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# Stabilization of Lime Treated Black Cotton Soil and Red Mud Mixture

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***Abstract*: Black cotton soils lack the required engineering properties for use as a foundation supporting layer under buildings and other uses. In the present study Red mud, derived from the aluminum industry for the production of alumina from bauxite during Bayer's process, and is generally discarded as a waste product and lime [$Ca(OH)_2$] is used to stabilize the black cotton soil. Compaction studies and unconfined compressive strength studies were conducted in order to see the efficacy of these materials in improving the strength of the soil. In this present work the Black Cotton Soil is stabilized by adding 10, 20, 30, 40 and 50 percentages of Red Mud. Same combinations are further studied by mixing 4% of Lime [$Ca(OH)_2$] to enhance the strength characteristics. Basic index properties like specific gravity, Atterberg's limit tests were conducted on the Black cotton soil, Red Mud and also combinations. Engineering properties like the unconfined compressive strength tests were conducted at 0,7,14 and 28 days curing periods only. The results show that red mud improves the geotechnical properties of the soil.**

***Keywords: Soil stabilization, Black Cotton Soil, Red Mud, Dry Density, Unconfined Compressive Strength, Curing Period.***

## I. INTRODUCTION

In recent years, due to the increase in population the demand for the construction industry has grown up. The all construction activities basically depends on the nature of the soil and its strength to resist the loads. If the soil is weak we need to stabilize the soil rather than to go for deep foundations which is uneconomical. Black cotton soil which is generally considered as weak soil, which is challenging for the civil engineers due to its property of high compressibility and shrinkage characteristics. On the other hand the rapid increase in the industrialization caused a major problem for the disposing of the industrial wastes derived from the certain industries which is in turn causes the environmental hazards. Therefore in this present investigation an attempt is made to stabilize the black cotton soil with red mud which is an industrial waste derived from aluminum industry and lime to increase the load carrying capacity or strength of the soil.

## II. MATERIALS USED

### *A. Black Cotton Soil*

Black cotton soils are also called as regur soils, they found in north-western region of India known as Deccan plateau region of India. They can be commonly seen in Karnataka, Madhya Pradesh, Gujrat and Maharashtra. It covers the 20% of the total land in India. The soil is suitable for growing cotton hence they are called as black cotton soil. It consists of clay minerals such as montmorillonite, iron, magnesium etc.

In the present work the soil is collected from Kadur taluk of Chikmagaluru District, Karnataka, India. The picture of the soil sample shown in fig.1.

*Fig.1 Black Cotton soil Sample*

The engineering and index properties of black cotton soil is shown in table 1

| S.NO | PROPERTIES | VALUES |
|---|---|---|
| 1. | Colour | Black |
| 2. | Specific Gravity | 2.58 |
| 3. | Gravel (%) | 10.25 |
| 4. | Sand (%) | 5.3 |
| 5. | Silt (%) | 5.0 |
| 6. | Clay (%) | 79.45 |
| 7. | Liquid Limit (%) | 51.5 |
| 8. | Plastic Limit (%) | 37.2 |
| 9. | Plasticity Index (%) | 14.3 |
| 10. | IS Classification | CH |
| 11. | Maximum Dry Density (MDD) in ($KN/m^3$) | 15.6 |
| 12. | Optimum Moisture Content (OMC) in (%) | 23.07 |
| 13. | Unconfined compressive Strength in (KPa) | 67.98 |

TABLE 1 PROPERTIES OF BLACK COTTON SOIL

### B. *Red Mud*

Red mud is an industrial waste generated during the manufacture of the aluminum from the bauxite ore during Bayer's process. In India 4.71 million tons of red mud produced every year. Red mud creates a lot of health hazards, if it is disposed without necessary precautions. Red mud is highly alkaline material and mineral components include hematite, goethite, gibbsite, calcite and complex silicates. In this study red mud is used as admixture for stabilizing the black cotton soil

In the present work red mud was obtained from Hindustan Aluminum Corporation (HINDALCO), Belagavi, Karnataka State, India.

