Andrzej Marynowicz Ph.D., Civ. Eng.
Physics of Materials Department
Faculty of Civil Engineering and Architecture
Opole University of Technology

Annex no. 3b

SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS
Description of works and scientific achievements

The summary was prepared according to art.16. par.2 of the law on academic degrees and academic title, and degrees and title in the field of art dated 14. march 2003r.

1. Name and surname: **Andrzej Marynowicz**
2. Diplomas and scientific degrees held, stating the name, location and year of obtaining them

- **2005**, Ph.D., Civ. Eng., field: technical sciences, scientific discipline: civil engineering; Ph.D. Thesis title: ***„Moisture analysis of materials and building partitions"***
  Supervisor: Jerzy Wyrwał Ph.D., D.Sc., Civ. Eng., Prof. of Opole University of Technology
  Reviewers: Prof. Piotr Klemm Ph.D., D.Sc., Civ. Eng., Łódź University of Technology; Prof. Jan Kubik Ph.D., D.Sc., Civ. Eng., Opole University of Technology
- **1999**, M.Sc., Civ. Eng., speciality: Computer Structure Analysis; Opole University of Technology, Faculty of Civil Engineering.
- **1994**, Building Technician, A Team of Technical Schools in Nysa

3. Information on previous employment in scientific units
   1.10.1999–31.05.2005 – assistant, Faculty of Civil Engineering, Opole University of Technology
   1.06.2005–30.09.2013 – adjunct, Faculty of Civil Engineering, Opole University of Technology
   1.10.2013– till now: adjunct, Faculty of Civil Engineering and Architecture, Opole University of Technology
4. Indication of the scientific achievement resulting from art. 16 par. 2 of the law dated 14 march 2003 r. on academic degrees and academic title, and degrees and title in the field of art (Dz. U. Nr 65, pos. 595 with changes)

a) Academic achievement is a work published in its entirety – the monograph:

Marynowicz A.: Wyznaczanie cieplnych właściwości materiałów budowlanych przy wykorzystaniu techniki termowizyjnej *(in Polish)*, Studia i Monografie z. 506, Oficyna Wydawnicza Politechniki Opolskiej, Opole 2019; ISSN 1429-6063, ISBN 978-83-66033-38-2; 166 s. (Annex no. 5; English title: ***Determination of thermal properties of building materials using the thermovision technique***)

b) Discussion of the scientific purpose of the above-mentioned work and the results achieved, together with a discussion of their possible use

One of the most frequently discussed issues in building physics is determining the thermal properties of building materials. The importance of this subject is primarily due to the important role that knowledge of these properties plays, especially in the context of thermal protection of buildings. Most building materials, which are the building blocks of building partitions, have a complex porous structure, thus their thermal properties strongly depend on the conditions in which these materials are used. For this reason, the need to have a measuring technique that allows you to examine basic thermal parameters in a quick and reliable manner becomes important. Few existing measurement methods allow to carry out such a measurement, but their main disadvantage is the low versatility, which manifests itself in the possibilities of measuring usually only a single parameter and also high sensitivity of the result of the measurement on the way it is carried out. This is mainly due to the fact that these measurements are usually contact one, causing the problem of surface preparation of the material being tested (ensuring smoothness), and failure to meet this condition results in large spreads of results.

Therefore, having in mind the above reasons, I have formulated and presented in the monograph the main goal of research, which is *the development of a non-contact method of simultaneous measurement of key thermal properties of porous building materials, such as thermal capacity and thermal diffusivity, which in turn will help determine their thermal conductivity.*

Knowledge of the aforementioned material parameters is of fundamental practical importance in issues related not only to the modeling of heat flow, but also in the quantitative description of the thermal stability of building partitions, and consequently of entire buildings. Due to the fact that the proposed method is non-contact, it creates a chance to conduct a measurement on the intact surface, which can be of key importance when measuring a material with a disturbed structure, e.g. moist or saline.

