# Parametric Study of Engineering Properties of Black Cotton soil Treated with Various Industrial Waste and Lime

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***Abstract:*** **Black cotton soil is one of the major soil deposits of India..they exhibit high swelling and shrinkage when exposed to changes in moisture content and hence have been found to be most troublesome from engineering considerations. In this paper we have made a parametric study of engineering properties of black cotton soil treated with various industrial waste with lime as an admixture. The black cotton soil used is collected from Davangere region of Karnataka. The industrial waste used are- 1.copper slag 2.mine tailings 3.red mud. In Davangere area this black cotton soil is spread over southern part of district. Rich proportion of montmorillonite is found in black cotton soil from mineralogical analysis. High percentage of montomorillonite renders high degree of expansiveness. Use of this type of land may suffer severe damage to the construction with the change in atmospheric conditions. Changes in various soil properties such as liquid limit, plastic limit, maximum dry density, optimum moisture content and plasticity index were studied.**

***Index Terms:*** **Black cotton soil, copper slag, mine tailings, red mud, lime.**

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## I. INTRODUCTION

The alteration of the geotechnical properties to satisfy the engineering requirements using numerous kinds of industrial wastes along with lime as admixture to improve engineering properties of black cotton soil. In India, soils are classified into six groups mainly alluvial soil, marine soil, laterite and lateritic deposits, expansive soils, sand dunes and boulder deposits. On an average 1 lakh sq km area is covered by lateritic soil deposits,3 lakh sq km area is covered by Black cotton soil, and 5 lakh sq km area is covered by sand dunes. Marine soils are available in the coastal belts, laterite and lateritic soil deposits are available in Maharashtra, Karnataka, and parts of Kerala. Black cotton soil is available in Maharashtra, Gujarat, Madhya Pradesh, North Karnataka, parts of Andhra Pradesh and Tamilnadu. Alluvial soils are available in indo-genetic plains, and sand dunes in Rajasthan and boulder deposits are available in the Himalayan regions. Black cotton soil contains a clay mineral called montmorillonite which is having a peculiar behavior of swelling in the presence of moisture and developing shrinkage cracks in dry season. Because of volumetric change in behavior the structure constructed on such soils will undergo differential settlements, cracks in buildings or total destruction of the structure however the structures can be constructed on such a soil by treating the expansive soil with a non-expansive material. This can be done by using ground improvement technique like mechanical stabilization, chemical stabilization, freezing and heating, reinforcing earth technique etc. This study provides details of changes in properties of black cotton soil like specific gravity, liquid limit, plastic limit, Maximum dry density, Optimum moisture content and plasticity index with varying percentages of industrial waste by taking optimum content of lime as 6%.

## II. LITERATUREREVIEW:

**Comparative Study of Black Cotton Soil Stabilization with RBI Grade 81 and Sodium Silicate(K.V. Madurwar1, P.P. Dahale2, A.N.Burile3)**Expansive soils are causing number of damages to the structures particularly light buildings and pavements compare to other natural hazards like earthquake, floods, etc. Thus, worldwide these soils are considered to be problematic soils and pose several challenges for engineers. So, as to utilize these soils in an effective way, proper treatment to the soil is required. With the same intention, an attempt is made to modify engineering properties of black cotton soils from Nagpur region, Maharashtra, India by using RBI Grade 81 and sodium silicate. Atterberg's limit, Compaction, California Bearing Ratio (C.B.R.), Unconfined Compressive Strength (U.C.S.) tests were carried out on the samples of soil and soil with stabilizers. Curing of samples is done for 7 days, 14 days and 28 days. RBI Grade 81 added to the soil in dry state in percentage (by weight) varying from 2% to 6% and sodium silicate 3% to 6% in solution (molar concentration). Comparisons of these two admixtures are done on the basis of test results obtained.

**Characteristics Of Black Cotton Soils Using Copper Slag With Cement As Admixture (Introduction to geotechnical engineering, an (2nd edition) by R.D.Holtz, William D.Kovacs and Thomas C.Sheahan. )**Thereby, from the results of the graphs obtained for different proportions for various cases it can be concluded that the heave of the soil has been reduced considerably with the effect of stabilization due to copper slag. Thus, the stabilization with copper slag with cement as admixture is effective enough to reduce the heave of the expansive soils.

## III. OBJECTIVES AND METHEDOLOGY

**Objectives**

1. Properties of Black cotton soil varying with different proportion of copper slag are analyzed.
2. Properties of Black cotton soil varying with different proportion of Gold mine tailings are analyzed.
3. Properties of Black cotton soil varying with different proportion of Red mud are analyzed.

