

BOŻENA ORLIK-KOŹDOŃ\*, MICHAŁ WŁODARCZYK\*\*, TOMASZ STEIDL\*

## INTERNAL THERMAL INSULATION IN THE TECHNICAL AND ARCHITECTURAL ASPECT

---

## CIEPLNE IZOLACJE WEWNĘTRZNE W ASPEKCIE TECHNICZNYM I ARCHITEKTONICZNYM

### Abstract

The paper presents the possibility of applying the internal systems of thermal insulation of heated rooms with design guidelines. It discusses the problems of the inner insulation effect, the re-use and new aesthetics on comfort room thermo-humidistat.

*Keywords: new technologies in construction, passive houses, thermal insulation, aesthetics of buildings, modernization and adaptation*

### Streszczenie

W artykule przybliżono możliwości zastosowania systemów dodatkowej wewnętrznej izolacji cieplnej pomieszczeń ogrzewanych wraz z wytycznymi projektowymi. Omówiono problematykę wpływu tejże izolacji przy zmianie sposobu użytkowania i estetyki na komfort cieplny pomieszczeń

*Słowa kluczowe: okładziny z kamienia naturalnego, transport wilgoci*

---

\* Ph.D. Eng. Bożena Orlik-Koźdoń, Ph.D. Eng. Tomasz Steidl, Faculty of Civil Engineering, Silesian University of Technology.

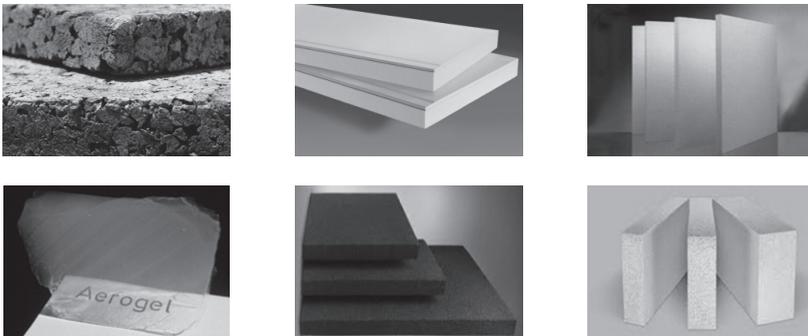
\*\* Ph.D. Eng. Arch. Michał Włodarczyk, EUROARTIS.

## 1. Introduction

Increasingly more often we are witnesses of changes in the structure and esthetics of the objects connected with re-use, adaptation and the varying market needs for spaces fulfilling the assumed standards of use. Particular care for the structure and the kind of technology necessary for additional thermal insulation is required by the adaptation of monuments as well as the ones protected monumentally (conservation). In these cases the change of functions often demands such interventions. Designing these kind of arrangements is quite complicated. The problems are thermal bridges, materials used, dysfunctions of the flow of water vapour through the external wall, as well as lack of ventilation. These problems, considering the negative scenario, may cause the lack of assumed results or even a worsening of the exploitation of rooms. During the making of the project on the expected thermal insulation inside a building, an important role is played by integrated designing with the participation of architects and civil engineers in order to exclude any disadvantageous effects. These negative effects may be related to internal thermo-modernization, use of modern technologies and applying the potential of architecture for achieving the effect of low-energy and energy-safe features.

## 2. Applied material and technology solutions

Among the material solutions now used, we may choose traditional ones, which follow the use of classic thermo-insulating materials or on the contrary, solutions based on modern thermal materials.



Ill. 1. The modern thermo-insulating materials: 1) cork-plates, 2) polyurethane plates, 3) climate plates, 4) aerogel, 5) foamglass, 6) hydroactive plates [8, 10]

The traditional technologies used in these solutions are among others styrofoam and glass wool, rock or wood; they may be set on the grate and finished with g-k plates or finished as in the ETICS method. The insulation with mineral wool is hermetically covered with a layer of efficient vapour-insulation.

Within the solutions with modern materials applied, two methods may be distinguished [8]:

- The needx of thermo-insulation with a hermetical vapour-insulating barrier from inside of the building.
- Systems which guarantee the free flow of a diffusion stream through the external wall.

