Chapter 1
Introduction

1.1 Motivation

Moisture is one of the main causes of pathologies in buildings and, thus, has always aroused great interest within the scientific community. The damage in buildings can occur both due to the presence of moisture itself or due to its evaporation. In fact, moisture and the drying process may cause the degradation of building materials and components, compromising their performance concerning durability, mechanical resistance, waterproofness and appearance. Moisture can also cause unhealthy conditions for users, either due to the biological growth or due to the degradation of building materials and components.

Moisture may have different causes, which can be grouped as follows: built-in moisture; rising damp; infiltrations due to wind-driven rain; surface condensations; moisture due to hygroscopic phenomena and moisture due to accidental causes.

An early diagnosis is crucial to avoid severe degradation. Indeed, it is imperative to detect moisture in an earlier stage, i.e. before significant visible signs occur, and to trace the leak through the building elements. The use of non-destructive techniques to detect moisture can be very useful, especially when the building is occupied, as further work and greater costs are avoided during the assessment.

Infrared thermography (IRT) is a non-contact and non-destructive testing technology that allows the evaluation of thermal behaviour of existing buildings and identification of potential problems (Maldague 1994; Hart 2001; Bagavathiappan et al. 2013). It converts the infrared radiation emitted from bodies into thermal images, showing the temperature distribution of the surface (Maldague 2001; Rao 2008), as shown in Fig. 1.1. Nowadays, from a practical point of view, this technique is mainly used considering only a qualitative evaluation of the results, based on the simple observation of the thermal images. However, the scientific community has been working in new quantitative approaches, which are more often related to the evaluation of the temperature differences between areas with and without thermal anomaly (Maldague 2002; Lai and Poon 2012; Vavilov 2014).

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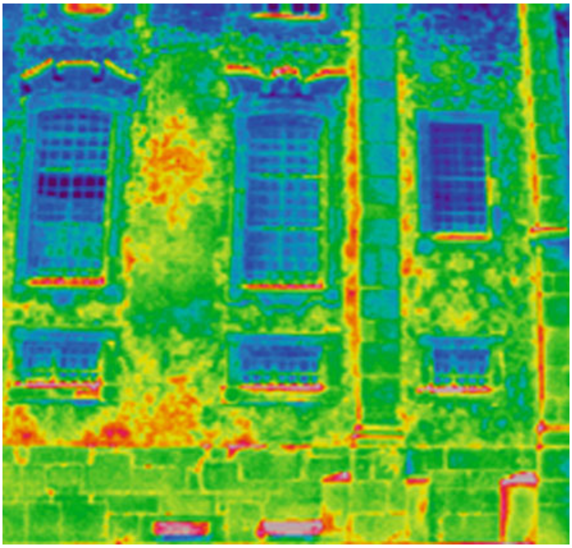

Fig. 1.1 Thermograph of a façade located in Porto, Portugal

However, IRT has several potential applications that have not yet been completely explored, such as detecting moisture in building components. Some authors have been working in this topic, proving that it is possible to use it to identify moisture in building elements as, for example, Balaras and Argiriou (2002), Avdelidis et al. (2003). However, only very few were able to establish a criterion for a quantitative assessment of the problem. Even when an attempt was made, the criteria and procedures were applied to a specific case study and its generalization to other building elements is not straightforward.

Therefore, it is still required additional research concerning the applicability of IRT to detect moisture and to characterize its consequences in building components. In this book, information relevant to this topic is collected and systematized, namely new work developed by the scientific community regarding detection of moisture in building materials and components using IRT is gathered, and it discusses the opportunities and limitations of IRT to assess moisture-related buildings pathologies using several practical models as example cases.

1.2 Main Developments on Using IRT to Assess Moisture

Two approaches can be applied to obtain the distribution of the surface temperature using infrared (IR) cameras: the passive and the active approach (Maldague 1993). Thermal images can be analysed qualitatively or quantitatively (Hart 2001). The quality of the thermal images can be affected by several parameters related to materials properties and to ambient conditions: (a) emissivity, which is crucial if a quantitative analysis is required (Avdelidis and Moropoulou 2003); (b) surface colour as it can mask defects (Barreira and Freitas 2007); (c) reflections on metal and glazed surfaces (surfaces with high reflectance) (Barreira and Freitas 2007); (d) meteorological conditions such as air temperature, precipitation, wind speed, cloud cover and direct sunlight (Chew 1998); (e) heat sources near the measurement area (Hart 2001); (f) period of the day (day or night) and time of year (summer or winter conditions) (Chew 1998); (g) distance between camera and target, which may attenuate thermal radiation and affects the images clarity and precision, for distances above 10 m (Chew 1998).

