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Review

Factors influencing airtightness and airtightness predictive models: A literature review

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ABSTRACT

In recent decades there has been a growing awareness regarding energy consumption in buildings. Unfortunately, at a time when all building actors should get involved in the challenge to reduce energy consumption, designers cannot rely on effective tools to help them in their decision making process concerning airtightness. This literature review allows the identification of two important issues: new airtightness predictive models are complex to develop and existing airtightness predictive models do not meet the needs of designers and contractors. This paper is divided into three main parts in addition to the introduction and the conclusion. The first part deals with the key concepts of infiltration and airtightness, the second part with influencing factors and the third part with airtightness predictive models. These different chapters highlight a need for standardization regarding the metrics used for data presentation, parameters definition and statistical quantification. The lack of standardization hinders the development of a new airtightness predictive tool for designers and contractors. Along with the problem of standardization, supervision and workmanship are parameters that are difficult to model. Their significant impact can explain why designers and contractors find some existing models unreliable. This paper concludes that none of the existing models can be used in their present form as design tools. Further work should focus on the standardization of data presentation and on the development of a new airtightness predictive model. The first step in the development of such a model is to draw an appropriate classification of "air paths."

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1. Introduction

A few years ago, worldwide political leaders recognized the need to set ambitious challenges in energy consumption. Europe [1,2], the United States [3] and Russia [4] developed energy strategies for the next decades. The building sector plays a large role in final energy consumption and thus requires particular attention. The European Commission adopted the 2010 Energy Performance of Buildings Directive [5] and the 2012 Energy Efficiency Directive [6]. Today, energy challenges concern the entire building sector, from field workers to researchers. Air infiltration can be responsible for up to 30% of the heating demand in winter [7–9] and it impacts insulation thermal performances, hygrothermal performances, occupant comfort, ventilation system efficiency and acoustic insulation [10–17]. Furthermore, industry members and organizations highlight the responsibility of air leakages in many types of building failures [18]. Despite its impact on energy consumption, air infiltration phenomenon remains poorly developed by researchers and equally mastered by designers and contractors.

Airtightness is the main envelope property impacting infiltration [19]. Most national regulations require minimum performances for new buildings. Up until now, the experience of designers and contractors, and practical guides were enough to ensure acceptable airtightness [20–22]. Airtightness requirements have been strengthened over the last few years. Today, their implementation is expensive and time-consuming due to the lack of knowledge and tools. Researchers need airtightness predictive models to model the infiltration phenomenon and designers and contractors need such models to control costs and time in implementing the regulations. Why, when designers and contractors need new tools, aren't predictive tools being developed that would be suitable for practical use?

This literature review reveals two issues: the lack of standardization hinders the development of new airtightness predictive models and existing airtightness predictive models do not meet the needs of designers and contractors. The lack of standardization is discussed in the first and second chapters while existing models are discussed in the third chapter. The first chapter deals with infiltration and airtightness key concepts, the second with airtightness influencing factors and the third with existing predictive models.

2. Key concepts

Authors develop in this chapter four key concepts: the air infiltration phenomenon, the difference between infiltration and airtightness, the measurement methods, the theory about flow through cracks and, finally, the nomenclature and metrics. This last section highlights an inconstancy between authors regarding the metrics.

2.1. Air infiltration phenomenon

Infiltration is the mass of air passing through cracks or other unintentional envelope openings. This airflow is driven by pressure difference across the envelope [23]. In buildings, such pressure difference occurs because of stack effect and wind pressure. The stack pressure difference is a gradient over the building height caused by a temperature difference. The wind pressure is caused by air flows around the building. It depends on location, geometry, air density, wind speed and wind direction [24]. Infiltration modeling is important since it is a key to understand and predict airtightness. Nevertheless, this literature review focuses on airtightness and not on infiltration.

2.2. Differences between infiltration and airtightness

Airtightness should not be confused with infiltration. On the one hand, infiltration is a physical phenomenon: under a pressure difference, air infiltrates the building through envelope cracks or unintentional openings. On the other hand, airtightness is the main envelope property impacting infiltration and is defined as the flow of air infiltrating the building at a pressure difference of 50 Pa. The infiltration phenomenon depends on wind speed, temperature and location while airtightness is intended to be independent of climate variations. Climate influence is reduced by taking a 50 Pa pressure difference [19].

Although airtightness and infiltration are different, they can be mathematically linked. The first empirical relation is known as "rule of thumb." It simply consists in the assumption that the infiltration in a building is 1/20th of its airtightness [25]. This relation does not take into account numerous parameters impacting the infiltration. In 1987 Sherman developed the well-known model: "LBL (Lawrence Berkeley Laboratory)" model. Sherman suggested correction factors to take into account the building height, the wind exposure and the type of cracks [26]. Another existing empirical model is the "AIM-2 (Alberta air Infiltration Model)" developed by Walker and Wilson in 1990. This model assumes that the total airflow is a function of the stack flow and the wind flow [27].

2.3. Airtightness measurement methods

For airtightness, measurement is crucial. Sadauskiene et al. show that energy performance calculations seem only reliable after verifying the building airtightness [28]. To our knowledge, correlated with Relander et al. [29], none of the references argue that estimations could replace measurements.

The most popular tests to measure airtightness is the fan pressurization method or blowerdoor test. It consists in the successive building pressurization and depressurization with a fan placed in an opening (door or window) [24]. Sensors record airflow required to maintain a given pressure difference. $Q-\Delta P$ couples are recorded and n and C (Eq. (2)) can be determined. Norm EN 13829 [30] suggests the use of the least square method to determine mean building value for n and then to determine C. Okuyama and Onishi [31] questioned this methodology. In their paper, Okuyama and Onishi suggest a weighted least-squares method, a correction of the parameter estimation equation and the deduction of the uncertainty propagation equation. In our view, although these authors