A Review on Utilization of Waste Red Mud in Concrete

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Abstract- Red mud is an industrial waste material generated during production of alumina from bauxite by Bayer Process. These Industrial waste hold some heavy aim of the paper is to study the compressive strength according to the age of the concrete structure using ultrasonic pulse velocity method. If the correlation between the ultrasonic pulse velocity and compressive strength according to the age is derived the compressive strength of early age of the concrete structure can be estimated at the new construction site and the compressive strength of the existing structure can be estimated at the remodeling construction site. The estimation equation confirmed that it is possible to estimate the compressive strength of concrete according to its age using nondestructive test methods.

Index terms: Alkali – activated slag cement, Compressive strength test, Red mud, Split tensile test, Ultra pulse velocity.

I. Introduction

Red mud is a waste material generated by the Bayer Process widely used to produce alumina from bauxite throughout the world. The aim of the present research work was to investigate the possibility of replacing the Portland cement by red mud.

The red mud is the main waste generated in aluminum and alumina production by the Bayer process from bauxite ore. Bauxite mines are located in three main climate regions: the Mediterranean, Tropical and Subtropical. World production of bauxite in 2008 was 205 million ton, and the main producing countries were Australia, China, Brazil, Guinea, India and Jamaica. Occupying the 3rd position in the world ranking in 2008, Brazil produced 26.6 million tons of bauxite. It also has the world's third largest bauxite ore reserves (around 3.5 billion tons), mainly concentrated in the north of the country (Pará state).

Red mud is an alkaline waste generated during ore leaching conducted to remove soluble impurities. It is generally classified as "hazardous" (class I), according to the Brazilian NBR 10004 standard. Roughly 0.3 – 1.0 tons of red mud waste are generated for each ton of aluminum produced. About 10.6 million tons of caustic red mud must be disposed annually during recent years in Brazil and world while generation reaches over 117 million tons/year. It is generally discharged as highly alkaline slurry (pH 10-13.5) with 15-40% solids, which is pumped away for appropriate disposal. Its chemical and mineralogical composition may temporarily change, depending on the source of bauxite and on the technological processing conditions. It is composed by six major oxides namely Al_2O_3, Fe_2O_3, Na_2O, SiO_2, CaO, and TiO_2, and a large variety of minor elements. Its strong alkaline character (Na_2O + NaOH = 2.0 – 20.0 wt %), restricts the disposal conditions in order to minimize environmental problems such as soil contamination and groundwater pollution.

II. Literature Review

Bayan, Al-Nu'man et. al. (2015) [1] the research paper investigated the relationship between the ultrasonic pulse velocity (UPV) and the compressive strength of concrete. The specimens used in the study were made of concrete with a varied cube compressive strength from 18 to 55MPa. Number of specimens was over 800 received from various construction projects of controlled concrete quality and tested by the Hawler Construction Laboratories (HCLabs) in Erbil, Kurdistan Region of Iraq, during the last half of 2014. The UPV measurement and compressive strength tests were carried out at the concrete age of 28 days. The experimental results show that although the UPV and the compressive strength of concrete are related, no unique relationship can be established to cover all concrete specimens. Results stated that UPV should be > 3.5 km/s, otherwise the concrete shall be considered poor and the strength is not conforming. Coring is recommended to be the deciding test. 2. The practice of HCLabs of conducting companion hammer test to obtain the rebound number (SonReb approach) is helpful. However, from the data of this work, rebound number values < 30 may indicate poor concrete.

Gowsalya and Bhagyalakshmi (2015) [2] the research paper presented experiment taking cementitious behaviour of the red mud into account, an experiment was carried out to partially replace the cement by red mud in concrete for different percentages (0%, 5%, 10%, 15%, 20%, 25%) and also its effects on the strength and other properties of the concrete was studied by compressive strength, split tensile strength for M30 grade concrete. Experimental results stated that increase in red mud content decreases the compressive as well as tensile strength of concrete. Optimum percentage of the replacement of cement by weight is found to be 20%.By this replacement results got are nearly equal to the results of controlled concrete. Workability of concrete may get affected with increase of red mud but it can be improved by adding superplastcizers. 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. We use mixture of red mud & cement for non structural work.

