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SUITABILITY OF RED MUD IN SUBGRADE USING RBI GRADE 81

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The waste generated by aluminum industry is known as bauxite residue or red mud. By nature, the red mud is toxic which creates problem for disposal. Due to the alkaline nature it is unsuitable for construction and vegetation. Every year more or less 75 million tons of red mud is generated worldwide. RBI grade 81 is a powdered cementitious stabilizer. It improves the engineering properties of several types of soils. This paper presents investigation carried out for better understanding on effect of RBI Grade 81 on red mud properties to be used in subgrades. It is found that with optimum dose of RBI grade 81 as 4%, liquid limit decreases and plastic limit increase. MDD values decrease slightly but the CBR value of the red mud increase with addition of RBI grade 81.

Keywords: Geotechnical engineering, Soil stability, Stabilizer, MDD, CBR.

1 GENERAL

The disposal of industrial waste products has always been a problem. Generally, the industrial wastes are toxic and reactive. Due to the highly hazardous nature, an environmental friendly method should be adopted for their disposal. Civil engineering structures like pavements, embankments, and highways are the main ways to use such wastes. Due to rapid urbanization, good quality soil is not readily available and the industrial waste material can be utilized in construction of roads and embankments which will help reducing pollution problems and indirectly improve the environment by preserving the natural soil.

The waste generated by aluminum industry is known as bauxite residue or red mud which is discharged when alumina is extracted from bauxite during the Bayer process. For each ton of alumina production, about 1.2 to 1.4 tons of red mud is generated depending on the type of bauxite ore used by the industry. So, for every year, about 75 million tons of red mud is generated worldwide. The iron compounds present in the bauxite ore gives the red color to the bauxite residue and hence it is called red mud.

By nature, the red mud is toxic which creates problem for disposal. Red mud consists of silica, iron, aluminum, titanium and calcium as well as an array of minor constituents, namely: K, Na, Cr, V, Ba, Ni, Cu, Mn, Zn, Pb etc., and the pH value of red mud is in the range from 10.5 to 13. Due to its harmful chemical composition and its high alkalinity, it is very dangerous to living world and environment. This large quantity waste is usually managed by discharging into natural or artificially made enclosed reservoirs, with effective dewatering by consolidation and sometimes followed by closure by capping. Due to the alkaline nature, it neither can be used for construction material nor for vegetation.

RBI Grade 81 is a powdered cementitious stabilizer that is composed of a number of naturally occurring compounds. It is odorless; the pH value of saturated paste made by it is 12.5, it is inert, insoluble in water, non-UV-degradable and chemically stable, simple to apply and hardens fast, durable, aesthetically pleasing and environmental friendly. It has the quality of improving engineering properties of several types of soils. It is very effective with silty-

clayey soils. Pore space in the soil mass is filled by a crystalline growth by hydration reaction. An irreversible inter-particle matrix is formed in the pore space by hydration. By the addition of low dosages of RBI Grade 81, the volume stability of poor soil increases. Hence, swelling and shrinkage of poor soil can be minimized. The hydration reaction of RBI Grade 81 with soil particles produces a matrix between whole particles that bind the soil by both chemical and frictional forces and hence particles together get converted into a hard, inflexible mass. This binding reduces the pore spaces without reduction in whole volume of soil mass. Strength of soil treated with RBI Grade 81 improves with age. It gains strength up to one year after application to soil. As it reduces pore spaces, the permeability of soil also decreases with addition of RBI Grade 8.

2 LITERATURE REVIEW

It is reported the use of RBI-81 in several soils such as lateritic soil, red soil, black cotton soil and clayey soil to study the effect of the stabilization product and to improve engineering properties of soil. They have reported that RBI Grade 81 is capable of improving engineering as well as index properties of soil (Madurwar *et al.* 2013, Patil and Patil 2013, Singh and Riar 2013, Haricharan *et al.* 2013, Mamta and Honna 2014, Naseem and Damgir 2014). Lekha and Ravi Shankar (2014) reported that fatigue life of RBI Grade 81 treated soil is very high.

Researcheres have studied the properties of red mud as stabilizer or as road construction material stabilized by cement, ground granular blast furnace slag, cement kiln dust, fly ash or geo-grids (Kalkan 2006, Rao *et al.* 2012, Wang and Liu 2012, Singh *et al.* 2014, Choudhary *et al.* 2015, Singh *et al.* 2015, Sahoo and Mohanty 2016). Deelwall *et al.* (2014) evaluated the properties of red mud for use as geotechnical material. They concluded that the red mud can be used as embankment material, back filling, etc. However, the author could not find any study on stabilization of red mud using RBI Grade 81. Because the RBI Grade 81 has many useful properties, it has been used in this study to improve engineering properties of red mud so that the red mud can be effectively utilized in sub-bases and similar constructions.

