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Influence of the commercial finishes of ornamental granites on roughness, colour and reflectance

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HIGHLIGHTS

- Four commercial finishes in two granites were aesthetically characterized.
- Finer grained granitic stones show more difficulties to achieve the desired roughness.
- Lightness and reflectance intensity directly depends on the superficial roughness.

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ABSTRACT

The effects of the four common commercial finishes (polished, honed, disc cutting and bush hammering) on several properties of ornamental granites were evaluated. Two granites of different texture, widely used as ornamental stones in NW Iberian Peninsula, were selected. Roughness, colour and reflectance (properties used as cleaning indicators of cultural heritage objects) of the surfaces subjected to each finish were characterized and the correlations among these parameters were obtained.

The results show that the roughness generated by disk cutting and polishing is higher in Vilachán than in Rosa Porriño, showing that the finer the grain size, the higher the roughness generated. The lightness parameter (L^*) in CIELAB space is dependent on the roughness of the surface. The rest of the colour parameters (a^*, b^*, C^*_{ab} and h_{ab}) does not depend on roughness and they are related mostly with the colour of the surface by itself. Reflectance features are not affected by the different content of forming minerals and superficial colour which condition the reflectance intensity of each commercial finish. Reflectance is directly related with the roughness of the granite; the rougher the surface the higher the reflectance intensity. In addition, the lightness L^* and the reflectance are directly related while the other colour parameters do not show any relation with the reflectance.

These results can be used as an aesthetical criteria in order to standardize an objective methodology to evaluate the cleaning effectiveness in the conservation of cultural heritage objects.

1. Introduction

In cultural heritage constructed with stones, the interaction between rock materials, the environment and other building materials originates the formation, among other forms of alteration, of patinas and superficial crusts [1–3]. These patinas and crusts (together with graffiti paintings as vandalism) are removed by different cleaning procedures which must be carefully controlled to preserve the characteristics of the stone. In order to evaluate the efficiency of different cleaning procedures it is important to know the characteristics of the original stone free of deposit or coatings. Then, the general effectiveness can be obtained taking into account, not only the degree of extraction, but also the modifications that the cleaning procedures by themselves could induce on the original surface. Among the most important parameters to be considered in the evaluation of the cleaning there are the colour and the roughness of the stone surface [2,4–7]. Recently, it has been demonstrated that the differences in reflectance spectra of cleaned granite surfaces with respect to surfaces without any kind of deposit [8–11] can be used to obtain a quantitative index of the cleaning level. Reflectance measurement were also used to evaluate the bio-cleaning with different lipases of acrylic marker pen inks from unglazed ceramic substrates [12].

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Granites are the main construction materials of cultural heritage in NW Iberian Peninsula. Despite their low porosity, granites have a sufficient capillary absorption coefficient to be bio-receptive [13]. For this reason, it is usual, in a temperate humid climate as that of the NW Iberian Peninsula, to find the surfaces of buildings built with granite affected by biogenic patinas (green algae and cyanobacteria – [[14 and references therein]). Likewise, although less receptive to the deposition of SO_2 than carbonate rocks, sulphated black crust is also reported in granite [15,16]. So, biogenic patinas, black crusts, together with graffiti (considered as vandalism) are therefore the usual causes of the cleaning interventions in the granitic heritage of NW Iberian Peninsula. On the other hand, the low porosity and the grained texture of granites make this rock to admit different superficial finishes (e.g. polished, honed, disc cutting and bush hammering) that increase its demand in the stone market. However, it has been reported that these different finishes affect to the colour, gloss and roughness of the stone [17]. Owing that some of these parameters are used to evaluate the cleaning effectiveness, it is of great interest to study the influence of different finishes on the superficial properties of the granite, particularly colour, roughness and reflectance. Besides, the knowledge of the relationship between the superficial properties for each finish could provide a standardized information for characterizing the granite finishes, which will be useful in the field of conservation and restoration of cultural heritage. In this sense, studies focused on this topic can be found in the literature, but mainly concerned the relationship between roughness and colour of the stone [17]. However, to the best of our knowledge, there is not any research on the relation between reflectance of the stone surface and its colour or roughness.

