Manufacture Processing of Green Cement (Calcium Sulfo Aluminate (CSA) from Bauxite Residue (Red mud)

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Abstract: *Alumina and aluminium processing creates a range of waste products; the most significant being is red mud. The storage of red mud is a major environmental problem due to its caustic nature, which may enhance the alkalinity of the environment and may represent a risk for all living organisms. Opportunities to reuse bauxite residue are being continually researched. In general, bauxite residue is utilized for road constructions, back fill and bricks for building constructions. Sustainable recycling technologies are necessary for the bauxite residue utilization for the recovery of rare earth elements and cement materials. Carbonation or* CO_2 *sequestration of carbon dioxide is a method pioneered for the bauxite residue is modified to reduce alkalinity. The carbonation of alkaline material is an inexpensive and safe process that leads to the formation of thermodynamically stable products. The use of the carbonation can be an advantageous solution for overcoming problems associated with red mud storage and the emissions of several thousand tons of* CO_2 *from aluminium manufacturers each year.*
Index Terms: *bauxite residue (red mud), rare earth elements, green cement (CSA), carbonation*

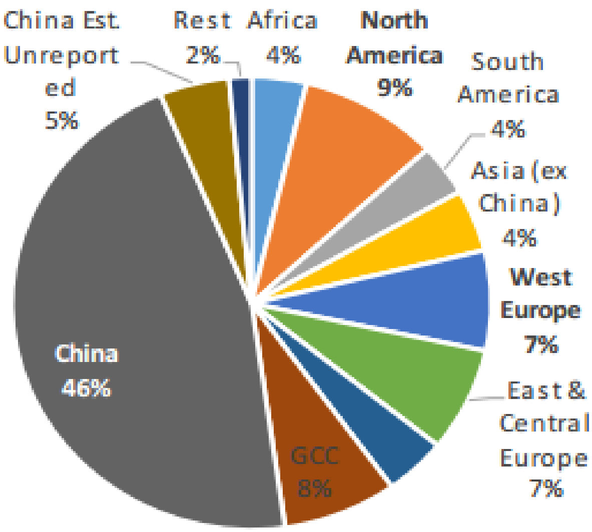
ACKNOWLEDGEMENTS

This research was supported by a grant (2013) from the Energy Technology Development Program (2013T100100021) funded by the Ministry of Trade, Industrial and Energy of the Korean government.

I. INTRODUCTION

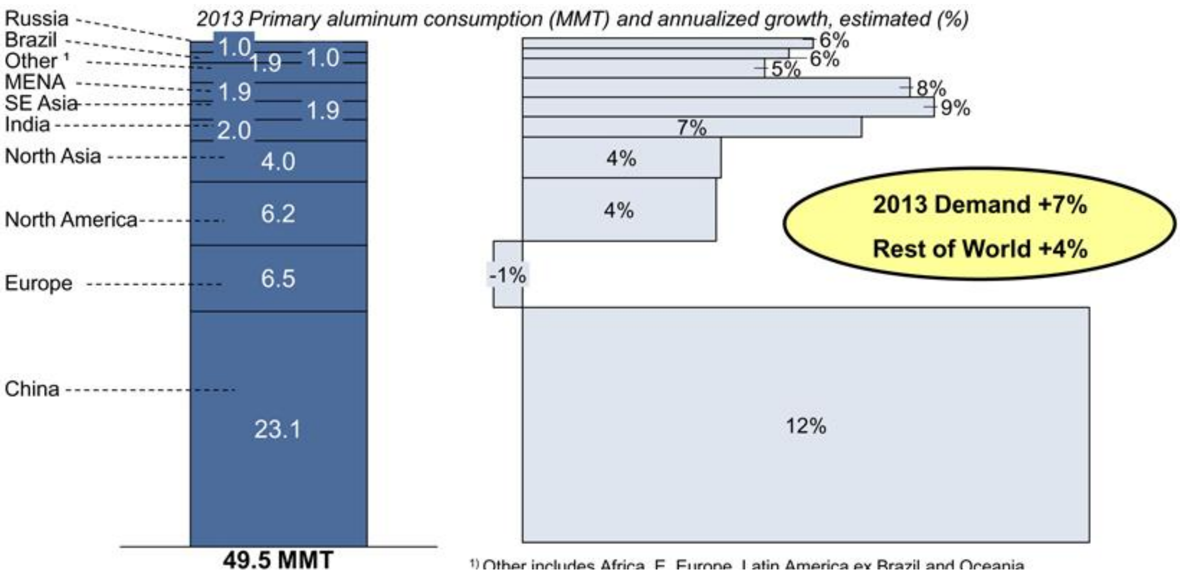
In alumina production or alumina refining, bauxite is converted to alumina (aluminium oxide) using the Bayer Process.[1] Aluminium is integral to our everyday lives, it's used in mobile phones, building construction, cars, buses, trains, planes, DVDs, laptops, outdoor furniture, beverage cans, aluminum foil, screw cap bottle tops, and so much more. Growth in primary aluminium production continues to be driven by china and the Arabian gulf. Fig.1 shows the global primary aluminum production in 2013 was a record 46 million tonnes.[2] Bauxite residue, sometimes referred to as 'red mud', and is the by-product of the Bayer process. In the Bayer process, bauxite ore is dissolved using sodium hydroxide. Alumina is extracted from the dissolved leaching solution and the residual bauxite residue is sent to a storage area.

