Practice in the Field of Thermal Retrofitting in Historic Buildings and Preservation of the Authentic Tissue of Façades of Historic Buildings in Poland

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Abstract. The pursuit to reduce emissions of harmful substances to the atmosphere resulting from the combustion of fuels for heating purposes makes a building more ecological and environmentally friendly. All operations aimed to limit emissions of pollutants into the atmosphere are motivated by the growing environmental awareness of developed societies and alarming reports on the global warming and its effects. In Poland, legal regulations are the answer to this problem. According to them, it is necessary to reduce the limit values of the heat transfer coefficient for partitions in rebuilt buildings. These values will be successively tightened until 1 January 2021. The compliance with the limits of the heat transfer coefficient is also required for historic buildings. For obvious reasons, historical buildings do not meet the technical requirements imposed on modern architectural structures. The constructional technique of partitions in historic buildings and building materials used in them require to undertake additional actions to provide thermal extra insulation of such buildings. The provision of extra insulation of historic buildings so that they can meet the assumed technical requirements is a challenge for designers and manufacturers of materials used for extra insulation in buildings.

The first part of the paper covers the influence of modern thermal retrofitting methods and techniques applied in historic buildings conducted under the provisions of law onto the preservation of authenticity of the historical tissue of monuments. The paper analyses a variety of traditional and most recent methods and materials used in the provision of thermal insulation of external vertical partitions in historic wooden and brick-based buildings with wooden and masonry structures. Then the second part of the paper based on the conducted analyses determines the effectiveness of the adopted thermal retrofitting techniques, threats resulting from the applied methods towards the authenticity of historic building structures. At the same time, a set of factors which are relevant to the preservation of the authentic character of historic buildings was specified. To sum up, on the grounds of the conducted research studies it was indicated that the thermal retrofitting methods applied currently in historic buildings based on the provision of extra insulation for vertical partitions (applied from the inside of buildings) in reversible techniques do not admittedly devastate the authentic structure of walls but still do not ensure the expected and required technical parameters (and in the case of wooden architecture they lead even to accelerated degradation). The effective thermal retrofitting methods involving external extra insulation of partitions damage the authentic tissue of monuments. As a result of stricter legal regulations and a lack of good thermal retrofitting methods, it may be necessary to decommission historic buildings from their use.
1. Introduction
Thermal retrofitting actions undertaken in order to reduce the emission of harmful substances into the atmosphere and the widely understood problems of environmental pollution and interventions taken in order to protect the environment and human life have been issues repeatedly discussed in the literature. At the same time, the protection of cultural heritage, its resources and potentials covers a broad field of issues among which questions on how to extend the duration of historical buildings become increasingly relevant. The protection of the environment, human health and life together with the protection of cultural heritage more often find common ground. The thermal retrofitting of historic buildings is an issue which affects a variety of aspects in the conservation of historical buildings. However, the thermal retrofitting techniques applied are not always economically or ecologically justified. The growth in building refurbishment works is creating a demand for suitable materials, retrofitting techniques and research. The differences between refurbishment of new-build projects and historical or valuable buildings are insufficiently recognised – mostly buildings without further cultural preservation requirements are studied [1]. Techniques and materials used routinely in non-historic buildings happen to be applied in historical buildings. The article is a review of technical and ethical issues of the applied methods of extra insulation of historic buildings in the light of stricter legal regulations in Poland.

