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Effect of Granite Dust and GGBS on Lime Stabilized Black Cotton Soil

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Abstract

Soil stabilization is a technique in which the properties of soil are improved and maintained at stable conditions so that it is capable of carrying the loads coming on it. This technique is used in many engineering works like road construction works, in providing base and sub base course layers etc. It can also be used to reduce the permeability and compressibility characteristics of the soil that will be used in construction of hydraulic structures. In using the soil which has been stabilized, the cost of construction also reduces to some extent. Presently in this project, Black Cotton Soil has been stabilized. The various stabilizers used were Lime, Granite Dust. Lime was added as constant percentage of 5%. Granite dust and was added in varying percentages of 10%, 20%, 30%.

Key words: *Black cotton soil, Granite Dust, Lime, Soil stabilization*

INTRODUCTION

A very wide range of Central India and some parts of South India is covered by expansive soils called as Black Cotton Soils. These deposits have been found as a residual part during the formation of basalt or trap rocks. It is black in colour and mainly used to grow cotton, for which, it is named as Black Cotton Soil. These soils have greater plastic limit as well as greater liquid limit. They include a clay mineral montmorillonite within it, due to which it exposes high swelling and shrinkage properties. Also, shear strength and

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bearing capacity of these kind of soils are very low and the soil is very highly compressible. Therefore, it is necessary to stabilize these kinds of soils.

MEANING OF STABILIZATION

The method which is used to enhance the index and engineering properties of the soil termed as Soil Stabilization. Need of stabilization depends on the properties of soil i.e., when the properties of soil does not meet the requirements of the proposed construction.

In order to stabilize the soil, usually admixtures, chemicals, cementing materials etc. are added to the soil which has to be stabilized. Soil Stabilization helps in decreasing the permeability, compressibility etc. However, Stabilization of Black Cotton Soil results in reduction of its swelling and shrinkage properties, increasing in its shear strength and bearing capacity, decreasing in plastic limit and liquid limit etc.

TYPES OF STABILIZATION

The following types of stabilization are generally practiced to stabilize the soil. Namely,

- Mechanical Stabilization
- Cement Stabilization
- Lime Stabilization
- Bituminous Stabilization
- Chemical Stabilization
- Thermal Stabilization
- Electrical Stabilization

I. Mechanical Stabilization

In this method, two or more types of natural soils are blended together in order to obtain a relatively distinct material.

This distinct material will have relatively better properties than the virgin soil.

This type of stabilization of soil is also called as granular stabilization.

The soil in this type of stabilization is divided into 2 parts,

a) Aggregates
b) Binders

Aggregates impart internal friction and incompressibility to the soil.

Binders impart cohesion and imperviousness to the soil.

However the properties of stabilized soil depends on

a) Aggregate strength
b) Composition of minerals.

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c) Gradation of mixed soil
d) Liquid limit and Plastic limit of the soil

This method is generally used to improve the bearing capacity of the subgrades which is relatively low.

II. Cement Stabilization

Ordinary Portland cement is mixed with the soil which has to be stabilized in this method to obtain a mix called as Soil-Cement. This mix is then blended with required quantity of water and compacted to obtain the stabilized soil mass.

There are 3 types of soil cement namely

a) Normal soil cement
b) Plastic soil cement
c) Cement modified soil

The strength of stabilized soil depends on soil type, quantity of cement and water used, method of compaction and curing, admixtures used etc.

This type of stabilization can be adopted in 3 ways,

a) Mix in place method.
b) Stationary plant method.
c) Travelling plant method.

III. Lime Stabilization

When lime is added to the soil which has to be stabilized, exchange of cations in the water layer takes place and hence the soil gets stabilized. Quick Lime is generally used as stabilizer as it stabilizes the soil very effectively and efficiently. Quantity of lime to be employed in stabilization process to stabilize the soil usually varies between 2% to 10% of soil weight. The bases and sub bases which are stabilized by this method will have water resistant barrier and hence it does not allow the rain water to pass through it.

IV. Bituminous Stabilization

Bitumen's are generally soluble in carbon di sulphide. They are the non-aqueous system of hydrocarbons. Asphalt is used in bituminous stabilization as binder. When bitumen is added to the soil to be stabilized, resulting mix is called as soil-bitumen which will be stabilized.

There are 4 types of soil-bitumen namely

a) Proper soil-bitumen.
b) sand-bitumen
c) water proofed clay concrete.
d) Oiled earth.

