International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 06 Issue: 07 | July - 2022 Impact Factor: 7.185 ISSN: 2582-3930

EXPERIMENTAL STUDIES ON CONCRETE UTILIZING RED MUD AS A PARTIAL REPLACEMENT OF CEMENT WITH HYDRATED LIME

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***Abstract*—** 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. 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 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. Presence of soda in the red mud which when used in clinker production neutralizes the sulphur content in the pet coke that is used for burning clinker enrooted cement production and adds to the cement's setting characteristics. Based on economics as well as environmental related issues, enormous efforts have been directed worldwide towards red mud management issues i.e. of utilization, storage and disposal. Different avenues of red mud utilization are more or less known 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 focuses on the suitability of red mud obtained for construction. Five test groups were constituted with the replacement percentages 0%, 5%, 10%, 15%, 20% of red mud and 5% of hydrated lime with cement in each series. To achieve Pozzolanic property of red mud, hydrated lime was added. This project report points out another promising direction for the proper utilization of red mud**..**

I. INTRODUCTION

It is beyond doubt that activity of primary industries often yields substantial of byproducts. The disposal in the original industrial site is favored by economic reasons through traditional storage in nearby dumps can be impractical owing to the considerable masses involved and environment restrictions the local exploration of these by-product is therefore a growing technological accepts of basic industries and one tenable option is there reuse as starting material for other productions

The huge amount of industrial byproducts or wastes which is becoming a client for increasing environmental pollution and generation of a huge amount of utilization resources. With a view to the above, this research is aimed at finding out utilization of such things/material/industrial byproduct for value added application and also helps to solve the environment problems. The present pieces of my research work aims at, to provide a valued input/utilization to industrial by-product/waste.

The recent year, the uses of the buildings materials of different types in additional to cement become very wide in the product in the product of concrete with limestone, so it is necessary to investigated they influence of the binder material on the concrete properties. In order to access the performance of this type of concrete, it is important to understand the changes in the concrete properties especially in case of exposure to elevated.

To overcome these problems there is a need of cost effective, alternative and innovative materials. In present study, red mud is used as SCM to replace cement partially from 0% to 25% at the increment of 5%.

It is generally discharged as highly alkaline slurry (pH 10-13.5) with 15-40% solids, which is pumped away for appropriate disposal. Its chemical and mineralogical composition may temporarily change, depending on the source of bauxite and on the technological processing condition. It is composed by six major oxides namely Al_2O_3, Fe_2O_3, Na_2O_3, SiO_2, CaO, and TiO_2, and a large variety of minor elements. Its strong alkaline character (Na_2O + NaOH = 2.0-20.0 wt. %), restricts the disposal conditions in order to minimize environmental problems such as soil contamination and groundwater The red mud is one of the major solid waste coming from Bayer process of alumina production. At present about 3 million tons of red mud is generated annually, which is not being disposed or recycled satisfactorily. The conventional method of disposal of red mud in ponds has often adverse environmental impacts as during monsoons, the waste may carried by run-off to the surface water courses and as a result of leaching may cause contamination of ground water: Further disposal of large quantities of Red mud dumped, poses increasing problems of storage occupying a lot of space.

1.1BAYERS PROCESS

The Bayer's process is the principle industrial means of refining bauxite to produce alumina (aluminium oxide). Bauxite, the most important ore of aluminium contains only 30 to 54% aluminium oxide, alumina, Al_2O_3, the rest being a mixture of silica various iron oxide, and titanium di-oxide. The aluminium oxide must be purified before it can be refined to aluminium metal.

In the Bayer process, bauxite is digested by washing with a hot solution of sodium hydroxide, NaOH at 175°C. This converts the aluminium oxidee chemical equation.

$$Al_2O_3 + 2NaOH + 3H_2O \rightarrow 2NaAl(OH)_4$$

II. MATERIALS AND METHODS

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

RED MUD

Red mud is collected from MALCO (Madras Aluminium Company), Mettur. It found that the red mud possessed similar properties of cement after conducting various tests. Figure 4.1 shows the red mud used in concrete.

Red mud

HYDRATED LIME

Hydrated lime is a type of dry powder made from limestone. It is created by adding water to quicklime in order to turn oxides into hydroxides. Combined with water and sand or cement, hydrated lime is most often used to make mortars and plasters. Its chemical name is calcium hydroxide, or Ca (OH) 2. Figure 4.2 shows the hydrated lime used in concrete.

Hydrated Lime

CEMENT

Ordinary Portland cement 53 grade with specific gravity 3.15 is used for investigation. Portland cement is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar and plaster. English masonry worker joseph Aspdin patended Portland cement in 1824 it was named because of its similarity on colour to Portland limestone, quarried from the English Isle of Portland and used extensively in London architecture. It consist bof a mixture of oxides of calcium, limestone with clay and grinding this product with a source of sulphate.

