Revista
GEOCIÊNCIAS

unesp

ISSN: 1980-900X (online)

PHYSICAL-MECHANICAL CHARACTERIZATION OF BRAZILIAN NATURAL STONES: APPARENT DENSITY, POROSITY, WATER ABSORPTION, AND CAPILLARITY DETERMINATIONS

CARACTERIZAÇÃO FÍSICO-MECÂNICA DE ROCHAS ORNAMENTAIS DO BRASIL: DETERMINAÇÃO DE DENSIDADE APARENTE, POROSIDADE, ABSORÇÃO HÍDRICA E CAPILARIDADE

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RESUMO - As rochas ornamentais são materiais naturais de grande nobreza e alta resistência química e física, propriedades que lhes proporcionam grande durabilidade. Quando expostas às condições intempéricas ao longo do tempo sofrem algum tipo de degradação, tendo como agente principal a percolação de fluídos, que por conta de suas composições são capazes de interferir com os fatores intrínsecos das rochas, seja em aplicações em ambientes internos ou externos. Nesse sentido, a caracterização tecnológica surge como ferramenta de diagnóstico previsional e de indicação assertiva quanto ao desempenho, durabilidade e sobre a necessidade de alguma ação protetiva para materiais pétreos. Por meio de análises petrográficas e ensaios que determinam características como porosidade e absorção, é possível identificar padrões e definir parâmetros, por exemplo, de permeabilidade dos materiais e sobre a necessidade ou não para a aplicação, em especial, de protetivos como os recentes óleo-hidrorrepelentes. Visando avaliar a eficácia de aplicação desses protetivos, dezessete rochas ornamentais brasileiras foram previamente ensaiadas, tendo como base as normas NBR 12766 para determinação dos índices físicos e a EN 1925 para determinação do coeficiente de absorção de água por capilaridade. Os resultados mostraram quatro padrões de permeabilidade com base no tempo de saturação e inclinação da curva de absorção e indicam que a relação entre a absorção total e valores de capilaridade nem sempre é direta. Com base nestas informações, indicações sobre tratamentos protetivos podem ser consideradas.
Palavras-chave: Caracterização tecnológica. Capilaridade. Óleo-hidrorrepelentes.

ABSTRACT - Natural stones are natural materials of high nobility and high chemical and physical resistance, properties that provide them with great durability. When exposed to weather conditions over time, they are exposed to many kinds of degradation, most of it being the percolation of fluids, which due to their compositions can interfere with the intrinsic characteristics of the rocks, either in environmental conditions or in different applications. In this sense, technological characterization emerges as a predictive diagnostic tool and assertive indication regarding performance, durability, and the need for protective action for stone materials. Using petrographic analysis and tests that determine characteristics such as porosity and absorption, it is possible to identify patterns and define parameters, such as, the permeability of the materials and the need, or lack thereof, for application of protectors as oil-water repellents in particular. To evaluate the effectiveness of applying these protectors, seventeen Brazilian ornamental rocks were previously tested, based on the NBR 12766 standards for determining the physical indexes and the EN 1925 for determining the water absorption coefficient by capillarity. The results showed four permeability patterns based on the saturation time and slope of the absorption curve and the relation between total absorption is not fully direct with the capillarity values. Based on this information, indications about protective treatments can be considered.
Keywords: Technological characterization. Capillarity. Oil-water repellents.

INTRODUCTION

Rocks are industrially irreproducible natural materials, of great nobility and high chemical and mechanical resistance that provide them with great durability.

Because of these characteristics, these materials have been used in applications over time (Costa, 2009). In order to better understand the properties and responses of these materials in relation to the effects of time on them, studies on different forms of degradation have been produced. Whether in historical or contemporary applications, it is known that when exposed to the weather over time and, both by intrinsic and extrinsic conditions related to use and application, may suffer some kind of degradation (Costa, 2021), being its main cause the action of fluid percolation, especially water. Usually associated with other elements, this percolation within the rock can result in changes that are strongly influenced by the intrinsic characteristics of these materials.

Considering that each rock has its physical and chemical characteristics and that these can be modified by the influence of factors, both intrinsic and extrinsic, the technological characterization becomes an important diagnostic and predictive simulation tool for assertive indication, taking into account both the question of surveys of these characteristics (Trugul & Zarif, 1999), as well as the evaluation of performance and durability of materials after applications, for example, of protectors. Therefore, knowing these properties in advance is important for situations in which the application of protection is necessary, either during or after the installation of stone materials. For this characterization, all tests are based on standardized procedures, generally of low cost and sophistication, but which provide important information. In cases where there is a need for applications of protectors, and according to diagnostic studies for rocks applied to monuments and which have undergone some intervention (Ozcelik & Ozguven, 2014), it is highlighted that in addition to the tests physic-mechanics, the previous performance of petrographic analysis alone can provide preliminary information on the absorption and permeability conditions of the materials.

