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Water-stone interaction in contemporary works of the built environment

Carlos Alves[a,1], Carlos Figueiredo[b], António Maurício[b]

[a]*LandS/Lab2PT (UID/AUR/04509/2013; POCI-01-0145-FEDER-007528) and School of Sciences, University of Minho, Portugal*
[b]*CERENA - Centro de Recursos Naturais e Ambiente (UID/ECI/04028/2013), Instituto Superior Técnico, University of Lisbon, Portugal*

Abstract

It is presented an overview of observations of features related to water-stone interactions in contemporary works of the built environment at several Portuguese locations, aiming to assess their relative importance and discuss their relation to engineering and architectural options.

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Keywords: geologic materials, alteration processes, built environment, natural stone

1. Introduction

Stones used in the built environment are exposed to several alterations processes[1] promoted by meteoric water (in the usual sense of water with an atmospheric origin). In that sense, water-rock interaction studies can be extended to the built environment to understand the susceptibility of building materials under their onsite application conditions. But this extension needs to consider specific conditions related to engineering and architectural options. This perspective concerns diverse kind of works, from major public engineering works to domestic environments. In this context, there is interest in understanding processes related to water related alteration processes as their impact could be addressed through moisture management. In the built environment, even situations where water-rock interaction is mostly limited to stone surface (as biological colonization and surface deposition) can have an important visual impact with deleterious effects.

In this work, based on our experience, we attempt a synthesis of observed features related to water-stone interaction in the built environment considering their implications in relation to processes characterization (since they allow the observation of the earlier stages) but also in terms of architectural and engineering options for new

* Corresponding author. Tel.: 351253604300.
E-mail address: casaix@dct.uminho.pt

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and old constructions. While our focus (and our experience) concerns mainly natural stone, the features considered extend to other inorganic porous materials such as mortar and the processes can affect other materials, such as paints, as well.

2. Materials and methods

The results discussed below were obtained by macroscopic field observations in contemporary built works of diverse towns of Portugal. One can consider diverse types of products of the interaction of meteoric water with building materials and detailed proposals and discussions can be found in[2] and references therein. However, in this publication, we will consider two main groups: i) stains (a term used here in a very wide sense for transformation features where the loss of matter is negligible and there could be even addition of matter); ii) erosive features (with loss of material). Occasionally, field macroscopic observations were complemented by laboratory studies by scanning electron microscopy for textural observations and identification of neoformations.

3. Stains

As referred to above, the term stains will be used for alteration features that do not mark significant loss of material (but the processes that caused the stains can contribute to erosive processes). Stains related to biological colonization and soiling (one is going to consider them together as it is not always easy to tell them apart macroscopically) are generalized in outdoor situations and can affect all kind of built elements. They can occur on different substrates, even on rocks with very low porosity such as grayish unweathered granite (Fig. 1a), depending mostly on the moisture conditions. Sometimes biostains show very heterogeneous distributions related to moisture zones as joints between stones or to specific architectural details (Fig. 1b) while other times can have a widespread distribution on surfaces such as whole portions of north façades. Hence, these stains show patterns related to moisture presence and can be used the other way around, as markers of moisture conditions. The visual degradation impact can be considered to be higher on light colored stones (being more conspicuous). Moisture stains are observed in stones with an impermeable surface and their distinction in relation to soiling is not always easy. Carbonate stains are not as generalized as biological colonization, since they seem to be related to more specific circumstances of water-materials (cement) interaction[3], but, nonetheless, they are very frequent on different kinds of contemporary works and could be found also in sheltered sites such as underground subway stations[4] and parking lots. As they are related to precipitation from flowing solutions, they can also be considered markers of the pathways of those solutions and evidences of masonry defects[4] and they tend to occur associated with solutions pathways such as joints or fissures (Fig. 1c). However, there are also carbonate deposits on large areas as for example in stairs, showing flooding-like distributions. There are observations[3] that point to a recurrent process of formation, at least in some instances, indicating a possible persistent source that is still active (and not limited to the initial instances of mortar application). Their visual impact could depend on the colour of the affected materials as they are more conspicuous when occurring over darkish materials. While their effect on the stones is one of staining and coating, we admit that the processes in their genesis could contribute to loss of pieces as seen in Fig. 1d. Salt efflorescences are related to water mobilization of salts and their crystallization by drying. Hence they tend to occur on sheltered locations that avoid the effects of leaching. They are very frequent in situations of painted walls where there is water infiltration and, in that situation, they can cause marked paint erosion (Fig. 1e) and even affect the mortar. They can be observed also in other locations such as staircase landings (Fig. 1f) to bathroom floors (Fig. 1g). In these constructions efflorescences, alkaline salts (in the sense, usually used in the Earth Sciences, of compound of an alkaline metal), mostly sodium sulfate, are dominant but other salts such as alkaline nitrates and calcium and magnesium sulfates have also been found[5]. It has been referred that alkaline soluble salts can promote limestone staining[6] and darkish stains have been observed in association with soluble salts. There are other, rarer, stains such as those related to sulfide oxidation (Fig. 1h) linked to a specific rock characteristic (they might be associated with some localized erosive effect, but it must be noted that, in at least one case, soluble sulfates have been identified associated with these stains[7]). There are also some instances of stains related to metals alteration products over stone surfaces. Other extremely rarer occurrences concern gypsum-rich black crusts[5] (which seem to highlight the