Study on Concrete by Replacing Cement with Red Mud, Fly Ash and Hydrated Lime

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ABSTRACT

At global level, red mud (RM) production is rising as a result of the expansion of the aluminum industry. In overall, 0.8 to 1.5 tons of RM can be produced for every ton of alumina produced. Globally, 1.7 billion tons of RM are produced each year due to the aluminum industry's quick development. Due to the hydroxide (NaOH) injected throughout the production of aluminum, RM typically has a pH between 10.5 to 12.5.

In this study, we're looking at how red mud is used in concrete. Here, we're making concrete cube and beam samples with red mud added in the recommended weight percentage. and figuring out its tensile, flexural, and compressive strengths. Taking into account various concrete grade levels. The results of this study will support the physical property changes in concrete that were noticed after red mud was added.

Keywords: Red mud, Compressive strength test, Split tensile test, Non-destructive test, concrete, physical properties

I. INTRODUCTION

Red mud, produced by the Bayer cycle, is a mechanical waste procured throughout the production of aluminum. It is estimated that more than 66 million tons of this waste are produced annually worldwide. For every large load of alumina produced, approximately 1.6 large tons of red mud are delivered. The red mud is typically spread on land or released into the ocean, contaminating the water, air, and soil nearby, especially in areas where this industry is present. In light of this, actions should be taken to reuse this loss in an environmentally friendly manner. Significant efforts are made worldwide to address the executives red mud in use, stockpiling, and removal with knowledge of both financial implications as well as issues related to the natural environment. Red mud is currently produced in roughly the same mass proportion as metallurgical alumina and is placed in either locked or fixed fake impoundments similar to landfills, causing serious environmental problems.

Red Mud Production

China produces and over 50% of the world's aluminum, while India accounts for only 5% of the metal's smelter production. The establishment of more and more aluminum industries today leads to increased alumina production, which in turn boosts red mud manufacturing. As can be seen from the pie chart, China accounts for more than half of the world's aluminum production, while the United States accounts for only about 5% of global production.

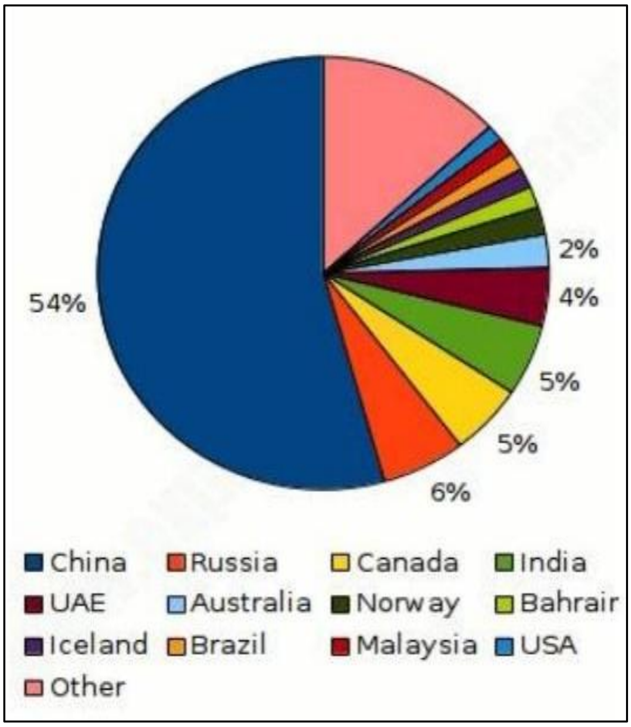

Fig 1.1 Pie chart indicating scenario of the percentage of production of Aluminium in the world

Use of Red Mud in Cement Production

Investigators from all over the world have looked into the usefulness of red mud in the manufacture of cement. About two million tonnes of red mud have been used in our country India to make cement. When making cement in Japan, red mud is used as a raw resources alongside other raw materials like clay as well as lime stone. Red mud was used to create cement, which also complies with standards. It was discovered that these cements' compressive strength was comparative to that of regular Portland cement. The cement made with 50% lime, 30% red mud, and 20% bauxite had a 28-day compressive strength of about 10 MPa.

