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DEVELOPMENT OF RED MUD CONCRETE

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ABSTRACT

Cement is an important ingredient and a binder in the manufacturing of concrete. But its production releases a large amount of CO_2 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. Experimental investigation was conducted in which cement was replaced with red mud in percentages of 0, 2, 4, 6, 8, 10,12, 14, 16, 18, and 20 while manufacturing concrete by weigh batching. The compressive strength increased with the increase in the percentage of red mud attaining a peak value at a replacement percentage in the preparation of concrete calcium chloride was added as an accelerator to hasten hardening of concrete. In another batch of concrete retarder was added to delay setting of concrete. For producing concrete with enhanced viscosity and controlled geological properties Gleniumstream 2 admixture was added in a separate batch of concrete to improve its stability and control its bleeding characteristics to increase the resistance to segregation and facilitating placement. Sulphonated naphthalene form aldehyde polymer (superplasticizer), a water reducing admixture (superplasticizers), was added to all concrete mixes in this investigation. Different admixtures were tried in concrete to understand their influence on hardening and strength gaining of concrete especially when red mud is added in the preparation of concrete. Load was applied gradually in increments on the specimens with the help of hydraulic cylinders in increments till the specimens failed. For each load increment deflection and strain readings were recorded. Cracks as soon as they formed were marked and their propagation was also monitored. The ultimate load sustained by each element was recorded. Load-deflection relation was plotted. The behavior of beams prepared with conventional and red mud concrete was identical. Among the joints the behavior of joint was better than the other joints with higher load capacity and ductility.

Keywords: Concrete, cement, red mud, partial replacement, compressive strength, structural applications, testing.

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I. INTRODUCTION

Concrete is the most versatile man- made construction material in the world and is being extensively used in all types of construction activities. The strength, durability and other characteristics of concrete depend upon the properties of its ingredients, the mix proportions, the method of compaction and other controls during placing, compaction, and curing. In the preparation of concrete, cement is an important ingredient which binds crushed stone and river sand in the presence of water. Over the years concrete has gained popularity as it can be prepared at site with local materials and cast in any desired shape and size. Initially, it is in fluid state and hardens with time gaining strength simultaneously while curing with water. At 28th day of its casting its strength, especially compressive strength, is evaluated.

This is an important parameter in judging its performance. The two important components are Quality and Solidness that choose its load carrying capacity. For this reason, waste materials obtained from industries and agriculture are integrated in the concrete as fractional replacement of cement. These are called supplementary cementitious materials having pozzolanic properties. The function of pozzolan is to neutralize the unstable calcium hydroxide released during hydration of cement. Otherwise, it will escape from the body of concrete leaving pores though which oxygen and moisture will ingress and attack reinforcing steel causing its corrosion. It is more imperative to prevent this to ensure long service life of the structures. The advances in concrete technology have paved the way to make the best use of locally available materials by proper mix proportioning and workmanship to produce a strong, durable, and uniform concrete.

The requirement for leading a proficient life is challenging for the rapid development of industries and they partially fulfil their tasks since many factors are not overcome by them successfully and one of that is safe disposal and utilization of waste generating at the end. The waste of aluminum industry known as red mud or bauxite residue is discharged when alumina is coming out from bauxite. During the most feasible Bayer process alumina is extracted from bauxite at elevated temperature and pressure with the presence of sodium hydroxide. Red mud generation is depending upon the type of bauxite used in industry. About 1.2-1.4 tons of red mud is generated per each ton of alumina produced. Each year, 75 million tons of red mud is produced worldwide. The iron compounds present in it confers the red color to it and hence it is called red mud.

The problem with the red mud is that it is toxic by nature. The chemical analysis conducted on red mud reveal that it contains silica, aluminum, iron, calcium, titanium, as well as an array of minor constituents, namely: Na, K, Cr, V, Ni, Ba, Cu, Mn, Pb, Zn etc., because of the harmful chemical composition present in it but the major problem of red mud is it is caustic in nature as the alkalinity is very high. The pH value of red mud is varies from 10.5 to 13. This waste is usually managed by discharge into engineered or natural impoundment reservoirs, with subsequent dewatering by gravity-driven consolidation and sometimes followed by capping for closure. Due to the alkaline nature it neither is used for construction material nor for vegetation.