2. Thermal retrofitting in the light of the current legal regulations in Poland
Thermal-retrofitting projects of architectural objects conducted in order to improve the energy efficiency of buildings and thus reduce their demand for energy are the most effective method of reducing the emission of harmful substances into the atmosphere, such as sulphur dioxide, nitrogen oxides, dust and carbon dioxide. In Poland, the Regulation of the Minister of Transport, Construction and Maritime Economy of 5 July 2013 entered into force on 1 January 2014 has been a response to fulfil the requirement to reduce emissions of pollutants into the atmosphere. The Regulation introduced changes to the technical conditions to be fulfilled by buildings and their location (Journal of Laws 2013, item 926). At the same time, the provision of paragraph 329 point 1 item 1 (which made it possible to reduce the limit values of the heat transfer coefficient for partitions in rebuilt buildings) was amended. These values will be successively tightened until 1 January 2021. The heat transfer coefficient \( U_C \) of walls, ceilings and ceiling-roofs was specified for all types of buildings. The values of heat transfer through partitions and through the ground must not be higher than \( U_C(\text{max}) \) as defined in the following table no. 1. None of historical building structures used in historic buildings meets the current requirements for thermal insulation. An energy performance certificate which is obligatory for new and renovated buildings does not apply to historic buildings included in the register of monuments, but it does apply to other monuments. Therefore, the above requirements were extended to historical buildings entered in the register of monuments. In accordance with the law in force in Poland in line with the Act dated 23 July 2003 on the protection and conservation of historical monuments and its subsequent amendments: the Act amending the Act on the protection and conservation of monuments dated 10 July 2015, the Act on museums and the consolidated Act on the protection and amendments of monuments dated 8 November 2017, a monument is defined to be "a property or a movable object, their parts or sets, being the work of people or connected with their activity and being a testimony of a past epoch or events the preservation of which is in the public interest due to its historical, artistic or scientific value [2]. This Act also regulates the forms and methods of protection of monuments (an entry in the register of monuments being one of them). Other monuments not entered in the register of monuments while being in the records of monuments are protected by their local spatial development plan or the study of spatial development conditions and directions within a given area (a municipality). From a formal point of view, these objects are covered by legal protection because the register of monuments is a collection of information about historical real estates, it makes the grounds for drawing up programmes of preservation over monuments by the regional (voivodeship) authorities it is subject to similar legal protection as objects entered into the register of monuments. However, they are not exempt from the obligation to have an energy performance certificate, which allows them to undertake thermal retrofitting operations. In total, about sixty thousand objects are registered in the register of monuments.
in Poland, more than one hundred thirty-four thousand objects in the records of monuments. The number of objects and their varied legal status do not allow for the full historical preservation of all monuments. Therefore, not every historic object can be decommissioned from use and become a museum object.

### Table 1. Comparison of thermal insulation parameters of selected vertical building partitions (external walls) with the parameters specified in the Act

| Kind of building | WT 2013 (until 31.12.2013) | WT 2014 (from 1.01.2014) | WT 2017 (until 1.01.2017) | WT 2021 (from 1.01.2021) |
|------------------|-----------------------------|--------------------------|--------------------------|--------------------------|
| Redecorated      | U ≤ 0.345 W·m⁻²·K⁻¹         | U ≤ 0.25 W·m⁻²·K⁻¹       | U ≤ 0.23 W·m⁻²·K⁻¹       | U ≤ 0.20 W·m⁻²·K⁻¹       |

Regulation of the Minister of Transport, Construction and Maritime Economy dated 5 July 2013.