Fig.1. (a): Global primary aluminum production, 2013



(Source: International Aluminum Institute)

Fig.1 (b): Global primary aluminum consumption, 2013



(Source: Alcoa Analysis, CRU)

II. ALUMINA PROCESSING

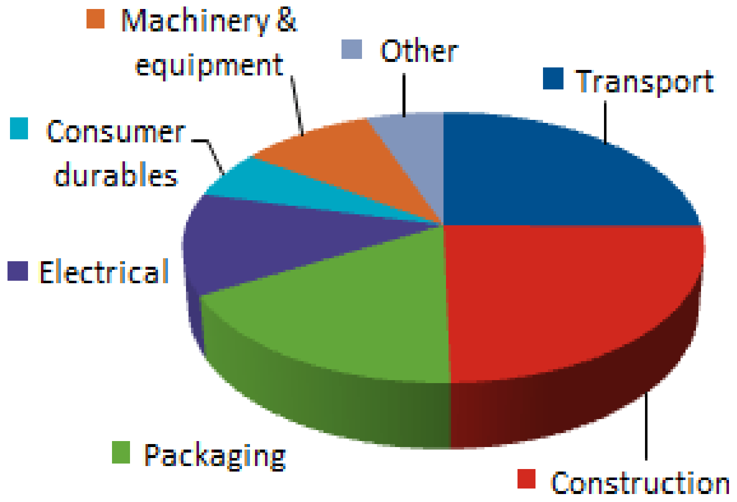
Refining alumina (aluminium Oxide) is the second step in the production of aluminium. Alumina is refined from bauxite using a chemical process known as the Bayer process. This process conducted by 3 ways[3]

i) Digestion
ii) Precipitation
iii) Calcination.

Bauxite Residue (Redmud)

Throughout the entire history of alumina production there has been a desire to utilize the bauxite residue created in the Bayer process with either by recovering additional products from it or using it. The red mud applications falls into several categories such as rare earths recovery, manufactured construction materials (cement, bricks, tiles, aggregate blocks and wood substitute) and bulk impermeable material for covering landfill. Considerable effort has been expended in finding applications for bauxite residue but a number of key factors affect the feasibility and economics of its adoption. The main application areas that have been evaluated are briefly summarized below (Fig.2).

Fig.2. Global primary aluminum applications



(Source: CRU, www.crugroup.com)

CO_2 sequestration of redmud (Carbonation of red mud)

Globally over 70 million tonnes of bauxite residue is generated annually through the manufacture of aluminium. Carbonation process technology has been proven to be commercially viable for red mud management. However the technology of further carbonation to produce bicarbonates (and sequester higher amounts of CO_2) has not yet been tested on a commercial scale and cannot be considered commercially viable. A potential benefit is the use of the neutralized residue as a soil amendment.

The developed innovative residue treatment process that delivers a range of sustainability benefits. The carbonation of red mud, in which CO_2 adds to bauxite residue which is a mixture of minerals that are left behind when alumina is removed from bauxite. Carbonation of red mud has tremendous environmental benefits, economic and social benefits by reducing residue drying times and less residue storage. We investigated the red mud carbonation and carbonation efficiency by XRD (Fig.3) and TG-DTA analysis of red mud (Fig.4).