*Fig.2 Red Mud*

Fig.2 shows the red mud sample and the engineering properties of the red mud is shown in table 2

| S.NO | PROPERTIES | VALUES |
|---|---|---|
| 1. | Colour | Red |
| 2. | Specific Gravity | 2.88 |
| 3. | Gravel (%) | .0 |
| 4. | Sand (%) | 14.4 |
| 5. | Silt (%) | 7.5 |
| 6. | Clay (%) | 78.1 |
| 7. | Liquid Limit (%) | 45.5 |
| 8. | Plastic Limit (%) | 32.3 |
| 9. | Plasticity Index (%) | 13.2 |
| 10. | Maximum Dry Density (MDD) in ($KN/m^3$) | 15.6 |
| 11. | Optimum Moisture Content (OMC) in (%) | 22.72 |
| 12. | Unconfined compressive Strength in (KPa) | 118.47 |

TABLE 2 PROPERTIES OF RED MUD

### C. *Lime [$Ca(OH)_2$]*

Generally there are two types of lime i.e. quicklime and hydrated lime. Lime improves the binding property of the soil and admixture. Most commonly used lime type in soil stabilization is of hydrated lime type. Fig.3. shows the hydrated lime which used in present work

In the present investigation lime was obtained from Nice Chemicals (P) Ltd, Kochi, Kerala State, India.

*Fig.3 Lime*

## III. METHODOLOGY

The experimental analysis are carried out on the black cotton soil with admixtures. The analysis is grouped into two combinations i.e. BCS+RM (10% to 50%) and BCS +RM (10% to 50%) +4% LIME. In both combinations red mud content is added in the increments of 10% to the weight of the soil. Here 4% lime is taken as the optimum lime content and is added with respect to the weight of the soil. The experiments includes specific gravity, Sieve analysis, Atterberg's limits, compaction test and unconfined compressive strength test. All the experiments are carried as per the Indian standard codes and procedures.

## IV. RESULTS AND DISCUSSIONS

### A. *Specific Gravity*

The specific gravity values of the combinations were determined by using pycnometer method and the results obtained are shown in table 3

| S.NO | COMBINATIONS | VALUES |
|---|---|---|
| 1. | BCS+10% RM | 2.46 |
| 2. | BCS+20% RM | 2.50 |
| 3. | BCS+30% RM | 2.47 |
| 4. | BCS+40% RM | 2.55 |
| 5. | BCS+50% RM | 2.57 |
| 6. | BCS+10% RM+4% LIME | 2.49 |
| 7. | BCS+20% RM+4% LIME | 2.46 |
| 8. | BCS+30% RM+4% LIME | 2.56 |
| 9. | BCS+40% RM+4% LIME | 2.60 |
| 10. | BCS+50% RM+4% LIME | 2.67 |

TABLE 3 SPECIFIC GRAVITY VALUES OF THE COMBINATIONS

### B. *Atterberg's Limits*

The Atterberg's limit includes liquid limit and plastic limit and plasticity index. The liquid limit test was conducted using cone penetrometer as per Indian standard code. The results are shown in table 4 and table 5

| COMBINATION | LIQUID LIMIT (%) | PLASTIC LIMIT (%) | PLATICITY INDEX (%) |
|---|---|---|---|
| BCS Alone | 51.5 | 37.2 | 14.3 |
| BCS+10% RM | 43 | 29.32 | 13.68 |

| | | | |
|---|---|---|---|
| BCS+20% RM | 35 | 23.5 | 11.5 |
| BCS+30% RM | 43.5 | 30.59 | 12.91 |
| BCS+40% RM | 43 | 28.88 | 14.12 |
| BCS+50% RM | 46 | 32.06 | 13.94 |

