Selected problems of thermal insulation of historical buildings

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Abstract

There are problems with historical buildings when changing the thermal insulation properties of buildings. The Energy Efficiency Act exempted historic buildings from certification. Not all old, historic buildings have monument protection. It is necessary to take into account the above mentioned facts in case of renovation and reconstruction of an old building. Otherwise, a normal building is approached and a building of historical value is treated differently. Methods hidden insulation, which preserves the authenticity of cultural monuments and real estate in the heritage areas, is a current challenge of heritage practice. The sustainability of the operation of historic buildings ultimately means the preservation and appropriate use of the heritage fund. Fortunately, the list of such interventions that do not jeopardize the monumental values or the use of the building is gradually increasing. This is mainly due to modern, increasingly sophisticated materials and technologies. In this paper we offer a basic overview of the most frequently used and practice-tested interventions in historical buildings, but we focus on details.

Key words: historical building, thermal insulation, cultural monument, buildings renovation, cultural heritage

1 Introduction

An important fact that affects historical buildings after a certain period of their exploitation is their significant renovation. The direction of restoration is divided into research of new materials and the application of simulations, which are considered as a new means to better understand what will happen to the historic building after its repair. Their connection with in situ measurements is seen as an indispensable tool in examining the structure of historic buildings and designing their renovation more effectively [1].

Based on new energy requirements, historic buildings that are undergoing renovation must also show improved thermal insulation properties of packaging structures. Therefore, it must also deal with critical details here. Conformance values can be achieved by a variety of available means, including correct design and evaluation of critical details by simulation, possibly in combination with measurements. However, it is essential to respect the basic rules

on the historical value of a building, while respecting the essential requirements lay down by fundamental renovation procedures and good building research methods and practices [2].

Other key topics in this area are, in particular, research into the indoor environment in historic buildings, damage to historical artifacts due to moisture and heat [3].

Last but not least, the question of the joint spread of moisture and heat across the building and the use of simulation tools is essential [4]. When restoring a historic building, the condition is to use materials that have been verified and are known to affect a particular type of historic building material. Material verification is focused not only on the impact on the building structure, but also on improving its thermo-technical properties while eliminating possible failures. The alternatives and the suitability of the applied thermal insulation layer in terms of the protection of monuments are different [5]. The question of whether thermal insulation and the improvement of the thermo-technical properties of a historical building are needed is addressed by Meier [6].

2 Historical building and monument protection

The term protection of historical monuments appeared in the 19th century. It was introduced in scientific circles by Georg Dehio in 1887. Thus, for the first time, the scientific company began to deal with the protection of historical building structures.

Among the most influential figures in this area was John Ruskin, who created a set of rules of architecture and stood up for preserving, not restoring historic buildings. William Morris also belongs to this category. His idea was that historical monuments and buildings should remain as they were handed over to us, our generation. They are to be a historical object and not a model. The founders of modern protection of historical monuments Alois Riegl, Max Dvořák - caused a shift from purism to more modern methods of care for historical and cultural monuments. The very term historical cultural monument expresses a selection group of movable and immovable things as important evidence of the historical development of society, its way of life and environment from the earliest times to the present. It is a manifestation of human creative work in various fields of human activity. The historical building structure carries a monumental value, which in addition to three-dimensional architectural elements also includes the fourth dimension - time.

Regulations regarding the function of the building, the authenticity of the restoration of architectural elements and the preservation of the original material composition are among the priorities in restoring the historic structure. The authenticity of the construction work is protected and must therefore be preserved. Therefore, the removal and unjustified replacement of historical materials should be excluded during the restoration.

Changes that have occurred over time on the building structure can also take on historical significance. They should therefore serve as an example of development and time layering. As recovery is considered to be a unique process, an individual approach to each monument is needed. The historical and architectural form is considered as the primary value. The content, i.e. the function, must be chosen appropriately, appropriately and largely adapted to the primary value. Otherwise, historical architecture is being rebuilt instead of restored. The decisive criterion is fair value. This includes not only the value of age, but also historical, social, landscape, urban, architectural, scientific, technical, and artistic craft value [6].

The conservation authorities strive to preserve not only architectural but also material substance. However, building materials change over time. Its properties change by changing the weather effects and their intensity. Over the years, the plaster loses the properties that it had or was required to produce and apply to the brick construction. This applies to all materials and therefore the question arises as to whether it is important to give preference to a historical substance or a historical construction. What is more valuable? It is worth considering whether in today's full development and research it is not appropriate to use modern materials and technologies to preserve historical construction [8].

