STABILIZATION OF RED MUD BY LIME, GYPSUM AND INVESTIGATING ITS POSSIBLE USE AS A GEOTECHNICAL MATERIAL IN THE CIVIL CONSTRUCTION

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ABSTRACT

The objective of the study was to evaluate the effectiveness and the behavior of red mud derived from the aluminum industry for the production of alumina from bauxite, and is generally discarded as a waste product. This red mud is stabilized by adding lime in different percentage and the behavior of the same is studied. In this present study the red mud is stabilized by 4, 8, and 12 percentages of lime. Same combinations are further studied by mixing 1% of gypsum to enhance the strength characteristics. Basic index properties like specific gravity, Atter Berg's limit, and Engineering properties like the unconfined compressive strength and California bearing ratio tests were conducted at 1 and 7 days curing periods only. From the test data it was observed that 12% lime with 1% gypsum has shown higher UCS value compared to other percentages for 7 days of curing. A higher value of CBR i.e. 7.9% was obtained for 12 %Lime. Hence Red mud stabilized with lime can be used as sub base, base course and also sub grade material for road construction.

KEY WORDS: *Stabilization, Bayer's process, Bauxite, Red mud, hydrated lime.*

I. INTRODUCTION

Every year due to Rapid Industrialization and Infrastructure development large quantities of industrial waste materials are produced. These require safe disposal unless demanding large areas of land for their disposal and create environmental pollution. Red mud is one of the bi-products obtained during refining process of Bauxite (ore of Aluminum, $Al_2O_3H_2O$). The process so called Bayer's process. Hence red mud is also referred as Bayer's process residue. Utilization of these materials in large quantities is especially in road construction. In the present study Red mud was stabilized with lime and the sample collected from HINDALCO located at Renukoot in Uttar Pradesh. Currently it is estimated to be 2.7 billion tons with an annual growth rate of over 120 million tons [1]. Earlier studies shows Red mud can be utilized for various purposes like agricultural, waste gas treatment, recovery of major metals and steel making. In this paper the sample was tested to characterize the geo technical properties of Red mud and Red mud lime mixes. Unconfined compressive strength and CBR were tested in proportions of 4, 8 and 12 percentages of Lime. UCS and was conducted at 1 and 7 days curing periods whereas CBR and other properties were conducted at 1 day itself.

II. MATERIALS AND TEST PROGRAM

2.1 Red mud

For the present work the red mud was collected from HINDALCO Ltd, Uttar Pradesh. The geotechnical properties of red mud like specific gravity (3.04), plasticity index (13.2), compaction

characteristics (OMC = 33.5, MDD = 1.53 gm/cc), Unconfined compression strength (0.123 MPa), permeability (5.786e-7cm/s) and California bearing ratio (4%, soaked) tests were investigated as per relevant IS codes. It can be seen that the red mud is highly alkaline with PH value of 11.3 and the specific gravity (3.04) is also very high compared to soil (usually 2.65). The high specific gravity of red mud is due to presence of iron rich minerals. As per IS soil classification it can be classified as silt of medium compressibility (MI). [2]

2.2 Lime

Lime in the form of quicklime (calcium oxide – CaO), hydrated lime (calcium hydroxide – Ca $[OH]_2$), or lime slurry can be used to treat soils[3]. Quicklime is manufactured by chemically transforming calcium carbonate (limestone – $CaCO_3$) into calcium oxide. Hydrated lime is created when quicklime chemically reacts with water. For the present work hydrated lime is used. The hydrated lime that reacts with clay particles and permanently transforms them into a strong cementitious matrix [4]

2.3 Gypsum

Anhydrous gypsum, Analytical quality is being used. Gypsum enhances the pozzolanic reaction between Red mud and hydrated lime. The analytical quality was chosen to avoid the interference of impurities which may retard the initial hydration process[5]

2.4 Combinations and preparations of mixes

The Red mud brought from the HINDALCO, Renukoot to the laboratory was dried in an oven at approximately 105 °C before grinding. Then, the mixtures of Red mud and lime (RL) materials were blended to prepare composite samples. The combinations with appropriate mixers are tabulated in table 1.

Table 1: shows the mix proportions of the ingredients with their designations

Sl No	Combinations	Designations	
		1 day	7 days
1	RM+0L+0G	RL	RL7
2	RM+4L+0G	L11	L71
3	RM+8L+0G	L12	L72
4	RM+12L+0G	L13	L73
5	RM+4L+1G	LG11	LG71
6	RM+8L+1G	LG12	LG72
7	RM+12L+1G	LG13	LG73

III. RESULTS AND DISCUSSION

3.1 Specific gravity

Specific Gravity of the combinations has been carried out as per the IS: 2720 (Part II) 1980. The experiment was performed from both pycnometer method and density bottle. The specific gravity of the above said combinations were tabulated in Table 2.

