in OMC of the sub grade soil helps in achieving the maximum dry density of the soil and thus helps in the strengthening characteristics of the sub grade soil.
- Silicates of sodium have a great influence on the properties of soils and by decreasing the plasticity characteristics of soils, these stabilizers help in increasing the dry density of the sub grade soil which increases its stability and load bearing capacity to ease the flow of heavy traffic through it.
- With the increase in optimum moisture content of the sub grade soil, the dry density decreases which in turn reduces the load carrying capacity and can cause failure of the roads during the passage of heavy traffic through it.
- The purpose of using Cao and Silicates of Sodium is that they are very cheap and easily available.
- This thesis work enables us to observe the changing characteristics of the sub grade soil by working at different moisture contents of the sub grade and changing the percentage of calcium oxide and sodium silicates.

III. SCOPE

Secondary resources are supported by a series of laboratory experiments have supported this investigation. However, the investigation results are restricted to a sub grade soil sample which is considered in the research. The results are also specific to the type of chemical additives used in the experiments, as well as the test methodologies used. As a result, findings for filed applications should be regarded as indicative rather than decisive.

IV. NEED OF PRESENT STUDY

It is a well acknowledged fact that characteristics of sub grade soil varies from place to place. After selecting a place for particular project, engineering properties of the soil based on the circumstances such as depth, foundation, type of foundation loads etc are surveyed. It has been seen that clayey type of soils is creating numerous issues to the structures. Variation of moisture percentage in soil leads to change in bearing strength and construction on such type of soils leads to long drawn out problems to the structure like it leads to increase in maintenance costs and sometimes more initial costs. Settlement problems can also arise due to fluctuation in water table in the vicinity of the structure on clayey soils. Evaluation of effective soil improvement techniques for soft clays with regard to highway construction has initiated due to rapid development of projects. Recent studies have revealed that the engineering characteristics of such soils can be improved by certain chemical stabilization. Engineers are increasingly building high earth embankment on poor foundation materials in order to minimize the impact and cost of highway construction. The penalty is high settlement and the Time required achieving acceptable consolidation. This penalty can be reduced by the use of vertical drainage system in some alluvial soils along with significant surcharge loading but at the cost of stability. It is not unusual for a 6 to 8m high, finished embankment section to be constructed initially & 8 to 12m high on very poor clay peat foundation incorporating vertical drains. The alluvial in such cases are usually (of limited thickness 3m to 12m) too thick to efficiently execute but “geometrically thin” compared to the 75m to 95m base of embankment.

Stability can be improved by incorporating material with tensile capacity into the base of the embankment. Early examples used natural reed and hazel branches and the use of metal strip was restricted by corrosion due to proximity of the water table. On the foundation of soft clay it is conventionally accepted that short term, undrained strength are likely to the most critical, particularly as in practice the installation of vertical drainage system would limit the lateral migration of high pour water pressure. It has been seen that reinforced earth retaining structures is more economical than their conventional counterparts.

However, such structures are collaborated with the use of a relatively high quality granular backfill containing less than 13% finer than 75um. The fact that fills of such quality may not be economically available. The use of cohesive frictional fill could obviously be advantageous to use fill of much higher clay content. Load bearing capacity can be increased and elastic settlement can be decreased of shallow foundation supported by soft clay soil by possible alternative would be to place to footing on a cohesive stabilized with lime and sodium silicate.

The present study of the researcher will help Changing the percentages of lime and sodium silicate to determine the maximum dry and optimum moisture content of a soil-lime-sodium-silicate combination. It will also help to know the enhancement in unconfined compressive strength and will help to look into increasing the California Bearing Ratio for the best mix.

Therefore, there is a need Lime and sodium silicate have been chosen for stabilisation to improve the qualities of any weak soil.

V. MATERIALS USED

A. Soil-Stabilization using Calcium oxide (CaO)

The strength, stiffness and durability of fine grained material can be improved by lime stabilization. Furthermore, fine grained fraction of granular soils is improved by making use of lime. In the base course of pavements systems, under concrete foundations, canal linings and on embankment, lime has also been used as stabilizer. When lime is added to soil, it produces maximum density products with a higher optimal moisture content than untreated soil and plasticity index decreases by lime.

