International Journal of
Science and Engineering Investigations vol. 7, issue 77, June 2018
ISSN: 2251-8843

Study of Parameters of Granitine Used in Floor with Addition of Limestone Powder

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Abstract- Granitine-based coatings are widely used as a low-cost coatings alternative and high durability. Aiming to use a sustainable material, which presents, in its composition, a type of inert waste from the mining industry, this article presents the outcomes from the implications of replacing part of the binder of the granitine pattern for limestone powder. Considering that previous similar studies were not identified, this research is pioneer and intends to conduct a series of tests to achieve its purpose. Trials for the characterization of ornamental rocks were used, for they are high quality coatings and with excellent durability, when its technological usage characteristics are observed, since currently there are no specific standards for granitine coatings. The features used by manufacturers for this type of coating (reference) were tested, and there were made others replacing the binder by limestone powder. Density tests, apparent porosity, water absorption, uniaxial compression strength, abrasive wear and linear thermal expansion were performed. Such tests allow parameters analysis of coating durability and quality, and is, therefore, considered appropriate to guide the study and its main goals. The achieved outcomes show a reduction for the compression resistance parameters, apparent density and water absorption in the samples with inert material. It could also be observed an increase in porosity and water absorption. There were not seen considerable changes related to the wear due to abrasion.

Keywords- *Granitine, Floor, Coating, Limestone Powder*

I. INTRODUCTION

Also known as granilite, the granitine is a concrete coating, therefore, basically made of water, Portland cement and aggregates, which are, for this type of flooring, called - different types and mineralogical compositions granulated stones [1], [2]. They are widely used material for coatings, especially floors, stairs and walls [3], [4], [5] in public and private buildings of various sectors [6], [7] such as schools, airports, hospitals, clubs, supermarkets and even residences.

It is considered a mechanically strong, hard and long term stable flooring [6], versatile, suitable for areas in which operate various types of requests [5], [8], including environments that feature an intense flow of people in movement [1] and that are also exposed to different types of weather conditions, including temperature and humidity variations especially when applied to external environments. Although broadly used and traded, the coating staging and application procedures are not yet standardized [1], which extends the input and method possibilities to be used, and makes the designing technique bounded, to a great extent, to the common sense of who performs it [1], [3].

Several factors explain the lack of specific rules for granitine coatings, and the aesthetic standard bottom of this material when compared to conventional ceramics and ornamental rocks is the main one.,. In fact, granitine floors are portrayed by simple and rustic but not uniform standards, in which the spare granulated stones make the coating plan irregular [1], although they can be applied to regular polishing processes [6] and resin application, which significantly improves the finishing. Granitine floors are called fulget when not polished 1]. In addition, the granitine-based coatings can be framed *in loco* or pre-framed [3], [4], with variable thicknesses and dimensions. They are typically run on a single and monolithic layer and adhered directly to the substrate [1]. Their manufacture, in general, do not demand a productive industrial chain, since the manpower that produces it also runs its installation. Thus, there are no associations or units of class that represent the product, which lead to lower supporting or incitement for research and development of this coating niche.

However, granitine floors are highly financially viable [7]. In Belo Horizonte, the capital city of the state of Minas Gerais, the cost/m ² of coatings in ornamental rocks is estimated in a 2000% higher cost/m ² of granitine and, also, that this material is about 200% cheaper than ceramic tile. Thus, the floor becomes a viable alternative for buildings in which functionality is more relevant than the aesthetic aspect.

Therefore, this article conducted tests used in ornamental rocks technological design that identify coatings physical and mechanical characteristics. From this perspective, there were used two features, a standard and another 20% binder replacement for an inert one-the stone dust, in order to check the impact of changes in material properties.

The limestone powder was chosen because it is an inert material [9], which usage contributes to the adoption of more sustainable practices. It's a quarrying reject [10], obtained by directly crushing rocks [11], whose size is less than 4.8 mm grainsize, being characterized as a medium sand [10]. Brazilian raw materials are composed of about 85%/granite/gneiss [12], materials with high intrinsic compression strength characteristic, capable of reaching values above 100 MPa.

II. MATERIALS AND METHODS

According to the aims of this study, an experimental and comparative method was adopted. Tests were performed on hardened state using limestone powder residue, replacing 0% and 20% of the binder.

