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Application of GGBS stabilized Redmud in Road Construction

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Abstract: - *Redmud is a waste product from Alluminium industry. For its bulk utilization a detailed experimental programme was conducted to study the behavior of Redmud when stabilized with GGBS (Ground Granular Blast Furnace Slag) which is a waste product from steel manufacturing plants. In this present study the Redmud was stabilized with 5, 10,15,20,25 and 30 percentages of GGBS. The unconfined compressive strength, Split tensile strength and California bearing ratio tests were conducted at 1, 3, 7 and 28 days curing periods only. From the test data it was observed that 25% GGBS has shown higher values compared to other percentages and at 28 days it has shown maximum values than other curing periods. A higher value of CBR i.e, 35% was obtained for 25%GGBS at 28 days curing period. Hence Redmud stabilized with GGBS can be used as subbase, base course and also subgrade material for road construction.*

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 areas of land for their disposal and create environmental pollution. India produces 15 metric tonns of slag annually as a bi-product from steel industries. Redmud is one of the bi-products obtained during refining process of Bauxite (ore of Alluminium, $Al_2O_32H_2O$). It is also called as Bayer's process residue. For every ton of alumina one tonn of Redmud produced. Utilization of these materials in large quantities is especially in road construction. The physical structure and gradation of GGBS depends on the chemical position of slag. It is a cementitious material they will lead to formation of C-S-H gels, C-A-H gels

An earlier research was done on Blast furnace slag for Bulk Geotechnical applications by Siva pullaiha et al 2011. Indra Ratna B has studied the utilization of lime, slag and flyash for improvement of colluvial soils. Wild S, Kinutha J M, Jones G I and Higgins were studied on effects of partial substitution of lime with GGBS on the strength properties.

In the present study Redmud was stabilized with GGBS and the sample collected from NALCO (National Aluminum Company) located at Daman Jodi in Orissa. Currently it is estimated to be 2.7 billion tons with an annual growth rate of over 120 million tonns. Earlier studies shows Redmud can be utilized for various purposes like agricultural, waste gas treatment, recovery of major metals and steel making. The sample was tested to characterize the geo technical properties of Redmud and Redmud GGBS mixes. Unconfined compressive strength, split tensile strength and CBR were tested in proportions of 5, 10,15,20,25 and 30 percentages of GGBS. UCS was conducted at 1, 3, 7 and 28 days curing periods whereas Split Tensile Strength and CBR were conducted at 7 and 28 days curing periods only. SEM (Scanning Electron Microscope) and EDS (Energy Distribution Spectrometer) were conducted to validate the experimental results that were obtained in the laboratory. The agglomeration of particles and the distribution of energy were also shown by Scanning Electron Microscope.

II. Results and Discussions:

Materials used in the present study are Redmud, and GGBS (Ground Granulated Blast Furnace Slag). Redmud collected from NALCO (National Aluminum Company) which is located at Damanjodi in Orissa. The GGBS collected from RINL (Rastriya Ispath Nigam Ltd) Visakhapatnam. The chemical compositions and Geotechnical properties of Redmud, and GGBS are as follows

Physical and Geotechnical properties of Redmud:

Property	Value
Colour	Red
Odour	Slightly pungent, earthy odour
p^H	12-13
Unconfined Compressive Strength (UCS) kg/cm^2	1.49
Liquid limit (%)	30
Plastic limit (%)	24
Plasticity index	6

Table: 1

Physical and Geotechnical properties of GGBS

Property	GGBS
Colour	White
Gravel fraction	0
Sand fraction	4
Fines (%)	96
Unconfined Compressive Strength (UCS) kg/cm^2	1.4
Liquid limit (%)	32
Plastic limit (%)	NP

Table: 2

Chemical composition of GGBS:

Formula	Compound %
Na_2O	4.36
MgO	0.96
Al_2O_3	17.03
SiO_2	12.94
K_2O	0.59
CaO	20.32
TiO_2	14.08
FeO	29.72

Table: 3

Chemical composition of Redmud:

Formula	Compound %
Na_2O	7.75
Al_2O_3	22.84
SiO_2	19.84
CaO	1.24
TiO_2	7.87
V_2O_5	0.68
FeO	39.32
ZnO	0.45

Table: 4

2.1 Compaction Characteristics:

The compaction characteristics like OMC's (optimum moisture contents), MDD's (maximum dry densities) were tested for various percentages of GGBS i.e., 5,10,15,20,25 and 30 by dry weight of soil mass as per IS: 2720 (part VII) - 1980.

