# An Experimental Study of Strengthening of Sub-Grade Soil by Using Calcium Oxide and Sodium Silicate

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***Abstract* - Locally available soils are readily available, and relatively cheap, but are often problematic and do not perform required geotechnical properties satisfactorily. In developing countries like India, needs for infrastructural and industrial projects are increasing rapidly. These require locally available soils with good bearing capacity and strength properties. But soil with required characteristics is not available at locations. In such situations, soil improvement or modification plays major role. To improve these properties the common method followed is stabilization. Soil stabilization using chemicals has been widely recommended for developing countries for the construction of various elements of pavements. In the past few years, many researches were focused on utilization of chemicals. Utilization of chemicals like sodium silicate, calcium oxide materials in soil stabilization is one of the alternative methods where high-volume consumption is possible. It also provides good material for construction activities. In this research an attempt was made to evaluate the effectiveness of locally available soil blended with Sodium Silicate and Calcium Oxide for soil stabilization by investigating the geotechnical characteristics in the laboratory.**

***Index Terms* - calcium oxide, lime, soil, strength.**

## I.INTRODUCTION

Construction works are facing problems in many parts of the world due to expansive soil or cotton soil or black soil. Road pavement and structure damages have been recorded regularly which results in fatalities and financial loss. Soil replacement could be done but it is highly priced process and also difficult in developing countries like India. Furthermore, pavement on clayey soil requires much thickness of base and subbase course as a result of which construction cost of project enhances. Expensive soils deposits found in the arid and semi-arid regions and because of their tendency to heave during the wet season, engineering constructions pose a challenge. Expensive soil causes damage in particular to pavements because they are light and covers large area. Swelling and shrinkage cannot take place if the degree of saturation of an expansive soil remains unchanged. *The most important element and of most concern to the practicing engineer is the effect of water content changes on expensive soils.* With alternate wet and dry seasons, large volume changes occur in a climate. The amount of volume change is a function of many factors such as type and amount of clay, initial compaction condition, and other factors like the depositional environment which determines particle arrangement, overburden pressure and the degree of weathering. Swelling causing factors are also expected to cause shrinkage but to different grades. So it is necessary to improve the soil strength which consequently will help to reduce thickness of pavement layers and project cost. So, one of the best and readily available methods for improvisation of soil properties is the soil stabilization .The main stabilizers which are used to improve the soil properties are gypsum, tyres, fly ash, lime, sodium silicate, calcium oxide, jute, rice-husk ash, baggase ash etc. A most widely used and highly priced stabilizer includes cement which directly increases the cost of project. The leaching properties of stabilized black cotton soil (BCS) was studied with up to 8% lime admixed with up to 10% iron ore tailing (IOT) by dry weight of soil compacted [1]. A study has been conducted to check the variation in factors influencing the dry density of fly ash and ash pond significantly and to determine the Geotechnical properties of pond ash and fly ash [2].**A** researcher investigated the influence on the swell percent, swell pressure and unconfined compression strength of highly plastic clays by lime, gypsum and lime with gypsum mixtures in the Batikent region to specify an appropriate mixture ratio for soil stabilization[3]. Another research was conducted, and the objective of this research was to study black cotton (BC) soil from Rajkot region and was treated with three different stabilizing agents - 1.Cement waste dust collected from Saurashtra Cement & Chemicals Limited, Ranavav Dist. Porbandar 2. Cement Dust + Lime Powder, 3. Lime Powder collected from the quarry of lime situated near Ranavav Dist. Porbandar, using cement dust, cement dust and lime (50-50 percentage) respectively. The, third test was executed with pure lime powder. The stabilizing agent was added in each test ranging from 1% to 9% [4]. It has been studied that the results indicate that the CBR values for 2.5 mm depths of penetration are lower than 5 mm depths of penetration in most of the cases. Unconfined compressive strength and CBR values considerably increases up to 2.5 % lime which can be taken as the optimum lime content for both the fly ashes. With addition of gypsum, these values enhance further significantly, the increase being significant with 2.5 % lime and 2.5% gypsum [5]. Further the purpose of other investigation was to study the compaction properties of soil mixed fly ash and lime using fly ash (class C category) from Panki Thermal Power Station, Kanpur and soil from Meza road, Pragraj[6]. The behavior of expansive clays treated with lime-fly ash admixtures by use of software package was studied and it has been recommended that a combination of fly ash with small percentage of lime can improve the characteristics of expansive soil[7]. Also the strength properties (UCS) of stabilized expansive clay have been studied with lime, calcium chloride, and rice-husk ash (RHA)[8]. The leaching characteristics of residual lateritic soils stabilized with fly ash and lime for geotechnical applications has been studied[9]. Furthermore, researcher studied the effect of fly ash on the swelling characteristics of expansive soil. In this study, high calcium and low-calcium class C fly ashes from the Soma and Tuncbilek thermal power plants, respectively, in Turkey, were used as stabilizers[10].

