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Review on Red Mud Concrete and its Structural Applications

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***Abstract*- The population growth rate is being increased day by day as well increasing the needs of people, which leads to the development of a lot of new industries. Solid wastes from the industries make serious environment issues. Red mud is one of the solid wastes obtained from aluminum industry. 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.**

INTRODUCTION OF RED MUD

Red mud is the composed of a mixture of solid and metallic oxide-bearing impurities, and presents one of the aluminium industry's most import disposal problems the red mud 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 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.

RED MUD

COMPOSTION OF RED MUD

Components	Al2O3	Fe2O3	SiO2	TiO2	CaO	Na2O
Weight %	20-22	40-45	12-15	1.8-2.0	1-2	4-5

LETERATURE REVIEW

INTRODUCTION

Extensive research on the production of cement using waste materials such as fly ash (FA), lime, red mud and gypsum as raw materials has been carried out over the years. Utilization of red mud in the production of cement not only diminishes its energy consumption but also enhances its early strength and resistance to sulphate attack. This chapter presents a review of literature pertaining to production of concrete using industrial and agricultural wastes including red mud obtained from aluminium industries.

RED MUD AS POZZOLAN

Waste materials that are commonly used for replacing cement are kaoline, Ground Granulated Blast Furnace Slag (GGBFS), fly ash (FA), rice husk ash (RHA), etc. Along with these, one more waste material from the industry, namely, red mud is also available as pozzolan. This waste is a result of the Bayer process of the extraction of aluminium from bauxite ore. This process is characterized by low energy efficiency (Balomenos et al. 2011). The global production of red mud is 117 million tonnes per annum (Kumar &Nayak 2015). The colour and name of this waste are derived from its iron oxide content. Generally, for every 3 tonnes of bauxite approximately 1 tonne of alumina is generated. Besides, from every 2 tonne of alumina about 1 tonne of aluminium is attained. According to Metilda et al. (2015), approximately, 0.3 – 1.0 tonne of red mud is created for every tonne of alumina produced. Globally, less than half of the red mud produced by aluminium industries is consumed and the remaining quantity is dumped in landfill (Rout et al. 2012).

The conventional method of depositing red mud in ponds is a real reason for adverse environmental degradation. The reason for this is that during monsoon the waste is normally carried by surface run off. This causes contamination of ground water (Sawant et al., 2013). Therefore indiscriminate disposal of such an enormous quantity of waste is a serious problem to the society and environment. In addition to this, the issue is further complicated by the fact that bauxite is normally subjected to sodium hydroxide treatment. Because of this reason red mud becomes highly caustic with pH ranging 10.5– 12.5. Therefore red mud becomes an environmental hazard. A way of cleaner disposal of red mud is to convert it into useful building material. The red mud is generally divided into Bayer red mud and Sintering red mud. This division has been done on the basis of the grade of bauxite and the method of production of alumina. Properties such as physical and chemical specific to red mud are determined by diverse morphology and structure of Bayer red mud and Sintering red mud. Therefore, it is essential for the purposes of comprehensive usage of Bayer and Sintering red mud separately to distinguish between the main characteristics such as chemical characteristics, mechanical operations, particle, morphology and structure (Wang & Liu 2012).

REVIEW OF RESEARCH ON APPLICATION OF RED MUD

Utilization of different categories of industrial wastes in the preparation of concrete to conserve the natural resources and to stop environmental degradation has been presented as a review by Sakthieswaran & Ganesan (2013). One of the highlights of this review is the use of red mud and chromium in the production of concrete. These wastes were incorporated in the concrete at 5%, 10%, and 15% by weight of cement. The compressive strength of concrete containing 5% of red mud and 5% of chromium together in concrete was equal to that of the control concrete. It was also observed that setting time of 5% red mud was found to increase when replacement level increased. One of the ways of disposing off red mud is to replace cement partially with percentages of red mud. So bulk utilization of red mud in concrete will reduce the quantities that go into the landfill surrounding the alumina industries. It would also conserve natural resources to support sustainable development.

The aim of the research conducted by Rathod et al. (2014) was to investigate the possibility of replacing the Portland cement with red mud. It has been observed that dumping of the waste in landfill negatively affects the environment. A solution to this problem has been found out by which Portland cement was replaced with red mud up to 40% by weight of cement. By the testing of the red mud concrete the authors evaluated the strength of concrete under compression and splitting tension. This exercise investigated the effects of red mud on the properties of hardened concrete. The test results indicated how its strength under compression and splitting tension diminished with the increase in red mud content. It was concluded from this investigation that optimum percentage of the replacement of cement with red mud by weight was found to be 25%. With such replacement percentage it was possible to obtain the strength of red mud concrete equal to that of controlled concrete.

