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NON-DESTRUCTIVE TECHNOLOGIES AS A TOOL FOR ARCHAEOLOGIST AND HISTORIAN OF ARCHITECTURE IN THE STUDIES AND RESEARCH OF THE INSTITUTE OF HISTORY OF ARCHITECTURE AND MONUMENT PRESERVATION OF CRACOW UNIVERSITY OF TECHNOLOGY

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ABSTRACT

Since we are carrying on the practice of architectural heritage protection, we are often confronted with the problem of necessary meeting and comparison the collected sources of information and historical documents with physically existing structure of the building. Even the need to take the necessary intervention, which aims to consolidate, or even emergency rescue of endangered object, requires the necessary tests, analytical research and monitoring applications to determine its technical condition. Usually apart from the design and structural research is also necessary to work with an architect, architectural historian or archaeologist – a co-operation necessary for the proper adjustment of the substance of the historic building and in order to define an integrated and interdisciplinary program of conservation.

A well-known medical principle of 'primum non nocere', that is present also in the building maintenance, creates an obligation to conduct research in a safe and minimally invasive manner compared to the authentic object's building substance and constitutes also the obligation to use 'non-destructive' research tools in the first instance.

The development of modern science and technology provided the researchers with the equipment and technologies with which we can minimize the interference into the material and authentic substance of the tested structure. These tools include GPR, thermovision, C14 dating method, spectrophotogram-metry and many others that allow for more precise definition of areas of research and testing. They are not, of course, the answer to the dilemma of 'to study or not to study?', but they allow for efficient and safer – in terms of architectural heritage protection – acquisition of knowledge about the structure and stratigraphy of the tested object.

The article presents the analysis of results of several of the most valuable Polish monuments of architecture, including among other the Castle in Sobotka Gorka, the Rotunda of Holly Virgin Mary at the Wawel Hill in Kraków and the building of IHAiKZ WAPK in Krakow.

Keywords: *Archaeological researches, Non-destructive technologies, GPR*

1. INTRODUCTION

The dynamic development of science especially for aerospace and military – led to the construction of new tools based on technologies and properties of radio-, light- and laser waves used in the study of materials, their components and structures. Many of these tools because of their low-invasive nature of the monitoring of the test substance are increasingly being adopted in the area of conservation and building maintenance related research. But it was spread a wrong and based on ignorance of the things opinion, that research of this type can replace the 'classic' study and research based on organoleptic

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sensory analysis of the object, especially in those cases where there is no direct access to it, and when such analysis is related to the necessity of removal of these parts or fragments that block and obstruct such access. This was reflected in the unreflective opposing the non-invasive research tests against invasive tests rightly considered as destructive, and also in the utopian anticipation of the complete elimination from the architecture researcher's 'research workshop' the invasive methods and methods which are physically penetrating a material substance. One of the first devices that allowed for more precise targeting of research and reasonable limitation of their area without detriment to the purpose of research was called was SIR radar (Subsurface Radar Interference), particularly useful in detecting subsurface anomalies, and therefore also of underground facilities and their relics [1]. For the first time in Poland, radar SIR was applied in Krakow, in the search and location of the crypt in the St. Peter and Paul church, conducted in the late 80s of the last century after raising the embargo which due to military reasons this device was covered.
Further extensive use of this device – today called GPR (Ground Penetrating Radar) – for civil purposes allows limited power of the transmitter used for the so-called 'shallow' subsurface penetration (up to several meters into the depths), while for military purposes the technology of 'deep' GPR is still being developed [2].
The radar study and research of subsurface facilities is based on the emission of electromagnetic waves, which being reflected from layers or objects with variable dielectric properties and being processed by dedicated software – provide a picture of a section through the given phase (medium).
Widespread use of GPR, being the device popular especially in archaeological research [3], can be however greatly expanded also in terms of penetration of the vertical and horizontal stratigraphy of individual parts and components of the building, such as walls, ceilings or floors. It is possible in the face of far-reaching miniaturization of equipment [4].

