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Investigations on optimum possibility of replacing cement partially by redmud in concrete

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Red mud is an industrial waste material generated during production of alumina from bauxite by Bayer process. These industrial wastes hold some heavy metals which are hazardous in nature. The aim of the paper is to investigate the possibility of partially replacing Portland cement in concrete by red mud and evaluating its compressive and splitting tensile strength. This study examines the effect of red mud on the properties of hardened concrete and compares with the conventional concrete. The test results revealed that 15% of cement can be optimally replaced by red mud beyond which compressive strength, split tensile strength and flexural strength starts decreasing. Cement replacement by red mud up to 15% yields characteristic strength greater than the conventional cubes. Further increase in percentage of red mud by 20, 25 and 30% tends to decrease the compressive strength. However, the optimum replacement level was observed as 15% without decrease in strength.

Key words: Red mud, workability, bayer process, compressive strength, split tensile strength.

INTRODUCTION

Red mud is the main waste generated from bauxite ore during production of aluminium and alumina by the Bayer process (Ashok and Suresh Kumar, 2014). The world's production of bauxite in 2009 was 205 million tons, and the main producing countries were Australia, China, Brazil, Guinea, India and Jamaica (Ribeiro et al., 2011). As per records of 2009, Brazil ranks third in bauxite production by producing 26.6 million tons of bauxite. It also holds the world's third largest bauxite ore reserves (around 3.5 billion tons), concentrated mainly in the northern part of the country. Roughly 0.3 to 1.0 tons of red mud waste are generated per ton of aluminium produced. Brazil has discarded about 10.6 million tons/year of caustic red mud in recent years and the worldwide generation of red mud exceeds 117 million tons/year.

For the betterment of waste management and generation of cost effective concrete, the inclusion of recycled waste material becomes essential. Most of the recent studies on concrete focus on the inclusion of waste material in concrete. This is due to the problems relating to the waste management. Thus the waste materials that resemble the properties required by concrete ingredients can be included for concreting.

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Table 1. Properties of cement.

S/No.	Properties	Test result
1.	Specific gravity	3.15
2.	Fineness	225
3.	Standard consistency	30%
4.	Initial setting time	33 min.
5.	Final setting time	231 min.
6.	Soundness	2.5

Table 2. Properties of red mud.

S/No.	Properties	Test result
1.	Specific gravity	2.51
2.	Fineness in sq.cm/gram	1000-3000
3.	pH	10.5 – 12.5

Bahoria et al. (2013) on their literature study collectively pictured various researches on waste and recycled materials that can be used as concrete ingredients. Material obtained from sludge treatment plants such as sludge ash, screenings, etc., were included in studies on concrete material replacements (Sahu et al., 2013; Kosior-Kazberuk, 2011; Sakthieaswaran and Ganesan, 2013; Deotale et al., 2012; Ramesh et al., 2014). By using hazardous waste materials such as glass waste and plastic waste, the environmental sustainability can be increased. Waste materials from coal industries contribute most basic properties of concrete material. However for the generation of pozzolona cement, waste materials such as fly ash, bottom ash are included. Some waste materials are being used for landfilling such as China clay waste (CCW), spent bricks, etc., (Sawant et al., 2011, Shetty et al., 2014, Dayalan and Beulah, 2014). Seeni et al. (2012) ensured the partial replacement of fine aggregate in concrete by using china clay industrial waste for an optimum of 30%. This replacement leads to the positive effects on concrete by reducing its cost with increase in strength. The effect of replacement of cement by neutralized red mud has been studied on design mix concrete of grade M50 (Sawant et al., 2013). Govindarajan and Jayalakshmi (2012) investigated of the influence of calcined red mud in cement hydration and concluded that compressive strength of cement containing 20% red mud was higher than the OPC at all hydration periods. Mohan Kushwaha et al. (2013) developed self compacting concrete using red mud. Manoj et al. (2014) developed brick from industrial waste red mud. compressive strength of concrete produced by replacing cement by unwashed red mud and when subjected to alternative wetting and drying for 50 cycles goes on increasing up to 10% replacement levels (Rudrasamy and Prakash, 2014). Ankit and Jayesh (2013) investigated the strength of concrete and optimum percentage of the partial replacement by replacing cement via stone waste. The fresh and hardened properties of self compacting concrete (SCC) using red mud as partial replacement for cementitious material along with used foundry sand as partial replacement for fine aggregate were evaluated by Shetty et al. (2014).

