DETAILED STUDY BY EXPLAINING PROPERTIES OF RED MUD ADMIXED CONCRETE

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Abstract— Red Mud is a waste generated by the aluminum industry (an average of 3million tons per year) in a Bayer's process and its disposal is a major problem for these industries as this is highly caustic and causes ground water contamination, leading to health hazards. 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 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.. Thus to protect our environment from the ill effect of red mud it is necessary to turn this waste into wealth. Red mud is a good binder material and can be used in concrete technology for construction practices with partial replacement with cement. The use of red mud with partial replacement of cement proves to be economical because red mud on being a by-product of alumina industry free of cost. Red mud increases the mechanical properties of concrete and as a result of which it is a good cementations material.
In this present research , we have done a comparative study on the fly ash and red mud as cementations admixtures and have discussed about the properties of red mud, its chemical composition and how it enhances the mechanical properties of concrete i.e., increases the compressive strength, flexural strength and tensile strength of concrete based on several research papers. We have also discussed about the properties of bricks that are manufactured out of red mud and how it is economical and how the use of it conserves the environment.

Keywords- Red mud, binder material, cementations material, compressive strength, flexural strength, tensile strength and cost analysis of red mud admixed concrete.

INTRODUCTION

Red mud is a by-product which is obtained during the Bayer's process of aluminium production. It is basically a waste material which is highly alkaline in nature and hence cannot be disposed off easily. If it is disposed in agricultural lands then that land becomes infertile for many years. Red mud is a solid waste product of the Bayer process, the principal industrial means of refining bauxite in order to provide alumina as raw material for the electrolysis of aluminum by the Hall-Heroult process. Red mud is composed of a mixture of solid and metallic oxide-bearing impurities, and presents one of the aluminum industry's most important disposal problems. The red colour is caused by the oxidized iron present, which can make up to 60% of the mass of the red mud. In addition to iron, the other dominant particles include silica, unbleached residual aluminum, and titanium oxide.

LITERATURE REVIEW

An overview of chemical processes to manufacture red mud construction products by Arum S. Wagh, PhD
Major deposits of red mud are in highly populated emerging economic regions. Recycling red mud as construction materials is important to these countries for economic as well as environmental reasons. Room-temperature-setting chemical reactions to solidify red mud into construction products may be one way to recycle red mud. We present two methods developed by us, one in Jamaica and the other in U.S.A. The first method (Geopolymeric method) takes advantage of the high alkalinity and high alumina content in red mud. Adding sodium silicate, we developed sodium alumina-silicate binding phases in red mud. Using this process, Jamaica Bauxite Institute constructed a demonstration sports pavilion with red mud bricks. The second process is a by-product of "Ferro-Ceramicrete" developed in Argonne National Laboratory for immobilization of nuclear weapons legacy waste. In this process, we took advantage of high content of iron oxide (hematite) in red mud, and partially reduced a small portion of it to initiate activation reaction with an acid-phosphate. This process produces rapid-setting alternative red mud cement that can be used to manufacture concrete, bricks, and building blocks. Both processes have been proven and used in other fields.

Strengths of red mud

- It is evident from the literature survey that red mud increases the strengths of concrete to a considerable extent.
- It reduces the capillary pores of concrete and hence reduces permeability.
- Red mud's pH value varies from 10 to 12 and as a result of which it prevents corrosion of reinforcement.
- Use of red mud proves to be economical as it comes free of cost.
- Red mud also serves as a decorative material.
- It prevents early fading of colour.
- It serves as a good binder material.

Weaknesses of red mud

- Due to its high alkalinity it damages agricultural lands,

- For disposing it should be washed seven times.
- There are chances of leakages from red mud lake.
- It contaminates the ground water table in case it is disposed underground.