**Experimental studies:** Black cotton soil, copper slag and lime were used in the present investigation; the experimental work was carried out in two stages. In the first stage basic tests like Wet Sieve analysis and Atterberg limits tests were conducted on soil obtained for investigation. Second stage consists of determining Optimum moisture content and maximum dry density of Black cotton soil with different combinations of cement and copper slag by Standard proctor method.

Table-1:Physical and chemical properties of black cotton soil:

| Properties | BCS |
|---|---|
| Colour | Black |
| Liquid limit (%) | 2.42 |
| Plastic limit (%) | 82.0 |
| Plasticity Index (%) | 47.2 |
| Shrinkage limit (%) | 34.8 |
| Fine sand fraction (%) | 8.4 |
| Silt fraction (%) | 21.2 |
| Clay fraction (%) | 68.8 |
| Maximum dry density (g/cc) | 1.43 |
| Optimum moisture content (%) | 20 |

| Chemical composition | Percentage |
|---|---|
| Silicon dioxide 52.85 | 52.85 |
| Alumina 12.24 | 12.24 |
| Iron oxide 8.04 | 8.04 |
| Titanium dioxide 0.24 | 0.24 |
| Calcium oxide 6.01 | 6.01 |
| Magnesium oxide 2.94 | 2.94 |
| Potassium oxide 0.48 | 0.48 |
| Sodium oxide | 0.26 |

**Test conducted**

**1.Specific gravity test**

Specific gravity of a substance denotes the number of times that substance is heavier than water. In simpler words we can define it as the ratio between the mass of any substance of a definite volume divided by mass of equal volume of water. In case of soils, specific gravity is the number of times the soil solids are heavier than equal volume of water. Different types of soil have different specific gravities, general range for specific gravity of so.

**2 . Atterberg limits test**

2.1 Liquid limit by casagrande's apparatus -This lab is performed to determine the plastic and liquid limits of a fine-grained soil. The liquid limit (LL) is arbitrarily defined as the water content, in percent, at which a part of soil in a standard cup and cut by a groove of standard dimensions will flow together at the base of the groove for a distance of 13 mm when subjected to 25 shock from the cup being dropped 10 mm in a standard liquid limit apparatus operated at a rate of two shocks per second. The plastic limit(PL) is the water content, in percent, at which a soil can no longer be deformed by rolling into 3.2 mm (1/8 in.) diameter threads without crumbling.

2.2 Plastic limit test- The plastic limit is determined by rolling out a thread of the fine portion of a soil on a flat, non-porous surface. The procedure is defined in ASTM Standard D 4318.If the soil is plastic, this thread will retain its shape down to a very narrow diameter. The sample can then be remolded and the test repeated As the moisture content falls due to evaporation, the thread will begin to break apart at larger diameters. The plastic limit is defined as the moisture content where the thread breaks apart at a diameter of 3.2 mm (about 1/8 inch)

**3. Standard proctor test :**

To obtain the relation between moisture content and dry density of soil using light compaction and hence to find out the value of maximum dry density (M.D.D.) and optimum moisture content (O.M.C.)

## IV. EXPERIMENTAL RESULTS

4.1. Specific gravity of BC soil with different combinations of industrial waste and 6% LIME (optimum):

| Sl.no | BCS with different combinations of | 0% | 5% | 10% | 15% | 20% | 25% | 30% | 35% | 40% |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | BCS + 6%lime + (%) copper slag | 3.52 | 3.58 | 3.62 | 3.66 | 3.68 | 3.70 | 3.72 | 3.74 | 3.79 |
| 2 | BCS + 6%lime + (%) mine tailings | 2.36 | 2.48 | 2.50 | 2.56 | 2.61 | 2.74 | 2.86 | 2.91 | 3.02 |
| 3 | BCS + 6%lime + (%) red mud | 3.15 | 3.21 | 3.28 | 3.31 | 3.33 | 3.62 | 3.69 | 3.84 | 3.91 |

Specific gravity increases with increase in industrial waste product percentage, this is also due to the fact of that Higher density of particles are replaced with lower density of BCS in the resulted in the increase of specific gravity.