To implement such a research problem, I proposed the use of a laser source in the form of an easily accessible semiconductor module requiring only low-current external power supply. On the other hand, to measure the temperature changes of the surface of the material examined, caused by the laser beam, I also suggested using a non-contact method in the form of a thermovision camera. Due to the selection of research instrumentation, in the monograph I explained its physical basis and the principles of its functioning, with particular emphasis on the possibility of using them to reliably measure the desired material parameters.

Thermography technology has been more and more commonly used in construction for over forty years, especially in the qualitative thermal diagnostics of buildings, but also in the assessment of the interior microclimate or the effectiveness of systems improving its quality. Analyzing the subject's literature, one can observe a growing interest in the use of thermovision for diagnostics of objects not only new, but also historic, also in the context of detection of dampness, or structural changes of the surface, caused by salinity or freezing.

In the second chapter of the monograph I described the basic measurement techniques using thermovision, both passive thermography methods and the use of active thermography, which is intensively developed primarily in industrial applications, eg for control of manufacturing processes and partly in material research. In this part I discussed the basic measurement techniques (including pulse, modulation and step heating techniques and selected mixed techniques). I have devoted a lot of space to approximate the basic methods of thermovision signal processing, due to the fact that this topic is intensively developed in world research.

In the third chapter, I discussed the basic components of a typical thermal imaging camera and two important issues related to thermal imaging, namely the "flow" of the radiation reading (and consequently the measured temperature) caused by the process of the camera detector warming up and the NETD parameter describing the thermal resolution cameras (or more strictly the value of the temperature reading above the noise of one's own matrix and other elements of the camera), and thus determining its measuring capabilities.

The fourth chapter contains key information that allows for a deeper understanding of the physical basis of thermovision measurement, which is inherently indirect. It results from the fact that the detector (matrix) of the camera registers directly only the total radiated electromagnetic (in a given spectrum), which contains many components connected directly or indirectly with the object under examination, and later, in subsequent signal processing processes, convert this reading on a user-friendly surface temperature map. Not only the information about the intensity of radiation of the examined body reaches the detector, but also the components associated with the stream reflected from the surface of the sample due to ambient radiation (including the camera operator), the composition of the own atmosphere radiation (which is of great importance in measurements distant objects), but also a component resulting from a partial reflection from the surface of the part of the incoming energy stream, e.g. a laser heating the surface of the sample. In this part of the work I also discussed the importance of a key parameter in thermal imaging, which is the emissivity of the surface, and also presented selected techniques for its measurement. The significance of the effect of emissivity on the results of my research was presented in the last part of the work, devoted to my own research.

The second basic component of the proposed measurement method is a laser module based on an easily accessible semiconductor laser. Bearing in mind the specific character of this device and its associated operational features used in further research, in chapter five I have brought closer the most important concepts describing laser emission and the properties of the beam itself. Knowledge of these issues is crucial when conducting measurements using a laser energy source. This is mainly due to the need to properly describe the beam intensity, which in turn allows you to correctly interpret the temperature field caused by it, and consequently perform an effective identification of the desired task parameters. The chapter also describes the most common descriptions of the laser beam intensity distributions, which ultimately allowed the selection of the most suitable one for further analysis.