Because of the higher content of fine material, concrete with red mud is more compact with smaller quantity of voids leading to greater strength. This is according to Bishetti & Pammar (2014) who have observed augmentation in the compressive strength for every percentage replacement level of 2.5% to 5%. However, it was observed that the strength decreased beyond a replacement of 20% of red mud. Strength in split tension of concrete containing red mud at 7 days and 28 days decreased gradually with an increase in percentage of replacement. Further, when compared to control concrete, workability of red mud concrete diminished with the addition of more quantity of red mud to concrete. In conclusion the authors have stated that the maximum limit of utilization of red mud in concrete was 20%.

Concrete and mortar cubes were cast by Vandhiyan & Ramkumar (2014). This is achieved by replacing cement with red mud in concrete and mortar. With these replacements, properties of concrete like compressive strength, consistency, and setting time were determined. From this investigation the authors have concluded that red mud could be used in the preparation of mortar and concrete for application to non-structural works.

Sawant et al. (2012) have stated that optimum utilization of neutralized red mud (NRM) in concrete was 15% as a partial replacement of cement.

Experimental studies were conducted by Ashok & Suresh Kumar (2014) who used red mud as a fractional substitution of cement with hydrated lime to enhance the pozzolanic activities of red mud. The authors constituted five test groups with percentage replacement of 0, 5, 10, 15, and 20 of red mud and hydrated lime percentage of 5 with each series and have observed that it did not affect the cement quality, rather improved compressive strength. Further it was concluded that replacement of 20% OPC (Ordinary Portland Cement) by calcined red mud was possible. Calcination of red mud at 700°C led to a pozzolanic material mainly reactive at early ages.

Mortar cubes were cast by Rana & Sathe (2015). They used cement with varying percentages of replacement of red mud with the addition of lime. The authors followed the same procedure for silica to find the optimum red mud replacement with addition of either lime or silica. First, mortar cubes were cast with varying percentages replacement of red mud. The red mud fractions in the mortar were 0%, 10%, 15%, 20% and 25% with the addition of lime by weight of red mud of 0%, 4%, 8% and 12%. The 7th day compressive strength of the mortar was measured by testing in the UTM (Universal Testing Machine) as per IS: 516 (1959). Afterwards, mortar cubes were prepared with varying red mud replacement such as 0%, 10%, 15%, and 20% with addition of lime by weight of red mud 0%, 10% and 20%. The 7th day compressive strength was determined by testing. These results were scrutinized to get the optimum red mud content.

From the collection of these test results it was inferred that replacement of 10% red mud with 20% silica by weight of red mud could be added effectively in concrete without compromising the strength. Further it was deduced that the cost of cement in concrete could be decreased by 6.43%resulting in economy. After conducting a few more tests the authors have suggested the future possibilities of using red mud as a partial 27 replacement in concrete in important R.C.C. works such as buildings, dams, pavements, etc. They have also found out various other parameters about this optimized concrete.

Subsequently the same authors cast control concrete cubes and cylinders using M30 grade concrete using only cement having ratio 0.553: 1; 2.325: 2.87 as per the mix design procedure for concrete and tested the concrete for 28 days strength. Then they cast concrete cubes and cylinders with optimized red mud with addition of lime or silica. The authors tested the specimens at 28 days and 90 days to evaluate the strength. They compared it with the controlled concrete. Also, cost analysis of this optimised concrete was examined.

The red mud used in the experiment conducted by Kushwaha et al. (2013) for the development of self compacting concrete was obtained from Hindustan Aluminium Company (HINDALCO), Belgaum. The fineness of red mud was 35 m2 /gm and its particle size was 75 m. Its density was 3 gm/cc. A Viscosity Modifying Admixture (VMA) GLENIUM STREAM 2 was added to the concrete to speed up its flow without segregation. GLENNIUMTM SKY 784 was also used in the experiment. The cement, sand and coarse aggregate were weighed in the ratio of 1:1:0.5. The ratio of FA to cement used was 1:3.5. The percentages of red mud added were 0, 1, 2, 3, 4, 5, 6, 7, 8, 10, 12, 15, and 16. With the dry mix, a 33% of water was added. The VMA was added at the rate of 100 ml/100 kg of cementitious materials. The authors have observed that the compressive strength of SCC produced with the combination of admixtures of SP and VMA increased up to 2% with the addition of red mud. The percentage enhancement in compressive strength at 2% addition of red mud was + 0.11. The optimum percentage of addition was found to be 2 with the combination of SP and VMA.

