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Utilization of Red Mud in Geopolymer Concrete-A Review

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Abstract— *Red mud is the major industrial waste produced by the Bayer process for the extraction of alumina from bauxite ores. Its treatment and disposal are a major difficulty to alumina refineries. So use of Red Mud as a construction material is the ideal solution.This paper presents some of the recent development works in utilization of Red Mud in Geopolymer Concrete.From the review of the past research works it can be concluded that Red Mud can be use in a Geopolymer Concrete from 10% to 40%.*

Keywords—*Redmud, Flyash, Metakaolin, strength parameters ,Rice husk.*

I. INTRODUCTION

Red mud is the major industrial waste produced by the Bayer process for the extraction of alumina from bauxite ores. Depending on the quality and purity of the bauxite ore, the quantity of red mud generated varies from 55-65% of the processed bauxite. [10] Producing 1 ton of alumina requires 1.5-2 ton of bauxite.This means that about 0.7 tons of red mud is generated per ton of produced alumina with the Bayer process.Taking into account that the world metallurgical alumina production in 2005 was 51,627,000 tons(Mineral Commodities Production and Trade Statistics 2005), it is estimated that the world production of red mud is roughly 35,000,000 tons per year in dry basis.Although intense research work on utilization of red mud was performed during the previous decades (Glanville and Winnipeg 1991;singh and Prasad 1996;Singh et al.1997;Marabini et al.1998;Yalchin and Sevinc 2000;Ayres et al.2001;Sagoe-Crentsil and Brown 2005;Cundi et al.2005),there is not a generally accepted technology that could be industrially applied. [5]
In addition, solid constituents of red mud include mainly iron oxides (mostly hematite), alumina, and some toxic heavy metals. It also can be slightly radioactive if the original bauxite contained radioactive minerals. Strong alkalinity and high water content are the two major environmental concerns for the safe and economical disposal of red mud. Thus, its treatment and disposal are a major difficulty to alumina refineries.

Red mud cannot be disposed easily. In most countries where red mud is produced, it is pumped into holding ponds.Red mud presents a problem as it takes up land area and can neither be built on nor farmed, even when the mud is dry one challenge is that drying the mud requires much energy.

Figure 1:Red Mud

Table 1:Chemical Composition of Red Mud

TEST DESCRIPTION	OBTAIN VALUE IN %
Silicon Dioxide as SiO_2	13.14
Aluminium Oxide as AL_2O_3	20.26
Iron Oxide as Fe_2O_3	42.25
Calcium Oxide as Cao	1.25
Sodium Oxide as Na_2O	4.36
Titanium Oxide as TiO_2	1.9
Finesse	2200 cm^2/gm
Specific Gravity	2.09

In the past, red mud was disposed from the plant site mainly two ways, including dumping it directly into the sea or onto the land creating huge ponds.So,use of red mud as a constituent of geopolymer concrete is reducing the environmental problems.

Unlike ordinary Portland/pozzolanic cements, geopolymers do not form calcium- silicate-hydrates (CSHs) for matrix formation and strength, but utilise the polycondensation of silica and alumina precursors to attain structural strength. Two main constituents of geopolymers are: source materials and alkaline liquids. The source materials on alumino-silicate should be rich in silicon (Si) and aluminium (Al). They could be by-product materials such as fly ash, silica fume, slag, rice-husk ash, red mud, etc. Geopolymers are also unique in comparison to other aluminosilicate materials (e.g. aluminosilicate gels, glasses, and zeolites). The concentration of solids in geopolymerisation is higher than in aluminosilicate gel or zeolite
This paper emphasize the constituents of Geopolymer concrete and its application.

II. LITERATURE REVIEW OF RECENT USE OF RED MUD IN GPC

Number of authors have reported their work on utilization of red mud in geopolymer concrete.