The environmental trouble linked with the disposal of red mud waste includes:

- The high pH (10.00-13.00).
- Contamination of underground water due to alkali seepage.
- Storage of red mud is not stable.
- Alkaline air effect to plant life.

Fig 1. Discharge of Red Mud as Slurry into the Pond

II. LITERATURE REVIEW

2.1 Utilization Of Wastes in Concrete Making

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 aluminums industries.

As stated, 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 causes strain in the environment. This is not advisable. To achieve sustainable construction the 3 R’s must be followed. They are reduced, 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.

The wastes currently available and used are industrial, agricultural, and biological. The industrial wastes are red mud, fly ash, ground granulated blast furnace slag (GGBFS), waste, wood wastes, coconut shell, coral shell, fly ash aggregates, etc.

2.1.1 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 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. 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.

The effect of micro silica, a water proofer and super plasticizer, on the durability of concrete to phosphoric acid attack, in addition to their sole and combined effects on workability, air content, modulus of elasticity, durability to freezing thawing, compressive strength and modulus of rupture after 28 days was investigated. Contents of different micro silica, water proofer and super plasticizer, considered were 10%, 15% and 20% by weight of cement for micro silica, 0.4, 0.6 and 0.8 L for water proofer and 0.15, 0.2 and 0.25 L for super plasticizer. The water to cement ratio was constant in this study. The degree of acid attack was evaluated by measuring the percentage changes in weight of concrete cubes. The results showed that the combined effect of micro silica and water proofer was the best to enhance the durability of concrete to phosphoric acid attack without major effect on the response of concrete to other factors. The optimum concrete mixes were 10% micro silica with medium portions of water proofer.

The new Concrete Society Publication, Cementitious Materials, CSTR74, covers the effects of cementitious materials such as blast furnace slag (GGBS), fly ash (FA), limestone fines and silica fume (micro silica) on the properties of concrete. In this connection King (2012) focuses on the effects of silica fume on the main properties of concrete in the fresh and hardened state as defined in the publication.

2.1.2 Special Concretes from Waste

An experimental analysis was conducted by Vanitha & Thandavamoorthy (2014) to verify the outcome of sugar cane bagasse ash (SCBA) when used as cement substitution material on the durability of concrete to sulphate attack. The cement was replaced by SCBA up to 10% by weight of cement with the addition of steel fiber. The w/c ratio adopted was 0.4. The mechanical test was carried out with the different ratios of 0%, 10%, 20% and 30% replacement level by weight of cement with bagasse ash. The optimum results obtained was obtained for compressive strength, split tensile and flexural strength at 10% replacement level. Therefore, with the best replacement level, bagasse ash concrete with and without steel fiber was used. To perform durability tests at 30, 60, 90, and 180 days.

To study the behavior of SCBA steel fiber reinforced concrete in HCL, MgSO4 and NaOH. The specimens were cast and cured in normal water for 28 days initially and then immersed in 3% HCL, 3%MgSO4 and 3% NaOH solutions for 30, 60, 90 and 180 days. The resistance to chemical attack was evaluated by measuring the weight loss and compressive strength. The results show that the use of bagasse ash steel fiber significantly enhances the durability concrete.

2.1.3 Waste as A Substitute for Fine Aggregate

Experimental investigations were carried out by Aggarwal et al. (2007) to study the influence of bottom ash which is the coarser material that falls into furnace bottom in modern large thermal power plants and constitute about 20% of total ash content of the coal fed in the boilers as a replacement of fine aggregates. The strength properties studied consisted of compressive strength, flexural strength and splitting tensile strength. The strength development for various percentages, i.e., 0 - 50% replacement of fine aggregates with bottom ash can easily be equated to the strength development of normal concrete at various age.

