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INFLUENCE OF USING GRANITE WASTE ON THE MECHANICAL PROPERTIES OF GREEN CONCRETE

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ABSTRACT

The behaviour of green concrete, having partial replacement of cement or sand with granite waste was studied. Laboratory testing of flexural strength, splitting tensile strength, and pull out for the samples mixtures were carried out to study the replacement effect on the mechanical properties of produced concrete. The study revealed that by comparing the mechanical properties of the control mix to the green concrete mixes containing 5% of fine granite waste as a partial replacement of cement, the splitting tensile strength was 20% higher, the flexural strength was 19% lower and the bond strength was slightly lower by 1%. Whereas, replacing sand in the concrete mixes by 10% granite waste granules led to significant increase in the splitting tensile strength and the flexural strength while the bond was slightly affected when compared to the control mix.

Keywords: recycling, granite, marble, residues, sustainability, mechanical properties.

INTRODUCTION

In the building industry, marble and granite have been commonly used for various architectural purposes like flooring, cladding etc., due to their beauty, strength and resistance to fire. The disposal of granite and marble industry consists of fine powder, granules as well as sludge that represent one of the environmental problems around the world. In Egypt, the sludge waste generated from granite processing is estimated over 30% of the volume of the sawn block.

RESEARCH SIGNIFICANCE AND OBJECTIVES

The huge unattended masses of granite and marble waste resulting from this industry, dumped on open land as shown in Figure-1, affect adversely the land productivity. In addition, this dumping process reduces the soil porosity and affects ground water which results in environmental pollution. Moreover, it forms dust which threats both agriculture and public health.

Figure-1. Hills of dumped marble/granite waste.

Therefore, utilization of the granite and marble waste in various industrial sectors especially the construction, agriculture, glass and paper industries would help to protect the environment.

The aim of this paper is to evaluate the mechanical performance of concrete using various replacement ratios of granite waste sludge resulting from granite process plants. Splitting tensile strength, flexure strength, and pull out tests were performed to evaluate the relevant properties of concrete mixes produced in the hardened state. In the form of fine powder granite waste, the cement was replaced using 5%, 10% and 15% by weight in the concrete mixture. In addition, in the form of granules granite waste, the sand was replaced using 10%, 17.5% and 25% by weight.

LITERATURE REVIEW

Some attempts have been made in construction industry to incorporate marble and granite waste in concrete in order to produce new green and sustainable concrete.

Valeria *et al* observed that marble powder had very high Blaine fineness value and noticed that the marble powder had a high specific surface area, implying that its addition in mortar or concrete, especially in self-compacting concrete, should impart more cohesiveness [1].

Baboo Rai *et al* found that using marble powder and granules as constituents of fines in mortar or concrete by partially reducing quantities of cement as well as other conventional fines could enhance the concrete properties such as relative workability, compressive, and flexural strengths [2].

Sounthararajan *et al* studied the effect of the lime content in marble powder for producing high strength concrete. They found that replacing waste marble powder up to 10% by weight of cement increases hardened concrete properties. A phenomenal increase in the compressive strength of 46.80 MPa at 7 days for 10% replacement of marble powder in cement content was noted and also showed improvement in other mechanical properties compared to controlled concrete [3].

Hanifi Binici *et al* found that marble-dust concrete has higher compressive strength than that of the corresponding lime stone-dust concrete having equal w/c and mix proportion. The results indicated also that the marble dust-concrete would probably have lower water permeability than the lime stone-dust concrete [4]. Compared to normal plain concrete of the same w/c ratio and the same cement, the concrete having high limestone filler content of suitable particle-size-distribution generally improves the strength characteristics [5, 6].

A step further, Ali Ergun carried out laboratory investigation of mechanical properties for the concrete specimens containing diatomite and waste marble powder (WMP). The author partially replaced 5% cement content by weight with WMP in one case and replaced 5% cement as well as 10% diatomite by weight with WMP in the other case. He found a better compressive and flexural strength and concluded that the mechanical properties of concrete could be improved by reducing cement and diatomite content as well as adding equal amount of WMP as a super plasticizing admixture [7].

