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EXPERIMENTAL INVESTIGATION ON CEMENT REPLACEMENT WITH RED MUD SLUDGE Of M60 GRADE CONCRETE

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Abstract - *The Bayer Process for the production of alumina from Bauxite ore is characterized by low energy efficiency and it results in the production of significant amounts of dust-like, high alkalinity bauxite residues known as red mud. Currently red mud is produced almost at equal mass ratio to metallurgical alumina and is disposed into sealed or unsealed artificial impoundments (landfills), leading to important environmental issues. It comprises of oxides of iron, titanium, aluminum and silica along with some other minor constituents. Presence of Alumina and Iron oxide in red mud compensates the deficiency of the same components in limestone which is the primary raw material for cement production. Presence of soda in the red mud which when used in clinker production neutralizes the sulfur content in the pet coke that is used for burning clinker enrooted cement production and adds to the cement's setting characteristics. Based on economics as well as environmental related issues, enormous efforts have been directed worldwide towards red mud management issues i.e. of utilization, storage and disposal. Different avenues of red mud utilization are more or less known but none of them have so far proved to be economically viable or commercially feasible. Experiments have been conducted under laboratory condition to assess the strength characteristics of the aluminum red mud. The project work focuses on the suitability of red mud obtained for construction. Five test groups were constituted with the replacement percentages 0%, 5%, 10%, 15%, 20%, 30% of red mud with cement in each series.*

***Key Words*; Red mud, Slump cone test, Compaction factor test, Split tensile strength Test: Flexural strength values:**

1. INTRODUCTION

Red sludge is a hazardous waste produced in the mining industry and is experiencing serious disposal problems as it is highly alkaline composed mainly of iron oxide2,4. There are some attempts made in production of brick, ceramic products like tiles, glazes, red mud polymer composites panels as substitute for wood, iron rich cement etc..,. For partial substitute but none of them proven economically satisfactory. With the use of red sludge as a partial replacement for cement makes concrete attain more strength than usual. Due to the contents of aluminum oxide and ferric oxide in the red sludge causes the bonding in concrete stronger while adding in some percentages.

1.1 Red mud

Red mud is a solid waste produced in the process of alumina production from bauxite following the Bayer process. More than 4 million tons of red mud is generated annually in India only. Presently, it is stored or dumped on land, or in the oceans near alumina refineries. However, its high alkalinity is a potential pollution to threat water, land and air. While high costs are associated with the large area of land required for storage of the residue. India is amongst the major producers of alumina in the world. There are some differences in mineralogical composition between the residues from India and other countries due to the difference in the ore type in its production processes. Significant achievements in treatment and utilization of red mud have been obtained in India in the last decade India is rich in mineral resources and has a long history of mining, mineral production and mineral utilization. India is among the top ten mineral producing countries in the world. The Indian to a great extent depends on the value of the minerals produced, as these represent a major portion of the raw materials for the country's industrial activities. Aluminum metal is commercially produced from bauxite ore mainly through two process steps. In the first step, alumina is obtained by the Bayer process and in the second, the alumina is electrolyzed in a Hall–Heroult cell to yield aluminum metal. However, the production of alumina from bauxite is associated with serious environmental problems. The red mud (bauxite residue) is the major waste material. Depending on the quality of bauxite, the quantity of red mud generated varies from 55 to 65% of the bauxite processed. All over the world disposal of red mud is being done either on land or in the nearby sea/ocean. Its high alkalinity is harmful to water, land and air of the surrounding area. High costs and large areas of land are also associated with the building of the red muddams (Mahadevan and Ramachandran, 1996).The treatment and utilization of red mud waste have been a major challenge for the alumina industry. Due to the environmental issues, India is also paying greater attention to the treatment of red mud wastes. Indeed, several achievements on red mud treatment have been made in India, e.g. storage as red mud ponds and reclamation, production of construction materials, preparation of new materials and recovery of valuable elements.

Figure 1: Red Mud

Red mud is a toxic by product of the industrial process that refines bauxite, raw aluminum ore, into aluminum oxide, or alumina. (Alumina is put through a separate process, electrolysis, to make aluminum metal.) Bauxite is a mixture of minerals. In addition to aluminum compounds it contains iron oxides, sand, clay and small amounts of a form of titanium oxide called anatase; it can also hold traces of radioactive minerals, such as uranium or thorium compounds. This raw material is bathed in a solution of a strong base sodium hydroxide (lye or caustic soda) at a high temperature and pressure. The aluminum compounds in the bauxite dissolve in the hot caustic solution while the other components remain behind. Everything that doesn't get dissolved in the process is called red mud, its rusty colour deriving from the iron compounds.

