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EXPERIMENTAL STUDY ON UTILIZATION OF INDUSTRIAL WASTE IN CONCRETE

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Abstract: **Rapid industrialization leads to the maximum discharge of waste products which in turn causing the environmental hazards. These wastes can be a substitute for conventional material, when utilized in a best way. 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. By taking cementatious behavior of the red mud into account, an experiment was carried out to partially replace the cement by red mud in concrete for different percentages and also its effects on the strength and other properties of the concrete.**

Index terms **– Industrial waste, Red Mud, Compressive Strength, Tensile strength, Slump.**

I. INTRODUCTION

Red mud is a by-product of the Bayer process, which is used for the production of alumina from bauxite. Washed and crushed bauxite is treated with a solution of hydroxide at an elevated temperature and pressure. This process brings all the recoverable alumina from bauxite into solution and the residue known as red mud. For each part of alumina produced by this process, about one part of red mud is generally discarded as a waste. In Western countries, about 35 million tons of red mud are produced yearly. Due to its caustic nature, it poses a major environmental problem. Disposal of this waste was the first major problem encountered by the alumina industry after the adoption of the Bayer process. The conventional method of disposal of red mud in ponds has often adverse environmental impacts as during monsoons, the waste may be 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.

Over the years, many attempts have been made to find a use for red mud, but none have proven to be economically satisfactory. These attempts were based mainly on the use of red mud as a partial substitute for clay in the production of bricks and other ceramic products. So far, the various uses of red mud developed includes, tiles, glazes and red mud–polymer composites panels as wood substitute, iron rich cement etc. Fundamental studies carried out for the extraction of iron oxide or titanium oxide are reported to be economically unsustainable and therefore red mud as such has been used for various applications. Red mud has also been used for catalytic hydro-de chlorination of tetrachloroethylene for the treatment of gold ores, in making silicate bonded unsintered ceramics, heavy clay products, sintered ceramics etc. In view of above, there is a great scope to evolve innovative strategy and to develop novel functional applications of red mud based materials, for effective utilization of red mud. The application of radiation technology in medicine, agriculture, nuclear reactor and other industries is increasing day by day all over the world.

Red mud, the main waste generated in aluminum and alumina production by the Bayer's process, is considered due to its high pH and discharged as high alkaline slurry. Red mud contains six major oxides named CaO, SiO_2, Fe_2O_3, Al_2O_3, TiO_2 and Na_2O and small quantities of numerous minor elements. And few of above mentioned oxides are present in cement also, hence red mud is called as a cementatious material.

II. REVIEW ON UTILIZATION OF RED MUD

A. Geotechnical Properties of Red-Mud

S.K Singh, Laljee Sahu & Dr. K.K Jain, B. H. U Institute of technology, Varanasi, has studied on the geotechnical properties of red mud.

Red mud obtained from Hindalco Industries Limited, Renukoot, U. P. has been used for their study. The properties of red mud has been used for their study were- as below

- Specific Gravity – 3.15
- Maximum dry density – 1.169 gm/cm^3
- Grain size distribution has:
  - 12 %- of clay
  - 80 %- of silt and
  - 08 %- of sand sizes
- Optimum moisture content - 25.6 percent
- Chemical composition shown that :
  Fe_2O_3 - 35%, Al_2O_3 – 19%, TiO_2 – 20%, SiO_2 – 8 %, Na_2O – 5%, CaO – 3 %, and loss of ignition- 10 %

B. Usage of Red mud in concrete

Sawant.A.B & S.G Sawant of KIT College of Kolhapur and Kumthekar. M. B of Govt College of engineering Karad in their paper entitled "Utilization of industrial waste (Red mud) in concrete" have discussed about the use of red mud in concrete. This paper covers significance of red mud over Portland cement by partial replacement of cement up to certain extent. Commercially available of normality in hydrochloric acid has been used for present neutralization process, because it enriches the silicon oxide and aluminum oxide content of red mud and it also eliminates harmful sodium oxide, in this paper M50 Grade of concrete mix

design is carried out for 7 and 28 days of compressive strength of specimen.

The decrease in initial setting time at 5% and 10% may be due to the light weight of neutralized red mud and finer particles of mud which fills the voids of the cement by which there may be increase in the density of the mix. Beyond 10% of neutralized red mud cement initial setting time increases may be due to reduction in the density of mix. The effect of replacement of cement by neutralized red mud has been studied on design mix concrete of grade M50. The water-cement ratio 0.36 is kept constant for different percentage replacement of cement by neutralized red mud. For M 50 concrete mix the optimum replacement is 15 %. It is observation that the average compressive strength decreases with increase in neutralized red mud content except for few percentage of replacement. The maximum compressive strength obtained is 60.238 N/mm^2, for pure cement concrete i.e. for 0% of replacement and minimum of 47.407 N/mm^2 with 25% of neutralized red mud at 28 days of curing period. For M50 grade concrete (0% replacement) the 28 days target strength is 58.25 N/mm^2. So from the studies carried out in this paper we are able to partially replace cement by neutralized red mud up to 15 %. From economical point of view the conventional concrete costing around 13.7 % more than the costing of neutralized red mud concrete (15 % replacement) with the nominal decrease in the compressive strength of 2.97 % than the actual 28 days compressive strength of M 50 grade concrete.

