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# EFFECTIVE USE OF INDUSTRIAL WASTES RED MUD, GGBFS BLENDED WITH CEMENT AS A GEOTECHNICAL CONSTRUCTION MATERIAL

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**ABSTRACT**

*Due to the growth of industries large amount of waste materials are releasing nowadays. Large amount of red mud is released from alumina industry during the refining process of bauxite i.e., from the Bayer's process. It is estimated to be 2.7 billion tones with an annual growth rate of 120 million tones.*

*In the present study an attempt has been made to observe the engineering properties of the waste materials like red mud and GGBFS and their feasibility whether they can be used as an geotechnical material individually and at various percentages of the cement. In this the samples were mixed in various proportions and tested for its characteristics and experimental works of unconfined compressive strength and coefficient of permeability were observed.*

*In the present study red mud samples were mixed with 10%, 20%, 30% …. 100% of*

*GGBFS and also with the cement of 2%,4%,6%,8%,10%, all these mixes were tested for its curing period of 28 days. Strength values increases with the increase of cement and GGBFS. The maximum value of unconfined compressive strength of 8.375 MPa was obtained at the mixed proportions of 60% red mud, 40% GGBFS and 10% of cement. The effective utilization of Red mud with GGBFS was identified as 20-40% of GGBFS with Red mud at 2-4% can be used in sub- base, base and surface courses in road construction and coefficient of permeability less than $10^{-7}$ cm/sec can be effectively used as liner material in landfills.*

## I. INTRODUCTION

Large quantities of industrial waste materials are produced every year due to rapid industrialization and infrastructure development. These require safe disposal unless demanding large area of land for their disposal and create environmental pollution. India produces 15 metric tons of slag annually as a by-product from steel industries. Utilization of this material in large quantities, especially in road construction is essential. The physical structure and gradation of ground granulated blast furnace slag GGBFS depends on the chemical composition of slag.

Red mud is an industrial waste obtained from aluminum industry from Bayer's process. Before the end of the decade of the 1980's red mud became a major concern in world environment discussions and international

attention focused on Jamaica alongside Austria and Guinea which by then were the world's three largest producers of Bauxite residue called red mud. In 1986 the building research institute (BRI) in Jamaica designed a research and development project involved the use of the Red mud process in the stabilized soil technology subsequent to that Jamaica bauxite instate (JBI) successfully took another project on red mud in Canada with the help of international development research council. The latter project was pursued between 1987 and 1955 and in addition to the JBI involved the university of Toronto and university of the West Indies.

Bauxite is the ore from which the material alumina is extracted by a particular industrial process and subsequently converted to the notably light weight metal, and for every 1 ton of alumina produced from bauxite an almost equivalent quantity (1 ton) of waste product called red mud is produced. This material is pumped from each plant as red colored slurry and has been disposed of traditionally by dumping in natural depressions. In the present study, red mud was stabilized using GGBFS and cement and tests like compaction strength and unconfined compressive and their application in geotechnical characteristics are verified.

## II. OBJECTIVES

- Individual Characterization of Red Mud and GGBFS as Geotechnical material.
- Compaction is in terms of OMC, MDD and strength in terms of unconfined compressive strength under curing period of 28 days are studied.
- Obtaining optimum characteristics by mixing different proportions of mixes.
- Use of Red Mud in geotechnical applications like construction of embankments, landfills, liners and roads.

## III. MATERIALS USED

### 3.1. Red Mud:

It is a waste product from Aluminium plant obtained during refining process of bauxite (ore of Aluminium $Al_2O_32H_2O$). Red Mud is highly complex material that differs due to the different bauxites used and the different parameters. Therefore Red Mud should be regarded as a group of materials. It has characteristics like water suspension, alkalinity, and high specific surface and fine particle size distribution.

### 3. 2.Cement:

Cement is used generally in many parts of world as it is a basic ingredient of mortar, concrete, stucco and most specially used grout. It is called basically as a Portland cement because on hardening its color resembles a rock near Portland in England. Cement used in this is OPC (43 grade cement).

### 3. 3.GGBFS:

It is obtained by quenching molten iron blast furnace slag immediately in water or steam to produce a glassy granular product that is then dried and ground into a fine powder. It is an excellent binder to produce high performance cement and concrete. The production technologies of GGBFS are traditional ball mill, high pressure roller press and vertical roller mill. IS 456 is the relevant code for production and applications of GGBFS in India. It has nearly 30% of calcium oxide so that it can be useful in improving the strength.

