

Performance Evaluation of Cladding Stone in Buildings and Urban Works

Flain E., Righi R., and Frazão E.

Abstract—The requirements regarding to aesthetic effect of the buildings require that coatings with dimension stones maintain their initial appearance even when subjected to various actions such as mechanics, chemistry, thermal and hygrometric related to its use and with the actions from the weather.

It is of knowledge of experts that finishes with dimension stones may be subject to the occurrence of diversified pathologies, depending on the characteristics of rocky materials used, of the constructive process adopted for the fixing of the plates to the support, the degree of control of the fixing of the plates, the use and maintenance stage and the degree of detailing of the project. This paper discusses the main factors involved in performance of stone veneers in buildings and in urban works and present typical examples of most frequent pathologies in such finishes.

Index Terms—Stone cladding, pathologies, stone veneers.

I. INTRODUCTION

When it opts for cladding stone on buildings and projects of urban works it is believed that these will have greater durability when compared to other flooring materials, plus some other advantages, such as reduced maintenance, property valuation, pleasant and aesthetic finishing associated to the rich and noble, among others. For these and other reasons, generally, justify higher initial costs compared to other coating materials.

The coatings with dimension stones are in accelerated growth in Brazil, which is reflected in bold designs, with the use of wide diversity of rock types in multiple uses and with varied and good aesthetic results. This fact is due to the intense effort of technological update of our professionals in the architecture, engineering and geology, the increasing training of labourers, the increase of knowledge of the characteristics of the rocks (which allows for a better selection of the most suitable for the intended use), the options for their attachment and adoption of modern project criteria.

This procedure has great importance today for the housing market to create new conditions for the development of a new product. The consumer's needs and desires are intimately linked to greater sophistication required of real estate final product [1].

Pathological manifestations occurring in cladding stone of floors of buildings constructed recently, comes to counter the

initial reasons for which chooses the project for these coatings. Such manifestations are translated by the loss of the initial characteristics of the Rocky material and, often, the loss of stability compromising the coating as a whole and the professionals responsible for their choice.

Pathological manifestations in these coatings can be associated with several factors that called intrinsic or extrinsic. The first refers to the characteristics of the materials and the second relates to the system of fixing of the plates to the substrate, the production process and environmental conditions. Among some factors involved are the following:

- The process of obtaining the stone plates; The production procedure, e.g. lack of or deficiency in design;
- The inadequate specification of materials due to lack of knowledge of their properties or even by the aesthetic appeal that provides;
- The lack of standardization, which specify the minimum quality standards;
- The precariousness of knowledge or technology domain of application;
- The deficiency or absence of production quality control, among others.

The most frequent pathologies observed in cladding stone of floors and urban works, very negative and that cause the devaluation are associated to factors listed above causing stains, debonding, cracks or fractures and abrasions. To avoid or minimize such pathologies the characteristics and properties of the Rocky material used for coating must be compatible with a number of key factors:

- The characteristics of the placement system (fixing) adopted. It can be by using conventional mortar (Traditional Process), adhesive mortar (Streamlined Process) [2] or the adoption of high floors, with amounts, currently very used.
- The location where the coating will be used (Interior or exterior);
- The type of building (residential, commercial, other);
- The intensity of traffic on the finish;
- The conditions of exposure to which they are subject.

In order to analyze and systematize the unwanted and complex processes that occur, are presented, then, some diseases associated with the fixing of stone plates with mortars, as well as some of its leading causes.

II. PATHOLOGIES LINKED TO FIXING BY CONVENTIONAL MORTAR

Staining, detachments, cracks of plates are the most

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frequent pathologies in cladding stone of floors laid down by the traditional process. It is common the occurrence of stains caused, mainly, by excess water from the mortar, cement impurities, sand and water of kneading. These factors, combined with high rock porosity, may enhance the staining. The cause of excess water is in inadequate dosage of mortar that, by exuding, penetrates the pores of the stone. So, if on the water permeation by the stone plaque, there is ion transport of cement, it decoupled these precipitation may occur in the pores of the stone. This can cause permanent stains. When taking of soluble salts to the surface of the plate will be the formation of efflorescence (patches of whitish coloration) by precipitation of salts. These are pathologies observed in Fig. 1. This pictures show these types of pathologies in a slate stone flooring. However these diseases also occur frequently in other types of rocky materials. In this case the most likely cause of the appearance of these pathologies is the excessive amount of kneading water used for the fixing mortar of the stone plates.