Table 2: Shows the specific gravity of the combinations

Sl No	Combinations	Designations	Specific Gravity
1	RM+0L+0G	RL	3.04
2	RM+4L+0G	L11	3.04
3	RM+8L+0G	L12	3.02
4	RM+12L+0G	L13	3.00
5	RM+4L+1G	LG11	3.04
6	RM+8L+1G	LG12	3.02
7	RM+12L+1G	LG13	3.00

From the table 2 it was found that after adding lime and gypsum, there is no abrupt change found in the specific gravity Hydrated lime is lighter material than the red mud. Obviously, when 12% lime was added to red mud then little decrement of specific gravity was found.

3.2 Standard Proctor test

Standard Proctor test was carried out to determine the maximum dry density and optimum moisture content of the red mud. The test is carried out as per the IS: 2720 (Part VII) Light compaction was adopted. The variation of dry density for different combinations of the lime gypsum mixed are plotted in fig: 1.

Table 3: Shows the optimum moisture content and maximum dry density of the combinations

Sl No	Combinations	Designations	MDD (gm/cc)	OMC (%)
1	RM+0L+0G	RL	1.53	33.5
2	RM+4L+0G	L11	1.56	32.4
3	RM+8L+0G	L12	1.59	31.6
4	RM+12L+0G	L13	1.6	31.1
5	RM+4L+1G	LG11	1.57	32.2
6	RM+8L+1G	LG12	1.59	31.3
7	RM+12L+1G	LG13	1.62	29.5

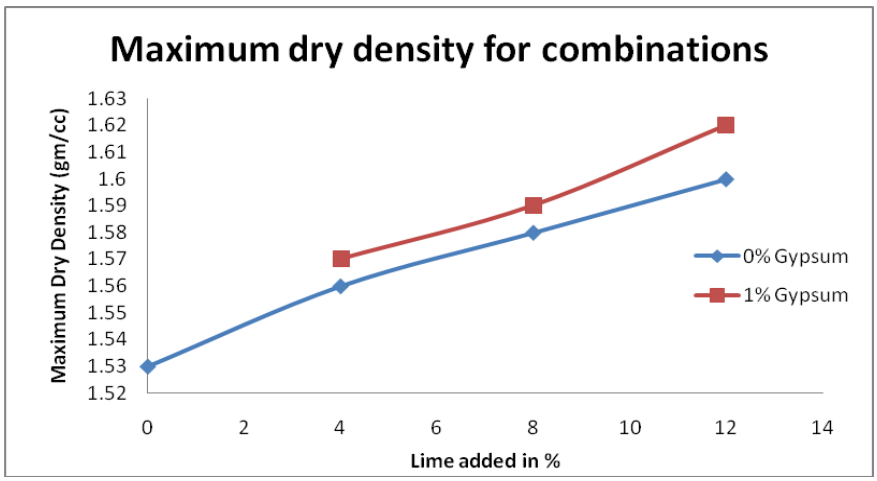

Fig 1: shows the variation of the dry density for different combinations

From Fig 1 it is found that as the lime content is increaed the dry density at OMC is also increased. The unstabilized red mud is having dry density 1.53 gm/cc at optimum moisture content of 33.5%. As the lime content is increased from 0 to 12% with the increament of 4%, the dry density also increased. At 12% addition of lime gives the more dry density. In the same graph it is also compared the dry density for the same increament of lime for 1% gypsum. When gypsum is added the dry density increased again for the same ratios of lime and red mud.

3.3 Atter Berg's limits

Liquid limit and plastic limits for the combinations were determined as per the IS: 2720 (Part V). Corresponding liquid limit, Plastic limit and plasticity index is shown in the table 4.

Table 4: shows the consistency limits, plasticity index and classification based on the plasticity chart of the combinations

Sl No	Combinations	Designations	Liquid Limit %	Plastic Limit %	Plasticity Index
1	RM+0L+0G	RL	45.5	32.3	13.2
2	RM+4L+0G	L11	42.1	31.2	10.9

3	RM+8L+0G	L12	38.6	30.4	8.8
4	RM+12L+0G	L13	35.2	28.5	6.5
5	RM+4L+1G	LG11	41	31	10
6	RM+8L+1G	LG12	37.5	29.4	8.1
7	RM+12L+1G	LG13	33.8	26.3	7.5

When lime is added to the red mud for the purpose of stabilization, the liquid limit is decreased consistently. For unstabilized red mud plasticity index was 13.2%. Therefore this classified as MI with respect to plasticity chart. Plasticity index decreased by 17.42% when 4% lime was added to the mixture. Again it is decreased by 19.2% and 26.13% when 8% and 12% lime was added to the red mud respectively. Addition of gypsum to the combination did not give significant change in it.

