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Original Research Article

DIAGNOSIS OF THE PLINTH ZONE IN BUILDINGS UNDER CONSERVATION PROTECTION

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A b s t r a c t

The results of thermographic research make it possible to model the actual operating conditions of selected parts of building structures. The article presents diagnostic analyses using thermographic tests of plinth zones in historic buildings. The results of the research form the basis for making decisions on thermo-renovation projects, and in historic buildings these decisions are additionally conditioned by the need to meet conservation requirements. The analysis carried out in this article shows that information about the temperature range in different parts of a building can be obtained using thermal imaging research, but not every result from research carried out with a thermal imaging camera can be used for further analysis. Thermal studies carried out only in accordance with the guidelines given in the standard allow for the acquisition of data that are necessary to carry out accurate simulations of the partition's operation over time and to select the most appropriate thermal insulation model.

Keywords: diagnostic test, thermal imaging surveys, plinth listed, historic building

1. INTRODUCTION

A necessary requirement for historic buildings during thermomodernisation is the observance of conservation principles and regulations, which should be taken into account already at the design stage [1,2]. An additional difficulty is the proper protection of the historic building's plinth zone against heat migration [3,4,] and problems related to capillary, condensation and hygroscopic transport of moisture [5,6,7]. The execution of a design related to the selection of appropriate technology and treatment guidelines for historic buildings should be preceded by a numerical analysis [8]. To create a model of plinth work in numerical programs, data on temperature, climate, humidity and salinity, as well as the structure of materials used in the analyzed partitions are required [9, 10]. In historic buildings, the most common material in plinth zones is clay brick. Due to the complex and disordered (discontinuous) structure of the porous material, the description of the physical processes and numerical modelling of

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the occurring phenomena, especially in a non-stationary environment, is a difficult issue [11, 12]. In order to ascertain the actual state of moisture and thermal parameters in the partitions of historic buildings, in situ surveys should be carried out [13, 14]. For conservation reasons, direct surveys are categorized as invasive processes that affect architecture and urban planning and thus cause damage to cultural assets. Acquiring the knowledge needed to diagnose an object in a non-invasive manner (e.g. thermographic surveys) [15, 16] is the most desirable method of surveying historic buildings. An important issue affecting the reliability of the acquired parameters is the proper conduct of the tests and the interpretation of the obtained results [17, 18]. Thermal imaging surveys do not disturb the structure of the conservation tissue and, thanks to the results obtained, it is possible to interpret the condition of the object at the actual moment [19, 20]. Lack of knowledge about the state of the 'insulated' partition is contrary to the methodology of carrying out this work and very often influences the degradation of the retrofitted partitions and thus reduces the durability of the object [21, 22].

2. CONSERVATION ISSUES IN RELATION TO HISTORIC BUILDINGS AND THEIR PLINTH ZONE

The renovation of a plinth, which is part of the façade of a building under conservation protection or located in a conservation zone, poses a major challenge for the designer as well as the contractor. In the case of historic buildings, the zone should be restored in accordance with the original design and appearance [17, 20].

A building subject to conservation protection individually listed in the register of historic buildings is protected in its entirety under the law. This makes it impossible to introduce changes to the façade, e.g. covering architectural details with a layer of thermal insulation or covering building plinths. Conservation requirements recommend preserving the authenticity of a listed building in its entirety, including maintaining the authenticity of its façade. Remembrances of the past should be preserved for future generations [21]. According to conservation requirements, it is not possible to change the external appearance of a listed building.

In such a case, there are no derogations and all works should take place underground or on the inside [17]. It is permissible to carry out works that alter the appearance of this part of the building only in non-frontal parts (e.g. outbuildings). In such areas it is permissible to carry out works that alter the original structure of the plinth, but only after obtaining the necessary conservation consents.