Soil type, quantity of asphalt used, type of mixing and compacting are the various

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parameters upon which the strength and stability of the stabilized soil mass depend.

V. Chemical Stabilization

The various chemicals that can be added to stabilize the soil are

- Calcium chloride
- Sodium chloride
- Sodium silicate.
- Polymers.
- Chrome lignin.
- Alkyl chloro silanes.
- Ferric chlorides.
- Sodium hexa metaphosphate.
- Phosphoric acid etc.

VI. Thermal Stabilization

It is of 2 types namely,

a) Heating

b) Freezing.

Moisture content of the soil reduces on heating the soil. The inter particle repulsion and electrical repulsion reduces upon heating and hence the soil gets stabilized.

When the soil is cooled, its strength gets reduced because of the higher inter particle repulsion. But when it is freezed, formation of ice takes place because of the freezing of pore water, which acts as cementing agent and hence the soil gets stabilized.

VII. Electrical Stabilization

Electro osmosis is the method used to stabilize the soil in this method. When direct current is passed between the electrodes which is placed in soil (usually clayey soils), pore water migrates from anode to cathode. Cathode is generally made as a well point through which water can be removed. A steel metal rod can be used as anode. When water is removed from the cathode, soil gets stabilized. However this is an expensive method.

OBJECTIVE AND SCOPE OF THE STUDY

The aim of this project is to stabilize the Black Cotton Soil by adding Lime, Granite Dust and Ground Granulated Blast Furnace Slag. Initially the properties of Black Cotton Soil have been determined and then the properties are improved by adding Lime. The properties of the Black Cotton Soil are then again improved by adding Granite Dust and GGBS. The main objective of this project is to improve the strength and stability characteristics of the Black Cotton Soil.

The soil that has been stabilized becomes a valuable engineering material. This

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product can be used in many construction works like construction of sub-grade layers in Highway pavement construction and it can also be used for the purpose of foundation works in many hydraulic structures. Granite Dust and other materials which are left as waste products, if used in stabilization process helps in effective and efficient usage of such materials. Thus stabilization process helps in an economical way to reduce the cost of construction also.

MATERIALS USED AND METHODOLOGY

Black cotton soil for our study was collected from Kollegala taluk of Chamarajanagara district. Since black cotton soil is expansive soil, it will have swelling and shrinkage property. Liquid limit and Plastic limit will also be high. Un-confined compressive strength will also be low. So, black cotton soil is taken for stabilization process. The various properties of Black Cotton soil are tabulated as follows

Table 1- Various Properties of Black Cotton soil

Sl. No.	Properties	Values obtained
1	Natural Moisture Content	22.04%
2	Specific gravity	2.31
3	Co-efficient of Curvature	1.09
4	Uniformity Co-efficient	11.79
5	Liquid Limit	60%
6	Plastic Limit	23.72%
7	Plasticity Index	36.28%
8	MDD	1466.78 g/cc
9	OMC	25%
10	Unconfined Compressive Strength (q_u)	1.587 kg/cm²
11	Free swell Index	62.5%
12	Cohesion	0.3 kg/cm²
13	Angle of Internal Friction	30º

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Lime was obtained from the local markets in Bangalore.

Granite dust was collected from Pacific Granite Industry, opposite Byadarahalli Police station, Magadi road, Bangalore.

GGBS was collected from an RMC plant located near Doddakallasandra, Kanakapura Road, Bangalore.

Initially the properties of the black cotton soil collected is determined. Then, stabilizers are added to the black cotton soil and the stabilized properties are determined. Percentage of lime added is kept constant as 5%, while the percentage of Granite dust and GGBS used are varied i.e., 10%, 20%, 30%. Totally 7 combinations was done.

Black Cotton Soil + 5% Lime
Black Cotton Soil + 5% Lime + 10% Granite Dust
Black Cotton Soil + 5% Lime + 20% Granite Dust
Black Cotton Soil + 5% Lime + 30% Granite Dust
Black Cotton Soil + 5% Lime + 10% GGBS
Black Cotton Soil + 5% Lime + 20% GGBS
Black Cotton Soil + 5% Lime + 30% GGBS

RESULTS AND DISCUSSION

I. Specific Gravity Test Results

Table 2- Specific Gravity Results

TYPE	SPECIFIC GRAVITY
Black Cotton Soil	2.31
BCS+ 5% Lime	2.35
BCS+ 5% Lime+ 10% Granite Dust	2.44
BCS+ 5% Lime+ 20% Granite Dust	2.54
BCS+ 5% Lime+ 30% Granite Dust	2.63
BCS+ 5% Lime+ 10% GGBS	2.41
BCS+ 5% Lime+ 20% GGBS	2.56
BCS+ 5% Lime+ 30% GGBS	2.67

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The results show that when Black Cotton Soil is blended with 5% lime, specific gravity increases from 2.31 to 2.35. When granite dust is added, the specific gravity still increases to a value of 2.63 at 30% granite dust addition. Similarly when 30% GGBS is added, the value reaches to 2.67. This shows the increase in specific gravity when stabilizers are added to the Black Cotton Soil.