Lime stabilisation has been widely employed in clays to reduce swelling potential and pressures. The strength of wet clay is usually improved when the right amount of lime is applied. The increase in strength is due in part to the clay's decreased plastic characteristics and in part to the pozzolanic reaction of lime with soil, which results in a cemented material with increased strength. In general, lime-treated soils are stronger and have a higher modulus of elasticity than untreated soils. Recommended percentage of lime for Soil stabilization varies from 2% to 10%. For coarse soils such as clay gravels, sandy soils with less than 50% silt- clay fraction, the recommended percentage of lime varies from 2% to 5%, whereas for soils with more than 50% silt clay fraction, the recommended percentage of lime lies between 5% to 10%.

B. Soil Sodium Silicate Stabilization [Na2SiO3]

Sodium silicate is accessible and inexpensive material. Virgin soil has low strength than the soil treated with sodium silicate. Swelling potential and swelling pressure can be reduced in clayey soils by sodium silicate stabilization. It functions by reacting with soil particles to form collides and then subsequently polymerizes to produce a gel that binds dirt particles together occupies the gaps or voids.

Methodology includes the master plan of a research that shows how the research is to be executed. It reveals all the major parts of the study like the sample, groups, materials, measures, treatments or programs etc that work together to address the research problem. It serves to plan, structure and execute the research to maximize the validity of the findings Research design stands for advance planning of the method to be adopted for collecting the relevant data and the techniques to be used in their analysis keeping in view the objectives of research and availability of staff, time and money.

VI. METHODOLOGY

Processing of Soil Samples

Soil in sufficient amount was brought from village in district Anantnag. Wooden hammer was used to pulverize soil to break lumps and was dried in air under covered area. The dried soil was sieved through 2.25mm sieve, and was mixed thoroughly and After that, it was sealed in polythene bags. The required amount of soil was extracted from polythene bags and dried in an oven for 24 hours at 105°C 5°C. At room temperature, the dirt was allowed to cool. We used hydrated lime and sodium silicate powder lumps were broken by the use of wooden hammer and sieved through 2.35mm IS sieve.

The several tests that have been performed, details of equipment's used and the procedure of tests have been described in the following sections.

Tests Executed on Sub Grade Soil

- Liquid limit test
- Plastic limit test.
- The Optimum Moisture Content O.M.C and maximum dry density are determined via a standard proctor test.
- Unconfined compressive strength test (UCS Test)
- California bearing ratio test (CBR Test).

RESULTS

Maximum dry density and optimum moisture content of various soil samples shows in Table 1 and Fig.1 Maximum dry density variation of soil having different percentages of calcium hydroxide with various percentages of sodium silicate.

Table 1 shows the M.D.D and O.M.C content on various soil samples.Table.2 shows the Variation of maximum dry density of soil samples having different percentages of lime (Sodium silicate = 0%).Table.3 shows the Variation of maximum dry density of soil samples having different percentages of lime (Sodium silicate = 0%).

Fig.1 shows the Maximum dry density variation of soil having different percentages of calcium hydroxide with various percentages of sodium silicate.Fig.2 shows the Maximum dry density variation with different percentages of lime [sodium silicate 0%].Fig. 3 shows the Maximum dry density variation with different percentages of lime [sodium silicate 0%]

Table.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	1.72	16.48
2	Soil+2.5%	0	1.64	18.97
3	Soil+5.0%	0	1.58	20.51
4	Soil+7.5%	0	1.53	22.56
5	Soil+0%	1.5	1.55	17.22
6	Soil+0%	3.0	1.47	17.80
7	Soil+0%	4.5	1.5	17.93
8	Soil+2.5%	1.5	1.40	18
9	Soil+2.5%	2.5	1.47	18.70
10	Soil+2.5%	3.5	1.40	18.89
11	Soil+5.0%	1.5	1.36	19.36
12	Soil+5.0%	2.5	1.42	19.76
13	Soil+5.0%	3.5	1.37	20.77
14	Soil+7.5%	1.5	1.35	21.36
15	Soil+7.5%	2.5	1.33	22.56
16	Soil+7.5%	3.5	1.31	23.55

