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A discussion concerning active infrared thermography in the evaluation of buildings air infiltration

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ABSTRACT

The EU is strongly committed to energy saving in buildings. Air leaks through the building envelope represent a significant percentage of buildings energy consumption. Locating and minimizing air leaks is thus necessary to optimize energy efficiency.

This work presents the results of an experimental campaign that aimed to promote a discussion concerning the opportunities and constraints of using active IRT to detect air leakage points. The potential of active IRT was evaluated both in a qualitative approach, by comparing the thermograms with the ones obtained with passive IRT, and in a quantitative one, by testing methods of numerically interpret the thermograms.

The results allowed concluding that active IRT increases the thermal contrast and the affected area, proving that active IRT combined with pressure differences is an effective methodology for detecting air infiltrations. In the quantitative approach different numerical methods can be used. Their selection depends on the aims of the study, as they can highlight different perspectives of the phenomenon.

1. Introduction

The EU and its member countries are committed to energy saving. The aim is to achieve a rational use of the energy required for buildings, reducing their consumption to sustainable limits [1]. The EU has committed itself to reduce the Union's energy consumption by 20% before 2020. To that end, buildings have to consume more efficiently and their energy loses must be minimized. This is achieved through good construction design for new buildings. In existing buildings, it is very important to locate and correct, if possible, thermal losses through the envelope, which, broadly speaking, can derive from heat transfer and ventilation, including infiltration.

According to recent studies, infiltrations can account between 10% and 50% of the energy demand [2–6]. In this sense, the airtightness of buildings is an important parameter that is necessary to know. The most common procedure to quantify the buildings airtightness is the Blower Door Test, which, through fan pressurization, applies a certain pressure difference, usually in steps of 10–50 Pa [5,7], between the inner space of the building and the outside while measuring the corresponding airflow. The Standard EN 13829:2006 [8] describes the methodology for measuring the air leakages through a building envelope with the Blower Door Test. However, this methodology cannot detect the location of the leakage points in the building envelope.

Infrared thermography (IRT) can be used for the evaluation of the surface temperatures of the facades. This technique is contactless and non-destructive and allows thermal images (thermograms) to be generated. It has already been widely used in the study of the energy efficiency of buildings [9–16], the pathology of building materials [17], as a tool for building diagnosis and definition of construction details [18–25], to detect moisture in building components [26–33], as a conservation evaluation tool for historic buildings [34–38] and to assess thermal comfort [39].

Air infiltration causes temperature differences around the leakage points on the building surface, which can be detected by IRT. These areas can be observed from the inside when buildings are depressurized [7,40–42]. The dimension of this thermal contrast zone depends mainly on the geometry of the defect and the pressure difference between indoors and outdoors [9]. Air leakages through building envelopes have already been analysed through IRT but only using a qualitative approach and passive methods [8,9,25,38–48].

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Fig. 1. Room under study and roller shutter handle manually controlled.

While passive IRT uses no external excitation energy to highlight the defective area, active IRT is based in using the energy of artificial heat sources to further enhance the thermal contrast between the sound and the defective areas [49–52]. Based on the characteristics of the materials, halogen lamps [52], ultraviolet radiation, flash [53], lasers or infrared lamps can be used as heat source. Active IRT has also been used in many situations to investigate building materials and their defects [54,55] through the quantitative analysis of transient thermal data [52,56,57].

By increasing the temperature gradient, active IRT can be particularly effective in the detection of leakage points, especially in moderate climates where the indoor/outdoor temperature difference is not large. The advantages of using active can be leveraged by both qualitative and quantitative interpretation of the thermograms. However, there is a lack in the literature regarding this specific issue. Therefore, this work aims to promote a discussion concerning the opportunities and constraints of using active IRT to detect leakage points. The potential of active IRT is evaluated both in a qualitative approach, by comparing the thermograms with the ones obtained with passive IRT, and in a quantitative one, by testing methods of numerically interpret the thermograms.

2. Framework

2.1. Case study

To carry out this experimental campaign, a room of a residential multi-storey building constructed in 1980 and located in Matosinhos (northwest of Portugal) was considered. More information about the room characteristics can be found in Barreira et al. [7]. The room has a single window with a roller shutter handle manually controlled and there are no air inlet devices (Fig. 1).

To assess air leakage only the bottom of the roller shutter handle was considered as previous tests pointed that, due to the localised nature of this specific leakage point, it was easier to be identified [7]. However, two different positions of the IR camera were assessed: (i) IR camera perpendicular to the roller shutter handle (PP); (ii) IR camera parallel to the roller shutter handle (PL). A cardboard sheet was used as a physical support enabling the detection of air infiltration in the thermal images. In scenario PP the cardboard sheet was placed in front of the leakage point, parallel to the wall surface (Fig. 2a and b), and in scenario PL the cardboard sheet was placed perpendicular to the leakage point and the wall (Fig. 2c and d).

Table 1
Main characteristics of the IR camera.

Measuring range	−20 °C to 100 °C
Accuracy	±2 °C or ±2% of the reading
Resolution	0.06 °C at 30 °C
Spectral range	8.0 to 14.0 µm
Thermal image	320(H) × 240(V) pixels
Field of view	21.7° (H) × 16.4° (V)
I.F.O.V	1.2 mrad
Focusing range	50 cm to infinite
Detector	Uncooled focal plane array (microbolometer)

2.2. Equipment

During this test campaign an IR camera, a temperature and relative humidity sensor, a portable weather station and a blower door apparatus were used. All devices were properly calibrated before the measurements according to the operation manual. The reflection calibration and ambient and background compensation of the IR camera were implemented before each measurement. Table 1 presents the main characteristics of the IR camera. To implement the active approach an IR lamp of 2500 W was used.

Air temperature and relative humidity were recorded using a 2-channel data logger, with a precision of ±0.35 °C and ±2.5% and a resolution of 0.03 °C and 0.03%, for temperature and relative humidity, respectively. The blower door model has a maximum flow at 50 Pa test pressure of 10,194 m^3/h and minimum flow at 10 Pa of 8.5 m^3/h. The gauge accuracy is ±1 Pa or ±2%, whichever is greater.

The weather station collects outdoor temperature (accuracy of ±1 °C and resolution of 0.1 °C), relative humidity (accuracy of ±5% and resolution of 1%), wind speed (between 0 and 89.3 m/s with an accuracy ±0.9 m/s + 5%) and wind direction (accuracy of ±11.25° and resolution of 22.5°).

2.3. Methodology

To assess the air leakage on the bottom of the roller shutter handle, the room was depressurized by the mechanical extract fan used in the Blower Door Test. All the information regarding the apparatus and can be found in [7]. The emissivity of the cardboard sheet used as physical support (white coloured) was 0.90. It was measured with a portable emissometer, according to the procedure described in ASTM C1371 – 04a [58]. The accuracy of the measured values is ±0.02. The emissometer output is 2.4 millivolts nominal, with sample emittance of 0.9 and sample temperature of 25 °C. The detector output is linear with emittance to within ±0.01 units and the time constant is 10 s, nominal (time to reach 63% of final value) [59].