The stabilizers used by the researcher in present study to improve the engineering characteristics of clayey soil were the Lime and Sodium Silicate. The main focus of this study is to increase the clayey soil strength by making use of Lime and Sodium Silicate (Stabilizers).

## II.MATERIALS

### *A. Properties of Sub Grade Soil*

The sub grade soil which was selected for analysis was collected from local site. It was collected from NH-73 village Dinarpur, Tehsil Shahbad, Distt Ambala Cantt of Haryana state.

Fig. 1 Soil used for sub-grade

### *B. Properties of Calcium Hydroxide Lime* [Ca (OH₂)]

Calcium hydroxide (slaked lime) was bought from local market for thorough study. It was purchased from local market.

### *C. Water*

Ordinary potable water (neat, clean and without any suspension material) from tap was utilized throughout the research.

### *D. Sodium Silicate [Na2SiO3]*

Sodium silicate was used in powdered form in experiments and was bought from local market. The price of sodium silicate is 70 Rupees per kg

Table.1 Properties of sub-grade Soil

| S.No | Properties | Report |
|---|---|---|
| 1 | Colour | Brown |
| 2 | Liquid limit (%) | 49.25 |
| 3 | Plastic limit (%) | 24.33 |
| 4 | Plasticity Index (%) | 24.92 |
| 5 | Specific Gravity | 2.45 |
| 6 | IS Classification | CL (clay of low compressibility) |
| 7 | Maximum dry density (gm/cc) | 1.72 |
| 8 | O.M.C (%) | 16.48 |

Table.2 Properties of Calcium Hydroxide [Ca $(OH)_2$]

| S.No | Properties | Report |
|---|---|---|
| 1 | Minimum content (Acidic – metric) | 90% |
| 2 | Maximum limit of additions(impurities) | |
| | (a) chlorides | 0.038% |
| | (b) Al, iron and insoluble mater | 1.2% |
| | (c) Arsenic as oxide | 0.0038% |
| | (d) Lead | 0.0037% |
| | (e) Al, iron and insoluble mater | 1.2% |

Table 3 Properties of Sodium Silicate [$Na_2SiO_3$]

| S. No. | Properties | Report |
|---|---|---|
| 1. | Colour | Colourless glassy |
| 2. | $Na_2O$ | 15.9% |
| 3. | $SiO_2$ | 31.4% |

## III.METHODOLOGY

### *A. Processing of Soil Samples*

Soil in sufficient amount was brought from local village. 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 was then stored in polythene bags. Required quantity of soil was taken from polythene bags and was dried in oven at 105℃ ± 5℃ for 24 hours. The soil was allowed to cool at room temperature. Hydrated lime and sodium silicate powder were taken 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 a variety of tests have been described in detail in the following sections

### *B. Tests Executed on Sub-Grade Soil*

(a) Liquid limit test
(b) Plastic limit test
(c) Sieve Analysis
(d) Specific Gravity Test
(e) Standard Proctor Compaction Test for determination of Optimum Moisture Content (O.M.C) and Maximum Dry Density (MDD)

(a) Liquid Limit Test

The water content in a soil at which it behaves almost as a liquid, but possess almost zero shear strength is called as the liquid limit of that soil. It flows to join the cut portion in just 25 no. of blows in Casagrande's liquid limit apparatus.