4.2 Liquid limit of BC soil with different combinations of industrial waste and 6% cement (optimum):

| Sl.no | BCS with different combinations of | 0% | 5% | 10% | 15% | 20% | 25% | 30% | 35% | 40% |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | bcs + 6%lime + (%) copper slag | 53.20 | 52.80 | 52.20 | 51.70 | 51.20 | 50.80 | 50.10 | 49.80 | 49.50 |
| 2 | bcs + 6%lime + (%) mine tailings | 49.50 | 48.60 | 47.01 | 46.60 | 45.80 | 45.20 | 44.80 | 43.78 | 43.21 |
| 3 | bcs + 6%lime + (%) red mud | 50.50 | 50.10 | 49.70 | 49.20 | 48.60 | 48.12 | 47.60 | 47.00 | 46.89 |

The decrease in liquid limit is due to reduction in the thickness of diffused double layer leading to decreases in the water holding capacity. This may also be due to replacement of fine grained black cotton soil with silty and coarse grained nature of the Red mud, which makes the mixture more frictional. With the increase in percentage of industrial waste up to 40%, then it reduces with further increase in percentage compared to immediate testing. This is due to the increase in the flocculation and entrapped water in large void spaces of flocculated structure. The effect of flocculation gradually decreases with increase in percentage of industrial waste because of increasing effect of dilution and hence decreases the liquid limit

4.3 Plastic limit of BC soil with different combinations of industrial waste and 6% cement (optimum):

| Sl.no | BCS with different combinations of | 0% | 5% | 10% | 15% | 20% | 25% | 30% | 35% | 40% |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | bcs + 6%lime + (%) copper slag | 25.60 | 25.01 | 24.70 | 24.16 | 23.98 | 23.56 | 22.22 | 21.20 | 20.01 |
| 2 | bcs + 6%lime + (%) mine tailings | 22.60 | 22.01 | 21.90 | 21.50 | 21.08 | 20.80 | 19.93 | 19.52 | 19.31 |
| 3 | bcs + 6%lime + (%) red mud | 26.14 | 25.9 | 25.20 | 24.80 | 24.10 | 23.78 | 23.12 | 22.84 | 22.23 |

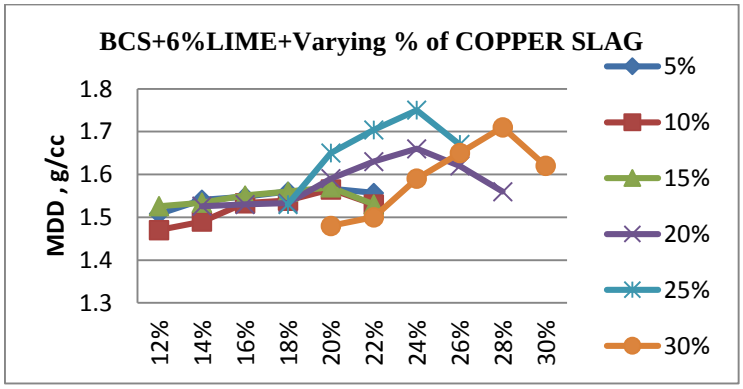
Plastic limit of black cotton soil continuously decreases with increase in percentages of industrial waste up to 40%. The decreases in plastic limit are due to the depression of diffused double layer thickness and consequent aggregation of particles. However, the black cotton soil treated with 40% of industrial waste has become non-plastic because of the presence of silt particles.

4.4. Standard proctor test for BC soil with different combinations of industrial waste and 6% cement (optimum):

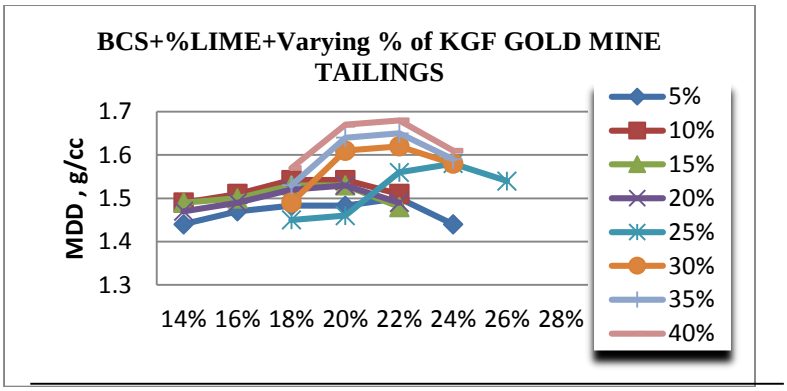
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | bcs + 6%lime + (%) copper slag | OMC(%) | 18 | 18 | 20 | 20 | 22 | 24 | 24 | 28 |
| | | MDD(g/cc) | 1.56 | 1.56 | 1.57 | 1.59 | 1.66 | 1.75 | 1.71 | 1.69 |
| 2 | bcs + 6%lime + (%) mine tailings | OMC(%) | 18 | 20 | 20 | 20 | 24 | 24 | 26 | 28 |
| | | MDD(g/cc) | 1.50 | 1.54 | 1.53 | 1.53 | 1.56 | 1.62 | 1.65 | 1.68 |
| 3 | bcs + 6%lime + (%) red mud | OMC(%) | 18 | 20 | 20 | 20 | 20 | 24 | 26 | 30 |
| | | MDD(g/cc) | 1.49 | 1.51 | 1.53 | 1.55 | 1.52 | 1.63 | 1.65 | 1.62 |