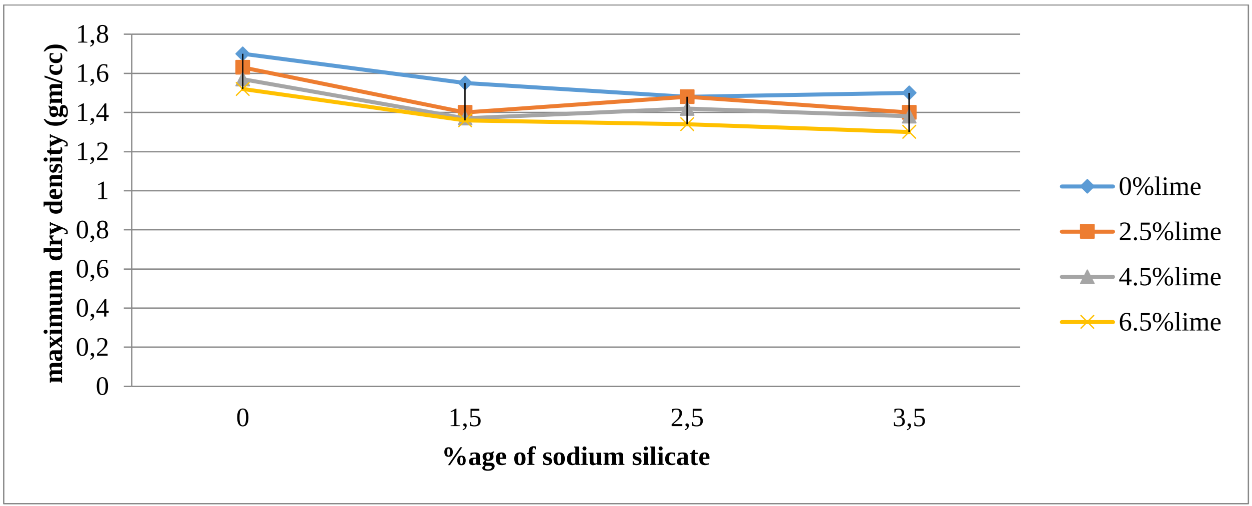

Figure.1 Maximum dry density variation of soil having different percentages of calcium hydroxide with various percentages of sodium silicate

- Effect of Lime on Maximum Dry Density
  On analysis of above table, it is observed that with the addition of 2.5% lime by weight to the soil sample, the max. dry density of the soil decreased from 1.72gm/cc to 1.64gm/cc.

Similarly, upon the addition of 5% and 7.5% lime by weight, the maximum dry density decreased from 1.72gm/cc to 1.58gm/cc respectively.

The reason of decrease in the max. dry density of soil with the increase in its lime content is that upon addition of lime to the soil, it quickly reacts to the clay minerals forming tough water insoluble gel of calcium silicate causing cementing of the particles together. It immediately blocks the soil pores. It gradually crystallizes into a hard calcium silicate hydrate which make it tough to compact and thus, decreasing the max. dry density of the soil.

- Effect of lime on optimum moisture content (OMC):

On analyzing the table 4.2.1, it is drawn out that with the increase in content of lime from 0 to 2.5%, the optimum moisture content increases from 16.48 to 18.97%.

Similarly, upon addition of lime from 2.5% to 5% and 7.5%, optimum moisture content increases from 18.97 to 20.51 and 22.57 respectively. The reason for increase in optimum moisture content is that upon addition of lime some water content is used for hydration of lime which increases the required amount of water and hence increase in optimum moisture content.

- Effect of sodium silicate on maximum dry density

On analysis, it is observed that maximum dry density decreased from 1.53gm/cc to 1.55gm/cc and 1.47gm/cc with increase in sodium silicate from 0% to 1.5% and 3% respectively.

Similarly, it goes on further decreasing upon addition of sodium silicate from 3% to 4.5%.

- Effect of sodium silicate on optimum moisture content:

Upon addition of sodium silicate to virgin soil, increasing pattern of O.M.C is obtained. Increasing the amount of sodium silicate from 0% to 1.5, 3% and 4.5% increases O.M.C to 17.22% to 17.80% and 17.93% respectively.Table.2 shows the Variation of maximum dry density of soil samples having different percentages of lime (Sodium silicate = 0%).Figure.2 shows the Maximum dry density variation with different percentages of lime [sodium silicate 0%].Table.3 shows the Variation of maximum dry density of soil samples having different percentages of lime (Sodium silicate = 0%).Figure 3 shows the Maximum dry density variation with different percentages of lime [sodium silicate 0%]

Table.2 Variation of maximum dry density of soil samples having different percentages of lime (Sodium silicate = 0%)

