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Effect of granite dust on mechanical and some durability properties of manufactured sand concrete

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HIGHLIGHTS

- Granite dust was mixed into manufactured sand concrete to replace the fly ash.
- The workability and drying shrinkage were improved.
- The mechanical and some durability properties were improved.
- Granite dust can be used as the supplementary cementitious material.

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ABSTRACT

The fabrication process of manufactured sands produces plenty of dust, which not only occupies the land and pollutes the environment but also causes dam breaks and collapses. To make full use of it, such granite dust was herein mixed into manufactured sand concrete as supplementary cementitious materials to replace fly ash in different proportions. The mechanical and some durability properties of these concretes were studied. The results showed an improvement in the workability of the manufactured sand concrete by introducing granite dust. The early strengths of manufactured sand concrete decreased with the fly ash replacement, but the compressive strengths, bending strengths and elastic modulus increased in the later stage when the replacement ratio was 20%. Compared with pure cement concrete, the 56 days chloride penetration resistance of the modified concretes was enhanced remarkably. Although the electric flux increased with the increasing granite dust dosage, it was always located at the low permeability level. The dynamic elastic modulus only had a slightly decrease after 350 freezing and thawing cycles when the granite dust dosage was within 20%, but it obviously dropped down when that dosage reached 30%. The drying shrinkage of the modified concrete was also inhibited within 14 days, compared with the pure cement concrete.

1. Introduction

As natural river sand mining is limited by the seasons and a national mining limitation policy has already been issued in China, there is a serious shortage of river sand, which is the main raw material of concrete. Manufactured sands from limestone, granite, basalt *etc.* have become the green and economical substitute for river sands used in high-performance concrete [1,2]. In the manufactured sand fabrication process, fine particles are inevitably generated. Usually, those particles that are smaller than 75 μm and that have the same mineralogical composition as the mother rocks are called stone dust or stone powder [3]. A certain content of stone dust is allowed to exist in the manufactured sands, but the limits are different under various standards, and the maximum is 10% [4]. However, the actual content of stone dust in the manufacturing process always exceeds the required value under standards. For instance, the statistics of 24 samples in 17 granite quarries in Guangdong province showed that the dust content was 4.7–22.2%, in which 16 samples' data exceeded 10% [5]. The excess dust needs to be washed out before use. As a result, over 10 million tons of granite sludge wastes are generated every year in China, lacking effective utilization [6]. It is necessary and pressing to address these issues properly to avoid such waste and pollution. Thus, turning granite dust into a building material resource is an

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effective technological approach to realize its large-scale high value added utilization.

Thus far, many studies have been performed on the applications of ground limestone [7–9], and the corresponding national standard and technical specification regarding concrete with ground limestone have been officially issued and implemented in China [10,11]. By contrast, research on the effects of granite dust in concrete is scarce; the first report was utilizing it to prepare aerated concrete and ceramics in 1991 [12]. However, the application of granite dust in concrete has attracted much attention recently. The study of the effects of granite dust on concrete performance focuses on two aspects. One is the cement replacement, and the other is the fine aggregate replacement. Elmoaty et al. [13] used granite dust (filtered by a 0.075-mm sieve) to replace cement by 5%, 7.5%, 10.0% and 15%. They found that the concrete compressive strength and tensile strength could be improved by 5% cement replacement, with the corrosion cracking time increasing in the meanwhile. No obvious changes could be observed for the microstructure and hydration products. Abukersh et al. [14] studied the workability and mechanical performances of concretes with 20–50% red granite dust. The experimental results showed that the introduction of granite dust improved the early strength and elastic modulus compared with the fly ash but reduced the concrete compressive strength. The performance of concrete mixed with granite and marble wastes was studied by Bacarji and coworkers [15]. The experimental and numerical analysis showed that there was a strong correlation between concrete compressive strength and the cement replacement ratio. In addition, it was confirmed that the granite and marble could be used as sustainable replacements of cement. Ramos et al. studied two types of granite dust with different fineness [16]. They found that the waste granite sludge could compact the concrete substrates and reduce the alkali aggregate reacting if the fineness was fine enough by grinding. Meanwhile, the chloride penetration resistance could be improved by 70% at most, and there were no serious impacts on the strength and workability. Some researchers also used the granite dust to prepare a hot asphalt mixture [17], ceramics and bricks [18,19] and so on.

