Thermal performance and air tightness

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Summary

In Hungary, most of the damage characterising residential building structures does not only stem from structural engineering or quality shortfalls but from building-physics reasons. The most frequently occurring moulding and vapour condensation problems indicate that in the designing and dimensioning of 'state-of-the-art' building structures, special care must be exercised.

Key words: Timber houses, building physics, air tightness, thermal insulation

1. Introduction

In Hungary the proportion of lightweight-structured residential houses built typically with light wall structures and assembled from different materials is rising continuously. Most of these houses have wooden frame or panel structures.

During the past decades Hungary has seen a considerable change in the extent of, and the requirements relating to, heat insulation. Some of the experiences gained in connection with traditional buildings (which, in Hungary, consist of brick wall structures and solid floors) have become obsolete and thus invalid, and now other important factors must also be taken into consideration during the design and construction phases, and also in supervising the implementation works.

Disregarding questions and problems that arise and come to the fore in the case of **lightweight-structured buildings** (such as the problem of thermal bridges, vapour

control, air tightness, ventilation, heat storage) may cause serious faults and failures in the completed building.
On the other hand, if all these problems are solved by good design, we can enjoy a number of advantages (such as better heat insulation, smaller wall cross-sections, shorter construction period, most implementation tasks becoming a sort of assembly work in nature, smaller dead weight of the building, etc.).

In my presentation I try to highlight some of the typical questions and problems based primarily on practical experiences gained in Hungary.

2. Thermal insulation

In Hungary the requirements relating to the heat insulation of residential buildings are regulated in TNM Decree No. 7./2006. (V. 24.).
At the first level of the energy-focused regulation the what is called „order of layers” requirement relating to different boundary structures and doors and windows should be met. (See Table 1.)

Table 1: Required heat transmittance values of building boundary layers

Boundary structures of a building	Required value of heat transmittance U [W/m^{2}K]
External wall	0.45
Flat roof	0.25
Attic floor	0.30
Boundary structures of heated attic area	0.25
Lower top-floor over unheated cellar	0.50
Glassed door or window on facade (with wooden or PVC frames)	1.60
Glassed door or window on facade (with metal frame)	2.00
Facade glass wall	1.50
Roof window	1.70
Facade door, or door between heated and unheated spaces	1.80
Wall between heated and unheated spaces	0.50
Wall between neighbouring heated buildings	1.50

At the second and third level the specific heat loss factor (the requirement relating to the average heat transmission coefficient of a building's boundary structures), and the highest permissible value of a building's combined energetic parameter, respectively, should be calculated in the function of the surface/volume proportion.

It can be stated without describing the details of these calculations that in a general case the Hungarian energetic requirements relating to the heat transmittance of walls and floors, and to the entire building <u>can easily be met</u> even in the case of lightweight-structured buildings. (ETAG 007 specifies only general requirements for thermal insulations.)

The „optimum" extent of thermal insulation will be determined by the present construction costs and the expectable energy prices. A long term increase in energy prices and a steady decrease in the various kinds of state funding and supports can now be predicted. Using the extent of heat insulation considered by experts as optimum we can approach the level of the German „passive" house, in which the annual energy requirement for heating is only 30 kWh/m^2 .
In accordance with the recommendations of ÉMSZ, a Hungarian professional organisation, the heat transmittance of the boundary structures should be as follows:

Table 2: Recommendations of ÉMSZ (Hungarian Federation of Roofing Contractors)

Building's boundary structures	Recommended value of heat transmission coefficient U [W/m^2K]
Outer wall	0.30
Flat roof	0.20
Attic floor	0.25
Boundary structures of heated attic area	0.20

The built-in heat insulation should be protected against both external and internal moisture by proper positioning or by means of various coatings, as moisture can considerably influence heat insulation capacity.

2. Vapour control inspection

It is necessary to check the vapour control characteristics of multi-layered wall and floor structures that often contain wood, wood-based boards and heat insulation sensitive to moisture. It is recommended to design the order of layers in such a way that there would be no condensation of moisture within the structures under the designed conditions (in case of residential rooms t_i = +20,0°C, t_e = -2,0°C, φ_i=65%, φ_e=90%). According to ETAG 007 the moisture content in the layers of wooden-framed structures may exceed the relative moisture content of 80% only for a limited period of time.
In general, such a condition can only be achieved by making a fairly efficient damp proof layer. The earlier practice (e.g. the application of non-continuous agricultural foil) can not be maintained any longer. Even a suitable damp proof layer can be ruined by perforating it after installation (e.g. because of the mounting of electrical cables/wires or fittings). Vapour control inspection can be performed in the manners specified by standards MSZ-04-140-2: 1991 or MSZ EN ISO 13788: 2002.

