Airtightness requirements for high performance building envelopes

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ABSTRACT

International building legislation is setting stronger and stronger requirements for the energy performance of buildings. An actual example is the impact of the Energy Performance of Buildings Directive in the European Union (EPBD) on the national requirements in the Member States. The improved energy performance of buildings can't be achieved by additional insulation or more effective buildings systems only. A major influence factor on the energy quality is the ventilation technology and also the airtightness of the building envelope. Some countries include in their energy decree already maximum air change rates, partly for all building types, partly only for those that include a mechanical ventilation system. Especially for high performance buildings which go beyond the national requirements, the infiltrations losses become a significant factor to the energy performance.

The paper is based on the work in the EU project ASIEPI (Assessment and Improvement of the EPBD Impact (for new buildings and building renovation) and presents an overview on the existing airtightness requirements in different European countries and the US. These requirements are opposed to airtightness requirements for high performance buildings in Germany (passive house), France (effinergie label) and the US (energysmart home, RESNET). Measurements of the envelope airtightness right after construction and some years later show the practicability of the requirements.

KEYWORDS

ASIEPI, airtightness, building envelope, requirements, high performance buildings

WHAT IS A HIGH PERFORMANCE BUILDING?

Buildings that do not only fulfil the national requirements, but are designed to use considerable less energy, are often called high performance buildings. There are different terms used in this area, from low energy building over passive houses and 3-litre houses to zero energy or zero emission buildings and many more. An information paper [1] soon available on the Buildings Platform summarises the used terms and definitions as well as the currently realised number of high performance buildings in the EU Member States. Though the definitions of the various types of high performance buildings differ from each other, the very most of them imply a building airtightness that is better than for regular buildings.

EXISTING BUILDING ENVELOPE AIRTIGHTNESS REQUIREMENTS IN THE EU MEMBER STATES

The implementation of the Energy Performance of Buildings Directive (EPBD) [2] has caused in most of the EU Member States more severe requirements for the energy demand of buildings. In order to meet these requirements, not only buildings components with better U-values and more efficient building systems have to be used, also the ventilation losses have to be reduced. A contribution to this necessary reduction is the improvement of the building envelope airtightness, mainly the airtightness of building components and joints. With the EPBD implementation or even before some of the countries have included minimum airtightness requirements in their building codes.

According to an investigation at the end of 2007 in the ASIEPI project [3] 7 of 14 EU Member States have minimum requirements regarding the building envelope integrated in their building codes. These are: the Czech Republic, Germany, Denmark, the Netherlands, and Great Britain. Spain has partial requirements focussing on windows. The existing minimum requirements that refer to new buildings (residential and non-residential) differ from country to country and are presented in the following table.

Table 1: Results of the German study on the impact of thermal bridges on the heating energy.

EU Member State	Air tightness requirements at 50 Pa pressure	
	Natural ventilation	Mechanical ventilation
Czech Republic	4.5 1/h	w/o heat recovery: 1.5 1/h with heat recovery: 1.0 1/h
Germany	3.0 1/h or 7.8 m³/h per m² floor area	1.5 1/h or 3.9 m³/h per m² floor area
	Leakage rate per façade area: 3.0 m³/m²h	
Denmark	1.5 l/s per m² floor area	
Norway	3.0 1/h	
The Netherlands	Dwellings: 200 dm³/s (at 10 Pa) Non-residential buildings: 200 dm³/s per 500 m³ (at 10 Pa)	
United Kingdom of Great Britain	New dwellings and new commercial and public buildings over 500 m²: 10 m³/m²h (stated as reasonable limit for the design air permeability in building regulations 2000 L1A and L2A)	

It has to be stated though that in all countries with air tightness requirements, except in the UK, there is no generally required compliance test. However, in Germany and Denmark pressure tests are required in some cases. In Denmark the pressure test is generally optional but can be required by building authorities. In Germany the pressure test has to be made if a mechanical ventilation system is considered in the calculation of the energy performance certificate of a new building. The reduction of the ventilation losses can only be taken into account if the airtightness was proven. In Finland the basic air leakage rate for calculation of the energy performance can be reduced if a pressure test or some other accepted method presents better performance.

The United States of America do not have a national energy code. Local code officials generally follow the International Energy Conservation Code (IECC). IECC 2009, when adopted by local jurisdiction does have a tightness requirement, either

7.0 1/h at 50 Pa pressure (7 ACH50) or a verified insulation/airbarrier checklist. Regional codes include other requirements concerning air change rates, air sealing or blower door tests. There are no minimum legal binding requirements in the US, but there are a lot of progressive local areas that are taking the lead on increasing energy requirements.

