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Performance of mortar and concrete incorporating granite sludge as cement replacement

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HIGHLIGHTS

- Feasibility of using granite sludge as a supplementary cementitious material.
- Three types of mixes were prepared using up to 40% granite sludge replacing cement.
- A mix of 20% granite sludge meets the requirements of concrete units & cement tiles.

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ABSTRACT

The main objective of the present study is to determine the feasibility of using granite sludge, produced during the manufacturing processes of ornamental stones, as a cement replacement in mortar and production of concrete blocks by assessing their physical, mechanical and durability performance. The granite sludge as well as cement were characterized using XRF, XRD, particle size distribution, specific surface area and specific gravity. Three types of mixes including "cement paste composites", "mortar" and "concrete" mixes, were prepared where the granite sludge was substituted for cement binder up to 40% at certain proportions of 0%, 10%, 20%, 30% and 40%. The physico-mechanical properties of all three types were determined at 7 d and 28 d, while the durability performance of hardened mortar and concrete mixes was determined at 28 d and 90 d, according to standard test methods of ASTM & BS EN and the results were compared with the specification requirements of these standards as well as Egyptian Standard Specifications (ESS). The test results clearly showed that the mortar and concrete mixes modified with granite sludge up to 20% cement replacement exhibited a negligible decline in physical and mechanical properties in addition to enhanced resistance to abrasion, freeze & thaw and sulfate attack. Furthermore, they are in compliance with the requirements of concrete bricks and paving units as well as mortar cement and cement tiles.

1. Introduction

The ornamental stone industry produces large amount of wastes which are present mainly in two forms, solids (generated during the extraction stage in quarries) and moist fine powder or sludge (produced during the manufacturing processes). The later one is the most predominant form resulting during all the processing stages at the manufacturing zones that are produced in too huge amount for stocking. The increased accumulation of this type of wastes at the dumpsites day by day is causing a serious environmental pollution especially after being dried by losing its water content. It turns into a fine dust that is able to be blown by the wind as suspended particles causing air pollution in the dumping areas and the nearby industrial, agricultural and domestic areas, and a potential threat to the human health. These air – suspended fine dust can be easily inhaled by humans causing severe respiratory diseases, visual and skin disorder among local people [1–3].

The amount of wastes generating during the ornamental stone industry operations including quarrying, sawing, polishing and cutting processes were estimated by several works. The production volume of natural stones in India was estimated of about 35.342 million t [4]. Pappu et al. (2007) [5] stated that about 6 million t of marble wastes in India were released during cutting, polishing and grinding processes. The decorative stone industries in Brazil generate a huge amount of waste, which can reach up to 40% during the quarrying and manufacturing processes and about 20–25%

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through cutting and sawing processes [1] of the total extraction or production volume of the block that was estimated of about 3 million t [6]. According to (El-Haggar, 2007) [7], the total waste generated from the ornamental stone industry processes starting with quarrying stage, passing through the manufacturing stage until the end product, is in the range of 50–60% of the rock volume.

In Egypt, it was estimated that the total amount of wastes resulting from ornamental stone industry at Shaq Al-Thoaban industrial cluster reaches around 800, 000 t per year that represents about 25% of the total quarrying production estimated at 3.2 million t [8].

The recycling of the wastes in the manufacturing of beneficial and sustainable products is considered one of the major environmental priorities at recent days. Although the construction sector is responsible for consuming natural resources and energy, it has an important role for its capacity of absorbing other industry's waste and by-products [9]. Owing to this fact, there is an interest by many researchers in using of marble and granite – processing wastes as the cheapest alternative material in manufacturing of various products of added value such as cement mortar, concrete bricks and paving blocks.

Several studies dealt with the incorporation of natural stone wastes in the concrete manufacturing processes as a suitable replacement for fine aggregates and cement binder up to certain optimum percentage level [10–20].

Regarding granite sludge waste, many studies have been carried out on the effect of using granite sludge waste as fine aggregates replacement in mortar and concrete products; Raman et al. (2011) [21] concluded that the granite quarry dust can be used as a partial substitute material to natural sand in the production of high strength concrete in the presence of rise husk ash. Hamza et al. (2011) [8] observed that all manufactured concrete bricks using granite slurry waste up to 40% comply with the Egyptian code requirement for structural bricks, and the optimum granite slurry content with a positive effect was 10%.