Table 3. Red mud composite materials.

S/No.	Composition	Rate (%)
1	$Fe_2 O_3$	48.50
2	$Al_2 O_3$	14.14
3	Na_2O	7.50
4	SiO_2	11.53
5	CaO	3.96
6	TiO_2	5.42
7	MnO	0.17

OBJECTIVE

(i) To find the optimum replacement of cement by red mud
(ii) To find the compressive strength, split tensile strength and flexural strength of red mud used concrete and conventional concrete.
(iii) To compare the compressive strength, split tensile strength and flexural strength of red mud concrete with the conventional concrete.

MATERIALS AND METHODS

Virgin materials were chosen as raw materials for concreting. 43 grade OPC cement, red mud, crushed rock of maximum 20 mm size and potable water were invested for the experiments. Locally available good river sand passing through 4.75 mm sieve was used.

Cement

Ordinary Portland Cement (43 Grade) confirming to IS: 8112-1989 was used throughout this investigation. Various tests were conducted on the cement to ensure their property as recommended by IS 8112. The physical properties of the cement were found as per IS: 4031- (Part 1 to 15) and are presented in Table 1.

Red mud

Red mud is one of the major solid wastes obtained as by-product from Bayer process of alumina extraction. At present about 3 million tonnes of red mud is generated annually which is not being disposed or recycled satisfactorily (Sawant et al., 2012). Red mud properties were obtained from M/S Mallco (India) limited, data sheet (Table 2). The chemical composites was ensured by the same industries and tabulated in Table 3.

Table 4. Properties of fine aggregate.

S/No.	Properties	Test result
1.	Specific gravity	2.85
2.	Fineness modulus	2.58
3.	Water absorption	1%
4.	Density	1754.3 kg/m^3
5.	Surface texture	Smooth.

Table 5. Properties of coarse aggregate.

S/No.	Properties	Test result
1.	Specific gravity	3.05
2.	Fineness modulus	7.5
3.	Water absorption	0.5%
4.	Density	1813.23 kg/m^3
5.	Surface texture	Smooth.

Table 6. Replacement of binding materials.

S/No.	Designation of specimen	Cement (%)	Red mud (%)
1	CS	100	0
2	R1	95	5
3	R2	90	10
4	R3	85	15
5	R4	80	20
6	R5	75	25

Fine aggregate

River sand was used as fine aggregate. The size of the sand used is less than 4.75 mm. The properties of fine aggregate investigated as per IS 383 - 1970 are presented in Table 4.

Coarse aggregate

Machine crushed granite obtained from a local quarry was used as coarse aggregate. The properties of the coarse aggregate are found as per IS 383-1970 code specification, shown in Table 5.

Water

Water used in this project was potable water.

Mix design

Based on the properties of the water, cement, fine aggregate and coarse aggregate design mix of M_{30} were calculated by following the recommendations of IS code IS 10262 - 2009. The final mix ratio was arrived as 1:1.462:2.695 with water cement ratio of 0.44. The measurement of materials was done by weighing using electronic weighing machine. Water was measured in weight. The red mud was used for replacing of cement by 5% intervals in weight up to 25% as shown in Table 6.

Casting and testing of specimens

M_{30} grade of concrete was prepared as per IS 10262-2009. Three cube specimens (150 x 150 x 150 mm) and three cylinders (150 x 300 mm) were casted for determining compressive strength and split tensile strength respectively. Prisms (100 x 100 x 500 mm) of 3 numbers were casted and tested for flexural strength of concrete. Casted specimens were cured in the curing pool for 7, 14 and 28 days. After curing the cubes and cylinders were tested in hydraulic compression testing machine and prisms were tested in UTM as per IS 516-1959 code specifications. The values of compressive strength, spilt tensile strength and flexural strength are tabulated.

RESULTS AND DISCUSSION

The compressive strength results are shown in Table 7. It was observed that the maximum compressive strength of 36.52 N/mm^2 was obtained at 15% replacement of cement by red mud. The compressive strength reduces

Table 7. Compressive strength on concrete cubes.

