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HYGROTHERMAL DESIGN OF BUILDINGS

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Abstract: *This paper aims to draw the attention to the need of buildings insulation which has the purpose to achieve economical buildings with rational consumption of fuel and energy, and to satisfy the hygrothermal comfort requirements imposed by the sanitary rules correlated with the type of activity performed.*

The resistance to the vapour permeability takes into account the possibility of condensation and moisture removal inside the construction elements. For this purpose it is necessary to know the basic elements to counteract the undesirable consequences of this phenomenon.

Key words: *permeability, vapour, water, thermal insulation*

1. The Objectives for Hygrothermal Design of Buildings

Thermal insulation of buildings aims to make economic buildings with rational consumption of fuel and energy, and to satisfy the hygrothermal comfort requirements imposed by sanitary rules, correlated with the type of activity performed.

Hygrothermal design of buildings will pursue [1]:

- **minimal thermal resistance** necessary for heat transfer thru delimiter elements for limiting heat flow and avoid condensation on inner surfaces of construction elements;
- **thermal stability necessary** of construction elements to limit indoor air temperature fluctuations on inner surfaces of the construction elements;
- **resistance to vapour permeability** in order to eliminate the possibility of condensation and moisture accumulation inside the construction elements;
- **resistance to air permeability** of exterior construction elements.

Interior construction elements will be verified by thermotechnical calculation only if there is a difference temperature between the rooms that exceeds 5K and / or relative humidity above 15%.

The building response to heat transfer can be addressed through:

- **laborious calculation methods**, which are based on solving differential equations of the laws of conduction, convection, radiation or combined transfer actions using numerical methods, graphic methods based on analogies, etc;
- **operative calculation methods**, presented in C 107/2005 norms that are conform with CEN / TC 89 N 35 IE.

These methods give satisfactory results for the current design of buildings.

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In what follows is presented in detail the vapour permeability resistance calculation.

2. Vapour Permeability

2.1. Overview

Water acts on construction materials and buildings in liquid (drops), solid (crystalline or amorphous) or gaseous (vapour) and can have influence in terms of:

- **thermotechnic**, as humidity variation affect the thermal properties of materials [conductivity, specific gravity and mass heat];
- **construction**, because the variation of humidity change the mechanical resistance, introduces tension as an effect of the contraction or swelling of the material or peeling as a result of the phenomenon of freezing and thawing;
- **hygienic**, as rising humidity in buildings over certain limits creates - on the one hand, conditions of disease or worsening of diseases like rheumatism, asthma or allergies, respectively - on the other hand favour the development of fungi (mould) in mass or on surface of the construction element.

The water that acts on the construction materials of construction, respectively on buildings may have the following origins:

▪ ground water - works by pressure or capillary ascent on the infrastructure;
▪ building primer water - which is dependent on the type of materials used and their installation technology (wet or dry processes);
▪ water from weather (rain, snow) – which acts on the building envelope;
▪ operating water – resulted from the hygienic and technological processes from buildings;
▪ biological water – as a result of respiration and evaporation processes from the skin surface of occupants;
▪ condensation - resulted from vapour condensation on the inner surface and mass of the construction elements in contact with it, if the temperature is below the dew point;
▪ hygroscopic water - as a result of the interaction between interior and exterior air humidity and exterior construction elements mass.

2.2. Water vapour. Physical measures

The air contains a quantity of water as vapour which determines its degree of humidity. It is expressed in many ways, among which:

- **absolute humidity of air** – represents the mass of water vapour contained in one m^3 moist air at a given temperature:

$$U_a = \frac{m_v}{V} \tag{1}$$

in which,

m_v is the mass of vapour [g];

V - air volume [m^3].

The maximum content of vapour at a certain temperature is called the saturation absolute humidity:

$$U_s = \max U_a \tag{2}$$

- **relative humidity of air** – represents the ratio between the mass vapour contained in $1m^3$ of moist air and the mass vapour corresponding to saturation, in the same conditions of pressure and temperature:

$$\varphi = \frac{U_a}{U_s} \cdot 100\ [\%] \tag{3}$$

Permeability through construction elements is determined by the pressure gradient existing between their faces, which in turn is caused by different content of vapour in the air. The vapour flow is a couplant flow of heat flow.