As I mentioned above, one of the key criteria for the selection of building materials is the knowledge of their thermal properties. Therefore, in the sixth chapter I focused on the characteristics of the most important measurement techniques of thermal properties of materials. This is related not only to the growing importance of issues related to thermal energy savings and the role of thermal conductivity and specific heat of the material (or more strict isobaric heat capacity that is the product of specific heat and material density)), but also with the broadly understood thermal comfort of rooms. In my research I devoted attention to the problem of simultaneous determination of both heat capacity and thermal diffusivity, which ultimately was to allow to determine the thermal conductivity of the tested materials. Therefore, in this part of the work I have brought closer the most common methods for measuring thermal conductivity, thermal diffusivity and, briefly, the DSC method for determining the specific heat. Due to the large variety of methods, I decided to divide them with insight to the type of contact with the test material, which was used to outline the advantages, but disadvantages and limitations of each of these methods. Analysis of their principles of operation draws attention to the fact that the vast majority of currently used methods requires from the user more or less complex sample preparation, which basically disqualifies them for applications in in-situ studies. In turn, those that enable this, such as the variant of the non-stationary method of hot wire, based on a one-sided probe, shows large dispersions of results, resulting primarily from the occurrence of contact resistance at the interface between the sensor and the tested substrate. In this context, the use of a non-contact thermal excitation is justified, especially since this topic is increasingly discussed in world research devoted to non-destructive and non-contact measurements. It should be noted here that the more or less available measurement methods discussed in Chapter 5 are not only characterized by relatively large equipment costs or the necessity of the said sample preparation, but also do not allow simultaneous testing of all sought-after quantities.

The most important scientific achievement is described in the seventh chapter. As I noted at the beginning, the measurement of the thermal properties of porous building materials is a complex issue, primarily due to their heterogeneous structure. Therefore, in this work I focused on the development of such a test method that allows you to measure these properties in a simple, quick and at the same time sufficiently reliable and giving the possibility of development towards the portable device. To achieve this goal, I developed a proprietary variant of the one-sided reflection method, using the aforementioned laser source of heat and registering with the thermal imaging camera the surface heat flow caused by it. I have tested three building materials, ie clinker brick facade with the addition of sand (the so-called "swedish"), designated in the experiment as CK, standard cement mortar, ZC and more and more practical, modern concrete made of reactive powders (Reactive Powder Concrete), RPC. The choice of materials was dictated, apart from functional traits, with clear differences in their structure, which served to demonstrate the suitability of the method for measuring heterogeneous materials.

Prior to the research, it was necessary to choose the methodology for the development of measurement data and to implement the best model describing the analyzed thermal phenomena. The searched properties, belonging to the group of material factors, define the fundamental features of the center, and their knowledge allows a meaningful description of the processes of heat flow in it. In the fields of science and technology in which we deal with obtaining information about the process based on the measurement of physical quantities, e.g. temperature or displacements, these parameters are obtained using either direct methods (eg thermal measurements described in the first and fifth chapter), or those belonging to a wide group of reverse methods. Based on the assumption that the measurement errors at individual points are independent, which in the case of thermal imaging camera results directly from the construction of the detector array, I used the maximum likelihood method to perform the research task, i.e. one of the inverse methods belonging to the group of statistical parametric estimation methods (to this group also belongs to the method of the least-squares MNK, or the Monte Carlo method).

The first step was to adopt the process and center model and solve the so-called simple task. Despite the fact that the materials tested show clear features of inhomogeneity, for example due to the relationship between their internal structure and porosity, practice shows that an analytical device used for homogeneous media can be used for their description on a sufficiently large scale. In this work, for the description of the temperature field caused by the laser beam, I used the solution proposed by Ready, known from the description of laser material processing. It describes the temperature field in a homogeneous medium subjected to a Gaussian surface energy stream. This solution is commonly found, for example in industrial applications, but in the case of attempts to describe the thermal response of a heterogeneous medium subjected to an irregular beam with characteristics significantly different from the Gaussian distribution, it was necessary to develop such approaches that solve this problem. Therefore, I suggested solving the problem in several stages. In the first stage, I measured the intensity distribution of the beam using a digital profilometer, which was used to averaging it so as to obtain an axisymmetric distribution, supplemented with information on the standard deviation of each point. The beam intensity distribution thus created was approximated, using the superposition principle of the sum of three Gaussian functions. I used this procedure again, in the second step, to approximate the measured temperature distribution on the surfaces of the tested samples using a thermal imaging camera. This time, I made the approximation and superposition using the previously mentioned Ready's analytical solution.