The systems with vapour-insulation from the inside of the building are working best in objects with a high level of humidity. In connection with the total denial of diffusion of the water vapour through the surface, the highest effectiveness of the ventilating installation should be ensured.

The systems, which guarantee the free flow of the diffusion stream, demand a high vapour-permeability of all of the external wall layers. In the case of living apartments or rooms destined for the long-term stay of people, the natural humidity regulation of interiors resulting in the free flow of vapour through the thermal insulation layers is the more profitable solution than the thermal insulation with vapour-insulation.

Table 1

**The internal thermal-insulation of walls – material and technology solutions**

	Insulating material	Installation on walls	Finishing of the inner surface
Thermal insulation with small diffusion resistance, lack of possibility of humidity diffusion	Mineral wool + vapour insulation	Wooden grate or aluminium profile	Thin-layer plaster (ETICS), Gypsum-cartoon plates
Thermal insulation with large diffusion resistance, lack of possibility of humidity diffusion	XPS, EPS+vapour insulation, Foamy glass, Polyurethane plates	Steel-profiles-grate, areally bonded (glued with the total surface) with the basis or the strand-point method	System spatula, Thin-layer plaster, Ceramic plates, Insulating wall-paper
Thermal insulation with small diffusion resistance, with possibility of humidity diffusion	Climatic plates, Hydroactive plates	Areally bonded (glued with the total surface)	Thin-layer plaster (system ETICS), System spatula

### 3. Designing of additional thermal insulation from inside

According to the legal requirements [1], on the inner surface of the external wall the condensation of water vapour, which enables the development of mould is not allowed. In order to keep this condition, in reference to the external walls and their construction junction, they shall be described by the temperature coefficient  $f_{Rsi}$  of a value, which is not lower than the demanded critical value. We can select it depending on the norm PN-EN ISO 13788 [2] referring to the method of counting the temperature of the internal surface necessary for avoiding the critical humidity of the surface and in-between-layer condensation [2].

The given method does not include many physical phenomena occurring in the layers of building walls. The other inconvenience is the accepted classification of internal air humidity based on the data created according to the buildings in Western Europe. In the standard [2] attachment A, the application of the local measuring-values for other climatic zones without delivering the land reference values, is permitted. We may assume that the Polish conditions of apartments' exploitation are in majority similar to the conditions in other countries, which does not mean that in the calculations we shall always take the given classification.

The Norm [2] is questionable as far as the quality of obtained results of calculations and the way of its interpretation is concerned. In spite of such doubts, this standard is the base for making the majority of thermal and humidity calculations in order to apply it to the projects in Polish conditions.

The recommended methods of calculations according to the Polish Norm PN EN ISO 13788 are matched to the typical building of the external wall. The terms are not strictly precise for carrying on the calculations serving the estimation of the thermal and humidity conditions of the external wall by the untypical design solution, which is additional thermal insulation from the inside of the existing wall.

The authors suggest the following evaluation methodology of the possibility of necessary thermal insulation from the inner side because of the probability of humidity and mould based on personal experiences and analysis of literature [4, 5, 7]:

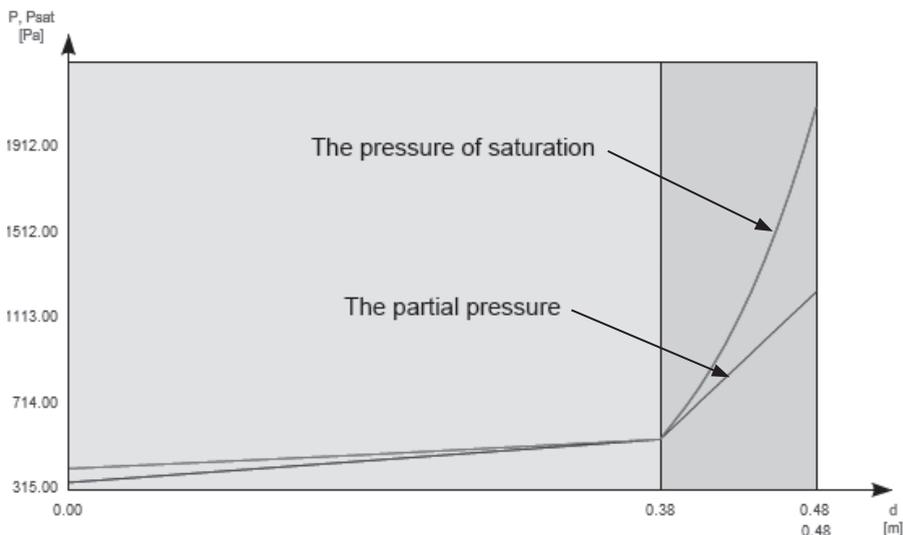
- Recognition of the material structure of the external wall along with making the outcrops and measuring the thickness of the existing layers.
- Measuring the surface humidity by means of non-invasive methods. Near ceramic walls thicker than 51 cm, a humidity analysis of the samples taken from the outcrop is necessary.
- Finding the kind of material of the external wall layers and matching the physical specifics using the accessible data [3, 6]. In the walls of monuments, the research on the wall properties, also recommend vapour-permeability of the ceramic material.
- Making an inventory of sensitive places: linear thermal bridges.
- An obligatory step is the calculation of the  $f_{Rsi}$  value in all of the connecting places of the thermally insulated external wall along with the close-fitting walls.
- The choice of material and technology of thermal insulation.
- Arranging a functional programme of the room, describing the possibility of ensuring the temperature and inner air humidity regulation, or assigning the exploitative air humidity, which must not be exceeded because of the condition  $M \leq 0$ , where  $M$  – [kG/m<sup>2</sup>a], a calculative amount of condensate for the conditions of the external climate according to the nearest meteorological station. Important is the rule of making the calculations for three average month values of the outer air temperature from the meteorological database, which is:  $t_{sr}, t_{max}$  i  $t_{min}$ .
- Calculation of the temperature at the point of junction of the layers: the existing external wall – the material of thermal insulation, considering the bidimensional thermal flow.
- The choice of thickness of the additional thermal insulation referring to the condition  $M_{min}$ , where  $M$  is the total calculative amount of the condensate [kg/m<sup>2</sup>a], counted according to [2]; the method of surface finishing including the painting cover, shall be taken into account during evaluation.

In all of the estimations carried on considering [2], it is advisable to exclude the counting of internal humidity, depending on external conditions. Apart from this, personal characteristics of the inner microclimate are applied and backed up with experience or with a survey.

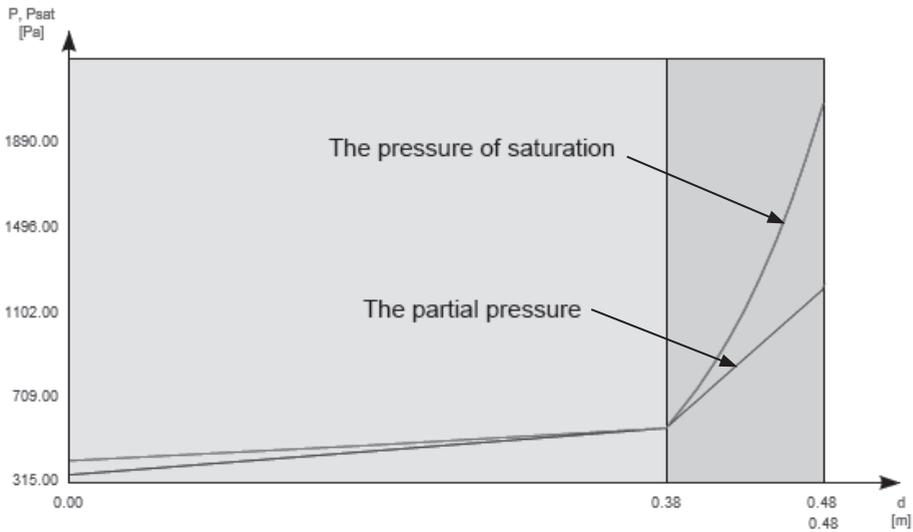
Moreover, as the last stage of the design, is to foresee the use of the warming-up method „IN” [9], for places particularly exposed to condensation. In these endangered places, as the survey shows, the value  $f_{Rsi} < f_{Rsimax}$ , is to be kept along with the assurance of a large diffusional resistance of the exterior layer in new-designed thermal insulation. A large diffusional resistance may be guaranteed by applying the appropriate foil or x sets of paintx covers matching the type of inner plaster.

