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Research Article

Effect of Partial Replacement of Crushed Fine Aggregates with an Industrial Waste (Red Mud) on Chloride Penetration of Concrete

M. P. Deshmukh[Á*], D.D. Sarode[Á] and Avijit Chaube[B]

[Á]Department of General Engg, Institute of Chemical Tech, Mumbai, India.

[B]Associated Cement companies, Thane, India.

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Abstract

Consumption of concrete, mortar and other cement based composites is over 20 billion tonnes per annum, globally. Natural sand/crushed fine aggregates(CFA) are important ingredients of concrete. Aggregates contributes 60% to 80% of the total concrete volume. The available sources of natural sand are getting exhausted because of excessive sand mining. Bulk utilisation of crushed fine aggregates is causing a great ecological imbalance of natural system. Hence there is an urgent need to explore a substitute material for fine aggregates in concrete. An inventory of about 3 billion tonnes of red mud (bauxite residue) is awaiting in stock-pilling yards for its utilization and 120 million tonnes of red mud is added every year in it. This high alkaline red mud generated during the production of allumina is posing a serious threat to the environment. An attempt is made here to substitute fine aggregate in concrete with raw red mud. For this, an experimental study is carried out by casting concrete cube moulds for 0%(control mix), 5%, 10%, 15%, 20% replacement of crushed fine aggregates with red mud. Concrete cubes are then tested for compressive and tensile strength. Rapid chloride permeability tests(RCPT) are also carried out to determine the effect of addition of red mud on durability of concrete. It is observed that addition of red mud imparts better resistance to chloride penetration. Thus, Conservation of crushed fine aggregates is achieved and a better durable and economical concrete can be produced for sustainable developments and clean technology.

Keywords: *Bauxite residue, Aggregate, Red mud, Permeability, Compressive, Tensile, Chloride.*

1. Introduction

Production of aluminium is expected to grow to over 50 million tonnes in 2015. Over 95% of the alumina manufactured globally is derived from bauxite ore by Bayer's process. Bayer's process for the production of alumina results in the production of significant amounts of dust-like, high alkaline bauxite residues known as red mud. It is one of the largest industrial by-products in modern society estimated at about 3000 million tonnes at the end of 2010 (*Power et al, 2009*) and the global inventory is growing approximately by 120 million tonnes per annum. Source of bauxite and the minerological process parameters determines the chemical and minerological composition of bauxite residue. About 1-1.6 tonnes of red mud is generated per tonne of allumina. The disposal cost of red mud is also very high (1-2% of allumina price).

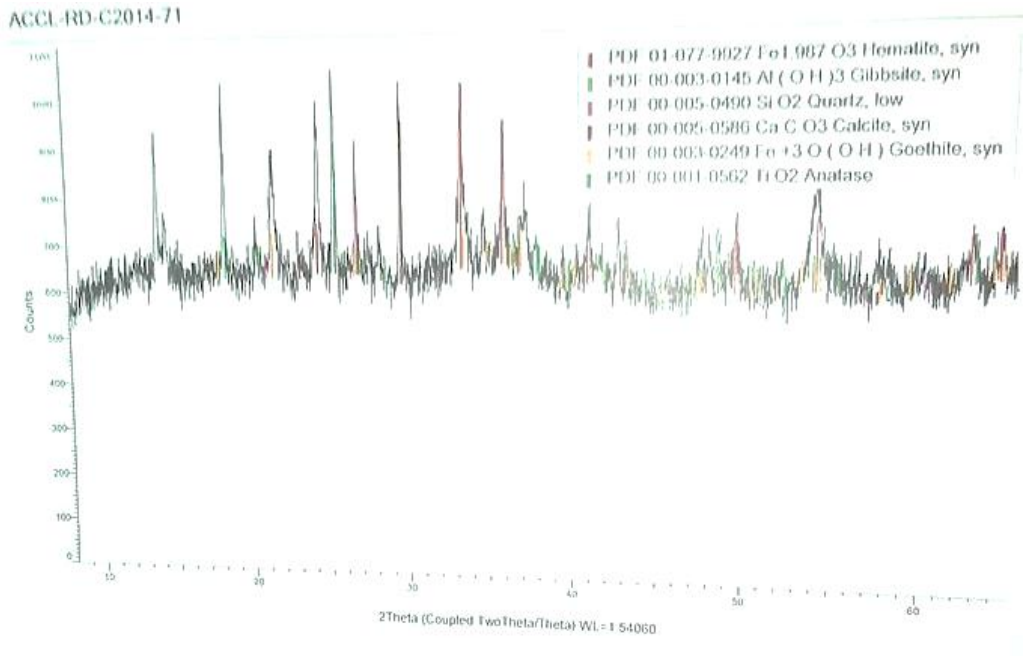
There is an urgent need to explore methods of utilisation of this high alkaline industrial waste for some constructive purpose. It is well established that red mud, as a pozzolanic material can be used in various cement and cement based composites for production of building blocks, tiles, paver blocks, bricks, precast components,etc. It is found that red mud concrete compomnents offers better resistance to chloride penetration, thus helps to improve durability of end products. Fly-ash is added to cement, as a binder material.

