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Mechanical properties and corrosion resistance of concrete modified with granite dust

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HIGHLIGHTS

- Granite dust of 5.0%, 7.5%, 10.0% and 15.0% as cement replacement and additional were used.
- Effect of granite dust on mechanical properties, corrosion resistance and hydration products were studied.
- An improvement on concrete mechanical properties at 5.0% granite dust as cement replacement.
- No change in hydration products, microstructure and degree of hydration due to using granite dust is observed.

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ABSTRACT

Granite dust is a waste material produced during cutting and polishing process of granite products. This research work presents an experimental investigation on physical, mechanical properties and reinforcement corrosion resistance of concrete modified with granite dust. The cement pastes modified with granite dust were examined using TGA, X-ray and SEM. Granite dust cement replacement or addition of 5.0%, 7.5%, 10.0% and 15.0% were used. The test results showed an improvement on concrete compressive strength at 5.0% granite dust as cement replacement and improvement on compressive strength at most levels of granite dust as cement addition. The tensile strength test results are confirmed the test results of concrete compressive strength. Also, the use of 5.0% granite dust increased the corrosion cracking time and no significant reduction in cracking time was observed at granite dust contents greater than 5.0%. Insignificant changes in hydration products, microstructure and degree of hydration due to using granite dust were observed. Finally, a reduction in water cement ratio around 0.03 was enough to cancel the reduction in concrete compressive strength as a result of granite dust up to 15.0% as cement replacement.

1. Introduction

The growth in industrial productions led to more resulting wastes. These wastes in most cases have environmental hazards. The transportation of these wastes to wastes collecting centers always cost a lot of money. A lot of wastes have been successfully added to concrete to minimize their hazards.

Variety of waste materials including tire rubbers, blast furnace slag, silica fume, fly ash and lime stone have been used in concrete production. These wastes have beneficial effect on concrete properties. These benefits include mechanical and durability aspects [1–6].

Marble and granite grains and dust are considered waste materials during production of marble and granite products. These wastes are produced during preparation and polishing processes. These processes produce a large amount of waste materials.

Marble grains either fine or coarse particles are used before in pavement production applications [7]. Marble and granite are used as coarse aggregate and fine aggregate to produce concrete mixes with different grades [8–11]. Effect of marble dust on properties of conventional concrete and self compacting concrete were studied [12–15]. There is a lack of information about the effect of using granite dust on concrete production compared with marble dust. Abukersh and Fairfield studied the effect of using granite as a partial cement replacement on mechanical properties of concrete. Abukersh and Fairfield studied the effect of using 20–50% of granite dust on compressive strength and tensile strength of concrete at different ages. The experimental test results showed that the use of granite dust at these levels reduces significantly the concrete compressive strength and had little negative effects on concrete tensile strength [16]. The effect of using granite dust on producing concrete bricks was also studied by Hamza et al. Hamza et al. studied the effect of using 10–40% of granite slurry on compressive strength of concrete bricks. The test results showed that the use of granite dust had a positive effect and the optimum granite content was 10%.

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Egypt is considered one of the most famous countries in producing marble and granite products. The large amount of granite and marble raw materials were found in many places in Egypt. Some of raw materials were imported from other countries and prepared in Egypt. The production rates of granite and marble products are increased with the time increase.

Most of marble and granite production factories lie in one or two centers in Egypt. This makes the possibility of collecting these wastes easy. As a results of hazards of the resulting wastes, Egyptian governments suggested funds to researchers to solve the resulting problems from large amount of wastes. The average weight of granite dust is about 30.0% from the original weight during cutting and preparing processes according to the information from producer. These wastes cause a main problem facing the owners of these factories so they support any project to minimize these problems.

2. Research significance

The main objectives of this paper are utilizing of the granite dust wastes to produce granite dust blended cement or study the effect of using granite dust on concrete properties. The experimental work includes three phases. These phases are mechanical properties of mortar and concrete, reinforcement corrosion resistance of concrete modified with granite dust and finally cement paste properties.

3. Experimental work

3.1. Materials

Ordinary Portland cement (ASTM Type I) was used throughout the program. This cement type is classified in Egyptian standard as CEM I 42.5N. Natural siliceous sand with fineness modulus of 2.4 was used. Pink lime stone with 9.5 mm maximum aggregate size was used. Commercially available granite dust from factories of granite preparation was used throughout the research work. Granite dust was collected and delivered in wet state. Granite dust was dried in oven before using in order to control the mixing water content. The specific gravity of used granite dust was 2.50. Granite dust was totally passed on sieve No. 200 (mesh size 0.075 mm). Granite dust will be part of the filler fraction. The grading of used granite dust is given in Fig. 1. Chemical composition of used cement and granite dust are given in Table 1. High range water reducing admixture Type F according to ASTM C 494 was used. The doses of chemical admixture were determined by trial to achieve 160 ± 20 mm slump. The used steel reinforcement bars were 10 mm smooth bars with grade 240/350 according to Egyptian specification ESS No. 262/2006.