The presence of impurities in the sands, such as iron oxides and hydroxides, particularly in their thin fractions can ($\# < 100$), highly alkaline medium, such as that promoted by water-cement mixture, if you dissociate and migrate, by capillarity, to the surface of the stone and then if rush and cause staining.

The spots can be distributed across the surface of the plates and in the surroundings of the joints. This case is compounded by the percolation of water cleaning, or rainwater, which leaching the mortar of settlement, or joint compound, producing substances that accelerate the staining.

In addition to the causes mentioned above, stains on cladding stone can be associated with the phase of use and improper maintenance [3]. These spots are frequently when using muriatic acid cleaning material impure hydrochloric after the settlement of the plates, which, when applied to granite, produces reddish spots of iron oxide, iron ions removal caused the composition of biotite. Some existing cleaning products in the Brazilian market, generally, are unsuitable for cleaning and maintenance of cladding stone which may also lead to staining of these.



Fig. 1. Spots and efflorescence on the surface of the stone coating distributed slate. Residential building stairway, with approximately 5 years, in the city of São Paulo. Probable cause: excess water of kneading of the mortar.

The cracking of the dimension stone can occur for several reasons, namely: if there is increased traction tension caused by the expansion of salts inside; failures in the distribution of the mortar of settlement; inappropriate mechanical properties

of rocky material. In addition to these may be associated with increased and by project failures Fig. 2.

The adherence of the mortars is related to the roughness of the plates and mineralogical characteristics of the rocks [4].

The attachment with mortars submit different grip resistors for the various rocks confirms the importance to consider the textural and structural, mineralogical aspects of each one of them [5].

As for the detachment of dimension stone, this can have several causes such as: excess water from settlement of the mortar, the lack of adequate preparation of the substrate and the difference between the coefficients of expansion of the material composition of the coating layer (substrate, settlement and mortar Rocky material); compounded by the under sizing of joints or by the adoption of dry joints in environments where excessive thermal variations occur.



Fig. 2. Crack in cladding stone. Probable cause: a deficiency in the distribution of the mortar of settlement.



Fig. 3. Rocky plates use caused by excessive traffic associated with the different characteristics and properties of carbonate rock. Airport floors in the city of São Paulo.

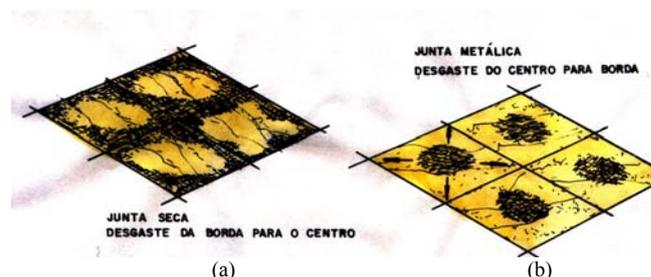


Fig. 4. The wear of rock plates associated to the characteristics and properties of the rock and the type of joint used. (a) Edge wear to the Center. (b) Wear from Center to edge.

III. PATHOLOGIES LINKED TO COATING PROJECT

You can define which main activities of a project of coating are:

- The definition of constructive process to be adopted;
- The choice and definition of the Rocky material and

other materials that will be used in the performance of the coating;

- The detailing of the execution procedures;
- The definition of the qualification standard of workmanship;
- The choice of equipment and tools, among others.

Thus, any deficiency in one or other of the activities listed above may cause a series of consequences, generating diseases, waste of materials and workmanship.

The Fig. 3 features a floor coated with two types of rocks (a marble and a "granite") that have very different properties and characteristics, a lower wear resistance than the other. It is undeniable the aesthetic effect provided the floor as a whole but the use and tear caused on less resistant rock cause discomfort to passers-by when moving on the floor. This proves inadequate choice of Rocky materials since the same are being used side by side as a floor coating with high transit airport floor.

The Fig. 4 presents two types of commonly used joints in coatings of floors and the effects caused by rocky material use when dry and metallic gaskets are adopted.

IV. PATHOLOGIES LINKED TO THE NATURE OF THE ROCKY MATERIAL

Regardless of the type of fixation for floor coatings adopted with rocky material, should always be given special attention to the nature of these materials, in both the compositional aspect, as in the physical-mechanical characteristics [6].

