Case Studies in Construction Materials 8 (2018) 87–96

Contents lists available at ScienceDirect

Case Studies in Construction Materials

journal homepage: www.elsevier.com/locate/cscm

Case study

Microstructures and physical properties of waste garnets as a promising construction materials

Habeeb Lateef Muttashar[a,*], Nazri Bin Ali[b], Mohd Azreen Mohd Ariffin[b], Mohd Warid Hussin[b]

[a] Department of Structure and Materials, Faculty of Civil Engineering & UTM Construction Research Centre University Technology Malaysia, 81310, UTM, Johor Bahru, Johor, Malaysia

[b] Forensic Engineering Centre, Faculty of Civil Engineering, University Technology Malaysia, 81310, UTM, Johor Bahru, Johor, Malaysia

ARTICLE INFO

Keywords:
Spent garnet
Sand
Micro-structures
Recycling
Concrete

ABSTRACT

Rapid industrial growth has witnessed the ever-increasing utilization of sand from rivers for various construction purposes, which caused an over-exploitation of rivers' beds and disturbed the eco-system. strong engineering properties of waste garnets offer a recycling alternative to create efficient construction materials. Recycling of garnets provides a cost-effective and environmentally responsible solution rather than dumping it as industrial waste. In this spirit, this article presents an investigation into the capacity of spent garnets as sand replacement. The main parameters studied were the evolution of leaching performance, microstructure of the raw spent garnet and sand specimens. The microstructures, boning vibrations and thermal properties of the raw materials were determined using X-ray diffraction (XRD), field emission scanning microscopy (FESEM), Fourier transform infrared (FTIR) spectroscopy, and thermo gravimetric analysis (TGA). Admirable features of the results suggest that the spent garnet is proven to be suitable replacement of sand. It is established that proper exploitation of spent garnet as an alternative to sand could save the earth from depleting the natural resources which is essential for sustainable development.

1. Introduction

Fast industrial expansion has witnessed the ever-increasing utilization of sand from rivers for several construction purposes [1], which led to an over-utilization of rivers' beds and disturbed the ecosystem [2]. Numerous problems have emerged including the increase of river bed depth, lowering of the water table, increase of salinity and destruction of river embankments [3]. Recently, intensive researches have established that modified concretes obtained by incorporating waste materials can lead to sustainable product development. Such concrete structures not only allow for greener and environmentally sound construction but also protect the excessive consumption of natural fine aggregates that are non-renewable [4]. Thus, proper use of fine aggregates in the concretes as alternative materials became an absolute necessity for the replacement of river sand. In this regard, utilization of waste garnets emerged as a promising alternative in its own right. So far, no details literature review has been performed on this new waste material that shows its potential towards concrete applications. In the context of Malaysia, the topic spent garnet is becoming a significant issue in terms of recycling this new waste material and further reuse as useful sand replacement in concrete. Statistics revealed that the amount of garnet imported from Australia to Malaysia in the year 2013 was 2000 t. This amount was imported by MMHE

* Corresponding author.
E-mail address: lmhabeeb2@live.utm.my (H.L. Muttashar).

https://doi.org/10.1016/j.cscm.2017.12.001
Received 28 August 2017; Accepted 8 December 2017
Available online 09 January 2018

(Malaysian Marine and Heavy Engineering Sdn. Bhd.). However, heavy mineral sands are the class of ore deposit that is a significant resource of rare earth elements and industrial minerals including diamond, garnet, sapphire, and other valuable gemstones or metals. The so called “garnet” is a generic word that refers to an assemblage of multifaceted minerals of silicate compounds containing Calcium (Ca), Magnesium (Mg), Ferrous iron (Fe) or Manganese (Mn), Aluminium (Al), Chromium (Cr), Ferric iron (Fe) or even Titanium (Ti) having analogous crystal lattice structures and varied chemical formulas Castel, 2010. Interestingly, the angular fractures and hardness properties of garnets together with their ability to be recycled make them advantageous for numerous abrasive applications. The common chemical composition of garnet is $A_3B_2(SiO_4)_3$ wherein the element “A” may be Ca, Mg, ferrous iron, or Mn, Al, Cr, ferric iron or Ti [5]. Garnets have major industrial uses such as water jet cutting, abrasive blast medium and powder, granule for water filtration, etc. [6]. In 2002, the total estimated global production of industrial garnet was 440,000 T, wherein China, Australia, India, and the USA were the major producers. The USA alone produced about 9% of the totally produced industrial garnet worldwide [7,8].

