Portuguese Building Stock Indoor Environmental Quality “in-Situ” Assessment

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ABSTRACT

Since the implementation of the Energy Performance of Building Directive, EPBD, in general, and the entrance into force of the respective Portuguese codes, in particular, buildings are requested to have better energy performances. However, during the buildings performance evaluation, energy issues should not be the only concerns since the indoor environmental quality is also as important. Thus, in this paper it is presented an “in-situ” evaluation of the Portuguese building stock regarding several parameters related to indoor environmental quality (IEQ), envelope thermal quality and operating conditions, natural illumination levels, thermal and acoustic comfort and indoor air quality. During the measurement campaign were evaluated several buildings that encompass different types of construction solutions, climatic zones and construction periods. One of the major objectives of this study was to support the development of building solutions that can optimize all the relevant parameters to the IEQ. Another important objective is the dissemination of the results through public entities, such as construction companies and design teams in order to influence the buildings projects to include other parameters than energy during the design process. Even though the measuring campaign is still in progress, there are already some preliminary results that show that, in average, the Portuguese buildings have a poor envelope thermal resistance, untreated thermal bridges, unsuitable natural illumination levels, several problems regarding high concentration of some pollutants like CO_2 or VOC and also problems with acoustic discomfort due to an inadequate sound insulation.

1. INTRODUCTION

Nowadays the improvement of the energy performance of the building stock is, without question, one of the biggest challenges that the construction sector has to face, as the European building stock is responsible for 33% of raw materials consumption, 33% of final energy consumption, and 50% of electricity use (Balaras, 2005). This issue is being tackled by an extensive public awareness to reduce the energy consumption, but mainly due to the implementation of more restrictive energy regulations.

From the energy performance perspective, the main building requirements are: increase the insulation thickness; reduce thermal bridges; and reduce the air changes. The latter parameter has to be thought carefully, since the reduction of air changes can decrease the intake of fresh outside air and thus increasing the consequent build-up of internally generated pollutants including fungi, microbial contamination, house dust mites, particulates and toxic air contaminants (chemicals) - gases, vapours and odours. However indoor air quality (IAQ) only has become an important occupational health and safety concern and a public and governmental awareness in the last decade.

The compatibilization of the buildings energy performance requirements with the indoor environmental quality (IEQ) – air quality, acoustic and thermal comfort, illumination – should be done in every building project, both for new and for existing buildings.

Portugal implemented in 2006, the National Building Energy and Indoor Air Quality Certification System, corresponding to the implementation of the Energy Performance of Building Directive, EPBD (EPBD, 2002), which imposes a minimum energy efficiency for the buildings and periodic IAQ audits for office buildings. However, in residential buildings, the only normative imposition related to IAQ is the obligation of a minimum air change rate of 0.6.

As 90% of the population spends about 90% of their time in enclosed spaces exposed to consistently higher concentrations of air pollutants than outdoors, which led to the increase of the allergies and asthma incidence rate, thus a good indoor air quality has a vital impact in human health.

Asthma affects of about 150 million persons worldwide and approximately 1 million in Portugal (10% of the population) and its incidence continues increasing, both in young as in elderly people (FPP, 2010). Several factors are thought to contribute to that, namely the atmospheric pollution by ozone and suspended particles, and the indoor pollution by the volatile organic compounds and tobacco smoke.

Indoor air pollution may have many sources in a dwelling, and indoor air quality can vary widely.

Particulates are seen by many as one of the most critical air pollutants, and some estimates have suggested that particulates are responsible for up to 10,000 premature deaths in the United Kingdom each year (UK DEFRADA, 2003).

An IAQ problem is suspected if people generally develop symptoms such as headaches, fatigue, shortness of breath, sneezing and coughing, dizziness, nausea, dryness and eye, nose, throat and skin irritation, hypersensitivity and allergies apparently linked to the time they spend in the building, within a few hours of starting being inside the building and feels better after leaving the building (Sick Building Syndrome - SBS). These symptoms may also be caused by other factors, and are not necessarily attributable to poor indoor air quality and it is rarely possible to prove these symptoms are related to any particular indoor air pollutant. In reality, the occupants are simultaneously exposed to a wide variety of indoor air contaminants and even low concentration levels can cause health problems if combined effects are considered.

As with any other work-related illness, not all people are affected. The more sensitive or more exposed people will experience symptoms sooner. Susceptibilities of individuals to the contaminants may vary and some may be sensitized with continued exposure. As indoor air quality deteriorates and/or the duration of exposure increases, more people tend to be affected and the symptoms tend to be more serious.