3. ANALYSIS OF THE PLINTH ZONE

Facility plinths can operate in a variety of media and at the boundary between these media. The most common media are air/ground or air/air. The working scheme adopted for the numerical analysis depends on several parameters, i.e. the dimensions of the plinth wall of the ground level adjacent to the partition under study. Due to the different characteristics of the two media, heat migration takes place at different intensities. In the ground medium, heat transfer occurs mostly by conduction. The heat transfer coefficient is different depending on the type, mineral composition and density of the ground. In the case of an air-filled medium surrounding a building envelope (building plinth), we are dealing with convection, i.e. heat transfer. For a given building envelope material, it is possible to determine the amount of heat energy that can pass through the envelope in a given time [7]. The thermal conductivity is related to the volume density of the ground. In the ground, the phenomena of filling air spaces with water occurs very frequently. A reduction in the number of free spaces between the soil particles drastically worsens the insulating capacity of this environment [12]. In order to generate reliable images of partitions operating under real-world conditions, it is important to adopt the correct method and appropriate boundary parameters for the tests carried out. Acquisition of the parameters needed for numerical analyses can be carried out by both destructive and non-destructive tests. For historic buildings, direct surveys are particularly dedicated, such surveys being conducted with thermal imaging cameras. Thermographic surveys as non-invasive surveys can be carried out using two methods. They are most often conducted using a qualitative method, which includes: correct determination of emissivity, environmental intelligence, influence of pressure, influence of installation and equipment of the object, influence of temperature, estimation of results, preparation of the device, determination of the reference temperature, scope of the tests, occurrence of reflected anomalies, indication of the place covered by the measurement, correction of the results obtained and determination of the air flow velocity [15, 16, 17].

The second method is quantitative testing, the execution of which is much more complex. A thermal imaging camera is used for these surveys; it records the intensity of the recorded thermal radiation observed by the IR camera [15, 16, 17]. Building thermography is a method of indicating and representing the temperature distribution over a portion of the surface of the building envelope. In the context of this standard, thermography is performed using an infrared radiation detection system that produces an image of the apparent radiant temperature measured on the surface of an object. The thermal radiation (infrared radiation energy flux) of the object surface is converted by the infrared radiation detection system into a thermal image representing the relative intensity of the thermal radiation of different parts of that surface. The intensity of the image is dependent on the surface temperature, surface characteristics, ambient conditions and the transducer itself.

The non-invasive thermal imaging method can be used to obtain a complete picture of the temperature situation of the building section under investigation. The non-invasive method gives a picture of the presence of thermal bridges, moisture problems and insulation discontinuities. This image can be obtained from reading the thermograms for the partition where the tests were carried out. The thermogram readings indicate problem areas in the building.

The thermal imaging camera is a very useful tool for assessing the technical condition of a building in terms of a qualitative thermal evaluation of the building. Thanks to the method, defects in the form of heat loss and defects in the form of damp spots can be detected, and it also enables design or execution defects to be detected.

However, the natural conditions under which thermal imaging surveys should be performed are not clearly defined. There is a gap in the literature and standard guidelines in this respect. Different values for the temperature difference between the inside and outside of the object under investigation are given, ranging from 10℃ to as much as 30℃. There is a common misconception among those developing expert reports that the detection of thermal problems performed by thermal imaging surveys can only be done in the cold months of the year. Contrary to belief, if an adequate temperature differential is maintained, the results of a thermal imaging survey will also be reliable in summer, provided that the interior of the object under investigation is adequately cooled when the outside air temperature is high.

For measurements of this type, it is important to remember to use:

- a reference temperature measurement - to determine the reference point for the emitted radiation,
- measurement with a reference radiator - to reduce interference from the measuring environment,
- measurement with reference plane determination - consisting of a reference temperature measurement and a measurement with a reference radiator and plane determination.
- comparative measurement - combining the above measurements.

The results obtained from quantitative measurements can also be used for qualitative evaluation due to their extensive measurement process.

4. IN SITU RESEARCH - A CASE STUDY

In order to verify the suitability of the qualitative method for data acquisition for the assessment of the plinth zone, a diagnostic analysis of two historical buildings undergoing light-wet thermal insulation retrofitting (ETICS) was carried out. The recording device was a BOSCH GTC 600C Professional camera [23]. In order to demonstrate the errors that can occur during the measurements, the tests were carried out under extremely unfavourable conditions. In addition, in order to verify the results obtained, tests were carried out in accordance with the requirements contained in the PN- EN 31829 standard [24].

Thermography as a method of presenting the surface temperature distribution is performed using an infrared radiation detection system that produces an image of the apparent radiation temperature measured on the surface of an object. The intensity of the image depends on the surface temperature, surface characteristics, ambient conditions and the transducer itself. The measurement procedure also includes the interpretation of thermal images (thermograms).