Sr. no.	**Lime%**	**Maximum dry density(gm/cc)**
1	0	1.70
2	2.5	1.63
3	4.5	1.57
4	6.5	1.52

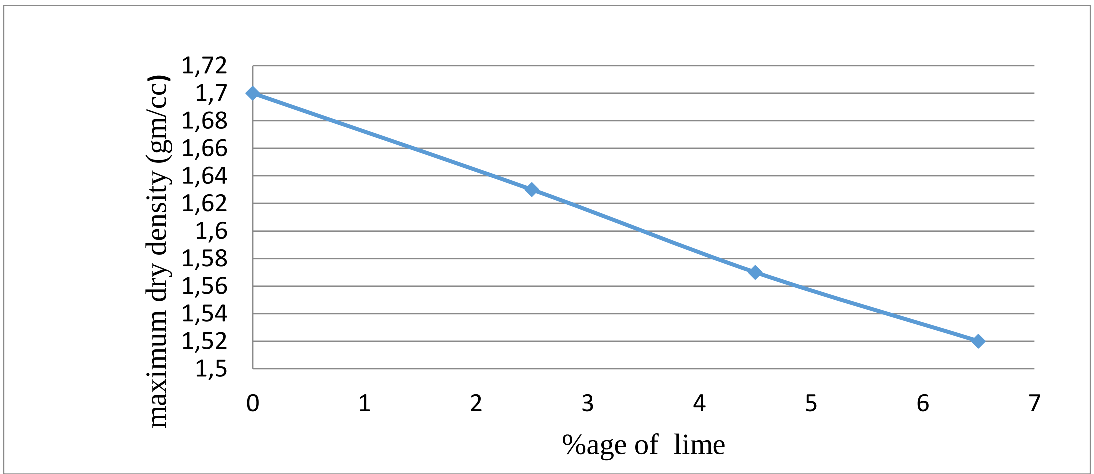

Figure.2: Maximum dry density variation with different percentages of lime [sodium silicate 0%]

Table.3 Variation of maximum dry density of soil samples having different percentages of lime (Sodium silicate = 0%)

Sr. no.	Lime%	Maximum dry density(gm/cc)
1	0	1.70
2	2.5	1.63
3	4.5	1.57
4	6.5	1.52

Fig. 3: Maximum dry density variation with different percentages of lime [sodium silicate 0%]
Table.4 shows the Variation of optimum moisture content of soil samples having 0%sodium silicate, with different percentages of lime (sodium silicate 0%) whereas Table 5 shows the Variation of UCS.
Fig. 4. shows the Variation of OMC of soil samples having 0% Sodium Silicate with different percentages of lime.

Table.4 Value of OMc & Lime

Sr. No.	**Lime%**	**O.M.C.%**
1	0	16.48
2	2.5	18.97
3	5.0	20.51
4	7.5	22.57

Fig. 4. shows the Variation of OMC of soil samples having 0% Sodium Silicate with different percentages of lime.Fig. 5 shows the Variation of unconfined compression strength of uncured soil.

