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STUDY ON COMPACTION AND STRENGTH CHARACTERISTICS OF FLY ASH-RED MUD CEMENT MIXES

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Abstract: Red mud is a waste product obtained from the Bayer process, which refines Bauxite into a form of Aluminium oxide called Alumina. The mud primarily contains non-Aluminium compounds present in the Bauxite ore and left as residues after its refining Aluminium oxide. Iron oxide, the compound from which the red colour component, but it also contains other compounds. Red mud containing about 96% fines and silt sized particles, Red mud can be used in an effective way by making of Red mud bricks, as a sub-base material for road construction, Red mud is mixed with various additives to attain impervious state which can be used as a liner, they can be also used as back fill material in case of embankments In the present study for the use of Red mud with Fly Ash in geotechnical application various percentages of cement was added. Tests like compaction, grain size distribution analysis, unconfined compressive strength, permeability were conducted to study the interaction of Red mud, Fly Ash and cement particles. Various combinations of Red Mud and Fly Ash was mixed with various percentages of cement (0, 2, 4, 6, 8, and 10) and cured for 3day, 7day, and 28day by maintaining 100% humidity. The specimens were tested for unconfined compressive strength. CBR tests for unsoaked and soaked conditions are also conducted by curing them for 7 days. From the test results it is identified that as the percentage of cement increases compression strength increases. Maximum values attained at 28 days curing periods. CBR values also increased with increase in the cement percentage both in unsoaked and soaked conditions which are cured for 7 days. In CBR values compared to soaked, unsoaked values are greater. Hence Red mud-Fly Ash-cement stabilized material can be effectively used in geotechnical applications.

I. INTRODUCTION

The production of caustic Red mud makes the Bayer process an environmentally challenging process. Red mud, which derives its name from the colour of iron oxides in the substance, comprises up to 60% of the Bauxite material, depending on the ore. For each tone of alumina produced, up to two tons of Red mud is generated. The exponential growth rate of the quantity of Red mud in the word, driven by global consumption of Aluminium, is a major environmental concern for the Aluminium industry and a hazard for the communities and ecosystems near production facilities. Though alumina can be produced from Bauxite under alkaline conditions using lime (Lime Sinter process), sodium carbonate (Deville Pechiney process), at high temperature in reducing environment with presence of coke and nitrogen (Serpeck process), the alkalinisation by the use of sodium hydroxide (Bayer process) is the most economical process which is employed for purification of Bauxite if it contains considerable amount ofFe2O3. The production process of alumina is shown is Fig. 1. In the Bayer process, Bauxite is digested by leaching it with a hot solution of sodium hydroxide, NaOH, at 106-240°C and at1-6 atm pressure. This converts the Aluminium minerals into tetra hydroxide aluminate Al (OH)4, while dissolving in the hydroxide solution. The other components of Bauxite except silica (present in kaolinite) do not dissolve. The insoluble compounds are separated by settling and the decant solution is further clarified by filtering off remaining solid impurities. The waste solid is washed and filter pressed to regenerate caustic soda and is called Red mud presenting a disposal problem. Next, the hydroxide solution is cooled and the dissolved Aluminium hydroxide precipitates as a white, fluffy solid. When heated to 1050°C (calcinated), the Aluminium hydroxide decomposes to alumina, giving off water vapour in the process. A large amount of the alumina so produced is then subsequently smelted in the Hall Heroult process in order to produce Aluminium. It is pumped through pipes into the Red mud pond which is of few hectares of area. It is available in red colour and contains moisture. It is formed by separating the red Bauxite from soil. It contains iron oxides in major percentage. Red mud stored on land currently is estimated to be over 2.7 billion tons with an Annual growth rate of over 120 million tons. The re use options of Red mud must be high and the unwanted material present in Red mud should be removed and treated. One of the most common and feasible way to utilize the Red mud is by stabilizing it with some admixtures and aims at characterization of the material through laboratory experiments. For every tons of Aluminium one tons of Red mud is produced.. The Indian Aluminium sector is characterized by large integrated players. In India there are five major plants which are producing Red mud along with Aluminium. They are HINDALCO (Hindustan Aluminium Company), INDAL (Indian Aluminium Company), NALCO (National Aluminium Company), MALCO (Madras Aluminium Company) and BALCO(Bharath Aluminium company ltd) Red mud is one of the by-products obtained during the refining of Bauxite (ore ofAlluminium-Al_20_3). It is also called as Bayer's process residue.

The process is as follows

Bauxite reacts with sodium hydroxide to form sodium Meta alluminate. The equation is as follows $Al_2O_32H_2O+2NaOH \rightarrow 2NaAlO_2 + 3H_2O$.

In this process Fe_2O_3 impurity is removed by filtration (Red

mud). The main composition of Bauxite is Al_2O_3(40-60%), SiO_2, Fe_2O_3, TiO_2.
If Al_2O_3 is in major percentage that is called as white Bauxite. If Fe_2O_3 is in major percentage, then it is called as Red Bauxite. Our present study is on red Bauxite residue. The Red mud is also called as Bayer's process residue. The formation of Red mud is as shown below. This Fe_2O_3 is mainly termed as rust leading to the damage in the presence of environment.