Fig.3. XRD of carbonated redmud(bauxite residue)

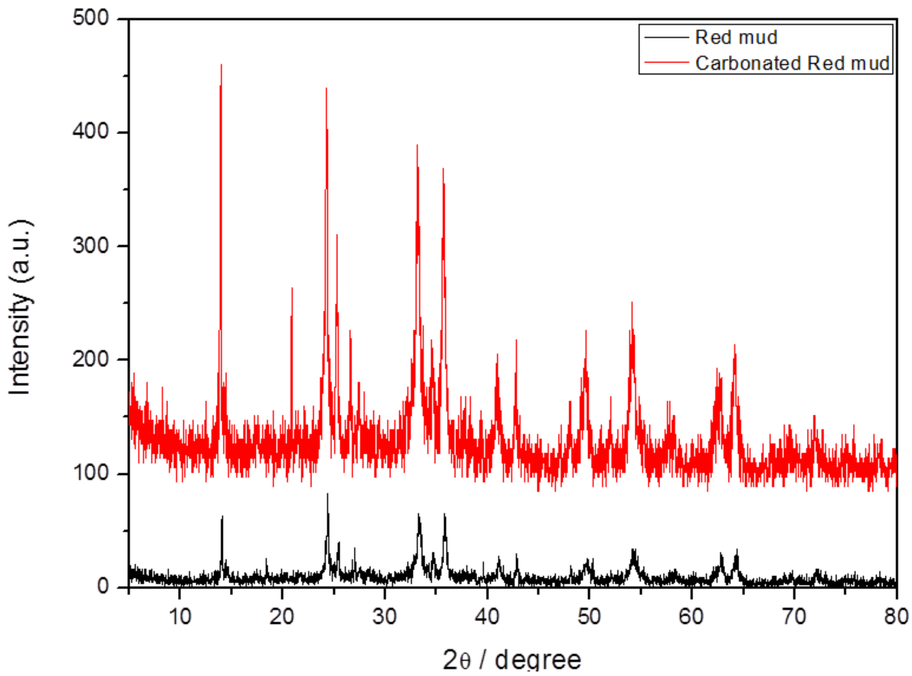
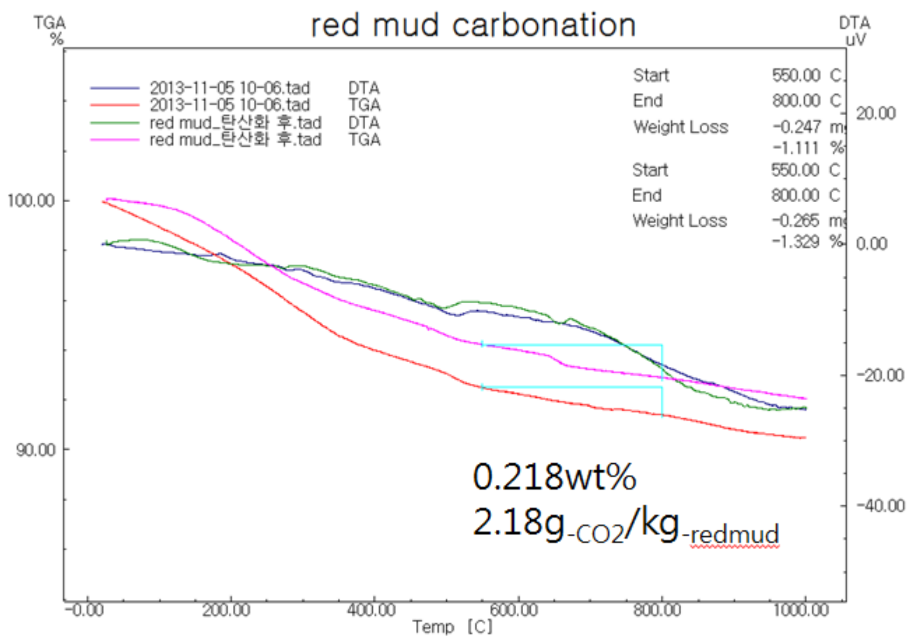


Fig.4. TG-DTA analysis of redmud



Cement Production from Redmud

Here, we reported the production of calcium sulfoaluminate (CSA) based cement from red mud. The CSA based cement synthesized by sintering process. This process requiring less energy and time and reducing costs in terms of setting time and changes in mechanical strength. The available work in the area is immense and there are different strategies and cementitious systems suggested[4-10].

Fig.5 &6 shows the difference between ordinary portland cement and CSA cement process and the materials and conditions presented in Table-1.