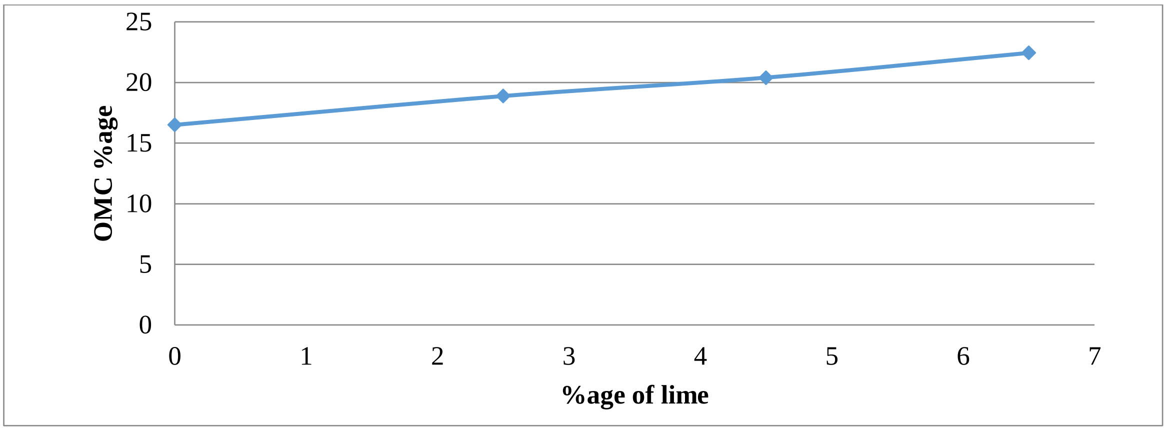

Figure. 4.Variation of OMC of soil samples

Results and observation for unconfined compressive strength values (uncured samples)
Table 6 shows the Variation of unconfined compression strength of uncured samples having different percentages of lime [sodium silicate =0%].Table 7 shows the Unconfined compressive strength of various cured samples.Table 8 shows the Comparison of unconfined compression strength of cured and uncured sample having 2.5% lime and varying percentage of sodium silicate.

Fig. 6 shows the Variation of unconfined compression strength of uncured soil samples having different percentages of lime [sodium silicate =0].Fig. 7 shows the Variation of unconfined compression strength of cured samples having different percentages of sodium silicate.Fig. 8 shows the Comparison of variation of unconfined compression strength of cured and uncured samples having 2.5% lime with varying percentage of sodium silica

Table 5. Variation of UCS of uncured samples having different percentages of Calcium hydroxide and sodium silicate

Sample No.	Soil+ lime	Sodium silicate %	Unconfined Compression strength (kg/cm²)	%Increase (compared to virgin soil)
1	Soil+0%	0	4.10	_
2	Soil+2.5%	0	5.78	38
3	Soil+5.0%	0	6.73	61
4	Soil+7.0%	0	7.48	79
5	Soil+0%	1.5	5.18	30
6	Soil+0%	3.0	7.48	78
7	Soil+0%	4.5	6.08	52
8	Soil+2.5%	1.5	6.00	49
9	Soil+2.5%	3.0	8.28	100
10	Soil+2.5%	4.5	8.14	97
11	Soil+5.0%	1.5	9.23	123
12	Soil+5.0%	3.0	9.69	135
13	Soil+5.0%	4.5	9.39	132
14	Soil+7.5%	1.5	10.48	154
15	Soil+7.5%	3.0	11.40	175
16	Soil+7.5%	4.5	11.44	176

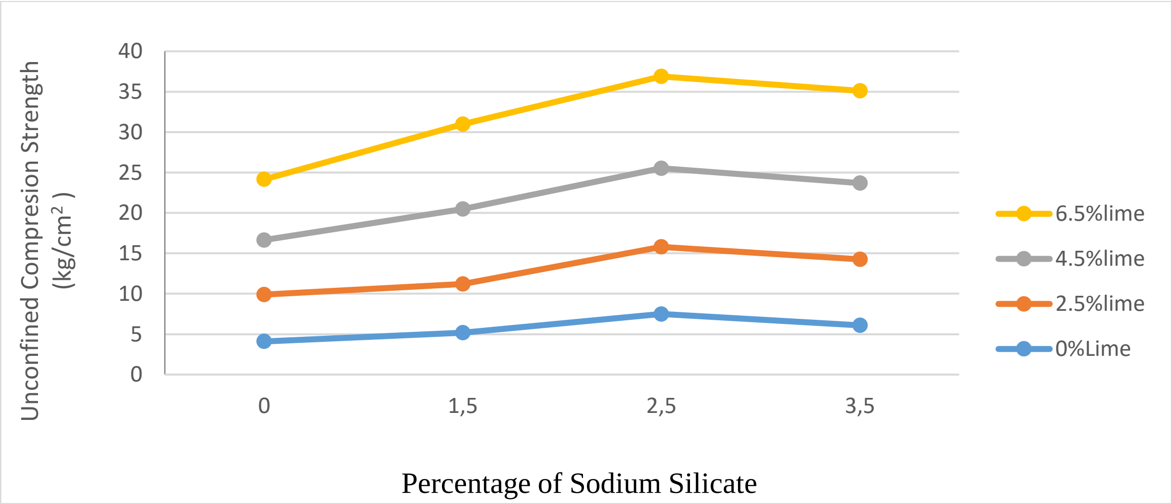

Figure. 5 Variation of unconfined compression strength of uncured soil

Table 6 Variation of unconfined compression strength of uncured samples having different percentages of lime [sodium silicate =0%]