MATERIALS

Materials Used

Cement

Ordinary Portland Cement (53 Grade) confirming to IS: 269-1976 was used throughout the investigation. Different tests were performed on the cement to ensure that it confirms to the requirements of the IS specifications. The physical properties of the cement were determined as per IS: 4031-1968 and are presented in table:3

Table 1. Physical properties 53 Grade Cement

S.NO	CHARACTERISTICS	VALUES
1	Standard consistency	**53**
2	Fineness of cement as retained on 90 micron sieve	**3%**
3	Initial setting time	**30 minutes**
4	Specific gravity	**3.15**
5	7days compressive strength	**37 Mpa**

Table 2. Chemical Properties of Cement

S.NO	COMPONENTS	WEIGHT
1	Lime (CaO)	63%
2	Silica (SiO_2)	22%
3	Alumina (Al_2O_3)	6%
4	Iron oxide (Fe_2O_3)	3%
5	Magnesium oxide (MgO)	2.5%
6	Sulphur trioxide & loss of ignition (SO_3)	1.5%
7	Alkalies	0.5%

Fine aggregates (IS 383 & IS 516):-

Locally available sand is used as fine aggregate in the cement mortar. The physical properties of sand are shown in below table. 5

Table 3. Physical Properties of River Sand

PROPERTY	RIVER SAND
Specific gravity	2.6
Sieve analysis	Zone-II

Coarse Aggregates:

Coarse aggregate are the crushed stone is used for making concrete. The maximum size of aggregate used for this investigation is 20mm and specific gravity is 2.78

Water: Water used for all construction works like masonry work, making concrete, mortar, bricks, or for other plain or reinforced general construction, should be clean and free from objectionable quantities of suspended materials, vegetables, or organic impurities like alkalis, salts, and other deleterious substances.

Red mud: Red mud's of Chhattisgarh are localized in occurrence and are found mostly in the BALCO. These soils occur in catenary sequence along with late rites and are found mainly as deposits by colluviation in foothills and small hillocks.
The rapid permeability of the surface mud also has been responsible for the characteristic development of these red mud's, which are very deep and homogeneous without much expression of horizons. The mud's have red colour, which has been attributed to the presence of Fe2O3 or Al2O3, SiO2 etc.

Refs.	India (%)	Jamaica (%)	Brazil (%)	Australia (%)	US (%)
Fe_2O_3	26.40	53.8	43.7	32.82	46.25
Al_2O_3	26.24	10.33	16.76	25.29	14.80
TiO_2	22.10	8.58	4.00	8.68	5.86
Na_2O	4.20	8.25	9.80	16.77	1.85
SiO_2	6.55	8.25	9.80	1.677	4.17
CaO	3.50	n.g.	n.g.	2.11	8.8
CO_2	0.00	n.g.	n.g.	n.g.	n.g.
LOI	10.88	n.g.	n.g.	7.66	n.g.

Table 3 Chemical composition of red mud in different countries

Method`s calculation (10262:2009) :

Volume of one cube = 3375 cm^3 (15cm*15cm*15cm)
= 3.375×10^{-3} m^3
Density Of Concrete = 24 MPa
= $(3.375 \times 10^{-3}) \times 24$
= 0.081 KN
= 81 N
Weight Of Cube = 81/9.81 = 8.256 Kg
Ratio Used = 1:1.5:3 (M20)

- Cement Required = 1.50 Kg
- Sand Required = 2.25 Kg
- Aggregate Required = 4.5 Kg

Total = 8.25 Kg

Mix composition (mud + ash)	Grain size analysis			Proctor density		Specific gravity
	Sand %	Silt %	Clay %	OMC %	Dry density (gm/cc)	
50%+50%	65	28	7	28	1.49	2.74
70%+30%	50	40	10	28	1.56	2.91
30%+70%	70	28	2	29	1.41	2.44
60%+40%	58	35	7	27	1.54	2.64
40%+60%	63	32	5	28	1.52	2.68

Table 4 - Particle size, compaction parameters & specific gravity of mix composition

Test for compressive strength.