1.2 Composition

The main constituents of the residue after the extraction of the aluminium component are unreacted metallic oxides. The percentage of these oxides produced by a particular alumina refinery will depend on the quality and nature of the bauxite ore and the extraction conditions. The table below shows the composition ranges for common chemical constituents, but the values vary widely.

Table 1 Chemical composition of red mud

CHEMICAL FORMULA	PERCENTAGE COMPOSITION (%)
Fe_2O_3	5-60
Al_2O_3	5-30
TiO_2	0.3-15
CaO	2-14
SiO_2	3-50
Na_2O	1-10

2. COMPOSITIONS OF CONCRETE

Concrete is a composite material composed of fine and coarse aggregate bonded together with fluid cement (cement paste) that hardens over time. Most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements, such as calcium aluminates cements. However, asphalt concrete, which is frequently used for road surfaces, is also a type of concrete, where the cement material is bitumen, and polymer concretes are sometimes used where the cementing material is a polymer. When aggregate is mixed together with dry Portland cement and water, the mixture forms fluid slurry that is easily poured and molded into shape. The cement reacts chemically with the water and other ingredients to form a hard matrix that binds the materials together into a durable stone-like material that has many uses. Often, additives (such as pozzolana or super plasticizers) are included in the mixture to improve the physical properties of the wet mix or the finished material. Most concrete is poured with reinforcing materials (such as rebar) embedded to provide tensile strength, yielding reinforced concrete.

Table 2 represents the difference between the grades of cement

TYPE OF CEMENT	33 GRADE (IS: 269-1989)	43 GRADE (IS:8112-1989)	53 GRADE (IS: 12269-1987)
PHYSICAL PROPERITES			
Minimum Compressive Strength, N/mm^2			
3 day	16	23	27
7 day	22	33	37
28 day	33	43	53
Fineness			
Minimum specific surface (Blaine's air permeability) m^2/kg	225	225	225
Setting times (minutes)			
Initial, minimum	30	30	30
Final,maximum	600	600	600
Soundness, expansion (Le Chatelier Test, mm), maximum	10.0	10.0	10.0
Autoclave test for MgO, % maximum	0.8	0.8	0.8
CHEMICAL PROPERTIES			
Loss on ignition, % maximum	5	5	5
Insoluble residue, % maximum	4	2	2
Magnesia Mgo, % maximum	6	6	6
SO3 , % maximum for:			
C3A>5 %	2.5	2.5	2.5
C3A<5 %	3	3	3
Lime saturation factor (LSF)	0.66 to 1.02	0.66 to 1.02	0.8 to 1.02

3. Methodologies

Slump cone test:

Slump cone test is used to determine the consistency of the cement concrete, that it indicates how much water is added to the mix. It is one of the physical parameters of concrete which affects the fines, strength and durability.

% Replacement of Cement	Slump value (mm)	Type of slump
00	25	True
05	25.5	True
10	27	True
15	27.5	True
20	29	True
25	29	True
30	**29.5**	**True**

Table 3 Slump Cone Values for M60 Grade Concrete

I have conducted slump cone test on the 30% replacement of red mud for M60 grade concrete and I have got 29.5mm value up to now others have conducted on 25% for M40 and M50 grade concrete. When we are using 30% of replacement in cement the industrial waste is reducing.

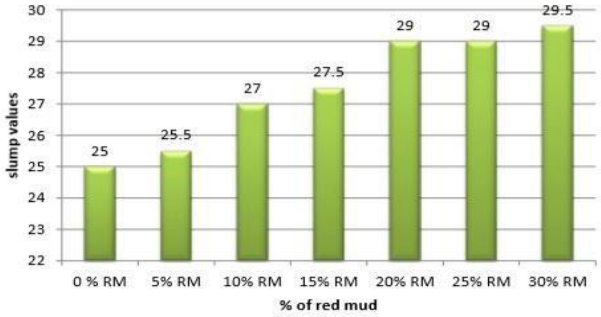

Figure 2 the red mud used in design mixes

Compaction factor test

Compaction factor test is used to determine the workability of the cement concrete where the volume of cement concrete is dropped into the hoppers and we determine the volume of the compacted concrete. Compaction factor is the ratio between volumes of partially compacted concrete to the volume of fully compacted concrete. It is not used in the site construction because the coarse aggregates used in this test must be less in size.