2. THE RESEARCHES RESULTS

2.1. Castle in Sobotka Gorka

Capabilities of GPR as an important auxiliary tool in planning studies and research, but which did not eliminate the need to carry the 'devastating' exposures to check the research hypotheses, are illustrated by the history of research conducted by IHAiKZ in Sobotka Gorka at a site involving the alleged Roman palace of Peter Wlast. The relics of this palace are preserved within the oldest part of the castle complex which is an oblong stone building, that in the Middle Ages was used for residential, and then sacral purposes [5].
Inside the interior of the former nave of the church was made a series of GPR surveys that gave a picture of relics appearing under the current floor (Fig. 1). However, the southern internal wall of the nave was subjected to tests based on thermovision.
The resulting echograms revealed disturbances of pulses of electromagnetic waves, interpreted as the subsurface occurrence of building structures in the form of two walls: the transverse and parallel one, extending along the northern wall. This division of the interior would be surprising and not typical for sacred buildings. Therefore, verification of GPR surveys began with a small probe identified in the point of intersection of two walls. As a result of this work, was unveiled a transverse wall integrally connected with the main wall of the Romanesque building. This wall was built using the same technology as perimeter walls of the oldest phase of this object.
In the case of parallel walls, one decided to expand the probe to the entire length of the room, in order to explain the nature of this relic. In the eleven meter-long earth profile emerged clearly four building excavations (trenches) located at similar distances to each other and having similar dimensions.
Detritally preserved fragments of foundation footing in one of these excavations suggested interpretation of the echogram of continuous wall as demolition residues of linearly deployed intra-nave pillars. They come probably from the second phase of construction of the Romanesque building, which as a result of establishing here the monks of Saint Augustine rule; the building was transformed from civic building into a church.
GPR studies and research in case of complex stratigraphy of the castle complex in Sobotka Gorka proved to be helpful both in establishing the test excavations, reasonably limiting the broad spatial penetration of the structure of historic property, as well as reliable in the sense of the nature of the findings. Unfortunately for the purposes related to precise documentation of the measurement and conducting the analysis of style, material and technological analysis, it became necessary to undertake and conduct invasive research.