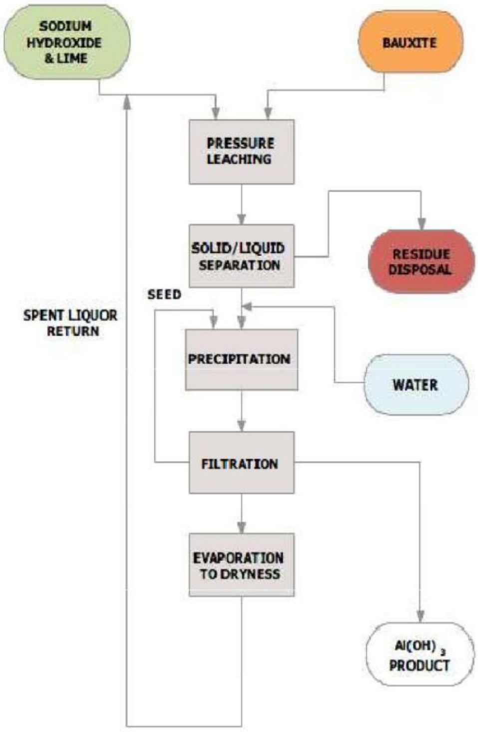

Fig.1(a) BAYER'S PROCESS

1.1CLASSIFICATION OF RED MUD:
There are three types of Red mud.

- Red mud
- Red mud gypsum
- Leached Red mud

Red mud: it is the actual waste product obtained from Bauxite refinery and pumped through pipes into Red mud pond. It is available in wet condition when pumped into the pond. The amount of Red mud produced depends on the type and grade of Bauxite. The physical and chemical characteristics are also depends on nature and grade of Bauxite. It contains large amounts of iron oxides and thus has a very high absorption capacity for phosphorus.
(ii) Red mud gypsum: The Red mud from the plant was air dried, crushed and sieved to lessthan 2mm. and 5 % of gypsum is added to it and thoroughly leached to remove soluble salts.
(iii)Leached Red mud: This is formed by through leaching with dilute acid to remove soluble salts. This is also air dried, crushed and passed through 2mm sieve.
The main differences among the three Red mud samples are shown :

Chemical Properties	Red mud	Red mud Gypsum	Leached Red mud
Ph	11.68	8.65	7.46
Bicarbonate extractable phosphorous(mg/Kg)	50.1	38.4	65.0
Fe(%)	0.12	0.18	0.14
Al(%)	1.49	1.50	1.62

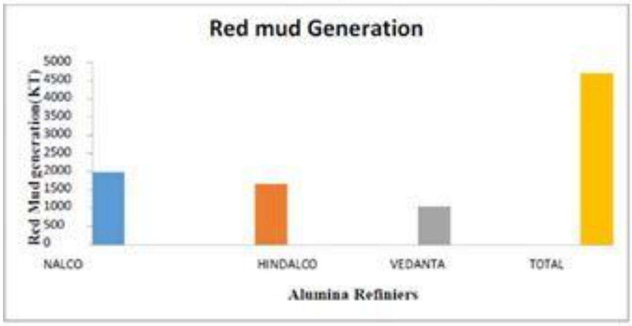

Fig: 2 Red mud Generation

Utilization of Red mud :
Till today, almost all over the world, Red mud is disposed off the plant site in two main ways depending on the facilities available and the surroundings. In countries such as France, England, Germany or Japan where availability of land for dumping is less and sea are nearby; the practice is to discharge the mud into the sea. Where free land is available nearby, the mud is pumped into pools and ponds constructed for this purpose .The water overflowing from the ponds after settling of the mud is recycled to the plant for partial recovery of the alkali carried away with the mud and the solid is left for sun drying. Before proceeding to possible solutions for recovery and use of Red mud it is pertinent to have a brief discussion on the issues of environmental concerns, Red muddy watering and disposal status, since they are interlinked. Red mud is not a particularly toxic material. Brown and Kirkpatrick applying Toxic Characteristic Leaching Procedure (TCLP- an EPA test procedure designed to determine the morbidity of wastes) and Multiple Extraction Procedures (MEP) conducted at Tulane on the Red mud of Kaiser Aluminium& Chemical Corporation ,Gramercy, conformed this aspect. Concentrations of all metal species were well below the EPA Regulatory Tresh old and Drinking Water Standards. In reality then the environmental concerns relate to two aspects: (i) the very large quantity of the Red mud generated, and (ii) its causticity. A typical alumina plant produces large amount of Red mud. In addition up to 2 tons of liquor at 5-20 gpl caustic (as Na2CO3) accompany with every ton of dry mud solids. Discussing the Red mud production and disposal problems in Australia, whose Aluminium production constitutes 39% of world production and the Red mud generation is 50% of that in the world, indicated that the treatment and disposal of Red mud is a major operation and may account for 30-50% of operations in an alumina refinery. Dewatering and disposal technologies assume great

significance.

Application

Bauxite residue (Red mud) has been used as an amendment on the very sandy agricultural soils.

Increasing phosphorus retention of very sandy soils including the use of Red mud to prevent phosphorus run off to rivers and inlets.

Increasing yields of (mainly) horticulture crops with and without extra additions of phosphorus potassium etc.

This is used in components layers in the road construction.

These are used in agricultural fields to improve sandy soils.

Additive to port land cement.

Component in light weight-aggregates.

Development of sand fraction as a construction material.

II. METHODOLOGY

1.Materials Used

2.1Red mud 2.2 Fly Ash 2.3Cement

2.1 Red mud:

It is a waste product from Aluminium plant obtained during refining process of Bauxite (ore of Aluminium $Al_2O_32H_2O$). It is also called as Bayer's process residue. It contains high number of compounds among those more frequent are shown below Hematite, goethite, gibbsite, boehmite, calcite, calcium Aluminium hydrate, sodalities, Aluminium silicates and kaolinite. 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. In the present study the Red mud sample is collected from NALCO (National Aluminium Company) which is located at Damanjodi in Orissa.

