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The usage of infrared thermography to study thermal performance of walls: a bibliographic review

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ABSTRACT

This article aims to present the influence of infrared thermography on masonry walls to detect pathological manifestations. A systematic review was carried out through research with automatic search and snow-balling, selection and sifting of articles to restrict them to the desired theme. After that, infrared thermography in the pathological manifestations was studied along with the thermal properties and their behavior, thermal bridges, temperature difference and air infiltrations. In general, some care must be taken during the execution of experiments and measurements. It has also been shown that infrared thermography is a complex technique and should be used.
Keywords: infrared thermography; thermal performance; pathological manifestations; thermal properties; air leakage.

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O uso da termografia infravermelha para o estudo do desempenho térmico de paredes: revisão bibliográfica

RESUMO

Este artigo tem por objetivo apresentar a utilização da termografia infravermelha em paredes de alvenaria no auxílio do desempenho térmico. Foi realizado uma revisão sistemática através de pesquisa com busca automática e snow-balling, seleção e peneiramento dos artigos para restringir os artigos ao tema desejado. Após isto, foi estudado sobre a termografia infravermelha nas manifestações patológicas, as propriedades térmicas e seu comportamento, pontes térmicas, diferença de temperatura e infiltrações de ar. De uma forma geral é necessário ter alguns cuidados durante a execução dos experimentos e medições. Ademais foi mostrado que a termografia infravermelha é uma técnica complexa e precisa de ser utilizada.

Palavras-chave: termografia infravermelha; desempenho térmico; manifestações patológicas; propriedades térmicas; vazamentos de ar

Uso de termografía infrarroja para estudiar el desempeño térmico de paredes: una revisión bibliográfica

RESUMEN

Este artículo tiene por objetivo presentar la influencia de la termografía infrarroja en paredes de albañilería para detectar manifestaciones patológicas. Se realizó una revisión sistemática a través de investigación con búsqueda automática y snow-balling, selección y cribado de los artículos para restringir los artículos al tema deseado. Después de esto, fue estudiado sobre la termografía infrarroja en las manifestaciones patológicas, las propiedades térmicas y su comportamiento, puentes térmicos, diferencia de temperatura e infiltraciones de aire. En general es necesario tener algunos cuidados durante la ejecución de los experimentos y mediciones. Además, se ha demostrado que la termografía infrarroja es una técnica compleja y precisa de ser utilizada.

Palabras clave: termografía infrarroja; rendimiento térmico; manifestaciones patológicas; propiedades térmicas; fugas de aire

1. INTRODUCTION

Walls can be evaluated in order to verify better quality for thermal performance. There are several forms of measurements according to the functionality or parameter to be observed, such as mechanical resistance, water absorption, capillarity, thermal performance, geometric characteristics. Those are some aspects that can be evaluated to obtain a satisfactory performance of the walls in a building.

The Brazilian performance standard NBR 15575 (ABNT, 2013) and the base standard on Thermal Performance, NBR 15220 (ABNT, 2005), complement each other: the first defines performance as "behavior in use of a building and its systems" while the second approaches the thermal concepts, properties and their calculations.

Infrared thermography is a non-invasive and non-destructive survey technique. Its capture is done through devices that show infrared radiation, through mechanisms of easy and fast use, though in a complex way. The use of the technique has become more frequent given its fast, precise and non-contact nature which makes possible for it to be used in a wide range of cases (Kylili et al., 2014). Infrared thermography uses a camera to measure the emitted infrared radiation of an object and