2. Material

The materials used in the presented research are described as the following:
Cement: 53 Grade, OPC-Associate Cement companies (specific gravity-3.15).
Red mud :Hindalco,Belgaon,Karnataka,India,(specific gravity-3.10).
Fine aggregate:CFA from Tata,Bhayenderpada,Thane with specific gravity 2.65.
Coarse aggregate: CA from Tata,Bhayenderpada,Thane with specific gravity 2.87.
Naphta based admixture 1.5%.
Fly-ash: Tata Fly-ash with specific gravity 2.89

Chemical properties of red mud checked by XRD indicates low percentage of CaO as compared to percentage of CaO in cement and gypsum. Low cementatious properties putforth limitations on the use of red mud as binder in concrete. but it is found that red mud reacts with water and cements and develops calcium

*Corresponding author **M. P. Deshmukh** is a Research Scholar; **D.D. Sarode** is working as Associate Professor and **Avijit Chaube** as Head-R&D.



XRD of red mud from Hindalco, Belgaon, Karnataka

silicate hydrate(CSH) gel that improves strength characterstics of composites. Pozzolana is aluminous and siliceous material which reacts with calcium hydroxide in presence of water. High Ferrous oxide content imparts red colour to the bauxite residue. Hence it is called red mud.The XRD of red mud from Hindalco, Belgaon, Karnataka, India are given below

Tabel 1:Chemical composition of red mud from Hindalco, Belgaon, karnataka,India

Sr.No.	Content	Percentage
01	Al_2O_3	20.5
02	Fe_2O_3	34.3
03	Na_2O	04.0
04	CaO	04.8
05	SiO_2	11.6
06	K_2O	0.17
07	Mn_2O_3	0.08
08	TiO_2	8.35
09	P_2O_5	0.32
10	MgO	0.40
11	SO_3	0.33
12	Ca_2O_3	0.15
13	LOI	15

3. Experimental Methods

Cement and Fly-ash are taken in the ratio **1:1** as a cementitios mass. Partical distribution of raw red mud to be added in concrete is carried out for better compaibility with the designed mix. Design mix of **1:3.52:3.26** is then prepared and concrete cubes of size 15cm*15 cm*15 cm are cast as per IS 516:1999.

This mix is taken as a Control mix and the cubes and beams are then demoulded after 24 hours of casting. The cubes and beams are then placed in water tanks for proper curing for specified period. The concrete cubes and beams are then tested after 3,7 & 28 days for compressive strength determination and flexural strength beams are tested at 28th day. Rapid chloride permeability tests (RCPT) is a one of the measure of durability of concrete. RCPT tests are conducted on concrete after 28 days of curing as per ASTM 1201-05.

3.1 Determination of compressive and flexural strength

Compressive strength of concrete cubes after a curing period of 3,7 and 28 days is tested in compression testing machine. Flexural strength is determined at 28 days for the beam as per IS 516:1999. Fine aggregates are then replaced with the raw red mud from Belgaon,Karnataka with of 5%,10%,15% and 20% replacement of crushed stone fine aggregates with various trials. Compressive strength and flexural strength values of concrete after 28 days determines decisive factor for its application in concrete components.

All the trials on red mud concrete are carried out at ACC lab,Thane,India.