This technology has been applied to buildings for a couple of decades to evaluate their performance (Hart 2001). IRT has been used to assess the floor covering comfort (Barreira and Freitas 2007), to detect insulation defects (Hart 2001), air leaks (Taylor et al. 2013; Barreira et al. 2017a; Lerma et al. 2018) and thermal bridges (Asdrubali et al. 2012), to evaluate thermal performance (Katunsky et al. 2013) and to inspect construction details (Cerdeira et al. 2011). IRT has also been used as a conservation evaluation tool for historic buildings treatments (Avdelidis and Moropoulou 2004), to detect defects in façades (Edis et al. 2014; Freitas et al. 2014) and as an inspection technique for frescoes assessment (Paoletti et al. 2013; Sfarra et al. 2016). The use of IRT in inspection procedures is well defined in standards such as ISO 6781 (1983), EN 13187 (1998) and ASTM-C 1060-90 (2003). A detailed comparison between the performances of different IR cameras can also be found in the literature (Bauer et al. 2015).

Some attempts of applying IRT to detect moisture in building components were already published, although mostly using only the qualitative approach (Balaras and Argiriou 2002; Avdelidis et al. 2003; Edis et al. 2014; Menezes et al. 2015). Nevertheless, the procedures to detect moisture in building components using IRT are still under discussion since it is still not clear if this technique can be used to detect moisture before any visible marks occur, such as efflorescence, biological growth, detachments or degradation of the material, and to trace a water leak through the building element. In addition, the potential of quantitative approaches applied to detect moisture in building materials and components remains largely untapped.

Changes in moisture content are related to changes in surface temperature and therefore can be detected by IRT, due to three physical phenomena:

- Evaporative cooling at the moist area: The evaporation at the surface is an endothermic reaction, which induces a decrease on the surface temperature (Rosina and Ludwig 1999; Avdelidis et al. 2003; Barreira and Freitas 2007; Grinzato et al. 2010; Bison et al. 2011a, b; Grinzato et al. 2011; Camino et al. 2014; Lerma et al. 2014; Barreira et al. 2016, 2017b).
- Reduced thermal resistance: The heat flow through wet materials is higher than through dry materials, which creates a heterogeneous 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 and Devine 1996; Edis et al. 2014, 2015).

- 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 course of a sunlit day, wet areas will store more solar energy than dry areas; thus, they will cool more slowly during the evening (Balaras and Argiriou 2002; Lerma et al. 2011; Edis et al. 2014, 2015).

From the above references, only a few were able to establish a criterion for a quantitative assessment of the problem. In those studies, the moisture content was assessed using different physical principles (evaporative cooling of the surface and increased heat storage capacity).

The quantitative analysis of the results of IRT can be carried out using the following techniques: principal component thermography (PCT), pulsed phase thermography (PPT), differential absolute contrast (DAC), thermographic signal reconstruction (TSR), full width at half maximum (FWHM) and higher order statistics thermography (HOST). Although having great potential, as they tend to minimize the influence of emissivity variation, environmental reflections, etc., they are still not widespread and may not always be applicable, especially during long-term monitoring where large areas are covered. In addition, the equipment that generally is required is also more complex and expensive.

From the literature review, one can state that assessing moisture-related phenomena by IRT is possible, yet difficult, especially if a quantitative evaluation is intended. In this area, the methodologies and the potential of IRT for qualitative approaches are stabilized but, on the other hand, a well-defined methodology for a quantitative approach is still an open issue that requires attention from the scientific community.

This book presents the results of several experimental campaigns where the potential of IRT for moisture assessment is evaluated. An analysis for tackling the parameters that can affect IRT accuracy was carried out, and the applicability of IRT to assess moisture and drying in building components was analysed both in indoor and outdoor conditions.

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