Construction and Building Materials 54 (2014) 123–136

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Review

Rising damp removal from historical masonries: A still open challenge

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HIGHLIGHTS

- Negative effects of rising damp in historical masonries are examined.
- International scientific papers are reviewed.
- Results obtained through different repair systems are discussed.
- Both laboratory and field experiences are taken into account.
- Open challenges for research are pointed out.

ARTICLE INFO

Article history:
Received 9 October 2013
Received in revised form 9 December 2013
Accepted 17 December 2013
Available online 11 January 2014

Keywords:
Rising damp
Capillarity
Masonry
Dehumidification
Technologies
Building materials

ABSTRACT

Rising damp is one of the main problems affecting historical masonry structures all over the world, as it jeopardises materials integrity, inhabitants' health and performances of the building envelope. Despite the great effort spent over last century to understand water capillary rise phenomenon, the problem of damp removal is still substantially open, as not only the technologies adopted in the field frequently fail, but their working principles in real masonries have not been fully elucidated yet.

This paper aims at providing, through a review of international literature, a coherent picture of the technologies so far proposed for the removal of rising damp and the results obtained, both in laboratory and on-site. Based on the results, the open challenges for research in this field are tentatively pointed out, according to the author's opinion.

Contents

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http://dx.doi.org/10.1016/j.conbuildmat.2013.12.054

1. Introduction and scope

The presence of water in historical brick, stone and earth masonry structures is one of the most prominent problems affecting architectural heritage [1] and, more in general, old buildings. Such presence may be ascribed to different origins: accidental causes (infiltration from roof, pipe leakage, etc.), condensation (both on external surface and inside the wall), wind driven rain [2,3], hygroscopic salts [4], flooding [5,6] and capillary rise from ground (where water is supplied by aquifers under clay soils, underground watercourse [7] or channels [8], agricultural irrigation [9], poor drainage of rainfalls [9], etc.).

Rising damp, in particular, is surely the most widespread phenomenon leading to moisture presence in building structures and it severely threatens both conservation and performance of ancient masonries, as it is responsible for:

a) *Degradation of ancient building materials*
Damp building materials may be exposed to freeze–thaw cycles [10], migration and crystallisation of soluble salts (with efflorescence and/or subflorescence formation) [11], chemical attack in polluted environment [12,13], biological decay [14], wind erosion and alveoilzation [15], clay swelling [16], washout of soluble fractions, corrosion of metallic elements, detachment of paints/tiles/mosaic, etc., with great damage for their integrity.

b) *Unsuitable indoor thermal–hygrometric conditions*
Damp walls lead to high values of indoor air relative humidity and mould growth on cold surfaces, thus causing uncomfortable indoor conditions [17,18] and negatively affecting the air quality and consequently the inhabitants' health. An interesting document about this was provided in 1892 by Kenwood [19], who pointed out that an incredibly large number of diseases were, if not induced, favoured by dampness and he was surprised that this phenomenon was hardly taken into account by medical community. In 1989 the absence of damp in building masonries was expressly included among the essential requirements for hygiene and health purposes according to the European "Construction Products Directive" (Annex I of Directive 89/106/EEC, now replaced by 305/2011) and it is considered as important as the requirements concerning mechanical resistance/stability and safety in case of fire.

c) *Poor thermal insulation efficiency of the external walls*
The presence of water within building material pores negatively affects their thermal insulation performance: a 1 wt% increase in moisture content is estimated to cause an increase up to 5% in the thermal conductivity of masonry [20], hence porous bricks and stones may experience an increase up to 100% in thermal conductivity due to saturation. Such unsuitable thermal transmittance of the damp envelope implies a large energy consumption for heating historical buildings and a large environmental impact.

d) *Decrease in mechanical performance of the masonry*
The presence of water within building material pores negatively affects also their compressive and shear strength [21]. In the walls at the ground floor, where loads are maximum and rising moisture is more intense, this problem is particularly serious and it might worsen the safety of the building in case of earthquake event.

The extensive occurrence of rising damp in old masonries is well known in the construction sector and it was pointed out by many authors. For example, about half of the renovation interventions in Belgium are linked to rising damp and hygroscopic salts and the relevance of this phenomenon is claimed to be fairly the same at a European and international level [22]. The worldwide dimension of the problem in existing buildings and architectural heritage is evident even after a quick glance at international literature [6,9,23–25].

Due to the serious effects connected to rising damp in masonries, water capillary rise is rightly regarded as a key factor in heritage conservation and an extremely high number of literature studies was devoted to investigating the mechanisms of water capillary rise from ground (see, e.g. [26–28]), its harmful effects (see, e.g., [10–16]) and the techniques for measuring moisture in structures (see, e.g., [29]).

Despite this, the removal of rising damp from historical masonries still remains extremely challenging, and the owners of historical buildings, the authorities in charge of their conservation and the conservation practitioners are still short of reliable solutions for the dehumidification of masonries and disoriented in coping with this issue. As a result, current restoration (or simply refurbishing) works are often carried out without any intervention for moisture removal and the materials decay and defects reappear after short time. As a matter of fact, if the main degradation cause is not removed, any intervention on materials is useless and further works will be soon necessary (Fig. 1).

The causes for this surrender towards the control of rising water are different and worth of analysis. On the one hand, solving the

Fig. 1. Persistent problems connected to rising damp in a recently restored part of the Monumental *Certosa* Cemetery in Bologna, Italy (XIX Cent.). Salt-rich moisture evaporates mainly through the most permeable material (sandstone base) leading to stone decay, and also causes the paint detachment.