Anuj Kumar, Sanjay Kumar used Red Mud and Fly ash in Geopolymer for develop a paving block. Red mud addition enhanced the intensity of reaction and structural reorganization but in the improvement in setting time and compressive strength was observed only in the sample containing 5-20% red mud.They found that use of Red mud and fly ash is environmentally safe and these materials are free of cost in India. They used 6M NaOH solution,7g solid sample and 3.5ml alkaline activator were used throughout the study.The amount of red mud varied between 0 and 40%.The liquid to powder ratio was kept 0.35 in all batches.Compressive strength was tested after 3 and 28 days curing.In comparison with cement based paving block of same quality, the reduction in raw material cost was 10%.The main advantages of this research is reduction in Carbon dioxide and utilization of industrial wastes.

Nan Ye, Jiakuan Yang, Xinyuan Ke, Jing Zhu, Yalin Li, Cheng Xiang, Huabin Wang, Lei Li, and Bo Xiao investigated that thermal pretreatment was applied to improve the solubility of red mud in alkaline solution to promote geopolymerization. In this study they used a local Bayer RM with low Fe_2O_3 content of about 9.5 wt% was used to eliminate the negative effect of Fe.They calcined RM in a muffle furnace under static air at 200^{0}C, 300^{0}C, 400^{0}C, 500^{0}C, 600^{0}C, 700^{0}C, 800^{0}C,900^{0}C and 1000^{0}C for 3h,respectively.Thermal treatment has a great influence on the aluminosilicate phase transformation of RM. To reuse as much RM as possible ,the RM/GBFS mass ratio of 5:5 with a satisfactory compressive strength was acceptable for the potential application in construction materials.XRD,FTIR and SEM results well-presented the geopolymerization process of the composite binder made from calcined RM and GBFS. They calcined a red mud at 800°C,the dissolution efficiencies of alumina and silica reached a maximum ,resulting in the highest compressive strength around 49.2MPa in 28 days of the composite binders.

Mo Zhang a , Tahar El-Korchi a, Guoping Zhang b, Jianyu Liang c and Mingjiang Tao a investigated the chemical composition of raw material and curing conditions,on the microstucture and mechanical properties of geopolymers synthesized from red mud and class F fly ash. They used UCT, scanning electron microscopy, XRD, Energy-dispersive X-ray spectroscopy (EDX) tests to characterized the all properties of geopolymers respectively. In this study authors synthesized Red mud –Fly ash based geopolymer at the ambient condition. They used 1:4 mass ratio of RM and FFA .Pre-curing at 100% Relative humidity has little improvement on the mechanical properties of RM, FA based geopolymers, which implies that ambient curing condition is more practical for synthesizing RM–FA based geopolymers. They found that Geopolymer strength increased continuously with curing for up to 180 days and Increasing Si/Al and Na/Al ratios resulted in an increase in geopolymer strength.The formation of amorphous geopolymer gels was confirmed from XRD and SEM characterization.

Jian He a, Jianhong Zhang b, Yuzhen Yu b and Guoping Zhang characterized two different geopolymers which were synthesized from metakaolin and the admixture of red mud and fly ash by unconfined compression testing,XRD and SEM-EDXS analyses,respectively. In this study authors used the raw materials to synthesize metakaolin based geopolymers include PowerPozz metakaolin ,sodium silicate solution consisting of 14 wt.% NaOH and 27 wt.% SiO2 , and sodium hydroxide.They used the MK-GP with a Si/Al molar ratio of 1.75 and the RM-GP with a RM/FA weight ratio of 50/50.For a given Si/Al ratio, the MK-GP exhibit much higher compressive strength and failure strain than the RM-GP. According to the compositional and micro structural analyses, the two geopolymers are both geopolymeric composites, but not pure geopolymers. In this study geopolymer samples,the MK-GP achieve a strength of 31 MPa,while the RM-GP have a strength of 13MPa.They found that source materials with higher reactivity higher Si/Al ratio, and higher concentration of alkaline solution can yield positive impact on the mechanical performance of the geopolymers.