Shailesh, Shivakumar et. al. (2014) [3] research paper presented different layers of site investigation and tests suitable at site. For surface tests rebound hammer test is

carried out and for through test ultrasonic pulse velocity test is carried out. The calibration of these tests & checking the quantity of concrete structural member was further mentioned. For the analysis, a typical frame model and of single storey of height 3 m is modeled using ETABS v9.7.4 software as the building was at the site(Production Block, BAMUL BANGALORE DIARY). The column cross section is taken as 0.45m x 0.45m. Beam size is taken as 0.45m x 0.50 m. The floor slabs are modeled as plates of 0.15m thickness. All the supports are modeled as fixed supports. Results stated that the strength of concrete in the tested RC columns, Beams and Slab was found to be 25kN/mm^2 , 20kN/mm^2 and 20kN/mm^2 Respectively. From the cover meter/ profometer study, the cover of concrete provided to the rebar's is adequate in the tested RC structural members. The data obtained from NDT techniques like grade of concrete, cover of concrete, and the reinforcement details, used to evaluate the current strength condition of the building using e-tab software and found satisfactory with existing results. From the profometer studies it was observed that the reinforcement provided is more than the required as per analytical results. The results obtained from ultra sonic pulse velocity and rebound hammer were found to be satisfactory.

Mohammadreza, Hamidian et. al. (2011) [4] in the research paper, the ultrasonic pulse velocity technique as a non-destructive testing of concrete was used to assess the effect of some criteria on high strength and light weight aggregate concrete. The study included several concrete mix design with ages of 7, 28 and 90 days. The results show that with increasing of concrete age, the velocity speed increase accordingly and this increase was slightly higher in HSC compare to LWAC. Also it was concluded that increasing the cement content caused a rapid pulse in pundit readings and reducing the w/c ratio, the pulse rate increased in most cases. The rate of reduction was almost same for both the HSC and LWAC as well. It was also confirmed that with high concrete slump, the aggregates with different density affect the concrete compression strength and ultrasonic pulse rates. Calibration curves for laboratory tests and UPV readings were drawn using regression analysis. The results show that, obtained R2 from the correlation curve of comparisons between pundit readings and selected concrete mix design is much more than obtained R2 from comparison of all pundit readings versa all compression strengths.

Seonguk, Sangki et. al. (2020) [5] the purpose of the research was to estimate the compressive strength according to the age of the concrete structure using ultrasonic pulse velocity method. If the correlation between the ultrasonic pulse velocity and the compressive strength according to the age is derived, the compressive strength of the early age of the concrete structure can be estimated at the new construction site and the compressive strength of the existing structure can be estimated at the remodeling construction site. Concrete structural specimens were constructed with 123 specimens by setting 9 parameters based on the design compressive strength of 24, 30, 40 MPa at 16, 20, 24, 48, 72, 120, 168, 360, 672 h. For the calculation of the average ultrasonic velocity according to the age of concrete, it is carried out according to KS F 2731, ASTM C597 and ACI 228-2R, and the concrete compressive strength is carried out according to KS F 2405.For the designed strengths of 24, 30, and 40 MPa, the ultrasonic pulse velocity in each specimen sharply increased from 16 to 72 h of age. It slowly increased to 120 h and then maintained a very slow increasing tendency up to 672 h. As a result of measuring the compressive strength, the average compressive strength was 2.07% of the designed strength at 16 h of age, 2.25% at 20 h, 3.21% at 24 h, 13.55% at 48 h, 31.42% at 72 h, 64.71% at 120 h, 80.89% at 168 h, 87.98% at 360 h, and 91.09% at 672 h. The proposed estimation equation confirmed that it is possible to estimate the compressive strength of concrete according to its age using nondestructive testing methods. In particular, the proposed estimation equation is expected to be helpful in preventing problems caused by formwork removal by providing construction sites with valuable information at early ages of the concrete.