TABLE 3 ATTERBERG LIMITS FOR BCS+RM COMBINATIONS

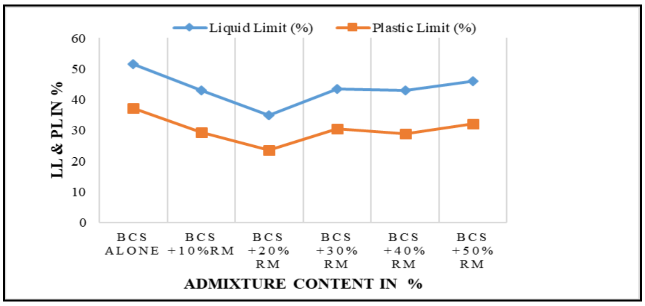


*Fig.4 Variation of liquid limit and plastic limit for BCS+RM Combinations*

From the above figure 4 and table 3 it can be clearly seen that the addition of the red mud to the black cotton soil decreases the liquid limit, plastic limit and also plasticity index. This may be due to the voids in the black cotton soil is filled with red mud which decreases the water retaining capacity of the soil. Hence atterberg limit decreases with increase in admixture content.

On the other type combination the addition of red mud and lime also decreases the liquid limit, plastic limit and plasticity index the reason for this reduction is similar to the above case. The experimental values of Atterberg's limit and their variation for BCS+RM+4% LIME combinations are shown in table 4 and fig.5 respectively.

| COMBINATION | LIQUID LIMIT (%) | PLASTIC LIMIT (%) | PLASTICITY INDEX (%) |
|---|---|---|---|
| BCS Alone | 51.5 | 37.2 | 14.3 |
| BCS+10% RM+4% LIME | 47 | 33.73 | 13.27 |
| BCS+20% RM+4% LIME | 45.5 | 32.51 | 12.99 |
| BCS+30% RM+4% LIME | 44 | 30.89 | 13.11 |
| BCS+40% RM+4% LIME | 42.5 | 30.08 | 12.42 |
| BCS+50% RM+4% LIME | 40 | 29.42 | 10.58 |

TABLE 4 ATTERBERG LIMITS FOR BCS+RM+4% LIME COMBINATIONS

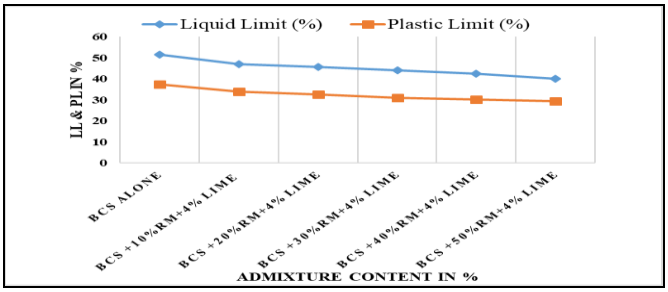


*Fig.5 Variation of liquid limit and plastic limit for BCS+RM+4%LIME Combinations*

*C. Compaction Test*

The compaction characteristics of the combinations were carried out by standard proctor test and mini compaction test apparatus as per the Indian standards and the results are shown below.

| S.NO | COMBINATION | MDD IN KN/m$^3$ | OMC IN % |
|---|---|---|---|
| 1. | BCS Alone | 15.6 | 23.07 |
| 2. | BCS+10% RM | 17.4 | 14.28 |
| 3. | BCS+20% RM | 16.5 | 21.43 |
| 4. | BCS+30% RM | 16.0 | 23.07 |
| 5. | BCS+40% RM | 15.9 | 20.50 |
| 6. | BCS+50% RM | 15.8 | 17.65 |

