Statistical analysis of the correlations between buildings air permeability indicators

Bassam Moujalled[1,2*], Benedikt Kölsch[1,3], Adeline Mélois[1,2], Valérie Leprince[3]

1 Cerema
BPE Research Team, 46, Rue St Théobald, F-38080,
L'Isle d'Abeau, France
**Corresponding author: bassam.moujalled@cerema.fr*

***2** Univ. Savoie Mont Blanc,*
CNRS, LOCIE,
73000 Chambéry, France

3 Cerema
2 rue Antoine Charial
Lyon, France

FOREWORD

The content presented comes from the paper under review "Quantitative correlation between buildings air permeability indicators: statistical analyses of about 500,000 measurements" (Moujalled, 2023a).

KEYWORDS

Building airtightness, measurements, database, field data, statistical analysis

1 COMPARISON OF AIR PERMEABILITY INDICATORS

Several building performance databases were created in recent years in many European countries thanks to the development of commissioning tests. This is particularly the case of building airtightness, where mandatory requirements with justification by measurement were introduced in France, UK, Belgium. This has led in these countries to the creation of national databases on building airtightness that includes more than 500,000 tests in France and the UK.

Comparing building performance across different countries can be challenging, as various indicators are used to measure the air permeability of buildings (table 1). These indicators depend on the specific application and the nation's regulation. The most frequently used indicators, calculated from the airflow rate and the structure dimensions, are the specific air leakage rate per envelope area and the air change rate. While in the majority of countries, the reference pressure is 50 Pa, countries such as the Netherlands or France adopt 10 and 4 Pa as their respective reference points (de Hoon 2016) (Moujalled, 2023b). Calculating the specific air leakage rate requires knowledge of the building envelope area. According to ISO 9972, this area is calculated from internal dimensions, including floor areas and junctions of internal walls. However, in French and Belgium regulations, the calculation considers the thermal loss envelope area A_{TE}, which includes the areas of the building envelope directly in contact with the exterior environment, but also in contact with adjacent unheated spaces or the ground (Moujalled, 2023b)(Van Gelder, 2023). Further, the French regulation excludes the lower floor area in this calculation, and the Belgium regulation refers to the external envelope area. Furthermore, the building volume, as required for air change rate calculation, is defined in the ISO standard as the internal building volume without considering the volume of walls, floors, cavities or furniture. However, the internal volume calculation in some countries differs from this definition. In Germany, it is the net room volume as a product from the net room area and the middle of the room height (GEG, 2020). These are all heated (or cooled) spaces. Besides, rooms that are only accessible from the outside can be excluded from the calculation if their air volume is less than 5% of the total volume. All these exceptions in national regulations make it even harder to compare the indicators.

Table 1. Comparison of air permeability indicators in five European countries

Country	Indicator	Definition	Calculation	Requirement
France	$Q_{4Pa\text{-}surf}$ [$m^3.h^{-1}.m^{-2}$]	Specific air leakage rate at 4 Pa divided by heat loss area excluding the basement floor	$Q_{4Pa\text{-}surf} = q_4 / A_{TBAT}$ q_4: air leakage rate at 4 Pa [$m^3.h^{-1}$] A_{TBAT}: thermal envelope area excluding the basement floor [m²]	Mandatory for new residential buildings
	n_{50} [h^{-1}]	Air change rate at 50 Pa	$n_{50} = q_{50} / V$ q_{50}: air leakage rate at 50 Pa [$m^3.h^{-1}$] V: internal volume [m^3]	Optional, commonly used
Germany	n_{L50} [h^{-1}]	Air change rate at 50 Pa	$n_{L50} = q_{50} / V_L$ q_{50}: air leakage rate at 50 Pa [$m^3.h^{-1}$] V_L: internal air volume [m^3]	Mandatory under certain conditions
	q_{E50} [$m^3.h^{-1}.m^{-2}$]	Specific air leakage rate at 50 Pa divided by the internal envelope area	$q_{E50} = q_{50} / A_E$ q_{50}: air leakage rate at 50 Pa [$m^3.h^{-1}$] A_E: envelope area [m²]	Additionally mandatory for buildings of an internal air volume > 1.500 m3
Belgium	V_{50} [$m^3.h^{-1}.m^{-2}$]	Specific air leakage rate at 50 Pa divided by heat loss area	$V_{50} = q_{50} / A_{test}$ q_{50}: air leakage rate at 50 Pa [$m^3.h^{-1}$] A_{test}: thermal envelope area [m²]	Indicator of the regulation
	n_{50} [h^{-1}]	Air change rate at 50 Pa	$n_{50} = q_{50} / V_{int}$ q_{50}: air leakage rate at 50 Pa [$m^3.h^{-1}$] V_{int}: internal volume [m^3]	Optional
UK	AP_{50} [$m^3.h^{-1}.m^{-2}$]	Specific air leakage rate at 50 Pa divided by the internal envelope area	$AP_{50} = Q_{50} / A_E$ Q_{50}: air leakage rate at 50 Pa [$m^3.h^{-1}$] A_E: envelope area [m²]	Required for new buildings > 500 m2 floor area
Netherlands	q_{v10} [$m^3.s^{-1}$]	Volumetric air flow at 10 Pa	q_{v10}: volumetric air flow at 10 Pa [$m^3.h^{-1}$]	Optional