Some deficiencies still exist in the research on granite dust applications in concrete. First, field application has not been adequately considered in the concrete design stage, where different structural parts and construction methods have different workability requirements. Second, mineral admixtures have not been introduced in most concrete designs. With the popularization of high-performance concrete, mineral admixtures have become absolutely necessary for the concrete. Third, the effects of granite dust on the performances of manufactured sand concrete are still insufficiently studied, where most comparison benchmarks have been natural aggregate concretes. Focusing on the above problems, granite dust was used as partial fly ash replacement in granite manufactured sand concrete to achieve the comprehensive application of granite dust and manufactured sand. The concrete slump was designed as 180 ± 10 mm, meeting the pumping requirements. The effects of the workability, mechanical property, durability and drying shrinkage were studied by different replacement ratios.

2. Experimental

2.1. Materials

Type P.O 42.5 Portland cement was used. Commercially available fly ash and grinding slag powder were used as the mineral mixture. The granite dust was filtered through a 0.075-mm sieve, and their XRD pattern is shown in Fig. 1, revealing that the main ingredients were granite and quartz. The size distribution of granite dust is shown in Fig. 2, and D10, D50, and D90 were 3.7 μm, 21.4 μm and 67.0 μm, respectively. The criterion D10 (D50 or D90) means that 10% (50% or 90%) of the dust have a diameter lower than this criterion. The fine aggregates were manufactured granite sands with a fineness modulus of 2.7, and their grading curve belonged to region II. The coarse aggregates were a 5–20-mm continuous-grading crushed stone. The superplasticizer was a polycarboxylate with a 29% water reducing rate.

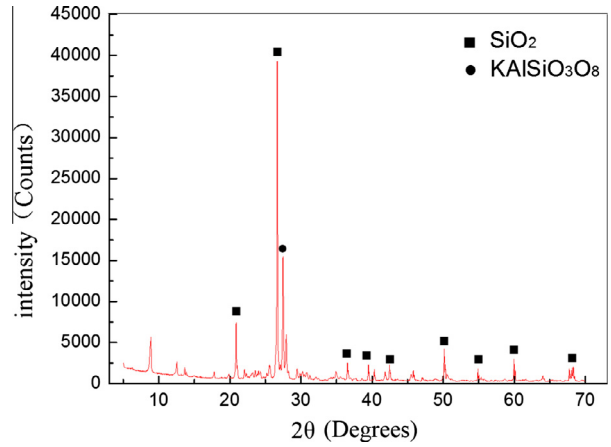

Fig. 1. XRD pattern of granite dust.

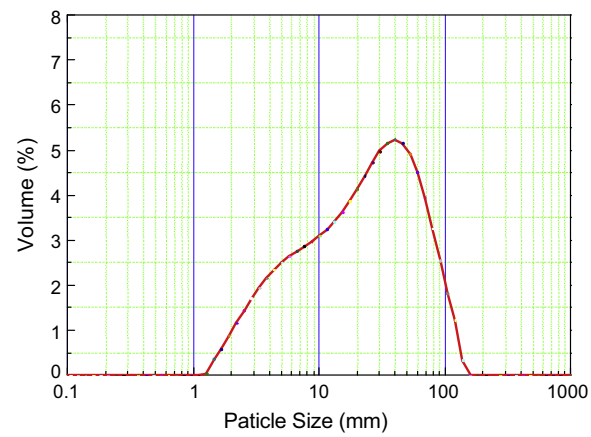

Fig. 2. Size distribution of granite dust.

2.2. Methods

The amount of cementitious materials was fixed as 440 kg/m^3. The pure cement concrete (JS4) and the concrete with 10% slag powder and 30% fly ash as the cement replacement (JS0) were used as the benchmarks. The granite dust was used as the fly ash replacement in proportions of 33.3%, 66.6% and 100%, which are equivalent to 10% (JS1), 20% (JS2) and 30% (JS3) of the total cementitious materials, respectively, as shown in Table 1. The concrete slump was adjusted to 170–190 mm by the superplasticizer, and the air content was adjusted to 3.5–4.5% by the air-entraining agent.

2.3. Testing

The concrete slump, air content and bleeding rate were tested following the ASTM standards [20–22]. The concrete state was observed when the concrete slump test was implemented. The compressive strength, bending strength and elastic modulus were measured according to the methods in BS EN 12390 [23] with 150 mm × 150 mm × 150 mm specimens. The chloride penetration resistance was tested following the electric flux method in ASTM C1202 [24]. The frost resistance test followed the rapid freezing and thawing method specified in ASTM C666/C666M [25]. The concrete drying shrinkage was measured by the contact method in ASTM C157 [26], and the test period began from the third day after the standard curing began.