# AIRTIGHTNESS IN BUILDINGS

## Part One

*by Lothar Moll*

*In this two-part article series, we examine the implications for airtightness in buildings. Airtightness is the crucial factor to ensure that thermal insulation really does insulate and that the building structure remains free of structural damage. Part One will deal with the effects of inadequate airtightness, while part two will explore how to achieve airtightness in buildings.*

Thermal insulation in a building separates two different microclimatic zones: the interior microclimate and the exterior microclimate. For climatic conditions in Europe and Russia, it is warm on the inside and cold on the outside in the wintertime, but the interior is cooler than the outside in the summertime. In both cases, a temperature difference is produced and this temperature difference attempts to equalise by air flow. In the wintertime, warm air from the building penetrates through the structure to the cooler side (i.e. outside). However, as it passes through the thermal insulation, this warm air cools constantly the further it moves to the outside. Cold air is able to absorb less moisture than warm air so that the water vapour entrained in the warm air ultimately precipitates as condensation. This condensation may lead to substantial structural damage in the building structure itself. Load-bearing building components may rot and lose their supporting capability. Likewise, moisture promotes the occurrence of mould which is harmful to health.

The consequences of such structural damage are immense both for the building structure itself and for the health of its occupants, but such consequences may be avoided permanently by taking very simple measures. When planning and carrying out the structural work, all that needs to be done is to ensure that moisture cannot penetrate the thermal insulation to a harmful extent, for example, air flow from the interior through the construction to the outside must be restricted. This is achieved by installing an airtight layer on the inside of the thermal insulation. The utmost care must be taken when planning and executing this procedure since this is crucial to effectiveness.

The term 'airtight' does not mean that the interior is hermetically sealed from the outside air, as if a plastic bag was used. The airtightness layer simply prevents air flow, i.e. air convection, while air exchange from inside to outside by diffusion still occurs.

### The Effects of Inadequate Airtightness

The term 'airtightness' means protecting the thermal insulation in the building envelope against penetrating moisture. The quality of the airtightness is determined by the freedom from leakages in the building envelope. The more leakages there are in the inner building envelope, such as the vapour barrier/vapour check, and the more leaky the building envelope is, the poorer will be the airtightness. A leak in the inner building envelope has a major impact in relation to structural physics.

Interior air flowing to the outside through leaks in the vapour barrier/vapour check transports a great deal of heat and consequently leads to a higher heating energy demand. As it flows through the thermal insulation, the warm air cools and condenses on the exterior building elements. The precipitating moisture is referred to as condensation and may lead to mould. A leak in the inner building envelope substantially impairs comfort for occupants: the room climate is too dry in the wintertime and the heat-protection effect in the summertime is reduced. Leaks also impair soundproofing of the structure.

In other words, airtightness is an important part for effective functioning of the thermal insulation layer. It is also a critical element in ensuring that the construction is free from structural damage and in maintaining a pleasant interior living and working climate both in wintertime and in summertime. In order to achieve effective airtightness, the overlaps of vapour barriers/vapour checks must be bonded with adhesive tape and joints to adjoining building elements must be reliably sealed permanently.

### Determining Leakages in the Building Envelope

The effects of inadequate airtightness were investigated by the Fraunhofer Institut für Bauphysik (Fraunhofer Structural Physics Institute) in Stuttgart, Germany, in a measurement study in 1989 and the results were published in various specialist periodicals (e.g. *DBZ* 12/89, Page 1639 ff.).

The Institute tested both the thermal insulation effect and moisture penetration with an interior vapour barrier together with thermal insulation comprising of mineral wool with an insulation thickness of 14-cm (that was the thermal insulation standard in Germany at the time). Leakages were created at the centre of the 1-m² vapour barrier surface area to represent a leak: 1-m long and of various widths: 1, 3, 5 and 10-mm. The leakages were located only in the vapour barrier and not in the thermal insulation itself.

A temperature difference of 20°C in the interior with respect to -10°C at the exterior was replicated in order to determine the heat losses. A temperature difference of 20°C on the inside with respect to 0°C on the outside (in order to avoid icing up of the quantity of water penetrating the structure) was produced for determining the humidity streams.

The pressure differences, at 10, 20, 30 and 40 Pa, corresponded to those that may typically act on the building envelope.