Some researchers working on more homogeneous substrates than granite, both in composition and colour (painting mock-ups or coloured metal), found that colour becomes lighter and less saturated when the surface becomes rougher [18,19]. This effect is more remarkable for darker or more saturated colour [18]. L^* coordinate was very sensitive to surface roughness in the specular component-excluded (SCE) measurement configuration, whereas it presented almost no change in the specular component-included (SCI) mode [20,21]. Relationships between a^* and b^* colour parameters and roughness differed regarding the substrate; also, a^* and b^* seemed to be more sensitive against roughness changes under the SCE measurement mode [20,21]. Chroma (C^*_{ab}) is much more sensitive to changes in roughness than hue (h_{ab}) following [18,20]. In the case of granites, differences in colour, especially in the lightness parameter (L^*), were reported for the same granite with different surface finishes [17]; however, no relationship was found between the roughness and the global colour change (ΔE^*_{ab}). In the same study and in agreement with [18], changes in colour related to roughness modifications are higher in stones with lowest L^* values [17].

Regarding the influence of roughness and colour on reflectance, only a work centred on commercial welding mask glass was found [21]. In this work, a direct relation between roughness and reflectance was reported measuring with SCE mode; the sensitivity of reflectance to increases in roughness when measuring in the SCI mode was, however, not so high. However, there are works that relate roughness with the capacity of a surface to reflect more light in directions close to the specular than in others, i.e., gloss [22]. Therefore, agreeing with works on materials different to granite [23,24], Sanmartín et al. [17] found an inverse relationship between gloss and roughness in granite; this relationship was only found for surfaces that are not too rough (Ra < 5 μm) because, if the roughness is very high, gloss seemed more sensitive to colour of the surface. Therefore, the authors advise the need to consider the mineral composition (which determines the colour of granite) when evaluating the relationship between roughness and reflectance. In this context, characterized by the absence of works about the relationship between reflectance and roughness in ornamental stones, it is undoubted that the roughness would generate a deviation (scattering) around the mean angle of reflectance. A surface with zero roughness would only show specular reflectance, appearing glossy. Conversely, for a surface with certain roughness, the light would be reflected in all directions and the intensity of this reflection would depend on the angle between the surface normal and the illuminant (Lambert's law) [25]. Therefore, specular reflectance depends only on superficial roughness while diffuse reflectance also depends on the crystals orientation or particles disposition on the surface [21].

In the current study, the relationship between the roughness, the colour measured in the CIELAB and CIELCH spaces and the reflectance of four different commercial finishes of two commonly used granites from NW Iberian Peninsula were performed. Roughness was characterized by means of confocal microscopy and scanning electron microscopy. The colour of each surface was measured in CIELAB and CIELCH colour spaces and the total reflectance was measured by a hyperspectral camera.

2. Materials and methods

2.1. Rocks and surfaces finishes

Two commercial quality ornamental granitic rocks quarried on the NW Iberian Peninsula were selected, called Vilachán and Rosa Porriño. Vilachán is a fine-grained panallotriomorphic heterogranular granite [26]. The modal analysis obtained under petrographic microscope, following [27] is: quartz (47%), K- feldspar (10%), plagioclase (15%), biotite (7%), muscovite (18%) and mineral accessories (3%). The grain sizes of the different minerals range between 2 mm and 0.3 mm. Water accessible porosity following [28] is 2.82%. Rosa Porriño is a two-mica coarse-grained granite with a panallotriomorphic heterogranular texture [26]. The mineralogical composition is quartz (40%), K- feldspar (27%), plagioclase (14%), biotite (8%), chlorite (4%), muscovite (2%) and mineral accessories (5%) following [27]. Grain sizes range through 10 mm (K-feldspar grains), 3.8–1.2 mm (quartz grains) and 2.0–0.3 mm (biotite grains). Water accessible porosity following [28] is 0.84%.

For both granite samples, four of the most common commercial finishes were used: polished, honed, disc cutting and bush hammering (Fig. 1). For each granite and finish, one slab of 10 cm × 10 cm × 2 cm was used. Polishing is the finishing process by which the surface is abraded by successively finer particles in order to obtain a flatty and glossy surface. By honing, a surface very similar to polished one is obtained, but without gloss. By means of this method, coarser particle size particles than in polishing are used, in order to obtain a matte surface. Disc cutting is a finish resulting from cutting the granite with steel sheets or diamond disks; it constitutes the finish on which the rest of the surface finishes is usually applied. The appearance of disc cutting finish is matte and rough. Bush hammering is carried out by beating the stone with a bush hammer, producing a homogeneous roughness. The hammer used was designed by a peak-valley high of 4 mm and a peak width of 8 mm.

2.2. Analytical techniques

2.2.1. Roughness characterization

The roughness of each 10 cm × 10 cm × 2 cm-slab with different finishes was quantitatively characterized with a confocal microscope (PLu 2300 Sensofar®). For each sample, six extended profiles of 8 mm with 10× and 2.5× objectives were performed in order to obtain the roughness parameters following [29]: Ra