After all, these tests have been carried out, before and after the application of protectors, and the interpretation of all the data obtained, it will be possible to evaluate the extent of penetration of products such as epoxy resins and oil-repellent agents, which constitutes the main object of research in progress. In particular, the evaluation of this extension is important, since the efficiency and durability of the treatments are influenced by the depth reached by the protectors in the rocky substrate. Regarding the tests carried out, but specifically, the capillarity test in stages of diagnosis for ornamental rocks, there are few published Brazilian studies, generally because the data acquisition during characterization proceedings is very delicate. Frascá (2003), Vidal et al. (2014), and other authors mention the difficulty that this test shows for granites and rocks with porosity < 1%. We should highlight the work in the conservation line by Grossi & Del Lama (2018) and Ferreira et al. (2020), who carried out the physical-mechanical characterization to evaluate the permeability of rocks applied in fallen monuments and six ornamental rocks through the determination of capillarity and desorption, without standardization.

In general, even though the protective inputs are customary and currently indispensable for the application of certain classes of ornamental rocks, studies involving assessments of alterability with or without their applications in research institutions are still not significant. Regarding studies evaluating the effectiveness of the application of protective agents in Natural Stones in Brazil, the works of Galan (2001) and Maranhão & Barros (2006), who tested some rocks, evaluating products and the effectiveness of treatments, can be mentioned as pioneers. More recently, the works of Calegario et al. (2019) and Quitete et al. (2020), studies on oxidation stains in two leucogranites, must be cited.

In this work and to further verify the effectiveness of the application of protectors, previous information was collected on physical-mechanical characteristics for 17 stone materials with wide application in the market. This information represents the results of determinations for apparent density, porosity, water absorption, and capillarity coefficient, obtained in the laboratory and following the standards NBR 12766 and EN 1925. In the development of the research, sixteen samples of Brazilian "commercial granites" are being worked on with typical compositions, but with different textures and structures and a massive “quartzite”. From this gathering of data and interpretations, it will be possible, in a second phase, to assess the need or not to adopt protective actions for each of the types analyzed. Both these data, as well as those to be obtained, will compose the database of a master's thesis in development, which seeks to compare, at the end of the study, the protective efficacy of the application of three commercial oil-water repellents.

MATERIALS, METHODS, AND TECHNIQUES

For the experimental stage, seventeen samples of fragment’s remanents from the sawing process were collected at the AAMOL (*Associação Ambiental Monte Líbano*) landfill in Cachoeiro de Itapemirim - ES, the main region that has been supporting ornamental plants in the country. From these samples, specimens were prepared following the normative specifications.

These seventeen samples include materials identified as granites, but only according to commercial names since petrographically only partly are igneous in origin. In large part, they are metamorphic. Despite having silicate compositions, they show distinct granulation, textures, and structures. On the market, these materials received the following trade names: “Yellow Ornamental”, “White Itaúnas”, “White Arabesco”, “Green Ubatuba”, “Yellow Santa Cecília”, “Yellow Corumbá”, “White Fortaleza”, “Grey Castelo”, “Coffe Imperial”, “Yellow Capri”, “Ocher Itabira”, “White Dallas”, Pegmatite “Feldspato”, “Red Brasília”, “Black Via-Láctea”, and “Black São Gabriel”, and a rare quartzite of high value called “Blue Macaúbas”.

For testing, six specimens with cubic dimensions of 125 cm³ (5 cm x 5 cm x 5 cm) were prepared for each of the samples, totaling 102 specimens. In this preparation, a bridge saw with a 350 mm diameter and 17 mm thick diamond disc was used. The labor and equipment were kindly provided by the Barbigran - Designer Stones Ltda. also in Cachoeiro de Itapemirim - ES. Reserve samples were stored for possible replacements and the production of petrographic slides.

The determination of physical-mechanical characteristics was performed following the rules for determining apparent porosity and apparent water absorption ABNT NBR 12766, which has been made in this way causes very fine porous rocks like quartzites and low quartz composition rocks reveal in our study very difficult water desorption patterns demanding drying temperature conditions upward of 100°C. Water absorption coefficient by capillarity EN 1925 has proceeded as usually applied in the literature (Peruzzi et al., 2003; Skowera & Przemyslaw, 2018) using LABTECRochas-CPMTC/UFMG equipments.

For the execution of the tests, a ventilated oven was used to dry the samples at 110 ± 5 ° C for at least three days, until they reached constant values below 0.1% of the mass of the test pieces, measured on a analytical balance with 0.01g accuracy carried with a hydrostatic measuring device and automatic recalibration.

The tests to determine the apparent densities, absorptions, and porosities were carried out by drying the samples and subsequent measurement of the masses in dry (A), saturated (B) condition after complete immersion in distilled water for 72 hours and submerged (C) by hydrostatic measurement. With these values, the apparent dry density can be calculated by the ratio of mass to volume using the equation $\rho a_{sec} = A/(B-C)*1000$ in kg/m^3. The saturated apparent density is calculated by the same principle of the previous equation following the equation $\rho a_{sat} = B/(B-C) * 1000$ in kg/m^3. The values of absorption and apparent porosity are represented in percentage, calculated by the equations $\alpha a = [(B-A)/A]*100$ (%) and $\eta a = [(B-A)/(B-C)]*100$ (%), respectively.

