BLOWER DOOR TESTS (EN 13829) FOR QUALITY ASSURANCE: GETTING AIR-TIGHT BUILDINGS IN RETROFITTING, TOO

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ABSTRACT

For retrofitting as well as for new buildings a good airtightness is an important issue. In Germany, Austria and Switzerland about 1000 persons conduct blower door tests according to EN 13829 in order to characterize the air permeability of buildings. Also, preliminary measurements of the air barrier are made, often by the craftsmen themselves. Early measurements allow to repair leakages more easily than when the building is completed.
In this lecture typical faults and the resulting problems as well as good solutions are introduced at planning and execution with two attic storey developments:

(1) In an appartment building thick insulation layers were built in during the attic storey development in the eighties. The subject airtightness was not considered. Consequence: The rooms lying to the east didn't get warm sufficiently.

(2) At the attic development in an one-family house of 1928 the airtight layer was planned in detail and checked with the blower door during the construction.

In the course of further redevelopment measures the n_{50} value of the complete building was improved from 5 h^{-1} to less than 2 h^{-1} and a ventilation system (central exhaust ventilator) was installed.

Different test methods were used: Zonal Pressure Measurement, Opening A Door, Guard Zone Measurement.

KEYWORDS

Airtightness, EN 13829, Blower Door Test, Retrofitting, Attic Storey Development, Quality Assurance

INTRODUCTION

The additional attic storey development is probably the most difficult retrofitting task with respect to the airtightness: Here meet solid and timber structure on each other, on the one hand. On the other hand, there are restrictions by the available construction and instructions of the authorities. And for the end an insulation must be carried out for the noise, fire and smoke protection also to the building part lying under this.

Visibly high-quality development is often planned primarily under architectural points of view. However, a high energetic standard only can be reached if an energy diagnosis is made in advance. And first of all a professional planning of the thermal bridges and airtightness details and ventilation technology must be carried out. Many different crafts must moreover cooperate.

An accompanying quality assurance with the blower door and a proof according to EN 13829 are the only guarantee to avoid problems later and to secure that the ventilation system works as planned. And the leakage locating already before a retrofitting during the energy diagnosis motivates the owners to take steps to improve airtightness and insulation.

It is above all in the attic that poor airtightness creates a problem for both the construction of the building and for human health: if the attic storey is inadequately sealed, the thermal buoyancy created within the building will cause air to flow up from the lower storeys, bringing noise, smells and also pollutants from the old ceiling construction into the new living space. If there is ever a fire, the smoke and flames can spread rapidly. Air will flow continuously, particularly at cold times of the year, through leaks in the new envelope from the inside to the outside. This can cause water vapor to condense out of the moist warm air onto structural elements. Structural damage and fungal growth may be the result.

TABLE 1
A good airtightness is important for

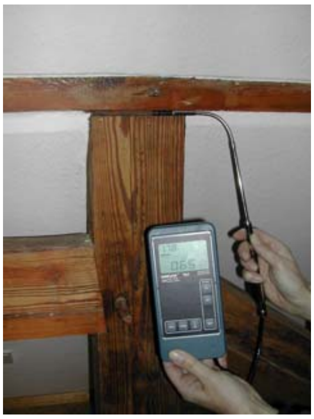
- reduction of energy consumption
- securing of demand-controlled ventilation
- providing a good indoor air quality
- protection against pollution (Radon from the ground, mould and odours from the cellar, odours from neighboring dwellings)
- protection against airborne noise (from the staircase, between dwellings, traffic noise)
- efficient smoke and fire protection
- increase of comfort and cosiness
- disclaiming of timber preservative

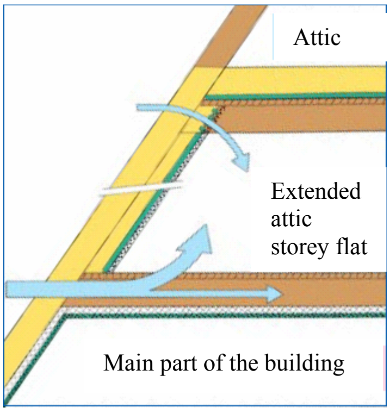
1st EXAMPLE: THE ROOF EXTENSION WILL NOT BE PROPERLY SEALED UNLESS AIRTIGHTNESS IS PLANNED