3.4 Permeability

Permeability test is carried out as per the IS: 2720 (Part XVII). The coefficient of permeability of the red mud specimen is found out using falling head method. For unstabilized red mud the coefficient of permeability was found to be 5.786e-7cm/s.

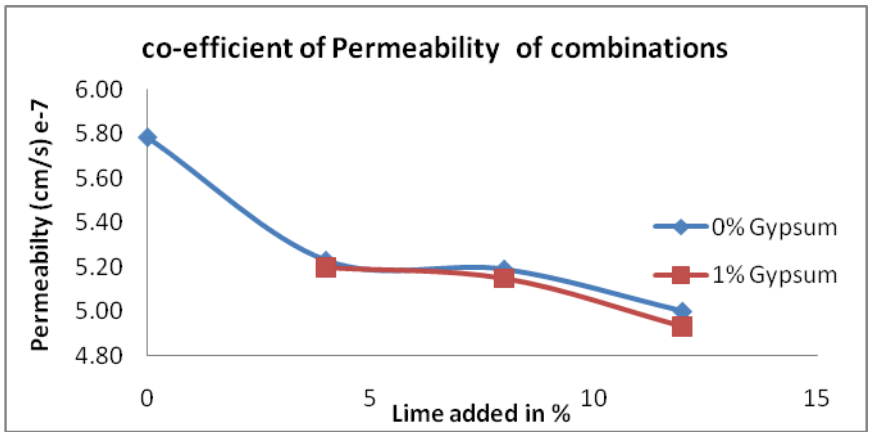

Fig 2: shows the co-efficient of Permeability of combinations

For unstabilized red mud the co efficient of permeability is in terms of $10^{-7.}$ When we add lime for the stabilization purpose the coefficient of permeability did not changed significantly. From Fig 2 it is clearly understood that as the lime content is increased the permeability is decreased. There is much effect found in permeability when gypsum was added.

3.5 Unconfined Compressive strength

The samples of sizes 38 mm diameter and height of 76 mm were prepared by static compaction method to achieve maximum dry density at their optimum moisture contents. Unconfined compressive strength tests were conducted at a strain rate of 1.25 mm/min. The results obtained are tabulated in table 5.

Table 5: shows the UCS value for combinations for 1 day and 7th day curing period.

Sl No	Combinations	UCS in Mpa	
		1 days strength	7 Days strength
1	RM+0L+0G	0.132	0.135
2	RM+4L+0G	0.212	0.216
3	RM+8L+0G	0.331	0.333
4	RM+12L+0G	0.31	0.314
5	RM+4L+1G	0.3	0.303
6	RM+8L+1G	0.391	0.395
7	RM+12L+1G	0.372	0.377

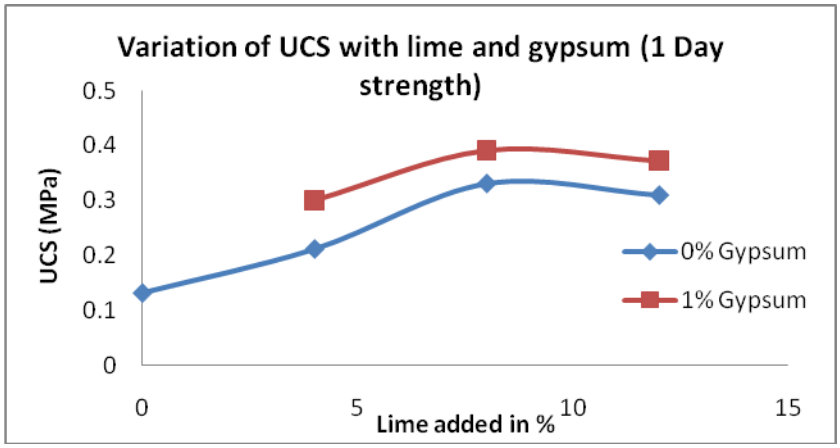

Fig 3: Plots variation of UCS for different mixes (1 Day)