In the capillary test, the samples were also dried for 72 hours and then subjected to the immersion of the specimens in a water layer of 3 ± 1 mm for three days in an uncontrolled environment at 20 ± 5° C as required by the standard but arranged in an airtight container. The values are presented in the form of a graph, where the absorbed mass, in grams, is divided by the area of the immersed base of the specimen, in square meters, as a function of the square root of time, in seconds.

The equation for this determination is then expressed by the linear regression coefficient of capillary absorption by the equation $C_{AC} = (m_i - m_d) /A.t_i^{1/2}$, where m_i is the absorption value in the fifth reading, in 180 minutes of testing; (m_d) is the value of the dry sample; (A) is the value of the immersed specimen area; and ($t_i^{1/2}$) the square root of time at the time of measurement. The mass values were measured over time on two progressive scales, thus seeking to decrease the standard deviation of measurements in samples with lower absorption speed. For the samples with the highest absorption, readings were performed at time intervals of 0, 10, 20, 30, 60, 180, 480, 1.440, 2.880, and 4.320 minutes as suggested by the standard, while for materials with low absorption speed capillary (“Quartzite Blue Macaúbas”, “Black São Gabriel” and “Black Via-Láctea”) the readings were performed at time intervals of 0, 30, 60, 90, 120, 180, 480, 1.440, 2.880 and 4.320 minutes.

DISCUSSION OF RESULTS

In this work, with the results achieved so far, it is possible to previously identify some permeability patterns, which may already indicate the need or not for the application of protective products.

In table 1, the results of the determinations of apparent dry and saturated density, apparent water absorption, and apparent porosity are presented for each of the analyzed samples, accompanied by their respective commercial and petrographic nomenclatures.

From the data obtained, no significant deviation is perceived between all determinations of the samples, which is evidenced by the parity of the results of both standards, especially regarding water absorption, as shown in figure 1. Regarding the presentation of the standard deviation, we must clarify that, as required by the standards, it is extremely important. From these data, we can obtain interesting information about their physical-textural relationships and their possible influences on percolation mechanisms.

Table 1 - NBR 12766 determinations of dry and saturated apparent density (kg / m³), water absorption (g), apparent porosity (%); and EN1925 with capillarity water absorption coefficient for samples with commercial and petrographic identifications. The presentation of the results of the samples is done in decreasing order of the values of Final Absorption - M_i *.

Comercial Name	Petrographic Nomenclature	ρa_{sec} (kg/m³)	σ (±)	ρa_{sat} (kg/m³)	σ (±)	αa (%)	σ (±)	ηa (%)	σ (±)	C_{AC} ($g/m^2/\sqrt{s}$)	σ (±)	Correlation (R^2)	Linear Regression Equation	Max. Absorp. - Mi (g/m²)	σ (±)
Yellow Florença	biotite Monzogranite	2.634,4	11,6	2.645,1	11,7	0,40	0,04	0,96	0,10	3,20	0,45	0,994	y = 3,1956x + 5,7497	544,0	49,6
White Itaúnas	Sienogranític garnet Gneiss	2.615,7	4,7	2.625,4	4,0	0,37	0,03	0,88	0,08	2,86	0,20	0,999	y = 2,789x + 4,8112	480,0	22,1
White Arabesco	Sienogranitic biotite garnet Gneiss	2.631,8	10,2	2.640,7	9,9	0,34	0,02	0,81	0,06	2,94	0,22	0,986	y = 2,9211x + 8,2692	448,7	26,2
Green Ubatuba	hypersthene biotite Charnockite	2.706,6	11,4	2.714,4	11,3	0,29	0,01	0,70	0,04	3,72	0,94	0,996	y = 3,7356x + 5,5754	408,8	18,2
Yellow Santa Cecília	Syenogranitic biotite garnet Gneiss	2.643,5	8,5	2.651,3	8,5	0,30	0,01	0,71	0,03	2,57	0,14	0,991	y = 2,5203x + 5,4455	380,7	21,1
Grey Corumbá	biotite Monzogranite	2.689,6	4,2	2.697,1	4,1	0,28	0,01	0,68	0,02	2,61	0,23	0,995	y = 2,6164x + 4,4087	376,0	8,4
White Fortaleza	biotite Syenogranite	2.626,6	3,8	2.633,6	3,8	0,26	0,00	0,63	0,01	3,17	0,18	0,998	y = 3,1793x + 2,8754	363,3	6,9
Grey Castelo	Protomilonitic biotite Monzogranite	2.663,2	4,2	2.670,4	2,4	0,27	0,01	0,64	0,01	3,07	0,08	0,995	y = 3,045x + 5,1462	367,2	5,9
Coffe Imperial	aegerine-augite Syenite	2.759,9	10,1	2.770,0	10,1	0,37	0,00	0,91	0,01	0,87	0,06	0,999	y = 1,4077x + 0,9725	505,6	6,7
Yellow Capri	biotite Granite	2.614,1	0,7	2.621,8	0,7	0,29	0,00	0,69	0,01	1,66	0,11	0,989	y = 1,7053x - 0,9547	379,3	6,9
Ocher Itabira	quartz biotite hornblende Monzonite	2.700,7	8,7	2.708,5	8,7	0,29	0,01	0,70	0,01	1,47	0,14	0,999	y = 1,449x + 0,3521	372,8	7,2
White Dallas	Monzogranitic garnet gneiss	2.679,7	15,3	2.686,7	15,1	0,26	0,02	0,64	0,06	1,67	0,17	0,994	y = 1,658x + 3,0175	356,0	13,3
Pegmatite "Feldspato"	muscovite Syenogranite	2.615,7	20,8	2.622,2	21,8	0,25	0,04	0,58	0,10	1,48	0,14	0,994	y = 1,4835x + 2,8739	336,0	53,4
Red Brasília	Syenogranite	2.618,9	1,7	2.624,8	1,8	0,23	0,02	0,54	0,05	0,93	0,15	0,995	y = 1,1606x + 3,19	293,6	12,2
Black Via Láctea	Mafic Granulite	3.061,4	13,3	3.065,4	13,3	0,13	0,01	0,36	0,02	0,47	0,06	0,997	y = 0,7509x + 1,5599	204,0	12,0
Black São Gabriel	quartz hypersthene diorite/norite	2.949,4	14,5	2.953,8	13,8	0,15	0,03	0,38	0,08	0,35	0,06	0,990	y = 0,5446x + 2,2336	200,8	33,4
Quartzite Blue Macaúbas	Kyanite dumortierite Quartzite	2.682,2	2,9	2.683,7	2,9	0,06	0,00	0,14	0,00	0,16	0,02	0,974	y = 0,2589x + 1,463	60,0	2,8

