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The Importance of Thermal Heat Bridges in Civil Engineering

Based on the heat transfer characteristics of a construction, the expected temperatures along interior surfaces must be evaluated in order to predict (and avoid) areas of potential moisture condensation. Beyond preventing damage to building materials caused by mould growth, adequate surface temperatures are also a relevant factor in the thermal comfort of an interior environment. An agreable climate in a room can be obtained, when relative humidity is between 40 and 60%. As the air in a room is warmer, the more vapor can absorb (and vice versa), influencing the thermal comfort index. Heat losses are influenced largely by thermal bridges of construction. The importance of the thermal heat bridges is strongly increasing today. In new developments the thermal optimization of junctions in today common low energy constructions receives very special standing. The subject of avoiding thermal bridges in passive houses became predominant.

***Keywords**: thermal heat bridges, heat flow, vapor diffusion, humidity, condens, dew point*

1. Introduction

Energy in the form of heat in building constructions is generally transmitted by a combination of conduction, convection, and radiation. When considering heat transfer within and through solid (homogeneous or non-homogeneous) building materials, heat conduction is the primary transmission factor; the effects of convection and radiation are typically negligible.

Heat losses are influenced largely by construction of a thermal bridges.

Thermal bridge is the border between areas with different levels of thermal insulation. In these portions, heat is lost in larger quantities than the rest of the surface and then on these portions condensation occurs because of moisture, the plaster is destroyed and the mold will appear.

There are two thermal bridges types: structural and geometric.

The structural thermal bridge systems or materials result from the installations or materials with high heat conductivity or without insulation, for instance, reinforced concrete elements, which pierce the outer wall isolation.

The geometric thermal bridges results from the corners of a homogenous unit construction, if a large external surface, carrying heat, is opposite to an internal surface. In the thermal bridge area the construction units surface temperature drops in winter. When falls below the dew point, water is condensed. For the thermal bridges it always appears the fungus risk.

In the area where two materials with different heat retention capacity come into contact, there is a loss of heat due to the thermal bridges appearance, which may occur in the closing elements made of the same material with thickness variations. For the building construction are used various heat resistant materials so heat loss occurs in the areas where the thermal insulation is interrupted.

Significant heat loss by thermal bridging usually occurs in the building outer walls (between carpentry and lintel). The condensation also occurs if the building elements are not thermally protected. The temperature variations due to the thermal bridges are, in time, negatively affecting the closing element materials behavior. Thermal bridges are directly influenced by the ratio between the thermal bridge width and element separation thickness [5]. As the bridge width is higher, the heat loss is higher. For example, for windows and door joinery is recommended that the mounting distances should not exceed 3mm in width and height. To reduce the thermal bridges and condensation appearance, at the intersection of two elements with different thermal resistance, it is recommend to use thermalproof materials (polyurethane foam).

The importance of the thermal heat bridges is strongly increasing today.

In new development the thermal optimization of junctions in today common low energy constructions receives very special standing. The subject of avoiding thermal bridges in passive houses became predominant.

During renovation one can significantly miss the target of heat energy savings if no attention has been paid to multidimensional heat flows incurred by thermal heat bridges. On the other hand thermally weak junction constructions easily lead to low interior surface temperatures, resulting in moisture wich then leads to the mould growth. Not only the comfort and health get significantly impaired but also resort structural damage shall result [6], [7].

2. The Dew Point

In terms of dew point a practical measurement indicator for the amount of vapour contained within the wet air of some specific temperature is given by the relative humidity. It can be measured directly and very precisely with simple instruments - e.g. the hygrometer. When wet air in contact with some surface of which the temperature is lower then that of the air, then it will show the vapour condensation on that surface when its temperature falls below the dew point temperature of the air. The dew point temperature is set by the value of temperature at which wet air of some specific vapour content will be saturated (by holding other parameters constant), i.e. the relative humidity is 100%.

The dew point temperature is simultaneously the degree of air moisture. If the dew point temperature is below the actual surface temperature there will be no condensation. To reliably preclude condensation the temperature at any place of the interior surface must be higher than the current dew point temperature of the air.

The term of "condensing humidity" is introduced when assessing surface temperatures in the context of condensation risk.

The "condensing humidity" is the value of relative air humidity at which, when it is exceeded, the vapour condensation will occur on the surface having some specific temperature. It can be calculated by a quotient of saturated vapour pressure at surface temperature and the pressure of saturation at specific air temperature.

The introduction of condensing humidity provides direct normative assessment of the temperature field calculated for some construction. For negative temperatures of exterior air the maximum allowed humidity for the interior space air has to be reduced by 1% by each degree of exterior air temperature decrease. The condensation risk must be concluded only when the "condensing humidity" calculated for the temperature of the coldest point at the surface goes below the one set within the standard [1].