It is clear from the below results that Liquid limit of the Black Cotton Soil, which was 60% reduced by 8% on addition of 5% lime. It then again considerably reduced to a value of 28.5 % on addition of 30% Granite Dust. But better results were obtained on addition of 30% GGBS than Granite Dust because liquid limit reduced to a value of 26.5% which is 2% lesser than that obtained by the addition of 30% Granite Dust.

II. Liquid Limit Test Results

Table 3- Liquid Limit Test Results

TYPE	LIQIUD LIMIT
Black cotton soil	60%
BCS+ 5% Lime	52%
BCS+ 5% Lime+ 10% Granite Dust	46%
BCS+ 5% Lime+ 20% Granite Dust	35%
BCS+ 5% Lime+ 30% Granite Dust	28.5%
BCS+ 5% Lime+ 10% GGBS	42%
BCS+ 5% Lime+ 20% GGBS	33%
BCS+ 5% Lime+ 30% GGBS	26.5%

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III. Plastic Limit Test Results

Table 4- Plastic Limit Test Result

TYPE	PLASTIC LIMIT(%)
Black cotton soil	23.72
BCS+ 5% Lime	22.7
BCS+ 5% Lime+ 10% Granite Dust	20.12
BCS+ 5% Lime+ 20% Granite Dust	18.69
BCS+ 5% Lime+ 30% Granite Dust	16.27
BCS+ 5% Lime+ 10% GGBS	19.4
BCS+ 5% Lime+ 20% GGBS	17.36
BCS+ 5% Lime+ 30% GGBS	14.99

Plastic limit of the Black Cotton Soil which was found to be 23.72% decreased to 22.7% on addition of 5% Lime. On addition of 30% Granite Dust it reduced to 16.27%. On addition of 30% GGBS the value of Plastic Limit got reduced to 14.99% from which the better results were obtained.

IV. Standard Proctor Test Results

Table 5- Standard Proctor Test Results

TYPE	OMC (%)	MDD (g/cc)
Black cotton soil	25	1466.78
BCS+ 5% Lime	19.5	1669.62
BCS+ 5% Lime+ 10% GD	18.5	1711.83
BCS+ 5% Lime+ 20% GD	17.84	1730.57
BCS+ 5% Lime+30% GD	17.26	1852.24
BCS+ 5% Lime+10% GGBS	17.64	1716.38
BCS+ 5% Lime+20% GGBS	15.9	1723.83
BCS+ 5% Lime+30% GGBS	15.27	1894.35

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OMC of the Black Cotton Soil which was found to be 25% got reduced to 19.5% on addition of 5% lime. On adding 30% granite dust it got reduced to 17.26% and on adding 30% GGBS it got reduced to 15.27%.

MDD of the Black Cotton Soil which was found to be 1466.78 g/cc increased to 1669.62 g/cc on addition of 5% lime. On adding 30% granite dust it increased to 1852.24 g/cc and on adding 30% GGBS it increased to 1894.35 g/cc.

V. Differential Free Swell Test Results

Free Swell Index of the Black Cotton Soil which was found to be 62.5% got reduced to 37.5% on addition of 5% lime. On adding 30% granite dust it got reduced to 7.5% and on adding 30% GGBS it got reduced to 6.25%.

