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Experimental Study on Industrial Waste Red Mud Sludge with M60 Grade Concrete

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ABSTRACT:- The Bayer process of the production of alumina from Bauxite ore is characterized by low energy efficiency and it results in the production of significant amount 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, aluminium and silica along with some other minor constituents. Presence of aluminium 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 sulphur content in the pet coke that is used burning clinker enrooted cement production and adds to the cement's settings characteristics. Based on the economics as well as environmental related issues, enormous efforts have been directed worldwide toward red mud management issues i.e. of utilization, storage and disposal. Different Avengers of red mud utilization are more or less known as 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 aluminium red mud. The project work focus on the suitability of red mud obtained for construction. Five test group were constructed with the replacement percentage 0%, 5 %, 10 %, 15 %, 20%, 30% of red mud with cement in each series.

I. INTRODUCTION

Red sludge is a hazardous waste produced in the mining industry and is expensive serious disposal problems as it is high alkalinity are composed mainly of iron oxide^{2,4}. There are some attempts made into production of Brick, ceramic products like tiles, glazes, red mud polymer composites panels as substitutes for wood, iron rich cement etc... for partially substitute but none of them proven economically satisfactory. With the use of red sludge as a partial replacement of cement makes concrete attains more strength than usual. Due to contents of aluminium oxide and ferric oxide in the red sludge causes of the bonding in concrete stronger while adding in some percentages.

Red mud:- Red mud is a solid waste produced in the process of aluminium production from dioxide following the Bayer process. More than 4 million tons of red mud is generally annually in India only. Presently, it is stored or dumped on land, or in the oceans near aluminium refineries. However, its high alkalinity is a potential pollution threat water, land and air. While high cost are associated with the large area of the land required for storage of the residue. India is amongst the major product producer of alumina in the world. There are some differences in the mineralogical components between the residues from India and other countries due to the difference in the way type in its production processes. Significant achievements in treatment and utilization of red mud have been obtained in India in the last decade in 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 mineral produced, as they represents a major portion of the raw materials for the country's industrial activities. Aluminium metal is a commercially produced from the bauxite ore mainly through two process steps. In the first step, alumina is obtained by the Bayer process and in the second, the aluminium is electrolysed in Hall-Heroult cell to yield aluminium metal. However, the production of aluminium 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 or ocean high alkalinity is harmful to water land and air of the surrounding area high cost and large area of the lands are also associated with the building of the red mud dams Madhavan and



Ramachandran 1996 the treatment and utilization of red mud waste have been major challenges for the aluminium industry due to the environmental issues India he is also paying greater attention to the treatment of red mud Wests India several achievements on red mud treatment have been made in India example storage has

Redmond ponds and recrimination production of the construction materials preparation of new materials recovery of valuable elements

Redmond is a toxic why product of the industrial process that refines dioxide raw aluminium ore into aluminium oxide or aluminium aluminium is put through a separate process electrolysis to make aluminium metal bagh is a mixture of minerals in addition to aluminium components it constraint contains iron oxides sand clay and small amounts of farm of titanium oxide called antes it can also hold trace of radioactive minerals such as uranium of chromium components this raw materials is bathed in a solution of strong base sodium hydroxide Lye or caustic soda at high temperature and pressure the aluminium components in the dioxide dissolved in the hot caustic solution while the other components remain beyond everything that doesn't get dissolved in the process of in the process called Redmond it's rusty colour deriving from the iron compounds.

Composition

The main constituents of residues after the extraction of aluminium components are unreacted metallic oxides. The percentage of the this 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 the common chemical constituents, but the values vary widely.

Table 1 chemical composition of red mud

CHEMICAL FORMULA	PERCENTAGE COMPOSITION (%)
Fe ₂ O ₃	5-60
Al ₂ O ₃	5-30
TiO ₂	0.3-15
CaO	2-14
SiO ₂	3-50
Na ₂ O	1-10

II. LITERATURE REVIEW

1) Sucharithapatal, B.K Pal [2016] Current status on industrial waste mud on overview have made investigated on the amount of redmud generated per ton of the alumina processed, various greatly with the type of bauxite ore used. Due to this hazardous nature it is a great challenge to researcher to develop new methods for the application of redmud. Various researchers work going on the storage, disposal and utilization of red mud in all over the world.

2) M.P.Suresh Kumar S.K.Gawtham [2015] were studied the potential utilization of industrial waste (red mud) in concrete. Have made investigation of on partial replacement of cement with red mud for studying mechanical properties of concrete. The percentage of redmud partial replacement of concrete are 0%, 5%, 10%, 15%, 20% for M20 grade concrete.

3) P. Ashok, M.P. Suresh Kumar [2015] experimental studies on current utilizing redmud and hydrated lime as a partial replacement of M30 grade. The percentage of red mud partially replacement of cement are 0%, 5%, 10%, 15%, 20%, and 25% and 5% hydrated lime partially replacement of cement.