II. LITERATURE SURVEY

P.Ashok and M.P. Suresh Kumar (2019) The purpose of the study paper was to explore the physico-chemical and mineralogical characterization of numerous industries wastes that could be used in the production of cement. Such industrial waste can be used as a raw material, blending component, or additive. As a result, the suitability of red mud for the construction sector was examined. The replacement percentages of red mud and hydrated lime with cement in each series were 0%, 5%, 10%, 15%, and 20%, respectively. Five test groups were created. Hydrated lime was added to the red mud to create its pozzolanic properties. The best use of NRM is 15% as a partial substitute of cement by NRM, according to the results of testing of 5 blended cement samples (5% to 25% substitute of Cement by NRM) with an increase of 5%. The cost of M 30 grade NRM concrete (i.e., 15 percent replacement) was approximately 7.48 percent lesser than the price of traditional concrete, with a rise in 28-day compressive strength of up to 21.712 percent. The proportion economy risen as the concrete grade risen, but the percentage increase in compressive strength decreased at the very same period. The best percentage of Neutralized Red Mud to use in concrete as a partial replacement for cement was 15%. Red mud works well as a substitute for cement because it allows for a high level of waste product usage. Red mud did not affect the properties of cement; somewhat more, it enhanced cement performance by speeding up setting and increasing compressive strength.

Mahin Sha O B et al (2016) The physical characteristics of blended cement (Portland cement substituted by 0%, 5%, 10%, 15%, 20%, and 25%) red mud with constant water ratio concrete design mix of grade M25 were made and design mix was investigated for compressive strength in the research article.

The ideal replacements rate for cement in terms of weight is discovered to be 20%. The results obtained through this replacements are almost on par with those of ordinary concrete. The best percentage of Red mud to use in concrete by replacing for cement, according to the study's conclusions, was 20 percent. According to the study's findings, red mud can be a creative addition to cement - based materials, but skilled engineers must make wise choices.

N.K. Mhaisgawl et al (2021) The purpose of the article was to examine the possibility of using red mud in place of Portland cement in concrete, as well as to assess the strength of a material in compression and cracking tensile tests. Five experimental groups were formed up of 0 percent method for increasing. With every arrangement of concrete, add 40 percent red dirt and 5 percent hydrated lime.

Results showed that Red Mud, when used as a replacement for concrete in the range of 0%, 5%, 10%, 15%, and 20%, may easily mimic the properties of concrete. Red mud and cement should be combined for non-structural construction. From a structural perspective, red mud concrete has potential use in the future.

Supriya Kulkarni (2018) The goal of this study is to investigate the use of geo-polymerization of industrial effluents to create a green substitute for concrete mixture. In this work, the physico - mechanical characteristics of geopolymer concrete made from red mud, fly ash, and ground granule blast furnace slag (GGBFS) were investigated. Moisture content, compressive strength, flexural strength, and tensile splitting strength are among the characteristics that have been tested.

According to the findings of the experiments, geopolymerization of red mud, fly ash, and GGBFS can be utilized as a sustainable substitute for traditional concrete. Geopolymer concrete was found to have 89.4% the compressive strength of regular concrete. Geopolymer concrete was found to have a modulus of rupture that was 84.26 percent greater than that of regular concrete. Geopolymer concrete was discovered to have a modulus of elasticity that was 81.21 percent greater than that of regular concrete. Geopolymer concrete is shown to absorb more water than traditional concrete. According to the findings, geo-polymerization of industrial effluents can be a good and environmentally friendly substitute for traditional concrete, Hence.