For the first building located in Poznan, thermal insulation was carried out on the external side. The construction of the partition consisted of solid bricks and 10 cm thick polystyrene boards. During the works carried out, the building was not under the protection of the conservator. The renovation work was carried out before 2017. The foundation wall of the building is 50 cm thick and made of solid brick, in addition a 10 cm thick polystyrene board was used up to ground level. The finishing layer was made of ceramic tiles. For the second building located in Poznan, thermal insulation was made with 10 cm thick PIR panels placed on the inside. As the entire building was under conservation protection, it was not possible to interfere with the walls of the building from the outside. The thermal insulation work did not include the plinth part of the building. The tests were conducted in standard conditions (Table 1) and abnormal conditions.

Table 1. Comparison of ideal weather conditions for conducting a thermal imaging test

Conditions	Standard guidelines
good weather conditions	dry, cloudy sky
test time	time before sunrise
temperature difference	the difference between the temperature inside the tested building and the temperature outside should be at least 15 C
wind	wind speed cannot exceed 1 m/s
season	thermal bridge tests are performed in winter and cool autumn and spring
camera orientation	avoid sharp viewing angles at the object

In situ investigations were carried out:

- 27.11.2024 - on a very cloudy day, air temperature 4°C, humidity about 97%, insolation about 150W/m², very cloudy, wind speed 4 m/s, external pressure 1022 hPa, surface emissivity coefficient ε=0.91 (Fig. 1),
- 22.10.2023 - after sunset, air temperature 11°C, humidity approx. 90%, insolation no 0W/m², very cloudy, wind speed 1m/s, external pressure 1010 hPa, surface emissivity coefficient ε=0.94, Remarks: measurement conditions stable, no disturbances (Fig. 2).

Images from the thermal imaging camera are shown below.

Fig. 1. Building with partially insulated plinth (B. Ksit)

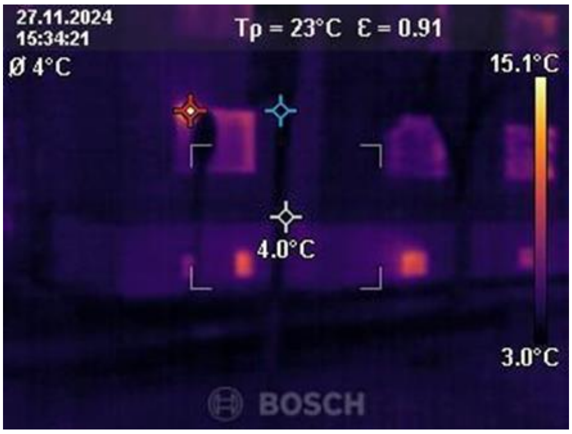

Fig. 2. Thermography of the building without plinth insulation (B. Ksit)

- In addition, measurements were taken:
- 28.09.2023 - survey conducted on a very bright day, air temperature 36°C, humidity about 46%, insolation about 1000W/m², cloud cover none, wind speed 2 m/s, external pressure 1019 hPa, surface emissivity factor ε=0.93 (Fig. 5);
- 24.11.2023 - tests conducted after sunset, air temperature 3-4°C, humidity ca. 80%, insolation low 243W/m², cloudiness medium, wind speed 5.2 m/s, external pressure 995 hPa, surface emissivity coefficient ε=0.93, remarks: during the measurements, an incorrect surface emissivity coefficient was adopted on purpose, which allowed a decrease in the precision of the measurement to be observed (Fig. 6).

Fig. 3. Building without plinth insulation (photo: B. Ksit)

Fig. 4. Building with insulation on the inside (photo: B. Ksit)

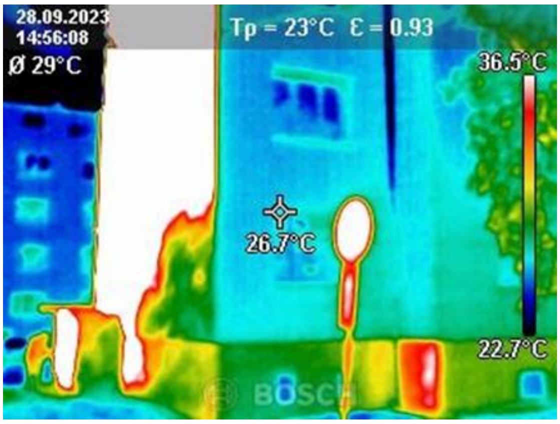

Fig. 5. Thermography of the building with plinth insulation (B. Ksit)

