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Weathering detection of granite from three asynchronous historical quarries of Sabrosa municipally (North Portugal)

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Abstract

Vale das Gatas granite is the main traditional building granite of Sabrosa municipality (North of Portugal). It is a two-mica granite porphyroid of coarse-medium crystal-size, characterised by the presence of pseudo-oriented phenocrystals of feldspars.

Quarries deepen as extraction techniques evolve over time. They were shallow in the Iron Age, and the granite extracted from them is more weathered and has more developed exfoliation microcracks than the one extracted from medieval quarries, when new techniques allowed the extraction of deeper and fresher granites. Current quarries can go tens of meters deep and produce fresh granite, which is less weathered and has exfoliation microcracks that are less developed.

Prehistoric, medieval and current quarries of the Vale das Gatas granite exist in Sabrosa municipality. Therefore, a great variety of monuments have been built with the same granite but with different weathering degrees. Replacement granite must have the same weathering degree as the original granite present in the monument to avoid different responses to the same decay agent.

Different weathering degrees of Vale das Gatas granite were assessed by non-destructive techniques to correlate their physical properties with the weathering degree. Thus, in addition to a microscopic study, density, porosity, capillary water uptake, colour, ultrasonic pulse velocity and thermal properties were determined. These properties allowed determining the weathering degree of Vale das Gatas granite and correlating it with the original historical quarries. In this way, replacement granites can be obtained for future restorations.

Introduction

Natural stones are essential building materials, and they make up much of the world's cultural heritage that has marked the history of humankind [1], [2], [3]. Granite is the most-used stone in Galicia-North of Portugal for historical constructions due to its great durability [4], [5], [6], [7].

The municipality of Sabrosa (North of Portugal) (Fig.1), is integrated in the first demarcated and regulated wine-making region of the world, the Douro Demarcated Region, which has a vast cultural, architectural and archaeological heritage that covers, essentially, almost all historical periods [8,9]. It was already inhabited in recent prehistoric times by humans, who constructed granite megalithic monuments such as the Madorras dolmen [10], and the megalithic schist monuments in the south of the municipality: Plainas da Mantelinha, Devesas, Cerro do Carvalhal, Meieira, Cerro das Devesas and Alto das Roseiras dolmens, among others. This municipality has a vast Iron-Age heritage in Sabrosa and surrounding areas. Some examples of Roman-period built heritage are the roman site of Quinta da Relva, with an associated Roman necropolis, in Provesende; and the Medieval Necropolis of Touças, in the village of Garganta, in São Martinho de Anta.

The municipality also has a vast built heritage associated with the secular clergy, especially from the 13th and 16th centuries, for example, Senhora da Veiga Chapel [11], in the medieval village of Roalde, and São Lourenço de Ribapinhão Church. It is also worth mentioning a vast architectural heritage, built mainly between the 18th and 19th centuries, related to the production and trade of wine. These are manor houses and emblazoned houses such as Solar do Morgado in Gouvinhas, and manor houses and emblazoned houses in the north of the Municipality: Solar dos Pizarro de Carvalho e Melo, Barros House, Fernão de Magalhães House and da Quinta Chapel, among others. Vale das Gatas granite was also used in many other monuments outside of Sabrosa municipality, such as Roman temples (Sanctuary of Panoias archaeological site) and Romanesque churches. Therefore, all these monuments are built with different weathering degrees of Vale das Gatas granite and it is necessary to identify parameters that quantify its weathering degree.

The conservation of heritage stones involves the study of their historical quarries and their characterisation with petrographic and petrophysical techniques, which allow scientists to establish the weathering degree and durability of building stones [12], [13], [14]. The oldest quarries were shallow because the stonemasons lacked specialised tools, and granite with significant weathering was extracted from them. Today's deeper granite quarries allow the extraction of fresher and therefore less altered granite [15]. The properties of a granite differ according to its weathering degree. In this way, the granites used in historical monuments generally have a more yellowish colour, greater porosity and lower density than the granites used in modern buildings. Therefore, petrographic and petrophysical properties of building granite are an indicator of weathering degree and durability [16], [17], [18].