#### 4. Example of designing the additional thermal insulation from inside

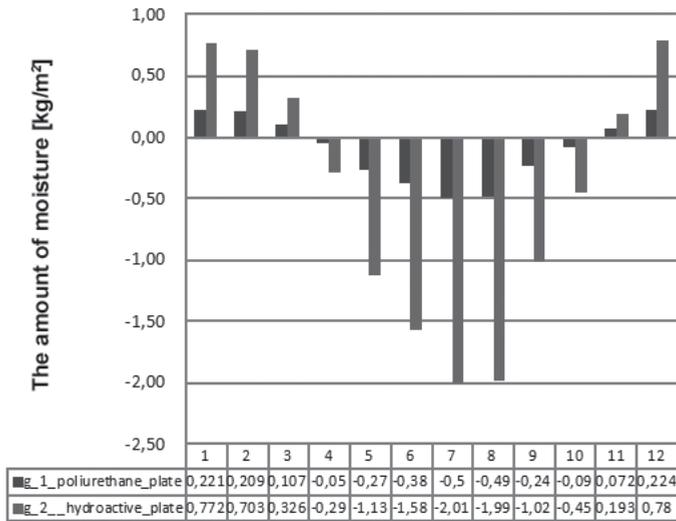
The example for analysis, is the typical brick wall 38 cm thick, together with the plaster. In the first scenario (W\_1), the external wall has been insulated with a polyurethane plate 10 cm thick (the physical parameters of modern materials according to producer information). The interior has been finished with acrylic plaster. In the second scenario (W\_2) the thermal insulation has been made of a hydroactive plate with the same finishing thickness from the inside by the system spatula. The humidity of the wall has been measured resulting in  $w_{sr} = 3\%$ . The program worked out by the authors allows for taking under consideration the material's initial humidity. In the work, only the differences in humidity growth were shown. The material data has been set based on [4]. The living conditions of the room have been arranged as for normal conditions, which means  $t_i = 20^\circ\text{C}$ ,  $\varphi_i = 50\%$  for all the months in a year. The building is located near to the meteorological station of Katowice. Relating to [2], the calculations of increasing the humidity in the brick wall have been made assuming that one condensation zone may appear. According to the calculation results, the vaporization of the whole condensation in the summer months is foreseen.



III. 2. Diagram example of diffusion for the external wall in the scenario W\_1. The external boundary conditions assumed for the coldest month of the year, which is in February (average values). The schedule of the pressure in the external wall

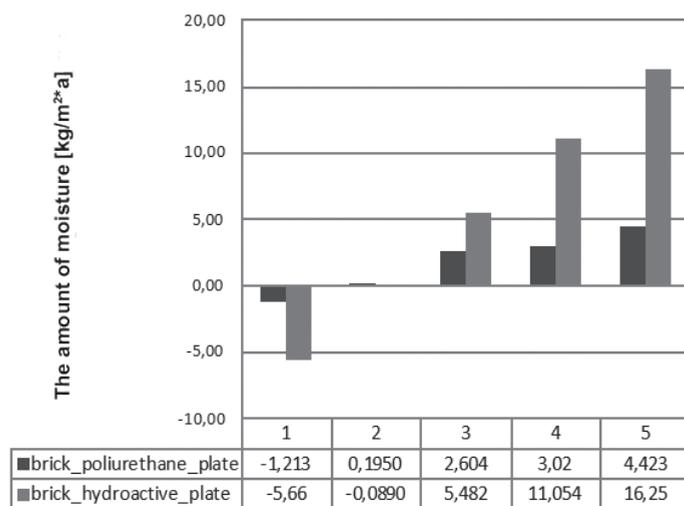


III. 3. Diagram example of diffusion for the external wall built in the scenario W\_2. The external boundary conditions assumed for the coldest month of the year, which is February (average values)

