EBC
Energy in Buildings and Communities Programme

BUILDING ENVELOPE AIRTIGHTNESS

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GENERAL RELEVANCE

The airtightness of a building reduces the air flows through the building envelope from outside to the inside (infiltration) and vice versa (exfiltration). During the heating period, the cold outside air can enter the building because of these air flows and needs to be heated. Similarly, the warm indoor air that escapes through several joints, cracks and porous surfaces is accompanied by a certain energy loss. Likewise during the cooling season the infiltration of hot outside air to the interior increases the cooling load of an air-conditioned building. This energy loss due to infiltration and exfiltration is not negligible – certainly in case of energy-efficient buildings – and must therefore absolutely be taken into account when analyzing the energy balance of a building. After all, it makes little sense to increase the insulation thickness without paying attention to the airtightness. The same is the case with introducing highly efficient ventilation heat recovery systems. Without improved airtightness, ventilation losses through the envelope become the major ventilation heat loss.

Additionally the in-/exfiltration can be detrimental for the hygrothermal performance of the building envelope and the indoor climate. In case of airtightness defects, in particular in light structures, warm and humid air may end up on the cold side of the insulation under influence of convection movements. This phenomenon can lead to internal condensation, which can damage the insulation and impair the functionality of the envelope. Furthermore the airtightness influences the acoustic quality (noise protection) and the risk of draft. Hence, it plays an important role in achieving a pleasant comfort for residents and users of a building. Unintended air exchange increases the heat load resulting in uncomfortable dry indoor air in winter (humidity < 30%). Also certain fire safety aspects are directly related to the airtightness of a structure.

RELEVANCE IN BUILDING COMPETITIONS & LIVING LABS

Taking the example of the Solar Decathlon the airtightness influences the results of the competition. Based on the rules from SDE 2019 (version 2.0) the airtightness will influence the number of points reached in the comfort conditions contest (max 100) as the indoor temperature & humidity, the air quality and the sound insulation will be quantified by measurement. Indirectly the air tightness level influences the building energy consumption and the correlated contest results.

Blower door tests are part of the current SDE19 competition rules and have been performed in competitions before as part of the building performance checks.

Co-heating tests with dynamic outdoor conditions represent an advanced performance check procedure resulting in an overall envelope performance indicator, not characterizing the airtightness explicitly.

Considering and testing the air tightness teaches student teams to understand the needs and criteria for energy efficient building envelopes in the design as well as the construction phase.

PARAMETERS

The level of airtightness is a global performance of the building envelope and depends on numerous levels and factors, such as the design of the building, the choice of materials and components, the design and execution of the construction details, the position of cables and ducts, the number of penetrations, etc. Almost all craftsmen who are successively employed at the construction site can affect the airtightness in a positive or negative way. Hence, a proper follow-up of the airtightness throughout the entire construction process, from design to execution and final inspection, is essential.

PERFORMANCE INDICATORS

The airtightness of a building can be expressed in different ways according to the ISO 9972:2015. Generally a reference pressure difference between the indoor and outdoor environment of 50 Pa is assumed, although other reference values can also be used (e.g. 4 Pa or 10 Pa). The leakage rate that infiltrates through the building envelope at this pressure difference, usually determined by a pressurization test, represents the sum of all leaks through the building envelope. The total air leakage rate at the reference pressure difference Δp_r is noted as $\dot{V}_{\Delta pr}$ and is expressed in m³/h.
To normalize this value to the size of a building, the air change rate $n_{\Delta pr}$ is introduced. This value is expressed in h^{-1} and calculated by dividing the mean air leakage rate at the reference pressure difference Δp_r by the internal volume V. The air change rate is a good criterion for the overall airtightness performance of a building. Alternative quantities that characterize a specific execution quality are the air permeability $q_{\Delta pr}$, by dividing $\dot{V}_{\Delta pr}$ by the envelope area A_E, (using overall internal dimensions), and the specific leakage rate $w_{\Delta pr}$, calculated by division of $\dot{V}_{\Delta pr}$ by the net floor area A_F. The last two quantities are both expressed in m³/(h.m²) and are independent of the size and compactness of the building. They are normally applied for large buildings. These terms are usually noted as $\dot{V}_{50}$, n_{50}, q_{50} and w_{50}, i.e. for the most common reference pressure difference across the building envelope of 50 Pa.
Except for the pressurization test, a pressure difference of 50 Pa between the indoor and outdoor environment only occurs exceptionally due to strong winds; the pressure difference between the inside and outside will usually be a lot lower than this value. Thus the average infiltration rate n_{inf} that really occurs as a result of deficiencies of the buildings airtightness will be much lower than the infiltration rate that would result from an artificial pressure difference of 50 Pa. Estimating the infiltration rate out of the empirically determined air change rate differs from country to country. It can be estimated by multiplying the n_{50} value by a factor that varies between 0.03 and 0.1, depending on the building type, its height and its exposure to the wind. A typical average value is 0.05. The resulting infiltration rate can be used to calculate the impact of the heat losses caused by infiltration on the energy use of a building via the equation $\varphi_{inf} = 0.34 * n_{inf} * V * \Delta\theta$, according to ISO 52016-1:2017 [ISO52016].