The first measurements of airtightness on an old German building (1920) were carried out as early as 1989 at the energy and environmental center e-u-z, Springe. The faults that we know to be typical were observed: During the development of a large attic storey apartment at the beginning of the 1980s, an insulation thickness of 200 mm and more was installed. At the time, this was revolutionary, but the creation of airtight joints was not given any consideration. The result was that the occupants complained about the difficulty of keeping their rooms warm when the cold, east winter wind blew against the broad side of the house. When the wind was strong, granulated cork trickled out of the beam sealing; when the weather was particularly cold, condensed water dripped into the bathroom and kitchen from the surrounds of the skylight windows. The radiator against the jamb wall of the house once froze. The thawed snow always made it very easy to see from the outside how warm air was flowing out along the joints to the beam ceiling and the interior walls. With 50 Pascal pressurization, artificial fog emerged from exactly these points.

Figures 1+2: Thawed snow and the appearance of fog at 50 Pa pressurization show how air is flowing at the internal walls, beam ceilings and attic areas, and that there are energy losses in spite of the 200 mm insulation thickness.

The overall airtightness of the extended attic storey apartment could not be measured, since an adequate differential pressure could not be reached: With an open BlowerDoor fan with a flow capacity of approx. 8000 m³/h [3], and with an apartment volume of approx. 500 m³, this means that n_{50} is greater than 16 h^{-1}. By comparison, the limit value for buildings with window ventilation in the Hessian Promotion Program for Low-Energy Houses [4] was $n_{50} \leq 3\ h^{-1}$. The reason for this extremely high value is to be found on the one hand in the absence of an airtightness concept for the attic storey, and on the other in the leaks to the main part of the building underneath. Both of these types of leakage are typical for attic storey extensions, even today.





Figures 3,4,5: Draughts at the joint between post and center purlin (0.65 m/s); flow through the ceiling (air flow rate at the ceiling opening 3.4 m/s) due to incomplete airtight layer at the ceiling joint

Typical leaks to the parts of the building situated underneath / to the main building

When the attic storey is developed above an existing ceiling, it is popularly assumed that this ceiling is already airtight, and that no particular steps need be taken other than for the new access door. Unfortunately, however, in most cases various leaks are already present, and the modification work creates yet more. Only when the extension is being carried out in order to extend the living space available inside a one-family house it is possible that these leaks may be negligible. When a new, self-contained living unit is being created, as in the case of the e-u-z, they can lead to significant problems. Consequences of these leaks – driven by the thermal pressures within the building, are:

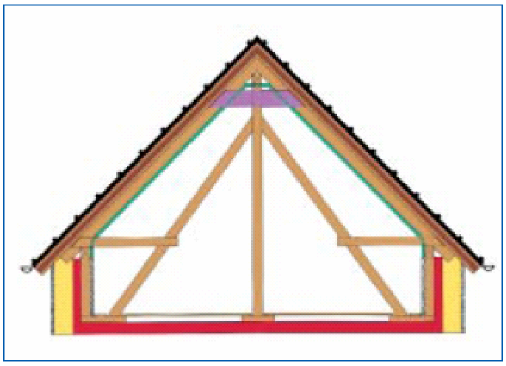
- poor airborne sound insulation (in both directions),
- the spread of smells from below to above (food, cigarette smoke) and out of storage rooms,
- possible ingress of pollutants from the ceiling into the new apartment consisting, for instance, of building material or of fungal spores resulting from earlier condensation out of the lower rooms,
- in the event of fire, first the smoke and then the flames will pass upwards through these channels.

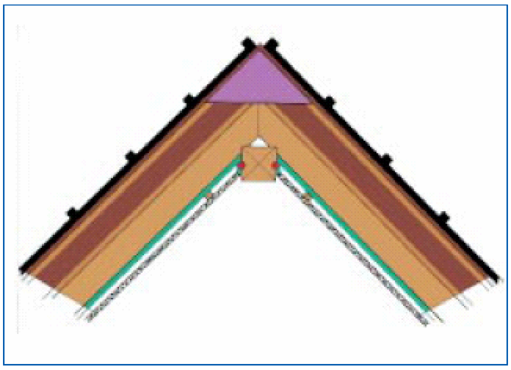
A high proportion of these leaks are not confined to wooden ceilings, but also occur with solid ceilings.

