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# Relationships between building characteristics and airtightness of Dutch dwellings

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## Abstract

Building airtightness is an important parameter to improve the energy efficiency of buildings. By means of a literature study, as well as the use of empirical data on the specific leakage of more than 300 dwellings, this paper provides insights in the relationships between building airtightness and eight individual variables. A total leakage construct was one of the adopted variables to distinguish cases. Correlational analyses, as well as ANOVA tests show that year of construction, total leakage, roof type, construction method and construction typology have significant relationships with building airtightness, but regression analysis suggests that only the year of construction and the total leakage influence the airtightness. Two-way ANOVA tests show that both have a significant interaction on building airtightness, in terms of specific leakage rate. Considering that the year of construction is related to multiple other variables influencing the airtightness of a building and the number of individual leakages and their sizes can only be assessed after completion, both variables cannot yet help us to estimate the specific air leakage of an object in advance.

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*Keywords:* Building airtightness; Specific leakage rate; Air leakage; Building characteristics, Dwellings

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## 1. Introduction

Airtightness is considered as an important element in improving the energy efficiency of buildings, as well as their comfort. In terms of an air permeability level, building airtightness has been included in building regulations in multiple countries. European legislation on the energy performance of buildings (Energy Performance Building Directive – EPBD) states that member states must calculate the energy efficiency of a building in their countries [1]. The ripple effect of this, for example, is evident in the Dutch Building Code [2], which among others requires residential buildings to comply with a certain level of energy performance and a given limit of total airflow. The term "airtightness" pertains to the intensity of the uncontrolled airflow through the building envelope as a result of pressure differences between interior and exterior air [3]. An improved building airtightness leads to lower air infiltration, reducing the cooling load and heat losses of buildings [4]. Multiple scholars have reflected on the importance of building airtightness with regards to energy efficiency [5, 6], thermal comfort and indoor air quality [7–10]. Ensuring a certain minimum level of building airtightness is also essential for the effectiveness of air-to-air heat recovery installed in ventilation systems [11, 12], affecting again the building's energy efficiency.

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However, when designing buildings it is still unclear what leakage can be expected. To ensure that a maximum uncontrolled air flow or minimum airtightness are met, only after completion a blower door test can be conducted to measure the air flow leaking into or out of the assigned building. Many studies have attempted to predict airtightness prior to a blower door test, even though, Relander [13] concluded that no such model can substantially replace the blower door test. However, predicting airtightness is a fruitful effort to achieve a desired level of building airtightness, especially in the case of Dutch regulations, that require a certain value of $q_{v10}$ or $w_{10}$ to calculate the Energy Performance Coefficient (EPC).

Therefore, this research aims at finding the relationships of building airtightness and characteristics related to the design or construction process of the building, which further can contribute at developing a model that can estimate building airtightness on the basis of characteristics. A literature study was conducted 1) to explore what definitions on infiltration, airtightness and unwanted ventilation are in use; 2) to find what factors influencing the airtightnes are already known and 3) to get insights into how do these factors influence the building. The empirical material for our study was derived from a database that contains blower door test reports of more than 300 Dutch dwellings. However, using the original blower door test reports we were also able to add data to the database by means of observed air leakages as captured by (infrared) pictures.

This paper proceeds as follows. Section 2 addresses our theoretical framework in which airtightness is being defined, air leakage measurements are being explained and variables influencing building airtightness are listed. Section 3 provides the research methodology. Section 4 presents the results, while Section 5 continues on the analysis of the data by means of correlation analysis, analysis of variance and regression analysis. Section 6 provides the discussion, before we finish with a conclusion in Section 7 and recommendations in Section 8.

**Nomenclature**

| | | |
|---|---|---|
| $V_m$ | Measured air flow rate | $m^3/h$ |
| $V_{env}$ | Air flow rate via building envelope | $m^3/h$ |
| $V_L$ | Air leakage rate | $m^3/h$ |
| $V_{50}$ | Air leakage rate at 50 Pa | $m^3/h$ |
| $C_{env}$ | Air flow coefficient | $m^3/(h\cdot Pa_n)$ |
| $C_L$ | Air leakage coefficient | $m^3/(h\cdot Pa_n)$ |
| $p$ | Pressure | Pa |
| $\Delta p$ | Induced pressure difference | Pa |
| $n$ | Air flow exponent | - |
| $A_E$ | Envelope area | $m^2$ |
| $A_F$ | Floor area | $m^2$ |
| $v$ | Internal building volume | $m^3$ |
| $N_{50}$ | Air change rate at 50 Pa | $h^{-1}$ |
| $Q_{50}$ | Air permeability at 50 Pa | $dm^3/(s\cdot m^2)$ |
| $w_{50}$ | Specific leakage at 50 Pa | $dm^3/(s\cdot m_2)$ |

## 2. Theoretical framework

This section introduces difference terms used to address building airtightness and variables related to building airtightness.

### *2.1. Defining building airtightness*

There are three quantities commonly used to express the airtightness of a building, namely in relation to its 1) envelope area, 2) building volume or 3) floor area [10, 19, 20]. Their usage depends on the context by means of regulation, location or purpose. Consequently and in line with NEN-EN 13829 [16], there are three different terms in use to address building airtightness.

Most studies seem to use the term *air permeability* ($m^3/h\cdot m^2$) as the target of their research [4, 8, 16, 19, 23, 24]. Air permeability is the capability of a surface to let air pass through – in this case, the capability of the building envelope itself. The lower the air permeability is, the more airtight a building is. Normalization on the basis of envelope area is particularly useful if one wants to define the quality of the envelope as a uniform “fabric” [10]. The terms air permeability and airtightness are sometimes interchangeably used, but they are actually reciprocal.

When the building volume is known and used to normalize measurement data, the result is normally expressed in air changes per hour at the reference pressure. This is the so called *air change rate* ($h^{-1}$). The air change rate is the second most common airtightness metric reported in the literature [7, 21, 22]. Since infiltration and ventilation rates are often quoted in air changes per hour, the air change rate is by many regarded as a convenient expression for this phenomenon.

A *specific leakage rate* ($m^3/h\cdot m^2$) at a certain pressure difference related to floor area, can be compared to the other two normalizations relatively easy be determined. One needs to take only two dimensions into account instead of three. Since the

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