A. Materials

The materials used to make the granitine reference feature (Trace 1) and the replacement feature (feature 2) were: Portland cement CP V-ARI (ABNT NBR 5733) [13], potable water (Ministry of Health, Ordinance No. 518), gravel 0 with grainsize between 5.0 mm to 9.5 mm. The inert material used as the binder replacement of was the limestone powder with grainsize below 4, 8 mm. The samples produced with these raw materials and their respective features are described in Table 1.

TABLE I. GRANITINE FEATURES COMPOSITION

Feature	Cement	Water	Granulated	Limestone Powder
1	1	0,55	2	-
2	0,8	0,55	2	0,2

B. Methods

In order to enable physical and mechanical tests and also verify the changes promoted by the cement replacement, two forms for sample molding were created with the following dimensions: 7x7x100cm and 6x6x100cm. Such samples, after cure held in room temperature for 28 days, were cut using a circular saw blade, so that its dimensions were equivalent to those specified for each type of test performed.

The bulk density properties, apparent porosity and water absorption were obtained following the requirements of ABNT NBR 15.845 – Coating rocks – Test Methods, Attachment B: bulk density, apparent porosity and water absorption [14]. This standard attests 10 molding samples of 6 dimensions cm x 6 cm x 6 cm. The samples were washed and stored for 48 hours in an oven at 70.0° c. After this period, the weighing was made in order to obtain the dry mass, then, the samples were submerged in water for 48 hours. At the end of this procedure, the material was weighed and the saturated mass was cataloged. Finally, the samples were weighed submerged in water, through a scale with this technology, thus obtaining the submerged mass. The bulk density (ρ), apparent porosity (η) and water absorption of the material (α) were calculated as prescribed, respectively, in the equations 1, 2 and 3, taking over as 1000 kg/m^3 the value of water bulk density.

$$\rho = \frac{\text{massa seca}}{\text{massa saturada - massa submersa}}\, x1000 \quad (1)$$

$$\eta = \frac{\text{massa saturada - massa seca}}{\text{massa saturada - massa submersa}}\, x\ 100 \quad (2)$$

$$\alpha = \frac{\text{massa saturada - massa seca}}{\text{massa seca}}\, x\ 100 \quad (3)$$

The parameters obtaining, related to the linear thermal expansion of the samples, followed the ABNT 15,845 determinations - Coating rocks – Test Methods, Attachment C: linear thermal expansion coefficient [14]. There were molded 2 prismatic samples of 9 cmx 3 cm x 3 cm. For compelling such test, a Pavitest/Contenco brand dilatometer was used (it promotes the heating and cooling of the samples in temperatures ranging from 0° C to 50° c). During this process, the sample length variation was supervised by an extensometer connected to a computer that records and stores data. In order not to occur a hysteresis of the material tested, thermal oscillation constantly varied at the rate of 0.3° C/min. At the end of the cycle, it was possible to calculate the linear thermal expansion coefficient, as exposed in the Equation 4.

$$\alpha = \frac{\Delta L}{L_0\, x\, \Delta T} \quad (4)$$

Data on uniaxial compression resistance were obtained according to ABNT 15845 determinations – Coating rocks – Test Methods, Attachment E: uniaxial compressive strength [14]. To perform the test, 6 cubic bodies with 7 cm edge were used. The samples were placed in Forney brand hydraulic press, with a nominal capacity of 2000 KN and slowly submitted to loading force till its rupture. The calculations performed for obtaining the rupture voltage are shown in The Equation 5.

$$\delta = \frac{F}{A} \quad (5)$$

The standard ABNT 12042 – Inorganic materials – Abrasion wear determination [15], responsible for guiding the abrasion wear tests perform, was used to obtain these parameters. There were molded 2 samples with 7 cm x 7 cm x 5 cm dimensions. The equipment used for carrying out the test was an amsler wear machine manufactured by Pavitest/Concept, which uses standardized sand as an abrasive. The samples thickness were measured with an extensometer in three distinct periods: before and after a journey of 500 m and after running more 500 m, with a total of 1000 m covered under the cast iron disk that comprises the test machine. Figures 1 to 6 illustrates the samples and equipments used for conducting the tests.