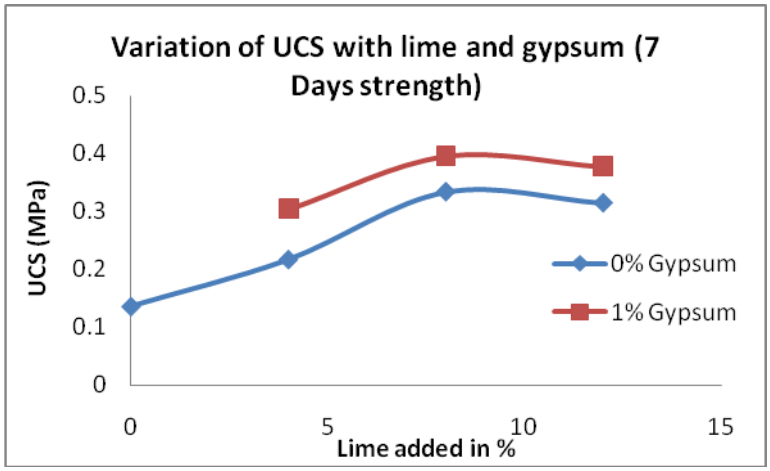

Fig 4: Plots variation of UCS for different mixes (7 Days)

It is very interesting behavior of red mud with lime is found in results of UCS test. For 1 day strength, as the lime percentage in the mix increases the UCS value also increased. But it is not true for all increment. It is showing that at 8 percent lime the UCS was found higher value. As the lime is increased above 8 percentages then the UCS value is decreased (Fig 3). For the same mixes of red mud and lime combinations after adding 1% of gypsum, the value of UCS increased parallelly as shown in fig 3. Fig 4 shows the UCS value of the identical mixes but it was determined after 7 days of curing periods. After 7 days of curing effect gives same behavior of red mud with lime and gypsum with little increased value of UCS.

3.5 California bearing ratio test

The sample of nearly 4.5 to 5 kg was compacted in a mould of volume 2250cc with 5 layers and 56 blows were given for each layer. For soaked CBR value, the different sample of identical size is prepared and kept soaking for 4 days with the surcharge. This test was conducted as per IS: 2720 (Part XXXI). The test results are entered in the table 6.

Table 6: shows the CBR value for all the combinations in both soaked and unsoaked condition.

Sl No	Combinations	CBR in %	
		Unsoaked	Soaked
1	RM+0L+0G	7.8	4.2
2	RM+4L+0G	11.4	6.1
3	RM+8L+0G	16.3	7.3
4	RM+12L+0G	18.3	7.4
5	RM+4L+1G	12.3	6.3

6	RM+8L+1G	16.83	7.6
7	RM+12L+1G	20.3	7.9

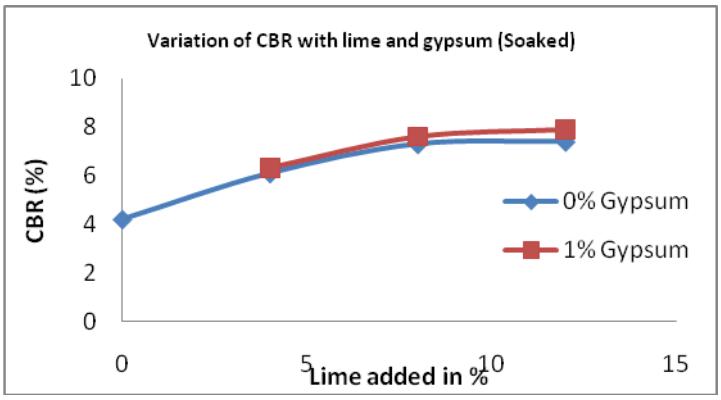

Fig 5: Shows the variation of CBR for different combinations (Soaked Conditions)

It is common tendency while reading the CBR value we give more importance to the soaked condition. The sample was kept for soaking for 4 days with surcharge. Fig 5 shows the variation of soaked CBR value for different combinations. Here it is found that as lime content increased it also increased the CBR value . Addition of gypsum to the red mud – lime combination did not give significant variation with little increment.

IV. CONCLUSIONS

1. Red mud when mixed with the lime or as the lime content increased the behavior of the mix was predictable. There is no abrupt change found in the results.
2. As per index properties point of view as the lime content increased in the mixes the properties like dry density increased accordingly.
3. In the mix as the lime added to it the plasticity is gradually decreased, which is good as a geotechnical point of view. At 12% addition of lime reduced plasticity index by 26.13% compared to that of unstabilized red mud.
4. Red mud itself has low permeable after compacting. On other hand after adding lime to it, the co-efficient of permeability further decreased.
5. As the strength point of view, in UCS test results it was found that, for 8% of lime additions gives maximum strength. Lime above 8% added decreases the UCS value. So optimistic mix among those combinations is 8% lime with 1% gypsum.
6. CBR value for the material which can be used as sub grade material should be more than 6% in soaked conditions for medium importance roads. The mixes above 4% lime gives more that 6% CBR value.

V. FUTURE SCOPE

- Red mud can also be stabilized by using fly ash and gypsum
- It is very necessary and one can study the leachate properties of the red mud. As the water flows through the red mud, the out coming water may have metals in it, which can leads to the damage of aquatic life.

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