Research on the property improvement of PVC using red mud in industrial waste residue

Xiaopeng Nie¹, Xingang Li and Songxian Shuai

Guizhou Construction Science Research & Design Institute Limited Company of CSCEC, 4 Ganping Road, Guiyang, 550006, China

E-mail: niexiaopeng2009@163.com

Abstract. Red mud is a red solid power waste that is discharged in the aluminium refinery industry during production. It is a strong alkali and can be categorized as polluting industrial residue. How to make comprehensive use of red mud has become a worldwide issue. In this paper, we put red mud into PVC (polyvinyl chloride polymer), taking advantage of the complicated chemical properties of red mud derived from the Bayer process. The results are compared with silica fume, coal ash and calcium carbonate under the same experimental conditions, which shows that improvement of PVC plastication can be achieved by adding red mud.

1. Introduction

Red mud is waste when refined alumina from bauxite. According to aluminum smelting methods which were divided into Bayer process red mud, Sintering red mud and joint method red mud. With the developing of the aluminum industry, the world produces almost 50 million tons of red mud annually. However, the main method for dealing with red mud is piling up in the world, so how to comprehensively utilize red mud is a world problem [1-4]. Because the red mud dealing with alkaline solution, the alkali content is very high, and the pH content of red mud is 15%~30%, from 10.0 to 12.5. Because we don't make full use of the amount of red mud, plenty of land it occupies will lead to alkaline soil, polluted groundwater and harm to health. In order to resolve the problem of environment pollution, scientific scholars research the physical and chemical properties of red mud in the every country [5-7].

We found that there are two ways to deal with red mud: one is to recycle valued metals from the red mud [8-10]; the other is as a common mineral resources [11-14].

Earlier research about recycling iron from red mud is from the 1950s, and mang refining technology has been patented. Laszlo et al.[15] tested the red mud content many metallic oxide such as Fe₂O₃, Al₂O₃ and TiO₂ which respectively is 66%(mass fraction, the same below), 13.3% and 6.1%. Ercagt et al. [16] retrieved Fe, TiO₂ and Al₂O₃ from smelting red mud in the electric-arc furnace. There has been not only research on retrieving metal, but also on recycling rare earth metals from red mud. Orhsenkhuenu [17] studied rare earth metals recycling under different acid soaking and leaching methods.

Study on red mud as a mineral resource, and put it in the cement. At present, research mainly

¹ Address for correspondence: Xiaopeng Nie, Guizhou Construction Science Research & Design Institute Limited Company of CSCEC, 4 Ganping Road, Guiyang, 550006, China. E-mail: niexiaopeng2009@163.com.
produces cement high in iron oxide, special cement and ordinary portland cement. Tsakiridis et al. have researched producing portland cement technology by adding 3.5% red mud in raw material. With this method, the cement possesses higher early strength than ordinary portland cement in mechanics performance. Except for red mud as raw material produce cement, Sglavo et al. [18] studied red mud mixes with clay calcining ceramics. Additionally, red mud can remove impurities; Gupta V K et al. [19] used H2O2 to treat Bayer process red mud to remove organic matter on the surface. Altundogan S et al. [20] studied red mud adsorption of As\textsuperscript{5+} and As\textsuperscript{3+}.

This paper mainly researches the effect of Bayer process red mud on PVC organic material.

2. Experiments

2.1. Equipment

The heat & cool mixer model is JZRL10/25. It is made of fuxin haoteer plastic machinery CO., LTD. A ZJL-200A torque rheometer controlled by computer is made of Chuang chun Intelligent Apparatus CO., LTD.

2.2. Material

This test used many organic materials, such as PVC, stabilizer, Yellow foaming agent etc. Those materials types are listed in table 1.

| name                  | type          | Place of production | remark       |
|-----------------------|---------------|---------------------|--------------|
| PVC                   | Tianyuan SG-8 | Yibin Sichuan       |              |
| stabilizer            | Shengtailong GB-01 | Shenyang Liaoning |              |
| Yellow foaming agent  | Joysun NH600A | Shanghai            |              |
| ACR                   | Ruifeng LP-901 | Zibo Shandong       |              |
| Processing agent KW58 | Joysun KW58   | Shanghai            |              |

In order to find the results, sub-nanometer fly ash, fly ash, calcium carbonate and micro-spheres were used as fillers [21].

There are many fillers, and they will lead to different test results, so it is necessary to analyze their material microcosmic structure and chemistry aspects. The physical properties of red mud are listed in table 2.

| Producing method       | Density \(\text{kg/cm}^3\) | Content (%) \(\geq 0.2 \text{ mm}\) | Content (%) \(\leq 0.008 \text{ mm}\) | Melting temperature \(\text{C}\) | Plastic index | Dry induction coefficient (khoo) |
|------------------------|-----------------------------|-------------------------------------|-------------------------------------|---------------------------|---------------|---------------------------------|
| Bayer process red mud  | 3.3~3.4                     | 1.8~2.6                             | 4.3~5.4                             | 1350~1370                 | 3.5~6.0       | <1.2                            |

After analysis and testing by the Institute of Geochemistry Chinese Academy of Science, the main chemistry components that the aluminum industry discharged bayer process red mud in Guizhou are shown in table 3.
Table 3. The main chemistry component of Bayer process red mud (wt %).

|       | SiO$_2$ | CaO  | Al$_2$O$_3$ | Fe$_2$O$_3$ | MgO   | Na$_2$O | TiO$_2$ | Ignition loss |
|-------|---------|------|-------------|-------------|-------|---------|---------|---------------|
| Value | 13.35   | 20.11| 33.34       | 4.16        | 0.36  | 5.00    | 5.10    | 15.79         |

Fly-ash: most pellets are globular (over 98%), with electron microscope found nanoparticles adhere to parts of the ball granule, developing framboidal texture, as shown in figure 1.

