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Assessment of the effectiveness of a dehumidification system by emission of electromagnetic fields: Proposal of a protocol

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ABSTRACT

In this paper the operation of a dehumidification system has been studied in operating conditions and a protocol for the assessment of its effectiveness is proposed. The physical principle of the used system is based on the interaction of a pulsed electromagnetic field with the masonry materials affected by rising damp phenomena. As it is well known, water has a crucial role in decay mechanisms both by a physical and by a chemical point of view. In fact, soluble salts transport phenomena, biological growth, stress due to expanding clays, freeze–thaw cycles, are among the most diffused examples of decay mechanisms. The target of any dehumidification systems, as the one under analysis, is very ambitious and crucial in the field of cultural heritage conservation; hence starts the authors need in understanding the involved physical mechanisms and in evaluating the effectiveness of these systems. Literature reports laboratory tests carried out with the target to acquire a better knowledge of the interaction mechanism between pulsed electromagnetic field and masonry materials, with and without water presence. Very often laboratory tests are followed by tests on pilot site chosen on purpose. In the example presented in the paper, ground floor masonries belonging to an historical building, with evident rising damp phenomena, was chosen. The building is located at Saltino, Reggello close to Florence, at 995 m asl. The rising of water affects at different levels several rooms of the building at ground floor, but on the north side of the house, the effects are greater. This contribute also proposes preliminary ideas to draw a standard aimed at build up a protocol for the performance assessment of dehumidification systems, based on different physical principles. A full knowledge of physical principles is mandatory to optimize the effectiveness of these systems. The procedure to assess the effectiveness of these systems must be standardized identifying the environmental parameters to be checked in relation to the ones directly measured on the masonry.

1. Introduction

In the last decade many apparatus and systems have been designed as innovative solutions to prevent dampness from capillary rise, without requiring invasive intervention on the masonry. In general, the search for a technology that achieves the maximum of efficiency and long life, combined to the simplicity of installation and use is declared [1].

A great deal of researches was published in scientific literature in the field of applied physics [2], applied chemistry [3], materials engineering [4,5], architectural conservation [6,7]. Nevertheless, the issue is still far from a complete understanding. In fact, the many variables play complex roles, and it is hard to understand – especially on site – if the system applied in order to reduce moisture in masonry, obtained the wanted effects. Working on Cultural Heritage, buildings conservation ethics advise to use not invasive methods. This is the reason because in this paper the authors studied the effectiveness of a system based on an electro-physical method, using multi-frequency pulses [8–11].

2. Material and methods

One of the main targets of this study is in proposing preliminary ideas to draw a standard aimed at build up a protocol for the performance assessment of dehumidification systems based on electromagnetic interaction mechanisms with masonry materials.

The choice to proceed with on site evaluation derived from instructions and prescriptions furnished by the manufacturer, advising their systems are not suitable for laboratory tests. For this reason, a site with evident rising damp problems has been selected.

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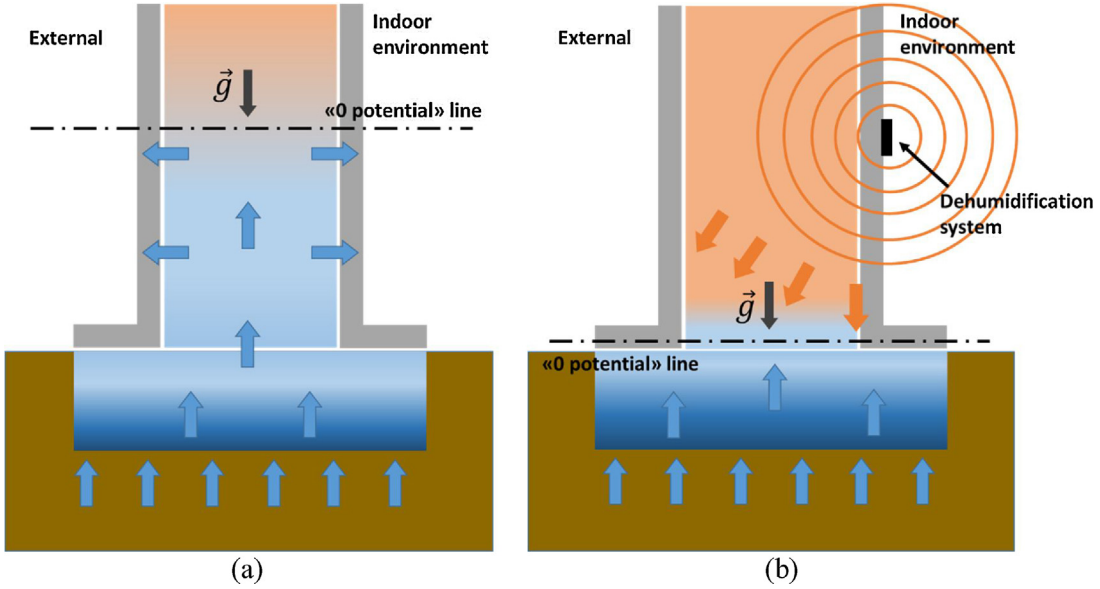

