Preparation of ceramsite from C&D waste and Baiyunebo tailings

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Abstract

In the present study, Ceramsite was prepared from C&D waste and Baiyunebo tailings. C&D waste was rich in SiO$_2$ and Al$_2$O$_3$, which was necessary chemical condition for sintering ceramsite. Baiyunebo tailings served as bloating and fluxing agent in sintering. The experimental results showed that: (a) Baiyunebo tailings decreased the sintering temperature of C&D waste; (2) iron oxide in Baiyunebo tailings produced gas in sintering, causing bloating effect. This paper presents a practical process for recycling C&D waste and Baiyunebo tailings, and also provides two new materials for ceramsite industry.

Keywords: Baiyunebo tailings; C&D waste; ceramsite; Bloating agent; wastes recycling

1. Introduction

Due to the rapid economy development and urbanization course, China has a C&D waste output of about 400-100 million tons $^1$. However, the reuse and recycle ratio of C&D waste in China is much lower than most of the developed countries $^2$. In recent years, C&D waste has caused various environmental problems and a huge economic loss $^3$. Baiyunebo mine area is famous as the largest source of rare earth in the world, while its tailings output is...
about 6 million tons. Baiyunebo tailings are disposed in an open dump, which causes pollution of soil and groundwater. Therefore, it is necessary and urgent to recycling tailings. In this study, the feasibility of sintering ceramsite from C&D waste and Baiyunebo tailings was examined. The bloating and fluxing effect of tailings was emphatically investigated.

### Nomenclature

| C&D waste | construction and demolition waste |

## 2. Materials and methods

### 2.1. Materials

The C&D waste employed in this study was obtained from a demolition site in Hohhot, Inner Mongolia, China. The C&D waste was made up of include brick scraps, concrete scraps, waste soil etc. Baiyunebo tailing was obtained from tailings dam of Baotou Iron and Steel Company in Baotou, Inner Mongolia, China. The chemical compositions of the C&D waste and Baiyunebo tailing are shown as table 1 and table 2 respectively.

### Table 1 Chemical composition of C&D waste (wt %)

| SiO₂ | CaO | Al₂O₃ | Fe₂O₃ | K₂O | MgO | Na₂O |
|------|-----|-------|-------|-----|-----|------|
| 57.4 | 14.9| 12.3  | 5.5   | 3.1 | 2.9 | 1.8  |

### Table 2 Chemical composition of Baiyunebo tailing (wt %)

| CaO | Fe₂O₃ | REO | MgO | MnO | BaO | Al₂O₃ |
|-----|-------|-----|-----|-----|-----|-------|
| 22.1| 18.2  | 7.5 | 5.3 | 2.9 | 3.1 | 1.3   |

### 2.2. Ceramsite preparation

The preparation process of ceramsite was shown as Fig. 1: (1) C&D waste and baiyunebo tailings were pulverized respectively by ball grinder and sieved to #100; (2) C&D waste was mixed with baiyunebo tailings in a certain proportion; (3) mixed materials was made into pellets (Φ10-15); (4) Pellets were placed in muffle furnace, and then heated according to a certain procedure.
3. Results and discussion

3.1. Chemical analysis

Compared with clay, the C&D waste contains a higher content of CaO and a lower content of Al₂O₃. Generally speaking, CaO acts as fluxing agent while sintering, and Al₂O₃ can increase sintering temperature because of its high melting point. Therefore, C&D waste could be sintered in a lower temperature than clay, based on the analysis of their chemical composition. A lower sintering temperature is beneficial to energy saving, which is an advantage for sintering C&D waste ceramsite.

Compared with clay, the content of SiO₂ and Al₂O₃ in Baiyunebo tailings were so low that Baiyunebo tailings could hardly serve as main materials for ceramsite. However, tailings were rich in iron oxide, which usually serve as gas producer in sintering. Therefore, tailings were used as bloating agent in this study. In addition, Baiyunebo tailings, which consist of metallic oxides, also can serve as fluxing agent to decrease sinter temperature.

3.2. Effect of tailing on sintering temperature

According to classical theory for ceramsite sintering, metallic oxides (except Al₂O₃) were identified as fluxing agent. Hence, Baiyunebo tailings, which were added into C&D waste, could decrease sintering temperature remarkably. As shown in Fig. 2, the raw C&D waste (with no tailings) had a sintering temperature of 1200°C. While adding 9.1% tailings, the sintering temperature was decreased to 1130°C. However, the effect of tailings on sintering temperature was not linear. While the addition of tailings was low, tailings influence sintering temperature a lot. With the tailings addition increasing, its influence on sintering temperature was weakened.
3.3. Tailings bloating effect

Iron oxides, with a content of 18.2% in tailings, served as main bloating agent in sintering. Therefore, particle density of ceramsite decreased with increasing tailings addition. Being similar to the effect on sintering temperature, a low tailings addition could give a sensitive effect on particle density, as shown in Fig. 3. The ceramsite obtained by 9.1% tailing addition were shown in Fig. 4.
3.4 Bloating mechanism

In sintering, there is a redox reaction between iron oxides in tailings and reducing agent (such as organic matter) in C&D waste. During reaction, ferric iron is reduced as lower valence iron while CO or CO$_2$ is produced. In order to verify this mechanism, some char (as reducing agent) was added to C&D waste that were sintered with tailing, and experiment results showed porosity in ceramsite was highly increased. Therefore, it is clearly showed that reactions between ferric iron in tailings and reducing agent in C&D waste are attributed to bloating effect.

Evolution of porosity during sintering process is showed as Fig. 5. Firstly, with temperature increasing, glass phase is formed gradually. Meanwhile, gas produced by redox reaction was enveloped by glass phase, and then pores are formed (as showed in Fig. 5a). Secondly, with the quantity of gas increasing, volume of single pore grow larger (as showed in Fig. 5b). Thirdly, with pore volume increasing, wall of adjoining pores gradually thinned, and then pores are fused (as showed in Fig. 5c). Fourthly, when glass phase can not provide enough space to accommodate the gas of a growing quantity, some gas will escape from ceramsite body (as showed in Fig. 5d). The emission of gas can explain the trend of Fig. 3. With the addition of tailing increasing, more and more gas escape from ceramsite body, instead of trapped in glass phase to form porosity structure. Therefore, the addition of tailing has a waning effect on porosity (or particle density) with tailing content increasing.
Fig. 5 Transformations of porous structure in ceramsite body in sintering process: (a) pore formation; (b) pore growing; (c) pore fusion; (d) gas emission

3.5. Industrial perspective

This study utilized C&D waste and tailing to prepare ceramsite, and its economic benefits are showed as follows: (1) C&D waste and tailing are low cost raw materials; (2) the addition of tailing decreases the sintering temperature, which can reduce the energy consumption and save production cost. Moreover, the process also has environmental benefits as follows: (1) it can release pressure of C&D waste on the environment; (2) application of C&D waste can save clay resource in ceramsite industry, and it is benefit to the protection of cultivated land. The ceramsite obtained by 9.1% tailing addition were tested for mechanical property. The result showed the ceramsite have a cylinder compressive strength of 9.6 MPa, meeting the Chinese standard for lightweight aggregate. In summary, this process, with both of economic benefits and environmental benefits, has a potential for industrial application.

4. Conclusion

Bloating ceramsite were prepared by C&D waste (as raw materials) and tailings (as bloating agent). The chemical compositions of C&D waste and tailings make up of the basic condition for ceramsite preparation. Tailings can decrease sintering temperature of raw materials. The bloating effect results from the gas produced by the redox reaction between tailings and C&D waste.

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