Sr. No.	Max. load At failure (N)	Size of bricks	Area of bricks (sq.mm)	Compressive strength (N/sq.mm)	Average compressive strength (N/sq.mm)
1	90000	190×90×90	17100	5.26	5.15
2	95000	190×90×90	17100	5.56	
3	85000	190×90×90	17100	4.97	
4	90000	190×90×90	17100	5.26	
5	80000	190×90×90	17100	4.68	
6	90000	190×90×90	17100	5.26	
7	100000	190×90×90	17100	5.85	

8	85000	190×90×90	17100	4.97	5.03
9	85000	190×90×90	17100	4.97	
10	70000	190×90×90	17100	4.09	
11	80000	190×90×90	17100	4.68	5.26
12	90000	190×90×90	17100	5.26	
13	100000	190×90×90	17100	5.85	
14	85000	190×90×90	17100	4.97	
15	95000	190×90×90	17100	5.56	
16	95000	190×90×90	17100	5.56	5.03
17	75000	190×90×90	17100	4.39	
18	85000	190×90×90	17100	4.97	
19	95000	190×90×90	17100	5.56	
20	80000	190×90×90	17100	4.68	

Table5- Observations & Calculation of compressive strength

Finite element method: The finite element method (FEM) (its practical application often known as finite element analysis (FEA)) is a numerical technique for finding approximate solution of partial differential equation (PDE) as well as integral equation. The solution approach is based either on eliminating the differential equation completely (steady state problem), or rendering the PDE into an approximation system of ordinary differential equation, which are then numerically integrated using standard technique such as Euler's method , Rungekutta, etc.

Brick type	Young`s modulus E in MPa	Poission's ratio
Ordinary brick	7000	0.15
50 red mud+50 fly ash	11501	0.345
60 red mud+40 fly ash	9201.1	0.344
70red mud+30 fly ash	6901.1	0.343
80 red mud+20 fly ash	4601.4	0.342
90red mud+10 fly ash	2301.6	0.341

Table 6- Material property of bricks

Analysis results for brick geometry:
With the help of ANALYSIS result obtained for case brick geometry, we can observe that Poisson ratio and young modulus in Normal bricks Length of Brick =190 mm Width of Brick = 90 mm Height of Brick= 90 mm Hole Dia. = 25 mm In normal bricks, composition value with Poisson ratio 0.15 and young modulus 70000 MPa the applied the load 90,000 N then displacement of bricks 0.069297mm and compressive stress 5.185MPa.

Finally compare results and analysis with FEM
Generally water absorption of ordinary brick of size 190x90x90(mm) range from 10% to 12%. It's hence in the trail I to IV water absorption average 14.11% and hence to max water absorption 11%.If the red mud quantity are more mixing of block than the found water absorption are increase v/s ordinary bricks.

Generally compressive strength of ordinary brick of size 190x90x90(mm) range from 5mpa. It's hence in the trail I to IV compressive strength average 5.11mpa and hence to max compressive strength 4mpa.If the red mud quantity are more mixing of block than the found compressive strength are increase v/s ordinary bricks.

Recommendations

In the present thesis work of experimental study was done on manufacturing and testing of bricks using red mud. Hence as per test and results of the study following points can we recommend on the properties of red mud bricks.

1. Red mud +fly ash brick is having the lowest water absorption and highest compressive strength.
2. Red +fly ash brick is having the water absorption of 12%.
3. Fly ash +clay bricks are having the highest water absorption.
4. Among the curing condition studied water cured bricks have shown higher compressive strength.
5. Among the various systems studied red mud based bricks have shown higher compressive strength.
6. Among the curing periods studies 28 days curing period had shown the highest compressive strength.
7. Saving of 50% of clay, which are very important materials.
8. Cly materials are the agriculture used.
9. Environmental saving.

10. Recycling of waste material, total disposal for water soil.
11. Potential problem solve, 0.5 mm saving of clay.
12. Jute / sisal fibre reinforced red mud/fly ash/ marble slurry dust.