Cement:

Cement used in this work is OPC (53-grade) cement. The manufactures of the cement used is Jaypee. OPC means Ordinary Portland Cement. Portland cement is the most common type of cement in general usage in many parts of the world, as it is a basic ingredient of concrete, mortar, stucco and most non-specialty grout.

Laboratory Testing:

The following tests were conducted on fly ash. The index and engineering properties of fly ash were determined.

(I) Grain Size Analysis (IS: 2720-part 4, 1985)

(II)Atterberg's Limits(IS: 2720-part 5, 1985)

(III) Specific Gravity (IS: 2720-part 3, 1980) (IV) Procter's compaction test (IS: 2720- Part 8, 1983)

(V) Unconfined Compressive Strength Test (IS: 2720-part - 10, 1991)

(VI) California Bearing Ratio Test (IS: 2720- Part 16, 1987)

I. Grain Size Analysis:

Sieve analysis was carried out using a set of standard I.S Sieves. The sample was oven dried and placed on the top of the sieve set and shaken by hand. The test was carried out according to IS: 2720 part-4. The set of sieves according to IS2720 are 4.75mm, 2.36mm, 1.18mm, 0.6mm, 0.425mm, 0.3mm, 0.15mm and 0.075mm. The fine fraction that passed through 75 micron sieve was taken and hydrometer analysis was carried out in 1000 ml for using the required quantity of Sodium Hexa meta phosphate as dispersing agent.

Coeffiient of uniformity Cu=D60/D10 Coefficient of curvature Cc= $(D30)^2/(D60*D10)$

Where

D_{10}= size of particle in mm corresponding 10% of finer. D_{30}= size of particle in mm corresponding 30% of finer. D_{60}= size of particle in mm corresponding 60% of finer

If Cu > 6 then that is well graded gravel; If Cu > 4 then that is well graded sand.

For both well graded gravels and sands the Cc must be in between 1 to 3.

II.Atterberg's Limits:

(i) Liquid Limit:

The liquid limit test was conducted as per IS: 2720 (part - 5), 1985. The test is conducted on Red mud after passing 425 micron IS sieve using Uppal's cone drop test. Nearly 150 to 200g of sample was taken and some amount of water content was added to make it paste. Put this paste in Uppal's brass mould, and then the cone was fixed such that the tip of cone touches the top of the sample placed in the brass mould. After that the dish is released to penetrate into the sample made in Uppal's mould. This is continued for 5 different water contents. This process was continued by increasing water content for every trail. After that a graph is drawn between penetration (abscissa) and water content (ordinate) on a normal graph sheet. The water content corresponding to 25mm was noted as liquid limit

(ii) Plastic Limit:

The plastic limit test was conducted as per I.S:2720 (part - 5)-1985. This is also called as thread test. Nearly 20 to 50g of soil sample was taken and makes it paste by adding some amount of water content. Make that paste into 3mm diameter threads by rolling on a plane glass plate. After that put these threads in a container then measure the water content by using oven. The water content present in these threads is reported as plastic limit.

III.Specific Gravity

Specific gravity was determined by using the fly ash fraction passing 4.75 mm IS sieve by using a density bottle of 50 ml capacity. The Test generally conducted by Pycnometer and Density bottle for coarse grained and fine grained soils respectively. Wet sieve analysis was conducted for fly ash. In this test .075mm sieve is used and dry soil sample passed through this sieve. Based on the %passing of soil sample the soil sample was classified. The test was conducted in accordance with IS: 2720 (part - 3)-1980.

IV. Proctor's Compaction

The compaction test was carried in the proctors mould. This was used to find the optimum moisture content and corresponding dry unit weight. This test was carried according to IS: 2720 (part 7)-1980.

Compaction:
A known quantity of oven-dried sample of Red mud with various percentages of water was mixed and transferred into compaction mould with a rammer of 2.56 kg, 3 layers and each layer subjected to 25 blows. For each set of results bulk unit weight, dry unit weight and corresponding water contents are determined. A graph has been developed between water content and dry unit weights known as compaction curve. From the compaction curve, optimum moisture content and maximum dry density was obtained. This test was carried according to IS: 2720 (part 8)-1983.

V. Unconfined Compressive Strength Test:
Unconfined compressive strength test at optimum moisture content is conducted as per IS: 2720 (part-10)1991. After preparation of the specimen it was cured in closed desiccators at room temperature for 1,3,7,14 and 28 days and at end of each curing period, specimens of a correspond mix were taken out and tested for their unconfined compressive strength.

Specimen Preparation
The samples were prepared by compaction to achieve maximum dry density at optimum water content. The mould consists of steel device with an internal diameter of 38 mm and height of 76 mm. The volume of steel tube was calculated as equal to the volume of the sample knowing the volume and the density required, the weight of the sample of trial mixes whose combination percentages chosen are determined and the water content corresponding to the optimum moisture content was added. This was transferred to the steel-tubing device. It was then compressed by rotating or pushing the pistons simultaneously from both the ends, which resulted in a sample of 38 mm diameter and 76 mm height. These samples were extracted with the help of a sample extruder. The ends of each specimen were trimmed flat perpendicular to its axes of specimen.

Curing
Four identical samples were prepared for their maximum density at optimum water content based on compaction curves obtained. The samples for various curing periods of testing, i.e., 1, 3, 7, 14 and 28 days are prepared. All the samples prepared were labelled according to the trial combination chosen. Samples were cured in desiccators and covered with moist cloth to maintain 100% humidity and prevent loss of any moisture from the samples. All the samples intended for immediate testing were tested after 2 hours.