Gowsalya. R and Bhagyalakshmi. A (2015) In the research project, it was evaluated whether red mud might partially substitute cement in concrete at various percentage (0, 5, 10, 15, 20, and 25%). Compressive strength and strength and flexural strength for cement concrete of M30 grade were used to study its impacts on the strength as well as other parameters of the concrete. The findings demonstrated that concrete's compression and tension strength are both decreased when more red soil is added. It has been determined that 20% is the appropriate replacement rate for cement in terms of weight. The outcomes of these substitutions are fairly comparable to those of controlled concrete. Red mud contents may make concrete more difficult to work with; however structural systems can improve its workability. The lighter weight of neutralizing red mud and its physical domain, which fill the cement's gaps and may raise the mix's density, may be the cause of the shorter first set times at 5 and 10 percent.

Nevin Koshy et al (2019) The research report investigated the manufacture of geopolymer paste material using two untreated inorganic compounds, Class-F fly ash and red mud. The red mud's high level of alkalinity was used to dissolve the silica inside the fly ash and red mud. The effects of the curing time, Si/Al, Na/Al, and liquid-to-solid (L/S) relations on the concrete strength of the finished products were evaluated. The mechanics, mineralogical, micro - structural, and pore features were also examined.

The distribution and production of different types of pores in the geo-polymeric matrices are affected by the rate of fly ash, where a high initial Si/Al ratio results in intermittent porosity in the final geo-polymeric matrix. The minimum L/S ratio of 0.35 was discovered to be ideal for producing higher-strength fly ash-red mud-based alumino - silicate materials with less porosity.

Tejaswini. C and Anupama Natesh (2019) The goal of the study was to evaluate the aluminum red mud's strength properties in order to replace some of the cement in concrete. Red mud was substituted for cement in percentages ranging from 0% to 60%, with an internal of 10%, to create the specimens. A 5 percent addition of hydrated lime was made to the mixture to improve its binding abilities.

The test results of new properties that are more apt to be submerged in water increase as red dirt content rises. This increase in water use was anticipated since the red mud, which is somewhat lighter in weight, has better particles and more volume, both of which require more water to achieve the same consistency.. Red mud's properties are decreased when its content is increased in concrete, yet red mud may still be used in concrete for environmental sustainability. As the content of red mud increases, the carbonation rate decreases. According to these findings, red mud had a stronger corrosion resistance. Red mud is added to concrete to make it resistant to sulphate assault. The red mud replacement's ideal content was 20 percent. The best method to reduce environmental damage and the constructions industry's carbon footprint may be to utilize red dye in concrete.

III. OBJECTIVES OF THE STUDY

In this research, red mud was used in place of cement in percentages of 5 percent, 10 percent, 15 percent, and 20 percent. The goals of this research are as follows:

- To assess the red mud's effect on the physical and mechanical properties of concrete.
- To ascertain the cube and beam-shaped concrete samples' compressive and tensile strengths.
- To ascertain concrete specimen split tensile test results.
- To ascertain the sample's carbon emission and improvement in concrete.
- Compressive strength should be evaluated using non-destructive testing destructive testing.

IV. METHODOLOGY

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: 4.1

Table 3.1 Physical properties of Cement

Physical Properties of 53 Grade Cement	
Characteristics	**Values**
Standard Consistency	53
Fineness of cement as retained on 90 micron sieve	3%
Initial Setting Time	30 ins
Specific Gravity	3.15
7 days compressive strength	37 pa

Table 3.2 Physical properties of Cement

Chemical Properties of Cement	
Components	**Weight**
Lime(CaO)	63%
Silica(SiO2)	22%
Alumina(Al2O3)	6%
Iron oxide(Fe2O3)	3%
Magnesium oxide(MgO)	2.50%
Sulphur trioxide & loss of ignition(SO3)	1.50%
Alkalies	0.50%

Fig 4.1 Cement

Coarse Aggregate

Locally available coarse aggregate having the maximum size of 20 mm down size and confirming to Table 2 of IS 383 are used in the present work. The specific gravity of coarse aggregate is found to be 2.64. The water absorption test on coarse aggregate is found to be 0.4%.The properties of coarse aggregate are given in table 4.3