Table 5- Free Swell Test Results

TYPE	FREE SWELL INDEX
Black cotton soil	62.5%
BCS+ 5% Lime	37.5%
BCS+ 5% Lime+ 10% Granite Dust	31.25%
BCS+ 5% Lime+ 20% Granite Dust	12%
BCS+ 5% Lime+ 30% Granite Dust	7.5%
BCS+ 5% Lime+ 10% GGBS	25%
BCS+ 5% Lime+ 20% GGBS	13.75%
BCS+ 5% Lime+ 30% GGBS	6.25%

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VI. Unconfined Compression Test Results

Table 6- Unconfined Compression Test Results

TYPE	q_u (kg/cm^2)
Black cotton soil	1.587
BCS+ 5% Lime	1.603
BCS+ 5% Lime+ 10% Granite Dust	1.662
BCS+ 5% Lime+ 20% Granite Dust	1.762
BCS+ 5% Lime+ 30% Granite Dust	1.795
BCS+ 5% Lime+ 10% GGBS	1.782
BCS+ 5% Lime+ 20% GGBS	1.803
BCS+ 5% Lime+ 30% GGBS	1.82

Fig 1 shows the variations in stress-strain behaviour of Black Cotton Soil after adding 5%Lime to it. The un-confined compressive strength of the Black Cotton Soil was 1.587 kg/cm². After adding 5% Lime, the un-confined compressive strength was found to be 1.603 kg/cm².

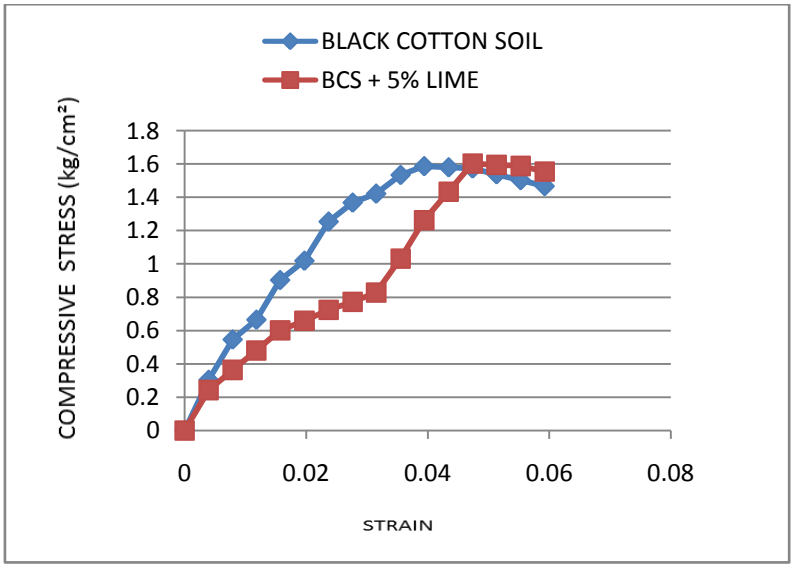


Figure 1- Variations in Stress Strain behaviour of Black Cotton Soil after adding 5%Lime

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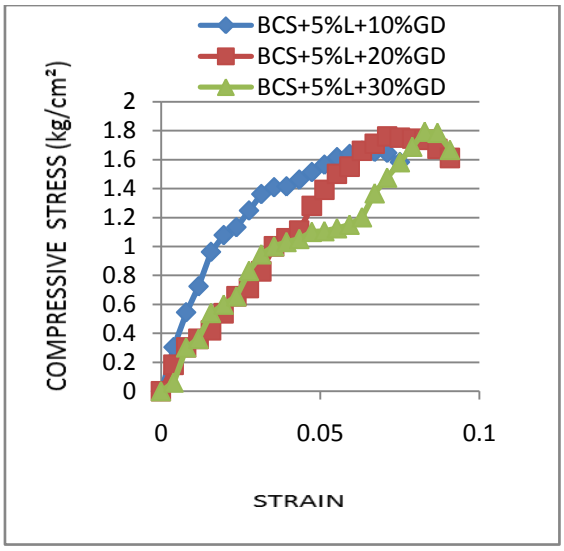


Figure 2- Variations in Stress Strain behaviour of Black Cotton Soil after adding Lime and Granite Dust

Fig 2 shows variations in Stress Strain behaviour of Black Cotton Soil after adding Lime and Granite Dust to it. The un-confined compressive strength which was 1.603 kg/cm² after adding 5% Lime now increased to 1.662 kg/cm² when 10% Granite Dust was added to it. After adding 20% Granite Dust, the un-confined compressive strength got increased to 1.762 kg/cm². Further, the un-confined compressive strength value got increased to 1.795 kg/cm² on addition of 30% Granite Dust.