convert it into a thermal radiation pattern, which is invisible to the human eye, in a visible image (Clark et al., 2003).
Several researchers have applied infrared thermography techniques for various uses (Bagavathiappan et al., 2013) such as emissivity measurement and determination of global heat transfer coefficient, thus demonstrating a positive potential (Porras-Amores et al., 2013). O'Grady (2017a) brings important information in his research: about 40% of the energy consumed in Europe comes from buildings. The previous study on thermal behavior of walls avoids errors in the construction phase. Once built, its on-site verification enables to find possible pathologies and/or design deficiencies that lead to a reduction in its thermal performance.
In Argentina, about one third of the energy produced is for the management of buildings, half of which is directed to heating and cooling. In addition, more than 30% is lost due to insufficient thermal insulation or even roofs and walls that are likely to overheating in summer and presenting heat leaks in winter (Marino et al., 2016).
According to the Green Building Council Brazil (2015), based on the national energy balance of 2015, about 50% of all the demanded electricity was for buildings. The consumption of electricity in Brazil, excluding losses, reaches 516.6 TWh: 258 TWh of the total, or the equivalent of BRL 60 billion, are consumed only by buildings. According to the EIA (2018), in the year of 2017 in the United States, about 39% of total energy produced was consumed by households and commercial sectors. In the European Union countries, the tertiary and residential sectors consume about 41% of all energy produced, 55% of which is heat. Similarly, in Serbia, where about 50% of the total energy consumed goes to the buildings, 60% of it is heat (Tanic et al., 2015). In view of this information, it is important to study the thermal behavior of walls.
Rural buildings in China consume a lot of energy and have poor thermal performance due to the type and situation of building materials (Diao et al., 2018). Thus, the detection and quantification of heat losses through buildings become relevant given their extreme importance for society.
There is still a lack of studies on the subject, making it difficult to research and obtain a better understanding of the scope regarding infrared thermography. As a subject that has more than 25 years of relevant studies, researchers are investing in this topic intentionally to explore the full extent of the usage of infrared thermography. In the light of foregoing, this work aims to perform a systematic review of the existing research on the usage of infrared thermography in order to study the parameters, their properties, and influence on the thermal performance of walls.

2. LITERATURE REVIEW

2. 1 History of infrared thermography

Infrared thermography was first used for purposes other than civil construction. Its principles were discovered by accident while scientist William Herchel was trying to solve an astronomical problem, in the 1800’s (Barr, 1961). Over the years, the technique was improved for use in several sectors (Lucchi, 2018). In 1830, Melloni, an Italian investigator, discovered that NaCl, in natural crystals large enough to be transformed into lenses and prisms, became the main infrared until the 1930's, the era of synthetic crystal (Flir, 2017). The first quantum detector was developed between 1870 and 1920 based on the interactions between the radiations, increasing the precision and considerably reducing the response time (Smith et al., 1958). The thermography was greatly improved during World War II, showing the importance of the technology especially at night. The propagation of the infrared images in the construction sector occurred in the 2000’s, with the use of barium-strontium titanate and microbolometer (Lucchi, 2018). In the last years, its use has increased dramatically, mainly in restoration, building construction, and survey works (Kylili et al., 2014; Bianchi et al., 2014). In addition, it is important to note that the use of this technique has been associated with a reduction in size equipment, cost reduction and resolution improvements, sensitivity and accuracy, operability and portability (Meola, 2012). The use has grown considerably over the last 15 years, mainly for civil engineering and restoration of historic buildings, thus facilitating a diffusion of European legislation not only for energy efficiency but also for energy auditing of buildings (Lucchi, 2018). However, even after 30 years since the beginning of its use, it has not yet been extensively exploited (Grinzato et al., 2002; Albatici and Tonelli, 2010).

2. 2 Standardization of infrared thermography in Brazil and worldwide

Around the world, the use of infrared thermography has been diffused for some years. There are standards regarding the subject such as those of ASTM, ISO and the European Union, which regulate the use of infrared thermography in buildings and their properties. Their use is widely recommended (ASTM, 2013a, ASTM, 2015a, ASTM, 2013b, ASTM, 2015b ISO, 2008, ISO, 2015, EN, 1999).

In Brazil, there is no standard for the topic, and it is often necessary to resort to international standards or adaptations of uses in other areas.

The Brazilian standard that has some aspect regarding the use of the infrared thermography is the NBR 15575 (ABNT, 2013a), which is divided into 6 parts and approaches aspects for a good building performance, including the thermal conditions. However, it does not refer to any field tests to verify this performance. Some Brazilian standards that refer to infrared thermography include NBR 15572 (ABNT, 2013b), NBR 15763 (ABNT, 2009) and NBR 15866 (ABNT, 2010), which cover techniques for its use.

According to Marques and Chavatal (2013) the thermal behavior of a house depends substantially on the interactive activity between the external walls, ceiling and floor. Nowadays, around the world, the walls are constructed with numerous materials in several layers (Robinson et al., 2017). In Brazil, most of the buildings still use traditional materials such as concrete, ceramic blocks and plaster. However, researchers are exploring other materials such as EVA (Silva et al., 2012) and vegetable fibers (Savastano Junior and Pimentel, 2000), in different percentages inserted in traditional materials, to aid in their behavior without removing their characteristics.