Temperature changes were measured on a measuring stand built for this purpose, equipped with an optical bench with a laser, a two-pristine beam correction system and a sample shield covered with a layer of sputtered graphite. This position, in combination with the size of the sample, made it possible to meet the requirement of reflection avoidance during the process of heating the semi-infinite body, without the participation of convection, consistent with the analytical model. In order to reduce the effect of individual emissivity of each of the tested materials, the samples were subjected to laser treatment in two configurations: once they had a surface in the natural state and once covered with a layer of sputtered graphite. The effect of these activities was reflected in the final results obtained, described below.

The search for the optimal solution, in this case the maximum likelihood function, was carried out using the regular parameter (grid) search algorithm, which is the simplest, but thanks to this very effective optimization method, often used in tasks of this type. Due to the characteristics of the camera's operation described in the third chapter and wishing to implement the optimization procedure discussed above, it would be necessary to search the domain of over one hundred parameters. It results from the necessity to establish a registered process for each frame, so-called background temperature (base), beyond the sought-after material parameters. I solved this problem using proprietary, semi-analytical solution of the optimization task, thanks to which the number of sought values decreased to four – two obtained as a result of grid searching (thermal diffusivity and scaling factor of surface heat source power) and two parameters calculated for each moment (the heat capacity scaling factor and the offset temperature). As a result of these calculations, the reliability of the fit was determined, in accordance with the assumptions of the applied method, for each pair of the desired process parameters. It also allowed to directly calculate the accuracy of the obtained results.

An important result of the research is the demonstration that in the case of ignorance of the emissivity of the material to be tested, it is necessary to cover it with a layer of graphite, while thermal diffusivity will be determined correctly for samples not covered with a graphite layer. This effect was observed for a sample of RPC concrete and ZC cement mortar, where the influence of the graphite layer emissivity on the emissivity of the samples was clearly marked here. The result obtained for the clinker brick sample CK showed similar values in both cases, which indicates a comparable value of graphite and brick emissivity.

The material parameters obtained by means of the above measures, i.e. heat capacity and thermal diffusivity, finally allowed to calculate the last sought-after value, i.e. the coefficient of thermal conductivity. The obtained results were compared with the results of reference measurements, showing good agreement.

All the calculation procedures described above were implemented using author's programs developed in the MATLAB computing environment.

Summing up, my research and analysis allowed me to formulate some key conclusions that can be considered as a significant contribution of the author to the subject of non-destructive testing of thermal properties of building materials:

- Using the proposed measurement set, consisting of a semiconductor laser and a thermal imaging camera, it is possible to reliably measure the thermal capacity, thermal diffusivity and thermal conductivity of inhomogeneous building materials, provided that the measurement is carried out in two steps, i.e. for a clean sample covered with a thin layer of graphite.
- The beam radius, previously taken as a constant component of the laser heating process model (in the boundary condition), is effective, depending on the type of material being tested, and should be determined independently for each measurement.
- Calculation and modeling applied in the work, consisting of, among others on the averaging of beam intensity and temperature distribution, as well as on the superposition of simple solutions, they proved to be suitable for the implementation of the research task, and may provide a basis for the further development of the method.
- The result of the parametric estimation is strongly influenced by the assumption, already at the stage of thermal imaging camera configuration, of the surface emissivity value. From a practical point of view, determining it individually for each sample or measurement situation is very labor-intensive and would require an additional measurement, therefore the solution proposed by the author in the form of a double measurement, i.e. a sample covered with and not covered with graphite, gave the opportunity to solve at this stage of the method development. problem of determining the emissivity of the tested material.

The analysis of the obtained results also results in the directions of further development of the developed method, primarily in terms of surface scanning (multi-point measurement), consideration of its roughness, or testing of materials with high porosity (e.g. aerated concretes) and orthotropic materials such as wood. The problem of determining the impact of material moisture on the obtained results remains also open.