The measures that characterize materials in terms of vapour permeability are:

- *vapour permeability coefficient* μ [g /m.h.mm.Hg], which depends on the porosity and temperature of the material; this is the amount of vapour in grams per hour that passes in one hour through a cube with sides of 1 meter, if between the opposite sides of it is a difference of pressure of 1 mmHg;

- *vapour permeability* Λ_v of an unitary construction element, which is determined by the relationship:

$$\Lambda_v = \frac{\mu}{d} \text{ [g/m}^2\text{h mm.Hg]} \quad (4)$$

- *vapour permeability resistance* R_v is calculated by one of the formulas [C107/6-2002]

$$R_v = \frac{1}{\Lambda_v} = \frac{d}{\mu} \text{ [m}^2\text{h mm.Hg/g]} \quad (5)$$

and/or

$$R_v = d\,\frac{R_D T_m}{K_D D} = d\,\frac{M}{K_D} \text{ [m}^2\text{hmm.Hg/g]} \quad (6)$$

in which,

d - is the thickness of the material [m];

$\frac{1}{K_D}$ – resistance factor to vapour permeation of the layer of material;

R_D – ct, parameter of perfect gas [J/Kg K];

T_m - annual average temperature of the construction element [K], which has values [2]:

- Climatic zone I T_{em} = + 10.5°C;
- Climatic zone II T_{em} = + 9.5°C;
- Climatic zone III T_{em} = + 7.5°C;
- Climatic zone IV T_{em} = + 6.5°C;

D = permeability coefficient of vapour [m²/s];

M = factor depending on the average temperature T_m [s⁻¹].

2.2. The behaviour of construction elements to vapour permeability

Vapour permeability takes place in unstationary regime as the factors that determine the phenomenon (temperature and humidity) are variable in time. Due to the complexity of phenomena in design technique are accepted simplified approach to the phenomenon of permeability, namely the assumption of stationary regime [3].

Buildings must be designed and constructed so as to avoid condensation. It manifests itself in two forms that may exist individually or simultaneously:

• dew deposits on the inner surfaces of the construction elements of the envelope, especially in the area of thermal bridges and corners;

• accumulation of water inside the construction elements.

The main causes of surface condensation are:

- surfaces temperature

$$T_{Si} = T_i - \frac{T_i - T_e}{\alpha_i R} \geq \theta_r \text{ [°C]} \quad (4)$$

in which,

Θ_r is the dew point temperature;

- amount of vapour in the air; water vapour concentration in the air is expressed by the relationship:

$$C_{vi} = C_{ve} + \frac{\sum G_{ij}}{nVr\rho_a} \text{ [Kg vap/ora]} \quad (8)$$

in which,

C_{vi}, C_{ve} represent average concentrations of vapour in indoor/ outdoor air [Kg vap/hour];

G_{ij} - average flows of indoor sources of vapour [Kg vap / hour];

V - ventilated space volume [m³];

ρ_a - air density [kg/m³];

n - ventilation rate [h⁻¹];

r - venting efficiency of vapour evacuation.

The behaviour of a construction element according C107/6 to vapour permeability is appropriate if:

• the amount of water from condensation in the construction element mass during the cold season m_w is less than the amount of water that could evaporate in the warm seasons m_v:

$$m_w < m_v \; [kg/m^3] \tag{9}$$

• increase the mass relative humidity (Δw) at the end of inside condensation, not exceed the maximum allowable:

$$\Delta w = \frac{100 m_w}{\rho \bullet d_w} < \Delta w_{adm} \, [\%] \tag{10}$$

in which,

d_w - the thickness of material in which water is accumulated [m], determined as shown in Fig. 1, according to the real-time accumulation.

ρ- is the apparent density of the material wetted by condensation;

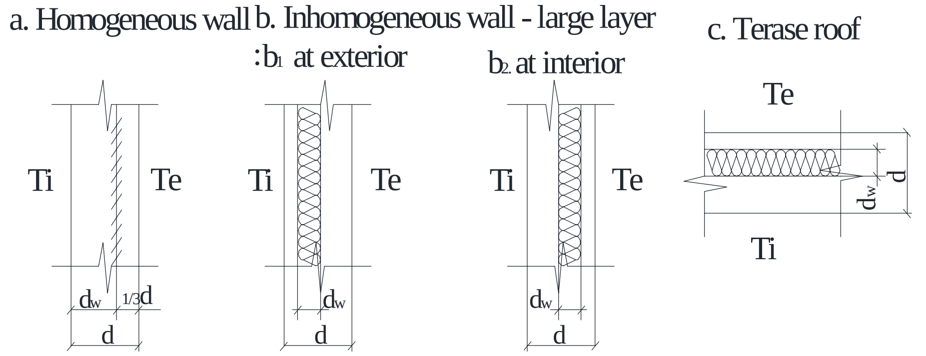


Fig. 1. *Accumulation of moisture from condensation from different types of elements*

To homogeneous exterior walls, that close rooms with relative humidity below 60%, it is not necessary to calculate vapour permeability. For exterior walls with complex structure, which close rooms with relative humidity above 60%, it is recommended to analyse the behaviour of vapour permeability and accumulation in the interior of the element, particularly in the thermal bridge, the joints between the walls, with floors, etc.

The methods for verifying the progressive accumulation of condensation and humidity mass at the end of condensation are presented in literature and regulations, and consist of analytical methods [Norm C107/6-2002], graphical methods, or can be obtained from the automatically numerical calculation using specialized programs that give direct m_w, m_v, Δw, Δw_{adm} values.

