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Original article

State-of-the-art on methods for reducing rising damp in masonry

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ABSTRACT

Several materials and technologies have been proposed over last century to fight the capillary rise of water from ground in historic masonry buildings. These methods involve different operational principles and different strategies to cope with rising damp, which is one of the most critical problems in the conservation of architectural heritage. However, despite the extensive use of these technologies in historic buildings, the data about their actual effectiveness in the field are still quite limited and the reasons for their success or failure in real masonries have not been fully elucidated yet. This paper provides an overview of the technologies for the removal of rising damp and a state-of-the-art on the results so far obtained by research, both in laboratory and on-site.

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1. Introduction

Rising damp is one of the main problems affecting historic masonry buildings, as it leads to severe consequences, in terms of both bad indoor conditions (high air relative humidity) and materials deterioration [1]. In particular, the presence of moisture in materials' pores, in combination with other environmental factors, may lead to biological attack, salt crystallization, chemical attack, swelling in clay bearing stones, frost damage, etc., finally causing materials loss and even structural problems [2].

The phenomenon of rising damp is very common in ancient buildings due to the presence of water in the ground in the proximity of the masonry and it has been studied long since [3]. The damp occurrence is due to the absence of waterproofing sheets and/or to the fact that traditional "water proofing systems" (e.g., blocks of very compact stones in the course near the ground) could be not sufficient. In a vertical capillary tube immersed at its bottom in a water basin, the rise of water is caused by the capillary forces arising between water and solid surface, due to the high wettability of solid surfaces (low contact angle water/solid), which is verified in the case of hydrophilic materials. In this simple case, the height of water rise (h) can be calculated by the Jurin's law: $h = 2\tau \sin\theta / r\rho g$, where τ is the surface tension of water, θ is the contact angle water/solid, r is the radius of the capillary tube, ρ is the density of water and g is the gravity acceleration.

Bricks, mortars and stones are porous, hydrophilic and hence highly sorptive, thus the driving force making water rise in masonry is capillarity, as in the example described above. However, differently from the case of a capillary tube, masonry is also subject to water evaporation through the internal and external surfaces and this difference makes the phenomenon of rising damp a dynamic rather than a static one [4] (Fig. 1a). In fact, a continuous water flow from ground is present in walls and the maximum height reached by damp is controlled by the relative 'weight' of the three factors involved: water supply from ground, water evaporation and, obviously, characteristics of the building materials (amount and size of pores, pores connectivity and tortuosity, etc.) (Fig. 1b). Modifications of one or more of these three factors result in a different height of rise. Where water supply is abundant, materials are very porous and evaporation is completely inhibited, rising damp may reach impressive heights, as in the case of St. Mark basilica in Venice [5].

2. Aim of the paper

Over approximately last century, the damp-proofing of buildings has become much more efficient and the general expectations about indoor comfort changed. High levels of moisture in walls are considered unacceptable and many repair systems have been proposed for coping with rising damp. However, despite the widespread use of these systems and their application in numerous buildings all over the world, we are far from a deep understanding of their functioning in real masonry and even of their rate of success or failure [1]. Hence, there is still a strong need of experimental results providing evidences on the functioning, effectiveness and limitations of these repair systems, and also on the reasons for their success or failure on site.

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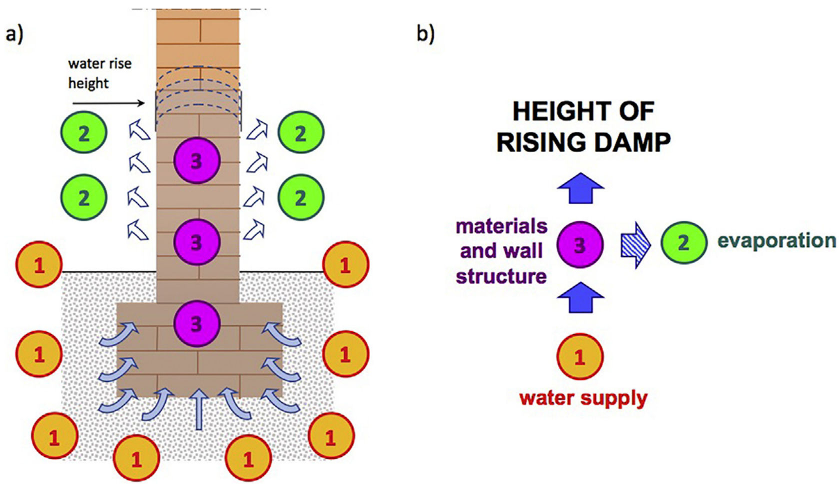

Fig. 1. (a) Dynamics of capillary water rise in a masonry, and (b) schematic representation of the three factors involved, which determine the resulting height of rising damp.