Manju Pawar *et al* studied the effect of using marble powder in mortar or concrete, by partially reducing quantities of cementitious material, on the relative compressive, tensile as well as flexural strengths. The compressive strength of sample cubes are increased with addition of waste marble powder up to 12.5 % replacement ratio by weight of cement and further increase of this ratio could decrease the compressive strength. Moreover, the tensile strength of sample cylinders was increased with addition of waste marble powder up to 12.5 % replace by weight of cement and further increase of this ratio causes drop on the tensile strength values. Thus, they concluded that the optimum percentage for replacement of marble powder with cement is almost 12.5 % cement for both cubes and cylinders [8].

EXPERIMENTAL PROGRAM

Materials

All the materials used in this research were local materials. The properties of these materials were determined according to the Egyptian Standard Specifications and the recommended code of practice.

Portland cement and aggregates: Commercial Torah Portland-limestone blended cement (OPC) according to the Egyptian standards was used. The fineness of cement was 9 % passing from sieve170 and its relative density (specific gravity) was 3.15. It's initial and final setting were 2 hrs and 3hrs 12 minutes resp. Natural sand from pyramids quarries Giza with a maximum size of 4.75 mm was used as fine aggregate. Course aggregate with a maximum nominal size of 19 mm was used.

Granite waste: A granite sludge powder was used, which was obtained as a by-product of granite sawing and shaping from Egyptian marble factory (gang saw granite type from Shaqu - Elteban zone). The granite powder had a high specific surface area. The granite waste was produced as ''slurry", a mud made of powder and water, then was dried up in order to have a constant W/C ratio in the designed mix.

Granite waste sludge was weighed before putting in an oven at a temperature of 200 C for 6 hours. The granite powder was then weighed back and the difference of weight (before and after drying) should be less than 10% to insure minimum water content. The granite waste fine powder used as cement replacement has particles passed through sieve no. 300. While, the granite waste granules used as sand replacement has particle passed through sieve no 4.76.mm.

Water: Clean tap water was used in the production of the concrete samples. The temperature of mixing water was maintained between 20-30 °C.

Concrete design mix

Based on the Egyptian Standard, design mix for 350 grade of concrete was prepared by partially replacing cement or fine aggregate with three different percentages by weight of granite fine powder waste (5%, 10%, and 15% for cement replacement) and granule waste (10%, 17.5%, and 25% for sand replacement). In addition, a control mix with 0% replacement of granite waste was prepared. A total of seven series of concrete specimens including the control specimen were prepared for this study as reported in Table-1.

ARPN Journal of Engineering and Applied Sciences

Table-1. Concrete design mixes.

Design Mix Number	Design Mix Appreviation	Design Mix Name	Quantity (kg)					W/C Ratio
			Cement	Fine Agg.	Course Agg.	Granite waste	Water	
Control Mix								
1	Control Mix	Control Mix	36	46	92	0	16.2	0.45
Cement Replacement								
2	S G C 5	Sawgang Granite 5% Cement Replacement	34.2	46	92	1.8	16.2	0.45
3	S G C 10	Sawgang Granite 10% Cement Replacement	32.4	46	92	3.6	16.2	0.45
4	S G C 15	Sawgang Granite 15% Cement Replacement	30.6	46	92	5.4	16.2	0.45
Sand Replacement								
5	S G F 10	Sawgang Granite 10% Sand Replacement	36	41.4	92	4.6	16.2	0.45
6	S G F 17.5	Sawgang Granite 17.5% Sand Replacement	36	37.95	92	8.05	16.2	0.45
7	S G F 25	Sawgang Granite 25% Sand Replacement	36	34.5	92	11.5	16.2	0.45

Specimens

Cylindrical specimens 150x300 mm were casted for the splitting tensile strength test and beam specimens 150x150x600 mm were casted for flexure strength test as shown in Figure-2.