## IV. RESULTS AND DISCUSSIONS

### 4. 1.CHARACTERISTICS OF RED MUD:

The material is used in the present study are Red Mud. It was collected from NALCO (National Aluminium Company) which is located at Damanjodi in Orissa. The Geotechnical properties and chemical compositions of Red Mud are as follows:

#### 4.1.1 Physical and Geotechnical properties of Red Mud

By performing various tests on Red mud for its characterization as per IS 2720 and results of these tests are illustrated in table 4.1(a).

**Table 4.1(a) Physical and Geotechnical properties of Red Mud**

| **Property** | VALUE |
|---|---|
| **Physical properties** | |
| Appearance | Mud |
| Colour | Red |
| Odour | Slightly pungent, earthy odour |
| Texture | Fine |
| Specific Gravity | 3.05 |
| **Grain size distribution** | |
| Fine sand size (%) | 0 |
| Silt size (%) | 88 |
| Clay size (%) | 12 |
| **Compaction characteristics** | |
| OMC (%) | 22 |
| MDD(g/cc) | 1.65 |
| **Consistency Characteristics** | |
| Liquid limit (%) | 32 |
| Plastic limit (%) | 24 |
| Plasticity Index (%) | 8 |
| **Strength Characteristics** | |
| **At OMC** | |
| Cohesion (C) ($t/m^2$) | 2.5 |
| Angle of shearing resistance (ǿ) (degree) | 32 |
| CBR value (soaked) | 5 |
| **Drainage characteristics** | |
| Coefficient of permeability (k), (cm/sec) | $2.8 \times 10^{-6}$ |

From the test results of Red mud, the following identifications are made. Red mud is a fine grained

material dominated by silt size particles which consists of 88 %. It has 12 % of clay particle and absence of sand size particles. Majority of the particle are in the range of 34 micron to 6 micron. Decreasing the size of particle increases the fineness and finally more water is needed to improve cohesion .As per the Indian Standard soil Classification System the given soil is ML.

Compaction characteristics of Red mud under modified proctor compaction test are given below. Optimum Moisture Content of 22.0% and Maximum Dry Density of 1.65 g/cc. So at this dry density of red mud attained high shear strength values in terms of cohesion i.e. 2.5 t/m$^2$ and angle of shearing resistance (ø) is 32$^0$. It also exhibited reasonable resistance value against the penetration in terms of CBR. From seepage it is identified as impervious material (k <10$^{-6}$cm/sec). Based on the geotechnical characterization it has good strength and compaction characteristics therefore it can be used as the sub grade, filling material in road construction activities.

The results obtained from the tests will be helpful in increasing the bearing capacity of foundations, decreasing the undesirable settlement of structures, Control of undesirable volume changes, Reduction in hydraulic conductivity, increasing the stability of slopes.

The knowledge of this property is much useful in solving problems involving yield of water bearing strata, seepage through earthen dams, stability of earthen dams, and embankments of canal bank affected by seepage, settlement etc.

**4.1.2 Chemical composition**

The various types of the chemical compounds present in red mud are as follows-Sodium dioxide, Aluminium Oxide, Silicon dioxide, Calcium Oxide, Titanium dioxide,Vanadium Oxide, Iron Oxide, Zinc Oxide.

It has very low amount of Cao. Hence it is not a self pozzolonic and it consists of 43 % of Alumina and Silica together and with oxides of Iron it is 82%. With the addition of admixtures like lime and cement etc. can make Red mud as a pozzolonic material with time.

**4.2 GROUND GRANULATED BLAST FURNACE SLAG (GGBFS):**

The material used in this present study is GGBFS. It is a residue of Blast furnace slag collected from steel industry i.e. Steel Plant, Visakhapatnam. The Geotechnical properties and chemical compositions of GGBFS are as follow

**4.2.1. Physical and Geotechnical properties of GGBFS:**

Initial test on the GGBFS is carried out for its characterization and the results of tests conducted are illustrated in the Table 4.2(a).