AIR TIGHTNESS REQUIREMENTS FOR HIGH PERFORMANCE BUILDINGS

As written in the introduction high performance buildings require in general an improved airtightness of the building envelope. Otherwise the desired low energy demands can't be achieved. Most of the various high performance buildings however have not specified values that have to be fulfilled.

Example 1: Passive house (Germany)

An exception is the so-called passive house. The passive houses originally created in Germany are calculated with a procedure that differs from the national German energy performance calculation standard, mostly in the area of the ventilation losses. The net heating energy demand of these houses has to be 15 kWh/m²a or lower and the primary energy demand for heating, ventilation, domestic hot water and household electricity shall not exceed 120 kWh/m²a. In the definitions set by a private organisation in Germany, which are applied in some other central European countries as well, the infiltration rate at 50 Pa overpressure is set to 0.6 1/h.

As the passive houses generally include a mechanical ventilation system which is also used for heating purposes, this value has to be compared to German air tightness requirements for buildings with mechanical ventilation systems: 1.5 1/h. The airtightness of a passive house is supposed to be more than twice as good as for a regular house.

Experiences from many pressure tests at the Fraunhofer Institute for Building Physics show that values below 1.0 1/h are difficult to achieve. However the Institute has tested some buildings, also some passive houses, which do meet this requirement in practice. Figure 1 shows two exemplary photos of a series of row houses built according to the passive house definition in Stuttgart, and which were monitored by the Fraunhofer Institute for Building Physics [4]. The results of the Blower Door tests made right after the construction phase (2000) and two years later are presented in figure 2.

Figure 1: North view (left) and South view (right) of the passive house buildings monitored including airtightness tests.

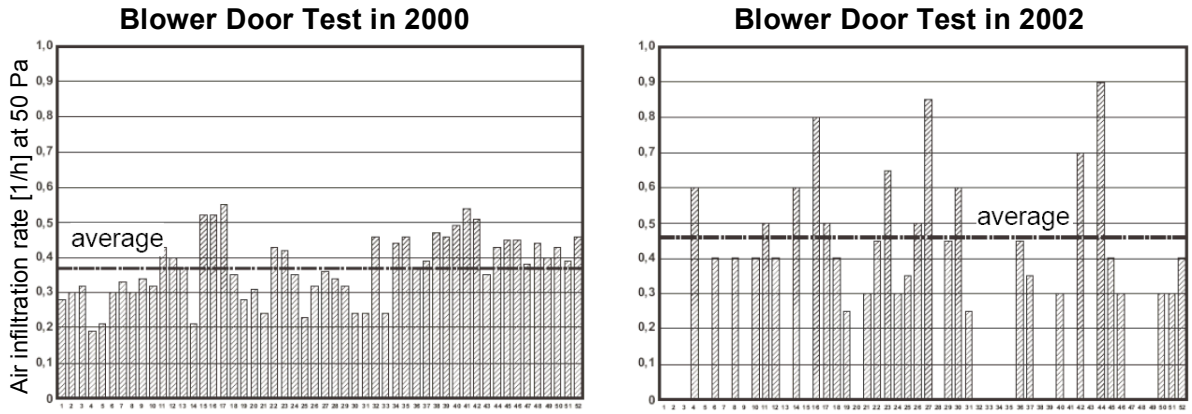

Figure 2: Results of airtightness measurements at 31 passive houses in Stuttgart, Germany measured right after the construction phase and 2 years later.

The results of the air leakage test show that the average infiltration rate of all 52 row houses measured right after the construction phase was 0.37 1/h and the average value of 31 of the houses measured two years later was 0.46 1/h. That proves not only that the very low leakage rates are possible, but also that they were only slightly worse after two years of building use. Yet in 5 of 31 buildings measured in 2002, the original goal of 0.6 1/h which was met at the end of the construction period could no longer be achieved.

Example 2: BBC-Effinergie (France)

The BBC-Effinergie label was created jointly by the Ministry of Housing and Effinergie association in 2007. Requirements to obtain the BBC-Effinergie label in new buildings are as follows [5]:

- The global energy consumption in dwellings shall be less than 50 kWh/year/m² multiplied by a factor depending on the altitude and the climate zone, resulting between 40 and 65 kWh/year/m².
- The airtightness must be measured and less or equal to 0.6 m3/h.m² under 4 Pa for single-family houses and less or equal to 1 m3/h.m² under 4 Pa for multi-family houses.
- The global energy consumption in tertiary buildings shall be 50% less than the level of RT 2005.