Production in both Australia and India was more than the USA. Currently, Russia and Turkey are mining garnet to meet mainly their domestic market demand. Besides, some garnet resources with tiny mining facilities are situated in Chile, Canada, Czech Republic, South Africa, Pakistan, Spain, Ukraine, and Thailand to meet their domestic demand. Industries in Australia have been steadily enhancing their garnet manufacturing and export. Meanwhile, China and India have augmented the garnet production and became vital supplier of garnet sources for other nations. Thus, use of spent garnet to make concrete in place of fine aggregates will avoid the over-usage of natural sand and gravels. This research effort is expected to bring modernization in the Malaysian construction industries, encourage builders and engineers to use eco-friendly spent garnet based GPCs than the conventional one made of natural river sand, create more jobs and save environment from further pollution.

2. Materials and methods

2.1. Materials

In this study, the spent garnet was acquired from southern Johor (Malaysia). Subsequently, various characterizations and tests were made. These include: visual inspection, physical properties, chemical composition and leaching behaviour. The morphology, mineral composition and thermal analysis were determined. Fig. 1 illustrates the physical appearance of spent garnet and sand used as fine aggregates.

The chemical composition of the spent garnet was determined using S4 Pioneer X-ray fluorescence spectroscopy (XRF) as displayed in Fig. 2. This spectrometer works by irradiating the samples in an intense X-ray beam from a radioisotope source. The primary source of the rays excites the sample by detaching the tightly bound inner shell electrons from their orbits in the excited atoms of the samples. When the excited atoms are relaxed to the original state, fluorescent X-rays are emitted. The energies of the detected emitted rays using an energy dispersive detector are used for the identification of elementsdioisotope source. The primary source of the rays excites the sample by detaching the tightly bound inner shell electrons from their orbits in the excited atoms of the samples. When the excited atoms are relaxed to the original state, fluorescent X-rays are emitted. The energies of the detected emitted rays using an energy dispersive detector are used for the identification of elements in the sample while the intensity of the X-rays is employed to determine the quantity of the elements. The crystalline and amorphous phase of the constituent materials was verified using X-ray diffraction (XRD) analysis. A Rigaku XRD machine (Fig. 3) was used.

The structural properties of the spent garnet in terms of bonding vibrations were determinedusing Fourier transform infrared (FTIR) spectroscopy. The room temperature absorption/transmission infrared spectra were recorded in the wavenumber range of 400–4000 cm^{-1}. Fig. 4 displays the Perking Elmer FTIR instrument that was used to identify the chemical functionality and molecular bonding. Using potassium bromide (KBr) pellet technique a transparent disk-shaped material was prepared and tested. The

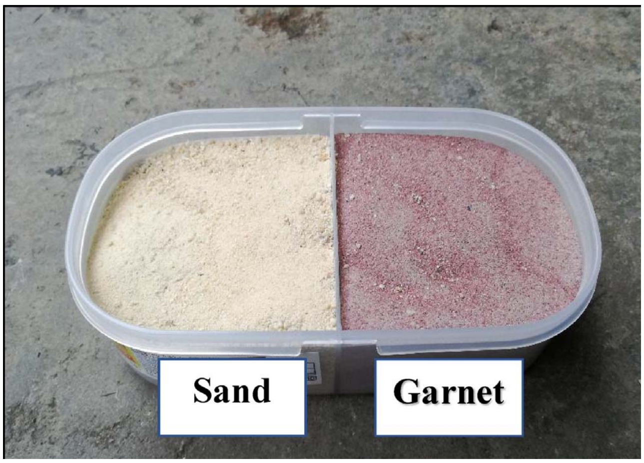

Fig. 1. Appearance of fine aggregates (sand and garnet) used in the concrete production.