3 Issues of thermal insulation in structures of historical buildings

The structure of historic buildings has one basic characteristic. It is a massive wall and also a large storage mass for storing thermal energy (accumulation). It is the value most influencing the thermo technical properties of the building structure. However, this is often neglected in stationary calculations. On the contrary, non-stationary methods can capture this influence (accumulation capabilities) as well as the effect of solar radiation, as well as all factors that affect the structure of the building. Taking them into account would bring some bonus to improving the thermal properties of the envelope structures of historic buildings. However, solar energy is only taken into account when calculating the total solar energy transmittance in the transparent part of the building structure. Taking into account its storage capacity, the building structure could meet the essential requirements even without the use of thermal insulation.

Figure 1: Scheme of building suitability for its renovation (advantages, disadvantages) own source:

At the time of construction of this type of building, people followed the basic rules of construction. They did not solve the problems of building physics; they did not know the term heat protection, energy recovery or high or low heat demand. The basic requirement was protection and durability. Today's requirements are stricter not only for new buildings but also for existing buildings.

Using measurement simulation programs allows us to create a real model using computer simulation. This gives us a better overview of the functioning of the building structure before and after the renovation. This in turn allows for more accurate and better design of measures to improve not only its thermal-moisture behavior, but also the improvement of the indoor climate and, above all, disruption of the centuries-old working environment of the structure.

3.1 Thermal bridges in historical building structures

The result of thermal bridges is a change in heat flow and a change in the internal surface temperature. A thermal bridge is defined by the standard STN EN ISO 10211 as part of a building envelope structure, where otherwise the same thermal resistance is changed due to the total or partial penetration of building materials of different thermal conductivity into the envelope structure. The change may also occur when the thickness of the material changes or the difference between the inner and outer surfaces, i.e. the joints of the walls, floors and tracks. Not only the labeling but also the evaluation of thermal bridges has changed in different time periods: “Their current definition is unambiguous, so it should be possible to minimize not only their occurrence, but also to minimize the consequences of their occurrence for existing buildings” (Sternová) [9].

Figure 2: Preparation of bitmap for calculation of thermal bridge, balcony: authors

There are several types of thermal bridges. Thermal bridges can generally be divided into [9]:

- structural: changes in the perimeter of the building: balconies, arcades, brackets, etc.
- material: change of the thermal conductivity coefficient in one or more layers of the building structure
- geometric: change of shape, joints of building structures, more cooled (exterior) surface than heated (interior)
- environmental-related thermal bridges: various local surface temperatures or additional heat sources e.g. heaters on the perimeter wall
- systematic: design error repeated when building has the same type of others buildings
- combined: combination of several types of thermal bridges

The standards STN EN ISO 10211 and STN EN ISO 14683 divide thermal bridges in terms of heat loss and spatial action into:

- linear thermal bridge: thermal bridge that has identical cuts in one direction - it can be described by two-dimensional temperature field
- point thermal bridge: a concentrated thermal bridge that can be described by a three-dimensional temperature field

Thermal bridges occur at any point in the joint between parts of the building structure or at places where the structure of the building material changes.

3.2 Calculations and experimental measurements of thermal properties in situ

In addition to theoretical studies on the effects of non-stationary boundary conditions on the internal surface temperature, it is necessary to verify that the results of the numerical calculations are identical to the experimental measurements.

Experimental measurements in laboratory conditions often lead to completely different hygrothermal conditions in the building structure and do not reflect the actual behavior of the building structure in external and internal environmental conditions. For such types of measurements, it is often not possible to evaluate whether the measured values or structural changes are caused by thermal or moisture effects on the structure or by changes in the properties of building materials [6]. Therefore, we performed measurements of some selected thermal insulation properties of the peripheral wall of a historical building (see Figure 2) and its details.

Figure 3: Measured of outside air temperature and intensity of solar radiation in evaluated period, monitored points in fragment of envelope structure – external wall fragment

In situ measurements allow us to record the effects of changes in the external and internal environment on the building structure itself. It reflects the real behavior of the building structure in conditions that are close to physical reality. Uncertainties in situ measurements are due to inaccuracies associated with defining input geometry, shape and material diversity, and defining boundary conditions. The influence of operating and weather conditions also plays an important role. Measurements of outdoor environment (temperature and intensity of solar radiation) were performed in January (see Fig. 3).

The purpose of the experimental measurement was to determine the effect of real non-stationary boundary conditions on the internal surface temperature of selected structures of the historic burgher house [7].

The selected monitoring points (Fig. 3) were deployed to take into account the expected critical points of the building structure. The measurement on the inner surface of the perimeter wall was short-term (7 days) performed in January (see Figure 4, 5). Due to the small number of monitored points, a network of horizontal and vertical axes was used to easily mark them.