Fig.5. Ordinary Portland Cement Process

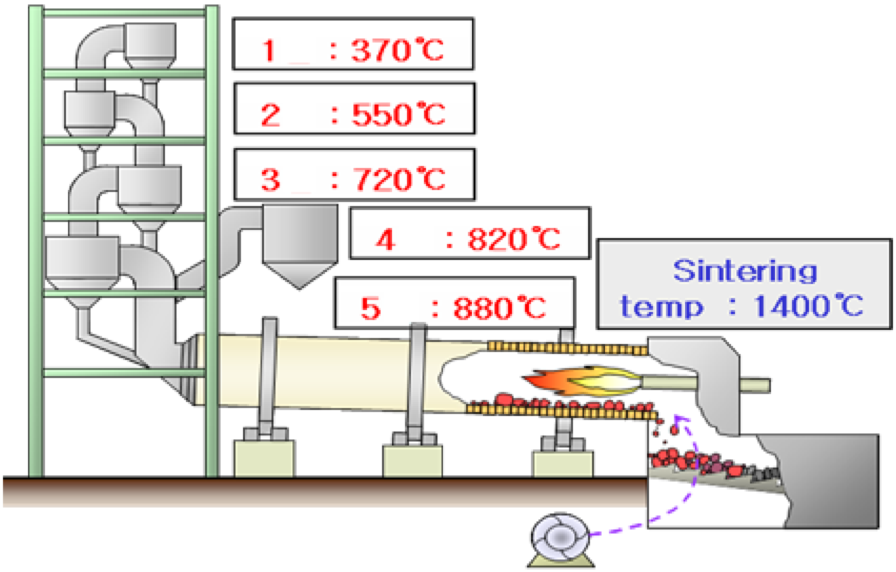


Fig.6. Calcium Sulfoaluminate(CSA) Process

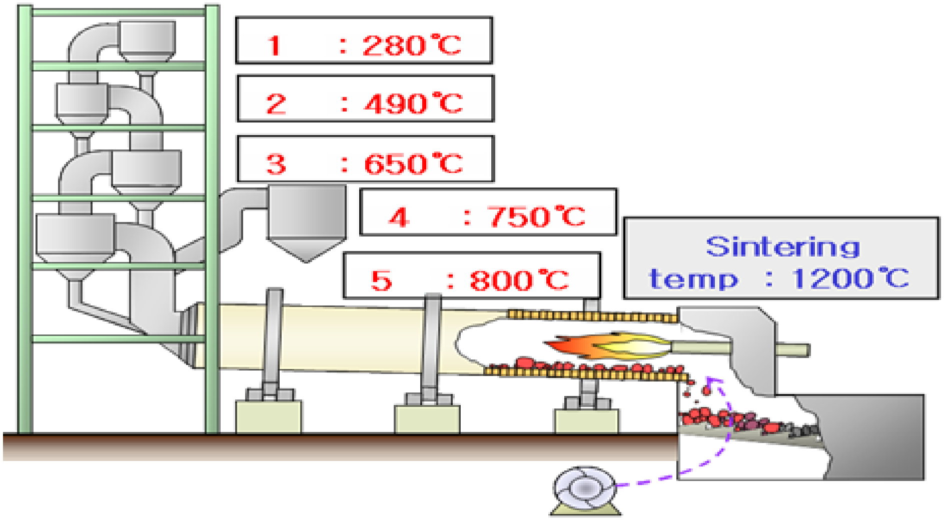


Table-1. Materials and Conditions of OPC and CSA

Materials	**OPC**	CSA	
Sintering Temp (°C)	1300~1400	1200[8hrs]	1100[8hrs]
Injection Rate	120	100	
Total Energy(kcal/kg-cl’)	700~720	620	500
Recycling Rate(%)	25~30	25	10
CSA Mineral Synthesis Rate (%)	-	14~16	14~16

Setting test of OPC and CSA Cement

When water is mixed with ordinary Portland cement its chemical components undergo a series of chemical reactions that cause it to set. All of these chemical reactions involve the addition of water to the basic chemical composition (Fig. 7). Here we measured several experimental parameters such as 1) Setting Test Setting time of crushed CSA clinker: Initial set is 0:14 min, ending set is 0:29 min.