Table 4.3 Properties of coarse aggregate

Description	Result
Specific gravity	2.85
Fineness modulus	7.5
Water absorption	0.31%
Moisture content	Nil

Fig 4.2 Coarse Aggregate

Red Mud

Red mud is composed of a mixture of solid and metallic oxide-bearing impurities, and presents one of the aluminium 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, unleached residual aluminium, and titanium oxide. Red mud cannot be disposed of easily. As a waste product of the Bayer process the mud is highly basic with a Ph ranging from 10 to 13. The characteristics of Red mud depend on the nature of the bauxite ore used. It has been neutralized by using commercially available HCl to bring down the ph from 10.6 to 8.6. And mud was sieved and uniform powder passing through 1.18 mm was used. The specific gravity of Red mud is found to be 2.93.

Fig 4.3 Red Mud

Table 3.5 Composition of Red Mud

Components	Weight %
Al_2O_3	20-22
Fe_2O_3	40-45
SiO_2	12-15
TiO_2	1.8-2.0
CaO	1.0-2.0
Na_2O	4-5
Particle Size	less than 44 microns
Appearance & Odor	Red, Earthy odor, slighty pungent

Red Mud used in Building Material

Building materials (bricks, cement, lime and their subsidiaries) are becoming increasingly uneconomical because of obsolescence, exhaustion of raw materials, low plant efficiencies and increasing costs. The use of red mud as a replacement for cement in the production of cementitious with mechanical, microstructure, and hygroscopic properties which is suitable to use in the civil construction sector has been demonstrated. The incorporation of industrial by-products in building materials may lead to concern regarding the presence of natural radionuclides in the component materials. However, bauxite and red mud contents in special cement appear to be viable from radiological aspect. Naturally occurring radioactive materials (NORM) such as 40K, 232Th, and 226Ra in the construction materials should be evaluated.

MIX DESIGN

Grade of concrete: M30 Cement: OPC 43grade

Target Strength : fck+1.65(s) =38.25
N/mm2 Cement content : 372 kg/m3

Water/Cement ratio : 0.45

River sand content : 726.91 kg/m 3 Coarse
Aggregate content : 1145.64 kg/m3

Chemical admixture : Conplast SP-430 (0.3% by weight of Cement)

Table 4.6 Mix Design

Cement	Fine aggregate	Coarse aggregate	water	Admixture
1	2.925	4.696	0.45	0.30%

Fig 4.4 Red mud Powder, Red mud Cubes and Mix Design Preparation.

V. RESULTS AND DISCUSSION

Compressive Strength

Table 5.1 Compressive Strength

Compressive Strength (MPa)				
Mix Design Designation	Curing Age (Days)	Avg. Weight (gm)	Avg. load (KN)	Avg. Comp. Strength (MPa)
	3	796	493	21.92
M30 GRADE	7	802	616	27.4
	28	806	826	36.72
	3	810	437	19.45
5 % Red Mud	7	802	581	25.83
+ Cement	28	788	812	36.1
	3	793	509	22.65
10 % Red Mud + Cement	7	795	561	24.96
	28	798	772	34.33
	3	801	541	24.06
15 % Red Mud + Cement	7	803	591	26.3
	28	802	637	28..33
	3	794	443	19.72
20 % Red Mud + Cement	7	792	462	20.54
	28	800	568	25.25

