Journal of Cleaner Production 159 (2017) 241–247

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Utilization of solid-cutting waste of granite as an alternative abrasive in abrasive waterjet cutting of marble

Gokhan Aydin*, Serkan Kaya, Izzet Karakurt

Mining Engineering Department, Karadeniz Technical University, 61080, Trabzon, Turkey

ARTICLE INFO

Article history:
Received 12 December 2016
Received in revised form
20 March 2017
Accepted 22 April 2017
Available online 13 May 2017

Keywords:
Abrasives
Abrasive waterjet
Marble
Granite particles
Cutting performance

ABSTRACT

Solid-cutting waste of granite is generated with considerable amounts during the machining processes. Utilization of this waste as an alternative material in various sectors such as construction and building would protect the environment and create a valuable source for the sectors. In this paper, an experimental study is carried out for the utilization of solid-cutting waste of granite as an abrasive material in abrasive waterjet (AWJ) cutting of marble. The solid-cutting waste of granite is downscaled with crushing and grinding. The obtained particles are then sieved in a range of size 150–300 μm. Some properties of the waste granite such as hardness and density are determined. Additionally, the cutting performance of the granite particles is compared to that of garnet based on some performance outputs including the cutting width, cutting depth, cutting-wear zone depth, kerf angle and surface roughness. During the cutting experiments, the cutting parameters are kept constant. Results show that the granite particles meet the requirements as an abrasive in the AWJ cutting of marble. It is revealed that the granite particles show similar performance with garnet in terms of the cutting width (granite: 2.10 mm and garnet: 2.21 mm) and the surface roughness (granite: 5.2 μm and garnet: 4.59 μm). It is determined that lower cutting depth (67% of the cutting depth produced by garnet, 15.62 mm) is obtained with the granite particles. Additionally, it is concluded that garnet produces lower kerf angles (70% and 79% of the kerf angle-access and kerf angle-exit produced by the granite particles, respectively). Finally, it can be noted that the granite particles can be effectively used in the cutting of marble and other rocks with similar density and hardness.

1. Introduction

A wide variety of machining processes are employed before the granite stone reaches to its usable form. The ornamental stone industry involves quarrying, sizing and polishing of different rocks. Solid-cutting wastes and fine powder are composed with considerable amounts (20–30% of the production by volume) during these applications (Soltan et al., 2016). These wastes are generally deposited in surface landfills affecting the land productivity adversely (Torres et al., 2009). Transporting and dumping of waste in landfills have significant costs. The use of waste in many industrial sectors could reduce the production costs and provide an opportunity for a new business (Allam et al., 2016).

Many studies have been carried out recently for the utilization of granite wastes. Dhanapandian et al. (2009) characterized and evaluated the possibilities of using the granite and marble sawing wastes as alternative raw materials in the production of bricks. Their study showed that the bulk density, compressive strength, flexural strength increased with the addition of wastes. It was suggested that granite and marble wastes could be incorporated up to 50% into clay materials in the production of bricks. Menezes et al. (2008) also characterized and evaluated the possibilities of using the granite sawing wastes as alternative ceramic raw materials in the production of ceramic bricks and tiles. The results showed that the granite wastes have similar physical and mineralogical characteristics with the conventional ceramic raw materials. It was concluded that the ceramic bodies produced from reformulated ceramic compositions had technological characteristics in agreement with the standardizations for ceramic bricks and tiles. The incorporation of wastes from natural rock cutting and polishing operations was studied for production of roof tiles by Torres et al. (2009). The results revealed that roof tiles incorporating 10% of granite presented excellent properties in terms of the water

* Corresponding author.
E-mail address: gaydin@ktu.edu.tr (G. Aydin).

http://dx.doi.org/10.1016/j.jclepro.2017.04.173
0959-6526/

Fig. 1. The marble samples.