Test Procedure
The test was conducted using unconfined compression test apparatus at a strain rate of 1.25 mm/min. The specimen to be tested was placed centrally in between the lower and upper platform of the testing machine. The proving ring readings were noted for each 0.5% of strains up to 5% of strain and 1% of strain greater than 5 % of strain and deformations are calculated and divisions are noted in deformation dial gauge. The loading was continued until three or more consecutive reading of the load dial showed a decreasing or a constant load or a strain of 20% had been reached.

III. RESULTS AND DISCUSSIONS

The Geotechnical properties and chemical compositions of Red mud and fly ash and characteristics of cement are as follows.

Property	Value
Appearance	Mud
Colour	Red
Odour	Slightly pungent, earthy odour
Specific gravity	2.9
Unconfined compressive strength (kg/cm^2)	1.49
Liquid limit(%)	32
Plastic limit(%)	24
Plasticity index (%)	8
CBR value (%)	4
Grain size distribution	
Fine sand (%)	5
Silt (%)	89
Clay and collides (%)	6
OMC (%)	22
MDD (g/cc)	1.78
Permeability (cm/sec)	4.3×10^{-6}

Table 3.1 properties

COMPACTION CURVE OF RED MUD:
To know the compaction characteristics of Fly Ash, IS heavy compaction test was performed as per IS: 2720 (part VIII)-1983. At every moisture content dry density was calculated using the formula, $\gamma_d = \gamma_b / (1+\omega)$.

Water content (%)	Dry density(g/cc)
13	1.2
16	1.52
18	1.66
22	1.78
26	1.68
29	1.50

Table: 3.2 Dry densities of Red mud

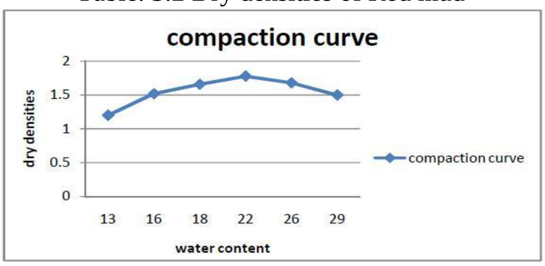

Fig: 3.1 Compaction curve

GRAIN SIZE DISTRIBUTION:

PARTICLE SIZE	FINER (%)
0.3	100
0.15	100
0.075	94.5
0.050	86
0.04	80
0.02	60
0.010	42.5
0.006	30
0.002	0.2

Table 3.3 Particle size distribution of Red Mud

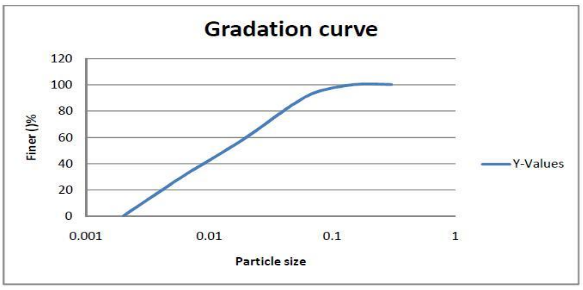

Fig : 3.2 Gradation curve for Red Mud

From the test results it is identified that majority of Red mud particles are dominated by silt size particles and also possess plasticity characteristics. It attained high dry density 1.78g/cc with an optimum moisture content of 22% due to high specific gravity and nature of particles. It has impervious characteristics ($k=4.3*10^{-6}$ cm/sec) with good undrained shear strength values and also incompressible in nature.

CHEMICAL COMPOSITION OF RED MUD:

Formula	Compound (%)
Na_2O	7.75
Al_2O_3	22.84
SiO_2	19.84
CaO	1.24
TiO_2	7.87
V_2O_3	0.68
FeO	39.32
ZnO	0.45

Table: 3.4 Chemical properties of Red mud

From the chemical composition, it is identified that it has 39.32% of ferrous and ferric oxides and reactive oxides (sio_2, Alo_3, & fe_2O_3) are nearly as 82%. It has low lime content of 1024. It is a non-self Puzzolanic and contains rich quantities of reactive oxides (>80%) and can be Puzzolanic high strength achiever by additives like lime, cement etc.

FLY ASH:

Fly Ash was collected from SIMHADRI, NTPC, paravada, Visakhapatnam and laboratory study was carried out for salient geotechnical characteristics of such gradation, Atterberg's limits, compaction and strength as per IS:2720.

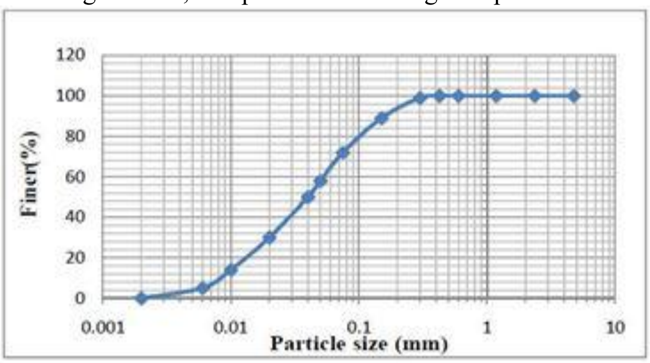

Fig:- 3.3 Gradation Curve of NTPC Fly Ash

From the graph Coefficient of uniformity: $C_u = 6.42$; Coefficient of curvature: $C_c = 0.88$.