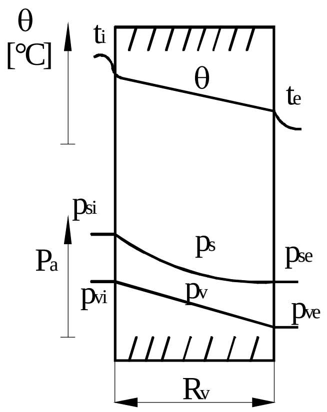
The graphic method consists of representing the curves temperatures or pressures pv (the partial pressure of vapour) and ps (saturation pressure). The construction element is represented having on the abscissa the resistance scale to vapour permeability Rv.

In Fig. 2 are presented the variations of temperature, pv pressure and ps pressure for an homogeneous construction element [2].

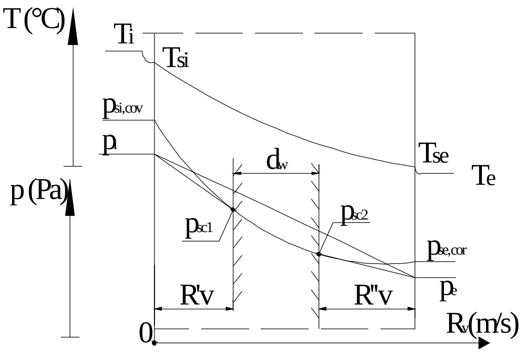
In Fig. 3 are graphically presented the variants of moisture accumulation in the cold season, for the multilayer construction elements [2].

Limiting the amount of moisture m_w during a winter, in the resistance elements structure can be done in several ways, for example:

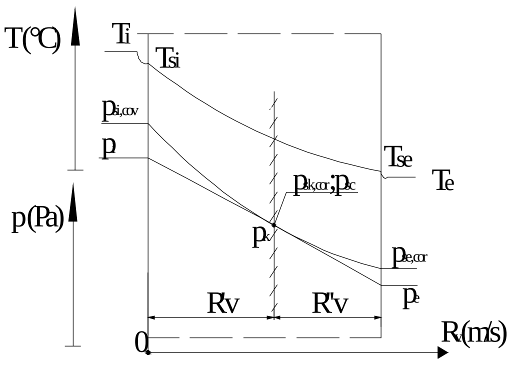
➢ ensuring the required thermal resistance and arrangement of the materials in the enclosure elements structure in increasing order of the vapour permeability, from the inside to the outside;



a) no condensation

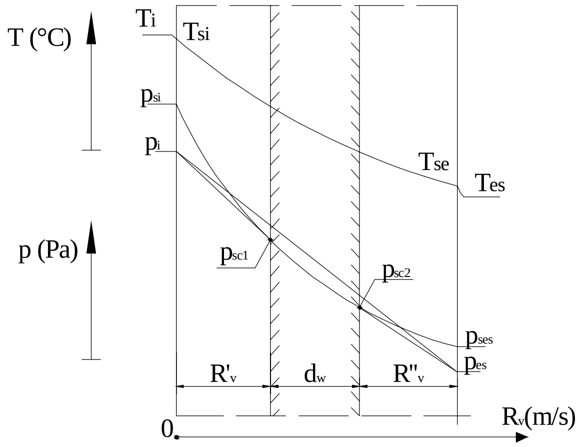


b) condensation occurs in a thick area

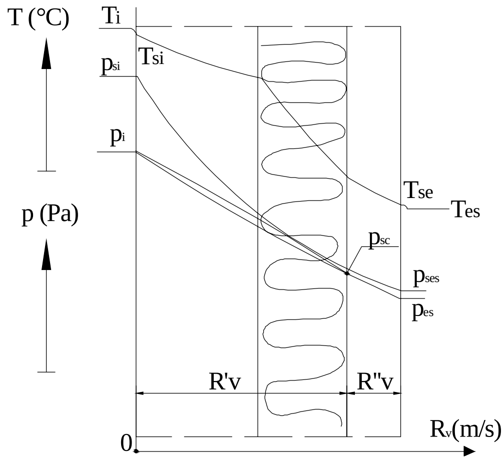


c) condensation in the tangent point plan

Fig. 2. *Graphical analysis of the condensation risk to monolayer elements*



a) producing structural condensation on a d_w thickness



b) condensation to an area

Fig. 3 *Accumulation of moisture in multi-layer elements*

- using a vapour barrier on the inner surface and in the enclosure elements structure; It is currently used as a vapour barrier film of oil-based paint, enamel, bitumen sheets, paper, glass fibre fleece bitumen, polyethylene and aluminium providing air spaces in relation to atmosphere (method of aeration) of the construction elements.

3. Conclusions

Finally, we can conclude that the hygrothermal design of buildings has as main objectives:

- ✓ the development of healthy buildings, that ensure the occupants comfort, i.e. living and working in satisfactory conditions;
- ✓ the development of thermo-energy performance buildings, which are in line with current regulations regarding energy audits both technically and economically.

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