3. The Thermal Transmittance Analytical Calculation

Heat conduction through homogeneous planar building components (i.e. composed of one or more layers of material with parallel surface planes) occurs in a single direction: normal to the component surface. This is referred to as one-dimensional heat flow, and is characterised by a constant surface temperature over the entire surface plane.

Such idealised conditions can only be assumed in limited regions of an actual building structure. Geometries of non-planar components (construction joints, floor-wall connections, balconies, etc.) give rise to heat flow patterns of more than one direction, that is, to two or three dimensional heat flow.

Thermal bridges, which in general occur at any junction between building components or where the building structure changes composition, have two consequences:

- a change in heat flow rate;
- a change in internal surface temperature compared with those of the unbridged structure.

Although similar calculation procedures are used, the procedures are not identical for the calculation of heat flows and of surface temperatures.

The thermal bridges are described in terms of linear and point thermal transmittances characteristic to building components analysed.

The linear thermal transmittance, Ψ heat flow rate in the steady state divided by length and by the temperature difference between the environments on either side of a thermal bridge [2], [3]. The linear thermal transmittance is used as a correction term for the linear influence of a thermal bridge.

The linear thermal transmittance is given by:

$$\Psi = L^{2D} - \sum_{j=1}^{J} U_j \cdot b_j \quad [W/m \cdot K] \tag{1}$$

where:

Ψ - the linear thermal transmittance *Psi* of the linear thermal bridge separating the two environments being considered;

L^{2D} - the thermal coupling coefficient obtained from a 2-D calculation of the component separating the two environments being considered;

U_j - the thermal transmittance of the 1-D component *j* separating the two environments being considered;

b_j - the length within the 2-D geometrical model over which the value U_j applies

J - the number of 1-D components

When determining the linear thermal transmittance, it is necessary to state which dimensions (e.g. internal or external) are being used because for several types of thermal bridges the value of the linear thermal transmittance depends on this choice.

The point thermal transmittance is given by:

$$\mathrm{X} = L^{3D} - \sum_{i=1}^{I} U_i \cdot A_i - \sum_{j=1}^{J} \Psi_j \cdot l_j \quad [W/K] \tag{2}$$

Where:

χ - the point thermal transmittance of the point thermal bridge separating the two environments being considered;

L^{3D} - the thermal coupling coefficient obtained from a 3-D calculation of the 3-D component separating the two environments being considered;

U_j - the thermal transmittance of the 1-D component j separating the two environments being considered;

A_j - the area over which the value U_j applies;

Ψ_j - linear thermal transmittances;

l_j - the length over which the value Ψ_j applies;

J - the number of 2-D components

I - the number of 1-D components

When determining Ψ and χ values, it is necessary to state which dimensions (e.g. internal or external) are being used because for several types of thermal bridges the Ψ and χ values depend on this choice..

Rewriting the above equation by replacing the linear thermal transmittance by its definition, provides following alternative means of calculating the point thermal transmittance:

$$X = L^{3D} + \sum_{i=1}^{I} U_i \cdot A_i - \sum_{j=1}^{J} L_j^{2D} \cdot l_j \quad (3)$$

An alternative expression for the total coupling coefficient $L_{i,j}$ which uses the linear and point thermal transmittances, Ψ and χ, is then given by

$$L_{ij} = \sum_{k=1}^{K} U_{k(ij)} \cdot A_k + \sum_{m=1}^{M} \Psi_{m(ij)} \cdot l_m + \sum_{n=1}^{N} X_{n(ij)} \quad (4)$$

Where:

$U_{k(i,j)}$ - the thermal transmittance of part k of the room or building;

A_k - the area over which the value $U_{k(i,j)}$ applies;

$\Psi_{m(i,j)}$ - the linear thermal transmittance Psi of part m of the room or building

l_m - the length over which the value $\Psi_{m(i,j)}$ applies;

$\chi_{n(i,j)}$ - the point thermal transmittance of part n of the room or building

K - the number of thermal transmittances

M - the number of linear thermal transmittances

N - the number of point thermal transmittances

In above formula ΣA_k is equal to the total surface area of the envelope.

$L_{i,j}$ is equivalent to the heat transfer coefficient, H often used in other standards.

The heat flow rate in the steady state is divided by the temperature difference between the environments on either side of a thermal bridge [2], [3].

The point thermal transmittance is used as a correction term for the influence of a point thermal bridge.

4. The Dew Point Calculation

When the standardized temperature of exterior air is set for the calculation to -12°C, then the relative humidity of the interior air (at 20°C temperature) shall never exceed 53% which is calculated as the difference between 65% and 12%.

If the "condensing humidity" calculated for the coldest surface point is above 53%, then, concluding the ÖNorm B8110-2:2003, there is no condensation risk [9].