COMPACTION TEST :

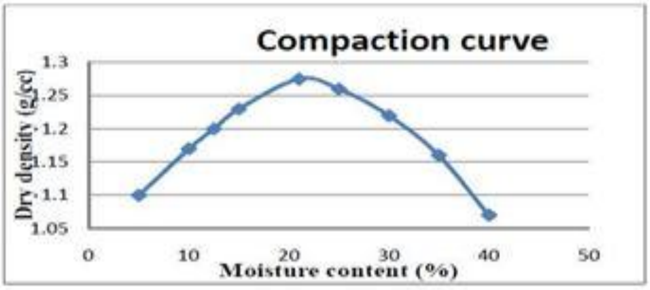

Fig: - 3.4 Compaction curve of NTPC Fly Ash

3.1 FLY ASH + RED MUD MIXES:

To study the interaction between Red mud and fly ash expressed their strengths in terms of compression strength and CBR. Tests like modified proctor compaction test for compaction characteristics, unconfined compression strength tests is for compressive strength, CBR test for CBR values were performed.

Compaction Characteristics Of Fly Ash-Red Mud:

FLY ASH +RED MUD	OMC	MDD
100 +0	21	1.28
90 +10	21.2	1.30
80 +20	21.4	1.33
70 +30	21.6	1.36
60 +40	21.8	1.4

Table: 3.10 Compaction Characteristics of Fly Ash-Red Mud

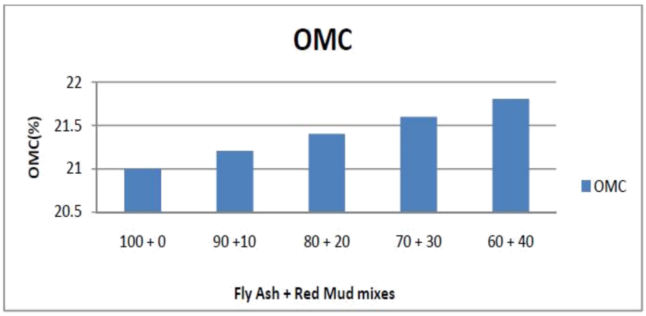

Fig : 3.5 OMC Curve With Different Combinations Of Red Mud + Fly Ash

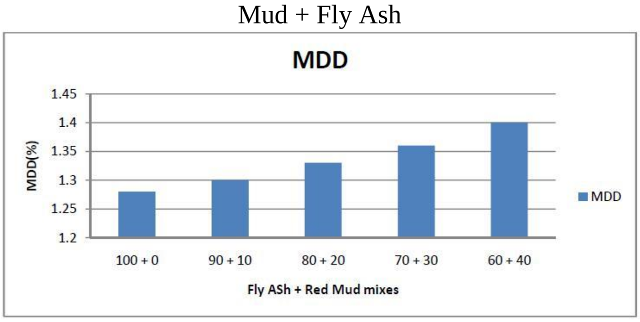

Fig: 3.6 MDD Curve with Different Combinations Of Red Mud + Fly Ash

Unconfined Compressive Strength values for Red mud-Fly Ash mixes:

FLY ASH (%)+RED MUD(%)	UCC (Kg/cm2)		
	3DAYS	7DAYS	28DAYS
100 +0	1.50	-	-
90 +10	1.9	2.2	2.5
80 +20	2.3	2.8	3.4
70 +30	2.6	3.2	3.7
60 +40	2.8	3.5	4

Table: 3.11Unconfined Compressive Strength for Fly Ash-Red Mud

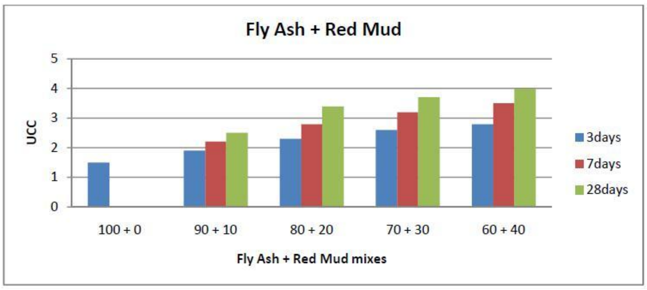

Fig: 3.7 UCC Curve with Different Combinations Of Fly Ash + Red Mud

California Bearing Ratio values for Red mud- Fly Ash mixes:

FLY ASH +RED MUD	CBR	
	7 DAYS	
	UNSOAKED	SOAKED
100 +0	8	4
90 +10	12	6.0
80 +20	14	7.0
70 +30	15	8
60 +40	16	8

Table: 3.12 CBR values for Red Mud – Fly Ash mixes

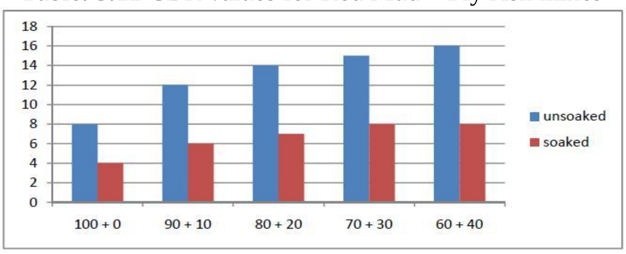

Fig: 3.8 variation of CBR values with various percentage of Fly Ash – Red Mud

Compaction Characteristics For Fly Ash(10%) + Red Mud(90%) + Cement(%):

CEMENT PERCENTAGE	OMC	MDD
0	21.2	1.3
2	21.5	1.32
4	21.8	1.35
6	22.2	1.38
8	22.6	1.42
10	23	1.44

Table: 3.13 Compaction Characteristics For Fly Ash(10%) + Red Mud(90%) + Cement(%)

