Evaluation of the Incorporation of Marble and Granite Residue in Coating Mortars

Euzebio Zanelato, Jonas Alexandre, Afonso Azevedo, Markssuel Marvila, Gustavo Xavier and Sergio Monteiro

Abstract The disposal of ornamental rock waste generates serious environmental impacts, where incorporation in construction materials would be a solution with low environmental impact. The objective of this work is to evaluate the performance of the incorporation of waste from the industry of both marble and granite in mortars. The residues were incorporated at different levels of incorporation (25, 50, 75 and 100%) using different mortar traces (1:1:6 and 1:2:9). The materials were characterized and the mortars were evaluated in the fresh state by the consistency index tests and Squeeze Flow. In the hardened state, mechanical strength, water absorption, and tensile strength tests were performed. The results indicated that the marble residue presents great potential of use, while the incorporation of granite shows a loss of performance.

Keywords Granite · Marble · Mortar

E. Zanelato (✉) · J. Alexandre · M. Marvila · G. Xavier
LECIV – Civil Engineering Laboratory, UENF - State University of the Northern Rio De Janeiro, Av. Alberto Lamego, 2000, Campos dos Goytacazes, Rio De Janeiro 28013-602, Brazil
e-mail: ebzanelato@gmail.com

E. Zanelato · A. Azevedo
IFF - Federal Institute Fluminense, DIRINF – Directorate of Infrastructure Rectory, Rua Cel. Valter Kramer, 357 - Parque Vera Cruz, Campos dos Goytacazes, Rio De Janeiro 28080-565, Brazil

A. Azevedo
TER – Department of Agricultural Engineering and Environment, UFF - Federal Fluminense University, Rua Passo da Pátria, 341, Niterói, Rio de Janeiro 24210240, Brazil

S. Monteiro
Department of Materials Science, IME - Military Institute of Engineering, Square General Tibúrcio, 80, Rio de Janeiro 22290-270, Brazil

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Introduction

The Brazilian ornamental stone industry presents excellent production and export performance with each passing year. The ornamental stone sector has an important share of the market, where in 2017 alone totaled US$ 1,107.1 million and 2.36 million tons in exports. Among the main responsible for the Brazilian ornamental stone market, Cachoeiro de Itapemirim—ES stands out as a pole of approximately 600 companies [1].

The processing performed on the rock to add value to the raw material is composed of cutting and polishing [2]. Both steps generate a huge amount of waste, which causes great environmental impacts in the region.

The production process of these ornamental rocks produces about 800,000 tons per year of waste in the states of Espirito Santo, Minas Gerais, Bahia, and Ceará. In general, waste is discharged into the environment without prior treatment, thus the industrial sector is penalized by environmentalists for damage to the local environment. Even places where this waste is deposited and collected suffer from the cost and lack of space in landfills [3].

An alternative to lessen the impact caused by this waste is to incorporate it into segments of the building industry, such as mortar and ceramic tiles. Waste reuse would decrease or even eliminate the volume of waste disposed of in landfills

The incorporation of the residue has already shown satisfactory results in incorporations in the red ceramic pieces, where there was an increase in mechanical performance and durability [4].

Mortar incorporation has also been tested by several authors [5–7], which also presented satisfactory results regarding rheology and also mechanical performance.

The objective of this work is to contribute to the increase of research related to the incorporation of residues from the ornamental rock industry and, more specifically, to compare the performance of mortars made of granite and marble in different levels of incorporation (0, 25, 50, 75, and 100%) using two different mortar strokes (1:1:6 and 1:2:9).

Materials and Methods

The materials used to make the mortar were characterized by grain size and grain density tests.

Two traces of mortar were used: 1:1:6 and 1:2:9 (Cement: Hydrated Lime: Sand). These traces were chosen because of their recurring use and proper plasticity for coating application. The 1:2:9 trace exhibits greater water retention and is widely used in locations that are most vulnerable to water loss by evaporation or absorption of the substrate where it was applied. The 1:1:6 trait exhibits greater mechanical strength as well as greater adhesion potential, however, depends on

Table 1 Tests performed on mortar and respective standards

Test	Standard
Consistency index	NBR 13276 [8]
Compressive strength	NBR 13279 [9]
Flexural tensile strength	NBR 13279 [9]
Water absorption	NBR 9778 [10]
Tensile strength	NBR 13528 [11]

suitable application conditions where the coating does not suffer a large volume of water loss.

Granite and marble residues were incorporated in substitution of hydrated lime at 25, 50, 75, and 100% levels beyond the reference without incorporation.

The mortars were made as recommended by NBR 13276. The tests performed and the respective standards are shown in Table 1.

Results

The results of characterization of the materials used in the manufacture of mortar are shown in Fig. 1 where the particle size distribution is illustrated.

The granulometric test shows a great similarity in the distribution of the grain size of marble with that of cement. The granite presented larger grain size than the previous ones, being smaller than the sand.

After the characterization of the materials, the mortars were made. The results of the consistency index tests indicated the amount of water to promote a 260 ± 5 mm spread. The quantities of materials used to make 2.5 kg of mortar are shown in Table 2.