FINE AGGREGATE

Locally available sand is used as fine aggregate in the cement mortar and specific gravity is 2.6

COARSE AGGREGATE

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

Fresh and clean water is used for casting and curing of specimen. The water is relatively free from organic matters, silt, oil, sugar, chloride and acidic material as per requirements of Indian standard. Combining water with a cementitious material forms a cement paste by the process of hydration. A cement paste glues the aggregate together fills voids within it, and makes floor freely.

III. MIX PROPORTION

Mix Design can be defined as the process of selecting ingredients of concrete and determine their relative proportions with the object of producing concrete of certain minimum strength and durability as economically as possible. The object of any mix proportion method is to determine an economical combination of concrete constituents that can be used for a first trail batch to produce a concrete that is close to that which can achieve a good balance between the various desired properties of concrete at the lowest possible cost.

The mix design methods being followed in different countries are mostly based on empirical relationships, charts and graphs developed from extensive experimental investigations. The various methods available are ACI mix design method, USBR mix design method, British mix design method and Indian Standard method. In this study mix design was done as per Indian Standard guidelines in IS: 10262-2009

Mix proportion

Cement	Red Mud	Fine aggregate	Coarse aggregate	W/C
1	0	1.27	2.42	0.45
0.95	0.05	1.27	2.42	0.45
0.9	0.10	1.27	2.42	0.45
0.85	0.15	1.27	2.42	0.45
0.80	0.20	1.27	2.42	0.45

- Type of Cement: The type of cement is important mainly through its influence on the rate of development of compressive strength of concrete as well as durability under aggressive environments. Ordinary Portland Cement (OPC) and Portland Pozzolona Cement (PPC) are permitted to be used in reinforced concrete construction.
- Maximum nominal size of aggregate: It is found that larger the maximum size of aggregate, smaller is the cement requirement for a particular water-cement ratio. Aggregate having a maximum nominal size of 20 mm or smaller are generally considered satisfactory.
- Minimum Water-Cement Ratio: The minimum water cement ratio for a specified strength depends on the type of cement.

IV. METHODOLOGY

RED MUD FROM

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STUDY OF PROPERTIES ON COLLECTED MATERIALS

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MIX DESIGN

↓

TESTING OF SPECIMEN

↓

COMPRESSIVE STRENGTH FOR CUBES (0%, 5%, 10%, 15%, 20%)

SPLIT TENSILE STRENGTH FOR CYLINDER (0%, 5%, 10%, 15%, 20%)

↓

Conclusion of the result

V. STRENGTH TEST CONDUCTED

SLUMP CONE TEST

This test is used to determine the workability of concrete. The apparatus is a cone of 10cm top diameter and 30cm bottom diameter and 30cm height.

It has two handles for lofting purpose. Initially the cone is cleaned and oil is applied on the inner surface. Then the concrete to be tested is placed into the cone in three layers. Each layer is compact 25times by a standard tamping rod. After filling the cone, it is lifted slowly and carefully in the vertical direction. Concrete is allowed to subside and this subsidence is called slump.

If the slump is even, then it is termed as true slump. If one half of cone slides it is called shear. If the entire concrete slides, it is called collapse. Shear slump indicates that concrete is non-cohesive and shows a tendency for segregation. Generally, the slump value is measured as the difference between the height of the mould and the average height after subsidence. Slump test is found to be the simple test and is widely used.

Slump Cone Apparatus

COMPACTION FACTOR TEST

The compaction factor is defined as the ratio of the mass of the concrete compacted in the compaction factor apparatus to the mass of the fully compacted concrete. It involves dropping a volume of concrete from one hopper to another and measuring the volume of concrete in the final hopper to that of fully compacted volume. The results of the compaction factor test can be correlated to slump, although the relationship is not linear. This test is difficult to run in the field and is not practical for large aggregates (over 1 inch) compared the slump test, the apparatus is bulky ans a balance is required to perform measurement

COMPRESSIVE STRENGTH TEST FOR CUBES

Compressive strength test is a mechanical test measuring the maximum amount of compressive load a material can bear before fracturing. The test piece, usually in the form of a cube, prism, or cylinder, is compressed between the platens of a compression-testing machine by a gradually applied load.

Brittle materials such as rock, brick, cast iron, and concrete may exhibit great compressive strengths; but ultimately they fracture. The crushing strength of concrete, determined by breaking a cube, and often called the cube strength, reaches values of about 3 tons per square inch, that of granite 10 tons per square inch, and that of cast iron from 25 to 60 tons per square inch.