Fig.2 Liquid limit determination

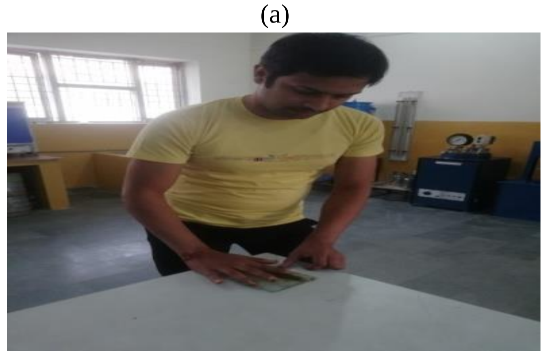
(b) Plastic Limit Test

Plastic limit of soil is determined by Plastic limit test as per IS: 2720 (Part 5) – 1985.The plastic limit of cohesive soil is the amount of moisture content of the soil below which plasticity disappears. It starts to crack when rolled into thin threads of 3mm dia. The method to obtain the plastic limit is given as under:

Procedure to Determine Plastic Limit:

- Consider about 20gm of the soil and add a small amount of water in the soil, mix it thoroughly.
- Now after mixing, on a glass plate roll the soil with fingers. The rate of rolling is kept in the range of 85 to 95 strokes / minute to obtain 3mm diameter.
- If without any crumbles on soil, the diameter of the threads can be reduced up to smaller than 3mm, it means that the moisture content is higher than the plastic limit. Mold the soil sample to reduce the moisture content and again roll it into a thread.
- Repeat kneading and rolling alternately till the thread crumbles.
- The crumbled soil thread collected and holds the pieces in the pan used to obtain the water content.
- Continue the procedure for at least two times using fresh soil samples every time.

(a)



(b)

Fig. 3(a) & (b) Plastic limit determination

(c) Sieve Analysis

The gradation of soil was performed on the soil sample. Small lumps were there but it was broken with the help of wooden hammer. A set of sieves was arranged with largest size sieve on the top and the smallest size sieve at the bottom. The soil was passed through different mm I.S sieves like 4.75mm, 2.36mm, 1.18mm, 600µ, 300µ, 150µ, 75µ. A pan was placed under the stack of I.S sieves for the collection of passed soils. The stack of I.S sieves was shaken with the help of sieve shaker for about 12 minutes. Weights of the soil retained on all the I.S sieves were accurately measured.

Table 4.Gradation test of soil

| Sieves (mm) | Weight of Sample retained (gram) | Weight of total Percentage of retained (%) | Cumulative percentage retained (%) | Percentage of passing (%) |
|---|---|---|---|---|
| 4.75 | 209 | 10.45 | 10.45 | 89.55 |
| 2.36 | 258 | 12.9 | 23.35 | 76.65 |
| 1.18 | 336 | 16.8 | 40.45 | 59.85 |
| 600µ | 211 | 10.55 | 50.7 | 49.3 |
| 300 µ | 273 | 13.65 | 64.35 | 35.65 |
| 150 µ | 257 | 12.85 | 77.2 | 22.8 |
| 75 µ | 207 | 10.35 | 87.55 | 12.45 |
| Pan | 249 | 12.45 | 100 | 0 |

(d) Specific Gravity Test

The mass of a unit volume of soil at a given temperature divided by the mass of the same volume of gas-free distilled water at the same temperature is known as specific gravity. In the phase relationship of air, water, and solids in a given volume of soil, the specific gravity of the soil is utilized. The test was carried out by Pycnometer as per IS 2720 Part 3 (1980). The Specific Gravity of quartz-rich soils can be calculated to be around 2.65, whereas silty and clayey soils can range from 2.6 to 2.9

Fig. 4 Pycnometer Bottle

(e) Standard Proctor Compaction Test

Maximum dry density was obtained by Modified Proctor Test. Cylindrical mould of internal diameter of 100 mm, height of mould 127.5 mm and volume of mould 1000 ml was used to perform the test. A detachable collar of 60 mm height adjusts on top of the mould and detachable bottom is used. The rammer utilized in this test weighs 2.6 kg with a fall of 310 mm and it has50mm face dia.

About 2.55 kg of oven-dried soil sample was held. Sample was blended uniformly with almost 9% of distilled water by mass. Sample (soil water mix) was kept in an air sealed container for almost 10 hours. The mould was wiped clean and dry, greased very lightly. The empty mould was weighed after being attached. The mould being attached to the collar is filled with soil sample in such a way that after compaction by rammer with 25 evenly distributed blows. Height is about one-third. The upper of the first layer was scratched by a knife and then compacting the second layer. The procedure is repeated for second and third layers.