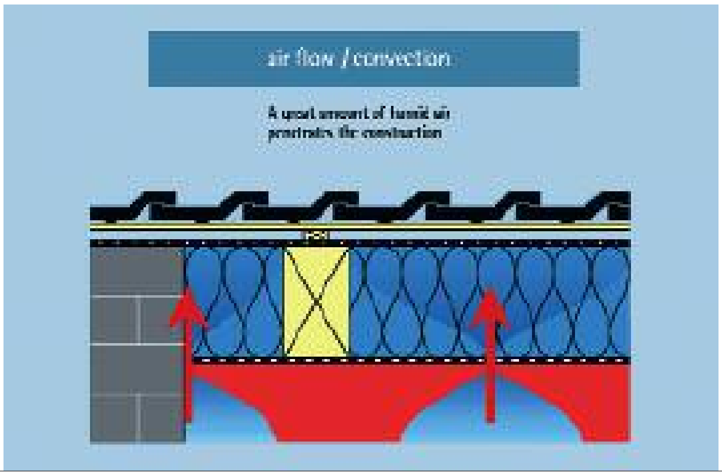

Figure 1

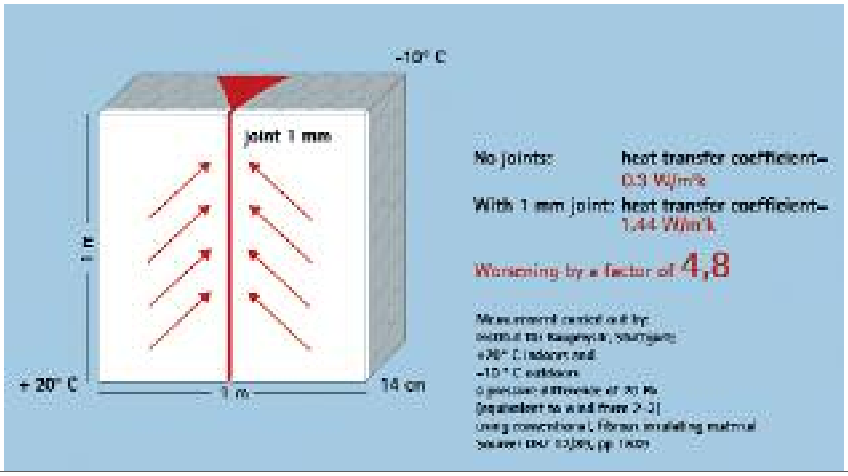

Figure 2

Pressure differences on the building envelope is produced both as a result of thermal reasons and as a result of the temperature difference between inside (warm) and outside (cold), besides temperature differences produced as the result of wind; by wind pressure and wind suction. A pressure difference of 20 Pa is produced, for instance, at an outside temperature of -10°C and wind force 3 or outside temperature of 0°C and wind force 4.

Initially, the two parameters under investigation – thermal insulation effect and moisture transmission – were measured with the seamless vapour barrier at various pressure differences. The structure with various leakages at different widths was then investigated, at all pressure differences. The measurement results were alarming and shocked specialists at the time.

**Benefits of Thermal Insulation**

When investigating the thermal insulation effect of the 14-cm thick thermal insulation with the seamless vapour barriers/vapour check, the measured heat transfer coefficient confirmed the theoretical value of 0.30 W/m²k. The thermal insulation was then measured with the leakages of various widths at the various pressure differences.

Even with the smallest leakage width of 1-mm and a pressure difference of 20 Pa, there was a reduction in insulation effect by a factor of 4.8. This means that the insulation value of the 14 cm-thick thermal insulation with a slight leak is no longer 0.30 W/m²K but only 1.44 W/m²K. Joint widths of 3-mm indicated reduction factors of 11. Consequently, leaks at the airtightness level – such as in the vapour barrier/vapour check – lead to a reduction in the thermal insulations' performance. The heating energy demand and, consequently, $CO_2$ emissions, increase many times over.

**Economic consequence:**

Viewed economically, the energy saving with thermal insulation is far less than expected if airtightness is inadequate or even non-existent. The heating bill – for oil, gas, electricity, wood, biomass or district heating – is far higher than previously calculated. This leads to a poor return on the investment in thermal insulation. If you had invested your money in a different system, you would have done better financially.

The value of the property is also dependent on energy consumption. A property with high monthly maintenance costs has a lower value than a property with low monthly costs. If the thermal insulation is so poor that the building cannot be heated adequately at subzero temperatures or in high winds, this means that elementary human needs for protection and warmth can no longer be met. No one wants to live or work in cold, draughty buildings. Such problematic properties can then no longer be rented or sold and their value drops substantially.