Figure 1. Dilatometer

Figure 2. Dry state samples

Figure 3. Saturated State Samples

Figure 4. Extensometer used for abrasive wear measuring

Figure 5. Amsler Wear

Figure 6. Compression press

III. RESULTS AND ANALYSYS

The outcomes found, after carrying out the tests according to the recommendations of the respective standards, are shown in graph form for a better understanding. Common outcomes to ornamental rocks are also exposed in order to facilitate comparative analysis, whereas the standards used as reference also concern this type of material. Although, the ornamental rocks comprise a wide range of materials, the parameters applied to granite will also be used, once rock coating standard specifies the properties of this material. Table 2 shows all the parameters outcomes analyzed for the different features considered.

TABLE II. CARRIED OUT TESTS OUTCOMES

Test	Feature 1	Feature 2
Uniaxial Compression Resistance (Mpa)	37,58	26,6
Amsler Wear 1000m (mm) (Abrasion)	5,86	5,92
Amsler Wear 500m (mm)	2,81	2,85
Water Absorption (%)	8,385	9,542
Apparent Porosity (%)	17,416	19,529
Bulk Density (Kg/m^3)	2077,923	2047,110
Thermal Expansion in the heating phase (10^{-3} mm/m^{o}C)	8,95	6,03
Thermal Expansion in the cooling phase (10^{-3} mm/m^{o}C)	7,16	5,46

A. Apparent porosity, bulk density, and water absorption

The bulk density of a coating is an important parameter for determining the coating overload imposed on the buildings due to the weight of the material. In addition, it assists determining the logistical cost of transportation, choice of compatible vehicles with the load to be transported, and the correct sizing of the packages, whereas these will be used during all stages of handling, ensuring the product conservation and quality maintenance. Figure 7 shows the average apparent density values obtained for the samples.

The graph shows a reduction in the density of the sample in which the binder was replaced for inert material. This reduction was not significant, being less than 2%. For granites, the ABNT 15844 specifies values higher than 2,550 kg/m3. As expected, the rock material presents greater density, and this data is often used to characterize the granite change state, in which the more modified the rock, the less the value of the apparent density [17]. On the other hand, the density is proportional to the resistance.

Apparent porosity is the parameter which aims to determine the amount of empty spaces present in the analyzed material. This factor is also related to the resistance and durability [18], since the higher the porosity, the lower the material resistance [17].Pore positioning is a preponderant factor when related to the permeability. When there is a connection of pores, the material permeability increases. This property controls the flow rate of the fluid into the solid [19]. Apparent porosity outcomes are described in Figure 8.

The Figure 8 shows a considerable increase in feature 1 porosity to feature 2. This increase in the amount of pores indicates material quality loss. Since both mechanical and physical parameters may be reduced by limiting the use and durability of the material, the ABNT 15844 [16] specifies the maximum 1% absorption. Thereby, the porosity increasing caused by cement replacement in feature 2 exceeds three times the maximum acceptable limit for granites, highlighting a major change in its property while as a coating floor.

Finally, the absorption of water, which is the property by which certain amount of liquid is able to fill the voids in the material, being expressed by the relation between the amount of absorbed water divided by the volume of interrelated pores [17]. This property is also measured in ceramic floors that receive a particular classification based on this characteristic. The water absorption values may indicate susceptibility to chemical weathering in outdoor environments, which is associated with the quantity of pollutants in the urban environments atmosphere, being responsible for both staining and quality loss. Thus, the analysis of this property directs the kinds of environments in which they are to be applied, whether internal or external, dry or moist, in order to increase the useful life of coatings. Figure 9 illustrates the samples outcomes for this property.