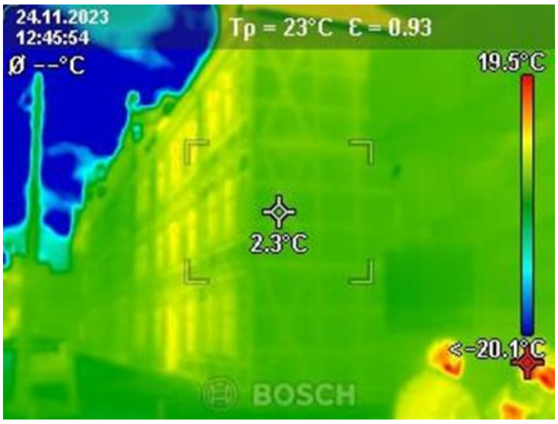

Fig. 6. Thermography of the building with plinth insulation (B. Ksit)

In the study carried out in September, an incorrect surface emissivity coefficient was deliberately adopted, which made it possible to observe a reduction in measurement precision.

The attached photos show the actual state of the plinth zone's work in the case of its warming (Photos 1, 5) and lack thereof (Photos 2,6). A visible phenomenon is the complete disruption of the IR reading when, just before the measurement, the surface was previously exposed to solar radiation. In the case of the determination of the temperature prevailing on the surface of the partition, for a building with plinth insulation under abnormal conditions (ambient temperature: 29°C, surface temperature: 36.5°C), the value was 30% higher than in the measurements carried out (ambient temperature: 4°C, surface temperature: 3°C) in accordance with the guidelines. For a building with internal insulation, but without an insulated plinth zone, the discrepancy was 70% under abnormal conditions (ambient temperature: 3°C, surface temperature: 9.7°C) of the value taken under normal conditions (ambient temperature: 10°C, surface temperature: 11°C).

5. CONCLUSIONS

Carrying out numerical analyses of partitions undergoing thermal upgrading is particularly important for historic buildings, for which it is not always possible to apply thermal insulation from the outside. As has been shown, information on the temperature range in different parts of the building can be obtained using thermal imaging surveys, but the accuracy of the data obtained is fully influenced by the recorder that carries out the measurement. In summary, not every result from a thermal imaging camera survey can be used for further numerical analysis.

The correctness of the measurement is a key issue, since, as the analysis shows, even carrying out tests under unsuitable weather conditions can significantly affect the recorded temperature values. Thermal imaging surveys carried out in accordance with the guidelines given in the standard [22] make it possible to obtain data using the in situ method, which are necessary to carry out accurate simulations of the partition's operation over time and to select the most favorable thermal insulation model, especially using the method from the inside. An additional element of the research carried out was to show that, in order to avoid additional heat loss and damage to the façade, the plinth section of a historic building, regardless of its position in relation to the ground, should be thermally insulated like the external walls of the building.