Energy costs have doubled and, in some cases, even quadrupled over the last three years. This rise in costs will increase still further in the years to come for political reasons (Middle East, Iran and Iraq) and owing to world demand (expansion in China), besides the natural reasons involved (natural disasters, e.g. hurricanes). Investment in effective thermal insulation, even at this early point, will be very worthwhile, both for new buildings and when renovating/modernising, and will mean an even higher return on investment in view of further increases in energy costs.

**Ecological Consequences**

Thermal insulation with a poor efficiency leads to higher $CO_2$ emissions that, in turn, further accelerate the greenhouse effect. We can extend the term environmental protection; the concern is not only to protect our environment in which we live and to protect resources, natural resources and foodstuffs. The concern now is also that we must protect ourselves against the effects of climate change. Cyclones, hurricanes, tornados and typhoons suck warm air from the earth's surface to the upper atmosphere and cold air from the upper atmosphere to the earth's surface, which consequently acts as valves for heat equalisation on the earth.

We need intelligent solutions to keep menacing trends in check. Energy saving and, consequently, cutting greenhouse gas emissions with airtight building envelopes is one important step towards achieving this.

**Energy Demand for Buildings**

Over 40 % of the world's annual energy demand is used to heat and cool buildings, consequently representing the largest energy share, even higher than the energy consumed by transport and industry. Effective thermal insulation allows energy consumption to be cut drastically. A low-energy building requires only 10 kWh (corresponding to 1 litres of oil or 10m³ of gas) to heat 1m² of living area to achieve pleasant interior temperatures even at subzero outside temperatures and a windy outside climate. New buildings in Germany with legally prescribed airtight building envelope and legally prescribed thickness of thermal insulation consume approx. 60 kWh (corresponding to 6 litres of oil or 60m³of gas). An energy consumption exceeding 500 kWh (50 l of oil or 500 m³ of gas) per m² of living area is not rare on buildings with poor airtightness and resultant heat losses through leakages.

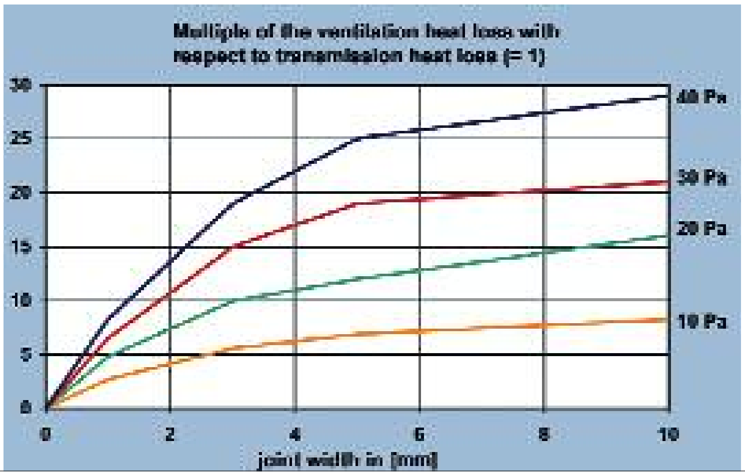

Figure 3

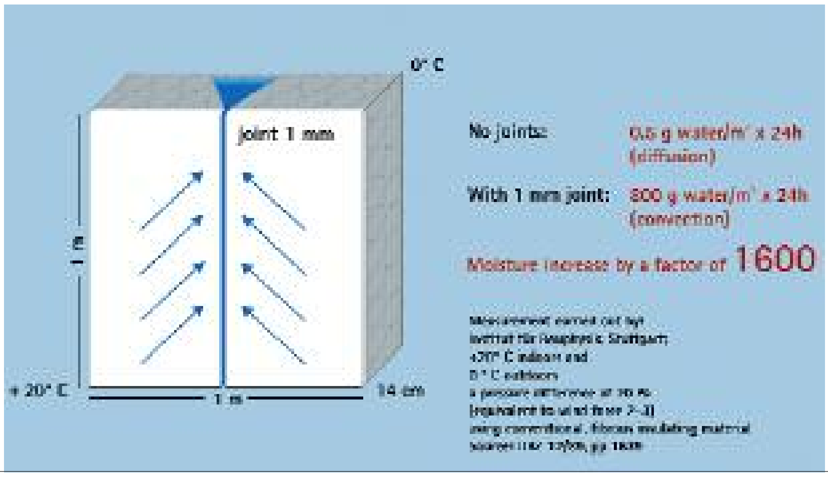

Figure 4

Figure 5
*The figures clearly indicate how the cold air flows along building components and cools the surfaces*