The thermal and acoustic, as well as the visual comfort, have also a significant effect, not only on the health and well-being, but also in productivity.

The IEQ is then an important factor in men well-being, health and productivity. The study of the combined effect of the different comfort stressors in the global comfort perceived by building occupants is thus very important to ensure a suitable IEQ. And as in residential buildings, inhabitants' behaviour can have also a significant impact on IEQ being, then, important its assessment.

Thus, in this paper it is presented an "in-situ" evaluation of the Portuguese building stock regarding several parameters related to indoor environmental quality, like thermal, acoustic and visual comfort and indoor air quality, but also the air change rate, the insulation level and existence of non-treated thermal bridges, related to the energy efficiency.

During the measurement campaign there were evaluated buildings that encompass different types of construction solutions, climatic zones and construction periods.

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2. OBJECTIVES

One of the major objectives of this study was to assess the indoor environmental conditions of the Portuguese buildings and to become aware of the main problems related to the IEQ, to support the development of building solutions that can optimize the energy efficiency and the IEQ.

Another important objective is the dissemination of the results through public entities, such as construction companies and design teams in order to influence the buildings projects in order to include other parameters than energy during the design process.

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3. METHODOLOGY

This paper presents the “in situ” assessment of the Indoor Environmental Quality and of the Energy Performance of several Portuguese buildings. The measurement campaign was divided in three major areas:

- Comfort conditions – Thermal comfort (air temperature, mean radiant temperature, relative humidity and air velocity), Acoustic comfort (A-weighted sound pressure level, L_{Aeq}), and daylighting conditions (Daylight factor, DF);
- IAQ conditions – measurement of the concentration of suspended particles, carbon dioxide, carbon monoxide, ozone, formaldehyde and total volatile organic compounds.
- Envelope thermal quality and characterization of the operating conditions of the buildings – Envelope U-Value, building air tightness (air change rate), and thermal bridges.

Also, a standard questionnaire was delivered to the inhabitants to also obtain a subjective assessment of the IEQ. The questionnaire was done according to the methodology defined on EN 15251 standard (EN 15251, 2007).

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A total of 16 buildings were assessed, until this time, selected to represent the typical Portuguese buildings. The buildings are from different decades of construction, have different locations and climatic zones and construction solutions.

Portugal is divided in three winter climatic zones (I1, I2, I3) and three summer climatic zones (V1, V2, V3) and is organized from less severe (index 1) to the most severe climate (index 3).

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3.1 Building Characteristics

As previously mentioned, the selected buildings intended to encompass a representative sample of the Portuguese buildings stock. These buildings were built in different years, have different typologies and construction solutions, as shown in Table 1 that may be considered representative.

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3.2 Measurement procedures

To measure “in situ” the parameters associated to the IEQ and energy efficiency they were followed the procedures defined in national and international standards (EN 7726, 1998; EN 7730, 2005; NP 1730, 1996; EN 15251, 2007; RSECE, 2006; NT-SCE-02, 2009; ASTM C1155, 1995).

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3.2.1 Thermal Comfort

The quantification of the thermal comfort was carried out applying the ASHRAE standards (ASHRAE 55, 2003) and ISO norms (ISO 7730, 2005), both recommending the measurement of the PPD – percentage of people dissatisfied – and the PMV – predicted mean value. According to ISO 7730, comfort conditions are reached whenever no more than 5% of people are dissatisfied and when the PMV value is zero, and according to ASHRAE 55 when the operative temperature, To, ranges from 20ºC to 25ºC and the relative humidity varies from 20% to 60% (ISO 7730, 2005; ASHRAE 55, 2003).

In order to obtain the required parameters for the calculation of PPD and PMV it was applied the measuring equipment Delta Ohm HD32.1, which monitors in parallel the following parameters:

1. Black bulb temperature;
2. Wind speed and direction;
3. Temperature and relative humidity;
4. Dry and wet bulb temperature.

3.2.2 Acoustic Comfort

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The assessment of the acoustic comfort was performed using the A-weighted sound pressure level, L_{Aeq}, according to the NP 1370 and the EN 15251 standards (NP 1730, 2006; EN 15251, 2007). The typical range of the A-weighted sound pressure level in residential buildings is 25 to 40 dB(A) for Living rooms and 20 to 35 dB(A) for Bedrooms (EN 15251, 2007).