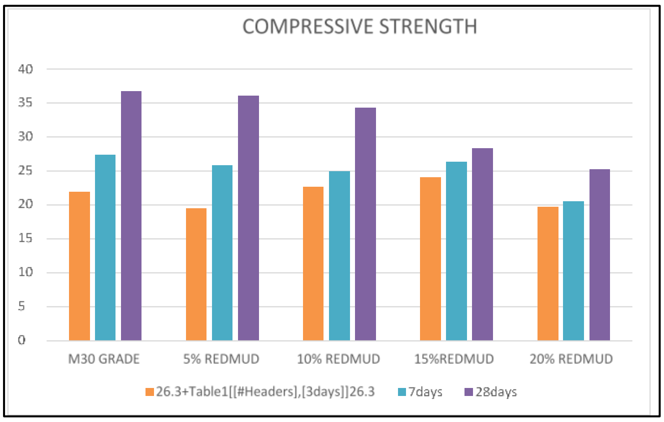

Fig 5.1 Compressive Strength

Table 5.2: Compressive Strength Calculation

S.No.	Size of Cube	Weight of Cube	Total Load KN	Load N/mm2	Mean Load	Prescribed Limit (N/mm2) after 7 Days	Prescribed Limit (N/mm2) For 28 Days
1	15 x 15 x 15 Cm	8345	485	21.556	22.22	21	30
2	15 x 15 x 15 Cm	8534	505	22.444			
3	15 x 15 x 15 Cm	8402	510	22.667			
4	15 x 15 x 15 Cm	8432	710	31.556	31.7		
5	15 x 15 x 15 Cm	8425	720	32			
6	15 x 15 x 15 Cm	8420	710	31.556			

Tensile Strength

Table 5.3 Tensile Strength

Tensile Strength (MPa)				
Mix Design Designation	Curing Age (Days)	Avg. Weight (gm)	Avg. load (KN)	Avg. tensile. Strength (MPa)
M30 GRADE	3	160	116	1.65
	7	160	183	2.6
	28	162	211	3
% Red Mud + Cement	3	158	129	1.83
	7	160	198	2.81
	28	156	225	3.19
10 % Red Mud + Cement	3	160	158	2.24
	7	162	214	3.03
	28	161	258	3.66
15 % Red Mud + Cement	3	158	154	2.19
	7	159	187	2.66
	28	160	247	3.51
20 % Red Mud + Cement	3	160	151	2.14
	7	156	171	2.43
	28	157	226	3.20

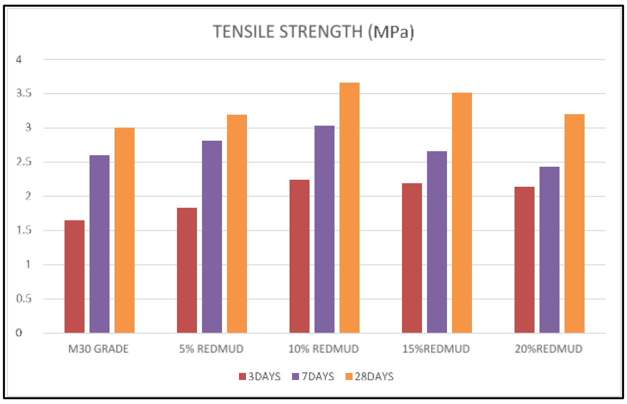

Fig 5.1 Tensile Strength

Table 5.4 Split Tensile Strength calculation

Grade	Age of specimen	Specimen	Dimension of sample	Load (KN)	Tensile Strength	Average strength
	28 days	Sample 1	150 x 300 mm	100	1.415428167	
M30	28 days	Sample 2	150 x 300 mm	102	1.44373673	1.420146261
	28 days	Sample 3	150 x 300 mm	99	1.401273885	

VI. CONCLSION

The purpose of the current experiment experiments is to determine whether using red mud in cement concrete is practical.

The compression strength of the red mud concrete are equal to those of concrete mixture with each percentage of replacement up to 20 percent.

The experiment investigation revealed that both the mechanical properties and the tensile strength of concrete diminish when red mud content was increased (higher than 10%).

An embankment landfill used for road building is a desirable choice with a high potential for large volumes reuse.

In-situ tests that validate the qualities of red mud from various sources and at various storage durations.

Using several stabilizing techniques and other soils to be employed as a clay liner, fill material, etc., to stabilize neutralizing red mud

The detection and screening of additional microorganisms in the red mud neutralizing.

The impact of another bioplastic on the stability of red mud.

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