# The Impact of Humidity on Thermal Protection of Enclosing Structures

**Mamuli Grdzelishvili, Alex Kopaliani, Ramaz Museridze**
*Georgian Technical University, M.Kostava st 77, Tbilisi 0160, Georgia*
mamuli.grdzelishvili@gtu.ge
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***Abstract**:* This article examines the temperature and humidity conditions of a thermally insulated building envelope when a thermal insulation layer is placed both internally and externally. The amount of moisture condensing in the building envelope during water vapor diffusion and its harmful effects on both the structure itself and the sanitary and hygienic conditions of the premises are determined. Recommended conditions for removing (evaporating) condensate from building envelopes are presented.
***Keywords:*** building envelopes, thermal insulation, thermal resistance, heat transfer, moisture penetration, diffusion, evaporation, condensation, temperature and humidity conditions, partial pressure, water vapor, sanitary and hygienic standards.

## Introduction

Thermal insulation of buildings is a set of structural measures that, in conjunction with microclimate systems, create a comfortable indoor environment while eliminating structural damage caused by moisture and mold. These measures, aimed at conserving heat in buildings, include thermal insulation of the building envelope in winter conditions and the elimination of heat leaks in summer.

During the construction, modernization, and reconstruction of residential, public, and administrative buildings, a number of thermal engineering requirements are imposed on them. These include comprehensive requirements, which involve determining the specific thermal performance of the building, and basic requirements, which involve determining the thermal performance of the structural elements of the building envelope [1].

Determining the thermal performance of buildings is particularly important in energy-efficient construction. The energy efficiency of buildings is determined by the amount of heat consumed over the course of a year. Buildings with an annual specific heat consumption in the range of (5 ÷ 50) kW h/(m² year) are considered high-quality. In Georgia, this value exceeds 300 kWh/(m²·year) according to design calculations.

## Main Part

The structural elements that comprise a building's thermal insulation must meet three basic requirements:

- The reduced thermal resistance of each enclosing structure must be no less than the standard value;
- The specific thermal performance of the building must be no more than the standard value;
- The temperature of the internal surfaces of the enclosing structures must be no less than the permissible value;
- These standard values are defined by various regulations.
- Thermal insulation of buildings will be guaranteed if these three basic requirements are met simultaneously. Fulfilling these three basic requirements requires several additional conditions, one of which is the moisture content of the enclosing structure, which determines the movement of water vapor within the structure by diffusion, or vapor permeability. Water vapor diffusion (thermal conductivity) and thermal conductivity of a closed structure are analogous processes. The former is characterized by the moisture permeability coefficient (thermal conductivity) μ [mg/m, h, Pa], and the latter by the thermal conductivity coefficient λ [W/m, °C].

When

$\mu/\lambda \geq 1$ - This layer is permeable;

$\mu/\lambda < 1$ - The layer is dense.

Penetrating layers are manufactured for thermal insulation. Depending on the type of layer (dense or permeable), enclosing structures are divided into five main classes (Fig. 1).