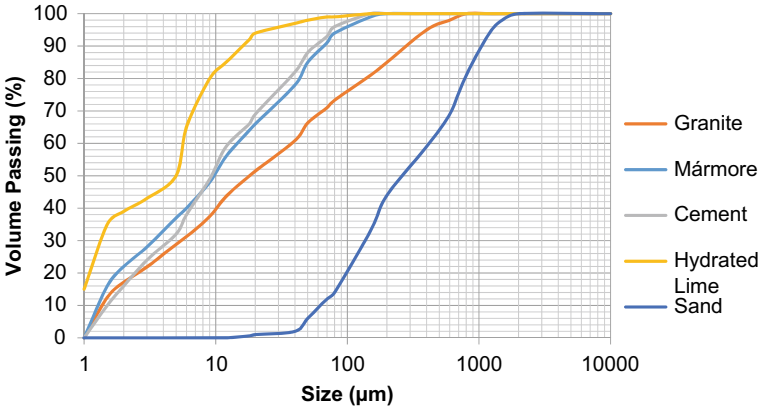

Fig. 1 Granulometry of the used materials

The consistency test results identified a drop in the amount of water as the incorporation content of the residue increased. The drop in the amount of water needed is greater in granite compared to marble. In both traces, the above trends were verified, however, the 1:2:9 trace presents the largest amount of water needed to achieve the same 1:1:6 trace spread. All these trends are justified by granulometry, where hydrated lime is the finest material than cement and waste has greater water absorption, so the traces with the largest amount of hydrated lime are the traces with the most water incorporated into the mixture. Table 2 presents the results of specific mass, unit mass, and moisture absorption.

Figure 2 shows the results of the hardened mortar water absorption test.

The results shown in Fig. 2 show the poor performance obtained by the waste in the water absorption test. Mortars tend to increase water absorption as the amount of residue added increases.

It is noteworthy that up to 50% of marble in both traces, the water absorption showed little significant growth. The results indicate that the grain packing remains similar up to 50% marble, where after this value, the porosity grows significantly.

The granite does not have proper packaging with the materials and thus has increased porosity throughout the increase of incorporation content.

Table 2 Quantity of materials to make 2.5 kg of mortar

Traço		Cement (g)	Hydrated lime (g)	Marble (g)	Granite (g)	Sand (g)	Water (g)
1:1:6	*Reference*	312.50	312.50	0.00	0.00	1875.0	703.0
	25% Marble	312.50	234.38	78.13	0.00	1875.0	696.0
	50% Marble	312.50	156.25	156.25	0.00	1875.0	691.0
	75% Marble	312.50	78.13	234.38	0.00	1875.0	688.0
	100% Marble	312.50	0.00	312.50	0.00	1875.0	680.0
	25% Granite	312.50	234.38	0.00	78.13	1875.0	682.0
	50% Granite	312.50	156.25	0.00	156.25	1875.0	674.0
	75% Granite	312.50	78.13	0.00	234.38	1875.0	661.0
	100% Granite	312.50	0.00	0.00	312.50	1875.0	643.0
1:2:9	*Reference*	208.33	416.67	0.00	0.00	1875.0	828.0
	25% Marble	208.33	312.50	104.17	0.00	1875.0	814.0
	50% Marble	208.33	208.33	208.34	0.00	1875.0	802.0
	75% Marble	208.33	104.17	312.50	0.00	1875.0	796.0
	100% Marble	208.33	0.00	416.67	0.00	1875.0	785.0
	25% Granite	208.33	312.50	0.00	104.17	1875.0	801.0
	50% Granite	208.33	208.33	0.00	208.34	1875.0	784.0
	75% Granite	208.33	104.17	0.00	312.50	1875.0	756.0
	100% Granito	208.33	0.00	0.00	416.67	1875.0	719.0

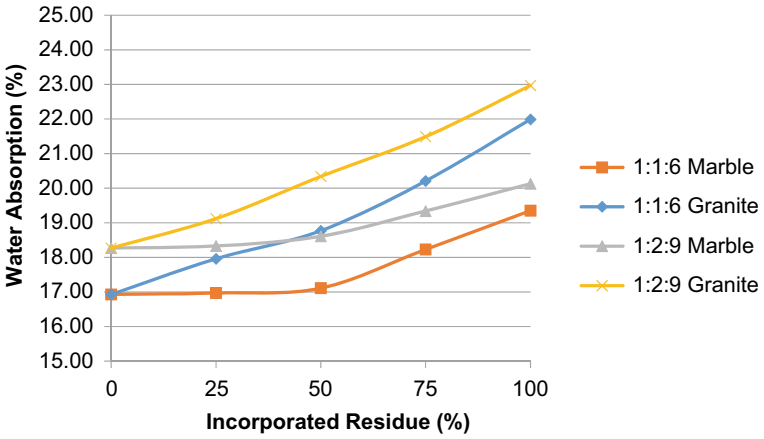

Fig. 2 Water absorption from mortars

Comparing the traces used, the trace with the most hydrated lime and the largest amount of water has the highest porosity, justified by the outflow of water that leaves voids after hardening.