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Table 1: Case studies building characteristics

Case Study	Typology	Year of Construction	City	Climatic Zone	Construction solution: Windows	Construction solution: Walls
CS1	Single family house	1989	Braga	I2, V2	Single glazing with aluminium frame	Single pane CMU
CS2	Single family house	1985	Braga	I2, V2	Single glazing with wood frame	Double pane brick masonry
CS3	Single family house	1982	Fafe	I2, V2	Double glazing with aluminium frame Double glazing with aluminium frame	Double pane brick masonry
CS4	Single family house	1982	Guarda	I3, V1	Single glazing with aluminium frame	Double pane brick masonry with injected PUR in the air gap
CS5	Dwelling	2002	Guimarães	I2, V2	Double glazing with aluminium frame	Double pane brick masonry with XPS in the air gap
CS6	Dwelling	2005	Guimarães	I2, V2	Double glazing with aluminium frame	Double pane masonry – stone + brick
CS7	Dwelling	1960	Porto	I1, V2	Single glazing with wood frame	Double pane brick masonry
CS8	Dwelling	1990	Porto	I1, V2	Single glazing with aluminium frame	Double pane brick masonry
CS9	Dwelling	2007	Maia	I1, V2	Double glazing with aluminium frame	Double pane brick masonry with XPS in the air gap
CS10	Dwelling	1995	Viseu	I2, V2	Double glazing with PVC frame	Double pane brick masonry with XPS in the air gap
CS11	Dwelling	1999	Guimarães	I2, V2	Double glazing with aluminium frame	Double pane brick masonry with XPS in the air gap
CS12	Single family house	1998	Guimarães	I2, V2	Double glazing with aluminium frame	Double pane brick masonry with XPS in the air gap
CS13	Single family house	1993	Guimarães	I2, V2	Double glazing with aluminium frame	Double pane brick masonry
CS14	Dwelling	1976	Guimarães	I2, V2	Single glazing with aluminium frame	Double pane brick masonry
CS15	Dwelling	1977	Guimarães	I2, V2	Single glazing with aluminium frame	Double pane brick masonry
CS16	Dwelling	2000	Guimarães	I2, V2	Double glazing with aluminium frame	Double pane brick masonry with XPS in the air gap

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3.2.3 Visual comfort

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The energy spent on lighting in buildings has an important influence on the global energy balance hence the Portuguese campaign to replace incandescent bulbs by fluorescent ones was very relevant.

Thus, it is also important the effective and efficient use of natural lighting to minimize the use of artificial lighting and increase the visual comfort.

A widespread parameter used to evaluate the natural lighting in buildings and thus the visual comfort, is the Daylight factor (DF). This parameter can be defined as the ratio between the illuminance at a certain point in the indoor space and the outside horizontal illuminance for a standard overcast sky. Some recommended values for this parameter are presented in Table 2.

The illuminance was measured with a luxmeter placed outside the analyzed space and with several luxmeters placed inside the room in order to create a 1 m spacing mesh of sensors. Proceeding with this study there were obtained the average DF of the several case studies for two situations: windows with curtains and with other shading devices not activated; and windows with curtains and with the other shading devices 70% activated, in accordance with the Portuguese thermal legislation methodology (RCCTE, 2006).

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Table 2: Recommended DF values for different space types

Space	**DF** (%)	
	Average	Minimum
Living room	1.5	0.5
Bedroom	1.0	0.3
Kitchen	2.0	0.6

Source: A Green Vitruvius (European Commission, 1999)

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3.2.4 Indoor Air Quality (IAQ)

The new thermal regulations in Portugal turned mandatory to carry out IAQ audits for office buildings but not for residential buildings. Therefore, for the present study, targeted to residential buildings, a similar methodology was followed for both physical and chemical pollutants (RSECE, 2006; NT-SCE-02, 2009) that were measured with portable measuring equipments. Table 3 lists the maximum reference concentrations of each pollutant according to the Portuguese regulation (RSECE, 2006; NT-SCE-02, 2009).

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Table 3: Maximum reference concentration of pollutants inside buildings (RSECE, 2006; NT-SCE-02, 2009)

Type of pollutants	**Parameter**	Maximum reference concentration	
		mg/m^3	ppm
Physical and Chemical	Suspended particles (PM_{10})	0.15	-
	Carbon Dioxide (CO_2)	1800	984
	Carbon Monoxide (CO)	12.5	10,7
	Ozone (O_3)	0.2	0,10
	Formaldehyde (CHOH)	0.1	0,08
	Volatile Organic Compounds (VOC)	0.6	0.26 (isobutylene) 0.16 (toluene)
	Radon, Rn	$400\ Bq/m^3$	

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3.2.5 Air tightness

The air tightness of the building is also an important indicator of the IAQ and of the energy performance of a building and it can be obtained by the building Air Changes Rate (ACH). If the building is naturally ventilated this parameter can be estimated using the methodology presented on the Portuguese residential building thermal code (RCCTE, 2006). However, in existing buildings, a more accurate ACH value can be obtained using measuring equipment such as the blower-door, which will pressurize/depressurize the building, measuring the air flow that enters/exits the dwelling while the pressure stabilizes, thus allowing the measurement of the air leak.