For existing buildings, the Ministry of Housing has not yet issued a label.

Figure 3: Single-family house with BBCEffinergie label [5].

Effinergie association released a first label on the following bases [5]:

- In dwellings, the global energy consumption shall be less than 80 kWh/year/m² multiplied by a factor depending on the altitude and the climate zone, resulting between 64 and 104 kWh/year/m².
- The airtightness must be measured and less or equal to 0.8 m3/h.m² under 4 Pa for single-family houses and less or equal to 1.3 m3/h.m² under 4 Pa for multi-family houses.
- In tertiary buildings, the global energy consumption shall be 40% less than the level of RT 2005.

The calculation of consumption in both cases is performed with tools based on Th-CE rules for new buildings and on Th-CEex for existing buildings. The reference area for the airtightness measurements is the envelope area minus the floor area. Measurements must be performed by authorised technicians.

In low energy buildings, infiltration losses represent an important part in the heat balance. To have the possibility to correct infiltration defects, Effinergie association suggests making an intermediate measure before closing the casing. The airtightness required for the BBC-Effinergie label is more than double as good as for the notional building (1.3 m³/hm²). The saved consumption due to the improvement of the airtightness in a typical family house in cold and hot climate (Nancy and Nice) is presented in figure 4.

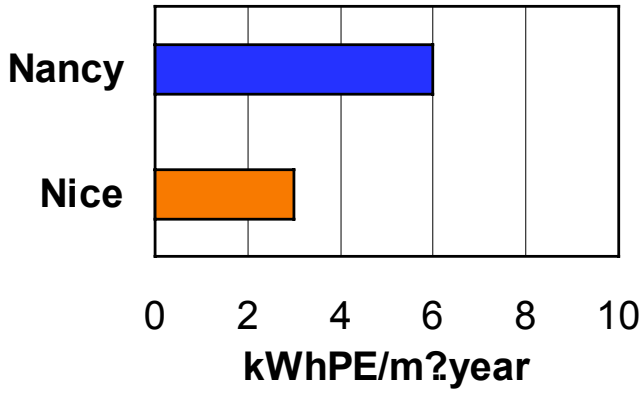

Figure 4: Primary energy consumption increase due to the deterioration of airtightness in a single-family house (from 0.6 to 1.3 m³/h.m²) [6]

Example 3: Energysmart Home Scale – E-Scale (USA)

The E-Scale is an easy-to-understand tool that helps homebuyers and homeowners make smart energy decisions when purchasing, renting, or updating a home. The E-Scale is based on the Home Energy Rating System (HERS) Index, developed by RESNET, the Residential Energy Services Network. The energy rating for the home will be conducted by RESNET-certified energy raters for the performance pathway. The current minimum airtightness requirement is ≤ 0.35 cfm per square foot of building envelope area at a pressure differential of 50 Pa.

CONCLUSIONS AND RECOMMENDATIONS

Infiltration losses have a significant influence on the energy use of buildings. The relative influence becomes bigger when the total energy use is lower, e.g. in high performance buildings. Especially in mechanically ventilated buildings the building shell should be airtight. Yet only few EU Member States have requirements for the airtightness for new or existing buildings included in their building codes and only two high performance building definitions could be found that contain specific requirements to the airtightness of the building shell. It was also shown that very low air infiltration rates (< 0.5 1/h at 50 Pa) can be achieved in practice and nearly retained for two years of building use.

Based on the analysis of requirements, but also on earlier information papers on airtightness available on the Building Platform (IP 72 [8] and IP 137 [9]) it is recommended that:

- Countries include airtightness requirements in their national building codes
- Countries add a requirement or at least a recommendation to measure the airtightness of the building during the construction phase in order to find and fix leakages. This would prevent the building from having air leakages that can't be fixed during commissioning.
- Countries add a requirement to measure the airtightness of the building shell after the construction phase before reduced ventilation rates for mechanical ventilated buildings can be used in the calculation of the energy performance (proof of airtightness).
- European and international standardisation committee proposes airtightness requirements or airtightness classification of buildings. These could include climatic grading.
- Definitions for high performance buildings should include even stronger requirements for the airtightness of the building shell (at least < 1.0 1l/h at 50 Pa)

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