2. 3 Methodology

According to Maldague (2001), infrared thermography is divided into two main techniques: active and passive. Lerma et al. (2018) say that the techniques do not meet the substrate in order to avoid damage or future recoveries.

The passive technique is one in which the temperature measurement is done under normal conditions, in objects that have their own thermal energy or somehow store energy by a natural source of heat, with temperature difference between the object studied and the environment (Kylili et al., 2014, Viégas, 2015). In the technique of active infrared thermography, an external source of artificial energy is required, generating a temperature variation over the object (Viégas, 2015). The use of passive thermography will depend on the energy available in nature, and can often suffer from wind, shade, weather and environmental conditions. As the principle of active thermography is the use of artificial heat sources, the use of lamps in the environment can be considered an alternative.

In the active thermography there are some techniques that are differentiated by the nature of the applied stimuli: heating lamps or ultrasound (Kylili et al., 2014). They are named as *Pulsed*, *Lock-in*, *Pulsed-Phase* (Maldague, 2001 apud Rocha, Póvoas, 2017), *Laser Spot Array Thermography* (Pei et al., 2016), *Principal Component Thermography* (Milovanovic et al., 2016; Rajic, 2002), among others.

Since infrared thermography began to be applied in civil construction, it has been used in the monitoring of buildings both quantitatively and qualitatively (Grinzato et al., 2002). The qualitative analysis is considered a technique of infrared thermography that provides instantaneous reports,

since the focus is the profile and not the values (ITC, 2014 apud Viégas, 2015), comparing the value relative to local access in relation to a point (Bagavathiappan et al., 2013).
In the quantitative thermography it is possible to define the severity of the situation for the studied object. The first analysis to be done must be the qualitative, since the quantitative one allows the numerical quantification of the evaluated parameters. If this order is not followed, the procedure is characterized only as a comparative analysis (ITC, 2014 apud Viégas, 2015). The data quantitative analysis allows a precise determination of the temperature in a point or a region (Bagavathiappan et al., 2013).
In order to measure the thermal performance of buildings, there are methods such as the laser spot thermography (LST) (Pei et al., 2016), heat flux meters (HFM) (Danielsky and Fröling, 2015) infrared thermovision (Albatici and Tonelli, 2010), among others.
These techniques are used for the measurement of thermal bridges (O'Grady, 2017a; Bianchi et al., 2014; BRÁS et al., 2014), air infiltration (Lerma et al., 2018), thermal transmittance (Simões et al., 2014; Donatelli et al. 2016), thermal emissivity (Abatici et al., 2013; Ciocia e Marinetti, 2012) and other properties.
The difference between the materials and their humidity, the emissivity to be analyzed, the noise caused by the reflective temperature readings are some of the factors that interfere in the analysis of the infrared thermography.

3. THERMAL PERFORMANCE OF WALLS

Global warming has brought increase in temperature. In this respect, the construction sector seeks improvements in energy efficiency through alternatives that avoid the thermal discomfort of buildings (Cani et al., 2012). The European Directive 2010/31/EU (European Parliament and ff The Council, 2010) provides a description of how energy efficiency of buildings has a role in achieving near zero consumption. Aversa et al. (2017) state that "for this to occur, energy analysis or auditing is an effective and rapid tool for new constructions, projects and in decision-making on the energy renovation of existing buildings often characterized by inefficiencies that lead to waste of energy". Due to the launching of the Performance Standard in Brazil, the NBR 15575 (ABNT, 2013), thermal comfort is presented in discussions. Thermal comfort is defined as the mind condition that expresses the user’s satisfaction with an environment (Ghahramani et al., 2018).

3. 1 Air leaks

Lerma et al. (2018) worked on a paper to promote a discussion on the opportunities and constraints of using active infrared thermography to detect air leaks. The potential is evaluated in a qualitative approach, comparing the thermograms of passive and active infrared thermography. In addition, there is a quantitative approach, testing methods for numerically interpreting thermograms. An experiment was carried out in a room of a 1980 construction, in the Northwest of Portugal. The experiment was performed in 8 days with different climatic conditions and the measurement was done both on the internal and external side. In the qualitative analysis it was detected, in the active approach, that air infiltrations begin to be visible when the pressure difference is 25Pa. As for the passive approach, the pressure difference must be greater for leaks. In the quantitative analysis, two different positions of the camera were used to detect air leaks: the perpendicular camera (PP) and the parallel camera (PL) to the hand shutter roller. The first technique detected air leaks through the pressure difference and the second detected the colder locations as air leakage points. The results showed that in the quantitative analysis the PP scenario allowed for a more detailed discussion. In the qualitative analysis, the active thermography showed the results clearly.
Grinzato et al. (1998) employed a methodology that resulted in a discussion on the detection and evaluation of imperfections in buildings. In order to detect air leaks, quantitative infrared