Fig.7. Setting test of OPC and CSA cement

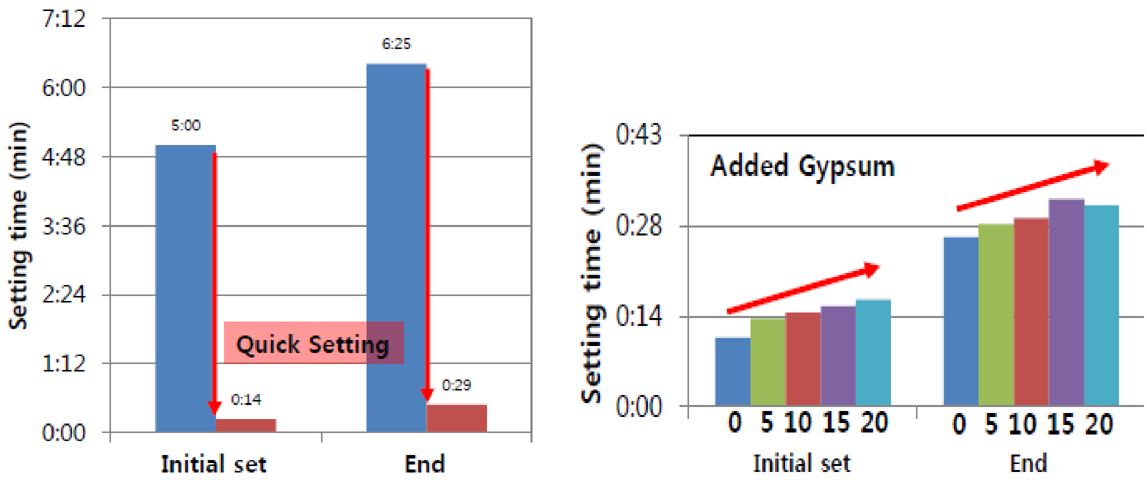
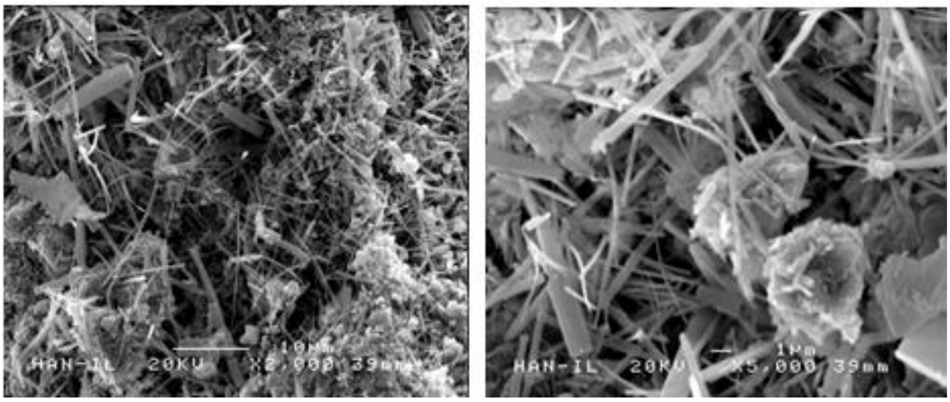


Fig.8. hydration effect of OPC and CSA cement

Hydration effect

Hydration product of CSA cement is produced ettringite (expansibility). CSA cement is shown rapid curing and expansiblity and it confirms by SEM analysis.(Fig.8 & Fig.9). Significant benefits can be derived from the lower energy consumption during production (temperature between 700-500^{0}C) and the reduced CO_2 emissions per mass of cement produced. In addition, due to their ability of ettringite to bind heavy metals, and CSA cements and their blends with Portland cement are of interest in the field of hazardous waste encapsulation. The major concern with CSA cement is associated with the main hydrating phase, ettringite, which is said to be prone carbonation. This work aimed at the synthesis of the calcium sulfoaluminate phase exhibits high strengths. More ettringite formation or expansion after drying it gives less cracking for buildings.
Fig.8 Hydration effect (After 1 hour) of ettringite

Fig.9 Hydration effect (After 12 hour) of ettringite



CONCLUSIONS

This preliminary data confirms the present study have indicated that the red mud carbonation at ambient conditions (temperature of 25$\pm$1°C and atmospheric pressure) could present an effective option for the carbon dioxide sequestration. The carbonation efficiency of red mud is 2.18 g CO_2/kg. The results are indexed an promising parameter for CSA is strength and it would be an interesting extension. The use of this type of system could thus become a source of additional income for aluminum manufacturers and reduce environmental problems associated with red mud storage.

ACKNOWLEDGEMENTS

This research was supported by a grant (2013) from the Energy Technology Development Program (2013T100100021) funded by the Ministry of Trade, Industrial and Energy of the Korean government.

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