2nd EXAMPLE: HOW TO MAKE THE SEAL – INCLUDE THE AIRTIGHT LAYER AT THE DESIGN AND STATIC CALCULATION STAGE!

In old roof woodwork often a large number of beams hinder an optimal airtightness. Achieving permanent sealing in accordance with technical regulations always implies avoiding, or at least minimizing, penetration of the wooden beams. For this reason in the second example – having learned from the experience of the first – it was decided at the initial design stage not to attach to the pillars and braces (altogether 8 items), but to join up to the seal of the diagonals to the ridge purlin along the existing cracks.

The static engineer almost made nonsense of this plan again: due to the planned doubling of the rafters (Agepan webbed beam AS 160), each pair of rafters was to be reinforced in the center by two shackles nailed to the side - this would have resulted in 36 new holes! This imposition was discovered just in time before obtaining the quotation. The solution was to fasten the Agepan beams above the ridge purlin by means of triangular boards - without penetration.





Figures 5+6: Original design offered by the static engineer to reinforce the ridge purlin for the rafters: penetrating shackles which cannot be easily, economically and permanently sealed … and the alternative that was built: triangles at the tips of the locking rafters outside the airtight layer, attached along the ridge purlin

Penetration to the existing main building

Although it is true that this is not a separate apartment, attention was paid to achieving the most airtight possible implementation for the following reasons:

- the very poor sound insulation in the original two-family house should at the very least be improved in the newly extended area.
- the new ventilation equipment should operate separately on each floor, since the thermal buoyancy in a 2.5-floor building that is not adequately sealed can overpower the suction generated by the ventilation equipment [4]
- it was also desirable to avoid drawing moist warm air through the largely unheated stairway
- and, last but not least, even the existing, solid separating wall from the main building with its ventilated cavity layer and the solid ceiling were not airtight to the outside.

Successful strategies for attic extensions

The problems could be solved in these ways:

- the roof is improved right up to the ridge, leaving the ridge purlin partly visible. In this way – as well as avoiding penetrations – the architectonic unity of the wood construction is displayed.
- there is room for the electrical installation in the additional insulation under the rafters between the supporting battens of the internal lining.
- installations are avoided in the new, single-skin gable wall.
- attachments are made, or lath work is put in place, at the joints between the solid ceiling and the jamb wall and between the jamb wall and the purlin before plastering.
- the internal walls are assembled inside the airtight layer and are screwed to the plasterboard internal skin of the sloping roof. A separating cut is included to improve sound insulation to the bathroom. Windproof sockets (such as those manufactured by Kaiser) are used to avoid the ingress of insulating material.

BlowerDoor measurements for quality assurance and as final evidence of airtightness

An extremely good BlowerDoor result was, of course, demanded in the building contract itself for this attic storey extension: a target of $n_{50} \leq 0.6\ h^{-1}$ (passive house limit value [6]) was set for the renovated part of the building. The builders therefore knew what they were taking on, and took the topic of airtightness seriously. At the detailed planning stage, the details of the leaks (and therefore also of avoiding thermal bridges) were optimized. As the work proceeded, the design plans had to be modified from time to time – the reason for this lay, on the one hand, with sloppy measurement and lack of a capacity for spatial visualization on the part of the designers, and, on the other hand, the selection of extremely new materials and unconventional methods by the client.

The BlowerDoor was used several times during the work: this was to achieve quality assurance while the vapor barrier was still visible. Unfortunately events could not proceed as desired in this relatively small building area, where the work of the various trades overlapped heavily.

The total airtightness was finally assessed using different methods. The original measurement had been $n_{50} = 5.2\ h^{-1}$. The size of the building as a whole was not identical with its size before the conversion, because the attic floor of the extension was enlarged, as was the stairway. For this reason, the improved result of $n_{50} = 2.4\ h^{-1}$ is not meaningful. A number of additional methods were therefore used in order to determine the airtightness of the separate parts of the building.