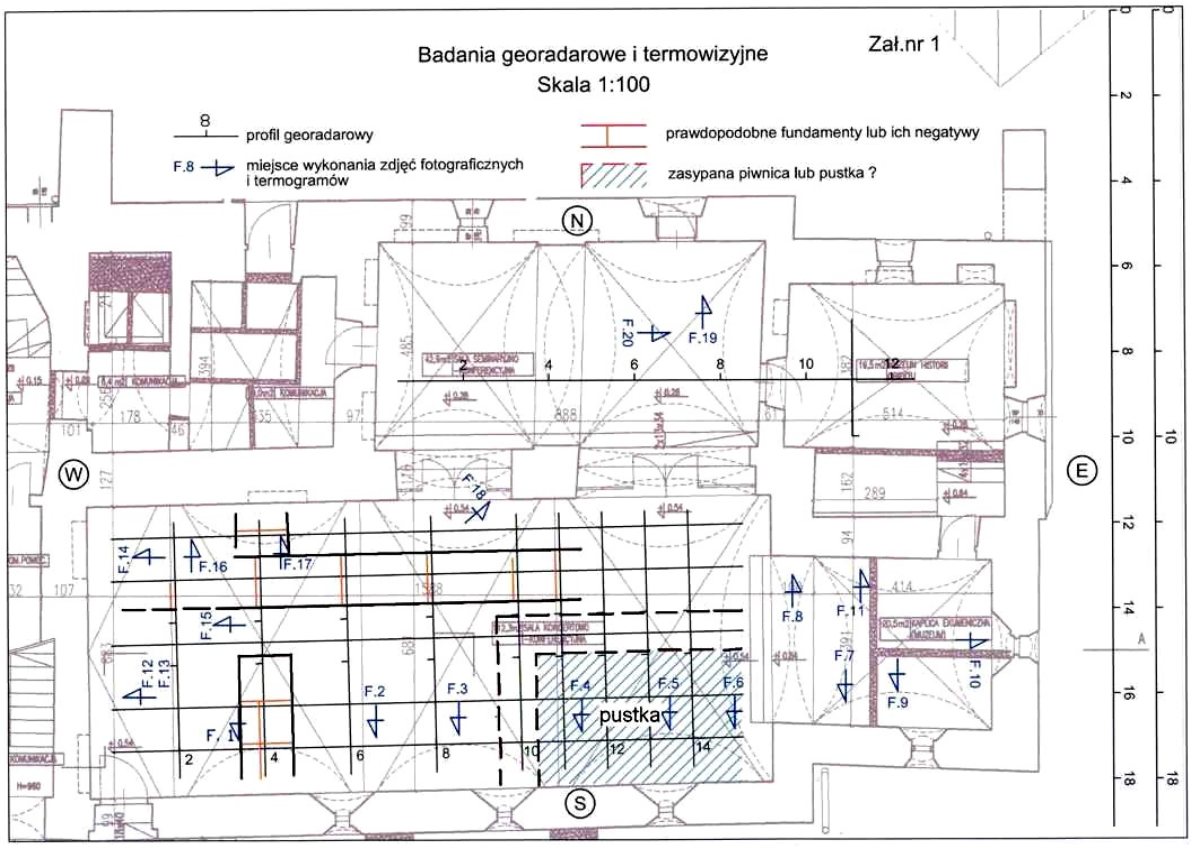

Fig. 1 The results of GPR researches of the Castel of Sobotka Gorka. Cracow Geodetic Company

However, the internal face of the south wall was subjected to thermal image-based research. The obtained thermograms showed clear traces of the two levels which – taking into account the results of the subsurface research – can be interpreted as the residual of utility levels associated with the first phase of the Romanesque building (lower level), and a second phase formed after the reconstruction of secular building and its adaptation to the needs of sacred building (higher level, probably associated with a gallery supported on pillars, which traces of founding were described above).

2.2. The Rotunda of the Holly Virgin Mary at the Wawel Hill

Particularly important for the new research hypotheses are GPR surveys conducted in the rotunda of the Holly Virgin Mary at Wawel Hill in 2009 within the statutory research of the IHAiKZ.

This commonly known facility being an example of the oldest building horizon in Poland (10th / 11th century), although was subjected to long-term research and archaeological explorations over the last century, remains still a mystery, for which the key is a solution applied to the system of external communications. Two contentious concepts, so as to reconstruct a body oif the building and functional and spatial solutions, to this day have their supporters and opponents in the world of science [6] .

The first of these concepts, the oldest one created by Szyszko-Bohusz who was the discoverer of the rotunda, shows us the massive and compact body of the rotunda, with a height of 11 meters, remaining in the type of Moravian buildings and old-Croatian rotunds, with the obvious connotations of southern Europe. A clear span interior of the Wawel rotunda with the small size of the space is communicated with the outside space using the door opening located in one of the eastern apses, which is probably not the original primary entrance.

The reason for a fundamental change in the concept of reconstruction of the rotunda was the discovery inside so-called fifth apse the relics of the staircase, which would indicate a two-level building with a cellar. A consequence of this hypothesis was the assumption regarding its height amounting to 15 meters, what severely disrupted the proportions of the object and still does not explain the question related to the entrance to this object. The only reasonable solution was the primary concept developed by Klementyna Żurowska, and involving the links between the rotunda and the palace. This concept, based on the typology of known residences of the Piast dynasty, in the absence of any relics had to fall, as proposed by the researcher – the palatial building, if it was established on the axis of the rotunda, would meet the huge rock ledge (a fault).