S.No.	**Lime%**	**Unconfined compression strength (kg/ cm²**
1	0	4.10
2	2.5	5.78
3	5.0	6.80
4	7.5	7.48

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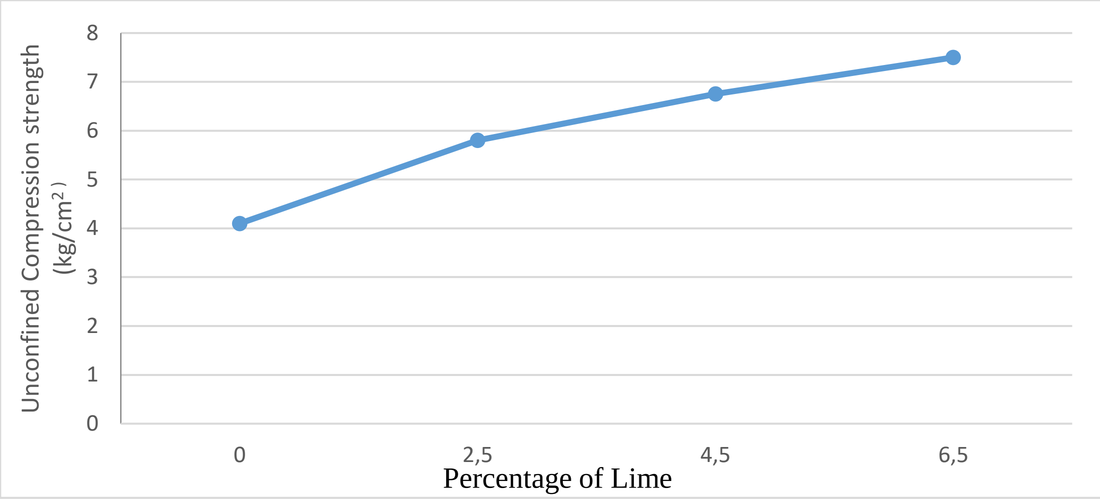

Figure. 6: Variation of unconfined compression strength of uncured soil samples having different percentages of lime [sodium silicate =0]

Result and observation of unconfined test for sample cured (curing time 7 days)

Table 7 Unconfined compressive strength of various cured samples

Sample No.	**Soil+Lime**	**Sodium silicate (%)**	**Unconfined compressive strength (kg/cm²)**
1	Soil +2.5%	0	5.80
2	Soil +2.5%	1.5	7.50
3	Soil +2.5%	3.0	8.38
4	Soil +2.5%	4.5	7.20
5	Soil +5.0%	0	7.48
6	Soil +5.0%	1.5	9.37
7	Soil +5.0%	3.0	10.30
8	Soil +5.0%	4.5	9.40

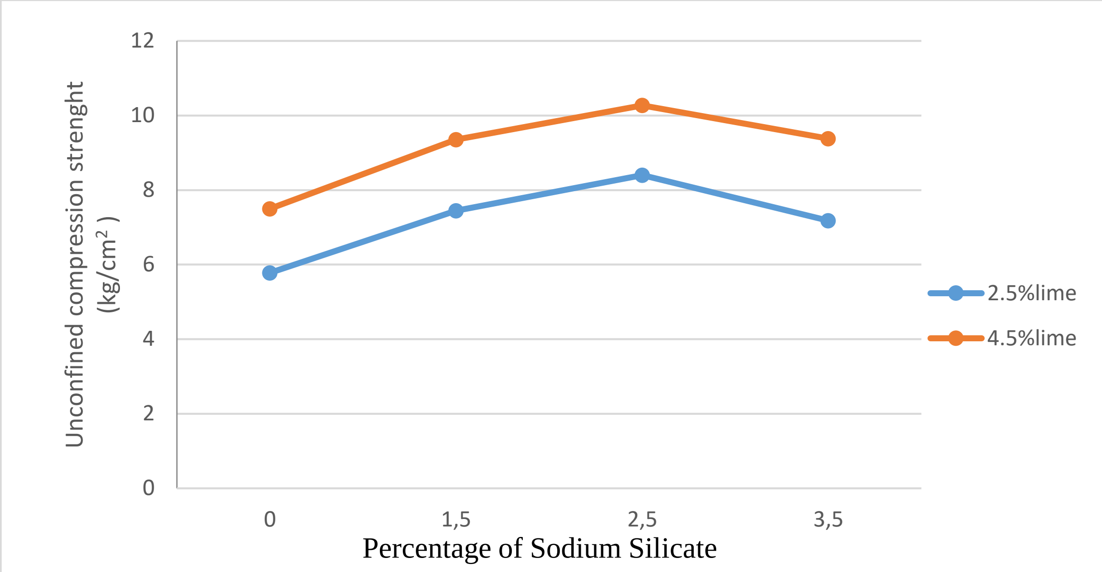

Figure. 7: Variation of unconfined compression strength of cured samples having different percentages of sodium silicate