OMC and MDD values for Redmud with GGBS:

GGBS (%)	OMC (%)	MDD (g/cc)
0	22.0	1.42
5	22.5	1.4
10	22.9	1.39
15	23.4	1.37
20	23.7	1.36
25	24.0	1.36
30	23.8	1.35

Table: 5

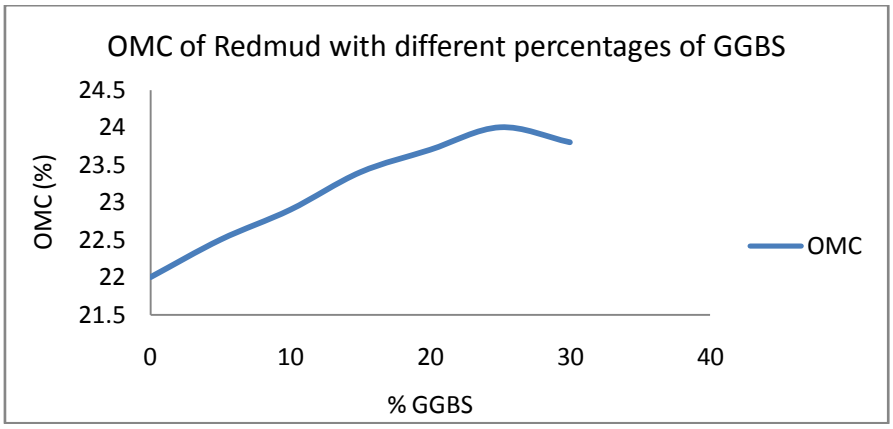


Fig: 1

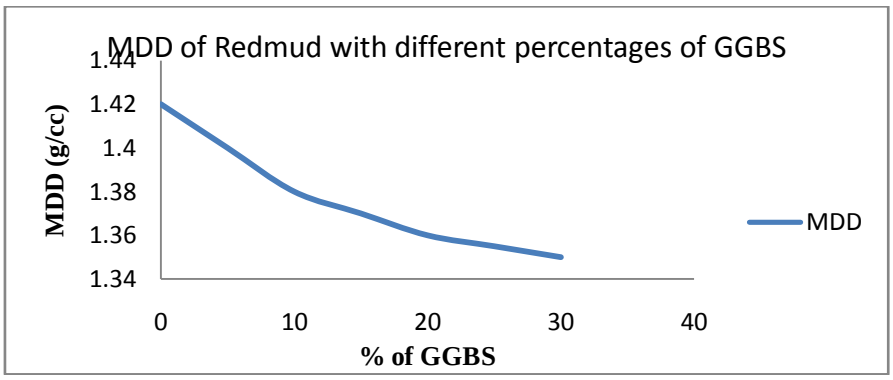


Fig: 2

Table no 5 and fig: 1, 2 show the variation of maximum dry densities and optimum moisture contents. As percentage of GGBS increases an increase in OMC, and decrease in MDD was observed. The decrease in MDD is due to flocculation of Redmud particles when GGBS added to it, and increase in OMC is due to high water content is needed for effective mobility of particles under flocculation condition. This decrease in MDD values is effective up to 25% of GGBS and then insignificant, similarly in case of OMC's also the increase is effective up to 25% addition of GGBS.

2.2 UCS for Redmud with GGBS (kg/cm^2):

The samples of sizes 38 mm diameter and height of 76 mm were prepared by dynamic compaction method to achieve maximum dry density at their optimum moisture contents. All the prepared samples were cured for 1 day, 3 days, 7 days and 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.