3.2.6 U-Value

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The thermal insulation of the buildings envelope affects the thermal comfort of their inhabitants (influencing the surface temperature and thus the thermal exchanges by radiation between the occupants and the surfaces) and it is also one of the most important indicators of the energy performance of a building. This parameter may be obtained using the publication ITE 50 – U-Values of Building Envelope Elements (Pina dos Santos and Matias, 2006), however, many existing buildings do not have, or have incorrect information, about the constitution of the walls. Thus, to determine this parameter it was applied the procedure defined on ASTM C1155 - 95 standard (ASTM C1155, 1995) that implies the measurement of the heat flow through the walls, as well as the measurement of interior and exterior surface temperatures.

3.2.7 Thermal bridges

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Thermal bridges are envelope areas that allow higher heat fluxes than those in the regular zone, and therefore they have a significant influence on the buildings overall thermal performance and emergence of pathologies related to moisture and mold. In the Portuguese residential building thermal code (RCCTE, 2006) it is presented a methodology to quantify the thermal bridges effect in several situations. However, since a significant number of the existing buildings do not have the necessaries plans and sections for a thorough identification of all the existing thermal bridges, they can only be identified using adequate measuring instruments, such as the infrared cameras.

4. RESULTS

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The results obtained through the measurement campaigns performed on several case studies are presented below according to the type of analysis done.

4.1 Thermal Comfort

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The assessment of the thermal comfort conditions was carried out through the calculation of the PPD – percentage of people dissatisfied – and the PMV – predicted mean value, measuring the air temperature and relative humidity, the black bulb temperature and the wind speed.

The measurements were performed during winter and most part of the dwellings did not have active heating systems, some had fireplaces and others had radiators that were only turned on when the occupants were in the room. In these circumstances, comfort conditions were not reached for the living room of some dwellings as Table 4 and Figure 1 show. According to ISO 7730, comfort conditions are reached whenever no more than 5% of people are dissatisfied and when the PMV value is zero (ISO 7730, 2005; ASHRAE 55, 2003).

Table 4: PMV and PPD for the living room of some dwellings

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Dwelling	PMV	PPD (%)
CS3 - Ground floor	-0.7	15.3
CS3 - 1st floor	-1.0	26.1
CS11	-0.5	10.2
CS12	-0.5	10.2
CS13	-0.1	5.2
CS14	-0.9	22.1
CS15	0.0	5.0
CS16	-0.4	8.3

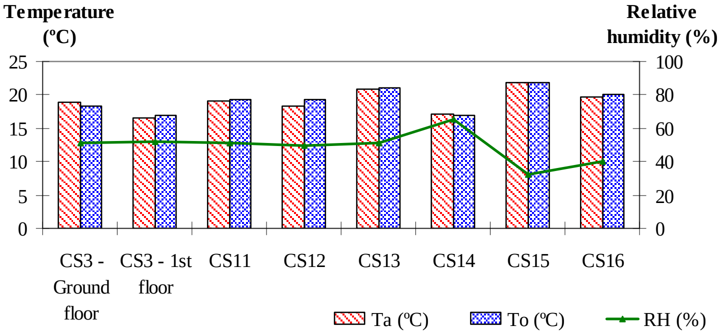

Figure 1: Mean air temperature (Ta), Operative temperature (To) and relative humidity (RH) of the living room of some dwellings

The living rooms with higher temperatures have a radiator (CS3 – groundfloor and CS16), that only works for short periods when the occupants are in the room, or have a fireplace (CS13 and CS15).

The comfort conditions varies from neutral (PMV=0) in CS15 to slightly cold in CS3 – 1st floor (PMV= -1.0). In most of the cases, the air temperature is close to the reference temperature defined in the Portuguese thermal code (RCCTE, 2006), 20ºC in winter, but due to the low surface temperatures, the heat exchanges by radiation are high and the occupants didn't feel comfortable, considering the temperature just unacceptable.