Kim Hyeok , Suk Pyo et. al. (2018) [6] Efflorescence which severely occurs in alkali-activated slag cement can cause reduction of strength and durability due to calcium leaching. In the work, efflorescence characteristics in pavement containing red mud which can be affected by strong alkaline were investigated through various tests such as compressive strength, porosity, absorption, efflorescence area, alkali leaching content, and properties of the efflorescence compound. The compressive strength of pavement was evaluated to be higher over 15.0 MPa in all cases regardless of replacement ratio of red-mud and binder type, which can provide a reasonable strength for walking and bike lanes. The pavement with red mud was applicable to parking lots only when the replacement ratio of red-mud is within 10%. The efflorescence area increased with a higher replacement ratio of red mud and its propagation appeared though the efflorescence was removed through evaporation of moisture. However, the area of efflorescence gradually decreased with the repetition of the test.

Fatema, Choudhary et. al. (2015) [7] The concrete is a heterogeneous material and the interpretation of relation between compressive strength and ultrasonic pulse velocity is complex. The attempts are made for estimating the strength and other properties of concrete for getting more reliable and dependable information of the quality of concrete without crushing. The study may contribute towards the development of a guideline to determine compressive strength using ultrasonic pulse velocity. Based on the extensive experimental works and studies, the conclusions drawn were that the variation of the age and aggregate type can generate effects those are sensible in the UPV. With the increasing age, the velocity also increases. At early age the increasing rate is rapid. Among different types of aggregates used in the study, it has been seen that for a particular strength recycled stone aggregate gives lower UPV than stone aggregate concrete and similar case is happening to recycle brick and brick aggregate.

Ramesh, Nagesh et.al (2013) [8] aim of the research work was to investigate the possibility of replacing the Portland cement by red mud. Because of storing issues, the waste negatively affects the environment. To solve this problem, Portland cement was replaced up to 40 % RM by wt of cement. And evaluating its compressive and splitting tensile strength of red mud concrete. This study examines the effects of red mud on the properties of hardened concrete. The test results show that how its compressive strength & splitting tensile strength decreases with increased red mud content, it is

concluded that Optimum percentage of the replacement of cement by weight is found to be 25%. By this percentage replacement one can have strength equal to the strength of controlled concrete.

Sara , Tao et. al. (2020) [9] the research paper presented an experimental study intended to synthesize a kind of geopolymer binder using RM as primary solid source which was thermally activated by NaOH and mixed with sodium silicate. In addition, composition optimization and Nano-SiO_2 were used to improve the binder properties. Results stated that Modifying the chemical compositions of RM has a close relationship with the geopolymer binder specifications. Increasing $SiO_2/Al2O_3$ was found to increase the compressive strength while decreasing Na_2O/Al_2O_3 could improve the workability. The W/S ratio has a significant effect on compressive strength and setting time. Adding Nano-SiO_2 with a suitable content could result in a high compressive strength. The Nano-SiO2 interacted with the minerals in the alkaline atmosphere and contributed to the formation of geopolymer gel and CSH. The compressive strength has increased to be 45 MPa at 28 days by adding Nano-SiO_2 with 0.4 wt% of RM content.

Xianhai Li et. al. (2019) [10] the research aimed to provide new insights into the wide application of YPS and RM for saving energy and reducing emissions and to develop a new method to study the fracture behavior of concrete. Red mud-yellow phosphorus slag-cement concrete (RM-YPS-CC) is prepared with 25% yellow phosphorus slag content (YPSC) and 10% red mud content (RMC) to replace a portion of the cement at the age of 28 days and was found in this study to satisfy the mechanical property requirements. More ettringite and portlandite were generated with the RM-YPS-CC than with the yellow phosphorus slag-cement concrete (YPS-CC).The cementitious materials were more interlaced, and there was more disorder in the crystals of the RM-YPS-CC, which formed a more complex spatial structure than the YPS-CC did. Without RM, the initial cracking strength on the surface of the concrete was 5–6 MPa, the maximum crack width was 3.96 mm, and the crack number was 8. However, the cracking strength was 26.5–27 MPa with RMC5, the maximum crack width was 0.66 mm with RMC15, and the crack number was 3 with RMC15. Moreover, studies using the digital image correlation (DIC) method indicated that the displacement distribution and evolution of the first crack area changed quickly at 10 MPa in either horizontal or vertical direction, and a similar trend was maintained.