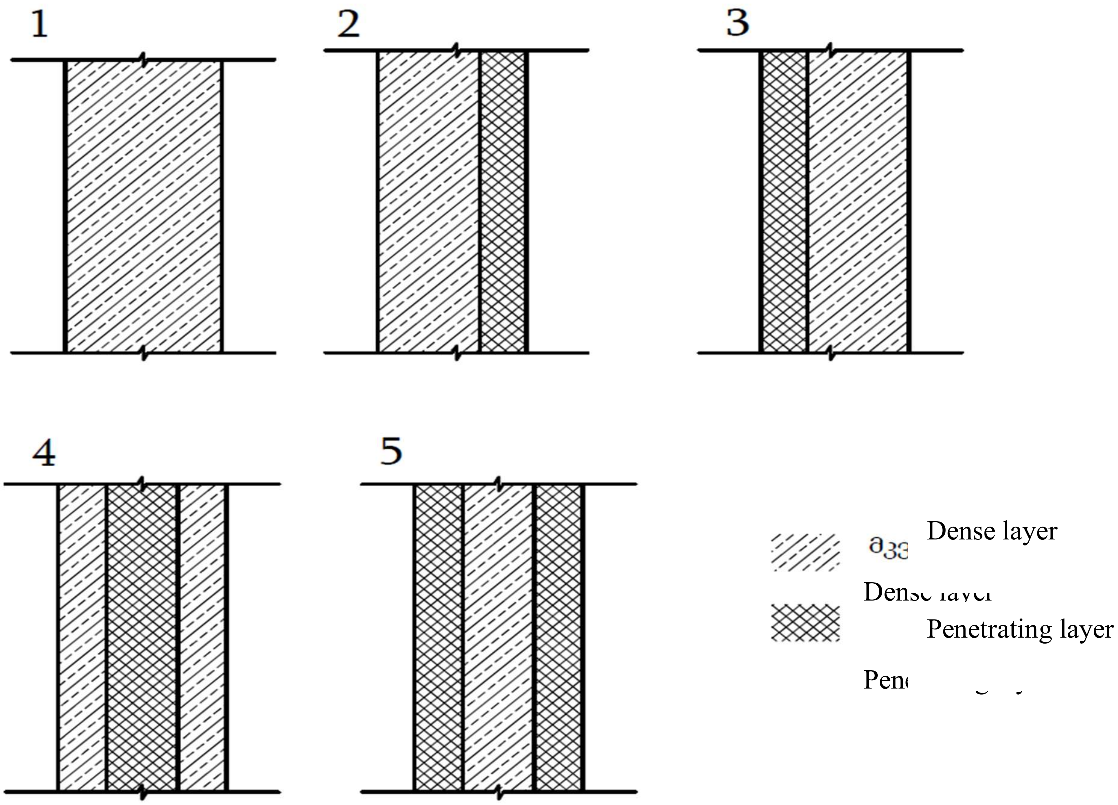



Fig. 1. Basic designs of enclosing structures: 1. Single-layer, 2. Two-layer with a dense layer on the sides of the enclosing structure (external insulation), 3. Two-layer with a permeable layer on the sides of the enclosing structure (internal insulation), 4. Three-layer with a permeable layer in the middle, 5. Three-layer with a dense layer in the middle

Themain characteristic of thermal protection of all five types of enclosing structures shown in the drawing is thermal resistance to heat transfer, which is ensured by the thermal resistance of dense and vapor-permeable (i.e. vapor-permeable) layers.

$$R_0=R_{sh}+\Sigma R_{Den}+R_{pen}+R_g \qquad (1)$$

Where – $R_{sh}$ and $R_g$ The heat transfer resistance to the internal and external surfaces of the enclosing structure is:$m^2,^oC/vt$;

- $\Sigma R_{Den}$ The sum of thermal resistances of dense layers
- $R_{sh}$ The thermal resistance of the penetrating or heat-insulating layer and its value according to formula (1) will be equal to

$$R_{Pen}=R_{Ther}= R_0-( R_{sh}+\Sigma R_{Den}+R_g) \qquad (2)$$

$R_0$ This value is a standardized value for any enclosing structure and is taken from tables [1] depending on the climatic conditions of the construction region. We will determine the thermal resistance of the insulating layer by easily determining its thickness (δθηί) and the thermal conductivity coefficient of the insulating layer material. ($\lambda_{\text{თბოიზ}}$) According to

$$\delta_{Ther}=[R_0-(R_{sh}+\Sigma R_{Den}+R_{\text{გ}})]\lambda_{Ther} \qquad (3)$$

Thus, determining the thickness of the thermal insulation layer based on the above considerations is not particularly difficult. However, the question of the placement of this layer within the enclosing structure arises. The literature often suggests that the thermal insulation layer should generally be placed outside the enclosing structure, which is incorrect (see Fig. 1). The placement of the thermal insulation layer within enclosing structures should be addressed taking into account their humidity conditions. Humidity conditions, i.e., the diffusion of water vapor within the enclosing structure, are considered in conjunction with heat transfer. Below, we examined this issue using a computer program [5] in accordance with regulatory requirements [1,3].