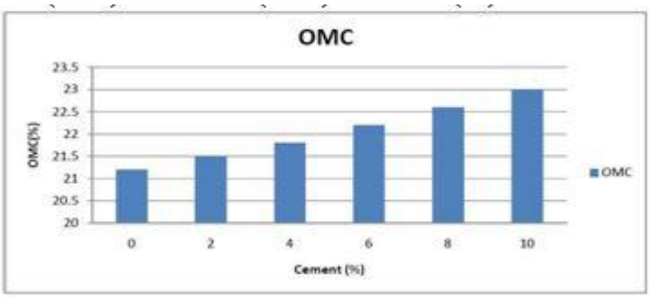

Fig : 3.9 Variation of OMC with percentage of cement

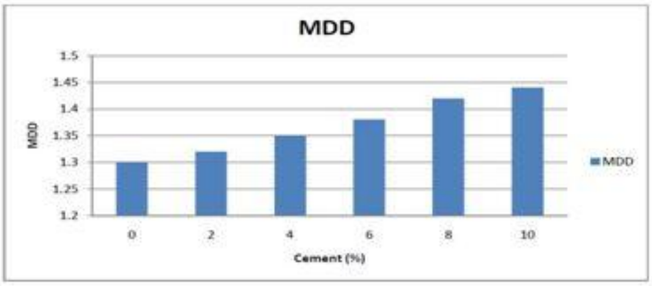

Fig : 3.10 Variation of MDD with percentage of cement

Compaction Characteristics Table For Fly Ash (80%) +Red Mud (20%) + Cement (%) :

CEMENT PERCENTAGE	OMC	MDD
0	21.4	1.33
2	21.6	1.36
4	21.7	1.39
6	22.0	1.42
8	22.3	1.45
10	22.6	1.48

Table: 3.14 Compaction Characteristics Table For Fly Ash (80%) +Red Mud (20%) + Cement (%)

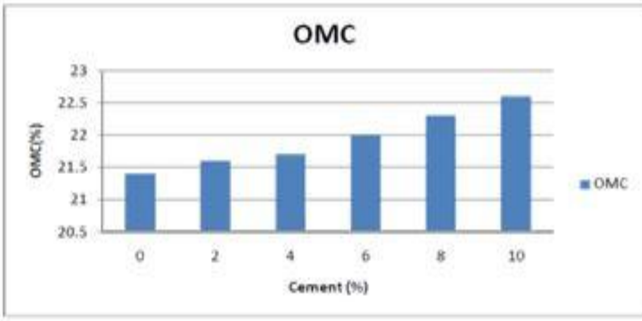

Fig : 3.11 Variation of OMC with percentages of cement

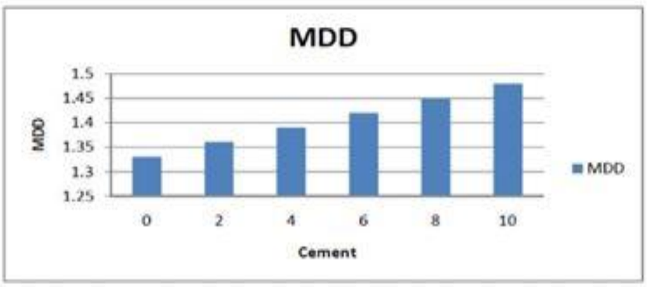

Fig: 3.12 Variation of MDD with percentage of cement

Compaction Characteristics For Fly Ash (70%) +Red Mud (30%) + Cement(%):

CEMENT PERCENTAGE	OMC	MDD
0	21.6	1.36
2	21.8	1.39
4	22.1	1.42
6	22.4	1.46
8	22.6	1.50
10	22.9	1.52

Table: 3.15Compaction Characteristics For Fly Ash (70%) +Red Mud (30%) + Cement(%):

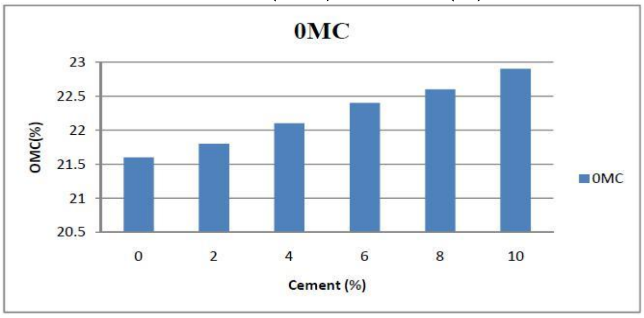

Fig : 3.13 Variation of OMC with percentage of cement

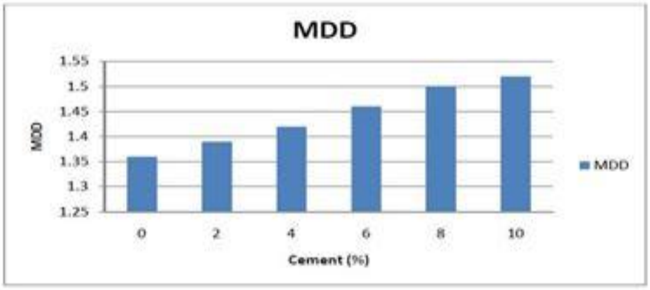

Fig : 3.14 Variation of MDD with percentage of cement

Compaction Characteristics for Fly Ash (60%) + Red Mud (40%) + Cement(%) :

CEMENT PERCENTAGE	OMC	MDD
0	21.8	1.4
2	22.1	1.43
4	22.4	1.46
6	22.7	1.49
8	22.9	1.51
10	23.1	1.53

Table: 4.16 Compaction Characteristics for Fly Ash (60%) + Red Mud (40%) + Cement(%)