III. OBJECTIVES OF THE WORK

The experiment was carried out to overcome the problems created due to huge requirement of the raw material for manufacturing of conventional building material and also to minimize hazards caused by Indusial waste on the environment.

Some other objectives are:

- The development of alternate low-cost and environment suitable building materials from industrial wastes is an economic way.
- Importance must be given to cheap and locally available building materials and hence it is necessary to check & utilize the suitable waste products to replace some of the conventional materials.
- Current demand of cement is far in excess of production and is rapidly increasing.

By keeping the above objectives in mind the aims of present work is to check the suitability and utilization of neutralized red mud as a partial replacement of Portland cement in concrete.

IV. MATERIALS USED

A. Cement:

In this experiment 43 grade Ordinary Portland Cement (OPC) with brand name Ramco Super is used for all concrete mixes. The cement used is fresh and without any lumps. The testing of cement is done as per IS: 8112-1989. The specific gravity of cement is found to be 3.15. The physical properties of cement used are as given in table

Sl. No.	Particulars	*Experimental result	As per standard
1	Normal consistency (%)	33	28-35
2	Fineness	294 m^2/kg	Not less than 225 m^2/kg
3	Soundness		
3a)	By Le-Chatelier Expn. (mm)	1.0 mm	Not more than 10 mm
3b)	By Autoclave Expn. (%)	0.042	Not more than 0.8
4	Setting time (minutes)		
4a)	Initial	183	Not less than 30
4b)	Final	289	Not more than 600
5	Compressive strength (MPa)		
5a)	3 days	32	Not less than 23
5b)	7 days	42	Not less than 33
5c)	28 days	54	Not less than 43
6	Temperature during testing	28° C	27° C ± 2%

Table.1 Physical properties of cement

* Experimental results as per Ramco Super-43 Grade

B. 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%

C. Fine aggregate:

The sand used for the experimental program is locally available river sand and passing through 4.75mm sieve as per IS 383 provision. The specific gravity of fine aggregate is found to be 2.62. The water absorption test on fine aggregate is found to be 1.0%

D. Red mud:

The Red mud used for the replacement of cement is brought from Steel industry obtained by Bayer's process, INDALCO Belgaum. 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 1.18mm was used. The specific gravity of Red mud is found to be 2.93

V. DESIGN MIX FOR M30 GRADE CONCRETE

Grade of concrete : M30
Cement : OPC Ramco Super 43 grade
Target Strength : $f_{ck}+1.65(s) = 38.25$ N/mm^2
Cement content : 372 kg/m^3
Water/Cement ratio : 0.45
River sand content : 726.91 kg/m^3
Coarse aggregate content : 1145.64 kg/m^3
Chemical admixture : Conplast SP-430 (0.7% by weight of Cement)

Cement	Fine Agg	Coarse Agg	Water	Admixture
1	1.95	3.08	0.45	0.7%

Table. 2: Mix Design Proportions

VI. CASTING OF CONCRETE CUBES AND CYLINDERS

The test moulds are kept ready before preparing the mix. The bolts of the moulds are tightened carefully because if not kept tight the concrete slurry may come out of the mould when compaction process takes place. Then moulds are cleaned and oiled on all contact surfaces and concrete is filled into moulds in 3 different layers and 25 blows must be given to each layer. The top surface of concrete is struck off level with a trowel. The identification number and date of casting are put on the top surface of the cubes and cylinders. Casted cubes and cylinders are de-moulded after 24 hours and kept for curing.

VII. TESTS FOR CONCRETE

A. Test for Compressive strength of concrete cubes:

To calculate the compressive strength of concrete cubes the compression testing machine (CTM) having capacity of 200 ton was used. In this test the strength obtained in tons. The measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross sectional area calculated from mean dimensions of the section and shall be expressed to the nearest "N/mm^2".

Out of many tests applied to the concrete, this is the outmost important which gives an idea about all the characteristics of concrete. For cube test, two types of specimens either cubes of 15 cm X 15 cm X 15 cm or 10cm X 10 cm x 10 cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15 cm x 15cm x 15 cm are commonly used. These specimens are tested by compression testing machine after 7 days curing and 28 days curing. Load is applied gradually at the rate of 140 kg/cm^2 per minute till the specimen fails. Load at failure divided by area of specimen gives the compressive strength of concrete.