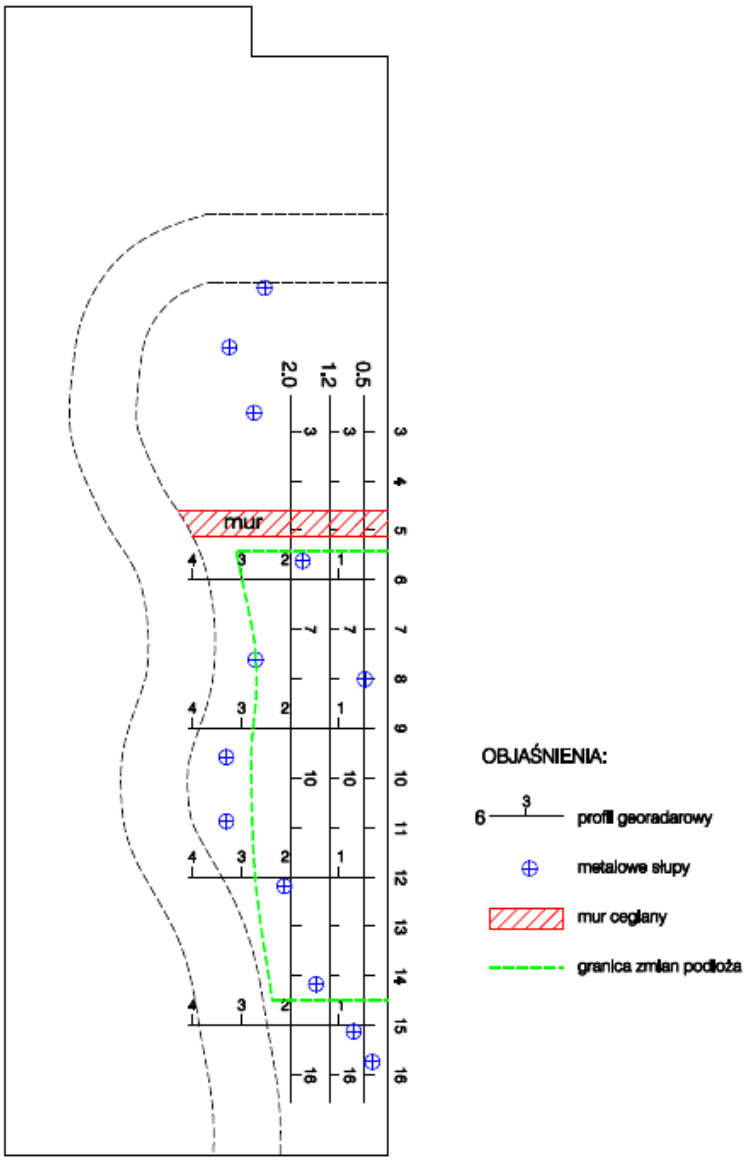

Fig. 2 The results of GPR researches of the Rotunda of the Holly Virgin Mary at the Wawel Hill. Cracow Geodetic Company. Scale 1:100

Today, being enriched with the results of new discoveries done by Hanna Kocka- Krenz, we know that Poznan palace, chronologically close to the St. Mary Rotunda on the Wawel Hill was cross-coupled with the palace chapel, and that a similar solution taking into account the topography of the land could be used also in Krakow. This new hypothesis proposed by the author of this article [7] , unfortunately, cannot be verified in the way of archaeological research, therefore, the question has been restricted to the use of GPR. Based on the obtained echograms, one has observed artificial alignment of the tested substratum, what certainly took place during the archaeological works and a numerous construction work, but in the tested area was outlined a clear boundary of substratum change, which may be associated with the old building development existing in the form of an elongated rectangle, situated transversely in relation to the rotunda (Fig. 2). In this case, given the results of excavations done in Sobótka-Górka, bringing a positive verification of both precision as well as high sensitivity of GPR capturing anomalies and fragmentarily preserved relics of exploded foundation pillars, the results of GPR research executed on the Wawel Castle should not remain marginalized and exploited.
Thermal images of the interior of the apse with preserved pre-Romanesque window, that were made during the same research operation did not capture the changes in temperature and thus did not confirm the anomalous trace of threads on the arc, which could testify to the existence at this altitude of ceiling or floor that covers the alleged crypt. Non-invasive tests conducted in the rotunda of the St. Mary, though as yet not confirmed by traditional research, confirm however high usefulness of GPR and thermography for scientific discussion and bring an element of inspiration for the search for alternative models of historical reality.

2.3. The building of IHAiKZ WAPK in Krakow

In addition to GPR, a method more and more widely used in conservation research, as already mentioned above also becomes a thermography, in other words a technology of thermal imaging by recording thermal radiation emitted by the physical body and measurement of this radiation in the mid-infrared band. Thermography as a research method can be based on the model of static (passive), which consists in measuring the natural (custom) temperature of the object, or the dynamic model (active) using thermal wave transmission in the direction of the object causing the diversity of its distribution through various materials and building structures stored inside a building.

Thermography has been used widely in tests and studies of outside wall on the courtyard of the IHAiKZ building located at Kanonicza Street 1 in Krakow, in connection with the forthcoming program of conservation repairs. This building is a unique monument being a part of canonical mansions built in the Middle Ages and heavily transformed during the Renaissance. At the time of the revaluation work conducted in the late 80s last century in the ground floor on the courtyard side, the researchers have discovered a well-preserved stonework of Renaissance arcades attributed to the workshop of Berrecci, and bricked up with monolithic brick wall in the course of the next reconstruction made during the nineteenth century. From the inside, in the hallway of ground floor, in specially designed niches are exhibited columns with bases and volute caps (capitals). It is alleged that on the upper floors might survive the fragments of open galleries, which could become a complement to the Renaissance cloisters – a common solution to the canons mansions of sixteenth century [8]. In preparing the next repair and conservation program, the Cracow University of Technology commissioned the relevant archaeological and architectural studies, also including the use of thermographic methods of elevations testing [9]. For the research was used a relatively modern system of thermal imaging [10], and this brought the colour thermal images with an assigned scale of the temperature values.