TABLE 5 COMPACTION TEST REULTS FOR BCS+RM COMBINATIONS

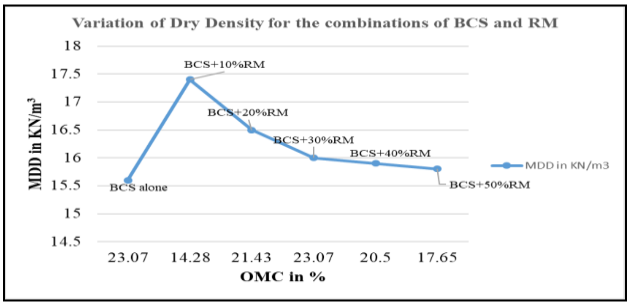


*Fig.6 Variation of MDD and OMC for BCS+RM Combinations*

MDD- Maximum Dry Density in KN/m$^3$
OMC- Optimum Moisture Content in %

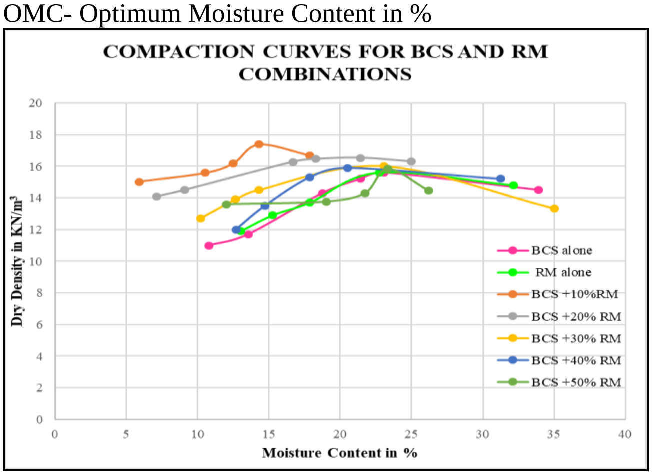


*Fig.7 Compaction Curves for BCS+RM Combinations*

The addition of the admixtures increases the maximum dry density of the soil from 15.6 KN/m$^3$ to 17.4 KN/m$^3$ for 10% combination after that the dry density decreases due to the increase in the finer particles of the red mud. But compared to plain black cotton soil the dry density is greater in the combinations this can be seen in table 5

On the other combination i.e. for BCS+RM+4% LIME combinations the dry density increases from 15.6 KN/m$^3$ to 16.8 KN/m$^3$ for 20% combination after that dry density decreases to a value greater than the dry density of black cotton soil alone. The values are shown in table 6.

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| S.NO | COMBINATION | MDD IN KN/m³ | OMC IN % |
|---|---|---|---|
| 1. | BCS Alone | 15.6 | 23.07 |
| 2. | BCS+10% RM+4% LIME | 16.2 | 27.27 |
| 3. | BCS+20% RM+4% LIME | 16.8 | 23.53 |
| 4. | BCS+30% RM+4% LIME | 16.3 | 24.0 |
| 5. | BCS+40% RM+4% LIME | 16 | 24.87 |
| 6. | BCS+50% RM+4% LIME | 15.7 | 33.34 |