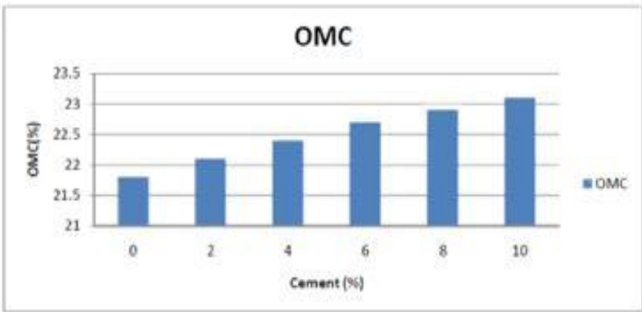

Fig : 3.15 Variation of OMC with percentage of cement

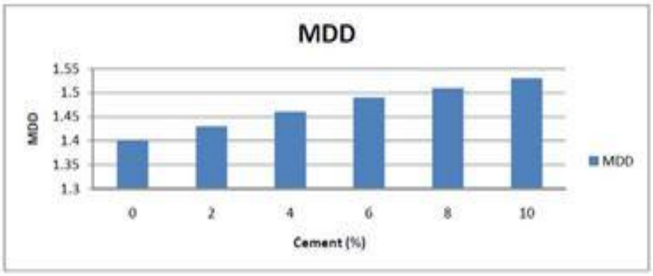

Fig : 3.16 Variation of MDD with percentage of cement

Unconfined Compressive Strength Values For Fly Ash- Red Mud- Cement Mixes:

Cement(%)	UCC (Kg/cm^2)		
	3 days	7 days	28 days
0	1.9	2.2	2.5
2	4.6	8.4	12.2
4	6.9	14.6	18.8
6	9.8	17.6	24.2
8	11.4	20.7	30.8
10	14.5	24.2	35.8

Table: 3.17 UCC values for Fly Ash (90%) + Red Mud (10%) + Cement (%)

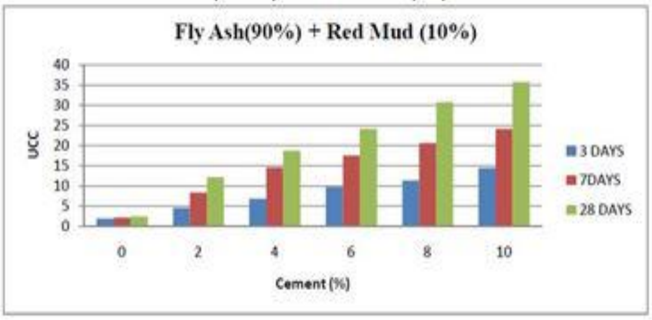

Fig: 3.17 Variations of UCC with different percentage of cement

Cement (%)	UCC(kg/cm^2)		
	3 days	7 days	28 days
0	2.3	2.8	3.4
2	5.4	10.2	14.8
4	8.2	16.2	20.7
6	11.4	19.4	26.3
8	13.6	22.9	32.7
10	15.8	26.1	38.4

Table: 3.18 UCC values for Fly Ash (80%) + Red Mud (20%) + Cement (%)

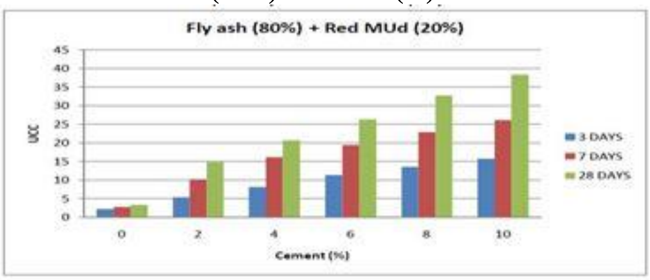

Fig: 3.18 Variations of UCC with different percentage of cement

Cement (%)	UCC(Kg/cm2)		
	3 days	7 days	28 days
0	2.6	3.2	3.7
2	6.8	12.4	16.7
4	9.6	18	23.2
6	13	21.6	29.6
8	15.8	24.8	35.8
10	18.4	28.6	41.5

Table: 4.19 UCC values for Fly Ash (70%) +Red Mud (30%) + Cement (%)

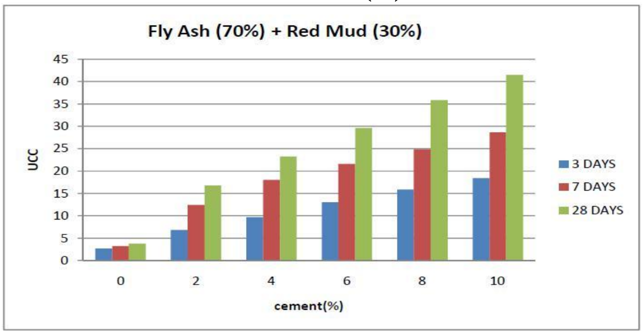

Fig: 4.19 Variations of UCC with different percentage of cement

cement	UCC/(Kg/cm2)		
	3 days	7 days	28 days
0	2.8	3.5	4
2	8.2	14.8	18.5
4	11	20.4	26.9
6	14.8	24.2	33.7
8	17.6	27.6	39.4
10	20.2	31.5	44.6

Table: 4.20 UCC values for Fly Ash (60%) +Red Mud (40%) + Cement (%)

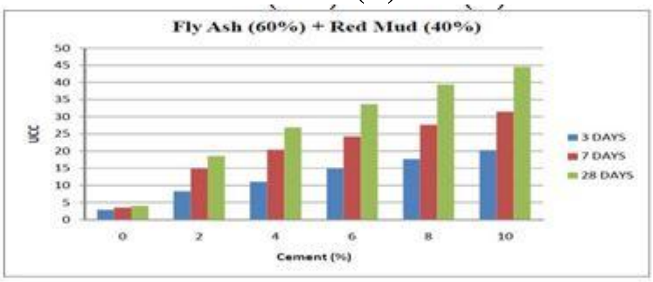

Fig: 3.20 Variations of UCC with different percentage of cement

cement	CBR test	
	7 DAYS	
	unsoaked	soaked
0	12	6
2	22	12
4	40	34
6	62	55
8	78	68
10	92	84