* Correlation coefficient (R^2) measured between the two variables, equation of linear regression at the 5th reading point, and maximum water absorption (saturation) with their respective standard deviation values (σ).

For example, in table 1 and figure 1 it can be seen that the largest variations of standard deviations (σ) in the determinations of porosity, water absorption, capillarity, and maximum capillarity absorption - M_i, correlate with the materials of greater heterogeneity in granulation, represented by the following types: Monzogranite “Yellow Ornamental”, Charnockite “Green Ubatuba”, gneisses “Yellow Santa Cecília” and “White Dallas”, pegmatitic Granite “Feldspato” and Norite “Black São Gabriel". Unlike these samples, the “White Itaúnas” gneiss, which is homogeneous and fine-grained, also showed a high standard deviation, showing that in addition to granulation, other petrographic characteristics and industrialization processes can influence the permeability and interconnectivity of micro-discontinuities.

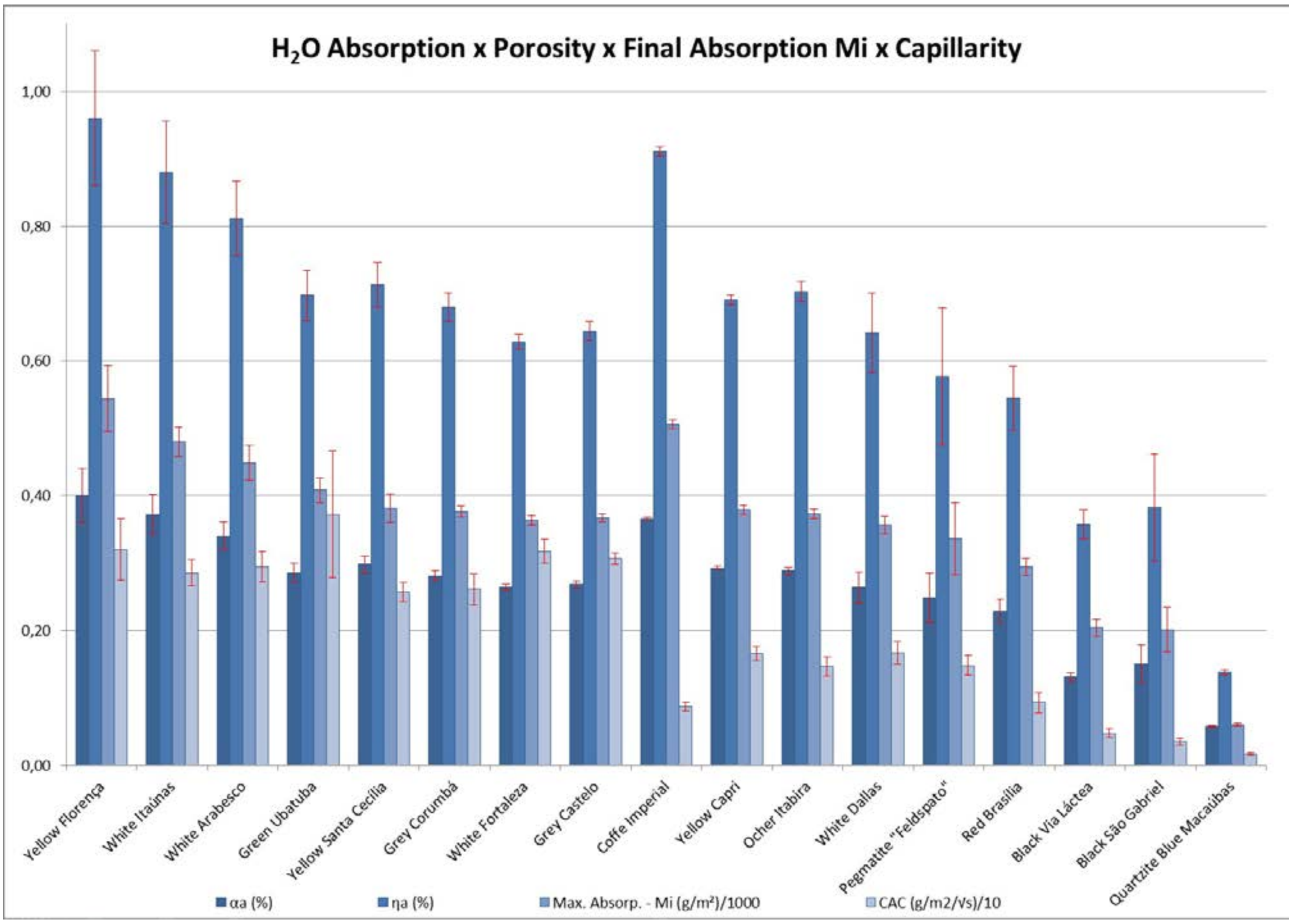

Figure 1 - A bar graph showing the Absorption and Apparent Porosity determinations and the final absorption values per capillarity M_i in grams per square meter divided by 1000 and capillarity coefficient in grams per square meter by the square root of time in seconds divided by 10.

It is also interesting to note that although these samples have very different values in all determinations, in some way, and for some of them, their mineralogies and strengths can contribute to the preservation of permeability patterns, in some very complex cases. Such is the case the mafic materials, such as the norite “Black São Gabriel” and the “Black Via-Láctea” granulite, or the poor spatial representation of the specimens with only 5 cm of edge in rocks with very large crystals, as in case of the monzogranite “Yellow Florence” and the pegmatitic granite “Feldspato”.

As for the relation between the values of capillarity absorption and standard deviation, the Charnockite “Green Ubatuba” should be highlighted among the samples, presenting the highest coefficient (3,72 ± 0,94 $g/m^2/s^{1/2}$), possibly due to the influence of the well-known mechanical fragility that these rocks present, and during the stages of extraction, sawing and preparation of the specimens, the propagation and intercommunication of micro-discontinuities occurred, thus generating the great standard deviation presented.

It is also important to note that silicate rocks are materials with relatively low porosity and the acquisition of data under this condition must be very accurate and precise, carried out in an isolated environment of air circulation and exchange of hygrothermal conditions. When preserved from advanced alteration, they present much lower values of water absorption by capillarity in proportion to the values presented by limestones and sandstones, very porous materials classically applied in monuments, more frequent in European countries.

With this data, correlations can be made in the future after the application of different kinds of hydrorrepelents commercialized in the industry, showing different patterns of permeability reduction, and guiding selections of applications and the necessity or not of protection intervention, giving the products more quality and longevity, what implies indirectly to the products more competitivity and sustainability over the global market.

Based on the slope of the water absorption curve by capillarity as a function of the root of time, we can represent the permeability of water in the rocks by determining the speed of water absorption and the time at which they reach saturation from a slope coefficient of the curve.

In figure 2 it is possible to identify four absorption patterns with their respective saturation times in approximately 3, 8, 24, and 48 hours. The only sample that did not show full horizontalization of the absorption curve was the norite "Black São Gabriel", which probably can be reached in 96 or 120 hours.