Specimen name	Compressive strength in N/mm^2		
	7th day	14th day	28th day
CS	20.25	25.75	33.02
R1	21.92	25.95	33.85
R2	22.15	27.15	35.75
R3	23.35	29.60	36.52
R4	22.05	26.05	33.85
R5	22.00	24.90	32.65

Table 8. Split tensile strength on concrete cylinders.

Specimen name	Split tensile strength in N/mm^2		
	7th day	14th day	28th day
CS	3.43	3.87	4.38
R1	3.57	3.89	4.44
R2	3.59	3.98	4.56
R3	3.69	4.15	4.61
R4	3.58	3.89	4.44
R5	3.58	3.81	4.36

Table 9. Flexural strength on concrete prisms.

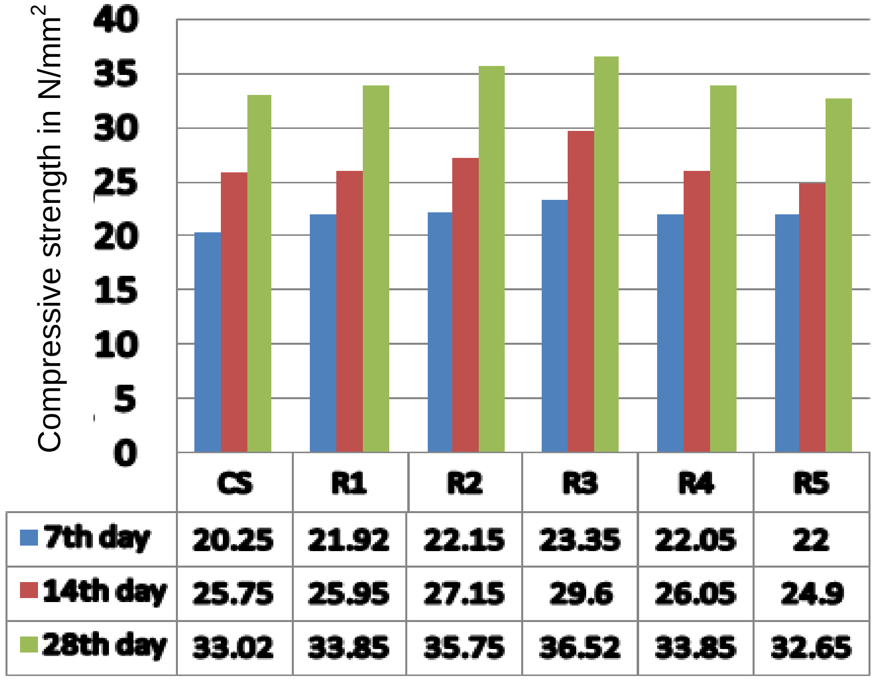
Specimen name	Flexural strength in N/mm^2		
	7th day	14th day	28th day
CS	3.15	3.55	4.02
R1	3.28	3.57	4.07
R2	3.29	3.65	4.19
R3	3.38	3.81	4.23
R4	3.29	3.57	4.07
R5	3.28	3.49	4.00

beyond 15% replacement of cement by red mud. As the concrete is weak in tension, tensile strength is one of the basic and important properties of concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. Determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The load at which splitting of specimen took place is recorded in Table 8.

In case of split tensile strength test, the maximum strength was obtained at 15% replacement of cement by red mud. At 28 days curing the split tensile strength value was 4.61 N/mm^2 which was greater than conventional concrete strength. The Maximum 28 days cured, flexural strength of prism is obtained for R3 specimen (that is) 15% replacement of cement by red mud and the various flexural values for the samples are tabulated in Table 9. The optimum replacement level of cement by red mud was obtained at 15% from the experimental investigation. From the Figures 1, 2 and 3, it can be noticed that increase in the percentage of red mud has proportionate increase in strength for all the ages. For percentage above 15 the strength decreases. Also the strength parameters of red mud replaced concrete were found to be greater than the conventional concrete.