Remove the collar of the mould, extra soil was trimmed off using the help of straight knife. The soil sample with mould and bottom plate was weighed A representative sample from the centre of the compacted soil specimen was drawn out for its moisture content estimation. Procedure was continued 5-7 times, after 2%increase in moisture quantity than the previous one till a decrease or no change in the weight of moist compacted soil in the mould found. Dry density and Moisture content was estimated for every set and then graph gives the OMC and MDD.

The steps were continued for estimating optimum water content and maximum dry density of sample of soil-lime mix and soil-lime-sodium silicate mix. Dry density was estimated by using the equation.

$$\gamma d = \frac{\gamma}{1+w}$$

where, γd = dry density (gm/cc).

γ= bulk density.

w = moisture content.

**(a)**

(b)

Fig. 4(a) & (b) Proctor Compaction Test

## IV. RESULTS AND DISCUSSION

### *A. General*

This chapter consists of outcomes of the tests and experiments performed towards the objective of the project. It consists of the outcomes from the Standard Proctor Test.

The outcomes and Results are accompanied by graphs and tables to have a detailed analysis of the experiments. The results are better explained by these graphs and tables to meet the basic and detailed objective of the project.

### *B. Results and Observation*

Table 5. Maximum dry density and optimum moisture content of various samples.

| S. No. | Soil+Lime | Sodium Silicate (%) | MDD (gm/cc) | OMC (%) |
|---|---|---|---|---|
| 1 | Soil+0% | 0 | 1.72 | 16.48 |
| 2 | Soil+2.5% | 0 | 1.64 | 18.97 |
| 3 | Soil+4.5% | 0 | 1.58 | 20.51 |
| 4 | Soil+6.5% | 0 | 1.53 | 22.56 |
| 5 | Soil+0% | 1.5 | 1.55 | 17.22 |
| 6 | Soil+0% | 2.5 | 1.47 | 17.80 |
| 7 | Soil+0% | 3.5 | 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+4.5% | 1.5 | 1.36 | 19.36 |
| 12 | Soil+4.5% | 2.5 | 1.42 | 19.76 |
| 13 | Soil+4.5% | 3.5 | 1.37 | 20.77 |
| 14 | Soil+6.5% | 1.5 | 1.35 | 21.36 |
| 15 | Soil+6.5% | 2.5 | 1.42 | 22.56 |
| 16 | Soil+6.5% | 3.5 | 1.31 | 23.55 |

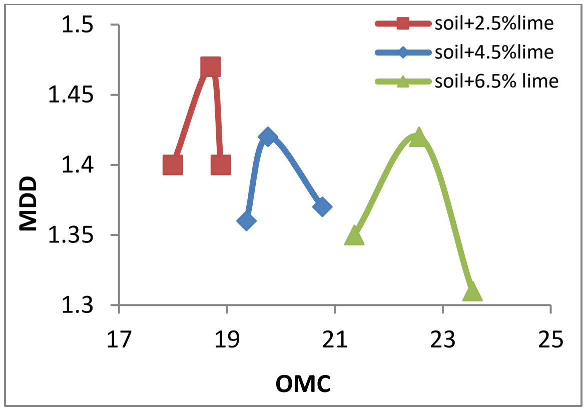



Figure: 5 Variation of Maximum dry density of soil having different Percentages of calcium oxide with various percentages of sodium silicate as 1.5%, 2.5% and 3.5% respectively.

### *C. 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 4.5% and 6.5% lime by weight, the maximum dry density decreased from 1.72gm/cc to 1.58gm/cc and 1.72gm/cc to 1.53gm/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 hydrates which make it tough to compact and thus, decreasing the max. dry density of the soil.

### *D. Effect of Lime on Optimum Moisture Content*

On analyzing the table 5, 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 4.5% and 2.5% to 6.5%, optimum moisture content increases from 18.97 to 20.51 and 22.56 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 increases in optimum moisture content.

*E. 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 2.5% respectively.