3 MATERIALS FOR THE STUDY

Table 1. Physical and Geotechnical Properties of Red Mud.

Properties	**Values**
Appearance	Mud
Color	Red
Specific Gravity	3.02
Unconfined Compressive Strength	1.5 kg/cm^2
Liquid Limit (%)	46
Plastic Limit (%)	36
Plasticity Index (%)	14
CBR Value	3.6
OMC (%)	35
MDD (gm/cc)	1.52
Permeability k (cm/sec)	4.3X10^{-6}
Grain Size Distribution	
Fine Sand	2.5%
Silt	94.5%
Clay and Collides	3%

The materials used in the present study are red mud and RBI Grade 81. Red Mud in the present study was obtained from NALCO (National Aluminum Company) plant located at Damanjodi in Orissa. Red mud is highly complex material that differs due to the different Bauxites used and the different parameters. Test majority of Red mud is dominated by silt size particles and also possess plasticity characteristics and imperviousness. The physical and

geotechnical properties of red mud used are presented in Table 1 and chemical properties in Table 2. Red mud is also shown in Figure 1.

Table 2. Chemical properties of red mud.

Compound	Composition
Na2O	7.7%
Al2O3	22.9%
SiO2	19.8%
CaO	1.24%
iO2	7.86%
V2O5	0.66%
FeO	39.4%
ZnO	0.43%

Figure 1. Red mud sample.

RBI Grade 81 was obtained from Alchemist Technology Ltd. Gurgaon. It is a unique and innovative product for the stabilization of a wide spectrum of soils in an efficient and cost-effective manner. It is an environmentally friendly, inorganic, hydration activated powder based stabilizer that reacts with soil particles to create layers that are interconnected through a complex inter particle framework. Properties of RBI Grade 81 used are presented in Table 3.

Table 3. Properties of RBI grade 81.

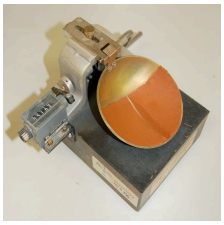
S.No.	**Chemical Composition**		**Physical Significance**	
1	CaO	52-56 %	Odor	Odorless
2	SiO2	15-19 %	pH	12.5 (Saturated paste)
3	SO3	9-11 %	Specific Gravity	2.5
4	Al2O3	5-7 %	Solubility	In water - 0.2 pts/100pt
5	Fe2O3	0-2 %	Freezing Point	None, Solid
6	MgO	0-1 %	Flammability	Non Flammable
7	Mn, K, Cu, Zn	0-3 %	Shelf Life	12 month (Dry Storage)
8	Fibres (polypropylene)	0-1 %	Storage	Dry Storage (Avoid moisture contact)
9	Additives	0-4 %	Bulk Density	700 kg/m3

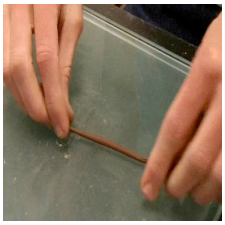
4 EXPERIMENTAL PROGRAM

Tests were carried out for understanding the effect of adding RBI Grade-81 on Red mud properties. Initially the Red mud and RBI Grade 81 are tested for their individual characteristics and geotechnical properties. After that the tests were carried out on red mud mixed with RBI Grade 8. Five combinations of samples by varying the RBI Grade 81 percentage (0%, 2%, 4%, 6% and 8%) were used. The index property tests conducted were Specific Gravity Test, Atterberg's Limits and Swelling Index. In engineering properties, Standard Proctor Test, UCS and CBR tests were conducted. Few samples tested in the laboratory are shown in Figure 2. All tests were conducted according to relevant IS Codes as given below:

1. Grain size distribution-Hydrometer Analysis (IS 2720 Part IV) (Conducted for individual materials only)
2. Specific gravity (IS 2720 Part III)
3. Liquid limit (IS 2720 Part V)
4. Plastic limit (IS 2720 Part V)
5. Plasticity Index (IS 2720 Part V)
6. Free swell index (IS 2720 Part IV)

7. Standard Proctor (IS 2720 Part VIII)
8. UCS (IS 2720 Part X)
9. CBR (IS 2720 Part XVI)


Liquid limit test


Plastic limit test


Free swell index test


Proctor test


Unconfined compression test


CBR test

Figure 2. Sample tests in the laboratory.

5 RESULTS AND DISCUSSION

5.1 Specific Gravity

The experiment was performed from both pycnometer and density bottle method. The specific gravity of different combinations is tabulated in Table 4. From the result, it is clear that with increase in the RBI Grade 81, the specific gravity decreases however there is no appreciable change found in the specific gravity value.