Fig. 1. (a) Basic mechanism of rising damp phenomenon; (b) basic operative principle of the electro-physical dehumidification system.

A historical building located at Saltino Reggello in Vallombrosa, close to Florence, at 995 m asl was chosen. The study focused on masonries at ground floor. The rising of water affects at different levels all the rooms of the building, but on the north side of the house, the effects are greater.

The dehumidification system was installed following the manufacturer specification and its effectiveness was assessed by monitoring for 10 months the following parameters:

- temperature and relative humidity in the indoor locations measured by data logger;
- outdoor temperature and relative humidity provided by Reggello, Vallombrosa weather station[1];
- temperature and moisture content of the masonry measured by temperature and hygrometric probes directly inserted inside the masonry, up to 15–20 cm in depth. Each probe was linked to a data logger (micro-destructive investigation);
- moisture content and salinity index of the masonry determined by Evanescent Field Dielectrometry method (non-destructive investigation).

2.1. Description of the dehumidification system

The system under survey is a masonry electro-physical dehumidification system equipped with multi-frequency pulses technology. The multi-frequency signal generates an electromagnetic field that interacts with water molecules and blocks them from rising. In Fig. 1 the mechanism of the dehumidification system is depicted in its basic principle. Basically, the effect of the generated electromagnetic field shifts the line of "potential 0" below the floor level, avoiding the diffusion of the water molecules in the masonry, and consequentially the evaporation from the plaster.

The line of "potential 0" corresponds to the height above the defined reference level, in this case the ground level, where the capillary forces is balanced form the gravitational force $\vec{g}$. Therefore, the effect of the dehumidification system should be the reducing of capillary forces with the consequent reduction of rising damp.

Differently from other similar systems, based on the effects of a single frequency, systems generating a train of pulses are able to radiate power in a spread frequencies range up to 10^4 Hz; the spectral density will be higher or lower in relation with the rising slope of the pulses front of the generated signal. The manufacturer informs that the growing in the spectral content should improve the efficacy of the system, hence providing excellent results on any kind of masonry, regardless the geometry of the capillary pores and the materials.

The manufacturer declares often the safety of their system in relation to the emission of electromagnetic radiations without any reference respect to National or European Standards. The Italian National Standard that regulates the exposure of population to electromagnetic, electric and magnetic fields is the Decree of the Prime Minister July 8, 2003,[2] while on the European scenario the Directive 2013/35/EU of 26 June 2013[3] and the ICNIRP statement (2010)[4] are valid.

The measurements of the magnetic flux density (B) emitted from the system in study allowed to verify the shape of the emitted signal (pulsed behavior) and the intensity of the emitted field, with relation to the actual Standards. The measurements were performed in the anechoic chamber of CNR-IFAC in Florence (see Fig. 2) by the ELT-400 magnetic field meter (by Narda STS).

The signal registered from the detector is plotted in Fig. 3 at several zooms, so it could be possible to model the interaction mechanism with the water molecules in the porous material. Fig. 4 shows the spectral density of power of the signal emitted from the dehumidification system. The spectral could be neglected under −40 dB, therefore the spectral density is significant up to 10^4 Hz.

In Fig. 5 the compliance of the exposure levels to magnetic flux density are reported versus the distance from the front side of the

[1] Weather station Vallombrosa [TOS01000901] – Reggello (FI); GB [m]: E 1705864, N 4845034; Quota slm [m] 980.00, by Functional Center for meteo-hydro monitoring of the Tuscany Region and LaMMA Consortium (Environmental Modelling and Monitoring Laboratory for Sustainable Development).

[2] Establishing the exposure limits, attention values and quality targets for the protection of the population from exposure to electric and magnetic fields at the network frequency (50 Hz) generated by power lines.

[3] Directive 2013/35/EU of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields).

[4] "ICNIRP statement – guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz)" Health Physics Vol 99 pp. 818–836, 2010.

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