TABLE 6 COMPACTION TEST REULTS FOR BCS+RM+4% LIME COMBINATIONS

MDD- Maximum Dry Density

OMC- Optimum Moisture Content

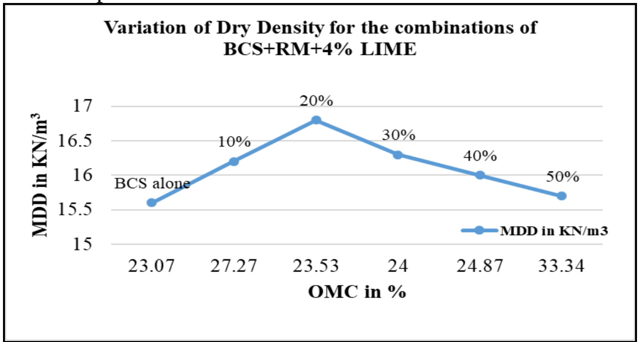


*Fig.8 Variation of MDD and OMC for BCS+RM+4% LIME Combinations*

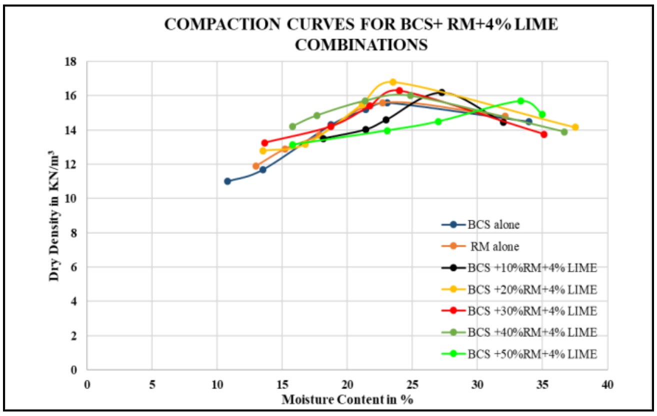


*Fig.9 Compaction Curves for BCS+RM+4% LIME Combinations*

### D. *Unconfined Compressive strength (UCS) Test*

The unconfined compressive strength tests for the combinations were conducted for various curing periods i.e. for immediate day followed by 7 days, 14 days and 28 days. The strength obtained for various combinations are shown below

| COMBINATION | UCS STRENGTH IN KPa | | | |
|---|---|---|---|---|
| | 0 DAYS | 7 DAYS | 14 DAYS | 28 DAYS |
| BCS+10% RM | 222.8 | 260.9 | 273.99 | 292.1 |
| BCS+20% RM | 93.96 | 140.19 | 146.27 | 152.9 |
| BCS+30% RM | 119.87 | 139.35 | 173.05 | 180.3 |
| BCS+40% RM | 219.07 | 249.90 | 271.09 | 281.7 |
| BCS+50% RM | 211.74 | 245.12 | 256.01 | 278.6 |

TABLE 7 UCS STRENGTH VALUES FOR BCS+RM COMBINATIONS FOR VARIOUS CURING PERIOD

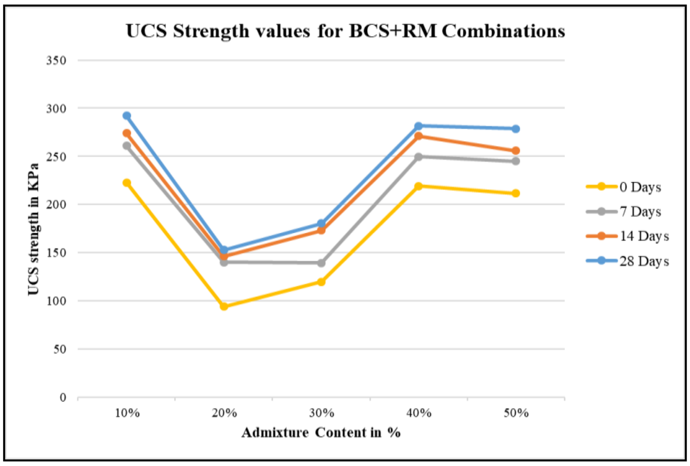


*Fig.10 Variation of UCS Strength for BCS+RM Combinations for various curing period*

It can be seen from Table 7 and fig.10 that the unconfined compressive strength of the BCS increased with the addition of the red mud up to 10% and there is a slight reduction beyond 10%. The increase in the UCS with addition of the Red Mud may be attributed to the formation of cementitious compounds between the soil and red mud. Curing of the mixes showed a significance improvement in the UCS. A marked increase of UCS is observed for 28 days curing. With the addition of red mud to the soil, the UCS value increased from 67.98 KPa to 222.8 KPa. Considerable improvement was observed at 10% red mud content in the soil. The UCS value increased from 222.8 KPa to 292.1 Kpa upon curing for 28 days.