The pull-out cube specimens were designed using RILEM 7-II- 128 as a guide [9]. The bars were embedded 10 times the bar diameter into the concrete specimen based on preliminary testing, with half of the length de-bonded using a section of polyvinyl chloride tubing working as a bond breaker. The RILEM report recommends casting the bars into concrete cubes that provide a clear cover of 4.5 times the bar diameter from the bar to the centre of each side of the horizontal cross section. The specimens designed for this experiment exceeded the RILEM 7-II-128 requirement on clear cover and featured a (150x150x150 mm) concrete cube for a steel rebar of 12 mm in diameter as shown in Figure-2, to eliminate the potential for splitting and ensure that all of the specimens failed in the same manner (pull-out).

Figure-2. Cylindrical, beam, and pull-out cube specimens.

All the concrete mixtures were blended for 5min in a laboratory counter-current mixer. Mixtures prepared were cast in the desired moulds they were kept for 24 h. After that, these specimens were cured in curing basins for 28 days.

Laboratory tests conducted

Slump tests were conducted as shown in Figure-3. Splitting tensile and flexure strengths of concrete mixtures were measured for each mix type in order to study the effect of using granite waste on the mechanical properties of concrete samples.

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A direct pull-out test was conducted to measure the bond performance of concrete mixtures containing granite waste material based on the RILEM 7-II-128 [9].

Universal testing machine of 1000 KN (Shematzo) was used to conduct all the above mentioned tests as shown in Figures 4(a), 4(b), 4(c)forsplitting tensile strength, flexure strength, and pull out tests consequently.

Figure-3. Slump test.

Figure-4(a). Splitting tensile strength test.

Figure-4(b). Flexure strength test.

Figure-4(c). Pull out test.

TEST RESULTS AND DISCUSSIONS

Splitting tensile strength

Splitting Tensile strength of concrete was tested on cylinders at different proportions of granite waste contents on 28 days. The test results are shown in Table-2. The results showed that the splitting tensile strength of mix containing 5% of fine granite waste as a partial replacement of cement (SGC5) was 20% higher than the control mix. This result can be attributed to the fact that granite possesses cementing properties.

At 10% replacement ratio of cement (SGC10), the value of the splitting tensile strength was dropped to be equal to the measured value of the control mix. By increasing the granite waste marble replacement ratio to 15%, the splitting tensile strength value decreased by 10% than the control mix.

By replacing the sand in the concrete mixes by granite granules in 10, 17.5, 25% replacement ratios,the values of the splitting tensile strength were 12%, 15%, and 21% higher than the control mix values. This could be attributed to the fact that the fine granules of waste granite filled the voids between the particles leeding to higher values of tensile strength as shown in Figure-5.

ARPN Journal of Engineering and Applied Sciences

Table-2. Laboratory test results.

Design mix		Splitting tensile strength N/mm^2	Flexure strength N/mm^2	Pull out strength (KN)
Control mix	CM	3.31	4.05	58.5
Cement replacement	S G C 5	3.99	3.26	59.33
	S G C 10	3.30	2.81	49.5
	S G C 15	2.96	2.52	48
Sand replacement	S G F 10	3.72	5.44	59.33
	S G F 17.5	3.83	4.15	56
	S G F 25	4.01	3.43	54.5