absorption, pyroplastic deformation index, and bending strength. Vijayalakshmi et al. (2012) investigated the suitability of granite powder waste as a substitute material for fine/natural aggregate in concrete production. The results showed that the mechanical properties of the concrete were not affected by the substitution of granite powder waste up to 15%. Therefore, the researchers recommended that the replacement of natural sand by granite powder waste up to 15% would be favorable for concrete making. The possibility of using the granite powder as a partial replacement of sand in concrete was investigated by Ghannam et al. (2016). The results showed that the compressive strength and the flexural strength of concrete increased with the addition of granite powder as partial replacement of sand. It was concluded that using 10% granite powder in concrete gave the best result (highest increase in compressive strength and the flexural strength) compared to other ratios. Sadek et al. (2016) investigated the possibility of using three types of waste powders (marble powder, granite powder and mixed powder) as mineral additives in self-compacting concrete. The results of the study showed that high volumes of the waste powders (up to 50%) could be used successfully as mineral additives in the production of self-compacting concrete. The results also indicated that self-compacting concrete incorporating mixed powder showed the superior performance followed by the granite powder and marble powder. Singh et al. (2016a) used granite cutting waste as a partial replacement of natural fine aggregate (river sand) in conventional concrete. The results indicated that optimum replacement percentage of the fine aggregate with granite cutting waste was about 30%. It was noted that the performance of concrete was significantly improved at this replacement level. The durability characteristics of the concrete incorporating granite cutting waste as a partial replacement for the fine aggregate was investigated by Singh et al. (2016b). The study revealed that concrete exhibited superior performance under adverse exposure conditions of acid attack, carbonation, sulphate attack, chloride penetration and elevated temperature at an optimum replacement of 25% granite cutting waste.

Table 1
Some properties of the marble used.

Standard	Property	Value
ASTM-C170	Compressive Strength	88.80 MPa
ASTM-C880	Flexural Strength	8.85 MPa
ASTM-C97	Density	2.68 g/cm^3
ASTM-C97	Water absorption	0.19%

As can be seen from relevant literature, the studies are mainly focused on the use of granite wastes in the production of self-compacting concrete, bricks-tiles, cement concrete as aggregate and filler. Differing from these studies, this study presents the first attempt for the use of solid-cutting waste of granite as an alternative abrasive material in the AWJ cutting application. Hardness, density, toughness and shape of granite particles are investigated in terms of the suitability as an abrasive material in the AWJ. Additionally, based on some performance outputs such as cutting depth and surface roughness, the cutting performance of granite particles is compared with garnet, which is commonly used as an abrasive material in the AWJ cutting applications.

Following the introduction section, the rest of the paper is organized as follows. The detailed info about the materials used and the methodology employed are presented in the Materials and Methods section. The results of the cutting experiments are given and analyzed in the Results and Discussion section. Core findings of the study are presented and some recommendations for further studies are made in the Conclusions and Recommendation section.

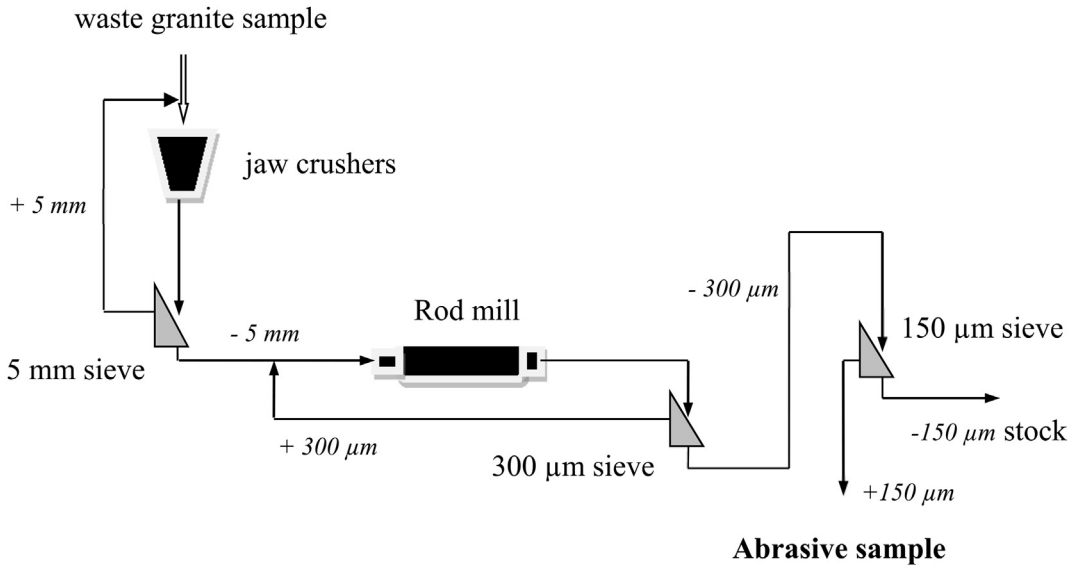

Fig. 2. The processes for preparation of the granite particles.