SIMULATION

In contrast to e.g. the performance of thermal insulation, the airtightness of a building cannot be calculated or accurately be predicted in the design phase. Aggregating data on component level, e.g. the porosity of a material, only provides a lower limit which is typically exceeded due to installation deficiencies at joints and cracks. Consequently, the airtightness can only be determined after the execution phase using a pressurization test.
In order to simulate the impact of airtightness on the air change rates in a building, a distribution of air flow cracks is typically modeled in an airflow network model. Often, one crack accounts for a certain area of a wall element. Due to the fluctuating pressure difference over the crack, the airflow through the crack varies. The parameters of the crack can be adapted to match the values found by the pressurization test.

A well-known tool for airflow simulations is CONTAM, developed by the National Institute for Standardization and Technologies (NIST, US). Other possible softwares / tools for multizone air flow modelling are TRNflow (Transsolar Energietechnik GmbH, Germany), COMIS (IEA Annex 23), etc. [TRNFLOW], [COMIS].

MONITORING

The airtightness of a building can be measured with a pressurization test, also called an infiltrometric test or blower door test. It is used for locating and correcting air leaks, as on orienting measurement during the works and as an 'official' measurement in order to be valorized in the context of the applicable regulations. The measurement method is described in ISO 9972:2015, replacing EN 13829:2001 and ISO 9972:2006 [ISO9972]. It consists of successively placing the building in over- and under pressure relative to the outside environment using a fan installed in an external opening (e.g. the front door or a window). The air flow rates of the fan required to ensure the different pressure levels within the building are measured at the fan. This corresponds to the total flow that penetrates through the leaks in the building envelope. The correlation between the air leakage rate and the induced pressure difference is expressed using an air leakage coefficient C_L and an air flow exponent n in the equation $\dot{V}_L = C_L*(\Delta p)^n$. The total air leakage rate at the reference pressure difference is calculated as the average of the measured values for the pressurization and depressurization test.

The standard also makes a distinction in the way in which the openings that were intentionally made in the building envelope must be treated: some openings need to be closed (e.g. exterior doors, windows), others must be taped (e.g. the openings of a mechanical ventilation system) and some cannot be sealed (e.g. fixed grilles for the supply of combustion air). See standard ISO 9972 for more details.

The execution of a pressurization test can be combined with the detection of air leaks. When there is an under pressure in the building, outside air can penetrate to the interior through all openings in the building envelope. These infiltrations can be traced with the help of smoke sticks, which make the air flows visible, with an anemometer to measure air velocity, with ultrasonic leak detectors or with soap water which will form bubbles in the event of a leak. Infrared thermography can also be used to detect leaks: if there is a sufficient temperature difference between the outside and inside environment, depressurizing the building will give rise to air infiltrations which in turn can cause a local temperature change of the inner surface of the building envelope. An infrared camera can thus be used to detect the surfaces cooled by the outside air.

Alternative tests to value the infiltration rate of a building envelope are, amongst others, the pulse test of University of Nottingham and the active tracer gas methods (see ISO 12569:2017 and ISO 20485:2017), [ISO12569].

For passive houses the n_{50} value should be below 0.6 h^{-1}. Countries with cold climates typically have more airtight constructions, and this performance level is often considered as standard practice. In countries with milder climates n_{50}-values of 10 h^{-1} and higher are no exception.