5. Discussion of other scientific and research achievements

My scientific activity began as early as the last year of studies at the Faculty of Civil Engineering at the Opole University of Technology, under the supervision of Prof. Jan Kubik, then head of the Department of Physics of Materials. As a result of being employed as an assistant in this department in October 1999 and at the same time commencing a doctoral study at the Cracow University of Technology, the subject of my scientific interests were issues related to building physics, and in particular the problem of experimental investigations of co-factors of moisture diffusion in porous building materials. This was reflected in the works published before the defense of the doctoral thesis mentioned in point II.A.5 and in sections E.24–E.30 of Annex 4. The result of further intensive scientific and research activity was a doctoral dissertation titled "*Analysis of moisturing of materials and building partitions*", carried out under the supervision of Prof. Jerzy Wyrwał, which I defended in February 2005. My achievements before obtaining the doctoral degree include 1 publication from the list A (item II.A.5, Annex 4), 7 publications from outside this list (item E.24–E.30 Annex 4), as well as speeches on four conferences (item I.L.20-I.L.24 Annex 4).

I started working as an adjunct professor in June 2005. In addition to the main subject matter of my research related to mass transport in construction capillary and porous materials, which resulted in publications (items II.A.2-3, II.E.7, II.E.20-21, Annex 4) and co-authored monograph published by the Committee of Civil Engineering of the Polish Academy of Sciences (item II.E.23, Annex 4), my research interests began to include thermomechanics and the theory of thermal field modeling, including the use of laser sources. This was possible mainly due to establishing lively cooperation with the team of professor Oleksandr Hachkevych (Opole University of Technology and Pidstryhach Institute of Applied Problems of Mechanics and Mathematics at the Ukrainian Academy of Sciences). As a result of this scientific cooperation, I participated in research, the result of which are publications II.E.3, II.E.5, II.E.8, II.E.11-13, II.E.19 according to Annex 4, and participation in seminars and conferences (item II.L, Annex 4). From 2007, my scientific interests began to include the subject of modeling effective thermal conductivity of materials (items II.A.4, II.E.17-18, II.E.22, Annex 4), and above all, from 2013, I investigated the interaction of laser radiation with porous materials, which resulted in publications

II.E.5, II.E.10, II.E.13 from Annex 4. The result of research in this direction was the presentation of an international QIRT conference in Gdańsk, 2016 (item II.L.1 Annex), publication of the article II.A.1 and, above all, development and publication of the monograph, described in item 4b of this summary (item I.A, Annex 4).

In addition to the above mentioned achievements in the field of building physics and thermo-mechanics, I took part in international programs in the framework of cross-border cooperation with the Czech Republic (item III.A of Annex 4). The result of this cooperation were primarily study visits, seminars and conferences devoted to scientific and technical problems accompanying renovation works on historic buildings (item II.L.11-13 Annex 4). My interest in technical problems related to historic buildings was also reflected in publications, resulting from expert opinions and technical opinions (items II.L.10, II.L.16-17, Annex 4). The result of this activity was also the promotorship of three Master's theses, awarded in the competitions of the Chief Conservator of the Republic of Poland and the Minister of Infrastructure (item II.J, Annex 4).

I extended my interest in the issues of antique timber constructions to research on modern timber constructions thanks to participation in the research program under the 7th Framework Program of the EU. As part of this activity, I completed a research internship at the seismic laboratory at the University of Bristol (in 2011 and 2012, item III.L.1, Annex 4), preceded by a preparatory course in experimental theory and practice at the European Research and Training Center of Seismic Engineering EUCENTRE in Pavia (Italy) in 2010 (item III.L.2, Annex 4). The results of the research conducted were published in the form of articles (items II.E.9, II.E.15) and delivered at a thematic conference (item II.L.4, Annex 4).

