EVALUATION OF RISING DAMP USING INFRARED THERMOGRAPHY

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ABSTRACT

Moisture is one of the most deteriorating factors of buildings components. To avoid severe degradation, which affects the building durability, it is important to detect moisture in an earlier stage. Using non-destructive techniques (NDT) to detect moisture is very important, especially in buildings with some historical relevance, where more intrusive testing may not be acceptable.

In this work it was analysed the applicability of infrared thermography, a NDT, to assess moisture in building walls caused by rising damp. Laboratory tests were carried out on a full-scale model, consisting on a limestone wall with about 2.00 x 1.80 x 0.20 m³, which was partially immersed in water. Thermograms were taken before the immersion started and during the absorption period of about 3 weeks. Simultaneously, a moisture detector was also used to evaluate qualitatively the moisture content of the wall.

The comparison between the two testing methods showed a good agreement in the results and proved that infrared thermography can be very useful to detect moisture caused by rising damp in an earlier stage.

1 INTRODUCTION

The problem of moisture in buildings has always aroused great interest, since moisture is one of the main causes of buildings pathology. Moisture may cause degradation of building materials and components, compromising their performance concerning durability, mechanical resistance, waterproofness and appearance. It can also cause unhealthy conditions for users, resulting from biological growth and degradation of materials and building components.

Rising damp coming from the ground that, by capillarity, rises through porous materials, is one of the main degradation causes of historical and ancient buildings. The main pathologies caused by rising damp are stained areas at the wall surface due to moisture and mould growth and, in more severe situations, deterioration of plaster and paint due to salts crystallization at the surface or behind the rendering (Figure 1a). Assessing rising damp is therefore essential to improve technical solutions that ensure the building’s durability.

Infrared thermography is a non-contact and non-destructive testing technology that can be applied to determine the surface temperature of an object. The detectors collect infrared radiation emitted by the surface and convert it into a thermal image with the distribution of the body superficial temperature, the thermograms. In this process, each colour expresses a certain range of temperatures (Figure 1b).
Two approaches can be used to obtain the surface temperature distributions using infrared cameras: the passive approach and the active approach (Maldague 1993). The thermal images can be analysed qualitatively or quantitatively (Hart 2001). This technology has been applied to buildings for a couple of decades, to evaluate the building performance (Hart 2001). It has been used to detect insulation defects, air leakages and heat losses. Inspection procedures are well defined in standards such as ASTM C 1060-90 (2003), ISO 6781 (1983) and CEN-EN 13187 (1998).

However, procedures to detect moisture in building components using infrared thermography are still under development. It is known that changes in moisture content can be related with changes in surface temperature and can be detected by infrared thermography, due to three physical phenomena:

- Evaporative cooling at the moist area: the evaporation at the surface is an endothermic reaction, which implies a decrease on the surface temperature (Rosina & Ludwig 1999, Moropolou et al. 2002, Barreira & Freitas 2007, Grinzato et al. 2010).

- Reduced thermal resistance: the heat flow through wet materials is higher than through dry materials, which creates a thermal pattern as the surface temperature over the wet material is higher, if the inspection is made from the outside during the colder season. This effect is pushed to extremes when the wetting occurs in thermal insulation materials (Rajewski & Devine 1996, ASTM C 1060-90 2003).

- Increased heat storage capacity of the moist material: 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, when the whole surface is cooling, wet areas will cool more slowly. During the sunlight day, wet areas will store more solar energy than dry areas, thus, they will cool more slowly during the night (Balaras & Argiriou 2002, ASTM C 1060-90 2003, Lerma et al. 2011).

Moisture content is traditionally assessed using destructive procedures. They require previous drilling the wall to collect samples, which are weighed in the laboratory, immediately after being removed from the wall and after drying. However, water content can also be assessed using non-destructive techniques, as moisture detectors. These techniques may not be as accurate as the destructive procedures, however, they are very easy to use and they deliver results in real time. Also, they are the only that can be used in buildings with historical relevance.
In this work, the qualitative and passive approaches were used in the thermographic measurements. A moist area in a full-scale wall caused by rising damp was assessed considering the effect of evaporative cooling. Simultaneously, a moisture detector was also used in the same area to evaluate, qualitatively, the moisture content of the specimen. The comparison between the two methods is presented.

2 LABORATORY MEASUREMENTS

2.1 Setting up the test

Laboratory tests were carried out on a full-scale model, consisting on a limestone wall with about 2.00 x 1.85 x 0.20 m$^3$, which was partially immersed in 0.35 m of water. The specimen is composed of 6 blocks with about 0.30 m high with horizontal mortar joints of about 1 cm thick. The absorption period was about 3 weeks. The measurements were performed only in the central area of the specimen as shown in Figure 2. Average temperature and relative humidity in the laboratory during the test period was around 19ºC and 70%, respectively.

![Figure 2: Full-scale model and area of the specimen where measurements were performed.](image)

The thermography equipment used was Thermo Tracer TH7800 made by NEC Avio Infrared Technoologies Co., Ltd (NEC nd). Thermograms were taken before the immersion started and during the absorption period. During the test period the IR camera was always kept in the same position. Emissivity was set to 0.9. This value may not correspond to the real emissivity value of the surfaces under study, however, as the qualitative approach was used, an estimated value of emissivity was considered acceptable. Standard calibration procedures were adopted before taking thermal images, namely, reflection calibration and ambient and background compensation, according to the operation manual of the equipment (NEC nd).