The research results, unfortunately, do not prejudge clearly positive outcomes, although the thermograms drawn in the morning and evening, thus a daytime eliminating the temporary heating of the surface, show more details that can be interpreted as evidence of an independent structure hidden in a brick wall. As the authors write in conclusion, "Differences in temperature and the characteristic thermal fields in the areas between the windows on the first floor (positive or negative – depending on time of day) recorded from the outside, indicate that in this place exist some material discontinuities, and thus there is a possibility of the existence of objects made of different material that are built-in to already existing wall (eg. pillars or columns). The similar temperature anomalies are present in this wall – they may be found on the floor II" [11].

3. CONCLUSIONS

The use of the non-destructive technologies in architectural and archaeological researches became the necessity because of additional possibilities bringing by this techniques. They enable to point the area of excavation preciously, limiting its destructive consequences. However, it is apparent that the thermal non-destructive testing can only be regarded as a serious support for research hypothesis and as an indicator specifying the places of the traditional tests, because only such tests can clearly confirm the research hypothesis or reject it.

REFERENCES

[1] Cianciara A. (2003) Zastosowanie georadarów do inwentaryzacji infrastruktury podziemnej. In: *Inżynieria Bezwykopowa* 09.

[2] Norgard J.D., Wicks M.C., Musselman R.L. (2005) Deep Ground Penetrating Radar (GPR). WIPD-D Models of Buried Sub-Surface Radiators. In: *Report Documentation The U.S. Air Force Academy, Colorado Springs, Applied Computational Electromagnetic Society Journal* , see also: Daniels J.J. (2000) Ground Penetrating Radar Fundamentals. In: *Appendix to a Report to the U.S.EPA, Region V.*

[3] Conyers L.B. (2004) Ground-penetrating radar for archeology. Rowman Altamira.

[4] Leuci G., Negri S., Carrozzo, M.T. (2003) Ground Penetrating Radar (GPR): an application for evaluating the state of maintenance of the building coating. In: *Annals of Geophysics,* vol. 46, n. 3.

[5] Stala K. (2010) Palatium możnowładcze Piotra Włostowica? Rekonstrukcja najstarszej fazy budowli romańskiej w Sobótce-Górce na podstawie najnowszych wyników badań archeologiczno-

-architektonicznych. In: *Wiadomości Konserwatorskie, no 27*, p. 67-78; see also: Stala K. (2010) Ecclesia de novo constructa. Kościół kanoników regularnych w Górce koło Sobótki. Rekonstrukcja drugiej fazy przebudowy palatium możnowładczego Piotra Włostowica. In: *Wiadomości Konserwatorskie*, No. 28, p. 91-100.
[6] Stala K. (2007) Tetrakonchos NMP, (św.św. Feliksa i Adaukta) na Wawelu jako przykład dziedzictwa antycznego w architekturze wczesnośredniowiecznej. Problemy interpretacyjne. In: *Wiadomości Konserwatorskie*, No. 21, p. 20-27.
[7] Stala K., *ibidem.*
[8] Bicz-Suknarowska M., Niewalda W., Rojkowska H. (1997) Zabudowa rezydencjonalna (Kanonicza) dawnego Okołu w XVI wieku. In: *Między gotykiem a barokiem. Sztuka Krakowa XVI i XVII wieku, Biblioteka Krakowska*, No. 136.
[9] Archaeological and architectural researches in court-yard of the building in Kanonicza 1 street-Pracownie Konserwacji Zabytków w Krakowie Spółka Akcyjna, Krakow 2011.
[10] Temperature distribution studies were performed with camera FLIR P-620 (offered by well-known U.S. company named FLIR SYSTEMS) working in the infrared spectral band 7,5-13 μm (microns) and developed with the Engineering and Technical Research Company DIAGNOTERM in Kraków in October 2011.
[11] The documentation above, part: thermal imaging test, p.14.