Table 4. Specific gravity and Atterberg's limits of red mud and RBI grade 81 mix.

Mix Combinations	Specific Gravity	LL	PL	PI
Red Mud + 0% RBI Grade 81	3.02	46	36	10
Red Mud + 2% RBI Grade 81	2.97	45	36	9
Red Mud + 4% RBI Grade 81	2.96	43	36	7
Red Mud + 6% RBI Grade 81	2.95	46	38	8
Red Mud + 8% RBI Grade 81	2.94	48	38	10

5.2 Atterberg's Limits

Table 4 shows Atterberg's limits for different combinations of red mud and RBI Grade 81. From the table, it is observed that with increase in the RBI Grade-81content, liquid limit is decreasing up to 4% addition of RBI Grade 81 and after that liquid limit is increasing but the plastic limit increases with increase in RBI Grade 81 content. The plasticity index decreases, up to addition of 4% of RBI grade 81 and after that it increases slightly. It shows that 4% RBI Grade 81 will provide better result and after that there won't be any improvement.

5.3 Free Swelling Index (FSI)

The free swelling index of red mud is zero. It shows that there won't be any problem associated with swelling of red mud soil. By adding 2% and 4% RBI Grade 81, there is no volumetric change observed in the soil mix. Beyond that dose swelling increases. This may

be due to some chemical reactions taking place during the hydration process. Table 5 shows the free swelling index (FSI) values of RBI Grade 81 treated red mud in various combinations.

Table 5. FSI, OMC, MDD, UCS and CBR values of red mud and RBI grade 81 mix.

Mix Combinations	FSI	OMC (%)	MDD (gm/cc)	UCS in kg/cm^2	Soaked CBR %
Red Mud + 0% RBI Grade 81	0%	35	1.52	2.12	3.6%
Red Mud + 2% RBI Grade 81	0%	34	1.50	2.70	11.0%
Red Mud + 4% RBI Grade 81	0%	33	1.49	3.08	19.5%
Red Mud + 6% RBI Grade 81	56%	35	1.47	3.40	27%
Red Mud + 8% RBI Grade 81	70%	36	1.42	3.72	38%

5.4 Standard Proctor Test

Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) obtained from standard proctor test are presented in Table 5. It was found that as the RBI Grade 81 content is increased the dry density at OMC decreases. The unstabilized red mud is having dry density 1.52 gm/cc at optimum moisture content of 35%, it decreases to 1.49 gm/cc at 33% OMC with 4% of RBI Grade 81. At 6% and 8% of RBI Grade 81 content there is further decrease in MDD values. There is no appreciable change in OMC values with higher doses of stabilizer.

5.5 Unconfined Compressive Strength (UCS)

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. The obtained value of unconfined compression strength (UCS) for raw red mud is 2.12 kg/cm^2 for 3 days curing. By adding 2% RBI Grade 81, the UCS strength increased to 2.70 kg/cm^2. For 4% of RBI Grade 81, the strength increased to 3.08 kg/cm^2. Maximum strength value is obtained at addition of 8% RBI Grade 81 to red mud. The UCS test is conducted for 3 days curing of sample. Further increase in the curing period, may cause increase because the material RBI Grade 81 takes time for attaining strength due to its cementitious properties.

5.6 California Bearing Ratio (CBR)

This test was conducted as per IS: 2720 (Part XXXI). 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. The test results are shown in the Table 5. Here it is found that the CBR value increases continuously with increasing the RBI Grade 8. The strength gain may be attributed to the cementing action of RBI Grade 81.

6 CONCLUSIONS

Based on the experimental results obtained it can be concluded that the red mud, a hazardous waste, can be successfully stabilized with RBI Grade-81 and the stabilized red mud can be used as subgrade material in pavement construction. The specific gravity of raw red mud is 3.02. By stabilization, there is a slight decrease in specific gravity which is obvious because of low specific gravity value of RBI Grade 81. The liquid limit of raw red mud is 46, which by stabilizing it with RBI Grade 81 up to 4%, decreases to 43. The plastic limit value of raw red mud increases with addition of RBI Grade 81. Due to the decreasing LL value and increasing PL value, the plasticity index decreases up to 4% addition. It shows the

effectiveness of the stabilizer. The free swell index shows that red mud is having zero swelling. Up to addition of 4% of red mud, no swelling is observed. Beyond that, the red mud just starts swelling slightly. The standard proctor test shows that the MDD value decreases continuously with addition of RBI Grade 8. The OMC first decreases up to addition of 4% of RBI Grade 81 and beyond that OMC is increasing. The UCS test results after 3 days curing shows that the strength increases by addition of RBI Grade 81. By increasing the period of curing further increase in strength may be possible due to its cementitious properties. The CBR test results show that the bearing capacity of soil increases with increase in stabilizer content.

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