



Experimental analysis of building airtightness in traditional residential Portuguese buildings



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ABSTRACT

It is currently recognized that the residential building sector is one of the largest energy consumers in the world. The energy crisis of the 1970s was important for drawing attention to the subject of energy consumption and the necessity to save energy. The airtightness of buildings is an important factor affecting a building's energy consumption and also energy-saving potential. On the other hand, the ventilation rate has also a significant effect on indoor air quality and is assumed to be an essential criterion of a building's performance. However, most of the existing research in this area has been developed in cold climates and there is a research gap with regard to countries in warmer climates such as those close to the Mediterranean Sea. Therefore, this research aimed to study the airtightness and ventilation rate of existing buildings by employing in-situ measurements.

In-situ measurements were achieved using the fan pressurization test (Blower Door Test) method.

According to the selected case studies, the results of the measurements indicate a correlation between building typology, airtightness, and ventilation rate.

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1. Introduction

In 2015, the building sector was responsible for 40% of energy consumption and 60% of electricity consumption in the EU [1]. Heating and ventilation systems account for the largest part of this total energy consumption in the construction sector [2]. Over the years, and in order to have better energy saving in existing buildings, suitable renovation actions have been recommended such as applying better insulation layers and sealing against air leakages [3]. Air leakage in buildings is an important manner to improve energy efficiency and thermal comfort. Moreover, it can also reduce carbon emissions [4]. Ventilation is one of the ways in which to improve indoor air quality (IAQ) and provide healthy air through diluting the pollutants from the building [5]. This can be achieved in two ways: mechanical ventilation and natural ventilation. Uncontrolled air leakage (i.e. air tightness) through a building envelope increases the energy consumption which has an effect on the ventilation rate.

The ventilation rate is calculated by determining the internal pressure of the house and balances the mass flow in and out [6]. Based on a study by Eskola (2007) [7], building air leakage is related to envelope airtightness and the pressure difference over the building envelope. Therefore, it is necessary and important to strike a balance between the ventilation rate and airtightness rate of the building. Air leakage from the building envelope is associated with three main categories: the first is the building typology, material, components as well as age and maintenance of the building [8]. The second is the exterior climate, including air velocity and temperature difference. The last category deals with the interaction between the building and the environment (e.g. wind direction, exposure, and shielding) [9].

According to the research carried out by Sinnott (2011) [10], airtightness means “the flow through the building envelope as a function of the pressure across it and thus leakage testing is based on the fundamental mechanics of airflow”. Moreover, airtightness illustrates the resistance of the building envelope to the airflow and is influenced by the different airflow paths in the building (2011) [11]. These paths are classified into two different sectors of interstitial spaces (spaces between floors and walls) and building envelope. Therefore, airtightness measurements can be used to provide air leakage parameters for models that analyze natural infiltration

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[12]. Airtightness and air leakage in buildings appear due to different architectural design features (like the location of windows, balconies, elevators, and materials), the existence of cracks and leakages in the construction and also the connections between floors. Therefore, in order to have an energy efficient ventilation system, appropriate attention should be devoted to the building's airtightness [13].

Infiltration, as one of the elements in this research area, can be defined as the penetration of air through the building construction, building components, cracks which these unintentional openings (cracks) in the building cause the pressure difference of the wind and/or temperature driven [14,13]. Since an airtight building has less airflow transfer through the envelope, it is important to plan intervention and retrofit actions so that the retrofitted building does not become too tight and favor condensation and mold growth [15]. Predicting the infiltration rate of a building is difficult, and different countries have different regulations in this regard. The Canadian Building Code [16] and the Swedish Building Code [17] indicate that ventilation rates should be different in each space due to its application. Therefore, they use a multi-zone regulation method for the infiltration rate. Most existing buildings are over-ventilated, especially by infiltrations [18], while the acceptable rate for buildings has been determined to be 0.35 ach based on the ASHRAE standards [19]. In Portugal, according to REH [20], the rate of air-change per hour is 0.4 ach in the winter period and 0.6 ach in the summer period.