The UCS strength values for BCS+RM+4% LIME combinations are shown in below table 8

| COMBINATIONS | UCS STRENGTH IN KPa | | | |
|---|---|---|---|---|
| | 0 DAYS | 7 DAYS | 14 DAYS | 28 DAYS |
| BCS+10% RM+4% LIME | 130.20 | 625.48 | 873.5 | 1062.2 |
| BCS+20% RM+4% LIME | 248.0 | 810.75 | 1016.9 | 1135 |
| BCS+30% RM+4% LIME | 207.04 | 605.28 | 696.94 | 954.9 |
| BCS+40% RM+4% LIME | 226.05 | 521.51 | 579.88 | 643.6 |
| BCS+50% RM+4% LIME | 139.71 | 195.87 | 243.66 | 271.8 |

TABLE 8 UCS STRENGTH VALUES FOR BCS+RM+4% LIME COMBINATIONS FOR VARIOUS CURING PERIOD

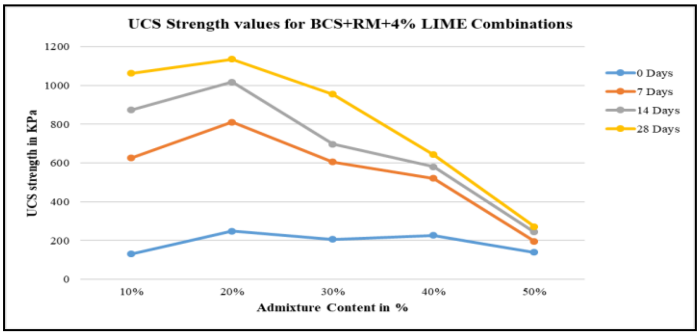


*Fig.11 Variation of UCS Strength for BCS+RM+4% LIME Combinations for various curing period*

The test results of unconfined compressive strength of lime treated black cotton soil and red mud are shown in table 8 and Fig.11. This illustrates the UCS of red mud and lime treated black cotton soil with different admixture contents for various curing periods. The UCS increased from 67.98 KPa to 248 Kpa with the addition of 20% of red mud to the lime treated BCS. Curing contributed to significant improvement in UCS. The UCS of at 20% RM and lime treated BCS content increased from 248 KPa to 1135 Kpa upon curing for 28 days. The reason for this improvement may be due to immediate and long term pozzolanic reaction of red mud and lime with soil.

## V. CONCLUSIONS

The following conclusions emerged from the present investigations on the stabilization of lime treated black cotton soil and red mud mixture.

- The addition of red mud as well as red mud with 4% lime decreases the liquid limit and plasticity index.
- The admixture impacts moisture-density relation of black cotton soil, the maximum dry density increases with the increase in the admixture content.
- The maximum dry density (MDD) of soil-RM mixes improved with the replacement of soil by red mud up to RM percentage of 10%, the dry density increased from 15.6 $KN/m^3$ to 17.4 KN $/m^3$
- The maximum dry density of soil-RM-4% lime combinations is also increased with the addition of red mud to the lime treated black cotton soil up to 20%. The dry density increased from 15.6 $KN/m^3$ to 16.8 $KN/m^3$.
- The UCS value is found to increase with the addition of red mud and also red mud along with 4% lime.
- The effect of curing time on UCS was evaluated using soil-RM and soil –RM-4% Lime combinations. The UCS value found to be increased with increase in the curing period.
- The maximum UCS was obtained for 10% RM combination for soil-RM mix. The UCS increased from 67.98 KPa to 222.8 KPa. After 28 days of curing period the unconfined compressive strength increased from 222.8 KPa to 292.1 KPa.
- The maximum UCS for lime treated black cotton soil and red mud mix was obtained for 20% combination. The UCS value increased from 67.98 KPa to 248 KPa after 28 days of curing the strength increased from 248 KPa to 1135 KPa. Hence it can be concluded that the UCS increases with the increase in curing period.
- The treatment of soil-RM mixes with 4% lime could further improve the properties of the mix and the maximum improvement was seen when 20% soil was replaced by red mud. Hence soil-RM-4% Lime combinations gives the more UCS strength compared to soil-RM combinations.
- Black cotton soil mixed with 10% Red mud and 20% red mud along with 4% Lime by weight of dry soil exhibits improved geotechnical properties in terms of unconfined compressive strength (UCS) and compaction characteristics.
- Hence it can be concluded that red mud can be used in stabilization of weak black cotton soil or clayey soil instead of simply disposed as industrial waste on the land.

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