thermography was applied on a solid wall with a crack in plaster, producing images before and after leaks for verification. It has been found that a thermal stimulus would be useful in detecting defects, be it solar irradiation, airflow, or radiant flux from an artificial source. The main disadvantage of the transient analysis is the considerable increase in processing time, hardly achieved without exclusive equipment.

3. 2 Thermal bridges

Thermal bridges are defined as "any and all building envelope in which the thermal resistance is significantly altered relative to the current envelope zone" (ISO, 2008 apud Castro, 2010). Changes in thermal resistance can be caused by full or partial penetration of the building envelope by materials with a different thermal conductivity, by varying their thickness and/or by a difference between internal and external areas, which occurs at wall/floor/ceiling junctions (Castro, 2010).

Asdrubali et al. (2012) performed a quantitative analysis, using infrared thermography, with a comparative experiment between an isolated and a non-isolated thermal bridge. The article proposes a methodology to perform a quantitative analysis of some types of thermal bridges, through simple thermographic surveys and subsequent analytical processing. The selected thermal bridge was given by the difference of the structure and the window glass. This wall was placed between 2 rooms, with temperature difference of 20ºC. Two analyzes were considered. The difference between the incidence factor of thermal bridges in relation to the two comparisons is 1.606 for the isolate, and 2.000 for the non-isolate. The influence factor calculated in situ is equal to 2.111 and the incidence factor of the thermal bridges calculated by the FLUENT program is equal to 1.262. Therefore, there is a reduction in thermal loss of the thermal bridge by about 40%. For a better performance, simulations were performed for a global heat loss in the winter. A heat loss of 4684W was found, 13.4% of which due to the thermal bridge. The correction of this thermal bridge would reduce the loss of heat to a value of 4307W and the incidence to 8.8%.

Bianchi et al. (2014) used a quantitative analysis of the infrared thermography in the field measurement with the objective of evaluating the energy losses through a 10m² building. The external walls, ceiling and floor were evaluated. For this, a comparison was made between 9 incident factors of calculated and identified thermal bridges. Overall the analysis shows that thermal bridges increase heat loss through building by 9%. The main results show that the procedure is a reliable tool to quantify the incidence of thermal bridges. O'Grady et al. (2017a and 2017b) applied a quantitative approach and showed the loss of heat by the thermal bridges through the temperature difference and the thermal transmittance. Grinzato et al. (1998) performed in their research experiments on three different types of walls: concrete, rock wool and concrete sandwich panel with a rod crossing the insulation layer. The purpose was to verify the behavior of the thermal bridge in the use of quantitative infrared thermography. See table 1 for more information.

Table 1. Summary of studies on thermal bridges

Author	Methodology	Main conclusions
Asdrubali, Baldinelli, Bianchi (2012)	Comparison of the results from quantitative infrared thermography with data obtained by heat flow meters and the results from a finite volume analysis.	The incidence factor of the thermal bridge correctly describes the dispersion degree of the singularity, quantifying the result of the thermal bridging correction.
Bianchi et al. (2014)	Use of quantitative infrared thermography to monitor the area to be studied.	Increased heat losses by approximately 9%.
O'Grady, Lechowska, Harte (2017a)	Use of quantitative infrared thermography on the study of thermal bridges through temperature difference and thermal transmission; experimental methodology proposed by the authors.	Wind impacts the loss of heat by the thermal bridge on the flat side. For thermal bridges with wind speeds between 0.5 m/s and 4 m/s, the relative deviation varied between + 5% and -9%.
O'Grady Lechowska, Harte (2017b)	Use of quantitative infrared thermography on the study of thermal bridges through temperature difference and thermal transmission; experimental methodology proposed by the author.	It works well in the laboratory. After being tested under real conditions, the methodology can be applied to any thermal bridge.