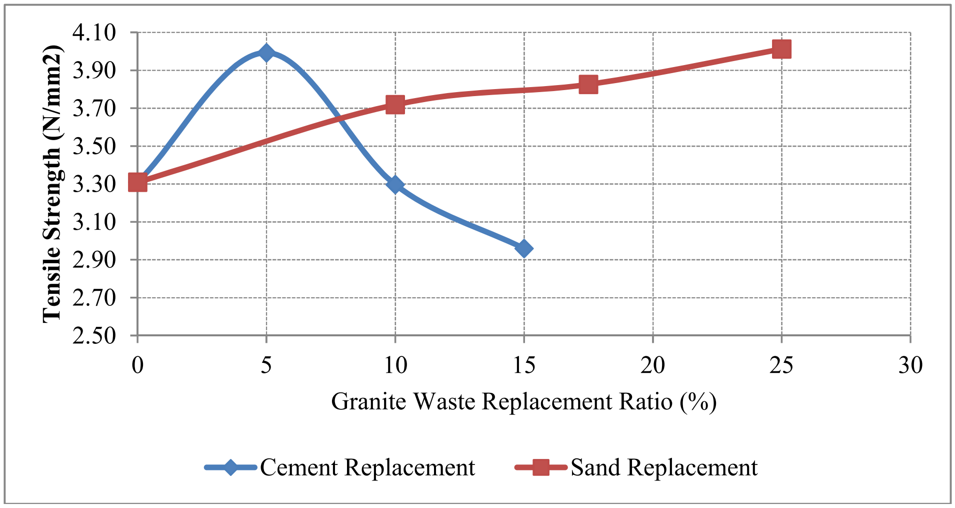

Figure-5. Relation between replacement ratios and splitting tensile strength.

Flexural strength

Flexural strength of concrete was tested on beams at different percentage of granite waste contents on 28 days. The test results are shown in Table-2. The results showed that the flexural strength of mix containing 5%, 10%, and 15% of fine granite waste as a partial replacement of cement were 19%, 30%, and 37%, respectively lower than the control mix as shown in Figure-6.

By replacing the sand in the concrete mixes with 10% of granite granules by weight (SGF10), the values of the flexural strength was increased by 34% more than that obtained from the control mix. By increasing the replacement ratio to 17.5% (SGF 17.5), the values of the flexural strength dropped back to be almost similar to that obtained from the control mix.

At a higher percentage of replacement 25% (SGF25), the values of the flexural strength were 15% lower than the control mix. This could be attributed to the fact that the increasing the fine granules content above an optimum level led to the segregation of aggregate.

ARPN Journal of Engineering and Applied Sciences

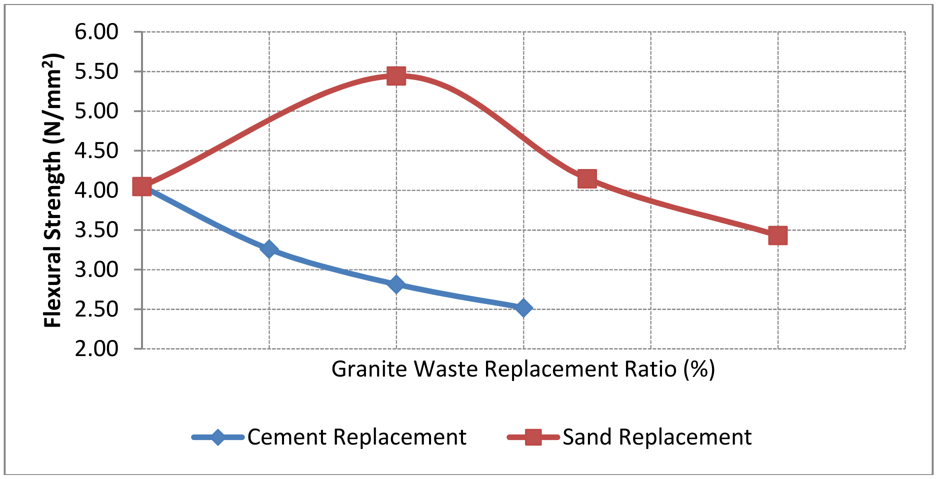

Figure-6. Relation between replacement ratios and flexural strength.

Pull out test

The pull out test was carried out to measure the bond strength between concrete and reinforcing steel. The bond strength has been tested after 28 days. The test results for different granite waste mixes are shown in Table-3.

The results showed that the bond strength of mix containing 5% of fine granite waste as a partial replacement of cement (SGC5) has slightly higher value than that obtained from the control mix by almost 1%. On the other hand, the higher replacement ratios of 10% and 15% gave lower strength values than that obtained from the control mix by 15% and 17%, respectively as shown in Figure-7.

By replacing the sand in the concrete mixes with granite granules by 10% (SGF 10), the values of the bond strength were increased by 1% more than that obtained from the control mix. By increasing the replacement ratio to 17.5% (SGF 17.5), there was a slight decrease in the bond strength by nearly 4% less than the control mix value. By increasing the replacement ratio to 25% (SGF 25) the values of the bond strength decreased also by about 6% compared to the value of the control mix.