Table: 3.21 CBR Test Values for Fly Ash (90%) + Red Mud (10%) + Cement (%)

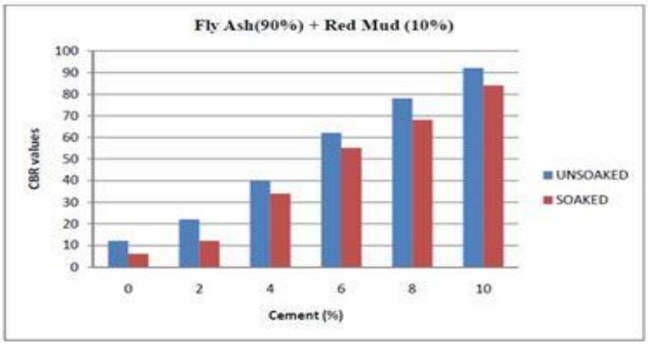

Fig : 3.21 Variation of CBR values with various percentage of cement

cement	CBR test	
	7 DAYS	
	unsoaked	soaked
0	14	7
2	26	14
4	45	38
6	68	62
8	84	78
10	102	92

Table: 3.22 CBR Test Values for Fly Ash (80%) +Red Mud (20%) + Cement (%)

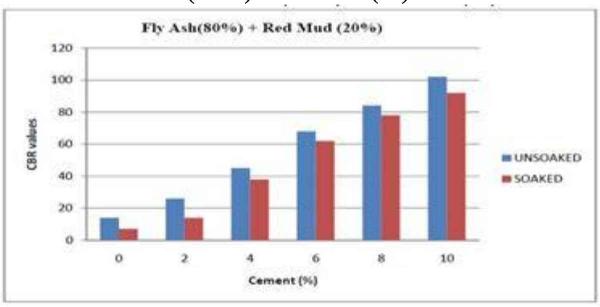

Fig : 3.24 variation of CBR values with various percentage of cement

cement	CBR test	
	7 DAYS	
	unsoaked	soaked
0	15	8
2	28	17
4	50	42
6	74	68
8	89	82
10	108	100

Table : 3.23 CBR Test Values for Fly Ash (70%) +Red Mud (30%) + Cement (%)

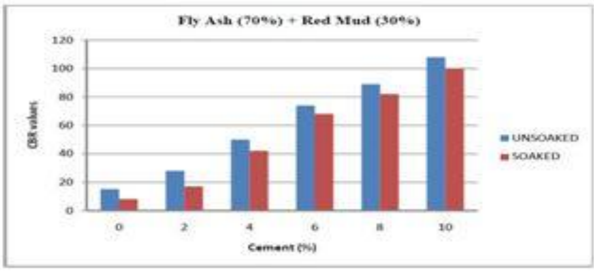

Fig:3.23 variation of CBR values with various percentage of cement

cement	CBR test	
	7 DAYS	
	unsoaked	soaked
0	16	8
2	30	20
4	58	50
6	80	72
8	106	98
10	124	100

Table: 3.24 CBR Test Values for Fly Ash (60%) +Red Mud (40%) + Cement (%)

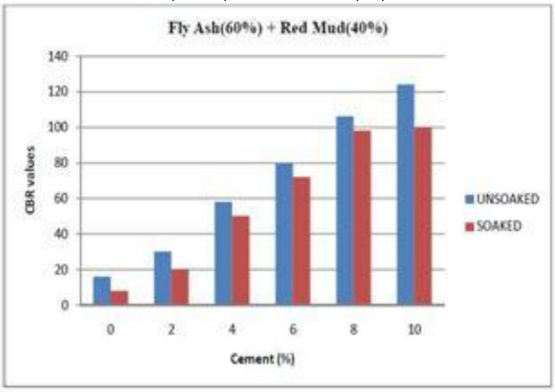

Fig : 3.24 variation of CBR values with various percentage of cement

IV. CONCLUSIONS

From the present study the following conclusions have drawn;

Red mud is a fine grained Industrial waste dominated by fines (<75mm particles) with silt sizes as prominent with high specific gravity (2.9) and high percentages of reactive oxides (SiO_2, Al_2O_3 and Fe_2O_3) as 80%. Addition of cement to Red mud and Fly Ash increases OMC values and decreases MDD values. Early days compressive strengths like 3 days and 7 days are1.9Kg/cm2- 20.2Kg/cm2 and 2.2Kg/cm2-31.5Kg/cm2 and their compressive strengths at 28 days are 2.5Kg/cm2-44.6 respectively with different combination of Fly Ash and Red Mud with different percentages of cement. These values are low at lower dosages (2%) and high at 6-10% dosages.

CBR values are more in case of unsoaked when compared with soaked values ranging from 12%-124% for unsoaked and 6%-120% for soaked conditions.

Fly Ash, Red Mud values mixes have obtained high compressive strength values are in the range 2.4kg/cm2–4kg/cm2 at 28 days of curing period and the OMC and MDD are ranging from 21%-21.8 and 1.28g/cc-1.4g/cc and the CBR values are ranging from 8-16% for unsoaked and 4-8% for soaked conditions.

Achievement of high strength values of Red mud-Fly Ash-cement mixes can be effectively used in various geo technical applications like sub base course and liners etc.

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