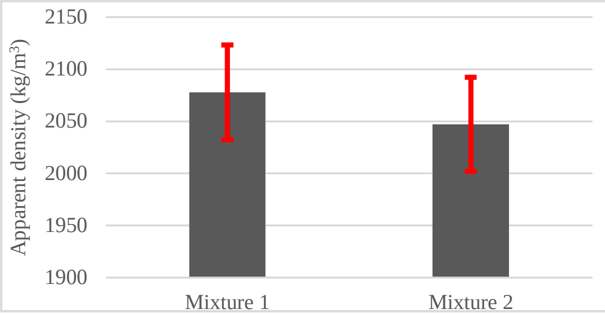

Figure 7. Apparent Density

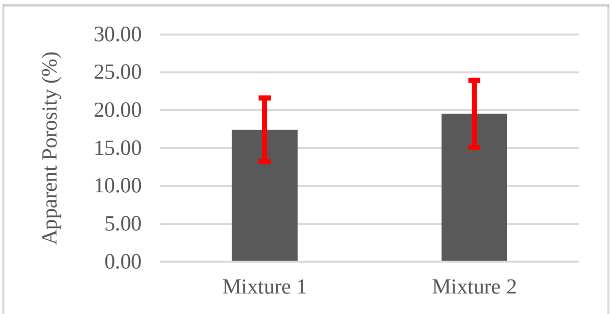

Figure 8. Apparent Porosity

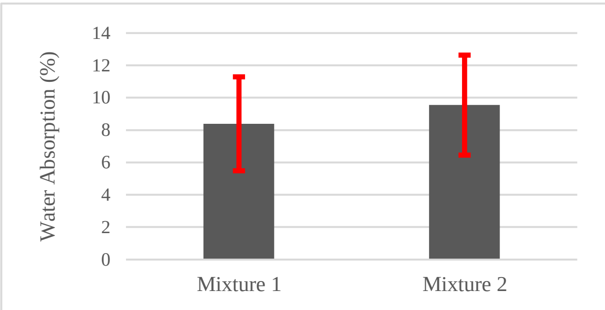

Figure 9. Water Absorption

Considering the occurrence of increased porosity in the sample with concrete replacement for limestone powder, it was expected that the result of water absorption would follow the same trend. Thus, the feature with replacement had an increase of almost 14% of its absorption when compared to the reference sample. The ABNT 15844 [16] specifies that water absorption is less than 0.4%. Taking it into account, it can be concluded that the coatings on granitine are less durable than the ornamental rocks, being the performance gap even more marked for the compound with binder replacement for inert material.

The perception for the material quality reducing contributes to the leading of new studies, particularly those related to measures of correction and waterproofing materials and resins application, since the use of such materials impairs the water absorption.

B. Linear thermal expansion coefficient

The linear thermal expansion coefficient is the main parameter used for the calculation of expansion joints, once this property allows a precise definition of the material performance when exposed to changes in temperature. Thus, dimensional variations are calculated based on such parameter and aim to avoid compressive stress between the boards because, if so, it can cause disorders, especially cracks and displatings. The previous results show, for granitine occurrence, an increase in pores and water absorption in the sample with replacement. For such sample, then, the thermal expansion tends to be lower than the reference sample, since the voids tend to absorb the expansion, resulting in lower dimensional variation on the boards. The obtained outcomes by the arithmetic average of the thermal expansion of heating and cooling phases are displayed in Figure 10.

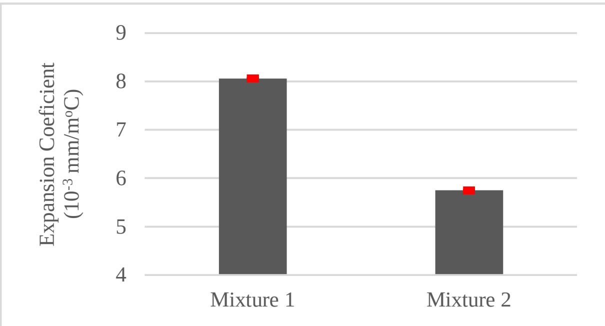

Figure 10. Expansion coefficient

The results confirm the linear thermal expansion coefficient reduction that showed a decrease of approximately 30%, indicating the loss of quality for the material with replacement. The ABNT 15844 Rocks coating - Requirements for granites states that the granites have an expansion coefficient less than 8.0 x 10-3 mm/m0C, consequently, the features showed a performance similar to the granite.

C. Uniaxial compression

The uniaxial compression strength is the parameter that evaluates the mechanical resistance of the concretes. Whereas the strength of cementitious compounds gain does not vary significantly after 28 days of molding, the measured values during this period are considered adequate as a mechanical strength reference. Thus, the samples features presented were disrupted after this period. Figure 11 shows the achieved results.

The strength compression average values show a decrease of nearly 30% on mechanical strength of the sample with replacement. Whereas this sample also presents higher porosity related to the reference feature, such result was already expected. Granitine compounds present an enormous disadvantage when compared to granite, which is a rock of high mechanical performance, with resistances greater than 100MPa [16].