Effect of red mud and iron ore tailing on the strength of SCC was studied by Shetty et al. (2014). This investigation was carried out with partial replacement of cement by red mud and sand by iron ore tailings. Red mud was used at 1%, 2%, 3% and 4%. For each level of red mud replacement, 10%, 20%, 30%, and 40% of fine aggregate consisting of river sand was replaced with Iron Ore Tailings (IOT). Experimental investigation was conducted on these concretes and determined the strength in compression, split tension and flexure. It was observed that the compressive strength obtained for all mixes was greater than that of the control concrete. The maximum strength in compression, split tension and flexure was obtained at a replacement of 2% red mud and 30% IOT.

Effect of replacing a part of the cement binder with red mud in concrete on the hardened properties such as strength and shrinkage was investigated by Tang (2014). An examination of the influence of the addition of red mud on the characteristics of cement mortars without previous calcination treatment that demanded less energy along with time and less costs in terms of setting time, pozzolanic activity and changes in mechanical strength was reported by Ribeiro et al. (2011). An attempt was made by Sawant et al. (2011) to check the effectiveness of NRM as a partial replacement of Portland cement.

Red mud as a partial substitute for fine particles in concrete was attempted by Deshmukh&Sarode (2014). Therefore concrete cubes were cast with 0%, 7%, 14%, 21%, and 28% replacement of fine particles in concrete with red mud. From this investigation it was found that this red mud concrete gives better compressive strength.

Brick from red mud was developed by Bhaskar et al. (2014). Among the various systems examined red mud based bricks have shown lighter compressive strength.

CONCLUSION

In the first part, utilization of red mud as a partial replacement of cement has been emphasized. Literature concerning this aspect was reviewed and a case has been made out as a supplementary cementitious material. This has been enlightened with literature evidence.

UTILIZATION OF WASTES IN CONCRETE MAKING

As stated in section 1.1 concrete is a popular and versatile material of construction. However, its ingredients are mostly drawn from nature. Quarrying these materials from natural resources leads to their depletion and also causes strain in the environment. This is not advisable. To achieve sustainable construction the 3 Rs have to be followed. They are: reduce, reuse and recycle. From this point of view, in the present scenario, wastes generated by industries and agriculture as well as other sources are available in abundance. They are simply dumped in landfills causing pollution of soil, water and air. Such wastes can be converted into useful building materials by using cleaner technology.

FLY ASH AS CEMENT SUBSTITUTE

A review pertaining to the current practice of preparing construction materials from industrial wastes such as FA, silica fumes, red mud, and copper slag has been presented by Ramesh et al. (2014). The authors have reported that industrial wastes are turned into valuable building materials to reduce the environmental pollution. Experimental investigation was conducted by Deotale et al. (2012) on the outcome of fractional substitution of cement by Rice Husk Ash (RHA) and FA in concrete. The authors have concluded that the strength of the concrete under compression improved up to a substitution level of 75% RHA and 22.5% FA of cement in concrete. Influence of mineral admixtures on compressive strength and water permeability of concretes containing fly ash (FA), silica fume (SF) and super pozza was experimentally investigated by Elsayed (2011). Permeability of concrete was determined according to DIN 1048 (Part 5). The research variables included cement type, ordinary Portland cement (OPC) or high slag cement (HSC), and mineral admixtures used as a partial cement replacement. They were incorporated into concrete at percentages of 5, 10 and 15 for silica fume and 10, 20 and 30 for fly ash or super pozza by weight of cement. Water-cement ratio of 0.40 was used. Tests were carried out at 28 days. From the tests, the lowest values measured in respect of water permeability were pertaining to the 10% super pozza and 10% silica fume or 20% fly ash mixes. The highest values of compressive strength of concretes determined was for 10% silica fume mix with ordinary Portland cement and was reduced with the increase in the replacement ratios for other mineral admixtures than ordinary Portland cement concrete. The main purpose of this work was to establish the water permeability and compressive strength of concrete to achieve the best concrete mixture having lowest permeability. The results were compared to those of the control concrete; ordinary Portland cement concrete without admixtures. The optimum cement replacement by FA, SP and SF in this experiment was 10% SP. The knowledge on the strength and permeability of concrete containing fly ash, and high slag cement could be beneficial in the utilization of these waste materials in concrete making, especially concerned with the durability.

CONCLUSION

Making concrete with the combination of Red Mud and cement with different percentages gives good results compared to control concrete. So the best way to use these materials is in combination.

Due to environmental issues in the production of cement, industrial by products like Red mud are used as supplementary materials in concrete and it saves cost of production of concrete, and makes it eco-friendly.

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