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4.2 Acoustic Comfort

The assessment of the acoustic comfort was performed using the A-weighted sound pressure level, L_{Aeq}. The measurements were done during the day. In Figure 2 are shown the results performed in the living room and in the bedroom. The main source of noise is traffic, as the buildings are located near heavy traffic roads. Due to that, the measured values are higher than the recommended ones (30 to 40 dB(A) for living rooms and 20 to 35 dB(A) for bedrooms). The measured values range from 35 dB(A) to 51 dB(A) in the bedrooms and from 35 dB(A) to 61dB(A) in the living rooms.

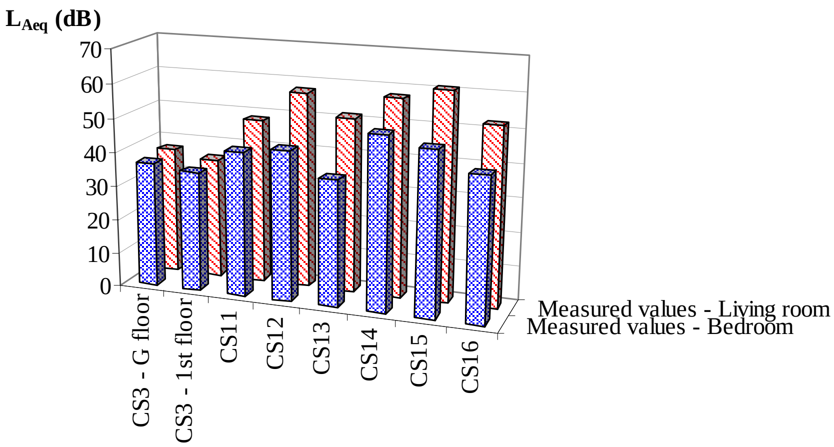

Figure 2: A-weighted sound pressure level, L_{Aeq} of the living room and of the bedroom of some dwellings

In general the occupants didn't complaint about the noise, except when the circulation of buses and trucks was significant and when the windows were open.

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4.3 Visual comfort

The evaluation of the natural lighting potential of the buildings was done, as mentioned, calculating the daylight factor, DF. The average DF obtained for the several case studies is shown in Figure 3 for the two situations studied: windows with curtains and with the other shading devices not activated; and windows with curtains and with the other shading devices 70% activated.

In general, the reference values are not fulfilled even for windows with curtains but with the other shading devices not activated. But, the daylight conditions in bedrooms and in living rooms should not be a major concern because, for the Portuguese luminous climate, the recommended external minimum illuminance considered for an overcast sky is exceeded in more than 90% of the time during the year (Santos, 2002).

The kitchens are the compartments that present the lower daylight factor, especially when the laundry is placed between the kitchen and the exterior facade as usually happens in Portuguese buildings.

The geometry of the compartment, the area of the window and its location, in general, are the reasons that have the major impact on the visual comfort inside the buildings.

The occupants didn't complain about the visual conditions of the rooms as they change the position of the curtains whenever needed. They also said that when the lighting levels were bellow their their needs they turned on the artificial light.

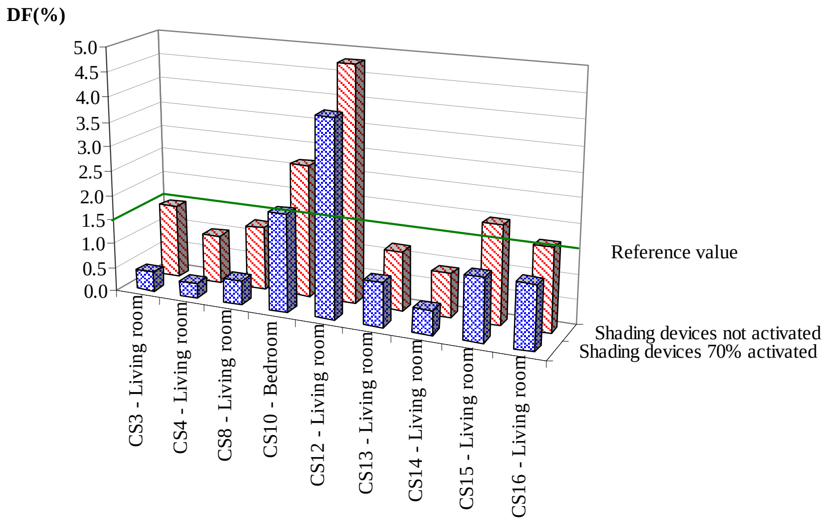

Figure 3: Daylight factor for some rooms of the different case studies

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4.4 Indoor Air Quality (IAQ)

The Indoor Air Quality (IAQ) was assessed through the measurement of the concentration of physical pollutants (CO, CO_2, CHOH, VOC, O_3, PM_{10}, Rn). Figure 4 shows the results of the IAQ measurements for one building. The presence of microbiological contaminants was not accessed.

