Marble Sludge Recycling by Using Geopolymerization Technology

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Abstract: The purpose of this study was to investigate the recycling potential of marble sludge, which is generated from the cutting and grinding of marble. Geopolymerization technology was applied to this aim. Waste marble sludge was combined with cement, fly ash, clay, gypsum, and blast furnace slag in different combinations to prepare paste samples without aggregate. NaSil NaOH and 8 M NaOH solutions were used as alkaline activators for geopolymerization. Samples were analyzed for unconfined compressive strength (UCS), and the formulations yielding the highest UCS results were determined. The sample prepared using the NaSil NaOH solution and containing 25% fly ash, 25% cement, 25% blast furnace slag, and 25% marble sludge yielded the highest UCS level among the samples, 52 MPa. The results of the study showed that marble sludge is a suitable material for geopolymerization purposes and yields high compressive strength compared to standard cement paste. **DOI:** 10.1061/(ASCE)HZ.2153-5515.0000415. *© 2018 American Society of Civil Engineers.*

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Introduction

More than 40% of the global natural stone reserves are located in Turkey, according to data from the Republic of Turkey's Ministry of Energy and Natural Resources (MENR 2017). Workable marble reserves constitute 4 billion m^3 of this reserve (MENR 2017). The marble sector in Turkey comprises 2,560 licensed marble quarries, 1,500 small- and medium-scale marble factories, and 7,500 workshops (MENR 2017). Fig. 1 shows the annual increase in Turkey's marble production.

Marble blocks are cut using water in marble quarries, and this process produces a waste called marble sludge. Improper management of this waste may cause various environmental problems. For example, in dry seasons, marble sludge converted to dust can be suspended in the air and precipitate on vegetation, which affects local ecosystems (Montero et al. 2009). Marble sludge deposited in riverbeds and around the quarries can reduce the porosity and permeability of the topsoil and prevent the drainage of the water (Montero et al. 2009). Furthermore, fine dust particles increase soil alkalinity and decrease soil fertility (Montero et al. 2009). Therefore, it is important to properly manage and recycle the marble sludge generated.

Several studies on marble sludge recycling exist in the literature. Aruntas et al. (2010) investigated the use of marble dust as an additive in cement production. Researchers ground the portland cement clinker with different amounts of marble dust and reported that marble dust can be used with a ratio of 10% in cement production (Aruntas et al. 2010). Corinaldesi et al. (2010) substituted sand with marble sludge with a ratio of 10% and obtained a feasible unconfined compressive strength (UCS) level. Topcu et al. (2009) and Alyamac and Ince (2009) showed that four different types of marble sludge generated in Turkey (Blaine fineness changing between 390 and 510 m^2/kg) can be used as filler in the production of self-compacting concrete. Ergün (2011) reported that a 5% substitution of cement with marble dust along with a superplasticizer additive resulted in a UCS level higher than the control sample. Yen et al. (2011) used marble sludge, sewage sludge, drinking water treatment plant sludge, and basic oxygen furnace sludge as replacements for limestone, sand, clay, and iron slag, respectively, as the raw materials for the production of cement in order to produce eco-cement. They found that it is feasible to use marble sludge to replace up to 50% of the limestone and also that other materials can serve as total replacements for the raw materials typically used in the production of cement (Yen et al. 2011). Another study (Pérez-Sirvent et al. 2007) showed that sediment samples polluted with heavy metals can be stabilized by mixing them with marble sludge.

Replacing marble sludge with cement is an environmentally friendly option since it will reduce CO_2 emissions caused by cement production while finding a waste management solution for the marble sludge generated. In the previous studies conducted with marble sludge, waste was replaced with cement or sand in limited amounts such as 5–10%, and its effect on cement's hydration behavior was investigated. This study investigated the possibility of higher substitution rates of cement with marble sludge and recycling by applying geopolymerization technology.

Davidovits first introduced the geopolymer concept in the 1970s. Several superior properties of geopolymers, such as high compressive strength, high tensile strength, low shrinkage, high acid resistance, high heat resistance, and low thermal conductivity, were reported (Duxson et al. 2007a). Thanks to these properties, geopolymers offer alternatives to cement concrete in terms of different construction materials, fire resistant coatings, fiber-reinforced composites, and waste immobilization solutions (Bakharev 2005; Kong and Sanjayan 2008; Sanusi et al. 2016; Singh et al. 2015).

Geopolymer technology, with its low carbon footprint, offers an environmentally friendly alternative to fly ash usage. Production of a fly ash–based geopolymer is a promising clean construction technology alternative with low CO_2 emission. Si:Al ratios in the solution, type and amount of the alkaline solution, temperature, and curing conditions are important factors in geopolymerization

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