This issue looks similar from the point of view of the variety of former utility functions which used to be fulfilled by monuments. The statistics of the register of monuments show that a very large part of them represents functions which cannot be practically continued at present (e.g. fortifications, palaces, industrial monuments, vernacular monuments). However, also monuments the original functions of which can be continued nowadays (sacral buildings, tenement houses, manors) in practice require at least thorough modernisation, and are often adapted to other utility functions. Monuments need to be transformed also due to economic reasons. Only the highest-value objects can be run in the form of museums and only a part of the objects can be subsidised from public funds when repair and conservation works happen to be conducted. The ongoing maintenance of the vast majority of monuments has to be covered from the funds of their owners and users. It means that these monuments must fulfill modern utility functions [3]. The practice of providing them with new functions comes, to some extent, out of necessity – this is the only solution ensuring the longevity of a given monument. Modernisation and – often related with it – adaptation to modern functions often result from economic considerations. New utility programs, under which rebuilding works and extensions are conducted, significantly change the form and substance of a given monument. Retrofitting operations lead to a decrease in its credibility understood as a testimony to the history. Authenticity, which is recognised in the contemporary conservation thought as the most important feature to preserve the integrity of a historic architectural work, is lost. Authenticity as a value seems to be an aggregate composition which consists of: authenticity of material, authenticity of technological and structural structure of an object, authenticity of function, form, impact and associations. Not all of these elements are of equal importance. However, if we consider the value of authenticity in relation to other values attributed to the same object, it seems that it should occur in front of others, and as such it should have an impact on the potential occurrence and intensity of other values. It results from the very gist of an architectural object as a work of art which in its definition has certain gaps and undefined spaces. To make such extra specification take place, it is required to engage a perception body which concretizes this work of art. Such concretisation by this perception body can take place on the following levels: artistic, aesthetic, scientific, historical and emotional and depends on his / her co-creative abilities. However, what will be concretisation made on an object devoid of authenticity, falsified one [4]? Professionals and scientists dealing with aspects of heritage conservation stand for the protection of the authentic tissue of such an object as its key value. The analysis of the value of a historical object is now a complex process. In this process, the present condition of this object is to be verified and at the same time its history – examined. The changing political, economic and social conditions in Poland over the last 25 years have integrated the aspects of cultural heritage protection into social and economic life. Linking a monument with the economy leads to the mitigation of the previously radical conservation doctrine. The authenticity of function, mentioned until recently as an unshakeable condition for the duration of a given monument, has been now subject to far-reaching concessions. The occasionally observed marginalisation not only of conservation knowledge, but also of the existing justifications for protection in favour of excessively
exposed economic justifications, and at the same time the relativisation of standards and rules of conduct for many conservators and community workers who perceive protection as their important own social mission, deprives them of the sense of work and results in discouragement. This is a very dangerous process, because it stands for weakening the milieu and eliminating people who are valuable, experienced and who understand the very essence of conservation issues. All social processes connected with the protection of monuments should be run aimed at taking care to preserve an object in full its value an authenticity. The use of materials and technological solutions which are extraneous to a historical structure, though fully accepted by decision-makers regarding the protection of cultural heritage, clearly distorts the harmony and integrity of a given monument and usually has negative effects. Nowadays, monument conservation in all its aspects refer to numerous fields of science. Specialists from the field of natural, economic, legal, social, management, marketing and IT sciences brought their own research equipment to the protection of monuments, which allowed to improve the process of acquisition and organisation of knowledge on monuments and the entire cultural heritage, and broadened forecasting capabilities and, in many cases, programming the future fate of monuments [5]. Unfortunately, in Poland, too often, it is not possible to reconcile interference into historical structures, which are required in the light of new threats to monuments and more broadly for the environment with the traditionally accepted conservation practice. From the point of view of the protection of authenticity of a historic structure, the most difficult is to fulfil the requirements imposed by the legislator on concerning the value of heat transfer coefficient UC(max) for external walls. Vertical external partitions of an architectural object, apart from the value of a given monumental structure itself, usually