The main IAQ problems detected were related with CO_2 concentration, due to human occupation, and with small concentrations of carbon monoxide (less than 1/10 of the maximum reference concentration) in kitchens (due to gas-stoves and gas water-heaters), in living rooms (that had open fireplaces) and in living and bedrooms when there were smokers in the dwellings. Associated to the presence of the fireplaces and smokers was also detected the presence of suspended particles in higher concentrations than in the other dwellings (0.05 mg/m^3 in average). The concentration of these three pollutants is also associated to the outdoors concentrations as the buildings are located near heavy traffic circulation roads.

The concentrations of formaldehyde (CHOH) and volatile organic compounds (VOC) detected were not very high but in bedrooms, with perfumes, and in living rooms, with scent candles, the CHOH and VOC concentrations reached values close to the maximum reference values. When measured after the house cleaning the maximum reference values were exceeded but decreased rapidly.

There was not detected the presence of ozone and the radon concentrations measured were in general not high.

The occupants considered the air quality just acceptable and reported the existence of a weak odour. The main complains of the occupants were related to the presence of VOC.

In general the occupants did not open the windows to ventilate the buildings because the outside temperature was low and the kitchen exhaustion system was only turned on in short periods due to the noise.

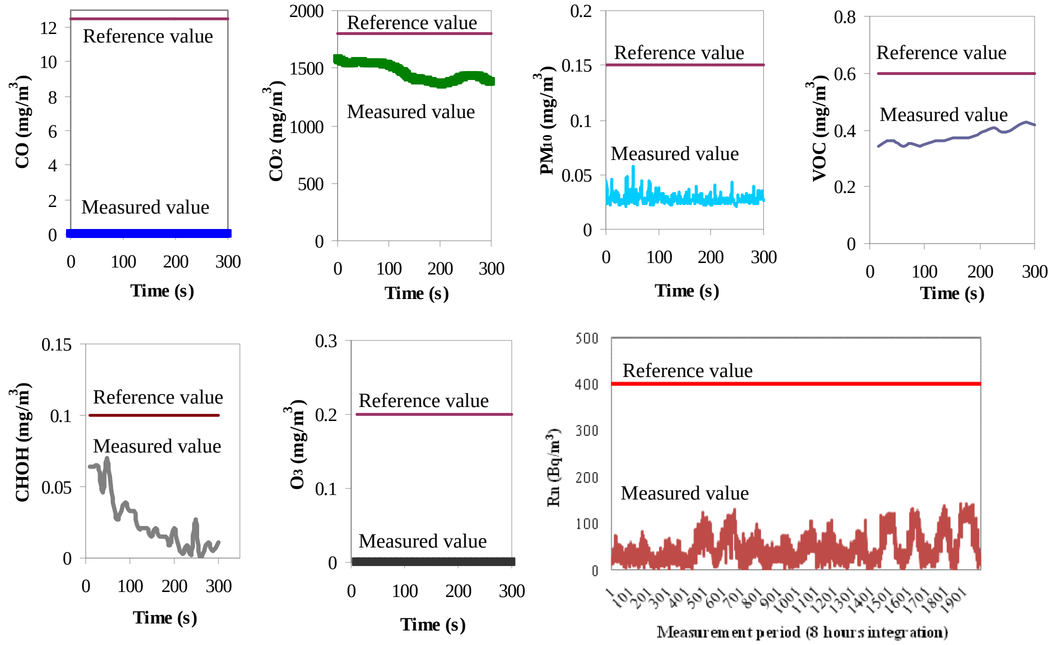

Figure 4: Pollutants concentration and maximum reference values in the living room of one of the dwellings

4.5 Air tightness

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Figure 5 shows the measured values of the number of air changes per hour (ACH) of the different case studies in analysis as well as the ACH values obtained following the methodology described in the Portuguese thermal code and also the minimum allowed ACH value (0.6h^{-1}).

The results show a good approximation between the measured and the calculated ACH values. However, the values are quite high and will also result in substantial heat losses. Thus, interventions at this level are also essential to increase the energy performance, mainly through the use of mechanical ventilation systems with heat recovery, which will be the most efficient way to achieve the optimum values for the air change rates in residential buildings, with minimum waste of energy.