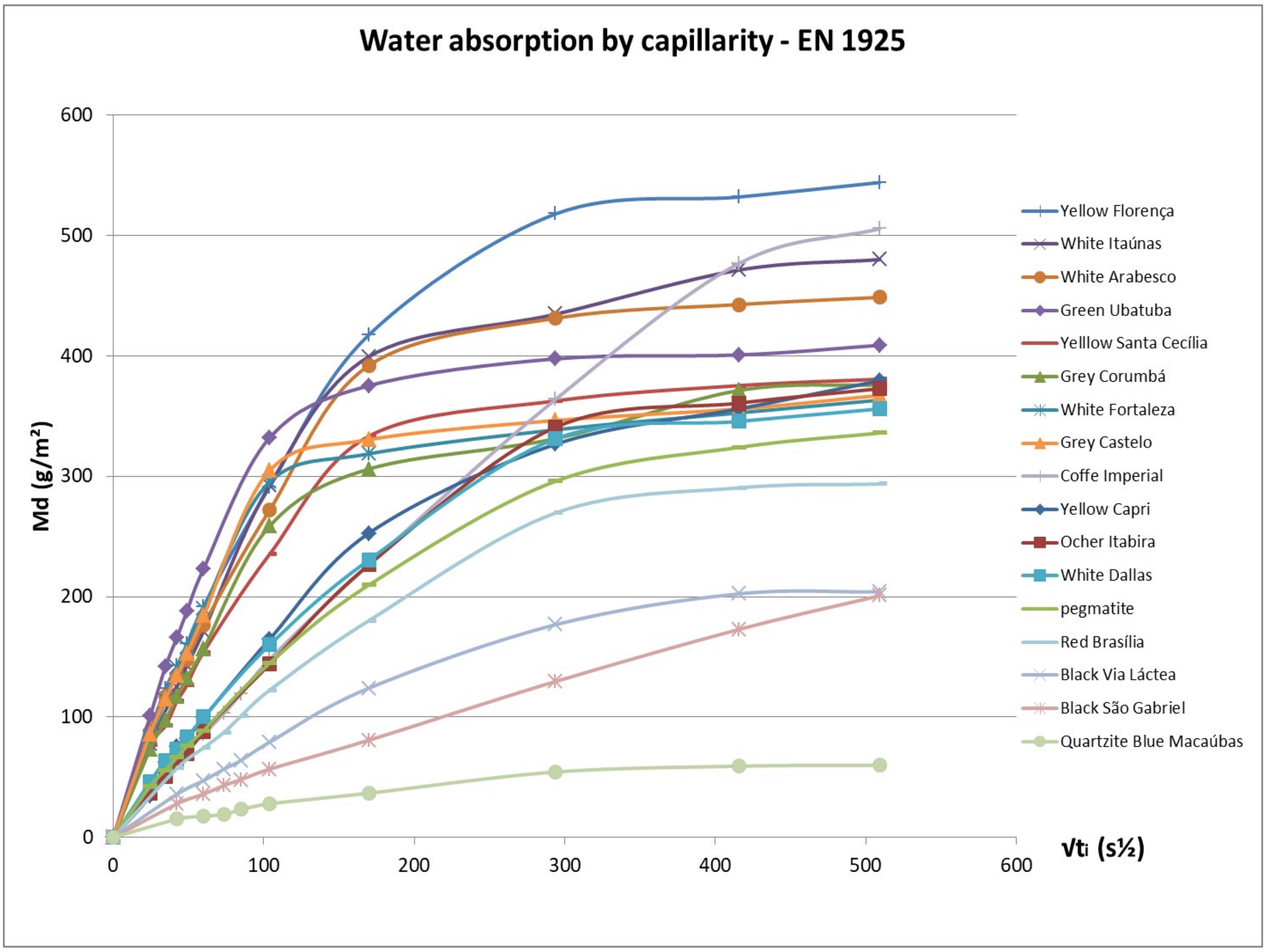

Figure 2 - Capillarity water absorption graph executed according to the EN 1925 Standard on 16 samples of silicate rocks of varying compositions and one quartzite siliceous. M_d = water absorption in grams per square meter; √t = square root of time in seconds.

With the graphic representation of these behaviors, four groups of samples were identified and ordered according to the increasing order of the values of absorption/porosity, capillarity, and saturation time. The first is predominantly represented by igneous rocks such as the "White Fortaleza" syenogranite, the "Grey Corumbá" monzogranite, the "Green Ubatuba" charnockite, and the protomilonitic monzogranite "Grey Castelo", reaching saturation in just 3 hours.

Interestingly, the "White Fortaleza" syenogranite had one of the lowest M_i final absorption values in this group (363,3 ± 6,9 g/m^2), but the second-highest capillary value (3,17 ± 0,18 g/m^2/s$^{1/2}$), which can be interpreted as a result of high interconnectivity of micro-discontinuities with smaller thickness dimensions.

The samples of a metamorphic nature, such as the syenogranitic gneiss “Yellow Santa Cecília” and the syenogranitic gneisses “White Arabesco” and “White Itaúnas” form the second group. They presented great variation in the final values of Mi absorption and high capillarity coefficients providing saturation in 8 hours, probably influenced by the lower integrity and non-regular textural-structural mineral interconnectivity of these rocks.

The syenogranitic gneiss “Yellow Santa Cecília” stands out for having the lowest capillary absorption coefficient (2,57 ± 0,140 $g/m^2/s^{1/2}$). The syenogranitic gneisses “White Itaúnas” (2,86 ± 0,20 $g/m^2/s^{1/2}$ and 480,0 ± 22,1 g/m^2) and “White Arabesco” (2,94 ± 0,22 $g/m^2/s^{1/2}$ and 448,7 ± 26,2 g/m^2), with different textures and grains, presented high absorption values and capillary coefficient with low deviations from the mean. This shows that in these rocks the textural web is well interconnected, which must be confirmed in comparisons after the application of the products.

The third pattern is the bulkiest. It is formed by the monzogranite “Yellow Florença”, sienogranite “Red Brasília”, pegmatite “Feldspato”, granite “Yellow Capri”, monzonite “Ocher Itabira”, leukogranitic gneiss “White Dallas” and quartzite “Blue Macaúbas”. The group reaches saturation in 24 hours and is composed predominantly of igneous rocks and only two metamorphic ones, with final M_i absorption values ranging from (544,0 ± 49,6 g/m^2 to 60,0 ± 2,8 g/m^2) and capillarity values (0,16 ± 0,02 $g/m^2/s^{1/2}$ to 3,20 ± 0,45 $g/m^2/s^{1/2}$) more dispersed among all groups, representing textural, structural and of varied integrity of the samples.

The “Yellow Florença” showed the highest final absorption among all samples. This behavior can be explained mainly by the lower integrity of rock produced by advanced degradation and the large granular heterogeneity identified macroscopically having phenocrystals up to 5 cm in diameter, given its lower mechanical resistance when subjected to compression tests, demanding the use of epoxy resins for structuring and surface finishing of the plates, a very common technique that benefits and commerce that material.