![Figure 1. Fly-ash in the SEM photograph.](image1)

Sub-nanometer silicon fume: most of the particles are angular, under the SEM discovered: nanoparticles adhere to parts of the ball granule, as shown in figure 2.

![Figure 2. Sub-nanometer silicon fume in the SEM photograph.](image2)

Its chemistry component includes CaO$_2$ SiO$_2$ MgO Fe$_2$O$_3$ KCl Ti, etc.

Sub-nanometer silicon fume: most of the particles are angular, under the SEM discovered: nanoparticles adhere to parts of the ball granule, as shown in figure 2. Light calcium carbonate: it is an important inorganic material that light calcium carbonate was
made by chemistry method. It is also called precipitated calcium carbonate, and it has fine grain size, high whiteness, good crystal form, lower prices, etc. [22].

Glazed hollow bead: it is an acidic glassy lava mineral with its internal porous surface closed. It is made of SiO$_2$ Al$_2$O$_3$ CaO. The SEM picture is shown in figure 3.

2.3. Testing method
The materials compounding as table 4.

| Raw material       | Copies(Volume ratio) | Raw material     | Copies(Volume ratio) |
|--------------------|----------------------|------------------|----------------------|
| PVC                | 75                   | ACR              | 3                    |
| filling            | 68                   | stabilizer       | 3                    |
| Yellow foaming agent| 1                    |                  |                      |

The temperature was set at 180°C, the affection of the rotor speed is 30 r/min, and the quantity of total material is 65 g.

3. Results and discussion
These figures show that under the same experiment, in figure 4 the curve of torque is a line parallel X-axis in the process of test, it proved adding this material PVC did not plastify. But the curve of torque in figure 5 shown PVC mixed with red mud would plastify, so the red mud as adding possess character that promotes PVC plasticized in this test condition.

![Figure 4. Testing curve.](image1)

![Figure 5. Testing curve.](image2)

4. Conclusions
We made the follow conclusions:
- As red mud contains rich chemical elements, it will help plasticized polyvinyl chloride plastified during maxing.
- Mixed with appropriately mount of red mud will instead of parties processing adding in PVC.

Acknowledgments
This paper was financially supported by the research project: research on optimize and integrated application of plastic form board and support systems (CSCEC-2014-Z-12)

References
[1] Zhu J, Lan J K 2008 *J Conservation and Utilization of Mineral Resource* 2 52-4
[2] He B Q, Zhou G H and Xue Y L 2001 *J. Light Metals* 2 24-6
[3] Zhou W X, Xie Y J and Liu B J 2002 *J. Concert.* 1 37-40
[4] Dong F Z, Liu X Z and Yao D 2004 *J. Utilization of Mineral Resource* 6 37-9
[5] Brunori C, Creminini C, Massanisso P, et al. 2005 *J. J. Hazard. Master* 117 55-63
[6] Paramguru R K, Rath P C and Misra V N 2005 *J. Miner. Process .Extr. Metall. Rev.* 26 1-29
[7] Gu H N and Wang N, et al. *J Acta Mieralogica Sinca* 29 397
[8] Smirnov D I and Molchanova T V 1997 *J. Hydrometallurgy* 3 249-59
[9] Ochsenkuhn P, Maria T and Hatzilyberis K S J 2002 *J Industrial and Engineering Chemistry Research* 23 5794-801
[10] Dobos S G, Horvath G and Felfoldi Z 1974 *J. Desalination* 12 151-9
[11] Vincenzo M S and Renzo C Bauxite 2000 *Journal of the European Ceramic Society* 1 235-44
[12] Vincenzo M S and Renzo C Bauxite 2000 *Journal of the European Ceramic Society* 6 245-52
[13] Maneesh S and Upadhayay S N 1997 *J. Cement and Concrete Research* 7 1037-46
[14] Laszlo T and Jozsef K 1957 *Journal of Hazardous Materials* 16 460-5
[15] Ercag E and Apak R Furnace 1997 *Journal of Chemical Technology and Biotechnology* 8 103-8
[16] Orhsenkuhnu P Bauxaline 2002 *J. Light Metals* 1 125-31
[17] Vangelatosa I, Angelopoulos G N and Boufounos D 2009 *Journal of Hazardous Materials* 1 473-8
[18] Tsakiridis P E and Agarzini Leonardou S 2004 *Journal of Hazardous Materials* 8 103-10
[19] Gupta V K, Gupte M and Sharma S 2001 *J. Water* 5 1125-34
[20] Altundogan H S, Altundogan S, Tmen F, et al. 2002 *J. Waste Management* 22 357-63
[21] Piga F P and Stoppa L 1993 *Journal of Management* 11 5-9
[22] Zhang D, Yang H T and Shen S Y 2001 *J. Non-Metallic Mines* 4 27-8