Various industrial waste materials like quarry dust, glass powder, ceramic dust and coal dust are used as partial replacement of fine aggregate and assessed the strength parameters and compared the profit percentages after replacement with waste materials. According to the study parameters, replacing 10% cement with SF and 30% fine aggregate with glass powder is the best choice for optimum strength. Moreover, the utilization of glass powder and silica fume together significantly reduces the workability and water absorption of the composite concrete mixture.

2.1.4 Waste as A Substitute for Coarse Aggregate

The experimental investigation presents the feasibility of making concrete using ceramic waste as a coarse aggregate at 25, 50, 75, 100 per cent replacement of crushed stone in conventional concrete. The mechanical and durability properties of this ceramic waste concrete were evaluated by casting specimens and testing them. The compressive strength of ceramic waste concrete with 25 per cent replacement of crushed stone aggregate was 27.80 per cent higher than conventional concrete. There was a decrease in split tensile strength of the corresponding concrete by 19.43 per cent. The flexural strength of the same concrete was observed to increase by 16.12 per cent. The weight loss due to acid attack of 25 per cent replacement of ceramic waste concrete at 30 days and 60 days were such a low value of 2.1 and 2.7 per cent, respectively, and hence durable.

It is observed that the compressive strength of concrete is found to be 20.35 % higher when coarse aggregate is replaced by 15% with two sizes of E-waste material. The flexural strength of concrete beam is found to be 15.69 % higher when coarse aggregate is replaced by 15% with two sizes of E-waste material. 20% of E-plastic waste can be used for the replacement of coarse aggregate.

2.1.5 Recycling of Aggregate and Addition of Fibers

According to Cherian & Praveen (2014) the subject of concrete recycling is regarded as very important in the general attempt for sustainable development in the present times. In a parallel manner, it is directly connected with increase of demolition structures demand for new structures and reduction of landfill. This paper by the authors reports the results of an experimental study on some of the properties of recycled aggregate concrete (RAC) as compared to those of the conventional concrete. The results were compared with natural aggregate concrete and recycled coarse aggregate concrete with cement content of 380 kg; natural coarse plus recycled fine aggregate concrete and recycled coarse aggregate plus recycled fine aggregate concrete for a cement content of 380 kg and natural aggregate concrete and recycled coarse aggregate concrete with cement content of 370 kg. Recycled aggregate could be used extensively for different works as the test results indicated that test parameters obtained from different sources are in acceptable range. The extensive use of recycled aggregate concrete thus presents a vital solution to the many problems faced by construction industry and makes the environment greener.

2.2 Red Mud as Pozzolan

Waste materials that are commonly used for replacing cement are kaolin, 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 aluminum from bauxite ore. This process is characterized by low energy efficiency. The global production of red mud is 117 million tons per annum (Kumar &Nayak 2015). The color and name of this waste are derived from its iron oxide content. Generally, for every 3 tons of bauxite approximately 1 ton of alumina is generated. Besides, from every 2 tons of alumina about 1 tons of aluminum is attained. Approximately, 0.3 – 1.0 tons of red mud is created for every ton of alumina produced. Globally, less than half of the red mud produced by aluminum industries is consumed and the remaining quantity is dumped in landfill.

2.2.1 Gap in Research

After a review of literature concerning the research relating to the use of red mud in concrete it has been identified that only basic issues have been addressed and research regarding red mud concrete for structural application is scanty. Hence the objective of the thesis is to formulate proposals in such a manner as to conduct detailed experimental investigation on the development of red mud concrete with accelerator, retarder, individually; evaluation of properties of these concretes; to find out the optimum replacement level of red mud.

III. CONCLUSION

The maximum compressive strength of concrete with 15% red mud content was 36.52 N/mm2 as against 33.02 MPa for control concrete. The split tensile strength of cylinder was 4.61 N/mm2 with 15% red mud concrete as against 4.38 N/mm2 for control concrete. The flexural strength of prism was 4.23 N/mm2 with 15% red mud concrete as against 4.02N/mm2 for control concrete. So, the optimum replacement level for cement by red mud was 15%.

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