Addition of industrial waste to black cotton soil at different percentages, maximum dry density increases with increase in w/c at certain value it reaches its optimum value & then with further increase in industrial waste value & increase water content the maximum dry density value decreases. This may be due to decrease in repulsive pressure of soil, which resist the compactive effort. Consequently soil particles become closer and increase is observed in spite of high specific gravity. Thus the decrease in the void ratio would be much more reflected in the increase of maximum dry density. The optimum value gradually increases with decrease in repulsion pressure & due to addition of industrial waste with higher water adsorption capacity.

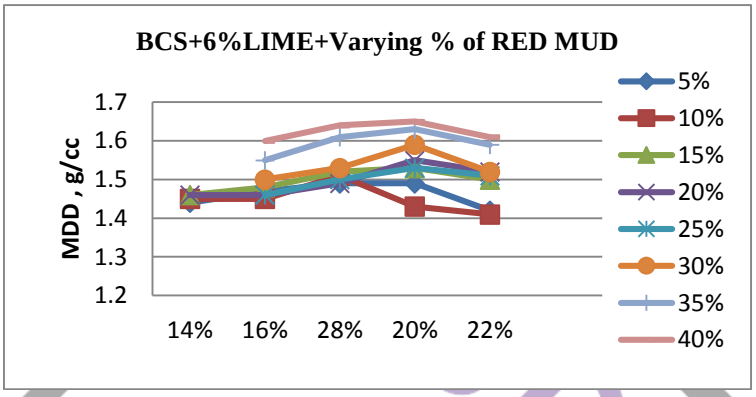
**4.5 Graph showing variation of OMC and MDD values for different combination of industrial waste and 6% lime(optimum):**




Graph 4.5.1. BCS+6% lime +Varying % of CS




Graph .4.5.2 BCS+6% lime +Varying % of KGF Gold Mine Tailings




Graph 4.5.3. BCS+6% lime +Varying % of Red Mud

## V. CONCLUSION

1. Liquid limit of black cotton soil and ore tailings mixtures decreases due to depression in the diffused double layer thickness associated with the clay particles and it increases with increase for black cotton soil and mine tailings mixture treated with lime due to prolonged equilibrium of the soil-lime-mine tailings mixture resulted in formation of coarser particle and more flocculated particle arrangement.
2. Plastic limit of black cotton soil and ore tailings mixtures decreases and due to decrease in the diffused double layer thickness of clay particles leads to increase in the shearing resistance at particle level and also flocculation of clay particles which leads to increase in plastic limit with curing periods.
3. Plasticity index of black cotton soil and mine tailing mixture treated with lime reduces compare to untreated black cotton soil, the reduction in plasticity index is the indication of improvement of properties of soil with the addition of lime mine tailings, red mud and copper slag.
4. Initially for BCS the specific gravity is 2.42 as we mix with admixtures the specific gravity goes on increasing, hence for any pavement work the specific gravity of BCS should me more.
5. It is widely accepted that the liquid limit test is essentially a measure of the shear strength of soil that is so soft it approaches the liquid stage
6. The above studies shows that the OMC and MDD of the soil increases with the percentage of increase in Admixtures
7. Addition of various percentages of mine tailings to both black cotton soil and red mud, the specific gravity increases in percentage of mine tailings. This may be due to higher density of mine tailings replace with lower density of soils resulted in the increase of the specific gravity.
8. Addition of various percentages of lime to mine tailings, the liquid limit increases on immediate testing.
9. The liquid limit of black cotton soil and red mud decreases when treated with various percentages of mine tailings on immediate testing.
10. The plastic limit of black cotton soil and red mud on addition of the various percentages of mine tailings decreases on immediate testing.
11. The specific gravity of black cotton soil with lime and red mud increases with increase in percentage of red mud compared to copper slag and mine tailings.
12. Maximum dry density increases and optimum moisture content increases for expensive soil treated with various percentage of mine tailings. This may be due to decrease in repulsive pressure of soil, which resist the compactive effort. Consequently soil particles become closer and decreases in the void ratio would be much more reflected on soil particles which resulted in increase of maximum dry density.

13. The plasticity index of the soil combined with lime and red mud decreases and thus the strength increases. Therefore, when compared to all other combinations, the combination of black cotton soil with lime and red mud gives the maximum strength.

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