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Development of Red Mud Concrete and Prepared Bricks

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ABSTRACT

Cement is an important ingredient and a binder in the manufacturing of concrete. But its production releases a large amount of CO2 to the atmosphere thus degrading the environment. This can be prevented by conserving the use of cement by replacing partially with waste materials. One such material is an industrial waste called red mud. While using the Bayer process for the extraction of aluminum from bauxite this waste is obtained. Experimental investigation was conducted in which cement was replaced with red mud in percentages of 0, 2, 4, 6, 8, 10,12, 14, 16, 18, and 20 while manufacturing concrete by weigh batching. The compressive strength increased with the increase in the percentage of red mud attaining a peak value at a replacement percentage in the preparation of concrete calcium chloride was added as an accelerator to hasten hardening of concrete. In another batch of concrete retarder was added to delay setting of concrete. For producing concrete with enhanced viscosity and controlled geological properties Gleniumstream 2 admixture was added in a separate batch of concrete to improve its stability and control its bleeding characteristics to increase the resistance to segregation and facilitating placement. Sulphonated naphthalene form aldehyde polymer (superplasticizer), a water reducing admixture (superplasticizers), was added to all concrete mixes in this investigation. Different admixtures were tried in concrete to understand their influence on hardening and strength gaining of concrete especially when red mud is added in the preparation of concrete. Load was applied gradually in increments on the specimens with the help of hydraulic cylinders in increments till the specimens failed. For each load increment deflection and strain readings were recorded. Cracks as soon as they formed were marked and their propagation was also monitored. The ultimate load sustained by each element was recorded. Load-deflection relation was plotted. The behavior of beams prepared with conventional and red mud concrete was identical. Among the joints the behavior of joint was better than the other joints with higher load capacity and ductility.

Keywords: Concrete, cement, red mud, partial replacement, compressive strength, structural applications, testing.

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I. INTRODUCTION

Concrete is the most versatile man- made construction material in the world and is being extensively used in all types of construction activities. The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, the mix proportions, the method of compaction and other controls during placing, compaction, and curing. In the preparation of concrete, cement is an important ingredient which binds crushed stone and river sand in the presence of water. Over the years concrete has gained popularity as it can be prepared at site with local materials and cast in any desired shape and size. Initially, it is in fluid state and hardens with time gaining strength simultaneously while curing with water. At 28th day of its casting its strength, especially compressive strength, is evaluated.

This is an important parameter in judging its performance. The two important components are Quality and Solidness that choose its load carrying capacity. For this reason, waste materials obtained from industries and agriculture are integrated in the concrete as fractional replacement of cement. These are called supplementary cementitious materials having pozzolanic properties. The function of pozzolan is to neutralize the unstable calcium hydroxide released during hydration of cement. Otherwise, it will escape from the body of concrete leaving pores though which oxygen and moisture will ingress and attack reinforcing steel causing its corrosion. It is more imperative to prevent this to ensure long service life of the structures. The advances in concrete technology have paved the way to make the best use of locally available materials by proper mix proportioning and workmanship to produce a strong, durable, and uniform concrete.

The requirement for leading a proficient life is challenging for the rapid development of industries and they partially fulfil their tasks since many factors are not overcome by them successfully and one of that is safe disposal and utilization of waste generating at the end. The waste of aluminum industry known as red mud or bauxite residue is discharged when alumina is coming out from bauxite. During the most feasible Bayer process alumina is extracted from bauxite at elevated temperature and pressure with the presence of sodium hydroxide. Red mud generation is depending upon the type of bauxite used in industry. About 1.2-1.4 tons of red mud is generated per each ton of alumina produced. Each year, 75 million tons of red mud is produced worldwide. The iron compounds present in it confers the red color to it and hence it is called red mud.

The problem with the red mud is that it is toxic by nature. The chemical analysis conducted on red mud reveal that it contains silica, aluminum, iron, calcium, titanium, as well as an array of minor constituents, namely: Na, K, Cr, V, Ni, Ba, Cu, Mn, Pb, Zn etc., because of the harmful chemical composition present in it but the major problem of red mud is it is caustic in nature as the alkalinity is very high. The pH value of red mud is varies from 10.5 to 13. This waste is usually managed by discharge into engineered or natural impoundment reservoirs, with subsequent dewatering by gravity-driven consolidation and sometimes followed by capping for closure. Due to the alkaline nature it neither is used for construction material nor for vegetation.

The environmental trouble linked with the disposal of red mud waste includes:

- The high pH (10.00-13.00).
- Contamination of underground water due to alkali seepage.
- Storage of red mud is not stable.
- Alkaline air effect to plant life.

Fig 1. Discharge of Red Mud as Slurry into the Pond

II. MATERIAL USED

2.1 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 color 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, unleashed 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 following is the composition of the Dry Red Mud of MALCO (Madras Aluminium Company Limited).

Table 1 Major chemical constituents ofred mud

Chemical composition	Values in percentages
Fe_2O_3	40.0-26.0
Al_2O_3	18.022.0
Na_2O	4.0-4.5
SiO_2	12.0-16.0
Cao	1.5-2.5
TiO2	2.5-3.5
LO1	11.015.0

Table 2 Properties of red mud

S. No.	Properties	Values
1	Specific gravity	2.51
2	Fineness	1000 – 3000 cm^2/gm
3	pH	10.5 – 12.5

The SEM micrographs depicted the complex microstructure of the red mud. The particles were flaky-shaped and agglomerates of about 1 μ m were visible, that were the results of the crushing and milling operations. Once properly diffused, the particles were very fine and seemed to mix easily with cement to produce homogeneous mixture.