POST PROCESSING OF RESULTS FROM SIMULATION & MONITORING

After a series of measurements during the blower door test, the negative and positive pressure measurements can both be showed in one diagram, showing the building leakage (air flow rate) as a function of the artificially induced building pressure. Usually there are 10 measuring points for both over- and under pressure in increments of no more than 10 Pa. By using a log-log plot, the monomial regression of the air flow equation $\dot{V}_L = C_L*(\Delta p)^n$ appears as a straight line. The air leakage rate at a reference pressure difference $\dot{V}_{\Delta pr}$ can easily be read from this logarithmic graph for the trend lines of both the pressurization and depressurization test and the total leakage rate is calculated as the average of these two values.

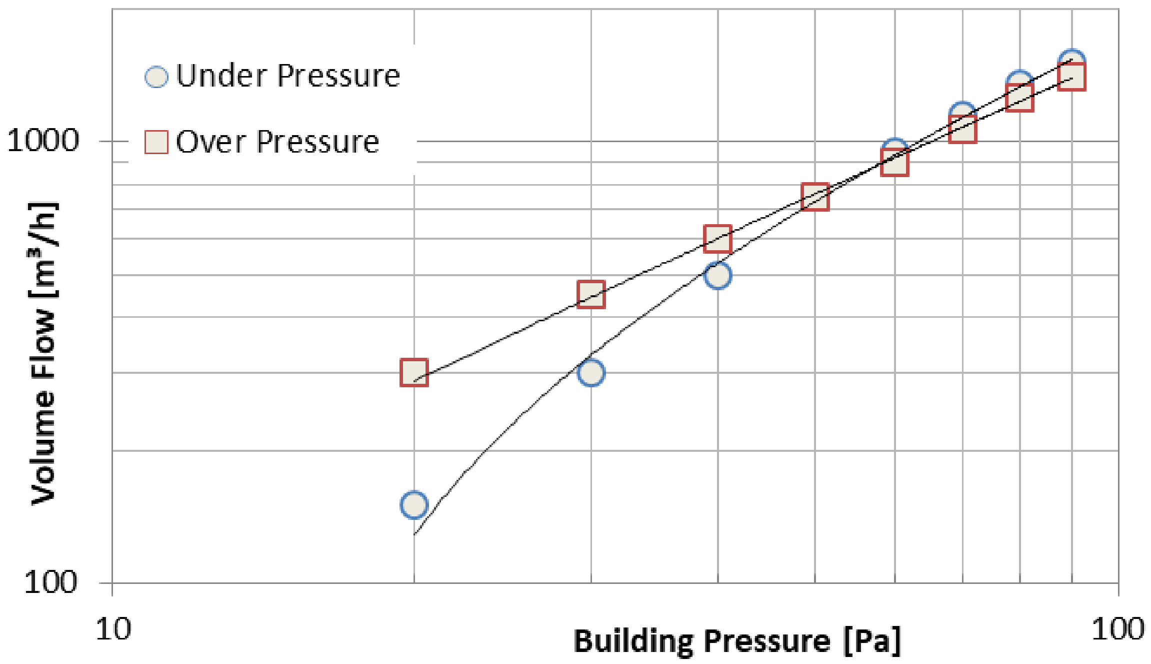

FIGURE 1: Typical graphical representation of a blower door test result. Source: S. Herkel, Fraunhofer ISE

FURTHER READING

[AIVC] "A guide to energy efficient ventilation", Annex 5, EBC, International Energy Agency, The Air Infiltration and Ventilation Centre, www.aivc.org

[ISO52016] ISO 52016-1:2017 Energy performance of buildings — Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads — Part 1: Calculation procedures, www.iso.org

[ISO9972] ISO 9972:2015 Thermal performance of buildings — Determination of air permeability of buildings — Fan pressurization method, www.iso.org

[ISO12569] ISO 12569:2017 Thermal performance of buildings and materials — Determination of specific airflow rate in buildings — Tracer gas dilution method, www.iso.org

[ISO20485] ISO 20485:2017 Non-destructive testing — Leak testing — Tracer gas method, www.iso.org

[TRNFLOW] TRNFlow – AIRFLOW SIMULATION IN BUILDINGS, Transsolar, https://trnsys.de/docs/trnflow/trnflow_uebersicht_en.htm (checked 26.05.2020)

[COMIS] Feustel H E, 1999, COMIS - an international multizone air-flow and contaminant transport model. LBNL - UK, Energy and Buildings, No 30, 1999, pp 3-18, https://www.aivc.org/resource/comis-international-multizone-air-flow-and-contaminant-transport-model