have décor in the form of architectural and stucco details, which determines the aesthetic and stylistic value of this object. Moreover, such décor should include plaster finishes and painting walls, which naturally constitute an inseparable component of the external characteristics of the object. Thermal insulation of historical buildings is one of the most difficult renovation treatments. Prior commencing the revitalisation of a historic building which involves conservation works, a "program of conservation works" should be conducted. A specialist who holds a diploma in historic monuments' conservation is entitled to perform such a program. The commencement of any construction, renovation, architectural, restoration or conservation works in a historic building requires a permit to conduct such works, which is issued in Poland by the Regional Office for the Protection of Historical Monuments and is regulated by law by the Regulation of the Minister of Culture and National Heritage of 28 June 2017. Properly performed operations in the field of thermal retrofitting should be each and every time preceded by numerous conservation treatments as well as individual structural and spatial analyses. Elementary knowledge about the location of a given object towards the compass cardinal points gives basic information on the planned effectiveness of extra insulation. It is a well-known fact that the best results are obtained when gable walls located to the north are insulated. It is also worth insulating western and south-western walls due to the characteristics of meteorological conditions in Poland. It is ineffective to insulate southern walls, especially with large window or balcony glazing. Conservation treatment should first of all focuses on the analysis of preservation of a wall structure, level of its moisture and salinity, degree of biological corrosion of wooden structures (infection by fungi and moulds). This is the result of this analysis which provides an answer on the scope of works required to prepare a partition for thermal retrofitting operations. The determination of an appropriate method of extra insulation also depends on preliminary and in-depth analyses. Properly-performed operations connected with drying and desalination of walls affect their physical properties. Even these basic operations will increase the thermal insulation of an object, and thus improve its economic situation in the form of a reduction in energy costs. As a result of a proper thermal retrofitting, we get an object which is both energy-efficient and has appropriate indoor climatic conditions. The issue of building indoor climatic conditions which are suitable for human health is as relevant as environmental aspects. Nowadays people spend about 90% of their time in buildings – working, learning and resting. Meanwhile, according to the World Health Organisation, 30% of buildings do not provide healthy climatic conditions and their lack affects human health and may cause ailments referred to as sick building syndrome [6].
When analysing insulation systems in historic buildings, first of all, it is necessary to prepare material and structural systematics for external walls, and then analyse potential, available insulation systems. In principle, a general distinction can be made between masonry and stud walls. These two general groups are split into individual subgroups singled out due to the material used for a given technology. For example, the group of masonry walls includes natural materials, i.e. stone in various categories and prefabricated materials, i.e. bricks, ceramic hollow bricks and a variety of other shaped blocks. In the case of framework structures (stud walls), wood is the most common material used as a structural material and plus various types of fillings. Taking into account the constantly widening group of objects considered historic, modernist objects with reinforced concrete as their construction material joined the group of framework structures (stud walls). Naturally, for each of the above-mentioned groups it is necessary to conduct separate analyses and studies on appropriate thermal retrofitting strategies. The specificity of the materials used to shape the structure of external walls requires in-depth analyses. The common ground for each of these examples, however, refers to the need to preserve the original tissue and thus their shared problem is to maintain original outer finishing coatings. They are the ones which – to a large extent – determine the visual character of an object and they are an intrinsic component of the style. Unfortunately, the preservation of these values is quite often in conflict with the technical requirements / funds for objects commissioned for use. Technologies on insulation of external walls can also be divided into two basic types. The first one, considered to be more effective, is the method of insulation placed from the outside of a wall. This insulation system also includes structures made of glass insulation panels (the so-called second wall). The second type of insulation, i.e. insulation conducted the inside, is preferred in the case of historic buildings, but is more often criticised due to numerous defects which are difficult to eliminate. External wall insulation ensures that water vapour condensation is moved out of walls. In this case, walls heat up together with rooms. Keeping the thermal balance between heated building interiors and external walls is a key argument for making use of wall insulation systems based on external insulation. It avoids the condensation of water vapour within partitions. If a building is insulated from the inside it contributes to the condensation of water vapour inside a partition, which leads to the dampening of its structures.