Table 8 Comparison of unconfined compression strength of cured and uncured sample having 2.5% lime and varying percentage of sodium silicate

Sr. No.	Sodium Silicate %	Unconfined compressive strength uncured (kg/cm²)	U.C. Strength cured (kg/cm²)
1	0	5.80	5.80
2	1.5	6.18	7.42
3	3.0	8.40	8.42
4	4.5	8.97	9.20

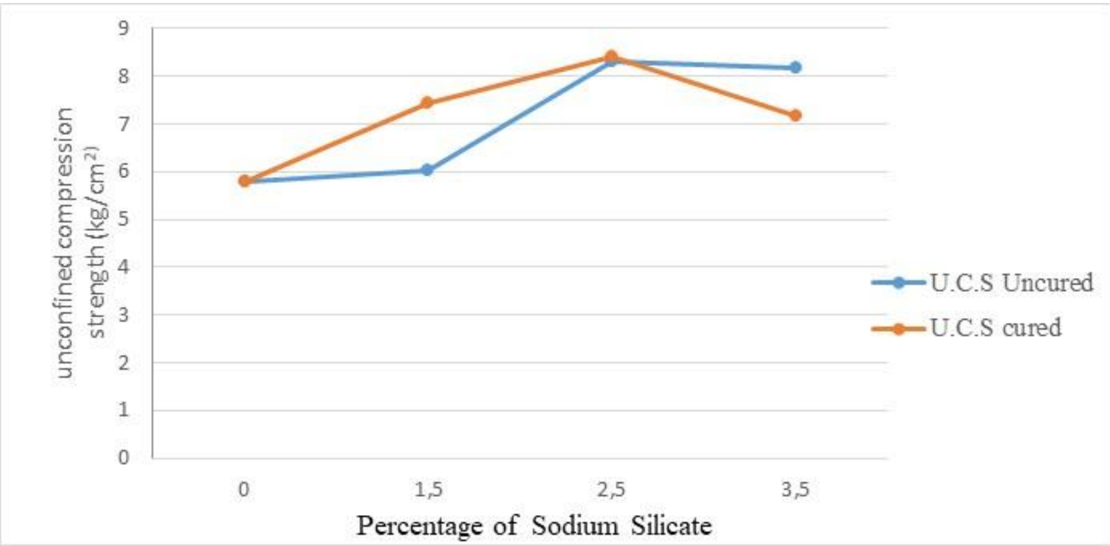

Figure. 8: Comparison of variation of unconfined compression strength of cured and uncured samples having 2.5% lime with varying percentage of sodium silicate

Observation for California Bearing Ratio TestCBR value = Test load/standard load x 100%

Table 9 shows the Penetration values with respect of Load. Table 10 shows the values for California Bearing Ratio Test.Fig. 9 Showing the CBR values of unsoaked virgin soil

Table 9 Standard load values for penetration values

Sr. No.	Penetration (mm)	Standard load (kg)
1.	2.5	1370
2.	5.0	2055

Table 10 Observations for California bearing ratio test

Penetration (mm)	Loads (kg) for different samples of soil					
	Virgin soil		Soil + 4.5% lime mix		Soil + 4.5% lime + 2.5% sodium silicate	
	Unsoaked	Soaked	Unsoaked	Soaked	Unsoaked	Soaked
0.5	20.2	12.6	76.5	19.5	86.5	38.2
1.0	37.7	21.7	123.2	35.3	141.3	61.3
1.5	56.6	29.2	159.3	49.5	190.2	83.5
2	73.3	36.2	185.5	62.5	231.6	103.3
2.5	83.5	41.6	215.2	74.2	256.6	118.4
3	93.2	48.2	235.5	83.5	301.5	129.2
3.5	101.5	53.3	261.2	90.3	331.3	140.3
4	110.3	57.5	277.2	97.5	353.5	150.4
4.5	115.5	61.2	295.5	101.5	370.2	159.2
5	123.5	64.5	306.3	107.2	387.5	167.5
5.5	127.2	67.7	307.2	115.3	401.2	174.2
6	132.6	70.6	315.6	116.5	410.4	181.5
6.5	135.7	73.5	323.7	120.2	419.2	188.3
7	139.3	75.4	338.2	125.5	425.6	193.2
7.5	143.4	77.6	345.2	130.2	433.2	198.3
8	145.5	79.2	353.5	133.5	443.5	204.2