Compressive strength = $\frac{load}{area}$ (N/mm^2)

Compressive strength tests

SPLIT TENSILE STRENGTH TEST FOR CYLINDER

It is standard test to determine the tensile strength of concrete in an indirect way. The compaction test is applied dramatically and uniformly along the length of cylinder until the failure of the cylinder along the vertical diameter. To allow the uniform distribution of this applied load and to reduce the magnitude of the high compressive stresses near the points of application of this load strips of plywood are placed between the specimen and loading platens of the testing machine. Split tensile strength test apparatus shown in Figure 5.3.

Split tensile strength = $\frac{2P}{\pi DL}$ (N/mm^2)

Split tensile test

VI. RESULT AND DISCUSSION

SLUMP TEST RESULT

Test results for workability of red mud concrete mix for M30 Grade

Table shows the slump test results for replacement percentage which falls in the slump range

% Replacement of cement	% of hydrated lime used	Slump value (mm)	Types of slump
0	5	25	True
5	5	25.5	True
10	5	27	True
15	5	27.5	True
20	5	29	True

COMPACTION FACTORE TEST RESULT

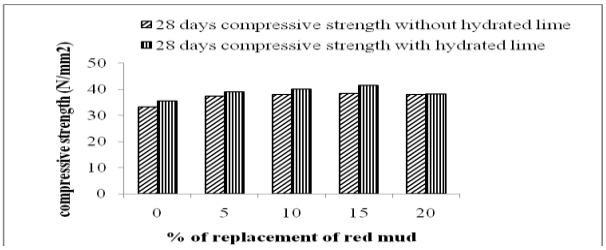
Table shows the compaction factor results for the replacement percentage shows good workability value.

% Replacement of cement	% of hydrated lime used	Compaction factor
0	5	0.85
5	5	0.87
10	5	0.89
15	5	0.92
20	5	0.94

COMPRESSIVE STRENGTH TEST RESULT

Table and Figure shows average result of compressive strength of cube at 28 days. The compressive strength results showed that the upto 15% of red mud replacement with cement gives ultimate strength.

Grade of concrete	% of red mud used	% Hydrated lime used	28 days compressive strength without hydrated lime (N/mm^2)	28 days compressive strength with hydrated lime (N/mm^2)
	0	5	33.30	35.60
	5	5	37.42	39.09
	10	5	38.12	40.20
	15	5	38.50	41.50
	20	5	38	38.20



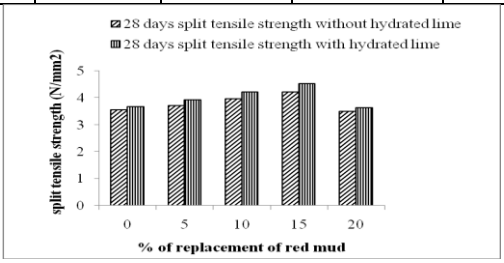
Average result of cube compressive strength.

SPLITE TENSILE STRENGTH TEST RESULT

Table and figure shows average result of split tensile trength of cylinder at 28 days. The split tensile strength results howed that the upto 15% of red mud replacement with cement gives ultimate strength

Grade of concrete	% of red mud used	% of hydrated lime used	28 days average split tensile strength without hydrated lime (N/mm^2)	28 days average split tensile strength with hydrated lime (N/mm^2)
	00	5	3.56	3.68
	05	5	3.72	3.92

	10	5	3.97	4.22
	15	5	4.23	4.54
	20	5	3.50	3.63



Average result of split tensile strength test

VII. CONCLUSION

- This study concluded that compressive strength of the concrete improved upto 17% for the replacement level of red mud with cement by 15% and 5% of hydrated lime compared to conventional concrete
- It could be said that replacement of red mud with cement improved the split tensile strength upto 23% for the replacement level of red mud with cement by 15% and 5% of hydrated lime compared to conventional concrete
- The compressive strength results of cubes and split tensile strengths of cylinder shows that the optimum percentage of replacement of red mud with that of cement was 15%and 5% of hydrated lime.
- The workability of concrete increases at all the percentage replacements containing 29% moisture content in red mud concrete with hydrated lime.
- The first crack load was taken using Two-point static load applied on all beams and at each increment of load deflection were noted. In control beam initiation of crack take place at a load of 10kN. For 5% of RM initiation of crack take place at a load of 14kN. 10% of RM initiation of crack take place at a load of 16kN. For 15% of RM initiation of crack take place at a load of 18kN. For 20% of RM initiation of crack take place at a load of 12kN.
- For higher replacement of red mud in cement (grater than 15%) the compressive and split tensile strength decreases due to an increase of free water content in the mix.

Hence the mix proportion containing 15% red mud with 5% hydrated lime is the optimum mix that can be used for costruction purposes.

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