The “Blue Imperial” Quartzite and its commercial designations variations like “Blue Macaúbas” are very interesting and valued quartzite lithotypes, performing great functionality besides its astonishing blue color in pronounced sedimentary structures which is highlighted by its exceptional mineral composition highlighted by kyanite and dumortierite. That Natural Stone performs the lowest absorption values among all samples (0,16 ± 0,02 $g/m^2/s^{1/2}$ and 60,0 ± 2,8 g/m^2), with a saturation goal reached in only one day, the fastest of the extremely low absorption materials. The interesting thing that stands out with this information is that even though the crystal organization in this rock is very compressed, as expected from massive quartzites, the common use of oil-water repellents by the ornamental sector in this type of rock is justified mainly due to the ability to inhibit moisture stains in addition to offering enhancement of the chromatic patterns like was made in “White Dallas” and “White Itaúnas”, well known by the industry for common chromatic degradation generated oxidation of biotites in “White Dallas” and garnet degradation in “White Itaúnas” (Calegario et al. 2019; Quitete et al., 2020), what gives the final products nasty iron oxides stains.

The fourth pattern identified is composed of the samples with the lowest value in the coefficient, reaching saturation in 48 hours, as is the case of the mafic granulite “Black Via-Láctea”, which did not present full linearity of the capillary absorption curve (0,47 ± 0,06 $g/m^2/s^{1/2}$) and final absorption (204,0 ± 12,0 g/m^2). The samples of “Black Via-Láctea” although the determination of capillarity coefficients results show extremely good correlation (R2 > 0,95 after the fifth measurement), must be proceeded according to exponential function where the mass of water absorbed by square meter is a function of mass absorbed after saturation, capillary front height in specimen profile and the square root of time.

The “Coffee Imperial” syenite, unexpectedly with the second-highest final absorption value M_i among all rocks (505,6 ± 6,7 g/m^2) and capillary absorption (0,87 ± 0,06 $g/m^2/s^{1/2}$), showing the absorption values are not always directly correlated with capillarity in rocks with very low porosity as are the silicate rocks. The macroscopic influence of the plastic fluidal structures developed during magma crystallization was marked by the juxtaposition of elongated oblate orthoclase crystals, giving it a wide sorting of options of aesthetic textures as mentioned by Navarro (2006). Microscopically the predominance of straight and concave-convex contacts between crystals and the intense presence of intra-granular micro-fissures clusters perpendicularly to the crystallographic B axis in orthoclase added the lack of quartz is responsible for the high water absorption presented with very slow permeability, which can be observed in figure 3 extracted in a premade thin section for this publication.