Figures 3 and 4 show, respectively, the results obtained in the flexural tensile strength and compressive strength tests.

Granite, as well as in absorption, shows a decrease in resistance throughout the increase of the incorporation content. Marble has increased strength up to 50% incorporation.

Comparing the results between the traces, it is clear the highest mechanical resistance achieved by the trace with more cement, the 1:1:6 trace.

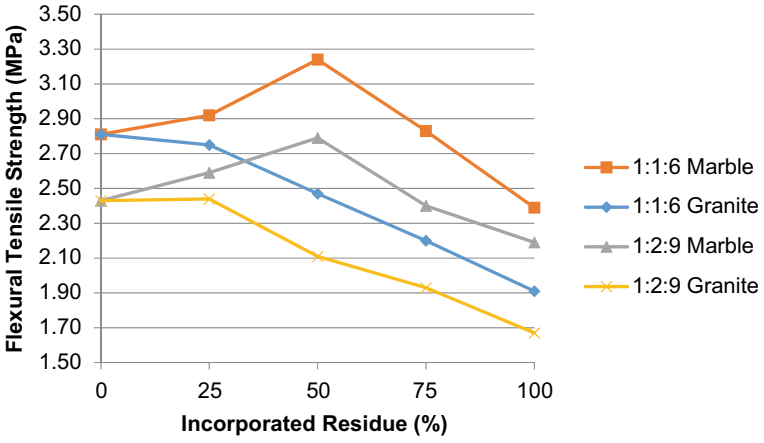

Fig. 3 Flexural tensile strength from mortars

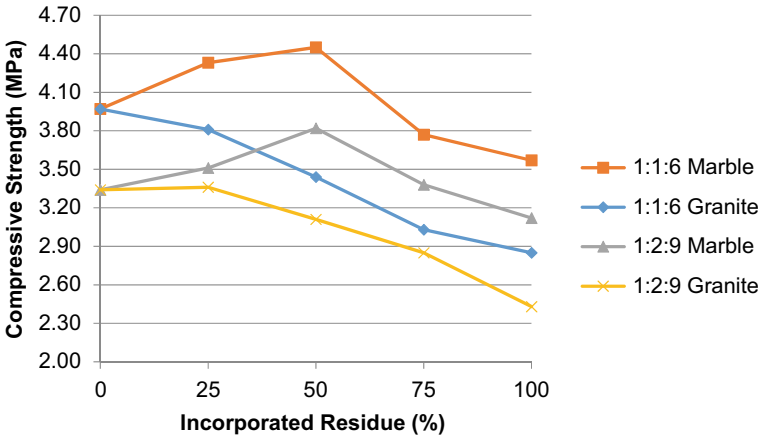

Fig. 4 Compressive strength from mortars

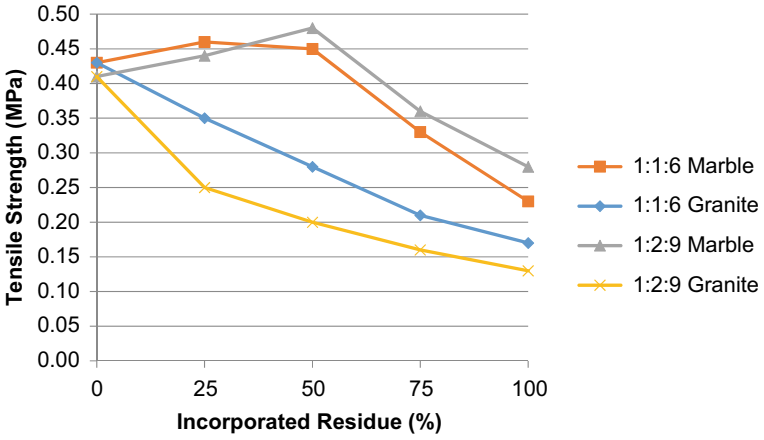

Fig. 5 Tensile strength from mortars

Figure 5 presents the results of the tensile strength test.

It is verified by the test the tendency of increase of the adhesion until the content of 50% of marble incorporation, however, the values present little growth considering the high dispersion of the adhesion results. Increasing marble incorporation above 50% promotes decreased adhesion.

In relation to granite, throughout the granite incorporation content, the adhesion results have decreased.

The results are justifiable considering that the rupture in all samples was in the mortar itself. The mortars were applied on a rough surface and in none of the samples the interface between the mortar and mortar presented poor adhesion.

Considering that the bond between the layers presented no problem and the predominant type of rupture was in the mortar, the tendency of the adhesion result is close to the mechanical resistance of the mortar.

Conclusion

After the results, it can be concluded that

- The characterization of the sands identified large volume of fines and lower specific mass in Waste sand compared to Natural sand.
- Waste sand incorporation decreases the mechanical strength of concrete. The difference is minimum up to 7 days and increases considerably at 28 days. Even after 28 days, waste sand concrete continues to show strong growth and a tendency to approach the final strength of concrete with natural sand.
- Waste sand concretes showed higher water absorption, both by immersion and capillarity. The void content of concrete increases as the incorporation of waste sand increases.

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