2.2 Cement

Ordinary Portland Cement (43 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.

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Table 3 Properties of cement

S.No.	Property	Value
1	Specific gravity	3.15
2	Initial settingtime	35 min
3	Final settingtime	600 Min
4	Standard consistency	30%
5	Soundness	2.5
6	Finenessmodulus	8|5%

The sand utilized for this experimental program is river sand which is available nearby and passing through 4.75 mm riddle as per necessities contained in IS 383 (1970). The specific gravity of fine aggregate was found to be 2.85. The water absorption test on fine aggregate indicated a value of 2.5%. Table 3.4 presents test results on fine aggregate.

Table 4 Properties of fine aggregate

S. No.	Properties	Values
1	Specific gravity	2.85
2	Fineness modulus	2.58
3	Water absorption	2.5%
4	Density	1754.3 kg/m^3
5	Surface texture	Smooth

2.3 Coarse Aggregate

The maximum size of coarse aggregate from stone crusher used for this investigation is 20 mm and specific gravity is 2.74. M Sand is used as fine aggregate in mix of having a nominal maximum size of 4.75 mm. The specific gravity of fine aggregate is 2.73.

Table 5 Properties of coarse aggregate

S. No.	Properties	Values
1	Specific gravity	3.05
2	Finenessmodulus	7.44
3	Water absorption	3.5%
4	Density	1813.23 kg/m^3
5	Surface texture	Smooth

2.4 Admixtures

In place of employing special cement every time for specific requirements in concrete making sometime an additive or an admixture is incorporated in cement. Most often this incorporation of different material in cement may yield the required results. Many such products are available in the market. They are collectively called chemical admixtures. Accelerators, retarders, viscosity modifying agents (VMA) and superplasticizers are some of the products that are used in the present investigation with the sole aim of comprehending the behavior of red mud concrete containing these admixtures.

III. MIX DESIGN PROCESS

IS method of mix design is based on IS 10262– 2009

Step 1

For the required characteristics strength of concrete calculated the target mean strength using the equation Target mean strength fck mean = fck + (t x s) where

fck is the required characteristic strength.

S = standard deviation which is a factor based on quality given in table

t = a statistic depending upon the proportion of low results, available in table.

Step 2

For the calculated target mean strength, the water cement ratio was found as specified in table of IS 456-2000

Step 3

Estimate the amount of entrapped air to be inspected in the concrete based on the maximum size of coarse aggregate by referring to the table.

Step 4

Calculate the amount of mixing water per m3 of concrete and the % of sand from mix design table.

Step 5

If the condition of design is different for standard condition specified in mix design table suitable corrections are to be made as per table

.

Step 6

From the chosen w/c ratio and the corrected water requirement, calculated the quantity of cement required. Check this quantity against the minimum specified in table of IS 456- 2000.

Step 7

With the known value of water quality, cement quality, air content and sand % the required quantities of sand and coarse aggregate were calculated from the following equation.

$$V = (C/Sc + W + 1/P \times fa / Sfa) \times 1/1000$$

Where

V - Gross volume of concrete – the volume of entrapped air

C - weight of cement

Fa - weight of fine aggregate

W - weight of water
Sc- specific gravity of cement
Sfa - specific gravity of fine aggregate
P - % of corrected sand
V - (C/Sc + W + 1/ (1-p) x ca / Sca) x 1/1000

Fig. 2. Red Mud on Site

Fig 3. Prepared Bricks with red mud

Concrete Mix for Preparation of Concrete

The mix ratio adopted was 1:1.462:2.695 with water cement ratio of 0.44. The measurement of materials was done by weigh batching. The red mud was used for replacing of cement at percentage intervals by weight. The red mud used for the replacement of cement was at 0%, 5%, 10%, 15%, 20% and 25% (Table 3.7). M30 grade of concrete designated by IS: 456 (2000) equivalents to BS: 8110 (1985) was designed as per IS 10262(2009).

S. No.	Specimen	Cement	Red mud
	Designation	(%)	(%)
1	CS	100	0
2	R1	98	2
3	R2	96	4
4	R3	94	6
5	R4	92	8
6	R5	90	10
7	R6	88	12
8	R7	86	14
9	R8	84	16
10	R9	82	18
11	R10	80	20

Table 6 Replacement of cement

IV. RESULT AND DISCUSSION

The value of the compressive strength of concrete was found to be the highest at the level of 15% replacement of red mud. The maximum compressive strength of concrete with 15% red mud content was 36.52 N/mm2 as against 33.02 M Pa for control concrete. The split tensile strength of cylinder was 4.61 N/mm2 with 15% red mud concrete as against 4.38 N/mm2 for control concrete. The flexural strength of prism was 4.23 N/mm2 with 15% red mud concrete as against 4.02 N/mm2 for control concrete. So, the optimum replacement level for cement by red mud was 15%. By using 15% replacement of cement by red mud, beams and joints were cast with the addition of admixtures like accelerator, retarder and VMA. All concrete mixes were prepared by adding the superplasticizer sulfonated form aldehyde polymer.

V. CONCLUSION

The maximum compressive strength of concrete with 15% red mud content was 36.52 N/mm2 as against 33.02 MPa for control concrete. The split tensile strength of cylinder was 4.61 N/mm2 with 15% red mud concrete as against 4.38 N/mm2 for control concrete. The flexural strength of prism was 4.23 N/mm2 with 15% red mud concrete as against 4.02N/mm2 for control concrete. So, the optimum replacement level for cement by red mud was 15%.

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