3.3 Thermal properties

Jorge (2011) shows that the walls are elements constructed to separate the environments. When the thermal energy is considered, it can be observed and quantified through the thermal properties. As any object, the walls have mechanical, chemical, and thermal properties. Among the thermal properties, the thermal transmittance, thermal diffusivity, thermal resistance, thermal capacity, heat transfer coefficient, and conductivity stand out.

Aversa et al. (2017) proposes the experimental study on the thermal behavior of opaque walls. They used active thermography stimulated with the objective of evaluating the effectiveness in a dynamic behavior for walls prototypes as well as verifying its success for application in situ. The authors compare a brick wall with a prototype wall with hemp fibers. It was clearly noted that hemp fibers contribute with the decrease factor (ratio between periodic thermal transmittance and thermal transmittance) from 0.87 to 0.92 for the walls with the fibers. In addition, the fibers increased the estimated time difference. It is concluded that different results were found. The next step should be measurement in situ.

Grinzato et al. (2002) used infrared thermography and calculated the thermal diffusivity of a brick sample from an old building in massive masonry, located in the Historical Arsenal of Venice. The authors performed six tests to aid in the mapping of humidity. First, a quantitative analysis was carried out with continuous monitoring and then a qualitative analysis mapped the moisture distribution due to the evaporation water cooling effect. The highest thermal diffusivity found was 5.2800×10^{7} m²/s and the lowest was $5.1288\ 10^{7}$ m²/s. The results showed a successful application to the mapping of moisture for the connection between the walls and the knowledge of the thermal diffusivity in bricks and plaster.

Robinson et al. (2017) aimed to study a simple and low-cost method to estimate the effective thermal diffusivity in structural walls of buildings. For this, they used infrared thermography as an experimental and low-cost method to calculate the thermal diffusivity of the concrete wall under

controlled conditions. The greatest difficulty found in this work was the control of heat loss through the lateral limits of the section, being calculated in situ, since in controlled environment, the lateral limits were isolated. This inexpensive experiment combined with a mathematical model resulted in a concrete diffusivity of 7.2 $m^2/s \pm 0.27$ m^2/s, which is sufficiently precise. For this experiment the lateral limits were isolated, but it was concluded that there is a great loss of heat for these limits.
Danielsky and Fröling (2015) investigated a quantitative methodology to analyze the thermal performance of building envelope in a non-stationary state condition, including two phases. They did experiments with wood wall exposed to external conditions to calculate the coefficient of heat transfer by convection; the value of 2.63 $W/(m^2K)$ was found. The external parameters used were wind speed, humidity, and snowfall. In addition, the heat flow through the wall was assumed to obtain stable state condition only sparsely and for short periods. HFM and infrared thermography were used for the calculation of both the heat transfer coefficient and conductivity. The results of 4% and 3%, respectively for the conductivity and the global transfer coefficient, were found compatible with differences between the methods, suggesting that the thermography method is more accurate.
Donatelli et al. (2016) used active thermography for two prototype walls under controlled environmental conditions and calculated the thermal transmittance in situ, comparing with the thermal transmittance calculated by a computer program. The results showed that the temperature measurements on software (FEA) are identical to those of a real wall, and that the procedure allows the measurement of temperature in prototype walls throughout the year without climatic interference.
O'Grady et al. (2017a) elaborated a study with an efficient, non-destructive method, based on an outside infrared thermographic survey, to determine the performance of the thermal bridge. For this, they compared the values of the thermal properties, mainly of the thermal transmittance, obtained by the quantitative infrared thermography, with the values of a hot box. A computer program was used to adjust the results. The thermal transmittance of these 2 methods with 3 different wind speeds was calculated and compared. For the thermal transmittance, the external convective coefficient was determined using the Jürges approximation and the Nusselt number. The results of this study demonstrated the suitability of both approaches for calculating the value of thermal transmittance; however, the Jürges approach is less time consuming. Infrared thermography is an effective tool for the determination of thermal transmittance.
O'Grady et al. (2017b) propose the use of a non-invasive and easy-to-use method to provide quantitative measurements of the actual thermal performance in the thermal bridge. They studied thermal properties and used quantitative infrared thermography in addition to an experimental program designed to quantify the thermal bridges and tested in a calibrated and controlled hot box. They used the calculation of the thermal transmittance and the temperature variation. Three samples were taken, sample 1 had the highest value found: 0.441 W/(mK) by hot box and 0.436 W/(mK) by thermography. It can be concluded that after being tested in the laboratory and presenting excellent results for the external conditions, the observations will be a challenge for the precision of the measurements by the infrared thermography.