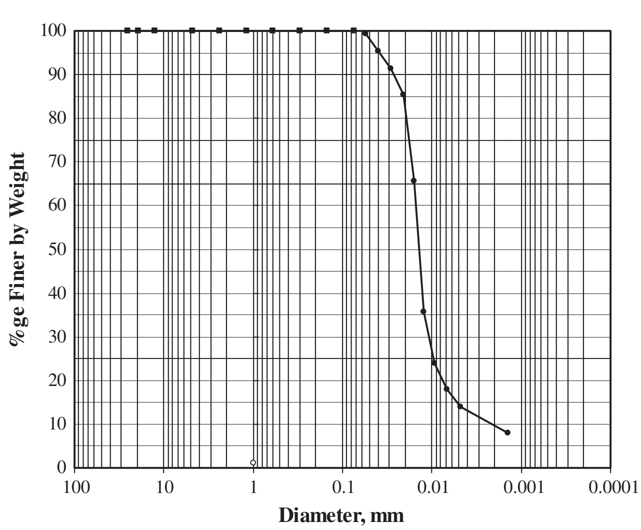

Fig. 1. The grading of used granite dust.

Table 1
Chemical analysis of cement and granite dust.

Constituent percent by weight	Cement	Granite dust
Silicon dioxide	20.10	85.5
Aluminum oxide	5.50	2.10
Ferric oxide	3.42	0.40
Calcium oxide	61.10	4.90
Magnesium oxide	4.03	2.50
Sulfur trioxide	2.57	1.80
Loss on ignition	2.75	1.10

3.2. Test parameters

The experimental program is divided into three sections. Section 1 is physical and mechanical properties of concrete modified with granite dust where Section 2 is the corrosion resistance of concrete with granite dust and finally effect of the presence of granite dust on hydration of cement paste, Section 3. The main considered parameters throughout the program are the effect of using granite dust as cement replacement and cement additional. The percentages of cement replacement and cement addition are 0.0%, 5.0%, 7.5%, 10.0% and 15.0% while the cement contents of control mix is 400 kg/m^3. It should be pointed out that concrete mixes incorporated 400 kg/m^3 cement and 0.45 w/c ratio represent a typical mix for reinforced concrete elements in constructions in Egypt. The dose of chemical admixture is 1.0% by weight of cement. This dose achieved concrete slump of 160 ± 20 mm for all concrete mixes. The mix proportions of used mixes are tabulated in Table 2.

3.3. Testing

3.3.1. Physical and mechanical properties

The considered tests throughout Section 1 are setting time of cement paste, expansion of cement paste, mortar compressive strength, concrete compressive strength, splitting tensile strength, and concrete porosity. Setting time of cement paste, expansion of cement paste and compressive strength of mortar were carried out according to ESS 2421. Concrete compressive strength was carried out using 150 mm cubes according to BS 1881: part 3, whereas splitting tensile strength was carried out using cylinders of 75 mm diameter and 150 mm length according to ASTM C 496. The porosity of concrete specimens was determined using 150 mm cube according to ASTM C 642. The ages of testing were 7, 14, 28 and 56 days for concrete compressive strength and splitting tensile strength, whereas porosity was determined at 28 days. Each test result throughout this research is the average of three specimens.

All the previous specimens were prepared by mechanical mixing, then casted in rigged steel molds. The specimens were demolded after 24 h. After demolding, concrete specimens were water cured up to the age of testing.

3.3.2. Corrosion resistance

Accelerated corrosion cell test was used. The used specimens for accelerated corrosion test were cylinders of 75*150 mm with steel bars of 10 mm diameter and 200 mm length placed at the middle of the specimens. After being demolded, the specimens were water cured for 28 days then they were immersed in corrosion cell. The electrolyte in this cell was 5.0% by weight of NaCl solution. A constant volt of 35.0 DC was applied between the anode (steel reinforcement) and the cathode (copper plate) for the majority of this research work. The current intensity was recorded with the time up to 240 h working. The time of the initial visible crack and weight loss in steel reinforcement were measured. Fig. 2 shows the used corrosion cell.

There are two methods to evaluate the performance of corrosion resistance of concrete specimens modified with granite dust. These methods are time of crack appearance and weight loss.

The theoretical weight of corroded steel rebar Mt can be calculated from the area under the curve of corrosion current versus time using Faraday's equation as follows [17]:

$$M_t = \frac{M * \int T dt}{Z * F}, \quad (1)$$

where M_t is the theoretical mass loss of corroded steel rebar in grams, M is the ferrous atomic weight = 55.86 g/mole, $\int T$ dt is the electric charge (area under current–time relation) in Amp sec, Z is the ionic charge per ferrous atom = 2, and F is the Faraday's constant = 96,485.3 Coulomb/mole of ferrous.

3.3.3. TGA and X-ray diffraction

Thermogravimetric analysis test (TGA) was conducted mainly to study the effect of the presence of granite dust on degree of hydration of cement which is a function of calcium hydroxide content.