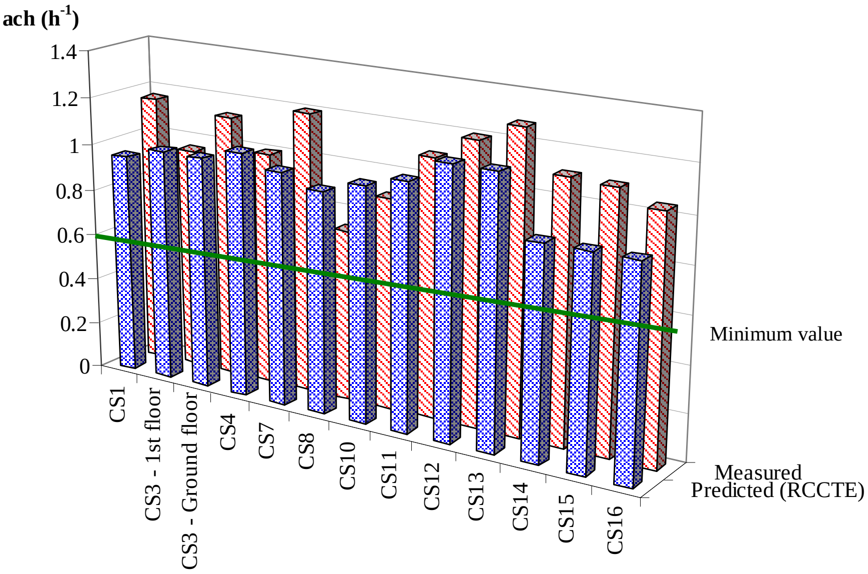

Figure 5: ACH of the different case studies

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4.6 U-Value

Figure 6 shows the measured U-Values for the envelope walls of the case studies and the ones obtained with the publication ITE 50 – U-Values of Building Envelope Elements and those recommended by the thermal code. The recommended U-value is 0.6 W/m^2.ºC, except for CS3 and CS4, located in a more severe climate, where the recommended value is 0.5 W/m^2.ºC.

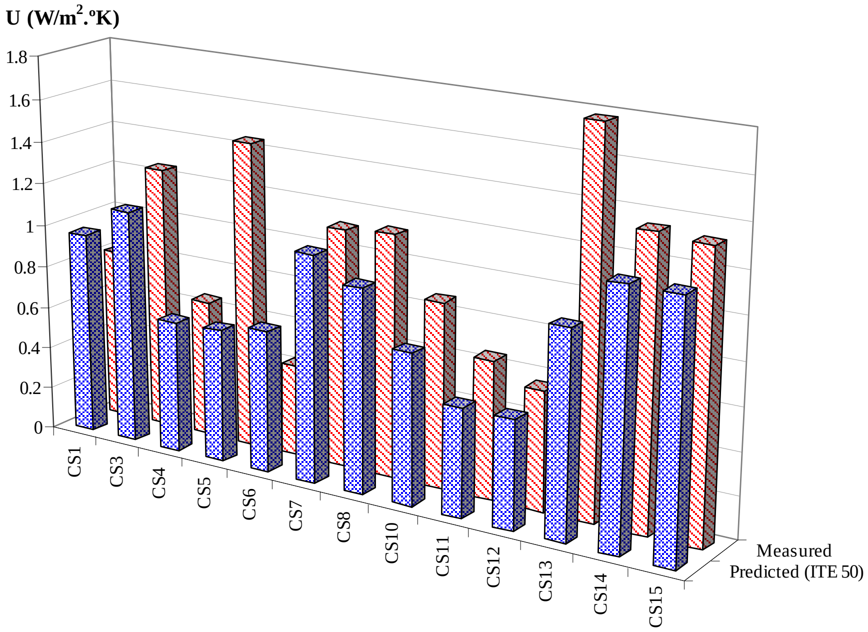

Figure 6: U-Value of the exterior walls for the different case studies

Through the analysis of the results it was possible to conclude that, in most of the cases, the measured U-values are slightly higher than those predicted by ITE 50 for the same walls and, in general, the U-Values are much higher than those recommended by actual Portuguese legislation, resulting in excessive heat losses through the envelope. Again it highlights the need of increasing significantly the insulation level of the envelope, being this one of the priority actions in refurbishment in order to achieve energy efficient and comfortable buildings.