Similarly, it goes on further decreasing upon addition of sodium silicate from 2.5% to 3.5%.

*F. 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%, 2.5% and 3.5% increases O.M.C to 17.22% to 17.80% and 17.93% respectively.

*G. Effect of Lime and Sodium Silicate on Maximum Dry Density:*

It has been seen that by keeping the percentage of lime constant and changing the percentage of sodium silicate, the dry density of soil decreases and we get the maximum density of 1.47gm/cc for the addition of 2.5% lime and 2.5% sodium silicate.

*H. Effect of Lime and Sodium Silicate on Optimum Moisture Content:*

It is clear that by keeping the percentage of lime constant and changing of the sodium silicate percentage, the optimum moisture content of soil increases. We get the maximum moisture content as 23.55 for the addition of 6.5% of lime and 3.5% of sodium silicate.

Table 6.Variation of maximum dry density of soil samples having different percentages of lime (Sodium silicate = 0%)

| S. No. | Lime% | Maximum dry density(gm/cc) |
|---|---|---|
| 1 | 0 | 1.72 |
| 2 | 2.5 | 1.63 |
| 3 | 4.5 | 1.57 |
| 4 | 6.5 | 1.52 |

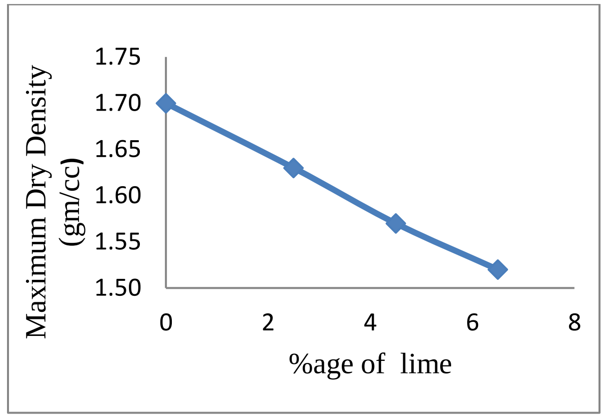



Figure 6. Variation of MDD of soil samples with different percentages of lime

Table 7. Variation of optimum moisture content of soil samples having different percentages of lime (sodium silicate 0%)

| Sr. No. | Lime% | O.M.C.% |
|---|---|---|
| 1 | 0 | 16.48 |
| 2 | 2.5 | 18.97 |
| 3 | 4.5 | 20.51 |
| 4 | 6.5 | 22.57 |

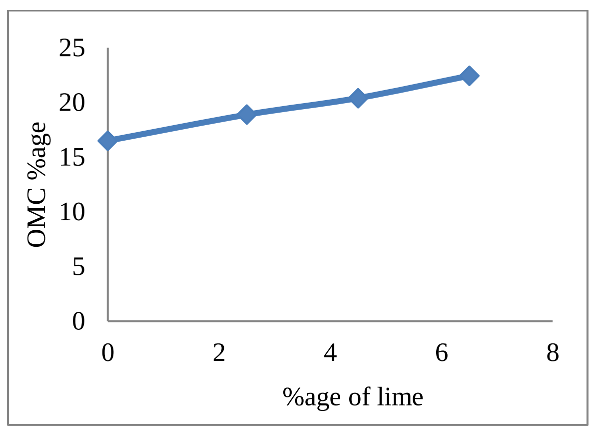



Figure 7.Variation of OMC of soil samples having different percentages of lime

## V. CONCLUSION

1. Calcium Oxide or Calcium Hydroxide [Cao or Ca(OH)2] acts immediately and enhances characteristics of soil such as resistance to shrinkage during wet conditions, decrease in

plasticity and subsequent elevation occurs in the compression resistance with the passage of time.
2. Calcium Oxide is employed aspre–eminent soil stabilizing material for highly active soils which undergo through frequent expansion and shrinkage.
3. The reaction is very fast and stabilization of soil begins within few hours.
4. The maximum dry density gets reduced by the addition of calcium oxide and sodium silicate to the sub-grade soil.
5. The optimum moisture content enhances by the addition of lime and sodium silicate to the sub-grade soil.

Hence, there is an overall gain in strength parameters of sub grades oil due to the addition of Calcium and sodium silicate at OMC of 8% to 14%.

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