Unconfined Compressive Strength for Redmud with GGBS:

GGBS (%)	Curing period (days)			
	1	3	7	28
5	1.85	2.75	3.94	6.62
10	3.24	5.2	8.43	12.77
15	4.83	8.84	12.45	16.85
20	6.54	10.6	14.82	20.8
25	7.86	12.12	16.08	24.5
30	6.65	10.24	13.85	19.02
35	6.32	9.35	12.42	17.86
40	6.02	9.2	11.96	17.2

Table: 6

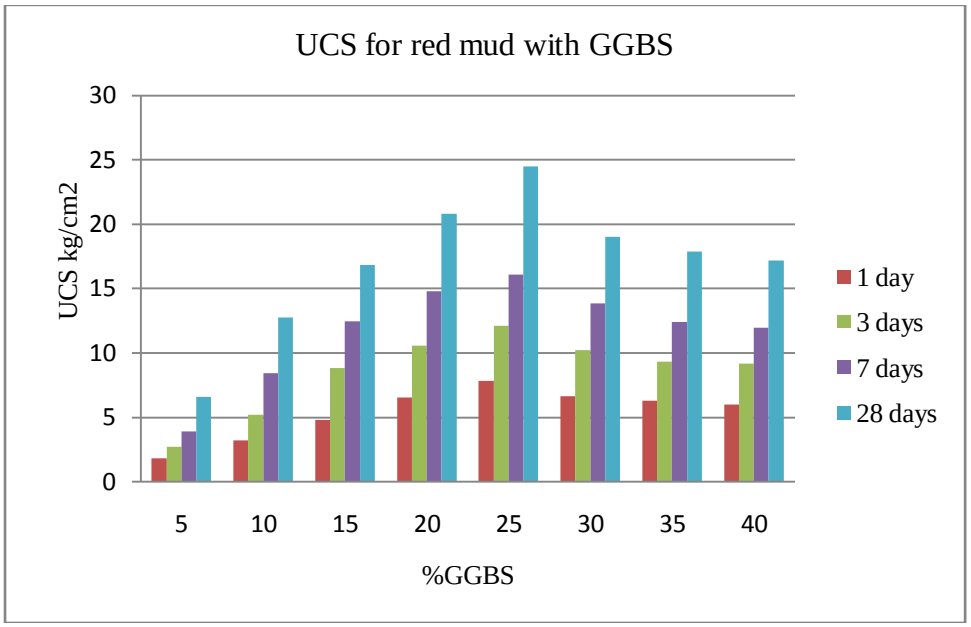


Fig: 3

Table no: 6 and Fig no: 3 show the variation of UCS with percentage of GGBS. From the data it can be seen that as percentage of GGBS and curing periods increases UCS values are increasing. A significant increase was observed up to 25 % and beyond this a study decrease in strength values were observed. At earlier curing periods a steady increase in UCS values and at 7 days and up to 28 days curing period a rapid increase in UCS values were observed. High strength values at higher dosage of GGBS and at higher curing periods are due to development of bond between silicates, aluminates available in Redmud and GGBS. At higher curing periods it is significant in developing crystalline particles under agglomeration process, and makes the above features of Redmud – GGBS mixes stronger.

2.3 Split Tensile Strength kg/cm^2:

The samples of sizes 38 mm diameter and height of 76 mm were prepared by static compaction method to achieve maximum dry densities at their optimum moisture contents. All the prepared samples were cured for 1 day, 3days, 7 days and 28 days by maintaining 100% humidity. The sample is loaded until splitting / failure takes after completion of their curing period at a strain rate of 1.25 mm/min.

Tensile strength, $S_t = 2P_u/ \pi Dt$

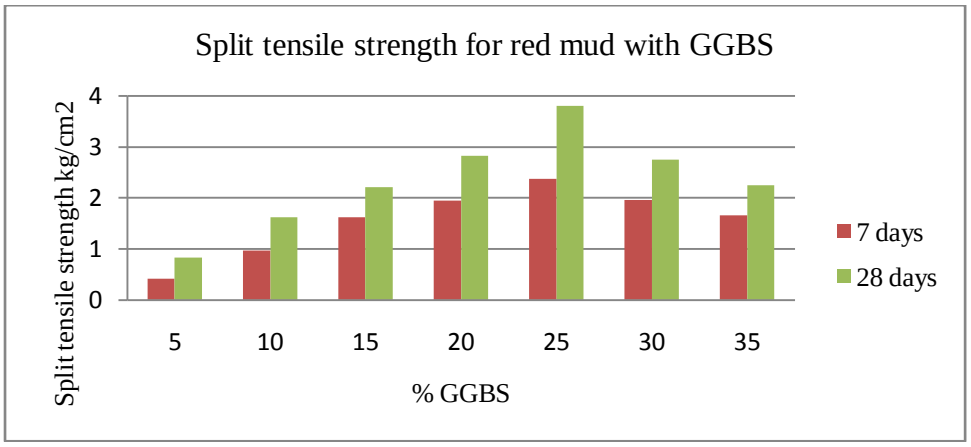
Where, P_u = ultimate load at which failure of sample.