Calculations:

$$Compresive\ strength = \frac{Maximum\ load}{Area}$$

$$C_s = P/A$$

B. Test for Split tensile strength of concrete cylinders:

As the concrete is weak in tension, tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. Cracking is a form of tension failure. The usefulness of the split tensile test for assessing the tensile strength of concrete in the laboratory is widely accepted and the usefulness of the above test for control purposes in the field is under investigation. The standard has been prepared with a view to unifying the testing procedure for this type of test for tensile strength of concrete. The load at which splitting of specimen takes place shall then be recorded. The compression testing machine (CTM) having capacity of 200 ton was used to determine the split tensile strength of the concrete cylinders.

Calculations:

The split tensile strength of the specimen is calculated from the formula,

$$T_{sp} = \frac{2P}{\pi dL}$$

Where,

P= maximum load
L= length of the specimen
d= diameter of the specimen.

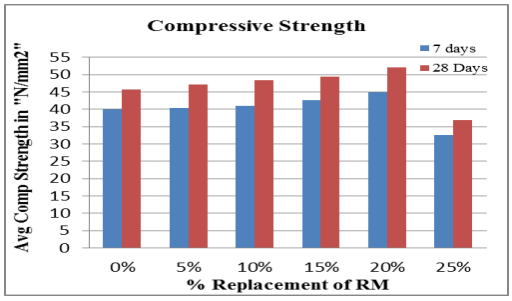
C. Test for measurement of workability:

Workability is one of the main factors to be considered as its going to affect the strength of the concrete. A workable concrete always possess a good strength. Unfortunately, there is no acceptable test which will measure the workability satisfactorily. But among the entire test Slump test is used extensively in site all over the world. Slump test consist of a frustum cone in which freshly prepared concrete to be poured then uniform blows should be given and cone is lifted with outmost care to measure the slump in millimeters.

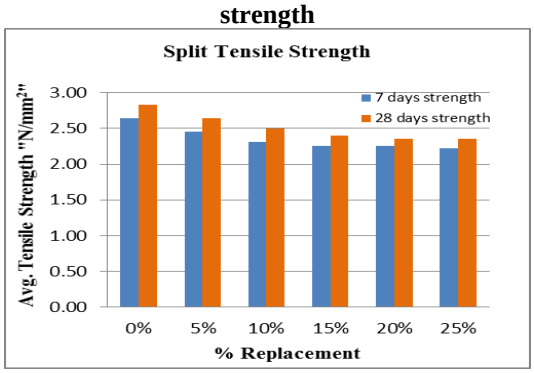
VIII. RESULT ANALYSIS

% Replacement	0	5	10	15	20	25
Cement	1	0.95	0.90	0.85	0.80	0.75
Red mud	0	0.05	0.10	0.15	0.20	0.25
7 days Comp. Strength in N/mm^2	40.00	40.44	41.04	42.67	44.89	32.44
28 days Comp. Strength in N/mm^2	45.63	47.11	48.44	49.33	52.00	36.89
7 days Tensile Strength in N/mm^2	2.64	2.45	2.31	2.26	2.26	2.22
28 days Tensile Strength in N/mm^2	2.83	2.64	2.50	2.40	2.36	2.36
Slump value in mm	65	61	60	55	51	47

Table. 3: Effect on strength and workability of concrete for different % replacement of Cement by Red mud



Graph. 1: Comparison of 7&28 days compressive strength



Graph 2: Comparison of 7&28 days tensile strength

IX. CONCLUSION

The following conclusions may be drawn from the experiment carried out for the partial replacement of cement by Red mud. It is feasible to produce cost effective concrete, possessing acceptable 7 days and 28 days strength by partial replacement, but properties of concrete strongly depends on the proportion of the ingredients. At each replacement level of cement with Red mud an increase in strength was observed with increase in age may be due to pozzalonic reaction of Red mud. Because of higher percentage of finer material, concrete obtained is more compact with smaller quantity of voids leading to higher strength.

- For each percentage replacement 2.5% to 5% increase in compressive strength is observed. But beyond 20% replacement of red mud the strength decreases.
- Split tensile strength of Red mud concrete at 7days and 28 days gradually decreases with increase in percentage replacement.
- Workability of Red mud concrete decreases with increase in percentage of replacement as compared to control mix.
- The above results show that the maximum utilization of Red mud in concrete is 20% as a partial replacement of cement.

This study concludes that Red mud can be innovative supplementary cementitious materials but judicious decision must be taken by engineers.

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