The influence of moisture on the thermo-technical properties of building materials in historical buildings is taken into account by the increased value of the thermal conductivity coefficient in the numerical calculation [8].

The measurement itself consisted of recording the internal surface temperature using θ_{si} temperature sensors and heat flux density plate's q (W/m^2). The COMET sensor (θ_{ai} , ϕ_i) was used to record indoor conditions. Data loggers were used to collect the measured data, which recorded the measured data with an hourly step.

Figure 4: The course of surface temperature in fragment of the peripheral windowsill wall - calculated
Figure 5: The course of surface temperature in fragment of the peripheral windowsill wall - measured [7]

The differences in the average measured and calculated surface temperatures at the point of the receding window sill are in the range of 1 to 3 K. The difference is probably due to the hot water distribution system in the radiators. Unevenness of the sheathing is one of the possible causes of a small difference in the calculated and measured surface temperatures (0.2 K). Boundary conditions, especially the outside air temperature used in the simulation, can also significantly contribute to the inaccuracies of the numerical model [10].

The different altitudes and local boundary conditions of the external environment play an important role at ambient air temperature. Neglected sunlight can also affect the internal surface temperature and heat flux density. Numerical calculation of surface temperatures was performed for all details with standard values of resistance to heat transfer (STN EN ISO 10211, 2007). These values take into account the variability of heat transfer resistances and their dependence on many factors. From the calculated surface temperatures at the points evaluated, a difference can be seen using different values of resistance to heat transfer.

Calculations using computer simulations taking into account the non-stationary state at boundary conditions (Fig. 3) were performed for four points 1-4 of the window sill masonry (see Fig. 6). On the basis of the above, it is possible to assess the selected points in terms of thermal protection of a historic building and its hygienic criteria.

The surface temperature, calculated at a lower value of resistance to heat transfer, has fallen below 6 days out of a total of 30 days (period considered) below the hygiene criterion. In the case of higher resistance to heat transfer, the temperature dropped below 12.6 °C (red horizontal line) for almost 12 days. In both cases, window constructions are rated with lower heat transfer resistance. Nevertheless, the heat transfer resistance at the connection point increases to evaluate the opaque portion of the packaging structure.

Figure 6: Diagram of building construction - window sill with points for non-stationary calculation 1-4
Figure 7: Calculated temperatures on the inner window sill at points 1,2,3,4, and outside air temperature

Calculations with the help of computer simulations taking into account the non-stationary state [11] were performed for points on the parapet masonry of the perimeter wall. The masonry is receding.

A more significant increase in the surface temperature occurred under the influence of solar radiation (values higher than 200W/m^2). The influence of solar radiation on the building structure ranges from 0.3 to 0.6 K. The most significant effect of solar radiation is at the critical point (connection of the window structure) to the masonry area (point 1).

4 Conclusion

In the practice of heritage protection, we can try to prioritize the so-called “hidden forms” of insulation that do not in any way alter the authentic appearance of the historic buildings, their decoration or characteristic details.

Let us try to name at least some basic procedures, which by no means can be understood universally. When we mention the use of a thermal plaster or painting, we mean only places where it is acceptable from the point of view of preservation of historical values. There are a number of authentic structures on which no foreign action is involved: historical paving, gray brickwork, natural plaster colored in mass, textured surfaces, face stone, terrazzo, terracotta elements, natural or grained wood and the like. We have to take into account, that before each thermal insulation procedure, it is required to consult with a monument office employee [12]:

- Before any intervention, it is desirable to submit a thermo-technical assessment to an independent expert who is not interested in the construction supply. Only such an expert can estimate the actual intervention needed in terms of efficiency and cost,
- Give preference to thermal insulation of foundation structures below ground level from the outside,
- thermal insulation of the ground floor above the unheated basement and in contact with the terrain.

- Insulation of the ceiling above the top floor (suitable embankment),
- Removal of thermal bridges, for example by insulating the smooth surface of the lining to a minimum thickness so as not to alter the proportions of the building openings,
- Preservation, implementation of new double-glazed windows with a double frame, or at least the addition of simple windows with internal wooden lining.
- For thermal insulation of vertical external walls, it is preferable to use alternative thin-layer thermal insulations that do not exceed the thickness of the facade coating; today there are thermal insulation coatings on the market, which have been proven to reduce heat losses based on laboratory results. Such a solution is more affordable compared to a contact thermal insulation system when all plumbing products and flashing need to be replaced, which dramatically increase the final cost of the construction intervention,

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