Divakar et al. (2012) [14] observed an enhancement in concrete strength using up to 35% granite cutting waste as fine aggregate compared to conventional concrete. Felix kala (2013) [22] observed that using of granite powder waste as a partial substitution for sand in the presence of admixtures as a partial replacement of cement has beneficial effects of the mechanical properties of high performance concrete, the test results revealed that the superior performance of concrete has been achieved at 25% granite powder replacement. Vijayalakshmi et al. (2013) [23] found out that using up to 15% granite powder waste substituting to natural sand is suitable for the concrete production without significantly affecting the strength and durability parameters.

According to Ribeiro and Holanda (2014) [24], it was observed that using up to 30% by weight granite cutting sludge as partial replacement for soil in soil-cement bricks manufacturing is suggested as optimum percentage, achieving an enhancement in physical and mechanical properties. Singh et al. (2016) [25] found that using up to 25% granite cutting waste as a partial replacement for fine aggregate led to an improvement in the durability characteristics of the concrete with variable w/c ratios of 0.30 and 0.40 under adverse exposure condition.

The test results carried by (Singh et al., 2016a) [26] revealed that incorporation of 25–40% granite cutting waste as partial substitute of natural river sand has a favorable influence on the strength and durability parameters of concrete. Singh et al. (2016b) [27] observed that the optimum percentage of using granite cutting waste as partial substitute of natural fine aggregate that produce concrete with better strength and durability characteristics compared to conventional concrete is about 30%. Singh et al. (2016c) [28] found out that the optimal replacement percentages for natural sand aggregate by granite cutting waste in the concrete production were 25% and the concrete produced was found to be efficient towards stability strength and durability.

Ghannama et al. (2016) [29] observed that the substitution of sand with granite powder increased the compressive, flexural and tensile strengths of concrete compared to the normal concrete and the maximum increase was recorded at 10% granite powder. Jeyaprabha et al. (2016) [30] observed an improvement in strength properties of mortar modified with 15% granite powder waste as river sand substitutes compared to river sand mortar at both normal conditions and under exposure to elevated temperature and water quenching.

The utilization of granite sludge as cement replacement was discussed by many authors; Mármol et al. (2010) [31] found that up to 10% of cement can be replaced with granite cutting waste in manufacturing of coloured/masonry mortar without sacrificing the compressive strength. Abukersh and Fairfield, (2011) [32] examined the potential for using recycled red granite dust of 20–50% as a partial cement substitute in concrete. They observed a good and acceptable workability as well as mechanical performances of concretes using up to 30% red granite dust. The results showed that the using of 30% red granite dust improved the early age concrete strength and elastic modulus compared with the fly ash, while reduced the compressive strength.

Abd Elmoaty (2013) [15] studied the concrete properties modified with granite dust waste as cement replacement and addition. The test results showed that using 5% of granite dust as cement replacement enhanced the mechanical and corrosion resistance properties of concrete, while an enhancement of mechanical properties of concrete are shown at high level of granite dust waste as cement addition. Al-Humaiedeh and Khushefati (2013) [33] observed that the replacement of cement by 10% of granite powder waste has no effect on the compressive strength of concrete, while addition up to 20% of granite powder waste substitute to fine aggregate improved the compressive strength of concrete. Ramos et al. (2013) [34] revealed that using granitic sludge waste, as partial cement replacement improved the durability of mortar without compromising workability and strength. Bacarji et al. (2013) [35] investigated the applicability of marble and granite residues as a sustainable alternative for cement replacement. They found out that using 5% could be considered as a promising sustainable alternative for cement.

Li et al. (2016) [36] investigated the workability, mechanical properties, durability and shrinkage performance of sand concrete using granite dust as supplementary cementitious materials replacing fly ash and found out that the optimum dosage of granite dust is 20% of the total cementitious materials. Medina et al. (2017) [20] studied the viability of designing new blended cements using up to 20% granite sludge substituting of the clinker and analysing its effect on the chemical, rheological, mechanical and microstructural properties of the end product. They found out that the new cements are apt for use in construction, in as much as they are compliant with the requirements laid down for Type II/A and IV/A cements in (BS EN 197-1/2011) [37].

The present study aims at evaluating the performance of cement composites, mortar and concrete blocks incorporating granite sludge as partial cement replacement at percentages 0%, 10%, 20%, 30% and 40% of the total weight of cement. Various required tests such as physical, mechanical and durability tests have been conducted to evaluate the performance of mortar and concrete blocks comparing with the international standard specifications concerning cement tiles and concrete paving units.