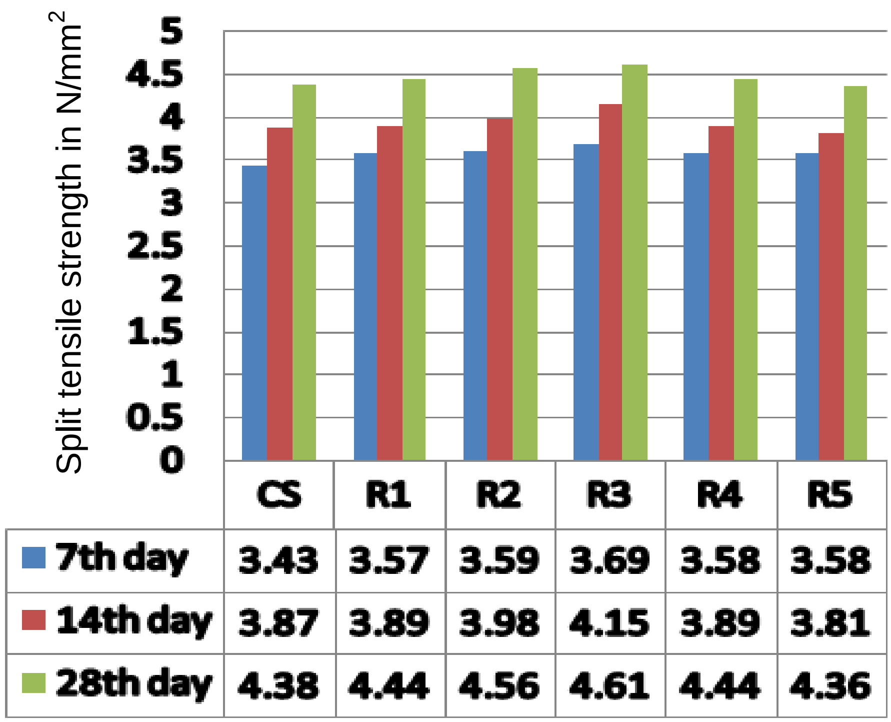
Conclusion

The effect of partial replacement of cement by red mud



	CS	R1	R2	R3	R4	R5
7th day	20.25	21.92	22.15	23.35	22.05	22
14th day	25.75	25.95	27.15	29.6	26.05	24.9
28th day	33.02	33.85	35.75	36.52	33.85	32.65

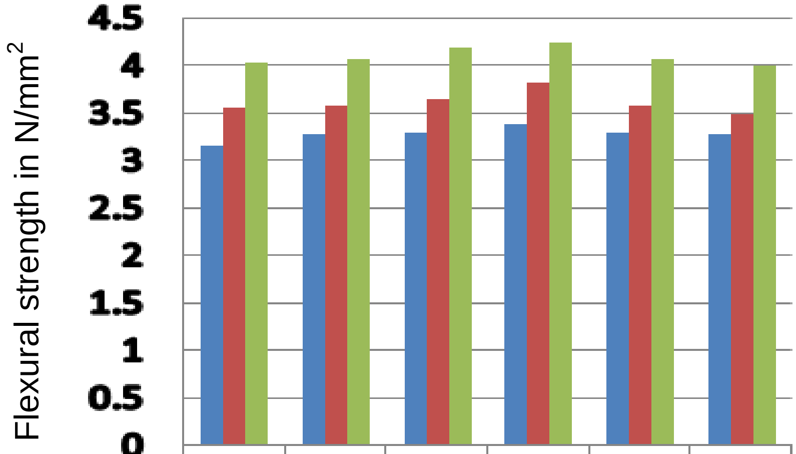
Figure 1. Compressive strength on cube specimens.



	CS	R1	R2	R3	R4	R5
7th day	3.43	3.57	3.59	3.69	3.58	3.58
14th day	3.87	3.89	3.98	4.15	3.89	3.81
28th day	4.38	4.44	4.56	4.61	4.44	4.36

Figure 2. Split tensile strength on cylinders.

has been studied on design mix concrete of grade M30. It is observed that the rate of gain in strength properties namely compressive, spilt tensile and flexure increases with increase in red mud content up to 15% and beyond



	CS	R1	R2	R3	R4	R5
7th day	3.15	3.28	3.29	3.38	3.29	3.28
14th day	3.55	3.57	3.65	3.81	3.57	3.49
28th day	4.02	4.07	4.19	4.23	4.07	4

Figure 3. Flexural strength on prisms.

which it started decreasing. The above results show that the maximum utilization of red mud in concrete is 15% as a partial replacement of cement. This study concludes that red mud can be used as an innovative supplementary cementitious alternative.

Conflict of Interest

The authors have not declared any conflict of interest.

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