3. Overview of modern thermal retrofitting techniques and materials used in historical objects

For most historic buildings, the application of insulation from the building inside is the only possible thermal retrofitting alternative. Within internal thermal retrofitting there are several insulation systems in place. Generally, it is possible to systematise internal insulation systems by distinguishing two methods of their installation:

- installation of an insulation system at a distance from the wall
- installation of an insulation system in contact with the wall.

The first one consists in building a wooden stud structure or a lightweight steel structure, and filling it with thermal insulation material. Such installation at a distance from the wall is a non-invasive insulation technique. The installation of such systems is reversible and is mostly preferred from the point of view of the conservation doctrine. The second system consists in mounting thermal insulation directly on the insulated wall using an adhesive binder. The system consists in combining and embedding a new material layer into the original structure. Due to the fact materials are combined, this is an irreversible technique. The most common thermal insulation materials used in the system built at a distance to the wall are based on mineral or glass wool, cellulose fibres or wood wool. Newer materials include insulation boards made of polyurethane foam with a thickness of 2 to 12 cm, low conductivity coefficient of $\lambda = 0.023\text{-}0.030$ W/(m-K), coated with a vapour barrier or anti-diffusion paper on one or both sides. In the case of the second system, which consists in mounting thermal insulation on the wall, a range of thermal insulation materials includes modern mineral materials with their porous structure ensuring high moisture absorption. These materials in the form of blocks or boards are mounted to a partition by means of system adhesives. The major advantage of these materials, apart from their thermal insulation properties, refers to their vapour permeability, fire resistance and dimensional precision. Modern
calcium-silicate climate boards made of calcareous silicate with a layer of polyurethane or boards made of hardened extruded polystyrene are characterised by low thickness, which results into retaining interior spatial parameters. Aero-gel – a type of extremely low-density rigid foam consisting of 90-99.8 air and porous nano-structure created by removing liquid from silica gel – is a modern material used more and more frequently in thermal retrofitting. This material usually occurs in the form of mats and lump mass. It can be transparent, which makes it suitable for thermal insulation of window glazing. The heat transfer coefficient for the aero-gel amounts to $\lambda = 0.012 - 0.018$ W/(m·K). VIP (Vacuum Insulation Panel) vacuum panels have the lowest coefficient of 0.007–0.008 W/(m·K). Among its undeniable advantages, this material is, however, hardly resistant to damage and demanding in terms of mounting conditions.

4. Practice of thermal insulation of historic buildings from the inside

Insulation of an object from the inside, in spite of its defects, is often the only possible option in the case of historical objects. However, this method is sometimes controversial due to the principles of building physics. However, this is not a universal method. It seems that achieving an appropriate wall heat coefficient value in accordance with modern technical requirements should not be considered to be of primary importance. The thoughtless striving to meet specific requirements dictated by practical reasons often leads to irreversible destruction. The issue of moisture is the most common effect of the mechanical approach to insulation. It occurs in intensively heated and poorly ventilated buildings. Unfortunately, most historical buildings in Poland, which have been undergoing retrofitting processes over the years, face these problems. The imperfection of technologies and materials used in Poland in recent decades, together with poor operational decisions, contributed to the deterioration of historical buildings and their technical conditions. The cheap technology of foam ed polystyrene panels, which is commonly used in Poland, brings the worst possible results. Styrofoam insulation turns out to have 'total effects' retaining moisture within building interiors and in partitions and giving only theoretical $U$-values. The complexity of the issue on insulation in historic buildings is partly due to limitations imposed by the specificity of individual buildings. There are potential risks in each of the building technologies in the case of masonry, brick or stone objects, where wall threads are subject to conservation protection, they cannot be insulated from the outside. A frequent lack of horizontal anti-moisture insulation is another problem. The capillary process of water rising and salt transportation occurs in masonry brick structures. Freezing and repeated water freezing-thawing processes in brick structures leads to the destruction of materials. Moisture retained in partitions is a perfect place for harmful micro-organisms and fungi to develop. In the case of stub structures made of wood, insulation from the inside leads to the freezing of construction materials. It is because a wooden structure remains within a lower temperature zone than in a non-insulated wall. With this type of wall structures and insulation, the thickness of thermal insulation must be limited to 5–6 cm, which naturally does not bring any effects in terms of thermal insulation. The internal thermal insulation of vertical partitions in wooden structures, similarly as in the case of masonry structures, causes specific humidity problems consisting in the condensation of water vapour diffusing through partitions. The application of vapour-barrier membranes is only a partial solution to the problem of water vapour diffusion because these membranes limit partitions in their capability to dry out towards the building interiors.