The rocks are made of minerals said essential, that serve to classify the type of rock; other minerals may be present, in the alternative, and are said to Accessories or varieties. Among these there are those that can decompose before environmental conditions, or microclimate, these unfavorable and, as a consequence, produce stains. Example of these components are the iron sulfides (pyrite, pyrrhotite and chalcopyrite) that can be present in common granites, metamorphic limestones and marbles; grenades in the dry white granites (albitites), nodules of clay black granites (diabases) and hypersthene in green granites (charnockites). There has been registered recently, several cases of staining orange or reddish colouration, granites and marbles, probably due to oxidation of pyrites of extremely small granulation (Fig. 5).



Fig. 5. Granite showing stains. Probable cause: oxidation of pyrites.

One of the features of the stone is the possibility of this present reasonably intense cracking and whether due to physical weathering, occurred in the mine, is in the process of tilling or in sawdust. The case is registered to some Granites,

which, due to low aptitude to polishing, due to this type of change, do not present a closing effective in polishing. To seek to achieve the desired degree of polishing, promotes an excessive mechanical request which leads to damage in the plot surface plate mineralogical of imperceptible to the naked eye, initially manifests itself after a few months or years, through the occurrence of shedding of crystals or emergence of roughness on the surface.

Another intrinsic property to the stones is its ability to absorb water, which is of value greater than 0.4 % [7], may facilitate the staining mainly when fixing the stones is performed with conventional mortar. On the other hand the stone coloring itself, given by its mineralogical constitution, can highlight the spots in greater or lesser intensity. The white and gray granites and quartzites, for example, provide greater contrast resulting from indelible stains or moisture (which can disappear when the water evaporation) than brown and red granites, even though the water absorption capacity is similar.

The water of kneading, when in excess, associated with excessive porosity of stone can cause stains on the surface of the coating immediately after the setting (Fig. 6).

Stains can also occur by liquid absorption from the external.

"The alteration of a rock is their breakdown and decomposition by natural physical and chemical agents, which turn this rock into another natural product, now in physico-chemical balance with the environment." [8]

The flexural strength affects the sizing criteria of plate (thickness/area relationship) if not comply can lead to these may not support actions that shall be subject, such as, support deslocations, so that it crack.

One of the undesirable features of rocks is a high water absorption capacity, which will lead to pathological manifestations after interaction with the mortars and with agents-degrading environment. This property can be connected to a high degree of mineralogical and microcracking change. The degree of change, even if initially low, may, however, evolve, if environmental and micro environmental conditions and very unfavourable acting on the plates. In this case the degree of microcracking also could increase and generate fractures. As a result, there will be decline in their physical and mechanical resistance and reducing the service life of the coating. The high degree of absorption can also create conditions for installation of fungi and other biological or microbiological organisms.

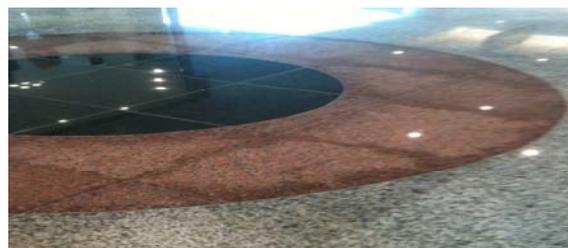


Fig. 6. Occurrence of stains on granite. Possible causes: water-absorption of settlement and mortar or washing water surface.

Other undesirable characteristic for the good condition of the coatings is the presence of harmful minerals which, under environmental conditions and aggressive micro

environmental, may change causing stains due to own products of its amendment or by providing the occurrence of efflorescence on the surface of the plates, regardless of those that may arise from the joints. Staining for mineralogical alteration or by efflorescence have, unfortunately, significant negative effect on the aesthetic finish shown in Fig. 7 a floor.



Fig. 7. Manifestation of mineralogical alteration of stone and occurrence of efflorescence. floor of the foyer building located at 3a. avenue, lined with granite coffee Bahia.

Above all these factors are, however, the physico-chemical properties of the rock itself of which the plates originated, because if the rock is carbonate in nature, such as marbles and limestones, their solubility to natural and artificial products of acid character will be much bigger and much more harmful effects than if the rock is silicatica in nature, as granite. These features when associated with an inadequate settlement process, also cause staining and degradation of the coating.

It has to be pointed out, that external facing must meet different needs other than aesthetic, and different surface textural finishes may affect the properties of cladding stone. For example a simple polish finishing on granite can reduce the strength of the stone by up to 7 % [9] and certainly affects strength increasing porosity and water absorption.