For the zone measurements using the "Opening-a-Door" method [7], the doors of the ground floor and the upper floor apartments were opened, and a depressurization measurement taken in each case. Using the volumetric flows from several series of measurements, a mean n_{50} of $1.2\ h^{-1}$ with a scatter of 20% was estimated.

Using Guard Zone (or Deduction) Measurements with two BlowerDoor systems, of which one was mounted in an external door and the second was mounted in the apartment doors, it was possible after several series of measurements to confirm an n_{50} value of $1.2\ h^{-1}$, with a scatter of 10%. In a further Guard Zone Measurements with three BlowerDoor systems built into the external door and into a window in each apartment, it was finally possible to determine a value of about $1\ h^{-1}$ for the extension. A great success, even if the ambitious target was not entirely reached!

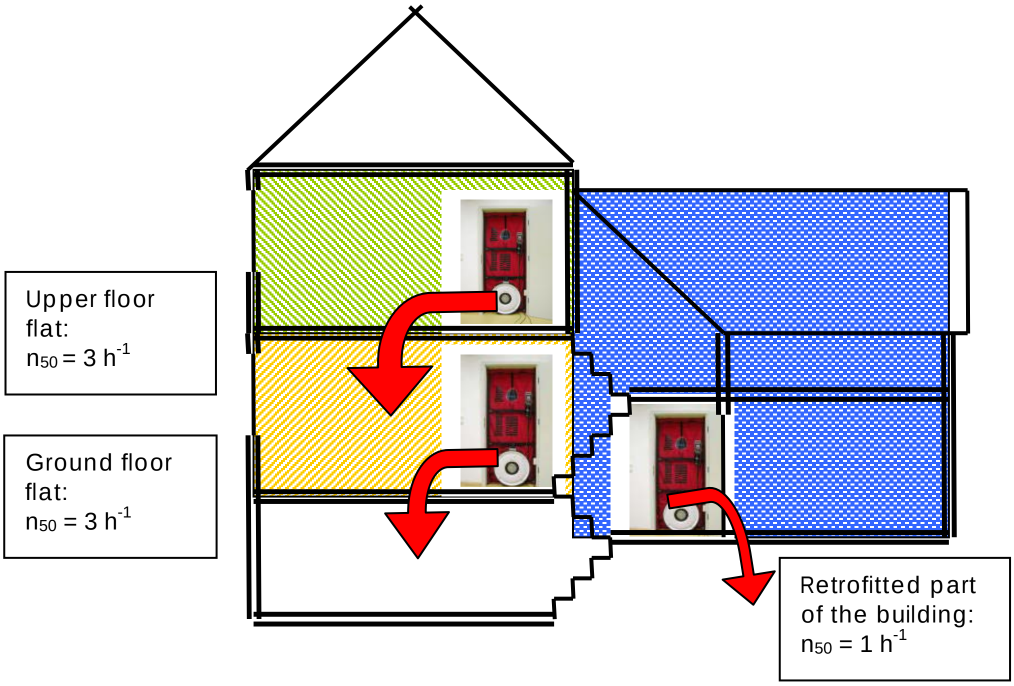


Figure 7: Guard Zone Measurement with 3 BlowerDoor systems to determine the air permeability of the improved part of the building (and at the same time for the unchanged part of the building, consisting of two apartments)

The BlowerDoor result was further improved through sealing done between the ground floor and the cellar. A replacement for the old trap-door is planned on the first floor. The cavity in the wall has since been blown in with SLS 20, reducing the leakage to the wood joist ceiling: $n_{50} = 1.5\ h^{-1}$ for the entire building!

CONCLUSIONS

A good n_{50} value can even be achieved when improving the attic storey of existing buildings, provided the airtight layer is explicitly designed and subject to quality assurance. The factors for success are assessment of the existing building using BlowerDoor measurements at the energy diagnosis stage, inclusion of the target value for n_{50} in the building contract, and the location of leaks using depressurization during the construction phase.

The complexity of existing roof woodwork means that a great deal of prior experience in the field of airtightness is necessary. Bringing in someone with an understanding of the BlowerDoor has been found valuable.

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