Tejaswini and Anupama (2018) [11] In the project an effort is made to assess the strength characteristics of the aluminum red mud as partial replacement for cement in concrete. Specimens were made by adding the red mud as replacement for cement in percentages from 0% to 60% at an internal of 10%. To enhances the binding properties hydrated lime of 5% is added to the mix. The incrementing the content of red mud reduces the strength properties of the concrete; however there is possibility of utilizing red mud in concrete in sustainable development. Carbonation rate reduces with the expansion in red mud content. This shows that red mud exhibited higher resistivity to corrosion. The addition of red mud makes the concrete resistive to sulphate attack. The optimum content of the red mud replacement is 20%. The use of red mud in concrete can be a best option to reduce the environmental pollution and the reduction of carbon footprint by the construction industry.

Kedara , Shinge et. al. (2015) [12] red mud and rice husk ash are used in partial quantities with the cement in mortar. With the ambit of the mechanical strength of the cement, the compressive, tensile and flexure behaviour of the mortar specimens was investigated. It was observed that 10% replacement of the red mud for cement is possible from a compressive, tensile and flexural strength point of view with a compromise in compressive strength. However, from a compressive strength point of view, rice husk ash is the best alternative material for the replacement of cement in mortar and can be used up to 10% to 15 %. Moreover, tensile and flexural strength reduced to some extent even for 5% rice husk quantity.

Sowmyashree et. al. (2016) [13] research paper focused on the compressive strength, split tensile Strength, flexural strength properties of concrete, which are the important parameters to be Studied in concrete production of different proportions of raw materials. However, when used in Combination with 30% red mud, cement and 5% lime the composites show significant Compressive strength of 50.05 N/mm^2 for the M40 grade of concrete. Tensile strength of.98N/mm^2 for M40 grade of concrete. Selected combinations of mixes were later used to produce a Beam of size 500 x 100 x 100mm. These beams are tested for flexural strength of results 3.29N/mm^2 for M40 grade of concrete. The use of red mud and hydrated lime in the production of Concrete is showing the same strength properties as in the case of conventional concrete for M40, Due to the presence of Al_2O_3 and SiO_2 in red mud and argillaceous content of hydrated lime.

Kulkarni (2018) [14] the objective of the research was to investigate a green alternate Material for conventional concrete using geo-polymerization of industrial wastes. In this study Geopolymer concrete using RM, FA and GGBFS were tested for various physical and mechanical Properties. The properties that were tested include water absorption, compressive strength, Flexural strength, tensile splitting strength. From the experimental results it was concluded that geopolymerization of red mud, fly ash and GGBFS can be used as a sustainable alternative material for conventional concrete. The Compressive strength of geopolymer concrete is found to be 89.4% of conventional concrete. The split tensile strength of geopolymer concrete is found to be 84.26% of conventional Concrete. The flexural strength of geopolymer concrete is found to be 81.21% of conventional Concrete. Water absorption of geopolymer concrete is found to be greater than of conventional Concrete.

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CONCLUSION

The environmental viability for red mud application can be obtained in two ways: neutralization and inertness. However, even the neutralization is not enough to ensure a safe application, since only the alkalinity is solved. The best option is to use the residue in applications that allows it to be inert, avoiding leaching to the environment. The best results shall be evaluated in used red mud along with super plasticizers with different proportion to receive the mean strength of concrete. Red mud can be effectively used as replacement material for cement and replacement enables the large utilization of waste product. Red mud did not effect of the cement properties, rather improved the cement quality by way reducing the setting time & improved compressive strength. Physical parameters of red mud are affected by calcination process.