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Assessing the humidification process of lightweight concrete specimens through infrared thermography

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Abstract

Moisture in building materials and components is a key aspect to be considered when assessing buildings performance, as it may influence their durability and mechanical resistance, thermal comfort and indoor air quality and buildings energy efficiency. Therefore, studying the humidification phenomena is of major relevance.
The presence of moisture in building materials/components is related to temperature variations. The surface temperature of the object can be measured using infrared thermography (IRT), a non-destructive technology to assess the buildings behaviour. Hence, it is important to understand its applicability to assess moisture related phenomena.
In the present study an analysis of the humidification phenomena using IRT was intended. Lightweight concrete specimens were used and tests were carried out under stable hygrothermal conditions. Two different humidification conditions were assessed: (1) partial humidification by the specimens' bottom surface; (2) partial humidification by the specimens' top surface. Thermal images were taken periodically during 24 hours. Both qualitative and quantitative analysis of the results was performed.
The results pointed that assessing the humidification phenomena using IRT is possible under stable conditions. The boundary conditions for the humidification process affected the results interpretation as it was easier to detect moisture when the surface under study was in direct contact with liquid water (partial humidification by the specimens' bottom surface). In this case clearer surface temperature differences could be found between the moist and the dry areas, which appear sooner in time. The surface temperature decrease was marked near the bottom during humidification by the bottom and near the top during humidification by the top, highlighting the effect of evaporation at the surface.

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1. Introduction

Moisture is one of the main causes of problems in buildings. It can have different sources like wind driven rain, rising damp coming from the ground, built-in moisture, etc. In most cases, moisture is related to damage of building materials and components, compromising their durability, mechanical resistance, waterproofness and appearance. It can also cause unhealthy conditions for users. Although moisture can have its effects in the vapor phase, most often it reaches the building components in the liquid phase.

The presence of moisture in building materials/components is related to temperature variations. Surface temperature can be measured using infrared thermography (IRT), a non-destructive technology to assess buildings behaviour [1-6]. Three different physical phenomena allow detecting moisture using IRT, namely, (a) evaporative cooling at the moist area as evaporation implies a decrease of the surface temperature [7-11]; (b) reduced thermal resistance of the wet materials implying higher surface temperature over the wet material, if the inspection is made from the outside during the colder season [12,13]; and (c) increased heat storage capacity of the moist material, as the surface temperature over a wet area responds more slowly to a change in the air temperature than the surface temperature over a dry area, thus, it will cool more slowly during the night after a sunny day [14-15].

The main goal of the present work was deeply understand how the humidification phenomena could be assessed using IRT. To that end, lightweight concrete specimens were used and tests were carried out under stable hygrothermal conditions. Two different humidification conditions were considered: (1) partial humidification by the bottom surface of the specimen; (2) partial humidification by the top surface of the specimen.

2. Test procedures

2.1. Methodology

To assess moisture using IRT, lightweight concrete specimens were used and tests were carried out under stable hygrothermal conditions, inside a climatic chamber (20±0.5 ºC and 60±2%). The specimens were humidified under different conditions: (1) partial humidification by the bottom surface (T.I); (2) partial humidification by the top surface (T.II). Before the humidification process began, the specimens were dried in an oven at 110±5 °C until their mass was stabilized to within 0.1% of their total mass when measured over 24 hours. Then they were cooled during 24 hours in a desiccator to the temperature of the climatic chamber.

Partial humidification by the specimen bottom surface (test T.I) occurred by placing it during 24 hours inside a tank filled with tap water to a level of 5±2 mm above the base of the specimen. This level was maintained during all the humidification period. To guarantee a suitable contact of the specimen bottom with the water, it was resting on point supports. Partial humidification by the specimen top surface (test T.II) was guarantee by maintaining a water level of 5±2 mm at the top of the specimen during 24 hours. That was possible by using a silicone sealant of about 10 mm thickness near the specimen edges (Fig. 1). The amount of water absorbed by the specimen in test T.I was 78 g and in test T.II was 58 g.

Thermal images were taken every 5 min during the first 8 hours and every 10 min during the remaining 16 hours, in a total of 24 hours of humidification process. A passive approach was used as no artificial thermal excitation was applied. The infrared (IR) camera remained in the same position during the entire test and the climatic chamber was lined with black cardboard to avoid reflections. No operator was inside the climatic chamber as the camera was programmed to capture the images periodically. All compensations imposed by the camera were carried out before the beginning of each test. Thermal images were analysed qualitatively and quantitatively (3 points in Fig. 1d).

2.2. Materials and equipment

The lightweight concrete specimens had 0.28 x 0.21 x 0.075 m^3 (Fig. 1). A dry density of 1351 kg/m^3 was assessed according to BS EN 12390-7:2000 [16] and a water absorption coefficient of $4.521x10^{-3}$ $g/(mm^2.h^{0.5})$ was measured