Cement Kg/m3	Red Mud Kg/m3	T.Cement-ious content Kg/m3	Water litres	W/(C+FA)	Fine Agg. Kg/m3	CA<20 mm Kg/m3	CA<10 mm Kg/m3	Slump mm	CS 7days MPa	CS 28day-s MPa
235	-	235	153.0	.65	703.27	783.65	522.43	100	20.5	36.0
280	-	280	163.0	.58	677.87	755.34	503.56	90	28.0	41.5
196	84	280	157.5	.56	673.37	750.33	500.22	100	18.0	36.0
210	90	300	160.0	.53	663.95	739.83	493.22	100	20.5	39.0
180	120	300	156.0	.52	664.07	739.96	493.31	95	19.0	35.0

Table7- Trial Mix Design of M20 Grade Concrete with Red Mud

Cement Kg/m3	Red Mud Kg/m3	T.Cementious content Kg/m3	Water litres	W/(C+FA)	Fine Agg. Kg/m3	CA<20 mm Kg/m3	CA<10 mm Kg/m3	Slump mm	Density Kg/m3	Setting time (Hrs.min.) Initial/ Final
235	-	235	143.0	0.61	703.27	783.65	522.43	80	2350	5.45 7.15
196	84	280	150.5	0.54	673.37	750.33	500.22	80	2365	7.15 8.25
180	120	300	152.0	0.51	664.07	739.96	493.31	80	2355	8.5 10.25

Table8- Mix Design 0f M20 Grade Concrete with Red Mud

RESULTS

Comparison for normal P.C.C (M20) red mud admixed concrete and fly ash admixed concrete:

Sr. No.	Comparison parameters	P.C.C concrete	Red mud admixed concrete	Flyash replaced concrete
1	**Compressive strength**	20 MPa	29.12 Mpa	33 Mpa
2	**Flexural strength**	1.8 Mpa	4.8 Mpa	3.8 MPa
3	**Cost**	Costlier than red mud admixed and fly ash admixed concrete.	Less costlier	Less costlier
4	**Colour**	Grey	Imparts brownish colour	Light grey
5	**Impact on environment**	Creates environmental pollution	Prevents environmental pollution	Prevents environmental pollution
6	**Resistance to cracking**	Less than red mud admixed and fly ash admixed concrete.	High resistance to cracking	High resistance to cracking
7	**Permeability**	22.4%	18.32%	19.5%
8	**Resistance to corrosion**	Lesser than red mud admixed and fly ash admixed concrete.	Imparts high resistance to corrosion.	Imparts high resistance to corrosion.
9	**Durability**	Lesser than red mud admixed and fly ash admixed concrete.	Higher	Higher
10	**Long ability**	Lesser than red mud admixed and fly ash admixed concrete.	Higher	Higher

Table 9: Red mud admixed concrete and fly ash admixed concrete comparison for M20 Grade concrete