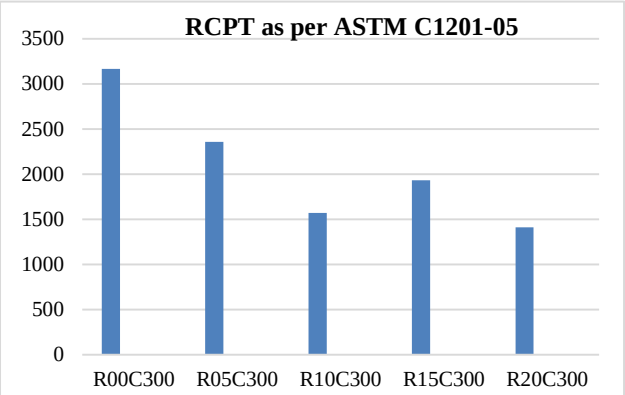
Following table indicates the compressive and tensile strength results of various trials :

Tabel 2: Compressive and flexural strength of concrete

Batch number	Symbol	3 Day Compr-essive Strenth (Mpa)	7 day Compr-essive Strenth (Mpa)	28day Compressive strength (Mpa)	28day Flexural strength (Mpa)
513	R00C300	13.33	18.67	24.33	3.8
516	R05C300	12.44	17.78	28.00	3.8
498	R10C300	09.34	14.22	19.12	3.2
524	R15C300	12.00	15.56	20.44	2.6
501	R20C300	14.22	16.89	20.00	3.0

3.2 Determination of RCPT values

In case of Reinforced concrete (RCC) components, resistance against corrosion of reinforcement is a necessity to work upon. Durability of structural component greatly depends upon preventing penetration of water, oxygen, carbon dioxide, and salts from the concrete surface to the reinforcement. The RCPT is a measurement of the electrical charge that travels between two sides of a concrete specimen during a specified period. This charge is correlated to chloride ions travelling through the pore system. Lower value indicates a higher resistance to chloride intrusion. Rapid chloride permeability (RCPT) test values are tabulated below:



4.Results and discussions

From the above experimental analysis, the compressive & flexural strength after replacement of CFA with and without raw red mud is determined to understand the effect of replacement of CFA with red mud. RCPT values are also analysed for control and varying percentages of red mud from 5-20% replacent of CFA.

Following table indicates the RCPT values :

Tabel 2: RCPT values of concrete, as per ASTM C1201-5

Batch No	Symbol	Chloride-ion penetration
513	R00C300	3166 (Moderate)
516	R05C300	2358 (Moderate)
498	R10C300	1571(Low)
524	R15C300	1931(Low)
501	R20C300	1411(Low)

Batch number 513 represents control mix 0% CFA replacement with red mud in 300 kg/m^3 of cement and fly-ash in the proportion (1:1). Batch number 516, 498, 524, 501 represents 5%, 10%, 15% and 20% replacement of CFA with corresponding quantity of red mud respectively.
It can be observed that the best results of compressive strength and flexural strength are obtained for batch no 516 (5% replacement of CFA with red mud). Even at 20% replacement of CFA with red mud , about 18% of compressive strength and 21% of flexural strength is reduced as compared to controll mix .

It has been observed that replacement of CFA in concrete with red mud in the range of 10-20 % does not have significant effect reduction of concrete strength. The compressive strength reduction is less than 20% as compared to controll mix.

Conclusions

It is clear from the above experimental results that;

Replacement of 5% of the CFA content with an industrial waste of allumina industry (red mud) improves the compressive strength of concrete from 24.33 MPA to 28 MPA Without reducing flexural strength of concrete, The RCPT values are reduced from 3166 to 2358. This is an indicative of better strength and durability of concrete.

Replacement of 20% of the CFA content with an industrial waste of allumina industry (red mud) reduces the compressive strength of concrete from 24.33 MPA to 20 MPA And flexural strength from 3.8 MPA to 3 MPA. The RCPT values are reduced from 3166 to 1411. This is an indicative of better resistance to chloride penetration.

Thus replacement of crushed fine aggregate with red mud from 5-20 % of the total CFA content in concrete gives better resistance to chloride penetration. Hence there is a scope for development of innovative concrete products such as conrete wall blocks, panels, paver blocks, chequered tiles,etc. This will also help to support the mission of Clean India by utilization of high alkalline industrial waste-red mud and at the same time it will reduce the consumption of natural resources-CFA. Cost of the end product will also be reduced with its specific applications.

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