3.4 Temperature measurement

Datcu et al. (2005) used quantitative infrared thermography to measure walls in order to improve the measurement of ambient temperature, both internal and external. The authors used an infrared mirror, which allows large measurements of surface temperature by infrared thermography under near-ambient conditions with greater accuracy. To validate the method, an experimental study was performed on a multilayer wall, which simulated an isolation pattern. The methodology addressed in the work allowed to quantify the average radiation around the object using a highly reflective and diffusive aluminum mirror. Then, two heat sources were used: one with 24 W/m^2 and the other

with 48 W/m^2. The results were compared to the results of the FLUENT program for the internal environment; as for the external environment, the wall temperature was compared with the window and the heat sink.
Lai et al. (2015) used quantitative passive infrared thermography to analyze the external wall of a skyscraper. Four concrete walls with different coatings were tested. The methodology was used when there were changes of heat flux and solar intensity. They used thermographic cameras and a computer program for analysis. Porras-Amores et al. (2013) used wall and surface measurements to locate the air temperature inside the building. The study focuses on the design of the system, its characterization, and quantification of its accuracy in different configurations. They applied a quantitative thermography to develop a precise measurement technique. An experiment was done in the garage and underground. Small variations in temperature were observed longitudinally.

4. CONCLUSION

As previously shown, infrared thermography may be used in combination with other methods for comparison of values and structures.
The method has a great applicability in the identification of air leak points. The use of active or passive thermography will generate different results. The active technique shows air leaks clearly. External stimuli aid in detection of air leaks, which may be highlighted as advantageous in the use of infrared thermography. Among the uncertainties identified were (1) the difficulties in the longer processing time of the transient analysis, which requires a unique equipment, and (2) the interpretation of the graph data and pressure versus temperature histograms. For future research, the comparison between the thermal images of passive infrared thermography and the active one in a quantitative approach would be very useful.
The advantages found in thermal bridges are simple and effective evaluations of their effect in the thermal energy behavior. Simplicity in the geometry of the building contributes to measured and calculated values. Given the uncertainty of energy consumption in the configuration with thermal bridges, the singular error due to the analysis of each thermal bridge must be taken into account. The incidence factor of the thermal bridge, analytically defined, depends on the internal temperature of both the air and the wall for the infrared thermographic camera to read. Among the applications on thermal bridges identified through the measurements, it should be highlighted the possibility of making interventions to improve the insulation. In addition, it is a useful method to analyze, refine and validate specially designed 3D simulation tools for the evaluation of energy performance in buildings, since they can evaluate thermal fields of internal and external walls.
Regarding the thermal properties, the thermal transmittance calculation was the most discussed topic, approaching several methods to calculate and compare the results. However, there are significant differences between the calculated thermal transmittance and the in-situ measurement. Moreover, some studies have emphasized that in situ measurement of thermal properties would be best performed in winter. A laboratory study indicates that the procedure implemented is aimed at measuring prototype walls throughout the year, without concern for climate change. The advantages of infrared thermography are the multidisciplinarity and integration of the results. Among the uncertainty, which was repeated in some studies, one may cite the way the applied methodology would behave or its result in normal conditions, that is, without laboratory control. The difficulties were quite specific, both regarding the use of infrared thermography in historical buildings due to several environmental factors, as well as the heat losses not controlled by the lateral limits of the section under test. there were no restrictions on applicability for this topic.
The approach of infrared thermography for temperature measurement was also used, which succeed as a comparative method. Infrared thermography has the advantage of displaying images with different identifications, to measure the surface temperature in a large area of an element under

construction. Thus, it provides more representative data in relation to point measurements. The difficulties were in the quantitative monitoring through conventional thermography. It presents problems in the measurement of surface temperature and air conditions inside the building. In addition, it can be applied to various surfaces.
In general, most of the work on infrared thermography approached quantitative analysis. The active approach is also widely explored. It was noticed that there is a multidisciplinarity between the topics covered, since some authors used infrared thermography to talk about more than one subject, enriching and complementing their studies.
Some authors used computer programs, mainly for the measurement of thermal properties, when there were experimental studies facilitating the comparison between experimental and theoretical values. The researches that used successful experiments with prototypes and controlled conditions contribute with important considerations that the next step would be the measurement in situ. Then, it is expected that infrared thermography will be increasingly exploited and bring better performances and energy savings in buildings.

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