4.7 Thermal bridges

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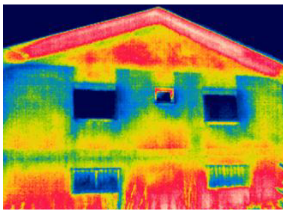
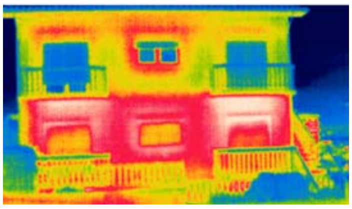
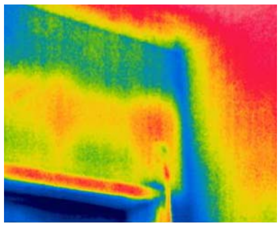
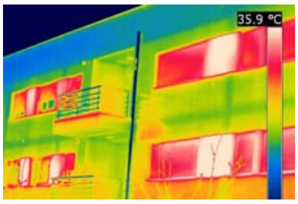
Figure 7 presents a set of thermographic pictures of some of the cases studied. Using this technique it is possible to identify the constructive structure of the building, the thermal bridges and their critical areas where there are higher heat losses, and thus the envelope zones that require priority treatment in rehabilitation. The pictures show that the pillars, beams, slabs and also the roller-shutter boxes are the main thermal bridges.

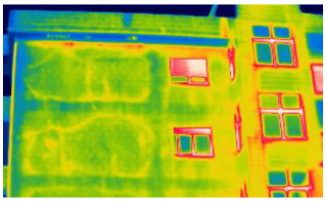

CS1


CS3


CS7



CS9


CS10 – outside view

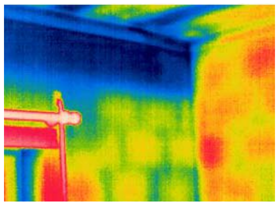

CS10 – inside view

Figure 7: Thermal Bridges of the different case studies

For example, observing the images of CS10, it is possible to clearly identify the structure of the building. These thermal bridges have a significant influence on the buildings thermal balance and are responsible for the most frequent pathologies observed in Portuguese buildings like moister stains. To prevent this pathology, insulation is needed that can be applied either in the exterior or in the interior side of the external façade.

5. CONCLUSIONS

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This paper presents the “in situ” assessment of the envelopes thermal quality and operating conditions as well as the Indoor Environmental Quality of several Portuguese buildings. The measurement campaign was divided in three major areas: characterization of the envelope and operating conditions of the buildings, comfort (thermal, acoustic, visual) and Indoor Air Quality.

With the envelope thermal quality and operating conditions measurements campaign carried out, it was possible to identify some of the most critical problems of the Portuguese building stock, the ones that need particular attention during the design phase and during the rehabilitation interventions.

The measurement campaign confirmed the necessity of drastically reducing the envelope U-values, using higher insulation levels, both in existing and in new buildings, since the current values are, in general, very close to the maximum allowed values by the Portuguese legislation which are significantly higher than the recommended ones. It is also mandatory to correct the many thermal bridges found in the buildings envelope, using a continuous external thermal insulation layer whenever possible, or reinforcing locally the insulation level by the inside.

It is also important to reduce the uncontrolled infiltrations through the envelope, using more airtight window frames and doors, with adjustable air inlets to ensure an adequate air change rate and, if necessary, using mechanical ventilation systems with heat recovery units. However, the control of the air change rate must be done very carefully in order to ensure the indoor air quality, since, even with high air change rates, there were detected high concentrations of some pollutants like carbon monoxide, volatile organic compounds and formaldehyde, and also small concentrations of carbon monoxide, associated to the use of gas stoves, gas water-heaters and fireplaces.

Improving the quality of the window frames and doors and increasing the insulation level of the façades, will also have a favourable effect on the acoustic and thermal comfort. However, to achieve the comfort conditions it is necessary to install heating systems, carefully selected to ensure energy efficiency.

With the daylight availability analysis, it was possible to conclude that if the shading devices are not activated, the DF values are close to the recommended ones, in living rooms and in bedrooms, but in kitchens, especially when the laundry is placed between the kitchen and the exterior facade, the daylight conditions are not adequate to the tasks that are usually performed in that space.

Finally it is important to enhance that the occupants' behaviour has a significant effect on the indoor environmental quality and energy efficiency of the buildings and must be taken into consideration during design phase and in rehabilitation processes. They should be informed of the correct way of using the buildings to ensure the comfort conditions, indoor air quality and energy efficiency. The existence of a "building manual" is a way of achieving this purpose.

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