V. PRODUCTION PROCEDURE-RELATED PATHOLOGIES

The production process-related pathologies were related in this text, however it is necessary to emphasize that all stages of the production process of these coatings are important to the end result expected. Fig. 8 illustrates the staining of a rock caused probably by the oxidation of grit used for sawing of boards. In one of the stages of the production process of these coatings an important aspect that should be remembered is that despite the Rocky materials present apparent feature of durability, they should not be stocked in the open and inappropriately as shown in Fig. 9 Characteristics of porosity and permeability and its geometry after the artificial shaping, provide superior requests when subjected breaks its resistance or staining when in contact with other materials, such as wood resin-coated, normally used for the execution of reinforced concrete molds or even by the chemical action of aggressive agents present in the atmosphere. Therefore, the transport and storage of the materials require specific care, aiming to prevent possible damage and decay, because its cost is significant in the total workforce.

Direct or adhered fixing systems consisting on cement bonding the entire back slab's surface has several drawbacks. Differential displacements and deformations under the same action between the slab's bed, the joint and the slab itself if

prevented are the main causes for the well-known malfunctions and failures [10].

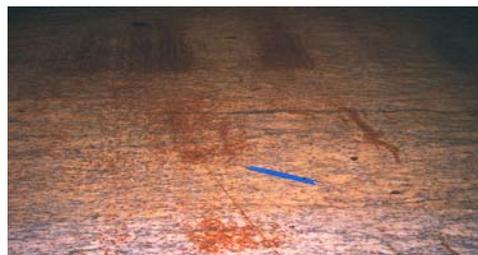


Fig. 8. Rocky plate staining. probable cause: grit oxidation used in step of sawdust.



Fig. 9. Rocky material inadequate storage in construction site. may cause permanent staining before and or after placement.

VI. FINAL CONSIDERATIONS

When the characteristics and properties of the materials used in cladding stone are duly considered by the designers and builders, always associated with the implementation process chosen and properly suited for rock, finishes will present better performance and greater durability.

The usage and maintenance step is a step of great importance to increase the durability of coatings and retain their original aesthetic effect, which unfortunately is neglected. This step is not normally considered in projects of coatings with rocky materials. It has been observed that many pathological manifestations occurring in this step due mostly to the lack of users of which procedures and products should be adopted for the maintenance and upkeep of the initial aesthetic effect of cladding stone.

Given the importance of this step is the responsibility of the designers envisage in cladding stone projects often to do periodic inspections and what products and procedures should be adopted.

Given the complexity of the subject area, it is believed that the survey and analysis of pathological manifestations present in the cladding stone of buildings and urban works, are of great importance to the improvement and for better understanding of the behavior of these coatings, serving also for the feedback loop design step.

REFERENCES

- [1] R. Righi and L. G. R. Castro, *The Construction Real Estate Development Product of Contemporary Architecture in São Paulo*, in duarte, Cristiane Rose et al. (Org.) *The place of design in teaching and research in architecture and urbanism*, Against the cover and Proarq UFRJ, 2007.
- [2] E. Flain, "Production technology of cladding of buildings with dimension stone," PhD. dissertation, Dept. Civil Eng., University of Sao Paulo, SP, 1995.
- [3] E. B. Frazão and L. G. Caruso, "Maintenance in cladding stone," in *Proc. National Symposium on Contruction Technology*, 1989, pp. 89-99.

- [4] L. Nogami, "Research of the influence of the petrographic characteristics and the roughness of" granite and marble "fixed with mortar," Thesis (PhD), School of engineering of São Carlos, University of Sao Paulo, 2013.
- [5] K. V. F. Grillo, "Comparative analysis of rocky type grip seated with three mortars," Dissertation Master, School of engineering of Sao Carlos, Sao Paulo University, 2010.
- [6] E. Frazão and J. Farjallat, "Selecting stones for coatings and properties required," *Rochas de Qualidade*, no. 124, pp. 80-94, 1995.
- [7] E. Frazão and J. Farjallat, "Technological characteristics of Brazilian silictaicas flooring rocks: proposal for setting of brasileira specification," *Rochas de Qualidade*, no. 128, pp. 80-94, 1996.
- [8] L. A. Barros, "Alteration and alterabilidade of rocks," National Institute of Scientific Research, Lisboa: University Technique of Lisbon, 1991.
- [9] R. S. Camposinhos and R. P. A. Camposinhos, "Dimension-stone cladding design with dowell anchorage," *Constr Mater*, vol. 162, no. 3, pp. 95-104, 2009.
- [10] R. S. Camposinhos, *Stone Cladding Engineering*, London: Springer, 2014, ch. 1, pp. 1-8.



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