**Table 4.2(a) Physical and Geotechnical properties of GGBFS**

| **Property** | VALUE |
|---|---|
| **Physical properties** | |
| Colour | White |
| Texture | Fine |
| Specific Gravity | 2.85 |

| | |
|---|---|
| **Grain size distribution** | |
| Fine sand size (%) | 4 |
| Silt size (%) | 96 |
| Clay size (%) | 0 |
| **Compaction characteristics** | |
| OMC (%) | 16 |
| MDD(g/cc) | 1.68 |
| **Consistency Characteristics** | |
| Liquid limit (%) | 32 |
| Plastic limit (%) | NP |
| Plasticity Index (%) | NP |
| **Strength Characteristics** | |
| **At OMC** | |
| Cohesion (C) ($t/m^2$) | 1 |
| Angle of shearing resistance (ǵ) (degree) | 33 |
| CBR value (soaked) | 4 |

From the test results of GGBFS,it is fine material dominated by silt size particles which consists of 96 %. Majority of particle in the range of 75µm to 2µm.as per Indian Standard Soil Classification System soil classified as MLN.

Compaction characteristics of GGBFS under modified proctor compaction test have an OMC of 16% and MDD of 1.68g/cc. It has good compaction characteristics.

## 4. 3.INTERACTION OF RED MUD WITH GGBFS:

To study the interaction of Red mud and GGBFS particles an attempt is made in terms of compaction and strength characteristics.

### 4.3. 1.Compaction Characteristics for Red Mud with GGBFS:

The compaction characteristics like OMC (optimum moisture contents), MDD (maximum dry density) were conducted for various percentages of GGBFS i.e., 10, 20, 30, 40… etc., by dry weight of Red mud mass as per IS: 2720 (part 7) – 1980 and compaction characteristics are shown in Table 4.3 (a)

**Table 4.3(a) Compaction characteristics of Red mud and GGBFS mixes**

| RM+GGBFS | OMC (%) | MDD(g/cc) |
|---|---|---|
| 100+0 | 22 | 1.65 |
| 90+10 | 21.5 | 1.66 |
| 80+20 | 20.8 | 1.67 |
| 70+30 | 20.0 | 1.69 |
| 60+40 | 19.3 | 1.7 |

| | | |
|---|---|---|
| 50+50 | 18.3 | 1.71 |
| 40+60 | 18.8 | 1.72 |
| 30+70 | 18.3 | 1.71 |
| 20+80 | 17.7 | 1.70 |
| 10+90 | 16.5 | 1.69 |
| 0+100 | 16.0 | 1.68 |

## 4. 4.UNCONFINED COMPRESSIVE STRENGTH OF RED MUD – GGBFS MIXES (kPa):

To know the unconfined compressive strength of Red Mud, GGBFS and cement mixes. All the prepared samples were cured for 28 days by maintaining 100% humidity. Unconfined compressive strength tests were conducted after completion of their curing periods at a strain rate of 1.25 mm/min as per IS 2720 part 10, and the results are tabulated table-4.4.(a)

**Table 4.4(a). Unconfined Compressive Strength of Red mud, GGBFS and CEMENT mixes upon 28 days of curing:**

| **RM+GGBFS** | 2% cement | 4% cement | 6% cement | 8% cement | 10% cement |
|---|---|---|---|---|---|
| 100+0 | 1.08 | 2.08 | 3.004 | 3.824 | 4.528 |
| 90+10 | 1.82 | 3.04 | 4.306 | 5.035 | 5.641 |
| 80+20 | 2.83 | 3.83 | 5.186 | 6.036 | 6.832 |
| 70+30 | 3.78 | 4.86 | 6.148 | 7.137 | 7.678 |
| 60+40 | 4.56 | 6.32 | 7.34 | 7.712 | 8.38 |
| 50+50 | 4.32 | 6.21 | 7.06 | 7.561 | 8.08 |
| 40+60 | 4.04 | 6.04 | 6.73 | 7.04 | 7.64 |
| 30+70 | 3.51 | 5.42 | 6.16 | 6.5 | 7.34 |
| 20+80 | 3.04 | 4.64 | 5.38 | 6.04 | 7.037 |
| 10+90 | 2.43 | 3.85 | 4.53 | 5.63 | 7.037 |
| 0+100 | 1.83 | 2.82 | 3.97 | 5.21 | 6.543 |

## 4. 5. PROPERTIES OF CEMENT

In this experimental work, the ordinary Portland cement of 43 grades was taken from locally available market. The characteristics of the cement were as follows:

1. Standard Consistency -31%
2. Initial and Final Setting Time – 128 min and 246 min
3. Specific Gravity – 3.05
4. Fineness – 2.00%
5. Compressive Strength (Mpa) – 48.21

The cement taken for this project has the CBR value is 4-6% and the value increases with the increase in the

curing period.

