High volume red mud composites for development of value added products in concrete industry

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Abstract: Red mud (Bauxite residue) is an industrial by-product produced in Bayer's process of production of alumina. An inventory of 3 Billion tons of high alkaline red mud is awaiting in stock-pilling yards for its bulk utilization at global level. Annual generation of 120 MTPA of red mud is putting an additional burden on the storage yards. Concrete is the largest consumable on the earth, next to water. Consumption of concrete has already crossed the mark of 20 Billion tons per annum, globally. Aggregates comprise 60% to 80% of concrete composite volume. The available sources of natural aggregates and sand are getting exhausted because of their excessive exploitation. This has caused in increasing the further exploitation of natural resources. Hence there is an urgent need to explore a substitute material for fine aggregates in concrete.An attempt is made here to substitute Crushed fine aggregate in concrete partially with raw red mud with 0 (control mix), 50, 100, 150 and 200 kg per cubic meter of concrete.Composite of high fly ash content (50% of cementitious mass) and red mud in concrete is tested for compressive strength, flexural strength, water-binder ratio and chloride permeability.

Keywords: ***Bauxite residue, red mud, crushed fines, industrial by-product, fly-ash***

1 Introduction

Alumina production was estimated to be around 45 million tons in 2011 and projected to touch 50 million tons in 2013, at global level. Over 95% of the alumina manufactured globally is derived from bauxite by Bayer process. Bayer's process for the production of alumina from bauxite ore results in the production of a significant amount of a dust-like, high alkaline bauxite residue known as red mud. It is one of the largest industrial by-products in modern society estimated at around 3000 million tons at the end of 2010 (Power et al, 2009) and the global inventory is growing approximately by 120 million tons per annum. In India, total bauxite ore consumption is 8.375 MT and annual generation of red mud is 5.5 MPTA. Red mud released in Bayer's process is highly alkaline in nature and is likely to contaminate soil and water and cause pollution.

1to 1.6 tons of red mud is generated per ton of alumina produced depending on the type of bauxite ore. The disposal cost of red mud is about 2% of the production cost of alumina. Large land areas are required for constructing stock piling yards for storage of red mud. Typical values of particle size distribution are 90 % of weight fraction is below 75 micron and specific surface area between 10-30 m^2/gm.

There is an urgent need to explore methods of utilization of this high alkaline industrial waste for some constructive purpose. The activity of utilizing a waste from one industry, converting it into a useful raw material, mixing it with other composites and using them in prescribed ways to solve a range of environmental remediation and waste problems is a reasoned example of sustainable waste management.

Concrete is composed of about 60-80% of aggregates. Due to the restrictions on the dredging of sand, large quantities of manufactured sand or crushed sand is used in mortar and concrete as a sand substitute. This involves a lot of energy and exploitation of natural resources. This necessitates an exploration of some substitutes for sand /crushed fine aggregates. There are examples in the literature that fillers may modify the properties of the hardened state as well as the properties of the fresh state of concrete. Fillers have been reported to accelerate the cement hydration in some cases. Examples of increased compressive strength also exist. This is believed to be due to a general filler effect, i.e. that the cement hydration products may grow faster and become more evenly distributed in the presence of small mineral particles.

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In addition to the general filler effect, there might be chemical effects because of high alkalinity, in some cases, pozzolanic reactions might occur.