Dimitrios D. Dimas, Ionna P. Gianno poulou and Dimitrios Panias studied the potential use of red mud for synthesis of inorganic polymeric materials through geopolymerization process .In this study the main focus was the production of inorganic polymeric materials. In this study authors used a mixture of red mud and metakaolin with mass ratio of 85:15.The red mud-based inorganic polymers that were produced in this work had relatively high compressive strength (20.5 MPa), very low cold water absorption (1.28%), and excellent water impermeability (0cm-3(CUBE)/cm2 per day), making them comparable or substantially better than the conventional construction ceramics .They found two most important drawbacks of these materials were their inefficient flexural strength and the absence of resistance in freezing thawing cycles.The red mud inorganic polymers at this stage of development cannot substitute for clay roofing tiles due to inefficient flexural strength and resistance to weathering.Finally,the synthesized polymers are promising materials for fire protection of construction due to their thermal stability and fire resistance.

Jian He a, Yuxin Jie b, Jianhong Zhang b, Yuzhen Yu b, Guoping Zhang used the raw materials for geopolymer synthesis include RM slurry, Rice husk ash ,sodium hydroxide and deionized water. They used Weight 0.4 ratio of RM/RHA.They found that geopolymers have compressive strengths of up to 20.5MPa, which is comparable to most Portland cements, suggesting that the RM–RHA geopolymers can be a potential cementitious construction material.
Mo Zhang a,b, Mengxuan Zhao a, Guoping Zhang c, Derrick Mannd, Kevon Lumsden d and Mingjiang Tao a studied the durability and leaching behavior of heavy metals of RFFG exposed to a sulfuric acid of pH 3.0 and deionized water of pH 7.0 and they found UCS, Young's modulus and flexural strength of the RFFG samples decreased by 30%, 70% and 45% after soaking in the sulfuric acid for 120 days respectively. Mass ratio of RM/FFA is 4:1 in geopolymer. Based on current study they concluded that the resistance of RFFGs against a low pH value sulfuric acid and deionized water was found comparable to OPC.

Nan Ye a, Jiakuan Yang a,Sha Liang a, Yong Hu a, Jingping Hu a, Bo Xiao a and Qifei Huang b used One-part geopolymer was synthesized by using Bayer red mud as main raw materials.Long-term strength of binder was significantly improved with addition of 20–30 wt% SF.Lower water/solid ratio contributed to increasing the strength.The compressive strength of geopolymer cured for 28 d reached 31.5 MPa.Geopolymerization of dissolved aluminosilicate and silica formed dense matrices.

H. Choo [a], S. Lim [a], W. Lee [a] and C. Lee [b] investigated one-part mix alkali activated materials using only waste materials. Therefore, in this study, fly ash with high unburned carbon particles (or high loss on ignition) was used as an aluminosilicate precursor and red mud was used as a NaOH supplier in the geopolymerization of fly ash.
Both the pH and unconfined compressive strength (UCS) values of the tested inorganic polymer blocks increase with an increase in red mud content (RMC)
The addition of red mud to fly ash allows an increased alkaline environment; therefore, the dissolution of silica and aluminum from the solid phases such as fly ash and/or red mud increases.

III. Discussion & conclusion:

Based on various research paper,it is observed that red mud can be used in a geopolymer concrete as a replacement of flyash upto 40%. By use of Geopolymer concrete the production of CO_2 is reduced which is generate from cement

manufacturing industries. Also it can be concluded that over the last decades,satisfactory research work has been conducted on mechanical,chemical, and durability aspects of Geopolymer concrete with varying proportion,curing temperature ,time and additives. Also satisfactory work has been conducted on different aspects of red mud in Geopolymer concrete.And with the use of red mud in geopolymer concrete the mechanical properties of concrete is increased upto some limit of red mud proportion.The environmental problems also reduced because of use of red mud in GPC.

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