It should be noted that according to this program, vapor permeability means the coefficient of diffusion resistance (μ). A water vapor diffusion resistance of unity is adopted as the standard, corresponding to an air layer 1 m thick. The vapor permeability (diffusion) resistance coefficient μ is a dimensionless number indicating how much tiles.

better or worse a building material transmits water vapor compared to air. Calculations are based on the interval between the minimum and maximum values (min/max). This μ value should not be confused with the μ value given in the table of thermal properties of building materials [1].

Figure 2 shows graphs of temperature and relative humidity changes for a standard, solid (without holes) fired brick made of concrete and clay, when the thermal insulation layer is located inside the enclosing structure. In the case of a concrete wall, the facing on the room side is made of marble tiles, and in the case of a brick wall, it is made of ceramic

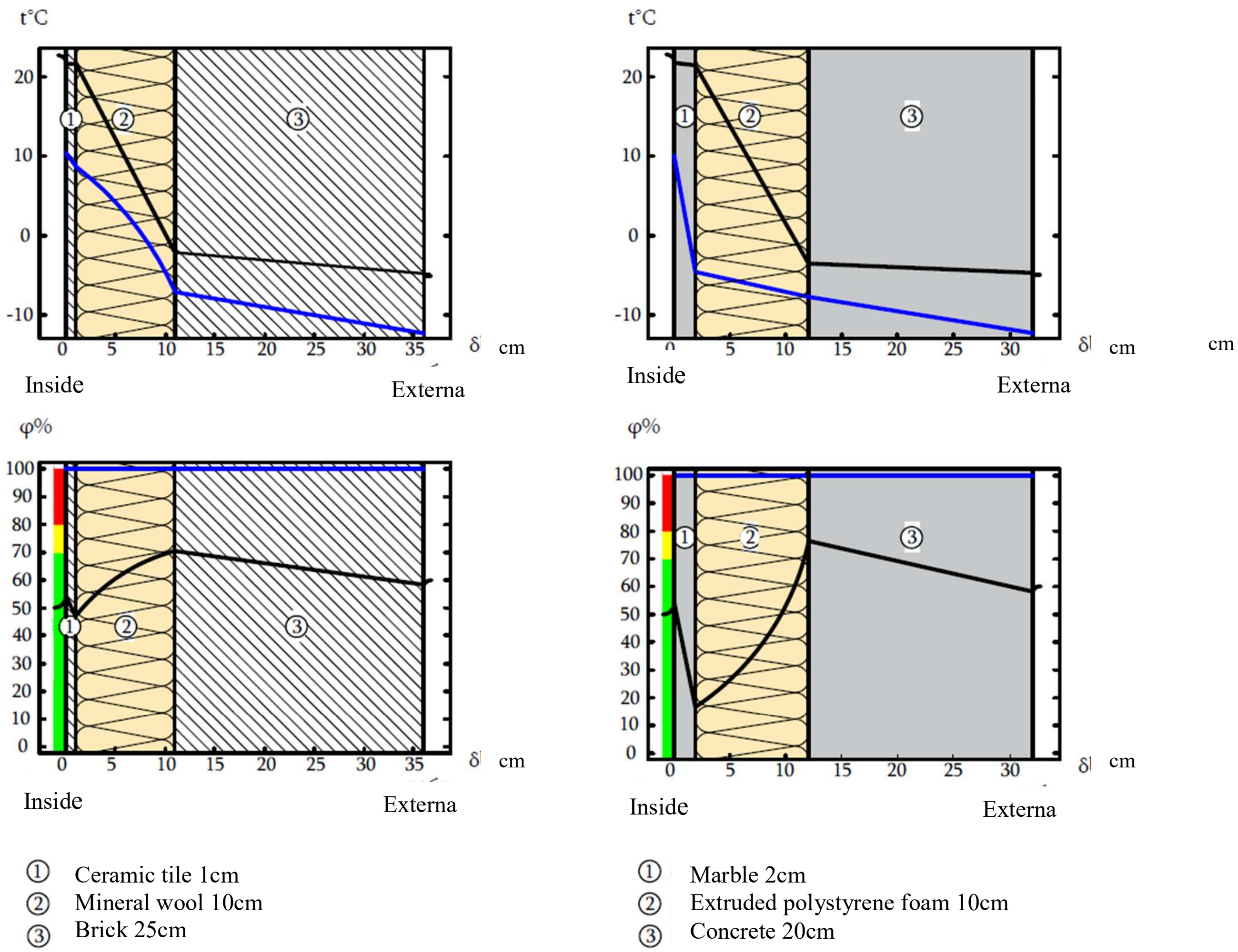
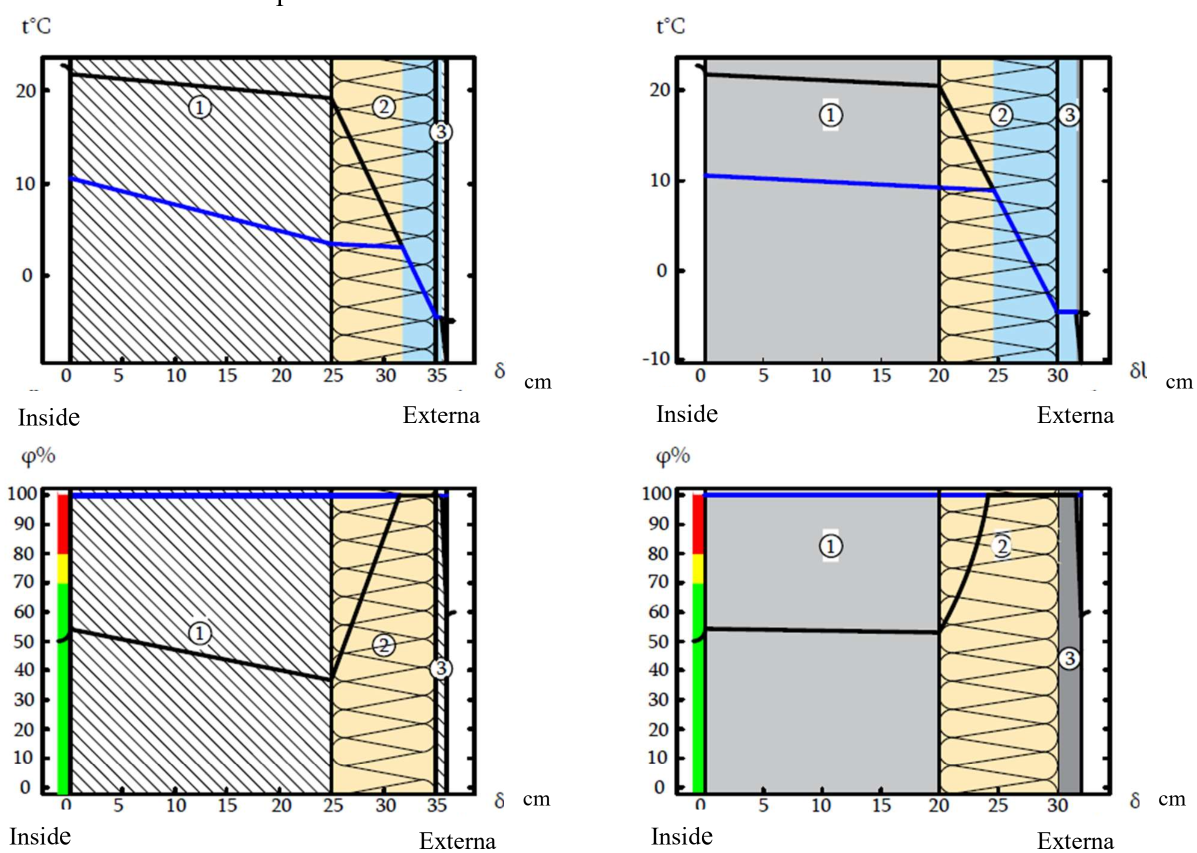



Fig. 2. Changes in temperature and humidity in a closed structure with internal insulation.