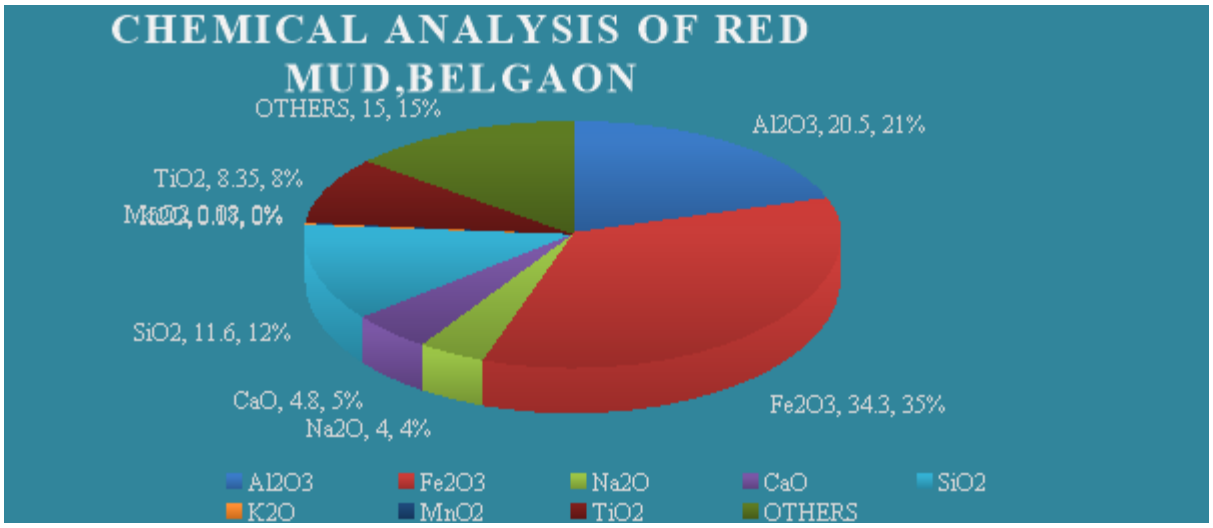

Fig.1. Chemical Analysis of Red Mud from Belgaum, Karnataka, India

2 Experimental Work

Experimental work involves designing the mix, proportioning, batching and mixing of all the ingredients in concrete. Cement (ACC 53 Grade, Fly-ash, Crushed fine aggregates (CFA), Red mud, coarse aggregates, ACC admixture 15B and water are mixed in a concrete mixer. The concrete is then tested for workability and upon having desired slump (120 mm), put into the cube and cylinder mold for casting as per IS 456:2001. At the end of 7th, 21st and 28th day of curing the cubes and beams are de-molded. The compressive, flexural, Chloride permeability is then found out. Water-binder ration is also calculated for each trial.

2.1 Determination of Compressive and Flexural strength of concrete

Control mix (without red mud) for 450 cementitious mass is prepared. Concrete cubes of size 15 cm x 15 cm x 15 cm are cast and cured as per IS 456:2001. Keeping rest of the composition constant and replacing crushed fines from control mix with red mud in 50, 100, 150 and 200 kg/m3, various trials are conducted. Compressive strength of cubes at 3, 7 and 28 days is tested in compression testing machine. Flexural strength determination is carried out on beam of size 70 cm*15cm*15cm after 28 days of curing of concrete are given in table 1.

2.2 Determination of RCPT values

In case of Reinforced concrete (RCC) components, resistance against corrosion of reinforcement is a necessity. Durability of structural components 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. RCPT Values given in table 1

2.3 Determination of water binder ratio in concrete

Fly ash is taken as 50% of the total cementitious mass in all mixes for all the trials. Water-binder ration is worked out for the composite ant values are given in table 1.

3 Results and Discussion

It can be observed from the results in 450 cementitious compositions that early strength development values of compressive strength of concrete are higher in all the trials from 12 to 15 as compared to the control mix with a maximum value of 28.44 MPA for trial no 14. Compressive strength after 28 days found to be in the range of

42.23 MPA to 52.45 MPA with the lowest value for trial no 13 and highest value for trial 11. Rapid chloride penetration resistance value was found to be lowest in trial no. 14 and highest in trial no. 11.
Compressive, flexural and rapid chloride penetration value indicates that the fineness of red mud avails more surface area for interface in concrete mass. High Alkalinity of red mud acts as accelerator (reactingagent/activator) and high specific gravity of 3.10 add to the strength characteristic of concrete. Even the water-binder ration is not altered much with the varying percentages of replacement of crushed fine aggregates with red mud.

Table 1 Comparison of Water-Binder Ratio, Compressive strength, Flexural Strength and RCPT values

Trial no	Water/Binder ratio	Red Mud (Kg/m^3)	3 day CS (MPa)	7 day CS (MPa)	28 day CS (MPa)	28 day FS (MPa)	RCPT
11	0.389	00	21.33	28	52.45	4.83	1773
12	0.387	50	22.22	28.45	49.78	5.12	1719
13	0.361	100	24	32	42.23	5.20	1152
14	0.385	150	28.44	33.56	51.12	5.42	945
15	0.385	200	22.22	28	33.78	3.90	1350

