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Treatment of rising damp in historic buildings: Experimental campaign of wall base ventilation and interface effect analysis

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The treatment of rising damp in historical building walls is a very complex procedure. In this work it is presented an extension of the continuous "in situ" results of the rising damp treatment conducted in a Portuguese historical church, using the wall base ventilation technology. The results, registered over four years, clearly reveal the best ventilations periods and indicate that the best solutions must correspond to admit outside air during summer periods and inside air during winter periods. Furthermore, another important aspect was to better understand the difference in absorption behaviour between walls with and without joints when the rising damp treatment is conducted. It also presented an experimental campaign and a critical analysis of water absorption in samples of clay brick with and without joints and joints with different contact configurations (perfect contact, hydraulic continuity and air space between layers). The results showed that when the moisture reaches the interface, the wetting process gets slower due to the interfaces hygric resistance. This resistance was more pronounced for joints with air space between layers and less for joints with hydraulic continuity.

1. Introduction

The treatment of rising damp is a problem difficult to solve and with a great importance in monuments and historical buildings. Since a long time ago, several treatment techniques were developed but not always with the required efficiency [1]. As examples, should be mentioned the following techniques:

- the creating a physical or chemical barrier;
- creating a potential against the capillary potential;
- applying atmospheric drainage;
- applying a coating with controlled porosity;
- concealing the anomalies, etc.

Several systems to control rising damp were also patented [1].

The traditional techniques used to treat rising damp problem showed, in the majority of the cases, ineffective, when applied to historical buildings with large thickness and heterogeneity walls. Based on the acquired knowledge, the LFC group was patented the HUMIVENT device, "Wall Base Ventilation System to Treat Rising Damp" [1], that consists of ventilating the wall base through the installation of a hygro-regulable mechanical ventilation device, that increases the evaporation and a consequent reduction of the level achieved by the damp front.

In addition, masonry is the prevalent solution for constructing building envelopes. While its constituent materials (clay bricks) are reasonably well understood, the hygric behaviour of masonry is often shown to deviate from the normal unsaturated flow theory. In literature, some researchers refer to an imperfect contact and hence an interface resistance in the brick-mortar bond plane [2–4]. In general, a building wall is composed by multiple layers, and this is the main reason to present a study of moisture transfer between layers.

All of these phenomena explain the retarded water uptake found in experimental investigations already performed [2,3]. In literature, several studies concerning the liquid transport in multilayered composites can be found [2–7], however, only a limited number of values for the interface resistance, in multilayered composites, were found [2–4].

2. Objectives of the research

This work could be divided in two parts: in the first part, the authors presents a continuation of the monitoring work previously published [8], with more experimental results to show the importance of the device (the wall-base ventilation system) developed by the research group. In a novel and related second part, the authors

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discuss in detail the analysis of the interface phenomena and its influence in the buildings behaviour. This is an important point for the wall base ventilation systems design described in the first part of this work.

The wall base ventilation system was installed in a historical church, of northern Portugal, and the results registered all along four years were analysed. With "in field" experimental results obtained with the wall base ventilation system technique and a better knowledge about joints influence in the absorption process, it is possible to optimize the HUMIVENT system functioning and designing it considering real multilayer walls.

The different mechanisms of moisture transport in building materials and elements have been investigated by different authors along the years. Although the analysis of the interface phenomena and its influence in the buildings behaviour have been scarcely investigated [2–7] and is an important point for the wall base ventilation systems design.

Based on this breach, it was intended to analyse the interface effect in the capillary process of building materials starting with the clay brick. This is a common material in Portuguese exterior walls, where usually mortar joints are found. In the foremost cases, Portuguese exterior walls are multilayer walls with materials in perfect contact and/or with an air space. In this work, an experimental research using clay brick samples for capillary tests and considering four different cases: monolithic and three interfaces: perfect contact, air space and hydraulic continuity (mortar) [9].

It is well known that moisture and specially rising damp is one of the primary causes for the observed damage on the building envelope [10], so the knowledge of the wall base ventilation system technique potential to the treatment of rising damp in building walls, increases the importance of this research with the goal of controlling the real moisture migration process. In conclusion, the interface effect analysis has two specific important purposes:

- the analysis of clay brick capillarity coefficient without interfaces (monolithic) and with three different interfaces: perfect contact, air space and hydraulic continuity (mortar);
- the calculation of the hydric resistance in the interface which affects the maximum flow transmitted (FLUMAX).