D = diameter of specimen, mm

Split Tensile Strength For Redmud With GGBS:

GGBS (%)	Curing period (days)	
	7	28
5	0.42	0.83
10	0.96	1.62
15	1.62	2.21
20	1.94	2.82
25	2.37	3.8
30	1.96	2.75
35	1.65	2.25

Table: 7



Figs: 4

Table no: 7 and Fig no: 4 show the variation of split tensile strength values, with increase in GGBS content. As the percentage of GGBS increases an increase in Split tensile strength values was observed. This maximum at 25% 0f GGBS and then a decrease was observed for further addition of GGBS. These values are high for 28 days curing compared to 7 days. This increase in the value is due to the pozzolanic action between the particles of GGBS and Redmud.

2.4 California Bearing Ratio (CBR):

The sample of nearly 4.5 to 5 kgs was compacted in a mould of volume 2250cc with 5 layers and 56 blows were given for each blow. All the prepared samples were cured for 7 days and 28 days by maintaining 100% humidity. The sample is loaded until splitting / failure load takes after completion of their curing period at a strain rate of 1.25 mm/min. this test was conducted as per IS 2720 part 16.

California Bearing Ratio for Redmud with GGBS:

GGBS (%)	Curing period (days)	
	7	28
5	5	8
10	10	15
15	16	22
20	20	28
25	25	35
30	21	30

Table: 8

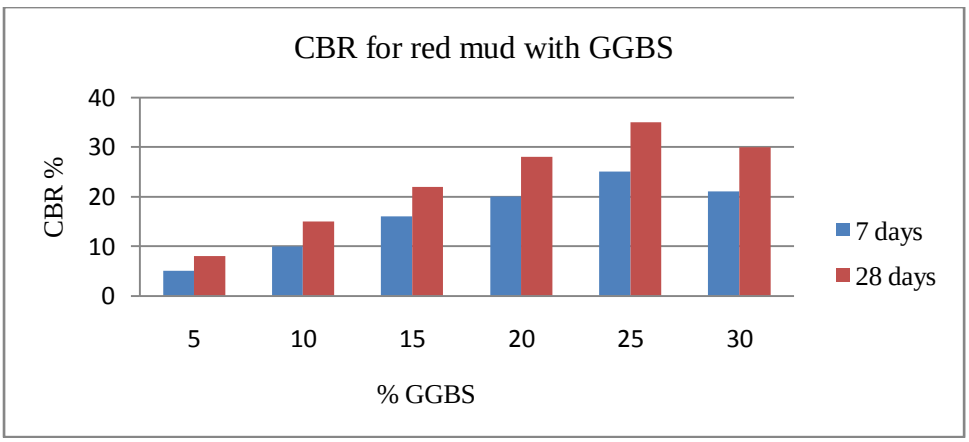


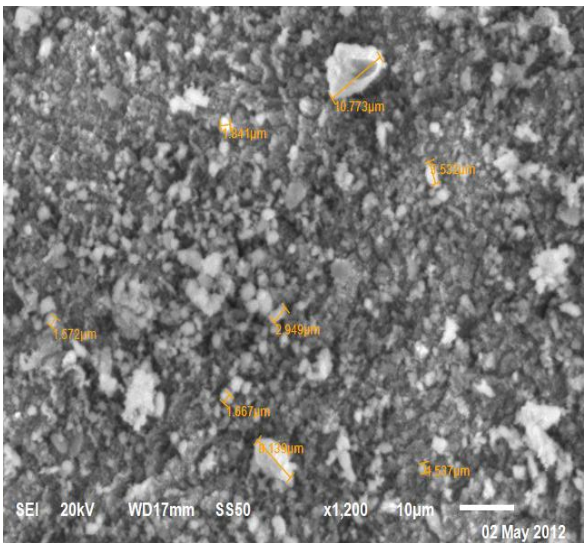
Fig: 5

Table no: 8 and fig no: 5 shows the variation of CBR with different percentage dosage of GGBS. An increase in CBR values were observed with an increase in percentage of GGBS and curing periods. The addition of GGBS more than 25% doesn't interact with the particles of Redmud. The values for 28 days curing period are more compared to 7 days curing. This increase is due to pozzolanic action between the particles of GGBS and Redmud.

