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Utilizing phosphate mine tailings to produce ceramisite

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HIGHLIGHTS

- Test materials are phosphate tailings and waste rock.
- Effects of material ratio, preheating temperature, preheating time, sintering temperature and sintering time.
- Available phosphorus content, 1 h water absorption rate and particle strength.
- Single factor experiment and optimization test.

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ABSTRACT

There are a large volume of phosphate tailings is produced in China each year. If the tailings are inappropriately disposed of, it may cause serious social problem. This paper presents a study to use phosphate mine tailings to make ceramisite materials, which can be used as building material. In the process, the phosphate tailings were mixed with soft interlayer and black shale materials. The effects of mass ratio among phosphate mine tailings, soft interlayer content and black shale and calcination parameters, such as preheating temperature, preheating time, sintering temperature and sintering time, on the properties of the ceramisite were investigated through single factor experimental testing. Based on the results of experimental tests, the calcination process was optimized. The single factor experimental study shows that the phosphorus content, water absorption rate and particle strength exhibit different correlations under the influence of the material ratio and calcination process. Further optimization tests were carried out and the results demonstrate the significance of influence factors following order: sintering temperature > preheating temperature > sintering time > preheating time. The calcination parameters were also obtained through optimization tests. Preheating temperature and time are 350 °C and 9.6 min respectively, and sintering temperature and time are 943 °C and 60 min respectively. Under those optimizing process, the available phosphorus content was determined to be 9.17%.

1. Introduction

Phosphate rocks are widely used as raw materials for fertilizer production, detergents production, animal food supplements, etc. The demand for phosphate rocks is growing [1,2]. For phosphate ores mining, the United States Geological Survey [3] estimated that the amount of mined phosphate ores worldwide was 198 million tonnes (Mt) in 2011 and 210 Mt in 2012. During mineral processing, tailings are produced as solid wastes. Large-scale mining and mineral processing generate huge amounts of tailings worldwide. During phosphate ores processing, about 30–40% of the ore mass is discarded as tailings after beneficiation operation [4,5]. In China, the medium and low grade phosphate ores make up 80% of the total phosphate ores and the mineral processing would generate 0.44 tonne phosphate tailings to produce 1 tonne phosphate concentrate by means of phosphorus enrichment. Currently, about 7 million tons of phosphate tailings is produced annually in China [6]. In addition, there are also huge amounts of phosphate tailings generated in earlier years. Therefore, how to deal with those tailings becomes one of the serious social problems because unsafe and inappropriate disposal methods may cause tailings dam failures that could result in heavy casualties and property losses.

In the daily mine operation, the tailings are generated and transported in the form of paste or slurry inform processing plant

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Table 1
Main accidents of tailings reservoirs in China.

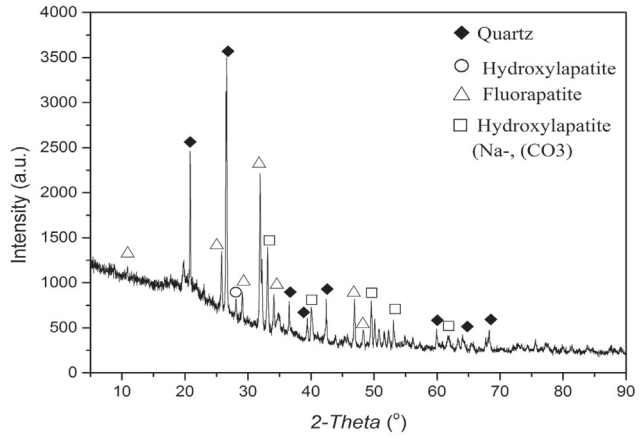
Name of dam	Tailings types	Construction Method	Year of failure	Persons killed
Huogudu, Yunnan Tin Group Co., Yunnan province	Tin	Upstream	1962	171
Niujiaolong, Shizhuyuan Non-ferrous Metals Co., Hunan province	Copper	Upstream	1985	49
Longjiaoshan, Daye Iron Ore mine, Hubei province	Iron	Upstream	1994	31
Dachang, Nandan Tin mine, Guangxi province	Tin	Upstream	2000	28
Zhenan Gold mine, Shanxi province	Gold	Upstream	2006	17
Xiangfen tailings pond, Shanxi province	Iron	Upstream	2008	277
Xinyi Zijin Tin mine, Guangdong province	Tin	Upstream	2010	28

Table 2
Main chemical composition of the three materials.