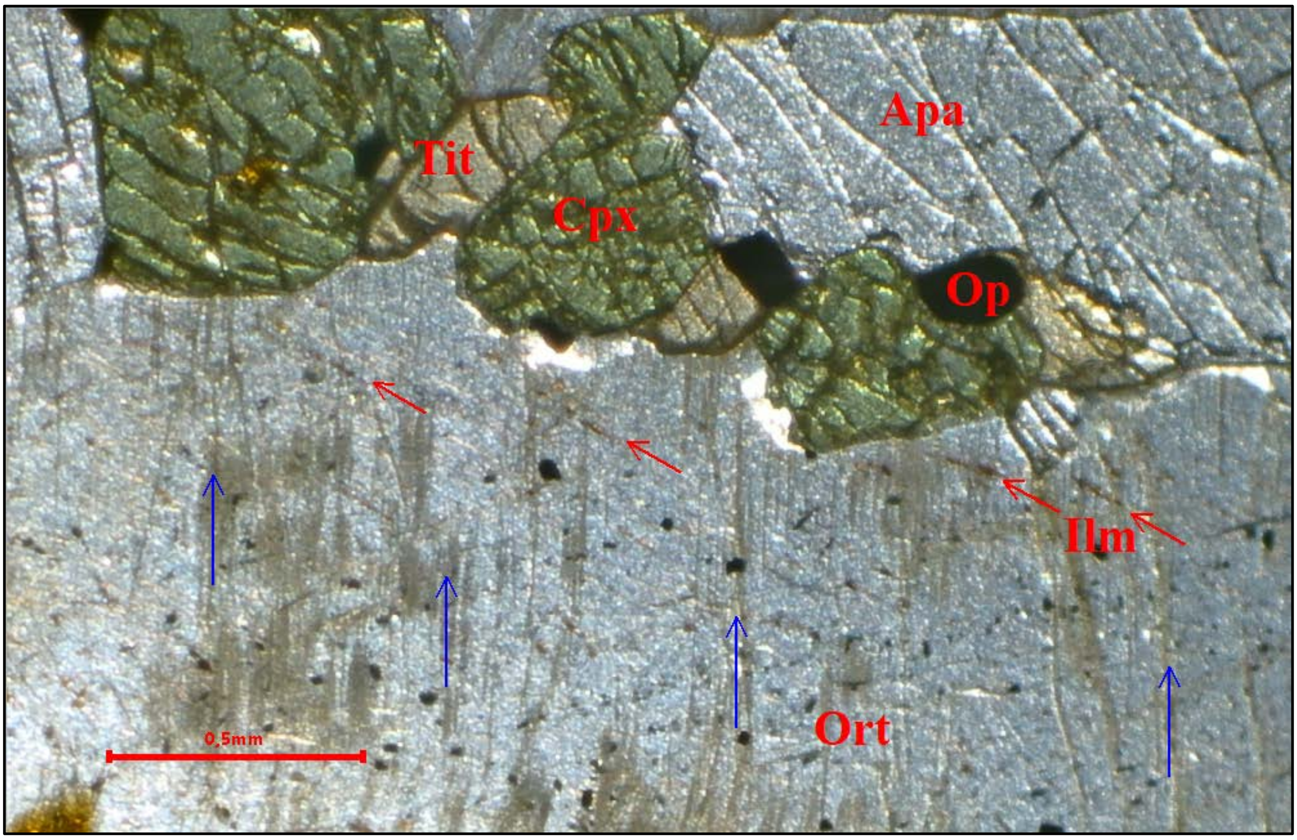

Figure 3 – Syenite "Coffe Imperial" visualized at natural light in 10x eyepiece magnification stereo-microscope showing perpendicular intra-granular micro-fissures (blue arrow) in orthoclase (Ort), oriented poikilitic ilmenite and opaques inclusions (Ilm = red arrows, Op = Opaques), and his straight-concave-convex contacts between clinopyroxene (Cpx), titanite (Tit) and apatite (Apa). Scale = 0,5 millimeters.

Authors have been publishing results of determinations developed in Brazilian Natural Stones in their research over the last two decades. The results compared with physical-mechanical determinations reached in this study are very similar to Frascá (2003) and Sossai (2006) in "Green Ubatuba" which highlights the high index of trans-granular micro-discontinuities that can be correlated with the high deviation values presented by this Natural Stone. Frascá (2003) also studied "Yellow Santa Cecília" presenting results with a small deviation from the ones reached in this study, but very different in terms of permeability, possibly interfered with by test procedures made by the author.

Nogami (2012) and Pazeto (2011) conducted independent studies on determinations of porosity and water absorption in "Red Brasília" and "Ocher Itabita". Their results show lower same values than those reached in this study, respectively. The former suggests that patterns by genetic features of magmatic corrosion in the formation of the crystalline structure are responsible for greater integrity and crystalline imbrication with smaller dimensions of micro-discontinuities like interstitial crystal contacts, cleavages, and microcracks, thus justifying the low permeability values presented in this study. Comparing "Ocher Itabira" with other felsic lithotypes tested, it shows low porosity, water absorption, and permeability, which can be hardly interpreted as the absence of interstitial quartz in composition, like "Cofee Imperial", even though crystals in this monzonite specifically present great intensity of intra-granular micro-fissures, but filled by secondary phyllosilicates.

It's important to reinforce the simplicity and benefits when intending to diagnose a rock using simple petrography and physical-mechanical tests.

