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Characteristics of water-retaining porous ceramics with sandblasting waste

Chih-Husan Ho [a], Huang-Mu Lo [b], Kae-Long Lin [c,*], Ju-Ying Lan [c]

[a] Department of Civil Engineering and Environmental Resources Management, Dahan Institute of Technology, Hualian City, Taiwan, ROC
[b] Department of Environmental Engineering and Management, Chaoyang University of Technology, Taichung City 41349, Taiwan, ROC
[c] Department of Environmental Engineering, National of ILan University, Yi-Lan City 26047, Taiwan, ROC

HIGHLIGHTS

- WRPC samples favorable chemical properties and heat stability at high heating temperatures.
- WRPC samples could maintain a good water-retention performance for 10–15 h and better than foamed glass.
- WRPC samples exhibited excellent water-retention performance at various heating temperatures.

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ABSTRACT

The study focuses on the characteristics of water-retention porous ceramics with sandblasting waste. Recycling of sandblasting waste collected from the surface treatment process in the solar industry. Sand blasting waste is mainly composed of Al_2O_3, and also contains very small portion of silicon and SiC. Water-retaining porous ceramic (WRPC) samples, comprising waste diatomite and sandblasting waste, with excellent humidity control performance were prepared. The appearance and structural properties of the samples were investigated through analysis of water absorption and compressive strength, X-ray diffraction, and scanning electronic microscopy. Moreover, the water retention performance levels of the samples at various heating temperatures were investigated. The WRPC samples prepared at the heating temperature of 1,270 °C meet the Standards for Japan Interlocking Block Pavement Engineering Association (compressive strength > 3 MPa, water absorption > 70%). At high heating temperatures, the quartz of the WRPC samples completely changed to cristobalite, thus affording the WRPC samples favorable chemical properties and heat stability. When the WRPC samples were sintered at high temperatures (1,200–1,270 °C), because of the driving force of sintering, the Scanning Electron Microscope (SEM) micrographs exhibited neck growth. The samples featured high compressive strength, low water absorption, and high water-retention performance. The results revealed that the WRPC samples could maintain a good water-retention performance for 10–15 h and better than in the foamed glass material (4 h). WRPC samples containing 5–20% sandblasting waste exhibited excellent water-retention performance at various heating temperatures.

1. Introduction

Sandblasting waste refers to the wastes produced in the process of the surface treatment process in the solar industry. Sand blasting waste is mainly composed of Al_2O_3, and also contains very small portion of silicon and SiC. According to statistics of the Taiwan Environmental Protection Administration regarding industrial wastes across the country, Taiwan produces 2,186 tons of sandblasting waste per year [1]. Diatomaceous earth is a porous material that can be used as an absorbent during filtering; however, its absorption properties disappear after long-term use, thus resulting in the material being discarded as waste. Diatomaceous earth is often used for filtering in food processing, and it eventually becomes waste diatomite [2]. Currently, the yearly production of diatomaceous earth in Taiwan is more than 5,000 tons. According to statistics of the Taiwan Environmental Protection Administration regarding industrial wastes across the country, Taiwan produces 7,718 tons of waste diatomite per year [1]. However, the Ministry of Economic Affairs reported that no more than

* Corresponding author.
E-mail address: klin@niu.edu.tw (K.-L. Lin).

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1,200 tons of these wastes were recycled and reused before being disposed of in landfills as industrial waste. Recent work has shown how hierarchically porous materials can be produced from macroporous diatomite [3]. Sayyari-Zahan et al. [4] introduced the potential of diatomite and re-use coal waste as a non chemical fertilizer to environmental improvement. The highest bio-available concentrations of K and P in soil obtained at 80 and 40 g/kg of diatomite and coal waste respectively. Ergün have shown that the usage of diatomite in place of cement for production of cement mortar and concrete did not improve the mechanical properties [5]. Zhang et al. suggested that the effect of activated waste diatomite on asphalt mixture's stability and durability was tested through mix design and performance test on a series of asphalt mixture, providing a new method and an approach for diatomite recycling [6]. Furthermore, Unal et al. [7] produced concrete blocks with diatomite, containing different aggregate granulometries and cement contents and low thermal conductivity, lightweight aggregate concrete with diatomite can be used to prove high isolation in the structure.