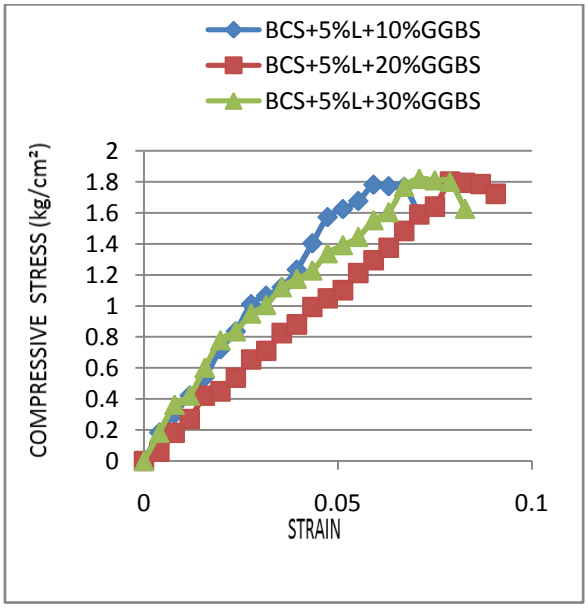


Figure 3- Variations in Stress Strain behaviour of Black Cotton Soil after adding Lime and GGBS

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Fig 3 shows variations in Stress Strain behaviour of Black Cotton Soil after adding Lime and GGBS to it. The un-confined compressive strength which was 1.603 kg/cm² after adding 5% Lime now increased to 1.782 kg/cm² when 10% GGBS was added to it. After adding 20% GGBS, the un-confined compressive strength got increased to 1.803 kg/cm². Further, the un-confined compressive strength value got increased to 1.82 kg/cm² on addition of 30% GGBS.

These values are tabulated in table 7.

VII. Shear Stress Parameters

Table 7 indicates increase in Cohesion values which was 0.3 kg/cm² for Black Cotton Soil. Upon addition of 5%Lime, it raised to 0.4 kg/cm². Further on adding Granite Dust of 10%, it raised to 0.46 kg/cm². Finally on adding 20% Granite Dust and 30% Granite Dust, it reached 0.54 kg/cm² and 0.68 kg/cm² respectively. Similarly on adding 10%, 20%, 30% GGBS, cohesion values were found to be 0.5 kg/cm², 0.65 kg/cm², 0.78 kg/cm² respectively.

Table 7 also indicates decrease in Angle of Internal Friction values which was 30^0 for Black Cotton Soil. Upon addition of 5%Lime, it reduced to 26^0. Further on adding Granite Dust of 10%, it reduced to 23^0. Finally on adding 20% Granite Dust and 30% Granite Dust, it reached 20^0 and 17^0 respectively. Similarly on adding 10%, 20%, 30% GGBS, the values of Angle of Internal Friction were found to be 22^0, 21^0 and 18^0 respectively.

Table 7- Shear stress parameters

TYPE	**C** (kg/cm^2)	**Φ^0**
Black cotton soil	0.3	30
BCS+ 5% Lime	0.4	26
BCS+ 5% Lime+10% G D	0.46	23
BCS+ 5% Lime+20% G D	0.54	20
BCS+ 5% Lime+30% G D	0.68	17
BCS+ 5% Lime+10% GGBS	0.5	22
BCS+ 5% Lime+20% GGBS	0.65	21
BCS+ 5% Lime+30% GGBS	0.78	18

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CONCLUSION

The following conclusions are made based on the test results obtained.

On addition of Granite dust,

- liquid limit decreased from 60% to 28.5%.
- plastic limit decreased from 23.72% to 16.27%.
- MDD increased from 1466.78g/cc to 1852.24g/cc.
- OMC decreased from 25% to 17.26%.
- Free swell index decreased from 62.5% to 7.5%.
- Unconfined compressive strength increased from 1.587 kg/cm² to 1.795 kg/cm².

On addition of GGBS,

- specific gravity increased from 2.31 to 2.67.
- liquid limit decreased from 60% to 26.5%.
- plastic limit decreased from 23.72% to 14.99%.
- MDD increased from 1466.78g/cc to 1894.35g/cc.
- OMC decreased from 25% to 15.27%.
- Free swell index decreased from 62.5% to 6.25%.
- Unconfined compressive strength increased from 1.587 kg/cm² to 1.82 kg/cm².

Based on the above observations made, addition of GGBS to black cotton soil is more effective in stabilizing it, than granite dust. Also the combination of BCS+5% Lime+ 30% GGBS is found to be a better stabilizing combination. As granite dust is not utilized for any of the purpose, also it is easily available, it can be used for stabilization process. Also, the stabilized soil can be used for sub-grade constructions and many other purposes, it helps in reduction of construction cost.

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