**Lack of Airtightness and Structural Damage**

The study by the Fraunhofer Institute of Building Physics also measured moisture penetration into the structure in conjunction with the thermal insulation performance. The vapour barrier had a diffusion resistance sd of 30-m (mvtr of 150 MNs/g). The measurement confirmed the theoretical moisture penetration rate of 0.5 g/m² into the structure. The quantities of moisture pose no problems for structures even in the case of vapour barriers/vapour checks which are more open to diffusion with an sd value of 2-m (mvtr of 10 MNs/g).

The moisture penetration through the leakages was determined in the second test. The results were alarming and explained many cases of structural damage: The moisture penetration by convection (air flow) was 800 g/m of leakage, per day with the smallest slit of only 1-mm width and at 20 Pa pressure difference. The figure was 1700 g/m with a leakage width of 3-mm.

The moisture penetration leads to condensation on the exterior components and prefabricated compound units and forms a water film that reduces the diffusion capability of the prefabricated compound unit or component. At subzero temperatures, the water film turns into a diffusion-tight ice layer. This can turn a prefabricated compound unit or component that is open to diffusion into a diffusion-tight barrier layer on the outside and lead to an even higher condensation precipitation in the structure.

Condensation precipitation when air cools starts below the dew point that is 9.2°C in the case of 'standard' inside air at a temperature of 20°C and 50 % relative humidity. 3.85g of water condenses from each cubic metre of air that penetrates a structure and cools to 0°C. The figure is even 6.55g of water with cooling to -10°C outside temperature.

**Moisture in the Structure and Mould Growth**

Moisture in the structure quickly leads to mould formation. Mould is associated with a destruction in the building fabric. Depending on the quantity of moisture and method of design, structural damage may occur even after only a short period or possibly only after several years. This means that the structure then requires costly renovation.

However, even more serious, mould poses a health risk to humans. A distinction is made between mould spores and so-called MVOCs (microbial volatile organic compounds), the gaseous substances emitted by mould. Mould spores are considered to be the biggest cause of allergies. The immune system can be damaged fundamentally by them, in some cases even irreparably. Spores and, above all, MVOCs are also suspected of being carcinogenic. If moulds spores and MVOCs are inhaled, the lung does not have any effective defence mechanism, and spores and MVOCs can then enter the body unhindered. The consequences for the health of occupants cannot generally be directly assigned to mould since symptoms are slowly progressing and diffuse. A sick immune system expresses itself by various symptoms.

**Causes of Cooling**

In relation to health risk, there is no difference between mould growth on the surface of the interior prefabricated compound layers or 'invisible' mould growth in the structure itself. The mould inside building structures is even potentially more harmful since it is not outwardly recognisable and cannot be attributed as the cause of sicknesses.

Visible mould can be seen and eliminated. Mould in the building structure may remain undetected for many years and, under certain circumstances, for many decades, and may lead to serious health problems. Mould occurs not only when the actual temperature drops below the dew point, i.e. when condensation precipitates, but also if the relative humidity merely lies above 80 % for extended periods of time within building elements.

Reduction in surface temperature of building elements can be caused by so-called thermal bridges or by defective airtightness. The colder and windier it is outside, the more the building elements will cool. A damp room climate leads to a higher dew point temperature and mould limit temperature and hence, an acceleration in mould growth. Referred to as 20°C air temperature, air at 50 % relative humidity has a dew point of 9.2°C and air with 65 % relative humidity has a dew point of 13.2°C. The range critical to mould is room air with 50% relative humidity at 12.6°C and room air with 65% relative humidity at 16.5°C.

**How to Detect Air Leaks**

Thermographic cameras show the surface temperatures of building structures. Red and white areas indicate high surface temperatures. Blue areas correspond to low surface temperatures at which cold air penetrates and leads to cooling of the building structures surfaces. The scale on the images below shows the assignment of temperatures to colour. The bluer the colour, the cooler the surface and hence the greater the risk of mould formation on the surface within building components. *(see Fig. 5)*

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