## 4. 6.RED MUD - GGBFS AND CEMENT MIXES:

### 4.6. 1.Red mud, GGBFS and cement mixes

For mixtures of Red mud and GGBFS of various proportions cement is added and modified proctor test was performed and the maximum dry densities are shown in the tables below. Similarly the same procedure is extent for 4%, 6%, 8% and 10% of cement and the results are shown in table 4.6(a).

**Table 4.6(a) Maximum dry densities of Red mud –GGBFS mixes at various proportions of cement**

| RB+GGBFS | 2% cement | 4% cement | 6% cement | 8% cement | 10% cement |
|---|---|---|---|---|---|
| 100+0 | 1.66 | 1.68 | 1.7 | 1.71 | 1.66 |
| 90+10 | 1.68 | 1.7 | 1.72 | 1.73 | 1.68 |
| 80+20 | 1.7 | 1.71 | 1.7 | 1.75 | 1.7 |
| 70+30 | 1.72 | 1.73 | 1.74 | 1.76 | 1.72 |
| 60+40 | 1.73 | 1.74 | 1.75 | 1.77 | 1.73 |
| 50+50 | 1.74 | 1.75 | 1.76 | 1.78 | 1.74 |
| 40+60 | 1.75 | 1.76 | 1.77 | 1.79 | 1.75 |
| 30+70 | 1.74 | 1.75 | 1.76 | 1.77 | 1.74 |
| 20+80 | 1.73 | 1.74 | 1.75 | 1.76 | 1.73 |
| 10+90 | 1.72 | 1.73 | 1.74 | 1.75 | 1.72 |
| 0+100 | 1.71 | 1.72 | 1.73 | 1.74 | 1.71 |

## V. CONCLUSIONS

The following conclusions were drawn:

1. GGBFS and Red Mud mix has shown very less values than Red Mud-GGBFS and cement mixes because of more presence of Aluminates and Silicates and iron oxides. It also reduces the more iron content which is present in the Red Mud than cement- red mud-GGBFS mixes.
2. 60% Red mud,40 % GGBFS and 10 % cement has shown higher unconfined compressive strength values of 8.38 MPa for the curing periods of 28 days.
3. Cement-Red Mud-GGBFS mixes changes the structure of soil and convert it into flocculated structure so that bonding between the particles is strong and hence increases the strength of mix.
4. All proportions of mixes have shown maximum values at higher curing period of 28days. Higher curing periods helps in improving the agglomeration among the particles of Red Mud, lime and GGBFS.
5. 10% cement addition of cement to the optimum mix which gives higher unconfined compressive strength values. In combination of mixes 40%GGBFS+60 %Red Mud with 2-

6% doses has decided as optimum mix which gives specified values for 7 days curing period.

6. The combination mix of GGBFS and cement has given higher values compared to individual additions of cement and GGBFS. This is because of effective agglomeration and rigid bond among the particles of Red Mud, GGBFS and cement.
7. The specific gravity of Red mud is greater than that of Ground Granulated Blast Furnace Slag, GGBFS and cement can be effectively used in stabilization and partial replacement of Red mud by GGBFS with cement can be effectively used as sub-base, base and surface course.

## VI. SCOPE FOR FURTHER STUDY

The further scope of present project work is about the aspects as shown below.

- The other parameters like C, Ø (shear parameters), permeability, Consolidation, can be studied to check its feasibility in the construction of embankments.
- The combination of admixtures can be added to fibers like Polystyrene, coir fiber and jute fibers etc.
- The study of hydration characteristics of mixes is helpful in analyzing the water retention behavior of mixes.
- Cost effective structures can be built with these mixes.
- The experiments like X-Ray Diffraction or differential thermal analysis can be done to know the mineralogical composition of mixes.
- Stabilized Red Mud can be used in landfill sites as liner material.

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