The black line on the temperature graph shows the temperature in the wall cavity, and the blue line shows the dew point temperature. The relative humidity graphs, in addition to showing the relative humidity in the wall cavity (black line), also show the maximum relative humidity. φ=100%, Curve (blue line). As can be seen from these graphs, the temperature and humidity curves do not intersect, indicating the absence of condensation in the building envelope, despite the thermal insulation layer being located on the interior side of the wall. This phenomenon is explained by the fact that marble and ceramic tiles have very low vapor permeability and act as a kind of vapor barrier in the building envelope. Water vapor does not diffuse from the room into these layers.

Figure 3 shows graphs depicting the thermal and humidity conditions of building envelopes made of the same materials when the thermal insulation layer is located on the exterior of the wall. The exterior cladding is made of the same marble and ceramic tiles. The temperature change graphs show that these temperature curves intersect across the wall thickness, indicating that at the points of intersection, the wall temperature drops to the dew point, and condensation of the diffused water vapor occurs. The region between the points of intersection of the temperature curves is called the condensation zone. A similar process is shown on the relative humidity graph. When the relative humidity within the wall thickness is 100%, condensation of diffused water vapor occurs. The region between the intersections of the relative humidity curve within the wall thickness and the φ=100% curve represents the condensation zone.




Condensate 28.5 g/m²hr
① Brick 25cm
② Mineral wool 10cm
③ Ceramic tile 1cm

Condensate 92.72 g/m²hr
① Concrete 20cm
② Extruded polystyrene foam 10cm
③ Marble 2cm

Fig. 3. Changes in temperature and humidity in a closed structure with external insulation.

The amount of moisture released in the condensation zone is calculated using the formula:

$$P=(e_{I.S}-e_{O.S})FZ\frac{\mu}{\delta} \quad (4)$$

Where $e_{I.S}$ and $e_{O.S}$ -The actual partial pressure on the inner and outer surfaces of the condensation zone is Pa;

F - Wall surface area,m²;

Z - Time, hours;

M - Vapor permeability coefficient,

mg/m.h.Pa;

Δ -wall thickness,m.

The amount of moisture released by a concrete wall is 92.72 g/m² h, while for a brick wall it's 28.5 g/m² h.

This released moisture promotes mold growth and the proliferation of various types of microorganisms indoors. With prolonged moisture release, salt crystallization is expected on the wall surface, which remains on the surface as white spots. Moisture release in building envelopes occurs over three or more months of the year. This period occurs primarily between November and January, when the air temperature is higher than the ambient temperature. This period is called the period of water vapor condensation in building envelopes.

The amount of condensation released in one month in the building envelopes discussed above is: in a brick wall: 28.5 x 24 x 30 = 20.5 kg/m², and in a concrete wall: 92.72 x 24 x 30 = 66.8 kg/m². The release of this amount of condensation is detrimental to both the sanitary condition of the premises and the strength of the structure. This amount of condensation must diffuse back into the environment during the warmer months of the year. This period is called the evaporation or drying period of the building envelope.

The building envelope must be designed so that the amount of moisture released during the condensation period is equal to the amount of moisture diffusing during the evaporation period. It should be noted that during the evaporation period, water vapor diffuses from the condensation zone both into the building envelope and outward. If condensation cannot completely evaporate during the drying period, excess condensation will accumulate. It is known that if the amount of condensation is less than 1 kg/m² and the amount of evaporation in summer exceeds the amount of condensation in winter, the building can be considered free of structural damage. If even a small amount of condensation remains in a building element after the evaporation period, it can accumulate undetected over many years to a level that causes structural damage due to moisture penetration.

When studying the moisture conditions of building envelopes, the standard reference materials [1, 2, 3] used in our calculations above can be used to determine the amount of evaporated and condensed moisture.

**Conclusion**

When designing building energy efficiency, significant attention is paid to reducing heat loss through the building envelope, which is naturally achieved by improving the thermal insulation properties of the structural elements that comprise these structures. To this end, attention should be paid to the process of water vapor diffusion within the building envelope during the design stage to prevent condensation and its detrimental impact on both the durability of the building's structural elements and the indoor microclimate during operation. Designing building envelopes based on the studies discussed above minimizes heat loss within these structures and completely eliminates the condensation of diffused water vapor on their surfaces and within them.

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