Freitas [2] showed that there is a maximum transmitted flow across the natural contact interface, which assumed that the rate of moisture flow reaching an interface has significant influence on the moisture transport across the interface. This value is an important input in numerical simulations with multilayer building components and is a parameter to be obtained experimentally [11].

3. Materials and methods of the research

3.1. Case study using the wall base ventilation system

The church (century: XII–XVI) is a historical building situated in northern Portugal, and listed as Portuguese national monument, 1910 [8], with heterogeneous and thick walls that presented a high wet front due to rising damp problems, as shown in Fig. 1.

The wall base ventilation system, developed by the Laboratory of Building Physics (LFC), was installed as a hygro-regulated system divided into two subsystems: northern and southern subsystems [1]. These two subsystems with air arrived from the church interior (southern subsystem) or air arrived from the outside (northern subsystem) were described in detail in a previous work [8]. Both outlets were controlled by an individual hygro-regulated ventilation system in order to avoid condensations and the occurrence of salts crystallizations and/or dissolutions.

3.2. Interfaces influence

It is well know that the exterior walls are usually multilayer walls with different type of joints which justify the moisture transfer knowledge about the continuity between layers. However, as referred in the Introduction section only a limited number of values for the interface resistance in multilayered composites could be found in literature [2–4]. Freitas [2] considered three different interfaces configurations: the hydraulic continuity, with interpenetration of both layers; the perfect contact, with contact between layers but without interpenetration and the air space between layers, without contact between layers.

In this work, different configurations were analysed, as showed in Table 1. For this laboratorial campaign, prismatic samples of clay brick ($\rho = 1925\ kg/m^3$) with $50 \times 50 \times 100\ mm^3$, monolithic or with different joints, were analysed in detail.

Previously, the specimens were placed in a climatic chamber with $22 \pm 0.5\ ^\circ C$ of temperature and $50 \pm 1\%$ of relative humidity, until the samples reached the equilibrium state. The imbibition process occurred in laboratory at isothermal conditions and the samples were previously dried in an oven, at a temperature of $65\ ^\circ C$ to stabilize the mass content. For each sample, all the surfaces were sealed except the top surface open to the ambient air and the bottom surface in contact with water, to ensure one-dimensional moisture transport.

Previous studies developed by Freitas [2] showed that in the situation of perfect contact, it can be considered that there are continuity in the temperature between the two layers and an

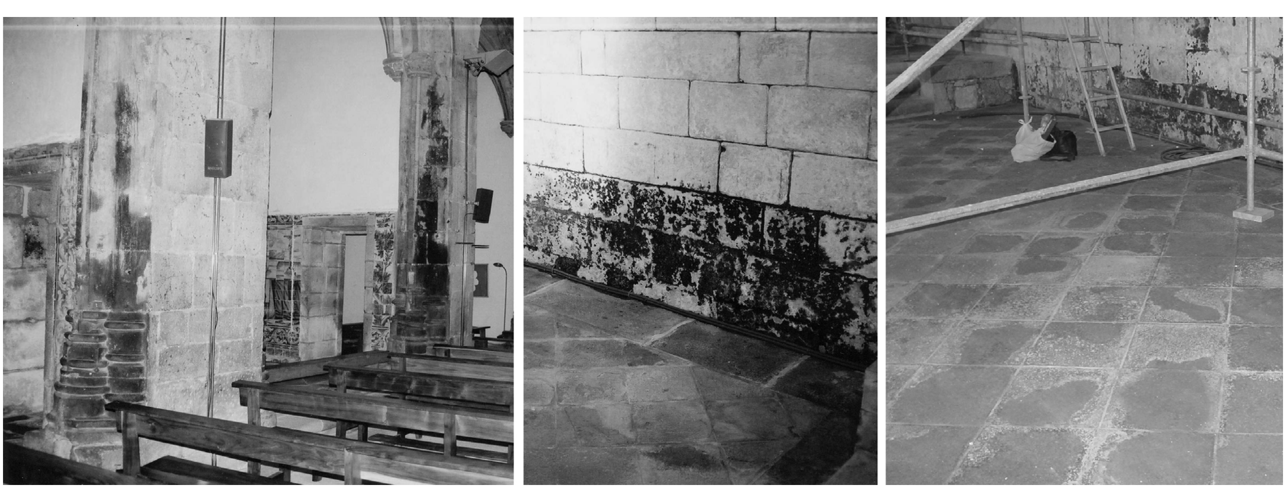

Fig. 1. Some building pathologies observed (surface condensations and rising damp).