Simultaneously, a moisture detector was also used to evaluate the moisture content of the wall. The moisture detector used was TRAMEX LS made by Tramex, Ltd. This non-destructive equipment operates on the principle that the electrical impedance of a material varies in proportion to its moisture content. The reading displayed by the equipment is a relative scale in percentage, which indicates the greater or lesser signal (lower values indicates lesser signal that corresponds to lower moisture content). To obtain precise moisture content the equipment must be calibrated (TRAMEX nd). During this work, only the qualitative approach was used as the moisture detector was not calibrated.

To compare the results obtained by thermography with the ones given by the moisture detector, a correlation between the relative scale of the detector results and the thermograms colour scale was established. As lower temperatures correspond to moister areas, because
evaporation is more intense, the colder colour was related with higher values of the detector relative scale and the warmer colour with the lower values (Figure 3).

![Thermograms colour scale](image)

**Figure 3:** a) Thermograms colour scale; b) Correlation between the relative scale of the detector results and the thermograms colour scale.

Before using the moisture detector it was defined a grid dividing the area to be analysed (Figure 4a). Using the measured values in each point of the grid a graph was created (Figure 4b). It must be clarified that the reading displayed by the equipment is a relative scale in percentage, which indicates the greater or lesser signal (lower values indicates lesser signal that corresponds to lower moisture content).

![Grid of the area under study](image)

**Figure 4:** a) Grid of the area under study; b) Example of the moisture detector results.

During the absorption period, whenever thermograms or measurements with the moisture detector were made, the highest visible moisture level above the water plan was also assessed. This was not always an easy task because the degradation of the specimen surface, due to previous tests, was very severe, as shown by Figure 2 taken before immersion began.

Numerical simulation was used to assess the expected results of rising damp in the full-scale model. It was performed with WUFI®2D-3.3, a transient two-dimensional model for combined heat, air and moisture transport in building components, developed by Fraunhofer IBP – Holzhirchen (WUFI 2013).

### 2.2 Measurements results

Figure 5 shows the variation in time of the highest visible moisture level. During the first 52 hours after partial immersion, the rise of the visible moisture level was very slow, increasing significantly in the next 220 hours. After that, the stabilization of the maximum value of the visible moisture level began. The delay of 24 hours in the measured visible moisture level points to some kind of hygric resistance to the water uptaken, related with salt crystallization due to previous tests.
Figures 6 to 10 show the thermal images and the results of the moisture detector along 532 hours of absorption. Figure 6 shows the thermal image (Figure 6a) and the moisture detector results (Figure 6b) before immersion began. Both results show that the specimen was dry.

![Figure 6: Measurements before immersion began: a) thermal image b) moisture detector results.](image)

Measurements 52 hours after the imbibition began (Figure 7) show that moisture was rising due to capillarity. The highest visible moisture level above the water plan is about 0.04 m (Figure 5), which correspond to the green isothermal above the water plan (blue line in Figure 7a). The yellow isothermal shows a transition area between the wet and dry surfaces of the specimen. The moisture detector results don’t show any rising damp, what was expectable as the moisture level didn’t achieved the first row of the grid (0.07 m).

![Figure 7: Measurements 52 hours after the imbibition began: a) thermal image b) moisture detector results.](image)

At the end of 340 hours after the imbibition began the highest visible moisture level above the water plan is about 26 cm (Figure 5), which corresponds to the highest point of the
green isothermal (Figure 8a). Once more, the yellow isothermal shows a transition area between the wet and dry surfaces. The thermal image shows that the moisture level (green isothermal) is higher in the centre of the image and lower near the verticals edges, which was not perceptible visually. That may be related with the effect on evaporation of rising damp of the edges of the specimen or with salt crystallization due to previous tests.

Figure 8b shows the results of the moister detector. The level of the moister area (dark blue) is above 0.28 m and it is almost constant. Comparing the thermal image with the results of the moisture detector, they are not completely in accordance, which is expectable as thermography only detects surface evaporation and the moisture detector assesses inner moist (around 2 cm penetration depth). Also the results of numerical simulation show that at the surface, the moisture level is lower than inside the specimen (Figure 9).

Figure 10 shows the results at the end of the test (532 hours of imbibition). Thermal images taken at 340 and 532 hours after the imbibition began are very similar, which indicates a stabilization of the rising damp at the surface. These results are in accordance with Figure 5 in which the measured value of the highest visible moisture level above the water plan is very similar.

One the other hand, the moisture detector results show that, inside the specimen the moisture level is still increasing (Figures 8b and 10b). This may be explained because evaporation is more preponderant than capillarity at the surface, which allows the stabilization of the superficial moisture level. Inside the specimen capillarity is the main driving force and the moisture level keeps increasing.
3 CONCLUSIONS

Experimental tests showed that thermography can detect moist areas due to capillarity, with the highest visible moisture level corresponding to a green isothermal. Thermography also allows to “see” a moist area corresponding to the transition between the wet and dry surfaces of the specimen, which is not visually detected.

There is an agreement between the thermal images and the results obtained with the moisture detector. The moisture detector points to higher level of rising damp, which was expected as thermography only detects surface evaporation and the moisture detector assesses inner moist. Numerical simulation results point that at the surface, moisture level is lower than at mid-thickness of the specimen.

In conclusion, this work indicates that thermography ought to be considered as a nondestructive assessment tool for the detection of moisture in porous materials, even when there are no visible signs on the surface. However, further test must be carried out, namely, it is necessary to establish test procedures and evaluation criteria to avoid misinterpretation.

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