The method of insulation from the inside, which remains the only possible option for historic buildings, requires more care and diligence in the execution of works due to the requirement to maintain continuity of the assumed thermal insulation between insulated walls and other building elements such as ceilings, roof, floors, foundation walls and basement walls. The elimination of thermal bridges guarantees the effectiveness of thermal retrofitting operations. The method of mounting insulation in contact with the wall is more effective in this case. This is the invasive method which does not provide the reversibility of undertaken retrofitting operations, which is much less preferred for a historical object. Good tightness of insulation is ensured by both blocks and climatic panels, however, the effect of full insulation is provided by aero-gels occurring in the form of mass, which can be applied into an insulated wall in a very precise manner. Efforts to reduce the energy consumption of newly constructed buildings, and in particular of the existing and exploited buildings, including historic ones, and thus to reduce the
emission of carbon dioxide (CO2) to the atmosphere, among others, often result in a deterioration in the quality of internal air. This is mainly due to the thoughtless air-tight sealing of buildings erected in previous decades, especially historic buildings in the course of renovation (conservation) works and not retrofitting ones, which so far allows to omit to fulfil the requirements resulting from the building standards (PN-EN 13779:2008; PN-EN 15251:2012) not always taking into account the latest results of research studies in the scope of the influence of the quality of internal air onto the state of human health. It applies in particular to a lack of adequate quality of internal air adjusted to the hygiene (health) requirements of persons staying in them [7]. A relevant problem which is sometimes ignored refers to the so-called space of good cooperation, which takes place between building materials used within a given building system. The introduction of new materials into the system, which occurs in the case of insulation, very often results in the disturbance of the natural balance and, as a result, the destruction of the system. For this reason, the method of mounting thermal insulation at a distance from the wall seems definitely to be more appropriate for historical buildings. The reversibility of retrofitting processes is beneficial from the point of view of preserving the authenticity of their historic structure.

5. Results and discussions
Due to the constantly deteriorating air quality in Poland, this year the government's smog control program is to be launched. Under the program, co-financing is planned for retrofitting operations in residential buildings combined with co-financing of works on the modernisation of heating systems. The funds collected in the National Fund for Environmental Protection and Water Management will be allocated for these purposes. The program will be implemented until 2027. Some historic buildings maintain their original function or are adapted to a new function and are still used as residential buildings. Due to the importance of authenticity for the preservation of the value of historical buildings, the only possible retrofitting operations is to insulate historical buildings from the inside. As the analyses show, despite significant progress in the material engineering, these are still not ideal methods. They are often ineffective and, if not conducted properly, may even result in accelerated destruction of the original structure. The vast majority of historic buildings in Poland are privately owned and, as such, often remain outside the scope of monitoring of their conservation conditions by the conservation services. Arbitrary actions undertaken by the owners of buildings are the most common cause of improper repair decisions. A particularly dramatic situation concerns historic wooden objects, which due to their specificity and adaptation difficulties, left without any intervention, fall into ruin and disappear irretrievably. The conservation principles of minimum necessary intervention, protection of original materials, non-invasiveness, reversibility and distinctiveness applied during retrofitting operations guarantee the full protection of value in historical objects. Adaptations which eliminate the possibility of contact with the authentic 'matter' of a given monument also eliminate its intangible assets. Moreover, they are not only in conflict with the conservatory doctrine rationale, but also, in the long run, with economic and social reasons. In Poland, in the face of new legal conditions, these operations require a broad discussion among specialists in various fields related to the protection of cultural heritage in order to standardise the assessment of adaptation projects at the stage of conservation settlements. There is a perceptible lack of methodology and procedures to be followed in the practice of retrofitting and adaptation works of historic buildings. Analyses are often conducted subjectively due to a lack of appropriate tools in the form of rigorous standards.

6. Conclusions
Within all operations related to the retrofitting and adaptation of historic buildings, thermal retrofitting processes are certainly the highest challenge. The new, stricter legal requirements on the requirements to achieve effective U-values analysed from the point of view of the preservation of authenticity of building structures in historical buildings require verification of the existing practices. Even the least invasive method based on the principle of reversibility of retrofitting measures taken today is not universal enough to be applied uncritically. As a result, a number of historic buildings will be potentially decommissioned from residential functions. The number of such objects is difficult to determine.
However, even upon some superficial analyses, it can be stated that it is much larger than the potential group of historic objects designated as museum objects. The rapid development of the material engineering in the scope of thermal insulation products allows for this problem to be viewed with optimism, however. The only factor which actually threatens the proper conduct of thermal retrofitting processes in historic buildings is the economic one.

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