Figure-7 clarifies that by using high replacement ratios of cement and sand, the bond strength decreases starting when using more than 5% cement replacement ratio, and 10% sand replacement ratio. However, the results showed that the bond strength rate of decrement was higher in cement replacement mixes compared to sand replacement mixes. This is due to the fact that the fine granules of granite waste used in sand replacement mixes filled the voids between the particles and participate in the bond strength value gained.

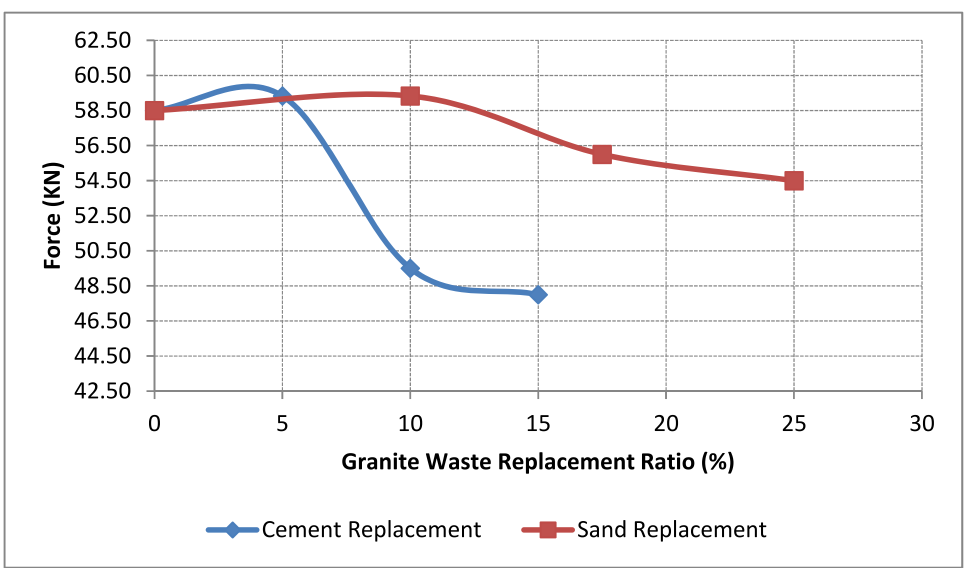

Figure-7. Relation between replacement ratios and Pull out strength.

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CONCLUSIONS

The splitting tensile strength for mixes containing 5% of fine granite waste as a partial replacement of cement was 20% higher than the control mix. Increasing the replacement ratio of cement 10% led to a value for the splitting tensile strength equal to that measured for the control mix. However, exceeding this ratio caused drop in tensile strength measured. Replacing sand in the concrete mixes by granules granite waste with up to 25% replacement ratio led to higher values of splitting tensile strength than that obtained from the control mix.

The flexural strength of mix containing 5%, 10% and 15% of fine granite waste as a partial replacement of cement were 19%, 30%, and 37%, respectively lower than the control mix. By replacing the sand in the concrete mixes by granite waste granules of 10% replacement ratio, the values of the flexural strength was increased by 34% higher than that obtained from the control mix. By increasing the replacement ratio to 17.5%, the values of the flexural strength dropped back to be almost similar to that obtained from the control mix. At a higher percentage of replacement 25%, the values of the flexural strength were lower than the compared of the control mix

The bond strength of mix containing 5% of fine granite waste as a partial replacement of cement was slightly higher than that obtained from the control mix by almost 1%. On the other hand, the higher replacement ratios gave lower values. By replacing the sand in the concrete mixes by granite granules of 10% replacement ratio, the values of the bond strength were increased by 1% higher than the control mix. By increasing the replacement ratio to 17.5%, there was a slight decrease in the bond strength by 4% less than the control mix value. Using the highest value of replacement, 25%, led to decrease the values of the bond strength by about 6% compared to the value of control mix.

The optimum percentage of cement replacement with granite fine powder was 5% and the optimum percentage of sand replacement with granite granules was 10% and could reach 17%.

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