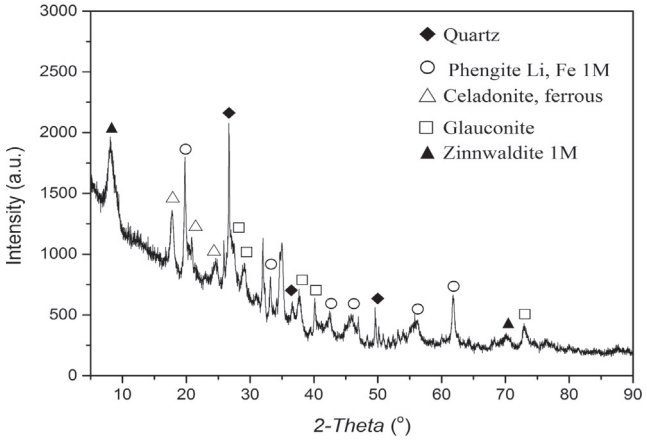
Composition	Phosphate tailings	Soft interlayer	Black shale
P_2O_5	17.76	7.61	2.29
MgO	1.07	4.07	5.02
Fe_2O_3	4.32	2.30	4.59
Al_2O_3	9.20	16.66	12.08
SiO_2	31.72	45.19	54.18
CaO	23.21	7.08	5.77
K_2O	1.71	5.97	9.38
Na_2O	0.15	–	1.71
Others	10.86	11.12	4.98

to tailings reservoir for disposal. The tailings reservoirs could store a large amount of tailings and other mineral wastes [7]. However, tailings pond failure may result in severe and sometimes catastrophic consequences [8–10]. Table 1 summarizes the main accidents of tailings reservoirs in China since 1962 [11]. The failure of phosphate tailings storage facility may cause serious environmental problems. For example, K. Gnandi et al. [12] found that the phosphate tailings contain relatively high levels of potentially toxic metals such as Cr, Cd, Cu, V, Ni, U, and Zn. The heavy elements could pollute the soil and surface/groundwater. The people who live in the downstream of the tailings facility could be exposed to health risks through drinking contaminated water with elevated heavy metal concentrations, food chain, etc. [13,14]. K. Gnandi et al. [15] conducted bioaccumulation investigations on crustaceans and fish sampled from coastal zone where the phosphate tailings were dumped into seawater. They found that the concentrations of metals in fish and crustacean were proportional to the distance between the tailings outfall and the sampling site. In other words, the concentration values decreased further away from the source of pollution. In recent years, regulations have increased the importance of environmental protection. With increasingly consumed phosphate sources, the industry begins to pay attention to transform phosphate tailings into asset.

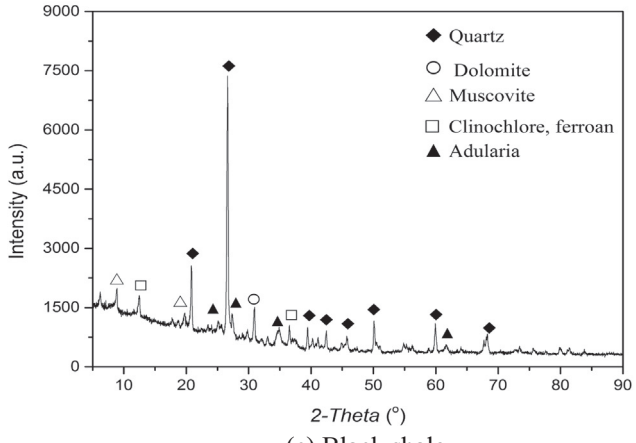
Until now, tailings have been successfully used as industrial raw materials. For example, Yang et al. [16] conducted the feasibility of utilizing low-silicon iron tailings and fly ash for production of fired bricks. They found that the physical properties at temperatures from 900 °C to 1000 °C were well conformed to Chinese Fired Common Bricks Standard [17].Wang et al. [18] studied the properties of asphalt mixtures which used magnetite tailings as a substitution of limestone aggregate. They found that the magnetite tailings can improve the high temperature treated property and slightly decrease splitting strength at low temperature of asphalt mixtures. Magnetite tailings can be broadly used as substitution of natural aggregates in asphalt mixtures in pavement engineering. Zheng et al. [19] conducted a feasibility study of recycling phosphate tailings in Portland cement as a filling material. They considered this as an environmentally friendly option to dispose of the phosphate tailings. Yin et al. [20] conducted the fabrication of foam glass which used iron tailings and waste glass with SiC powders as



(a) Phosphate tailings



(b) Soft interlayer



(c) Black shale

Fig. 1. XRD spectrum of phosphorus tailings, soft interlayer and black shale.