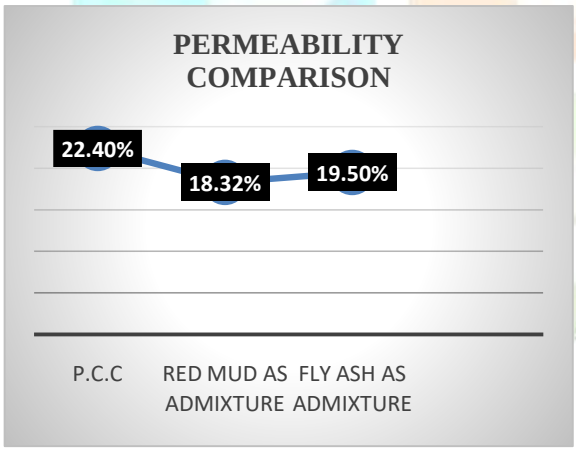

Fig 1- Permeability comparison

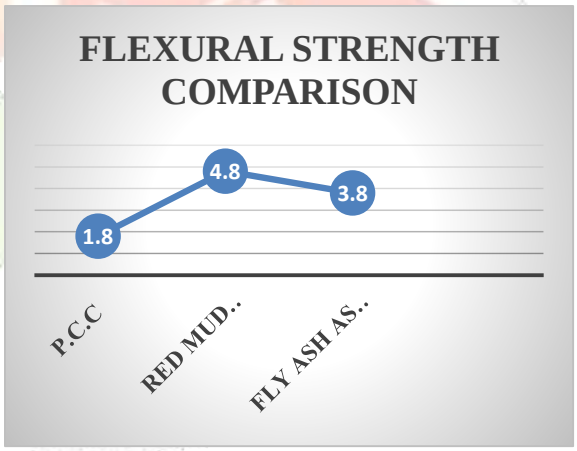

Fig 2- Flexural strength comparison

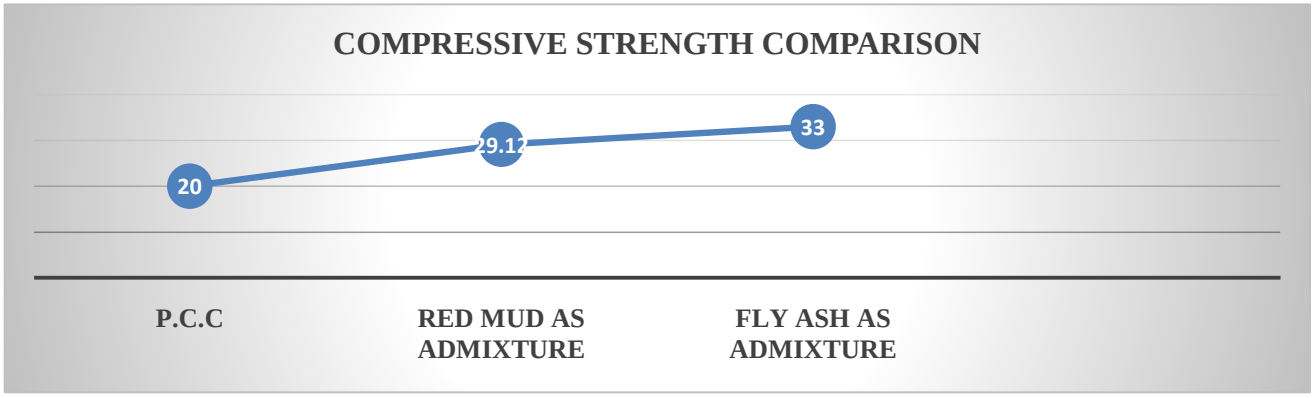

Fig -3 Compressive strength comparison

CONCLUSION

From the above discussion we can come to the conclusion that red mud on being replaced with cement improves its mechanical properties and proves to be economical. On the basis of literature survey, it is evident that red mud serves as a good binder material and has proved to be a good cementations material. Red mud reduces the capillary pores of concrete and hence as the percentage of red mud in concrete increases there is a consequent decrease in the percentage of water absorbed. Red mud contains components that in combination with lime produce calcium aluminates hydrates. These reaction products are able to develop strength. Thus for the purpose of economical construction and for increasing the mechanical properties of concrete red mud has proved to be effective in all respects.

A simple mixing of 70% red mud and 30% CaO gives a product with compressive strength of 7MPa. The hydrates formed after 4 days are Ca $(OH)_2$ C_4AH_{13} and C_4AH_{11}.by addition of 10% gypsum a compressive strength of 15 MPa is obtained after 7 days.
At later ages, etteringite expansion will occur. These results have been confirmed by more recent experiments. Cements prepared by mixing red mud with and or portlandite show a decrease of the flexural strength as function of time. Red mud does not impart much compressive strength when compared to fly ash, but it has been observed that flexural strength and resistance to permeability increases in red mud cement concrete. Although using red mud is less feasible than using fly ash but it is necessary to use or recycle red mud as it has many harmful environmental effects.

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