For lightweight-structured buildings it is increasingly recommended to check the internal surface temperature of boundary structures that will probably develop a heat-bridge. For the purpose of such checkings the 2- or 3-dimension finite element methods are quite suitable. By using the computer-aided modelling technique described in standard MSZ EN ISO 10211-1:1998 the weak points (such as connections, corners, footing, etc.) of the structure designed can be identified and corrected. In addition to the temperature data given as finite elements the temperature-code or isothermal graphic representations provide a clear picture of the surface and internal heat distribution of the building structures.
Given the conditions for dimensioning aimed at the protection of the structural state of buildings, temperatures below dew-point may not be permitted on the internal surfaces of residential rooms (ti = +20,0°C, te = -5,0°C, φi = 65%,). From the computerised examinations it can be seen that heat insulations or heat insulation systems applied over the entire surface can be used advantageously, as these eliminate the effect of structural heat bridges.

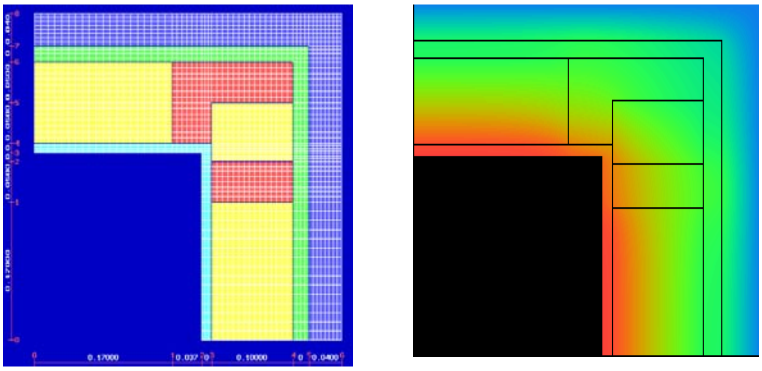

Figure 1: Finite element model and temperature distribution in a corner nodal point of a lightweight-structured building

3. Summer overheating

The risk of building overheating in the summer or the energy demand of powered cooling should be mitigated by using structural, shading and natural ventilation solutions. It is recommended to design to the extent possible a heat storage layer in the form of, for example, a floor structure. Shading of doors and windows should be provided for.

As there can be great differences in shading demands between the various rooms in a building depending on the orientation of the rooms, the designer may decide to assess the risk of overheating for each room or each zone.

If the average value of internal heat load arising from normal use and related to the period of using the building does not exceed the value of $q_b \leq 10$ W/m^2 , the risk of overheating is acceptable, if the difference between the daily average values of internal and external temperatures corresponds to the relationship: $\Delta t_{bsummer} \leq 2$ K .

4. Air tightness, exchange of air

Development of filtration should be avoided by all means, because in addition to a considerable heat loss it can cause the moistening of the structure. It is necessary to find already in the design stage of the building all the possibilities and solutions through which air-tightness can be ensured.

In order to maintain a constant air quality, at least a 0.5-fold exchange of air is required. As up-to-date windows, when closed, do not provide any measurable exchange of air, air should be exchanged by means of ventilation. Up-to-date ventilation equipment pre-warm fresh air using the foul air, reducing thereby ventilation-induced heat loss (Heat Recovery Ventilation). These equipment work with a minimum noise level and energy consumption.

5. Inspection during construction

As apparent from what I have said so far, the precise installation of all the heat insulation and vapour control layers is of primary importance from the viewpoint of the building's correct and appropriate physical functioning.
After the completion of the windows, doors and the internal vapour control system it is possible to test the air-tightness of the building (or of some of the building's rooms). The purpose of the on-site test to be performed in accordance with the specifications of standard **MSZ EN 13829:2001 is** to determine the air permeability characteristics of the boundary surfaces. During the application of the test method an overpressure is brought about in the building, and then the degree of air-tightness and the extent of the exchange of air can be calculated from the pressure drop measured. Exchange of air to an extent higher than justified should be avoided in the buildings.
By colouring the air or measuring air velocity the leaks could be found.

Figure .: Air-tightness test of a timber house

6. Inspection of the completed building

Thermal photographs provide uncompromised evidence in respect of the real thermal engineering quality of a completed building. One precondition (among a number of other ones) for taking correct thermal photographs is a temperature difference of higher than 15 °C on the two sides of a boundary structure.
In the photos deficiencies of air-tightness can also be well observed in addition to structural and geometrical heat-bridges.