% Replacement of Cement	Compaction factor
00	0.85
05	0.87
10	0.89
15	0.92
20	0.94
25	0.95
30	**0.95**

Table 4 Compaction Factor Values of M60 Grade Concrete

I have conducted Compaction Factor test on the 30% replacement of red mud for M60 grade concrete and I have got 0.95 value up to now others have conducted on 25% for M40 and M50 grade concrete. When we are using 30% of replacement in cement the industrial waste is reducing. As well as it gives the workability of fresh concrete the value is satisfactory.

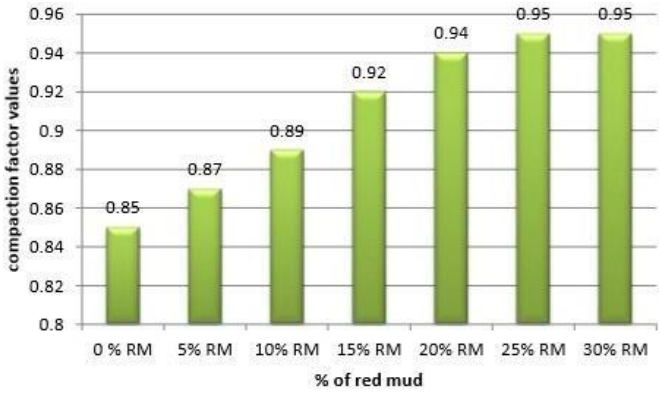

Figure 3 red mud used in design mixes

Compressive strength Test

Compressive strength is one of the critical property of concrete to be tested as it is linked with load carrying capacity and durability. Most of the desirable properties of concrete are qualitatively related to its compressive strength Compression test is used to measure the ultimate load of the material until it get fracture. The test specimen may in any form but we use cubes of size 150mm ×150mm × 150mm in this analysis. The cube is placed between the plates of the compressive testing machine .the rocks and steel materials exhibits more strength .the crushing strength of the cube is determined.

Garde of concrete	% of red mud used	28 days compressive strength (N/mm^2)
M_{60}	00	66.40
	05	74.84
	10	76.24
	15	77.00
	20	76
	25	76.5
	30	**75**

Table 5 Compressive Factor Values of M60 Grade Concrete

I have conducted Compressive Strength test on the 30% replacement of red mud for M60 grade concrete and I have got 75 N/mm2 value up to now others have conducted on 25% for M40 and M50 grade concrete. When we are using 30% of replacement in cement the industrial waste is reducing. The test is conducted and we have got the best result for compression so we can use this mix proportion

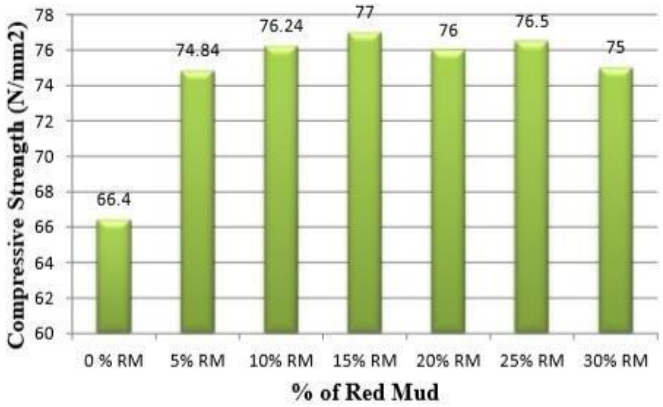

Figure 4 red mud sludge and compressive strength

Split tensile strength Test:

Split tensile strength of property of concrete. the concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. The cracking is a form of tension failure it determines the tensile strength of the concrete. The test specimen size is 15cm diameter and 30cm long

Garde of concrete	% of red mud used	28 days split tensile strength (N/mm^2)
M_{60}	00	3.56
	05	3.72
	10	3.97
	15	3.80
	20	3.50
	25	3.56
	30	**3.66**

Table 6 the Split Tensile Strength of M60 Grade Concrete

I have conducted Split Tensile Strength test on the 30% replacement of red mud for M60 grade concrete and I have got 3.66 N/mm2 value up to now others have conducted on 25% for M40 and M50 grade concrete. When we are using 30% of replacement in cement the industrial waste is reducing.