III. COMPOSITION OF CONCRETE

Concrete is a composite material composed of fine fine and coarse aggregate bonded together with a fluid (cement paste) that hardens overtime. Most concretes are used lime-based concrete such as Portland cement concrete or



concretes madewith other hydraulic cements, such as calciumaluminium cements. However, asphalt concrete, which is frequently used for road surfaces, is also type of concrete, where the cement material is bitumen, and polymer concrete are sometimes used where the cementing materials is a polymer. When aggregate is mixed together with dry Portland cement and water, the mixture forms a slurry that is easily poured and molded into shapes. 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 the many uses. Often, additive (such as pozzolans or superplasticizer) are included in mixture of improved to physical properties of wet mix or the finished material. Most concrete is poured with reinforcing materials (such as rebar) embedded to provide tensilestrength, 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 PROPERTIES			
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
SO ₃ , % maximum for:			
C ₃ A > 5 %	2.5	2.5	2.5
C ₃ A < 5 %	3	3	3
Lime saturation factor (LSF)	0.66 to 1.02	0.66 to 1.02	0.8 to 1.02

Name of test	Size of Aggregate		Specification limits
	20mm	10mm	
Specific Gravity	2.82	2.80	-
Water Absorption	-	-	-
Free Surface Moisture	Nil	Nil	-
Aggregate Impact Value	13.55		-
Flakiness Index	-		-

IV. EXPERIMENTAL WORK

Experimental design of M60 grade with 5% redmudDesign stipulations:

Characteristics of compressive strength =60 N/mm²

Maximum size of aggregate = 20 mm

Degrees of quantity of aggregate =Good

Maximum cement content = 480 kg/m³

Minimum cement content = 300 kg/m³

Maximum water cement ratio= 0.4

Proposed water cement ratio = 0.4

Slump = 50 – 125



Test data for materials:

Type of cement=OPC

Grade of cement = 53 grade

Specific gravity of cement = 3.15

Replacing material = Red mud sludge

Dosage =5%

Specific gravity of replacing material = 2.86

Coarse Aggregate = 10mm,20 mm

Fine aggregate =Zone II

Target strength:[As per IS: 10262 - 2009 Table 1 's' value is taken as 5]

Target strength of concrete = $f_{ck} + 1.65 X S = 60+1.65 \times 5=68.25\text{MPa}$

[As per IS: 456- 2000] water cement ratio = 0.29 Water content:[As per IS:10262 -2009 Table 2]

Selection of water content = $186 + (6 / 100) \times 186 = 197.16\text{kg/m}^3$

Cement content: Cement content= $197.16/0.29 = 679.862\text{kg/m}^3$

Red mud sludge to be replaced by 5% to the cement Red mud content = $679.862 \times (5/100)= 33.993 \text{ kg/m}^3$

Therefore,the cement content = $679.862 - 33.993 = 645.869 \text{ kg/m}^3$

Aggregate calculations:

Corrected coarse aggregate = $0.02+ 0.62$

$$= 0.64\text{kg/m}^3$$

[0.62 from the table in IS: 456-2009 Zone 2 for 20 mm]

The coarse aggregate is to be pumped then it reduced by 10% the coarse aggregate = $0.64 \times (90 / 100)$

$$= 0.576\text{m}^3/\text{sec}$$

The fine aggregate value = $1-0.576$

$$= 0.424\text{me}/\text{sec}$$

Volumes:

Volume of concrete = 1m^3

Volume of cement content = $\{(\text{mass of cement})/ (\text{Sp. gof cement})\} \times (1 / 1000)$

$$= (645.8) / (3.15)\} \times (1 / 1000)$$

$$= 0.205\text{m}^3$$



Volume of total aggregate = 1 - {Vol. of water +
vol.of red mud}

$$= 1 - \{0.205 + 0.197 + 0.012\}$$

$$= 0.586 \text{ m}^3$$

Weight of coarse aggregate = Volume x F.A content x Sp. g of F.A x 1000

$$= 0.586 \times 0.576 \times 2.8 \times 1000$$

$$= 945.285 \text{ kg/m}^3$$

Weight of fine aggregate = Volume x F.A content x Sp. g of F.A x 1000

$$= 0.586 \times 0.424 \times 2.7 \times 1000$$

$$= 670.853 \text{ kg/m}^3$$

Volumes:

Cement = 645.869 kg/m³

Water = 197.16 kg/m³

Fine aggregate = 670.853 kg/m³

Coarse aggregate = 945.285 kg/m³

Red mud = 33.993 kg/m³

Total concrete weight = 2493.160 kg/m³

Ratio:

Table 3 cement fine aggregate coarse aggregate water red mud

Cement	Fine aggregate	Coarse aggregate	Water	Red mud
645.869	670.853	945.285	197.16	33.993
1	1.039	1.464	0.305	0.053
50	51.934	73.179	15.263	2.632

Mix proportion = 1: 1.039: 1.464

Casting of One cube:

Volume of the cube = 150mm x 150 mm x 150mm

$$= 0.0034 \text{ m}^3$$

Cement content = 645.869 x 0.0034

$$= 2.196 \text{ kg}$$

Redmud content = 33.993 x 0.0034



= 0.116 kg

Coarse aggregate content = 945.285 x 0.0034

= 3.214 kg

Fine aggregate content = 670.853 x 0.0034

= 2.281 kg

Table 4 5% Red Mud

Tests on Fresh and hardened concrete	Values
Slump Cone (mm)	25.5
Compaction Fator	0.87
Compression Strength (N/mm ²)	74.84
Split Tensile Strength (N/mm ²)	3.72
Flexural Strength (N/mm ²)	81