As all crystalline stones, building granite present in monuments and buildings is sensitive to the effects of temperature due to its low porosity and its mineral heterogeneity that lead to a differential thermal expansion [19], [20], [21], [22], [23] and the generation of irreversible microcracks beyond a certain temperature threshold [24], [25], [26], [27]. In addition, for fresh and low porosity granites, textural features such as quartz/feldspar ratio, mineral orientation, and crystal-size determine its behaviour [28], [29], [30], [31], [32]. The repetition of cyclic variations such as day-night, seasons or thermal shock during summer storms over the years and centuries, produce decay in the form of microcracks, with different intensity depending on the time and conditions of environmental exposure.

New techniques are being developed for the study of stone ashlars thermal response that can be applied in situ, such as infrared thermography (IRT). The natural cooling of a stone is related to its thermal properties [33] and can be expressed by the cooling rate index (CRI) [34]. This index can correlate the porosity and the cooling speed of stones. The CRI decreases with increasing porosity because the lower diffusivity of the air relative to that of a solid [33, 35]. In addition, for lower porosity stones, mineralogy also plays an important role in the CRI [36, 37]. Each mineral has different thermal properties that can be detected by IRT. In addition, some properties such as thermal expansion may lead to differences between internal and external behaviour of ashlars. This technique allows also to detect notable porosity variations given by the thermal behaviour of the ashlar faces, which may reflect the changes in the bulk microstructure. Thermal stresses distributed in granites induce tensile stresses in a thin region near the ashlar face,

producing microcracking, and compressive stresses in a large area in the middle, producing healing or closing of microcracks [37].

Section snippets

Research aims

The aim of this study is to assess the petrophysical properties of Vale das Gatas granite on three asynchronous historical quarries of Sabrosa municipality, North of Portugal. In addition, these three weathering degrees of Vale das Gatas granite were subjected to infrared thermography to determine the cooling rate index (CRI). The methods used, and data obtained are useful for heritage conservation purposes. The characterisation of Vale das Gatas granite weathering degree in each historical…

Sampling

Vale das Gatas granite outcrops in the municipality of Sabrosa (Portugal). It is a two-mica granite porphyroid of coarse-medium crystal-size, characterised by the presence of elongated and oriented feldspars. Countless historical Vale das Gatas granite quarries exist in North Sabrosa municipality. These quarries are usually shallow, and their granite is frequently weathered, which produces a yellowish colour due to the oxidation of its minerals, especially of those containing Fe. Fieldwork was…

Petrographic microscopy (PM)

Vale das Gatas granite is a coarse-medium crystal-size granite with elongated pseudo-oriented phenocrystals of feldspars. It shows a typical inequigranular porphyroid texture, in which larger crystals (feldspars) are surrounded by a phaneritic matrix of smaller crystal-size. It consists mainly of intermediate composition plagioclase associated with orthoclase, microcline and quartz. The K-feldspar (K-Fsp) are euhedral. The feldspar is orthoclase (≈10-40mm) with perthite textures.

Laminar…

Discussion

Many properties such as colour, mineralogy, texture, porosity and capillarity characterise a granite and therefore, its weathering degree [38], [39], [40]. The Neolithic quarries of Sabrosa municipality are shallow and therefore the exfoliation fractures are more developed. VG3 presents a marked difference in all properties compared to VG1 and VG2, as can be seen in Figs.5, 6 and Table2. This is because the exposure time of VG3 to atmospheric agents is much longer than VG1 and VG2.

Colour…

Conclusions

Vale das Gatas granite is a two-mica coarse-medium crystal-size granite with elongated pseudo-oriented feldspars.

There are numerous monuments in Sabrosa and surrounding areas (North Portugal) built with different weathering degrees of Vale das Gatas granite.

Vale das Gatas granite quarries present extremely relevant evidence for the understanding of the use of quarries throughout the human occupation of Trás-os-Montes e Alto Douro region.

Granites mined in prehistoric times are much more…

Acknowledgements

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…Mineralogy: Each mineral has different thermal properties and thus different diffusivity. For low porosity stones, CRI is also affected by mineralogy [27,29]. Table 4 shows the thermal properties of each mineral extracted from literature.…

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