D. Wear resistance

Amsler wear is a test used to verify the wear resistance of a material when submitted to quartz friction, which is one of the most abundant minerals of the earth's crust and hardness 7 classified on the Mohs scale. Thereby, the tests' obtained parameters guide the suitability of use of the material in a particular environment, considering, mainly, the flow of people referred to the enclosure. Figures 12 and 13 show the samples thickness wear after running 500 m and 1000 m respectively.

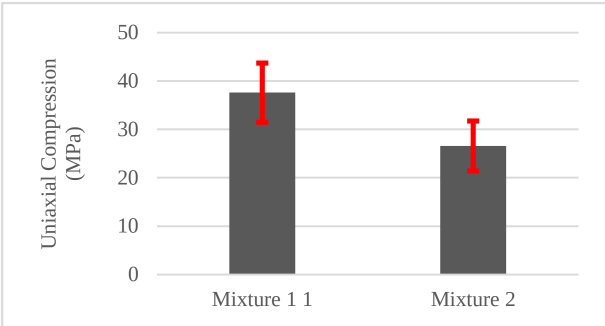

Figure 11. Uniaxial Compression

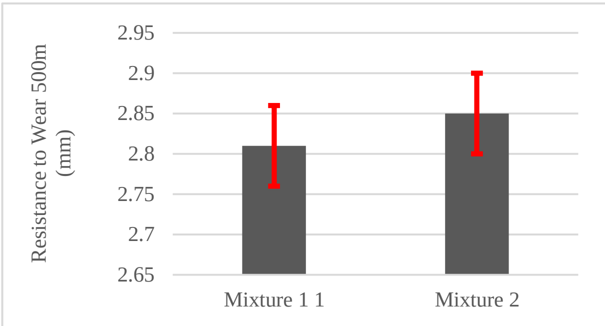

Figure 12. Resistance to Wear 500m

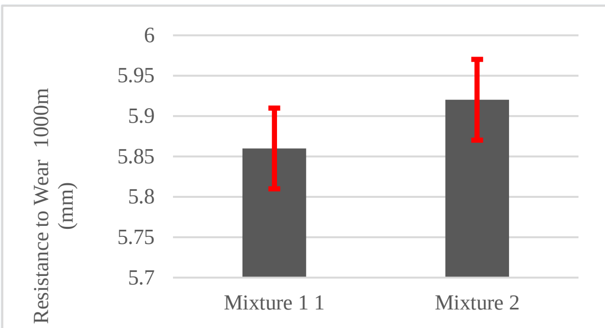

Figure 13. Resistance to Wear 1000m

The difference in values for the two features in this study was less than 1.5% for the two journeys. This shows that the replacement of the binder for the inert material did not significantly affect this property. The ABNT 15844 [16] establishes the value of 1 mm for each 1000 m run as granites wear limit. Granitine features showed a wear of almost 6 times higher than the allowed for granites, considering the distance cited in the standard. These results show that granite is an excellent material to be used as floor coatings. Materials such as marble - not indicated for this type of use – present a wear of 1000 m around 7.03 mm. Therefore, granitine compounds are medium quality materials for usage as floor coatings.

IV. CONCLUSION

The tests made in this study lead to a conclusion that the partial replacement of the binder conveyed significant changes in coating properties. It could be noticed that the greatest impact of limestone powder inclusion occurs in compressive strength, which falls considerably in its containing compounds. These compounds also present an increase in porosity and a nearly residence of abrasion parameters. The thermal performance of the material with replacement tends to overcome the reference sample, since lower thermal expansion values were obtained. Hence, the quest for an appropriate feature which provides economic gains and contributes to the technical quality of the material is of possible occurrence and should be the object of researches and studies in the future. It is important to emphasize that the samples tested did not receive polishing or resins application, and that these technologies may represent a promising alternative to counteract the waste of performance in some properties found in the new formulations. Thus, the analysis of such material, after polishing and resins application, is a recommendation for studies which aim to innovate and improve the coating materials used in civil construction.

ACKNOWLEDGMENT

The authors of this article thank the Brazilian agencies: National Counsel of Technological and Scientific Development (CNPq), Coordination for the Improvement of Higher Education Personnel (CAPES), and the Research Support Foundation of Minas Gerais (FAPEMIG) for the support provided to this study.

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