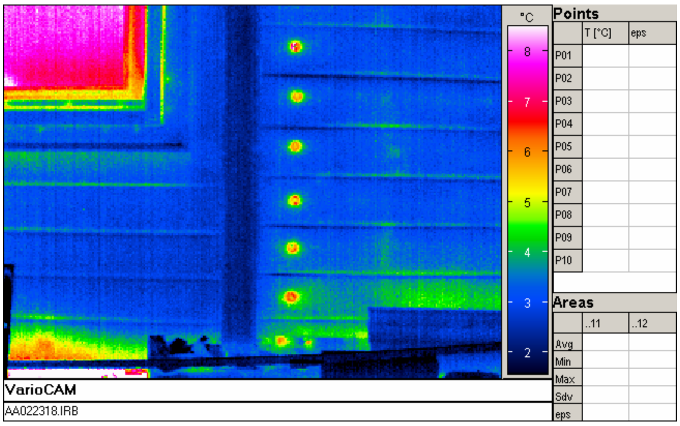

Figure 2: Fastening elements of a timber house as point thermal bridges

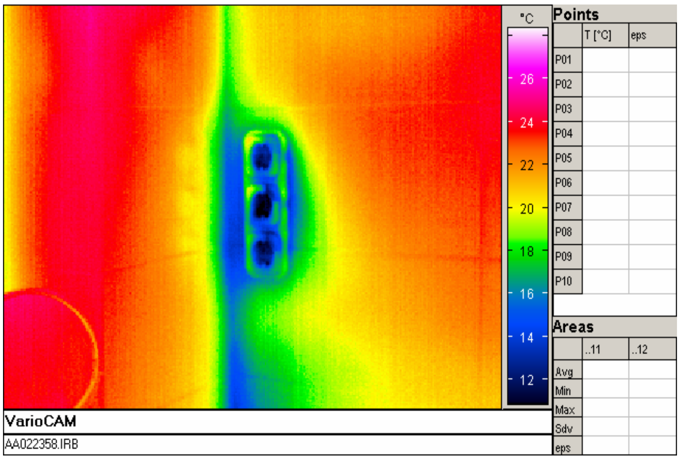

Figure 3: Filtration next to an electrical wall-socket

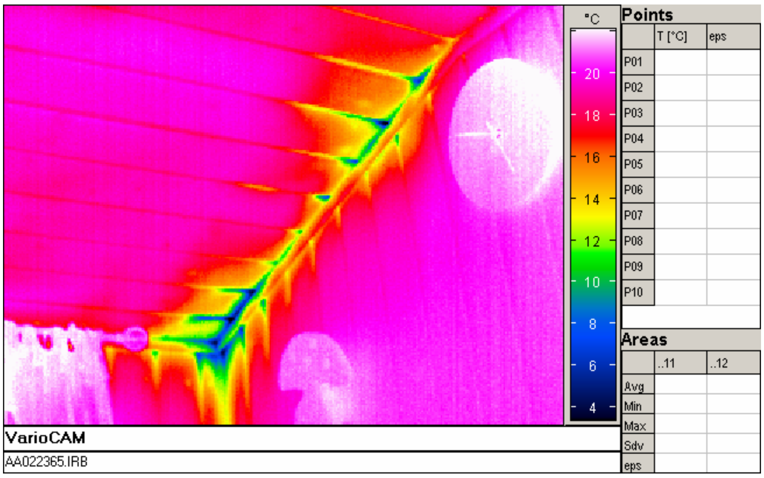

Figure 4.: Joint effect of a geometrical thermal bridge and filtration

7. Doors and windows

In the case of lightweight-structured buildings, given their boundary structures' low heat transmission coefficient, the quality of windows is a very important factor. In respect of building physics, unfavourable effects would arise if, for example, a window with a heat transmittance of U = 2.5-3.0 W/m^{2}K were built in a structure with a heat transmittance of U = 0.2-0.3 W/m^{2}K. Therefore, only the application of wooden or plastic framed windows provided with up-to-date heat insulated glass and a Low-E coating can be recommended.

In Hungary the new European standards relating to the new test methods of windows and to the classification of the test results have also been introduced. As a result of taking the European standards (EN) over, there have been important changes not only in the markings, but also in the measurement methods and in the ways of assessing the measurement data.

8. Summary

A further spread of lightweight-structured buildings – including wooden houses – can be expected. In the case of wooden houses most of the presently occurring frequent construction faults and mistakes can be avoided by taking the above discussed aspects concerning the design and implementation of vapour control and air-tightness into consideration.

9. References

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