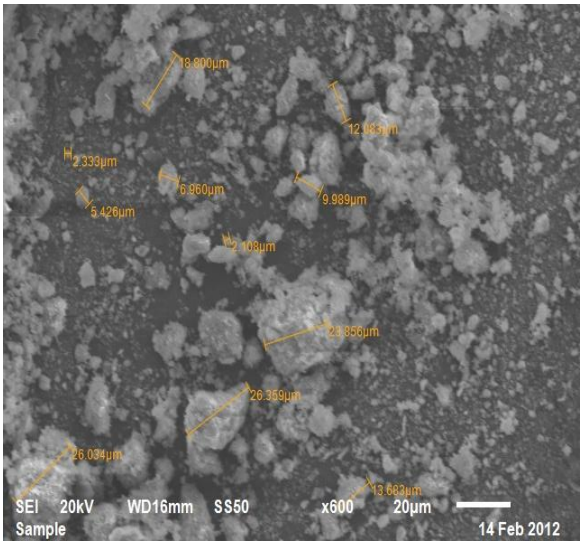
2.5 Analysis of SEM and EDS:

The variation in the agglomeration of particles is shown below for Redmud and GGBS stabilized Redmud. The CaO content was increased with addition of GGBS. The particle size increases from 10 microns to 23 microns and increase in calcium oxide percentage is 1.24 to 20.32. Due to the increase in particle size the agglomeration was done between the particles of Redmud and GGBS.

Redmud



Redmud with GGBS



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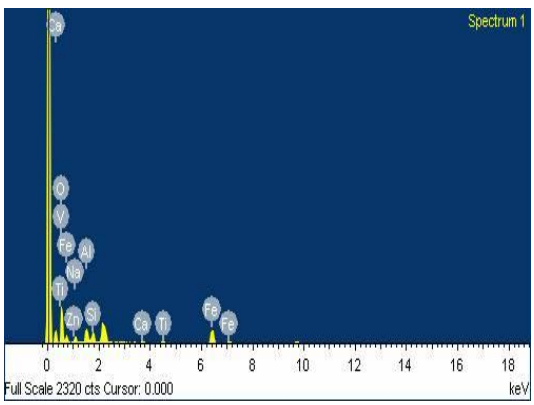

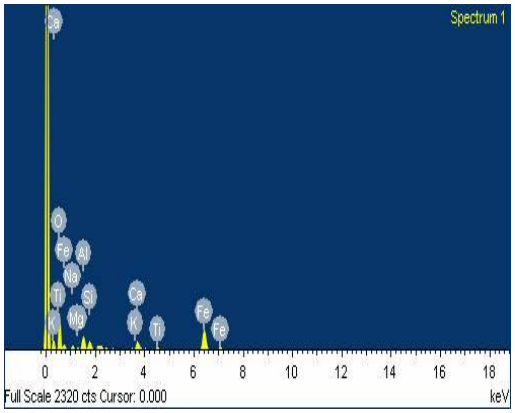

To validate the experimental findings the samples are studied under scanning electron microscope (SEM) to get magnified photo graphs of the particles and their interaction when mixed with GGBS in various proportions. The samples are also studied to obtain the chemical composition (in % by weight) to analyze the effect of various chemical compounds in the geotechnical parameters like density and strength. The agglomeration of particles was observed to be good at 25% GGBS with Redmud mix especially for 28 days cured mix.

III. Conclusions:

Addition of higher percentage of GGBS has shown higher values up to 10% addition further addition of GGBS doesn't play any vital role in increasing the strength of Redmud GGBS mix.

As the percentage of GGBS increases the water content required for stabilization is more up to 25% addition of GGBS and then a marginal decrease was observed.

From the test results the optimum mix obtained is 25% GGBS with Redmud.

The agglomeration of particles is very good as the percentage of GGBS increases.

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