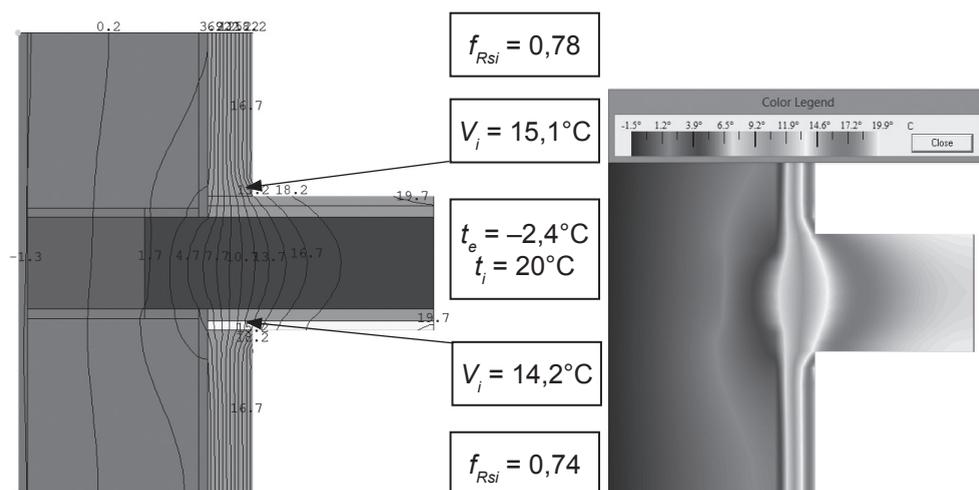


III. 4. Humidity accumulation in the external wall layer for the scenario W\_1 and W\_2. External boundary conditions – meteorological station in Katowice (average values)

The linear bridges have been inventoried, along the connections with ceilings and walls dividing the thermally insulated room from other rooms. The appropriate calculations have been made for such a bridge using the programme Therm 7. The calculations were made for internal temperature: 20°C and external temperature accepted for the coldest temperature in Katowice weather station, i.e., -2,4°C.



III. 5. Setting up of the amount of the condensate  $M$  [kg/m<sup>2</sup>] by the changing living-conditions: humidity  $\varphi_1 - 50\%$ ;  $\varphi_2 - 60\%$ ;  $\varphi_3 - 70\%$ ;  $\varphi_4 - 80\%$ ;  $\varphi_5 - 90\%$  by the constant temperature  $t_i = 20^\circ\text{C}$



III. 6. Example of calculations of surface condensation in the thermal bridge in the case of the inner thermal insulation: beam of wooden ceiling in the brick wall W\_1. Calculations, programme Therm 7. III. 8. Scheduling information – distribution of temperature area

From the analysis of the simulation results we can observe that in spite of the warming from the inside, the constructional part of the wall stays under the influence of the external environment's temperature. The reallocation of the negative temperature isotherms deep into the wall is a disadvantageous phenomenon not only for the inside of the wall, but also for the surface of contact of the internal plane with the new insulation, in other words, in the

adherent layer. At the unfavorable parameters of the internal environment's microclimate with negative external temperatures, the theoretical probability of steam condensation as well as other undesirable effects, including for instance mould, will occur exactly in this layer. For the examined case, the risk of occurrence of surface condensation was specified calculating the so-called temperature factor  $f_{Rsi}$  on the internal surface; this factor has a superior value than the critical value given in the technical specifications [1].