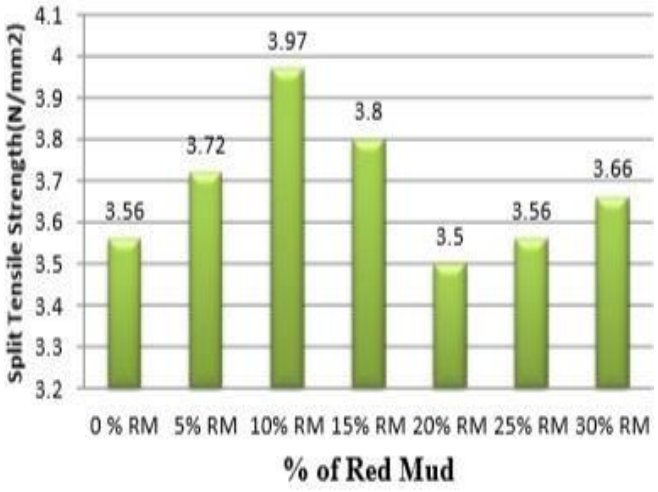

Figure 5 red mud sludge and split tensile strength

Flexural strength values:

It is also called as modulus of rupture, bending strength, fracture strength and is a material property, defined as the stress in a material just before it yields in a flexural strength. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in stress. To overcome this type of failure main steel is provided at the bottom of the beam.

Table 7 Flexural Strength of M60 Grade Concrete

% of red mud added	Ultimate flexural strength (KN)	Deflection(mm)
00	76	5.02
05	81	5.07
10	83	5.43
15	92	5.70
20	76	4.90
25	74	4.00
30	**74**	**3.90**

I have conducted Flexural Strength test on the 30% replacement of red mud for M60 grade concrete and I have got 74 N/mm2 value up to now others have conducted on 25% for M40 and M50 grade concrete. When we are using 30% of replacement in cement the industrial waste is reducing. By this I can say that we are using less quantity of concrete (E.g.: A column of 300mm*300mm can be replaced by 200mm*200mm).

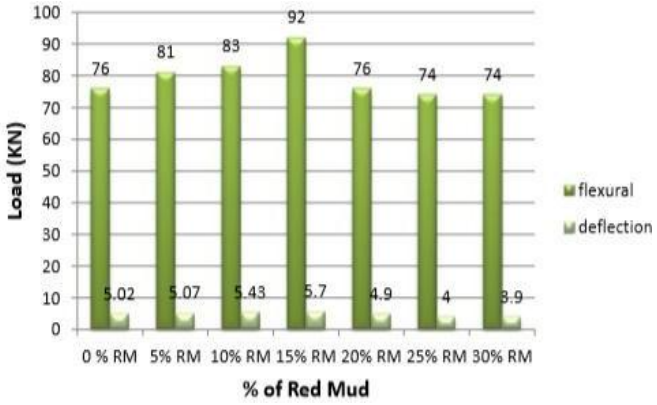

Figure 6 red mud sludge and flexural strength

4. CONCLUSIONS

1. After testing of 6 blended cement samples (5% to 30 % replacement of Cement by NRM) with an increment of 5 %, it can be said that the optimum use of NRM is 15% as a partial replacement of cement by NRM.
2. The cost of M60 grade NRM Concrete (i.e. 15 % Replacement) is around 7.48 % less than the Conventional Concrete, with an increase up to 21.712 % in the 28 days Compressive strength.
3. The percentage economy is increased with the increase in the grade of concrete but at the same time there is a reduction in the percentage increase in the Compressive Strength Considering all the above point it is interesting to say that the optimum utilization of Neutralized Red Mud in concrete is 15 % as a partial replacement of cement by NRM.
4. Red mud can be effectively used as replacement material for cement and replacement enables the large utilization of waste product.
5. Red mud did not effect of the cement properties, rather improved the cement quality by way reducing the setting time & improved compressive strength.
6. Used for road construction as an embankment landfill is an attractive option with a high potential for large volume reuse. Replacement of 30% OPC by calcined red mud is thus possible.

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