Taiwan is hot and humid during summer, is characterized by a monsoon island climate, and is often struck by typhoons; moreover, it experiences frequent earthquakes because of its location in a fault zone in the Pacific. Because of the increasing levels of noise, air, and other types of pollution in Taiwan, as well as the high frequency of earthquakes, steel-reinforced concrete buildings have become the preferred residential buildings. However, the internal temperature and humidity in reinforced concrete buildings are usually high in summer day. It makes the living conditions unbearable. People often easily feel stifled. Furthermore, the mold and bacteria are proposed grow rapidly [8]. The mental and physical health of the residents can be easily compromised by living in such an unhealthy spatial environment. In addition to the occurrence of the "urban heat island" effect, because most of the ground surface in the city has become impermeable because of the increasing number of buildings and the hot living environment, the ground's water retention capacity has decreased [9].

In thermodynamics, sintering is a process that occurs naturally when a microsystem approaches minimum energy [10]. Specifically, when exposed to high-heat treatment, the surface energy of particulate matter forms a gradient, resulting in its diffusion. The atoms in the particles, however, move toward contact points on some of the particulate matter components, gathering all the particles at lower energy levels. As the particles are connected by a neck-shaped structure, the sintering process further shrinks and densifies the particles, thereby resulting in high mechanical strength of the sintering samples [11]. Several materials with water-retention properties have been developed for use in various types of functional pavement systems. In this kind of system, the particular cooling effect usually created by the vapor evaporation on the surface. It happened by the pavements which containing water-retaining materials and/or water-retention porous ceramics [12].

Water-retaining materials include allophane [12]; diatomaceous earth [13]; and low-grade silica, glass, and alumina [14]. Water-retaining construction materials could facilitate the water retention of the land and mitigate temperature increase. Thus, effective water-retaining materials could effectively control ambient temperature and reduce room temperature and the need to use air conditioners. The water absorption and retention capacities of water-retention porous ceramics (WRPC) can facilitate water cycling, thereby controlling climate change, alleviating temperature increase, and preventing urban heat island effects. Because the problems of energy conservation and carbon dioxide emissions are becoming increasingly critical, research on mitigating the urban heat island effect is imperative. In the present study, WRPC samples were prepared at heating temperatures of 1,000–1,270 °C and sandblasting waste replacement levels of 0–20%. The porous properties, water absorption, compressive strength, and water-retention performance of the resulting WRPC samples were determined to assess their suitability for overcoming the urban heat island effects.

2. Materials and methods

2.1. Materials

The sandblasting waste and waste diatomite were collected from surface treatment process in the solar industry and the food-processing industry and refinery plants located in Taipei County. The waste diatomite used in this study with a moisture content of 38.82%. In accordance with the standard test method published by the Environmental Analysis Laboratory, Taiwan National Institute for Environmental Analysis (NIEA) R 208.03C was mixed with distilled water at a ratio of 1:10, and the pH value of the resulting solution was 7.21. According to the results of the

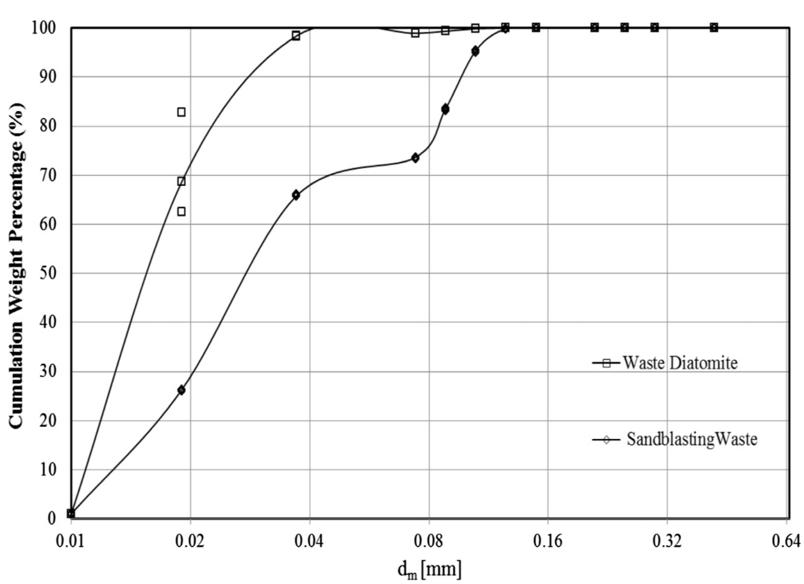

Fig. 1. Particle size distribution of the raw materials.