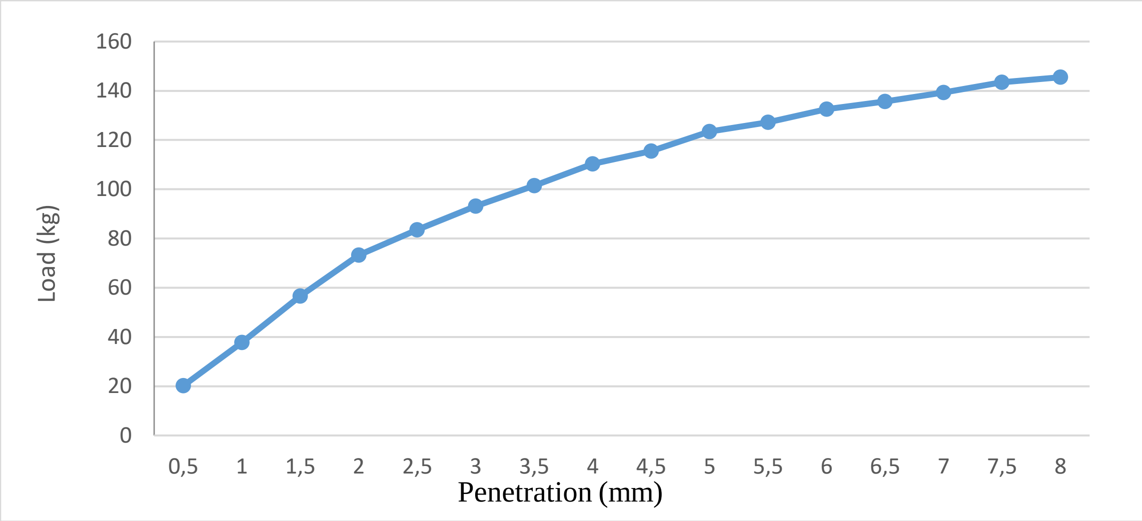

Figure. 9: Showing CBR values of unsoaked virgin soil

VIII. CONCLUSION

- Calcium Oxide or Calcium Hydroxide [Cao or Ca (OH)2] acts quickly to improve soil qualities such as resistance to shrinkage in wet conditions, decrease in flexibility, increase in CBR value, and eventual elevation in compression resistance as time passes.
- For extremely dynamic soils that expand and compress often, calcium oxide is used as the most effective soil stabilising ingredient.
- The reaction is fairly quick, and the soil begins to stabilise within a few hours.
- The addition of calcium oxide and sodium silicate to the subgrade soil reduces the maximum dry density.
- The addition of lime and sodium silicate to the subgrade soil improves the ideal moisture content.
- When compared to virgin soil, the unconfined compression strength of the soil + 4.5% lime + 2.5% sodium silicate mix rose by 137%. When cured soil + 4.5% lime + 2.5% sodium silicate was compared to virgin soil, the unconfined compression strength rose by 152%.
- At 2.5 mm penetration, the California bearing ratio of soil + 4.5% lime rose by 160 % (unsoaked) and 80% (soaked), and at 5.0 mm penetration, it climbed by 115.9% (unsoaked) and 66.9% (soaked).
- At 2.5 mm penetration, the California bearing ratio of soil + lime 4.5% + sodium silicate 2.5% rose by 211% (unsoaked) and 186% (soaked), respectively, while at 5.0 mm penetration, it increased by 172.4% (unsoaked) and 161.2 %.
- Hence, there is an overall gain in strength parameters of sub grade soil due to the addition of Calcium and sodium silicate at OMC of 8% to 14%.

CONFLICTS OF INTEREST

The author declare that they have no conflicts of interest.

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