V. RESULTS AND DISCUSSIONS

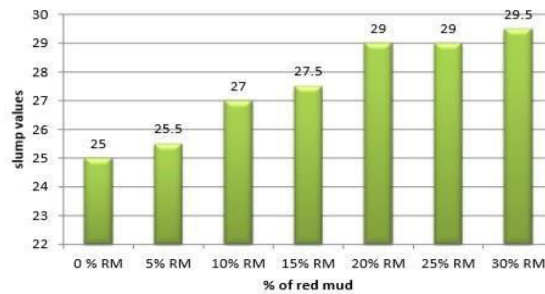
Slum cone test

Slum contest 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 the concrete which affects the fines, strength and durability.

Table 6 Slump Cone Values ForM60 Grade Concrete

% 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

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



Grab 1 the red mud used in design mixes

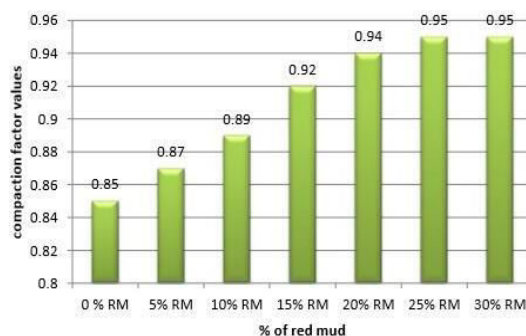
Compaction factor test

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 volume 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.

Table 7 compaction factor values of m 60 grade concrete

% 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

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 cement the industrial waste is reducing. As well as it gives the workability of fresh concrete the value of satisfactory.



Graph 2 red mud used in design mixes

Compressive strength Test

Compressive strength is one of the critical properties 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 gets fracture. The test specimen may be in any form but we use cubes of size 150mm x 150mm x 150mm in this analysis. The cube is placed between the plates of the

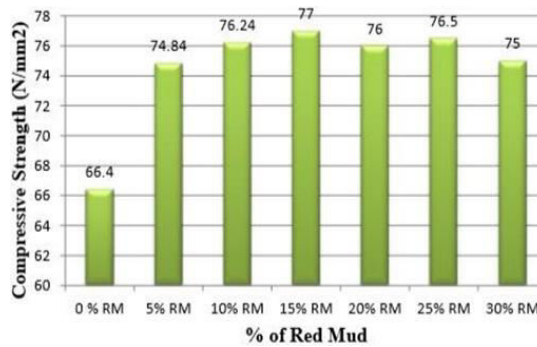


compressive testing machine. the rocks and steel materials exhibits more strength. the crushing strength of the cube is determined

Table 8 compressive factor values of m 60 grade concrete

Grade 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

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 the 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



Graph 3 red mud sludge and compressive strength

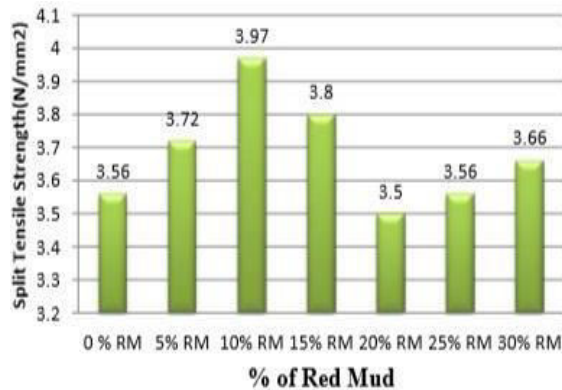
Split tensile strength test

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

Table 9 split tensile strength of m 60 grade concrete

Grade 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

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)



Graph 4 red mud sludge and split tensile strength

VI. CONCLUSION

After testing the samples (red mud concrete cubes) with an increase of red mud sludge from 5% to 30% replacement in cement. Red mud concrete is preferable economically than ordinary concrete because it gives earlier strength to the concrete, resistance to sulphate attack, increase the optimum moisture content and decrease the maximum dry density. Red mud will not affect the cement characteristics because red consists of dicalcium silicate ($2\text{CaO}\cdot\text{SiO}_2$) and reduces the setting time of cement. From this experimental study following points can be drawn: 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. The cost of M60 grade NRM Concrete, (i.e., 15% Replacement) is around 7.48% less than Conventional concrete, with an increase up to 21.712% in the 28 days Compressive strength. 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 above the point it is interesting to say that the optimum utilisation of Neutralized Red Mud in concrete is 15% as a partial replacement of concrete by NRM. Red mud can be effectively used as replacement material for cement and replacement enables the large utilization of waste product. Red mud did not affect the cement properties, rather improved the cement quality by way of reducing the setting time & improved compressive strength. Used for road construction as an embankment landfill is an attractive option with high potential for large volume reuse. Replacement of 30% OPC by calcined red mud is thus possible.

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