2 CORRELATIONS BETWEEN BUILDINGS AIR PERMEABILITY INDICATORS

Statistical analysis was conducted on the French database with a total of 406,717 measurements. The analysis of the geometric data showed that the compactness factor is thus a good characterisation of the building geometry. It considers both the shape of the building and the contact with adjacent buildings or parts of buildings: around 0.8 for a typical single-family house and non-residential buildings, low values for multi-family apartments, especially for apartments on an intermediate level with one or two facades (0.2). However, this factor was calculated with the thermal envelope area as calculated in France without the lower floor area. If the entire thermal envelope area is used to calculate the compactness factor, this may introduce a bias that needs to be estimated.

Regarding the pressure exponent, the results are in close agreement with the literature, with a median and mean of around 0.66 and a standard deviation of around 0.06, whatever the type of building or its geometry. No parameter that could influence the pressure exponent has been identified, except for the presence of some specific leakages only for non-residential buildings. The correlations between the different indicators have been calculated according to the building type and compactness. Results show strong linear correlations between the different indicators with correlation coefficients between 0.80 and 0.99. The correlations between the specific air leakage rates qE4, qE10 and qE50 depends only on the pressure exponent. It does not vary with the buildings' geometry, same for the correlations between the air change rates n10 and n50. However, the correlations between the specific leakage rate and the air change rate are dependent on the geometry of the buildings. The more compact the building (i.e., the smaller the compactness factor), the greater the slope of the regression line. Using these tables, we can increase the reliability of the estimation of the indicators by knowing the right building type and geometry. A general correlation can be used with a higher estimation error if the geometry data is missing. The full results of the correlations according to the building type and the building compactness can be found in (Moujalled, 2023a).

As the thermal envelope area in the French database excludes the lower floor area, it would be interesting to perform analysis with other databases that include both the volume and the total envelope area to create a similar conversion equation for every existing indicator. In addition, cross analyses between databases are needed to compare the geometry parameters calculated according to different national regulations (i.e., internal and external volumes with and without walls). Finally, the correlations between airflow rates at 4, 10 and 50 Pa need to be compared to other data using directly measured airflow rates.

3 REFERENCES

B. Moujalled, B. Kölsch, A. Mélois, V. Leprince, Quantitative correlation between buildings air permeability indicators: statistical analyses of about 500,000 measurements, under review. (2023).

B. Moujalled, A. Mélois, VIP 45.6: Trends in building and ductwork airtightness in France, AIVC. (2023). https://www.aivc.org/resource/vip-456-trends-building-and-ductwork-airtightness-france.

Gesetz zur Einsparung von Energie und zur Nutzung erneuerbarer Energien zur Wärme- und Kälteerzeugung in Gebäuden (Gebäudeenergiegesetz - GEG), 2020.

German Institute for Standardization, DIN EN ISO 9972:2018-12. Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization method, (2018).

HM Government, The Building Regulations 2010 - Approved Document L, Conservation of fuel and power, Volume 1: Dwellings, 2021 edition incorporating 2023 amendments, 2021. https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l.

L. Van Gelder, M. De Strycker, C. Delmotte, A. Janssens, AIVC VIP 45.5: Trends in building and ductwork airtightness in Belgium, AIVC. (2023).

M. de Hoon, Air Tightness - Predicting the performance of a building envelope, Delft University of Technology, Delft, 2016. http://repository.tudelft.nl/.