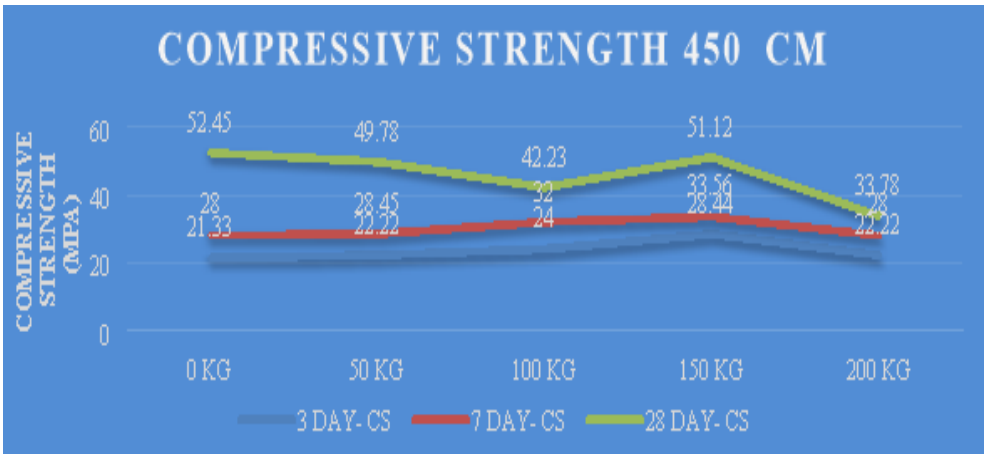

Fig. 2. Comparison of Compressive strength for 3, 7 and 28 day

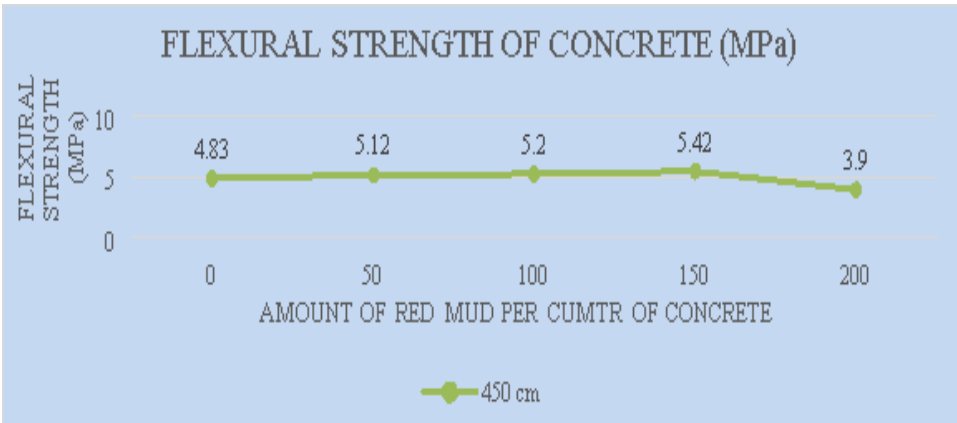

Fig. 3. Comparison of Flexural strength for 28 day curing period with concrete mixtutes having different quantities of Red Mud and cementitious mass

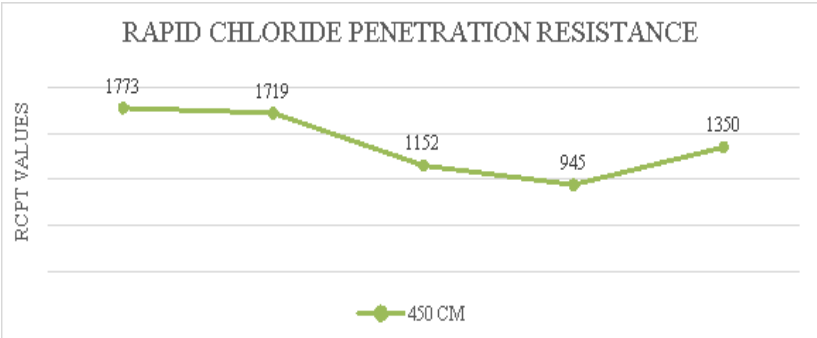

Fig. 4. Comparison of RCPT values for different compositions of concrete mixtures

4 Conclusions

It can be concluded that an industrial waste product from alumina industry, Red mud, can be utilized for replacement of crushed fines in concrete without affecting strength parameters. It also helps to improve the chloride ion penetration resistance of concrete. Bulk utilization of red mud will resolve the environmental pollution and sustainability issues. It will also help in conservation of natural resources and conversion of waste into wealth. High volume fly ash (225 Kg/cum) and Industrial waste from alumina industry –bauxite residue aka red mud (150 kg/cum) together helps to improve strength characteristic. It also promotes conservation of natural materials such as crushed fine/ manufactured sand, fines etc. utilization of highly alkaline fine grained industrial waste from bauxite processing industry -red mud helps in reducing the land, water and air pollution and supports mission-clean India.

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