## 5. Conclusions

The method of thermal insulation of an external wall from inside of a building depends on a few factors: The assumed way of the room use, the kind of wall material, the kind of material used for additional thermal insulation as well as the technology of its fixing. Considering the vapour-permeability of such insulation is of much importance. The external walls thermally insulated on the inside are to be precisely analyzed. This analysis will take into account the influence of all the factors affecting the density and distribution of the penetrating diffusional stream of water vapour. The appropriate type of thermo-insulating material, the right thickness of its layer, the way of finishing of the interior surface of the wall and the remaining solutions of the insulation details including particularly meaningful thermal bridges, may be described based on the results of the analysis. The humidity condition of the external wall before insulating is the factor, which may in a significant way disturb the results obtained in the assumed calculation method. This status is to be described in the most possibly detailed way before making the calculation. The second element, which has an important impact on the effect correctness, is the foreseen way the room is used by the user [5]. This aspect shall be treated as the basic one, because it determines the actual state of the external wall's humidity.

The inner insulations are being applied mainly in the existing structures as additional thermal insulation from the inside of the external wall. Besides, very often it is a chance for saving the building by the process of re-use, returning it back to life. In these cases we refer to them as the processes of adaptation or revitalization. Its applicability may also be helpful in improving the acoustic character of a room, hiding a part of the installations or even fixing the heating elements in the finishing layer. In architectural objects under monumental protection, this way of insulating seems frequently to be the only possibility to warm them up. This is the economical and long-term process, keeping at the same time the historical appearance of a monument. Nevertheless, the methodology presented in the paper, which analysis the thermal modernization is necessary. On the one hand, it reduces the risk of the disturbance of the vapour-permeability of external walls and therefore the destruction of the walls in a building can be avoided in extreme cases. On the other hand, the decrease of the living surface is the inconvenience of such insulation. Though, this intervention allows to significantly increase the comfort of the use of a room and simultaneously to decrease the energy demand. Presently, this fact plays a major role and is of undeniable advantage to the directly affected inhabitants.

## References

- [1] Rozporządzenie Ministra Infrastruktury z dn. 12 kwietnia 2002 r. w sprawie warunków technicznych, jakim powinny odpowiadać budynki i ich usytuowanie (Dz. U. Nr 75, poz. 690), z późniejszymi zmianami.
- [2] PN-EN-ISO 13788:2003. Ciepłno-wilgotnościowe właściwości komponentów i materiałów budowlanych i elementów budynku – Temperatura powierzchni wewnętrznej dla uniknięcia krytycznej wilgotności i kondensacji międzywarstwowej – Metody obliczania.
- [3] PN-EN 12524:2002 Właściwości ciepłno-wilgotnościowe materiałów.
- [4] Kuenzel H.M., Kiessl K., *Calculation of Heat and Moisture Transfer in Exposed Building Components*, International Journal of Heat Mass Transfer, 40 (1), 1997, 159-167.
- [5] Krause P., Steidl T., Orlik B., *Renowacja ścian zewnętrznych w aspekcie izolacyjności termicznej*, Konferencja szkoleniowa: Renowacja Budynków i Konserwacja Zabytków, Warszawa 03.10.2012.
- [6] Pogorzelski J.A., *Fizyka Budowli część X. Wartości obliczeniowe właściwości fizycznych*, Materiały Budowlane, 3/2005, 79-81.
- [7] Pel L., Kopinga K., *Moisture transport in porous building materials*, Eindhoven University of Technology, 1995.
- [8] Steidl T., Orlik B., *Docieplanie przegród zewnętrznych od wewnątrz*, Materiały, technologie i projektowanie, IZOLACJE, 4/2013.
- [9] Wójcik R., *Docieplanie od wewnątrz*, Inżynier Budownictwa, Nr 04/2011 ([www.inzynierbudownictwa.pl/ocieplanie\\_od\\_wewnatrz](http://www.inzynierbudownictwa.pl/ocieplanie_od_wewnatrz), 4608).
- [10] Włodarczyk M., Steidl T., *Nowe termoizolacje w aspekcie technicznym i architektonicznym*, Czasopismo Techniczne, 2-A/1/2011.
- [11] Włodarczyk M., *Ściany zewnętrzne budynków w aspekcie zdrowia*, Konferencja „Architektura i technika a zdrowie”, materiały sympozjum w publikacji, Gliwice 2012.