REFERENCES

1. Hoła, A et al. 2024. Preliminary microstructural research of clay solid bricks taken from historic buildings located in Poland. Archives of Civil and Mechanical Engineering **24(3)**, 159.
2. Drobiec, Ł et al. 2021. Analysis of Reasons for the Structural Collapse of Historic Buildings. Sustainability **13**, 10058.
3. Krause P et al. 2020. The Impact of Internal Insulation on Heat Transport through the Wall: Case Study. Applied Sciences **10(21)**:7484.
4. Rymarczyk, T et al. 2021.Historical Buildings Dampness Analysis Using Electrical Tomography and Machine Learning Algorithms. Energies **14(5)**, 1307.
5. Klemm, P and Gawin, 1993. Przybliżony model matematyczny opisujący procesy skojarzonego transportu ciepła i wilgoci w ośrodkach kapilarnoporowatych [An approximate mathematical model describing the coupled heat and moisture transport processes in capillary-porous media] P. Klemm 1993. *Fizyka materiałów i konstrukcji budowlanych. Wybrane modele i metody badań [Physics of Building Materials and Structures. Selected Models and Testing Methods]* Vol. I. Łódź University of Technology Press.
6. Koniorczyk, et al. 2022. Stochastic energy-demand analyses with random input parameters for the single-family house. Building Simulation **15**, 357–371.
7. Ksit, B 2023. Diagnostyka wilgotnościowa obiektów budowlanych. Metodyka i procedury badań. [Moisture Diagnostics in Buildings. Testing Methods and Procedures]. Poznań University of Technology Press.
8. Ksit, B et al. 2022. Numerical simulation of the impact of water vapour and moisture blockers in energy diagnostics of ventilated partitions. Materials 15(22), 8257.
9. Krause, P, Nowoświat, A, Pawłowski, KP 2020. The Impact of Internal Insulation on Heat Transport through the Wall: Case Study. Applied Sciences 18.
10. Basińska, M, Kaczorek, D, Koczyk, H 2021. Economic and Energy Analysis of Building Retrofitting Using Internal Insulations. Energies 14, 2446.
11. Gawin, D, Kossecka, E. Komputerowa Fizyka Budowli - Program komputerowy WUFI i jego zastosowanie w analizach cieplno-wilgotnościowych przegród budowlanych [Computational

Building Physics – The WUFI software and its application in thermal and moisture analyses of building partitions]. Łódź University of Technology Press.
12. Nowoświat, A et al. 2018. Estimation of thermal transmittance based on temperature measurements with the application of perturbation numbers. Heat and Mass Transfer. Waerme und Stoffuebertragung **54(5)**, pp. 1477–1489.
13. Hoła, J, Sadowski, Ł 2022. Non-Destructive Testing in Civil Engineering. Applied Sciences 12(14), 7187.
14. Błaszczyński, T, Ksit, B, Monczyński, B 2020. The Influence of Injection Agents Applied for Carrying out Secondary Horizontal Damp Proof Courses on Masonry Mortar Properties. *Current Topics and Trends on Durability of Building Materials and Components* Proceedings of the 15th International Conference on Durability of Building Materials and Components, DBMC 2020, 381 – 3882020.
15. Krause, P, Steidl, T, Nowoświat, A 2011. Diagnostyka termowizyjna. Katalog termogramów wzorcowych. Sprawozdanie Etap I – Diagnostyka in situ izolacyjności cieplnej [Thermal imaging diagnostics. Catalogue of reference thermograms. Report: Stage I – On-site thermal insulation diagnostics].
16. Biernacka, M et al. 2022. Heat capacity anomaly near magnetic phase transition. Journal of Magnetism and Magnetic **54815 (4)** 168978.
17. Gawin, D, Pesavento, F, Koniorczyk, M, Schrefler, BA 2020. Poro-mechanical model of strain hysteresis due to cyclic water freezing in partially saturated porous media. International Journal of Solids and Structures **206**, 322-339.
18. Ksit, B, Szymczak-Graczyk, A, Nazarewicz, B 2022. Diagnostics and renovation of moisture affected historic buildings. Civil and Environmental Engineering Reports **1 (32)**, 59-73.
19. Ksit, B, Szymczak-Graczyk, A, Pilch, R 2022. Numerical simulation of the impact of water vapour and moisture blockers in energy diagnostics of ventilated partitions. Materials 15(22), 8257.
20. Skrzypczak I et al. 2023. A practical hybrid approach to the problem of surveying a working historical bell considering innovative measurement methods. Heritage Science **11**, 152.
21. Nowogońska, B 2020. Consequences of abandoning renovation: Case study-neglected industrial heritage building. Sustainability **12(16)**, 6441.
22. Laks, I, Walczak Z, Szymczak-Graczyk, A, Ksit, B, Mądrawski, J 2019. Hydraulic and legal conditions for buildings in floodplains-case study of Kalisz city (Poland). IOP Conference Series: Materials Science and Engineering **471**, 102050.
23. Sitarz, S, Ksit, B 2024. Technical report. Poznan [in Polish].
24. PN-EN 31829 Właściwości cieplne budynków. Określenie przepuszczalności powietrznej budynku-metoda podczerwieni [Thermal properties of buildings. Determining a building’s air permeability – the infrared method].