Anomalous patterns of permeability and mineral degradation can be elucidated using some options of sophisticated analytic resources. Generally focused on Monument Stone Conservation or Restoration, some works around the world present destructive and non-destructive technics applied to characterize Natural Stones pretending to help and guide protective interventions, highlighting works of Montoto & Mateos (2006) studying in matrix scale the water pathways in granites utilizing wide options of microscopy; and visualizing the water uptake by capillarity and the effectiveness of consolidants and oil-hydrorrepelents in sandstones and limestones utilizing High-speed thermal neutron tomography developed by Masschaela et al. (2004).

CONCLUSION AND FINAL CONSIDERATIONS

The results of the determinations of physical-mechanical characteristics are reliable and in part correlate with results found in other publications. The low standard deviation values for all samples in both tests show the good reproducibility and repeatability of the test procedures performed.

The results demonstrate, as expected, the direct correlation between porosity, water absorption, and capillarity water absorption values, at the end of the test in 72 hours, and that this correlation is not always accompanied by the permeability demonstrated by the capillarity coefficients. It is also possible to establish four groups with different capillary absorption behaviors and with different saturation times. It is believed that the distinction of these patterns in groups can serve as a guide for the selection of representtative samples to be tested in the next steps and an indication of the need or not for protective actions.

The next steps, it is intended to prepare thin sections to perform petrographic analyzes based on the Brazilian standard NBR 15845-1. These analyzes will be carried out before the application of surface protection involving the use of three oil-water repellents purchased on the market. With this, a greater understanding of the permeability of the samples is sought. After these applications in specimens, we intend to perform the physical-mechanical tests again to evaluate the effectiveness of the products by comparing the reduction of capillarity.

ACKNOWLEDGMENTS

The authors wish to acknowledge LABTECRochas-IGC-UFMG for their financial support during our research. This paper contains the results of the M.Sc. dissertation of the first author at the UFMG, with a scholarship from CAPES. Special thanks to the AAMOL (Associação Ambiental Monte Líbano) to Marmoraria Barbigran – *Designer Stones* Ltda.

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Submetido em 30 de abril de 2022
Aceito para publicação em 15 de novembro de 2022