As a result, most existing buildings have interesting natural ventilation technology and infiltration is one of the fundamental sources of ventilation in these buildings [21]. Air infiltration is normally a neglected factor in the design of natural ventilation, although more attention should be devoted to it. There is a wide domain of research concerning building airtightness and numerous measurement techniques used to monitor it. However, most of them have been investigated in cold climate conditions such as those in Canada [22], the USA [23–25], and Europe (especially in Northern Europe) [26–28].

Most of these studies on building airtightness have investigated the effect of different factors such as construction properties, dwelling age, building typology, building design, specification, testing process, climate condition, season, and building material properties over the airtightness idea.

One of the most important studies was carried out by Papaglastra (2009) [29] who investigated the airtightness of buildings in different European countries. According to this study, the value of

the rate of air change at a pressure of 50pa (n_{50}) varies from 1.09 (h^{-1}) in Norway to 6.38 (h^{-1}) in Greece. The results of the research show that Norwegian buildings are “tighter” due to the cold climate in Norway and that buildings in Greece have more “leakage” (see Table 1).

Additionally, Pinto et al. (2011) have also measured the air permeability of a dwelling and its components in Portuguese housing stock [30]. The research showed that the rate of air permeability has a wide range due to the building components such as windows, roller shutter boxes, main entrance door, etc.

Nowadays, the energy potential of buildings is extremely important. Due to the observed gap in the literature regarding air filtration and airtightness in buildings in areas close to the Mediterranean, we aimed to study the infiltration rate, air permeability and also air change rate in buildings in Portugal.

This study aimed to answer the following questions:

- What is the air change rate in the selected buildings?
- What is the minimum air change rate to maintain good air quality and acceptable thermal performance?

Based on the results obtained, it is possible to find a relation between building properties and air change and infiltration rate.

2. Materials and methodology

Generally, there are two different approaches employed to study/analyze ventilation and air infiltration, namely, simulations and measurements. Since measurement methods involve high costs, most researchers use simulations. For this reason, the number of researchers using measurement methods is decreasing, even though the results are more realistic and reliable than those obtained from simulations. There are two methods employed to measure air leakage: tracer gas and fan pressurization methods/Blower Door Test (BDT). The former is more accurate despite the fact that it requires well-trained experts and also higher costs. The latter method is comparatively inexpensive, simpler and more popular than the former.

BDT is the most commonly used technique to measure the air leakage of a building envelope and was first used in Sweden (1977). Today, standardized test procedures for performing BDT are described in the European Standard EN-13829 [31], which is implemented in most European countries, and will also be used in

Table 1
Summary of n_{50} in 7 European countries [29].

Country	Sources	Types of building tested	Mean n_{50}	Min n_{50}	Max n_{50}	St. dev	St. dev. mean	median
Belgium	Belgium building research institute (BBRI)	18houses, 1 industry, 2 offices	4.99	0.5	22.5	2.1	1.02	3.70
Greece	National and Kapodistrian university of Athens, group of building environment research (NKUA)	39 houses	6.38	1.87	13.1	3.15	0.49	2.64
The Netherlands	Netherland organization for applied scientific research (TNO)	110 houses, 108 apartments	1.48	0.06	6.20	1.03	0.70	1.26
France	Centre de Etudes Techniques de 1 Equipmet de Lyon (CETE de Lyon)	327 houses, 242 apartments, 10 industries, 5 offices, 4 hotels, 5 information, 7 multiple use halls, 4 sports, 4 whole apartment building, 46 others	3.38	0.04	60.96	4.42	1.31	2.55
Norway	Striftelsen SINTEF (Tampere university of Technology)	17 houses	1.09	0.17	2.79	0.86	0.79	0.74
Finland	Department of Civil Eng. Helsinki university of technology, HVAC laboratory	70 houses, 58 apartments	2.54	0.3	16.2	2.33	0.92	2.05
Germany	Blower Door GmbH Energia und Umweltzentrum (EUZ)	13houses, 3 industries, 2 offices, 2 homes for elderly people, 2 shops, 1 hospital, 1 school, 1 library, 2 others.	1.21	0.01	4.70	1.07	0.88	1.00

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