If this is not the case, the construction assessed must be considered non conformant with standards. The areas affected by the condensation risk can be easily made visible by drawing the isolinie of 53% of condensing humidity at that surface [6].

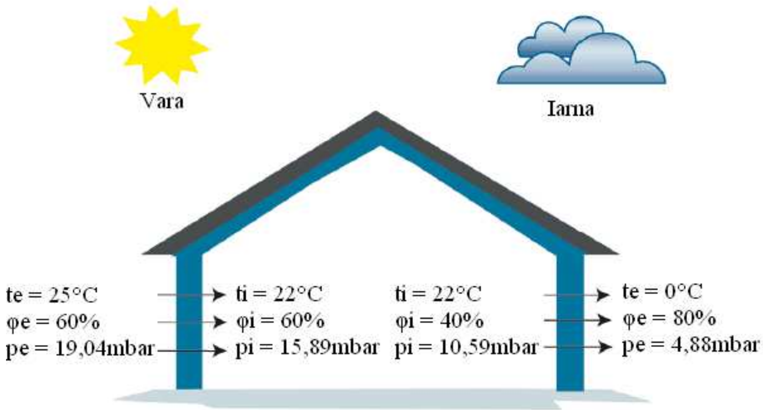

Figure 4. Climatic parameters of the indoor and outdoor air (summer - winter)

By taking into account the negative effects caused by moisture (mold, odor, lichens, damaged insulation, unhealthy indoor climate) on the outside and inside surfaces of the building, it is necessary to control the moisture in any form [5].

To avoid the moisture appearance it is necessary to determine the dew point. Thus interior and exterior thermal parameters of a building both in summer and winter are considered (Figure 1).

The dew point temperature is the temperature value for which a mixture of vapor and gas with vapor constant content has to be cooled under constant pressure, because, due to saturation with vapors, first liquid droplets will appear. More specifically, if inside a room the humidity (whose volume is constant) remains constant, there is a certain temperature below which the water vapor condenses until the temperature increases above the critical level. For the dew point control an airwasher may be used, which may be unnecessary if the parameters should be left unchecked and it can be dangerous to health if its unpropriate utilization maintain the relative humidity below 40%.

To detect the surfaces on which condensation may be formed, the dew point temperature, vapor pressure and total humidity calculation was achieved by using a software based on knowing the air temperature and relative humidity.

In winter, the walls temperature is slightly lower than the air inside the room and, therefore, these areas are sensitive to dampness and mold.

Thermal comfort index is an index wich corroborates the air temperature with relative humidity (phisical parameter that is equal to the amount of water vapor which exists in a gaseous mixture of air and water) to determine an apparent temperature (the one felt by the human body) [4].

In Table 1 are shown the calculation results.

Table 1.

	t_i [°C]	t_e [°C]	φ_i [%]	t_{pr} [°C]	p_v [mbar]	φ_t [g/m^3]
Summer	22	25	60	13,89	15,89	11,67
Winter	22	0	40	7,81	10,59	7,78

Where:

t_i [°C] - the inside temperature,

t_e [°C] - the outdoor temperature,

φ_i [%] - the indoor air relative humidity,

t_{pr} [°C] - the dew point,

p_v [mbar] - the vapor pressure,

φ_t [g/m^3] - the total moisture.

A pleasant climate in a room is done, when relative humidity is between 40% and 60%. As the air inside a room is warmer, the more vapor can absorb (and vice versa), influencing the thermal comfort index.

In order to ensure an adequate comfort index during the summer, the absolute humidity value is equal to 11.67 g/m^3 and the dew point temperature is of 13.89°C. To achieve the same comfort index values in winter, the absolute humidity and dew point temperature values are much lower.

In conclusion, for the considered room condensate will be formed on the surfaces with a lower than 13.89ºC temperature in summer and 7.81°C in the winter.

The spaces decorations with indoor plants aims both the home appearance and climate improvment. The last aspect is accomplished through the air filtration by the plants which asorb the carbon dioxide and eliminate the oxygen.

5. Conclussions

When the thermal performance of building components are analyzed, two different types of information are to be found: the thermal transmission and surface temperatures.

The first type entails to evaluate the heat transfer characteristics of a building assembly, i.e. the form and quantity of heat losses and gains, in order to finally obtain the following [6]:

- a reliable estimation of heating and cooling loads (costs),
- acceptable heat flow rates,as well as
- energy conserving design alternatives.

Based on the heat transfer characteristics of a construction, the expected temperatures along interior surfaces must be evaluated in order to predict (and avoid) areas of potential moisture condensation. Beyond preventing damage to building materials caused by mould growth, adequate surface temperatures are also a relevant factor in the thermal comfort of an interior environment.

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