In recent years, coordinated efforts have been made towards this aim, through literature reviews [1,6–8], structured databases [9] and European projects [10].

In this paper, a brief state-of-the-art on the systems for the mitigation of rising damp in masonry is provided, as a contribution towards a better understanding of such systems.

3. Literature survey

In this work, a review of international papers concerning the repair of rising damp in masonry was carried out. These papers include papers published in international journals (both peer-reviewed and not; both available on-line and not), book chapters and contributions in conference proceedings. The scientific literature produced up to 2017 was considered.

A total of 65 papers was found, and their distribution over years is reported in Fig. 2. It can be clearly observed that the literature on this subject is concentrated mostly after 2005 and that year 2017 suggests a pronounced growth of interest.

Within these 65 papers, a distinction was made among: the literature review papers, the papers recommending one or more repair systems (with no experimental results) and the papers presenting experimental results found in laboratory studies and/or on-site surveys. In Fig. 3, the results are shown and some remarks can be done. Firstly, the number of scientific papers (46) is relatively small in proportion to the impact of rising damp in historic buildings and the number of repair systems that have been proposed during the last decades, and this suggests that more scientific investigations are needed. Secondly, the number of papers in which repair systems are recommended without providing any experimental evidence or results about their effectiveness (13) is very high in comparison to scientific papers and this surely feeds some confusion in this field. In fact, in these papers the authors state that the relevant systems are effective, also providing examples of buildings in which they were applied, but the statements are not supported by any quantitative data or result. By the way, the present literature survey was not specifically addressed to 'recommendation' papers, hence they were found unintentionally among the others, which means that their actual number is probably higher, especially in the national literature, not considered here. Finally, the number of literature review [6] is quite high in comparison to scientific papers and this might be a sign of the need of making some clearness in a quite confused field.

In this work, only the papers presenting quantitative results on the effectiveness of the repair systems were considered. These were published mostly in international journals, but to a large extent also in conference proceedings (about one third), as shown in Fig. 4 (left).

Within the 46 scientific papers presenting experimental findings, different research approaches were followed, as shown in

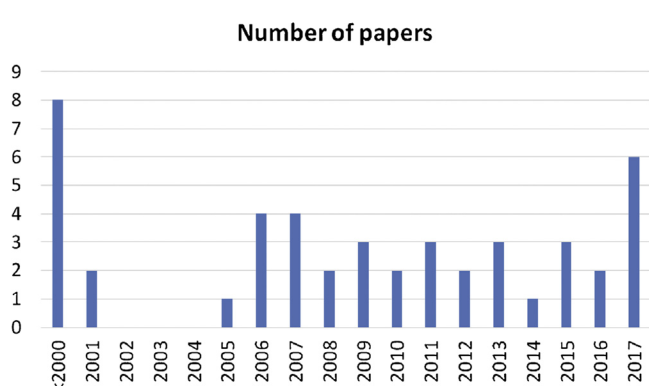

Fig. 2. International papers per year.

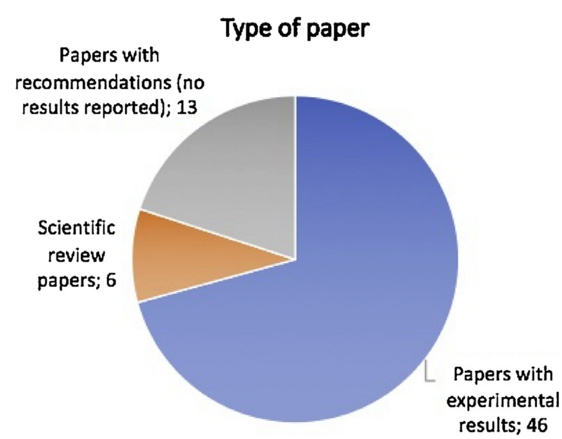

Fig. 3. Number and type of papers found in international literature up to 2017 (included).

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