As an active civil engineer, I am a member of the Opole Chamber of Civil Engineers (from 2007) and the PZiTB branch in Opole (since 1999). Therefore, a separate group of work and professional activities are those related to my project practice in the field of building constructions. I have compiled publications in this area in connector 3 (items II.E.1-2, II.E.4, II.E.6 Annex 4). The result of many years of engineering practice are also realizations, listed in p. II.B, appendix 3, as well as expert opinions and technical opinions, compiled in p. III.M. My master's thesis, which was awarded in 2018 by the Minister of Investment and Development (item III.J.2, Annex 4), was also created under my supervision. Since 2012 I have been a court expert in the field of building structures at the District Court in Opole.

After the defense of the doctoral dissertation, on February 9, 2005, I published as an author or co-author 27 scientific papers, including 4 in journals indexed in the JCR database (item II.A.1-4 Annex 4), one monograph (item II.A.23 Annex 4), 8 chapters of the monograph (items II.E.3, II.E.5, II.E.8, II.E.11-13, II.E.16. II.E.19 Annex 4) and 19 papers at national (3) and international (16) conferences, item II.L. Annex 4.

A summary of the publication's output, along with the number of citations and indicators of scientific achievements, is presented in Table 1. A detailed list of publications is included in Annex 4.

Table 1. Summary of the publication's achievements

Type of publication		**Before the Ph.D.**	**After the Ph.D.**
Monographies		-	**2**
Chapters of monographies		-	**8**
Articles in international journals (including the JCR base acc. to ISI Web of Science)		2 (1)	**10 (4)**
Articles in national journals		6	**7**
Papers at international conferences (including indexed on Web of Science)		2	**16 (1)**
Papers at national conferences		3	**3**
Total		13	**46**
Citations			
WoS		3	**27**
Scopus		3	**24**
Google Scholar		4	**59**
Total IF: 6,243	incl.:	**1,192**	**5,051**
Hirsch Index acc. to:			
WoS		1	**3**
Scopus		1	**2**
Google Scholar		1	**4**

In addition to the scientific activity, I am also involved in didactics within my work at Opole University of Technology. As part of the classes, I developed framework and detailed plans for six subjects, of which five included lectures (item III.I.1, Annex 4). I conducted classes at first and second cycle, both on a full-time and part-time basis. I have developed a program and a schedule for a postgraduate study under the name "Energy-efficient construction with Energy Characteristics and Building Audit". I also conducted classes as part of the Erasmus program in English (item III.1.I.1, Annex 4) and twice as part of the Socrates-Erasmus program at the University of Gaziantep (Turkey), in the years 2007 and 2008 (item III.A.4 Annex 4).

In the years 2006–2008 I coordinated, on behalf of the Opole University of Technology, the European educational pilot project Leonardo da Vinci TEMTIS (Educational Materials for Designing and Testing of Timber Structures, Project number: CZ/06/B/F/PP-168007), item III.A.2, Annex 4. The project, whose main coordinator was the Technical University of Ostrava, was attended by 11 partners from seven countries. As a result, public didactic materials were created, including two co-authored textbooks for designing wooden structures according to Eurocode 5 (item III.Q.6, Annex 4).

In the period from October 1, 2008 to September 30, 2008, I was the head of the Department of Physics of Materials at the Faculty of Civil Engineering.

Since 2005 I have been representing the Opole University of Technology in the Main Committee of the Knowledge and Building Skills Olympiad, in which several hundred secondary school students from all over the country take part every year (annually more than 700 participants in the district stage and around 80 in the central stage). The organizer and coordinator of OWiUB is Warsaw University of Technology. From 2016 I am the Vice-Chairman of the Main Committee and the Chairman of the Central Competition Jury.

I was awarded the 2nd degree award by the Rector of the Opole University of Technology in 2006 (see III.D.5, Annex 4), and in 2012 for the didactic activity of the 2nd degree team award, also by the Rector of the Opole University of Technology (see III.D.2 Annex 4). In 2016, I received the medal of the National Education Commission (see III.D.1, Annex 4). I received also a silver honorary badge for active involvement in PZiTB (see III.D.3, Annex 4).